

## The Interstellar Medium

- = the gas disk
- Includes ionized, neutral, molecular gas ( $H^+$ ,  $H^0$ ,  $H_2$ ) = (H I, H II,  $H_2$ )

## Molecular clouds [12.1,12.2]

- Massive interstellar gas clouds
  - Up to  $\sim 10^5 M_\odot$
  - 100's of LY in diameter.
- High density by interstellar medium standards
  - Up to  $10^5$  atoms per  $cm^3$
- Shielded from UV radiation by dust, so atoms combined into molecules.
  - Mostly  $H_2$ , but not easily detectable
  - Also  $H_2O$ ,  $NH_3$ , CO etc.
    - form emission lines in observable passbands
    - CO is usual tracer.
      - mm wave observations ( $\rightarrow$  low angular resolution)
- All stars form in molecular clouds.

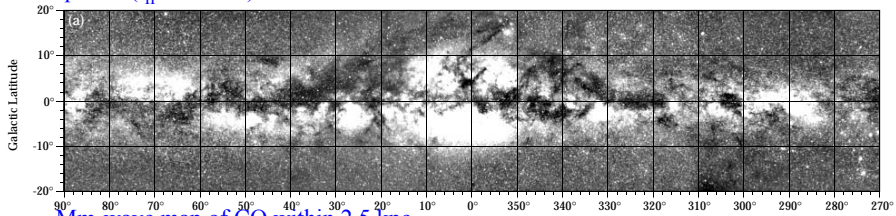
### Fraction by mass

H	73%
He	25%
Metals	2%

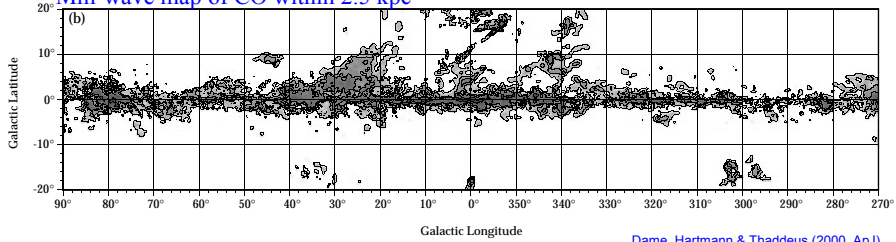
# CO map of Milky Way

Molecular clouds are in the disk and are associated with dust.

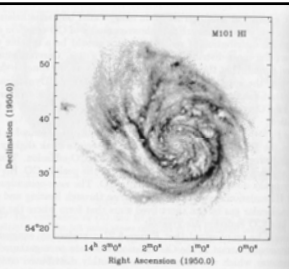
Optical ( $I_{II} = +/- 90^\circ$ )



Mm-wave map of CO within 2.5 kpc



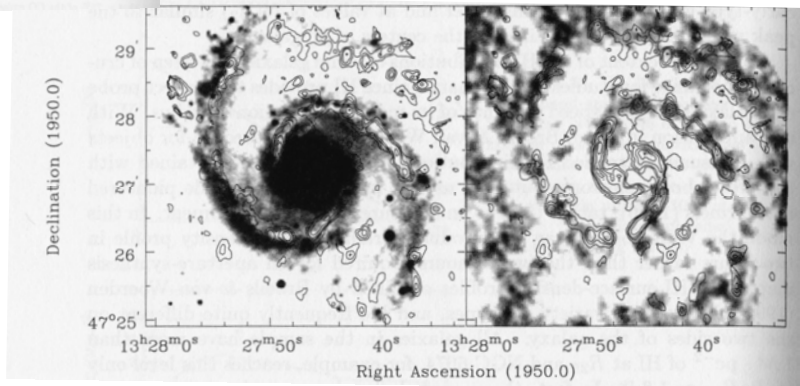
Dame, Hartmann & Thaddeus (2000, ApJ)



M101  
H I (21 cm)  
traces spiral structure

M51

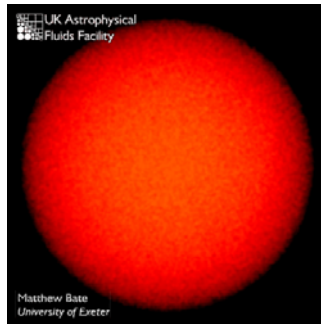
Molecular clouds occur in spiral arms



CO contours over  
red image

CO contours over  
21 cm map

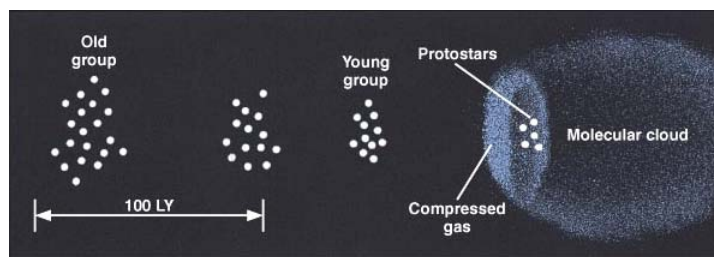
## Computer simulation of Star Formation in a Molecular Cloud



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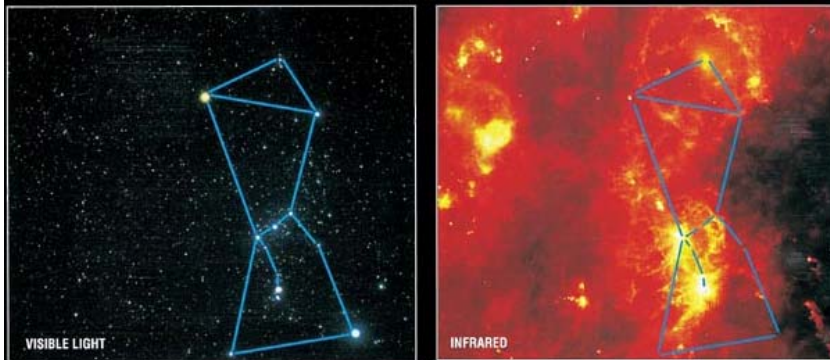
- Collapse and fragmentation of 50 solar-mass cloud.
  - Initially 1 light-year in diameter.

## Star formation thought to propagate in wave through dense molecular clouds



- Photons from very luminous O stars heat and blow away surrounding gas.
- So slightly older clusters no longer shrouded by dusty gas
- Compression of gas further inside cloud causes inward wave of star formation (“triggered” star formation).

## Orion Molecular Cloud



- 100 pc across
- 200,000  $M_{\odot}$
- Only a few of its stars close to the near edge can be seen in visible light.
  - But infrared images penetrate the dust and show many more stars.

## The Orion-Monoceros Molecular Clouds

Orion A	$1.0 \times 10^5 M_{\odot}$
Orion B	0.8
Mon R2	0.9
Total complex	$4 \times 10^5 M_{\odot}$

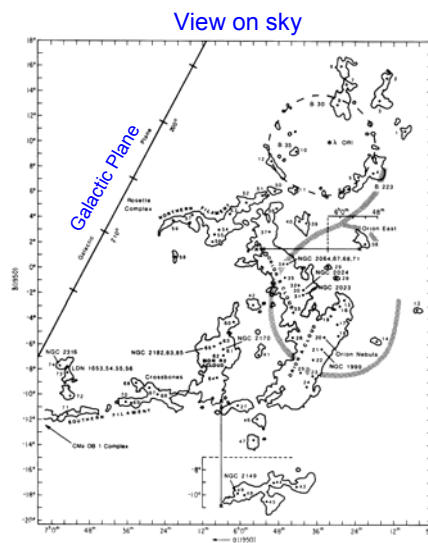
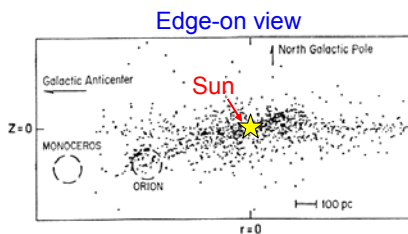
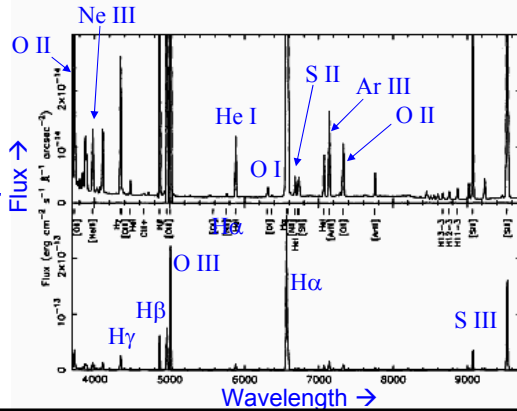
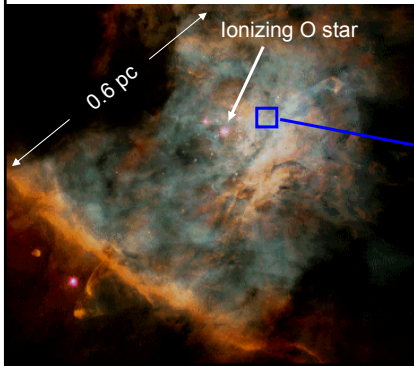
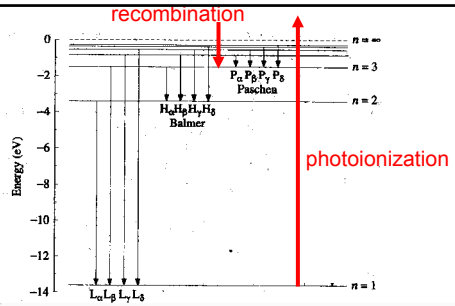


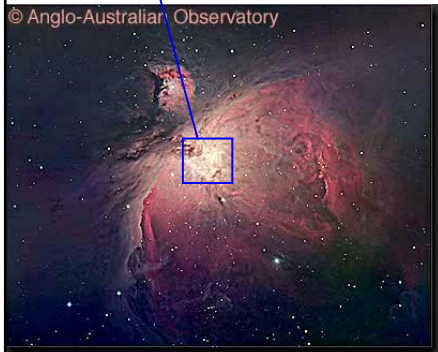
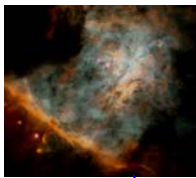
FIG. 3.—Schematic diagram of the molecular clouds: the lower contour from Fig. 2. Data with numbers, corresponding to those in Table 1, indicate locations of CO emission peaks. Some NGC numbers indicate the centrally prominent objects coincident with CO peaks. The extent of CO emission from Monoceros' loop is indicated by the shaded arc (from O'Dell, York, and Herzer 1987; Isobe 1973). The dashed line roughly indicates the extent of the Ori ring of clouds.

# The Orion Nebula

- Ionized by UV photos from hot star.
- Recombination lines from H, He.
- + lines from heavier elements due to collisional excitation.
- → measure chemical abundances.



HII region is small cavity at edge of much bigger molecular cloud



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Earth

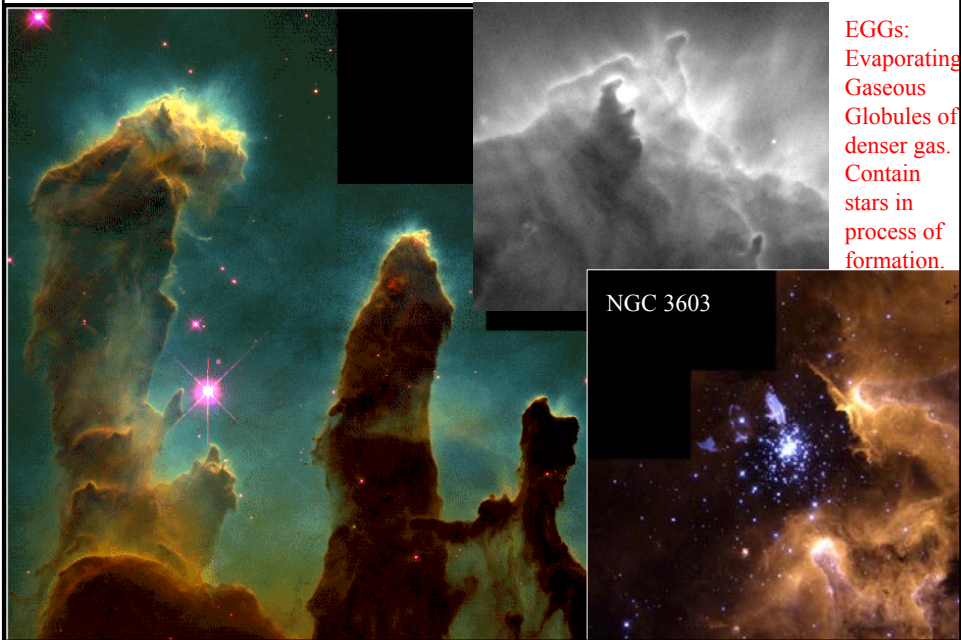


Ionized gas

Ionizing stars

- Ionized region has “blown out” of near side of dense cloud.
  - “Blister” HII Region
- Many more similar star-formation regions buried deep inside cloud.

# M16 "Pillars of Creation"



Nearby star-forming regions:

SOAR mosaic  
200 O stars

30 Doradus, in the Large Magellanic Cloud

SOAR mosaic  
100 O stars

NGC 3603

M 17  
1 pc (3.26 light years)  
H<sub>2</sub> CO etc. (25 km s<sup>-1</sup>)  
H<sup>+</sup> (10 km s<sup>-1</sup>)  
H<sup>+</sup> (0-50 km s<sup>-1</sup>)  
H<sup>+</sup> 8-17 km s<sup>-1</sup> expanding component  
H<sup>+</sup> 20 km s<sup>-1</sup> component  
Line of sight through Pos. 1

M 17  
12 O stars

One O star

Orion

