Non-Identical Twin "Neutron" Stars

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Since the early work by Wheeler and collaborators [1], there have been two reasons to believe that there are no stable stellar configurations of higher density than the neutron star sequence. The physical basis of this expectation is that white dwarfs are stabilized by degenerate electron pressure which fails at such density that electron capture reduces their effectiveness. Stability is reestablished at densities orders of magnitude higher when the baryon Fermi pressure (and ultimately the repulsive interaction) supports "neutron" stars.

What else is there to stabilize a higher density sequence? The Baryon Fermi pressure is *replaced* by the Fermi pressure of quarks if deconfinement occurs. And deconfinement is expected to occur in the density range of *neutron* stars. In this event, purely hadronic neutron stars and hybrid stars, those with a quark matter interior, form part of the same sequence. This picture seems to fit with a result obtained by Wheeler et. al. who showed analytically for a polytropic equation of state that there is a continuous infinity of turning points in the mass-radius relation, but all configurations with densities higher than the first mass limit for neutron stars are unstable to acoustical vibrations, and end either by exploding or imploding to a black hole. It seemed plausible that this result was not peculiar to the polytropes, but would hold for any (at least reasonably) smooth equation of state.

To our surprise we have found exception to the expectation. Under certain combinations of parameters defining the nuclear and quark deconfined equations of state, there exists a second sequence of high density stellar configurations. The first sequence—the "neutron stars"—is terminated by the softening in the equation of state by the mixed phase when a substantial core of mixed phase is attained. A new sequence at higher density is stabilized by replacement of the mixed phase by a pure quark phase core. There are therefore configurations of the same mass but radically different quark composition. An example of these non-identical twins is shown in Fig. 1 where we compare the density profiles.

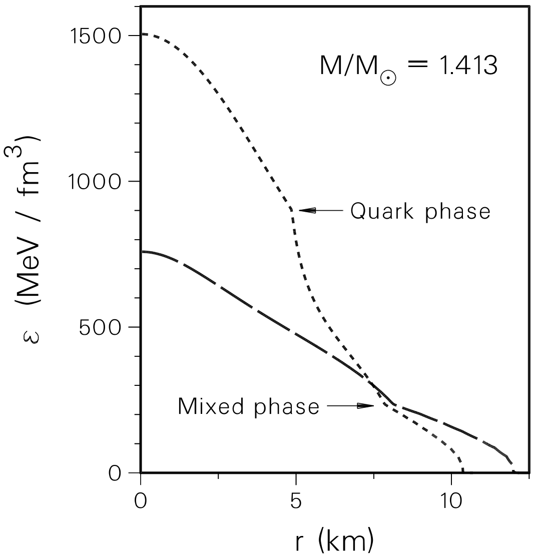

Figure 1: Compact stars of the same mass but radically different composition and matter distribution are both stable.

References

[1] B. K. Harrison, K. S. Thorne, M. Wakano and J. A. Wheeler, *Gravitation Theory and Gravitational collapse*, (University of Chicago Press, Chicago, 1965).