Monday, March 7, 2016

No office hours today

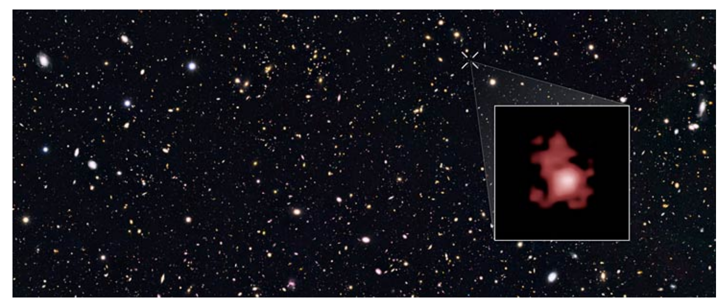
Class will be held Friday

Reading for Exam 3, April 1:

Chapter 6, Section 6.7 (radioactive decay), Chapter 7 (SN 1987A)

Astronomy in the news?

Record set for most distant galaxy, formed 13.4 billion years ago, only 400 million years after the Big Bang (redshift = 11). Previous record held by Texas Astronomer Steve Finkelstein. Both use the Hubble Space Telescope.



Goal

To understand how stars, and Type Ia supernovae, evolve in binary systems.

Bottom line:

There are two plausible ways by which a binary star system can lead to a Type Ia supernova:

1) The first white dwarf to form, from the originally most massive star, grows to very near the Chandrasekhar mass, ignites carbon and explodes while the other star is still transferring mass. My preferred explanation, but not firmly proven. Models give good spectra, but no companion yet seen before or after the explosion.

2) Two white dwarfs form, spiral together, the least massive one is torn apart when it fills its Roche lobe and the most massive one grows to near the Chandrasekhar mass, ignites carbon and explodes. Expect not to see a companion, but I am pessimistic that these models predict the right spectra.

Astronomers are trying to determine which (if either or both) works.

One Minute Exam

In a binary white dwarf system, the smaller mass white dwarf is destroyed because:

➡ It has the larger Roche lobe

⬅ As it loses mass, more mass loss is induced

⬆ Gravitational radiation pulls it apart

⬇ Carbon ignites it its center

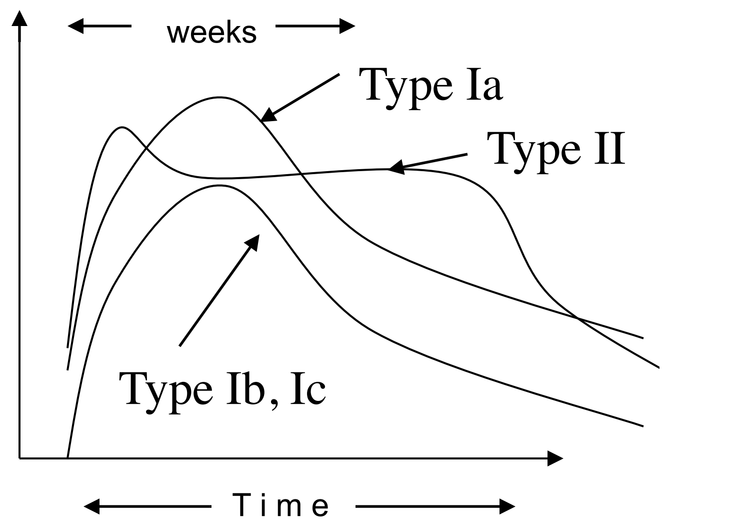
Goal - to understand what makes supernovae shine (Section 6.7).

Light Curves

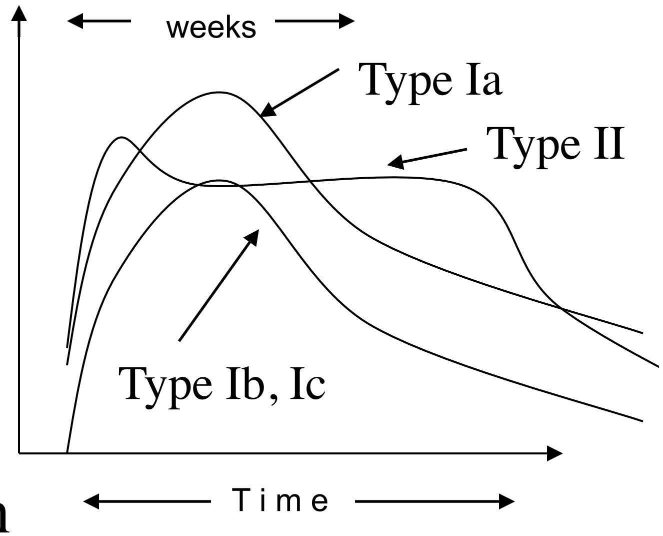
Why is the light curve different for Type II?

Why is the light curve similar for Type Ia, Ib. Ic?

Why are Type Ia brighter than Type Ib, Ic?



Light Curves



Ejected matter must expand and dilute before photons can stream out and supernova becomes bright: ***must expand to radius ~ 100 × Earth orbit***

Maximum light output ~ 2 weeks after explosion

Type II in red giants have head start, radius already about the size of Earth's orbit; light on plateau comes from *heat of original explosion*

Ejected matter cools as it expands: for white dwarf (Type Ia) or bare core (Type Ib, Ic) tiny radius about the size of Earth, must expand huge factor > 1,000,000 before sufficiently transparent to radiate.
All heat of explosion is dissipated in the expansion
By time they are transparent enough to radiate, there is no original heat left to radiate
Need another source of energy for Type I a, b, c to shine at all!

Goal - to understand what makes Type Ia,b,c supernovae shine.

Type Ia start with C, O: number of protons equal to number of neutrons (built from helium building blocks)

Iron has 26p 30n ***not equal***

C, O burn too fast (~1 sec) for weak nuclear force to convert p to n (§1.2.1)

Similar argument for Type Ib, Ic, core collapse. Shock wave hits silicon layer that surrounds the iron core. Silicon has #p = #n, burns too quickly for weak nuclear force to convert p to n.

Fast explosion of C/O in Type Ia and shock hitting layer of Si in Type Ib, Ic make element closest to iron (with same total p + n), but with #p = #n, **Nickel-56.**

Nickel-56: 28p, 28n <u>total 56</u> -- Iron-56: 26p, 30n <u>total 56</u>

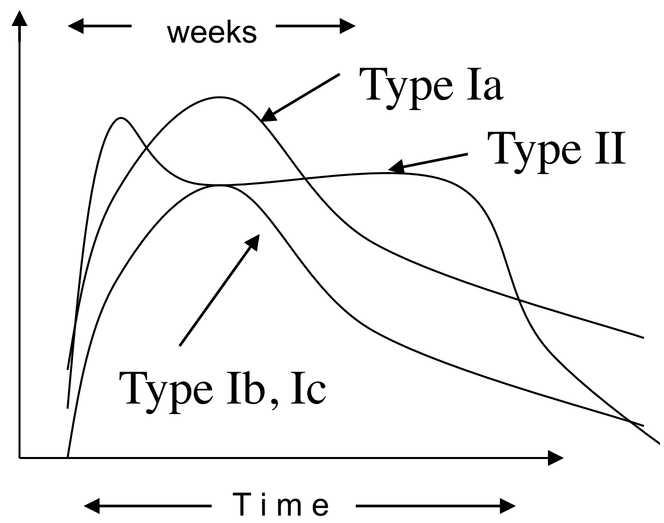
Ni-56 is unstable to **radioactive decay**

Nature wants to produce iron at bottom of nuclear "valley"
Decay caused by (slow) weak force p → n

Nickel -56	γ-rays heat →	Cobalt-56	γ-rays heat →	Iron-56
28p	"half-life"	27p	"half-life"	26p
28n	6.1 days	29n	77 d	30n

Secondary heat from radioactive decay γ-rays makes Type I a, b, c shine

Type Ia are brighter than Type Ib and Ic because they produce more nickel-56 in the original explosion.



The thermonuclear burning of C and O in a white dwarf makes about 0.5 - 0.7 solar masses of nickel-56.

A core collapse explosion that blasts the silicon layer makes about 0.1 solar masses of nickel-56.

Type II also produce about 0.1 solar mass of nickel-56, but the explosion energy radiated from the red giant envelope in the plateau tends to be brighter. After the envelope has expanded and dissipated, the remaining radioactive decay of Cobalt-56 is seen.

One Minute Exam

The light from Type Ia supernovae does not come from the heat of the original explosion because:

➡ The supernova must have a size 100 times the Earth's orbit in order to radiate

⬅ Type Ia produce iron in the center

⬆ When carbon burns quickly, nickel is produced

⬇ The thermonuclear burning of carbon does not produce much heat

One Minute Exam

Type Ic supernovae are usually dimmer than Type Ia supernovae because:

➡ Type Ic form neutron stars

⬅ Type Ic have no hydrogen or helium

⬆ Type Ic have binary companions

⬇ Type Ic produce less nickle-56

Sky Watch Objects

Lyra - Ring Nebula, planetary nebula in Lyra

Cat's Eye Nebula, planetary nebula in constellation Draco

Sirius - massive blue main sequence star with white dwarf companion

Algol - binary system in Perseus

Vega - massive blue main sequence star in Lyra

Antares - red giant in Scorpius

Betelgeuse - Orion, Red Supergiant due to explode "soon" 15 solar masses

Rigel - Orion, Blue Supergiant due to explode later, 17 solar masses

Aldebaran - Bright Red Supergiant in Taurus, 2.5 solar masses (WD not SN)

Castor, Rigel - massive blue main sequence stars

Capella, Procyon - on their way to becoming red giants

Sky Watch Targets

Binary Stars

Sirius
Algol, Beta Persei in Perseus
Antares, Alpha Scorpii in Scorpius
Beta Lyrae in Lyra
Rigel, Beta Orionis in Orion (triple star system)
Spica in Virgo

M82 in the Big Dipper, host galaxy of SN 2014J

SN 1006 - Lupus/Centaurus (difficult this time of year)

SN 1054 Crab Nebula - Taurus

SN 1572 Tycho - Cassiopeia

SN 1604 Kepler - Ophiuchus

Cassiopeia A - Cassiopeia

Vela supernova – Vela

SS Cygni - brightest dwarf novae in the sky, Cygnus,

U Geminorum - dwarf nova in Gemini

CP Pup, classical nova toward constellation Puppis in 1942

Pup 91, classical nova toward Puppis in 1991

QU Vul, classical nova toward constellation Vulpecula,

GK Per -Perseus, both a classical nova eruption and dwarf nova.

U Sco - Scorpius, recurrent nova

RS Oph – Ophiuchus, recurrent nova

T Pyx in constellation Pyxis.

Goal:

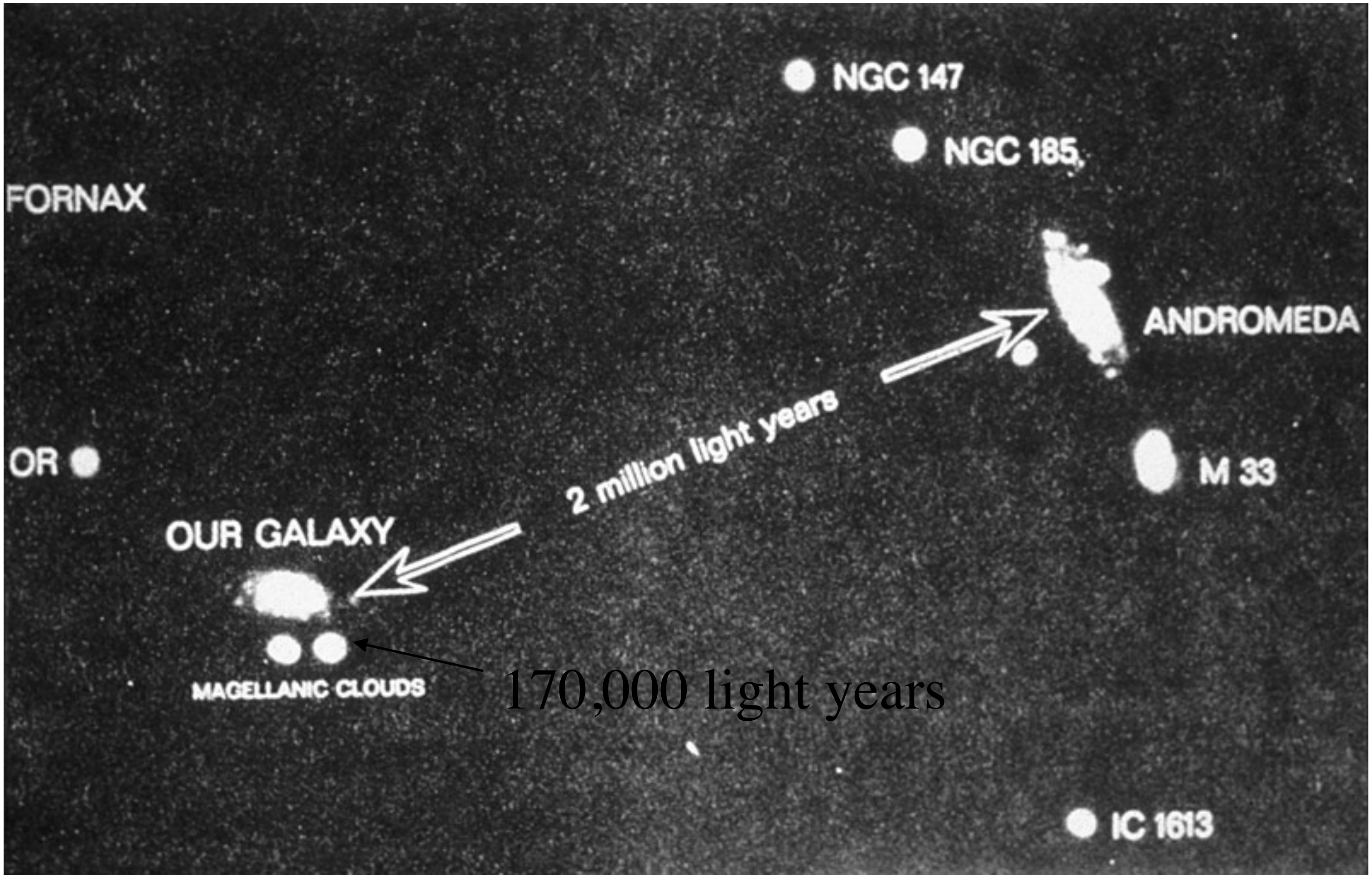
To understand the nature and importance of SN 1987A for our understanding of massive star evolution and iron core collapse.

Kepler

SN 1987A
first naked eye
supernova since
Kepler's in 1604

Tycho

Local group



NGC 147
NGC 185
FORNAX
ANDROMEDA
2 million light years
OR
M 33
OUR GALAXY
MAGELLANIC CLOUDS
170,000 light years
IC 1613

Large Magellanic Cloud, irregular galaxy, large scale

Large Magellanic Cloud, closeup (color)

LMC negative