Chandrasekhar Limit Encyclopedia Article

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By combining special relativity with quantum **mechanics**, **Subrahmanyan Chandrasekhar** showed that if the **mass** of a star were greater than a critical value, then that star could not evolve into a white dwarf. It would instead collapse into a **neutron** star or a black hole. The critical value of mass, about 1.4 times the mass of the **Sun**, is called the Chandrasekhar limit.

Once a main sequence star, like our Sun, expends the amount of fuel available for **nuclear fusion** in its core, it begins to collapse. The star is supported against its self-gravity by a quantum mechanical effect called electron-degeneracy **pressure**. This degeneracy pressure is a consequence of Wolfgang Pauli's exclusion principle, which prohibits any pair of electrons from having the same set of **quantum numbers**, and Werner Heisenberg's uncertainty principle, which presents a fundamental uncertainty in the precision to which the electron's position and **momentum** can be simultaneously known.

By extending earlier investigations of Ralph Fowler and Arthur Eddington, Chandrasekhar realized that the **density** at the center of a white dwarf is many times greater than its average density. Assigning different momentum states to each **electron**, one eventually reaches a point where the momentum becomes comparable to the electron's rest **energy**. At that point, the relativistic mass of the electron needs to be taken into account.

Non-relativistic considerations alone would suggest that the radius of a white dwarf scales as $M^{-1/3}$, where M is the mass of the star. Given two white dwarf **stars** of different radii, the more massive star is the smaller one. The radius of a white dwarf reaches zero in the limit of infinite mass. Because a relativistic electron gas provides less pressure support at a given density than a non-relativistic electron gas, introducing the relativistic corrections to the analysis means that the radius of the white dwarf hits zero at a finite value of M. This critical value, which can be expressed in terms of various fundamental constants, is the Chandrasekhar limit. Stars that are more massive than the critical value cannot be supported by the degeneracy pressure of electrons. Rather, they evolve into something else, **neutron stars** or **black holes**.