PSALTer results panel

Wave operator and propagator

Spin-parity form	Covariant form	Multiplicities
$0^+ \mathcal{T}^{\perp} == 0$	$\partial_\beta \partial_\alpha \mathcal{T}^{\alpha\beta} == 0$	1
$1^- \mathcal{T}^{\perp\alpha} == 0$	$\partial_\chi \partial_\beta \partial^\alpha \mathcal{T}^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \mathcal{T}^{\alpha\beta}$	3
Total expected gauge generators:		4

$$\mathcal{S} == \iiiint \Big(\tfrac{1}{8}\big(-4 a_0 \mathcal{A}_{\alpha\chi\beta} \mathcal{A}^{\alpha\beta\chi} + 8 \mathcal{A}^{\alpha\beta\chi} \mathcal{W}_{\alpha\beta\chi} + 8 \mathcal{T}^{\alpha\beta} h_{\alpha\beta} + 4 a_0 h^{\alpha\beta} \partial_\beta \mathcal{A}_{\alpha\ \chi}^{\ \chi} - 4 a_0 \mathcal{A}^{\alpha\beta\chi} \partial_\beta h_{\alpha\chi} + 2 a_0 \mathcal{A}^{\alpha\beta}{}_{\alpha} \partial_\beta h^\chi{}_\chi +$$
$$2 a_0 h^{\alpha\beta} \partial_\beta \partial_\alpha h^\chi{}_\chi - a_0 \partial_\beta h^\chi{}_\chi \partial^\beta h^\alpha{}_\alpha - 4 a_0 h^{\alpha\beta} \partial_\chi \mathcal{A}_{\alpha\ \beta}^{\ \chi} - 2 a_0 h^\alpha{}_\alpha \partial_\chi \mathcal{A}^{\beta\ \chi}_{\ \beta} + 2 a_0 h^\alpha{}_\alpha \partial_\chi \mathcal{A}^{\beta\chi}{}_\beta +$$
$$2 a_0 \partial^\beta h^\alpha{}_\alpha \partial_\chi h_\beta{}^\chi + 2 a_0 \mathcal{A}^{\alpha\ \beta}_{\ \alpha} (2 \mathcal{A}^\chi{}_{\beta\chi} - \partial_\beta h^\chi{}_\chi + 2 \partial_\chi h_\beta{}^\chi) + 4 h_7 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\chi \partial_\alpha h^\delta{}_\delta +$$
$$4 h_8 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\chi \partial_\alpha h^\delta{}_\delta - 4 a_0 h^{\alpha\beta} \partial_\chi \partial_\beta h_\alpha{}^\chi + 2 a_0 h^\alpha{}_\alpha \partial_\chi \partial_\beta h^{\beta\chi} + 2 a_0 h^{\alpha\beta} \partial_\chi \partial^\chi h_{\alpha\beta} -$$
$$2 a_0 h^\alpha{}_\alpha \partial_\chi \partial^\chi h^\beta{}_\beta - 4 h_8 \partial_\beta \mathcal{A}_{\chi\ \delta}^{\ \delta} \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} - 4 h_7 \partial_\chi \mathcal{A}_{\beta\ \delta}^{\ \delta} \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} - 4 h_7 \partial_\chi \partial_\beta h^\delta{}_\delta \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} -$$
$$4 h_8 \partial_\chi \partial_\beta h^\delta{}_\delta \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} - 2 a_0 \partial_\beta h_{\alpha\chi} \partial^\chi h^{\alpha\beta} + a_0 \partial_\chi h_{\alpha\beta} \partial^\chi h^{\alpha\beta} - h_7 \partial_\chi \partial_\beta h^\delta{}_\delta \partial^\chi \partial^\beta h^\alpha{}_\alpha -$$
$$h_8 \partial_\chi \partial_\beta h^\delta{}_\delta \partial^\chi \partial^\beta h^\alpha{}_\alpha - 4 h_7 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\delta \mathcal{A}_{\alpha\ \chi}^{\ \delta} - 4 h_8 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\delta \mathcal{A}_{\alpha\ \chi}^{\ \delta} + 8 h_7 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \mathcal{A}_{\beta\ \chi}^{\ \delta} +$$
$$8 h_8 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \mathcal{A}_{\beta\ \chi}^{\ \delta} + 2 h_7 \partial_\chi \partial^\chi h^{\alpha\beta} \partial_\delta \partial_\beta h_\alpha{}^\delta + 2 h_8 \partial_\chi \partial^\chi h^{\alpha\beta} \partial_\delta \partial_\beta h_\alpha{}^\delta - 2 h_7 \partial_\alpha \partial^\chi h^{\alpha\beta} \partial_\delta \partial_\beta h_\chi{}^\delta -$$
$$2 h_8 \partial_\alpha \partial^\chi h^{\alpha\beta} \partial_\delta \partial_\beta h_\chi{}^\delta + 4 h_7 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \partial_\beta h_\chi{}^\delta + 4 h_8 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \partial_\beta h_\chi{}^\delta + 2 h_7 \partial^\chi \partial^\beta h^\alpha{}_\alpha \partial_\delta \partial_\beta h_\chi{}^\delta +$$
$$2 h_8 \partial^\chi \partial^\beta h^\alpha{}_\alpha \partial_\delta \partial_\beta h_\chi{}^\delta - 8 h_7 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\delta \partial_\chi h_\alpha{}^\delta - 8 h_8 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\delta \partial_\chi h_\alpha{}^\delta - 2 h_7 \partial_\alpha \partial^\chi h^{\alpha\beta} \partial_\delta \partial_\chi h_\beta{}^\delta -$$
$$2 h_8 \partial_\alpha \partial^\chi h^{\alpha\beta} \partial_\delta \partial_\chi h_\beta{}^\delta + 4 h_7 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \partial_\chi h_\beta{}^\delta + 4 h_8 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \partial_\chi h_\beta{}^\delta + 2 h_7 \partial^\chi \partial^\beta h^\alpha{}_\alpha \partial_\delta \partial_\chi h_\beta{}^\delta +$$
$$2 h_8 \partial^\chi \partial^\beta h^\alpha{}_\alpha \partial_\delta \partial_\chi h_\beta{}^\delta - h_7 \partial_\chi \partial^\chi h^{\alpha\beta} \partial_\delta \partial^\delta h_{\alpha\beta} - h_8 \partial_\chi \partial^\chi h^{\alpha\beta} \partial_\delta \partial^\delta h_{\alpha\beta} + 4 h_7 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\delta \partial^\delta h_{\alpha\chi} +$$
$$4 h_8 \partial_\beta \mathcal{A}^{\alpha\beta\chi} \partial_\delta \partial^\delta h_{\alpha\chi} + 2 h_7 \partial_\alpha \partial^\chi h^{\alpha\beta} \partial_\delta \partial^\delta h_{\beta\chi} + 2 h_8 \partial_\alpha \partial^\chi h^{\alpha\beta} \partial_\delta \partial^\delta h_{\beta\chi} - 4 h_7 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \partial^\delta h_{\beta\chi} -$$
$$4 h_8 \partial^\chi \mathcal{A}^{\alpha\ \beta}_{\ \alpha} \partial_\delta \partial^\delta h_{\beta\chi} - 2 h_7 \partial^\chi \partial^\beta h^\alpha{}_\alpha \partial_\delta \partial^\delta h_{\beta\chi} - 2 h_8 \partial^\chi \partial^\beta h^\alpha{}_\alpha \partial_\delta \partial^\delta h_{\beta\chi}\big)\Big)[t, x, y, z]\, dz\, dy\, dx\, dt$$

	$3^- \mathcal{W}_s^{\parallel}{}_{\alpha\beta\chi}$
$3^- \mathcal{W}_s^{\parallel} \dagger^{\alpha\beta\chi}$	$-\frac{2}{a_0}$

	$3^- \mathcal{A}_s^{\parallel}{}_{\alpha\beta\chi}$
$3^- \mathcal{A}_s^{\parallel} \dagger^{\alpha\beta\chi}$	$-\frac{a_0}{2}$

	$0^+ \mathcal{T}^{\perp}$	$0^+ \mathcal{T}^{\parallel}$	$0^+ \mathcal{W}_s^{\perp t}$	$0^+ \mathcal{W}_s^{\parallel}$	$0^+ \mathcal{W}_s^{\perp h}$
$0^+ \mathcal{T}^{\perp} \dagger$	0	0	0	0	0
$0^+ \mathcal{T}^{\parallel} \dagger$	0	$\frac{4(2k^2(h_7+h_8)+a_0)}{k^2 a_0^2}$	0	$\frac{4 i k (h_7+h_8)}{\sqrt{3} a_0^2}$	$-\frac{8 i \sqrt{\frac{2}{3}} k (h_7+h_8)}{a_0^2}$
$0^+ \mathcal{W}_s^{\perp t} \dagger$	0	0	$-\frac{-6k^2(h_7+h_8)+a_0}{3 a_0^2}$	$\frac{5}{3 a_0}$	$\frac{2\sqrt{2}}{3 a_0}$
$0^+ \mathcal{W}_s^{\parallel} \dagger$	0	$-\frac{4 i k (h_7+h_8)}{\sqrt{3} a_0^2}$	$\frac{5}{3 a_0}$	$-\frac{-2k^2(h_7+h_8)+a_0}{3 a_0^2}$	$\frac{2\sqrt{2}(-2k^2(h_7+h_8)+a_0)}{3 a_0^2}$
$0^+ \mathcal{W}_s^{\perp h} \dagger$	0	$\frac{8 i \sqrt{\frac{2}{3}} k (h_7+h_8)}{a_0^2}$	$\frac{2\sqrt{2}}{3 a_0}$	$\frac{2\sqrt{2}(-2k^2(h_7+h_8)+a_0)}{3 a_0^2}$	$\frac{8(2k^2(h_7+h_8)-a_0)}{3 a_0^2}$

	$0^+ h^{\perp}$	$0^+ h^{\parallel}$	$0^+ \mathcal{A}_s^{\perp t}$	$0^+ \mathcal{A}_s^{\parallel}$	$0^+ \mathcal{A}_s^{\perp h}$
$0^+ h^{\perp} \dagger$	0	0	0	0	0
$0^+ h^{\parallel} \dagger$	0	$\frac{1}{4}(-2k^4(h_7+h_8)+k^2 a_0)$	0	$\frac{i k^3 (h_7+h_8)}{2\sqrt{3}}$	$-\frac{5 i k^3 (h_7+h_8)}{4\sqrt{6}}$
$0^+ \mathcal{A}_s^{\perp t} \dagger$	0	0	0	$\frac{a_0}{2}$	$\frac{a_0}{4\sqrt{2}}$
$0^+ \mathcal{A}_s^{\parallel} \dagger$	0	$-\frac{i k^3 (h_7+h_8)}{2\sqrt{3}}$	$\frac{a_0}{2}$	$-\frac{2}{3} k^2 (h_7+h_8)$	$\frac{2k^2(h_7+h_8)+3a_0}{12\sqrt{2}}$
$0^+ \mathcal{A}_s^{\perp h} \dagger$	0	$\frac{5 i k^3 (h_7+h_8)}{4\sqrt{6}}$	$\frac{a_0}{4\sqrt{2}}$	$\frac{2k^2(h_7+h_8)+3a_0}{12\sqrt{2}}$	$\frac{1}{12}(-7k^2(h_7+h_8)-3a_0)$

	$2^+ h^{\parallel}{}_{\alpha\beta}$	$2^+ \mathcal{A}_s^{\parallel}{}_{\alpha\beta}$	$2^+ \mathcal{A}_s^{\perp}{}_{\alpha\beta}$	$2^- \mathcal{A}_s^{\parallel}{}_{\alpha\beta\chi}$
$2^+ h^{\parallel} \dagger^{\alpha\beta}$	$-\frac{1}{8} k^2 (k^2 (h_7+h_8)+a_0)$	$-\frac{i k^3 (h_7+h_8)}{4\sqrt{3}}$	$-\frac{i k^3 (h_7+h_8)}{2\sqrt{6}}$	0
$2^+ \mathcal{A}_s^{\parallel} \dagger^{\alpha\beta}$	$\frac{i k^3 (h_7+h_8)}{4\sqrt{3}}$	$\frac{1}{6}(-k^2(h_7+h_8)-3a_0)$	$-\frac{k^2(h_7+h_8)}{3\sqrt{2}}$	0
$2^+ \mathcal{A}_s^{\perp} \dagger^{\alpha\beta}$	$\frac{i k^3 (h_7+h_8)}{2\sqrt{6}}$	$-\frac{k^2(h_7+h_8)}{3\sqrt{2}}$	$-\frac{1}{3} k^2 (h_7+h_8)+\frac{a_0}{4}$	0
$2^- \mathcal{A}_s^{\parallel} \dagger^{\alpha\beta\chi}$	0	0	0	$\frac{a_0}{4}$

	$2^+ \mathcal{T}^{\parallel}{}_{\alpha\beta}$	$2^+ \mathcal{W}_s^{\parallel}{}_{\alpha\beta}$	$2^+ \mathcal{W}_s^{\perp}{}_{\alpha\beta}$	$2^- \mathcal{W}_s^{\parallel}{}_{\alpha\beta\chi}$
$2^+ \mathcal{T}^{\parallel} \dagger^{\alpha\beta}$	$\frac{8(h_7+h_8-\frac{a_0}{k^2})}{a_0^2}$	$\frac{4 i k (h_7+h_8)}{\sqrt{3} a_0^2}$	$-\frac{8 i \sqrt{\frac{2}{3}} k (h_7+h_8)}{a_0^2}$	0
$2^+ \mathcal{W}_s^{\parallel} \dagger^{\alpha\beta}$	$-\frac{4 i k (h_7+h_8)}{\sqrt{3} a_0^2}$	$\frac{2(k^2(h_7+h_8)-3a_0)}{3 a_0^2}$	$-\frac{4\sqrt{2} k^2 (h_7+h_8)}{3 a_0^2}$	0
$2^+ \mathcal{W}_s^{\perp} \dagger^{\alpha\beta}$	$\frac{8 i \sqrt{\frac{2}{3}} k (h_7+h_8)}{a_0^2}$	$-\frac{4\sqrt{2} k^2 (h_7+h_8)}{3 a_0^2}$	$\frac{4(4k^2(h_7+h_8)+3a_0)}{3 a_0^2}$	0
$2^- \mathcal{W}_s^{\parallel} \dagger^{\alpha\beta\chi}$	0	0	0	$\frac{4}{a_0}$

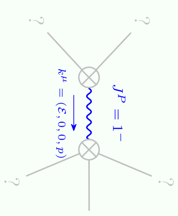
	$1^+ \mathcal{W}_s^{\perp}{}_{\alpha\beta}$	$1^- \mathcal{T}^{\perp}{}_\alpha$	$1^- \mathcal{W}_s^{\perp t}{}_\alpha$	$1^- \mathcal{W}_s^{\parallel t}{}_\alpha$	$1^- \mathcal{W}_s^{\perp h}{}_\alpha$	$1^- \mathcal{W}_s^{\parallel h}{}_\alpha$
$1^+ \mathcal{W}_s^{\perp} \dagger^{\alpha\beta}$	$\frac{4}{a_0}$	0	0	0	0	0
$1^- \mathcal{T}^{\perp} \dagger^\alpha$	0	0	0	0	0	0
$1^- \mathcal{W}_s^{\perp t} \dagger^\alpha$	0	0	$\frac{1}{3}\left(\frac{1}{k^2(-h_7+h_8)-3a_0}+\frac{4k^2(h_7+h_8)-4a_0}{a_0^2}\right)$	$\frac{1}{3}\sqrt{5}\left(\frac{1}{k^2(-h_7+h_8)-3a_0}+\frac{2}{a_0}\right)$	$\frac{2\sqrt{2}(2k^4(h_7-h_8)(h_7+h_8)+k^2(7h_7+5h_8)a_0+a_0^2)}{3a_0^2(k^2(h_7-h_8)+3a_0)}$	$\frac{4}{3}\left(\frac{1}{a_0}-\frac{2}{k^2(h_7-h_8)+3a_0}\right)$
$1^- \mathcal{W}_s^{\parallel t} \dagger^\alpha$	0	0	$\frac{1}{3}\sqrt{5}\left(\frac{1}{k^2(-h_7+h_8)-3a_0}+\frac{2}{a_0}\right)$	$\frac{4}{3a_0}-\frac{5}{3k^2(h_7-h_8)+9a_0}$	$\frac{2\sqrt{10}(k^2(h_7-h_8)+a_0)}{3a_0(k^2(h_7-h_8)+3a_0)}$	$\frac{4\sqrt{5}(k^2(h_7-h_8)+a_0)}{3a_0(k^2(h_7-h_8)+3a_0)}$
$1^- \mathcal{W}_s^{\perp h} \dagger^\alpha$	0	0	$\frac{2\sqrt{2}(2k^4(h_7-h_8)(h_7+h_8)+k^2(7h_7+5h_8)a_0+a_0^2)}{3a_0^2(k^2(h_7-h_8)+3a_0)}$	$\frac{2\sqrt{10}(k^2(h_7-h_8)+a_0)}{3a_0(k^2(h_7-h_8)+3a_0)}$	$\frac{8}{3}\left(\frac{k^2(h_7+h_8)+2a_0}{a_0^2}-\frac{4}{k^2(h_7-h_8)+3a_0}\right)$	$\frac{4}{3}\sqrt{2}\left(\frac{1}{a_0}-\frac{8}{k^2(h_7-h_8)+3a_0}\right)$
$1^- \mathcal{W}_s^{\parallel h} \dagger^\alpha$	0	0	$\frac{4}{3}\left(\frac{1}{a_0}-\frac{2}{k^2(h_7-h_8)+3a_0}\right)$	$\frac{4\sqrt{5}(k^2(h_7-h_8)+a_0)}{3a_0(k^2(h_7-h_8)+3a_0)}$	$\frac{4}{3}\sqrt{2}\left(\frac{1}{a_0}-\frac{8}{k^2(h_7-h_8)+3a_0}\right)$	$\frac{4}{3}\left(\frac{5}{a_0}-\frac{16}{k^2(h_7-h_8)+3a_0}\right)$

	$1^+ \mathcal{A}_s^{\perp}{}_{\alpha\beta}$	$1^- h^{\perp}{}_\alpha$	$1^- \mathcal{A}_s^{\perp t}{}_\alpha$	$1^- \mathcal{A}_s^{\parallel t}{}_\alpha$	$1^- \mathcal{A}_s^{\perp h}{}_\alpha$	$1^- \mathcal{A}_s^{\parallel h}{}_\alpha$
$1^+ \mathcal{A}_s^{\perp} \dagger^{\alpha\beta}$	$\frac{a_0}{4}$	0	0	0	0	0
$1^- h^{\perp} \dagger^\alpha$	0	0	0	0	0	0
$1^- \mathcal{A}_s^{\perp t} \dagger^\alpha$	0	0	$\frac{1}{6}(-k^2 h_7 - 2a_0)$	$\frac{1}{6}\sqrt{5}(k^2 h_8 + a_0)$	$\frac{2k^2 h_7 + a_0}{12\sqrt{2}}$	$\frac{1}{12}(-2k^2 h_8 + a_0)$
$1^- \mathcal{A}_s^{\parallel t} \dagger^\alpha$	0	0	$\frac{1}{6}\sqrt{5}(k^2 h_8 + a_0)$	$\frac{1}{6}(-5k^2 h_7 + 2a_0)$	$\frac{1}{12}\sqrt{\frac{5}{2}}(-2k^2 h_8 + a_0)$	$\frac{1}{12}\sqrt{5}(2k^2 h_7 + a_0)$
$1^- \mathcal{A}_s^{\perp h} \dagger^\alpha$	0	0	$\frac{2k^2 h_7 + a_0}{12\sqrt{2}}$	$\frac{1}{12}\sqrt{\frac{5}{2}}(-2k^2 h_8 + a_0)$	$\frac{1}{12}(-k^2 h_7 + a_0)$	$\frac{k^2 h_8 - 2a_0}{6\sqrt{2}}$
$1^- \mathcal{A}_s^{\parallel h} \dagger^\alpha$	0	0	$\frac{1}{12}(-2k^2 h_8 + a_0)$	$\frac{1}{12}\sqrt{5}(2k^2 h_7 + a_0)$	$\frac{k^2 h_8 - 2a_0}{6\sqrt{2}}$	$\frac{1}{12}(-2k^2 h_7 - a_0)$

Massive and massless spectra

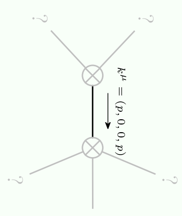
Massive particle

Pole residue:	$\frac{34}{h_7 - h_8} > 0$
Square mass:	$-\frac{3 a_0}{h_7 - h_8} > 0$
Spin:	1
Parity:	Odd



Massless particle

Pole residue:	$-\frac{1}{a_0} > 0$
Polarisations:	2



Unitarity conditions

$h_7 \in \mathbb{R}$ && $a_0 < 0$ && $h_8 < h_7$