STAR FORMATION

BY -SAMARTH MISHRA

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).

Three types of nebulae:

- Emission nebulae
- Reflection nebulae
- Dark nebulae

Emission 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.

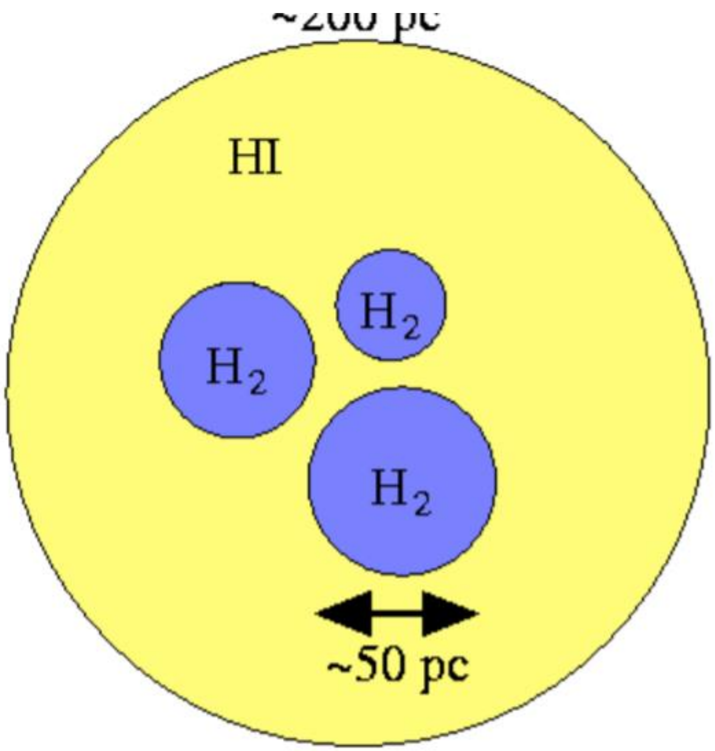
Dark nebula are so opaque that the dust grains block any starlight from the far side from getting through.

Giant Molecular Clouds

- Basic units of star formation
- Typical mass ~104 - 107 Msun, size ~100 pc, density ~100–300 cm-3 , temperature ~10–20 K
- ~1/4 of ISM mass in our Galaxy
- Usually far away -distance uncertainty
- Hard to study in high-z galaxies

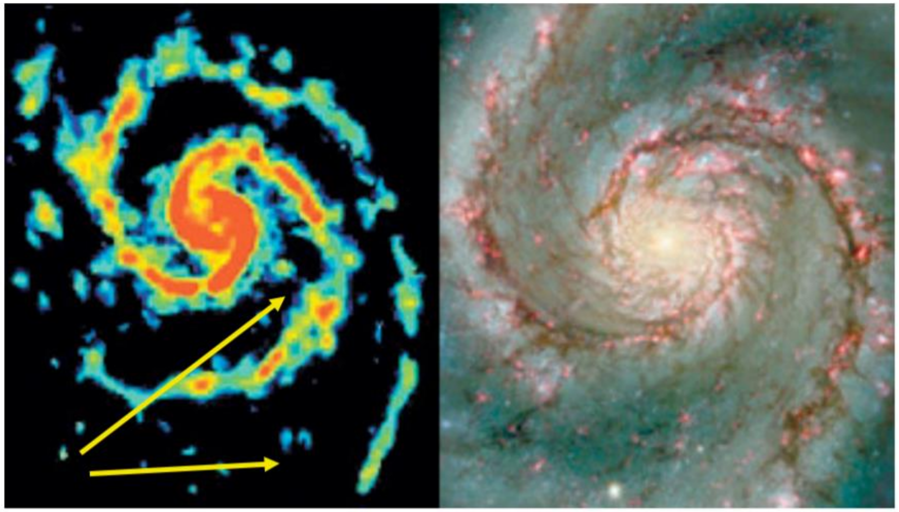
Anatomy of a GMC

- Atomic-molecular complexes
- H/H2 due to FUV-dissociation
- Lifetime ~ 20 – 50 Myr



GMC locations

- Some are along spiral arms.
- Some are far away.
- Star-formation efficiency: ~ 5–10 %

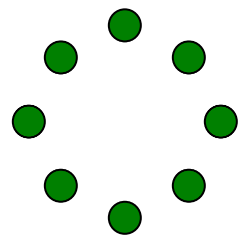


M51 seen in ^{12}CO (Koda et al.) and visible

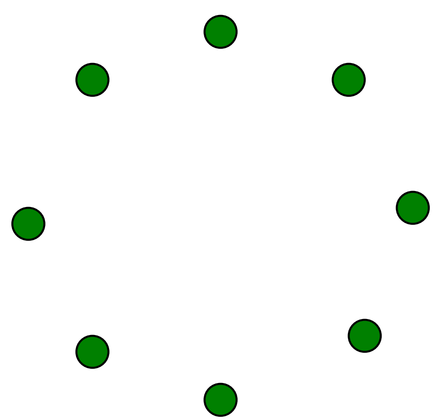
Gravitational collapse

Which configuration has more potential energy?

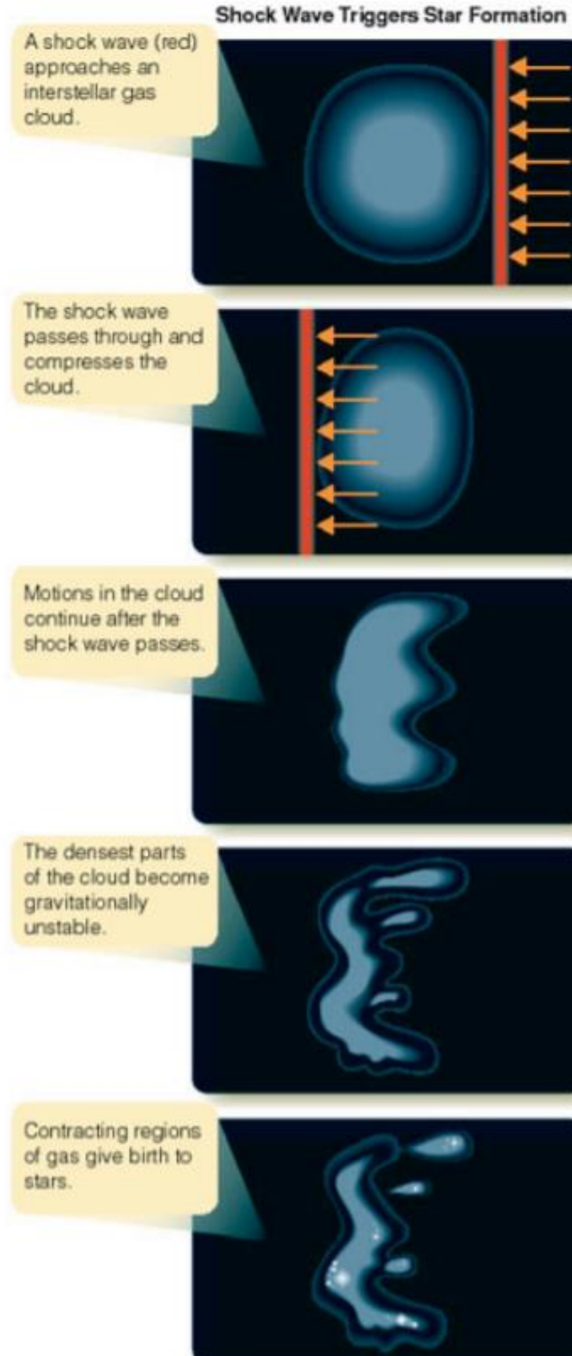
A



B



Supernova shocks trigger SF



Potential energy due to gravity

Sphere of mass *M* and radius *R*

$$U = -\frac{3}{5} G \frac{M^2}{R}$$

Gravitational potential energy is released as sphere shrinks

Sphere Gravitational Potential Energy

For a self-gravitating sphere of constant density ρ, mass M, and radius R, the potential energy is given by integrating the gravitational potential energy over all points in the sphere,

$$U = -\int_0^R \frac{G(\frac{4}{3}\pi\rho r^3)(4\pi r^2\rho\,dr)}{r} \quad (1)$$

$$= -\tfrac{16}{3}\pi^2 G\rho^2 \int_0^R r^4\,dr \quad (2)$$

$$= -\tfrac{16}{15}\pi^2\rho^2 G R^5, \quad (3)$$

where G is the gravitational constant, which can be expressed in terms of

$$M = \tfrac{4}{3}\pi R^3\rho \quad (4)$$

as

$$U = -\frac{3GM^2}{5R} \quad (5)$$

(Kittel *et al.* 1973, pp. 268-269).

Which clouds will collapse?

- Gravitational force causes objects to collapse.
- What keeps objects from collapsing?
- In the solar system, the motion of the planets keeps them from falling in to the Sun.
- In a gas, the random motions of the gas atoms can support the gas against gravity.

Energy of gas cloud

Gravitational potential energy:

Sphere of mass *M* and radius *R*

$$U = -\frac{3}{5} G \frac{M^2}{R}$$

Kinetic energy of *N* atoms

$$K = N \frac{3}{2} kT = \frac{M}{m_H} \frac{3}{2} kT$$

Energy of gas cloud

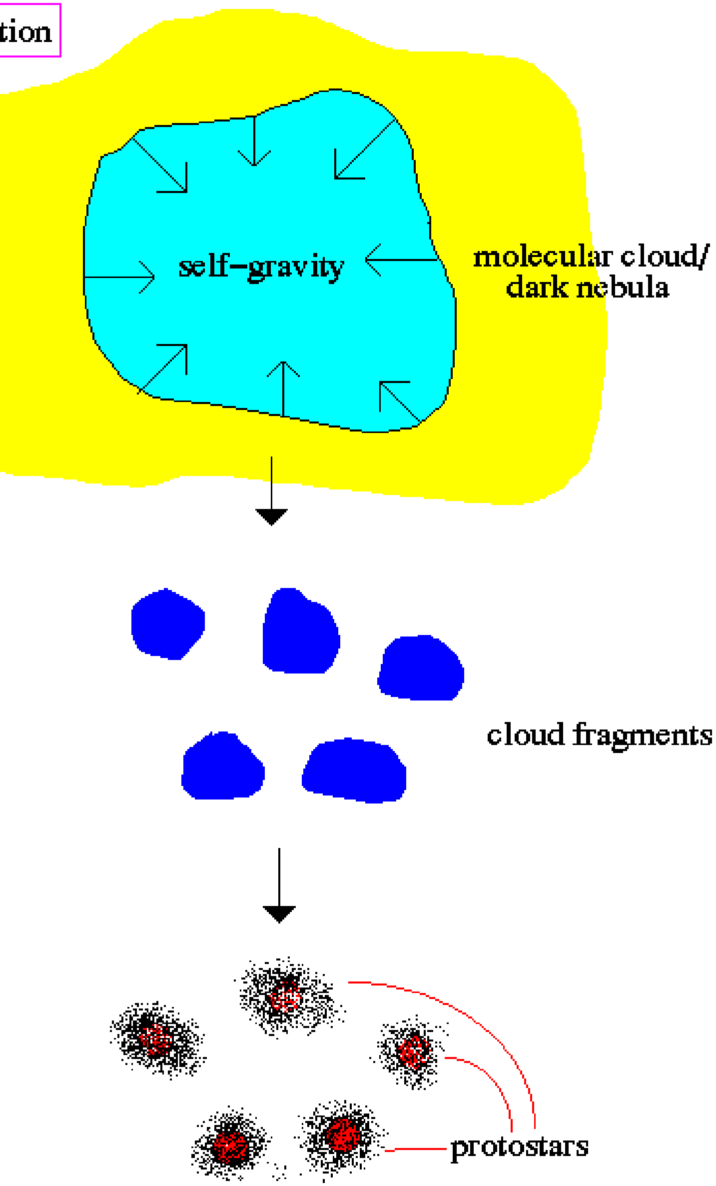
$$E = \frac{M}{m_H}\frac{3}{2}kT - \frac{3}{5}G\frac{M^2}{R}$$

If $E < 0$ then gas cloud collapses

If $E > 0$ then gas cloud can support itself

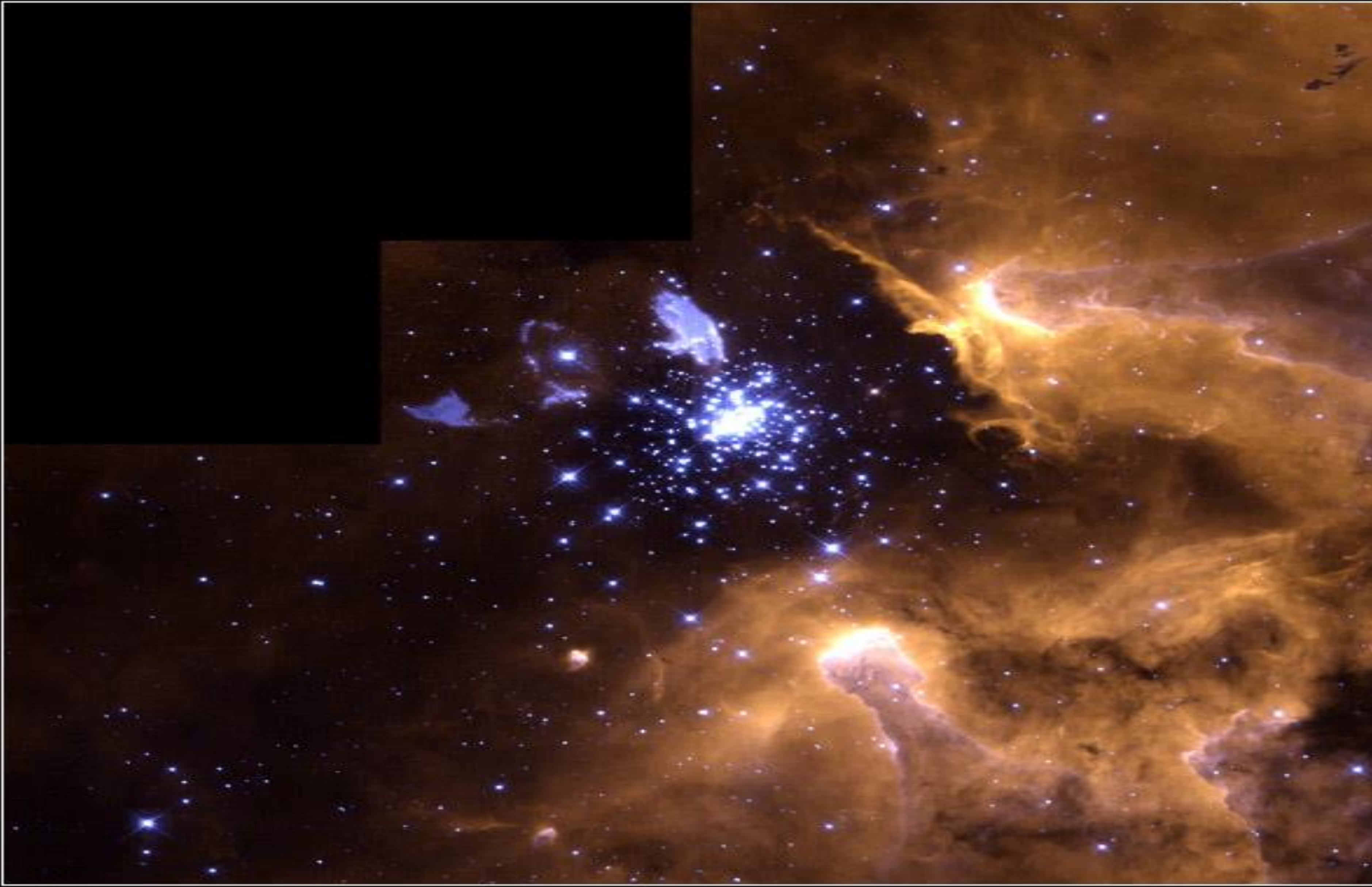
Density of gas cloud is n

$$M = \tfrac{4}{3}\pi R^3 n \cdot m_H$$



Protostars form by collapse of molecular clouds

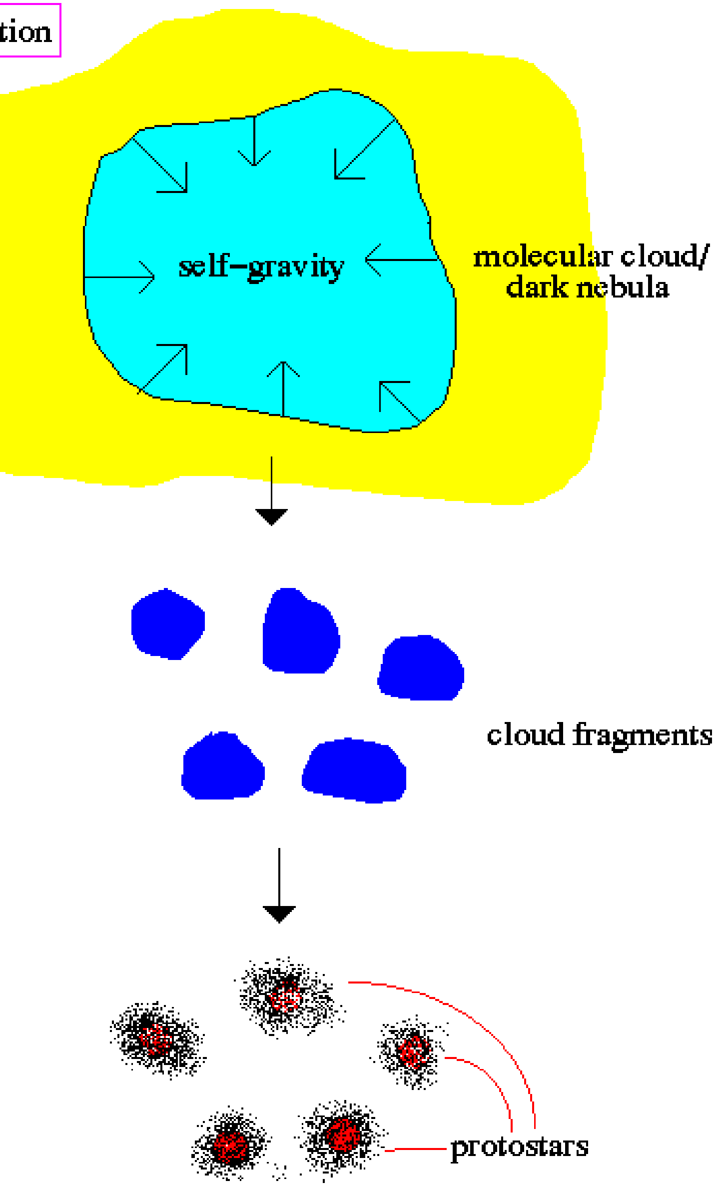
- Clouds must form **dense** and **cold** clumps or cores to collapse
- Typically, multiple stars will form from one gas cloud



NGC 3603 **HST • WFPC2**

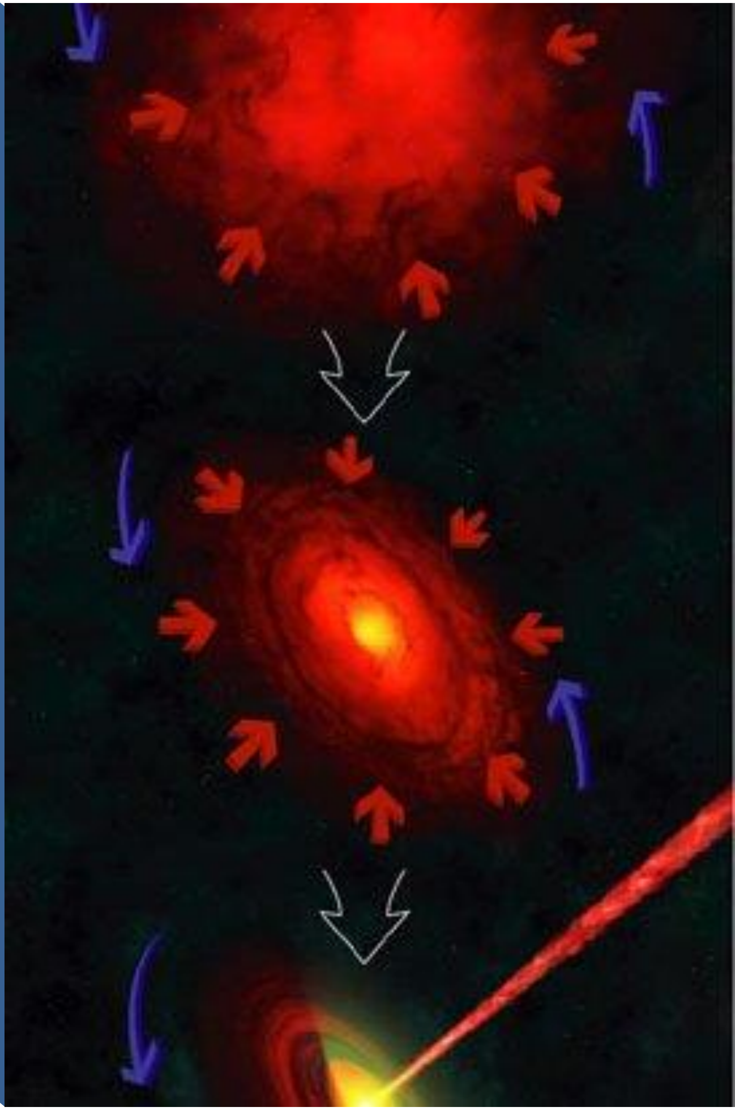
PRC99-20 • STScI OPO • June 1, 1999

Wolfgang Brandner (JPL/IPAC), Eva K. Grebel (Univ. Washington), You-Hua Chu (Univ. Illinois, Urbana-Champaign) and NASA



- 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.



During the birth process, stars both gain and lose mass

.

CRITICAL RADIUS OF GAS CLOUD {JEANS LENGTH}

if $\rho = \frac{M}{4/3 \pi R^3}$

$$\Rightarrow \frac{\frac{4}{3}\pi R_J^3 \rho}{R_J} = \frac{5}{2}\frac{KT}{GM}$$

$R_J \rightarrow$ Jeans length (smallest radius of cloud for which binding is pos.

Solving for R_J

$$R_J = \left(\frac{15KT}{8\pi G M \rho}\right)^{1/2}$$

$$\left[\left(\frac{15}{8\pi}\right)^{1/2} = 0.77\right] \simeq 1$$

$$\underline{R_J = \left(\frac{KT}{GM\rho}\right)^{1/2}}$$

Critical size of gas cloud

- We can rewrite JEANS LENGTH in terms of n, the number of particles per unit volume (n = p/m), and then We can also use equation to give us the minimum mass

$$M_J = (4\pi/3) R_J^3 \rho$$

$$= (4\pi/3)(kT/Gn$$

$$\cong 4(kT/Gm)^{3/2} \rho$$

$$= 4(kT/Gm)^{3/2} ($$

SO, IS THIS END…..??

Further we would like to know,

- the conditions under which stars will form.
- know which types of interstellar clouds are most likely to form stars,
- which locations within the clouds are the most likely sites of star formation.
- whether star formation is spontaneous or whether it needs some outside trigger.