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Rotating Black Holes in Chern-Simons Modified Gravity

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Chern-Simons (CS) modified gravity

This theory is inspired by

- Superstring theory (e.g. Smith et al. (2008))
- Loop quantum gravity (Mercuri & Taveras (2009))
- Effective field theory for inflation (S. Weinberg (2008))

Action: $$I = \int d^4x \sqrt{-g} \left[-\frac{1}{16\pi} R + \underline{\frac{l}{64\pi} \vartheta(x)\, {}^*R^{\alpha}{}_{\beta}{}^{\mu\nu} R^{\beta}{}_{\alpha\mu\nu}} + \cdots \right]$$

Parity symmetry is broken!

The Schwarzschild metric satisfies the field equations.

This theory passes the classical tests of GR.

<u>**However the Kerr metric does not satisfy the field equations**</u>. $\left(\varepsilon^{\mu\nu\alpha\beta} R^{\tau}{}_{\sigma\alpha\beta} R^{\sigma}{}_{\tau\mu\nu} \neq 0 \right)$

Rotating Black Holes

We obtained slowly rotating BH solutions in the two models of CS modified gravity:

- **(I) Non-dynamical model,**
- **(II) Dynamical model.**

Perturbation around the Schwarzschild spacetime:

Metric: $$g_{\mu\nu} = g^{(0)}{}_{\mu\nu} + g^{(1)}{}_{\mu\nu} \qquad g^{(1)}{}_{\mu\nu} \sim O(\varepsilon)$$

$$(\varepsilon \propto J)$$

Background   Rotational correction

Summary

- Non-dynamical model:

  The BH has a spinning cosmic string on the rotational axis. The solution gives the flat rotation curve at a large distance from the BH.

- Dynamical model:

  The solution reduces to the GR solution as the coupling constant vanishes. In this solution, the frame-dragging effect is suppressed by the effect of the scalar field.

See in detail

- K. Konno et al., PRD **76**, 024009 (2007) (arXiv:0706.3080).
- K. Konno et al., PRD **78**, 024037 (2008) (arXiv:0807.0679).
- K. Konno et al., Prog. Theor. Phys. **122**, 561 (2009) (arXiv: 0902.4767).
- K. Konno et al., Mod. Phys. Lett. A **25**, 2655 (2010) (arXiv: 1006.2202).