Announcements

- Homework #5 is due on Tuesday, Oct. 4.
- Facebook page “UIowa 29:50 Fall 2011” and facebook group “UI 29:50 Fall 2011” now exist.
- I will try to update status on the page.
- Joining the group would allow you to meet each other via facebook.

By what factor would the observed brightness of a star change if an observer moved from 1 parsec away from the star to 10 parsecs away from the star?

A) Increase by a factor of 100
B) Increase by a factor of 10
C) Stay the same
D) Decrease by a factor of 10
E) Decrease by a factor of 100

Star A has three times the radius and one third the temperature of star B.

A) Star A has 1/81 the luminosity of star B.
B) Star A has 1/9 the luminosity of star B.
C) Star A has the same luminosity of star B.
D) Star A has 9 the luminosity of star B.
E) Star A has 81 the luminosity of star B.

A star has 4 times the mass and 128 times the luminosity of the Sun. The star's lifetime will be _____ times that of Sun.

A) 32

B) 4

C) 1

D) ¼

E) 1/32

Star Formation

The stuff between the stars

Nebulae

Giant molecular clouds

Collapse of clouds

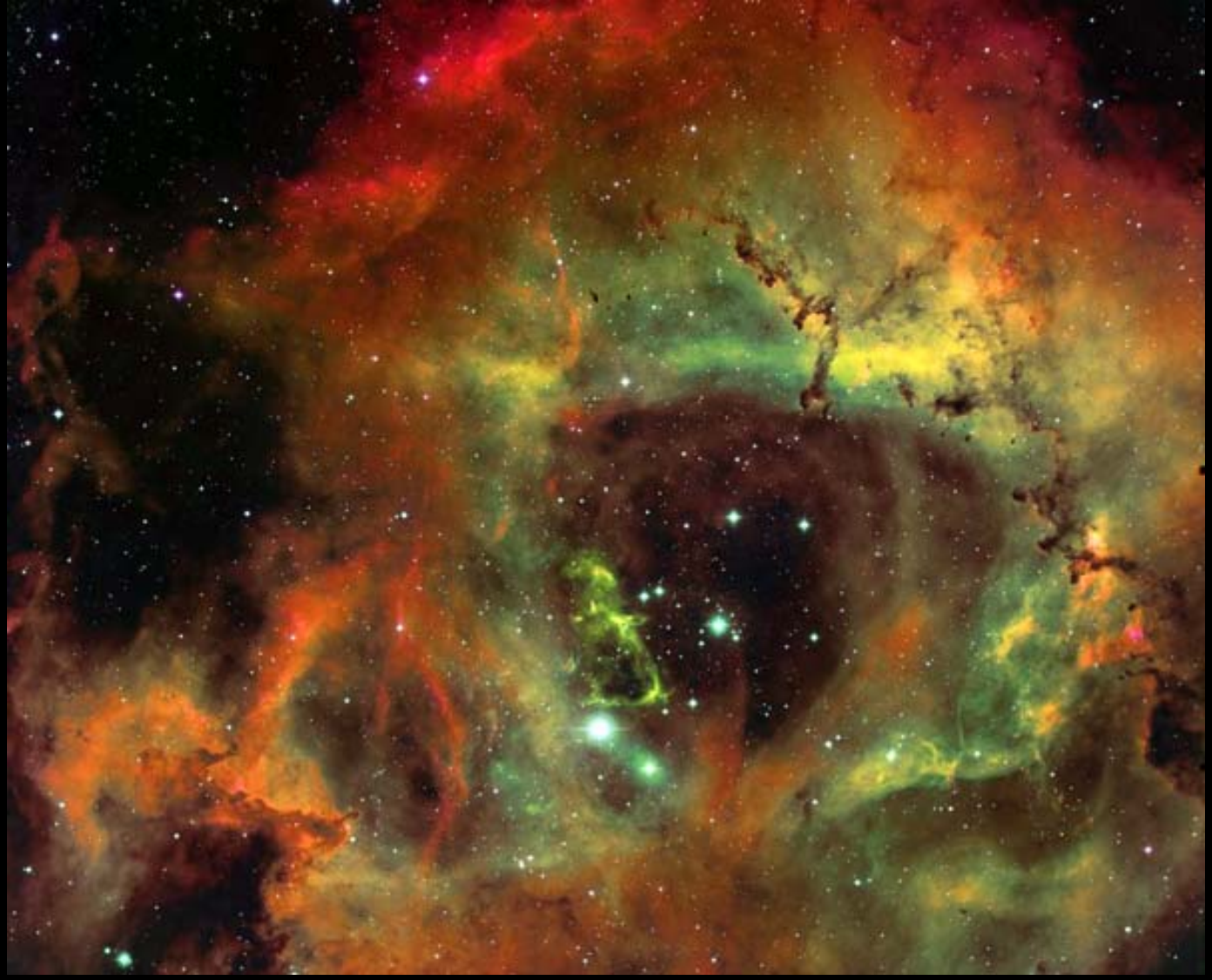
Protostars

Interstellar medium

- Space between the stars within a galaxy is not empty.
- The **interstellar medium** (ISM) consists of gas and dust.
- Gas is mainly hydrogen, but also contains other elements and molecules.
- Density is typically around 1 atom per cubic centimeter.

Clouds and nebula

- The interstellar medium is not uniform, but varies by large factors in density and temperature.
- The clumps in the interstellar medium are clouds or nebulae (one nebula, two nebulae).
- There are three types of nebulae
  - Emission nebulae
  - Reflection nebulae
  - Dark nebulae



Emission nebulae emit their own light because luminous ultraviolet stars (spectral type O,B) ionize gas in the nebula. The gas then emits light as the electrons return to lower energy levels. In this image Red = Hydrogen, Green = Oxygen, Blue = Sulfur.

Reflection nebulae do not emit their own light. Dust scatters and reflects light from nearby stars.

Dark nebula are so opaque that the dust grains block any starlight from the far side from getting through.

How nebula emit/absorb light

- Emission lines: photons strike atoms and excite electrons to higher energy levels, the atoms then produce emission lines as the electrons return to lower energy levels.
- Reflection: photons bounce off dust, there is no change in the photon energy. Usually some fraction of the photon get absorbed.
- Absorption: photons are absorbed by atoms and/or dust.

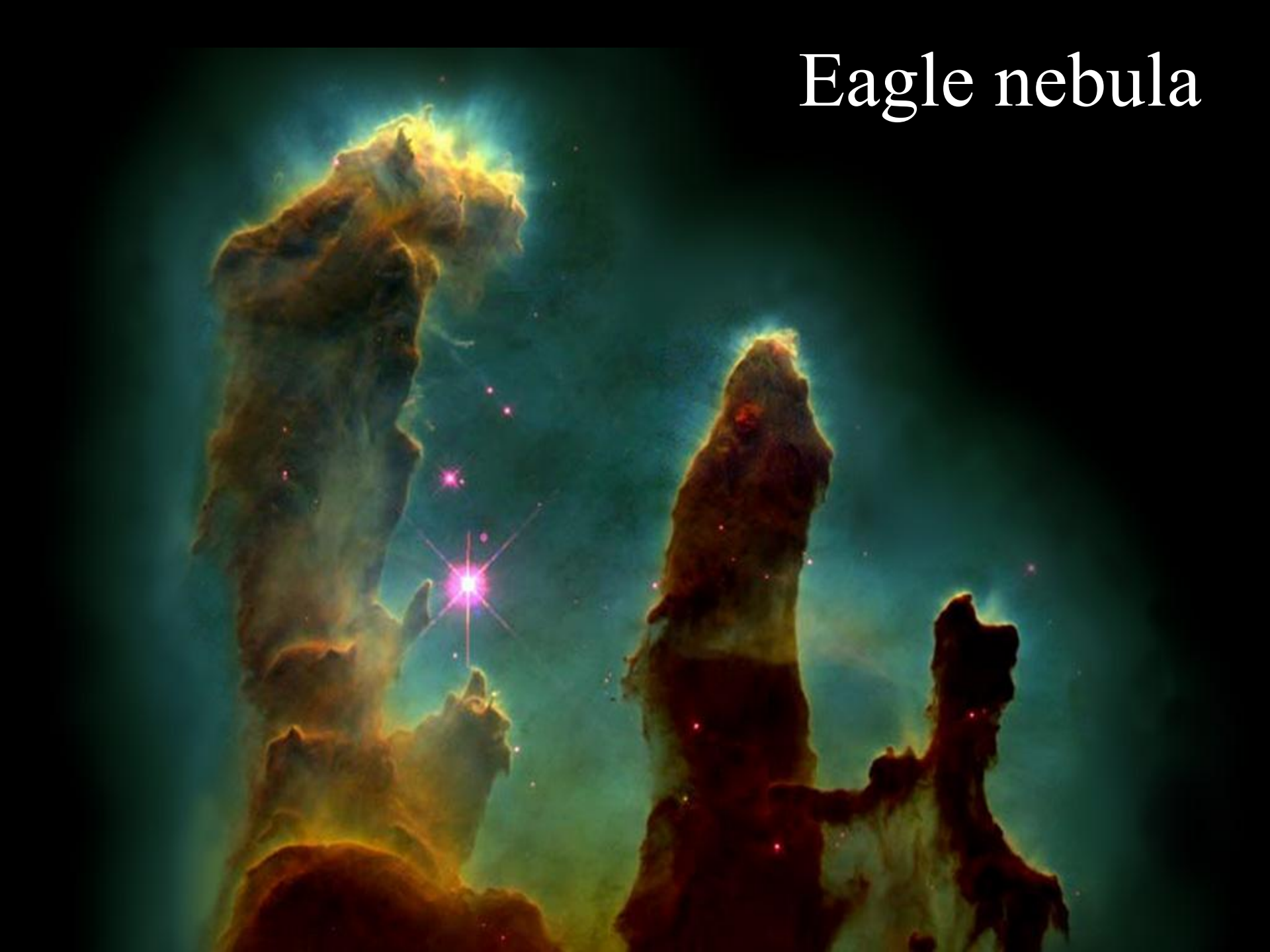
Reflection nebulae emit light as a result of

A) Ultraviolet radiation from O and B stars
B) Nuclear fusion
C) Dust scattering light from stars
D) Ionized gas

Molecular clouds

- Dark nebula are usually molecular clouds
- Molecular clouds are relatively dense and are very cold, often only 10 K.
- Giant molecular clouds can contain as much as 10^4 solar masses of gas and be 10 light years across.
- Molecular clouds are the primary sites for star formation.

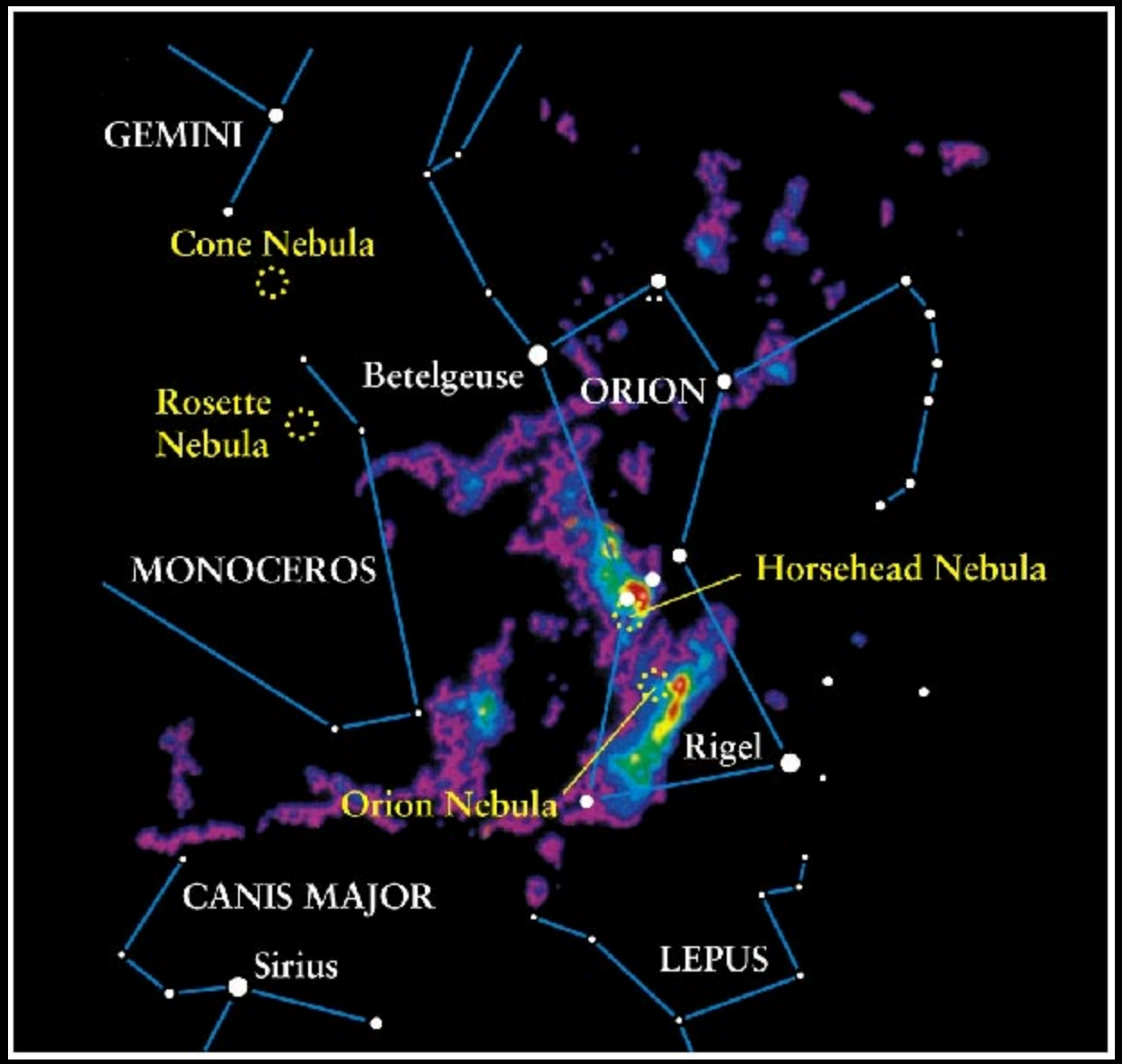
Eagle nebula



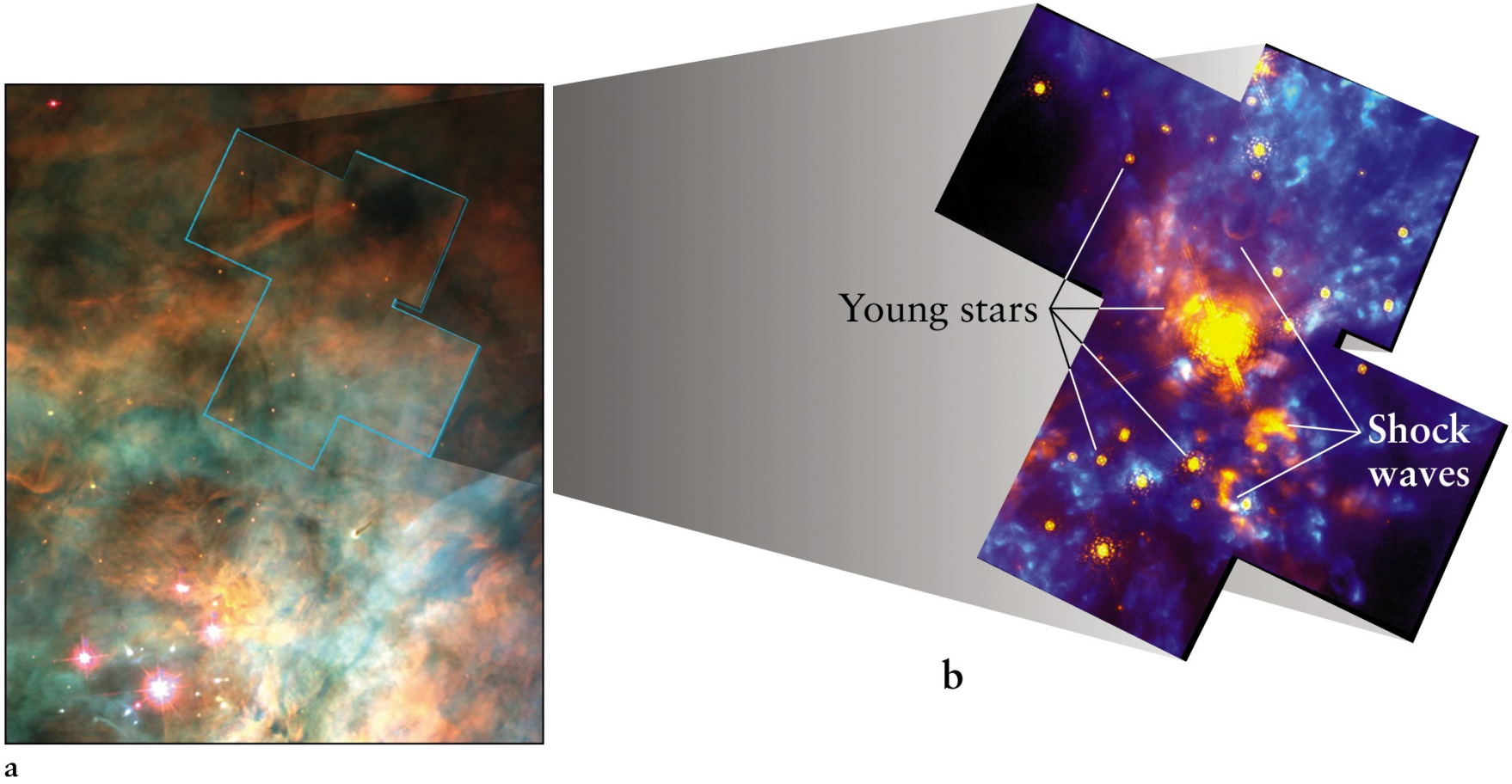
Eagle nebula in infrared

Star birth can begin in giant molecular clouds

Carbon monoxide map



Protostars form in cold, dark nebulae



Visible (left) and infrared (right) views of the Orion nebula show new stars. These new stars can only been seen in infrared because the protostar's cocoon nebula absorbs most of the visible light.

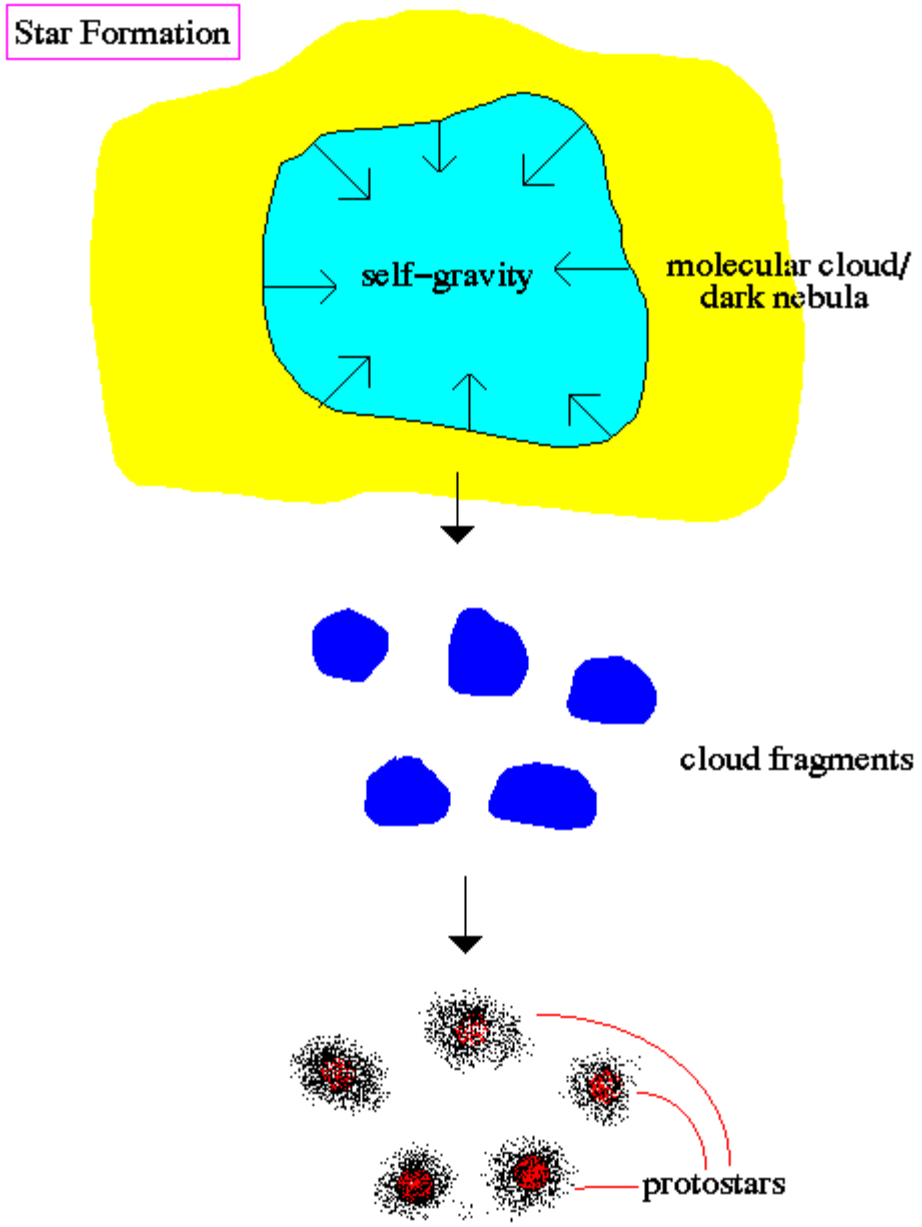
So, stars form in molecular clouds

But how?

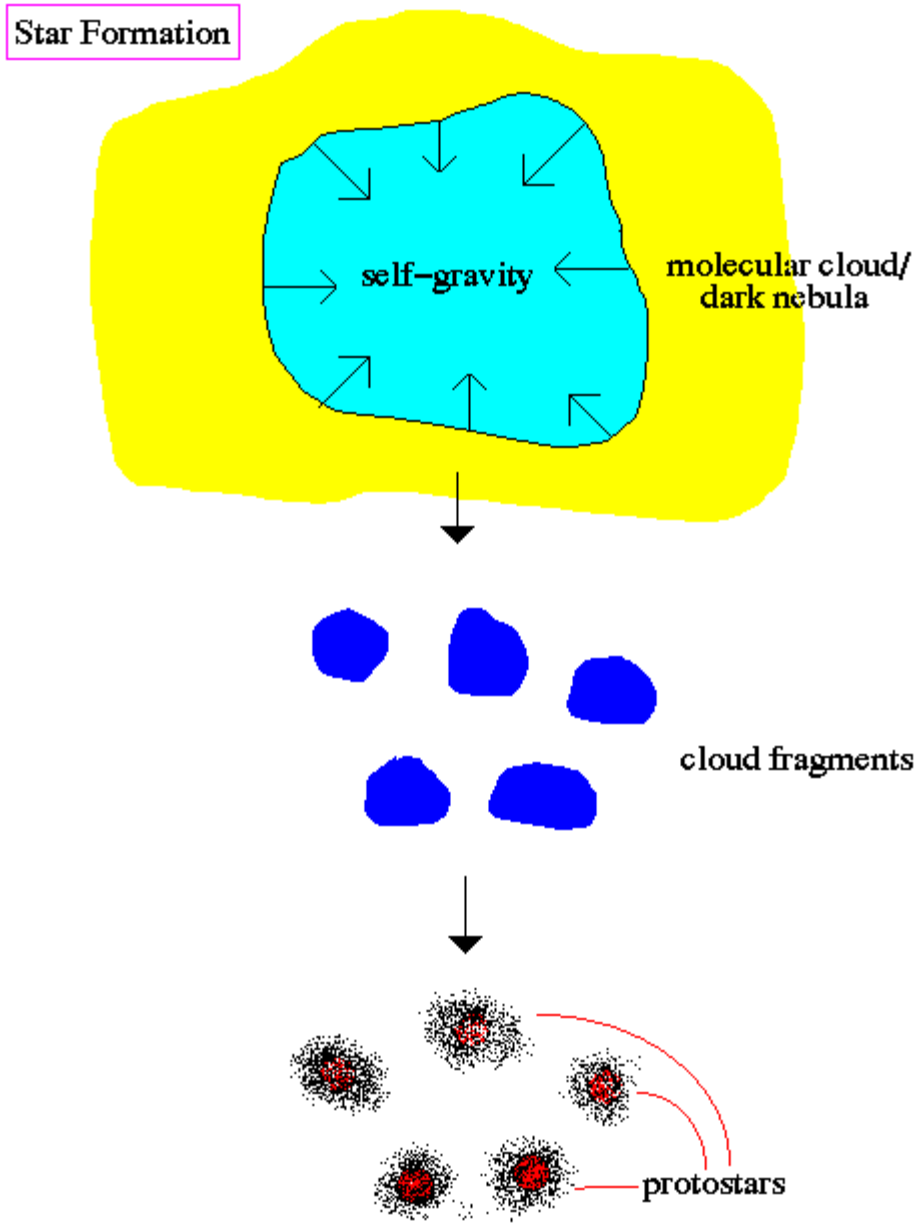
Show animation

Protostars form by collapse of molecular clouds

- Clouds must form **dense** and **cold** clumps or <u>cores</u> to collapse
- Gravity of the core causes it to start to collapse and also pull in more gas

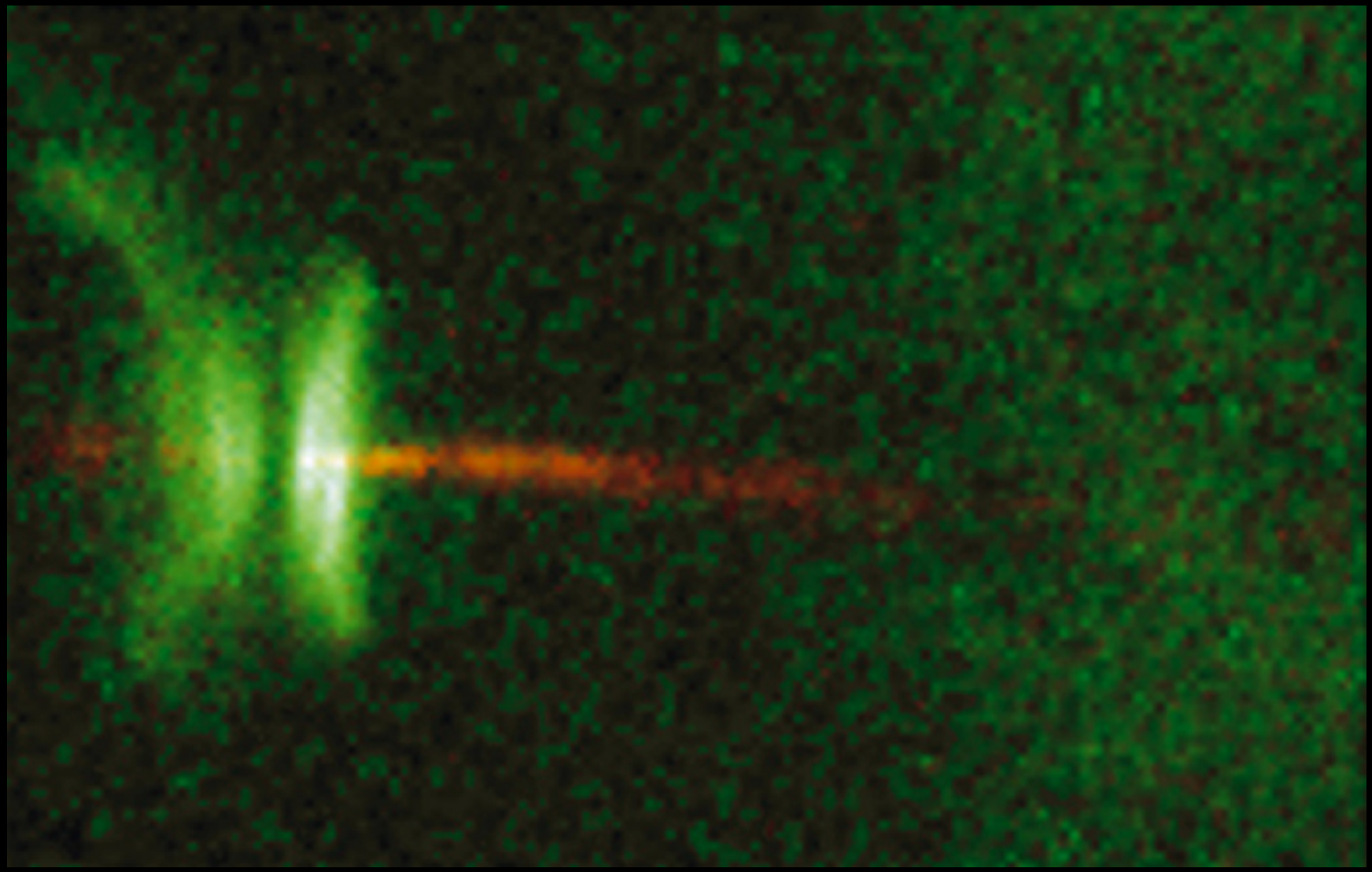


- As the gas/dust falls in, it picks up speed and energy. It is slowed by friction and the energy is converted to heat.
- As long as the protostar is transparent, the heat can be radiated away.
- When the protostar becomes so dense it is opaque, then the heat stars to build up, the pressure increases, and the rapid collapse slows.



- Gas in the cloud keeps falling onto the protostar.
- The collapsing gas tends to start rotating around the protostar as it falls in forming a disk and a jet.
- Eventually, the protostar develops a wind, like the solar wind but much stronger. This out flowing wind stops the in falling matter.
- The protostar keeps contracting under it own gravity. The protostar is powered by gravity via contraction - not by fusion.
- The protostar becomes a star when it has contracted so much that it is dense and hot enough to begin nuclear fusion.

Disk and jet of a protostar



Watch for:

- Collapse of cloud
- Rotation of cloud
- Formation of disk near protostar

Show animation again

The core of a proto-star remains relatively cool until which of the following happens?

A) The protostar becomes opaque.

B) Nuclear reactions begin in the core.

C) The chemical composition of the star changes.

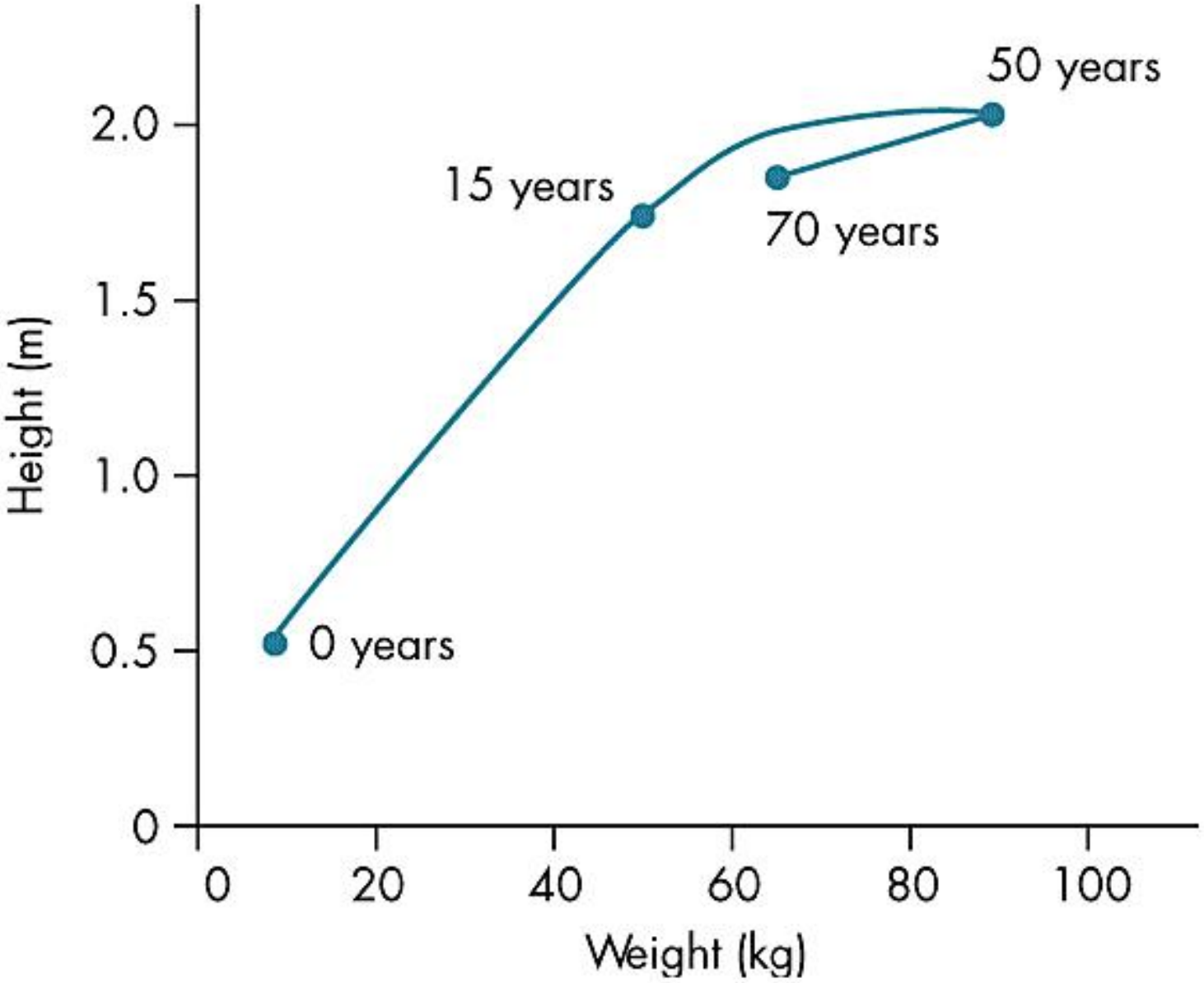
D) The protostar's rotation slows down.

Evolution of stars

Stars change over their lifetimes (from formation to death).

We can track these changes via motion of the star in the HR diagram.

HW diagram for people



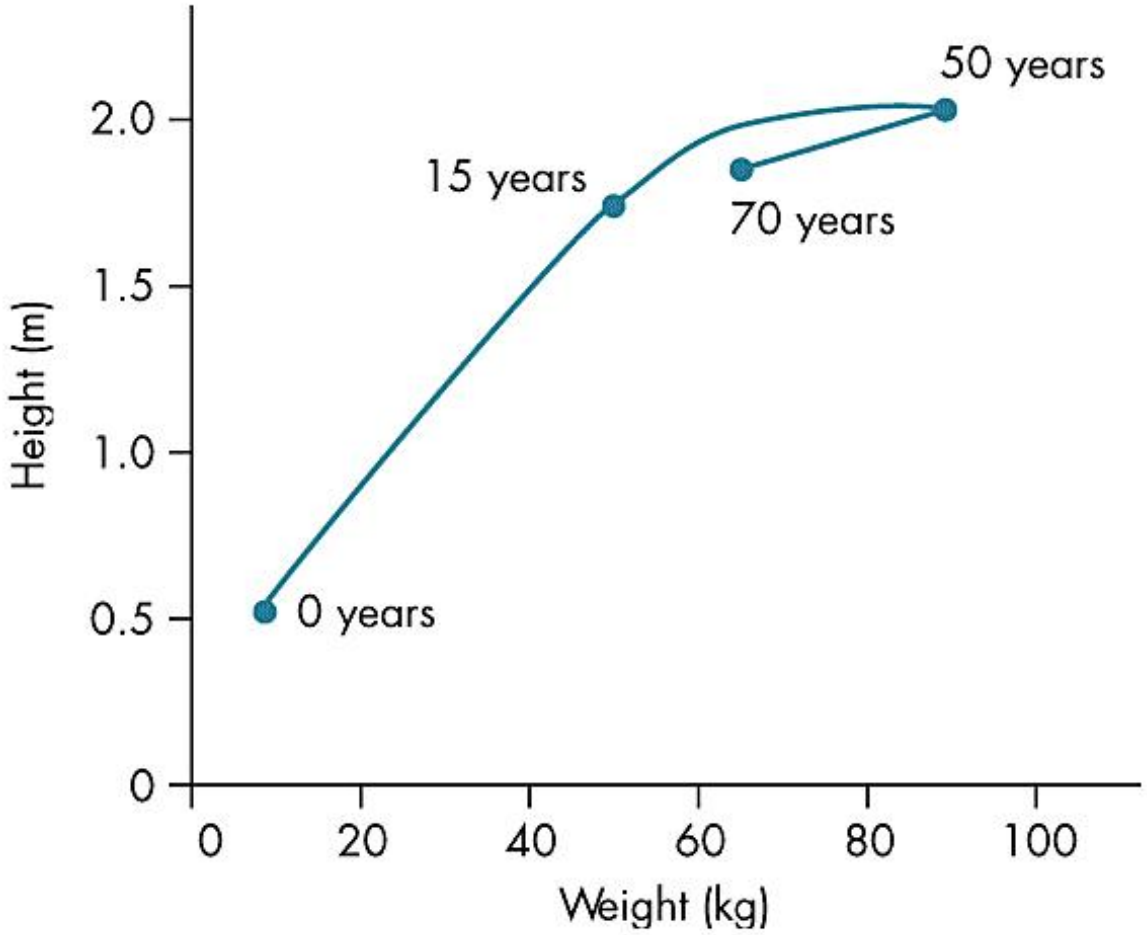
The Height-Weight diagram was for one person who we followed over their entire life.

How could we study the height-weight evolution of people if we had to acquire all of the data from people living right now (no questions about the past)?

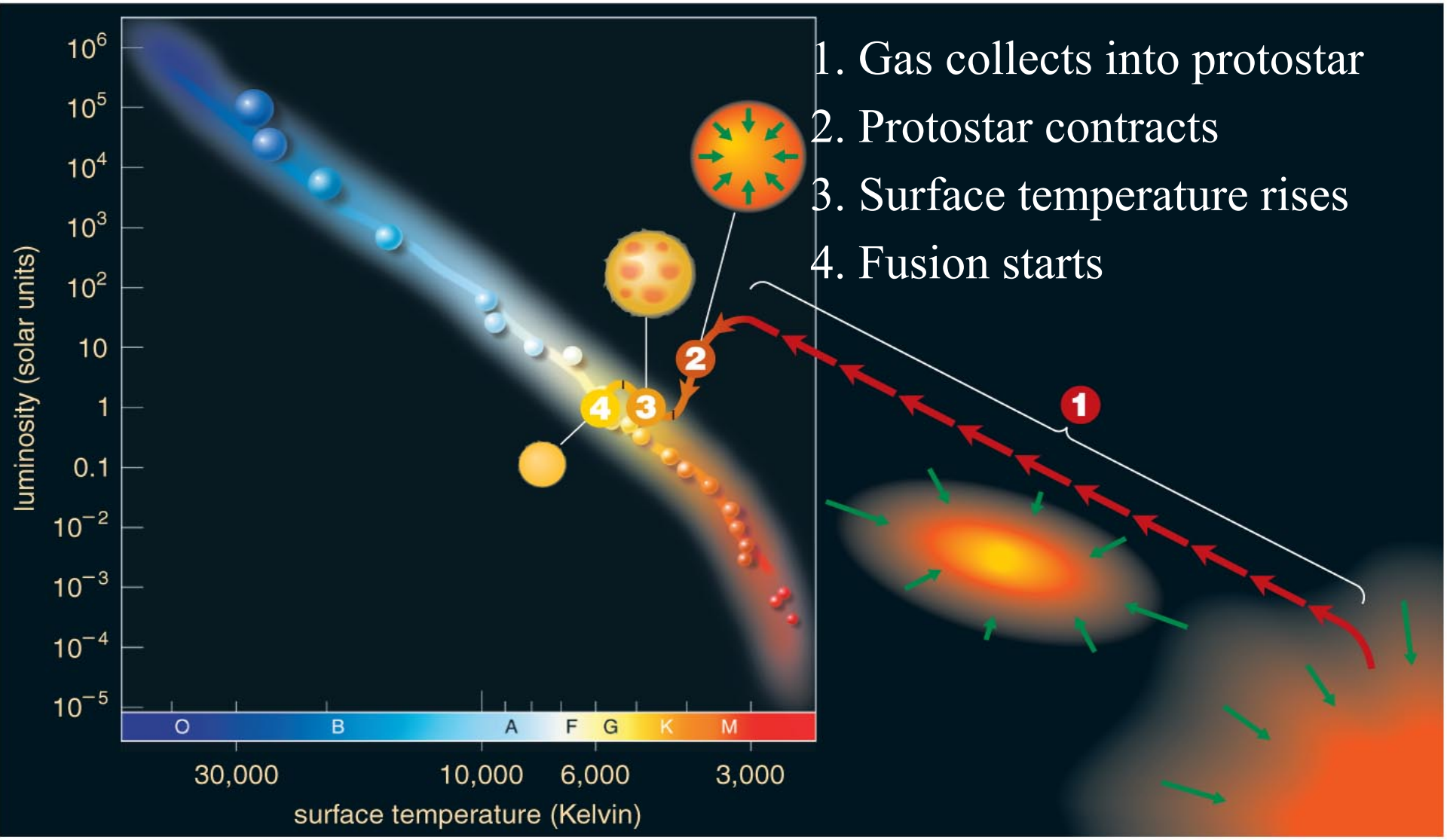
- We could fill in a single HW diagram using lots of different people. We should see a similar path.
- We can also estimate how long people spend on particular parts of the path by how many people we find on each part of the path.

Thinking about the population of the US, which part of the HW diagram is the most sparsely populated?

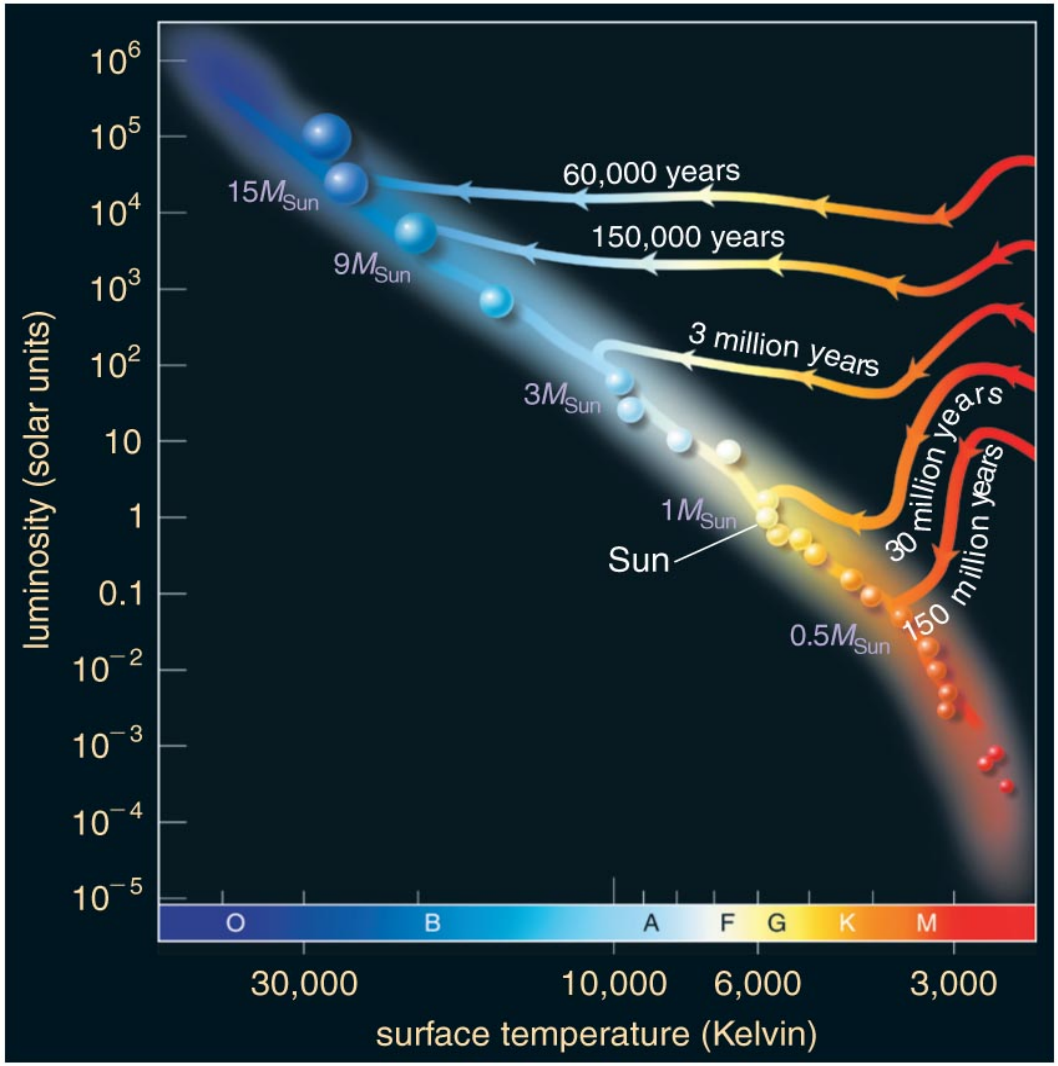
A) 0-15 years
B) 30-50 years
C) 50-70 years
D) Alaska



Star formation on HR diagram



Tracks for Different Masses



Models show that Sun required about 30 million years to go from protostar to main sequence

Higher-mass stars form faster

Lower-mass stars form more slowly

Review Questions

What is the interstellar medium?

What are reflection, emission, and dark nebulae?

Where do protostars form?

How is a protostar heated?

When does a protostar become a star?

How does a protostar move on the HR diagram?