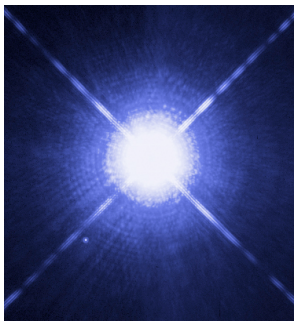
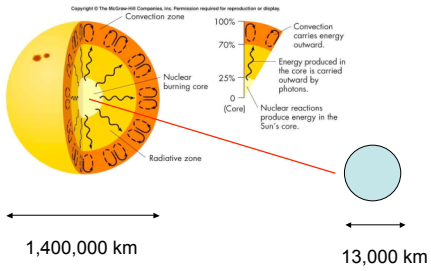
Dead Stars



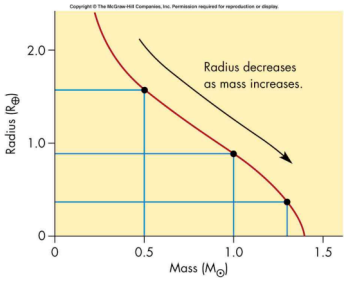
Last time: theoretical physics says that the present-day core of the Sun will eventually become an incredibly compact, incredibly dense **white dwarf**



1,400,000 km

13,000 km

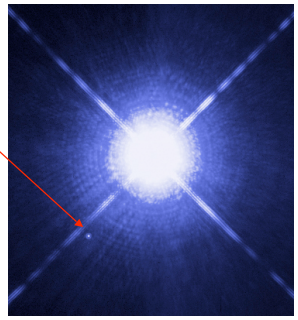
White dwarfs have weird properties…the mass-radius relationship



Note the scales: solar masses but **Earth** radii!

They do exist! The white dwarf stars

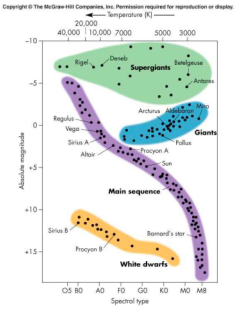
- Sirius is a binary star. Its companion is a white dwarf
- Appendix 12 (nearest stars) lists 2 of them, so they must be very common



View from a spaceship in the Sirius system

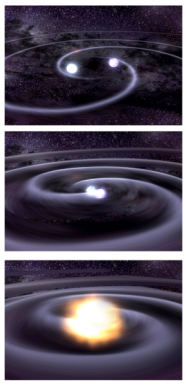
We know the white dwarfs must have the properties as described (we're not making this up)

- We know the mass of Sirius B (1.02 versus 2.40 solar masses for Sirius A)
- Even though it is hotter than Sirius A, it is much fainter (look at difference in absolute magnitudes
- The only way to do this is with small WD radius

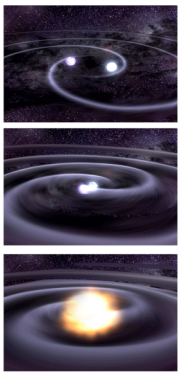


There are many known examples of white dwarfs; they are a common phenomenon in the galaxy

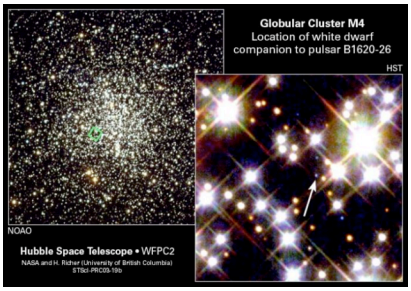
http://www.astronomy.villanova.edu/WDCatalog/index.html



White dwarfs are the first class of **stellar remnants**, the end products of stellar evolution



We also see evidence that they are the end products of stellar evolution, *dead stars*

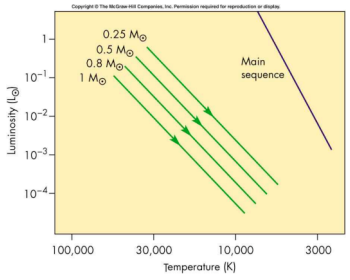


The Hubble Space Telescope showed that the globular star cluster M4 is full of them

An indication of how extreme white dwarfs are

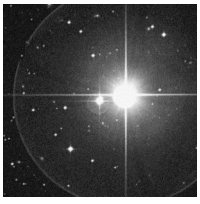
- The mean density of the Sun, d=M/V=1.4 g/cc
- Density of Sun at core: 160 g/cc
- Mean density of a white dwarf=M/V=1.8 E+06 g/cc =1.8 metric tons/cc

What is the life cycle of a white dwarf?



They sit stably and cool off over periods of hundreds of millions of years

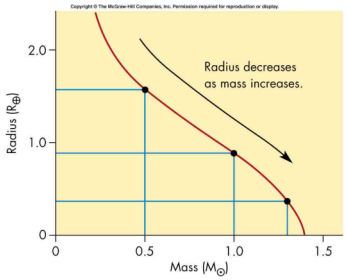
Last word on white dwarfs



The naked-eye star 40 Eridani, a binary. 40 Eri B is a white dwarf

"Most stars end their lives as white dwarfs. These glowing embers scattered throughout space are a galaxy's memory of its past glory. Because no fusion occurs in their interiors, white dwarfs simply cool off at an essentially constant radius as they slowly deplete their supply of thermal energy"…Carroll and Ostlie, "Modern Astrophysics"

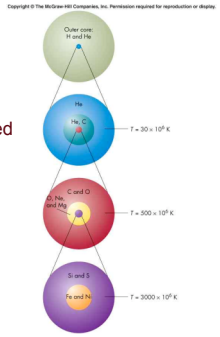
What's next?



Does anyone notice something odd about this diagram?

What happens to massive stars?

Cores are chemically differentiated
And too massive to be held up
By electron degeneracy force…
The cores collapse



Core collapse of a massive star has two consequences

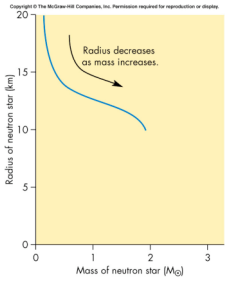
- Massive explosion (10^{44} Joules)
- Production of a neutron star

Formation of a neutron star from stellar core

- As core collapses, matter becomes compressed
- Electrons and protons forced together e+p > n + nu (neutronization)
- Core of the collapsing star becomes a neutron fluid
- Neutronization produces a burst of neutrinos
- Neutron fluid in core becomes degenerate and rigid

The physics of a self-gravitating neutron blob (neutron star)

- Radius versus mass relation for neutron star
- Notice size of neutron star
- Masses extend above Chandrasekhar limit



Theoretical prediction of the existence of a neutron star

- The remnant after the explosion of a massive star
- An object having the mass of the Sun (or more) but in an object with the diameter of Iowa City!
- An equivalent to the Chandrasekhar mass (largest possible mass of a neutron star)
- Do they exist?