Comment on Strange Stars

Alcock, Farhi, and Olinto have proposed an interesting "Model for the 5 March 1979 Gamma-Ray Transient."[1] They explain this remarkable event in terms of the impact of a lump of strange matter on a strange star.[2-4] As strange matter is hypothesized to be the ground state of hadrons, the authors point out that "neutron stars would almost certainly be made of strange matter, not neutrons, and we call these stars 'strange stars.'" The purpose of this Comment is to note an observational feature of pulsar glitches which conflicts with the hypothesis of strange stars. This arises from a structural distinction between neutron stars and strange stars. The distinction is independent of any particular models for glitches.

Glitches are sudden jumps in rotation frequency with $\Delta\Omega/\Omega \sim 10^{-6}$ for some glitches and $\Delta\Omega/\Omega \sim 10^{-9}$ for others. Fourteen glitches have been observed from seven pulsars.[5] This sample contains pulsars of different ages, suggesting that glitches are experienced by all pulsars. Indeed, the rate of observed glitches is statistically consistent with the hypothesis that all radio pulsars experience glitches.[6] The occurrence of glitches raises the question whether strange stars could exhibit such behavior.

For most glitches measurements of the spin-down rate $\dot{\Omega}$ allow a determination of a discontinuity in $\dot{\Omega}$ associated with the glitch. A fractional change $\Delta\dot{\Omega}/\dot{\Omega} \sim 10^{-2}$–$10^{-3}$ accompanies the change in Ω in all cases. No discontinuous changes in the observed electromagnetic radiation are associated with the glitches. The events must therefore reflect changes in the internal dynamics of the star rather than changes in magnetospheric torques. The sudden change in the spin-down rate $\dot{\Omega}$ and its subsequent relaxation must involve the decoupling and recoupling of some physically distinct component of the star's interior to these torques. The effective moment of inertia of such a component i would be given by $I_i/I \cong \Delta\dot{\Omega}/\dot{\Omega}$. Neutron stars have such a component, the inner crust including the densities beyond neutron drip.[7] Hence a crystal lattice[8] or an ordered inhomogeneous medium[9] exists up to densities $\sim 2\times 10^{14}$ g/cm^{-3}. Most of the crustal moment of inertia resides at densities above the density for neutron drip, $\rho \cong 4\times 10^{4}$ g/cm^{-3}, where neutrons occupy continuum as well as bound states. The fractional moment of inertia of the neutron-star inner crust is precisely of order 10^{-2}.

By contrast, strange stars possess either no crust or a crystalline crust at densities below neutron drip. Matter beyond neutron drip would be unstable in the presence of a strange core to the star.[4] The strange matter comprising the bulk of such a star is homogeneous and exhibits a very modest density variation.[4] Strange stars can furnish a physically distinct component (crust) with at most 10^{-5} of the moment of inertia of the star. It has been noted that glitches pose difficulties for the strange-star hypothesis.[3,4] The objection that has been spelled out here is independent of any detailed properties of the interior, like superfluidity. Strange stars at present do not have any internal structural differentiation to explain the observed magnitude of $\Delta\dot{\Omega}/\dot{\Omega}$ in the glitches. The ~ 450 known radio pulsars constitute the majority of astronomical objects believed to be neutron stars. The other class of such objects, the ~ 50 accreting x-ray sources, are thought to have evolutionary links to radio pulsars. Unless new strange-star models can supply $\dot{\Omega}$ jumps of the observed magnitude, the observed objects cannot be identified with strange stars as a class. The proposal that the 5 March event occurred on a strange star would thus require that strange stars and neutron stars both exist. The fraction of "neutron stars" that are strange would have to be adjusted to address the statistics of γ-ray transients, as well as the lack of other observational manifestations of the class of strange stars. The lifetime of conventional neutron stars should then reflect a time scale for the transition from neutron matter into strange matter.

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