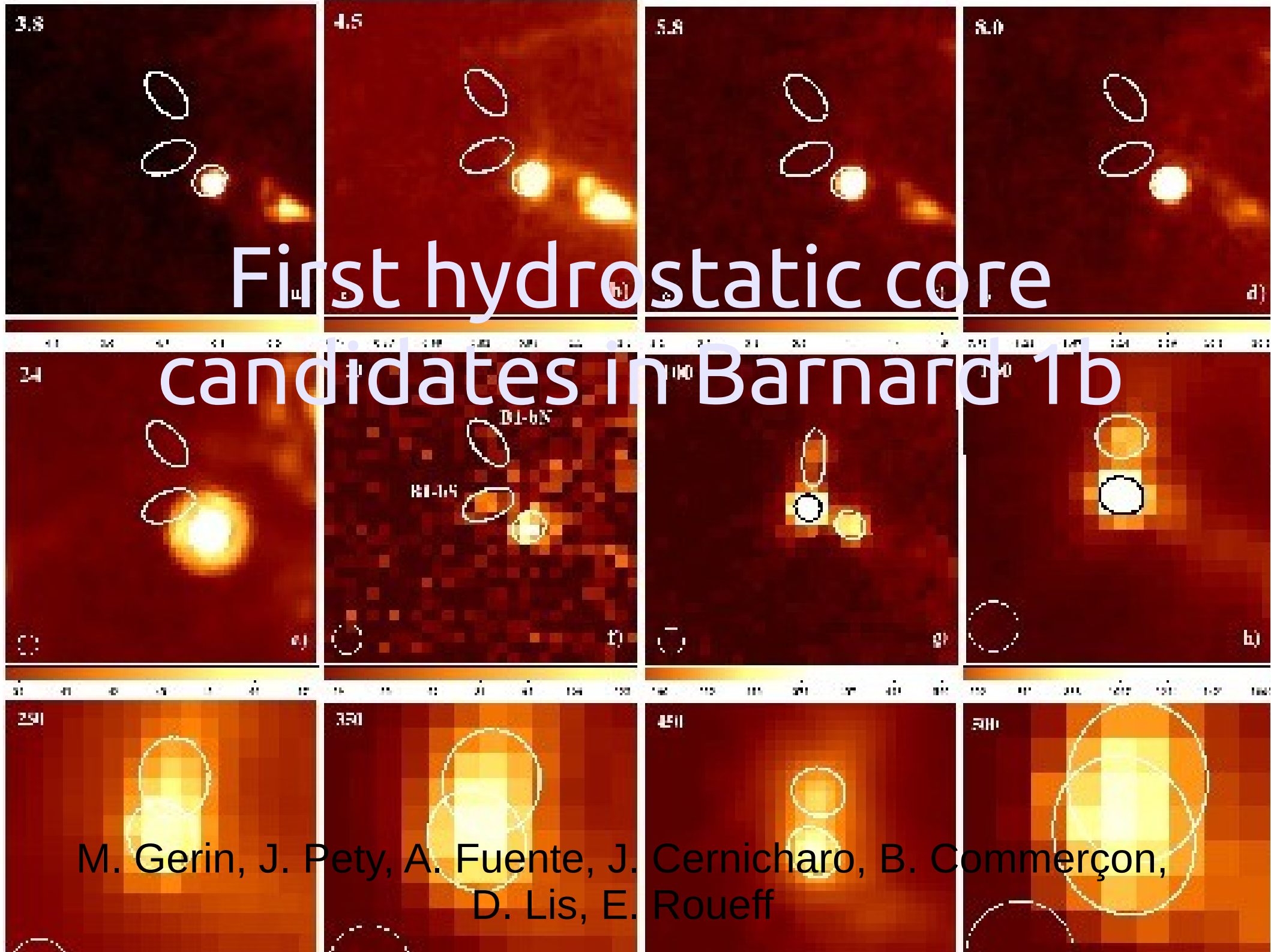
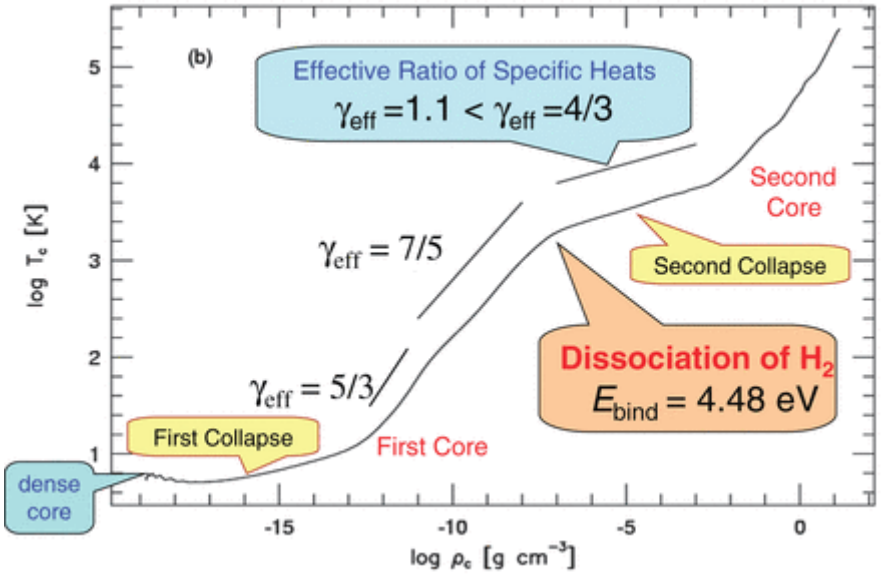
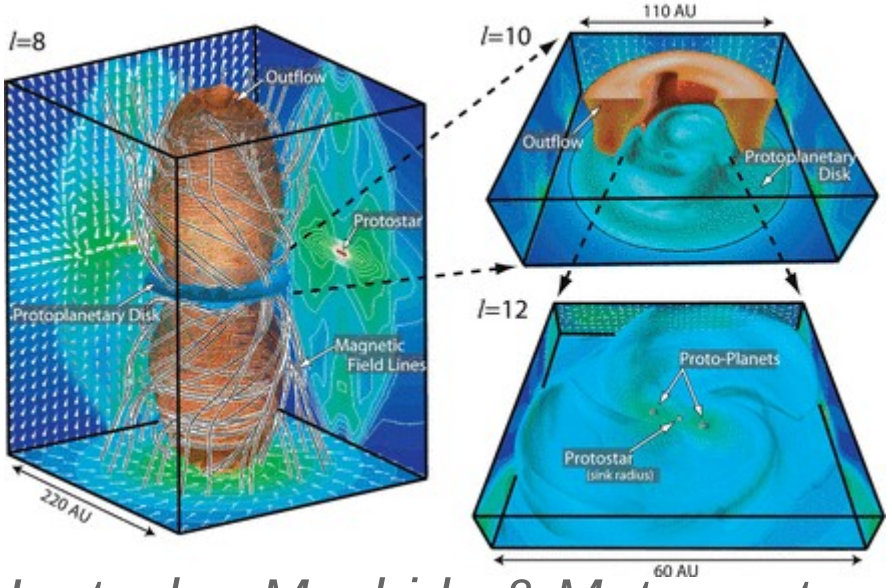


First hydrostatic core candidates in Barnard 1b

M. Gerin, J. Pety, A. Fuente, J. Cernicharo, B. Commerçon, D. Lis, E. Roueff



Masunaga & Inutsuka
2000 ApJ 531, 350



Inutsuka, Machida & Matsumoto
2010 ApJ 718, L58

Collapse

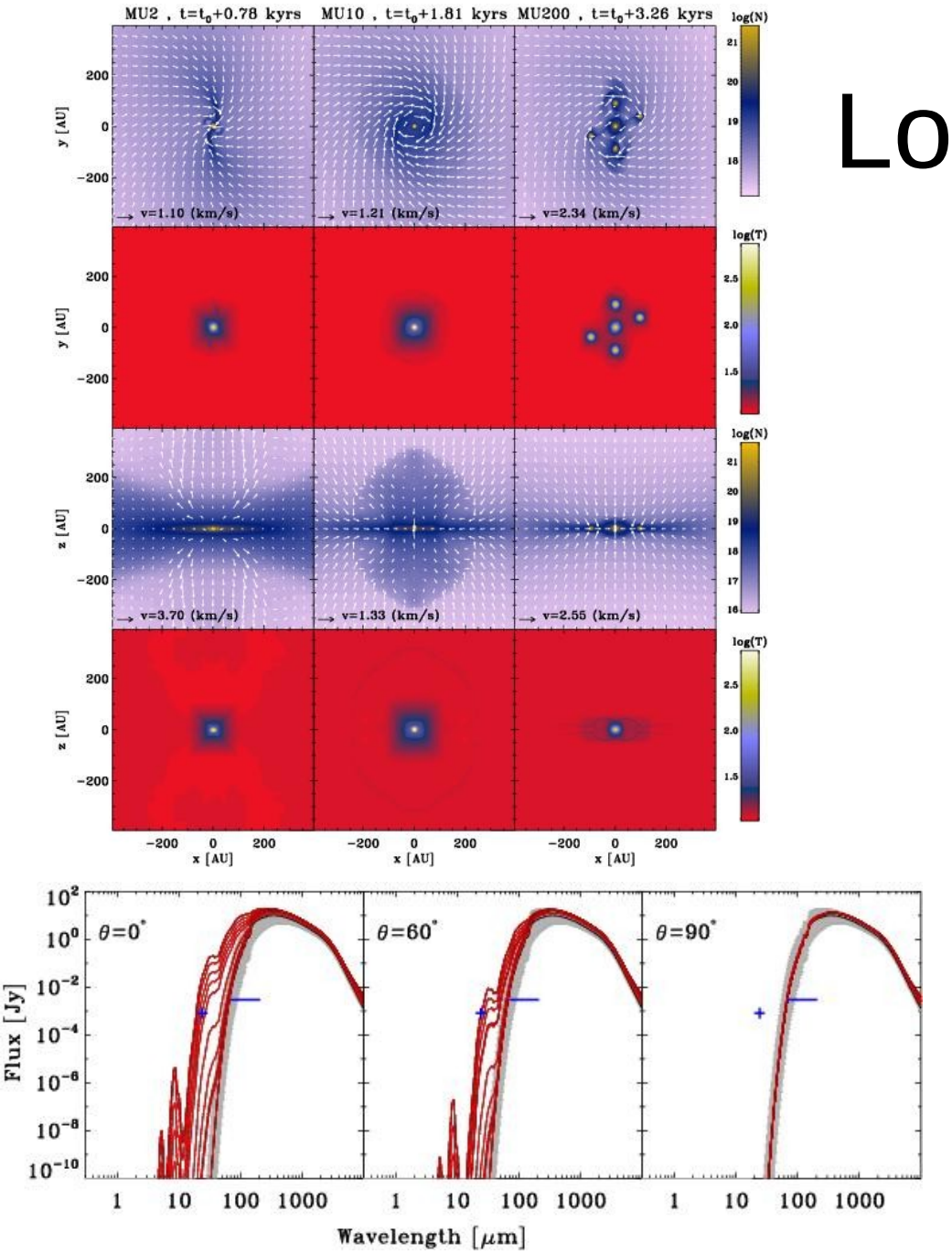
Pre-stellar core ~ isothermal sphere

1st Collapse
First HydroStatic Core (FHSC)
(500 – 10^3 yrs)

2nd Collapse & H_2 dissociation
2nd hydrostatic core &
(few days)

Coupling rotation, collapse with a magnetic field
→ slow outflows at the FHSC stage
→ jets at the 2nd core stage

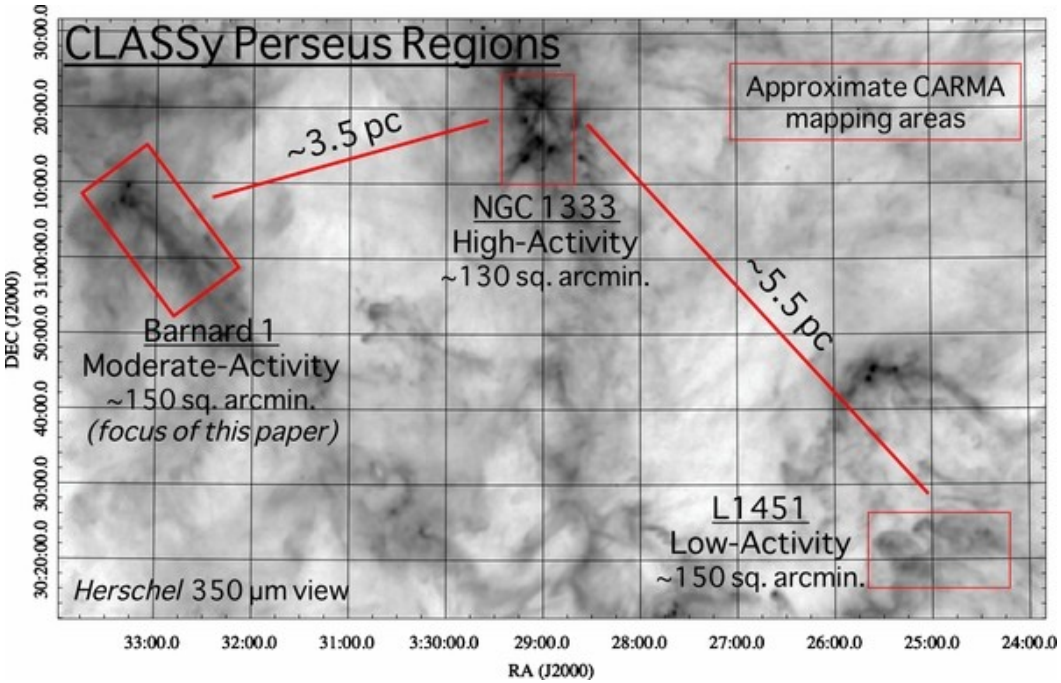
Looking for 1st cores

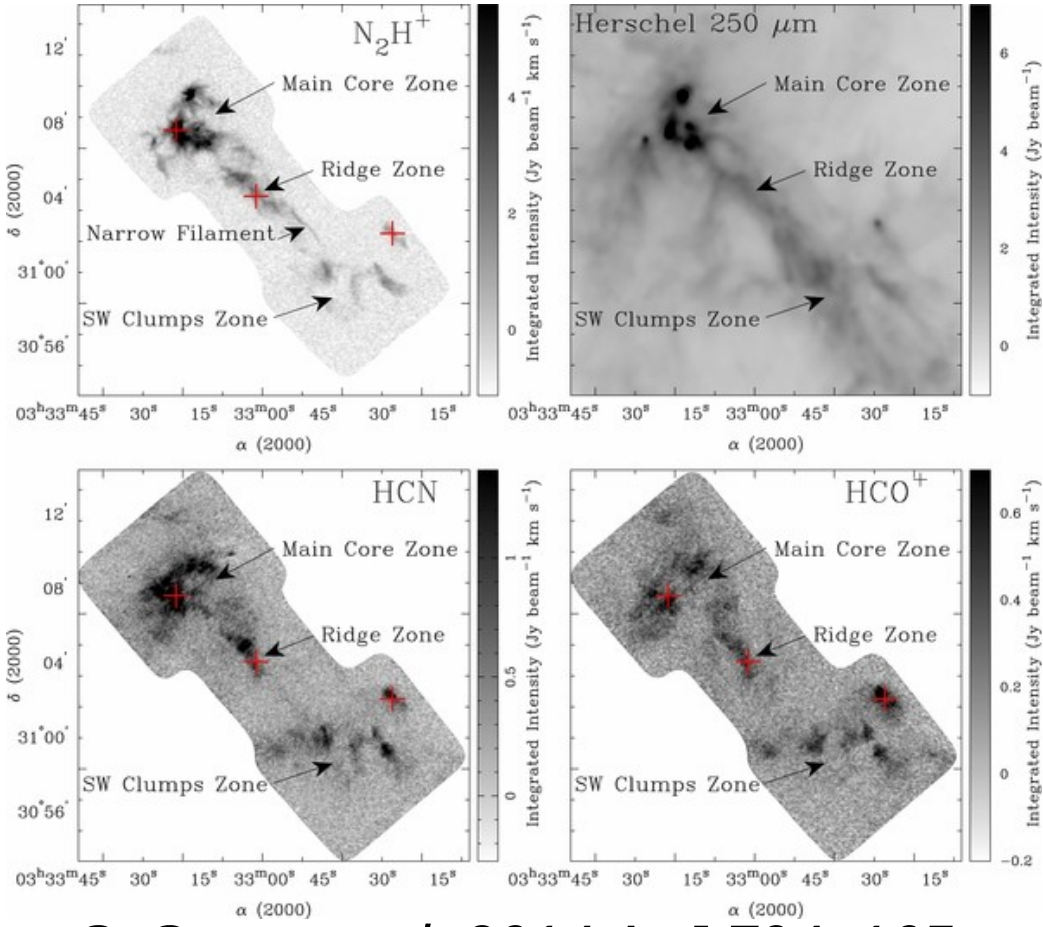


Commerçon et al. 2012 A&A

- Essential step in the star formation process
- Short-lived stage → rare objects
- MHD simulations + Radiative transfer → predictions of the Spectral Energy Distribution (SED) and of the emerging continuum & line radiation
- Compact object with “cold” SED
- Slow outflows

Barnard 1

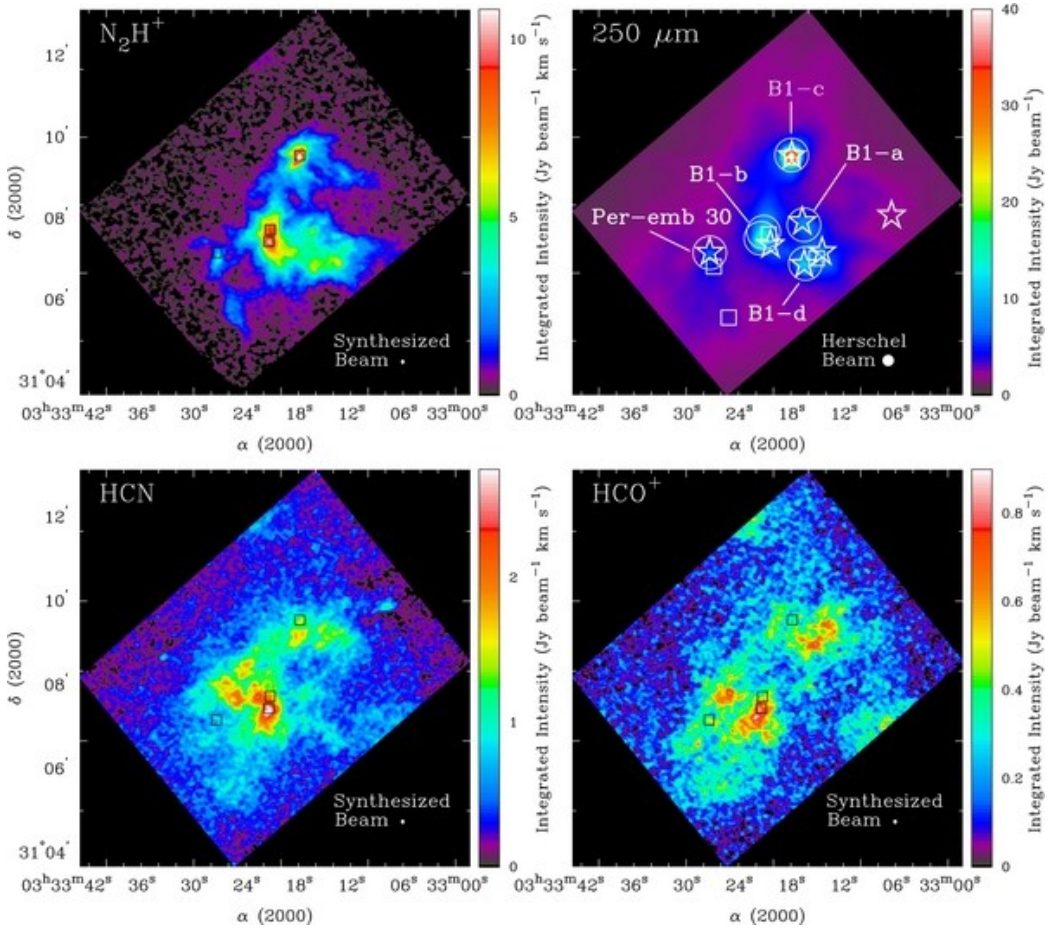




S. Storm et al. 2014 ApJ 794, 165

- A moderate activity star forming region in Perseus (230 pc, 1” = 230 AU)
- A main region with large column densities and several YSOs and a long “tail”

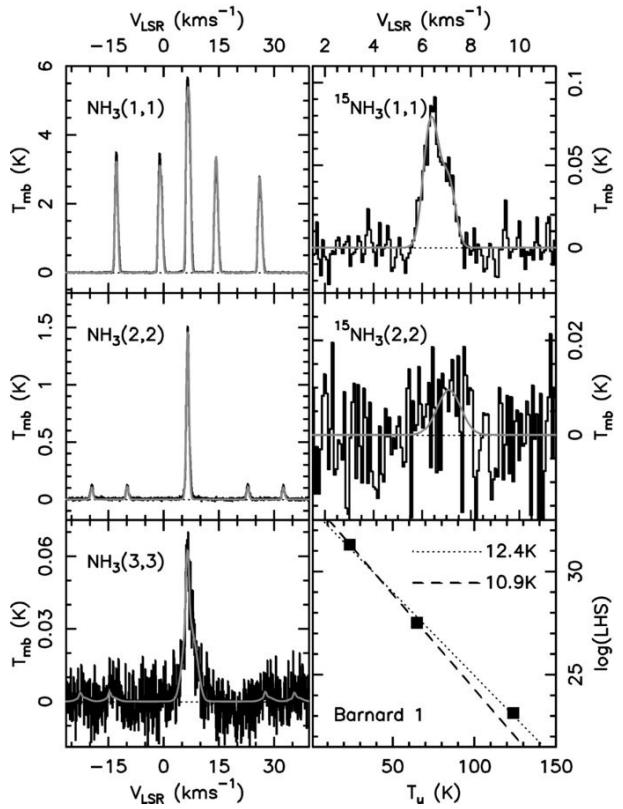
Barnard 1 – Main core



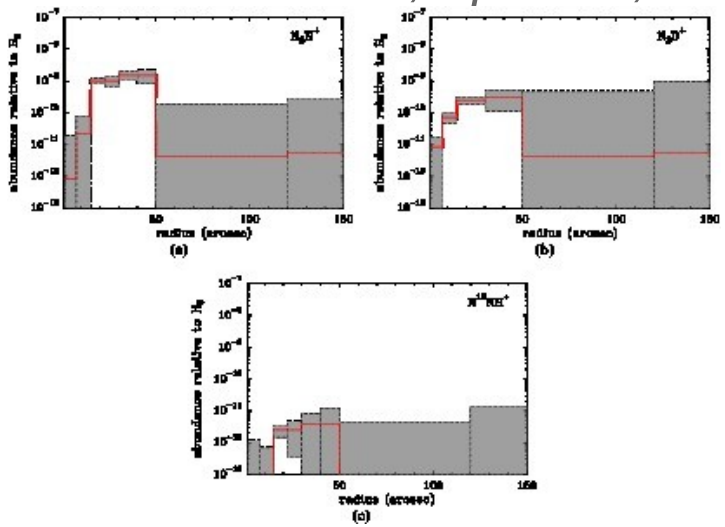
S. Storm et al. 2014 ApJ 794, 165

4 dust continuum peaks →
4 dense cores with $N(H_2) > 10^{23}$ cm^{-2}
Embedded star formation (IR source detected by *Spitzer*)
B1a → YSO
B1b → ?
B1c → YSO
B1d → YSO

Barnard 1b : a very special dense core

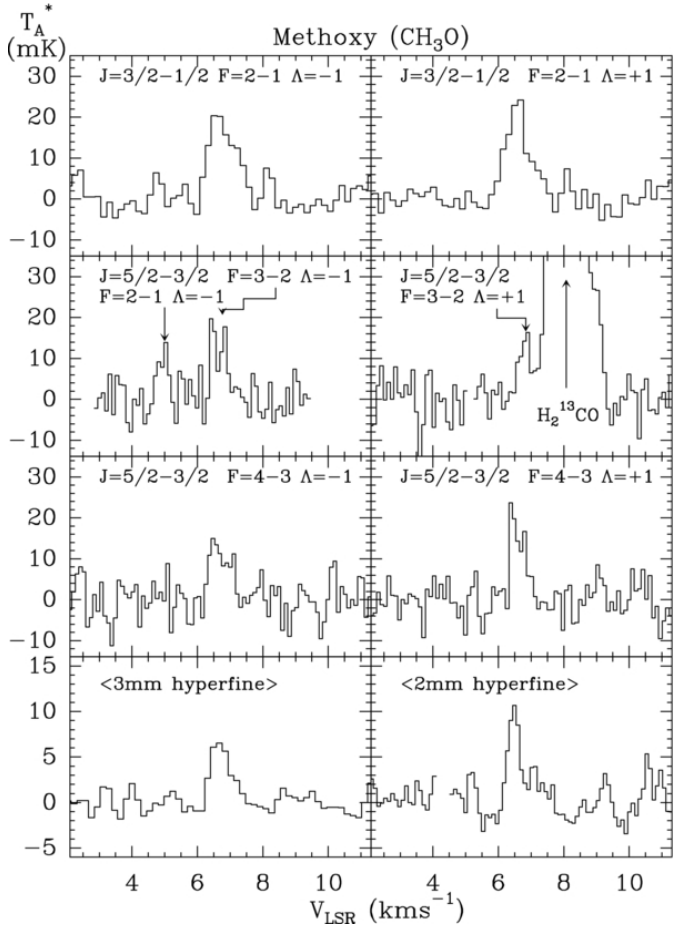


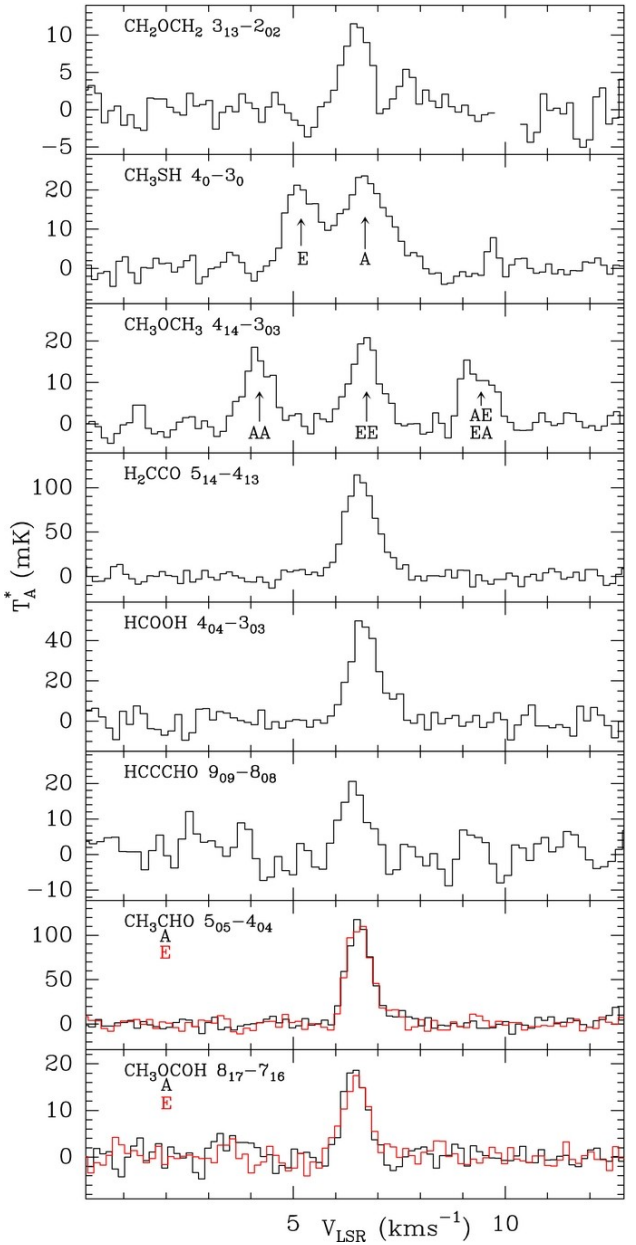
D. Lis et al. 2010, ApJ 710, L49



F. Daniel et al. 2013 A&A 560, A3

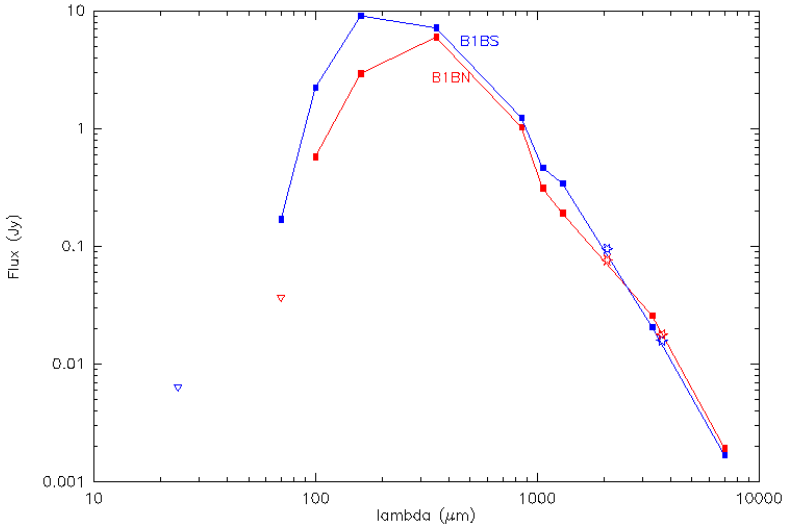
- High column density : $N(H_2) > 10^{23}$ cm^{-2}
- High densities $n(H_2) > 10^5$ cm^{-3}
- Cold gas T ~ 12K
- Large column densities of singly and multiply deuterated species : ND_3, $^{15}NH_2D$, D_2S, D_2CS, … (Roueff et al., Marcelino et al., Gerin et al.,)
- Depletions in the densest regions (N_2H^+, NH_3) (Daniel et al.)
- Detection of organic species CH_3O, HCOOH, CH_3SH, HCCCHO, CH_3CHO, ... *(Cernicharo et al. 2012 ApJ 759, L43)*
- Two far infrared / submillimeter compact sources B1b-N & B1b-S and one IR source B1b-W

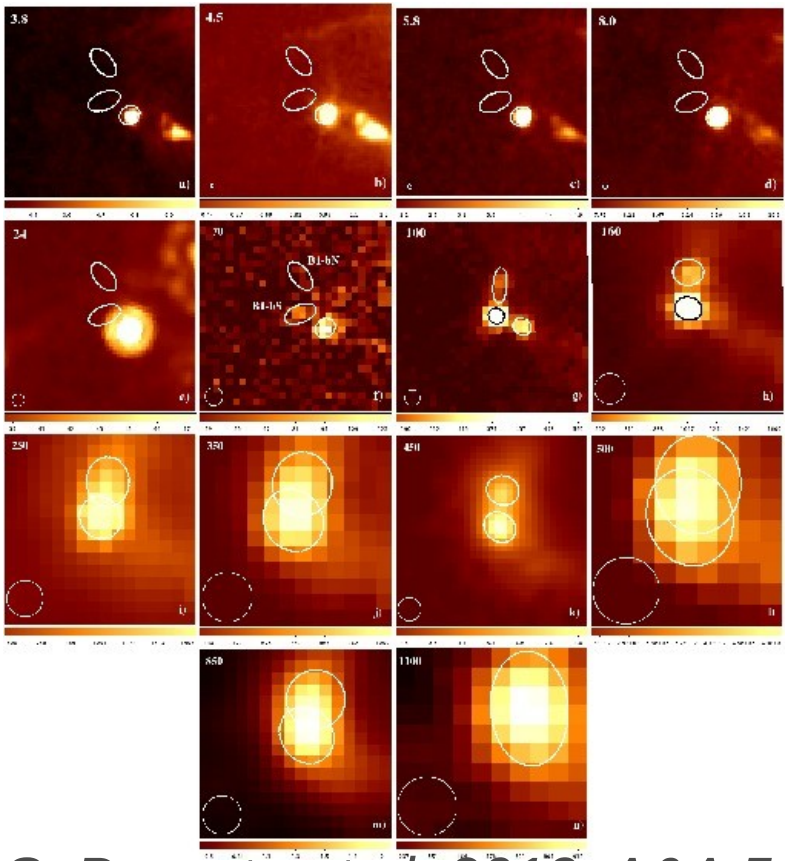


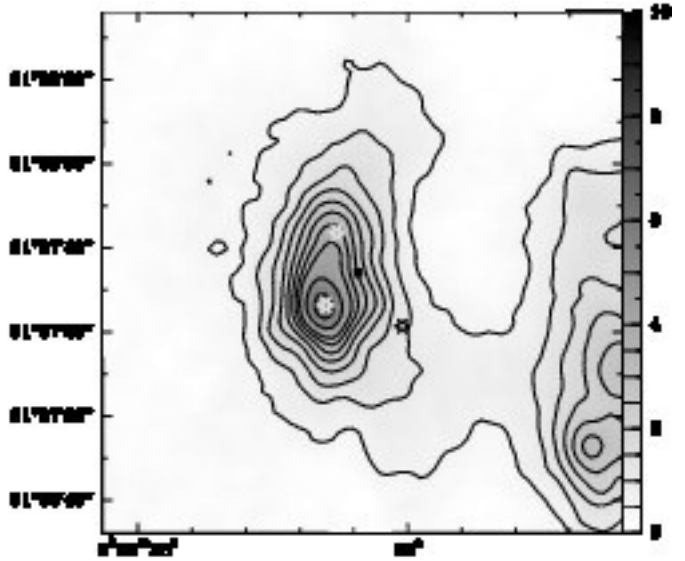


Cernicharo et al. 2012 ApJ 759, L43)

FHSC in Barnard 1b







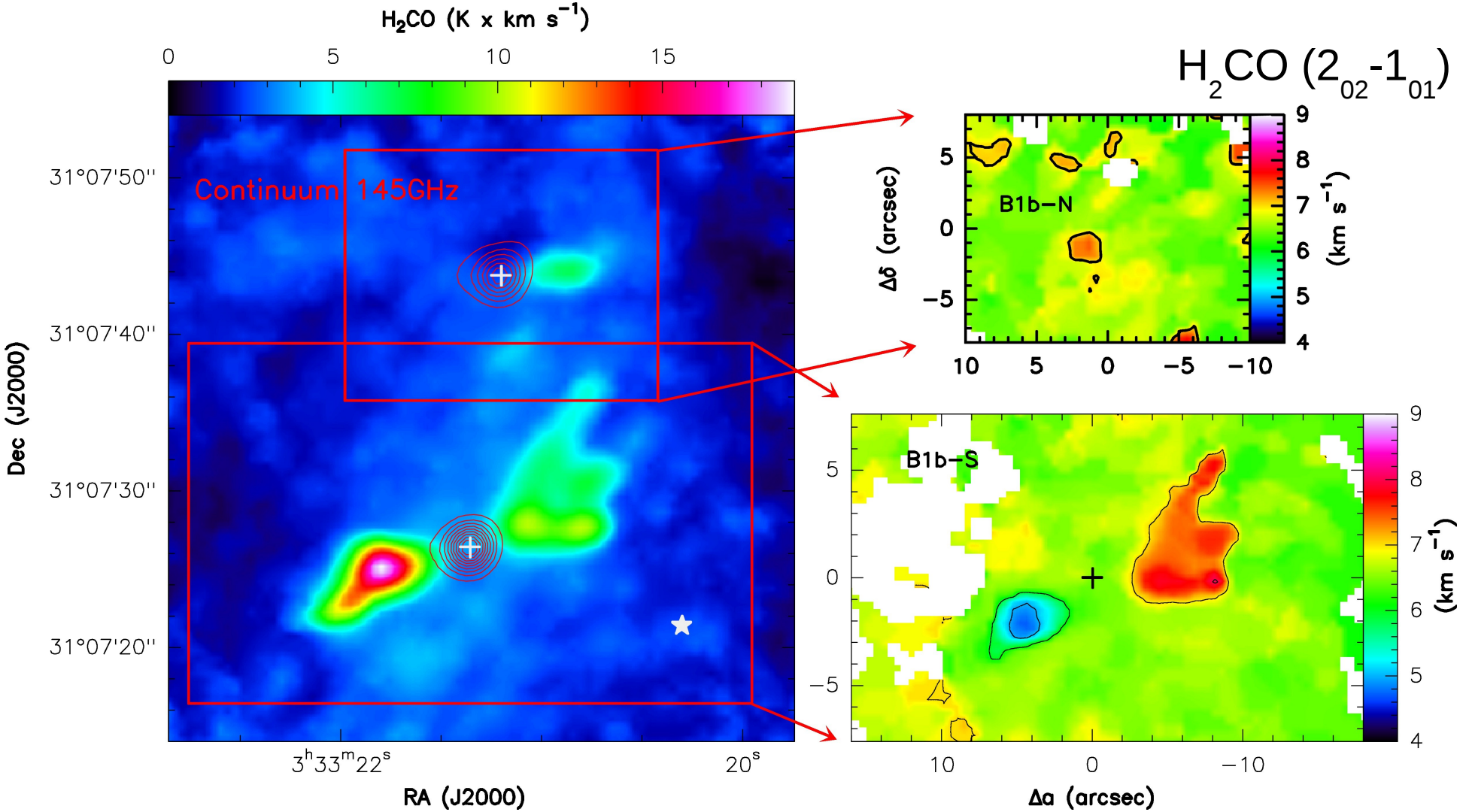
350 μm

- 2 compact sources B1b-N and B1b-S with “cold” SED → FHSC candidates

- Highly embedded YSO detected by Spitzer B1b-W

S. Pezzuto et al. 2012, A&A 547, A54

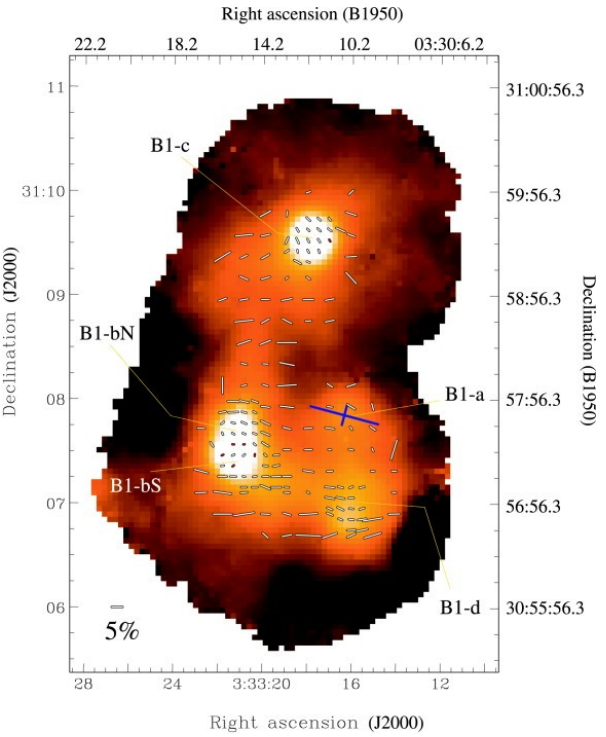
PdBI Observations



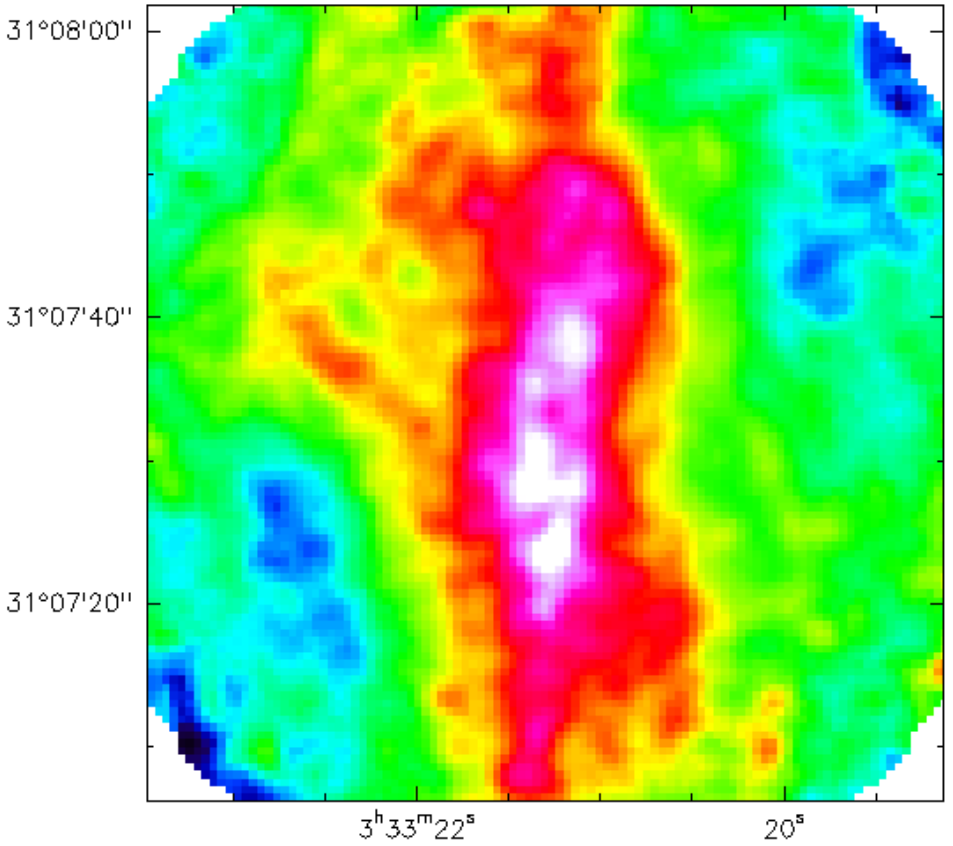
7-field mosaic in C+D configurations at 145GHz + IRAM-30m short spacings

Beam : 2.2 x 2.3” (500 AU) PA = 108°

H_2CO (2_{02}-1_{01}) ; CH_3OH (3_K - 2_K) ; c-C_3H_2 (3_{12} - 2_{21}) ; DCO^+(2 - 1) ; DCN (2 - 1) ; Continuum



B. Matthews et al.,



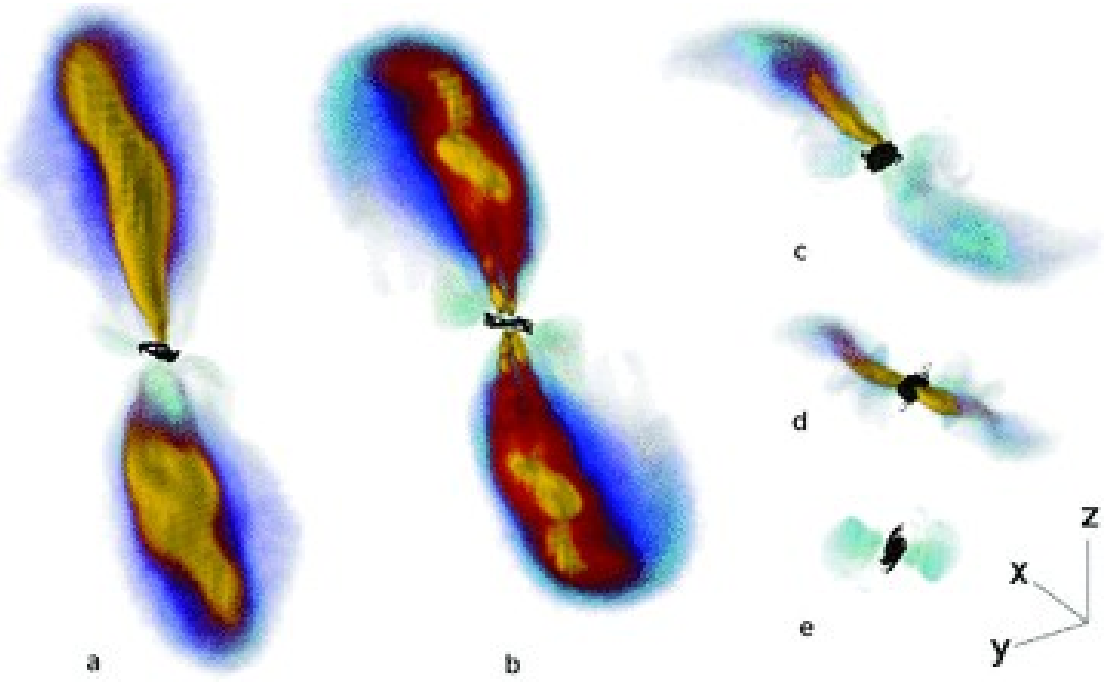
DCO^+

- Strong emission in the dense N-S ridge
- // projected direction magnetic field
- Association with CH_3OH minimum
- Local DCO^+ minimum at the FHSC positions
- Infall signatures in the line profile

Analysis

- Each compact source is associated with an outflow with moderate velocities : 5 – 7 km/s and small sizes 500 – 2000 UA
- Short dynamical time scales 10^3 – $5x10^3$ yrs
- Intensity and velocity structures down to the resolution in the outflows
- The outflows are not aligned with the direction of the magnetic field
- B1b - S : outflow inclination constrained from the opening angle : $23° < i < 67°$
- B1b – S : significant angle between outflow axis and magnetic field $30° < \beta < 67°$
- B1b – N : $\beta > 36°$ and likely larger than for B1b - S

Collapse with an angle between rotation and magnetic field



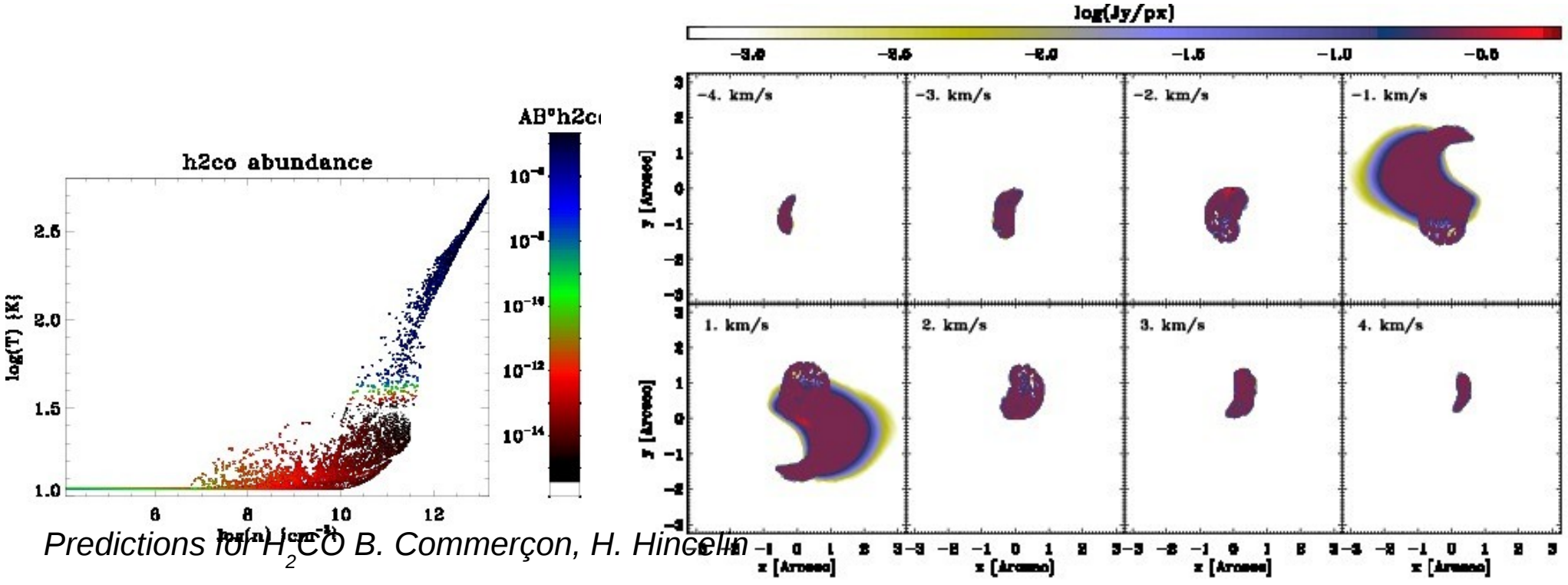
- Same age, different angles
  a = 20°, b = 45°, c= 70°, d = 80°, e = 90°
  (colors = speed)
- Strong asymmetries

- Observed structures consistent with simulations of inclined outflows

A. Ciardi, P. Hennebelle 2010 MNRAS 409 L39

Conclusions

- B1bN is a good candidate for a First Hydrostatic Core
- B1bS may be close to that stage
- The velocity field of the inner envelope is needed at higher angular resolution to compare with models



Predictions for H_2CO B. Commerçon, H. Hincelin