Aspects of Flat-Space Holography and Higher Spins

DESY Theory Workshop 2023

Michel Pannier

Friedrich-Schiller-Universität Jena
Theoretisch-Physikalisches Institut

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Outline

1 Motivation: Farewell to AdS

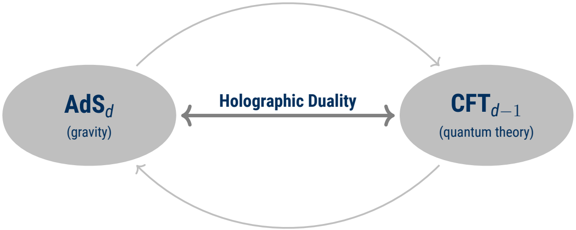
2 Peculiarities of Flat-Space Holography

3 Higher Spins in Flat Space: Massless and Massive

4 Discussion: What's next?

Motivation: Farewell to AdS

Expectations on Holography



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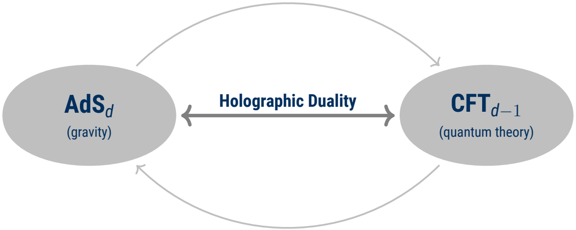

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- unitarity of time evolution
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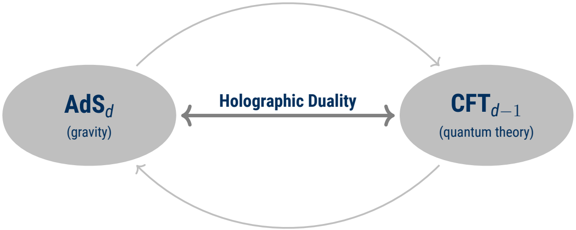

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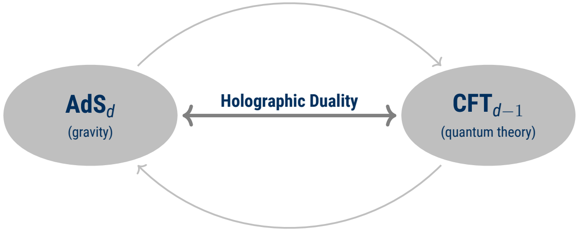

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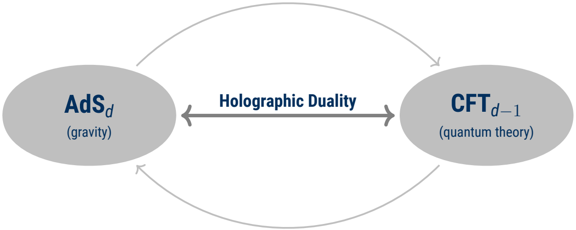

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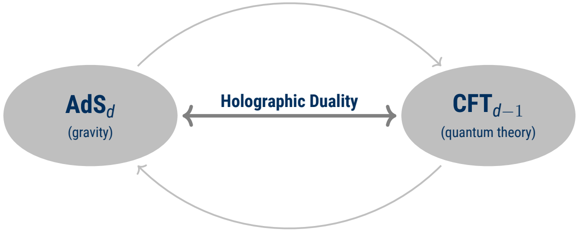

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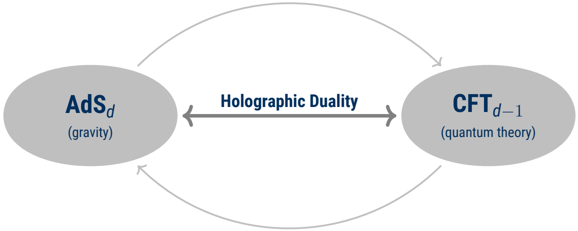

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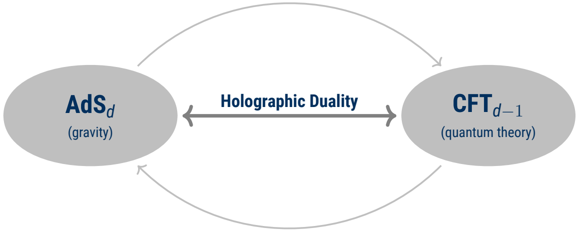

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Lessons from AdS/CFT

Towards Quantum Gravity:

$$\text{Einstein gravity}$$

$$\text{generalisation} \Big\downarrow \Big\uparrow \text{sub-sector}$$

$$\textbf{higher-spin gravity}$$

$$\text{Higgs mechanism} \Big\downarrow \Big\uparrow \text{tension-less limit}$$

$$\text{String Theory}$$

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Towards understanding Holography: (in 3d flat space)

- absence of dynamical degrees of freedom
- absence of natural length scale
- missing entries in holographic dictionary

couple to massive fields

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- definition of asymptotics
- higher-spin symmetry algebra
- matter-coupling prescription

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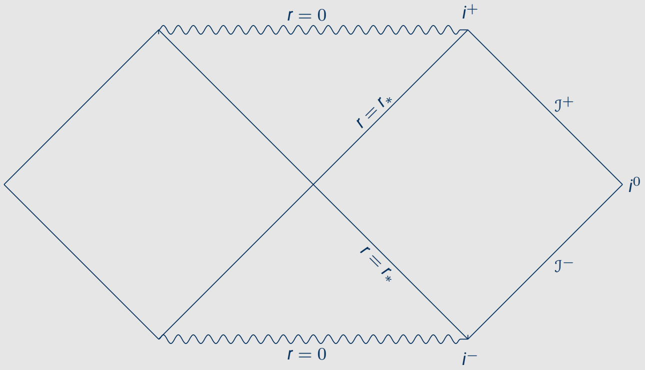
First-principle considerations, no $\Lambda \to 0$ limit!

Peculiarities of Flat-Space Holography

Carrollian View on Flat Spacetimes

Causal Structure: $(d > 3)$



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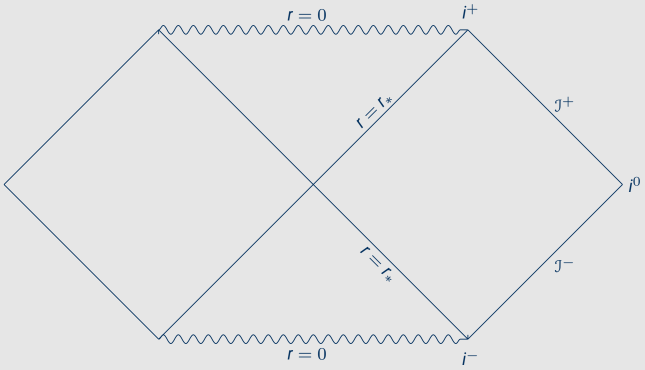

Special Features:

- lightlike conformal boundary
- different boundary regions
- particular boundary conditions, asymptotic symmetry: BMS
  [Bondi/van der Burg/Metzner, 1962]
  [Sachs, 1962]
- dual field theory: Carrollian CFT
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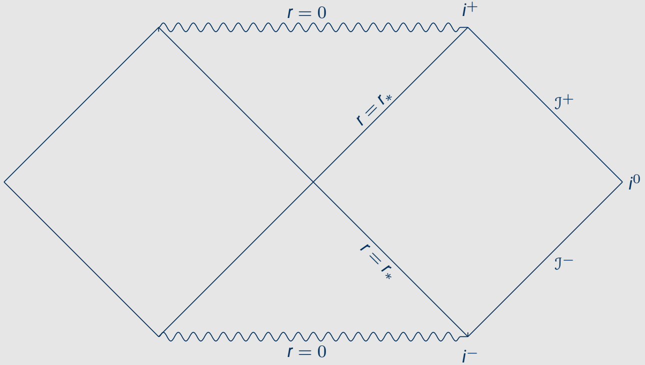

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(alternatively: **Celestial Holography**)
See also Charlotte's talk!

Asymptotically Flat Spacetimes

[Cornalba/Costa, hep-th/0203031; Barnich/Troessaert, 1001.1541]

Most General Asymptotically Flat Metric

$$ds^2 = M(\phi)du^2 - 2dudr + 2N(u,\phi)dud\phi + r^2 d\phi^2$$

Eddington-Finkelstein coordinates (u, r, ϕ)

- u: outgoing retarded time (light-like)
- r: radial coordinate ($r \to \infty$ is asymptotic direction)
- ϕ: angular coordinate on S^1

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$$\updownarrow$$

Chern-Simons Formulation

$$\omega = \left(J_1 - \frac{M(\phi)}{4}J_{-1}\right)d\phi\,,$$

$$e = \left(P_1 - \frac{M(\phi)}{4}P_{-1}\right)du + \frac{1}{2}P_{-1}dr + \left(rP_0 - \frac{N(u,\phi)}{2}P_{-1}\right)d\phi$$

[Afshar/Bagchi/Fareghbal/Grumiller/Rosseel, 1307.4768]

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Isometries: Poincaré algebra

$\mathfrak{iso}(2,1) \simeq \mathfrak{isl}(2,\mathbb{R}) \simeq \mathfrak{sl}(2,\mathbb{R}) \in \mathbb{R}^3$

$$[J_m\,, J_n] = (m-n)J_{m+n}$$
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Higher Spins in Flat Space: Massless and Massive

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second-order Casimir elements:

$$\mathcal{M}^2 = (P_0)^2 - P_1 P_{-1}\,,$$
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[Ammon/MP/Riegler, 2009.14210]

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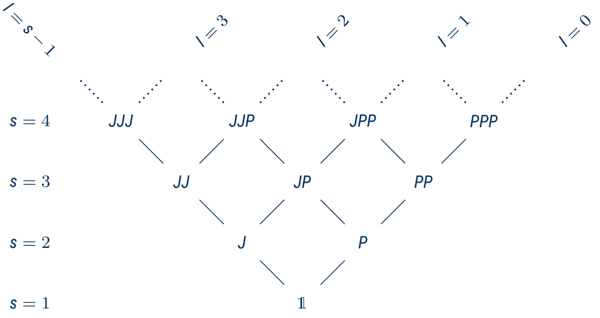

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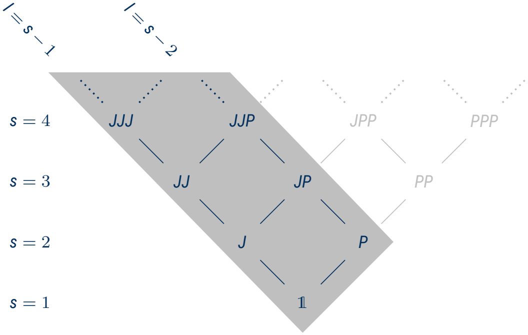

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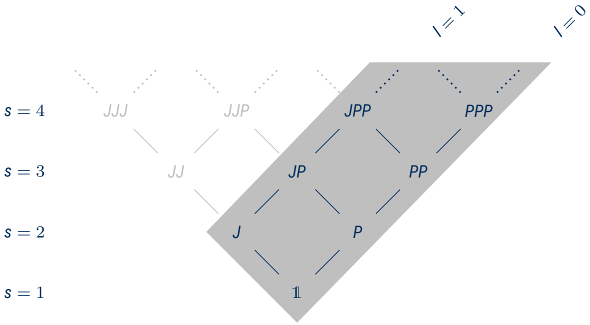

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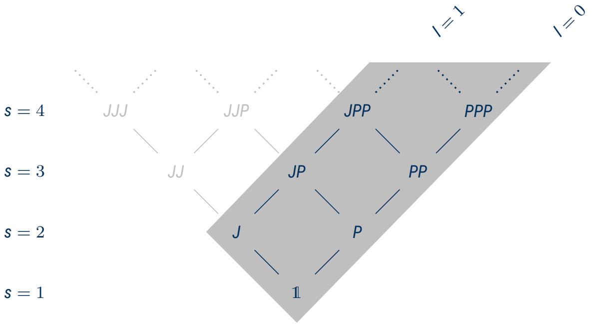

[Campoleoni/Pekar, 2110.07794]

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Algebraic Emergence of Massive Higher-Spin Fields

[Ammon/MP, 2211.12530]

$s = 4$: JJJ JJP JPP PPP

$s = 3$: JJ JP PP

$s = 2$: J P

$s = 1$: $\mathbb{1}$

Master Equation

$$\mathrm{d}C + [\omega \, , C]_\star + e \star C = 0$$

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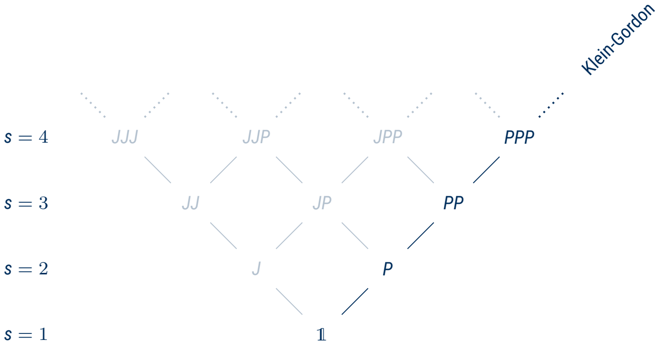

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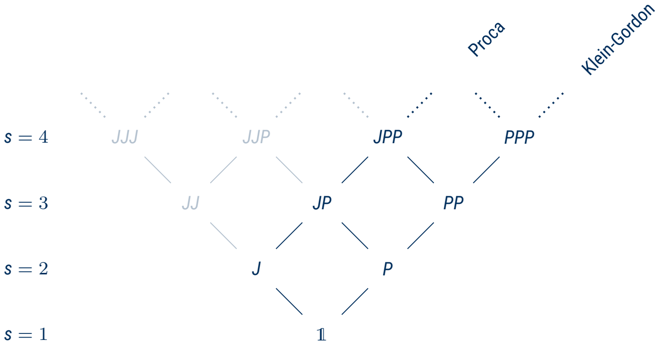

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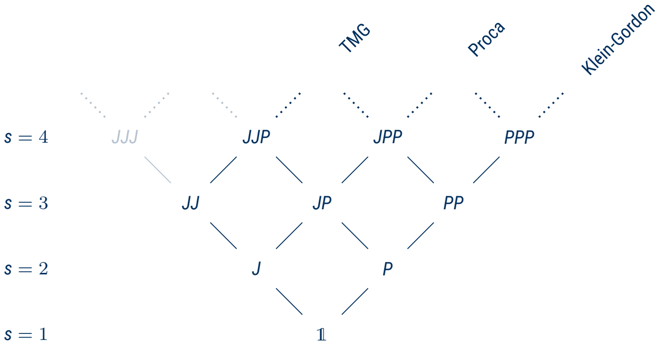

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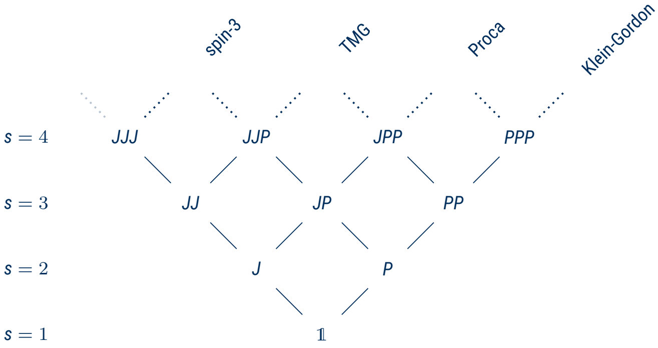

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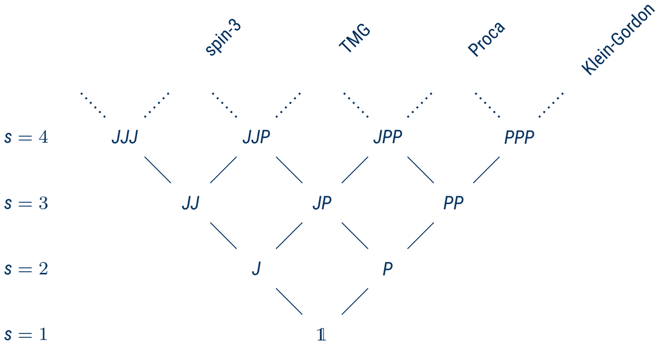

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Fierz-Pauli Equations

massive, spin-σ field:

$$\begin{aligned} \left(\Box - \mathcal{M}^2\right) \phi_{\mu_1 \dots \mu_\sigma} &= 0 \\ \nabla^\mu \phi_{\mu \mu_2 \dots \mu_\sigma} &= 0 \\ g^{\mu\nu} \phi_{\mu\nu\mu_3 \dots \mu_\sigma} &= 0 \end{aligned}$$

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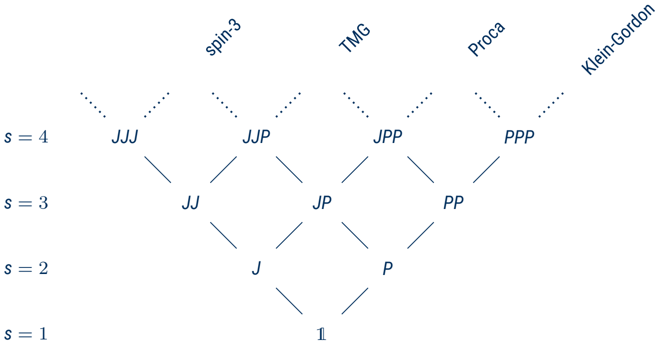

The master equation provides an unfolding of the complete Fierz-Pauli system!

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Discussion: What's next?

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  [Ammon/Gray/Moran/MP/Wölfl, 2012.09173] [MP, 2023]

Thanks for your attention!

Boundary Conditions for Flat-Space Higher-Spin

$$\omega = \left(J_1 - \frac{1}{4} \sum_{s=2}^{\infty} Z^{(s)}(\phi) J_{-1} (P_{-1})^{s-2} \right) d\phi \,,$$

$$e = \left(P_1 - \frac{1}{4} \sum_{s=2}^{\infty} Z^{(s)}(\phi)(P_{-1})^{s-1} \right) du + \frac{1}{2} P_{-1} dr + \left(rP_0 - \frac{1}{2} \sum_{s=2}^{\infty} W^{(s)}(u,\phi)(P_{-1})^{s-1} \right) d\phi$$

$$M(\phi) \equiv Z^{(2)}(\phi) \,,$$
$$N(u,\phi) \equiv W^{(2)}(u,\phi)$$

$$\partial_\phi Z^{(s)}(\phi) = 2\partial_u W^{(s)}(u,\phi)$$