

Interstellar Medium

- The matter between the stars: cold gas (<100K) and dust
- NGC 2170 near Orion
- α&β Centauri, Coal Sack
- Southern Cross (below)



Dust-Found in the Plane of a Galaxy

- Despite near vacuum great distances add up to block background star's light
- M51 and NGC 891



Hawaiian Starlight™

Edge-On Spiral Galaxy NGC 891
From W. M. Keck - Hawaii

NGC 891 is a spiral galaxy seen edge-on and located 10 million light years away from Earth. It is a very young galaxy, containing many young stars and a large amount of interstellar gas and dust. The spiral structure is being formed from the galactic disk due to supersonic winds it produces, resulting from the sudden and violent replacement of massive stars. Many millions of years ago, the disk was tilted at an angle to the background, about 30°, but has since been flattened by the influence of three massive galaxies.

NGC 891 est une galaxie spirale vue par le télescope à l'île de Maui. Située à 10 millions d'années-lumière de la Terre, elle est une jeune galaxie contenant de nombreux jeunes étoiles et de la matière interstellaire. La structure spirale est formée dans le disque galactique en raison des vents supersoniques qu'il produit, résultant de la soudaine et violente remplacement de gigantesques étoiles. Il y a plusieurs millions d'années, le disque était tourné à un angle par rapport au fond, environ 30°, mais il a depuis été aplati par l'influence de trois galaxies massives.

CFHT CANADA FRANCE HAWAII TELESCOPE www.cfht.hawaii.edu

Trifid Nebula

(Nebula means cloud)

Emission, Reflection, Dark Nebulae

Red,

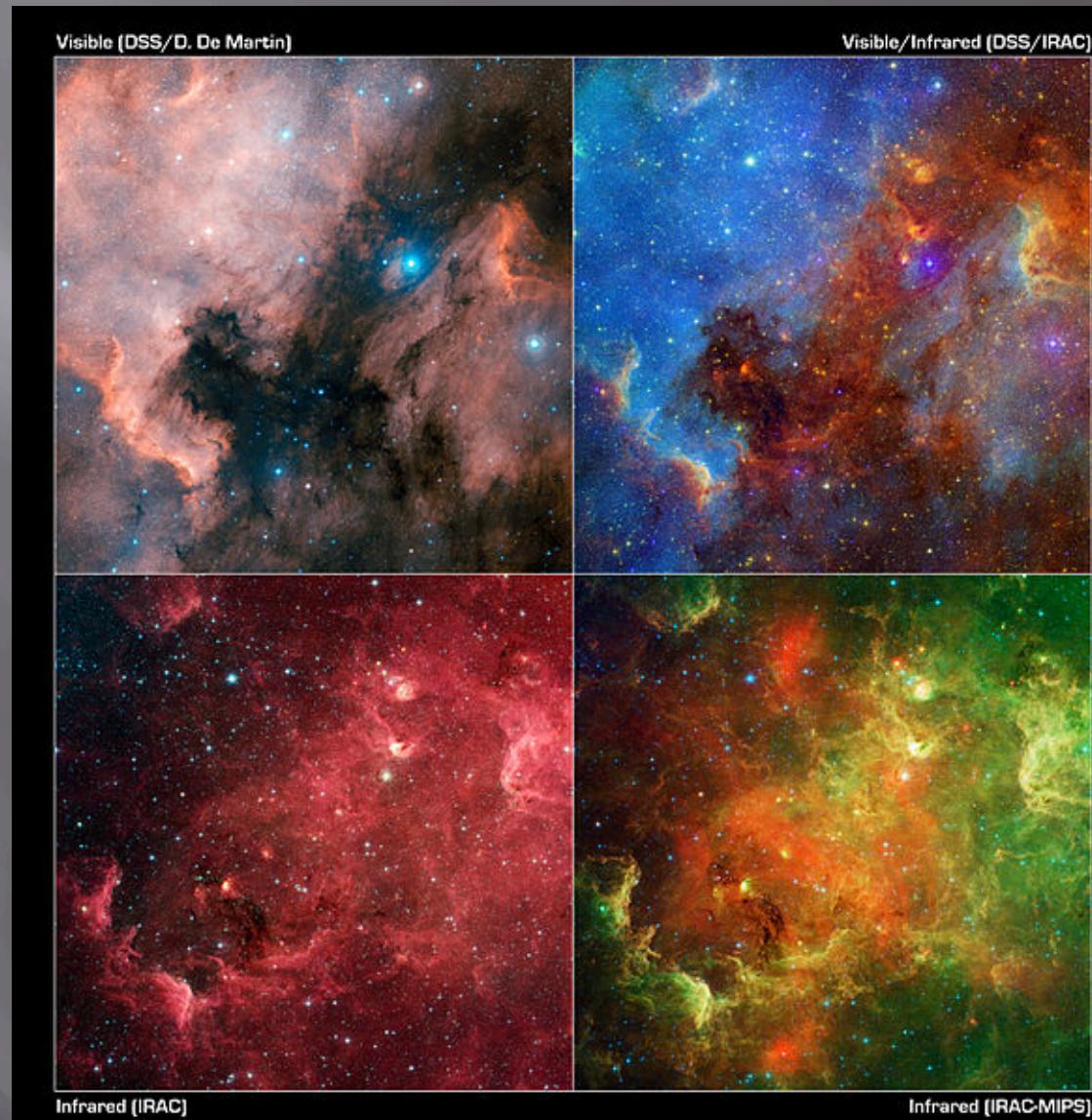
Blue,

Black



Emission Nebula

- Emission Nebula =
HII region
composed of
ionized hydrogen
- North American &
Pelican: Diam=15ly
distance=1500ly



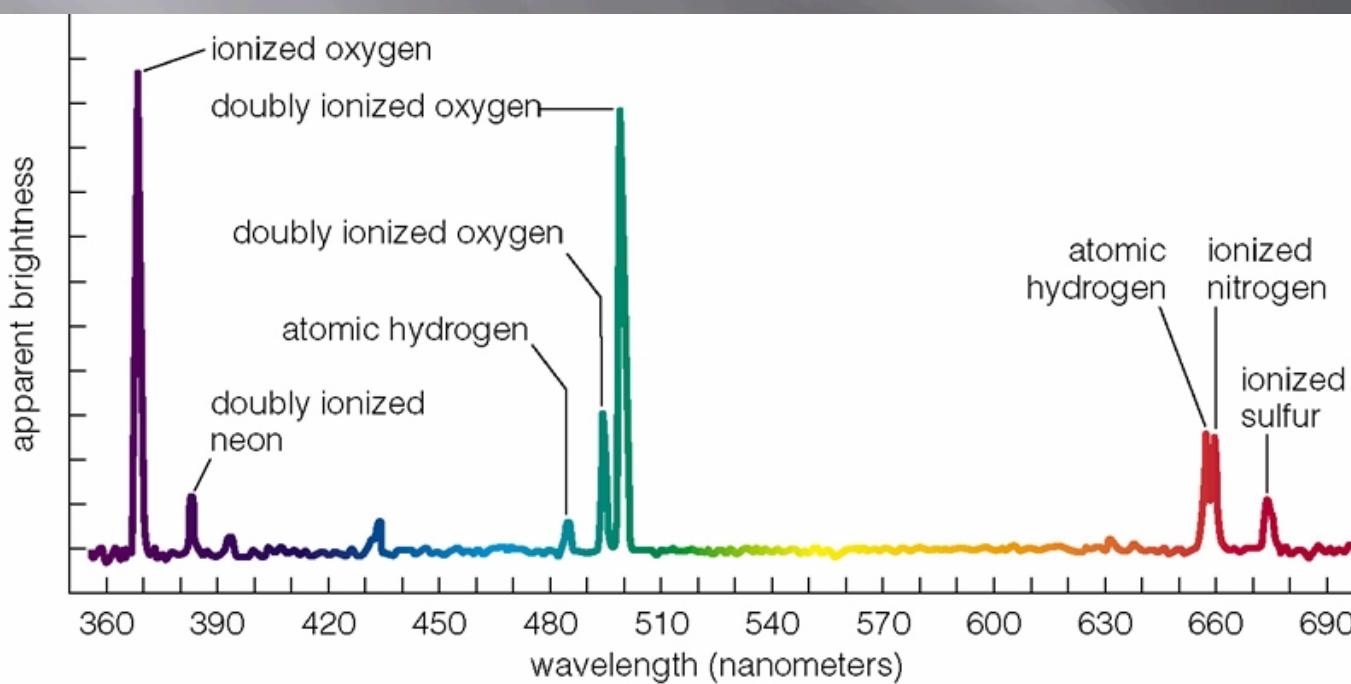
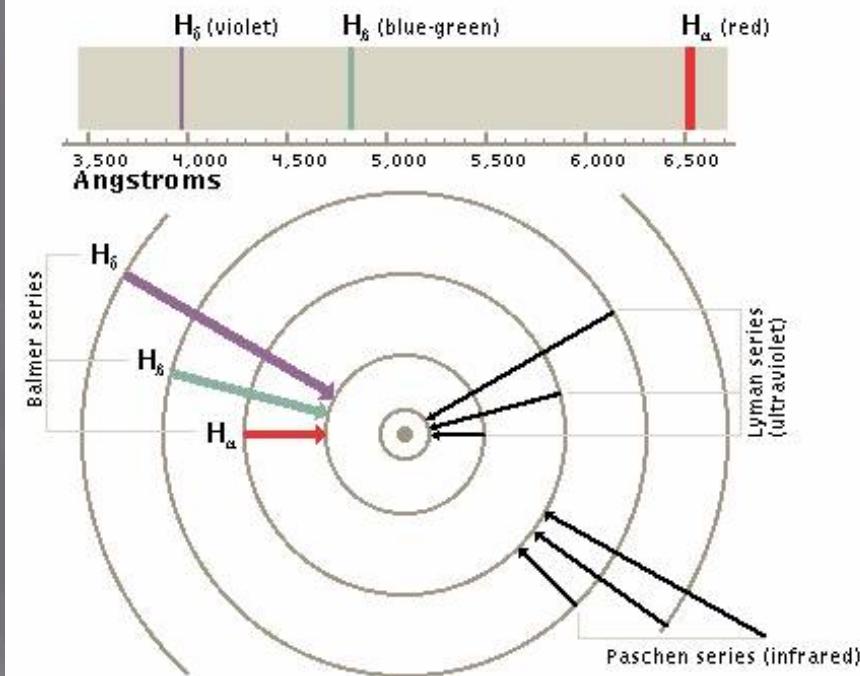
Emission Nebula IC1396

- UV from star(s) hotter than B1V cause Hydrogen fluorescence
- Dust Lanes cross the HII region

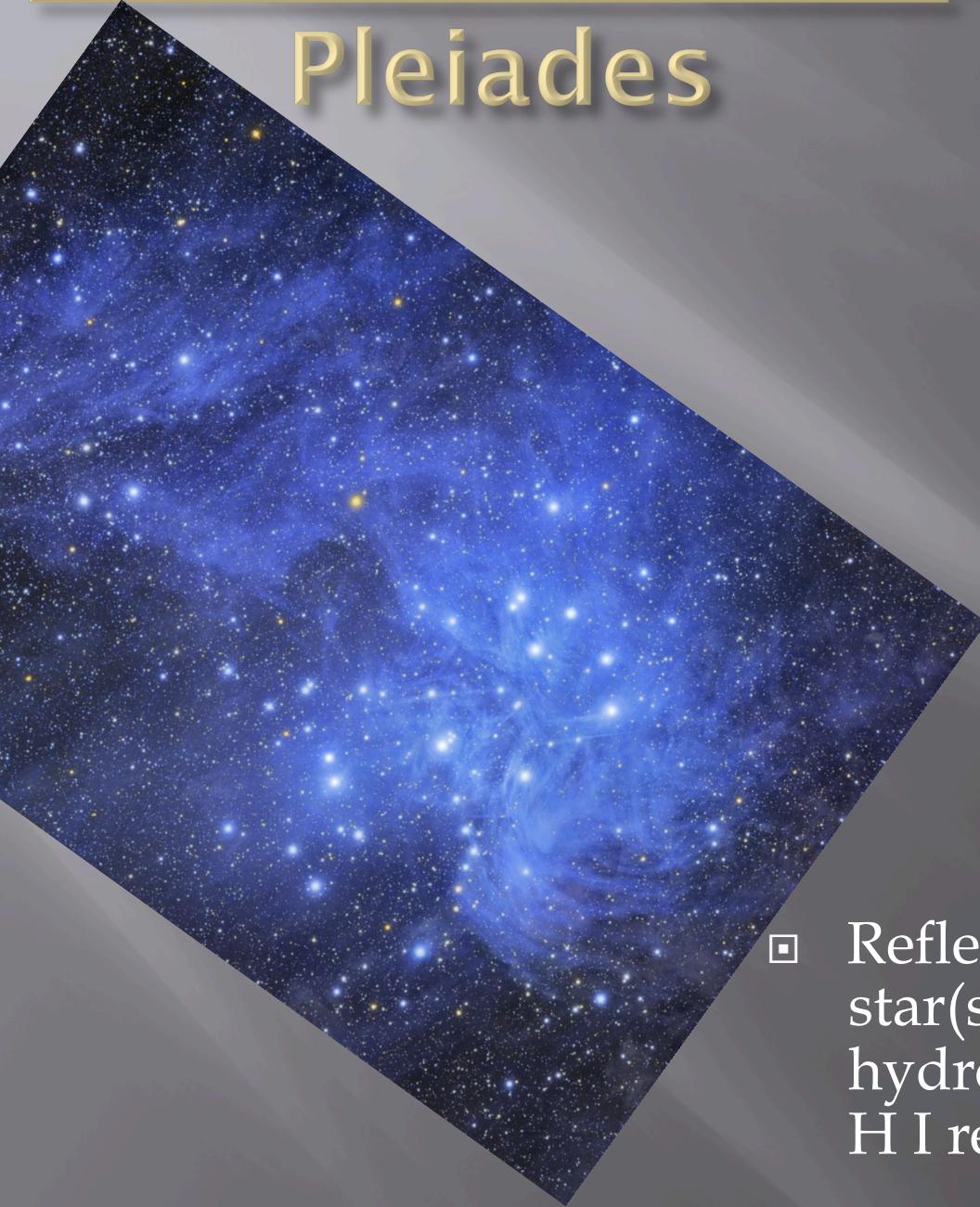


Emission Nebula Spectrum

- Kirchhoff's laws: emission lines mean low density gas
- Hydrogen emission lines plus
- Forbidden lines occur when electron makes transition from a metastable level



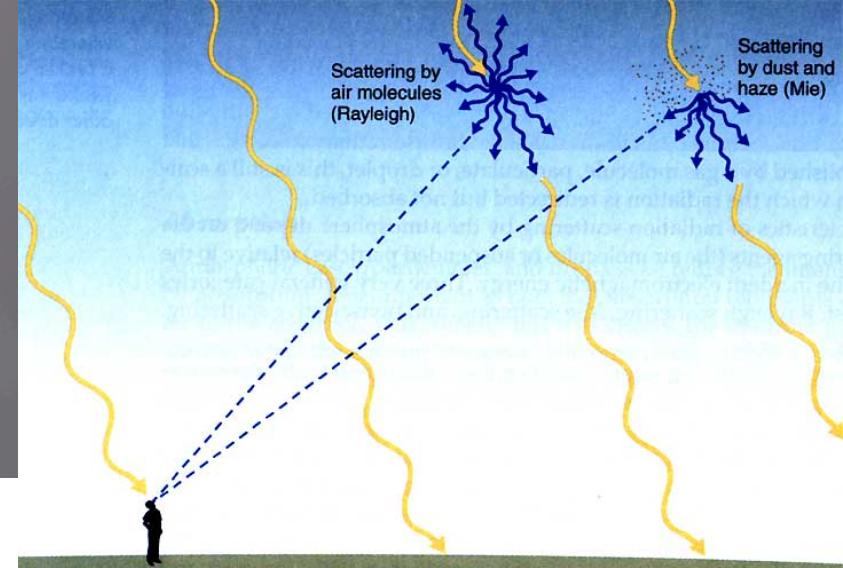
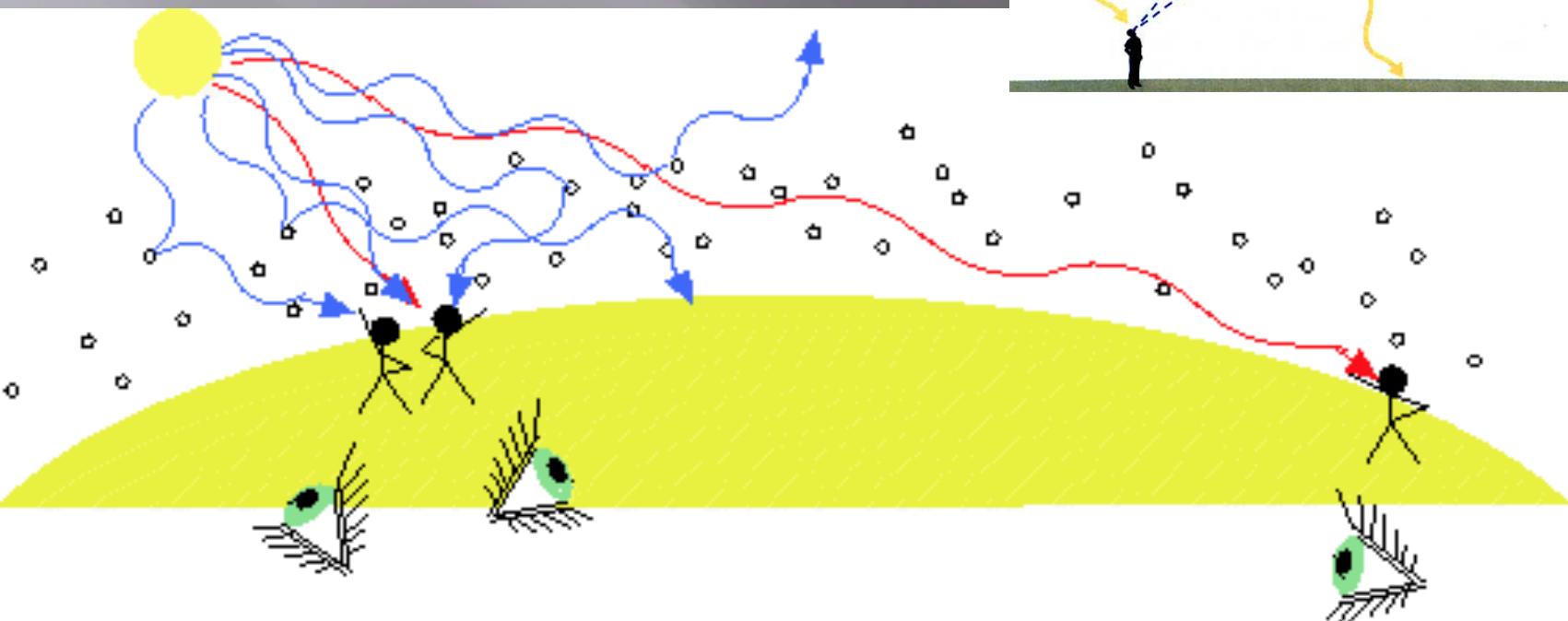
Reflection Nebula: Pleiades



© Anglo-Australian Obs./Royal Obs. Edinburgh

- Reflection Nebula caused when star(s) are not hot enough to ionize hydrogen = neutral hydrogen = H I region ~100K

Why is the Sky Blue?



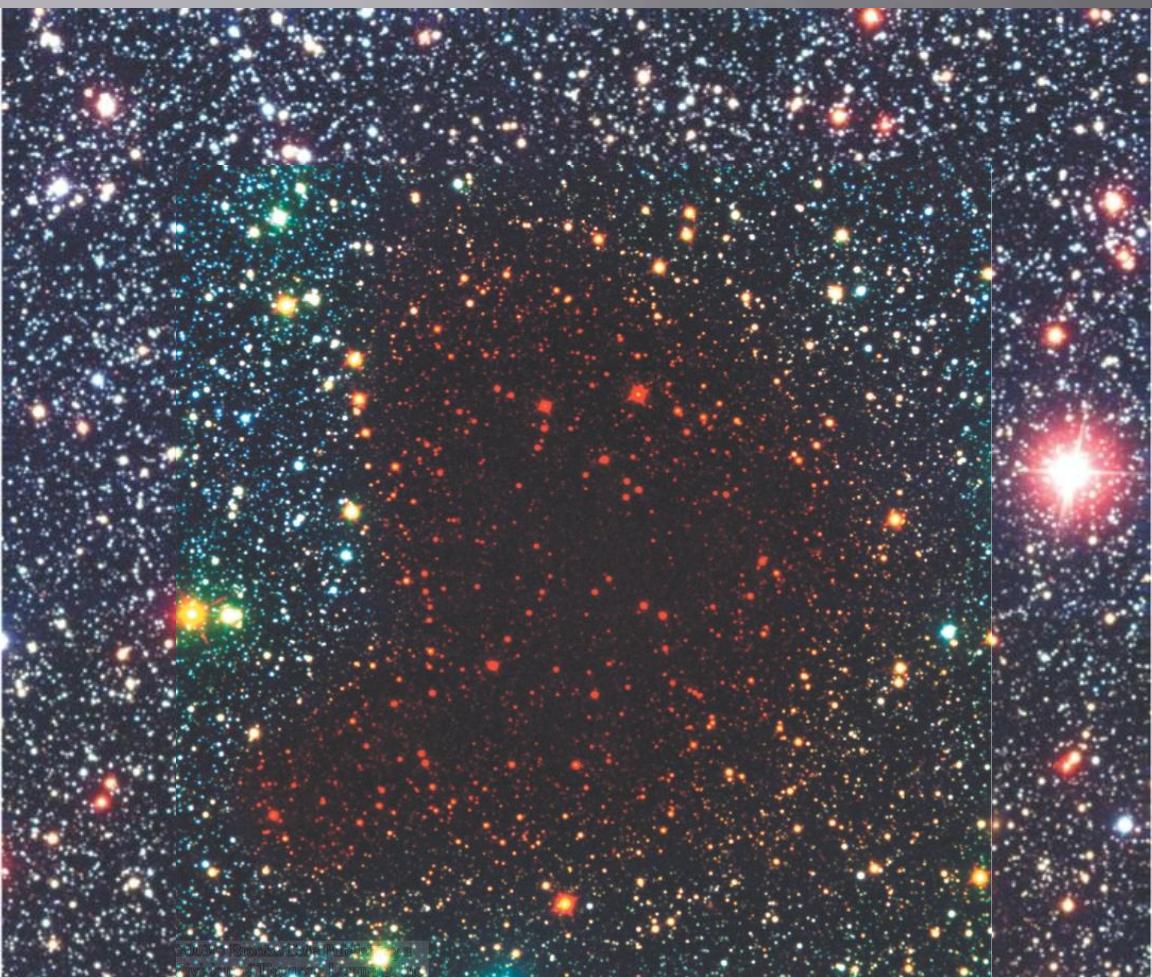
Blue light scatters more than red light. When the Sun is high in the sky you will see all of the colors if you look right at the Sun. But looking in other directions, you will see just the blue colors because some of the blue sunlight will be scattered back to you. When the Sun is near the horizon, the blue sunlight is scattered away leaving only the red and orange sunlight--the Sun appears red.

Dark Nebula= Dark Dust Cloud

- Snake Nebula=Molecular Clouds=Molecular H =H₂
- Temperature ~30K Density 10⁴ atoms/cubic cm
- Blown by winds?



Interstellar Extinction



- Dust makes the stars fainter (=Interstellar Extinction) and redder

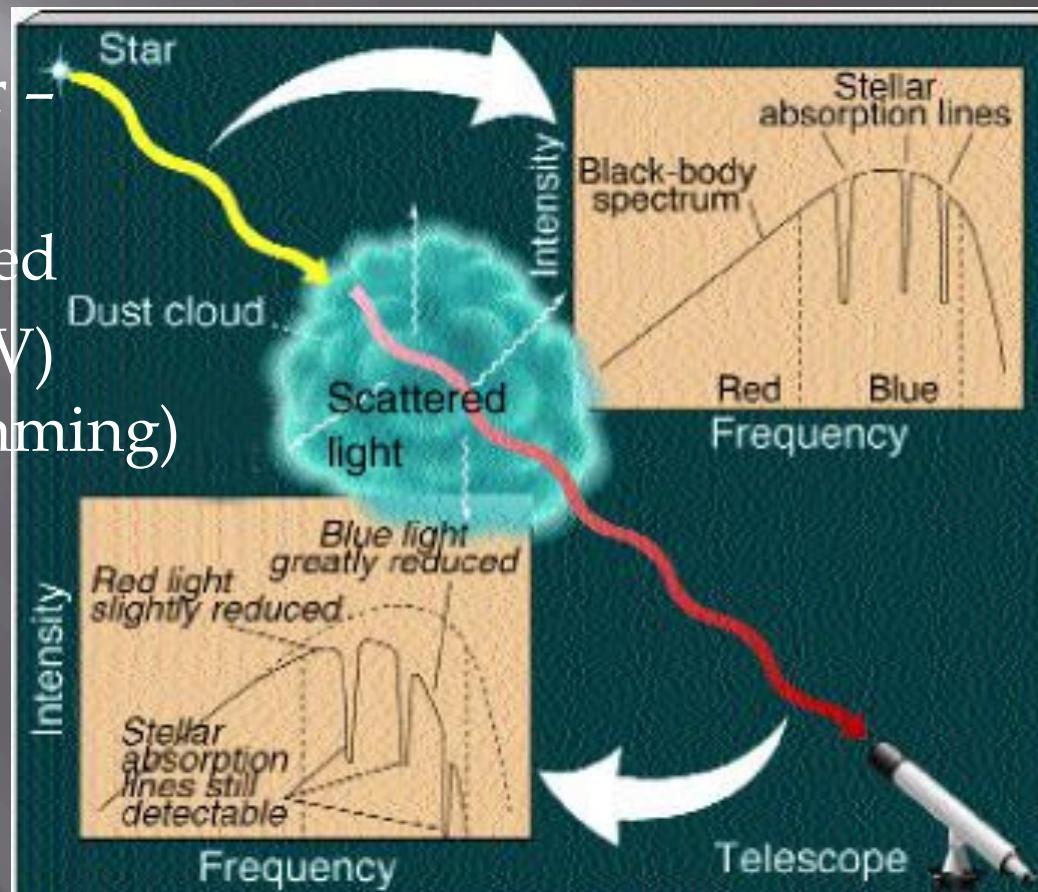
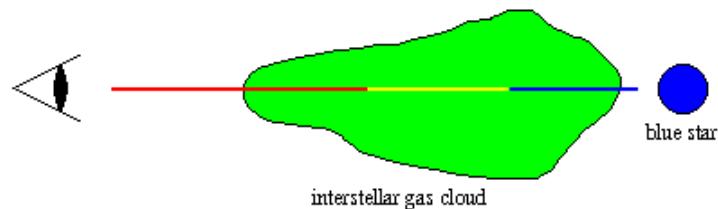
Figure 10.1a

Interstellar Reddening

- Blue photons scatter more easily than red photons
- So a star's color is redder seems cooler
- Spectral type is unchanged
- So difference in color (B-V) measures extinction (dimming)

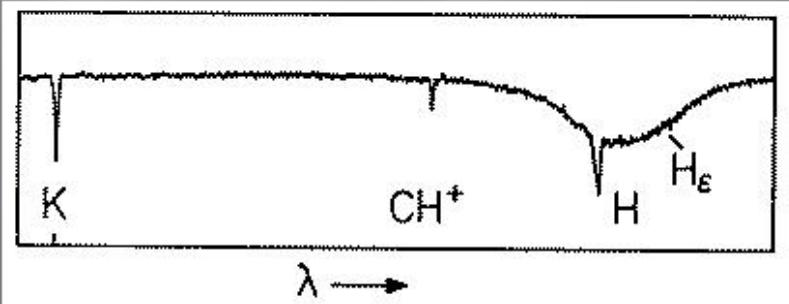
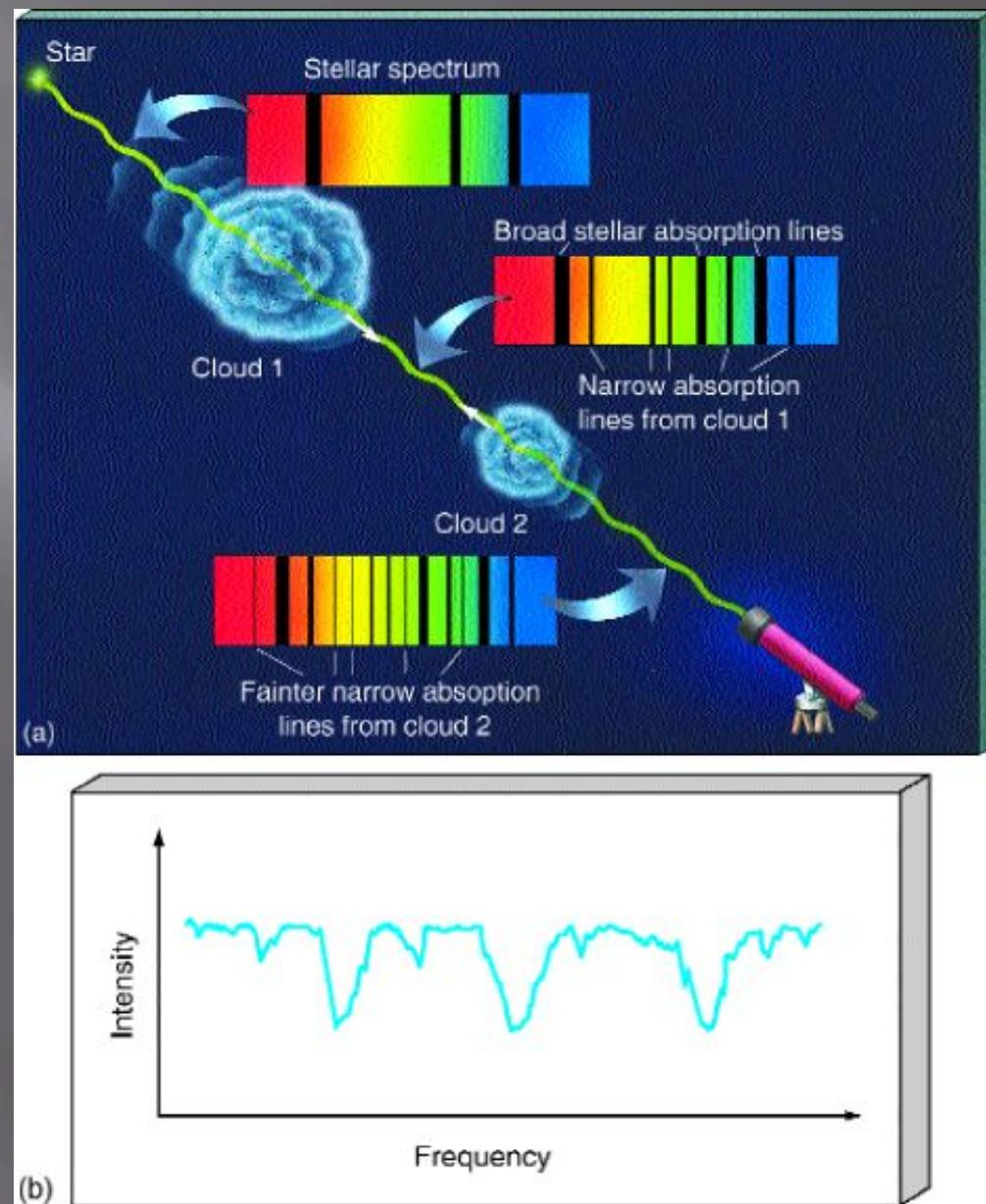
Interstellar Reddening

Light from a remote star has part of its blue component removed by interfering gas clouds. The result is a redder color for the star.



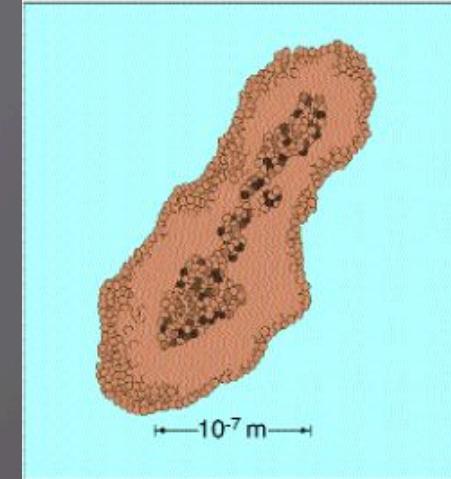
Interstellar Absorption Lines

- Cool low pressure foreground gas produces thin absorption lines of “wrong” ionization / temperature / radial velocity



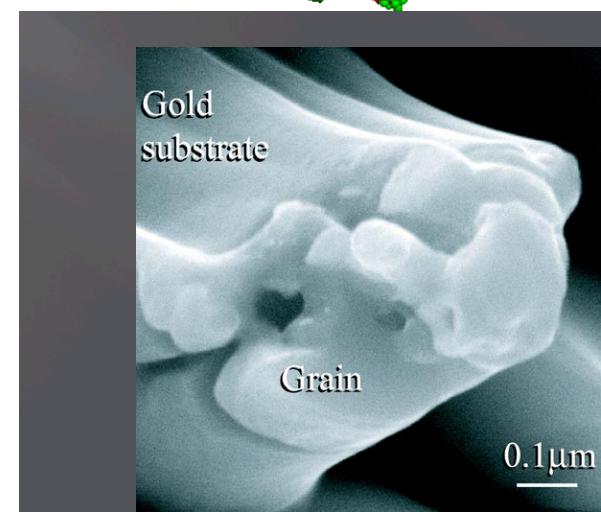
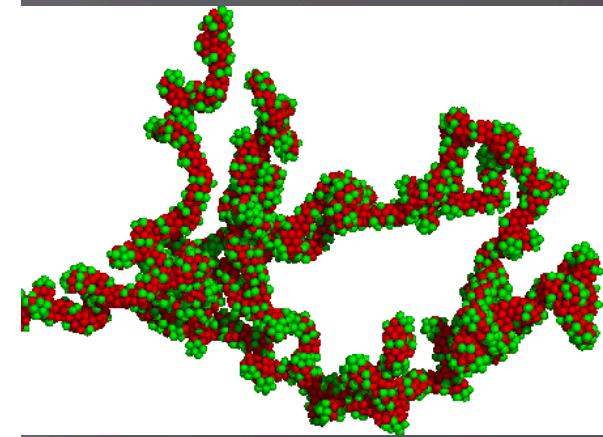
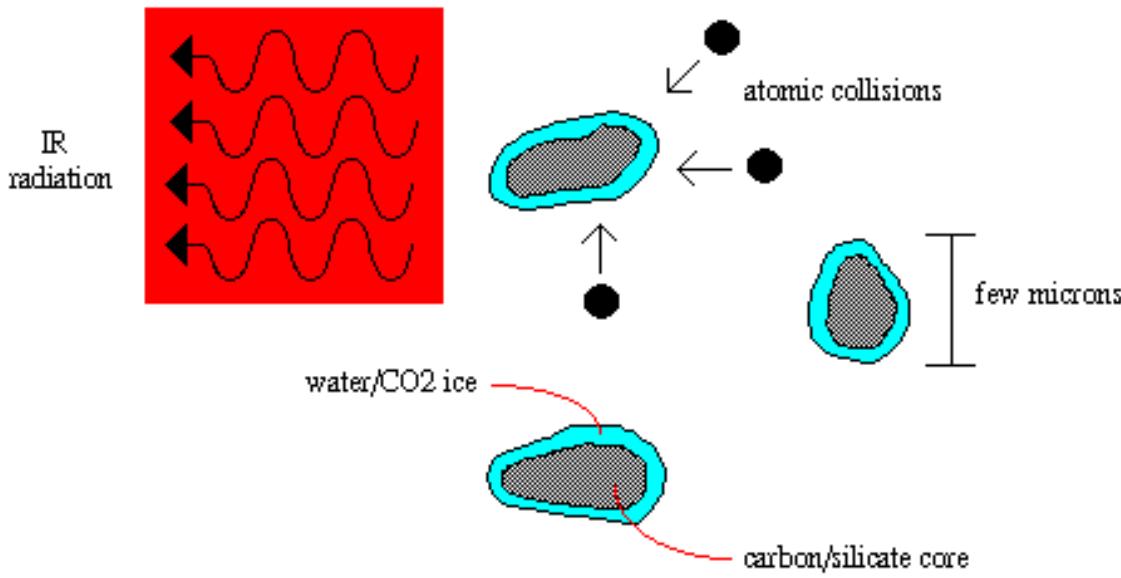
Interstellar Dust Grains

- Carbon chains coated with ices about 0.0005mm = 0.5 micron
- Grain formed in Red Giant atmosphere found in meteorite (different isotopic abundances)



Interstellar Dust

Interstellar dust forms in the envelopes around red supergiants. Their structure is a carbon/silicate core often surrounded by water or carbon dioxide ice. Collisions with atoms causes the dust to emit a thermal spectrum in the IR.



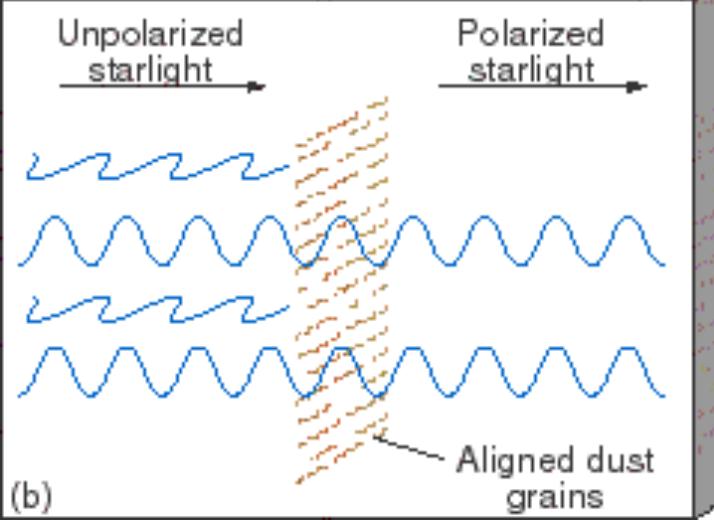
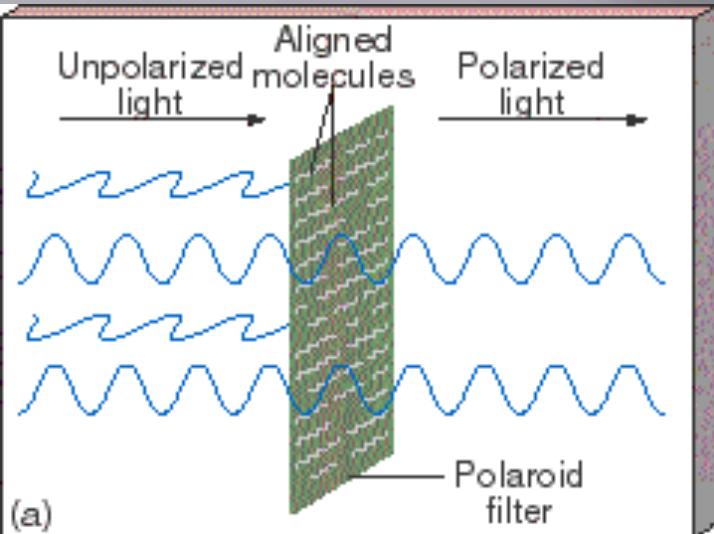


Light is Wave

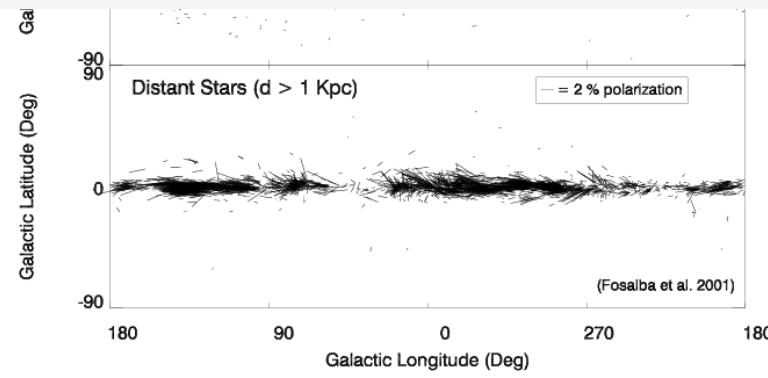
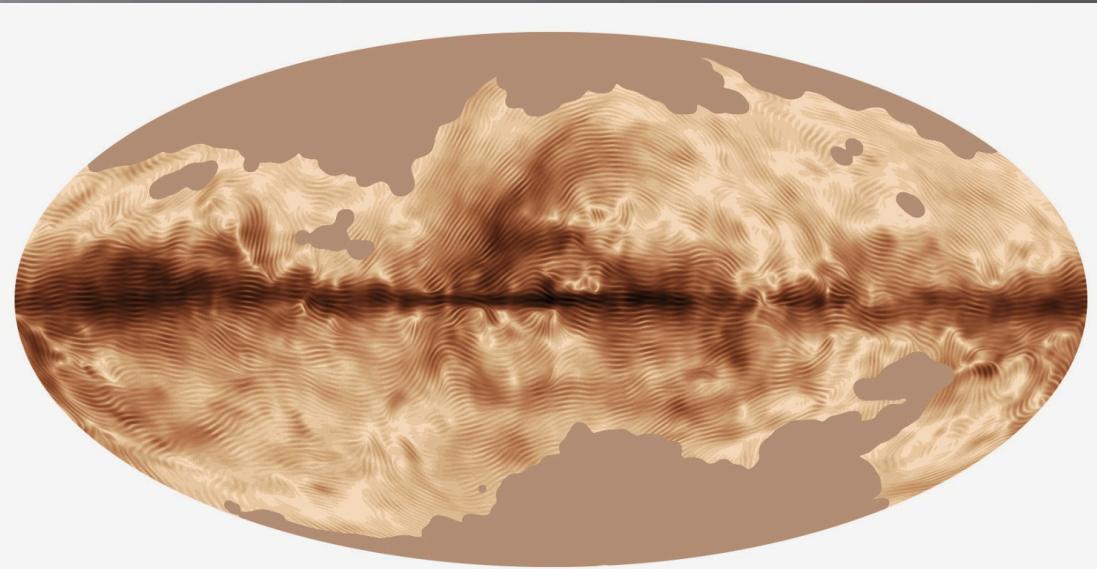
- Sunlight vibrating side to side is reflected
- Glare is eliminated by sunglasses with lines going up and down



Dust Causes Polarization

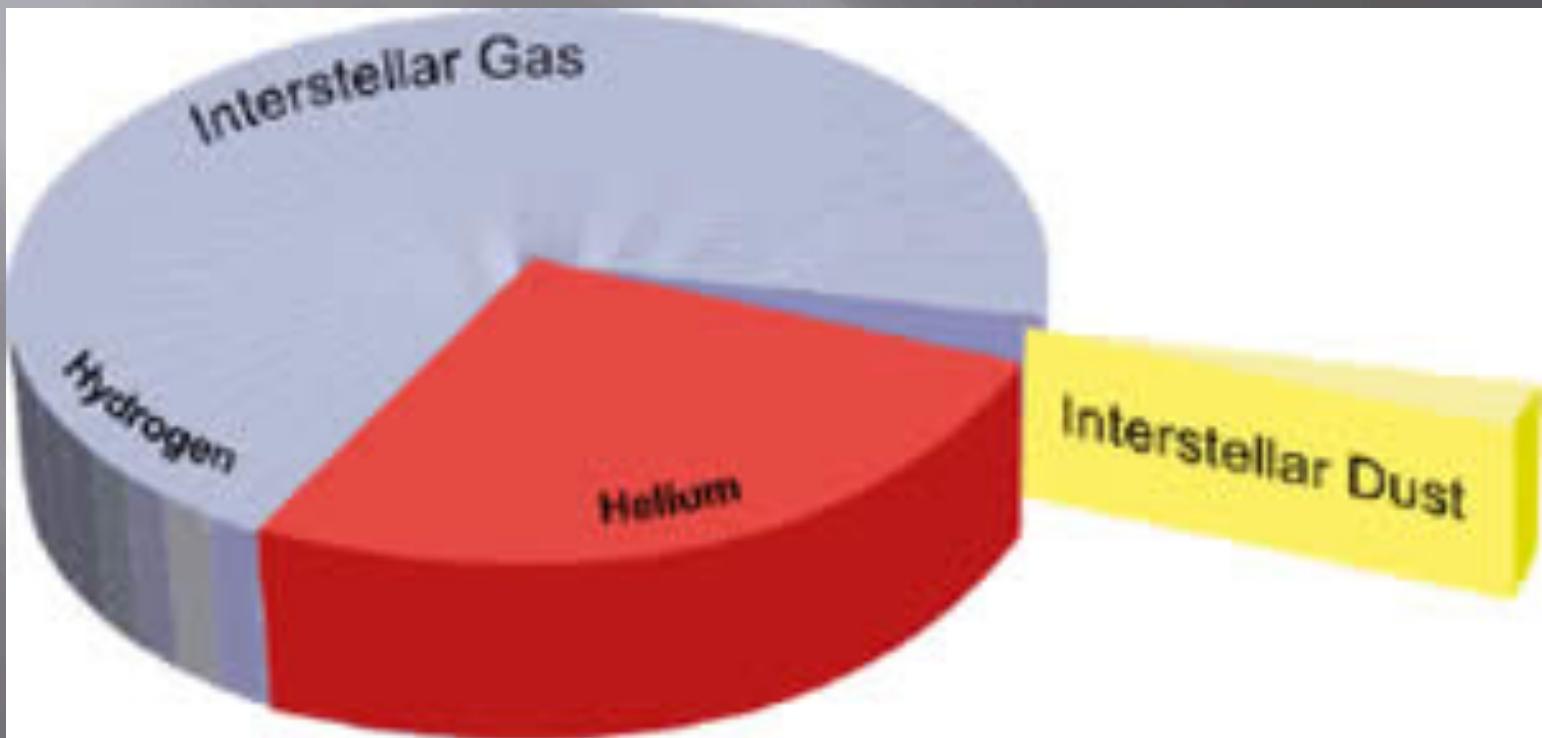


- Lines show orientation of field
- PLANCK sees dust emission
- Direction of field and amount of dust measured by looking at a distant star thru polarizer



Interstellar Medium = ISM

- In ISM approximately 1 atom per cubic centimeter and on Earth $30,000,000,000,000,000$ per cubic centimeter
- 75% Hydrogen, 24% Helium, 1% rest

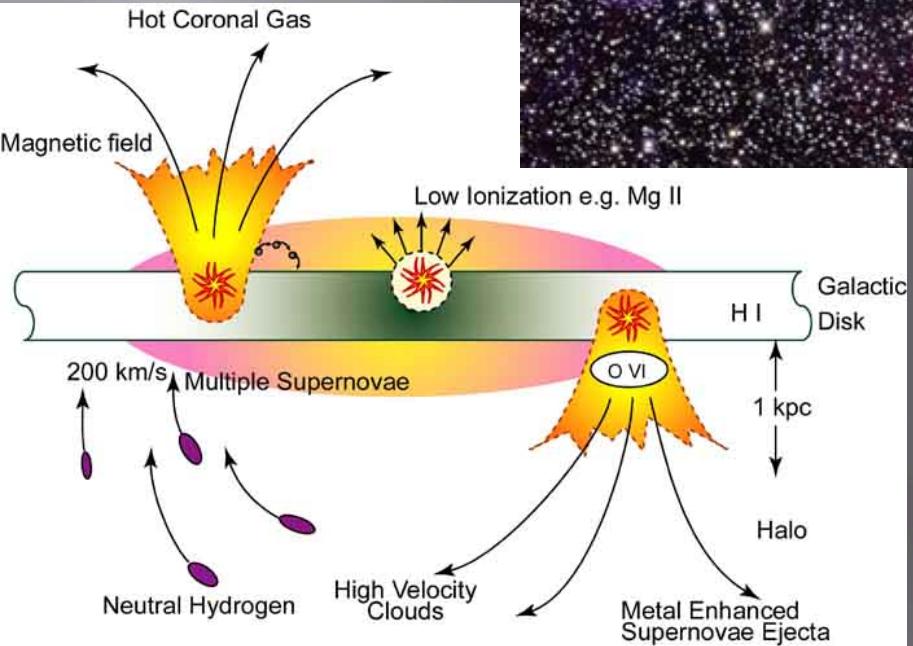


Four Components of ISM

- Four components to Interstellar Medium
 1. Molecular clouds: 1% of ISM by volume
 2. Small neutral HI clouds: 11-25%
 3. Warm intercloud medium HII: 20-50%
 4. Coronal Gas: 30-70%



Coronal Gas



- Ejected by Supernovae
- Seen in X-ray & Ultraviolet
- Temp=Millions Kelvin
- 10^{-3} atoms/cm³

Intercloud medium

Intercloud medium is H II = ionized hydrogen

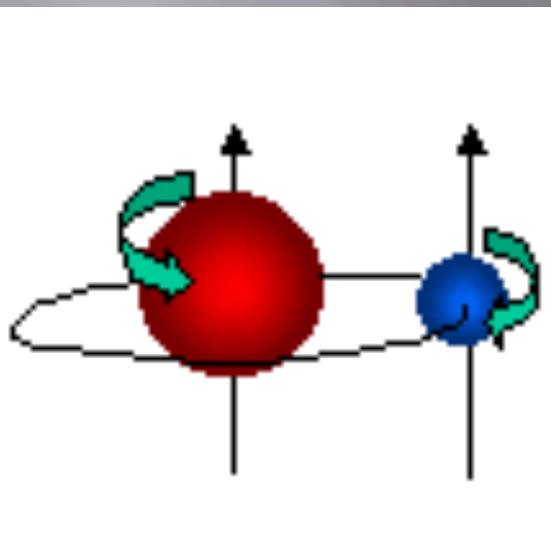
Temperature of thousands of degrees

Density of 0.1 atom/cm³



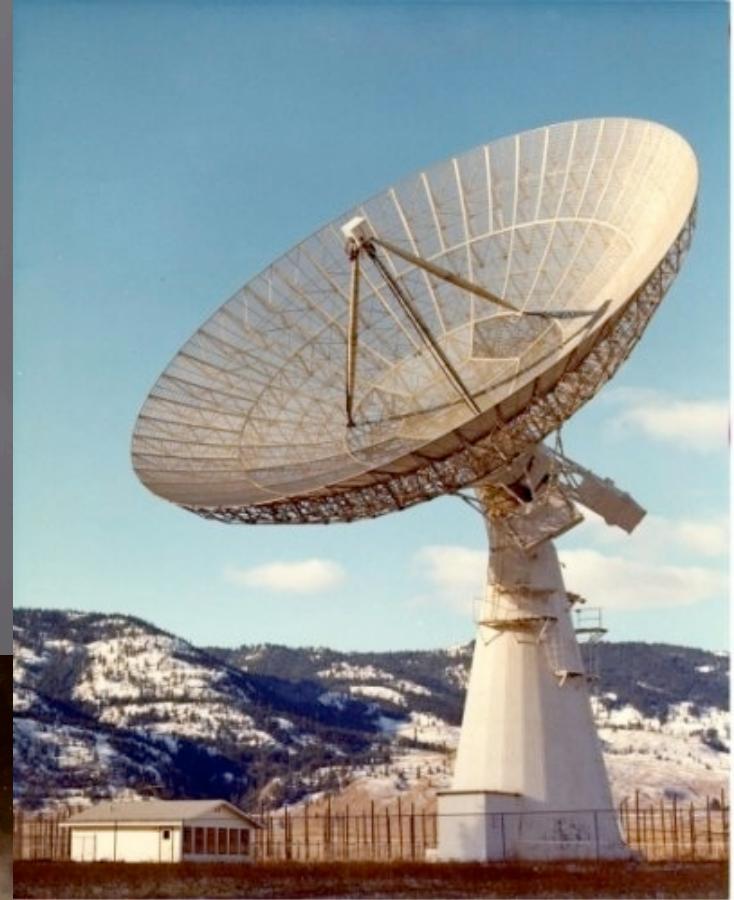
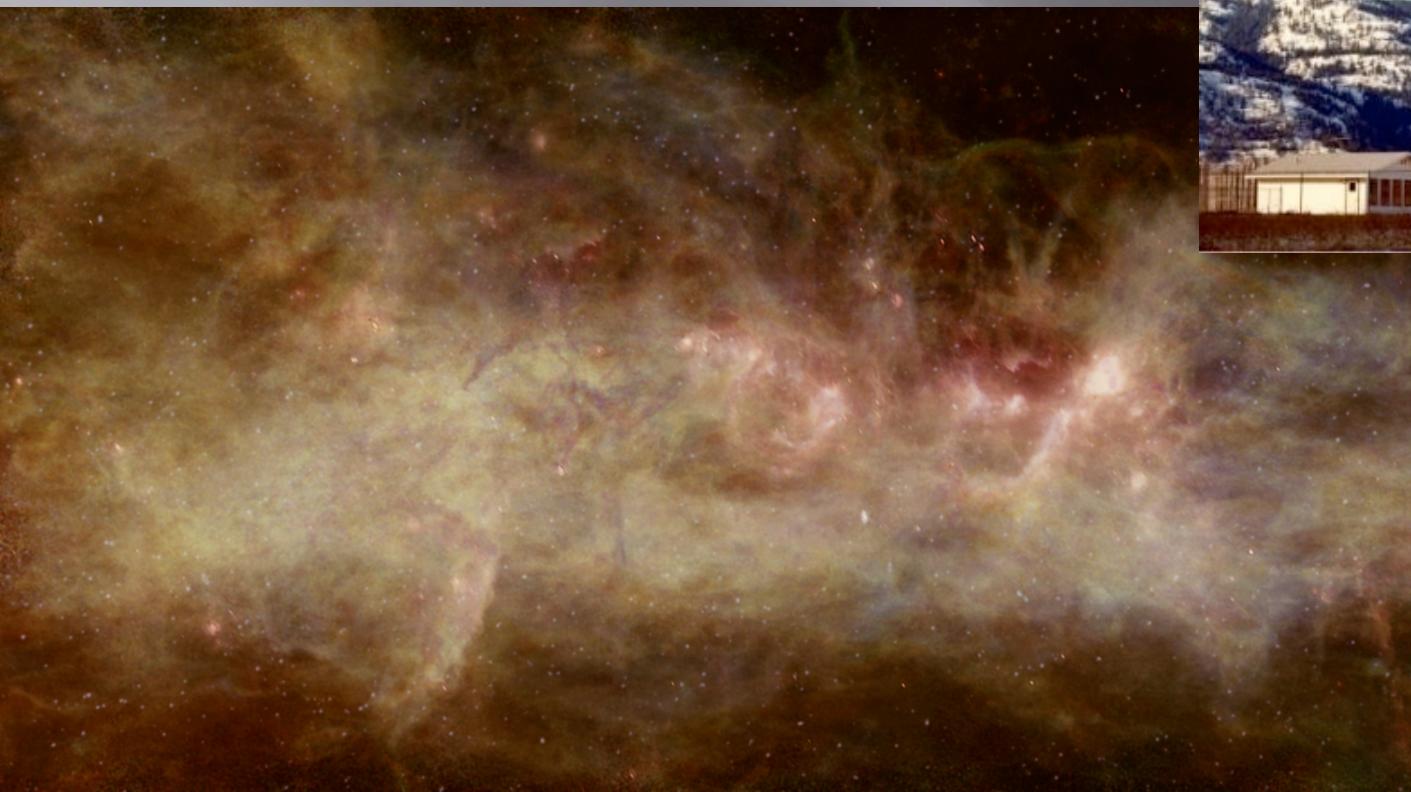
H I Regions = Clouds of Neutral Hydrogen Atoms

- Charged proton and electron spin generating magnetic field
- Magnetic fields aligned has a higher energy
- Energy of forbidden transition between metastable states is equal to one 21 centimeter photon



Canadian Galactic Plane Survey 21cm

- ❑ Advantages: Can detect HI clouds
- ❑ Even through dust clouds
- ❑ Shows shock waves & turbulence on all scales – from supernovae?



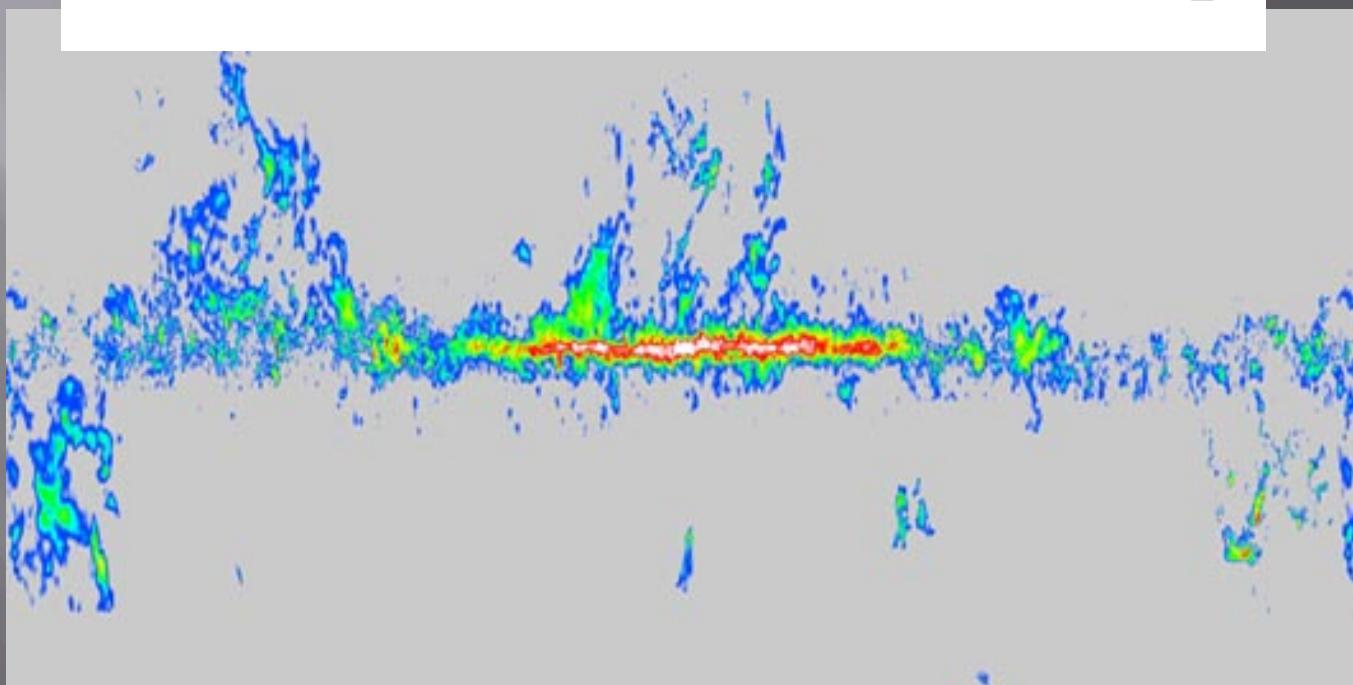
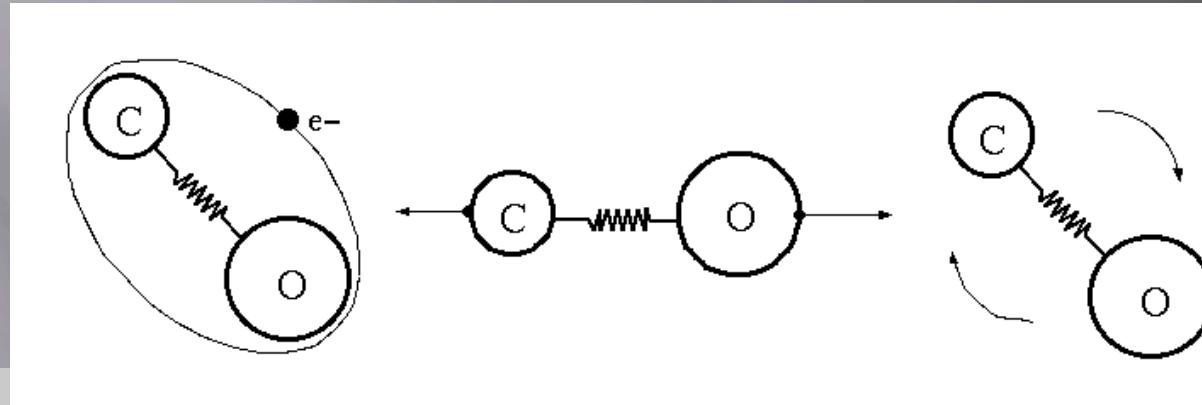
Giant Molecular Clouds

- Molecules of Hydrogen, Carbon Monoxide, etc.
- Protected by dust from UV
- Radiate in Radio
- Very cold ~ 20 K
- $10,000$ atoms / cm^3
- 15-60 pc diameter
- 100-1,000,000 solar masses



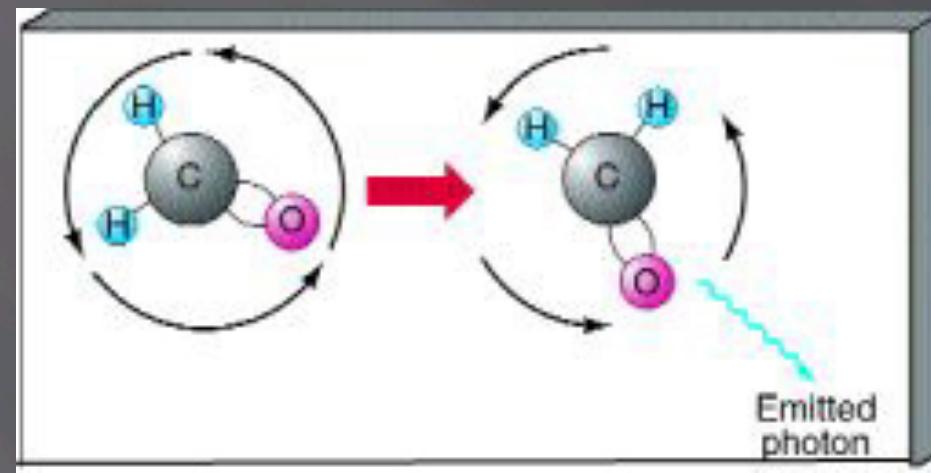
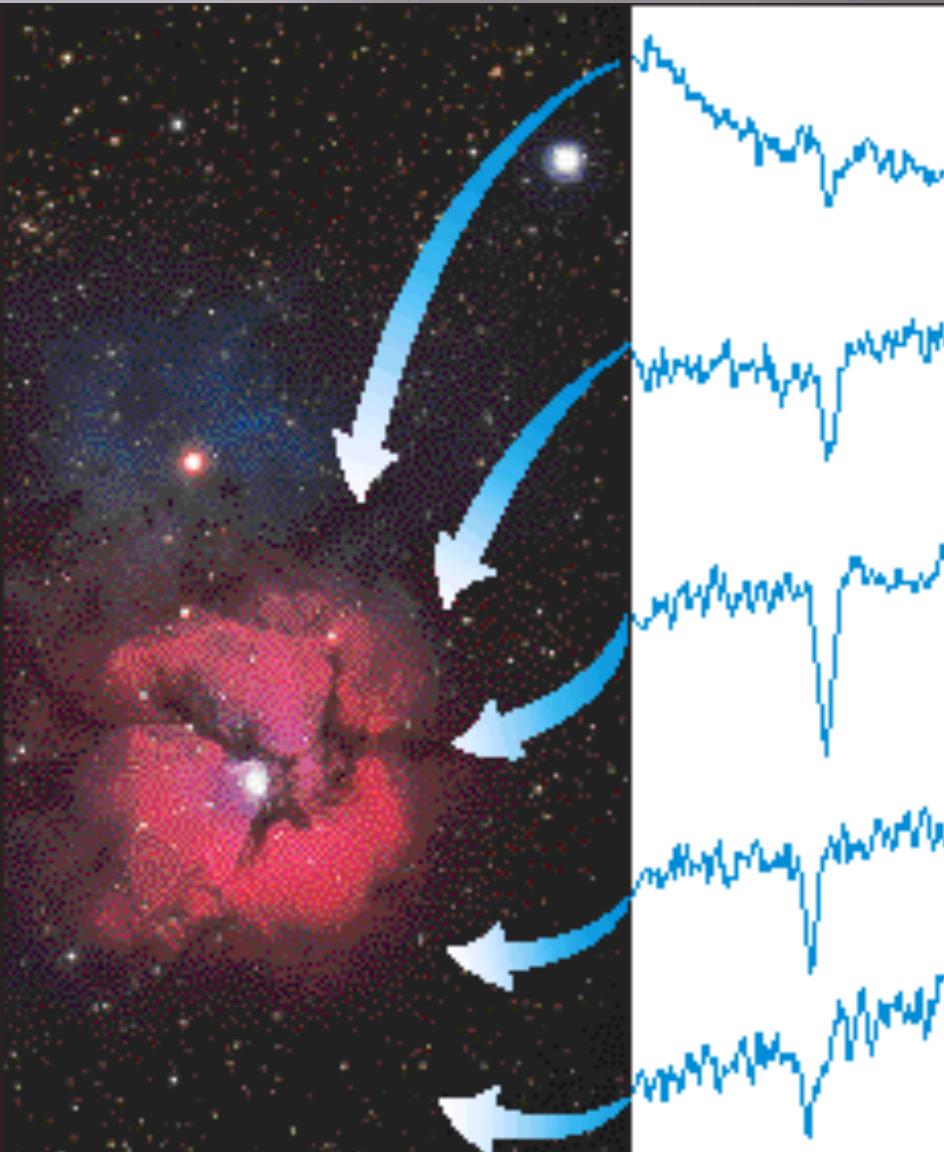
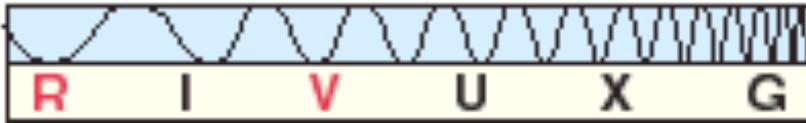
Molecular Hydrogen H₂

- Molecular Hydrogen emits only in UV/Visible so
- Use CO to map Galaxy thru dust



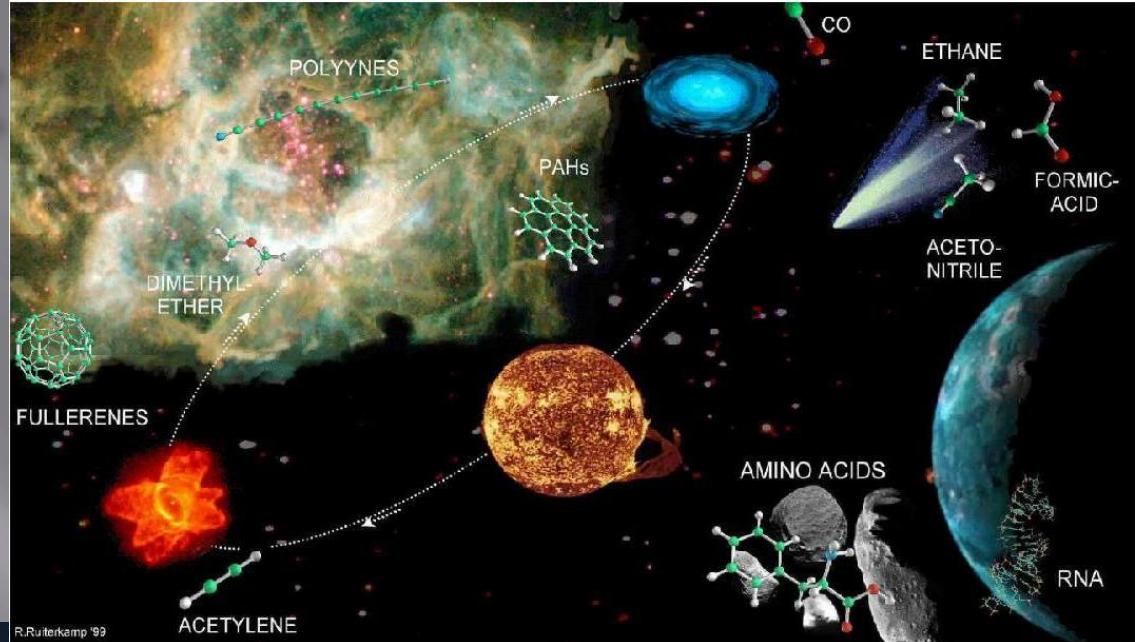
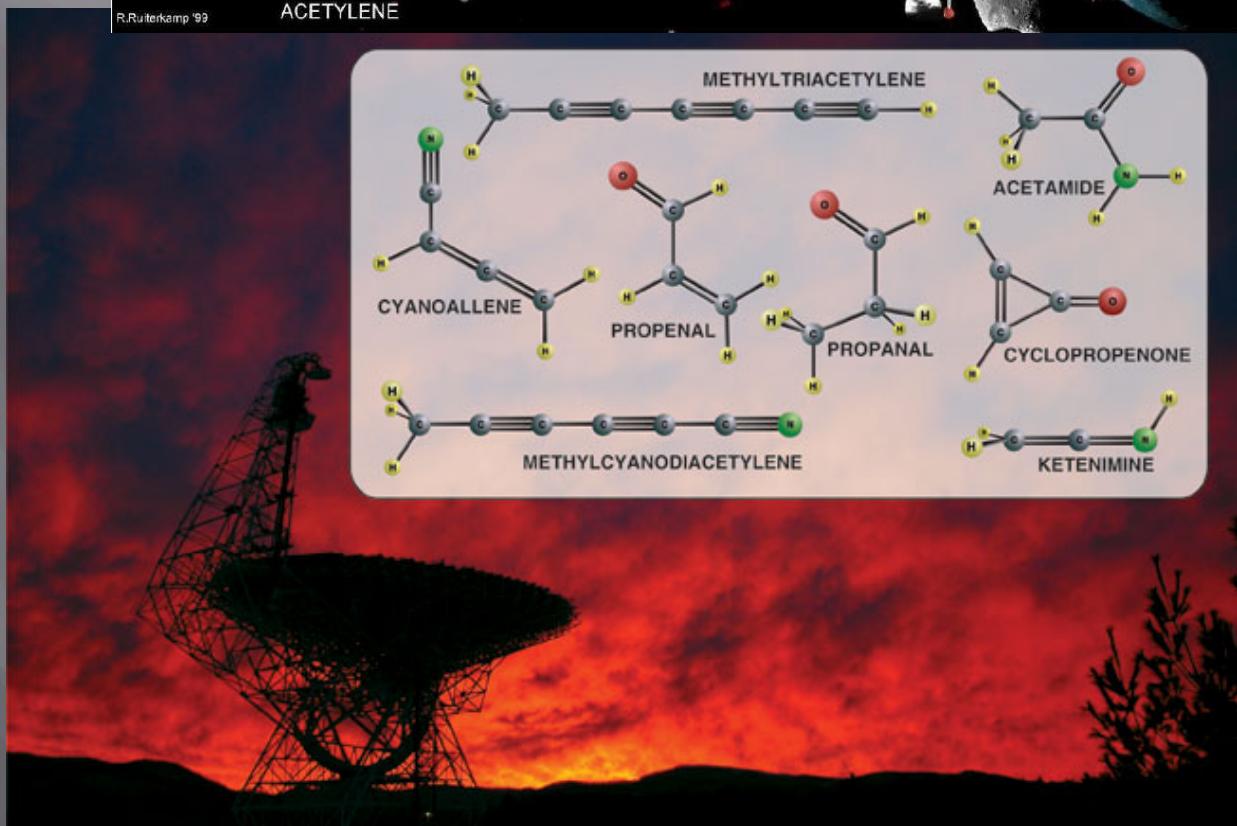
Trifid Nebula

- ❑ Lots of formaldehyde found in dusty lanes
- ❑ Where it is protected from UV and Visible light
- ❑ Temperature sinks to 10K



182 Different Molecules

- Including complex carbon molecules up to $C_{14}H_{10}$ & C_{70}
- Green Bank Radio Telescope
- IRAM 30m telescope in Spain

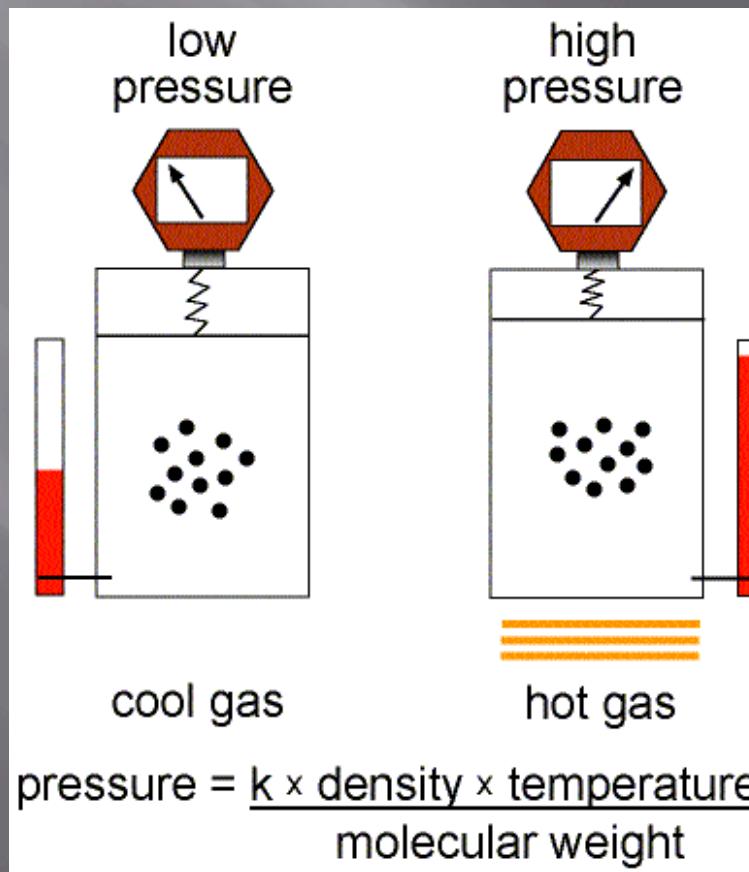


The interstellar medium is composed of:

- a. 75% Hydrogen and 25% Helium
- b. Hot hydrogen HII regions, cool hydrogen HI regions, and very cold molecular hydrogen clouds
- c. Red emission nebulae, Blue reflection nebulae and Black Dark dust clouds
- d. Some dust which reddens, blocks (extinction), and polarizes the background star's light
- e. All of the above are true

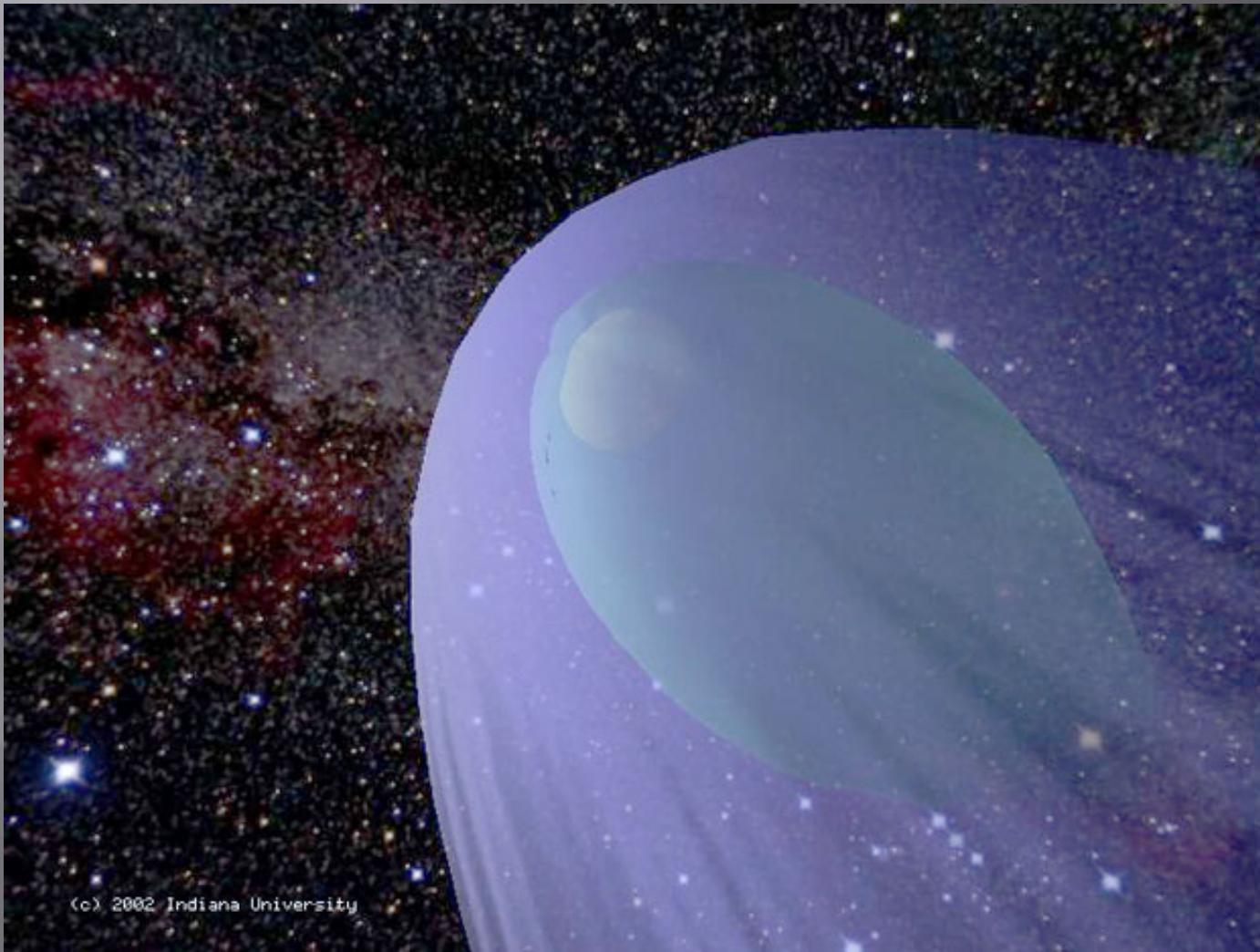
Equal Pressure Among 4 Components of ISM

- Speed/kinetic energy of particles depends on temperature
- $30K = >300 \text{ meters/sec} = 1000 \text{ km/hour}$
- Pressure = Density X Temperature X constant
- Pressure = number of particles X how fast they are moving



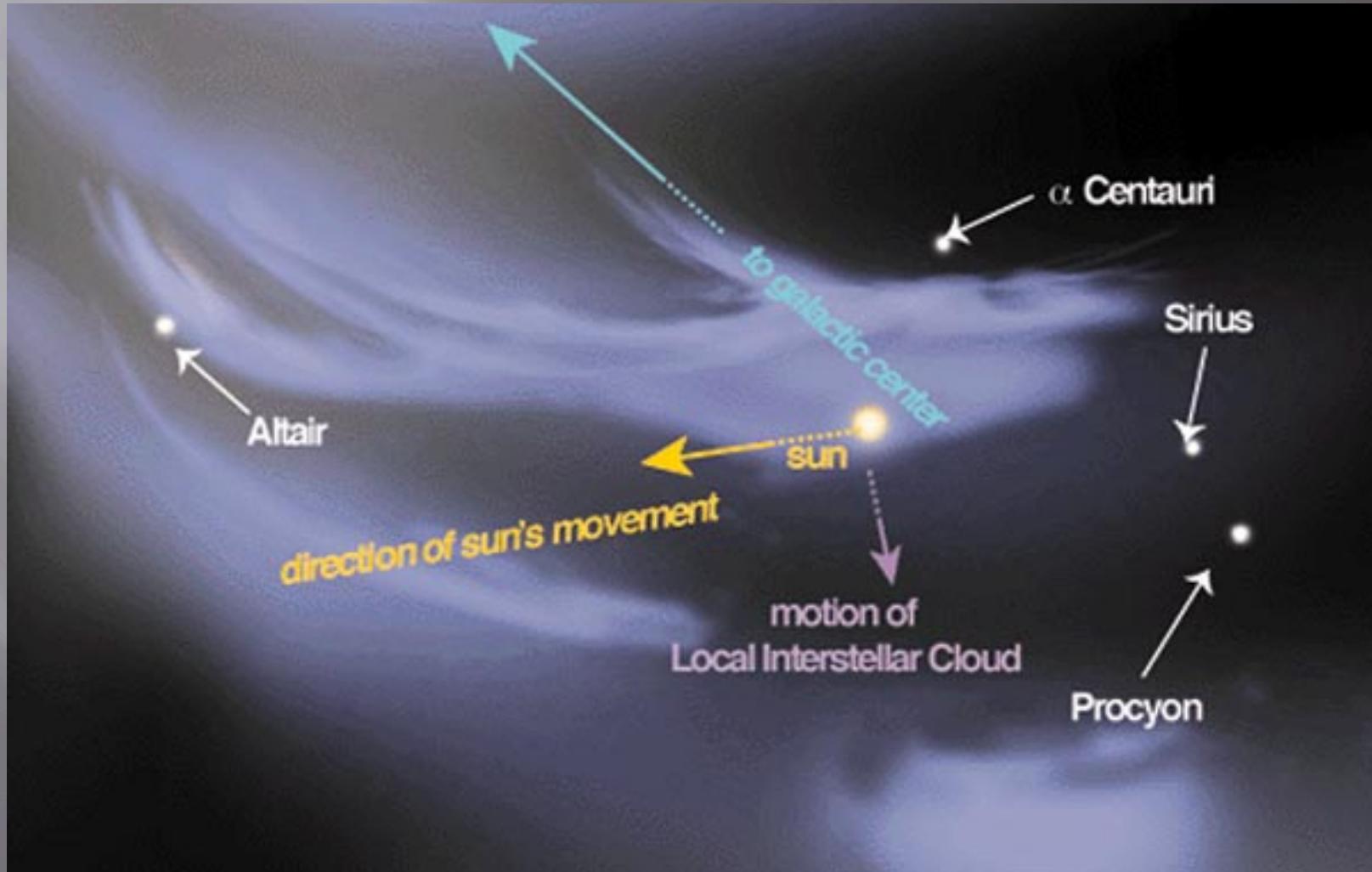
Heliosphere

- Sun ploughs through Interstellar Medium



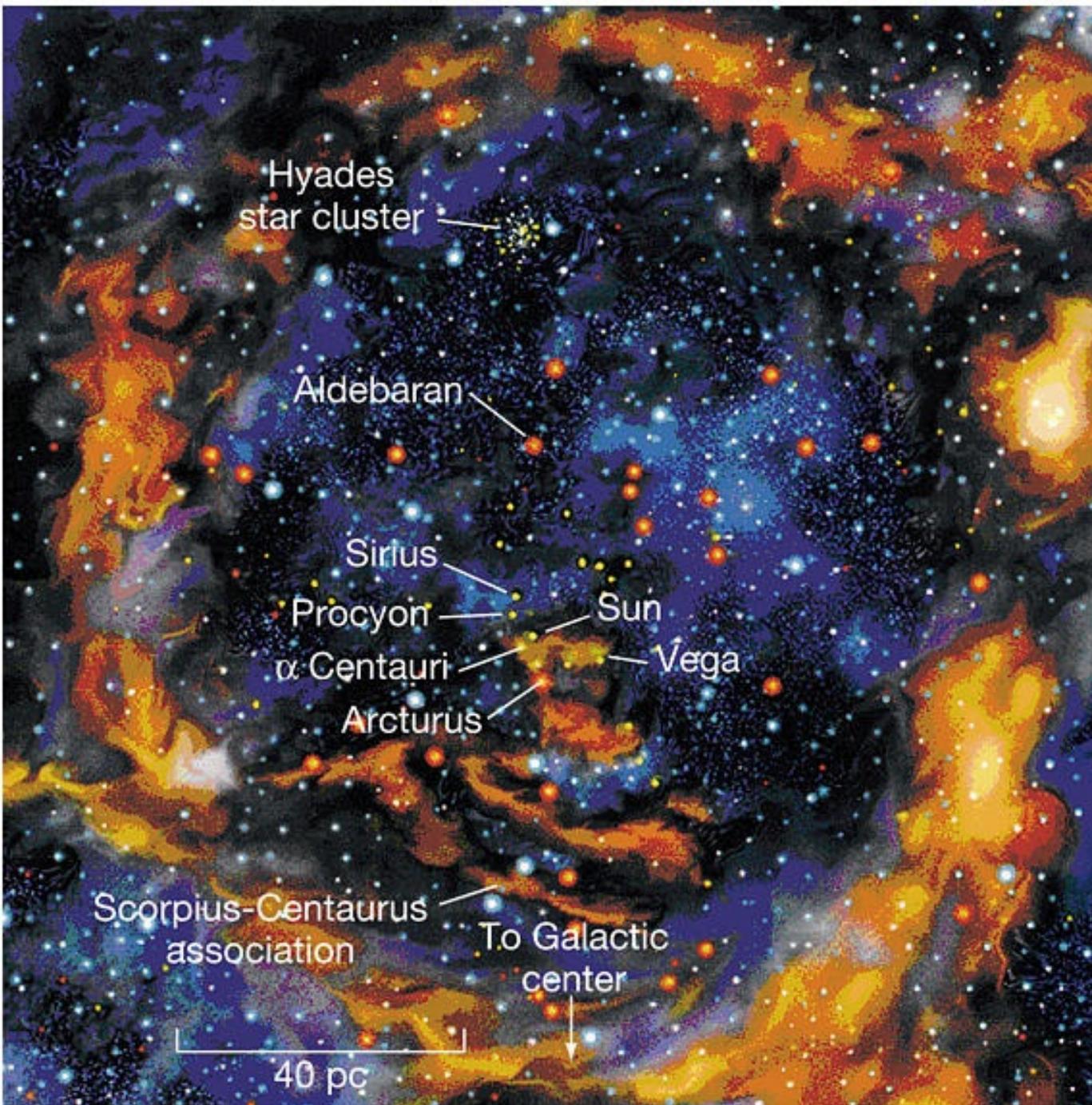
Local Interstellar Cloud

- Approximately 30 light years across



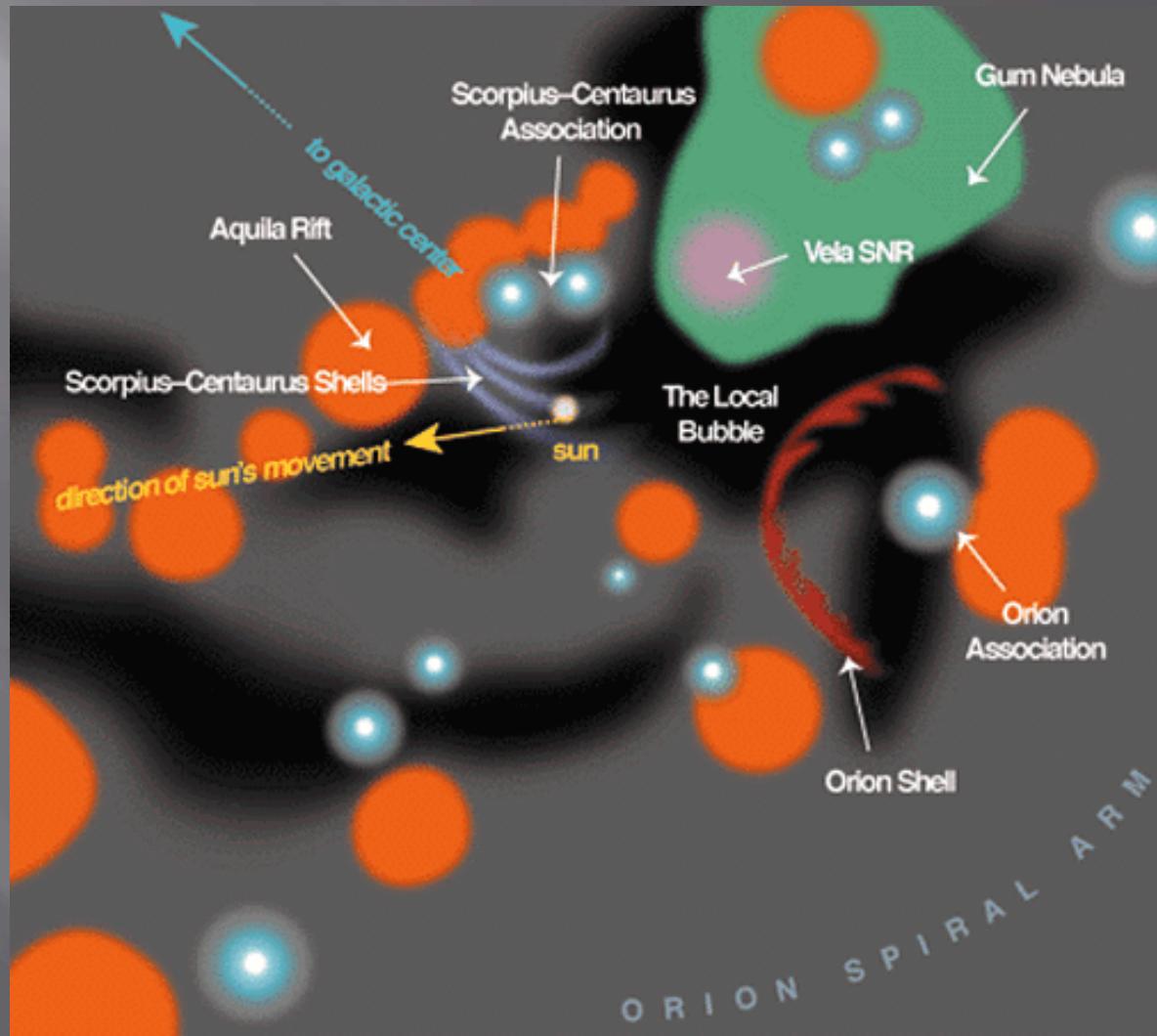
Local Bubble = Local Void

- 300 light years across
- Supernova 10 or 20 million years ago



Local Bubble & Galactic Neighbors

- Surrounding 1500ly
- Four Components of ISM
- Giant Molecular Cloud = star forming region - orange
- Local interstellar HI cloud - violet
- Local Bubble HII - black
- Vela SN Remnant = Coronal - pink

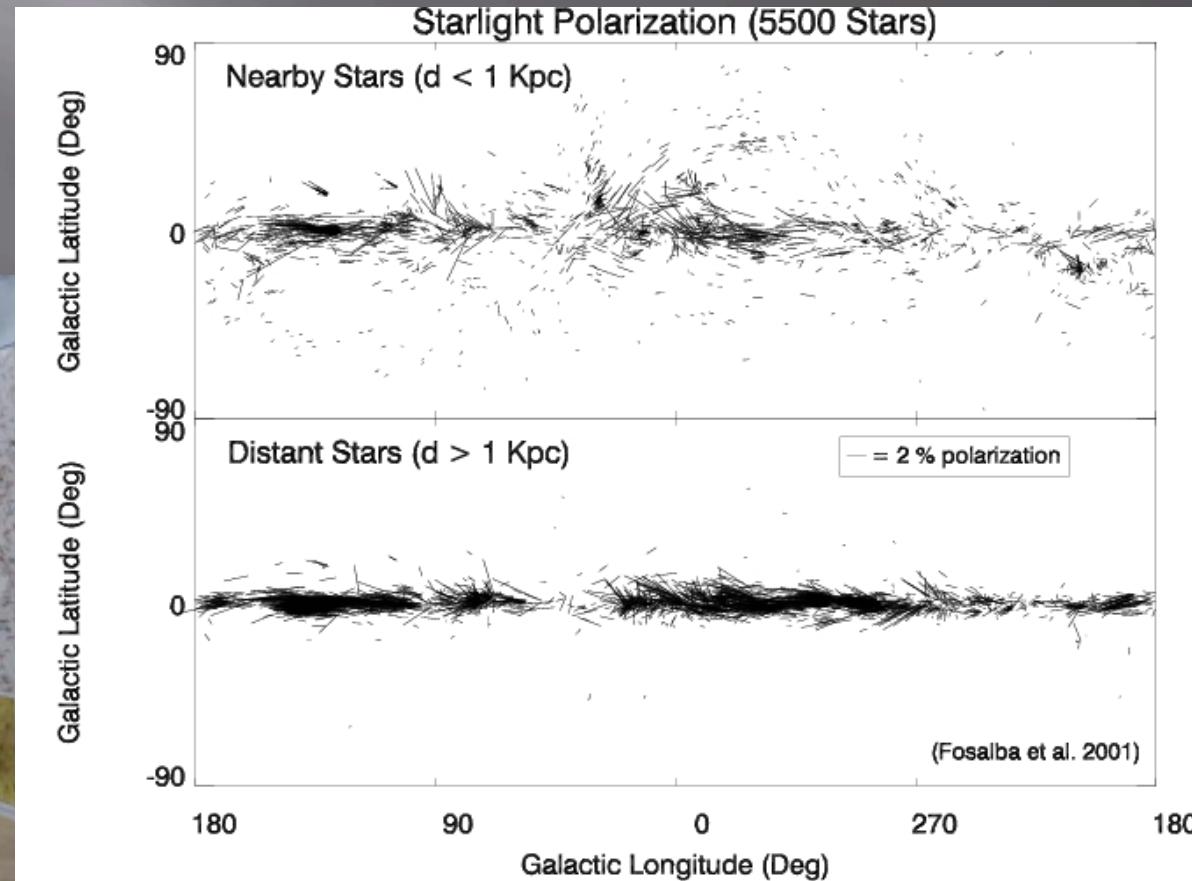
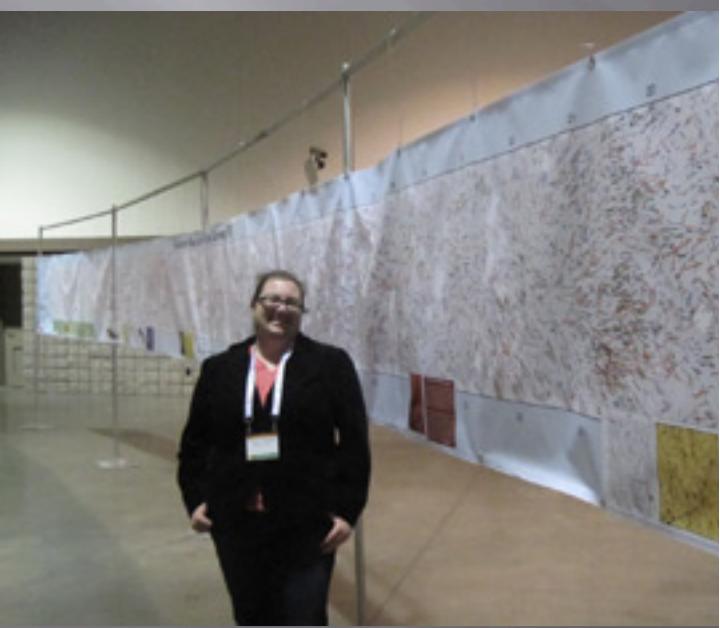
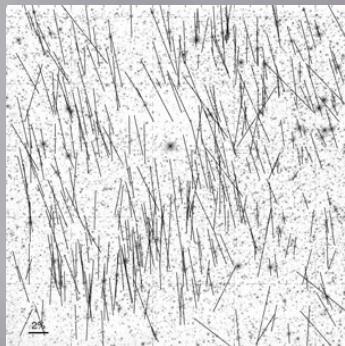


Every Home Needs One



Mapping Galactic Magnetic Field

- Dust grains aligned by galactic magnetic field
- 40 foot poster from Jan 2013 AAS



Dark Cloud and Stars

- Lupus 3 is ~600ly and ~5ly across
- Stars formed ~1 million years ago



Interstellar Extinction Curve

- Dust is not just in clouds
- UV is scattered more than IR so very small particles (1 micron)
- Some kind of carbon molecule makes the bump

