CONTENTS

I. AXIAL

A. Gluon propagator in the light-like gauge

The general expression for Feynman gluon propagator in the light-like gauge $p_2^\mu A_\mu = 0$ in the background field (**??**) has the form

$$i\langle T\{A^a_\mu(x)A^b_\nu(y)\}\rangle \;=\; (x|\big(g^\perp_{\mu i} - \frac{p_{2\mu}}{p_*}p_i\big)\frac{1}{P^2+i\epsilon}\big(\delta^i_\nu - p^i\frac{p_{2\nu}}{p_*}\big) - \frac{p_{2\mu}p_{2\nu}}{p_*^2}|y)^{ab} \tag{1}$$

Using the expression (**??**) for $\frac{1}{P^2+i\epsilon}$ we get

$$\begin{aligned}\langle T\{A^a_\mu(x)A^b_\nu(y)\}\rangle \;=\; & \Big[-\theta(x_*-y_*)\int_0^\infty \frac{d\!\!{}^-\alpha}{2\alpha} + \theta(y_*-x_*)\int_{-\infty}^0 \frac{d\!\!{}^-\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}\\ \times\; & (x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big(g^\perp_{\mu i} - \frac{2p_{2\mu}}{\alpha s}p_i\big)\mathcal{O}_\alpha(x_*,y_*;p_\perp)\big(\delta^i_\nu - p^i\frac{2p_{2\nu}}{\alpha s}\big)e^{i\frac{p_\perp^2}{\alpha s}y_*}|y_\perp)^{ab} + i(x|\frac{p_{2\mu}p_{2\nu}}{p_*^2}|y)^{ab}\end{aligned} \tag{2}$$

For the complex conjugate amplitude one obtains in a similar way

$$-i\langle \tilde T\{A^a_\mu(x)A^b_\nu(y)\}\rangle \;=\; (x|\big(g^\perp_{\mu i} - \frac{p_{2\mu}}{p_*}p_i\big)\frac{1}{P^2-i\epsilon}\big(\delta^i_\nu - p^i\frac{p_{2\nu}}{p_*}\big) - \frac{p_{2\mu}p_{2\nu}}{p_*^2}|y)^{ab} \tag{3}$$

and

$$\begin{aligned}\langle \tilde T\{A^a_\mu(x)A^b_\nu(y)\}\rangle \;=\; & \Big[-\theta(y_*-x_*)\int_0^\infty \frac{d\!\!{}^-\alpha}{2\alpha} + \theta(x_*-y_*)\int_{-\infty}^0 \frac{d\!\!{}^-\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}\\ \times\; & (x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big(g^\perp_{\mu i} - \frac{2p_{2\mu}}{\alpha s}p_i\big)\mathcal{O}_\alpha(x_*,y_*;p_\perp)\big(\delta^i_\nu - p^i\frac{2p_{2\nu}}{\alpha s}\big)e^{i\frac{p_\perp^2}{\alpha s}y_*}|y_\perp)^{ab} - i(x|\frac{p_{2\mu}p_{2\nu}}{p_*^2}|y)^{ab}\end{aligned} \tag{4}$$

where we used Eq. (**??**) for $\frac{1}{P^2-i\epsilon}$.

The "cut" propagator in the background field $A_\bullet(x_*,x_\perp)$ is given by Eq. (**??**)

$$\begin{aligned}&\langle \tilde A^a_\mu(x)A^b_\nu(y)\rangle\\ &\;=\; -(x|\big(g^\perp_{\mu i} - \frac{p_{2\mu}}{p_*}p_i\big)\frac{1}{P^2-i\epsilon}p^2 2\pi\delta(p^2)\theta(p_0)p^2\frac{1}{P^2+i\epsilon}\big(\delta^i_\nu - p^i\frac{p_{2\nu}}{p_*}\big)|y)^{ab}\end{aligned} \tag{5}$$

Using Eq. (**??**) for scalar propagator we obtain

$$\begin{aligned}\langle \tilde A^a_\mu(x)A^b_\nu(y)\rangle = \;& -\int_0^\infty \frac{d\!\!{}^-\alpha}{2\alpha}\;e^{-i\alpha(x-y)_\bullet}\\ &\times(x_\perp|\big(g^\perp_{\mu i} - \frac{2p_{2\mu}}{\alpha s}p_i\big)e^{-i\frac{p_\perp^2}{\alpha s}x_*}\tilde{\mathcal{O}}(x_*,\infty)\mathcal{O}(\infty,y_*)e^{i\frac{p_\perp^2}{\alpha s}y_*}\big(\delta^i_\nu - p^i\frac{2p_{2\nu}}{\alpha s}\big)|y_\perp)^{ab}\end{aligned} \tag{6}$$

where, as usual, $\tilde{\mathcal{O}}$ is built of the $\tilde A$ fields in the left functional integral in Eq. (**??**).

B. Viz xigs

$$S_\Phi \;=\; \Omega\int d^4z\;F^a_{\mu\nu}(z)F^{a\mu\nu}(z)\Phi(z) \;=\; \frac{4\Omega}{s}\int d^4z\;F^a_{*i}(z)F^{ai}_\bullet(z)\Phi(z) \;=\; \frac{4\Omega}{s}\int d^4z\;\partial_*A^a_i(z)F^{ai}_\bullet(z)\Phi(z) \tag{7}$$

$$\langle A^a_\mu(x)\ e^{iS_{\rm A}+iS_\Phi}\rangle\ =\ i\Omega\frac{4}{s}\int d^4y\ \langle A^a_\mu(x)\partial_* A^b_i(y)F^{bi}_\bullet(y)e^{iS_{\rm A}}\rangle\Phi(y) \tag{8}$$

$$=\ \Omega\frac{4}{s}\int d^4y\ (x|\big[\big(g^\perp_{\mu j}-\frac{p_{2\mu}}{p_*}p_j\big)\frac{1}{P^2+i\epsilon}\big(\delta^j_\nu-p^j\frac{p_{2\nu}}{p_*}\big)-\frac{p_{2\mu}p_{2\nu}}{p_*^2}\big]ip_*|y)^{ab}\delta^\nu_i F^{bi}_\bullet(y)\Phi(y)$$

$$=\ 2i\Omega\int d^4y\ F^{bi}_\bullet(y_*,y_\perp)\Phi(y)\frac{\partial}{\partial y_\bullet}\Big[-\theta(x_*-y_*)\int_0^\infty\frac{đ\alpha}{2\alpha}+\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}$$

$$\times\ (x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big(g^\perp_{\mu i}-\frac{2p_{2\mu}}{\alpha s}p_i\big)\mathcal{O}_\alpha(x_*,y_*;p_\perp)e^{i\frac{p_\perp^2}{\alpha s}y_*}|y_\perp)^{ab}\Big]$$

$$\simeq\ \Omega\int d^4y\ \Big[\theta(x_*-y_*)\int_0^\infty đ\alpha-\theta(y_*-x_*)\int_{-\infty}^0 đ\alpha\Big]e^{-i\alpha(x-y)_\bullet}(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big(g^\perp_{\mu i}-\frac{2p_{2\mu}}{\alpha s}p_i\big)|y_\perp)[x_*,y_*]^{ab}_y F^{bi}_\bullet(y_*,y_\perp)\Phi(y)\Big]$$

$$=\ i\Omega\frac{4}{s}\int d^4y\ \big[\langle A^a_\mu(x)\partial_* A^{b,\alpha>0}_i(y_\bullet,y_\perp)e^{iS_{\rm QCD}}\rangle[\infty,y_*]^{bc}_y F^{ci}_\bullet(y_*,y_\perp)+\langle A^a_\mu(x)\partial_* A^{b,\alpha<0}_i(y_\bullet,y_\perp)e^{iS_{\rm QCD}}\rangle[-\infty,y_*]^{bc}_y F^{ci}_\bullet(y_*,y_\perp)\big]\Phi(y)$$

II. IN THE BF

ПРОПАГАТОР

$$\langle A^a_\mu(x)A^b_\nu(y)\rangle \tag{9}$$

$$=\ \Big[-\theta(x_*-y_*)\int_0^\infty\frac{đ\alpha}{2\alpha}+\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}\big\{(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}(x-y)_*}$$

$$\times\ \big[\mathcal{G}^{ab}_{\mu\nu}(x_*,y_*;p_\perp)+\mathcal{Q}^{ab}_{\mu\nu}(x_*,y_*;p_\perp)\big]|y_\perp)+(y_\perp|\bar{\mathcal{Q}}^{ab}_{\mu\nu}(x_*,y_*;p_\perp)e^{-i\frac{p_\perp^2}{\alpha s}(x-y)_*}|x_\perp)\big\}$$

ГDE

$$\mathcal{G}_{\mu\nu}(x_*,y_*;p_\perp)\ = \tag{10}$$

$$=\ g_{\mu\nu}[x_*,y_*]+g\int_{y_*}^{x_*}dz_*\ \Big(-\frac{2i}{\alpha s^2}(z-y)_*g_{\mu\nu}\big\{2p^j[x_*,z_*]F_{\bullet j}(z_*)-i[x_*,z_*]D^jF_{\bullet j}(z_*)\big\}$$

$$+\ \frac{4}{\alpha s^2}(\delta^j_\mu p_{2\nu}-\delta^j_\nu p_{2\mu})[x_*,z_*]F_{\bullet j}(z_*)\Big)[z_*,y_*]$$

$$+\ \frac{8g^2}{\alpha s^3}\int_{y_*}^{x_*}dz_*\int_{y_*}^{z_*}dz'_*\ \big[ig_{\mu\nu}(z'-y)_*-\frac{2}{\alpha s}p_{2\mu}p_{2\nu}\big][x_*,z_*]F_{\bullet j}(z_*)[z_*,z'_*]F_\bullet{}^j(z'_*)[z'_*,y_*]$$

$$\mathcal{Q}^{ab}_{\mu\nu}(x_*,y_*;p_\perp)\ =\ -\frac{4ig}{\alpha^2s^3}p_{2\mu}p_{2\nu}\int_{y_*}^{x_*}dz_*([x_*,z_*]D^jF_{\bullet j}(z_*)[z_*,y_*])^{ab} \tag{11}$$

$$+\ \frac{g^2}{\alpha s^2}\int_{y_*}^{x_*}dz_*\int_{y_*}^{z_*}dz'_*\bar\psi(z_*)[z_*,x_*]t^a[x_*,y_*]t^b[y_*,z'_*]\gamma^\perp_\mu\not{p}_1\gamma^\perp_\nu\psi(z'_*),$$

$$\bar{\mathcal{Q}}^{ab}_{\mu\nu}(x_*,y_*;p_\perp)\ =\ -\frac{g^2}{\alpha s^2}\int_{y_*}^{x_*}dz_*\int_{z_*}^{x_*}dz'_*\bar\psi\gamma^\perp_\nu\not{p}_1\gamma^\perp_\mu[z_*,y_*]t^b[y_*,x_*]t^a[x_*,z'_*]\psi(z'_*)$$

As we mentioned, this formula is correct for the point y inside the shock wave and the point x inside or outside.

Without quarks

$$\langle A^a_\mu(x)F^b_{\bullet i}(y)\rangle \tag{12}$$

$$=\ i\Big[-\theta(x_*-y_*)\int_0^\infty\frac{đ\alpha}{2\alpha}+\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}(x-y)_*}\big[\alpha\frac{s}{2}\mathcal{G}^{ab}_{\mu i}(x_*,y_*;p_\perp)-\mathcal{G}^{ab}_{\mu *}(x_*,y_*;p_\perp)p_i\big]|y_\perp)\ =$$

$$=\ i\Big[-\theta(x_*-y_*)\int_0^\infty\frac{đ\alpha}{2\alpha}+\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}(x-y)_*}\big\{[x_*,y_*]\big(\frac{\alpha s}{2}g_{\mu i}-p_{2\mu}p_i\big)-\frac{2p_{2\mu}}{s}\int_{y_*}^{x_*}dz_*[x_*,z_*]F_{\bullet i}(z_*)[z_*,y_*]\big\}|y_\perp)$$

A. Viz xigs

$$\langle A^a_\mu(x)\ e^{iS_A+iS_\Phi}\rangle\ =\ i\Omega\frac{4}{s}\int d^4y\ \langle A^a_\mu(x)(\partial_*A^b_i-\partial_iA^b_*(y))F^{bi}_\bullet(y)e^{iS_A}\rangle\Phi(y)\ =\ \frac{4\Omega}{s}\Big[\theta(x_*-y_*)\int_0^\infty\frac{đ\,\alpha}{2\alpha}$$

$$-\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\,\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big\{[x_*,y_*]\big(\alpha\frac{s}{2}g_{\mu i}-p_{2\mu}p_i\big)-\frac{2}{s}p_{2\mu}\int_{y_*}^{x_*}dz_*[x_*,z_*]F_{\bullet i}(z_*)[z_*,y_*]\big\}|y_\perp)^{ab}F^b_{\bullet i}(y_*)\Phi(y)$$

$$=\ \frac{4\Omega}{s}\Big[\theta(x_*-y_*)\int_0^\infty\frac{đ\,\alpha}{2\alpha}-\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\,\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big\{[x_*,y_*]\big(\alpha\frac{s}{2}g_{\mu i}-p_{2\mu}p_i\big)-ip_{2\mu}(\partial_i[x_*,y_*])\big\}|y_\perp)^{ab}F^b_{\bullet i}(y_*)\Phi(y)$$

$$=\ \frac{4\Omega}{s}\Big[\theta(x_*-y_*)\int_0^\infty\frac{đ\,\alpha}{2\alpha}-\theta(y_*-x_*)\int_{-\infty}^0\frac{đ\,\alpha}{2\alpha}\Big]e^{-i\alpha(x-y)_\bullet}(x_\perp|e^{-i\frac{p_\perp^2}{\alpha s}x_*}\big(\alpha\frac{s}{2}g_{\mu i}-p_{2\mu}p_i\big)[x_*,y_*]|y_\perp)^{ab}F^b_{\bullet i}(y_*)\Phi(y)$$

$$=\ i\Omega\frac{4}{s}\int d^4y\ \big[\langle A^a_\mu(x)(\partial_*A_i-\partial_iA_*)^{b,\alpha>0}(y_\bullet,y_\perp)\rangle[\infty,y_*]^{bc}_yF^{ci}_\bullet(y_*,y_\perp)+\langle A^a_\mu(x)(\partial_*A_i-\partial_iA_*)^{b,\alpha<0}(y_\bullet,y_\perp)\rangle[-\infty,y_*]^{bc}_yF^{ci}_\bullet(y_*,y_\perp)\big]\Phi(y)$$

$$=\ i\Omega\frac{4}{s}\int d^4y\ \big[\langle A^a_\mu(x)F^{b,\alpha>0}_{*i}(y_\bullet,y_\perp)\rangle[\infty,y_*]^{bc}_yF^{ci}_\bullet(y_*,y_\perp)+\langle A^a_\mu(x)F^{b,\alpha<0}_{*i}(y_\bullet,y_\perp)\rangle[-\infty,y_*]^{bc}_yF^{ci}_\bullet(y_*,y_\perp)\big]\Phi(y)\tag{13}$$

III. LVERTEX

$A_\bullet(x_*,x_\perp)$, $B_*(x_\bullet,x_\perp)$

$$\begin{aligned}D^\mu\mathcal{G}_{\mu i}\ &=\ -\frac{2}{s}f^{abc}(B^b_*\partial_iA^c_\bullet+A^b_\bullet\partial_iB^c_*)\\ D^\mu\mathcal{G}_{\mu\bullet}\ &=\ \frac{2}{s}f^{abc}\big[B^b_*\partial_\bullet A^c_\bullet-\frac{s}{2}\big(\frac{1}{\partial_*}B^b_*\big)\partial^2_\perp A^c_\bullet\big]+\frac{2}{s}f^{abm}f^{cdm}A^b_\bullet B^c_*A^d_\bullet\\ D^\mu\mathcal{G}_{\mu *}\ &=\ \frac{2}{s}f^{abc}\big[A^b_\bullet\partial_*B^c_*-\frac{s}{2}\big(\frac{1}{\partial_\bullet}A^b_\bullet\big)\partial^2_\perp B^c_*\big]+\frac{2}{s}f^{abm}f^{cdm}B^b_*A^c_\bullet B^d_*\end{aligned}\tag{14}$$

Chek:

$$\partial^\nu D^\mu\mathcal{G}_{\mu\nu}\ =\ \frac{2}{s}f^{abc}\Big[-\partial_i(B^b_*\partial_iA^c_\bullet+A^b_\bullet\partial_iB^c_*)\tag{15}$$

$$+\ \partial_*\big[B^b_*\partial_\bullet A^c_\bullet-\frac{s}{2}\big(\frac{1}{\partial_*}B^b_*\big)\partial^2_\perp A^c_\bullet\big]+\frac{2}{s}f^{abm}f^{cdm}A^b_\bullet\partial_*B^c_*A^d_\bullet+\partial_\bullet\big[A^b_\bullet\partial_*B^c_*-\frac{s}{2}\big(\frac{1}{\partial_\bullet}A^b_\bullet\big)\partial^2_\perp B^c_*\big]+\frac{2}{s}f^{abm}f^{cdm}B^b_*\partial_\bullet A^c_\bullet B^d_*\Big]$$

If $\alpha\beta s\gg\perp^2$ the Lipatov vertex reduces to usual one.

$$C^a_*(\alpha)B^b_*(\alpha_1)B^c_*(-\alpha-\alpha_1)\bar\psi\big(t^a\frac{1}{\alpha+i\epsilon}t^b\frac{1}{\alpha+\alpha_1+i\epsilon}t^c-t^a\frac{1}{\alpha+i\epsilon}t^c\frac{1}{\alpha_1-i\epsilon}t^b+t^b\frac{1}{\alpha_1+i\epsilon}t^a\frac{1}{\alpha+\alpha_1+i\epsilon}t^c\tag{16}$$

$$+t^c\frac{1}{\alpha+\alpha_1-i\epsilon}t^a\frac{1}{\alpha_1-i\epsilon}t^b-t^b\frac{1}{\alpha_1+i\epsilon}t^c\frac{1}{\alpha-i\epsilon}t^a+t^c\frac{1}{\alpha+\alpha_1-i\epsilon}t^b\frac{1}{\alpha-i\epsilon}t^a\Big)\hat p_1\psi$$

$$=\ C^a_*(\alpha)B^b_*(\alpha_1)B^c_*(-\alpha-\alpha_1)\bar\psi\Big(t^at^bt^c\frac{1}{(\alpha+i\epsilon)(\alpha+\alpha_1+i\epsilon)}-t^at^ct^b\Big[\frac{1}{(\alpha+i\epsilon)(\alpha+\alpha_1)}+\frac{1}{(\alpha_1-i\epsilon)(\alpha+\alpha_1)}\Big]$$

$$+t^bt^at^c\frac{1}{(\alpha_1+i\epsilon)(\alpha+\alpha_1+i\epsilon)}+t^ct^at^b\frac{1}{(\alpha+\alpha_1-i\epsilon)(\alpha_1-i\epsilon)}-t^bt^ct^a\Big[\frac{1}{(\alpha-i\epsilon)(\alpha+\alpha_1)}+\frac{1}{(\alpha_1+i\epsilon)(\alpha+\alpha_1)}\Big]$$

$$+\ t^ct^bt^a\frac{1}{(\alpha+\alpha_1-i\epsilon)(\alpha-i\epsilon)}\Big)\hat p_1\psi\ =\ C^a_*(\alpha)B^b_*(\alpha_1)B^c_*(-\alpha-\alpha_1)\bar\psi\Big(\frac{\big[t^a,[t^b,t^c]\big]}{\alpha(\alpha+\alpha_1)}+\frac{\big[t^b,[t^a,t^c]\big]}{\alpha_1(\alpha+\alpha_1)}\Big)\hat p_1\psi$$

$$\sim\ C^a_*(\alpha,\beta)B^b_*(\alpha_1)B^c_*(-\alpha-\alpha_1)\partial^2A^n_\bullet(-\beta)\Big[\frac{f^{amn}f^{bcm}}{\alpha(\alpha+\alpha_1)}+\frac{f^{acm}f^{bmn}}{\alpha_1(\alpha+\alpha_1)}\Big]\tag{17}$$

Zapishem po-drugomu

$$\sim\ C^k_*(\alpha_1+\alpha_2)B^a_*(-\alpha_1)B^b_*(-\alpha_2)\bar\psi\Big(\frac{\big[t^a,[t^b,t^k]\big]}{\alpha_1(\alpha_1+\alpha_2)}+\frac{\big[t^b,[t^a,t^k]\big]}{\alpha_2(\alpha_1+\alpha_2)}\Big)\hat p_1\psi$$

$$\sim\ C^c_*(\alpha_1+\alpha_2,\beta)B^a_*(-\alpha_1)B^b_*(-\alpha_2)\partial^2A^n_\bullet(-\beta)\Big[\frac{f^{amn}f^{bcm}}{\alpha_1(\alpha_1+\alpha_2)}+\frac{f^{acm}f^{bmn}}{\alpha_2(\alpha_1+\alpha_2)}\Big]\tag{18}$$

1. Lvertices

$$-i\langle\psi(x)\bar{\psi}(y)\rangle_{A_*} = \frac{2}{s}\langle\psi(x)\bar{\psi}(z)\rangle\hat{p}_1 A_*(z)\langle\psi(z)\bar{\psi}(y)\rangle - \frac{2}{s}\langle\psi(x)\bar{\psi}(z)\rangle A_*(z)(z|\frac{1}{P_*}|z')A_*(z')\hat{p}_1\langle\psi(z')\bar{\psi}(y)\rangle \tag{19}$$

$$S_{\rm eff} = \frac{2}{s}\int d^4z\ \bar{\psi}(z)\hat{p}_1 A_*\psi(z) - \frac{2}{s}\int d^4zd^4z'\ \bar{\psi}(z)\hat{p}_1 A_*(z|\frac{1}{P_*+i\epsilon}|z')A_*(z')\langle\psi(z') \tag{20}$$

Y HAC $A_* = B_* + C_*$ U HADO expand do 3x powers of C_*.

First term of expansion (the lvertex)

$$S_{\rm eff} = \frac{2}{s}\int d^4z\ \bar{\psi}(z)\hat{p}_1 C_*\psi(z) - \frac{2}{s}\int d^4zd^4z'\ \bar{\psi}(z)\hat{p}_1\big[C_*(z)(z|\frac{1}{p_*+B_*+i\epsilon}|z')B_*(z') + B_*(z)(z|\frac{1}{p_*+B_*+i\epsilon}|z')C_*(z')$$
$$- B_*(z)(z|\frac{1}{p_*+B_*+i\epsilon}C_*\frac{1}{p_*+B_*+i\epsilon}|z')B_*(z')\big]\psi(z')$$
$$= \frac{2i}{s}\int d^4z\int dz'_\bullet\bar{\psi}(z_*,z_\perp)\hat{p}_1\{\theta(z_\bullet>z'_\bullet)C_*(z)[z_\bullet,z'_\bullet]_zB_*(z'_\bullet,z_\perp) + \theta(z_\bullet>z'_\bullet)B_*(z_\bullet,z_\perp)[z_\bullet,z'_\bullet]_zC_*(z)$$
$$-\int dz'_\bullet d''_\bullet\theta(z_\bullet>?z'_\bullet)\theta(z'_\bullet>?z''_\bullet)B_*(z_\bullet,z_\perp)[z_\bullet,z'_\bullet]_zC_*(z')[z'_\bullet,z''_\bullet]B_*(z''_\bullet,z_\perp)\}\bar{\psi}(z_*,z_\perp)$$
$$=?\frac{2}{s}\int d^4z\int dz'_\bullet\bar{\psi}(z_*,z_\perp)\hat{p}_1\{[-\infty,z_\bullet]C_*(z)[z_\bullet,-\infty]-C_*(z)\}\bar{\psi}(z_*,z_\perp) \tag{21}$$

Po-drugomu

$$S_{\rm eff} = \frac{2}{s}\int d^4z\ \bar{\psi}(z)\hat{p}_1 A_*\psi(z) - \frac{2}{s}\int d^4zd^4z'\ \bar{\psi}(z)\hat{p}_1 A_*(z|\frac{1}{P_*+i\epsilon}|z')A_*(z')\langle\psi(z') \tag{22}$$
$$= \frac{2}{s}\int d^4zd^4z'\ \bar{\psi}(z)\hat{p}_1\big[p_* - (z|p_*\frac{1}{P_*+i\epsilon}p_*|z')\big]\langle\psi(z') = -\frac{s}{2}\int d^4zdz'_\bullet\theta(z_\bullet-z'_\bullet)\bar{\psi}(z_*,z_\perp)\hat{p}_1\frac{\partial}{\partial z_\bullet}\frac{\partial}{\partial z'_\bullet}[z_\bullet,z'_\bullet]_z\psi(z_*,z_\perp)$$
$$= \int d^2z_\perp dz_*dz_\bullet\bar{\psi}(z_*,z_\perp)[\infty,z_\bullet]_zC_*(z)[z_\bullet,-\infty]_z\psi(z_*,z_\perp) \tag{23}$$

bikoz

$$\frac{\partial}{\partial z_\bullet}\frac{\partial}{\partial z'_\bullet}{\rm Pexp}\Big\{i\frac{2}{s}\int_{z'_\bullet}^{z_\bullet}dz''_\bullet\ (B_*+C_*)\Big\} = \frac{\partial}{\partial z_\bullet}\frac{\partial}{\partial z'_\bullet}i\frac{2}{s}\int_{z'_\bullet}^{z_\bullet}dz''_\bullet\ [z_\bullet,z''_\bullet]C_*(z''_\bullet)[z''_\bullet,z'_\bullet] \tag{24}$$

Eq. (22) korrespondz 2

$$\int dz_*\Big(t^at^bt^c\int_{z_*}^{\infty}dz'_*\int_{z_*}^{z'_*}dz''_* + t^at^ct^b\int_{z_*}^{\infty}dz'_*\int_{-\infty}^{z_*}dz''_* + t^ct^at^b\int_{-\infty}^{z_*}dz'_*\int_{-\infty}^{z'_*}dz''_*\Big)e^{-i\alpha_1z'_\bullet-i\alpha_2z''_\bullet-i\alpha z_\bullet}B^a_\bullet(\alpha_1)B^b_\bullet(\alpha_2)C^c_\bullet(\alpha)$$
$$= \delta(\alpha_1+\alpha_2+\alpha)\Big[-\frac{t^at^bt^c}{(\alpha_1-i\epsilon)(\alpha_1+\alpha_2-i\epsilon)} + \frac{t^at^cbt^b}{(\alpha_1-i\epsilon)(\alpha_2+i\epsilon)} - \frac{t^ct^at^b}{(\alpha_2+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)}\Big)B^a_\bullet(\alpha_1)B^b_\bullet(\alpha_2)C^c_\bullet(\alpha) \tag{25}$$

Perepishem fla (16)

$$C^c_*(\alpha)B^a_*(\alpha_1)B^c_*(\alpha_2=-\alpha-\alpha_1)\bar{\psi}\big(t^c\frac{1}{-\alpha_1-\alpha_2+i\epsilon}t^a\frac{1}{-\alpha_2+i\epsilon}t^b + t^c\frac{1}{-\alpha_1-\alpha_2+i\epsilon}t^b\frac{1}{-\alpha_1+i\epsilon}t^a + t^a\frac{1}{\alpha_1+i\epsilon}t^c\frac{1}{-\alpha_2+i\epsilon}t^b$$
$$+t^b\frac{1}{\alpha_2+i\epsilon}t^c\frac{1}{-\alpha_1+i\epsilon}t^a + t^a\frac{1}{\alpha_1+i\epsilon}t^b\frac{1}{\alpha_1+\alpha_2+i\epsilon}t^c + t^b\frac{1}{\alpha_2+i\epsilon}t^a\frac{1}{\alpha_1+\alpha_2+i\epsilon}t^c\big)\hat{p}_1\psi$$
$$= C^c_*(\alpha)B^a_*(\alpha_1)B^b_*(\alpha_2)\bar{\psi}\Big(\frac{t^ct^at^b}{(\alpha_2-i\epsilon)(\alpha_1+\alpha_2-i\epsilon)} + \frac{t^ct^bt^a}{(\alpha_1-i\epsilon)(\alpha_1+\alpha_2-i\epsilon)}$$
$$+ \frac{t^at^ct^b}{(\alpha_1+i\epsilon)(-\alpha_2+i\epsilon)} + \frac{t^bt^ct^a}{(\alpha_2+i\epsilon)(-\alpha_1+i\epsilon)} + \frac{t^at^bt^c}{(\alpha_1+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)} + \frac{t^bt^at^c}{(\alpha_1+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)}\Big)\hat{p}_1\psi$$
$$= C^c_*(\alpha)B^a_*(\alpha_1)B^b_*(\alpha_2)\bar{\psi}\Big(\frac{\big[[t^c,t^a],t^b\big]}{\alpha_2(\alpha_1+\alpha_2)} + \frac{\big[[t^c,t^b],t^a\big]}{\alpha_1(\alpha_1+\alpha_2)}\Big)\hat{p}_1\psi$$
$$\sim C^c_*(\alpha,\beta)B^a_*(\alpha_1)B^b_*(\alpha_2)\partial^2A^n_\bullet(-\beta)\Big[\frac{f^{acm}f^{bmn}}{\alpha_2(\alpha_1+\alpha_2)} + \frac{f^{bcm}f^{amn}}{\alpha_1(\alpha_1+\alpha_2)}\Big] \tag{26}$$

Nau, gipoteza dlya retarded fankshns

$$\int d^2z_\perp dz_* dz_\bullet \bar\psi(z_*,z_\perp)[-\infty,z_\bullet]_z C(z)[z_\bullet,-\infty]_z\psi(z_*,z_\perp) \tag{27}$$

korrespondz 2

$$\begin{aligned}
&\int dz_*\Big(t^at^bt^c\int_{z_*}^{-\infty}dz'_*\int_{z_*}^{z'_*}dz''_* + t^at^ct^b\int_{z_*}^{-\infty}dz'_*\int_{-\infty}^{z_*}dz''_* + t^ct^at^b\int_{-\infty}^{z_*}dz'_*\int_{-\infty}^{z'_*}dz''_*\Big)e^{-i\alpha_1z'_\bullet-i\alpha_2z''_\bullet-i\alpha z_\bullet}B^a_\bullet(\alpha_1)B^b_\bullet(\alpha_2)C^c_\bullet(\alpha)\\
=&\ \delta(\alpha_1+\alpha_2+\alpha)\Big[-\frac{t^at^bt^c}{(\alpha_1+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)}+\frac{t^at^ct^b}{(\alpha_1+i\epsilon)(\alpha_2+i\epsilon)}-\frac{t^ct^at^b}{(\alpha_2+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)}\Big)B^a_\bullet(\alpha_1)B^b_\bullet(\alpha_2)C^c_\bullet(\alpha)\\
=&\ \delta(\alpha_1+\alpha_2+\alpha)\Big[-\frac{t^a[t^b,t^c]}{(\alpha_1+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)}-\frac{[t^c,t^a]t^b}{(\alpha_2+i\epsilon)(\alpha_1+\alpha_2+i\epsilon)}\Big)B^a_\bullet(\alpha_1)B^b_\bullet(\alpha_2)C^c_\bullet(\alpha)
\end{aligned}\tag{28}$$

ИТОГО

$$\begin{aligned}
D^\mu\mathcal{G}_{\mu i} &= -\frac{2}{s}f^{abc}(B^b_*\partial_iA^c_\bullet + A^b_\bullet\partial_iB^c_*)\\
D^\mu\mathcal{G}_{\mu\bullet} &= \frac{2}{s}\bar D^{aa'}_\bullet f^{a'bc}B^b_*A^c_\bullet - \big(\frac{1}{\bar P_*+i\epsilon}B_*\big)^{ab}\partial_\perp^2A^b_\bullet = \frac{2}{s}\bar D^{ab}_\bullet\bar G^b_{*\bullet} - \big(\frac{1}{\bar P_*+i\epsilon}B_*\big)^{ab}\partial_\perp^2A^b_\bullet\\
D^\mu\mathcal{G}_{\mu *} &= \frac{2}{s}\bar D^{aa'}_* f^{a'bc}A^b_\bullet B^c_* - \big(\frac{1}{\bar P_\bullet+i\epsilon}A_\bullet\big)^{ab}\partial_\perp^2B^b_* = -\frac{2}{s}\bar D^{ab}_*\bar G^b_{*\bullet} - \big(\frac{1}{\bar P_\bullet+i\epsilon}A_\bullet\big)^{ab}\partial_\perp^2B^b_*\\
D^\mu\mathcal{G}_{\mu\nu} &= \bar D^\mu\bar G_{\mu\nu} - \partial^2\bar A_\mu - l_\mu, \qquad l^a_\mu \equiv \frac{2}{s}p_{1\mu}\big(\frac{1}{P_\bullet}\bar A_\bullet\big)^{ab}\partial_\perp^2\bar A^b_* + \frac{2}{s}p_{2\mu}\big(\frac{1}{P_*}\bar A_*\big)^{ab}\partial_\perp^2\bar A^b_\bullet
\end{aligned}\tag{29}$$

Chek:

$$\begin{aligned}
\bar D^\nu D^\mu\mathcal{G}_{\mu\nu} &= \frac{2}{s}f^{abc}\Big[-\partial^i(B^b_*\partial_iA^c_\bullet + A^b_\bullet\partial_iB^c_*)\\
&+ \frac{2}{s}(\bar D_*)^{aa'}\big[\frac{2}{s}\bar D^{a'b}_\bullet\bar G^b_{*\bullet} - \big(\frac{1}{\bar P_*+i\epsilon}B_*\big)^{a'b}\partial_\perp^2A^b_\bullet\big] + \frac{2}{s}(\bar D_\bullet)^{aa'}\big[-\frac{2}{s}\bar D^{a'b}_*\bar G^b_{*\bullet} - \big(\frac{1}{\bar P_\bullet+i\epsilon}A_\bullet\big)^{a'b}\partial_\perp^2B^b_*\big]\\
&= \frac{4}{s^2}[\bar D_*,\bar D_\bullet]^{ab}\bar G^b_{*\bullet} - \frac{2}{s}f^{abc}\partial_i(B^b_*\partial_iA^c_\bullet + A^b_\bullet\partial_iB^b_*) - \frac{2}{s}f^{abc}(B^b_*\partial_\perp^2A^c_\bullet + A^b_\bullet\partial_\perp^2B^c_*) = 0
\end{aligned}\tag{30}$$

2. *Exersize with scalar quarks*

Vertex: $\bar\phi_k(x)\phi_k(x)\Phi(x)$

$$\begin{aligned}
&i\bar\phi^m_A(x)\phi^m_C(x)\int d^4z\ \bar\phi^k_C(z)\{p^\mu,A_\mu\}_{kl}\phi^l_B(z) = \int d^4z\ \bar\phi^m_A(x)(z|2\alpha\frac{1}{m^2+\vec p^2-\alpha\beta s-i\epsilon}|x)_{mk}A^{kl}_\bullet(z_*,z_\perp)\phi^l_B(z)\\
&\stackrel{\alpha\geq 0}{=} -\int d^4z\ \bar\phi^m_A(x_*,x_\perp)(x|\frac{2}{\beta s+i\epsilon}|z)A^{kl}_\bullet(z_*,z_\perp)\phi^l_B(z_\bullet,z_\perp) = -\frac{2}{s}\int dz_*\ \bar\phi^k_A(x_*,x_\perp)A^{kl}_\bullet(z_*,x_\perp)\int\frac{d\!\!\!{}^-\beta}{\beta+i\epsilon}e^{-i\beta(x_*-z_*)}\phi^l_B(x_\bullet,x_\perp)\\
&= \bar\phi^k_A(x_*,x_\perp)\frac{2i}{s}\int_{-\infty}^{x_*}dz_*A^{kl}_\bullet(z_*,x_\perp)\phi^l_B(x_\bullet,x_\perp) \to \bar\phi^k_A(x_*,x_\perp)[x_*,-\infty]^{kl}_x\phi^l_B(x_\bullet,x_\perp)
\end{aligned}\tag{31}$$

which agrees with

$$\bar\phi^k(x)\langle\phi^k(x)\phi^l(y)\rangle_A = \bar\phi^k(x)[x_*,-\infty]^{kl}(x|\frac{i}{p^2+i\epsilon}|y) \Rightarrow \bar\phi^k_A(x)[\phi^k_B(x)+\phi^k_C(x)] = \int d^4z\ \bar\phi^k_A(x)(x|\frac{1}{P^2+i\epsilon}p^2|z)^{kl}\phi^l_B(z) \tag{32}$$

First order in B_*

$$\begin{aligned}
&\int d^4zd^4z'\ (x|\frac{1}{(p+A)^2+i\epsilon}\{p,A\}|z')^{kl}\phi^l_B(z')(x|\frac{1}{(p+A)^2+i\epsilon}\{p+A,B\}|z)^{km}\phi^m_A(z)\\
&\stackrel{\alpha\geq 0}{=} [x_*,-\infty]^{kl}_x\phi^l_B(x_\bullet,x_\perp)\frac{1}{s}(x|\frac{1}{P^2+i\epsilon}\{P_\bullet,B_*\}|z)^{km}\phi^m_A(z)\\
&= \bar\phi^k_A(x_*,x_\perp)\frac{2i}{s}\int_{-\infty}^{x_*}dz_*A^{kl}_\bullet(z_*,x_\perp)\phi^l_B(x_\bullet,x_\perp) \to \bar\phi^k_A(x_*,x_\perp)[x_*,-\infty]^{kl}_x\phi^l_B(x_\bullet,x_\perp)
\end{aligned}\tag{33}$$

A. Gluon in the bF gauge

Split the fields in up, down, and "eikonal" $A\to A+B+C$. The field B (up) do not depend on z_* (at least, the dependence is negligible). Similarly, fields A (down) do not depend on $z_\bullet$. The propagator of C fields will be local in $x_\perp$.

$$F_{\mu\nu} ~=~ (A+B)_{\mu\nu}+(D_\mu C_\nu-\mu\leftrightarrow\nu)-i[C_\mu,C_\nu],\qquad (A+B)_{\mu\nu}~\equiv~A_{\mu\nu}+B_{\mu\nu}-i[A_\mu,B_\nu]-i[B_\mu,A_\nu] \tag{34}$$

$$\begin{aligned}-\frac{1}{4}F^a_{\mu\nu}F^{a\mu\nu}-\frac{1}{2}[(D_\mu C_\mu]^2 ~=~& -\frac{1}{2}\mathrm{Tr}\{(A_{\mu\nu}+B_{\mu\nu}-i[A_\mu,B_\nu]-i[B_\mu,A_\nu])^2\}\\ +\,2\mathrm{Tr}\{C^\nu D^\mu(A+B)_{\mu\nu}\}-&\frac{1}{2}\mathrm{Tr}\{C^\mu(D^2g_{\mu\nu}-2i[(A+B)_{\mu\nu},)C^\nu\}-2i\mathrm{Tr}\{D^\mu C_\nu[C^\mu,C^\nu]\}+...\end{aligned} \tag{35}$$

Linear term

$$2\mathrm{Tr}\{C^\nu D^\mu(A+B)_{\mu\nu}\}~=~C^{a\nu}(D^\mu(A+B)_{\mu\nu})^a \tag{36}$$

$$\begin{aligned}C^a_\alpha(x)~\to~& A^a_\alpha(x)+B^a_\alpha(x)+i\int dz~\langle C^a_\alpha(x)C^{\mu b}(x)\rangle(D^\mu(A+B)_{\mu\nu})^b\\ =~& A^a_\alpha(x)+B^a_\alpha(x)+\int dz~(x|\Big(\frac{1}{P^2g_{\alpha\nu}+2i(A+B)_{\alpha\nu}}\Big)^{ab}(D^\mu(A+B)_{\mu\nu})^b|z)\end{aligned} \tag{37}$$

Now we keep all orders in A but only one in B. By kinematics, this only B must be from $(D^\mu(A+B)_{\mu\nu})$ since pure A's cannot produce C gluon. Thus,

$$(D^\mu(A+B)_{\mu\nu})~\to~(D^2g_{\nu\mu}-2iA_{\nu\mu})^{ab}B^{b\mu}-D_\nu D_\mu B^\mu \tag{38}$$

Also, B alone cannot produce C gluon so the term $(\partial^2g_{\nu\mu}-\partial_\mu\partial_\nu)B^\mu$ must be subtracted, so

$$(D^\mu(A+B)_{\mu\nu})^b~\to~(D^2g_{\nu\mu}-2iA_{\nu\mu})^{bc}B^{c\mu}-(D_\nu D_\mu B^\mu)^b-(\partial^2g_{\nu\mu}-\partial_\mu\partial_\nu)B^{b\mu} \tag{39}$$

and we get

$$\begin{aligned}&A^a_\alpha(x)+B^a_\alpha(x)+C^a_\alpha(x)~\to~A^a_\alpha(x)+B^a_\alpha(x)+i\int dz~\langle C^a_\alpha(x)C^{b\nu}(z)\rangle(D^\mu(A+B)_{\mu\nu})^b(z)~=~A^a_\alpha(x)+B^a_\alpha(x)\\ &+\int dz~(x|\Big(\frac{1}{P^2g_{\alpha\nu}+2iA_{\alpha\nu}}\Big)^{ab}(D^2g_{\nu\Omega}-2iA_{\nu\Omega}-D_\nu D_\Omega)^{bc}|z)B^{c\Omega}(z)-\int dz~(x|\Big(\frac{1}{P^2g_{\alpha\nu}+2iA_{\alpha\nu}}\Big)^{ab}(\partial^2g_{\nu\Omega}-\partial_\nu\partial_\Omega|z)B^{b\Omega}(z)\\ &=~A^a_\alpha(x)+\int dz~(x|P_\alpha\frac{1}{P^2}P^\mu|x)^{ab}B^b_\mu(z)-\int dz~(x|\Big(\frac{1}{P^2g_{\alpha\nu}+2iA_{\alpha\nu}}\Big)^{ab}(\partial^2g_{\nu\Omega}-\partial_\nu\partial_\Omega|z)B^{b\Omega}(z)~+~O(D^\mu A_{\mu\nu})\end{aligned} \tag{40}$$

If $\alpha=*$

$$\begin{aligned}&\int dz~(x|P_*\frac{1}{P^2+i\epsilon}P^\Omega|x)^{ab}B^b_\Omega(z)-\int dz~(x|\frac{1}{P^2+i\epsilon}(\partial^2p_{2\Omega}-\partial_\Omega\partial_*)|z)^{ab}B^{b\mu}(z)\\ &=~\int dz~(x|\frac{\alpha}{P^2}P_\bullet|z)^{ab}B^m_*(z)-\int dz~(x|\frac{1}{P^2}(\partial^2-\frac{2}{s}\partial_\bullet\partial_*)|z)^{ab}B^b_*(z)\\ &=~\int dz~(x|\frac{\alpha}{P^2}P_\bullet|z)^{ab}B^m_*(z)+\int dz~(x|\frac{1}{P^2}(\alpha p_\bullet-p_\perp^2)|z)^{ab}B^b_*(z)~=~B^a_*(x)-~\int dz~(x|\frac{\alpha}{P^2+i\epsilon}A_\bullet|x)^{ab}B^b_*(z)\end{aligned} \tag{41}$$

Decompose $B_*(z_\bullet)~=~B^{\alpha>0}_*+B^{\alpha<0}_*~=~B^+(z_\bullet)+B^-(z_\bullet)$

$$\begin{aligned}&\int dz~(x|\frac{\alpha}{P^2+i\epsilon}A_\bullet|z)^{ab}B^{b+}_*(z)~+~\int dz~(z|\frac{\alpha}{P^2+i\epsilon}A_\bullet|x)^{ab}B^{b-}_*(z)\\ &=~\frac{1}{2}\int dz~(z|\frac{1}{P_\bullet+i\epsilon}A_\bullet|z)^{ab}B^{b+}_*(z)~+~\frac{1}{2}\int dz~(x|\frac{1}{P_\bullet-i\epsilon}A_\bullet|z)^{ab}B^{m-}_*(z)\\ &=~\frac{1}{2}B^a_*(x)+\frac{is}{4}\int dz~\frac{\partial}{\partial z_*}(x|\frac{1}{P_\bullet+i\epsilon}|z)^{ab}B^{b+}_*(z)~+~\frac{is}{4}\int dz~\frac{\partial}{\partial z_*}(x|\frac{1}{P_\bullet-i\epsilon}|z)^{ab}B^{m-}_*(z)\\ &=~\frac{1}{2}B^a_*(x)+\frac{1}{2}\int dz_*~\frac{\partial}{\partial z_*}\theta(x_*-z_*)[x_*,z_*]^{ab}B^{b+}_*(x_\bullet,x_\perp)~-~\frac{1}{2}\int dz_*~\frac{\partial}{\partial z_*}[x_*,z_*]^{ab}\theta(z_*-x_*)B^{b-}_*(x_\bullet,x_\perp)\\ &=~\frac{1}{2}B^a_*(x)-\frac{1}{2}[x_*,-\infty]^{ab}B^{b+}_*(x_\bullet,x_\perp)~-~\frac{1}{2}\int dz_*~[x_*,\infty]^{ab}B^{b-}_*(x_\bullet,x_\perp)\end{aligned} \tag{42}$$

ΓDE DBOЙKA?

1ce again in the leading order in B:

$$D^\mu(A+B)_{\mu *} \;=\; (D_A^\mu - i[B^\mu)(A_{\mu *} + D_\mu^A B_* - D_*^A B_\mu) \;+\; O(B^2) \;=\; D_A^2 B_* - \frac{2}{s} D_*^A D_\bullet^A B_* \tag{43}$$

$$\begin{aligned}
C_*^a(x) \;&\to\; A_*^a(x) + B_*^a(x) + i\int dz\ \langle C_*^a(x) C^{\mu b}(x)\rangle (D^\mu(A+B)_{\mu\nu})^b \\
=\; & B_*^a(x) + \int dz\ (x|\frac{1}{(p+A)^2}|z)^{ab}(D^\mu(A+B)_{\mu *} - (A=0))^b(z) =\; B_*^a(x) - \int dz\ (x|\frac{1}{(p+A)^2}(\{p,A\} - \alpha A_\bullet)|z)^{ab} B_*(z) \\
=\; & B_*^a(x) - \int dz\ (x|\frac{1}{2\alpha P_\bullet + i\epsilon}(2\alpha A_\bullet - \alpha A_\bullet)|z)^{ab} B_*(z) \;=\; B_*^a(x) - \int dz\ (x|\frac{1}{P_\bullet + i\epsilon\alpha}(A_\bullet - \frac{1}{2}A_\bullet)|z)^{ab} B_*(z)
\end{aligned} \tag{44}$$

$$\int dz\ (x|\frac{1}{P_\bullet + i\epsilon\alpha} A_\bullet |z)^{ab} B_*(z)$$

$$\begin{aligned}
&\int dz\ (x|\frac{1}{P_\bullet + i\epsilon\alpha} A_\bullet|z)^{ab} B_*(z) \;=\; \int dz\ (x|\frac{1}{P_\bullet + i\epsilon} A_\bullet|z)^{ab} B_*^{b+}(z) \;+\; \int dz\ (z|\frac{1}{P_\bullet - i\epsilon} A_\bullet|x)^{ab} B_*^{b-}(z) \\
=\; & \int dz\ (z|\frac{1}{P_\bullet + i\epsilon} A_\bullet|z)^{ab} B_*^{b+}(z) \;+\; \int dz\ (x|\frac{1}{P_\bullet - i\epsilon} A_\bullet|z)^{ab} B_*^{m-}(z) \\
=\; & B_*^a(x) + \frac{is}{4}\int dz\ \frac{\partial}{\partial z_*}(x|\frac{1}{P_\bullet + i\epsilon}|z)^{ab} B_*^{b+}(z) \;+\; \frac{is}{2}\int dz\ \frac{\partial}{\partial z_*}(x|\frac{1}{P_\bullet - i\epsilon}|z)^{ab} B_*^{m-}(z) \\
=\; & B_*^a(x) + \int dz_*\ \frac{\partial}{\partial z_*}\theta(x_* - z_*)[x_*, z_*]^{ab} B_*^{b+}(x_\bullet, x_\perp) \;-\; \int dz_*\ \frac{\partial}{\partial z_*}[x_*, z_*]^{ab}\theta(z_* - x_*) B_*^{b-}(x_\bullet, x_\perp) \\
=\; & B_*^a(x) - [x_*, -\infty]^{ab} B_*^{b+}(x_\bullet, x_\perp) \;-\; \int dz_*\ [x_*, \infty]^{ab} B_*^{b-}(x_\bullet, x_\perp) \;=\; B_*^a(x) - [x_*, -\infty\alpha]^{ab} B_*^b(x_\bullet, x_\perp)
\end{aligned} \tag{45}$$

B. Lorentz gauge

$$D^\mu G_{\mu\nu} \;=\; D^\mu A_{\mu\nu} + D^\mu B_{\mu\nu} \;\Rightarrow\; (D^2 g_{\mu\nu} - 2iG_{\mu\nu}^{A+B} - D_\mu D_\nu) C^\nu \;=\; (D^\mu G_{\mu\nu})^{A+B} - D^\mu A_{\mu\nu} - D^\mu B_{\mu\nu} \tag{46}$$

Lorentz gauge $\partial^\mu C_\mu \;=\; 0$

$$C_\mu \;=\; \int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iG_{\mu\nu} - P_\mu A_\nu}|z)[(D^\mu G_{\mu\nu})^{A+B} - D^\mu A_{\mu\nu} - D^\mu B_{\mu\nu}](z) \tag{47}$$

In the leading order in B

$$\begin{aligned}
C_\mu \;&=\; -\int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu} - P_\mu A_\nu}|z)[(P^2 g_{\nu\Omega} + 2iA_{\nu\Omega} - P_\nu P_\Omega - p^2 g_{\nu\Omega} + p_\nu p_\Omega)|z) B^\Omega(z) \\
&=\; -\int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu} - P_\mu A_\nu}|z)[(P^2 g_{\nu\Omega} + 2iA_{\nu\Omega} - P_\nu A_\Omega - p^2 g_{\nu\Omega})|z) B^\Omega(z) \\
&=\; -B_\mu + \int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu} - P_\mu A_\nu} p^2|z) B_\nu(z) =\; -B_\mu + \frac{2}{s}\int dz\ (x|\frac{1}{P^2 g_{\mu\bullet} + 2iA_{\mu\bullet} - P_\mu A_\bullet} p^2|z) B_*(z)
\end{aligned} \tag{48}$$

$$C_* \;=\; -B_* + \int dz\ (x|\frac{1}{P^2 - \frac{2}{s}P_* A_\bullet} p^2|z) B_*(z) \;=\; -B_* + \int dz\ (x|\frac{1}{P_\bullet - \frac{1}{2}A_\bullet - i\epsilon\alpha} p_\bullet|z) B_*(z) \tag{49}$$

C. Background-Lorentz gauge

$$(\partial_\mu - iA_\mu - iB_\mu)C^\mu \;=\; 0 \Rightarrow$$

$$C^a_\mu \;=\; \int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iG_{\mu\nu}}|z)^{ab}[(D^\mu G_{\mu\nu})^{A+B} - D^\mu A_{\mu\nu} - D^\mu B_{\mu\nu}]^b(z) \tag{50}$$

In the leading order in B

$$\begin{aligned}
C^a_\mu \;&=\; -\int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu}}|z)[(P^2 g_{\nu\Omega} + 2iA_{\nu\Omega} - P_\nu P_\Omega - p^2 g_{\nu\Omega} + p_\nu p_\Omega)|z)^{ab} B^{b\Omega}(z)\\
&=\; -\int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu}}|z)[(P^2 g_{\nu\Omega} + 2iA_{\nu\Omega} - P_\nu A_\Omega - p^2 g_{\nu\Omega})|z)B^\Omega(z)\\
&=\; -B_\mu + \int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu}}p^2|z)B_\nu(z) + \int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu}}P_\nu A_\Omega|z)B_\Omega(z)\\
&=\; -B_\mu + \frac{2}{s}\int dz\ (x|\frac{1}{P^2 g_{\mu\bullet} + 2iA_{\mu\bullet} - i\epsilon}p^2|z)^{ab} B^b_*(z) + \frac{2}{s}\int dz\ (x|\frac{1}{P^2 g_{\mu\nu} + 2iA_{\mu\nu} - i\epsilon}P_\nu A_\bullet|z)^{ab} B^b_*(z)
\end{aligned} \tag{51}$$

$$\begin{aligned}
C^a_* \;&=\; -B^a_* + \int dz\ (x|\frac{1}{P^2 + i\epsilon}p^2|z)^{ab} B^b_*(z) + \int dz\ (x|\frac{1}{P^2 + i\epsilon}\alpha A_\bullet|z)^{ab} B^b_*(z)
\end{aligned} \tag{52}$$

$$= \; -\frac{1}{2}\int dz\ (x|\frac{1}{P_\bullet + i\epsilon\alpha}A_\bullet|z)^{ab} B^b_*(z)$$

$$\Rightarrow\ C_*(x) \;=\; \frac{i}{s}\int_{-\infty}^{x_*} dz_*[x_*, z_*]_x[A_\bullet(z_*, x_\perp), B_*(x_\bullet, x_\perp)][z_*, x_*]_x \;=\; -\frac{1}{2}B_*(x_\bullet, x_\perp) + \frac{1}{2}[x_*, -\infty\alpha]_x B_*(x_\bullet, x_\perp)[-\infty\alpha, x_*]_x$$

In the first order in A and B

$$C_* \;=\; -\int dz\ (x|\frac{1}{p^2 + i\epsilon}(2\alpha A_\bullet - \alpha A_\bullet)|z)B_*(z)\ \Leftrightarrow\ C^a_* \;=\; -if^{abc}\int dz\ (x|\frac{1}{p^2 + i\epsilon}(2\alpha A^b_\bullet - \alpha A^b_\bullet)(z)B^c_*(z) \tag{53}$$

ΦΟΡΜΥΛΑ

$$P_\mu \frac{1}{P^2 g_{\mu\nu} + 2iG_{\mu\nu}} \;=\; \frac{1}{P^2}P_\nu + \frac{1}{P^2}D^\alpha G_{\alpha\beta}\frac{1}{P^2 g_{\beta\nu} + 2iG_{\beta\nu}} \tag{54}$$

1. *From 3-gluon vertex*

Vershina

$$\exp\big\{-ig\int dz f^{mnl} A^m_\mu A^n_\nu (D^\mu A^\nu)^l\big\} \;=\; \exp\big\{\frac{g}{3!}\int đk_1 đk_2\ A^m_\mu(k_1)A^n_\nu(k_2)A^l_\Omega(-k_1-k_2)\ f^{mnl}\Gamma^{\mu\nu\Omega}(k_1, k_2, -k_1-k_2)\big\}$$

$$\Gamma_{\mu\nu;\Omega}(k_1, k_2) \equiv \Gamma_{\mu\nu\Omega}(k_1, k_2, -k_1-k_2) = (k_1-k_2)_\Omega g_{\mu\nu} + (2k_2+k_1)_\mu g_{\nu\Omega} + (-2k_1-k_2)_\nu g_{\Omega\mu} \tag{55}$$

$$\begin{aligned}
&\langle C^a_\alpha(x)\ \exp\big\{\frac{g}{3!}\int đk_1 đk_2\ (A+B+C)^m_\mu(k_1)(A+B+C)^n_\nu(k_2)(A+B+C)^l_\Omega(-k_1-k_2)\ f^{mnl}\Gamma^{\mu\nu\Omega}(k_1, k_2, -k_1-k_2)\big\}\rangle\\
&=\; f^{mnl}\int đk_1 đk_2 \langle C_\alpha(x) C^l_\Omega(-k_1-k_2)\rangle \frac{g}{2}(A+B)^m_\mu(k_1)(A+B)^n_\nu(k_2)\Gamma^{\mu\nu\Omega}(k_1, k_2, -k_1-k_2)\\
&=\; gf^{mnl}\int đk_1 đk_2 \langle C_\alpha(x) C^l_\Omega(-k_1-k_2)\rangle A^m_\mu(k_1)B^n_\nu(k_2)\Gamma^{\mu\nu\Omega}(k_1, k_2, -k_1-k_2)\\
&=\; -i\frac{2}{s}gf^{mnl}\int đk_1 đk_2 \frac{e^{-i(k_1+k_2)x}}{(k_1+k_2)^2}[(2\alpha_1+\alpha_2)p_1 - (2\beta_2+\beta_1)p_2 + (k_1-k_2)^\perp]_\alpha A^m_\bullet(k_1)B^n_*(k_2)\\
&=\; -i\frac{2}{s}gf^{mnl}\int đk_1 đk_2 \frac{e^{-i\alpha_2 x_\bullet - i\beta_1 x_* + i(k_1+k_2, x)_\perp}}{\alpha_2\beta_1 s - (k_1+k_2)^2_\perp + i\epsilon}[\alpha_2 p_1 - \beta_1 p_2 + (k_1-k_2)^\perp]_\alpha A^m_\bullet(k_{1_\perp}, \beta_k)B^n_*(k_2)\\
&=\; \frac{2}{is}gf^{mnl}\int đk^\perp_1 đk^\perp_2 \frac{e^{-i\alpha_2(x-z_2)_\bullet - i\beta_1(x-z_1)_* + i(k_1+k_2, x)_\perp - i(k_1, z_1)_\perp - i(k_2, z_2)_\perp}}{\alpha_2\beta_1 s - (k_1+k_2)^2_\perp + i\epsilon}[\alpha_2 p_1 - \beta_1 p_2 + (k_1-k_2)^\perp]_\alpha A^m_\bullet(z_1)B^n_*(z_2)dz_{1*}dz_{2\bullet}đ\alpha_2 đ\beta_1
\end{aligned}$$

Assumption: drop $(k_1+k_2)^2_\perp$ in the denominator

$$= \frac{2}{is} g f^{mnl} \int đ k_1^\perp đ k_2^\perp e^{-i\alpha_2(x-z_2)_\bullet - i\beta_1(x-z_1)_* + i(k_1+k_2,x)_\perp - i(k_1,z_1)_\perp - i(k_2,z_2)_\perp} \frac{[\alpha_2 p_1 - \beta_1 p_2 + (k_1-k_2)^\perp]_\alpha}{\alpha_2\beta_1 s + i\epsilon} A^m_\bullet(z_1) B^n_*(z_2) dz_{1*} dz_{2\bullet} đ\alpha_2 đ\beta_1$$
$$= \frac{2}{is^2} g f^{mnl} \int dz_{1*} dz_{2\bullet} đ\alpha_2 đ\beta_1 \; e^{-i\alpha_2(x-z_2)_\bullet - i\beta_1(x-z_1)_*} \Big(\big[\frac{p_1}{\beta_1 + i\epsilon\alpha_2} - \frac{p_2}{\alpha_2 + i\epsilon\beta_1}\big] A^m_\bullet(x_\perp, z_{1*}) B^n_*(x_\perp, z_{2\bullet})$$
$$+ \frac{i}{\alpha_2\beta_1 + i\epsilon} \big[(\partial^\perp_\alpha A^m_\bullet(x_\perp, z_{1*})) B^n_*(x_\perp, z_{2\bullet}) - A^m_\bullet(x_\perp, z_{1*}) \partial^\perp_\alpha B^n_*(x_\perp, z_{2\bullet})\big]\Big) \tag{56}$$

$$C^a_*(x) = \frac{1}{is} g f^{mnl} \int dz_{1*} dz_{2\bullet} đ\alpha_2 đ\beta_1 \; e^{-i\alpha_2(x-z_2)_\bullet - i\beta_1(x-z_1)_*} \frac{1}{\beta_1 + i\epsilon\alpha_2} A^m_\bullet(x_\perp, z_{1*}) B^n_*(x_\perp, z_{2\bullet})$$
$$= -\frac{1}{s} f^{amn} \int_{-\infty}^{x_*} dz_* \; A^m_\bullet(x_\perp, z_*) B^{n+}_*(x_\perp, x_\bullet) + \frac{1}{s} f^{amn} \int_{x_*}^{\infty} dz_* \; A^m_\bullet(x_\perp, z_*) B^{n-}_*(x_\perp, x_\bullet)$$
$$= \frac{1}{2}([x_*, -\infty]^{(1)}_x)^{an} B^{n+}_*(x_\perp, x_\bullet) + \frac{1}{2}([x_*, \infty]^{(1)}_x)^{an} B^{n-}_*(x_\perp, x_\bullet) = \frac{1}{2}([x_*, -\infty\alpha]^{(1)}_x)^{ab} B^b_*(x_\perp, x_\bullet) \tag{57}$$

D. Scalars

Linear term

$$\bar\phi_C[(p+A+B)^2 - (p+B)^2]\phi_B + \bar\phi_C[(p+A+B)^2 - (p+A)^2]\phi_A + \bar\phi_B[(p+A+B)^2 - (p+B)^2]\phi_C + \bar\phi_A[(p+A+B)^2 - (p+B)^2]\phi_C$$
$$= \bar\phi_C(\{p+A, B\} + B^2)\phi_A + \bar\phi_C(\{p+B, A\} + A^2)\phi_B + \bar\phi_A(\{p+A, B\} + B^2)\phi_C + \bar\phi_B(\{p+B, A\} + A^2)\phi_C \tag{58}$$

In the first order in B_*

$$\phi_A(x) + i\phi_C \int dz \bar\phi_C[(p+A+B)^2 - (p+A)^2]\phi_A(z) = \phi_A(x) - \int dz \; (x|\frac{1}{(p+A+B)^2 + i\epsilon}|z)[(p+A+B)^2 - (p+A)^2]\phi_A(z)$$
$$= \int dz \; (x|\frac{1}{(p+A+B)^2 + i\epsilon}(p+A)^2|z)\phi_A(z) = \phi_A(x) - \int dz \; \phi_A(x)(x|\frac{1}{(p+A)^2 + i\epsilon}\{p+A, B\}|z)\phi_A(z)$$
$$= \phi_A(x) - \frac{2}{s}\int dz \; (x|\frac{1}{\alpha}|z) B_*(z)\phi_A(z) + \frac{1}{s}\int dz \; (x|\frac{1}{\alpha P_\bullet + i\epsilon}|z)[A_\bullet, B_*]\phi_A(z)$$
$$= [x_\bullet, \infty\beta]^{(1)}_x \phi_A(x_*, x_\perp) + \frac{1}{s}\int dz \; (x|\frac{1}{\alpha P_\bullet + i\epsilon}|z)[A_\bullet, B_*]\phi_A(z)$$
$$= [x_\bullet, \infty\beta]^{(1)}_x \phi_A(x_*, x_\perp) + \frac{1}{s}\int dz \; (x|\frac{1}{\alpha P_\bullet + i\epsilon}[A_\bullet, B_*]\frac{1}{P_\bullet + i\epsilon\alpha} A_\bullet|z)\phi_A(z) + \frac{1}{s}\int dz \; (x|\frac{1}{\alpha P_\bullet + i\epsilon} A_\bullet|z) B_*(z)\phi_A(z) \tag{59}$$

Dobavka:

$$C_*(x) = \frac{i}{s}\int_{-\infty}^{x_*} dz_* [x_*, z_*]_x [A_\bullet(z_*, x_\perp), B_*(x_\bullet, x_\perp)][z_*, x_*]_x = -\frac{1}{2} B_*(x_\bullet, x_\perp) + \frac{1}{2}[x_*, -\infty\alpha]_x B_*(x_\bullet, x_\perp)[-\infty\alpha, x_*]_x$$

$$\frac{2i}{s}\int dz_\bullet \; C_*(z_\bullet)\phi_A(x_*, x_\perp) = \frac{1}{s}\int dz_\bullet \; ([z_*, -\infty]_x B_*(x_\perp, z_\bullet)[z_*, -\infty]_x - B_*(z_\perp, x_\bullet))\phi_A(x_*, x_\perp) \tag{60}$$

$$\bar\phi_B(x)+i\int dz\bar\phi_B(z)[(p+A+B)^2-(p+B)^2]\phi_C(z)\bar\phi_C ~=~ \bar\phi_B(x)-\int dz~\bar\phi_B(z)(z|[(p+A+B)^2-(p+B)^2]\frac{1}{(p+A+B)^2+i\epsilon}|x)$$
$$=~\int dz~\bar\phi_B(z)(z|(p+B)^2\frac{1}{(p+A+B)^2+i\epsilon}|x)$$
$$=~\int dz~\bar\phi_B(z)(z|p^2\Big[\frac{1}{(p+A)^2}-\frac{1}{(p+A)^2+i\epsilon}\{p+A,B\}\frac{1}{(p+A)^2+i\epsilon}\Big]|x)+\int dz~\bar\phi_B(z)(z|\{p,B\}\frac{1}{(p+A)^2+i\epsilon}|x)$$
$$=~\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}-\frac{1}{s}p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}\{P_\bullet,B_*\}\frac{1}{\alpha P_\bullet+i\epsilon}|x)+\frac{1}{s}\int dz~\bar\phi_B(z)(z|\{p_\bullet,B_*\}\frac{1}{\alpha P_\bullet+i\epsilon}|x)$$
$$=~\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}|x)~+~\frac{1}{s}\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}[A_\bullet,B_*]\frac{1}{\alpha P_\bullet+i\epsilon}|x)$$
$$=~\bar\phi_B(x_\bullet,x_\perp)[-\infty,x_*]~+~\frac{1}{s}\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}[A_\bullet,B_*]\frac{1}{\alpha P_\bullet+i\epsilon}|x)$$
$$=~\bar\phi_B(x_\bullet,x_\perp)[-\infty,x_*]~+~\frac{1}{s}\int_{-\infty}^{x_\bullet}dz_\bullet~\bar\phi_B(z_\bullet,x_\perp)B_*(z_\bullet,x_\perp)[-\infty,x_*]_x-\frac{1}{s}\int_{-\infty}^{x_\bullet}dz_\bullet~\bar\phi_B(z_\bullet,x_\perp)[-\infty,x_*]_xB_*(z_\bullet,x_\perp) \tag{61}$$

1 mo term

$$\bar\phi_B(x)+i\int dz\bar\phi_B(z)[(p+A+B+C)^2-(p+B)^2]\phi_C(z)\bar\phi_C ~\ni~ \int dz~\bar\phi_B(z)(z|2\alpha C_\bullet\frac{1}{(p+A)^2+i\epsilon}|x)$$
$$=$$
$$= \tag{62}$$

CYMMA

$$\bar\phi_B(x_\bullet,x_\perp)[-\infty,x_*][x_\bullet,\infty]_x^{(1)}\phi_A(x_*,x_\perp)+\frac{1}{s}\bar\phi_B(x_\bullet,x_\perp)\int dz~(x|\frac{1}{\alpha P_\bullet+i\epsilon}|z)[A_\bullet,B_*]\phi_A(z)$$
$$+\frac{1}{s}\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}[A_\bullet,B_*]\frac{1}{\alpha P_\bullet+i\epsilon}|x)\phi_A(x_*,x_\perp)~+~B_*\leftrightarrow C_*$$
$$=~\frac{1}{2}\bar\phi_B(x_\bullet,x_\perp)[x_\bullet,\infty]_x^{(1)}[-\infty,x_*]_x\phi_A(x_*,x_\perp)+\frac{1}{2}\bar\phi_B(x_\bullet,x_\perp)[-\infty,x_*]_x[x_\bullet,\infty]_x^{(1)}\phi_A(x_*,x_\perp)$$
$$+\Big[\frac{1}{s}\bar\phi_B(x_\bullet,x_\perp)\int dz~(x|\frac{1}{\alpha P_\bullet+i\epsilon}|z)[A_\bullet,B_*]\phi_A(z)+~\frac{1}{s}\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}[A_\bullet,B_*]\frac{1}{\alpha P_\bullet+i\epsilon}|x)\phi_A(x_*,x_\perp)~+~B_*\leftrightarrow C_*\Big]$$
$$=~\bar\phi_B(x_\bullet,x_\perp)[x_\bullet,\infty]_x^{(1)}[-\infty,x_*]_x\phi_A(x_*,x_\perp)+\frac{1}{2}\bar\phi_B(x_\bullet,x_\perp)\big(\frac{1}{\alpha}B_*(x)[-\infty,x_*]_x-[-\infty,x_*]_x\frac{1}{\alpha}B_*(x)\big)\phi_A(x_*,x_\perp)$$
$$+\Big[\frac{1}{s}\bar\phi_B(x_\bullet,x_\perp)\int dz~(x|\frac{1}{\alpha P_\bullet+i\epsilon}|z)[A_\bullet,B_*]\phi_A(z)+~\frac{1}{s}\int dz~\bar\phi_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}[A_\bullet,B_*]\frac{1}{\alpha P_\bullet+i\epsilon}|x)\phi_A(x_*,x_\perp)~+~B_*\leftrightarrow C_*\Big] \tag{63}$$

1. Zabyl

$$e^{i\int dz'C^\mu D_\mu G^{\mu\nu}(z')}e^{i\int dz\bar\phi_B\{p+A+B,C\}\phi_C}\bar\phi_C(x) ~=~ -\int dz'D_\mu G^{a\mu\nu}\langle C^\nu(z')C_\Omega(z)\rangle^{ab}\bar\phi_B\{p+A+B,t^b\}\langle\phi_C(z)\bar\phi_C(x)\rangle$$
$$=~-\int dz\bar\phi_B(z)\{p+A,C^{(1)}(z)\}\langle\phi_C(z)\bar\phi_C(x)\rangle ~=~ -\int dz\bar\phi_B(z)(z|\{p+A,C^{(1)}\}\frac{1}{(p+A)^2+i\epsilon}|x)$$
$$=~\frac{2}{s}\int dz\bar\phi_B(z)C_*(z)(z|2P_\bullet\frac{1}{2\alpha P_\bullet+i\epsilon}|x) ~=~ \frac{2}{s}\int_{-\infty}^{x_*}dz~\bar\phi_B(z_\bullet,x_\perp)C_*(z_\bullet,x_\perp) \tag{64}$$

2. Cbu

From Eq. (51) we get

$$
\begin{aligned}
C^a_\bullet \;&=\; \frac{2}{s}\int dz\;(x|\frac{1}{P^2g_{\bullet\bullet}+2iA_{\bullet\bullet}-i\epsilon}p^2+\frac{2}{s}\frac{1}{P^2g_{\bullet\bullet}+2iA_{\bullet\bullet}-i\epsilon}P_*A_\bullet+\frac{1}{P^2g_{\bullet i}+2iA_{\bullet i}-i\epsilon}P_iA_\bullet+\frac{1}{P^2}P_\bullet A_\bullet|z)^{ab}B^b_*(z)\\
&=\; \frac{2}{s}\int dz\;(x|\frac{4}{P^2}A_{\bullet i}\frac{1}{P^2}A_\bullet{}^i\frac{1}{P^2}\alpha(2p_\bullet+A_\bullet)-2i\frac{1}{P^2}A_{\bullet i}\frac{1}{P^2}p^iA_\bullet+\frac{1}{2\alpha P^2}(2\alpha P_\bullet-p_\perp^2+p_\perp^2)A_\bullet|z)^{ab}B^b_*(z)\\
&=\; \frac{2}{s}\int dz\;(x|\frac{1}{\alpha^2}\frac{1}{P_\bullet}A_{\bullet i}\frac{1}{P_\bullet}A_\bullet{}^i\frac{1}{P_\bullet}\alpha(2p_\bullet+A_\bullet)-\frac{i}{2\alpha^2}\frac{1}{P_\bullet}A_{\bullet i}\frac{1}{P_\bullet}p^iA_\bullet+\frac{1}{2\alpha}A_\bullet+\frac{1}{4\alpha P_\bullet}p_\perp^2A_\bullet|z)^{ab}B^b_*(z)\\
&\simeq\; \int dz\;(x|\frac{1}{\alpha s}A_\bullet|z)^{ab}B^b_* \;=\; \frac{1}{2}[x_\bullet,-\infty\beta]^{ab}_xA^b_\bullet(x_*,x_\perp)-\frac{1}{2}A^a_\bullet(x_*,x_\perp)
\end{aligned}
\tag{65}
$$

IV. SCALARS AGAIN

Scalars move in the "external" field $(A+B+C)_\mu$

3. Fi A

$$
\begin{aligned}
&\phi_A(x)+i\phi_C\int dz\;\bar\phi_C[(p+A+B+C)^2-(p+A)^2]\phi_A(z)\\
&=\; \phi_A(x)-\int dz\;(x|\frac{1}{(p+A+B+C)^2+i\epsilon}|z)[(p+A+B+C)^2-(p+A)^2]\phi_A(z)\\
&=\; \int dz\;(x|\frac{1}{(p+A+B+C)^2+i\epsilon}(p+A)^2|z)\phi_A(z) \;=\; \phi_A(x)-\int dz\;(x|\frac{1}{(p+A)^2+i\epsilon}\{p+A,B+C\}|z)\phi_A(z)\\
&=\; \phi_A(x)-\int dz\;(x|\frac{1}{(p+A)^2+i\epsilon}\big(\frac{4}{s}P_\bullet(B_*+C_*)-\frac{2}{s}[P_\bullet,B_*+C_*]+2\alpha C_\bullet+\{p_i,C^i\}\big)|z)\phi_A(z)\\
&=\; \phi_A(x)-\int dz\;(x|\frac{1}{(p+A)^2+i\epsilon}\big(\frac{4}{s}P_\bullet(B_*+C_*)-\frac{2}{s}[P_\bullet,B_*+C_*]+2[\alpha,C_\bullet]+\{p_i,C^i\}\big)|z)\phi_A(z)
\end{aligned}
\tag{66}
$$

Since

$$
C^a_* \;=\; -\frac{1}{2}\int dz\;(x|\frac{1}{P_\bullet+i\epsilon\alpha}A_\bullet|z)^{ab}B^b_*(z),\qquad\qquad C^a_\bullet \;=\; \int dz\;(x|\frac{1}{\alpha s}A_\bullet|z)^{ab}B^b_*
\tag{67}
$$

we get

$$
\begin{aligned}
&P^{ab}_\bullet(B_*+C_*)^b \;=\; \frac{1}{2}A^{ab}_\bullet B^b_* \;\;\Rightarrow\;\; [P_\bullet,B_*+C_*] \;=\; \frac{1}{2}[A_\bullet,B_*]\\
&2\alpha C^a_\bullet \;=\; \frac{1}{s}A^{ab}_\bullet B^b_* \;\;\Rightarrow\;\; [\alpha,C_\bullet] \;=\; \frac{1}{s}[A_\bullet,B_*]
\end{aligned}
\tag{68}
$$

$$
\Rightarrow\;\; \{p^\mu+A^\mu,B_\mu+C_\mu\} \;\simeq\; \frac{4}{s}(p+A)_\bullet(B_*+C_*)
\tag{69}
$$

and there4

$$
\phi_A(x)+i\phi_C\int dz\bar\phi_C[(p+A+B+C)^2-(p+A)^2]\phi_A(z)
\tag{70}
$$

$$
=\; \phi_A(x)-\int dz\;(x|\frac{1}{(p+A)^2+i\epsilon}\frac{4}{s}P_\bullet(B_*+C_*)|z)\phi_A(z) \;=\; \phi_A(x)-\frac{2}{s}\int dz\;(x|\frac{1}{\alpha P_\bullet+i\epsilon}P_\bullet(B_*+C_*)|z)\phi_A(z)
$$

$$(x|\frac{1}{\alpha P_\bullet + i\epsilon}|z) \;=\; -i\delta(x_\perp - z_\perp)[x_*, z_*]\Big(\theta(x_* - z_*)\int_\sigma^\infty \frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet} - \theta(z_* - x_*)\int_{-\infty}^{-\sigma}\frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\Big) \tag{71}$$

$$(x|P_\bullet\frac{1}{\alpha P_\bullet}|z) \;=\; \frac{s}{2}\delta(x_\perp - z_\perp)\delta(x_* - z_*)\Big[\int_\sigma^\infty \frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet} + \int_{-\infty}^{-\sigma}\frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\Big] \;=\; -\frac{is}{4}\delta(x_\perp - z_\perp)\delta(x_* - z_*)\epsilon(x_\bullet - z_\bullet)$$

$$(x|\frac{1}{P_\bullet + i\epsilon\alpha}|z) \;=\; -i\delta(x_\perp - z_\perp)[x_*, z_*]\Big(\theta(x_* - z_*)\int_\sigma^\infty đ\alpha\; e^{-i\alpha(x-z)_\bullet} - \theta(z_* - x_*)\int_{-\infty}^{-\sigma}đ\alpha\; e^{-i\alpha(x-z)_\bullet}\Big)$$

$$\int_\sigma^\infty \frac{d\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet} \;=\; -\frac{i\pi}{2} - \ln\sigma(x_\bullet - z_\bullet - i\epsilon) - C \;+\; O(\sigma(x-z)_\bullet) \tag{72}$$

$$\int_{-\infty}^{-\sigma} \frac{d\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet} \;=\; -\frac{i\pi}{2} + \ln\sigma(x_\bullet - z_\bullet + i\epsilon) + C \;+\; O(\sigma(x-z)_\bullet)$$

DAΛEE,

$$\frac{2}{s}\int dz(x|P_\bullet\frac{1}{\alpha P_\bullet}|z)[B_*(z) + C_*(z)]\phi_A(z) \;=\; \frac{1}{2}\int dz_\bullet\Big[\int_\sigma^\infty \frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet} \tag{73}$$

$$\times\; \big(B_*^+(z_\bullet, x_\perp) + [x_*, -\infty]B_*^+(z_\bullet, x_\perp)[-\infty, x_*]\big) + \int_{-\infty}^{-\sigma}\frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\big(B_*^-(z_\bullet, x_\perp) + [x_*, \infty]B_*^-(z_\bullet, x_\perp)[\infty, x_*]\big)\Big]\phi_A(x)$$

$$=\; -\frac{i}{2}\int_{-\infty}^{x_\bullet} dz_\bullet\big(B_*(z_\bullet) + [x_*, -\infty]B_*(z_\bullet)[-\infty, x_*]\big)\phi_A(x) + \frac{i}{2}\int_{x_\bullet}^\infty dz_\bullet\big(B_*(z_\bullet) + [x_*, -\infty]B_*(z_\bullet)[-\infty, x_*]\big)\phi_A(x)$$

$$+\; \frac{1}{2}[x_*, -\infty]\int dz_\bullet\int_{-\infty}^{-\sigma}\frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\big(U_x^\dagger B_*^-(z_\bullet, x_\perp)U_x - B_*^-(z_\bullet, x_\perp)\big)[-\infty, x_*]\phi_A(x) \tag{74}$$

where we uzd

$$B_*(x) + C_*(x) \;=\; \frac{1}{2}B_*^+(x_\bullet, x_\perp) + \frac{1}{2}[x_*, -\infty]B_*^+(x_\bullet, x_\perp)[-\infty, x_*] \;+\; \frac{1}{2}B_*^-(x_\bullet, x_\perp) + \frac{1}{2}[x_*, \infty]B_*^-(x_\bullet, x_\perp)[\infty, x_*] \tag{75}$$

ИТОГО

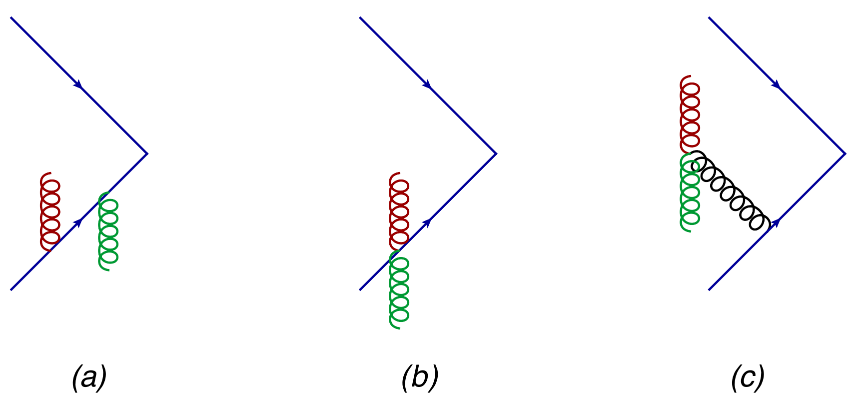

FIG. 1. Niz.

$$\phi_A(x) + i\phi_C\int dz\bar\phi_C[(p + A + B + C)^2 - (p + A)^2]\phi_A(z) \;=\; \phi_A(x) - \frac{2}{s}\int dz\; (x|\frac{1}{\alpha P_\bullet + i\epsilon}P_\bullet(B_* + C_*)|z)\phi_A(z)$$

$$=\; \phi_A(x) + \frac{i}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\big(B_*(z_\bullet) + [x_*, -\infty]B_*(z_\bullet)[-\infty, x_*]\big)\phi_A(x) - \frac{i}{s}\int_{x_\bullet}^\infty dz_\bullet\big(B_*(z_\bullet) + [x_*, -\infty]B_*(z_\bullet)[-\infty, x_*]\big)\phi_A(x)$$

$$-\; \frac{1}{s}[x_*, -\infty]\int dz_\bullet\int_{-\infty}^{-\sigma}\frac{đ\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\big(U_x^\dagger B_*^-(z_\bullet, x_\perp)U_x - B_*^-(z_\bullet, x_\perp)\big)[-\infty, x_*]\phi_A(x) \tag{76}$$

4. Fi Be

$$\bar{\phi}_B(x)+i\int dz\bar{\phi}_B(z)[(p+A+B+C)^2-(p+B)^2]\phi_C(z)\bar{\phi}_C(x)$$
$$=\ \bar{\phi}_B(x)-\int dz\ \bar{\phi}_B(z)(z|[(p+A+B+C)^2-(p+B)^2]\frac{1}{(p+A+B+C)^2+i\epsilon}|x)$$
$$=\ \int dz\ \bar{\phi}_B(z)(z|(p+B)^2\frac{1}{(p+A+B+C)^2+i\epsilon}|x)\ =\ \int dz\ \bar{\phi}_B(z)(z|p^2\frac{1}{(p+A)^2+i\epsilon}|x)$$
$$+\int dz\ \bar{\phi}_B(z)(z|\{p,B\}\frac{1}{(p+A)^2+i\epsilon}-p^2\frac{1}{(p+A)^2}\{p+A,B+C\}\frac{1}{(p+A)^2}|x)$$
$$=\ \int dz\ \bar{\phi}_B(z)(z|p_\bullet\frac{1}{P_\bullet+i\epsilon\alpha}|x)+\int dz\ \bar{\phi}_B(z)(z|-\frac{4}{s}p_\bullet C_*\frac{1}{(p+A)^2+i\epsilon}|x)$$
$$=\ i\frac{s}{2}\int dz\ \bar{\phi}_B(z)\frac{\partial}{\partial z_*}(z|\frac{1}{P_\bullet+i\epsilon\alpha}|x)-i\int dz\ \bar{\phi}_B(z)\frac{\partial}{\partial z_*}C_*(z)(z|\frac{1}{\alpha P_\bullet+i\epsilon}|x)$$
$$=\ \frac{s}{2}\int dz\ \bar{\phi}_B(z)\delta(x_\perp-z_\perp)\frac{\partial}{\partial z_*}[z_*,x_*]\Big(\theta(z_*-x_*)\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}-\theta(x_*-z_*)\int_{-\infty}^{-\sigma}d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}\Big)$$
$$-\int dz\ \delta(x_\perp-z_\perp)\bar{\phi}_B(z)\frac{\partial}{\partial z_*}C_*(z)[z_*,x_*]\Big(\theta(z_*-x_*)\int_\sigma^\infty\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}-\theta(x_*-z_*)\int_{-\infty}^{-\sigma}\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}\Big)$$
$$=\ \int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}-\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}\Big)$$
$$-\ \frac{2}{s}\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)C_*(z_*=\infty,z_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}$$
$$+\ \frac{2}{s}\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)C_*(z_*=-\infty,z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}$$
$$=\ \int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}-\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}$$
$$-\ \frac{1}{s}\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)\big\{U_xB_*^+(z_\bullet,x_\perp)U_x^\dagger-B_*^+(z_\bullet,x_\perp)\big\}[\infty,x_*]\int_\sigma^\infty\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}$$
$$+\ \frac{1}{s}\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)\big\{U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x-B_*^-(z_\bullet,x_\perp)\big\}[-\infty,x_*]\int_{-\infty}^{-\sigma}\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}\tag{77}$$

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$$C_*(x)\ =\ -\frac{1}{2}B_*^+(x_\bullet,x_\perp)+\frac{1}{2}[x_*,-\infty]B_*^+(x_\bullet,x_\perp)[-\infty,x_*]\ -\ \frac{1}{2}B_*^-(x_\bullet,x_\perp)+\frac{1}{2}[x_*,\infty]B_*^-(x_\bullet,x_\perp)[\infty,x_*]\tag{78}$$
$$\Rightarrow\ C_*(x_*=\infty)\ =\ -\frac{1}{2}B_*^+(x_\bullet,x_\perp)+\frac{1}{2}U_xB_*^+(x_\bullet,x_\perp)U_x^\dagger,\qquad C_*(x_*=-\infty)\ =\ -\frac{1}{2}B_*^-(x_\bullet,x_\perp)+\frac{1}{2}U_x^\dagger B_*^-(x_\bullet,x_\perp)U_x$$

From LSZ:

$$\int dx_\bullet\ e^{i\alpha_Hx_\bullet}\mathcal{O}(x_\bullet)\ \ \Rightarrow\ \ \mathcal{O}(x_\bullet)\ =\ \int_0^\infty d\!\!\!{}^-\alpha\ \mathcal{O}(\alpha)\ e^{-i\alpha x_\bullet}$$

$\Rightarrow$ the third term in the r.h.s. of Eq. (77) does not contribute

$$\Rightarrow\ \bar{\phi}_B(x)+i\int dz\bar{\phi}_B(z)[(p+A+B+C)^2-(p+B)^2]\phi_C(z)\bar{\phi}_C(x)$$
$$=\ \int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}-\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}$$
$$+\ \frac{1}{s}\int dz_\bullet\ \bar{\phi}_B(z_\bullet,x_\perp)\big\{U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x-B_*^-(z_\bullet,x_\perp)\big\}[-\infty,x_*]\int_{-\infty}^{-\sigma}\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}$$

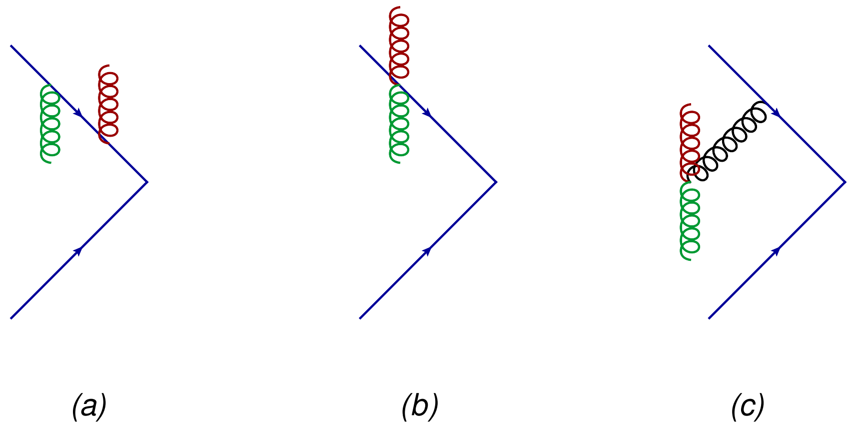

FIG. 2. BEPX.

5. CYMMA

Trivial term

$$\Big(\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}-\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma} d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}\Big)\phi_A(x_*,x_\perp)$$
$$\stackrel{\rm LSZ}{=}\ -\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma} d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}\phi_A(x_*,x_\perp)\ =\ \int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)[-\infty,x_*]\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(x-z)_\bullet}\phi_A(x_*,x_\perp)$$
$$=\ \bar\phi_B^+(x_\bullet,x_\perp)[-\infty,x_*]\phi_A(x_*,x_\perp) \tag{79}$$

The term in Fig. 3

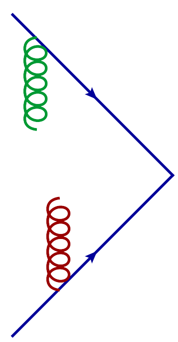

FIG. 3. Figa.

$$\text{Fig.3}\ =\ -\int dz\bar\phi_B(z)[(p+A)^2-p^2]\phi_C(z)\bar\phi_C(x)\phi_C(x)\int dz'\bar\phi_C[(p+A+B+C)^2-(p+A)^2]\phi_A(z')$$
$$=\ \int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}-\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma} d\!\!\!{}^-\alpha\ e^{-i\alpha(z-x)_\bullet}$$
$$\times\Big\{\frac{i}{s}\int_{-\infty}^{x_\bullet}dz'_\bullet\big(B_*(z_\bullet)+[x_*,-\infty]B_*(z'_\bullet)[-\infty,x_*]\big)\phi_A(x)-\frac{i}{s}\int_{x_\bullet}^\infty dz'_\bullet\big(B_*(z'_\bullet)+[x_*,-\infty]B_*(z'_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$-\ \frac{1}{s}[x_*,-\infty]\int dz'_\bullet\int_{-\infty}^{-\sigma}\frac{d\!\!\!{}^-\alpha}{\alpha}e^{-i\alpha(x-z')_\bullet}\big(U_x^\dagger B_*^-(z'_\bullet,x_\perp)U_x-B_*^-(z'_\bullet,x_\perp)\big)[-\infty,x_*]\phi_A(x)\Big\} \tag{80}$$

In the leading order in $A_\bullet$

$$\text{Fig.3} \;=\; \int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)\frac{2i}{s}\int_{x_*}^\infty dz_* A_\bullet(z_*,x_\perp)\int_\sigma^\infty \bar{d}\alpha\ e^{-i\alpha(z-x)_\bullet} - \int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)\int_{-\infty}^{x_*} dz_* A_*(z_*,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z-x)_\bullet}$$
$$\times\Big\{\frac{2i}{s}\int_{-\infty}^{x_\bullet} dz_\bullet B_*(z_\bullet)\phi_A(x) - \frac{2i}{s}\int_{x_\bullet}^\infty dz_\bullet B_*(z_\bullet)\phi_A(x)\Big\}$$

First term $\sim B_*$

$$\text{Fig.2} \;=\; \big\{\bar\phi_B(x) + i\int dz\bar\phi_B(z)[(p+A+B+C)^2-(p+B)^2]\phi_C(z)\bar\phi_C(x)\big\}\phi_A(x)$$
$$+\ \bar\phi_B(x)\big\{\phi_A(x) + i\phi_C\int dz\bar\phi_C[(p+A+B+C)^2-(p+A)^2]\phi_A(z)\big\} - \bar\phi_B(x)\phi_A(x)$$
$$=\ \frac{1}{s}\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)\big\{U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x - B_*^-(z_\bullet,x_\perp)\big\}[-\infty,x_*]\int_{-\infty}^{-\sigma}\frac{\bar{d}\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}\phi_A(x)$$
$$+\ \frac{i}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\Big(\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty \bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet} - \int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet}\Big)$$
$$\times\ \big(B_*(z_\bullet) + [x_*,-\infty]B_*(z_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$-\ \frac{i}{s}\int_{x_\bullet}^{\infty} dz_\bullet\Big(\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty \bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet} - \int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet}\Big)$$
$$\times\ \big(B_*(z_\bullet) + [x_*,-\infty]B_*(z_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$-\ \frac{1}{s}\Big(\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)[\infty,x_*]\int_\sigma^\infty \bar{d}\alpha'\ e^{-i\alpha'(z'-x)_\bullet} - \int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)[-\infty,x_*]\int_{-\infty}^{-\sigma}\bar{d}\alpha'\ e^{-i\alpha'(z'-x)_\bullet}\Big)$$
$$\times\ [x_*,-\infty]\int dz_\bullet\int_{-\infty}^{-\sigma}\frac{\bar{d}\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\big(U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x - B_*^-(z_\bullet,x_\perp)\big)[-\infty,x_*]\phi_A(x) \tag{81}$$

After LSZ

$$\big\{\bar\phi_B(x) + i\int dz\bar\phi_B(z)[(p+A+B+C)^2-(p+B)^2]\phi_C(z)\bar\phi_C(x)\big\}\phi_A(x) \tag{82}$$
$$+\ \bar\phi_B(x)\big\{\phi_A(x) + i\phi_C\int dz\bar\phi_C[(p+A+B+C)^2-(p+A)^2]\phi_A(z)\big\} - \bar\phi_B(x)\phi_A(x)$$
$$=\ \frac{1}{s}\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)\big\{U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x - B_*^-(z_\bullet,x_\perp)\big\}[-\infty,x_*]\int_{-\infty}^{-\sigma}\frac{\bar{d}\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}\phi_A(x)$$
$$-\ \frac{i}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet}\big([-\infty,x_*]B_*(z_\bullet) + B_*(z_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$+\ \frac{i}{s}\int_{x_\bullet}^{\infty} dz_\bullet\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet}\big([-\infty,x_*]B_*(z_\bullet) + B_*(z_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$+\ \frac{1}{s}\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha'\ e^{-i\alpha'(z'-x)_\bullet}\int dz_\bullet\int_{-\infty}^{-\sigma}\frac{\bar{d}\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\big(U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x - B_*^-(z_\bullet,x_\perp)\big)[-\infty,x_*]\phi_A(x)$$

In the leading order in $A_\bullet$

$$\text{Fig.2} \;=\; \frac{1}{s}\int dz_\bullet\ \bar\phi_B(z_\bullet,x_\perp)\big\{U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x - B_*^-(z_\bullet,x_\perp)\big\}[-\infty,x_*]\int_{-\infty}^{-\sigma}\frac{\bar{d}\alpha}{\alpha}e^{-i\alpha(z-x)_\bullet}\phi_A(x)$$
$$-\ \frac{i}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet}\big([-\infty,x_*]B_*(z_\bullet) + B_*(z_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$+\ \frac{i}{s}\int_{x_\bullet}^{\infty} dz_\bullet\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha\ e^{-i\alpha(z'-x)_\bullet}\big([-\infty,x_*]B_*(z_\bullet) + B_*(z_\bullet)[-\infty,x_*]\big)\phi_A(x)$$
$$+\ \frac{1}{s}\int dz'_\bullet\ \bar\phi_B(z'_\bullet,x_\perp)\int_{-\infty}^{-\sigma}\bar{d}\alpha'\ e^{-i\alpha'(z'-x)_\bullet}\int dz_\bullet\int_{-\infty}^{-\sigma}\frac{\bar{d}\alpha}{\alpha}e^{-i\alpha(x-z)_\bullet}\big(U_x^\dagger B_*^-(z_\bullet,x_\perp)U_x - B_*^-(z_\bullet,x_\perp)\big)[-\infty,x_*]\phi_A(x)$$

V. POLE

A. Scalar model

$$\int D\phi\ \phi(x)e^{iS(\phi)} \ = \ 0, \qquad S(\phi) \ = \ \int d^4x\Big[-\frac{1}{2}\phi(\partial^2+m^2)\phi - \frac{\Omega}{4!}\phi^4\Big] \tag{83}$$

Sdvig $\phi \to \phi + \bar\phi$

$$\int D\phi\ [\bar\phi(x)+\phi(x)]e^{iS(\phi)} \ = \ 0, \qquad S(\phi) \ = \ S(\bar\phi) - \frac{1}{2}\phi\big(\partial^2+m^2+\frac{\Omega}{2}\bar\phi^2\big)\phi - \phi\big(\partial^2+m^2+\frac{\Omega}{6}\bar\phi^2\big)\bar\phi - \frac{\Omega}{6}\phi^3\bar\phi - \frac{\Omega}{4!}\phi^4 \tag{84}$$

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$$\int D\phi\ \phi(x)e^{i\int d^4x\big(-\frac{1}{2}\phi\big(\partial^2+m^2+\frac{\Omega}{2}\bar\phi^2\big)\phi - \phi\big(\partial^2+m^2+\frac{\Omega}{6}\bar\phi^2\big)\bar\phi - \frac{\Omega}{6}\phi^3\bar\phi - \frac{\Omega}{4!}\phi^4\big)} \tag{85}$$

Sdvig $\phi \to \phi - \tilde\phi$.

$$\begin{aligned}
&\exp\Big\{i\int d^4x\Big(-\frac{1}{2}(\phi-\tilde\phi)\Box(\phi-\tilde\phi) - (\phi-\tilde\phi)\big(\Box - \frac{\Omega}{3}\bar\phi^2\big)\bar\phi - \frac{\Omega}{6}(\phi-\tilde\phi)^3\bar\phi - \frac{\Omega}{4!}(\phi-\tilde\phi)^4\Big)\Big\} \\
&= \ \exp\Big\{i\int d^4x\Big(-\frac{1}{2}\tilde\phi\Box\tilde\phi + \tilde\phi\big(\Box - \frac{\Omega}{3}\bar\phi^2\big)\bar\phi + \frac{\Omega}{6}\tilde\phi^3\bar\phi - \frac{\Omega}{4!}\tilde\phi^4\Big) \\
&+ i\int d^4x\Big(-\frac{1}{2}\phi\big(\Box - \Omega\tilde\phi\bar\phi + \frac{\Omega}{2}\tilde\phi^2\big)\phi - \phi\big(\Box\bar\phi - \frac{\Omega}{3}\bar\phi^3 + \frac{\Omega}{2}\tilde\phi\bar\phi^2 + \frac{\Omega}{6}\tilde\phi^3\big) + \frac{\Omega}{6}(\bar\phi-\tilde\phi)\phi^3 - \frac{\Omega}{4!}\phi^4\Big)\Big\} \ = \ \text{free}
\end{aligned} \tag{86}$$

where $\Box \equiv \partial^2 + m^2 + \frac{\Omega}{2}\bar\phi^2$.

ПО-DРУГОМУ: ВО ВНЕШНЕМ ПОЛЕ $\bar\phi$

$$\int D\phi\ \phi(x)e^{i\int d^4x\big(-\frac{1}{2}\phi\Box\phi - \phi\big(\Box - \frac{\Omega}{3}\bar\phi^2\big)\bar\phi - \frac{\Omega}{6}\phi^3\bar\phi - \frac{\Omega}{4!}\phi^4\big)} \tag{87}$$

$$\begin{aligned}
&= \ -i\int D\phi\ e^{i\int d^4x\big(-\frac{1}{2}\phi\Box\phi\big)}\phi(x)\int d^4z\Big[\phi\big(\Box - \frac{\Omega}{3}\bar\phi^2\big)\bar\phi(z) + \frac{\Omega}{6}\bar\phi\phi^3(z)\int d^4z'd^4z''\phi\big(\Box - \frac{\Omega}{3}\bar\phi^2\big)\bar\phi(z')\phi\big(\Box - \frac{\Omega}{3}\bar\phi^2\big)\bar\phi(z'')\Big] \\
&= \ -\bar\phi + \frac{\Omega}{3}\frac{1}{\Box}\bar\phi^3 - \frac{\Omega}{3}\frac{1}{\Box}\bar\phi^3 + ...
\end{aligned} \tag{88}$$

1. *Shifts?*

Suppose $\partial^\mu \bar A_\mu = 0$

$$\int DA\ (A_\mu + \bar A_\mu)(x)\ e^{iS(A+\bar A) + i\int d^4z\frac{1}{2}(\bar D^\alpha A^a_\alpha)^2} \ = \ \int DA\ A_\mu(x)\ e^{iS(A)}e^{i\int d^4z\frac{1}{2}(\bar D^\alpha A^a_\alpha)^2} \ = \ 0 \tag{89}$$

If $\bar A_\mu = \bar\aleph^\dagger_\mu$

$$\int DA\ (A_\mu + \bar\aleph^\dagger_\mu)(x)e^{iS(A+\bar\aleph^\dagger)}e^{i\int d^4z\frac{1}{2}(\bar D^\alpha A^a_\alpha)^2} \ = \ \bar\aleph^\dagger_\mu(x) + \int DA\ A_\mu(x)e^{i\int d^4z\big(\frac{1}{2}A^a_\alpha(\bar D^2)^{ab}A^{\alpha b} - gf^{abc}\bar D^\alpha A^{a\beta}A^b_\alpha A^c_\beta\big)} \tag{90}$$

In abelian theory in the $A_0 = 0$ gauge the shift $A_i \to A_i + \partial_i\Omega(\vec x)$ is allowed since both $(\partial_0\delta_{ik} - W_{ik})\partial_k\Omega(t,\vec x)\big|_{t=\infty} = 0$ and $(\partial_0\delta_{ik} + W_{ik})\partial_k\Omega(t,\vec x)\big|_{t=-\infty} = 0$ vanish (here $W_{ik} \equiv \frac{\partial^2\delta_{ik} - \partial_i\partial_k}{\sqrt{-\partial^2}}$). This is the redundant gauge symmetry which should be eliminated.

In Feynman gauge $\partial^2\Omega = 0 \Leftrightarrow \Omega \ = \ \int\frac{d^3k}{|k|}\big(a_k e^{-i|k|x_0 + i\vec k\cdot\vec x} + a^*_k e^{i|k|x_0 - i\vec k\cdot\vec x}\big)$

B. Gauge field

$$\bar{A}_\mu = \Omega^\dagger_\mu + \Delta_\mu$$

$$\int DA\ A_\mu(x)e^{iS(A+\bar{A})} \ = \ e^{iS(\bar{A})}\int DA\ A_\mu(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta}-\bar{D}^\alpha\bar{D}^\beta)^{ab}A^b_\beta+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{91}$$

$$\bar{D}_\xi\bar{G}^{a\xi\alpha} \ = \ (D^2_\Omega g_{\alpha\xi}-D^\Omega_\alpha D^\Omega_\xi)\Delta^\xi \tag{92}$$

$$\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta}-\bar{D}^\alpha\bar{D}^\beta \ = \ D^2_\Omega g_{\alpha\beta}-D^\Omega_\alpha D^\Omega_\beta-i\{D^\Omega_\xi,\Delta^\xi\}g_{\alpha\beta}-2i\big((\bar{D}^\alpha\Delta^\beta)-\alpha\leftrightarrow\beta\big)+i\Delta_\alpha D^\Omega_\beta-D^\Omega_\alpha\Delta_\beta$$

1. bF

$$\int DA\ A^a_\mu(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{93}$$

$$= \ \int d^4z\ (x|\frac{1}{\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta}}|z)^{ab}\bar{D}_\xi\bar{G}^{b\xi\beta}(z) \ = \ -\int d^4z\ (x|\frac{1}{P^2_\Omega g_{\alpha\beta}+\{P^\Omega_\xi,\Delta^\xi\}g_{\alpha\beta}+2i\big((\bar{D}^\alpha\Delta^\beta)-\alpha\leftrightarrow\beta\big)}(P^2_\Omega g_{\beta\xi}-P^\Omega_\beta P^\Omega_\xi)\Delta^\xi$$

$$= \ -\Delta_\alpha(x)+(x|\frac{1}{P^2_\Omega}P^\Omega_\alpha P^\Omega_\xi|z)\Delta^\xi(z) \tag{94}$$

$$A^{(0)}_\mu \ = \ \bar{A}_\mu \ = \ \Omega^\dagger_\mu+\Delta_\mu \qquad A^{(1)}_\mu(x) \ = \ -\Delta_\mu+\tilde{A}^{(1)}_\mu \ = \ -\big(g_{\mu\nu}-\frac{P^\Omega_\mu P^\Omega_\nu}{P^2_\Omega}\big)\Delta^\nu, \qquad \tilde{A}^{(1)}_\mu \ \equiv \ \int dz\ (x|\frac{1}{P^2_\Omega}P^\Omega_\mu P^\Omega_\xi|z)\Delta^\xi(z)$$

$$A^{(0)}_\mu(x)+A^{(1)}_\mu(x) \ = \ \Omega^\dagger_\mu+\int dz\ (x|\frac{1}{P^2_\Omega}P^\Omega_\mu P^\Omega_\xi|z)\Delta^\xi(z) \ \Rightarrow \ F^{(0+1)}_{\mu\nu} \ = \ \int dz\ \bar{D}^\Omega_\mu(x|\frac{1}{P^2_\Omega}P^\Omega_\nu P^\Omega_\xi|z)\Delta^\xi(z) \ - \ \mu\leftrightarrow\nu \ = \ 0 \tag{95}$$

2. Second order

$$D^{ab}_\mu f^{bmn}\Delta^m_\alpha\Delta^n_\beta = f^{amn}(D_\mu\Delta_\alpha)^m\Delta^n_\beta+f^{amn}\Delta^m_\alpha(D_\mu\Delta_\beta)^n$$

$$D_\mu[\Delta_\alpha,\Delta_\beta] = \partial_\mu[\Delta_\alpha,\Delta_\beta]-ig[A_\mu,[\Delta_\alpha,\Delta_\beta]]$$

$$= [\partial_\mu\Delta_\alpha,\Delta_\beta]+[\Delta_\alpha,\partial_\mu\Delta_\beta]-ig[\Delta_\alpha,[A_\mu,\Delta_\beta]]+ig[\Delta_\beta,[A_\mu,\Delta_\alpha]] \ = \ [D_\mu\Delta_\alpha,\Delta_\beta]+[\Delta_\alpha,D_\mu\Delta_\beta] \tag{96}$$

$$\bar{G}^a_{\xi\alpha} \ = \ \bar{D}^\Omega_\xi\Delta^a_\alpha-\bar{D}^\Omega_\alpha\Delta^a_\xi+gf^{abc}\Delta^b_\xi\Delta^c_\alpha \tag{97}$$

$$\bar{D}^\xi\bar{G}^a_{\xi\alpha} \ = \ (\bar{D}^{ab\xi}_\Omega-gf^{abc}\Delta^{c\xi})(\bar{D}^\Omega_\xi\Delta^b_\alpha-\bar{D}^\Omega_\alpha\Delta^b_\xi+gf^{bmn}\Delta^m_\xi\Delta^n_\alpha)$$

$$= \ (\bar{D}^2_\Omega g_{\xi\alpha}-\bar{D}^\Omega_\xi\bar{D}^\Omega_\alpha)\Delta^\xi+gf^{abc}[2\Delta^b_\xi(\bar{D}^\xi_\Omega\Delta_\alpha)^c-\Delta^b_\alpha(\bar{D}^\xi_\Omega\Delta_\xi)^c-\Delta^b_\xi(\bar{D}^\Omega_\alpha\Delta^\xi)^c]$$

$$\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta}-\bar{D}^\alpha\bar{D}^\beta \ = \ \bar{D}^2_\Omega g_{\alpha\beta}-\bar{D}^\Omega_\alpha\bar{D}^\Omega_\beta-i\{\bar{D}^\Omega_\xi,\Delta^\xi\}g_{\alpha\beta}-2i\big((\bar{D}^\alpha\Delta^\beta)-\alpha\leftrightarrow\beta\big)+i\Delta_\alpha\bar{D}^\Omega_\beta-\bar{D}^\Omega_\alpha\Delta_\beta \ + \ O(\Delta^2)$$

$$A_\mu = \Omega^\dagger_\mu+\Delta_\mu+A^{(1)}_\mu+A^{(2)}_\mu = \Omega^\dagger_\mu+\tilde{A}^{(1)}_\mu+A^{(2)}_\mu \Rightarrow F_{\mu\nu} = \bar{D}^\Omega_\mu\tilde{A}^{(1)}_\nu+\bar{D}^\Omega_\mu A^{(2)}_\nu-\mu\leftrightarrow\nu-i[\tilde{A}^{(1)}_\mu,\tilde{A}^{(1)}_\nu]$$

$$\int DA\ A^a_\mu(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{98}$$

$$= \ \int d^4z\ \Big[(x|\frac{1}{\bar{P}^2g_{\mu\beta}+2i\bar{G}_{\mu\beta}}|z)^{ab}\bar{D}_\xi\bar{G}^{b\xi\beta}(z) \ -i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b}_\xi A^{1c}_\mu(z)+(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(\bar{D}^\Omega_\xi A^{1c}_\mu-\bar{D}^\Omega_\mu A^{1c}_\xi)(z)\Big] \ =$$

$$=\int d^4z\ (x|\frac{1}{P^2_\Omega g_{\mu\beta}+\{P^\Omega_\xi,\Delta^\xi\}g_{\mu\beta}+2i\big((\bar{D}^\Omega_\mu\Delta_\beta)-\mu\leftrightarrow\beta\big)}|z)^{aa'}[-(P^2_\Omega g_{\beta\xi}-P^\Omega_\beta P^\Omega_\xi)^{a'b}\Delta^{b\xi}+gf^{a'bc}[2\Delta^b_\xi\bar{D}^\xi_\Omega\Delta^c_\beta-\Delta^b_\beta(\bar{D}^\xi_\Omega\Delta_\xi)^c-\Delta^b_\xi(\bar{D}^\Omega_\beta\Delta^\xi)^c]$$

$$= \ -\Delta^a_\mu(x)+(x|\frac{P^\Omega_\mu P^\Omega_\xi}{P^2_\Omega}|z)^{ab}\Delta^{b\xi}(z)+(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}[2\Delta^b_\xi\bar{D}^\xi_\Omega\Delta^c_\mu-\Delta^b_\mu(\bar{D}^\xi_\Omega\Delta_\xi)^c-\Delta^b_\xi(\bar{D}^\Omega_\mu\Delta^\xi)^c]$$

$$- \ (x|\frac{1}{P^2_\Omega}\big[\{P^\xi_\Omega,\Delta_\xi\}g_{\mu\beta}+2i(\bar{D}^\Omega_\mu\Delta_\beta-\mu\leftrightarrow\beta)\big]|z)^{ab}A^{1b\beta}(z)-i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b}_\xi A^{1c}_\mu(z)+(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(\bar{D}^\Omega_\xi A^{1c}_\mu-\bar{D}^\Omega_\mu A^{1c}_\xi)(z)$$

$\int d^4z$ is assumed

$$\tilde{A}^{(1)}_\nu + A^{(2)}_\nu = (x|\frac{P^\Omega_\nu P^\Omega_\xi}{P^2_\Omega}|z)^{ab}\Delta^{b\xi}(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{1b}_\xi\Delta^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}[\Delta^b_\xi\bar{D}^\xi_\Omega\Delta^c_\nu - \Delta^b_\xi(\bar{D}^\Omega_\nu\Delta^\xi)^c](z) \quad (99)$$

$$- (x|\frac{1}{P^2_\Omega}\big[\{\bar{P}^\xi_\Omega,\Delta_\xi\}g_{\nu\beta} + 2i(\bar{D}^\Omega_\nu\Delta_\beta - \bar{D}^\Omega_\beta\Delta_\nu)\big]|z)^{ab}A^{1b\beta}(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b}_\xi A^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(\bar{D}^\Omega_\xi A^{1c}_\nu - \bar{D}^\Omega_\nu A^{1c}_\xi)(z)$$

$$= (x|\frac{P^\Omega_\nu P^\Omega_\xi}{P^2_\Omega}|z)^{ab}\Delta^{b\xi}(z) - i(x|\frac{P^\Omega_\nu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}A^{1c}_\xi(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b\xi}(\bar{D}^\Omega_\xi\tilde{A}^{1c}_\nu - \bar{D}^\Omega_\nu\tilde{A}^{1c}_\xi)(z)$$

where we uzd $\tilde{A}^1_\mu = \Delta_\mu + A^1_\mu$ and

$$-(x|\frac{1}{P^2_\Omega}\big[\{\bar{P}^\xi_\Omega,\Delta_\xi\}g_{\nu\beta} + 2i(\bar{D}^\Omega_\nu\Delta_\beta - \nu\leftrightarrow\beta)\big]|z)^{ab}A^{1b\beta}(z) \quad (100)$$

$$= -(x|\frac{\bar{P}^\xi_\Omega}{P^2_\Omega}|z)^{aa'}\Delta^{a'c}_\xi A^{1c}_\nu(z) - i(x|\frac{1}{P^2_\Omega}|z)^{aa'}\Delta^{a'c}_\xi\bar{D}^\Omega_\xi A^{1c}_\nu(z) - 2i(x|\frac{1}{P^2_\Omega}|z)^{aa'}\bar{D}^\Omega_\nu\Delta^{a'b}_\beta A^{1b\beta}(z) + 2i(x|\frac{1}{P^2_\Omega}|z)^{aa'}\bar{D}^\Omega_\beta\Delta^{a'b}_\nu A^{1b\beta}(z)$$

$$= -i(x|\frac{\bar{P}^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi A^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi\bar{D}^\Omega_\xi A^{1c}_\nu(z) - 2(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}\bar{D}^\Omega_\nu\Delta^c_\xi(z) + 2(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\bar{D}^\Omega_\xi\Delta^c_\nu A^{1b\xi}(z)$$

and

$$\Big[-i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Delta^b_\xi + A^{1b}_\xi)(\Delta^c_\nu + A^{1c}_\nu)(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Delta^b_\xi + A^{1b\xi})(\bar{D}^\Omega_\xi\Delta^c_\nu + \bar{D}^\Omega_\xi A^{1c}_\nu - \bar{D}^\Omega_\nu\Delta^c_\xi - \bar{D}^\Omega_\nu\tilde{A}^{1c}_\xi)(z)\Big]_{\Delta\otimes A^1} \quad (101)$$

$$= -i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}[\Delta^b_\xi A^{1c}_\nu + A^{1b}_\xi\Delta^c_\nu](z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi(\bar{D}^\Omega_\xi A^{1c}_\nu - \bar{D}^\Omega_\nu A^{1c}_\xi)(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(\bar{D}^\Omega_\xi\Delta^c_\nu - \bar{D}^\Omega_\nu\Delta^c_\xi)(z)$$

$$= -i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi A^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi(\bar{D}^\Omega_\xi A^{1c}_\nu - \bar{D}^\Omega_\nu A^{1c}_\xi)(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(2\bar{D}^\Omega_\xi\Delta^c_\nu - \bar{D}^\Omega_\nu\Delta^c_\xi)(z)$$

$$= i(x|\frac{P^\Omega_\nu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}A^{1c}_\xi - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi A^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^b_\xi\bar{D}^\Omega_\xi A^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(2\bar{D}^\Omega_\xi\Delta^c_\nu - 2\bar{D}^\Omega_\nu\Delta^c_\xi)(z)$$

(bikoz $\bar{D}^\Omega_\xi A^{1\xi} = 0$).

The result iz

$$\int DA\ [\bar{A}^a_\nu(x) + A^a_\nu(x)]e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} = \Omega^a_\nu + \int d^4z\ (x|\frac{P^\Omega_\nu\bar{P}^\xi_\Omega}{P^2_\Omega}|z)^{ab}\Delta^b_\xi(z)$$

$$- \int d^4z\ \Big[i(x|\frac{P^\Omega_\nu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}A^{1c}_\xi + i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\nu(z)\Big] \quad (102)$$

bikoz $(\bar{D}^\Omega_\xi\tilde{A}^{1c}_\nu - \bar{D}^\Omega_\nu\tilde{A}^{1c}_\xi) = 0$

Nau $A_\mu = \Omega^\dagger_\mu + \tilde{A}^{(1)}_\mu + A^{(2)}_\mu \Rightarrow F_{\mu\nu} = \bar{D}^\Omega_\mu\tilde{A}^{(1)}_\nu + \bar{D}^\Omega_\mu A^{(2)}_\nu - \mu\leftrightarrow\nu - i[\tilde{A}^{(1)}_\mu,\tilde{A}^{(1)}_\nu]$ sou

$$\int DA\ F^a_{\mu\nu}(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \quad (103)$$

$$= \int d^4z\ \Big[-(x|\frac{P^\Omega_\mu P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\nu(z) - \mu\leftrightarrow\nu\Big] + f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x)$$

$$= \int d^4z\ \Big[(x|\frac{D^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{D}^\Omega_\mu\tilde{A}^{1b\xi})\tilde{A}^{1c}_\nu(z) - \mu\leftrightarrow\nu\Big] + f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x)$$

$$= \int d^4z\ \Big[(x|\frac{\bar{D}^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{D}^\Omega_\xi\tilde{A}^{1b}_\mu)\tilde{A}^{1c}_\nu(z) - \mu\leftrightarrow\nu\Big] + f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x)$$

$$= \int d^4z\ \Big[(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{D}^2_\Omega\tilde{A}^{1b}_\mu)\tilde{A}^{1c}_\nu(z) + (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{D}^\Omega_\xi\tilde{A}^{1b}_\mu)\bar{D}^\xi_\Omega\tilde{A}^{1c}_\nu(z) - \mu\leftrightarrow\nu\Big] + f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x)$$

$$= \int d^4z\ \Big[(x|\frac{\bar{D}^2_\Omega}{2P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^b_\mu\tilde{A}^{1c}_\nu(z) + (x|\frac{1}{2P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{D}^2_\Omega\tilde{A}^{1b}_\mu)\tilde{A}^{1c}_\nu(z) - (x|\frac{1}{2P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\mu\bar{D}^2_\Omega\tilde{A}^{1c}_\nu(z) - \mu\leftrightarrow\nu\Big] + f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x)$$

$$= -f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x) + \int d^4z\ \Big[(x|\frac{1}{2P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{D}^2_\Omega\tilde{A}^{1b}_\mu)\tilde{A}^{1c}_\nu(z) + (x|\frac{1}{2P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\nu\bar{D}^2_\Omega\tilde{A}^{1c}_\mu(z) - \mu\leftrightarrow\nu\Big] + f^{abc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\nu(x) = 0$$

4E U T D.

ЕЩ,Ё РАЗ: $\bar{A}_\mu = i\Omega\partial_\mu\Omega^\dagger + \delta A_\mu$

$$\int DA\ A^a_\mu(x) e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2 g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha \bar{D}_\xi \bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{104}$$

$$= -\delta A^a_\mu(x) + \int d^4z\ \Big[(x|\frac{P^\Omega_\mu P^\Omega_\xi}{P^2_\Omega}|z)^{ab}\delta A^{b\xi}(z) - i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\delta A^{b\xi}\tilde{A}^{1c}_\xi(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z)\Big]$$

gde $\tilde{A}^{1a}_\xi \ \equiv\ \int d^4z\ (x|\frac{P^\Omega_\xi \bar{P}^\eta_\Omega}{P^2}|z)^{ab}\delta A^b_\eta(z)$

3. *Gauge matrix*

$$\Omega^\dagger_\mu = i\Omega\partial_\mu\Omega^\dagger \Rightarrow \Omega^\dagger_\mu + \tilde{A}^{(1)}_\mu \ = \ i(1-\Omega\delta\Omega^\dagger)\Omega\partial_\mu\Omega^\dagger(1+\Omega\delta\Omega^\dagger) \Rightarrow$$

$$\tilde{A}^{(1)}_\mu \ = \ (i\partial_\mu + [\Omega^\dagger_\mu)\Omega\delta\Omega^\dagger \quad\Rightarrow\quad \tilde{A}^{1a}_\mu \ = \ (P^\Omega_\mu)^{ab}(\Omega\delta\Omega^\dagger)^b$$

where $(\Omega\delta\Omega^\dagger)^b \equiv 2\mathrm{tr}\{t^b\Omega\delta\Omega^\dagger\}$. Wi get

$$(\Omega\delta\Omega^\dagger)^a \ = \ \int dz\ (x|\frac{\bar{P}^\xi_\Omega}{P^2_\Omega}|z)^{ab}\Delta^b_\xi(z) \ = \ \Omega^{ac}_x\int dz\ (x|\frac{p^\xi}{p^2}|z)\Omega^{\dagger cb}_z\Delta^b_\xi(z)$$

$$\Rightarrow\ \delta\Omega^\dagger_x\Omega_x \ = \ \int dz\ (x|\frac{p^\xi}{p^2}|z)\Omega^\dagger_z\Delta_\xi(z)\Omega_z \tag{105}$$

Second order ($\Omega^\dagger_\mu \equiv \Omega i\partial_\mu\Omega^\dagger$)

$$\Omega[1 - \delta_1\Omega^\dagger\Omega - \delta_2\Omega^\dagger\Omega + \frac{1}{2}(\delta_1\Omega^\dagger\Omega)^2]i\partial_\mu[1 + \delta_1\Omega^\dagger\Omega + \delta_2\Omega^\dagger\Omega + \frac{1}{2}(\delta_1\Omega^\dagger\Omega)^2]\Omega^\dagger$$

$$= \ [1 - \Omega\delta_1\Omega^\dagger - \Omega\delta_2\Omega^\dagger + \frac{1}{2}(\Omega\delta_1\Omega^\dagger)^2]\Omega i\partial_\mu\Omega^\dagger[1 + \Omega\delta_1\Omega^\dagger + \Omega\delta_2\Omega^\dagger + \frac{1}{2}(\Omega\delta_1\Omega^\dagger)^2]$$

$$= \ [1 - \Omega\delta_1\Omega^\dagger - \Omega\delta_2\Omega^\dagger + \frac{1}{2}(\Omega\delta_1\Omega^\dagger)^2]\Omega^\dagger_\mu[1 + \Omega\delta_1\Omega^\dagger + \Omega\delta_2\Omega^\dagger + \frac{1}{2}(\Omega\delta_1\Omega^\dagger)^2]$$

$$+ \ [1 - \Omega\delta_1\Omega^\dagger - \Omega\delta_2\Omega^\dagger][i\partial_\mu(\Omega\delta_1\Omega^\dagger) + i\partial_\mu(\Omega\delta_2\Omega^\dagger) + \frac{1}{2}i\partial_\mu(\Omega\delta_1\Omega^\dagger)^2]$$

$$= \ \Omega^\dagger_\mu + (i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger) + (i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_2\Omega^\dagger) + \frac{1}{2}\big[(i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger), \Omega\delta_1\Omega^\dagger\big] \tag{106}$$

УРАВНЕНИЕ ($(i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger) = \tilde{A}^{(1)}_\mu$)

$$2\mathrm{tr}\big\{t^a\Big(\Omega^\dagger_\mu + (i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger) + (i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_2\Omega^\dagger) + \frac{1}{2}\big[(i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger), \Omega\delta_1\Omega^\dagger\big]\Big)\big\} \tag{107}$$

$$= \ \Omega^a_\mu + \int d^4z\ (x|\frac{P^\Omega_\mu \bar{P}^\xi_\Omega}{P^2_\Omega}|z)^{ab}\Delta^b_\xi(z) + \int d^4z\ \Big[i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}A^{1c}_\xi(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z)\Big]$$

$$\Rightarrow\ 2\mathrm{tr}\big\{t^a\Big((i\partial_\mu + [\Omega^\dagger_\mu)(\Omega\delta_2\Omega^\dagger) + \frac{1}{2}\big[\tilde{A}^{(1)}_\mu, \Omega\delta_1\Omega^\dagger\big]\Big)\big\} \ = \ (P^\Omega_\mu)^{ab}(\Omega\delta_2\Omega^\dagger)^b + \frac{i}{2}f^{abc}\tilde{A}^{1b}_\mu(\Omega\delta_1\Omega^\dagger)^c$$

$$= \ \int d^4z\ \Big[i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde{A}^{1c}_\xi(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z)\Big]$$

$$\Rightarrow\ (P^\Omega_\mu)^{ab}(\Omega\delta_2\Omega^\dagger)^b \ = \ \int d^4z\ \Big[-i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde{A}^{1c}_\xi(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z)\Big] - \frac{i}{2}f^{abc}\tilde{A}^{1b}_\mu(\Omega\delta_1\Omega^\dagger)^c$$

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$$if^{abc}\tilde{A}^{1b}_\mu(\Omega\delta_1\Omega^\dagger)^c + i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z) \;=\; if^{abc}\tilde{A}^{1b}_\mu(\Omega\delta_1\Omega^\dagger)^c + i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(P^\Omega_\xi)^{bm}(\Omega\delta\Omega^\dagger)^m\tilde{A}^{1c}_\mu(z)$$

$$= \; if^{abc}\tilde{A}^{1b}_\mu(\Omega\delta_1\Omega^\dagger)^c + if^{abc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\mu(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b(P^\Omega_\xi\tilde{A}^{1c}_\mu(z) \;=\; -i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b i\bar{D}^\Omega_\mu\tilde{A}^{1c}_\xi(z)$$

$$= \; -i(x|\frac{P^\xi_\Omega P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\xi(z) + i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\mu\tilde{A}^{1c}_\xi(z)$$

$$\Rightarrow \; -i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z) \;=\; \frac{i}{2}f^{abc}\tilde{A}^{1b}_\mu(\Omega\delta_1\Omega^\dagger)^c + \frac{i}{2}(x|\frac{P^\xi_\Omega P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\xi(z) \tag{108}$$

$\Rightarrow$ Eq. (107) takes the form

$$(P^\Omega_\mu)^{ab}(\Omega\delta_2\Omega^\dagger)^b \;=\; \int d^4z\,\Big[-i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde{A}^{1c}_\xi(z) + \frac{i}{2}(x|\frac{P^\xi_\Omega P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\xi(z)\Big]$$

$$\Rightarrow\; (\Omega\delta_2\Omega^\dagger)^a \;=\; \int d^4z\,\Big[-i(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde{A}^{1c}_\xi(z) + \frac{i}{2}(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\xi(z)\Big]$$

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$$(x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde{A}^{1c}_\xi(z) \;=\; (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}(P_\xi(\Omega\delta_1\Omega^\dagger))^c(z)$$

$$= \; (x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}(\Omega\delta_1\Omega^\dagger)^c(z) - (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{P}^\Omega_\xi\Delta^{b\xi})(\Omega\delta_1\Omega^\dagger)^c(z)$$

$$= \; (x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}(\Omega\delta_1\Omega^\dagger)^c(z) - (x|\frac{1}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\bar{P}^\Omega_\xi\tilde{A}^{1b\xi})(\Omega\delta_1\Omega^\dagger)^c(z)$$

$$= \; (x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}(\Omega\delta_1\Omega^\dagger)^c(z) - (x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b\xi}(\Omega\delta_1\Omega^\dagger)^c(z) \;=\; -(x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}A^{1b\xi}(\Omega\delta_1\Omega^\dagger)^c(z)$$

$\Rightarrow$ ИМЕЕМ

$$(\Omega\delta_2\Omega^\dagger)^a \;=\; \int dz\,\Big[-i(x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}(\Omega\delta_1\Omega^\dagger)^c(z) - \frac{i}{2}(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\xi(z)\Big]$$

4. Symmetric raz

$\bar{A}$ - arbitrary. $\bar{A}_\mu + \Delta_\mu = \Omega_\mu$ = pure gauge

$$\int DA\; A^a_\mu(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{109}$$

$$= \; \int d^4z\;(x|\frac{1}{\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta}}|z)^{ab}\bar{D}_\xi\bar{G}^{b\xi\beta}(z) \;=\; \int d^4z\;(x|\frac{1}{\bar{P}^2_\Omega g_{\alpha\beta} - \{P^\Omega_\xi,\Delta^\xi\}g_{\alpha\beta} - 2i\big((\bar{D}^\alpha\Delta^\beta)-\alpha\leftrightarrow\beta\big)}(P^2_\Omega g_{\beta\xi} - P^\Omega_\beta P^\Omega_\xi)\Delta^\xi$$

$$= \; \Delta_\alpha(x) - (x|\frac{1}{P^2_\Omega}P^\Omega_\alpha P^\Omega_\xi|z)\Delta^\xi(z)$$

$$\int DA\;\big(\bar{A}^a_\mu(x) + A^a_\mu(x)\big)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{110}$$

$$= \; \bar{A}^a_\mu(x) + \Delta_\alpha(x) - (x|\frac{1}{P^2_\Omega}P^\Omega_\alpha P^\Omega_\xi|z)\Delta^\xi(z) \tag{111}$$

Using Eq. (104) wi get

$$\int DA\; A^a_\mu(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{112}$$

$$= \; \Delta^a_\mu(x) + \int d^4z\,\Big[-(x|\frac{P^\Omega_\mu P^\Omega_\xi}{P^2_\Omega}|z)^{ab}\Delta^{b\xi}(z) - i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde{A}^{1c}_\xi(z) - i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\mu(z)\Big]$$

gde $\tilde{A}^{1a}_\xi \equiv \int d^4z\ (x|\frac{P^\Omega_\xi P^\eta_\Omega}{P^2_\Omega}|z)^{ab}\Delta^b_\eta(z)$

5. Symmetric dva

$$\begin{aligned}\bar{D}^\xi\bar{G}^a_{\xi\alpha} &= (\partial^{ab\xi} - gf^{abc}\bar{A}^{c\xi})(\partial_\xi\bar{A}^b_\alpha - \partial_\alpha\bar{A}^b_\xi + gf^{bmn}\bar{A}^m_\xi\bar{A}^n_\alpha) - \\ &= (\partial^2 g_{\xi\alpha} - \partial_\xi\partial_\alpha)\bar{A}^{a\xi} + gf^{abc}[2\bar{A}^b_\xi(\partial^\xi\bar{A}_\alpha)^c - \bar{A}^b_\alpha(\partial^\xi\bar{A}_\xi)^c - \bar{A}^b_\xi(\partial_\alpha\bar{A}^\xi)^c] - g^2 f^{abc}\bar{A}^{c\xi}f^{bmn}\bar{A}^m_\xi\bar{A}^n_\alpha \\ \bar{P}^2 g^{\alpha\beta} + 2i\bar{G}^{\alpha\beta} &= (p^2 + \{p^\xi, \bar{A}_\xi\} + \bar{A}^2)g_{\alpha\beta} + 2i\bar{G}^{\alpha\beta}\end{aligned}$$

$$\int DA\ A^a_\mu(x)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} = \int d^4z\ (x|\frac{1}{\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta}}|z)^{ab}\bar{D}_\xi\bar{G}^{b\xi\beta}(z) \tag{113}$$

$$= \int d^4z\ (x|\frac{1}{(p^2 + \{p^\xi, \bar{A}_\xi\} + \bar{A}^2)g_{\alpha\beta} + 2i\bar{G}^{\alpha\beta}}\Big(- (p^2 g_{\xi\alpha} - p_\xi p_\alpha)\bar{A}^\xi + gf^{abc}[2\bar{A}^b_\xi(\partial^\xi\bar{A}_\alpha)^c - \bar{A}^b_\alpha(\partial^\xi\bar{A}_\xi)^c - \bar{A}^b_\xi(\partial_\alpha\bar{A}^\xi)^c]\Big)$$

$$= -\bar{A}_\alpha + \int dz\ (x|\frac{p_\alpha p_\xi}{p^2}|z)\bar{A}^\xi(z) \tag{114}$$

6. bF gauge for arbitrary $\bar{A}$

At $\Omega^\dagger = 1$ and $\Delta \to \bar{A}$ the Eq. (99) gives $\tilde{A}^{(1)}_\nu = (x|\frac{p_\nu p_\xi}{p^2}|z)^{ab}\bar{A}^{b\xi}(z)$ and

$$A^{(1)}_\nu + A^{(2)}_\nu = -\bar{A}_\nu(x) + (x|\frac{p_\nu p_\xi}{p^2}|z)\bar{A}^{a\xi}(z) - i(x|\frac{p_\nu}{p^2}|z)f^{abc}\bar{A}^{b\xi}\tilde{A}^{1c}_\xi(z) - i(x|\frac{p^\xi}{p^2}|z)f^{abc}\tilde{A}^{1b}_\xi\tilde{A}^{1c}_\nu(z)$$

By inspection of f-la (141) at $\Omega^\dagger = 1$ and $\Delta \to \bar{A}$ we see that if $\partial^\xi\bar{A}_\xi = 0$ vi get $\tilde{A}^{(1)}_\xi = \int dz\ (x|\frac{p_\xi p^\eta}{p^2}|z)\bar{A}_\eta(z) = 0$ so

$$\int DA\ \big(\bar{A}^a_\mu(x) + A^a_\mu(x)\big)e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} = 0 \tag{115}$$

C. In 2 dimensions

$i\Omega\partial_*\Omega^\dagger = A_\bullet \Rightarrow \Omega^\dagger = [\pm\infty, x_*]$, $A_\bullet(x_*) = i[x_*, \pm\infty]\partial_\bullet[\pm\infty, x_*]$. We take $\Omega^\dagger(x_*) = [-\infty, x_*]$ and $\Delta_* = B_*$

$$(\Omega\delta_1\Omega^\dagger)^a = \int dz\ (x|\frac{\bar{P}^\xi_\Omega}{P^2_\Omega}|z)^{ab}\Delta^b_\xi(z) = \Omega^{ac}_x\int dz\ (x|\frac{p^\xi}{p^2 + i\epsilon p_0}|z)\Omega^{\dagger cb}_z\Delta^b_\xi(z) = \Omega^{ac}_{x_*}\frac{2}{s^2}\int dz_* dz_\bullet\ (x|\frac{1}{\alpha + i\epsilon}|z)\Omega^{\dagger cb}_{z_*}\Delta^b_*(z_\bullet)$$

$$= \frac{1}{s}\int dz_\bullet\ (x|\frac{1}{\alpha + i\epsilon}|z)B^a_*(z_\bullet) = -i\frac{1}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\ B^a_*(z_\bullet) \Rightarrow \Omega\delta_1\Omega^\dagger = \frac{1}{2}[-\infty, x_\bullet]^{(1)} \tag{116}$$

$$\tilde{A}^{(1)}_* = \frac{1}{2}B_*, \qquad \tilde{A}^{(1)}_\bullet = i\frac{1}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\ [B_*(z_\bullet), A_\bullet(x_*)]$$

Chek: $\partial_*\tilde{A}_\bullet + D_\bullet\tilde{A}_* = D_\bullet B_*$

$$\begin{aligned}(\Omega\delta_2\Omega^\dagger)^a &= \int dz\ \Big[- i(x|\frac{\bar{P}^\Omega_\xi}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}(\Omega\delta_1\Omega^\dagger)^c(z) - \frac{i}{2}(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\xi(z)\Big] \\ &= \frac{2}{s}\int dz\ \Big[- \frac{i}{2}(x|\frac{P^\Omega_*}{P^2_\Omega}|z)^{aa'}f^{a'bc}B^b_\bullet(\Omega\delta_1\Omega^\dagger)^c(z) - \frac{i}{2}(x|\frac{P^\Omega_\bullet}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_*(z)\Big] \\ &= \frac{i}{2}f^{abc}\frac{4}{s^2}\int_{-\infty}^{x_*} dz_\bullet\int_{-\infty}^{z_*} dz'_\bullet\ B^b_*(z_\bullet)B^c_*(z'_\bullet) - \frac{i}{2}f^{abc}\frac{2}{s}(x|\frac{P^\Omega_*}{P^2_\Omega}|z)^{aa'}f^{a'bc}(\Omega\delta_1\Omega^\dagger)^b\tilde{A}^{1c}_\bullet(z)\end{aligned}$$

1. Exampel po-drugomu

$x=(x_*,x_\bullet),\ x_R=(-x_*,x_\bullet),\ x_L=(x_*,-x_\bullet)$

$$\Omega^\dagger \;=\; \theta(x_*)\theta(x_\bullet)[x,-\infty x]+\theta(x_*)\theta(-x_\bullet)[x,-\infty x_R]+\theta(-x_*)\theta(x_\bullet)[x,-\infty x_L]+\theta(-x_*)\theta(-x_\bullet)[x,\infty x]$$
$$\Omega^\dagger_\mu \;=\; A_\mu(x)+\theta(x_*)\theta(x_\bullet)\int_{-\infty}^1 tdt\ [x,tx]x^\rho G_{\rho\mu}(tx)[tx,x]+...$$

2. Trial Λ

$$\Omega(x)\;=\;[x,0],\qquad \Omega_\mu\;=\;i[x,0]\partial_\mu[0,x]\;=\;-i(\partial_\mu\Omega)\Omega^\dagger$$

$$\Omega_\mu\;=\;\bar A_\mu(x)-\int_0^1 tdt\ [x,tx]x^\rho G_{\rho\mu}(tx)[tx,x]$$
$$\Rightarrow\ \Delta_\mu\;=\;-\int_0^1 tdt\ [x,tx]x^\rho G_{\rho\mu}(tx)[tx,x]$$

From f-la (104)

$$\int DA\ A^a_\mu(x)e^{i\int d^4z\left(\frac12 A^a_\alpha(\bar D^2 g^{\alpha\beta}-2i\bar G^{\alpha\beta})^{ab}A^b_\beta+A^a_\alpha\bar D_\xi\bar G^{a\xi\alpha}-gf^{abc}\bar D^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{117}$$
$$=\;\Delta^a_\mu(x)+\int d^4z\ \Big[(x|-\frac{P^\Omega_\mu P^\Omega_\xi}{P^2_\Omega}|z)^{ab}\Delta^{b\xi}(z)-i(x|\frac{P^\Omega_\mu}{P^2_\Omega}|z)^{aa'}f^{a'bc}\Delta^{b\xi}\tilde A^{1c}_\xi(z)-i(x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{aa'}f^{a'bc}\tilde A^{1b}_\xi\tilde A^{1c}_\mu(z)\Big]$$

gde $\tilde A^{1a}_\xi\ \equiv\ \int d^4z\ (x|\frac{P^\Omega_\xi P^\eta_\Omega}{P^2}|z)^{ab}\Delta^b_\eta(z)$ which corresponds to $\Omega^\dagger_\mu=i\Omega^\dagger\partial_\mu\Omega\Rightarrow$

$$\Omega_\mu+\tilde A^{(1)}_\mu\;=\;i(1-\delta\Omega\Omega^\dagger)\Omega\partial_\mu\Omega^\dagger(1+\delta\Omega\Omega^\dagger)$$

$\Rightarrow$

$$\Omega^\dagger\;=\;(1-\delta_1\Omega\Omega^\dagger)\Omega,\quad \tilde A^{(1)}_\mu\;=\;(i\partial_\mu+[\Omega_\mu)\delta\Omega\Omega^\dagger\quad\Rightarrow\quad \tilde A^{1a}_\mu\;=\;(P^\Omega_\mu)^{ab}(\delta\Omega\Omega^\dagger)^b$$

where $(\Omega^\dagger\delta\Omega)^b\equiv 2\mathrm{tr}\{t^b\Omega^\dagger\delta\Omega\}$. Wi get

$$(\delta\Omega\Omega^\dagger)^a\;=\;\int dz\ (x|\frac{P^\xi_\Omega}{P^2_\Omega}|z)^{ab}\Delta^b_\xi(z)\;=\;\Omega^{ac}_x\int dz\ (x|\frac{p^\xi}{p^2}|z)\Omega^{\dagger cb}_z\Delta^b_\xi(z)$$
$$\Rightarrow\ \Omega^\dagger_x\delta\Omega_x\;=\;-\int_0^1 tdt\int dz\ (x|\frac{p^\xi}{p^2}|z)\ [0,tz]z^\rho G_{\rho\xi}(tz)[tz,0] \tag{118}$$

$$\Omega^\dagger_x\delta\Omega_x\;=\;\int dz\ (x|\frac{p^\xi}{p^2}|z) \tag{119}$$

Second order ($\Omega^\dagger_\mu\equiv\Omega i\partial_\mu\Omega^\dagger$)

$$\Omega[1-\delta_1\Omega^\dagger\Omega-\delta_2\Omega^\dagger\Omega+\frac12(\delta_1\Omega^\dagger\Omega)^2]i\partial_\mu[1+\delta_1\Omega^\dagger\Omega+\delta_2\Omega^\dagger\Omega+\frac12(\delta_1\Omega^\dagger\Omega)^2]\Omega^\dagger$$
$$=\;[1-\Omega\delta_1\Omega^\dagger-\Omega\delta_2\Omega^\dagger+\frac12(\Omega\delta_1\Omega^\dagger)^2]\Omega i\partial_\mu\Omega^\dagger[1+\Omega\delta_1\Omega^\dagger+\Omega\delta_2\Omega^\dagger+\frac12(\Omega\delta_1\Omega^\dagger)^2]$$
$$=\;[1-\Omega\delta_1\Omega^\dagger-\Omega\delta_2\Omega^\dagger+\frac12(\Omega\delta_1\Omega^\dagger)^2]\Omega^\dagger_\mu[1+\Omega\delta_1\Omega^\dagger+\Omega\delta_2\Omega^\dagger+\frac12(\Omega\delta_1\Omega^\dagger)^2]$$
$$+\ [1-\Omega\delta_1\Omega^\dagger-\Omega\delta_2\Omega^\dagger][i\partial_\mu(\Omega\delta_1\Omega^\dagger)+i\partial_\mu(\Omega\delta_2\Omega^\dagger)+\frac12 i\partial_\mu(\Omega\delta_1\Omega^\dagger)^2]$$
$$=\;\Omega^\dagger_\mu+(i\partial_\mu+[\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger)+(i\partial_\mu+[\Omega^\dagger_\mu)(\Omega\delta_2\Omega^\dagger)+\frac12\big[(i\partial_\mu+[\Omega^\dagger_\mu)(\Omega\delta_1\Omega^\dagger),\Omega\delta_1\Omega^\dagger\big] \tag{120}$$

3. Background-Lorentz gauge

$$(\partial_\mu - iA_\mu - iB_\mu)C^\mu \;=\; 0 \Rightarrow$$

$$C^a_\mu \;=\; \int dz\ (x|\frac{1}{P^2_{A+B}g_{\mu\nu} + 2iG^{A+B}_{\mu\nu}}|z)^{ab}[(D^\mu G_{\mu\nu})^{A+B} - D^\mu A_{\mu\nu} - D^\mu B_{\mu\nu}]^b(z) \tag{121}$$

For $\bar{A} = \frac{2}{s}A_\bullet(x_*, x_\perp) + \frac{2}{s}B_*(x_\bullet, x_\perp)$ we get $D^\mu A_{\mu\nu} + D^\mu B_{\mu\nu} \;=\; \partial^2 \bar{A}$

If $\bar{A}_\mu + \Delta_\mu = \Omega_\mu$ = pure gauge from Eq. (109) we get

$$\int DA\ A^a_\mu(x) e^{i\int dz\left(\frac{1}{2}A^a_\alpha(\bar{D}^2 g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha \bar{D}_\xi \bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta - A^a_\xi \partial^2 \bar{A}^{a\xi}\right)} \tag{122}$$

$$= \int dz\ (x|\frac{1}{\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta}}|z)^{ab}\big(\bar{D}_\xi \bar{G}^{b\xi\beta}(z) - \partial^2 \bar{A}^{b\beta}(z)\big)$$

$$= \int dz\ (x|\frac{1}{\bar{P}^2_\Omega}\big[(P^2_\Omega g_{\alpha\xi} - P^\Omega_\alpha P^\Omega_\xi)|z)\Delta^\xi(z) - (x|\frac{1}{\bar{P}^2_\Omega}p^2|z)\bar{A}^b_\alpha(z)\big]$$

$$= \Delta_\alpha(x) - \int dz\ (x|\frac{1}{P^2_\Omega}P^\Omega_\alpha P^\Omega_\xi|z)\Delta^\xi(z) - \int dz\ (x|\frac{1}{\bar{P}^2_\Omega}p^2|z)\bar{A}^b_\alpha(z) \;=\; \Omega^\dagger_\alpha - \int dz\ (x|\frac{1}{\bar{P}^2_\Omega}p^2|z)\bar{A}^b_\alpha(z)$$

$$-\int dz\ (x|\frac{1}{\bar{P}^2_\Omega}p^2|z)\bar{A}^b_\alpha(z) \;=\; \frac{4i}{s}p_{1\alpha}\int dz\ \frac{\partial}{\partial z_*}(x|\frac{1}{\bar{P}^2_\Omega}p_*|z)\bar{A}^b_*(z) + \frac{4i}{s}p_{2\alpha}\int dz\ \frac{\partial}{\partial z_\bullet}(x|\frac{1}{\bar{P}^2_\Omega}p_\bullet|z)\bar{A}^b_\bullet(z)$$

VI. PURE GAUGE IN 2D

$$\bar{G}^a_{\xi\alpha} \;=\; \partial_\xi \bar{A}^a_\alpha - \partial_\alpha \bar{A}^a_\xi + gf^{abc}\bar{A}^b_\xi \bar{A}^c_\alpha \tag{123}$$

$$\bar{D}^\xi \bar{G}^a_{\xi\alpha} - (\partial^2 g_{\xi\alpha} - \partial_\xi\partial_\alpha)\bar{A}^\xi \;=\; (\partial^{ab\xi} - gf^{abc}\bar{A}^{c\xi})(\partial_\xi \bar{A}^b_\alpha - \partial_\alpha \bar{A}^b_\xi + gf^{bmn}\bar{A}^m_\xi \bar{A}^n_\alpha) - (\partial^2 g_{\xi\alpha} - \partial_\xi\partial_\alpha)\bar{A}^\xi$$

$$= gf^{abc}[2\bar{A}^b_\xi(\partial^\xi \bar{A}_\alpha)^c - \bar{A}^b_\alpha(\partial^\xi \bar{A}_\xi)^c - \bar{A}^b_\xi(\partial_\alpha \bar{A}^\xi)^c] + O(g^2) \;=\; gf^{abc}\big[\partial^\xi(\bar{A}^b_\xi \bar{A}^c_\alpha) + \bar{A}^{b\xi}(\partial_\xi \bar{A}^c_\alpha - \partial_\alpha \bar{A}^c_\xi)\big] - g^2 f^{abc}\bar{A}^{c\xi}f^{bmn}\bar{A}^m_\xi \bar{A}^n_\alpha$$

$$\bar{D}^2 g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta} - \bar{D}^\alpha \bar{D}^\beta \;=\; \partial^2 g_{\alpha\beta} - \partial_\alpha\partial_\beta - i\{\partial_\xi, \bar{A}^\xi\}g_{\alpha\beta} - 2i\big((\bar{D}^\alpha \bar{A}^\beta) - \alpha \leftrightarrow \beta\big) + i\bar{A}_\alpha\partial_\beta - \partial_\alpha \bar{A}_\beta \;+\; O(\bar{A}^2)$$

Trivial order

$$\int DA\ A^a_\nu(x) e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2 g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha \bar{D}_\xi \bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta - \frac{1}{2}A^a_\alpha \partial^2 \bar{A}^{a\alpha}\right)} =$$

$$= \int d^4z\ (x|\frac{1}{p^2}|z)f^{abc}\big[\partial^\xi(\bar{A}^b_\xi \bar{A}^c_\nu) + \bar{A}^{1b\xi}(\partial_\xi \bar{A}^{1c}_\nu - \partial_\nu \bar{A}^{1c}_\xi)\big] \overset{\partial_\mu \bar{A}_\nu = \partial_\nu \bar{A}_\mu}{=} \int d^4z\ (x|\frac{1}{p^2}|z)f^{abc}\partial^\xi\big(\bar{A}^b_\xi \bar{A}^c_\nu(z)\big) \tag{124}$$

Since $\bar{G}^a_{\mu\nu} \;=\; gf^{abc}\bar{A}^b_\mu \bar{A}^c_\nu \overset{x\to\infty}{\to} 0$ and $\bar{A}^\xi \partial_\xi \bar{A}_\nu \overset{x\to\infty}{\to} 0$

$$G^a_{\mu\nu}(\bar{A} + A) \;=\; -i\int d^2z\ (x|\frac{p_\mu}{p^2}|z)f^{abc}\bar{A}^b_\xi \partial^\xi \bar{A}^c_\nu(z) - \mu \leftrightarrow \nu + gf^{abc}\bar{A}^b_\mu \bar{A}^c_\nu \;=\; \int d^2z\ (x|\frac{1}{p^2}|z)f^{abc}\partial_\mu \bar{A}^b_\xi \partial^\xi \bar{A}^c_\nu(z) - \mu \leftrightarrow \nu + gf^{abc}\bar{A}^b_\mu \bar{A}^c_\nu$$

$$= \int d^2z\ (x|\frac{1}{p^2}|z)f^{abc}\partial_\xi \bar{A}^b_\mu \partial^\xi \bar{A}^c_\nu(z) - \mu \leftrightarrow \nu + gf^{abc}\bar{A}^b_\mu \bar{A}^c_\nu \;=\; \frac{1}{2}\int d^2z\ (x|\frac{\partial^2}{p^2}|z)f^{abc}\bar{A}^b_\mu \bar{A}^c_\nu(z) - \mu \leftrightarrow \nu + gf^{abc}\bar{A}^b_\mu \bar{A}^c_\nu \;=\; 0 \tag{125}$$

A. LO in $\bar{G}$

With our $\bar{A}$

$$\bar{G}^a_{\xi\alpha} \;=\; gf^{abc}\bar{A}^b_\xi \bar{A}^c_\alpha \tag{126}$$

$$\bar{D}^\xi \bar{G}^a_{\xi\alpha} - (\partial^2 g_{\xi\alpha} - \partial_\xi\partial_\alpha)\bar{A}^\xi \;=\; (\partial^{ab\xi} - gf^{abc}\bar{A}^{c\xi})gf^{bmn}\bar{A}^m_\xi \bar{A}^n_\alpha \;=\; g\bar{D}^{ab\xi}f^{bmn}(\bar{A}^m_\xi \bar{A}^n_\alpha) \;=\; gf^{amn}\bar{A}^m_\xi(\bar{D}^\xi \bar{A}_\alpha)^n$$

$$A^{(1)a}_\alpha \equiv \int DA\ A^a_\alpha(x)e^{i\int d^2z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta-A^a_\alpha\partial^2\bar{A}^{a\alpha}\right)} =$$

$$= \int d^2z\ (x|\frac{1}{\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta}}|z)^{aa'}f^{a'bc}\bar{A}^b_\xi(\bar{D}^\xi\bar{A}_\beta)^c(z) = \int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{A}^b_\xi(\bar{D}^\xi\bar{A}_\alpha)^c(z) + O(\bar{G}^2) \tag{127}$$

$\Rightarrow$

$$A^{(1)a}_\bullet = \frac{2i}{s}\int d^2z\ (x|\frac{P_\bullet}{P^2}|z)G_{\bullet*}(z), \quad A^{(1)a}_* = -\frac{2i}{s}\int d^2z\ (x|\frac{P_*}{P^2}|z)G_{\bullet*}(z) \tag{128}$$

$$G^a_{\mu\nu}(\bar{A}+A^{(1)}) \simeq G^a_{\mu\nu}(\bar{A})+(\bar{D}_\mu A^{(1)}_\nu-\mu\leftrightarrow\nu)^a = \int d^2z\ (x|\frac{\bar{D}_\mu}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{A}^b_\xi(\bar{D}^\xi\bar{A}_\nu)^c(z)-\mu\leftrightarrow\nu + gf^{abc}\bar{A}^b_\mu\bar{A}^c_\nu$$

$$= \int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[(\bar{D}_\mu\bar{A}_\xi)^b(\bar{D}^\xi\bar{A}_\nu)^c(z) + (\bar{A}_\xi)^b(\bar{D}_\mu\bar{D}^\xi\bar{A}_\nu)^c(z)\big]-\mu\leftrightarrow\nu+gf^{abc}\bar{A}^b_\mu\bar{A}^c_\nu$$

$$= \int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[(\bar{D}_\mu\bar{A}_\xi-\bar{D}_\xi\bar{A}_\mu)^b(\bar{D}^\xi\bar{A}_\nu)^c(z) - (\bar{A}^\xi)^b(D^2g_{\mu\xi}-\bar{D}_\mu\bar{D}^\xi)\bar{A}_\nu)^c(z)\big]-\mu\leftrightarrow\nu \tag{129}$$

Y HAC $\bar{D}^{ab}_*\bar{A}^b_\bullet = \bar{G}^a_{*\bullet}$

$$G^a_{\bullet*}(\bar{A}+A^{(1)}) = \int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc} \tag{130}$$

$$\times\big[(\bar{D}_\bullet\bar{A}_\xi-\bar{D}_\xi\bar{A}_\bullet)^b(\bar{D}^\xi\bar{A}_*)^c(z)-(\bar{A}^\xi)^b(D^2g_{\bullet\xi}-\bar{D}_\bullet\bar{D}^\xi)\bar{A}_*)^c(z)-(\bar{D}_*\bar{A}_\xi-\bar{D}_\xi\bar{A}_*)^b(\bar{D}^\xi\bar{A}_\bullet)^c(z)+(\bar{A}^\xi)^b(D^2g_{*\xi}-\bar{D}_*\bar{D}^\xi)\bar{A}_\bullet)^c(z)\big]$$

$$= \frac{2}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[(\bar{D}_\bullet\bar{A}_*-\bar{D}_*\bar{A}_\bullet)^b(\bar{D}_\bullet\bar{A}_*)^c(z)-(\bar{D}_*\bar{A}_\bullet-\bar{D}_\bullet\bar{A}_*)^b(\bar{D}_*\bar{A}_\bullet)^c(z)$$
$$-(\bar{A}_\bullet)^b(\bar{D}_*\bar{D}_\bullet\bar{A}_*+\bar{D}^2_*\bar{A}_\bullet)^c(z)+(\bar{A}_*)^b(\bar{D}_\bullet\bar{D}_*\bar{A}_\bullet+\bar{D}^2_\bullet\bar{A}_*)^c(z)\big]$$

$$= \frac{2}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[-(\bar{A}_\bullet)^b(\bar{D}_*\bar{D}_\bullet\bar{A}_*+\bar{D}^2_*\bar{A}_\bullet)^c(z)+(\bar{A}_*)^b(\bar{D}_\bullet\bar{D}_*\bar{A}_\bullet+\bar{D}^2_\bullet\bar{A}_*)^c(z)\big]$$

$$= \frac{2}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[(\bar{A}_\bullet)^b(\bar{P}_*\bar{P}_\bullet\bar{A}_*+\bar{P}^2_*\bar{A}_\bullet)^c(z)-(\bar{A}_*)^b(\bar{P}_\bullet\bar{P}_*\bar{A}_\bullet+\bar{P}^2_\bullet\bar{A}_*)^c(z)\big]$$

$$= \frac{2}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[(\bar{A}_\bullet)^b(\bar{P}_*\bar{A}_\bullet)^{cd}\bar{A}^d_*(z)+(\bar{A}_\bullet)^b(\bar{P}_*\bar{A}_*)^{cd}\bar{A}^d_\bullet(z)-(\bar{A}_*)^b(\bar{P}_\bullet\bar{A}_*)^{cd}\bar{A}^d_\bullet(z)+(\bar{A}_*)^b(\bar{P}_\bullet\bar{A}_\bullet)^{cd}\bar{A}^d_*(z)\big]$$

$$= \frac{2}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[(\bar{A}_\bullet)^b(i\bar{D}_*\bar{A}_\bullet)^{cd}\bar{A}^d_*(z)+i(\bar{A}_\bullet)^b\bar{A}^{cd}_\bullet\partial_*\bar{A}^d_*(z)+(\bar{A}_\bullet)^b(i\partial_*\bar{A}_*)^{cd}\bar{A}^d_\bullet(z) - (\bullet\leftrightarrow*)\big]$$

$$= \frac{2i}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\big[\bar{A}^b_\bullet\bar{G}^{cd}_{*\bullet}\bar{A}^d_*(z)+\bar{A}^b_*\bar{G}^{cd}_{*\bullet}\bar{A}^d_\bullet(z)\big] \tag{131}$$

ΠΟ-DΡΥΓΟΜΥ: from Eq. (127) we get

$$A^{(1)a}_\alpha = -i\int d^2z\ (x|\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{aa'}f^{a'bc}\bar{A}^b_\xi\bar{A}^c_\alpha(z) + O(\bar{G}^2) =$$

$$\Rightarrow A^{(1)a}_\bullet = \frac{2i}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)\bar{G}_{\bullet*}(z), \quad A^{(1)a}_* = -\frac{2i}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}G^b_{\bullet*}(z) + O(\bar{G}^2) \tag{132}$$

$\Rightarrow$

$$G^a_{\bullet*}(\bar{A}+A^{(1)}) \simeq G^a_{\bullet*}(\bar{A})+\bar{D}_\bullet A^{(1)}_*-\bar{D}_*A^{(1)}_\bullet = \bar{G}^a_{\bullet*}-\frac{2}{s}\int d^2z\ (x|\bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_*+\bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{\bullet*}(z) = O(\bar{G}^2) \tag{133}$$

B. NLO: $\bar{G}^2$

$$
\begin{aligned}
A^{(1+2)a}_\alpha \ &\equiv\ A^{(1)a}_\alpha + A^{(2)a}_\alpha \ =\ \int DA\ A^a_\alpha(x) e^{i\int d^2z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2 g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha \bar{D}_\xi \bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta - A^a_\alpha \partial^2 \bar{A}^{a\alpha}\right)} = \\
=\ &\int d^2z\ \Big[-i(x|\frac{1}{\bar{P}^2 g_{\alpha\beta}+2i\bar{G}_{\alpha\beta}}\bar{P}^\xi|z)^{ab}\bar{G}^b_{\xi\beta}(z) \\
-\ &i(x|\frac{1}{\bar{P}^2 g_{\alpha\beta}+2i\bar{G}_{\alpha\beta}}\bar{P}^\xi|z)^{aa'}f^{a'bc}A^{(1)b}_\xi A^{(1)b}_\beta - (x|\frac{1}{\bar{P}^2 g_{\alpha\beta}+2i\bar{G}_{\alpha\beta}}|z)^{aa'}f^{a'bc}A^{(1)b\xi}(\bar{D}_\beta A^{(1)b}_\xi - \bar{D}_\xi A^{(1)b}_\beta)\Big]\ +\ O(\bar{G}^3) \\
=\ &\int d^2z\ \Big[-i(x|\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{ab}\bar{G}^b_{\xi\alpha}(z) - 2(x|\frac{1}{\bar{P}^2}\bar{G}_{\alpha\beta}\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{ab}\bar{G}^b_{\xi\beta}(z) \\
-\ &i(x|\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{aa'}f^{a'bc}A^{(1)b}_\xi A^{(1)c}_\alpha - (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b\xi}(\bar{D}_\alpha A^{(1)c}_\xi - \bar{D}_\xi A^{(1)c}_\alpha)\Big]\ +\ O(\bar{G}^3)
\end{aligned}
\tag{134}
$$

$$
\begin{aligned}
A^{(1+2)a}_\bullet \ &=\ \int d^2z\ \Big[-\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{8}{s^2}(x|\frac{1}{\bar{P}^2}\bar{G}_{*\bullet}\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
-\ &\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet - \frac{2}{s}(x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet(\bar{D}_\bullet A^{(1)c}_* - \bar{D}_* A^{(1)c}_\bullet)\Big]\ +\ O(\bar{G}^3) \\
A^{(2)a}_* \ &=\ \int d^2z\ \Big[\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{8}{s^2}(x|\frac{1}{\bar{P}^2}\bar{G}_{*\bullet}\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
+\ &\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_*|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet + \frac{2}{s}(x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b}_*(\bar{D}_\bullet A^{(1)c}_* - \bar{D}_* A^{(1)c}_\bullet)\Big]\ +\ O(\bar{G}^3)
\end{aligned}
\tag{135}
$$

$$
\begin{aligned}
G^a_{\mu\nu}(\bar{A}+A^{(1)}+A^{(2)})\ &=\ \bar{G}^a_{\mu\nu} + (\bar{D}_\mu A^{(1)}_\nu - \mu\leftrightarrow\nu)^a + (\bar{D}_\mu A^{(2)}_\nu - \mu\leftrightarrow\nu)^a + gf^{abc}A^{(1)b}_\mu A^{(1)c}_\nu\ +\ O(\bar{G}^3) \\
G^a_{*\bullet}(\bar{A}+A^{(1)}+A^{(2)})\ &=\ \bar{G}^a_{*\bullet} + (\bar{D}_* A^{(1+2)}_\bullet - \bar{D}_\bullet A^{(1+2)}_*)^a + gf^{abc}A^{(1)b}_* A^{(1)c}_\bullet\ +\ O(\bar{G}^3)
\end{aligned}
\tag{136}
$$

Potochnee

$$
\begin{aligned}
&G^a_{*\bullet}(\bar{A}) + \bar{D}_* A^{(1)}_\bullet - \bar{D}_\bullet A^{(1)}_* \\
&=\ \bar{G}^a_{\bullet *} - \frac{2}{s}\int d^2z\ (x|\bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_* + \bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z)\ =\ \frac{2}{s}\int d^2z\ (x|\frac{1}{\bar{P}^2}\bar{P}_\bullet\bar{G}_{*\bullet}\bar{P}_*\frac{1}{\bar{P}^2} + \frac{1}{\bar{P}^2}\bar{P}_*\bar{G}_{*\bullet}\bar{P}_\bullet\frac{1}{\bar{P}^2}|z)^{ab}\bar{G}^b_{*\bullet}(z) + O(\bar{G}^3)
\end{aligned}
\tag{137}
$$

DAΛEE

$$
\begin{aligned}
(\bar{D}_* A^{(1+2)}_\bullet - \bar{D}_\bullet A^{(1+2)}_*)^a \ &=\ \int d^2z\ \Big[-\frac{2}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) - \frac{8i}{s^2}(x|\bar{P}_*\frac{1}{\bar{P}^2}\bar{G}_{*\bullet}\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
-\ &\frac{2}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet + \frac{2i}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet(\bar{D}_\bullet A^{(1)c}_* - \bar{D}_* A^{(1)c}_\bullet) \\
-\ &\frac{2}{s}(x|\bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{8i}{s^2}(x|\bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{G}_{*\bullet}\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
-\ &\frac{2}{s}(x|\bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_*|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet + \frac{2i}{s}(x|\bar{P}_\bullet\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b}_*(\bar{D}_\bullet A^{(1)c}_* - \bar{D}_* A^{(1)c}_\bullet)\Big]\ +\ O(\bar{G}^3)
\end{aligned}
\tag{138}
$$

Bikoz $\bar{D}_\bullet A^{(1)}_* - \bar{D}_* A^{(1)}_\bullet = \bar{G}_{*\bullet}$

$$
(\bar{D}_* A^{(1+2)}_\bullet - \bar{D}_\bullet A^{(1+2)}_*)^a \ =\ -f^{abc}A^{(1)b}_* A^{(1)c}_\bullet + \int d^2z\ \Big[-\frac{2}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet + \bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z)
\tag{139}
$$

$$
\begin{aligned}
+\ &\frac{8i}{s^2}(x|\frac{1}{\bar{P}^2}(\bar{P}_\bullet\bar{G}_{*\bullet}\bar{P}_* - \bar{P}_*\bar{G}_{*\bullet}\bar{P}_\bullet)\frac{1}{\bar{P}^2}|z)^{ab}\bar{G}^b_{*\bullet}(z) - \frac{2i}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{G}^b_{*\bullet}A^{(1)c}_\bullet - \frac{2i}{s}(x|\bar{P}_\bullet\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{G}^b_{*\bullet}A^{(1)c}_*\Big]\ +\ O(\bar{G}^3) \\
=\ &-f^{abc}A^{(1)b}_* A^{(1)c}_\bullet - \bar{G}^a_{*\bullet} + \int d^2z\ \Big[\frac{4i}{s^2}(x|\frac{1}{\bar{P}^2}(\bar{P}_\bullet\bar{G}_{*\bullet}\bar{P}_* - \bar{P}_*\bar{G}_{*\bullet}\bar{P}_\bullet)\frac{1}{\bar{P}^2}|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
-\ &\frac{4}{s^2}(x|\bar{P}_*\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{G}^b_{*\bullet}(z)\int dz'(z|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z')^{cd}G^d_{*\bullet}(z') + \frac{4}{s^2}(x|\bar{P}_\bullet\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{G}^b_{*\bullet}(z)\int dz'(z|\frac{1}{\bar{P}^2}\bar{P}_*|z')^{cd}G^d_{*\bullet}(z')\Big]\ +\ O(\bar{G}^3) \\
=\ &-\bar{G}^a_{*\bullet} - f^{abc}A^{(1)b}_* A^{(1)c}_\bullet\ +\ O(\bar{G}^3)
\end{aligned}
\tag{140}
$$

$\Rightarrow G^a_{\mu\nu}(\bar{A}+A^{(1)}+A^{(2)})\ =\ O(\bar{G}^3)$ for any $\frac{1}{\bar{P}^2\pm i\epsilon}$ or $\frac{1}{\bar{P}^2\pm i\epsilon p_0}$

C. Pure gauge in a simple way

$$\bar{A}^\mu \;=\; \frac{2}{s}p_1^\mu \bar{A}_\bullet(x_*) + \frac{2}{s}p_2^\mu \bar{A}_*(x_\bullet), \qquad \bar{G}^a_{*\bullet}(x_*,x_\bullet) \;=\; f^{abc}\bar{A}^b_*(x_\bullet)\bar{A}^c_\bullet(x_*)$$

Rewrite Eq. (134)

$$\begin{aligned}
A^{(1+2)a}_\alpha \;&\equiv\; A^{(1)a}_\alpha + A^{(2)a}_\alpha \;=\; \int DA\; A^a_\alpha(x) e^{i\int d^2z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2 g^{\alpha\beta} - 2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha \bar{D}_\xi \bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta - A^a_\alpha \partial^2 \bar{A}^{a\alpha}\right)} = \\
&= \int d^2z\,\Big[-i(x|\frac{1}{\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta}}\bar{P}^\xi|z)^{ab}\bar{G}^b_{\xi\beta}(z) \\
&- i(x|\frac{1}{\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta}}\bar{P}^\xi|z)^{aa'}f^{a'bc}A^{(1)b}_\xi A^{(1)b}_\beta - (x|\frac{1}{\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta}}|z)^{aa'}f^{a'bc}A^{(1)b\xi}(\bar{D}_\beta A^{(1)b}_\xi - \bar{D}_\xi A^{(1)b}_\beta)\Big] \;+\; O(\bar{G}^3) \\
&= \int d^2z\,\Big[-i(x|\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{ab}\bar{G}^b_{\xi\alpha}(z) - 2(x|\frac{1}{\bar{P}^2}\bar{G}_{\alpha\beta}\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{ab}\bar{G}^b_{\xi\beta}(z) \\
&- i(x|\frac{1}{\bar{P}^2}\bar{P}^\xi|z)^{aa'}f^{a'bc}A^{(1)b}_\xi A^{(1)c}_\alpha - (x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b\xi}(\bar{D}_\alpha A^{(1)c}_\xi - \bar{D}_\xi A^{(1)c}_\alpha)\Big] \;+\; O(\bar{G}^3)
\end{aligned} \tag{141}$$

$$\frac{1}{\bar{P}^2} \;=\; \frac{s}{4}\frac{1}{\bar{P}_\bullet \bar{P}_* + \frac{i}{2}\bar{G}_{*\bullet}} \;\simeq\; \frac{s}{4}\frac{1}{\bar{P}_\bullet \bar{P}_*} - \frac{is}{8}\frac{1}{\bar{P}_\bullet \bar{P}_*}\bar{G}_{*\bullet}\frac{1}{\bar{P}_\bullet \bar{P}_*} \;+\; O(\bar{G}^2)$$

From Eq. (141) we get

$$\begin{aligned}
A^{(1+2)a}_\bullet \;&=\; \int d^2z\,\Big[-\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{8}{s^2}(x|\frac{1}{\bar{P}^2}\bar{G}_{*\bullet}\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
&\qquad - \frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet - \frac{2}{s}(x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet \bar{G}^c_{*\bullet}\Big] \;+\; O(\bar{G}^3) \\
&= \int d^2z\,\Big[-\frac{i}{2}(x|\frac{1}{\bar{P}_*}|z)^{ab}\bar{G}^b_{*\bullet}(z) - \frac{1}{4}(x|\frac{1}{\bar{P}_\bullet \bar{P}_*}\bar{G}_{*\bullet}\frac{1}{\bar{P}_*}|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{1}{2}(x|\frac{1}{\bar{P}_\bullet \bar{P}_*}\bar{G}_{*\bullet}\frac{1}{\bar{P}_*}|z)^{ab}\bar{G}^b_{*\bullet}(z) \\
&\qquad - \frac{i}{2}(x|\frac{1}{\bar{P}_*}|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet - \frac{1}{4}(x|\frac{1}{\bar{P}_\bullet \bar{P}_*}\bar{G}_{*\bullet}\frac{1}{\bar{P}_*}|z)^{ab}\bar{G}^b_{*\bullet}(z)\Big] \;+\; O(\bar{G}^3) \\
&= \int d^2z\,\Big[-\frac{i}{2}(x|\frac{1}{\bar{P}_*}|z)^{ab}\bar{G}^b_{*\bullet}(z) - \frac{i}{2}(x|\frac{1}{\bar{P}_*}|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet\Big]
\end{aligned} \tag{142}$$

$\Rightarrow$

$$A^{(1)a}_\bullet \;=\; -\frac{i}{2}\int d^2z\;(x|\frac{1}{\bar{P}_*}|z)^{ab}\bar{G}^b_{*\bullet}(z), \qquad A^{(2)a}_\bullet \;=\; -\frac{i}{2}\int d^2z\;(x|\frac{1}{\bar{P}_*}|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet \tag{143}$$

Similarly,

$$A^{(1)a}_* \;=\; \frac{i}{2}\int d^2z\;(x|\frac{1}{\bar{P}_\bullet}|z)^{ab}\bar{G}^b_{*\bullet}(z), \qquad A^{(2)a}_* \;=\; \frac{i}{2}\int d^2z\;(x|\frac{1}{\bar{P}_\bullet}|z)^{aa'}f^{a'bc}A^{(1)b}_* A^{(1)c}_\bullet \tag{144}$$

Now

$$(\bar{D}_* A^{(1+2)}_\bullet - \bar{D}_\bullet A^{(1+2)}_*)^a \;=\; -\bar{G}^a_{*\bullet} - f^{abc}A^{(1)b}_* A^{(1)c}_\bullet \;\Leftrightarrow\; \bar{G}_{*\bullet}(\bar{A} + A^{(1)} + A^{(2)}) \;=\; O(\bar{G}^3) \tag{145}$$

is evident.

D. Pure gauge for the retarded propagators

$$\begin{aligned}
A^{(1)a}_\bullet \;&=\; -\frac{i}{2}\int d^2z\;(x|\frac{1}{\bar{P}_* + i\epsilon}|z)^{ab}\bar{G}^b_{*\bullet}(z) \;=\; \frac{i}{2}\int_{-\infty}^{x_\bullet} dz_\bullet\;\big([x_\bullet, z_\bullet]A_*(z_\bullet)\big)^{ab}\bar{A}^b_\bullet(x_*) \;\simeq\; -\frac{1}{2}f^{abc}\int_{-\infty}^{x_\bullet} dz_\bullet A^b_*(z_\bullet)\bar{A}^c_\bullet(x_*) \\
A^{(1)a}_* \;&=\; \frac{i}{2}\int d^2z\;(x|\frac{1}{\bar{P}_\bullet}|z)^{ab}\bar{G}^b_{*\bullet}(z) \;=\; \frac{i}{2}\int_{-\infty}^{x_*} dz_*\;\big([x_*, z_*]A_\bullet(z_*)\big)^{ab}\bar{A}^b_*(x_\bullet)
\end{aligned} \tag{146}$$

$$\frac{2}{s}\bar{D}_*\bar{D}_\bullet\theta(x_*-z_*)[x_*,z_*]\theta(x_\bullet-z_\bullet)[x_\bullet,z_\bullet] \;=\; \frac{s}{2}\delta(x_*-z_*)\delta(x_\bullet-z_\bullet) \;=\; \delta^{(2)}(x-z)$$
$$(x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z) \;=\; (x|\frac{1}{(\bar{P}_*+i\epsilon)(\bar{P}_\bullet+i\epsilon)}|z) \;=\; -\frac{2}{s}\theta(x_*-z_*)[x_*,z_*]\theta(x_\bullet-z_\bullet)[x_\bullet,z_\bullet] \tag{147}$$

$$\bar{A}_\bullet(x_*)+A_\bullet^{(1)a}(x) \;=\; [x_*,-\infty]i\partial_\bullet[-\infty,x_*]-\frac{i}{2}\int d^2z\ (x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z)^{ab}\bar{G}^b_{*\bullet}(z) \;=\; \Omega i\partial_\bullet\Omega^\dagger$$
$$\Omega^\dagger=[-\infty,x_*](1+\delta\Omega^\dagger) \quad\Rightarrow\quad \delta\Omega^a=-\frac{i}{2}\int d^2z\ (x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z)^{ab}\bar{G}^b_{*\bullet}(z)$$
$$\Rightarrow\ \delta\Omega^\dagger \;=\; \frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}z_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\ [x_*,z_*][x_\bullet,z_\bullet]\bar{G}_{*\bullet}[z_\bullet,x_\bullet][z_*,x_*] \tag{148}$$

1. A $\Omega_0^\dagger=[-\infty x,x]$ model

$$[x,-\infty x]i\partial_\bullet[-\infty x,x] \;\equiv\; [x,-\infty x]\frac{is}{2}\frac{\partial}{\partial x_*}[-\infty x,x] \;=\; \bar{A}_\bullet(x)+\frac{2}{s}x_\bullet\int_{-\infty}^1 tdt\ [x,tx]G_{*\bullet}(tx)[tx,x]$$
$$[x,-\infty x]i\partial_*[-\infty x,x] \;\equiv\; [x,-\infty x]\frac{is}{2}\frac{\partial}{\partial x_\bullet}[-\infty x,x] \;=\; \bar{A}_*(x)-\frac{2}{s}x_*\int_{-\infty}^1 tdt\ [x,tx]G_{*\bullet}(tx)[tx,x] \tag{149}$$

$$\bar{A}_\bullet(x_*)+A_\bullet^{(1)a}(x) \;=\; \bar{A}_\bullet(x_*)-\frac{i}{2}\int d^2z\ (x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z)^{ab}\bar{G}^b_{*\bullet}(z) \;=\; \Omega i\partial_\bullet\Omega^\dagger$$
$$\Omega^\dagger=[-\infty x,x](1+\delta\Omega^\dagger) \quad\Rightarrow\quad (i\partial_\bullet+[\bar{A}_\bullet,)\delta\Omega^a \;=\; -\frac{i}{2}\int d^2z\ (x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z)^{ab}\bar{G}^b_{*\bullet}(z)-\frac{2}{s}x_\bullet\int_{-\infty}^1 tdt\ [x,tx]^{ab}G^b_{*\bullet}(tx)$$
$$\Rightarrow\ \delta\Omega^a \;=-\frac{i}{2}\int d^2z\ (x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z)^{ab}\bar{G}^b_{*\bullet}(z)+?\frac{ix^2}{s}\int_{-\infty}^1 tdt\ [x,tx]^{ab}G^b_{*\bullet}(tx)\ +\ O(D_\bullet G_{*\bullet})$$
$$=\ \frac{i}{2}\int d\frac{2}{s}z_*\int d\frac{2}{s}z_*\ [x_*,z_*][x_\bullet,z_\bullet]\bar{G}_{*\bullet}(z_*,z_\bullet)[z_\bullet,x_\bullet][z_*,x_*]+? \tag{150}$$

E. Propagator

$$\int DA\ A^m_\mu(x)A^n_\nu(y)e^{i\int d^2z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)}$$
$$\ni\ -igf^{abc}\int DA\ A^m_\mu(x)A^n_\nu(y)\int dz\ \bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta(z)e^{i\int d^2z'\left(\frac{1}{2}A^a_\alpha(\bar{D}^2g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}\right)}$$
$$=\ -igf^{abc}\int dz\ \Big[\langle A^m_\mu(x)A^{b\alpha}(z)\rangle_{\bar{A}}\langle A^{c\beta}(z)A^n_\nu(y)\rangle_{\bar{A}}\big(\bar{D}_\alpha A^{(1)a}_\beta-\bar{D}_\beta A^{(1)a}_\alpha\big)$$
$$+\langle A^m_\mu(x)\big(\bar{D}^\alpha A^{a\beta}-\bar{D}^\beta A^{a\alpha}\big)(z)\rangle_{\bar{A}}A^{(1)b}_\alpha\langle A^c_\beta(z)A^n_\nu(y)\rangle_{\bar{A}}+\langle A^m_\mu(x)A^c_\beta(z)\rangle_{\bar{A}}A^{(1)b}_\alpha\langle\big(\bar{D}^\alpha A^{a\beta}-\bar{D}^\beta A^{a\alpha}\big)(z)A^n_\nu(y)\rangle_{\bar{A}}\Big]$$
$$=\ if^{abc}\int dz\ (x|\frac{1}{\bar{P}^2g_{\mu\alpha}+2i\bar{G}_{\mu\alpha}}|z)^{mb}\big(\bar{D}_\alpha A^{(1)a}_\beta-\bar{D}_\beta A^{(1)a}_\alpha\big)(z|\frac{1}{\bar{P}^2g_{\beta\nu}+2i\bar{G}_{\beta\nu}}|y)^{cn}$$
$$-\ f^{abc}\int dz\ (x|\frac{1}{\bar{P}^2g_{\mu\beta}+2i\bar{G}_{\mu\beta}}\bar{P}_\alpha-\frac{1}{\bar{P}^2g_{\mu\beta}+2i\bar{G}_{\mu\alpha}}\bar{P}_\beta|z)^{ma}A^{(1)b}_\alpha(z)(z|\frac{1}{\bar{P}^2g_{\beta\nu}+2i\bar{G}_{\beta\nu}}|y)^{cn}$$
$$+\ f^{abc}\int dz\ (x|\frac{1}{\bar{P}^2g_{\mu\beta}+2i\bar{G}_{\mu\beta}}|z)^{mc}A^{(1)b}_\alpha(z)(x|\bar{P}_\alpha\frac{1}{\bar{P}^2g_{\beta\nu}+2i\bar{G}_{\beta\nu}}-\bar{P}_\beta\frac{1}{\bar{P}^2g_{\alpha\nu}+2i\bar{G}_{\alpha\nu}}|z)^{an} \tag{151}$$

$$= -\int dz\ (x|\frac{1}{\bar P^2 g_{\mu\alpha}+2i\bar G_{\mu\alpha}}|z)^{mb}\big(\bar D_\alpha A^{(1)}_\beta - \bar D_\beta A^{(1)}_\alpha\big)^{bc}(z|\frac{1}{\bar P^2 g_{\beta\nu}+2i\bar G_{\beta\nu}}|y)^{cn}$$
$$+ i\int dz\ (x|\frac{1}{\bar P^2 g_{\mu\beta}+2i\bar G_{\mu\beta}}\bar P_\alpha - \frac{1}{\bar P^2 g_{\mu\alpha}+2i\bar G_{\mu\alpha}}\bar P_\beta|z)^{ma}A^{(1)ac}_\alpha(z)(z|\frac{1}{\bar P^2 g_{\beta\nu}+2i\bar G_{\beta\nu}}|y)^{cn}$$
$$+ i\int dz\ (x|\frac{1}{\bar P^2 g_{\mu\beta}+2i\bar G_{\mu\beta}}|z)^{mc}A^{(1)ca}_\alpha(z)(x|\bar P_\alpha\frac{1}{\bar P^2 g_{\beta\nu}+2i\bar G_{\beta\nu}} - \bar P_\beta\frac{1}{\bar P^2 g_{\alpha\nu}+2i\bar G_{\alpha\nu}}|z)^{an}$$
$$= i\int dz\ (x|\frac{1}{\bar P^2 g_{\mu\alpha}+2i\bar G_{\mu\alpha}}\big[\{\bar P_\xi, A^{(1)\xi}\}g_{\alpha\beta} + 2i(\bar D_\alpha A^{(1)}_\beta - \bar D_\beta A^{(1)}_\alpha)\big]\frac{1}{\bar P^2 g_{\beta\nu}+2i\bar G_{\beta\nu}}|y)^{mn}$$
$$- i\int dz\ (x|\frac{1}{\bar P^2 g_{\mu\alpha}+2i\bar G_{\mu\alpha}}A^{(1)}_\alpha\bar P_\beta\frac{1}{\bar P^2 g_{\beta\nu}+2i\bar G_{\beta\nu}}|y)^{mn} - i\int dz\ (x|\frac{1}{\bar P^2 g_{\mu\beta}+2i\bar G_{\mu\beta}}\bar P_\beta A^{(1)}_\alpha\frac{1}{\bar P^2 g_{\alpha\nu}+2i\bar G_{\alpha\nu}}|z)^{mn} \quad (152)$$

VII. CHOBA

ΠPOδYEM

$$\frac{1}{2}(\bar D^\mu - iX^\mu)^{ma}A^a_\mu(\bar D^\nu - iX^\nu)^{mb}A^b_\nu = \frac{1}{2}(\bar D^\mu A_\mu)^a(\bar D^\nu A_\nu)^a + f^{abc}(\bar D^\xi A_\xi)^a X^b_\eta A^{c\eta} + \frac{1}{2}A^a_\mu(X^\mu X^\nu)^{ab}A^b_\nu$$
$$= \frac{1}{2}(\bar D^\mu A_\mu)^a(\bar D^\nu A_\nu)^a - i(\bar D^\xi A_\xi)^a X^{ab}_\eta A^{b\eta} + \frac{1}{2}A^a_\mu(X^\mu X^\nu)^{ab}A^b_\nu \quad (153)$$

$$\Box^{ab}_{\mu\nu} = \bar P^2 g_{\mu\nu} + 2i\bar G_{\mu\nu} + \bar P_\mu X_\nu + X_\mu\bar P_\nu + X_\mu X_\nu \ \Leftrightarrow\ \bar P^2 g_{\mu\nu} + 2i\bar G_{\mu\nu} + 2X_\mu\bar P_\nu + X_\mu X_\nu \quad (154)$$

bikoz

$$\int dz\ A^{a\mu}\bar P^{aa'}_\mu X^{a'b}_\nu A^{b\nu}(z) = \int dz\ A^{b\nu}X^{ba'}_\nu\bar P^{a'a}_\mu A^{a\mu}(z) = \int dz\ A^{a\mu}X^{aa'}_\mu\bar P^{a'b}_\nu A^{b\nu}(z)$$

$$\bar C^m_\mu(x) = \int DA\ A^m_\mu(x)e^{i\int d^2z\big(-\frac14[G^a_{\mu\nu}(A+\bar A)]^2 - \frac12[(\bar D_\mu - i\bar C_\mu)A^\mu]^2\big)}$$
$$= \int DA\ A^m_\mu(x)e^{i\int d^2z\big(-\frac14\bar G^{a\mu\nu}\bar G^a_{\mu\nu} - \frac12 A^{a\alpha}\Box^{ab}_{\alpha\beta}A^{\beta b} + A^a_\alpha\bar D_\xi\bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha A^{a\beta}A^b_\alpha A^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta\big)}$$
$$\stackrel{A\to A+\bar C}{=} \int DA\ [A^m_\mu(x) + \bar C^m_\mu(x)]\ e^{i\int d^2z\big(-\frac14\bar G^{a\mu\nu}\bar G^a_{\mu\nu} - \frac12\bar C^{a\alpha}\Box^{ab}_{\alpha\beta}\bar C^{\beta b} + \bar C^a_\alpha\bar D_\xi\bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha\bar C^{a\beta}\bar C^b_\alpha\bar C^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}\bar C^{a\alpha}\bar C^{b\beta}\bar C^c_\alpha\bar C^d_\beta\big)}$$
$$\times\ \exp i\int dz\Big\{A^{a\alpha}\Big(-\Box^{ab}_{\alpha\beta}\bar C^{b\beta} + (\bar D\bar G)^a_\alpha + f^{abc}\big(2\bar C^b_\beta\bar D^\beta\bar C^c_\alpha - \bar C^b_\beta\bar D_\alpha\bar C^{c\beta} - \bar C^b_\alpha\bar D^\beta\bar C^c_\beta\big) - f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\alpha\bar C^d_\beta\Big)$$
$$+ \frac12 A^{a\alpha}\Big(-\Box_{\alpha\beta} - 2i(\bar D_\alpha\bar C_\beta) + 2\bar C_\beta\bar P_\alpha - 2g_{\alpha\beta}(\bar C^\xi\bar P_\xi) - g_{\alpha\beta}\bar C_\xi\bar C^\xi + \bar C_\beta\bar C_\alpha - [\bar C_\alpha,\bar C_\beta]\Big)A^{b\beta}$$
$$- gf^{abc}(\bar D_\alpha - i\bar C_\alpha)^{aa'}A^{a'}_\beta A^{c\alpha}A^{d\beta} - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta\Big\} \quad (155)$$

HAЙDËM ИKC

$$\frac12 A^{a\alpha}\Big(-\Box_{\alpha\beta} - 2i(\bar D_\alpha\bar C_\beta) + 2\bar C_\beta\bar P_\alpha - 2g_{\alpha\beta}(\bar C^\xi\bar P_\xi) - g_{\alpha\beta}\bar C_\xi\bar C^\xi + \bar C_\beta\bar C_\alpha - [\bar C_\alpha,\bar C_\beta]\Big)^{ab}A^{b\beta} \quad (156)$$
$$= \frac12 A^{a\alpha}\Big(-\bar P^2 g_{\alpha\beta} - 2i\bar G_{\alpha\beta} - 2X_\alpha\bar P_\beta - X_\alpha X_\beta - 2i\bar D_\alpha\bar C_\beta + 2\bar C_\beta\bar P_\alpha - 2g_{\alpha\beta}(\bar C^\xi\bar P_\xi) - g_{\alpha\beta}\bar C_\xi\bar C^\xi + \bar C_\beta\bar C_\alpha - [\bar C_\alpha,\bar C_\beta]\Big)^{ab}A^{b\beta}$$
$$= \frac12 A^{a\alpha}\Big(-(\bar P+\bar C)^2 g_{\alpha\beta} - 2i\big(\bar G_{\alpha\beta} + \bar D_\alpha\bar C_\beta - \bar D_\beta\bar C_\alpha - i[\bar C_\alpha,\bar C_\beta]\big) + \bar C_\alpha\bar C_\beta - 2[\bar P_\beta,\bar C_\alpha] + 2\bar C_\beta\bar P_\alpha - 2X_\alpha\bar P_\beta - X_\alpha X_\beta\Big)^{ab}A^{b\beta}$$
$$= \frac12 A^{a\alpha}\Big(-(\bar P+\bar C)^2 g_{\alpha\beta} - 2i\big(\bar G_{\alpha\beta} + \bar D_\alpha\bar C_\beta - \bar D_\beta\bar C_\alpha - i[\bar C_\alpha,\bar C_\beta]\big)\Big)^{ab}A^{b\beta}$$

ΠPИ YCΛOBИИ ШTO $X_\mu = \bar C_\mu$ az ekspekted.

ИTAK, the gauge-fixing term is

$$\frac12(\bar D^\mu - i\bar C^\mu)^{ma}A^a_\mu(\bar D^\nu - i\bar C^\nu)^{mb}A^b_\nu = \frac12(\bar D^\mu A_\mu)^a(\bar D^\nu A_\nu)^a + f^{abc}(\bar D^\xi A_\xi)^a\bar C^b_\eta A^{c\eta} + \frac12 A^a_\mu(\bar C^\mu\bar C^\nu)^{ab}A^b_\nu$$
$$= \frac12(\bar D^\mu A_\mu)^a(\bar D^\nu A_\nu)^a - i(\bar D^\xi A_\xi)^a\bar C^{ab}_\eta A^{b\eta} + \frac12 A^a_\mu(\bar C^\mu\bar C^\nu)^{ab}A^b_\nu \quad (157)$$

so

$$\Box^{ab}_{\mu\nu} \;=\; \bar P^2 g_{\mu\nu} + 2i\bar G_{\mu\nu} + \bar P_\mu \bar C_\nu + \bar C_\mu \bar P_\nu + \bar C_\mu \bar C_\nu \tag{158}$$

$$\begin{aligned}
&\bar C^m_\mu(x) \;=\; \int DA\; A^m_\mu(x) e^{i\int d^2z\left(-\frac14[G^a_{\mu\nu}(A+\bar A)]^2 - \frac12[(\bar D_\mu - i\bar C_\mu)A^\mu]^2\right)}\\
&=\; \int DA\; A^m_\mu(x) e^{i\int d^2z\left(-\frac14 \bar G^{a\mu\nu}\bar G^a_{\mu\nu} - \frac12 A^{a\alpha}\Box^{ab}_{\alpha\beta}A^{\beta b} + A^a_\alpha \bar D_\xi \bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha A^{a\beta}A^b_\alpha A^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta\right)}\\
&\overset{A\to\underline{A}+\bar C}{=}\; \int DA\;[A^m_\mu(x) + \bar C^m_\mu(x)]\; e^{i\int d^2z\left(-\frac14 \bar G^{a\mu\nu}\bar G^a_{\mu\nu} - \frac12 \bar C^{a\alpha}(\bar P^2 g_{\alpha\beta} + 2i\bar G_{\alpha\beta})^{ab}\bar C^{\beta b} + \bar C^a_\alpha \bar D_\xi \bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha \bar C^{a\beta}\bar C^b_\alpha \bar C^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}\bar C^{a\alpha}\bar C^{b\beta}\bar C^c_\alpha \bar C^d_\beta\right)}\\
&\times\; \exp i\int dz\Big\{A^{a\alpha}\Big(-(\bar P^2 g_{\alpha\beta} + 2i\bar G_{\alpha\beta})^{ab}\bar C^{b\beta} + (\bar D\bar G)^a_\alpha + f^{abc}(2\bar C^b_\beta \bar D^\beta \bar C^c_\alpha - \bar C^b_\beta \bar D_\alpha \bar C^{c\beta}) - f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\alpha \bar C^d_\beta\Big)\\
&-\; \frac12 A^{a\alpha}\Big((\bar P + \bar C)^2 g_{\alpha\beta} + 2i\big(\bar G_{\alpha\beta} + \bar D_\alpha \bar C_\beta - \bar D_\beta \bar C_\alpha - i[\bar C_\alpha, \bar C_\beta]\big)\Big)^{ab} A^{b\beta}\\
&-\; gf^{abc}(\bar D_\alpha - i\bar C_\alpha)^{aa'}A^{a'}_\beta A^{c\alpha}A^{d\beta} - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta\Big\}
\end{aligned}\tag{159}$$

ИМЕЕМ УР-Е НА $\bar C_\mu$ В ВИДЕ

$$(\bar P^2 g_{\alpha\beta} + 2ig\bar G_{\alpha\beta})^{ab}\bar C^{b\beta} \;=\; \bar D^{ab\xi}\bar G^b_{\xi\alpha} + gf^{abc}(2\bar C^b_\beta \bar D^\beta \bar C^c_\alpha - \bar C^b_\beta \bar D_\alpha \bar C^{c\beta}) - g^2 f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\alpha \bar C^d_\beta \tag{160}$$

В КОМПОНЕНТАХ

$$\begin{aligned}
2(\bar P_\bullet \bar P_*)^{ab}\bar C^b_\bullet \;&=\; \bar D^{ab}_\bullet \bar G^b_{*\bullet} + i\bar G^{ab}_{*\bullet}\bar C^b_\bullet + g\bar D^{aa'}_\bullet(f^{a'bc}\bar C^b_*\bar C^c_\bullet) + 2gf^{abc}\bar C^b_\bullet \bar D_* \bar C^c_\bullet - g^2 f^{abm}f^{cdm}\bar C^b_\bullet \bar C^c_\bullet \bar C^d_*\\
2(\bar P_* \bar P_\bullet)^{ab}\bar C^b_* \;&=\; -\bar D^{ab}_* \bar G^b_{*\bullet} - i\bar G^{ab}_{*\bullet}\bar C^b_* - g\bar D^{aa'}_*(f^{a'bc}\bar C^b_*\bar C^c_\bullet) + 2gf^{abc}\bar C^b_* \bar D_\bullet \bar C^c_* - g^2 f^{abm}f^{cdm}\bar C^b_* \bar C^c_* \bar C^d_\bullet
\end{aligned}\tag{161}$$

ПЕРЕПИШЕМ НА БУДУЩЕЕ

$$\begin{aligned}
&2(\bar P_\bullet \bar P_*)^{ab}\bar C^b_\bullet \;=\; \bar D^{ab}_\bullet \bar G^b_{*\bullet} + i\bar G^{ab}_{*\bullet}\bar C^b_\bullet + g\bar D^{aa'}_\bullet(f^{a'bc}\bar C^b_*\bar C^c_\bullet) + 2gf^{abc}\bar C^b_\bullet \bar D_* \bar C^c_\bullet - g^2 f^{abm}f^{cdm}\bar C^b_\bullet \bar C^c_\bullet \bar C^d_*\\
&\Rightarrow\; (\bar P_\bullet \bar P_* + \bar P_* \bar P_\bullet)^{ab}\bar C^b_\bullet \;=\; \bar D^{ab}_\bullet \bar G^b_{*\bullet} + 2i\bar G^{ab}_{*\bullet}\bar C^b_\bullet + gf^{abc}\bar D_\bullet \bar C^b_* \bar C^c_\bullet + gf^{abc}\bar C^b_* \bar D_\bullet \bar C^c_\bullet + 2gf^{abc}\bar C^b_\bullet \bar D_* \bar C^c_\bullet - g^2 f^{abm}f^{cdm}\bar C^b_\bullet \bar C^c_\bullet \bar C^d_*\\
&\Rightarrow\; (\mathcal P_\bullet \bar P_* + \mathcal P_* \bar P_\bullet)^{ab}\bar C^b_\bullet\\
&=\; -f^{abc}\bar C^b_\bullet \bar D_* \bar C^c_\bullet - f^{abc}\bar C^b_* \bar D_\bullet \bar C^c_\bullet + \bar D^{ab}_\bullet \bar G^b_{*\bullet} + 2i\bar G^{ab}_{*\bullet}\bar C^b_\bullet - gf^{abc}\bar C^b_\bullet \bar D_\bullet \bar C^c_* + gf^{abc}\bar C^b_* \bar D_\bullet \bar C^c_\bullet + 2gf^{abc}\bar C^b_\bullet \bar D_* \bar C^c_\bullet - g^2 f^{abc}f^{klc}\bar C^b_\bullet \bar C^k_\bullet \bar C^l_*\\
&=\; \bar D^{ab}_\bullet \bar G^b_{*\bullet} - 2i\bar C^{ab}_\bullet \bar G^b_{*\bullet} + gf^{abc}\bar C^b_\bullet(\bar D_* \bar C^c_\bullet - \bar D_\bullet \bar C^c_* - f^{ckl}\bar C^k_\bullet \bar C^l_*) \;=\; \bar D^{ab}_\bullet \bar G^b_{*\bullet} - i\bar C^{ab}_\bullet \bar G^b_{*\bullet} \;=\; \mathcal D^{ab}_\bullet \bar G^b_{*\bullet}
\end{aligned}\tag{162}$$

where $\mathcal A_\bullet \equiv \bar A_\bullet + \bar C_\bullet$, $\mathcal P_\bullet = \bar P_\bullet + \bar C_\bullet$ and similarly for $*$

НАДО expand do $\bar G^3_{*\bullet}$. РАЗБИВАЕМ $\bar C = \bar C_1 + \bar C_2 + \bar C_3$

ФОРМУЛА: $\bar P_* \frac{1}{\bar P_\bullet \bar P_* \pm i\epsilon}\bar P_\bullet \;=\; \bar P_\bullet \frac{1}{\bar P_* \bar P_\bullet \pm i\epsilon}\bar P_* \;=\; 1$ (ПРИ ЛЮБОМ ОБХОДЕ СИНГУЛАРНОСТИ).

$$\begin{aligned}
\bar C^1_\bullet \;&=\; -\frac{i}{2\bar P_\bullet \bar P_*}\bar P_\bullet \bar G_{*\bullet} \quad\Leftrightarrow\quad \bar C^{1a}_\bullet(x) \;=\; -\frac{i}{2}\int d^2z(x|\frac{1}{\bar P_\bullet \bar P_*}\bar P_\bullet|z)^{ab}\bar G^b_{*\bullet}(z) \quad\Rightarrow\quad \bar D_* \bar C^1_\bullet \;=\; -\frac12 \bar G_{*\bullet}\\
\bar C^1_* \;&=\; \frac{i}{2\bar P_* \bar P_\bullet}\bar P_* \bar G_{*\bullet} \quad\Leftrightarrow\quad \bar C^{1a}_*(x) \;=\; \frac{i}{2}\int d^2z(x|\frac{1}{\bar P_* \bar P_\bullet}\bar P_*|z)^{ab}\bar G^b_{*\bullet}(z) \quad\Rightarrow\quad \bar D_\bullet \bar C^1_* \;=\; \frac12 \bar G_{*\bullet}
\end{aligned}\tag{163}$$

$$\begin{aligned}
(x|\frac{1}{\bar P_* \bar P_\bullet + i\epsilon p_*}\bar P_*|z) \;&=\; (x|\frac{1}{\bar P_\bullet + i\epsilon}|z) \;=\; -i\delta(x_\bullet - z_\bullet)\theta(x_* - z_*)[x_*, z_*]^{\bar A_\bullet}\\
(x|\frac{1}{\bar P_\bullet \bar P_* + i\epsilon p_*}\bar P_\bullet|z) \;&=\; (x|\frac{1}{\bar P_* + i\epsilon}|z) \;=\; -i\delta(x_* - z_*)\theta(x_\bullet - z_\bullet)[x_\bullet, z_\bullet]^{\bar A_*}
\end{aligned}\tag{164}$$

ЕСЛИ $\bar A_*(x_\bullet) \to 0$ ПРИ $x_\bullet \to \pm\infty$, ТО

$$\begin{aligned}
\bar C^{(1)}_*(x) \;&=\; -\frac{i}{s}\int_{-\infty}^{x_*} dz_*\;[x_*, z_*]^{A_\bullet}[\bar A_*(x_\bullet), \bar A_\bullet(z_*)][z_*, x_*]^{A_\bullet} \quad\Rightarrow\quad \bar C^{(1)}_*(x_*, x_\bullet = \pm\infty) \;=\; \bar C^{(1)}_*(x_* = -\infty, x_\bullet) \;=\; 0\\
\bar C^{(1)}_\bullet(x) \;&=\; \frac{i}{s}\int_{-\infty}^{x_\bullet} dz_\bullet\;[x_\bullet, z_\bullet]^{A_*}[\bar A_*(z_\bullet), \bar A_\bullet(x_*)][z_\bullet, x_\bullet]^{A_*} \quad\Rightarrow\quad \bar C^{(1)}_\bullet(x_\bullet, x_* = \pm\infty) \;=\; \bar C^{(1)}_\bullet(x_\bullet = -\infty, x_*) \;=\; 0
\end{aligned}\tag{165}$$

АНАЛОГИЧНО, $\bar C^{(1)}_\bullet(x_* = -\infty, x_\bullet) \;=\; \bar C^{(1)}_\bullet(x_* = \pm\infty, x_\bullet) \;=\; 0$

$$2(\bar P_\bullet\bar P_*)^{ab}\bar C_\bullet^{(2)b} = i\bar G^{ab}_{*\bullet}\bar C_\bullet^{(1)b}+g\bar D_\bullet^{aa'}(f^{a'bc}\bar C_*^{(1)b}\bar C_\bullet^{(1)c})-gf^{abc}\bar C_\bullet^{(1)b}\bar G^c_{*\bullet} \;\Rightarrow\; \bar C_\bullet^{(2)a} = -\frac{i}{2}\Big(\frac{1}{\bar P_\bullet\bar P_*}\bar P_\bullet\Big)^{aa'}f^{a'bc}\bar C_*^{(1)b}\bar C_\bullet^{(1)c}$$

$$2(\bar P_*\bar P_\bullet)^{ab}\bar C_*^{(2)b} = -i\bar G^{ab}_{*\bullet}\bar C_*^{b}-g\bar D_*^{aa'}(f^{a'bc}\bar C_*^{(1)b}\bar C_\bullet^{(1)c})+gf^{abc}\bar C_*^{(1)b}\bar G^c_{*\bullet} \;\Rightarrow\; \bar C_*^{(2)a} = \frac{i}{2}\Big(\frac{1}{\bar P_*\bar P_\bullet}\bar P_*\Big)^{aa'}f^{a'bc}\bar C_*^{(1)b}\bar C_\bullet^{(1)c} \quad (166)$$

$$G^a_{*\bullet}(\bar A+\bar C^{(1)}+\bar C^{(2)}) = \bar G^a_{*\bullet}+(\bar D_*\bar C_\bullet^{(1)}-\bar D_\bullet\bar C_*^{(1)})^a+(\bar D_*\bar C_\bullet^{(2)}-\bar D_\bullet\bar C_*^{(2)})^a+f^{abc}\bar C^{(1)b}\bar C^{(1)c} = 0 \quad (167)$$

HAM HADO EЩЁ

$$\bar D_*\bar C_\bullet^{(2)a} = -\frac12 f^{abc}\bar C_*^{(1)b}\bar C_\bullet^{(1)c}, \qquad \bar D_\bullet\bar C_*^{(2)a} = \frac12 f^{abc}\bar C_*^{(1)b}\bar C_\bullet^{(1)c} \quad (168)$$

Similarly to Eq. (165) $\bar C_\bullet^{(2)}(x_*=-\infty,x_\bullet) = \bar C_*^{(2)}(x_*,x_\bullet=-\infty) = 0$

TPETИЙ ПOPADOK

$$2(\bar P_\bullet\bar P_*)^{ab}\bar C_\bullet^{(3)b}$$
$$= i\bar G^{ab}_{*\bullet}\bar C_\bullet^{(2)b}+g\bar D_\bullet^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c})+2gf^{abc}\bar C_\bullet^{(1)b}\bar D_*\bar C_\bullet^{(2)c}+2gf^{abc}\bar C_\bullet^{(2)b}\bar D_*\bar C_\bullet^{(1)c}-g^2f^{abm}f^{cdm}\bar C_\bullet^{(1)b}\bar C_\bullet^{(1c}\bar C_*^{(1)d}$$
$$= g\bar D_\bullet^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c})+2gf^{abc}\bar C_\bullet^{(1)b}\bar D_*\bar C_\bullet^{(2)c}-g^2f^{abm}f^{cdm}\bar C_\bullet^{(1)b}\bar C_\bullet^{(1)c}\bar C_*^{(1)d} = g\bar D_\bullet^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c})$$
$$\Rightarrow\; \bar C_\bullet^{(3)a} = -\frac{i}{2}\Big(\frac{1}{\bar P_\bullet\bar P_*}\bar P_\bullet\Big)^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c}) \quad (169)$$

Similarly

$$2(\bar P_*\bar P_\bullet)^{ab}\bar C_*^{(3)b}$$
$$= -i\bar G^{ab}_{*\bullet}\bar C_*^{(2)b}-g\bar D_*^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c})+2gf^{abc}\bar C_*^{(1)b}\bar D_\bullet\bar C_*^{(2)c}+2gf^{abc}\bar C_*^{(2)b}\bar D_\bullet\bar C_*^{(1)c}-g^2f^{abm}f^{cdm}\bar C_*^{(1)b}\bar C_*^{(1c}\bar C_\bullet^{(1)d}$$
$$= -g\bar D_*^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c})+2gf^{abc}\bar C_*^{(1)b}\bar D_\bullet\bar C_*^{(2)c}-g^2f^{abm}f^{cdm}\bar C_*^{(1)b}\bar C_*^{(1)c}\bar C_\bullet^{(1)d} = -g\bar D_*^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c})$$
$$\Rightarrow\; \bar C_*^{(3)a} = \frac{i}{2}\Big(\frac{1}{\bar P_*\bar P_\bullet}\bar P_*\Big)^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c}) \quad (170)$$

HAM δYDET HADO

$$\bar D_*\bar C_\bullet^{(3)a} = -\frac12 f^{abc}(\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c}) \quad (171)$$

Again, $\bar C_\bullet^{(3)}(x_*=\pm\infty,x_\bullet) = \bar C_*^{(3)}(x_*,x_\bullet=\pm\infty) = 0 \Rightarrow \bar C_\bullet(x_*=\pm\infty,x_\bullet) = \bar C_*(x_*,x_\bullet=\pm\infty) = 0$

$$\Rightarrow\; (\bar A+\bar C)_\bullet(x_*,x_\bullet=-\infty) = \bar A_\bullet(x_*), \qquad (\bar A+\bar C)_*(x_*=-\infty,x_\bullet) = \bar A_*(x_\bullet) \quad (172)$$

ΦOPMYΛA:

$$\frac12\bar G^a_{*\bullet}+\bar D_*\bar C_\bullet^{(1)a}+\bar D_*\bar C_\bullet^{(2)a}+\bar D_*\bar C_\bullet^{(3)a}+\frac12 f^{abc}(\bar C_*^{(1)b}\bar C_\bullet^{(1)c}+\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c}) = 0$$

И ПOЭTOMY

$$F^a_{*\bullet}(\bar A+\bar C^{(1)}+\bar C^{(2)}+\bar C^{(3)}) \quad (173)$$
$$= \bar G^a_{*\bullet}+(\bar D_*\bar C_\bullet^{(1)}-\bar D_\bullet\bar C_*^{(1)})^a+(\bar D_*\bar C_\bullet^{(2)}-\bar D_\bullet\bar C_*^{(2)})^a+(\bar D_*\bar C_\bullet^{(3)}-\bar D_\bullet\bar C_*^{(3)})^a+f^{abc}(\bar C_*^{(1)b}\bar C_\bullet^{(1)c}+\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c}) = 0$$

HAδΛYDEHИE

$$\bar D_*\bar C_\bullet^{(i)}+\bar D_\bullet\bar C_*^{(i)} = 0 \quad\Leftrightarrow\quad (i\partial_\mu+[\bar A_\mu,)\bar C^\mu = (i\partial_\mu+[\bar A_\mu,+[\bar C_\mu,)\bar C^\mu = 0 \quad (174)$$

4Й ПOPADOK (see Eqs. (167) and (171))

$$2(\bar P_\bullet\bar P_*)^{ab}\bar C_\bullet^{(4)b}$$
$$= i\bar G^{ab}_{*\bullet}\bar C_\bullet^{(3)b}+g\bar D_\bullet^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(3)c}+\bar C_*^{(2)b}\bar C_\bullet^{(2)c}+\bar C_*^{(3)b}\bar C_\bullet^{(1)c})+2gf^{abc}\bar C_\bullet^{(1)b}\bar D_*\bar C_\bullet^{(3)c}+2gf^{abc}\bar C_\bullet^{(2)b}\bar D_*\bar C_\bullet^{(2)c}+2gf^{abc}\bar C_\bullet^{(3)b}\bar D_*\bar C_\bullet^{(1)c}$$
$$-g^2f^{abm}f^{cdm}\bar C_\bullet^{(2)b}\bar C_\bullet^{(1c}\bar C_*^{(1)d}-g^2f^{abm}f^{cdm}\bar C_\bullet^{(1)b}\bar C_\bullet^{(2)c}\bar C_*^{(1)d}-g^2f^{abm}f^{cdm}\bar C_\bullet^{(1)b}\bar C_\bullet^{(1c}\bar C_*^{(2)d}$$
$$= g\bar D_\bullet^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(3)c}+\bar C_*^{(2)b}\bar C_\bullet^{(2)c}+\bar C_*^{(3)b}\bar C_\bullet^{(1)c})$$
$$\Rightarrow\; \bar C_\bullet^{(4)a} = -\frac{i}{2}\Big(\frac{1}{\bar P_\bullet\bar P_*}\bar P_\bullet\Big)^{aa'}f^{a'bc}(\bar C_*^{(1)b}\bar C_\bullet^{(3)c}+\bar C_*^{(2)b}\bar C_\bullet^{(2)c}+\bar C_*^{(3)b}\bar C_\bullet^{(1)c}) \quad (175)$$

$$\Rightarrow\ \bar D_*\bar C_\bullet^{(4)}\ =\ -\frac{1}{2}f^{abc}(\bar C_*^{(1)b}\bar C_\bullet^{(3)c}+\bar C_*^{(2)b}\bar C_\bullet^{(2)c}+\bar C_*^{(3)b}\bar C_\bullet^{(1)c}),\qquad \bar D_\bullet\bar C_*^{(4)}\ =\ \frac{1}{2}f^{abc}(\bar C_*^{(1)b}\bar C_\bullet^{(3)c}+\bar C_*^{(2)b}\bar C_\bullet^{(2)c}+\bar C_*^{(3)b}\bar C_\bullet^{(1)c}) \tag{176}$$

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$$F_{*\bullet}^a(\bar A+\bar C^{(1)}+\bar C^{(2)}+\bar C^{(3)}+\bar C^{(4)}) \tag{177}$$

$$= \ \bar G_{*\bullet}^a+(\bar D_*\bar C_\bullet^{(1)}-\bar D_\bullet\bar C_*^{(1)})^a+(\bar D_*\bar C_\bullet^{(2)}-\bar D_\bullet\bar C_*^{(2)})^a+(\bar D_*\bar C_\bullet^{(3)}-\bar D_\bullet\bar C_*^{(3)})^a+(\bar D_*\bar C_\bullet^{(4)}-\bar D_\bullet\bar C_*^{(4)})^a$$
$$+\ f^{abc}(\bar C_*^{(1)b}\bar C_\bullet^{(1)c}+\bar C_*^{(1)b}\bar C_\bullet^{(2)c}+\bar C_*^{(2)b}\bar C_\bullet^{(1)c}+\bar C_*^{(1)b}\bar C_\bullet^{(3)c}+\bar C_*^{(2)b}\bar C_\bullet^{(2)c}+\bar C_*^{(3)b}\bar C_\bullet^{(1)c})\ =\ 0 \tag{178}$$

and

$$\bar D_*\bar C_\bullet\ =\frac{i}{2}[\bar C_*,\bar C_\bullet]-\frac{1}{2}\bar G_{*\bullet}\ =\ -\bar D_\bullet\bar C_* \tag{179}$$

NB: we never used any assumptions on $\bar A_\bullet$ and $\bar A_*$

VIII. Ω

Here $\bar A_\bullet(z_*)$ and $\bar A_*(z_\bullet)$

1. Ω do $\bar A^3$

$$\Omega(x_*,x_\bullet)\ =\ 1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x'_*\theta(x'-x'')_*\bar A_\bullet(x'_*)\bar A_\bullet(x''_*)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar A_*(x'_\bullet)\bar A_*(x''_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big) \tag{180}$$

$$\Omega^\dagger(x_*,x_\bullet)\ =\ 1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\theta(x'-x'')_*\bar A_\bullet(x''_*)\bar A_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar A_*(x''_\bullet)\bar A_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big) \tag{181}$$

Trivial chek:

$$\Omega^\dagger(x_*,x_\bullet)\Omega(x_*,x_\bullet)\ =\ \Big[1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\theta(x'-x'')_*\bar A_\bullet(x''_*)\bar A_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar A_*(x''_\bullet)\bar A_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big)\Big]$$
$$\times\ \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x'_*\theta(x'-x'')_*\bar A_\bullet(x'_*)\bar A_\bullet(x''_*)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar A_*(x'_\bullet)\bar A_*(x''_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big)\Big]\ =\ 1 \tag{182}$$

Non-trivial chek:

$$i\partial_\bullet\Omega^\dagger(x_*,x_\bullet)\ =\ \bar A_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)\bar A_\bullet(x_*)-\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x_*)\big)$$
$$\Rightarrow\ \Omega i\partial_\bullet\Omega^\dagger(x_*,x_\bullet)\ =\ \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)\Big]$$
$$\times\ \Big[\bar A_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)\bar A_\bullet(x_*)-\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x_*)\big)\Big]$$
$$=\ \bar A_\bullet(x_*)-\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet[\bar A_\bullet(x_*),\bar A_*(x'_\bullet)]\Rightarrow\ (\Omega i\partial_\bullet\Omega^\dagger)^a(x_*,x_\bullet)\ =\ \bar A_\bullet^a(x_*)-\frac{1}{2}f^{abc}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*^b(x'_\bullet)\bar A_\bullet^c(x_*) \tag{183}$$

which agrees with Eq. (146)

$$\delta\omega = -\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big) = -\frac{1}{s}\int d^2z\ \theta(x_*-z_*)\theta(x_\bullet-z_\bullet)\{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\} \tag{184}$$

Next step

$\Omega^\dagger(x_*,x_\bullet)\Omega(x_*,x_\bullet)$

$$\begin{aligned}
&\ni \frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_\bullet(x'_*)\big(\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\big)\\
&-\frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\bar{A}_\bullet(x''_*)\\
&-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{x'_*}^{x_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\\
&=\frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big([\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)]\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)[\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)]\big)
\end{aligned} \tag{185}$$

Guess

$$\begin{aligned}
\Omega(x_*,x_\bullet) &= 1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x'_*\theta(x'-x'')_*\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet) \qquad (186)\\
&-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\\
&-\frac{i}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big([\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)]\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)[\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)]\big)\\
&-\frac{i}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big([\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)]\bar{A}_*(x'_*)+\bar{A}_\bullet(x'_*)[\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)]\big)\ +\ ?
\end{aligned}$$

$$\begin{aligned}
\Omega^\dagger(x_*,x_\bullet) &= 1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\theta(x'-x'')_*\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet) \qquad (187)\\
&-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\\
&-\frac{i}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big([\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)]\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)[\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)]\big)\\
&-\frac{i}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big([\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)]\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)[\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)]\big)\\
&+\frac{i}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\{\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)\}\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\{\bar{A}_\bullet(x'_*),\bar{A}_\bullet(x''_*)\}\big)\\
&+\frac{i}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big(\{\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)\}\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\{\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)\}\big)
\end{aligned}$$

$$\begin{aligned}
i\partial_\bullet\Omega^\dagger(x_*,x_\bullet) &= \bar{A}_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)-\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)\big)\\
&+\frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big([\bar{A}_\bullet(x_*),\bar{A}_\bullet(x'_*)]\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)[\bar{A}_\bullet(x_*),\bar{A}_\bullet(x'_*)]\big)\\
&+\frac{1}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\big([\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)]\bar{A}_\bullet(x_*)+\bar{A}_\bullet(x_*)[\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)]\big)\\
&-\frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\{\bar{A}_\bullet(x_*),\bar{A}_\bullet(x'_*)\}\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\{\bar{A}_\bullet(x_*),\bar{A}_\bullet(x'_*)\}\big)\\
&-\frac{1}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\big(\{\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)\}\bar{A}_\bullet(x_*)+\bar{A}_\bullet(x_*)\{\bar{A}_*(x'_\bullet),\bar{A}_*(x''_\bullet)\}\big)
\end{aligned} \tag{188}$$

$$\Omega(x_*,x_\bullet)i\partial_\bullet\Omega^\dagger(x_*,x_\bullet) \;=\; \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x'_*\theta(x'-x'')_*\bar A_\bullet(x'_*)\bar A_\bullet(x''_*)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar A_*(x'_\bullet)\bar A_*(x''_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big)\Big]$$
$$\times\Big[\bar A_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)\bar A_\bullet(x_*)-\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x_*)\big)$$
$$+\frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big([\bar A_\bullet(x_*),\bar A_\bullet(x'_*)]\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)[\bar A_\bullet(x_*),\bar A_\bullet(x'_*)]\big)$$
$$+\frac{1}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\big([\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)]\bar A_\bullet(x_*)+\bar A_\bullet(x_*)[\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)]\big)+X3\Big]$$
$$-\frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\{\bar A_\bullet(x_*),\bar A_\bullet(x'_*)\}\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\{\bar A_\bullet(x_*),\bar A_\bullet(x'_*)\}\big)$$
$$-\frac{1}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\big(\{\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)\}\bar A_\bullet(x_*)+\bar A_\bullet(x_*)\{\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)\}\big) \qquad (189)$$

$$=\;\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\;\bar A_\bullet(x'_*)\big(\bar A_\bullet(x_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x_*)\big)+\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\;\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\bar A_\bullet(x_*)$$
$$+\frac{1}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_\bullet}d\frac{2}{s}x''_\bullet\;\bar A_*(x'_\bullet)\big(\bar A_\bullet(x_*)\bar A_*(x''_\bullet)+\bar A_*(x''_\bullet)\bar A_\bullet(x_*)\big)-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\theta(x'-x'')_\bullet\bar A_*(x'_\bullet)\bar A_*(x''_\bullet)\bar A_\bullet(x_*)$$
$$-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big)\bar A_\bullet(x_*)$$
$$+\frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big([\bar A_\bullet(x_*),\bar A_\bullet(x'_*)]\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)[\bar A_\bullet(x_*),\bar A_\bullet(x'_*)]\big)$$
$$-\frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\{\bar A_\bullet(x_*),\bar A_\bullet(x'_*)\}\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\{\bar A_\bullet(x_*),\bar A_\bullet(x'_*)\}\big)$$
$$+\frac{1}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\big([\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)]\bar A_\bullet(x_*)+\bar A_\bullet(x_*)[\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)]\big)\Big]$$
$$-\frac{1}{4}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x'_\bullet}d\frac{2}{s}x''_\bullet\big(\{\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)\}\bar A_\bullet(x_*)+\bar A_\bullet(x_*)\{\bar A_*(x'_\bullet),\bar A_*(x''_\bullet)\}\big)$$
$$=\;-\frac{1}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'-x'')_\bullet\big[\bar A_*(x'_\bullet),[\bar A_*(x''_\bullet),\bar A_\bullet(x_*)]\big]\qquad\text{az it shud bi} \qquad (190)$$

И ПОЭТОМУ

$$\Omega^\dagger(x_*,x_\bullet)\;=\;1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar A_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\bar A_\bullet(x''_*)\bar A_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar A_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\bar A_*(x''_\bullet)\bar A_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)\big)$$
$$+\;\frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar A_\bullet(x''_*)\bar A_\bullet(x'_*)\bar A_*(x'_\bullet)+\bar A_*(x'_\bullet)\bar A_\bullet(x''_*)\bar A_\bullet(x'_*)\big)$$
$$+\;\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big(\bar A_*(x''_\bullet)\bar A_*(x'_\bullet)\bar A_\bullet(x'_*)+\bar A_\bullet(x'_*)\bar A_*(x''_\bullet)\bar A_*(x'_\bullet)\big) \qquad (191)$$

$$
\begin{aligned}
\Omega(x_*,x_\bullet) \;=\;& 1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet)\\
&-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\\
&-\;\frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\big)\\
&-\;\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big(\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\big)
\end{aligned}
\tag{192}
$$

$$
\begin{aligned}
\Omega^\dagger(x_*,x_\bullet) \;=\;& 1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet)\\
&-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\\
&+\;\frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\big)\\
&+\;\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big(\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\big)
\end{aligned}
\tag{193}
$$

$$
\begin{aligned}
i\partial_\bullet\Omega^\dagger(x_*,x_\bullet) \;=\;& \bar{A}_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x_*)-\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)\big)\\
&-\;\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\big)\\
&-\;\frac{1}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\big(\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)+\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\big)
\end{aligned}
\tag{194}
$$

2. Ω *do* $\bar{A}_*^2\bar{A}_\bullet^2$

$$
\begin{aligned}
\Omega^\dagger(x_*,x_\bullet)\Omega(x_*,x_\bullet) \;=\; & \Big[1 - i\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*) - \int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) - i\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet) \\
& - \int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) - \frac{1}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big) \\
& + \frac{i}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\big) \\
& + \frac{i}{2}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\big(\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\big) + X3^\dagger\Big] \\
& \times\Big[1 + i\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*) - \int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) + i\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet) \\
& - \int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - \frac{1}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big) \\
& - \frac{i}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\big) \\
& - \frac{i}{2}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\big(\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\big) + X3\Big] \\
& \ni\ -\frac{1}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\int_{-\infty}^{x_*} d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_\bullet(x'_*)\big(\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)+\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\big) \\
& + \int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) \\
& - \frac{1}{2}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x''_\bullet\ \bar{A}_*(x'_\bullet)\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)+\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\big) \\
& + \int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) \\
& + \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\int_{-\infty}^{x_*} d\frac{2}{s}x''_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}x''_\bullet\big(\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)+\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\big) \\
& - \frac{1}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_*} d\frac{2}{s}x''_\bullet\big(\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\big)\bar{A}_*(x''_\bullet) \\
& - \frac{1}{2}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\int_{-\infty}^{x_*} d\frac{2}{s}x''_*\big(\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\big)\bar{A}_\bullet(x''_*)\ +\ X3+X3^\dagger
\end{aligned}
\tag{195}
$$

$$
\begin{aligned}
\Rightarrow\ -X3-X3^\dagger \;=\; & \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet) \\
& \times\Big[-2\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) - 2\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - 2\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) - 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) \\
& + 4\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) + 4\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) \\
& - 2\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) - 2\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) - 2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) \\
& + \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) + \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) \\
& + \bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) + \bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
& + \bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) \\
& + \bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) + \bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) \\
& - 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - 2\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) - 2\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) \\
& - 2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) - 2\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) - 2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) - 2\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\Big]
\end{aligned}
\tag{196}
$$

$$
\begin{aligned}
-X3-X3^{\dagger} \;=\; & \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet) \\
\times \Big[& -\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) - 2\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - 2\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
& -\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) - 2\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) \\
& +\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) \\
& +\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) + \bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
& +\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) \\
& +\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) + \bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) \\
& -2\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) - 2\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) \\
& -2\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) - 2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) - 2\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\Big]
\end{aligned} \tag{197}
$$

$$
\begin{aligned}
-X3-X3^{\dagger} \;=\; & \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet) \\
\times \Big[& -\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) - 2\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - \bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
& -\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) - \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) \\
& +\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) \\
& +\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
& +\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) \\
& +\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) \\
& -\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) - \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) \\
& -\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) - 2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) - \bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\Big]
\end{aligned} \tag{198}
$$

$$
\begin{aligned}
-X3_1 \;=\; & \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\big(-2\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - 2\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\big) \\
& -\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*) - \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) + \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)
\end{aligned} \tag{199}
$$

$$
\begin{aligned}
-X3-X3^{\dagger}+X3_1+X3_1^{\dagger} \;=\; & \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet) \\
\times \Big[& -\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) - \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) \\
& +\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
& +\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*) \\
& -\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet) - \bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\Big]
\end{aligned} \tag{200}
$$

$$
\bar{C}^{(2)}_\bullet \;=\; \frac{i}{8}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\,[[\bar{A}_*(x'_\bullet),\bar{A}_\bullet(x'_*)],[\bar{A}_*(x''_\bullet),\bar{A}_\bullet(x_*)]] \tag{201}
$$

$$
\begin{aligned}
\Omega(x_*,x_\bullet)i\partial_\bullet\Omega^\dagger(x_*,x_\bullet) \;=\; & \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*) - \int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) + i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet) \\
& - \int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - \frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big) \\
& - \frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\big) \\
& - \frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big(\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\big)\Big] \\
& \times\Big[\bar{A}_\bullet(x_*) - i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*) - \frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)\big) \\
& \qquad - \frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\big) \\
& \qquad - \frac{1}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\big(\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)+\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\big) + i\partial_\bullet X3^\dagger\Big] \\
= \; & -\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\big(\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\big)\bar{A}_\bullet(x_*) \\
& \qquad + i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\;\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*) \\
& + \frac{i}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_\bullet}d\frac{2}{s}x''_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\big(\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)+\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)\big) \\
& - \frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\int_{-\infty}^{x_\bullet}d\frac{2}{s}x''_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\;\bar{A}_*(x'_\bullet)\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)+\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\big) \\
& - \frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\bar{A}_\bullet(x'_*)\big(\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)+\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\big) + i\partial_\bullet X3^\dagger \\
= \; & \frac{i}{8}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\,[[\bar{A}_*(x'_\bullet),\bar{A}_\bullet(x'_*)],[\bar{A}_*(x''_\bullet),\bar{A}_\bullet(x_*)]]
\end{aligned}
\tag{202}
$$

$$
\begin{aligned}
i\partial_\bullet X3^\dagger \;=\; & \frac{i}{8}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}x'_* \\
\times\Big[& \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*) - \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*) - \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) + \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) \\
& - \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) - \bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) \\
& + 4\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*) + 4\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*) - 8\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*) \\
& - 2\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) - 2\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*) - 2\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*) \\
& - 2\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet) - 2\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet) - 2\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*) - 2\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*) \\
& + 4\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) + 4\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*) + 4\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet) + 4\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*) \\
& + 4\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*) + 4\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\Big]
\end{aligned}
\tag{203}
$$

$$
\begin{aligned}
X3_1^\dagger \;=\; & \frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet)\big(2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) + 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) \\
& + \bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) - \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*) - \bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\big)
\end{aligned}
\tag{204}
$$

$$
\begin{aligned}
= \; & \frac{1}{4}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\;\theta(x'_*-x''_*)\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\;\theta(x'_\bullet-x''_\bullet) \\
& \times\big(2\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) + 2\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) - [\bar{A}_\bullet(x''_*),\bar{A}_*(x''_\bullet)][\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)]\big)
\end{aligned}
\tag{205}
$$

$$
\begin{aligned}
i\partial_\bullet(X3^\dagger - X3_1^\dagger) \ &= \ \frac{i}{8}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_* \\
&\times \Big[-\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)+\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) - \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet) \\
&- \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)-\bar{A}_\bullet(x_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\Big]
\end{aligned}
\tag{206}
$$

$\Rightarrow$

$$
\begin{aligned}
(X3^\dagger - X3_1^\dagger) \ &= \ \frac{1}{8}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet) \\
&\times \Big[\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)+\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) - \ \bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)-\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) \\
&- \bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) - \bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)+ \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)+ \bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\Big] \\
&= \ \frac{1}{8}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\big([\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)][\bar{A}_*(x''_\bullet),\bar{A}_\bullet(x'_*)] + [\bar{A}_*(x''_\bullet),\bar{A}_\bullet(x'_*)][\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)]\big)
\end{aligned}
\tag{207}
$$

итого

$$
\begin{aligned}
X3^\dagger \ &= \ \frac{1}{8}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\Big(4\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*) + 4\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet) \\
&\qquad - 2[\bar{A}_\bullet(x''_*),\bar{A}_*(x''_\bullet)][\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)] - \ [\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)][\bar{A}_\bullet(x'_*),\bar{A}_*(x''_\bullet)] - [\bar{A}_\bullet(x'_*),\bar{A}_*(x''_\bullet)][\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)]\Big)
\end{aligned}
\tag{208}
$$

$$
\begin{aligned}
X3 \ &= \ \frac{1}{8}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\Big(4\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) + 4\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) \\
&\qquad - 2[\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)][\bar{A}_\bullet(x''_*),\bar{A}_*(x''_\bullet)] - \ [\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)][\bar{A}_\bullet(x'_*),\bar{A}_*(x''_\bullet)] - [\bar{A}_\bullet(x'_*),\bar{A}_*(x''_\bullet)][\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)]\Big)
\end{aligned}
\tag{209}
$$

$$
\begin{aligned}
\Omega(x_*,x_\bullet) \ &= \ 1 + i\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*) - \int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) + i\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet) \\
&- \int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) - \frac{1}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big) \\
&- \ \frac{i}{2}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet) + \bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\big) \\
&- \ \frac{i}{2}\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\int_{-\infty}^{x_*} d\frac{2}{s}x'_*\big(\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*) + \bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\big) \ + \ O(\bar{A}_*^3\bar{A}_\bullet) \ + \ O(\bar{A}_*\bar{A}_\bullet^3) \\
&+ \ \frac{1}{8}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\Big(4\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet) + 4\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*) \\
&- \ 2[\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)][\bar{A}_\bullet(x''_*),\bar{A}_*(x''_\bullet)] - \ [\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)][\bar{A}_\bullet(x'_*),\bar{A}_*(x''_\bullet)] - [\bar{A}_\bullet(x'_*),\bar{A}_*(x''_\bullet)][\bar{A}_\bullet(x''_*),\bar{A}_*(x'_\bullet)]\Big)
\end{aligned}
\tag{210}
$$

Guess:

$$
\begin{aligned}
\Omega(x_*,x_\bullet) \ &= \ \frac{1}{2}[-\infty,x_*][-\infty,x_\bullet] + \frac{1}{2}[-\infty,x_\bullet][-\infty,x_*] - \frac{1}{4}\big[[-\infty,x_\bullet],[-\infty,x_*]\big]\big[[-\infty,x_\bullet],[-\infty,x_*]\big] \\
&+ \ \frac{1}{4}\int_{-\infty}^{x_*} d\frac{2}{s}x'_* d\frac{2}{s}x''_*\ \theta(x'_* - x''_*)\int_{-\infty}^{x_\bullet} d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet - x''_\bullet)\big[[\bar{A}_\bullet(x'_*),\bar{A}_*(x'_\bullet)],[\bar{A}_\bullet(x''_*),\bar{A}_*(x''_\bullet)]\big]
\end{aligned}
\tag{211}
$$

IX. $\bar{C}_i$ IN THE 1ST ORDER IN $p_\perp$

From Eq. (160) we get

$$(\bar{P}^2 g_{\alpha\beta} + 2ig\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta} \;=\; \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha} - \partial^2\bar{A}^a_\alpha + gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha - \bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}) - g^2 f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta \tag{212}$$

$$\Leftrightarrow\;\; [(\bar{P}+\bar{C})^2]^{ab}\bar{C}^b_\alpha \;=\; -2ig\bar{G}^{ab}_{\alpha\beta}\bar{C}^{b\beta} + \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha} - \partial^2\bar{A}^a_\alpha - gf^{abc}\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta} \;=\; (\bar{D}-i\bar{C})^{ab\xi}\bar{G}^b_{\xi\alpha} - \partial^2\bar{A}^a_\alpha - ig\bar{G}^{ab}_{\alpha\beta}\bar{C}^{b\beta} - gf^{abc}\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}$$

S kvarkami

$$(\bar{P}^2 g_{\alpha\beta} + 2ig\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta} \;=\; \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha} + gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha - \bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}) - g^2 f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta + \bar{\Upsilon}\gamma_\alpha t^a\Upsilon \;\Rightarrow \tag{213}$$

$$[(\bar{P}+\bar{C})^2]^{ab}\bar{C}^b_\alpha \;=\; -2ig\bar{G}^{ab}_{\alpha\beta}\bar{C}^{b\beta} + \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha} + \bar{\Upsilon}\gamma_\alpha t^a\Upsilon - gf^{abc}\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta} \;=\; (\bar{D}-i\bar{C})^{ab\xi}\bar{G}^b_{\xi\alpha} + \bar{\Upsilon}\gamma_\alpha t^a\Upsilon - ig\bar{G}^{ab}_{\alpha\beta}\bar{C}^{b\beta} - gf^{abc}\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}$$

$$[(\bar{P}+\bar{C})^2]^{ab}\bar{C}^b_\alpha \;=\; (\bar{P}^2)^{ab}\bar{C}^b_\alpha - 2gf^{abc}\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha + g^2 f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta \;+ f^{abc}\bar{C}^b_\alpha\bar{D}^\beta\bar{C}^c_\beta, \tag{214}$$

$$2i(\bar{G}_{\alpha\beta} + \bar{D}_\alpha\bar{C}_\beta - \bar{D}_\beta\bar{C}_\alpha - i[\bar{C}_\alpha,\bar{C}_\beta])^{ab}\bar{C}^b_\beta \;=\; 2i\bar{G}_{\alpha\beta}\bar{C}^b_\beta - 2gf^{abc}\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha + 2gf^{abc}\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta} + 2g^2 f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta$$

Eq. (212) in components

$$\begin{aligned}
\big(2\bar{P}_\bullet\bar{P}_* - \frac{s}{2}p_\perp^2\big)^{ab}\bar{C}^b_\bullet \;&=\; \bar{D}^{ab}_\bullet\bar{G}^b_{*\bullet} + i\bar{G}^{ab}_{*\bullet}\bar{C}^b_\bullet - is\bar{G}^{ab}_{\bullet i}\bar{C}^{bi} + \; g\bar{D}^{aa'}_\bullet(f^{a'bc}\bar{C}^b_*\bar{C}^c_\bullet)\\
&+ 2gf^{abc}\bar{C}^b_\bullet\bar{D}_*\bar{C}^c_\bullet - g^2 f^{abm}f^{cdm}\bar{C}^b_\bullet\bar{C}^c_\bullet\bar{C}^d_* + \frac{s}{2}gf^{abc}(2\bar{C}^b_i\partial^i\bar{C}^c_\bullet - \bar{C}^b_i\bar{D}_\bullet\bar{C}^{ci}) - \frac{s}{2}g^2 f^{abm}f^{cdm}\bar{C}^{bi}\bar{C}^c_\bullet\bar{C}^d_i,\\
\big(2\bar{P}_*\bar{P}_\bullet - \frac{s}{2}p_\perp^2\big)^{ab}\bar{C}^b_* \;&=\; -\bar{D}^{ab}_*\bar{G}^b_{*\bullet} - i\bar{G}^{ab}_{*\bullet}\bar{C}^b_* - is\bar{G}^{ab}_{*i}\bar{C}^{bi} - \; g\bar{D}^{aa'}_*(f^{a'bc}\bar{C}^b_*\bar{C}^c_\bullet)\\
&+ 2gf^{abc}\bar{C}^b_*\bar{D}_\bullet\bar{C}^c_* - g^2 f^{abm}f^{cdm}\bar{C}^b_*\bar{C}^c_*\bar{C}^d_\bullet + gf^{abc}(2\bar{C}^b_i\partial^i\bar{C}^c_* - \bar{C}^b_i\bar{D}_*\bar{C}^{ci}) - g^2 f^{abm}f^{cdm}\bar{C}^{bi}\bar{C}^c_*\bar{C}^d_i,\\
\big(\bar{P}_*\bar{P}_\bullet + \bar{P}_\bullet\bar{P}_* - \frac{s}{2}p_\perp^2\big)\bar{C}^b_i \;&=\; \bar{D}^{ab}_*\bar{G}^b_{\bullet i} + \bar{D}^{ab}_\bullet\bar{G}^b_{*i} + 2ig(\bar{G}^{ab}_{\bullet i}\bar{C}^b_* + \bar{G}^{ab}_{*i}\bar{C}^b_\bullet) + gf^{abc}(2\bar{C}^b_*\bar{D}_\bullet\bar{C}^c_i + 2\bar{C}^b_\bullet\bar{D}_*\bar{C}^c_i - \bar{C}^b_\bullet\partial_i\bar{C}^c_* - \bar{C}^b_*\partial_i\bar{C}^c_\bullet)\\
&- g^2 f^{abm}f^{cdm}(\bar{C}^b_\bullet\bar{C}^c_i\bar{C}^d_* + \bar{C}^b_*\bar{C}^c_i\bar{C}^d_\bullet) + \frac{s}{2}gf^{abc}(2\bar{C}^b_j\partial^j\bar{C}^c_i - \bar{C}^b_j\partial_i\bar{C}^{cj}) - g^2 f^{abm}f^{cdm}\bar{C}^{bj}\bar{C}^c_i\bar{C}^d_j
\end{aligned} \tag{215}$$

In the leading order in ∂_i

$$(\bar{P}_*\bar{P}_\bullet + \bar{P}_\bullet\bar{P}_*)\bar{C}^b_i \tag{216}$$

$$\begin{aligned}
&= \bar{D}^{ab}_*\bar{G}^b_{\bullet i} + \bar{D}^{ab}_\bullet\bar{G}^b_{*i} + 2ig(\bar{G}^{ab}_{\bullet i}\bar{C}^b_* + \bar{G}^{ab}_{*i}\bar{C}^b_\bullet) + gf^{abc}(2\bar{C}^b_*\bar{D}_\bullet\bar{C}^c_i + 2\bar{C}^b_\bullet\bar{D}_*\bar{C}^c_i - \bar{C}^b_\bullet\partial_i\bar{C}^c_* - \bar{C}^b_*\partial_i\bar{C}^c_\bullet) - \; g^2 f^{abm}f^{cdm}(\bar{C}^b_\bullet\bar{C}^c_i\bar{C}^d_* + \bar{C}^b_*\bar{C}^c_i\bar{C}^d_\bullet)\\
&\Leftrightarrow\;\; [(\bar{P}+\bar{C})_*(\bar{P}+\bar{C})_\bullet + (\bar{P}+\bar{C})_\bullet(\bar{P}+\bar{C})_*]\bar{C}^b_i \;=\; (\bar{D}-i\bar{C})^{ab}_*\bar{G}^b_{\bullet i} + (\bar{D}-i\bar{C})^{ab}_\bullet\bar{G}^b_{*i} + gf^{abc}(\bar{C}^b_*\bar{G}^c_{\bullet i} + \bar{C}^b_\bullet\bar{G}^c_{*i}) - gf^{abc}(\bar{C}^b_\bullet\partial_i\bar{C}^c_* + \bar{C}^b_*\partial_i\bar{C}^c_\bullet)\\
&\Leftrightarrow\;\; [(\bar{P}+\bar{C})_*(\bar{P}+\bar{C})_\bullet + (\bar{P}+\bar{C})_\bullet(\bar{P}+\bar{C})_*]\bar{C}^b_i \;=\; (\bar{D}-i\bar{C})^{ab}_*\bar{G}^b_{\bullet i} + (\bar{D}-i\bar{C})^{ab}_\bullet\bar{G}^b_{*i} - gf^{abc}[\bar{C}^b_\bullet\partial_i(\bar{A}+\bar{C})^c_* + \bar{C}^b_*\partial_i(\bar{A}+\bar{C})^c_\bullet]
\end{aligned}$$

ЕЩЁ РАЗ: УРАВНЕНИЕ НА $\bar{C}_i$

$$\begin{aligned}
&[(\bar{P}+\bar{C})^2]^{ab}\bar{C}^b_i \;=\; -2ig\bar{G}^{ab}_{i\beta}\bar{C}^{b\beta} + \bar{D}^{ab\xi}\bar{G}^b_{\xi i} - \partial^2\bar{A}^a_i - gf^{abc}\bar{C}^b_\beta\partial_i\bar{C}^{c\beta}\\
&= \;-gf^{abc}\bar{C}^b_\beta\partial_i\bar{C}^{c\beta} - gf^{abc}\bar{A}^b_\beta\partial_i\bar{A}^{c\beta} - 2gf^{abc}\bar{C}^{b\xi}\partial_i\bar{A}^c_\xi \;=\; -gf^{abc}(\bar{A}+\bar{C})^b_\beta\partial_i(\bar{A}+\bar{C})^{c\beta} + \partial_i(f^{abc}\bar{A}^{b\xi}\bar{C}^c_\xi)\\
&= \;-gf^{abc}(\bar{P}+\bar{C})^b_\beta\partial_i(\bar{A}+\bar{C})^{c\beta} - \partial_i\partial^\xi(\bar{A}+\bar{C})^a_\xi + i\partial_i(\bar{A}^{ab}_\xi\bar{C}^{b\xi}) = \;-gf^{abc}(\bar{P}+\bar{C})^b_\beta\partial_i(\bar{A}+\bar{C})^{c\beta} \;=\; ig(\bar{P}+\bar{C})^{ab}_\beta\partial_i(\bar{A}+\bar{C})^{b\beta}\\
&\Rightarrow\;\; (\Omega p^2\Omega^\dagger)^{ab}\bar{C}^b_i \;=\; -(\Omega p_\beta\Omega^\dagger)^{ab}\partial_i(\Omega\partial_\beta\Omega^\dagger)^b \;=\; -i\Omega^{ab}\partial^2(2\mathrm{Tr}\{t^b(\partial_i\Omega^\dagger)\Omega\}
\end{aligned} \tag{217}$$

gde $\bar{A}_\bullet + \bar{C}_\bullet \;=\; i\Omega\partial_\bullet\Omega^\dagger$ and $\bar{A}_* + \bar{C}_* \;=\; i\Omega\partial_*\Omega^\dagger$

Wi uzd ФОРМУΛΑ

$$\Omega^{ab}\partial_\mu\big((\partial_\nu\Omega^\dagger)\Omega\big)^b \;=\; \Omega^{ab}\partial_\mu(2\mathrm{Tr}\{t^b(\partial_\nu\Omega^\dagger)\Omega\}) \;=\; 2\mathrm{Tr}\{t^b\Omega\partial_\mu\partial_\nu\Omega^\dagger + t^b(\partial_\nu\Omega)\partial_\mu\Omega^\dagger\} \;=\; \partial_\nu 2\mathrm{Tr}\{t^b\Omega\partial_\mu\Omega^\dagger\}$$

$$\Rightarrow\;\; \Omega^{\dagger ab}\partial_i(\Omega\partial_\bullet\Omega^\dagger)^b \;=\; \partial_\bullet(\partial_i\Omega^\dagger\Omega)^a \qquad \text{and} \qquad \Omega^{\dagger ab}\partial_i(\Omega\partial_*\Omega^\dagger)^b \;=\; \partial_*(\partial_i\Omega^\dagger\Omega)^a \tag{218}$$

Solution of Eq. (217)

$$2\mathcal{P}_*\mathcal{P}_\bullet\bar{C}_i \;=\; i(\mathcal{P}_*\partial_i\mathcal{A}_\bullet + \mathcal{P}_\bullet\partial_i\mathcal{A}_*) \qquad\Rightarrow\qquad \bar{C}^a_i \;=\; -i\int d^4z\;\Omega^{ab}_x(x|\frac{1}{p^2}|z)\partial^2((\partial_i\Omega^\dagger)\Omega)^b \tag{219}$$

$$\begin{aligned}
&= \;-is\int d^4z\;\Omega^{ab}_x(x|\frac{1}{p^2}|z)\frac{\partial}{\partial z_*}\frac{\partial}{\partial z_\bullet}((\partial_i\Omega^\dagger_z)\Omega_z)^b \;=\; (\Omega i\partial_i\Omega^\dagger)^a + \frac{4}{s}\Omega^{ab}_x\int d^2z_\perp dz_\bullet(x|\frac{p_*}{p^2}|z)((\partial_i\Omega^\dagger_z)\Omega_z)^b\Big|_{z_*=-\infty}\\
&+ \frac{4}{s}\Omega^{ab}_x\int d^2z_\perp dz_*(x|\frac{p_\bullet}{p^2}|z)((\partial_i\Omega^\dagger_z)\Omega_z)^b\Big|_{z_\bullet=-\infty} - 2i\Omega^{ab}_x\int d^2z_\perp(x|\frac{1}{p^2}|z)((\partial_i\Omega^\dagger_z)\Omega_z)^b\Big|_{z_*=z_\bullet=-\infty}\\
&= \;(\Omega i\partial_i\Omega^\dagger)^a - i\Omega^{ab}_x[(\partial_i\Omega^\dagger(x_\perp,x_\bullet,-\infty_*)\Omega(x_\perp,x_\bullet,-\infty_*)]\\
&\qquad - i\Omega^{ab}_x[(\partial_i\Omega^\dagger(x_\perp,x_*,-\infty_\bullet)\Omega(x_\perp,x_*,-\infty_\bullet)] + i\Omega^{ab}_x[(\partial_i\Omega^\dagger(x_\perp,-\infty_*,-\infty_\bullet)\Omega(x_\perp,-\infty_*,-\infty_\bullet)]
\end{aligned}$$

$$\bar{C}_i^a \;=\; (\Omega i\partial_i\Omega^\dagger)^a + i\Omega_x^{ab}([-\infty_*,x_*]_x^{\bar{A}_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar{A}_\bullet})^b + i\Omega_x^{ab}([-\infty_\bullet,x_\bullet]_x^{\bar{A}_*}\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar{A}_*})^b \tag{220}$$

Properti:

$$\bar{C}_i(x) \stackrel{x_*\to-\infty}{\to} 0, \qquad \bar{C}_i(x) \stackrel{x_\bullet\to-\infty}{\to} 0 \tag{221}$$

Now

$$\begin{aligned} F_{\bullet i}^a \;&=\; \partial_\bullet\bar{C}_i^a - \partial_i(\bar{A}_\bullet+\bar{C}_\bullet)^a - i(\bar{A}+\bar{C})_\bullet^{ab}\bar{C}_i^b \;=\; \Omega^{am}\partial_\bullet(\Omega^{\dagger mb}\bar{C}_i^b) - i\partial_i(\Omega\partial_\bullet\Omega^\dagger)^a \\ &=\; \Omega^{ab}\partial_\bullet\Big(i((\partial_i\Omega^\dagger)\Omega_x)^b - i[(\partial_i\Omega^\dagger(x_\perp,x_*,-\infty_\bullet)\Omega(x_\perp,x_*,-\infty_\bullet)]^b\Big) - i\partial_i(\Omega\partial_\bullet\Omega^\dagger)^a \\ &=\; -i\Omega_x^{ab}\partial_\bullet\big([\partial_i\Omega^\dagger(x_\perp,x_*,-\infty_\bullet)]\Omega(x_\perp,x_*,-\infty_\bullet)\big)^b \;\equiv\; -i\Omega_x^{ab}\partial_\bullet 2\mathrm{Tr}\{t^b[\partial_i\Omega^\dagger(x_\perp,x_*,-\infty_\bullet)]\Omega(x_\perp,x_*,-\infty_\bullet)\} \end{aligned} \tag{222}$$

At $x_\bullet=-\infty$ $(\bar{A}_\bullet+\bar{C}_\bullet)(x_*,x_\bullet=-\infty) \;=\; \bar{A}_\bullet(x_*)$ so

$$\Omega(x_\perp,x_*,-\infty_\bullet) \;=\; [x_*,-\infty_*]_x^{(\bar{A}_\bullet)} \;\Rightarrow\; (\partial_i\Omega^\dagger(x_\perp,x_*,-\infty_\bullet)\Omega(x_\perp,x_*,-\infty_\bullet) \;=\; \frac{2i}{s}\int_{-\infty}^{x_*}dz_*\;[-\infty_*,z_*]_x^{(\bar{A}_\bullet)}\bar{G}_{\bullet i}(x_\perp,z_*)[z_*,-\infty_*]_x^{(\bar{A}_\bullet)} \tag{223}$$

И ПОЭТОМУ

$$F_{\bullet i}^a(x) \;=\; \Omega_x^{ab}\;2\mathrm{Tr}\{t^b[-\infty_*,x_*]_x^{(\bar{A}_\bullet)}\bar{G}_{\bullet i}(x_\perp,x_*)[x_*,-\infty_*]_x^{(\bar{A}_\bullet)}\} \;=\; \Omega_x^{ab}[-\infty_*,x_*]_x^{(\bar{A}_\bullet)bc}\bar{G}_{\bullet i}^c(x_\perp,x_*) \tag{224}$$

and there4

$$\Rightarrow\; F_{*i}^{a(\bar{A}+\bar{C})}(x)F_\bullet^{ai(\bar{A}+\bar{C})}(x) \;=\; \bar{G}_{*i}^a(x_\perp,x_\bullet)\big([x_\bullet,-\infty_\bullet]_{x_\perp}^{(\bar{A}_*)}[-\infty_*,x_*]_{x_\perp}^{(\bar{A}_\bullet)}\big)^{bc}\bar{G}_{\bullet i}^c(x_\perp,x_*) \tag{225}$$

С КВАРКАМИ

$$\begin{aligned} [(\bar{P}+\bar{C})^2]^{ab}\bar{C}_i^b \;&=\; -2ig\bar{G}_{i\beta}^{ab}\bar{C}^{b\beta} + \bar{D}^{ab\xi}\bar{G}_{\xi i}^b + \bar{\Upsilon}\gamma_i t^a\Upsilon - gf^{abc}\bar{C}_\beta^b\partial_i\bar{C}^{c\beta} \\ &=\; -gf^{abc}(\bar{A}+\bar{C})_\beta^b\partial_i(\bar{A}+\bar{C})^{c\beta} + \partial_i(f^{abc}\bar{A}^{b\xi}\bar{C}_\xi^c) + \bar{\Upsilon}\gamma_i t^a\Upsilon \\ &=\; -gf^{abc}(\bar{P}+\bar{C})_\beta^b\partial_i(\bar{A}+\bar{C})^{c\beta} - \partial_i\partial^\xi(\bar{A}+\bar{C})_\xi^a + i\partial_i(\bar{A}_\xi^{ab}\bar{C}^{b\xi}) + \bar{\Upsilon}\gamma_i t^a\Upsilon \\ &=\; ig(\bar{P}+\bar{C})_\beta^{ab}\partial_i(\bar{A}+\bar{C})^{b\beta} + \bar{\Upsilon}\gamma_i t^a\Upsilon \end{aligned} \tag{226}$$

3. *First order in $\bar{A}_\bullet,\bar{A}_*$*

$$\begin{aligned} \bar{C}_\bullet^{1a}(x) \;&=\; -\frac{i}{2}\int dz(x|\frac{1}{p_*+i\epsilon}|z)\bar{G}_{*\bullet}^a(z) \;=\; -\frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon}|z)\bar{A}_*^b\bar{A}_\bullet^c(z), \\ \bar{C}_*^{1a}(x) \;&=\; \frac{i}{2}\int d^2z(x|\frac{1}{p_\bullet+i\epsilon}|z)\bar{G}_{*\bullet}^a(z) = \frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon}|z)\bar{A}_*^b\bar{A}_\bullet^c(z), \\ \bar{C}_i^{1a}(x) \;&=\; \frac{1}{2}\int dz(x|\frac{1}{p_*p_\bullet+i\epsilon p_0}|z)(\bar{D}_*\bar{G}_{\bullet i}^a(z)+\bar{D}_\bullet\bar{G}_{*i}^a(z)) \;=\; -\frac{1}{2}f^{abc}\int dz(x|\frac{1}{p_*p_\bullet+i\epsilon p_0}|z)(A_\bullet^b\partial_iA_*^c + A_*^b\partial_iA_\bullet^c) \\ F_{\bullet i}^{(1)a}(x) \;&=\; \frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon}|z)(\bar{A}_\bullet^b\partial_i\bar{A}_*^c+\bar{A}_*^b\partial_i\bar{A}_\bullet^c) + \frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon}|z)\partial_i\big(\bar{\bar{A}}_*^b\bar{\bar{A}}_\bullet^c(z)\big) \\ &=\; if^{abc}\int dz(x|\frac{1}{p_*+i\epsilon}|z)\bar{A}_*^b\partial_i\bar{A}_\bullet^c(z) \;=\; f^{abc}\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\;\bar{A}_*^b(z_\bullet)\partial_i\bar{A}_\bullet^c(x_*) \;=\; -f^{abc}\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\;\bar{A}_*^b(z_\bullet)\bar{G}_{\bullet i}^c(x_*) \\ F_{*i}^{(1)m}(x) \;&=\; if^{mcd}\int dz(x|\frac{1}{p_\bullet+i\epsilon}|z)\bar{A}_\bullet^a\partial_i\bar{A}_*^b(z) \;=\; -f^{mab}\int_{-\infty}^{x_*}d\frac{2}{s}z_*\;\partial_i\bar{A}_*^a(x_\bullet)\bar{A}_\bullet^b(z_*) \;=\; f^{mab}\int_{-\infty}^{x_*}d\frac{2}{s}z_*\;\bar{G}_{*i}^a(x_\bullet)\bar{A}_\bullet^b(z_*) \\ \Rightarrow\; F_\bullet^{(1)ai}F_{*i}^{(1)a}(x) \;&=\; f^{mab}f^{mcd}\bar{G}_*^{ai}(x_\bullet)\;i\int_{-\infty}^{x_*}d\frac{2}{s}z_*\;\bar{A}_\bullet^b(z_*)\;i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\;\bar{A}_*^c(z_\bullet)\bar{G}_{\bullet i}^d(x_*) \end{aligned} \tag{227}$$

А НА САМОМ ДЕЛЕ (see Eq. (225))

$$F_\bullet^{(1)ai}F_{*i}^{(1)a}(x) \;=\; f^{mac}f^{mbd}\bar{G}_{*i}^a(x_\bullet)\;i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\;\bar{A}_*^c(z_\bullet)\;i\int_{-\infty}^{x_*}d\frac{2}{s}z_*\;\bar{A}_\bullet^b(z_*)\bar{G}_{\bullet i}^d(x_*)$$

КАК ТАК?

$$f^{mab}f^{mcd} - f^{mac}f^{mbd} \;=\; -\,f^{adm}f^{bcm} \tag{228}$$

$$\bar C^{1a}_\bullet(x) \;=\; -\frac{i}{2}\int dz (x|\frac{1}{P_* + i\epsilon}|z)^{ab}\bar G^b_{*\bullet}(z), \qquad \bar C^{1a}_*(x) \;=\; \frac{i}{2}\int d^2z (x|\frac{1}{P_\bullet + i\epsilon}|z)^{ab}\bar G^b_{*\bullet}(z),$$
$$\bar C^{1a}_i(x) \;=\; \frac{1}{2}\int dz (x|\frac{1}{P_*P_\bullet + i\epsilon p_0}|z)^{ab}\big(\bar D_*\bar G^b_{\bullet i}(z) + \bar D_\bullet \bar G^b_{*i}(z) + 2ig\bar G^{ab}_{\bullet i}\bar C^{(1)b}_* + 2ig\bar G^{ab}_{*i}\bar C^{(1)b}_\bullet)\big)$$
$$F^{(1)a}_{\bullet i}(x) \;=\; \bar D_\bullet \bar C^{1a}_i(x) - \partial_i \bar C^{1a}_\bullet \;=\; -\frac{i}{2}(x|\frac{1}{P_* + i\epsilon}|z)^{ab}(\bar D_*\bar G^b_{\bullet i}(z) + \bar D_\bullet \bar G^b_{*i}(z)) + \frac{1}{2}\int dz (x|p_i\frac{1}{P_* + i\epsilon}|z)^{ab}\bar G^b_{*\bullet}(z)$$
$$+\,\frac{i}{2}\int dz (x|\frac{1}{P_* + i\epsilon}\bar G_{\bullet i}\frac{1}{P_\bullet + i\epsilon}|z)^{ab}\bar G^b_{*\bullet} \;=$$
$$f^{mab}f^{mcd}\bar G^{ai}_*(x_\bullet)\; i\int_{-\infty}^{x_*} d\frac{2}{s}z_*\;\bar A^b_\bullet(z_*)\; i\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet\;\bar A^c_*(z_\bullet)\bar G^d_{\bullet i}(x_*)$$
$$+\,\frac{i}{2}\bar F^{ai}_*\int dz (x|\frac{1}{P_* + i\epsilon}\bar G_{\bullet i}\frac{1}{P_\bullet + i\epsilon}|z)^{ab}\bar F^b_{*\bullet} - \frac{i}{2}\bar F^{ai}_\bullet\int dz (x|\frac{1}{P_\bullet + i\epsilon}\bar G_{*i}\frac{1}{P_* + i\epsilon}|z)^{ab}\bar F^b_{*\bullet}$$
$$\stackrel{?}{=}\; f^{mac}f^{mbd}\bar G^a_{*i}(x_\bullet)\; i\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet\;\bar A^c_*(z_\bullet)\; i\int_{-\infty}^{x_*} d\frac{2}{s}z_*\;\bar A^b_\bullet(z_*)\bar G^d_{\bullet i}(x_*) \tag{229}$$

From Eq. (192)

$$\Omega(x) \;=\; [x_\bullet,-\infty][x_*,-\infty] + \frac{i}{2}\int_{-\infty}^{x_*} d\frac{2}{s}z_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet\;\bar G_{*\bullet}(z) + O(\bar A^3) \tag{230}$$

and from Eq. (224)

$$F^a_{\bullet i}(x) \;=\; \Omega^{ab}_x[-\infty_*,x_*]_x^{(\bar A_\bullet)ab}\bar F^b_{\bullet i}(x_\perp,x_*) \;=\; [-\infty_*,x_\bullet]_x^{(\bar A_*)bc}\bar G^c_{\bullet i}(x_\perp,x_*) \;-\frac{1}{2}f^{abc}\int_{-\infty}^{x_*} d\frac{2}{s}z_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet\;\bar G^b_{*\bullet}(z)\bar G^c_{\bullet i}(x_\perp,x_*) \tag{231}$$

НАЙДЁМ $F^{(1)}_{ik}$

$$\bar C^a_i \;=\; (\Omega i\partial_i\Omega^\dagger)^a + C^a_{1i} + C^a_{2i}, \quad C^a_{1i} \;=\; i\Omega^{ab}_x([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar A_\bullet})^b, \quad C^a_{2i} \;=\; i\Omega^{ab}_x([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^b \tag{232}$$

$$\Omega^{\dagger aa'}F^{a'}_{ik}(x) \;=\; \Omega^{\dagger aa'}(\Omega\partial_i\Omega^\dagger)^{a'b}(C_1+C_2)^b_k - i\leftrightarrow k + \Omega^{\dagger aa'}f^{a'bc}(C_1+C_2)^b_i(C_1+C_2)^c_k \tag{233}$$
$$=\; i2\mathrm{Tr}t^a(\partial_i[-\infty_*,x_*]_x^{\bar A_\bullet})\partial_k[x_*,-\infty_*]_x^{\bar A_\bullet} + i2\mathrm{Tr}t^a(\partial_i[-\infty_\bullet,x_\bullet]_x^{\bar A_*})\partial_k[x_\bullet,-\infty_\bullet]_x^{\bar A_*} - i\leftrightarrow k$$
$$-\,f^{abc}([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar A_\bullet})^b([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_k[x_*,-\infty_*]_x^{\bar A_\bullet})^c - f^{abc}([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^b([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_k[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^c$$
$$-\,f^{abc}([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar A_\bullet})^b([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_k[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^c - f^{abc}([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^b([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_k[x_*,-\infty_*]_x^{\bar A_\bullet})^c$$
$$=-\,f^{abc}([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar A_\bullet})^b([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_k[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^c - f^{abc}([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^b([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_k[x_*,-\infty_*]_x^{\bar A_\bullet})^c$$
$$\Rightarrow$$
$$F^{(1)a}_{ik}(x) \;=-\;\Omega^{aa'}_x f^{a'bc}\big\{([-\infty_*,x_*]_x^{\bar A_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar A_\bullet})^b([-\infty_\bullet,x_\bullet]_x^{\bar A_*}\partial_k[x_\bullet,-\infty_\bullet]_x^{\bar A_*})^c \;-\; i\leftrightarrow k)\big\} \tag{234}$$

A. Eff action

$$-\frac{1}{4}\bar G^{a\mu\nu}\bar G^a_{\mu\nu} - \frac{1}{2}\bar C^{a\alpha}(\bar P^2 g_{\alpha\beta} + 2i\bar G_{\alpha\beta})^{ab}\bar C^{\beta b} + \bar C^a_\alpha \bar D_\xi \bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha \bar C^{a\beta}\bar C^b_\alpha \bar C^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}\bar C^{a\alpha}\bar C^{b\beta}\bar C^c_\alpha \bar C^d_\beta$$
$$=\; -\frac{1}{4}\bar G^{a\mu\nu}\bar G^a_{\mu\nu} - \frac{1}{2}\bar C^a_\alpha g f^{abc}(2\bar C^b_\beta \bar D^\beta \bar C^c_\alpha + \frac{1}{2}gf^{abc}\bar C^a_\alpha \bar C^b_\beta \bar D_\alpha \bar C^{c\beta} + \frac{1}{2}\bar C^a_\alpha \bar D_\xi \bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha \bar C^{a\beta}\bar C^b_\alpha \bar C^c_\beta + \frac{g^2}{4}f^{abm}f^{cdm}\bar C^{a\alpha}\bar C^{b\beta}\bar C^c_\alpha \bar C^d_\beta$$
$$=\; -\frac{1}{4}\bar G^{a\mu\nu}\bar G^a_{\mu\nu} + \frac{1}{2}gf^{abc}\bar C^a_\alpha \bar C^b_\beta \bar D_\alpha \bar C^{c\beta} + \frac{1}{2}\bar C^a_\alpha \bar D_\xi \bar G^{a\xi\alpha} + \frac{g^2}{4}f^{abm}f^{cdm}\bar C^{a\alpha}\bar C^{b\beta}\bar C^c_\alpha \bar C^d_\beta$$
$$=\; -\frac{1}{4}\big[\bar G^{a\alpha\beta} + \bar D^\alpha \bar C^{a\beta} - \bar D^\beta \bar C^{a\alpha} + gf^{akl}\bar C^{k\alpha}\bar C^{l\beta}\big]\big[\bar G^a_{\alpha\beta} + \bar D_\alpha \bar C^a_\beta - \bar D_\beta \bar C^a_\alpha + gf^{acd}\bar C^{c\alpha}\bar C^{d\beta}\big] + ? \tag{235}$$

X. IN 4 DIMENSIONS

$$A_\mu^{(1+2+...)} \equiv \int DA\ A_\mu(x) e^{i\int d^4z\left(\frac{1}{2}A^a_\alpha(\bar{D}^2 g^{\alpha\beta}-2i\bar{G}^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha(\bar{D}_\xi\bar{G}^{a\xi\alpha}-\partial^2\bar{A}^a_\alpha - l^a_\alpha) - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\right)} \tag{236}$$

gde (cm. Eq. (29)

$$l^a_\mu \equiv \frac{2}{s}p_{1\mu}\big(\frac{1}{P_\bullet}\bar{A}_\bullet\big)^{ab}\partial_\perp^2\bar{A}^b_* + \frac{2}{s}p_{2\mu}\big(\frac{1}{P_*}\bar{A}_*\big)^{ab}\partial_\perp^2\bar{A}^b_\bullet \tag{237}$$

Y HAC $\partial^\xi\bar{A}_\xi = 0$

$$\bar{D}^\xi\bar{G}^a_{\xi\bullet} - \partial^2\bar{A}^a_\bullet = \frac{2}{s}\bar{D}_\bullet\bar{G}^a_{*\bullet}, \quad \bar{D}^\xi\bar{G}^a_{\xi*} - \partial^2\bar{A}^a_* = -\frac{2}{s}\bar{D}_*\bar{G}^a_{*\bullet}, \quad \bar{D}^\xi\bar{G}^a_{\xi i} = \frac{2}{s}\bar{D}_*\bar{G}^a_{\bullet i} + \frac{2}{s}\bar{D}_\bullet\bar{G}^a_{*i} \tag{238}$$

$$A^{(1)a}_\alpha \equiv \int d^4z\ (x|\frac{1}{\bar{P}^2}|z)^{ab}(\bar{D}^\xi\bar{G}_{\xi\alpha} - l_\alpha)^b(z) \tag{239}$$

$$\begin{aligned}
A^{(1)a}_* &= \int d^4z\ (x|\frac{1}{\bar{P}^2}|z)^{ab}\Big[-\frac{2}{s}\bar{D}_*\bar{G}^b_{*\bullet}(z) - \big(\frac{1}{P_\bullet}\bar{A}_\bullet\big)^{bc}\partial_\perp^2\bar{A}^c_*\Big] = \int d^4z\ \Big[\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) - (x|\frac{1}{\bar{P}^2}\frac{1}{P_\bullet}\bar{A}_\bullet|z)^{ab}\partial_\perp^2\bar{A}^b_*\Big]\\
A^{(1)a}_\bullet &= \int d^4z\ (x|\frac{1}{\bar{P}^2}|z)^{ab}\Big[\frac{2}{s}\bar{D}_\bullet\bar{G}^b_{*\bullet}(z) - \big(\frac{1}{P_*}\bar{A}_*\big)^{bc}\partial_\perp^2\bar{A}^c_\bullet\Big] = \int d^4z\ \Big[-\frac{2i}{s}(x|\frac{1}{\bar{P}^2}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) - (x|\frac{1}{P^2}\frac{1}{P_*}\bar{A}_*|z)^{ab}\partial_\perp^2\bar{A}^b_\bullet\Big]\\
A^{(1)a}_i &= \frac{2}{s}\int d^4z\ (x|\frac{1}{\bar{P}^2}|z)^{ab}[\bar{D}_*\bar{G}^a_{\bullet i} + \bar{D}_\bullet\bar{G}^a_{*i}](z)\ +\ O(\bar{G}^2) = \frac{2}{s}\int d^4z\ (x|\frac{1}{\bar{P}^2}|z)^{ab}[2\bar{D}_\bullet\bar{G}^a_{*i} - \partial_i\bar{G}^a_{*\bullet}](z)\ +\ O(\bar{G}^2)
\end{aligned} \tag{240}$$

$$\begin{aligned}
&G^a_{*\bullet}(\bar{A}+A^{(1)}) = \bar{G}^a_{*\bullet} + \int d^4z\ \Big[-\frac{2}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet + \bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) + i(x|\bar{P}_*\frac{1}{P^2}\frac{1}{P_*}\bar{A}_*|z)^{ab}\partial_\perp^2\bar{A}^b_\bullet - i(x|\bar{P}_\bullet\frac{1}{P^2}\frac{1}{P_\bullet}\bar{A}_\bullet|z)^{ab}\partial_\perp^2\bar{A}^b_*\\
&= \int d^4z\ \Big[-\frac{1}{s}(x|\big[\bar{P}_*,[\bar{P}_\bullet,\frac{1}{\bar{P}^2}]\big] + \big[\bar{P}_\bullet,[\bar{P}_*,\frac{1}{\bar{P}^2}]\big] - \frac{i}{2\hat{P}^2}\{p^i,\{\bar{P}^\xi,\bar{G}_{\xi i}\}\}\frac{1}{\bar{P}^2}|z)^{ab}\bar{G}^b_{*\bullet}(z) + (x|\frac{1}{\bar{P}^2}|z)^{ab}\partial_\perp^2\bar{G}^b_{*\bullet}(z)\\
&- (x|\frac{1}{\bar{P}^2}|z)^{ab}f^{a'bc}[\bar{A}^b_*\partial_\perp^2\bar{A}^c_\bullet + (\partial_\perp^2\bar{A}^b_\bullet)\bar{A}^c_*] + (x|\frac{1}{P^2}\{p^\xi,\bar{G}_{*\xi}\}\frac{1}{P^2}\frac{1}{P_*}\bar{A}_*|z)^{ab}\partial_\perp^2\bar{A}^b_\bullet - (x|\frac{1}{P^2}\{p^\xi,\bar{G}_{\bullet\xi}\}\frac{1}{\bar{P}^2}\frac{1}{P_\bullet}\bar{A}_\bullet|z)^{ab}\partial_\perp^2\bar{A}^b_*\Big]\\
&= \int d^4z\ \Big[(x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{G}^b_{*i}(z)\bar{G}_\bullet{}^i(z) - \frac{1}{s}(x|\big[\bar{P}_*,[\bar{P}_\bullet,\frac{1}{\bar{P}^2}]\big] + \big[\bar{P}_\bullet,[\bar{P}_*,\frac{1}{\bar{P}^2}]\big] - \frac{i}{2\hat{P}^2}\{p^i,\{\bar{P}^\xi,\bar{G}_{\xi i}\}\}\frac{1}{\bar{P}^2}|z)^{ab}\bar{G}^b_{*\bullet}(z)\\
&+ (x|\frac{1}{P^2}\{p^\xi,\bar{G}_{*\xi}\}\frac{1}{P^2}\frac{1}{P_*}\bar{A}_*|z)^{ab}\partial_\perp^2\bar{A}^b_\bullet - (x|\frac{1}{P^2}\{p^\xi,\bar{G}_{\bullet\xi}\}\frac{1}{\bar{P}^2}\frac{1}{P_\bullet}\bar{A}_\bullet|z)^{ab}\partial_\perp^2\bar{A}^b_*\Big]
\end{aligned} \tag{241}$$

bikoz $\frac{2}{s}\bar{P}_*\frac{1}{\bar{P}^2}\bar{P}_\bullet + \frac{2}{s}\bar{P}_\bullet\frac{1}{\bar{P}^2}\bar{P}_* = 1 + \frac{1}{s}\big[\bar{P}_\bullet,[\bar{P}_*,\frac{1}{\bar{P}^2}]\big] + \frac{1}{s}\big[\bar{P}_*,[\bar{P}_\bullet,\frac{1}{\bar{P}^2}]\big] + \frac{1}{2}\{p^2_\perp,\frac{1}{\bar{P}^2}\}$.

If $\bar{G}_{\bullet i} = \frac{s}{2}\Omega U_i\Omega^\dagger\delta(x_*)$ and $\bar{G}_{*i} = \frac{s}{2}\Omega V_i\Omega^\dagger\delta(x_\bullet)$, the first term

$$\int d^4z\ \Big[(x|\frac{1}{\bar{P}^2}|z)^{aa'}f^{a'bc}\bar{G}^b_{*i}(z)\bar{G}^{ci}_\bullet(z) = -i\int d^2z_\perp\ (x|\frac{1}{\bar{P}^2}\Omega^\dagger|0,z_\perp)^{ab}[U_i,V^i]^b \tag{242}$$

agrees with Eq. (52) from hep-ph/9812311

$$\begin{aligned}
&G^a_{*i}(\bar{A}+A^{(1)}) = -\partial_i(\bar{A}_* + A^{(1)}_*) + \bar{D}_*A^{(1)}_i = \bar{G}_{*i} + \bar{D}_*A^{(1)}_i - \partial_iA^{(1)}_*\\
&= \bar{G}_{*i} - \int d^4z\ \Big[\frac{2}{s}(x|p_i\frac{1}{\bar{P}^2}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) - i(x|p^i\frac{1}{\bar{P}^2}\frac{1}{P_\bullet}\bar{A}_\bullet|z)^{ab}\partial_\perp^2\bar{A}^b_* + \frac{4}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}\bar{A}_\bullet|z)^{ab}\bar{G}^b_{*i}(z) - \frac{2}{s}(x|\bar{P}_*\frac{1}{\bar{P}^2}p_i|z)\bar{G}^b_{*\bullet}(z)\Big]
\end{aligned}$$

If we throw away $p^2_\perp$

From Eq. (134) and (29)

$$A^{(1+2)a}_\alpha \equiv A^{(1)a}_\alpha + A^{(2)a}_\alpha = \int DA\ A^a_\alpha(x) e^{i\int d^4z\left(\frac12 A^a_\alpha(\bar D^2 g^{\alpha\beta} - 2i\bar G^{\alpha\beta})^{ab}A^b_\beta + A^a_\alpha \bar D_\xi \bar G^{a\xi\alpha} - gf^{abc}\bar D^\alpha A^{a\beta}A^b_\alpha A^c_\beta - A^a_\alpha l^{a\alpha}\right)} =$$
$$= \int d^4z\ \Big[(x|\frac{1}{\bar P^2 g_{\alpha\beta} + 2i\bar G_{\alpha\beta}}|z)^{ab}\Big[(\bar D^\xi \bar G_{\xi\beta} - \partial^2 \bar A_\beta)^b(z) - \frac{2}{s}p_{2\beta}\big(\frac{1}{P_*}\bar A_*\big)^{ab}\partial^2_\perp \bar A^b_\bullet - \frac{2}{s}p_{1\beta}\big(\frac{1}{P_\bullet}\bar A_\bullet\big)^{ab}\partial^2_\perp \bar A^b_*\Big] \tag{243}$$
$$- i(x|\frac{1}{\bar P^2 g_{\alpha\beta} + 2i\bar G_{\alpha\beta}}\bar P^\xi|z)^{aa'}f^{a'bc}A^{(1)b}_\xi A^{(1)b}_\beta - (x|\frac{1}{\bar P^2 g_{\alpha\beta} + 2i\bar G_{\alpha\beta}}|z)^{aa'}f^{a'bc}A^{(1)b\xi}(\bar D_\beta A^{(1)b}_\xi - \bar D_\xi A^{(1)b}_\beta)\Big]$$
$$= \bar A^{(1)}_\alpha + \int d^2z\Big[-2i(x|\frac{1}{\bar P^2}\bar G_{\alpha\beta}\frac{1}{\bar P^2}|z)^{ab}(\bar D^\xi \bar G_{\xi\beta} - \partial^2 \bar A_\beta)^b(z) - \frac{2}{s}p_{2\beta}\big(\frac{1}{P_*}\bar A_*\big)^{ab}\partial^2_\perp \bar A^b_\bullet - \frac{2}{s}p_{1\beta}\big(\frac{1}{P_\bullet}\bar A_\bullet\big)^{ab}\partial^2_\perp \bar A^b_*\Big]$$
$$- i(x|\frac{1}{\bar P^2}\bar P^\xi|z)^{aa'}f^{a'bc}A^{(1)b}_\xi A^{(1)c}_\alpha - (x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b\xi}(\bar D_\alpha A^{(1)c}_\xi - \bar D_\xi A^{(1)c}_\alpha)\Big]$$

$$A^{(1+2)a}_* = \frac{2i}{s}\int d^4z\ (x|\frac{1}{\bar P^2}\bar P_*|z)^{ab}\bar G^b_{*\bullet}(z) + \frac{2}{s}\int d^4z\ \Big[\frac{4}{s}(x|\frac{1}{\bar P^2}\bar G_{*\bullet}\frac{1}{\bar P^2}\bar P_*|z)^{ab}\bar G^b_{*\bullet}(z) - 2i(x|\frac{1}{\bar P^2}\bar G_*{}^i\frac{1}{\bar P^2}|z)^{ab}(\bar D_*\bar G^b_{\bullet i} + \bar D_\bullet \bar G^b_{*i})(z)$$
$$- i(x|\frac{1}{\bar P^2}P_*|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet A^{(1)c}_*(z) - \frac{is}{2}(x|\frac{1}{\bar P^2}p^i|z)^{aa'}f^{a'bc}A^{(1)b}_i A^{(1)c}_*(z)$$
$$- (x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b}_*(\bar D_* A^{(1)c}_\bullet - \bar D_\bullet A^{(1)c}_*)(z) - \frac{s}{2}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)bi}(\bar D_* A^{(1)c}_i - \partial_i A^{(1)c}_*)(z)\Big]$$
$$= A^{(1)a}_* + \frac{2}{s}\int d^4z\ \Big[\frac{4}{s}(x|\frac{1}{\bar P^2}\bar G_{*\bullet}\frac{1}{\bar P^2}\bar P_*|z)^{ab}\bar G^b_{*\bullet}(z) - 2i(x|\frac{1}{\bar P^2}\bar G_*{}^i|z)\frac{s}{2}A^{(1)b}_i(z)$$
$$- i(x|\frac{1}{\bar P^2}P_*|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet A^{(1)c}_*(z) - \frac{is}{2}(x|\frac{1}{\bar P^2}p^i|z)^{aa'}f^{a'bc}A^{(1)b}_i A^{(1)c}_*(z)$$
$$+ \frac{2}{s}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b}_*(z)(z|\bar P_*\frac{1}{\bar P^2}\bar P_\bullet + \bar P_\bullet\frac{1}{\bar P^2}\bar P_*|z')^{cc'}\bar G^{c'}_{*\bullet}(z') - \frac{s}{2}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)bi}(\bar D_* A^{(1)c}_i - \partial_i A^{(1)c}_*)(z)\Big]$$
$$= A^{(1)a}_* + \frac{2}{s}\int d^4z\ \Big[-i(x|\frac{1}{\bar P^2}\bar G_{*\bullet}|z)^{ab}A^{(1)b}_*(z) - i(x|\frac{1}{\bar P^2}P_*|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet A^{(1)c}_*(z)$$
$$- 2i(x|\frac{1}{\bar P^2}\bar G_*{}^i|z)\frac{s}{2}A^{(1)b}_i(z) - \frac{is}{2}(x|\frac{1}{\bar P^2}p^i|z)^{aa'}f^{a'bc}A^{(1)b}_i A^{(1)c}_*(z) - \frac{s}{2}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)bi}(\bar D_* A^{(1)c}_i - \partial_i A^{(1)c}_*)(z)$$
$$+ \frac{1}{s}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b}_*(z)(z|\{p^2_\perp, \frac{1}{\bar P^2}\}|z')^{cc'}\bar G^{c'}_{*\bullet}(z')\Big]$$

Similarly,

$$A^{(1+2)a}_\bullet = A^{(1)a}_\bullet + \frac{2}{s}\int d^4z\ \Big[i(x|\frac{1}{\bar P^2}\bar G_{*\bullet}|z)^{ab}A^{(1)b}_\bullet(z) + i(x|\frac{1}{\bar P^2}P_\bullet|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet A^{(1)c}_*(z)$$
$$- 2i(x|\frac{1}{\bar P^2}\bar G_\bullet{}^i|z)\frac{s}{2}A^{(1)b}_i(z) - \frac{is}{2}(x|\frac{1}{\bar P^2}p^i|z)^{aa'}f^{a'bc}A^{(1)b}_i A^{(1)c}_\bullet(z) - \frac{s}{2}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)bi}(\bar D_\bullet A^{(1)c}_i - \partial_i A^{(1)c}_\bullet)(z)\Big]$$
$$- \frac{1}{s}(x|\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet(z)(z|\{p^2_\perp, \frac{1}{\bar P^2}\}|z')^{cc'}\bar G^{c'}_{*\bullet}(z')\Big]$$

ΠΟΕΤΟΜΥ

$$\bar D_* A^{(1+2)a}_\bullet - \bar D_\bullet A^{(1+2)a}_* = -\frac{2}{s}\int d^4z\ (x|\bar P_*\frac{1}{\bar P^2}\bar P_\bullet + \bar P_\bullet\frac{1}{\bar P^2}\bar P_*|z)^{ab}\bar G^b_{*\bullet}$$
$$+ \frac{2}{s}\int d^4z\ \Big[(x|\bar P_*\frac{1}{\bar P^2}\bar G_{*\bullet}|z)^{ab}A^{(1)b}_\bullet(z) + (x|\bar P_\bullet\frac{1}{\bar P^2}\bar G_{*\bullet}|z)^{ab}A^{(1)b}_*(z) + (x|\bar P_*\frac{1}{\bar P^2}P_\bullet + \bar P_\bullet\frac{1}{\bar P^2}P_*|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet A^{(1)c}_*(z)$$
$$- 2(x|\bar P_*\frac{1}{\bar P^2}\bar G_\bullet{}^i|z)\frac{s}{2}A^{(1)b}_i(z) - \frac{s}{2}(x|\bar P_*\frac{1}{\bar P^2}p^i|z)^{aa'}f^{a'bc}A^{(1)b}_i A^{(1)c}_\bullet(z) + i\frac{s}{2}(x|\bar P_*\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)bi}(\bar D_\bullet A^{(1)c}_i - \partial_i A^{(1)c}_\bullet)(z)\Big]$$
$$+ 2(x|\bar P_\bullet\frac{1}{\bar P^2}\bar G_*{}^i|z)\frac{s}{2}A^{(1)b}_i(z) + \frac{s}{2}(x|\bar P_\bullet\frac{1}{\bar P^2}p^i|z)^{aa'}f^{a'bc}A^{(1)b}_i A^{(1)c}_*(z) - i\frac{s}{2}(x|\bar P_\bullet\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)bi}(\bar D_* A^{(1)c}_i - \partial_i A^{(1)c}_*)(z)\Big]$$
$$+ i\frac{1}{s}(x|P_*\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b}_\bullet(z)(z|\{p^2_\perp, \frac{1}{\bar P^2}\}|z')^{cc'}\bar G^{c'}_{*\bullet}(z') + i\frac{1}{s}(x|P_\bullet\frac{1}{\bar P^2}|z)^{aa'}f^{a'bc}A^{(1)b}_*(z)(z|\{p^2_\perp, \frac{1}{\bar P^2}\}|z')^{cc'}\bar G^{c'}_{*\bullet}(z')\Big] \tag{244}$$

XI. С КВАРКАМИ

$\partial_\perp^2 A_\bullet$ МАЛО $\Leftrightarrow \partial_\perp^2 A_\bullet \sim m_\perp^2 \Rightarrow \psi_A \sim m_\perp$. Similarly, $\partial_\perp^2 B_* \sim m_\perp^2 \Rightarrow \psi_B \sim m_\perp$

$$\begin{aligned}
&\bar\psi_B(x_\bullet) - \int d^2z\ \bar\psi_B(z_\bullet)(z|(\bar A+\hat C)\frac{1}{(\hat p+\bar A+\hat B+\hat C)}|x) \ =\ \int d^2z\ \bar\psi_B(z_\bullet)(z|(\hat p+\hat B)\frac{1}{(\hat p+\bar A+\hat B+\hat C)}|x)\\
&=\ \int d^2z\ \bar\psi_B(z_\bullet)\hat p_2\big(\frac{\partial}{\partial z_*}-\frac{\overleftarrow{\partial}}{\partial z_*}\big)(z|\frac{1}{(\hat p+\bar A+\hat B+\hat C)}|x) =\ i\int d^2z\ \bar\psi_B(z_\bullet)\hat p_2\big(\frac{\partial}{\partial z_*}-\frac{\overleftarrow{\partial}}{\partial z_*}\big)\Omega(z)(z|\frac{1}{\hat p-i\epsilon p_0}|x)\Omega^\dagger(x)\\
&=\ \frac{i}{s}\int d^2z\ \bar\psi_B(z_\bullet)\hat p_2\big(\frac{\partial}{\partial z_*}-\frac{\overleftarrow{\partial}}{\partial z_*}\big)\Omega(z)(z|\frac{\hat p_1}{\beta-i\epsilon}|x)\Omega^\dagger(x) =\ \frac{1}{s}\bar\psi_B(x_\bullet)\Omega(-\infty_*,x_\bullet)\Omega^\dagger(x_*,x_\bullet)\hat p_2\hat p_1
\end{aligned}\tag{245}$$

Similarly

$$\begin{aligned}
&\psi_A(x_*) - \int dz\ (x|\frac{1}{\hat p+\hat A+\hat B+\hat C}(\hat B+\hat C)|z)\psi_A(z_*) \ =\ \int dz\ (x|\frac{1}{\hat p+\hat A+\hat B+\hat C}(\hat p+\hat A)|z)\psi_A(z_*)\\
&=\ -\int dz\ i\frac{\partial}{\partial z_\bullet}(x|\frac{1}{\hat p+\hat A+\hat B+\hat C}|z)\hat p_1\psi_A(z_*) \ =\ -\Omega_x\int dz\ i\frac{\partial}{\partial z_\bullet}(x|\frac{1}{\hat p}|z)\Omega_z^\dagger\hat p_1\psi_A(z_*) \ =\ -\Omega_x\int dz\ i\frac{\partial}{\partial z_\bullet}(x|\frac{\hat p_2}{\alpha s+i\epsilon}|z)\Omega_z^\dagger\hat p_1\psi_A(z_*)\\
&=\ -\frac{1}{s}\Omega_x\int dz_\bullet\frac{\partial}{\partial z_\bullet}\theta(x_\bullet-z_\bullet)\Omega^\dagger(z_\bullet,x_*,x_\perp)\hat p_2\hat p_1\psi_A(x_*,x_\perp) \ =\ \frac{\hat p_2\hat p_1}{s}\Omega_x\Omega^\dagger(-\infty_\bullet,x_*,x_\perp)\psi_A(x_*,x_\perp)
\end{aligned}\tag{246}$$

$$\begin{aligned}
&\frac{1}{s^2}\bar\psi_B(x_\bullet)\Omega(-\infty_*,x_\bullet)\Omega^\dagger(x_*,x_\bullet)\hat p_2\hat p_1\gamma_\mu^\perp\hat p_2\hat p_1\Omega(x_*,x_\bullet)\Omega^\dagger(-\infty_\bullet,x_*)\psi_A(x_\bullet)\\
&=\ \bar\psi_B(x_\bullet)\Omega(-\infty_*,x_\bullet)\gamma_\mu^\perp\Omega^\dagger(-\infty_\bullet,x_*)\psi_A(x_*)
\end{aligned}\tag{247}$$

In the first order in $\partial_\perp$

$$\begin{aligned}
\xi(x)\ &=\ \psi_A(x) - \int dz\ (x|\frac{1}{\hat p+\hat{\bar A}+\hat B+\hat C}(\hat B+\hat C)|z)\psi_A(z) \ =\ -\Omega_x\int dz\ i\frac{\partial}{\partial z_\bullet}(x|\frac{\hat p_2}{\alpha s+i\epsilon}+\frac{\hat p_\perp}{\alpha\beta s+i\epsilon p_0}|z)\Omega_z^\dagger\hat p_1\psi_A(z)\\
&=\ \Omega_x[-\infty,x_*]_x^{\hat A_\bullet}\psi_A(x) + \Omega_x\int_{-\infty}^{x_*} d\frac{2}{s}z_*(\hat\partial_\perp[-\infty,z_*]_x^{\hat A_\bullet})\hat p_1\psi_A(z_*,x_\perp,x_\bullet)
\end{aligned}\tag{248}$$

Chek:

$$\begin{aligned}
&(i\hat\partial+\hat A+\hat B+\hat C)\xi(x)\ =\ \Omega_x i\hat\partial\Omega_x^\dagger\xi(x)\ =\ \Omega_x[-\infty,x_*]_x^{\hat A_\bullet}\Big(\frac{2}{s}\hat p_2(i\partial_\bullet+\hat A_\bullet)+\frac{2}{s}\hat p_1 i\partial_*+i\hat\partial_\perp\Big)\psi_A(x)\\
&+\ \Omega_x(i\hat\partial_\perp[-\infty,x_*]_x^{\hat A_\bullet})\psi_A(x) + \Omega_x i\hat p_2\frac{\partial}{\partial x_*}\int_{-\infty}^{x_*} d\frac{2}{s}z_*(\hat\partial_\perp[-\infty,z_*]_x^{\hat A_\bullet})\hat p_1\psi_A(z_*,x_\perp,x_\bullet)\ +\ \mathcal{O}\Big(\big(\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}\big)^2\Big)\\
&=\ \Omega_x(i\hat\partial_\perp[-\infty,x_*]_x^{\hat A_\bullet})\Big(1-\frac{\hat p_2\hat p_1}{s}\Big)\psi_A(x)\ =\ \mathcal{O}\Big(\big(\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}\big)^2\Big)
\end{aligned}\tag{249}$$

Similarly

$$\psi_B(x) - \int dz\ (x|\frac{1}{\hat p+\hat{\bar A}+\hat B+\hat C}(\hat{\bar A}+\hat C)|z)\psi_B(z)\ =\ \Omega_x[-\infty,x_\bullet]_x^{\hat A_*}\psi_B(x) + \Omega_x\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet(\hat\partial_\perp[-\infty,z_\bullet]_x^{\hat A_*})\hat p_2\psi_A(z_\bullet,x_\perp,x_*)\tag{250}$$

2. *Conservation of em current?*

$$\begin{aligned}
\partial^\mu\bar\psi_A\gamma_\mu\psi_A\ &=\ \bar\psi_A(\overleftarrow{\hat\partial}+\hat\partial)\psi_A\ =\ \bar\psi_A(\overleftarrow{\hat\partial}+i\hat{\bar A}+\hat\partial-i\hat{\bar A})\psi_A\ =\ 0\\
\partial^\mu\bar\psi_B\gamma_\mu\psi_B\ &=\ \bar\psi_B(\overleftarrow{\hat\partial}+\hat\partial)\psi_B\ =\ \bar\psi_A(\overleftarrow{\hat\partial}+i\hat{\bar B}+\hat\partial-i\hat{\bar B})\psi_A\ =\ 0\\
\partial^\mu(\bar\psi_A+\bar\psi_B)\gamma_\mu(\psi_A+\psi_B)\ &=\ i\bar\psi_B(\hat{\bar A}-\hat{\bar B})\psi_A - i\bar\psi_A(\hat{\bar A}-\hat{\bar B})\psi_B\ \neq\ 0?
\end{aligned}\tag{251}$$

A. OδЩAЙA HAYKA

$$\Box^{ab}_{\mu\nu} = \bar{P}^2 g_{\mu\nu} + 2i\bar{G}_{\mu\nu} + \bar{P}_\mu\bar{C}_\nu + \bar{C}_\mu\bar{P}_\nu + \bar{C}_\mu\bar{C}_\nu \tag{252}$$

$$\xi \equiv \xi_a(x_\bullet, x_\perp) + \xi_b(x_*, x_\perp),$$
$$\frac{2\hat{p}_1}{s}\big(i\partial_* + \bar{A}_*(x_\bullet, x_\perp)\big)\xi_a(x_\bullet, x_\perp) + i\gamma_i\partial^i\xi_a(x_\bullet, x_\perp) = 0, \qquad \frac{2\hat{p}_2}{s}\big(i\partial_\bullet + \bar{A}_\bullet(x_*, x_\perp)\big)\xi_b(x_*, x_\perp) + i\gamma_i\partial^i\xi_b(x_*, x_\perp) = 0 \tag{253}$$

Approximately $\hat{p}_1\xi_a = \hat{p}_2\xi_b = 0$ (up 2 $p_\perp^2$)

$$\bar{C}^m_\mu(x) = \int DA\ A^m_\mu(x) e^{i\int dz\left(-\frac14[G^a_{\mu\nu}(A+\bar{A})]^2 - \frac12[(\bar{D}_\mu - i\bar{C}_\mu)A^\mu]^2\right) + (\bar\psi+\bar\xi)(\hat{\bar{P}}+\hat{A})(\psi+\xi)}$$
$$= \int DAD\bar\psi D\psi\ A^m_\mu(x)\exp\Big\{i\int dz\big(-\frac14\bar{G}^{a\mu\nu}\bar{G}^a_{\mu\nu} - \frac12 A^{a\alpha}\Box^{ab}_{\alpha\beta}A^{\beta b} + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta\big)$$
$$+ \bar\xi\hat{\bar{P}}\xi + \bar\xi\hat{A}\xi + \bar\xi\hat{\bar{P}}\psi + \bar\psi\hat{\bar{P}}\xi + \bar\xi\hat{A}\psi + \bar\psi\hat{A}\xi + \bar\psi\hat{\bar{P}}\psi + \bar\psi\hat{A}\psi\Big\} \tag{254}$$

gde

$$\partial_\perp^2\bar{A}^a_\bullet(x_*, x_\perp) = g\bar\xi_b t^a\gamma_\bullet\xi_b(x_*, x_\perp), \qquad \partial_\perp^2\bar{A}^a_*(x_\bullet, x_\perp) = g\bar\xi_a t^a\gamma_*\xi_a(x_\bullet, x_\perp) \tag{255}$$

$$\int dx\ \bar\xi\hat{\bar{P}}\xi(x) = \int dx\ (\bar\xi_a + \bar\xi_b)\big[\big(i\frac{\partial}{\partial x_\bullet} + \frac{2}{s}\bar{A}_*(x_\bullet, x_\perp)\big)\hat{p}_1 + \big(i\frac{\partial}{\partial x_*} + \frac{2}{s}\bar{A}_\bullet(x_*, x_\perp)\big)\hat{p}_2 + i\gamma_i\frac{\partial}{\partial x_i}\big](\xi_a + \xi_b) \tag{256}$$

$$\chi(x) = \int DA\ \psi(x) e^{i\int dz\left(-\frac14[G^a_{\mu\nu}(A+\bar{A})]^2 - \frac12[(\bar{D}_\mu - i\bar{C}_\mu)A^\mu]^2\right) + (\bar\psi+\bar\chi)(\hat{\bar{P}}+\hat{A})(\psi+\xi)}$$
$$= \int DA\ A^m_\mu(x)\exp\Big\{i\int dz\big(-\frac14\bar{G}^{a\mu\nu}\bar{G}^a_{\mu\nu} - \frac12 A^{a\alpha}\Box^{ab}_{\alpha\beta}A^{\beta b} + A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta\big)$$
$$+ \bar\xi\hat{\bar{P}}\xi + \bar\xi\hat{A}\xi + \bar\xi\hat{\bar{P}}\psi + \bar\psi\hat{\bar{P}}\xi + \bar\xi\hat{A}\psi + \bar\psi\hat{A}\xi + \bar\psi\hat{\bar{P}}\psi + \bar\psi\hat{A}\psi\Big\} \tag{257}$$

Sdvig $A \to A + \bar{C}$, $\psi \to \psi + \chi$

$$\int DA\ A^m_\mu(x)\psi(y) e^{i\int dz\left(-\frac14[G^a_{\mu\nu}(A+\bar{A})]^2 - \frac12[(\bar{D}_\mu - i\bar{C}_\mu)A^\mu]^2\right) + (\bar\psi+\bar\chi)(\hat{\bar{P}}+\hat{A})(\psi+\xi)} \tag{258}$$

$$\int DA\ [A^m_\mu(x) + \bar{C}^m_\mu(x)][\psi(y) + \chi(y)]$$
$$\times\ e^{i\int dz\left(-\frac14\bar{G}^{a\mu\nu}\bar{G}^a_{\mu\nu} - \frac12\bar{C}^{a\alpha}(\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta})^{ab}\bar{C}^{\beta b} + \bar{C}^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha} - gf^{abc}\bar{D}^\alpha\bar{C}^{a\beta}\bar{C}^b_\alpha\bar{C}^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}\bar{C}^{a\alpha}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta + (\bar\xi+\bar\chi)(\hat{\bar{P}}+\hat{\bar{C}})(\xi+\chi)\right)}$$
$$\times\ \exp i\int dz\Big\{A^{a\alpha}\Big(-(\bar{P}^2 g_{\alpha\beta} + 2i\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta} + (\bar{D}\bar{G})^a_\alpha + f^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha - \bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}) - f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta + (\bar\xi + \bar\chi)\gamma_\alpha t^a(\xi + \chi)\Big)$$
$$+ \bar\psi(\hat{\bar{P}} + \hat{\bar{C}})(\xi + \chi) + (\bar\xi + \bar\chi)(\hat{\bar{P}} + \hat{\bar{C}})\psi$$
$$- \frac12 A^{a\alpha}\Big((\bar{P} + \bar{C})^2 g_{\alpha\beta} + 2i\big(\bar{G}_{\alpha\beta} + \bar{D}_\alpha\bar{C}_\beta - \bar{D}_\beta\bar{C}_\alpha - i[\bar{C}_\alpha, \bar{C}_\beta]\big)\Big)^{ab}A^{b\beta} + \bar\psi(\hat{\bar{P}} + \hat{\bar{C}})\psi + (\bar\xi + \bar\chi)\hat{A}\psi + \bar\psi\hat{A}(\xi + \chi)$$
$$- gf^{abc}(\bar{D}_\alpha - i\bar{C}_\alpha)^{aa'}A^{a'}_\beta A^{c\alpha}A^{d\beta} - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta + \bar\psi\hat{A}\psi\Big\} \tag{259}$$

UMEEM YP-E (226) HA $\bar{C}_\mu$ U $\chi, \bar\chi$ B BUDE ($\Upsilon = \xi + \chi$)

$$(\bar{P}^2 g_{\alpha\beta} + 2ig\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta} = \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha} + gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha - \bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}) - g^2 f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta + \bar\Upsilon\gamma_\alpha t^a\Upsilon$$
$$(\hat{\bar{P}} + \hat{\bar{C}})\Upsilon = 0, \qquad \bar\Upsilon(\hat{\bar{P}} + \hat{\bar{C}}) = 0 \tag{260}$$

$$[(\bar P+\bar C)^2]^{ab}\bar C^b_\alpha \;=\; -2ig\bar G^{ab}_{\alpha\beta}\bar C^{b\beta}+\bar D^{ab\xi}\bar G^b_{\xi\alpha}-gf^{abc}\bar C^b_\beta\bar D_\alpha\bar C^{c\beta}+\bar\Upsilon t^a\gamma_\alpha\Upsilon\;+f^{abc}\bar C^b_\alpha\bar D^\beta\bar C^c_\beta$$
$$=?\; -gf^{abc}\bar C^b_\beta\bar D_\alpha\bar C^{c\beta}-gf^{abc}\bar A^b_\beta\bar D_\alpha\bar A^{c\beta}-2gf^{abc}\bar C^{b\xi}\partial_i\bar A^c_\xi \;=\; -gf^{abc}(\bar A+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}+\partial_i(f^{abc}\bar A^{b\xi}\bar C^c_\xi)$$
$$=\; -gf^{abc}(\bar P+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}-\partial_i\partial^\xi(\bar A+\bar C)^a_\xi+i\partial_i(\bar A^{ab}_\xi\bar C^{b\xi})= -gf^{abc}(\bar P+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta} \;=\; ig(\bar P+\bar C)^{ab}_\beta\partial_i(\bar A+\bar C)^{b\beta}$$
$$\Rightarrow\;(\Omega p^2\Omega^\dagger)^{ab}\bar C^b_i \;=\; -(\Omega p_\beta\Omega^\dagger)^{ab}\partial_i(\Omega\partial_\beta\Omega^\dagger)^b \;=\; -i\Omega^{ab}\partial^2(2\mathrm{Tr}\{t^b(\partial_i\Omega^\dagger)\Omega\} \tag{261}$$

S kvarkami

$$(\bar P^2g_{\alpha\beta}+2ig\bar G_{\alpha\beta})^{ab}\bar C^{b\beta} \;=\; \bar D^{ab\xi}\bar G^b_{\xi\alpha}+gf^{abc}(2\bar C^b_\beta\bar D^\beta\bar C^c_\alpha-\bar C^b_\beta\bar D_\alpha\bar C^{c\beta})-g^2f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\alpha\bar C^d_\beta+\bar\Upsilon\gamma_\alpha t^a\Upsilon\;\Rightarrow \tag{262}$$
$$[(\bar P+\bar C)^2]^{ab}\bar C^b_\alpha \;=\; -2ig\bar G^{ab}_{\alpha\beta}\bar C^{b\beta}+\bar D^{ab\xi}\bar G^b_{\xi\alpha}+\bar\Upsilon\gamma_\alpha t^a\Upsilon-gf^{abc}\bar C^b_\beta\bar D_\alpha\bar C^{c\beta} \;=\; (\bar D-i\bar C)^{ab\xi}\bar G^b_{\xi\alpha}+\bar\Upsilon\gamma_\alpha t^a\Upsilon-ig\bar G^{ab}_{\alpha\beta}\bar C^{b\beta}-gf^{abc}\bar C^b_\beta\bar D_\alpha\bar C^{c\beta}$$

$$[(\bar P+\bar C)^2]^{ab}\bar C^b_\alpha \;=\; (\bar P^2)^{ab}\bar C^b_\alpha-2gf^{abc}\bar C^b_\beta\bar D^\beta\bar C^c_\alpha+g^2f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\alpha\bar C^d_\beta\;+f^{abc}\bar C^b_\alpha\bar D^\beta\bar C^c_\beta, \tag{263}$$
$$2i(\bar G_{\alpha\beta}+\bar D_\alpha\bar C_\beta-\bar D_\beta\bar C_\alpha-i[\bar C_\alpha,\bar C_\beta])^{ab}\bar C^b_\beta \;=\; 2i\bar G_{\alpha\beta}\bar C^b_\beta-2gf^{abc}\bar C^b_\beta\bar D^\beta\bar C^c_\alpha+2gf^{abc}\bar C^b_\beta\bar D_\alpha\bar C^{c\beta}+2g^2f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\alpha\bar C^d_\beta$$

ЕЩЁ РАЗ: УРАВНЕНИЕ (226) НА $\bar C_i$

$$[(\bar P+\bar C)^2]^{ab}\bar C^b_i \;=\; -2ig\bar G^{ab}_{i\beta}\bar C^{b\beta}+\bar D^{ab\xi}\bar G^b_{\xi i}-gf^{abc}\bar C^b_\beta\partial_i\bar C^{c\beta}\;+\bar\Upsilon t^a\gamma_i\Upsilon\;+f^{abc}\bar C^b_i\bar D^\beta\bar C^c_\beta$$
$$=\; -gf^{abc}\bar C^b_\beta\partial_i\bar C^{c\beta}-gf^{abc}\bar A^b_\beta\partial_i\bar A^{c\beta}-2gf^{abc}\bar C^{b\beta}\partial_i\bar A^c_\beta\;+f^{abc}\bar C^b_i\bar D^\beta\bar C^c_\beta+\bar\Upsilon t^a\gamma_i\Upsilon$$
$$=\; -gf^{abc}(\bar A+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}+\partial_i(f^{abc}\bar A^{b\beta}\bar C^c_\beta)\;+f^{abc}\bar C^b_i\bar D^\beta\bar C^c_\beta+\bar\Upsilon t^a\gamma_i\Upsilon$$
$$=\; -gf^{abc}(\bar P+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}-\partial_i\partial^\beta(\bar A+\bar C)^a_\beta+i\partial_i(\bar A^{ab}_\beta\bar C^{b\beta})\;+f^{abc}\bar C^b_i\bar D^\beta\bar C^c_\beta+\bar\Upsilon t^a\gamma_i\Upsilon$$
$$=\; -gf^{abc}(\bar P+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}\;-\partial_i\bar D^\beta\bar C^a_\beta\;+f^{abc}\bar C^b_i\bar D^\beta\bar C^c_\beta+\bar\Upsilon t^a\gamma_i\Upsilon \;=\; ig\mathcal P^{ab}_\beta\partial_i\mathcal A^{b\beta}+\bar\Upsilon t^a\gamma_i\Upsilon\;-\mathcal D_i\bar D^\beta\bar C^a_\beta$$
$$\Rightarrow\;\mathcal P^2\mathcal A_i \;=\; ig\mathcal P^{ab}_\beta\partial_i\mathcal A^{b\beta}+\bar\Upsilon t^a\gamma_i\Upsilon\;-\mathcal D_i\bar D^\beta\bar C^a_\beta \tag{264}$$

In the leading order

$$(\Omega p^2\Omega^\dagger)^{ab}\bar C^b_i \;=\; -(\Omega p_\beta\Omega^\dagger)^{ab}\partial_i(\Omega\partial_\beta\Omega^\dagger)^b \;=\; -i\Omega^{ab}\partial^2(2\mathrm{Tr}\{t^b(\partial_i\Omega^\dagger)\Omega\} \tag{265}$$

В КОМПОНЕНТАХ

$$\bar P^2\bar C^a_\bullet \;=\; \bar D^{ab\xi}\bar G^b_{\xi\bullet}-2ig\bar G^{ab}_{\bullet\beta}\bar C^{b\beta}+gf^{abc}(2\bar C^b_\beta\bar D^\beta\bar C^c_\bullet-\bar C^b_\beta\bar D_\bullet\bar C^{c\beta})-g^2f^{abm}f^{cdm}\bar C^{b\beta}\bar C^c_\bullet\bar C^d_\beta+(\bar\xi+\bar\chi)\gamma_\bullet t^a(\xi+\chi)$$
$$(\hat{\bar P}+\hat{\bar C})(\xi+\chi) \;=\; 0,\qquad (\bar\xi+\bar\chi)(\hat{\bar P}+\hat{\bar C}) \;=\; 0 \tag{266}$$

$$\frac{2}{s}(\mathcal P_*\mathcal P_\bullet+\mathcal P_\bullet\mathcal P_*)^{ab}\bar C^b_i \;=\; -(\partial^2_\perp g_{ij}+\partial_i\partial_j)\bar C^{aj}+gf^{abc}(2\bar C^b_j\partial^j\bar C^c_i-\bar C^b_j\partial_i\bar C^{cj})-g^2f^{abm}f^{cdm}\bar C^b_j\bar C^c_i\bar C^{dj}$$
$$+\bar\Upsilon t^a\gamma_i\Upsilon+\frac{2}{s}(\bar D_*\bar G_{\bullet i}+\bar D_\bullet\bar G_{*i})-\frac{2}{s}gf^{abc}(\bar C^b_*\partial_i\bar C^c_\bullet+\bar C^b_\bullet\partial_i\bar C^c_*)$$
$$=\; -\mathcal D^jF^a_{ij}+f^{abc}\bar C^b_i\partial^j\bar C^c_j+\bar\Upsilon t^a\gamma_i\Upsilon+\frac{2}{s}(\bar D_*\bar G_{\bullet i}+\bar D_\bullet\bar G_{*i})-\frac{2}{s}gf^{abc}(\bar C^b_*\partial_i\bar C^c_\bullet+\bar C^b_\bullet\partial_i\bar C^c_*) \tag{267}$$

СРАВНИ С УР. (226)

$$[(\bar P+\bar C)^2]^{ab}\bar C^b_i \;=\; -2ig\bar G^{ab}_{i\beta}\bar C^{b\beta}+\bar D^{ab\xi}\bar G^b_{\xi i}-\partial^2\bar A^a_i-gf^{abc}\bar C^b_\beta\partial_i\bar C^{c\beta}$$
$$=\; -gf^{abc}\bar C^b_\beta\partial_i\bar C^{c\beta}-gf^{abc}\bar A^b_\beta\partial_i\bar A^{c\beta}-2gf^{abc}\bar G^{b\xi}\partial_i\bar A^c_\xi \;=\; -gf^{abc}(\bar A+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}+\partial_i(f^{abc}\bar A^{b\xi}\bar C^c_\xi)$$
$$=\; -gf^{abc}(\bar P+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta}-\partial_i\partial^\xi(\bar A+\bar C)^a_\xi+i\partial_i(\bar A^{ab}_\xi\bar C^{b\xi})= -gf^{abc}(\bar P+\bar C)^b_\beta\partial_i(\bar A+\bar C)^{c\beta} \;=\; ig(\bar P+\bar C)^{ab}_\beta\partial_i(\bar A+\bar C)^{b\beta}$$

$$\big(2(\bar P_\bullet\bar P_*)-\frac{s}{2}p^2_\perp\big)^{ab}\bar C^b_\bullet \;=\; \bar D^{ab}_\bullet\bar G^b_{*\bullet}+i\bar G^{ab}_{*\bullet}\bar C^b_\bullet+g\bar D^{aa'}_\bullet(f^{a'bc}\bar C^b_*\bar C^c_\bullet)+2gf^{abc}\bar C^b_\bullet\bar D_*\bar C^c_\bullet-g^2f^{abm}f^{cdm}\bar C^b_\bullet\bar C^c_\bullet\bar C^d_*$$
$$+\;\frac{s}{2}\Big[f^{abc}\big(2g\bar G^b_{\bullet i}\bar C^{ci}+2\bar C^b_i\partial^i\bar C^c_\bullet-\bar C^b_i\bar D_\bullet\bar C^{ci}\big)+g^2f^{abm}f^{cdm}\bar C^b_i\bar C^c_\bullet\bar C^{di}+\bar\xi_at^a\hat p_1\xi_b+\bar\xi_bt^a\hat p_1\xi_a+\bar\xi_at^a\hat p_1\xi_a+\bar\xi t^a\hat p_1\chi+\bar\chi t^a\hat p_1\xi+\bar\chi t^a\hat p_1\chi\Big]$$

$$2(\bar P_\bullet\bar P_*)^{ab}\bar C^b_\bullet \;=\; \bar D^{ab}_\bullet\bar G^b_{*\bullet}+i\bar G^{ab}_{*\bullet}\bar C^b_\bullet+g\bar D^{aa'}_\bullet(f^{a'bc}\bar C^b_*\bar C^c_\bullet)+2gf^{abc}\bar C^b_\bullet\bar D_*\bar C^c_\bullet-g^2f^{abm}f^{cdm}\bar C^b_\bullet\bar C^c_\bullet\bar C^d_*$$
$$-\;\frac{s}{2}\partial^2_\perp(\bar A^a_\bullet+\bar C^a_\bullet)+\frac{s}{2}\Big[f^{abc}\big(2g\bar G^b_{\bullet i}\bar C^{ci}+2\bar C^b_i\partial^i\bar C^c_\bullet-\bar C^b_i\bar D_\bullet\bar C^{ci}\big)+g^2f^{abm}f^{cdm}\bar C^b_i\bar C^c_\bullet\bar C^{di}+(\bar\xi+\bar\chi)t^a\hat p_1(\xi+\chi)\Big]$$
$$=\;\bar D^{ab}_\bullet\bar G^b_{*\bullet}+i\bar G^{ab}_{*\bullet}\bar C^b_\bullet+g\bar D^{aa'}_\bullet(f^{a'bc}\bar C^b_*\bar C^c_\bullet)+2gf^{abc}\bar C^b_\bullet\bar D_*\bar C^c_\bullet-g^2f^{abm}f^{cdm}\bar C^b_\bullet\bar C^c_\bullet\bar C^d_*$$
$$+\;\frac{s}{2}(\partial_i-i\bar C_i)^{ab}\partial^i(\bar A^b_\bullet+\bar C^b_\bullet)-i\frac{s}{2}F^{ab}_{\bullet i}\bar C^c_i+\frac{s}{2}(\bar\xi+\bar\chi)t^a\hat p_1(\xi+\chi) \tag{268}$$

where we uzd

$$F^a_{\bullet i} \;=\; \mathcal{D}^{ab}_\bullet \bar{C}^b_i - \partial_i \mathcal{A}^a_\bullet \;=\; (\partial_\bullet - i\bar{A}_\bullet - i\bar{C}_\bullet)\bar{C}_i - \partial_i(\bar{A}_\bullet + \bar{C}_\bullet)$$

$$\begin{aligned}
&2(\bar{P}_\bullet + \bar{C}_\bullet)(\bar{P}_* + \bar{C}_*)^{ab}\bar{C}^b_\bullet \;= \qquad (269)\\
&= \;\bar{D}^{ab}_\bullet \bar{G}^b_{*\bullet} + i\bar{G}^{ab}_{*\bullet}\bar{C}^b_\bullet + g\bar{D}^{aa'}_\bullet(f^{a'bc}\bar{C}^b_*\bar{C}^c_\bullet) + 2gf^{abc}\bar{C}^b_\bullet\bar{D}_*\bar{C}^c_\bullet - g^2 f^{abm}f^{cdm}\bar{C}^b_\bullet\bar{C}^c_\bullet\bar{C}^d_*\\
&+ \frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i(\bar{A}^b_\bullet + \bar{C}^b_\bullet) - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon + 2(D_\bullet)^{aa'}f^{a'bc}\bar{C}^b_\bullet\bar{C}^c_* - 2gf^{abc}\bar{C}^b_\bullet\bar{D}_*\bar{C}^c_\bullet + 2g^2 f^{abm}f^{cdm}\bar{C}^b_\bullet\bar{C}^c_\bullet\bar{C}^d_*\\
&= \;(\bar{D} - i\bar{C})^{ab}_\bullet \bar{G}^b_{*\bullet} + \;\frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i(\bar{A}^b_\bullet + \bar{C}^b_\bullet) - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon + (D_\bullet)^{aa'}f^{a'bc}\bar{C}^b_\bullet\bar{C}^c_* + g^2 f^{abm}f^{cdm}\bar{C}^b_\bullet\bar{C}^c_\bullet\bar{C}^d_*\\
&= \;-i\mathcal{P}^{ab}_\bullet\bar{G}^b_{*\bullet} + \;\frac{s}{2}\big(-\mathcal{D}^i F^{ab}_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big) - \frac{is}{2}\mathcal{P}^{ab}_\bullet\partial^i\bar{C}^b_i - i(\mathcal{P}_\bullet)^{aa'}gf^{a'bc}\bar{C}^b_\bullet\bar{C}^c_* \;=\; 2(\mathcal{P}_\bullet\mathcal{P}_*)^{ab}\bar{C}^b_\bullet\\
&= \;-i\mathcal{P}^{ab}_\bullet\bar{G}^b_{*\bullet} + i\mathcal{P}^{ab}_\bullet F^b_{*\bullet} - \frac{is}{2}\mathcal{P}^{ab}_\bullet\partial^i\bar{C}^b_i - i(\mathcal{P}_\bullet)^{aa'}gf^{a'bc}\bar{C}^b_\bullet\bar{C}^c_* + \frac{s}{2}\big(\mathcal{D}^{ab}_\bullet F^b_{*\bullet} - \mathcal{D}^i F^{ab}_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big)
\end{aligned}$$

$\Rightarrow$

$$2\mathcal{P}^{ab}_*\bar{C}^b_\bullet \;=\; i(F^a_{*\bullet} - \bar{G}^a_{*\bullet}) - \frac{is}{2}\partial^i\bar{C}^a_i + igf^{abc}\bar{C}^b_*\bar{C}^c_\bullet \quad\Leftrightarrow\quad 2\bar{P}^{ab}_*\bar{C}^b_\bullet \;=\; i(F^a_{*\bullet} - \bar{G}^a_{*\bullet}) - \frac{is}{2}\partial^i\bar{C}^a_i - igf^{abc}\bar{C}^b_*\bar{C}^c_\bullet \qquad (270)$$

$$2\mathcal{P}^{ab}_\bullet\bar{C}^b_* \;=\; -i(F^a_{*\bullet} - \bar{G}^a_{*\bullet}) - \frac{is}{2}\partial^i\bar{C}^a_i - igf^{abc}\bar{C}^b_*\bar{C}^c_\bullet \quad\Leftrightarrow\quad 2\bar{P}^{ab}_\bullet\bar{C}^b_* \;=\; -i(F^a_{*\bullet} - \bar{G}^a_{*\bullet}) - \frac{is}{2}\partial^i\bar{C}^a_i + igf^{abc}\bar{C}^b_*\bar{C}^c_\bullet$$

1. $\bar{c}_*$ and $\bar{c}_\bullet$

Define

$$\bar{C}_\bullet \;=\; \tilde{C}_\bullet + \bar{c}_\bullet, \quad \mathcal{A} \equiv \bar{A}_\bullet + \tilde{C}_\bullet = \Omega^\dagger i\partial_\bullet\Omega, \quad \mathcal{A} \equiv \bar{A}_* + \tilde{C}_* = \Omega^\dagger i\partial_*\Omega \qquad (271)$$

$$\begin{aligned}
&2(\bar{P}_\bullet\bar{P}_*)^{ab}\bar{c}^b_\bullet \;=\\
&= \;i\bar{G}^{ab}_{*\bullet}\bar{c}^b_\bullet + g\bar{D}^{aa'}_\bullet f^{a'bc}(\tilde{C}^b_*\bar{c}^c_\bullet + \bar{c}^b_*\tilde{C}^c_\bullet) + 2gf^{abc}(\tilde{C}^b_\bullet\bar{D}_*\bar{c}^c_\bullet + \bar{c}^b_\bullet\bar{D}_*\tilde{C}^c_\bullet) - g^2 f^{abm}f^{cdm}(\tilde{C}^b_\bullet\tilde{C}^c_\bullet\bar{c}^d_* + \tilde{C}^b_\bullet\bar{c}^c_\bullet\tilde{C}^d_* + \bar{c}^b_\bullet\tilde{C}^c_\bullet\tilde{C}^d_*)\\
&+ \frac{s}{2}(\partial_i - iC_i)^{ab}\partial^i(\bar{A}^b_\bullet + \tilde{C}^b_\bullet) - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}(\bar{\xi} + \bar{\chi})t^a\hat{p}_1(\xi + \chi) \qquad (272)
\end{aligned}$$

$$\begin{aligned}
&\Rightarrow\; 2(\bar{P}_\bullet + \tilde{C}_\bullet)(\bar{P}_* + \tilde{C}_*)^{ab}\bar{c}^b_\bullet \;=\; -2f^{abc}\tilde{C}^b_\bullet\bar{D}_*\bar{c}^c_\bullet - 2\bar{D}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_*\bar{c}^c_\bullet) - 2f^{abm}f^{cdm}\tilde{C}^b_\bullet\tilde{C}^c_*\bar{c}^d_\bullet\\
&+ i\bar{G}^{ab}_{*\bullet}\bar{c}^b_\bullet + g\bar{D}^{aa'}_\bullet f^{a'bc}(\tilde{C}^b_*\bar{c}^c_\bullet + \bar{c}^b_*\tilde{C}^c_\bullet) + 2gf^{abc}(\tilde{C}^b_\bullet\bar{D}_*\bar{c}^c_\bullet + \bar{c}^b_\bullet\bar{D}_*\tilde{C}^c_\bullet) - g^2 f^{abm}f^{cdm}(\tilde{C}^b_\bullet\tilde{C}^c_\bullet\bar{c}^d_* + \tilde{C}^b_\bullet\bar{c}^c_\bullet\tilde{C}^d_* + \bar{c}^b_\bullet\tilde{C}^c_\bullet\tilde{C}^d_*)\\
&+ \frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i(\bar{A}^b_\bullet + \tilde{C}^b_\bullet) - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}(\bar{\xi} + \bar{\chi})t^a\hat{p}_1(\xi + \chi)\\
&= \;i\bar{G}^{ab}_{*\bullet}\bar{c}^b_\bullet - g\bar{D}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_\bullet\bar{c}^c_*) - g\bar{D}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_*\bar{c}^c_\bullet) + 2gf^{abc}\bar{c}^b_\bullet\bar{D}_*\tilde{C}^c_\bullet - g^2 f^{abm}f^{cdm}(\tilde{C}^b_\bullet\tilde{C}^c_\bullet\bar{c}^d_* - \tilde{C}^b_\bullet\bar{c}^c_\bullet\tilde{C}^d_* + \bar{c}^b_\bullet\tilde{C}^c_\bullet\tilde{C}^d_*)\\
&+ \frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i(\bar{A}^b_\bullet + \tilde{C}^b_\bullet) - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}(\bar{\xi} + \bar{\chi})t^a\hat{p}_1(\xi + \chi)\\
&= \;-f^{abc}\bar{G}^b_{*\bullet}\bar{c}^c_\bullet - g\bar{\mathcal{D}}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_\bullet\bar{c}^c_*) - g\mathcal{D}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_*\bar{c}^c_\bullet) + 2gf^{abc}\bar{c}^b_\bullet\bar{D}_*\tilde{C}^c_\bullet - g^2 f^{abm}f^{cdm}\bar{c}^b_\bullet\tilde{C}^c_\bullet\tilde{C}^d_*\\
&+ \frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}(\bar{\xi} + \bar{\chi})t^a\hat{p}_1(\xi + \chi)\\
&= \;-g\bar{\mathcal{D}}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_\bullet\bar{c}^c_*) - g\mathcal{D}^{aa'}_\bullet(f^{a'bc}\tilde{C}^b_*\bar{c}^c_\bullet) + \;\frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon \qquad (273)
\end{aligned}$$

wæ wi uzd $\bar{D}_*\tilde{C}_\bullet \;=\; -\frac{1}{2}f^{abc}\tilde{C}^b_*\tilde{C}^c_\bullet - \frac{1}{2}\bar{G}^a_{*\bullet}$

$$\begin{aligned}
2\mathcal{P}_\bullet\mathcal{P}_*\bar{c}^a_\bullet \;&=\; -g\bar{\mathcal{D}}^{aa'}_\bullet f^{a'bc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \;\frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - i\frac{s}{2}F^{ab}_{\bullet i}\bar{C}^c_i + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon\\
2\mathcal{P}_*\mathcal{P}_\bullet\bar{c}^a_* \;&=\; -g\bar{\mathcal{D}}^{aa'}_* f^{a'bc}(\tilde{C}^b_*\bar{c}^c_\bullet + \tilde{C}^b_\bullet\bar{c}^c_*) + \;\frac{s}{2}(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - i\frac{s}{2}F^{ab}_{*i}\bar{C}^c_i + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon \qquad (274)
\end{aligned}$$

$$\begin{aligned}
\bar{c}^a_\bullet \;&=\; \frac{i}{2\mathcal{P}_\bullet\mathcal{P}_*}\bar{\mathcal{P}}^{aa'}_\bullet f^{a'bc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \;\frac{s}{4\mathcal{P}_\bullet\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ab}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big]\\
\bar{c}^a_* \;&=\; \frac{i}{2\mathcal{P}_*\mathcal{P}_\bullet}\bar{\mathcal{P}}^{aa'}_* f^{a'bc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \;\frac{s}{4\mathcal{P}_\bullet\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - iF^{ab}_{*i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big] \qquad (275)
\end{aligned}$$

$\Rightarrow$

$$\mathcal{P}_*\bar{c}^a_\bullet = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_\bullet}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ab}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big]$$
$$= \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_\bullet}[-\mathcal{D}^iF^a_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{is}{4}\partial^i\bar{C}_i$$
$$\mathcal{P}_\bullet\bar{c}^a_* = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - iF^{ab}_{*i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big]$$
$$= \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_*}[-\mathcal{D}^iF^a_{*i} + \bar{\Upsilon}t^a\hat{p}_2\Upsilon] - \frac{is}{4}\partial^i\bar{C}_i \tag{276}$$

$\Rightarrow$

$$\bar{P}_*\bar{c}^a_\bullet = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* - \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_\bullet}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ab}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big]$$
$$= \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* - \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_\bullet}[-\mathcal{D}^iF^a_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{is}{4}\partial^i\bar{C}_i = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* - \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{i}{2}F^{1a}_{*\bullet} - \frac{is}{4}\partial^i\bar{C}_i \tag{277}$$
$$\bar{P}_\bullet\bar{c}^a_* = \frac{i}{2}gf^{abc}(\tilde{C}^b_*\bar{c}^c_\bullet - \tilde{C}^b_\bullet\bar{c}^c_*) + \frac{s}{4\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - iF^{ab}_{*i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_2\Upsilon\big] = \frac{i}{2}gf^{abc}(\tilde{C}^b_*\bar{c}^c_\bullet - \tilde{C}^b_\bullet\bar{c}^c_*) - \frac{i}{2}F^{1a}_{*\bullet} - \frac{is}{4}\partial^i\bar{C}_i$$
$$\Rightarrow\ \bar{P}_*\bar{c}^a_\bullet + \bar{P}_\bullet\bar{c}^a_* = \frac{s}{4\mathcal{P}_\bullet}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ab}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big] + \frac{s}{4\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - iF^{ab}_{*i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_2\Upsilon\big]$$

$$\Rightarrow\ \frac{2}{s}(\bar{P}_*\bar{c}_\bullet + \bar{P}_\bullet\bar{c}_*)^a + i\partial^i\bar{C}_i$$
$$= \frac{1}{2\mathcal{P}_\bullet}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ab}_{\bullet i}\bar{C}^b_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon - \mathcal{D}_\bullet\partial^i\bar{C}_i\big] + \frac{1}{2\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - iF^{ac}_{*i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_2\Upsilon - \mathcal{D}_*\partial^i\bar{C}^a_i\big]$$
$$= -\frac{1}{2\mathcal{P}_\bullet}[\mathcal{D}^iF^a_{\bullet i} - \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{1}{2\mathcal{P}_*}[\mathcal{D}^iF^a_{*i} + \bar{\Upsilon}t^a\hat{p}_2\Upsilon] = 0 \qquad \text{due to formula 290} \tag{278}$$

$$F_{\bullet i} = \mathcal{D}_\bullet\bar{C}_i - \partial_i\mathcal{A}_\bullet, \quad [\mathcal{D}_\bullet, \mathcal{D}_i] = -iF_{\bullet i}$$
$$\Rightarrow\ (\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ac}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon - \mathcal{D}_\bullet\partial^i\bar{C}^a_i = \mathcal{D}^{ab}_i(\mathcal{D}_\bullet\bar{C}^i - F_\bullet{}^i)^b - iF^{ac}_{\bullet i}\bar{C}^c_i - (\mathcal{D}_\bullet\mathcal{D}^i)^{ab}\bar{C}^b_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon$$
$$= iF^{ab}_{\bullet i}\bar{C}^{bi} - \mathcal{D}^iF^a_{\bullet i} - iF^{ac}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon = -\mathcal{D}^iF^a_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon \tag{279}$$

From Eq. (276) we get

$$F^{(1)}_{*\bullet} = \mathcal{D}_*\bar{c}_\bullet - \mathcal{D}_\bullet\bar{c}_* = -\frac{is}{4\mathcal{P}_\bullet}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_\bullet - iF^{ab}_{\bullet i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_1\Upsilon\big] + \frac{is}{4\mathcal{P}_*}\big[(\partial_i - i\bar{C}_i)^{ab}\partial^i\mathcal{A}^b_* - iF^{ab}_{*i}\bar{C}^c_i + \bar{\Upsilon}t^a\hat{p}_2\Upsilon\big] \tag{280}$$
$$= -\frac{is}{4\mathcal{P}_\bullet}\big[-\mathcal{D}^iF^a_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon + \mathcal{D}_\bullet\partial^i\bar{C}^a_i\big] + \frac{is}{4\mathcal{P}_*}\big[-\mathcal{D}^iF^a_{*i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon + \mathcal{D}_*\partial^i\bar{C}^a_i\big] = \frac{is}{4\mathcal{P}_\bullet}[\mathcal{D}^iF^a_{\bullet i} - \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{is}{4\mathcal{P}_*}[\mathcal{D}^iF^a_{*i} - \bar{\Upsilon}t^a\hat{p}_2\Upsilon]$$

Useful f-las

$$F_{\bullet i} = \Omega_x[-\infty_*, x_*]^{\bar{A}^\bullet}_x\bar{G}_{\bullet i}(x_*, x_\perp)[x_*, -\infty_*]^{\bar{A}^\bullet}_x\Omega^\dagger_x, \quad \big([-\infty_*, x_*]^{\bar{A}^\bullet}_x\bar{G}_{\bullet i}(x_*, x_\perp)[x_*, -\infty_*]^{\bar{A}^\bullet}_x\big)^{ab} = -if^{abc}\big([-\infty_*, x_*]^{\bar{A}^\bullet}_x\big)^{cd}\bar{G}^d_{\bullet i}(x_*, x_\perp) \tag{281}$$

$$F^{(1)a}_{\bullet i} = \big(\Omega_x[-\infty_*, x_*]^{\bar{A}^\bullet}_x\big)^{ab}\bar{G}^b_{\bullet i}(x_*, x_\perp) \tag{282}$$

From Eq. (220)

$$\bar{C}_i(x) = \Omega_x i\partial_i\Omega^\dagger_x + i\Omega_x[-\infty_*, x_*]^{\bar{A}^\bullet}_x(\partial_i[x_*, -\infty_*]^{\bar{A}^\bullet}_x)\Omega^\dagger_x + i\Omega_x[-\infty_\bullet, x_\bullet]^{\bar{A}^*}_x(\partial_i[x_\bullet, -\infty_\bullet]^{\bar{A}^*}_x)\Omega^\dagger_x \tag{283}$$

$$\big(\frac{is}{4\mathcal{P}_*\mathcal{P}_\bullet}F_{\bullet i}\big)^{ab}F^{bi}_* = \big(\frac{-s}{4\mathcal{P}_*\mathcal{P}_\bullet}\big)^{aa'}f^{a'bc}F^b_{\bullet i}F^{ci}_* = -\frac{s}{4}f^{abc}\bar{C}^{1a}_i\bar{C}^{2bi} \tag{284}$$

Dlya prichinnogo obxoda (see Eq. (333))

$$\bar{\Upsilon}t^a\hat{p}_1\Upsilon = \big(\Omega_x\Omega^\dagger(x_*, -\infty_\bullet, x_\perp)\big)^{am}\bar{\xi}_bt^m\hat{p}_1\xi_b = \big(\Omega_x[-\infty_*, x_*]^{\bar{A}^\bullet}_x\big)^{am}\bar{\xi}_bt^m\hat{p}_1\xi_b \tag{285}$$

ЕЩЁ РАЗ (see Eq. (271) for definitions)

$$\bar{C}^a_i = (\Omega i\partial_i\Omega^\dagger)^a + i\Omega^{ab}_x([-\infty_*, x_*]^{\bar{A}^\bullet}_x\partial_i[x_*, -\infty_*]^{\bar{A}^\bullet}_x)^b + i\Omega^{ab}_x([-\infty_\bullet, x_\bullet]^{\bar{A}^*}_x\partial_i[x_\bullet, -\infty_\bullet]^{\bar{A}^*}_x)^b = \Omega^a_i + \bar{C}^{1a}_i + \bar{C}^{2a}_i \tag{286}$$

$$2\mathcal{P}_\bullet\mathcal{P}_*\bar{c}^a_\bullet = -g\bar{\mathcal{D}}^{aa'}_\bullet f^{a'bc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) - \frac{s}{2}\mathcal{D}^iF^a_{\bullet i} + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon + \frac{s}{2}\mathcal{D}_\bullet\mathcal{D}^i\bar{C}^a_i$$
$$2\mathcal{P}_*\mathcal{P}_\bullet\bar{c}^a_* = -g\bar{\mathcal{D}}^{aa'}_* f^{a'bc}(\tilde{C}^b_*\bar{c}^c_\bullet + \tilde{C}^b_\bullet\bar{c}^c_*) - \frac{s}{2}\mathcal{D}^iF^a_{*i} + \frac{s}{2}\bar{\Upsilon}t^a\hat{p}_1\Upsilon + \frac{s}{2}\mathcal{D}_*\mathcal{D}^i\bar{C}^a_i \quad (287)$$

⇒ Equation:

$$\mathcal{P}_*\bar{c}^a_\bullet = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_\bullet}[-\mathcal{D}^iF^a_{\bullet i} + \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{is}{4}\partial^i\bar{C}_i = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{i}{2}F^{1a}_{*\bullet} - \frac{is}{4}\partial^i\bar{C}_i$$
$$\mathcal{P}_\bullet\bar{c}^a_* = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) + \frac{s}{4\mathcal{P}_*}[-\mathcal{D}^iF^a_{*i} + \bar{\Upsilon}t^a\hat{p}_2\Upsilon] - \frac{is}{4}\partial^i\bar{C}_i = \frac{i}{2}gf^{abc}(\tilde{C}^b_\bullet\bar{c}^c_* + \tilde{C}^b_*\bar{c}^c_\bullet) - \frac{i}{2}F^{1a}_{*\bullet} - \frac{is}{4}\partial^i\bar{C}_i \quad (288)$$

From Eq. (285), (281), (282), and (333) we get

$$\mathcal{D}^iF^m_{\bullet i} - \bar{\Upsilon}t^m\hat{p}_1\Upsilon = (\partial_i - i\Omega^i - iC^i_{(1)} - iC^i_{(2)})^{ma}F^a_{\bullet i} - (\Omega(x)[-\infty_*, x_*]^{\hat{A}_\bullet}_x)^{ma}\bar{\xi}_bt^a\hat{p}_1\xi_b = \Omega^{ma}_x\Big(\partial^i[-\infty_*, x_*]^{ab}_{\bar{A}_\bullet}\bar{G}^b_{\bullet i}$$
$$+ ([-\infty_*, x_*]_{\bar{A}_\bullet}(\partial^i[x_*, -\infty_*]^{\bar{A}_\bullet})[-\infty_*, x_*]_{\bar{A}_\bullet}) + ([-\infty_\bullet, x_\bullet]_{\bar{A}_*}(\partial^i[x_\bullet, -\infty_\bullet]^{\bar{A}_*})[-\infty_*, x_*]_{\bar{A}_\bullet})^{ab}\bar{G}^b_{\bullet i} - [-\infty_*, x_*]^{ab}_{\bar{A}_\bullet}\bar{\xi}_bt^b\hat{p}_1\xi_b\Big)$$
$$= \Omega^{ma}_x([-\infty_\bullet, x_\bullet]_{\bar{A}_*}(\partial^i[x_\bullet, -\infty_\bullet]^{\bar{A}_*})[-\infty_*, x_*]_{\bar{A}_\bullet})^{ab}\bar{G}^b_{\bullet i}(x_*) = \Omega^{ma}_xf^{abc}\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet[-\infty_\bullet, z_\bullet]^{bk}_{\bar{A}_*}\bar{G}^k_{*i}(z_\bullet)[-\infty_*, x_*]^{cl}_{\bar{A}_*}\bar{G}^{li}_\bullet(x_*)$$
$$= if^{abc}\big(\frac{1}{\mathcal{P}_*}F_{*i}\big)^bF^{ci}_\bullet \quad (289)$$

$$\Rightarrow \frac{s}{4\mathcal{P}_\bullet}(\mathcal{D}^iF^m_{\bullet i} - \bar{\Upsilon}t^m\hat{p}_1\Upsilon) = \frac{s}{4}\Omega^{ma}_xf^{abc}\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet[-\infty_\bullet, z_\bullet]^{bk}_{\bar{A}_*}\bar{G}^k_{*i}(z_\bullet)\frac{1}{p_\bullet}[-\infty_*, x_*]^{cl}_{\bar{A}_*}\bar{G}^{li}_\bullet(x_*) \quad (290)$$
$$= \Omega^{ma}_x(-\frac{isf^{abc}}{4})\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet[-\infty_\bullet, z_\bullet]^{bk}_{\bar{A}_*}\bar{G}^k_{*i}(z_\bullet)\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_*[-\infty_*, z_*]^{cl}_{\bar{A}_\bullet}\bar{G}^{li}_\bullet(z_*) = \frac{is}{4}f^{mbc}\big(\frac{1}{\mathcal{P}_*}F_{*i}\big)^b\big(\frac{1}{\mathcal{P}_\bullet}F_\bullet{}^i\big)^c = -\frac{s}{4\mathcal{P}_*}(\mathcal{D}^iF^m_{*i} - \bar{\Upsilon}t^m\hat{p}_2\Upsilon)$$

From Eqs. (280), (298) and (290) we get

$$F^{(1)a}_{*\bullet} = -\frac{s}{2}f^{abc}\big(\frac{1}{\mathcal{P}_*}F_{*i}\big)^b\big(\frac{1}{\mathcal{P}_\bullet}F_\bullet{}^i\big)^c = \Omega^{aa'}_x(-if^{a'bc})\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet[-\infty_\bullet, z_\bullet]^{bk}_{\bar{A}_*}\bar{G}^k_{*i}(z_\bullet)\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_*[-\infty_*, z_*]^{cl}_{\bar{A}_\bullet}\bar{G}^{li}_\bullet(z_*) \quad (291)$$

$$\Rightarrow \mathcal{D}_\bullet F^a_{*\bullet} = \frac{s}{4}[\mathcal{D}^iF^a_{\bullet i} - \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{is}{4\mathcal{P}_*}\mathcal{D}_\bullet[\mathcal{D}^iF^a_{*i} - \bar{\Upsilon}t^a\hat{p}_2\Upsilon] = \frac{s}{2}[\mathcal{D}^iF^a_{\bullet i} - \bar{\Upsilon}t^a\hat{p}_1\Upsilon] \Rightarrow \mathcal{D}^\mu F^a_{\bullet\mu} = \bar{\Upsilon}t^a\hat{p}_1\Upsilon \quad (292)$$

ΠΡΕDΠΟΛΟЖИΤΕΛ'ΗΟ, $\mathcal{D}^\mu F^a_{\mu\nu} = -\bar{\Upsilon}t^a\gamma_\nu\Upsilon$ ΒΟ ΒСΕΧ ΠΟΡΑDΚΑΧ ΠΟ $\partial_\perp$

$$\mathcal{P}_*\bar{c}^a_\bullet = \frac{1}{2}\tilde{C}^{ab}_\bullet\bar{c}^b_* + \frac{1}{2}\tilde{C}^{ab}_*\bar{c}^b_\bullet + \frac{i}{2}F^{1a}_{*\bullet} - \frac{is}{4}\partial^i\bar{C}^a_i$$
$$\mathcal{P}_\bullet\bar{c}^a_* = \frac{1}{2}\tilde{C}^{ab}_\bullet\bar{c}^b_* + \frac{1}{2}\tilde{C}^{ab}_*\bar{c}^b_\bullet - \frac{i}{2}F^{1a}_{*\bullet} - \frac{is}{4}\partial^i\bar{C}^a_i \quad (293)$$

$$\bar{c}^{(0)a}_\bullet = \big(\frac{i}{2\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet}, \qquad \bar{c}^{(0)a}_* = -\big(\frac{i}{2\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet},$$
$$\bar{c}^{(1)a}_\bullet = \frac{i}{4}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{i}{4}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} - \big(\frac{is}{4\mathcal{P}_*}\big)^{ab}\partial^i\bar{C}^b_i$$
$$\bar{c}^{(1)a}_* = \frac{i}{4}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{i}{4}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} - \big(\frac{is}{4\mathcal{P}_\bullet}\big)^{ab}\partial^i\bar{C}^b_i$$
$$\bar{c}^{(2)a}_\bullet = \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}\partial^i\bar{C}^b_i$$
$$+ \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}\partial^i\bar{C}^b_i$$
$$\bar{c}^{(2)a}_* = -\frac{i}{8}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} + \frac{i}{8}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{8}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}\partial^i\bar{C}^b_i$$
$$- \frac{i}{8}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} + \frac{i}{8}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{8}\big(\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}\partial^i\bar{C}^b_i$$
(294)

$$
\begin{aligned}
\bar{c}_\bullet^{(3)a} \;=\; & \frac{i}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{i}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}\partial^i\bar{C}^b_i \\
& + \frac{i}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{i}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}\partial^i\bar{C}^b_i \\
& - \frac{i}{16}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} + \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}\partial^i\bar{C}^b_i \\
& - \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\big)^{ab}F^{1b}_{*\bullet} + \frac{i}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_*}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{8}\big(\frac{1}{\mathcal{P}_*}\tilde{C}_\bullet\frac{1}{\mathcal{P}_\bullet}\tilde{C}_*\frac{1}{\mathcal{P}_*}\big)^{ab}\partial^i\bar{C}^b_i
\end{aligned}
\tag{295}
$$

$\bar{c} = c + d$

$$
\begin{aligned}
\big(2\mathcal{P}_* - \tilde{C}_*\big)^{ab}d^b_\bullet &= \tilde{C}^{ab}_\bullet d^b_* - \frac{is}{2}\partial^i\bar{C}^a_i \;\Rightarrow\; d^a_\bullet = \big(\mathcal{P}_\bullet\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(-\frac{is}{2}\partial^i\bar{C}^b_i\big) \\
\big(2\mathcal{P}_\bullet - \tilde{C}_\bullet\big)^{ab}d^a_* &= \tilde{C}^{ab}_* d^b_\bullet - \frac{is}{2}\partial^i\bar{C}^a_i \;\Rightarrow\; d^a_* = \big(\mathcal{P}_*\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(-\frac{is}{2}\partial^i\bar{C}^b_i\big)
\end{aligned}
\tag{296}
$$

$$
\begin{aligned}
\big(2\mathcal{P}_* - \tilde{C}_*\big)^{ab}c^b_\bullet &= \tilde{C}^{ab}_\bullet c^b_* + iF^{1a}_{*\bullet} \;\Rightarrow\; c^a_\bullet = \big((\mathcal{P}_\bullet - \bar{C}_\bullet)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) + X_1 \\
\big(2\mathcal{P}_\bullet - \tilde{C}_\bullet\big)^{ab}c^a_* &= \tilde{C}^{ab}_* c^b_\bullet - iF^{1a}_{*\bullet} \;\Rightarrow\; c^a_* = -\big((\mathcal{P}_* - \bar{C}_*)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) - X_2
\end{aligned}
\tag{297}
$$

Chek:

$$
\begin{aligned}
& \big((2\mathcal{P}_* - \tilde{C}_*)(\mathcal{P}_\bullet - \tilde{C}_\bullet)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) + \tilde{C}^{ab}_\bullet\big((\mathcal{P}_* - \tilde{C}_*)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) \\
&= \Big(\big(2\mathcal{P}_*\mathcal{P}_\bullet - 2\mathcal{P}_*\tilde{C}_\bullet - \tilde{C}_*\mathcal{P}_\bullet + \tilde{C}_*\tilde{C}_\bullet + \tilde{C}_\bullet\mathcal{P}_* - \tilde{C}_\bullet\tilde{C}_*\big)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\Big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) = \frac{i}{2}F^{1a}_{*\bullet} + \ldots
\end{aligned}
\tag{298}
$$

$$
\begin{aligned}
& \big((2\mathcal{P}_\bullet - \tilde{C}_\bullet)(\mathcal{P}_* - \tilde{C}_*)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) + \tilde{C}^{ab}_*\big((\mathcal{P}_\bullet - \tilde{C}_\bullet)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) \\
&= \Big(\big(2\mathcal{P}_\bullet\mathcal{P}_* - 2\mathcal{P}_\bullet\tilde{C}_* - \tilde{C}_\bullet\mathcal{P}_* + \tilde{C}_\bullet\tilde{C}_* + \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_*\tilde{C}_\bullet\big)\frac{1}{2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*}\Big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) = \frac{i}{2}F^{1a}_{*\bullet} + \ldots
\end{aligned}
\tag{299}
$$

bikoz

$$
2\mathcal{P}_*\mathcal{P}_\bullet - 2\mathcal{P}_*\tilde{C}_\bullet - \tilde{C}_*\mathcal{P}_\bullet + \tilde{C}_*\tilde{C}_\bullet + \tilde{C}_\bullet\mathcal{P}_* - \tilde{C}_\bullet\tilde{C}_* - (2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_*) = -2[\mathcal{P}_*, \tilde{C}_\bullet] + [\tilde{C}_*, \tilde{C}_\bullet] = i\bar{G}_{*\bullet} \tag{300}
$$

due to Eq. (179).

ПРОВЕРИМ АНЗАТС ($\mathcal{Z} \equiv 2\mathcal{P}_*\mathcal{P}_\bullet - \tilde{C}_*\mathcal{P}_\bullet - \tilde{C}_\bullet\mathcal{P}_* = \bar{P}_*\mathcal{P}_\bullet + \bar{P}_\bullet\mathcal{P}_*$)

$$
\begin{aligned}
c^a_\bullet &= \big((\mathcal{P}_\bullet - \tilde{C}_\bullet)\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) - \big(\mathcal{P}_\bullet\frac{1}{\mathcal{Z}}i\bar{G}_{*\bullet}\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) \\
c^a_* &= -\big((\mathcal{P}_* - \tilde{C}_*)\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) - \big(\mathcal{P}_*\frac{1}{\mathcal{Z}}i\bar{G}_{*\bullet}\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big)
\end{aligned}
\tag{301}
$$

ОТ УР. (288) DO УР. (303) КОЕ-ГDЕ НЕТУ DВОЕК В ЗНАМЕНАТЕЛЕ

$$
\begin{aligned}
\big(2\mathcal{P}_* - \tilde{C}_*\big)^{ab}c^b_\bullet - \tilde{C}^{ab}_\bullet c^b_* &= \big((2\mathcal{P}_* - \tilde{C}_*)(\mathcal{P}_\bullet - \tilde{C}_\bullet) + \tilde{C}_\bullet(\mathcal{P}_* - \tilde{C}_*)\big)\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) \\
-\big((2\mathcal{P}_* - \tilde{C}_*)\mathcal{P}_\bullet\frac{1}{\mathcal{Z}}i\bar{G}_{*\bullet}\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) + \big(\tilde{C}_\bullet\mathcal{P}_*\frac{1}{\mathcal{Z}}i\bar{G}_{*\bullet}\frac{1}{\mathcal{Z}}\big)^{ab}\big(\frac{i}{2}F^{1b}_{*\bullet}\big) &= \frac{i}{2}F^{1b}_{*\bullet}
\end{aligned}
\tag{302}
$$

РЕШЕНИЕ УРАВНЕНИЙ (288)

$$
\begin{aligned}
\bar{c}^a_\bullet &= i\big(\bar{P}_\bullet\frac{1}{\mathcal{Z}}\big)^{ab}F^{1b}_{*\bullet} - i\big(\mathcal{P}_\bullet\frac{1}{\mathcal{Z}}i\bar{G}_{*\bullet}\frac{1}{\mathcal{Z}}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{2}\big(\mathcal{P}_\bullet\frac{1}{\mathcal{Z}}\big)^{ab}\partial^i\bar{C}^b_i \\
\bar{c}^a_* &= -i\big(\bar{P}_*\frac{1}{\mathcal{Z}}\big)^{ab}F^{1b}_{*\bullet} - i\big(\mathcal{P}_*\frac{1}{\mathcal{Z}}i\bar{G}_{*\bullet}\frac{1}{\mathcal{Z}}\big)^{ab}F^{1b}_{*\bullet} - \frac{is}{2}\big(\mathcal{P}_*\frac{1}{\mathcal{Z}}\big)^{ab}\partial^i\bar{C}^b_i
\end{aligned}
\tag{303}
$$

gde $\mathcal{Z} \equiv \bar{P}_*\mathcal{P}_\bullet + \bar{P}_\bullet\mathcal{P}_* = \mathcal{P}_\bullet\bar{P}_* + \mathcal{P}_*\bar{P}_\bullet$, $\mathcal{P} = \bar{P} + \tilde{\mathcal{A}}$, $\tilde{\mathcal{A}}_\bullet = \bar{A}_\bullet + \tilde{C}_\bullet = i\Omega\partial_\bullet\Omega^\dagger$, $\tilde{\mathcal{A}}_* = i\Omega\partial_*\Omega^\dagger$

Chek: $\mathcal{P}_*\bar{c}_\bullet - \mathcal{P}_\bullet\bar{c}_* = iF^{(1)}_{*\bullet}$, $\bar{P}_*\bar{c}_\bullet + \bar{P}_\bullet\bar{c}_* = -\frac{is}{2}\partial^i\bar{C}_i$

В ПЕРВОМ ПОРАДКЕ $\mathcal{P}_\bullet \equiv p_\bullet + \mathcal{A}_\bullet$, $\mathcal{A}_\bullet \equiv \bar{A}_\bullet + \tilde{C}_\bullet$, $\mathcal{A}_i \equiv \tilde{C}_i = \Omega_i + C_{1i} + C_{2i}$, and

$$2\mathcal{P}_*\mathcal{P}_\bullet\tilde{C}_i = i(\mathcal{P}_*\partial_i\mathcal{A}_\bullet + \mathcal{P}_\bullet\partial_i\mathcal{A}_*)$$

В СЛЕДУЩЕМ ПОРАДКЕ

$$\bar{C}_i = \tilde{C}_i + \bar{c}_i, \quad F_{\bullet i} = F^{(1)}_{\bullet i} + F^{(2)}_{\bullet i} = \mathcal{D}_\bullet\bar{C}_i - \partial_i\mathcal{A}_\bullet + \mathcal{D}_\bullet\bar{c}_i - \mathcal{D}_i\bar{c}_\bullet \tag{304}$$

ИЗ УР. Eq. (226) ПОЛУЧАЕМ

$$(2\mathcal{P}_*\mathcal{P}_\bullet)^{ab}\bar{c}^b_i \tag{305}$$

$$= (-\{\mathcal{P}_*, \bar{c}_\bullet\} - \{\mathcal{P}_\bullet, \bar{c}_*\} + \frac{s}{2}(p+\bar{C})^2_\perp)^{ab}\bar{C}^b_i - f^{abc}(\bar{c}^b_*\partial_i\mathcal{A}^c_\bullet + \bar{c}^b_\bullet\partial_i\mathcal{A}^c_*) - \mathcal{D}^{ab}_*\partial_i\bar{c}^b_\bullet - \mathcal{D}^{ab}_\bullet\partial_i\bar{c}^b_* + \frac{is}{2}\mathcal{P}^{ab}_j\partial_i\tilde{C}^{bj} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon$$

$$= (-\mathcal{P}_*\bar{c}_\bullet - \mathcal{P}_\bullet\bar{c}_* - \frac{s}{2}\mathcal{P}_j\mathcal{P}^j)^{ab}\bar{C}^b_i + f^{abc}(\bar{c}^b_*F^{(1)c}_{\bullet i} + \bar{c}^b_\bullet F^{(1)c}_{*i}) - \mathcal{D}^{ab}_*\partial_i\bar{c}^b_\bullet - \mathcal{D}^{ab}_\bullet\partial_i\bar{c}^b_* + \frac{is}{2}\mathcal{P}^{ab}_j\partial_i\tilde{C}^{bj} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon$$

$$= (-\mathcal{P}_*\bar{c}_\bullet - \mathcal{P}_\bullet\bar{c}_*)^{ab}\bar{C}^b_i + f^{abc}(\bar{c}^b_*F^{(1)c}_{\bullet i} + \bar{c}^b_\bullet F^{(1)c}_{*i}) - \mathcal{D}^{ab}_*\partial_i\bar{c}^b_\bullet - \mathcal{D}^{ab}_\bullet\partial_i\bar{c}^b_* - \frac{s}{2}\mathcal{D}^jF^{(1)a}_{ij} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon =$$

$$-(\mathcal{P}_*\bar{c}_\bullet + \mathcal{P}_\bullet\bar{c}_*)^{ab}\bar{C}^b_i - \mathcal{D}^{ab}_*\partial_i\bar{c}^b_\bullet - \mathcal{D}^{ab}_\bullet\partial_i\bar{c}^b_* - \mathcal{D}_*F^{(2)a}_{\bullet i} - \mathcal{D}_\bullet F^{(2)a}_{*i} + \big((\mathcal{D}_* - i\bar{c}_*)F^{(1+2)a}_{\bullet i} + (\mathcal{D}_\bullet - i\bar{c}_\bullet)F^{(1+2)a}_{*i} + \frac{s}{2}\mathcal{D}^jF^{(1)a}_{ji} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon\big)$$

$$= (\mathcal{P}_*\bar{C}_i)^{ab}\bar{c}^b_\bullet + (\mathcal{P}_\bullet\bar{C}_i)^{ab}\bar{c}^b_* + i\mathcal{P}^{ab}_*\partial_i\bar{c}^b_\bullet + i\mathcal{P}^{ab}_\bullet\partial_i\bar{c}^b_* - \mathcal{D}_*F^{(2)a}_{\bullet i} - \mathcal{D}_\bullet F^{(2)a}_{*i} = (\mathcal{P}_*\mathcal{P}_i)^{ab}\bar{c}^b_\bullet + (\mathcal{P}_\bullet\mathcal{P}_i)^{ab}\bar{c}^b_* - \mathcal{D}_*F^{(2)a}_{\bullet i} - \mathcal{D}_\bullet F^{(2)a}_{*i} \tag{306}$$

$$(2\mathcal{P}_*\mathcal{P}_\bullet)^{ab}\bar{c}^b_i = (\mathcal{P}_*\mathcal{P}_i)^{ab}\bar{c}^b_\bullet + (\mathcal{P}_\bullet\mathcal{P}_i)^{ab}\bar{c}^b_* - f^{abc}(F^{(1)b}_{\bullet i}\bar{c}^c_* + F^{(1)b}_{*i}\bar{c}^c_\bullet) + \frac{s}{2}\mathcal{D}^jF^{(1)a}_{ji} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon \tag{307}$$

$$\Rightarrow (2\mathcal{P}_*\mathcal{P}_\bullet)^{ab}\bar{c}^b_i = (\mathcal{P}_*\mathcal{P}_i + iF^{(1)}_{*i})^{ab}\bar{c}^b_\bullet + (\mathcal{P}_\bullet\mathcal{P}_i + iF^{(1)}_{\bullet i})^{ab}\bar{c}^b_* + \frac{s}{2}\mathcal{D}^jF^{(1)a}_{ji} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon$$

$$= (2\mathcal{P}_*\mathcal{P}_i)^{ab}\bar{c}^b_\bullet + 2iF^{(1)ab}_{\bullet i}\bar{c}^b_* + \mathcal{D}_iF^{(1)}_{*\bullet} + \frac{s}{2}\mathcal{D}^jF^{(1)a}_{ji} + \frac{s}{2}\bar{\Upsilon}\gamma_i t^a\Upsilon \tag{308}$$

$\Rightarrow$

$$F^{(2)a}_{\bullet i} = -i\mathcal{P}^{ab}_\bullet\bar{c}^b_i + i\mathcal{P}^{ab}_i\bar{c}^b_\bullet = \big(\frac{1}{\mathcal{P}_*}F^{(1)}_{\bullet i}\big)^{ab}\bar{c}^b_* - \big(\frac{i}{2\mathcal{P}_*}\big)^{ab}\mathcal{D}_iF^{(1)}_{*\bullet} - \big(\frac{is}{4\mathcal{P}_*}\big)^{ab}\big(\mathcal{D}^jF^{(1)a}_{ji} + \bar{\Upsilon}\gamma_i t^a\Upsilon\big) \tag{309}$$

Check of YM equations for the field

$$A^{[2]a}_\bullet = \bar{A}_\bullet + \tilde{C}_\bullet + \bar{c}_\bullet, \quad A^{[2]a}_* = \bar{A}_* + \tilde{C}_* + \bar{c}_*, \quad A^{[3]a}_i = \tilde{C}_i + \bar{c}_i, \quad \Upsilon^{[1]} = \Omega_x([-\infty_\bullet, x_\bullet]^{\hat{A}_*}_x\xi_a(x) + [-\infty_*, x_*]^{\hat{A}_\bullet}_x\xi_b(x)) \tag{310}$$

$$\mathcal{D}_*F^{(1)a}_{\bullet i} + \mathcal{D}_*F^{(2)a}_{\bullet i} - i\bar{c}_*F^{(1)a}_{\bullet i} = -\frac{1}{2}\mathcal{D}_iF^{(1)a}_{*\bullet} - \frac{s}{4}(\mathcal{D}^jF^{(1)a}_{ji} + \bar{\Upsilon}\gamma_i t^a\Upsilon),$$

$$\mathcal{D}_\bullet F^{(1)a}_{*i} + \mathcal{D}_\bullet F^{(2)a}_{*i} - i\bar{c}_\bullet F^{(1)a}_{*i} = \frac{1}{2}\mathcal{D}_iF^{(1)a}_{*\bullet} - \frac{s}{4}(\mathcal{D}^jF^{(1)a}_{ji} + \bar{\Upsilon}\gamma_i t^a\Upsilon)$$

$$\Rightarrow \frac{2}{s}\big[\mathcal{D}_*F^{(2)a}_{\bullet i} - i\bar{c}_*F^{(1)a}_{\bullet i} + \mathcal{D}_*F^{(2)a}_{*i} - i\bar{c}_*F^{(1)a}_{*i}\big] + \mathcal{D}^jF^{(1)a}_{ji} = -\bar{\Upsilon}\gamma_i t^a\Upsilon$$

$$\Rightarrow D^\mu F^{[3]a}_{\mu i} = \bar{\Upsilon}\gamma_i t^a\Upsilon + O(\partial^4_\perp) \tag{311}$$

For $\bullet$ projection, rewrite Eq. (292)

$$\mathcal{D}_\bullet F^{[2]a}_{*\bullet} = \frac{s}{4}[\mathcal{D}^iF^{[1]a}_{\bullet i} - \bar{\Upsilon}t^a\hat{p}_1\Upsilon] - \frac{is}{4\mathcal{P}_*}\mathcal{D}_\bullet[\mathcal{D}^iF^{[1]a}_{*i} - \bar{\Upsilon}t^a\hat{p}_2\Upsilon] = \frac{s}{2}[\mathcal{D}^iF^{[1]a}_{\bullet i} - \bar{\Upsilon}t^a\hat{p}_1\Upsilon] \Rightarrow \mathcal{D}^\mu F^a_{\bullet\mu} = \bar{\Upsilon}t^a\hat{p}_1\Upsilon + O(\partial^3_\perp) \tag{312}$$

ГDЕ $F^{[1]a}_{\bullet i}$ DАЕТЦА ФОРМУЛОЙ (224)

3. First order in $\bar{A}_\bullet, \bar{A}_*$

$$\bar{C}_\bullet^{1a}(x) \;=\; -\frac{i}{2}\int dz(x|\frac{1}{p_*+i\epsilon p_\bullet}|z)\bar{G}^a_{*\bullet}(z) \;=\; -\frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon p_\bullet}|z)\bar{A}^b_*\bar{A}^c_\bullet(z), \tag{313}$$
$$\bar{C}_*^{1a}(x) \;=\; \frac{i}{2}\int d^2z(x|\frac{1}{p_\bullet+i\epsilon p_*}|z)\bar{G}^a_{*\bullet}(z) = \frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon p_\bullet}|z)\bar{A}^b_*\bar{A}^c_\bullet(z),$$
$$\bar{C}_i^{1a}(x) \;=\; \frac{1}{2}\int dz(x|\frac{1}{p_*p_\bullet+i\epsilon}|z)(\bar{D}_*\bar{G}^a_{\bullet i}(z)+\bar{D}_\bullet\bar{G}^a_{*i}(z)) \;=\; -\frac{1}{2}f^{abc}\int dz(x|\frac{1}{p_*p_\bullet+i\epsilon}|z)(A^b_\bullet\partial_iA^c_*+A^b_*\partial_iA^c_\bullet)$$
$$F_{\bullet i}^{1a}(x) \;=\; \frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon p_\bullet}|z)(\bar{A}^b_\bullet\partial_i\bar{A}^c_*+\bar{A}^b_*\partial_i\bar{A}^c_\bullet)+\frac{i}{2}f^{abc}\int dz(x|\frac{1}{p_*+i\epsilon p_\bullet}|z)\partial_i\big(\bar{A}^b_*\bar{A}^c_\bullet(z)\big) \;=\; if^{abc}\int dz(x|\frac{1}{p_*+i\epsilon p_\bullet}|z)\bar{A}^b_*\partial_i\bar{A}^c_\bullet(z)$$
$$F_{*i}^{1a}(x) \;=\; if^{abc}\int dz(x|\frac{1}{p_\bullet+i\epsilon p_*}|z)\bar{A}^b_\bullet\partial_i\bar{A}^c_*(z)$$

$$\int dx\; F^{1a}_{*i}F^{1ai}_\bullet(x) \;=\; -\frac{4}{s}f^{mab}f^{mcd}\int dzdz'(z|\frac{1}{p^2+i\epsilon}|z')\bar{A}^a_*\partial_i\bar{A}^b_\bullet(z)\bar{A}^c_\bullet\partial_i\bar{A}^d_*(z')$$

4. Two $\partial_\perp$'s, one $\bar{A}_\bullet$ and one $\bar{A}_*$

$$\bar{C}_i^{1a}(x) \;=\; \frac{2}{s}\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)(\bar{D}_*\bar{G}^a_{\bullet i}(z)+\bar{D}_\bullet\bar{G}^a_{*i}(z)) \;=\; -\frac{2}{s}f^{abc}\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)(A^b_\bullet\partial_iA^c_*+A^b_*\partial_iA^c_\bullet) \tag{314}$$
$$F_{\bullet i}^{(1)}(x) \;=\; -\int dz\;(x|\frac{1}{p_*+i\epsilon}|z)\bar{A}^{ab}_*\bar{G}^b_{\bullet i}(z) \;\;\Rightarrow\;\; \partial^iF^{(1)}_{\bullet i} \;=\; \int dz\;(x|\frac{1}{p_*+i\epsilon}|z)\bar{G}^{ab}_{*i}\bar{G}^{bi}_\bullet(z)-\int dz\;(x|\frac{1}{p_*+i\epsilon}|z)\bar{A}^{ab}_*\partial^i\bar{G}^b_{\bullet i}(z)$$

From Eq. (272) we get

$$\bar{c}^a_\bullet(x) \;=\; -\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)\big[\partial^2_\perp(\bar{A}_\bullet+\bar{C}_\bullet)(z)-\bar{\Upsilon}t^a\hat{p}_1\Upsilon(z)\big], \qquad \bar{c}^a_*(x) \;=\; -\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)\partial^2_\perp\bar{C}_*(z)$$
$$\bar{D}_*\bar{c}^a_\bullet(x) = \frac{s}{8}\int dz(x|\frac{1}{p_\bullet+i\epsilon p_0}|z)\partial^2_\perp\frac{1}{\bar{P}_*+i\epsilon}\bar{G}_{*\bullet}(z) \;\simeq\; \frac{s}{8}\int dz(x|\frac{1}{(p_\bullet+i\epsilon)(p_*+i\epsilon)}|z)\partial^2_\perp\bar{G}_{*\bullet}(z) \tag{315}$$

B. Quark fields in the target and projectile

1. In the target

$\bar{A}_\bullet(x_*,x_\perp)$ and $\xi_b(x_*,x_\perp)$.
Dirac:

$$\frac{2}{s}\hat{p}_2(i\partial_\bullet+\bar{A}_\bullet)\xi_b(x_*,x_\perp)+i\gamma^i\partial_i\xi_b(x_*,x_\perp) \;=\; 0 \tag{316}$$

PA3δUBAEM

$$\xi \;=\; \xi^{(1)}+\xi^{(2)} \qquad \xi^{(1)} \;\equiv\; \frac{\hat{p}_2\hat{p}_1}{s}\xi, \;\; \xi^{(2)} \;\equiv\; \frac{\hat{p}_1\hat{p}_2}{s}\xi$$

YP-E DUPAKA:

$$\frac{2}{s}\hat{p}_2(i\partial_\bullet+\bar{A}_\bullet)\xi^{(2)}_b(x_*,x_\perp)+i\gamma^i\partial_i\xi^{(1)}_b(x_*,x_\perp) \;=\; 0, \qquad i\gamma^i\partial_i\xi^{(2)}_b(x_*,x_\perp) \;=\; 0$$
$$(i\partial_\bullet+\bar{A}_\bullet)\xi^{(2)}_b(x_*,x_\perp) \;=\; i\gamma_i\partial^i\hat{p}_1\xi^{(1)}_b(x_*,x_\perp) \tag{317}$$

Solution of the free Dirac (Weyl) equation

$$\nu^\alpha = \int\frac{d^3p}{(2\pi)^3}\left(c(p)(p\cdot\bar{\sigma})\sigma_0]^\alpha{}_\beta\varphi^\beta e^{-ipx}+d^*(p)[(p\cdot\bar{\sigma})\sigma_0]^\alpha{}_\beta\kappa^\beta e^{ipx}\right) \tag{318}$$

$p_x+ip_y\equiv\tilde{p},\ p_x-ip_y=\tilde{p}^*$

$$\bar{\sigma}_\mu p^\mu\ =\ \begin{pmatrix} p_0+p_z & p_x-ip_y\\ p_x+ip_y & p_0-p_z\end{pmatrix}\ =\ \sqrt{s}\begin{pmatrix}\frac{p_\perp^2}{\beta s} & \frac{\tilde{p}^*}{\sqrt{s}}\\ \frac{\tilde{p}}{\sqrt{s}} & \beta\end{pmatrix},\qquad \sigma_\mu p^\mu\ =\ \begin{pmatrix} p_0-p_z & -p_x+ip_y\\ -p_x-ip_y & p_0+p_z\end{pmatrix}\ =\ \sqrt{s}\begin{pmatrix}\beta & -\frac{\tilde{p}^*}{\sqrt{s}}\\ -\frac{\tilde{p}}{\sqrt{s}} & \frac{p_\perp^2}{\beta s}\end{pmatrix} \tag{319}$$

$$\bar{\sigma}_\mu p^\mu\sigma_0\begin{pmatrix}1\\0\end{pmatrix}\ =\ 2p_0\cos\frac{\theta}{2}\begin{pmatrix}\cos\frac{\theta}{2}\\ e^{i\phi}\sin\frac{\theta}{2}\end{pmatrix},\qquad \bar{\sigma}_\mu p^\mu\sigma_0\begin{pmatrix}0\\1\end{pmatrix}\ =\ 2p_0\sin\frac{\theta}{2}e^{-i\phi}\begin{pmatrix}\cos\frac{\theta}{2}\\ e^{i\phi}\sin\frac{\theta}{2}\end{pmatrix} \tag{320}$$

$$\nu^\alpha(x)\ =\ \int\frac{d^3p}{(2\pi)^3}\begin{pmatrix}\frac{p_\perp^2}{\beta s} & \frac{\tilde{p}^*}{\sqrt{s}}\\ \frac{\tilde{p}}{\sqrt{s}} & \beta\end{pmatrix}\Big(c(p)\begin{pmatrix}1\\0\end{pmatrix}e^{-ipx}+d^*(p)\begin{pmatrix}0\\1\end{pmatrix}e^{ipx}\Big) \tag{321}$$

$$\nu^*_{\dot{\alpha}}(x)\ =\ \int\frac{d^3p}{(2\pi)^3}\big[d^*(p)(0,1)e^{-ipx}+c^*(p)(1,0)e^{ipx}\big]\begin{pmatrix}\frac{p_\perp^2}{\beta s} & \frac{\tilde{p}^*}{\sqrt{s}}\\ \frac{\tilde{p}}{\sqrt{s}} & \beta\end{pmatrix} \tag{322}$$

(see Eqs. (6.93)-(6.98) from AQM)

If $A_\bullet$ does not depend on $x_\perp$

$$\nu_\alpha(x)\ =\ [x_*,-\infty]^{\bar{A}_\bullet}\int\frac{d^3p}{(2\pi)^3}\begin{pmatrix}\frac{p_\perp^2}{\beta s} & \frac{\tilde{p}^*}{\sqrt{s}}\\ \frac{\tilde{p}}{\sqrt{s}} & \beta\end{pmatrix}\Big(c(p)\begin{pmatrix}1\\0\end{pmatrix}e^{-ipx}+d^*(p)\begin{pmatrix}0\\1\end{pmatrix}e^{ipx}\Big) \tag{323}$$

$$\bar{\sigma}_\mu p_1^\mu\ =\ \sqrt{s}\begin{pmatrix}1&0\\0&0\end{pmatrix},\ =\ \sigma_\mu p_2^\mu\qquad \sigma_\mu p_1^\mu\ =\ \sqrt{s}\begin{pmatrix}0&0\\0&1\end{pmatrix},\ =\ \bar{\sigma}_\mu p_2^\mu\qquad \frac{\bar{p}_1p_2}{s}\ =\ \begin{pmatrix}1&0\\0&0\end{pmatrix},\qquad \frac{\bar{p}_2p_1}{s}\ =\ \begin{pmatrix}0&0\\0&1\end{pmatrix} \tag{324}$$

$$\nu^{(1)}_\alpha(x)\ =\ \frac{\bar{p}_2p_1}{s}\nu_\alpha(x)\ =\ \text{big},\qquad \nu^{(2)}_\alpha(x)\ =\ \frac{\bar{p}_1p_2}{s}\nu_\alpha(x)\ =\ \text{small} \tag{325}$$

UЗ DUAГРАММ

$$\Big\{1+\big(\frac{\hat{p}_1}{s}+\frac{\hat{k}_\perp}{k_\perp^2}\beta_k\big)\hat{p}_2\big([x_*,-\infty]-1\big)\Big\}u(k)e^{-ikx}\ =\ \big\{1+\frac{\hat{k}}{k_\perp^2}\beta_k\hat{p}_2\big([x_*,-\infty]-1\big)\big\}u(k)e^{-ikx}\ =\ [x_*,-\infty]u(k)e^{-ikx} \tag{326}$$

If $A_\bullet$ depends on $x_\perp$, in the first order in $\partial_\perp$ we get

$$\begin{aligned}
&\big(\frac{2}{s}(i\partial_\bullet+\bar{A}_\bullet)\hat{p}_2+\frac{2}{s}i\partial_*\hat{p}_1+i\partial_i\gamma^i\big)\Big\{\big(1-i\frac{\beta_k\hat{p}_2}{k_\perp^2}\gamma_j\partial^j\big)[x_*,-\infty]_x+2i\frac{k^j}{k_\perp^2}\beta_k\int_{-\infty}^{x_*}d\frac{2}{s}z_*\ (x_*-z_*)[x_*,z_*]_xF_{\bullet j}(z_*,x_\perp)[z_*,-\infty]_x\Big\}u(k)e^{-ikx}\\
&=\ \Big\{i\gamma^i\partial_i[x_*,-\infty]_x-\big(\alpha_k\hat{p}_1+k_i\gamma^i\big)i\frac{\beta_k\hat{p}_2}{k_\perp^2}\gamma_j\partial^j[x_*,-\infty]_x-2\hat{p}_2\frac{k^j}{k_\perp^2}\beta_k\int_{-\infty}^{x_*}d\frac{2}{s}z_*\ [x_*,z_*]_xF_{\bullet j}(z_*,x_\perp)[z_*,-\infty]_x\Big\}u(k)e^{-ikx}\\
&=\ \Big\{i\gamma^i\partial_i[x_*,-\infty]_x-\big(\alpha_k\hat{p}_1+\hat{k}_\perp\big)i\frac{\beta_k\hat{p}_2}{k_\perp^2}\gamma_j\partial^j[x_*,-\infty]_x-2\hat{p}_2\frac{k^j}{k_\perp^2}\beta_ki\partial_j[x_*,-\infty]_x\Big\}u(k)e^{-ikx}\ +\ \mathcal{O}(\partial_i\partial_j)\\
&=\ \Big\{i\gamma^i\partial_i[x_*,-\infty]_x-i\big(\gamma^j\partial_j-\frac{\hat{p}_2\hat{p}_1}{s}\gamma^j\partial_j-2\frac{k^j}{k_\perp^2}\beta_k\hat{p}_2\partial_j+\beta_k\hat{p}_2\gamma^j\frac{\hat{k}_\perp}{k_\perp^2}\partial_j\big)[x_*,-\infty]_x-2\hat{p}_2\frac{k^j}{k_\perp^2}\beta_ki\partial_j[x_*,-\infty]_x\Big\}u(k)e^{-ikx}\\
&=\ \Big\{\big(\gamma^j\frac{\hat{p}_2\hat{p}_1}{s}+\beta_k\gamma^j\hat{p}_2\frac{\hat{k}_\perp}{k_\perp^2}\big)i\partial_j[x_*,-\infty]_x\Big\}u(k)e^{-ikx}\ =\ \frac{\gamma^j\hat{p}_2\hat{p}_1}{k_\perp^2}\beta_k(\alpha_k\hat{p}_1+\hat{k}_\perp)u(k)e^{-ikx}i\partial_j[x_*,-\infty]_x\ =\ 0\ +\ \mathcal{O}(\partial_i\partial_j)
\end{aligned} \tag{327}$$

UТОГО В ПЕРВОМ ПОРАDКЕ ПО $\partial_i\bar{A}_\bullet$ ПОΛУ4АЕМ

$$\begin{aligned}
\xi_b(x)\ =&\ \int dk_\perp d\beta_k\Big\{\Big([x_*,-\infty]_x-\frac{\beta_k\hat{p}_2}{k_\perp^2}\gamma^j\int_{-\infty}^{x_*}d\frac{2}{s}z_*\ [x_*,z_*]_xF_{\bullet j}(z_*,x_\perp)[z_*,-\infty]_x\\
&+2i\frac{k^j}{k_\perp^2}\beta_k\int_{-\infty}^{x_*}d\frac{2}{s}z_*\ (x_*-z_*)[x_*,z_*]_xF_{\bullet j}(z_*,x_\perp)[z_*,-\infty]_x\Big\}\big(c_1u(k)e^{-i\frac{k_\perp^2}{\beta_ks}x_\bullet-i\beta_kx_*+i(k,x)_\perp}+c_2v(k)e^{i\frac{k_\perp^2}{\beta_ks}x_\bullet+i\beta_kx_*-i(k,x)_\perp}\big)\\
=&\ [x_*,-\infty]_x\xi_b^{\rm free}(x)-\frac{2\hat{p}_2}{s}(i\gamma_j\partial^j[x_*,-\infty]_x)\frac{\partial_\bullet}{\partial_\perp^2}\xi_b^{\rm free}(x)+\frac{4i}{s}\int_{-\infty}^{x_*}d\frac{2}{s}z_*\ (x_*-z_*)[x_*,z_*]_xF_{\bullet j}(z_*,x_\perp)[z_*,-\infty]_x\frac{\partial^j\partial_\bullet}{\partial_\perp^2}\xi_b^{\rm free}(x)\ +\ \mathcal{O}(\partial_i\partial_jA_\bullet)
\end{aligned} \tag{328}$$

It looks like the light-cone expansion in powers of $\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}$.

PA3δUEHUE $\xi^{\rm free} \;=\; \xi^{(1)}_{\rm free}+\xi^{(2)}_{\rm free}, \qquad \xi^{(1)}\;\equiv\;\frac{\hat{p}_2\hat{p}_1}{s}\xi,\;\; \xi^{(2)}\;\equiv\;\frac{\hat{p}_1\hat{p}_2}{s}\xi,\; \xi^{(1)}_{\rm free}\sim 1,\; \xi^{(2)}_{\rm free}\sim\frac{k_\perp}{\sqrt{s}}$

$$\xi^b_{(2)} \;=\; [x_*,-\infty]\xi^{(2)b}_{\rm free}+\frac{4i}{s}\int_{-\infty}^{x_*}d\frac{2}{s}z_*\;(x_*-z_*)[x_*,z_*]_xF_{\bullet j}(z_*,x_\perp)[z_*,-\infty]_x\frac{\partial^j\partial_\bullet}{\partial_\perp^2}\xi^{(2)b}_{\rm free}(x)\;+\;\mathcal{O}\Big(\big(\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}\big)^2\Big)$$

$$\xi^b_{(1)} \;=\; [x_*,-\infty]\xi^{(1)b}_{\rm free}-\frac{2\hat{p}_2}{s}(i\gamma_j\partial^j[x_*,-\infty]_x)\frac{\partial_\bullet}{\partial_\perp^2}\xi^{(2)b}_{\rm free}(x)\;+\;\mathcal{O}\Big(\big(\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}\big)^2\Big) \tag{329}$$

3AC, $\xi^b_{(2)}\;=\;\mathcal{O}\Big(\big(\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}\big)\Big)\xi^b_{(1)}$

2. *In the projectile*

$\bar{A}_\bullet(x_\bullet,x_\perp)$ and $\xi_a(x_\bullet,x_\perp)$
PA3δUBAEM

$$\xi\;=\;\xi^{(1)}+\xi^{(2)}\qquad \xi^{(1)}\;\equiv\;\frac{\hat{p}_2\hat{p}_1}{s}\xi,\quad \xi^{(2)}\;\equiv\;\frac{\hat{p}_1\hat{p}_2}{s}\xi$$

YP-E DUPAKA:

$$\frac{2}{s}\hat{p}_1(i\partial_*+\bar{A}_*)\xi_a(x_\bullet,x_\perp)+i\gamma^i\partial_i\xi_a(x_\bullet,x_\perp)\;=\;0$$
$$\frac{2}{s}\hat{p}_1(i\partial_*+\bar{A}_*)\xi^{(1)}_a(x_\bullet,x_\perp)+i\gamma^i\partial_i\xi^{(2)}_a(x_\bullet,x_\perp)\;=\;0,\qquad i\gamma^i\partial_i\xi^{(1)}_a(x_\bullet,x_\perp)\;=\;0 \tag{330}$$

C. KΛACC. YP-E KBAPKOB

1. *KΛACC. YP-E B ΠEPBOM ΠOPADKE ΠO $p_\perp$*

$\bar{C}_*\;=\;\Omega^\dagger i\partial_*\Omega-\bar{A}_*$ where Ω is given by Eq. (210). From that equation we C that

$$\Omega(x_\bullet,-\infty_*,x_\perp)\;=\;[x_\bullet,-\infty_\bullet]^{\bar{A}_*}_{x_\perp},\qquad \Omega(x_*,-\infty_\bullet,x_\perp)\;=\;[x_*,-\infty_*]^{\bar{A}_\bullet}_{x_\perp} \tag{331}$$

In the leading order

$$(\hat{\bar{P}}+\hat{\bar{C}})\Upsilon(x)\;=\;\Omega_xi\hat{\partial}\Omega_x^\dagger\Upsilon(x)\;=\;0 \tag{332}$$

The solution is given by Eq. (248) and (250)

$$\Upsilon(x)\;\equiv\;\xi(x)+\chi(x)\;=\;\Omega(x)[-\infty_\bullet,x_\bullet]^{\hat{A}_*}_x\xi_a(x)+\Omega(x)[-\infty_*,x_*]^{\hat{A}_\bullet}_x\xi_b(x)$$
$$=\;\Omega(x)[-\infty_\bullet,x_\bullet]^{\hat{A}_*}_x\frac{\hat{p}_1\hat{p}_2}{s}\xi_a(x)+\Omega(x)[-\infty_*,x_*]^{\hat{A}_\bullet}_x\frac{\hat{p}_2\hat{p}_1}{s}\xi_b(x)\;+\;\mathcal{O}\Big(\big(\frac{k_\perp^{\rm gluon}}{k_\perp^{\rm quark}}\big)\Big) \tag{333}$$

Chek of the solution:

$$(\hat{\bar{P}}+\hat{\bar{C}})\Upsilon(x)\;=\;\Omega(x)i\hat{\partial}[-\infty_\bullet,x_\bullet]^{\hat{A}_*}_x\xi_a(x)\;+\;\Omega(x)i\hat{\partial}[-\infty_*,x_*]^{\hat{A}_\bullet}_x\xi_b(x)\;= \tag{334}$$
$$=\;\Omega_x[-\infty_\bullet,x_\bullet]^{\hat{A}_*}_x\Big(\frac{2}{s}\hat{p}_1(i\partial_*+\hat{A}_*)+\frac{2}{s}\hat{p}_2i\partial_\bullet+i\hat{\partial}_\perp\Big)\xi_a(x)\;+\;\Omega_x[-\infty_*,x_*]^{\hat{A}_\bullet}_x\Big(\frac{2}{s}\hat{p}_2(i\partial_\bullet+\hat{A}_\bullet)+\frac{2}{s}\hat{p}_1i\partial_*+i\hat{\partial}_\perp\Big)\xi_b(x)$$

Boundary conditions

$$[\xi(x)+\chi(x)]\Big|_{x_\bullet=-\infty}\;=\;\Omega(x_*,-\infty_\bullet,x_\perp)[-\infty_*,x_*]^{\hat{A}_\bullet}_x\xi_b(x)\;=\;\xi_b(x)$$
$$[\xi(x)+\chi(x)]\Big|_{x_*=-\infty}\;=\;\Omega(x_\bullet,-\infty_*,x_\perp)[-\infty_\bullet,x_\bullet]^{\hat{A}_*}_x\xi_a(x)\;=\;\xi_a(x) \tag{335}$$

where we uzd Eq. (331).

XII. AFTER GAUGE TRANSFORMATION WITH $\Omega(x)$

A. ODHO ΠΟΛΕ $\bar{A}_i(x_\bullet)$

Gauge transformation $\bar{A}(x_\bullet,x_\perp)\ \to\ V(x_\bullet,x_\perp)$

$$\begin{aligned}
&\bar{A}_*(x_\bullet,x_\perp)\ \to\ [-\infty_\bullet,x_\bullet]_x^{\bar{A}_*}\big(i\partial_*+\bar{A}_*\big)[x_\bullet,-\infty_\bullet]_x^{\bar{A}_*}\ =\ 0\ =\ V_*\\
&\bar{A}_i(x_\bullet,x_\perp)\ \to\ [-\infty_\bullet,x_\bullet]_x^{\bar{A}_*}\big(i\partial_i+0\big)[x_\bullet,-\infty_\bullet]_x^{\bar{A}_*}\ =\ [-\infty_\bullet,x_\bullet]_x^{\bar{A}_*}i\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar{A}_*}\ \equiv\ V_i(x_\bullet,x_\perp)\\
&V_{ik}\ =\ \partial_i\bar{A}_k(x_\bullet,x_\perp)-\partial_k\bar{A}_i(x_\bullet,x_\perp)-i[\bar{A}_i(x_\bullet,x_\perp),\bar{A}_k(x_\bullet,x_\perp)]\ =\ 0\\
&V_{*i}\ =\ \partial_*V_i(x_\bullet,x_\perp)\ =\ [-\infty_\bullet,x_\bullet]_x^{\bar{A}_*}\bar{G}_{*i}(x_\perp,x_\bullet)[x_\bullet,-\infty_\bullet]_x^{\bar{A}_*},\qquad V_\bullet\ =\ V_{\bullet i}\ =\ 0
\end{aligned}\tag{336}$$

$$\begin{aligned}
&\int DA\ e^{i\int dz\left(-\frac14[G^a_{\mu\nu}]^2+\bar\psi\hat{\bar{P}}\psi\right)}\ e^{i\int d^2z_\perp d\frac{2}{s}z_\bullet\ A^a_i(z)\bar{V}^a_{*i}(z_\bullet,z_\perp)}\Big|^{z_*=\infty}_{z_*=-\infty}\\
&\Rightarrow\ \int DA\ e^{i\int dz\left(-\frac14[G^a_{\mu\nu}(A+V)]^2-\frac12(\bar{D}_\mu A^\mu)^2\right)+(\bar\psi+\bar\xi)(\hat{\bar{P}}+\hat{V})(\psi+\xi)}\ e^{i\int d^2z_\perp d\frac{2}{s}z_\bullet\ A^a_i(z)\bar{V}^a_{*i}(z_\bullet,z_\perp)}\Big|^{z_*=\infty}_{z_*=-\infty}\\
&=\ \int DAD\bar\psi D\psi\ A^m_\mu(x)\exp\Big\{i\int dz\big(-\frac12A^{a\alpha}(P^2g_{\alpha\beta}+2iV_{\alpha\beta})^{ab}A^{\beta b}+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\\
&-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta+\ \bar\xi\hat{\bar{P}}\xi+\bar\xi\hat{A}\xi+\bar\xi\hat{\bar{P}}\psi+\bar\psi\hat{\bar{P}}\xi+\bar\xi\hat{A}\psi+\bar\psi\hat{A}\xi+\bar\psi\hat{\bar{P}}\psi+\bar\psi\hat{A}\psi\big)\Big\}
\end{aligned}\tag{337}$$

DPYΓOE ΠΟΛΕ

$$\begin{aligned}
&\bar{A}_\bullet(x_*,x_\perp)\ \to\ [-\infty_*,x_*]_x^{\bar{A}_\bullet}\big(i\partial_\bullet+\bar{A}_\bullet\big)[x_*,-\infty]^{\bar{A}_\bullet}\ =\ 0\ =\ U_*\\
&\bar{A}_i(x_*,x_\perp)\ \to\ [-\infty_*,x_*]_x^{\bar{A}_\bullet}\big(i\partial_i+0\big)[x_*,-\infty_*]^{\bar{A}_\bullet}\ =\ [-\infty_*,x_*]_x^{\bar{A}_\bullet}i\partial_i[x_*,-\infty_*]_x^{\bar{A}_\bullet}\ \equiv\ U_i(x_*,x_\perp)\\
&U_{ik}\ =\ \partial_i\bar{A}_k(x_\bullet,x_\perp)-\partial_k\bar{A}_i(x_\bullet,x_\perp)-i[\bar{A}_i(x_\bullet,x_\perp),\bar{A}_k(x_\bullet,x_\perp)]\ =\ 0\\
&U_{\bullet i}\ =\ \partial_\bullet U_i(x_\bullet,x_\perp)\ =\ [-\infty_*,x_*]_x^{\bar{A}_\bullet}\bar{G}_{\bullet i}(x_\perp,x_*)[x_*,-\infty_*]_x^{\bar{A}_\bullet},\qquad U_\bullet\ =\ U_{\bullet i}\ =\ 0
\end{aligned}\tag{338}$$

B. CYMMA DBYX ΠΟΛΕЙ

$$\begin{aligned}
&\int DA\ e^{i\int dz\left(-\frac14[G^a_{\mu\nu}(A+V+U)]^2-\frac12(\bar{D}_\mu A^\mu)^2\right)+(\bar\psi+\bar\xi)(\hat{\bar{P}}+\hat{V}+\hat{U})(\psi+\xi)}\ e^{i\int d^2z_\perp d\frac{2}{s}z_\bullet\ A^a_i(z)\bar{V}^a_{*i}(z_\bullet,z_\perp)}\Big|^{z_*=\infty}_{z_*=-\infty}\ e^{i\int d^2z_\perp d\frac{2}{s}z_\bullet\ A^a_i(z)\bar{U}^a_{\bullet i}(z_*,z_\perp)}\Big|^{z_\bullet=\infty}_{z_\bullet=-\infty}\\
&=\ \int DAD\bar\psi D\psi\ A^m_\mu(x)\exp\Big\{i\int dz\big(-\frac14\bar{G}^{a\mu\nu}\bar{G}^a_{\mu\nu}-\frac12A^{a\alpha}(P^2g_{\alpha\beta}+2iV_{\alpha\beta})^{ab}A^{\beta b}+A^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha A^{a\beta}A^b_\alpha A^c_\beta\\
&-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta+\ \bar\xi\hat{\bar{P}}\xi+\bar\xi\hat{A}\xi+\bar\xi\hat{\bar{P}}\psi+\bar\psi\hat{\bar{P}}\xi+\bar\xi\hat{A}\psi+\bar\psi\hat{A}\xi+\bar\psi\hat{\bar{P}}\psi+\bar\psi\hat{A}\psi\big)\Big\}
\end{aligned}\tag{339}$$

$$\begin{aligned}
&\bar{G}_{\mu\nu}\ =\ U_{\mu\nu}+V_{\mu\nu}-i[U_\mu,V_\nu]-i[V_\mu,U_\nu]\ \Rightarrow\ \bar{G}_{*\bullet}\ =\ 0,\quad \bar{G}_{\bullet i}\ =\ U_{\bullet i},\quad \bar{G}_{*i}\ =\ V_{*i},\quad \bar{G}_{ik}\ =\ -i[U_i,V_k]-i[V_i,U_k]\\
&\bar{D}^i\bar{G}_{i\bullet}-(\partial_i-i[U_i,)U_{i\bullet}\ =\ -i\partial_\bullet[U_i,V^i],\quad \bar{D}^i\bar{G}_{i*}-(\partial_i-i[V_i,)V_{i*}\ =\ i\partial_*[U_i,V^i]
\end{aligned}\tag{340}$$

From (282)

$$F^{(1)}_{\bullet i}(x)\ =\ \Omega_xU_{\bullet i}(x_\perp,x_*)\Omega^\dagger_x,\qquad F^{(1)}_{*i}(x)\ =\ \Omega_xV_{*i}(x_\perp,x_\bullet)\Omega^\dagger_x\tag{341}$$

From Eq. (220)

$$\bar{C}^a_i\ =\ (\Omega i\partial_i\Omega^\dagger)^a+i\Omega^{ab}_x([-\infty_*,x_*]_x^{\bar{A}_\bullet}\partial_i[x_*,-\infty_*]_x^{\bar{A}_\bullet})^b+i\Omega^{ab}_x([-\infty_\bullet,x_\bullet]_x^{\bar{A}_*}\partial_i[x_\bullet,-\infty_\bullet]_x^{\bar{A}_*})^b\ =\ \Omega^a_i+\Omega(U_i+V_i)\Omega^\dagger\tag{342}$$

From Eqs. (234) and (280)

$$F^{(1)}_{*\bullet}(x)\ =\ \Omega_x[U_i,V^i]\Omega^\dagger(x),\qquad F^{(1)}_{ik}(x)\ =\ -i\Omega_x[U_i,V_k]\Omega^\dagger(x)\ -\ i\leftrightarrow k\tag{343}$$

Consider Ω applied to $\mathcal{A}_\bullet=\bar{A}_\bullet+\bar{C}_\bullet$, $\mathcal{A}_*=\bar{A}_*+\bar{C}_*$ and $\mathcal{A}_i=\bar{C}_i$

$$\Omega^\dagger_x\mathcal{A}_\bullet\Omega(x)+i\Omega^\dagger_x\partial_\bullet\Omega(x)\ =\ \Omega^\dagger_x\mathcal{A}_*\Omega(x)+i\Omega^\dagger_x\partial_*\Omega(x)\ =\ 0,\qquad \Omega^\dagger_x\mathcal{A}_i\Omega(x)+i\Omega^\dagger_x\partial_i\Omega(x)\ =\ U_i+V_i\tag{344}$$

C. General sdvig

$$\int DAD\bar{\psi}D\psi\ A_\mu^m(x)\psi(y)e^{i\int dz\left(-\frac{1}{4}[G^a_{\mu\nu}(A+\bar{A})]^2-\frac{1}{2}[(\bar{D}_\mu-i\bar{C}_\mu)A^\mu]^2\right)+(\bar{\psi}+\bar{\xi})(\hat{\bar{P}}+\hat{A})(\psi+\xi)} \tag{345}$$

Sdvig $A\to A+\bar{C}$, $\psi\to\psi+\chi$. Notation: $\Upsilon\ =\ \xi+\chi$, $\mathbb{A}\ =\ \bar{A}+\bar{C}$

$$\begin{aligned}
=&\ \int DAD\bar{\psi}D\psi\ [A_\mu^m(x)+\bar{C}_\mu^m(x)][\psi(y)+\chi(y)]\\
&\times\ e^{i\int dz\left(-\frac{1}{4}\bar{G}^{a\mu\nu}\bar{G}^a_{\mu\nu}-\frac{1}{2}\bar{C}^{a\alpha}(\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta})^{ab}\bar{C}^{\beta b}+\bar{C}^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha\bar{C}^{a\beta}\bar{C}^b_\alpha\bar{C}^c_\beta-\frac{g^2}{4}f^{abm}f^{cdm}\bar{C}^{a\alpha}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})(\hat{\bar{P}}+\hat{\bar{C}})(\xi+\chi)\right)}\\
&\times\ \exp i\int dz\Big\{A^{a\alpha}\Big(-(\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta}+(\bar{D}\bar{G})^a_\alpha+f^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)\Big)\\
&+\ \bar{\psi}(\hat{\bar{P}}+\hat{\bar{C}})(\xi+\chi)+(\bar{\xi}+\bar{\chi})(\hat{\bar{P}}+\hat{\bar{C}})\psi\\
&-\ \frac{1}{2}A^{a\alpha}\Big((\bar{P}+\bar{C})^2g_{\alpha\beta}+2i\big(\bar{G}_{\alpha\beta}+\bar{D}_\alpha\bar{C}_\beta-\bar{D}_\beta\bar{C}_\alpha-i[\bar{C}_\alpha,\bar{C}_\beta]\big)\Big)^{ab}A^{b\beta}+\bar{\psi}(\hat{\bar{P}}+\hat{\bar{C}})\psi+(\bar{\xi}+\bar{\chi})\hat{A}\psi+\bar{\psi}\hat{A}(\xi+\chi)\\
&-\ gf^{abc}(\bar{D}_\alpha-i\bar{C}_\alpha)^{aa'}A^{a'}_\beta A^{c\alpha}A^{d\beta}-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta+\bar{\psi}\hat{A}\psi\Big\}\\
=&\ \int DAD\bar{\psi}D\psi\ [A_\mu^m(x)+\bar{C}_\mu^m(x)][\psi(y)+\chi(y)]e^{i\int dz[-\frac{1}{4}\mathbb{G}^{a\mu\nu}\mathbb{G}^a_{\mu\nu}+\bar{\Upsilon}\hat{\mathbb{P}}\Upsilon\ -\frac{1}{2}(\bar{D}^\beta\bar{C}^a_\beta)^2]}\\
&\qquad\times\ e^{i\int dzA^{a\alpha}[-(\mathbb{P}^2g_{\alpha\beta}+2i\mathbb{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta}-i\bar{C}^{ab}_\beta\mathbb{D}_\alpha\bar{C}^b_\beta+(\bar{D}\bar{G})^a_\alpha+\bar{\Upsilon}\gamma_\alpha t^a\Upsilon+\bar{\psi}\hat{\mathbb{P}}\Upsilon+\bar{\Upsilon}\hat{\mathbb{P}}\psi\ +i\bar{C}^{ab}_\alpha\bar{D}_\beta\bar{C}^b_\beta]}\\
&\qquad\quad\times\ e^{i\int dz[-\frac{1}{2}A^{a\alpha}(\mathbb{P}^2g_{\alpha\beta}+2i\mathbb{G}_{\alpha\beta})A^{b\beta}+\bar{\psi}\hat{\mathbb{P}}\psi+\bar{\Upsilon}\hat{A}\psi+\bar{\psi}\hat{A}\Upsilon-\ gf^{abc}A^{a\alpha}A^{b\beta}\mathbb{D}_\alpha A^c_\beta-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta+\bar{\psi}\hat{A}\psi]}
\end{aligned} \tag{346}$$

whæ wi uzd

$$\begin{aligned}
&-(\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta}+f^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta\\
&=\ -\Big((\bar{P}+\bar{C})^2g_{\alpha\beta}+2i\big(\bar{G}_{\alpha\beta}+\bar{D}_\alpha\bar{C}_\beta-\bar{D}_\beta\bar{C}_\alpha-i[\bar{C}_\alpha,\bar{C}_\beta]\big)\Big)^{ab}\bar{C}^{b\beta}-i\bar{C}^{ab}_\beta\mathcal{D}_\alpha\bar{C}^b_\beta\ +i\bar{C}^{ab}_\alpha\bar{D}_\beta\bar{C}^b_\beta\\
&=\ -\big(\mathbb{P}^2g_{\alpha\beta}+2iG_{\alpha\beta}(\mathbb{A})\big)^{ab}\bar{C}^{b\beta}-i\bar{C}^{ab}_\beta\mathbb{D}_\alpha\bar{C}^b_\beta\ +i\bar{C}^{ab}_\alpha\bar{D}_\beta\bar{C}^b_\beta\ \equiv\ -\big(\mathbb{P}^2g_{\alpha\beta}+2i\mathbb{G}_{\alpha\beta}\big)^{ab}\bar{C}^{b\beta}-i\bar{C}^{ab}_\beta\mathbb{D}_\alpha\bar{C}^b_\beta\ +i\bar{C}^{ab}_\alpha\bar{D}_\beta\bar{C}^b_\beta
\end{aligned} \tag{347}$$

and (without paying attention to boundaries)

$$\begin{aligned}
&-\frac{1}{4}\bar{G}^{a\mu\nu}\bar{G}^a_{\mu\nu}-\frac{1}{2}\bar{C}^{a\alpha}(\bar{P}^2g_{\alpha\beta}+2i\bar{G}_{\alpha\beta})^{ab}\bar{C}^{\beta b}+\bar{C}^a_\alpha\bar{D}_\xi\bar{G}^{a\xi\alpha}-gf^{abc}\bar{D}^\alpha\bar{C}^{a\beta}\bar{C}^b_\alpha\bar{C}^c_\beta-\frac{g^2}{4}f^{abm}f^{cdm}\bar{C}^{a\alpha}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+\bar{\Upsilon}(\hat{\bar{P}}+\hat{\bar{C}})\Upsilon\\
&=\ -\frac{1}{4}\mathbb{G}^{a\mu\nu}\mathbb{G}^a_{\mu\nu}+\bar{\Upsilon}\hat{\mathbb{P}}\Upsilon\ -\frac{1}{2}(\mathbb{D}^\beta\bar{C}^a_\beta)^2
\end{aligned} \tag{348}$$

$$\begin{aligned}
&D^\xi G^a_{\xi\mu}(\bar{A}+\bar{C})\ =\ (\bar{D}^\xi-i\bar{C}^\xi)^{ab}(\bar{G}^b_{\xi\mu}+\bar{D}_\xi\bar{C}^b_\mu-\bar{D}_\mu\bar{C}^b_\xi-i\bar{C}^{bc}_\xi\bar{C}^c_\mu)\ =\ \bar{D}^\xi\bar{G}^a_{\xi\mu}+(\bar{D}^2g_{\mu\xi}-2i\bar{G}_{\mu\xi})^{ab}\bar{C}^{b\xi}-\bar{D}_\mu\bar{D}^\xi\bar{C}^a_\xi\\
&-\ i(\bar{D}^\xi\bar{C}_\xi)^{ab}\bar{C}^b_\mu-i\bar{C}^{ab}_\xi\bar{D}^\xi\bar{C}^b_\mu-i\bar{C}^{\xi ab}\bar{D}_\xi\bar{C}^b_\mu+i\bar{C}^{\xi ab}(\bar{D}_\mu-i\bar{C}_\mu)\bar{C}^b_\xi\\
&=\ \bar{D}^\xi\bar{G}^a_{\xi\mu}+(\bar{D}^2g_{\mu\xi}-2i\bar{G}_{\mu\xi})^{ab}\bar{C}^{b\xi}-(\bar{D}_\mu-i\bar{C}_\mu)\bar{D}^\xi\bar{C}^a_\xi+i\bar{C}^{\xi ab}(\bar{D}_\mu-i\bar{C}_\mu)\bar{C}^b_\xi-2i\bar{C}^{\xi ab}\bar{D}_\xi\bar{C}^b_\mu\\
&=\ -(\bar{D}_\mu-i\bar{C}_\mu)\bar{D}^\xi\bar{C}^a_\xi\ -\ (\bar{P}^2g_{\mu\beta}+2i\bar{G}_{\mu\beta})^{ab}\bar{C}^{b\beta}+(\bar{D}\bar{G})^a_\mu+f^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\mu-\bar{C}^b_\beta\bar{D}_\mu\bar{C}^{c\beta})-f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\mu\bar{C}^d_\beta
\end{aligned} \tag{349}$$

wich agriiz wiz Eq. (160).

Another rewriting:

$$D^\xi G^a_{\xi\mu}(\bar{A}+\bar{C})+(\bar{D}_\mu-i\bar{C}_\mu)\bar{D}^\xi\bar{C}^a_\xi\ =\ -(\bar{P}^2g_{\mu\beta}+2i\bar{G}_{\mu\beta})^{ab}\bar{C}^{b\beta}+(\bar{D}\bar{G})^a_\mu+i\bar{C}^{\xi ab}(\bar{D}_\mu-i\bar{C}_\mu)\bar{C}^b_\xi-2i\bar{C}^{\xi ab}\bar{D}_\xi\bar{C}^b_\mu \tag{350}$$

If $\bar{C}$ and χ are the solutions of Eq. (260)

$$\begin{aligned}
&(\bar{P}^2g_{\alpha\beta}+2ig\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta}\ =\ \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha}+gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-g^2f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)\\
&(\hat{\bar{P}}+\hat{\bar{C}})(\xi+\chi)\ =\ 0,\qquad(\bar{\xi}+\bar{\chi})(\hat{\bar{P}}+\hat{\bar{C}})\ =\ 0
\end{aligned} \tag{351}$$

we get

$$\int DAD\bar\psi D\psi\ A^m_\mu(x)\psi(y)e^{i\int dz\left(-\frac14[G^a_{\mu\nu}(A+\bar A)]^2-\frac12[(\bar D_\mu-i\bar C_\mu)A^\mu]^2\right)+(\bar\psi+\bar\chi)(\hat{\bar P}+\hat A)(\psi+\xi)} \tag{352}$$
$$= \int DAD\bar\psi D\psi\ [A^m_\mu(x)+\bar C^m_\mu(x)][\psi(y)+\chi(y)]e^{i\int dz(-\frac14\mathbb{G}^{a\mu\nu}\mathbb{G}^a_{\mu\nu}+\bar\Upsilon\hat{\mathbb{P}}\Upsilon)}$$
$$\times\ e^{i\int dz[-\frac12 A^{a\alpha}(\mathbb{P}^2g_{\alpha\beta}+2i\mathbb{G}_{\alpha\beta})A^{b\beta}+\bar\psi\hat{\mathbb{P}}\psi+\bar\Upsilon\hat A\psi+\bar\psi\hat A\Upsilon-\ gf^{abc}A^{a\alpha}A^{b\beta}\mathbb{D}_\alpha A^c_\beta-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta+\bar\psi\hat A\psi]}\ =\ \big(\mathbb{A}(x)-\bar A(x)\big)\big(\Upsilon(y)-\xi(y)\big)$$
$$\times\int DAD\bar\psi D\psi\ e^{i\int dz(-\frac14\mathbb{G}^{a\mu\nu}\mathbb{G}^a_{\mu\nu}+\bar\Upsilon\hat{\mathbb{P}}\Upsilon)}e^{i\int dz[-\frac12 A^{a\alpha}(\mathbb{P}^2g_{\alpha\beta}+2i\mathbb{G}_{\alpha\beta})A^{b\beta}+\bar\psi\hat{\mathbb{P}}\psi+\bar\Upsilon\hat A\psi+\bar\psi\hat A\Upsilon-\ gf^{abc}A^{a\alpha}A^{b\beta}\mathbb{D}_\alpha A^c_\beta-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta+\bar\psi\hat A\psi]}$$

We can solve Eq. (351)

$$(\bar P^2g_{\mu\xi}+2i\bar G_{\mu\xi})^{ab}\bar C^{b\xi}+(\bar D_\mu-i\bar C_\mu)\bar D^\xi\bar C^a_\xi-i\bar C^{\xi ab}(\bar D_\mu-i\bar C_\mu)\bar C^b_\xi+2i\bar C^{\xi ab}\bar D_\xi\bar C^b_\mu-(\bar D\bar G)^a_\mu\ =\ (\bar\xi+\bar\chi)\gamma_\mu t^a(\xi+\chi)$$
$$\Leftrightarrow\ D^\xi G^a_{\xi\mu}(\bar A+\bar C)+(\bar D_\mu-i\bar C_\mu)\bar D^\xi\bar C^a_\xi\ =\ (\bar\xi+\bar\chi)\gamma_\mu t^a(\xi+\chi) \tag{353}$$

by iterations $\bar C_\xi=\Omega_\xi-\bar A_\xi+s_\xi$, $\chi=\Omega\xi-\xi+\lambda$. At the first step we get

$$D^2_\Omega s^a_\mu-is^{ab}_\mu D^\xi_\Omega(\Omega_\xi-\bar A_\xi)^b\ =\ -D^\Omega_\mu D^\xi_\Omega(\Omega_\xi-\bar A_\xi)+\bar\xi\Omega^\dagger t^a\gamma_\mu\Omega\xi \tag{354}$$

For our Ω we have

$$D^\xi_\Omega(\Omega_\xi-\bar A_\xi)^a\ =\ \partial_\xi(\Omega_\xi-\bar A_\xi)^a-i(\Omega_\xi)^{ab}(\Omega_\xi-\bar A_\xi)^b\ =\ \partial_\xi\Omega_\xi+i(\Omega_\xi)^{ab}\bar A^b_\xi\ =\ \bar D^{ab}_\xi\Omega^{\xi b}\ =\ \bar D^{ab}_\xi(\Omega^\xi-\bar A^\xi)^b\ =\ \partial^i\Omega_i \tag{355}$$

so the equation turns 2

$$[\partial^2+i(\partial^i\tilde\Omega_i)]^{ab}(\Omega^\dagger s_\mu)^b\ =\ -\partial_\mu\partial^i\tilde\Omega_i+\bar\xi t^a\gamma_\mu\xi \tag{356}$$

gde $\tilde\Omega_\mu\ \equiv\ \Omega^\dagger i\partial_\mu\Omega$

D. First iteration

If $\bar A_i=0$ for projectile and target, for self-consistency we must require

$$\bar\xi_a\gamma_i\xi_a\ =\ \partial_\bullet\bar G_{*i}\ =\ 0,\qquad \bar\xi_b\gamma_i\xi_b\ =\ \partial_*\bar G_{\bullet i}\ =\ 0 \tag{357}$$

First iteration ($\Omega_i\equiv\Omega^\dagger i\partial_i\Omega$)

$$\tilde C_\parallel\ =\ \Omega i\partial_\parallel\Omega^\dagger-\bar A_\parallel,$$
$$\tilde C^a_i\ =\ \Omega^{ab}_x(U_i+V_i-\Omega_i-\Sigma_i)^b,\qquad \Sigma_i\ \equiv\ \frac{s}{4}\int_{-\infty}^{x_*}d\frac{2}{s}z_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\ [\bar\Sigma^a(z_\bullet,x_\perp)t^b\gamma_i\Sigma_b(z_*,x_\perp)+\bar\Sigma^b(z_*,x_\perp)t^b\gamma_i\Sigma_a(z_\bullet,x_\perp)]$$
$$\tilde\Upsilon\ =\ \Omega(x)(\Sigma^a+\Sigma^b),\quad \Sigma_a(x_\bullet,x_\perp)\ =\ [-\infty_\bullet,x_\bullet]^{\hat A_*}_x\xi_a(x),\quad \Sigma_b(x_\bullet,x_\perp)\ =\ [-\infty_*,x_*]^{\hat A_\bullet}_x\xi_b(x) \tag{358}$$

is a solution of equations (226), (248) and (250)

$$[\mathcal{P}_*\mathcal{P}_\bullet+\mathcal{P}_\bullet\mathcal{P}_*]^{ab}\tilde C^b_\bullet\ =\ -i\tilde C^{ab}_\bullet\mathcal{D}_\bullet\tilde C^b_*-i\tilde C^{ab}_*\mathcal{D}_\bullet\tilde C^b_\bullet+\bar D_\bullet\bar G^a_{*\bullet}$$
$$[\mathcal{P}_*\mathcal{P}_\bullet+\mathcal{P}_\bullet\mathcal{P}_*]^{ab}\tilde C^b_*\ =\ -i\tilde C^{ab}_*\mathcal{D}_*\tilde C^b_\bullet-i\tilde C^{ab}_\bullet\mathcal{D}_*\tilde C^b_*-\bar D_*\bar G^a_{*\bullet}$$
$$[\mathcal{P}_*\mathcal{P}_\bullet+\mathcal{P}_\bullet\mathcal{P}_*]^{ab}\tilde C^b_i\ =\ ig[\mathcal{P}^{ab}_*\partial_i\mathcal{A}^b_\bullet+\mathcal{P}^{ab}_\bullet\partial_i\mathcal{A}^b_*]+\frac{s}{2}\Omega^{ab}(\bar\Sigma_a\gamma_it^b\Sigma_b+\bar\Sigma_b\gamma_it^b\Sigma_a)$$
$$\hat{\mathcal{P}}\Upsilon(x)\ =\ \Omega^\dagger(\hat U\Sigma_a+\hat V\Sigma_b) \tag{359}$$

with initial conditions

$$\tilde C_\mu(x_*\to-\infty)\ =\ \tilde C_\mu(x_*\to-\infty)\ =\ 0\ \ \Leftrightarrow\ \ \mathcal{A}_*(-\infty,x_\bullet,x_\perp)\ =\ A_*(x_\bullet,x_\perp),\quad \mathcal{A}(x_*,-\infty,x_\perp)\ =\ A_\bullet(x_\bullet,x_\perp),$$
$$\mathcal{A}_i(-\infty,x_\bullet,x_\perp)\ =\ \mathcal{A}_i(x_*,-\infty,x_\perp)\ =\ 0,\qquad \Upsilon(-\infty,x_\bullet,x_\perp)\ =\ \xi_a(x_\bullet,x_\perp),\quad \Upsilon(x_*,-\infty,x_\perp)\ =\ \xi_b(x_*,x_\perp) \tag{360}$$

Here $\mathcal{A}_*\ =\ \bar A_*+\tilde C_*$, $\mathcal{P}_*=\bar P_*+\tilde C_*$, and $\mathcal{A}_\bullet=\bar A_\bullet+\tilde C_\bullet$, $\mathcal{P}_\bullet=\bar P_\bullet+\tilde C_\bullet$ and

$$\big(\hat p+\frac{2}{s}\hat p_1\bar A_\bullet\big)\xi_a(x_*,x_\perp)\ =\ \big(\hat p+\frac{2}{s}\hat p_2\bar A_\bullet\big)\xi_b(x_*,x_\perp)\ =\ 0\quad\Rightarrow\quad(\hat p+\hat V)\Sigma_a\ =\ (\hat p+\hat U)\Sigma_b\ =\ 0 \tag{361}$$

gde $\hat{U}\equiv\gamma_i U^i$, $\hat{V}\equiv\gamma_i V^i$

$$\begin{aligned}\mathcal{G}_{*\bullet} &= 0, \quad \mathcal{G}_{*i} = \Omega(V_{*i}-\partial_*\Sigma_i)\Omega^\dagger, \quad \mathcal{G}_{\bullet i} = \Omega(U_{\bullet i}-\partial_\bullet\Sigma_i)\Omega^\dagger,\\ \mathcal{G}_{ik} &= \Omega\big(-i[U_i,V_k]-i[V_i,U_k]-(\mathbb{D}_i\Sigma_k-i\leftrightarrow k)-i[\Sigma_i,\Sigma_k]\big)\Omega^\dagger\end{aligned} \tag{362}$$

gde

$$\Sigma_i^a(x) \equiv \int_{-\infty}^{x_*} d\frac{2}{s}z_*\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet \left[\bar\Sigma^a(z_\bullet,x_\perp)t^b\gamma_i\Sigma_b(z_*,x_\perp)+\bar\Sigma^b(z_*,x_\perp)t^b\gamma_i\Sigma_a(z_\bullet,x_\perp)\right] \tag{363}$$

$$\mathcal{G}_{\bullet i}(x) \stackrel{x_\bullet\to-\infty}{\rightarrow} \bar G_{\bullet i}(x_*,x_\perp), \qquad \mathcal{G}_{*i}(x) \stackrel{x_*\to-\infty}{\rightarrow} \bar G_{*i}(x_\bullet,x_\perp), \qquad \Sigma_i^a(x) \stackrel{x_*\to\pm\infty}{\rightarrow} 0 \tag{364}$$

1. Sdvig $A\to A+\mathcal{A}$

$$\begin{aligned}&\int d^4x\ \Big(-\frac{1}{4}[G_{\mu\nu}(A+\mathcal{A})]^2+\frac{1}{2}(\mathcal{D}^\mu A_\mu+\mathcal{D}^\mu\tilde C_\mu)^2+(\bar\Upsilon+\bar\psi)(\hat{\mathcal{D}}+\hat A)(\Upsilon+\psi)\Big)\\ &= \int d^4x\ \Big(-\frac{1}{4}\mathcal{G}_{\mu\nu}^2+\frac{1}{2}(\bar D^\mu\tilde C_\mu)^2+A_\alpha^a\big(\mathcal{D}_\mu\mathcal{G}^{a\mu\alpha}+\bar\Upsilon\gamma_\alpha t^a\Upsilon-\mathcal{D}^\alpha\bar D^\mu\tilde C_\mu^a\big)+\bar\psi\hat{\mathcal{D}}\Upsilon+\bar\Upsilon\hat{\mathcal{D}}\psi+\frac{1}{2}A_\mu^a\big(\mathcal{D}^2g^{\mu\nu}-2i\mathcal{G}^{\mu\nu}\big)^{ab}A_\nu^b\\ &- gf^{abc}A^{a\alpha}A^{b\beta}\mathcal{D}_\alpha A_\beta^c-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A_\alpha^cA_\beta^d+\bar\psi\hat A\psi\Big)\\ &+ \int d\frac{2}{s}x_\bullet dx_\perp\ [A^{ai}(\infty,x_\bullet,x_\perp)\mathcal{G}_{*i}^a(\infty,x_\bullet,x_\perp)-(\infty\to-\infty)]+\int d\frac{2}{s}x_*dx_\perp\ [A^{ai}(x_*,\infty,x_\perp)\mathcal{G}_{\bullet i}^a(x_*,\infty,x_\perp)-(\infty\to-\infty)]\end{aligned} \tag{365}$$

2. Gauge transformation

Gauge transformation: $\mathbb{A}_\mu = \Omega^\dagger i\partial_\mu\Omega+\Omega^\dagger\mathcal{A}_\mu\Omega, \qquad A^{\rm quant}_{\rm new} = \Omega^\dagger A^{\rm quant}\Omega$

$$\begin{aligned}&\mathbb{A}_\bullet = \mathbb{A}_* = 0, \quad \mathbb{A}_i = U_i+V_i-\Sigma_i, \quad G_{*\bullet}(\mathbb{A}) = 0,\\ &G_{*i}(\mathbb{A}) = V_{*i}-\partial_*\Sigma_i, \quad G_{\bullet i}(\mathbb{A}) = U_{\bullet i}-\partial_\bullet\Sigma_i, \quad G_{ik}(\mathbb{A}) = -i[U_i,V_k]-i[V_i,U_k]-(\mathbb{D}_i\Sigma_k-i\leftrightarrow k)-i[\Sigma_i,\Sigma_k]\\ &D^\mu G_{\mu i}(\mathbb{A}) = \frac{2}{s}\partial_*G_{\bullet i}(\mathbb{A})+\frac{2}{s}\partial_\bullet G_{*i}(\mathbb{A})+(\partial^k-i\mathbb{A}^k)G_{ki}(\mathbb{A}) = -\bar{\mathbb{Y}}\gamma_it^a\mathbb{Y}+(\partial^k-i\mathbb{A}^k)G_{ki}(\mathbb{A}),\\ &D^\mu G_{\mu\bullet}(\mathbb{A}) = -(\partial^i-i\mathbb{A}^i)G_{\bullet i}(\mathbb{A}), \qquad D^\mu G_{\mu *}(\mathbb{A}) = -(\partial^i-i\mathbb{A}^i)G_{*i}(\mathbb{A})\end{aligned} \tag{366}$$

gde

$$\mathbb{Y} = \Sigma_a+\Sigma_b = [-\infty_\bullet,x_\bullet]_x^{\hat A_*}\xi_a(x)+[-\infty_*,x_*]_x^{\hat A_\bullet}\xi_b(x) \tag{367}$$

so

$$\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y} = \bar\Sigma^bt^a\gamma_\bullet\Sigma_b, \quad \bar{\mathbb{Y}}\gamma_*t^a\mathbb{Y} = \bar\Sigma^at^a\gamma_*\Sigma_a, \quad \bar{\mathbb{Y}}\gamma_it^a\mathbb{Y} = \bar\Sigma_at^a\gamma_i\Sigma_b+\bar\Sigma_bt^a\gamma_i\Sigma_b \tag{368}$$

Sdvig $A\to A+\mathbb{A}$, $\psi\to\psi+\mathbb{Y}$ (bez surface terms):

$$\begin{aligned}&\int d^4x\ \Big(-\frac{1}{4}[G_{\mu\nu}(A+\mathbb{A})]^2+\frac{1}{2}(\mathbb{D}^\mu A_\mu)^2+(\bar{\mathbb{Y}}+\bar\psi)(\hat{\mathbb{D}}+\hat A)(\mathbb{Y}+\psi)\Big)\\ &= \int d^4x\ \Big(-\frac{1}{4}\mathcal{G}_{\mu\nu}^2+A_\alpha^a\big(\mathbb{D}_\mu\mathcal{G}^{a\mu\alpha}+\bar{\mathbb{Y}}\gamma_\alpha t^a\mathbb{Y}\big)+\bar\psi\hat{\mathbb{D}}\mathbb{Y}+\bar{\mathbb{Y}}\hat{\mathbb{D}}\psi+\frac{1}{2}A_\mu^a\big(\mathbb{D}^2g^{\mu\nu}-2i\mathcal{G}^{\mu\nu}\big)^{ab}A_\nu^b\\ &- gf^{abc}A^{a\alpha}A^{b\beta}\mathbb{D}_\alpha A_\beta^c-\frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A_\alpha^cA_\beta^d+\bar\psi\hat A\psi\Big)\end{aligned} \tag{369}$$

ИЩЕМ $\mathcal{C}$ and Υ ТАКИЕ 4ТО

$$\mathcal{C}(x)\Psi(y) \;=\; \int DAD\bar\psi D\psi\; A(x)\psi(y)e^{\int d^4x\;\left(-\frac14[G_{\mu\nu}(A+\mathbb{A})]^2+\frac12(\mathbb{D}^\mu A_\mu)^2+(\bar{\mathbb{Y}}+\bar\psi)(\hat{\mathbb{D}}+\hat A)(\mathbb{Y}+\psi)\right)} \tag{370}$$

ТОГДА $\mathcal{A}=\mathbb{A}+\mathcal{C}$ И $\Upsilon=\Psi+\mathbb{Y}$ - РЕШЕНИЕ УР-Й

$$\delta\Big\{\int d^4x\;\Big(-\frac14[G_{\mu\nu}(A+\mathbb{A}+\mathcal{C})]^2+\frac12[\mathbb{D}^\mu(A_\mu+\mathcal{C}_\mu)]^2+(\bar{\mathbb{Y}}+\bar\Psi+\bar\psi)(\hat{\mathbb{D}}+\hat{\mathcal{C}}+\hat A)(\mathbb{Y}+\Psi+\psi)\Big)\Big\} \;=\; 0$$

$$\Rightarrow\;\mathcal{D}^\mu\mathcal{G}^a_{\mu\nu}+\mathbb{D}_\nu\mathbb{D}^\mu\mathcal{C}^a_\mu+\bar\Upsilon\gamma_\nu t^a\Upsilon \;=\; 0,\qquad \hat{\mathcal{D}}\Upsilon \;=\; 0 \tag{371}$$

НАДО ПРОВЕРИТ' $\mathbb{D}^\mu\mathcal{C}_\mu=0$ (order by order?)

Formulas

$$D^\mu G_{\mu\bullet}(\mathbb{A})+t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b) \;=\; -\partial^iG_{\bullet i}(\mathbb{A})+i[\mathbb{A}^i,G_{\bullet i}(\mathbb{A})]+t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b)$$
$$=\; -\partial^i\big([-\infty_*,x_*]_x^{\bar A\bullet}\bar G_{\bullet i}(x_\perp,x_*)[x_*,-\infty_*]_x^{\bar A\bullet}\big)+i[U^i+V^i-\Sigma^i,U_{\bullet i}-\partial_\bullet\Sigma_i]+t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b)$$
$$=\; -[-\infty_*,x_*]_x^{\bar A\bullet}\partial^i\bar G_{\bullet i}(x_\perp,x_*)[x_*,-\infty_*]_x^{\bar A\bullet}\big)-i\int_{-\infty}^{x_*}d\frac2s z_*[-\infty_*,z_*]_x^{\bar A\bullet}\bar G_\bullet{}^i(x_\perp,z_*)[z_*,x_*]_x^{\bar A\bullet}\bar G_{\bullet i}(x_\perp,x_*)[x_*,-\infty_*]_x^{\bar A\bullet}$$
$$+\,i\int_{-\infty}^{x_*}d\frac2s z_*[-\infty_*,x_*]_x^{\bar A\bullet}\bar G_\bullet{}^i(x_\perp,x_*)[x_*,z_*]_x^{\bar A\bullet}\bar G_{\bullet i}(x_\perp,z_*)[z_*,-\infty_*]_x^{\bar A\bullet}+t^a(\bar\xi_b[x_*,-\infty_*]^{\bar A\bullet}\hat p_1t^a[-\infty_*,x_*]^{\bar A\bullet}\xi_b)+i[U^i,U_{\bullet i}]$$
$$+\,i[V^i-\Sigma^i,U_{\bullet i}-\partial_\bullet\Sigma_i] \;=\; i[V^i,U_{\bullet i}]-i[\Sigma^i,U_{\bullet i}]-i[V^i,\partial_\bullet\Sigma_i]+i[\Sigma^i,\partial_\bullet\Sigma_i] \tag{372}$$

Similarly

$$D^\mu G_{\mu*}(\mathbb{A})+t^a(\bar\Sigma_a\gamma_*t^a\Sigma_a) \;=\; i[U^i,V_{*i}]-i[\Sigma^i,V_{*i}]-i[U^i,\partial_*\Sigma_i]+i[\Sigma^i,\partial_*\Sigma_i] \tag{373}$$

Also,

$$D^\mu G^a_{\mu i}(\mathbb{A})+t^a(\bar{\mathbb{Y}}\gamma_it^a\mathbb{Y}) \;=\; (\partial^k-i\mathbb{A}^k)G_{ki}(\mathbb{A})\;+\;\frac2s\partial_*G_{\bullet i}(\mathbb{A})+\frac2s\partial_\bullet G_{*i}(\mathbb{A})\;+\big[\bar\Sigma^at^b\gamma_i\Sigma_b+\bar\Sigma^bt^b\gamma_i\Sigma_a\big]$$
$$=\;(\partial^k-iU^k-iV^k+i\Sigma^k)(i[U_i,V_k]+i[V_i,U_k]$$
$$+\,(\mathbb{D}_i\Sigma_k-i\leftrightarrow k)+i[\Sigma_i,\Sigma_k])\;-\big[\bar\Sigma^a(x_\bullet,x_\perp)t^b\gamma_i\Sigma_b(x_*,x_\perp)+\bar\Sigma^b(x_*,x_\perp)t^b\gamma_i\Sigma_a(x_\bullet,x_\perp)\big]+\big[\bar\Sigma^at^b\gamma_i\Sigma_b+\bar\Sigma^bt^b\gamma_i\Sigma_a\big]$$
$$=\;(\partial^k-i\mathbb{A}^k)G_{ki}(\mathbb{A})\;=\;i\mathbb{D}^{ab}_k([U_i,V^k]+i[V_i,U^k])^b\;+\;O(\partial_\perp^4) \tag{374}$$

СНА4АЛА δЕЗ КВАРКОВ (4 $\frac{1}{p_*p_\bullet}$ С Eq. (147))

$$A^{[2]}_\bullet(x)\;=\;\frac{1}{p_\parallel^2}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}\;=\;\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}\;=\;\frac{is}{4p_*p_\bullet}[V^i,U_{\bullet i}]\;=\;\frac i2\int_{-\infty}^{x_\bullet}dz_\bullet\;[U^i(x_*,x_\perp),V_i(z_\bullet,z_\perp)]$$
$$A^{[2]}_*(x)\;=\;\frac{1}{p_\parallel^2}\mathbb{D}^\mu\mathbb{G}_{\mu*}\;=\;\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu*}\;=\;\frac{is}{4p_*p_\bullet}[U^i,V_{\bullet i}]\;=\;\frac i2\int_{-\infty}^{x_*}dz_*\;[V^i(x_\bullet,x_\perp),U_i(z_*,z_\perp)]$$
$$A^{[3]a}_i(x)\;=\;\frac{1}{p_\parallel^2}\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+2i\frac{1}{p_\parallel^2}\mathbb{G}^{ab}_{*i}\frac{1}{p_\parallel^2}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+2i\frac{1}{p_\parallel^2}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_\parallel^2}\mathbb{D}^\mu\mathbb{G}^b_{\mu*}$$
$$=\;\frac{s}{4p_*p_\bullet}\mathbb{D}^k\mathbb{G}^a_{ki}+\frac{is^2}{8}\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\frac{is^2}{8}\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu*} \tag{375}$$

$$F^{[3]}_{\bullet i}\;=\;\partial_\bullet\frac{1}{p_\parallel^2}\mathbb{D}^\mu\mathbb{G}_{\mu i}-\mathbb{D}_i\frac{1}{p_\parallel^2}\mathbb{D}^j\mathbb{G}_{j\bullet}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}$$
$$=\;-\frac{is}{4p_*}\mathbb{D}^k\mathbb{G}_{ki}-\mathbb{D}_i\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}$$
$$\Rightarrow\;F_{\bullet i}(A)\;=\;\mathbb{G}_{\bullet i}+F^{[3]}_{\bullet i}\;=\;\mathbb{G}_{\bullet i}-\frac{is}{4p_*}\mathbb{D}^k\mathbb{G}_{ki}-\mathbb{D}_i\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}$$
$$=\;\mathbb{G}_{\bullet i}-\frac{is}{4p_*}\mathbb{D}^k\mathbb{G}_{ki}-\frac{s}{4p_*p_\bullet}\mathbb{D}_i\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}+\frac s4\frac{1}{p_*}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu*}-\frac s4\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}$$

$$\begin{aligned}
D_*F^a_{\bullet i}(A) \;&=\; \partial_*\mathbb{G}^a_{\bullet i}+\partial_*F^{[3]a}_{\bullet i}-iA^{[2]ab}_*\mathbb{G}^b_{\bullet i} \;=\; \partial_*F^{[3]a}_{\bullet i}+i\mathbb{G}^{ab}_{\bullet i}A^{[2]b}_* \\
=\;& -\frac{s}{4}\mathbb{D}^k\mathbb{G}^a_{ki}-\partial_*\mathbb{D}_i\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}-i\mathbb{G}^{ab}_{\bullet i}\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu *}-i\frac{s}{4}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+i\frac{s}{4}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu *} \\
=\;& -\frac{s}{4}\mathbb{D}^k\mathbb{G}^a_{ki}-\partial_*\mathbb{D}_i\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}-i\frac{s}{4}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet} \;=\; -\frac{s}{4}\mathbb{D}^k\mathbb{G}^a_{ki}+i\mathbb{D}_i\frac{s}{4p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet} \\
D_\bullet F^a_{*i}(A) \;&=\; -\frac{s}{4}\mathbb{D}^k\mathbb{G}^a_{ki}+i\mathbb{D}_i\frac{s}{4p_*}\mathbb{D}^\mu\mathbb{G}_{\mu *}
\end{aligned} \tag{376}$$

From Eq. (375)

$$\frac{s}{4p_*}\mathbb{D}^\mu\mathbb{G}_{\mu *}+\frac{s}{4p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet} \;=\; i\partial_*A^{[2]}_\bullet(x)+i\partial_\bullet A^{[2]}_*(x) \;=\; 0 \tag{377}$$

and therefore

$$\frac{2}{s}D_*F^a_{\bullet i}(A)+\frac{2}{s}D_\bullet F^a_{*i}(A)+\mathbb{D}^k\mathbb{G}^a_{ki} \;=\; i\mathbb{D}_i\Big(\frac{1}{2p_*}\mathbb{D}^\mu\mathbb{G}_{\mu *}+\frac{1}{2p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}\Big) \;=\; O(\partial_\perp^4)$$

$$\begin{aligned}
&-\frac{is}{4p_*}\mathbb{D}^k\mathbb{G}_{ki}-\mathbb{D}_i\frac{s}{4p_*p_\bullet}\mathbb{D}^\mu\mathbb{G}_{\mu\bullet} \\
&=\; \frac{s}{4p_*}(\partial^k-iU^k-iV^k)([U_i,V_k]+[V_i,U_k])-(p_i+U_i+V_i)\frac{s}{4p_*p_\bullet}[V^k,U_{\bullet k}] \\
&=\; -\frac{1}{2}\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet\;(i\partial^k+U^k+V^k)^{ab}([U_i,V_k]+[V_i,U_k])^b(x_*,z_\bullet)+\frac{1}{2}(i\partial_i+U_i(x)+V_i(x))^{ab}\int_{-\infty}^{x_\bullet} d\frac{2}{s}z_\bullet\;[V^k(z_\bullet),U_k(x_\bullet)]^b
\end{aligned} \tag{378}$$

C KBAPKAMU

$$\begin{aligned}
A^{[2]}_\bullet(x) \;&=\; \frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}+t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b)\big) \;=\; \frac{i}{2}\int_{-\infty}^{x_\bullet}dz_\bullet\;[U^i(x_*,x_\perp),V_i(z_\bullet,z_\perp)] \;+\; O(\partial_\perp^4) \\
A^{[2]}_*(x) \;&=\; \frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}_{\mu *}+t^a(\bar\Sigma_a\gamma_* t^a\Sigma_a)\big) \;=\; \frac{i}{2}\int_{-\infty}^{x_*}dz_*\;[V^i(x_\bullet,x_\perp),U_i(z_*,z_\perp)] \;+\; O(\partial_\perp^4) \\
A^{[3]a}_i(x) \;&=\; \frac{1}{p_\parallel^2}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)+2i\frac{1}{p_\parallel^2}\mathbb{G}^{ab}_{*i}\frac{1}{p_\parallel^2}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar\Sigma_b\gamma_\bullet t^b\Sigma_b\big)+2i\frac{1}{p_\parallel^2}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_\parallel^2}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu *}+\bar\Sigma_a\gamma_* t^b\Sigma_a\big) \\
&=\; \frac{s}{4p_*p_\bullet}\mathbb{D}^k\mathbb{G}^a_{ki}+\frac{is^2}{8}\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^b\mathbb{Y}\big)+\frac{is^2}{8}\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu *}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big)
\end{aligned} \tag{379}$$

gde wi uzd $\bar\Sigma_a\gamma_\bullet t^b\Sigma_a \;=\; \bar\Sigma_b\gamma_* t^b\Sigma_b \;=\; 0$

$$\begin{aligned}
&F^{[3]}_{\bullet i} \;= \\
&=\; -\frac{is}{4p_*}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\mathbb{D}_i\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}\big)+\frac{s}{4}\frac{1}{p_*}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu *}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big)+\frac{s}{4}\frac{1}{p_*}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^b\mathbb{Y}\big) \\
&\Rightarrow\; D_*F^a_{\bullet i}(A) \;=\; \partial_*\mathbb{G}^a_{\bullet i}+\partial_*F^{[3]a}_{\bullet i}-iA^{[2]ab}_*\mathbb{G}_{\bullet i} \;=\; -\partial_*\partial_\bullet\Sigma_i+\partial_*F^{[3]a}_{\bullet i}+i\mathbb{G}^{ab}_{\bullet i}A^{[2]b}_* \\
&=\; -\partial_*\bar\partial_\bullet\Sigma_i-\frac{s}{4}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\partial_*\mathbb{D}_i\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}\big)-i\mathbb{G}^{ab}_{\bullet i}\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu *}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big) \\
&-i\mathbb{G}^{ab}_{*i}\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^b\mathbb{Y}\big)+i\frac{s}{4}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu *}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big) \\
&=\; -\frac{s}{4}(\bar\Sigma^a t^a\gamma_i\Sigma_b+\bar\Sigma^b t^a\gamma_i\Sigma_a)-\frac{s}{4}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)+i\mathbb{D}_i\frac{s}{4p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}\big)
\end{aligned} \tag{380}$$

$$A^{[2]}_\bullet(x) = \frac{1}{p^2}\big(\mathbb{D}^\mu\mathbb{G}_{\mu\bullet} + t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b)\big) = i\int d^4z(x|\frac{1}{p^2}|z)\big([V^i,U_{\bullet i}] - [\Sigma^i,U_{\bullet i}] - [V^i,\partial_\bullet\Sigma_i] + [\Sigma^i,\partial_\bullet\Sigma_i]\big)$$
$$A^{[2]}_*(x) = \frac{1}{p^2}\big(\mathbb{D}^\mu\mathbb{G}_{\mu *} + t^a(\bar\Sigma_a\gamma_* t^a\Sigma_a)\big) = i\int d^4z(x|\frac{1}{p^2}|z)\big([U^i,V_{*i}] - [\Sigma^i,V_{*i}] - [U^i,\partial_*\Sigma_i] + [\Sigma^i,\partial_*\Sigma_i]\big)$$
$$A^{[3]a}_i(x) = \frac{1}{p^2}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i} + \bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big) + 2i\frac{1}{p^2}\mathbb{G}^{ab}_{*i}\frac{1}{p^2}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet} + \bar\Sigma_b\gamma_\bullet t^b\Sigma_b\big) + 2i\frac{1}{p^2}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p^2}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu *} + \bar\Sigma_a\gamma_* t^b\Sigma_a\big) \quad (381)$$

E. ЕЩЁ РАЗ: ПАРАМЕТР $\partial_\perp$

First approximation:

$$\mathbb{A}_\bullet = \mathbb{A}_* = 0, \quad \mathbb{A}_i = U_i + V_i, \quad G_{*\bullet}(\mathbb{A}) = 0,$$
$$G_{*i}(\mathbb{A}) = V_{*i}, \quad G_{\bullet i}(\mathbb{A}) = U_{\bullet i}, \quad G_{ik}(\mathbb{A}) = -i[U_i,V_k] - i[V_i,U_k]$$
$$\mathbb{Y} = \Sigma_a + \Sigma_b = \Sigma_a = [-\infty_\bullet, x_\bullet]^{\hat A_*}_x\xi_a(x), \quad \Sigma_b = [-\infty_*, x_*]^{\hat A_\bullet}_x\xi_b(x) \quad (382)$$

СВОЙСТВА САМОСОГЛАСОВАННОСТИ

$$\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y} = \bar\Sigma^b t^a\gamma_\bullet\Sigma_b, \quad \bar{\mathbb{Y}}\gamma_* t^a\mathbb{Y} = \bar\Sigma^a t^a\gamma_*\Sigma_a, \quad \bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y} = \bar\Sigma_a t^a\gamma_i\Sigma_b + \bar\Sigma_b t^a\gamma_i\Sigma_b,$$
$$\partial^i\mathbb{G}^a_{\bullet i} = \bar\Sigma_a\gamma_\bullet t^a\Sigma_a, \quad \partial^i\mathbb{G}^a_{*i} = \bar\Sigma_b\gamma_* t^a\Sigma_b \quad (383)$$

$$D^\mu G_{\mu i}(\mathbb{A}) = \frac{2}{s}\partial_* G_{\bullet i}(\mathbb{A}) + \frac{2}{s}\partial_\bullet G_{*i}(\mathbb{A}) + (\partial^k - i\mathbb{A}^k)G_{ki}(\mathbb{A}) = (\partial^k - i\mathbb{A}^k)G_{ki}(\mathbb{A}),$$
$$D^\mu G_{\mu\bullet}(\mathbb{A}) = -(\partial^i - i\mathbb{A}^i)G_{\bullet i}(\mathbb{A}), \quad D^\mu G_{\mu *}(\mathbb{A}) = -(\partial^i - i\mathbb{A}^i)G_{*i}(\mathbb{A}), \quad (384)$$

Sdvig $A\to A+\mathbb{A}$, $\psi\to\psi+\mathbb{Y}$ (bez surface terms):

$$\int d^4x\,\Big(-\frac{1}{4}[G_{\mu\nu}(A+\mathbb{A})]^2 + \frac{1}{2}(\mathbb{D}^\mu A_\mu)^2 + (\bar{\mathbb{Y}}+\bar\psi)(\hat{\mathbb{D}}+\hat A)(\mathbb{Y}+\psi)\Big)$$
$$= \int d^4x\,\Big(-\frac{1}{4}\mathcal{G}^2_{\mu\nu} + A^a_\alpha\big(\mathbb{D}_\mu\mathcal{G}^{a\mu\alpha} + \bar{\mathbb{Y}}\gamma_\alpha t^a\mathbb{Y}\big) + \bar\psi\hat{\mathbb{D}}\mathbb{Y} + \bar{\mathbb{Y}}\hat{\mathbb{D}}\psi + \frac{1}{2}A^a_\mu\big(\mathbb{D}^2 g^{\mu\nu} - 2i\mathcal{G}^{\mu\nu}\big)^{ab}A^b_\nu$$
$$- gf^{abc}A^{a\alpha}A^{b\beta}\mathbb{D}_\alpha A^c_\beta - \frac{g^2}{4}f^{abm}f^{cdm}A^{a\alpha}A^{b\beta}A^c_\alpha A^d_\beta + \bar\psi\hat A\psi\Big) \quad (385)$$

ИЩЕМ $\mathcal{C}$ and Υ ТАКИЕ ЧТО

$$\mathcal{C}(x)\Psi(y) = \int DAD\bar\psi D\psi\; A(x)\psi(y)e^{\int d^4x\,\left(-\frac{1}{4}[G_{\mu\nu}(A+\mathbb{A})]^2 + \frac{1}{2}(\mathbb{D}^\mu A_\mu)^2 + (\bar{\mathbb{Y}}+\bar\psi)(\hat{\mathbb{D}}+\hat A)(\mathbb{Y}+\psi)\right)} \quad (386)$$

ТОГДА $\mathcal{A} = \mathbb{A} + \mathcal{C}$ И $\Upsilon = \Psi + \mathbb{Y}$ - РЕШЕНИЕ УР-Й

$$\delta\Big\{\int d^4x\,\Big(-\frac{1}{4}[G_{\mu\nu}(A+\mathbb{A}+\mathcal{C})]^2 + \frac{1}{2}[\mathbb{D}^\mu(A_\mu+\mathcal{C}_\mu)]^2 + (\bar{\mathbb{Y}}+\bar\Psi+\bar\psi)(\hat{\mathbb{D}}+\hat{\mathcal{C}}+\hat A)(\mathbb{Y}+\Psi+\psi)\Big)\Big\} = 0$$
$$\Rightarrow \mathcal{D}^\mu\mathcal{G}^a_{\mu\nu} + \mathbb{D}_\nu\mathbb{D}^\mu\mathcal{C}^a_\mu + \bar\Upsilon\gamma_\nu t^a\Upsilon = 0, \quad \hat{\mathcal{D}}\Upsilon = 0 \quad (387)$$

НАДО ПРОВЕРИТ' $\mathbb{D}^\mu\mathcal{C}_\mu = 0$ (order by order?)

ЛИНЕЙНИЙ ЧЛЕН В ИНТЕГРАЛЕ (385)

$$D^\mu G_{\mu\bullet}(\mathbb{A}) + t^a(\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}) = -\partial^i G_{\bullet i}(\mathbb{A}) + i[\mathbb{A}^i, G_{\bullet i}(\mathbb{A})] + t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b) = i[V^i,U_{\bullet i}]$$
$$D^\mu G_{\mu *}(\mathbb{A}) + t^a(\bar{\mathbb{Y}}\gamma_* t^a\mathbb{Y}) = -\partial^i G_{*i}(\mathbb{A}) + i[\mathbb{A}^i, G_{*i}(\mathbb{A})] + t^a(\bar\Sigma_b\gamma_* t^a\Sigma_b) = i[U^i,V_{*i}]$$
$$D^\mu G_{\mu i}(\mathbb{A}) = -\mathbb{D}^k\mathbb{G}_{ik}(\mathbb{A}) = i(\partial^k - i[U_k+V_k)([U_i,V_k] + [V_i,U_k]) \quad (388)$$

ПОЛЕ $\mathcal{C}_\mu$

$$\mathcal{C}_\bullet \;=\; A^{[2]}_\bullet(x) \;=\; \frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}_{\mu\bullet}+t^a(\bar\Sigma_b\gamma_\bullet t^a\Sigma_b)\big) \;=\; \frac{i}{2}\int_{-\infty}^{x_\bullet}dz_\bullet\;[U^i(x_*,x_\perp),V_i(z_\bullet,z_\perp)] \;+\; O(\partial_\perp^4)$$
$$\mathcal{C}_* \;=\; A^{[2]}_*(x) \;=\; \frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}_{\mu*}+t^a(\bar\Sigma_a\gamma_* t^a\Sigma_a)\big) \;=\; \frac{i}{2}\int_{-\infty}^{x_*}dz_*\;[V^i(x_\bullet,x_\perp),U_i(z_*,z_\perp)] \;+\; O(\partial_\perp^4)$$
$$\mathcal{C}_i \;=\; A^{[3]a}_i(x) \;=\; \frac{1}{p_\parallel^2}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)+2i\frac{1}{p_\parallel^2}\mathbb{G}^{ab}_{*i}\frac{1}{p_\parallel^2}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar\Sigma_b\gamma_\bullet t^b\Sigma_b\big)+2i\frac{1}{p_\parallel^2}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_\parallel^2}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\bar\Sigma_a\gamma_* t^b\Sigma_a\big)$$
$$=\; \frac{s}{4p_*p_\bullet}\big(\mathbb{D}^k\mathbb{G}^a_{ki}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\frac{s^2}{8}\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}[V^j,U_{\bullet j}]^b-\frac{s^2}{8}\frac{1}{p_*p_\bullet}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}[U^j,V_{*j}]^b$$
$$=\; \frac{s}{4p_*p_\bullet}\big(\mathbb{D}^k\mathbb{G}^a_{ki}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-i\frac{s^2}{8}\frac{1}{p_*p_\bullet}V^{ab}_{*i}\frac{1}{p_*}[U^j,V_j]^b+i\frac{s^2}{8}\frac{1}{p_*p_\bullet}U^{ab}_{\bullet i}\frac{1}{p_\bullet}[U^j,V_j]^b \tag{389}$$

Check $\mathbb{D}^\mu\mathcal{C}_\mu=0$:

$$\frac{2}{s}\partial_*\mathcal{C}_\bullet+\frac{2}{s}\partial_\bullet\mathcal{C}_* \;=\; 0,\qquad \frac{2}{s}\partial_*\mathcal{C}_\bullet+\frac{2}{s}\partial_\bullet\mathcal{C}_*+\mathbb{D}^i\mathcal{C}_i \;=\; O(\partial_\perp^4) \tag{390}$$

$$F^{[3]}_{\bullet i} \;=\; \partial_\bullet A^{[3]}_i(x)-\mathbb{D}_iA^{[2]}_\bullet(x)$$
$$=\; -\frac{is}{4p_*}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\mathbb{D}_i\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}\big)+\frac{s}{4}\frac{1}{p_*}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big)+\frac{s}{4}\frac{1}{p_*}\mathbb{G}^{ab}_{*i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^b\mathbb{Y}\big)$$
$$=\; \frac{is}{4p_*}(\mathbb{D}^k\mathbb{G}^a_{ik}-\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y})+\mathbb{D}^{ab}_i\frac{s}{4p_*}[U^j,V_j]^b+\frac{s}{4}\frac{1}{p_*}U^{ab}_{\bullet i}\frac{1}{p_\bullet}[U^j,V_j]^b \tag{391}$$

$$D_*F^a_{\bullet i}(A) \;=\; \partial_*\mathbb{G}^a_{\bullet i}+\partial_*F^{[3]a}_{\bullet i}-iA^{[2]ab}_*\mathbb{G}_{\bullet i} \;=\; -\,\partial_*F^{[3]a}_{\bullet i}+i\mathbb{G}^{ab}_{\bullet i}A^{[2]b}_*$$
$$=\; -\frac{s}{4}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\partial_*\mathbb{D}_i\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}\big)-i\mathbb{G}^{ab}_{\bullet i}\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big)$$
$$-\,i\mathbb{G}^{ab}_{*i}\frac{s}{4p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^b\mathbb{Y}\big)+i\frac{s}{4}\mathbb{G}^{ab}_{\bullet i}\frac{1}{p_*p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^b_{\mu*}+\bar{\mathbb{Y}}\gamma_* t^b\mathbb{Y}\big)$$
$$=\; -\frac{s}{4}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)+i\mathbb{D}_i\frac{s}{4p_\bullet}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu\bullet}+\bar{\mathbb{Y}}\gamma_\bullet t^a\mathbb{Y}\big) \;=\; \frac{s}{4}(\mathbb{D}^k\mathbb{G}^a_{ik}-\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y})-\frac{is}{4}\mathbb{D}_i[U^j,V_j] \tag{392}$$

We get YM equation:

$$\mathcal{D}_*\mathcal{F}^a_{\bullet i} \;\equiv\; D_*F^a_{\bullet i}(\mathcal{A}) \;=\; -\frac{s}{4}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\frac{s}{4}\mathbb{D}_i[V^j,U_j] \;+\; O(\partial_\perp^4)$$
$$\mathcal{D}_\bullet\mathcal{F}^a_{*i} \;\equiv\; D_\bullet F^a_{*i}(\mathcal{A}) \;=\; -\frac{s}{4}\big(\mathbb{D}^\mu\mathbb{G}^a_{\mu i}+\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y}\big)-\frac{s}{4}\mathbb{D}_i[U^j,V_j] \;+\; O(\partial_\perp^4)$$
$$\Rightarrow\; \frac{2}{s}(\mathcal{D}_*\mathcal{F}^a_{\bullet i}+\mathcal{D}_\bullet\mathcal{F}^a_{*i}) \;=\; -\,\mathbb{D}^k\mathbb{G}^a_{ki}-\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y} \;+\; O(\partial_\perp^4) \;\Rightarrow\; \mathcal{D}^\mu\mathcal{F}_{\mu i} \;=\; -\,\bar{\mathbb{Y}}\gamma_i t^a\mathbb{Y} \;+\; O(\partial_\perp^4) \tag{393}$$

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$$(x|\frac{1}{p^2+i\epsilon}|z) \;=\; \frac{i}{4\pi}\ln[-(x-z)_*+i\epsilon(x-z)_\bullet]+\frac{i}{4\pi}\ln[(x-z)_\bullet-i\epsilon(x-z)_*]+\mathrm{const} \tag{394}$$

Cutoffs: we are solving YM equation in a region where $(x-z)_\perp^2\ll m_\perp^{-2}$ where $m_\perp^{-2}$ is a characteristic transverse size of $\bar A_*$ and/or $\bar A_\bullet$. Let a be the characteristic α's in $\bar A_\bullet$ and b be the characteristic β's in $\bar A_*$.

ТОГDA:

$$(x|\frac{1}{p^2+i\epsilon}|z) \;=\; \frac{i}{4\pi}\ln[-b(x-z)_*+i\epsilon(x-z)_\bullet]+\frac{i}{4\pi}\ln[a(x-z)_\bullet-i\epsilon(x-z)_*] \tag{395}$$

if $abs \gg m_\perp^2$ (see Eq. (416)) and

$$(x|\frac{1}{p^2+i\epsilon}|z) \;=\; \frac{i}{4\pi}\ln[-\frac{4}{s}(x-z)_*(x-z)_\bullet m_\perp^2+i\epsilon] \;=\; \frac{i}{4\pi}\ln[-\frac{2m_\perp}{\sqrt{s}}(x-z)_*+i\epsilon(x-z)_\bullet]+\frac{i}{4\pi}\ln[\frac{2m_\perp}{\sqrt{s}}(x-z)_\bullet-i\epsilon(x-z)_*] \tag{396}$$

if $abs \ll m_\perp^2$. so

$$\begin{aligned}(x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}\bar{P}_*|z) \;&=\; (x|\frac{1}{\bar{P}_\bullet+i\epsilon p_*}|z) \;=\; -\frac{(2\pi)^{-1}}{x_\bullet-z_\bullet-i\epsilon(x-z)_*}[x_*,z_*]^{A_\bullet}\\ (x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|z) \;&=\; (x|\frac{1}{\bar{P}_*+i\epsilon p_\bullet}|z) \;=\; -\frac{(2\pi)^{-1}}{x_*-z_*-i\epsilon(x-z)_\bullet}[x_\bullet,z_\bullet]^{A_*}\end{aligned} \tag{397}$$

(cf. Eq. (147)).

$$\begin{aligned}(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}|y) \;&=\; (x|\frac{1}{\bar{P}_*+i\epsilon p_\bullet}|z)(z|\frac{1}{\bar{P}_\bullet+i\epsilon p_*}|y) \;=\; \frac{1}{4\pi^2}\int dz\;\frac{[x_\bullet,z_\bullet]^{A_*}}{x_*-z_*-i\epsilon(x-z)_\bullet}\frac{[z_*,y_*]^{A_\bullet}}{z_\bullet-y_\bullet-i\epsilon(z-y)_*}\\ &=\; \frac{1}{4\pi^2}\int dz\;\Big(\frac{[x_\bullet,z_\bullet]^{A_*}}{x_*-z_*-i\epsilon}-2\pi i\theta(z-x)_\bullet\delta(x_*-z_*)\Big)\Big(\frac{[z_*,y_*]^{A_\bullet}}{z_\bullet-y_\bullet-i\epsilon}-2\pi i\theta(y-z)_*\delta(z_\bullet-y_\bullet)\Big)\\ (x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}|y) \;&=\; (x|\frac{1}{\bar{P}_\bullet+i\epsilon p_*}|z)(z|\frac{1}{\bar{P}_*+i\epsilon p_\bullet}|y) \;=\; \frac{1}{4\pi^2}\int dz\;\frac{[x_*,z_*]^{A_\bullet}}{x_\bullet-z_\bullet-i\epsilon(x-z)_*}\frac{[z_\bullet,y_\bullet]^{A_*}}{z_*-y_*-i\epsilon(z-y)_\bullet}\end{aligned} \tag{398}$$

ECΛU $\bar{A}_*(x_\bullet)\to 0$ ΠPU $x_\bullet\to\pm\infty$, TO

$$\begin{aligned}\bar{C}_*^{(1)}(x) \;&=\; -\frac{1}{2\pi s}\int dz_*dz_\bullet\;\frac{1}{x_\bullet-z_\bullet-i\epsilon(x-z)_*}[x_*,z_*]^{A_\bullet}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)][z_*,x_*]^{A_\bullet} \quad\Rightarrow\quad \bar{C}_*^{(1)}(x_*,x_\bullet=\pm\infty) \;=\; 0\\ \bar{C}_*^{(1)}(x_\bullet,x_*=\infty) \;&=?\; -\frac{1}{2\pi}\int dz_\bullet\;\frac{1}{x_\bullet-z_\bullet+i\epsilon}([\infty_*,-\infty_*]^{A_\bullet}-1)^{ab}\bar{A}_*^b(z_\bullet)\end{aligned} \tag{399}$$

OΠEPDEΛEHUE

$$\begin{aligned}A_\bullet^{(+)}(x_*) \;&=\; -\frac{i}{2\pi}\int dz_*\frac{1}{x_*-z_*-i\epsilon}A_\bullet(z_*), \qquad A_\bullet^{(-)}(x_*) \;=\; \frac{i}{2\pi}\int dz_*\frac{1}{x_*-z_*+i\epsilon}A_\bullet(z_*)\\ A_*^{(+)}(x_\bullet) \;&=\; -\frac{i}{2\pi}\int dz_\bullet\frac{1}{x_\bullet-z_\bullet-i\epsilon}A_*(z_\bullet), \qquad A_*^{(-)}(x_\bullet) \;=\; \frac{i}{2\pi}\int dz_\bullet\frac{1}{x_\bullet-z_\bullet+i\epsilon}A_*(z_\bullet)\end{aligned} \tag{400}$$

$$\begin{aligned}(\bar{A}_\bullet+\bar{C}_\bullet^{(1)})(x_*) \;&=\; \bar{A}_\bullet^{(+)}(x_*)+\frac{i}{2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet[\bar{A}_*(x'_\bullet),\bar{A}_\bullet^{(+)}(x_*)]+\bar{A}_\bullet^{(-)}(x_*)-\frac{i}{2}\int_{x_\bullet}^{\infty}d\frac{2}{s}x'_\bullet[\bar{A}_*(x'_\bullet),\bar{A}_\bullet^{(-)}(x_*)]\\ (\bar{A}_*+\bar{C}_*^{(1)})(x_\bullet) \;&=\; \bar{A}_*^{(+)}(x_\bullet)+\frac{i}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*[\bar{A}_\bullet(x'_*),\bar{A}_*^{(+)}(x_\bullet)]+\bar{A}_*^{(-)}(x_\bullet)-\frac{i}{2}\int_{x_*}^{\infty}d\frac{2}{s}x'_*[\bar{A}_\bullet(x'_*),\bar{A}_*^{(-)}(x_\bullet)]\end{aligned} \tag{401}$$

1. $F_{\bullet i}$

Solution of Eq. (217)

$$\bar{C}_i^a \;=\; -i\int d^4z\;\Lambda_x^{ab}(x|\frac{1}{p^2+i\epsilon}|z)\partial^2((\partial_i\Lambda^\dagger)\Lambda)^b = \;-\frac{4i}{s}\int d^4z\;\Lambda_x^{ab}(x|\frac{1}{p^2}|z)\partial_*\partial_\bullet((\partial_i\Lambda_z^\dagger)\Lambda_z)^b \tag{402}$$

$$\begin{aligned}\bar{C}_i^a \;&=\; -i\int d^4z\;\Lambda_x^{ab}(x|\frac{1}{p^2}|z)\partial^2((\partial_i\Lambda^\dagger)\Lambda)^b\\ &=\; -is\int d^4z\;\Lambda_x^{ab}(x|\frac{1}{p^2}|z)\frac{\partial}{\partial z_*}\frac{\partial}{\partial z_\bullet}((\partial_i\Lambda_z^\dagger)\Lambda_z)^b \;=\; (\Lambda i\partial_i\Lambda^\dagger)^a-\frac{4}{s}\Lambda_x^{ab}\int d^2z_\perp dz_\bullet(x|\frac{p_*}{p^2}|z)((\partial_i\Lambda_z^\dagger)\Lambda_z)^b\Big|_{z_*=-\infty}^{z_*=\infty}\\ &-\frac{4}{s}\Lambda_x^{ab}\int d^2z_\perp dz_*(x|\frac{p_\bullet}{p^2}|z)((\partial_i\Lambda_z^\dagger)\Lambda_z)^b\Big|_{z_\bullet=-\infty}^{z_\bullet=\infty}-2i\Lambda_x^{ab}\int d^2z_\perp(x|\frac{1}{p^2}|z)((\partial_i\Lambda_z^\dagger)\Lambda_z)^b\Big|_{z_*=-\infty}^{z_*=\infty}\Big|_{z_\bullet=\infty}^{z_\bullet=-\infty}\end{aligned} \tag{403}$$

Now

$$F^a_{\bullet i}(x) \;=\; \partial_\bullet\bar{C}^a_i - \partial_i(\bar{A}_\bullet+\bar{C}_\bullet)^a - i(\bar{A}+\bar{C})^{ab}_\bullet\bar{C}^b_i \;=\; \Lambda^{am}\partial_\bullet(\Lambda^{\dagger mb}\bar{C}^b_i) - i\partial_i(\Lambda\partial_\bullet\Lambda^\dagger)^a$$
$$= \; -\frac{4}{s}\Lambda^{ab}_x\int dz\;(x|\frac{p_\bullet}{p^2+i\epsilon}|z)\partial_*\partial_\bullet((\partial_i\Lambda^\dagger_z)\Lambda_z)^b - i\partial_i(\Lambda\partial_\bullet\Lambda^\dagger)^a \;=\; -\frac{4}{s}\Lambda^{ab}_x\int dz\;(x|\frac{p_\bullet}{p^2+i\epsilon}|z)\partial_*\Lambda^{\dagger bc}\partial_i(\Lambda_z\partial_\bullet\Lambda^\dagger_z)^c - i\partial_i(\Lambda\partial_\bullet\Lambda^\dagger)^a$$
$$= \; -\frac{4}{s}\Lambda^{ab}_x\int dz_*\;(x|\frac{p_\bullet}{p^2+i\epsilon}|z)\Lambda^{\dagger bc}_z\partial_i(\Lambda_z\partial_\bullet\Lambda^\dagger_z)^c\Big|^{z_\bullet=\infty}_{z_\bullet=-\infty} \;=\; -\frac{4}{s}\Lambda^{ab}_x\int dz_*\;(x|\frac{p_\bullet}{p^2+i\epsilon}|z)\partial_\bullet(\partial_i\Lambda^\dagger_z\Lambda_z)^b\Big|^{z_\bullet=\infty}_{z_\bullet=-\infty}$$
$$= \; \frac{1}{2\pi}\Lambda^{ab}_x\int dz_*\;\Big(\frac{1}{x_*-z_*+i\epsilon}\Lambda^{\dagger bc}_z\partial_i(\Lambda_z\partial_\bullet\Lambda^\dagger_z)^c\Big|_{z_\bullet=\infty} - \frac{1}{x_*-z_*-i\epsilon}\Lambda^{\dagger bc}_z\partial_i(\Lambda_z\partial_\bullet\Lambda^\dagger_z)^c\Big|_{z_\bullet=-\infty}\Big)$$
$$= \; \frac{1}{2\pi}\Lambda^{ab}_x\int dz_*\;\Big(\frac{1}{x_*-z_*+i\epsilon}\partial_\bullet(\partial_i\Lambda^\dagger_z\Lambda_z)^b\Big|_{z_\bullet=\infty} - \frac{1}{x_*-z_*-i\epsilon}\partial_\bullet(\partial_i\Lambda^\dagger_z\Lambda_z)^b\Big|_{z_\bullet=-\infty}\Big) \tag{404}$$

where we uzd eq. (218).

U ΠΟ∋TOMY

$$\int dx\;F^a_{\bullet i}(x)F^{ai}_*(x)$$
$$= \; -\int dz_\bullet\;\partial_*(\partial_i\Lambda^\dagger_z\Lambda_z)^a\Big|^{z_*=\infty}_{z_*=-\infty}\int dz'_*(z_*,z_\bullet|\frac{1}{p_*p_\bullet+i\epsilon}|z'_*,z'_\bullet)\partial_\bullet(\partial_i\Lambda^\dagger_z\Lambda_z)^a\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty} \tag{405}$$

2. *Action*

$\bar{A}+\bar{C}\equiv\mathcal{A},\qquad \chi+\xi\equiv\Upsilon$

$$\int d^4x\Big(-\frac{1}{4}[G^a_{\mu\nu}(A+\bar{A})]^2 - \frac{1}{2}[(\bar{D}_\mu - i\bar{C}_\mu)A^\mu]^2) + (\bar{\psi}+\bar{\Upsilon})(\hat{\mathcal{P}}+\hat{A})(\psi+\Upsilon)\Big)$$
$$\Rightarrow\;\int d^4x\Big(-\frac{1}{4}[G^a_{\mu\nu}(A+\mathcal{A})]^2 - \frac{1}{2}(\mathbb{D}^\mu A_\mu + \bar{D}^\mu\bar{C}_\mu)^2 + \bar{\Upsilon}(\hat{\mathcal{P}}+\hat{A})\Upsilon\Big)$$
$$= \;\int d^4x\Big(-\frac{1}{4}(\mathcal{G}^a_{\mu\nu})^2 - \mathcal{G}^a_{\mu\nu}\mathcal{D}^\mu A^{a\nu} - A^{a\mu}\frac{1}{2}(\mathcal{D}^2g_{\mu\nu} - 2i\mathcal{G}_{\mu\nu})^{ab}A^{b\nu} - (\mathcal{D}^\mu A^a_\mu)\bar{D}^\nu\bar{C}^a_\nu - \frac{1}{2}(\bar{D}^\mu\bar{C}^a_\mu)^2 + (\bar{\psi}+\bar{\Upsilon})(\hat{\mathcal{P}}+\hat{A})(\psi+\Upsilon)\Big)$$
$$= \;\int d^4x\Big(-\frac{1}{4}(\mathcal{G}^a_{\mu\nu})^2 - \frac{1}{2}(\bar{D}^\mu\bar{C}^a_\mu)^2 + A^{a\nu}(\mathcal{D}^\mu\mathcal{G}^a_{\mu\nu} + \mathcal{D}^\nu\bar{D}^\mu\bar{C}^a_\mu) - A^{a\mu}\frac{1}{2}(\mathcal{D}^2g_{\mu\nu} - 2i\mathcal{G}_{\mu\nu})^{ab}A^{b\nu} + (\bar{\psi}+\bar{\Upsilon})(\hat{\mathcal{P}}+\hat{A})(\psi+\Upsilon)\Big)$$
$$-\;\int d\frac{2}{s}x_*\;dx_\perp\;(\mathcal{G}^a_{\bullet\mu}A^{a\mu} + A^a_\bullet\bar{D}^\mu\bar{C}^a_\mu)\Big|^{x_\bullet=\infty}_{x_\bullet=-\infty} - \int d\frac{2}{s}x_\bullet\;dx_\perp\;(\mathcal{G}^a_{*\mu}A^{a\mu} + A^a_*\bar{D}^\mu\bar{C}^a_\mu)\Big|^{x_*=\infty}_{x_*=-\infty} \tag{406}$$

Classical equations: $\hat{\mathcal{P}}\Upsilon \;\equiv\; (\bar{P}+\bar{C})(\xi+\chi) \;=\; 0$ and

$$\mathcal{D}^\mu\mathcal{G}^a_{\mu\nu} + \mathcal{D}^\nu\bar{D}^\mu\bar{C}^a_\mu + \bar{\Upsilon}t^a\gamma_\nu\Upsilon \;=\; 0$$
$$\Leftrightarrow\quad (\bar{P}^2g_{\alpha\mu} + 2i\bar{G}_{\alpha\mu})^{ab}\bar{C}^{c\mu} \;=\; \bar{D}^\mu\bar{G}^a_{\mu\alpha} + f^{abc}\bar{C}^{b\mu}(2\bar{D}_\mu\bar{C}^c_\alpha - \bar{D}_\alpha\bar{C}_\mu)^c + f^{abm}f^{cdm}\bar{C}^{b\mu}\bar{C}^c_\mu\bar{C}^d_\alpha + \bar{\Upsilon}t^a\gamma_\alpha\Upsilon \tag{407}$$

which coincides with Eqs. (160).

The action from Eq. (259) has the form

$$\int d^4x\big(-\frac{1}{4}(\mathcal{G}^a_{\mu\nu})^2 - \frac{1}{2}(\bar{D}^\mu\bar{C}^a_\mu)^2\big) \tag{408}$$

$$(\bar{P}^2g_{\alpha\beta} + 2ig\bar{G}_{\alpha\beta})^{ab}\bar{C}^{b\beta} \;=\; \bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha} + gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha - \bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}) - g^2f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta + (\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)$$
$$(\hat{\bar{P}}+\hat{\bar{C}})(\xi+\chi) \;=\; 0,\qquad (\bar{\xi}+\bar{\chi})(\hat{\bar{P}}+\hat{\bar{C}}) \;=\; 0 \tag{409}$$

3. *Self-consistency of $\bar{D}^\mu\bar{C}_\mu = 0$*

$$\mathcal{D}^\mu\mathcal{G}^a_{\mu\alpha} \;=\; (\bar{D}^\mu - i\bar{C}^\mu)^{ab}(\bar{G}^b_{\mu\alpha} + \bar{D}_\mu\bar{C}^b_\alpha - \bar{D}_\alpha\bar{C}^b_\mu + f^{bmn}\bar{C}^m_\mu\bar{C}^n_\alpha)$$
$$= \;\bar{D}^\mu\bar{G}^a_{\mu\alpha} + (\bar{D}^2g_{\alpha\mu} - 2i\bar{G}_{\alpha\mu})^{ab}\bar{C}^{c\mu} + f^{abk}f^{mnk}\bar{C}^{\mu b}\bar{C}^m_\mu\bar{C}^n_\alpha + f^{amn}\bar{C}^m_\mu(\bar{D}^\mu\bar{C}_\alpha - \bar{D}_\alpha C^\mu)^n$$
$$\Rightarrow\;(\bar{P}^2g_{\alpha\mu} + 2i\bar{G}_{\alpha\mu})^{ab}\bar{C}^{c\mu} \;=\; \bar{D}^\mu\bar{G}^a_{\mu\alpha} + f^{abc}\bar{C}^b_\mu(\bar{D}^\mu\bar{C}^c_\alpha - \bar{D}_\alpha\bar{C}^{\mu c}) + f^{abm}f^{cdm}\bar{C}^{b\mu}\bar{C}^c_\mu\bar{C}^d_\alpha + f^{abc}\bar{C}^b_\alpha\bar{D}^\mu\bar{C}^c_\mu + \bar{\Upsilon}t^a\gamma_\alpha\Upsilon$$
$$\Leftrightarrow\;(\bar{P}^2g_{\alpha\mu} + 2i\bar{G}_{\alpha\mu})^{ab}\bar{C}^{c\mu} \;=\; \bar{D}^\mu\bar{G}^a_{\mu\alpha} + f^{abc}\bar{C}^{b\mu}(2\bar{D}_\mu\bar{C}^c_\alpha - \bar{D}_\alpha\bar{C}^c_\mu) + f^{abm}f^{cdm}\bar{C}^{b\mu}\bar{C}^c_\mu\bar{C}^d_\alpha + \bar{\Upsilon}t^a\gamma_\alpha\Upsilon \tag{410}$$

A. Iz $\bar{D}^{\mu}\bar{C}_{\mu}$ zero?

$$
\begin{aligned}
\bar{C}^{a\mu} &= \big(\frac{1}{\bar{P}^2 g_{\mu\alpha}+2ig\bar{G}_{\mu\alpha}}\big)^{ma}\Big(\bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha}+gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-g^2f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)\Big)\\
\Rightarrow\ \bar{D}_\mu\bar{C}^{m\mu} &= \big(\frac{1}{\bar{P}^2}\bar{D}^\alpha\big)^{ma}\Big(\bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha}+gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-g^2f^{abn}f^{cdn}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)\Big)\\
&- i\big(\frac{1}{\bar{P}^2}\bar{D}^\lambda\bar{G}_{\lambda\rho}\frac{1}{\bar{P}^2 g_{\rho\alpha}+2i\bar{G}_{\rho\alpha}}\big)^{ma}\Big(\bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha}+gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-g^2f^{abn}f^{cdn}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)\Big)\\
&= \big(\frac{1}{\bar{P}^2}\big)^{mn}\Big[gf^{nbc}\Big(2\bar{D}^\alpha\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha+2\bar{C}^b_\beta\bar{D}^\alpha\bar{D}^\beta\bar{C}^c_\alpha-\bar{D}^\alpha\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta}-\bar{C}^b_\beta\bar{D}^2\bar{C}^{c\beta}-g^2f^{nbl}f^{cdl}\bar{D}^\alpha\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta\Big)\\
&- g^2f^{nbl}f^{cdl}\bar{C}^{b\beta}(\bar{D}^\alpha\bar{C}^c_\alpha\bar{C}^d_\beta+\bar{C}^c_\alpha\bar{D}^\alpha\bar{C}^d_\beta)+(\bar{\xi}+\bar{\chi})(\overleftarrow{\hat{\bar{D}}}\,t^n+t^n\hat{\bar{D}})(\xi+\chi)\Big] \qquad (411)\\
&- i\big(\frac{1}{\bar{P}^2}\bar{D}^\lambda\bar{G}_{\lambda\rho}\frac{1}{\bar{P}^2 g_{\rho\alpha}+2i\bar{G}_{\rho\alpha}}\big)^{ma}\Big(\bar{D}^{ab\xi}\bar{G}^b_{\xi\alpha}+gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\alpha-\bar{C}^b_\beta\bar{D}_\alpha\bar{C}^{c\beta})-g^2f^{abn}f^{cdn}\bar{C}^{b\beta}\bar{C}^c_\alpha\bar{C}^d_\beta+(\bar{\xi}+\bar{\chi})\gamma_\alpha t^a(\xi+\chi)\Big)
\end{aligned}
$$

where wi uzd Eq. (54)

1. *Two $\partial_\perp$'s, one $\bar{A}_\bullet$ and one $\bar{A}_*$*

$$
\begin{aligned}
\bar{C}^{1a}_i(x) &= \frac{2}{s}\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)(\bar{D}_*\bar{G}^a_{\bullet i}(z)+\bar{D}_\bullet\bar{G}^a_{*i}(z)) = -\frac{2}{s}f^{abc}\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)(A^b_\bullet\partial_iA^c_*+A^b_*\partial_iA^c_\bullet)\\
F^{(1)}_{\bullet i}(x) &= -\int dz\ (x|\frac{1}{p_*+i\epsilon}|z)\bar{A}^{ab}_*\bar{G}^b_{\bullet i}(z) \ \Rightarrow\ \partial^iF^{(1)}_{\bullet i} = \int dz\ (x|\frac{1}{p_*+i\epsilon}|z)\bar{G}^{ab}_{*i}\bar{G}^{bi}_\bullet(z)-\int dz\ (x|\frac{1}{p_*+i\epsilon}|z)\bar{A}^{ab}_*\partial^i\bar{G}^b_{\bullet i}(z)\\
\bar{c}^a_*(x) &= -\int dz(x|\frac{1}{p^2+i\epsilon p_0}|z)\partial^2_\perp\bar{C}_\bullet(z)\\
\bar{D}_*\bar{c}^a_\bullet(x) &= \frac{s}{8}\int dz(x|\frac{1}{p_\bullet+i\epsilon p_0}|z)\partial^2_\perp\frac{1}{\bar{P}_*+i\epsilon}\bar{G}_{*\bullet}(z) \simeq \frac{s}{8}\int dz(x|\frac{1}{(p_\bullet+i\epsilon)(p_*+i\epsilon)}|z)\partial^2_\perp\bar{G}_{*\bullet}(z) \qquad (412)
\end{aligned}
$$

B. Λ do $\bar{A}^2$

ПОПЫТКА

$$
\Lambda i\partial_\bullet\Lambda^\dagger(x_*,x_\bullet) \qquad (413)
$$

$$
\begin{aligned}
&= \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}^{(+)}_\bullet(x'_*)-i\int_{x_*}^{\infty}d\frac{2}{s}x'_*\bar{A}^{(-)}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}^{(+)}_\bullet(x'_*)+\int_{x_*}^{\infty}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}^{(-)}_\bullet(x'_*)\\
&\quad+\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{x'_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}^{(+)}_\bullet(x'_*)-\int_{x_*}^{\infty}d\frac{2}{s}x'_*\int_{x'_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}^{(-)}_\bullet(x'_*)\Big]\\
&\times i\partial_\bullet\Big[1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}^{(+)}_\bullet(x'_*)+i\int_{x_*}^{\infty}d\frac{2}{s}x'_*\bar{A}^{(-)}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}^{(+)}_\bullet(x'_*)+\int_{x_*}^{\infty}d\frac{2}{s}x'_*\int_{-\infty}^{x'_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}^{(-)}_\bullet(x'_*)\\
&\quad+\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{x'_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}^{(+)}_\bullet(x'_*)-\int_{x_*}^{\infty}d\frac{2}{s}x'_*\int_{x'_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}^{(-)}_\bullet(x'_*)\Big]\\
&= \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}^{(+)}_\bullet(x'_*)-i\int_{x_*}^{\infty}d\frac{2}{s}x'_*\bar{A}^{(-)}_\bullet(x'_*)\Big]\Big[\bar{A}_\bullet(x_*)\\
&- i\int_{-\infty}^{x_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}^{(+)}_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}^{(-)}_\bullet(x_*)+\ i\int_{x_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}^{(+)}_\bullet(x_*)+i\int_{x_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}^{(-)}_\bullet(x_*)\Big]\\
&= \Big[1+i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}^{(+)}_\bullet(x'_*)-i\int_{x_*}^{\infty}d\frac{2}{s}x'_*\bar{A}^{(-)}_\bullet(x'_*)\Big]\Big[\bar{A}_\bullet(x_*)-i\int_{-\infty}^{x_*}d\frac{2}{s}x''_*\bar{A}^{(+)}_\bullet(x''_*)\bar{A}_\bullet(x_*)+\ i\int_{x_*}^{\infty}d\frac{2}{s}x''_*\bar{A}^{(-)}_\bullet(x''_*)\bar{A}_\bullet(x_*)\Big] = \bar{A}_\bullet(x_*)
\end{aligned}
$$

$\Lambda^\dagger = \Omega^\dagger(1+\delta\lambda)$

$$\Lambda i\partial_\bullet\Lambda^\dagger(x_*,x_\bullet) ~=~ (1-\delta\lambda)\Omega i\partial_\bullet\Omega^\dagger(1+\delta\lambda) ~=~ \bar{A}_\bullet+\bar{C}_\bullet+(i\partial_\bullet+[\bar{A}_\bullet+\bar{C}_\bullet,)\delta\lambda \tag{414}$$
$$=~ \bar{A}_\bullet-\frac{i}{2}\int d^2z~(x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}|z)^{ab}\bar{G}^b_{*\bullet}(z)+(i\partial_\bullet+[\bar{A}_\bullet+\bar{C}_\bullet,)\delta\lambda ~=~ \bar{A}_\bullet-\frac{i}{2}\int d^2z~(x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}|z)^{ab}\bar{G}^b_{*\bullet}(z)$$
$$\Rightarrow~\bar{P}_\bullet\delta\lambda^a ~=~ \frac{i}{2}\int d^2z~(x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon p_0}-\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}|z)^{ab}\bar{G}^b_{*\bullet}(z)$$
$$\Rightarrow~\delta\lambda ~=~ \frac{2}{s}\int d^2z~(x|\frac{1}{p^2+i\epsilon p_0}-\frac{1}{p^2+i\epsilon}|z)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\int d^2z~(x|\delta(p_\bullet)\frac{1}{p_*}|z)\big(c_1\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+c_2\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)$$

$$\delta\lambda ~=~ -i\frac{2}{s}\int d^2z~(x|2\pi\delta(p^2)\theta(-p_0)|z)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)] ~=~ \frac{i}{2\pi s}\int d^2z~\ln\big(-\frac{4}{s}(x-z)_*(x-z)_\bullet-i\epsilon(x-z)_0\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)] \tag{415}$$
$$=~\frac{i}{\pi s^2}\int dz_*dz_\bullet~\big\{\ln\big(-(x-z)_*-i\epsilon\big)+\ln\big((x-z)_\bullet+i\epsilon\big)\big\}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\int d^2z~(x|\delta(p_*)\frac{1}{p_\bullet}|z)\big(d_1\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+d_2\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)$$

Cutoffs:

$$\delta\lambda ~=~ -i\frac{2}{s}\int d^2z~(x|2\pi\delta(p^2)\theta(-p_0)|z)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)] ~=~ -i\int d^2z\int d\!\!\!{}^-\alpha d\!\!\!{}^-\beta~e^{-i\alpha(x-z)_\bullet-i\beta(x-z)_*}2\pi\delta(\alpha\beta s)\theta(-p_0)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$
$$=~-\frac{2\pi i}{s}\int d^2z\int d\!\!\!{}^-\alpha d\!\!\!{}^-\beta~e^{i\alpha(x-z)_\bullet+i\beta(x-z)_*}\Big(\frac{\theta(\beta)}{\beta}\delta(\alpha)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\frac{\theta(\alpha)}{\alpha}\delta(\beta)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\frac{\theta(\alpha)}{\alpha}\delta(\beta)X3\Big)$$
$$=~-\frac{2i}{s^2}\int dz_\bullet dz_*\int_a^\infty\frac{d\!\!\!{}^-\alpha}{\alpha}~e^{i\alpha(x-z)_\bullet}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{2i}{s^2}\int dz_\bullet dz_*\int_b^\infty\frac{d\!\!\!{}^-\beta}{\beta}~e^{i\beta(x-z)_*}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$
$$=~\frac{i}{\pi s^2}\int dz_*dz_\bullet~\big\{\ln b(x_*-z_*+i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\ln a(x_\bullet-z_\bullet+i\epsilon)\big([\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+X3\big)\big\} \tag{416}$$

Similarly

$$\delta\lambda ~=~$$
$$=~\frac{i}{\pi s^2}\int dz_*dz_\bullet~\big\{-\ln a(x_\bullet-z_\bullet+i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\ln b(x_*-z_*+i\epsilon)\big([\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+X3'\big)\big\} \tag{417}$$

Guess

$$\delta\lambda ~=~ \frac{i}{\pi s^2}\int dz_*dz_\bullet~\big\{-\ln a(x_\bullet-z_\bullet+i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\ln b(x_*-z_*+i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]\big\} \tag{418}$$

И ТОГДА

$$\Omega^\dagger(1+\delta\lambda) ~=~ 1-\frac{2}{s^2}\int_{-\infty}^{x_*}dz_*\int_{-\infty}^{x_\bullet}dz_\bullet\big(\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)+\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)\big) \tag{419}$$
$$+~\frac{i}{\pi s^2}\int dz_*dz_\bullet~\big\{-\ln a(x_\bullet-z_\bullet+i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\ln b(x_*-z_*+i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]\big\} \tag{420}$$

$$\ln(x_\bullet-z_\bullet-i\epsilon(x-z)_*) ~=~ \ln(x_\bullet-z_\bullet+i\epsilon)-2\pi i\theta(x_*-z_*)\theta(z_\bullet-x_\bullet)$$
$$\ln\big(-(x-z)_\bullet+i\epsilon(x-z)_*\big) ~=~ \ln(-x_\bullet+z_\bullet-i\epsilon)+2\pi i\theta(x_*-z_*)\theta(x_\bullet-z_\bullet) \tag{421}$$

$\Rightarrow$

$$\Omega^\dagger(1+\delta\lambda) ~=~ 1-\frac{2}{s^2}\int_{-\infty}^{x_*}dz_*\int_{-\infty}^{x_\bullet}dz_\bullet\big(\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)+\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)\big) \tag{422}$$
$$+~\frac{i}{\pi s^2}\int dz_*dz_\bullet~\big\{-\ln a(x_\bullet-z_\bullet+i\epsilon)\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+\ln a(x_\bullet-z_\bullet+i\epsilon)\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)+2\pi i\theta(x_*-z_*)\theta(x_\bullet-z_\bullet)\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)$$
$$+\ln b(x_*-z_*+i\epsilon)\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)-\ln b(x_*-z_*+i\epsilon)\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)+2\pi i\theta(x_*-z_*)\theta(x_\bullet-z_\bullet)\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)\big\} \tag{423}$$

ЕЩЁ ПОПЫТКА:

$$\Lambda^\dagger(x_*,x_\bullet) ~=~ \Lambda_{(1)}(1+\delta\lambda) ~=~ 1-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z_\bullet\bar{A}_*(z_\bullet)-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)+\delta\lambda \tag{424}$$

$$\Lambda i\partial_\bullet\Lambda^\dagger(x_*,x_\bullet) \;=\; (1-\delta\lambda)\Lambda_{(1)}i\partial_\bullet\Lambda^\dagger_{(1)}(1+\delta\lambda) \;=\; \bar{A}_\bullet+\frac{2i}{s}\int_{-\infty}^{x_\bullet}dz_\bullet\bar{A}_*(z_\bullet)\bar{A}_\bullet(x_*)+i\partial_\bullet\delta\lambda \;=\; \bar{A}_\bullet-\frac{i}{2}\int d^2z\;(x|\bar{P}_\bullet\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}|z)^{ab}\bar{G}^b_{*\bullet}(z)$$

$$\Rightarrow\; i\partial_\bullet\delta\lambda \;=\; -\frac{2}{s}\int d^2z\;(x|\frac{p_\bullet}{p^2+i\epsilon}|z)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{2i}{s}\int_{-\infty}^{x_\bullet}dz_\bullet\bar{A}_*(z_\bullet)\bar{A}_\bullet(x_*)$$

$$=\;\frac{1}{4\pi}\int d^2z\;\frac{1}{x_*-z_*-i\epsilon(x-z)_\bullet}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{2i}{s}\int_{-\infty}^{x_\bullet}dz_\bullet\bar{A}_*(z_\bullet)\bar{A}_\bullet(x_*)\;=$$

$$\Rightarrow\;\delta\lambda \;=\; -\frac{2}{s}\int d^2z\;(x|\frac{1}{p^2+i\epsilon}|z)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{4}{s^2}\int_{-\infty}^{x_\bullet}dz_\bullet\int_{\pm\infty}^{x_*}dz_*\;\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+f(x_\bullet)$$

$$=\;-\frac{i}{2\pi s}\int d^2z\;\ln(-a(x-z)_\bullet+i\epsilon(x-z)_*)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{i}{2\pi s}\int d^2z\;\ln(-a(x-z)_*+i\epsilon(x-z)_\bullet)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$

$$+\int d^2z\;(x|\delta(p_\bullet)\frac{1}{p_*}|z)\big(c_1\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+c_2\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)-\frac{4}{s^2}\int_{-\infty}^{x_\bullet}dz_\bullet\int_{-\infty}^{x_*}dz_*\;\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)$$

$$=\;-\frac{i}{2\pi s}\int d^2z\;\ln(-a(x-z)_\bullet-i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{i}{2\pi s}\int d^2z\;\ln(-a(x-z)_*-i\epsilon[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$

$$+\int d^2z\;\{(x|\delta(p_\bullet)\frac{1}{p_*}|z)\big(c_1\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+c_2\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)-\frac{1}{s}\theta(x_*-z_*)\theta(x_\bullet-z_\bullet)\big(\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)\}$$

Similarly

$$\Lambda i\partial_*\Lambda^\dagger(x_*,x_\bullet) \;=\; (1-\delta\lambda)\Lambda_{(1)}i\partial_*\Lambda^\dagger_{(1)}(1+\delta\lambda) \;=\; \bar{A}_*+(i\partial_*+[\bar{A}_*,)\delta\lambda \;=\; \bar{A}_*+\frac{i}{2}\int d^2z\;(x|\bar{P}_*\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}|z)^{ab}\bar{G}^b_{*\bullet}(z)$$

$$\Rightarrow\;\delta\lambda \;=\; \frac{i}{2\pi s}\int d^2z\;\ln(-a(x-z)_\bullet-i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+\frac{i}{2\pi s}\int d^2z\;\ln(-a(x-z)_*-i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$

$$+\int d^2z\;\{(x|\delta(p_*)\frac{1}{p_\bullet}|z)\big(c_2\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+c_1\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)-\frac{1}{s}\theta(x_*-z_*)\theta(x_\bullet-z_\bullet)\big(\bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*)+\bar{A}_\bullet(z_*)\bar{A}_*(z_\bullet)\big)\}$$

$\Rightarrow$ (cf. Eq. (184)

$$\delta\lambda \;=\; \frac{i}{2\pi s}\int d^2z\;\Big[\big(\ln[-a(x-z)_\bullet-i\epsilon]-\ln[-b(x-z)_*-i\epsilon]\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]+2\pi i\theta(x_*-z_*)\theta(x_\bullet-z_\bullet)\big\{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\big\}\Big]$$

$$=\;\delta\omega+\frac{i}{2\pi s}\int d^2z\;\Big[\big(\ln[-a(x-z)_\bullet-i\epsilon]-\ln[-b(x-z)_*-i\epsilon]\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]\qquad(425)$$

Chek

$$\Lambda^{(1)}_\bullet(x) \;=\; \bar{C}^{(1)}_\bullet(x) \;=\; -\frac{2}{s}\int d^2z(x|\frac{p_\bullet}{p^2+i\epsilon}|z)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)] \;=\; \frac{1}{2\pi s}\int dz_*dz_\bullet\;[x_\bullet,z_\bullet]^{A_*}\frac{[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]}{x_*-z_*-i\epsilon(x-z)_\bullet}[z_\bullet,x_\bullet]^{A_*},$$

$$\Lambda^{(1)}_*(x) \;=\; \bar{C}^{(1)}_*(x) \;=\; -\frac{1}{2\pi s}\int dz_*dz_\bullet\;\frac{1}{x_\bullet-z_\bullet-i\epsilon(x-z)_*}[x_*,z_*]^{A_\bullet}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)][z_*,x_*]^{A_\bullet}\qquad(426)$$

$$\bar{C}^{(1)}_\bullet(x) \;=\; \frac{2i}{s}\int_{-\infty}^{x_\bullet}dz_\bullet\bar{A}_*(z_\bullet)\bar{A}_\bullet(x_*)+i\partial_\bullet\delta\lambda\qquad(427)$$

$$=\;\frac{2i}{s}\int_{-\infty}^{x_\bullet}dz_\bullet\bar{A}_*(z_\bullet)\bar{A}_\bullet(x_*)+\frac{1}{4\pi}\int d^2z\;\frac{1}{(x-z)_*+i\epsilon}[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\frac{i}{s}\int_{-\infty}^{x_\bullet}dz_\bullet\{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\}\;=\;\text{r.h.s. of Eq. (426)}$$

C. Λ do $\bar{A}^3$

$$\Lambda \;=\; \Omega M \;\;\Rightarrow\;\; \Lambda_\mu \;=\; i\Lambda\partial_\mu\Lambda^\dagger \;=\; i\Omega M\partial_\mu M^\dagger\Omega^\dagger \;=\; i\Omega\partial_\mu\Omega^\dagger+\Omega i(M\partial_\mu M^\dagger)\Omega^\dagger\Rightarrow\; iM\partial_\mu M^\dagger \;=\; \Omega^\dagger(\Lambda_\mu-\Omega_\mu)\Omega\qquad(428)$$

1. do $\bar{A}^2$

$$\Lambda_\bullet - \Omega_\bullet \;=\; -\frac{i}{2}\int d\frac{2}{s}z_\bullet \,\Big(\theta(x_\bullet - z_\bullet)[\bar{A}_*(z_\bullet), \bar{A}_\bullet(x_*)] + \frac{i}{2\pi}\int dz_* \,\frac{1}{x_* - z_* - i\epsilon(x-z)_\bullet}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]\Big) \tag{429}$$
$$=\; \frac{1}{4\pi}\int d\frac{2}{s}z_\bullet dz_* \frac{1}{x_* - z_* + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)] \qquad \Rightarrow \qquad i\frac{s}{2}\frac{\partial}{\partial x_*}M^\dagger \;=\; \frac{1}{4\pi}\int d\frac{2}{s}z_\bullet dz_* \frac{1}{x_* - z_* + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]$$

Similarly,

$$\Lambda_* - \Omega_* \;=\; \frac{-1}{4\pi}\int d\frac{2}{s}z_\bullet dz_* \frac{1}{x_\bullet - z_\bullet + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)] \qquad \Rightarrow \qquad i\frac{s}{2}\frac{\partial}{\partial x_\bullet}M^\dagger \;=\; -\frac{1}{4\pi}\int d\frac{2}{s}z_\bullet dz_* \frac{1}{x_\bullet - z_\bullet + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)] \tag{430}$$

$\Rightarrow$

$$M^\dagger - 1 \;=\; \frac{i}{2\pi s}\int d^2z \,\Big(\ln[-a(x-z)_\bullet - i\epsilon] - \ln[-b(x-z)_* - i\epsilon]\Big)[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)] \tag{431}$$

2. do $\bar{A}^3$

$$\Lambda_\bullet - \Omega_\bullet \;=\; -\frac{i}{2}\int d\frac{2}{s}z_\bullet \;[x_\bullet, z_\bullet]^{A_*}\Big(\theta(x_\bullet - z_\bullet)[\bar{A}_*(z_\bullet), \bar{A}_\bullet(x_*)] + \frac{i}{2\pi}\int dz_* \,\frac{1}{x_* - z_* - i\epsilon(x-z)_\bullet}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]\Big)[z_\bullet, x_\bullet]^{A_*}$$
$$=\; \frac{1}{4\pi}\int d\frac{2}{s}z_\bullet dz_* \;[x_\bullet, z_\bullet]^{A_*}\frac{1}{x_* - z_* + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)][z_\bullet, x_\bullet]^{A_*}$$
$$\Rightarrow\; iM\partial_\bullet M^\dagger \;=\; \frac{1}{4\pi}\Big[1 - i\int_{-\infty}^{x_\bullet} d\frac{2}{s}z'_\bullet \bar{A}_*(z'_\bullet) - i\int_{-\infty}^{x_*} d\frac{2}{s}z'_* \bar{A}_\bullet(z'_*)\Big]\;\int d\frac{2}{s}z_\bullet dz_*$$
$$[x_\bullet, z_\bullet]^{A_*}\;\frac{1}{x_* - z_* + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)][z_\bullet, x_\bullet]^{A_*}\Big[1 + i\int_{-\infty}^{x_\bullet} d\frac{2}{s}z'_\bullet \bar{A}_*(z'_\bullet) + i\int_{-\infty}^{x_*} d\frac{2}{s}z'_* \bar{A}_\bullet(z'_*)\Big]$$
$$=\; \frac{1}{4\pi}\Big[1 - i\int_{-\infty}^{x_*} d\frac{2}{s}z'_* \bar{A}_\bullet(z'_*)\Big]\int d\frac{2}{s}z_\bullet dz_* \;\frac{1}{x_* - z_* + i\epsilon}[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]\Big[1 + i\int_{-\infty}^{x_*} d\frac{2}{s}z'_* \bar{A}_\bullet(z'_*)\Big]$$
$$+\; \frac{1}{4\pi}\int d\frac{2}{s}z_\bullet dz_* \;\frac{1}{x_* - z_* + i\epsilon}\Big[1 - i\int_{-\infty}^{z_\bullet} d\frac{2}{s}z'_\bullet \bar{A}_*(z'_\bullet)\Big][\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]\Big)\Big[1 + i\int_{-\infty}^{z_\bullet} d\frac{2}{s}z'_\bullet \bar{A}_*(z'_\bullet)\Big]$$
$$\Rightarrow\; M^\dagger \;\ni\; -\frac{i}{2\pi s}\int d^2z \;[-\infty_\bullet, z_\bullet]^{A_*}\ln[-b(x-z)_* - i\epsilon]\big)[\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)][z_\bullet, \infty_\bullet]^{A_*}$$
$$-\; \frac{1}{2\pi s}\int d^2z \int_{-\infty}^{x_*} d\frac{2}{s}z'_* \;\ln\frac{x_* - z_* - i\epsilon}{z'_* - z_* - i\epsilon}[\bar{A}_\bullet(z'_*), [\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]] \tag{432}$$

Guess

$$M^\dagger - 1 \tag{433}$$
$$=\; -\frac{i}{2\pi s}\int d^2z \;[-\infty_\bullet, z_\bullet]^{A_*}_{(1)}\ln[-b(x-z)_* - i\epsilon][\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)][z_\bullet, \infty_\bullet]^{A_*}_{(1)} - \;\frac{1}{2\pi s}\int d^2z \int_{-\infty}^{x_*} d\frac{2}{s}z'_* \;\ln\frac{x_* - z_* + i\epsilon}{z'_* - z_* + i\epsilon}[\bar{A}_\bullet(z'_*), [\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]]$$
$$+\; \frac{i}{2\pi s}\int d^2z \;[-\infty_*, z_*]^{A_\bullet}_{(1)}\ln[-a(x-z)_\bullet - i\epsilon][\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)][z_*, \infty_*]^{A_\bullet}_{(1)} + \;\frac{1}{2\pi s}\int d^2z \int_{-\infty}^{x_\bullet} d\frac{2}{s}z'_\bullet \;\ln\frac{x_\bullet - z_\bullet + i\epsilon}{z'_\bullet - z_\bullet + i\epsilon}[\bar{A}_*(z'_\bullet), [\bar{A}_*(z_\bullet), \bar{A}_\bullet(z_*)]]$$

Check (see Eq. (426) and Eq. (165)) :

$$\Big[1+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z'_\bullet\bar A_*(z'_\bullet)+i\int_{-\infty}^{x_*}d\frac{2}{s}z'_*\bar A_\bullet(z'_*)\Big]i\frac{s}{2}\big(\frac{\partial}{\partial x_\bullet}M^\dagger\big)\Big[1-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z'_\bullet\bar A_*(z'_\bullet)-i\int_{-\infty}^{x_*}d\frac{2}{s}z'_*\bar A_\bullet(z'_*)\Big]\ +\ \Omega_* \tag{434}$$

$$= \ \Big[1+i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z'_\bullet\bar A_*(z'_\bullet)+i\int_{-\infty}^{x_*}d\frac{2}{s}z'_*\bar A_\bullet(z'_*)\Big]\Big\{-\frac{1}{4\pi}\int d^2z\ \frac{1}{(x-z)_\bullet+i\epsilon}[-\infty_*,z_*]^{A_\bullet}_{(1)}[\bar A_*(z_\bullet),\bar A_\bullet(z_*)][z_*,\infty_*]^{A_\bullet}_{(1)}$$

$$+\ \frac{i}{4\pi}\int d^2z\ \frac{1}{x_\bullet-z_\bullet+i\epsilon}\int_{-\infty}^{x_\bullet}d\frac{2}{s}z'_\bullet\ [\bar A_*(z'_\bullet),[\bar A_*(z_\bullet),\bar A_\bullet(z_*)]]\Big\}\Big[1-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}z'_\bullet\bar A_*(z'_\bullet)-i\int_{-\infty}^{x_*}d\frac{2}{s}z'_*\bar A_\bullet(z'_*)\Big]\ +\ \Omega_*$$

$$= \ -\frac{1}{4\pi}\int d^2z\ \frac{1}{(x-z)_\bullet+i\epsilon}[x_*,z_*]^{A_\bullet}[\bar A_*(z_\bullet),\bar A_\bullet(z_*)][z_*,x_*]^{A_\bullet}-\frac{i}{s}\int_{-\infty}^{x_*}dz_*\ [x_*,z_*]^{A_\bullet}[\bar A_*(x_\bullet),\bar A_\bullet(z_*)][z_*,x_*]^{A_\bullet}$$

$$= \ -\frac{1}{4\pi}\int d^2z\ \frac{1}{(x-z)_\bullet-i\epsilon(x-z)_*}[x_*,z_*]^{A_\bullet}[\bar A_*(z_\bullet),\bar A_\bullet(z_*)][z_*,x_*]^{A_\bullet}$$

D. Λ do $\bar A_*^2\bar A_\bullet^2$

From Eq. (166) and Eq. (426)

$$\Lambda_\bullet^{(2)a}\ =\ -\frac{i}{2}\big(\frac{1}{\bar P_\bullet\bar P_*}\bar P_\bullet\big)^{aa'}f^{a'bc}\Lambda_*^{(1)b}\Lambda_\bullet^{(1)c} \tag{435}$$

$$\Rightarrow\ \Lambda_\bullet^{(2)}\ =\ -\frac{1}{2}\int dz\ (x|\frac{1}{p_*+i\epsilon p_\bullet}|y)[\Lambda_*^{(1)}(y),\Lambda_\bullet^{(1)}(y)]\ =\ \frac{1}{4\pi}\int dy\ \frac{1}{x_*-y_*-i\epsilon(x-y)_\bullet}[\Lambda_*^{(1)}(y),\Lambda_\bullet^{(1)}(y)]$$

$$=\ -\frac{1}{64\pi^3}\int dydzdz'\frac{1}{x_*-y_*-i\epsilon(x-y)_\bullet}\frac{1}{y_\bullet-z_\bullet-i\epsilon(y-z)_*}\frac{1}{y_*-z'_*-i\epsilon(y-z')_\bullet}[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]]$$

$$=\ -\frac{1}{64\pi^3}\int dydzdz'\Big[\frac{1}{x_*-y_*+i\epsilon}+2\pi i\delta(x_*-y_*)\theta(x_\bullet-y_\bullet)\Big]\Big[\frac{1}{y_\bullet-z_\bullet+i\epsilon}+2\pi i\delta(y_\bullet-z_\bullet)\theta(y_*-z_*)\Big]$$

$$\times\ \Big[\frac{1}{y_*-z'_*+i\epsilon}+2\pi i\delta(y_*-z'_*)\theta(y_\bullet-z'_\bullet)\Big][[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]]$$

$$=\ -\frac{1}{64\pi^3}\int dydzdz'\frac{1}{x_*-y_*+i\epsilon}\frac{1}{y_\bullet-z_\bullet-i\epsilon}\frac{1}{y_*-z'_*+i\epsilon}[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]]$$

$$-\ \frac{i}{32\pi^2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet\int dzdz'\frac{1}{y_\bullet-z_\bullet-i\epsilon}\frac{1}{x_*-z'_*+i\epsilon}[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]]$$

$$-\ \frac{i}{32\pi^2}\int dydz'\int_{-\infty}^{y_*}d\frac{2}{s}z_*\frac{1}{x_*-y_*+i\epsilon}\frac{1}{y_*-z'_*+i\epsilon}[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]]$$

$$-\ \frac{i}{32\pi^2}\int dydz\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet\frac{1}{x_*-y_*+i\epsilon}\frac{1}{y_\bullet-z_\bullet-i\epsilon}[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(y_*)]]$$

$$+\ \frac{1}{16\pi}\int dy\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet\int_{-\infty}^{y_*}d\frac{2}{s}z_*\frac{1}{x_*-y_*+i\epsilon}[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(y_*)]]$$

$$+\ \frac{1}{16\pi}\int dz\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet\frac{1}{y_\bullet-z_\bullet+i\epsilon}[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(x_*)]]$$

$$+\ \frac{1}{16\pi}\int dz'\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}z_*\frac{1}{y_*-z'_*+i\epsilon}[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]]$$

$$+\ \frac{i}{8}\int_{-\infty}^{x_*}d\frac{2}{s}y_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}z_*\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(x_*)]]$$

From Eq. (201)

$$\Lambda_\bullet^{(2)}-\Omega_\bullet^{(2)} = -\frac{1}{64\pi^3}\int dydzdz'\frac{1}{x_*-y_*-i\epsilon(x-y)_\bullet}\frac{1}{y_\bullet-z_\bullet-i\epsilon(y-z)_*}\frac{1}{y_*-z'_*-i\epsilon(y-z')_\bullet}\big[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]\big]$$
$$-\frac{i}{8}\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet d\frac{2}{s}x''_\bullet\ \theta(y_\bullet-x''_\bullet)\int_{-\infty}^{x_*}d\frac{2}{s}z_*\big[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(x''_\bullet),\bar A_\bullet(x_*)]\big]$$
$$= -\frac{1}{64\pi^3}\int dydzdz'\frac{1}{x_*-y_*+i\epsilon}\frac{1}{y_\bullet-z_\bullet-i\epsilon}\frac{1}{y_*-z'_*+i\epsilon}\big[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]\big]$$
$$-\frac{i}{32\pi^2}\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet\int dzdz'\frac{1}{y_\bullet-z_\bullet-i\epsilon}\frac{1}{x_*-z'_*+i\epsilon}\big[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]\big]$$
$$-\frac{i}{32\pi^2}\int dydz'\int_{-\infty}^{y_*}d\frac{2}{s}z_*\frac{1}{x_*-y_*+i\epsilon}\frac{1}{y_*-z'_*+i\epsilon}\big[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]\big]$$
$$-\frac{i}{32\pi^2}\int dydz\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet\frac{1}{x_*-y_*+i\epsilon}\frac{1}{y_\bullet-z_\bullet-i\epsilon}\big[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(y_*)]\big]$$
$$+\frac{1}{16\pi}\int dy\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet\int_{-\infty}^{y_*}d\frac{2}{s}z_*\frac{1}{x_*-y_*+i\epsilon}\big[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(y_*)]\big]$$
$$+\frac{1}{16\pi}\int dz\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet\int_{-\infty}^{y_\bullet}d\frac{2}{s}z'_\bullet\frac{1}{y_\bullet-z_\bullet+i\epsilon}\big[[\bar A_*(z_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(x_*)]\big]$$
$$+\frac{1}{16\pi}\int dz'\int_{-\infty}^{x_\bullet}d\frac{2}{s}y_\bullet\int_{-\infty}^{x_*}d\frac{2}{s}z_*\frac{1}{y_*-z'_*+i\epsilon}\big[[\bar A_*(y_\bullet),\bar A_\bullet(z_*)],[\bar A_*(z'_\bullet),\bar A_\bullet(z'_*)]\big]$$

XIV. DOUBLE FUNTEGRAL

Fields A to the right of the cut, fields $\tilde A$ to the left.

$$\langle\tilde A^a_\mu(x)A^b_\nu(y)\rangle \stackrel{bF}{=} -(x|\frac{1}{\tilde P^2 g_{\mu\xi}+2i\tilde G_{\mu\xi}-i\epsilon}p^2 2\pi\delta(p^2)\theta(p_0)p^2\frac{1}{\tilde P^2\delta^\xi_\nu+2i\tilde G^\xi{}_\nu+i\epsilon}|y)^{ab} \tag{436}$$

1. How we get retarded propagator

$$\int D\tilde\phi D\phi\ \phi(x)e^{-iS(\tilde\phi)-i\tilde J\tilde\phi}e^{iS(\phi)+iJ\phi} = -\int dz\ (x|\frac{1}{p^2+i\epsilon}|z)J(z)-i\int dz\ (x|2\pi\delta(p^2)\theta(-p_0)|z)\tilde J(z)$$
$$= \int dz\ \frac{i}{4\pi^2[-(x-z)^2+i\epsilon]}J(z)-\int dz\ \frac{i}{4\pi^2[-(x-z)^2-i\epsilon(x-z)_0]}J(z)$$
$$\int D\tilde\phi D\phi\ \tilde\phi(x)e^{-iS(\tilde\phi)-i\tilde J\tilde\phi}e^{iS(\phi)+iJ\phi} = i\int dz\ (x|2\pi\delta(p^2)\theta(p_0)|z)J(z)-\int dz\ (x|\frac{1}{p^2-i\epsilon}|z)\tilde J(z)-$$
$$= \int dz\ \frac{i}{4\pi^2[-(x-z)^2+i\epsilon(x-z)_0]}J(z)-\int dz\ \frac{i}{4\pi^2[-(x-z)^2-i\epsilon]}\tilde J(z) \tag{437}$$

so if $J=\tilde J$

$$\phi(x) = \tilde\phi(x) = -\int dz\ (x|\frac{1}{p^2+i\epsilon p_0}|z)J(z) = \frac{1}{4\pi^2}\int dz\ 2\pi\delta\big((x-z)^2\big)\theta(x_0-z_0)J(z) \tag{438}$$

A. In two (longitudinal) dimensions

Eq. (161)

$$2(\bar P_\bullet\bar P_*)^{ab}\bar C^b_\bullet = \bar D^{ab}_\bullet\bar G^b_{*\bullet}+i\bar G^{ab}_{*\bullet}\bar C^b_\bullet+g\bar D^{aa'}_\bullet(f^{a'bc}\bar C^b_*\bar C^c_\bullet)+2gf^{abc}\bar C^b_\bullet\bar D_*\bar C^c_\bullet-g^2f^{abm}f^{cdm}\bar C^b_\bullet\bar C^c_\bullet\bar C^d_*$$
$$2(\bar P_*\bar P_\bullet)^{ab}\bar C^b_* = -\bar D^{ab}_*\bar G^b_{*\bullet}-i\bar G^{ab}_{*\bullet}\bar C^b_*-g\bar D^{aa'}_*(f^{a'bc}\bar C^b_*\bar C^c_\bullet)+2gf^{abc}\bar C^b_*\bar D_\bullet\bar C^c_*-g^2f^{abm}f^{cdm}\bar C^b_*\bar C^c_*\bar C^d_\bullet \tag{439}$$

and same

$$2(\bar{\bar{P}}_\bullet\bar{\bar{P}}_*)^{ab}\bar{\bar{C}}^b_\bullet = \bar{D}^{ab}_\bullet\bar{\bar{G}}^b_{*\bullet} + i\bar{\bar{G}}^{ab}_{*\bullet}\bar{\bar{C}}^b_\bullet + g\bar{\bar{D}}^{aa'}_\bullet(f^{a'bc}\bar{\bar{C}}^b_*\bar{\bar{C}}^c_\bullet) + 2gf^{abc}\bar{\bar{C}}^b_\bullet\bar{\bar{D}}_*\bar{\bar{C}}^c_\bullet - g^2f^{abm}f^{cdm}\bar{\bar{C}}^b_\bullet\bar{\bar{C}}^c_\bullet\bar{\bar{C}}^d_*$$
$$2(\bar{\bar{P}}_*\bar{\bar{P}}_\bullet)^{ab}\bar{\bar{C}}^b_* = -\bar{\bar{D}}^{ab}_*\bar{\bar{G}}^b_{*\bullet} - i\bar{\bar{G}}^{ab}_{*\bullet}\bar{\bar{C}}^b_* - g\bar{\bar{D}}^{aa'}_*(f^{a'bc}\bar{\bar{C}}^b_*\bar{\bar{C}}^c_\bullet) + 2gf^{abc}\bar{\bar{C}}^b_*\bar{\bar{D}}_\bullet\bar{\bar{C}}^c_* - g^2f^{abm}f^{cdm}\bar{\bar{C}}^b_*\bar{\bar{C}}^c_*\bar{\bar{C}}^d_\bullet \quad (440)$$

РЕШЕНИЕ

$$\bar{C}^{1a}_\bullet(x) = -\frac{i}{2}\int d^2z\,\Big[(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{is}{4}(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}p^4 2\pi\delta(p^2)\theta(-p_0)\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet|z)^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big]$$
$$\bar{C}^{1a}_*(x) = \frac{i}{2}\int d^2z\,\Big[(x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z) + \frac{is}{4}(x|\frac{1}{\bar{\bar{P}}_*\bar{\bar{P}}_\bullet+i\epsilon}p^4 2\pi\delta(p^2)\theta(-p_0)\frac{1}{\bar{\bar{P}}_*\bar{\bar{P}}_\bullet-i\epsilon}\bar{\bar{P}}_*|z)^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big]$$
$$\bar{\bar{C}}^{1a}_\bullet(x) = -\frac{i}{2}\int d^2z\,\Big[(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet|z)^{ab}\bar{\bar{G}}^b_{*\bullet}(z) - \frac{is}{4}(x|\frac{1}{\bar{P}_\bullet\bar{P}_*-i\epsilon}p^4 2\pi\delta(p^2)\theta(p_0)\frac{1}{\bar{P}_\bullet\bar{\bar{P}}_*+i\epsilon}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z)\Big]$$
$$\bar{\bar{C}}^{1a}_*(x) = \frac{i}{2}\int d^2z\,\Big[(x|\frac{1}{\bar{\bar{P}}_*\bar{\bar{P}}_\bullet-i\epsilon}\bar{\bar{P}}_*|z)^{ab}\bar{\bar{G}}^b_{*\bullet}(z) - \frac{is}{4}(x|\frac{1}{\bar{\bar{P}}_*\bar{\bar{P}}_\bullet-i\epsilon}p^4 2\pi\delta(p^2)\theta(p_0)\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}\bar{P}_*|z)^{ab}\bar{G}^b_{*\bullet}(z)\Big] \quad (441)$$

НА ∞-ТИ (СМ. УР-Е (397))

$$(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|z) = (x|\frac{1}{\bar{P}_*+i\epsilon p_\bullet}|z) = -\frac{(2\pi)^{-1}}{x_*-z_*-i\epsilon(x-z)_\bullet}[x_\bullet,z_\bullet]^{\bar{A}_*} \quad (442)$$

СВОЙСТВО

$$(x|\bar{P}_*\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}p_*^2p_\bullet^2 2\pi\delta(p^2)\theta(-p_0)\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet|z)$$
$$= (x|\big[P_*-\bar{P}_*\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}(\bar{P}_\bullet A_*+A_\bullet p_*)\big]2\pi\delta(p^2)\theta(-p_0)\big[\bar{\bar{P}}_\bullet-(p_\bullet\bar{\bar{A}}_*+\bar{\bar{A}}_\bullet\bar{\bar{P}}_*)\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet\big]|y)$$
$$= (x|\bar{P}_*\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}A_\bullet p_* 2\pi\delta(p^2)\theta(-p_0)p_\bullet\bar{\bar{A}}_*\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet|y) = 0 \quad (443)$$

И ПОЭТОМУ (СР. С ФОРМУЛОЙ (163))

$$\bar{D}_\bullet\bar{C}^{(1)}_* = -\bar{D}_*\bar{C}^{(1)}_\bullet = \frac{1}{2}\bar{G}_{*\bullet}, \qquad \bar{\bar{D}}_\bullet\bar{\bar{C}}^{(1)}_* = -\bar{\bar{D}}_*\bar{\bar{C}}^{(1)}_\bullet = \frac{1}{2}\bar{\bar{G}}_{*\bullet} \quad (444)$$

1. *Wightman propagators in 2d*

$$(x|\frac{1}{\bar{P}_*\bar{P}_\bullet+i\epsilon}\bar{P}_*|z) = (x|\frac{1}{\bar{P}_\bullet+i\epsilon p_*}|z) = -\frac{(2\pi)^{-1}[x_*,z_*]^{A_\bullet}}{x_\bullet-z_\bullet-i\epsilon(x-z)_*}, \qquad (x|\frac{1}{\bar{P}_*\bar{P}_\bullet-i\epsilon}\bar{P}_*|z) = \frac{(2\pi)^{-1}[x_*,z_*]^{A_\bullet}}{x_\bullet-z_\bullet+i\epsilon(x-z)_*}$$
$$(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|z) = (x|\frac{1}{\bar{P}_*+i\epsilon p_\bullet}|z) = -\frac{(2\pi)^{-1}[x_\bullet,z_\bullet]^{\bar{\bar{A}}_*}}{x_*-z_*-i\epsilon(x-z)_\bullet}, \qquad (x|\frac{1}{\bar{P}_\bullet\bar{P}_*-i\epsilon}\bar{P}_\bullet|z) = \frac{(2\pi)^{-1}[x_\bullet,z_\bullet]^{\bar{\bar{A}}_*}}{x_*-z_*+i\epsilon(x-z)_\bullet} \quad (445)$$

$$(z|2\pi\delta(p^2)\theta(p_0)|z')(z'|p_*p_\bullet\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y) = (z|2\pi\delta(p^2)\theta(p_0)|z')(z'|\big[\bar{P}_\bullet-(p_\bullet\bar{A}_*+\bar{A}_\bullet\bar{P}_*)\frac{1}{\bar{P}_\bullet\bar{P}_*-i\epsilon}\bar{P}_\bullet\big]|y)$$
$$\equiv (z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|p_*\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y) + i\int dz'_\bullet(z|2\pi\delta(p^2)\theta(p_0)|z')(z'|p_*\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y)\Big|_{z'_*=-\infty}^{z'_*=\infty} \quad (446)$$
$$= i\int dz'_*(z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y)\Big|_{z'_\bullet=-\infty}^{z'_\bullet=\infty} + i\int dz'_\bullet(z|2\pi\delta(p^2)\theta(p_0)|z')(z'|p_*\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y)\Big|_{z'_*=-\infty}^{z'_*=\infty}$$
$$= i\int dz'_*(z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y)\Big|_{z'_\bullet=-\infty}^{z'_\bullet=\infty} + i\int dz'_\bullet(z|2\pi\delta(p^2)\theta(p_0)p_*|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y)\Big|_{z'_*=-\infty}^{z'_*=\infty}$$
$$= i\int dz'_*(z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|y)\Big|_{z'_\bullet=-\infty}^{z'_\bullet=\infty}$$

$$
\begin{aligned}
&(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet p_* 2\pi\delta(p^2)\theta(p_0)p_\bullet p_*\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|z)\\
&\equiv\ (x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}\big[1-(p_\bullet A_* + P_*A_\bullet)\big]2\pi\delta(p^2)\theta(p_0)\big[\bar{P}_\bullet - (p_\bullet\bar{A}_* + \bar{A}_\bullet\bar{P}_*)\frac{1}{\bar{P}_\bullet\bar{P}_* - i\epsilon}\bar{P}_\bullet\big]|y)\\
&=\ i\int dz'_*(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}\big[1-(p_\bullet A_* + P_*A_\bullet)\big]2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|y)\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty}\\
&=\ i\int dz'_*d^2z(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet p_*|z)(z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|y)\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty}\\
&=\ \int dz'_*dz_*(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet|z)(z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|y)\Big|^{z_\bullet=\infty}_{z_\bullet=-\infty}\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty}
\end{aligned}
\tag{447}
$$

$$
\begin{aligned}
&(x|\frac{1}{p^2-i\epsilon}|z)\ =\ -\frac{i}{4\pi}\ln[-(x-z)_* - i\epsilon(x-z)_\bullet] - \frac{i}{4\pi}\ln[(x-z)_\bullet + i\epsilon(x-z)_*]\ =\ -\frac{i}{4\pi}\ln[-(x-z)_*(x-z)_\bullet - i\epsilon]\\
&\ =\ -\frac{i}{4\pi}\ln[-(x-z)_* + i\epsilon] - \frac{1}{2}\theta(x-z)_*\theta(x-z)_\bullet - \frac{i}{4\pi}\ln[(x-z)_\bullet - i\epsilon] + \frac{1}{2}\theta(x-z)_*\theta(x-z)_\bullet\\
&(x|2\pi\delta(p^2)\theta(p_0)|z)\ =\ -\frac{1}{4\pi}\ln[-(x-z)_* + i\epsilon] - \frac{1}{4\pi}\ln[(x-z)_\bullet - i\epsilon]\ =\ -\frac{i}{4\pi}\ln[-(x-z)_*(x-z)_\bullet + i\epsilon(x-z)_0]\\
&(x|2\pi\delta(p^2)\theta(p_0)p_\bullet|z)\ =\ -\frac{is}{8\pi}\frac{1}{x_*-z_*-i\epsilon},\qquad (x|2\pi\delta(p^2)\theta(-p_0)p_\bullet|z)\ =\ -\frac{is}{8\pi}\frac{1}{x_*-z_*+i\epsilon}\\
&(x|\frac{1}{p^2+i\epsilon p_0}|z)\ =\ -\frac{1}{2}\theta(x_*-z_*)\theta(x_\bullet - z_\bullet)\\
&(x|\frac{1}{p^2-i\epsilon}|z) - (x|\frac{1}{p^2+i\epsilon p_0}|z)\ =\ (x|2\pi i\delta(p^2)\theta(p_0)|z)
\end{aligned}
\tag{448}
$$

$$
\begin{aligned}
&\int dz'_*\ (z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|y)\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty}\\
&=\ \frac{is}{16\pi^2}\int dz'_*\ \frac{1}{(z_*-z'_*-i\epsilon)[z'_*-y_*-i\epsilon(z'-y)_\bullet]}[z'_\bullet, y_\bullet]^{A_*}\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty}\ =\ -\frac{s}{8\pi(z_*-y_*-i\epsilon)}[\infty_\bullet, y_\bullet]^{\bar{A}_*}\\
&\Rightarrow\ -\int dz'_*dz_*(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet|z)(z|2\pi\delta(p^2)\theta(p_0)p_\bullet|z')(z'|\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|y)\Big|^{z_\bullet=\infty}_{z_\bullet=-\infty}\Big|^{z'_\bullet=\infty}_{z'_\bullet=-\infty}\\
&=\ \frac{s}{8\pi}\int dz_*(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet|z)\Big|^{z_\bullet=\infty}_{z_\bullet=-\infty}\frac{[\infty_\bullet, y_\bullet]^{\bar{A}_*}}{z_*-y_*-i\epsilon}
\end{aligned}
$$

$$
(x|\frac{1}{\bar{P}_\bullet\bar{P}_* - i\epsilon}|y)\ =\ -\frac{i}{4\pi}[x_\bullet, y_\bullet]\ln[-(x-y)_* - i\epsilon(x-y)_\bullet]\ +\ \text{solution of }\ \bar{P}_\bullet\bar{P}_*(...)\ =\ 0
$$

$$
\begin{aligned}
&(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet p_* 2\pi\delta(p^2)\theta(p_0)p_\bullet p_*\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|y)\ =\ -\frac{is}{8\pi(x_*-y_*-i\epsilon)}[x_\bullet, \infty_\bullet]^{\bar{\bar{A}}_*}[\infty_\bullet, y_\bullet]^{\bar{A}_*}\\
&(x|\frac{1}{\bar{\bar{P}}_*\bar{\bar{P}}_\bullet - i\epsilon}p_\bullet p_* 2\pi\delta(p^2)\theta(p_0)p_\bullet p_*\frac{1}{\bar{P}_*\bar{P}_\bullet + i\epsilon}\bar{P}_*|y)\ =\ -\frac{is}{8\pi(x_\bullet-y_\bullet-i\epsilon)}[x_*, \infty_*]^{\bar{\bar{A}}_\bullet}[\infty_*, y_*]^{\bar{A}_\bullet}
\end{aligned}
\tag{449}
$$

Check of Eq. (443)

$$
\bar{\bar{P}}_*(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}p_\bullet p_* 2\pi\delta(p^2)\theta(p_0)p_\bullet p_*\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}\bar{P}_\bullet|z) =\ -\frac{is}{8\pi(x_*-y_*-i\epsilon)}\bar{\bar{P}}_*[x_\bullet, \infty_\bullet]^{\bar{\bar{A}}_*}[\infty_\bullet, y_\bullet]^{\bar{A}_*}\ =\ 0
\tag{450}
$$

ЕЩЁ DВА ПРОПАГАТОРА

$$
\begin{aligned}
&(x|\frac{1}{\bar{P}_\bullet\bar{P}_* + i\epsilon}p_\bullet p_* 2\pi\delta(p^2)\theta(-p_0)p_\bullet p_*\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_* - i\epsilon}\bar{\bar{P}}_\bullet|y)\ =?\ -\frac{is}{8\pi(x_*-y_*+i\epsilon)}[x_\bullet, \infty_\bullet]^{\bar{A}_*}[\infty_\bullet, y_\bullet]^{\bar{\bar{A}}_*}\\
&(x|\frac{1}{\bar{P}_*\bar{P}_\bullet + i\epsilon}p_\bullet p_* 2\pi\delta(p^2)\theta(-p_0)p_\bullet p_*\frac{1}{\bar{\bar{P}}_*\bar{\bar{P}}_\bullet + i\epsilon}\bar{\bar{P}}_*|y)\ =?\ -\frac{is}{8\pi(x_\bullet-y_\bullet+i\epsilon)}[x_*, \infty_*]^{\bar{A}_\bullet}[\infty_*, y_*]^{\bar{\bar{A}}_\bullet}
\end{aligned}
\tag{451}
$$

Na ∞-ti: from Eq. (441) we get

$$\bar{C}^{1a}_\bullet(x) = -\frac{i}{2}\int d^2z\ \Big[(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z)+\frac{is}{4}(x|\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}p^4 2\pi\delta(p^2)\theta(-p_0)\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet|z)^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big]$$
$$= \frac{i}{4\pi}\int d^2z\ \Big[\frac{1}{x_*-z_*-i\epsilon(x-z)_\bullet}([x_\bullet,z_\bullet]^{\bar{A}_*})^{ab}\bar{G}^b_{*\bullet}(z)-\frac{1}{x_*-z_*+i\epsilon}([x_\bullet,\infty_\bullet]^{\bar{A}_*}[\infty_\bullet,z_\bullet]^{\bar{A}_*})^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big]$$
$$\bar{\bar{C}}^{1a}_\bullet(x) = -\frac{i}{2}\int d^2z\ \Big[-\frac{is}{4}(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}p^4 2\pi\delta(p^2)\theta(p_0)\frac{1}{\bar{P}_\bullet\bar{P}_*+i\epsilon}\bar{P}_\bullet|z)^{ab}\bar{G}^b_{*\bullet}(z)+(x|\frac{1}{\bar{\bar{P}}_\bullet\bar{\bar{P}}_*-i\epsilon}\bar{\bar{P}}_\bullet|z)^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big]$$
$$= \frac{i}{4\pi}\int d^2z\ \Big[\frac{1}{x_*-z_*-i\epsilon}([x_\bullet,\infty_\bullet]^{\bar{\bar{A}}_*}[\infty_\bullet,z_\bullet]^{\bar{A}_*})^{ab}\bar{G}^b_{*\bullet}(z)-\frac{1}{x_*-z_*+i\epsilon(x-z)_\bullet}([x_\bullet,z_\bullet]^{\bar{\bar{A}}_*})^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big] \tag{452}$$

If $x_*\to\infty$ both $\bar{C}^{1a}_\bullet(x),\bar{\bar{C}}^{1a}_\bullet(x)\to 0$, if $x_*\sim 1$ and $x_\bullet\to\infty$ they coincide.

Another check: $\bar{A}=\bar{\bar{A}}=A$

$$\bar{C}^{1a}_\bullet(x) = \bar{\bar{C}}^{1a}_\bullet(x) = -\frac{1}{2}\int d^2z\ \delta(x_*-z_*)\theta(x_\bullet-z_\bullet)([x_\bullet,z_\bullet]^{A_*})^{ab}G^b_{*\bullet}(z) \tag{453}$$

which coincide with Eq. (163).

B. Matrix ℵ

$$\aleph^{\dagger(0)} = 1+i\int_{x_*}^\infty d\frac{2}{s}x'_*\ \bar{A}_\bullet(x'_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}x'_\bullet\ \bar{A}_*(x'_\bullet),\qquad \tilde{\aleph}^{\dagger(0)} = 1+i\int_{x_*}^\infty d\frac{2}{s}x'_*\ \bar{\bar{A}}_\bullet(x'_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}x'_\bullet\ \bar{\bar{A}}_*(x'_\bullet) \tag{454}$$

First order

$$i(\aleph\partial_\bullet\aleph^\dagger)^a = \bar{A}^a_\bullet+\frac{i}{4\pi}\int d^2z\ \Big[\frac{1}{x_*-z_*-i\epsilon(x-z)_\bullet}([x_\bullet,z_\bullet]^{\bar{A}_*})^{ab}\bar{G}^b_{*\bullet}(z)-\frac{1}{x_*-z_*+i\epsilon}([x_\bullet,\infty_\bullet]^{\bar{A}_*}[\infty_\bullet,z_\bullet]^{\bar{A}_*})^{ab}\bar{\bar{G}}^b_{*\bullet}(z)\Big]$$
$$\Rightarrow\ i(\aleph\partial_\bullet\aleph^\dagger) = \bar{A}_\bullet+\frac{1}{4\pi}\int d^2z\ \Big(\frac{1}{x_*-z_*-i\epsilon(x-z)_\bullet}[\bar{A}_*,\bar{A}_\bullet](z)-\frac{1}{x_*-z_*+i\epsilon}[\bar{\bar{A}}_*,\bar{\bar{A}}_\bullet](z)\Big) \tag{455}$$

Probuem

$$\aleph^\dagger = 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{A}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{A}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{A}_\bullet(z'_*)\bar{A}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{A}_*(z'_\bullet)\bar{A}_*(z_\bullet)$$
$$-\frac{i}{2\pi s}\int d^2z\ \big(\ln(x_*-z_*-i\epsilon(x-z)_\bullet)[\bar{A}_*,\bar{A}_\bullet](z)-\ln(x_*-z_*+i\epsilon)[\bar{\bar{A}}_*,\bar{\bar{A}}_\bullet](z)\big)+X3$$
$$\Rightarrow\ i\partial_\bullet X3 = i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{A}_*(z_\bullet)\bar{A}_\bullet(x_*) \tag{456}$$
$$X3 = -\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{A}_*(z_\bullet)\bar{A}_\bullet(z_*) = -\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\}-\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ [\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$

$\Rightarrow$

$$\aleph^\dagger = 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{A}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{A}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{A}_\bullet(z'_*)\bar{A}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{A}_*(z'_\bullet)\bar{A}_*(z_\bullet)$$
$$-\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\}-\frac{i}{4\pi}\int d\frac{2}{s}z_*d\frac{2}{s}z_\bullet\ \big(\ln(x_*-z_*-i\epsilon)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\ln(x_*-z_*+i\epsilon)[\bar{\bar{A}}_*(z_\bullet),\bar{\bar{A}}_\bullet(z_*)]\big)$$

Adding the $*\leftrightarrow\bullet$ term we get

$$\aleph^\dagger(x_*,x_\bullet) = 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{A}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{A}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{A}_\bullet(z'_*)\bar{A}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{A}_*(z'_\bullet)\bar{A}_*(z_\bullet)$$
$$-\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\} \tag{457}$$
$$-\frac{i}{4\pi}\int d\frac{2}{s}z_*d\frac{2}{s}z_\bullet\ \{\big(\ln(x_*-z_*-i\epsilon)-\ln(x_\bullet-z_\bullet-i\epsilon)\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\big(\ln(x_*-z_*+i\epsilon)-\ln(x_\bullet-z_\bullet+i\epsilon)\big)[\bar{\bar{A}}_*(z_\bullet),\bar{\bar{A}}_\bullet(z_*)]\}$$

Check: $\bar{A}=\bar{\tilde{A}}$

$$\aleph^\dagger \ = \ 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{A}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{A}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{A}_\bullet(z'_*)\bar{A}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{A}_*(z'_\bullet)\bar{A}_*(z_\bullet)$$
$$-\ \frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\}-\ \frac{1}{2}\int d\frac{2}{s}z_*d\frac{2}{s}z_\bullet\ \big(\theta(x_*-z_*)-\theta(x_\bullet-z_\bullet)\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]$$

Reminder:

$$\Omega^\dagger \ = \ \Big[1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\Big]$$

From Eqs. (193) and (192) we see that

$$\Omega(\infty_\bullet,\infty_*)\Omega^\dagger(x_*,x_\bullet) \ = \ \Big[1+i\int d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int d\frac{2}{s}x'_*d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\bar{A}_\bullet(x'_*)\bar{A}_\bullet(x''_*)+i\int d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet)$$
$$-\int d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_*(x'_\bullet)\bar{A}_*(x''_\bullet)-\frac{1}{2}\int d\frac{2}{s}x'_*d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\Big]$$
$$\times\ \Big[1-i\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\bar{A}_\bullet(x'_*)-\int_{-\infty}^{x_*}d\frac{2}{s}x'_*d\frac{2}{s}x''_*\ \theta(x'_*-x''_*)\bar{A}_\bullet(x''_*)\bar{A}_\bullet(x'_*)-i\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\bar{A}_*(x'_\bullet)$$
$$-\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet d\frac{2}{s}x''_\bullet\ \theta(x'_\bullet-x''_\bullet)\bar{A}_*(x''_\bullet)\bar{A}_*(x'_\bullet)-\frac{1}{2}\int_{-\infty}^{x_*}d\frac{2}{s}x'_*\int_{-\infty}^{x_\bullet}d\frac{2}{s}x'_\bullet\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)\Big] \quad (458)$$

$$\ni\ \int d\frac{2}{s}x'_*d\frac{2}{s}x'_\bullet\Big\{-\frac{1}{2}[1+\theta(x_\bullet-x'_\bullet)\theta(x_*-x'_*)]\big(\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\big)+\theta(x_\bullet-x'_\bullet)\bar{A}_\bullet(x'_*)\bar{A}_*(x'_\bullet)+\ \theta(x_*-x'_*)\bar{A}_*(x'_\bullet)\bar{A}_\bullet(x'_*)\Big\}$$
$$=\ \int d\frac{2}{s}x'_*d\frac{2}{s}x'_\bullet\Big(-\frac{1}{2}\theta(x'_\bullet-x_\bullet)\theta(x'_*-x_*)\{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\}+\frac{1}{2}\big(\theta(x_*-x'_*)-\theta(x_\bullet-x'_\bullet)\big)[\bar{A}_*(x'_\bullet),\bar{A}_\bullet(x'_*)]\Big)$$

$\Rightarrow$

$$\aleph^\dagger(\bar{\tilde{A}}=\bar{A})\ =\ \Omega(\infty_*,\infty_\bullet)\Omega^\dagger(x_*,x_\bullet) \quad (459)$$

Similarly

$$i(\tilde{\aleph}\partial_\bullet\tilde{\aleph}^\dagger)^a\ =\ \bar{\tilde{A}}_\bullet+\frac{1}{4\pi}\int d^2z\ \Big(\frac{1}{x_*-z_*-i\epsilon}[\bar{A}_*,\bar{A}_\bullet](z)-\frac{1}{x_*-z_*+i\epsilon(x-z)_\bullet}[\bar{\tilde{A}}_*,\bar{\tilde{A}}_\bullet](z)\Big) \quad (460)$$

compare 2

$$i(\aleph\partial_\bullet\aleph^\dagger)^a\ =\ \bar{A}_\bullet+\frac{1}{4\pi}\int d^2z\ \Big(\frac{1}{x_*-z_*-i\epsilon(x-z)_\bullet}[\bar{A}_*,\bar{A}_\bullet](z)-\frac{1}{x_*-z_*+i\epsilon}[\bar{\tilde{A}}_*,\bar{\tilde{A}}_\bullet](z)\Big)$$

$$\tilde{\aleph}^\dagger\ =\ 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{\tilde{A}}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{\tilde{A}}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{\tilde{A}}_\bullet(z'_*)\bar{\tilde{A}}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{\tilde{A}}_*(z'_\bullet)\bar{\tilde{A}}_*(z_\bullet)$$
$$-\ \frac{i}{2\pi s}\int d^2z\ \big(\ln(x_*-z_*-i\epsilon)[\bar{A}_*,\bar{A}_\bullet](z)-\ln(x_*-z_*+i\epsilon(x-z)_\bullet)[\bar{\tilde{A}}_*,\bar{\tilde{A}}_\bullet](z)\big)+\tilde{X}3$$
$$\Rightarrow\ i\partial_\bullet\tilde{X}3\ =\ i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{\tilde{A}}_*(z_\bullet)\bar{\tilde{A}}_\bullet(x_*) \quad (461)$$
$$\tilde{X}3\ =\ -\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{\tilde{A}}_*(z_\bullet)\bar{\tilde{A}}_\bullet(z_*)\ =\ -\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{\tilde{A}}_*(z_\bullet),\bar{\tilde{A}}_\bullet(z_*)\}-\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ [\bar{\tilde{A}}_*(z_\bullet),\bar{\tilde{A}}_\bullet(z_*)]$$

$\Rightarrow$

$$\tilde{\aleph}^\dagger(x_*,x_\bullet)\ =\ 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{\tilde{A}}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{\tilde{A}}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{\tilde{A}}_\bullet(z'_*)\bar{\tilde{A}}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{\tilde{A}}_*(z'_\bullet)\bar{\tilde{A}}_*(z_\bullet)$$
$$-\ \frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{\tilde{A}}_*(z_\bullet),\bar{\tilde{A}}_\bullet(z_*)\} \quad (462)$$
$$-\ \frac{i}{4\pi}\int d\frac{2}{s}z_*d\frac{2}{s}z_\bullet\ \big\{\big(\ln(x_*-z_*-i\epsilon)-\ln(x_\bullet-z_\bullet-i\epsilon)\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\big(\ln(x_*-z_*+i\epsilon)-\ln(x_\bullet-z_\bullet+i\epsilon)\big)[\bar{\tilde{A}}_*(z_\bullet),\bar{\tilde{A}}_\bullet(z_*)]\big\}$$

Compare 2 Eq. (457):

$$\aleph^\dagger = 1+i\int_{x_*}^\infty d\frac{2}{s}z_*\ \bar{A}_\bullet(z_*)+i\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\ \bar{A}_*(z_\bullet)-\int_{x_*}^\infty d\frac{2}{s}z_*\int_{z_*}^\infty d\frac{2}{s}z'_*\ \bar{A}_\bullet(z'_*)\bar{A}_\bullet(z_*)-\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{z_\bullet}^\infty d\frac{2}{s}z'_\bullet\ \bar{A}_*(z'_\bullet)\bar{A}_*(z_\bullet)$$
$$-\frac{1}{2}\int_{x_\bullet}^\infty d\frac{2}{s}z_\bullet\int_{x_*}^\infty d\frac{2}{s}z_*\ \{\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)\} \tag{463}$$
$$-\frac{i}{4\pi}\int d\frac{2}{s}z_*d\frac{2}{s}z_\bullet\ \big\{\big(\ln(x_*-z_*-i\epsilon)-\ln(x_\bullet-z_\bullet-i\epsilon)\big)[\bar{A}_*(z_\bullet),\bar{A}_\bullet(z_*)]-\big(\ln(x_*-z_*+i\epsilon)-\ln(x_\bullet-z_\bullet+i\epsilon)\big)[\bar{\tilde{A}}_*(z_\bullet),\bar{\tilde{A}}_\bullet(z_*)]\big\}$$

1. $\bar{C}_i$ and $\bar{\tilde{C}}_i$

YP-E (217)

$$\begin{aligned}(\aleph p^2\aleph^\dagger)^{ab}\bar{C}_i^b &= -(\aleph p_\beta\aleph^\dagger)^{ab}\partial_i(\aleph\partial_\beta\aleph^\dagger)^b = -i\aleph^{ab}\partial^2(2\mathrm{Tr}\{t^b(\partial_i\aleph^\dagger)\aleph\}\\ (\tilde\aleph p^2\tilde\aleph^\dagger)^{ab}\bar{\tilde{C}}_i^b &= -(\tilde\aleph p_\beta\tilde\aleph^\dagger)^{ab}\partial_i(\tilde\aleph\partial_\beta\tilde\aleph^\dagger)^b = -i\tilde\aleph^{ab}\partial^2(2\mathrm{Tr}\{t^b(\partial_i\tilde\aleph^\dagger)\tilde\aleph\}\end{aligned} \tag{464}$$

gde $\bar{A}_\bullet+\bar{C}_\bullet = i\aleph\partial_\bullet\aleph^\dagger$ and $\bar{A}_*+\bar{C}_* = i\aleph\partial_*\aleph^\dagger$. Also, we used f-la (218).

ПО АНАЛОГИИ С УРАВНЕНИЕМ (219)

$$\begin{aligned}\bar{C}_i^a &= -i\int d^2z\ \aleph_x^{ab}(x|\frac{1}{p^2+i\epsilon}|z)\partial^2((\partial_i\aleph^\dagger)\aleph)^b+\int d^4z\ \aleph_x^{ab}(x|2\pi\delta(p^2)\theta(-p_0)|z)\partial^2((\partial_i\tilde\aleph^\dagger)\tilde\aleph)^b\\ \bar{\tilde{C}}_i^a &= -i\int d^2z\ \tilde\aleph_x^{ab}(x|\frac{1}{p^2-i\epsilon}|z)\partial^2((\partial_i\tilde\aleph^\dagger)\tilde\aleph)^b-\int d^4z\ \tilde\aleph_x^{ab}(x|2\pi\delta(p^2)\theta(p_0)|z)\partial^2((\partial_i\aleph^\dagger)\aleph)^b\end{aligned} \tag{465}$$

$$\begin{aligned}\bar{C}_i^a &= -i\int d^2z\ \aleph_x^{ab}(x|\frac{1}{p^2+i\epsilon}|z)\partial^2((\partial_i\aleph^\dagger)\aleph)^b+\int d^2z\ \aleph_x^{ab}(x|2\pi\delta(p^2)\theta(-p_0)|z)\partial^2((\partial_i\tilde\aleph^\dagger)\tilde\aleph)^b\\ &= -is\int d^2z\ \aleph_x^{ab}(x|\frac{1}{p^2}|z)\frac{\partial}{\partial z_*}\frac{\partial}{\partial z_\bullet}((\partial_i\aleph_z^\dagger)\aleph_z)^b+s\int d^2z\ \aleph_x^{ab}(x|2\pi\delta(p^2)\theta(-p_0)|z)\frac{\partial}{\partial z_*}\frac{\partial}{\partial z_\bullet}((\partial_i\tilde\aleph^\dagger)\tilde\aleph)^b\\ &= (\aleph i\partial_i\aleph^\dagger)^a+\frac{4}{s}\aleph_x^{ab}\int d^2z_\perp dz_\bullet(x|\frac{p_*}{p^2+i\epsilon}|z)((\partial_i\aleph_z^\dagger)\aleph_z)^b\Big|_{z_*=-\infty}^{z_*=\infty}+\ \frac{4}{s}\aleph_x^{ab}\int d^2z_\perp dz_*(x|\frac{p_\bullet}{p^2+i\epsilon}|z)((\partial_i\aleph_z^\dagger)\aleph_z)^b\Big|_{z_\bullet=-\infty}^{z_\bullet=\infty}\\ &-2i\aleph_x^{ab}\int d^2z_\perp(x|\frac{1}{p^2+i\epsilon}|z)((\partial_i\aleph_z^\dagger)\aleph_z)^b\Big|_{z_\bullet=-\infty}^{z_\bullet=\infty}\Big|_{z_*=-\infty}^{z_*=\infty}\\ &+?\ \frac{4i}{s}\aleph_x^{ab}\int d^2z_\perp dz_\bullet(x|2\pi\delta(p^2)\theta(-p_0)p_*|z)((\partial_i\tilde\aleph_z^\dagger)\tilde\aleph_z)^b\Big|_{z_*=-\infty}^{z_*=\infty}+?\ \frac{4i}{s}\aleph_x^{ab}\int d^2z_\perp dz_*(x|2\pi\delta(p^2)\theta(-p_0)p_\bullet|z)((\partial_i\tilde\aleph_z^\dagger)\tilde\aleph_z)^b\Big|_{z_\bullet=-\infty}^{z_\bullet=\infty}\\ &+?\ 2\aleph_x^{ab}\int d^2z_\perp(x|2\pi\delta(p^2)\theta(-p_0)|z)((\partial_i\tilde\aleph_z^\dagger)\tilde\aleph_z)^b\Big|_{z_\bullet=-\infty}^{z_\bullet=\infty}\Big|_{z_*=-\infty}^{z_*=\infty}\end{aligned} \tag{466}$$

XV. BFKL?

A. ВКЛАД КВАРКОВ

$$\begin{aligned}(\hat{\bar{P}}+\hat{\bar{C}})\Upsilon &\equiv (\hat{p}+\hat{\bar{A}}+\hat{\bar{B}}+\hat{\bar{C}})(\xi_a+\xi_b+\chi) = 0 \quad\Rightarrow\\ \chi &= -\frac{1}{\hat{\bar{P}}+\hat{\bar{C}}}(\hat{\bar{B}}+\hat{\bar{C}})\xi_a-\frac{1}{\hat{\bar{P}}+\hat{\bar{C}}}(\hat{\bar{A}}+\hat{\bar{C}})\xi_b\end{aligned} \tag{467}$$

$$\Upsilon(x) = -i\int dz_\bullet d^2z_\perp(x|\frac{1}{\hat{\bar{P}}+\hat{\bar{C}}}|z)\Big|_{z_*=-\infty}^{z_*=\infty}\gamma_*\xi_a(z_\bullet)-i\int dz_*d^2z_\perp(x|\frac{1}{\hat{\bar{P}}+\hat{\bar{C}}}|z)\Big|_{z_\bullet=-\infty}^{z_\bullet=\infty}\gamma_\bullet\xi_b(z_*) \tag{468}$$

In the leading order

$$
\begin{aligned}
\chi(x) &= -\int d^4z (x|\frac{1}{\hat{p}}|z)\gamma_*\hat{\bar{A}}_\bullet(z_*)\xi_a(z_\bullet) - \int d^4z (x|\frac{1}{\hat{p}}|z)\gamma_\bullet\hat{\bar{A}}_*(z_\bullet)\xi_b(z_*) \\
&= -\int dz_*dz_\bullet (x_\parallel|\frac{1}{p_\bullet+i\epsilon p_*}|z_\parallel)A_\bullet(z_*,x_\perp)\xi_a(z_\bullet,x_\perp) - \int dz_*dz_\bullet (x_\parallel|\frac{1}{p_*+i\epsilon p_\bullet}|z_\parallel)A_*(z_\bullet,x_\perp)\xi_b(z_*,x_\perp) \\
&= \frac{1}{2\pi}\int dz_*dz_\bullet \frac{1}{x_\bullet - z_\bullet - i\epsilon(x-z)_*}A_\bullet(z_*,x_\perp)\xi_a(z_\bullet,x_\perp) + \frac{1}{2\pi}\int dz_*dz_\bullet \frac{1}{x_* - z_* - i\epsilon(x-z)_\bullet}A_*(z_\bullet,x_\perp)\xi_b(z_*,x_\perp) \\
\bar{\chi}(x) &= \frac{1}{2\pi}\int dz_*dz_\bullet\ \bar{\xi}_a(z_\bullet,x_\perp)A_\bullet(z_*,x_\perp)\frac{1}{z_\bullet - x_\bullet - i\epsilon(z-x)_*} + \frac{1}{2\pi}\int dz_*dz_\bullet\ \bar{\xi}_b(z_*,x_\perp)A_*(z_\bullet,x_\perp)\frac{1}{z_* - x_* - i\epsilon(z-x)_\bullet}
\end{aligned}
\tag{469}
$$

1. *Double counting?*

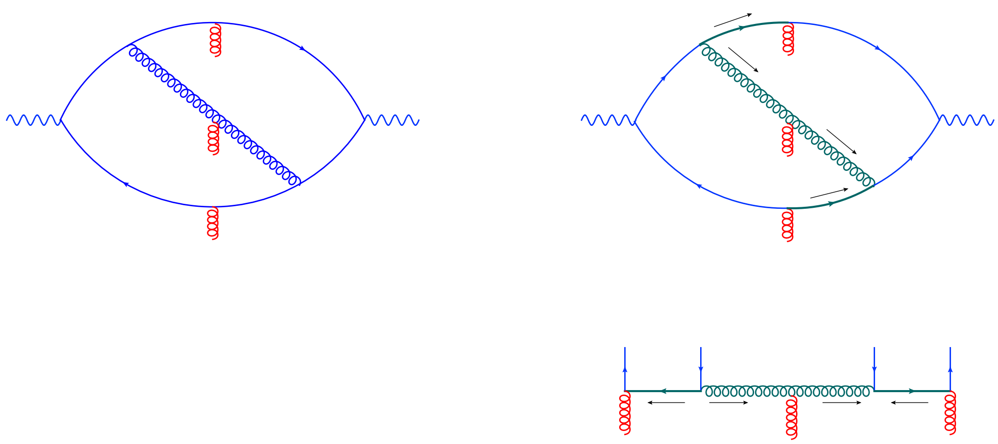

FIG. 4. Problema: projectile fields or central "C" fields? Arrows denote direction of α's.

B. $F_{\mu\nu}$ up to one $A_\bullet$ and one A_*

From Eq. (260)

$$
\begin{aligned}
p^2\bar{C}^a_* &= \bar{D}^\xi\bar{G}^a_{\xi *} + \bar{\xi}_a\gamma_* t^a\xi_a + \bar{\xi}_a\gamma_* t^a\chi + \bar{\chi}\gamma_* t^a\xi_a \ = \ -\frac{2}{s}\partial_*\bar{G}^a_{*\bullet} + \bar{\xi}_a\gamma_* t^a\chi + \bar{\chi}\gamma_* t^a\xi_a, \\
&= -\frac{2}{s}\partial_*\bar{G}^a_{*\bullet} + \frac{1}{2\pi}\int dz_*dz_\bullet\Big[\frac{\bar{\xi}_a(x_\bullet,x_\perp)\hat{p}_2 t^a A_\bullet(z_*,x_\perp)\xi_a(z_\bullet,x_\perp)}{x_\bullet - z_\bullet - i\epsilon(x-z)_*} + \frac{\bar{\xi}_a(z_\bullet,x_\perp)A_\bullet(z_*,x_\perp)t^a\hat{p}_2\xi_a(x_\bullet,x_\perp)}{z_\bullet - x_\bullet - i\epsilon(z-x)_*}\Big] \\
&= -\frac{2}{s}\partial_*\bar{G}^a_{*\bullet} + \frac{1}{2\pi}\int dz_*dz_\bullet \mathrm{V.p.}\frac{1}{x_\bullet - z_\bullet}\big[\bar{\xi}_a(x_\bullet,x_\perp)\hat{p}_2 t^a t^b\xi_a(z_\bullet,x_\perp) - \bar{\xi}_a(z_\bullet,x_\perp)t^b t^a\hat{p}_2\xi_a(x_\bullet,x_\perp)\big]\int dz_* A_\bullet(z_*,x_\perp) \\
&\qquad + \frac{1}{2}f^{abc}\bar{\xi}_a t^b\hat{p}_2\xi_a(x_\bullet,x_\perp)\int dz_*\ \epsilon(x_* - z_*)A^c_\bullet(z_*,x_\perp) \\
p^2\bar{C}^a_\bullet &= \bar{D}^\xi\bar{G}^a_{\xi\bullet} + \bar{\xi}_b\gamma_\bullet t^a\xi_b + \bar{\xi}_b\gamma_\bullet t^a\chi + \bar{\chi}\gamma_\bullet t^a\xi_b \ = \ \frac{2}{s}\partial_\bullet\bar{G}^a_{*\bullet} + \bar{\xi}_b\gamma_\bullet t^a\chi + \bar{\chi}\gamma_\bullet t^a\xi_b, \\
p^2\bar{C}^a_i &= \bar{D}^\xi\bar{G}_{\xi i} \ = \ \frac{2}{s}\big(\bar{D}_*\bar{G}_{\bullet i} + \bar{D}_\bullet\bar{G}_{*i}\big) \ = \ -\frac{2}{s}f^{abc}\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)
\end{aligned}
\tag{470}
$$

$$
\begin{aligned}
\bar{C}^{(1)a}_*(x) &= \frac{2i}{s}\int d^4z\ (x|\frac{p_*}{p^2+i\epsilon}|z)\bar{G}^a_{*\bullet}(z), \qquad \bar{C}^{(1)a}_\bullet(x) \ = \ -\frac{2i}{s}\int d^4z\ (x|\frac{p_\bullet}{p^2+i\epsilon}|z)\bar{G}^a_{*\bullet}(z), \\
\bar{C}^{(1)a}_i &= -\frac{2}{s}f^{abc}\int d^4z\ (x|\frac{1}{p^2+i\epsilon}|z)\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)(z)
\end{aligned}
\tag{471}
$$

$$\begin{aligned}
F^{(1)a}_{*\bullet}(x) &= \bar{G}_{*\bullet}(x) - \frac{4}{s}\int d^4z\ (x|\frac{p_*p_\bullet}{p^2+i\epsilon}|z)\bar{G}^a_{*\bullet}(z) \ = \ \int d^4z\ (x|\frac{1}{p^2+i\epsilon}|z)\partial^2_\perp \bar{G}^a_{*\bullet}(z)\\
F^{(1)a}_{\bullet i}(x) &= \bar{G}^a_{\bullet i}(x) + \frac{2i}{s}f^{abc}\int d^4z\ (x|\frac{p_\bullet}{p^2+i\epsilon}|z)\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)(z) + \frac{2}{s}\int d^4z\ (x|\frac{p_\bullet p_i}{p^2+i\epsilon}|z)\bar{G}^a_{*\bullet}(z)\\
&= \bar{G}^a_{\bullet i}(x) + \frac{4i}{s}f^{abc}\int d^4z\ (x|\frac{p_\bullet}{p^2+i\epsilon}|z)\bar{A}^b_*\partial_i\bar{A}^c_\bullet(z)\\
F^{(1)a}_{*i}(x) &= \bar{G}^a_{*i}(x) + \frac{4i}{s}f^{abc}\int d^4z\ (x|\frac{p_*}{p^2+i\epsilon}|z)\bar{A}^b_\bullet\partial_i\bar{A}^c_*(z)\\
F^{(1)a}_{ij}(x) &= -\frac{4}{s}f^{abc}\int d^4z\ (x|\frac{1}{p^2+i\epsilon}|z)\big(\partial_i\bar{A}^b_*\partial_j\bar{A}^c_\bullet(z) - i\leftrightarrow j\big)
\end{aligned} \tag{472}$$

1. $F_{\bullet i}$ up to $\bar{A}^2_\bullet\bar{A}_*$

From Eq. (260)

$$\begin{aligned}
\bar{P}^2\bar{C}^a_i + \frac{4ig}{s}\big(\bar{G}^{ab}_{i\bullet}\bar{C}^b_* + \bar{G}^{ab}_{i*}\bar{C}^b_\bullet\big) &= \bar{D}^{ab\xi}\bar{G}^b_{\xi i} + gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_i - \bar{C}^b_\beta\partial_i\bar{C}^{c\beta}) - g^2f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_i\bar{C}^d_\beta + \bar{\Upsilon}\gamma_i t^a\Upsilon\\
\Rightarrow\ p^2\bar{C}^{(2)a}_i &= -\frac{4}{s}\big(\bar{A}_*p_\bullet + \bar{A}_\bullet p_*\big)^{ab}\bar{C}^{(1)b}_i + \frac{4ig}{s}\big(\bar{G}^{ab}_{\bullet i}\bar{C}^{(1)b}_* + \bar{G}^{ab}_{*i}\bar{C}^{(1)b}_\bullet\big) + \bar{\xi}_a\gamma_i t^a\xi_b + \bar{\xi}_b\gamma_i t^a\xi_a\\
\Rightarrow\ \bar{C}^{(2)a}_i(x) &= \frac{8}{s^2}\int d^4z\ (x|\frac{1}{p^2}\big(\bar{A}_*\frac{p_\bullet}{p^2} + \bar{A}_\bullet\frac{p_*}{p^2}\big)|z)^{aa'}f^{a'bc}\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)(z) + \frac{8}{s^2}\int d^4z\ (x|\frac{1}{p^2}\big(\bar{G}_{*i}\frac{p_\bullet}{p^2} - \bar{G}_{\bullet i}\frac{p_*}{p^2}\big)|z)^{ab}\bar{G}^b_{*\bullet}(z)\\
&+ \int d^4z\ (x|\frac{1}{p^2}\big(\bar{\xi}_a\gamma_i t^a\xi_b + \bar{\xi}_b\gamma_i t^a\xi_a\big)
\end{aligned} \tag{473}$$

$$\begin{aligned}
\bar{P}^2\bar{C}^a_\bullet + 2ig\bar{G}^{ab}_{\bullet\xi}\bar{C}^{b\xi} &= \bar{D}^{ab\xi}\bar{G}^b_{\xi\bullet} + gf^{abc}(2\bar{C}^b_\beta\bar{D}^\beta\bar{C}^c_\bullet - \bar{C}^b_\beta\bar{D}_\bullet\bar{C}^{c\beta}) - g^2f^{abm}f^{cdm}\bar{C}^{b\beta}\bar{C}^c_\bullet\bar{C}^d_\beta + \bar{\xi}_b\gamma_\bullet t^a\xi_b\\
\Rightarrow\ \bar{P}^2\bar{C}^a_\bullet + 2ig\bar{G}^{ab}_{\bullet\xi}\bar{C}^{b\xi} &= -\frac{2i}{s}\bar{A}^{ab}_\bullet\bar{G}^b_{*\bullet} \quad\Rightarrow\ p^2\bar{C}^{(2)a}_\bullet \ = \ -\frac{4}{s}\bar{A}_\bullet p_*\bar{C}^{(1)a}_\bullet - 2ig\bar{G}^{ab}_{\bullet i}\bar{C}^{(1)bi} - \frac{2i}{s}\bar{A}^{ab}_\bullet\bar{G}^b_{*\bullet}\\
\Rightarrow\ \bar{C}^{(2)a}_\bullet(x) &= -\frac{2i}{s}\int d^4z\ (x|\frac{1}{p^2}\bar{A}_\bullet\frac{1}{p^2}|z)^{ab}\partial^2_\perp\bar{G}^b_{*\bullet}(z) + \frac{4i}{s}\int d^4z\ (x|\frac{1}{p^2}\bar{G}_{\bullet i}\frac{1}{p^2}|z)^{aa'}f^{a'bc}\big(\bar{A}^b_\bullet\partial^i\bar{A}^c_* + \bar{A}^b_*\partial^i\bar{A}^c_\bullet\big)(z)
\end{aligned} \tag{474}$$

$$\begin{aligned}
&F^{(2)a}_{\bullet i}(x) \ = \ \partial_\bullet\bar{C}^{(2)a}_i(x) - i\bar{A}^{ab}_\bullet\bar{C}^{(1)b}_i(x) - \partial_i\bar{C}^{(2)a}_\bullet(x)\\
&= -\frac{8i}{s^2}\int d^4z\ (x|\frac{p_\bullet}{p^2}\bar{A}_\bullet\frac{p_*}{p^2}|z)^{aa'}f^{a'bc}\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)(z) + \frac{8i}{s^2}\int d^4z\ (x|\frac{p_\bullet}{p^2}\bar{G}_{\bullet i}\frac{p_*}{p^2}|z)^{ab}\bar{G}^b_{*\bullet}(z)\\
&- i\int d^4z\ (x|\frac{p_\bullet}{p^2}\big(\bar{\xi}_a\gamma_i t^a\xi_b + \bar{\xi}_b\gamma_i t^a\xi_a\big) + \frac{2i}{s}\bar{A}^{aa'}_\bullet\int d^4z\ (x|\frac{1}{p^2}|z)f^{a'bc}\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)(z)\\
&+ \frac{2}{s}\int d^4z\ (x|\frac{p_i}{p^2}\bar{A}_\bullet\frac{1}{p^2}|z)^{ab}\partial^2_\perp\bar{G}^b_{*\bullet}(z) - \frac{4}{s}\int d^4z\ (x|\frac{p_i}{p^2}\bar{G}_{\bullet j}\frac{1}{p^2}|z)^{aa'}f^{a'bc}\big(\bar{A}^b_\bullet\partial^j\bar{A}^c_* + \bar{A}^b_*\partial^j\bar{A}^c_\bullet\big)(z)\\
&= -\frac{2i}{s}\int d^4z\ (x|\frac{p^2_\perp}{p^2}\bar{A}_\bullet\frac{1}{p^2}|z)^{aa'}f^{a'bc}\big(\bar{A}^b_\bullet\partial_i\bar{A}^c_* + \bar{A}^b_*\partial_i\bar{A}^c_\bullet\big)(z) + \frac{2i}{s}\int d^4z\ \bar{G}^{ab}_{\bullet i}(x)(x|\frac{1}{p^2}|z)\bar{G}^b_{*\bullet}(z)\\
&+ \frac{2i}{s}\int d^4z\ (x|\frac{p^2_\perp}{p^2}\bar{G}_{\bullet i}\frac{1}{p^2}|z)^{ab}\bar{G}^b_{*\bullet}(z) - \ i\int d^4z\ (x|\frac{p_\bullet}{p^2}\big(\bar{\xi}_a\gamma_i t^a\xi_b + \bar{\xi}_b\gamma_i t^a\xi_a\big)\\
&+ \frac{2}{s}\int d^4z\ (x|\frac{p_i}{p^2}\bar{A}_\bullet\frac{1}{p^2}|z)^{ab}\partial^2_\perp\bar{G}^b_{*\bullet}(z) - \frac{4}{s}\int d^4z\ (x|\frac{p_i}{p^2}\bar{G}_{\bullet j}\frac{1}{p^2}|z)^{aa'}f^{a'bc}\big(\bar{A}^b_\bullet\partial^j\bar{A}^c_* + \bar{A}^b_*\partial^j\bar{A}^c_\bullet\big)(z)
\end{aligned} \tag{475}$$

2. Action

$$\int d^4x\ \bar{G}^{ai}_*(x)F^{(2)a}_{\bullet i}(x) \ = \tag{476}$$