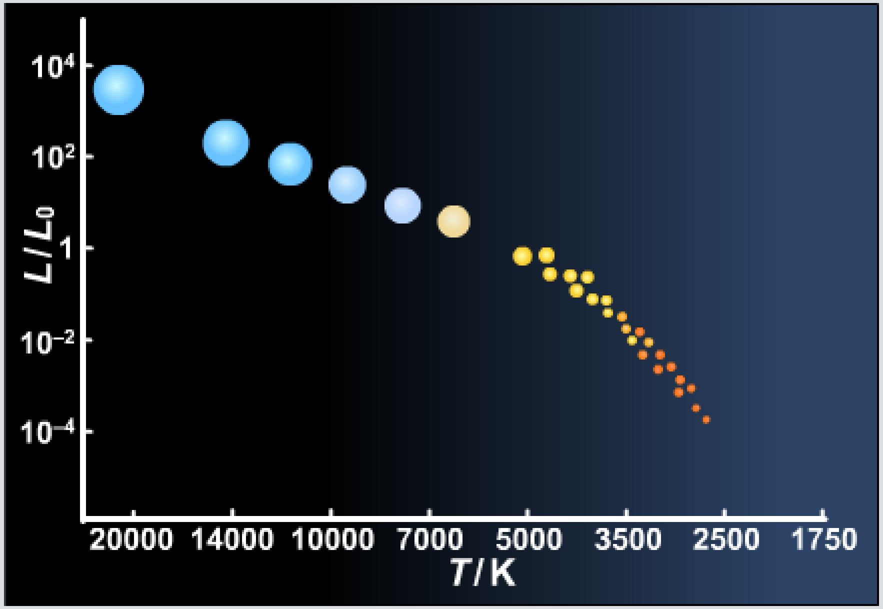
Properties of Stars



Power output of a star

The amount of energy a star radiates per second, in all directions, is its **luminosity**. This is its **power output**.

Stefan's law states that the luminosity of a star is directly proportional to its surface area, and to the fourth power of its temperature:

$$P = \sigma A T^4$$

$(\sigma = 5.7 \times 10^{-8}\,\mathrm{J\,K^{-4}\,m^{-2}\,s^{-1}})$

Where σ is known as the Stefan-Boltzmann constant.
So a cool red giant can have the same power output as a smaller but hotter star.

$A_1 = 6 \times 10^{18}\,\mathrm{m}^2$

$T_1 = 6000\,\mathrm{K}$

Sun

$A_2 = 3 \times 10^{19}\,\mathrm{m}^2$

$T_2 = 4000\,\mathrm{K}$

red giant

$P_1 = 4 \times 10^{26}\,\mathrm{W}$

$P_2 = 4 \times 10^{26}\,\mathrm{W}$

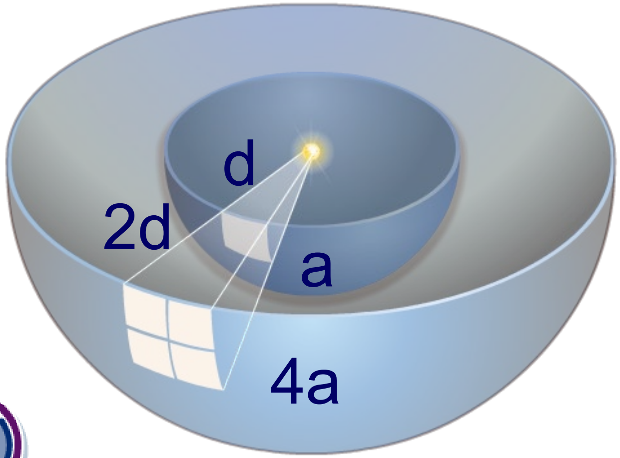
Flux and the inverse square law

The more distant a star, the dimmer it appears. Why is this?

The vacuum of space **does not absorb light**, so the total amount of light is not reduced as you get further away from the star. But the further away you are, the larger the sphere the light is spread over, so the lower the **intensity** of the light.

This intensity is called **flux**. It measures the power per square meter by dividing the total power (luminosity) by the area of the sphere at that distance:

$$F = \frac{P}{4\pi d^2}$$



Flux is inversely proportional to the square of the distance from a source.

This is an **inverse square law**.

Apparent magnitude

The apparent brightness of a star when viewed from Earth depends on the luminosity of the star, and how far away it is. Flux depends on both of these, but varies over a huge scale.

Apparent magnitude (***m***) uses a logarithmic scale to give an idea of the **order of magnitude** of the star's brightness:

$$m = -2.5 \log F + \text{constant}$$

The constant is based on the brightness of a comparison star, usually Vega, one of the brightest stars in the night sky.

Apparent magnitude makes it possible to put all celestial objects on a scale from roughly –30 (the Sun) to +30 (the faintest objects visible in the Hubble Space Telescope).

Absolute magnitude

Related to apparent magnitude is **absolute magnitude** (*M*). This removes the effect of distance by giving the apparent magnitude of a star if it were at a standard distance of 10 pc.

If *d* is the distance to the star, then *M* is given by:

$$m - M = 5\log(d/10)$$

Q. If apparent magnitude is a logarithmic scale describing flux, then absolute magnitude is a logarithmic scale describing what other variable? **Luminosity.**

Q. Some objects, such as certain types of supernova, always have the same absolute magnitude. If *m* and *M* are known for a particular supernova, what can you calculate using the formula above? **How far away it is.**

Brightness – questions

Life cycle of a small star

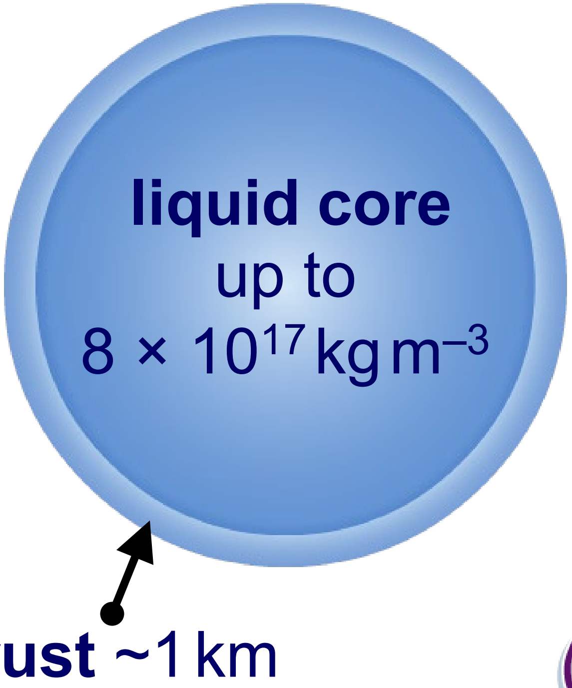
Life cycle of a large star

Neutron stars

After a 1.4–2 solar mass star has exploded in a supernova, only the inner core of the star remains.

This core will have a radius of only 10 km, and a density more than **14 orders of magnitude** higher than that of the Sun, and close to the density of an atomic nucleus. This is a **neutron star**.

The outer shell is thought to be composed of a solid crust of atomic nuclei. Inside this crust is a liquid interior composed almost entirely of neutrons, increasing in density towards the center to reach nearly 10^{18} kg m^{-3}.



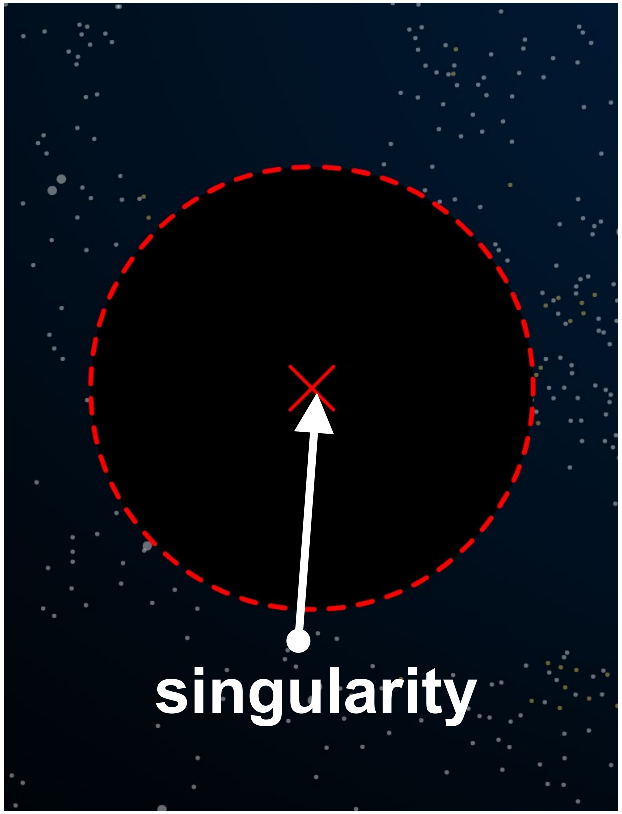
The Hertzsprung-Russell diagram

Black holes

When a large star ends its life in a supernova, the central core that is left behind is so massive that the neutrons inside it are destroyed by gravitational forces.

It becomes smaller and more dense than a neutron star, and eventually its center collapses into a point of infinite density called a **singularity**.

Its gravitational field is now so strong that nothing can escape it, including light, so it appears black. This is a **black hole**.

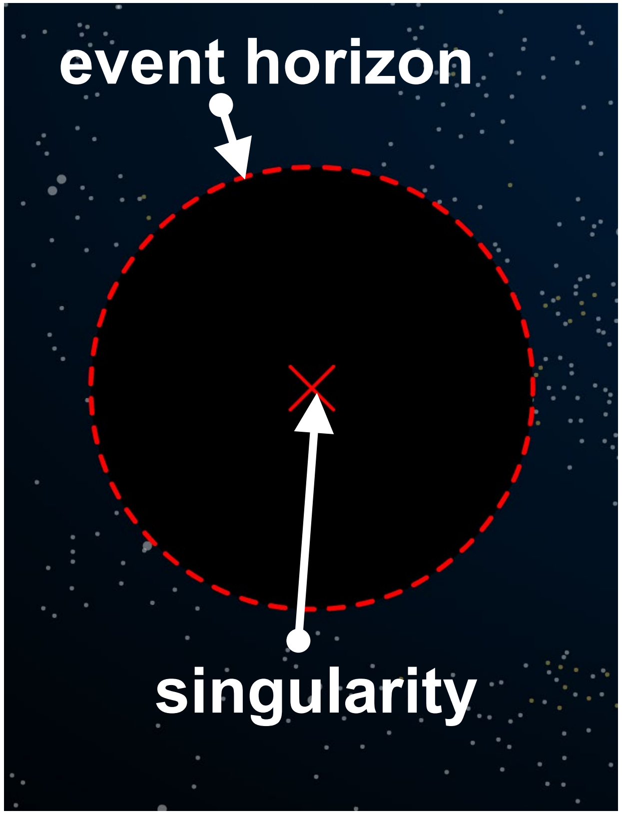


Event horizons

Every black hole is surrounded by an **event horizon**. Nothing that occurs within this boundary can ever affect the Universe outside it, and anything that crosses this horizon will fall into the black hole.

To an outside observer, an object falling into the black hole slows down as it approaches the event horizon, never quite crossing it.

From the object's point of view, it crosses the event horizon and falls towards the singularity.



Understanding stars