Astronomy 150:
Killer Skies

This Class (Lecture 5):
Star Formation

Next Class:
More Meteors

HW1 due on Sun. As you have to access Nat History Building, you can't wait until the last minute.

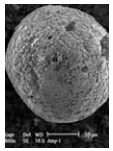
Music: *Kelly Watch the Stars* – Air

HW1

- Look at assignment on Compass before you go.
  - Not timed. Can look at it as much as you want.
- Do not submit though.
- Can print it out, write down relevant points, etc.
- Then go to Nat History building.
  - Take notes or whatever.
- Then, come back bring up HW again, fill it in, then submit.

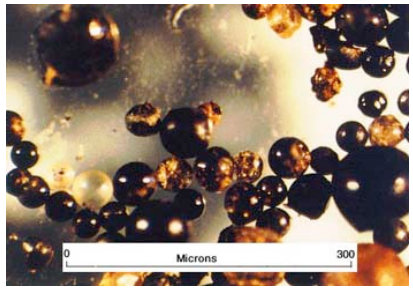
HW2: Micro-Meteorites

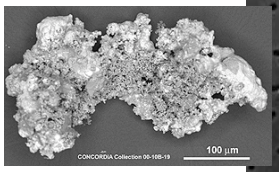
- Group project!
- Find a flat container– the bigger surface area the better.
- Fill with water and leave outside (away from buildings and tress), perhaps on a roof if possible, for a few days.
- Strain through a coffee filter or paper towels.

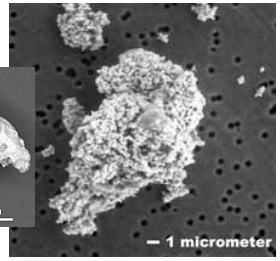


HW2: Micro-Meteorites

- Use a magnet to find the magnetic dust.
- Probably most of those are from space.
- So small, they fall to Earth unchanged.
- Estimate amount of micro-meteorites falling onto the Earth per year.







You need to Register You Clicker

- Go to **link on syllabus** to register your clicker ASAP.
- **Bring it to class every day.**
- **15 people still not registered!**

- If you can't read your iclicker ID, you can go the Illini bookstore (at the bag-check counter), "vote" with your clicker, and your clicker ID will be displayed on the base unit.

https://online-s.physics.uiuc.edu/cgi/courses/shell/iclicker.pl

Night Obs

- Dates:
  - Monday, Sept. 21st
  - Tuesday, Sept. 22nd
  - Wednesday, Sept. 23rd
  - Thursday, Sept. 24th
  - Monday, Sept. 28th
  - Tuesday, Sept. 29th
  - Wednesday, Sept. 30th
  - Thursday, Oct. 1st

Go to assignment page on class website for more info.

You MUST download worksheet before you go.

Computer Labs

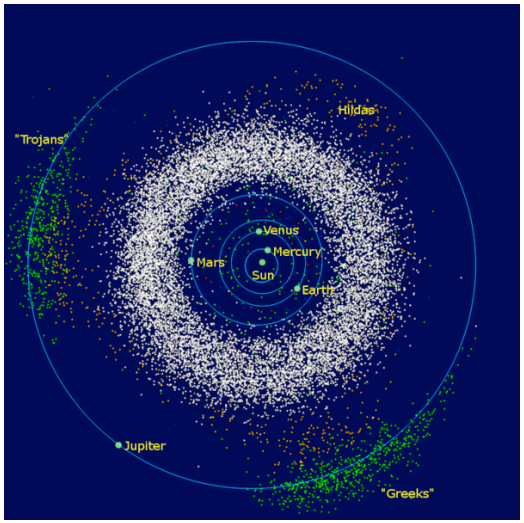
- Computer labs to look for real killer asteroids.
- Dates:
  - Monday Sept 28th
  - Monday, Oct 5th
  - Monday, Oct 12th
- Places:
  - Nevada Labs
  - Oregon Labs

- Limited space each day, so you ***MUST*** have a reservation for that day and that lab!
- See Assignments webpage for more info and to sign up!
- Lectures are cancelled for those dates.

Outline

- What are comets and asteroids?
- Where did they come from?
- How was the Sun born?

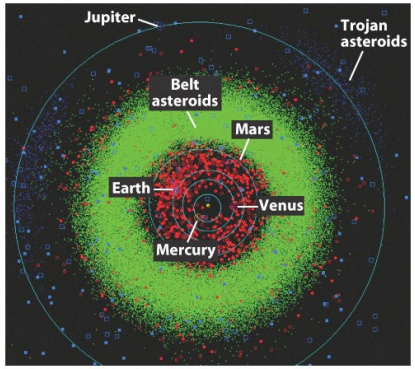
Asteroids and the Asteroid Belt



Apollos

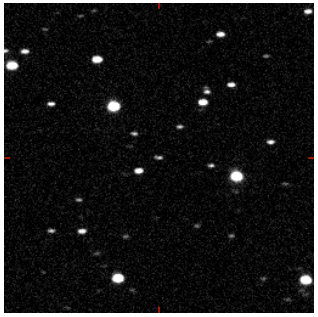
Some asteroids are on orbits that cross Earth's orbit

- Called *Apollo asteroids*
- At least 3000 are known
- In 1972, one skipped off the Earth's atmosphere



Near Earth Asteroids

- Short-lived (few million years)
  - Orbital decay and Sun accretion
  - Collision with inner planets
  - Ejected from system by interactions
- Must be replenished
- Gravity interactions with asteroids and Jupiter can send them Earth-ward



2004 FH (30 meter) passing 10% the Earth-Moon distance

Outer Solar System

THE MIDDLE SOLAR SYSTEM

This animation shows the motion of the middle part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth Mars and Jupiter are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

The individual frames were generated on an OpenVMS system, using the PGPLOT graphics library. The animation was put together on a RISC OS 4.03 system using !InterGif.

http://www.cfa.harvard.edu/iau/Animations/Animations.html

Inner Solar System

THE INNER SOLAR SYSTEM

This animation shows the motion of the inner part of the solar system over a two-year time period. The sun is at the center and the orbits of the planets Mercury, Venus, Earth and Mars are shown in light blue (the locations of each planet are shown as large crossed circles). Comets are shown as blue squares (numbered periodic comets are filled squares, other comets are outline squares). Main-belt minor planets are displayed as green circles, near-Earth minor planets are shown as red circles.

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Near Earth Asteroids

A Ride With The Earth

An animation centered on Earth showing the known objects that have approached to within 20 million km between July 2007 and June 2008. See the Animations Page on the MPC website for a description of the symbols used in this animation.

Some large asteroids have Earth-crossing orbits

Orbits cross but not necessarily collide… why?

Right now, over 3000 Earth-crossing asteroids are known.
And over 1000 potential dangerous ones. http://cfa-www.harvard.edu/iau/Animations/Animations.html

Question

What can we say about the Near Earth Asteroids?

a) They have always orbited nearby the Earth.
b) That they are all made of mostly iron.
c) That they collide with the Earth every few hours.
d) That they can only exist in near Earth orbit for a few million years and are replenished by asteroid belt objects.
e) That they typical travel in unique orbits that move them from Mercury to Venus to Earth, and to Mars, with a 10% chance of collision at each body.

NEOs have Affected our Environment for Eons…and will Continue to do so

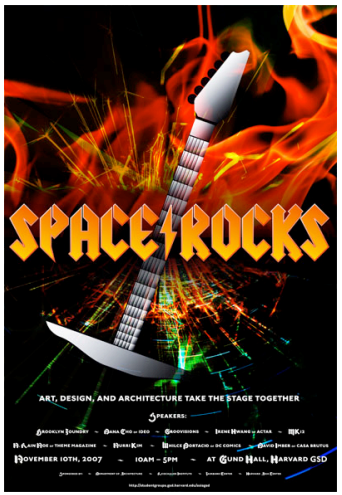
- Early sources of water, organic molecules on Earth
- Bombardment "blizzard": the Late Heavy Bombardment, ~3.9 Ga, which frustrated the origin of life
- External cause for "punctuated equilibrium" evolution, mass extinctions, rise of new species
- Rare, modern threat to humanity
- Future source of raw materials, spacefaring tourist destinations

Terms

- **Asteroid:** A relatively small, inactive, rocky body orbiting the Sun (>50 meters).
- **Comet:** A relatively small, at times active, object whose ices can vaporize in sunlight forming an atmosphere (coma) of dust and gas and, sometimes, a tail of dust and/or gas.
- **Meteoroid:** A small particle from a comet or asteroid orbiting the Sun (<50 meters).
- **Meteor:** The light phenomena which results when a meteoroid enters the Earth's atmosphere and vaporizes; a shooting star.
- **Meteorite:** A meteoroid that survives its passage through the Earth's atmosphere and lands upon the Earth's surface.

Where are These Rocks From?

- Asteroids
- Meteoroids
- Comets
- … yes, but why are they so old and where are they from?

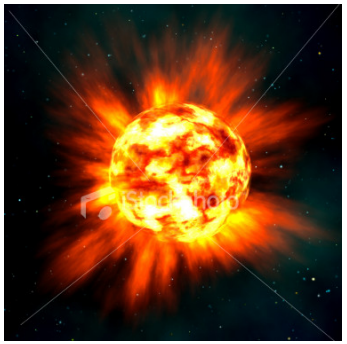


The Early Days

- We'll come back to this, but the Universe is around 13.7 billion years old.
- About 400,000 years after the Big Bang (we'll come back to this), the Universe was mostly hydrogen (92%)

Making Heavy Elements

- The first stars were born and died.
- When a massive star dies, it goes **supernova** and explodes. (We'll come back to this.)
- When it does this, the elements forged during its life enrich space.
- Supernovae provide much of the building blocks for planets… and us!
- **We are recycled supernova debris!**
- **We are Star stuff.**



The Interstellar Medium (ISM)

- Stuff between the stars in a galaxy.
- Sounds sort of boring, but
  - Actually very important
  - Features complex physical processes hidden in safe dust clouds

- Every star and planet, and maybe the molecules that led to life, were formed in the dust and gas of clouds.

- Exists as either
  - Diffuse Interstellar Clouds
  - Molecular Clouds

Keyhole Nebula

What is the Age of the Solar System?

- Earth: oldest rocks are 4.4 billion yrs
- Moon: oldest rocks are 4.5 billion yrs
- Mars: oldest rocks are 4.5 billion yrs
- Meteorites: oldest are 4.6 billion yrs
- Sun: models estimate an age of 4.5 billion yrs

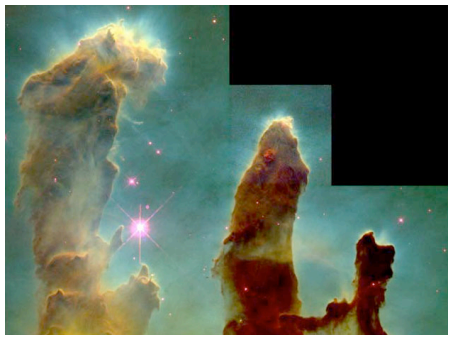
- **Age of Solar System is probably around 4.6 billion years old**

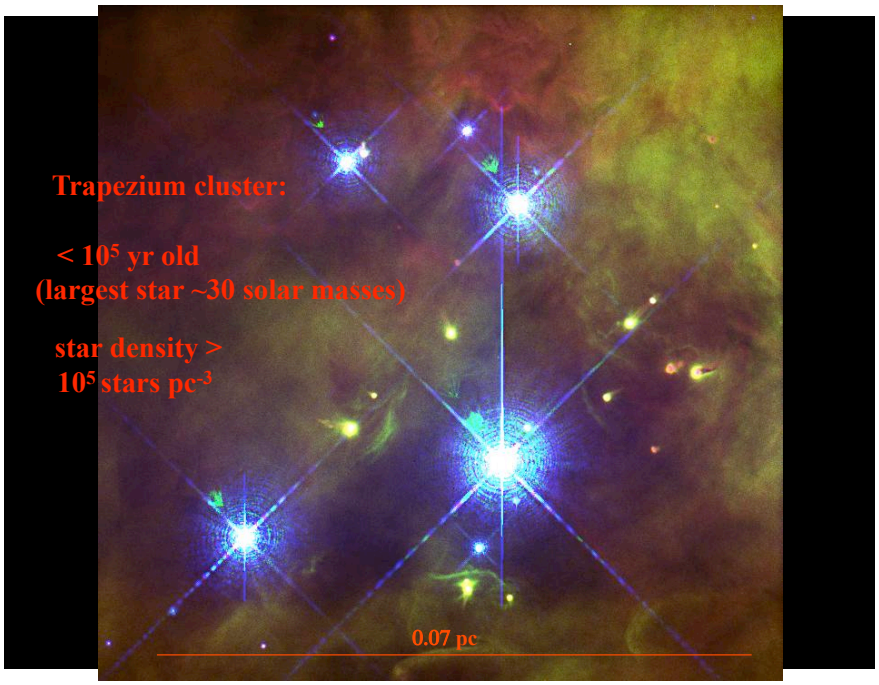
Origin of Solar System: Solar Nebula Theory

"*nebula*" = cloud

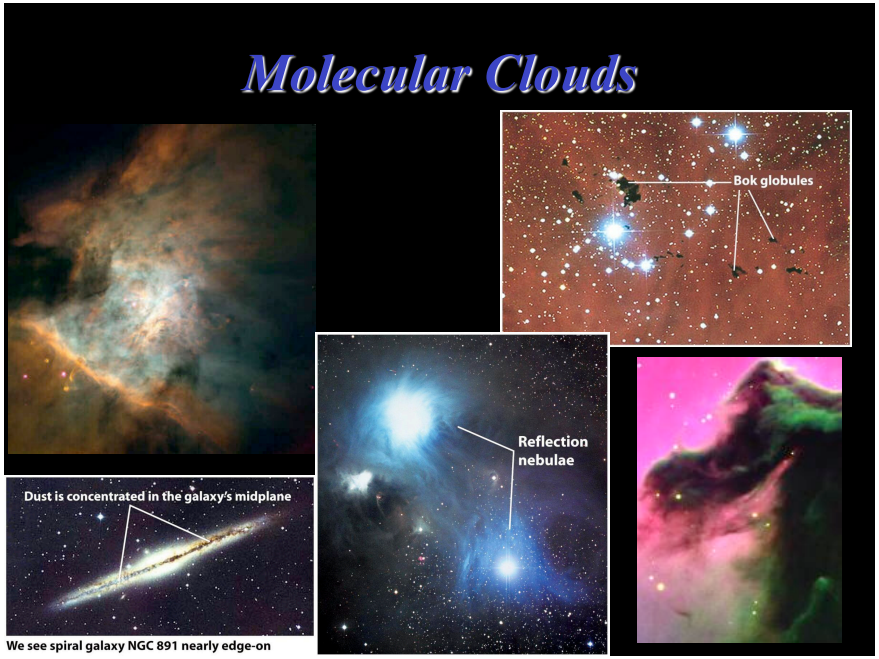
Gravitational Collapse

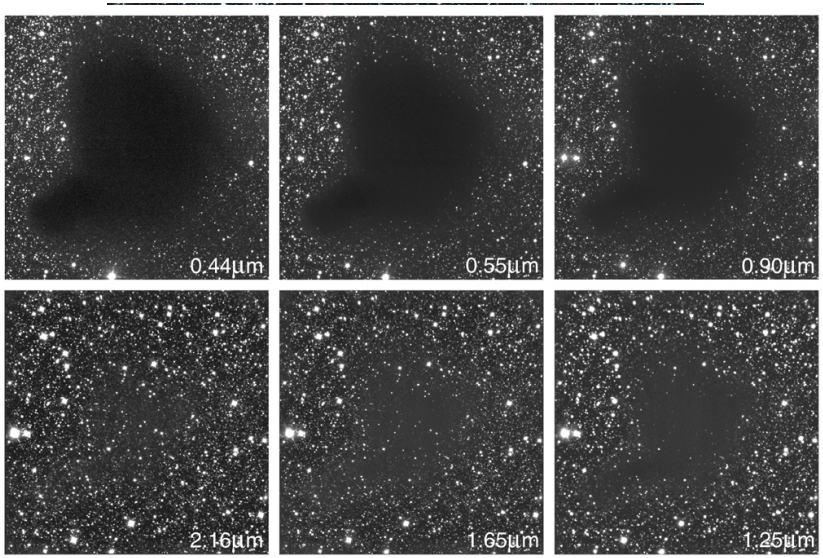
- The basic idea was put forth by Immanuel Kant (the philosopher)– Solar System came from a Gas Nebula.
- 4.6 billion years ago: a slowly spinning ball of gas, dust, and ice with a composition of mostly hydrogen and helium formed the early Solar System.
- This matches nearly exactly with the modern idea of star formation.





Molecular Clouds



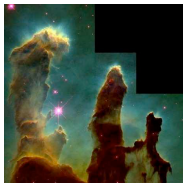


The Dark Cloud B68 at Different Wavelengths (NTT + SOFI)

ESO PR Photo 29b/99 (2 July 1999)

© European Southern Observatory

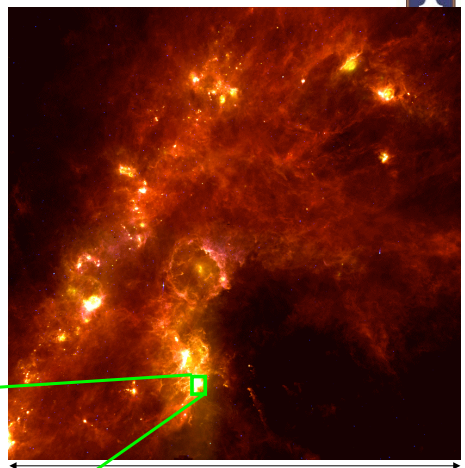
Molecular Clouds



- Interstellar clouds are important molecular factories.
- Analogous to clouds in our atmosphere
- Primarily molecular hydrogen (~93%) and helium (~6%) with (~1%) heavy molecules– molecules or dust.
- H_2 is not good at emitting photons, so easier to see larger molecules emitting– especially CO (which tells the temperature of these clouds).

Giant Molecular Clouds

- Cool: < 100 K
- Dense: $10^2 - 10^5$ H_2 molecules/cm^3
  (still less dense than our best vacuum)
- Huge: 30 – 300 lyrs across, $10^5 - 10^6$ solar masses
- CO molecular emission & dust emission trace structure

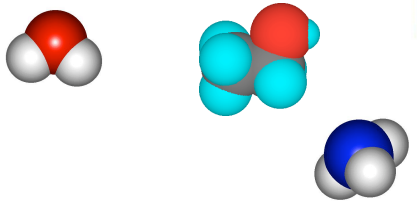


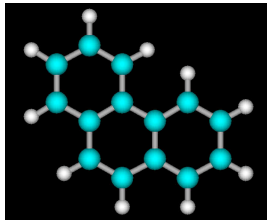
100 degrees

Infrared image from *IRAS*

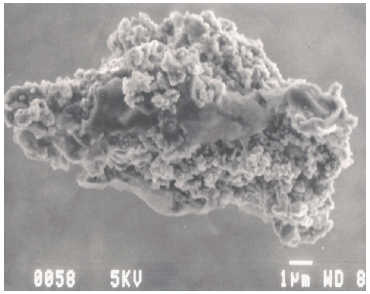
Other Things Besides Hydrogen in Molecular Clouds

- Molecules (e.g.)
  - Carbon monoxide (CO)
  - Water (H_2O)
  - Ammonia (NH_3)
  - Formaldehyde (H_2CO)
  - Glycine (NH_2CH_2COOH)?
  - Ethyl alcohol (CH_3CH_2OH)
  - Acetic Acid (CH_3COOH)
  - Urea [$(NH_2)_2CO$]
- Dust particles
  - Silicates, sometimes ice-coated
  - Soot molecules





Polycyclic aromatic hydrocarbons (PAH)



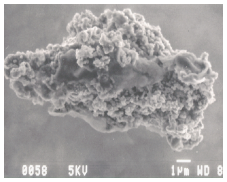
Dust particle (interplanetary)

Question

Molecular clouds, where stars form, are mostly made up out of

a) dust
b) a rich assortment of molecules that range from alcohol to urea
c) Hydrogen
d) water
e) Molecular hydrogen or H_2

In Dust We Trust

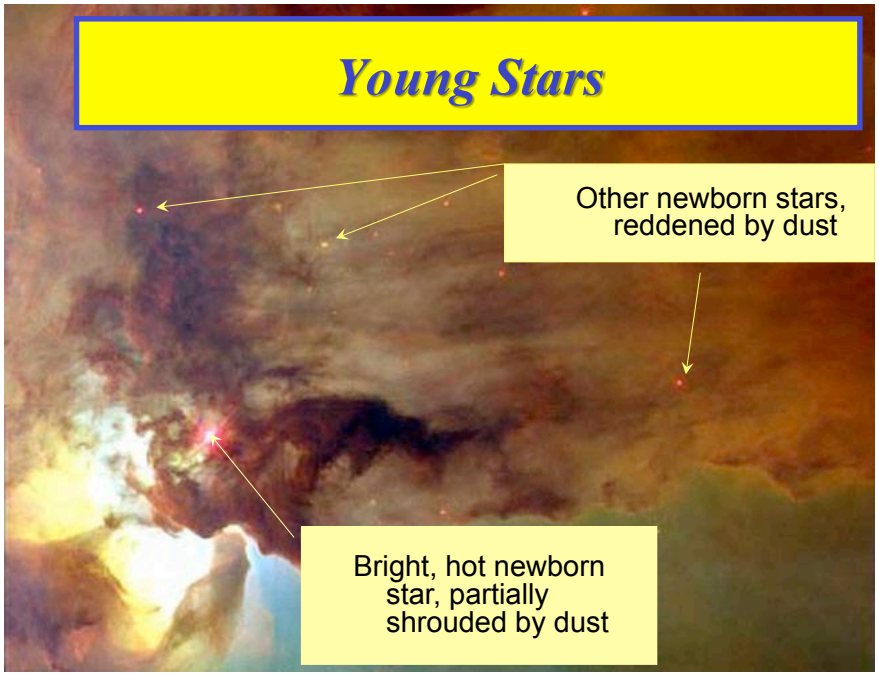


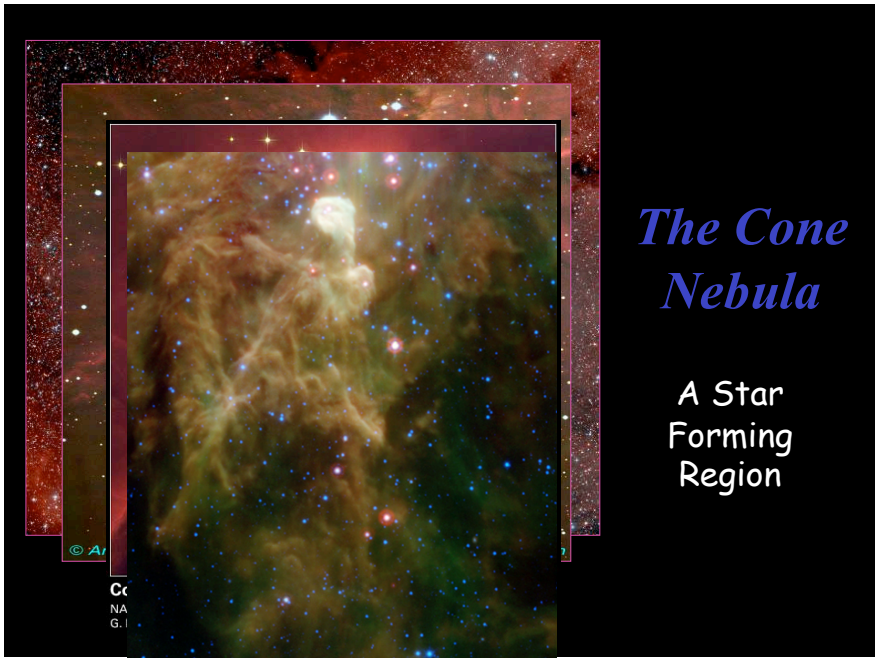
- Small (< 1 micron), solid particles in space
- Two types:
  - Primarily carbon (sort of like what we call soot)
  - Silicates, minerals of silicon and oxygen (sort of like what we call dust)
- Produced in material flowing from old stars, but mixed in space.
- Some of the micrometeorites could be primordial interstellar dust!

How Do We Know that Stars Form in Molecular Clouds ?

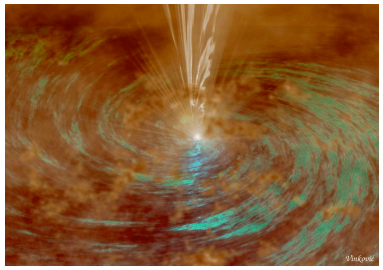
- Young stars are seen near molecular clouds.
- In infrared light, we can see into the deeper regions of clouds, and see clusters of young stars with circumstellar material (dust and gas) surrounding them.
- Stars are continuously being formed in our galaxy.

http://antwrp.gsfc.nasa.gov/apod/ap030630.html





Star Formation



Stars are born in cold, dense interstellar clouds

- Cold gas
- Dust grains

Star formation is probably triggered by

- Cloud turbulence
- Collision with another cloud
- Nearby supernova explosion
- Nearby hot star wind
- Disturbance from the Galaxy

Question

Stars are born

a) in molecular clouds.
b) in supernovae.
c) in black holes.
d) on Broadway.
e) in empty space.