ASTR 1120 – March 6

Next exam will be soon. Tuesday, March 18.

Website
http://casa.colorado.edu/~wcash/APS1120/APS1120.html

Problem Sets 5 is due.
Old graded PS’s and Exams at back of room
SN1987A

- First naked eye supernova since 1604.
- Discovered by Ian Shelton. Feb 23, 1987 UT 23.316
- Showed hydrogen escaping at 30,000km/s

- In Large Magellanic Cloud
- Tiny galaxy orbiting the Milky Way.

- Huge international response of the astronomy community.
Progenitor

Star that exploded was tracked down. Not terribly prominent.

SK-69 202
B3 Supergiant  $m=12.4$  $M=-7.8$
$T=16,000K, \ R= 40R_\odot$

Distance 55,000pc – actually outside Milky Way.
Stellar History

- Burned H 10,000,000 years
- He 1,000,000
- C 300
- Ne 5 months
- O 6
- Si 2 days
- POW!!!!
Rings

HST image of SN1987A a few years after the event.

Center is dim
3 Bright rings

Illuminated by the flash
Hourglass shape again
Means there was mass loss prior to the explosion
Impending Collision

Blast wave is about to hit the ring.
Big Rings

With this geometry there is only a few light months delay.
Neutrino Astronomy

Ground Level

Fill mineshaft with water
Put photo detectors around the inside
Neutrino Going Through Water

\[ \nu + e^- \rightarrow \nu + e^- \]
(scattering)

\[ \nu + P \rightarrow n + e^+ \]
light produced by secondary interactions
Super Kamiokande
Detection of SN1987A

- Kamiokande II, Japan: 12 events at 15s
- IMB, Ohio: 8 events at 5.6s

Mont Blanc neutrino detector saw a marginal signal 4.7 hours earlier. Real???

In 1987A we detected the formation of a new neutron star!
Neutron Stars

- At the center of a Type II supernova
- Settles into neutron degeneracy
- $M \sim 1.4M_\odot$ and $R \sim 8$km
- A solid ball of neutrons – giant atomic nucleus
- Predicted in 1930’s (after white dwarfs explained)
- Thought unobservable -- $m \sim 30$
- Dark rocks
Lot of Neutron Stars

- Probably $10^8$ of them in Milky Way
- Closest is less than 10pc (don’t know where it is)
Chandrasekhar Limit

- Neutron Star mass limit about 2.1M☉
- Some theoretical disagreement about exact value

- But its larger than White Dwarf C.L.
- Otherwise no stability point after collapse
- Most measured NS have $M \approx 1.4M_☉$

- Beyond that – NS will collapse to black hole.
Structure

8km

hyperons

neutrons dense iron liquid

Λ’s, K’s, etc

Created by *extreme* pressure
Mass Radius Relation

\[ R \propto \frac{1}{\sqrt[3]{M}} \]

As mass increases star gets smaller.
Like ball of foam.
Just like WD
NS Density

\[ \rho = \frac{M}{\frac{4}{3} \pi R^3} = \frac{3 \times 10^{33}}{4 \times (8 \times 10^5)^3} = 1.5 \times 10^{15} \text{ g / cc} \]

Water has a density of 1 g/cc

Lead 11 g/cc

Gold 19 g/cc

quadrillion times density of gold!

NOT NORMAL MATTER!!

1 cubic centimeter masses a billion tons!
Surface Gravity

\[ a = \frac{GM}{R^2} = \frac{7 \times 10^{-11} \times 2 \times 10^{30}}{(7 \times 10^3)^2} = 3 \times 10^{12} \text{ m/s}^2 \]

This 3 trillion gees

If you weigh 150lbs on Earth, you would weigh

450 trillion pounds on a neutron star!

As much as a whole mountain.
Escape Velocity

\[ V_e = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2 \times 6.7 \times 10^{-11} \times 2 \times 10^{30}}{7 \times 10^3}} = \sqrt{4 \times 10^{16}} = 2 \times 10^8 \text{ m/s} \]

Speed of light is 3 \times 10^8 \text{ m/s}, so escape velocity is .60% of c.
Gravitational Redshift

Even light loses energy climbing out of this hole.

\[ \frac{GMm}{R} = \alpha mc^2 \]

\( \alpha = .26 \)

At 5000Å have 1300Å shift to red
Magnetic Field

\[ B = B_o \left( \frac{R}{R_o} \right)^3 \]

When a star shrinks from 10^9 m to 10^7 m

\[ \frac{R_0}{R} = 10^5 \]

So B increases from 1Gauss to trillions of Gauss
Pulsars

• Neutrons Stars considered unobservable
• Forgot the effect of magnetic fields
• When a magnetic spins it creates electric fields
• Electric fields create accelerated electrons
• Accelerated electrons create strong radio signals
• Pulsar is a spinning, magnetized neutron star
Intense Magnetic Field

Field not necessarily aligned with spin axis
Particles get thrown out along the polar axes (cannot cross field lines)
Beam radio signal along magnetic axis too.
From Above

Every time beam sweeps by we see a pulse
Lighthouse Analogy
Pulse Trains

- http://www.jb.man.ac.uk/~pulsar/Education/Sounds/sounds.html