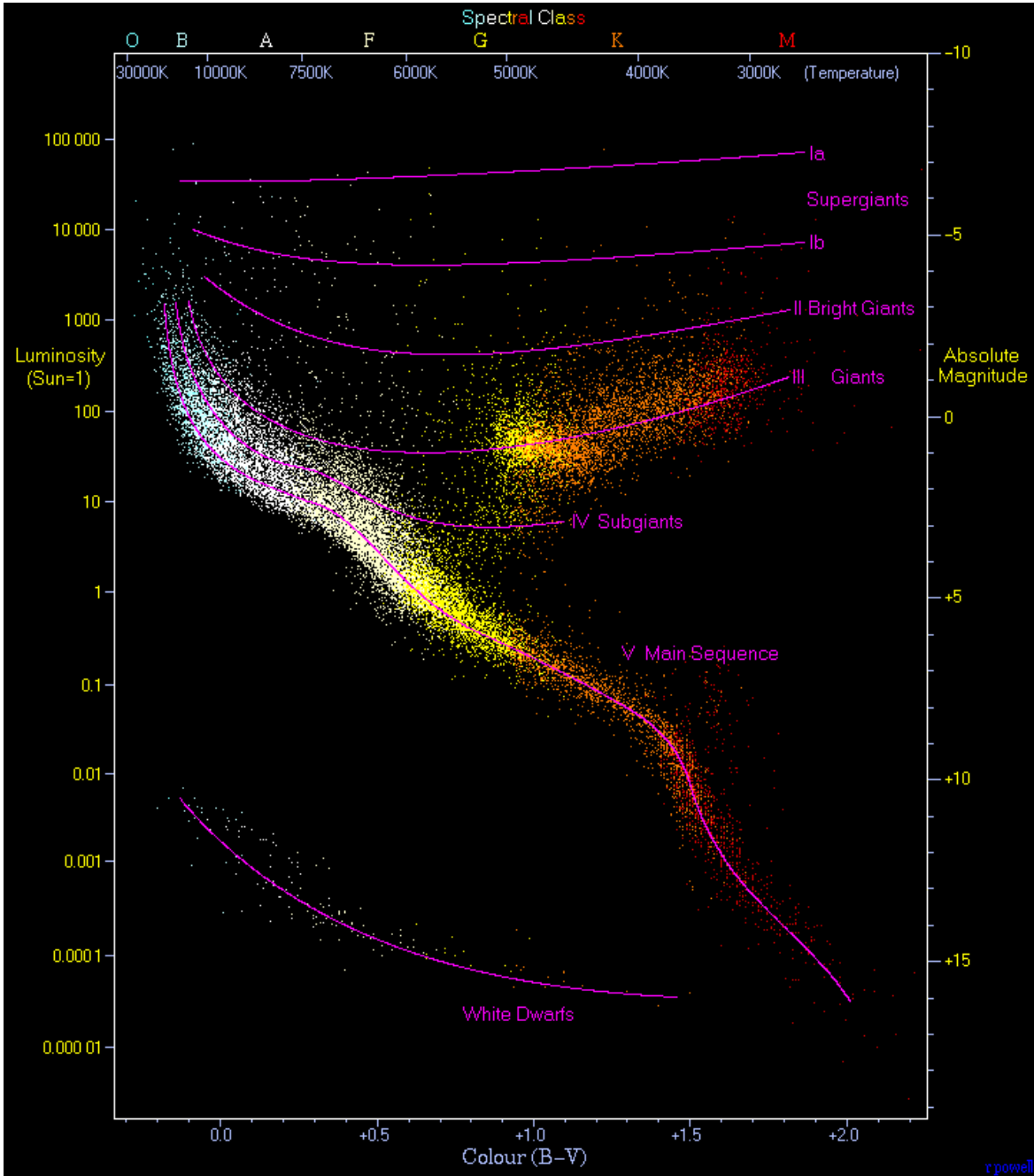
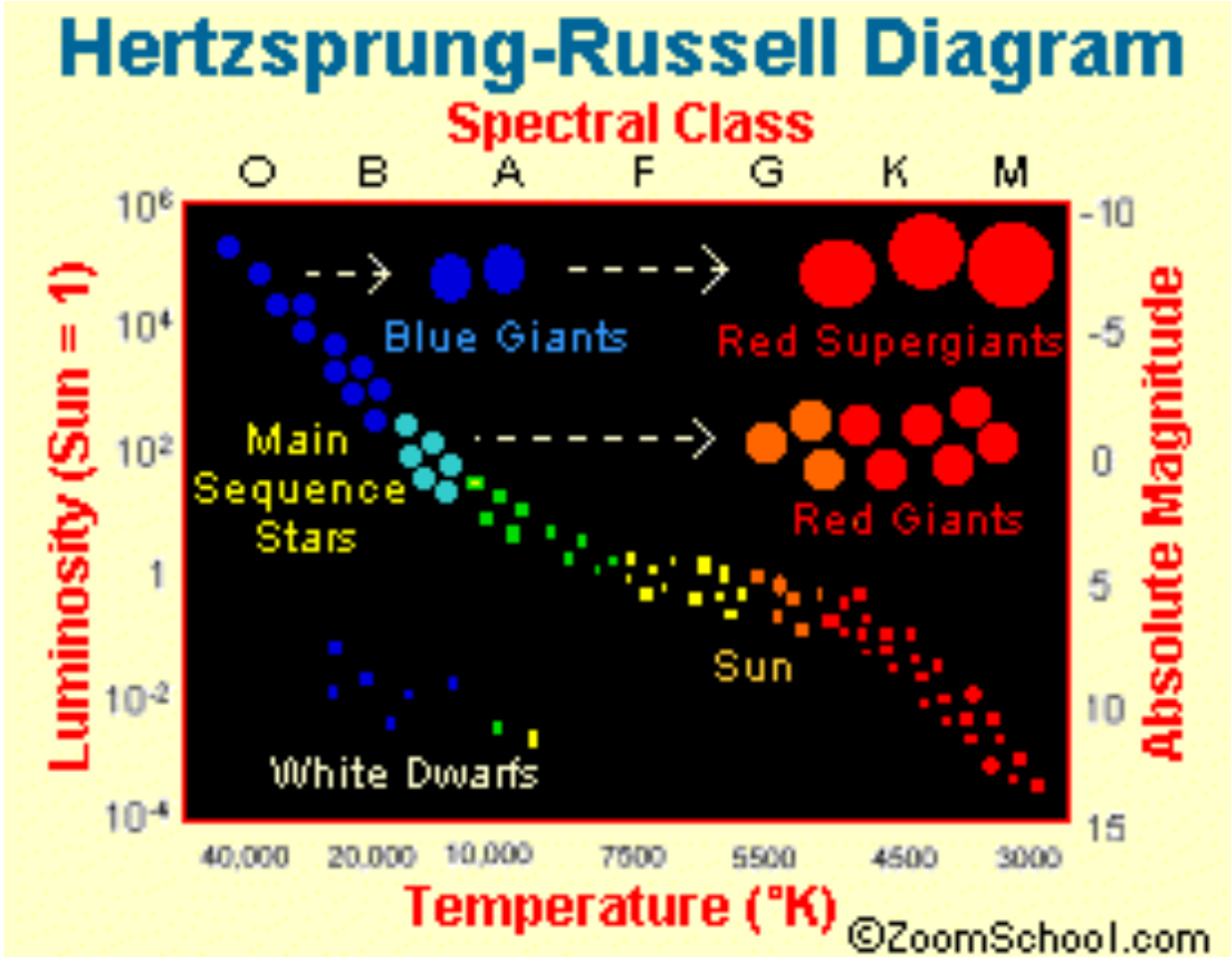
Color-Magnitude Diagram

- Also called **HR Diagram**
- Measure the **apparent magnitude**
- Distance gives **Absolute Magnitude/ Luminosity**
- **Spectral class** or **(B-V)** gives temperature increasing to left
- Luminosity in log scale



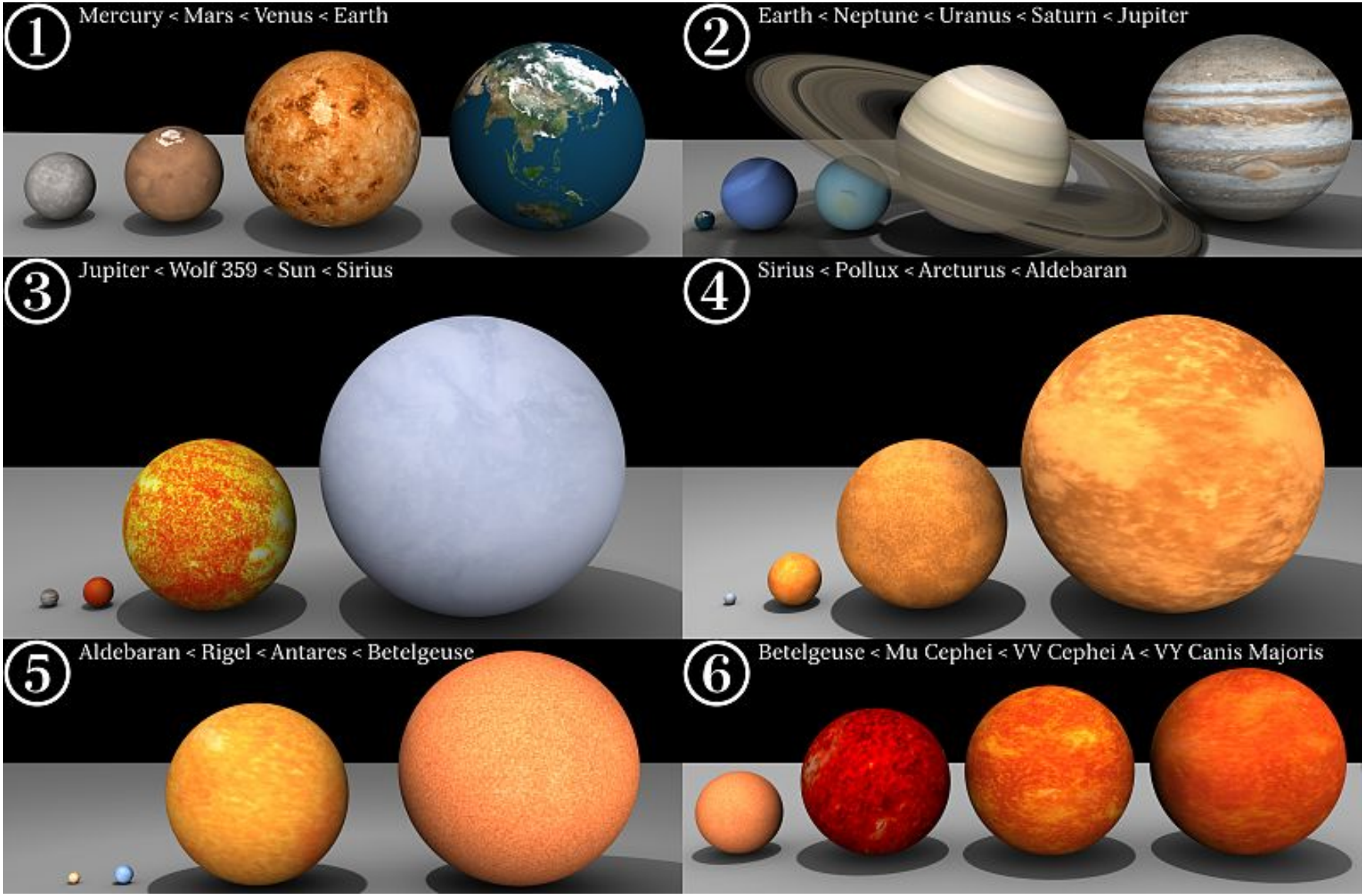
Four Main Regions

- **White Dwarfs:** very hot, the size of Earth, not luminous
- **Main Sequence** stars are the size of the sun, various luminosity
- **Red/Blue Giants** rare, very luminous stars
- **Supergiants** even more rare and even more luminous

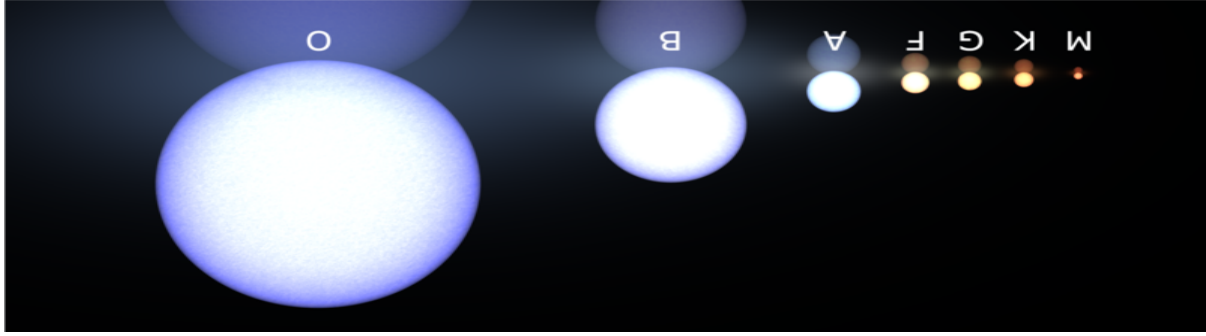


Radii of Stars

- From Luminosity & Temperature => Radii

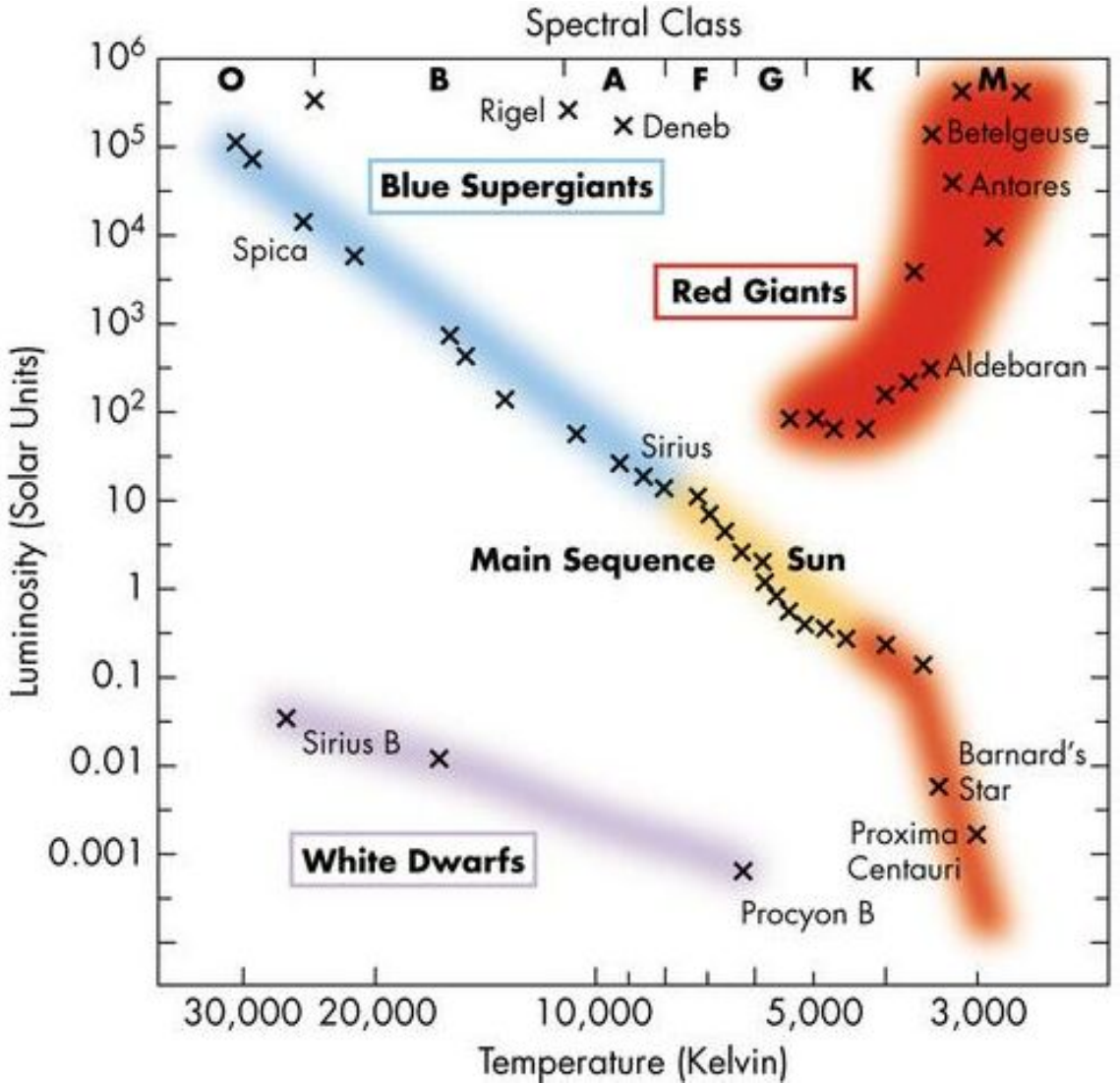


H-R Diagram Sorts the Stars

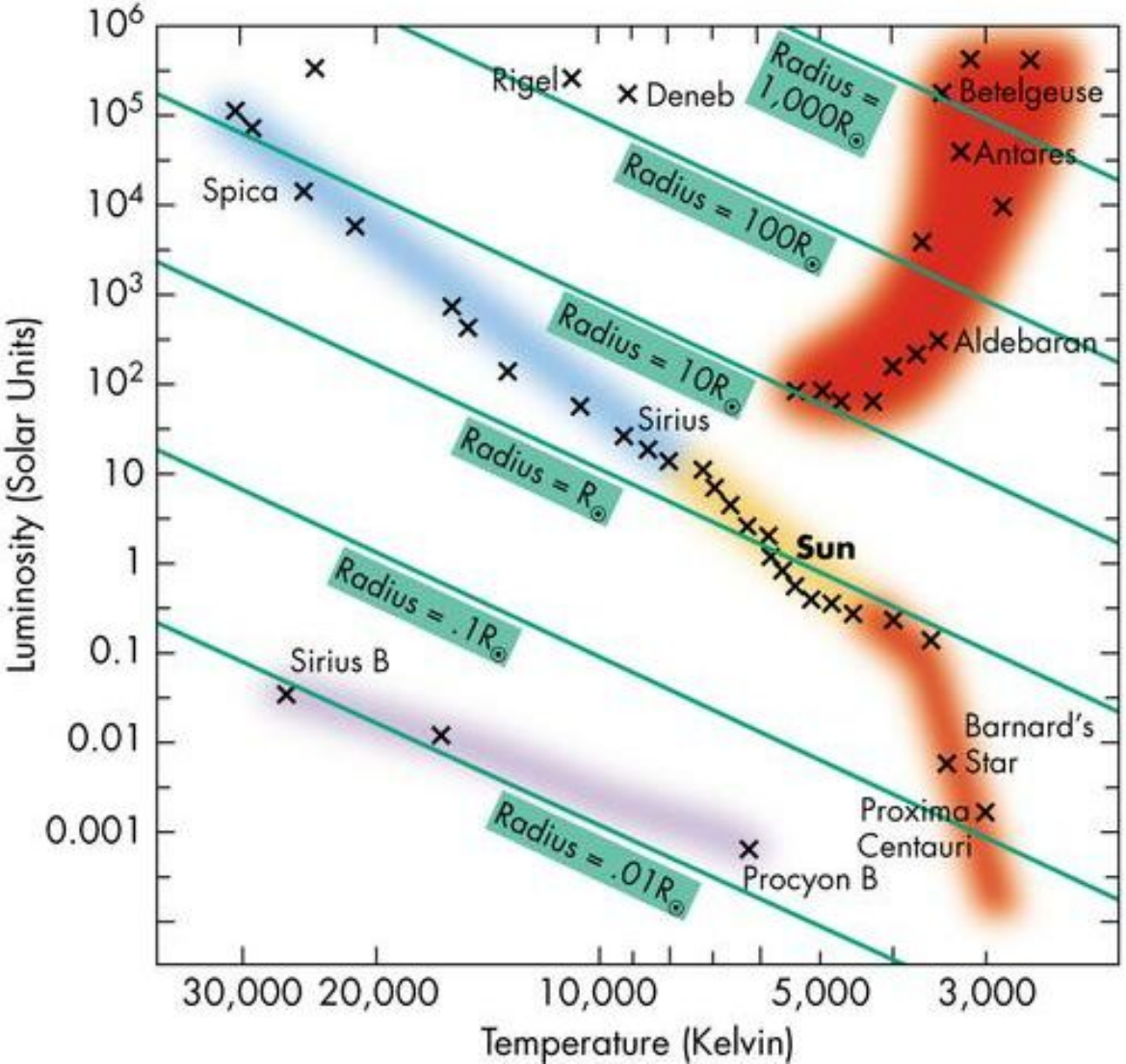


According to

- Luminosity
- Temperature
- Size=Radius
- Mass
- Density
- Lifetime



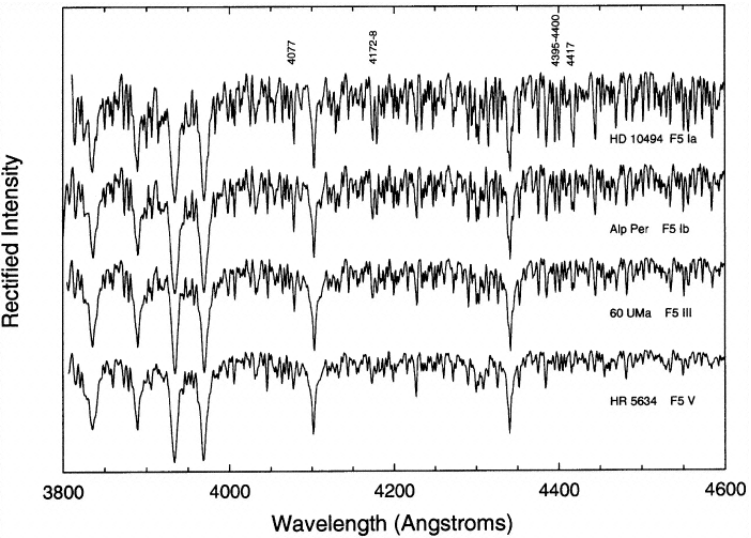
Lines of Equal Radius

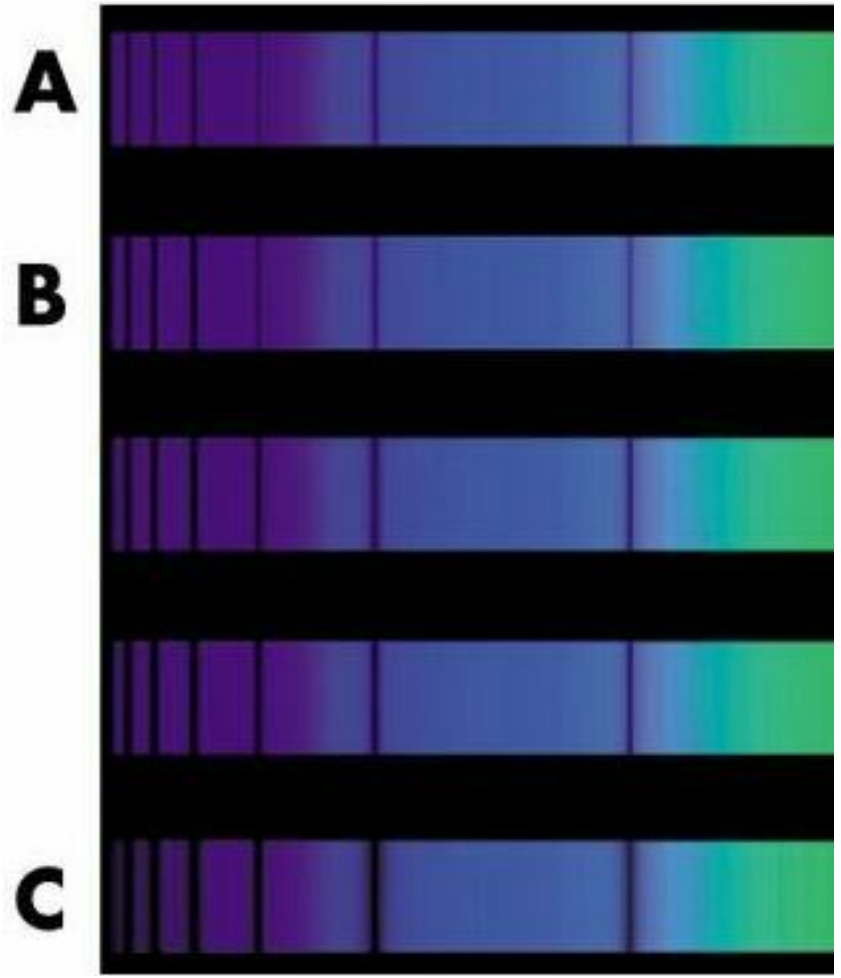


- Straight lines because $L \propto R^2 T^4$
- Earth radius=0.01 R_{sun}
- 1AU=200 R_{sun}
- Jupiter's distance from sun is 1000 R_{sun}
- Density ranges from 3,000,000 for White Dwarfs to 1 for Main Sequence to 0.000001 for supergiants

Luminosity Classes from Spectral Lines

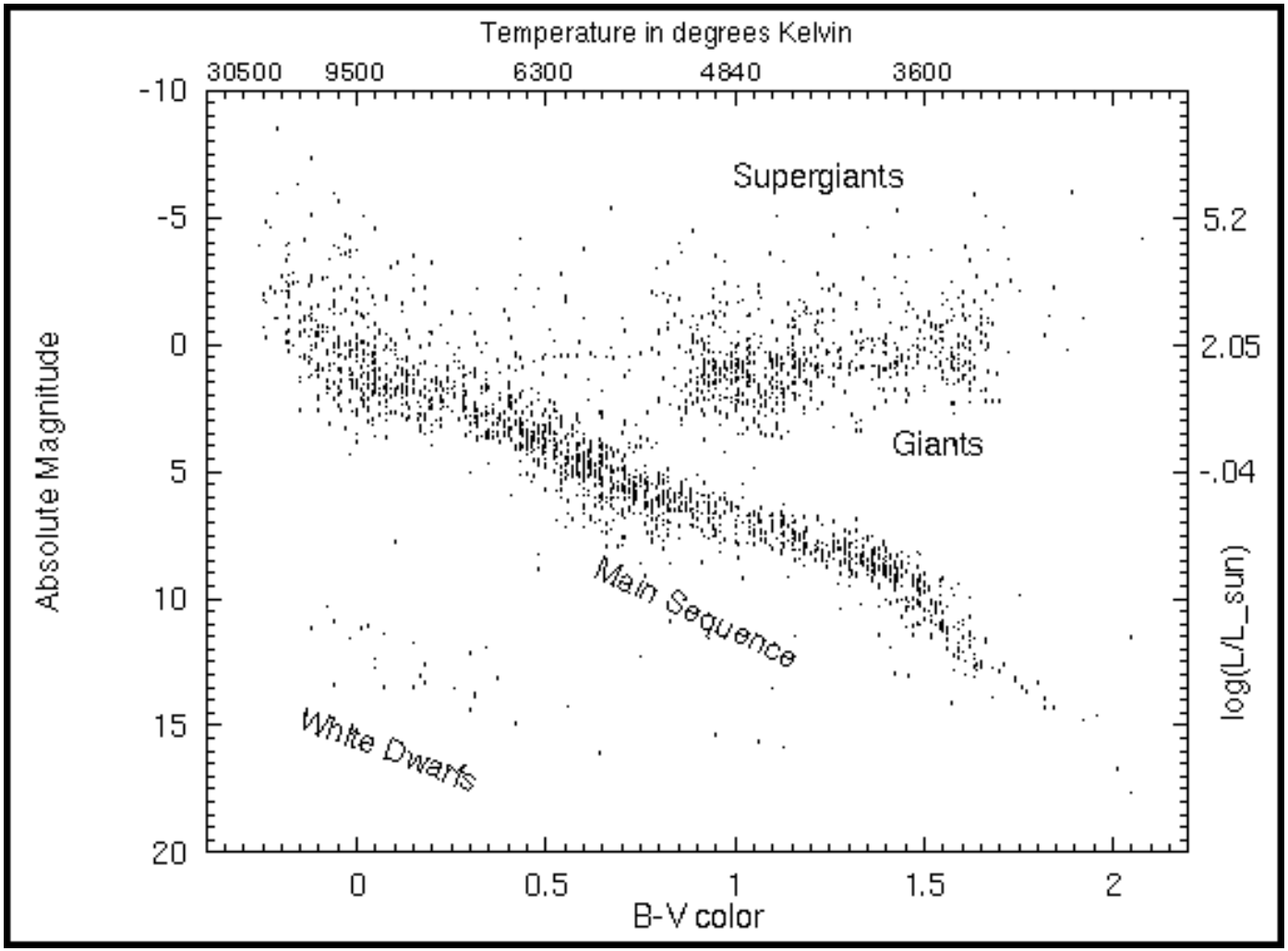
- Density governs how often an atom collides while emitting a photon
- Supergiants I
- Giants III
- Main Sequence V
- White Dwarfs



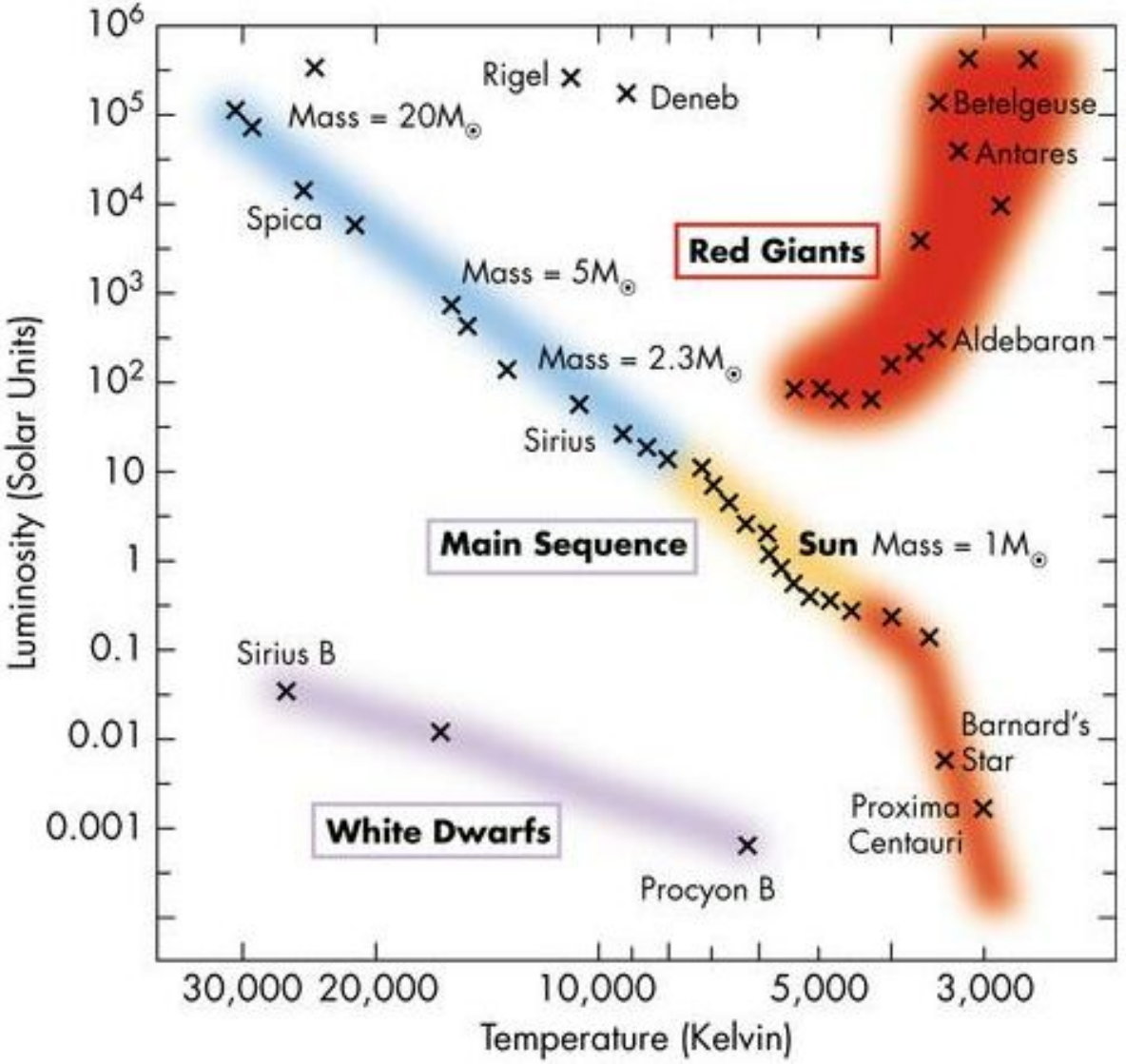


Spectroscopic Parallax

- For any star: temperature / spectral class / (B-V) + Luminosity Class
- Then we can find its absolute magnitude and its distance



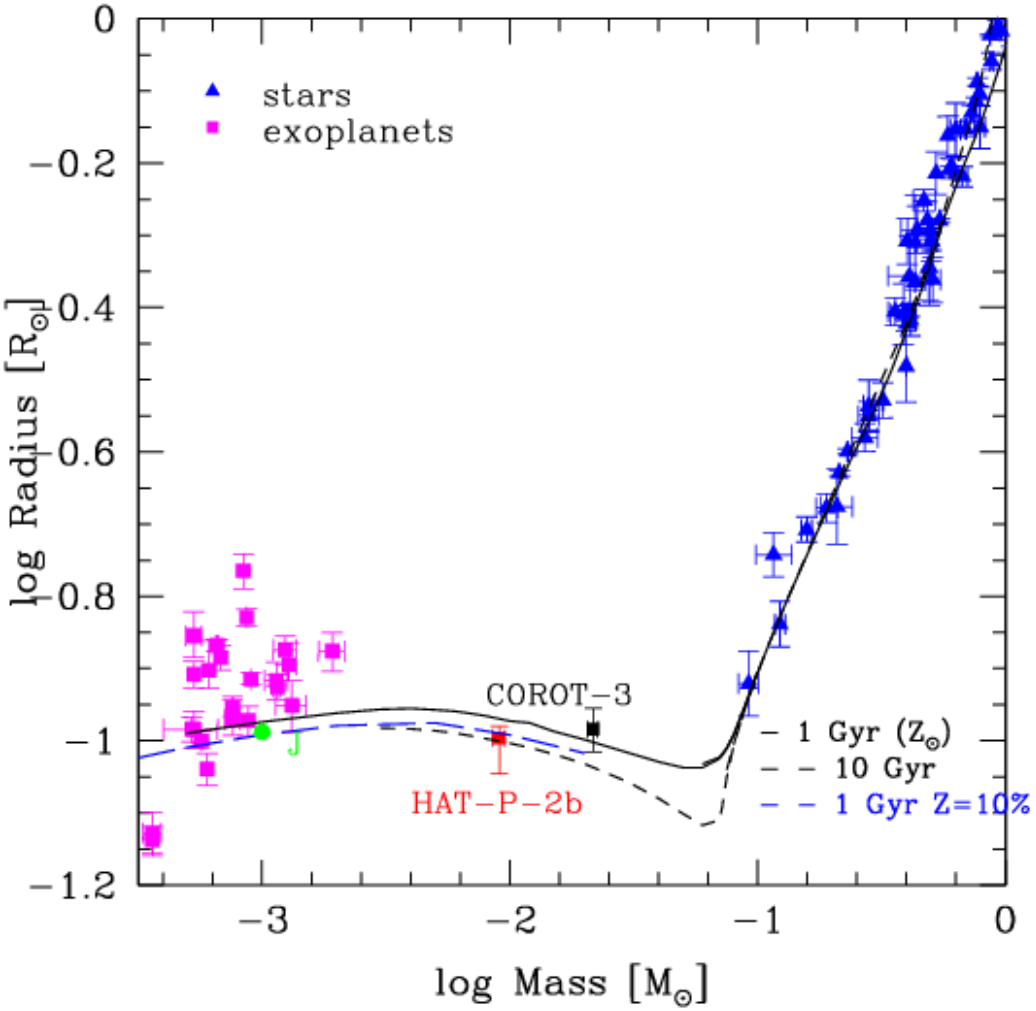
Main Sequence Position Depends on Mass



- Mass from binary stars
- Masses from ~40 solar masses to 0.08 solar masses at bottom
- Mass determines size, temperature, brightness, lifetime, rarity

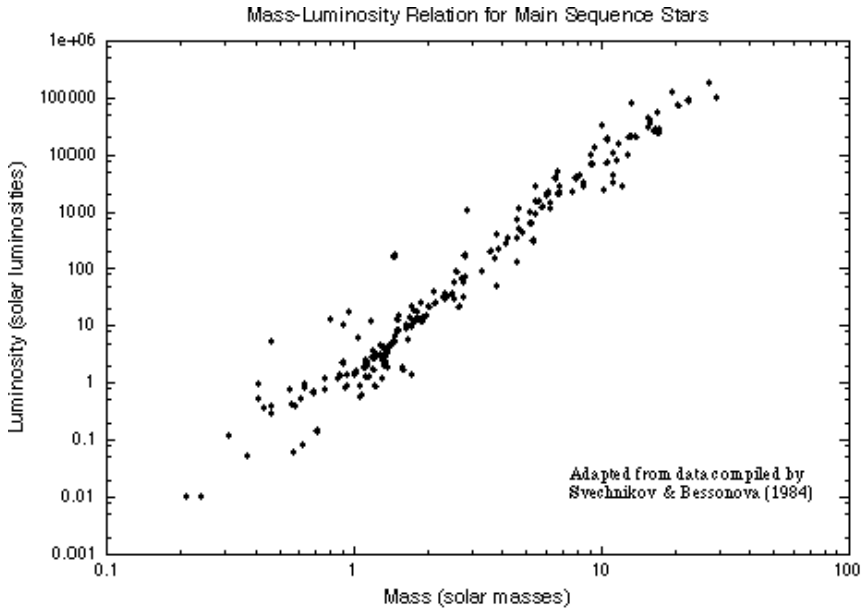
Stellar Mass-Radius Relation

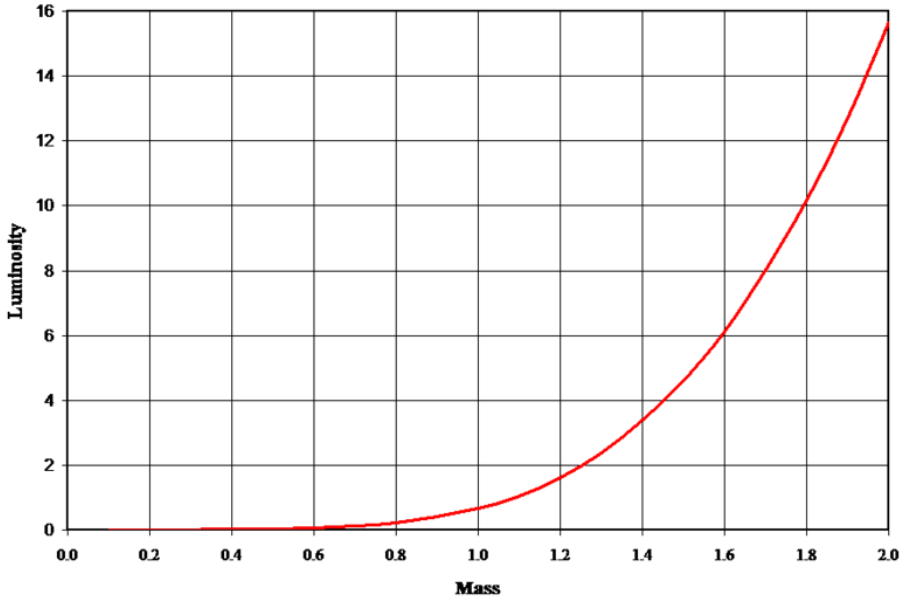
- Main sequence star: radius increases with mass
- Brown Dwarfs & Planets all about same radius



Stellar **Mass-Luminosity Relation**

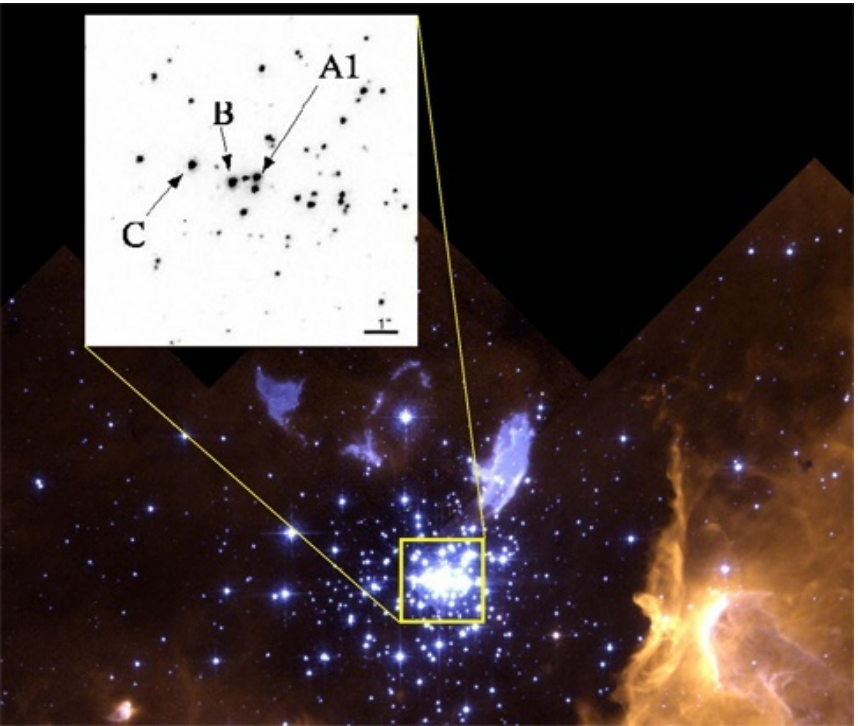
- Relation holds for main sequence stars – not giants, white dwarfs
- Luminosity depends on mass to 3.5 power $L \propto M^{3.5}$

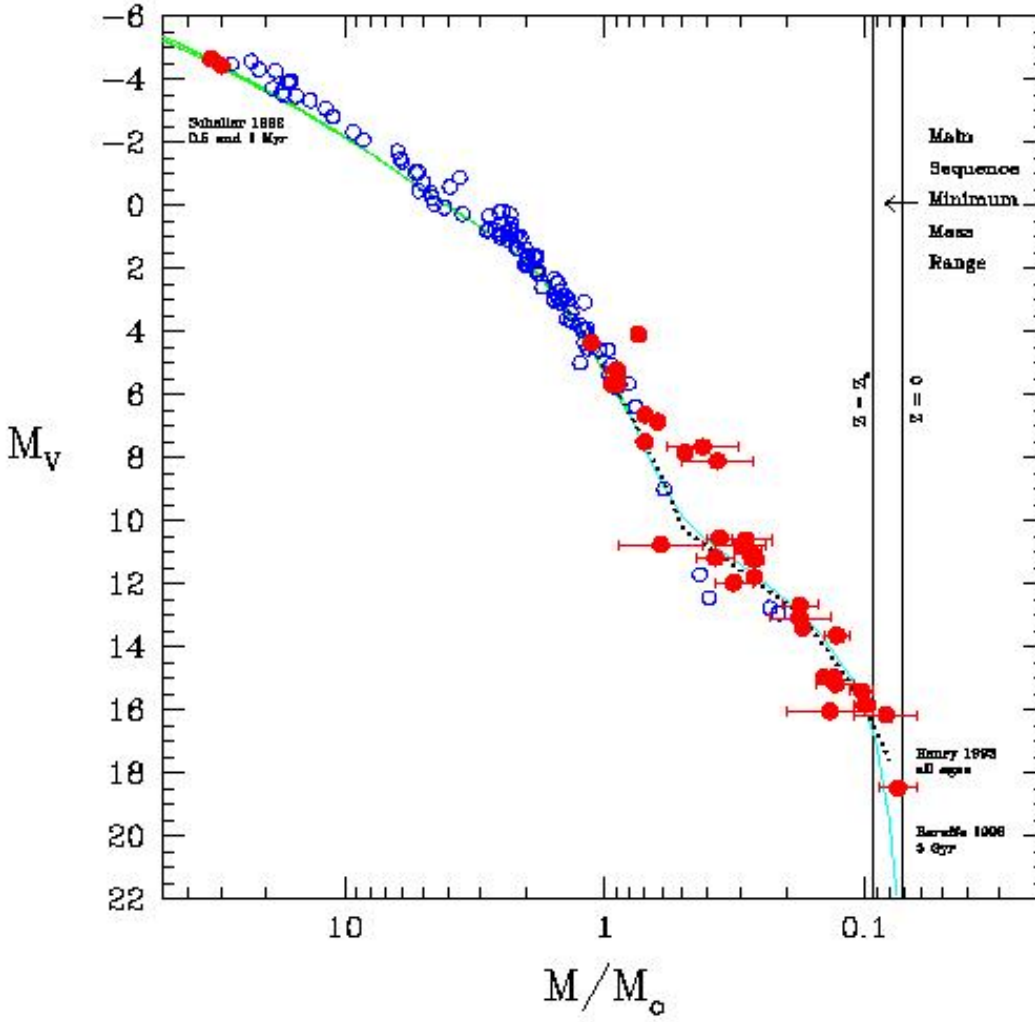




Absolute Magnitude/ Mass Relation

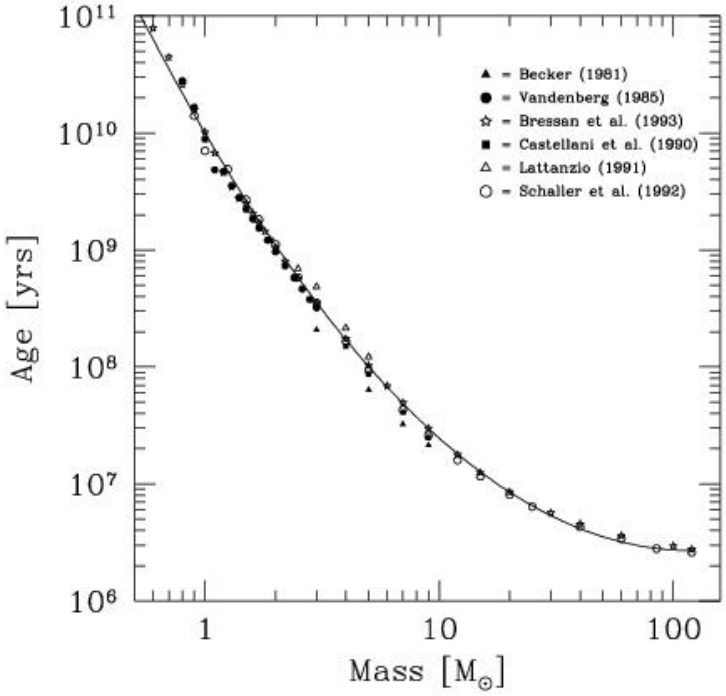
- Masses from 114 solar masses(=A1) to
- 0.08 Solar Masses = Brown Dwarfs
- Absolute Magnitudes from –6 to +18

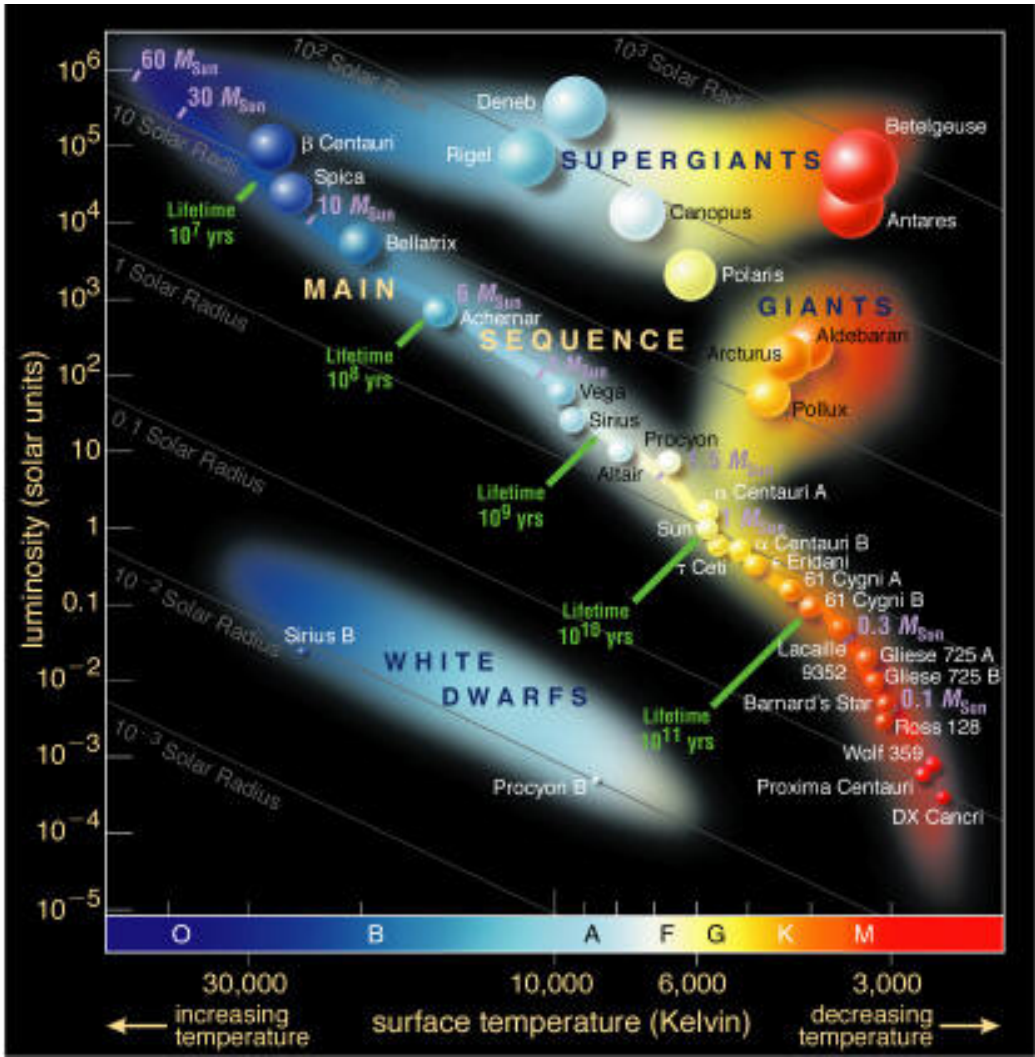




Stellar Lifetime

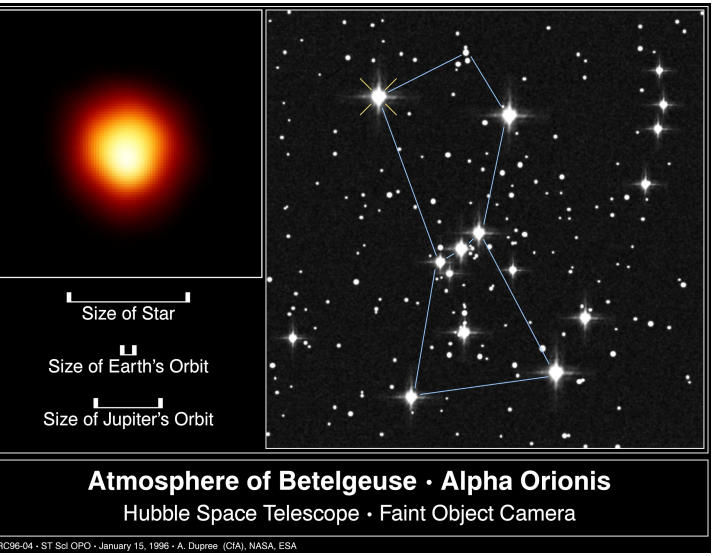
- Lifetime depends on Star's Mass (Fuel) ÷ Star's Luminosity (How much energy is being radiated away per second)
- Luminosity α Mass$^{3.5}$
- Lifetime α 1/Mass$^{2.5}$

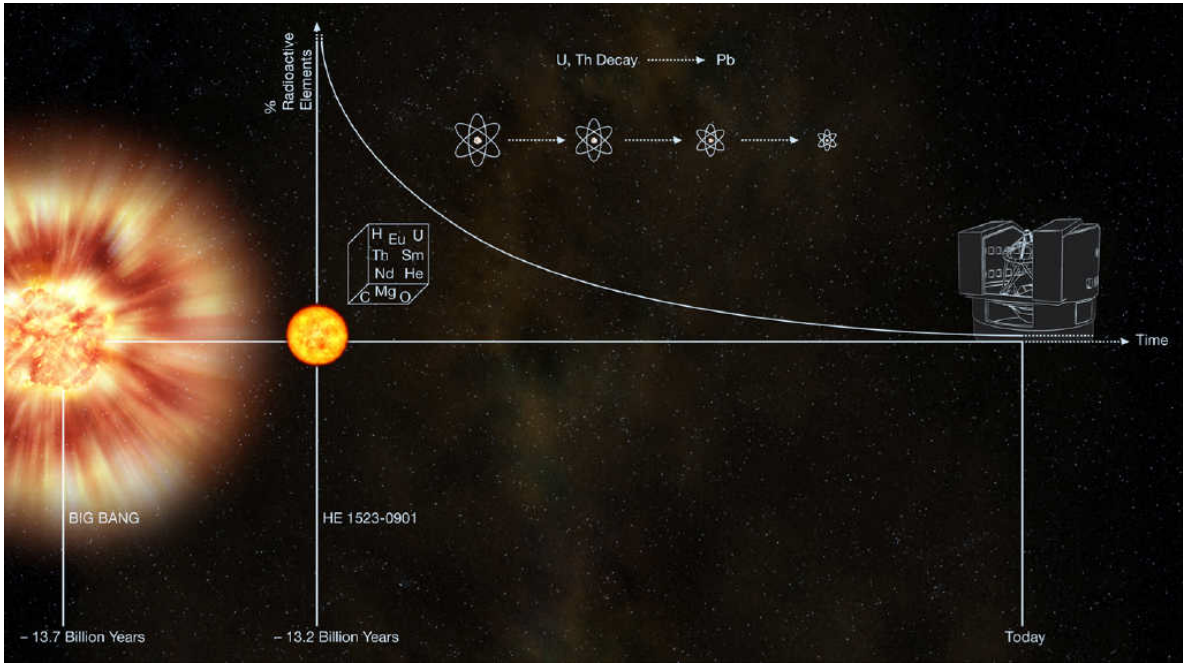




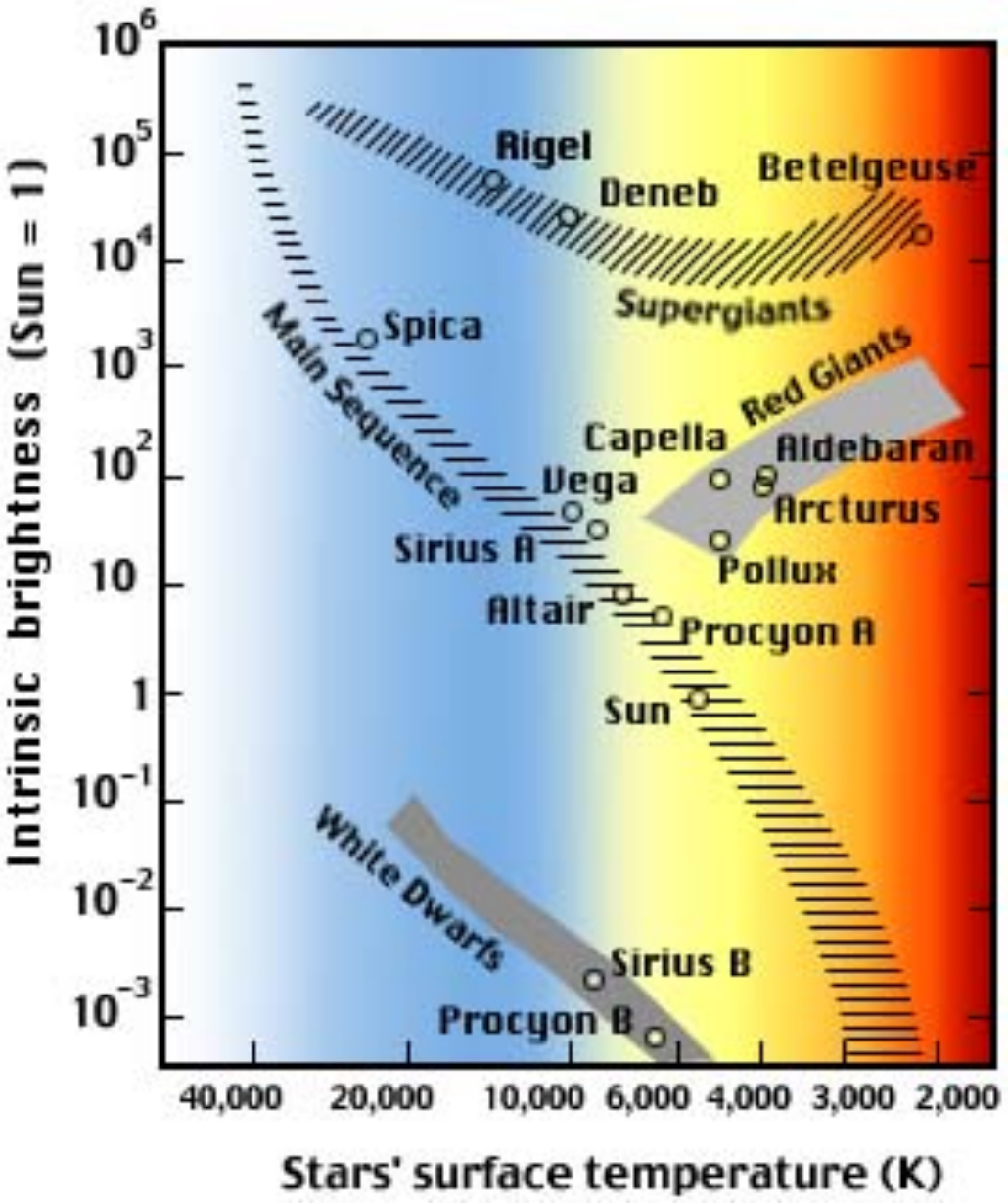
Youngest/Oldest Stars

- Youngest stars still forming
- Betelgeuse: ~10million yr
- Sun: 4.5Billion yr
- New oldest star HD140283 13Billion





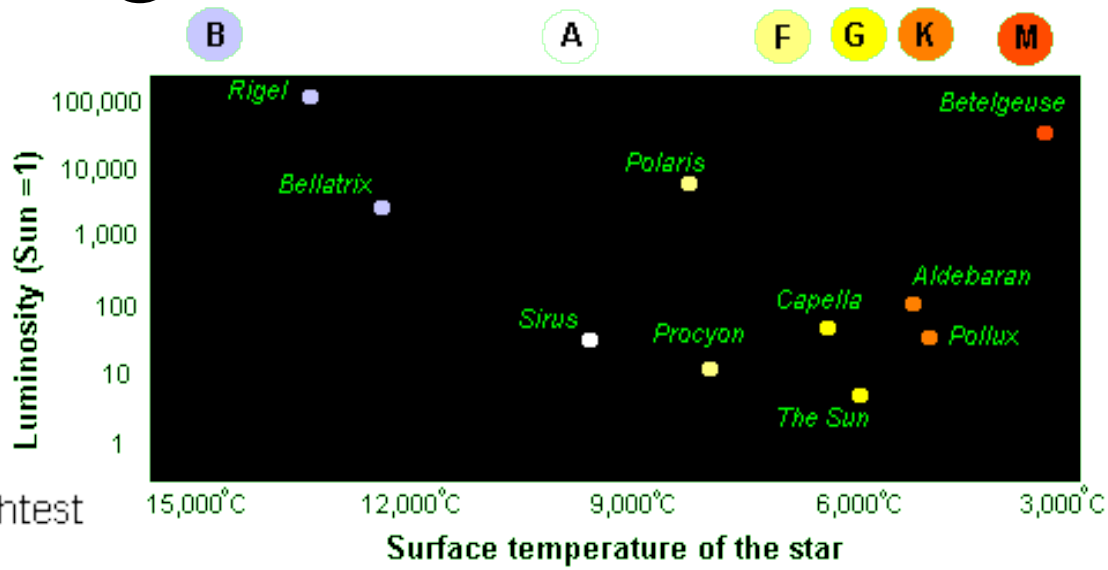
How Many Stars of Each Kind?

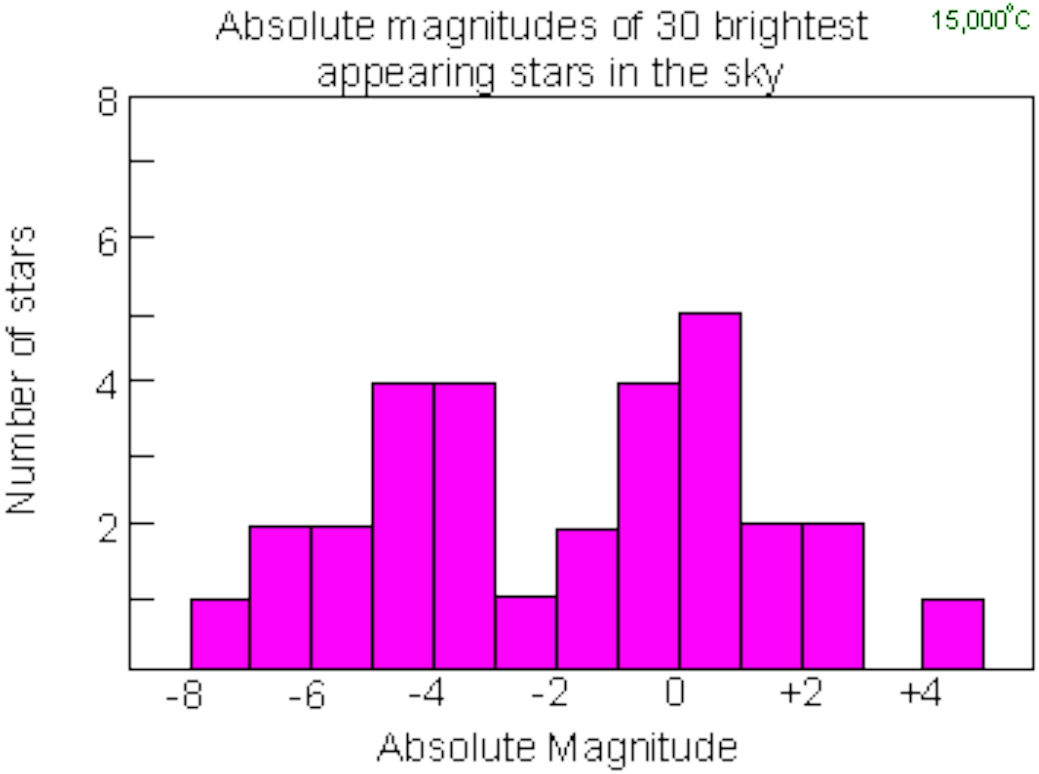


- Range from a million times sun to a thousand times less bright
- To find the **Luminosity Function**:
- You must choose your sample carefully to make valid conclusions

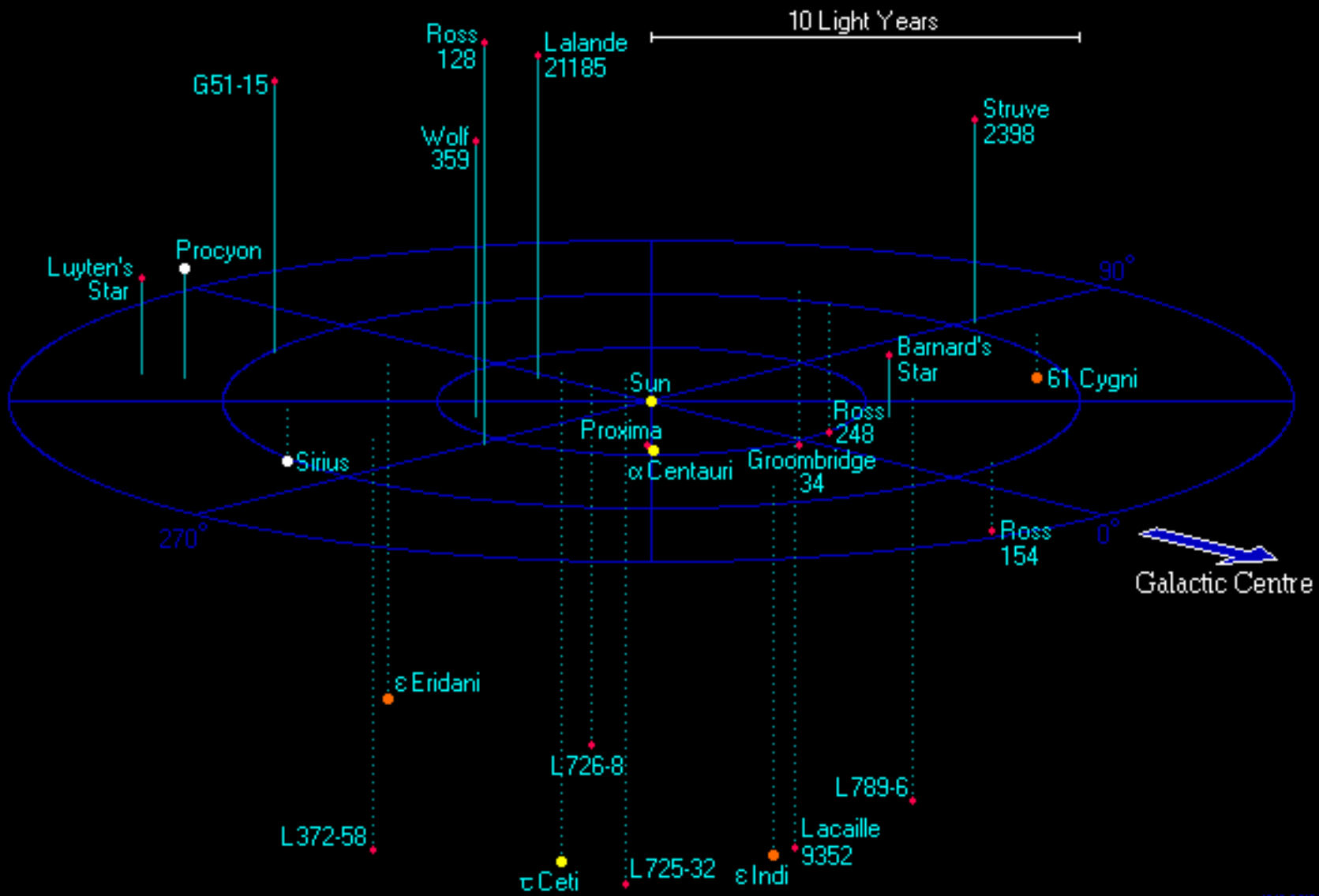
Census of the Brightest Visible Stars

- Selection effect: Very biased toward/by the rare intrinsically bright stars



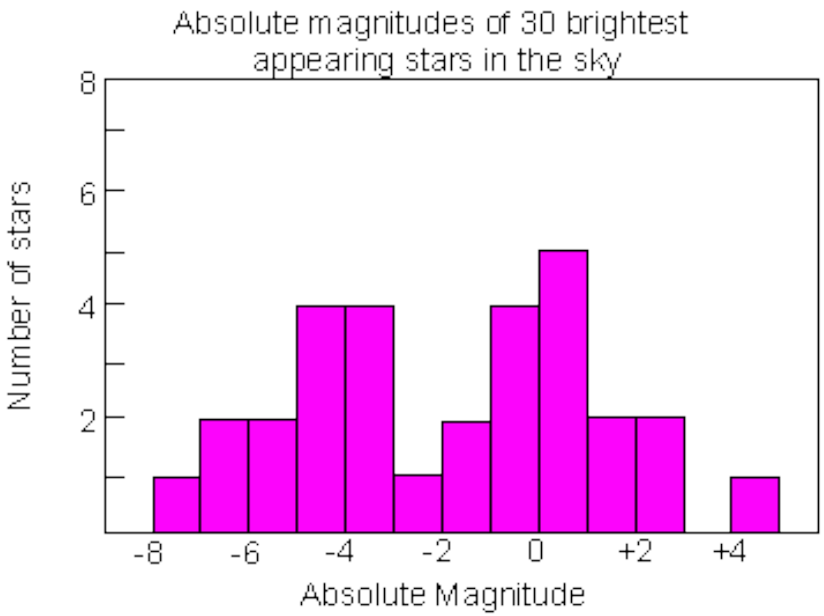


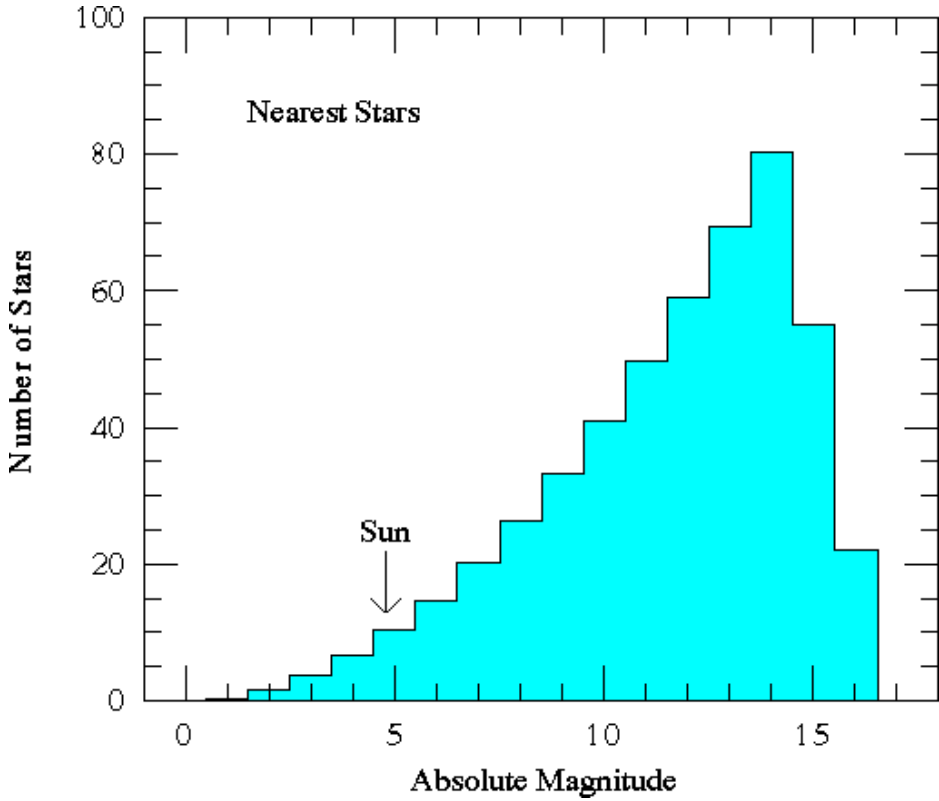
Nearest Stars: Mostly Red Dwarfs



Census of the Local Stars

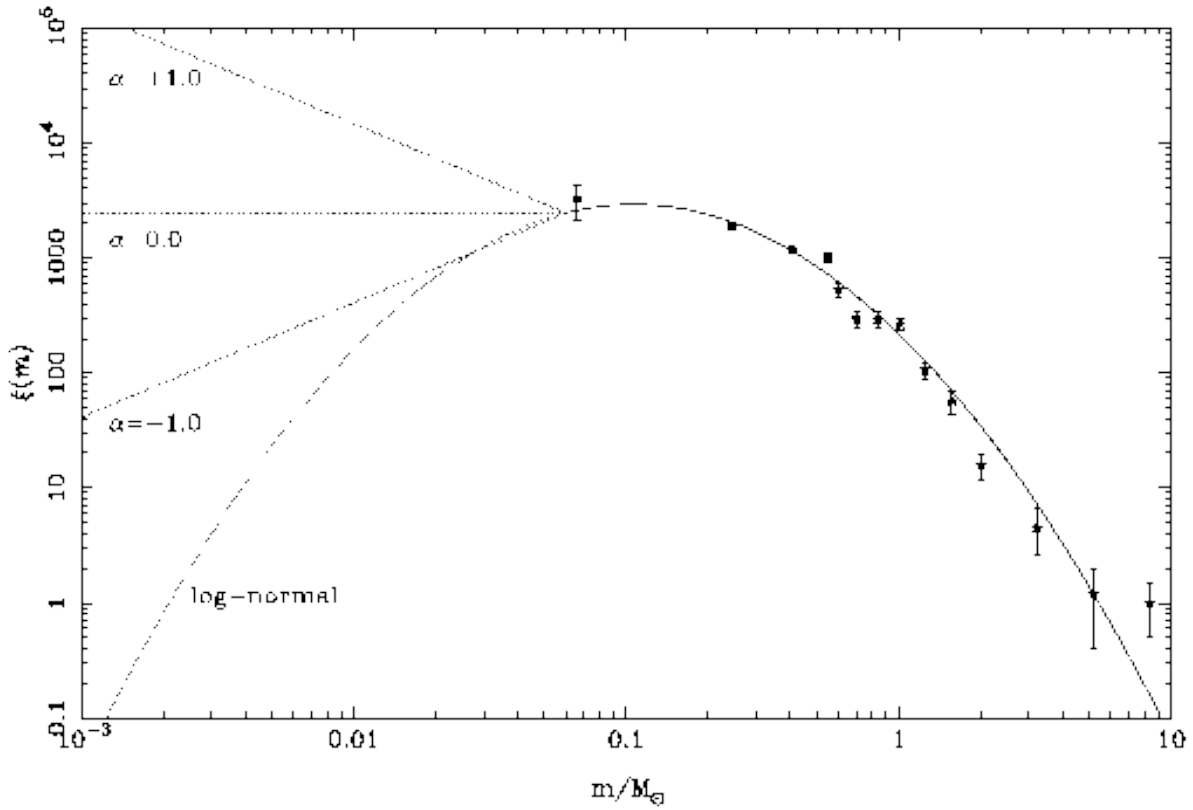
- Within 10 parsecs = 354 stars in 249 systems with 10 planets
- One O-star per 30 X 10^6 cubic parsecs ~100pc distant
- Lots of faint M stars & few bright stars





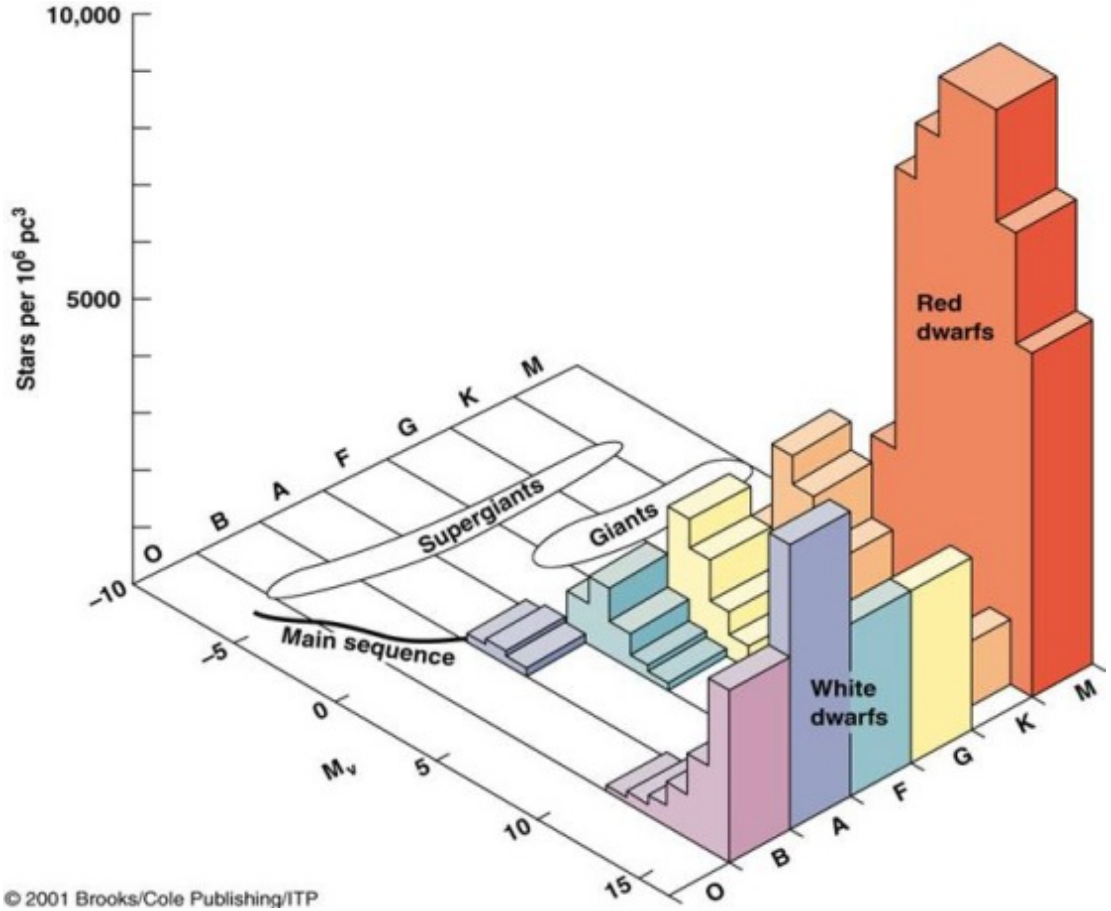
Stellar Mass Function

- Given the local stellar census & the mass-luminosity relation we can find the number of stars for each mass
- Very few high mass stars and lots of low mass stars
- Unknown numbers of objects below 0.08 solar masses

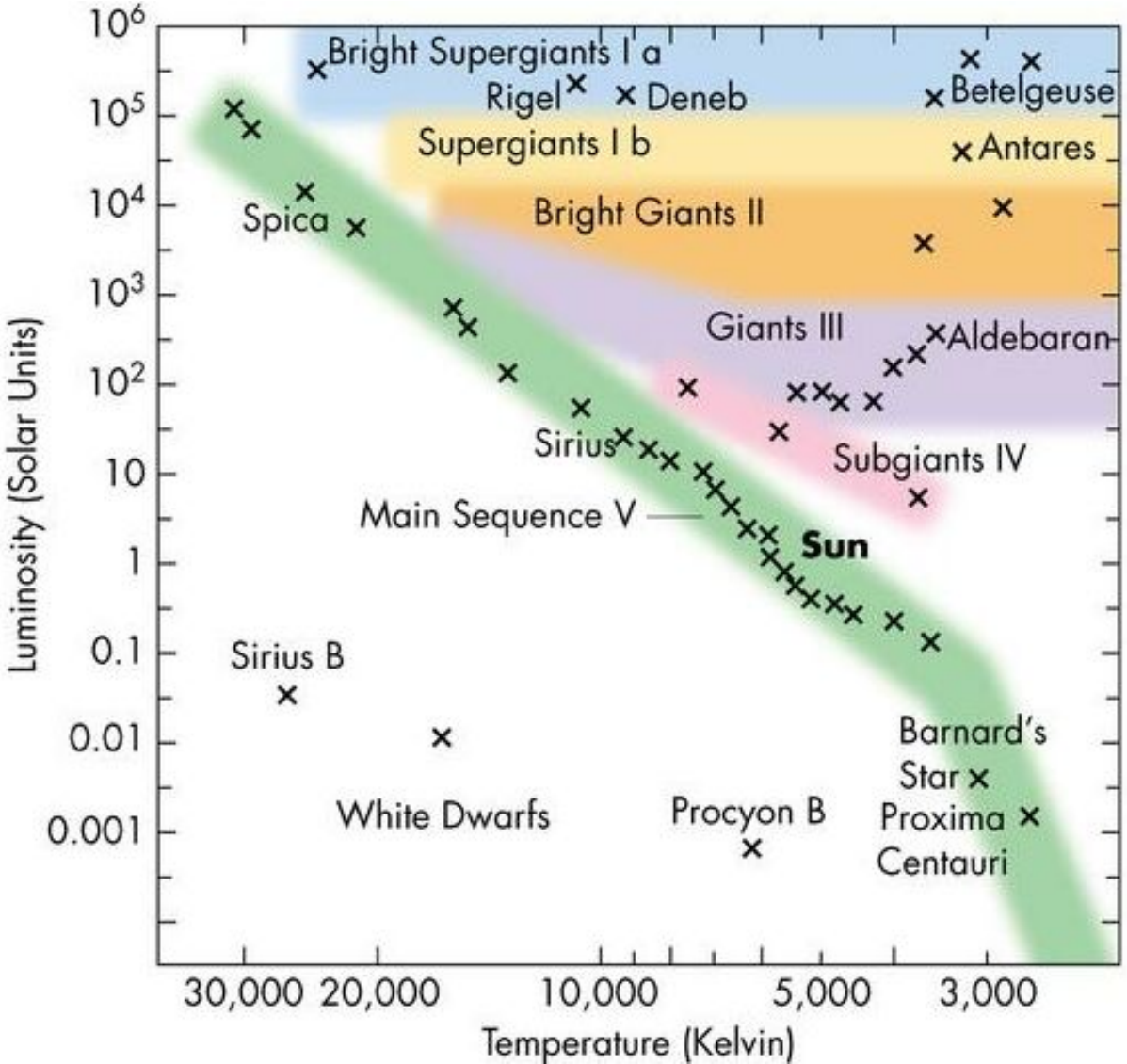


- Luminosity Function
- 90% main sequence; 9% white dwarfs; 1% giants

Stellar Census



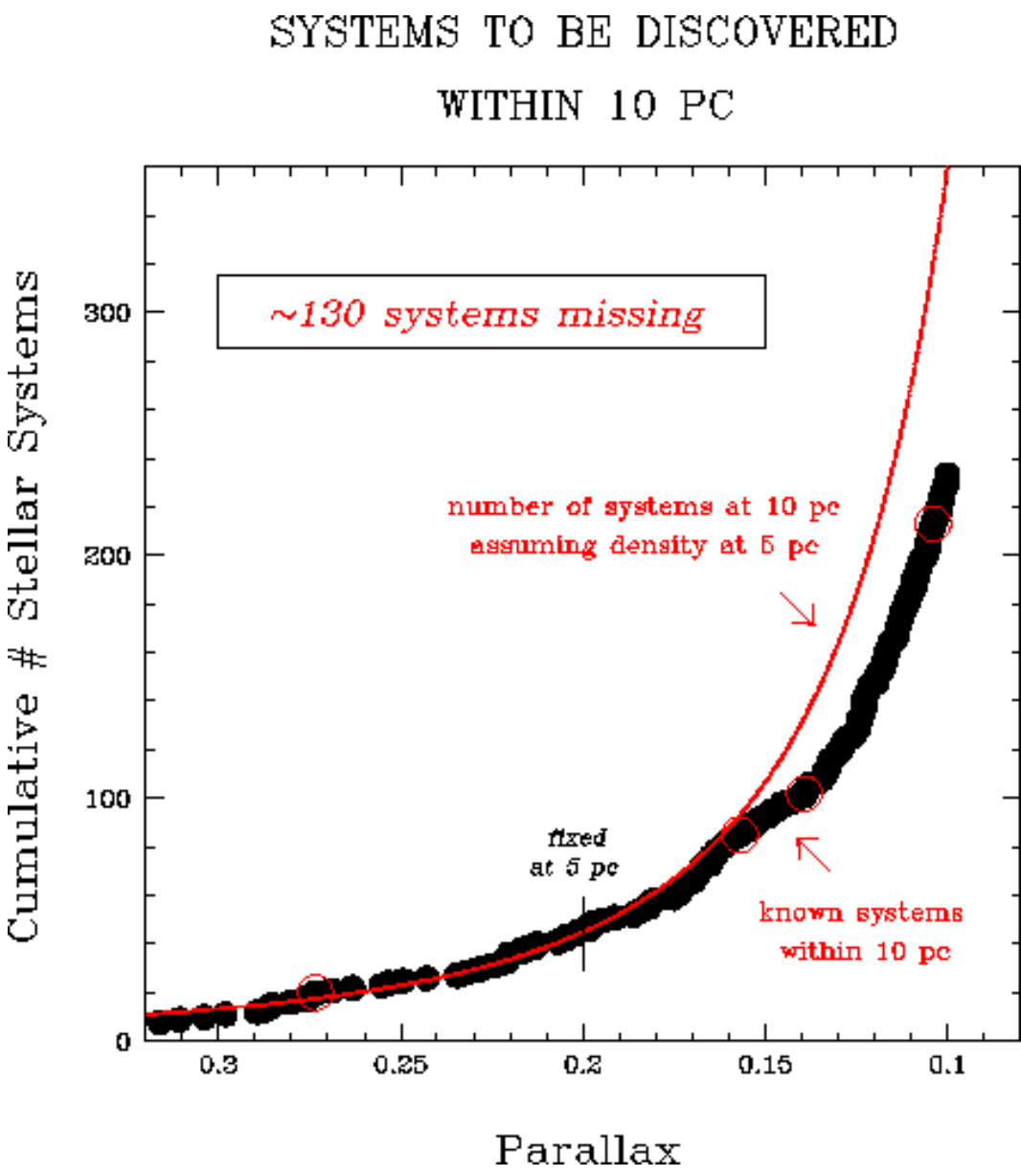
Luminosity Classifications



- Supergiants I & II
- Giants III
- Subgiants IV
- Main Sequence V
- White Dwarfs

Local Stellar Census

- NSTARS is still trying to find all stars nearer than 10 parsecs
- Parallax of 0.1”
- M stars are faint and hard to find

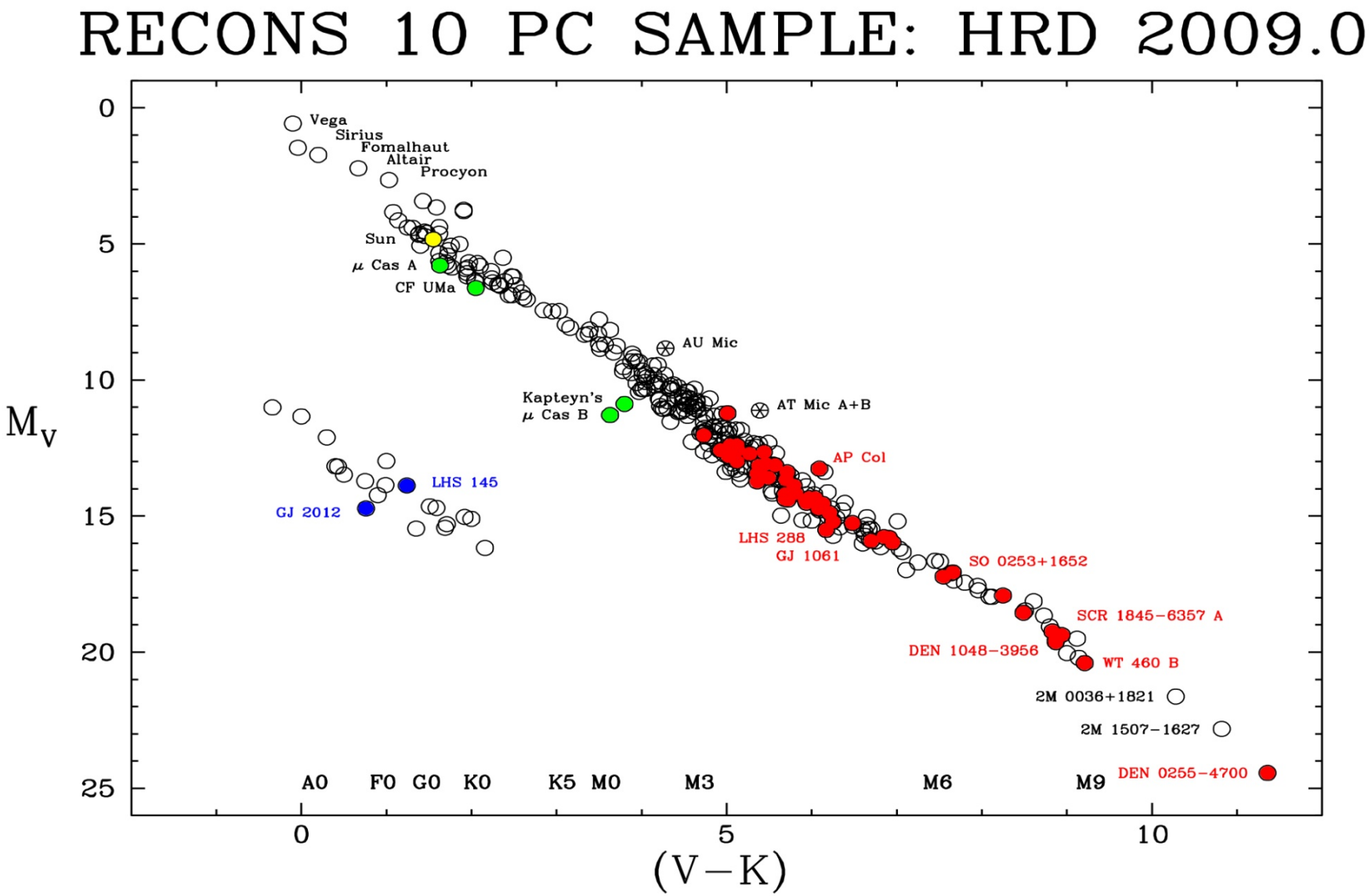


New Exoplanets

- Eclipse the star
- Smaller than Earth
- Not in habitable zone

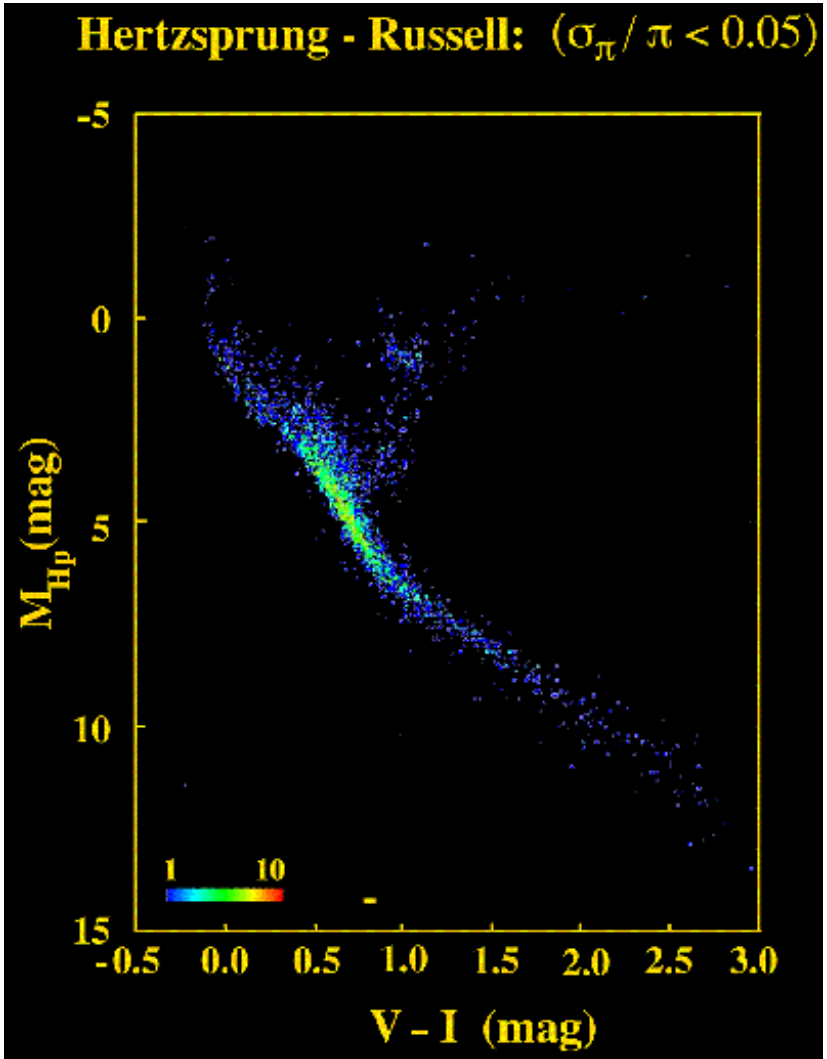
HR Diagram of the Nearest Stars

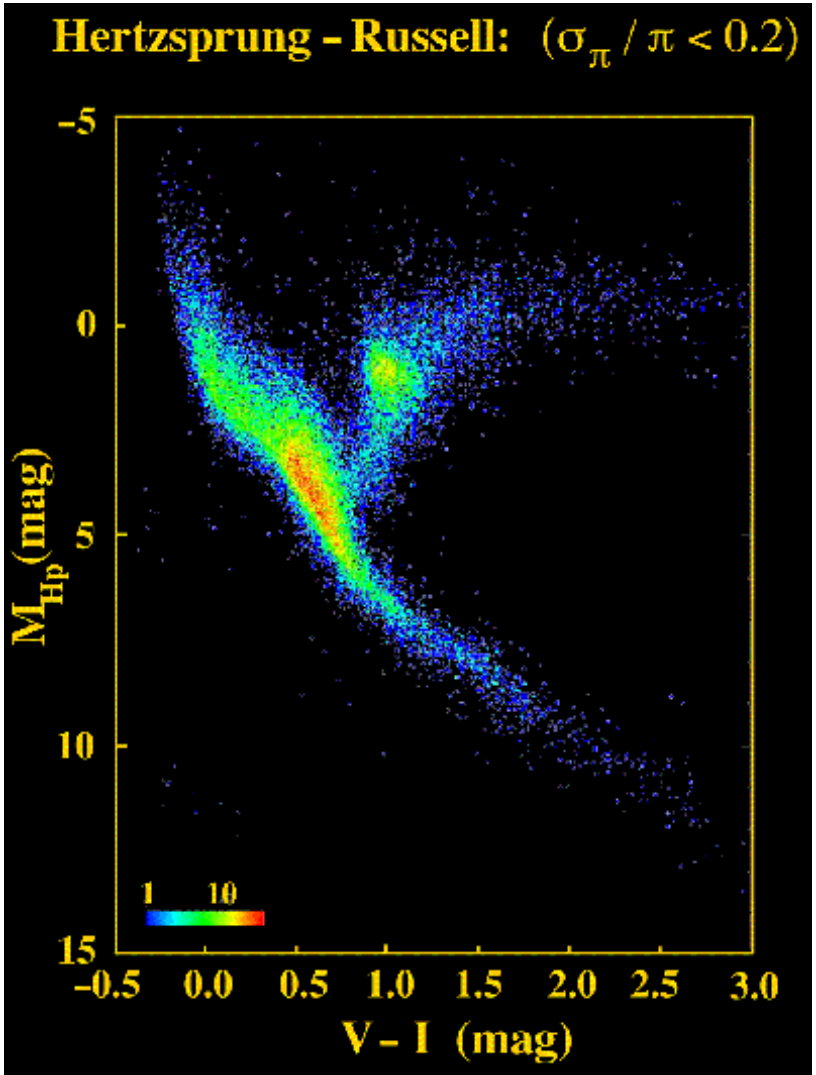
- Very biased towards red dwarfs



Hipparcos Color Magnitude Diagram

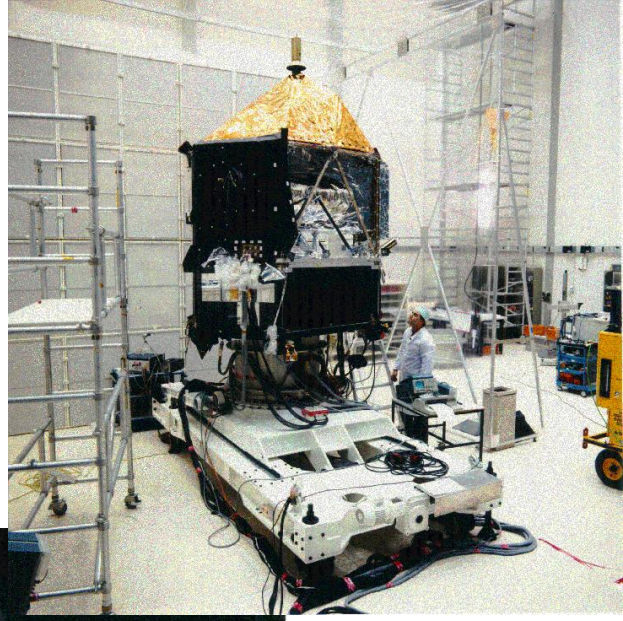
- As we include fainter stars we get more distant/bright ones and more intrinsically faint ones.

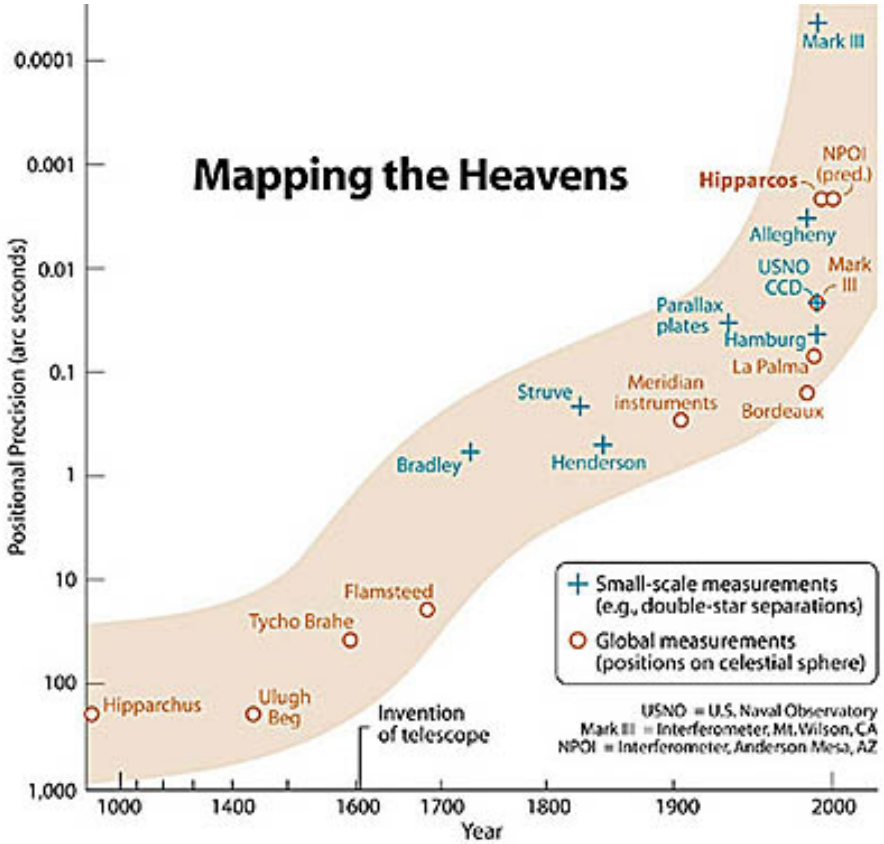


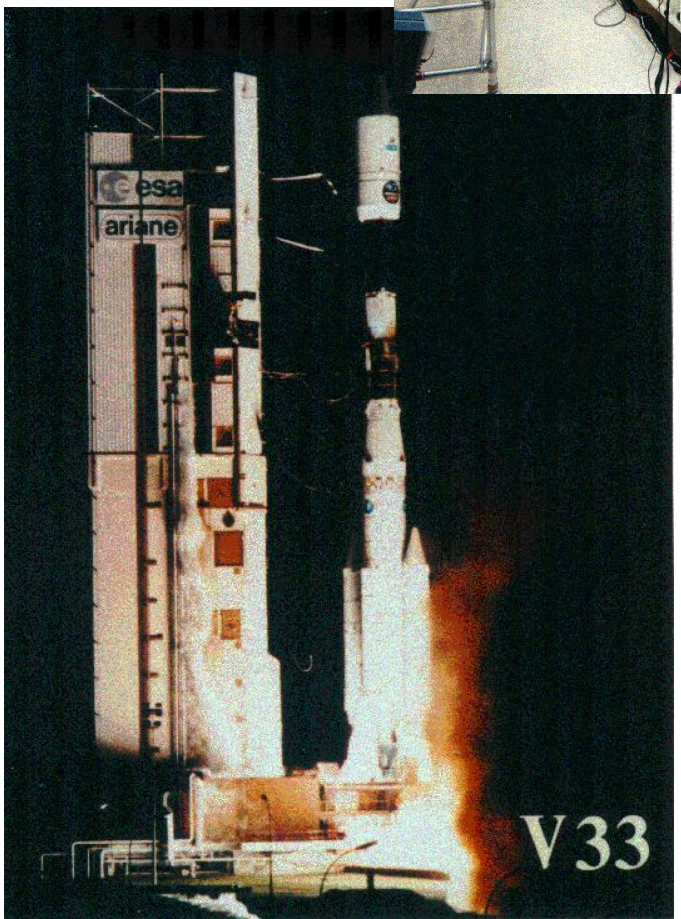


Hipparcos Satellite

- Atmosphere restricts us to ±0.002”
  = ± 5pc @ 50pc
- Launched in 1990 and measured 100,000 positions to 0.0001”



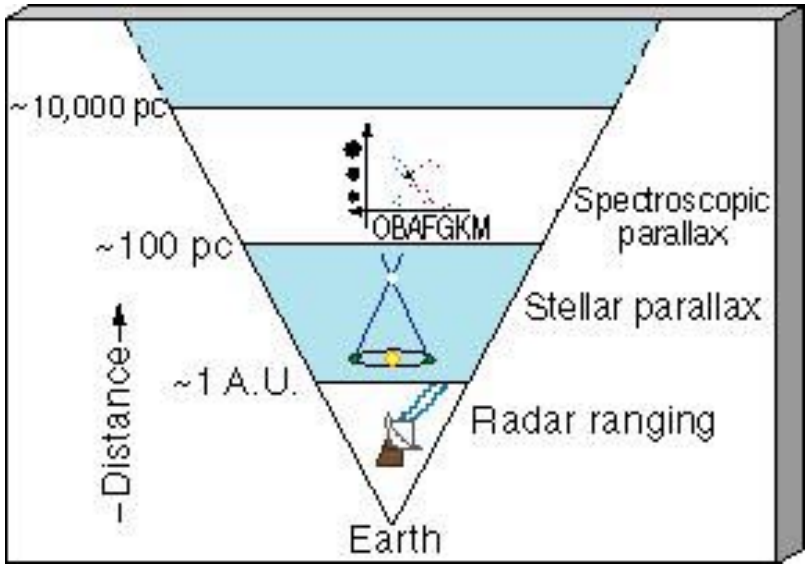




Distance Modulus

- $\mu = m - M$
- Fainter means farther
- For distance in parsecs:

- $D=10^{((m-M+5)/5)}$
- $m-M=5 \log D-5$

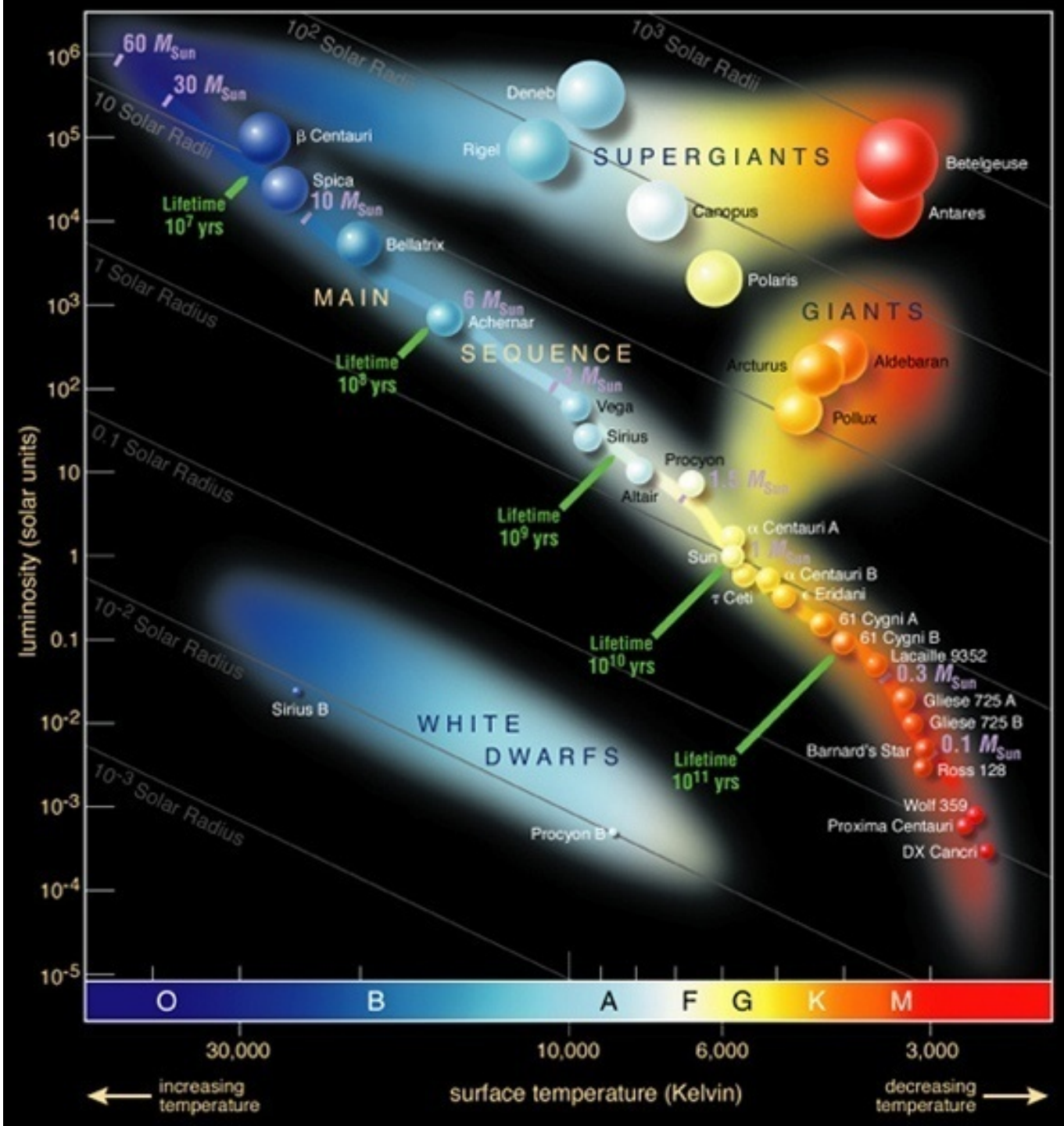


	m	M	=m-M	Distance	Spectral Type	
Deneb	1.5	-7.5			A2Ia	
Algol	2	0			**B8V**	
61 Cygni	5	8			K5V	
HR 8799	5	2			A2V	

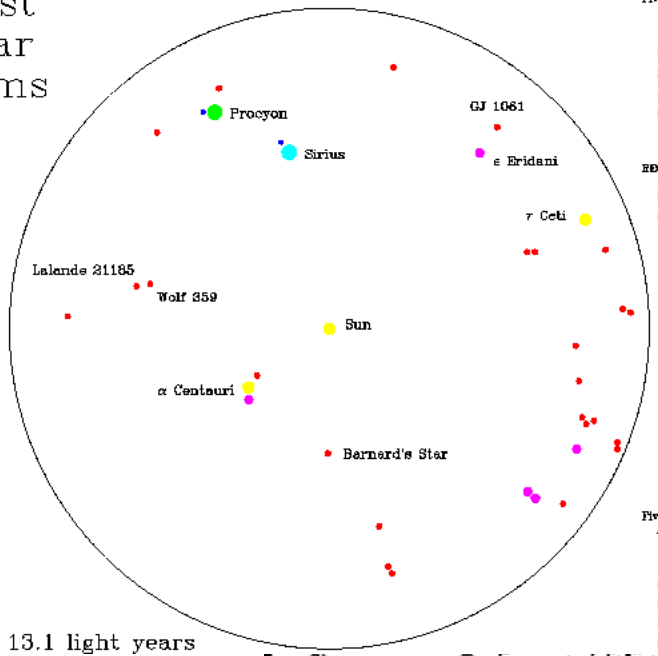
Table 9-1

m-M	Dist		m-M	Dist		m-M	Dist		m-M	Dist
-5	1 pc		0	10 pc		5	100 pc		10	1000pc
-4	1.6 pc		1	16 pc		6	160 pc		11	1600pc
-3	2.5 pc		2	25 pc		7	250 pc		12	2500pc
-2	4 pc		3	40 pc		8	400 pc		13	4000pc
-1	6.3 pc		4	63 pc		9	630 pc		14	6300pc

HR Diagram


luminosity (solar units)
10^6
10^5
10^4
10^3
10^2
10
1
0.1
10^{-2}
10^{-3}
10^{-4}
10^{-5}
60 M_{Sun}
30 M_{Sun}
10^2 Solar Radii
10^3 Solar Radii
10 Solar Radii
1 Solar Radius
0.1 Solar Radius
10^{-2} Solar Radius
10^{-3} Solar Radius
Deneb
Rigel
SUPERGIANTS
Betelgeuse
Antares
Canopus
Polaris
β Centauri
Spica
10 M_{Sun}
Lifetime 10^7 yrs
Bellatrix
MAIN
6 M_{Sun}
Achernar
SEQUENCE
GIANTS
Arcturus
Aldebaran
Pollux
Lifetime 10^8 yrs
3 M_{Sun}
Vega
Sirius
Procyon
1.5 M_{Sun}
Altair
Lifetime 10^9 yrs
α Centauri A
Sun
1 M_{Sun}
α Centauri B
ε Eridani
τ Ceti
61 Cygni A
61 Cygni B
Lacaille 9352
0.3 M_{Sun}
Gliese 725 A
Gliese 725 B
Lifetime 10^{10} yrs
Sirius B
WHITE DWARFS
Barnard's Star
0.1 M_{Sun}
Ross 128
Lifetime 10^{11} yrs
Wolf 359
Proxima Centauri
DX Cancri
Procyon B
O
B
A
F
G
K
M
30,000
10,000
6,000
3,000
increasing temperature
surface temperature (Kelvin)
decreasing temperature

Nearest 25 Star Systems



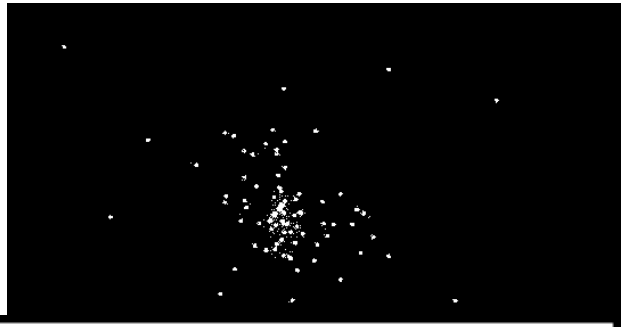
Five Nearest Systems

1. α Centauri
2. Barnard's Star
3. Wolf 359
4. Lalande 21185
5. Sirius

RECONS Discovery

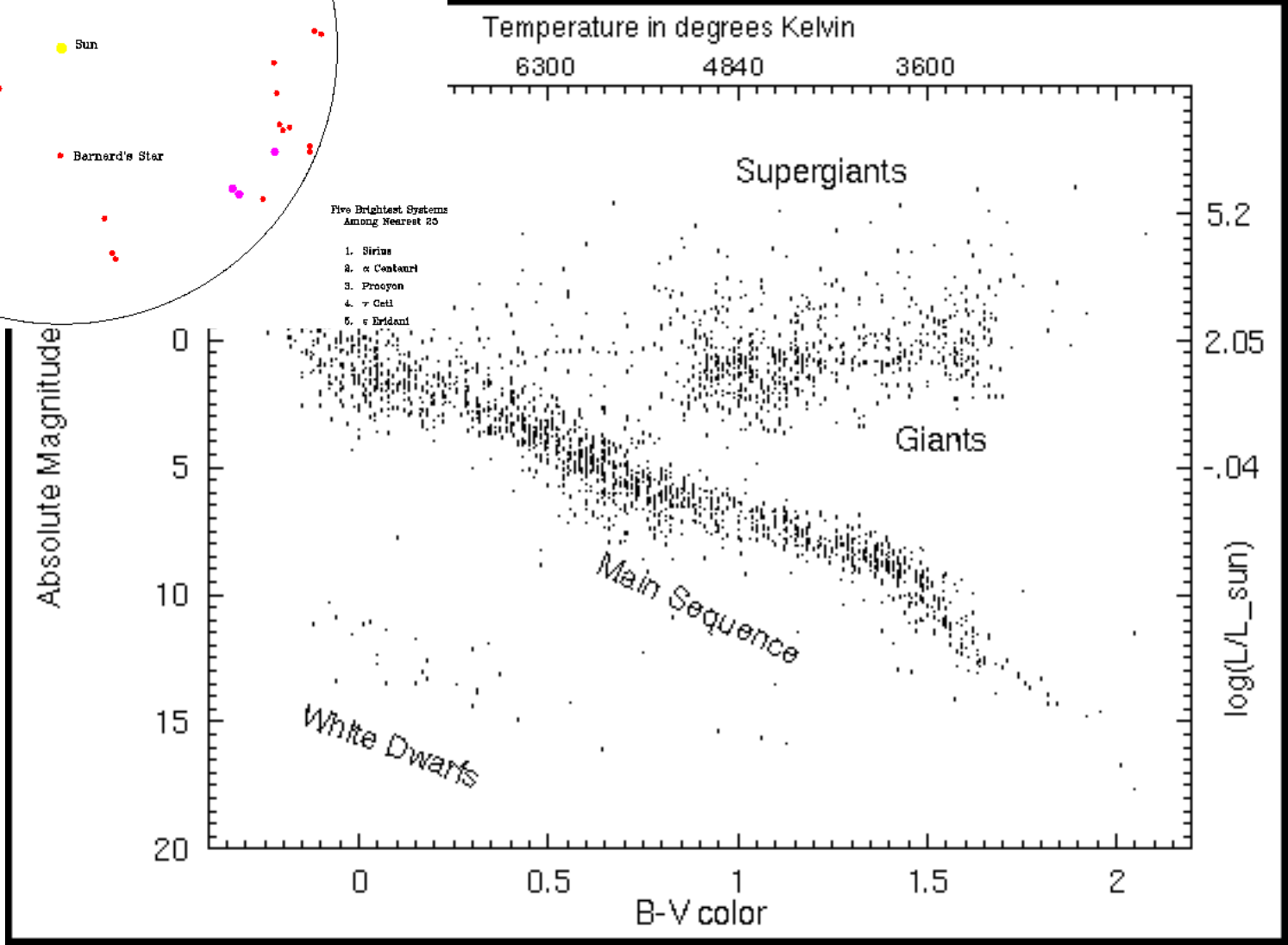
20. GJ 1061
(11.9 light years)

horizon = 13.1 light years

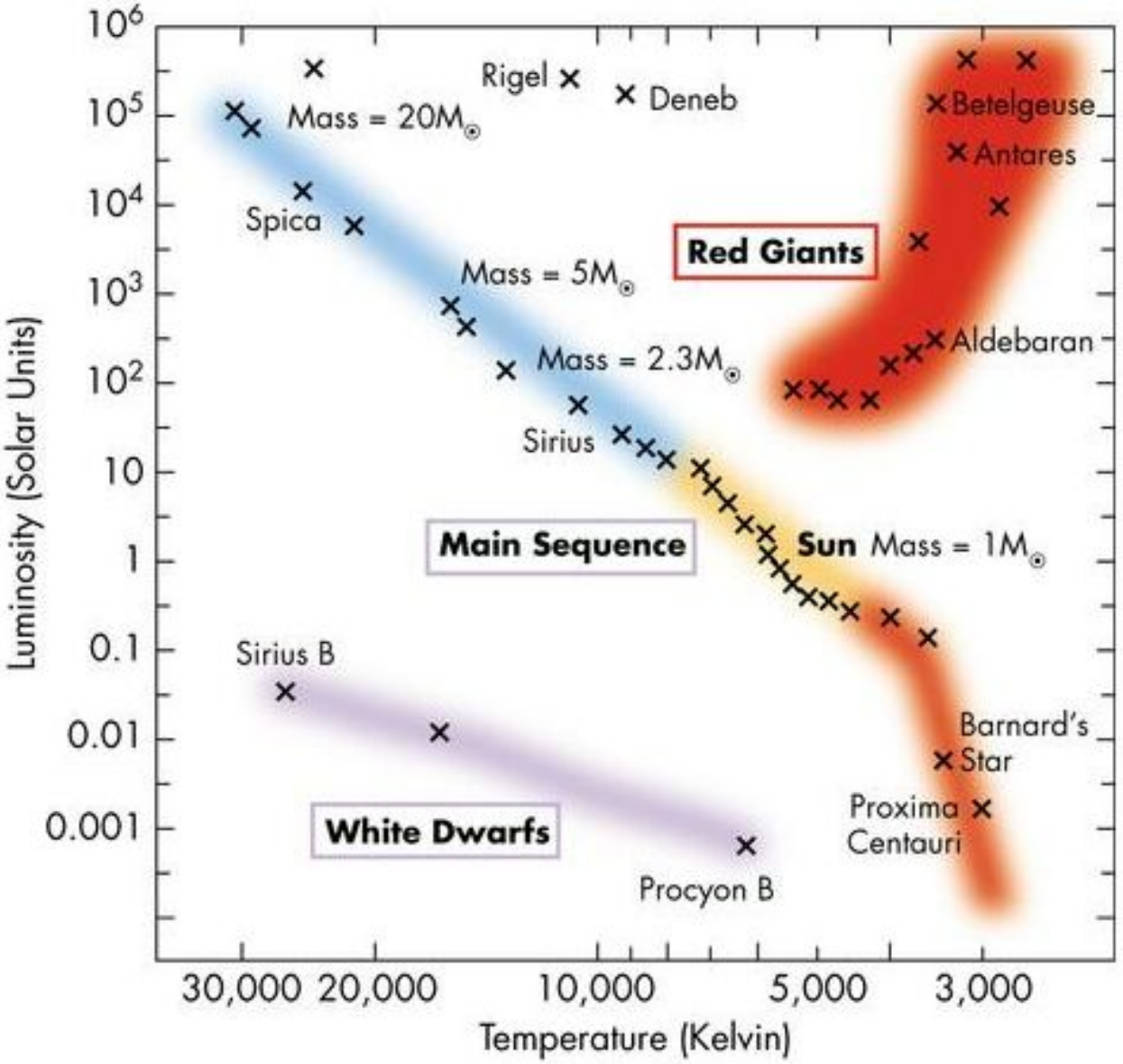


Five Brightest Systems Among Nearest 25

1. Sirius
2. α Centauri
3. Procyon
4. τ Ceti
5. ε Eridani

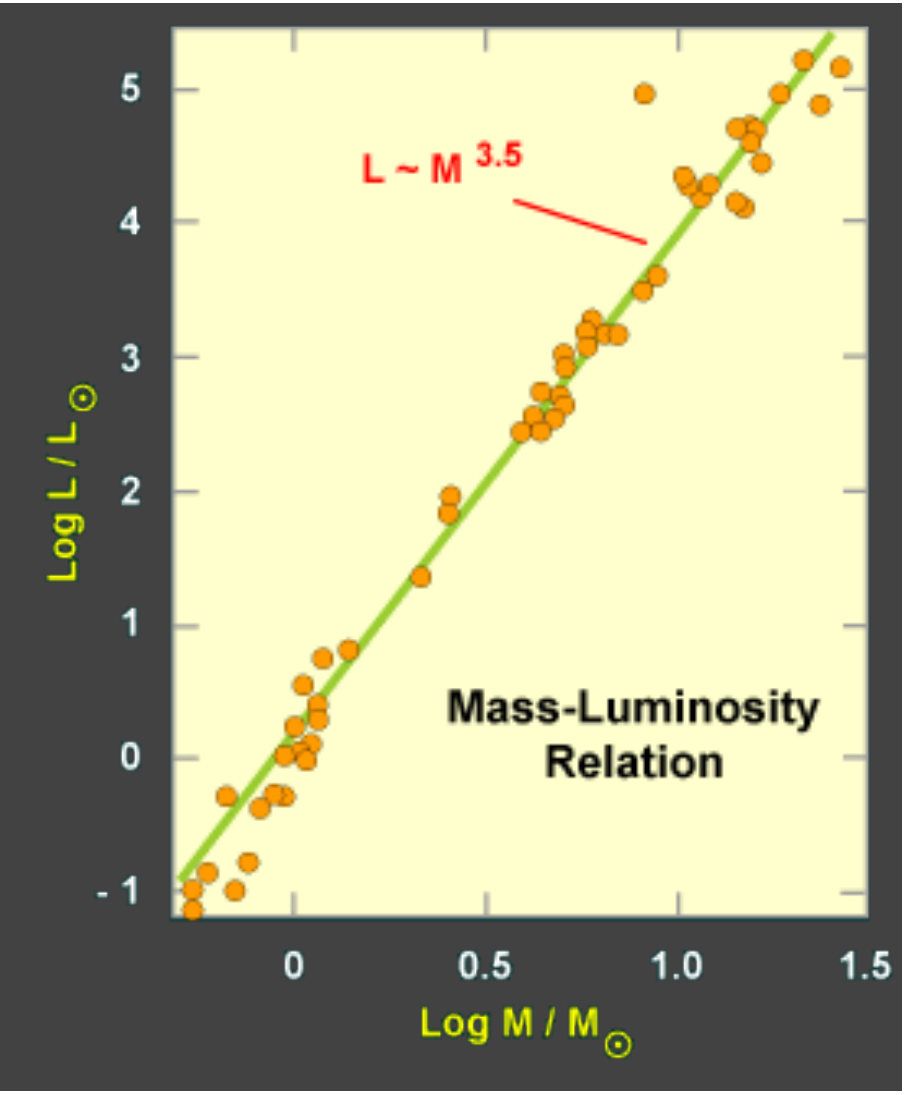


Red Giants and White Dwarfs



- A few bright cool stars
- Very few small hot stars

Stellar Mass-Luminosity Relation



- Big stars are bright stars
- From Eclipsing or Visual Binaries plus radial velocity curve we get Masses and maybe Diameters
- Plus spectral types gives Temperature and Luminosity

New 23rd Nearest Star –May 03

- 3.8 parsecs from Earth; 300,000X fainter than sun
- Teegarden's star