THE UNIVERSITY OF TEXAS AT AUSTIN

Astro 301/ Fall 2006

(50405)

Introduction to Astronomy

http://www.as.utexas.edu/~sj/a301-fa06

Instructor: Professor Shardha Jogee

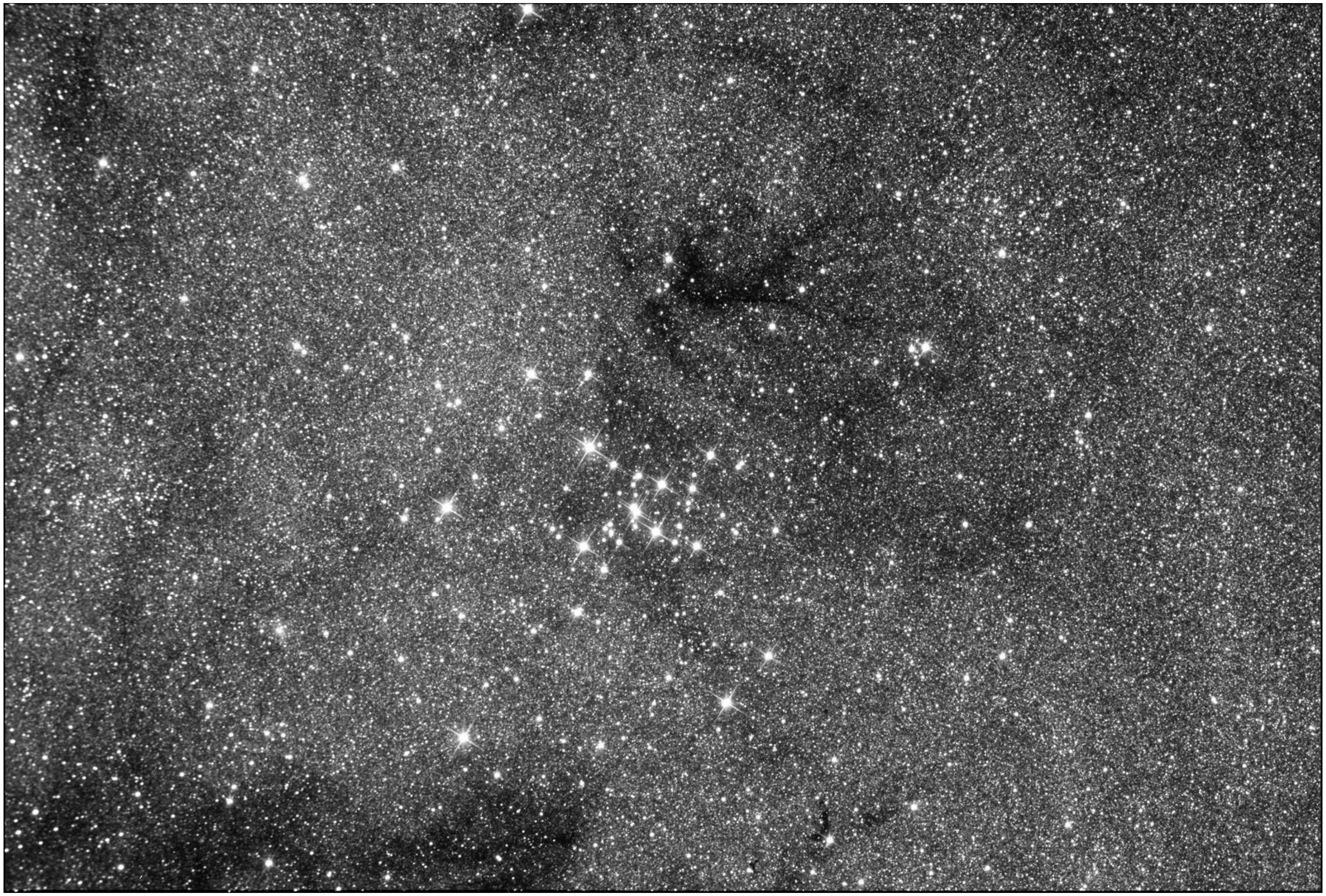
TAs: Biqing For, Candace Gray, Irina Marinova

Lecture 15 Tu Oct 24

Recent and upcoming topics in class

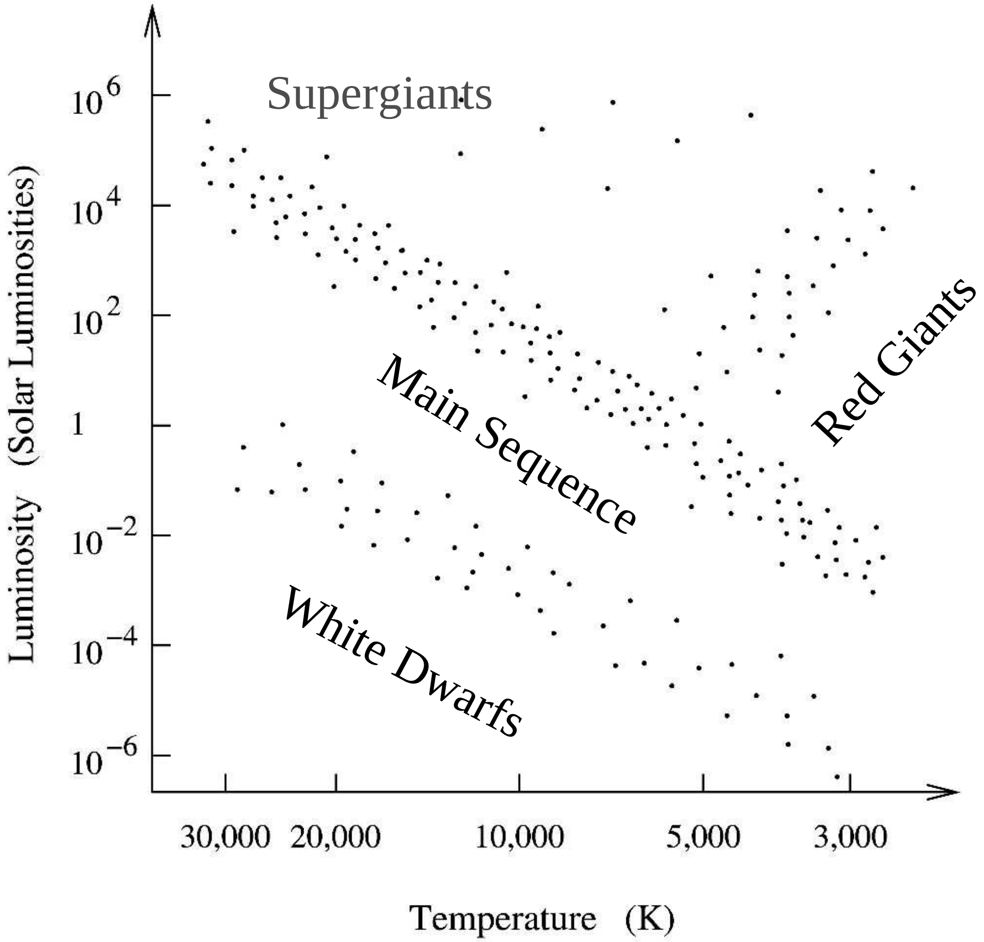
-- Unveiling the properties of stars from their light (continuum emission)
- Luminosity versus Flux
- Spectrum of an object: continuum emission, absorption lines, emission lines
- Kirchhoff's first law
- Wien's law: relating surface temperature and wavelength of maximum emission
- The temperatures of stars
- Stefan Boltzmann's law : relating surface temperature and surface flux of a star
- The luminosity function of stars
- The Hertzsprung-Russell diagram.
- Groupings of stars on H-r diagram: dwarfs, main sequence, giants, supergiants
- Luminosities, Temperatures, Radii and Average Density of stars

Astronomy Picture of the Day



M87:open clusters of stars, 1000 lyr away, in constellation Scorpius. Spans 25 lyrs across
Already noted by greek astronomer Ptolemy in the year 130 AD.
Contains about 100 stars in total, and is about 200 million years old. Note blue hot massive stars!

The Hertzsprung - Russell Diagram



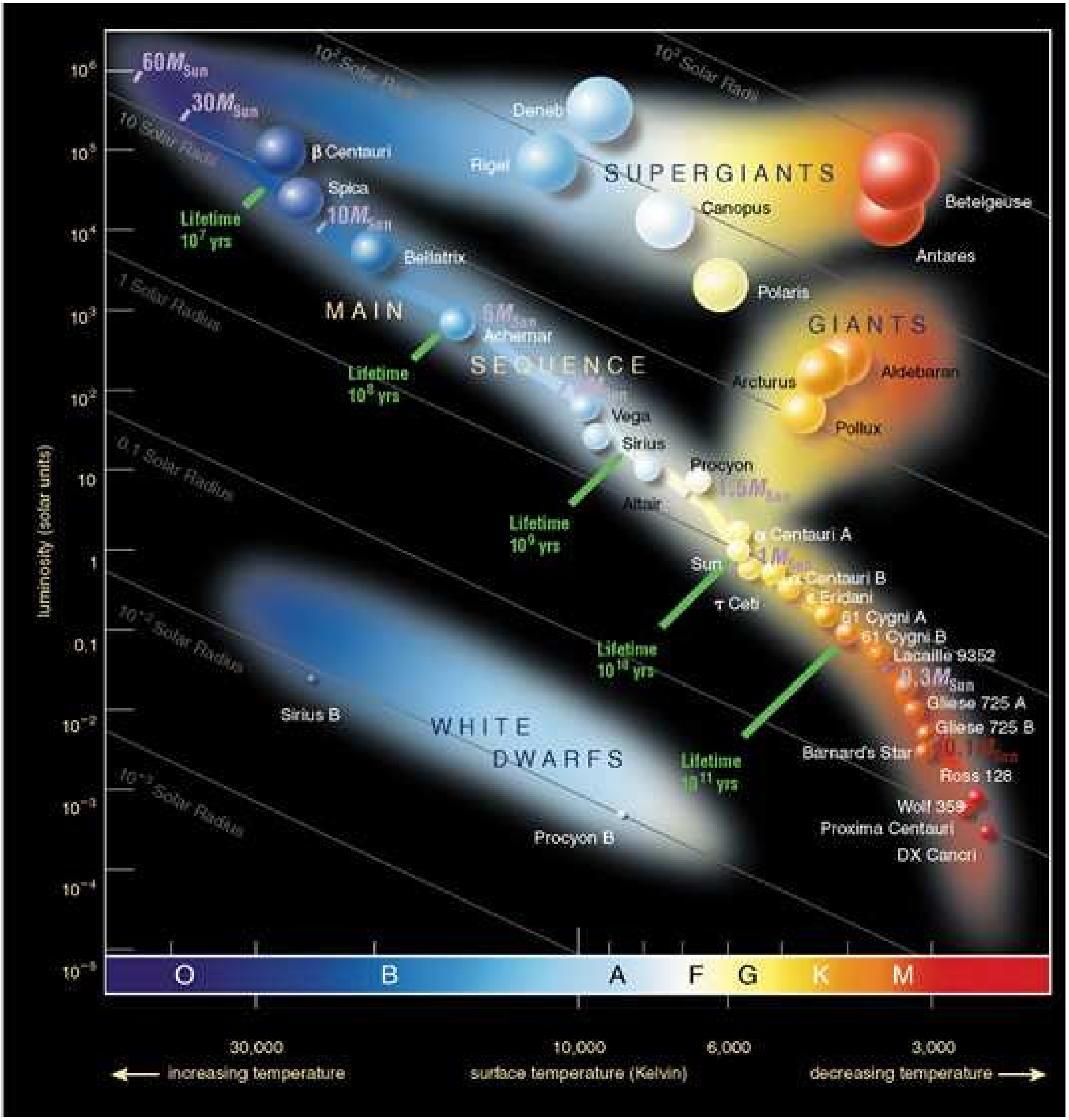
The first H-R diagram was plotted by Hertzsprung in 1911, and (independently) by Russell in 1913

Ejnar Hertzsprung Danish)
1937 Bruce medalist

Henry Norris Russell

-1925 Bruce medalist

Hertzsprung-Russell (H-R) diagram



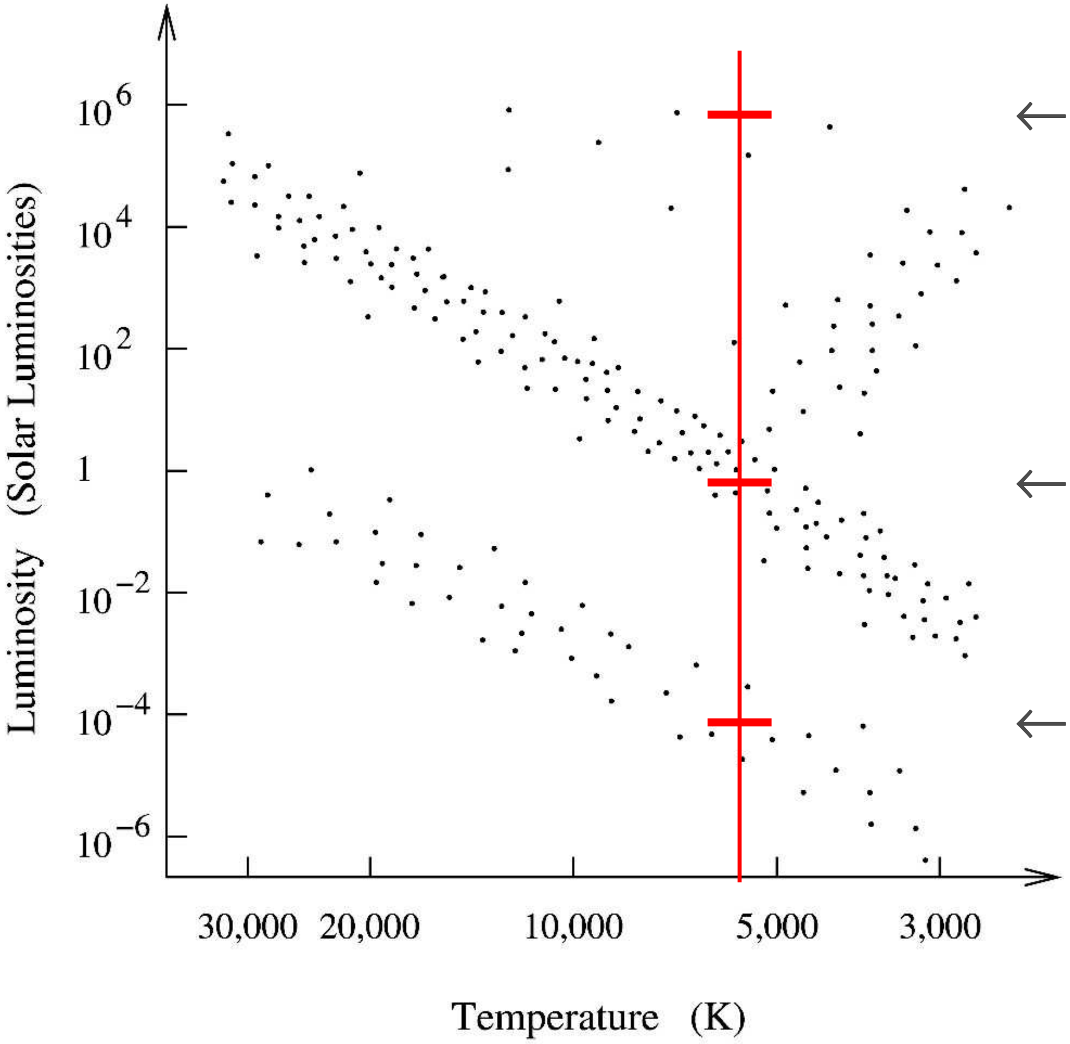
Many properties of H-R diagram can be understood using the relation that we derived earlier from the Stefan-Boltzmann Law and the defintion of flux :

The luminosity L of a star of radius R and surface temperature is given by

$$L= (4 \pi R^2) \sigma T^4$$

and is proportional to R^2T^4

The Hertzsprung - Russell Diagram

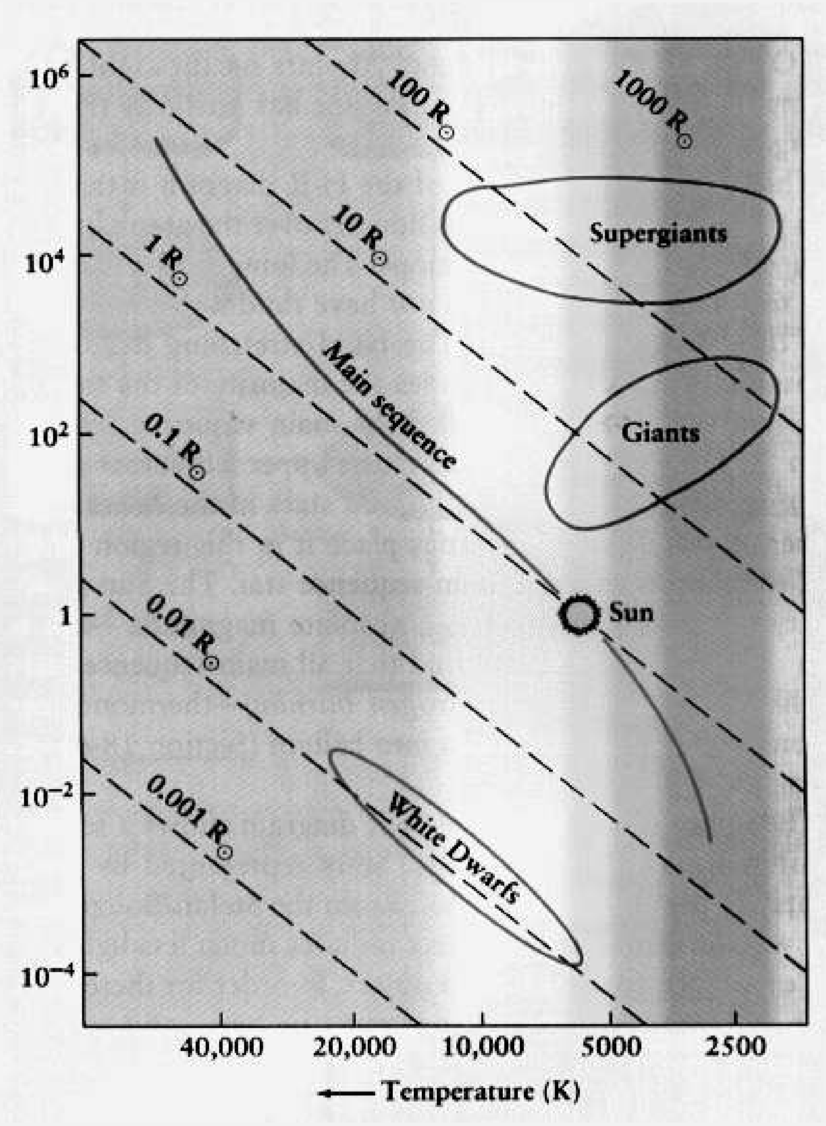


← Supergiant stars: 10^6 L$_{/}$

← Main sequence stars: 1 L$_{/}$

← White dwarfs: 10^{-4} L$_{/}$

The Radii of Stars in the H-R Diagram



How do we infer the surface temperature, luminosity and radius of a star?

1) Measure **total flux F** of star = apparent brightness

= energy received per s per unit area (J s-1 m-2)

2) If we know the distance d, then we can use the relation between flux and luminosity L to infer **the luminosity**.

Flux F = Luminosity L / Area of sphere of radius d = $L/4 \pi d^2$

3) Measure the **continuum spectrum**, namely the intensity of continuum light as a function of wavelength.

à Apply Wien's law to get the **surface temperature T**

4) Use Luminosity L from (2) and surface temperature T from (3) to calculate **the radius R** since we know (see last lecture) that the luminosity L is

$$L= (4 \pi R^2) \sigma T^4$$

Average Density

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \qquad [\text{in grams/cm}^3]$$

Some densities of materials on the Earth:

Air at sea level: 10^{-3} gm/cm^3

Balsa wood: 0.15 gm/cm^3

Water: 1 gm/cm^3

Lead: 11 gm/cm^3

Osmium: 22 gm/cm^3

The Average Density of the Sun

$M_{/} = 2 \times 10^{33}$ gm

$R_{/} = 7 \times 10^{10}$ cm

$V_{/}$ = Volume of the sun = $\frac{4}{3}\pi R_{/}^{3}$

$= 1.33 \times 3.14 \times (7 \times 10^{10})^3 = 1.4 \times 10^{33}\ \text{cm}^3$

$$\text{Density} = \frac{M_{/}}{V_{/}} = \frac{2\times10^{33}\,\text{gm}}{1.4\times10^{33}\,\text{cm}^3} = 1.4\ \text{gm/cm}^3$$

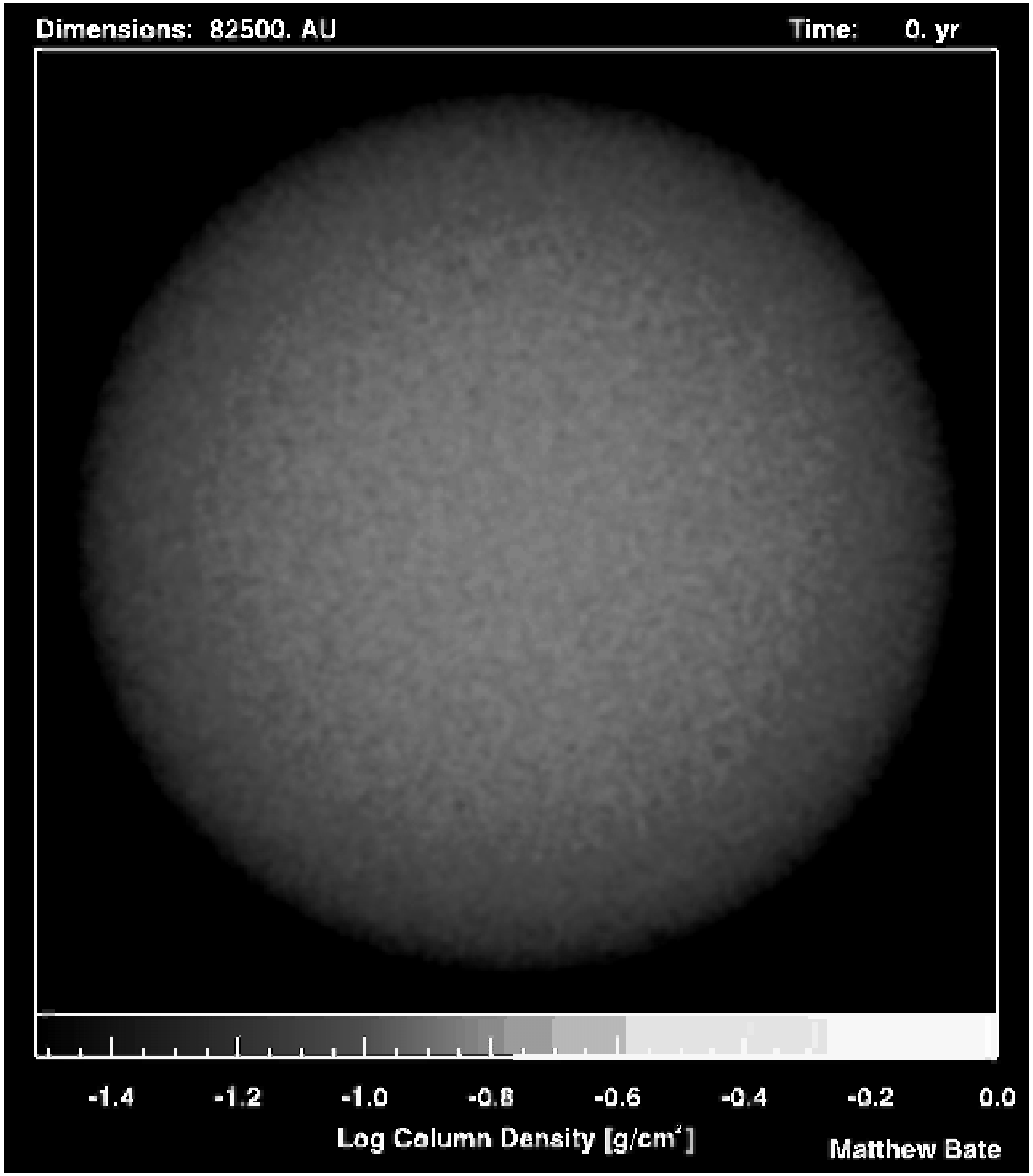
The <u>average</u> density of the Sun is about the same as the density of water!

Luminosities, Radii, and Average Densities of Stars

Type of Star	**Luminosity ($L_{/}$)**	**Radius ($R_{/}$)**		**Average Density (gm/cm^3)**
White dwarf	10^{-4}	0.01	(Earth Radius)	10^{6}
Main Sequence	1	1		1
Red Giant	10^{3}	50	(1/4 AU)	10^{-5}
Supergiant	10^{6}	1000	(5 AU)	10^{-9}

Birth, Evolution, and Death of Stars

Formation a Sun-like star and its planetary system



Start with a **gas cloud** whose
- mass ~ 50 times that of our Sun.
- diameter~1.2 light years (~10^{16}m)
- temperature ~ 10 K.

(low density=red, high density=yellow

The cloud collapses under its own gravity, and fragments to form **dense gas clumps and eventually stars.**

Swirling discs of gas around the newly born stars may later form **planetary systems like our own Solar System.**

Many properties of stars are determined by their mass

1. Stars are born from a collapsing H cloud with a range of masses

   M = 0.5 to 150 solar masses

   In class discussion: why this mass range?

2. Mass of a star determines

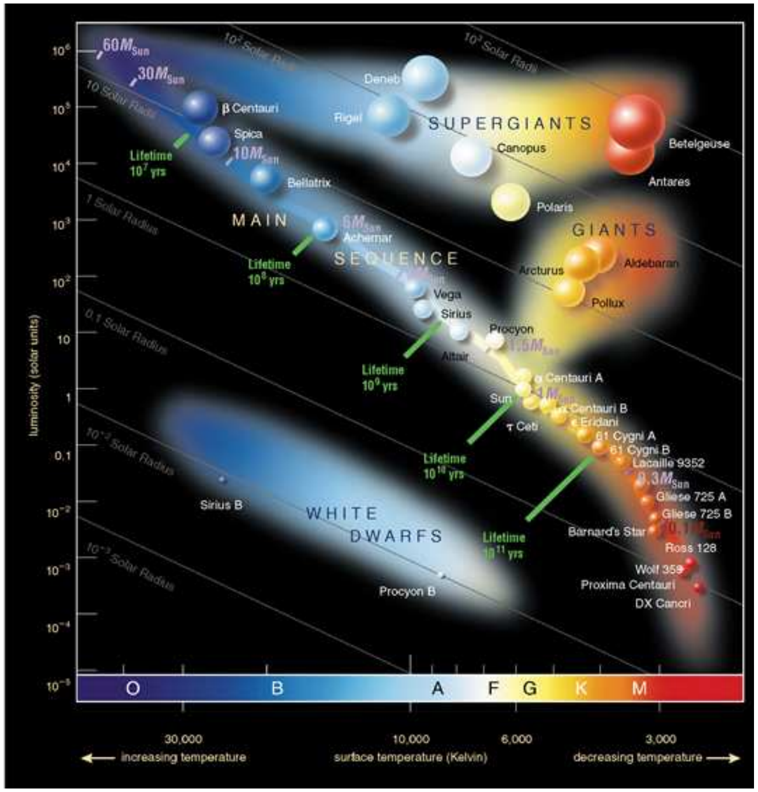
   - its luminosity, temperature and radius on the main sequence
   - its lifetime on the main sequence
   - its end products when it dies

3. Differences expected between 3 groups

   Low mass stars M = 0.5 to 1.5 solar masses

   Intermediate mass : M = 2 to 8 solar masses

   High mass stars: M > 8 solar masses



Evolution and Death of Low Mass Stars