

Monday, March 21, 2016

Exam 3, April 1, Exam 4 April 15:

Astronomy in the news?

Neutron stars

Alone and in binary systems

Reading Chapter 8 - Sections 8.1, 8.2, 8.5, 8.6, 8.10

Combination of quantum pressure from neutrons and repulsion of neutrons at very close distances by strong nuclear force \Rightarrow pressure to withstand gravity.

Analog of Chandrasekhar mass - maximum mass of neutron star - uncertainty over nuclear repulsion, maximum mass $\sim 2 M_{\odot}$

Probably 100 million to a billion neutron stars in the galaxy, cold, tiny, and dark.

Nearest, undetected, may be only 10 light years or so away.

Vast majority of about 2000 known neutron stars are alone in space, detected as “pulsars.”

$\sim 20 - 30$ have binary companions, ordinary stars, white dwarfs, other neutron stars, and black holes.

Goal:

To understand how isolated neutron stars are observed as
“pulsars.”

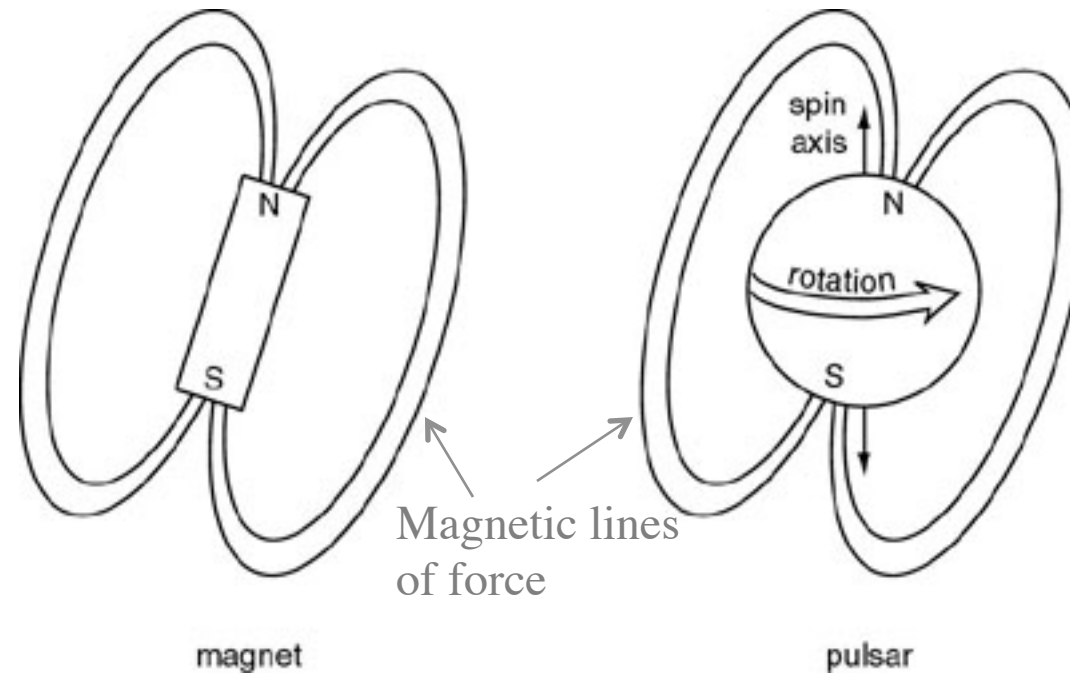
Two new principles of physics:

A moving magnetic field can can and will generate radiation.

Ionized gas, plasma, can move *along* lines of magnetic force, but cannot move *across* them. Magnetic fields will drag or channel plasma.

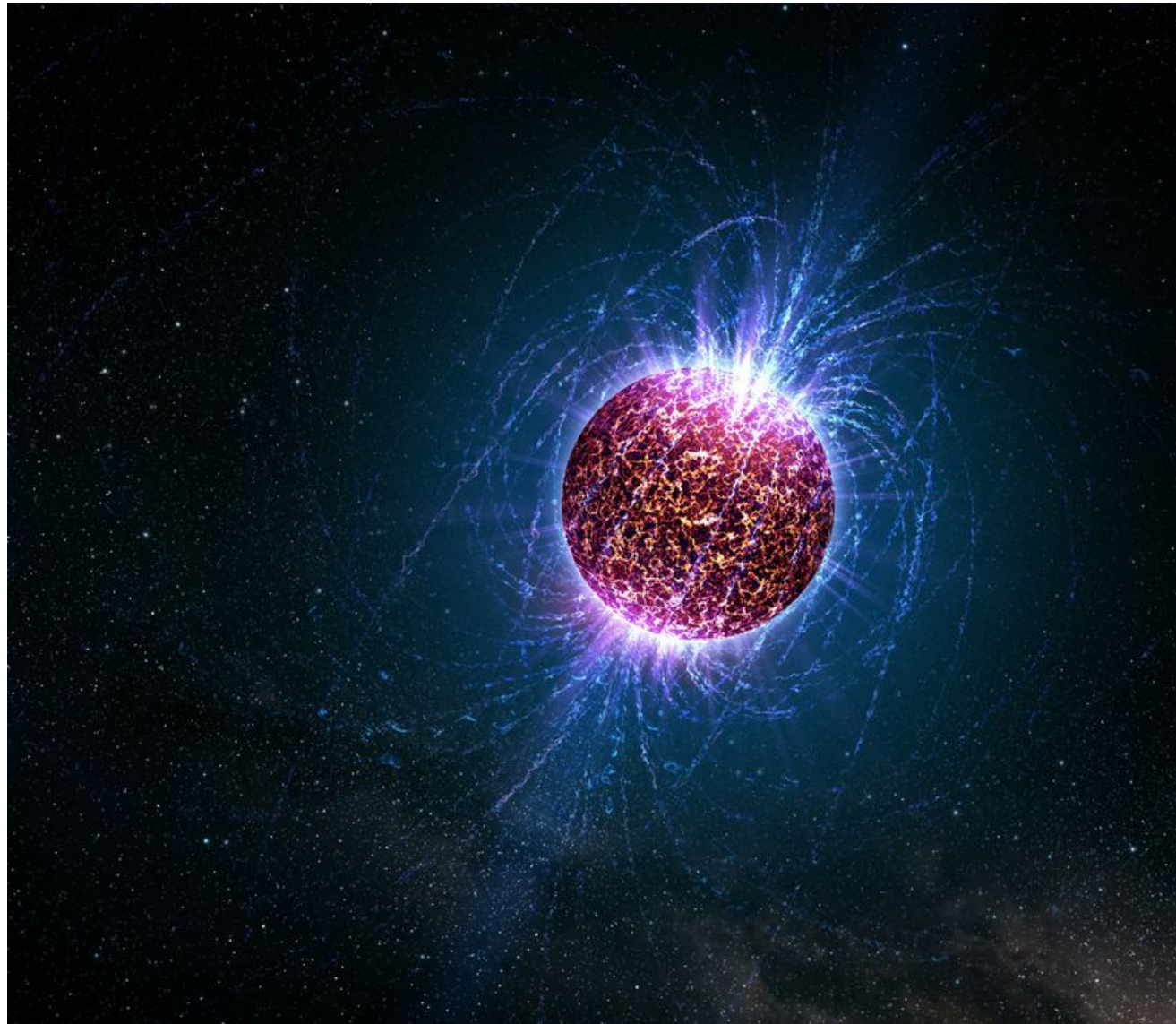
One possibility - field axis is tilted.

Radio Pulsars could be rotating, magnetic neutron stars with magnetic axis **tilted** with respect to spin axis.



Most radio pulsars rotate about once per second, young ones faster, Crab pulsar rotates 30 times per second - would rip apart anything but a neutron star

Artist's conception of neutron star with tilted magnetic field.



Courtesy
Casey Reed,
Penn State
University.

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

Tilted Poles: whip magnetic field around \Rightarrow huge electric fields create huge currents, “thunderstorms” \Rightarrow 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

Flashlights

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

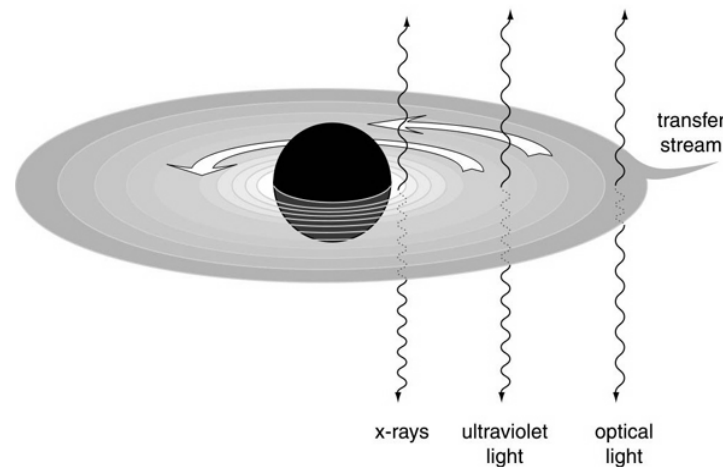
Detected by Texas astronomers in white dwarf binary in 2012.

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 \Rightarrow X-rays

High gravity of NS, rapid motion in inner disk, great friction, heat
 \Rightarrow X-rays from disk



Matter lands on, collides with NS Surface \Rightarrow 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

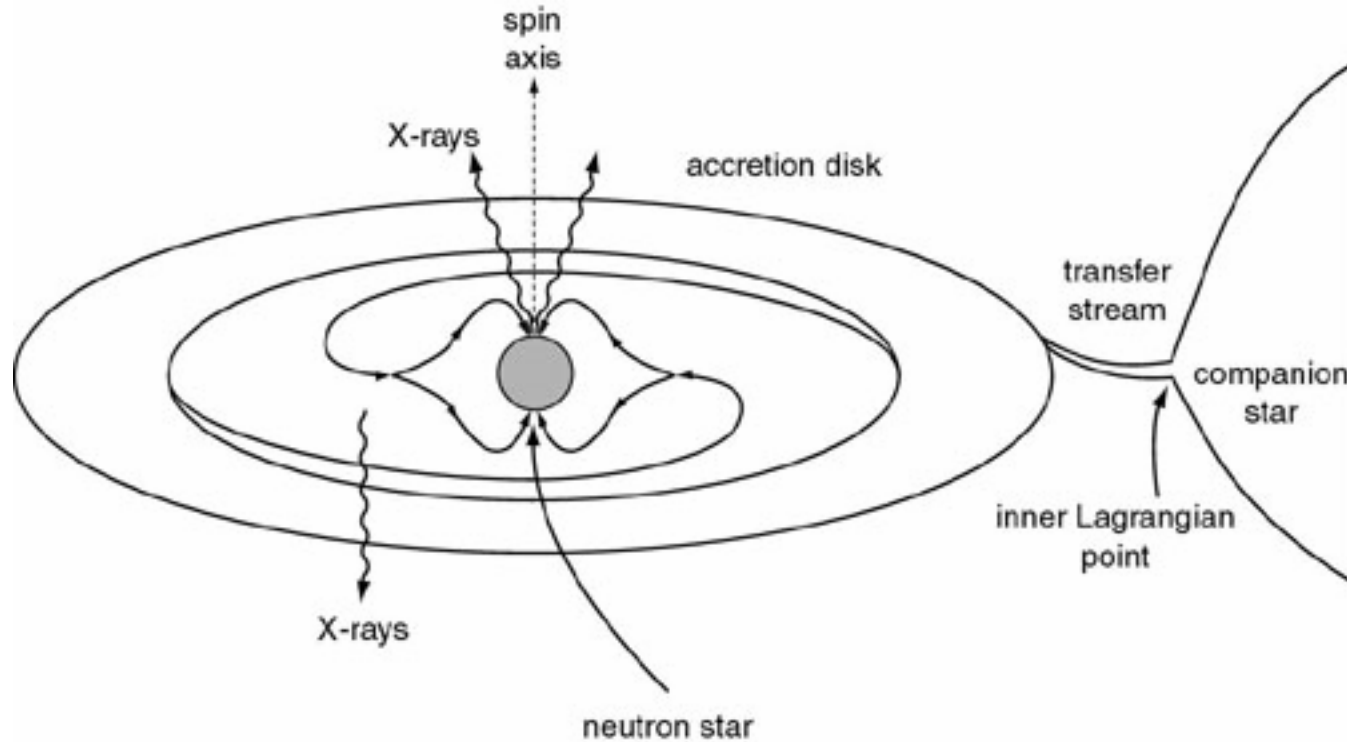
This process automatically channels matter to *magnetic* poles

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.