White dwarfs.

Stars are composed of hydrogen, helium and other elements manufactured by nuclear reactions. The temperature of a star is high enough so that atoms are ionized. If the density is not extremely high, this collection of ions and electrons behaves like an ideal ideal gas, its pressure P, temp. T and number density n are given by the formula $P = nkT$, k Boltzmann's constant.

But for a star composed of ideal gas this pressure P cannot to support it under gravitational collapse. From the above formula one needs a large thermal energy (large T) to obtain large values of pressure at a given density. But stars radiate energy from their surface, they cannot maintain pressure required for self support except with an additional energy source

However stars are not composed of ideal gas. Electrons obey Pauli exclusion principle of quantum mechanics. No two electrons can occupy exactly the same state. As a consequence of this fact there is an additional pressure exerted by electrons. Under ordinary conditions this quantum mechanical effect is negligible, but at very high densities it is very important. When the density of matter in a star becomes greater than about five million times the density of water, electrons contribute a pressure P due to this effect given by

$$P \sim hcn^{4/3}$$ (n = number of electrons per unit volume)

(At somewhat lower densities P is proportional to $n^{5/3}$). This is known as the electron degeneracy pressure. The important thing about the electron degeneracy pressure is that it does not require the presence of large thermal energy (high temperature so that it can be maintained even as the star radiates energy.

How much pressure is needed to support a star under collapse? The requirement for hydrostatic equilibrium of a star is that at each radius r the Newtonian gravitational force be balanced by the force arising from the pressure of the gas. The equation is

$$\frac{dP}{dr} = -G\,\frac{m(r)}{r^2}\,\rho\,.$$

From this equation it is not difficult to show that in order to support itself against collapse, the pressure P_c at the centre of the star must be roughly $P_c \sim G M^{2/3} \rho^{4/3}$. M = total mass of the star

To see if electron degeneracy pressure ~~could~~ can support a star, we must compare the pressure it yields to the central pressure needed for support. As the above approximate formulas show, the pressure obtainable at high densities and the pressure need for support have the same dependence on electron number density (since the mass ~~on~~ density ρ is proportional to N). Support will be possible when the coeff of $n^{4/3}$ in the formula for electron degeneracy pressure is greater than the coeff of $n^{4/3}$ in the formula for central pressure needed. Since this latter coefficient depends on the mass M of the star, this means that stars with sufficiently small mass can be supported ~~a~~ while stars with large mass cannot.

Detailed calculations first performed by S. Chandrasekhar, show that for stars with mass less than about 1.3 times the mass of the Sun, electron degeneracy pressure permanently halts collapse. For stars with mass less than about half a solar mass this happens before the phase of helium ~~a~~ burning can occur; for stars with greater mass (but less than 1.3 solar masses) it occurs at a later stage of evolution. Stars that are supported by electron degeneracy pressure are called "white dwarfs"

dwarfs because they are very condensed and thus small in size, "white" because their surface temperature is very high when they enter this phase. No further evolution occurs for white dwarfs, they simply cool down for ever. Many stars in our ~~vicit~~ vicinity are white dwarfs. Our Sun will end its life as a white dwarf.