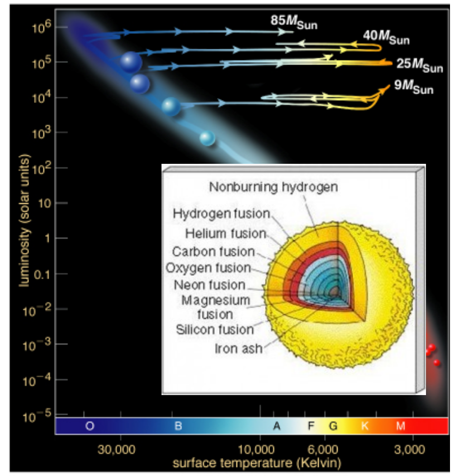
Quiz 7 Feedback

1. Structure of a high-mass star before core collapse; why the core collapses and what it becomes.

Just before the core collapses, the evolved high-mass star is a kind of "onion" with layers of different elements made by nuclear fusion. The lighter elements are in the outer layers, with (mostly) H at the surface, He layers next, then C, O, Ne, etc., as you go deeper, until you reach the core, which is made of Fe. The star is now in a "fix" because Fe (iron) cannot be used as an energy-producing fuel like the lighter elements can.

Without fusion, the core cools off, but this lowers the pressure, so that gravity "wins" again. The core contracts, paradoxically getting hotter because gravitational energy is being released.

Later Life Stages of High-Mass Stars



- As the shells of fusion around the core increase in number, the star swings "back and forth" between the red and blue sides of the HR diagram.
- Once the core has turned to Fe "ash," it can no longer produce thermal energy, so it collapses, producing ….
- a neutron star at the center, and an expanding cloud of gas: a "supernova remnant."

The "Iron Catastrophe"

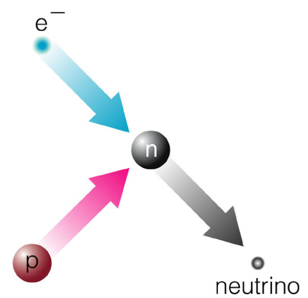
- The non-degenerate iron core contracts & heats;
- No new energy-producing fusion reactions possible
- Instead, the nuclei *disintegrate*: Fe ⇒ He, p+, e^-, n's
- But this *uses up* energy, so the thermal pressure falls.
- When you take away the pressure support, gravity "wins" the eternal battle of the forces, and
- an even faster collapse takes place (0.25 sec)

Quiz 7 Feedback

1. continued. … (see slides from 10/25 and 10/30)

The core is now so hot (billions of °K) that the emitted photons, which are gamma rays (highest energies of any photons), have enough energy to tear the Fe nuclei apart. When the nuclei absorb the photons, they are broken up into smaller building blocks: protons, electrons, neutrons, alpha particles (= He nuclei). This process is called *photodisintegration* because photons cause the Fe nuclei to disintegrate. Once the photons are gone, using up huge amounts of energy, the pressure plummets and the core collapses catastrophically (in less than a second). The core is crushed to nuclear densities, and the free protons and electrons are squeezed together, becoming neutrons, hence the term *neutronization*. This reaction also produces a neutrino. The core becomes a *neutron star*, accompanied by a neutrino "burst."

Birth of a Neutron Star



A neutron star is the ball of neutrons left behind when the core of a massive star collapses, leading to a supernova explosion.

Deep in its collapsing core, the electrons and protons combine, making neutrons *and neutrinos*.

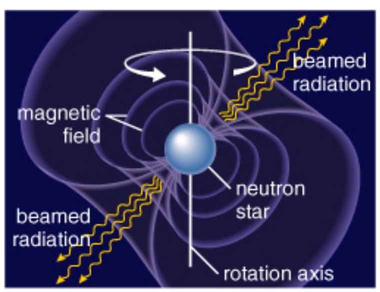
The neutrons collapse until the core is so dense that neutron degeneracy pressure stops the collapse; the core is then a ***neutron star.***

Quiz 7 Feedback

2. What is a pulsar, and why does it "blink"?

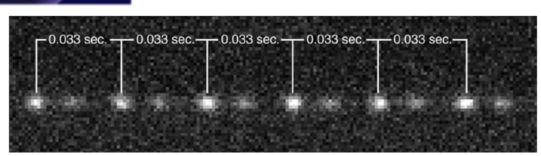
A pulsar is a rapidly spinning neutron star, with a strong magnetic field, that appears to emit short bursts or blips of radio emission. (Finding pulsars inside supernova remnants such as the Crab Nebula basically nailed this identification.)
Pulsars emit their radio waves in narrow beams emerging from its magnetic poles. If these poles are not aligned with the poles of rotation, we see the radio waves briefly as the beam "sweeps past" us, then see nothing while it is sweeping around in another part of the sky.

The Lighthouse Model for Pulsars



When the beam is briefly pointed at us, the observers, we see a brighter star image than when it has swept past and points in a different direction. A time sequence of pictures looks like this:

For an animation, see the link below.



http://relativity.livingreviews.org/open?pubNo=lrr-1998-10&page=node3.html