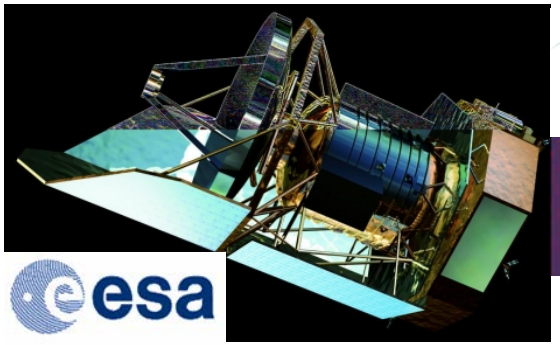


Formation and Development of Molecular Clouds
Cologne, Oct 6 2011

The earliest phases of OB star formation revealed by the Herschel key program HOBYS

Martin Hennemann – HOBYS consortium

Lab. AIM/Service d'Astrophysique

CEA Saclay

http://hobys-herschel.cea.fr

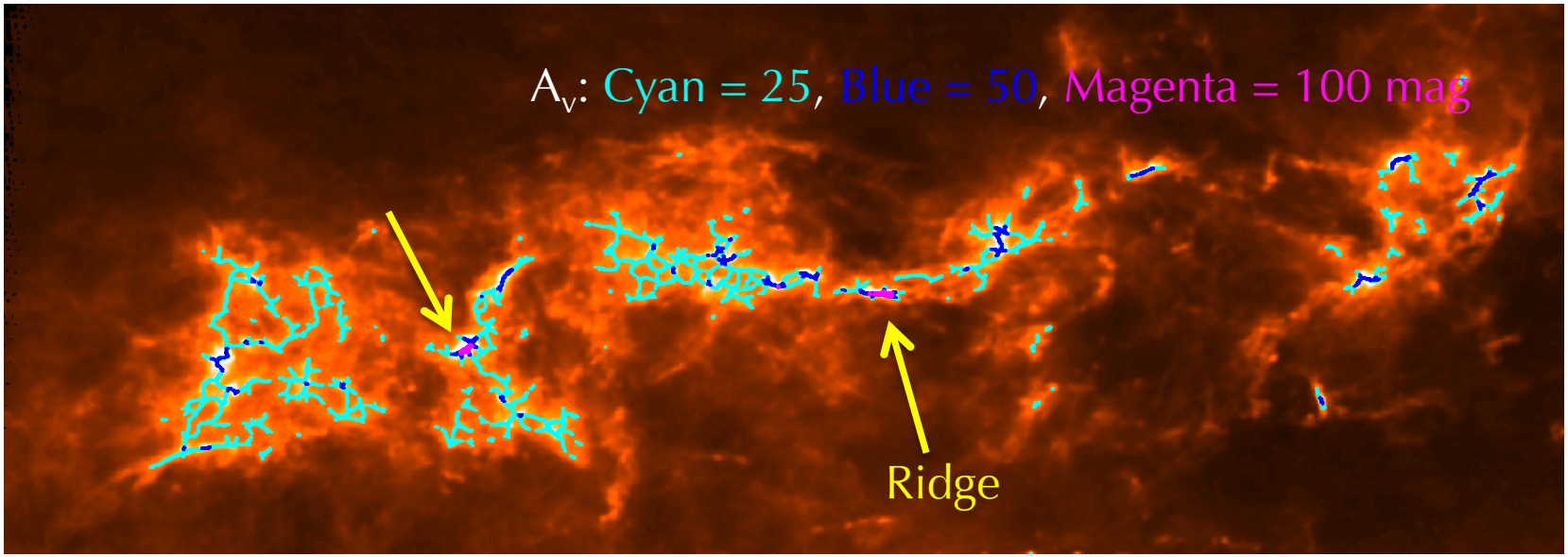
HOBYS cheat sheet

- Main questions:
  - What mechanisms form OB stars, and on which timescales?
  - What are the direct precursors of high-mass stars?
  - What are the (initial) conditions (density, temperature, kinematics…) within clouds/filaments forming OB stars?
  - What is the effect of feedback on the star formation activity?
- Method: Unbiased survey of cloud complexes forming OB stars/well-behaved HII regions within 3kpc with Herschel
- Goals:
  - Statistically significant sample of high-mass YSOs: ca. 250 expected – enough to study mass range up to 20 $M_{\odot}$
  - Characterize their immediate and large-scale environment
- People: Motte, Zavagno, Bontemps et al./SPIRE consortium SAG3

P. Didelon, T. Hill, V. Minier, Q. Nguyen-Luong, N. Schneider, Ph. André, T. Csengeri, A. Men' shchikov, N. Peretto, A. Abergel, L. D. Anderson, D. Arzoumanian, M. Attard, M. Benedettini, Z. Balog, J.-P. Baluteau, J.-Ph. Bernard, P. Cox, L. Deharveng, D. Elia, C. Fallscheer, J. Di Francesco, A.-M. di Giorgio, M. Griffin, P. Hargrave, M. Huang, J. Kirk, V. Könyves, S. Leeks, J. Z. Li, A. Marston, P. Martin, S. Molinari, G. Olofsson, P. Palmeirim, P. Persi, M. Pestalozzi, S. Pezzuto, D. Polychroni, M. Reid, A. Rivera, H. Roussel, D. Russeil, K. Rygl, S. Sadavoy, P. Saraceno, M. Sauvage, T. Sousbie, E. Schisano, B. Sibthorpe, L. Spinoglio, S. Stickler, L. Testi, D. Teyssier, R. Vavrek, D. Ward-Thompson, G. White, C. D. Wilson, A.Woodcraft

(Some) HOBYS first results

- Properties of clumps, massive dense cores, and protostars in Rosette (Di Francesco+ 2010, Motte+ 2010, Hennemann+ 2010), W48 (Nguyen Luong+ 2011acc),…
- Large-scale structure and feedback in Vela C (Hill+ 2011), Rosette (Schneider+ 2010, 2011ip),…
- High-mass star-forming "ridges": Example of Vela C

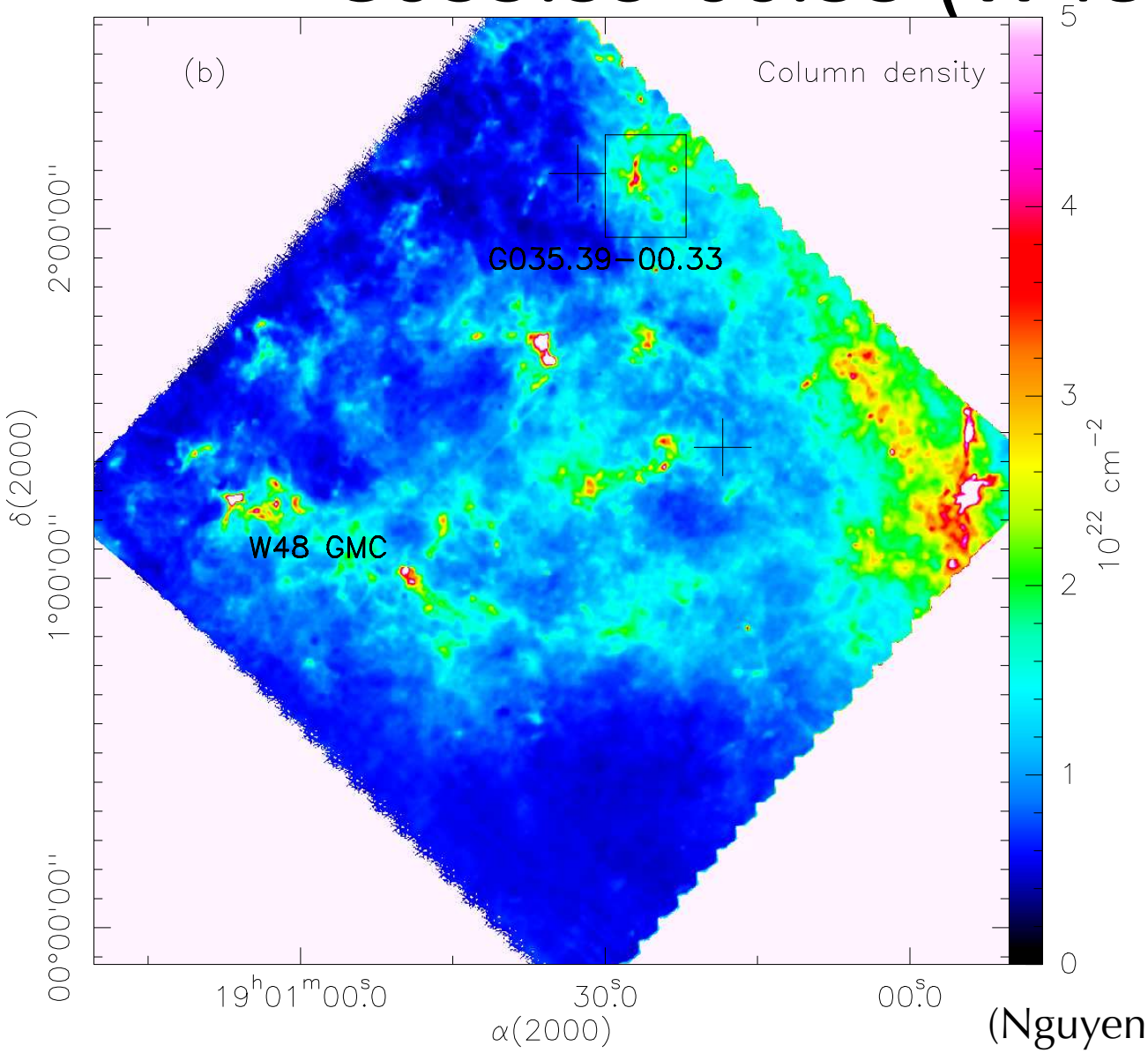


- Where will CCAT help?
  - Constrain submm emission on 0.1pc scale
  - Provide velocity information on 0.1pc scale

Compact objects in HOBYS fields

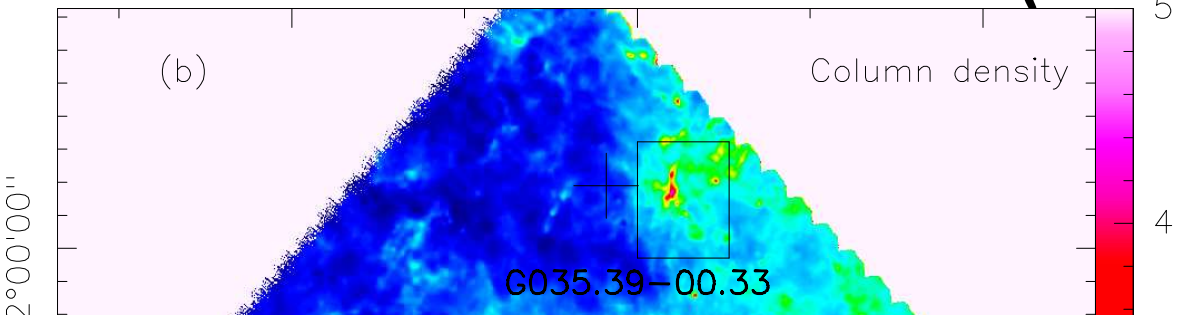
- OB star precursor candidates: “Massive Dense Cores” (ca. 0.1 pc size, density > 10^5 cm^{-3})
- Statistical samples from large mm-mapping (Motte+ 2007, Russeil+ 2010)
- Characteristic properties: Envelope mass & bolometric luminosity (➔ Stellar mass)
- Herschel covers SED peak ➔ luminosity and dust temperature
- Herschel allows to cover large fields
- Herschel is sensitive to lower masses

Massive dense cores in IRDC G035.39-00.33 (W48, 3kpc)



(Nguyen Luong+ 2011; Rygl+ in prep.)

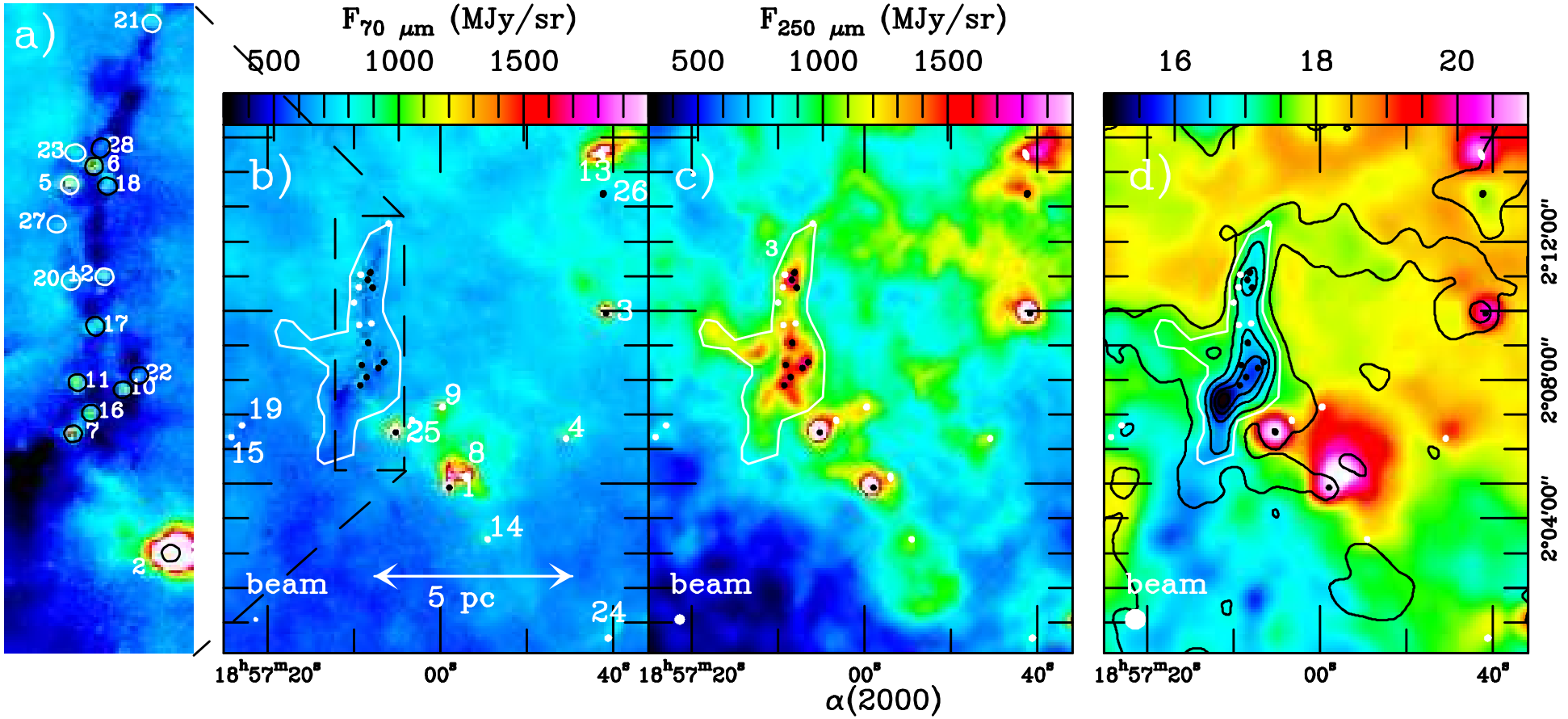
Massive dense cores in IRDC G035.39-00.33 (W48, 3kpc)



N_H~3-8 x 10^{22} cm^{-2}, T~14-17 K

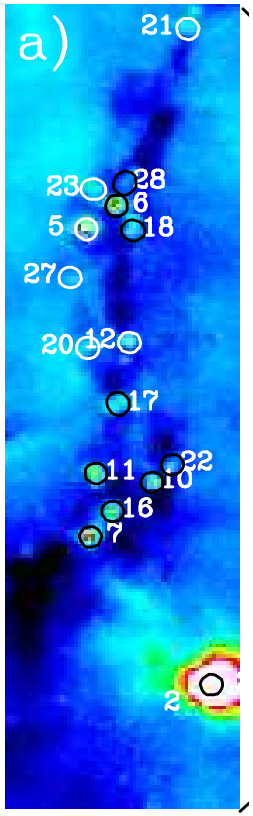
ca. 4000 $M_\odot$ (A_V > 30)

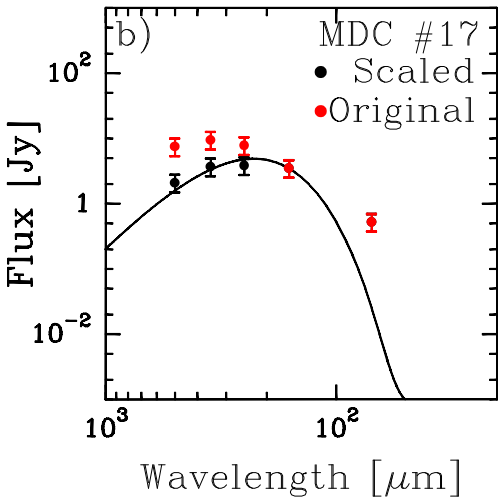
getsources: 13 objects > 20$M_\odot$

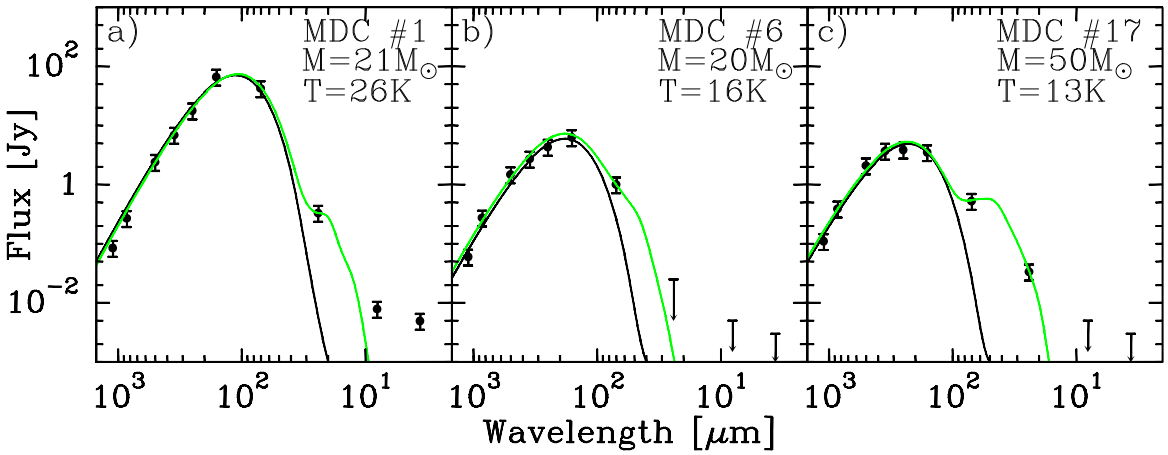


SED flux scaling for large beams

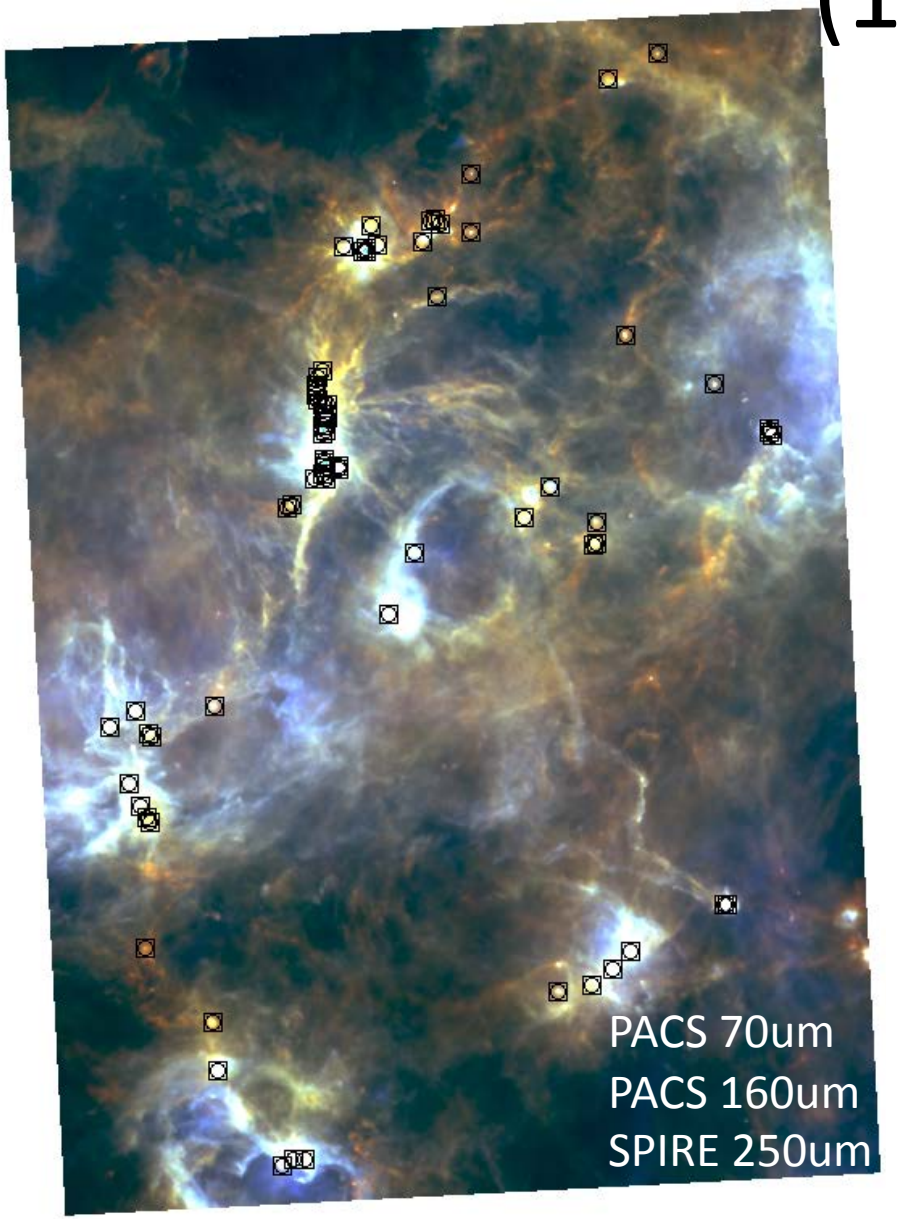
- Difficulties in building Herschel-only SEDs:
  - 0.1pc dense core scale not resolved in submm
  - Structure of the cold environment traced in submm shows no firm boundaries?
- Rescaling of fluxes from large beams with size ratio: $F^{SED} = F \times FWHM_{160\mu m} / FWHM$
  - Assumes density ~ r^{-2}, weak temperature gradient, optically thin emission





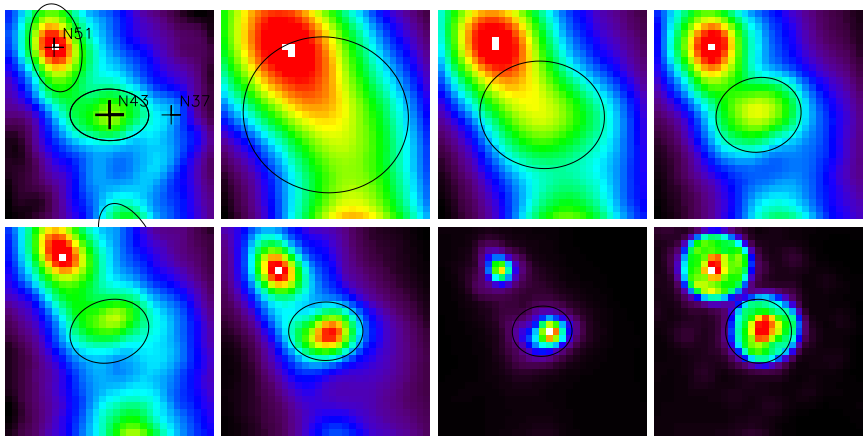


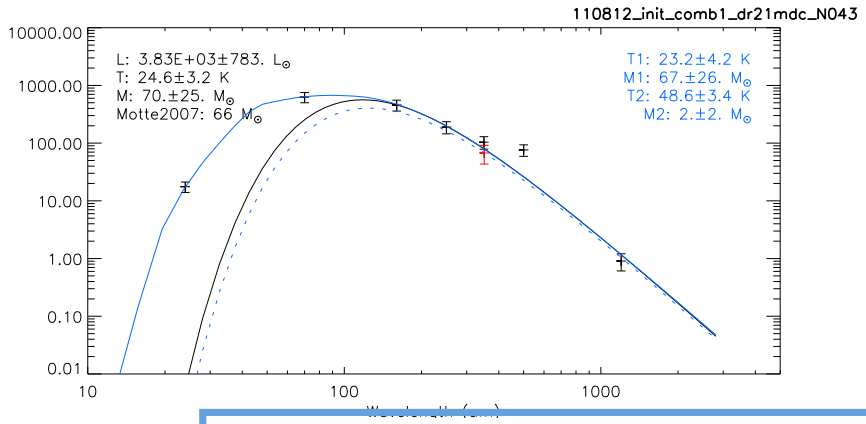
Massive dense cores in Cygnus X North (1.7kpc)

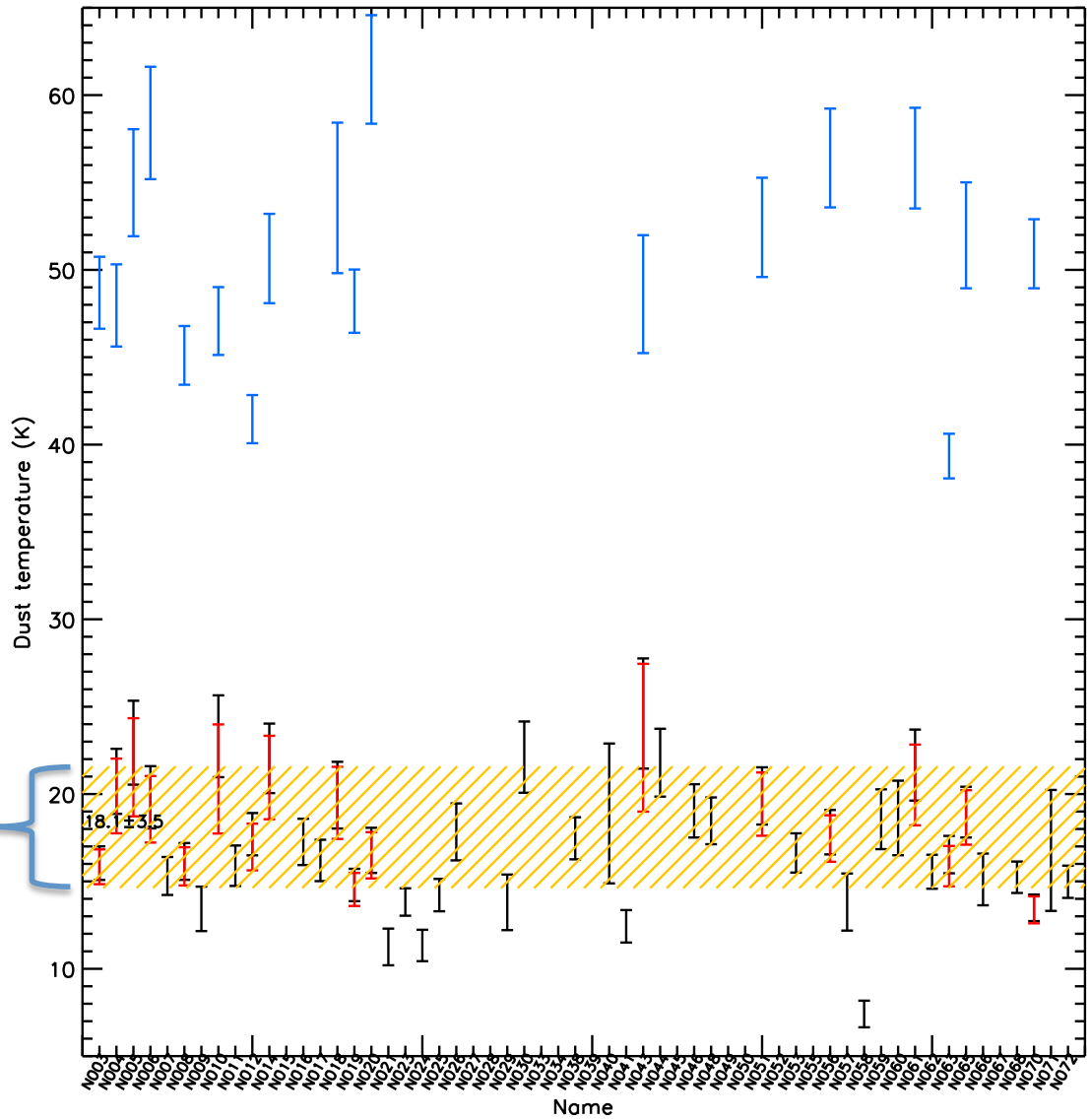


- Motte+ 2007: 3 deg2 1.2mm survey found 72 dense cores in Cygnus X North
- 21 MDCs (> 40 $M_{\odot}$) assuming 20K
- all show protostars / outflow activity
- Very short lifetime of prestellar phase

MDCs in Cygnus X North – Dust temperature



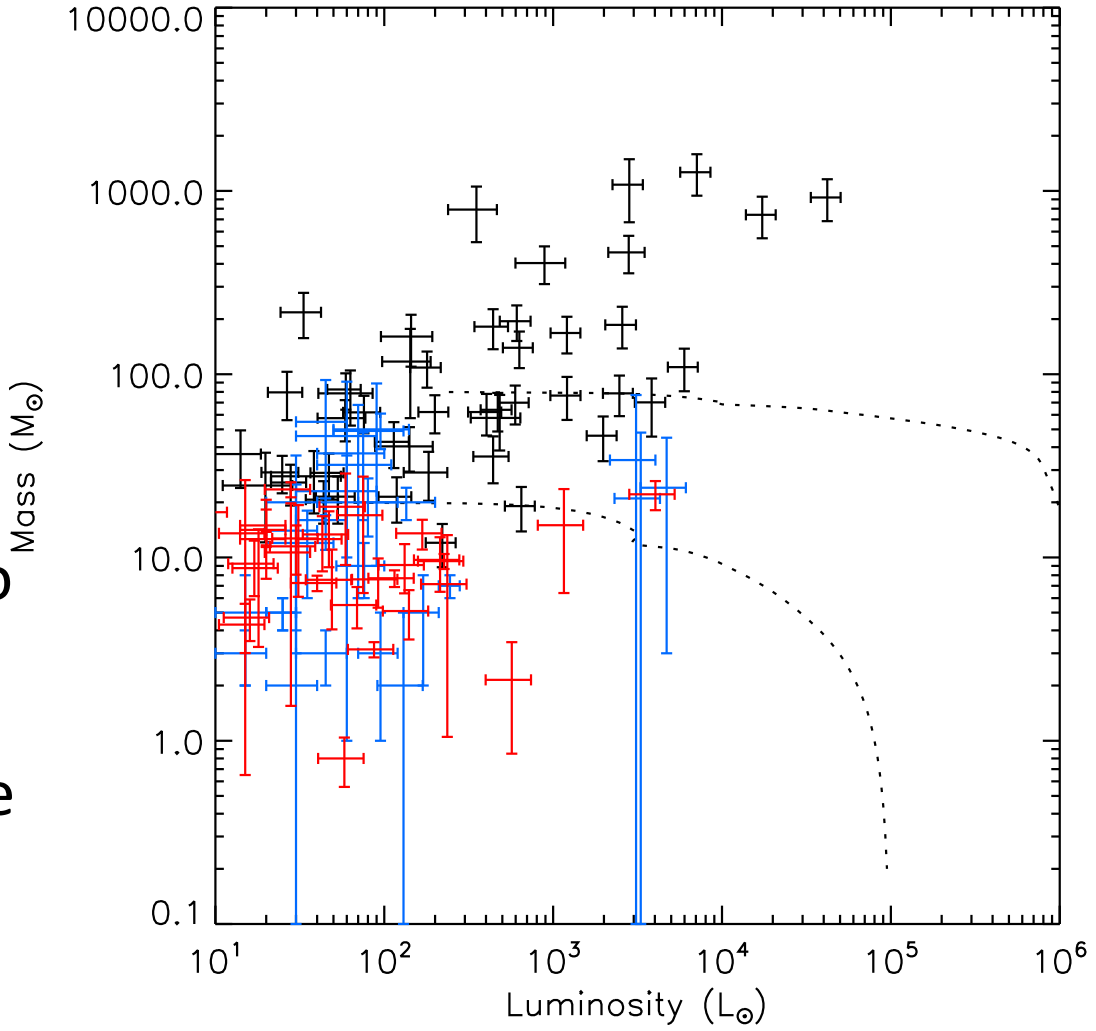




Dust temperature for >160μm: T = 18.1 ± 3.5 K

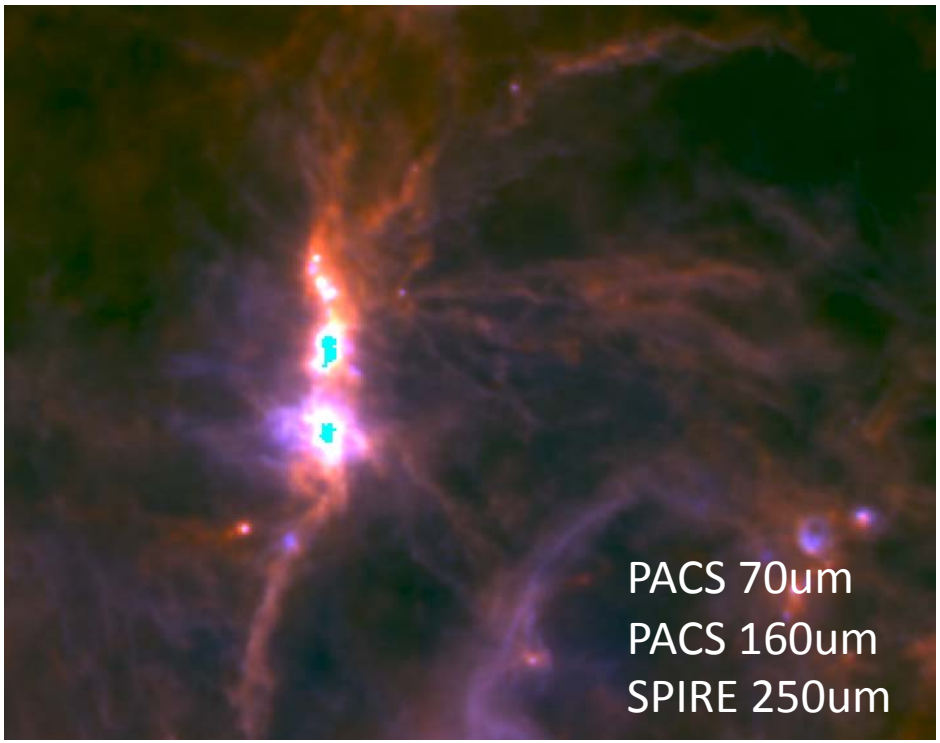
Evolution of Massive Dense Cores

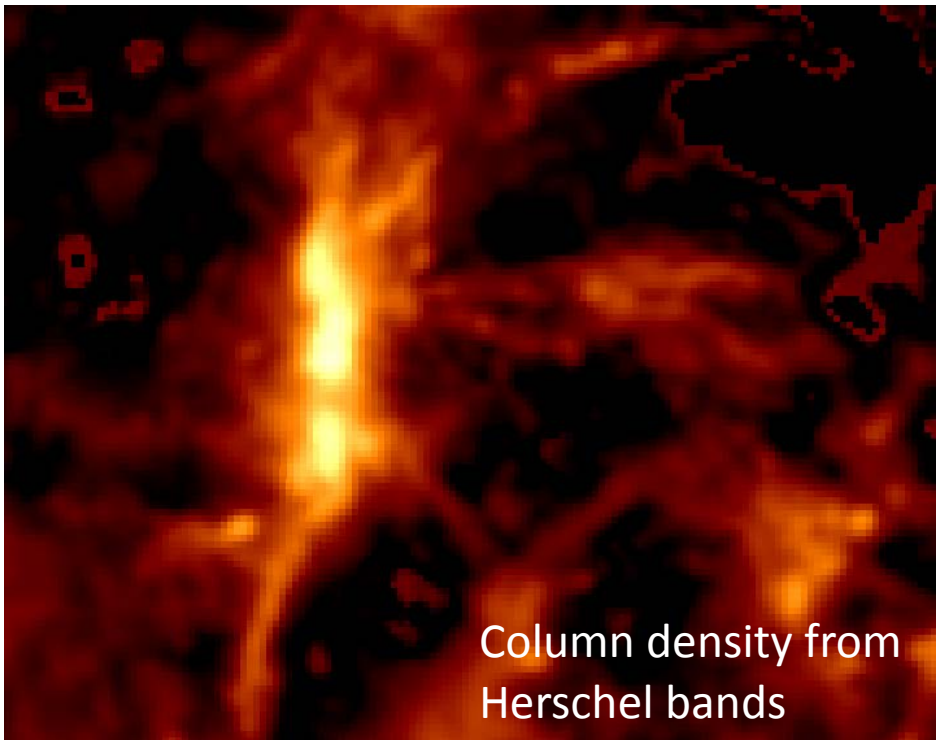
- Preliminary evolutionary diagram for MDCs in
  - Cygnus X North (biased)
  - IRDC G035.39-00.33 (biased)
  - Rosette GMC (biased)
- Cygnus X North: missing very evolved cores due to selection at 1.2mm
- Model tracks for MDCs/ protocluster clumps to be improved:
  - size of mass reservoir?



The massive DR21 filament – An accreting "ridge"?

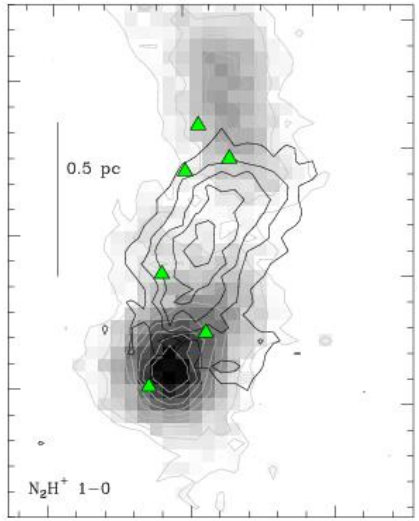
- Filament containing DR21 & DR21(OH) is most active part in Cygnus X: <n> ~ 10^4 cm^{-3}, M ~ 34000 $M_\odot$
- Column density map traces fainter, perpendicular, possibly connected "subfilaments"
- Outflow interpretation unlikely

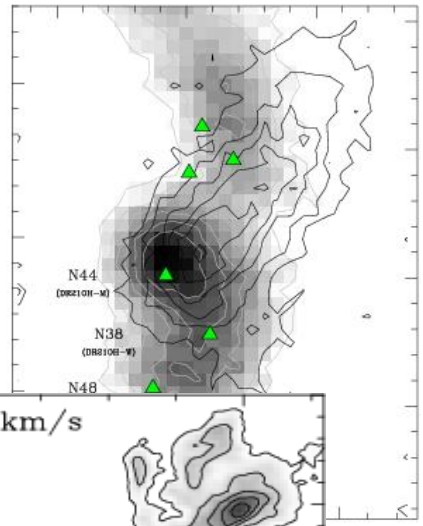


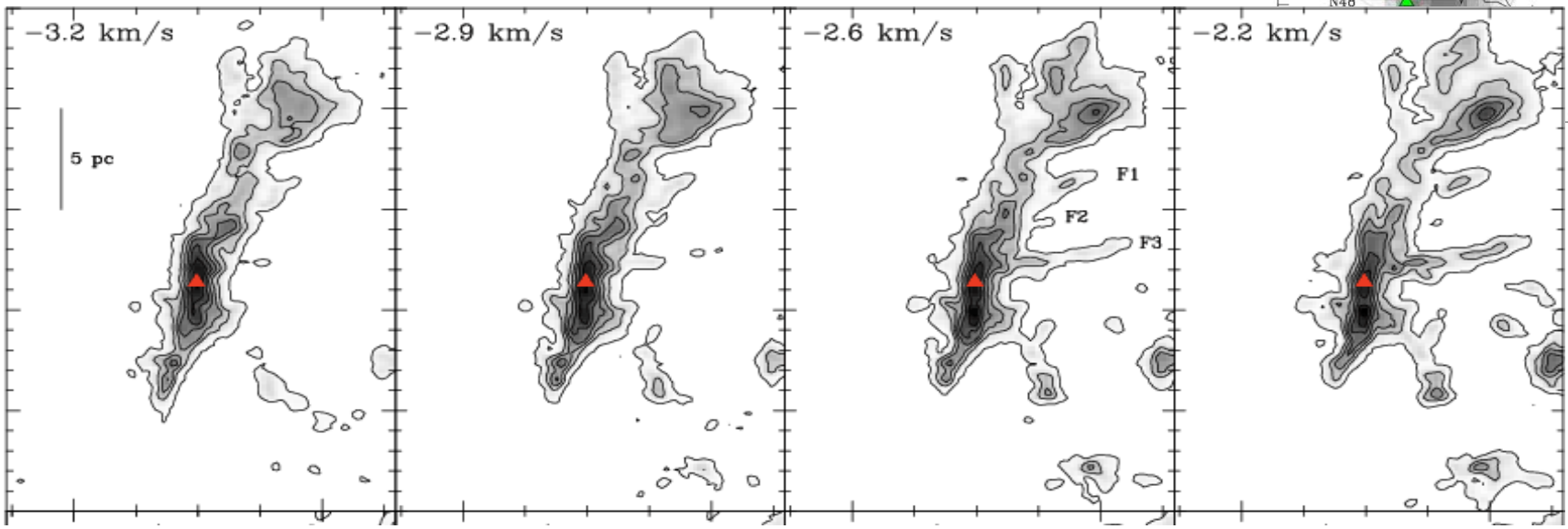


Subfilaments traced in molecular line emission

- Schneider+ 2010: EW oriented subfilaments
- Most prominent F3:
  - ~3km/s velocity range, ~7 pc projected length
  - M~2600 $M_\odot$, <n> ~7 x 10^3 cm^{-3}
- Probably connected with denser NE-SW segment traced in $H^{13}CO+$ / N_2H+ to DR21(OH)-M and maybe with flows within the clump (Csengeri et al. 2010)
- Estimated input mass rate: 2 x 10^{-3} $M_\odot$/yr







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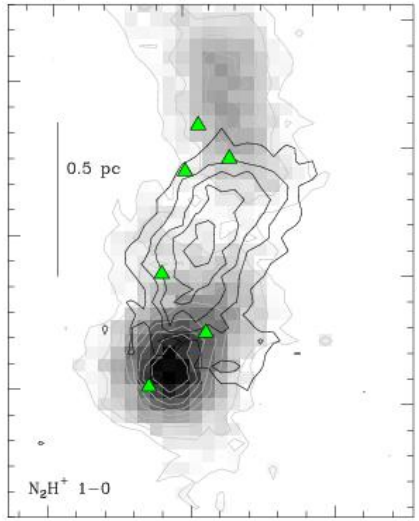

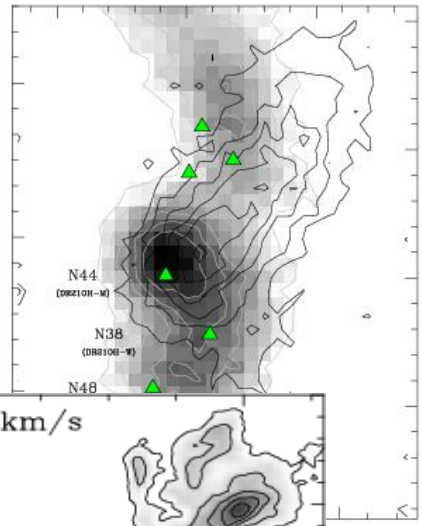

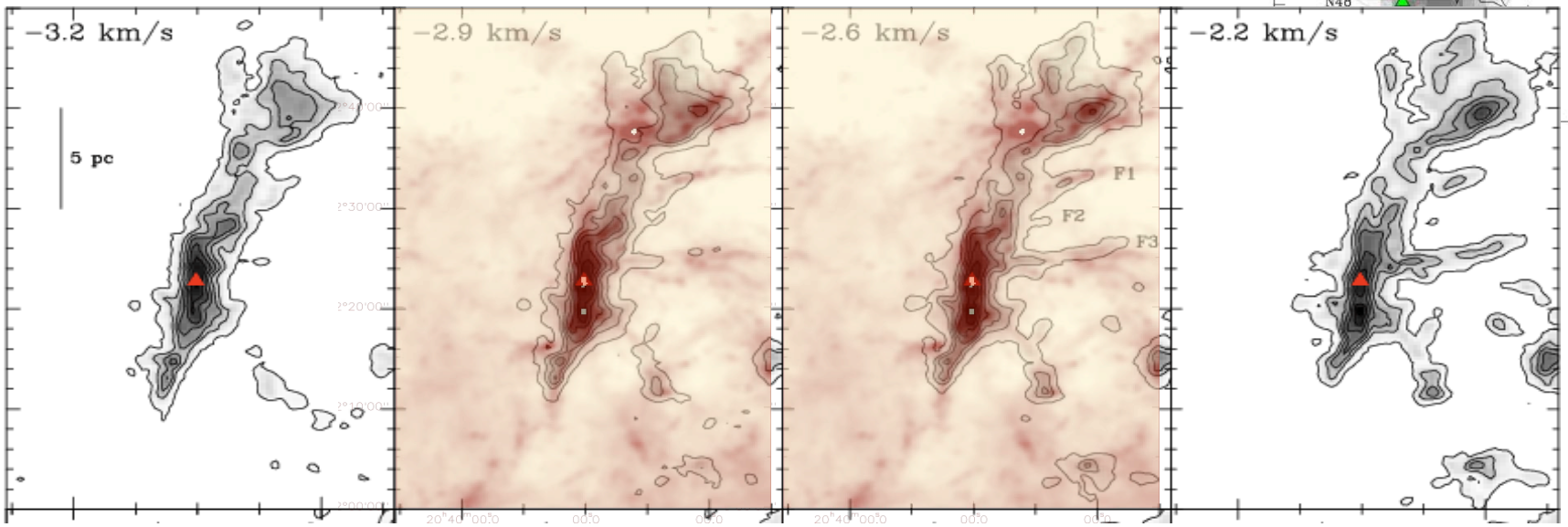

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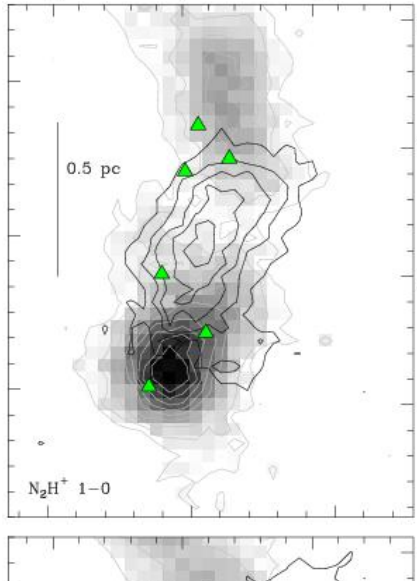

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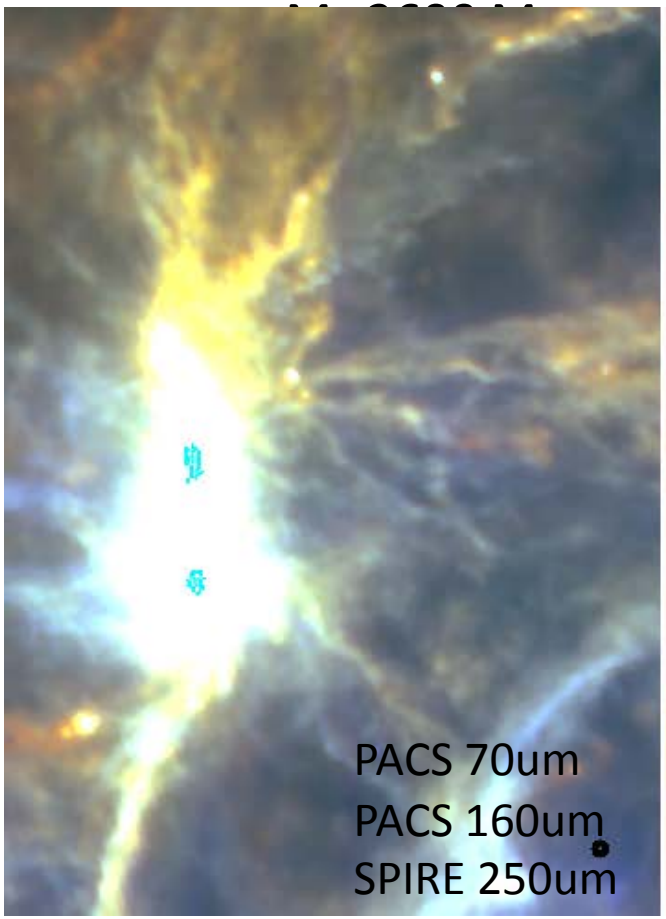

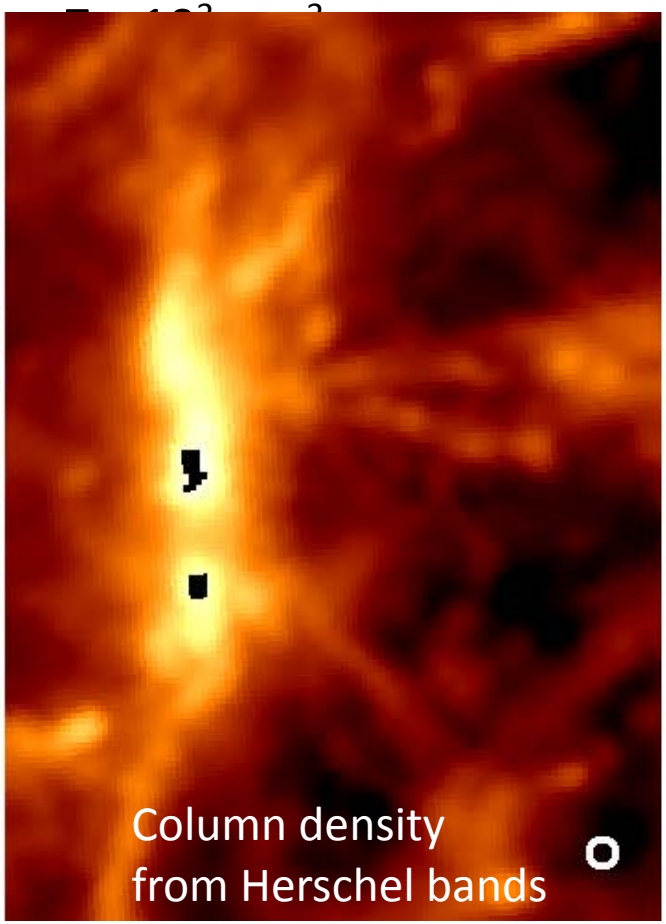

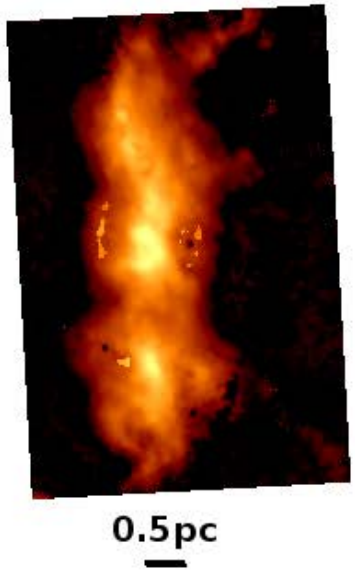

Column density from Herschel + SHARCII + MAMBO

Prospects for CCAT

- Column density information on 0.1pc scale out to 3kpc required to constrain:
  - massive dense core envelope structure
  - properties of subfilaments: possible remains of accretion flows into massive filaments/“ridges”
- Velocity information for subfilaments