Earth 101
Introduction to Astronomy

Properties of Stars

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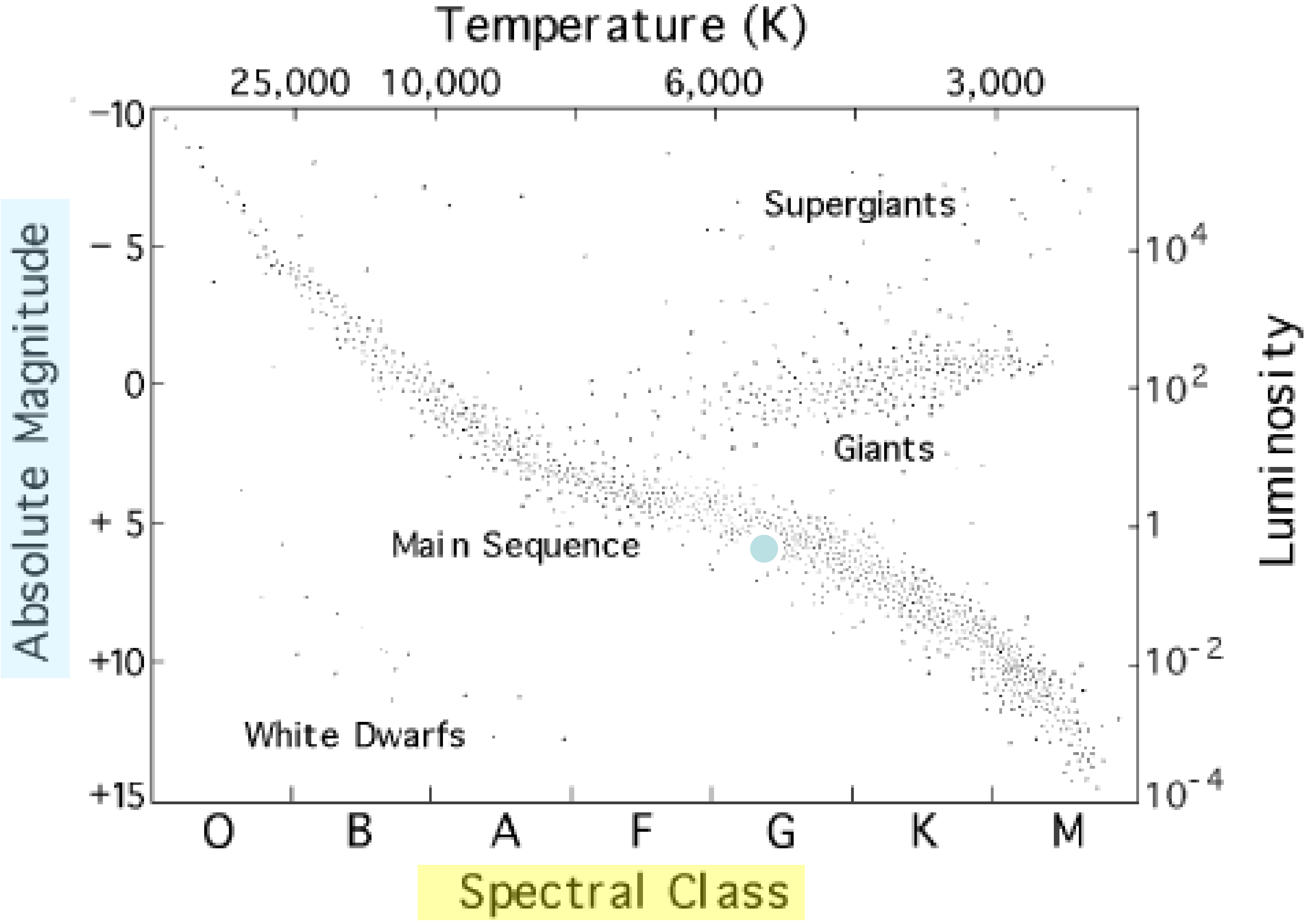
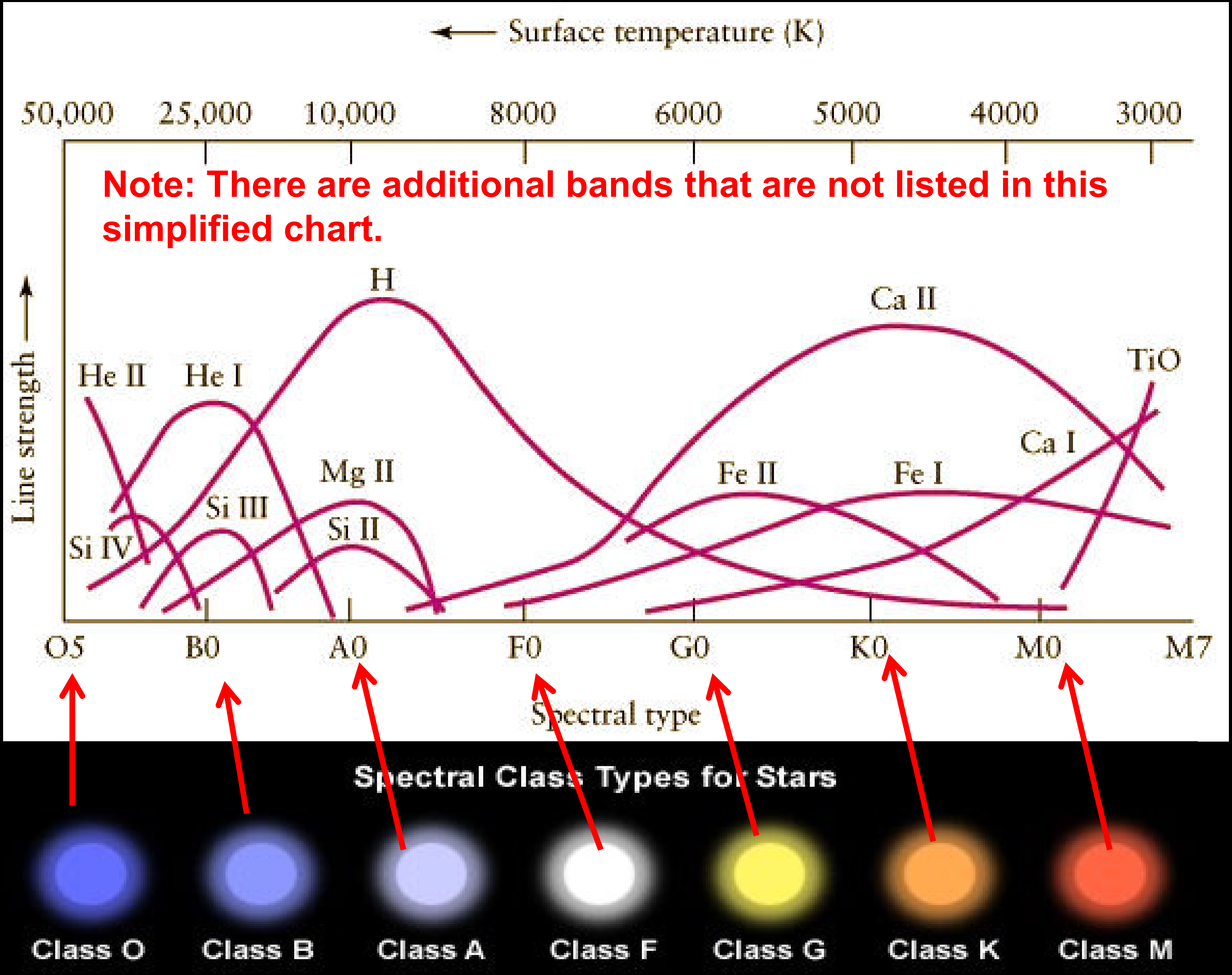
OpenStax Ch 18
Properties of Stars (from Starlight only)
More on HR Diagram
Stellar Spectra in detail

Photo/Material Credit:
- Fred Marschak
- Dr. Jatila van der Veen
- Erin O'Connor + others

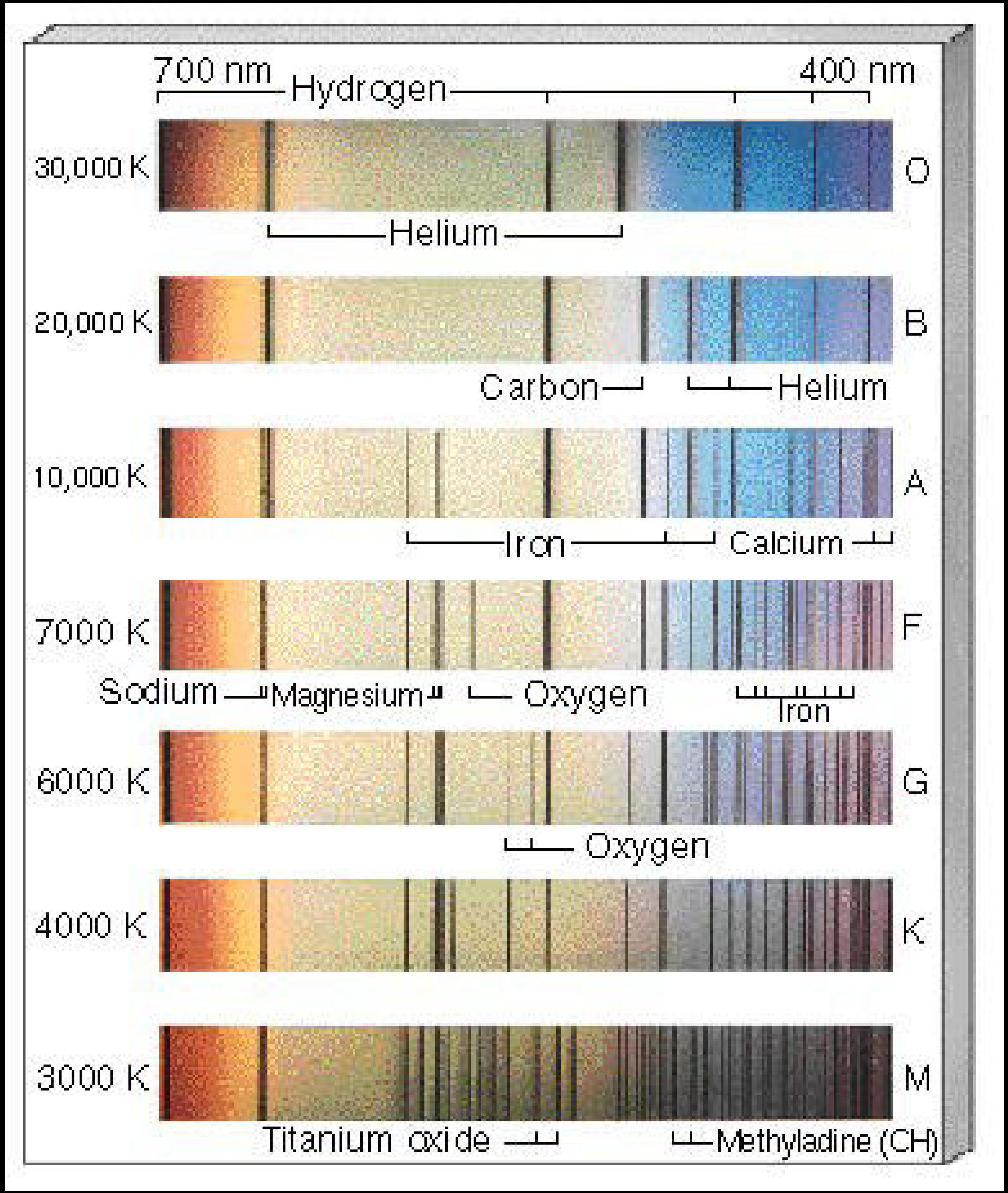
HJNP

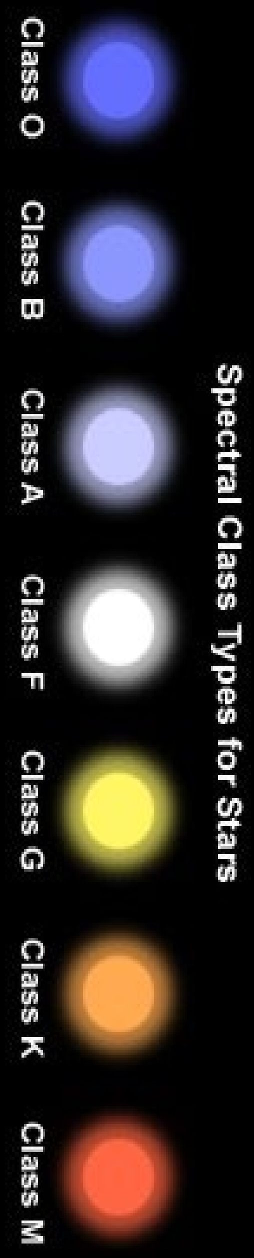
Hertzsprung - Russell Diagram


Temperature (K)
25,000
10,000
6,000
3,000
−10
− 5
0
+ 5
+10
+15
Absolute Magnitude
10^4
10^2
1
10^-2
10^-4
Luminosity
Supergiants
Giants
Main Sequence
White Dwarfs
O
B
A
F
G
K
M
Spectral Class



← Surface temperature (K)
50,000
25,000
10,000
8000
6000
5000
4000
3000
Note: There are additional bands that are not listed in this simplified chart.
Line strength →
H
Ca II
He II
He I
TiO
Ca I
Mg II
Fe II
Fe I
Si III
Si II
Si IV
O5
B0
A0
F0
G0
K0
M0
M7
Spectral type
Spectral Class Types for Stars
Class O
Class B
Class A
Class F
Class G
Class K
Class M



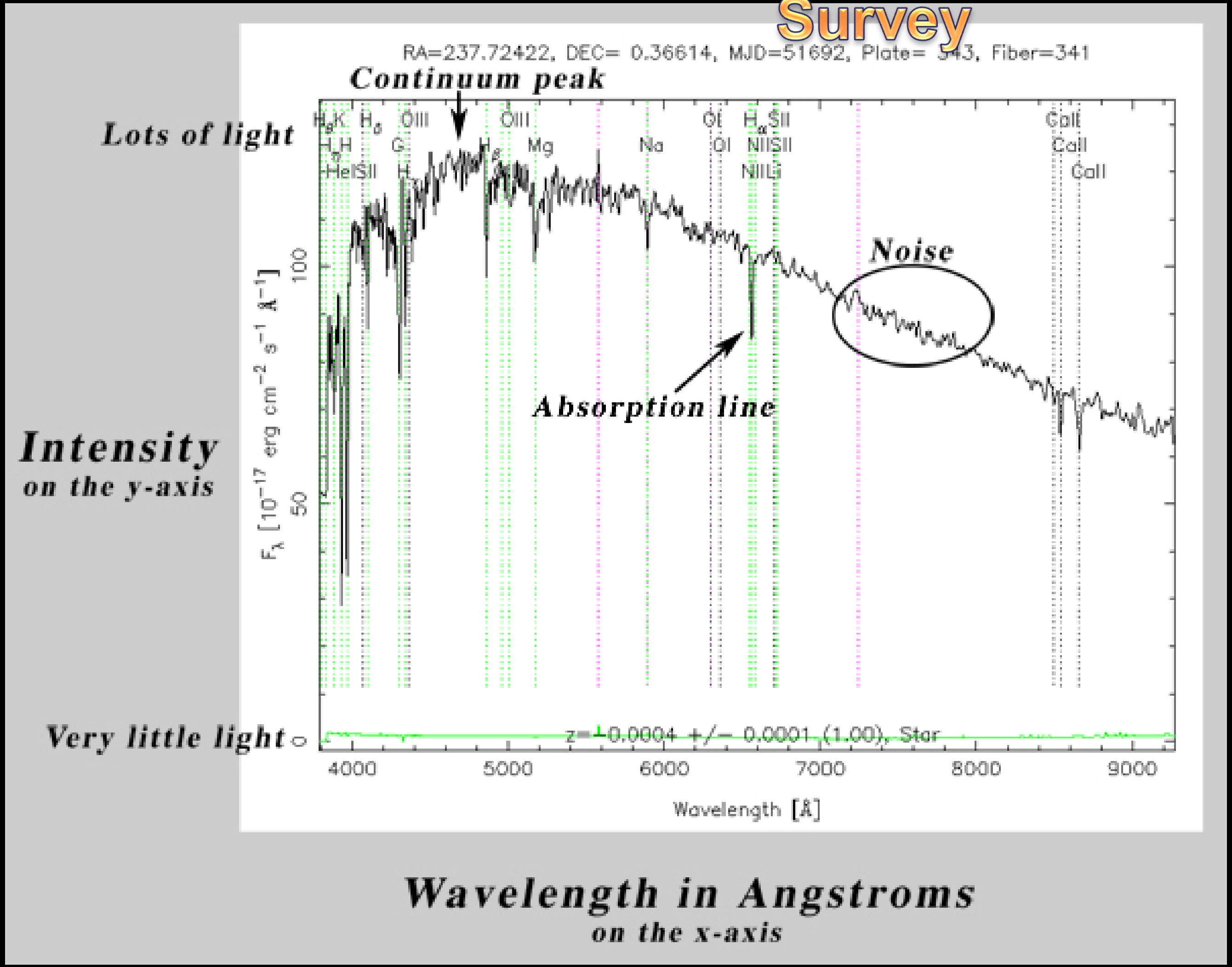


A photographic (analog) spectrum

Peak of the continuum spectrum is where the brightest colors are.

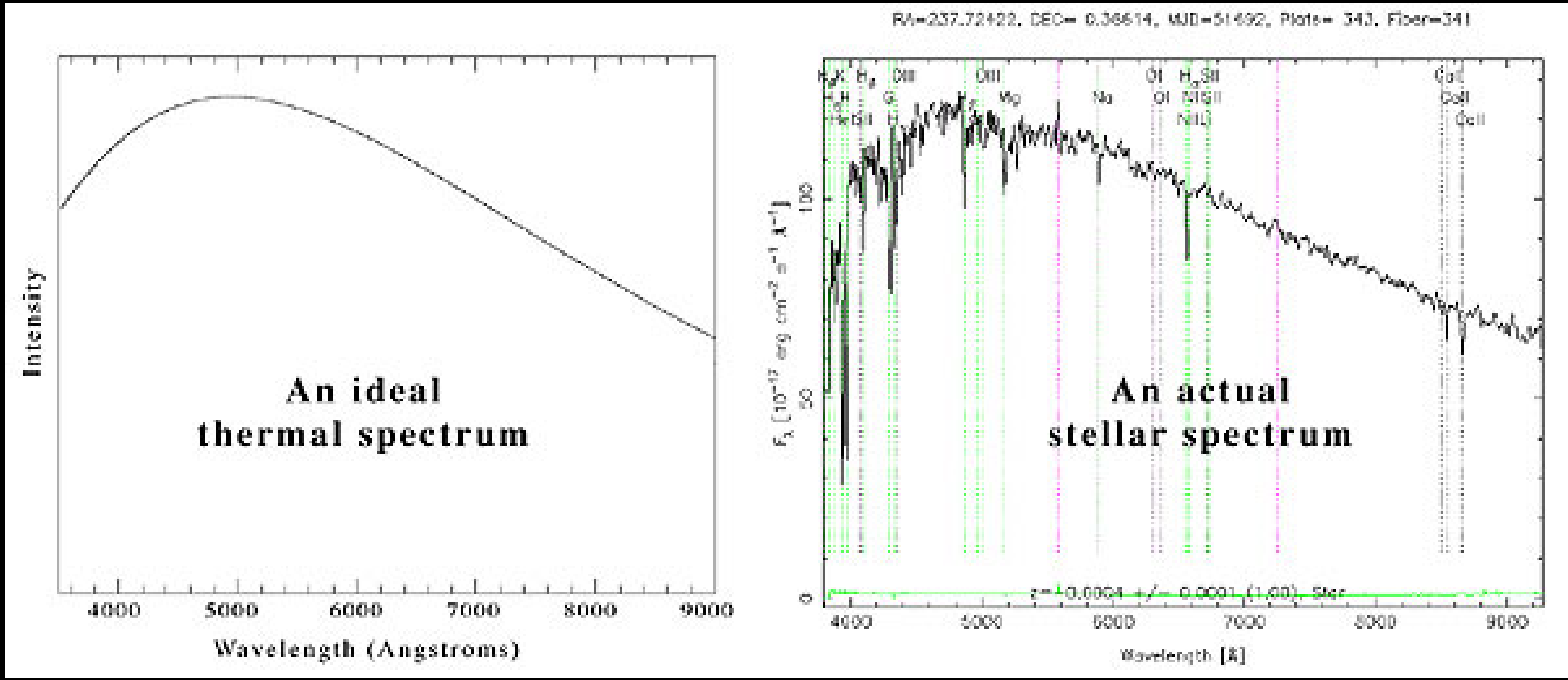
Wider lines: stronger absorption of that element

A digital spectrum measured with the Sloan Digital Sky Survey

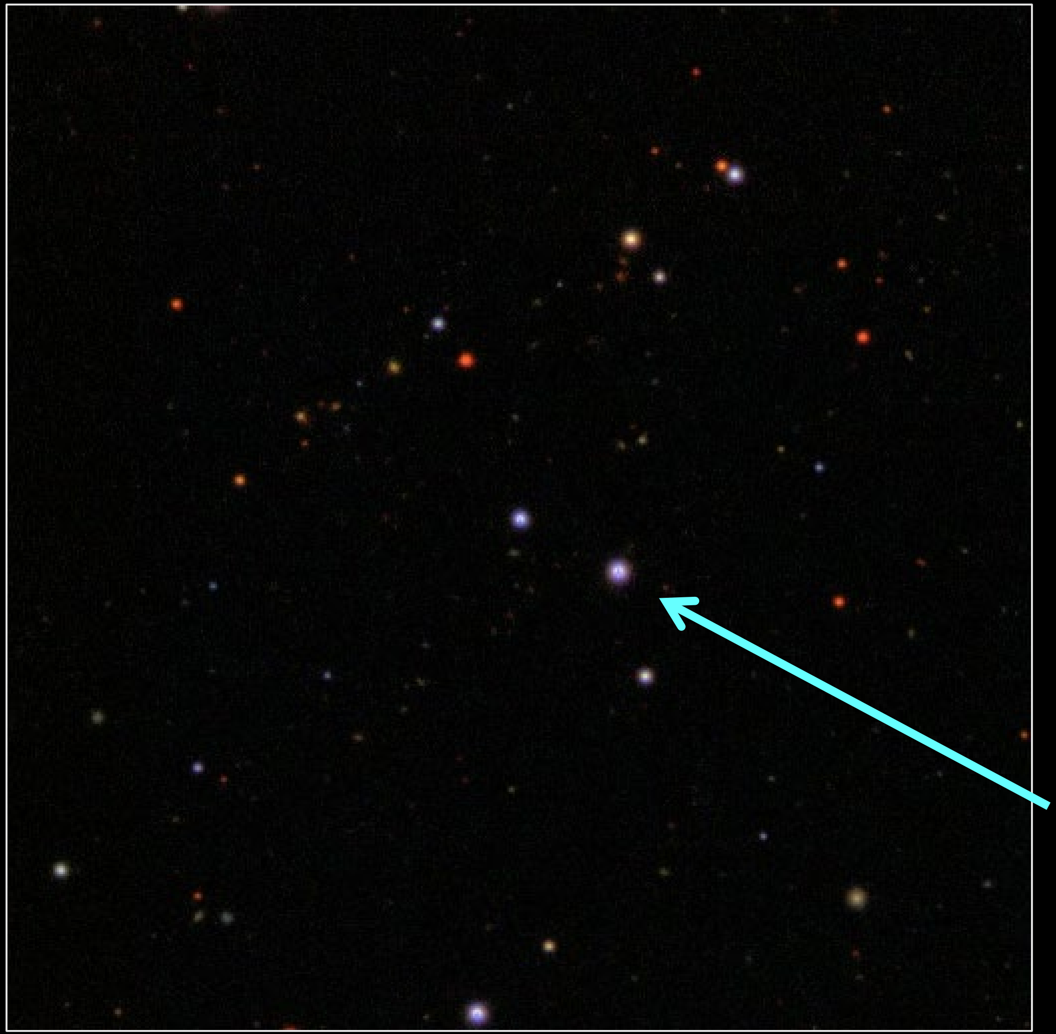


Source:
http://cas.sdss.org/dr6/en/proj/basic/spectraltypes/stellarspectra.asp

Notice that an actual stellar spectrum consists of the Planck curve (left) and the absorption lines superimposed on the Planck, or black body, curve (right):

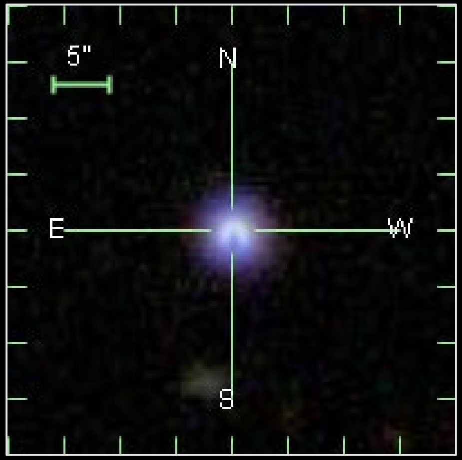


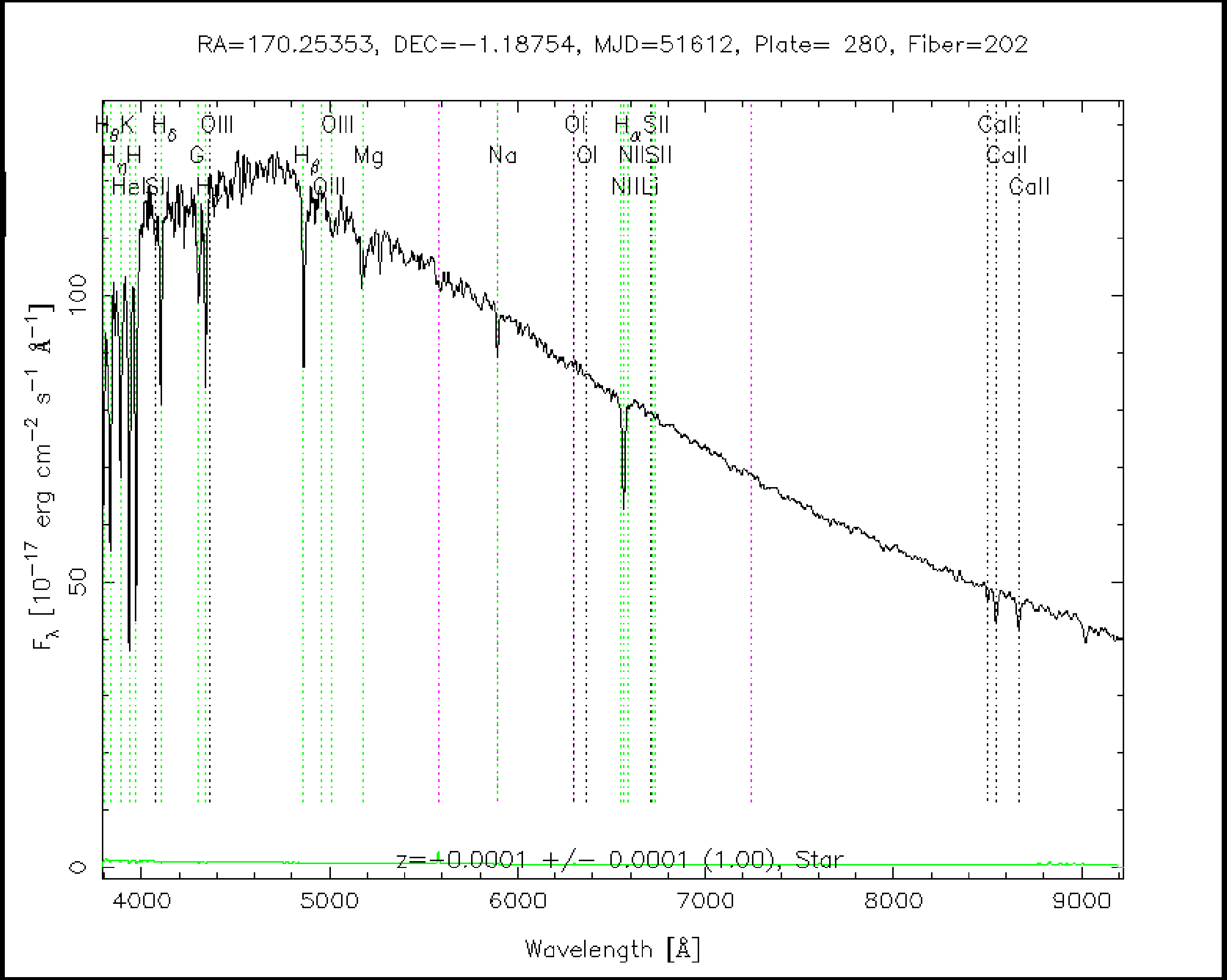
The peak wavelength tells you the approximate surface temperature, and the absorption lines tell you the stellar classification (O B A F G K M).



We will analyze some
actual stellar spectra, and learn
how to read the absorption lines
and classify stars according to
their spectra.

For example: this blueish-whitish
star, shown in the example
on the next page...





A real stellar spectrum!

Know these definitions:

1) A ***spectrum*** (the plural is *spectra*) is a graph of the amount of light something gives off (how bright the object is) at different wavelengths.

The Sloan Digital Sky Survey (SDSS) measures wavelength in units of Ångstroms (symbol Å),

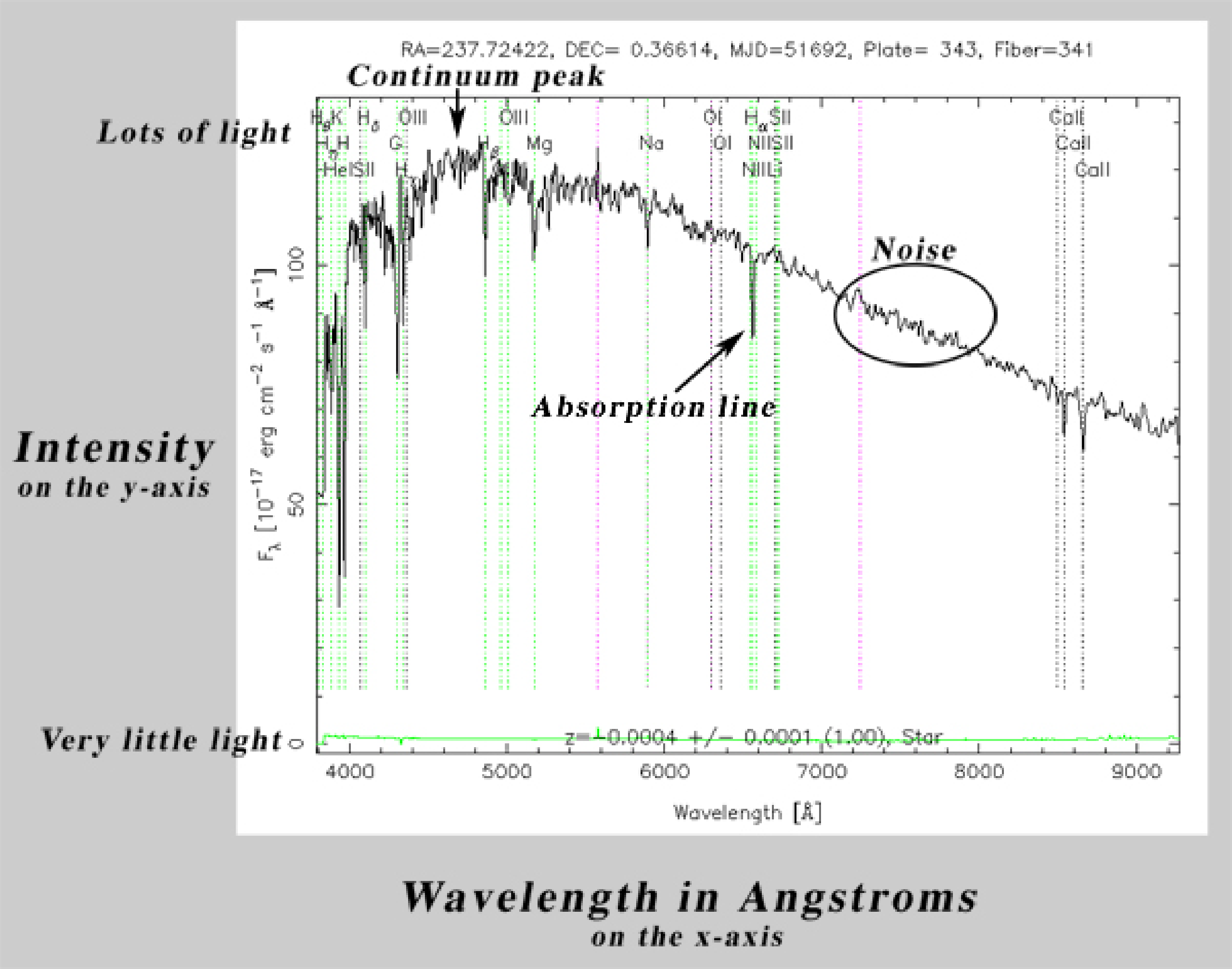
1 Ångstrom = 10^{-10} meters = 0.1 nm, or 10^{-1} nm.

The wavelengths of SDSS spectra go from around 4000 Å (just into ultraviolet light) to 9000 Å (infrared light).

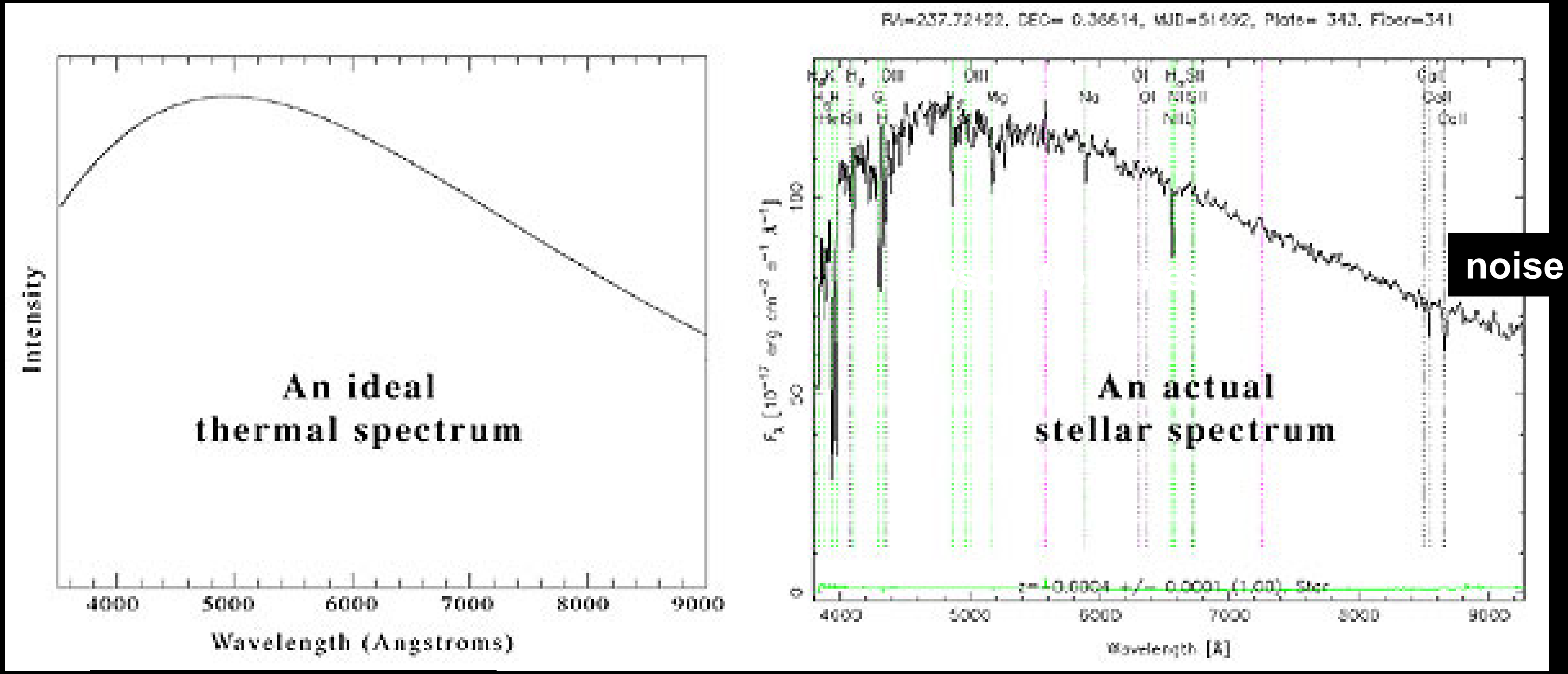
How to read the graph:

Vertical axis:
INTENSITY
Units are energy/cm^2/sec/wavelength

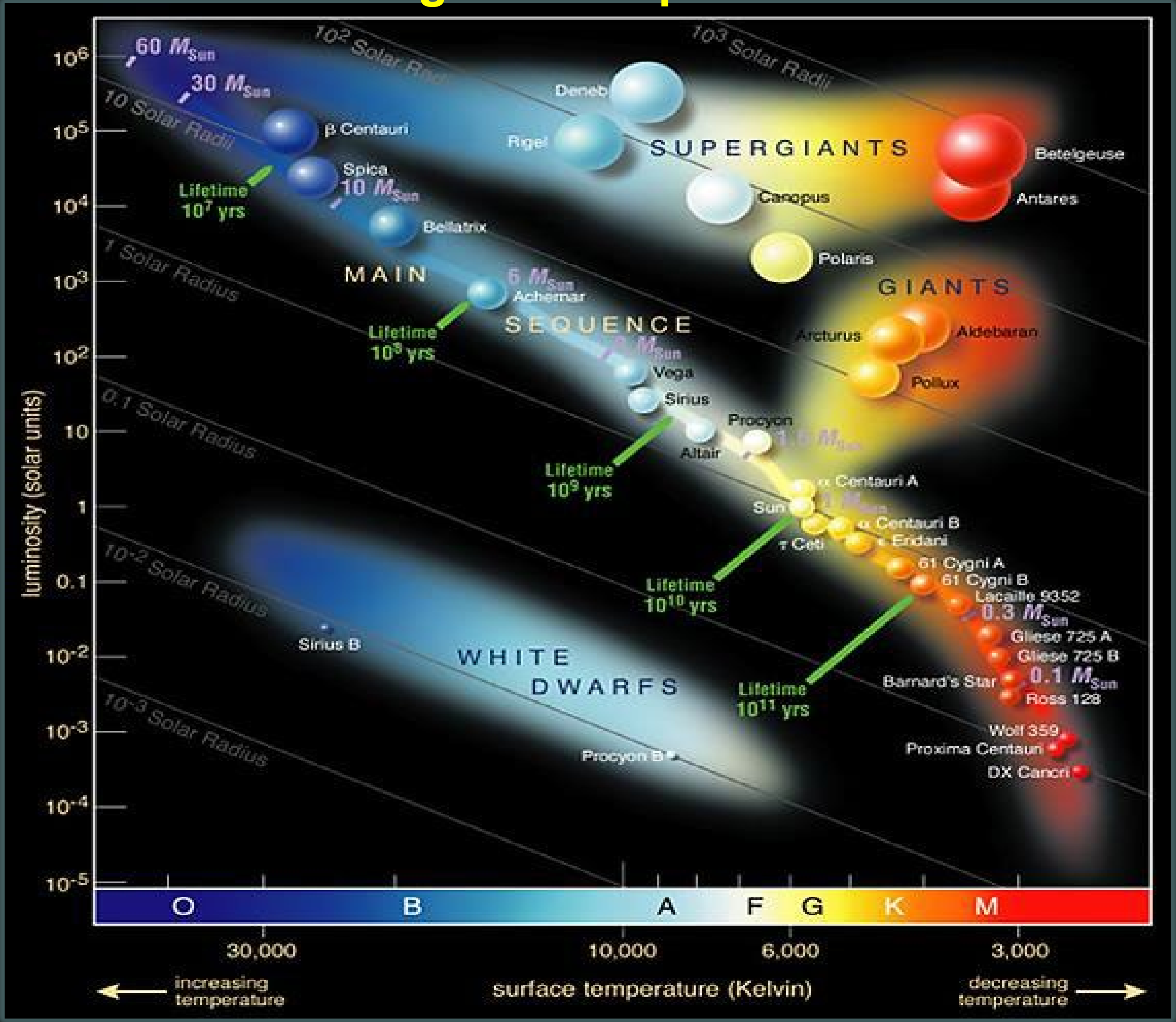
Horizontal axis:
WAVELENGTH
Units are Ångstroms, 10^{-10} m



2) Continuum peak - the top of the broad "hill" in the spectrum
3) Absorption line - one of the narrow "valleys" in the spectrum
4) Noise - some small random fluctuation in the spectrum; noise is usually much smaller than the absorption lines



Refer to the H-R Diagram for spectral classifications:



Source of the spectra for this lab can be found here:
http://cas.sdss.org/dr6/en/proj/basic/spectraltypes/studentclasses.asp

Absorption bands that are used to identify stars:

H = Hydrogen (H-α, H-β, H-γ, H-δ)
He = Helium
Ca = Calcium
Na = Sodium
Mg = Magnesium
O = Oxygen
Ti = Titanium
N = Nitrogen
Si = Silicon
G = "G-band" a complex of molecules, mainly due to CH molecule
H&K bands of ionized CA

Absorption band tables from the SDSS that are used in figuring out stellar spectra

Spectral Lines	Wavelengths (Angstroms)
H_α, H_β, H_γ	6600, 4800, 4350
Ionized Calcium H and K Lines	3800 - 4000
Titanium Oxide	lots of lines from 4900 - 5200, 5400 - 5700, 6200 - 6300, 6700 - 6900
G Band (CH complex)	4250
Sodium	5800
Helium (neutral)	4200
Helium (ionized)	4400

Table of Spectral Type, Temperature range, and expected spectral lines for Main Sequence stars from the SDSS

Spectral Type	Temperature (Kelvin)	Spectral Lines

You can use these example spectra from the SDSS to check your answers:
http://classic.sdss.org/dr5/algorithms/spectemplates/index.html

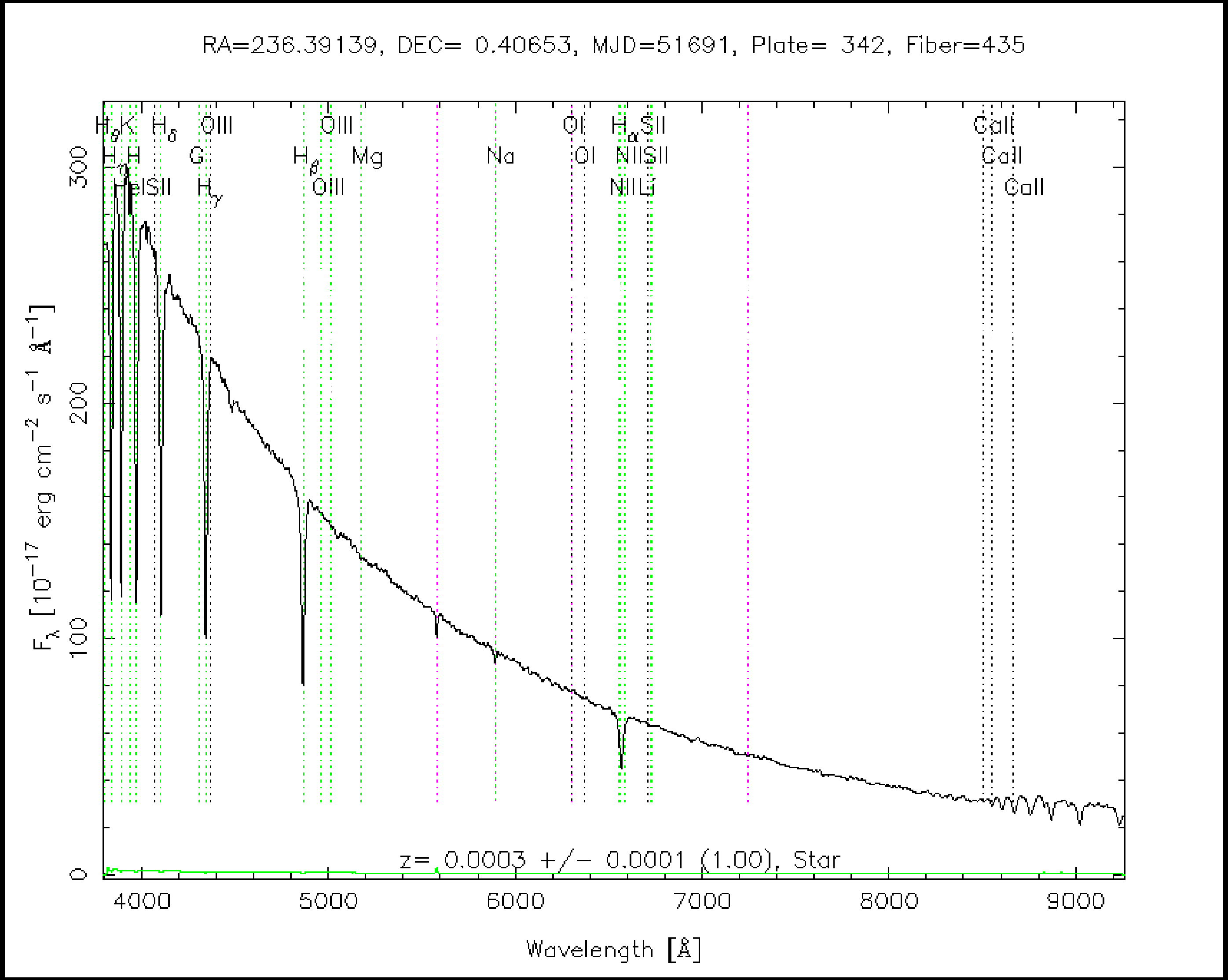
For each spectrum, click on the thumbnail image to see a full sized image. (You can also click on the word “gif” to the right of the thumbnail.)

Note: Color can be deceiving! Choose the classification according to the absorption spectrum.

An example:

Color: blue

λ_{max}: around 4000 Å or 400 nm



H-α? **yes**

H-β? **yes**

List other elements:
G-band
H-γ
H-δ
H & K bands of ionized Ca
He?
weak Na

Best Guess Spectral class: A to F

After you complete the analysis of the stellar spectra, answer these questions.

1. Comparing luminosities:

Go back and compare stars 1 and 2. They are both blue, and their peak wavelengths are in the violet range, so they might be O-type stars, or blue giants.

BUT: Star #1appears brighter than star #2 in the image, yes?

Look at the numbers on the y-axis. These numbers tell you the amount of light emitted per unit area for each star. Note the top numbers:

Star #1:

Star #2:

Since they both have the same peak wavelength, hence same surface temperature, and assuming that the measured light is related to **apparent magnitude** (m_v) which star is closer to us?

How can you tell?

If the luminosity were in **Absolute Magnitude** (M_v), which one would be larger?

How can you tell?

Be sure you understand the answers to these questions.

Table 15.1(a) The Spectral Sequence

Spectral Type	Example(s)	Temperature Range	Key Absorption Line Features	Brightest Wavelength (color)
O	Stars of Orion's Belt	>30,000	Lines of ionized helium, weak hydrogen lines	<97 nm (ultraviolet)*
B	Rigel	30,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	97–290 nm (ultraviolet)*
A	Sirius	10,000 K–7,500 K	Very strong hydrogen lines	290–390 nm (violet)*
F	Polaris	7,500 K–6,000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*
G	Sun, Alpha Centauri A	6,000 K–5,000 K	Weak hydrogen lines, strong lines of ionized calcium	480–580 nm (yellow)
K	Arcturus	5,000 K–3,500 K	Lines of neutral and singly ionized metals, some molecules	580–830 nm (red)
M	Betelgeuse, Proxima Centauri	<3,500 K	Molecular lines strong	>830 nm (infrared)

*** All stars above 6,000 K look more or less white to the human eye because they emit plenty of radiation at all visible wavelengths.**

another useful summary:

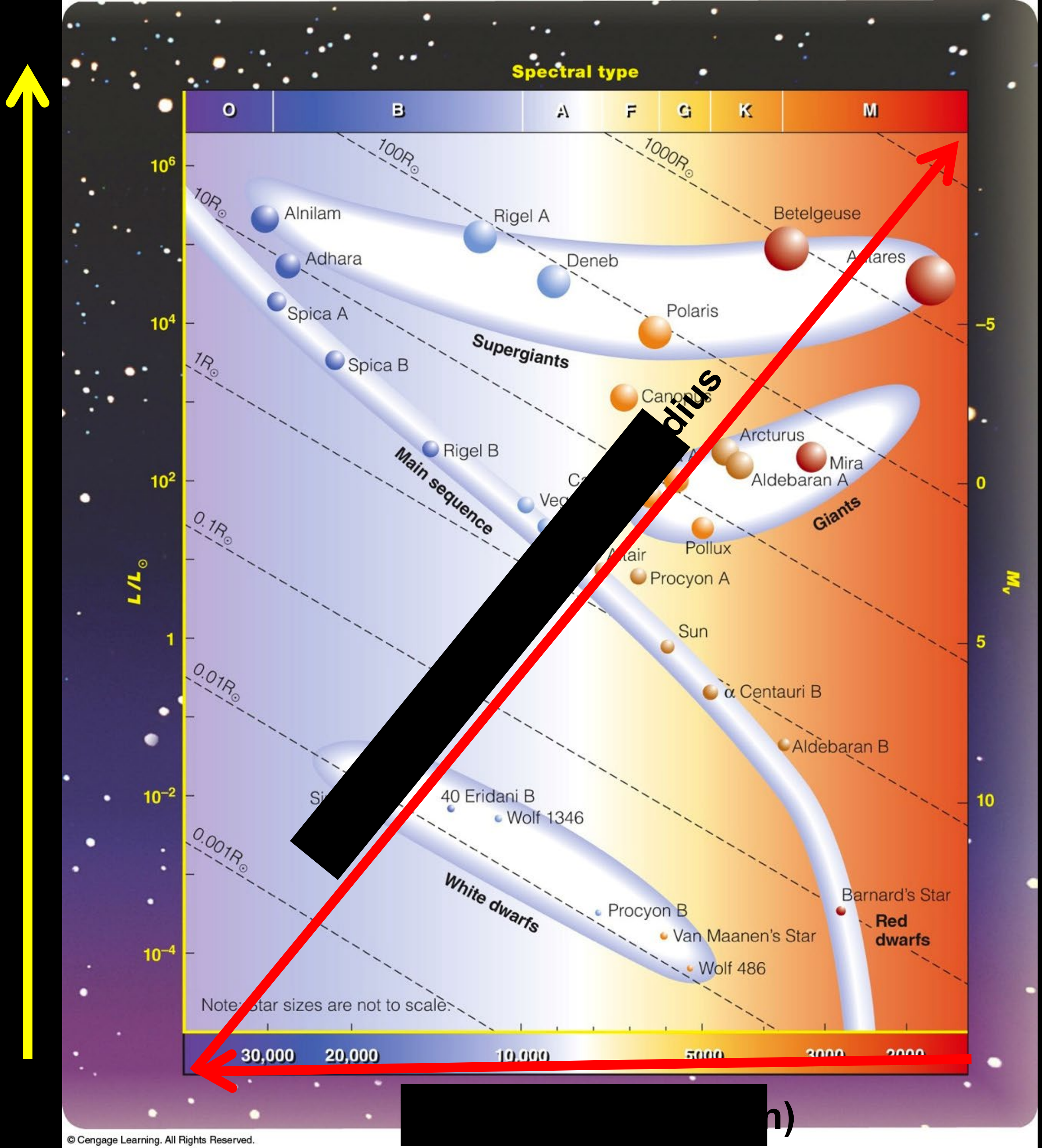
Stars: spectral types

Spectral Type	Colour	Temperature (K) Surface / core	Spectral characteristics
M	Red	3000	Molecular lines (e.g. TiO, vanadium oxide), very strong neutral metal lines
K	Orange	4000	Strong Ca lines, strong neutral metal lines, ± TiO, extremely weak hydrogen lines
G	Yellow	6000	Ca^+ lines strong, ionised metal lines weakening, neutral metal lines weakening, CH strong, hydrogen lines very weak
F	White	8000	Ionised (e.g. Fe^+, Mg^+, Si^+) and neutral metal lines, hydrogen lines weakening
A	White/blue	10 000	Hydrogen lines strong, ionised metal lines strong, weak neutral metal lines
B	Blue/UV	25 000	Strong He lines, strong hydrogen lines, Mg^+ and Si^+ lines
O	Blue/UV	50 000	Strong He^+ lines, weak He and hydrogen Balmer lines, Si^{3+}, O^{2+}, N^{2+} and C^{2+} lines

Spectral Class	Colour	Mass	Radius	Luminosity	Temperature (K)
M	red	0.1	0.1	0.001	3 000
K	orange	0.5	0.3	0.03	4 500
G	yellow	1	1	1	5 500
F	white	1.5	1.2	5.0	7 000
A	white	2.5	2	50	9 000
B	blue	10	5	10 000	17 000
O	blue	40+	20	500 000	40 000

Mass, Radius and Luminosity are given reltive to those of the Sun, which is a yellow G class star. (Mass of the Sun ≡ 1 solar mass ≡ $1M_{\odot}$ = 1.99 x 10^{30} kg; radius of the Sun ≡ one solar radius ≡ $1R_{\odot}$ = 6.96 x 108 m; luminosity of the Sun ≡ one solar luminosity ≡ $1L_{\odot}$ = 3.83 x 10^{26} W, where 1 Watt ≡ 1W ≡ 1J/s ≡ $1Js^{-1}$).

A visual summary: Interpreting the HR diagram



More details coming in Stars 03 and the next lab!