

Testing (Quantum) Gravity with Pulsar-Black Hole Systems

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1312.4017, 1409.3391

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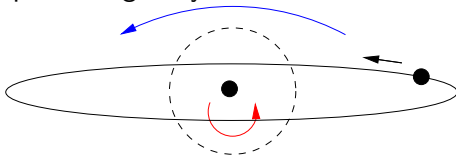
GC Magnetar PSR J1745-2900



(credit: MPIfR/Ralph Eatough) mysterious discovery in 2013, likely orbiting galactic center black hole. Rafikov-Lai (2006): precision GR test?

Lensing Prospects

- ▶ idealized setup: pulsar orbiting BH at $\sim 10,000r_S$
- ▶ inclination similar to Einstein radius $\sim 1^\circ$
- ▶ images form double slit interferometer near conjunction
- ▶ Fringes sensitive to $\sim 10^{-15}$ metric features: spin, etc
- ▶ quantum gravity?

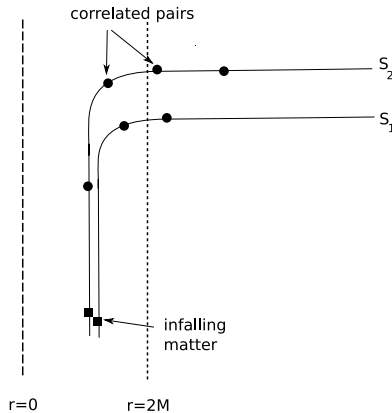


The binary orbit in the rest frame of the lens and viewed from a small inclination angle. When the source goes behind the lens and approaches the Einstein radius (the dotted circle), we can see both a far image (blue) and a close image (red). When far from the Einstein radius, the interior image becomes very faint.

Hawking Dilemma

- ▶ No Hair: all black holes look identical after a short time (hour?)
- ▶ radiation only depends on outside of BH
- ▶ emitted radiation does not depend on formation history
- ▶ leads to microscopic time irreversibility of physics!
- ▶ breakdown of causality/unitarity?
- ▶ An initial pure state evolves into mixed state after a Page time (half the mass is lost).

Monogamy of Entanglement



from Mathur, 0909.1038

Firewalls

- ▶ Almheiri, Marolf, Polchinski, Sully (2012)
- ▶ Schwinger pair creation at horizon: maximal entanglement
- ▶ late time photons must correlate with early photons: purity
- ▶ Quantum monogamy of entanglement violated!
- ▶ Solution: firewall near horizon kills the messenger: would-be experimentalists/reporters who reveal violations
- ▶ Hawking 2014: microscopic violation of time reversibility?

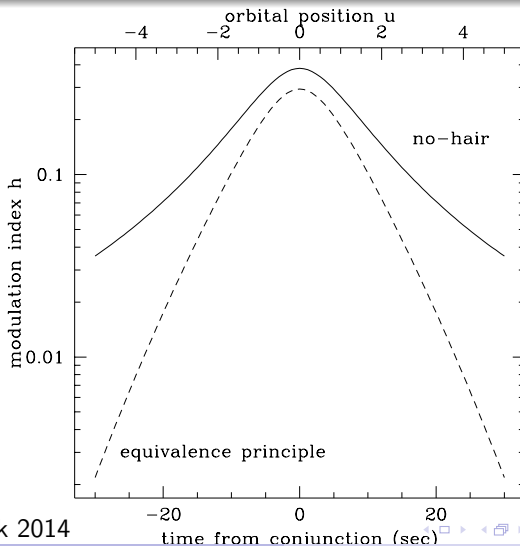
Firewalls: alternatives

AMPS: A possible alternative to the firewall is thus that this postulate should be relaxed, giving some novel (and perhaps non-local) evolution that extends a finite distance from black hole.

Orders of orders of magnitude

- ▶ Saha, partition function: $\frac{P(n_1)}{P(n_0)} = \frac{g_1}{g_0} \exp\left(-\frac{\Delta E}{k_B T}\right)$
- ▶ probability to observe in substantially non-Schwarzschild state:
- ▶ $\Delta E \sim mc^2$
- ▶ $\exp\left(-\frac{\Delta E}{k_B T}\right) \sim \exp(10^{77})$
- ▶ $S_1 \sim k_B \log g_1 \gtrsim 10^{77}$
- ▶ no-hair may be a great mis-estimate, off by $\exp(10^{77})$ orders of magnitude!

Quantitative test



New surveys



10 pulsar-neutron star binaries, 1 pulsar-BH binary candidate known. New surveys (e.g. SKA, CHIME+) will increase number 10+ fold.

Horizon

- ▶ LIGO: impact on gravitational wave emission?
- ▶ could think of final inspiral as a gravitational waves propagating in a fuzzy background?
- ▶ Event Horizon Telescope: strong lensing?
- ▶ measure collapsed states, or generate a fuzzy image?

Conclusions

- ▶ one pulsar - BH system discovered
- ▶ Promising future if high inclination BH-PSR systems are discovered
- ▶ potential precision probe: interference of lensed pulsar images
- ▶ sufficient for direct spin measurement
- ▶ Astrophysical test of non-local quantum gravity?
- ▶ potential implications for LIGO, EHT?