# Review for Test #3 Nov 8

Topics:

- Stars (including our Sun)
- The Interstellar medium
- Stellar Evolution and Stellar Death
- Neutron stars, pulsars and magnetars
- Black Holes and General Relativity

Methods

- Conceptual Review and Practice Problems Chapters 11, 12, 13, 14
- Review lectures (on-line) and know answers to clicker questions
- Try practice quizzes on-line
- Bring:
- Two Number 2 pencils and your UNM ID
- Simple calculator (no electronic notes)

Reminder: There are NO make-up tests for this class

# Test #3 Review

How to take a multiple choice test

1) Before the Test:
- Study hard (~2 hours/day Friday through Monday)
- Get plenty of rest the night before

2) During the Test:
- Draw simple sketches to help visualize problems
- Solve numerical problems in the margin
- Come up with your answer first, then look for it in the choices
- If you can’t find the answer, try process of elimination
- If you don’t know the answer, Go on to the next problem and come back to this one later
- TAKE YOUR TIME, don’t hurry
- If you don’t understand something, ask me.

# Test #3 Useful Equations

parallactic distance $d = 1/p$ where p is parallax in arcsec and d is in parsecs

Schwarschild Radius:

$$R = \frac{2\,GM}{c^2}$$

Lifetimes of stars (on the main sequence):

$L = 10^{10}/M^2$ years where M is the Mass in solar masses and L is the Lifetime

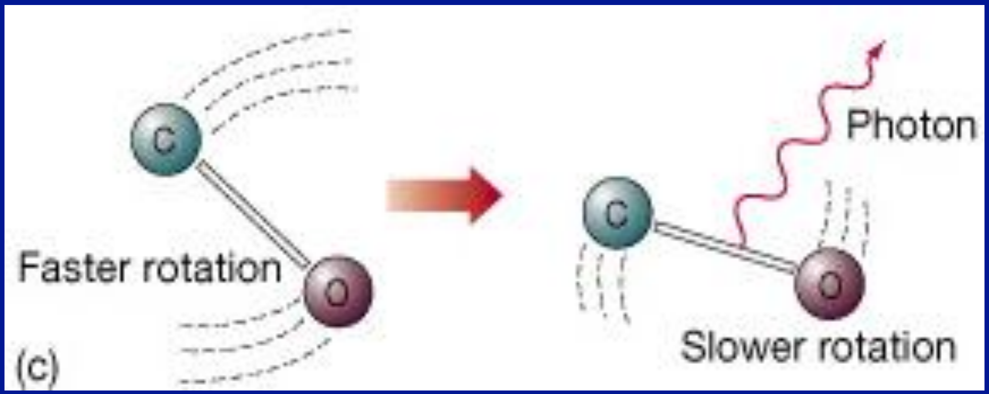
Equivalence of Matter and Energy:

$$E = mc^2$$

We can observe emission from molecules. Most abundant is $H_2$ (don't confuse with H II), but its emission is extremely weak, so other "trace" molecules observed:

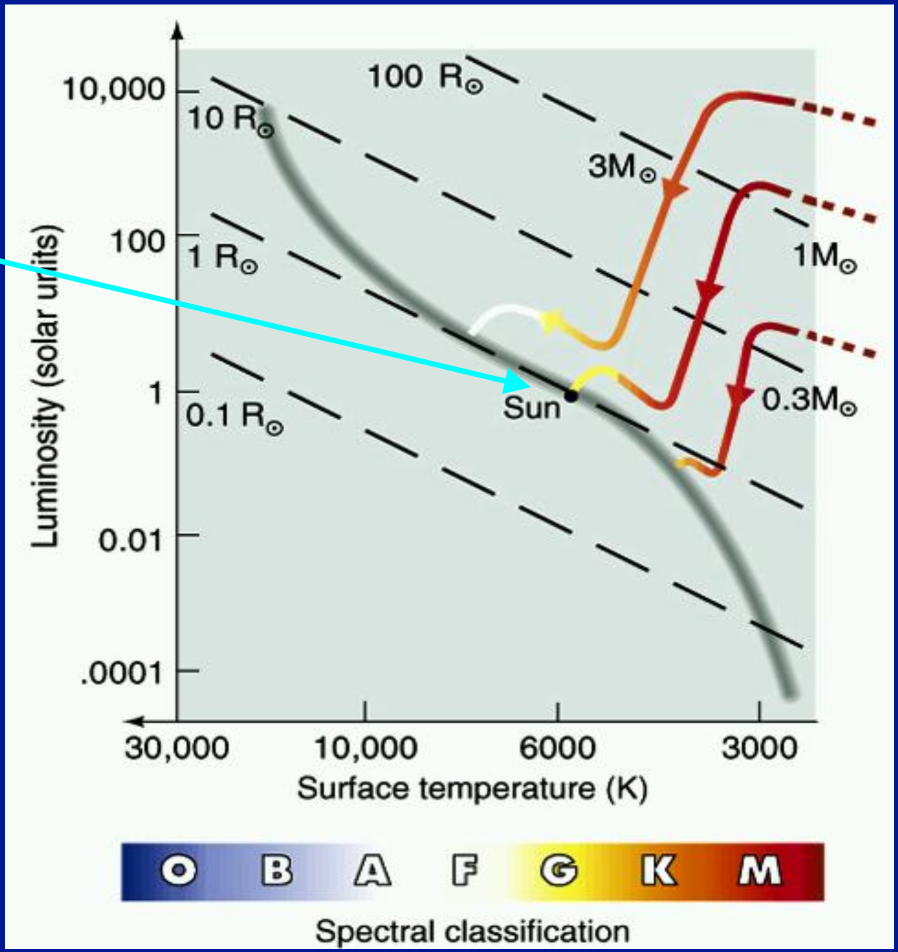
- $CO$ (carbon monoxide)
- $H_2O$ (water vapor)
- $HCN$ (hydrogen cyanide)
- $NH_3$ (ammonia)
- etc. . .

These emit photons with wavelengths near 1 mm when they make a rotational energy level transition. Observed with radio telescopes.



Finally, fusion starts, stopping collapse: a star!

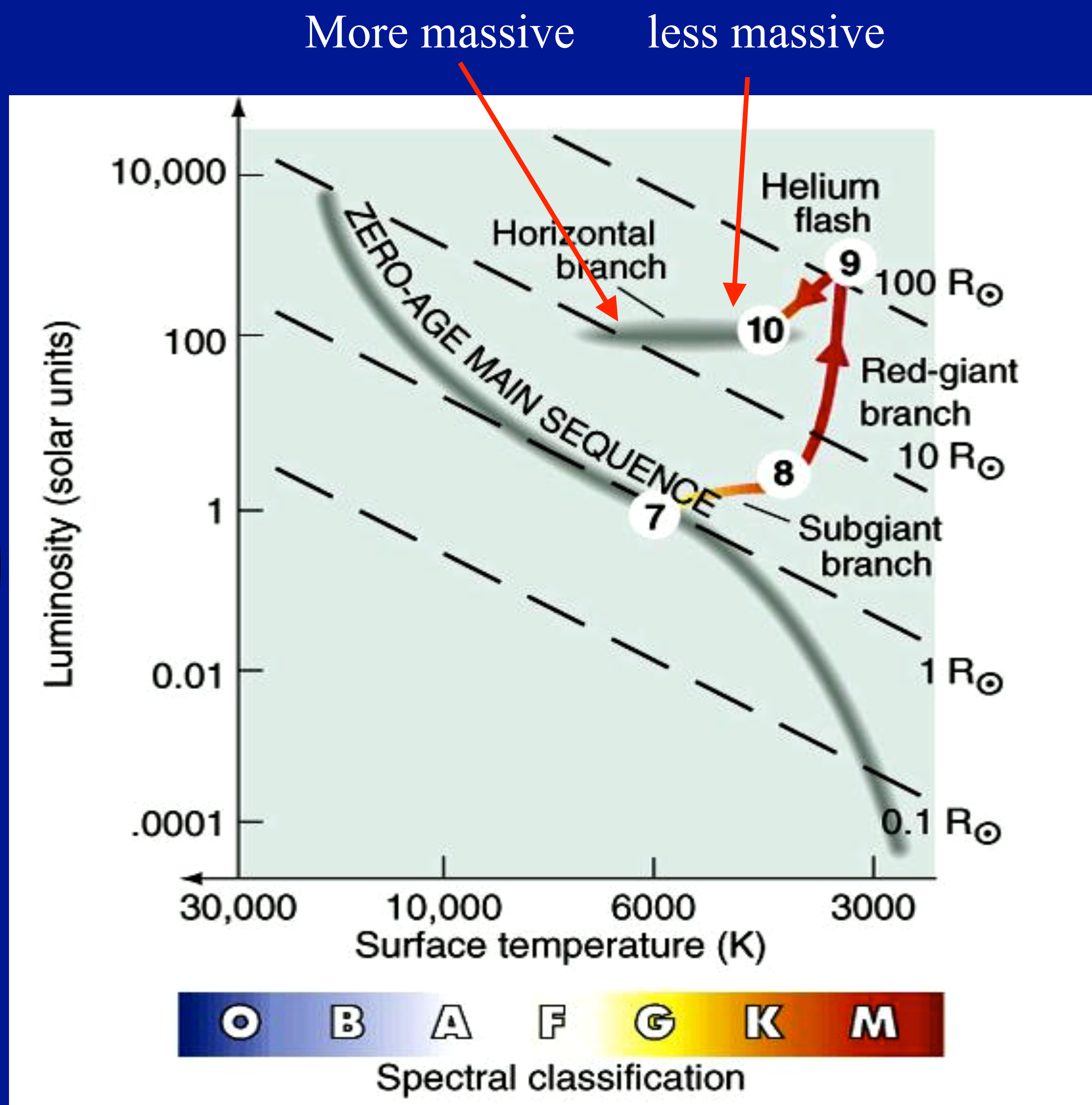
Star reaches Main Sequence at end of Hayashi Track




One cloud ($10^3$ - $10^6$ $M_{Sun}$) forms many stars, mainly in clusters, in different parts at different times.

Massive stars (50-100 $M_{Sun}$) take about $10^6$ years to form, least massive (0.1 $M_{Sun}$) about $10^9$ years. Lower mass stars more likely to form.
In Milky Way, a few stars form every year.

Horizontal branch star structure

# Helium Runs out in Core

- All He -> C. Not hot enough
- for C fusion.

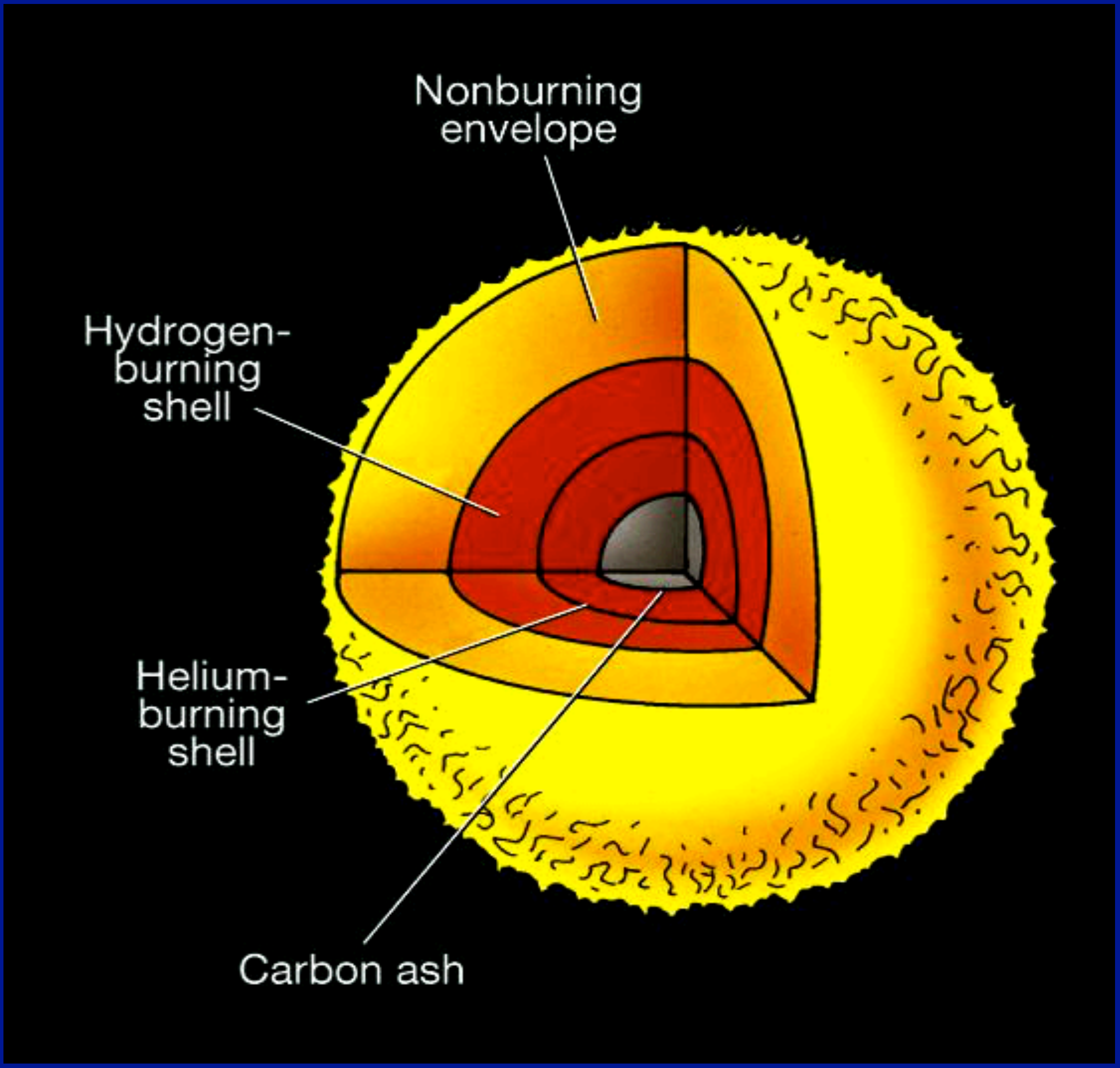
- Core shrinks and heats up.

- Get new helium burning shell (inside H burning shell).

- High rate of burning, star expands, luminosity way up.

- Called "Red Supergiant" (or Asymptotic Giant Branch) phase.

- Only ~$10^6$ years for 1 $M_{Sun}$ star.




Red Supergiant

# White Dwarfs

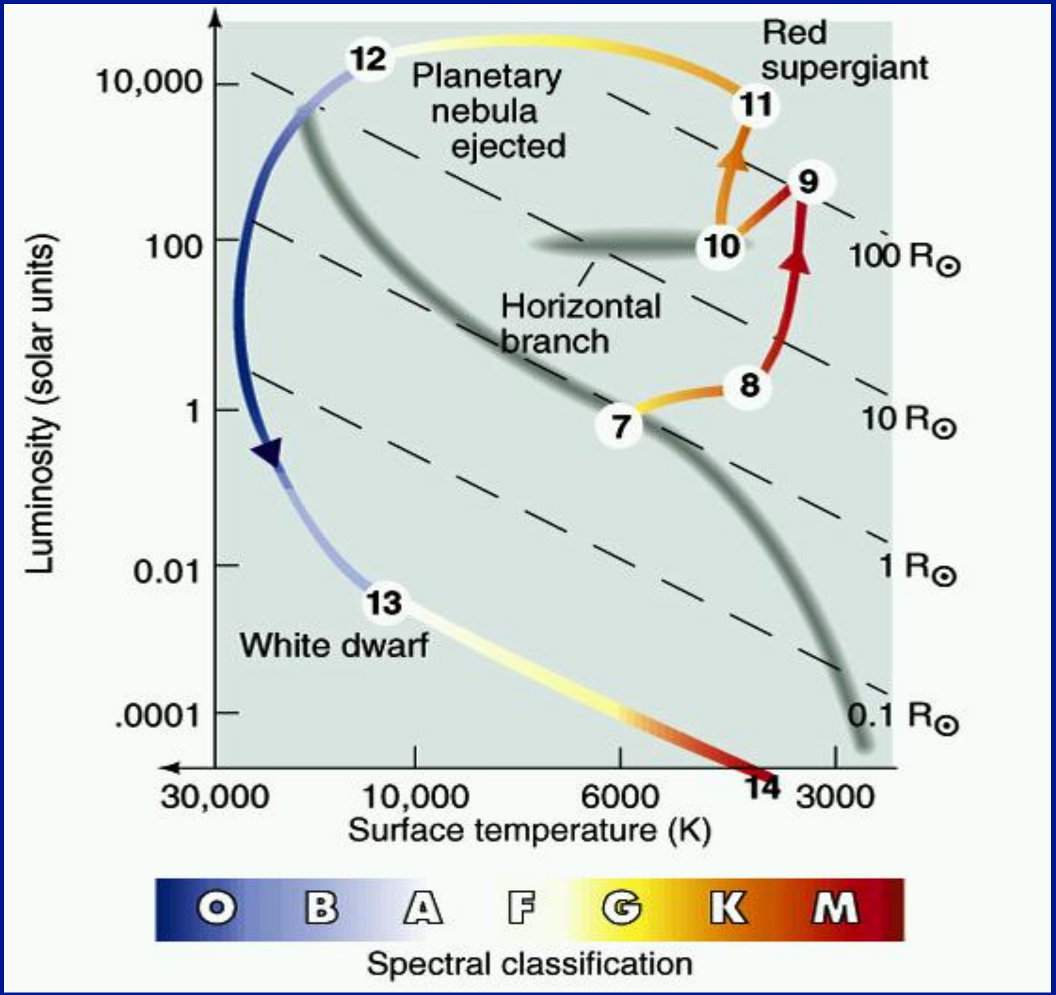
- Dead core of low-mass star after Planetary Nebula thrown off.

- Mass: few tenths of a $M_{Sun}$ .

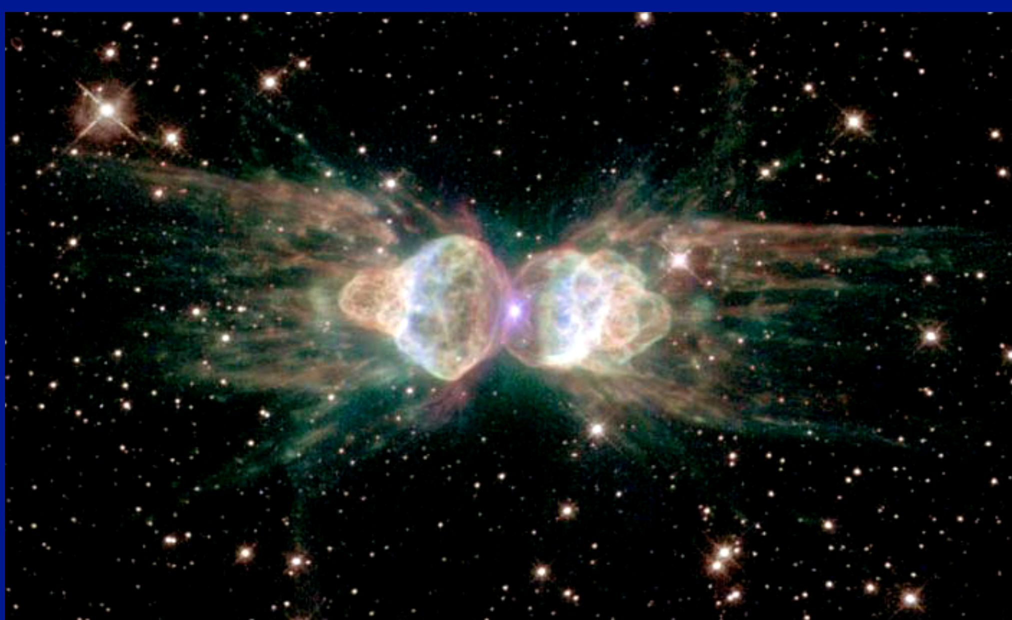
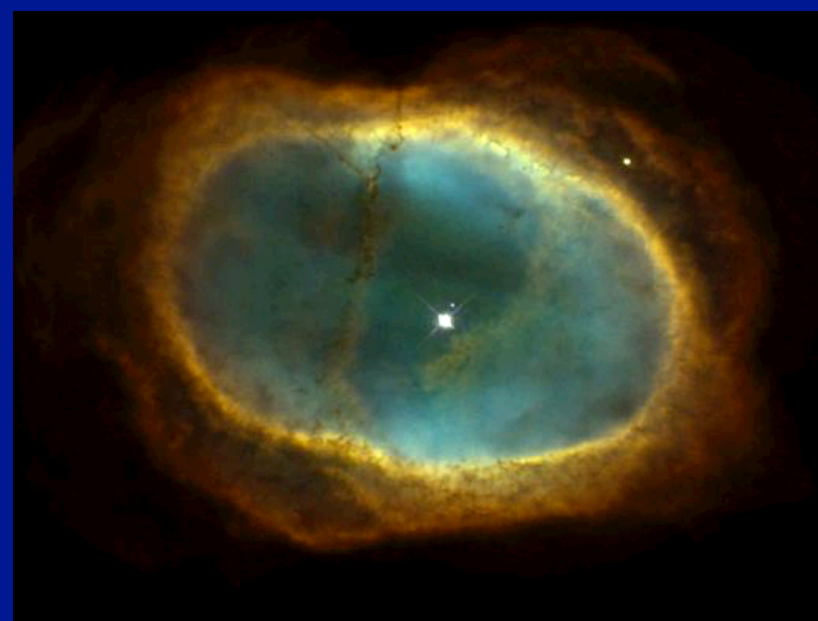
-Radius: about $R_{Earth}$ .

- Density: $10^6$ g/cm$^3$! (a cubic cm of it would weigh a ton on Earth).

- White dwarfs slowly cool to oblivion. No fusion.





# Final States of a Star

1. White Dwarf
   If initial star mass $< 8\ M_{Sun}$ or so

   No Event + PN

2. Neutron Star
   If initial mass $> 8\ M_{Sun}$ and $< 25\ M_{Sun}$

   Supernova + ejecta

3. Black Hole
   If initial mass $> 25\ M_{Sun}$

   GRB + Hypernova + ejecta

# Death of a High-Mass Star

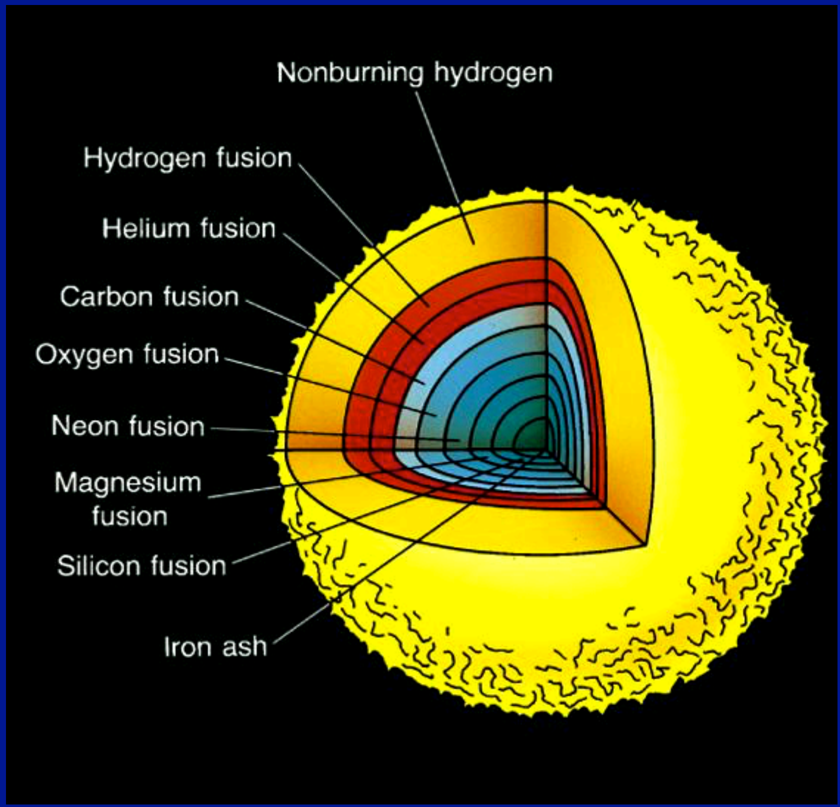
$M > 8\ M_{Sun}$

Iron core

Iron fusion doesn't produce energy (actually requires energy) => core collapses in < 1 sec.

$T \sim 10^{10}$ K, radiation disrupts nuclei,

p + e => n + neutrino




Collapses until neutrons come into contact. Rebounds outward, violent shock ejects rest of star => A Core-collapse or Type II Supernova

Ejection speeds 1000's to 10,000's of km/sec! (see DEMO)

Remnant is a "neutron star" or "black hole".

Such supernovae occur roughly every 50 years in Milky Way.

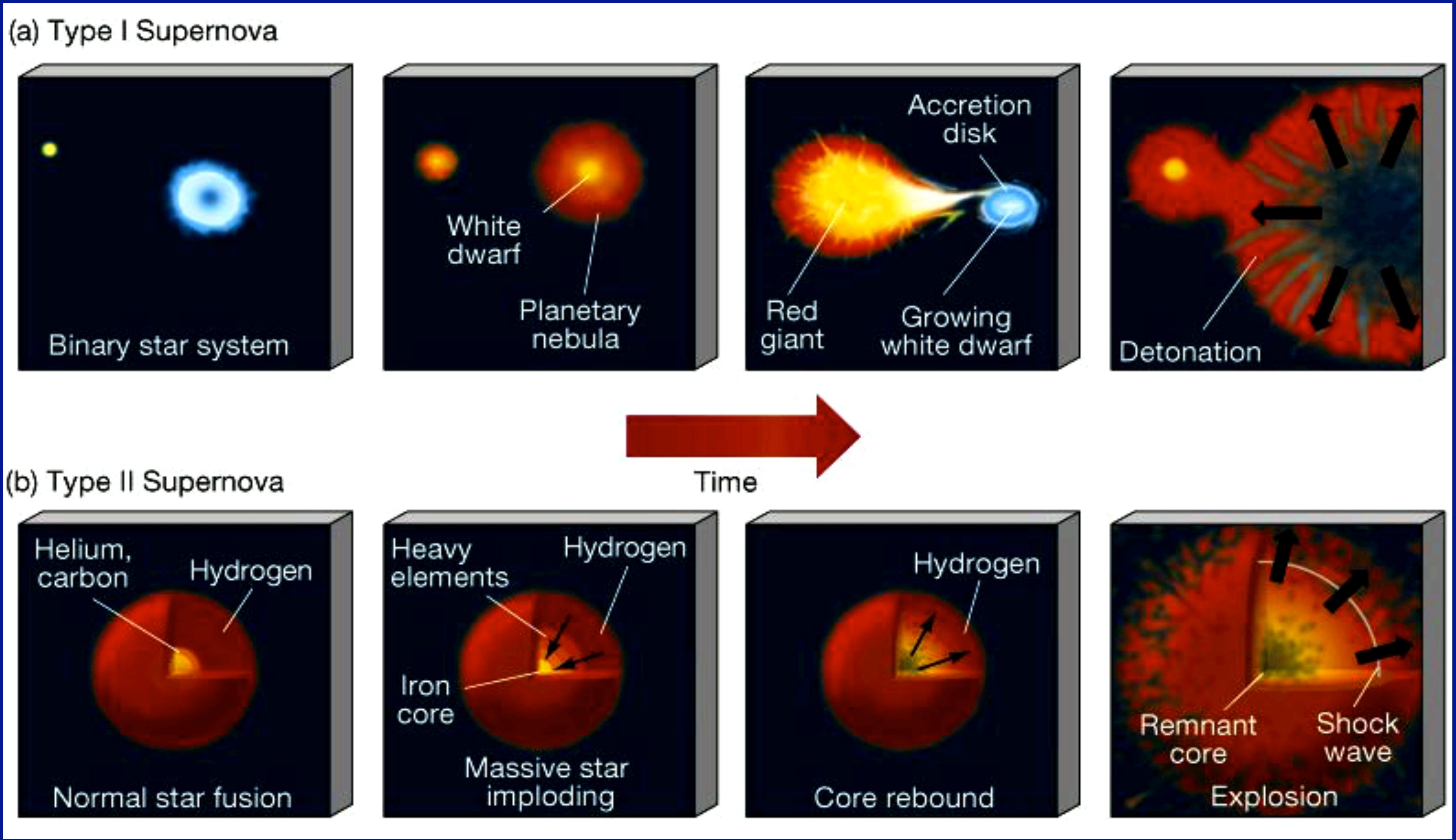
# Example Supernova: 1998bw

SN 1998bw in Spiral Galaxy ESO184-G82

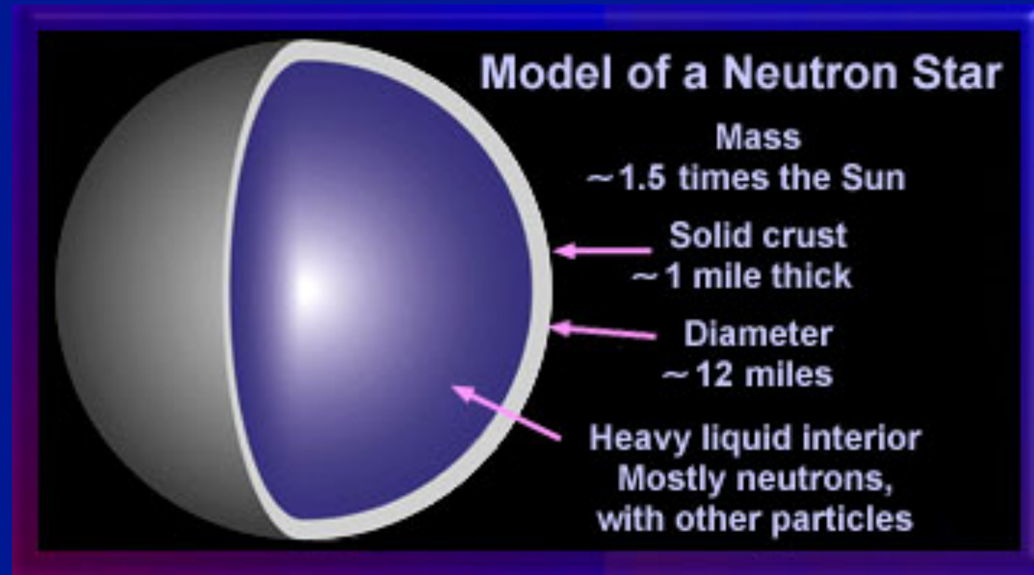
ESO PR Photo 39a/98 ( 15 October 1998 )



# Remember, core collapse (Type II) and carbon-detonation (Type I) supernovae have very different origins



# Neutron Stars




Leftover core from Type II supernova - a tightly packed ball of neutrons.

Diameter: 20 km only!

Mass: 1.4 - 3(?) $M_{Sun}$

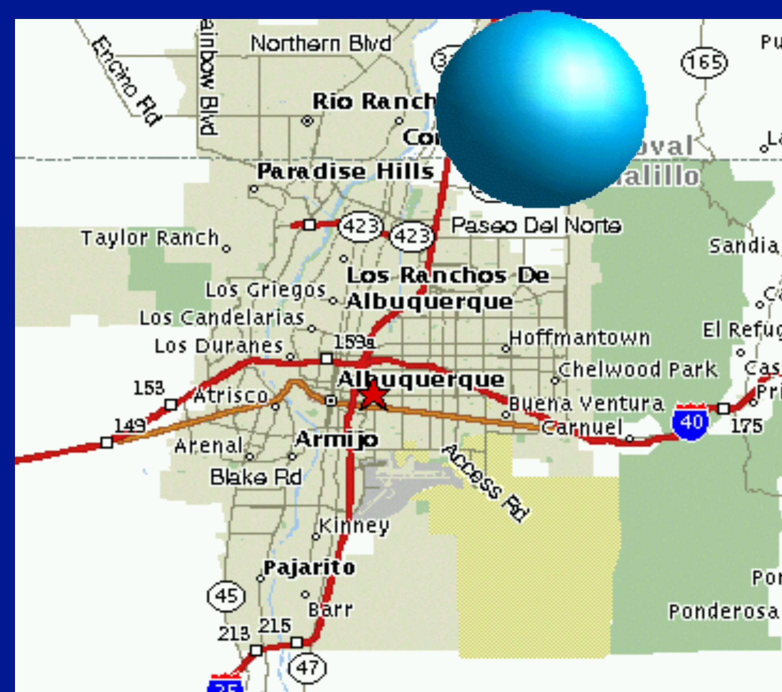
Density: $10^{14}$ g / $cm^3$ !

Surface gravity: $10^{12}$ higher

Escape velocity: 0.6c

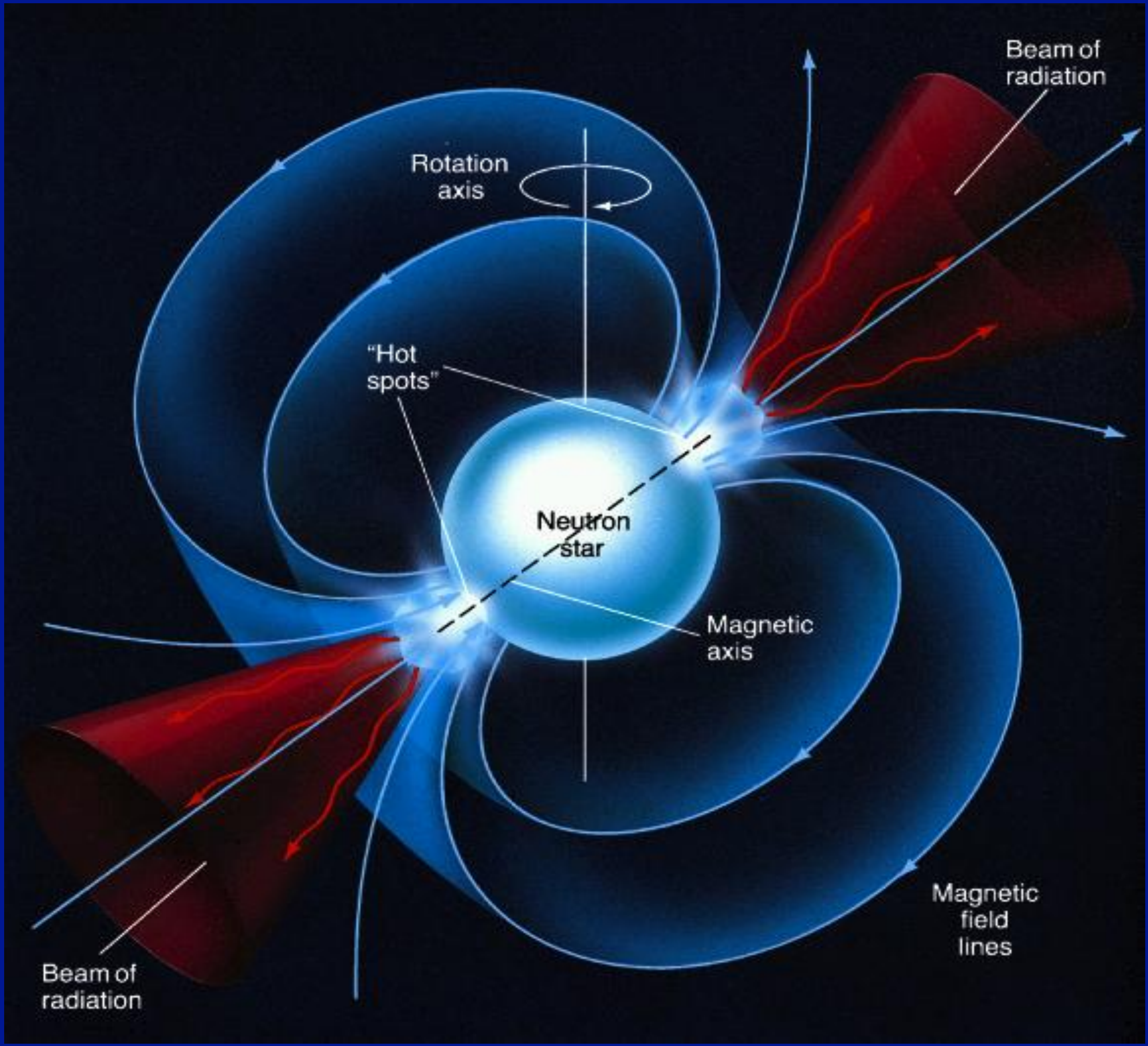
Rotation rate: few to many times per second!!!

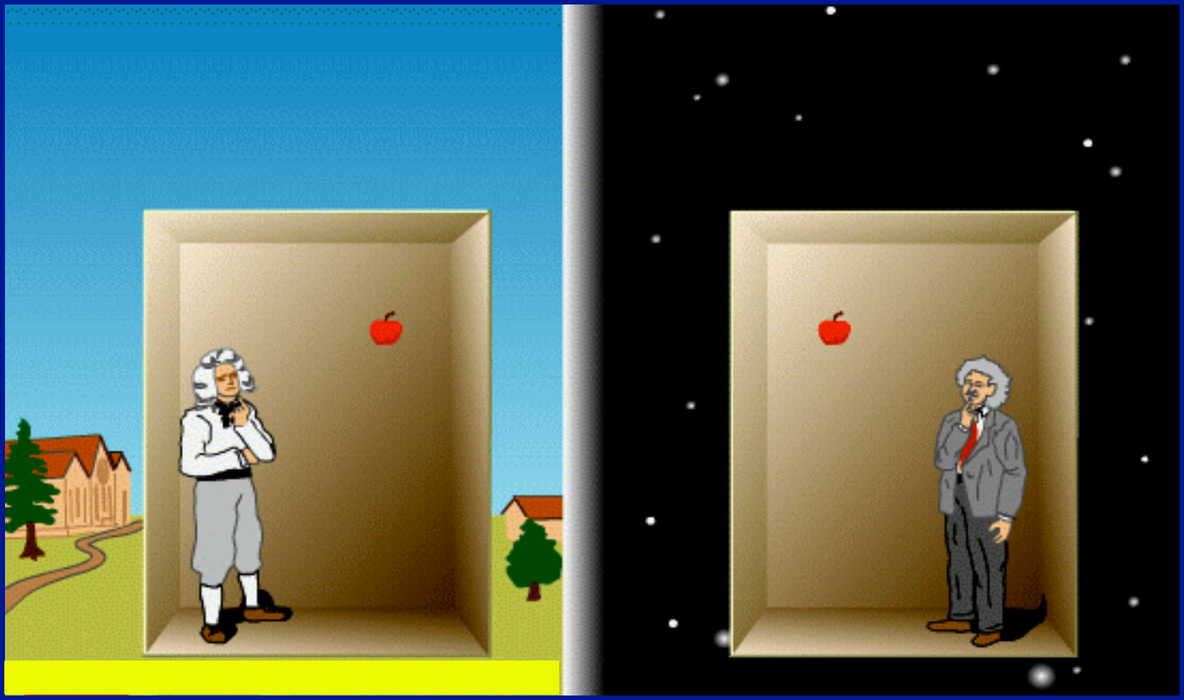
Magnetic field: $10^{12}$ x Earth's!




A neutron star over the Sandias?

# The Lighthouse model of a pulsar





4. Gravity and acceleration are equivalent. An apple falling in Earth's gravity is the same as one falling in an elevator accelerating upwards, in free space.

5. All effects you would observe by being in an accelerated frame of reference you would also observe when under the influence of gravity.

# Black Holes have no Hair

Properties of a black hole:

- Mass
- Spin (angular momentum)
- Charge (tends to be zero)