Coincident Down-chirps in GW150914 Betray the Absence of Event Horizons

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A century has elapsed since gravitational waves were predicted. Their recent detection by the LIGO-Virgo collaboration represents another feather in Einstein's cap and attests to the technological ingenuity of experimentalists. However, the news has been portrayed as affirmation of the existence of black holes, objects whose defining characteristics are event horizons. Whilst a gravitational wave chirp is indicative of coalescing bodies and the inferred masses, $29{\pm}4M_{\odot}$ and $36{\pm}5M_{\odot}$, rule out neutron stars, a prominent yet overlooked feature in the Hanford and Livingston spectrograms points to a curious mass ejection during the merger process. The spectral bifurcations, beyond which down-chirps are clearly discernible, suggest that a considerable quantity of matter spiralled away from the binary system at the height of the merger. Since accretion disks cannot survive until the latter stages of coalescence, a black hole model seems untenable, and Einstein's expectation that black holes can neither form nor ingest matter in a universe of finite age would appear to be upheld. By virtue of general relativity's logical consistency and the fact that gravity propagates at light speed, gravitational collapse must terminate with the formation of pathology-free temporally suspended objects.

1 The black hole controversy

Einstein realised in 1916 that spacetime could mediate the propagation of energy-transporting gravitational waves travelling at light speed [1]. This entirely theoretical deduction was recently confirmed by the LIGO-Virgo collaboration, demonstrating once again the impeccable physical insights of this great scientist. However, the conclusion drawn on the back of this detection, that coalescing black holes triggered the waves [2], directly contradicts Einstein's published stance [3] regarding the outcome of gravitational collapse.

The first static solution to the field equations of general relativity was found that same year describing the gravitational influence of an idealised, infinite density point mass on asymptotically flat space [4]. Due to the Birkhoff theorem, regions of Schwarzschild's metric accurately represent the gravity external to spherically symmetric bodies such as irrotational stars and planets. However, Einstein appreciated that in the immediate vicinity of Schwarzschild's point mass the solution was physically unrealistic, being unreachable from regions outside the event horizon [3].

Einstein's cogent objection to black holes is easily illustrated by a concrete example. If a ray of light moving directly towards a Schwarzschild black hole can neither arrive at the event horizon nor penetrate it, then no particle can. For a lightlike radial trajectory leading towards the event horizon, the Schwarzschild metric reduces to $(dr/dt)^2 = (2m/r - 1)^2$. Assigning initial coordinates $(r, t) = (r_0, 0)$ to a photon, radius $r_1 < r_0$ is attained at time $t_1 > 0$, which can be readily obtained through integration:

$$t_1 = \int_{r_0}^{r_1} \frac{dr}{2m/r - 1} = \int_{r_0}^{r_1} \left(-1 - \frac{2m}{r - 2m} \right) dr\,, \qquad (1)$$

$$t_1 = r_0 - r_1 + 2m \ln\left(\frac{r_0 - 2m}{r_1 - 2m} \right). \qquad (2)$$

As the photon nears the horizon, $r_1 \to 2m(1 + \epsilon)$ where $0 < \epsilon \ll 1$. Since ϵ is a factor in the denominator of the logarithm, t_1 grows without limit as $\epsilon \to 0$. Accordingly, even though proper time does not advance for lightlike particles, global relationships within the spacetime impose an insurmountable temporal impediment to their arrival at the event horizon. For timelike particles the situation is much the same. As general relativity is a deterministic theory, this calculation has profound implications, despite its brevity. Even in the most favourable of circumstances a black hole cannot absorb matter and, hence, a universe initially devoid of black holes remains forever devoid of black holes. Since general covariance is integral to this theory, changes of coordinates, as detailed for example in references 5–6 of [2], cannot alter this fundamental conclusion.

Although the stationary black hole metrics satisfy the field equations, they lack a dynamical formation mechanism. It is known that event horizons never quite form during gravitational collapse in a universe of finite age [6–12]. Some theorists claim that infalling matter can arrive at the event horizon of a pre-existing black hole in finite proper time, but in practice this is forbidden by the existence of inviolable temporal relationships that permeate spacetime [13]. In addition, a variety of imprecise arguments commonly advanced for the existence of black holes have been robustly refuted [5].

Some stubborn problems now occupying the time of theoretical physicists are symptomatic of misunderstandings. Belief in black holes has given rise to difficulties such as the information paradox [14], loss of causality within rotating black holes, singularities of infinite mass density and the fact that when matter is trapped within an event horizon, it has no means of influencing external matter, even gravitationally. Furthermore, tension has arisen between the observed characteristics of certain astrophysical phenomena and popular black hole models. In particular, the finite lifetimes and extreme energetics of quasars and active galactic nuclei (AGN) are difficult to reconcile with nearby galaxy clusters which have only reprocessed around 10% of their primordial gas reserves, yet harbour quiescent galactic nuclei.

The ultrarelativistic emission of charged particles by quasars along biaxial jets alludes to an electromagnetically active central engine of some form. Whereas any charge accruing on a spheroidal black hole would be rapidly neutralised, a gravitationally collapsed object of toroidal topology would be defended by a magnetosphere whose flux lines run locally parallel to its surface [13, 15]. This inference clashes with the "principle of topological censorship", a theorem that is irrelevant if a spacetime has no trapped surfaces [16]. Hence, the characteristics of quasars and AGN offer empirical evidence that gravitational collapse produces "dark holes" lacking event horizons [13]. Quasar extinction would coincide with topological collapse and charge nullification.

Appreciation of the impossibility of event horizon formation inspired the first detailed proposal concerning a future mechanism for dark energy decay. It involves the discharge of vacuum energy via the Unruh effect by intense accelerations exposed within the deepest innards of dark holes [17]. The same work also highlights a novel objection to the existence of black holes relating to their unacceptable influence on the total entropy of the universe. A single supermassive black hole devouring matter could potentially double the entropy of the visible universe in the space of a few seconds, despite poor opportunities for interactions of the captured matter.

2 The dawn of gravitational wave astronomy

Since the announcement that gravitational waves have been detected it has emerged that the GW150914 event closely coincided with a gamma ray burst originating in the same sector of the sky [19]. Suggesting a common source, the binary system must have, as the authors put it, become "unexpectedly active" during coalescence. The possibility that one or more neutron stars were involved can be rejected due to the large masses involved [2,20]. The gamma rays are clearly inconsistent with the no-hair conjecture: any accreting matter should be ejected well before the merger [21]. It is therefore interesting to revisit the gravitational wave data to look for any other evidence of unanticipated peculiarities.

Two such examples draw the eye. In the spectrograms of *both* laser interferometers a down-chirp can be clearly discerned, bifurcating from the somewhat stronger up-chirp during the final crescendo of the merger (see Figure 1). These appear to be comfortably above the noise floor of each detector. The down-chirps are not only present in both spectrograms, they are identically located and share the same characteristics: important hallmarks of a genuine signal.

For a binary dark hole or binary frozen star model, significant mass loss is conceivable during a cataclysmic merger of this kind. The particles held in suspension by time dilation would be strongly perturbed by the gravitational ripples, transporting here a total energy estimated at $3M_{\odot}c^2$ [2]. The combination of this disruption and the violent rotation, particularly during the non-axisymmetric dumbbell phase of coalescence, could plausibly give rise to significant expulsion of matter at the peripheral fringes of the system. The spectral traces are consistent with matter being centrifugally launched with a radial velocity component of approximately $0.04c$. There is also a marked acceleration of the chirp following the shedding of mass, as might be anticipated if the rest mass energy of the ejecta was comparable to the energy radiated in gravitational waves.

From (2), at late times an infalling photon asymptotically approaches the radius $r = 2m$. Why must the photon halt at the exact radius of the event horizon? Why does general relativity only marginally forbid the growth and formation of black holes? Could matters have been any different?

Einstein's theory of gravitation was built upon special relativity which insists that nothing can travel faster than the speed of light in vacuum, prohibiting objects from exerting any form of superluminal influence. As in Newton's theory, gravity has infinite range. This demands that gravitons be massless, with current experimental constraints providing an upper limit of 1.2×10^{-22} eV. Signals from LIGO's geographically separated interferometers support the expectation that gravity travels at the speed of light [2]. Were the speed of gravity any different, the terminal radius of the photon would change, and philosophical problems would ensue.

If photons could only asymptotically approach some radius $r > 2m$, gravitational time dilation could then grow without limit in relatively moderate circumstances, curbing the maximum curvature of spacetime irrespective of Planck-scale limitations. If photons could asymptotically approach some radius $r < 2m$ then event horizons could form, bringing with them all the pathologies associated with black holes. Only if gravity travels at the speed of light can spacetime be arbitrarily warped without fear of event horizon formation, points of infinite mass density, time travel paradoxes or violation of unitarity. Like gravity, electromagnetism has unlimited range. Electric fields are mediated by virtual photons. If black holes did exist then the electric fields of charged particles would vanish upon capture, creating an 'electrical paradox' akin to the very widely acknowledged information paradox. Fortunately, Einstein appears to have formulated a consistent theory of gravitation in which anomalies are avoided but all else is permitted. A strongly curved spacetime may be vital for the timely decay of dark energy [17], a possible requirement for gravity to propagate no slower than light.

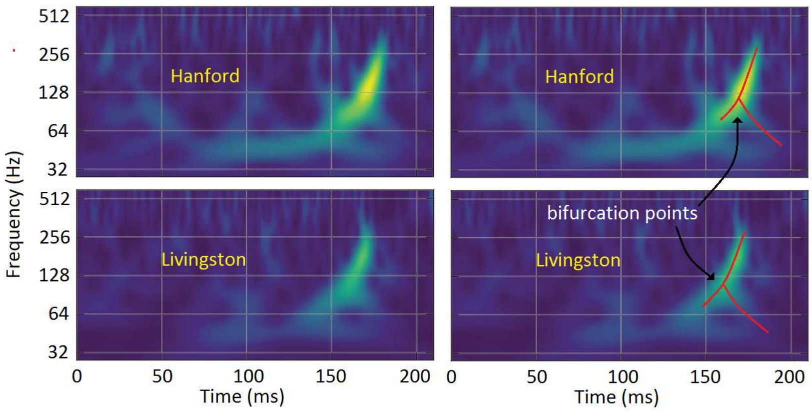

Fig. 1: The gravitational wave spectrograms for the Hanford (top) and Livingston (bottom) Advanced LIGO detectors [2]. Right column: spectral traces have been annotated to show the primary up-chirp and a matching pair of bifurcations beyond which the decline in frequency and amplitude suggests the ejection of mass spiralling away from the merging binary system.

3 Discussion

Gravitational waves have the capability to rectify some long-standing theoretical misconceptions. With improvements in sensitivity already scheduled we shall soon know whether mass-ejections are a generic feature of dark hole coalescence events. If so, we might in time witness some spectacular mergers of supermassive dark holes in the aftermath of galactic mergers within galaxy clusters. For coalescing bodies of large and favourably aligned angular momenta, the resulting gravitational wave signatures could be morphologically very distinct from GW150914 due to the formation of a toroidal dark hole with an unusually lengthy ringdown phase [15, 17]. The publicity and interest surrounding the announcement that gravitational waves have been detected is understandable. However, there has been little or no mention of the fact that the presence of a black hole event horizon cannot be verified even in principle [22] or that Einstein had mathematical grounds for dismissing the notion that black holes exist [3]. Black hole proponents might care to take note that our civilisation still awaits evidence that any of Einstein's predictions concerning gravity were incorrect.

Submitted on February 23, 2016 / Accepted on February 28, 2016

References

1. Einstein A. Approximative integration of the field equations of gravitation. *Sitzungsber. Preuss. Akad. Wiss. Berlin*, 1916, v. 1, 688.
2. Abbott B. P. et al., LIGO & VIRGO collaborations. Observation of gravitational waves from a binary black hole merger. *Phys. Rev. Lett.*, 2016, v. 116, 061102.
3. Einstein A. On a stationary system with spherical symmetry consisting of many gravitating masses. *Annals of Mathematics*, 1939, v. 40, 4.
4. Schwarzschild K. Über das gravitationsfeld eines massenpunktes nach der Einsteinschen theorie. *Sitzungsber. Preuss. Akad. Wiss. Berlin*, 1916, v. 1, 189.
5. Weller D. Five fallacies used to link black holes to Einstein's relativistic space-time. *Prog. Phys.*, 2011, v. 7 (1), 93.
6. Oppenheimer J. R. & Snyder H. On continued gravitational contraction. *Phys. Rev.*, 1939, v. 56 (5), 455.
7. Vachaspati T., Stojkovic D. & Krauss L. M. Observation of incipient black holes and the information loss problem. *Phys. Rev. D*, 2007, v. 76 (2), 024005.
8. Kiselev V. V., Logunov A. A. & Mestvirishvili M. A. Black holes: theoretical prediction or fantasy? *Physics of Particles and Nuclei*, 2006, v. 37 (3), 317–320.
9. Kiselev, V. V. E., Logunov A. A. & Mestvirishvili M. A. The physical inconsistency of the Schwarzschild and Kerr solutions. *Theor. & Math. Physics*, 2010, v. 164 (1), 972–975.
10. Shiekh A. Y. Approaching the event horizon of a black hole. *Adv. Stud. Theor. Phys.*, 2012, v. 6 (23), 1147–1152.
11. Chafin C. E. Globally Causal Solutions for Gravitational Collapse. arXiv: gr-qc/1402.1524.
12. Piñol M. A model of dust-like spherically symmetric gravitational collapse without event horizon formation. *Prog. Phys.*, 2015, v. 11 (4), 331.
13. Spivey R. J. Dispelling black hole pathologies through theory and observation. *Prog. Phys.*, 2015, v. 11, 321–329.
14. Mathur S. D. The information paradox: a pedagogical introduction. *Class. Quant. Grav.*, 2009, v. 26 (22), 224001.
15. Spivey R. J. Quasars: a supermassive rotating toroidal black hole interpretation. *MNRAS*, 2000, v. 316 (4), 856–874.
16. Friedman J. L., Schleich K. & Witt D. M. Topological censorship. *Phys. Rev. Lett.*, 1993, v. 71 (10), 1486.
17. Spivey R. J. A non-anthropic solution to the cosmological constant problem. *Prog. Phys.*, 2016, v. 12 (1), 72–84.
18. Spivey R. J. A cosmological hypothesis potentially resolving the mystery of extraterrestrial silence with falsifiable implications for neutrinos. *Physics Essays*, 2015, v. 28 (2), 254–264.
19. Connaughton V. et al. Fermi GBM observations of LIGO gravitational wave event GW150914. arXiv: astro-ph.HE/1602.03920v3.
20. Oppenheimer J. R. & Volkoff G. M. On massive neutron cores. *Physical Review*, 1939, v. 55 (4), 374.
21. Loeb A. Electromagnetic counterparts to black hole mergers detected by LIGO. arXiv: astro-ph.HE/1602.04735v1.
22. Abramowicz M. A., Kluzniak W. & Lasota J. P. No observational proof of the black-hole event-horizon. *Astronomy & Astrophysics*, 2002, v. 396 (3), L31–L34.