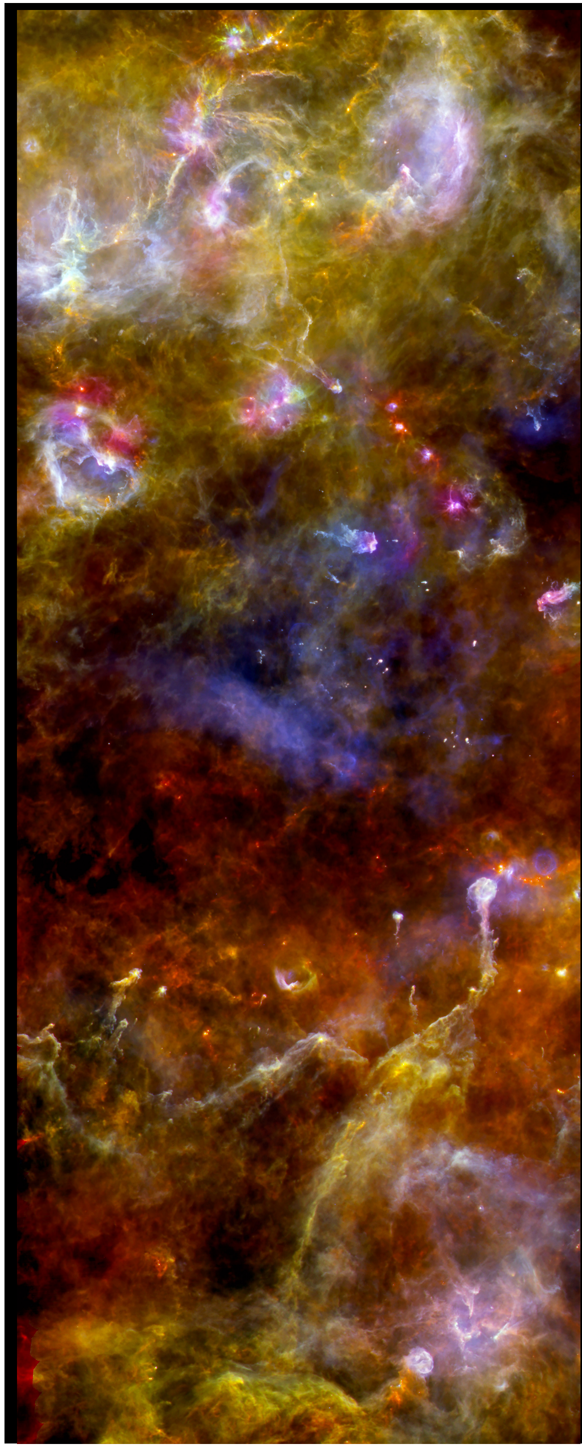
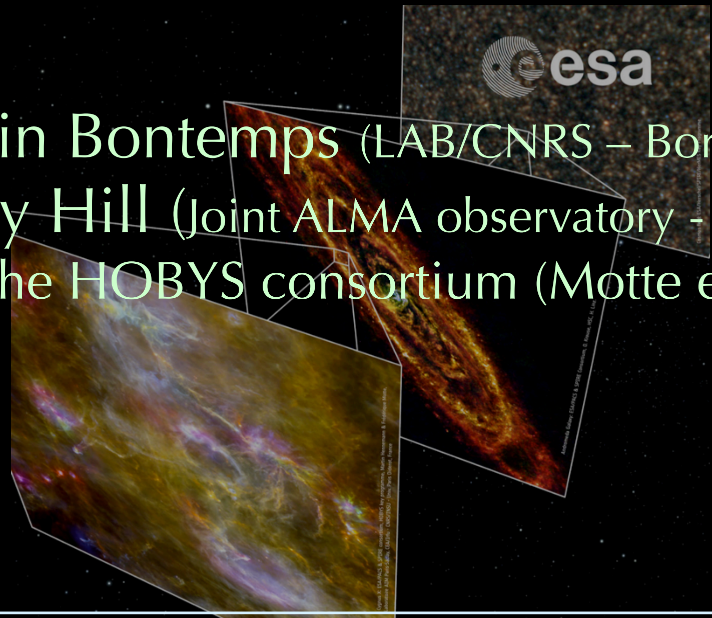


Cygnus- Herschel
HOBYS

70 - 500 μm

The role of Ridges in high mass star formation



Sylvain Bontemps (LAB/CNRS – Bordeaux)
Tracey Hill (Joint ALMA observatory - Chile)
and the HOBYS consortium (Motte et al.)

1. High-mass SF and filaments
2. Massive filaments or Ridges
3. Kinematics and large scale infall
4. Open issues

How high-mass stars form?

Theoretical views:

- Slow evolution of turbulence supported (massive) dense cores (McKee & Tan 2003; Krumholz & Mckee 2005; …).
- Fast dynamical evolution and turbulent support (Padoan & Nordlund 02; Hennebelle & Chabrier 08, 09): high-mass stars from large scale, low density regions (large M_{Jeans}).
- Fast gravo-turbulent low-mass fragmentation (~ t_{ff}) and competitive accretion in proto-clusters (Bate et al. 2003; Bonnell et al. 2003).

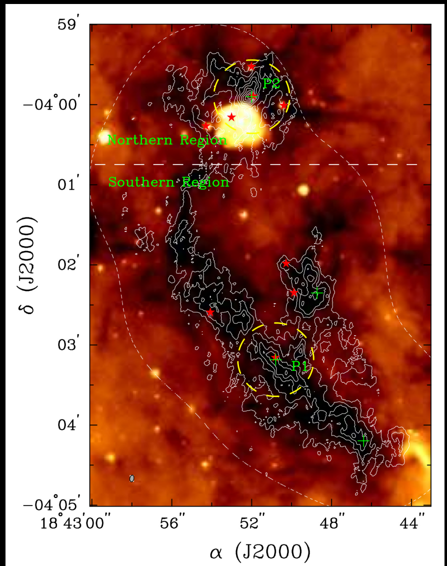
Surveys for high-mass protostars

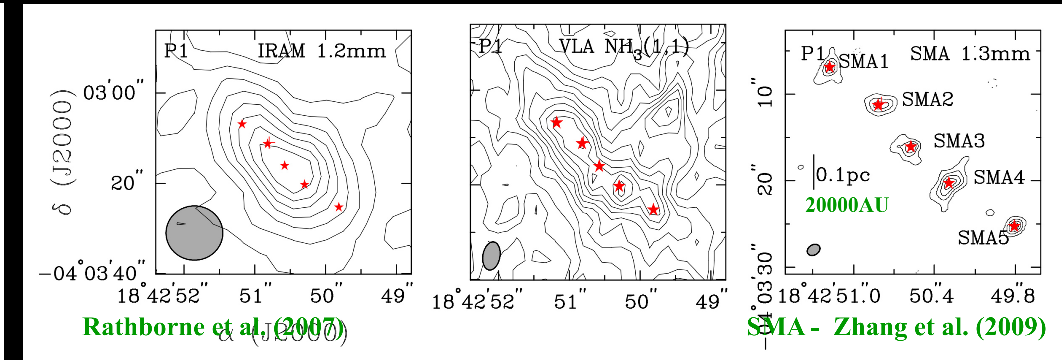
- IRAS: the ~ 2000 red, bright IRAS sources Wood & Churchwell (1989)
- Masers: samples of high-mass SFRs Molinari et al. (1996), Plume et al. (1997), all refs in Kurtz et al. (2000)
- pre-UCHII regions: IRAS sources, no cm Sridharan, Beuther et al. (2002)
- MM continuum: IRAS samples Muller et al. (2002), Faundez et al. (2004), …
- IRDCs: not only high-mass Simon, Rathborne et al. (2006); Pillai et al. (2006); Peretto & Fuller (2009).
- MM complete imaging: W43, Cygnus X Motte et al. (2003, 2007)
- Galaxy-scale MM surveys: ATLASGAL Schuller et al. (2009), Csengeri et al. (2014) + Hi-GAL Molinari et al. (2010), Elia et al. (2010)

Fragmentation in massive clumps/cores

High-spatial resolution observations:

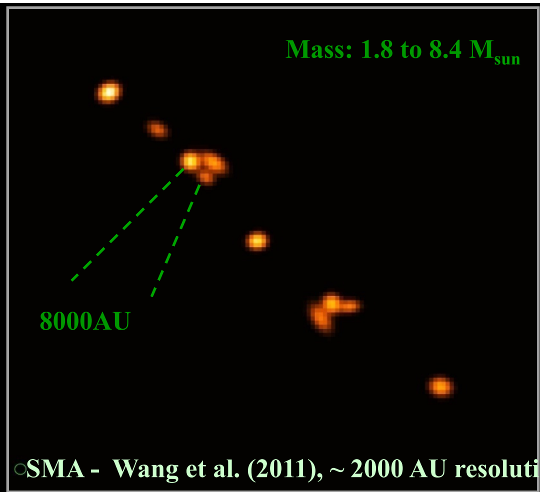
- Beuther et al. (2007); Leurini et al. (2007); Brogan et al. (2010); Rathborne et al. (2007, 2009), Zhang et al. (2009), Bontemps et al. (2010); Wang et al. (2011); Palau et al. (2014); Beuther et al. (2013, 2014).

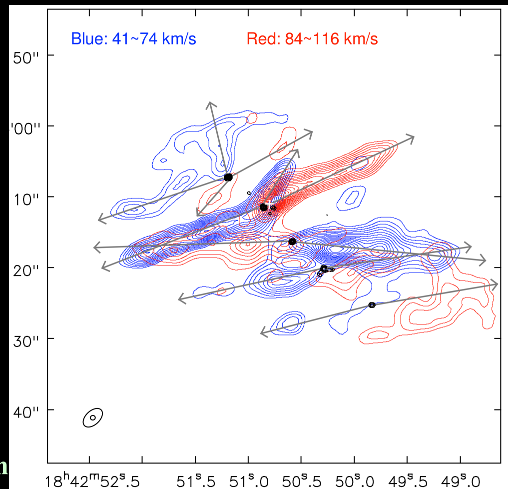




Need to reach

~ 2000 AU scale





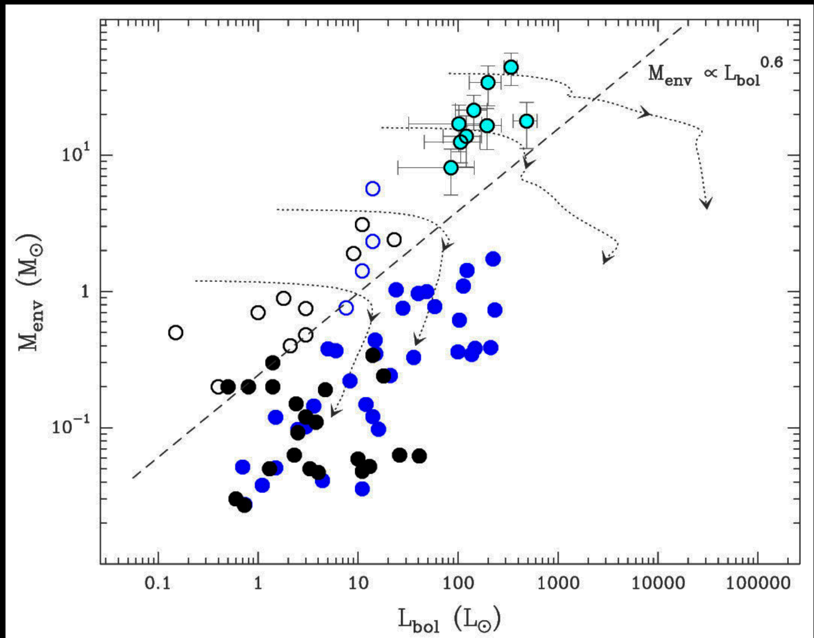
High-mass Class 0 and Super-Jeans cores

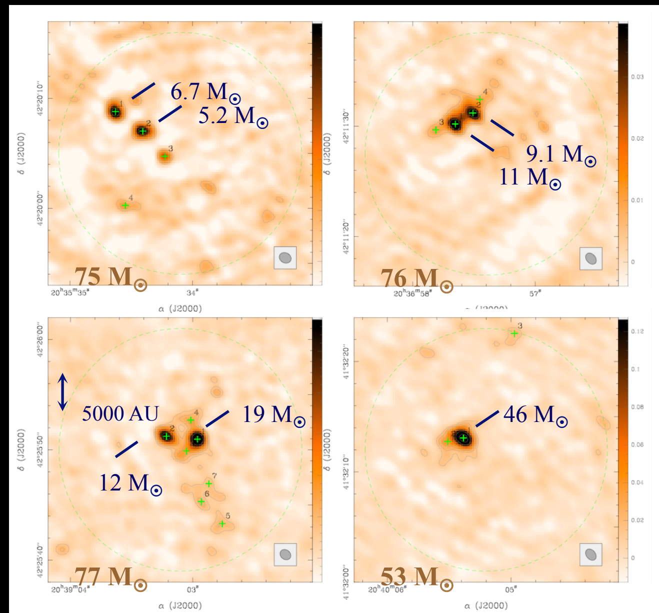
Local (thermal) Jeans Mass of < 1 M_{sun}.

How can we get such massive cores?

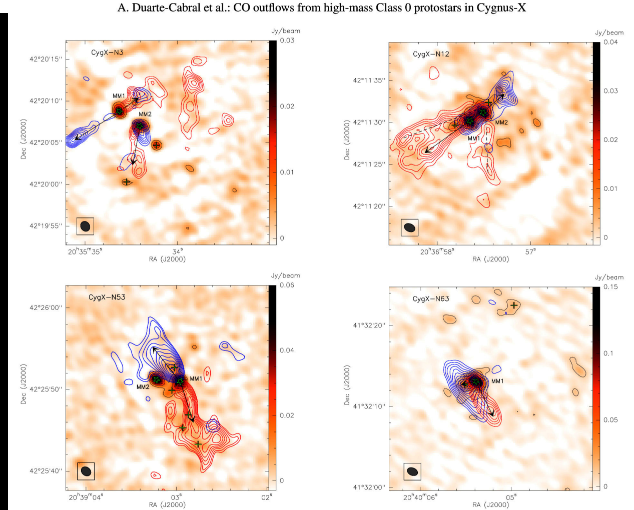
Here we have cores up to ~50 x Jeans Masses.

They collapse and actually form high-mass stars.

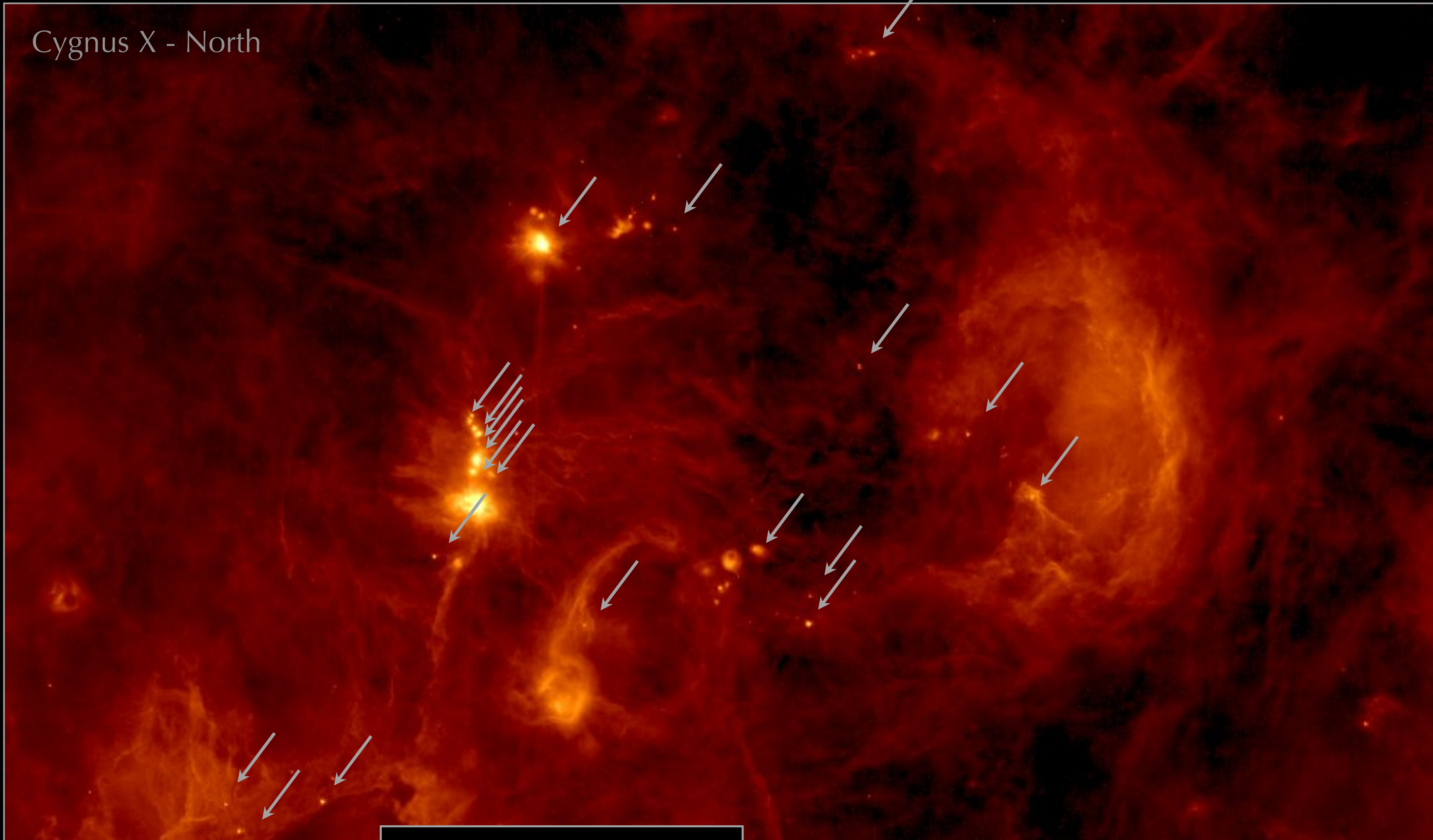




A. Duarte-Cabral et al.: CO outflows from high-mass Class 0 protostars in Cygnus-X



Short statistical lifetime for massive clumps



HOBYS - SPIRE consortium

Motte et al. (2007)

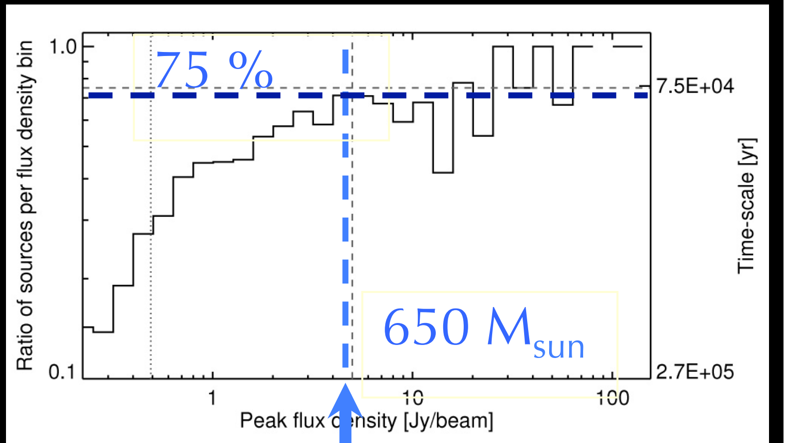
Hennemann et al. in prep

Herschel/SPIRE 250 µm

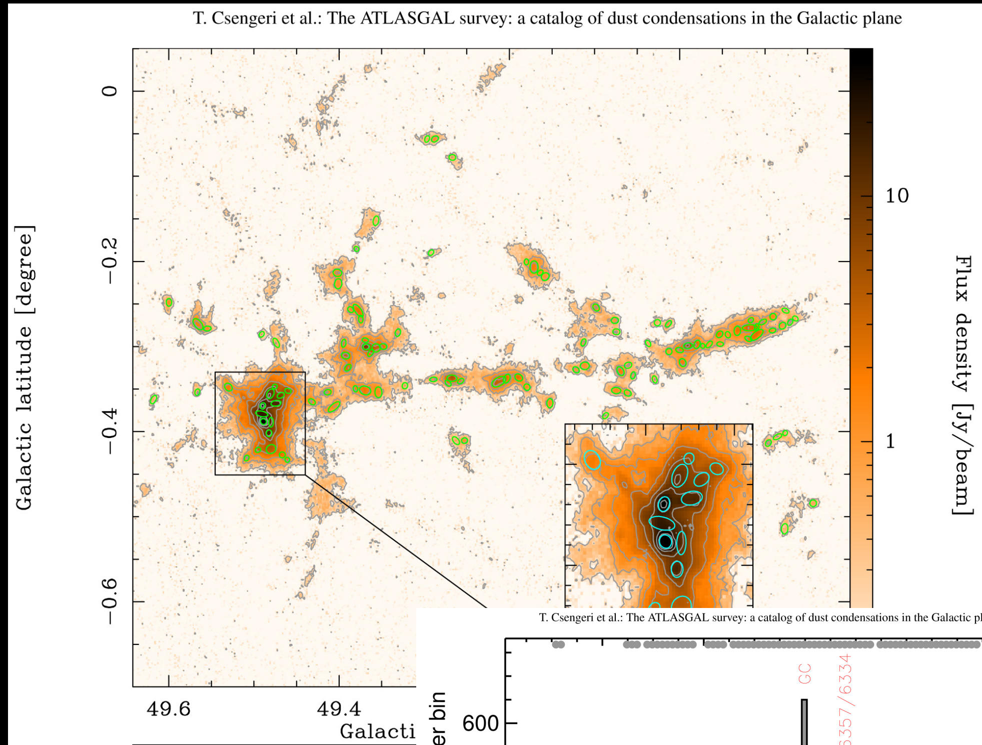
Herschel/PACS 70 µm

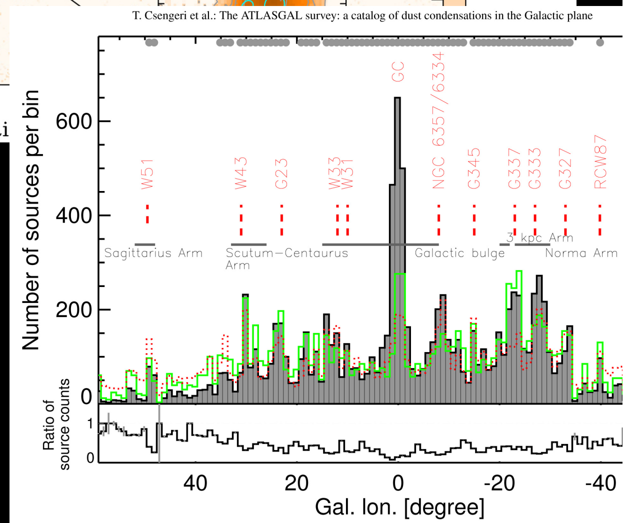
Galaxy-wide statistics on ~ 0.3 pc clumps

Fraction of clumps with HMSF (for more than ¼ of the Galaxy): 75 % at high mass



ATLASGAL - Csengeri et al. (2014)





- 7.5 10^4 yr for 0.3 pc leads to 4 km/s typical accretion speed.
- Formation of massive clumps is supersonic.

How high-mass stars form?

Observations:

- Super-Jeans cores exist and they form high-mass stars.
- Fast massive core formation.

Theoretical views:

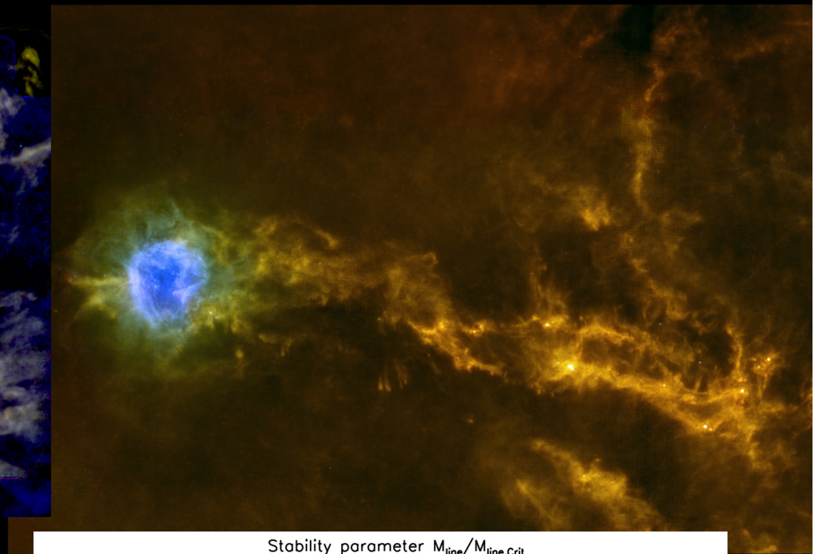
Large effective Jeans masses?

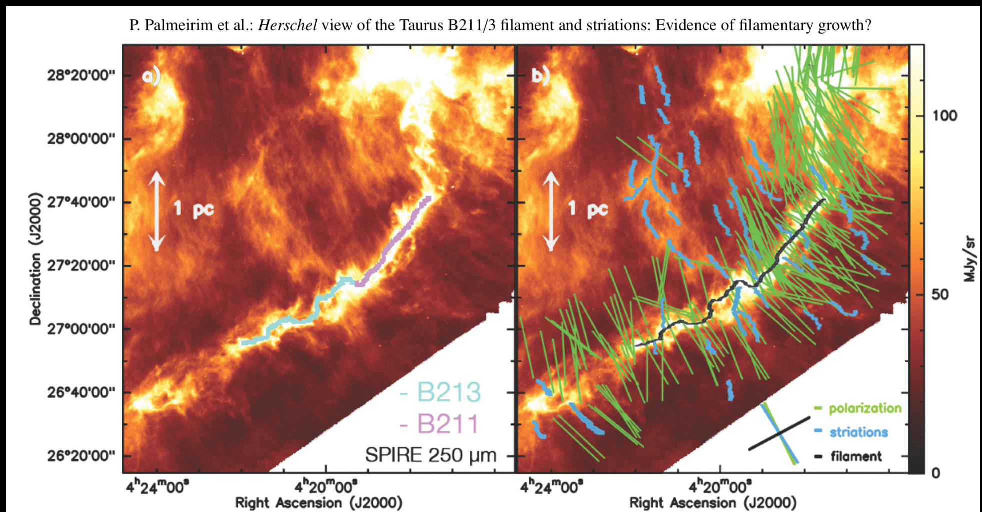
- To get $M_{Jeans} = 20\ M_{\odot}$ one needs T_{gas} ~ 200 K or Δv_{FWHM} ~ 3 km/s.

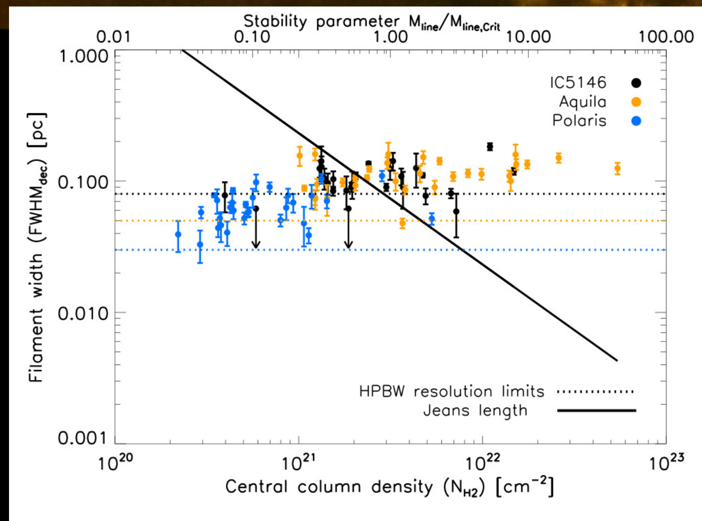
- Pre-stellar phase has to be dynamical (formed by supersonic motions).

- High-mass star formation requires “special conditions”.
- Dynamical, and large (effective?) Jeans conditions.

Filaments and low-mass star formation





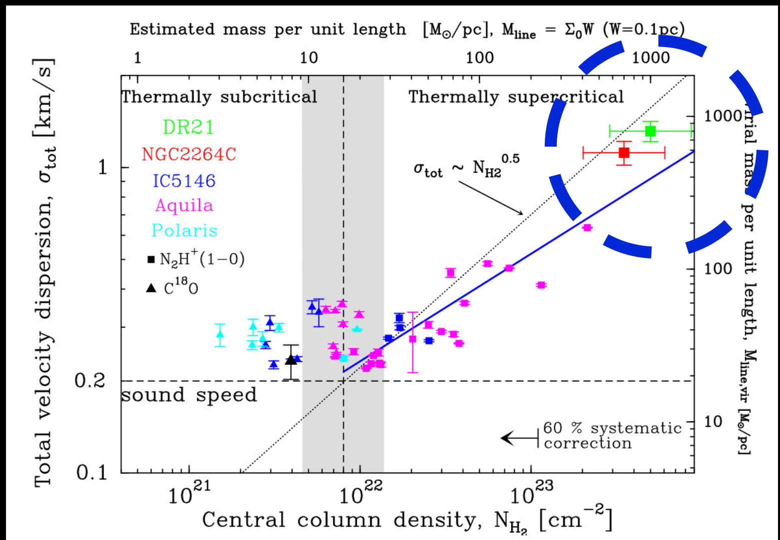


Palmeirim et al. (2013)

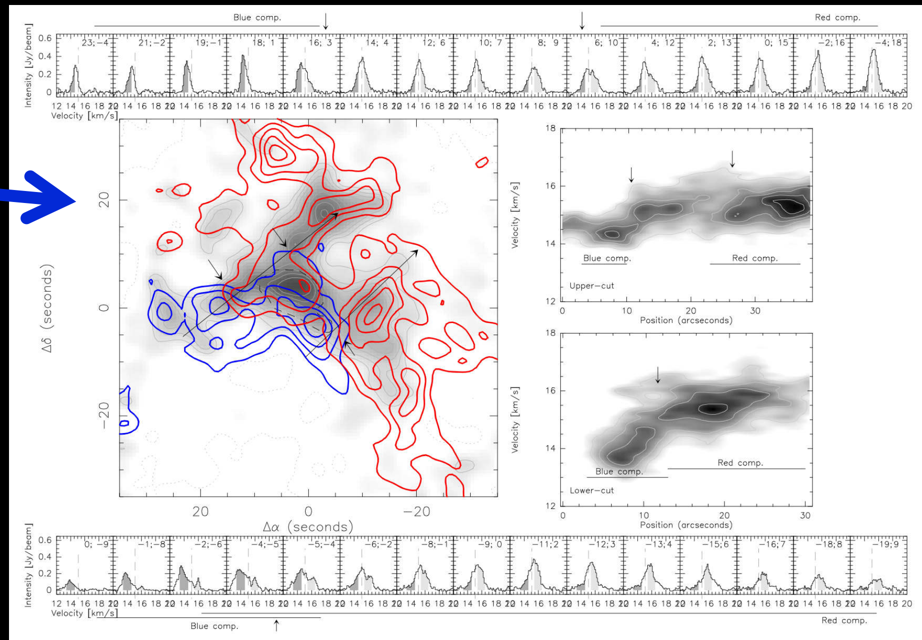
Arzoumanian et al. (2011)

What about high-mass star formation?

- Massive filaments with coalescence of cores.
- Cloud collisions to form massive networks of filaments?

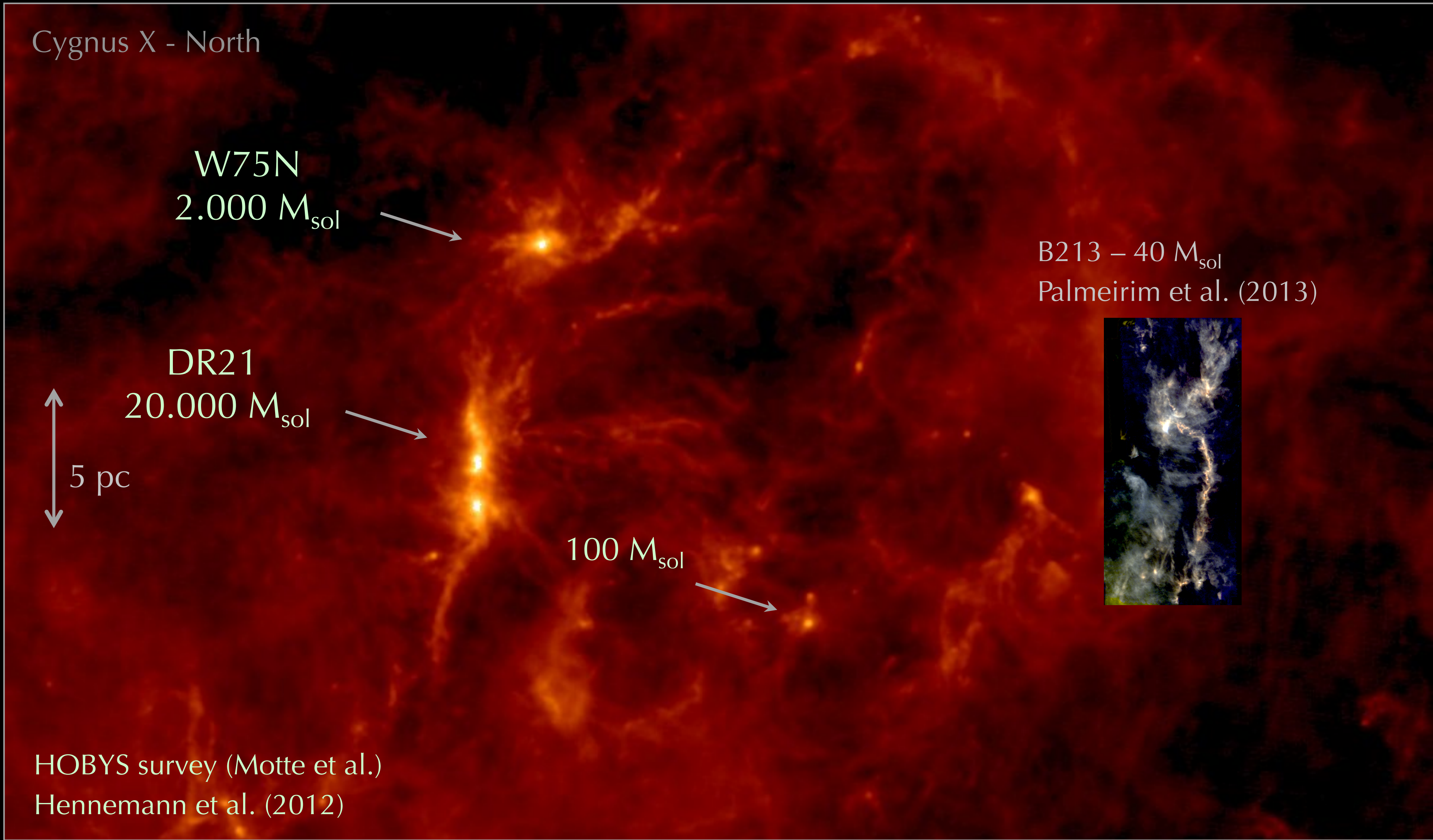


Arzoumanian et al. (2013)



- Velocity shears (Csengeri et al. 2011, A&A 527, 135).
- (small-scale) Flows, most probably convergent (e.g. Vazquez-Semadeni et al. 2009)

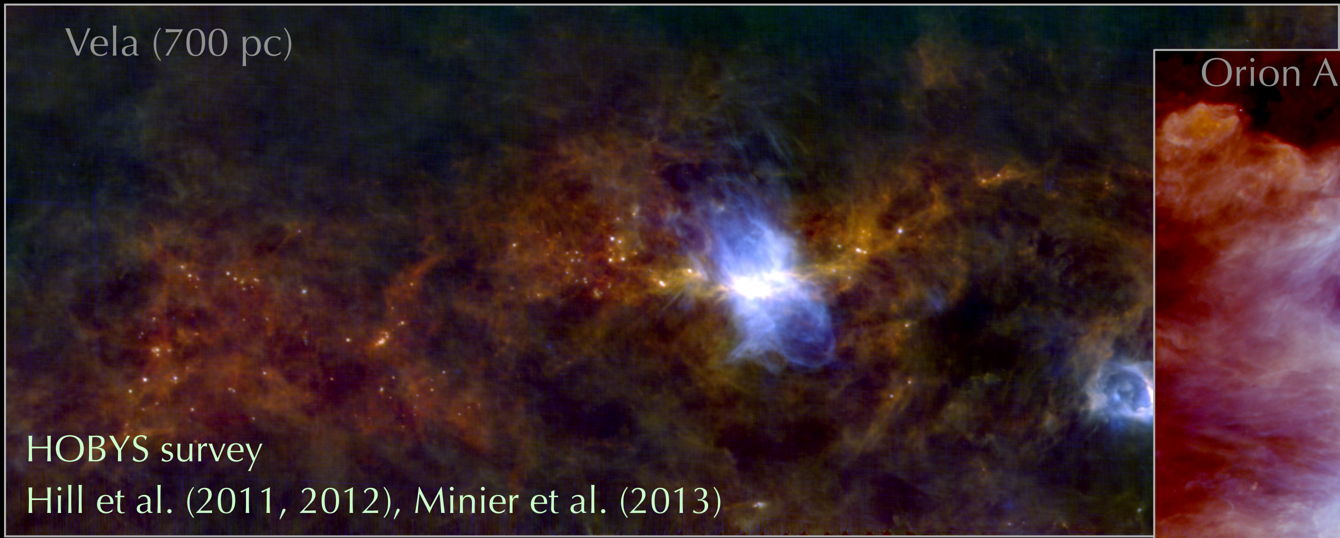
What about high-mass star formation?

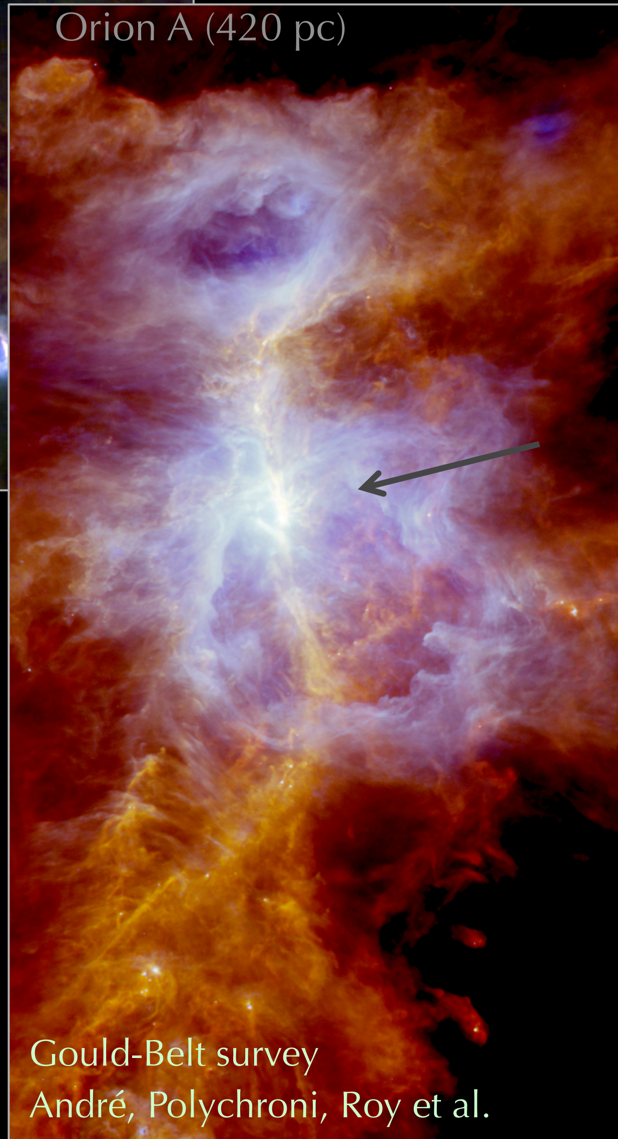


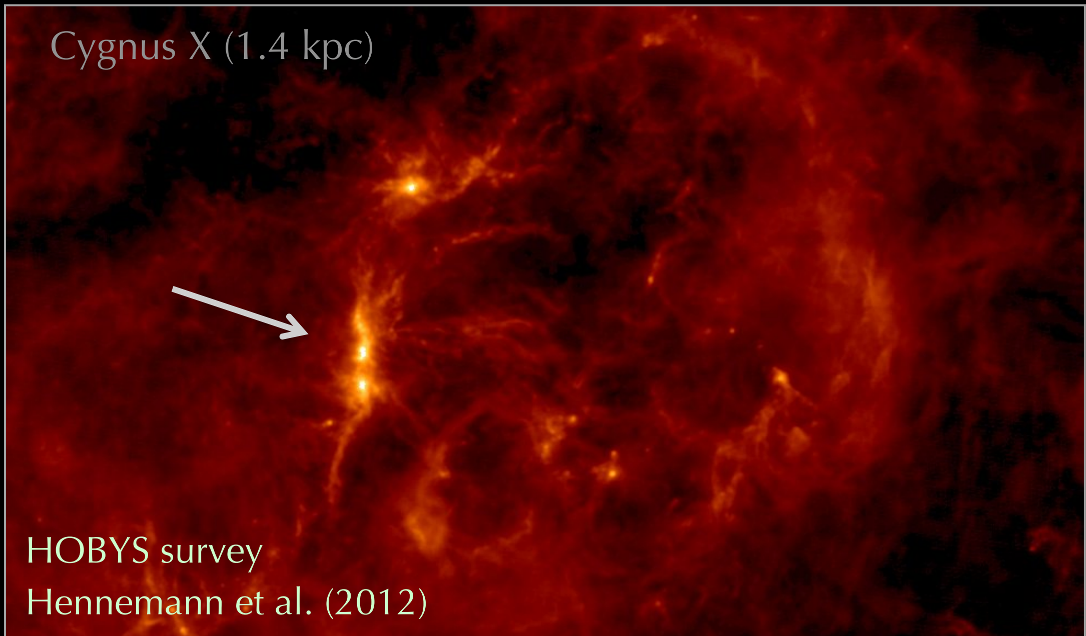
HOBYS - SPIRE consortium

Herschel/SPIRE 250 μm

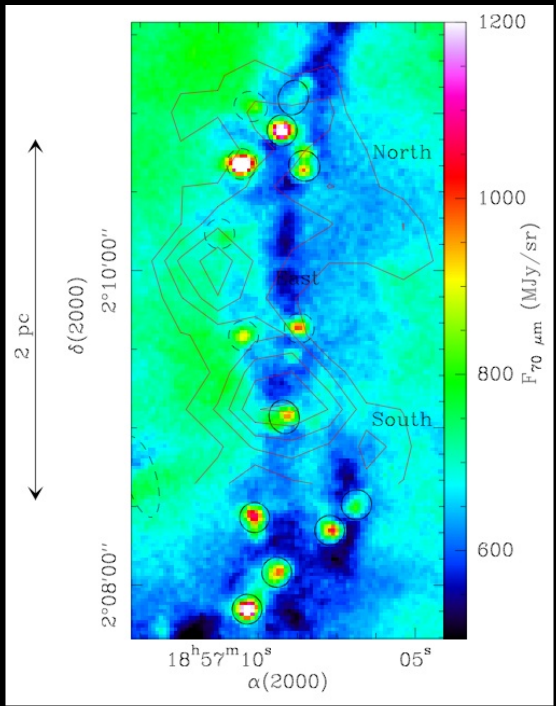
A number of ridges in nearby GMCs





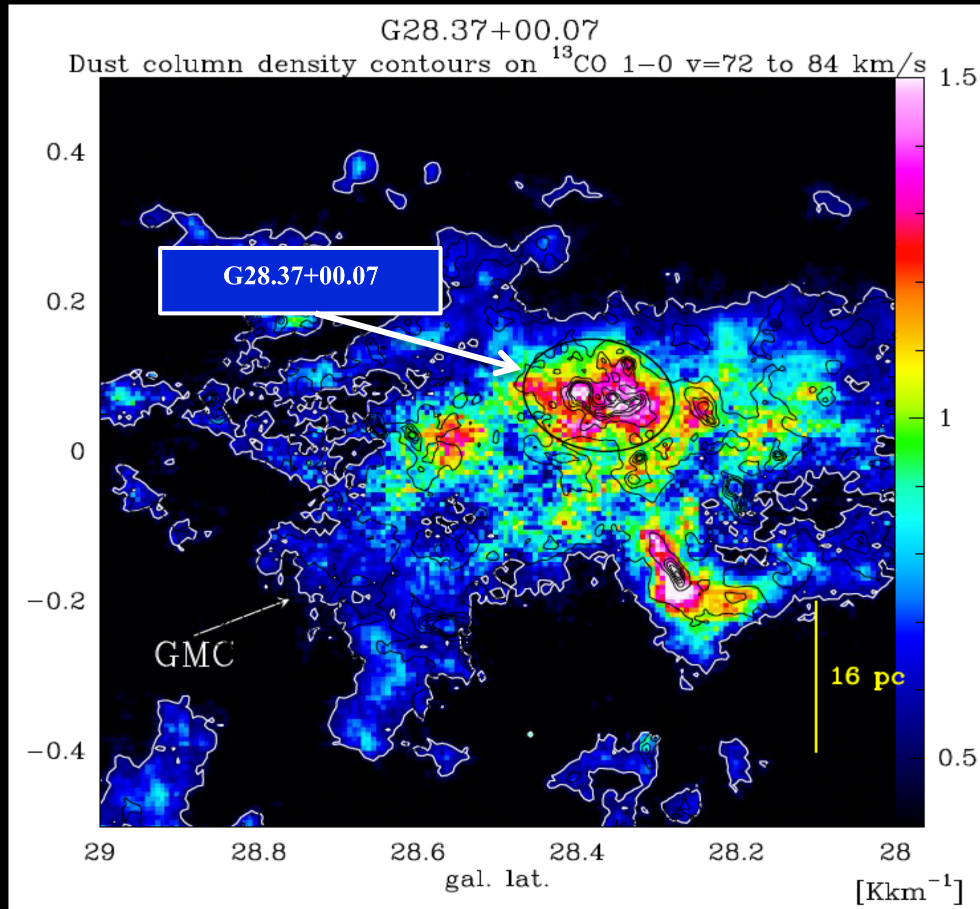


Some IRDCs are ridges in distant GMCs



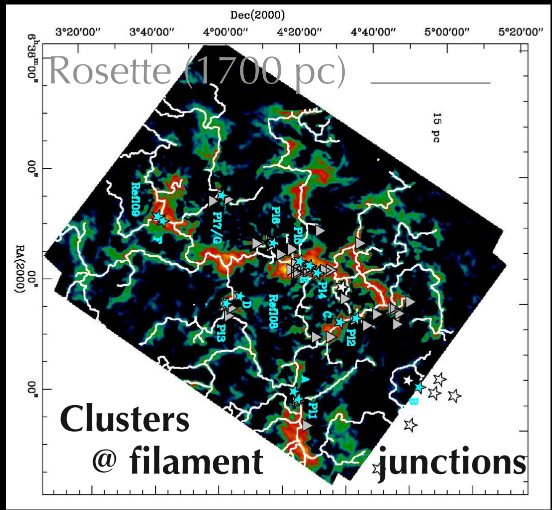
G35.39-0.33 (Nguyen-Luong et al. 2011), G32.03+0.05 (Battersby et al., 2014)

Teyssier et al. 2002; Simon et al. 2006; Kainulainen, Alves et al. 2011

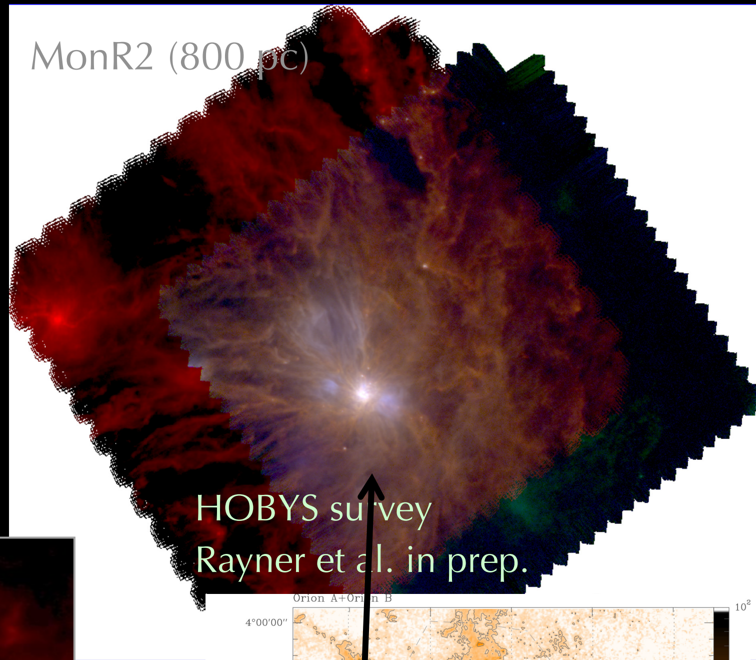


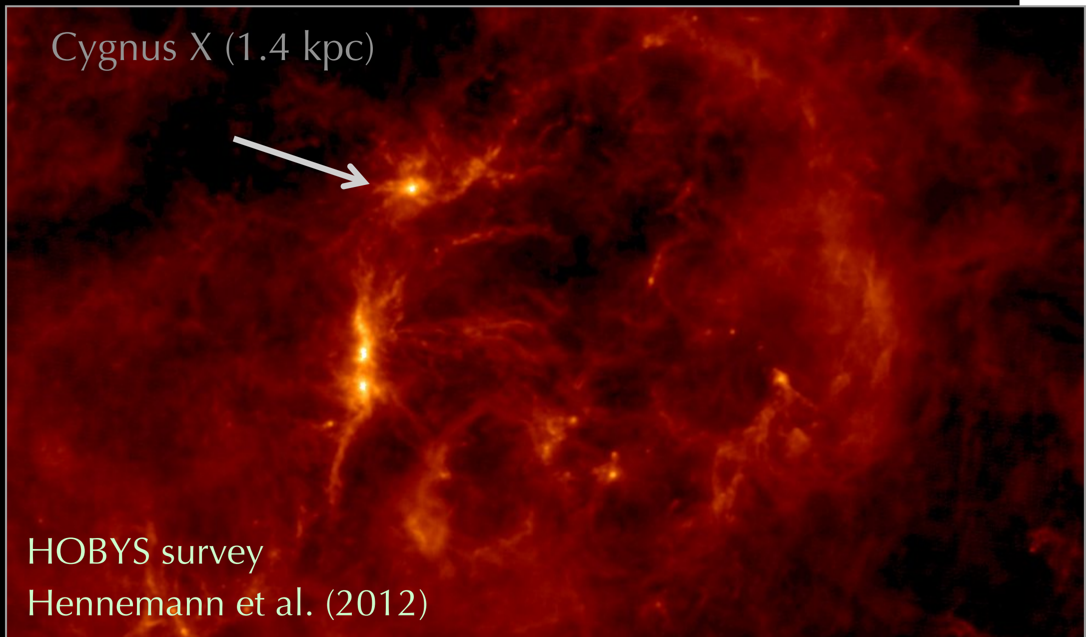
Schneider, Csengeri et al., 2014

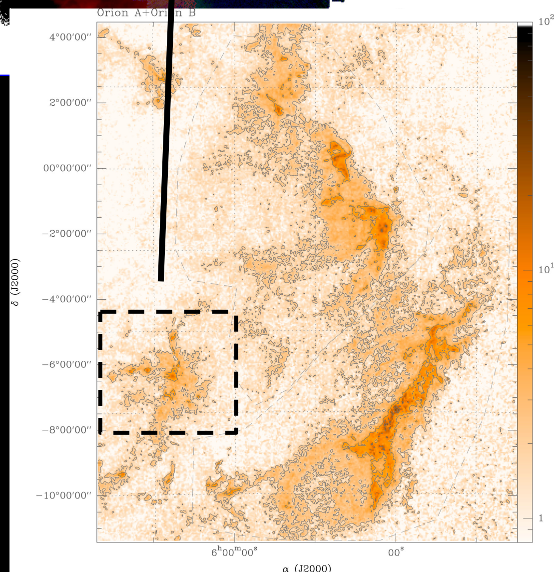
… but also massive hubs



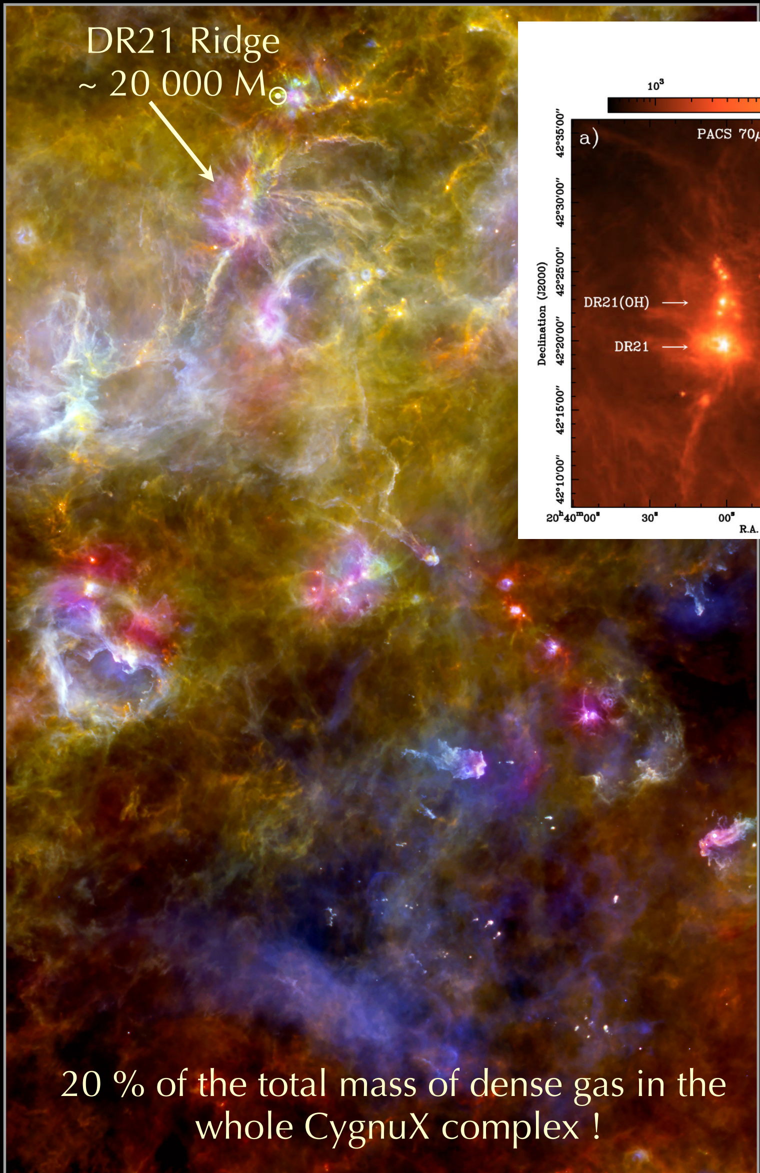
Schneider et al. (2012)

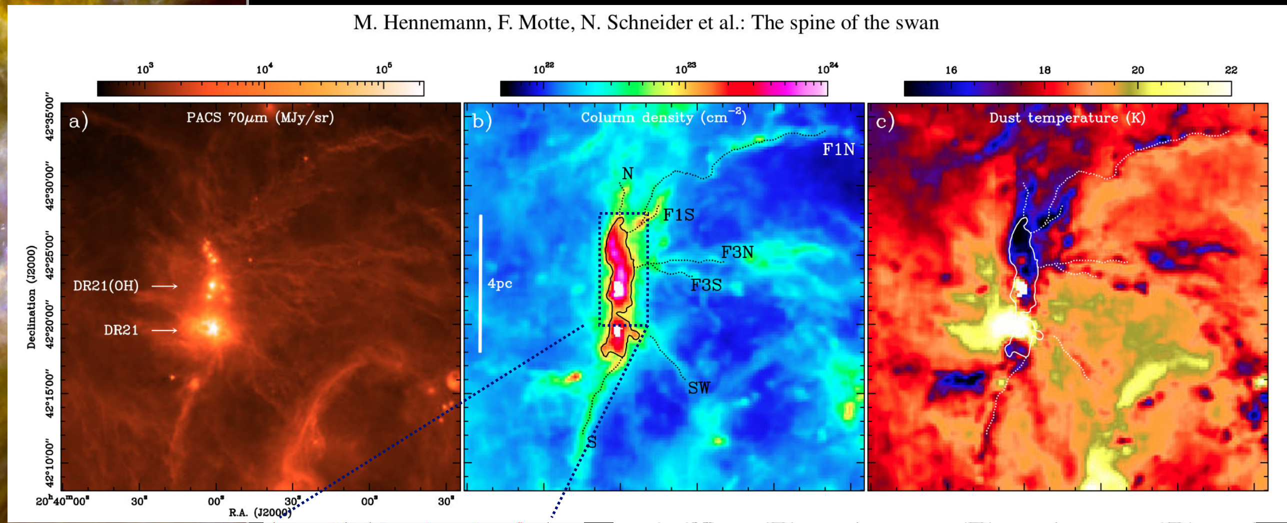


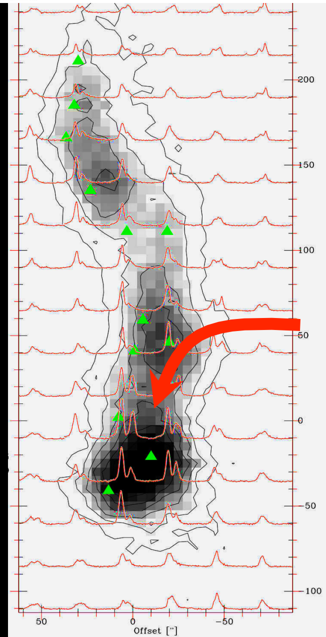


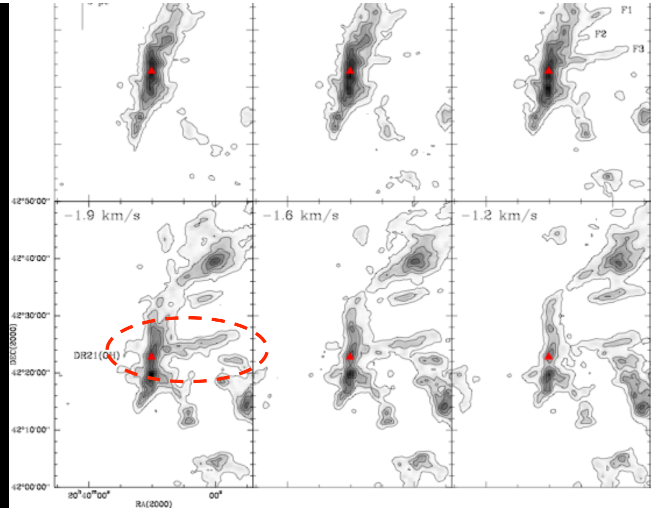


High-density ridges under dynamical influence …

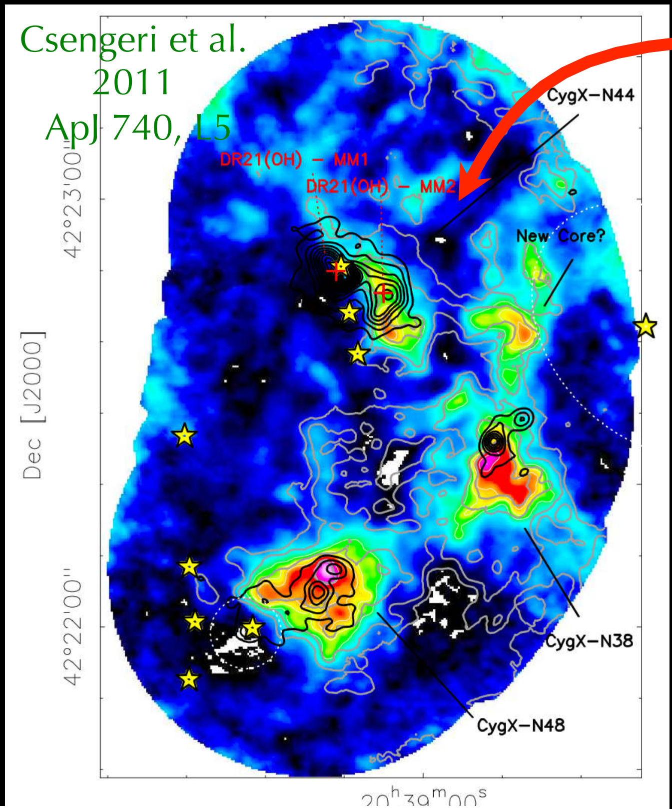


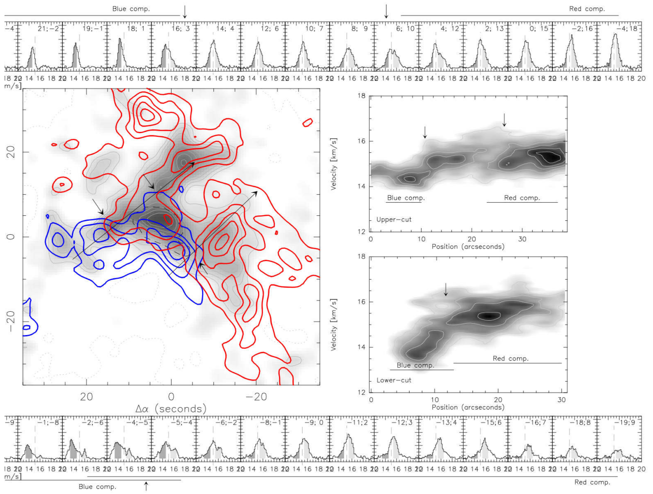






Schneider et al. (2010), Csengeri et al. (2011), Hennemann et al. (2012).





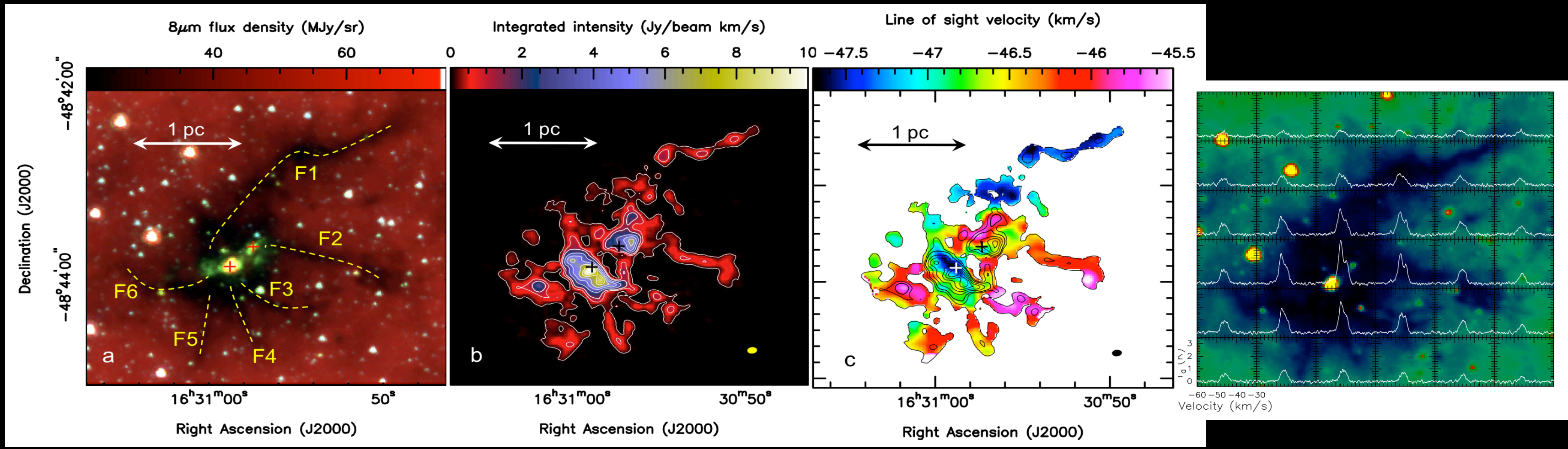
Dynamical features

- Infall / contraction (10^{-2} M_{sun}/yr) see Schneider et al. (2010).
- "Refill" from large scales (2 Myr timescale).
- Short crossing times but long-living … (such as MCs in the colliding flow view).
- see Schneider et al. (2010), and Csengeri et al. (2011), Peretto et al. 2014, Louvet et al. 2014).

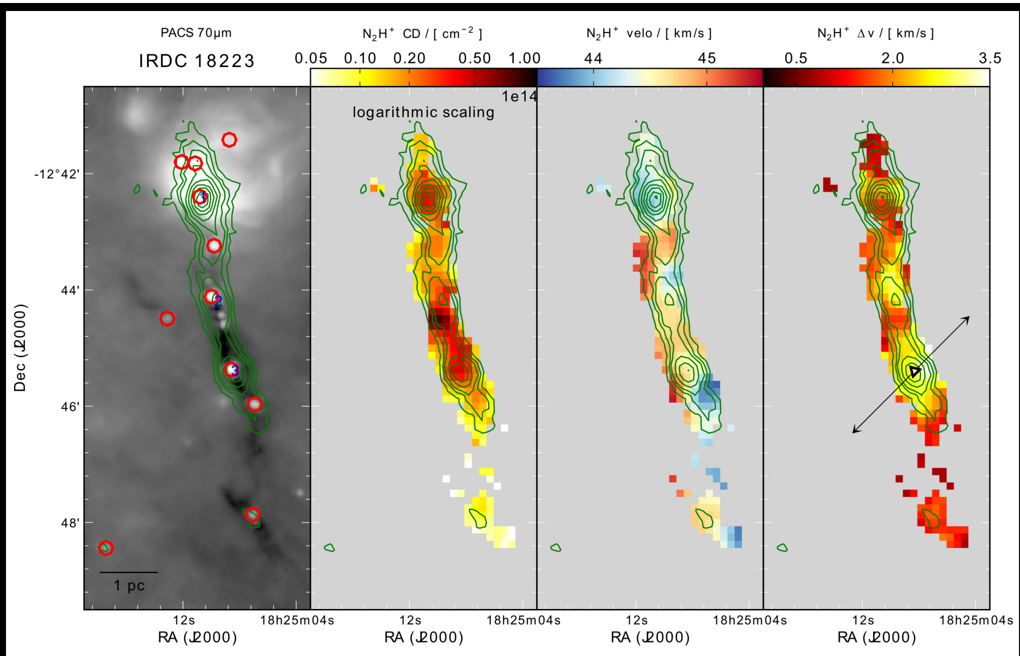
Hierarchical fragmentation

- The clump splits into 3 massive clumps.
- Dynamic dominated (τ_{cross} >~ τ_{ff}).
- Individual protostars at 0.02 pc scale.

Other evidences in massive filaments/ridges



Peretto et al. (2013, 2014)



Tackenberg et al. (2014)

Open Issues

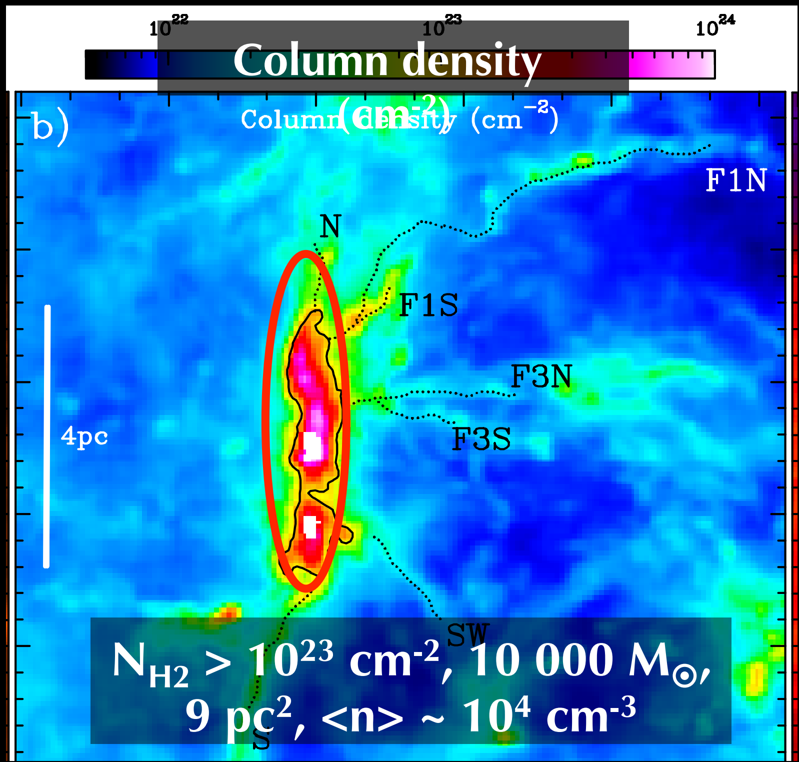
- Do all high-mass stars form in ridges … it does not seem so, how? Two modes?
- What is the relationship with lighter filaments? Are they just massive filaments or do they form differently? What is the formation scenario for ridges?
- Relation between ridge formation and SF (different IMF?), different mode of SF?

Most ridges should form by cloud global collapse

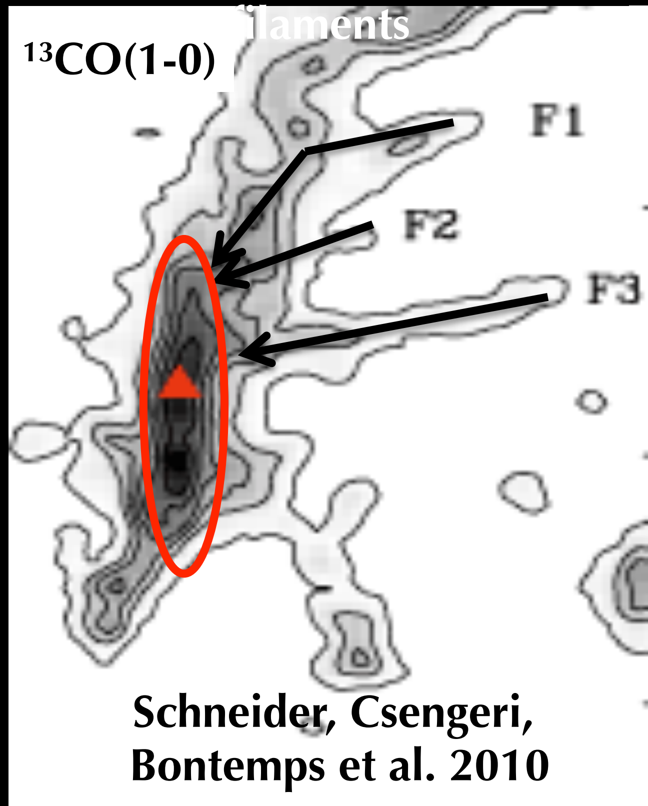
- Forced-fall (pressure-driven infall) of the DR21 ridge further fed by

Gas flows along sub-filaments

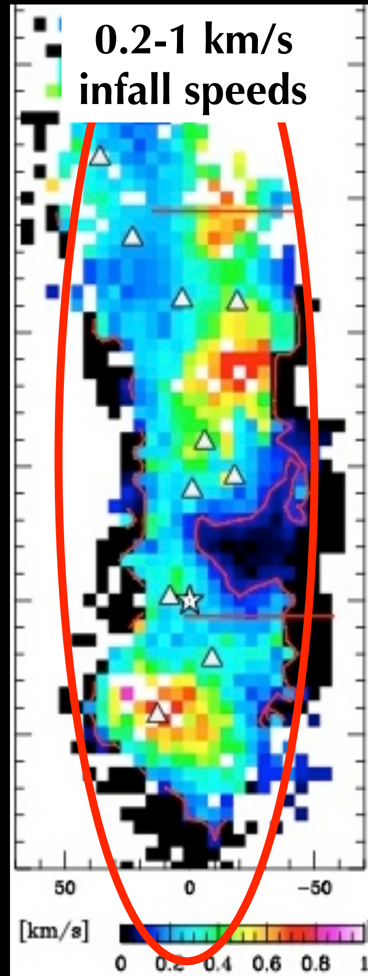
Global infall



Hennemann, Motte, Schneider et al. 2012



Schneider, Csengeri, Bontemps et al. 2010

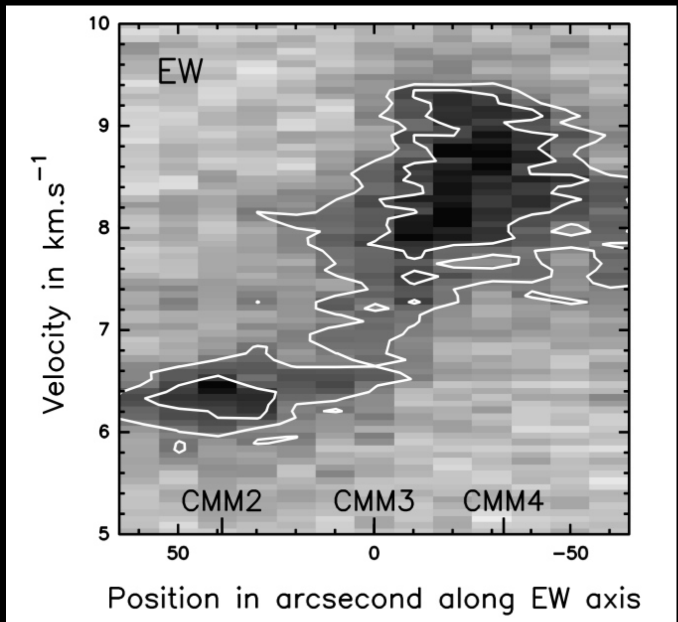


- Similar kinematics and SiO shocks for the W43-MM1 & MM2 ridges (Nguyen Luong et al. 2013; Louvet et al. in prep.)

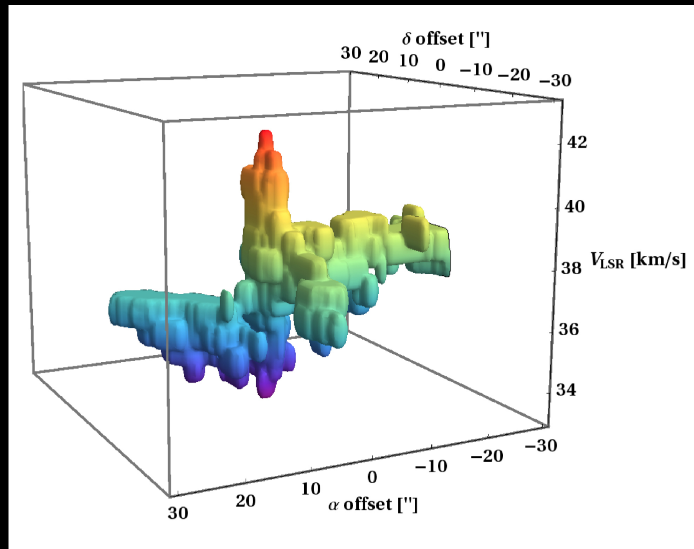
Other evidences in massive clumps/cores

Velocity Discontinuities in massive dense cores:

- Peretto et al. (2006); Rodon et al. (2008); Galvan-Madrid et al. (2010)



Peretto et al. (2006)



Galvan-Madrid et al. (2010)

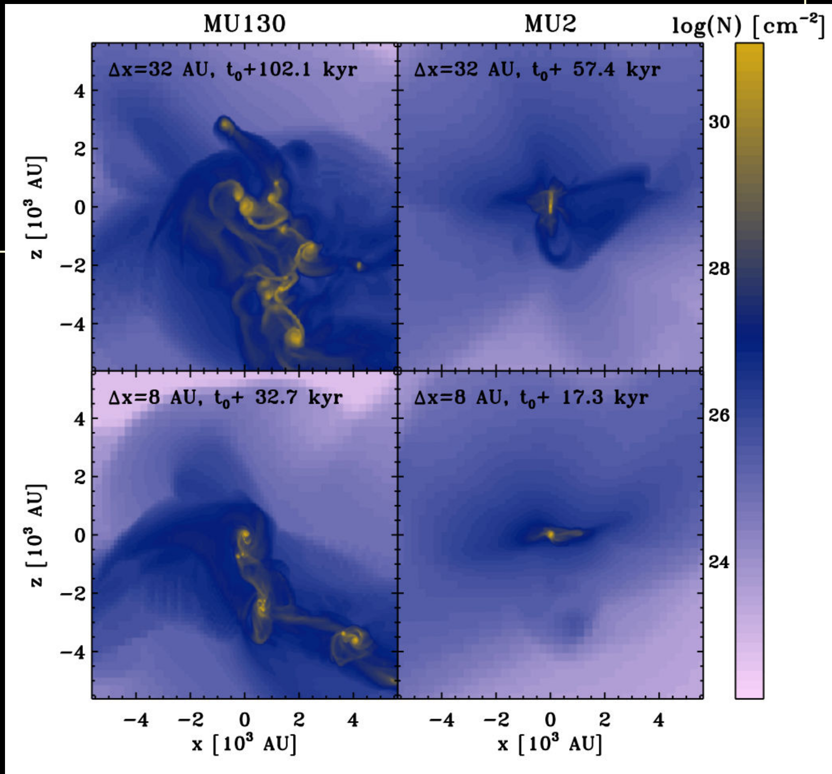
Origin of Super-Jeans cores

Large effective Jeans masses?

- To get M_{Jeans}= 20 $M_{\odot}$ one needs T_{gas} ~ 200 K or Δv_{FWHM} ~ 3 km/s.

How to avoid fragmentation at later stage?

- Cooling and turbulence dissipation decrease M_{Jeans} on short timescales at such high densities (of the order of 10^7 cm^{-3}).
- Driven turbulence?
- Magnetic field?
- Radiation from the protostar?



RMHD simu. with RAMSES

- Magnetic field braking.
- Increases accretion on 1st core.
- Enhances T_{gas}.
- Prevents fragmentation.

Commerçon et al. (2011), ApJ 742, L9

See also Palau et al. (2014) for other evidences