

Wednesday, March 11, 2015 (Class Friday)

Reading for Exam 3:

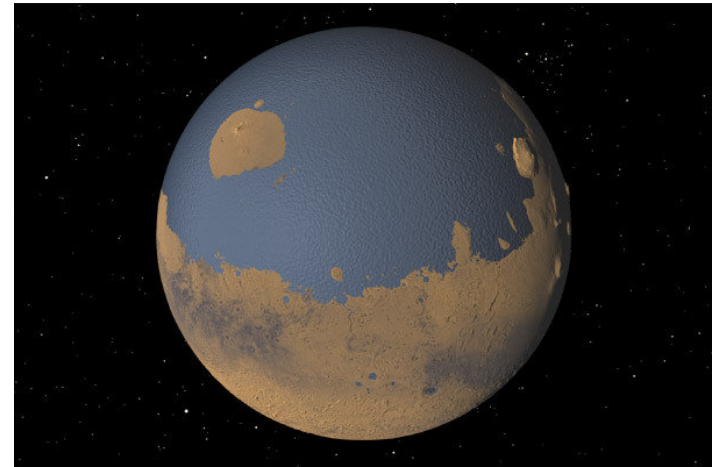
Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A)

Background in Chapters 3, 4, 5.

Background: Sections 3.1, 3.2, 3.3, 3.4, 3.5, 3.8, 3.10, 4.1, 4.2, 4.3, 4.4, 5.2, 5.4 (binary stars and accretion disks).

Astronomy in the news?

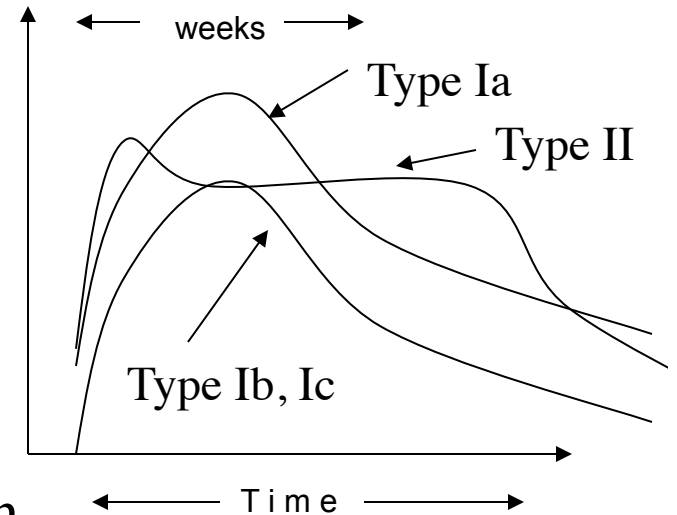
New summary of evidence that Mars had an ocean billions of years ago, mostly in the Northern hemisphere, average depth 450 feet.



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

Light Curves

Ejected matter must expand and dilute before photons can stream out and supernova becomes bright: *must expand to radius $\sim 100 \times \text{Earth orbit}$*



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*

How is iron made in the explosion?

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 total 56 -- Iron-56: 26p, 30n total 56

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

Nature wants to produce iron at bottom of nuclear “valley”

Decay caused by (slow) weak force $p \rightarrow n$

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

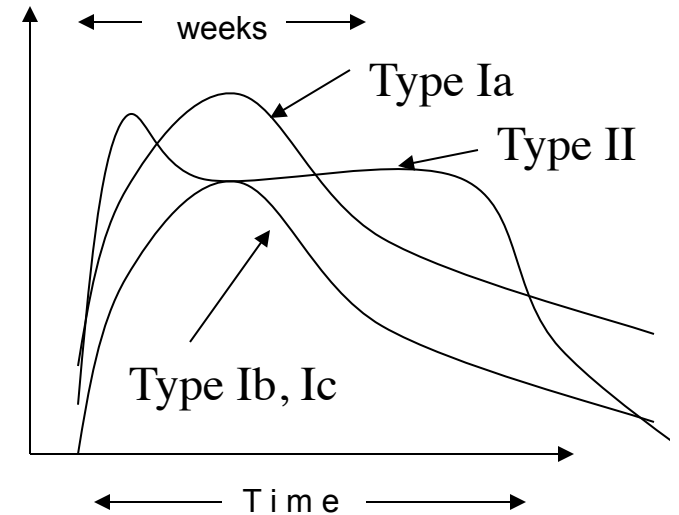
Secondary heat from radioactive decay γ -rays makes Type I a, b, c shine

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.



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

Polaris in Ursa Minor (multiple star system)

Others...

Supernovae

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

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

Cataclysmic Variables

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.

WD1242-105 binary white dwarf pair near Virgo

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 nickel-56

Goal:

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

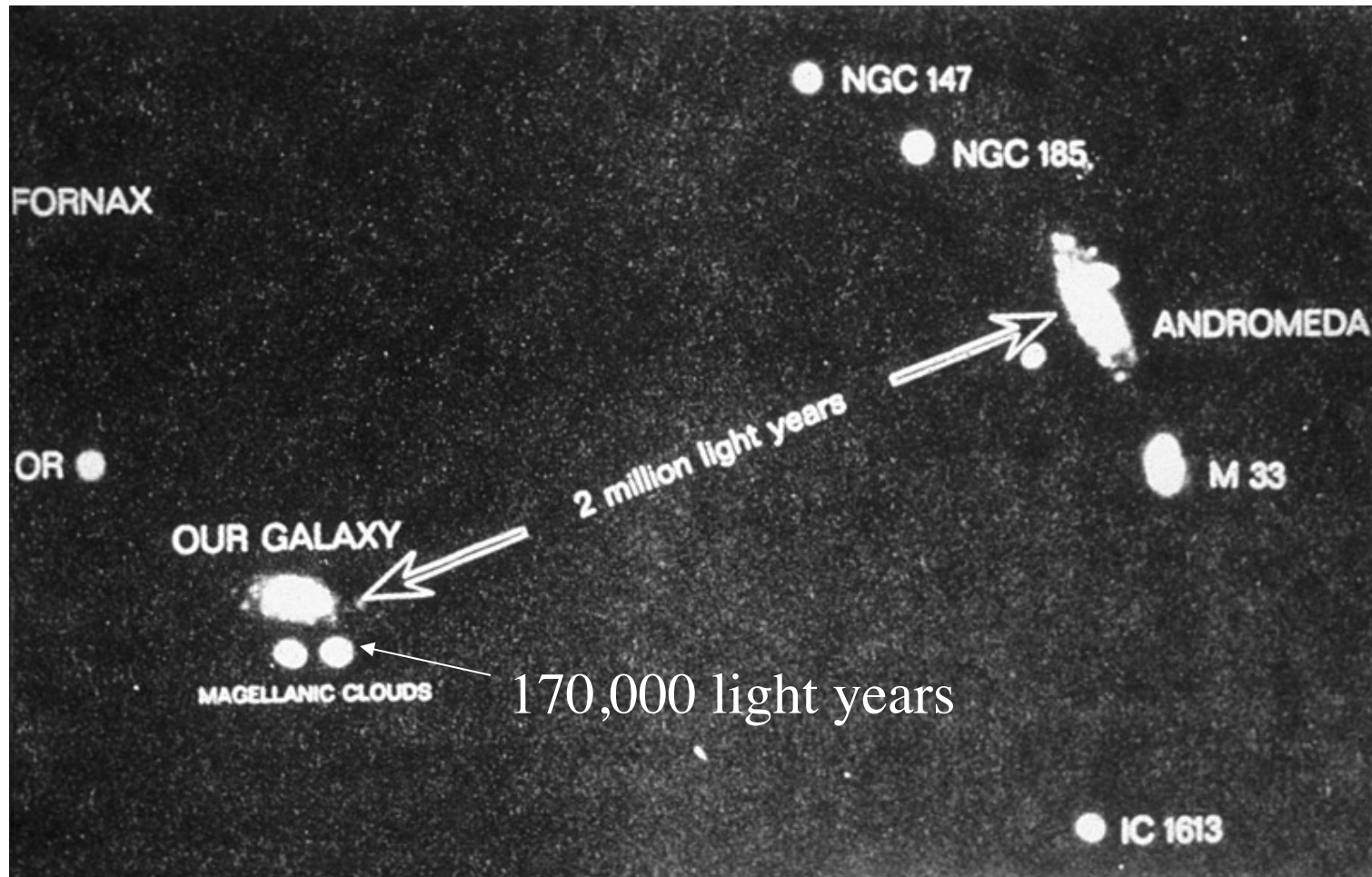
Kepler

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



Tycho

Local group



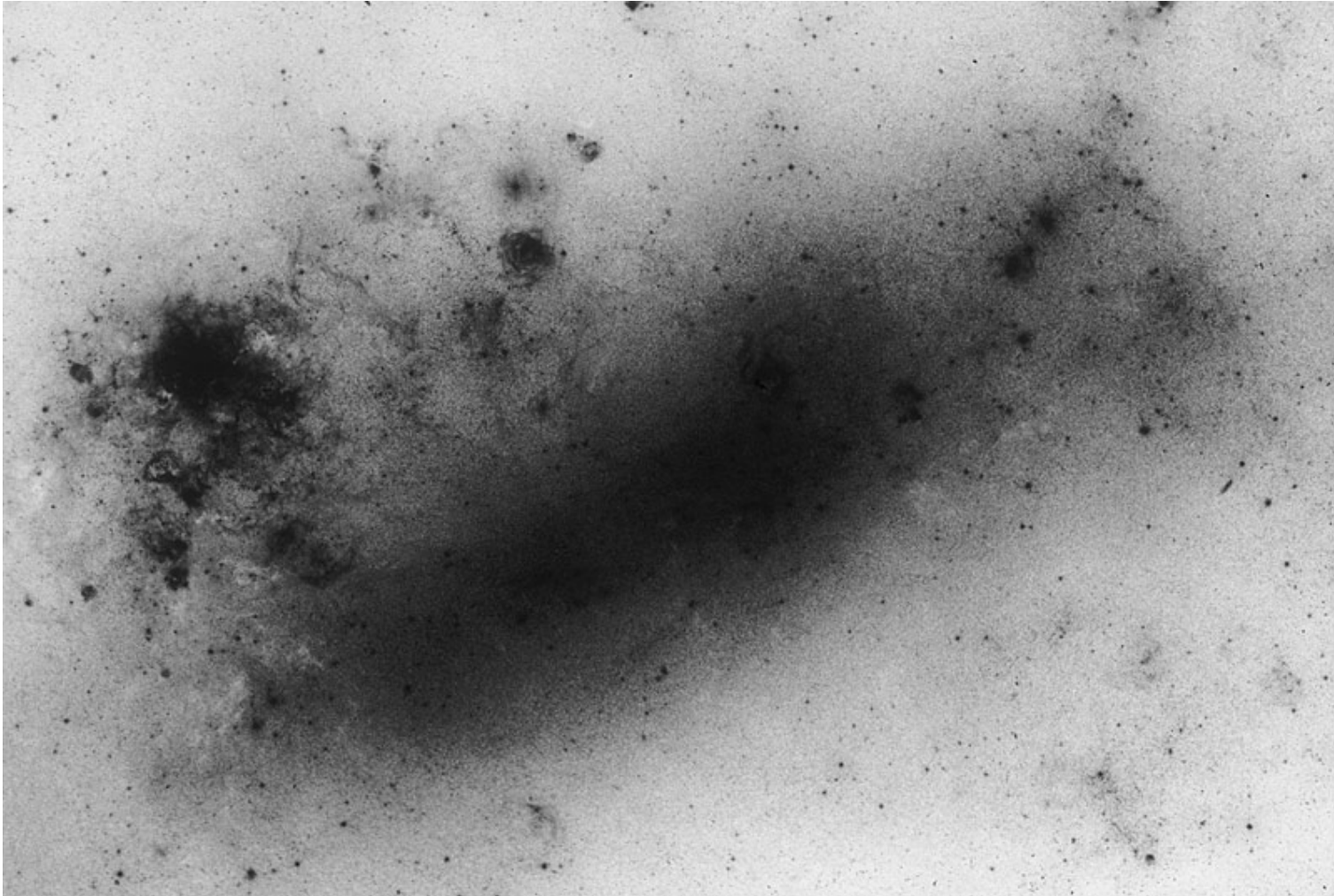
Large Magellanic Cloud, irregular galaxy, large scale



Large Magellanic Cloud, closeup (color)



LMC negative



Rob McNaught patrol photos - the day before



2-22-87

The first known photo of SN 1987A hours after shock breakout



2-23-87