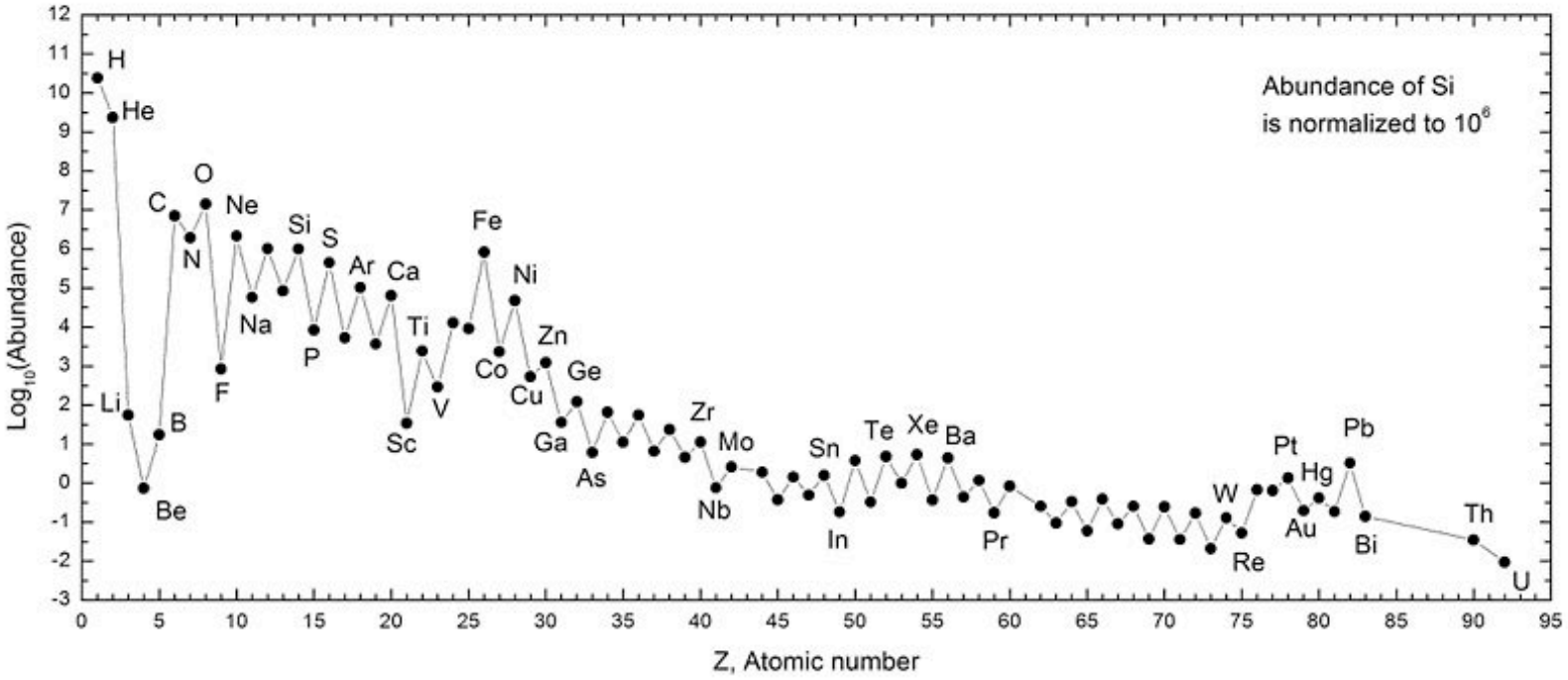
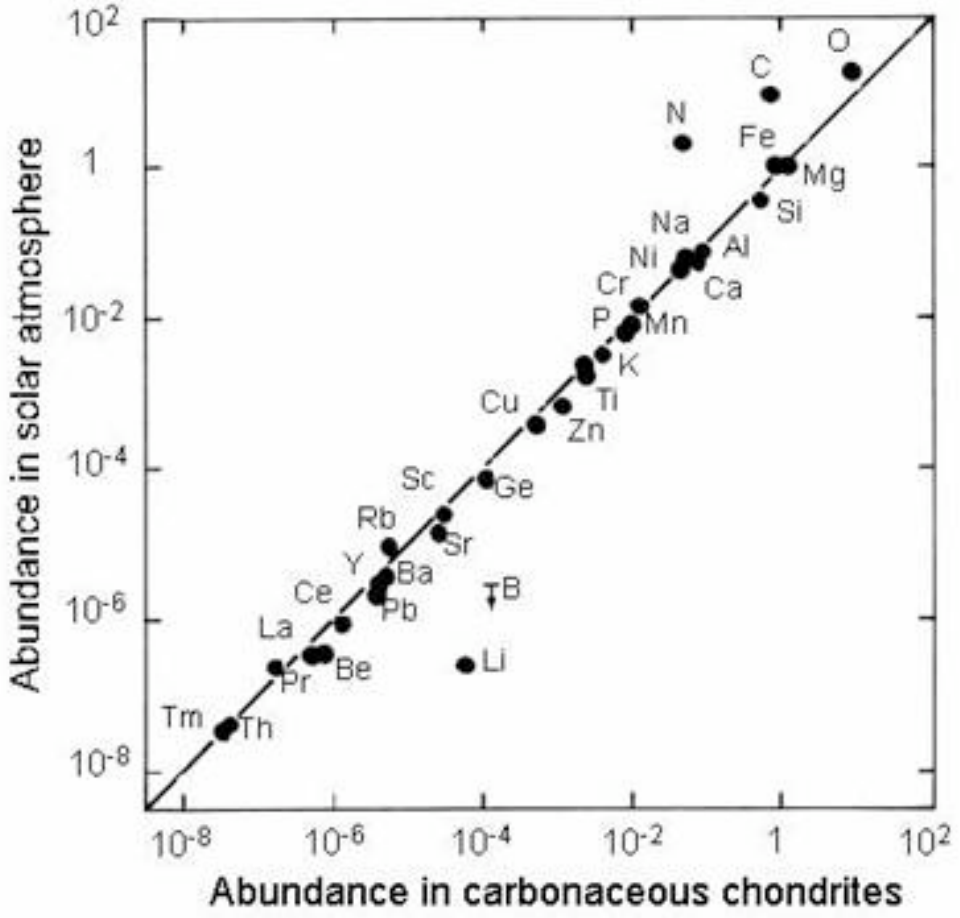
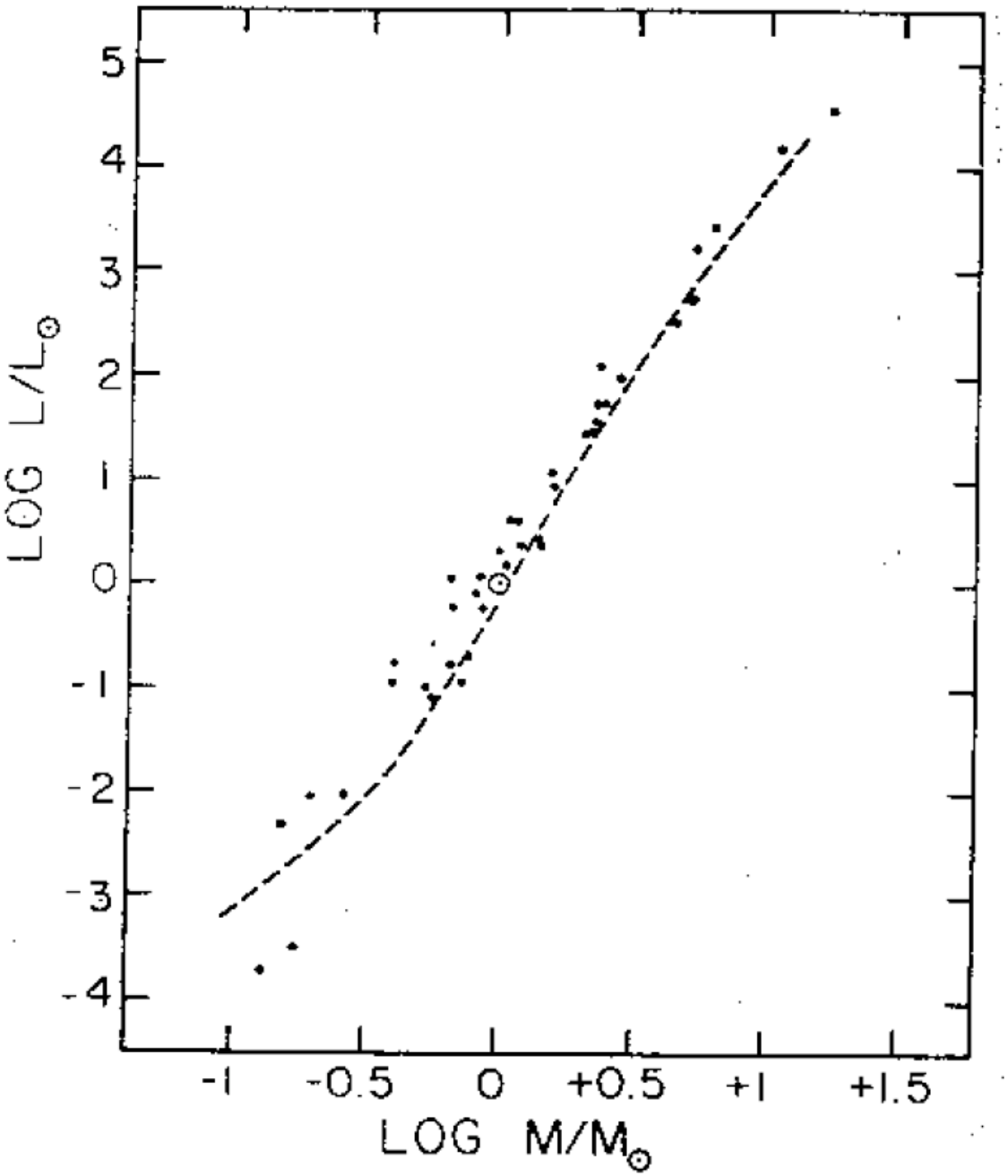
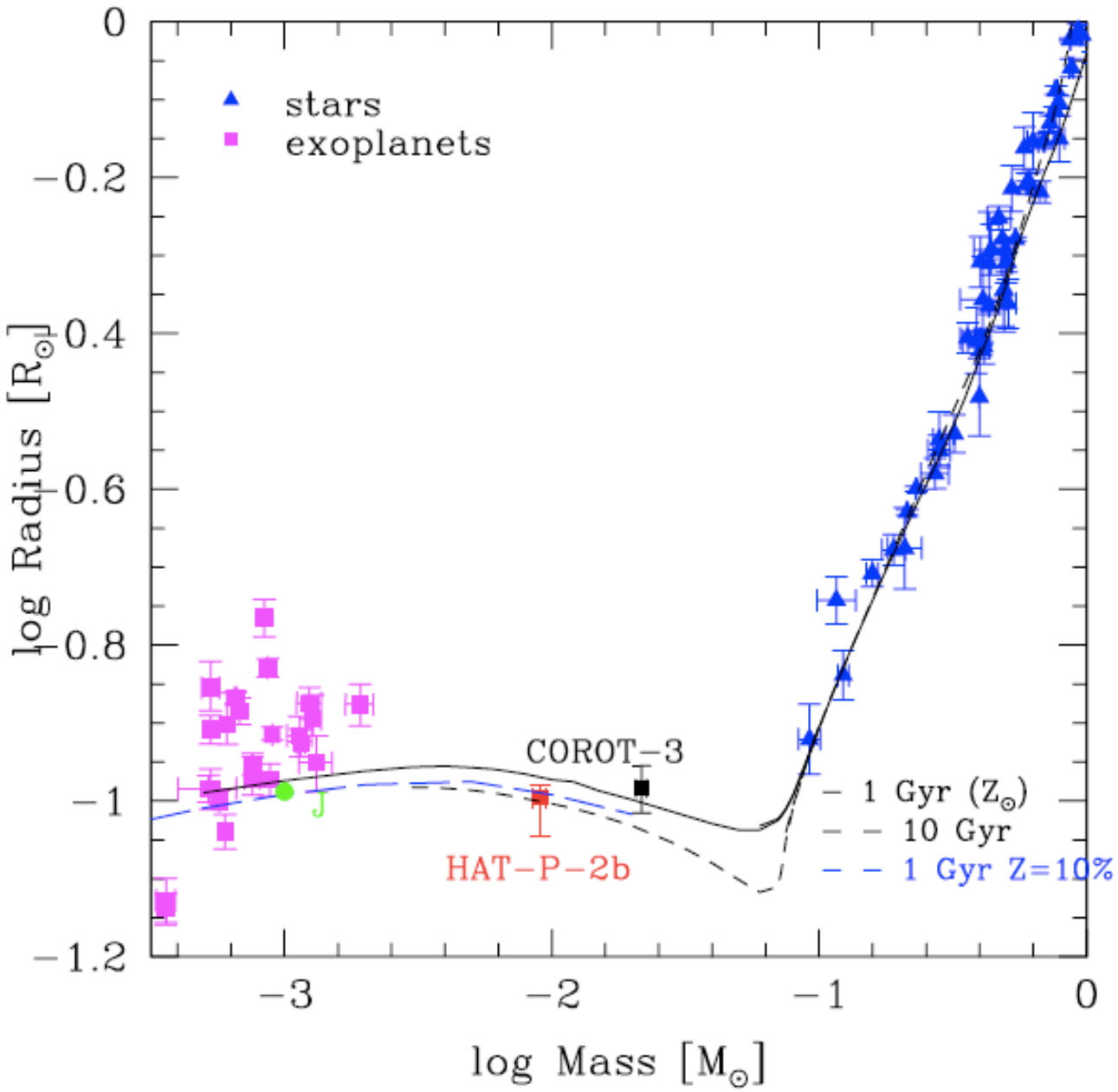


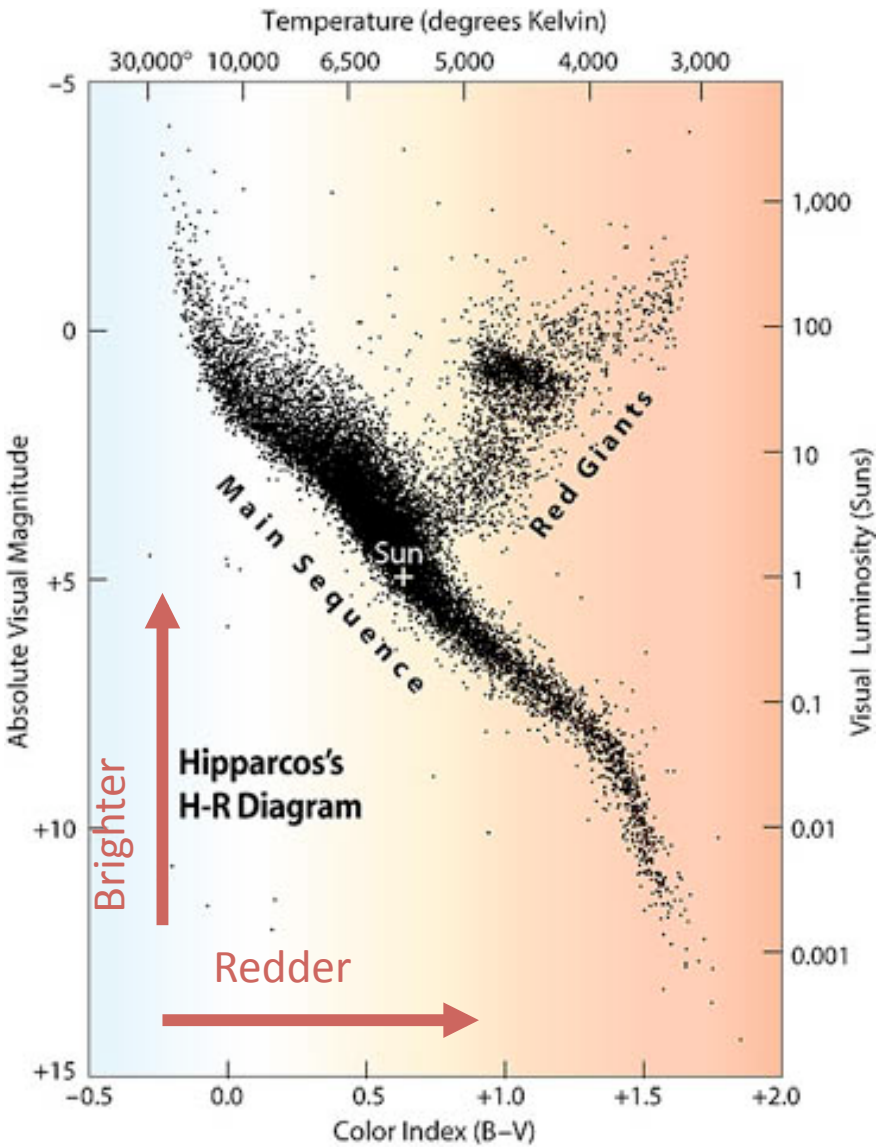

Element abundances in the Solar system (data from Lodders 2003)

What makes planets is what makes stars, minus the lightest stuff

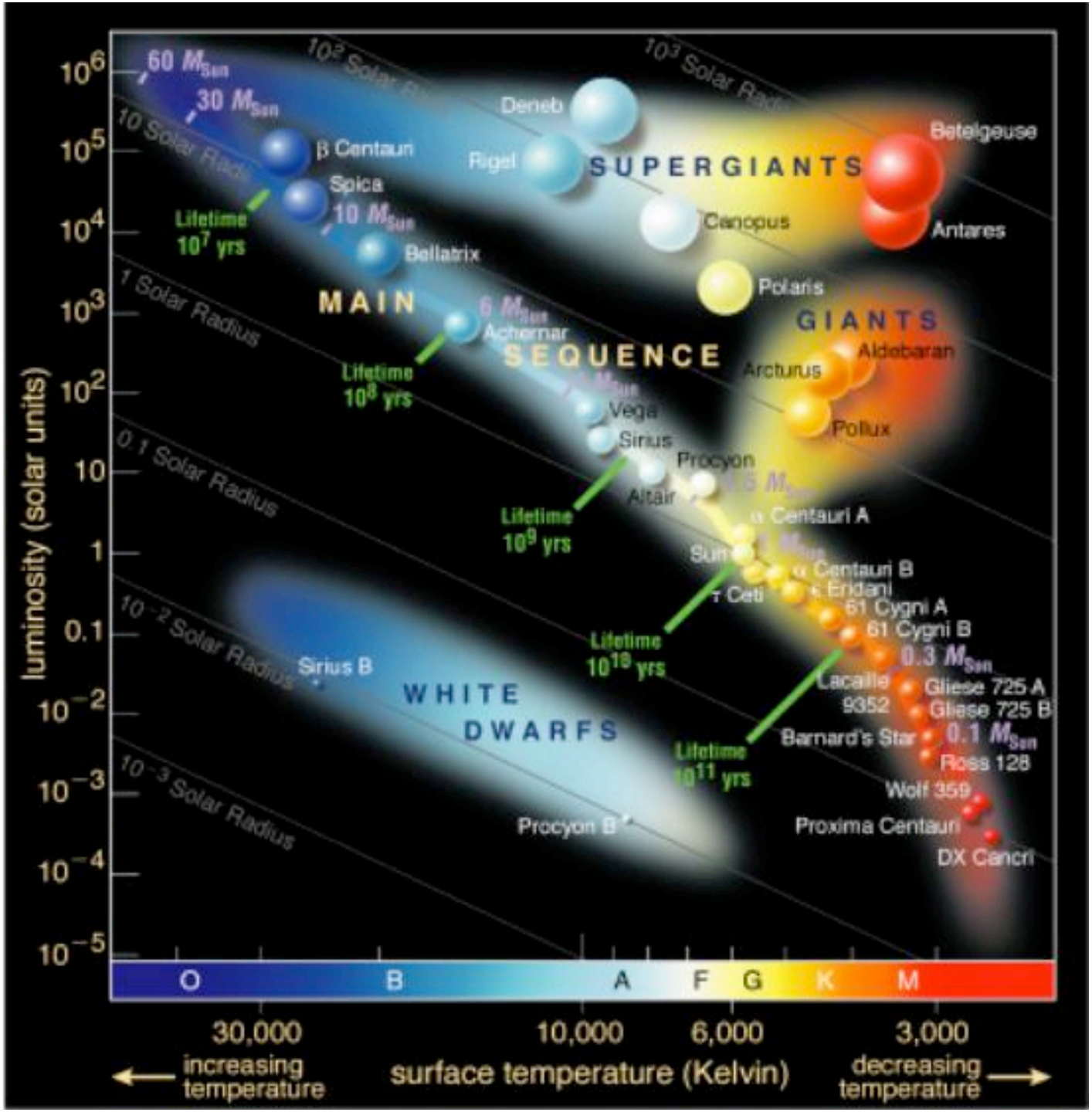



5
4
3
2
1
0
-1
-2
-3
-4
LOG L/L⊙
-1
-0.5
0
+0.5
+1
+1.5
LOG M/M⊙


stars
exoplanets
COROT−3
HAT−P−2b
J
1 Gyr (Z⊙)
10 Gyr
1 Gyr Z=10%
log Radius [R⊙]
log Mass [M⊙]
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
−3
−2
−1
0

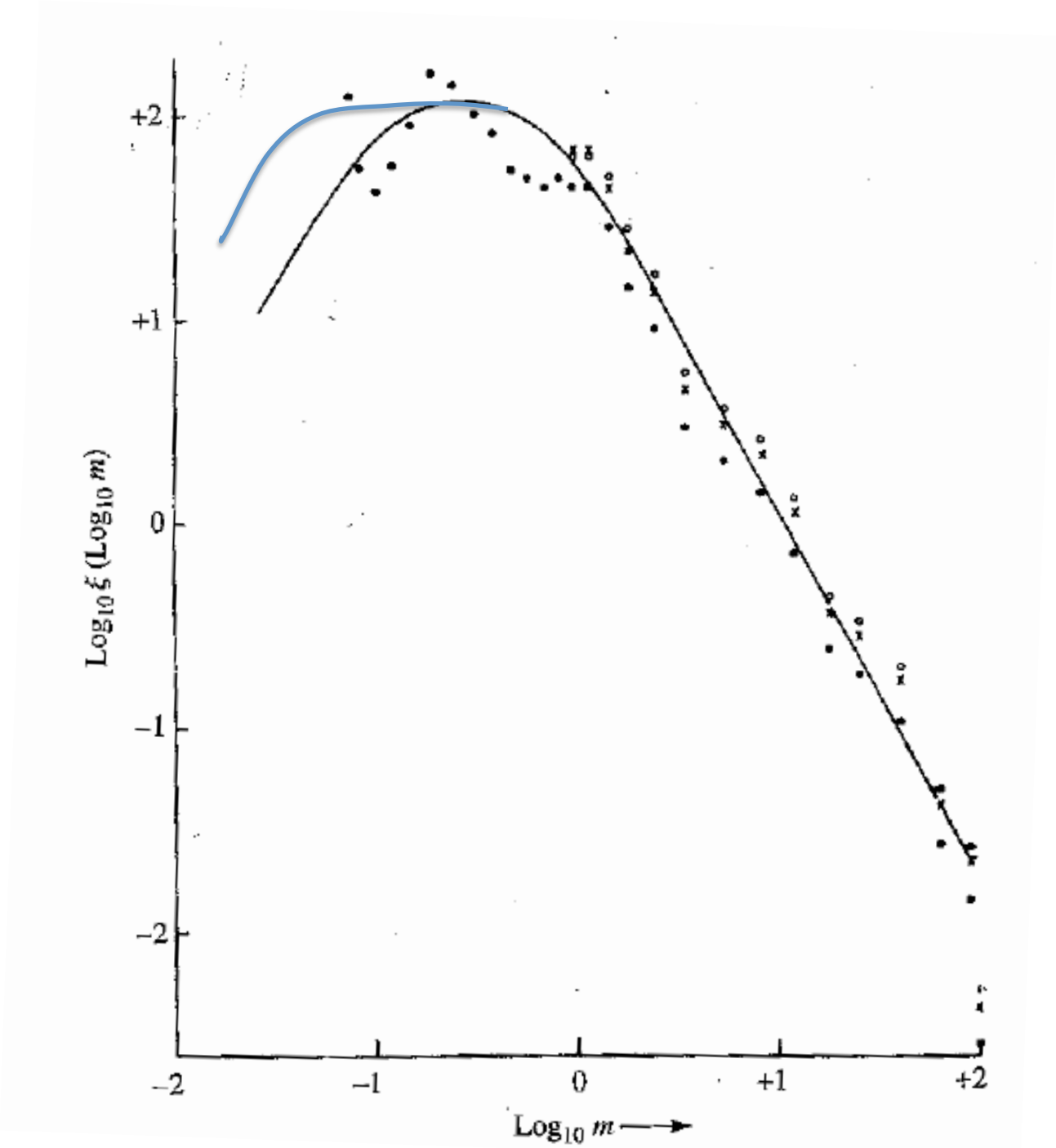


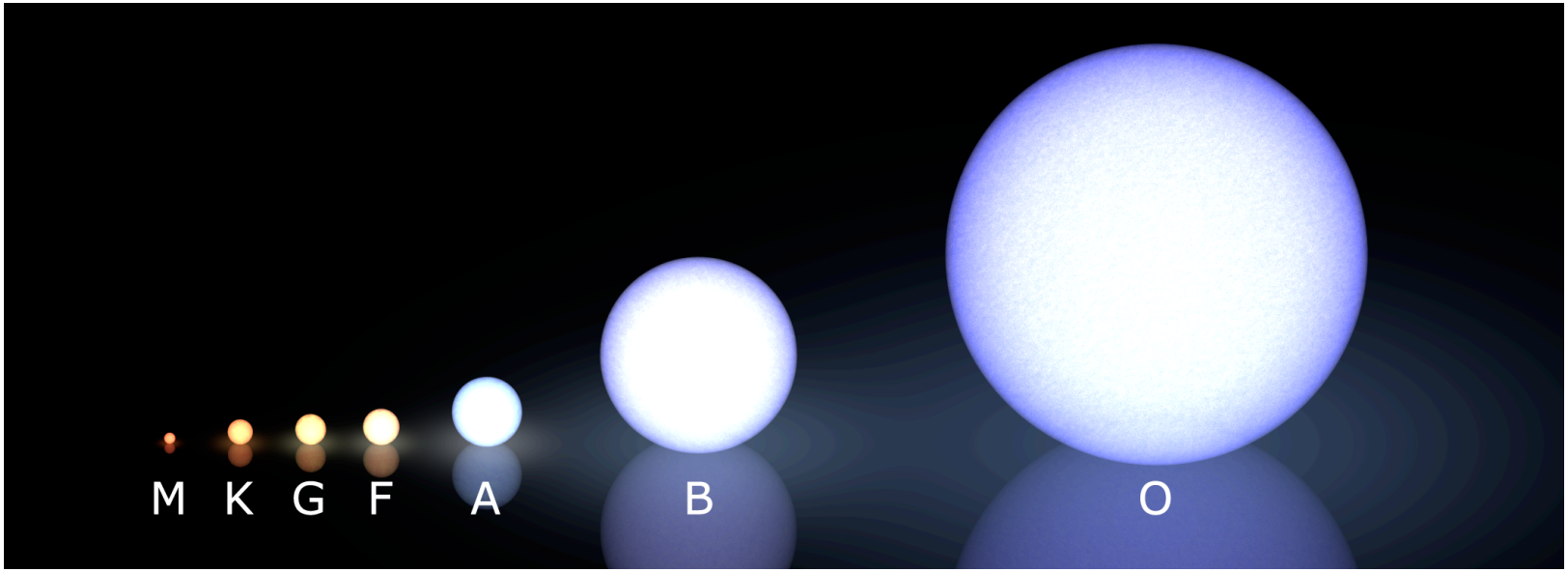

HR diagram of 20,853 stars with distances and colors measured by Hipparcos (borrowed from Catherine Turon's web site).


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

# Initial Mass Function

Salpeter (1953)
Miller & Scalo (1979)

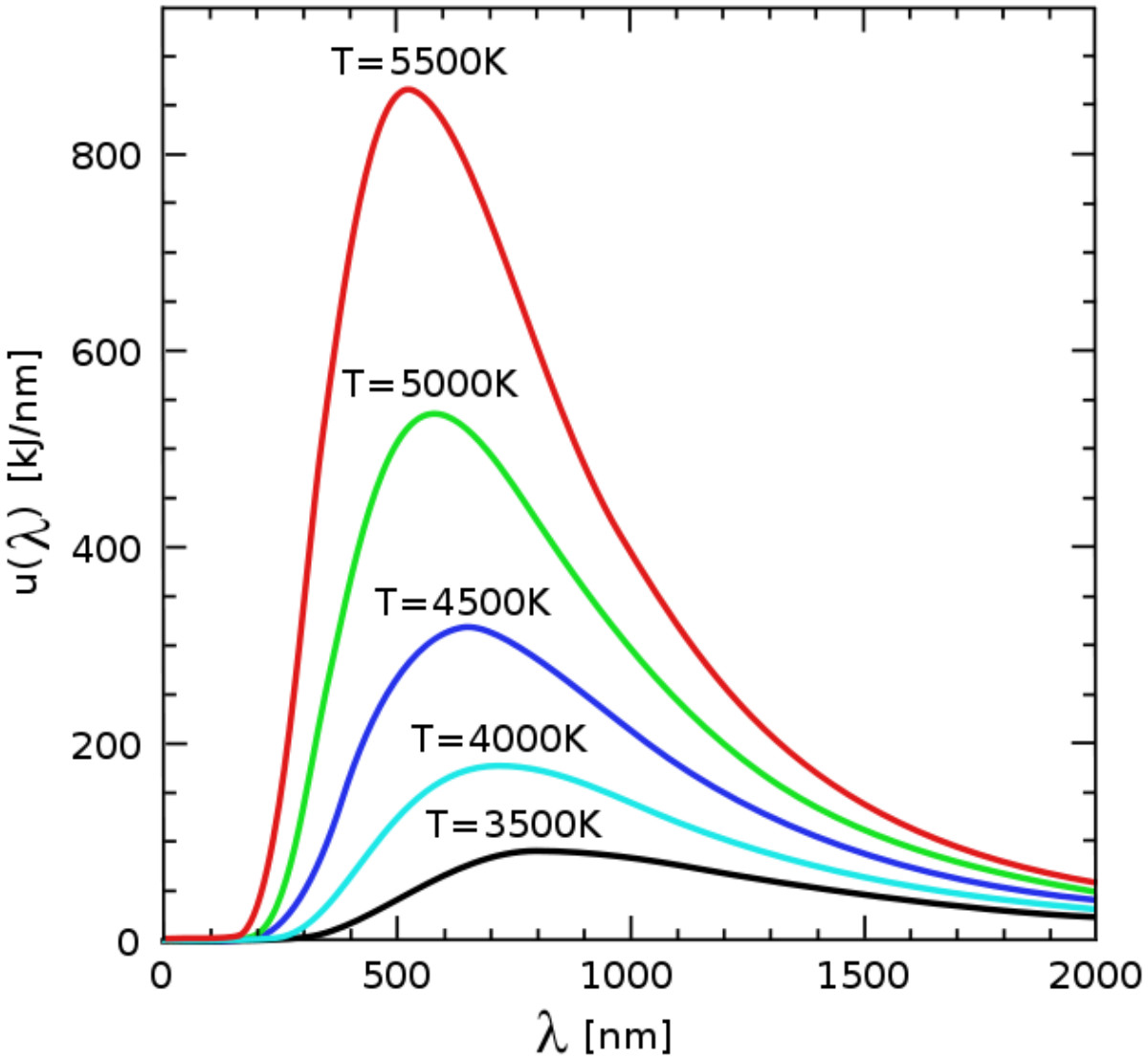



M
K
G
F
A
B
O

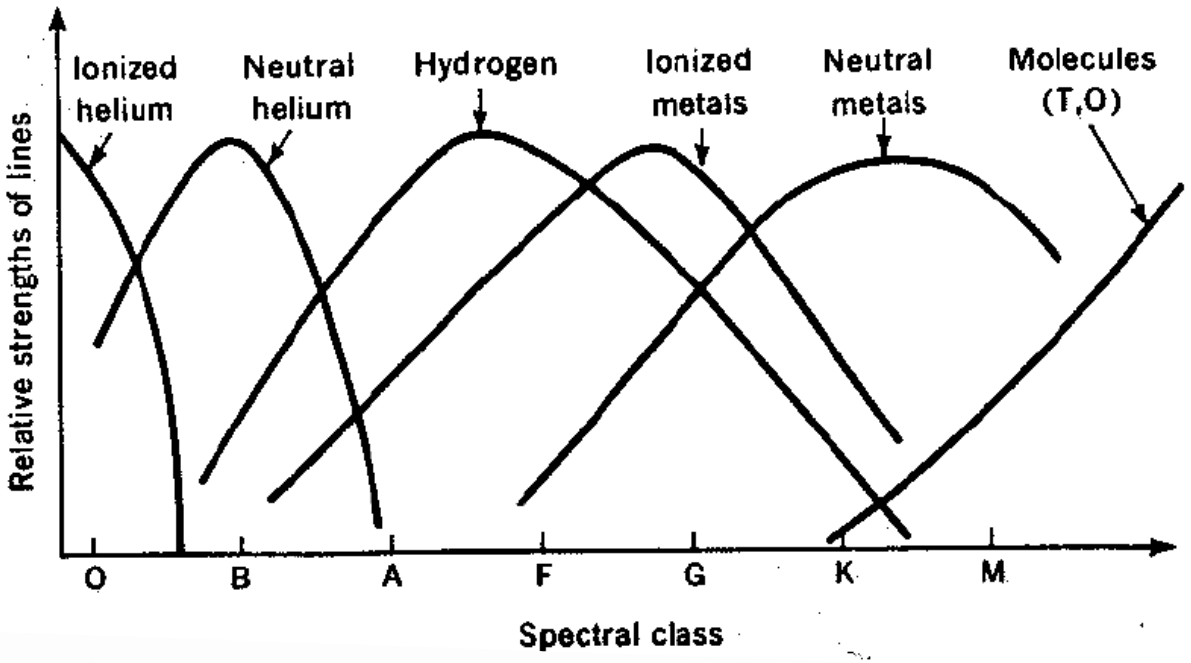
# SPECTRAL TYPES AND TEMPERATURES ON THE MAIN SEQUENCE

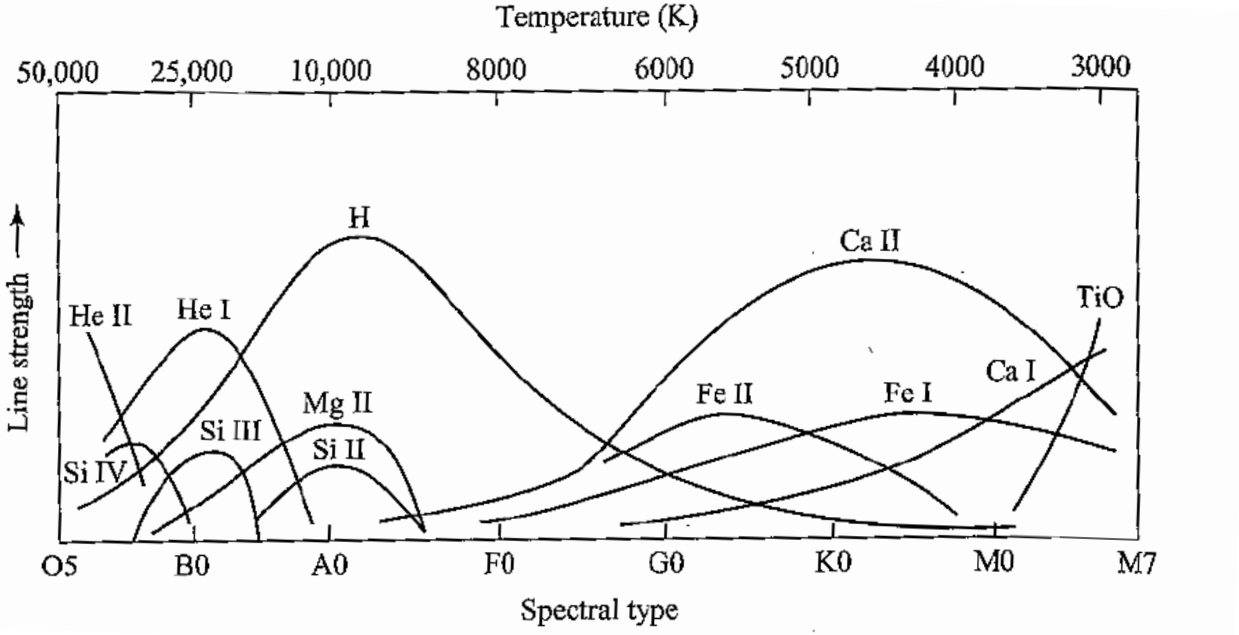
(mainly from Gray: The Observation and analysis of Stellar Photospheres 2nd ed., Cambridge Univ. Press )

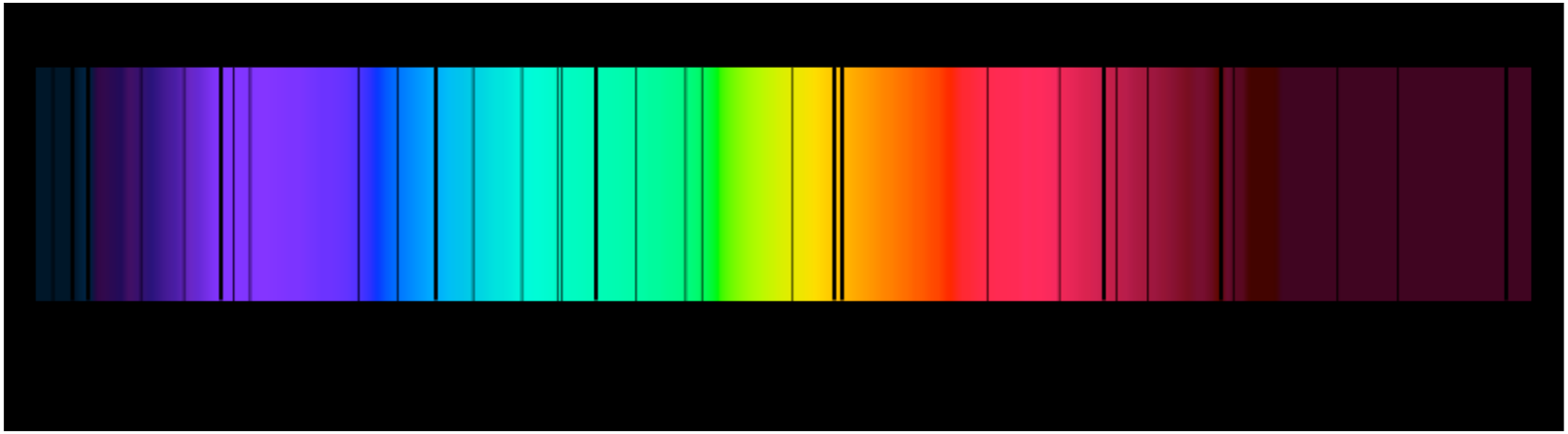
| | | | |
|---|---|---|---|
| O5 | 50,000 | G5 | 5,680 |
| O8 | 39,000 | K0 | 5,270 |
| B0 | 36,000 | M0 | 4,045 |
| B5 | 16,000 | M5 | 3,000 |
| B8 | 12,600 | M8 | 2,200 |
| A0 | 9,700 | L0 | 2,000 |
| A5 | 7,880 | L8 | 1,500 |
| F0 | 6,950 | T0 | 1,300 |
| F5 | 6,445 | T8 | 800 |
| G0 | 5,950 | | |

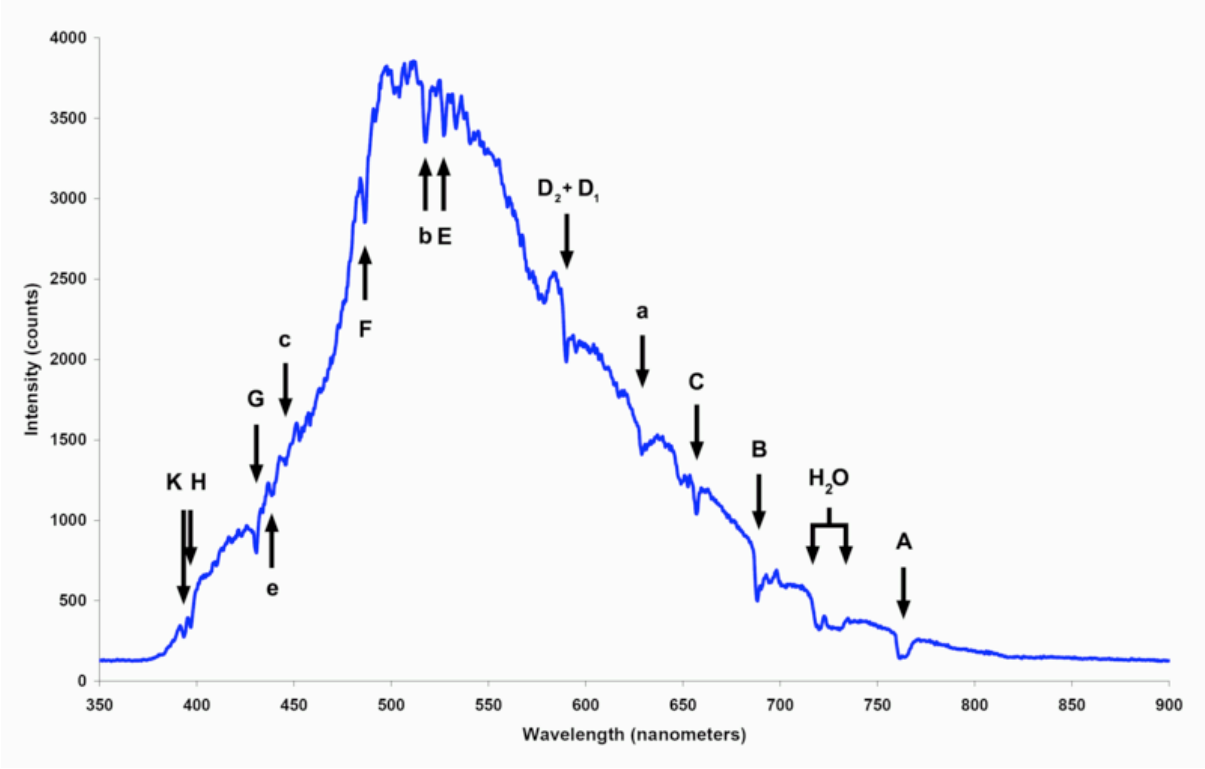



The Planck function for temperatures from 3500 - 5500 K (graphic stolen from wikipedia)

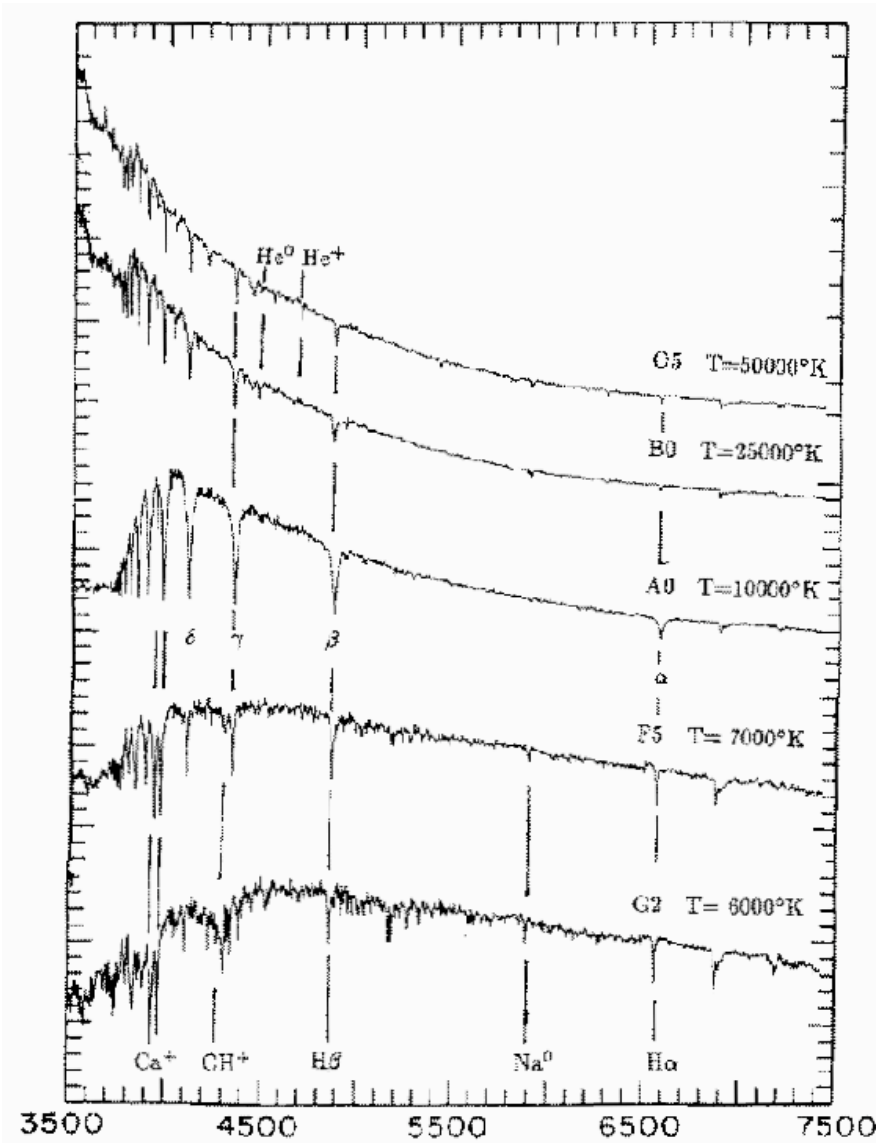

Ionized helium
Neutral helium
Hydrogen
Ionized metals
Neutral metals
Molecules (T,O)
Relative strengths of lines
O
B
A
F
G
K
M
Spectral class

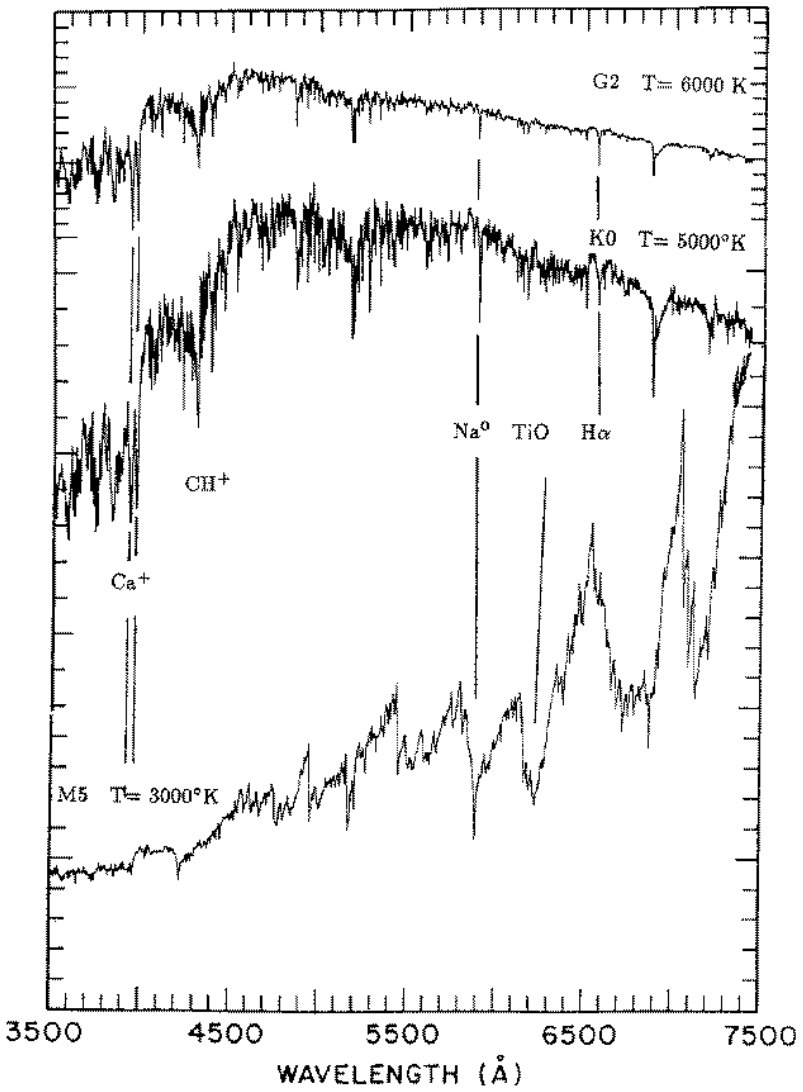

Temperature (K)
50,000
25,000
10,000
8000
6000
5000
4000
3000
Line strength
H
Ca II
TiO
He II
He I
Ca I
Fe II
Fe I
Mg II
Si III
Si II
Si IV
O5
B0
A0
F0
G0
K0
M0
M7
Spectral type



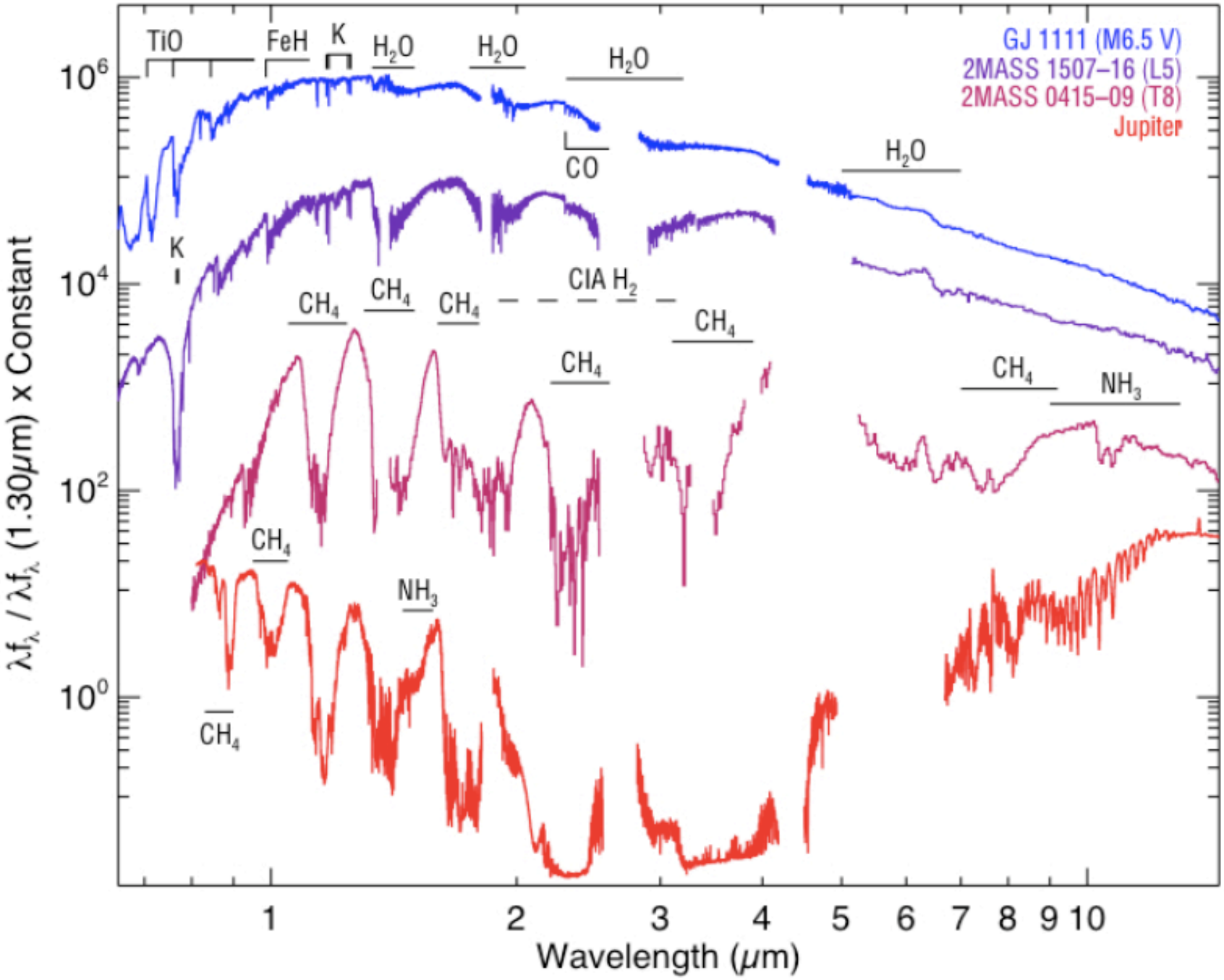



Solar spectrum, shown as through a prism (top) and in a plot of intensity vs. wavelength (side) (images taken from wikipedia)



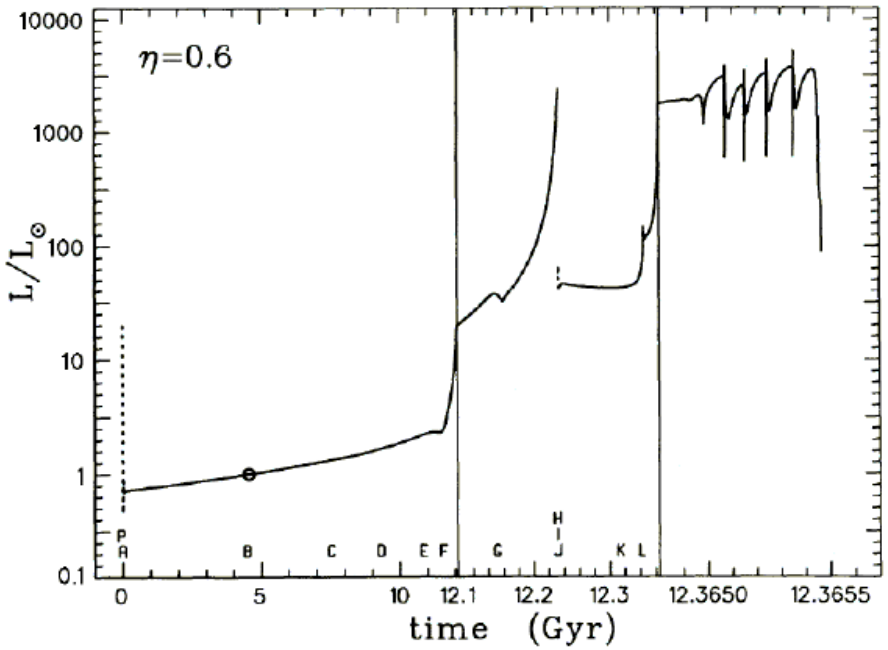




Spectra for O - G stars (left) and G - M stars (right)

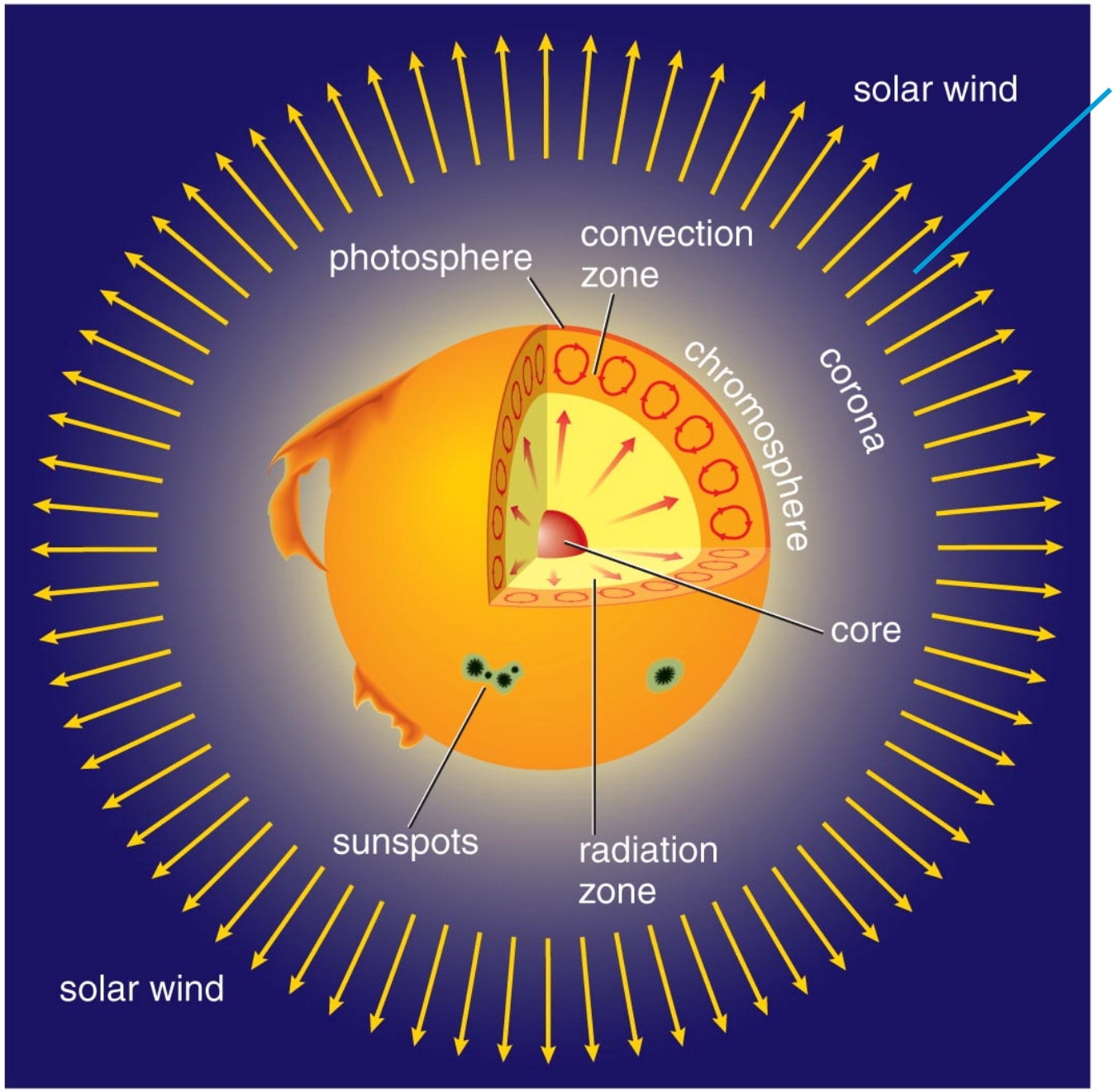

GJ 1111 (M6.5 V)
2MASS 1507–16 (L5)
2MASS 0415–09 (T8)
Jupiter
TiO
FeH
K
H2O
H2O
H2O
CO
H2O
K
CH4
CH4
CH4
CIA H2
CH4
CH4
CH4
NH3
CH4
NH3
CH4
λfλ / λfλ (1.30μm) x Constant
Wavelength (μm)

The following data are taken from a 1992 article in the *Astrophysical Journal*, in which the authors performed detailed computer models of the history and future evolution of our Sun.

| Label | Time | Mass | Luminosity | Temp. | Radius |
|---|---|---|---|---|---|
| P | 0 Gyr | 1 $M_{sun}$ | 19.95 $L_{sun}$ | 4400 K | 7.71 $R_{sun}$ |
| A | 0.048 | 1 | 0.7015 | 5586 | 0.897 |
| B (now) | 4.55 | 1 | 1 | 5779 | 1 |
| C | 7.56 | 1 | 1.33 | 5843 | 1.13 |
| D | 9.37 | 1 | 1.67 | 5819 | 1.275 |
| E | 10.91 | 1 | 2.21 | 6517 | 1.575 |
| F | 11.64 | 0.9998 | 2.73 | 4902 | 2.3 |
| G | 12.15 | 0.9935 | 34 | 4540 | 6.38 |
| H | 12.233 | 0.7249 | 2349 | 3107 | 165.8 |
| I | 12.233 | 0.7249 | 57.7 | 4595 | 12.0 |
| J | 12.234 | 0.7241 | 41.0 | 4724 | 9.5 |
| K | 12.316 | 0.7133 | 42.4 | 4819 | 9.4 |
| L | 12.345 | 0.708 | 130 | 4375 | 20 |
| M | 12.365 | 0.538 | 2999 | 3160 | 180.3 |
| N | 12.365 | 0.541 | 5190 | 3660 | 177.0 |
| O | 12.365 | 0.541 | 90 | 74080 | 0.058 |

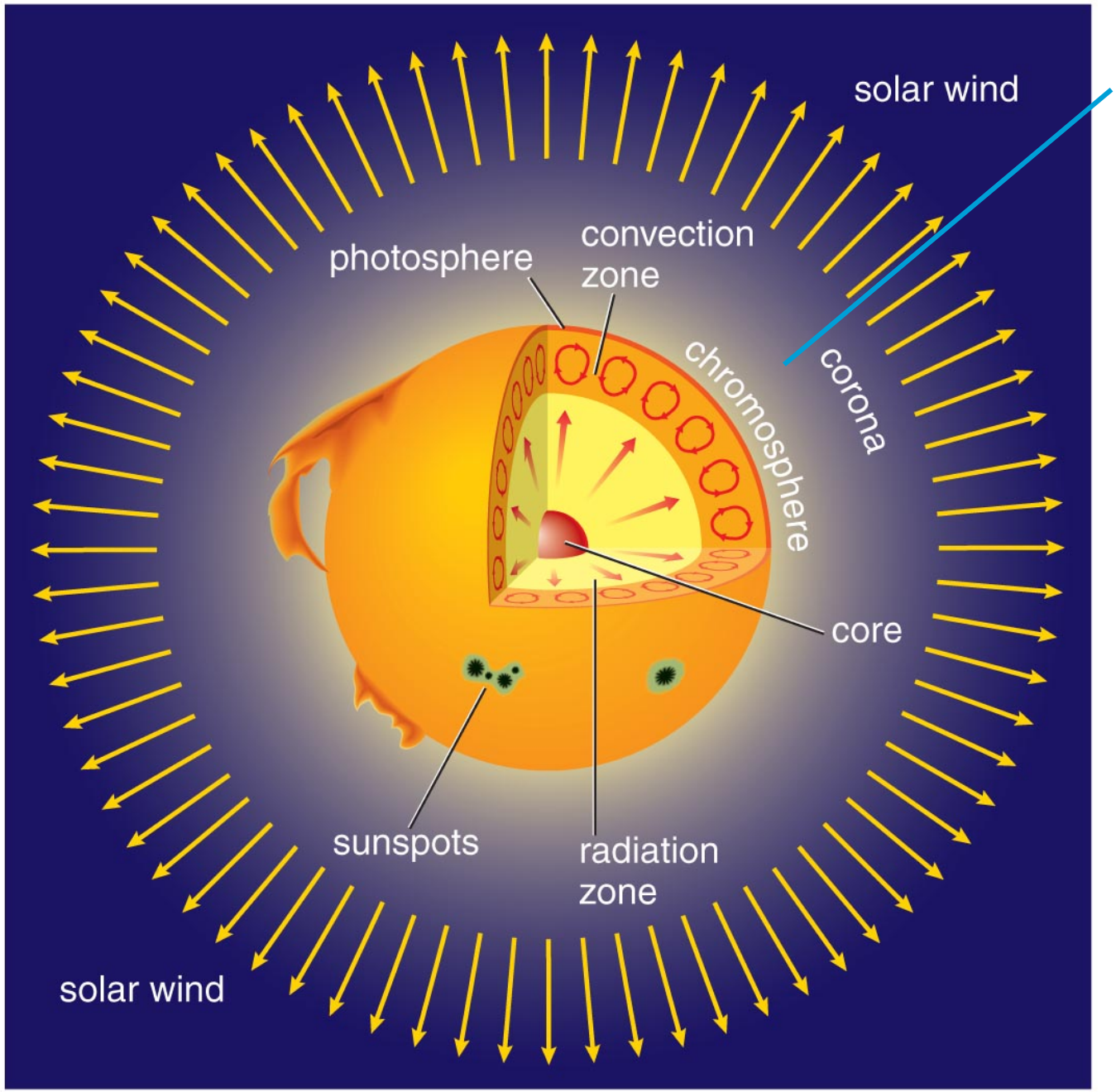



(Note: Gyr = 1 billion years)




***Solar wind:***

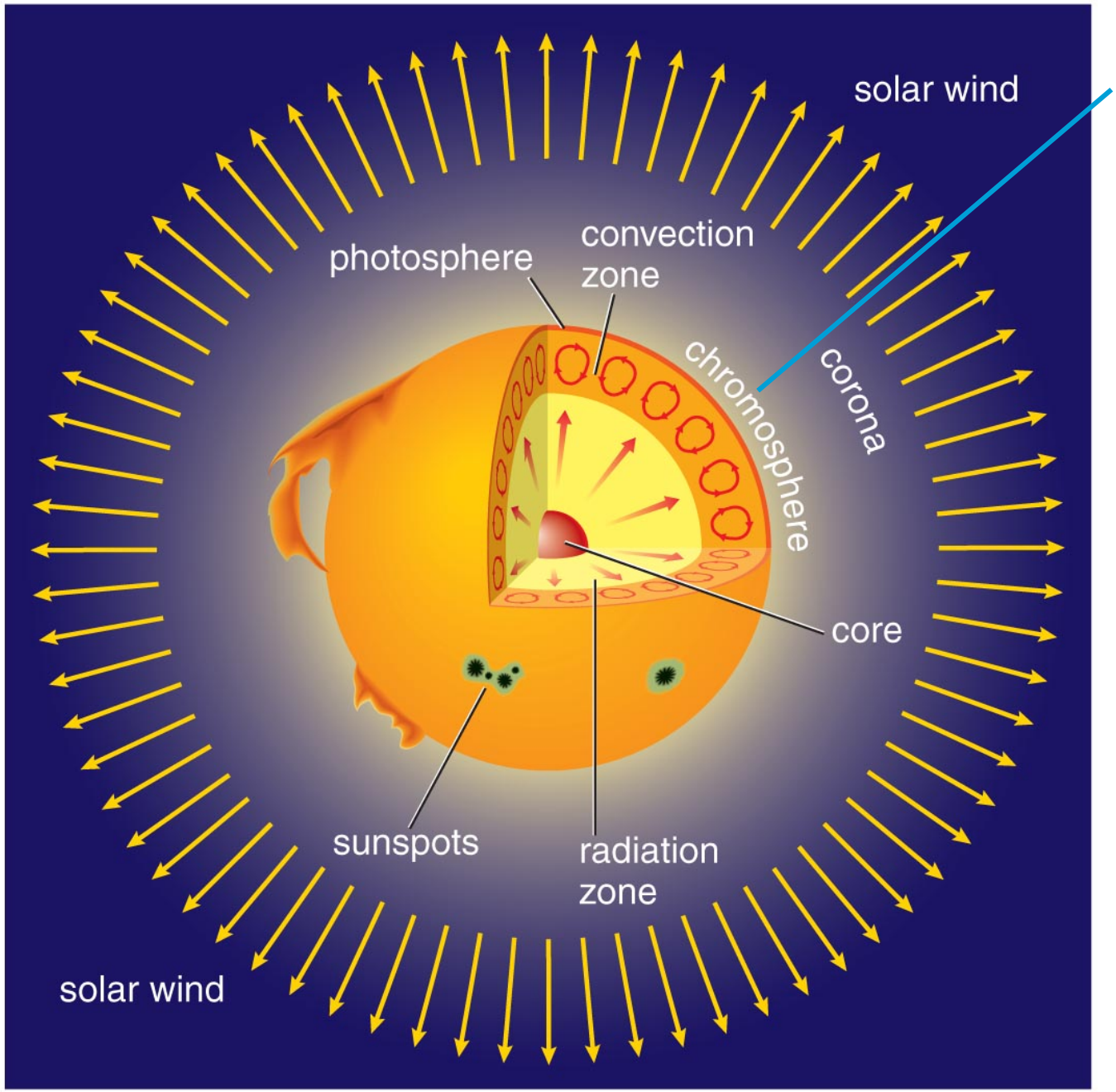
A flow of charged particles from the surface of the Sun




***Corona:***

Outermost layer of solar atmosphere

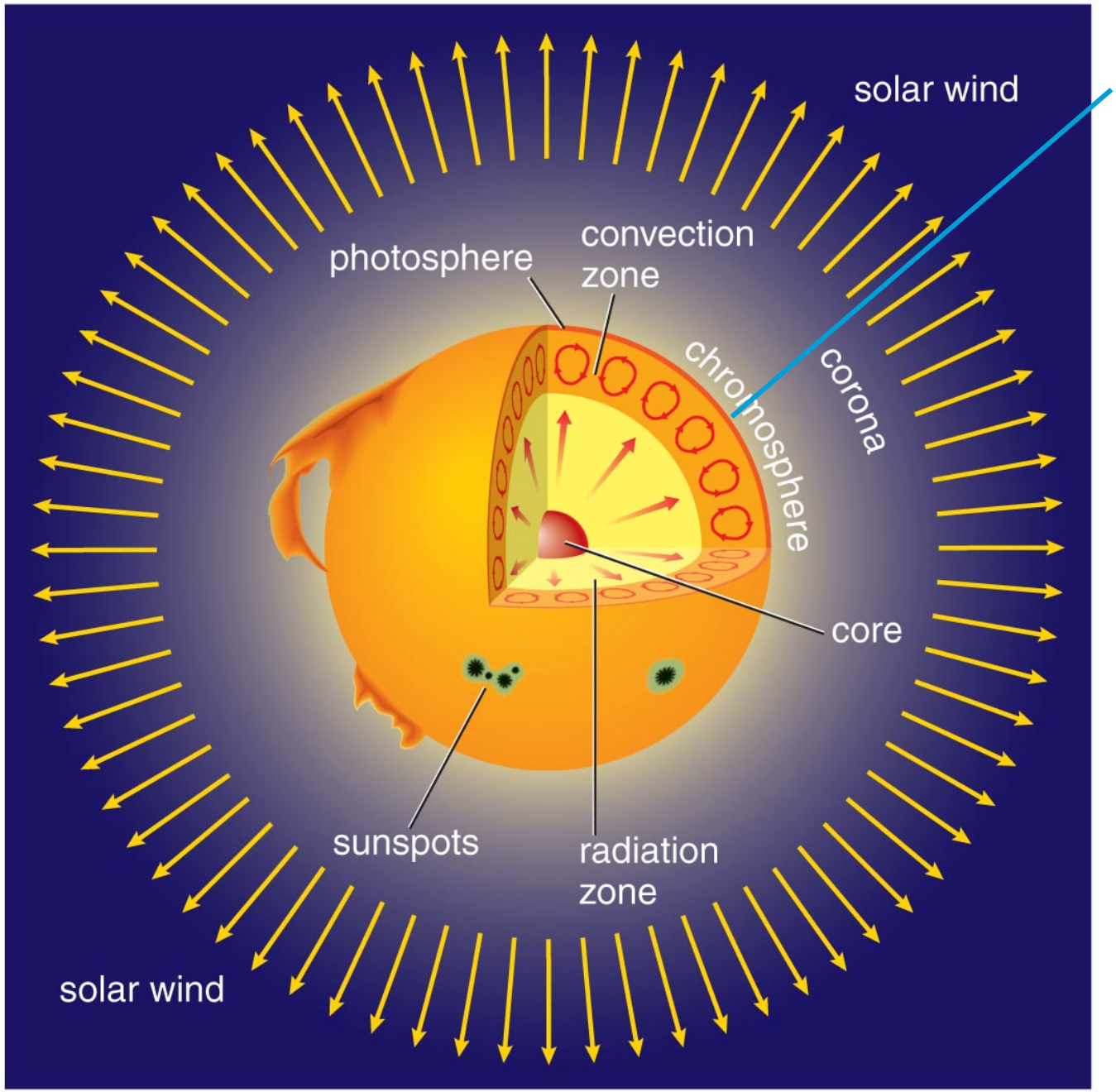
~1 million K




***Chromosphere:***

Middle layer of solar atmosphere

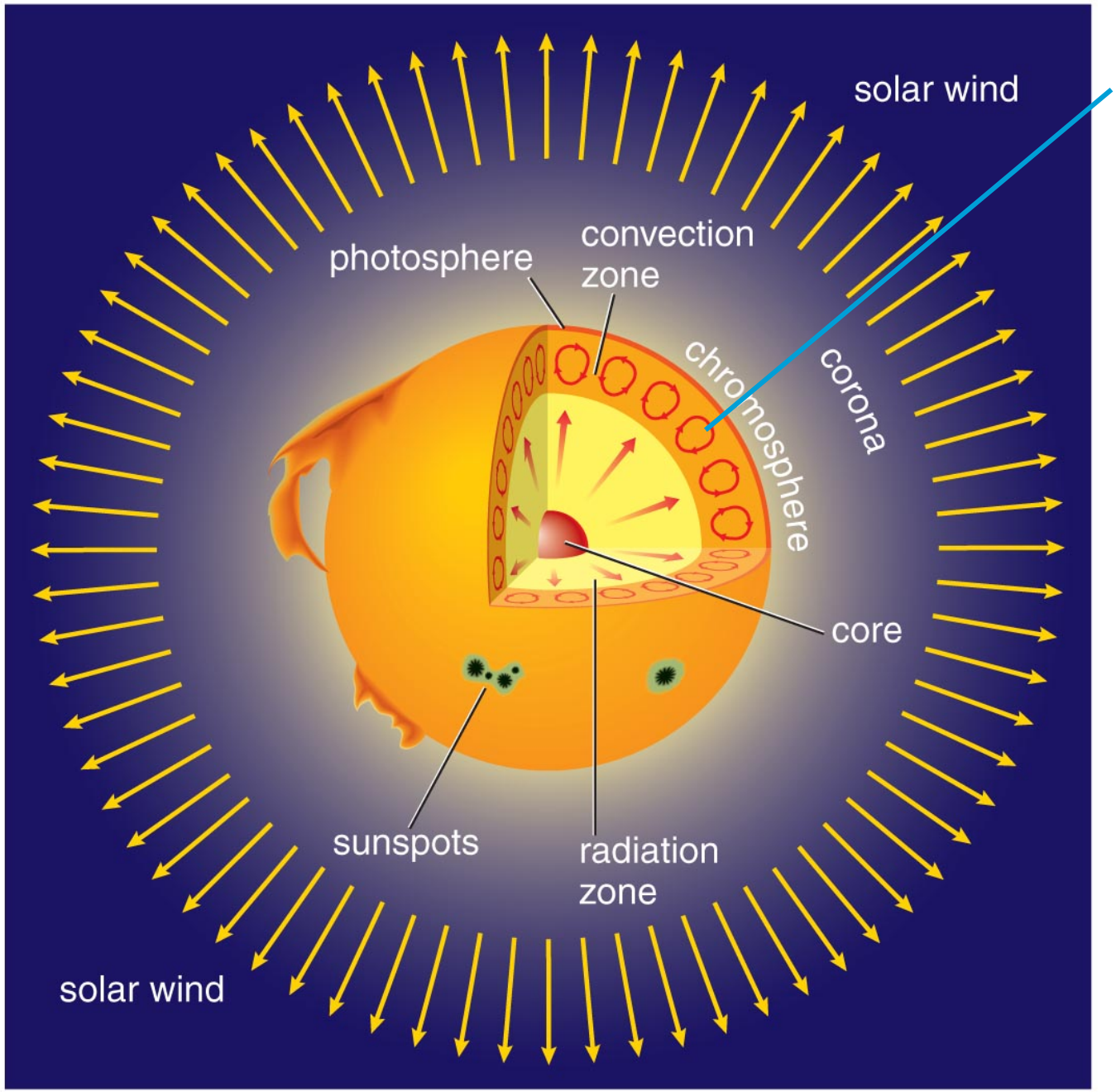
~ $10^4$–$10^5$ K




***Photosphere:***

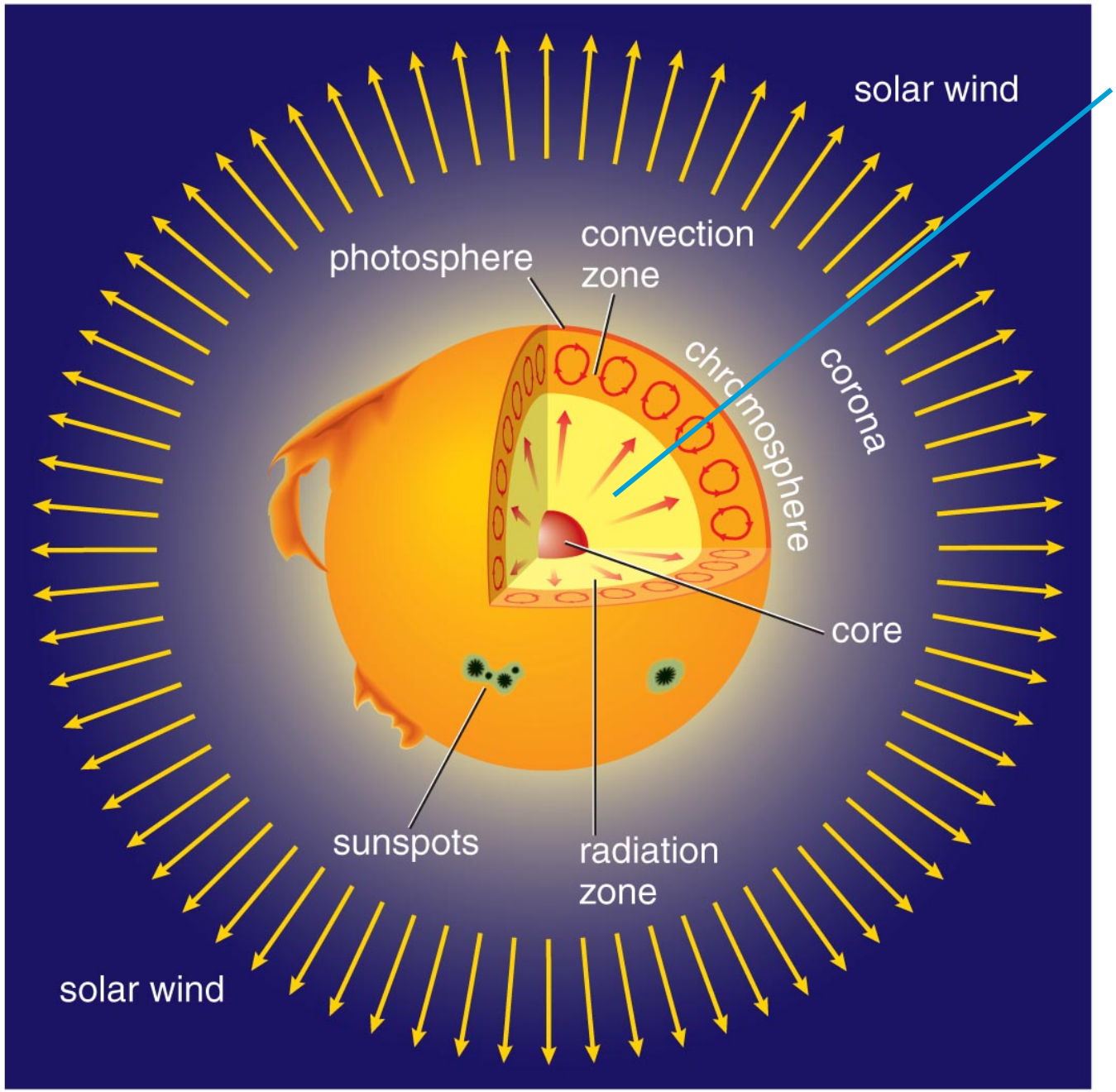
Visible surface of Sun

~ 6000 K



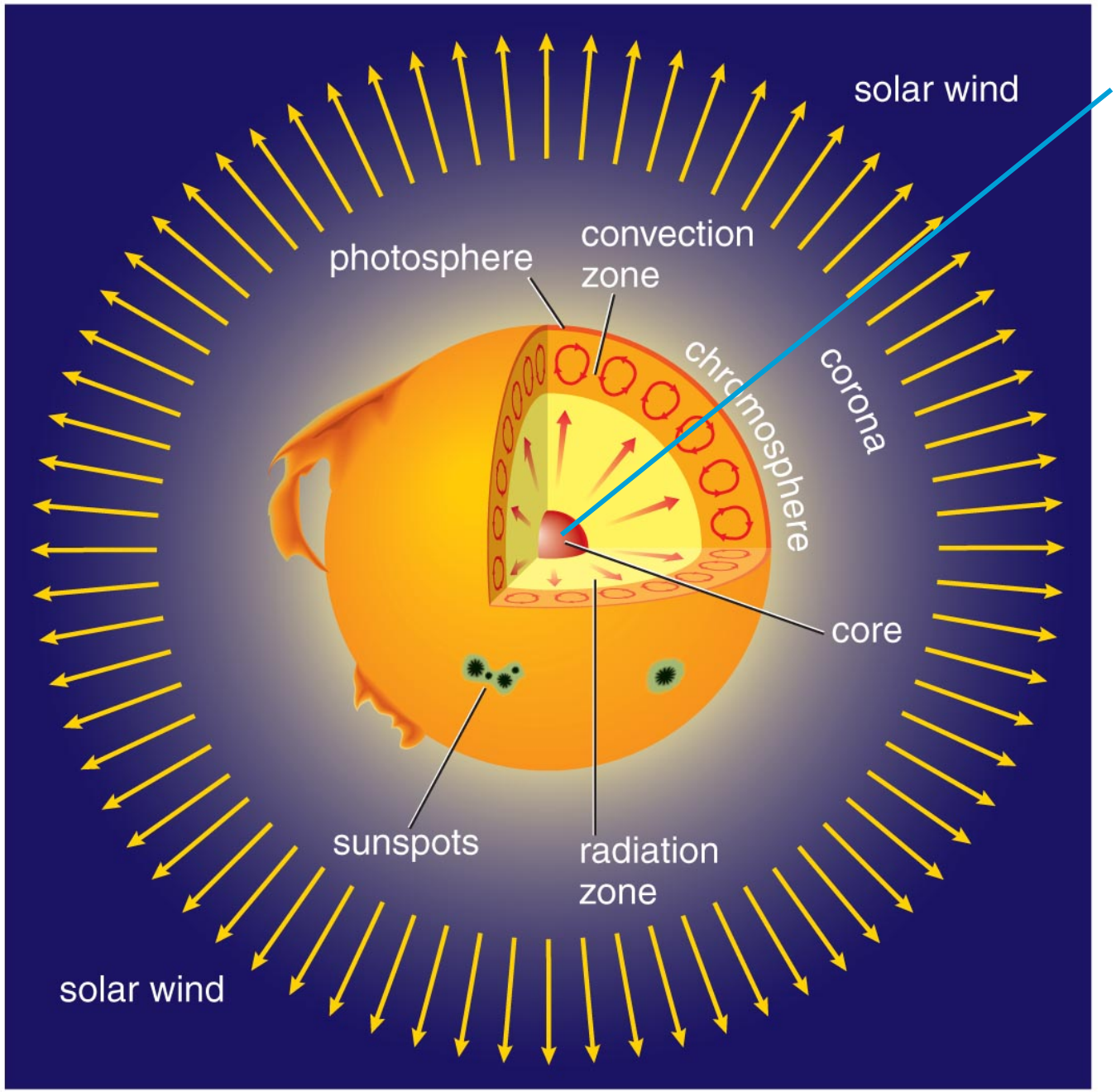

***Convection Zone:***

Energy transported upward by rising hot gas




***Radiation Zone:***

Energy transported upward by photons




***Core:***

Energy generated by nuclear fusion

~ 15 million K