Origin of the stellar Initial Mass Function (IMF) in the W43-MM1 ridge

Fabien Louvet
(Universidad de Chile & IPAG Grenoble)

Special credits to: F. Motte, T. Nony, S. Bontemps, A. Gusdorf, P. Didelon, P. Hennebelle, Q. Nguyen Luong, N. Peretto, N. Schneider, T. Csengeri, A. Zavagno,
and the *Herschel*/HOBYS and W43-HERO consortia.

Formation of massive clusters and high-mass stars

Open questions:

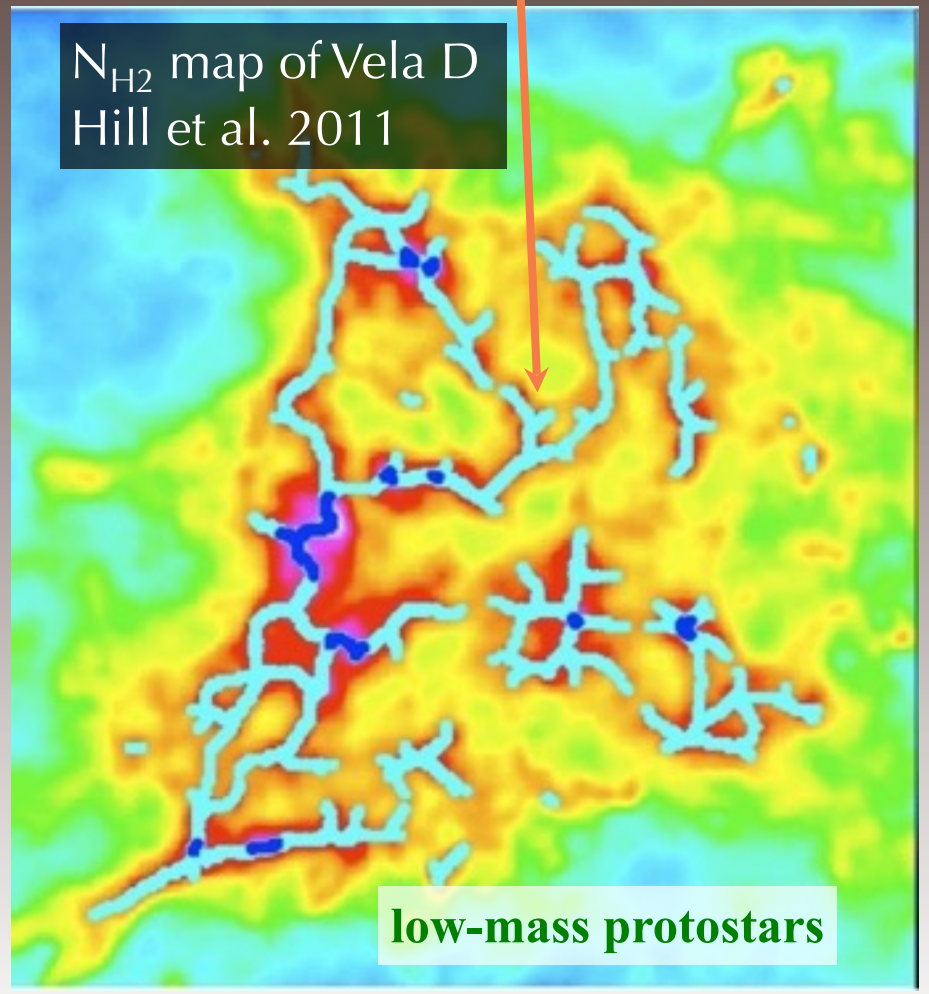
- Where do high-mass stars and massive clusters form?
- Thresholds for (high-mass) star formation?
- cf. Kelsey's talk: what kind of physical conditions give birth to what kind of stars?
- Is stellar feedback essential to define the final mass of massive stars? How is the IMF in massive clusters?

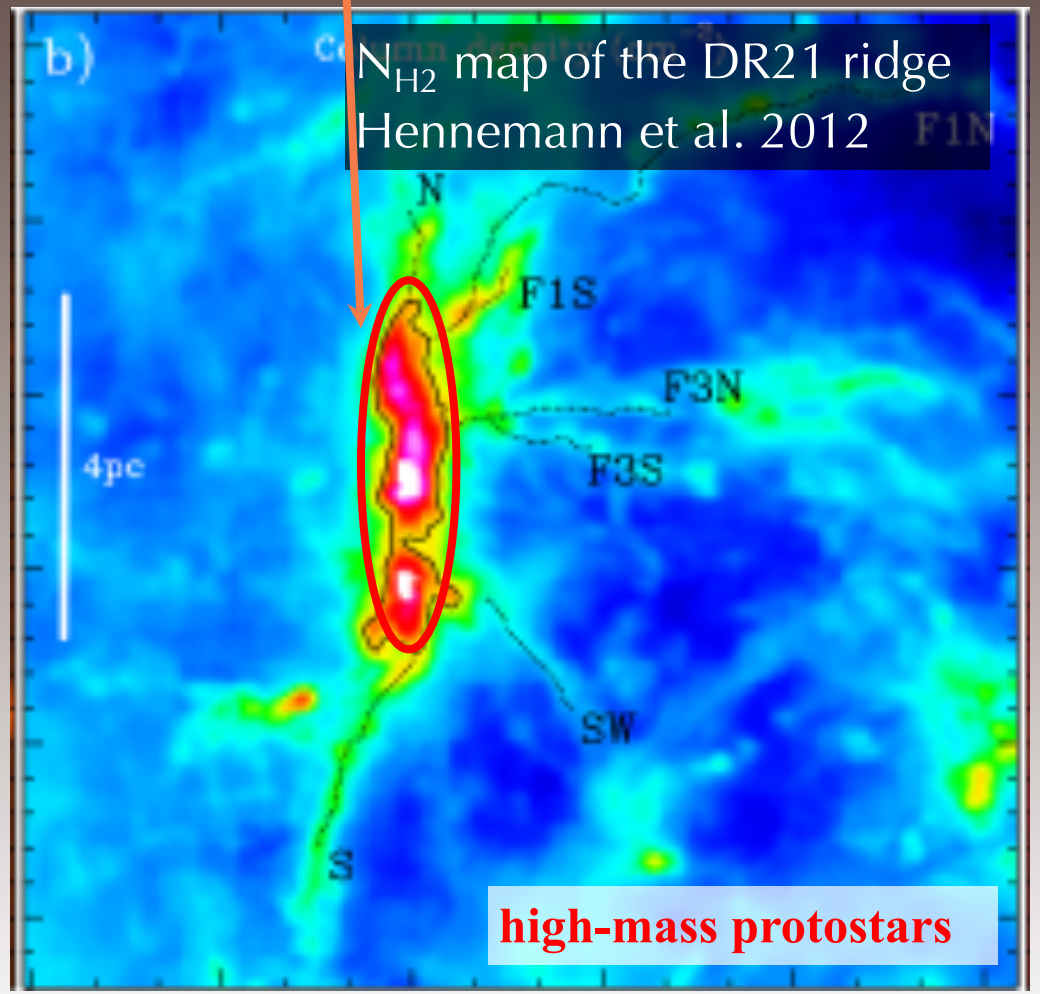
What can we make to start answering?

- Outline morphological differences between high-mass star forming regions and low-mass star forming regions.
- Study of the relation between cloud features and star-formation.

Different cloud structures form low- & high-mass stars

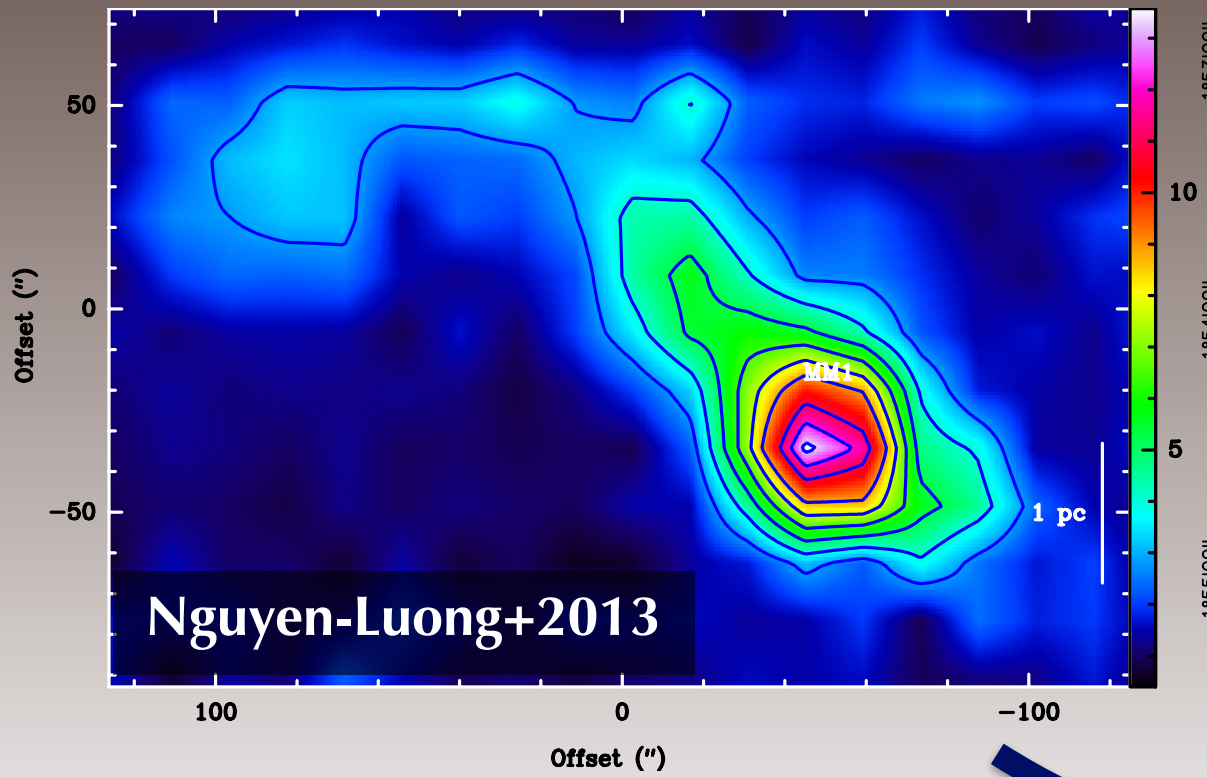
- Disorganized network of filaments versus single dominating filamentary clouds

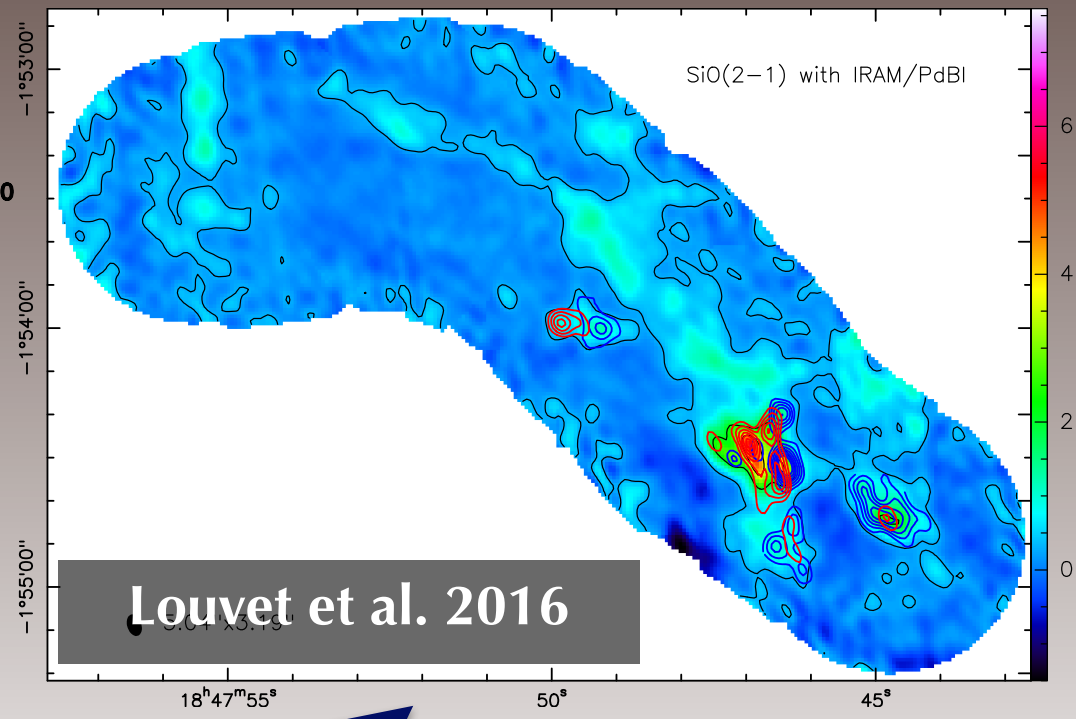




Low-velocity shocks in/on Ridges and Hubs

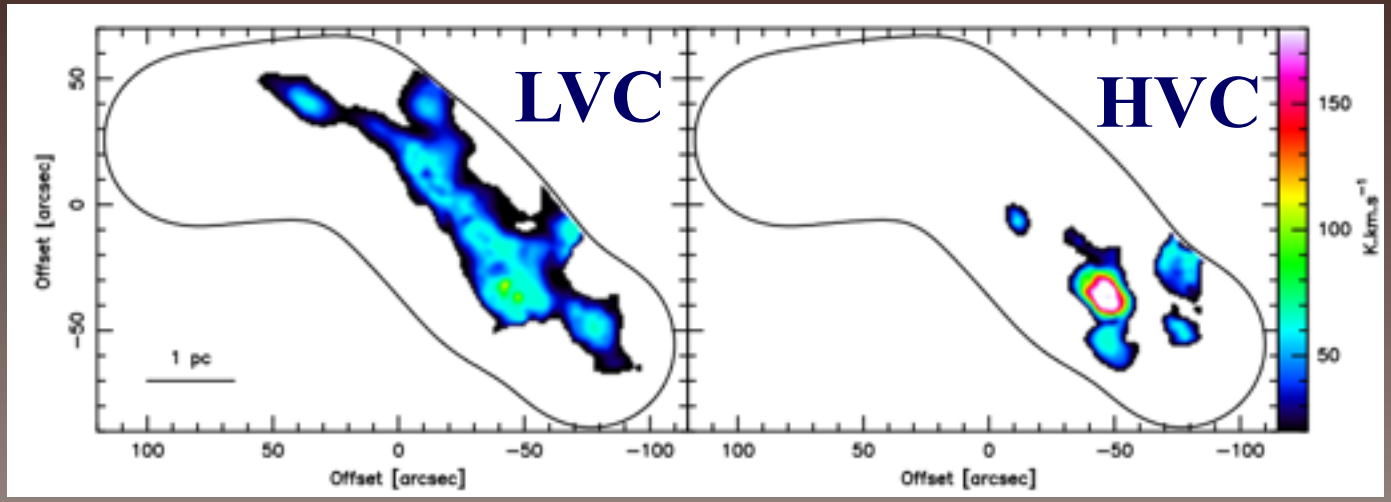
Large scale SiO emission in high-mass star forming regions:
e.g G035.39-00.33 W43 G028.23-00.19
e.g. Jimenez-Serra+2010; Nguyen Luong+2011, 2013; Sanhueza+2013
⟶ SiO is mostly known to trace high-velocity shocks

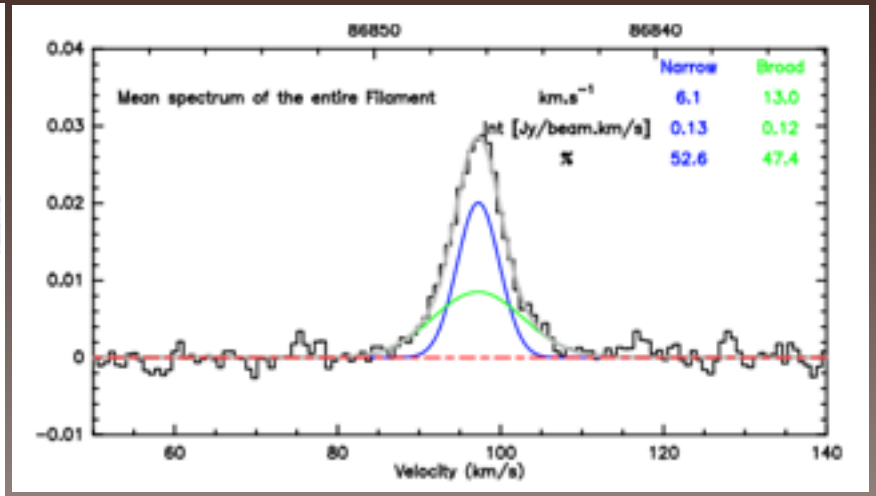


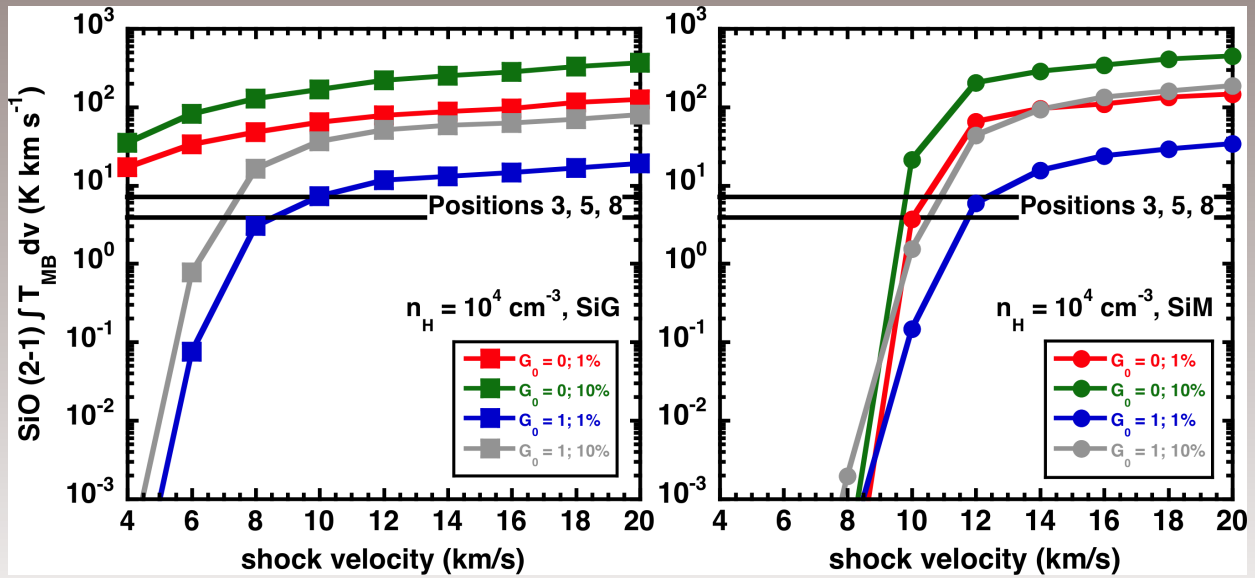


Interferometry?

Low-velocity shocks in/on Ridges and Hubs







>280 dedicated of shock models

Best fit with low-velocity shocks (~8-12 km/s) & 10% of the SiO in the gas phase

From Louvet et al. 2016

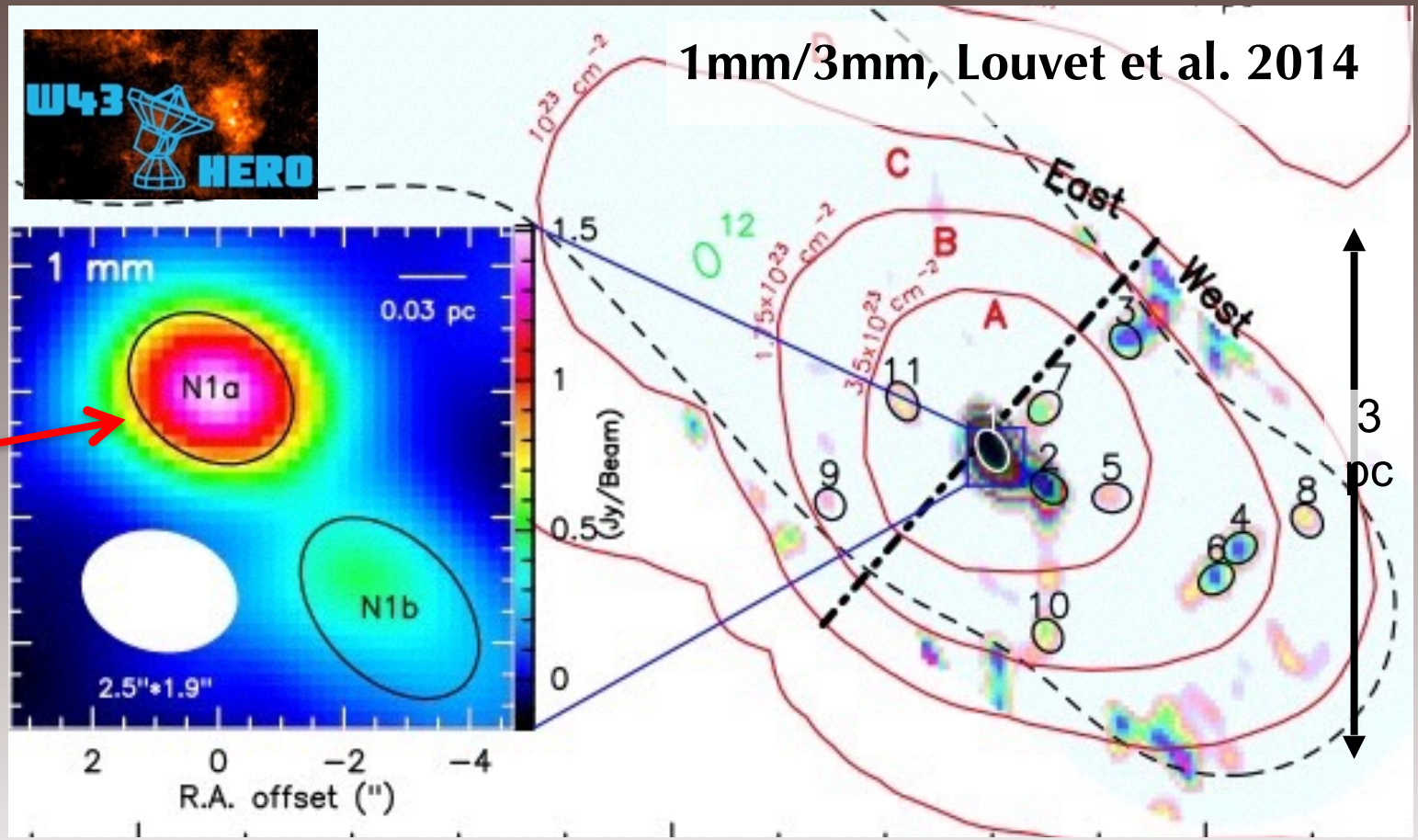
Are thresholds and constant SFE correct in ridges?

Lada et al. (2010, 2012) relation between SFR and cloud mass implicitly assumes a constant SFE in regions above the SF threshold (n_{H2}> 1.5 10^4 cm^{-3}).
See also Evans et al. 2014, André et al. 2014,… and SFR theoretical models.

IRAM Plateau de Bure census of protostars in the W43-MM1 ridge

- finds the most massive protostar: N1a: 300-1000 $M_\odot$ 0.03 pc

- investigates SFE within subregions A, B, C, D of different density



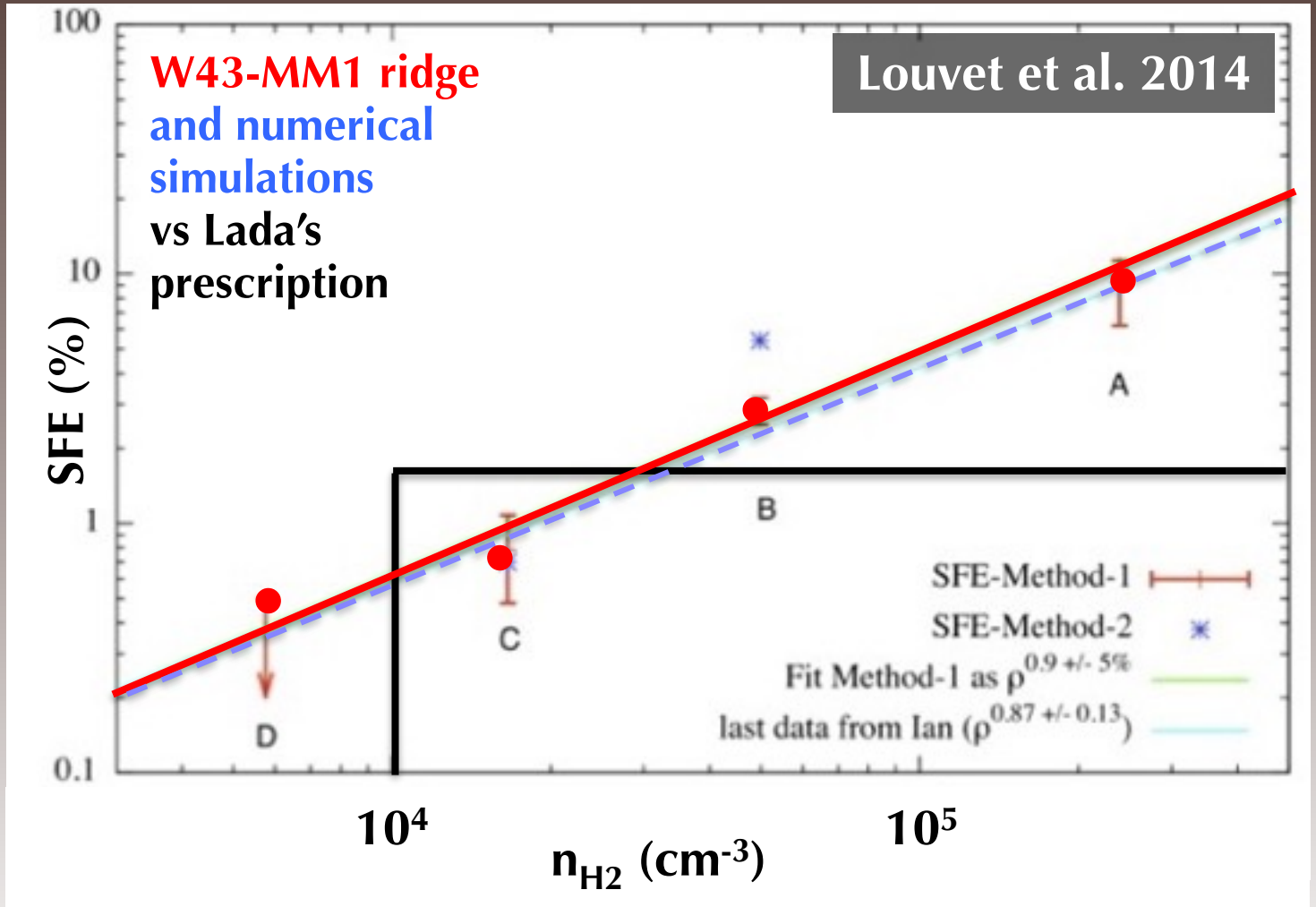
Are thresholds and constant SFE correct?

SFE measured within the W43-MM1 ridge and in numerical simulations increases with n_{H2} (Louvet et al. 2014).

In contradiction with Lada's 2010/2012 prescription…

In agreement with previous CFE studies (e.g., Bontemps et al. 2010)

⇒ Cloud density controls the SFE and the mass of the most massive stars that will form.



See also Jorgensen+2007, Hatchell&Fuller+2008

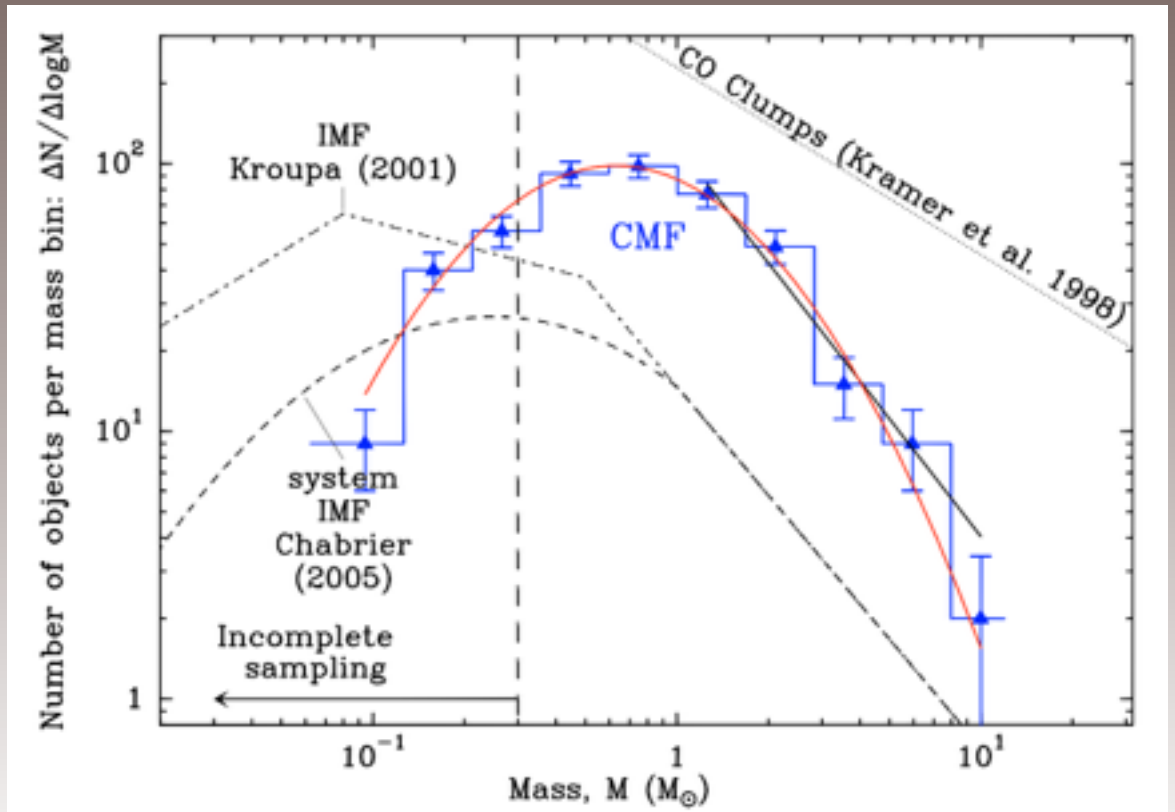
The quest of the origin of the Initial Mass Function

NIR Extinction and Herschel images of the Gould Belt clouds shows a good correspondance between the CMF and the stellar IMF (Alves et al. 2007; André et al. 2010; Könyves et al. 2010, 2015).

Studies limited to <5 $M_\odot$ stars…

in regions not typical of the main mode of star formation in galactic disks.

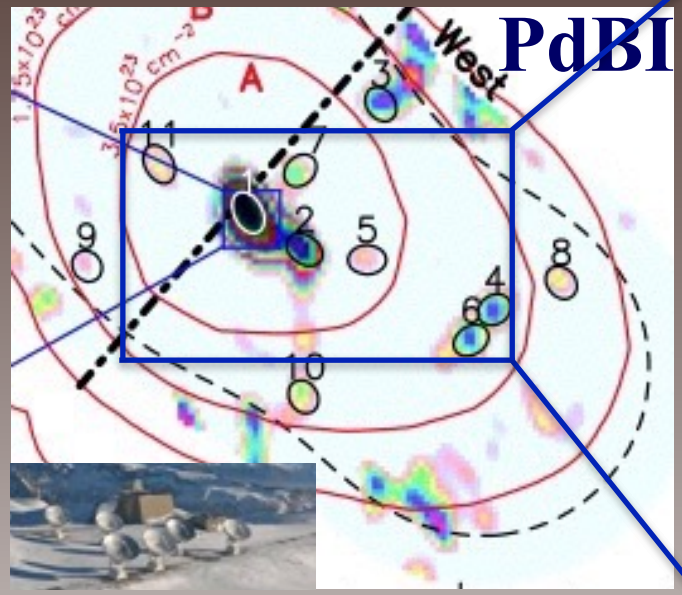
From Könyves et al. 2010



Well… have a look at Hatchell & Fuller+2008

An ALMA view of the W43-MM1 mini-starburst protocluster

Louvet et al. (2014)



x 10 in resolution
x 3 in sensitivity

ALMA?

Extraction of ~500 sources with the Getsources extraction tool (Men'shchikov+2012)

Reduced to ~280 sources after physical analysis

1.3 mm
Scales 0.5″-7″ (with ACA & TP)
Mass completeness: ~ 1–3 $M_\odot$

An ALMA view of the IMF origin in the mini-starburst protocluster of the W43-MM1 ridge

~300 pre- and proto-stellar cores of 2500 AU size.

The 3-100 $M_\odot$ part of the CMF is much flatter than the IMF.

Possible evolutions:

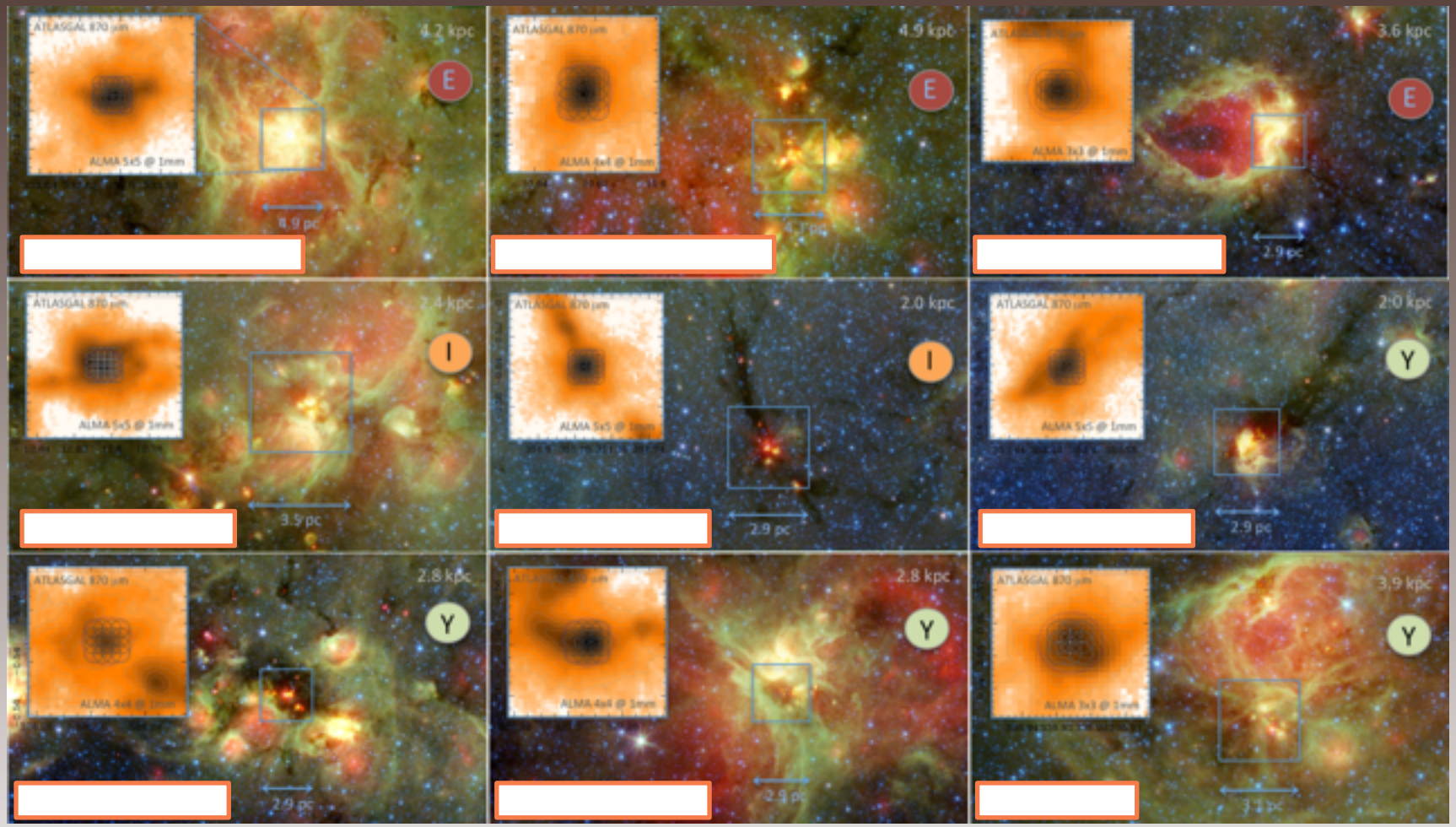
- *OB star feedback* will steepen the final IMF
- *The high-mass cores will fragment* (below 2500 AU)
- *Core mass = available mass for accretion?*
- SFE increases with <n>

The IMF will be atypical?

Motte, Nony, Louvet et al. subm to Nature

See also Hatchell & Fuller+2008, Myers+2009b

ALMA-IMF Large Programm
PI: F. Motte (ESO)
Co-PI: F. Louvet (Chile), A. Ginsburg (NRAO), P. Sanhueza (NAOJ)



- 15 Protoclusters
- Distance of 2-6 kpc
- Different stages

The take away

- High-mass stars form in supermassive clouds

We call those structures *ridges or hubs* (2-10 pc^3 with density > 10^4-10^5 cm^{-3}). They are hierarchical structure, dominating their environment.

- The star formation efficiency does correlate with the cloud volume density

In opposition with the prediction of Lada (2010, 2012) there is no threshold in density above which the SFE would be constant (in W43-MM1).

- Formation of clouds, cores and stars is concomitant in HMSFR
- Origin of the initial mass function of stars (IMF)?

Core mass function (CMF) of the W43-MM1 mini-starburst cluster is top-heavy. Will it evolve? By which means?

⇒ The instantaneous IMF of a massive cluster may strongly depend on its pristine density & age? +kinematics, B field…

Please join the effort of the consortium of the ALMA-IMF Large Program!