

Star Formation

The stuff between the stars

Nebulae

Giant molecular clouds

Collapse of clouds

Protostars

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) $\frac{1}{4}$

E) $\frac{1}{32}$

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.





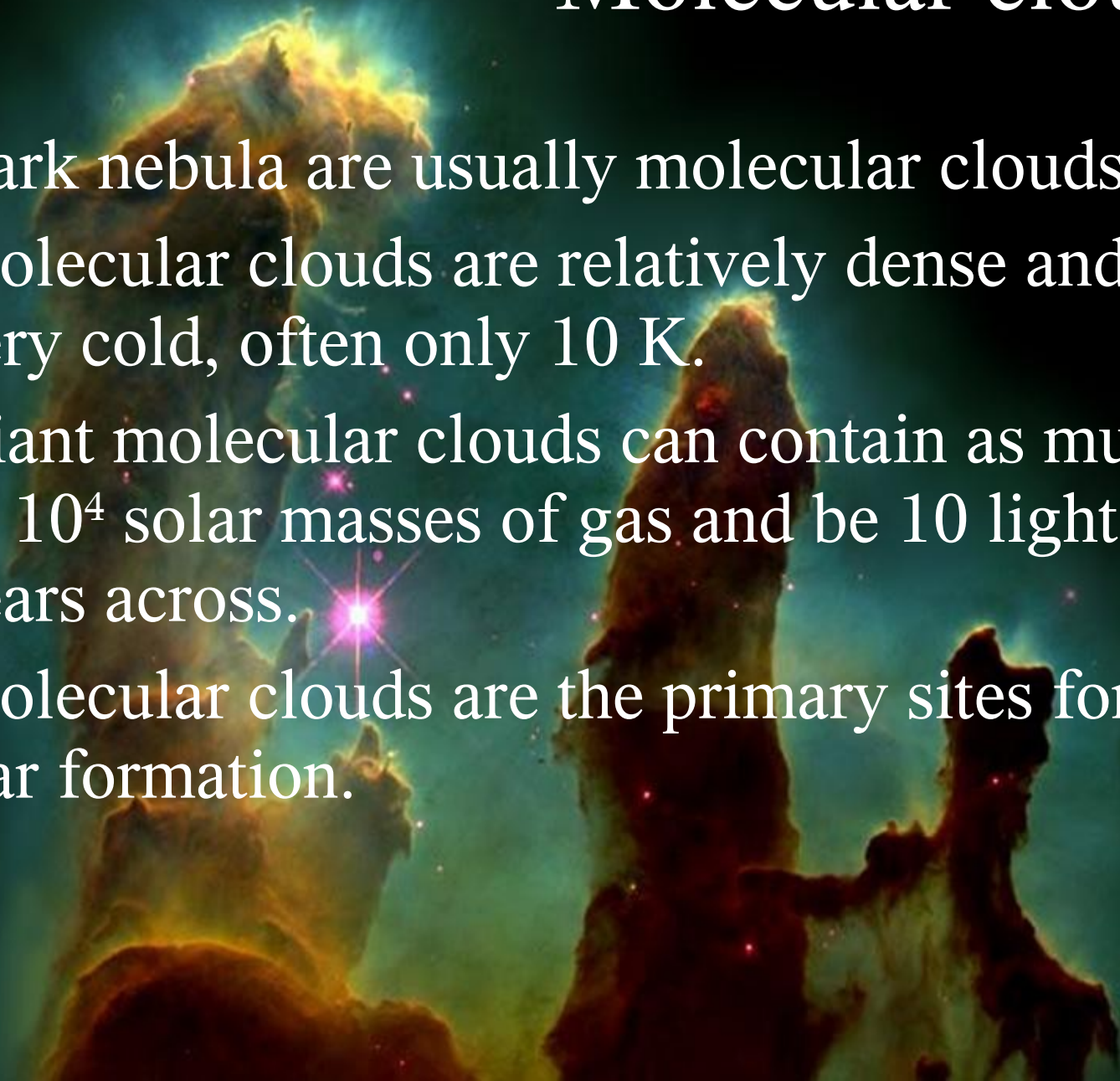
Dark nebula
are so opaque
that the dust
grains block
any starlight
from the far
side from
getting
through.

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

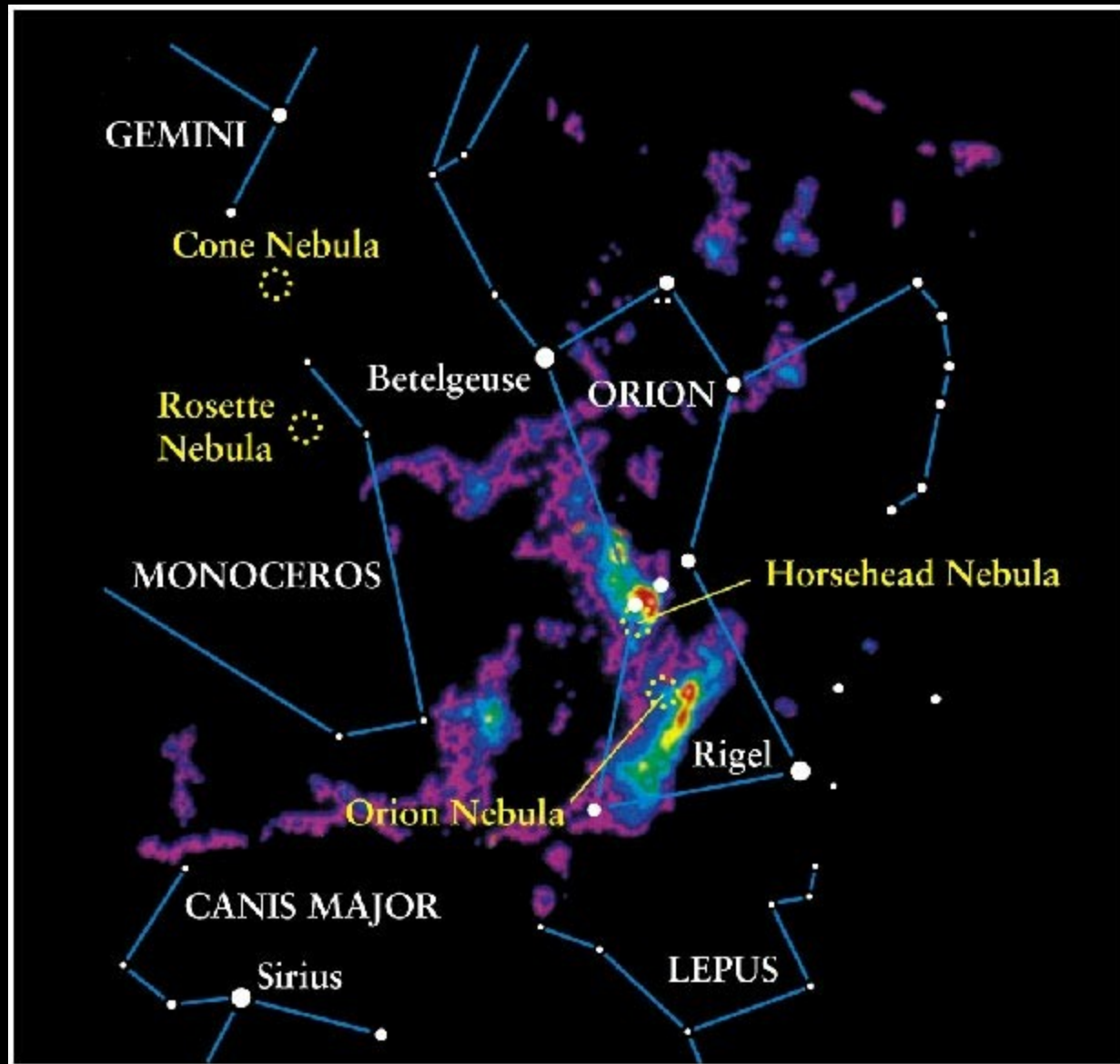


Eagle nebula
in infrared

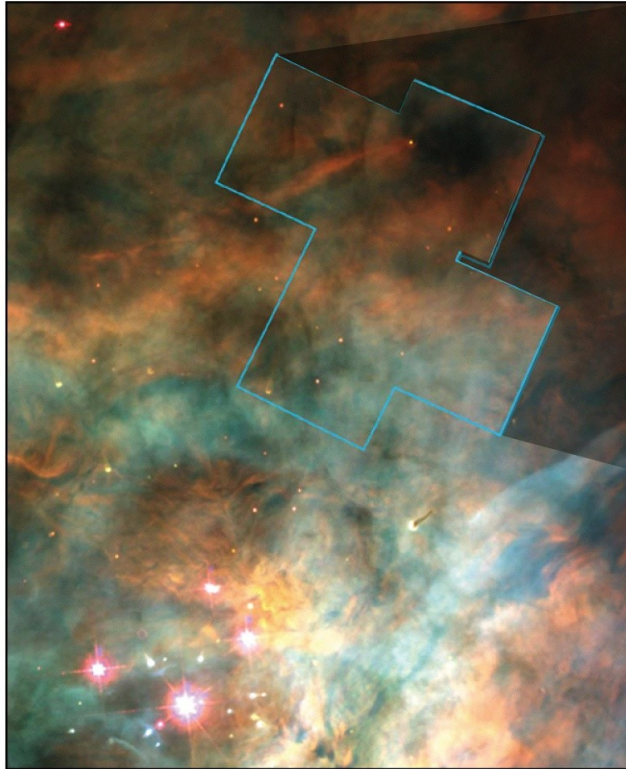


Star birth can begin in giant molecular clouds

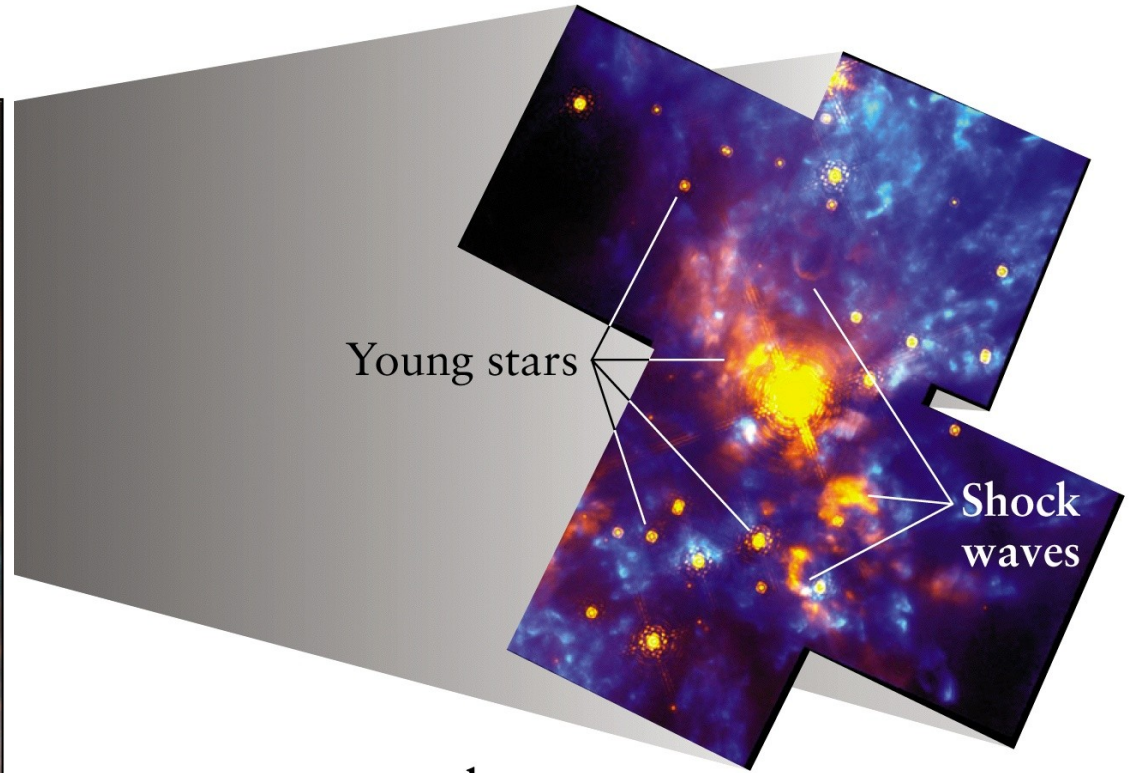
Carbon
monoxide
map



Protostars form in cold, dark nebulae



a



b

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

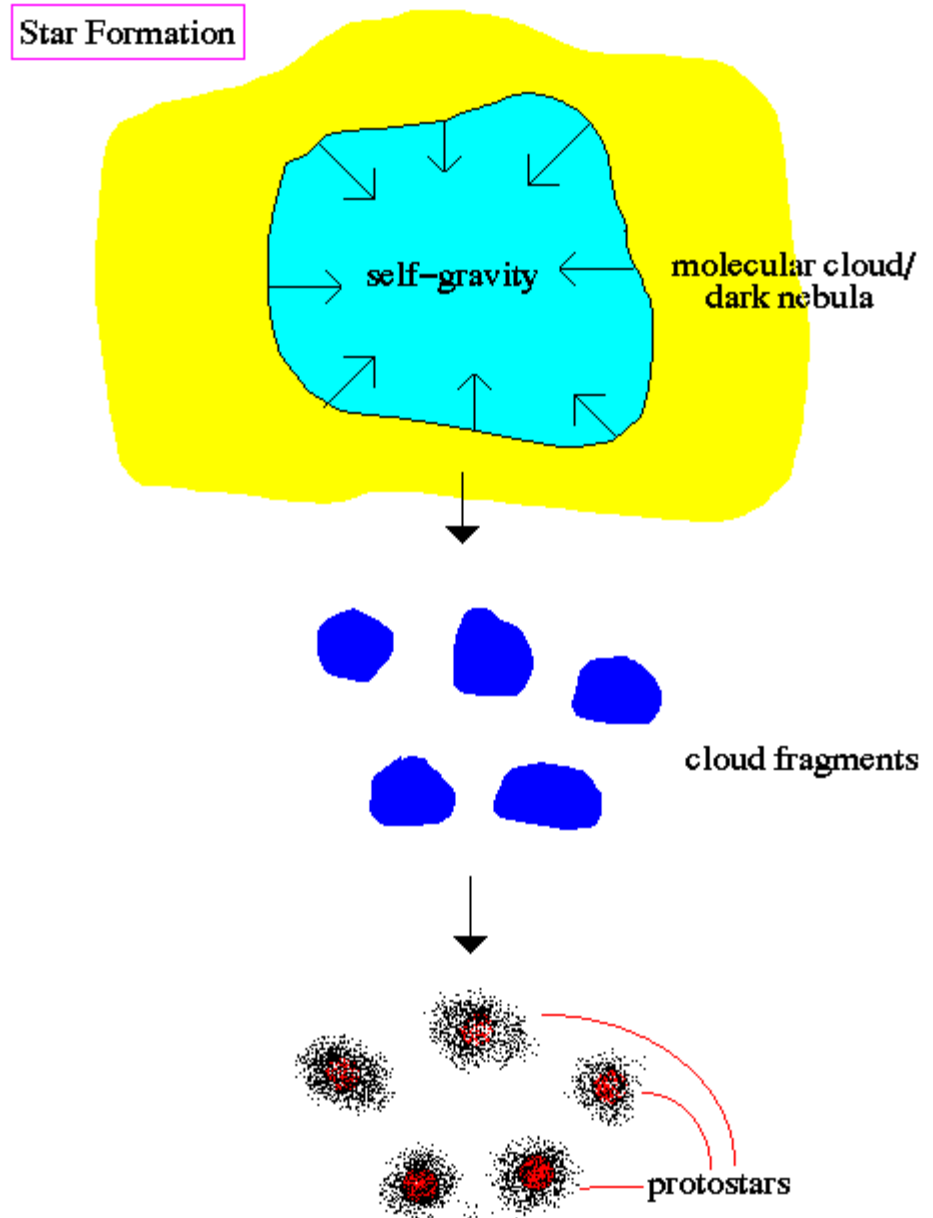
So, stars form in molecular clouds

But how?

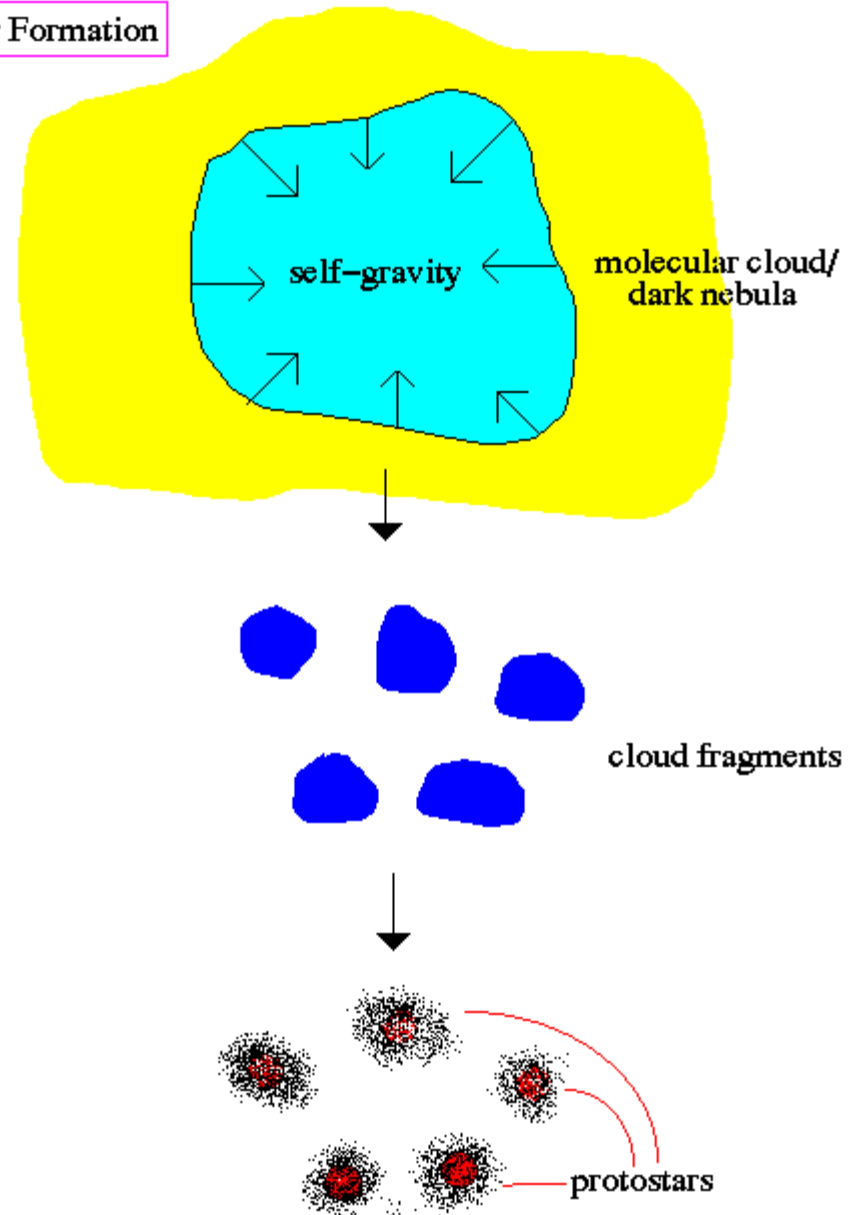
Show [animation](#)

Protostars form by collapse of molecular clouds

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



Star Formation

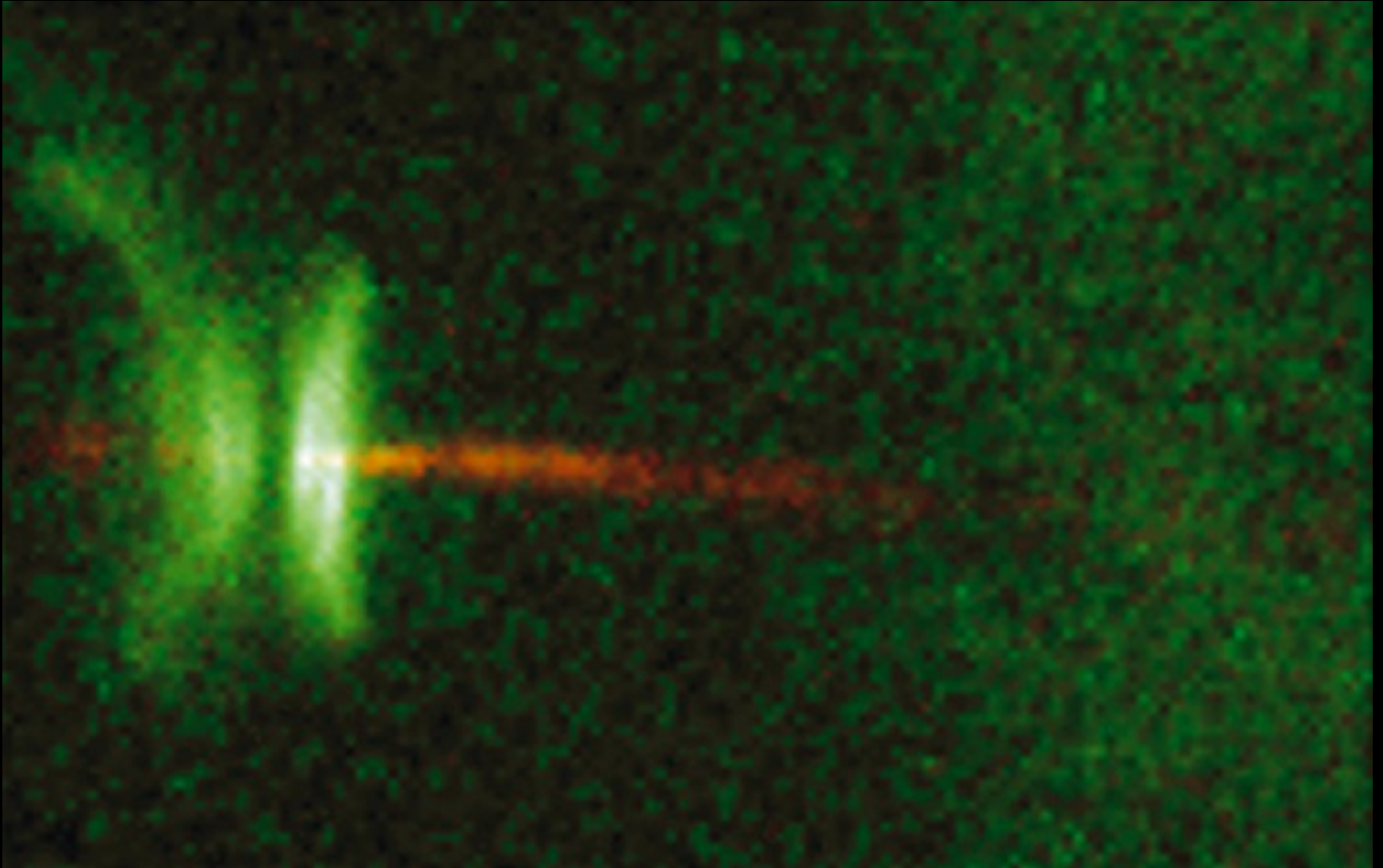


- As the gas/dust falls in, it picks up speed and energy. It is slowed by friction and the energy is converted to heat.
- As long as the protostar is transparent, the heat can be radiated away.
- When the protostar becomes so dense it is opaque, then the heat starts to build up, the pressure increases,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

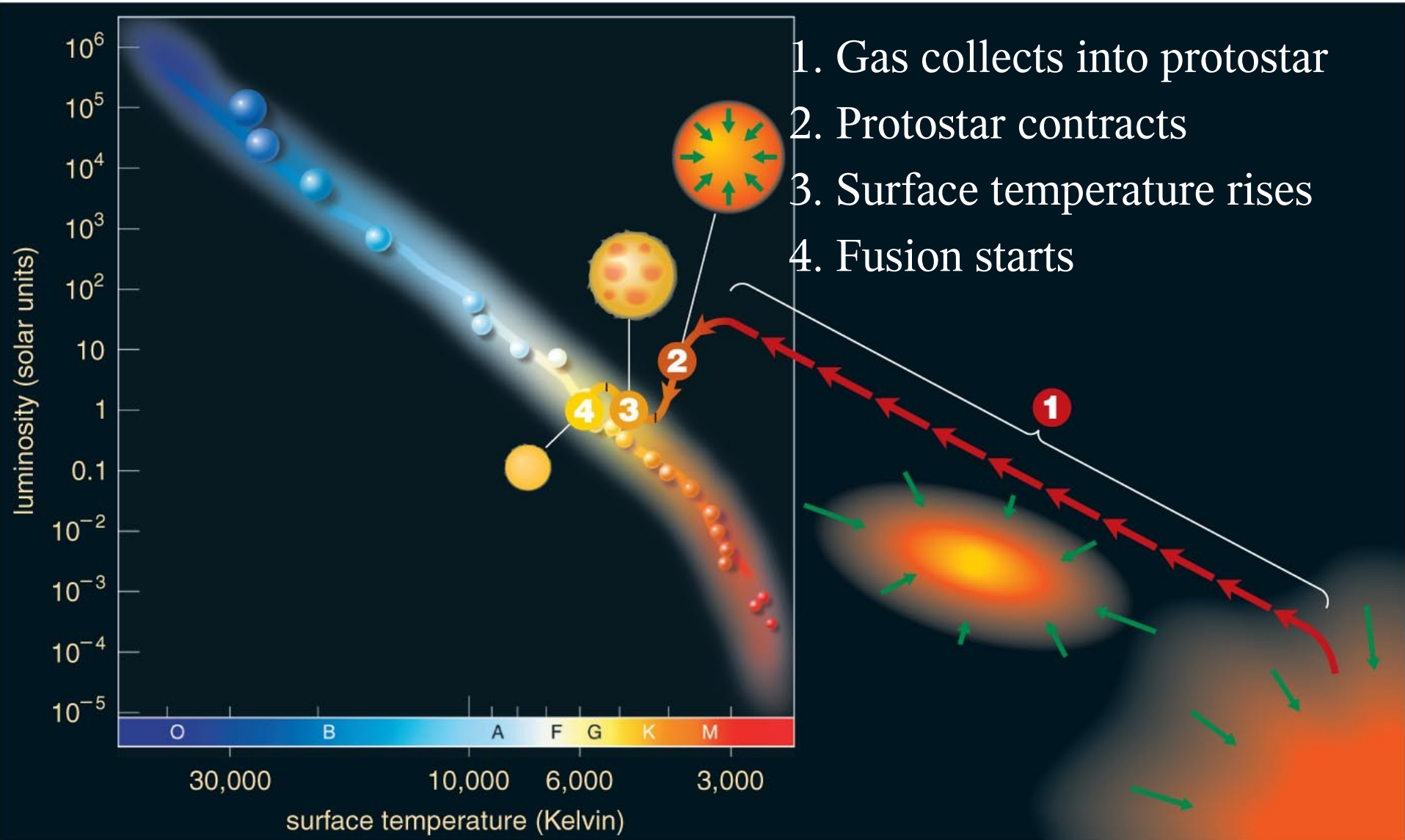
Formation of disk near protostar

Show animation again

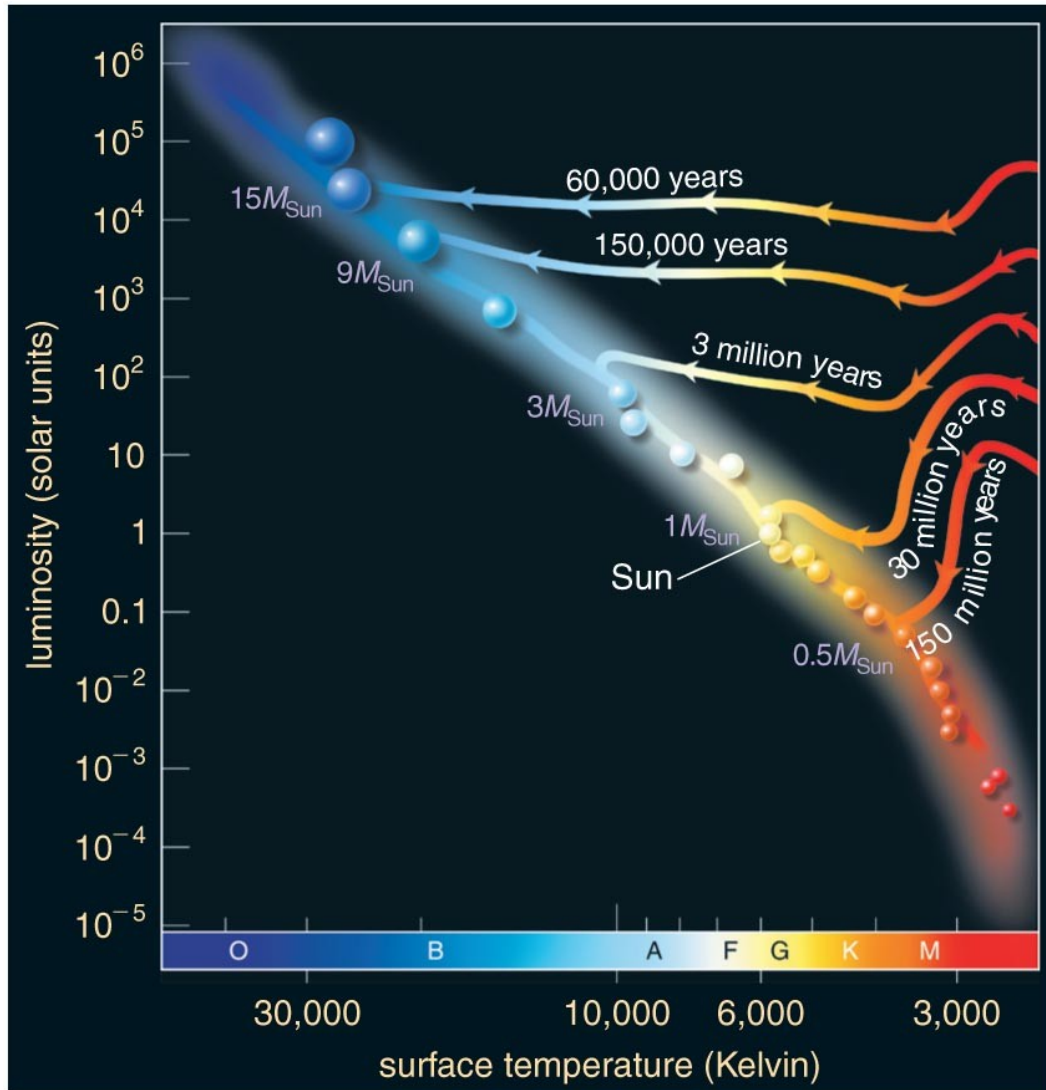
The core of a proto-star remains relatively cool until which of the following happens?

- 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.

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?