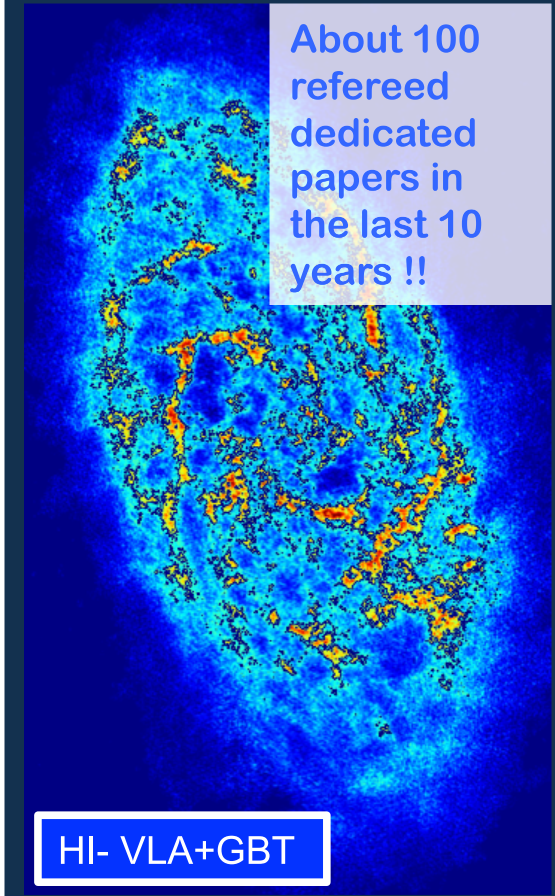
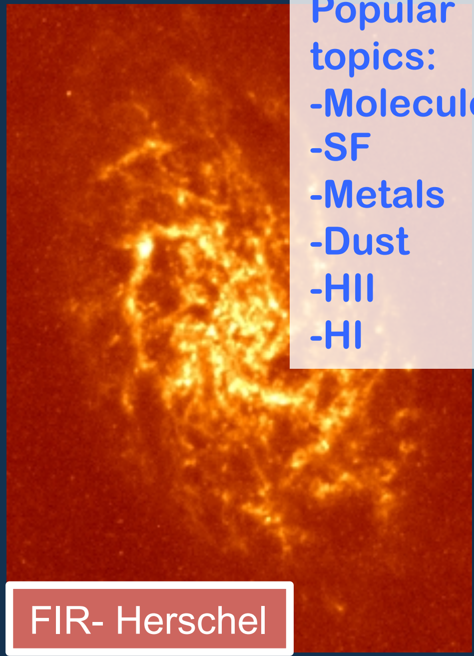
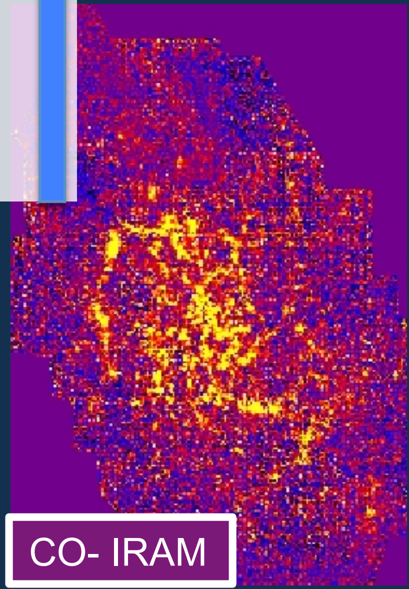
IAU-XXX GA
Vienna-2018

About 100 refereed dedicated papers in the last 10 years !!

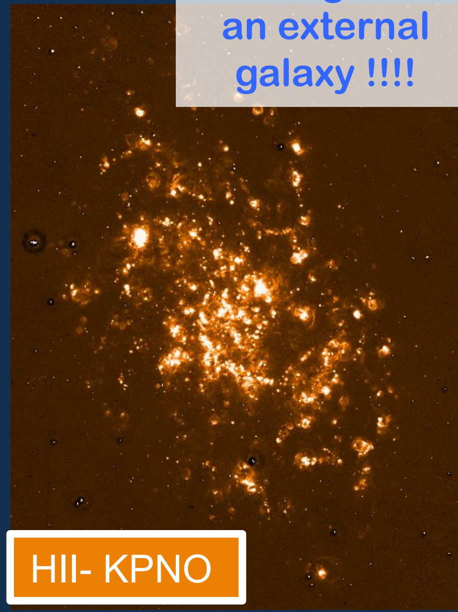




Popular topics:
-Molecules
-SF
-Metals
-Dust
-HII
-HI



It is the most studied ISM throughout an external galaxy !!!!



The interstellar medium of M33

Edvige Corbelli – INAF - Arcetri , Italy

Additional hot topics to ISM for M33:

Variable ★
Dark matter
LG member
Clusters
....
Life search!

M33 is

- ***The third largest LG member, likely approaching M31 now***
- ***An undisturbed blue flocculent spiral galaxy, outer warped disk and clouds***
- ***Hosted by a dark halo of mass: $3x10^{11}$ M_o***
- ***A pure disk with baryonic mass: $7x10^{9}$ M_o, 2/3 stars, 1/3 gas***
- ***Making stars with a SFR=0.5 M_o/yr***

APOD-Image Credits: Malcolm Park

Today focus on

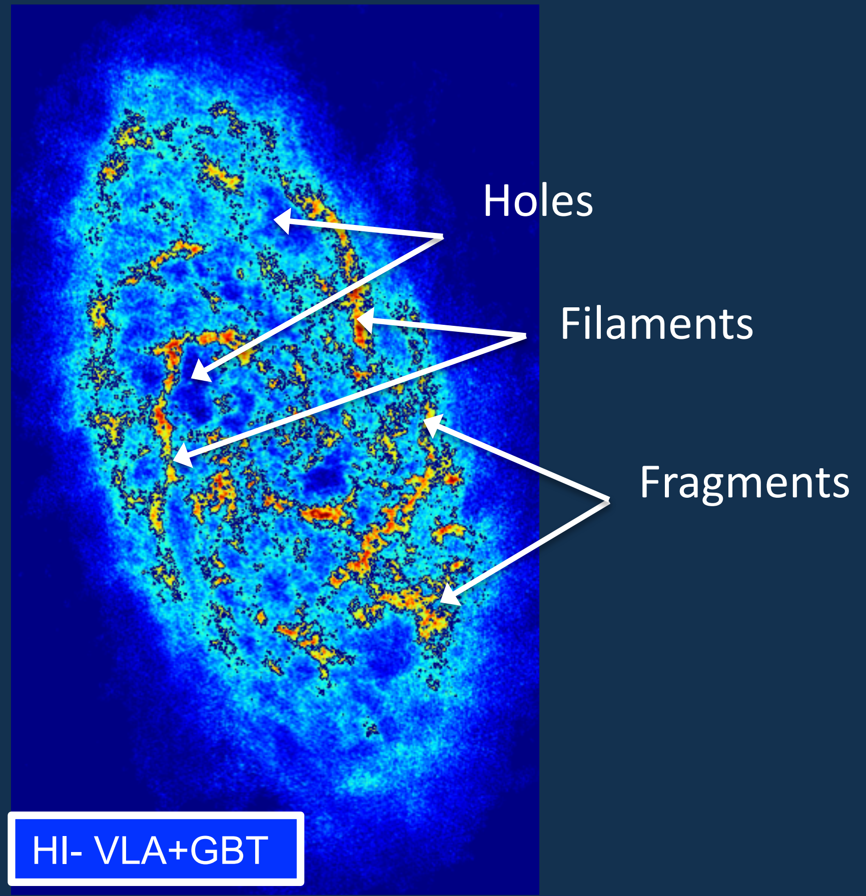
Feedback versus gravity in the ISM: what drives SF ?

- SPH: Large scale simulations and the need for feedback *(Dobbs et al. 2018)*
- GMC: Lifecycle of molecular clouds and SF sites *(Corbelli et al. 2017)*
- PDF: Self-gravity footprints across the M33 disk *(Corbelli et al. 2017)*

Major collaborators: J.Braine (GMC), B. Elmegreen (PDF), C. Dobbs + A. Petit (SPH)

--Do extended filaments or spiral arms grow in isolated disks?

--Is SF feedback needed to fragment them as to reproduce the ISM morphology?

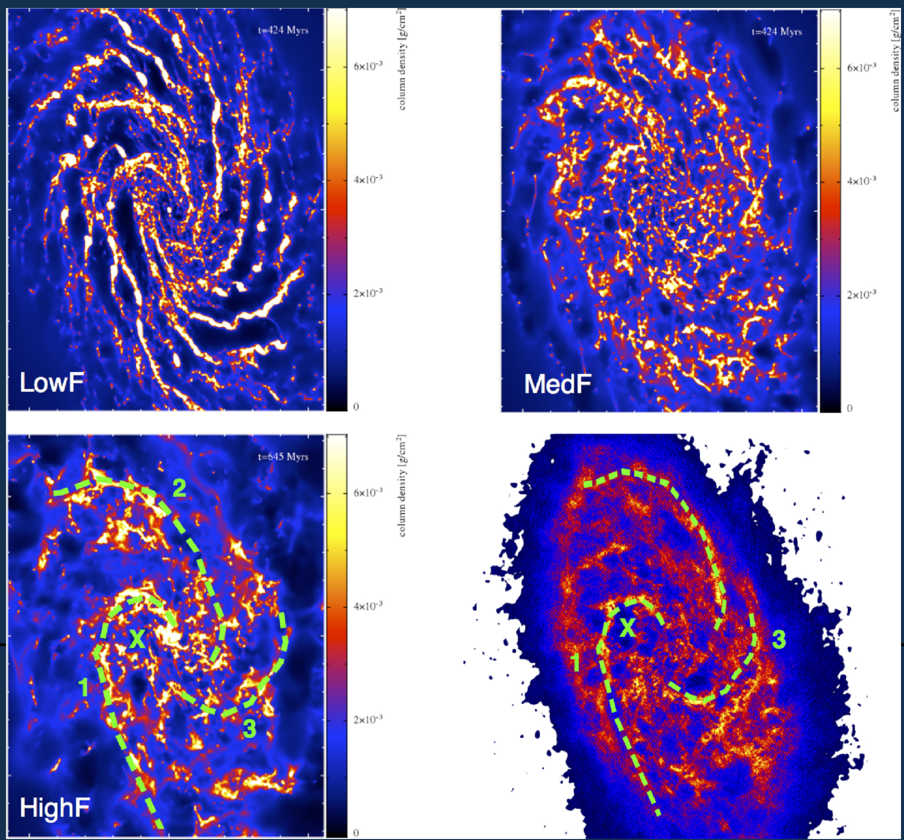


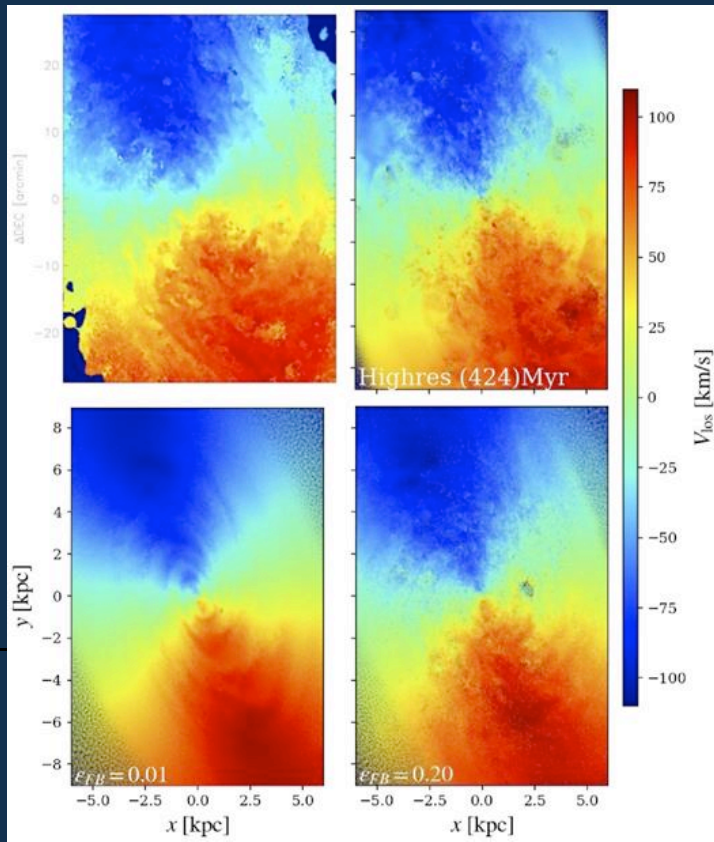
--SPH simulations using dark halo NFW, stellar and gaseous disk data.

--Stellar feedback coupled or uncoupled to star formation efficiency is injected as kinetic and thermal energy

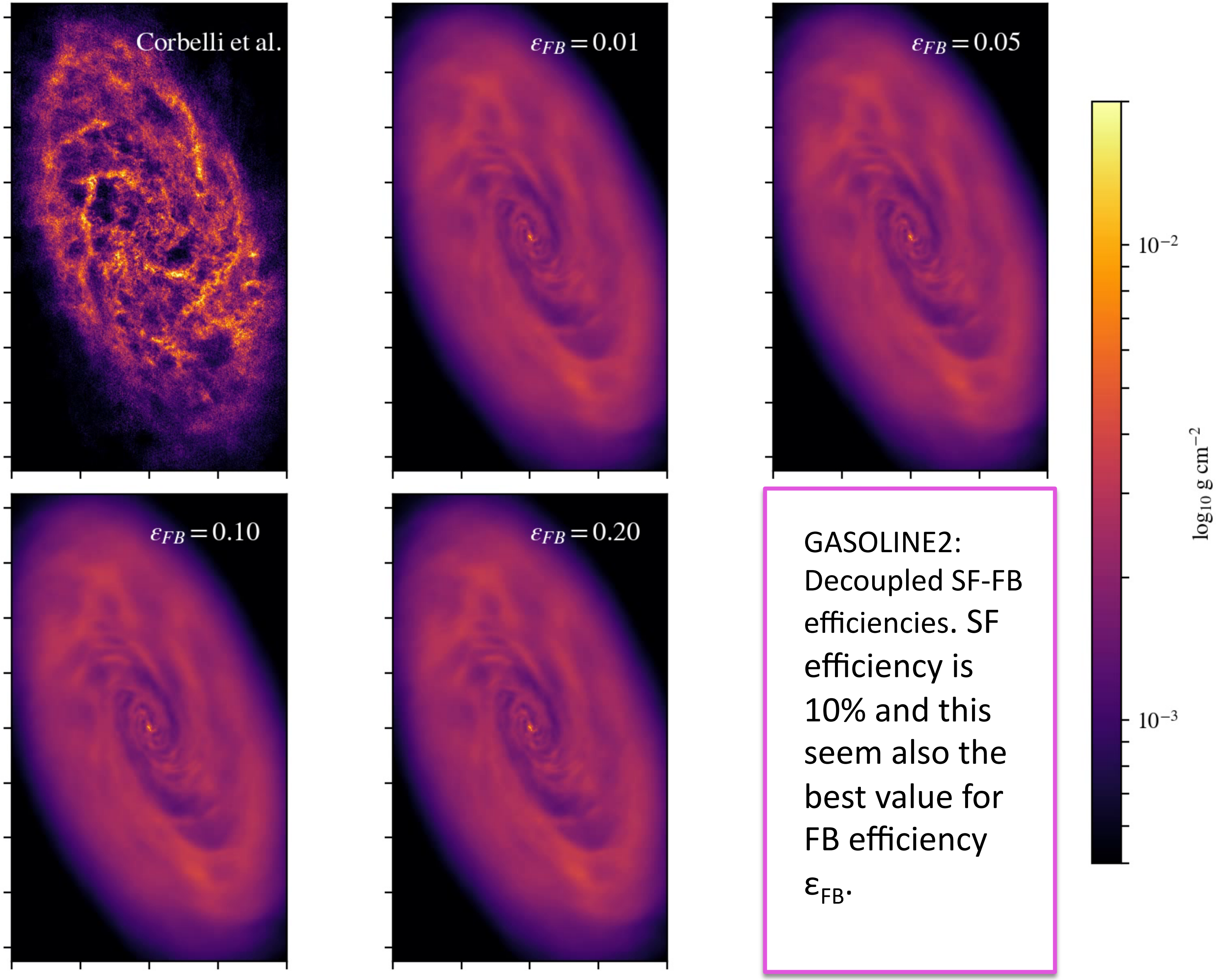
--Low efficiency and feedback (0.01)model is dominated by shocks and many spiral arms since it has a stronger response to the gravitational instabilities that develops in the star+gas

--High feedback (0.2) model matches better the observed morphology of filament fragments and holes and the small scale features of the velocity field, but it requires a higher SFR than observed





SPHNG – Coupled SF and VB efficiency LowF=0.01, MedF=0.05, HighF=0.2



GASOLINE2: Decoupled SF-FB efficiencies. SF efficiency is 10% and this seem also the best value for FB efficiency ε_{FB}.

A total gas conversion efficiency of 0.1 for SFR=0.5 M_o/yr implies that in about one rotational period (4x 10 ^{8} yrs) M33 is able to convert $2x10^8$ M_o (the Molecular Cloud mass) into ★.

To know the efficiency of molecular mass conversion we needs to estimate the MC lifetime or the free –fall time.

Using a population of Young Stellar Cluster Candidates we have inferred that MCs in M33 have a short lifetime, 14 Myrs, hence in each cycle the MC gas conversion efficiency is 3% .
A similar estimate can be inferred from the t_{ff}/t_{dep} ratio.

Molecular clouds

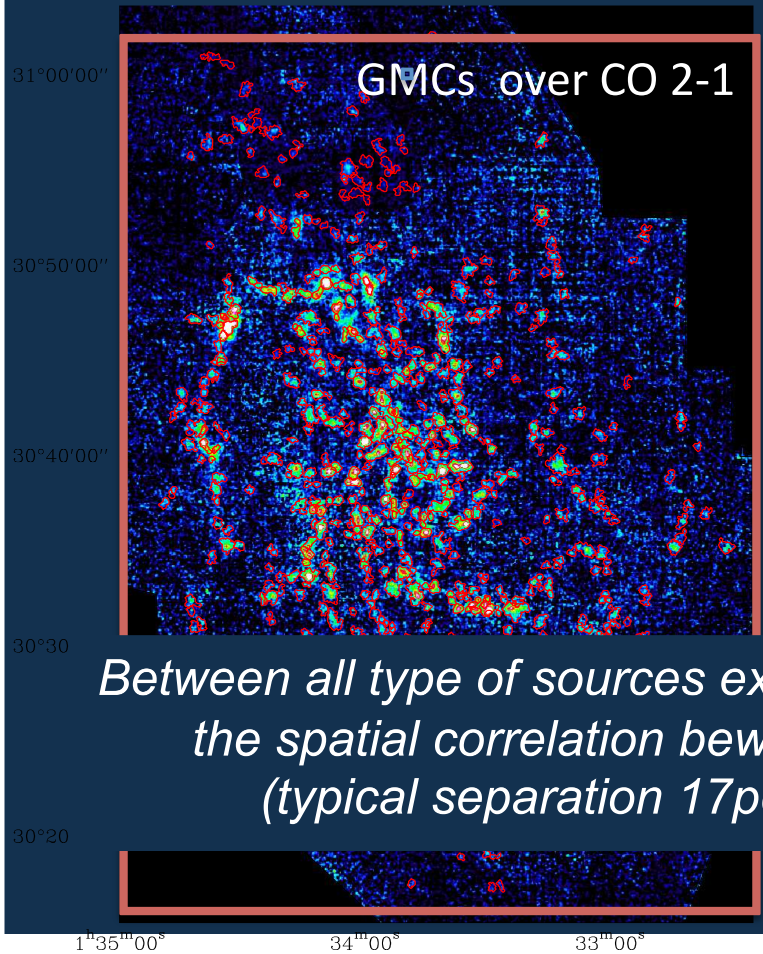
IRAM-30m CO J=2-1 all-disk map

Gratier et al. 2010-12, Druard et al. 2014

Using this database*:*

566 GMCs with mass $2x10^6$ –$2x10^4$ $M_\odot$ make up ½ of total molecular mass

Corbelli E., Braine J. et al.. 2017



Young Stellar Cluster Candidates

Spitzer MIR maps

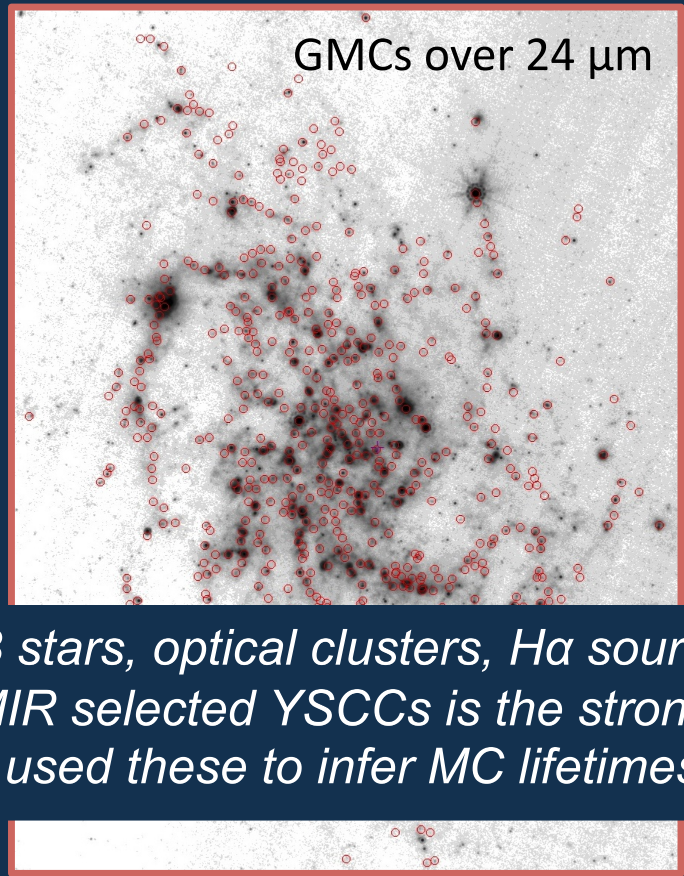
Verley et al. 2007,2009

Using the 24 μm map:

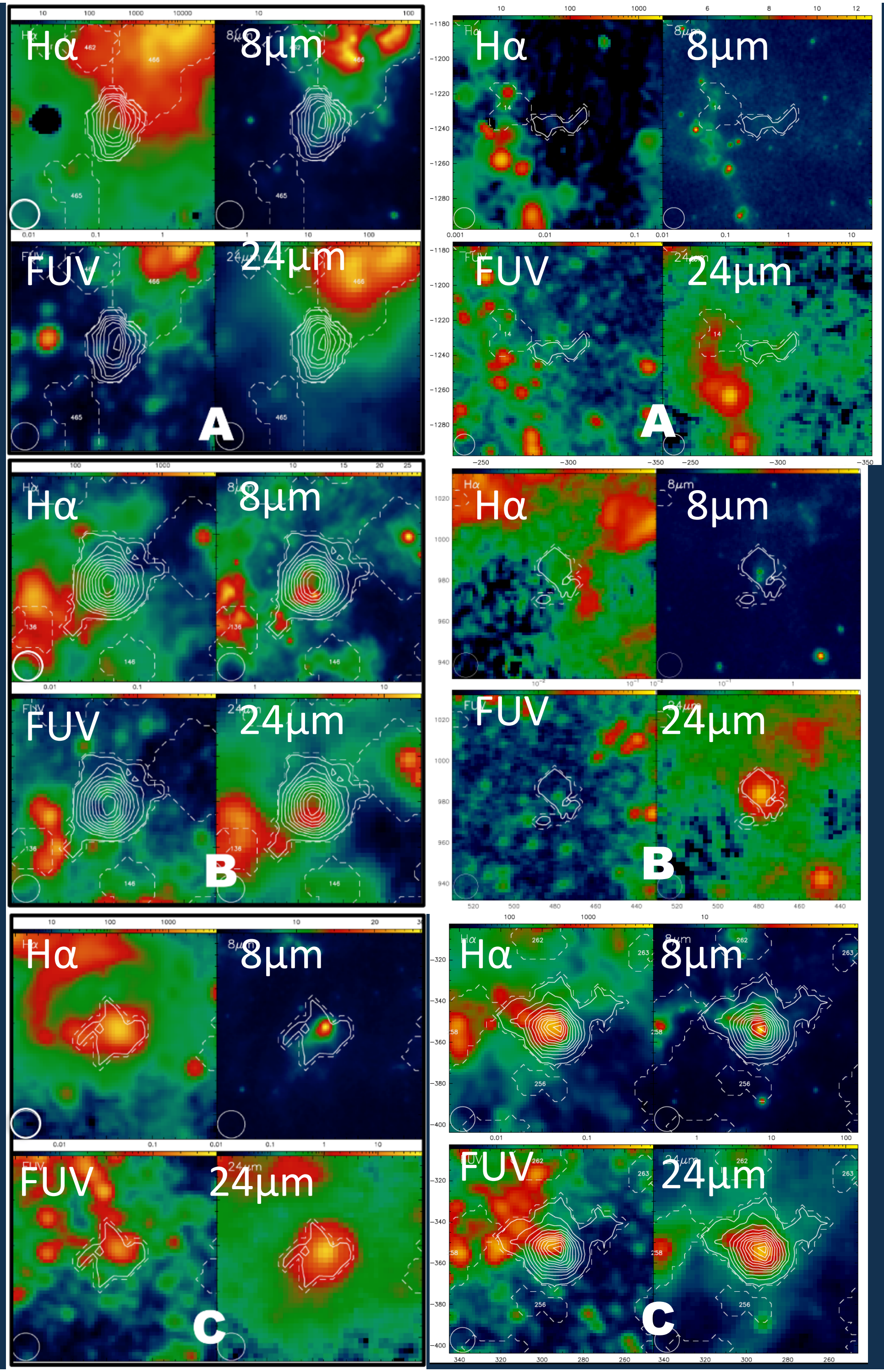
915 MIR-FIR sources, 630 of which are likely YSCCandidate at R<7kpc

Several SED-fits =>masses & ages

Sharma S., Corbelli E. et al. 2011



Between all type of sources examined (OB stars, optical clusters, Hα sources,.. the spatial correlation bewteen MCs-MIR selected YSCCs is the strongest (typical separation 17pc). We have used these to infer MC lifetimes.



Use Hα, FUV, 24-8 µm to classify GMCs as:

A (inactive - 32%)

B (embedded SF - 16%)

C (exposed SF - 52%)

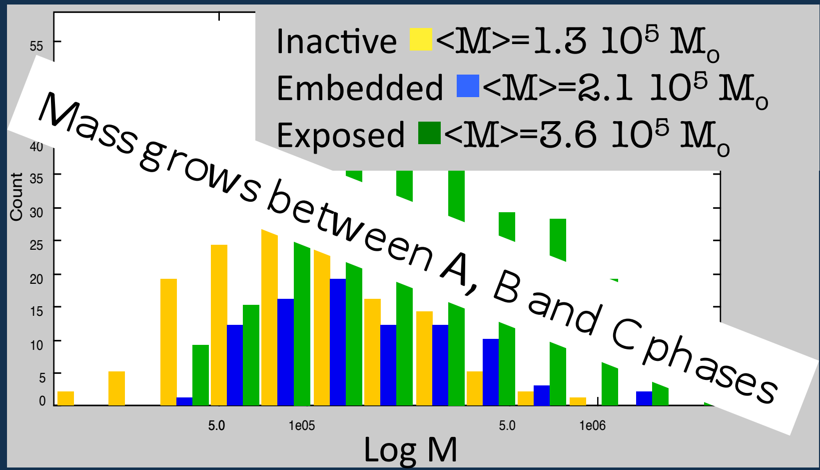
a few are ambiguous (D, 4% of total)

Panels for Hα, FUV, 8 and 24µm show emission intensity at cloud location; white contours are the GMCs. Two clouds for each class are shown.

Is A-B-C an evolutionary sequence?

Molecular cloud timeline in M33

- Using YSCC age determination and the number of clouds in each class we infer GMC total lifetime after major assembly and prior to dispersal : 14 Myrs



A inactive = 3.8 Myrs

B fully embedded = 2.4 Myrs

C exposed = 8 Myrs

Lifetime for GMCs in M33 is shorter than in the LMC:

(Yamaguchi et al. 2001, Kawamura et al. 2009)

The exposed phase, once the YSC breaks through the GMC, is shorter

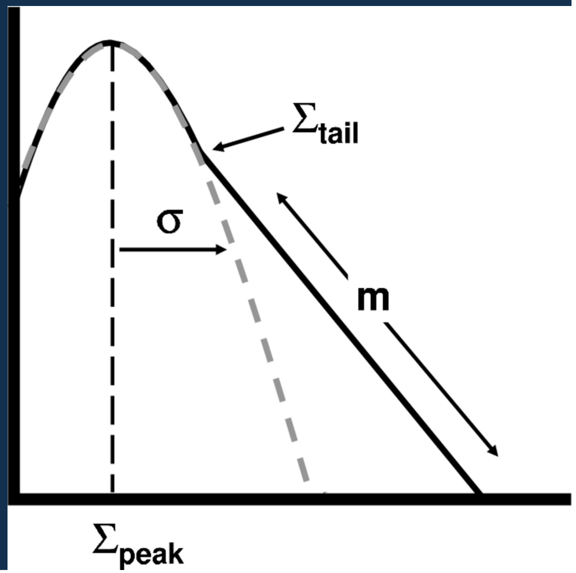
--What regulated the efficiency?

--Is local feedback that stops SF or gravitational collapse occurs only on small localized regions of MCs?

--Look at the Probability Distribution Function of atomic and molecular gas: gravity or turbulence ?

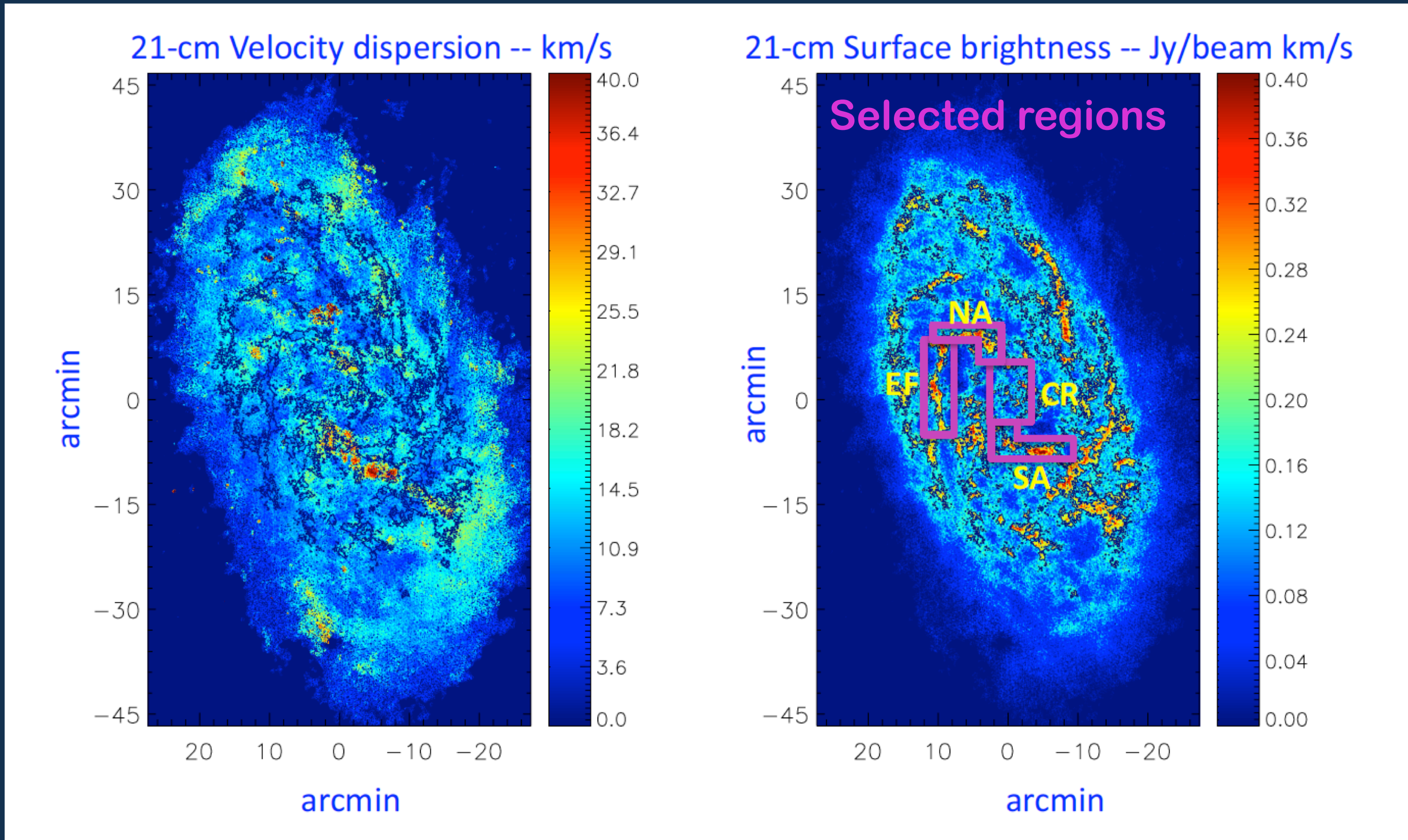
--Does PDF depend on time or location ?

Numerical simulations have shown that compressible turbulence, driven by feedbacks, shapes the gas PDF as a log-normal function but, if self-gravity becomes dominant above a certain density in a cloud, the PDF develops a power-law tail.



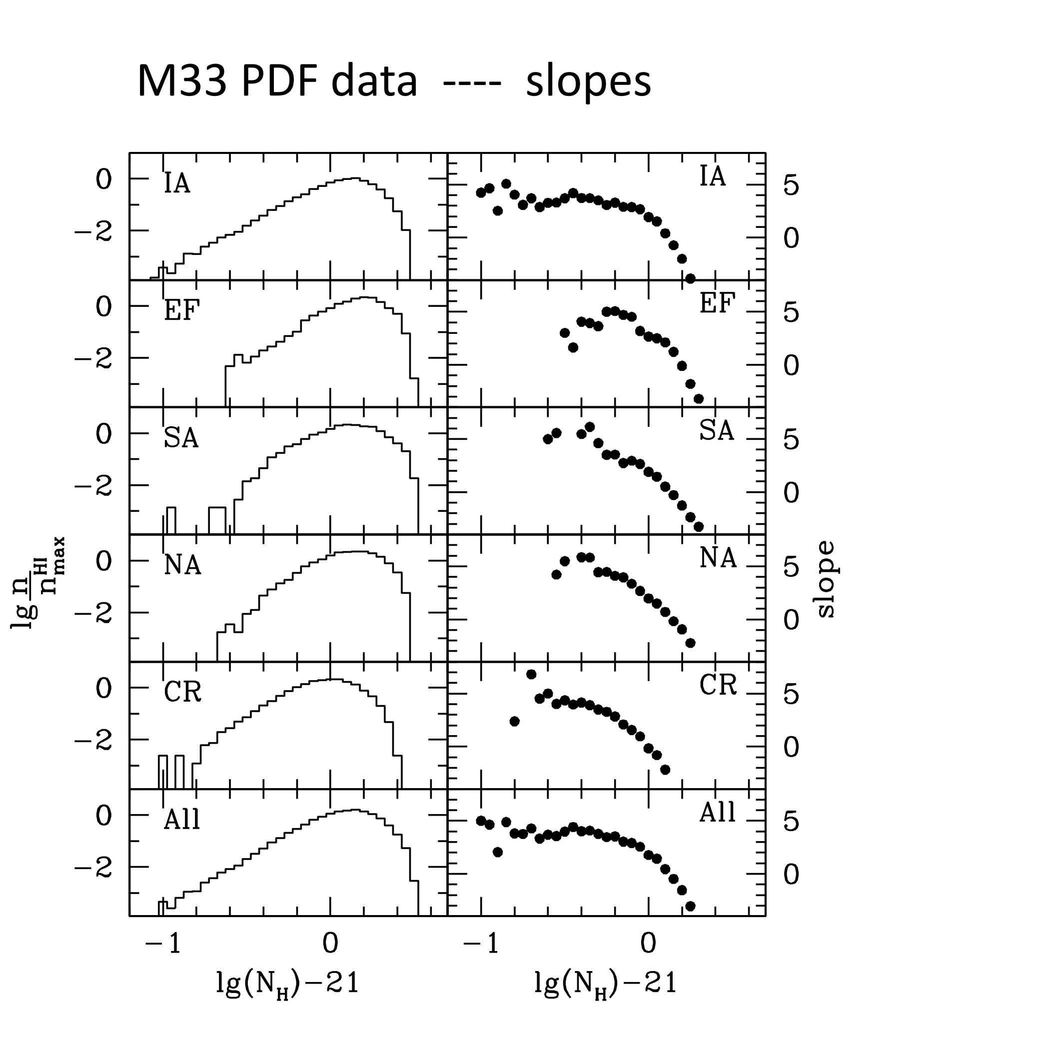
The column density PDF (or N-PDF) of the ISM in M33

Only a few studies of extragalactic PDF:
HII,HI -> M51+M31, LMC *(Berkhuijsen… 2015, Wada.. 2000)*: no PL tail
H2 -> M31(100pc),LMC+M51(50pc) *(Hughes.. 2013)*: no PL tail
H2 -> M83(40pc *Egusa.. 2018*),M33(50pc *Druard.. 2014*): some PL tail



$<\sigma_{21}>$=13 km/s
no radial variations
(see also Koch et al. 2018)

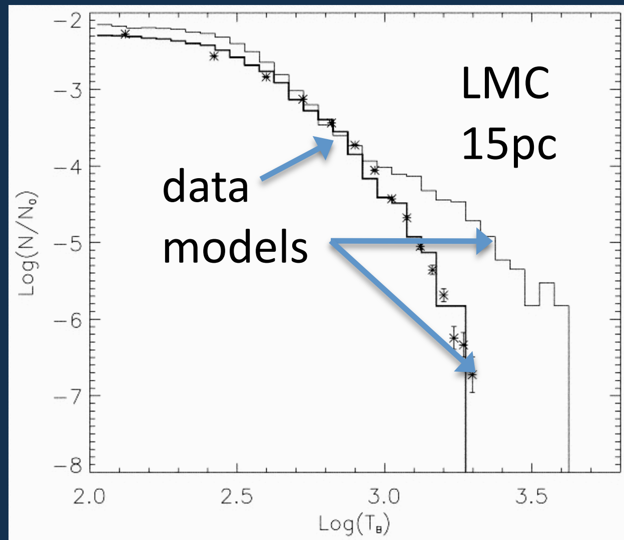
Atomic gas in GMC envelopes *(20-40pc res)*



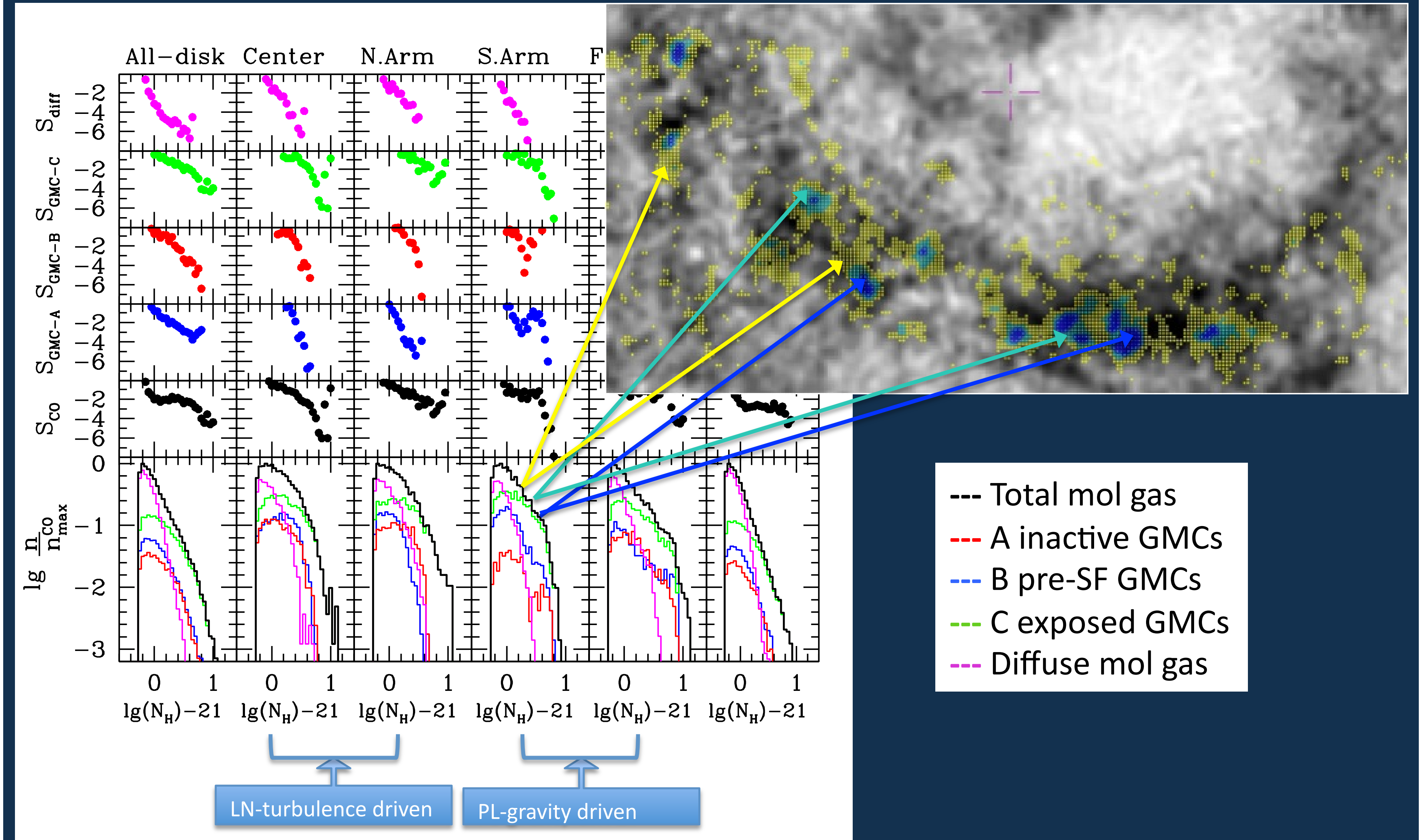
N_{Hlim}= 2.5 10^{21} cm^{-2}

HI → H2

Center + InterArms:
low density PL tail might be due to cavities warm/cold interfaces $\gamma > 1$



Molecular gas in GMC and diffuse *(50 pc res)*



- The high pressure and SFR in the central region shapes the GMC PDF as log-normal prior and during star formation . Turbulence dominates on 50pc scale.

- In the outermost filament rich in molecules, power-laws are detected above 10^{21} H atoms/cm^2 suggesting a stratification of density regulated by self-gravity at all evolutionary stages.

- Total gas PDF width decreases radially for R>2~kpc suggesting that turbulence might become subsonic as outer disk flares and atomic gas gets warmer.

- GMCs along northern and southern arm have different PDFs and properties. Deviations from a LN are detected only in the south, where GMCs get compressed and become active as they cross the arm sequence is present across the arm.

Local galaxy are becoming powerful tools to investigate the variety of ISM conditions and the delicate balance between different physical processes ….

From cluster scales….