Complex Cloud Structure with CCAT

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Prospects for High Resolution Spectroscopy with CCAT
Köln, 2011 October 6

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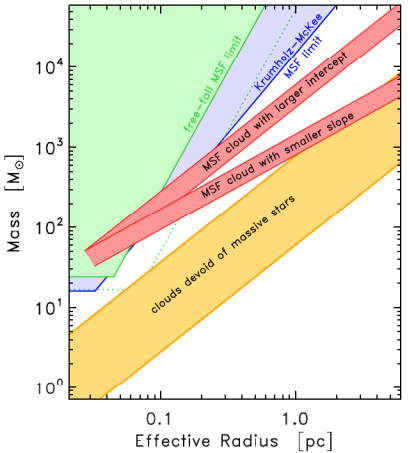
Global Structure of Molecular Clouds



basic idea:
explore cloud properties over a vast range of spatial scales

Main Co–Authors

T. Pillai, R. Shetty, G. Parmentier, P.C. Myers, A.A. Goodman
on published papers

Crucial Collaborators

Di Li, Qizhou Zhang

. . . and others. . .

Outline

1. Contour–to–Contour Structure Analysis
2. Relation to CCAT Science
3. Summary

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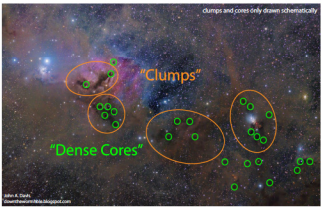
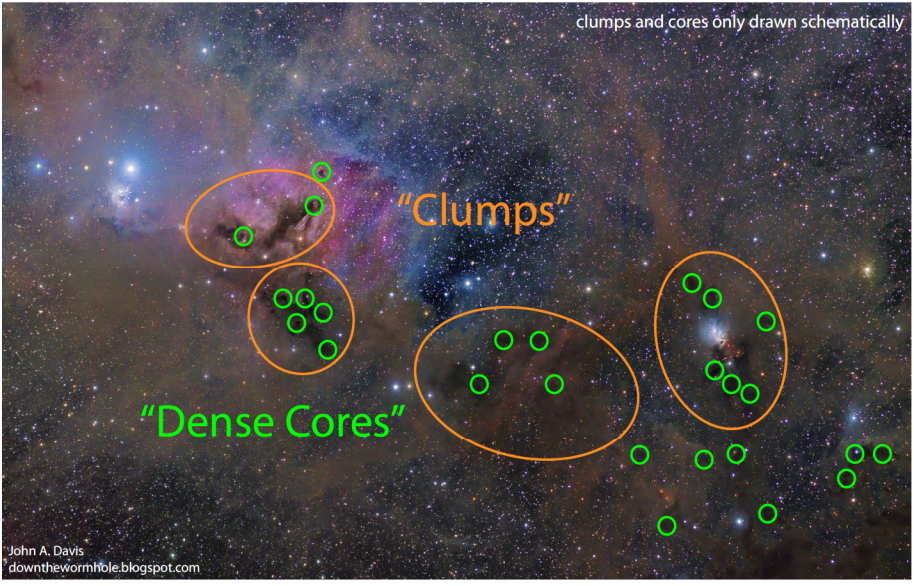


References

Rosolowsky et al. (2008)

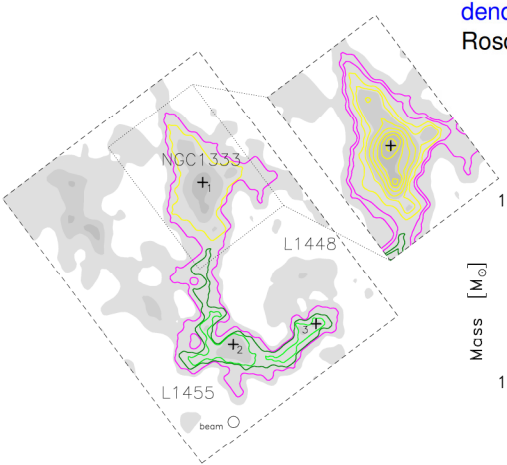
Kauffmann et al. (2010a,b,c), paper I–III

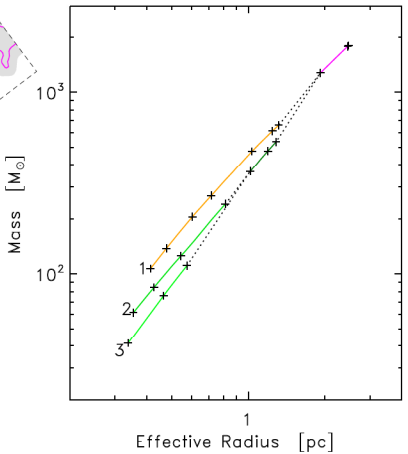
Sub–Structure in Molecular Clouds



Method

dendrograms:
Rosolowsky et al. (2008)

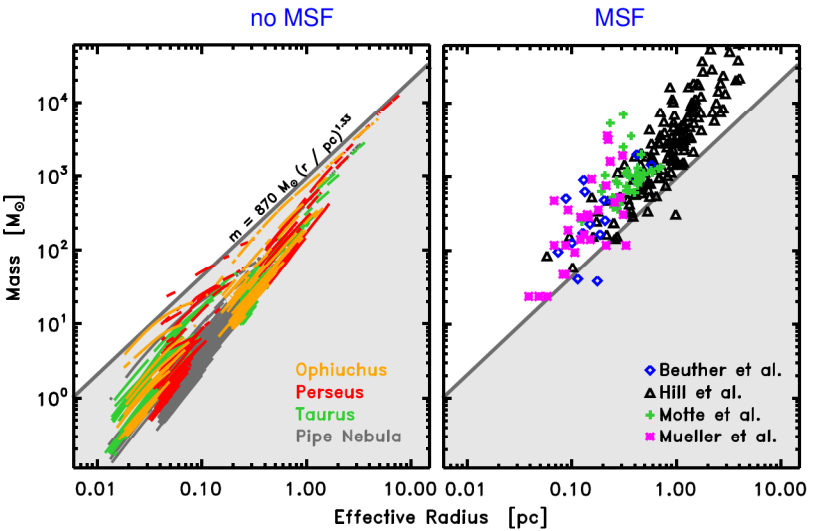




extinction data: Ridge et al. (2006)

$$r_{\mathrm{eff}} = (A/\pi)^{1/2}$$

Clouds with and without Massive Star Formation



$m(r) \sim 870\, M_\odot\, (r/\mathrm{pc})^{1.33}$ is an approximate MSF threshold

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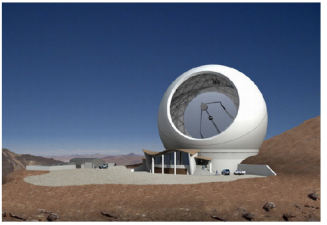
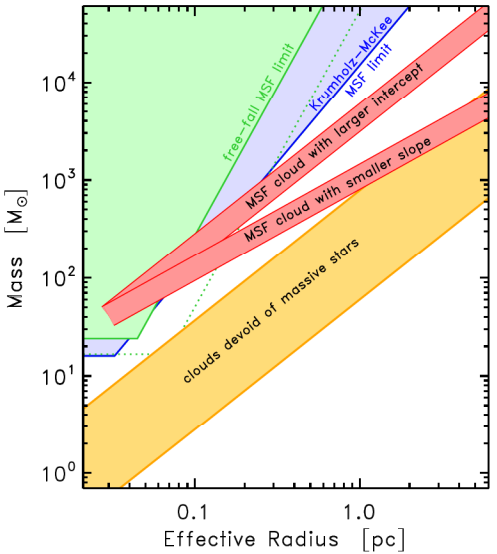


Papers in Preparation

with Thushara Pillai, Di Li, Qizhou Zhang

Dust Continuum: MSF at Small Spatial Scale



MSF at small spatial scale:

- probes immediate MSF birth environment
- tests model predictions

observational problem: interferometer filtering

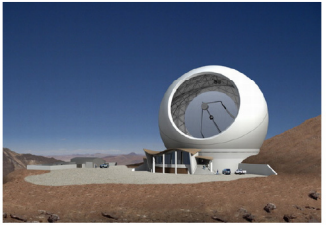
CCAT can help

zero–spacing dust continuum observations

. . . requires excellent spectral coverage

⇒ imaging spectrographs? (like DESHIMA)

CCAT and Emission Line Observations



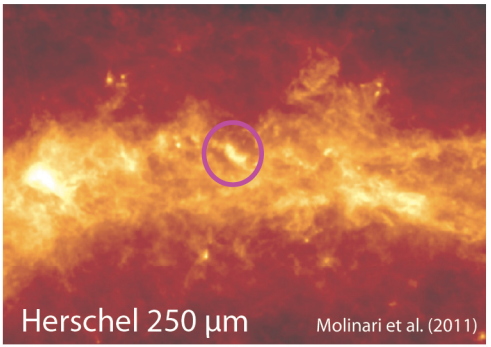
physical problems:

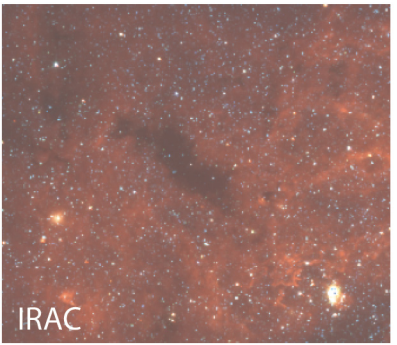
- chemistry — probes physical conditions, cloud ages, YSO feedback
- kinematics — probes physical conditions and feedback
- "invisible" gas — material only detectable in specific tracers

research fields:

- YSO feedback — e.g., to assess how turbulence is injected into clouds
- cloud formation and evolution — spatial trends in chemistry, kinematics
- galaxies — e.g., characterization of star formation conditions

Example 1: Galactic Center Cloud M0.25+0.11





$M \sim 10^5\ M_\odot$

$\Rightarrow$ similar to Orion A

$r \sim 2.5$ pc

$\Rightarrow$ like a molecular clump

little star formation, H_2O maser is only signpost

rather cold with ~ 18 K

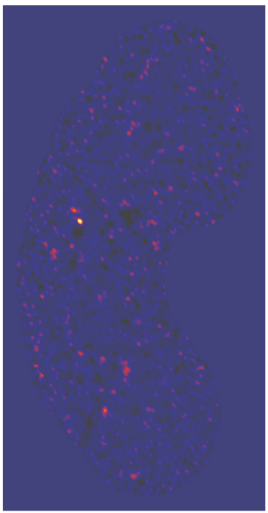
(Lis et al. 1994, 1998, 2001)

also see: Longmore et al. (submitted)

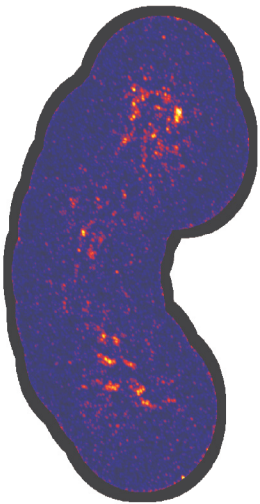
G0.25, “The Brick”

Example 1: Galactic Center Cloud M0.25+0.11

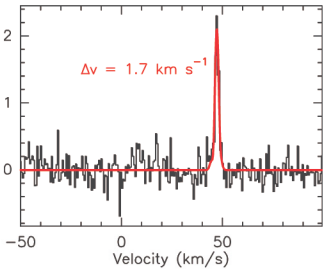
280 GHz continuum



N2H+ (3–2)



SMA data



main results:

- no dust cores
- many faint N_2H^+ cores
- low line widths, down to $\lesssim 1\ \mathrm{km\,s^{-1}}$
- cores spread out over $\sim 40\ \mathrm{km\,s^{-1}}$ velocity range

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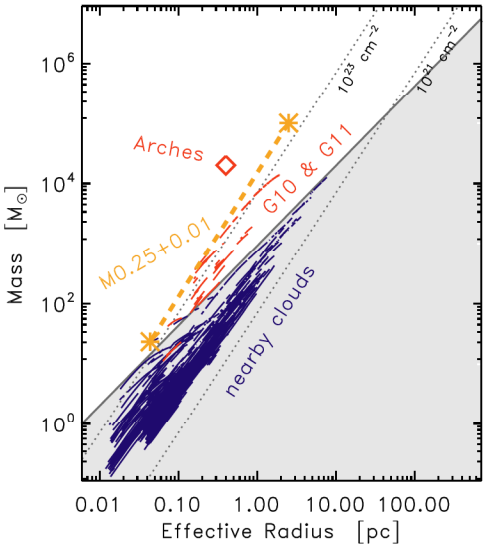


analysis:

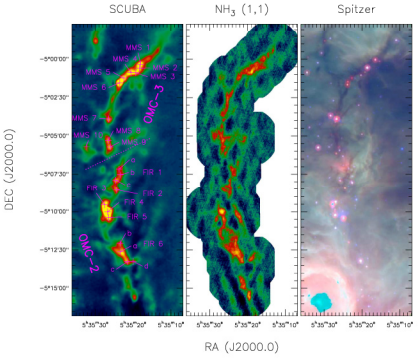
- structure with $\sim$ 2 pc radius
- must be compared with wide–field maps of local clouds
- analysis of small–scale structure also needed

reference maps from CCAT

can help when maps have large spatial dynamic range

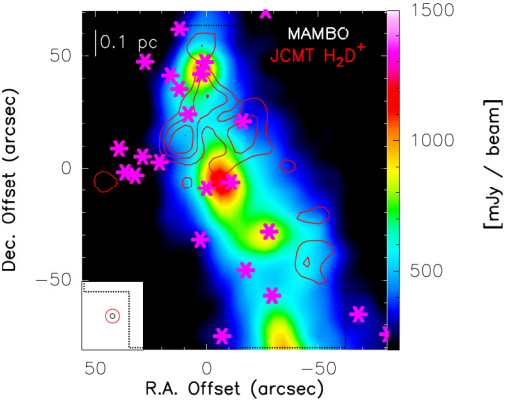
Example 2: Peculiar Conditions and “Invisible” Gas

dense gas kinematics



Kauffmann, Li & Zhang (in prep.)

otherwise “invisible” regions

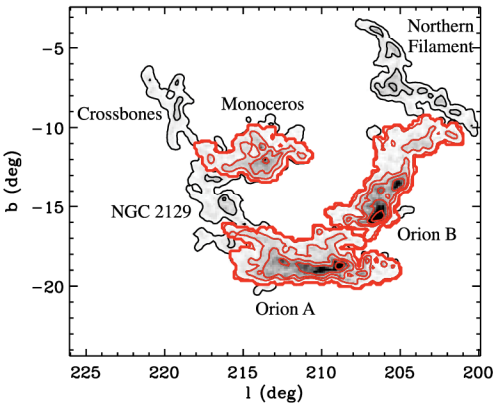


Pillai et al. (in prep.)

MAMBO: Motte et al. (2007)

Example 3: Mapping Cloud Kinematics

bound regions



Rosolowsky et al. (2008)

virial parameter:

$$\alpha = \frac{M_{\rm vir}}{M}$$

$\alpha < 2 \quad \Rightarrow \quad$ cloud bound

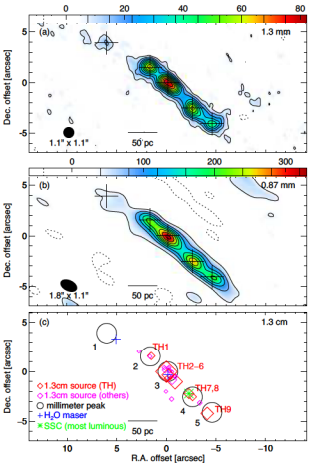
cloud identification:
identify clouds as largest bound structures

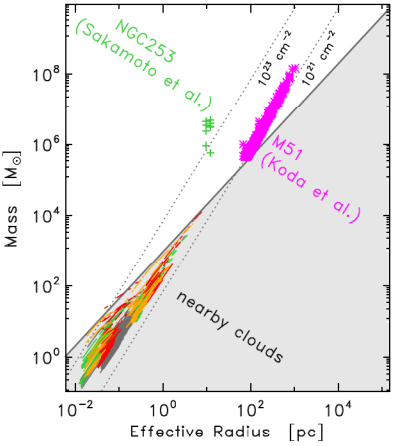
CCAT cloud complex maps

maps can decipher kinematic substructure

Example 4: Other Galaxies

Sakamoto et al. (2011)





wide–field CCAT maps

allow to study galactic and extragalactic clouds at the same spatial scale

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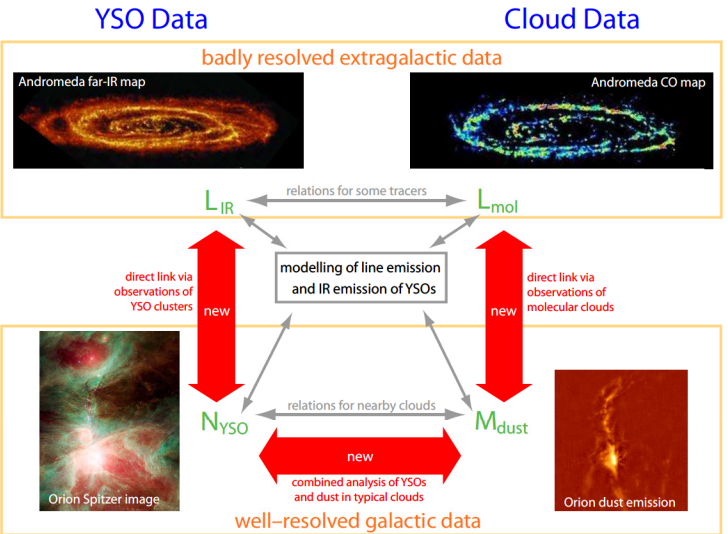

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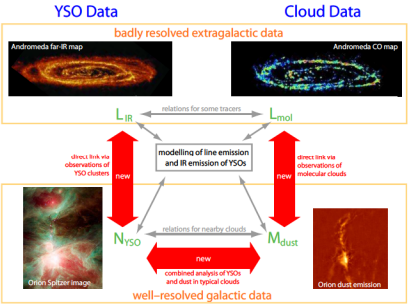

complete CCAT maps of cloud

allows understanding of extragalactic star formation laws

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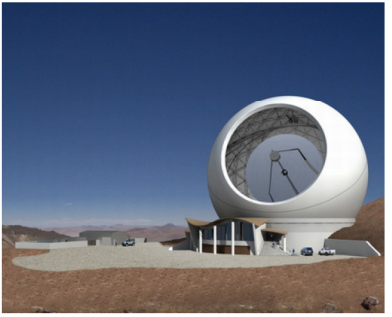
Complex CCAT Maps: Their Use and Analysis

contour–to–contour analysis

. . . also known as dendrograms

ideal tool to characterize cloud structure over a vast range of spatial scales



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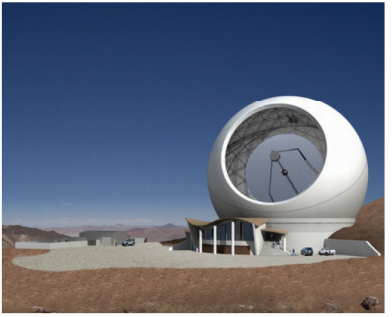

CCAT tasks

- dust zero spacing data
- probe peculiar lines
- measure cloud kinematics
- produce comparison data for distant clouds

systematic work can explain extragalactic star formation laws

CCAT map requirements

- wide fields
- high spatial dynamic range
- imaging spectrographs