Observational Programme in Kent

- ***ASTRO-F, WFCAM, SCUBA-2, SALT***
- ***UKIRT: individual protostellar outflows***
- ***SAO/MMT/LBT: individual high- mass protostars***
- ***NTT/Calar Alto + SEST: rho Ophiuchus***
- ***2MASS/NTT: Rosette Giant Molecular Complex***

Star Formation Panoramas

- *Functions*
- *Fractions*
- *Frequencies*
- *…insight into the Processes*

- *Embedded in clouds*
- *Clouds are extended*

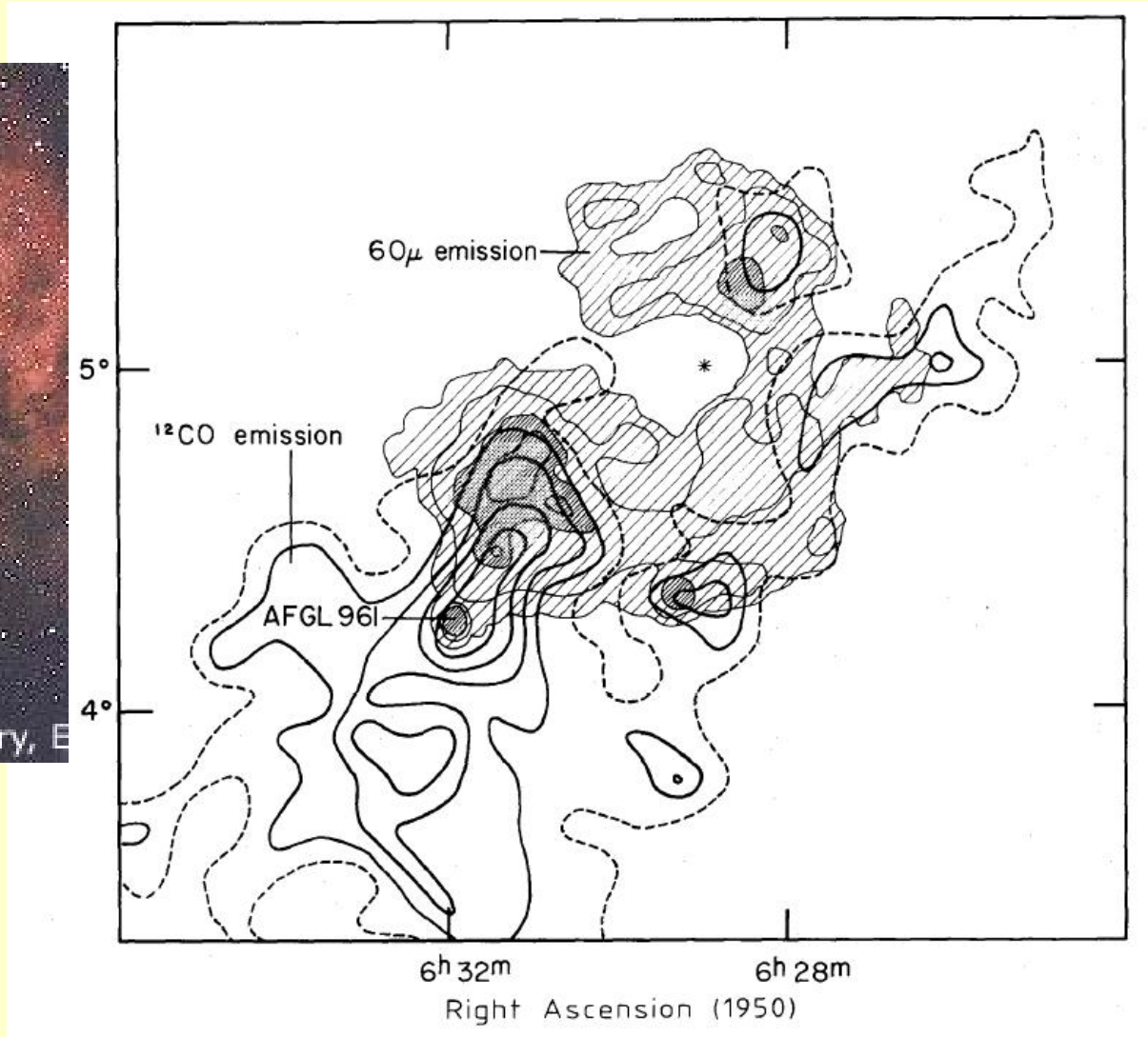
- *Roland Gredel (Heidelberg)*
- *Tigran Khanzadyan (Porto)*
- *Jinzeng Li (Beijing)*
- *Thomas Stanke (Hawaii)*
- *Chris Davis (Hawaii)*

Modes and seeds of star formation

- Spontaneous contractions
- Turbulent-induced collapse
- Radiation Driven Implosions
- External trigger
- Sequential internal triggers
- Shock-swept fragmenting shell

The Rosette Nebula and Complex

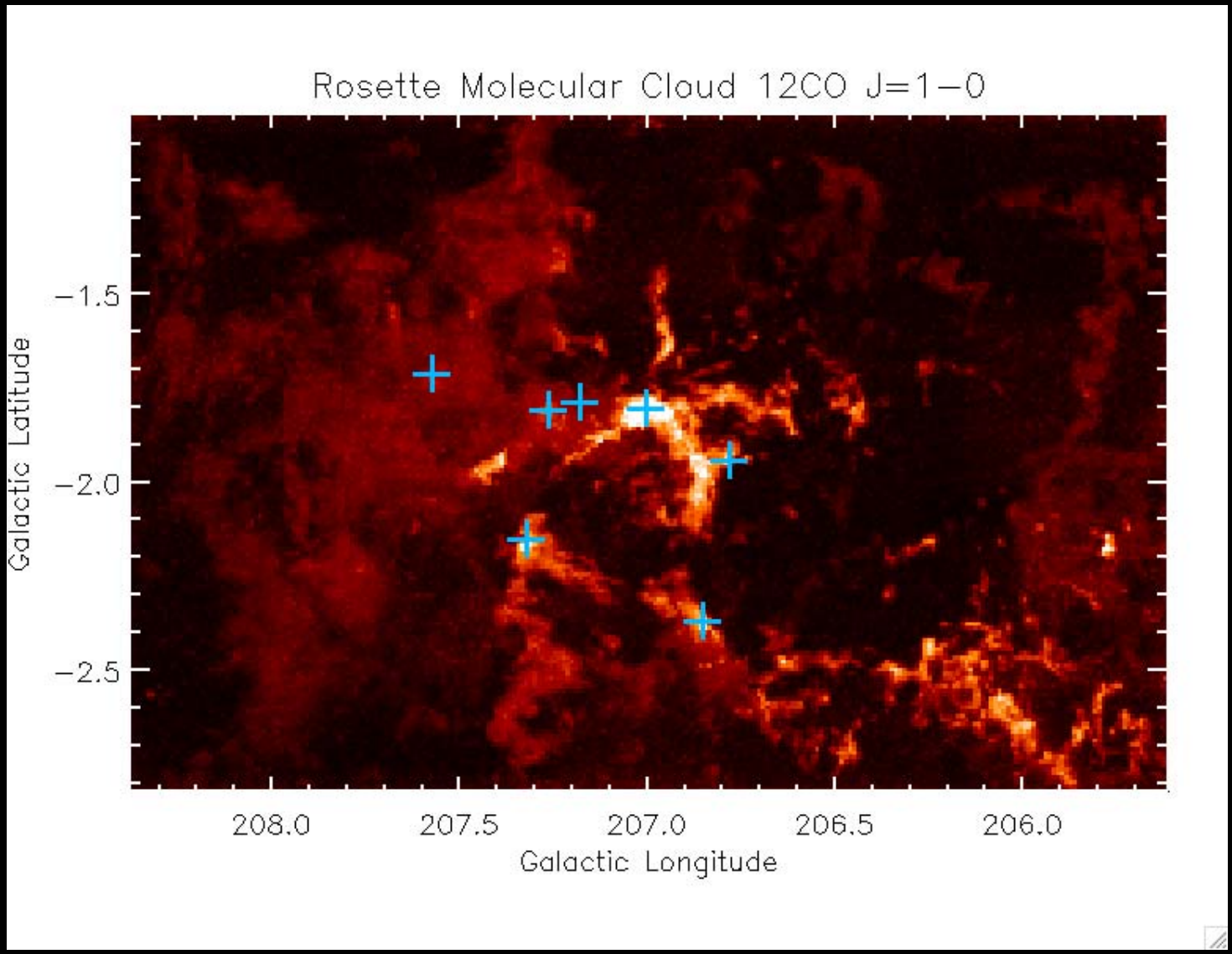
- H II region
- Distant: 1.4 kpc
- Size 30pc



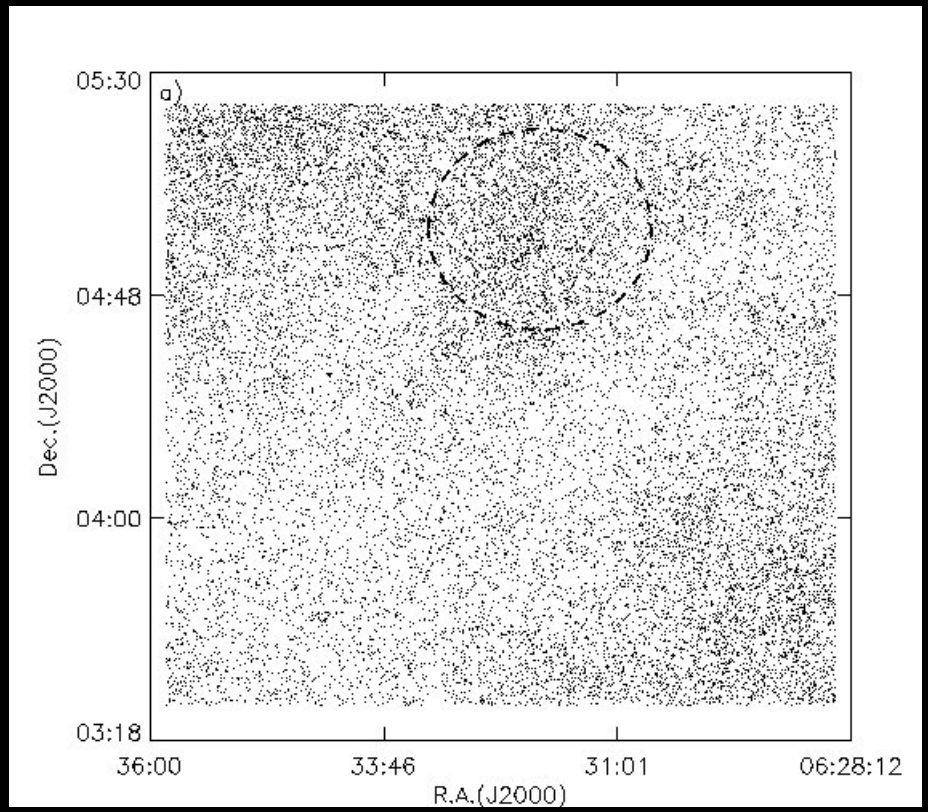
Cox et al 1990

CO filaments J. Williams et al IAU 227

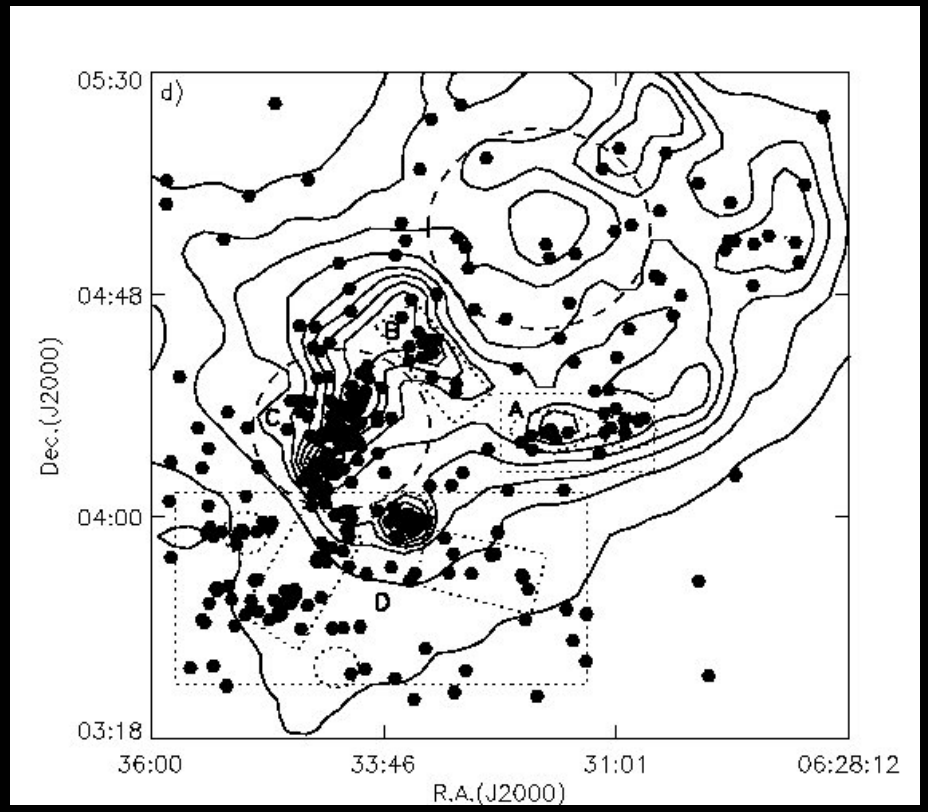
K-band clusters: Phelps and Lada



The Rosette Complex: 2MASS, **H-Ks colour**



H-Ks < 0.2

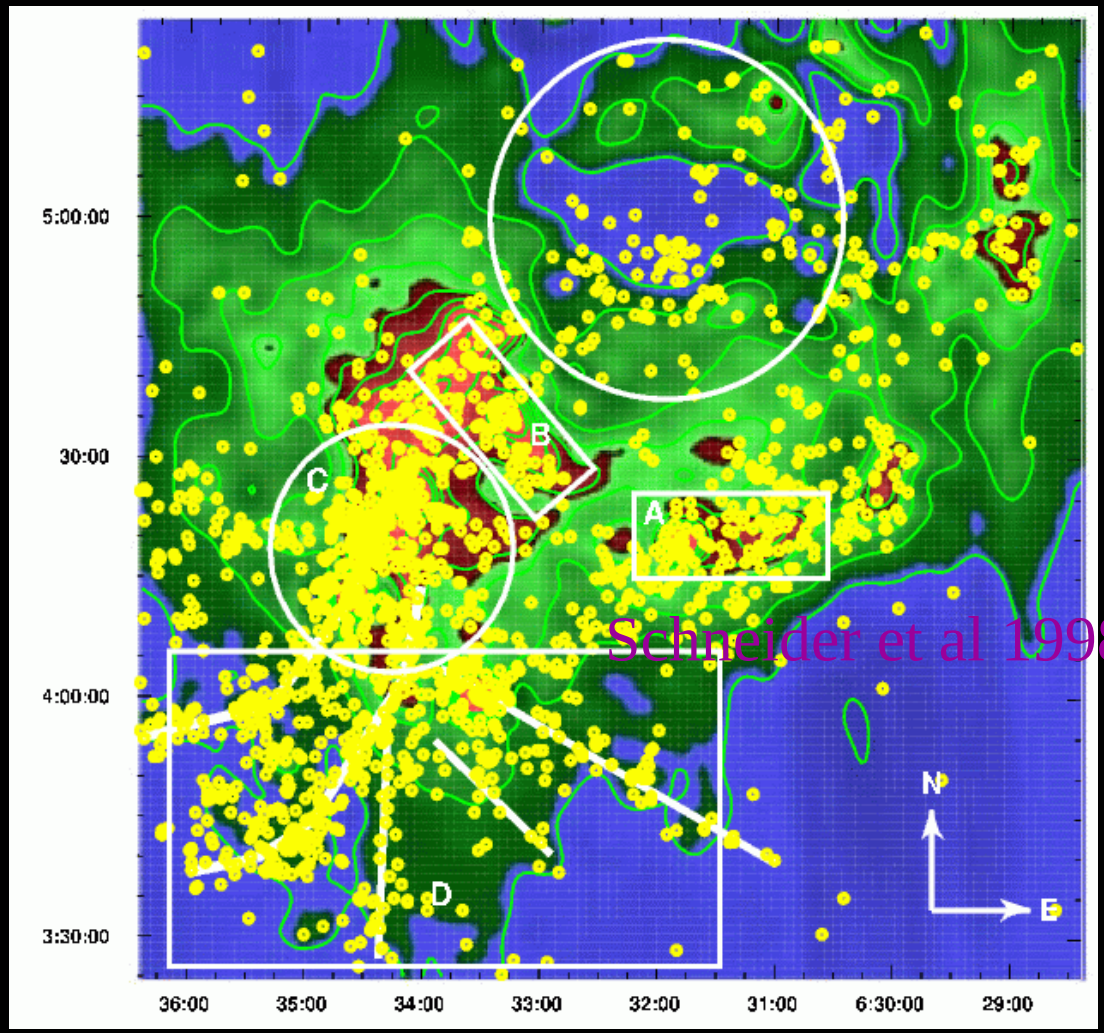


H-Ks > 1.0

The Rosette Seeds *Jinzeng Li & Smith*

- 2MASS: JHK analysis:
- colour-colour
- colour-magnitude
- KLF
- clustering

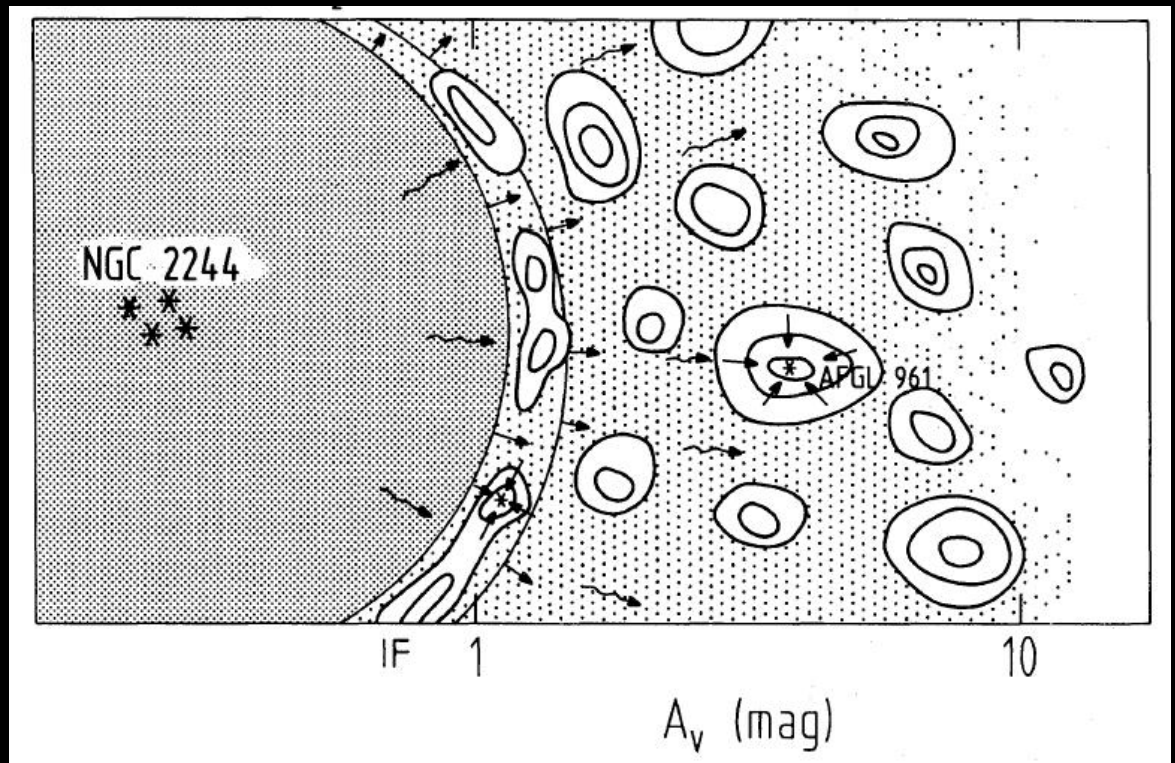
- Widespread clustering
- High-mass star formation
- Identify 4 Regions:
- A & B: `baked' shell
- C: AFGL 961E
- D: The Rosette Tree?



Evolution of the RMC

(Jinzeng Li & Smith)

- Ionisation front; originating from NGC2244
- Ultraviolet leaks through
- Radiation Driven Implosions
- NO: need local SF - no correlation/connection
- …….OR ……..



Evolution of the RMC

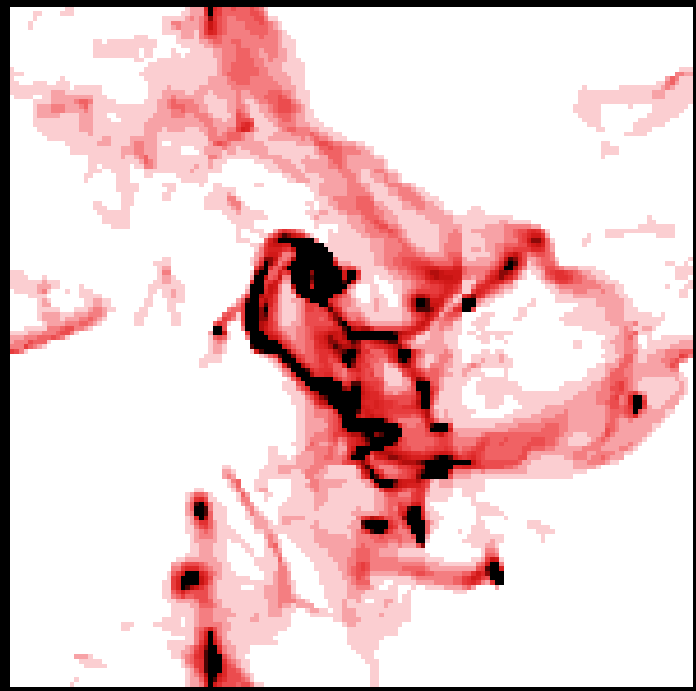
(Jinzeng Li & Smith)

- Sequential, originating from from NGC2244
- A TREE
- Spontaneous in AFGL 961 cluster, spreads along branches
- NO: AFGL 961 is the youngest
- …….OR ……..

Evolution of the RMC

(Jinzeng Li & Smith)

- Triggered, compressed shells from NGC2244
- PLUS, a large-scale cloud collapse: gravo-turbulent collapse

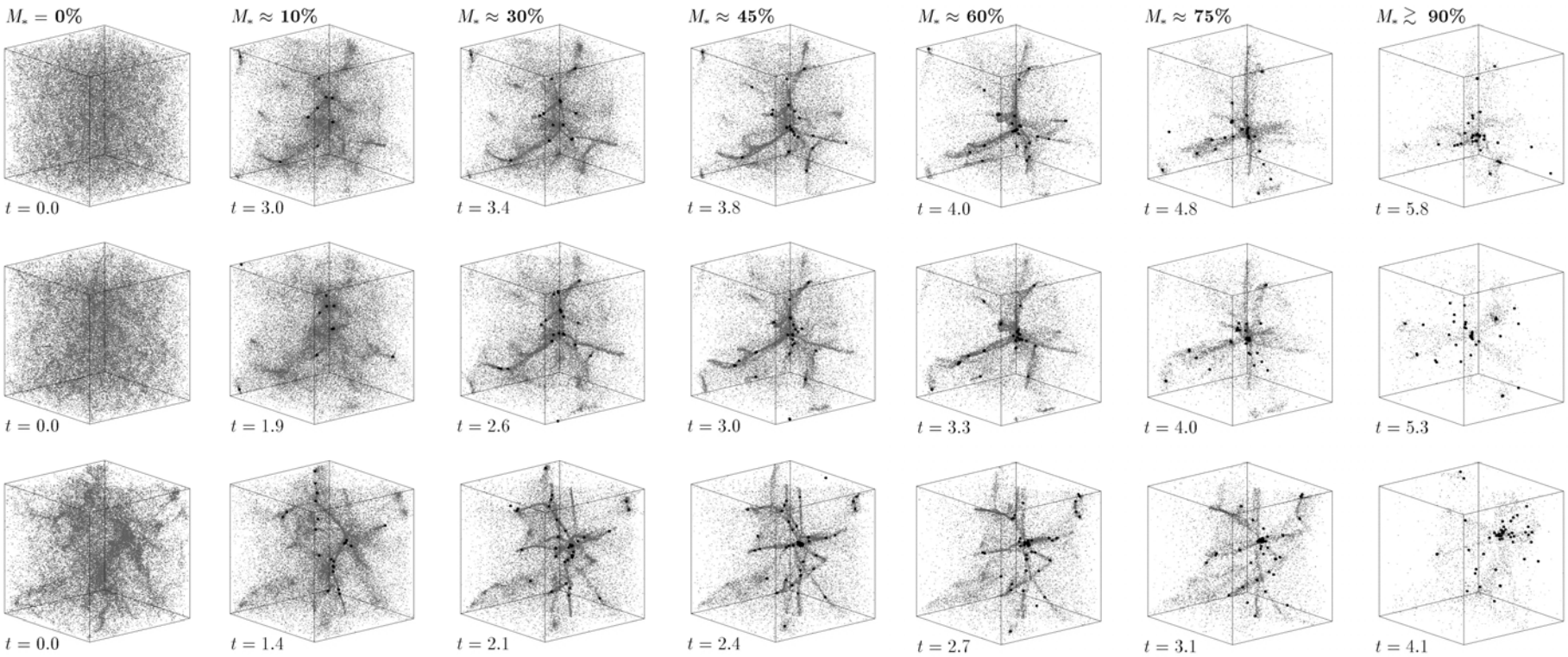


- Externally driven turbulence.
- Flow along sheets, into filaments
- Region C sub-clusters: intersection points
- Simulation with gravity: Smith et al 2000
- (Model D2 of Klessen et al 2000).

Gravoturbulent simulations

(Klessen & Burkert 2000)

- SPH code, 222 Jeans masses, isothermal



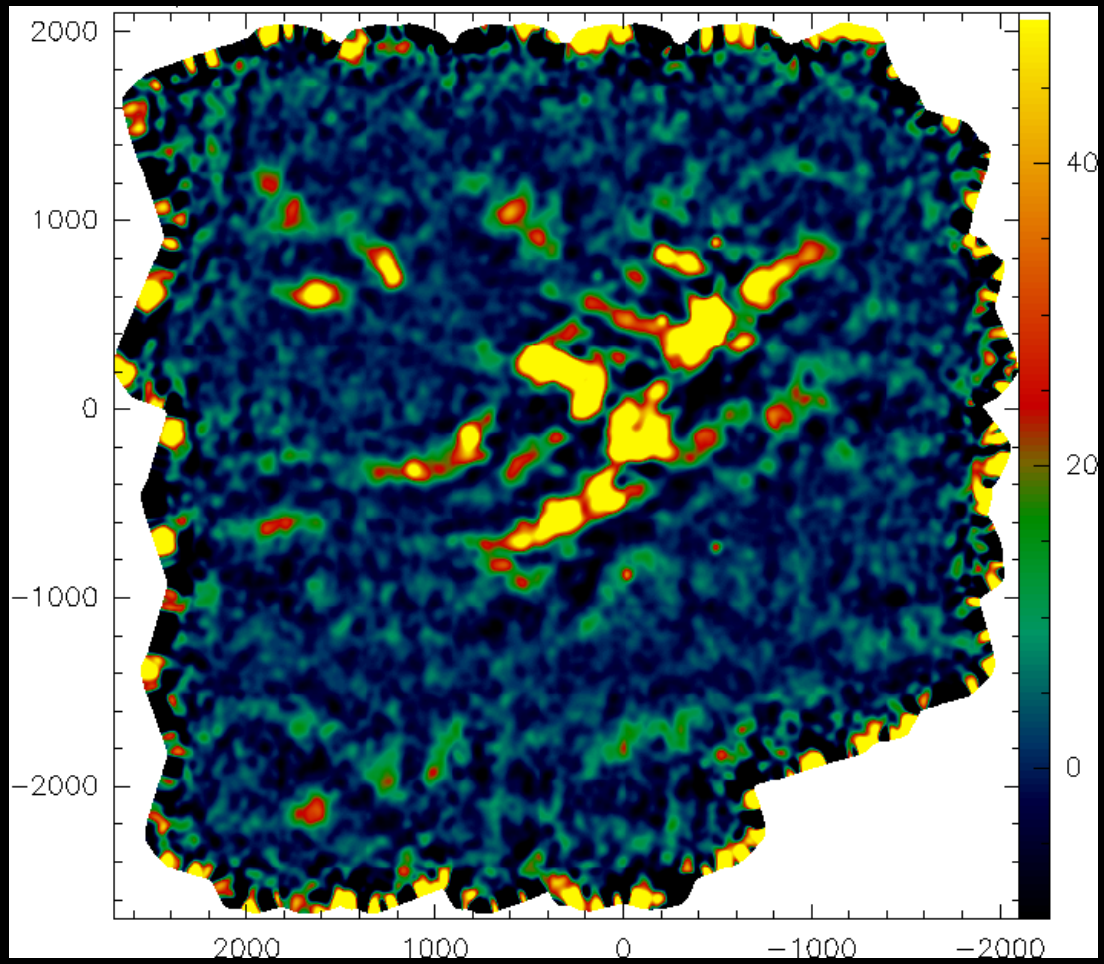
rho Ophiuchus: a nearby star-forming cloud

Millimetre: bright dust cores
(Visible: dark patches)

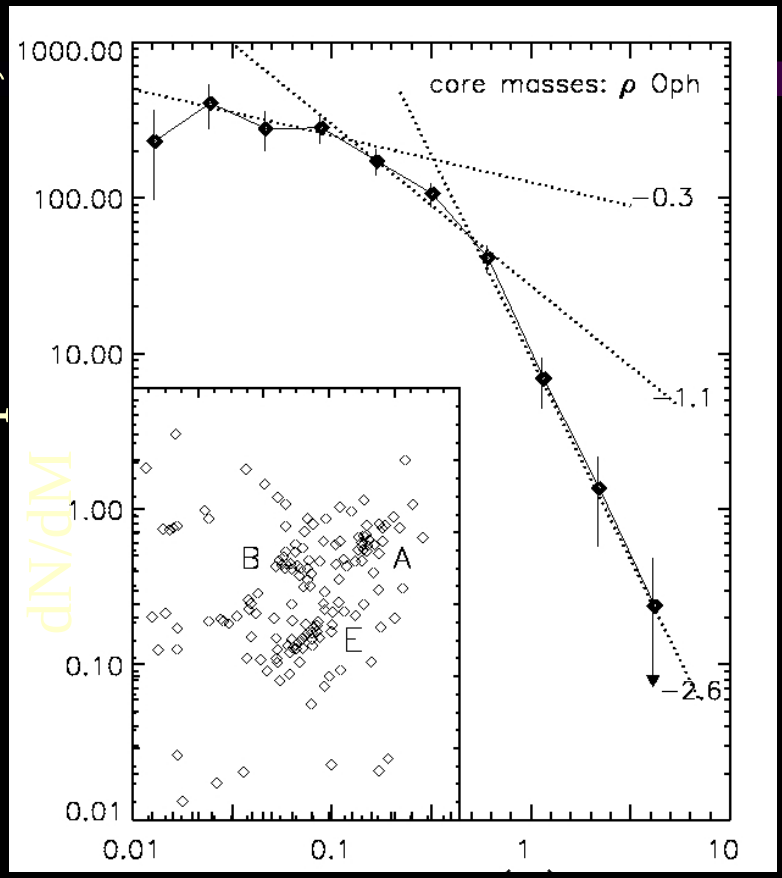
ESO SEST 1.2mm: 1^o x 1.2^o

Young stars: 10^6 yr
Cores: 10^6 yr
A few protostars: 10^4 yr

Clouds are young: ephemeral

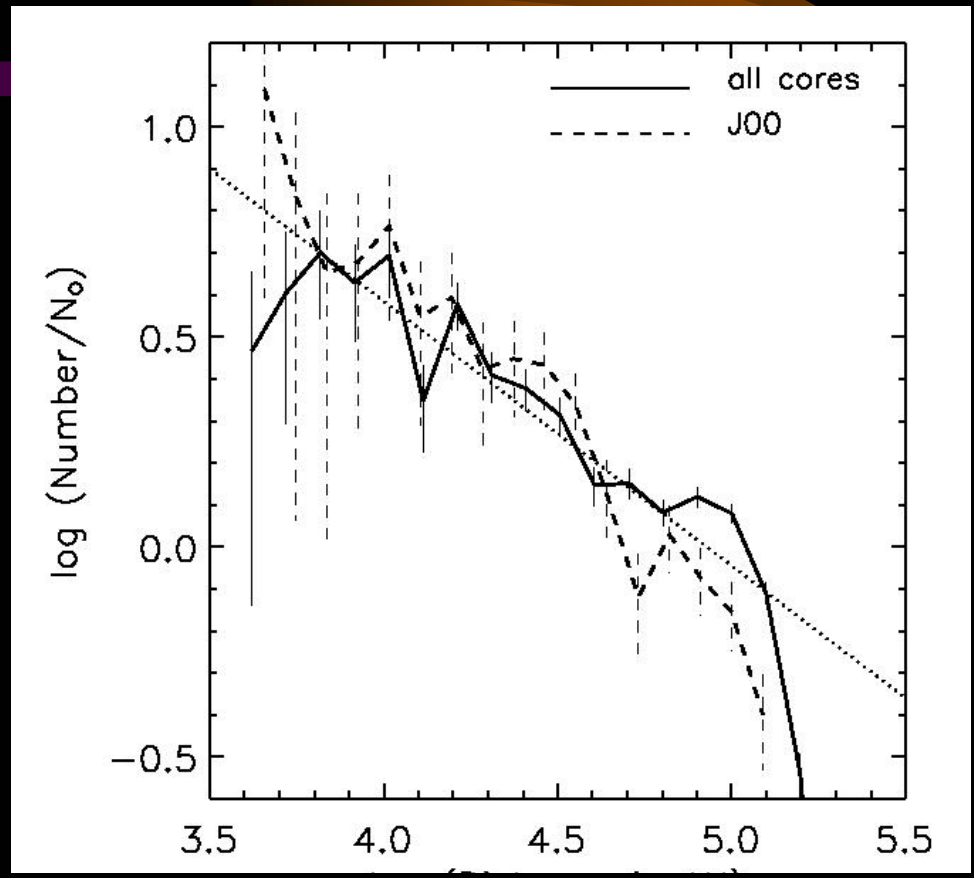


Distribution in mass

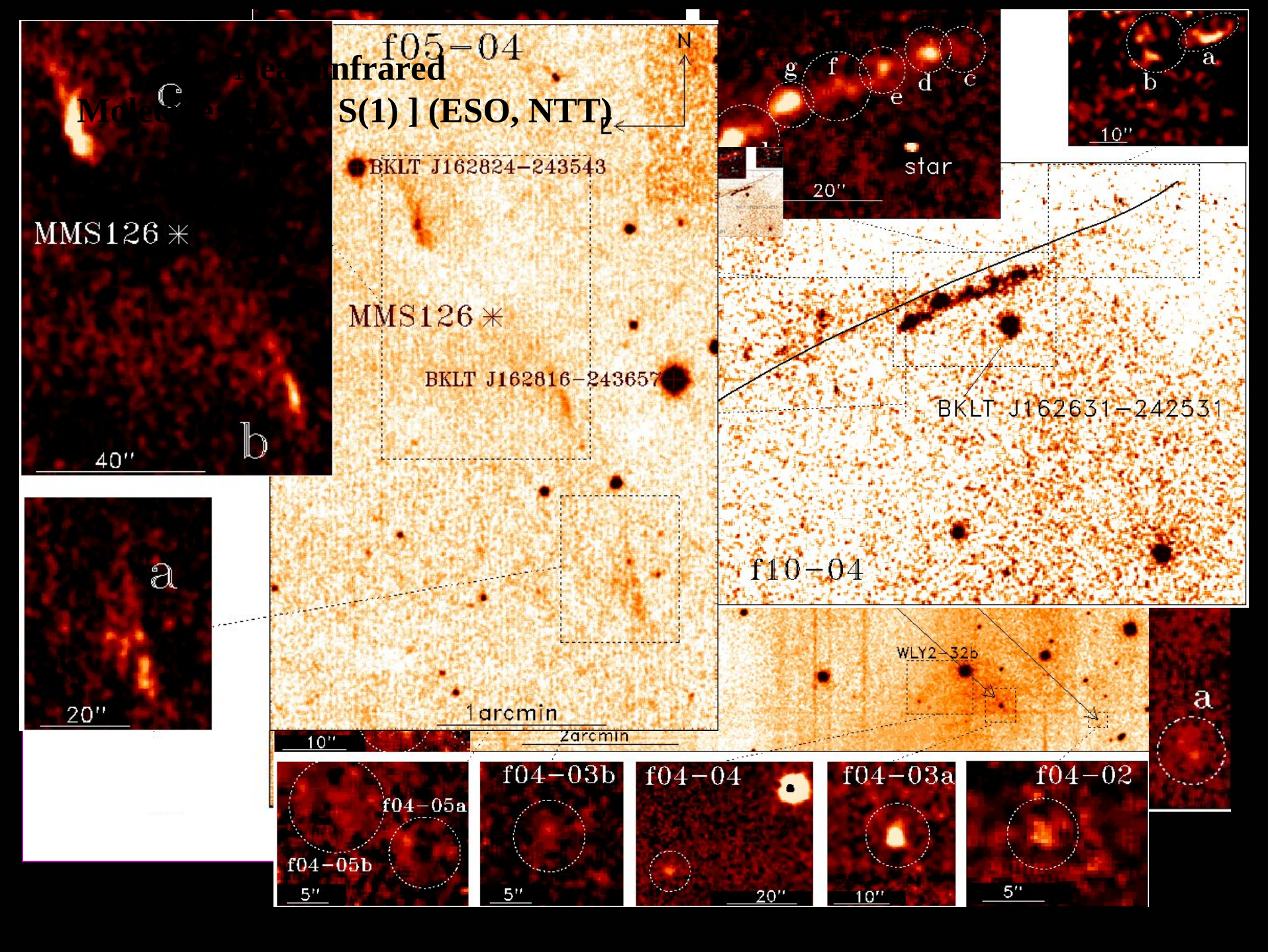


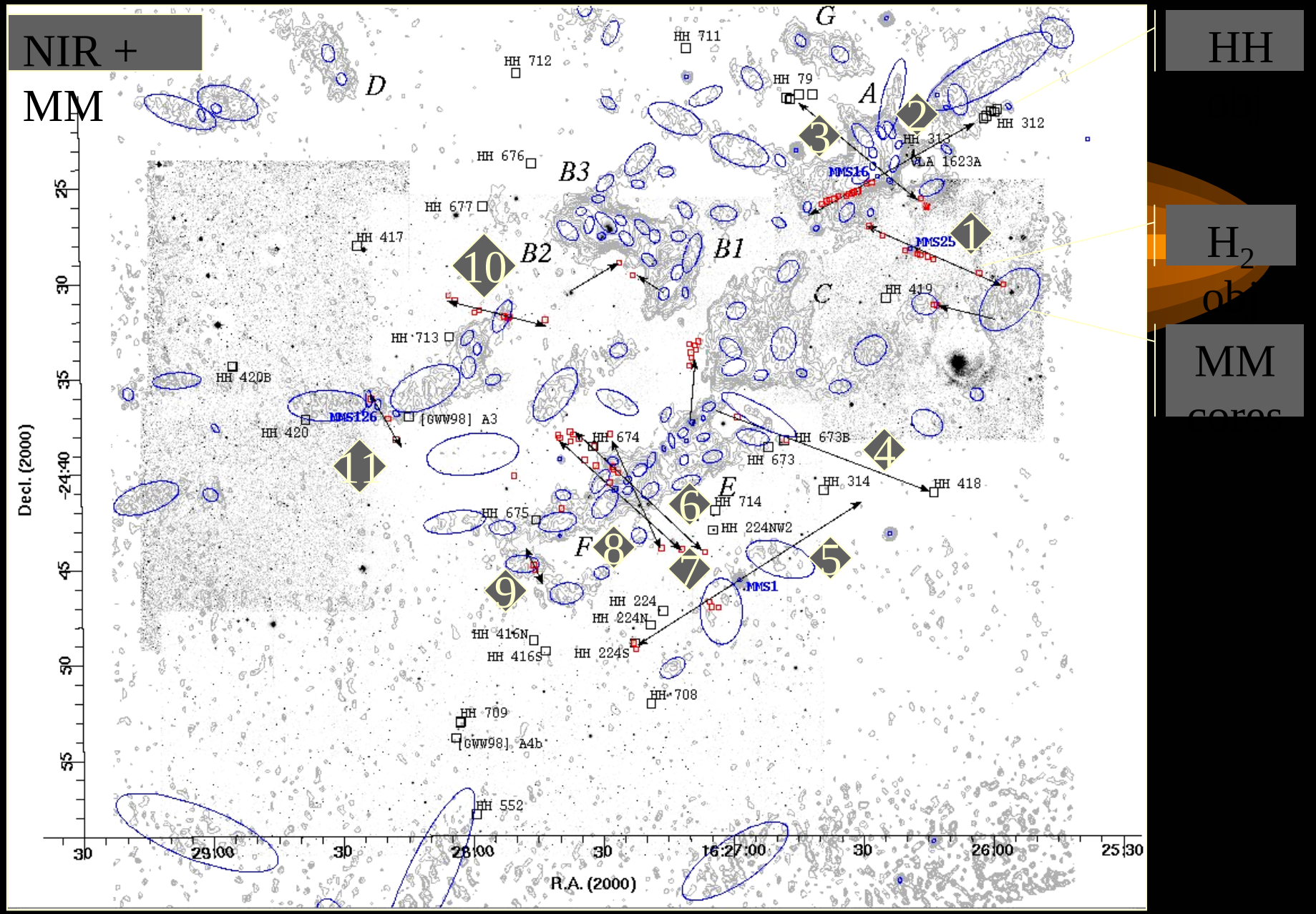
Log (core mass)

Distribution in space

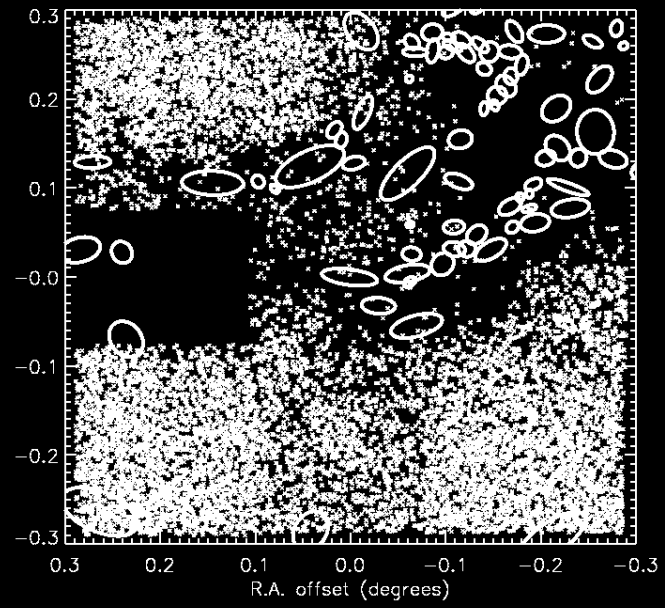


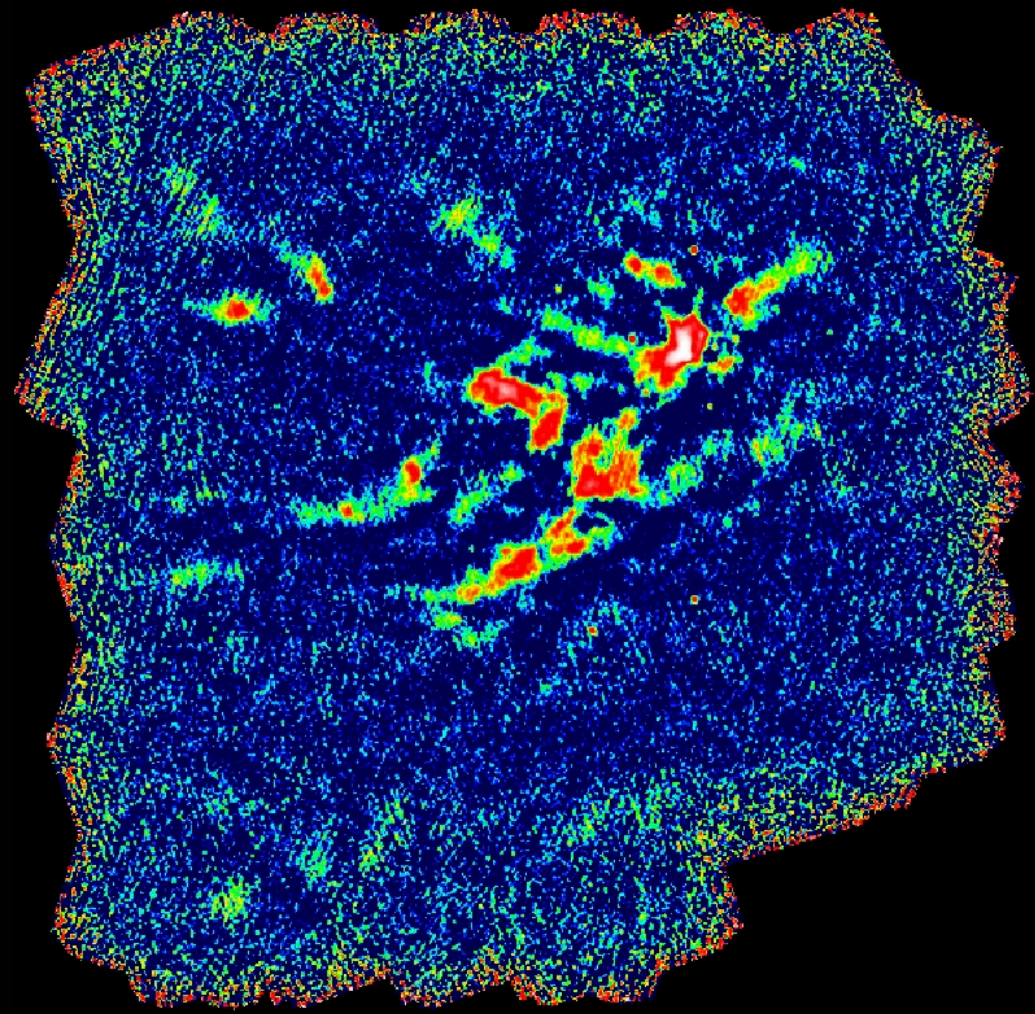
Log (separation in AU


Near-Infrared
Molecular H2 [1-0 S(1)] (ESO, NTT)
f05−04
N
E
BKLT J162824−243543
MMS126 ✳
BKLT J162816−243657
1 arcmin
2 arcmin
MMS126 ✳
c
b
40″
a
20″
10″
g
f
e
d
c
star
20″
a
b
10″
BKLT J162631−242531
f10−04
WLY2−32b
a
10″
f04−05a
f04−05b
5″
f04−03b
5″
f04−04
20″
f04−03a
10″
f04−02
5″


NIR +
MM
HH
H_2
MM
G
D
A
B3
B2
B1
C
E
F
HH 711
HH 712
HH 79
HH 312
HH 313
VLA 1623A
MMS16
MMS25
HH 676
HH 677
HH 417
HH 419
HH 713
HH 420B
HH 420
MMS126
[GWW98] A3
HH 674
HH 673B
HH 673
HH 314
HH 418
HH 714
HH 675
HH 224NW2
MMS1
HH 224
HH 224N
HH 224S
HH 416N
HH 416S
HH 708
HH 709
[GWW98] A4b
HH 552
1
2
3
4
5
6
7
8
9
10
11
Decl. (2000)
R.A. (2000)
-24:40
25
30
35
45
50
55
30
29:00
30
28:00
30
16:27:00
30
26:00
25:30

rho Ophiuchus: JHK photometry



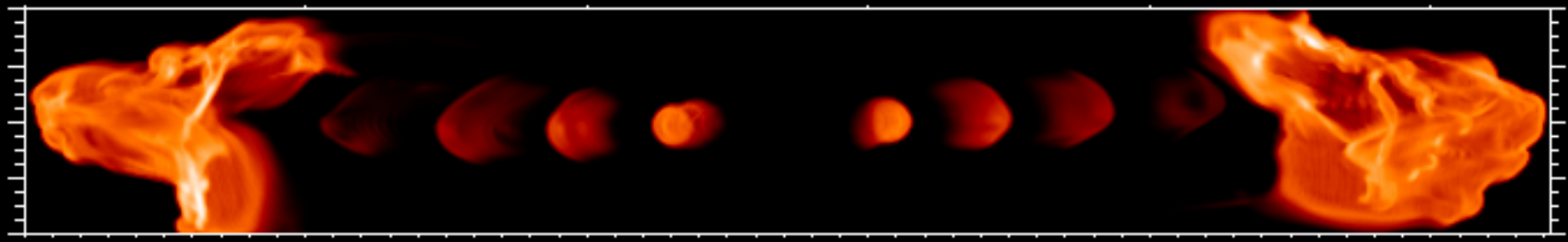


Prospects

- To *find* the protostars in NIR: need wide-field H2 surveys
- To find YSOs in NIR: need JHK surveys.
- SPITZER - IRAC: Class I/Class II
- ASTRO-F + Herschel: Class 0 protostars

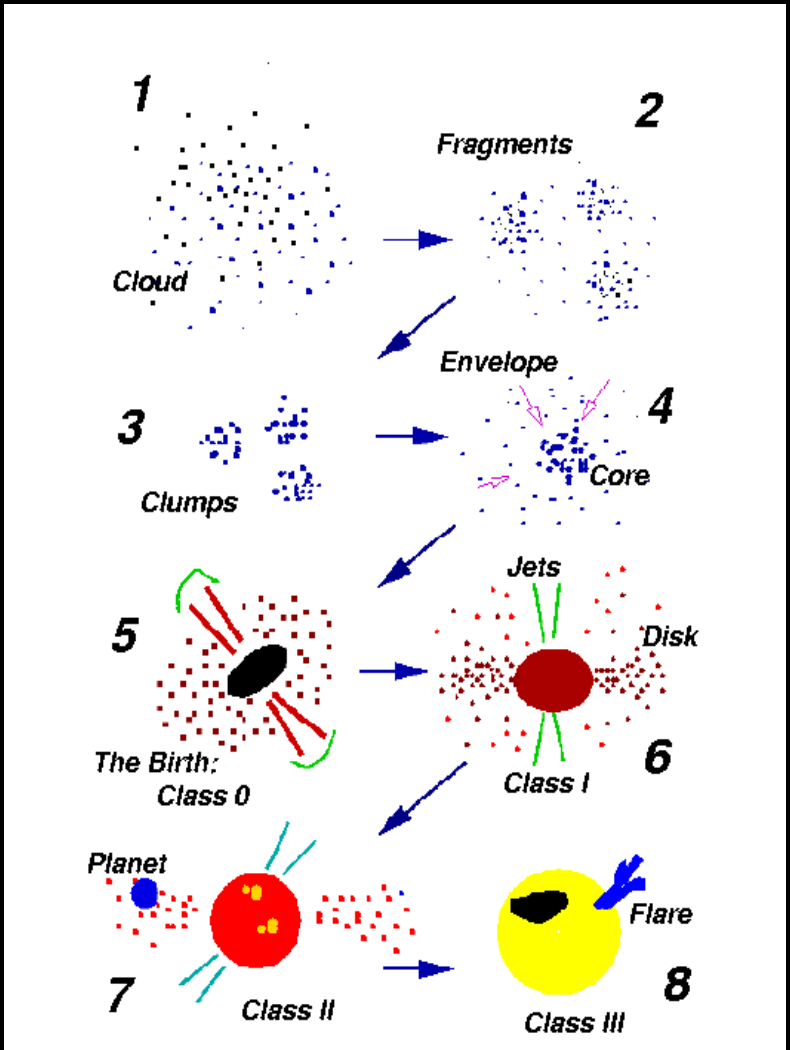
H_2 surveys: thrust from launcher + resistance from environment

To be continued...



The End.

Thank you for your attention.



The Revolution

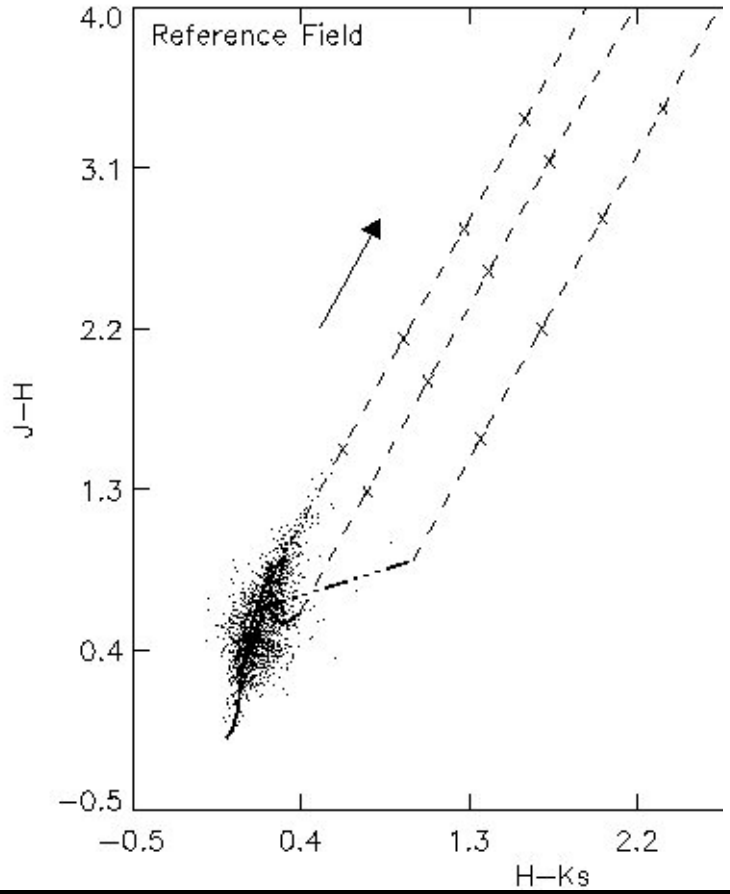
1. Rapid conception
2. Holy grail
3. Inflow - outflow enigma
4. Massive stars
5. Planets, brown dwarves
6. Starbursts
7. Primordial stars

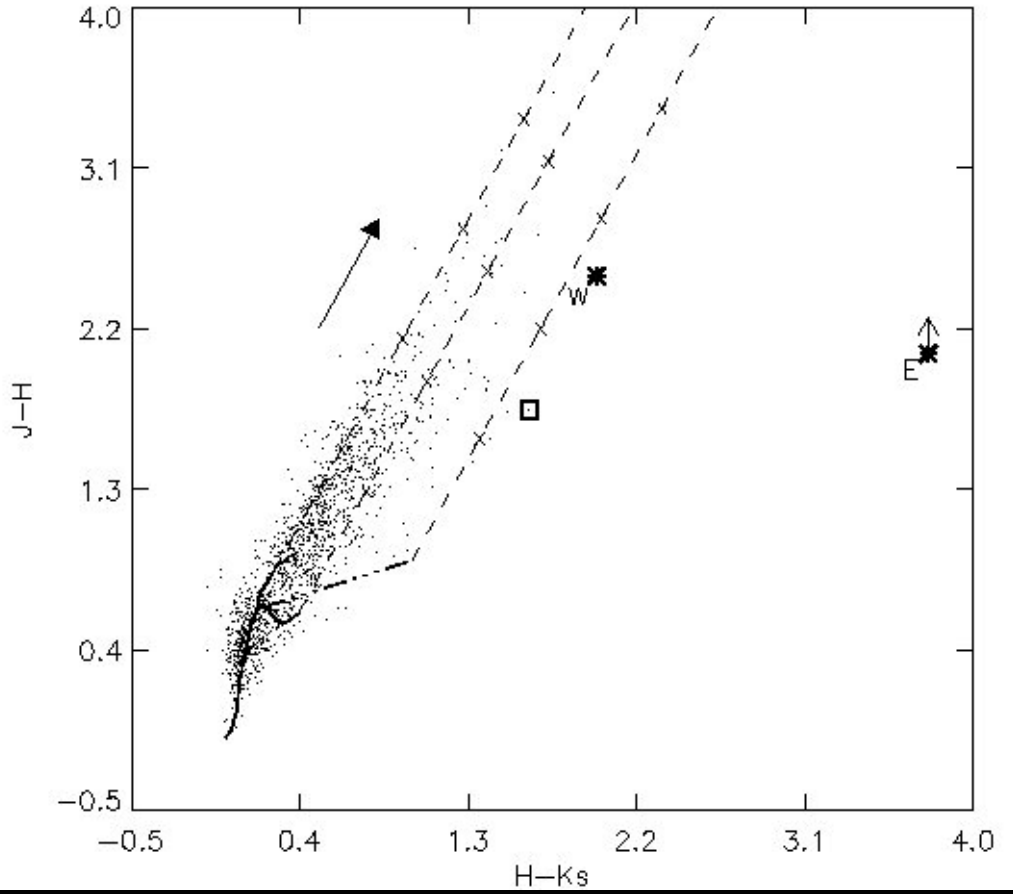
Massive star formation: The Big Issues

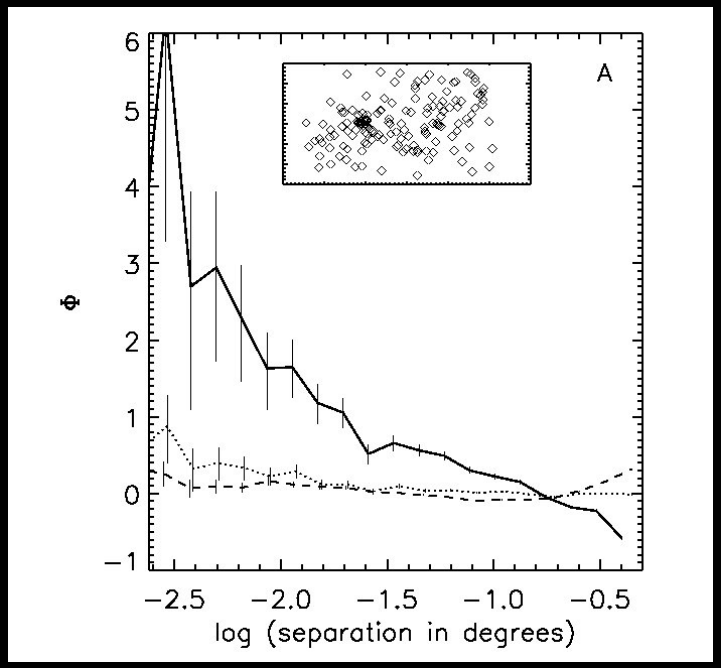
- Fragmentation of Giant Clouds
- Gas to Stars: accretion or mergers?
- Cores to Clusters; efficiency, IMF
- Modes: Spontaneous, Triggered, Sequential,…...
- Relaxation: dynamics, dispersion of stars
- History: Galactic scales: extrapolate?
- Physics: shocks, turbulence, magnetic field, radiation, gravity

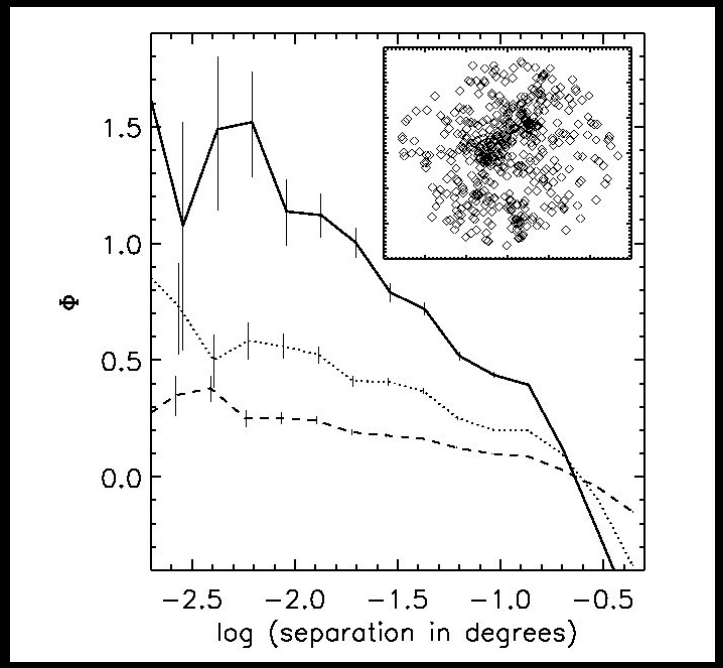
Turbulence, Gravity, Feedback, Regulation, Interaction, Triggering: COMPLEX SYSTEM

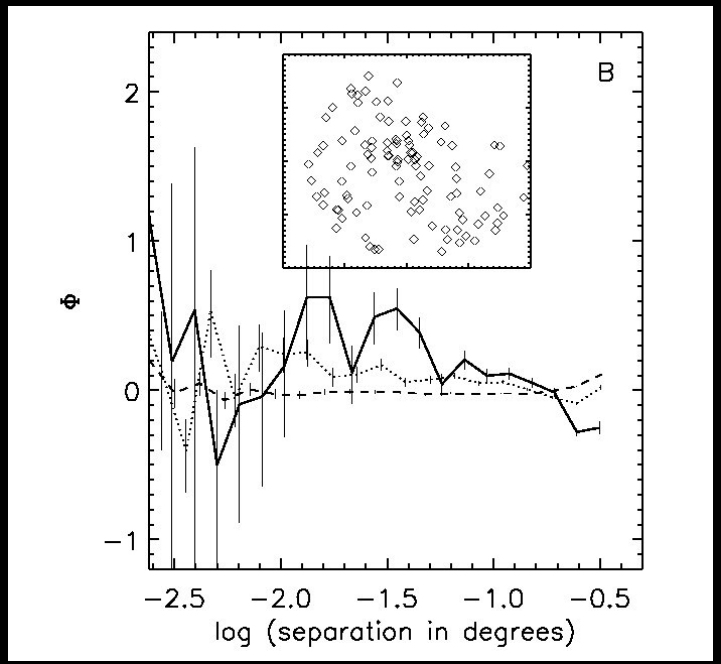
The Rosette Complex

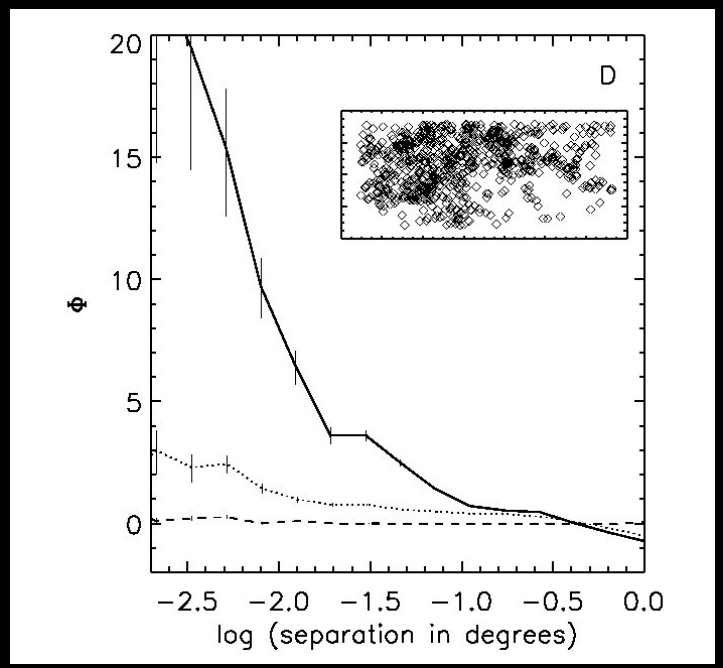










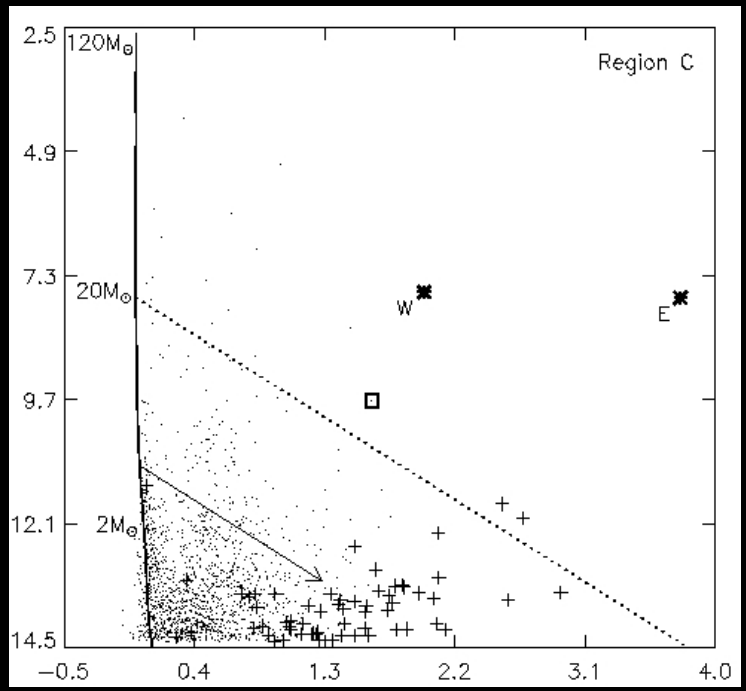


Spatial distributions:

Two-point correlation function

AFGL 961

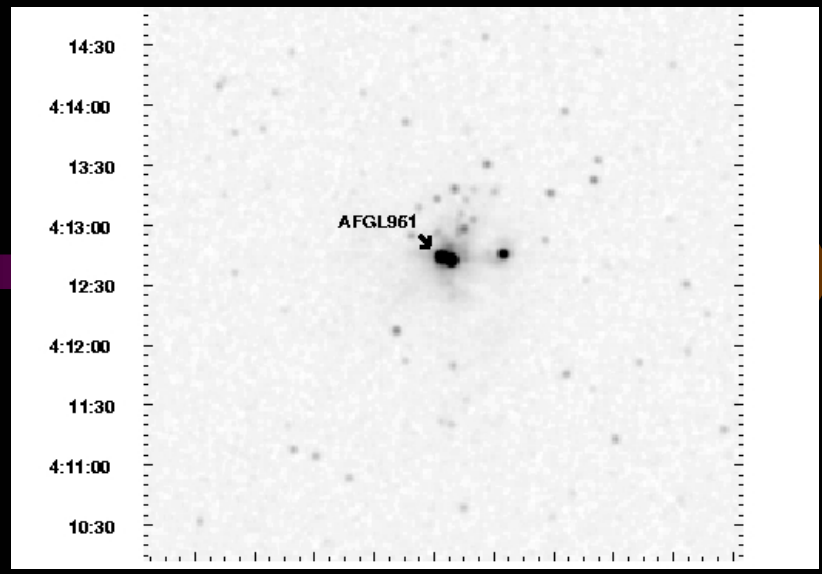
- JHK images: details in 5' region
- Colour-Magnitude diagram
- **Most massive star: 130 M_{sun} !!!!**
- Triple system? All 3: IR excesses
- Cavity: stars visible in cavity.

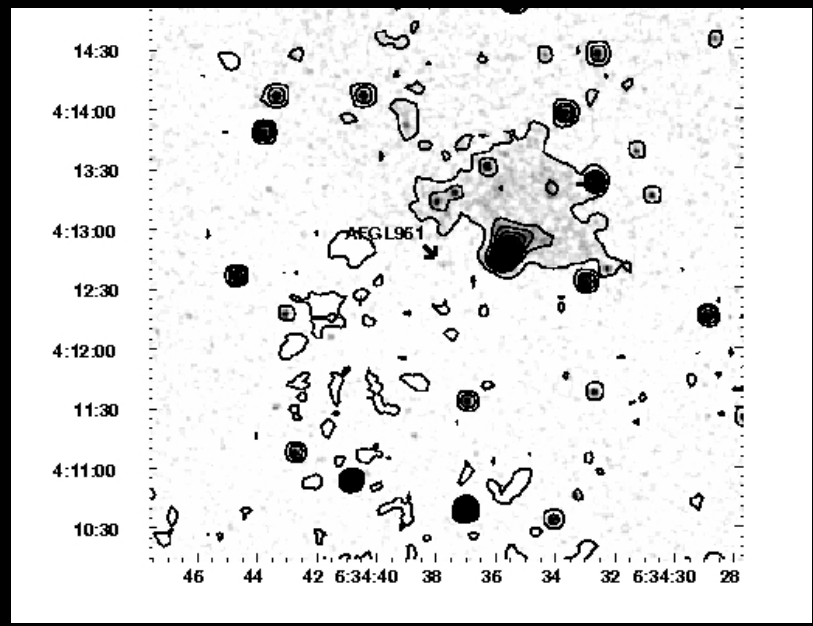


Magnitude, Ks

Colour, H-Ks

Infrared

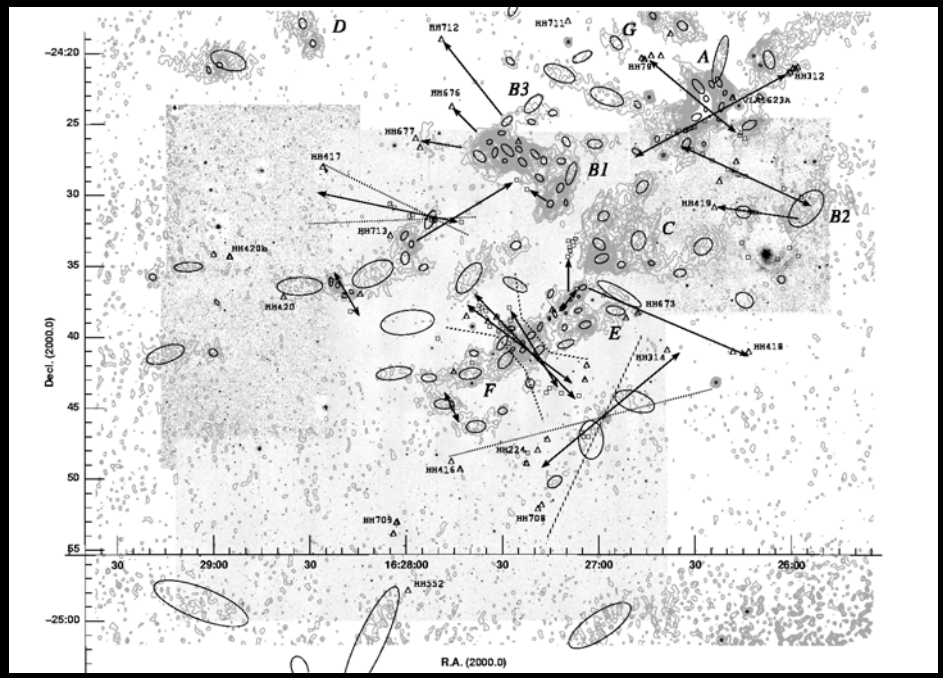


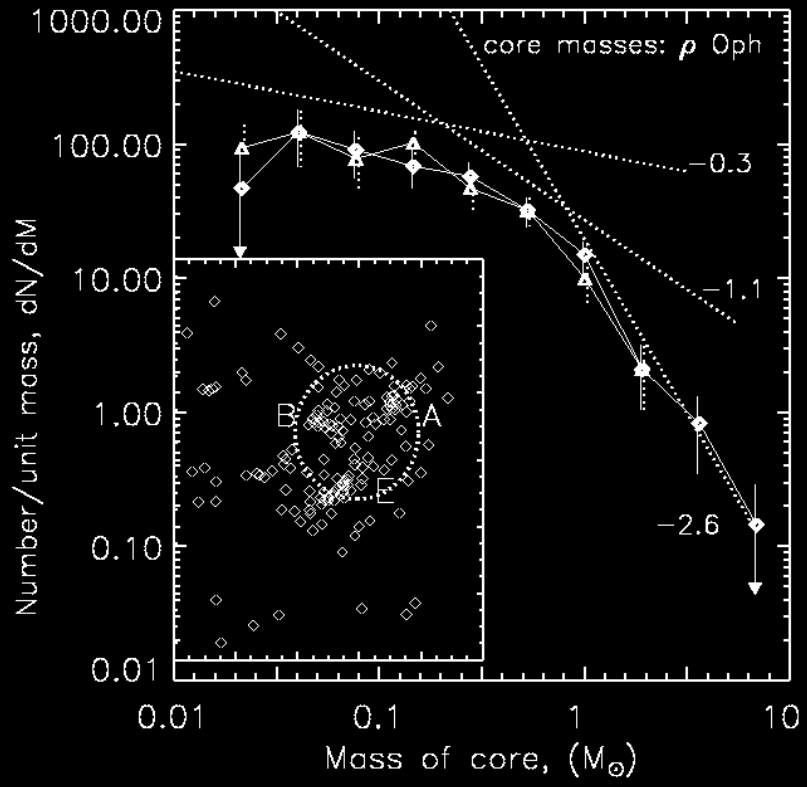


Optical

What controls star formation?

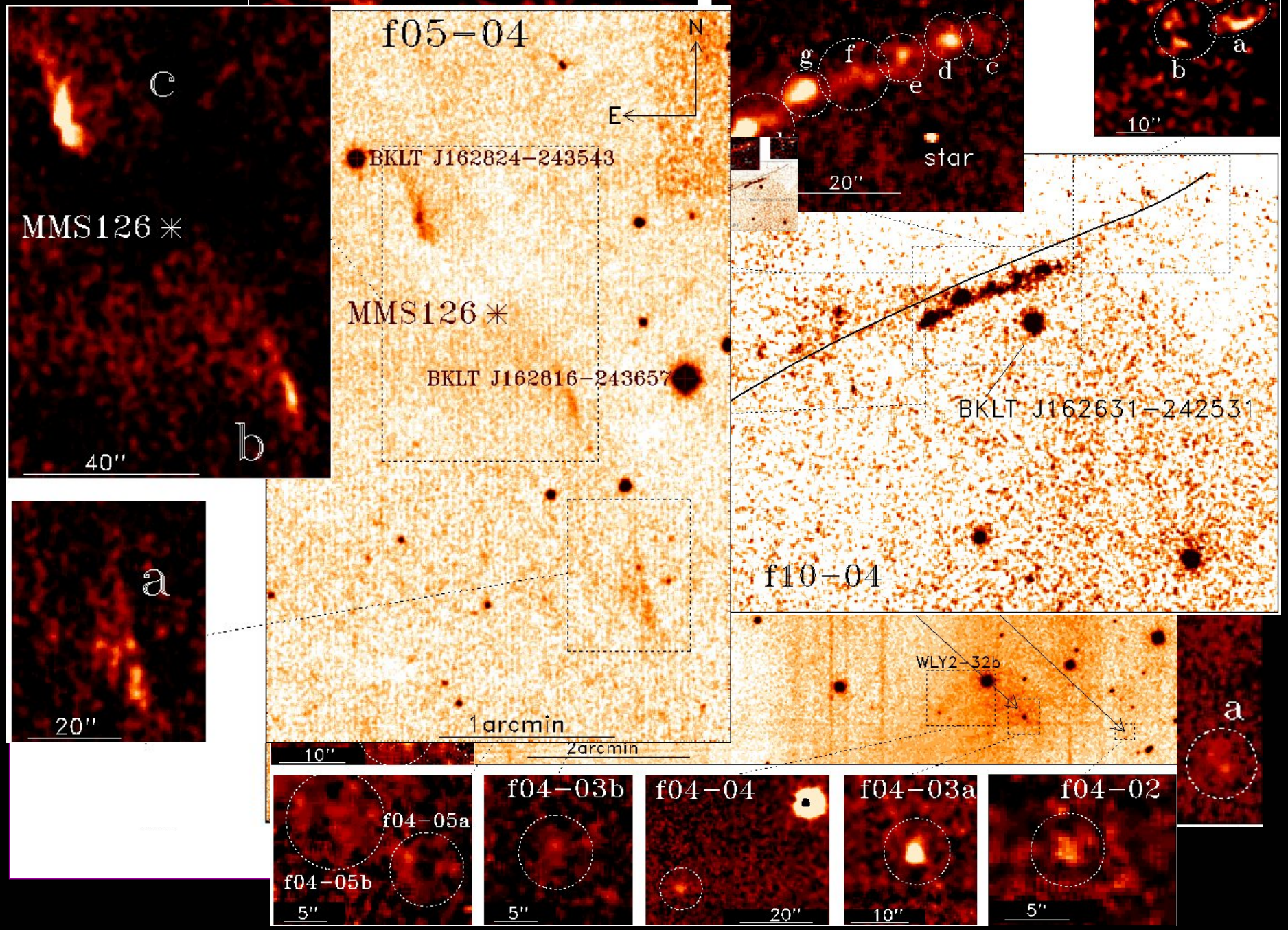
12 outflows





Clustered,

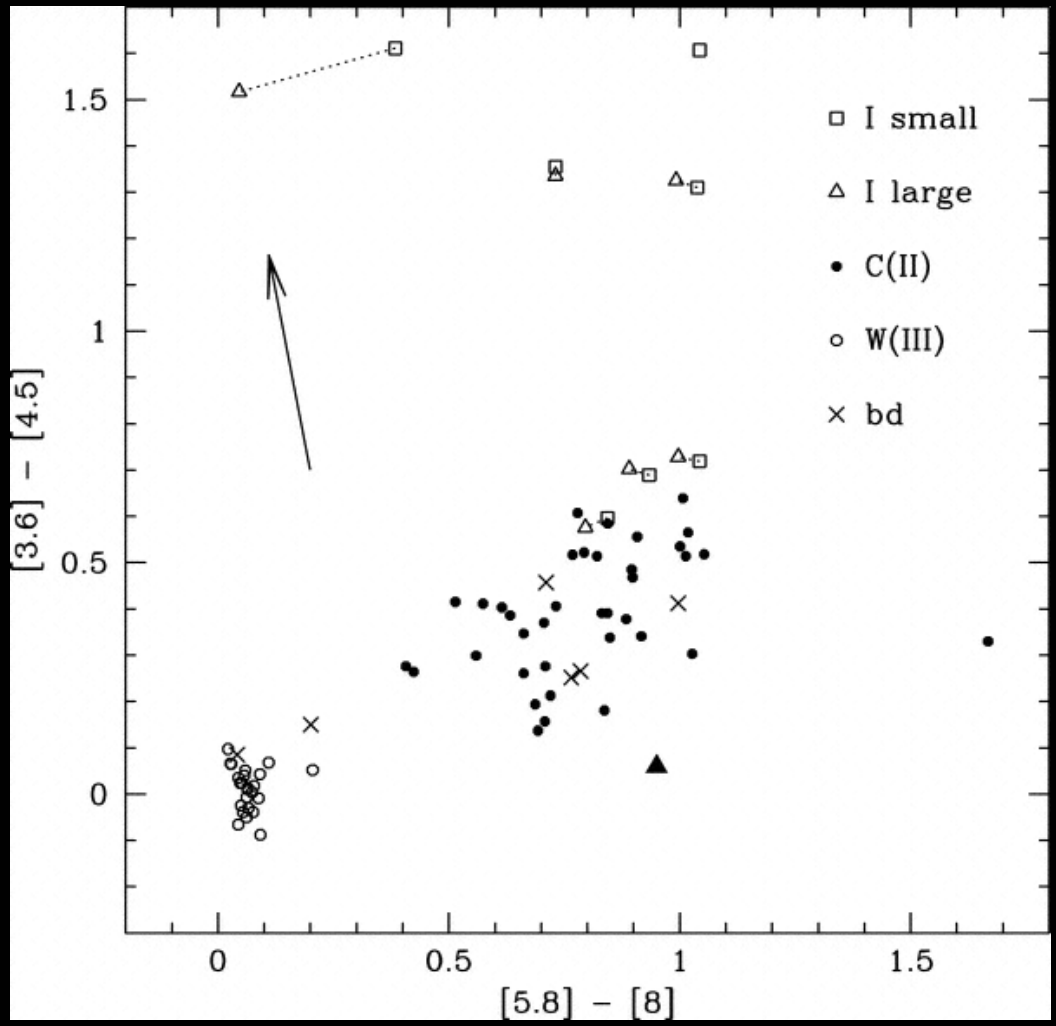
Masses


f05−04
N
E
BKLT J162824−243543
MMS126 ✳
BKLT J162816−243657
MMS126 ✳
c
b
40″
a
20″
1arcmin
2arcmin
g
f
e
d
c
star
20″
a
b
10″
BKLT J162631−242531
f10−04
WLY2−32b
a
10″
f04−05a
f04−05b
5″
f04−03b
5″
f04−04
20″
f04−03a
10″
f04−02
5″

Evolution of protostars

Colour-Color diagrams

- 2MASS
- SPITZER - IRAC……..
- VISIR/VLT (10mu, 20mu)
- ASTRO-F + Herschel



Hartmann et al 2005