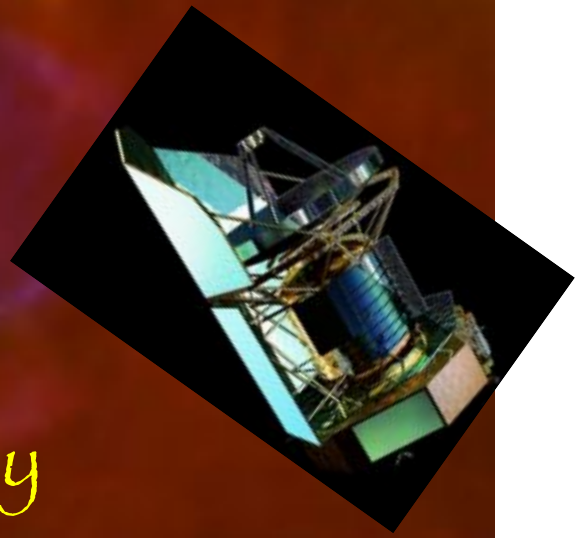
HERSCHEL (HOBYS) AS A PATHFINDER FOR ALMA



Tracey Hill – AIM Paris-Saclay

PI: F. Motte, A. Zavagno, S. Bontemps,
N. Schneider, M. Hennemann, J. Di Francesco, Ph. André, P. Saraceno, M. Griffin, A. Marston, D. Ward-Thompson, G. White,
V. Minier, A. Men'shchikov, Q. Nguyen-Luong
and A. Abergel, L. D. Anderson, Z. Balog, J.-P. Baluteau, J.-Ph. Bernard, P. Cox, L. Deharveng, P. Didelon, A.-M. di Giorgio, P. Hargrave, M. Huang, J. Kirk, S. Leeks, J. Z. Li, P. Martin, S. Molinari, G. Olofsson, N. Peretto, P. Persi, S. Pezzuto, H. Roussel, D. Russeil, S. Sadavoy, M. Sauvage, B. Sibthorpe, L. Spinoglio, L. Testi, D. Teyssier, R. Vavrek, C. D. Wilson, A. Woodcraft + other new comers

BACKGROUND: MASSIVE STAR FORMATION

Open Questions:

How do High Mass (OB > $8M_\odot$) stars form?

- Quasi-static vs dynamic scenario
- powerful gas (competitive) accretion vs coalescence
- Scaled up low mass star formation?

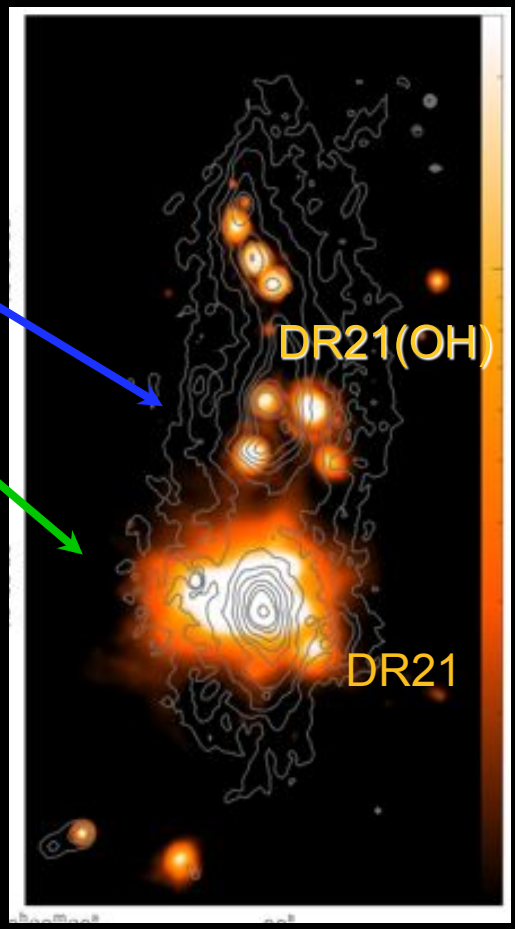
What are the initial conditions (density, temperature, kinematics) for high-mass star formation?

Observational evolutionary sequence:

- HII regions -> UC HII -> HII
- High mass protostars: evolving from envelope-dominated to star-dominated.
  - (e.g. Molinari et al. 1998, Bontemps et al. 2010)
  - Associated with hot cores, masers, powerful outflows, no radio cm
  - Identified within: IR-quiet protostellar dense cores (e.g. Motte et al. 2007), IR-bright protostellar dense cores or HMPOs or Hot Molecular Cores (e.g Beuther et al. 2002, Cesaroni et al. 2005)
- Massive prestellar cores (?) in IRDCs (e.g. Peretto & Fuller 2009)

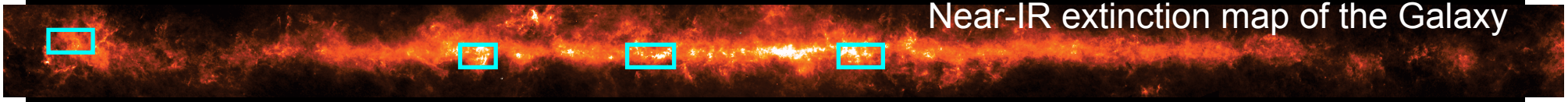
THE HERSCHEL IMAGING SURVEY OF OB YOUNG STELLAR OBJECTS (HOBYS)

- Identify & characterise the precursors of OB stars
  - High-mass analogues of prestellar cores – do they exist?
  - Massive IR-quiet protostellar dense cores
  - Massive IR-bright protostellar dense cores
- Measure core/envelope mass & bolometric luminosity
  - Build an evolutionary diagram
  - Estimate lifetime of each evolutionary stage
- Make the link between cloud structure and star formation
  - Differentiate low & high-mass star-forming filaments.
- Assess the importance of triggering
  - By comparing well-behaved HII regions to more common HMSF regions



MAMBO 1.25 mm
Spitzer 24 μm

SAMPLE & OBSERVATIONS



- Image all OB star-forming complexes < 3 kpc
  - Expect ~250 high-mass protostars
  - Statistical importance
  - Study precursors of stars up to 20$M_{\odot}$
- Wide-field PACS/SPIRE images (70, 160,250, 350, 500μm)
  - HPBW = 6"-36.9" @ 0.7-3 kpc => down to 0.05-0.3 pc cloud structures
- Complementarity
  - Progenitors of low mass stars – Gould Belt Survey (André et al)
  - Precursors of OB stellar clusters – HI-GAL Survey (Molinari et al)

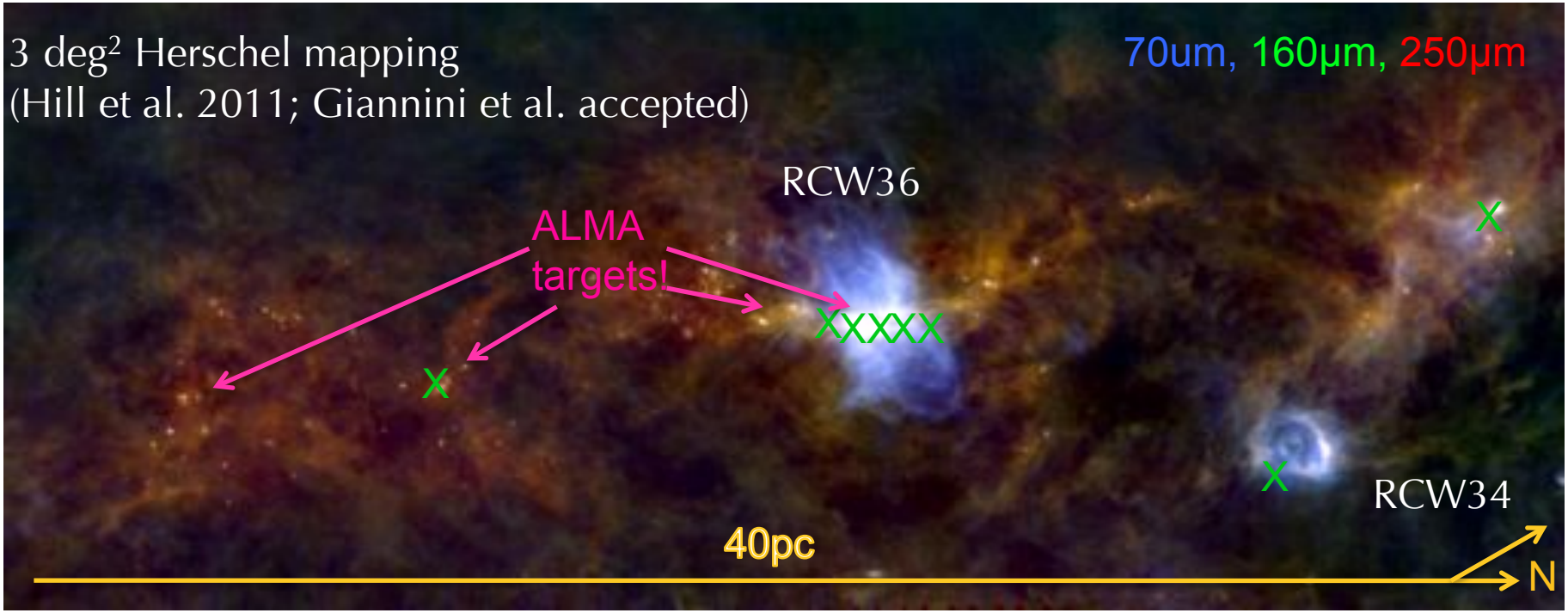
HOBYS TARGETS

Molecular cloud complexes	Area (deg ^{2})	Dist (kpc)	rms$_{250\mu m}$ (mJy/beam)	SPIRE+PACS Time (hr)	Responsible Team(s)
Vela	3.1	0.7	20	13	Rome/**Saclay**
Mon R1-R2 **Rosette**	2.0 1.5	0.8 1.5	20	15	Cardiff/**Saclay** **Saclay**/Canada
Cygnus X	6	1.7	20	25.5	**Saclay**/HSC
M16/M17/Sh40	2.5	1.7	20	10.5	HSC/RAL
NGC 6334 **NGC 6357**	1.7 1.7	1.7	20	7 7	**Marseille**/Rome RAL/**Marseille**
W3/KR140	1.5	2.2	20	6.5	Canada/Rome
NGC 7538	0.6	2.8	20	2.5	Canada/Cardiff
W48	3.9	3.0	20	16.5	**Saclay**/Rome

THE FIRST HERSCHEL IMAGES REVEAL:

- Extensive networks of filaments, among which "ridges" (dominating super critical filaments) are forming high mass stars.
  - The Vela C Ridge – Hill et al., 2011, A&A 533, 94
    - Giannini et al., accepted. Minier et al., in prep.
  - The IRDC G35.39-00.33 in W48 – Nguyen Luong et al., 2011
- Feedback of OB star clusters on molecular cloud structure, such as heating, pillars and triggered star formation.
  - Reid et al., NGC 7538, Hill et al., M16; Schneider et al., Rosette, Hennemann et al., DR21
- Clusters of protostars
  - Among which a few good candidates are high-mass class 0 protostars and starless cores.

CHARACTERISATION OF A RIDGE IN VELA C

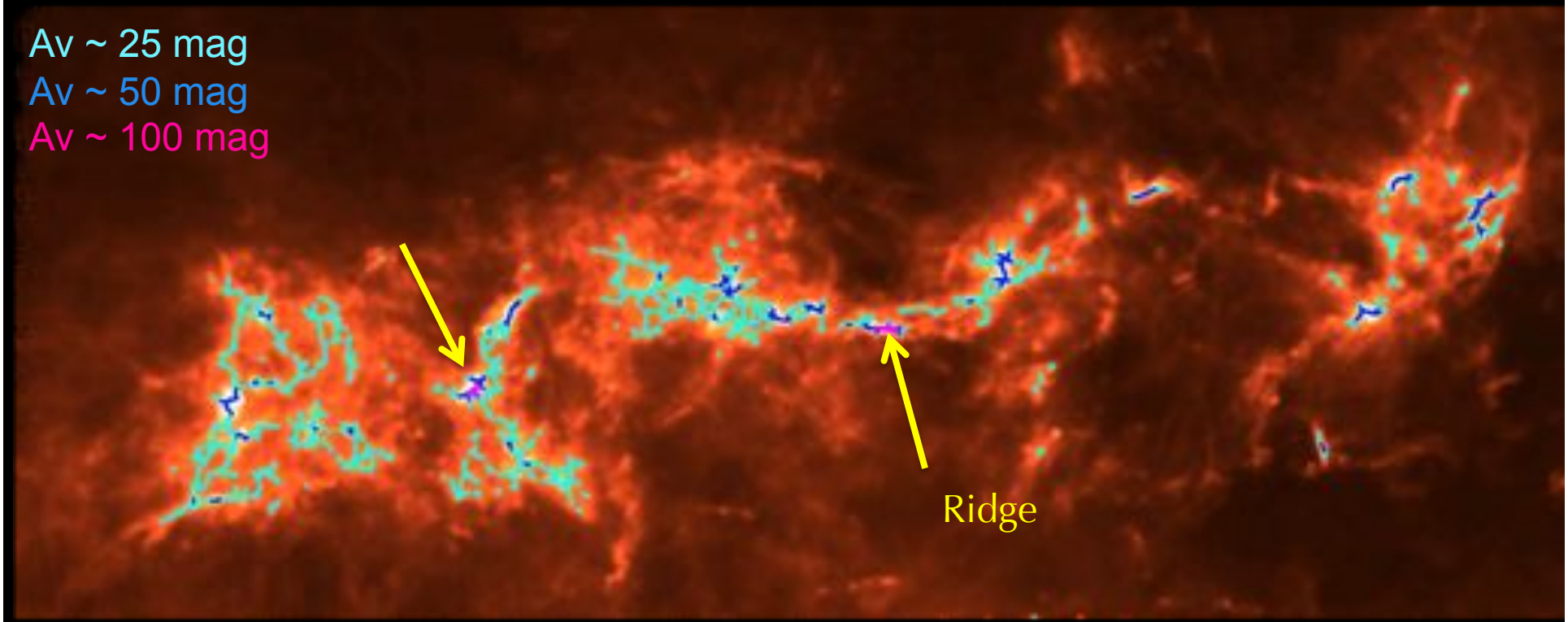


- The Vela C molecular Cloud (700pc, 5 x10^5 $M_\odot$), 2 HII regions.
- Sources extracted with getsources, a multi-wavelength, multi-resolution sources extraction algorithm (Men'shchikov et al. 2011) .
- 13 high-mass sources 14-70 $M_\odot$

- ~ 0.04 pc cloud structures -> protostellar or prestellar cores, i.e., the direct progenitors of individual high-mass stars.

IDENTIFYING FILAMENTS & RIDGES

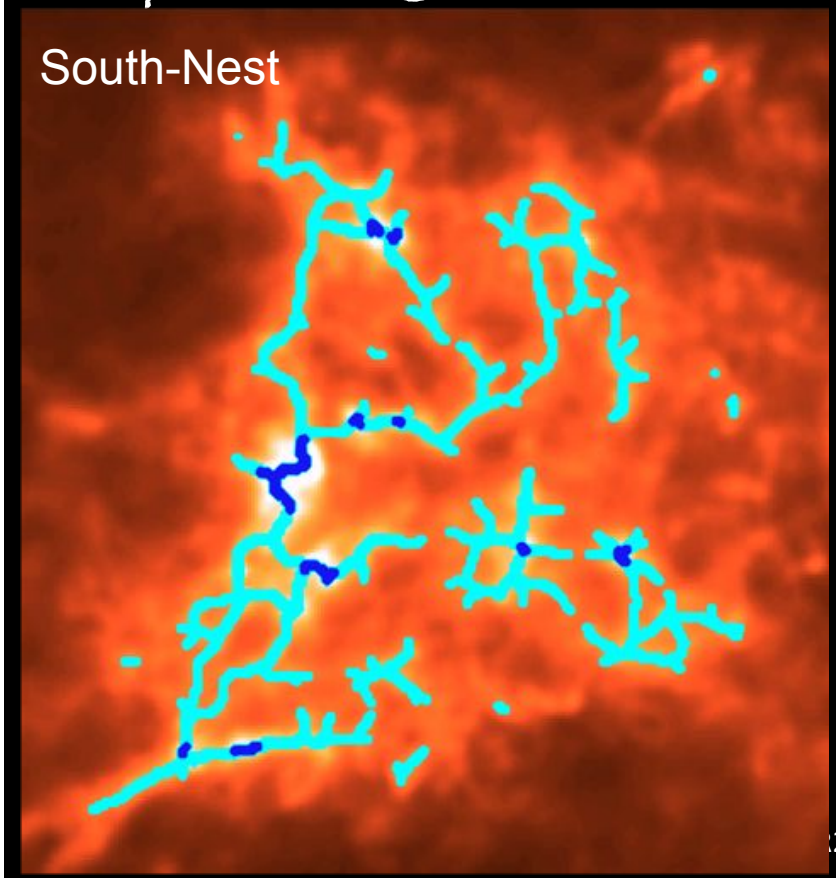
- Dust temperature and column density from greybody fits (37")
- Census of filaments: DisPerSE (Sousbie 2011)
- Above Av > 50 mag all filaments identified have supercritical masses per unit length and are thus likely forming stars

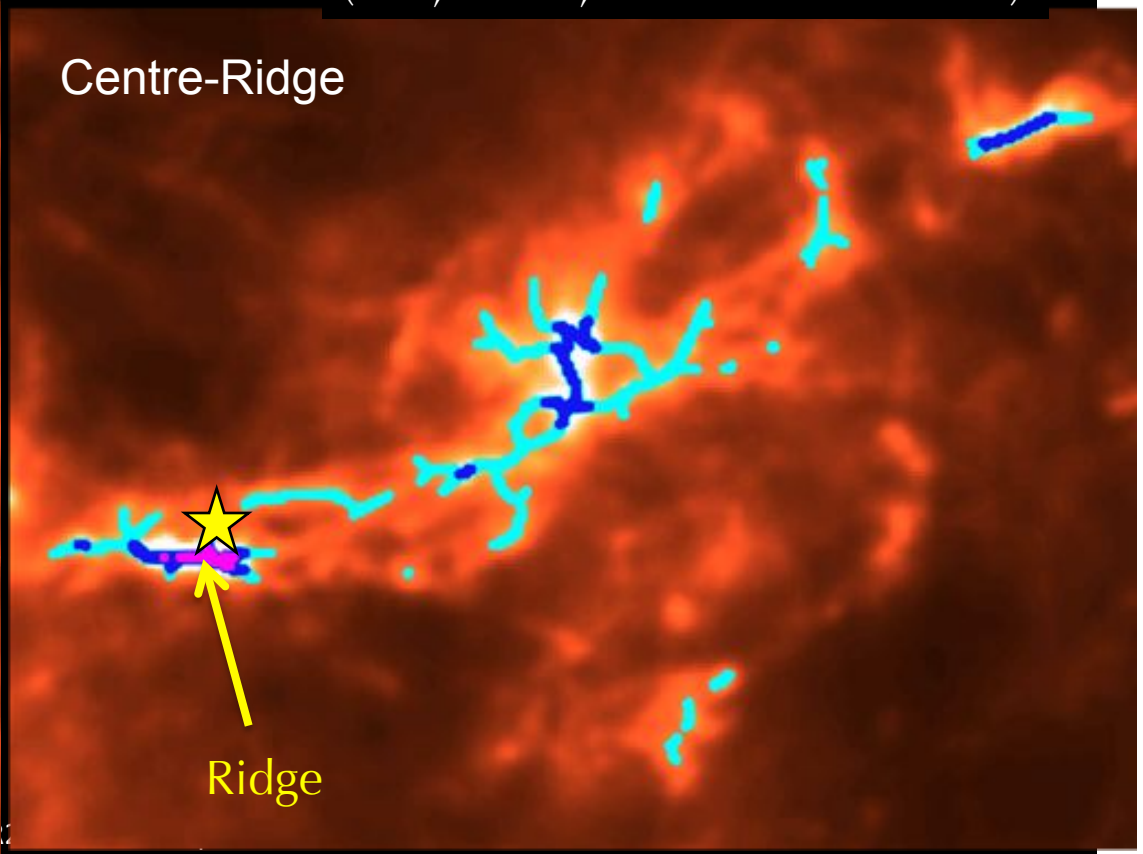


CLOUD STRUCTURE IN SUB-REGIONS

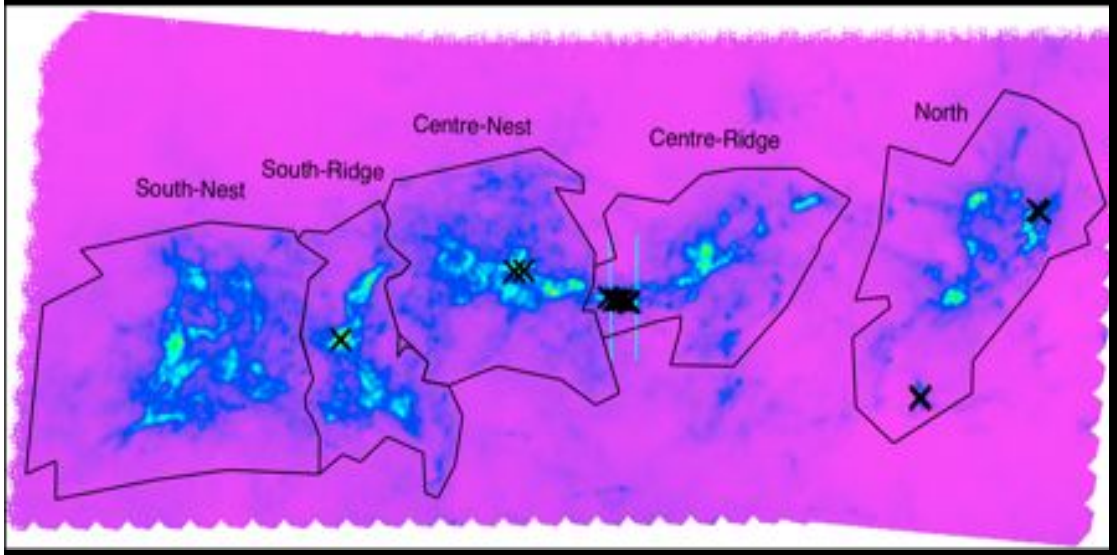
- Disorganised network of filaments vs single dominating ridge.
- High-mass stars form preferentially in ridges, high-column density (Av > 100 mag), wide (>0.3 pc) filaments present in specific regions.

(Hill, Motte, Didelon et al. 2011)

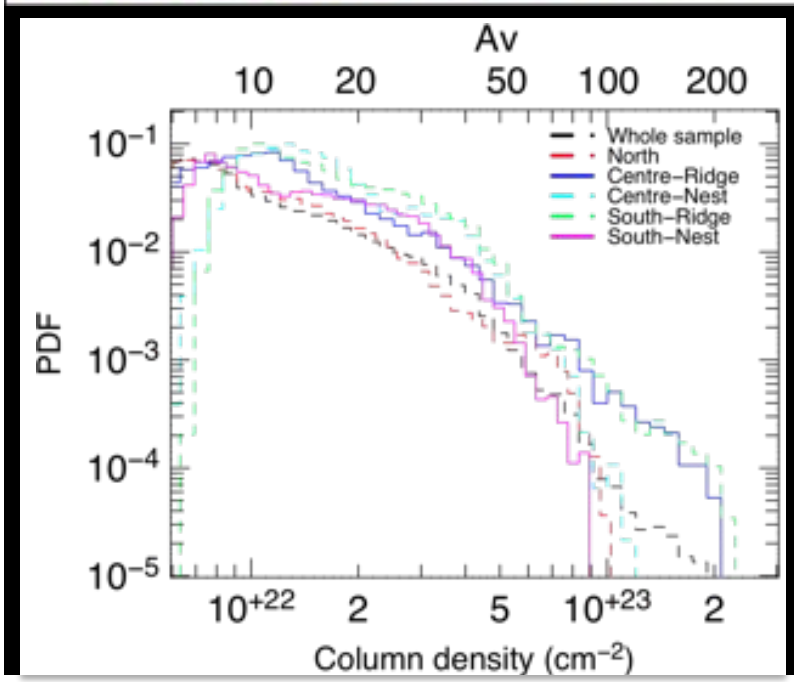




Mechanisms at play



- PDFs
- At Av~ 7 mag, Vela C segregates into 5 sub -regions of similar mass
- South-Nest and Centre-Ridge two most contrasting

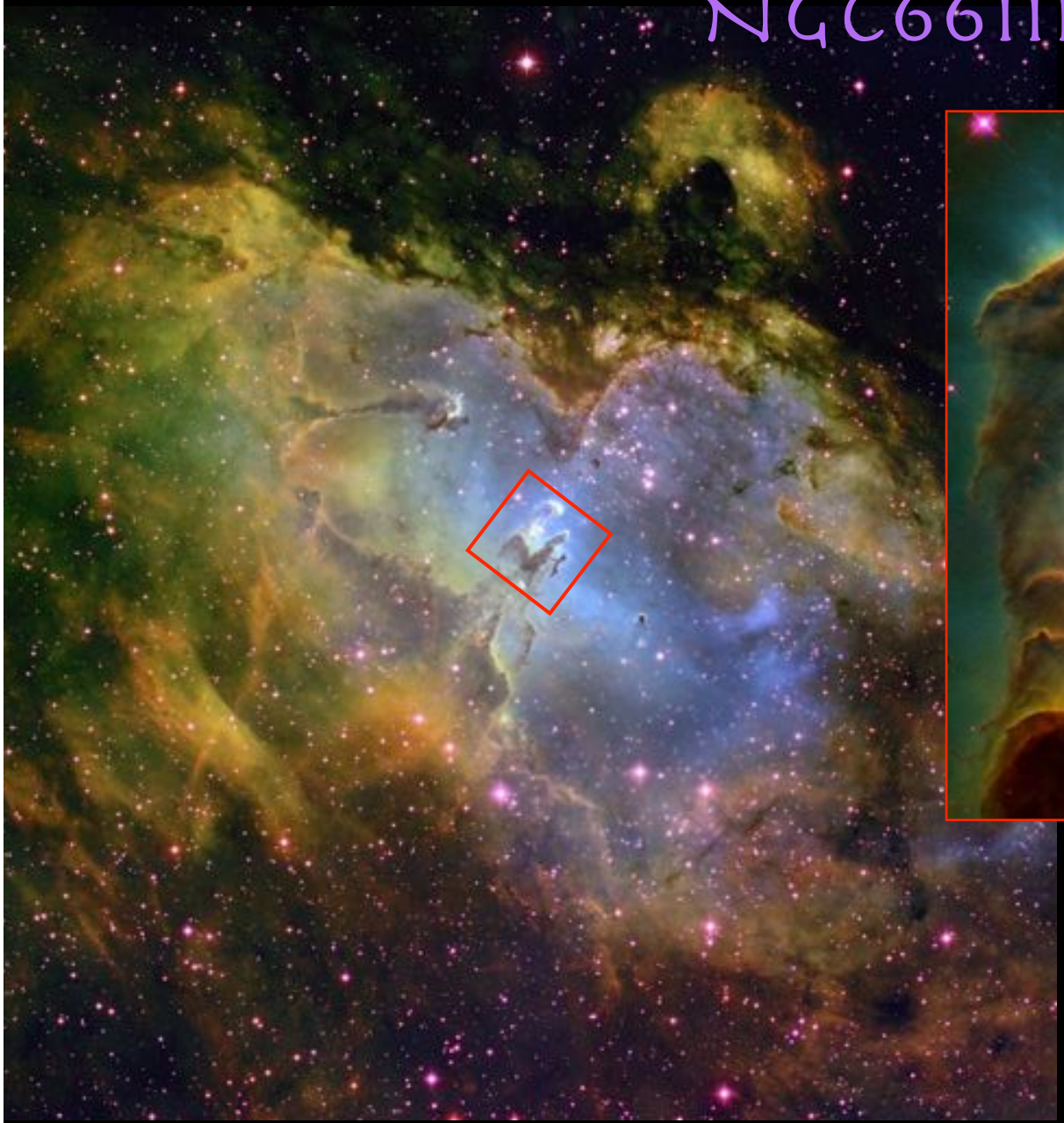


- CR has a high col den. tail and flatter PDF slope than SN.

➢ May suggest that gravity rather than turbulence is shaping the cloud.

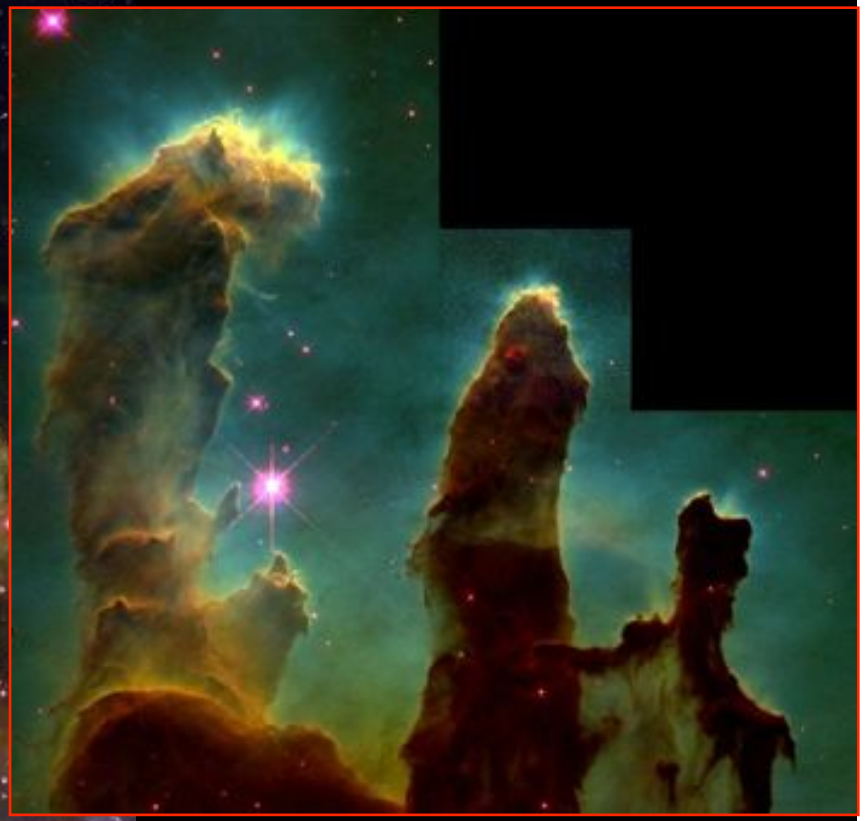
- Flatter PDF observed for coherent structures created via constructive large-scale flows in some numerical simulations (Federrath et al., 2010)

M16 UNDER THE INFLUENCE OF NGC66111



Picture credit: T.A. Rector & B.A. Wolpa

Picture Credit: J. Hester & P. Scowen

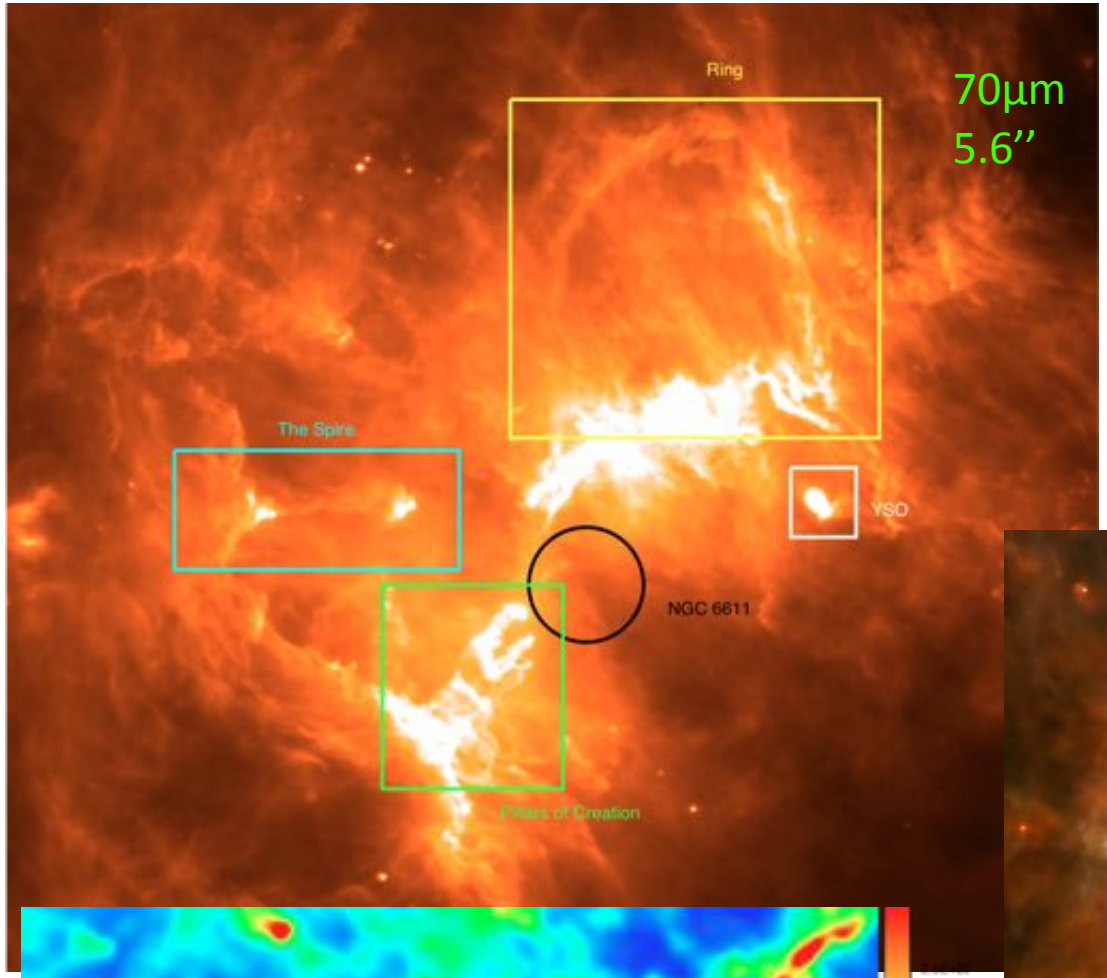


Pillars of Creation

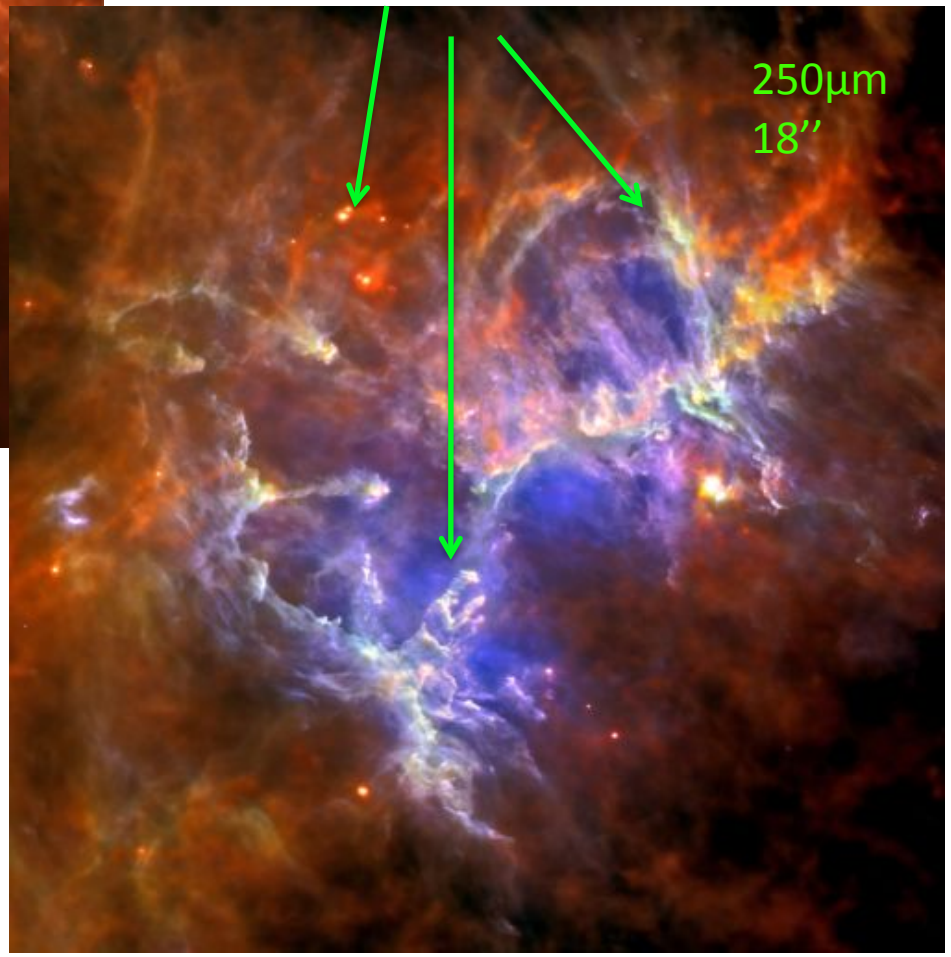
H-alpha, Oxygen [OIII], Sulfur [SII]

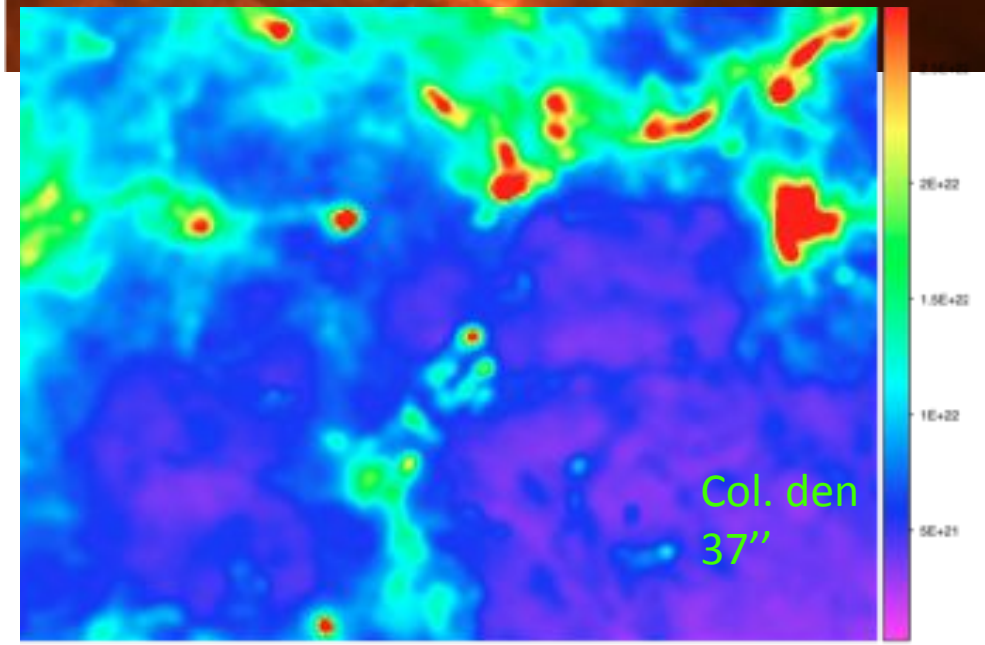
THE EAGLE HAS LANDED

(Hill, Motte, Didelon et al. In prep)



ALMA targets





APOD!

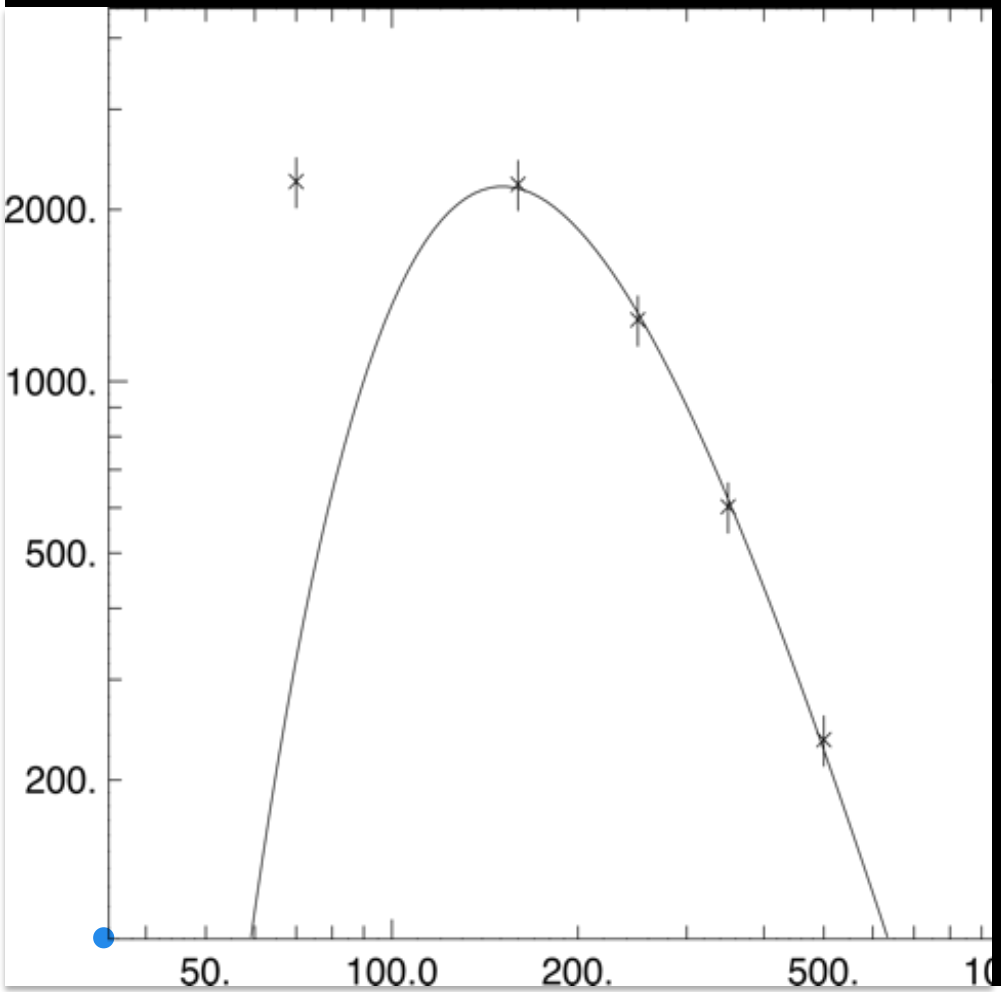
- http://apod.nasa.gov/apod/ap120203.html

SUMMARY

- Initial results from the HOBYS key program are promising for star formation studies.
- Stars form in filaments.
- Ridges are super-filaments, of high column density.
  - ~100Av (1×10^{23} cm^{-2})
  - High mass stars preferentially form in ridges
- High resolution, multi-wavelength Herschel observations cover the peak of emission of prestellar cores.
  - Constraining evolutionary diagrams (L:M)
- Identifying class-0 like high mass progenitors and massive dense cores.

THE NICHE OF HERSCHEL -1

- 5 wavelength bands to characterise SEDs
  - Characterise evol parameters, e.g. lum, mass,

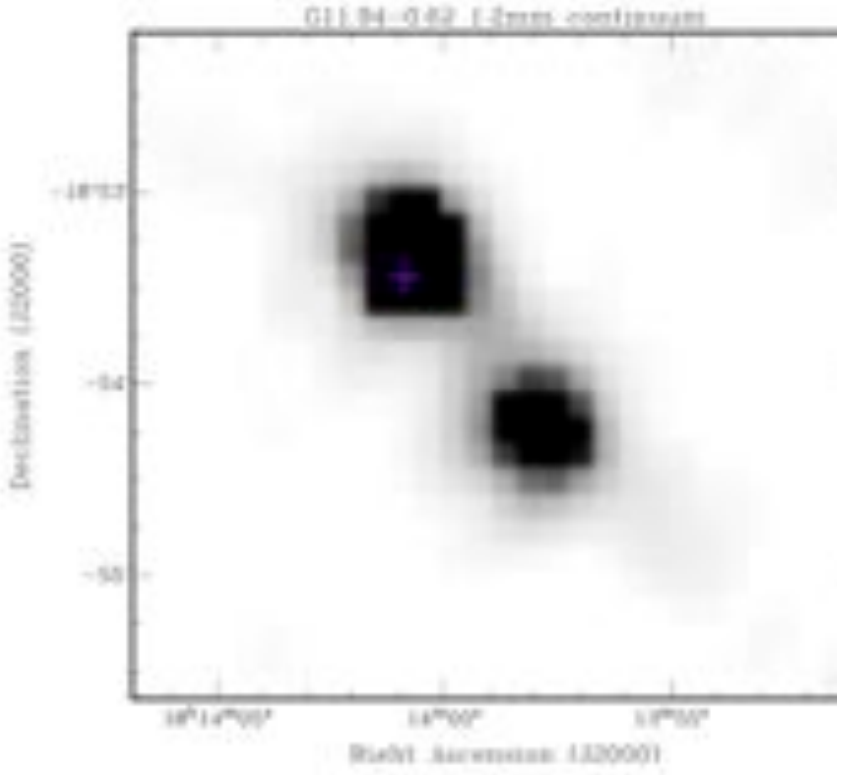


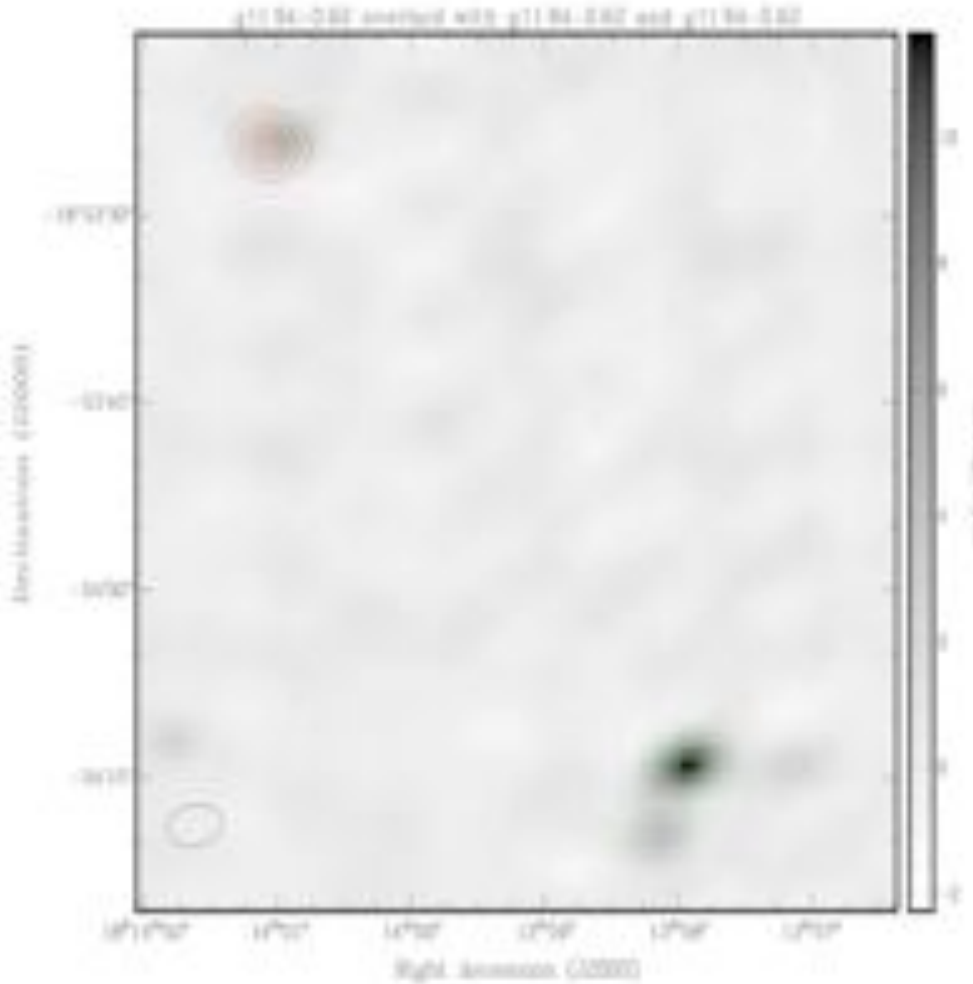
- Identify the earliest precursors of high-mass stars
- Alternatively identify a spectrum of sources from all stages of evolution

- Characterize SF sequence.

THE NICHE OF HERSCHEL -2

- Fragmentation studies
  - Cores or clumps?
  - Hill ATCA, 3/7mm

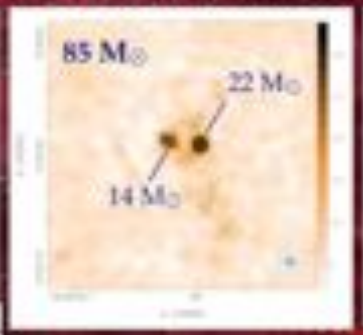


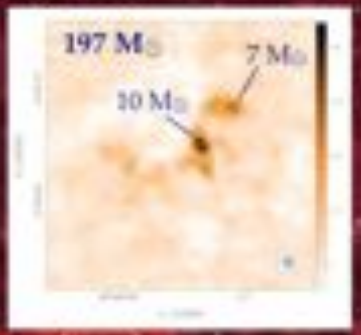


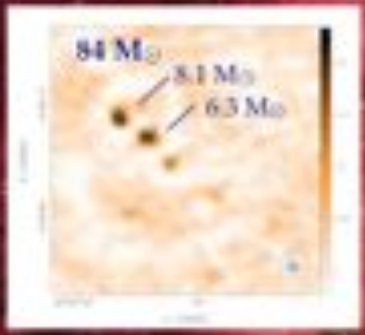
From a sample of massive dense cores ...

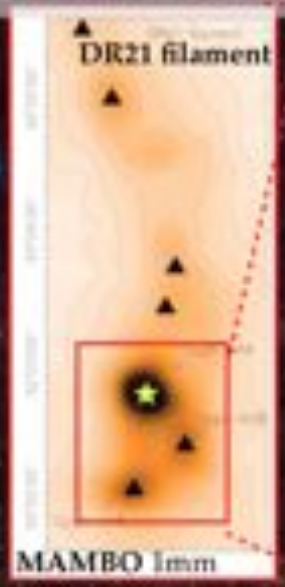
MAMBO dust continuum survey:
(Motte et al 2007)

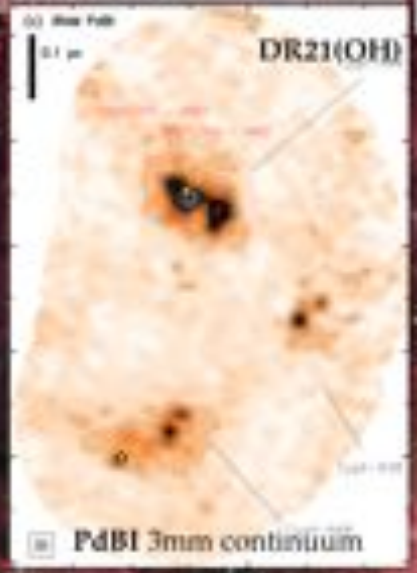
- Massive Dense Cores (MDCs)
- high-mass equivalent to low-mass dense cores
- IR-quiet & IR-bright MDCs

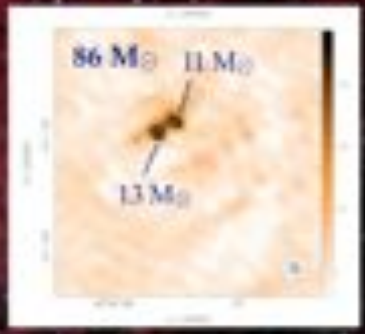


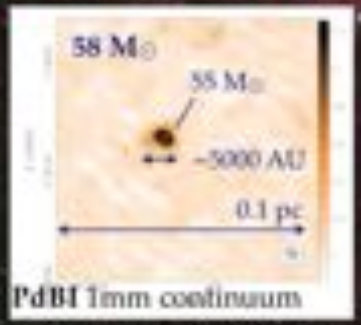












Bontemps et al. (2010 A&A, 524, 18)

- MDCs are subfragmented
- MDCs form high-mass stars

... to a sample of high-mass protostars

Cygnus-X Legacy Project; Spitzer, Hora et al.

Courtesy T.Csengeri.

A PATHFINDER FOR ALMA

- HOBYS identifies the best locations for ALMA studies
  - Filaments, ridges, protostars, prestellar cores
  - Can identify and characterise sites forming high-mass star forming cores in advance
    - ALMA: fragmentation -> individual star-forming cores, spectral lines, chemical evolution etc.
    - High resolution velocity information – Ridge Vela C, 3D cavity M16, examine scenarios from PDFs
- Strong complementarity
  - With PACS resolution & with SPIRE bands
- HOBYS traces diffuse extended emission which ALMA can not
  - Provides info. re. cloud structure & star –forming environments
  - On large scales!.