Introduction to Astronomy and Astrophysics I

Lecture 6

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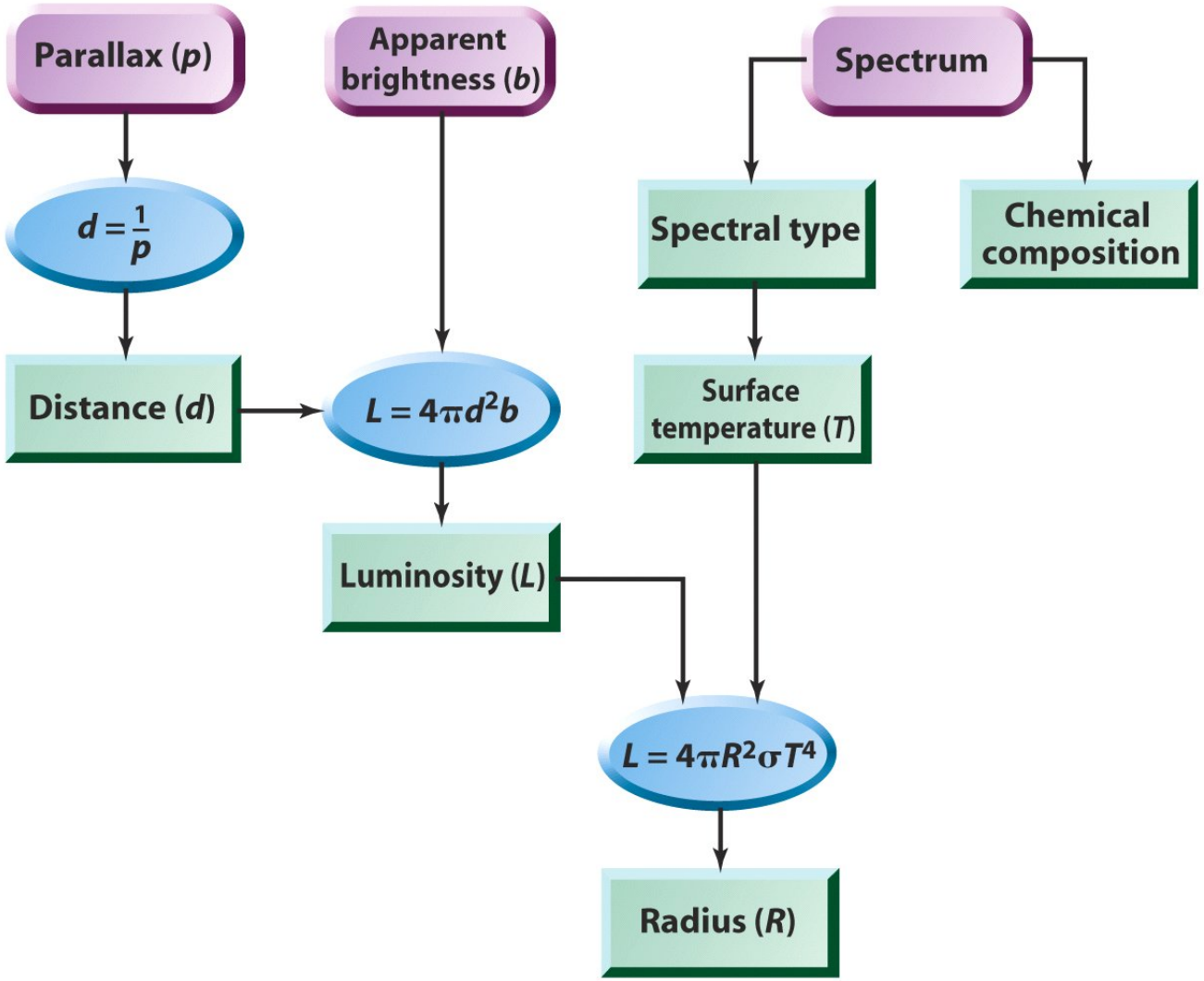
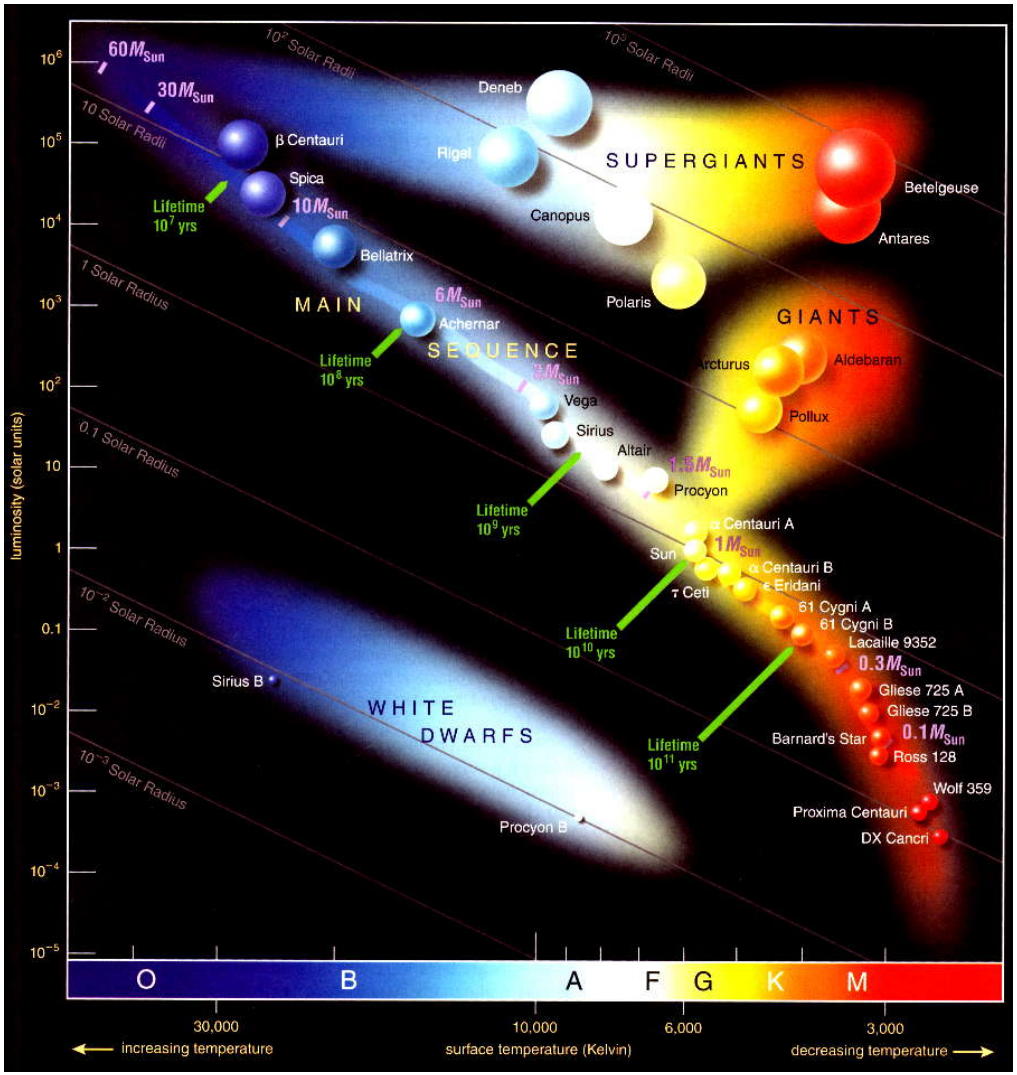
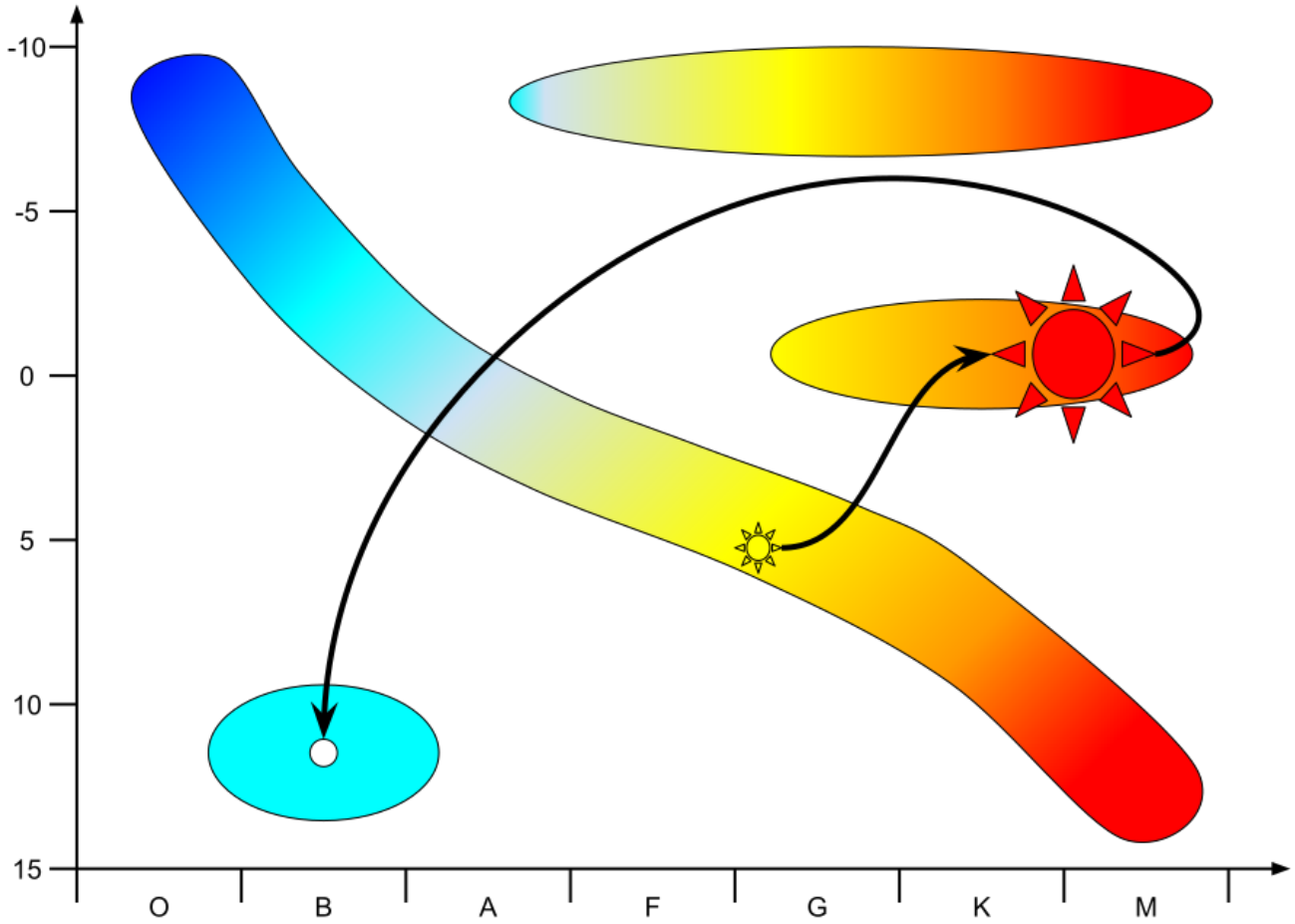
Translating observations to physical parameters using physical laws



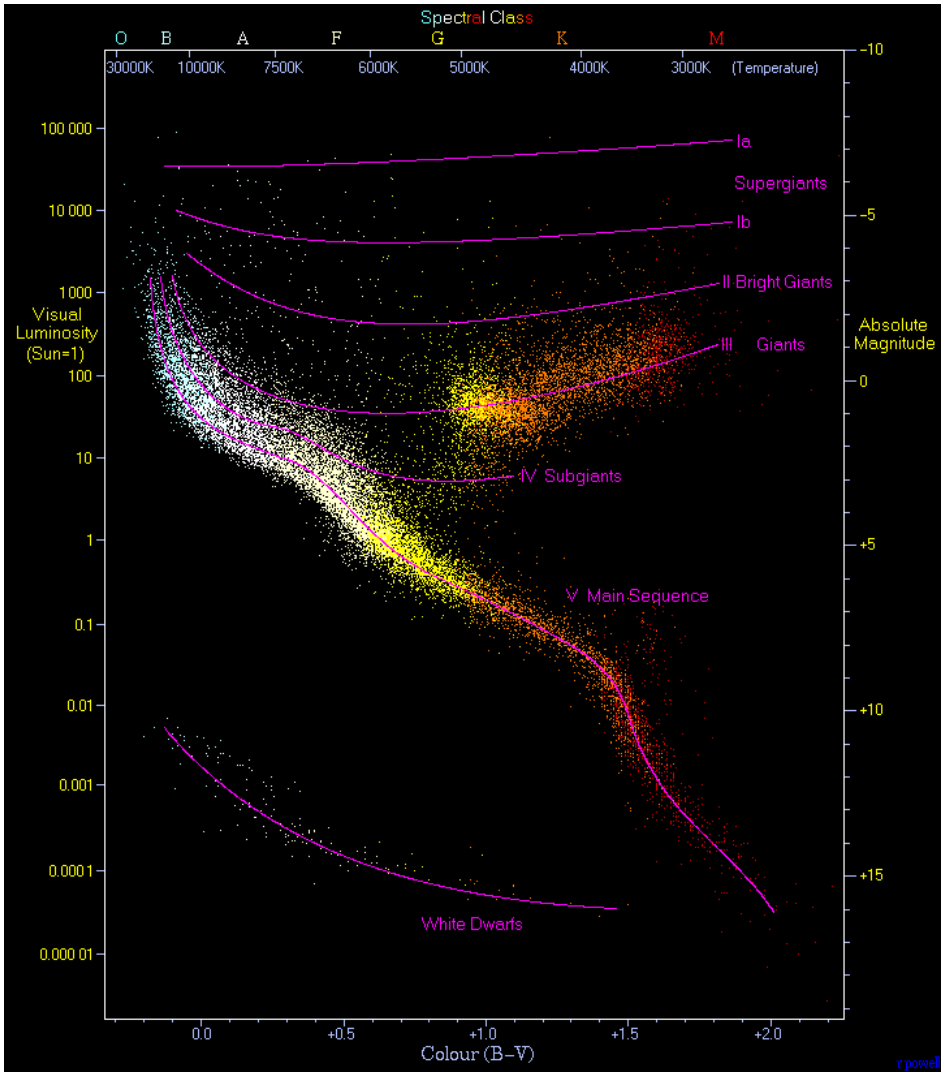
Hertzsprung-Russell diagram



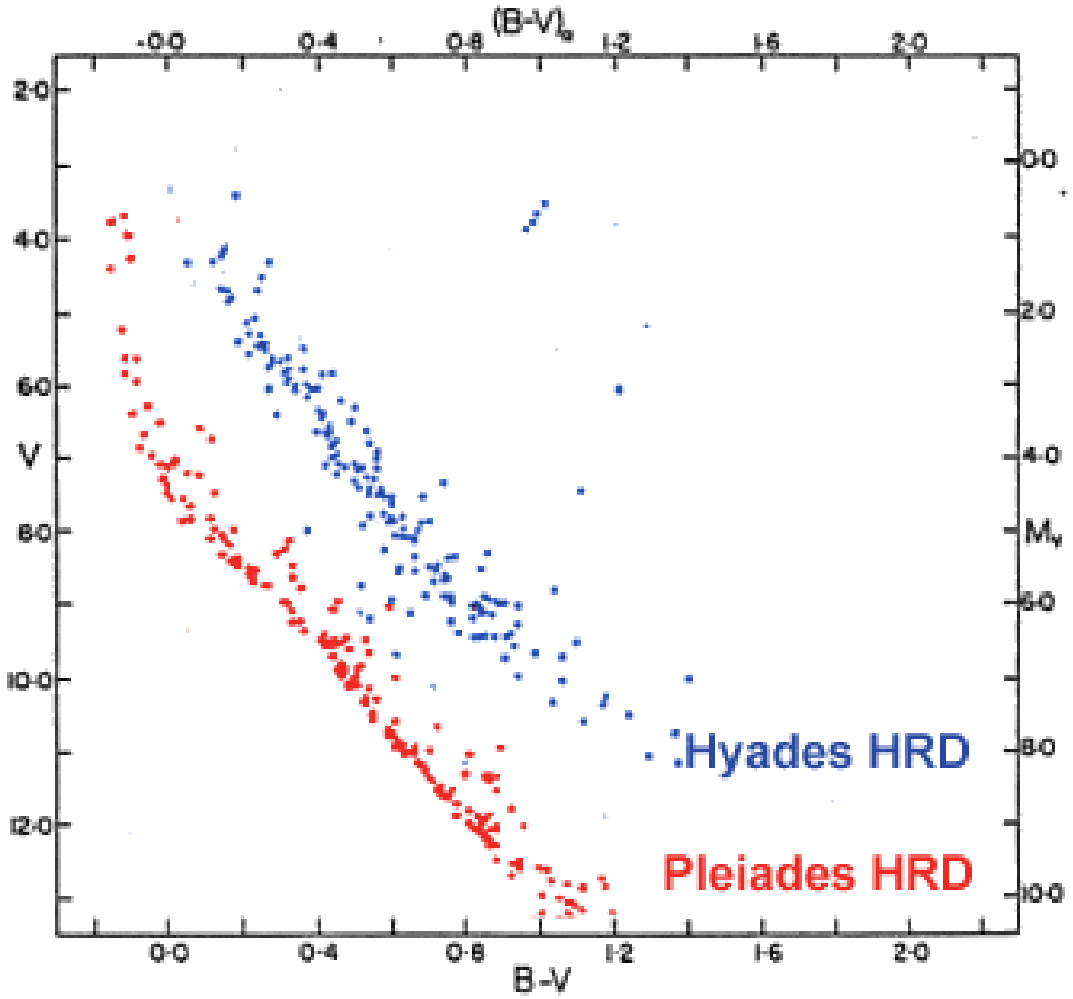
Sun on the HR diagram



Hipparcos HR diagram



Hyades Pleides



Stellar Mass: most important parameter for stars

determines (for a star on the main sequence):

1. Surface temperature
2. Radius
3. Luminosity

It also essentially determines its life history on and off the main sequence. It even determines if the star will end up as a white dwarf or neutron star.

Stellar spectrum

Basically a black body superposed with number of absorption and emission lines.
Blackbody is characterised by a single number, the temperature T.

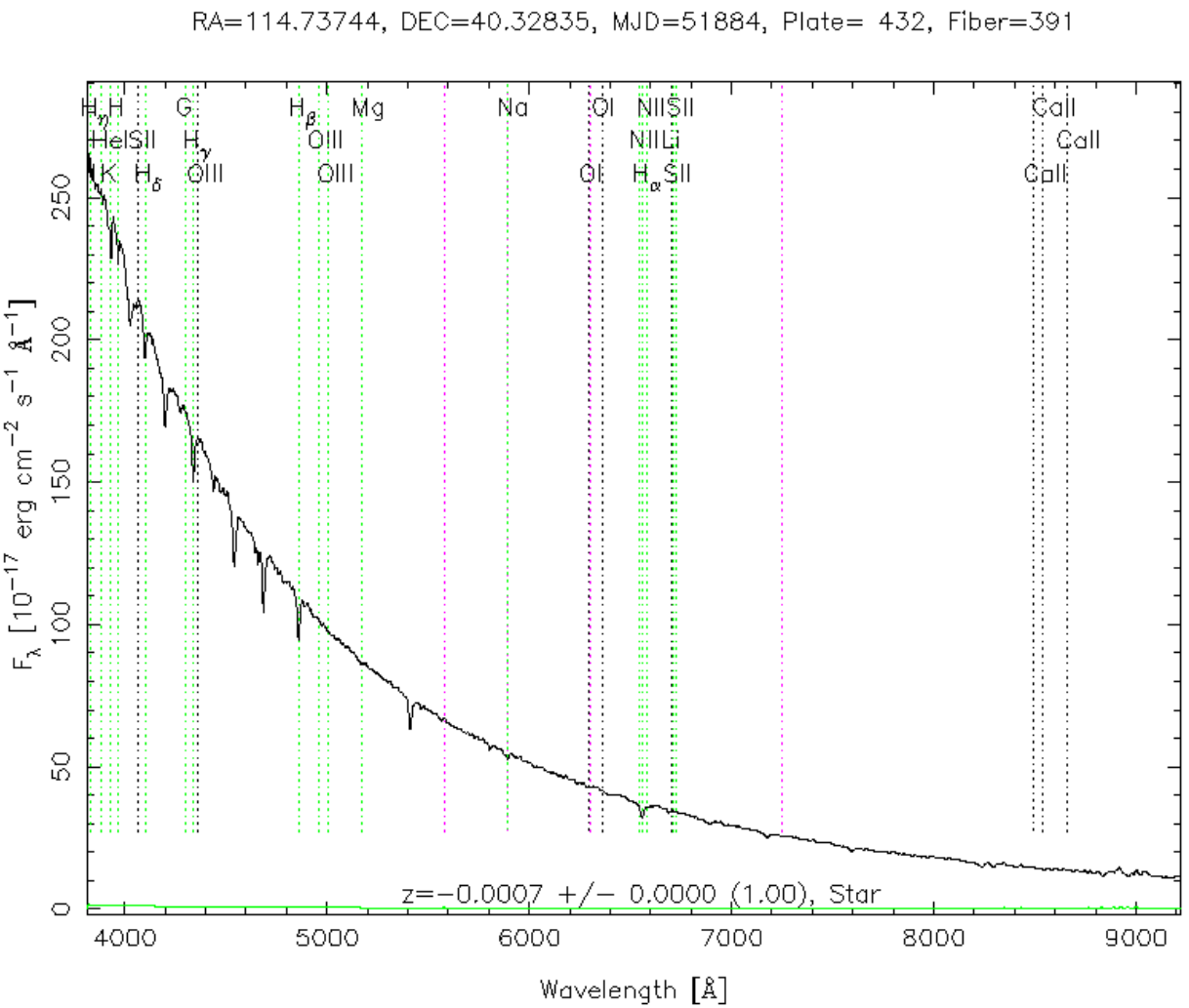
Stellar Spectral Types

Most stars are currently classified using the letters O, B, A, F, G, K, and M, where O stars are the hottest and the letter sequence indicates successively cooler stars up to the coolest M class. According to informal tradition, O stars are called "blue", B "blue-white", A stars "white", F stars "yellow-white", G stars "yellow", K stars "orange", and M stars "red", even though the actual star colors perceived by an observer, may deviate from these colors.

Stellar Spectral Subtypes

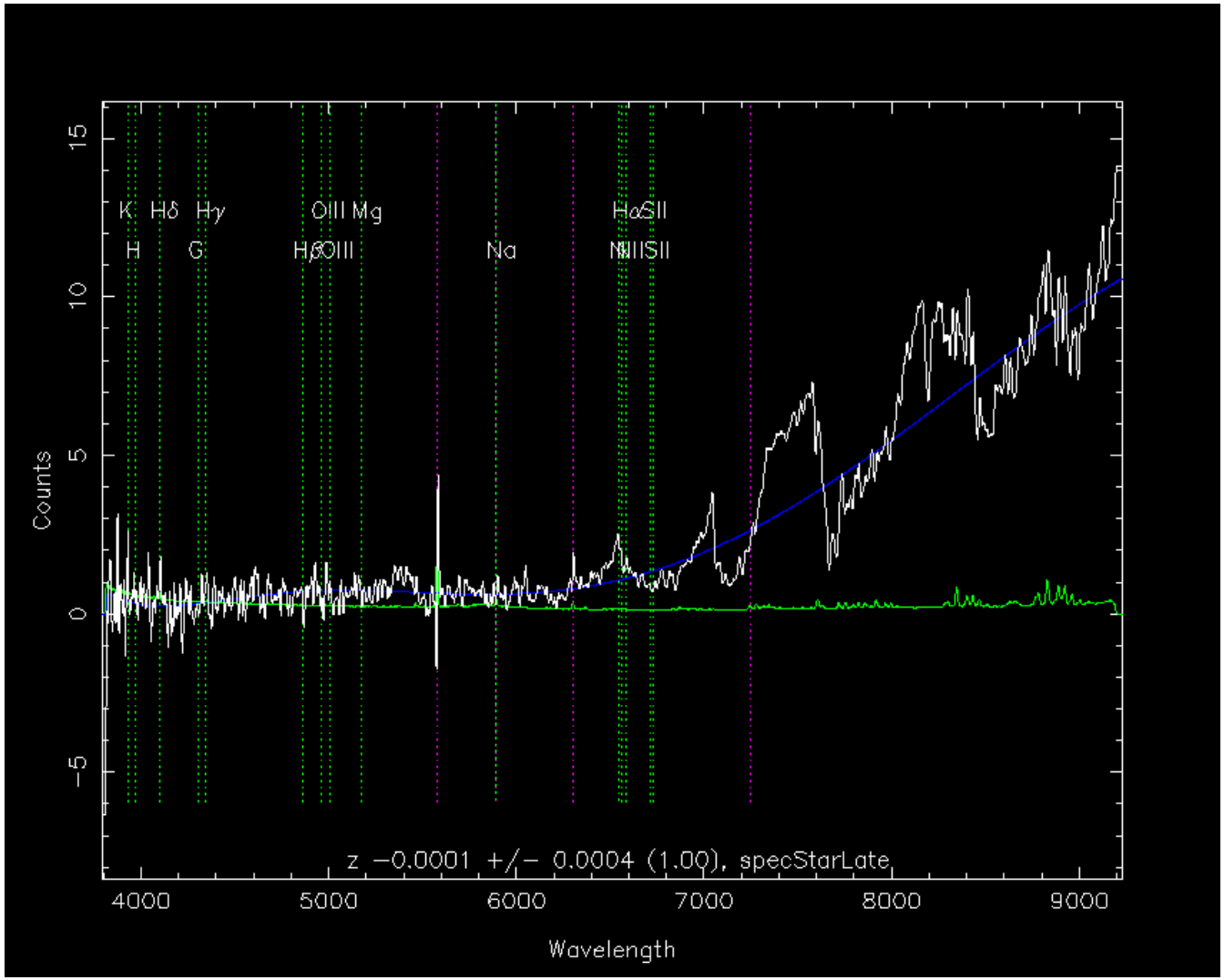
In the Morgan-Keenan system, the spectrum letter is enhanced by a number from 0 to 9 indicating tenths of the range between two star classes, so that A5 is five tenths between A0 and F0. Lower numbered stars in the same class are hotter. Also included in the Morgan-Keenan system is the luminosity class expressed by the Roman numbers I, II, III, IV and V, expressing the width of certain absorption lines in the star's spectrum. This feature is a general measure of the size of the star, and thus of the total luminosity output from the star. Class I are generally called supergiants, class III simply giants and class V either dwarfs or more properly main-sequence stars. For example, our Sun has the spectral type G2V, which might be interpreted as "a 'yellow' two tenths towards 'orange' main-sequence star". Sirius has type A1V.

O type star spectrum



Credit: SDSS

M type star spectrum



Credit: SDSS

Population I (Pop I) Stars

- **Metallicity:** High, with $Z \gtrsim 0.01$ (where Z represents the fraction of a star's mass that is not hydrogen or helium).
- **Location:** Found mainly in the disk of the Milky Way, especially in the spiral arms.
- **Age:** Relatively young.
- **Kinematics:** Circular orbits around the Galactic center, with low velocities relative to the Sun.
- **Examples:** The Sun, most of the stars in open clusters.

Population II (Pop II) Stars

- **Metallicity:** Low, with $Z \lesssim 0.01$.
- **Location:** Found in the halo and the bulge of the Milky Way, as well as in globular clusters.
- **Age:** Old, typically 10-13 billion years old, among the oldest stars in the Galaxy.
- **Kinematics:** Highly elliptical orbits with high velocities relative to the Sun.
- **Examples:** Stars in globular clusters like M13, ω Cen.

Comparison of the two types of populations

- **Metallicity:**
  - Pop I: High
  - Pop II: Low
- **Location:**
  - Pop I: Galactic disk, spiral arms
  - Pop II: Halo, bulge, globular clusters
- **Age:**
  - Pop I: Young
  - Pop II: Old
- **Kinematics:**
  - Pop I: Circular orbits in disk
  - Pop II: Elliptical orbits in bulge or halo

Importance of Metallicity

- **Star Formation:** Metal-rich environments lead to faster cooling of gas clouds, aiding star formation.
- **Stellar Evolution:** Higher metallicity influences the lifetime and evolution of a star.
- **Tracing Galactic Evolution:** The distribution of Pop I and Pop II stars helps trace the build-up of the Milky Way.

Domination of light and mass

Pop I (young): massive stars dominate light; low mass stars dominate mass Pop II (old): giants dominate light; M.S. stars dominate mass
What are Pop III stars?

Two types of Variables

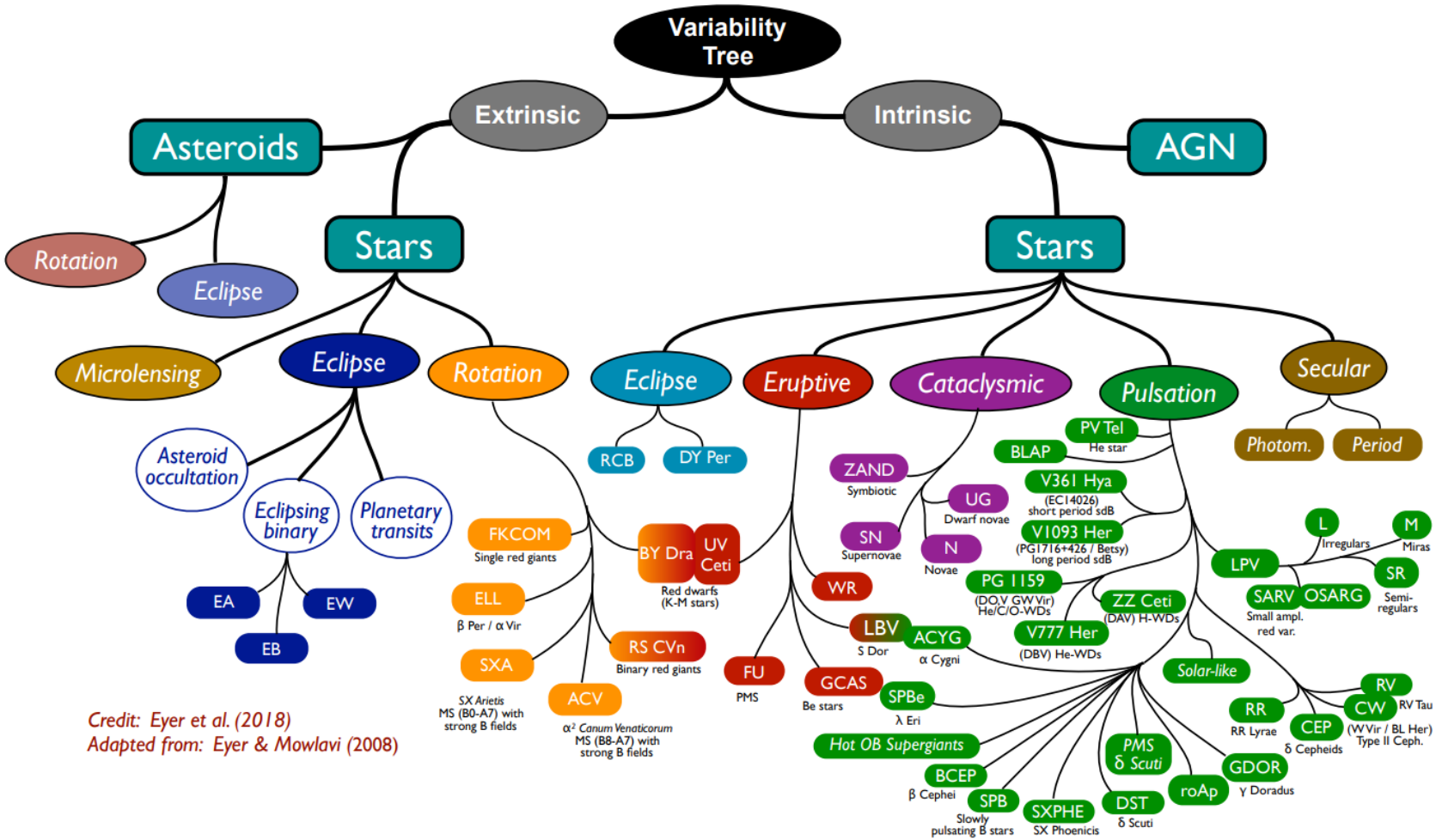
1. Intrinsic variables
2. Extrinsic variables

Amateur astronomers have historically played a major role in variable star studies e.g. AAVSO

Intrinsic or Extrinsic?

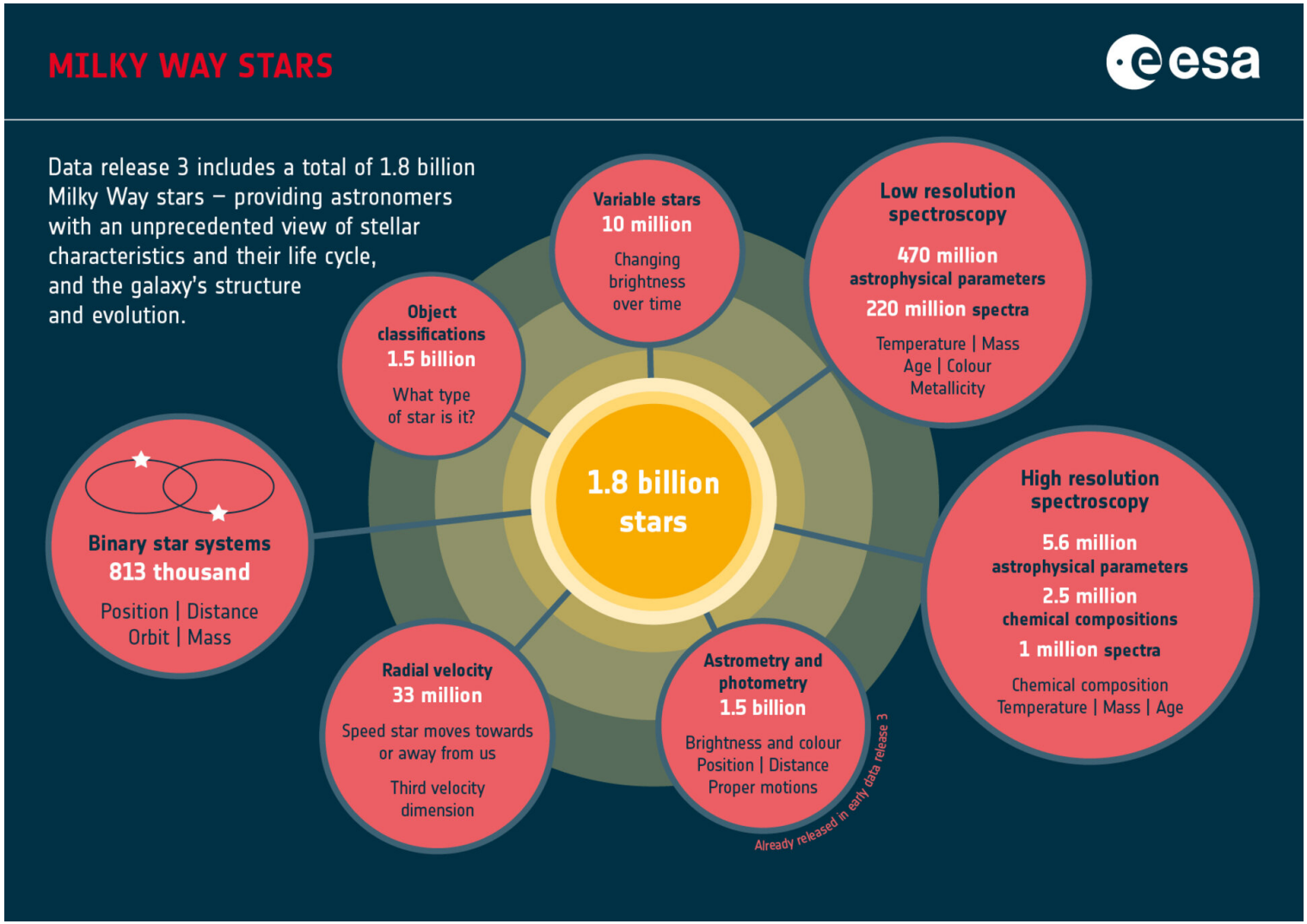
For two centuries, after the discovery of variable stars, the debate on whether the variation was intrinsic or extrinsic raged. This was mainly driven by a urge to explain all variability in terms of a *single model*, a grand unified theory of stellar variability. Sometimes, the search for simplicity can lead us up a blind alley.
Things should be simplified as much as possible, but don't overdo it.
Only in the 20th century after the advent of spectroscopy and quantum mechanics, was it realised that there are many classes of variable stars. The General catalog of variable stars (GCVS) lists 88 categories of intrinsic variables, including 34 different kinds of pulsating stars!

Variability tree

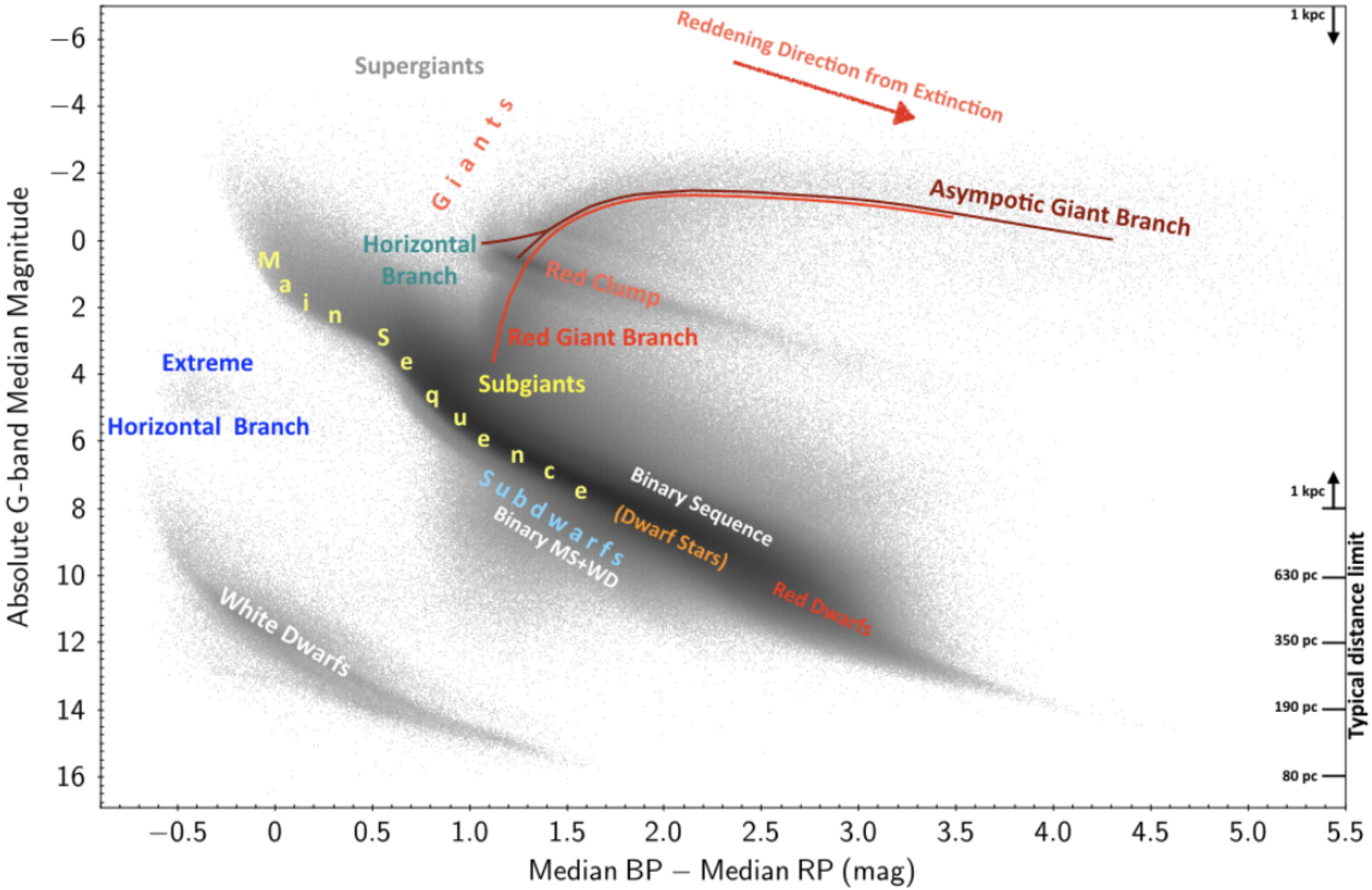


Credit: Eyer et al. (2018)
Adapted from: Eyer & Mowlavi (2008)

Gaia DR3 numbers



Gaia HRD


Supergiants
Giants
Reddening Direction from Extinction
1 kpc
Asympotic Giant Branch
Horizontal Branch
Red Clump
Red Giant Branch
Main Sequence
Subgiants
Extreme Horizontal Branch
Binary Sequence (Dwarf Stars)
Subdwarfs
Binary MS+WD
Red Dwarfs
White Dwarfs
1 kpc
630 pc
350 pc
190 pc
80 pc
Typical distance limit
Absolute G-band Median Magnitude
Median BP − Median RP (mag)
−6
−4
−2
0
2
4
6
8
10
12
14
16
−0.5
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5

What fraction of stars are variable?