Massive Protostars and Small Proto-clusters

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Clustering around candidate massive (proto)stars

Eoin Clerkin (Masters Thesis, October 2004, Univ of Porto)

Shocked H2 emission in rings and toroids around massive protostars

C.J. Davis, R. Bachiller, A.J.L. Fernandes, T. Hunter, S.Kurtz

Ring Shaped (Proto)Clusters

D.Shepherd, C.J.Davis, M. Tafalla, D.K.Ojha, L.Testi

Motivation

Stars of B7 or earlier are found to be associated with conspicous groups or clusters.

Testi et al. 1999, A&A, 342, 512
Hillenbrand, L., PhD Thesis.

What about candidate massive protostars ?

Search for Precursors to UCHII regions

Palla et al., 1991, A&A, 246, 249

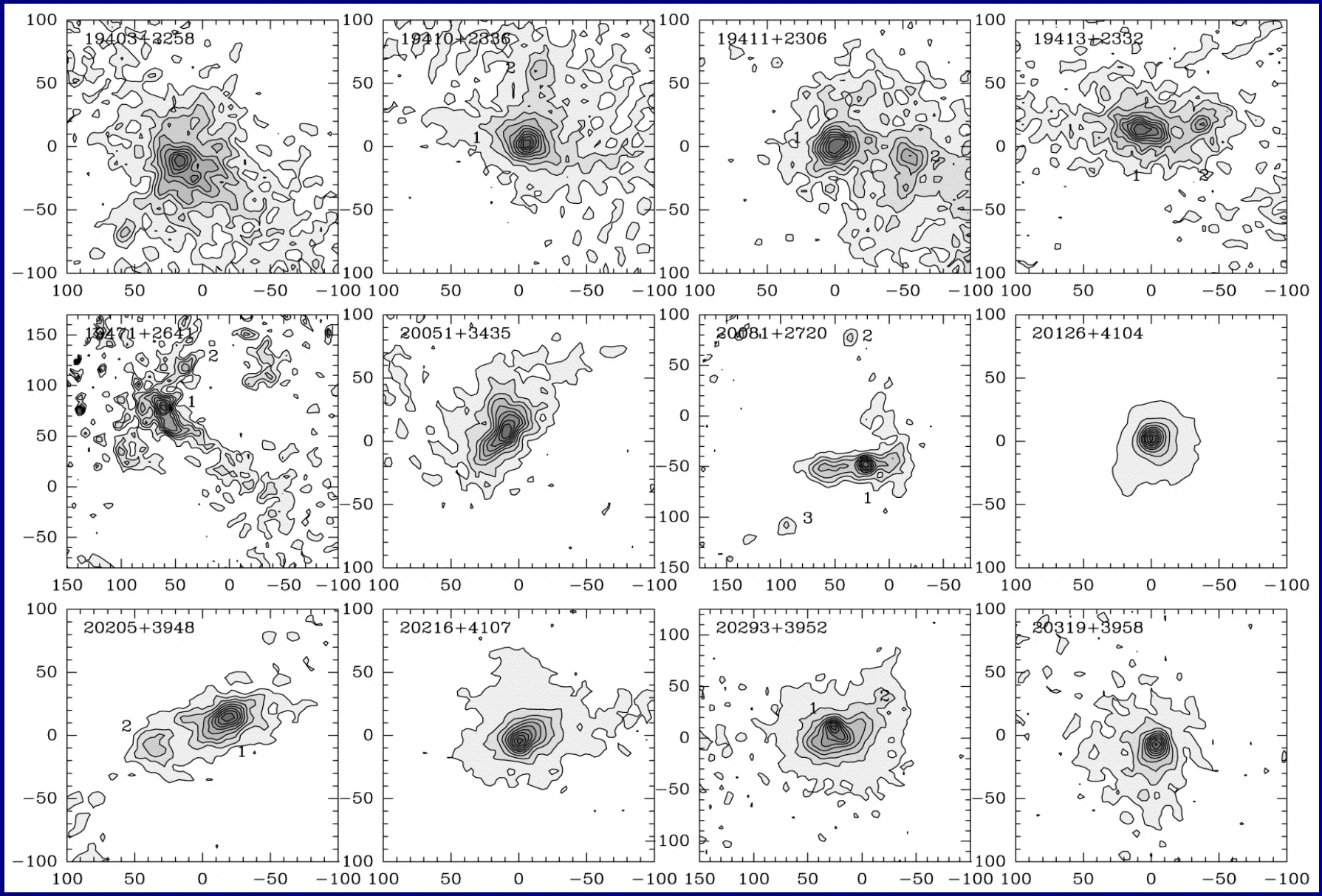
Molinari et al, 1996, A&A, 308, 573 NH3 Emission

1998, A&A, 336, 339 Radio Emission

2000, A&A, 355, 617 Dust Emission

Sridharan et al, 2002, ApJ, 266, 931
Sources without radio significant free-free emission.

Beuther et al, 2002, ApJ, 566, 945 Dust Cont Mapping



Beuther et al, 2002, ApJ, 566, 945

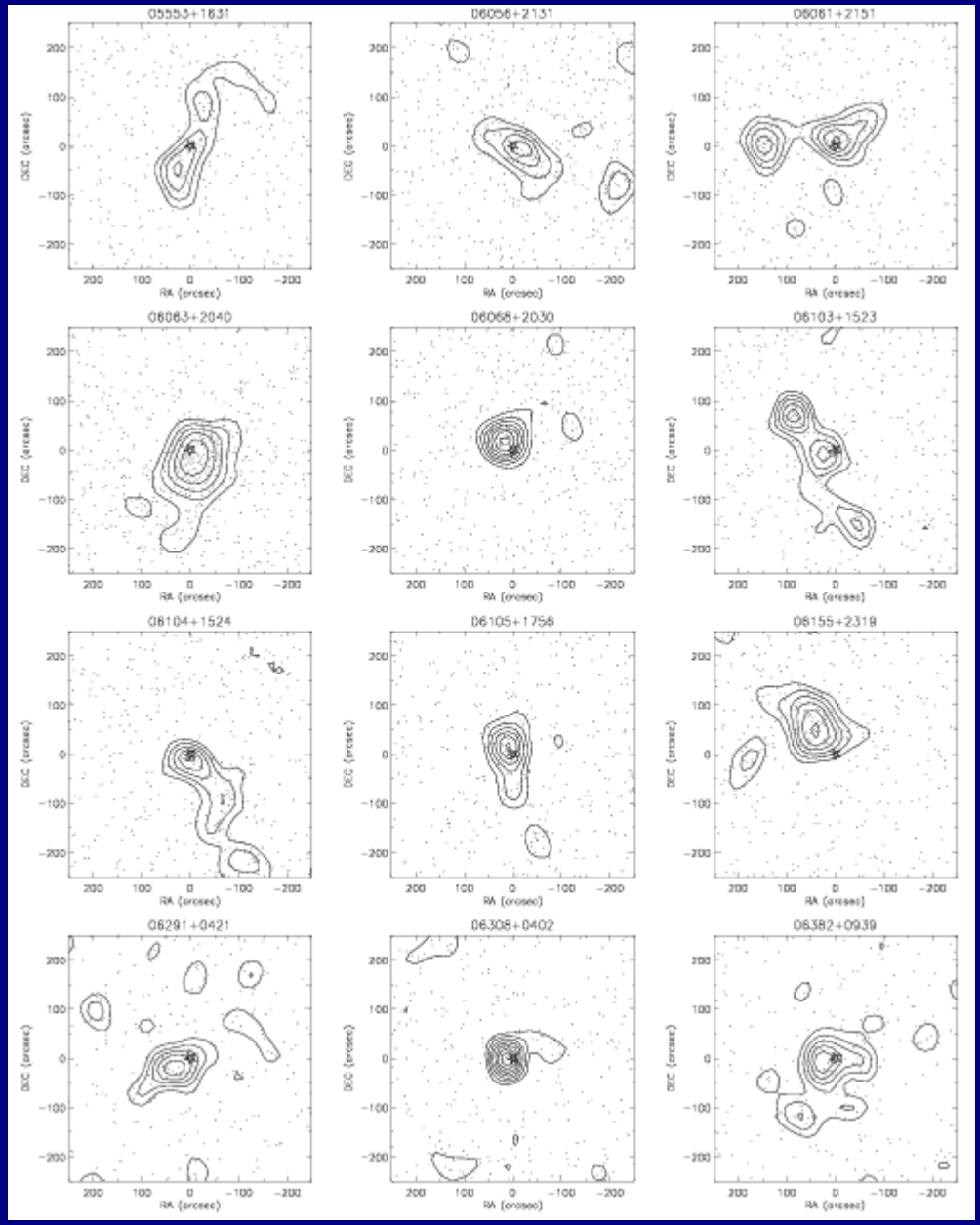
2MASS study of Candidate Precursors to UCHII region

Target Selection Molinari et al, 1996, A&A, 308, 573
Sridharan et al, 2002, ApJ, 266, 931

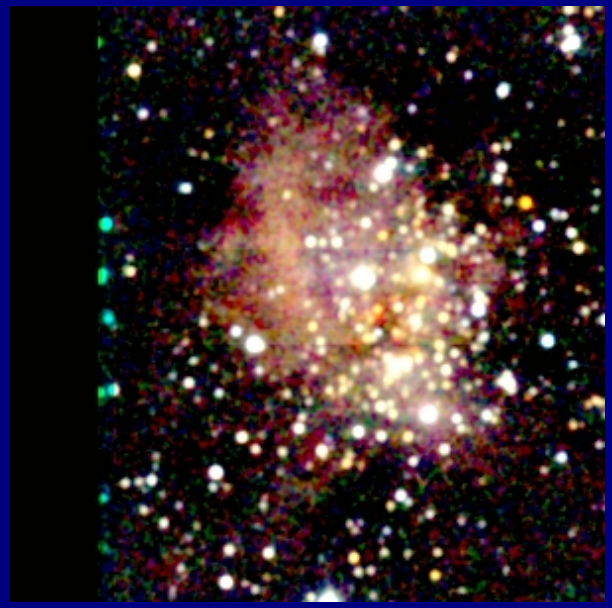
Size Selection 400''-500'' boxes based on dust cont maps

Data Source 2MASS GATOR All sky point source catalog
Data Constraints ccflag= 0, c ; phqual= ABCD in K band

Technique: Nyquist sampled binning of sources into bins of
60''-80'' to produce stellar density contours



Kumar & Clerkin, 2005, to be submitted to A&A



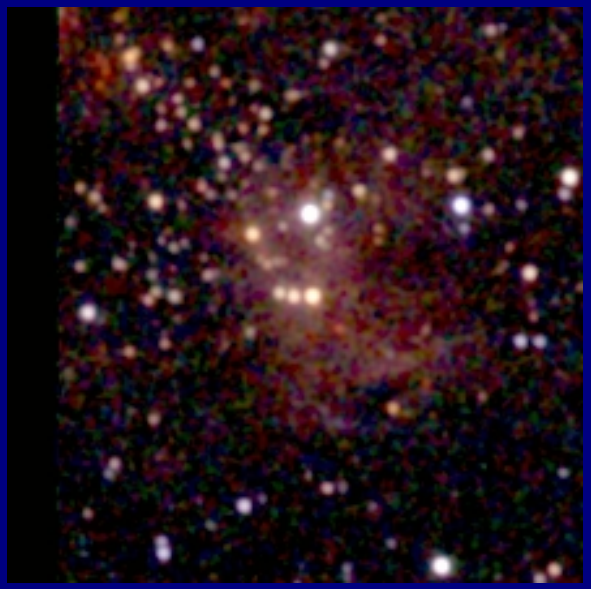



Fig. 4.5: figure continued

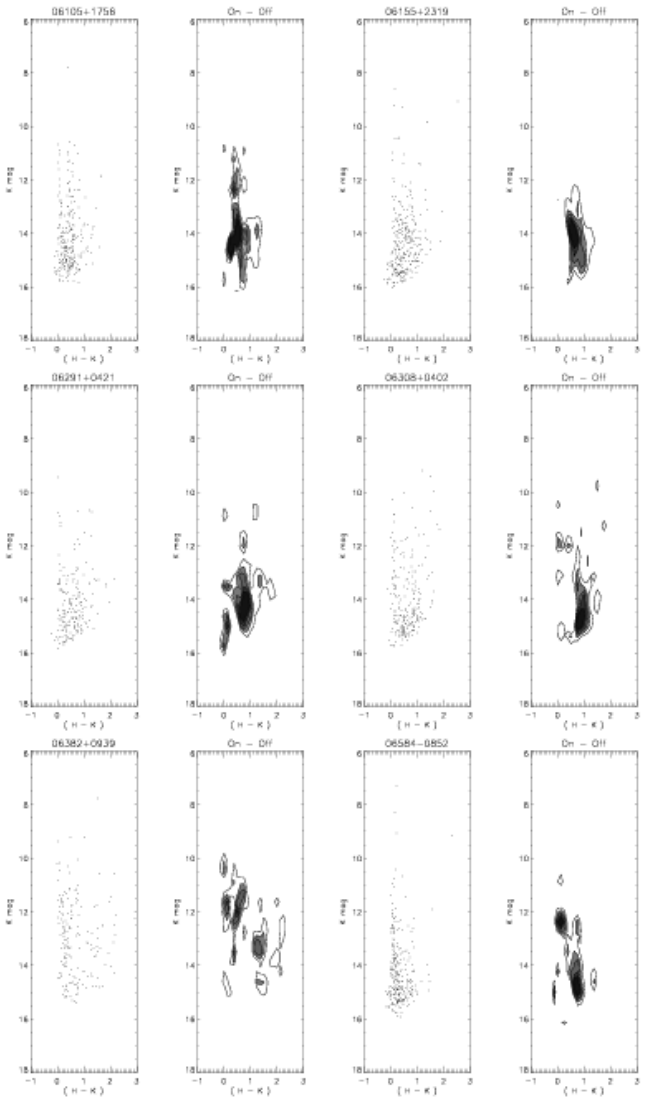
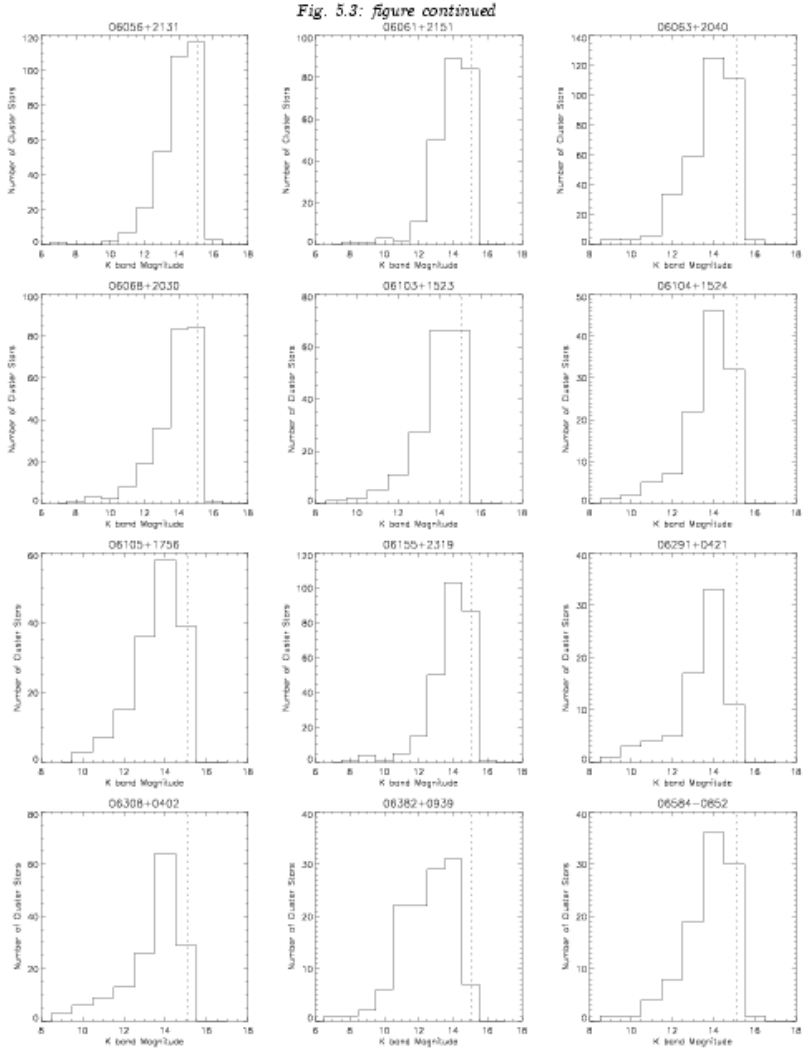


Fig. 5.3: figure continued



Embedded clusters detected and their properties

Percentage detection: 54/215 ~ 25%

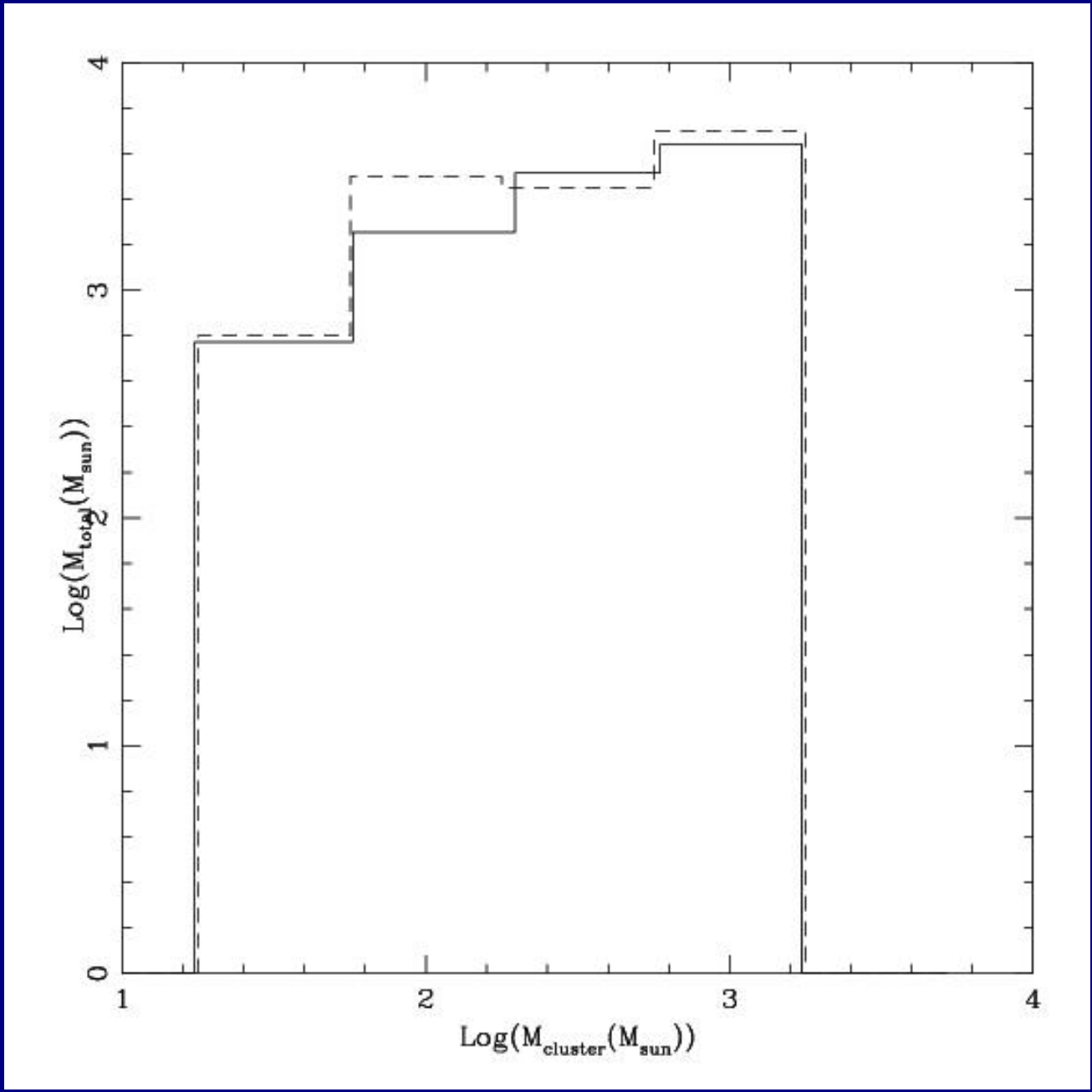
99 sources in the RA range 05h-06h and 20h-00h
indicates percentage detection of
63% Sridharan, 51% Mol L, 54% Mol H

Probably, the 25% detection rate for the overal sample is only an effect of galactic plane extinction at 2micron

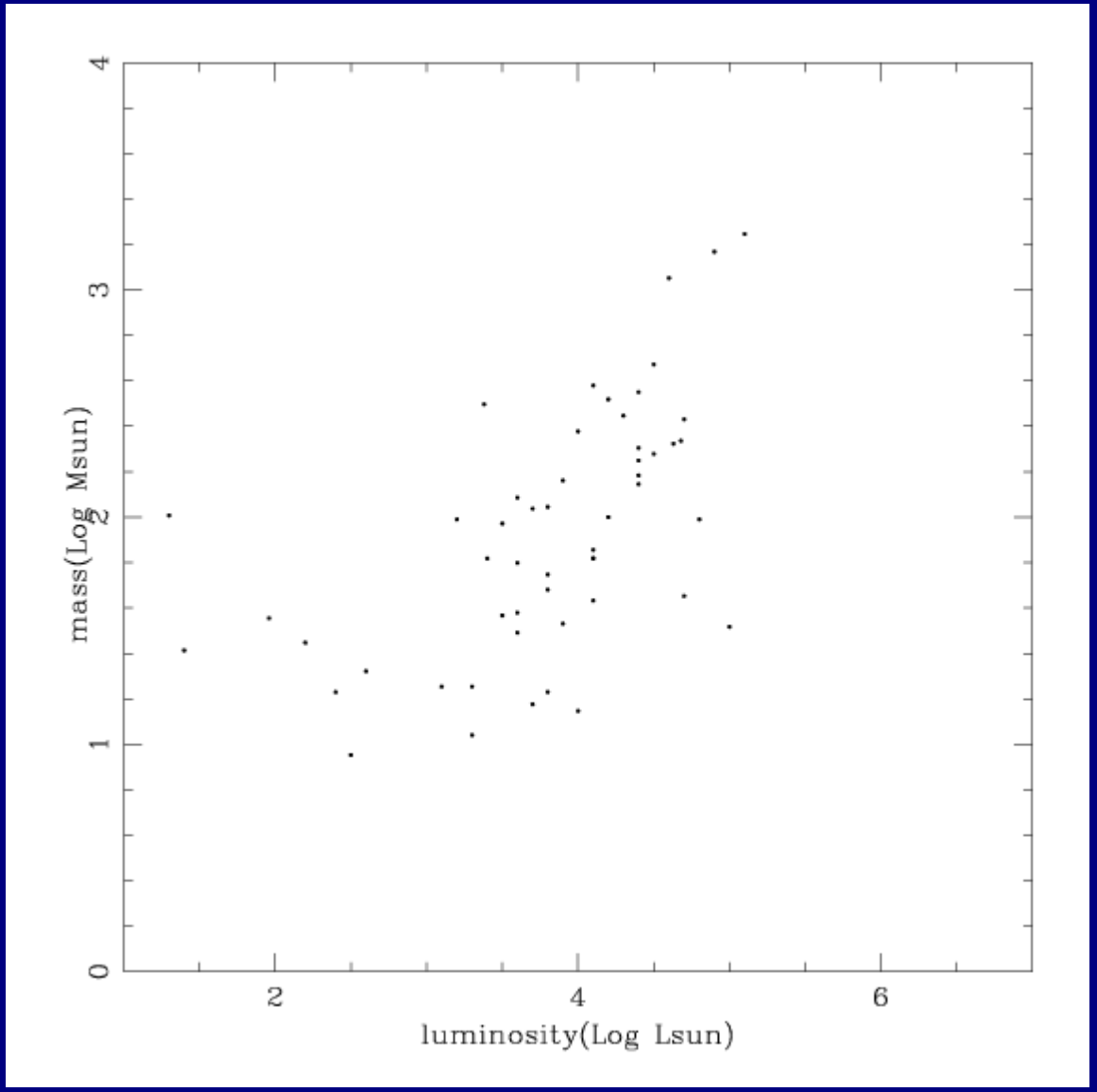
Structure: single peaks: ~ 30
multiple peaks: ~24

Dotted Graph is from Lada & Lada, 2003, ARAA, 41, 57

Solid Graph from the sample of clusters around candidate massive protostars



Embedded Cluster Mass Distribution Function

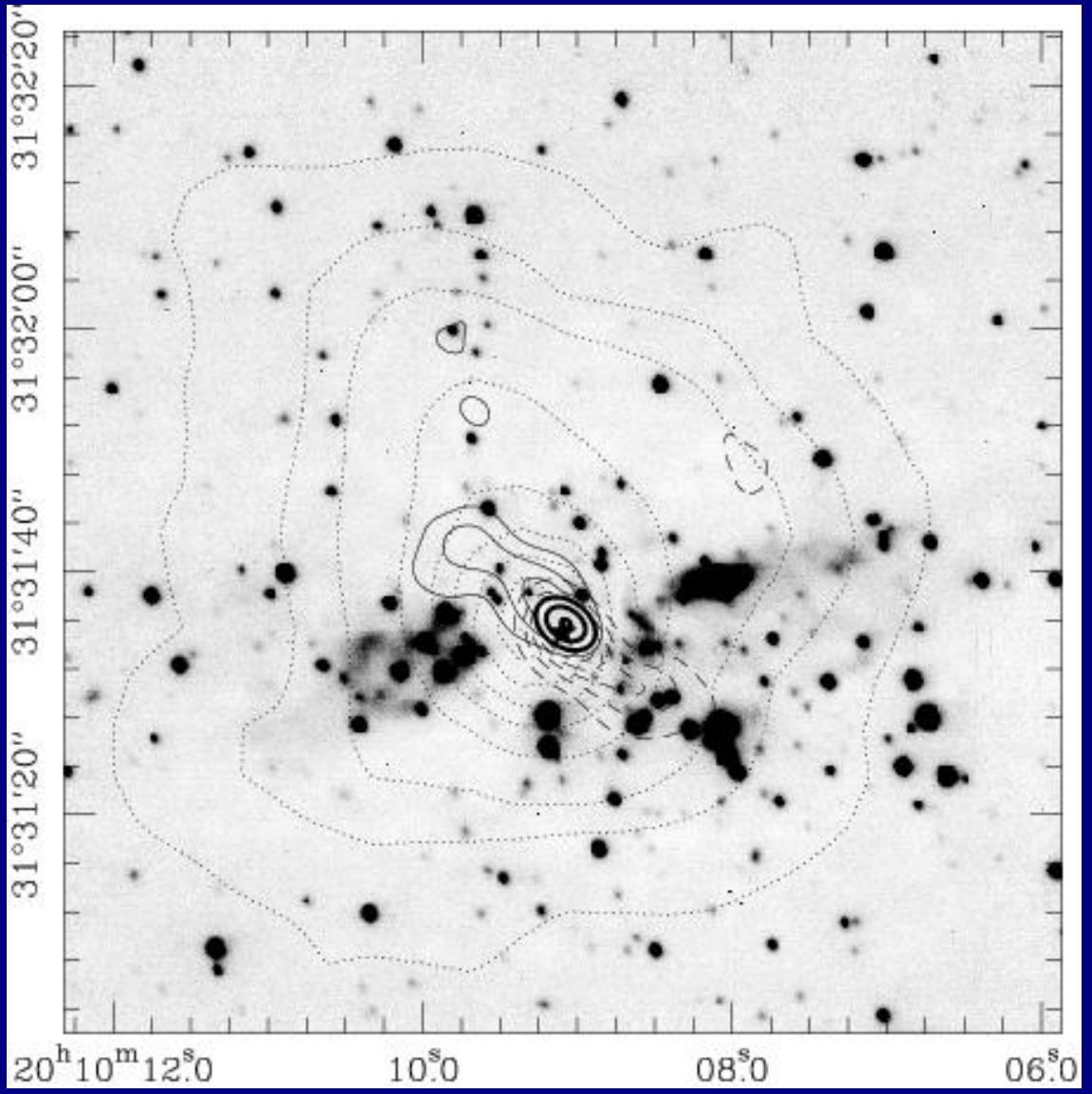

mass(Log Msun)
luminosity(Log Lsun)
0
1
2
3
4
2
4
6

Onsala 1 UCHII region

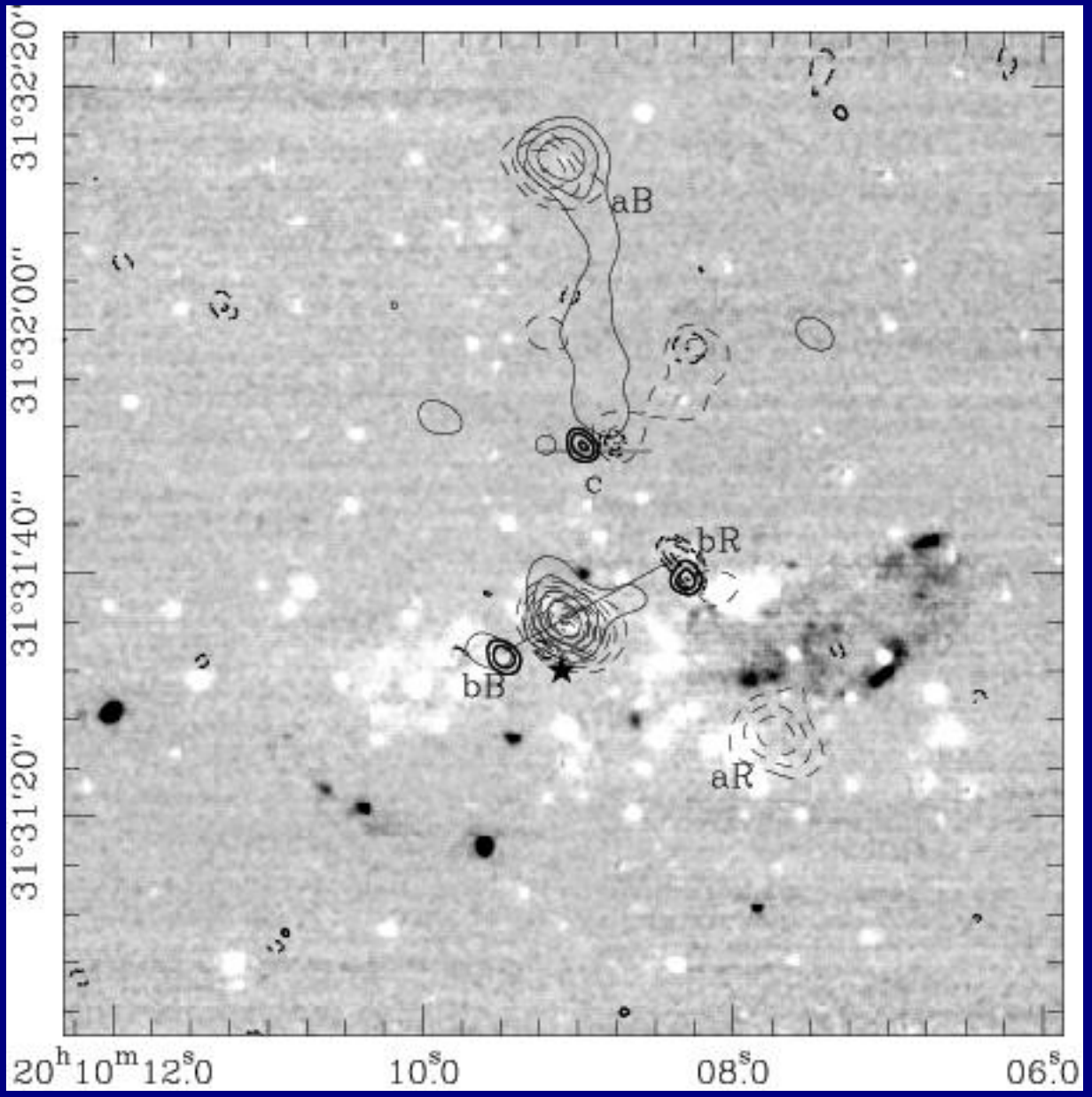
Blue and red shifted $H^{13}CO^{+}$ emission shown with solid and dased contours.

1.3mm, 3mm continuum emission shown with dotted and heavy contours..

Grey scale background is a 2.2micron K-band image.



Kumar, Tafalla & Bachiller, 2004, A&A, 426, 195


31°32'20"
31°32'00"
31°31'40"
31°31'20"
aB
c
bR
bB
aR
20h10m12s.0
10s.0
08s.0
06s.0

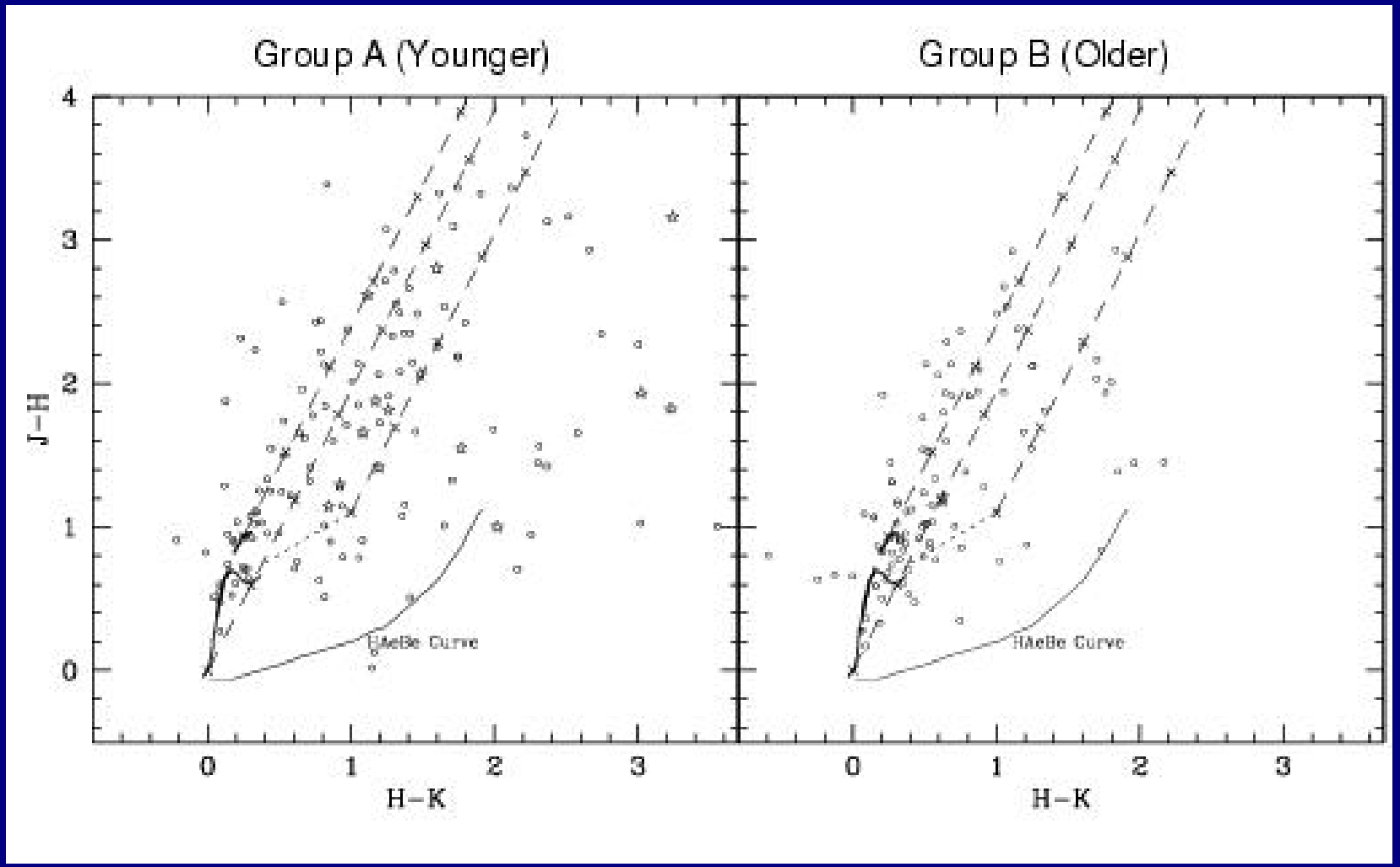
Massive Stars are born late in the evolution of an embedded cluster

Herbig, G. H., 1962, ApJ, 135, 736
Stahler, S. W., 1985, ApJ, 293, 207

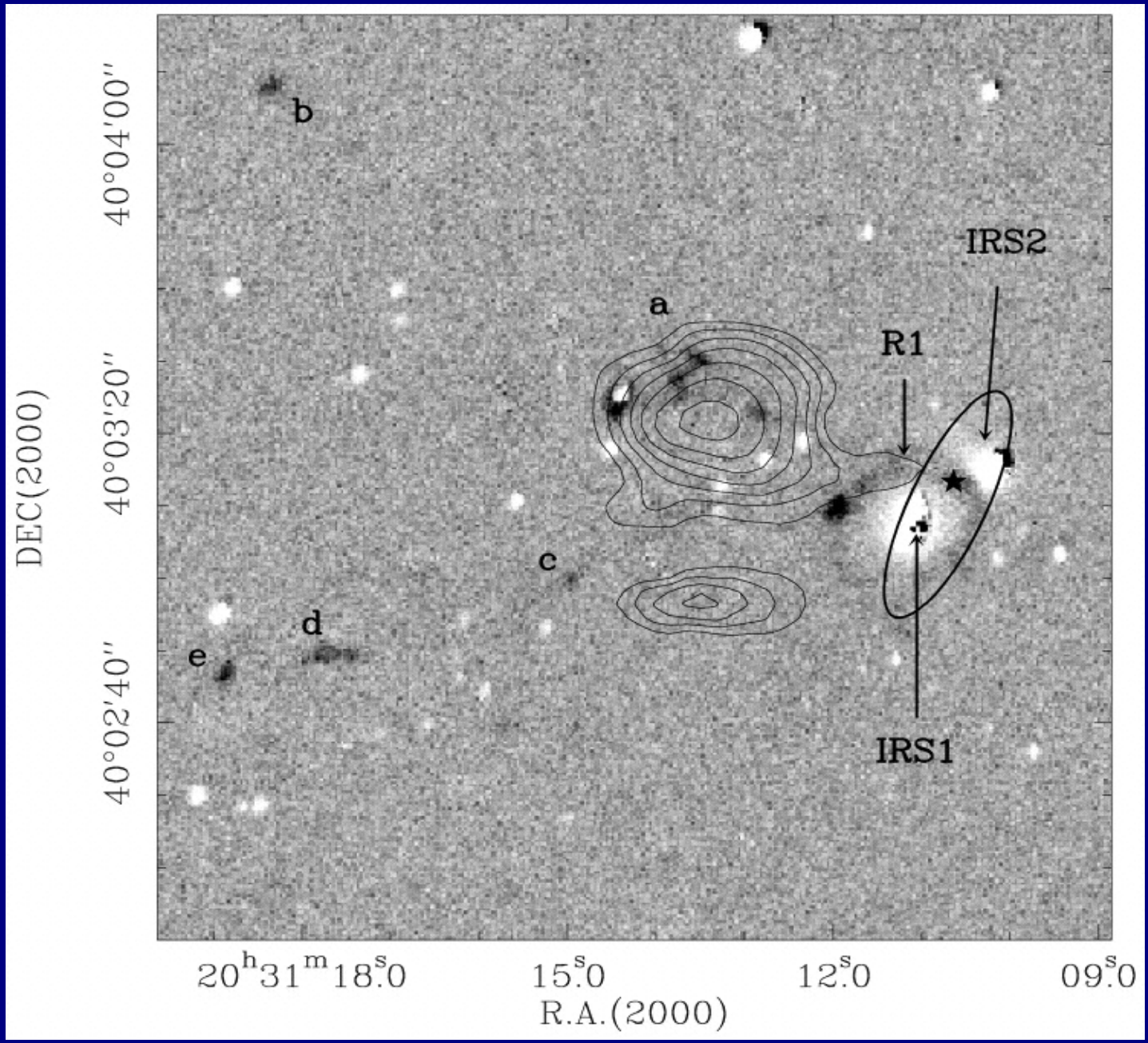
54 Embedded clusters detected around candidate massive protostars

These embedded clusters are composed of stars that fall into the zone of T-Tauri stars and HaeBe stars, indicating a prominent low mass population

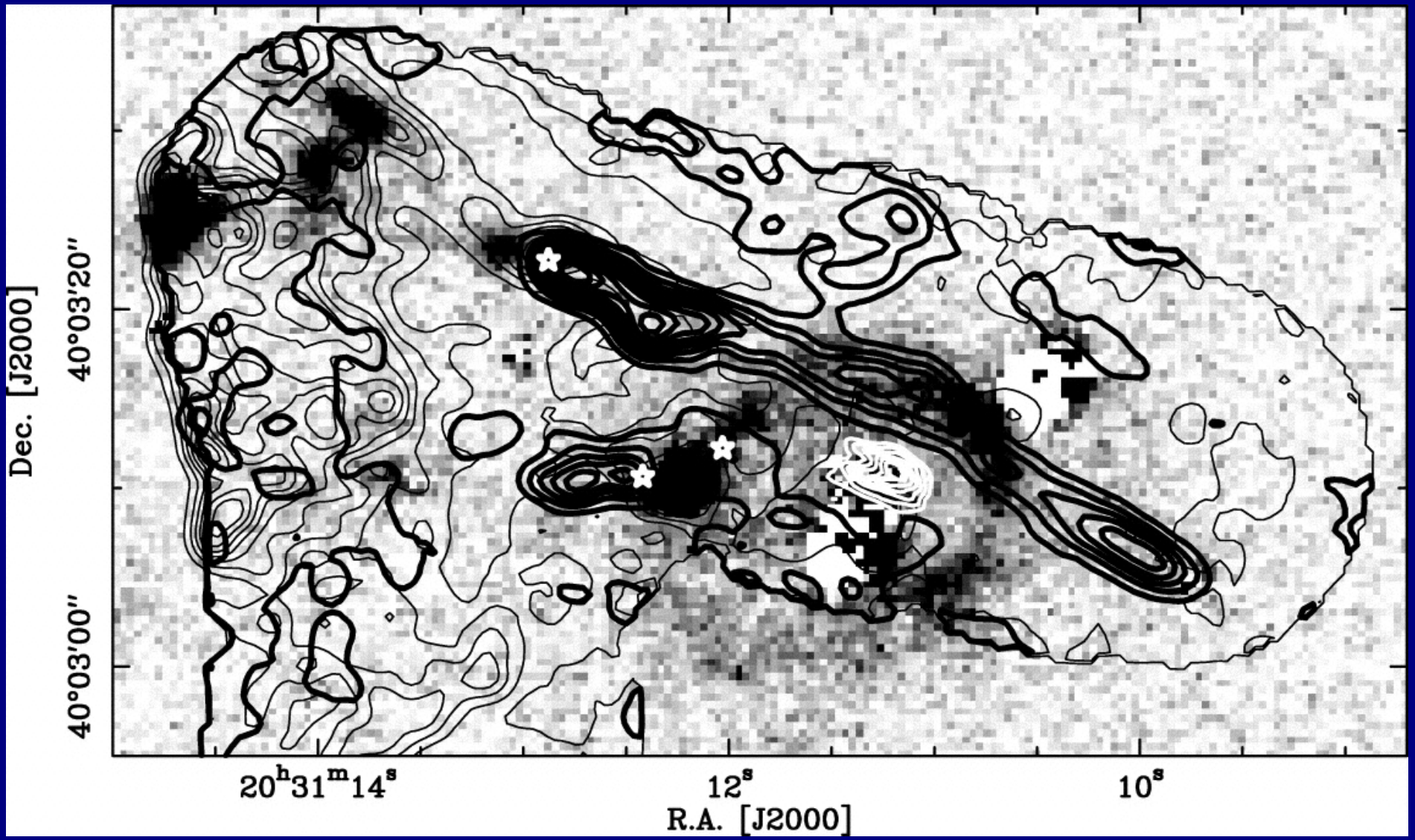
Best Massive Protostellar candidates for NIR studies



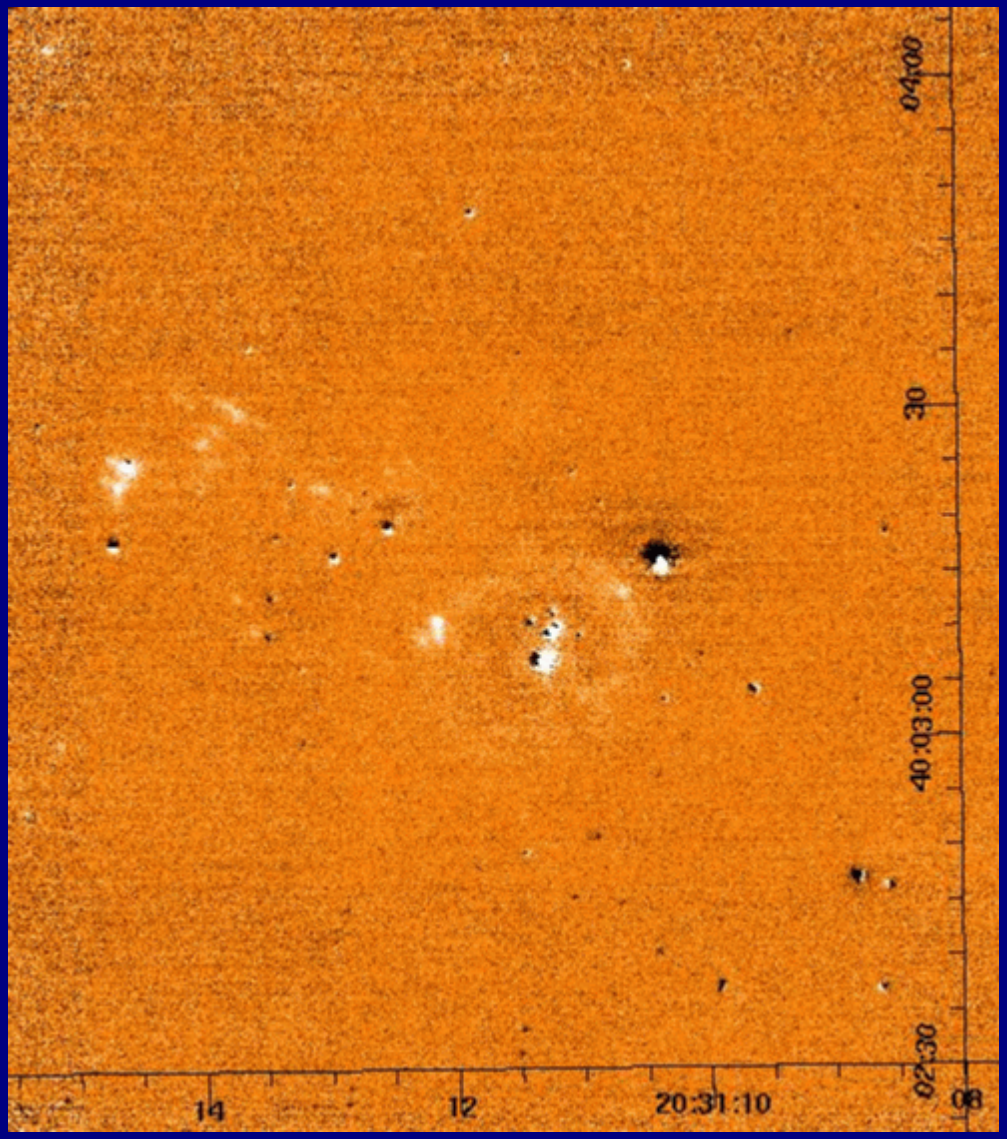
2MASS counterparts of the mm peaks (Group A) and VLA peaks (Group B) from surveys of candidate precursors to UCHII regions.



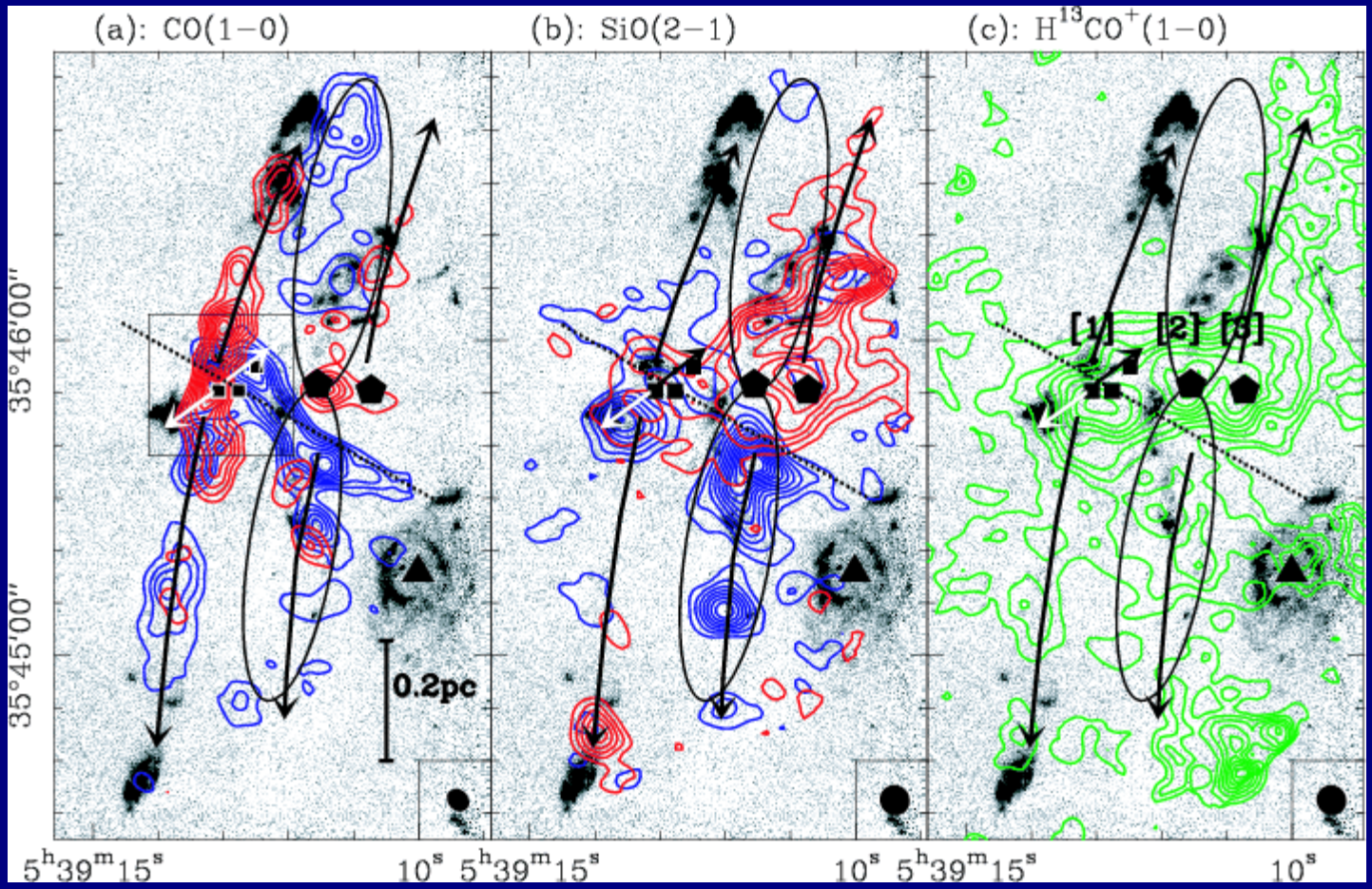
Kumar, Bachiller & Davis, 2002, ApJ, 576, 313



Beuther, Schilke & Gueth, 2004, ApJ, 608, 330



Varricatt, et al, 2005, in preparation



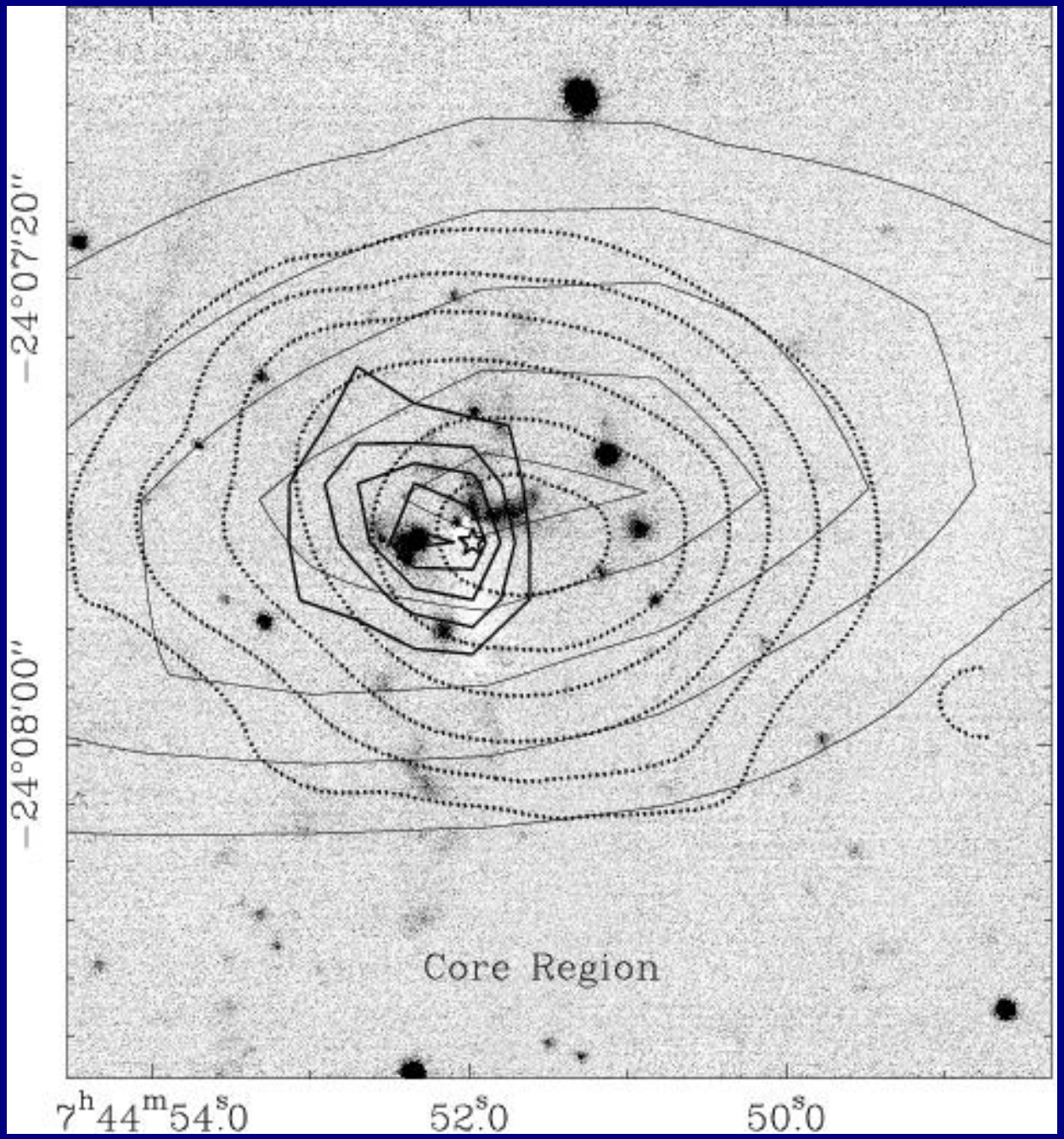
Beuther et al, 2002, A&A, 387, 931

Grey Scale = H_2 Image

Thick contours : 350um

Dotted contours: $C^{18}O$

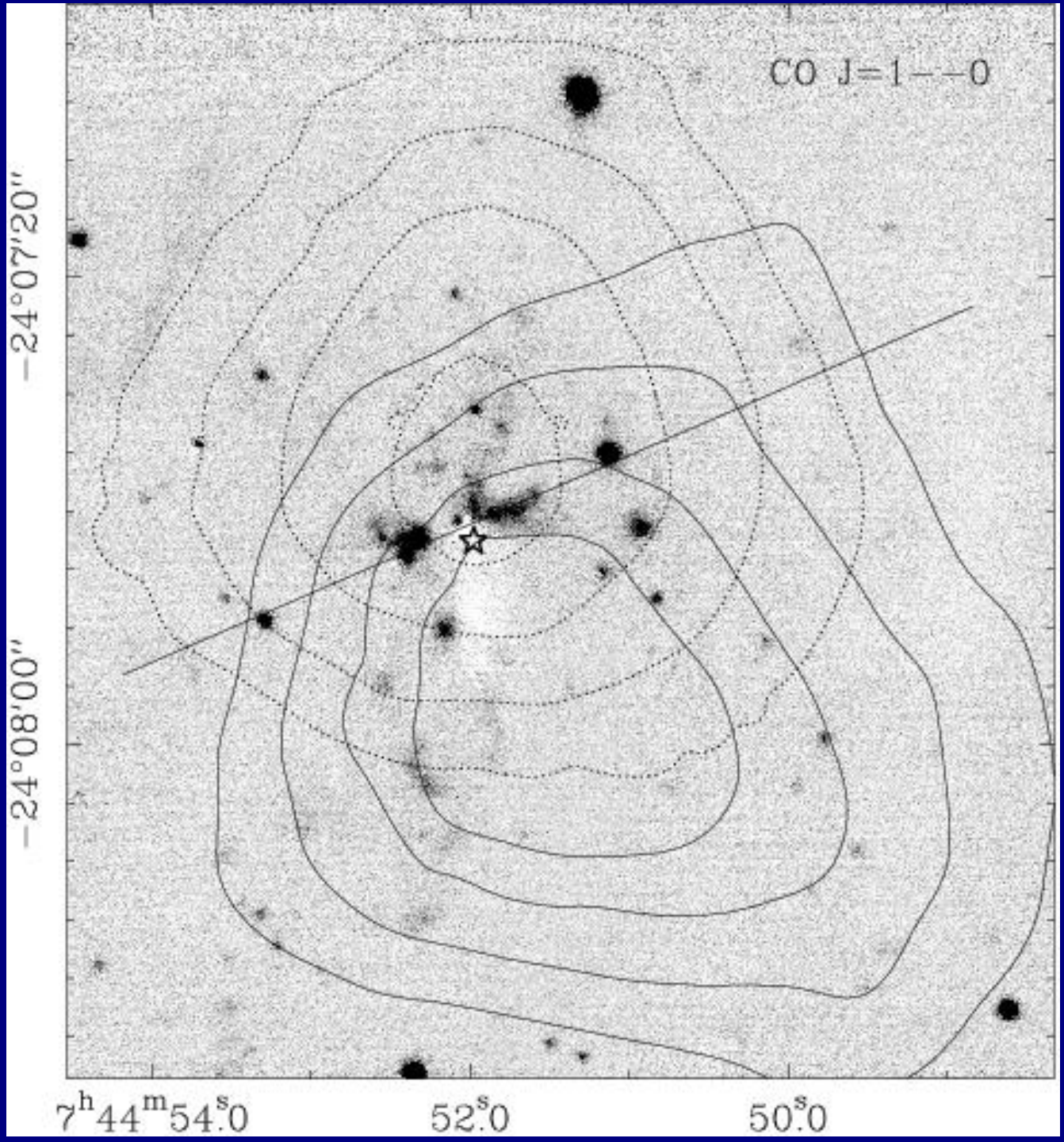
Normal contours: 12um



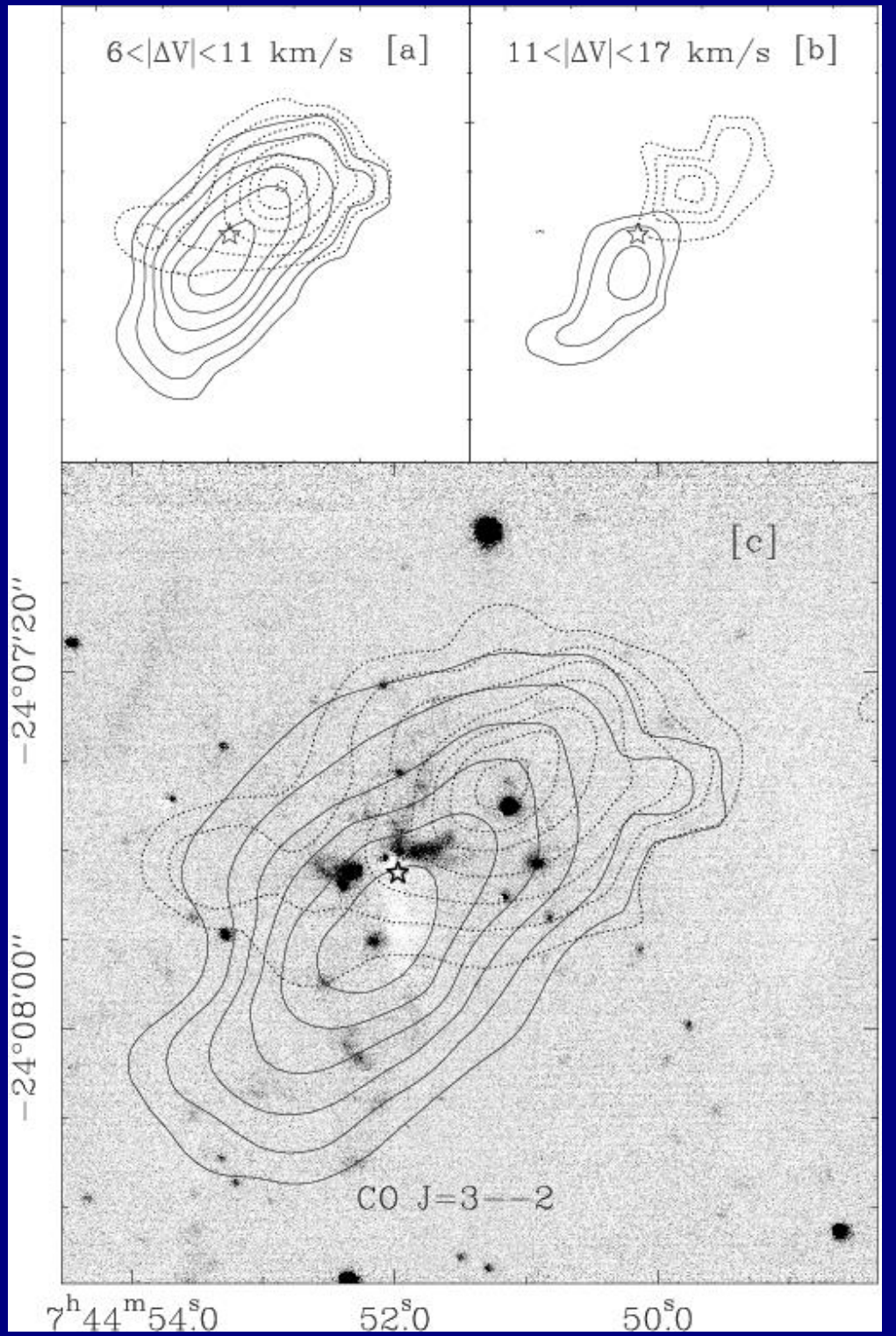
Kumar et al, 2003, A&A, 412, 175

CO J= 1 -- 0 contours

Shepherd & Churchwell, 1996, ApJ, 457,267



CO J = 3 --2 contours
10.4m Caltech Submm Observatory



Have we really identified any O-type protostars?!

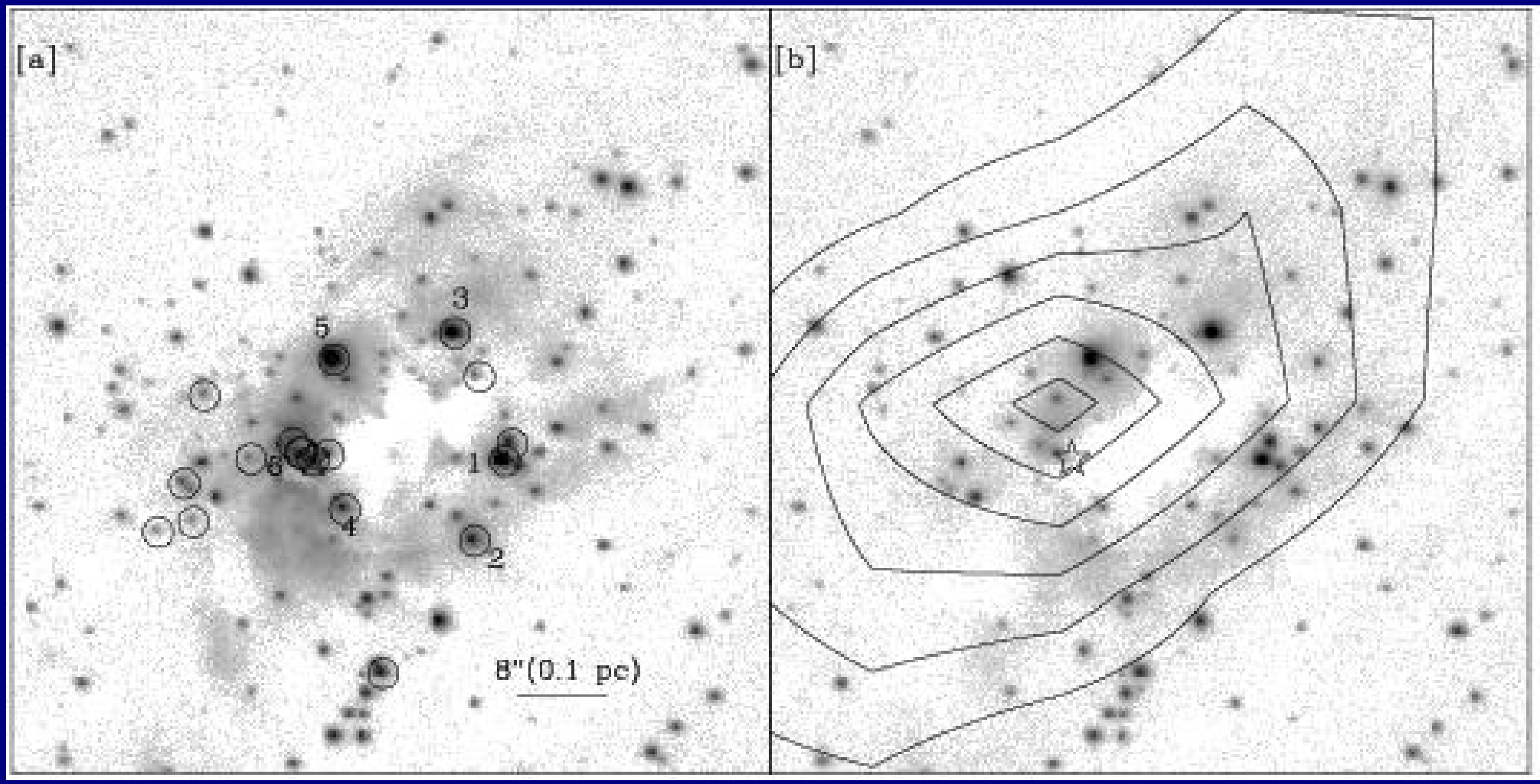
Do they exist at all?!

These clusters are simple and neat laboratories to study cluster formation because probably there is only “one massive young star” in each cluster and not as confused as an Orion or Monoceros

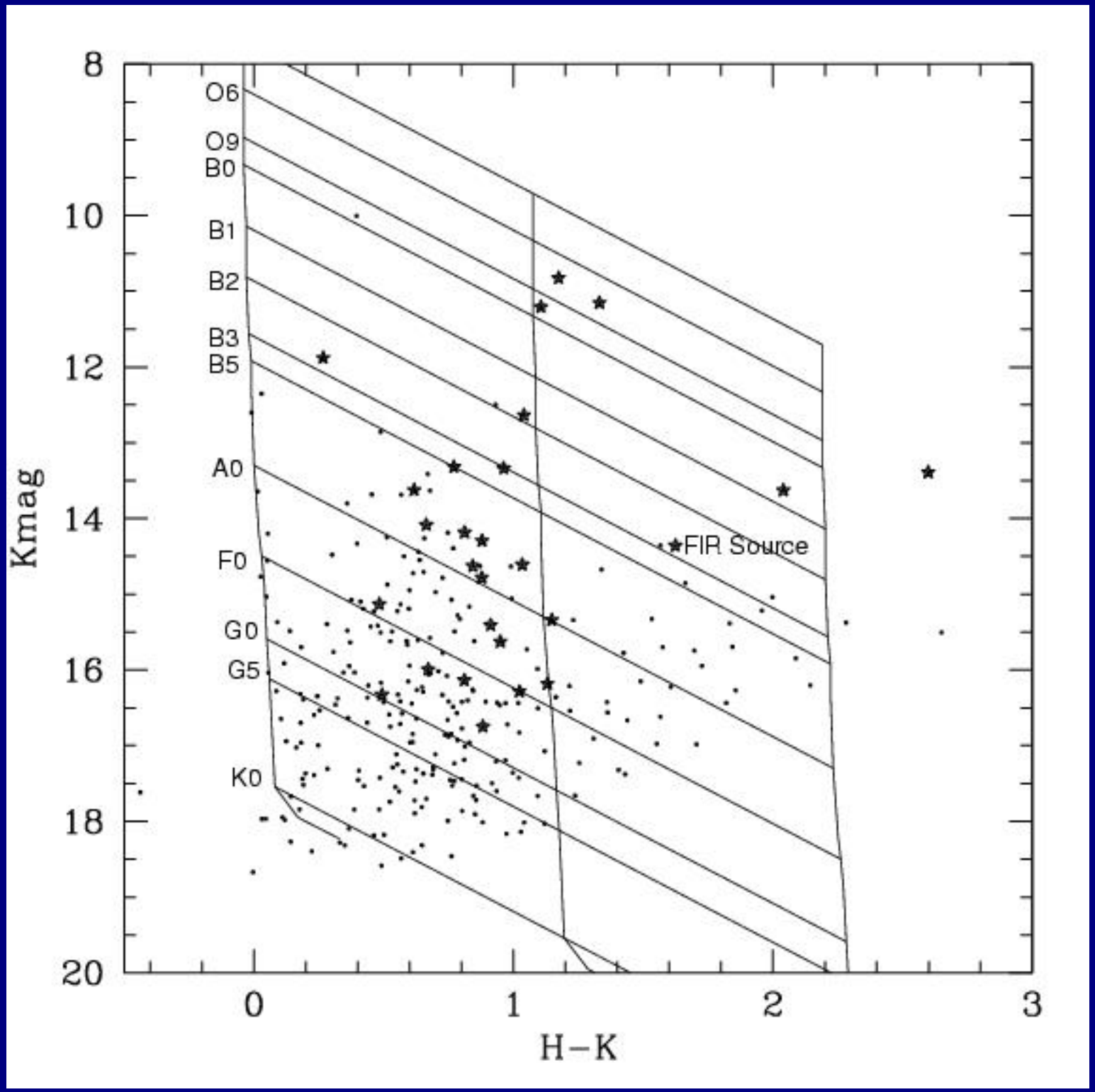
These are also probably the least dynamically relaxed samples of embedded clusters known to us.

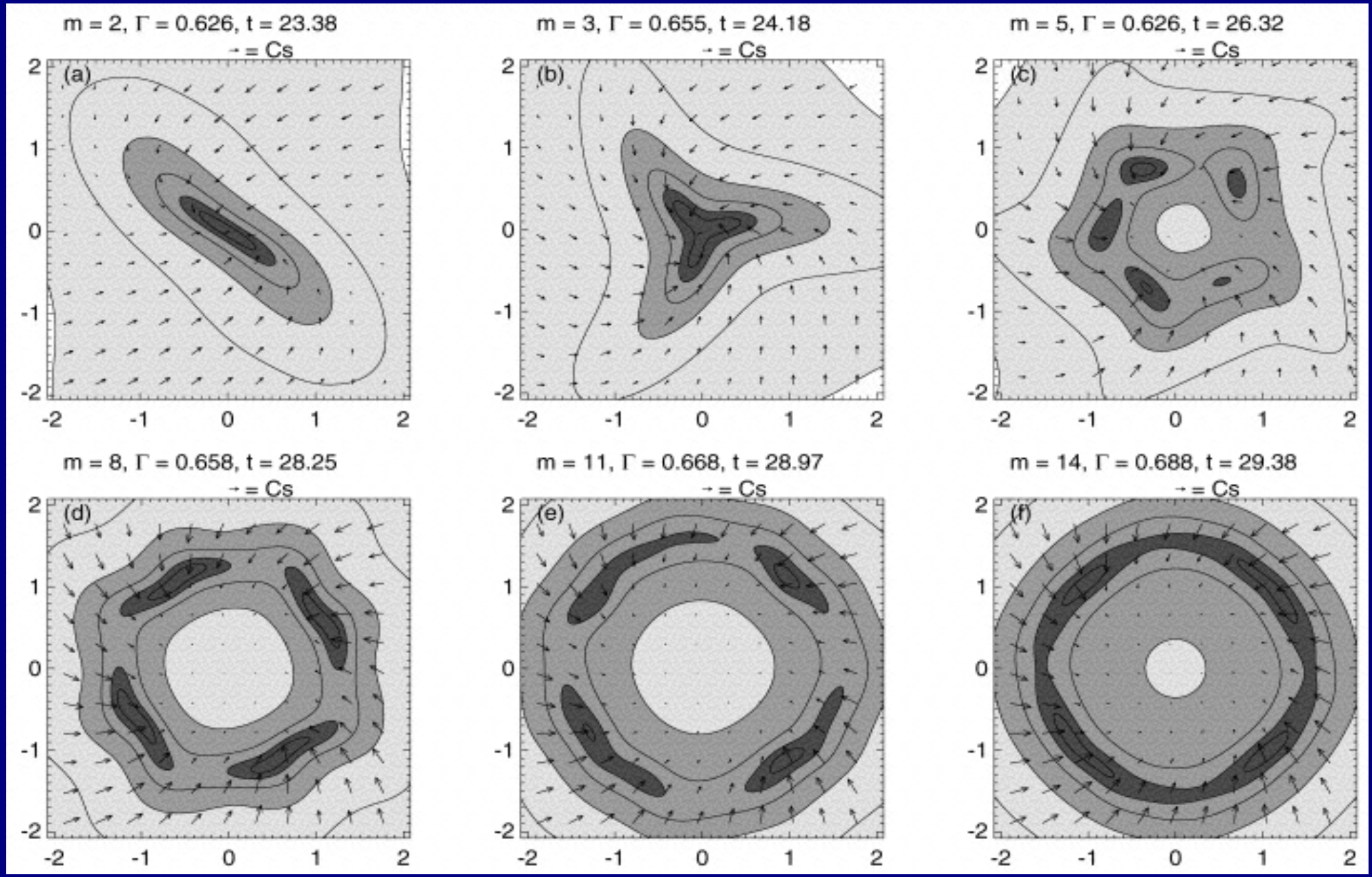
These clusters are much farther off, prone to relatively higher extinctions, so the problem may not be really as nice as it appears!

NIR visible young stellar (Proto)clusters



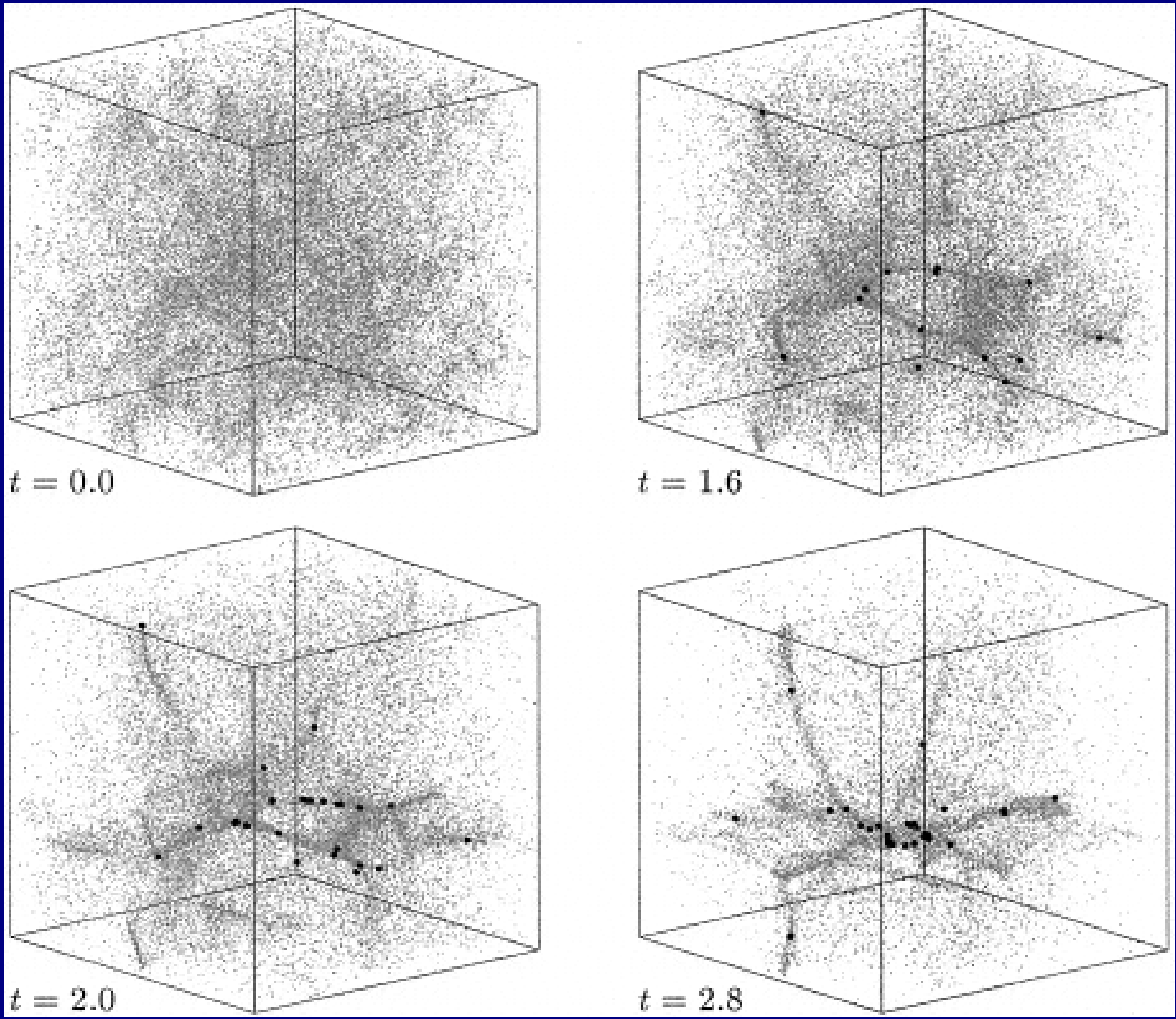
Kumar, Ojha & Davis, 2003, ApJ, 598, 1107


8
10
12
14
16
18
20
Kmag
0
1
2
3
H−K
O6
O9
B0
B1
B2
B3
B5
A0
F0
G0
G5
K0
FIR Source

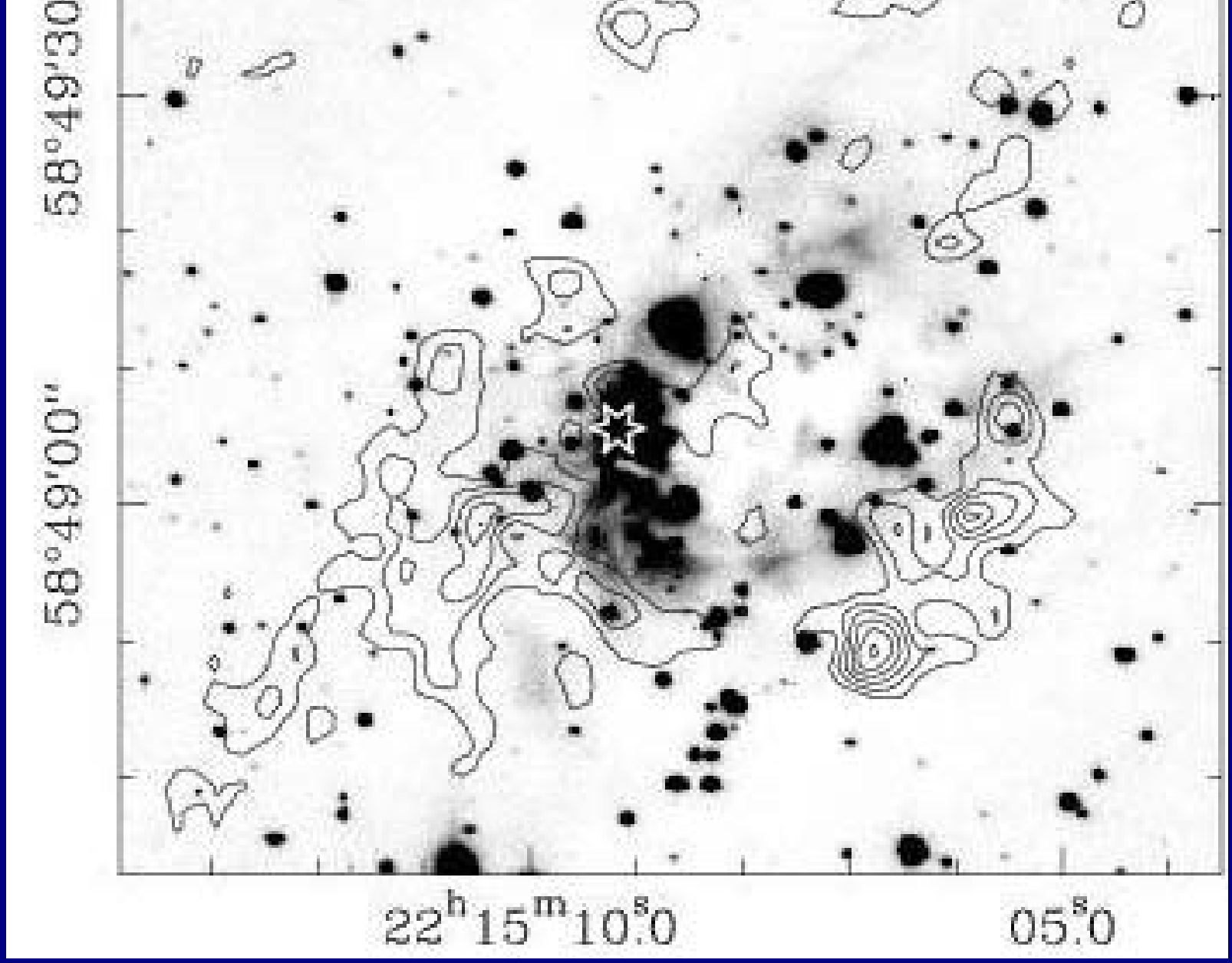


Li & Nakamura, 2002, ApJ, 578, 256

Fragmentation of magnetically subcritical cloud into multiple supercritical cores

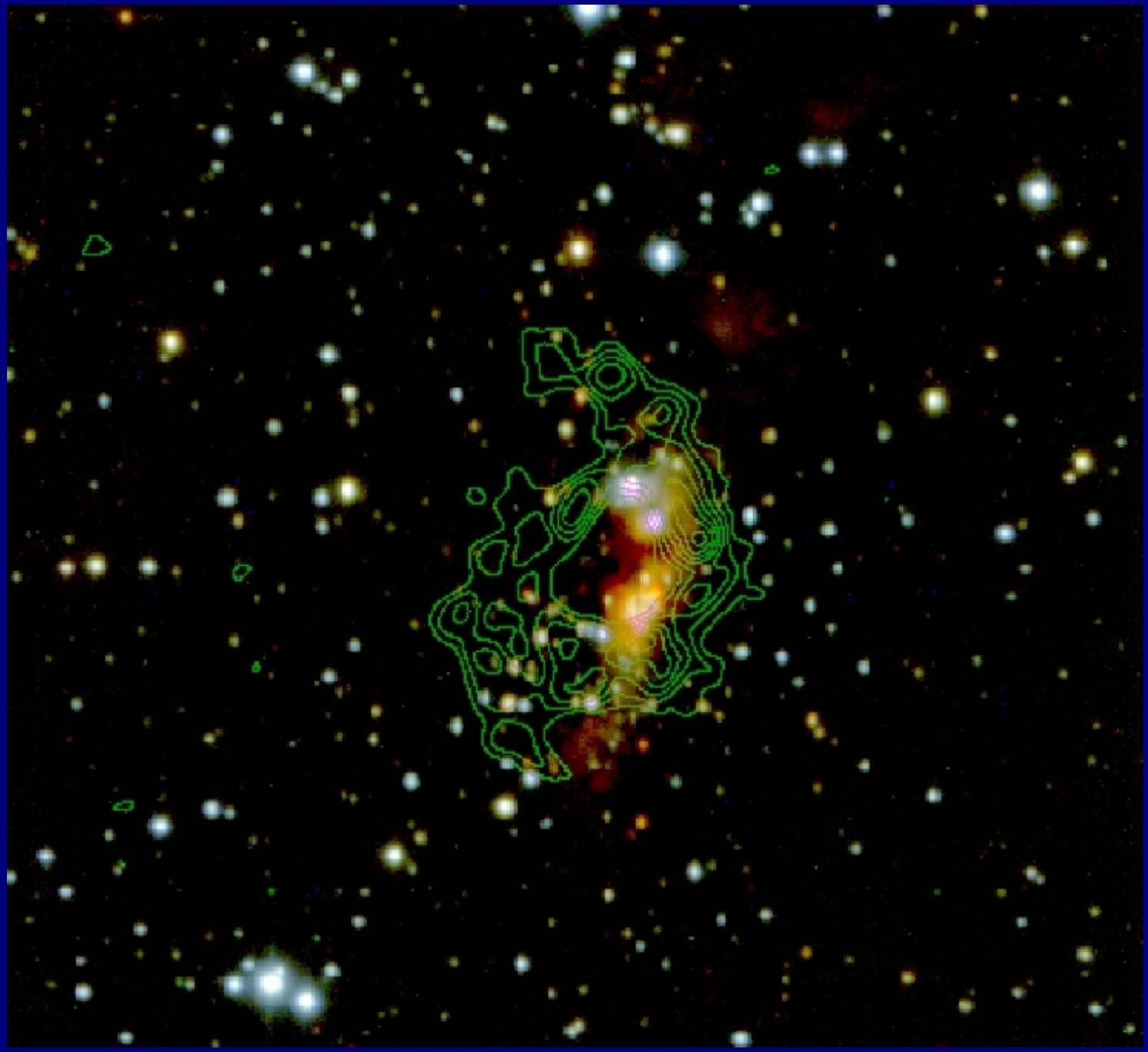


Klessen, Burkert & Bate, 1998, ApJ, 501, L205



NH3 (J,K) (1,1) contours from VLA D-configuration

Kumar, Shepherd & Tafalla, 2005, in preparation



Summary

Embedded clusters associated with pre-UCHII phases of massive stars imply massive star formation begins atleast after 0.5-1 Million years after the onset of low mass star formation.

Most of the stellar mass comes from big clusters in our galaxy

Massive protostars show signatures of shock activity in the equatorial plane that needs further investigation

Small protoclusters associated with massive protostars show intriguing new results. Further investigation needed to check infall signatures and overall gas motion in these ring clusters.