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Do Event Horizons Really Exist?

or

Gravitation Without Divergences

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Summary

- Black holes surrounded by event horizons are standard solutions of orthodox gravitational theory, and are believed to have been observed in galactic centers and binary stars.
- But the theory has never been critically tested for strong fields, and observations of compact astronomical objects do not validate event horizons with divergent spacetime.
- Non-divergent models give rise to compact objects without event horizons, that are not strictly black holes.
- Recent observations of black holes from the Event Horizon Telescope and the Laser Interferometric Gravitational-Wave Observatory may represent confirmation bias of noisy data.
- The prudent scientific approach is to regard black holes and event horizons as interesting mathematical objects that may or may not exist in the real universe.

Weak and Strong Grav. Potentials

- General Relativity (GR) predicts time dilation and length contraction as function of normalized grav. potential ϕ (ratio of grav. to rest energy)
  - At distance R from mass M, $\phi = -GM/Rc^2 = -R_s/2R$, where R_s is Schwarzschild radius of M
  - Largest ϕ in solar system is at surface of sun: $\phi = -2 \times 10^{-6}$
- GR verified in tests for $|\phi| << 1$.
  - Curvature of light by sun, rotation of perihelion of Mercury, grav. red shift.
- Black holes and event horizons correspond to $\phi \rightarrow 1$.
  - GR ***not*** verified or tested in this regime.

Large ϕ Gravity Undetermined

- GR time dilation ~ $(1+2\phi)^{-0.5} \approx 1 - \phi + (3/2)\,\phi^2$ ….
- But many formulas have same low-order behavior
  - $(1- \phi/n)^n \approx 1 - \phi + [n(n-1)/2]\,(\phi/n)^2$ … for any n
  - $\exp(-\phi) \approx 1 - \phi + \phi^2/2$ …
- A divergence in time at a location where ϕ is finite seems non-physical.
  - May be mathematical artifact of model extrapolated outside region of validity.
- $(1-\phi)$ is simplest expression, no higher order terms.
  - *Select this as simple model for comparison with GR [1].*

Divergence in Gravitational Theory

	Orthodox Theory	Non-Divergent Theory
Time Dilation	$(1+2\phi)^{-0.5}$	$(1-\phi)$
Length Contraction	$(1+2\phi)^{0.5}$	$1/(1-\phi)$

- Orthodox theory diverges for $\phi = -0.5$, for $R = R_s$
  - Corresponds to event horizon, factors are undefined
- Simple non-divergent theory matches orthodox theory for $|\phi| \ll 1$.
  - Defined for all R and all values of ϕ.
- Impossible to distinguish two theories based on tests in solar system.

Non-Divergent Gravity

- Without event horizon, non-divergent gravity bends light with index of refraction $n = (1-\phi)^2 > 1$.
  - For large $|\phi|$, large n traps most photon trajectories.
  - But narrow cone of radial light emission (with red shift)
- So non-divergent theory leads to gravitationally compact “dim star” rather than black hole [2].
- Permits access to dense phase with large $\phi >> 1$, possibly dense quark-lepton plasma similar to early universe.
- *All space is continuous – no separated regions.*

Black Hole Candidates [3]

- Massive stars
  - Theoretical predictions that stars with greater than 3 solar masses should collapse to black hole.
  - But difficult to determine solar masses of isolated stars.
- Stars in binary systems
  - Orbiting stars with matter streaming from one to another (“accretion disk”).
  - Many such black-hole binaries identified.
- Supermassive objects in centers of galaxies
  - Most galaxies have at their center a compact object with millions of solar masses: “supermassive black hole.”

Evidence for Event Horizons?

- X-ray emission from binary black holes consistent with modeling of event horizon, but not unique.
  - Would also follow from non-divergent models.
- Need accurate measurement of $\phi(R)$ approaching 0.5, together with time dilation (grav. red shift).
  - No location within solar system or close enough to measure accurately.
- Many observations of light bending for very distant objects, but with no independent measurement of ϕ.
- No direct or indirect verification of GR at or near event horizon – still consistent with non-divergence.

LIGO Detection of Black Hole Mergers

- Laser Interferometric Gravity Wave Observatory (LIGO) created to detect gravitational radiation from spiraling mergers of binary black holes.
  - Signals measured from two or more distant detectors, correlated and fit to theoretical model.
- In 2016 [4], signals detected that were interpreted as merger of 2 black holes, each 30 solar masses, in distant galaxy 1 billion light years away.
  - Widely acclaimed, Nobel Prize for LIGO in 2017.
- But one researcher [5] questioned whether these signals were real, as opposed to noise selected with a matching filter.
  - *"It is a truism that, if gravitational waves are all you look for, gravitational waves are all you will ever find." [6]*
- So do these really prove the existence of black holes?

EHT Image of Black Hole

- A report in 2019 [7] provided an image of a supermassive black hole in another galaxy, observed with the "Event Horizon Telescope", EHT, an array of 8 distant radio telescopes designed to image supermassive black holes.
  - This was not a simple image, but rather a digitally processed signal in the presence of noise at the limit of spatial resolution.
  - This appears to show an image of a black central region surrounded by a bright ring, i.e., a black hole surrounded by a bright event horizon.
- However, I suggest that this may provide an example of confirmation bias – they saw exactly what they were looking for.
  - *This may not be as convincing as has been presented.*

Conclusions

- A black hole with a surrounding event horizon is one of the most dramatic predictions of GR.
- Recent astronomical observations of black holes, in galactic centers and binary stars, are widely seen as convincing.
- However, all quantitative tests of GR have been for the grav. potential $\phi \sim 10^{-6}$, whereas $\phi = 0.5$ for the divergence defining the event horizon.
- An alternative simple model matches GR for weak gravity, but avoids divergence for larger ϕ, and enables smooth transition to a "dim star" with $\phi >> 1$, which is not a black hole.
- Despite LIGO and EHT results, we should be skeptical of black holes, at least until accurate measurements for large ϕ are available.

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