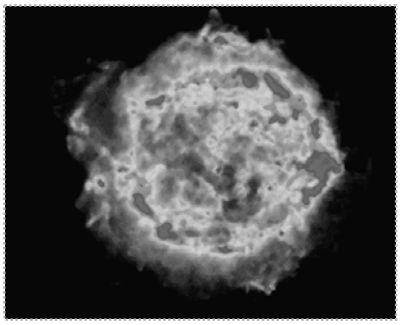
ASTR 1120: Stars & Galaxies



Cas A SNR
VLA - radio

Prof. Juri Toomre TA: Ben Brown

Lecture 23 Fri 4 Mar 05

zeus.colorado.edu/astr1120-toomre

Today in Bizarre-Land

- *Pulsars* – fast spinning neutron stars with fierce magnetic fields; gradually slow down
- *Synchrotron radiation* makes the light seen as pulses – and thus Crab nebula + pulsar shines (and pulses) brightly in many wavelengths
- How *mass transfer from binary companion* can *spin-up pulsar*

- *Review Set 2* available today. Ben Brown runs *review session* next Wed night (9 Mar, here), *Second Mid-Term Exam* on Friday 11 March
- *Homework 6* due Monday -- re-read *18.4 Black Holes* carefully for Mon lecture

Clicker review – red giants

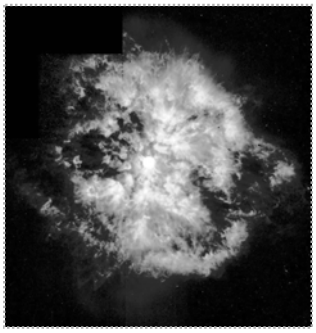
- *The main source of energy for a star as it grows in size to become a red giant is* _____ .

B.

- *A.* gravitational contraction
- *B.* hydrogen fusion in a shell around core
- *C.* helium fusion in the core
- *D.* hydrogen fusion in the core

How do SN and stellar winds touch us?

- *All heavy elements are created and dispersed through our galaxy by stars*
- *Without supernovae, nothing heavier than IRON is made*
- *WE ARE STAR STUFF !*
- *Our atoms were once parts of stars that died more than 4.6 billion years ago -- swept up into solar system when Sun formed*



Hot star: fierce winds

SN: Crab Nebula M1

4 July 1054

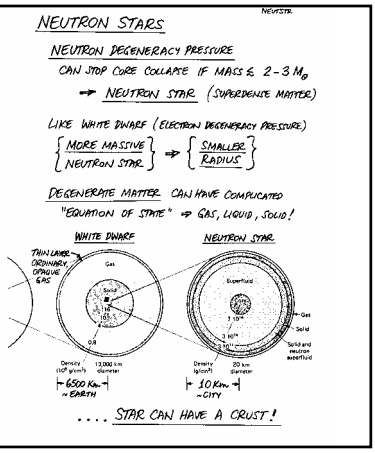
REMINDER

Neutron stars

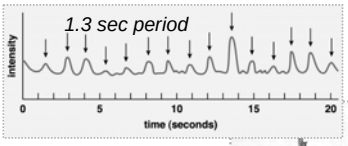
More massive, smaller in size!

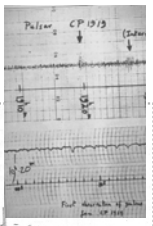
Star with a crystal crust !

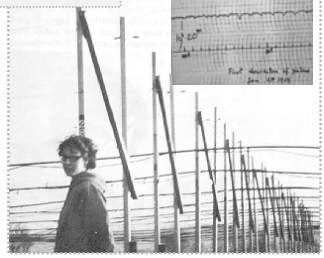
Idea of neutron stars first suggested in 1930s (Landau, Zwicki, Baade, Oppenheimer) … but seemed like wild dreaming



Observing the`First' Pulsar: BIG discovery

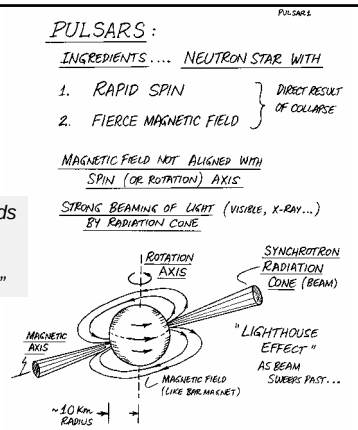






- Jocelyn Bell : Cambridge (UK) graduate student in 1967 (+ Anthony Hewish) discovered pulsars by accident
- Little Green Men (LGM) ? Just WHAT could cause signal?

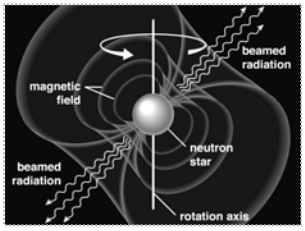
"Pulsar" = rotating neutron star



Fierce magnetic fields
+ sizzling electrons
+ fast rotation
→ finest "lighthouse"

Thomas Gold 1968

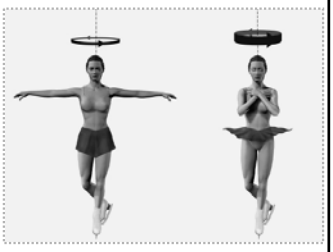
Pulsars and Neutron Stars



Pulsars are lighthouses in our Galaxy!

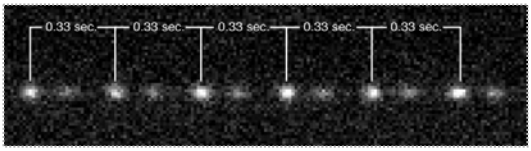
Why pulsars spin so fast: Vast shrinking conserves angular momentum

- *Collapse to a neutron star increases both rotation and magnetic fields*
- *Newly collapsed neutron stars can rotate hundreds to thousands of times per second !*



Mystery resolved when pulsar discovered in Crab Nebula (known to be supernova remnant) -- Messier 1 or M1 !

The Crab pulsar also pulses in visual light



Spinning Bowling Ball Demo

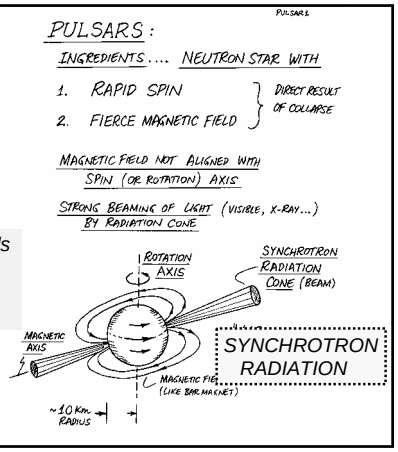
Neutron Star in the Lab

+ Sound on the Web

REMINDER

"Pulsar"
= rotating neutron star

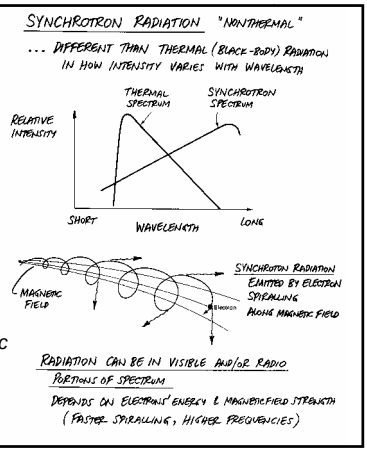
Fierce magnetic fields
+ sizzling electrons
+ fast rotation
→ finest "lighthouse"



Synchrotron radiation

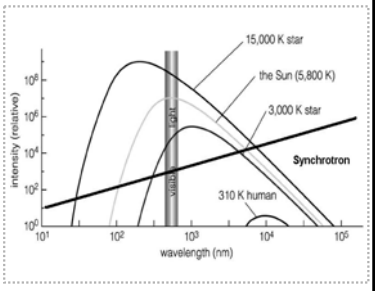
beaming from neutron star … and many other energetic places (quasars)

"scream from electrons" spiralling along magnetic fields – like in particle accelerators



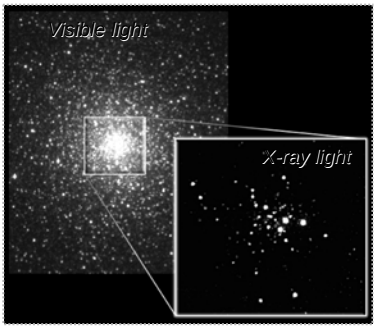
Synchrotron Radiation

- *Fast electrons in strong magnetic fields → neutron stars, black holes*
- *Different shape from thermal radiation: emits at all wavelengths, strongest in radio*



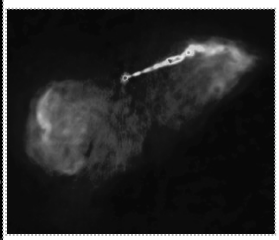
Visible vs. X-ray emission

- *Thermal light from stars → visible and IR*
- *Synchrotron light from neutron stars → X-ray and radio*



Visible Light vs. Radio
Thermal vs. Synchrotron

Elliptical galaxy -- visible



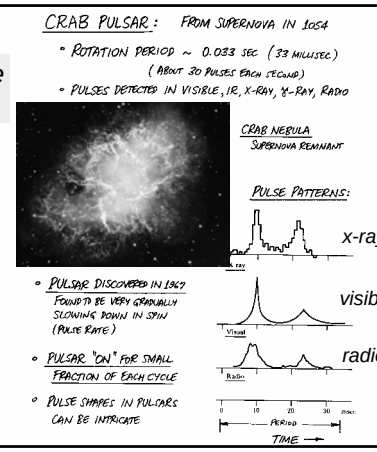
Same galaxy -- radio

Back to famous friend !

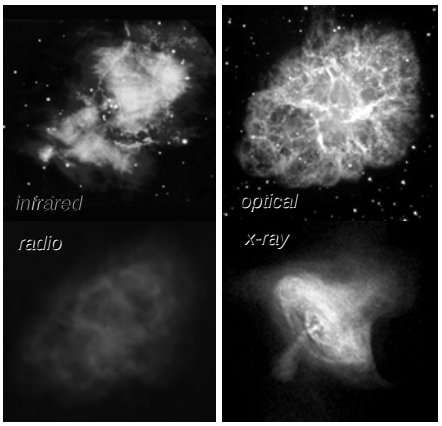
SN: Crab Nebula M1

4 July 1054

Crab's pulse patterns

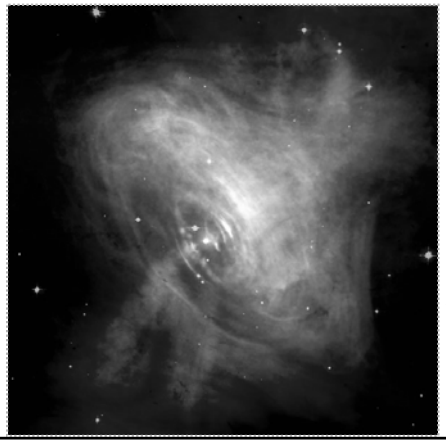


Crab Nebula SNR



Crab pulsar at work: Nov 00 – Apr 01

Chandra X-ray *HST Visible*

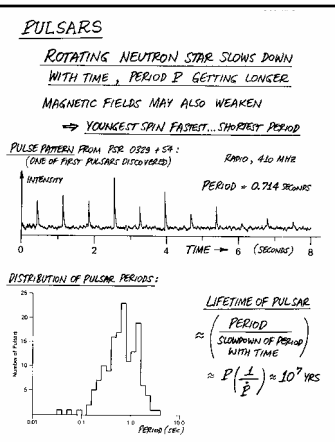


Chandra X-ray view of Crab center

Gradual slowing down of pulsar rotation

Energy emitted in pulses comes from rotational kinetic energy

(Listen to pulsars from our website)



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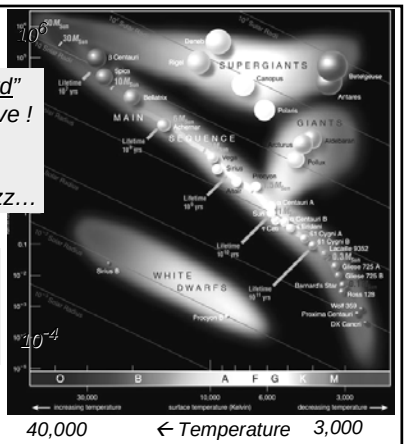


"Stellar graveyard" is very much alive !

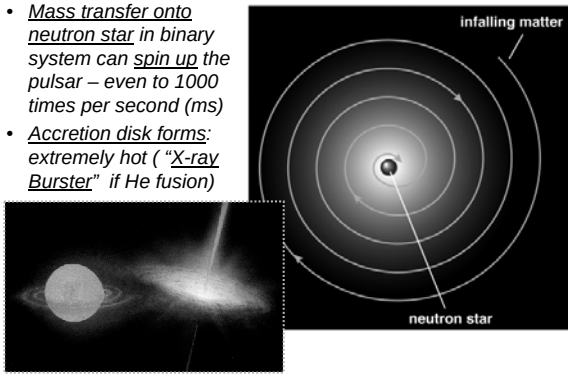
Mass transfer in binaries adds jazz…

white dwarfs, neutron stars or black holes -- all can play !

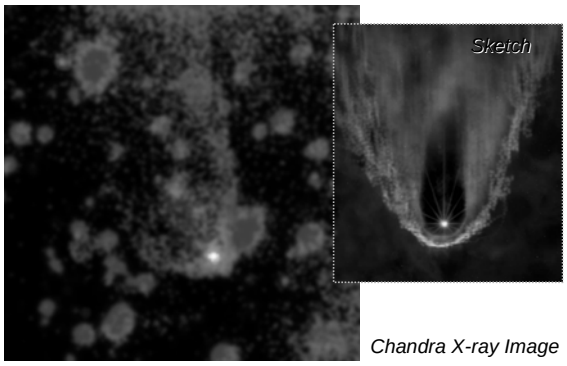
40,000 *← Temperature* *3,000*

Making a millisecond pulsars – spin it up!

- *Mass transfer onto neutron star in binary system can spin up the pulsar – even to 1000 times per second (ms)*
- *Accretion disk forms: extremely hot ("X-ray Burster" if He fusion)*



"Black Widow" millisecond pulsar –
evaporating companion star in cocoon has spun it up



Chandra X-ray Image

Clicker: Where have all the white dwarfs gone ..?

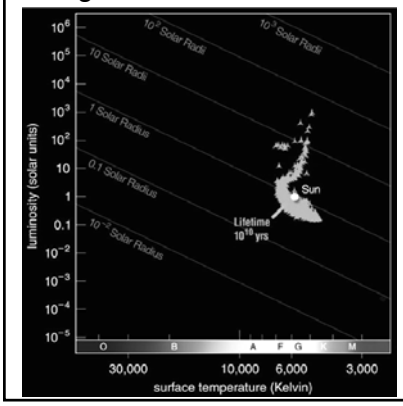
- *Imagine two star clusters, one 10 billion years old, and one very young. Which is more likely to have a lot of white dwarfs?*

- *A. the old one*
- *B. the young one*
- *C. can't tell*

A.

- Hint: what mass stars create white dwarfs?

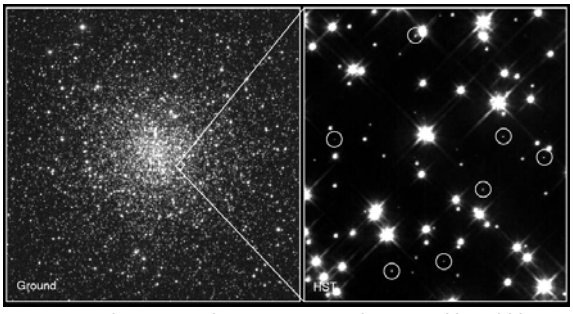
Old globular cluster – lots of white dwarfs



White dwarfs are mostly made by low-mass stars

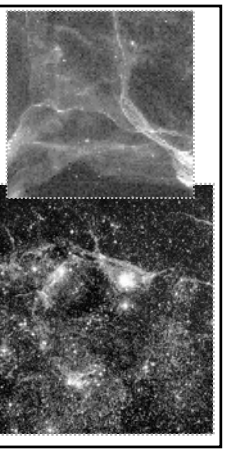
Their evolution proceeds slowly, so must wait for cluster to age

Old globular clusters have white dwarfs!



M3 from ground *Close-up with Hubble*

Observing Supernovae



- *About 1 per century per galaxy (none in Milky Way since 1604)* ☹
- *Bright explosion visible for weeks/months - some visible in daytime!*
- *Remnant visible for 10,000+ years as huge bubbles and "veils" – longer in radio*