

# The “Local Group” of Galaxies

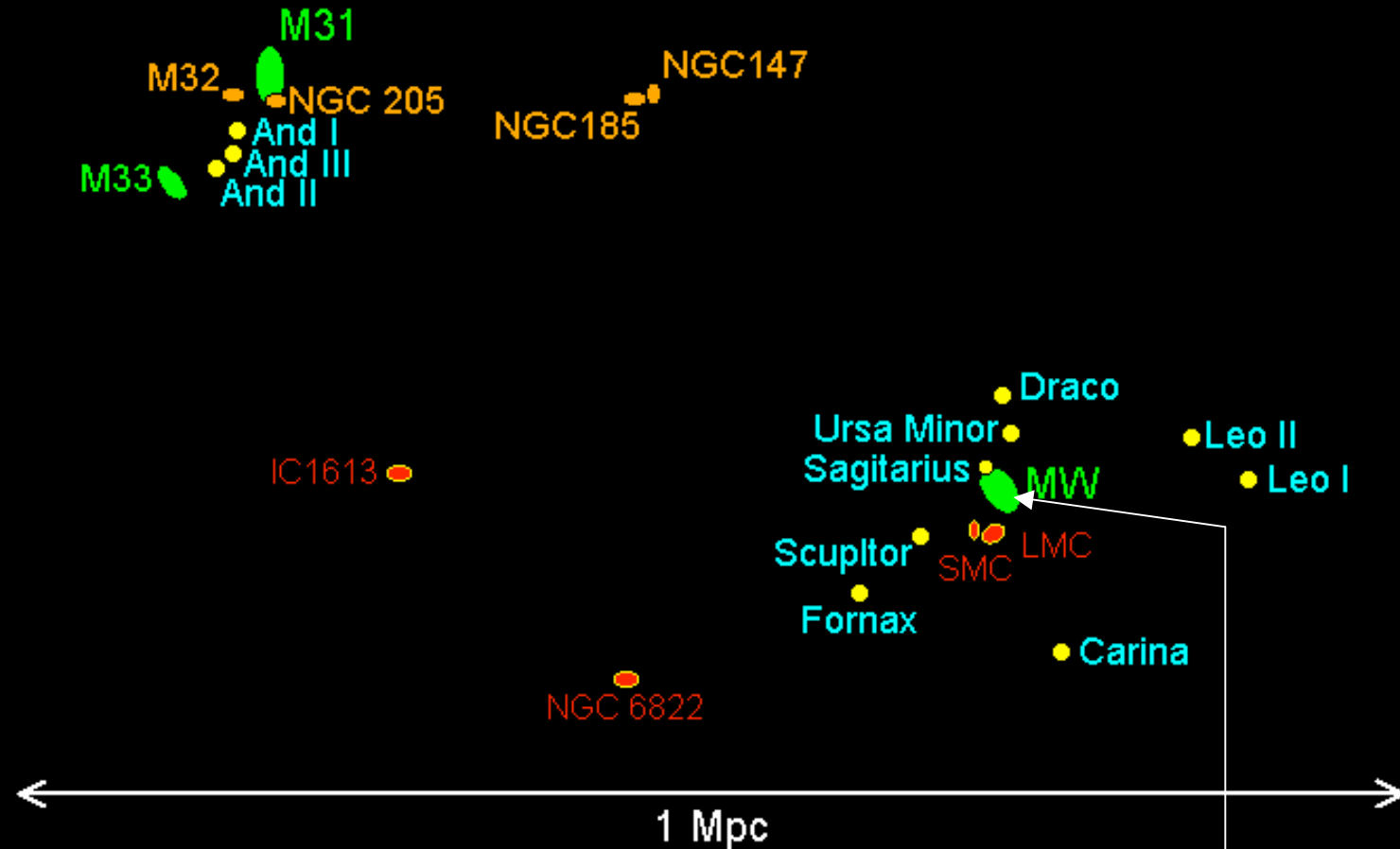
## Two large spiral galaxies

- Milky Way & Andromeda (Messier 31 or M31)
- Distance between them:  $D = 700 \text{ kpc} = 2.3 \times 10^6 \text{ light yrs}$

## Each large spiral galaxy has several smaller satellite galaxies in orbit around it

- Milky Way: Large Magellanic Cloud (LMC), Small Magellanic Cloud (SMC), Sagittarius dwarf, etc
- Andromeda: Messier 32 (M32), NGC 205, NGC 147, etc

# The Local Group



You are here

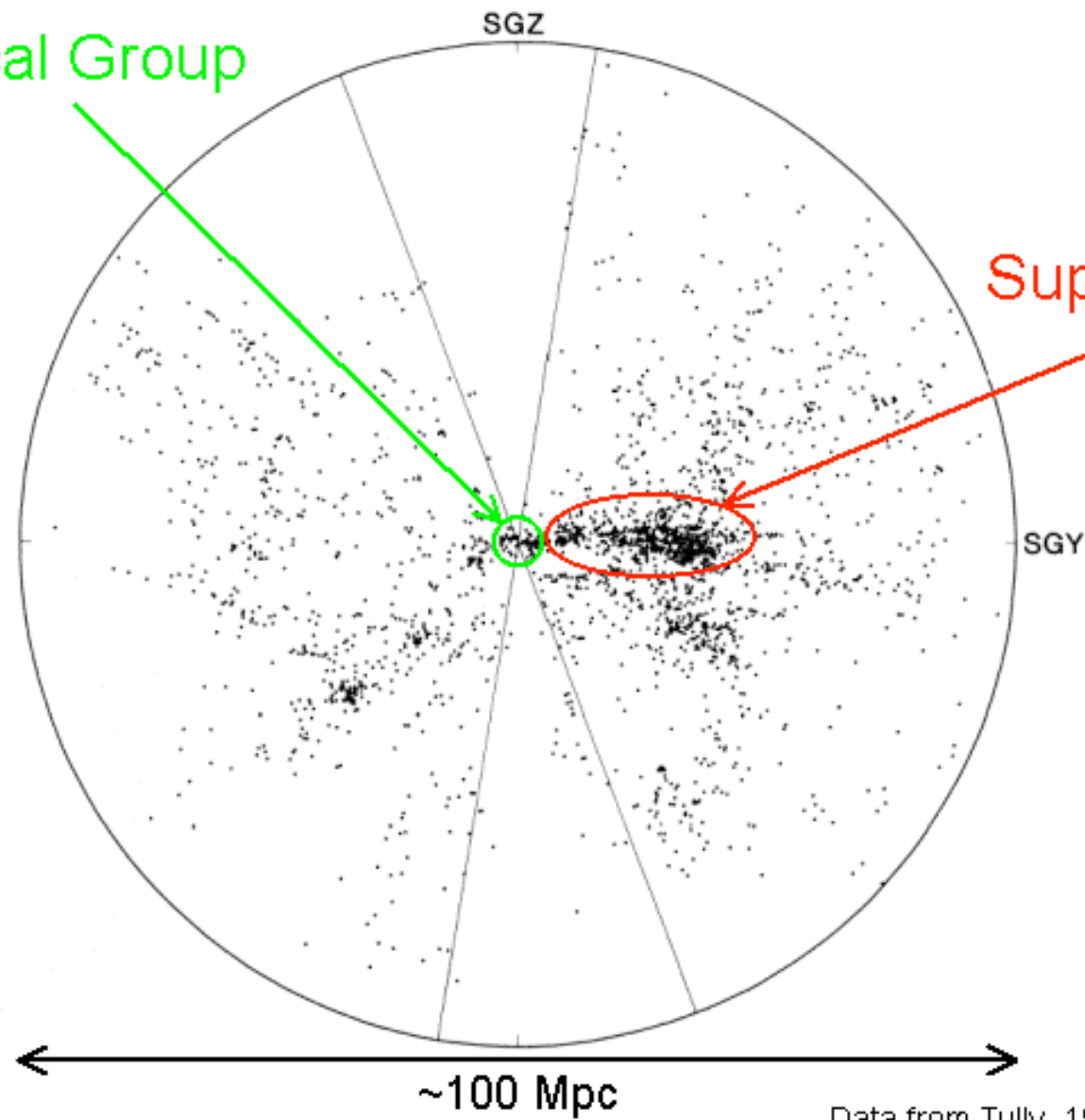
## clicker Quiz #19

Which of the following statements about the EPOCH OF CONFINEMENT is **TRUE**?

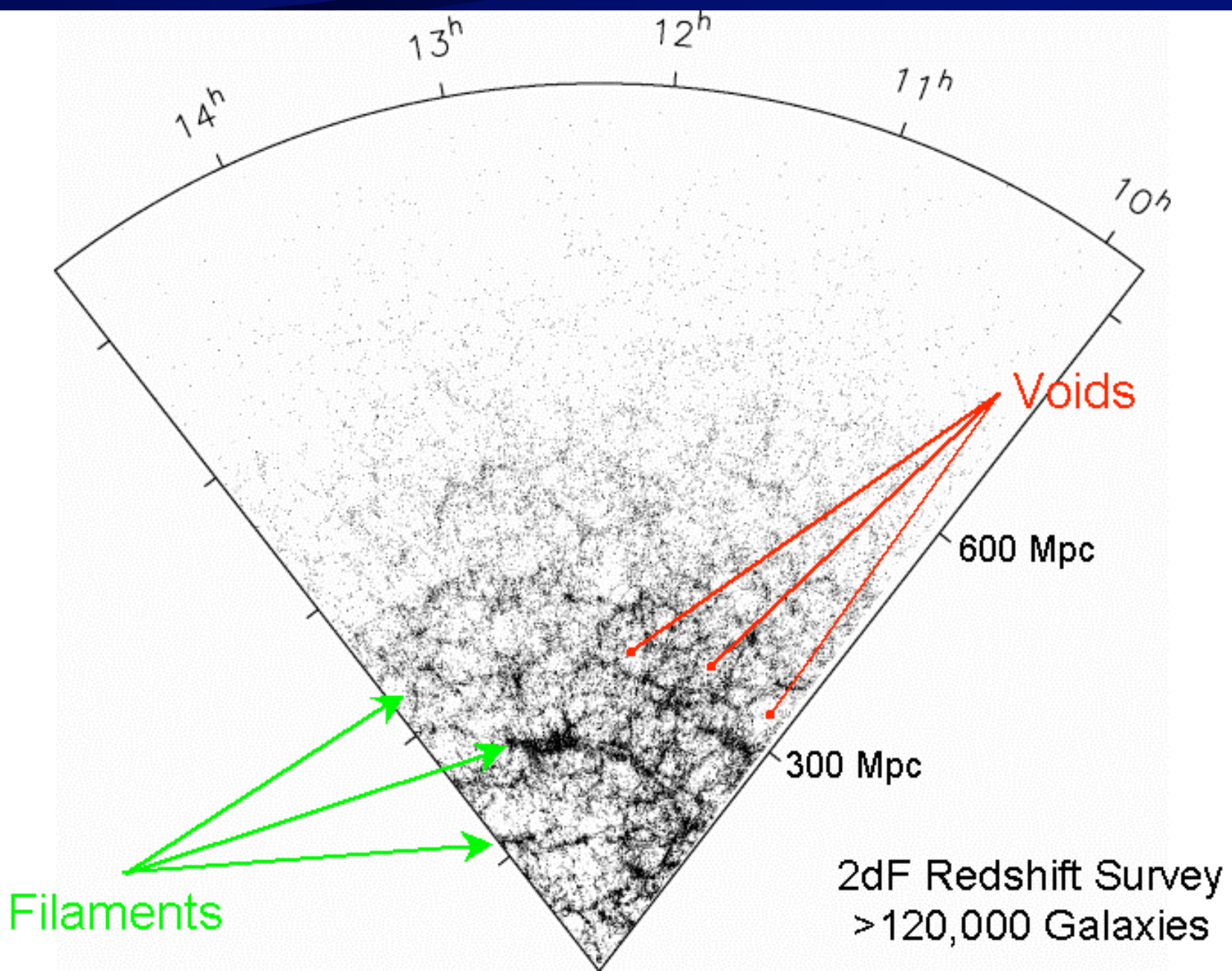
- A. At this instant, quarks became bound in sets of three to produce protons and neutrons, while matter and radiation continued to interact strongly
- B. The Universe was matter dominated at this epoch
- C. Protons and electrons formed stable hydrogen atoms for the first time at this epoch, and the matter in the Universe became mostly transparent to radiation
- D. This epoch was immediately followed by Inflation

Local Group

Local Supercluster



Data from Tully, 1982, ApJ, 257, 389



# A Star is Born!

- **Giant molecular** clouds: consist of mostly  $H_2$  plus a small amount of other, more complex molecules
- Dense cores can begin to collapse under their own **gravitational attraction**
- As a cloud core collapses, the **density** and **temperature** of the gas **increase** → more blackbody radiation
- **Opacity** — the gas is not transparent to the radiation, and the radiation interacts with the gas particles exerting an outward pressure known as **radiation pressure**
- The intense radiation from hot, young stars **ionizes** the gaseous interstellar medium surrounding it — this is known as an **HII region**



Young star cluster: NGC 3603

# Proto-stars

- Gravitational collapse is usually accompanied by the formation of an **accretion disk** and **bi-polar jets** of outflowing material



- The remnants of an accretion disk can ultimately give rise to **planets** — these disks are often referred to as **protoplanetary disks**

# Hayashi tracks

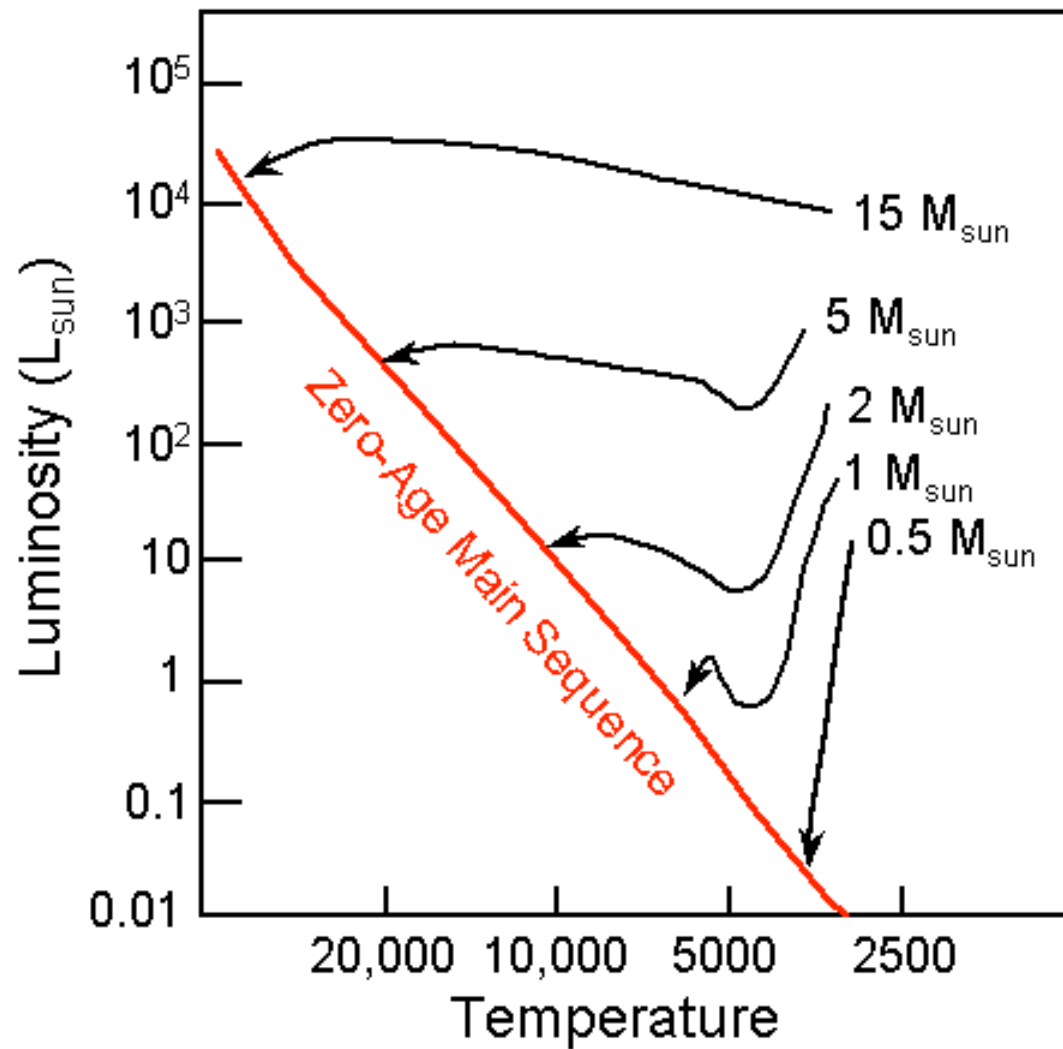
- A proto-star's temperature and luminosity can be plotted on a Hertzsprung-Russell diagram or **HR diagram**
- Proto-stars tend to become **hotter** but **less luminous** during the process of **gravitational contraction**; the decrease in luminosity is mostly a result of the proto-star becoming **smaller**
- The exact track in an HR diagram followed by a contracting proto-star depends on its **mass**
- These tracks are called **Hayashi tracks**, after the Japanese astrophysicist who first researched this problem

## i>clicker Quiz #23

The Moon's spin period about its own axis is the same as its orbital period around the Earth. Which of the following statements can be **TRUE** about a Moon-based astronomer?

- A. She sees the Earth rise and set once every spin period
- B. She sees the Sun rise and set once every spin period
- C. She does not experience day and night
- D. She always sees the Sun

# Pre-Main Sequence Evolution

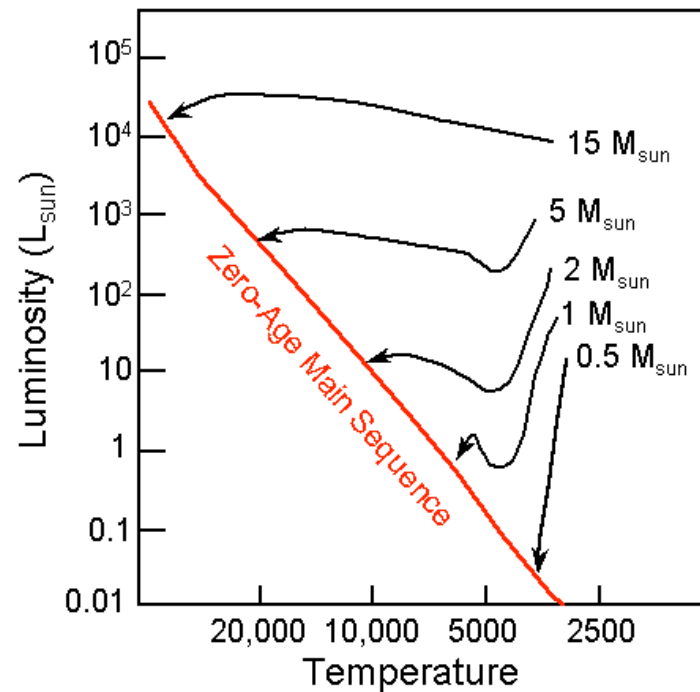


## i>clicker Quiz #24

How much bigger / smaller is a  $15 M_{\text{sun}}$  star main sequence compared to an  $0.5 M_{\text{sun}}$  main sequence star?

- A. 50 times smaller
- B. 10 times smaller
- C. 10 times larger
- D. 3 times larger

Pre-Main Sequence Evolution



# Properties of a Newborn Star

- The **Zero Age Main Sequence** (ZAMS) represents the onset or start of nuclear burning (fusion)
- The properties of a star on the ZAMS are primarily determined by its **mass**, somewhat dependent on composition (He and heavier elements)
- The classification of stars in an HR diagram by their **spectral type** (OBAFGKM) is a direct measure of their **surface temperature**
- A study of the exact shape of the ZAMS in an HR diagram indicates that **more massive stars have larger radii** than less massive stars

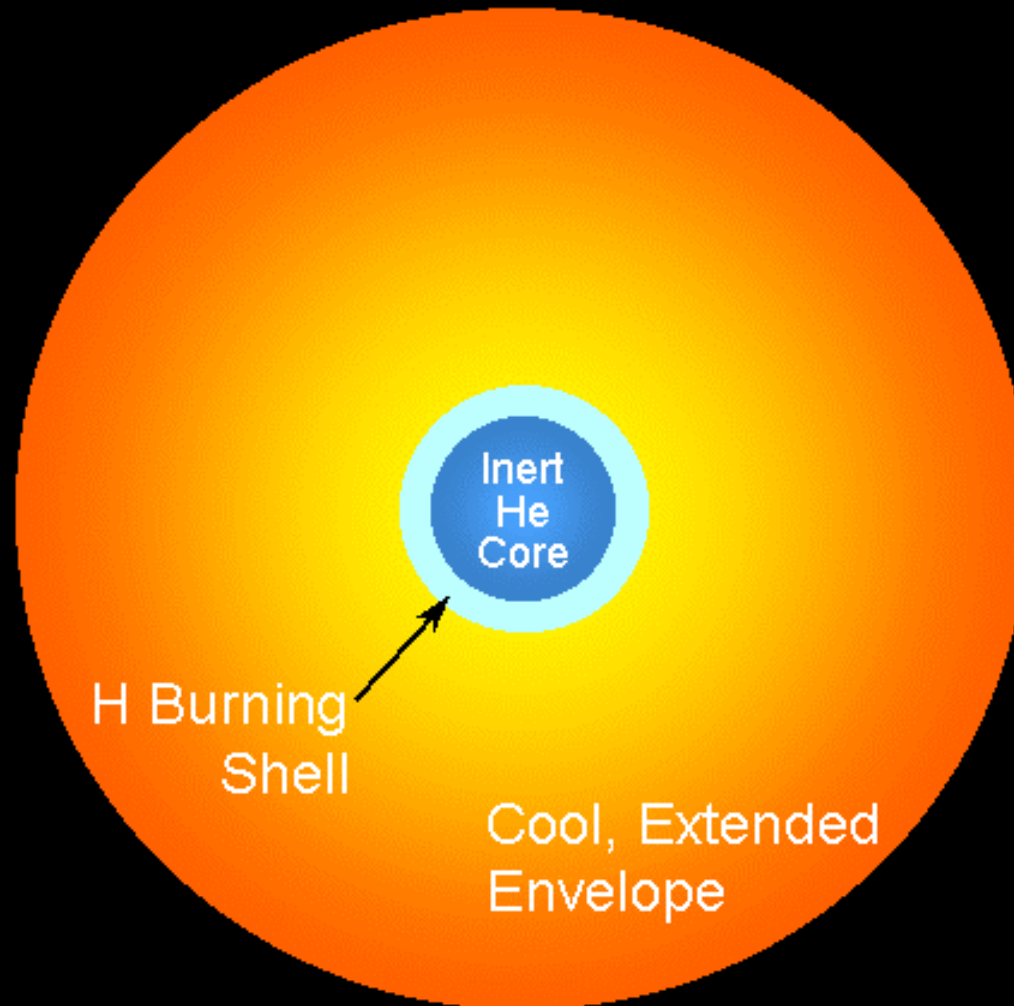
# Evolution (Aging) of a Star

- A star remains on the **main sequence** as long as it is **burning hydrogen** (converting it to helium) in its center or **core**; A main sequence star is also called a **dwarf**
- The time spent by a star on the main sequence (i.e., the time it takes to finish burning hydrogen in its core) depends on its **mass**
- Stars like the Sun have main sequence lifetimes of several billion years; **Less massive** stars — **longer lifetimes**; **more massive** stars — **shorter lifetimes** (as short as a few million years)
- A given star **spends most of its lifetime on the main sequence** (main sequence lifetime  $\sim$  total lifetime); Very rapid evolution beyond main sequence

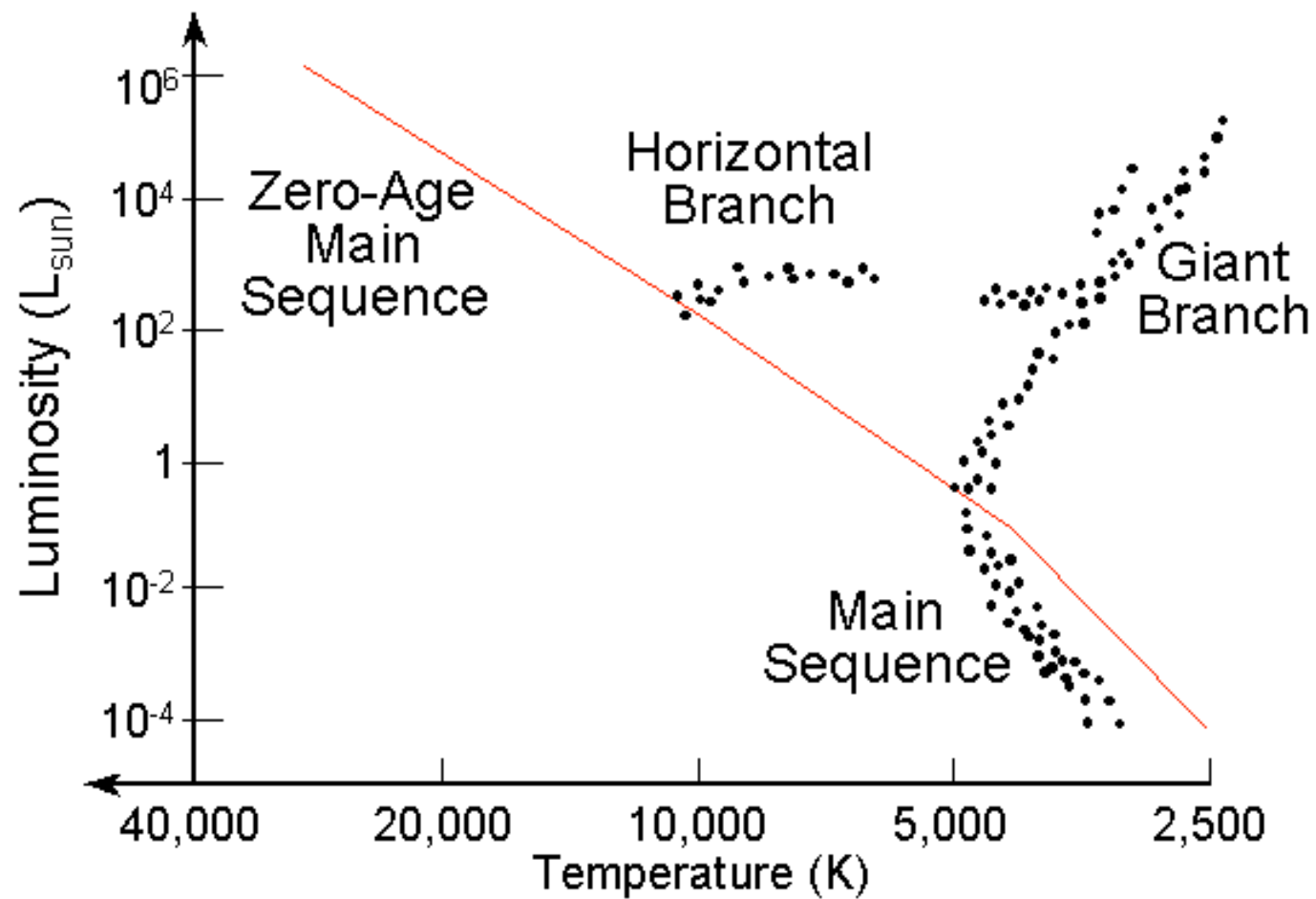
# Evolution on the HR Diagram

- Luminosity classes in an HR diagram (I through V) are based on the evolutionary phase of a star — whether it is a dwarf, subgiant, giant, or supergiant
- **Main sequence** → **Subgiant/Red giant**: From burning hydrogen in the core to burning hydrogen in a shell that surrounds an inert (i.e., non-burning) helium core
- **Red giant** → **Horizontal Branch**: Helium ignition (or helium flash) occurs at the tip of the red giant branch, after which the star burns helium in its core
- Subsequent thermal pulses are associated with the burning of successively heavier elements (carbon, oxygen, etc.)

# Red Giant Star



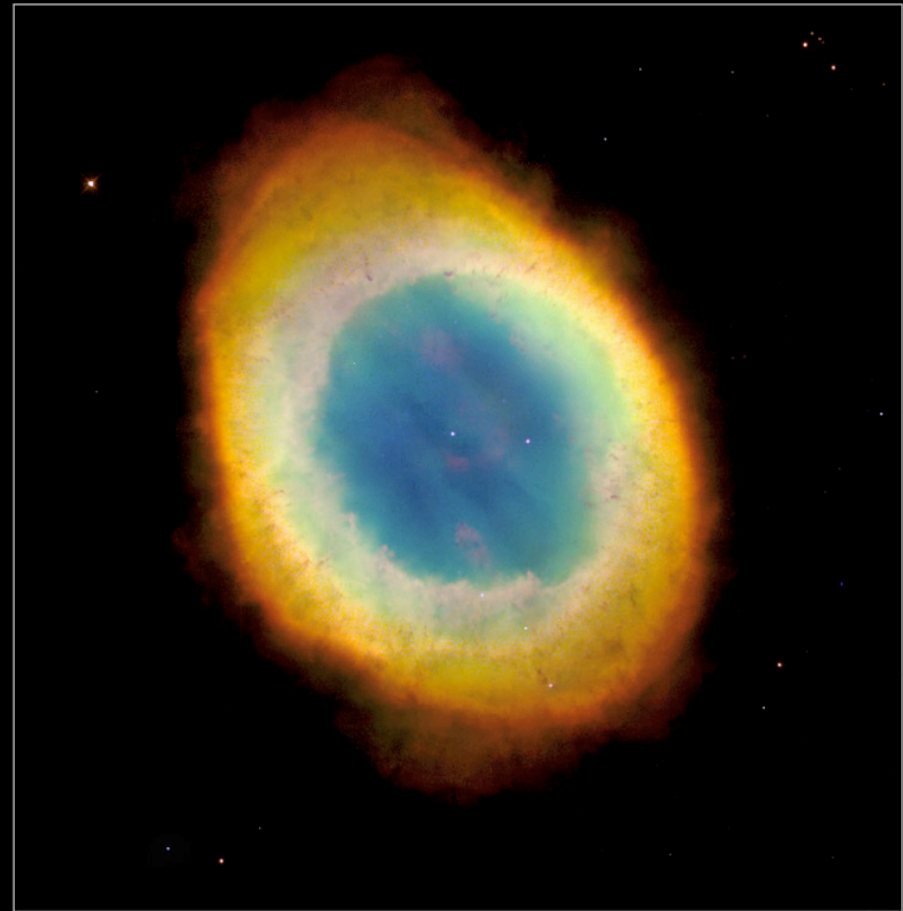
## Typical Globular Cluster H-R Diagram



# Planetary Nebulae

- The loosely bound outer material is ejected by **radiation pressure** driving a **superwind**
- This is known as the **planetary nebula** phase of a star (actually, this phase has **nothing** to do with planet formation!)

Ring Nebula



Hubble  
Heritage