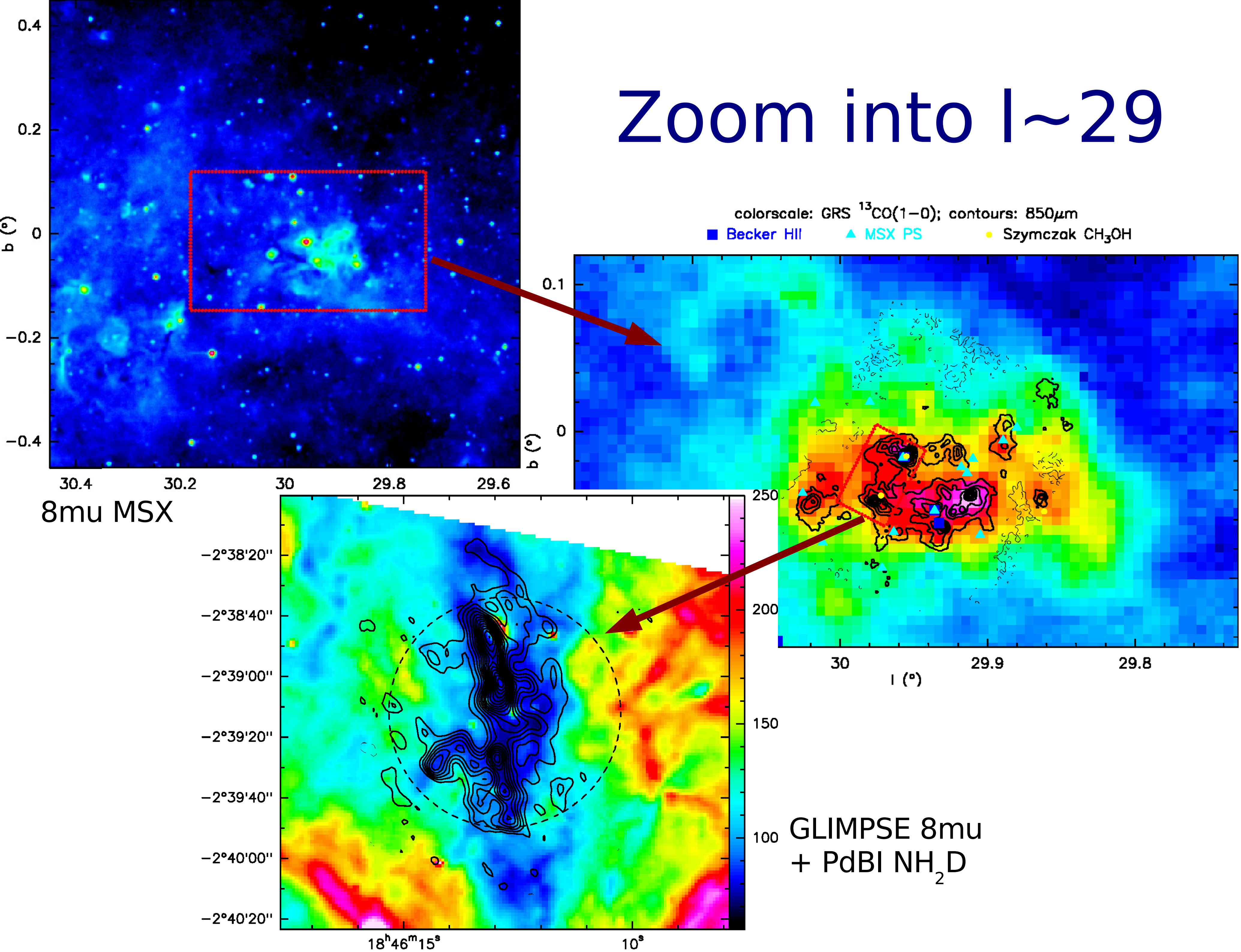
Initial conditions for massive star formation

Friedrich Wyrowski

Max Planck Institute for Radioastronomy
Bonn, Germany

Zoom into l~29



Remarks & Scope

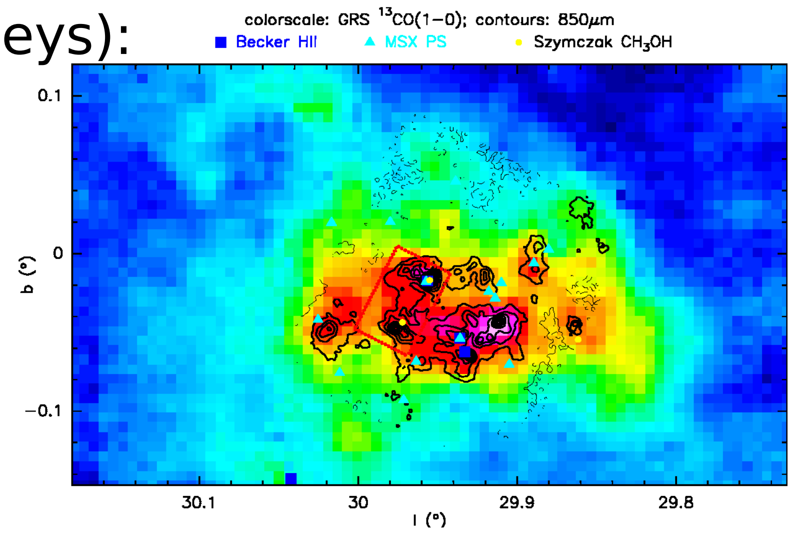
- Literature growing rapidly!
  - Let me know of important work you might know of but which I did not cover

- Focus on observational side of initial stages
- Focus on “cold” stages before
  - IR bright MYSOs
  - Hot molecular cores
  - UCHII regions

Outline

- Introduction
  - Zoom into G29
  - Remarks & Scope
- Large scale environs:
  - Giant molecular clouds
  - Infrared Dark Clouds
- Searching for initial stages of MSF:
  - IR/maser selected
  - Dust surveys
- Cold clumps:
  - phys/chem. Properties
  - Dynamics
  - SEDs
  - Clump mass function
  - (Trigger?)
- Cores in IR-quiet clumps
- Summary & outlook

Cloud structure and Terminology e.g. Williams+ 2000



- GMC properties (from large scale CO surveys):
  - Diameters ~ 10 - 100 pc
  - Masses~$10^{5-6.5}$ $M_\odot$
  - Mean densities ~
  - several 100 cm^{-3} but strongly clumped
- Clumps:
  - Coherent, overdense structures in l-b-v
  - Might form/are forming whole clusters
  - *typical single dish mm telescope mapping targets*
- Cores:
  - Might form/are forming individual stars/multiple systems
  - *Usually interferometers needed to resolve them*

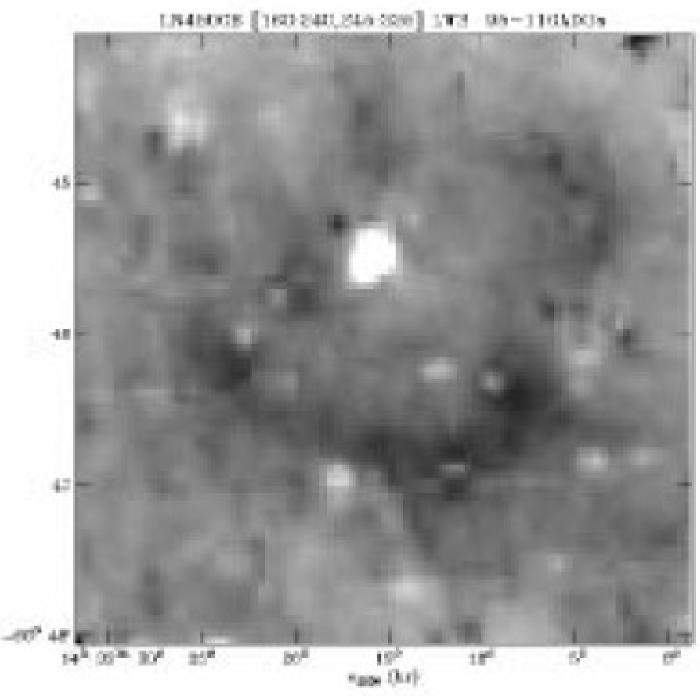
Two different interpretations of GMC observations

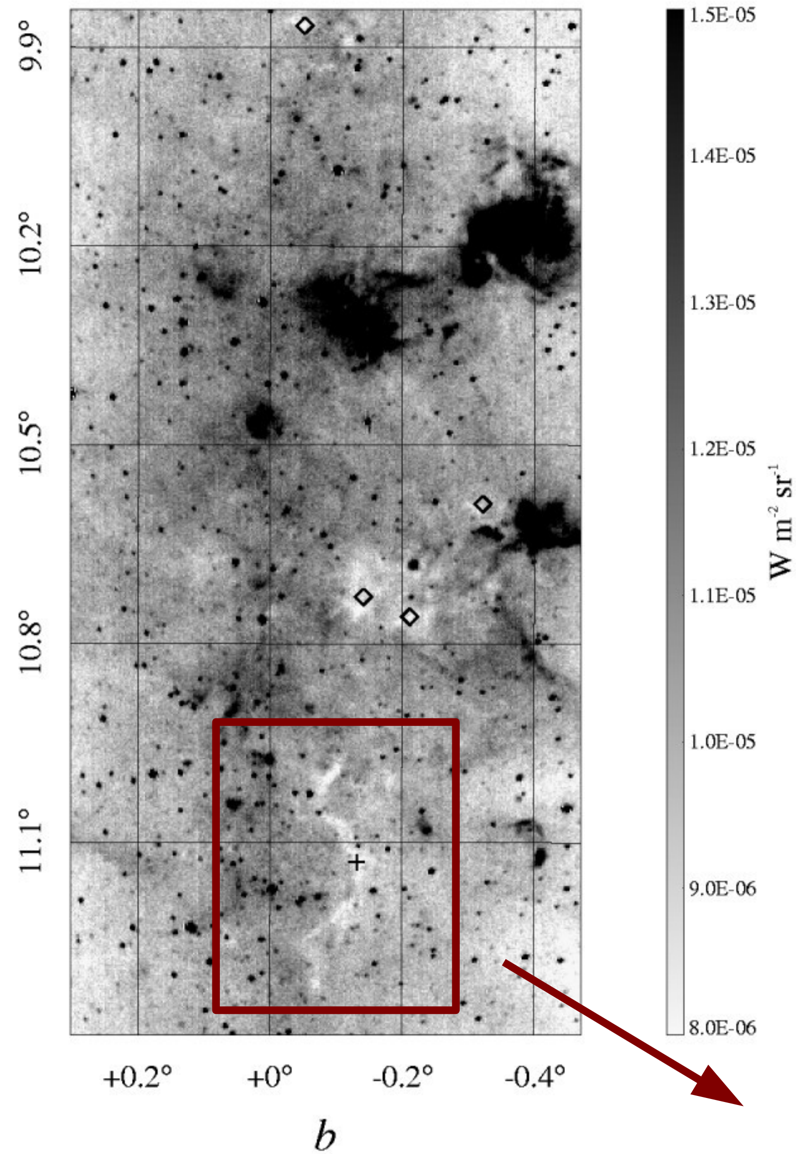
- GMC as dynamic, transient objects (e.g. Ballesteros-Paredes+ PP V)
  - Formed by large scale colliding gas flows
  - Lifetime ~ dynamical crossing time
- Quasi-equilibrium self-gravitating objects (McKee 1999)
  - Formed by large scale self-gravitating instabilities
  - Lifetime ~ many crossing times
- See e.g. McKee & Ostriker (2007) for more details

- How can we identify cold parts of GMCs?

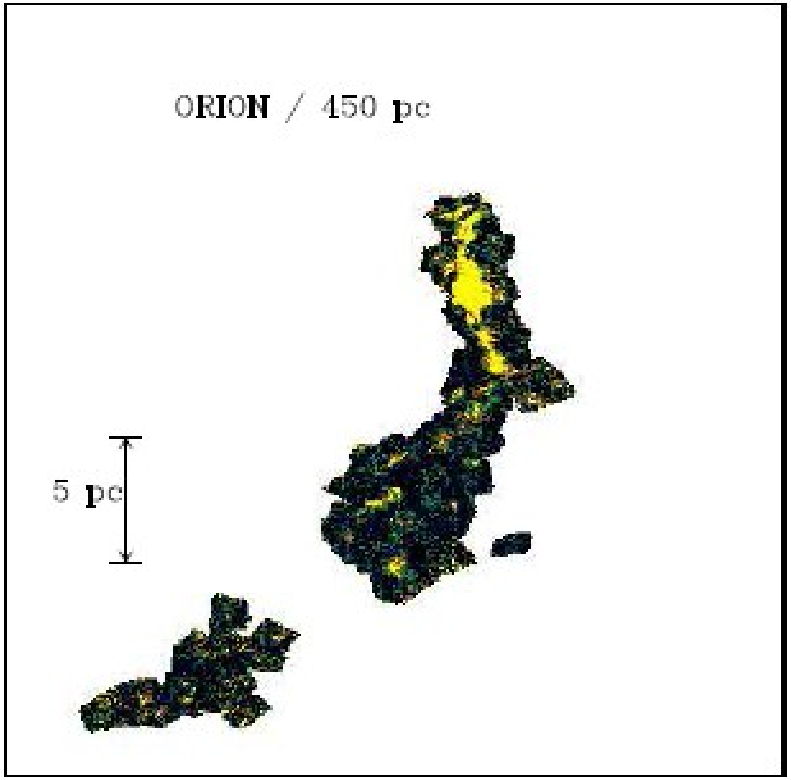
Discovery of Infrared Dark Clouds

- ISOCAM: Perault+ 96
- MSX: Egan+ 98
- Detected by their absorption of the bright, diffuse MIR emission of the Galactic plane





Comparison: OMC vs G11.11



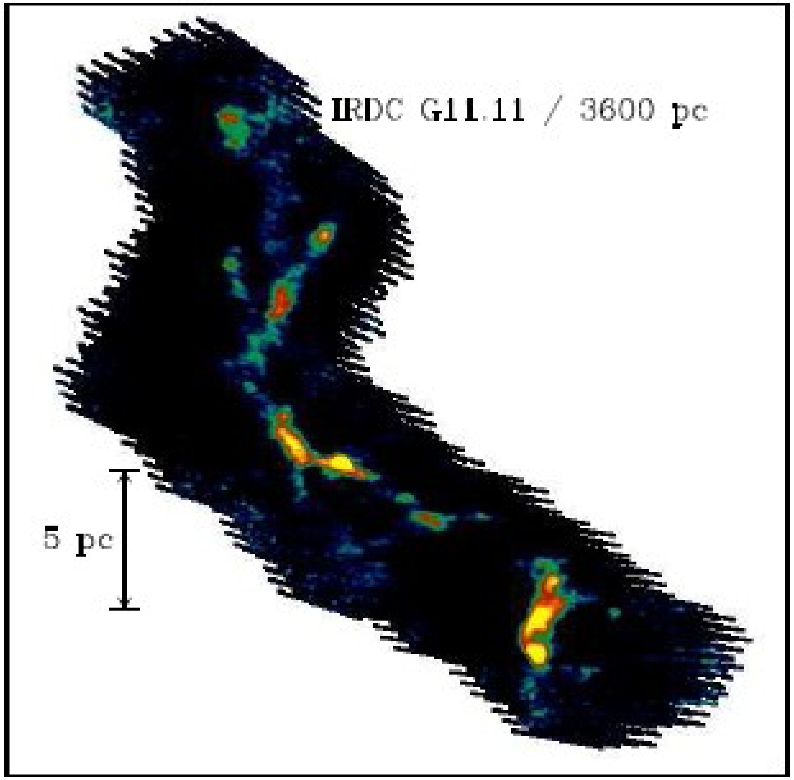
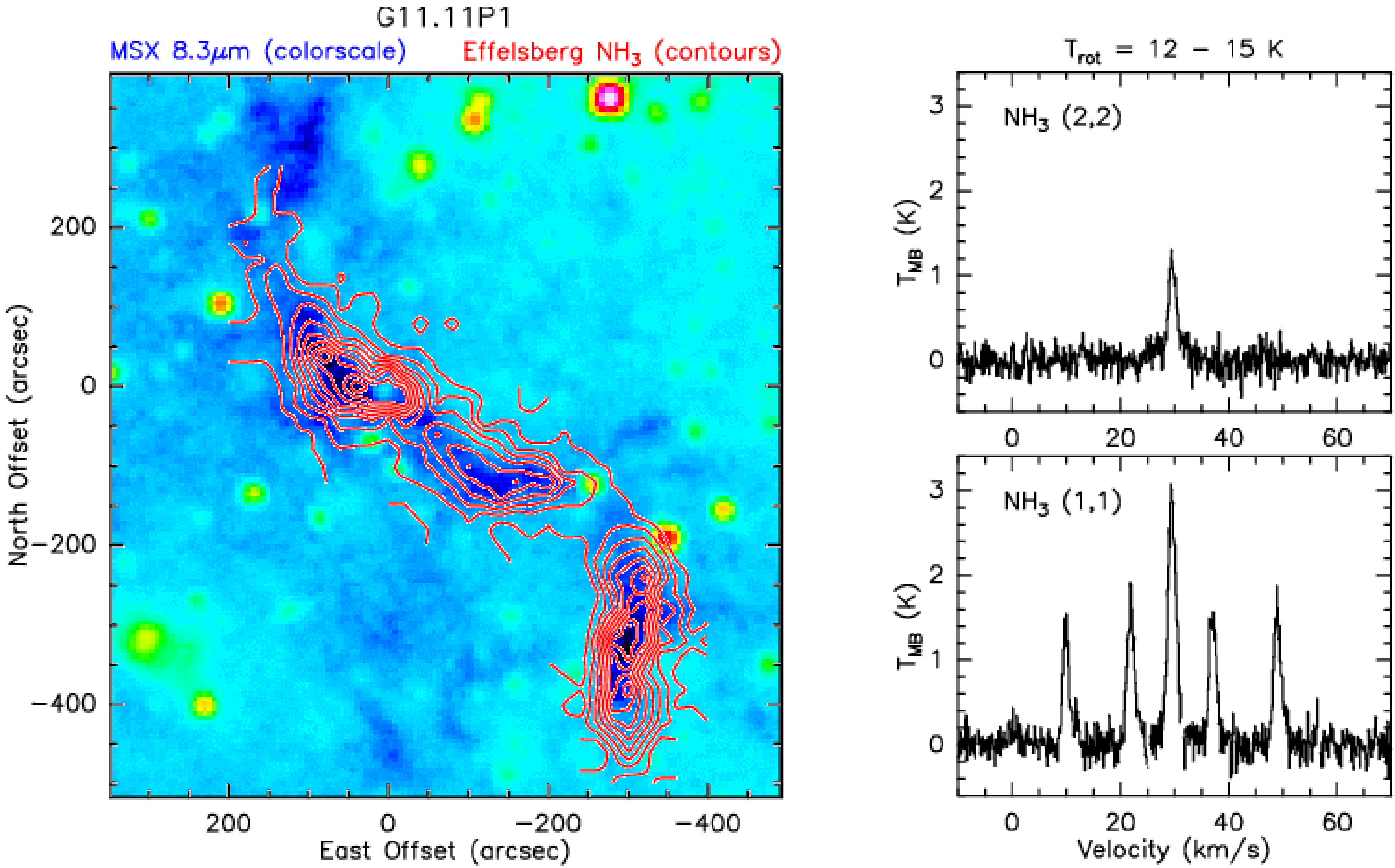


Figure 1.1: *Left panel:* 1.2 mm dust continuum map of the Orion Molecular Cloud 1 (courtesy T. Stanke). *Right panel:* 850 μm map of G11.11-0.12 (Johnstone et al. 2003).

- --> can resemble high CD parts of GMCs
- But also many smaller clouds, down to “IR dark clumps”
- Depend on evolutionary state and geometry of GMC

Ammonia in IRDCs

Pillai+ 2006



Searching for initial stages of MSF

Surveys to study early phases of MSF

- IRAS colour selection criteria for UC HII regions (Wood & Churchwell 1989) -> UCHII regions ~ 10^5 yrs
  - But are all these IRAS UC HIIs really UC HIIs?
  - --> Subsequently many hot cores found associated with the UCHIIs
- H_2O/CH_3OH masers might trace YSOs <10^5 yrs
  - Walsh+ 1997,1998, 2003; Plume+ 1997; Szymczak+ 2002
  - But maser amplification line-of-sight dependent !
- New IR criteria for (radio-quiet) massive protostars
  - Same UC HII criteria but no association w/ 5GHz continuum
  - Must be pre-UC HII – but are they all OB protostars?
  - Palla+, Molinari+ 1996-2002; Sridharan/Beuther+ 2002
  - Red MSX: Hoare+
- But all of these searches probe already some form of ongoing SF and *cannot* (directly) identify an earlier cold precluster phase.

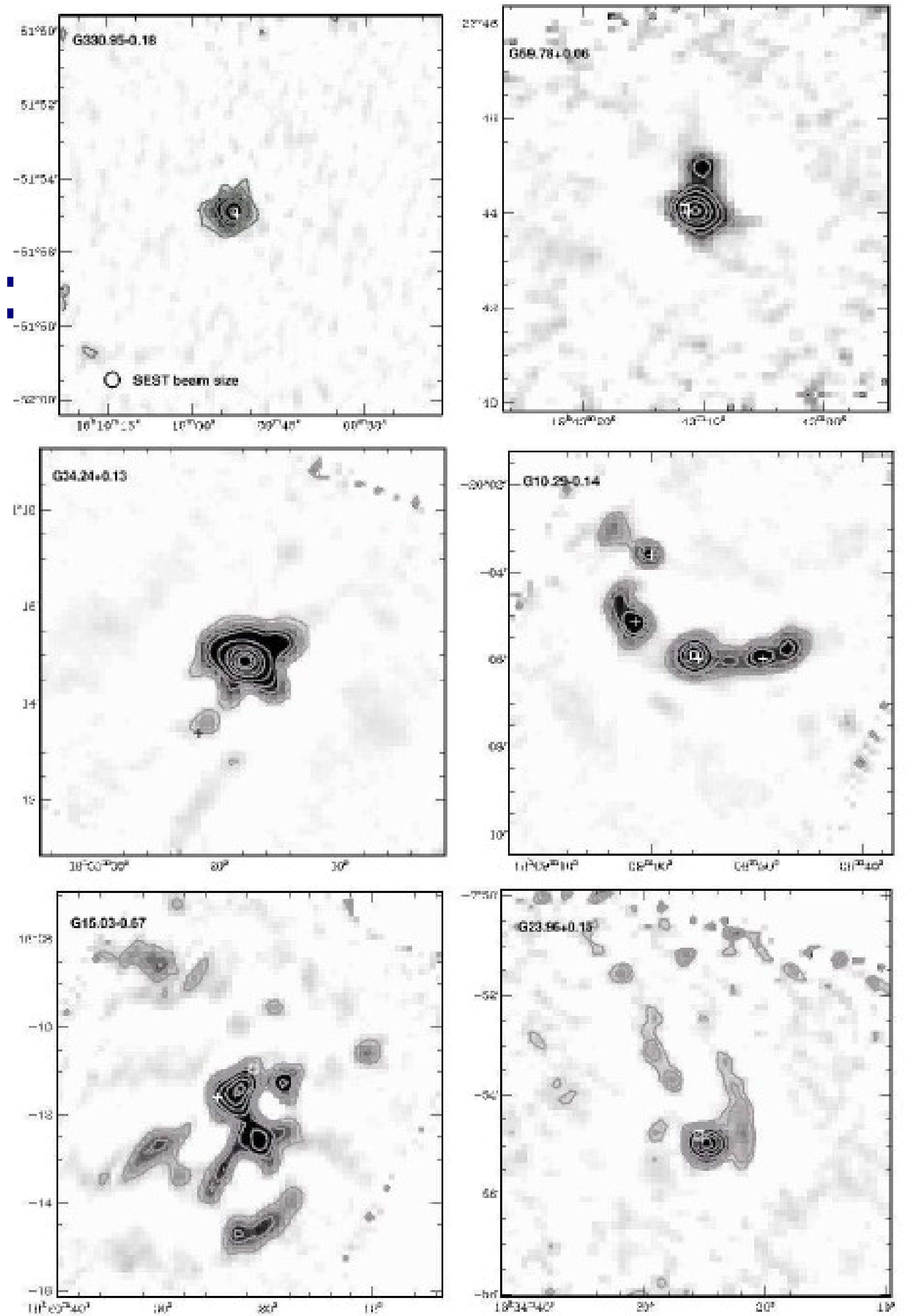
Current studies for earlier cold phase

- Larger environs of targeted surveys:
  - Ultracompact HII regions: Hill+, Thompson+
  - IRAS color selected: Klein+, Sridharan+, Beltran+, Faundez/Garay+
  - CH_3OH maser selected: Hill+
- IRDC selected surveys:
  - Carey+, Teyssier+, Rathborne+
- Unbiased surveys:
  - Cygnus X, Motte+
  - NGC6334, Munoz+
  - ISOPHOT serendipity, Krause+
  - Galactic plane surveys

Images of CH3OH and/or UCHII regions:

Hill+ 2005/6

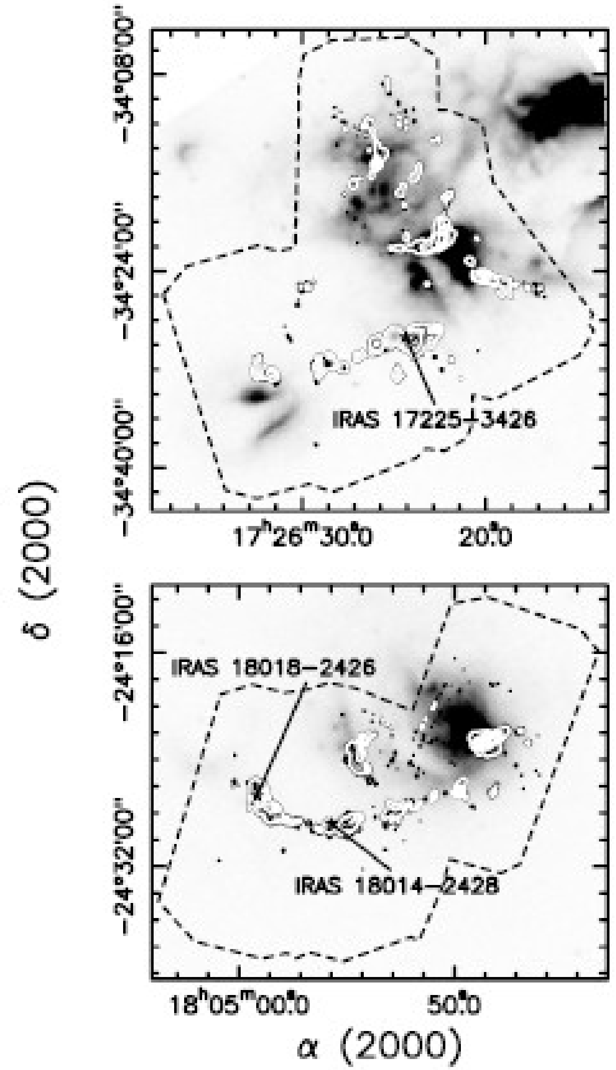
- SEST/SIMBA
- 131 SFR, 404 clumps, 253 mm only of which 45% w/o MSX MIR
- $\sim 100 M_{\odot}$ sensitivity limit
- + SCUBA: β dust



Southern extension of Palla/Molinari sample:

Beltran+ 2006

- 245 SFR
- 95 mm clumps w/o MSX
- Hill, Beltran mm-only less massive but assuming same T. could be same mass but colder
- Clump mass spectra



Outer Galaxy dust emission survey:

Klein+ 2005

- Continuum imaging of 47 IRAS selected SFR
- 128 mm clumps, 12 IR/Radio-quiet > $100M_\odot$

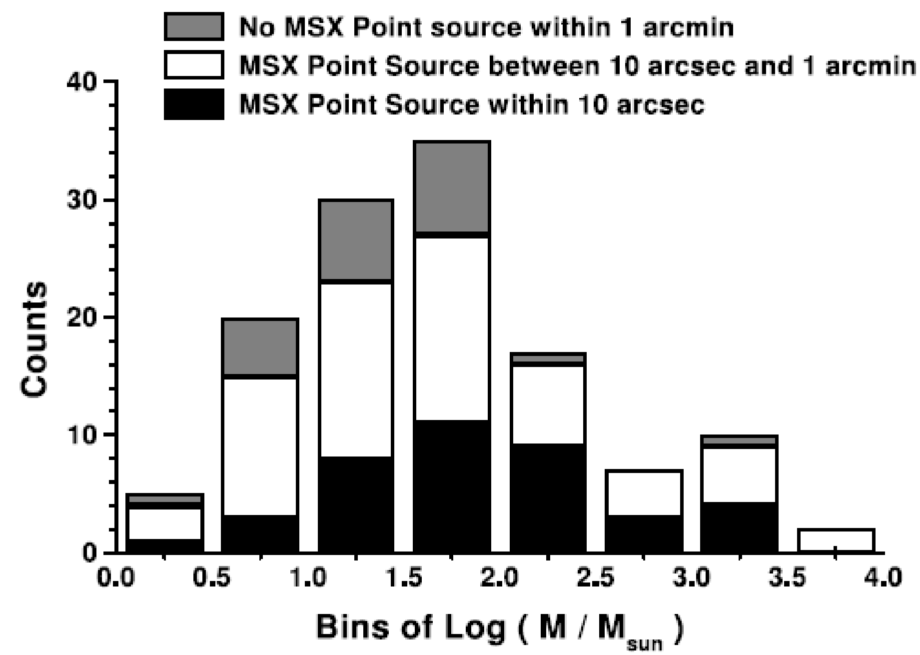


FIG. 3.—Histogram of cloud components and their *MSX* associations vs. mass bins.

TENTATIVE STAGES OF MASSIVE STAR FORMATION

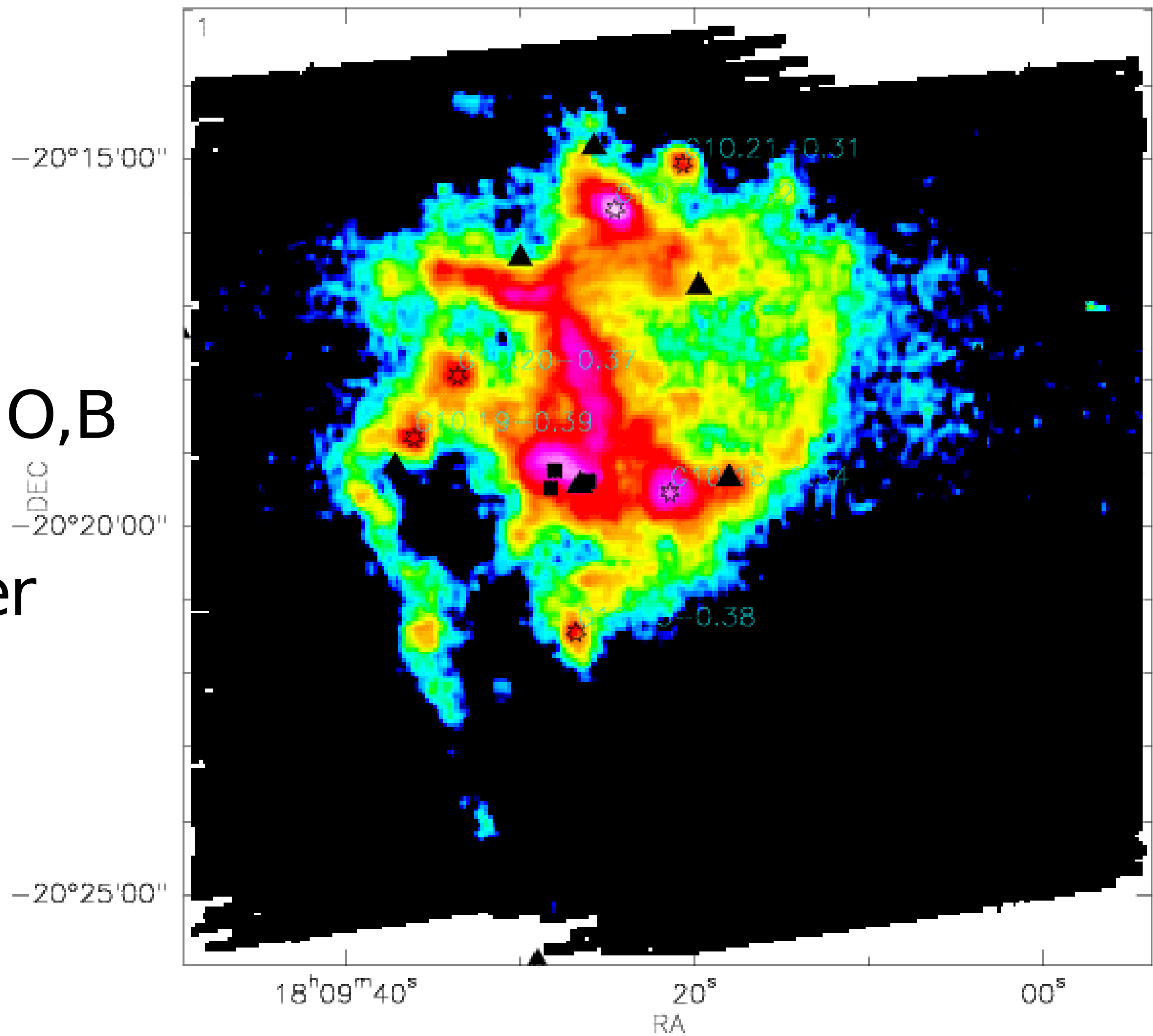
Stage	Morphology	Detectable at	Example
0: PPclCs	Massive cloud core without collapse	mm	IRAS 06073+1249 core 2
1: Early protocluster	Massive stars have begun to form deeply embedded in the cluster	mm	IRAS 03211+5446 core 1
2: Protocluster	The forming massive stars begin to clear a cavity, an H II region begins to evolve	mm, FIR, radio	IRAS 05197+3355 core 1
3: Evolved protocluster	The cluster starts to emerge but is still embedded	mm, FIR, MIR, radio	IRAS 04329+5047 core 1
4: Young cluster	The cluster has emerged from its parental cloud	mm, FIR, MIR, NIR	IRAS 03211+5446 core 2
5: Cluster	The cluster has dispersed its parental cloud	MIR, NIR	IRAS 05345+3157, IRAS 05281+3412

NOTE.—The examples for stage 0 and stage 1 are of course pre-protocluster candidates, but the assignment to stage 0 and stage 1 is arbitrary.

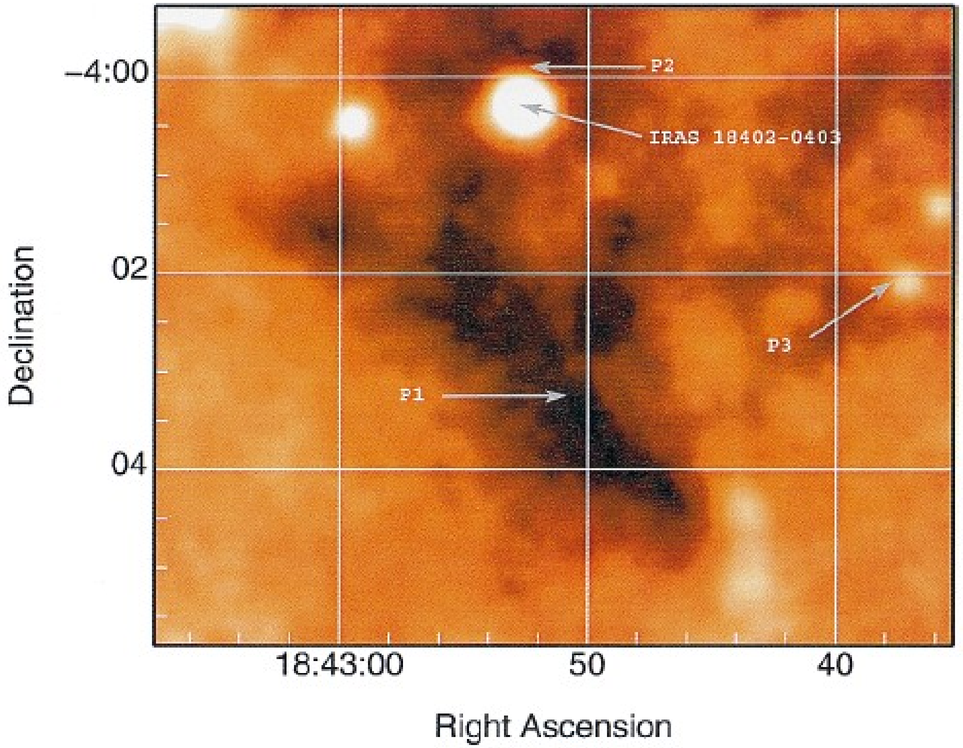
SCAMPS: The SCUBA massive precluster survey:

Thompson+ 2005

- 13'x13' imaging of 37 UCHII
  - 700 clumps
- See poster by Pestalozzi+
  - Masses sufficient for cluster formation, but luminosities still below O,B stars
  - -> early stage of cluster formation



Cold dust emission from IRDCs
Carey+2000, Teyssier+2002,Rathborne+2006



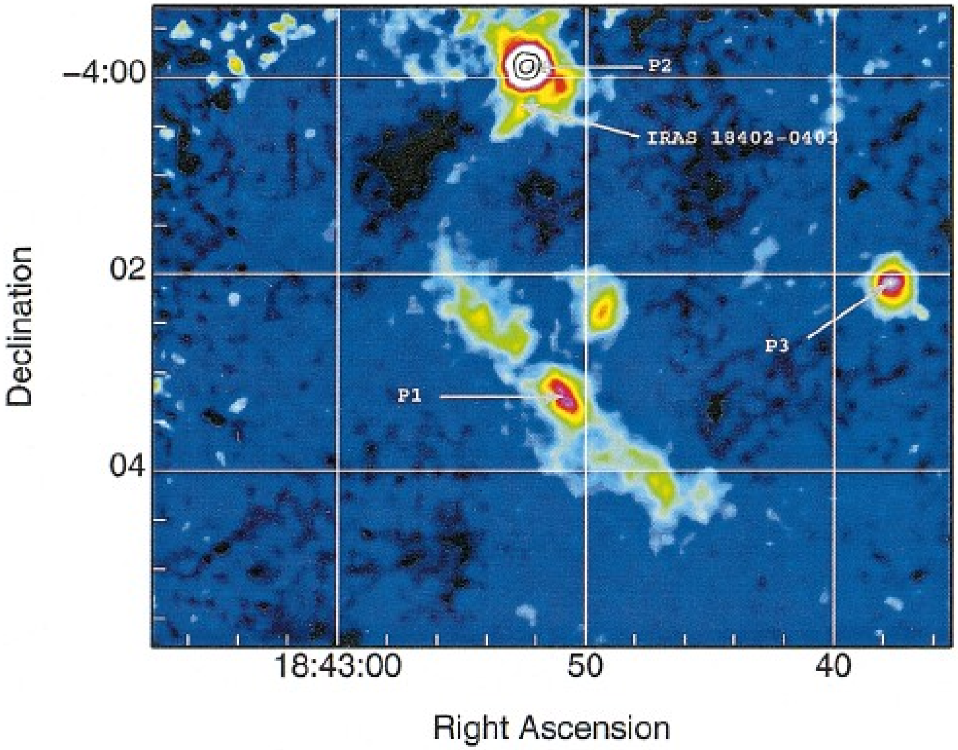
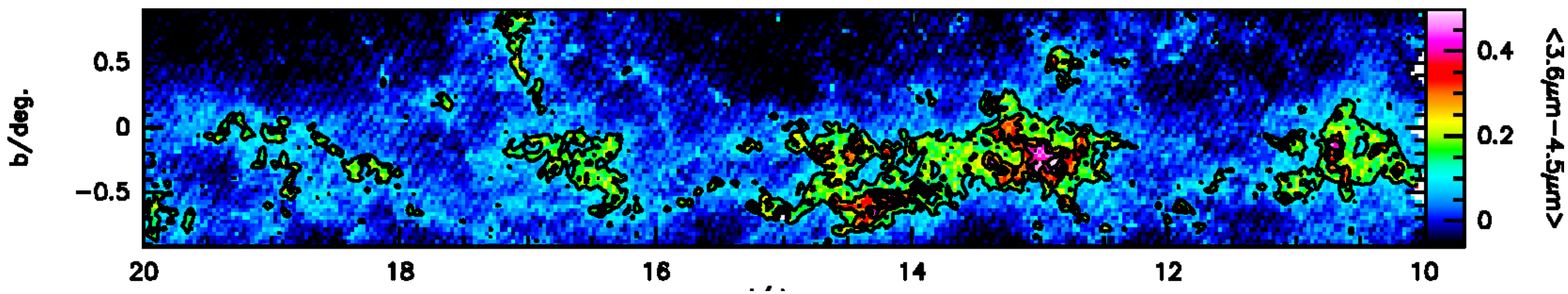
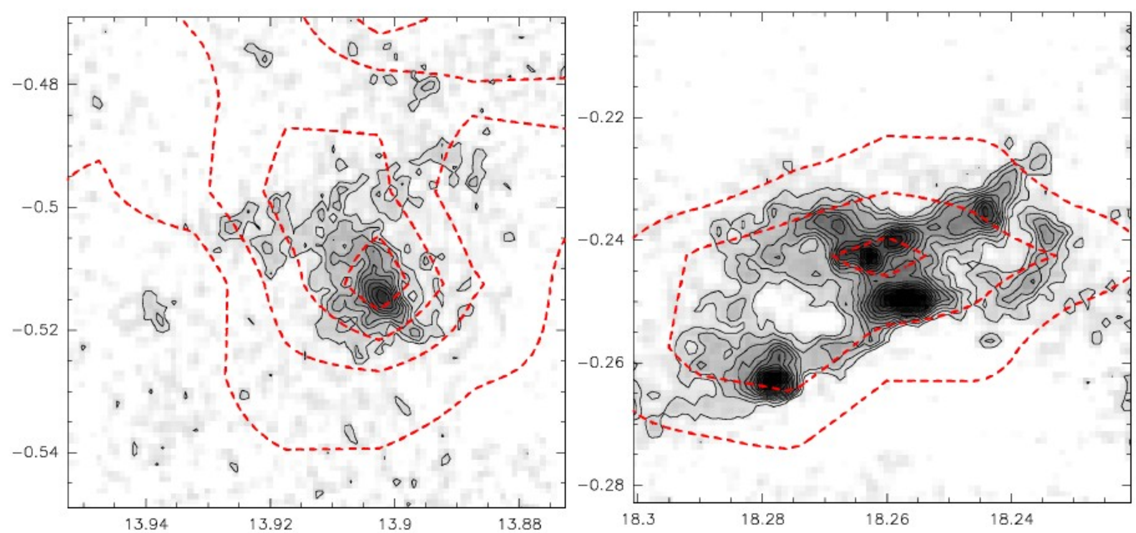


Fig. 3.—*Left*: *MSX* 8 μm image showing the mid-infrared extinction of G28.34+0.06. *Right*: SCUBA scan map of 850 μm emission from the same region. The color scale of the SCUBA image has been adjusted to emphasize the structure of the clouds. Contours are overlaid on the burned-out core of P2 at the 3.0 and 4.5 Jy beam^{-1} levels to show the location of this very bright pointlike source more clearly. The coordinate system, projection, and pixel spacing are the same as in Fig. 1. The intensity levels in the 8 μm image range from 10 to 60 MJy sr^{-1}. The 850 μm intensity range is from -0.4 to 1.6 Jy beam^{-1}.

Massive high extinction clouds



- NICE method with GLIMPSE 3.5/4.5mu
- Select highest extinction peaks:
  - Many well known MSFR
  - Studied massive IRDCs
  - + new regions!
- MAMBO imaging, Ammonia, mm/submm follow ups
- --> Poster by Rygl+



- wide range of morphologies:
  - Diffuse
  - Core-halo
  - Multipeaked, filamentary

ISO FIR detctions

Krause+ 2003

- ISOPHOT serendipity
  - F(170)>2 F(100)
  - --> Tdust<18K
- Cold center: candidate for massive prestellar clump

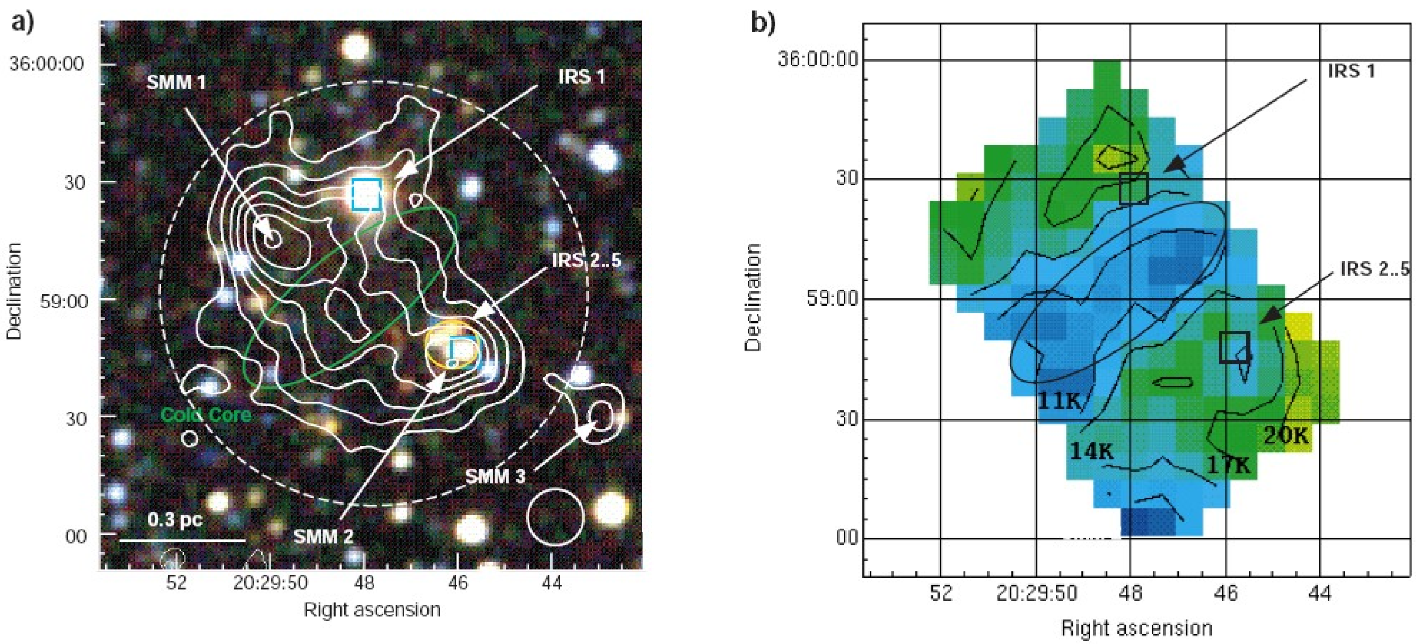


Fig. 2. a) 850 μm continuum map of the compact ISOPHOT Serendipity Survey source FIR1, overlaid on a near-infrared JHK_S-composite constructed from 2MASS data. Three compact dust condensations (SMM 1, SMM 2 and SMM 3) are detected, which are located in a diffuse extended emission. Mid-infrared sources detected by the MSX-satellite are marked with boxes. The submillimeter knot SMM 2 is associated with a small cluster of embedded NIR sources (IRS 2...5) as detected by the 2MASS and MSX surveys. IRS 1 was identified as a very young Herbig B2 star by our follow-up spectroscopy. The two compact submillimeter sources SMM1 & SMM3 without any infrared counterparts are candidate Class 0 objects. The position of the very cold cloud core is indicated by an ellipse. Contour levels are starting at 67 and increasing by 33 mJy/beam. The size of the SCUBA beam is indicated in the lower right, the dashed circle corresponds to the ISOPHOT beam. b) The dust color temperature distribution across FIR 1 shows the presence of a very cold ($T_d \sim 11$ K) core at the center of the cloud. The temperature profiles towards north-east and south-west indicate an external heating by the infrared sources IRS 1–5. The temperature is calculated from the submillimeter spectral index between 450 μm and 850 μm, assuming a dust emissivity $\beta = 2$.

Large scale studies:
Cygnus X and NGC 6334
Motte+ 2007, Munoz+ 2007

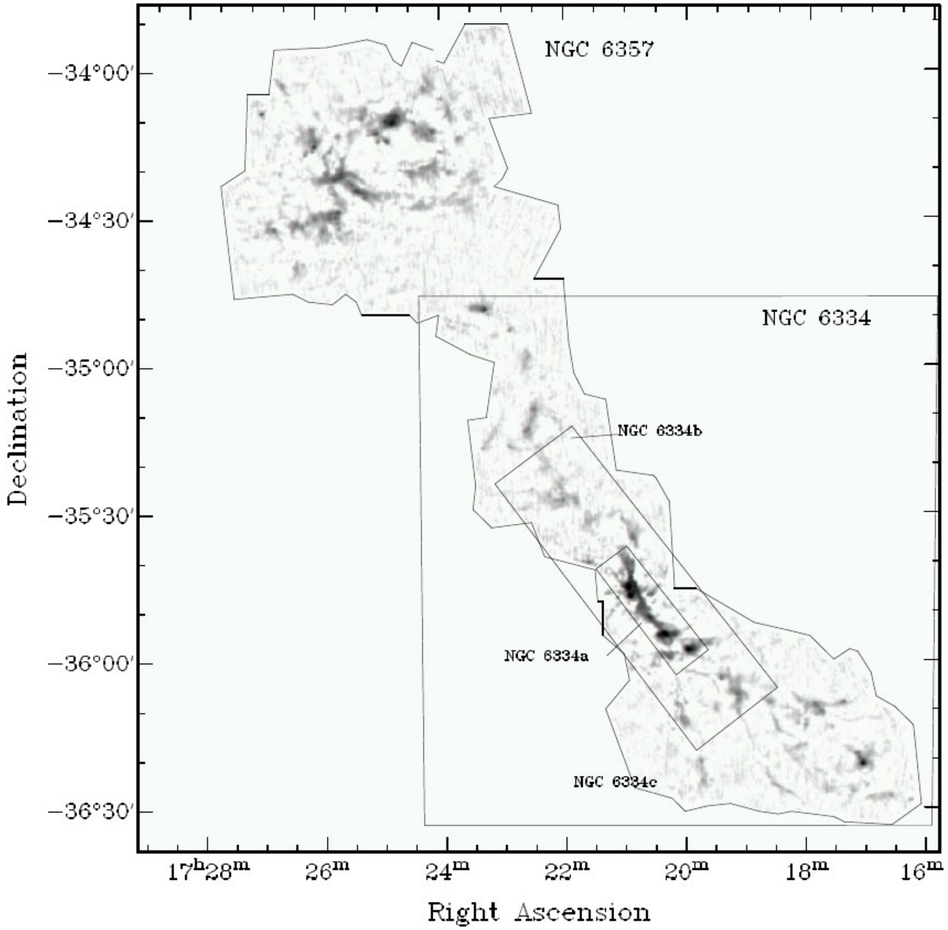


FIG. 1.— Grey scale image of the 1.2 mm emission towards NGC 6334 and NGC 6357. The polygonal line was used to exclude the noisy borders of the mapped region. The large square indicates the area defined as NGC 6334 in the present analysis. It encloses 182 of the 347 clumps found using *clfind2d*. Also labeled are the three sub-regions chosen for statistical analysis: the central region NGC 6334a (see Figure 2); a larger extension NGC 6334b; and finally NGC 6334c which includes only the clumps outside of NGC 6334b.

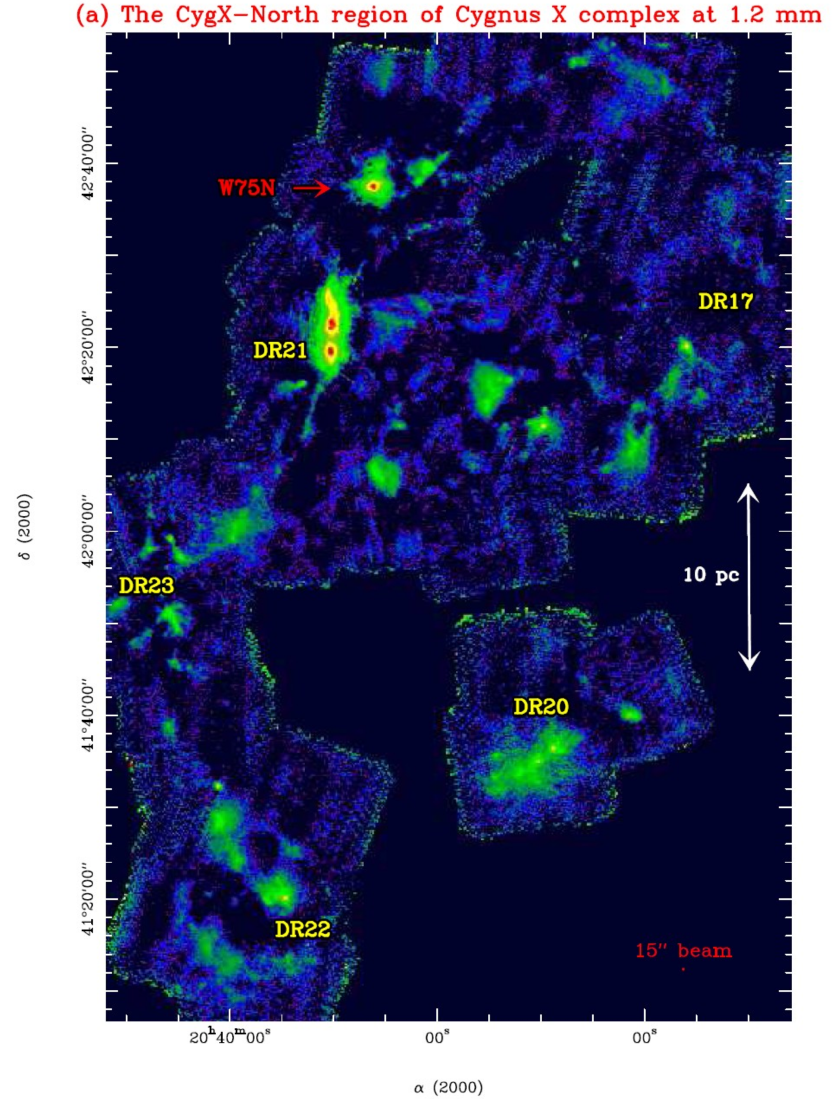
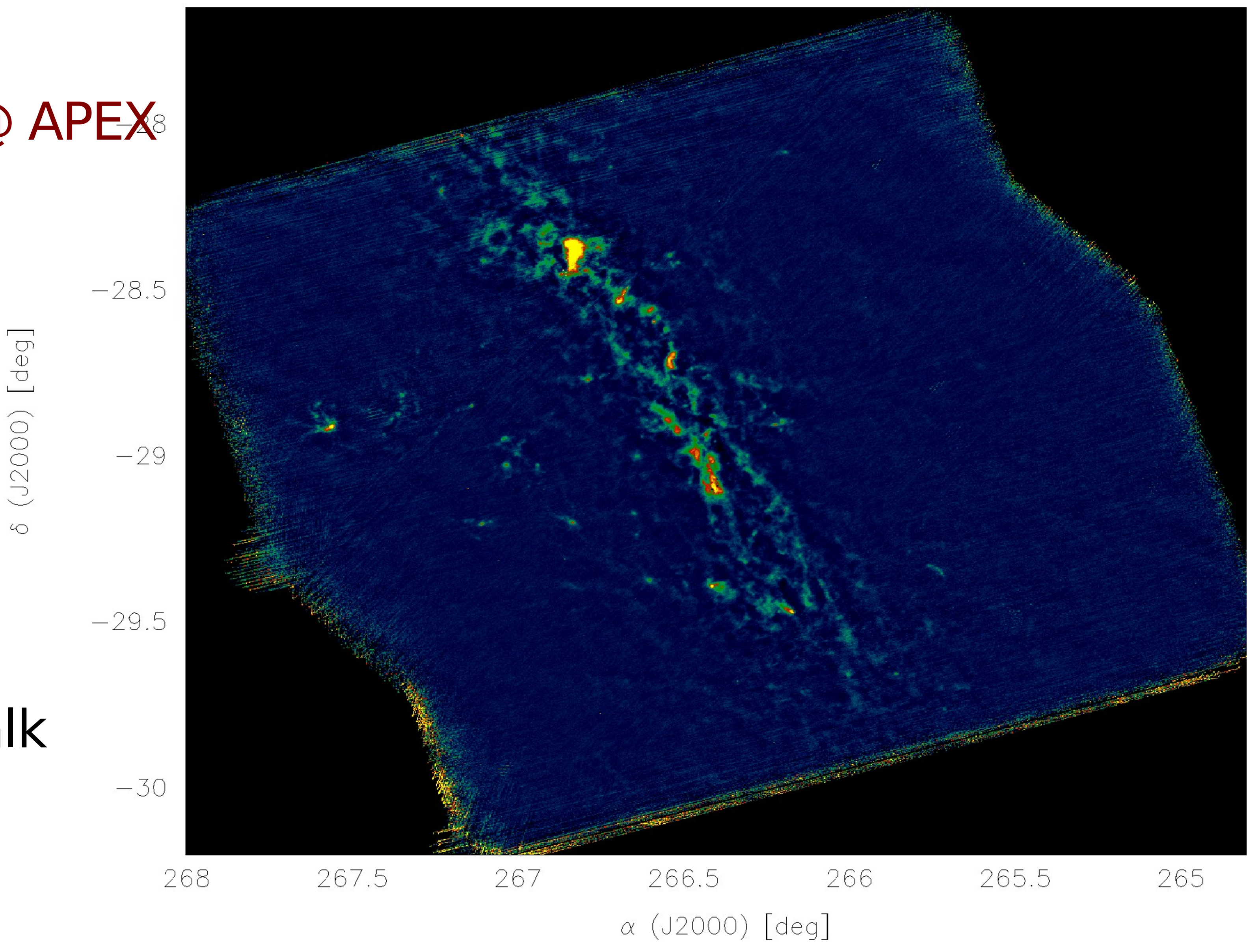


Fig. 2. Millimeter continuum imaging of the Cygnus X molecular cloud complex obtained with the MAMBO and MAMBO-2 cameras installed at the IRAM 30 m telescope. These 1.2 mm maps have been smoothed to an effective angular resolution of 15″, allowing a sensitivity of 0.1–5 pc cloud structures. The main radio sources (Downes & Rinehart 1666) and a few well-known sources are indicated as reference marks. **a** The "CygX-North" region (see Fig. 1 for its location): maximum flux is ~ 8 500 mJy beam^{-1} (color scale is saturated beyond 500 mJy beam^{-1}) and rms noise level is $\sigma = 10 - 20$ mJy beam^{-1}.

Galactic Plane surveys

- ATLASGAL
  - LABOCA @ APEX
  - --> GC
- BOLOCAM
- SCUBA2
- MIPSGAL !!
- Herschel

- --> Krause talk



Summary:
Seaching for initial stages

- Current surveys produce large numbers of cold massive clumps !
- Statistics for very massive clumps which might turn into rich OB clusters still small --> Galactic plane surveys needed
- Variety of selection criteria yield sources in a variety of environs:
  - with/without powerful OB clusters nearby
  - Range of locations throughout the Galaxy
- Some follow ups to determine their properties completed (--> next section of talk), several still ongoing

Massive cold clump properties

- Physical conditions: R,M,n,T
- Spectral Energy Distributions
- Infall
- Chemistry
- Clump mass functions

- NGC2264,CygX, some IRDC results --> Talks Motte, Peretto, Jackson

Cold clumps from Faundez sample

- Garay+ 2004
- Note: R, M, n similar to cores with IRAS and/or UCHII sources, but Tdust much lower
- Later studies:
  - Rathborne+ 2006: evidence for massive YSOs in G34
  - Beuther+ 2006: MSF in G18

TABLE 2

DERIVED PARAMETERS

		1.2 mm				CS (2 → 1)		
SIMBA SOURCE (1)	D (kpc) (2)	R (pc) (3)	T_d (K) (4)	M [a] ($M_\odot$) (5)	n [a] (cm^{-3}) (6)	R (pc) (7)	M_{vir} ($M_\odot$) (8)	n (cm^{-3}) (9)
G305.136+0.068	3.4	0.27	<16	1.1×10^3	2×10^5	0.30	1.1×10^3	2×10^5
G333.125−0.562.........	3.5	0.34	<17	2.3×10^3	2×10^5	0.68	2.2×10^3	3×10^4
G18.606−0.076...........	3.7	0.20	<15	4.0×10^2	2×10^5	...	...	...
G34.458+0.121	3.8	0.24	<17	7.8×10^2	2×10^5	0.64	1.5×10^3	2×10^4

[a] Lower limit.

Garay 2005

- Massive H_2O and SIMBA clumps vs. Myers LMSF sources
- Scaling relations similar to LM sources but dv, n considerably higher

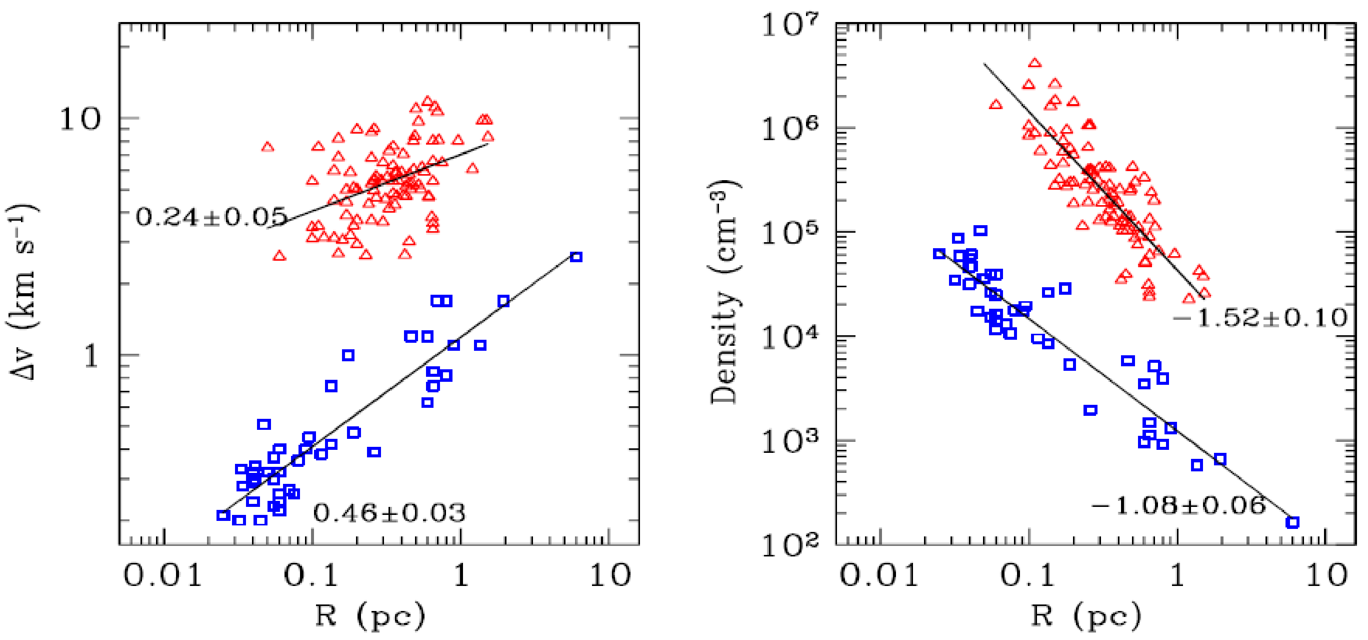
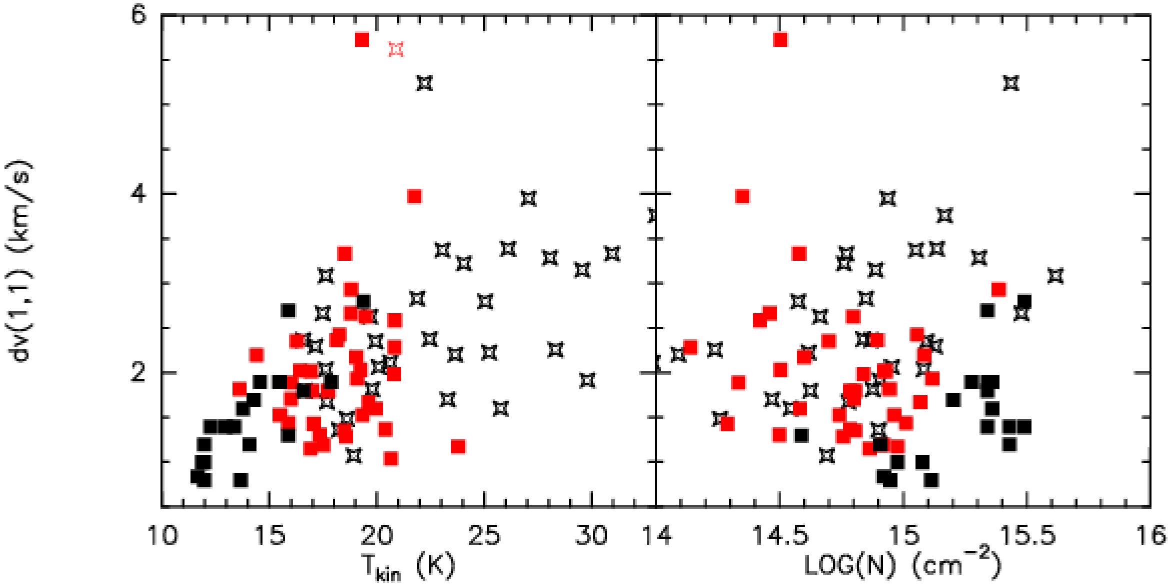


Figure 1. Correlations between physical parameters of molecular cores. Left: Line width versus radius. Right: Density versus radius. Squares: Dense cores in dark clouds. Data from Myers (1983). Triangles: Massive and dense cores. Lines are least squares linear fits to the data points.

Ammonia properties of massive clumps in IRDCs

Pillai+ 2006

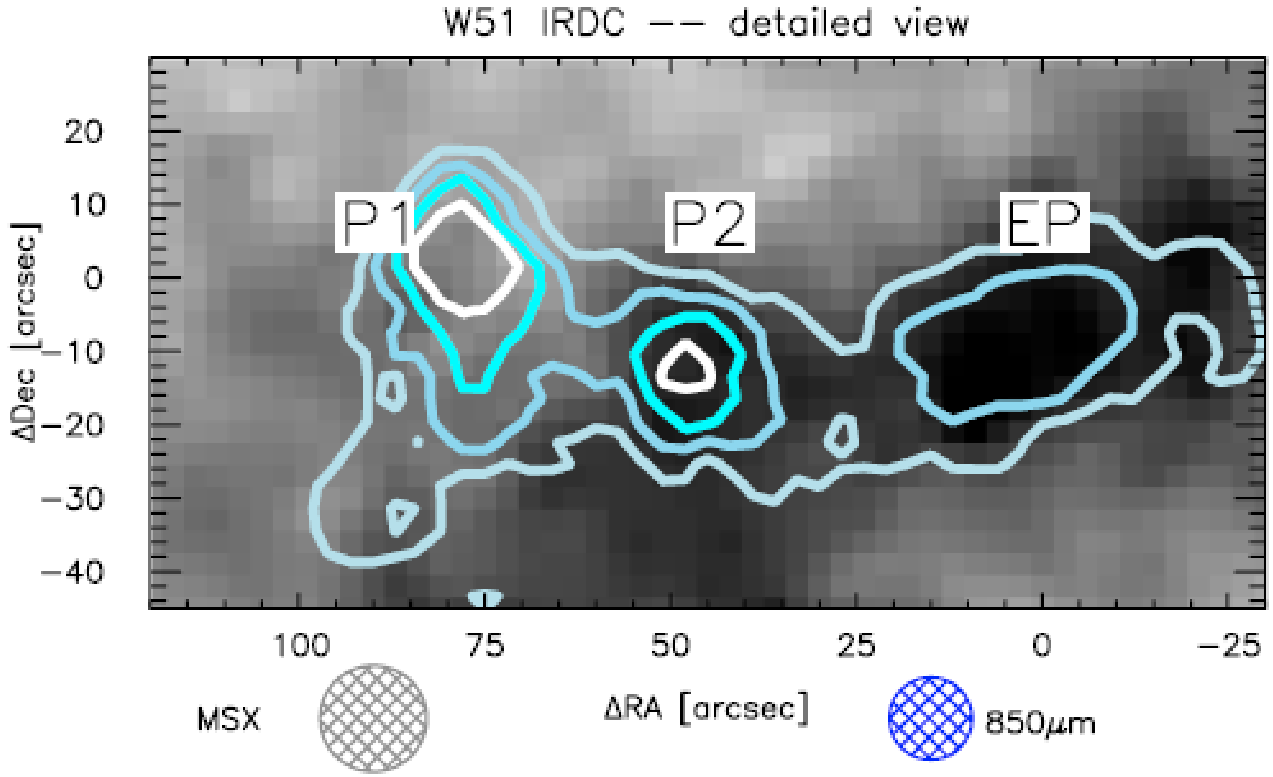


- Comparison of
  - IRDC clumps (black)
  - HMPOs (red)
  - Hot cores (stars)

- IRDC dv smaller but still higher then LMSCs
- Clear temperature trend

Detailed modeling of IRDCs clumps: Ormel+ 2005

- Dust continuum + HCO^+
- Heating, increase of turbulence in all 3 cores



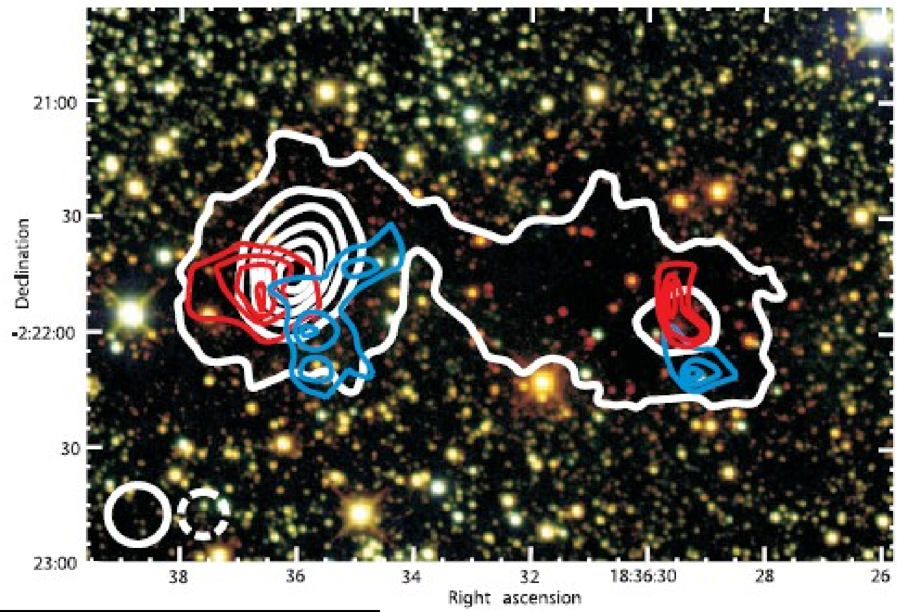
Results continuum model						
Core	p	$\mathcal{M}$ $[M_\odot]$	R [a] $['']$	L $[L_\odot]$	χ^2	$\langle \tau_{8.3\ \mu m} \rangle$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
P1	$2.2^{+0.3}_{-0.2}$	91^{+25}_{-21}	37^{+5}_{-7}	330^{+370}_{-180}	12.6	0.53
P2	$2.0^{+0.3}_{-0.5}$	100^{+30}_{-26}	41^{+6}_{-9}	300^{+1000}_{-230}	7.5	0.55
EP	$2.2^{+0.3}_{-0.3}$	130^{+25}_{-24}	51^{+7}_{-7}	19^{+110}_{-17}	2.2	0.58

[a] Angular radius. A linear radius of 0.1 pc corresponds to $R = 7.65''$.

Results line model								
Model	v^{turb}	v^{exp}	$\mathcal{M}/f$	$X\mathcal{M}$	χ^2	χ^2_ν	f	X
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
P1	$2.6^{+0.8}_{-0.7}$	$-0.41^{+0.20}_{-0.18}$	1100^{+170}_{-220}	$1.6^{+0.3}_{-0.3}$	24.7	0.77	$0.09^{+0.04}_{-0.03}$	17^{+10}_{-6}
P2	$3.5^{+0.8}_{-0.5}$	$-0.50^{+0.09}_{-0.10}$	530^{+190}_{-180}	$8.4^{+14}_{-4.2}$	24.5	0.84	$0.19^{+0.18}_{-0.09}$	84^{+210}_{-53}
EP	$2.9^{+0.9}_{-0.9}$	$-0.39^{+0.19}_{-0.15}$	650^{+120}_{-80}	$1.8^{+0.4}_{-0.4}$	27.4	0.98	$0.20^{+0.07}_{-0.06}$	14^{+7}_{-5}
EP-c	$3.9^{+1.9}_{-1.4}$	$-0.50^{+0.23}_{-0.20}$	910^{+150}_{-130}	$2.1^{+0.6}_{-0.4}$	33.1	1.18	$0.19^{+0.07}_{-0.06}$	13^{+6}_{-5}

ISOPHOT detections:
Birkmann+ 2006

- ISOPHOT serendipity
- 16.5/12 K
- 75/280 $M_\odot$
- Infall spectra but also outflow wings



ı JHK_s. White contours give the 850 μm flux
ʹy beam^{-1}. The thin contours show the red
-30] km s^{-1}) CO(2–1) emission. The beam

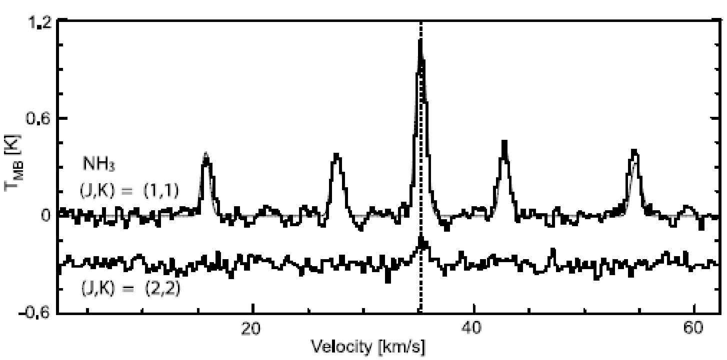


Fig. 5.—Spectra of the NH_3 (J, K) = (1, 1) and (2, 2) inversion transitions toward ISOSS J18339−0221 SMM2. A fit to the hyperfine structure of the (1, 1) line is also shown.

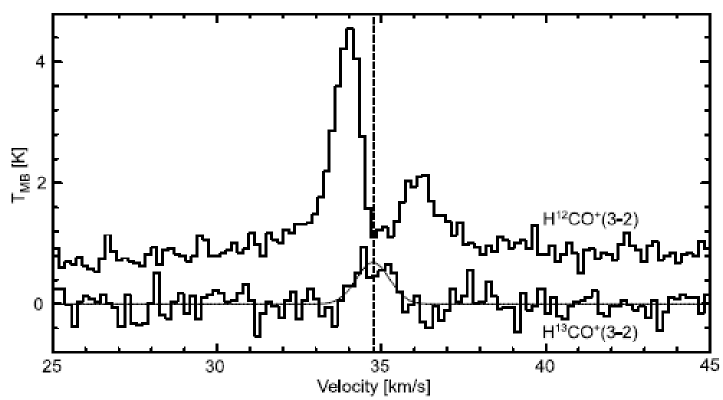


Fig. 6.—$H^{12}CO^+(3-2)$ and $H^{13}CO^+(3-2)$ taken at SMM1. The vertical dashed line marks the central velocity of the optical thin line; the optically thick transition shows redshifted self absorption.

Spectral energy distributions

- Rathborne+ 2006
- Birkmann+ 2006
- Beuther+ 2007

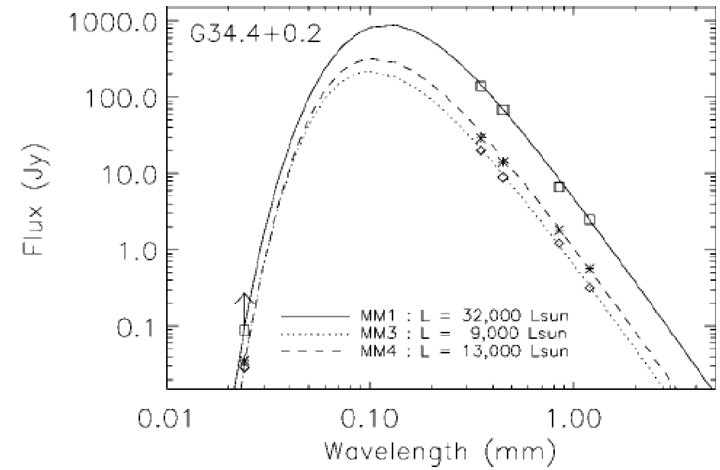


FIG. 3.—Broadband continuum SED for the three cores. Included on this plot are peak fluxes at 24 μm, 350 μm, 450 μm, 850 μm, and 1.2 mm. The curves are graybody fits to the data, which yield values of $\beta \sim 1.8$, $\tau_{250} \sim 0.25$, and $T_D \sim 33$ K (15″ source diameter; see also Table 2). The derived bolometric luminosities are labeled for each core. MM1 saturates the MIPS array; hence, the quoted 24 μm flux is a lower limit.

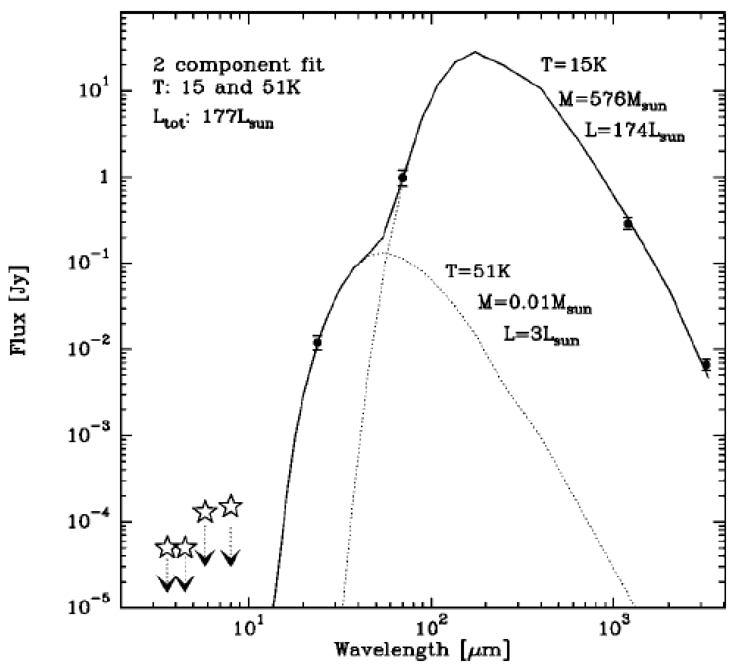


FIG. 2.—Spectral energy distribution of IRDC 18223-3. The dots with error bars mark the detections at 24 and 70 μm on the short-wavelength Wien side of the peak, and at 1.2 and 3.2 mm on the Rayleigh-Jeans part of the spectrum. The four stars below 10 μm show the *Spitzer* IRAC upper limits in the near-infrared. The solid line presents a two-component fit with one cold component at ~15 K and one warmer component at ~51 K. The two dotted lines show the two components separately. The resulting physical parameters for each component are labeled accordingly.

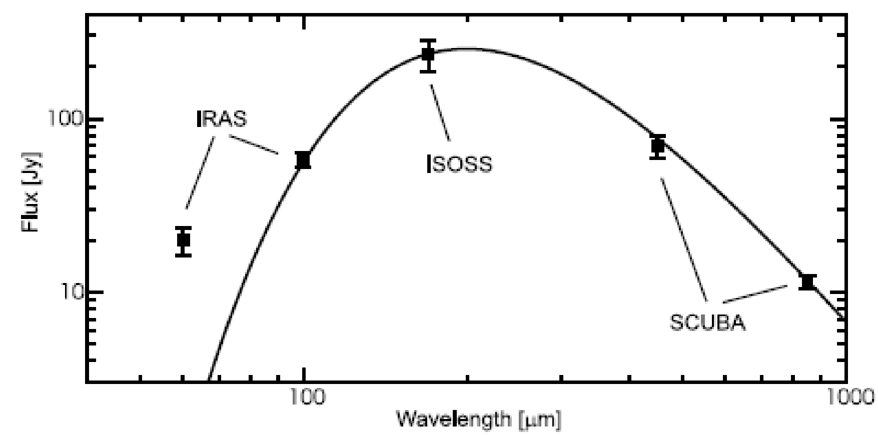
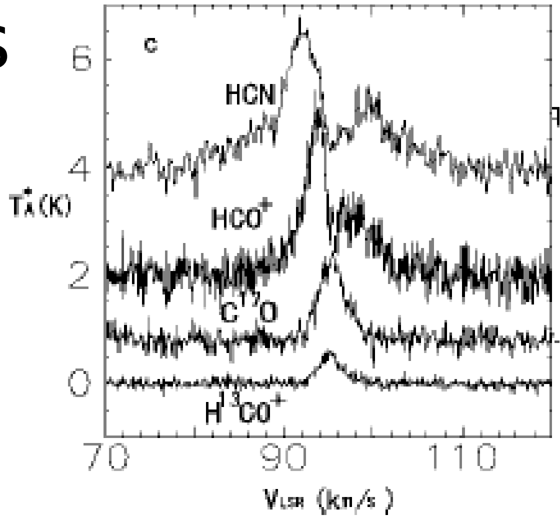


FIG. 4.—Spectral energy distribution of ISOSS J18364−0221. For wavelengths longward of 100 μm, the SED is dominated by the optically thin thermal emission of large grains and well fitted with a modified blackbody with an emissivity index of $\beta = 2$; the point at 60 μm is not taken into account.

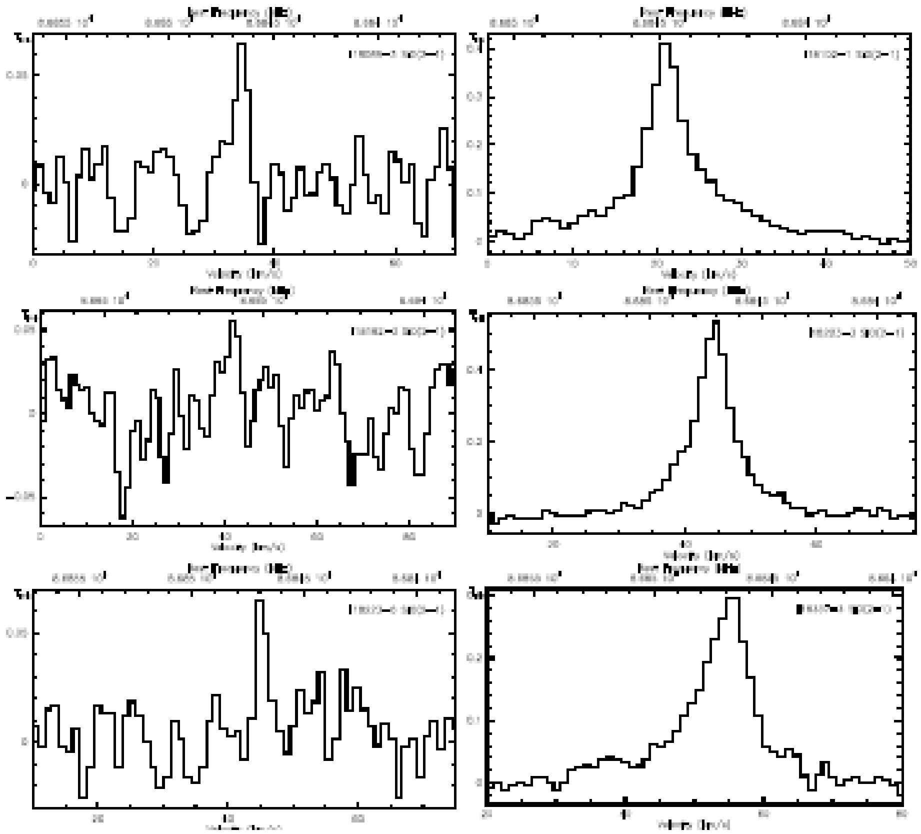
Evidence for infall

- HMPOs, Fuller+ 2005: 0.2-1 10^{-3} $M_{\odot}$/yr
- UCHIIs, Keto++, Wyrowski+ 2006
- H2O maser dense clumps, Wu+ 2003: B/R statistics similar to low mass clumps
- Possible earlier stages:
  - G25.38, Wu+ 2005: 3.4 10^{-3} $M_{\odot}$/yr
  - ISOSS J18339, Birkmann+ 2006
  - Check also SCAMPS and high extinction clouds posters (Pestalozzi+, Rygl+)



MM lines from IR dark clumps:
Beuther&Sridharan 2007

- Mm lines towards 43 IR dark clumps
- SiO: 18 sources --> SF
- dv(H13CO+)>dv(NH3 11): increase of turbulence to denser inner part
- CH3CN 14%, CH3OH 40%
  - CH3OH abundance close to values of low mass cores



Deuterium fractionation:
Fontani+ 2006

- IRAS selected HMPOs
  - CO depletion
  - N2H+ deuteration
- Cold dense gas remnant from the HMPO formation or secondary cores in the beam?

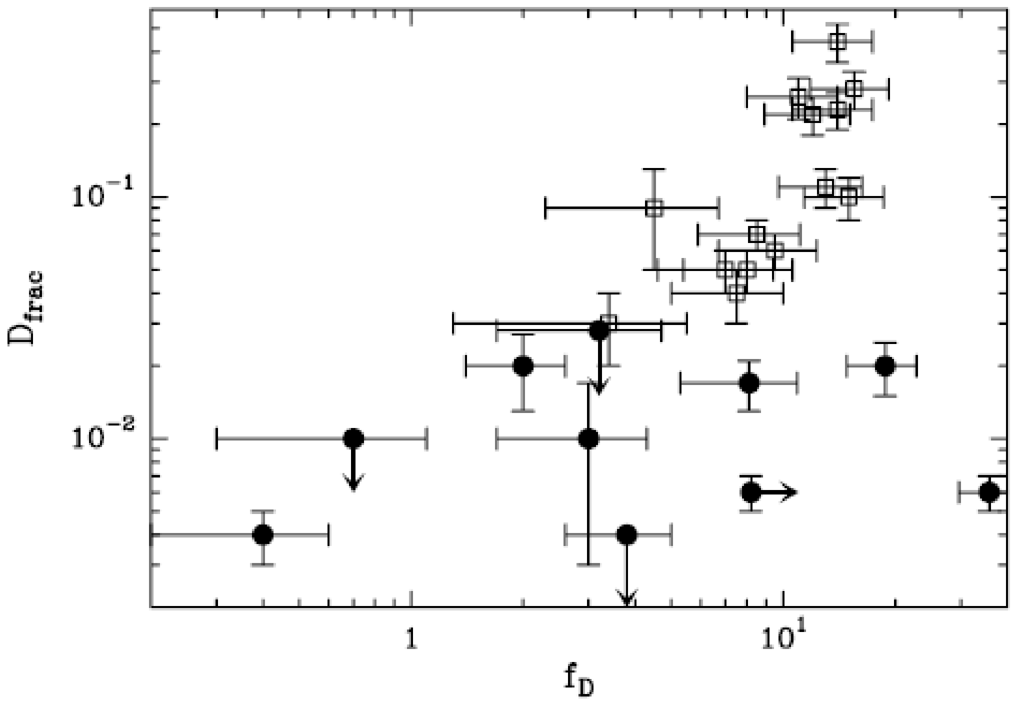
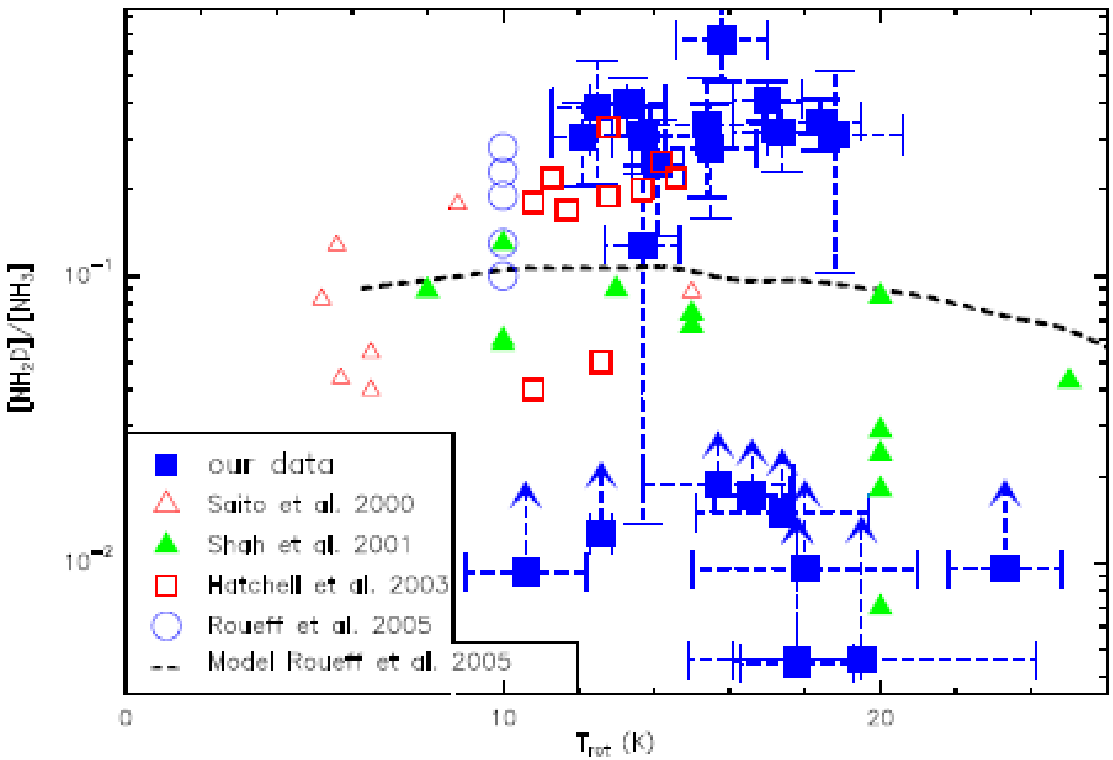


Fig. 2. Deuterium fractionation (D_{frac}) versus integrated CO depletion factor (f_D) for our sources (filled circles) and the low-mass pre-stellar cores of Crapsi et al. (2005) (open squares). The arrows indicate the upper limits on D_{frac} (see Table 9) or the lower limit on f_D (see Table 11).

Deuterium fractionation:
Pillai+ 2007

- SCAMPS and clumps in IRDCs
  - CO depletion
  - NH2D deuteration
- $[NH_2D]/[NH_3]$ ~ 0.005–0.6
  - Low values are lower limits
  - --> largest deuteration so far measured in massive clumps



- No trend with T, except deuteration low above 20 K
- Roueff+ 2005: steady state gas phase chem.
- Roberts+2003, n~3E6: $[NH_2D]/[NH_3]$ ~ 0.4-0.8

Clump mass functions:

Reid & Wilson 2006ab

- .5.5x5.5 pc SCUBA image of M17
- > 100 clumps
- Clump mass function either
  - Double power law
  - Lognormal
- 22 low+high mass regions:
  - LM: best fit w lognormal
  - HM: double power low
    - alpha_high close to Salpeter value

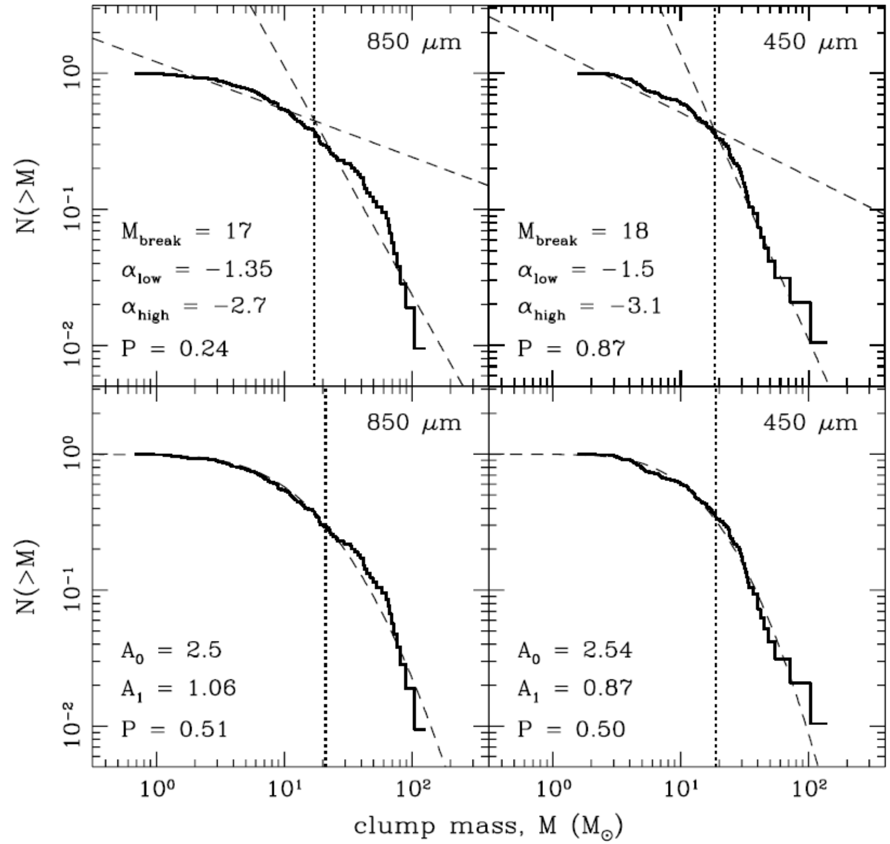
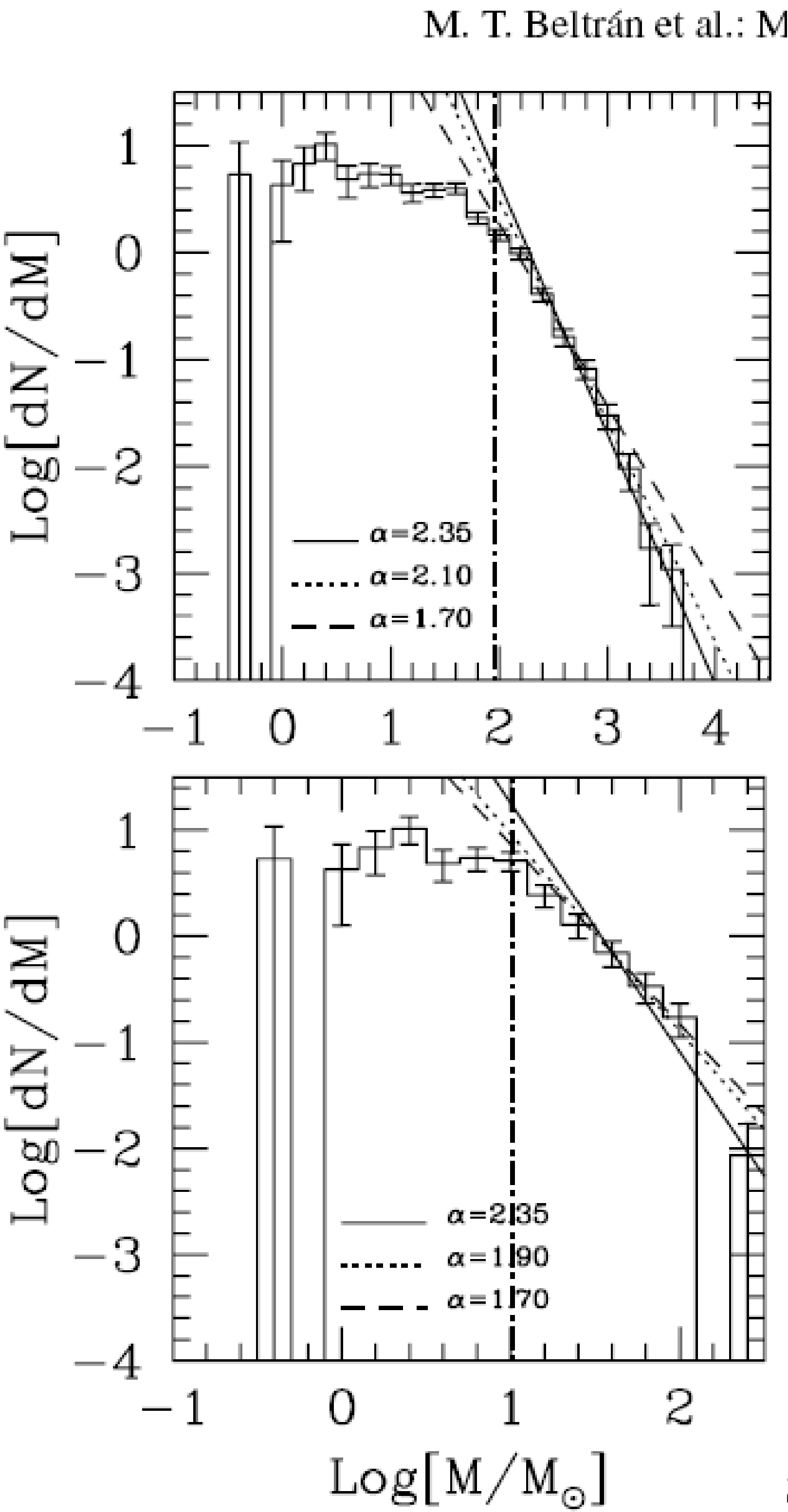


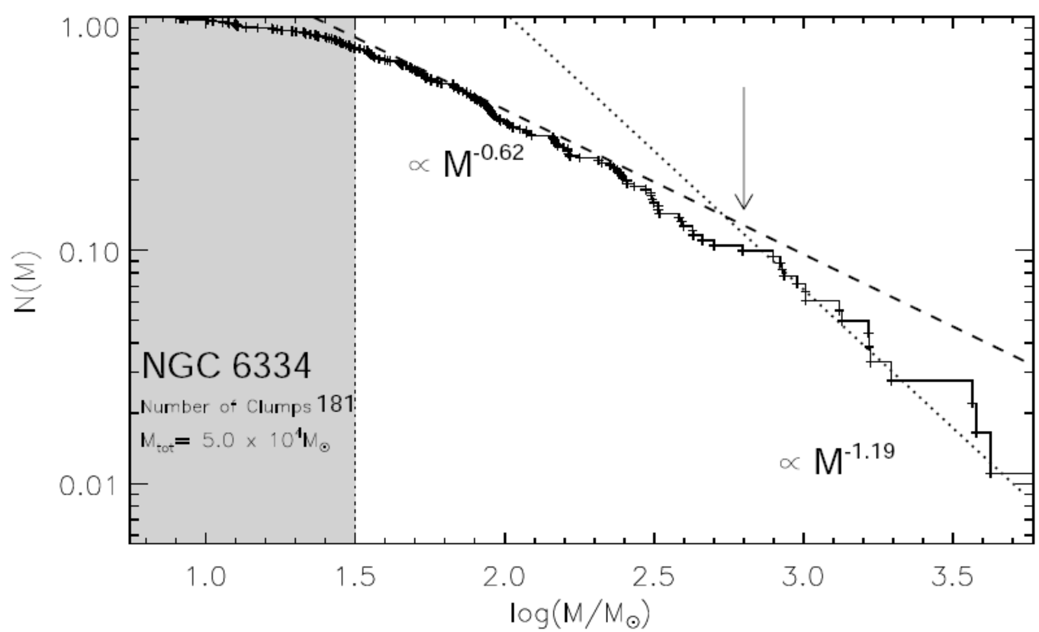
Fig. 5.—Same as Fig. 4, but for the cumulative mass function. *Top:* Mass functions are fitted with broken power laws (*dashed lines*), whose break points are parameters of the fit (*dotted lines*). In the 850 μm CMF, three power laws (not shown) are required to obtain a good fit. For consistency, we show only the fit with power laws. The exponents of the best-fit power laws are shown in the lower left corner of each panel. *Bottom:* Data are fitted to the CMF corresponding to a logno DMF (see eq. [8]), with best-fit parameters as shown; the vertical dotted line represents the mean mass derived from the lognormal fit. Values for all the fitted parame with uncertainties, are given in Table 3. The *P* values are goodness-of-fit measures, with values ≳0.1 indicating a good fit (see § 5.1).



Clump mass functions:

Beltran+ 2006, Munoz+ 2007

- High mass clumps consistent with Salpeter like slopes



— Normalized cumulative mass function $\mathcal{N}(M)$. The grey area corresponds to the region affected by completeness uncertainties in Figure 4. The arrow delimits the top 10% of the CMF where a power-law fit to the CMF (dotted line) yields an apparent -like slope.

Summary:
Properties of massive cold clumps

- High masses and densities in comparison to their low mass cousins
- Clump mass functions: Salpeter like for high mass end, still some scatter, T dependence might be needed for M
- Infall: ongoing through a large variety of stages!
- Evidence for depletion and, for some sources, deuteration as high as low mass cousins
- Range of star formation activity still hiding in the clumps!
  - --> Check SF activity with high angular resolution studies

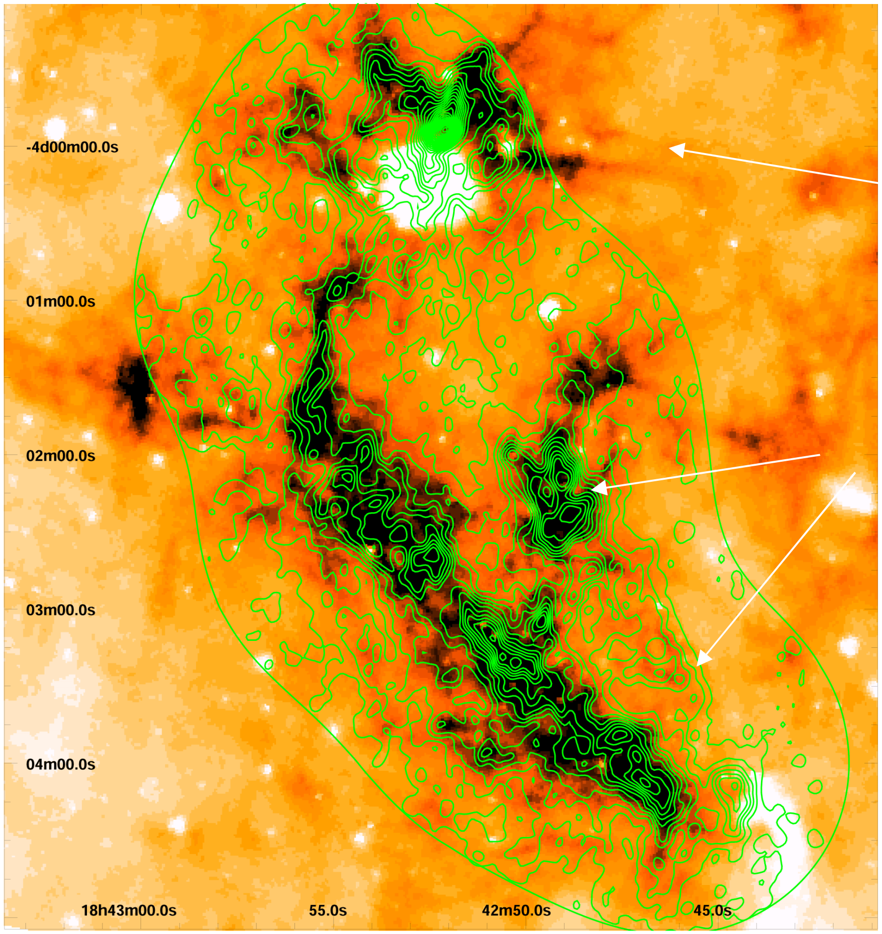
Cores (interferometric studies)

G28.34+0.06: Small Scale Structure

Wang+ 2007

NH_3 in contour, 8micron in color

4 pc



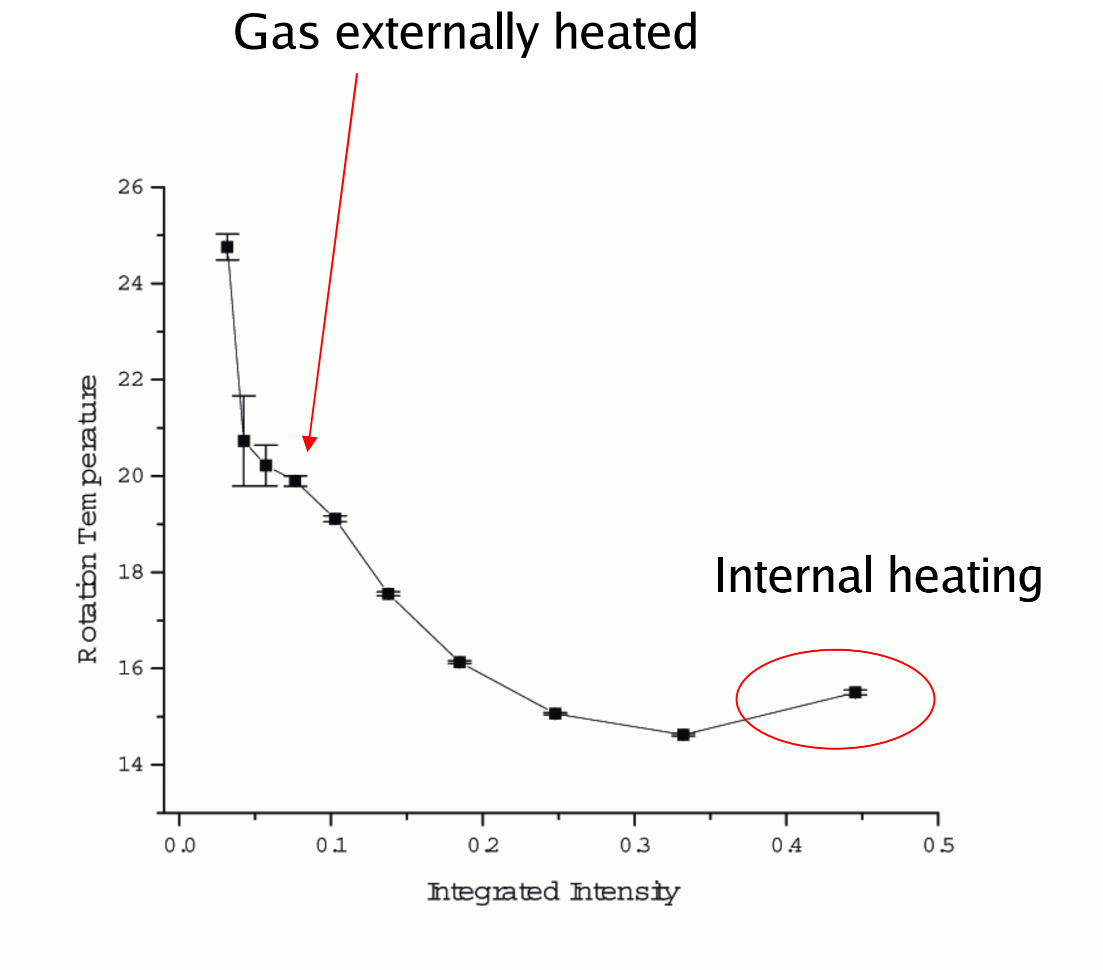
Northern Region
L~ 10^4 Lsun, H_2O maser
T>30K. v > 3.5 km/s
Protostellar Core

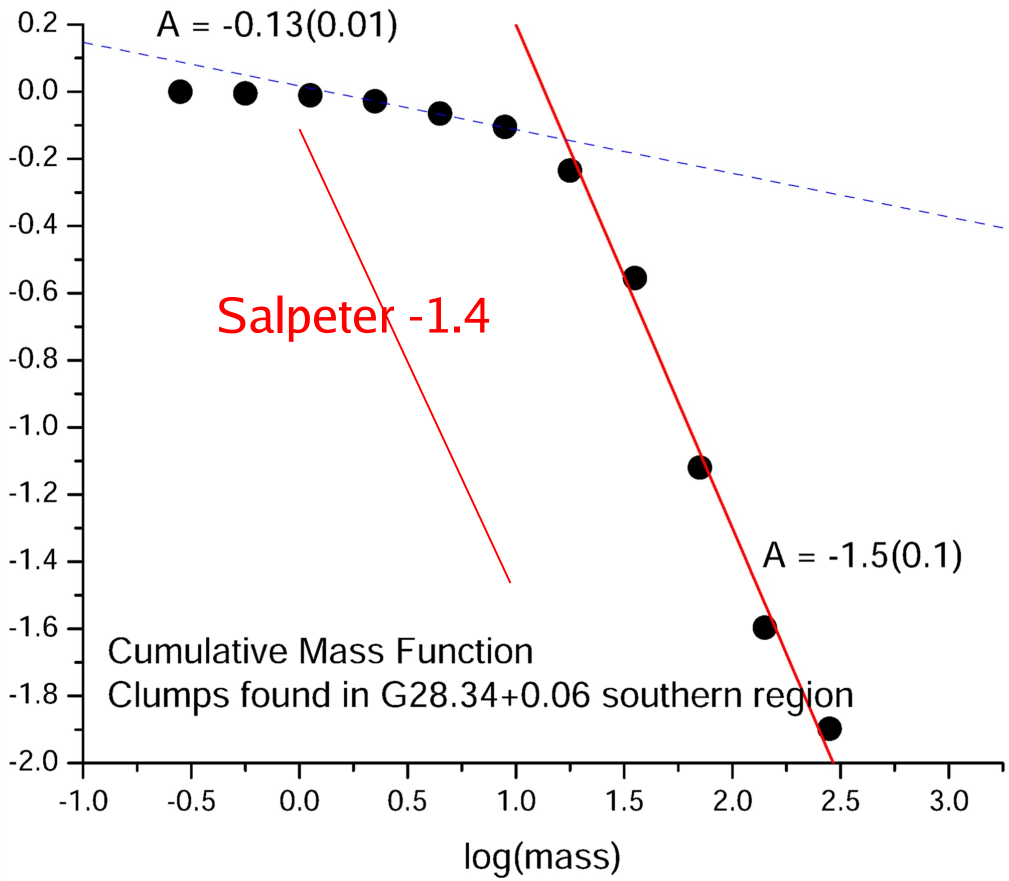
Southern Region
Quiescent cores
T<20K v < 2 km/s

Wang et al. 2007

G28.34 quiescent region: temperature and clump mass spectrum

Wang+ 2007

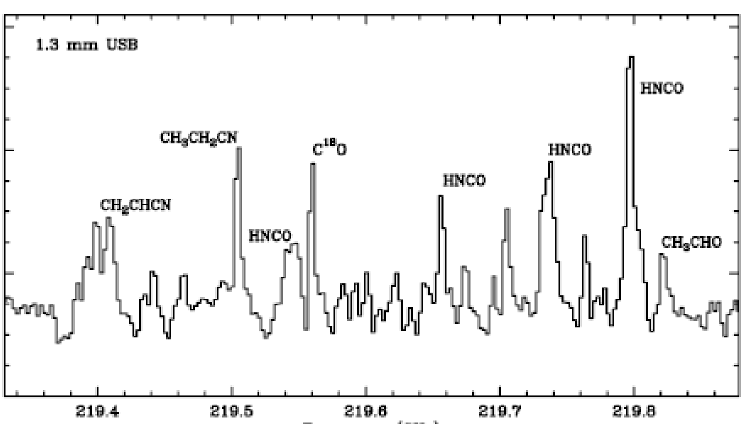




PdBI images of IRDCs:

Rathborne+ 2007

- PdBI study of 4 clumps in IRDCs
- --> 12 cores
- 1 hot core !
- Hierarchical fragmentation



No. 2, 2007 PROTOSTELLAR CONDENSATIONS IN IRDC CORES 1087

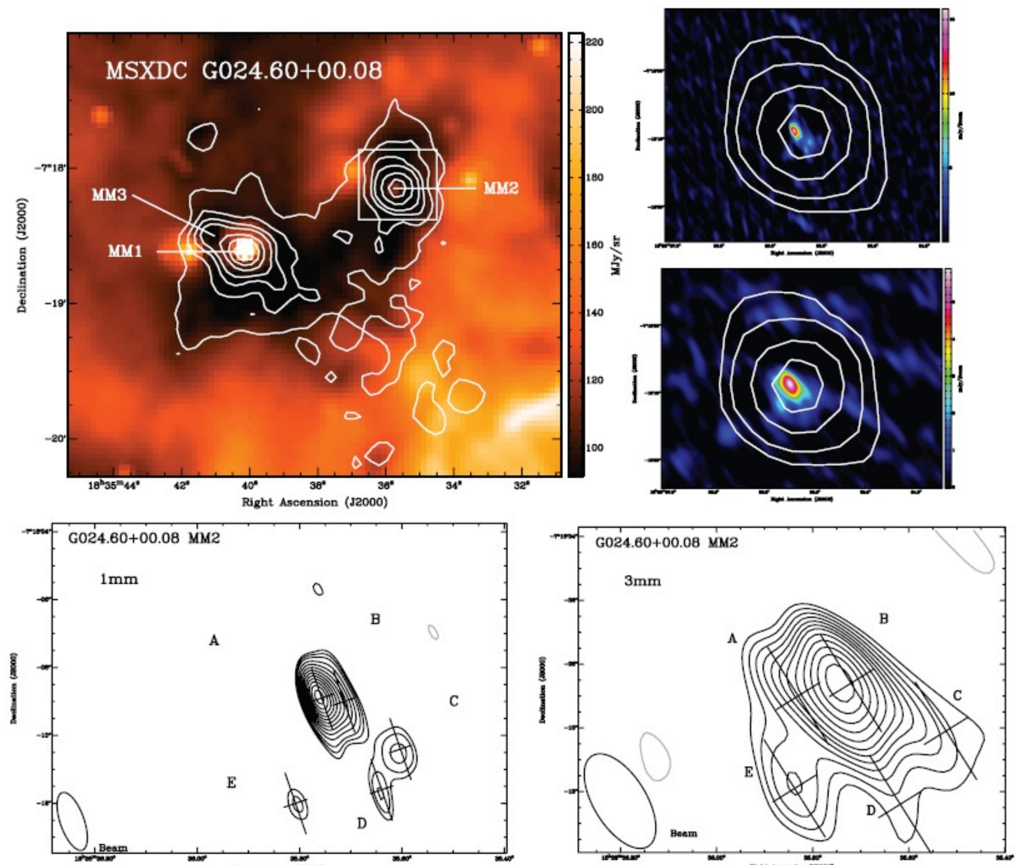


FIG. 4.—*Top left*: *Spitzer*/MIPS 24 μm image (6″ angular resolution) of G024.60+00.08 overlaid with contours of 1.2 mm continuum emission obtained with the IRAM 30 m telescope (11″ angular resolution; contour levels are 30, 60, 90, 120, 180, 240, 300 mJy beam^{-1}). The box outlines the extent of the high-resolution images. *Top right*: IRAM Plateau de Bure Interferometer 1.3 mm (*upper*) and 3 mm (*lower*) continuum images toward core MM2 overlaid with the lower resolution 1.2 mm continuum emission (contour levels are 90, 120, 180, 240, 300 mJy beam^{-1}). *Bottom*: IRAM Plateau de Bure Interferometer 1.3 mm (*left*) and 3 mm (*right*) continuum contour images of core MM2 (1.3 mm contour levels are −4, 4, 4.5, 5, 6, 7, 8, 9 mJy beam^{-1}; 3 mm contour levels are −1.2, 1.2 [5 σ] to 3.2 in steps of 0.3 mJy beam^{-1} and 3.5 to 6 in steps of 0.5 mJy beam^{-1}). Marked on these images are the condensations identified within the core (the cross centers mark the center of the Gaussian fits, their sizes and position angles correspond to the beam). Table 3 lists their properties. Note that the bright core MM2 is resolved into five condensations (A, B, C, D, and E). The close proximity of these condensations suggests that this core is forming a protocluster.

IRDC 18223-3
Beuther+ 2006

- 180 $M_\odot$
- Outflow
- Turbulence increase to center
- Quiescent secondary core

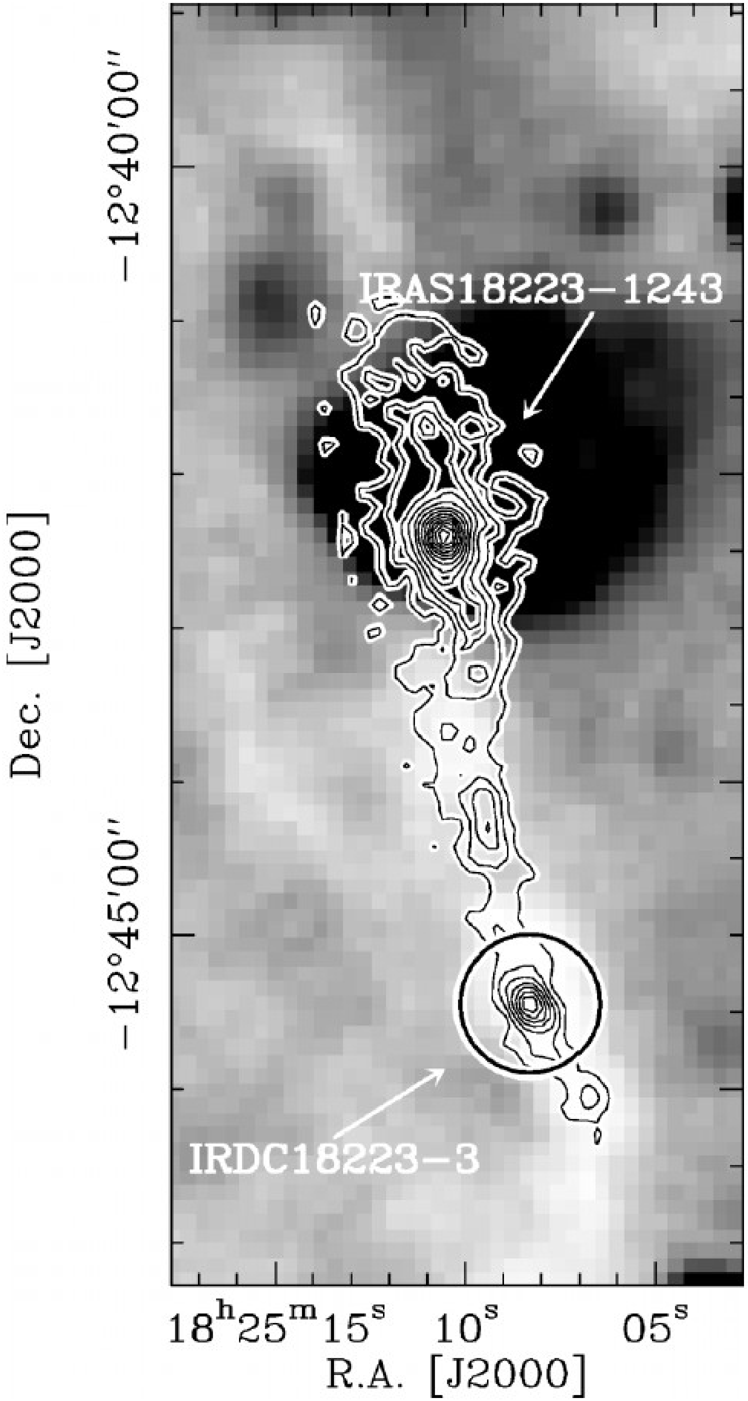


FIG. 1.—Contour overlay of the 1.2 mm single-dish continuum map (Beuther et al. 2002a) on the 8 μm *MSX* image (*gray scale*). The contour levels are from 38 mJy in 38 mJy steps. The northern source is the HMPO IRAS 18223−1243, and the southern source is the HMSC candidate IRDC 18223−3. The black circle outlines the primary beam of the PdBI observations.

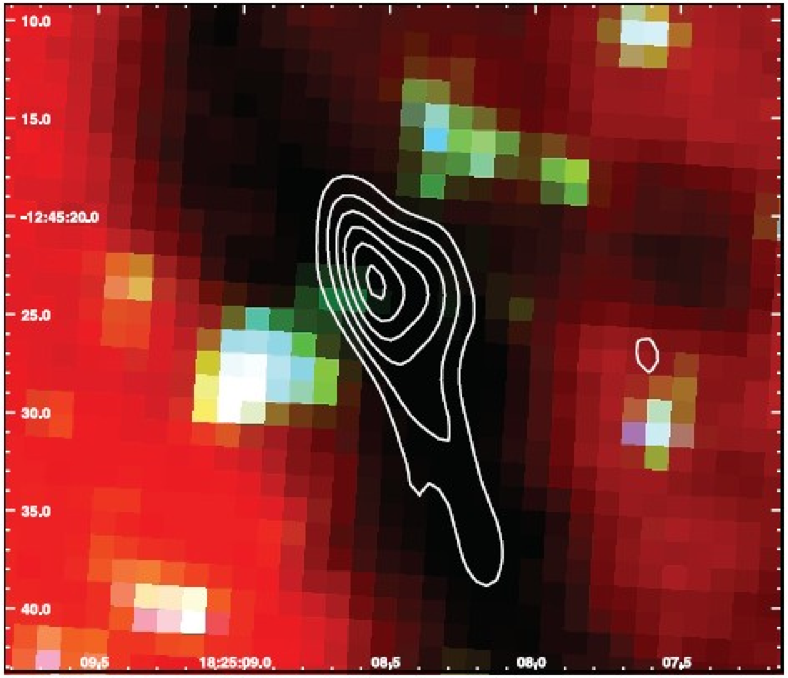


FIG. 2.—Three-color image of the *Spitzer* IRAC observations at 3.6 (*blue*), 4.5 (*green*), and 8.0 μm (*red*). The contours show the PdBI 93 GHz continuum map from 1.08 mJy (3 σ) in 0.72 mJy steps (2 σ). The axes are in R.A. (J2000.0) and decl. (J2000.0).

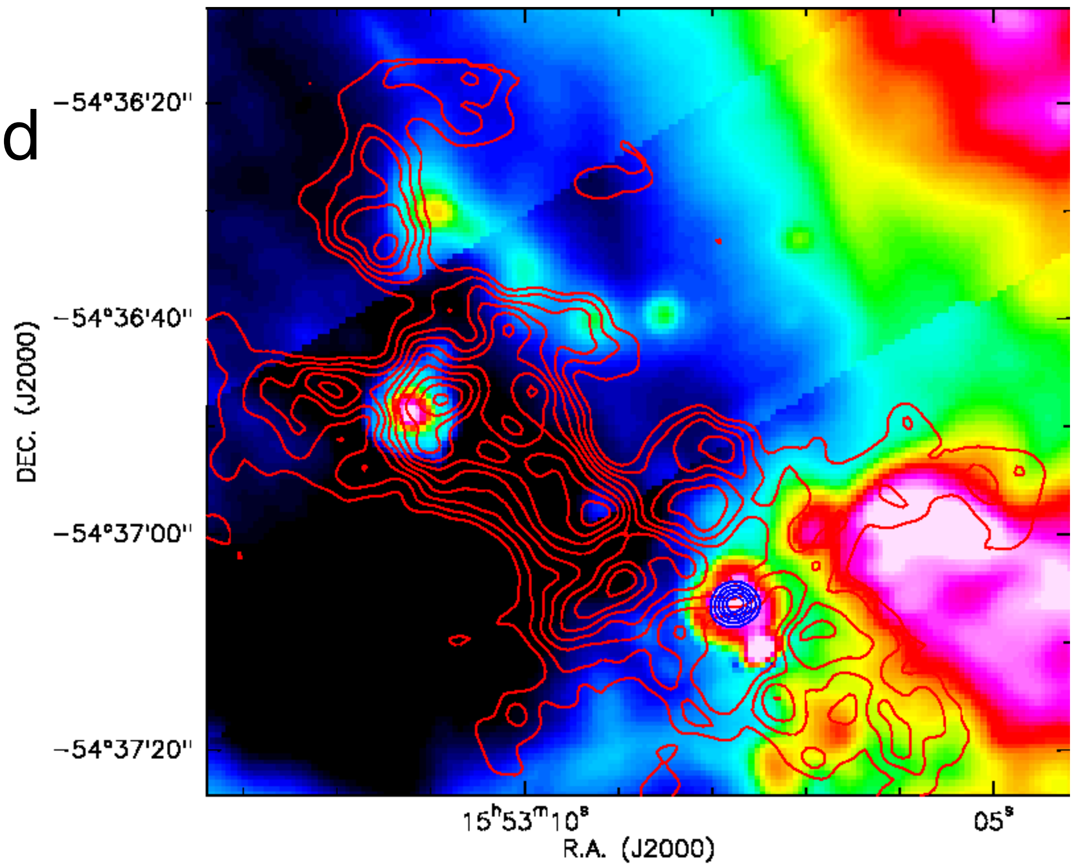
N_2H^+ ATCA/APEX results

Wyrowski+ 2007

- Compact 3mm cont/CH3CN source offset from UCHII
- N_2H^+ 1-0 constrains N_{col} and T_{kin} (20K)
- Density: line ratios of higher transitions
  - ➔ $n > 5x10^6$ cm^{-3}
- Core sizes 0.1–0.2 pc
- M>Mvir: unstable

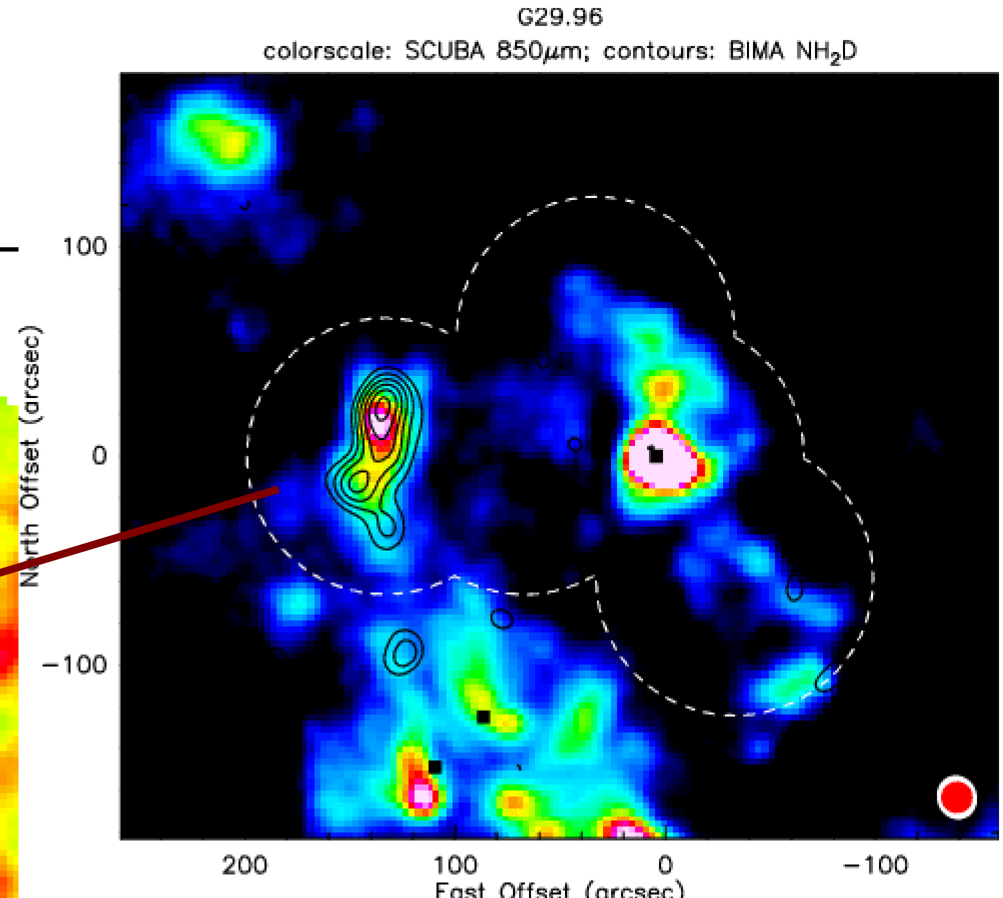
➔ Promising candidates for massive pre/proto stellar cores

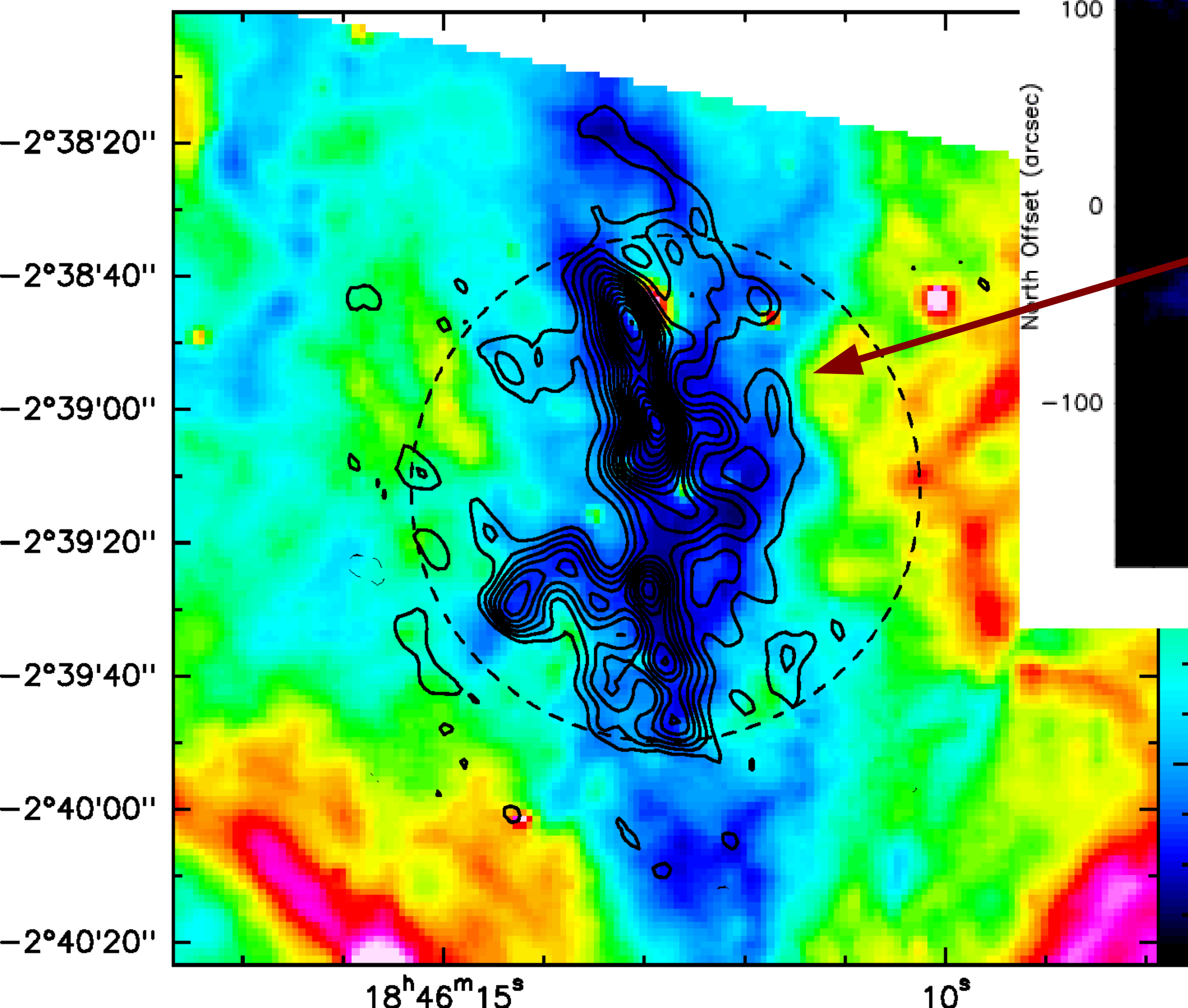
G327.3-0.6: GLIMPSE 8mu + N_2H^+



Interferometric observations of deuterated ammonia

Pillai 2006





Contours: NH_2D

Colorscale: 8mu (left)

850mu (top)

SMA dust cont + N_2H^+ from pre-protostellar cores
Pillai+ poster

- 1mm continuum: 60 – 800 $M_\odot$
- Mean densities~2 $10^6 cm^{-3}$
- 12/15 cores w/o MIR
- Strong N_2H^+ (3-2), narrower lines (1 km/s) towards starless cores
- Velocity dispersion of cores in a clump ~ 5 km/s

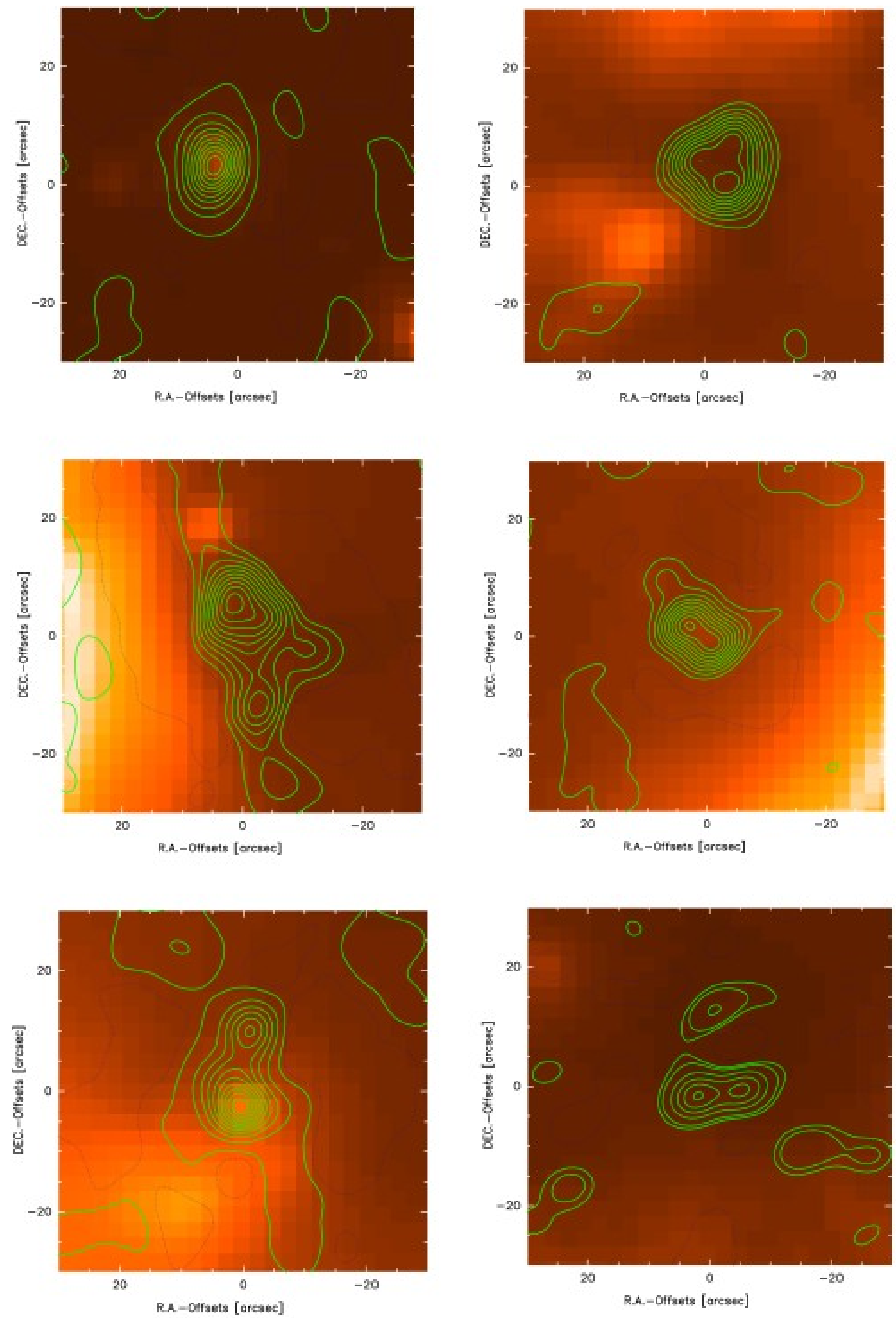


Figure 1: MIPS 24 micron emission (colorscale) with 279 GHz continuum emission from SMA subcompact configuration observations overlaid

Conclusions & Outlook

- Prolific times for the identification of precluster clump candidates !
- Properties of clumps fairly well known now
- Many cases, where SF activity can be found on a closer look.
  - Good: these clumps turn into stars
  - Bad: pure "starless" objects still rare
- For better statistics unbiased large scale surveys are on the way in a variety of wavebands
  - Submm bolometer surveys
  - MIR/FIR (MIPSGAL + Herschel in the future)
- Core properties will be stronger constrained by high resolution studies (with ALMA on the horizon)

Yes, Malcolm, we are making progress !!