# Particle spectrograph

## Wave operator and propagator



**Quadratic (free) action**

$$\mathcal{S} = \int\int\int\int \left[\frac{1}{8}\left(8\,h^{\alpha\beta}\,\mathcal{T}_{\alpha\beta} - 4\,\Gamma^{\alpha\beta\chi}\left(a_0\,\Gamma_{\beta\chi\alpha} - 2\,\Delta_{\alpha\beta\chi} + a_0\,\partial_\beta h_{\alpha\chi}\right) + 2\,a_0\,\Gamma^\alpha{}_\alpha\,\partial_\beta h^{\beta\chi}{}_\chi - \right.\right.$$
$$2\,a_0\,h^\chi{}_\chi\,\partial_\beta\Gamma^\alpha{}_\alpha{}^\beta + 2\,a_0\,h^\chi{}_\chi\,\partial_\beta\Gamma^{\beta\alpha}{}_\alpha - 4\,a_0\,\partial_\beta h^{\alpha\beta}\partial_\chi h_{\alpha}{}^\chi +$$
$$4\,a_0\,h^{\alpha\beta}\partial_\beta\partial_\alpha h^\chi{}_\chi - a_0\,\partial_\beta h^\chi{}_\chi\,\partial^\beta h^\alpha{}_\alpha + 2\,a_0\,\partial_\chi h_{\alpha\beta}\partial^\chi h^{\alpha\beta} +$$
$$4\,a_0\,\partial^\beta h^\alpha{}_\chi\,\partial_\alpha h_\beta{}^\chi + 2\,a_0\,\Gamma^\alpha{}_\beta\left(2\,\Gamma^\chi{}_{\beta\chi} - \partial_\beta h^\chi{}_\chi\right) + 2\,\partial_\chi h_\beta{}^\chi -$$
$$8\,a_0\,h^{\alpha\beta}\,\partial_\chi\partial_\beta h_\alpha{}^\chi + 2\,a_0\,h^\alpha{}_\alpha\,\partial_\chi\partial_\beta h^{\beta\chi} +$$
$$4\,a_0\,h^\alpha{}_\alpha\,\partial_\chi\partial^\chi h_{\alpha\beta} - 2\,a_0\,h^\alpha{}_\alpha\,\partial_\chi\partial^\chi h_\beta{}^\beta -$$
$$2\,a_0\,\partial_\beta h_{\alpha\chi}\,\partial^\chi h_{\alpha\beta} + 3\,a_0\,\partial_\chi h_{\alpha\beta}\partial^\chi h^{\alpha\beta} +$$
$$4\,a_0\,h_{\beta\chi}\,\partial^\chi\Gamma_\alpha{}^\beta\big)\big](t,x,y,z)\,dz\,dy\,dx\,dt$$

**Source constraints**

| SO(3) irreps | Multiplicities |
|---|---|
| | **Fundamental fields** |
| $\partial_\beta\partial_\chi\mathcal{T}^{-\alpha\beta} == 0$ | 1 |
| $\mathcal{T}_0^{\#2} == 0$ | 1 |
| $\partial_\alpha\Delta^{\alpha\beta}{}_\beta == 0$ | 1 |
| $\Delta_0^{\#3} + 2\,\Delta_0^{\#4} + 3\,\Delta_0^{\#2} == 0$ | 1 |
| $\partial_\chi\partial_\beta\partial^\alpha\mathcal{T}^{-\beta\chi} == \partial_\chi\partial_\beta\mathcal{T}^{-\alpha\beta}$ | 3 |
| $\mathcal{T}_1^{\#1\alpha} == 0$ | 3 |
| $\partial_\chi\partial^\beta\Delta^{\beta\chi}{}_\chi == \partial_\chi\partial^\chi\Delta_\alpha{}^{\alpha\beta}$ | |
| $2\,\Delta_1^{\#6\alpha} + \Delta_1^{\#4\alpha} + 2\,\Delta_1^{\#5\alpha}\,\partial_\chi\Delta_1^{\#3\alpha} == 0$ | 8 |
| **Total constraints/gauge generators:** | |

## Massive and massless spectra



**Quartic pole**

Pole residue: $0 < \dfrac{1}{a_0}\,\&\&\,\dfrac{1}{a_0} > 0$

Polarisations: 2

**Quadratic pole**

Pole residue: $\dfrac{6+\sqrt{26}}{a_0} > 0$

Polarisations: 2

**Quadratic pole**

Pole residue: $-\dfrac{1}{a_0} > 0$

Polarisations: 2

**Quadratic pole**

Pole residue: $\dfrac{1}{a_0} > 0$

Polarisations: 1

(No massive particles)

**Quadratic pole**

Pole residue: $\dfrac{6-\sqrt{26}}{a_0} > 0$

Polarisations: 2

## Unitarity conditions

(Unitarity is demonstrably impossible)