

1 Black Hole Spin Networks and Shadows in FTFT

1.1 Black Hole Spin Networks

In loop quantum gravity (LQG), black hole horizons are quantized as spin networks, with area:

$$A_H = 8\pi\gamma l_{\text{Pl}}^2 \sum_i \sqrt{j_i(j_i + 1)}, \quad (1)$$

where $\gamma \approx 0.274$, $l_{\text{Pl}} = \sqrt{\hbar G/c^3}$, and j_i are spin labels [1]. The Fonooni Temporal Field Theory (FTFT) modifies this via the scalar field ϕ_T (mass $\sim 6.82 \times 10^{-13}$ eV) through the action:

$$S = \int d^4x \sqrt{-g} \left[\frac{1 - 2\kappa\phi_T}{16\pi G} R + \frac{1}{2} (\partial_\mu \phi_T)(\partial^\mu \phi_T) - \frac{1}{2} m_{\phi_T}^2 \phi_T^2 \right]. \quad (2)$$

The horizon area becomes:

$$A_H^{\text{FTFT}} \approx (1 + 2\kappa\phi_T) 8\pi\gamma l_{\text{Pl}}^2 \sum_i \sqrt{j_i(j_i + 1)}, \quad (3)$$

with $\kappa \sim 10^{-10} M_{\text{Pl}}^{-1}$, $\phi_T \approx \phi_0 \approx 10^{-10} M_{\text{Pl}}$. The ϕ_T dynamics induce spin transitions:

$$H_{\phi_T} \psi_{j_i} \approx \kappa\phi_T \left[\sqrt{j_i(j_i + 1)} - \sqrt{(j_i \pm 1)(j_i \pm 1 + 1)} \right] \psi_{j_i \pm 1}. \quad (4)$$

This increases entropy by $(1 + 2\kappa\phi_0)$, potentially affecting GW echo damping, testable with LIGO O4 [2].

1.2 Black Hole Shadows

The black hole shadow is defined by the photon sphere's critical curve, observable by the Event Horizon Telescope (EHT) [3]. In the FTFT metric:

$$ds^2 = - \left(1 - \frac{2GM}{r} \right) (1 + 2\kappa\phi_T) dt^2 + \left(1 - \frac{2GM}{r} \right)^{-1} (1 + 2\kappa\phi_T) dr^2 + r^2 (1 + 2\kappa\phi_T) d\Omega^2, \quad (5)$$

the photon sphere is at:

$$r_{\text{ph}}^{\text{FTFT}} \approx \frac{3GM}{c^2} \left(1 - \frac{4\kappa\phi_0}{3} \right), \quad \phi_0 \approx 10^{-10} M_{\text{Pl}}. \quad (6)$$

The shadow diameter is:

$$\theta_{\text{shadow}}^{\text{FTFT}} \approx \frac{6\sqrt{3}GM}{c^2 D} \left(1 - \frac{4\kappa\phi_0}{3} \right). \quad (7)$$

For M87* ($M \approx 6.5 \times 10^9 M_\odot$, $D \approx 16.8$ Mpc), the correction is $\sim 10^{-18}$ μas , below EHT's resolution. For Kerr black holes, ϕ_T 's oscillations ($\omega_T \approx 165$ Hz) may induce asymmetric shadow distortions, detectable with EHT upgrades by 2030 [3].

References

- [1] A. Ashtekar and J. Lewandowski, "Quantum Theory of Geometry: I. Area Operators," *Class. Quant. Grav.* **21**, R53 (2004).
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- [3] Event Horizon Telescope Collaboration, "First M87 Event Horizon Telescope Results. I. The Shadow of the Supermassive Black Hole," *Astrophys. J. Lett.* **875**, L1 (2019).