Main Sequence Stars and their Lifetimes

Recall the four intrinsic properties

1. **Luminosity**   (from Brightness and Distance)

2. **Mass**   (from Doppler shifts in Binary Stars)

3. **Temperature**   (from stellar spectrum – Blackbody curve)

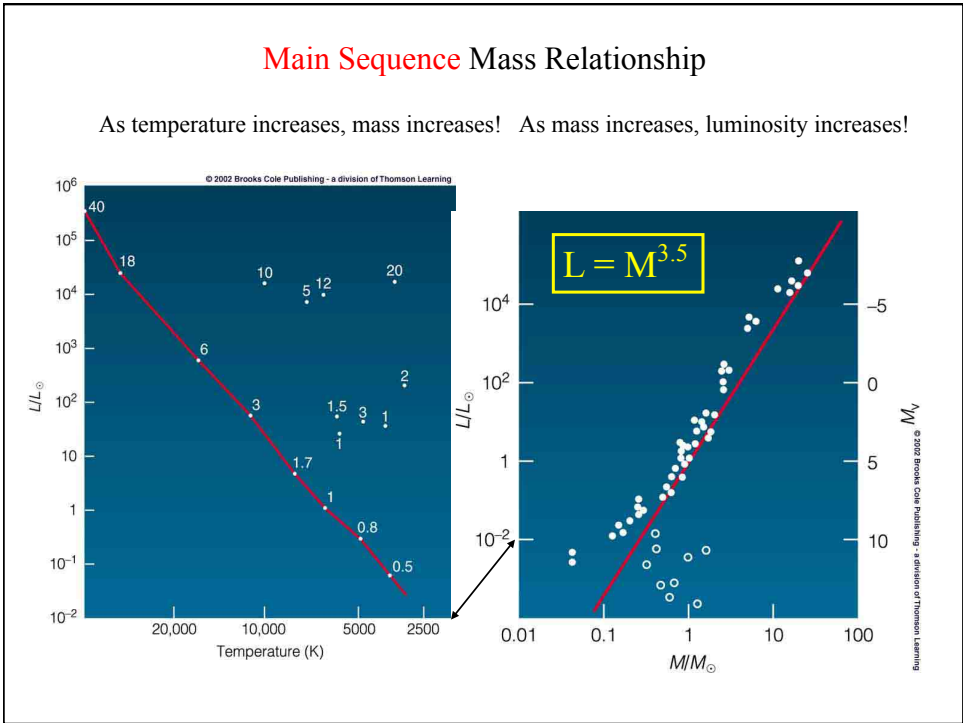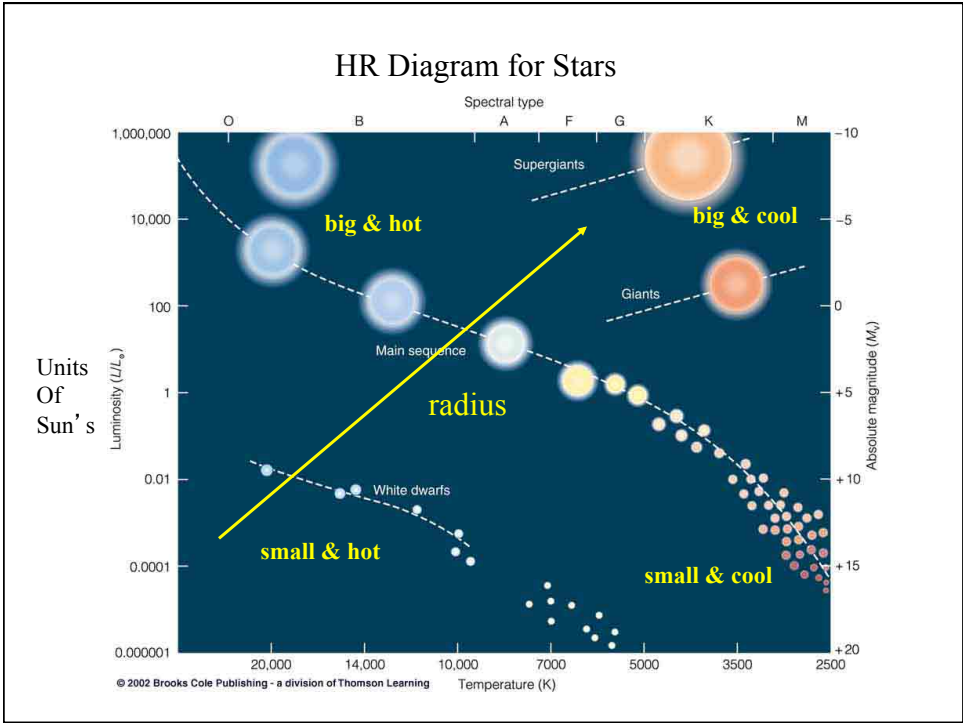4. **Radius**   (from Luminosity and Temperature)

Main Sequence
is

O, B, A, F, G, K, M

increasing temperature ⟵——————————⟶ decreasing temperature

increasing size ⟵——————————⟶ decreasing size

increasing mass ⟵——————————⟶ decreasing mass

increasing luminosity ⟵——————————⟶ decreasing luminosity

This applies to the Main Sequence Only
Giants and White Dwarfs do NOT obey all these trends.

How do we get length of time a star "lives" on the Main
Sequence before it becomes a Red Giant and starts to die?

HR Diagram for Stars

Main Sequence Mass Relationship

As temperature increases, mass increases!   As mass increases, luminosity increases!

$$L = M^{3.5}$$

The Life Expectancies of Main Sequence Stars, Part 1

BASIC PRINCIPLES OF LIFETIMES

The more fuel; the longer the life time…
The slower the consumption of fuel, the longer the life time…

$$\text{Lifetime} = \frac{\text{Amount of Fuel}}{\text{Rate of Fuel Consumption}}$$

The **Amount of Fuel** is proportional to the star's mass, **M**

The **Rate of Fuel Consumption** is proportional to the star's luminosity, **L**

The luminosity depends upon mass! **L = M$^{3.5}$**

The Life Expectancies of Main Sequence Stars, Part 2

Therefore, the lifetime can be written using only the star's mass! If we write the mass in solar units, then the lifetime is given in solar lifetimes.
The sun's lifetime is roughly 10 billion years, or Lifetime = 10 x 10^9 yr

$$\text{Lifetime} \sim \frac{M}{L} = \frac{M}{M^{3.5}} = \frac{1}{M^{2.5}}$$

Large Mass Stars Have Shorter Lives

M   **0.5 solar mass star** lives 5-6 solar life times, or **56 x 10^9 years**

A   **4.0 solar mass star** lives 0.031 solar life times, or **310 x 10^6 years**

O   **40.0   solar mass star** lives 0.0001 solar life times, or **1 x 10^6 years**

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Main Sequence
is

O, B, A, F, G, K, M

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increasing temperature ⟵——————————⟶ decreasing temperature

increasing size ⟵——————————⟶ decreasing size

increasing mass ⟵——————————⟶ decreasing mass

increasing luminosity ⟵——————————⟶ decreasing luminosity

decreasing lifetime ⟵——————————⟶ increasing lifetime

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The more massive a star, the shorter is its lifetime on the Main Sequence

The most massive stars live about 1 million years.
The sun lives about 10 billion years.
The lowest mass stars can live up to 50 billion years!

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