Rotating Black Holes in Chern-Simons Modified Gravity

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Chern-Simons (CS) modified gravity

This theory is inspired by

\[ \{ \begin{array}{l}
\bullet \text{ Superstring theory (e.g. Smith et al. (2008))} \\
\bullet \text{ Loop quantum gravity (Mercuri & Taveras (2009))} \\
\bullet \text{ Effective field theory for inflation (S. Weinberg (2008))}
\end{array} \]

Action: 

\[ I = \int d^4x \sqrt{-g} \left[ -\frac{1}{16\pi} R + \frac{l}{64\pi} \mathcal{G}(x) R^\alpha_{\beta \mu \nu} R^\beta_{\alpha \mu \nu} + \ldots \right] \]

Parity symmetry is broken!

The Schwarzschild metric satisfies the field equations.

\[ \rightarrow \text{ This theory passes the classical tests of GR.} \]

However the Kerr metric does not satisfy the field equations. 

\[ (\epsilon^{\mu \nu \alpha \beta} R^\tau_{\sigma \alpha \beta} R^\sigma_{\tau \mu \nu} \neq 0) \]
Rotating Black Holes

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

\[
\begin{align*}
(\text{I}) & \quad \text{Non-dynamical model}, \\
(\text{II}) & \quad \text{Dynamical model}.
\end{align*}
\]

Perturbation around the Schwarzschild spacetime:

**Metric:**

\[
g_{\mu\nu} = g_{\mu\nu}^{(0)} + g_{\mu\nu}^{(1)} \quad g_{\mu\nu}^{(1)} \sim O(\varepsilon) \quad (\varepsilon \propto J)
\]
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