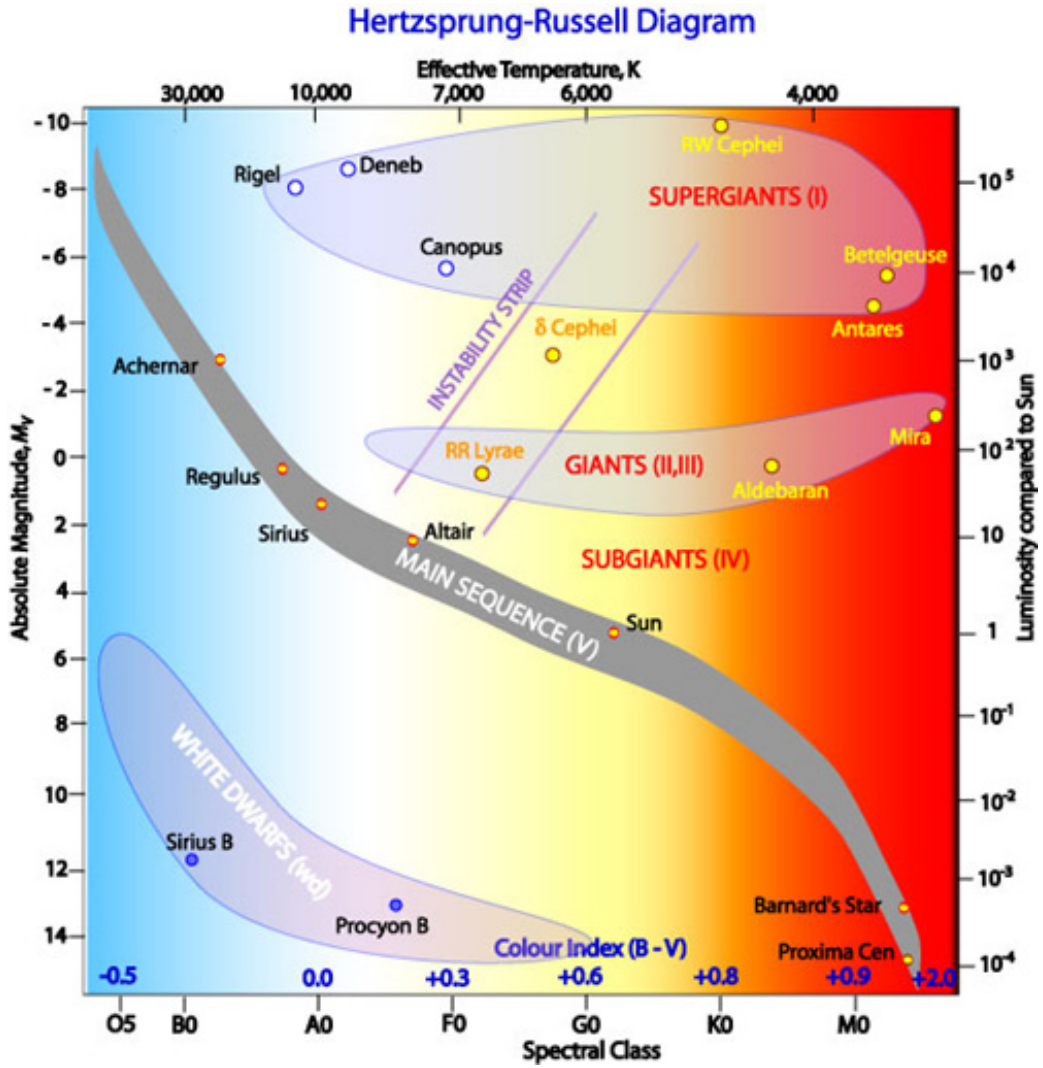
Astronomisch Practicum I

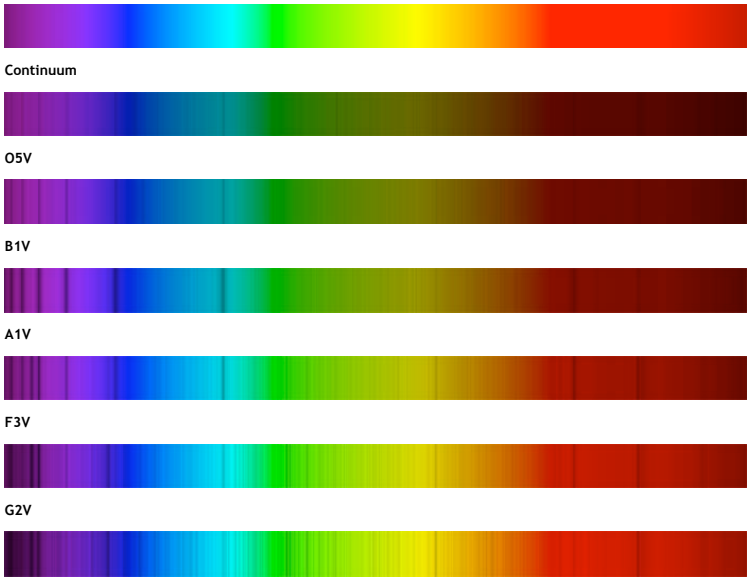
Hertzsprung Russell Diagram



Jörg R. Hörandel

Spectral classes

To see how this spectral classification scheme works study the sequence of spectra shown below. It shows spectra for different stars has photographic plots. In reality photographic spectra would not show colour as the plates were monochrome but the colour has been added here to highlight the different wavelengths.



Spectral Class Summary

Spectral Class	Effective Temperature (K)	Colour	H Balmer Features	Other Features	M/M_{Sun}	R/R_{Sun}	L/L_{Sun}	Main Sequence Lifespan
O	28,000 - 50,000	Blue	weak	ionised He^+ lines, strong UV continuum	20 - 60	9 - 15	90,000 - 800,000	1 - 10 Myr
B	10,000 - 28,000	Blue-white	medium	neutral He lines	3 - 18	3.0 - 8.4	95 - 52,000	11 - 400 Myr
A	7,500 - 10,000	White	strong	strong H lines, ionised metal lines	2.0 - 3.0	1.7 - 2.7	8 -55	400 Myr - 3 Gyr
F	6,000 - 7,500	White-yellow	medium	weak ionised Ca^+	1.1 - 1.6	1.2 - 1.6	2.0 - 6.5	3 - 7 Gyr
G	4,900 - 6,000	Yellow	weak	ionised Ca^+, metal lines	0.85 - 1.1	0.85 - 1.1	0.66 - 1.5	7 - 15 Gyr
K	3,500 - 4,900	Orange	very weak	Ca^+, Fe, strong molecules, CH, CN	0.65 - 0.85	0.65 - 0.85	0.10 - 0.42	17 Gyr
M	2,000 - 3,500	Red	very weak	molecular lines, eg TiO, neutral metals	0.08 - 0.05	0.17 - 0.63	0.001 - 0.08	56 Gyr
L?	<2,000	Tentative new (2000) classification for very low mass stars.			<0.08	May or may not be fusing H in cores?		

Main sequence stars

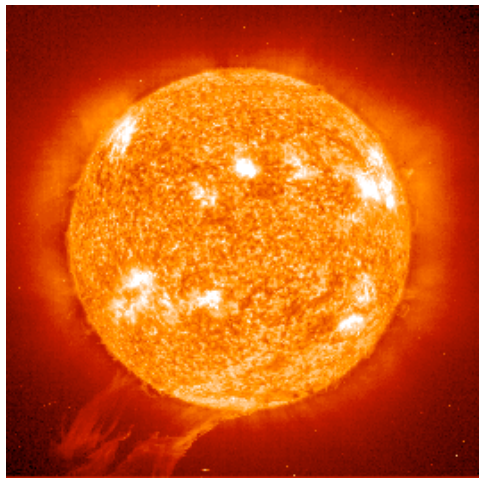
mass - brightness relation

$$L \propto M^{3.5}$$

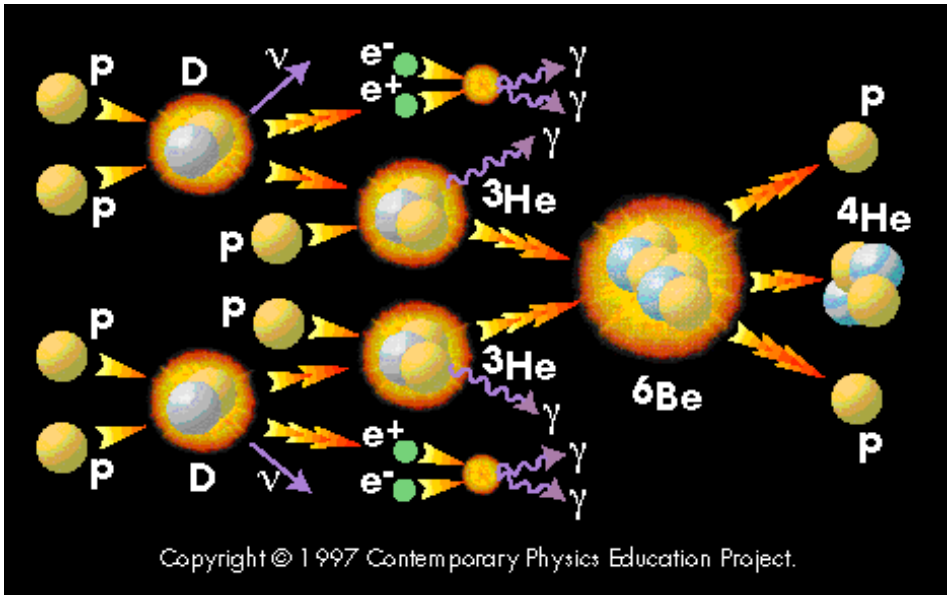
radius - brightness relation

$$R \propto M^{0.6}$$

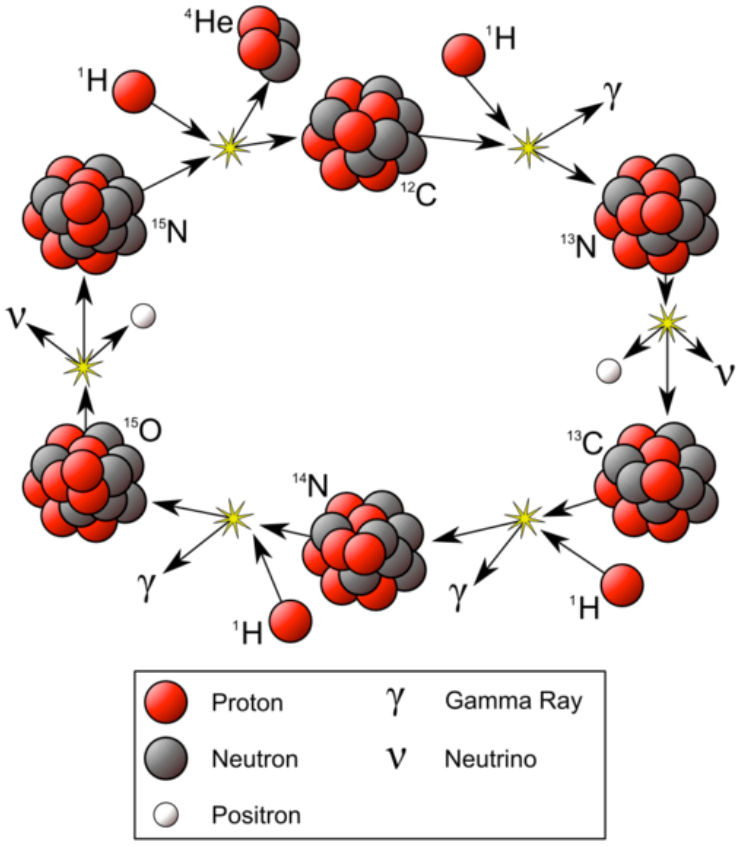
Hydrogen burning



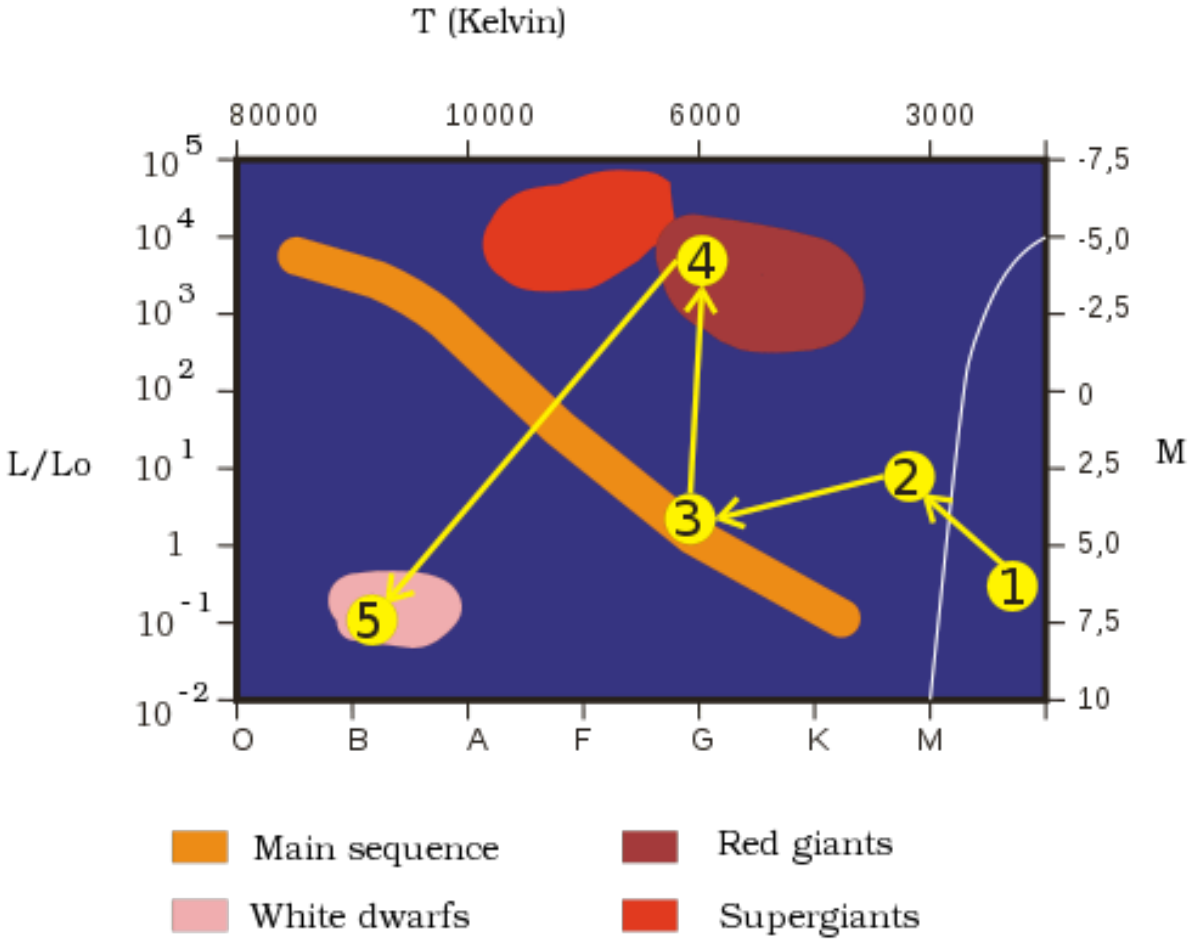
p-p cycle



CNO cycle

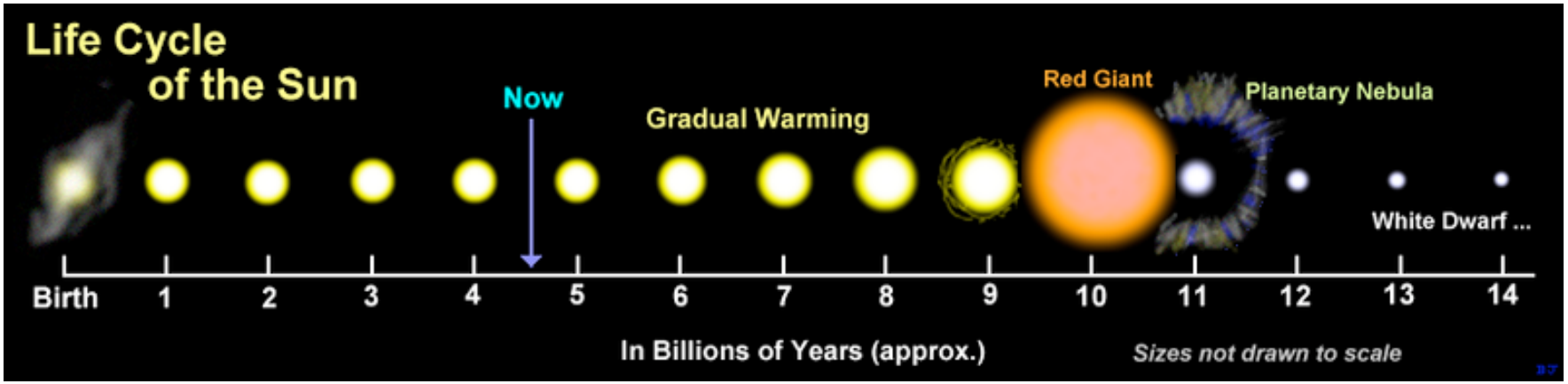


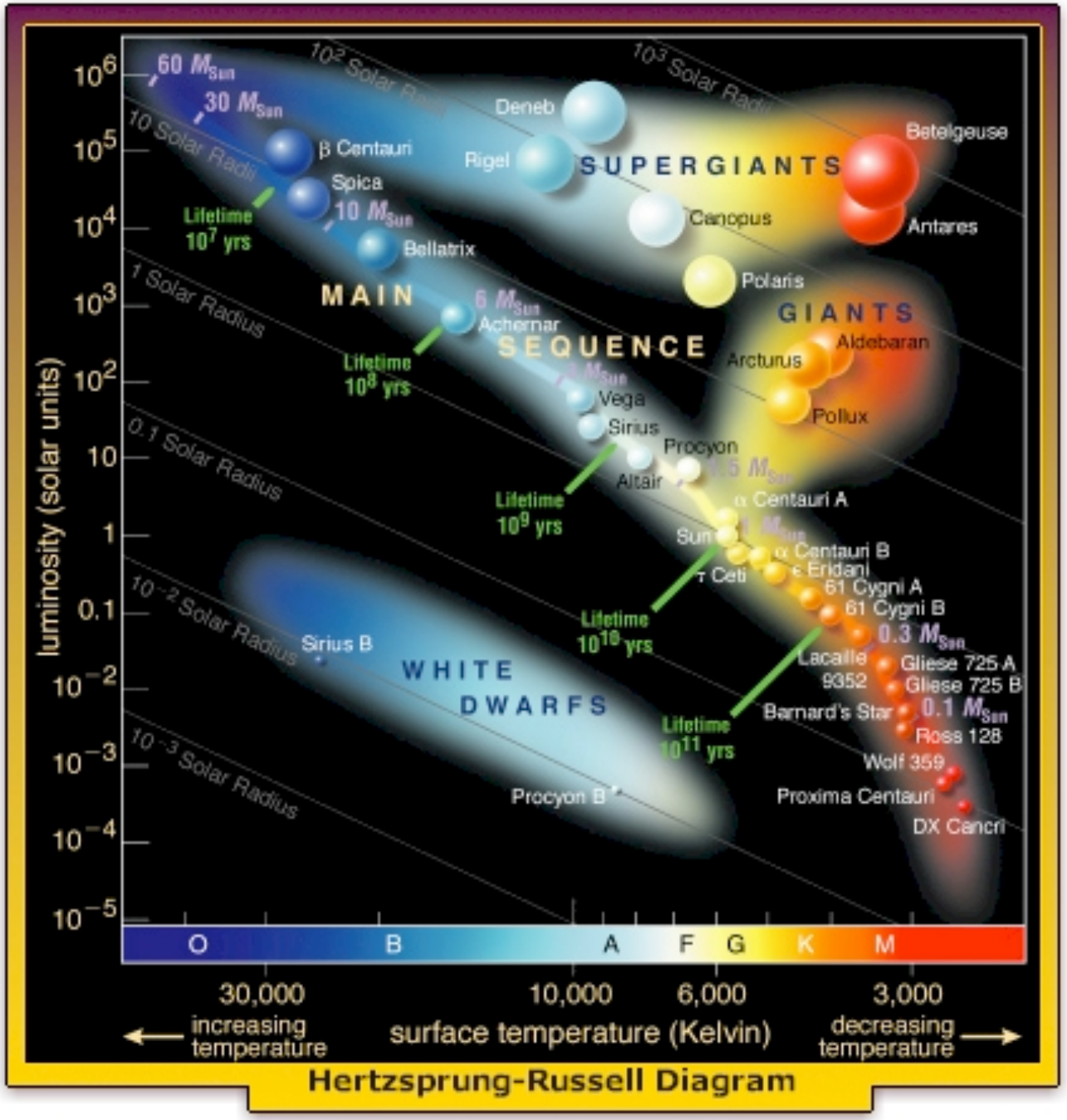
Stellar evolution



Simplified illustration of the evolution of a star with the mass of the Sun.
The star forms from a collapsing cloud of gas (1),
and then undergoes a contraction period as a protostar (2),
before joining the main sequence (3).
Once the Hydrogen at the core is consumed it expands into a red giant (4),
then sheds its envelope into a planetary nebula and degenerates into a white dwarf (5).

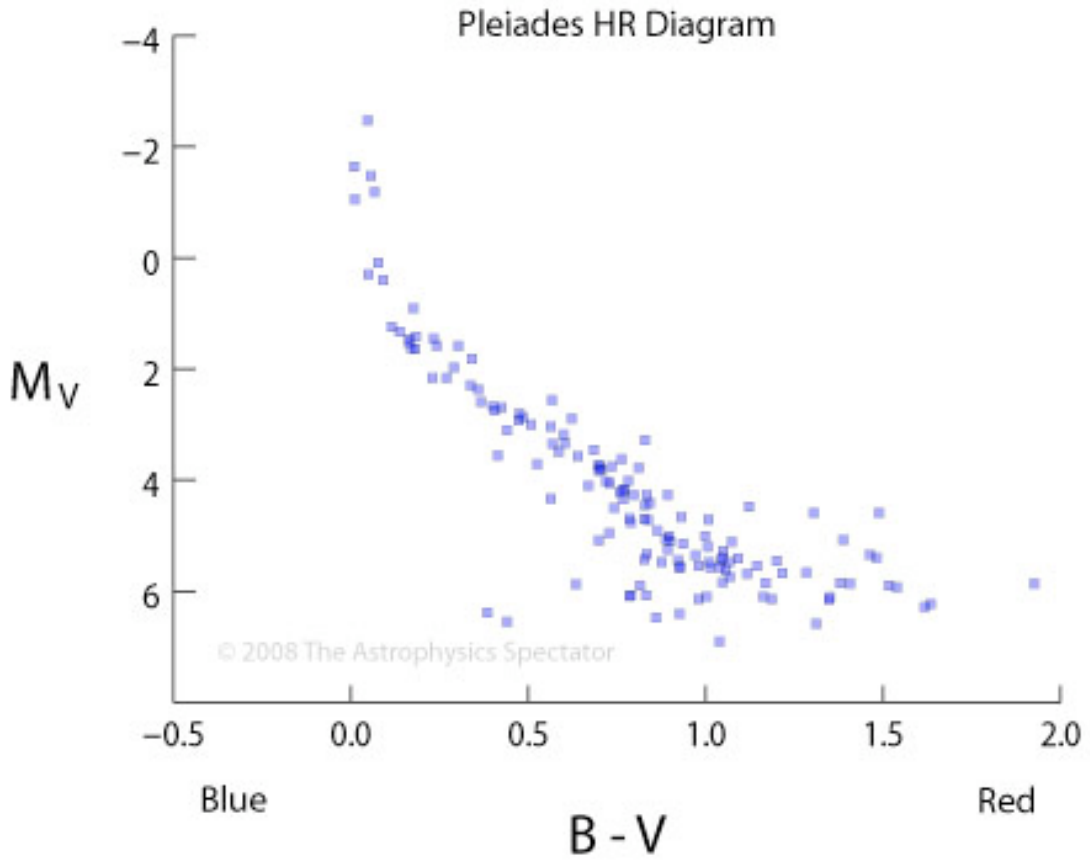
Stellar evolution




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

HRD of open clusters

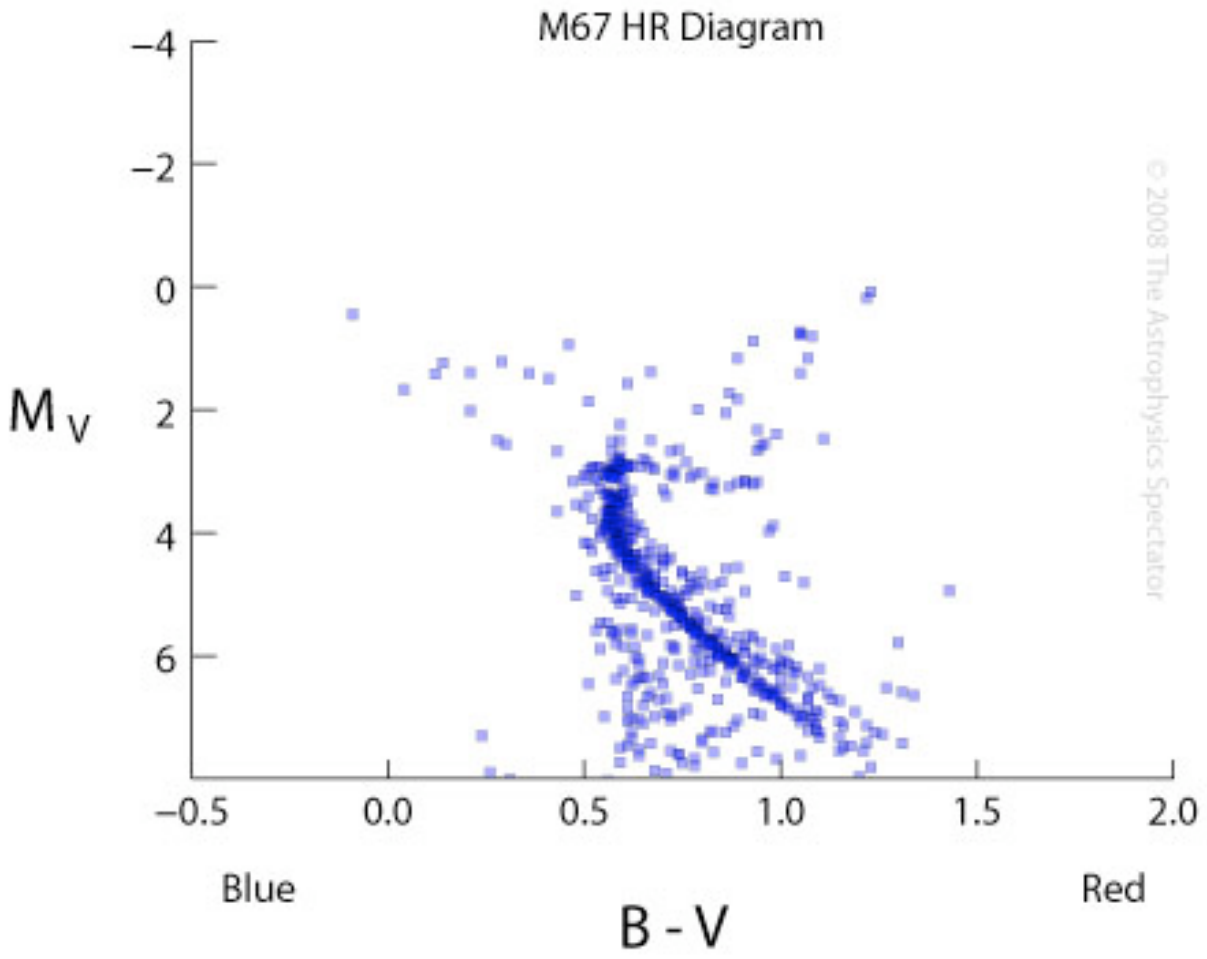
plejades



The Hertzsprung-Russell Diagram for 145 stars of the Pleiades open cluster. The vertical axis is absolute visual magnitude (M_V), and the horizontal axis is color index, which is apparent magnitude in the B (blue) band minus the apparent magnitude in the V (visual) band. The data on this plot are for stars at the position of the cluster and with velocities that suggest membership in the cluster with 50% certainty. The data is taken from Kharchenko et al. (2004),[2] and they are available through the VizieR service in catalog J/AN/325/740/csoca.

HRD of open clusters

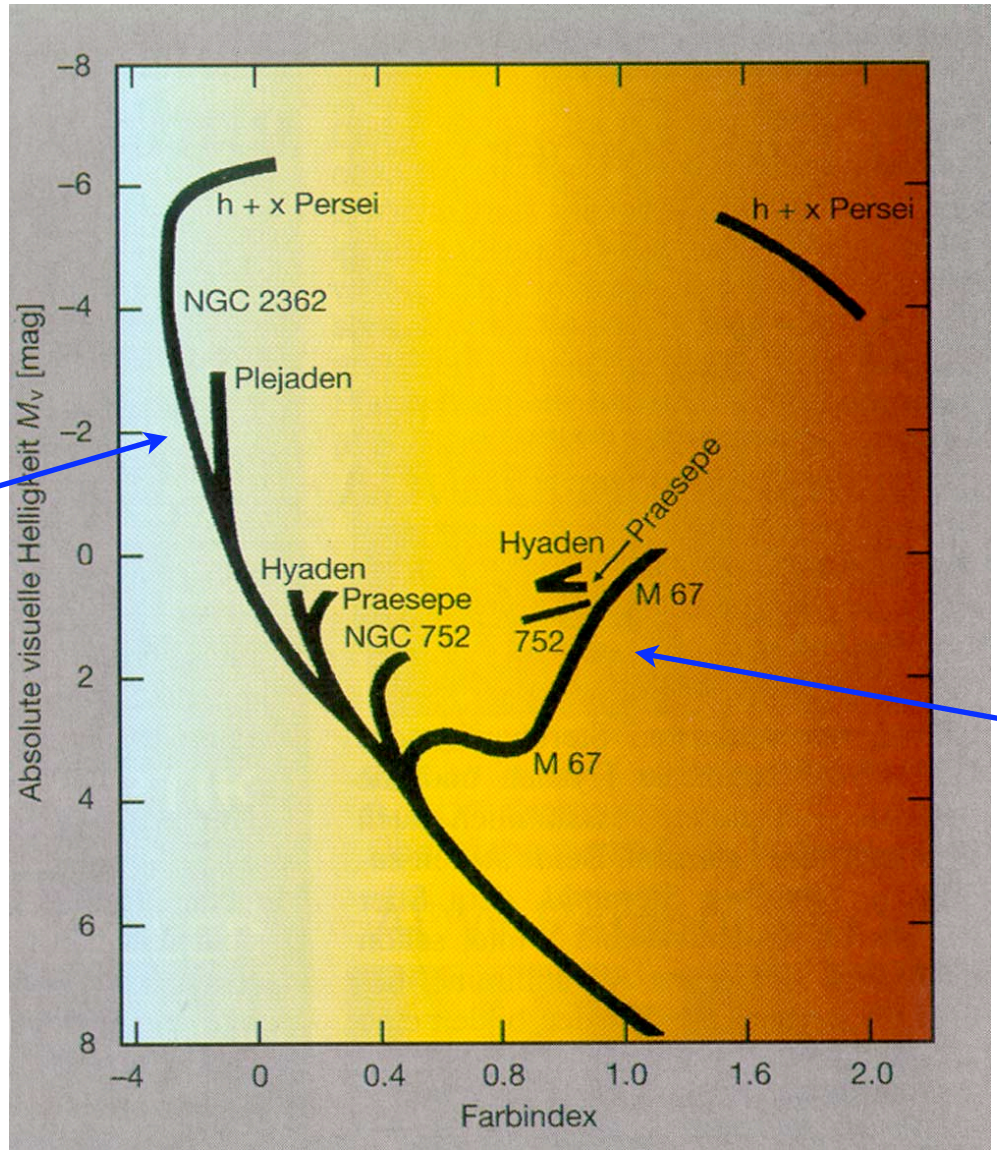
M67



The Hertzsprung-Russell Diagram for stars of the open cluster Messier 67. The diagram contains 637 stars from a survey compete between 12.5 < B < 18.5 and 12.5 < V < 18.5. The distance of the cluster is set to 908 parsecs (Kharchenko et al. 2005).[3] The data is taken from Stassun et al. (2002), which is available through the VizieR service as catalog J/A+A/382/899/table3.[4]

HRD of open clusters

combined HRD for clusters of different age



young cluster

old cluster