First results from Hi-GAL: the Herschel infrared Galactic Plane Survey

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Hi-GAL team

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et al.

Hi-GAL

The Herschel infrared Galactic Plane Survey

$-60° < l < 60°$ $|b|<1°$ - 70/160/250/350/500μm – 343 hours

Toward a Predictive Global Model of Galactic Star Formation

- The High-Mass Star Formation Timeline
- Measure the star formation rate and history Galaxy-wide
- Cold dust in the Galactic Plane and the Formation of Molecular Clouds
- Understanding star formation laws and the nature of thresholds as a function of ISM properties across a full range of galactocentric radii metallicity and environmental conditions
- Determining the relative importance of global *vs* local, spontaneous *vs* triggering, agents that give rise to star formation.
- Build bottom-up recipes and prescriptions useful for Xgal science

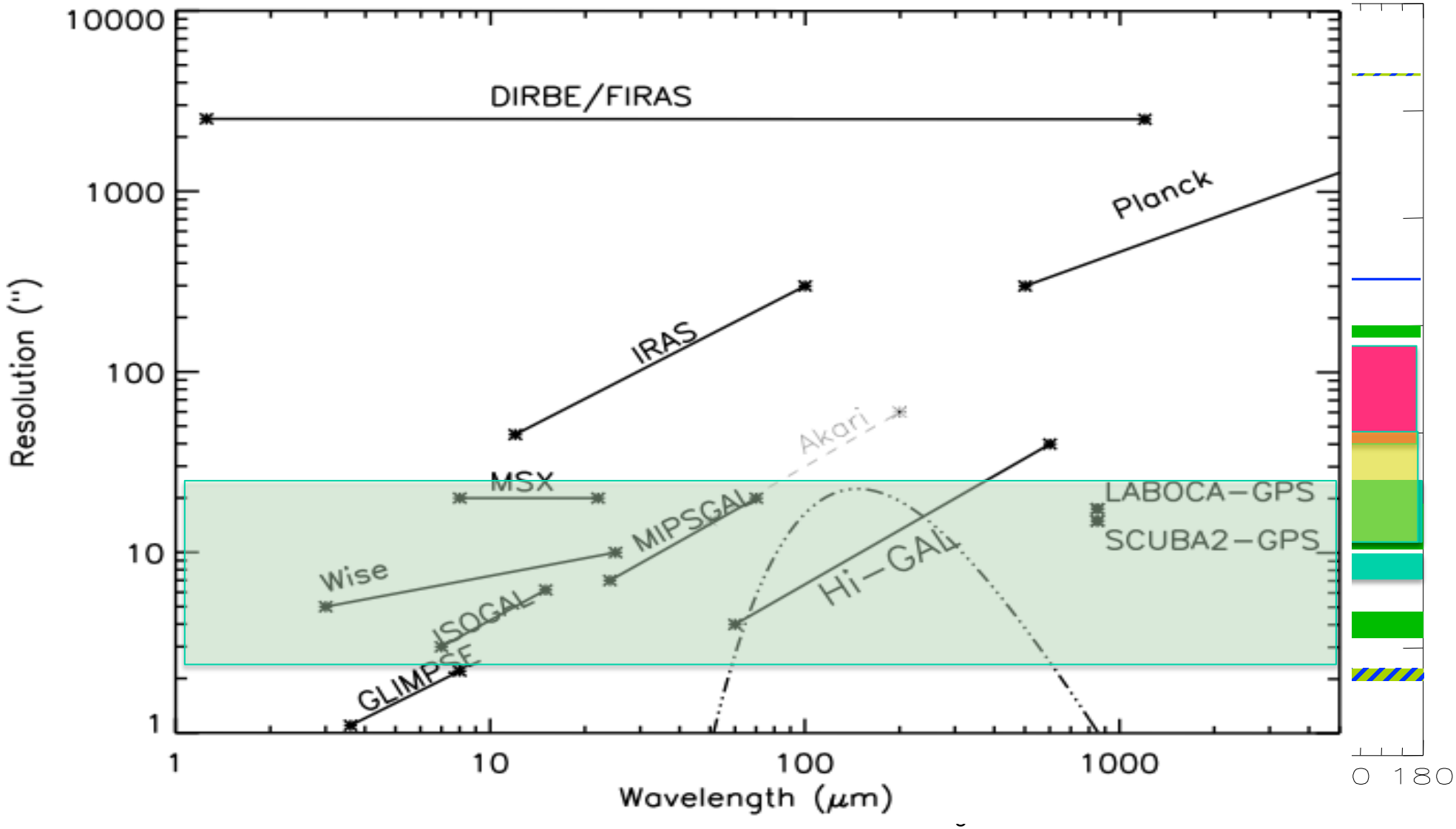
PACS/SPIRE 70/160/350 Com te

W43

PACS 160

The black circle is the ALMA Band 9 primary beam !!
Herschel is crucial and Hi-GAL will be ready

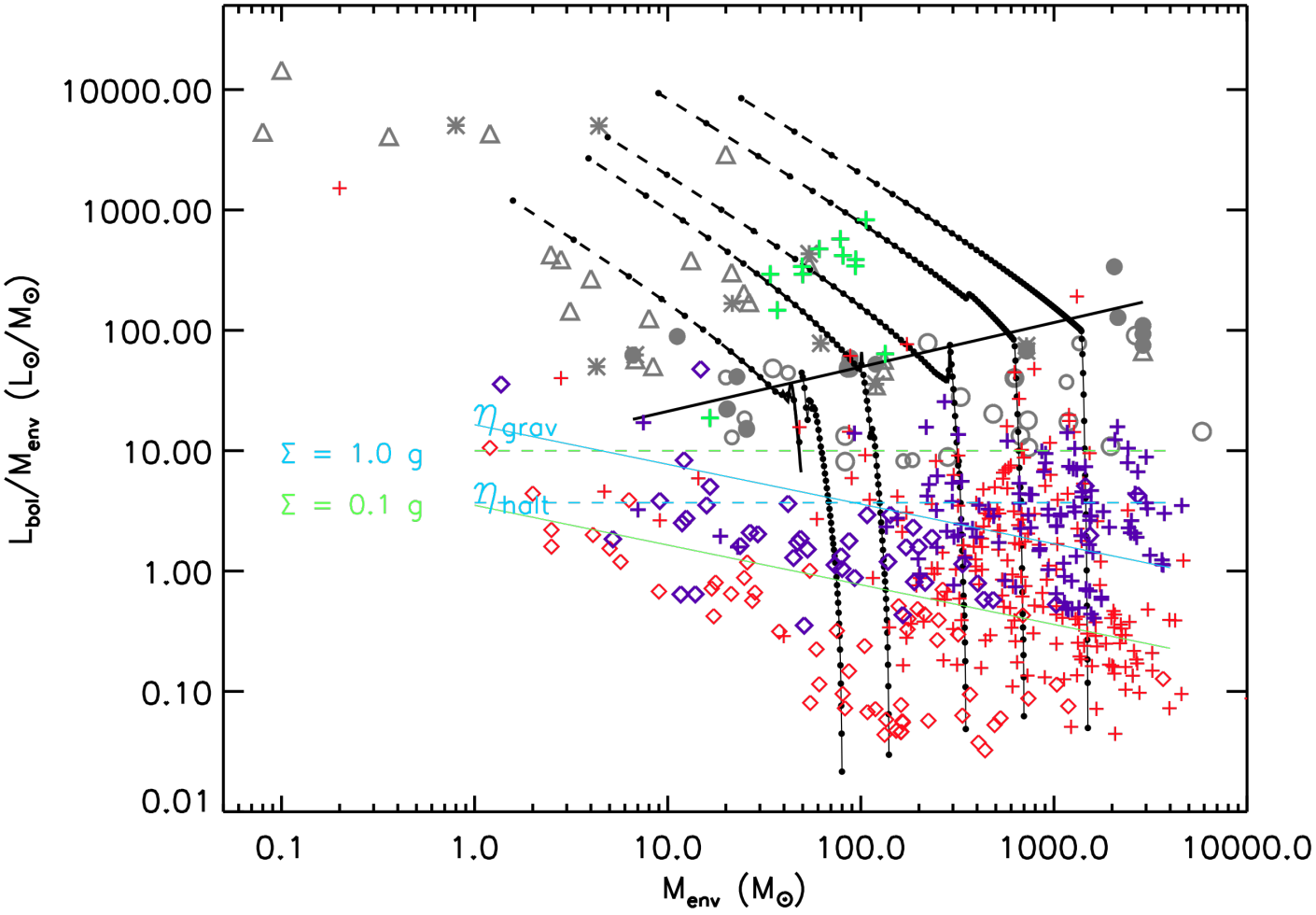
Hi-GAL in the context



First Papers

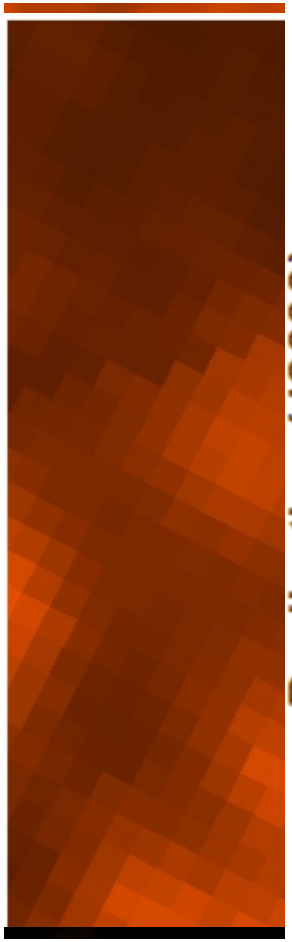
- (T-P2) Molinari+ : *The Hi-GAL Milky Way*
- (T-A5) Elia+ : *The Protostellar population in the Hi-GAL SDP fields*
- (T-A7) Peretto+ : *Temperature and column density structure in InfraRed Dark Clouds*
- (P1-06) Bally+ : *The W43 Mini-Starburst*
- Zavagno+ : *Triggered Star Formation in N49*
- (P1-23/P2-13) Martin+, (Joncas+) : *Morphological properties of the ISM*
- (P1-04) Bernard+ : *The ISM temperature and the ISRF intensity*
- (T-A7) Paladini+ : *Dust in HII regions*
- (P2-15) Wilcock+ : *Radiative transfer modeling of IRDCs*
- (P2-03) Russeil+ : *Distance determination for YSOs in the Hi-GAL SDP fields*
- (T-A2) Billot+ : *Clustered and diffuse Star Formation*
- (P1-12) Olmi+ : *The mass function of pre-stellar and protostellar cores*
- (P2-08) Paradis, Veneziani+ : *Temperature and β variation of dust in the ISM*
- (T-A7) Compiègne+ : *The contribution of Very Small Grains in the ISM budget*
- (P2-07) Pestalozzi+ : *The Galactocentric distribution of YSOs*
- (P1-09) Cesaroni+ : *The Infrared-Radio correlation in intermediate and massive YSOs*
- Beltràn+ : *The G29.9 Star Forming Region*
- (T-P6) Thompson+ : *Star Formation and FIR properties of IRDCs*

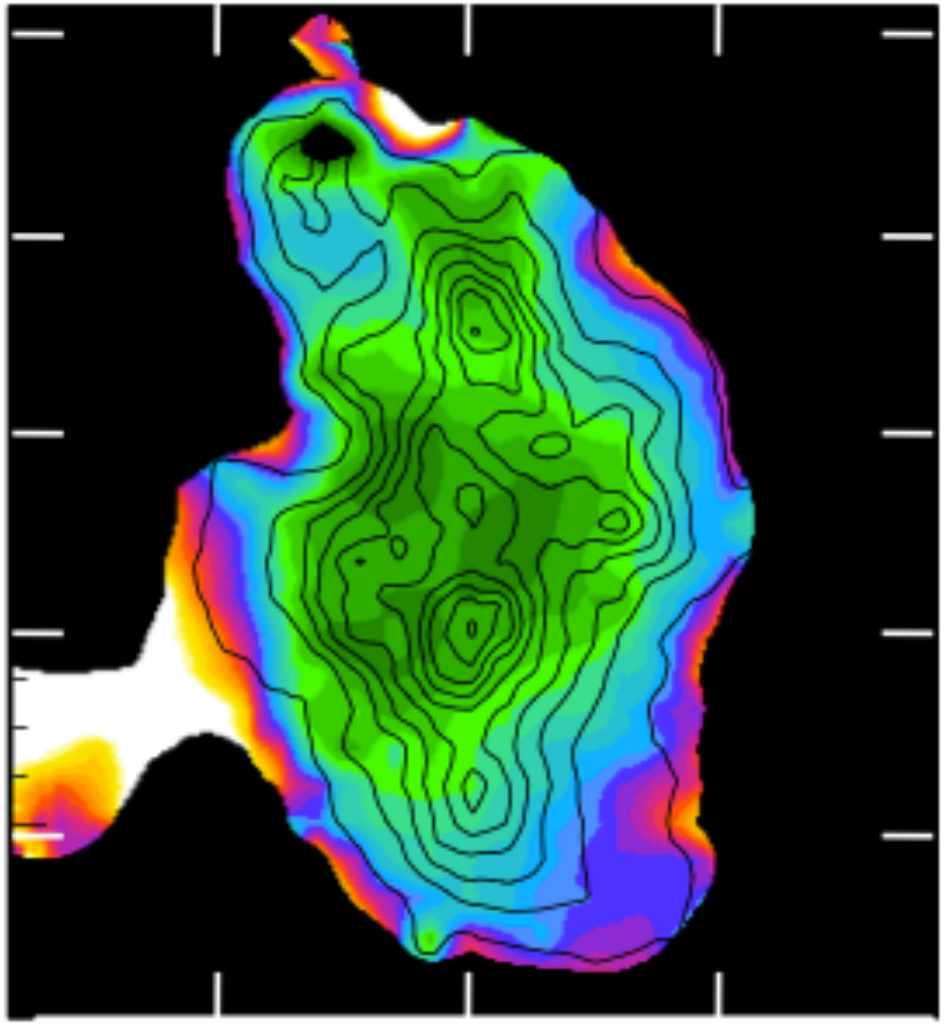
Star Formation

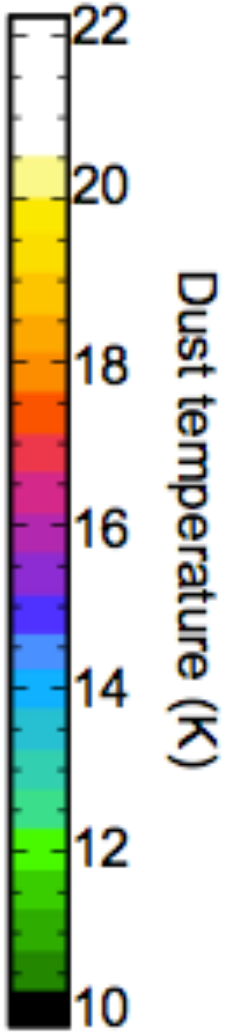


- Detailed 10^3-λ SED modeling
- YSO evolutionary classification from pre-stellar to ZAMS (Elia+ 2010)
- SF Timeline + SFR + SFH

IRDCs: Shadows…and Lights







PS 24

CS 70

CS 160

RE 250

RE 350

RE 500

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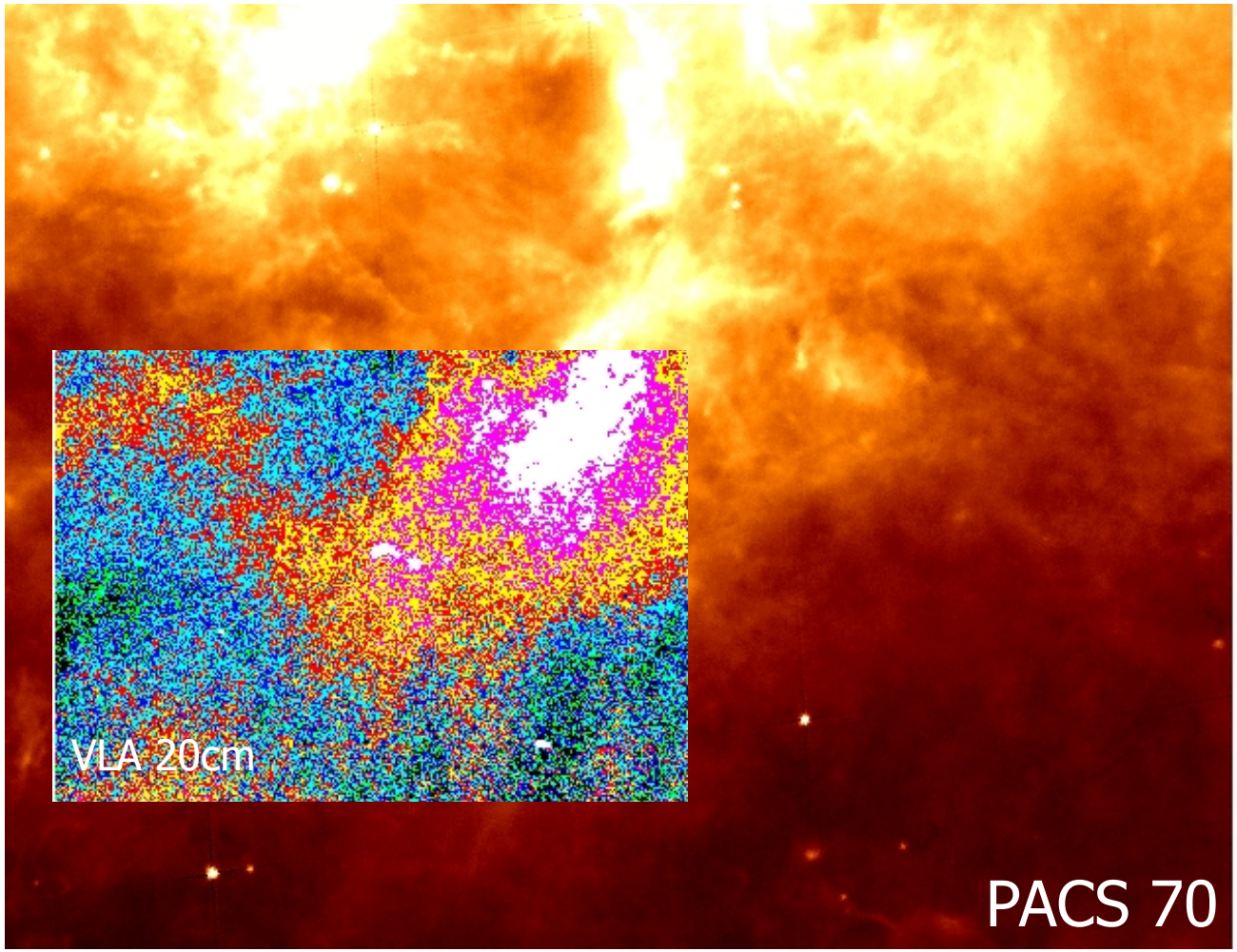
- The ea
- The lif

HII Regions

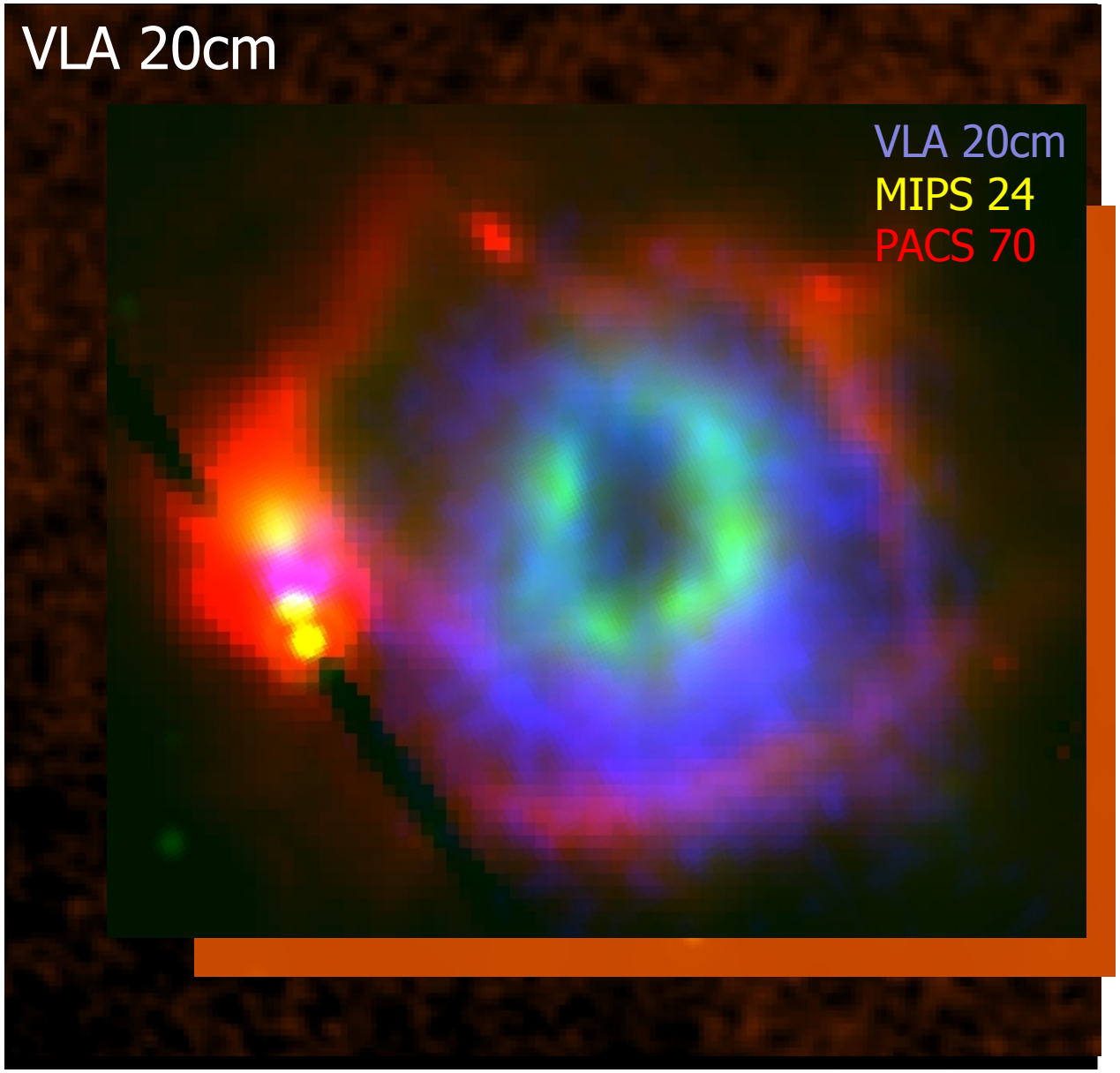


- SF → ISM feedback (Bally+ 2010)
- ISM compression and triggered SF (Zavagno+ 2010)
- Dust properties in HII regions (Paladini+ 2010)
- Dust properties at shock fronts

Bubbles

N49 – a small HII region from an OV star (Churchwell et al. 2006)

- Heated dust from HII compression
- Triggered star formation (Zavagno+ 2010)



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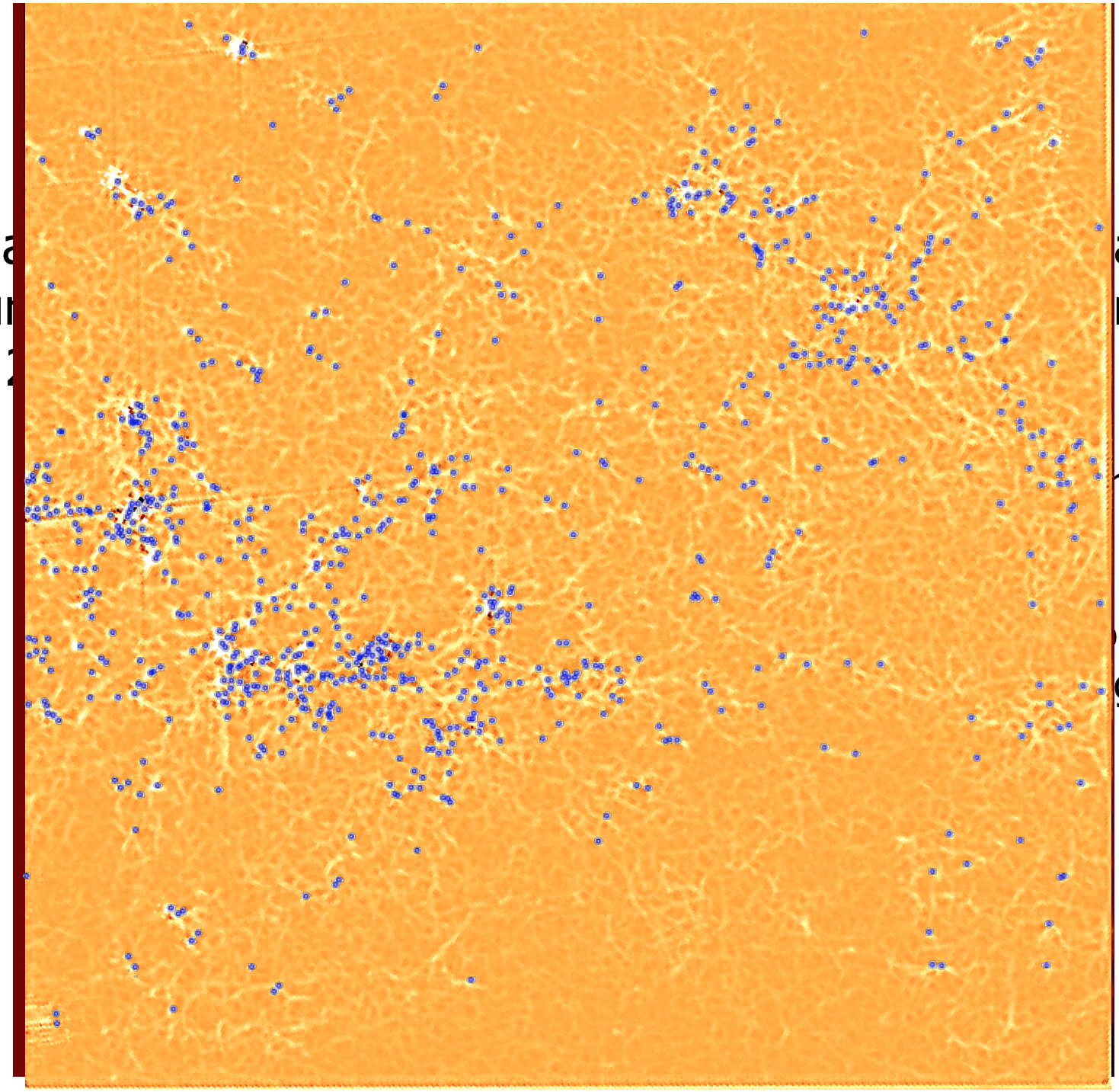

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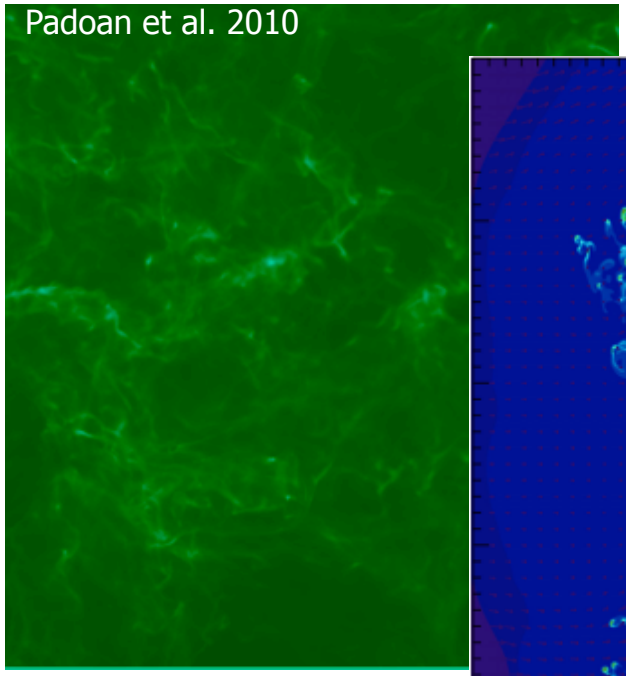
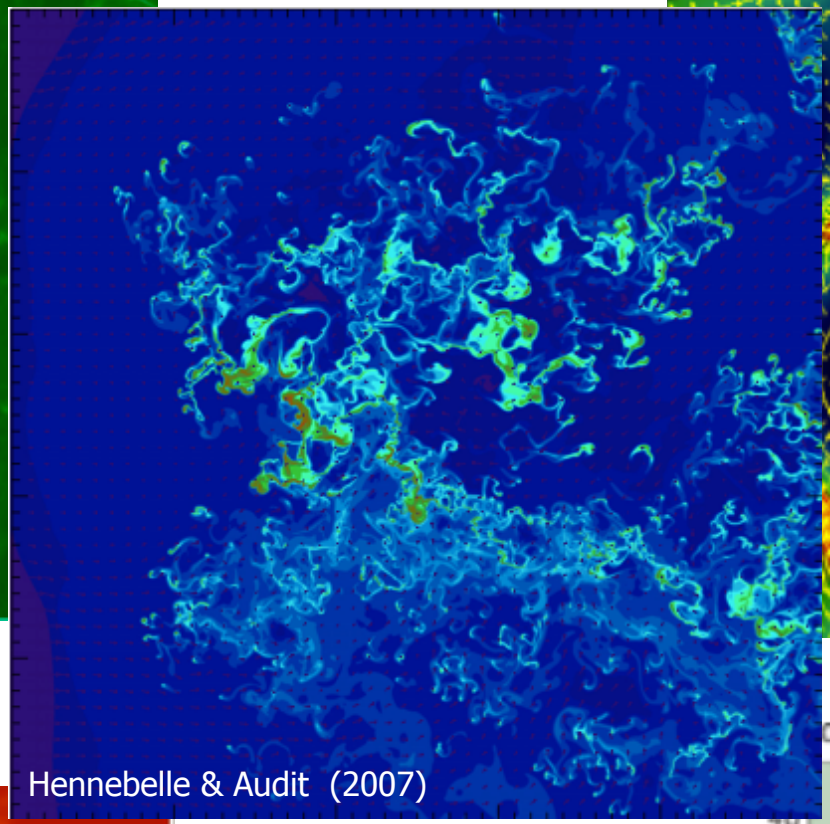
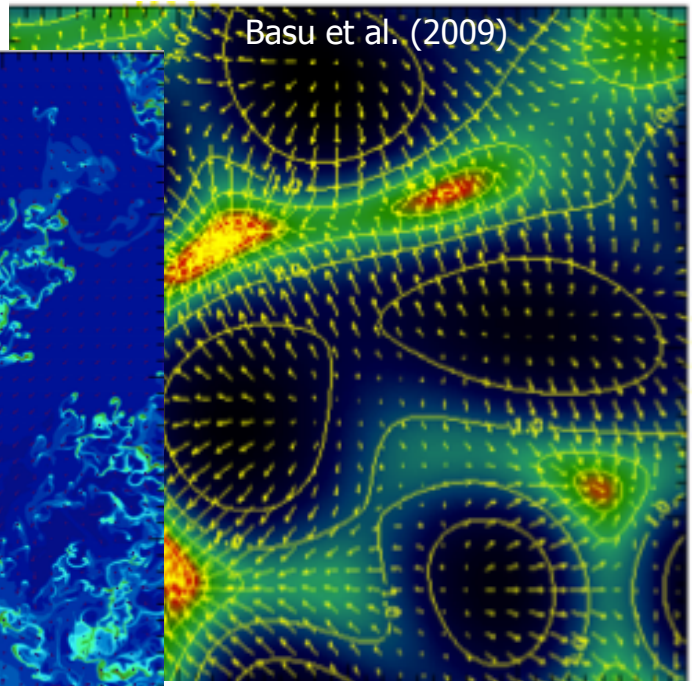
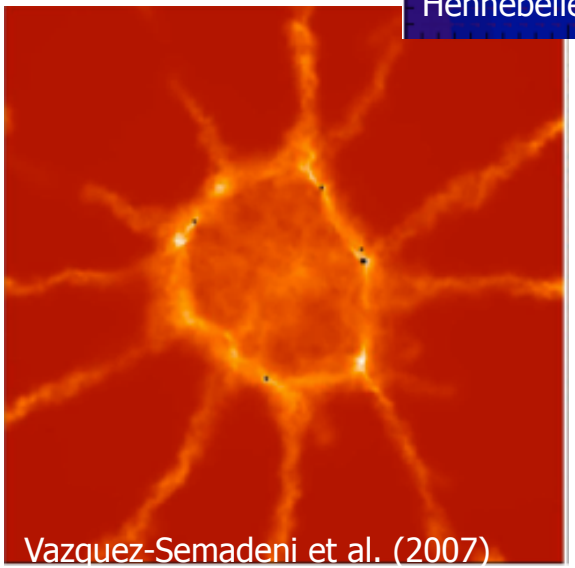
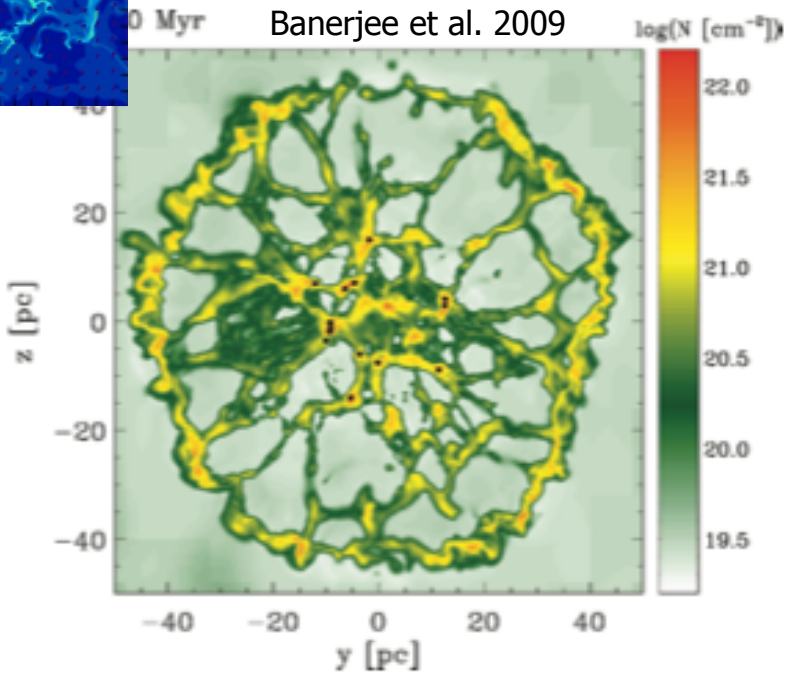








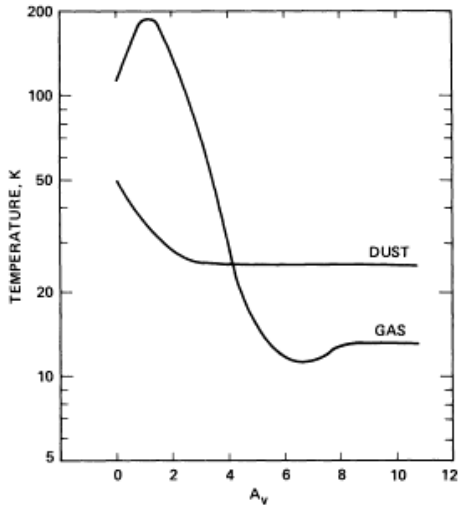
Filaments everywhere !!!!

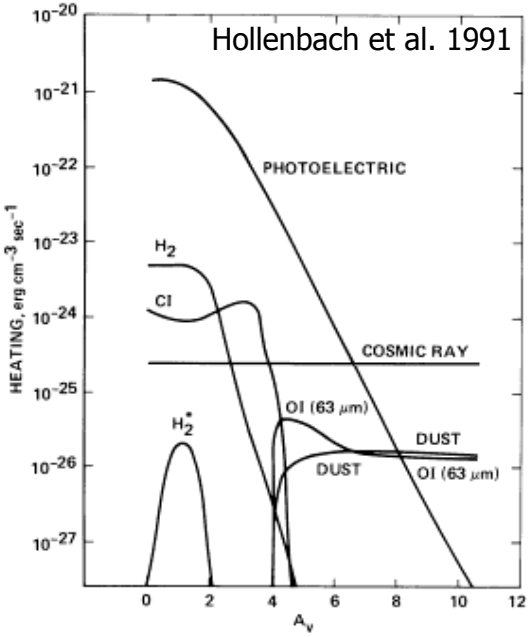


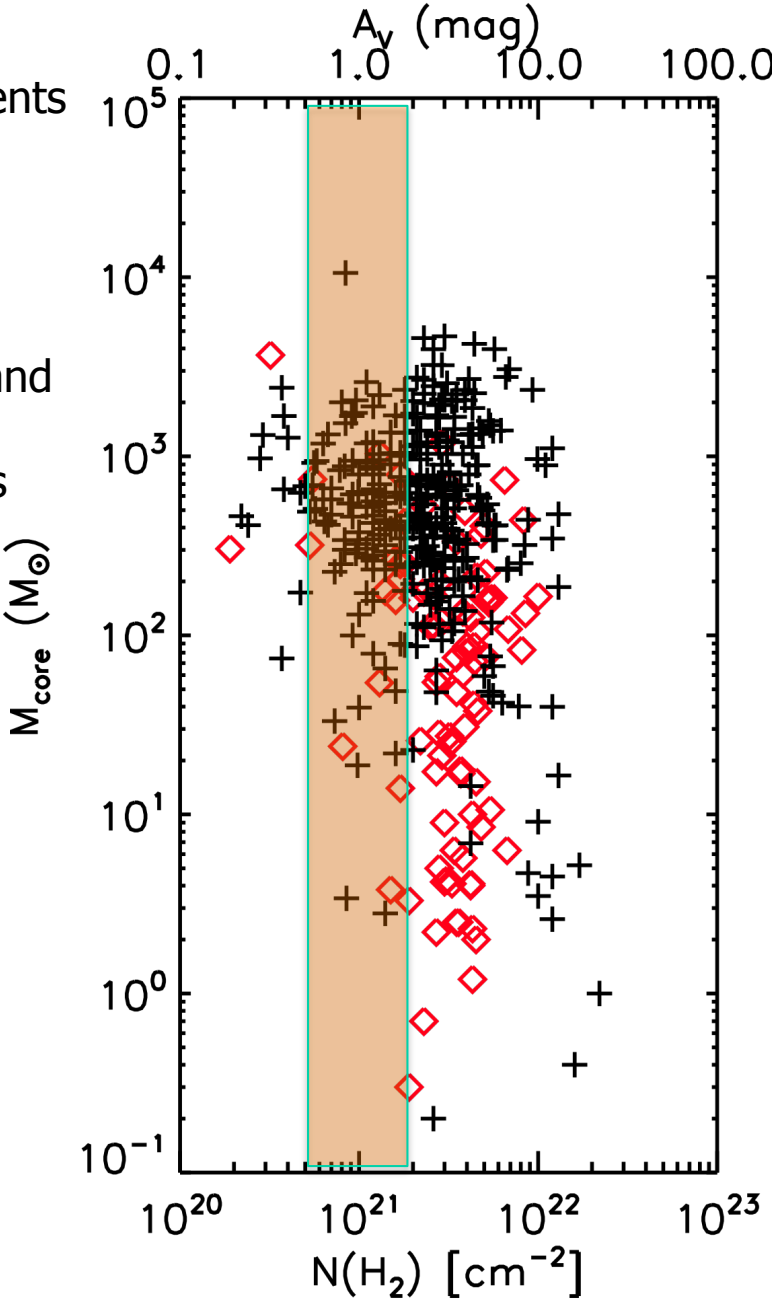
Filament and "cores"

- Compact sources are mostly found associated to filaments
- No apparent correlation between mass of compact sources and the column density of the hosting filament
- Strong suggestion of a threshold effect around $A_V \approx 1$

- $A_V \approx 1$ is where H_2 self-shielding starts to be effective and photoelectric heating rate starts dropping
- Rapid imbalance between heating and cooling triggers instabilities: thermal, gravitational

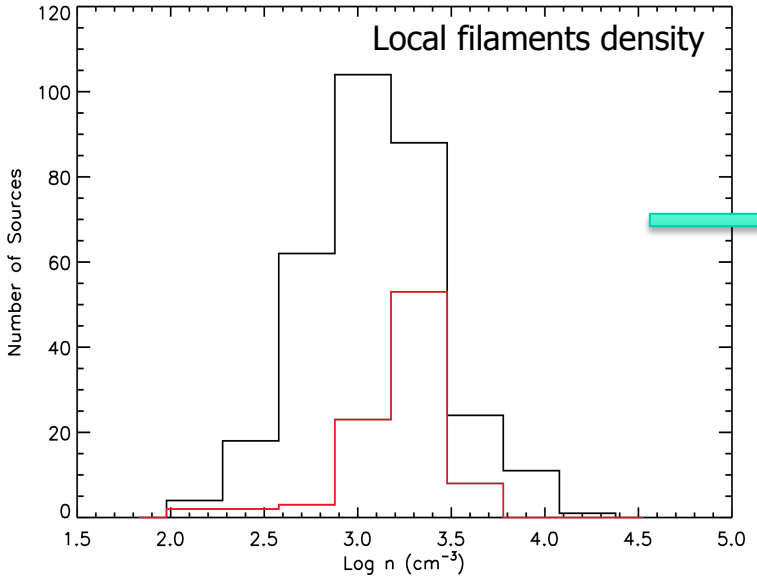


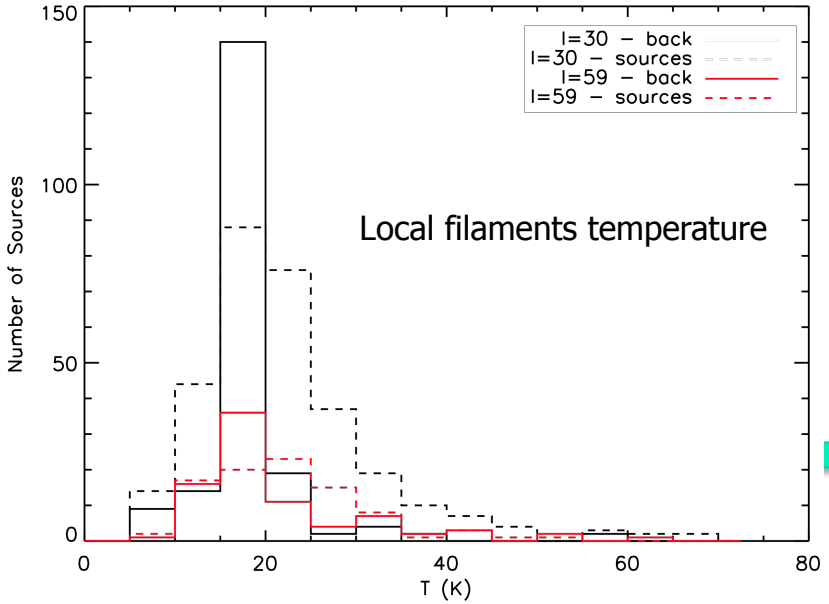




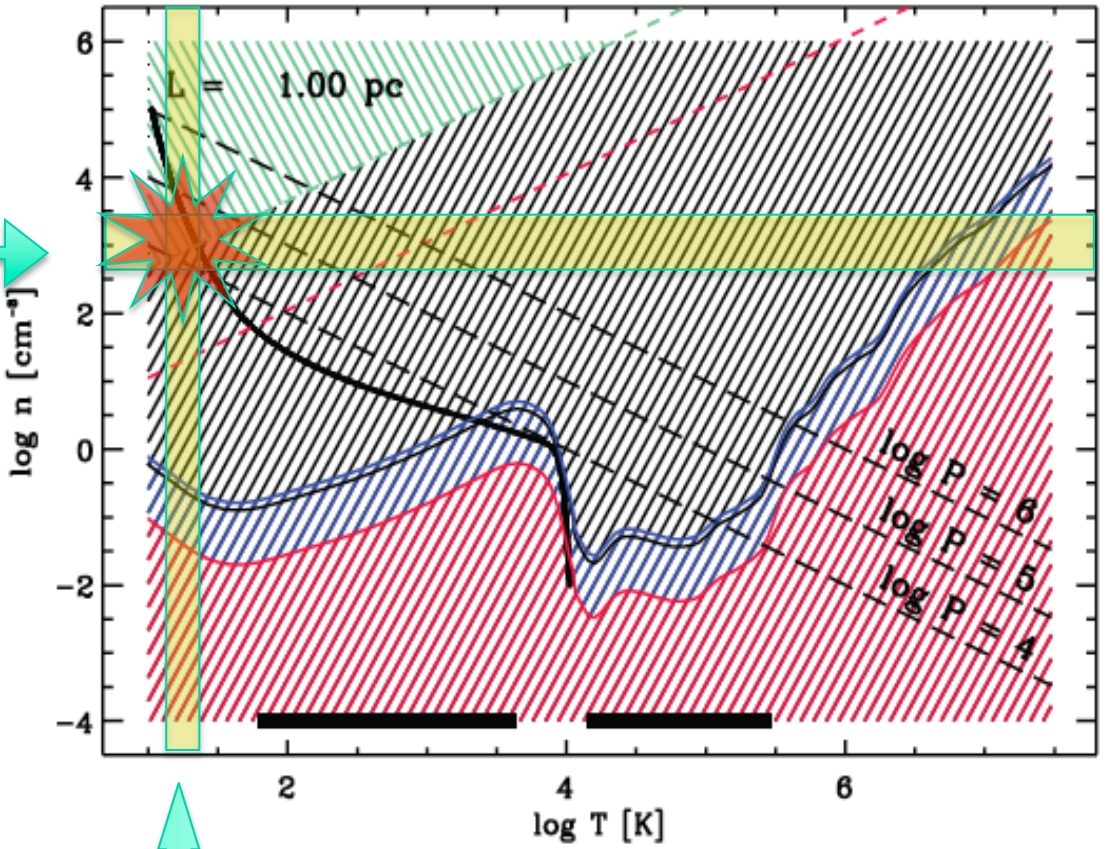
Filament fragmentation

Preliminary filament section measurements in the l=59° region give values between 0.5 and 1pc.



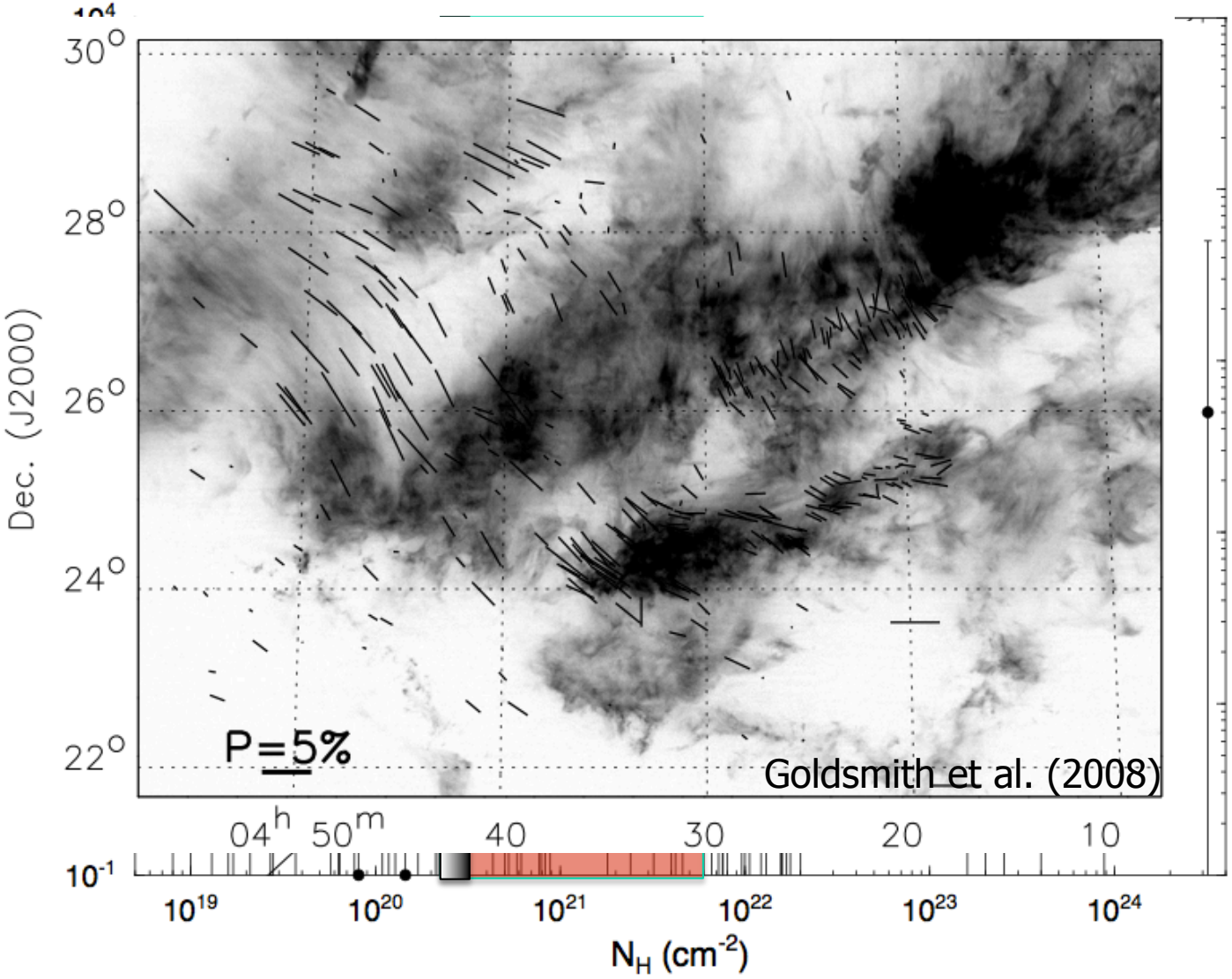


Heitsch et al. 2008



Speculation: filaments form from diffuse ISM and grow in column density until at $A_V \approx 1$ heating and cooling go out of balance. Gravitational instability comes in and high-density fragments start to appear.

Filament fragmentation

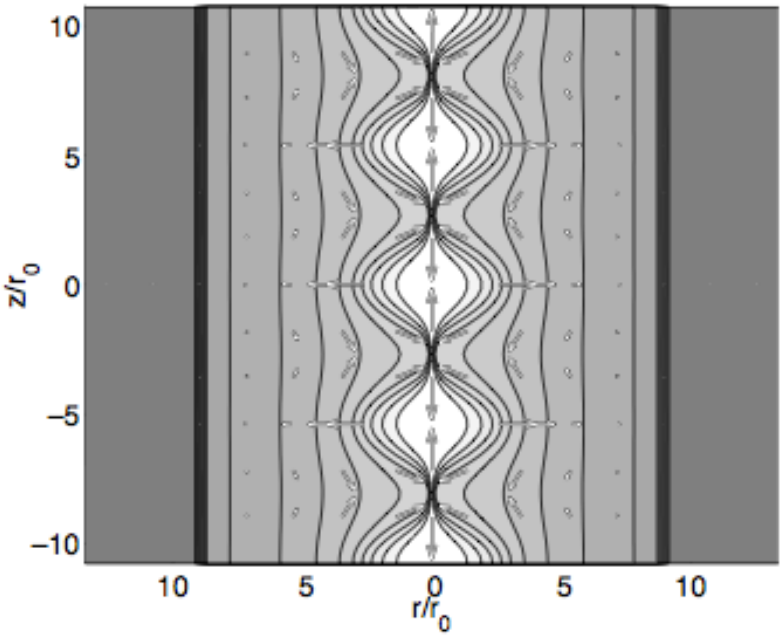


- We have increasing evidence that that low column density material may be magnetically supported, while higher density structures are supercritical
- High-density cores show increasing values of the magnetic field, compatible with gravitational collapse not dominated by B (Crutcher et al. 2010)

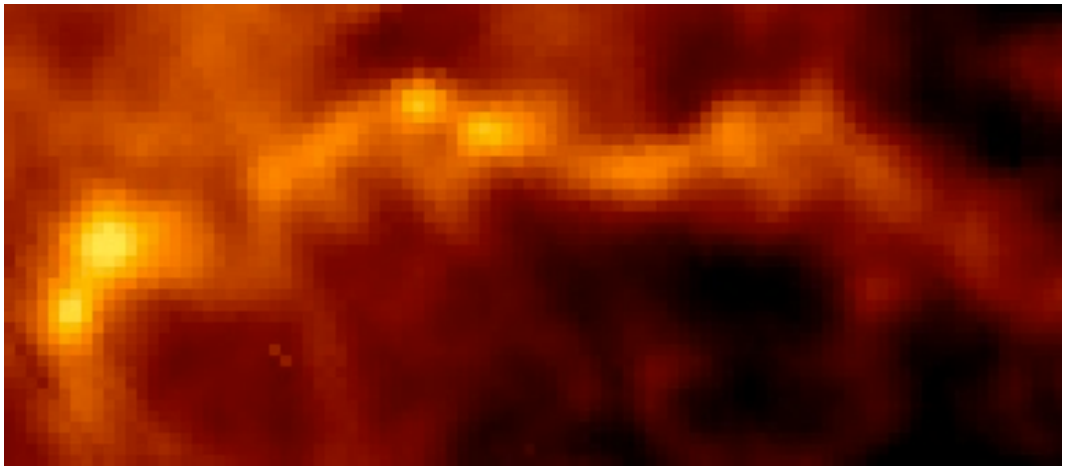
Filaments hosting compact sources span a $N(H_2)$ range which is compatible with structures losing magnetic support and starting to collapse

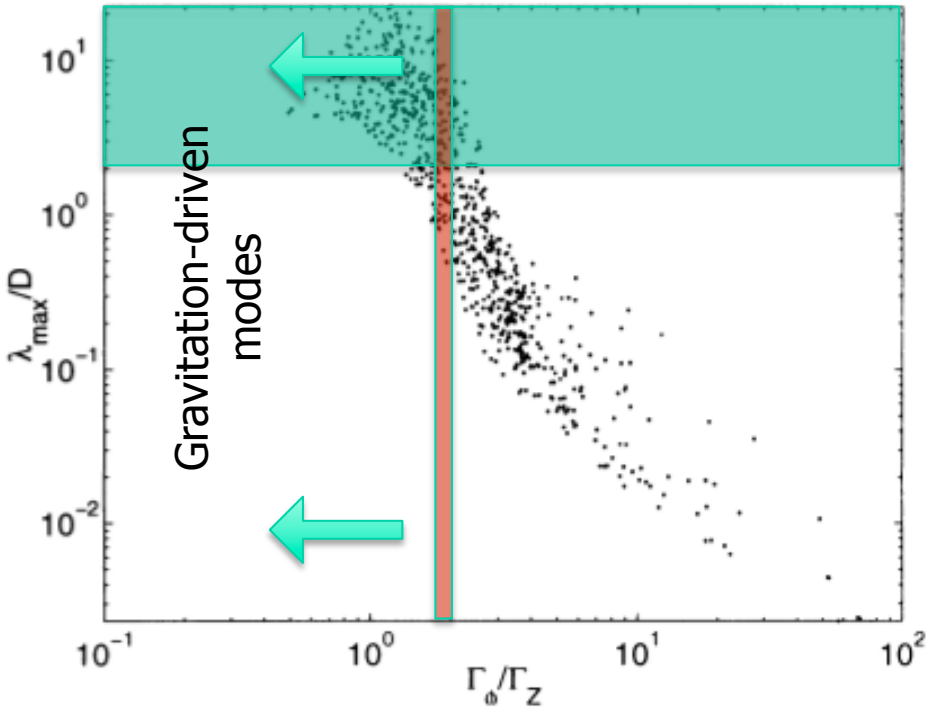
Filament fragmentation

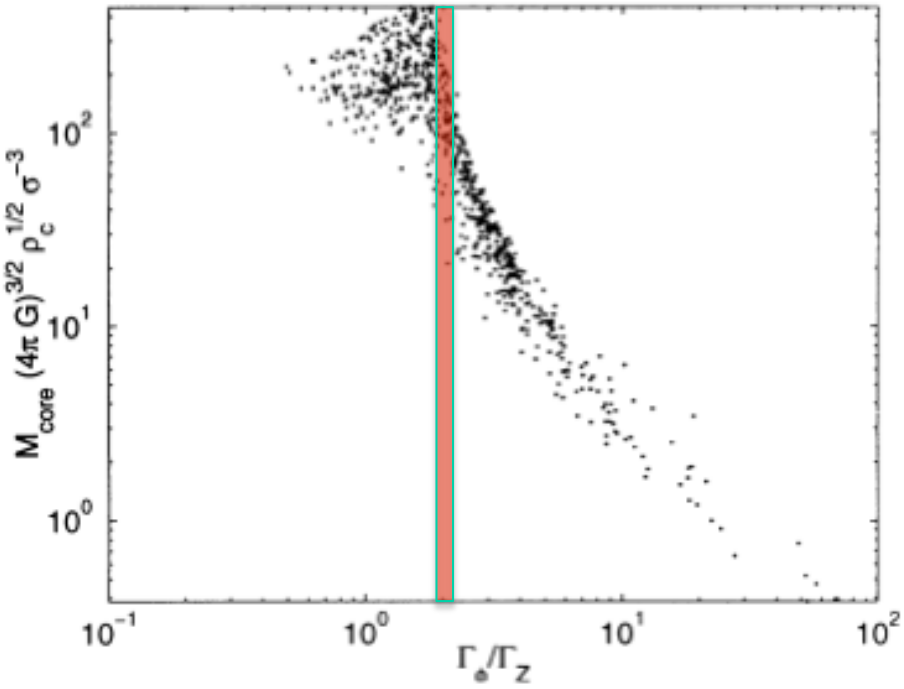
Fiege & Pudritz 2000



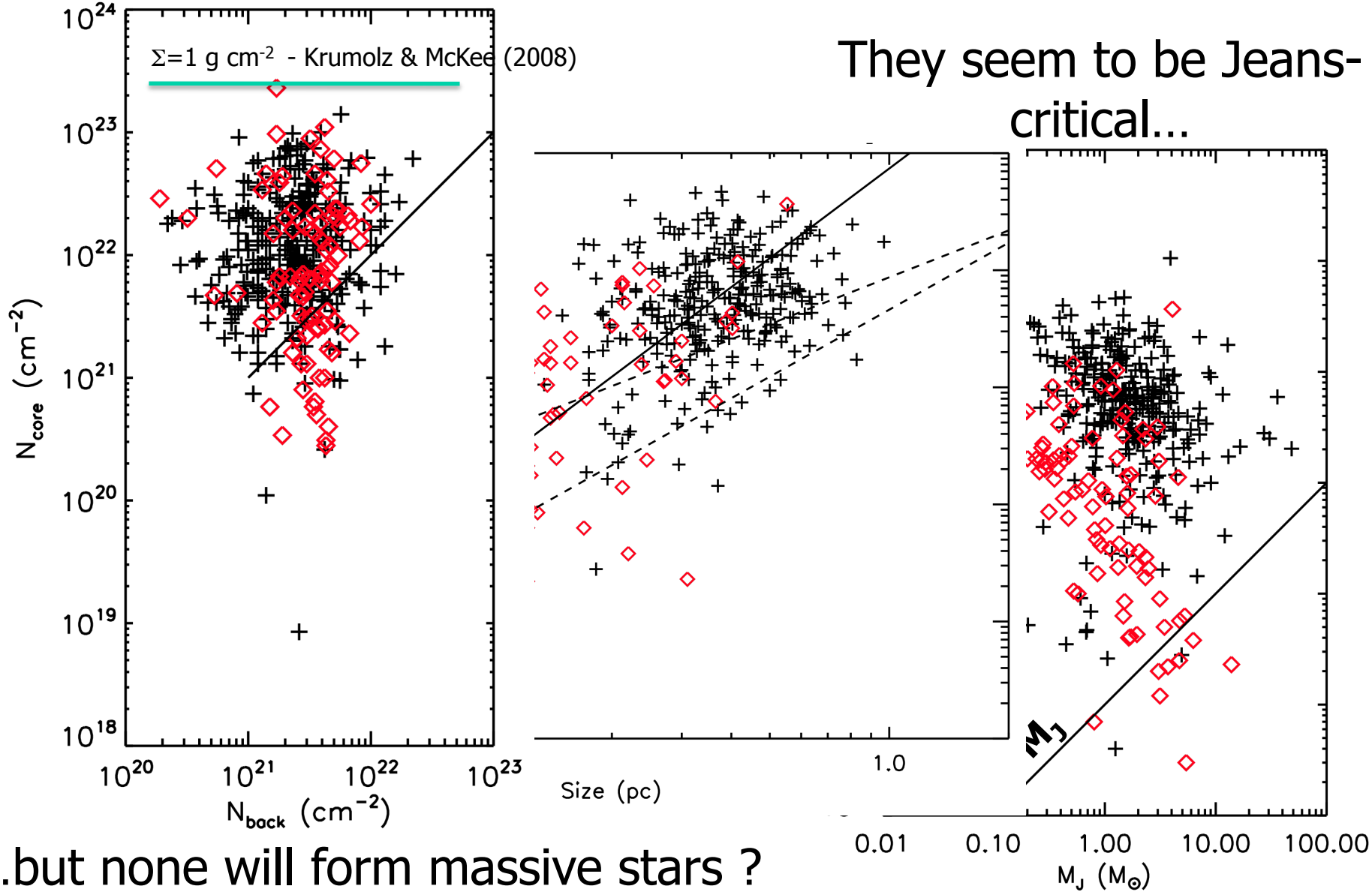
Growth of gravitational instabilities and fragmentation in filaments surrounded by helical magnetic fields







Nature of the compact sources



They seem to be Jeans-critical...

...but none will form massive stars ?

(see pres. D. Elia)

First conclusions

- Compact dust condensations are preferentially found in association with dusty filamentary structures
- Compact sources seem to appear where a threshold in column density is exceeded: this seems to be of the order of $A_V \approx 1$
  - It is compatible with the regime for the onset of gravitational instabilities which fragment the filaments into chains of compact structures
  - It is compatible with typical column densities where structures are no longer supported by magnetic fields
- The diffuse ISM organizes into filaments which are the "incubators" where compact protostellar/protocluster-generating structures are prepared
- Clumps appear for the most part to be Jeans-critical and hence compatible with collapse, but interestingly enough their column density would not seem sufficient to form massive stars…although L/M would suggest the opposite.
- The transition from filaments to Jeans-unstable compact structures seem to be then quite fast, (preliminary, tentatively,…) suggesting that precursors of massive star forming regions (the analogue to the low-mass pre-stellar cores) may not exist.

General Conclusions

- The early Hi-GAL early science production (out of two tiles) is a success for the project.

- The Hi-GAL SDP program proves that the quality of the data and the data processing approach will allow us to effectively attack the science goals (…and maybe fulfill them)

- Hi-GAL is fully confirming its promise to become one of the longer-lasting legacies of the HERSCHEL satellite, with extraordinary potential for serendipitous science.

The future is bright

- Follow-up proposals (IRAM, JCMT, SMA) are already awaiting hopefully positive outcome, and more will follow in years to come….starting with ALMA
- Herschel Spectroscopy follow-up is an obvious development in many areas

At the end of 2010… the outer Galaxy will still keep its secrets…

…but our hope for the end of the mission is…

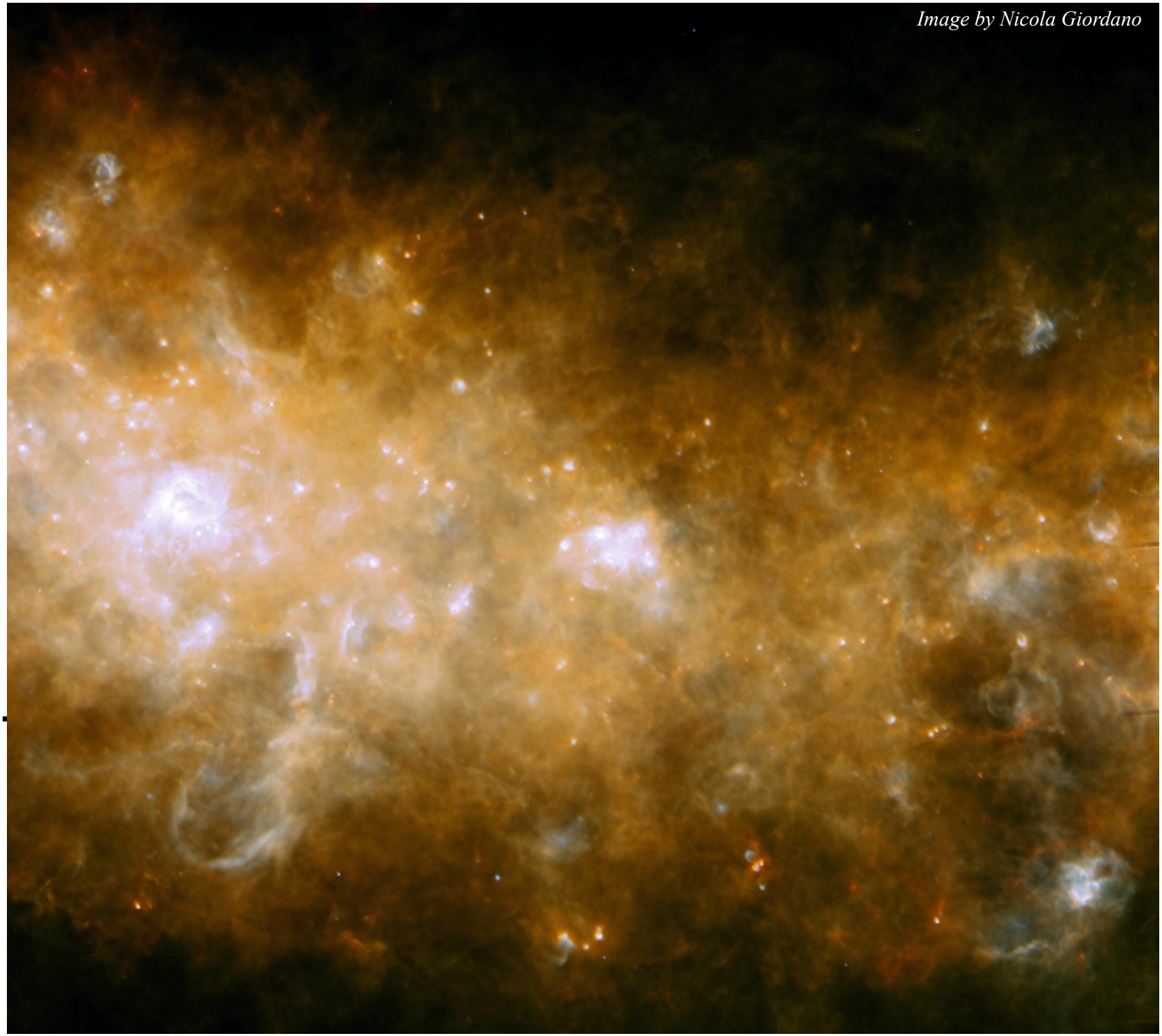
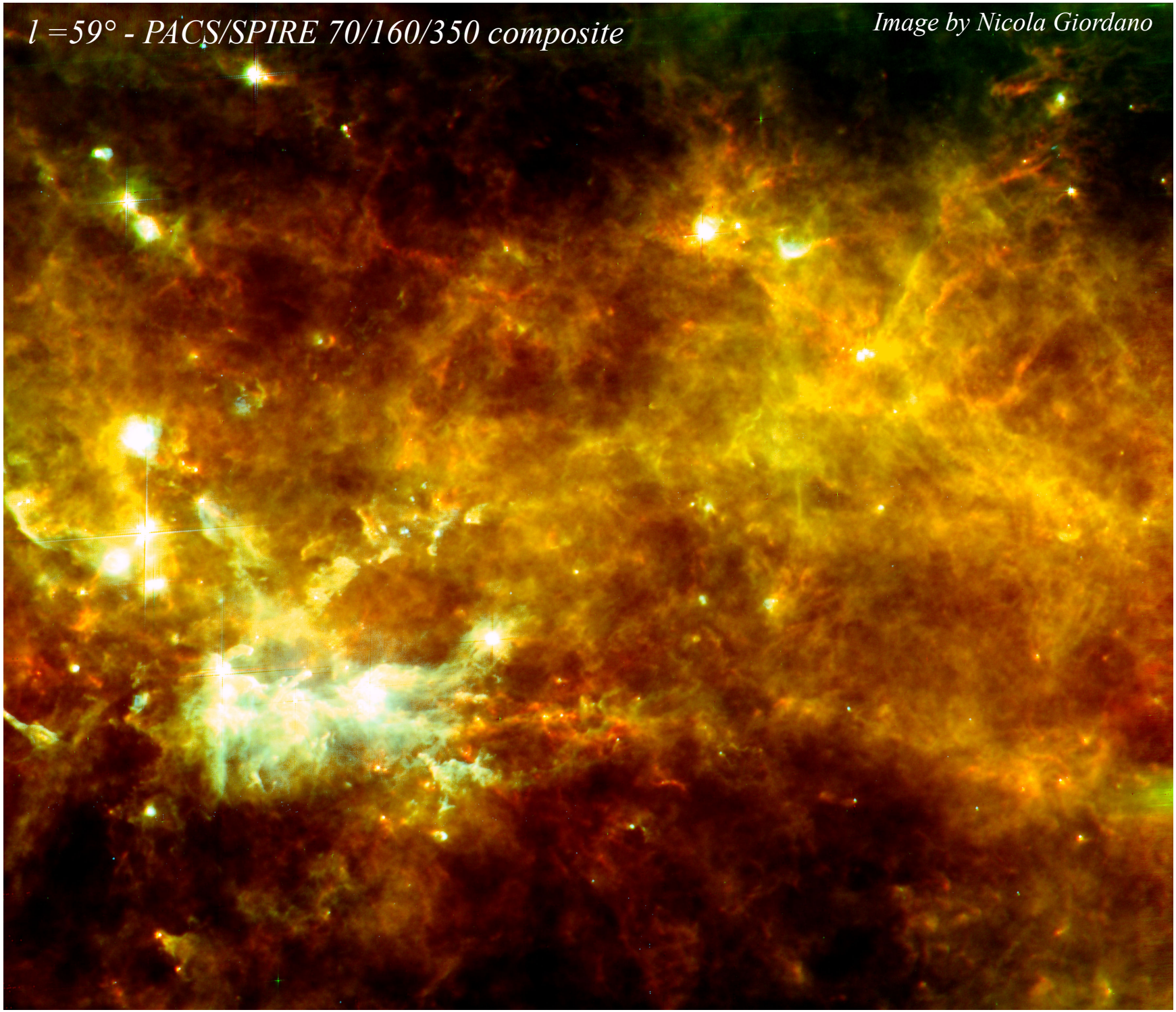


Image by Nicola Giordano


l =59° - PACS/SPIRE 70/160/350 composite
Image by Nicola Giordano