Tuesday, October 8, 2009

Exam 2 - 1 week from today, Chapter 6, Supernovae Reading for Exam 2: Chapter 6 (omit Section 6.7), Chapter 7, Chapter 2: 2.1, 2.4, 2.5

Astronomy in the news -

Pic of the Day -Lunar south pole, site for impact tomorrow to search for water.



# Sky Watch

Can only count each object once for credit, but can do any objects missed earlier in later reports.

Add relevant objects that I don't specifically mention in class, other examples of planetary nebulae, main sequence stars, red giants, binary stars, supernovae....

Don't wait until the last minute. It might be cloudy.

The Earth orbits around the Sun, some objects that were visible at night become in the direction of the Sun, "up" in daylight, impossible to see, other objects that were inaccessible become visible at night. Check it out.

Second Sky Watch Report Due at Exam, October 15.

#### Sky Watch Objects mentioned so far

- 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

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

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 (not this time of year)

### New possibility - Jet-induced supernova (Ch 6, p. 94)



Crab Nebula

Cassiopeiae A

SN 1987A

Are jet-like flows typical? Are they important?

Studies (last 10 years) show that all Core Collapse Supernovae (massive stars: Type II, Ib, Ic) are out-of-round.

Perhaps combination football, frisbee, or something else. Death Star Explosion

Suernovae show shapes consistent with (but not necessarily proving) jet-like flow.

Calculations show jets emerging from newborn neutron star can explode the star, make it out-of-round.

Predict a jet/torus "bagel and breadstick" shape

#### What jets do -

Bagel and breadstick, jet/torus shape "natural."





user: smc Wed Apr 9 10:46:35 2008



Computer models predict a jet/torus, "bagel and breadstick" structure

Couch et al. 2009

This is the first new idea to understand these supernovae in

thirty years.

Bagel and Breadstick Halloween costume, 2008,

Marquette University, Milwaukee



How to define a particular direction in space?

Rotation - rotation axis.

How to make a jet? Some variation on squeeze and squirt (toothpaste mechanism)

Rotate magnetic neutron star, amplify the magnetic field, eject mass if field is strong enough.

*Magnetic lines of force*, locus of equal field strength, act somewhat like rubber bands, they are elastic and tend to rebound if deformed and can be twisted and coiled.

Twisted magnetic fields have tension along them and exert pressure sideways and along the lines of force.

Rubber band - twist moves along the rubber band.

What jets do -

Bagel and breadstick, jet/torus shape "natural."

Strong enough jet can explode the star, but neutrinos also play a role - complicated problem!

Account qualitatively for out-of-round polarization.

Test for shape (jet/torus), prediction of different elements exploded in different directions.

## Initially spherical model,



Spherical Explosion oxygen, silicon, calcium, and iron would be exploded in all directions



Jet-induced Explosion axis/torus structure

> user: smc Mon Feb 9 14:59:09 2009

One Minute Exam

Why do astronomers think that jets may be involved in the core collapse explosion of massive stars?:

Iron makes jets

Jets make calcium and oygen

All core collapse supernovae are out of round

Cassiopeia A has a collapsed object in the center of the explosion

Back to physics of Type Ia Supernovae - exploding white dwarfs

Chapter 6, Section 6 in Cosmic Catastrophes

Type II (Ib, Ic) energy from falling, gravity, Type Ia energy from thermonuclear explosion. About the same energy, that required to explode a core with the mass of the Sun, radius of the Earth.

Type Ia - many, if not all, are old  $\Rightarrow$  only credible idea is to grow a white dwarf by mass transfer in a binary system.

Type Ia - see O, Mg, Si, S, Ca early on, iron later => iron inside



Models based on Chandrasekhar-mass C/O white dwarfs give observed composition structure!

Large quantum pressure deep inside the white dwarf -- high density and temperature overcome charge repulsion - very unregulated ignite Carbon  $\Rightarrow$  runaway  $\Rightarrow$ total explosion, no neutron star or black hole.

Models give thorough burning to iron on inside, only partial burning of C and O leaving O, Mg, Si, S, Ca in outer layers.

Two stages to explosion:

Deflagration - slower than speed of sound, like a flame Detonation - supersonic shockwave, faster than the speed of sound - like a stick of dynamite

All data, UV, optical, IR, X-ray are consistent with this picture

Pressure waves that cause a star to expand and explode travel at about the speed of sound.

An exploding star expands at about the speed of sound in the ejected matter.

A deflagration cannot catch up with the pressure waves it creates, nor with the outer expanding matter.

A detonation will propagate faster than pressure waves or exploding, expanding matter.

*Detonations* do not give the star time to react.

 $\Rightarrow$ For *detonation alone*, the white dwarf would be turned essentially entirely to iron, *Wrong!* 

*Deflagrations* give the outer parts of the white dwarf time to expand, quench burning.

 $\Rightarrow$ For *deflagration alone*, the outer parts are never burned, explosion would be relatively weak, substantial unburned carbon and oxygen must be expelled.

Careful observation in the *infrared* show no carbon survives the explosion, so *Wrong!*