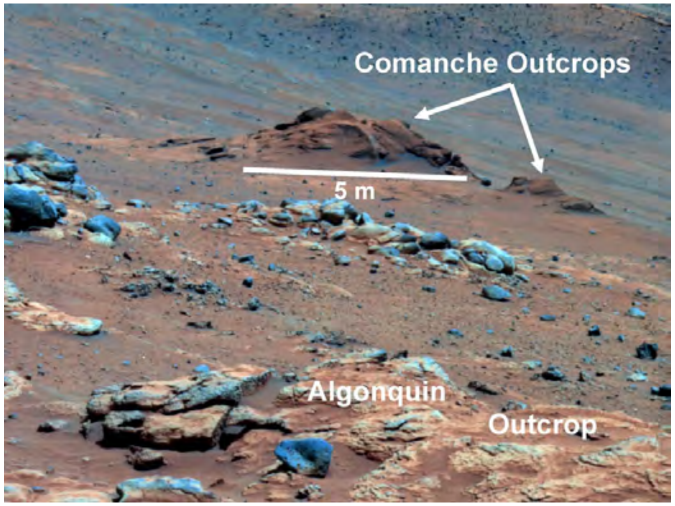
August 30, 2010

Reading assignment, Cosmic Catastrophes, Chapter 6 plus Section 5.1, Section 1.2.4 and Section 2.3 for background

Last lecture posted as pdf on class web site

Astronomy in the News? NASA consulted on the psychology of isolation on behalf of the trapped Chilean miners.

Pic of the Day – some early water on Mars might not have been acidic. Note Mars is "bigger" than the Moon when viewed from close up.



White Dwarfs
(Section 5.1)

White Dwarf – dense core left behind by low mass stars (less than 8 solar masses) after red giant and planetary nebular phase.

Essentially every white dwarf formed since beginning of the Galaxy is still here 10-100 billion of them (~ 100 billion stars total), but a few white dwarfs have blown up.

Most are dim, undiscovered, see only those nearby, none naked eye

Sirius, brightest star in the sky, has a white dwarf companion. Can't see the white dwarf with the naked eye, too small, dim, but Sirius is easy if you look for it at the right time.

Find Sirius for the extra credit sky watch project.

Discussion Point:

White dwarfs have about the same mass as the Sun and about the same radius as the Earth.

How does the gravity of a white dwarf compare to the Sun and the Earth, and why?

What do we know about white dwarfs?

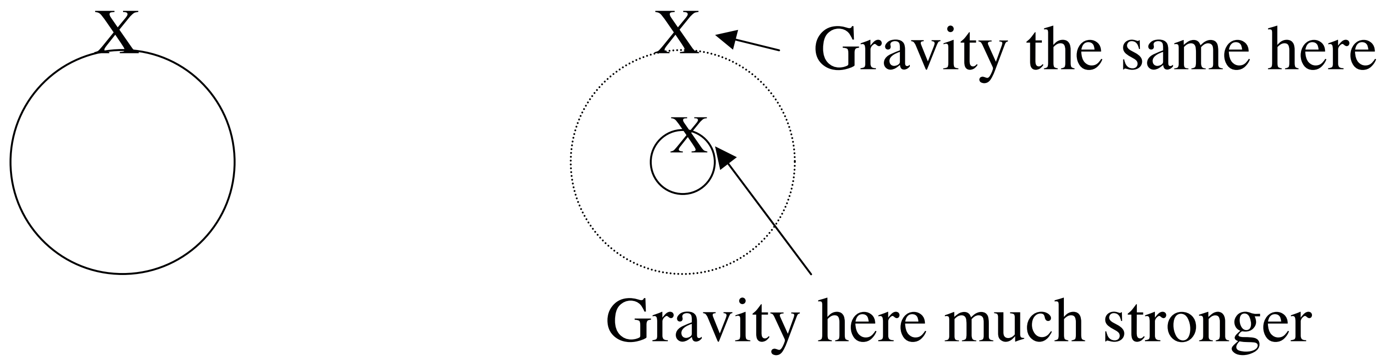
Mass ~ Sun
Most are single, 0.6 $M_\odot$ (solar masses)
Some in binary systems, higher mass

Size ~ Earth ~1% radius of Sun

$$\text{Density} = \frac{\text{mass}}{\text{volume}} \rightarrow \frac{10^6 \text{ grams}}{\text{c. c.}} \sim \frac{\text{tons}}{\text{cubic centimeter}}$$

OR MORE!

HUGE GRAVITY!



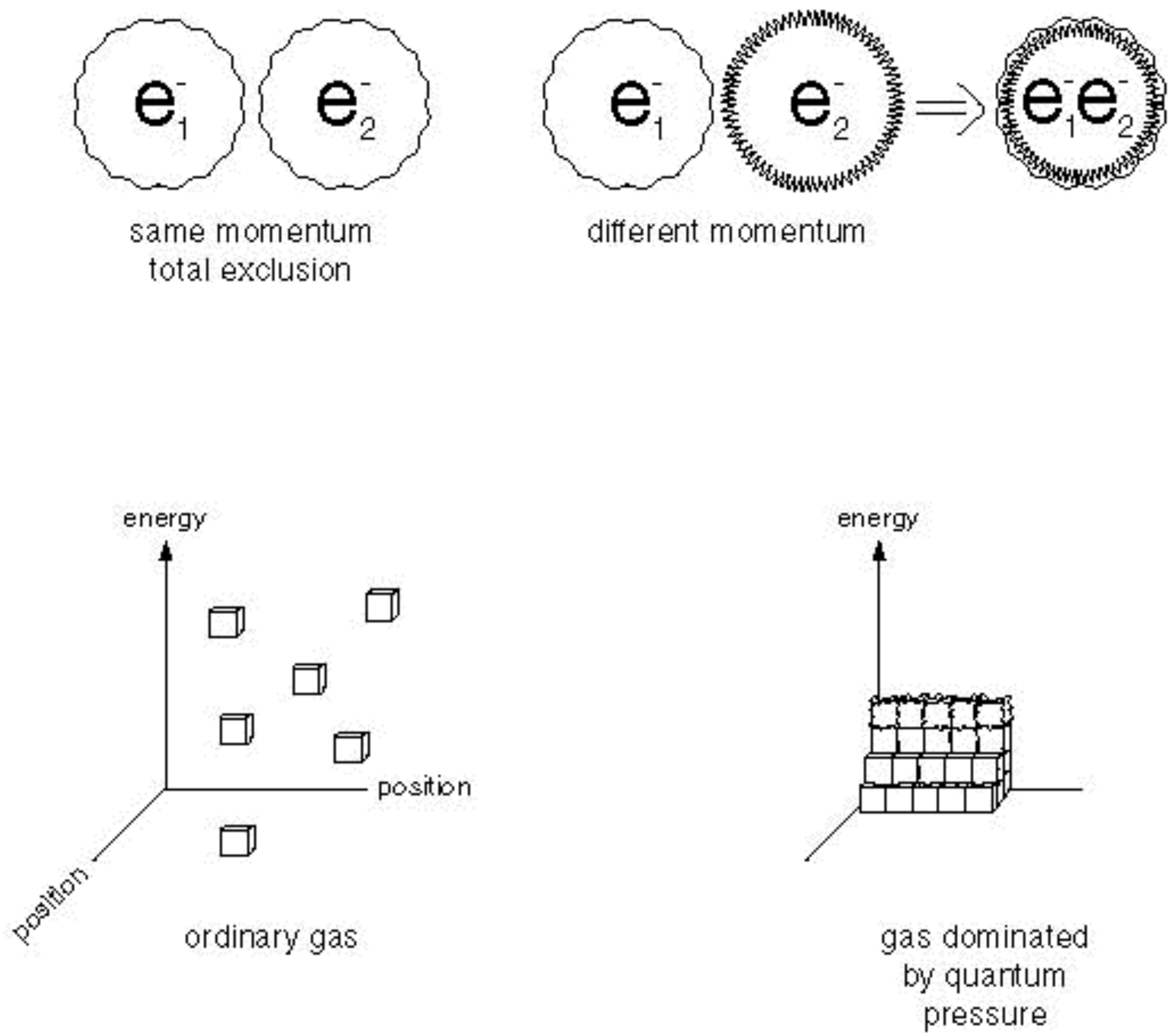
Same mass, smaller size, gravity on *surface* is larger because you are closer to the *center*.

Gravity on surface acts *as if* all mass beneath were concentrated at a point in the center -- Newton/Calculus

Huge gravity compresses a white dwarf --
requires special pressure to support it
(Section 1.2.4, Section 2.3)

- ***Normal pressure*** -- thermal pressure
- Motion of hot particles -- Pressure depends on Temperature
- ***Quantum Pressure*** -- Quantum Theory
- Uncertainty Principle -- Can't specify position of any particle exactly. If you squeeze and "locate" a particle more precisely, its energy gets more uncertain, and larger on average.
- Exclusion Principle -- No two identical particles (electrons, protons, neutrons) can occupy same, place with same energy, but they can if one has more "uncertainty" energy.
- ***Pressure depends only on density, not on temperature***

Figure 1.4



e^-_1
e^-_2
same momentum
total exclusion
e^-_1
e^-_2
$e^-_1 e^-_2$
different momentum
energy
position
position
ordinary gas
energy
gas dominated
by quantum
pressure

Demonstration thermal pressure, quantum pressure - need volunteers.

Discussion point:

How does the different form of the pressure, thermal or quantum, affect the behavior of stars?

What happens if the star puts in excess nuclear energy?

What happens if the star loses excess energy to space?

Same mass in all three cases

One Minute Exam: Where is gravity strongest?

A.

B.

C.

Insufficient information

Quantum Pressure -- just depends on squeezing particles, electrons for white dwarf, to very high density

-- depends on density only

-- *does not* depend on temperature

Important Implication:

Normal

Radiate energy, pressure tries to drop, star contracts and gets **hotter** (and higher pressure)

White Dwarf

Radiate energy, *temperature does not matter*, pressure, size, remain constant, star gets **cooler**

Opposite behavior

Normal Star - *Regulated*

put in energy, star expands, cools

White Dwarf - *Unregulated*

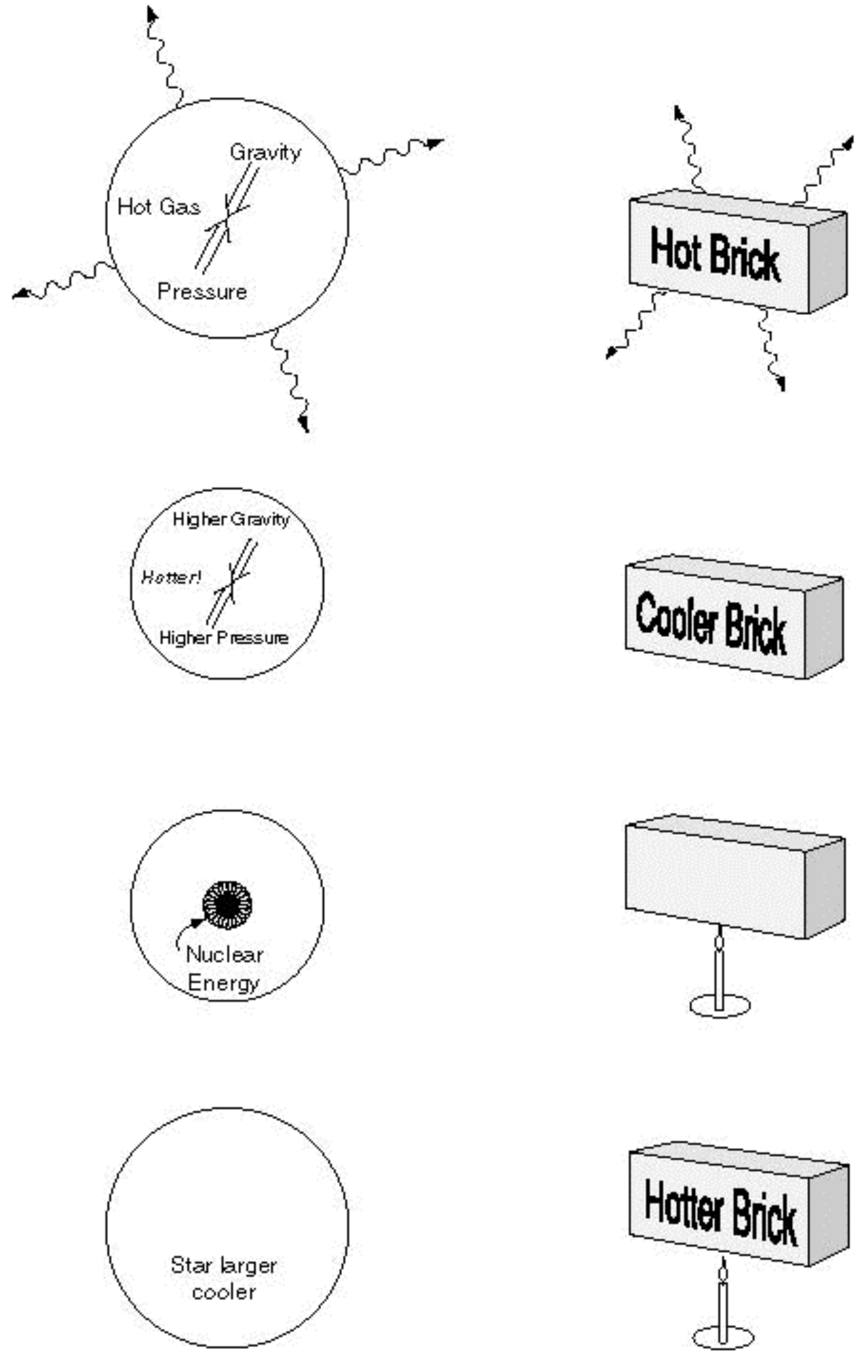
put in energy, hotter, more nuclear burning -- explosion!

Figure 1.3

A normal star can and will radiate away thermal energy and hence structural energy.

A brick cannot radiate its structural energy,

A white dwarf cannot radiate away its quantum energy.



Behavior of white dwarf, Quantum Pressure, worked out by S. Chandrasekhar in the 1930's

Limit to mass the Quantum Pressure of electrons can support

Chandrasekhar limit ~ 1.4 $M_{\odot}$
density ~ billion grams/cc ~ 1000 tons/cubic centimeter

Maximum mass of white dwarf.

If more mass is added, the white dwarf must collapse or explode!

One Minute Exam

If nuclear reactions start burning in an ordinary star like the Sun, what happens to the temperature?

➡ The temperature goes up

⬅ The temperature remains constant

⬆ The temperature goes down

⬇ Insufficient information to answer the question

One Minute Exam

If nuclear reactions start burning in a white dwarf, what happens to the temperature?

→ The temperature goes up

← The temperature remains constant

↑ The temperature goes down

↓ Insufficient information to answer the question

SUPERNOVAE

Catastrophic explosions that end the lives of stars,

Provide the heavy elements on which planets and life as we know it depends,

Energize the interstellar gas to form new stars,

Produce exotic compact objects, neutron stars and black holes,

Provide yardsticks to measure the history and fate of the Universe.

Reading:

Chapter 6 Supernovae

Also § 2.1, 2.2, 2.4 & 2.5 for background

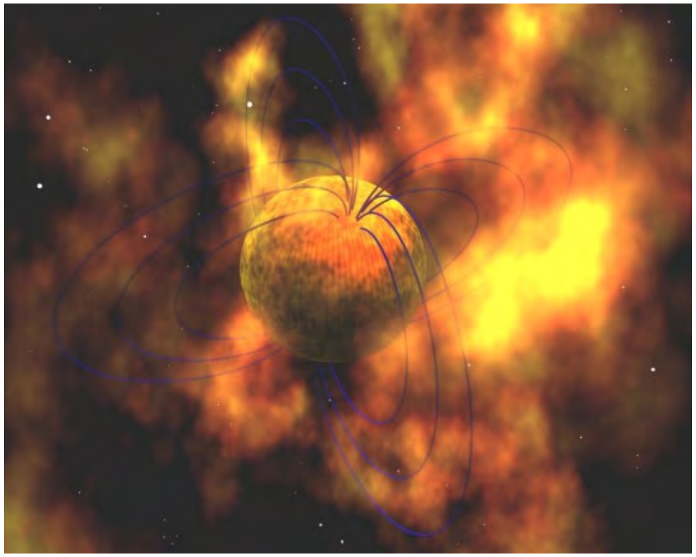
Issues to look for in background:

Why is it necessary for a thermonuclear fuel to get hot to burn - charge repulsion § 2.1 & 2.2

Core Collapse § 2.4 & 2.5

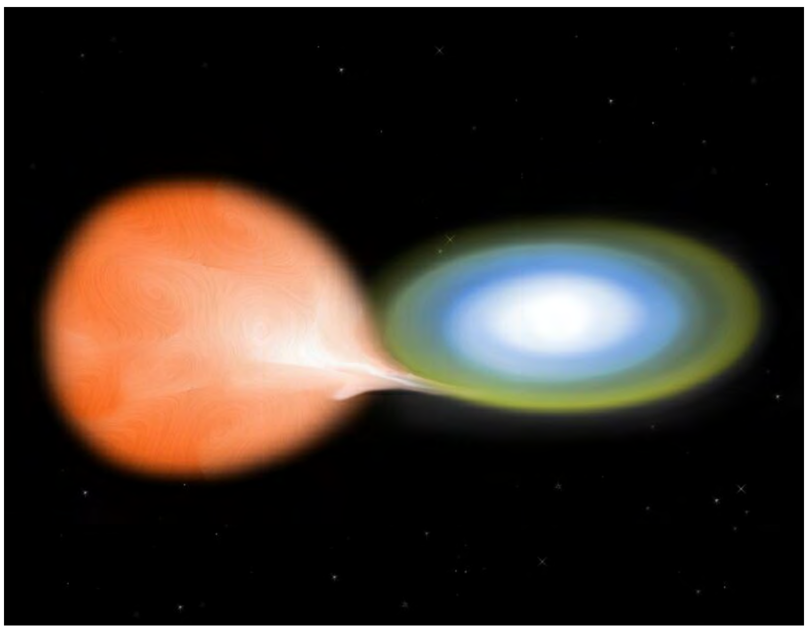
One type of supernova is powered by the ***collapse*** of the core of a massive star to produce

a ***neutron star***, or perhaps a ***black hole***

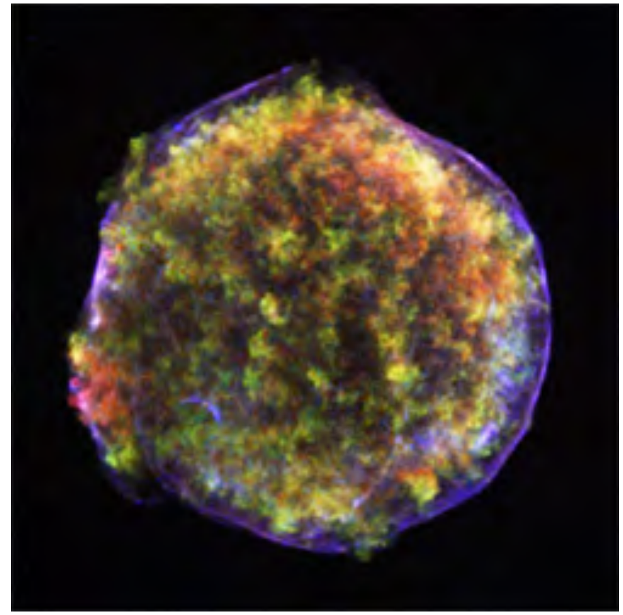


The mechanism of the explosion is still a mystery.

The other type of supernovae (Type Ia) is thought to come from a white dwarf that grows to an explosive condition in a binary system.



Chandra X-ray Observatory image
Of Tycho's supernova of 1572



These explode completely, like a stick of dynamite, and leave no compact object (neutron star or black hole) behind.

Chapter 6 Supernovae

Historical Supernovae - ***in our Milky Way Galaxy*** observed with naked eye over 2000 years especially by Chinese (preserved records), but also Japanese, Koreans, Arabs, Native Americans, finally Europeans.

SN 386	earliest record	NS, jet?
SN 1006	brightest	No NS
SN 1054	Crab Nebula	NS, jets
SN 1181	(Radio Source 3C58)	NS, jets
SN 1572	Tycho	No NS
SN 1604	Kepler	No NS
~1680	Cas A	NS? jets
SN 1987A	nearby galaxy	NS? jets
Vela	10,000 years ago	NS, jets

January 27, 2010

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Also § 2.1, 2.2, 2.4 & 2.5 for background

Astronomy in the News? See if President Obama says anything about science, NASA in the State of the Union Address. What is the future of the US human space flight program, and the NASA science program?

Pic of the Day - Saturn's moons Titan and Tethys from the Cassini spacecraft orbiting Saturn.