“...My God, it’s full of stars!”
$N^*$

The number of stars in the Galaxy
The Galaxy

M31, the Andromeda Galaxy
2 million light years from Earth
The Shape of the Galaxy

A flattened spiral with a central bulge
The Size of the Galaxy

• Diameter: 100,000 light years
• Thickness: 1000 light years
• Average distance between stars: 4 ly
• How do you estimate $N_*$?
\[ N_* = 4 \times 10^{11} \]
Stars

Observables:
- Brightness
- Color
- Spectra
- Position
Brightness

- **Magnitude** scale: rooted in history

- The brightest stars were designated *Stars of the first magnitude*
- Lesser luminaries were *Stars of the second magnitude*

- The Greeks recognized 5 magnitudes.

- The eye has an approximately logarithmic response: *magnitude differences correspond to brightness ratios*
Magnitudes

Consequently, magnitudes are

• **Logarithmic**, and
• **Backwards**

The **brightest stars** have the **smallest magnitudes**
Magnitudes

The magnitude scale was quantified in the 17th and 18th centuries

• 1 magnitude difference = ratio of 2.512 in brightness
• 5 magnitudes = factor of 100 in brightness
  \((2.512^5 = 100)\)
• **Vega** has a magnitude of 0.0 (definition)
• Brighter stars have negative magnitudes
  – Sirius: mag = -1.6
  – Sun: mag = -26
  – Full moon: mag = -12
  – Venus (at brightest): mag = -4
  – Faintest naked eye stars: mag = +6.5
  – Faintest objects detected: mag ~ +30
Magnitudes

Apparent magnitudes (m): what we see

Absolute magnitudes (M): pegged to luminosity

M is the magnitude you would see at a distance of 10 parsecs (32.6 light years)

$M_\odot = 4.8$

Distance modulus (DM): a measure of distance

$DM = m - M = 5 \log(d) - 5$
Colors

- The eye perceives colors only in the brightest stars.
- Stars have colors because, to a first approximation, they radiate as blackbodies.
Astronomical Colors

**Colors** are differences in magnitudes
(= ratio of fluxes)

- B-V color = B mag - V mag
- Larger values are redder colors
- Smaller values are bluer colors
- By definition, the colors of Vega = 0

Color is indicative of temperature
Red indicates **cool**
Blue indicates **hot**
Bandpasses

Human response to visible light (cone cells)
Astronomical Bandpasses

UBVRI Filter Characteristics

UBVRI filter responses
Spectra of Stars

- All stars have an opaque photosphere
  - continuum emission
- Most stars have absorption line spectra
  - cool photosphere
- Some also show emission lines
  - hot or extended circumstellar gas
Spectral Types

- O
- B
- A
- F
- G
- K
- M
- L
- T
- Y

![Spectral Types Diagram]
Spectral Types

An empirical scale based on appearance of the spectrum

• Originally based on the strengths of absorption lines: A, B, C, D, E …

• Now reordered into a temperature sequence

• Spectral types have **subtypes**, e.g., B0, B1, B2 … B9
• Spectral types have **qualifiers**, e.g., M5e
Spectral Types

- **O**: Hottest stars; temps from $\sim 20,000K$ to $>100,000K$. Weak helium absorption.
- **B**: Temperatures from 10,000 to 20,000K. Noticeably blue. Examples: Rigel, in Orion, and Spica, in Virgo.
- **A**: Temperatures from 8000-10,000K. They appear white. Strong absorption lines of hydrogen. Examples: Vega, Altair, Sirius.
- **F**: slightly hotter than the Sun. Absorption lines of metals appear. Procyon is an F star.
- **G**: temperatures between 5000 and 6000K. Appear yellow. Examples: Sun, Centauri, Capella.
- **K**: Temperatures 3000 - 5000K. Appear orange. Arcturus is a K star.
- **M**: the coolest stars; 2000 - 3000K. Molecules can survive ($H_2O$, CO, VO, TiO). Noticeably red. Examples: Betelgeuse, Antares.
- **L, T, and Y** objects are brown dwarfs, not stars.
Spectral Type Mnemonics

OBAFGKM

• **O Be A Fine Girl/Guy, Kiss Me.**
• **Old Bald And Fat Generals Keep Mistresses.**
• **O Boy, An F Grade Kills Me.**
• **Only Boring Astronomers Find Gratification Knowing Mnemonics**
The Hertzsprung-Russell Diagram

- X-axis: color, temp, spectral type
- Y axis: absolute magnitude, luminosity

Reveals giants, dwarfs, and the main sequence

(distances from parallax)
Luminosity Classes

- **I**: supergiants
- **II**: bright giants
- **III**: giants
- **IV**: subgiants
- **V**: dwarfs - the main sequence
- **VI**: subdwarfs
- **WD**: white dwarfs

A luminosity, or pressure sequence. Observable in the spectra.

The Sun is G2V
H-R Diagram
Understanding the H-R Diagram

- Most stars are on the **main sequence**.
  - Stars spend most of their life on the main sequence
  - Most stars are faint and red
- Giants and supergiants are visible from great distances.
  - Giants and supergiants are rare.
Binary Stars

Stellar masses can be determined using Newton’s version of Kepler’s third law, 

$$(M_1 + M_2) = \left(\frac{4\pi^2}{G}\right) \frac{a^3}{P^2}$$
Types of Binary Stars

• Visual pairs
• Eclipsing binaries ⇒

← Spectroscopic binaries
Star Clusters

All members have the same
• Age
• Distance from Earth
• Composition

A testing ground for theories of
• Star formation
• Stellar evolution
Globular Clusters

47 Tucanae
Galactic, or Open Clusters

h and Persei
Stars

- Stars are in *hydrostatic equilibrium*: gravitational pressure balances gas pressure.

- Stars are generally **stable** for long times.

- Stellar properties are determined solely by their **mass**, **composition**, **age**, and **rotation rate**.

- The properties of *main sequence stars* are largely determined by their **masses**.

- Single stars are spherical, unless distorted by rotation.
Relevance to AST 248

• Planets orbit stars
• Planetary temperature set by \((L_*/d^2)^{1/4}\)
  – More luminous stars have wider habitable zones
• Stellar lifetime set by mass and luminosity
  – More luminous stars have shorter lifetimes