Evolution of Stars into Pulsars

Raymond HV Gallucci, PhD, PE
8956 Amelung St., Frederick, Maryland, 21704
e-mails: gallucci@localnet.com, r_gallucci@verizon.net

Despite much obeisance paid to black holes by 'Standard Model' cosmologists (not to mention Hollywood, e.g., the recent film "Interstellar," alleged to have a basis in physics, but really pure science fiction), dissident physicists, led by Stephen Crothers, have re-examined the original analysis by Karl Schwarzschild which, due to an error by David Hilbert, has provided much of the basis for the alleged existence of black holes. This substantial body of work suggests black holes cannot exist, leading me to the logical conclusion that the densest stars possible are neutron stars (or perhaps, if such are possible, 'quark' stars) which have relatively small but 'non-singular' dimensions. Both the mass and "pulse" rate of many neutron stars (also known as pulsars) have been recorded. Examination of these data opens an avenue of speculation based on their angular momenta that perhaps could aid in the understanding of how 'heavy" (relative to our sun) rotating stars might evolve into pulsars.

1. Introduction

For over a decade, Stephen Crothers (with acknowledgement of earlier work by Leonard Abrams) has repeatedly written and lectured on the fallacy of black holes, citing the original work of Karl Schwarzschild and the error perpetrated by David Hilbert that subsequently led to uniting Einstein's general relativity with the fiction of black holes as part of today's 'Standard Model" for cosmology (see, e.g. [1]). Crothers specifically focuses on Hilbert's and many subsequent physicists' misinterpretation of a parameter 'r' in Schwarzschild's analysis as the radius of a sphere when Schwarzschild used it only once when specifying his solution for the 'proper' radius of the sphere 'R' as $R = (r^3 + \alpha^3)^{1/3}$. While r can go to zero, α cannot, being a function of non-zero parameters, including Gauss' gravitational constant and the density of the sphere. Thus, in Schwarzschild's solution, R has a minimum value of α (> 0), precluding stellar collapse into a singularity and, therefore, formation of a black hole.

A natural extension of this is that the smallest possible star would be a non-singularity with radius R, such as a neutron star (or, if such is possible, a 'quark' star [2]), i.e., one with a non-zero volume. Therefore, it is quite possible that when astronomers claim to have identified yet another black hole somewhere in the universe, what they really are finding is a neutron star. Neutron stars rotate, emitting a beam of electromagnetic radiation that intersects the earth, so are also known as pulsars. Many pulsars have been identified, with a convenient list including their rotation (pulse) frequency and mass having been assembled by Paulo Freire. [3,4] This paper works from the list to try to ascertain a potentially interesting property of pulsars.

2. Relationship between Pulsar Mass and Pulse Frequency?

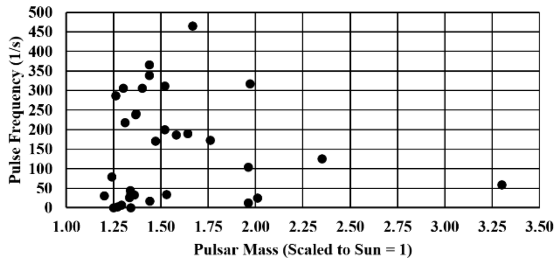
Table 1 lists the pulsars identified by Freire in two groups, with the second (below the line) cited as 'super-massive neutron stars' in [4], although there is overlap between the two groups (note that the masses are scaled to our sun's mass = 1).

Table 1. List of Pulsar Rotation (Pulse) Frequency and Mass (from Freire [3,4])

Pulsar	Freq (1/s)	Mass (Θ)
J2222-0137	30.471	1.200
J1802-2124	79.066	1.240
J0737-3039B	0.360	1.249
J0751+1807	287.458	1.260
J1141-6545	2.539	1.270
J1906+0746	6.941	1.291
J1910-5958A	306.167	1.300
J1713+0747	218.811	1.310
B1534+12	26.382	1.333
J0737-3039A	44.054	1.338
B2302+46	0.937	1.340
J1756-2251	35.135	1.341
B2127+11C	32.755	1.358
J1807-2500B	238.881	1.366
J0337+1715	365.953	1.438
J1909-3744	339.315	1.438
B1913+16	16.940	1.440
J1738+0333	170.937	1.470
J0621+1002	34.657	1.530
B1855+09	186.494	1.580
J1012+5307	190.267	1.640
J1903+0327	465.135	1.667
J0437-4715	173.688	1.760
J1614-2230	317.379	1.970
J0348+0432	25.561	2.010
J1824-2452C	240.484	1.367
J1911-5958A	306.167	1.400
J0024-7204H	311.493	1.520
J0514-4002A	200.378	1.520
J1748-2446I	104.491	1.960
J1748-2446J	12.447	1.960
B1516+02B	125.835	2.350
J1748-2021B	59.665	3.300

Figure 1 plots these masses vs. 'pulse' frequency, suggesting there may be at least two groupings: (1) pulsars with mass ≤~2.0 $M_\odot$ with 'low' pulse frequency (≤~100/s), and (2) pulsars with pulse frequencies >~100/sec. There is a potential anomaly for the most massive pulsar (~3.3 $M_\odot$) in that its frequency is <100/s, such that it could be placed into either group. While no trend (other than roughly constant pulse frequency) is evident for the first group, a suggestion of decreasing pulse frequency with increasing mass is evident for the second. We explore this further.

Figure 1. Pulsar 'Pulse' Frequency vs. Mass



3. Pulsar Angular Momentum

This prompts examination of the angular momentum ‘L’ associated with these pulsars, which is the product of the moment of inertia ‘I’ (assuming a solid sphere, which certainly is applicable to something as dense as a neutron star) and the rotational speed ‘ω’ (pulse frequency), i.e., $L = I\omega$. L can be written in terms of mass ‘M’ and rotational speed exclusively, as follows:

$M = 4\rho\pi r^3/3$ (ρ = density of pulsar, r = radius)
$r = (3M/4\pi\rho)^{1/3}$
$I = 2Mr^2/5$ (solid sphere) $= (2/5)(3/4\pi\rho)^{2/3}M^{5/3}$
$L = (2/5)(3/4\pi\rho)^{2/3}M^{5/3}\omega$

Assuming a pulsar is composed of pure neutronium ($\rho \approx 4\text{x}10^{17}$ kg/m^3 [5]) and the sun’s mass $\approx 2\text{x}10^{30}$ kg [6], the data from Table 1 can be used to generate angular momenta for each pulsar, as shown in Table 2 and Figure 2.

Again, two groupings are evident, although not necessarily for the same pulsars as before: (1) pulsars with mass $\leq\sim 2.0\ M_\odot$ with ‘low’ angular momentum ($\leq\sim 1\text{x}10^{40}$ kg-m^2/s), and (2) pulsars with pulse frequencies $\geq\sim 3\text{x}10^{40}$ kg-m^2/s. Now the most massive pulsar falls clearly within the second grouping. Linear curve fits are also shown for each grouping:

(1) $L_{lo}(\text{x}10^{-39}) = 2.96M - 0.224$ (dashed line)
(2) $L_{hi}(\text{x}10^{-39}) = 2.59M + 42.40$ (solid line)

At the approximate midpoints of the mass ranges for each group, 1.6 $M_\odot$ for the first (‘low’) and 2.3 $M_\odot$ for the second (‘high’), the corresponding angular momenta are about 5 and $50\text{x}10^{39}$ kg-m^2/s, respectively, i.e., about a factor of 10 difference. Might this suggest that pulsars could be classified into two distinct groups based on their angular momenta?

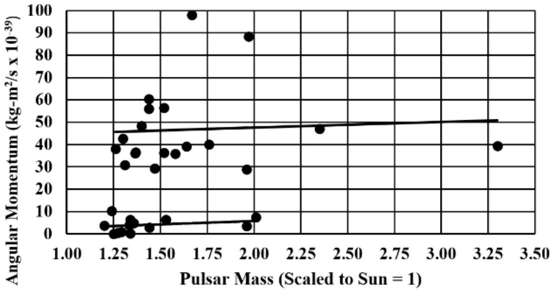
4. Speculation

The fastest spinning pulsar in Freire’s list is J1903+0327 with a frequency of 465/s. It appears as the maximum vertical point on both Figures 1 and 2. This corresponds to a period of 0.0021 sec, qualifying it as a ‘millisecond pulsar.’ [7] Currently the fastest confirmed pulsar is J1748-2446ad, spinning at 716/s (period = 0.0014 s) with an estimated mass just slightly < 2 $M_\odot$. [8] With a corresponding angular momentum of $\sim 2\text{x}10^{41}$ kg-m^2/s, it would lie vertically at the highest point in both Figures (off the scales shown).

Table 2. List of Pulsar Angular Momenta

Pulsar	$L = I\omega$ (kg-m^2/s)	$L/10^{39}$
J2222-0137	3.72E+39	3.717
J1802-2124	1.02E+40	10.187
J0737-3039B	4.69E+37	0.047
J0751+1807	3.80E+40	38.037
J1141-6545	3.40E+38	0.340
J1906+0746	9.56E+38	0.956
J1910-5958A	4.27E+40	42.678
J1713+0747	3.09E+40	30.893
B1534+12	3.83E+39	3.834
J0737-3039A	6.44E+39	6.443
B2302+46	1.37E+38	0.137
J1756-2251	5.16E+39	5.158
B2127+11C	4.91E+39	4.910
J1807-2500B	3.61E+40	36.142
J0337+1715	6.03E+40	60.339
J1909-3744	5.60E+40	55.960
B1913+16	2.80E+39	2.800
J1738+0333	2.92E+40	29.244
J0621+1002	6.34E+39	6.338
B1855+09	3.60E+40	35.984
J1012+5307	3.91E+40	39.064
J1903+0327	9.81E+40	98.133
J0437-4715	4.01E+40	40.115
J1614-2230	8.85E+40	88.450
J0348+0432	7.37E+39	7.366
J1824-2452C	3.65E+40	36.451
J1911-5958A	4.83E+40	48.289
J0024-7204H	5.63E+40	56.346
J0514-4002A	3.62E+40	36.246
J1748-2446I	2.89E+40	28.875
J1748-2446J	3.44E+39	3.440
B1516+02B	4.71E+40	47.053
J1748-2021B	3.93E+40	39.288

Figure 2. Pulsar Angular Momentum vs. Mass



Another alleged (but not confirmed) to be rotating even faster at 1122/s (period = 0.00089 s) is J1739-285, although its mass is not reported. [9] Some speculate it may be a quark star, even denser than a neutron star (if such is possible). Might what have been reported to be black holes (impossibilities according to Schwarzschild’s analysis, upon which much of the theory of the existence of black holes is erroneously based) actually be ‘sub-millisecond pulsars,’ i.e., neutron stars rotating so rapidly that their rotation rates are essentially indistinguishable from continuous ‘pulsing?’ If so, they would have angular momenta greater than that estimated for J1748-2446ad[1] and possibly constitute a third grouping in Figure 2, off-scale vertically.

Whether or not there is any basis for groupings of pulsars by angular momentum is clearly speculative at this point. My analysis is constrained by the lack of pulse rates with corresponding masses for the 'heavier' pulsars, i.e., above approximately two solar masses (Freire's listings show only six). If black holes are actually neutron (or quark) stars, as implied by the work of Crothers, et al., with definitive, albeit 'small,' non-singular radii AND have measurable rotation rates (presumably 'sub-millisecond'), then additional data could be added to the lists here and the analysis expanded to determine if my results are merely an anomaly due to limited data vs. 'something else.' If 'something else,' then it could be possible to predict the evolution of certain rotating stars into pulsars by calculating the pre-pulsar angular momentum,[2] which would be conserved after the supernova explosion such that the pulsar would fall into one of the two (or, speculatively, three?) groupings.

5. References

1. S. Crothers, "The Schwarzschild Solution and its Implications for Gravitational Waves," Mathematics, Physics and Philosophy in the Interpretation of Relativity Theory, Sept. 4-6, 2009, Budapest, *http://www.phil-inst.hu/~szekely/PIRT_BUDAPEST/* (also available via Crothers' website *http://www.sjcrothers.plasmaresources.com/papers.html*).
2. *http://en.wikipedia.org/wiki/Quark_star*
3. *www3.mpifr-bonn.mpg.de/staff/pfreire/NS_masses.html*
4. P. Freire, "Super-Massive Neutron Stars," *http://arxiv.org/pdf/0712.0024.pdf*.
5. *http://en.wikipedia.org/wiki/Neutronium*
6. *http://en.wikipedia.org/wiki/Sun*
7. *https://en.wikipedia.org/wiki/Millisecond_pulsar*
8. *https://en.wikipedia.org/wiki/PSR_J1748-2446ad*
9. *https://en.wikipedia.org/wiki/XTE_J1739-285*

---

[1] Assuming at least twice the rotational speed, which would result in an angular momentum above that for J1748-2446ad even if only one solar mass.

[2] For example, if our sun were a 'pre-pulsar' of 3 solar masses rotating at its once per 25-day rate at its equator ($4.6\text{x}10^{-7}$/s), with the density equal to that at its center ($\sim 1.6\text{x}10^{5}$ kg/m^{3}), it would have an angular momentum of $\sim 4.8\text{x}10^{40}$ kg-m^{2}/s. [6] It would be expected to evolve via a supernova explosion into a pulsar in the group with the 'higher' angular momentum in Figure 2.