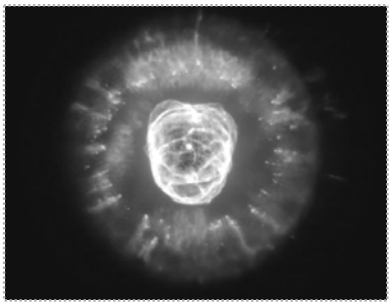
ASTR 1120: Stars & Galaxies



Eskimo planetary nebula

Prof. Juri Toomre TA: Ben Brown

Lecture 17 Fri 18 Feb 05

zeus.colorado.edu/astr1120-toomre

Topics for Today

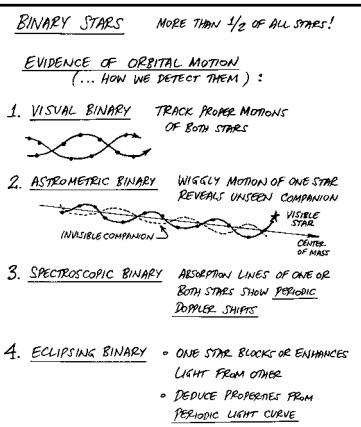
- Look further at *BINARY STARS* to measure STELLAR MASS
- We shall estimate *LIFETIMES* of stars on main sequence (MS)
- Observed *MASS-LUMINOSITY* relation reveals that *massive stars* have very short lives!
- *HW 4* due today, new *HW # 5* passed out
- Start overview reading *Chap 17 Star Stuff*

REMINDER

BINARY STARS

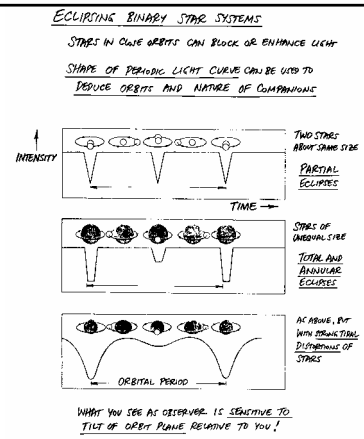
4 varieties:

Visual
Astrometric
Spectroscopic
Eclipsing

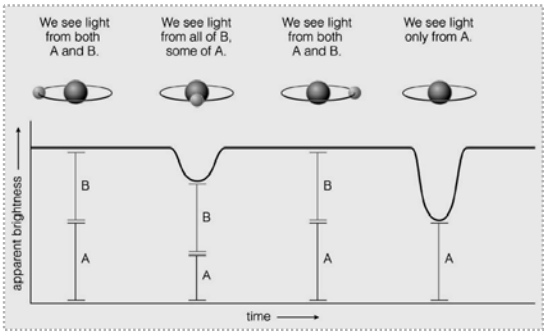


Eclipsing binaries

one star gets in front or behind other



Eclipsing: Variations in brightness with time



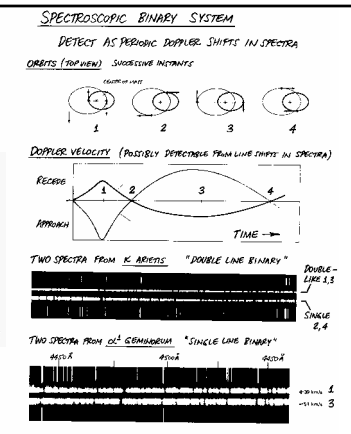
Very useful (can even infer stellar radii), but RARE … viewing angle has to be right on edge!

Spectroscopic binaries

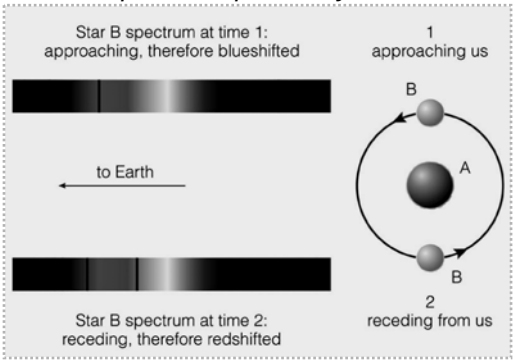
Most common of all

Don't see stars individually
-- but see shifting absorption lines

Sometimes TWO sets

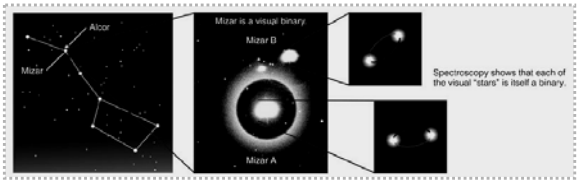


Spectroscopic Binary



Harder to interpret, since don't know viewing angle

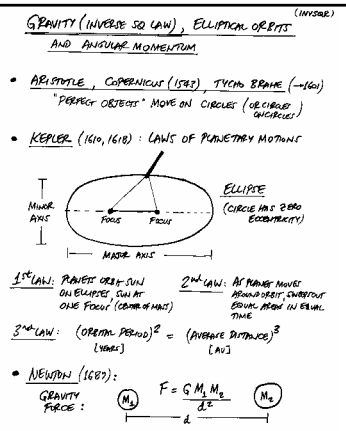
Mizar the "deamon" – four stars, actually



Recall from Chap 3:

KEPLER devised 3 laws for planetary (or stellar) motions

In 1687, NEWTON explained them as balance of gravity and centrifugal force

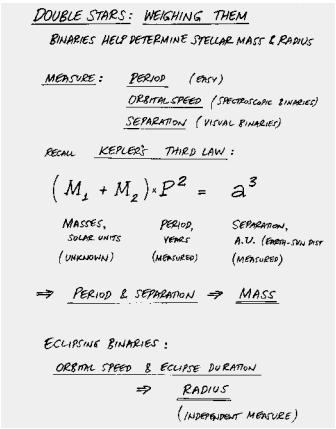


So why all the fuss with BINARIES?

Can really weigh a star !

STELLAR MASSES can be inferred from watching orbits

(via law of gravity – Kepler and Newton)

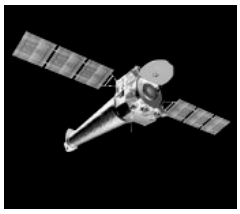


From mid-term answers

D.

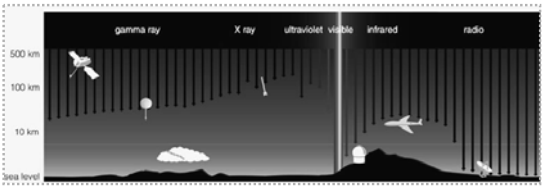
- *Chandra X-Ray Observatory is located:*

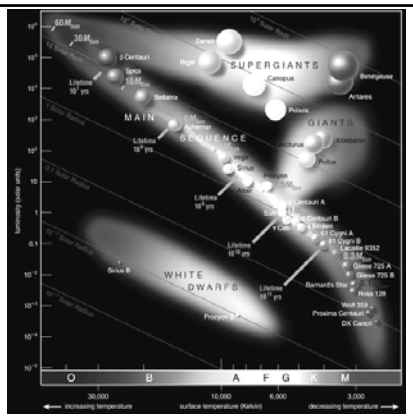
- A. in a deep gold mine in South Dakota
- B. on Mauno Kea, Hawaii
- C. on the high altitude desert in Chile
- D. in Earth orbit
- E. flying in a 747 with telescope cutout

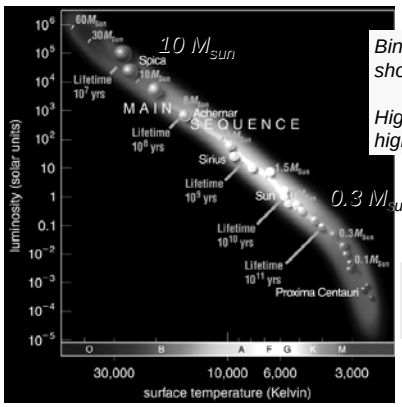


Chandra X-Ray Observatory was launched into orbit in 1999 – X-rays cannot penetrate atmosphere

Latest (2003) "Great Observatory" is Spitzer Space Observatory, in IR range of wavelengths





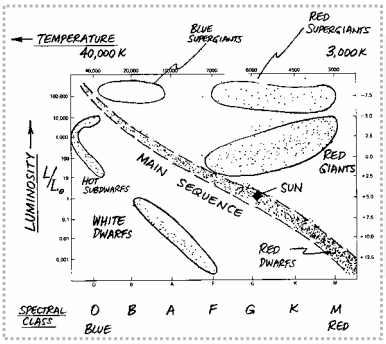


Binary stars show:

Higher on MS, higher MASS

But how long does a star live there ?

Main sequence (MS) stars



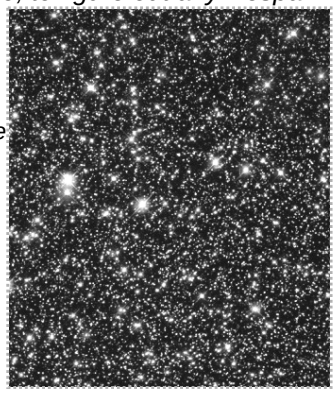
Burning <u>hydrogen in their cores</u>

<u>Temperatures are hotter</u> for more massive stars (crush of gravity)

<u>More luminous</u> (higher fusion rates)

Look at broad sample, to figure out any lifespan

- *Stars take millions to billions of years to go through their life stages - we rarely see a single star change*
- *Observing many different stars lets us figure out the sequence of a single star's life*



Lifetimes on Main Sequence (MS)

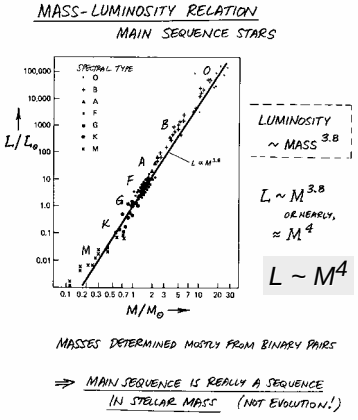
- *Stars spend 90% of their lives on MS*
- *Lifetime on MS = amount of time star burns <u>hydrogen (gradually) in its core</u>*
- *For <u>Sun</u>, this is about 10 billion years*
- *For <u>more massive stars</u> (OBAF), lifetime is (much) shorter*
- *For <u>less massive stars</u> (KM), lifetime is longer*
- *But <u>how</u> do we get these numbers?*

"Observed" MASS -- LUMINOSITY relation for main sequence

But why such a <u>steep</u> variation with mass ?

BIGGER CRUSH OF GRAVITY needs

→ HIGHER central PRESSURE (or temperature)
→ FASTER BURNING (CNO-fusion-cycle comes into play)



Estimating LIFE on MS

Four steps in our estimate

Simple play with numbers – just be bold!

"LIFE EXPECTANCY" ON MAIN SEQUENCE

1. CONSIDER SUN ($1\ M_\odot$) AS EXAMPLE:
   ~ 10% BY TOTAL MASS CAN CORE BURN 0.1
   0.7% MASS ⇒ ENERGY 0.007
2. TOTAL ENERGY SUPPLY: $(E = mc^2)$
   $E_{TOTAL} = 0.1 \times 0.007 \times \underbrace{M_\odot c^2}_{1.8 \times 10^{54}\ ergs}$
   $= 1.3 \times 10^{51}\ ergs$
3. ENERGY LOST AT RATE: (LUMINOSITY)
   $L_\odot = 3.9 \times 10^{33}\ ergs/sec$
4. LIFETIME ON MAIN SEQUENCE:
   LUMINOSITY × LIFETIME = TOTAL ENERGY OUTPUT
   $L_\odot \times t_{LIFE} = E_{TOTAL}$
   OR $t_{LIFE} \sim \frac{E_{TOTAL}}{L_\odot} = 3 \times 10^{17}\ sec$
   $= 10$ BILLION YEARS (BY)!

SUN IS MIDDLE AGED, OR ABOUT 5 BY OLD

How long can other stars burn H in their cores?

More massive star have (very) short lives

TIME TO BURN UP HYDROGEN IN CORE
... OR "LIFE ON MAIN SEQUENCE"

OTHER STARS COMPARED TO SUN:

ENERGY: $E_{TOTAL} \propto$ MASS $(\propto M)$
$\propto$ PROPORTIONAL TO

LUMINOSITY: $L \propto (MASS)^{3.8}\ (\simeq M^4)$ ← MASS-LUMINOSITY RELATION

LIFETIME: $t_{LIFE} \sim \frac{E_{TOTAL}}{L} \propto M^{-3}$ (ROUGHLY)

⇒ MASSIVE STARS HAVE SHORT LIVES!

MASS $(M_\odot)$	LIFETIME (MILLION YEARS)
1	10,000 MY = 10 BY
2	700
3	250
5	70
10	20
15	10
30	5

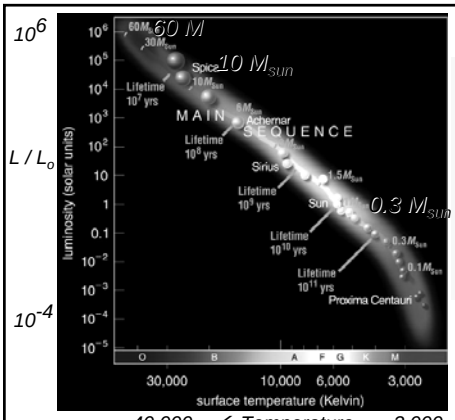
(LEVELS OFF AT A FEW MY)

Short lives of massive stars on MS

- *Rock-star analogy:*

More massive, hotter, more luminous stars <u>burn through the available fuel faster</u> -- leading to early burnout

C-N-O fusion cycle is the way massive stars do it !



Thus we get this huge range of LIFETIMES on MS

Higher on MS, <u>higher MASS</u>, <u>shorter LIFE</u>

How to hold up all stars: <u>PRESSURE</u>

- *What is difference between FORCE and PRESSURE ?*
- *Can a BED OF NAILS support an astronomer ? Or YOU ? … time for truth*
- *Maybe it is all about PRESSURE ….. which is FORCE divided by AREA*