The Evaporation of Graviton Condensates

Tobias Stirner

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Content

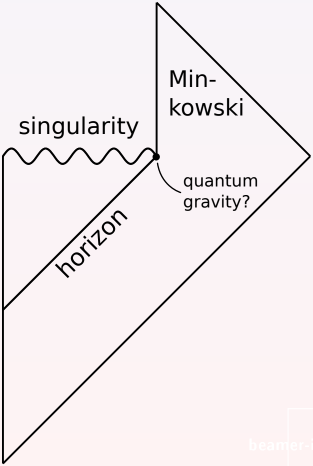
Why Graviton Condensate?

A graviton condensate

- gives quantum notion of BH
- could complete quantum gravity in UV

Issues with Hawking radiation

- thermal spectrum
- information paradoxon



Graviton Condensate

Properties of a graviton condensate

- criticality: $\alpha N = 1$
- maximal packing: $\lambda = R = l_P \sqrt{N}$

Quantum phenomena correspond to semi-classical effects of black holes.

Evaporation rate

$$\frac{dN}{dt} = -\alpha^2 N^2 E_{esc} = -\frac{1}{l_P \sqrt{N}} \quad \Rightarrow t_{coll} \propto N_0^{3/2}$$

with escape energy $E_{esc} = \frac{\alpha N}{\lambda}$

Graviton Toy Model

Lagrangian density in Fourier space

$$\mathcal{L}_{\mathbf{k}_1} = \psi^\dagger_{\mathbf{k}_1} \left(i\partial_t - |\mathbf{k}_1| \right) \psi_{\mathbf{k}_1} + M_\mathrm{P}^{-1} \int \mathrm{d}^3\mathbf{k}_2 \, \mathrm{d}^3\mathbf{k}_3 \, f\left(\mathbf{k}_i\right) \left(\psi^\dagger_{\mathbf{k}_1} \psi^\dagger_{\mathbf{k}_2} \psi_{\mathbf{k}_3} + \mathrm{h.c.} \right) \delta^{(3)} \left(\sum \mathbf{k}_i \right)$$

Assumptions:

- gravitons: relativistic, complex scalars
- one polarization
- no trapping potential

Ansatz and EoM

Ansatz for condensed fields $\phi_{\mathbf{k}} \neq \psi_{\mathbf{k}}$

$$\phi_{\mathbf{k}}(t) = \sqrt{N(t)}R(t)^{3/2}\exp\left\{-\frac{1}{2}\mathbf{k}^2 R^2(t) + \mathrm{i}\vartheta(t)\right\}$$

Averaged Lagrangian gives equations of motion

$$\begin{aligned} R &= l_\mathrm{P}\sqrt{N}, \\ \dot{N} &= -\frac{c}{l_\mathrm{P}}\sqrt{\frac{1}{N} - \frac{1}{c}} \quad \text{with } c \propto N_0 \gg 1 \end{aligned}$$

Constant c problematic, collapse time $t_\mathrm{coll} \propto N_0^{1/2}$ too short.
Possible solution: interaction with vacuum

Conclusions and Outlook

Conclusions

- graviton condensates could resolve issues of BHs
- considered toy model does not reproduce results

Outlook

- reduction of assumptions
- experiments with critical condensates

Literature

- G. Dvali and C. Gomez:
  "Black Hole's Quantum N-Portrait", Fortsch. Phys. 61 (2013) 742-767, arXiv:1112.3359v1 [hep-th]
- V. Foit and N. Wintergerst:
  "Self-Similar Evaporation and Collapse in the Quantum Portrait of Black Holes", Phys. Rev. D92 (2015) 064043, arXiv:1504.04384 [hep-th]
- A. Kamenev:
  "Field Theory of Non-Equilibrium Systems", Cambridge University Press, 2011

Additional Formulae

Lagrangian density for condensed fields

$$\mathcal{L}_{\mathbf{k}_1} = -\frac{i}{2}\left(\dot{\phi}_{\mathbf{k}_1}\phi^\dagger_{\mathbf{k}_1} - \phi_{\mathbf{k}_1}\dot{\phi}^\dagger_{\mathbf{k}_1}\right) - |\mathbf{k}_1|\,\phi_{\mathbf{k}_1}\phi^\dagger_{\mathbf{k}_1}$$
$$+ M_\mathrm{P}^{-1}\int \mathrm{d}^3\mathbf{k}_2\,\mathrm{d}^3\mathbf{k}_3\,\frac{f_3(\mathbf{k}_i)}{\sqrt{2}}\left(\phi^\dagger_{\mathbf{k}_1}\phi^\dagger_{\mathbf{k}_2}\phi_{\mathbf{k}_3} + \mathrm{h.c.}\right)\delta^{(3)}\left(\sum \mathbf{k}_i\right).$$

Lagrangian after plugging the Gaussian ansatz and averaging over **k**

$$L = N\dot{\vartheta} - \frac{3N}{2R} + \frac{c_3 N^{3/2}}{M_\mathrm{P} R^2}\cos(\vartheta) \quad \text{with } c_3 > 0.$$

Coupled equations of motion for ϑ and N:

$$\dot{\vartheta} = \frac{M_\mathrm{P}}{2c_3\sqrt{N}\cos(\vartheta)}, \qquad \dot{N} = -\frac{M_\mathrm{P}\sin(\vartheta)}{c_3\cos^2(\vartheta)}\sqrt{N}$$