

# Wave operator and propagator

Quadratic (free) action

$$\begin{aligned}
S = & \int \int \int \left( \frac{1}{6} \omega_{\alpha}^{\alpha i} \omega_{\alpha}^{\kappa} \omega_{\alpha}^{\beta \chi} \tau_{\alpha \beta} + 6 \omega^{\alpha \beta \chi} \sigma_{\alpha \beta \chi} + 8 t_3 \omega_{\alpha}^{\kappa} \omega_{\alpha}^{\beta} \partial_{\alpha} f^{\alpha i} - \right. \\
& 8 t_3 \omega_{\alpha}^{\kappa} \omega_{\alpha}^{\beta} \partial_{\alpha} f^{\alpha} + 4 t_3 \partial_{\alpha} f^{\alpha} \partial_{\alpha} f^{\alpha} - 3 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - \\
& 3 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - 3 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta i} \partial_{\alpha} \omega_{\alpha}^{\beta} + \\
& 6 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - 3 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta i} \partial_{\alpha} \omega_{\alpha}^{\beta} + \\
& 6 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} + 8 r_2 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - \\
& 4 r_2 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} + 4 r_2 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - \\
& 24 r_3 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - 2 r_2 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} + \\
& 2 r_2 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - 4 r_2 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} + \\
& 6 r_5 \partial_{\alpha} \omega_{\alpha}^{\kappa} \partial_{\alpha} \omega_{\alpha}^{\alpha i} - 6 r_5 \partial_{\alpha} \omega_{\alpha}^{\kappa} \partial_{\alpha} \omega_{\alpha}^{\alpha i} + \\
& 4 t_3 \partial_{\alpha} f^{\alpha} \partial_{\alpha} f^{\alpha} - 8 t_3 \partial_{\alpha} f^{\alpha} \partial_{\alpha} f^{\alpha} - 6 r_5 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} + \\
& 12 r_5 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} + 6 r_5 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} - \\
& \left. 12 r_5 \partial_{\alpha} \omega_{\alpha}^{\beta} \partial_{\alpha} \omega_{\alpha}^{\beta} \right) [t, x, y, z] dz dy dx dt
\end{aligned}$$

(No massive particles)

$$r_3 < 0 \& \& (r_5 < -\frac{r_3}{2} \parallel r_5 > -2r_3) \parallel r_3 > 0 \& \& -2r_3 < r_5 < -\frac{r_3}{2}$$

$\#_1^1 + \alpha\beta$	$\omega_{1^1 + \alpha\beta}^{\#1}$	$\omega_{1^1 + \alpha\beta}^{\#2}$	$f_{1^1 + \alpha\beta}^{\#1}$	$\omega_{1^1 - \alpha}^{\#1}$	$\omega_{1^1 - \alpha}^{\#2}$	$f_{1^1 - \alpha}^{\#1}$	$f_{1^1 - \alpha}^{\#2}$
$\#_1^1 + \alpha\beta$	$k^2 (2r_3 + r_5)$	0	0	0	0	0	0
$\#_1^2 + \alpha\beta$	0	0	0	0	0	0	0
$\#_1^1 + \alpha\beta$	0	0	0	0	0	0	0
$\#_1^1 + \alpha$	0	0	0	$k^2 (\frac{r_3}{2} + r_5) + \frac{2t_3}{3}$	$-\frac{\sqrt{2}t_3}{3}$	0	$-\frac{2}{3} i k t_3$
$\#_1^2 + \alpha$	0	0	0	$-\frac{\sqrt{2}t_3}{3}$	$\frac{t_3}{3}$	0	$\frac{1}{3} i \sqrt{2} k t_3$
$\#_1^1 + \alpha$	0	0	0	0	0	0	0
$\#_1^2 + \alpha$	0	0	0	$\frac{2 i k t_3}{3}$	$-\frac{1}{3} i \sqrt{2} k t_3$	0	$\frac{2 k^2 t_3}{3}$

$$\begin{array}{c}
\begin{array}{ccc}
\omega_{2^+ \alpha\beta}^{\#1} & f_{2^+ \alpha\beta}^{\#1} & \omega_{2^- \alpha\beta\chi}^{\#1} \\
\omega_{2^+}^{\#1} \dagger \alpha\beta & -\frac{3k^2 r_3}{2} & 0 & 0 \\
f_{2^+}^{\#1} \dagger \alpha\beta & 0 & 0 & 0 \\
\omega_{2^-}^{\#1} \dagger \alpha\beta\chi & 0 & 0 & 0
\end{array} \\
\begin{array}{cccc}
\sigma_0^{\#1} \dagger & \tau_0^{\#1} & \tau_0^{\#2} & \sigma_0^{\#1} \\
\sigma_0^{\#1} \dagger & \frac{1}{(1+2k^2)^2 t_3} & -\frac{i\sqrt{2}k}{(1+2k^2)^2 t_3} & 0 & 0 \\
\tau_0^{\#1} \dagger & \frac{i\sqrt{2}k}{(1+2k^2)^2 t_3} & \frac{2k^2}{(1+2k^2)^2 t_3} & 0 & 0 \\
\tau_0^{\#2} \dagger & 0 & 0 & 0 & 0 \\
\sigma_0^{\#1} \dagger & 0 & 0 & 0 & \frac{1}{k^2 r_2}
\end{array}
\end{array}
\begin{array}{c}
\begin{array}{ccc}
\sigma_{2^+}^{\#1} & \tau_{2^+}^{\#1} & \sigma_{2^-}^{\#1} \alpha\beta\chi \\
\sigma_{2^+}^{\#1} \dagger \alpha\beta & -\frac{2}{3k^2 r_3} & 0 & 0 \\
\tau_{2^+}^{\#1} \dagger \alpha\beta & 0 & 0 & 0 \\
\sigma_{2^-}^{\#1} \dagger \alpha\beta\chi & 0 & 0 & 0
\end{array} \\
\begin{array}{cccc}
f_0^{\#2} & \omega_0^{\#1} & f_0^{\#1} & \omega_0^{\#1} \\
f_0^{\#2} & 0 & 0 & 0 & k^2 r_2 \\
f_0^{\#2} & 0 & 0 & 0 & 0 \\
f_0^{\#1} & -i\sqrt{2}k t_3 & 2k^2 t_3 & 0 & 0 \\
\omega_0^{\#1} & t_3 & i\sqrt{2}k t_3 & 0 & 0 \\
\omega_0^{\#1} \dagger & \omega_0^{\#1} \dagger & f_0^{\#1} \dagger & f_0^{\#2} \dagger & \omega_0^{\#1} \dagger
\end{array}
\end{array}$$