Looking at the physics of what a quark star-black hole binary would create in terms of GW signals and new physics.

Andrew Beckwith [1]

[1] Physics Department, Chongqing University, College of Physics, Chongqing University People's Republic of China,
rwill9955b@gmai.com

Abstract:

\ A quark star, black hole pairing as a would-be Gravitational wave generator is brought up. Quark stars are, anyway, likely to be black holes, above a certain mass limit, whereas a quark star in itself obey thermodynamic "laws" which in certain ways differ from the traditional black hole models. We list some of the probable consequences of such a binary, making predictions as to certain GW phenomenon which will have observational consequences. I.e., a GW "change in energy" from a black hole- Quark star pair would likely be within 90% of that of comparatively massed black hole- black hole binary pair. The electromagnetic "profile" of the two cases would differ dramatically, and we conclude our inquiry with an open question if a generalized uncertainty principle could play a role in comparing the 7th and 8th equations of our presentation,

1. Introduction

It is simple enough to visualize what happens if a quark star and a black hole binary exists and what this says about GW generation is open to speculation.

See this, I.e., speculation which is revealed as to what has been suggested is an actual quark star-black hole binary pair.

In addition, we also in the end of this document include what may be a linkage as to what is known as GRBs and the formation of a quark star, from a massive GRB formation explosion,

The following are from an article as to the weird physics of quark star black hole binary pairs.

In a sense profoundly elementary but with significant surprises in the conclusion,

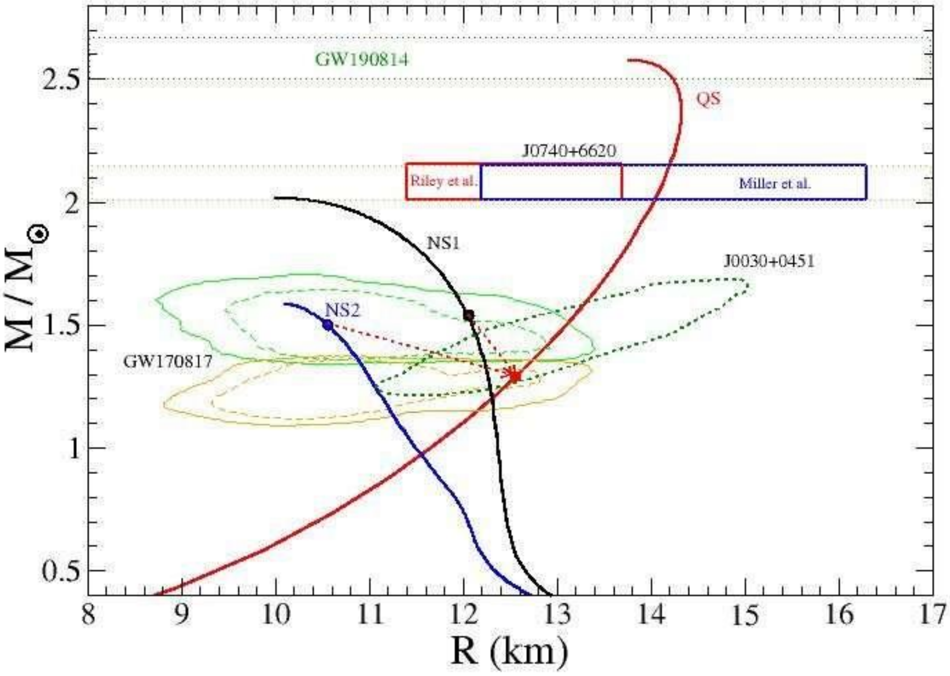

Figure 1 from [1]

- Text of what Figure 1 is referring to is
- Quote
- *On the 14th of August 2019, the LIGO-Virgo collaboration detected a gravitational wave signal believed to be associated with the merging of a binary stellar system composed of a black hole with a mass of 23 times the mass of the sun ($M\odot$) and a compact object with a mass of about 2.6 $M\odot$. The nature of GW190814's secondary star is enigmatic, since, according to the current astronomical observations, it could be the heaviest neutron star, or the lightest black hole ever observed.*
- *End of quote*
- *From [2] we have the following quote*

- *Quote*
- **NSs and QSs could coexist, as has been proposed and discussed in detail in several papers [26–34].**
- **End of quote**
- **I.e., one of the models proposed is, in [3] making a pitch for a sudden release of energy as to the following mechanism**
- **Quote**
- **The total energy released in the NS→SS conversion is given by the difference between the total binding energy of the strange star BE(SS) and the total binding energy of the neutron star BE(NS)**
- **End of quote**
- **In so many words, the template for examining what may be happening, hinges upon having a bust of energy, and a difference of energy between a neutron star and a strange star being released. We see though that this does NOT have a lot to do with how to observe a change in Gravitational energy as given in the following.**

  What does this have to do with a quark star-black hole binary? Simply put, look at Maggiore, Volume 1 [4] as to what is stated if one has a change in energy, on page 175 which is stated as

$$\Delta E_{Gravitational-radiation-binaries} \approx 8\times10^{-2}\tilde{\mu}c^{2}$$
$$\tilde{\mu} \equiv reduced-mass-of-system \qquad \textbf{(1)}$$

The nub of this is that for a binary system with a black hole, and quark star that the value of Eq. (1) would be enormous, whereas we can do a further refinement by writing the reduced mass as

$$\tilde{\mu} = \frac{m_1 m_2}{m_1 + m_2} \qquad \textbf{(1a)}$$

And then from [4] we would be observing a binding energy given as with respect to a Schwarzschild metric [4],[5]

$$E_{Gravitational-radiation-BINDING\_ENERGY} \approx 5.7\times10^{-2}\tilde{\mu}c^{2} \quad \textbf{(2)}$$

In doing so, we have to consider what happens to the reduced mass, if we have a transfer from say a Neutron star to a quark star, as one of the constituent components of the reduced mass [6],[7],[8],[9]

II. Neutron Star to Quark star transformation, and its energy release

The smallest, most massive, most compressed neutron *star* **possible is about 17 kilometers in** *diameter*. **A** *quark star* **can be smaller than 11 kilometers** *diameter, Having said that consider, now a transfer of a neutron star to a quark star and what it entails [10]*

Quote

The possible existence of two families of compact stars, neutron stars and quark stars, naturally leads to a scenario in which a conversion process between the two stellar objects occurs with a consequent release of energy of the order of 10^53 erg”, [11]

End of quote

In so many words, we can have that we would have that 10^53 ergs is **6.24150913 × 10^{55} giga electron volts, or 6.24 times 10^ 55 GeV. Hence, this transfer of energy from Neutron star to quark star would entail a gigantic pulse of energy, whereas a quark star would have about 10% less energy than a typical black hole of equal mass. Note the following.**

Quote

The dust cloud surrounding black holes becomes heated by the incredible gravitational forces, which emits extremely powerful radiation. A quark star is expected to emit radiation, just 10% less powerful.

End of quote

I.e., the final stop as far as deciding. i.e., a GRB could in fact be signaling a transfer from a neutron star to quark star [10][11], whereas [12] specifically refers to accreditation disks of a quark star as different from a black hole.

For a black hole, note the following [12]

In the Biermann battery mechanism for B field creation about a black hole, the mere act of electric charges in an accreditation disk about a black hole will create magnetic fields, and this has been understood since 1975. We likely would still, by [12] see an

accreditation disk about a quark star, with, also, B field generation.

From [12]

A. **However, strange stars exhibit a low-luminosity but high-temperature bremsstrahlung spectrum, which, in combination with the emission properties of the accretion disc, may be the key signature to differentiate massive, strange stars from the black hole.**

B. **The punch line shows up on page 12 of [13]**

Quote

The characteristics of the disk spectra around black holes and quark stars also exhibit significant differences. For black holes, the maxima of the spectra are located at higher frequencies and reach higher values than those for quark stars. In case of the static CFL quark stars with the maximal total mass, both the spectral amplitude, and the frequency at which the maximum is located, have lower values than those for the rotating cases (with higher maximal masses).'

i.e., see this, below, this is our figure 2. i.e., CFL would be for a quark star whereas Kerr BH would be for a Kerr black hole.

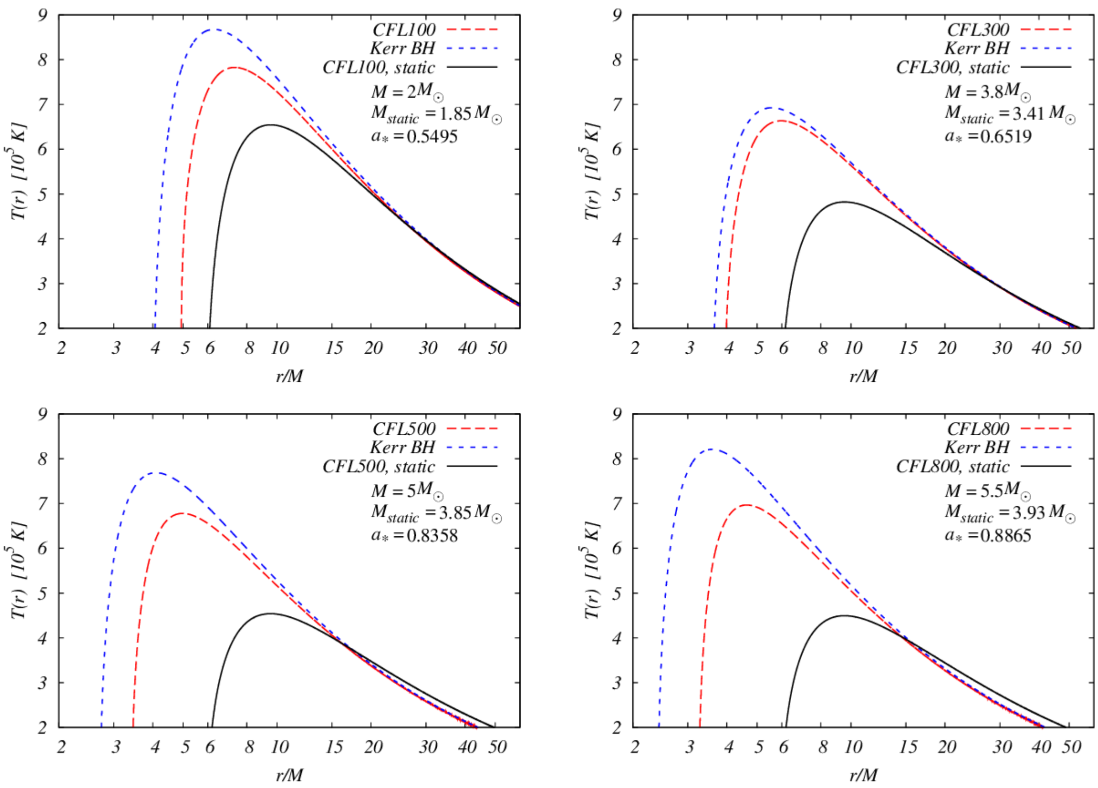

Figure 2, from [12] where we have that as to the results from [12] and its figure 4
quote

The temperature profiles of the thin accretion disk around rotating black holes and quark stars with the same total mass M and spin parameter a. The static configuration is also presented.

End of quote

This is for electromagnetic generation of E and M signals from a quark star versus what we would see for a straight-out black hole would be extremely different.

On the other hand, the existence of a gamma ray burst, and a gravitational wave source would still have co existing properties as seen below.

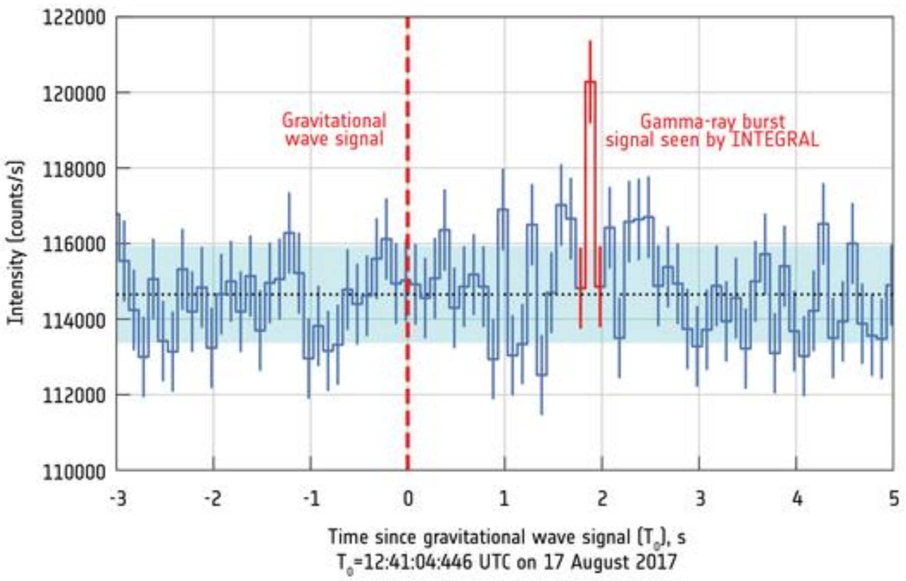

Figure 3, from [13] states that there would be close synchronization of time between a gravitational wave signal, and gamma ray bursts, in an event likely connected to a quark star being formed

Likely, the GW signal created between a black hole, black hole binary, would obey Eq. (2) and be ALMOST duplicated by a black hole, Quark Star.As in Figure 2 though, for [12], the differences would show up most decisively in Magnetic field behavior between the Quark star and black holes. i.e. electromagnetics and the temperature mappings of the accreditation disks would be very different.

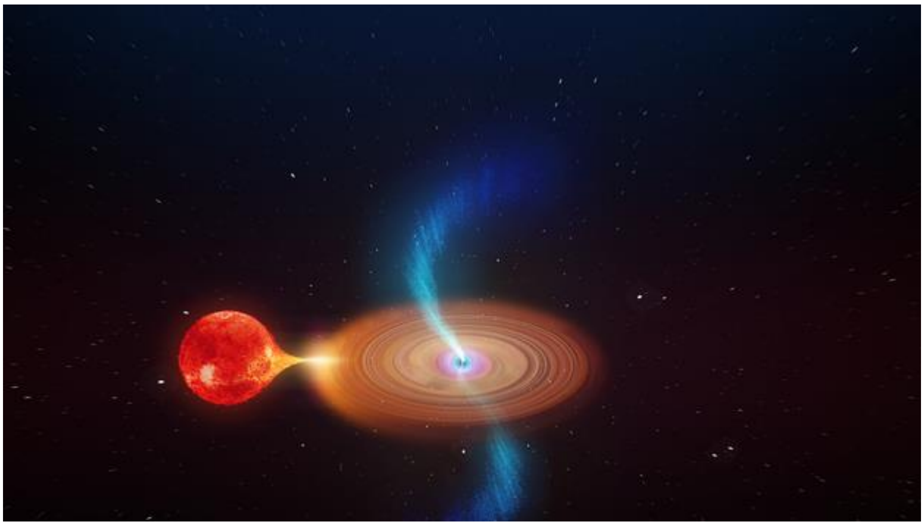

Figure 4 from [14], i.e. **Artist's impression of a black hole accreting material from a companion star.**

The companion star would likely be a quark star, with an accreditation disk being siphoned off to feed the black hole as is show in figure 4, with the situation described as in [14]

Figure 4 is what would happen, if we were looking at the physics of [1],[2],[3], and it leads to the following question to ask, i.e., how can we combine the results of both a GRB burst and a quark star-black hole?

To do this, consider [15] which has them a reference as to what is called of black hole mining. To do this use from [15] the so-called black hole mining in a black hole atmosphere argument to have a high temperature, Low Luminosity behavior of a quark star.

i.e., on page 340,

$$\Delta E_{\min ed} \approx \frac{4}{3} \cdot \breve{a} G_{\breve{a}} \cdot \frac{T_H^4}{\breve{\alpha}^3} \cdot V \qquad (3)$$

Here, will refer to a so-called atmosphere's law of blueshift, [16]

$$T = \left(T_H / \breve{\alpha} \right) = atmosphere - law - of - blueshift \qquad (4)$$

The precise language is that a quark star has a very temperature value and low Luminosity. i.e. which could be obtained, in [16] , page 16, via

$$L = Lu\min osity(Quark - Star) = \sigma T_H{}^4 \left(R_{eff} \right) \times 4\pi R_{eff}{}^2 \quad (5)$$

Whereas we have for Eq. (5) being low, that T_H is much smaller than Planck temperature, whereas Eq. (4) will be comparatively enormous for a quark star, due to the smallness of a picked $\breve{\alpha}$ term, the Eq. (5) term would be comparatively enormous. Hence, to first order, due to the specifics of the quark star being formed, we could state.

$$\Delta E_{\min ed} \approx \frac{4}{3} \cdot \breve{a} G_{\breve{a}} \cdot \frac{T_H^4}{\breve{\alpha}^3} \cdot V \propto 6.24 \times 10^{55} GeV \qquad (6)$$

Note, Eq. (6) is for a GRB which, initially is NOT dominated by GW.

In this case, the alleged change in "mined" energy would be enormous and related to a GRB 'signal' for an evolution from a neutron star to a quark (strange)

star. Due to the smallness of a picked $\breve{\alpha}$ term, whereas we will use the following term for GW release of energy for a quark-star black hole binary.

$$\Delta E_{quark-star-black-hole} \approx 5.7 \times \left(\frac{m_{quark-star} \cdot m_{Black-hole}}{m_{quark-star} + m_{Black-hole}} \right) \cdot c^{2} \tag{7}$$

This should be compared, Eq. (7) with respect to a derivation in [16] in page 98 which does not include relativistic effects but is the result of a slamming of a quark star with a black hole.

Note that in the below, if the magnitude of Eq. (7) and Eq. (8) are the same, it will then.

lead to a question as to how to interpret the final period of rotation of a quark star with a black hole, before merger of the two masses, which we call $\tilde{T}_1^{2/3}$ which the final period of rotation between the two masses prior to ringdown merger of the two, to the 2/3rd power.

$$-\Delta E(quark - star - BH - merge)$$
$$\approx \frac{(2\pi G)^{2/3} \cdot \left(m_{quark-star} + m_{Black-hole} \right)^{2/3}}{2\tilde{T}_1^{2/3}} \cdot \left(\frac{m_{quark-star} \cdot m_{Black-hole}}{m_{quark-star} + m_{Black-hole}} \right) \tag{8}$$

III. Conclusion and future question to ask, which is significant.

Figures 3, 4, and Eq. (6), Eq. (7) and Eq. (8) need to be numerically simulated. But the real question is, after the GRB blow up would as an example there be an accreditation disk as show with regards, say to a

quark star. The models indicate yes, but we do not know even now the precise nature of the electromagnetic signals, or how long they would be lasting,

As an example, the Bierman battery model has been proposed to give a tentative magnetic field, in tandem with GW releases, as specified. What is that B field detail, as compared to the final Period of rotation, as specified in Eq. (8)? We still do not know. In addition, Eq. (7) and Eq. (8) assume that we have special relativity applied? Could as an example, quantum effects enter in, as say in a GOP (Generalized Uncertainty principle) as specified in [17], whereas also [18] and [19] have further issues awaiting review.

FINALLY

Our final comment which needs to be investigated. See this from [20], namely the issue of Bose Einstein condensation w.r.t Gravitons as a condensate for the formation of black holes , and does this play a role in our binary of a quark star- black hole model?

We think it does, IN A MAJOR way. Here is the idea , i.e. that Black holes, as Bose Einstein condensates of gravitons, will naturally interact with respect to the physics of Eq. (4), Eq. (7) and Eq. (8) and are essential to theoretical justifications of our inquiry

$$m \approx \frac{M_P}{\sqrt{N_{gravitons}}}$$

$$M_{BH} \approx \sqrt{N_{gravitons}} \cdot M_P$$

$$R_{BH} \approx \sqrt{N_{gravitons}} \cdot l_P$$

$$S_{BH} \approx k_B \cdot N_{gravitons}$$

$$T_{BH} \approx \frac{T_P}{\sqrt{N_{gravitons}}} \tag{9}$$

Here, the first term, m, is in the effective mass of a graviton. This is my take as to how to make all this commensurate as to special relativity.

$$m \approx \frac{m_g}{\sqrt{1-\left(\frac{v_g}{c}\right)^2}} \approx \frac{M_P}{\sqrt{N_{gravitons}}} \approx 10^{-10}\,grams \tag{10}$$

$$\therefore N_{gravitons} \approx 10^{10} \tag{11}$$

Does Eq. (9), Eq. (10) and Eq. (11) dovetail in our investigation of Eq. (4), Eq. (7) and Eq. (8)? We believe the answer is yes, and that we need to understand this fully in order to answer foundational questions.

References

1. Ingrid Fadelli , "**Could the source of the GW190814 event be a black hole-strange quark star system?**" https://phys.org/news/2021-06-source-gw190814-event-black-hole-strange.html

2. **I. Bombaci, A. Drago , D. Logoteta , G. Pagliara and I. Vida˜na, "Was GW190814 a black hole – strange quark star system?", https://arxiv.org/pdf/2010.01509.pdf**

3. **I. Bombaci and B. Datta, Astrophys. J. Lett. 530, L69 (2000), astro-ph/0001478.**

4. **M. Maggiore, "Gravitational waves, Volume 1, Theory and experiments", Oxford University Press, 2008, New York City, New York, USA**

5. Landau and Lifshitz, Volume II, (1979), **Course Of Theoretical Physics Vol 2 The Classical Theory Of Fields 4ed Revised (Pb 2017)** Section 102, Problem 1

6. **Z. Berezhiani, I. Bombaci, A. Drago, F. Frontera, and A. Lavagno, Astrophys. J. 586, 1250 (2003), astroph/0209257.**

7. **I. Bombaci, I. Parenti, and I. Vida˜na, Astrophys. J. 614, 314 (2004), astro-ph/0402404.**

8. **A. Drago, A. Lavagno, and G. Pagliara, Phys. Rev. D69, 057505 (2004), nucl-th/0401052.**

9. **A. Drago, A. Lavagno, and G. Pagliara, Phys. Rev. D89, 043014 (2014), 1309.7263.**

10. **Giuseppe Pagliara, "On the conversion of neutron stars into quark stars", https://arxiv.org/abs/1312.1083**

11. Alessandro Drago, Giuseppe Pagliara, Irene Parenti **, " Transition to Quark Matter and long Gamma Ray Bursts",** Nuovo Cim.B121:1355-1361,2006, https://arxiv.org/abs/astro-ph/0701240

12. **Z. Kovacks, K.S. Cheng, and T Harko, "Can Stellar mass black holes be quark Stars?", https://arxiv.org/pdf/0908.2672.pdf ,**

13. **https://sci.esa.int/web/integral/-/59670-gamma-ray-burst-after-gravitational-waves**

14. **https://sci.esa.int/web/integral/-/61323-black-hole-accreting-material-from-its-companion-star**

15. Kip Thorne, Richard Price, and Douglas MaCDonald," Black holes, the Membrane Paradigm", Yale University Press, Yale, New Haven, CT , USA, 1986

16. Steven Weinberg, "Lectures on Astrophysics" , Cambridge University Press, Cambridge, United Kingdom, 2020

17. Andrew Beckwith, and Stepan Moskaliuk, "Generalized Heisenberg Uncertainty Principle in Quantum Geometrodynamics and General Relativity", September 2017, Ukrainian Journal of Physics, https://ujp.bitp.kiev.ua/index.php/ujp/article/view/2018650/757 , Ukr. J. Phys. 2017. Vol. 62, No. 8, pp 727-740

18. Juan Maldacena, "Comments on Magnetic Black holes", https://arxiv.org/pdf/2004.06084.pdf, *J. High Energ. Phys.* 2021, **79** **(2021).**

19. Kip S. Thorne, Wojciech H. Zurek, and Richard Price, "The Thermal atmosphere of a black hole", pp 280-340 of "Black Holes, the Membrane Paradigm", Edited by Kip Thorne, Richard Price, and Douglas MacDonald, Yale University Press, New Haven, Conn., 1986

20. P.H. Chavanis, " Self Gravitating Bose-Einstein Condensates", pp 151-194, of Quantum Aspects of Black Holes, with Xavier Calmet, Editor, of Fundamental Theories of Physics, 178, Springer Nature, Cham, Switzerland, 2012