Wednesday, March 23, 2017

Reading for Exam 3:

Chapter 6, end of Section 6 (binary evolution), Section 6.7 (radioactive decay), Chapter 7 (SN 1987A), 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). Plus superluminous supernovae, **not in the book**.

**Review Sheet posted on web site and Canvas**

Astronomy in the news?
Astronomers have discovered the brightest neutron star ever found, 1,000 times brighter than researchers previously thought was possible. The extreme brightness of this neutron star may be explained if it has a complex magnetic field with more than two poles (rather than a simple magnetic field with just a pair of poles).

Editorial comment: research and teaching at UT

# Goal:

To understand how isolated neutron stars are observed as "pulsars."

**Radio emission from "sparks" "thunderstorms," blobs of plasma, perhaps at tilted magnetic poles or "speed of light" circle**

Tilted Poles: whip magnetic field around ⇒ huge electric fields create huge currents, "thunderstorms" ⇒ radio "static"

Blobs of plasma locked to magnetic fields lines, like beads sliding on a wire.

Speed of light circle - distance from rotation axis at which plasma whipped around by "stiff" magnetic field would be moving at the speed of light. The field and plasma must be disrupted there.

**In either case, radiation is produced steadily from off-center blobs of plasma, see "pulses" by "lighthouse" mechanism**

*The neutron star itself does not pulse!*

Results from NASA ***Fermi Observatory***, launched June 2008, that detects high-energy Gamma Rays

Radio may come from magnetic poles, but most of the *power* is in high-energy gamma rays and occurs in regions beyond the neutron star, near the speed of light circle.

# Goal:

To understand how neutron stars behave in accreting binary systems.

Radio pulsars are alone in space or in non-transferring binary system

Vast majority of known radio (and gamma-ray) pulsars are alone in space

~ two dozen pulsars have binary companions

Binaries special - use Kepler's laws to measure mass

Orbital decay $\Rightarrow$ Gravitational Radiation - Nobel Prize 1993

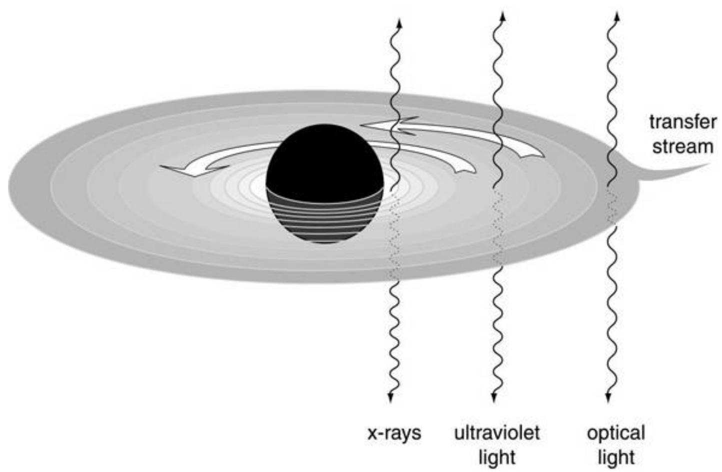
Orbital decay detected by Texas astronomers in white dwarf binary in 2012.

Some neutron stars are in binaries with mass transfer

Mass transfer floods the magnetic field/poles with gas/plasma, short circuits, kills the radio (and gamma-ray) mechanism.

With mass transfer $\Rightarrow$ accretion disk => X-rays

High gravity of NS, rapid motion in inner disk, great friction, heat => **X-rays from disk**




Matter lands on, collides with NS Surface => **X-rays from NS surface**

*Uhuru* satellite launched from Kenya 1972 found sky ablaze in X-rays: Neutron stars and black holes in binary systems. Many satellites launched since then, including *Chandra Observatory* and the *Fermi Observatory*.

Nobel prize in 2002 for this and related discoveries.

# Goal:

To understand how ***magnetic*** neutron stars behave in accreting binary systems.

For strong magnetic field matter connects to, flows *along* magnetic lines of force (can't flow across field lines of force)

Analogous to beads sliding along a wire

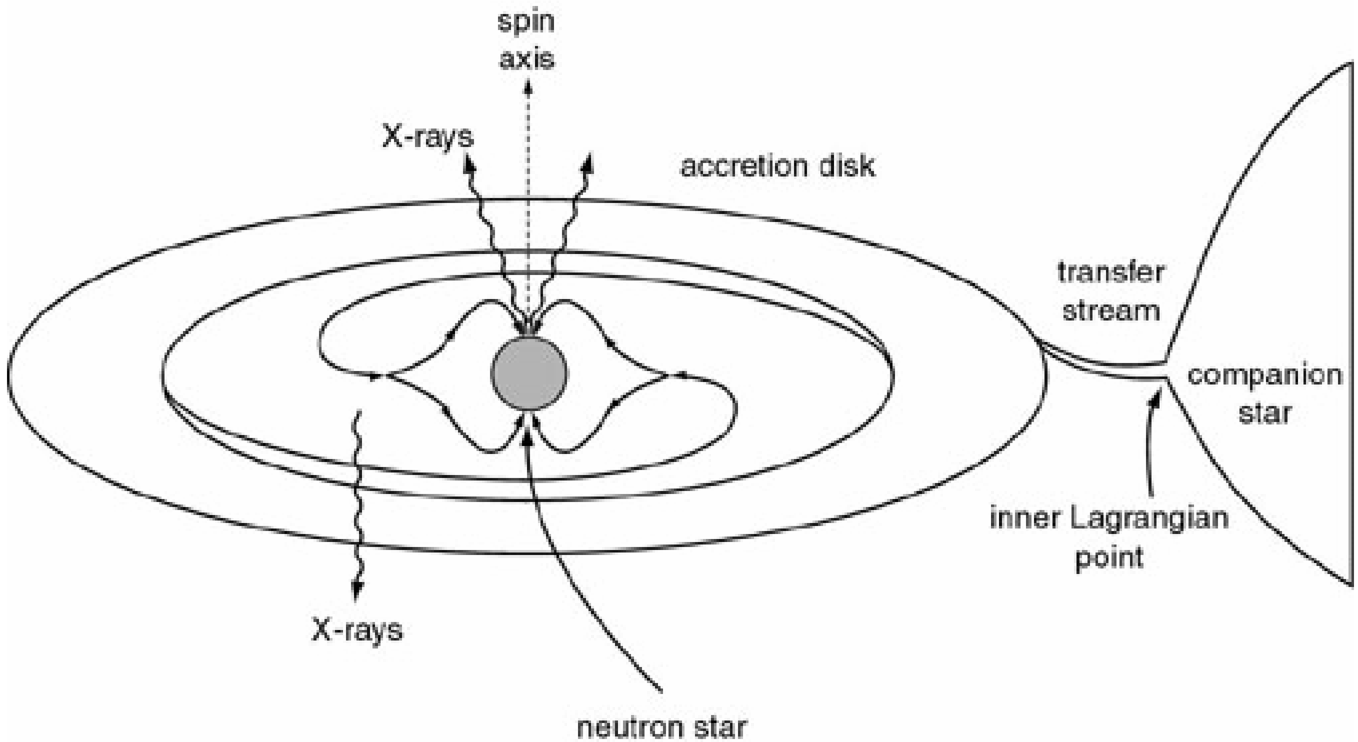
This process automatically channels matter to *magnetic* poles

Matter slams into neutron star at the poles, gets hot, emits X-rays (but kills radio, gamma rays)

Rotation with tilted magnetic field can give X-ray "pulses" by the light house mechanism.

Note that will get X-rays from poles when accreting even if the magnetic poles are aligned with the rotation axis, just won't get lighthouse "pulses" (unlike radio mechanism that requires tilted poles to radiate at all).

Figure 8.2

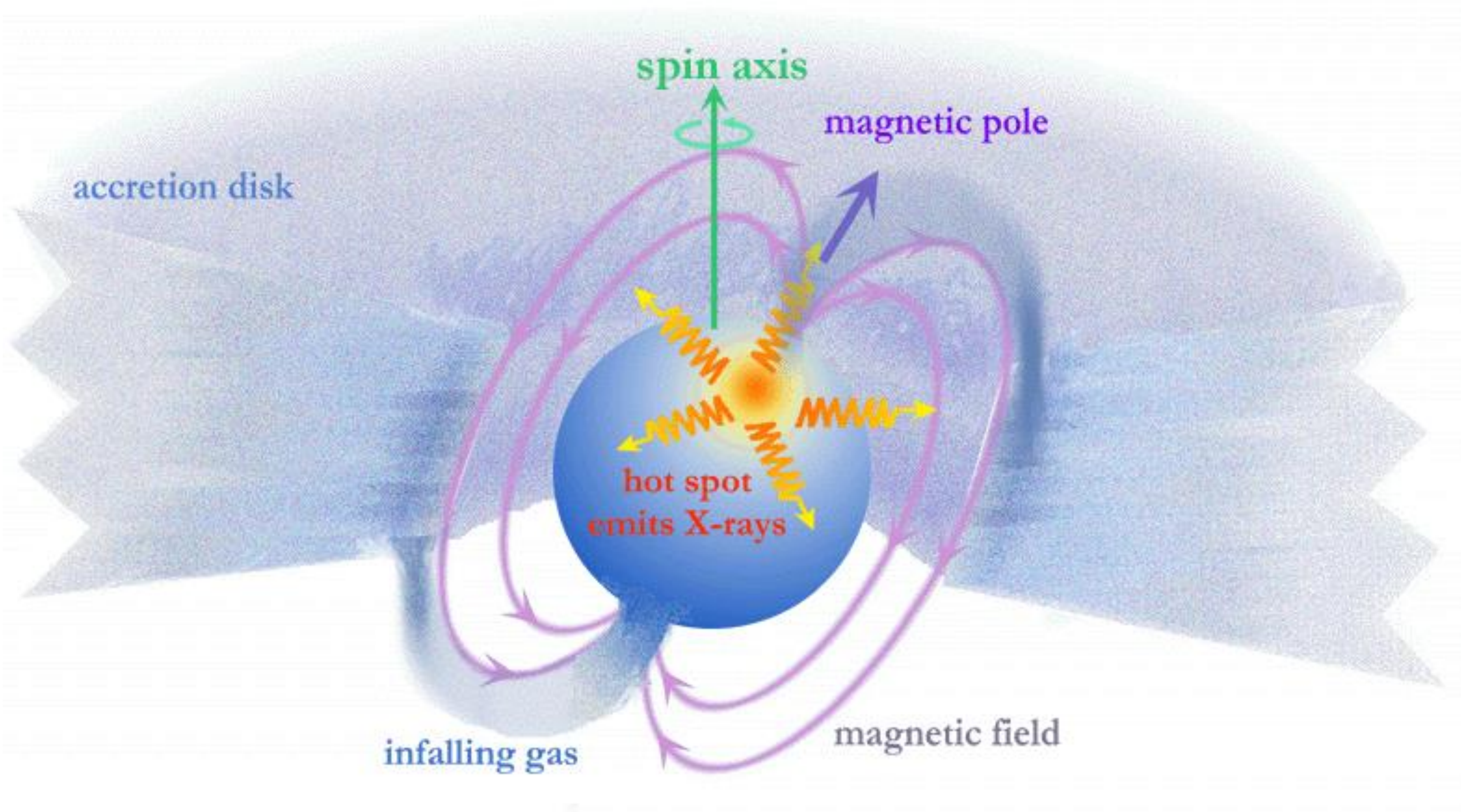



Some neutron stars are in binary systems. They accrete mass through an accretion disk and produce ***X-rays***. X-rays are produced even if the magnetic poles are aligned with the rotation axis, but do not get "pulses" from the light house effect.

Goal:

To understand how neutron stars are observed as X-ray "pulsars."

Accretion onto *tilted* magnetic poles can give pulses of X-rays by “lighthouse” mechanism (or other “off-center” effect)



Neutron stars for Sky Watch

Single neutron stars: Geminga (Section 8.11) in Gemini

Gravitational radiation from pulsar in binary system - Aquila

X-ray pulsars, Her X-1 in Hercules, Cen X-4 in Centaurus

Other neutron star binary systems.

# Goal:

To understand the nature of neutron stars with exceptionally large magnetic fields.

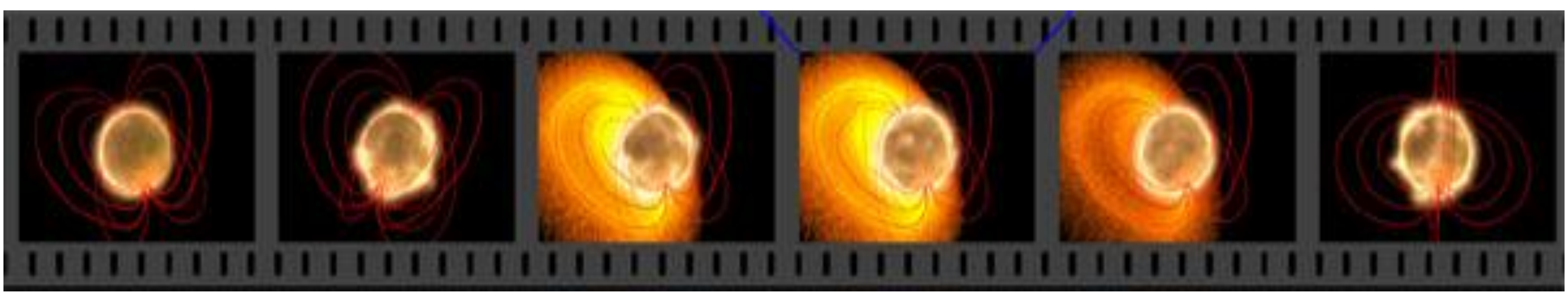
<u>Soft Gamma Ray Repeaters</u> - 6 known

One flared in the Large Magellanic Cloud galaxy, energy arrived in March 5, 1979.

Another flared in our Galaxy, energy arrived August 27, 1998, caused aurorae from 1000's of light years away.

Yet another flared in our Galaxy with energy arriving December 27, 2004, from the far side of the Galactic center, perhaps 10's of 1000's of light years away, brightest release of energy ever seen in the Galaxy, 100 times more powerful than August 1998 burst.

Magnetic eruption in neutron star [not necessarily in binary system.]



Theory - break patch of iron-like “crust” of neutron star that is threaded by magnetic lines of force, convert magnetic energy to heat (1998 burst) or completely rearrange magnetic field configuration, for instance by swapping north and south magnetic poles (2004 burst).

Require “wiggling” of very strong magnetic fields, 100 × Crab pulsar

$\Rightarrow$ ***Magnetar*** - very highly magnetic pulsar.

Anomalous X-ray Pulsars (AXP) also require very large magnetic fields, but have not been seen to burst, maybe old magnetars.

Origin of magnetars compared to “normal” pulsars not yet known.

Formation might be related to Cosmic Gamma-ray bursts (Chapter 11).

X-ray, Gamma-ray satellites should see many of these brightest bursts (December 27, 2004) in distant galaxies.

# Skywatch Extra Credit Targets
constellations only, not all visible

## Magnetar Candidates

| Name | Location | Rotation (seconds) | Year Discovered |
|---|---|---|---|
| SGR 0526-66 | Large Magellanic Cloud | 8.0 | 1979 |
| SGR 1900+14 | Aquila | 5.16 | 1979 |
| SGR 1806-20 | Sagittarius | 7.56 | 1979 |
| SGR 1801-23 | Sagittarius | - | 1997 |
| SGR 1627-41 | Ara | 6.4 | 1998 |
| AXP 1E 2259+586 | Cassiopeia | 7.0 | 1981 |
| AXP 1E1048.1-5937 | Carina | 6.4 | 1985 |
| AXP 4U 0142+61 | Cassiopeia | 8.7 | 1993 |
| AXP 1RXS J170849-400910 | Scorpius | 11.0 | 1997 |
| AXP 1E 1841-045 | Scutum | 11.8 | 1997 |
| AXP AX J1844-0258 | Aquila | 7.0 | 1998 |
| AXP CXOU J010043.1-721134 | Small Magellanic Cloud | 8.0 | 2002 |
| AXP XTE J1810-197 | Sagittarius | 5.5 | 2003 |
| AXP CXO J164710.2-455216 | Ara | 10.6 | 2005 |