A Potential Astrophysical Test of Quantum Gravity

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Overview

- First pulsar orbiting black discovered in 2013!
- Hawking Information problem
- Fuzzballs
- Pulsar lensing

Magnetar PSR J1745-2900

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

Black Hole Information

Hawking (1974): black holes radiate: $T = hc/k_B r_s \sim \mu$K. High entropy: number of photons emitted $S/k_B \sim 10^{77}$. Very slow: one photon of $\lambda \sim r_s \sim$ km each $\lambda/c \sim$ms. (1981): information loss? Evaporation is a Schwinger mechanism, does not depend on inside of black hole.

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).

Entropy solution

- string theory to the rescue!
- Strominger-Vafa (1996): counting of microstates
- unitarity saved?
- Stringy counting not possible in classical limit: what happens with Hawking's argument?

Fuzzballs

Samir Mathur+ (2002+): solutions to Hawking problem must be either non-local or hairy.

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:
- $\Delta E \sim mc^2$
- $\frac{\Delta E}{k_B T} \sim 10^{77}$
- $S_1 \sim k_B \log g_1 \gtrsim 10^{77}$
- no-hair may be a great mis-estimate, off by 10^{77} orders of magnitude!

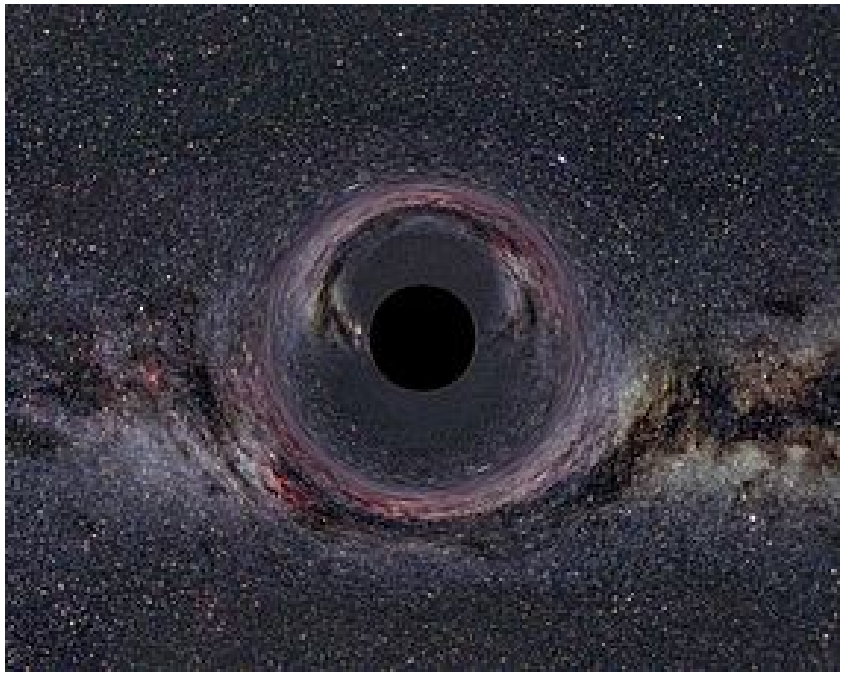
Fuzzballs

- round black holes have minimum surface, are most unlikely!
- constructive stringy solutions of some eigenstates: no horizon for no entropy
- classical Black Holes are superpositions of "naked" microstates
- evades Hawking's argument: no scharzschild background
- multipole deviation from GR $\sim (r_S/r)^{l+2}$

Landscape

- Firewall: aging of BH, destruction of observer
- remnants (Cornucopions)
- loops
- loss of unitarity/causality
- scientific test?

Lens

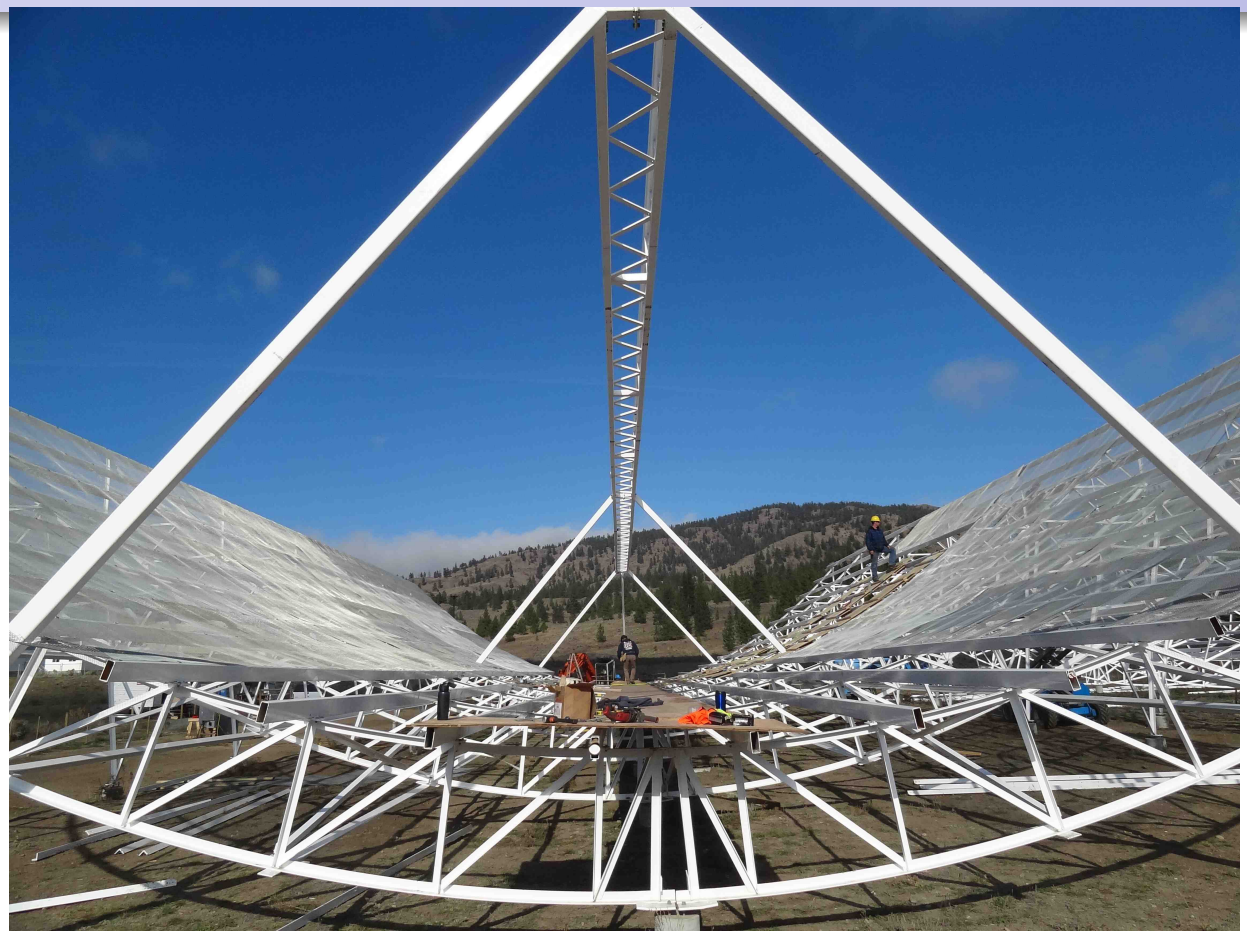


(credit: wikipedia) multiple imaging of pulsars: Boyle+ (2011+), Pen+ (2011+): interference of lensed images. Measure space-time metric to $\sim$ mm at Einstein radius.

Lensing Prospects

- ideal setup: pulsar orbiting BH at $\sim 10,000 r_S$
- inclination similar to Einstein radius $\sim 1^o$
- two main images form double slit interferometer (Young) near conjunction
- quantum lens: expect image decoherence $\sim 10^{-6} r_S \sim$ cm
- order unity effect in scintillation pattern

New surveys



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

Conclusions

- Astrophysical test of quantum gravity?
- Promising future if high inclination BH-PSR binaries are discovered
- large cylinder telescopes (e.g. CHIME+) for searching
- scientific test for some scenarios of quantum gravity: coherence of pulsar scintillation