Summary: Stellar Distances

<u>Geometrical Methods</u>

Trigonometric Parallaxes: Triangulation
Moving Group Parallaxes: Size & Distance

<u>Photometric Methods</u>

Photometric Parallaxes: The Inverse-Square Law

<u>Special Methods</u>

Statistical Parallaxes: Stellar Groupings
Dynamic Parallaxes: Binary Stars
Indirect Methods: Pulsating Stars

<u>Results</u>

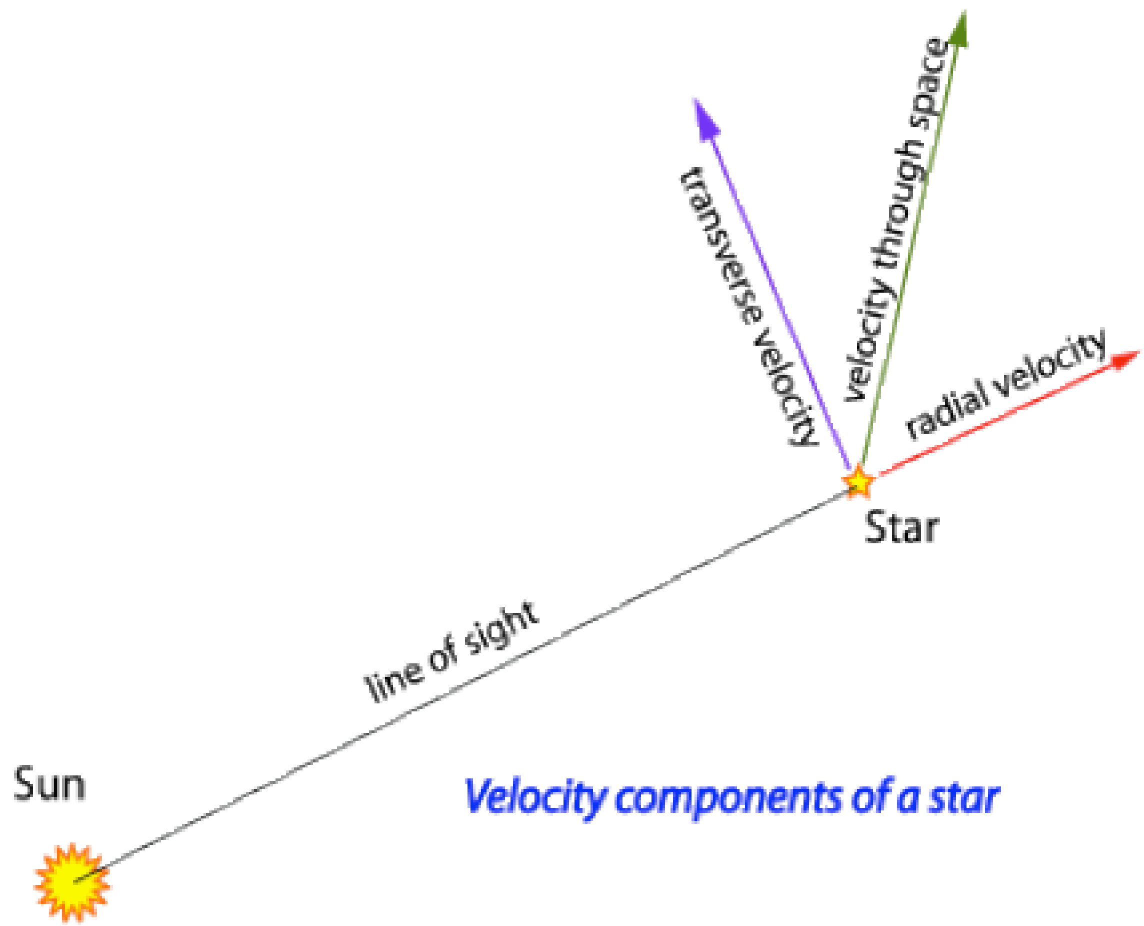
Next Nearest Star (α Centauri): d = 1.3 parsec
Typical Local Stellar Separation: $\langle \Delta d \rangle \sim 3$ parsecs

1 parsec (pc) = 206,265 astronomical units = 3.09×10^{13} kilometers

Stellar Motions

The space velocity, v, can always be separated into a radial component, v_r, and a tangential component, v_t

$$v^2 = v_r^2 + v_t^2$$



The <u>radial</u> part is what causes the <u>distance</u> to change.
The <u>tangential</u> part is what causes the <u>direction</u> to change.

Stellar Motions

The radial and tangential components are perpendicular to one another, so the space velocity is given by:

$$v^2 = v_r^2 + v_t^2$$

(Remember Pythagoras?)

The radial and tangential parts of a star's velocity are determined separately - and in quite different ways.

Determining the Radial Velocity

Radial velocities are obtained by observing the star's spectrum and making use of the <u>Doppler Effect</u>:

$$v_r/c = (\lambda - \lambda_o)/\lambda_o$$

(λ_o is the <u>emitted</u> wavelength, λ the <u>observed</u> wavelength)

Generally many absorption lines of known wavelength in a star's spectrum are measured to obtain an accurate value for the star's radial velocity.

Determining the Tangential Velocity

The <u>proper motion</u> of a star, μ , is the annual rate at which its location (direction) on the celestial sphere changes.
(This is in addition to the annual parallactic motion.)
It is usually expressed in seconds-of-arc per year.

Tangential velocities are obtained by measuring <u>both</u> a star's proper motion, μ , and its distance, d:

$$+v_t \text{(km/s)} = 4.74\mu \text{ (''/yr) } d \text{(pc)}$$

(The "constant" 4.74 is appropriate for the units used.)

(Note: 1 km/s = 2,235 mph = 1,944 knots)

The distance, d, is usually obtained from a measurement of the trigonometric parallax, p. Recollect that

$$d \text{(pc)} = 1/p \text{ ('')}$$

Stellar Motions: Observations

Proper Motions

The largest known proper motion is μ = 10.3 "/yr.
(This is for Barnard's star, a nearby red dwarf.)
Perspective: Barnard's Star takes almost 100 years to move the angular diameter of the full Moon!

Typical values for the 100 nearest stars, are about 1"/yr.
(Implying typical tangential speeds of a few tens of km/s.)

Radial Velocities

Typical values for stars run from 0 to about 200 km/s with a few tens of km/s being typical.

Conclusion: Stars in the solar neighborhood move in essentially random directions - with typical speeds of a few tens of kilometers per second.

But the Sun moves too! The Solar Motion is 19.7 km/s

Stellar Colors & Luminosities

Color and Temperature

The color of a star is related to its surface temperature.
“surface” = “photosphere”

Observed color is *almost* independent of the star’s distance.
Interstellar dust makes stars look redder over long distances

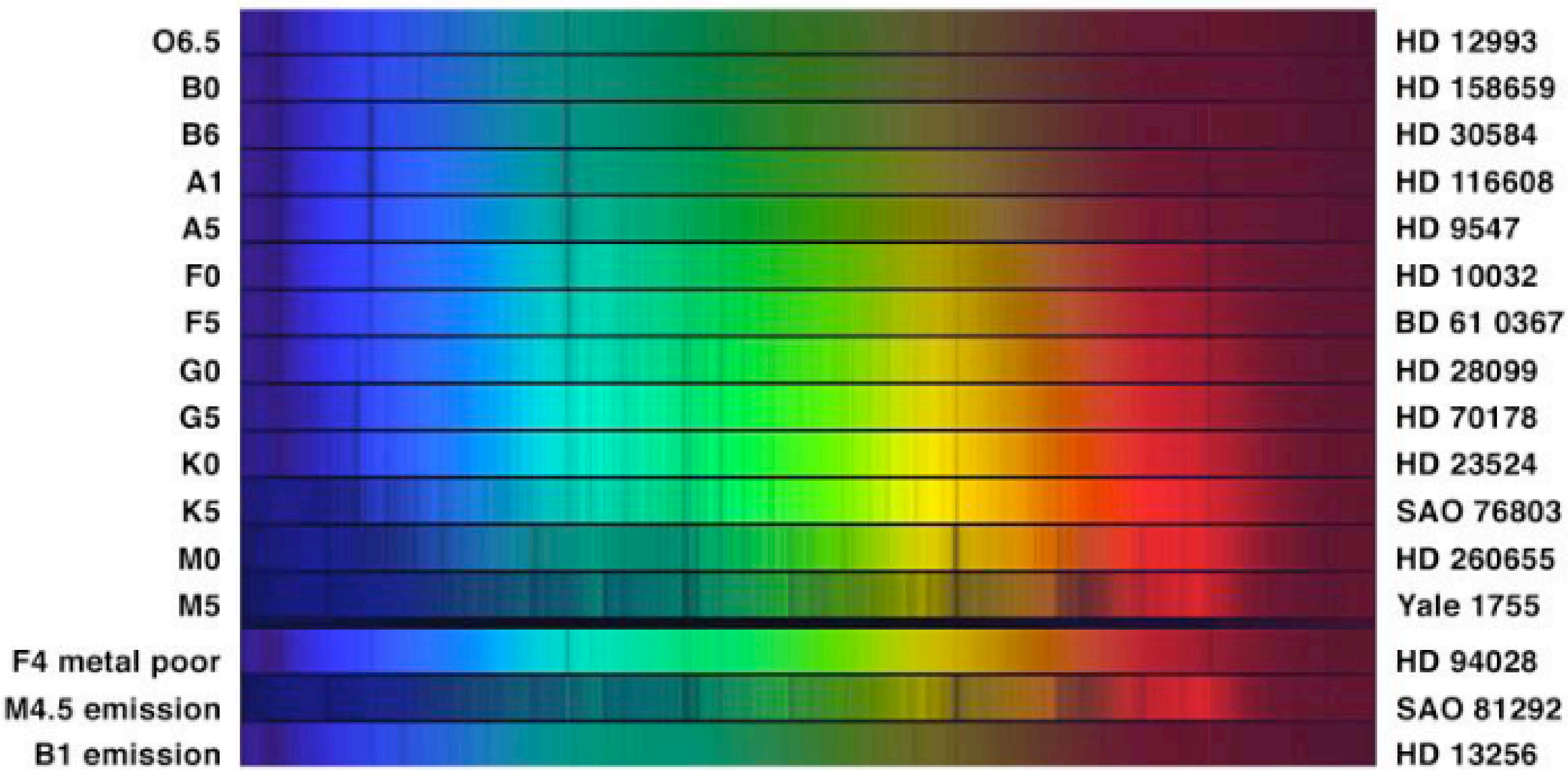
Temperatures can also be inferred from the appearance of a star’s spectrum - the pattern of spectral lines.
This spectral typing is not affected by interstellar dust.

Surface temperatures of stars almost all lie between 40,000°K for the “bluest” stars to about 3,000°K for the “reddest” stars.
Relatively few objects have temperatures outside this range.

The Sun’s surface temperature is about 5,800 °K

Color & Spectral Type

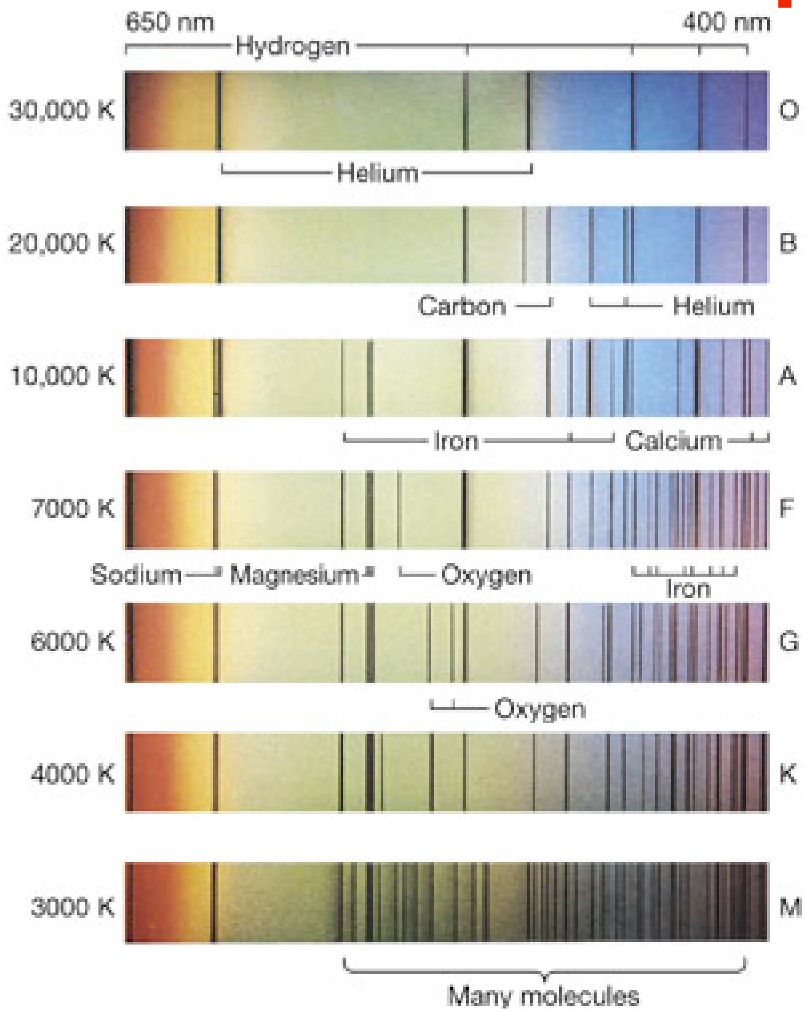
Stars can be arranged ("typed") based on the appearance of their spectra. The appearance of the spectrum is closely correlated with color

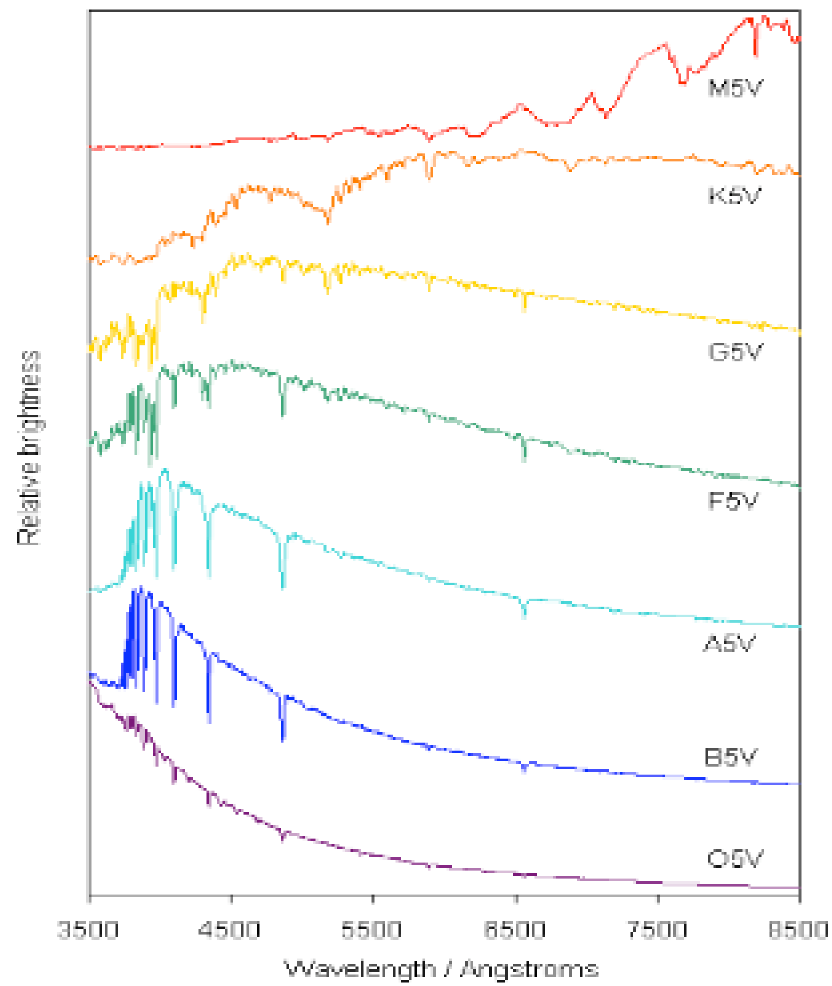


↑ **Spectral Types from O (hottest) through M (coolest) with decimal divisions like ... F6, F7, F8, F9, G0, G1, G2,....**

The Sun is of spectral type G2

OBAFGKM: Spectral Types of Stars





Note the temperature scale here.
Red is to the left, Hot is to the top

Red is to the right here and the coolest stars are at the top

Color, Spectral Type, and Luminosities

Luminosity

A star's luminosity, L, is determined from its measured apparent brightness, F, if its distance, d, is known:

$$L = 4\pi d^2 F$$

For the Sun

$F = 1{,}360$ watts/m^2 ("The Solar Constant")
$d = 150{,}000{,}000$ km ("The Astronomical Unit)

so

$$L_{Sun} = 3.8 \times 10^{26} \text{ watts}$$

For Main Sequence Stars

$$L_{M5V} \approx 10^{-2}\, L_{Sun} \quad \text{to} \quad L_{O5V} \approx 10^{+6}\, L_{Sun}$$

↑ **Full Spectral Type M5V: The M5 indicates a very cool red star. The Roman Numeral "V" indicates a Main Sequence luminosity class. An O5V star is among the hottest main sequence stars.**
The Sun is a G2V star.

Luminosities, Temperature & Size

The Luminosity, L, of an opaque glowing object depends upon its temperature, T, and surface area according to

$L = 4\pi R^2 \sigma T^4$ (Stefan's law)

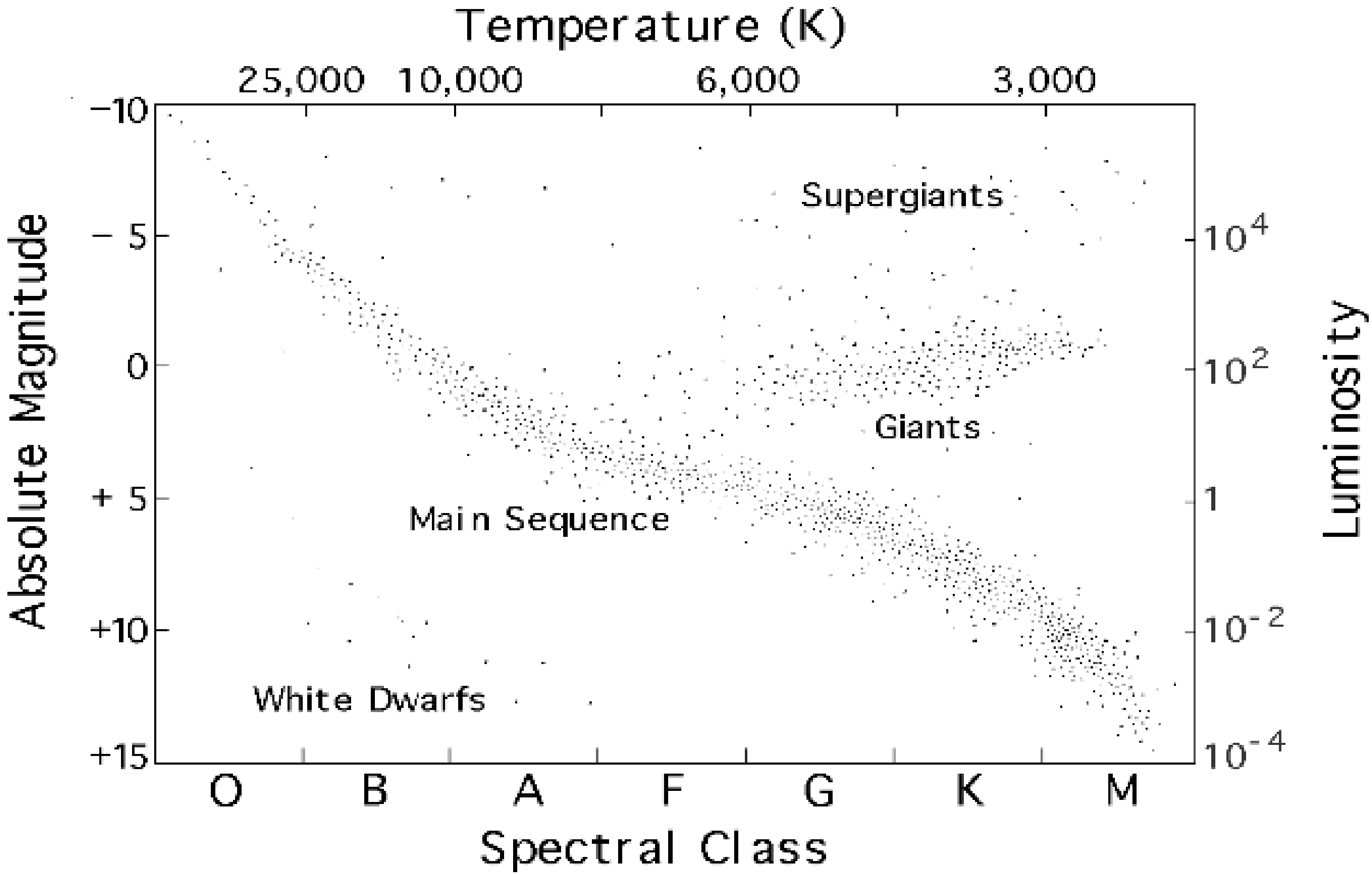
Here σ is Stefan's Constant and $4\pi R^2$ is the <u>surface area</u> of a spherical star of radius R.

If we know the luminosity, L, and the temperature T, of a star we can determine its radius R.

Some stars of a given spectral type are much more luminous (hence larger) than main sequence stars of the same type. These are supergiants and giants (classes I - IV)

Some stars of a given spectral type are much less luminous than main sequence stars of the same color or temperature. These are the white dwarf stars (class VI, usually "wd")

The Hertzsprung-Russell Diagram



Digression: Astronomical Magnitudes and Absolute Magnitudes

1 magnitude corresponds to a factor of 2.512 in luminosity or brightness

5 magnitudes corresponds to a factor of 100

More positive magnitudes correspond to fainter luminosities

Summary: The Sizes of Stars

The Sun

The Radius of the Sun is $R_{Sun} \approx$ 700,000 km

(about 400,000 miles)

Main Sequence Stars

(Happy Stars)

$R_{M5V} \approx 0.3\ R_{Sun}$ **to** $R_{O5V} \approx 18\ R_{Sun}$

Giants & Supergiants

(Dying Stars)

$R_{M5I} \approx 1{,}000\ R_{Sun}$ **to** $R_{O5I} \approx 12\ R_{Sun}$

White Dwarfs & Neutron Stars

(Stellar Corpses)

$R_{wd} \approx 0.01\ R_{Sun}$ **(about the size of the Earth)**

$R_{ns} \approx 10^{-5}\ R_{Sun}$ **(about the size of Las Cruces)**

Some stars can end their lives as Black Holes