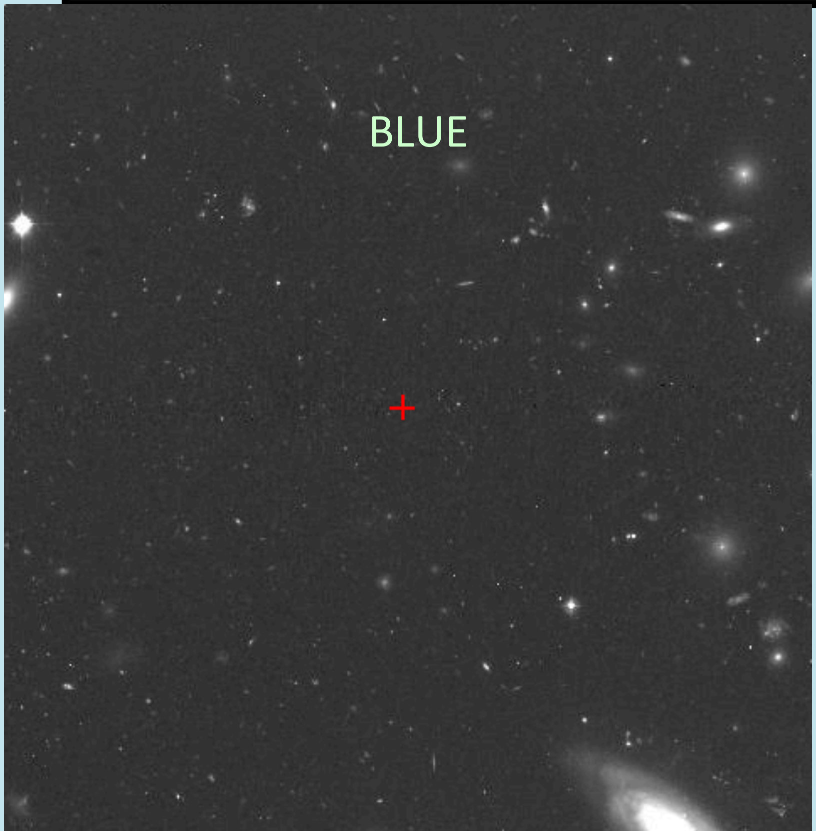
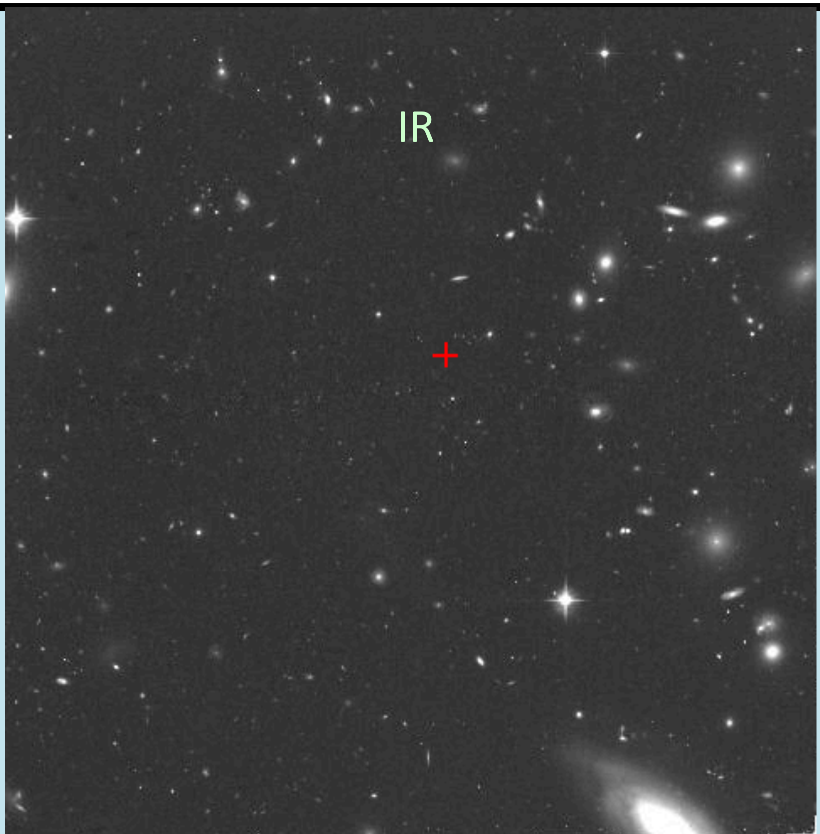
Getting information from astronomical images

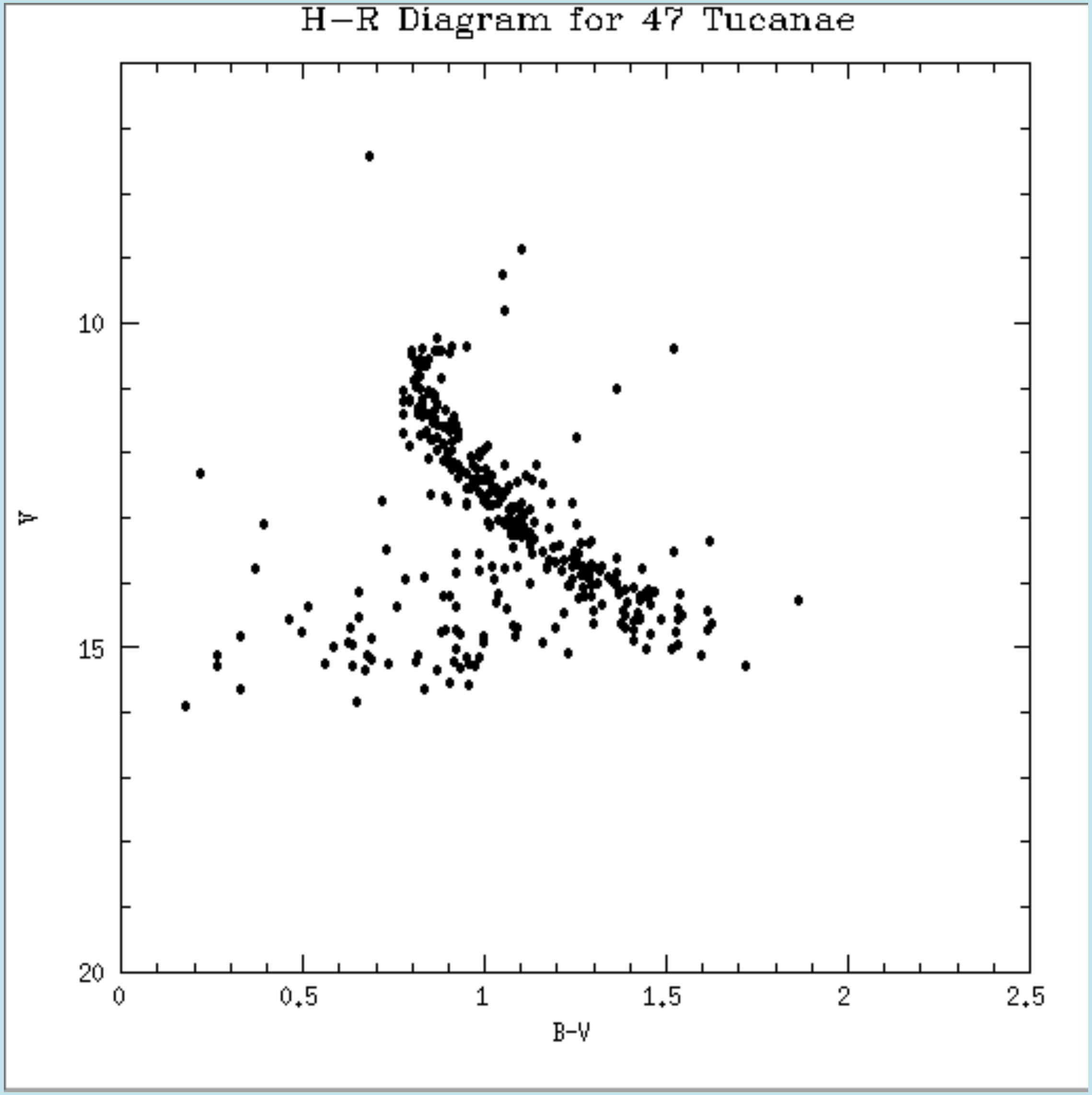
We can determine **temperature, power emitted (luminosity), distance, lifetimes, ages** and **metal abundances** of stars by measuring their flux in two different wavelengths (e.g. Blue and "Visible"; Blue and IR, Red and IR, UV and Red etc...)



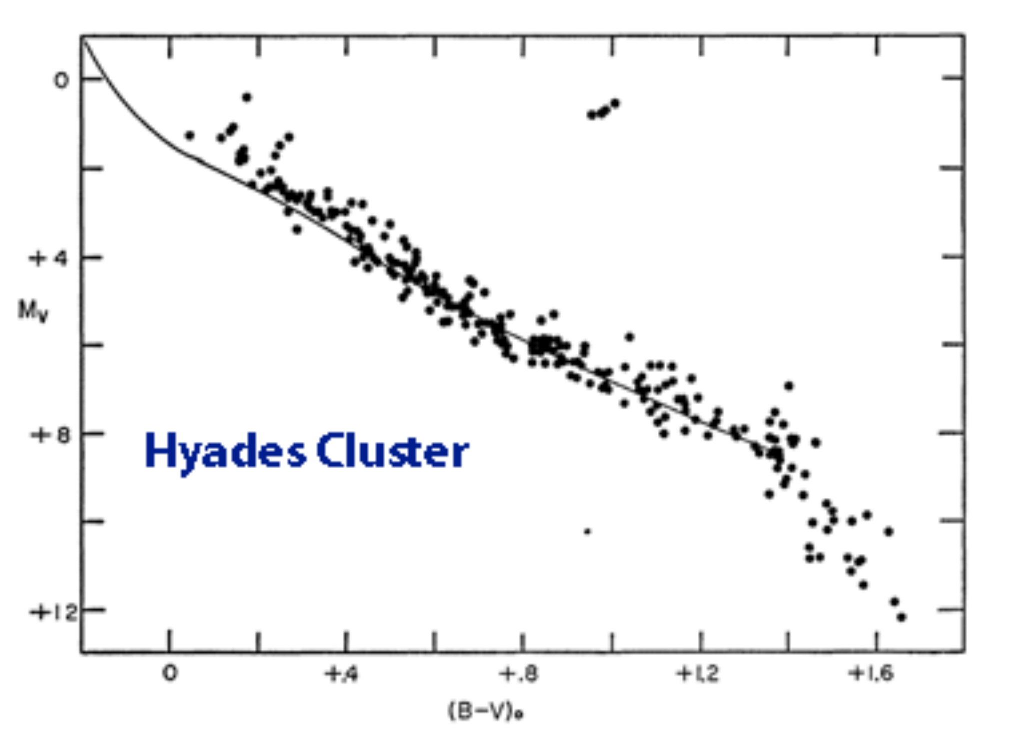


Getting information from astronomical images: Hertzsprung-Russell Diagram

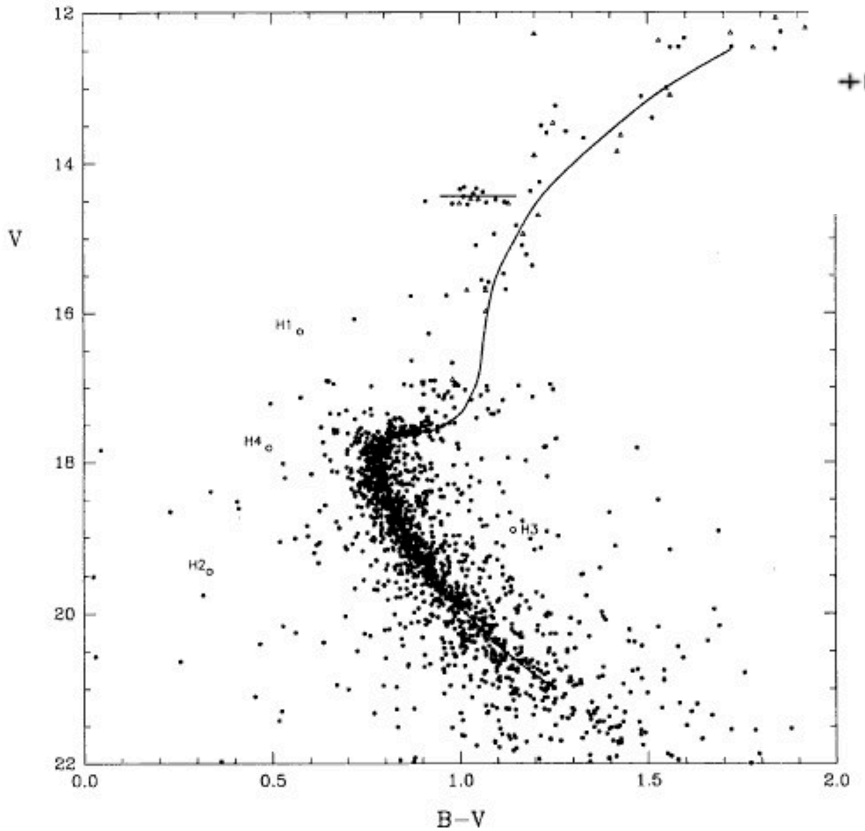
HR Diagram is a plot of brightness or flux from one band against the "color" of the star(s). Color is the ratio of fluxes in two wavelengths (B-V, V-R, etc). How your data falls on this plot will determine stellar age, lifetime, etc.



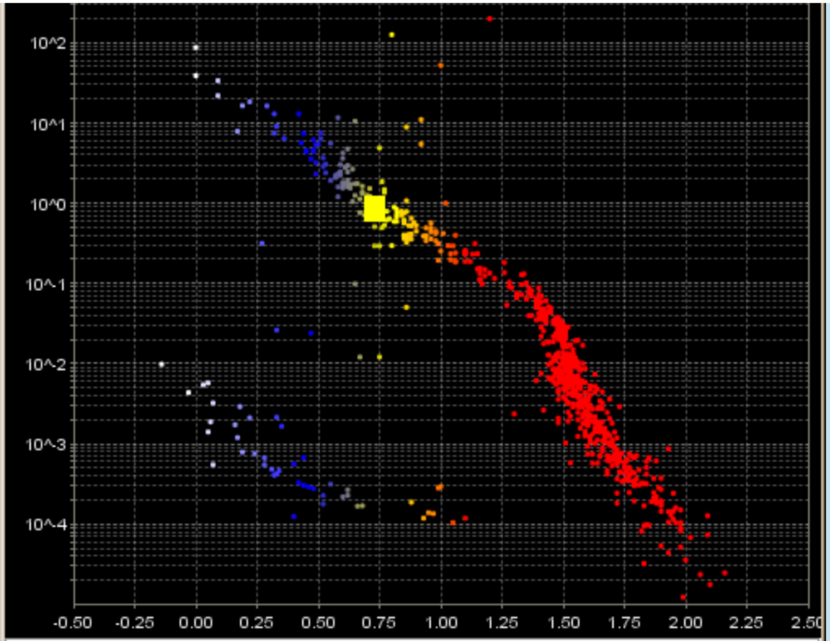
HR diagrams



Hyades Cluster
M_V
0
+4
+8
+12
+.4
+.8
+1.2
+1.6
$(B-V)_o$

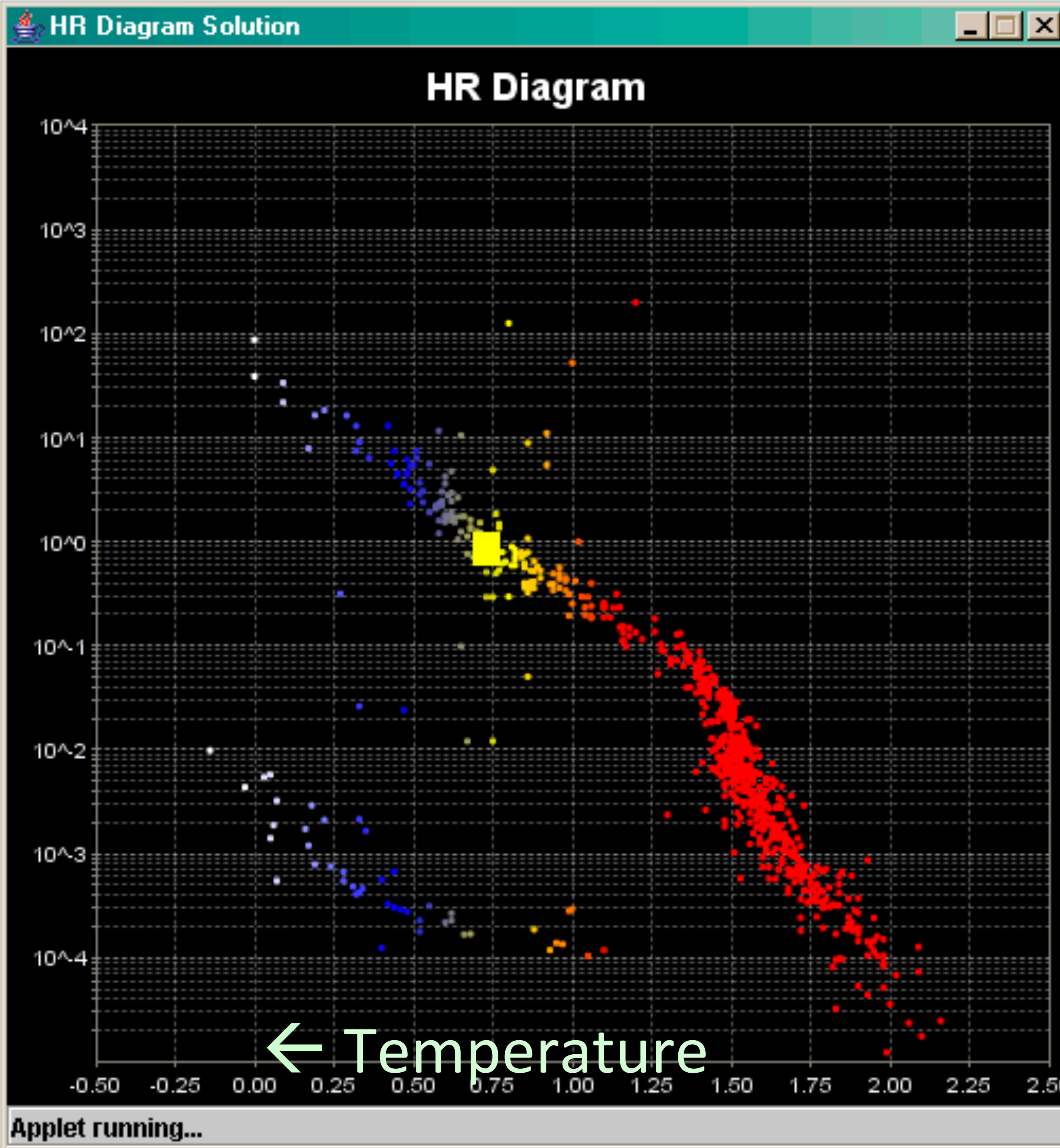


V
B−V
12
14
16
18
20
22
0.0
0.5
1.0
1.5
2.0
H1
H2
H3
H4

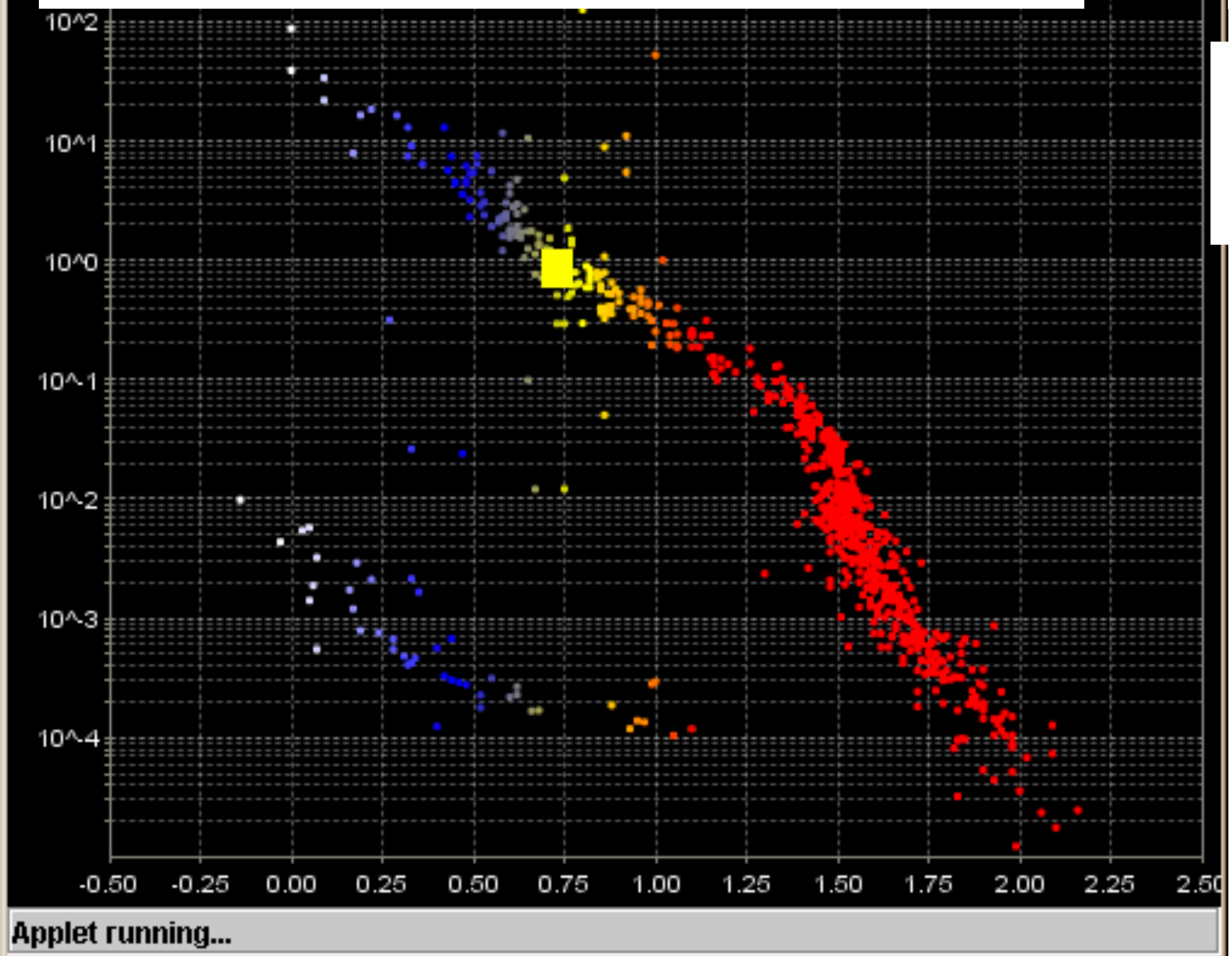


10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25

Luminosity →


HR Diagram Solution
HR Diagram
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-3
10^-4
-0.50
-0.25
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
← Temperature
Applet running...

Underlying physics model of main sequence (MS) stars→



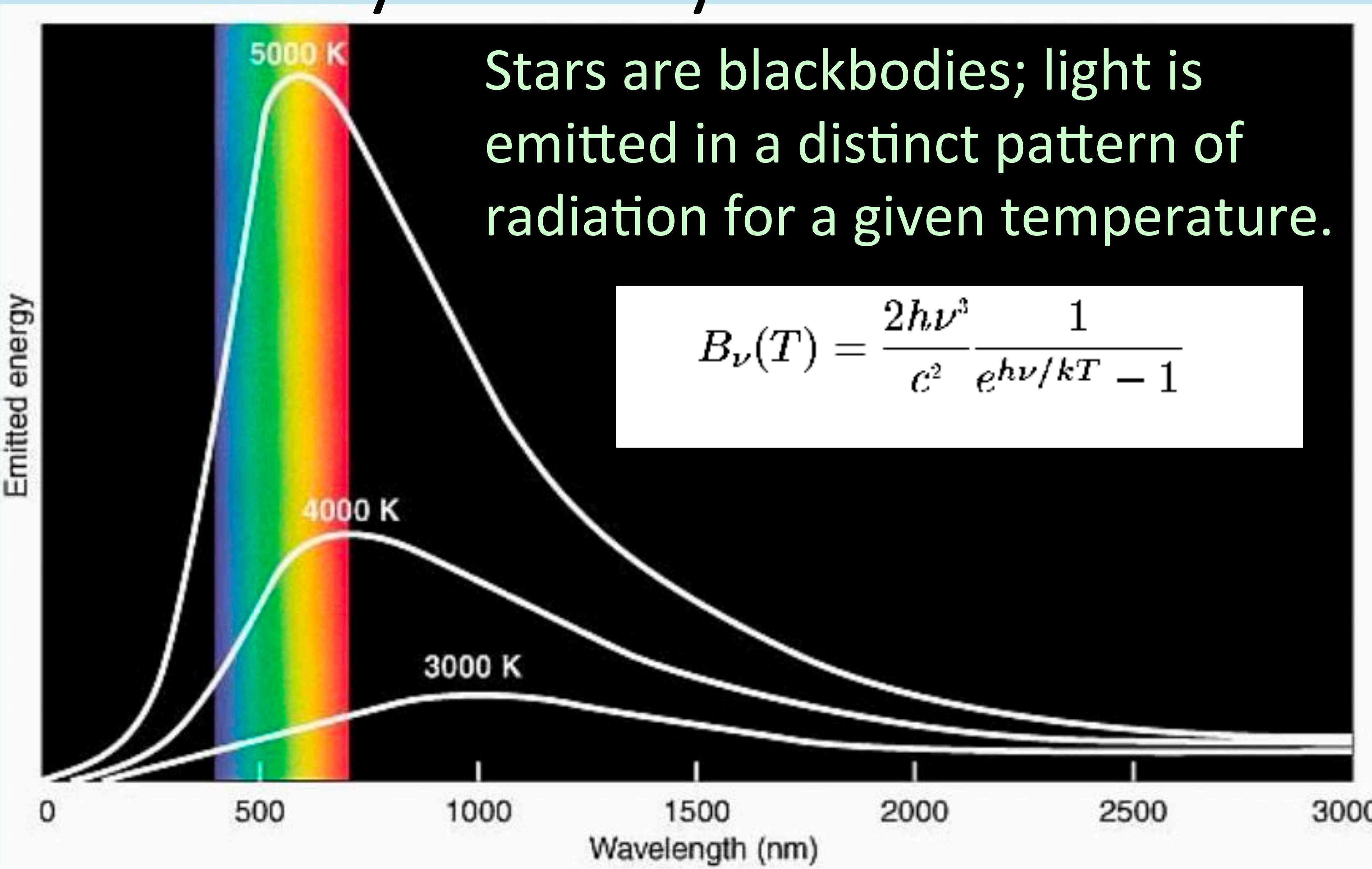
$$\frac{dM_r}{dr} = \rho(r) 4\pi r^2$$

$$\frac{dP(r)}{dr} = -\frac{GM_r \rho(r)}{r^2}$$

$$\frac{dL_r}{dr} = \epsilon \rho(r) 4\pi r^2,$$

$$f(r) = -\lambda \frac{dT(r)}{dr}$$

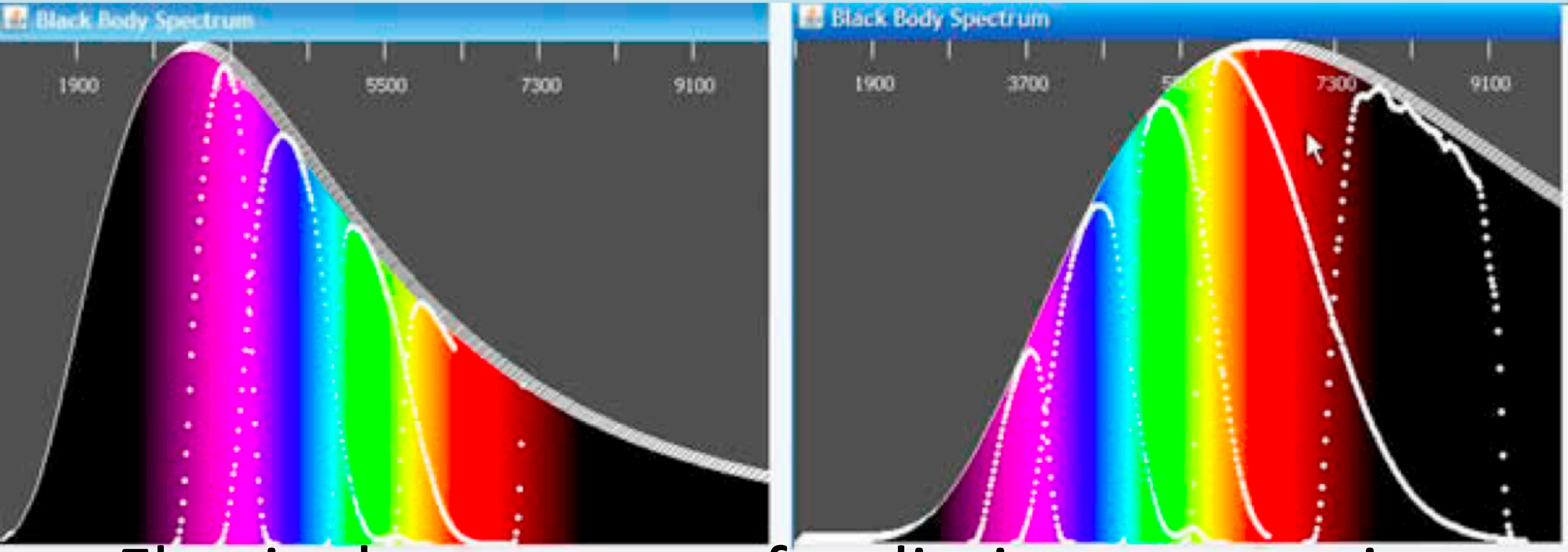
Physics: Why this works



Stars are blackbodies; light is emitted in a distinct pattern of radiation for a given temperature.

$$B_\nu(T) = \frac{2h\nu^3}{c^2}\frac{1}{e^{h\nu/kT} - 1}$$

White lines are filter bandpasses. Different amounts of flux are emitted in each band for a given temperature.



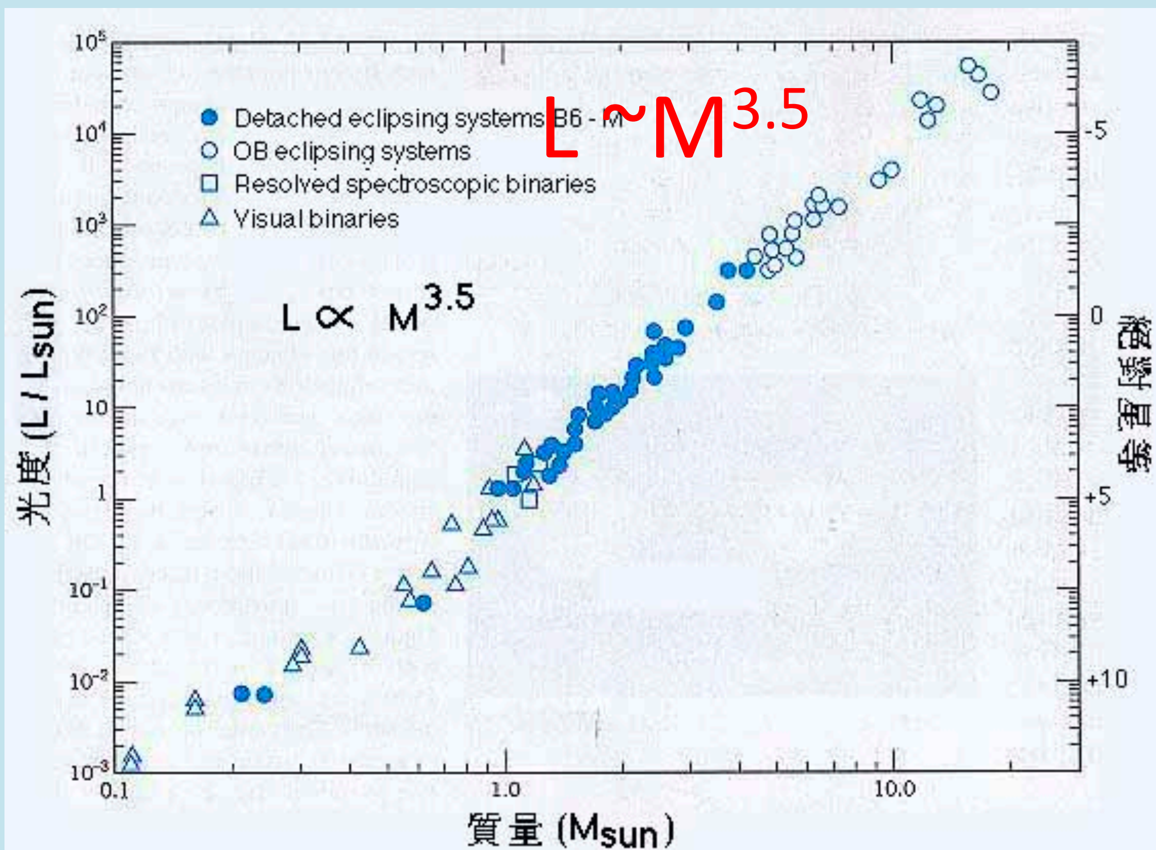
Flux is the amount of radiation we receive at Earth (~Luminosity/distance^2)

Mass and Temperature

- What determines MS stellar surface temperature?
  → **Mass**
- Each layer in star is in balance between gravity pressing down and pressure generated from core.
- More massive stars need more pressure generated to support star which comes from hot photons generated by nuclear reactions in core (fusion of hydrogen into helium)
- Result – big stars have hotter surface temperature and emit more photons.
- Other than these physics equations, how do we know that hotter stars are more massive?

Luminosity and Mass Relationship

Masses are measured from MS binary stars and Kepler's 3rd law $(M1+M2) \sim a^3/p^2$



Implications of Luminosity and Mass Relationship

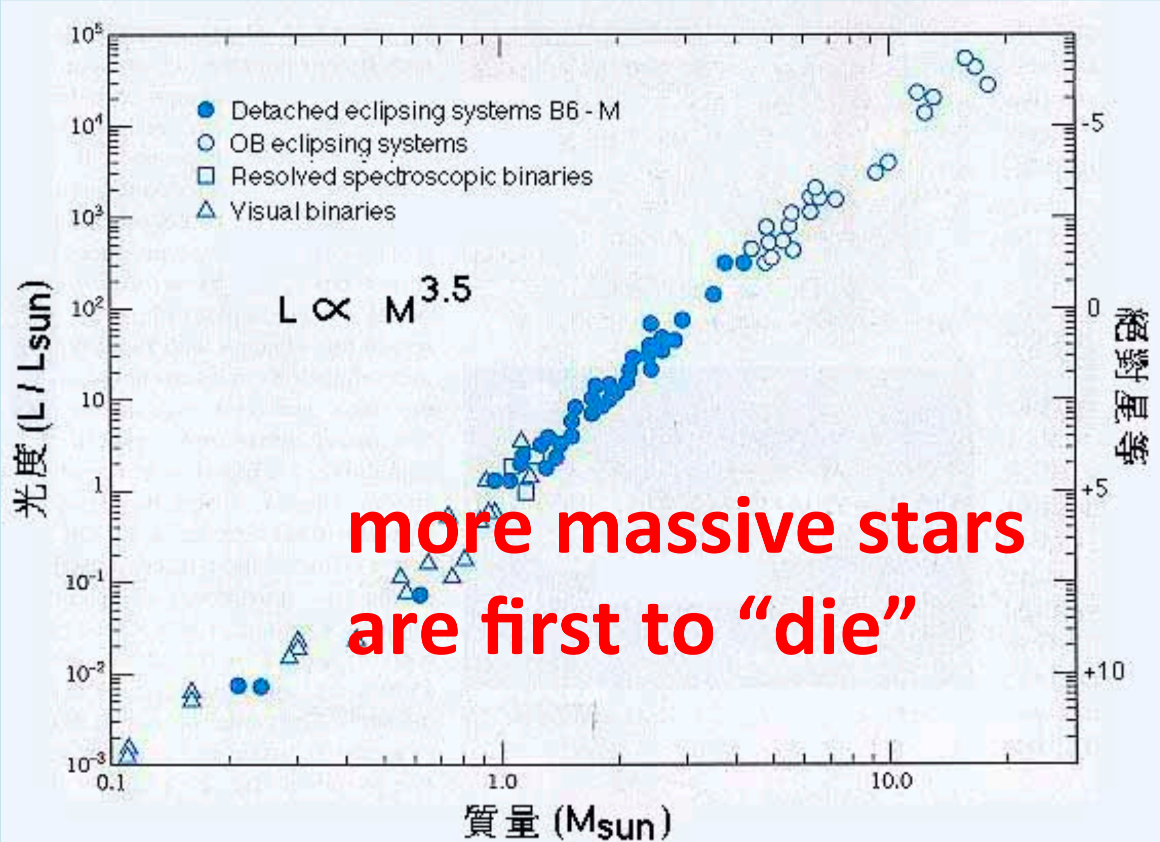
Lifetime of star is simply:

Lifetime = fuel/power output or

Lifetime ~ M/L

In solar units this is:

$M/L*10^{10}$ years

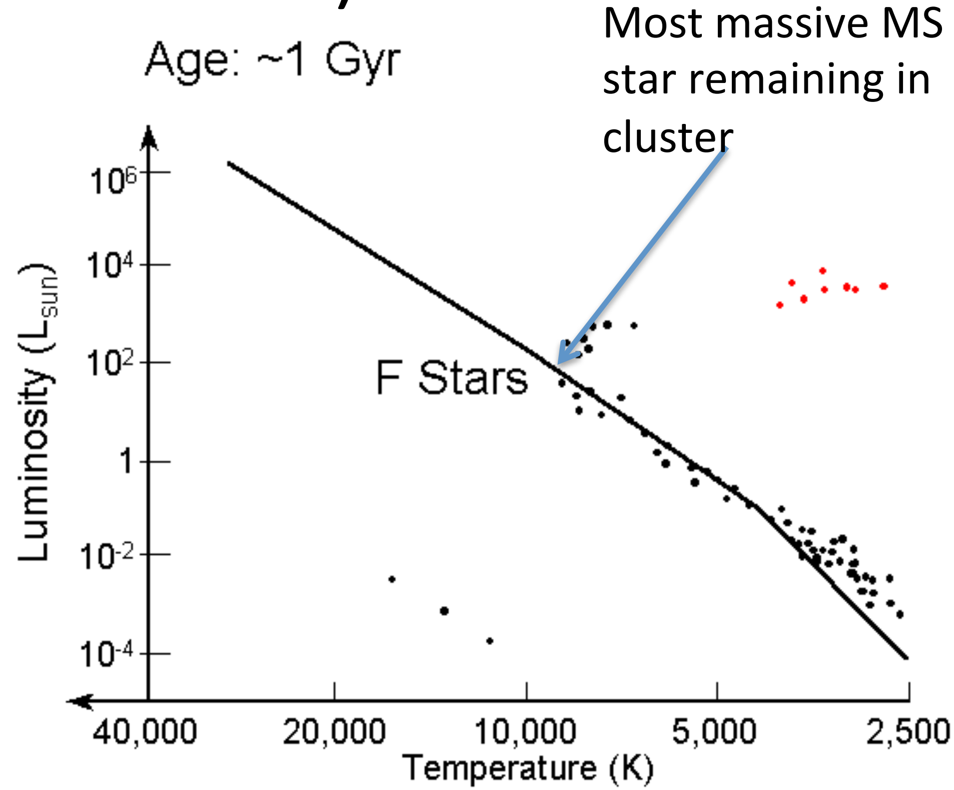


Stellar Clusters as Laboratories

- Stars are "born" from a collapsed molecular cloud of gas. Several stars are created at once, not one at a time.
- Stars still gravitationally bound to their "siblings" are part of a cluster
- Clusters are ideal to study:
  - ***<u>Stars are the same age</u>***
  - Same initial chemical composition
  - ***<u>same distance to Earth</u>***

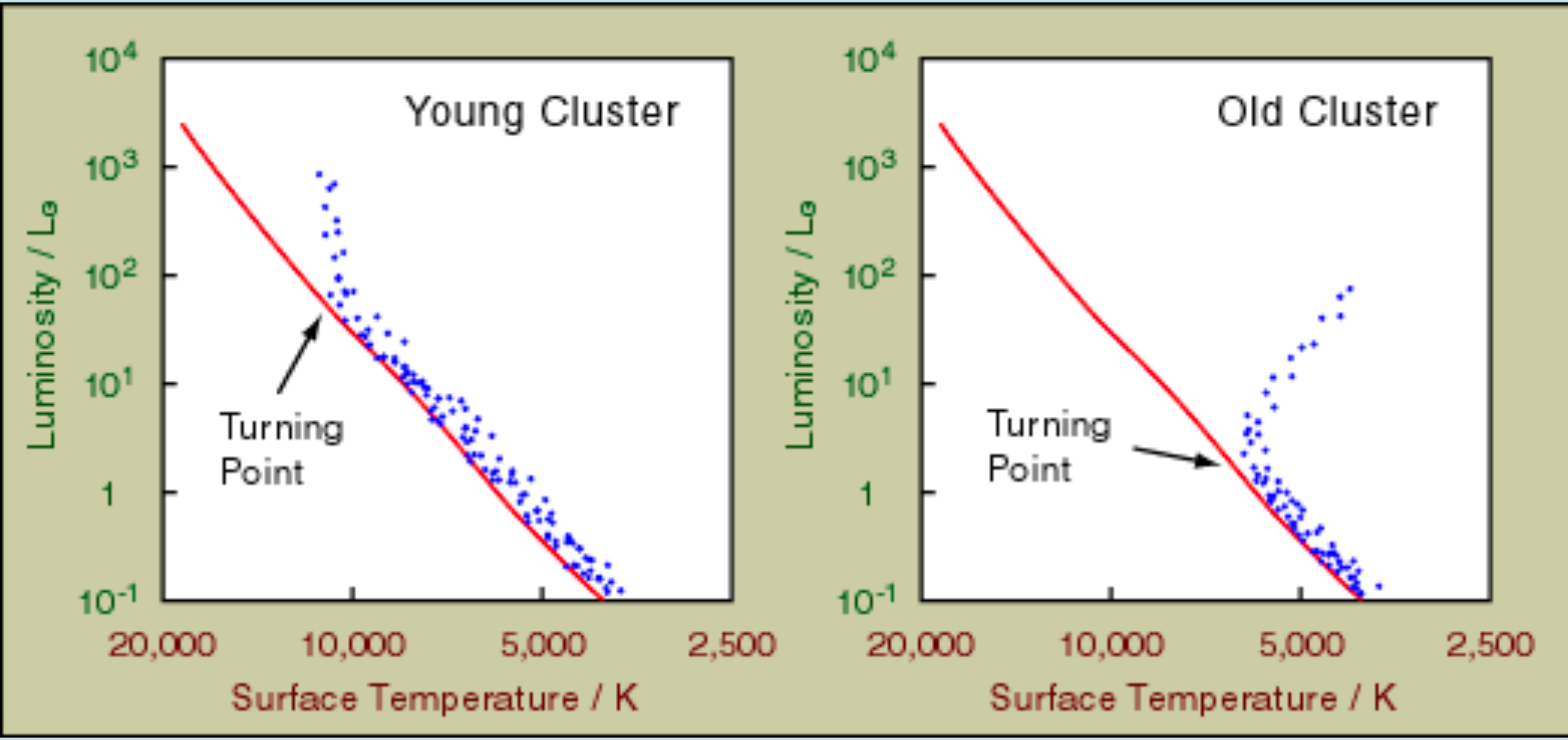
Age of Clusters

- Bigger MS stars die* first. Knowing lifetimes of stars we can determine age of a cluster.
- Dead stars expand and redden in color (surface temperature cools)



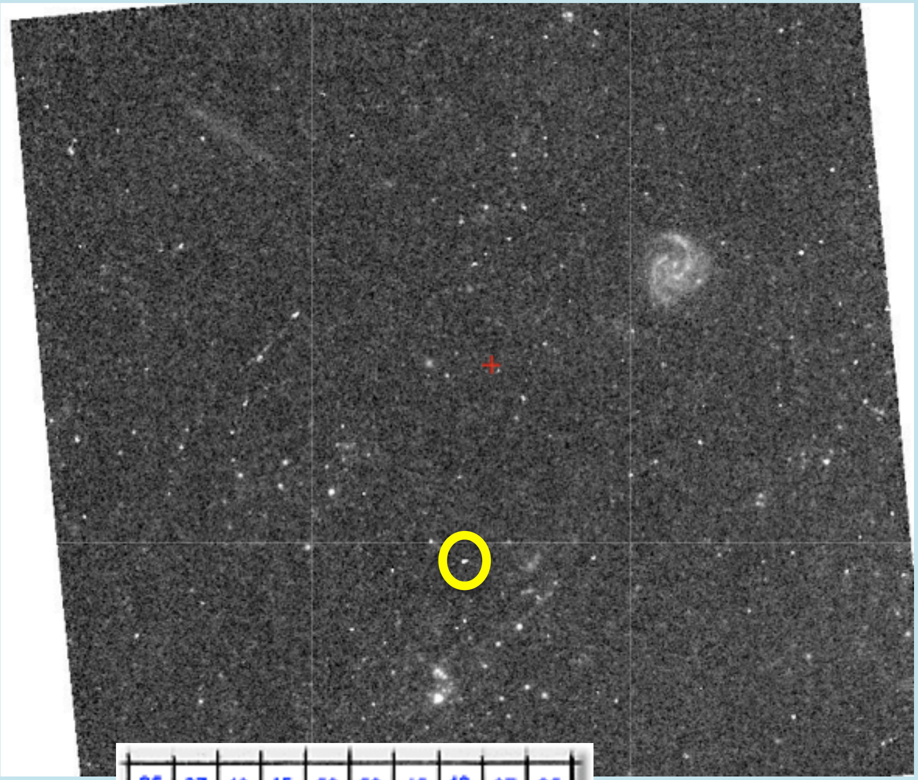
*die means stars fuse most of their core hydrogen into helium. Star evolves to next stage

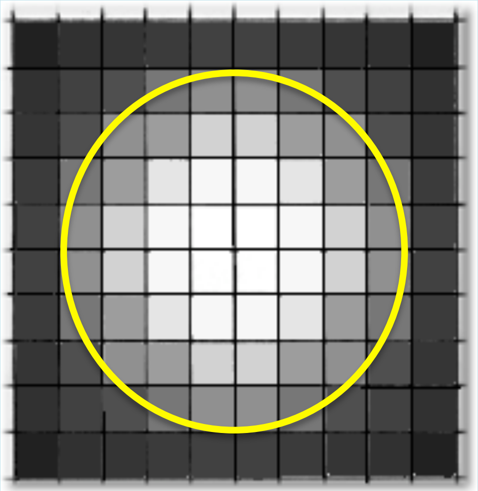
From luminosity we find mass and lifetime.



Lab 2: Measuring Flux

- "Count" the number of photons of star in a small aperture on image.
- Subtract the background sky
- = **brightness or flux of star.**





25	37	40	45	50	50	45	40	37	25
37	50	62	100	125	125	100	62	50	37
40	62	125	139	200	200	139	125	62	40
45	100	139	223	245	245	223	139	100	45
50	125	200	245	255	255	245	200	125	50
50	125	200	245	255	255	245	200	125	50
45	100	139	223	245	245	223	139	100	45
40	62	125	139	200	200	139	125	62	40
37	50	62	100	125	125	100	62	50	37
25	37	40	45	50	50	45	40	37	25

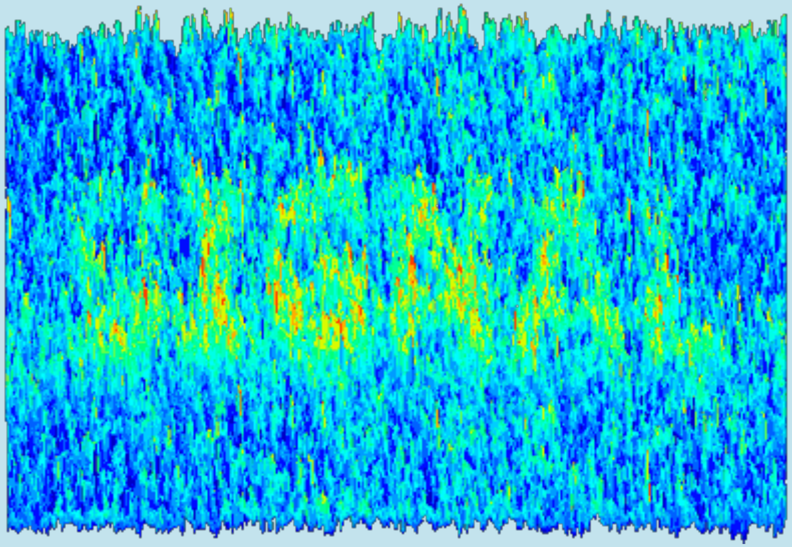
Flux is converted to magnitudes

- Apparent magnitude: $m = -2.5\log_{10}(F) + \text{const.}$
- Can be written as m, m_{filter} (e.g. m_B) or filter abbreviation (e.g. B, V or R)
- Absolute magnitude: Flux measured at 10pc away from object ($F=L/d^2$) $M = -2.5\log_{10}(L) + 5+\text{const.}$
- Can be written as M_{filter} (e.g. M_B) or filter abbreviation (e.g. B, V or R)

Object	Apparent Magnitude (V)	Absolute Magnitude (V)	B-V
Sun	-27	4.8	0.6
Moon	-12.5	-	-
Venus	-5	-	-
Sirius	-1.47	1.42	0
VY Canis Majoris	8	-9.4	2.24
Rigel	0.12	-6.69	-0.13
Naked Eye limit	6.5	-	-
Andromeda Galaxy	3.44	-21.5	0.91
Most distant galaxy found	29 (in red filter)	??	??

Lab 2: Signal to Noise

- Read discussion in lab, based on poisson statistics. Uncertainty ~$N^{1/2}$ where N is the number of photons
- Conceptually, sky subtracted flux must be larger than the spread in noise of the background signal

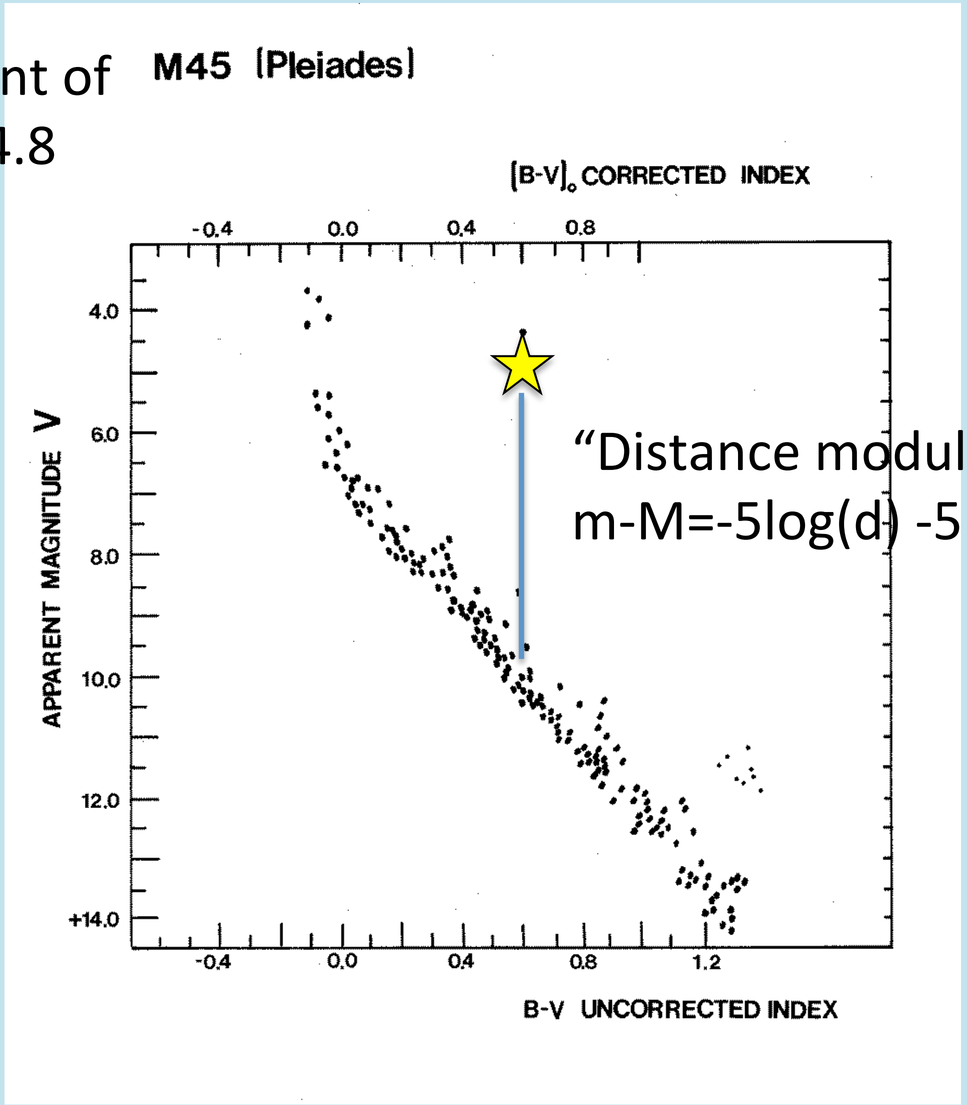


Finding Distance

Sun: B-V=0.6

B-V is independent of distance. $M_V = +4.8$

Flux that we measure from Earth is apparent magnitude →



"Distance modulus"

$m-M=-5\log(d) -5$

Finding Age

Compare the apparent magnitude of the most massive star to a sun-like star in the cluster:

Both stars are at the same distance, so you can directly compare their luminosities