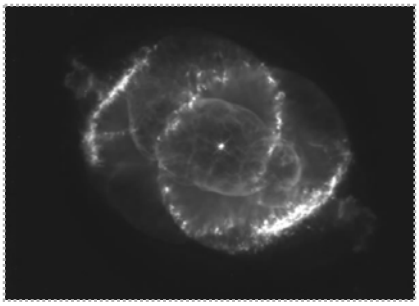
ASTR 1120: Stars & Galaxies



Cat's Eye Planetary Nebula

Prof. Juri Toomre TA: Ben Brown

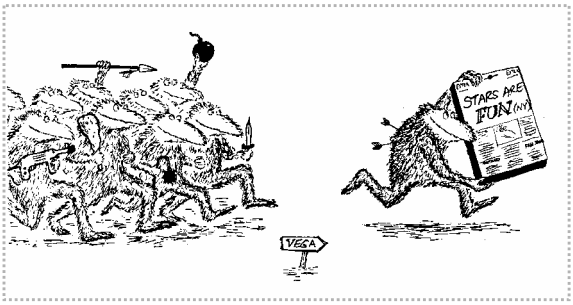
Lecture 16 Wed 16 Feb 05

zeus.colorado.edu/astr1120-toomre

Topics for Today

- How do we measure *brightness* of stars: and why *apparent vs absolute magnitudes*?
- We shall use *binary stars* to determine *stellar masses*
- Detail read *16.5 H-R Diagram + 16.6 Star Clusters* -- overview read *Chap 17 Star Stuff*
-
- *Mid-Term Exam 1* (graded) returned today – plus answer sheets
- *Homework Set 4* due in class this Friday
- *Solar Observing Day 2 – tomorrow (bright)*
- *Review (Crib) Sheet # 1* competition today

So did we really love this exam?



RESULTS FROM FIRST MID-TERM EXAM

FIRST MID-TERM EXAM

- *Grade boundaries, based on 145 points:*
- *If 123/145 (85%) or over, A's [24%]*
- *112/145 (77%) or over, B's [28%]*
- *84/145 (58%) or over, C's [36%]*
- *70/145 (48%) or over, D's [7%]*

Also +, plain, and – within these ranges

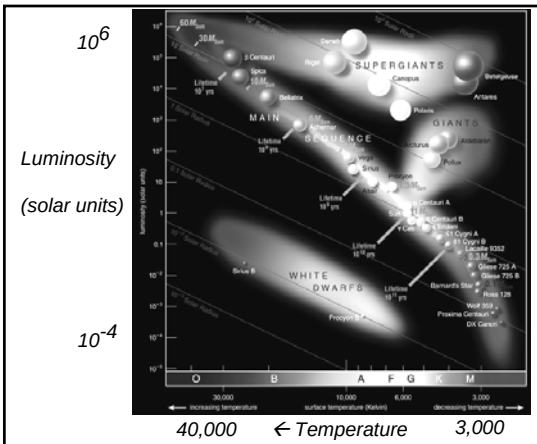
Median grade 78%; highest 98% (1), 97% (1)

Go through answer sheet – and talk to us if do not understand our choices. Keep exam + answers for future review (comp final)

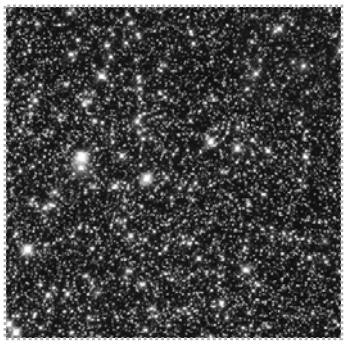
Oh to describe a star ! B.

- *Which is a red supergiant ?*

- *A. Spectral type G2, luminosity class V*
- *B. Spectral type M2, luminosity class I*
- *C. Spectral type O9, luminosity class I*
- *D. Spectral type M1, luminosity class V*



Magnitudes: Apparent vs Absolute



- *Giving measures to stellar luminosities*
- *Built on choices made by Greeks!*

Stellar MAGNITUDES

MAGNITUDES : BLAME WEIRD SCALE ON GREEKS .... AND REPAIR BY HERSCHEL

1. GREEKS ASSIGNED
   BRIGHTEST STAR MAGNITUDE 1
   :
   FAINTEST STAR VISIBLE TO EYE MAG 6
   } DIFFERENCE OF 5 "MAGNITUDES"
2. HERSCHEL CONCLUDED THIS WAS ABOUT 100 : 1 IN BRIGHTNESS
   ASSIGNED APPARENT MAGNITUDE $m_V = 0$ TO BRIGHT STARS VEGA AND RIGEL KENT
3. NOW THE PRESENT SYSTEM :
   BRIGHTNESS UP ↑ BY FACTOR 2.512
   MAGNITUDE DOWN ↓ BY 1 UNIT

MAGNITUDE	RELATIVE BRIGHTNESS
5	1.0
4	2.512
3	6.310 = $(2.512)^2$
2	15.849 = (")^3
1	39.811 = (")^4
0	100.000 = (")^5

Weird system: brighter is smaller magnitude, even negative!

Of cultural importance, even if a bit confusing (secret society!)

Measuring BRIGHTNESS

magnitudes

m

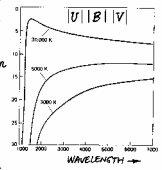
apparent mag: what looks like in sky

M

absolute mag: what would look like if at 10pc distance (LUMINOSITY)

MEASURES OF BRIGHTNESS FIRST STARS, NOW GALAXIES...

1. APPARENT MAGNITUDE m
   ACTUALLY MEASURE HOW BRIGHT AN OBJECT APPEARS IN SKY
   DEPENDS ON SPECTRAL REGION (COLOR) WHERE MEASURED
   USE FILTERS : m
   U ULTRA-VIOLET ⇒ m_U
   B BLUE m_B
   V VISUAL m_V
   etc...



2. BOLOMETRIC MAGNITUDE
   ADD UP BRIGHTNESS AT ALL WAVELENGTHS
   ... BUT DIFFICULT TO MEASURE
3. ABSOLUTE MAGNITUDE M
   MAGNITUDE STAR WOULD HAVE IF AT DISTANCE OF 10 PARSECS (32.6 LY)
   NEED m AND DISTANCE !

(Slightly) screwy world of MAGNITUDES

IF can estimate distance, then can determine M given m

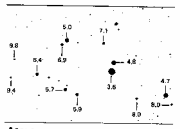
M = m if at distance 10pc

MAGNITUDES: HANDY RESULTS TO RECALL

5 MAGNITUDES = FACTOR OF 100 IN BRIGHTNESS

MAGS. CAN BE NEGATIVE

BOL. MAG. < APPARENT MAG.



ABSOLUTE MAGNITUDE M < APPARENT MAG m IF DISTANCE > 10 PC (32.6 LY)

M > m IF DISTANCE < 10 PC

VISUAL MAGNITUDES OF "NEARBY OBJECTS"

Object	Apparent Magnitude (m_v)	Distance (ly)	Absolute Magnitude (M_v)
Sun	−26.7	1.5×10^{-8}	+ 4.8
Moon (full)	−12.5	4.0×10^{-9}	+30.1
Venus (at brightest)	− 4.4	4.4×10^{-8}	+29.0
Sirius	− 1.5	8.8	+ 1.4
Rigil Kent (Alpha Centauri)	0.0	4.3	+ 4.4
Vega	0.0	25.0	+ 0.3
Deneb (Alpha Cygni)	+ 1.3	1.8×10^3	− 7.2
G51-15 (nearby star)	+14.8	11.9	+17.0
Andromeda Galaxy	+ 3.5	2.25×10^6	− 21.2

Color Index: B - V

magnitudes assigned using photometric FILTERS

(quicker than taking spectra to classify stars)

COLOR INDEX : QUICK MEASURE OF SPECTRAL CLASS OF STAR

$B - V = m_B - m_V$

FILTERS: (BLUE) (VISUAL) DIFFERENCE OF TWO APPARENT MAGNITUDES

- FOR BLUER (OR HOTTER) STAR
  m_B SMALLER (BRIGHTER)
  m_V LARGER (FAINTER)
  ⇒ $B-V$ SMALLER (OR MORE NEGATIVE)

- OPPOSITE FOR REDDER (OR COOLER) STAR

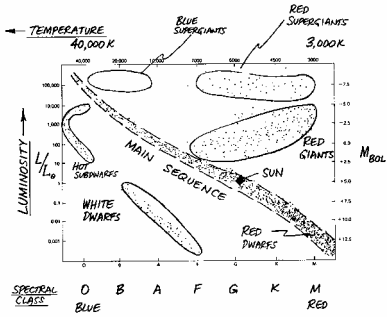
SPECTRAL CLASS	INTRINSIC COLOR	B-V COLOR INDEX	SURFACE TEMPERATURE
O	BLUE	−0.32	41,000 K
B	BLUE	−0.22	30,000
A	BLUE-WHITE	ZERO	9,000
F	WHITE	+0.33	7,000
G	YELLOW-WHITE	+0.60	6,000
K	ORANGE	+0.81	5,000
M	RED	+1.41	3,000

Hertzsprung-Russell (H-R) Diagram

Luminosity (magnitude) vs Spectral class (temperature)

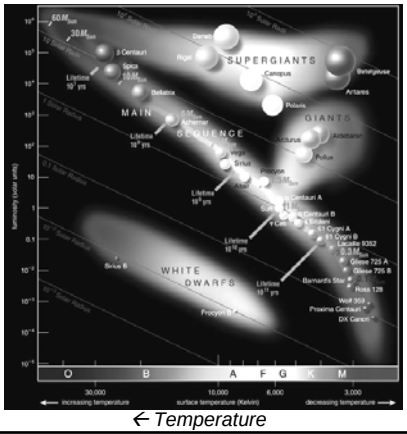
H-R DIAGRAM

EJNAR HERTZSPRUNG (DANISH) } 1911 - 1913
HENRY NORRIS RUSSELL (AMERICAN)



Stellar puzzle B.

- *Two stars, Antony and Cleopatra, are both of spectral class M3, and of the <u>same</u> apparent brightness (magnitude) in the sky. Cleopatra shows <u>narrow absorption lines</u> in her spectrum, Anthony <u>broad</u> ones. Which star must be far more distant?*
- *A. Antony*
- *B. Cleopatra*



← *Temperature*

Cleopatra has

<u>NARROW absorption lines</u> → giant or supergiant

MUCH MORE LUMINOUS

Estimating the size of a star -- its <u>RADIUS</u>

Stefan-Boltzmann

MEASUREMENTS OF STARS:

TEMPERATURE (FROM SPECTRAL LINES)

BRIGHTNESS } ⇒ LUMINOSITY

DISTANCE ("NEARBY" STARS < 100 pc)

RECALL STEFAN – BOLTZMANN LAW:

$$L = 4\pi R^2 \times \sigma \times T^4$$

L: LUMINOSITY (MEASURED); R: STAR'S RADIUS (UNKNOWN); σ: CONSTANT; T: TEMPERATURE (MEASURED)

⇒ LUMINOSITY & TEMP ⇒ RADIUS

BUT HOW TO GET THE MASS?

(TRICKIER: USE BINARIES)

"<u>Proper motions</u>"

wiggly motions (parallax)

and binaries …

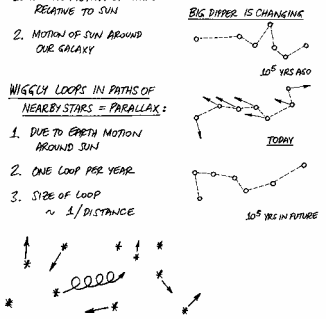
STELLAR MOTIONS IN SKY...
WITH RESPECT TO "FIXED STARS"

PROPER MOTION CAUSED BY:

1. ACTUAL MOTION OF STARS RELATIVE TO SUN
2. MOTION OF SUN AROUND OUR GALAXY

WIGGLY LOOPS IN PATHS OF NEARBY STARS = PARALLAX:

1. DUE TO EARTH MOTION AROUND SUN
2. ONE LOOP PER YEAR
3. SIZE OF LOOP ~ 1/DISTANCE



<u>BINARY STARS</u>

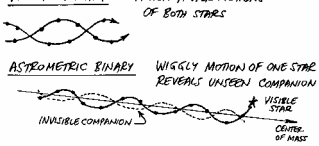
4 varieties:

Visual
Astrometric
Spectroscopic
Eclipsing

BINARY STARS MORE THAN ½ OF ALL STARS!

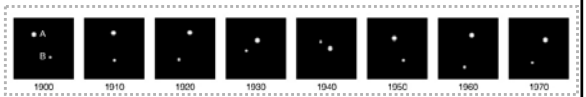
EVIDENCE OF ORBITAL MOTION (... HOW WE DETECT THEM):

1. VISUAL BINARY — TRACK PROPER MOTIONS OF BOTH STARS
2. ASTROMETRIC BINARY — WIGGLY MOTION OF ONE STAR REVEALS UNSEEN COMPANION



3. SPECTROSCOPIC BINARY — ABSORPTION LINES OF ONE OR BOTH STARS SHOW PERIODIC DOPPLER SHIFTS
4. ECLIPSING BINARY
   - ONE STAR BLOCKS OR ENHANCES LIGHT FROM OTHER
   - DEDUCE PROPERTIES FROM PERIODIC LIGHT CURVE

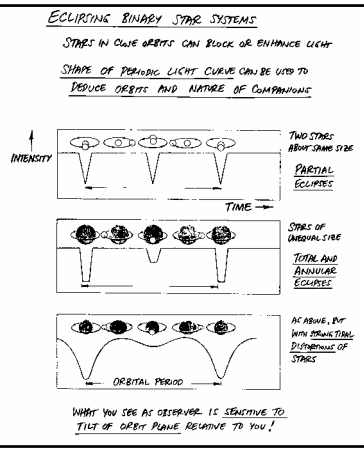
<u>Visual binary</u>: Sirius A and Sirius B



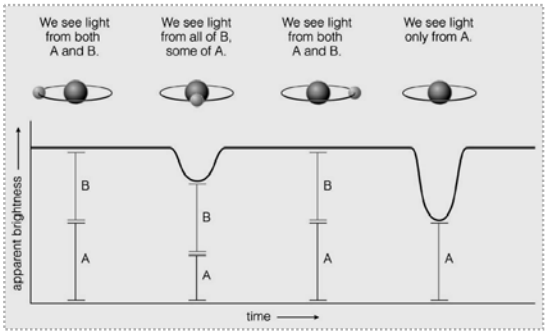
Rare: need to be very near, widely spaced

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!