Strange White Dwarfs

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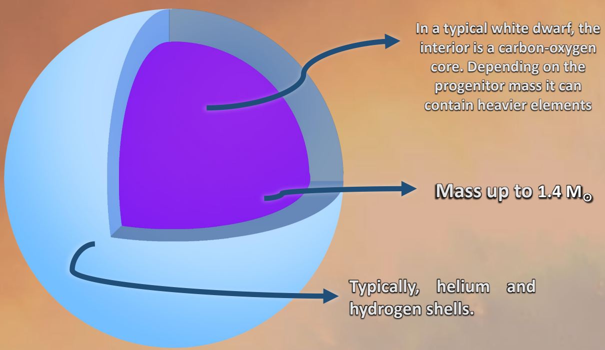
Abstract: More than 20 years ago, Glendenning and Weber [1] proposed the existence of white dwarfs with a core of strange quark matter. More recently, by looking at radial modes, Alford et al. [2] concluded that those objects are unstable. Instead, our analysis shows that if the star is not strongly perturbed and ordinary matter cannot transform into strange quark matter, this type of object is stable. On the other hand, ordinary matter can be transformed into strange quark matter if the star undergoes a violent process, such as a nova, causing the system to become unstable and collapse into a strange quark star. In this way, km-sized objects with subsolar masses can be produced.

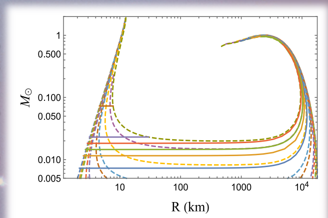


WHITE DWARF

A white dwarf is a stellar remnant that is mostly made of electron-degenerate matter, it is extremely dense, with a mass comparable to the Sun.
White dwarfs are formed when the progenitor star has a mass between 0.08 $M_\odot$ and around 10 $M_\odot$ and **runs out of nuclear fuel** at the conclusion of its evolutionary cycle, causing its core to **collapse** as its outer layers expand. Only when the electrons' degeneration pressure is sufficient to support the structure it stops collapsing. Depending on its mass, the nuclear reaction in the progenitor can continue until the heaviest element in the core is ^{56}Fe.

STRANGE DWARF

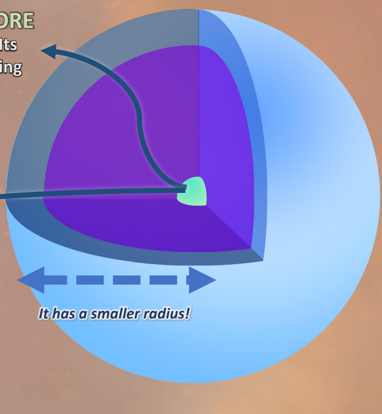
During their life, white dwarfs **can acquire a strange quark matter core** (collecting ***strangelets***!) that could affect observational features such as the radius and, to a lesser extent, the mass, and the possible evolution in binary systems [1]. This shrinking effect is supposed to be observable with astrophysical analyses [3].
Strange dwarf equation of state is **bi-parametric**: to fix a structure one has to give the central energy density and the maximum energy density reached by the ordinary matter, ε_{trans}. Since in our analysis we will consider the case in which the **quark matter content does not change**, a better choice is to fix the **quark content of the core** and the **central energy density**. The stars obtained by using these parameters are stable also for the empirical Bardeen, Thorne, and Meltzer (BTM) criteria.



Mass-Radius diagram for strange dwarfs. Dashed: each curve is obtained at a different transition density, by varying the quark content of the core. Solid: curves obtained by fixing the quark content of the core.

STRANGE MATTER CORE

Acquired during its life. Its dimensions vary depending on the abundance of strangelets.



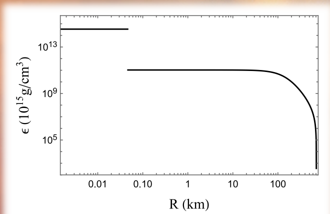
COULOMB BARRIER

Coulomb barrier prevents ordinary matter and strange quark matter from touching and mixing unless ordinary matter reaches neutron drip density (about 4×10^{11} g/cm^3).

STRANGE DWARF STABILITY: RADIAL OSCILLATIONS

To determine whether a star is **stable or not**, one must check for **stability against radial oscillations**. Since the equation of state contains a **discontinuity** in the energy density, it is fundamental to account for it properly. The differential equation for radial oscillations is obtained by perturbing the hydrostatic equilibrium equation in general relativity and it reads as:

$$(H\,\xi')' = -(\omega^2 W + Q)\xi$$



Energy density as a function of the radius for a strange dwarf having a strange core consisting of 10^{50} baryons and a central energy density of 3.44519×10^{14} g/cm^3.

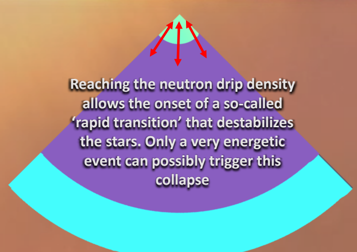
where ω is the oscillation frequency, ξ the **radial displacement**, H, Q and W are functions that depend on the physical quantities of the considered star (pressure, energy density, gravitational potential etc.). When solving the radial oscillations equation one must account for the fact that ordinary matter doesn't mix with strange quark matter. This is embedded in the **continuity** of the displacement ξ and of the pressure fluctuations $\Delta P \propto \xi' c_s^2 (P + \varepsilon)$ [4,5] namely the **discontinuity** of the energy density (ε) and of the sound speed (c_s^2) must be **compensated by the discontinuity** of the derivative of the radial displacement (ξ').

STRANGE DWARF (IN)STABILITY

We demonstrate that the strange dwarfs which **don't permit the mixing of the core** with the rest of the star during radial oscillations are **stable**. Nevertheless, if the star reaches the **neutron drip density** (4×10^{11} g/cm^3) near the core, neutrons can pass the Coulomb barrier leading to a different type of oscillation: in this case, the radial displacement function ξ **gains a discontinuity** in correspondence to the phase transition and the star becomes **unstable**. This new condition needs to be implemented in the solution of the radial oscillations equation. Obviously, at this point, the equation of state of the strange dwarf is no more characterized by having a core with a constant number of quarks because their number is increased by the conversion of the neutrons.
The instability of the strange dwarf makes it **collapse to a strange star**.

PRODUCTION OF SUB-SOLAR MASS COMPACT OBJECTS

The key assumption of this work is the **validity of the Bodmer-Witten hypothesis** on the absolute stability of strange quark matter: at zero pressure strange quark matter is more bound than iron. In strange dwarfs, ordinary matter can be transformed into strange quark matter if the star undergoes a violent process, such as a **nova**, causing the system to become unstable and collapse into a strange quark star. If the strange dwarf is in a **binary system** it can accrete mass and the system instability would be triggered by **density fluctuations near the Chandrasekhar mass**. Depending on the dimension of the core, the **time scale of the collapse**, namely the time scale of the conversion of the ordinary matter into quark matter **can be smaller** than the **typical time scale of a supernova explosion**. In this case, the process of strange matter conversion can be **dominant** over the deflagration process, leading to the **formation of a subsolar mass strange star**. In conclusion, this mechanism can produce objects having small masses and radii of the order of a few kilometers.



References

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