Observational ISM and Star Formation

<u>This Class (Lecture 7):</u>

Core Masses &
Josh Dolence

<u>Next Class:</u>

More Collapse &
Duncan Christie

Music: *We Are All Made of Stars* – Moby

Astro-ph

1. Protostar Formation in Magnetic Molecular Clouds beyond Ion Detachment I/II/III
   (Kostas Tassis & Telemachos Mouschovias)
   - Formulates the problem of the formation of magnetically supercritical cores in magnetically sub-critical parent molecular clouds, and the subsequent collapse of the cores to high densities, past the detachment of ions from magnetic field lines
   - Follows the ambipolar-diffusion--driven formation and evolution of a fragment in a magnetically supported molecular cloud, until a hydrostatic protostellar core forms at its center

http://arxiv.org/abs/astro-ph/0702036 or 0702037/0702038

Astro-ph

2. Testing grain-surface chemistry in massive hot-core regions
   (S. E. Bisschop, J. K. Jorgensen, E. F. van Dischoeck and E. B. M. de Wachter)
   - Submillimeter line-survey toward 7 high-mass YSOs aimed at detecting complex organic species
   - Try to establish the chemical origin of a set of complex organic molecules thought to be produced by grain surface chemistry
   - Find two families: hot and cold species

http://arxiv.org/abs/astro-ph/0702066

Talks

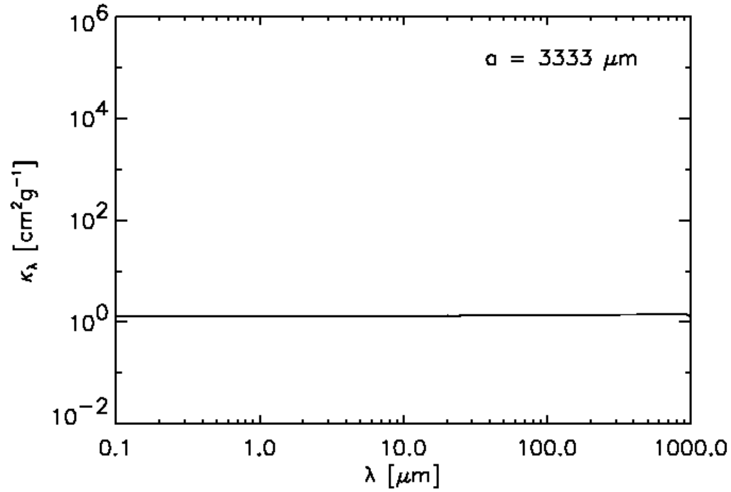
1. The Journey of the Sun Through Our Galactic Environment and Its Effect on the Heliosphere and Earth (Priscilla Frisch)
   - Astronomy Colloquium, Tuesday, 1600, in classroom
2. Graduate Student from Australia, Annie Hughes, will give a talk on her research interest of molecular cloud structure and evolution and the far-infrared/radio correlation, with particular emphasis on the LMC.
   - Star Formation Lunch, Thursday, Noon, in classroom
3. Connecting Local and Global Star Formation
   (Erik Rosolowsky)
   - Journal Club, Friday, Noon, in classroom ($1.50/slice of pizza)

Outline

- Structure of molecular clouds?
- How are they formed?

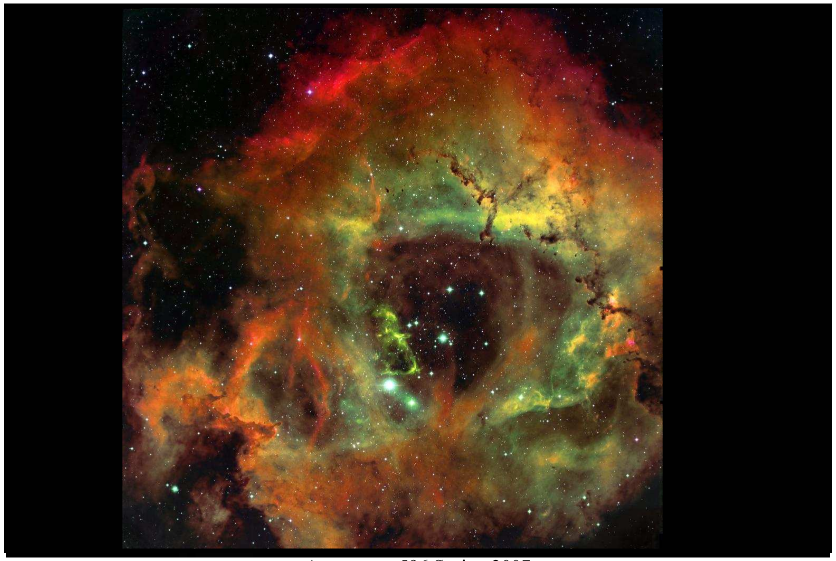
Dust Opacities Example: Silicate

Opacity of amorphous olivine (silicate) for different grain sizes



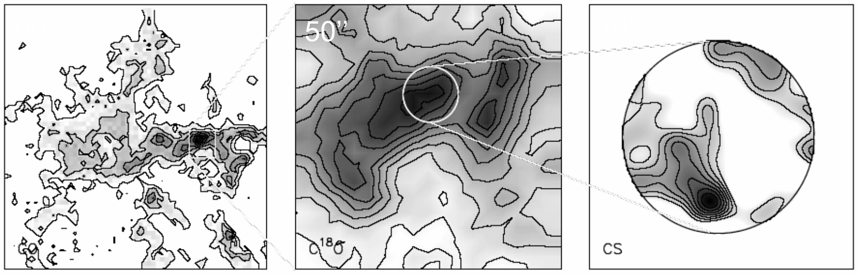
http://www.mpia-hd.mpg.de/homes/dullemon/lectures/starplanet/index.html

The Rosette HII Region & Molecular Cloud



Structure of Molecular Clouds

- What is the topology of molecular clouds?
  - CO maps show that molecular gas is inhomogeneous
    - Discrete clumps?
      - Clouds, clumps & cores?
    - Hierarchical/self-similar/fractal?



Giant Molecular Clouds

<u>Structure of GMCs: two descriptions</u>

- Clump picture: hierarchical structure
  - Clouds (≥ 10 pc)
  - Clumps (~1 pc)
    - Precursors of stellar clusters
  - Cores (~0.1 pc)
    - High density regions that form individual stars or binaries

- Fractal picture: clouds are scale-free

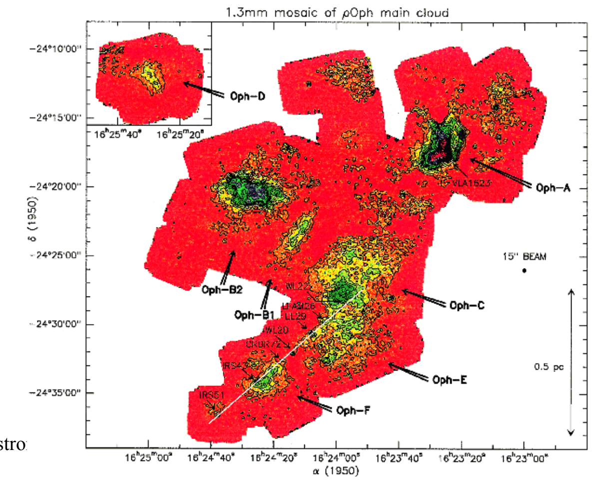
$V \propto A^{D/2}$ $D \approx 1.4$ fractal dimension

Core mass spectrum

Most clumps don't form stars. But if they do, they form many.

Core mass spectrum is more interesting for predicting the stellar masses of the newborn stars.

Deep 1.3 mm continuum map of ρ Ophiuchi (140 pc) with 0.01 pc (= 2000 AU) resolution.
(Motte et al. 1998)



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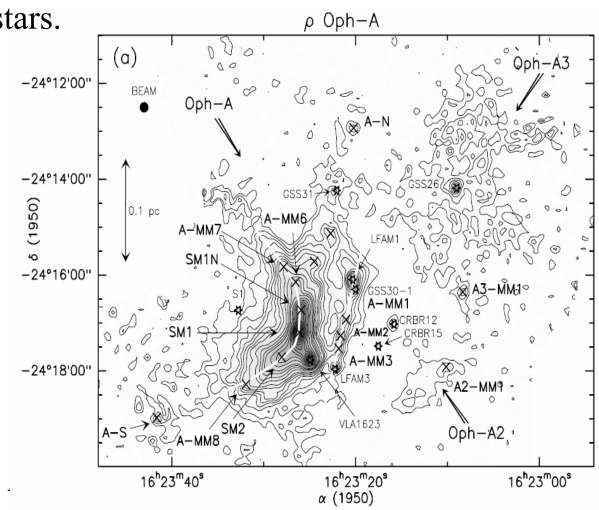


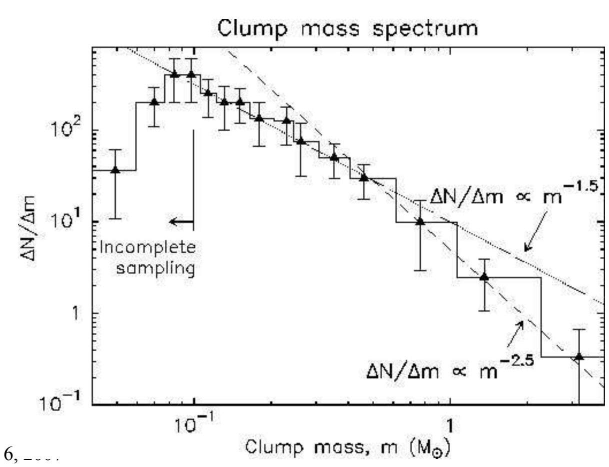
Core mass spectrum

$$\frac{dN}{dM} \propto M^{-1.5}$$

for M < 0.5 $M_\odot$

$$\frac{dN}{dM} \propto M^{-2.5}$$

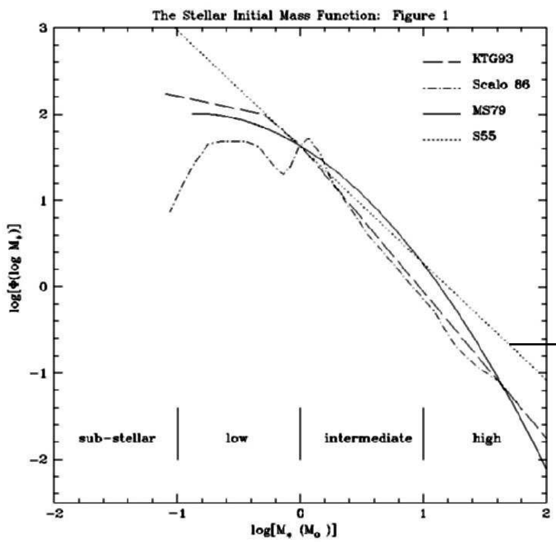
for M > 0.5 $M_\odot$



Motte et al. 1998

Core mass spectrum

Similar to stellar IMF (Initial Mass Function)



Stellar IMF:
Meyer et al. PP IV

Salpeter (1955) IMF:

$$\frac{dN}{dM} \propto M^{-2.35}$$

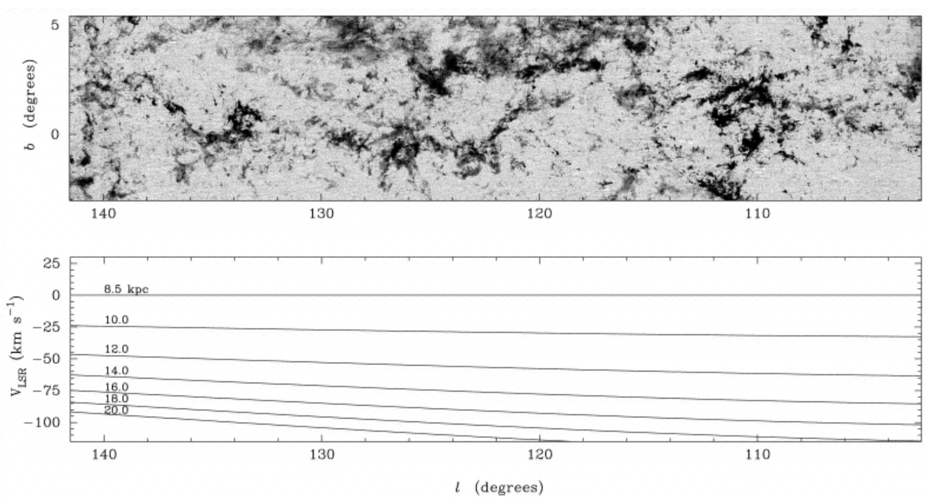
Where are Molecular Clouds?

FCRAO outer Galaxy Survey
(Heyer et al. 1998 ApJS 115 241)

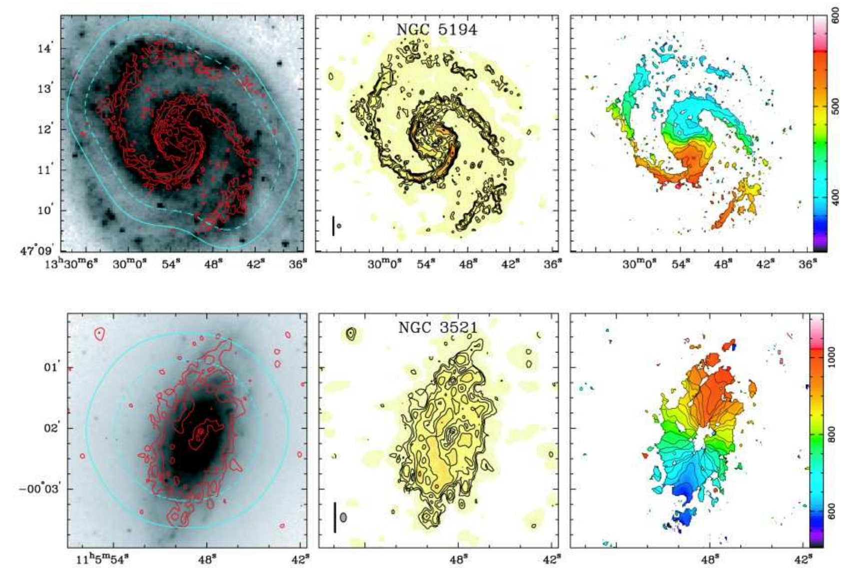
- No kinematic distance ambiguity & less confusion
- Regions with little or no CO emission
  - Cleared of molecular gas by O stars
    - Photodissociation, stellar winds & supernova explosions
    - These processes may sweep up molecular gas and compress it to form the next generation of stars
  - CO is exclusively found in spiral arms
    - H_2 Arm/interarm contrast ~ 30:1 --- HI is 2.5:1
    - Molecular clouds form in a compressed atomic medium
    - Lifetime < arm crossing time ~ 10^7 yr
      - Consistent with depletion rate of H_2 by star formation

Interarm CO?

- FCRAO CO survey of the outer Galaxy
  - Local arm (0 to -10 km/s) and Perseus arm (-40 km/s)
  - No CO between



Helfer et al. 2003 ApJS 145 259



Formation of Molecular Clouds

- What is the dominant factor in the formation of molecular clouds?
  - Gravity, radiation, magnetic fields?
  - GMCs are known to be self gravitating
    - Mean internal pressures exceeds that of the ISM by ~ 10
    - GMCs are short lived
      - Minimum lifetime is ~ 20 Myr (age of oldest associated stars)
      - GMCs are older than their crossing times
    - Gravity must play a role, but there are low mass, high latitude molecular clouds that are not self-gravitating
      - H_2 chaff/fluff ($M < 10^3 M_\odot$)

HI into H_2?

Three categories (Elmegreen 1990):

- Collisional agglomeration of smaller H_2 clouds (or HI flows?)
- Shocks
  - Supernova remnants, galactic shocks
- Gravo-thermal instability in the disk.

Agglomeration of H_2 clouds doesn't make sense. Not enough fluff around.

Collapsing

- We have molecular cloud cores, now what happens?