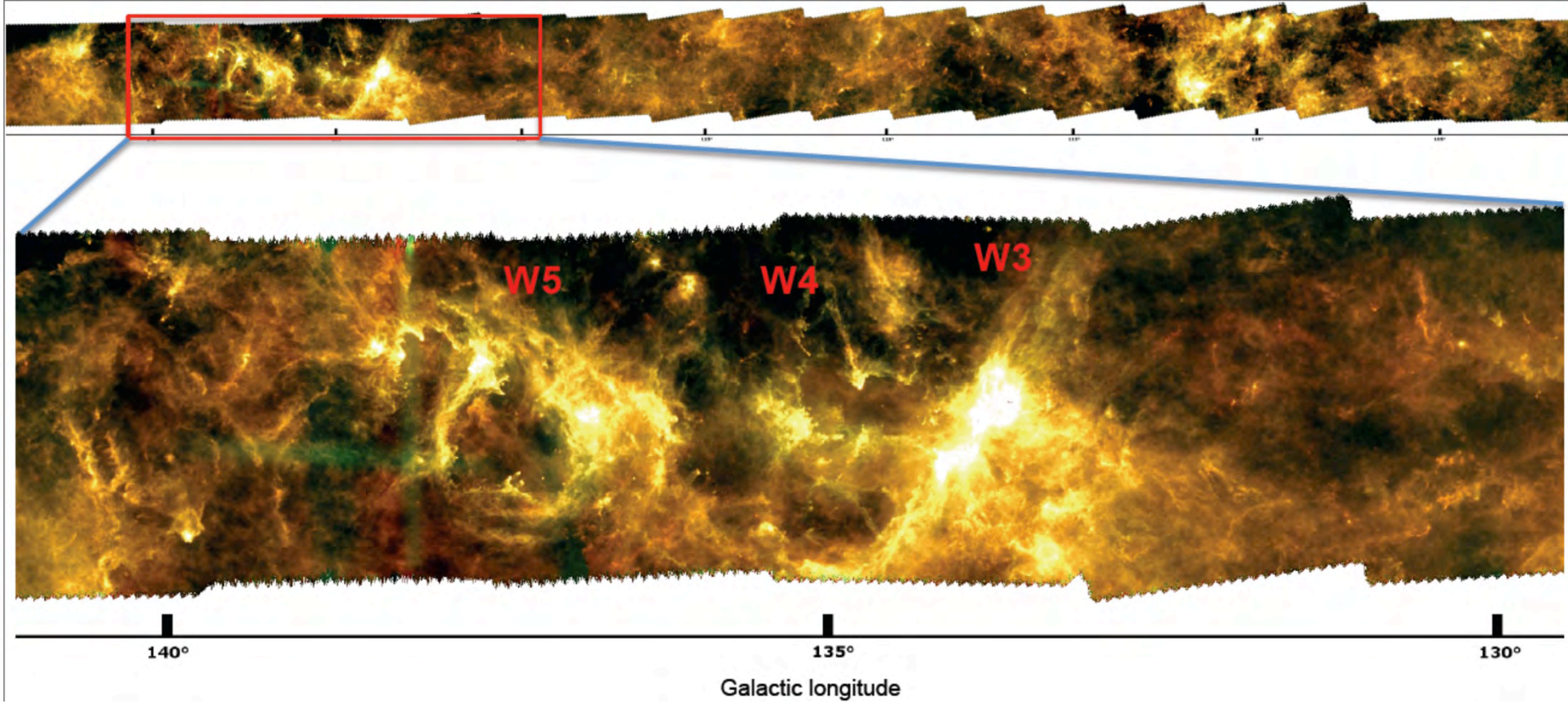
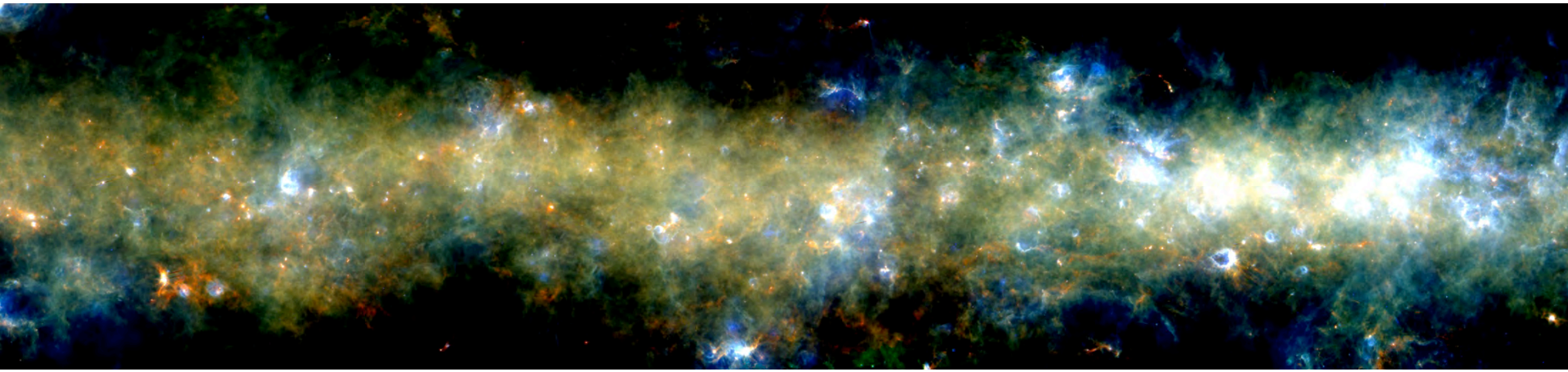


A Herschel view of massive star formation on the outer Galaxy

Manuel Merello
IAPS-INAF

Sergio Molinari, D. Elia, A.M. Di Giorgio, E. Schisano, S. Pezzuto, M. Benedettini,
Hi-GAL collaboration

Thanks to the last generation of Galactic Plane Surveys



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

Hi-GAL

The Herschel infrared Galactic Plane Survey

Simultaneous 5-bands (*70-160-250-350-500*μm) continuum mapping of 720 sq. deg. of the Galactic Plane ($|b| \leq 1°$) (Molinari+2010b)

With almost 900 hours observing time is the largest OPEN TIME Herschel KP

Galaxy-wide Census, Luminosity, Mass and SED of dust structures at all scales from massive YSOs to Spiral Arms

The entire Plane has been observed. Images access (with registered astrometry and absolute flux calibration) and compact source catalogues for longitudes between 65° and 290° (full Inner Galaxy) will come on line soon.

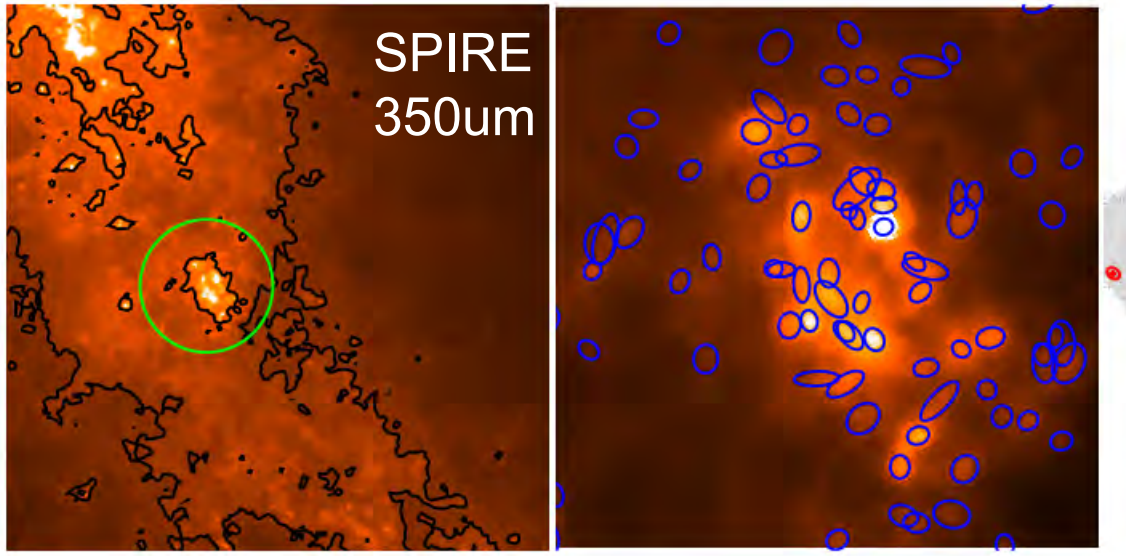
Hi-GAL is statistics: Huge output…

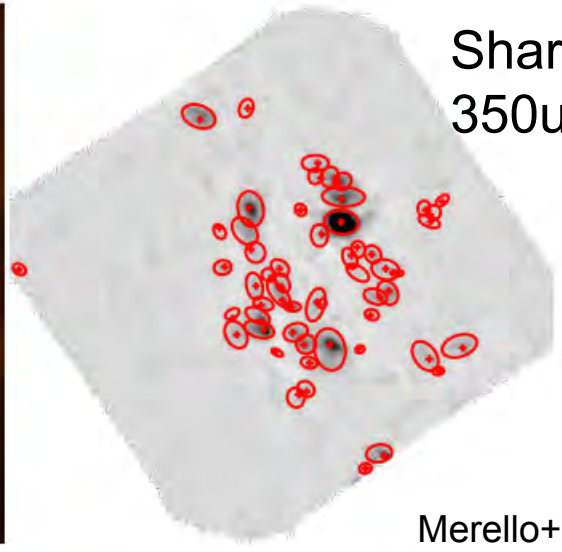
•First-generation Photometric Catalogues created using CuTEx package (Molinari+11) for the inner Galaxy (done several times….)

•Naïve band-merging produces a catalogue of **519400** entries (Molinari+ 2015, in prep)

•Clump catalogue downselected filtering “nice” SEDs with at least three adjacent counterparts 160-500μm yields **99180** entries

Band	$N_{sources}$
PACS-70μm	122 971
PACS-160μm	292 051
SPIRE-250μm	280 258
SPIRE-350μm	161 855
SPIRE-500μm	85 880





Merello+2015

Hi-GAL is statistics: Huge output…

Source extraction / photometry

Using 2nd derivative (Molinari et al. 2010) | Photometry catalogues | Band merging

VLSR extraction

^{13}CO cubes from GRS and Exeter-FCRAO CO GP Survey, NH_3 observations

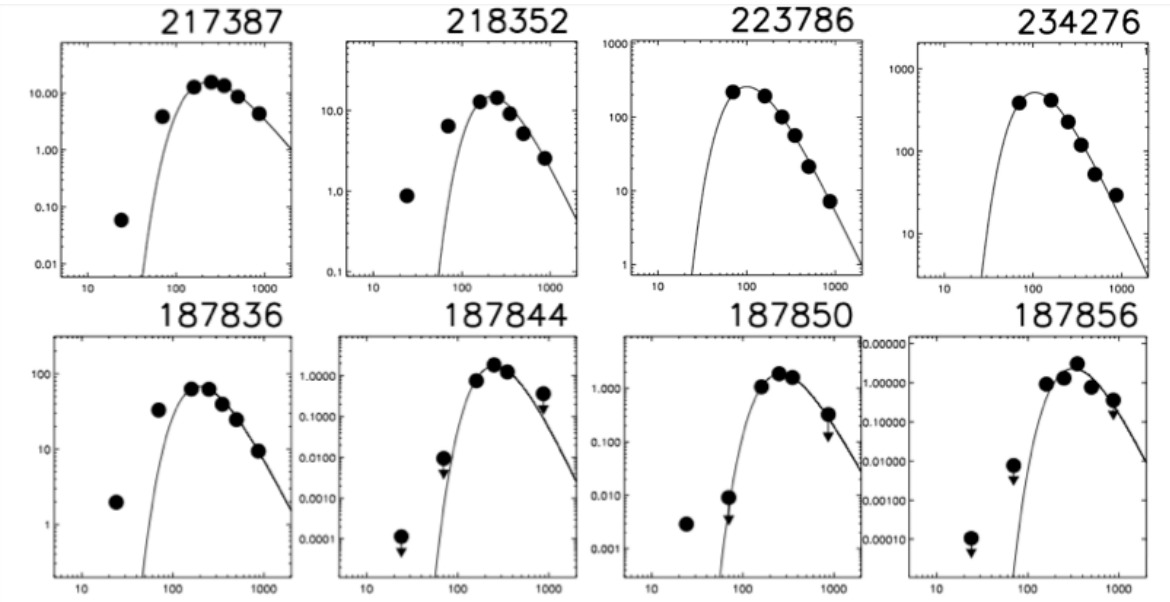
Kinematic distance calculation

Using rotation curves (Brand & Blitz 1993, Reid et al. 2008)

Distance recommendation

Extinction maps | Known distances | HI absorption

Russeil+ 2010



- For the 99180 inner Galaxy sources with counterparts in at least three bands, we augment SED coverage with ATLASGAL, BGPS, MIPSGAL, WISE, MSX
- A first set of distance estimates (with different levels of reliability) has been carried out excluding l<14° and l>350°, yielding T, L, M and size, for **56656** sources

Elia+ 2015, in prep

Results from Hi-GAL survey: Tips of the Galactic Bar

(Veneziani et al., submitted)

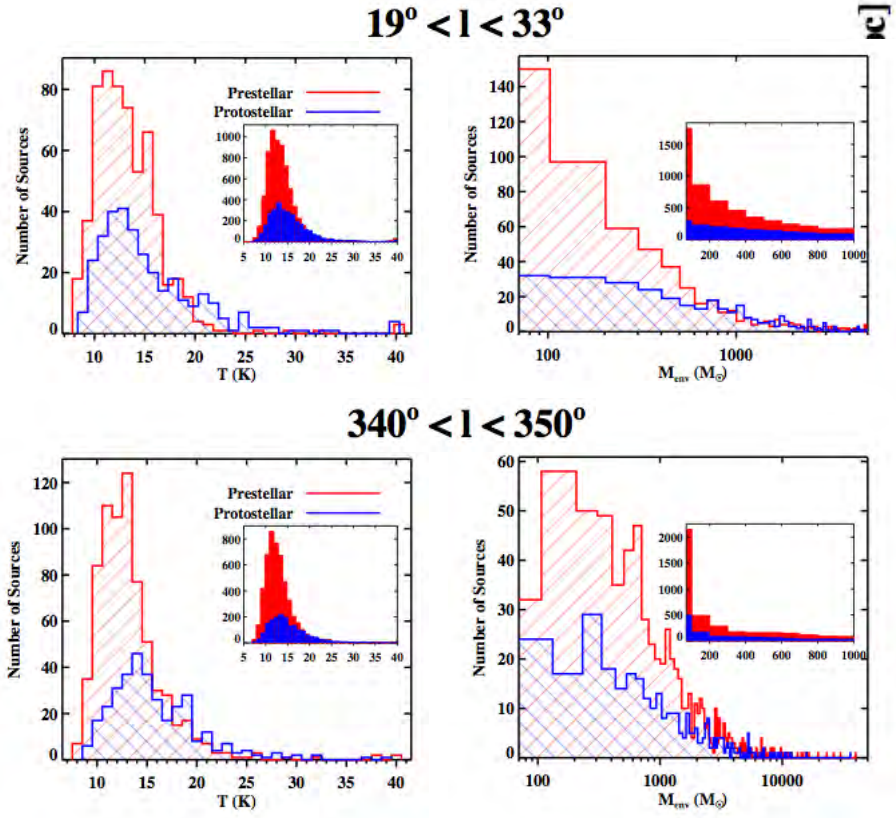
19 < *l* < 33, 340 < *l* < 350

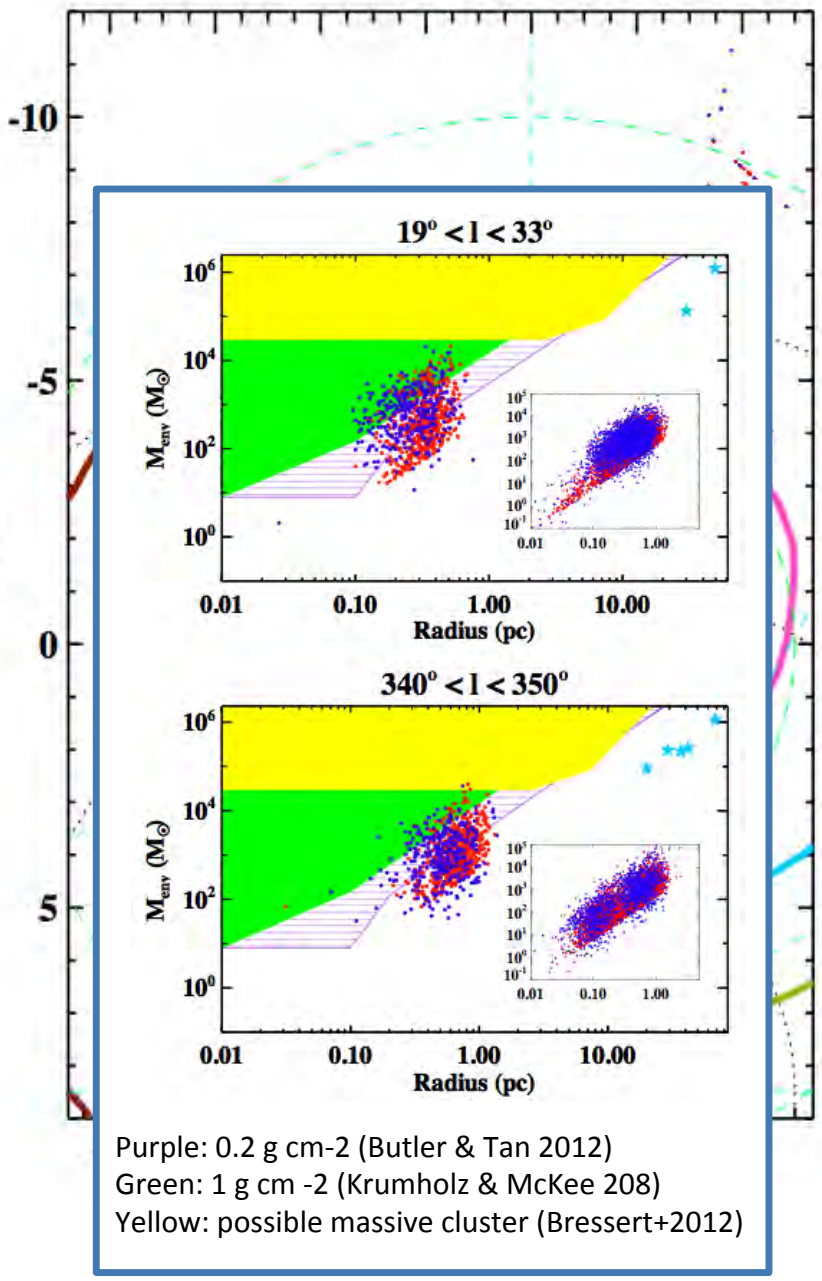
Prestellar candidates (without 70 um)

Protostellar candidates (with 70 um)

(IV Q) NANTEN 12CO(2-1) (Mizuno & Fukui 2004)

(I Q) FCRAO GRS 13CO(2-1) (Jackson+2006)



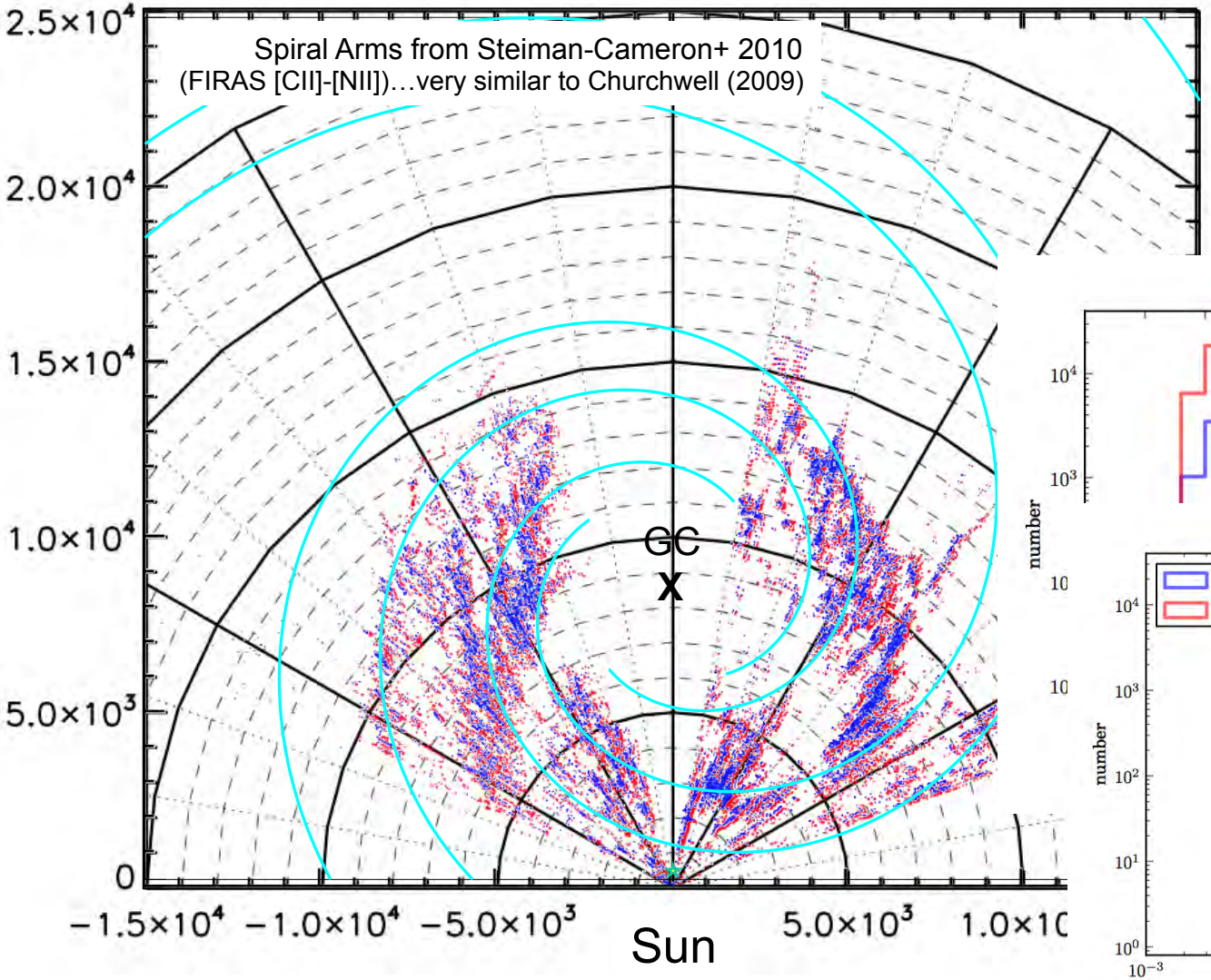


Purple: 0.2 g cm-2 (Butler & Tan 2012)

Green: 1 g cm -2 (Krumholz & McKee 208)

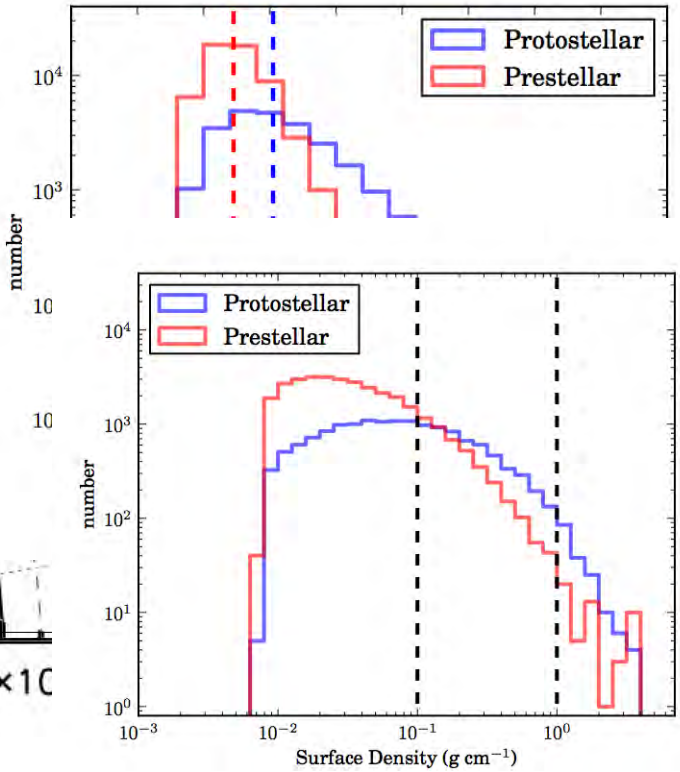
Yellow: possible massive cluster (Bressert+2012)

Global distribution of star formation from Hi-GAL

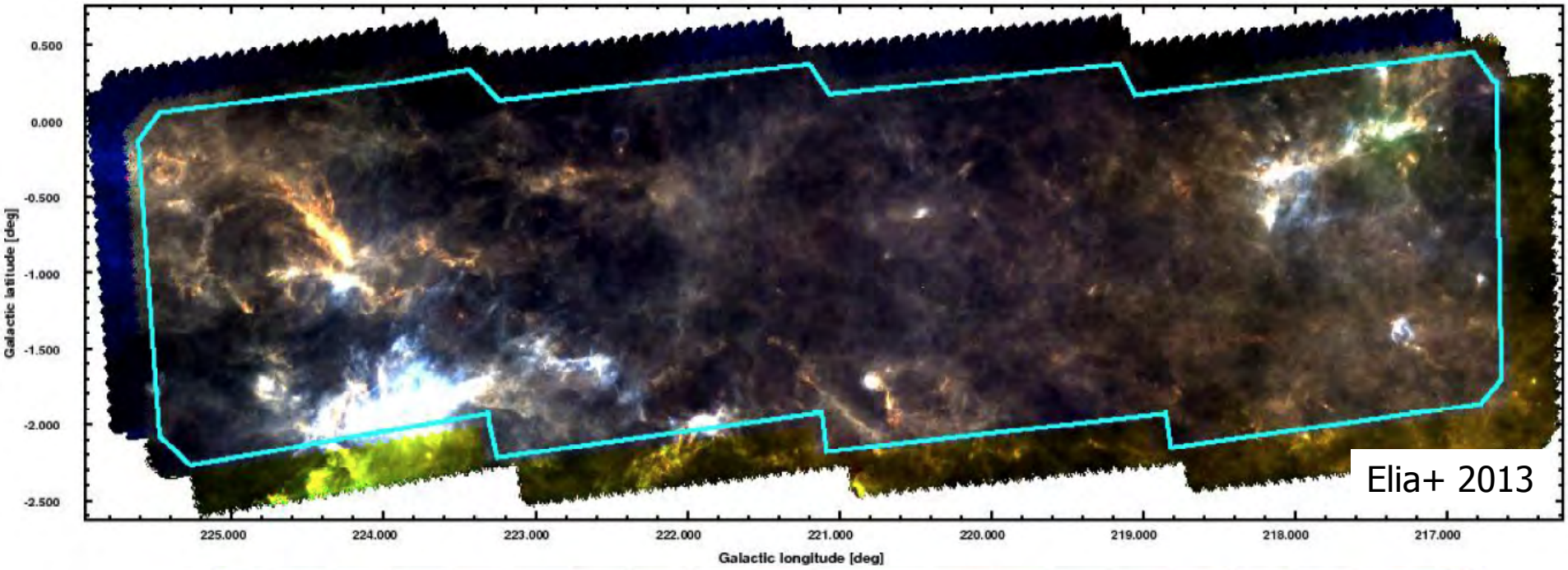


- Prestellar (no 70μm)
- Protostellar (70μm)

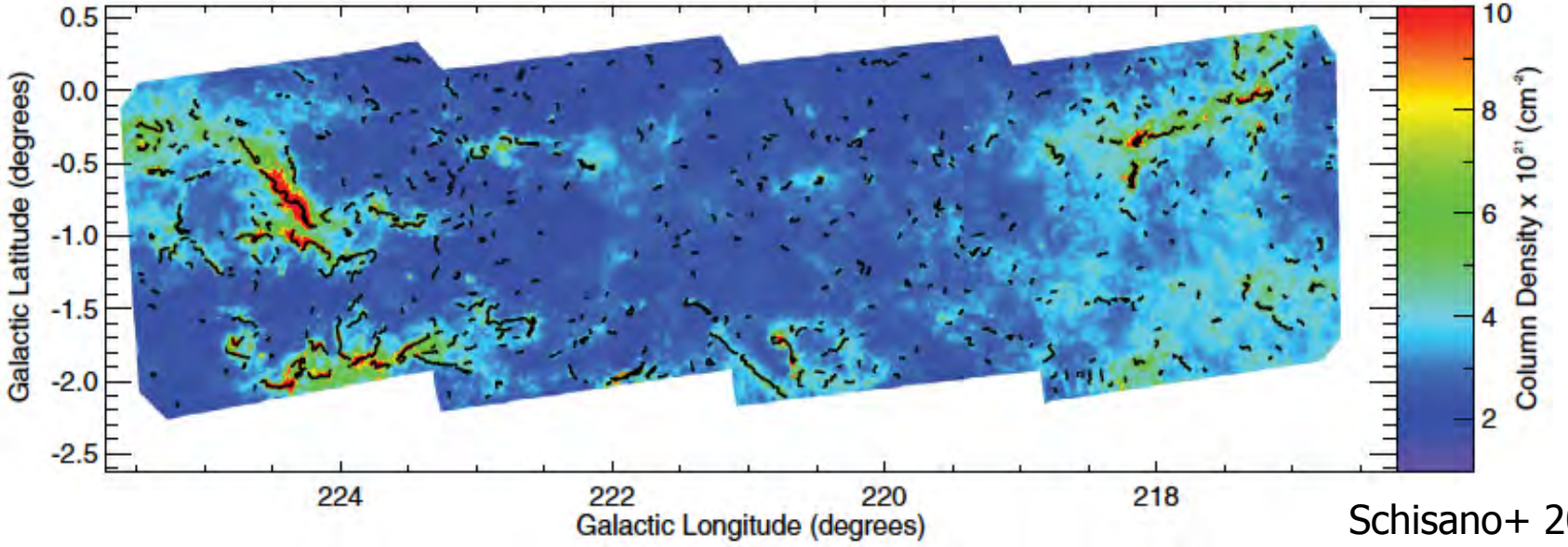
Molinari+2015, in prep



Herschel view of the outer Galaxy (III Q)

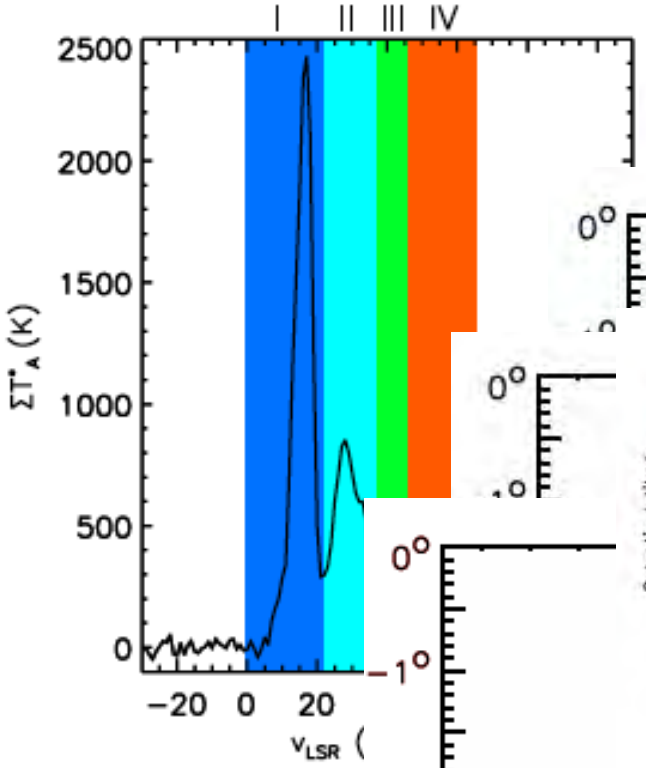


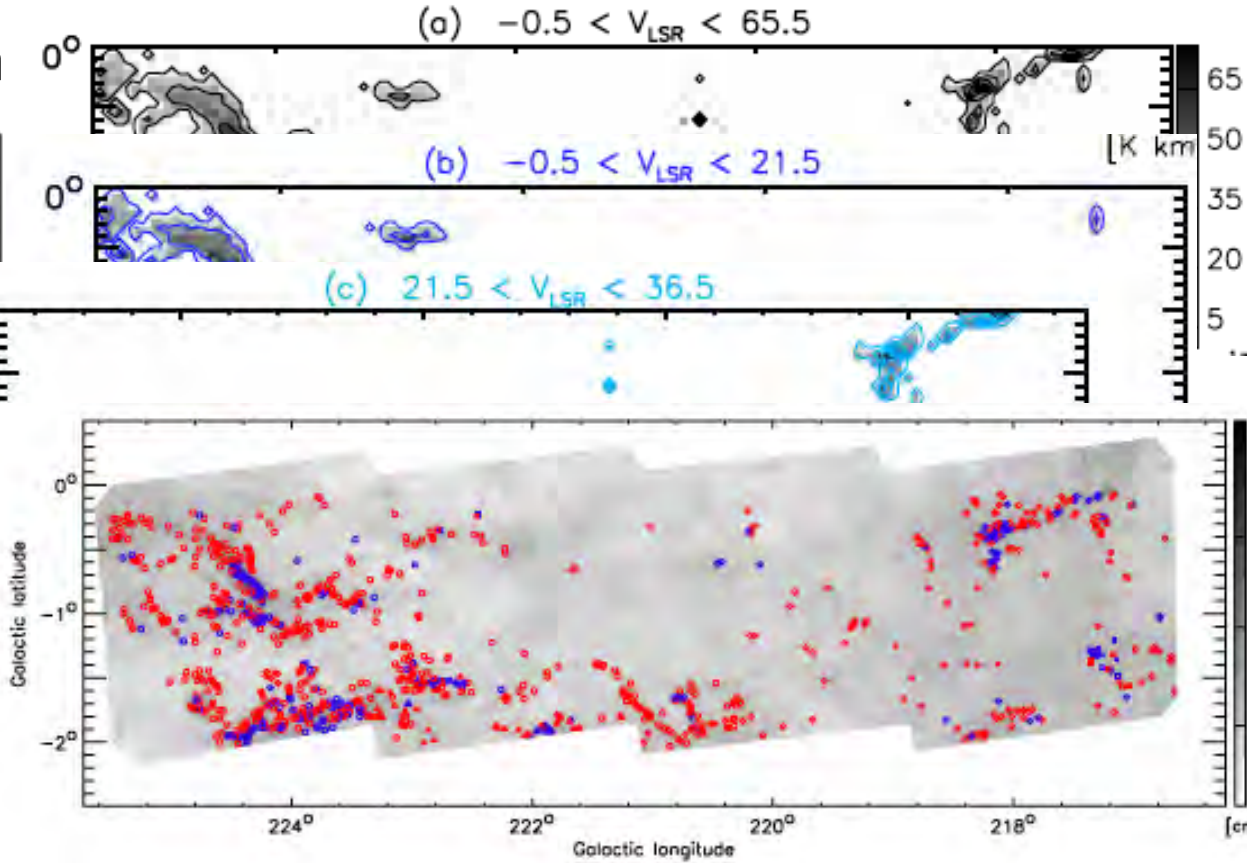
Elia+ 2013

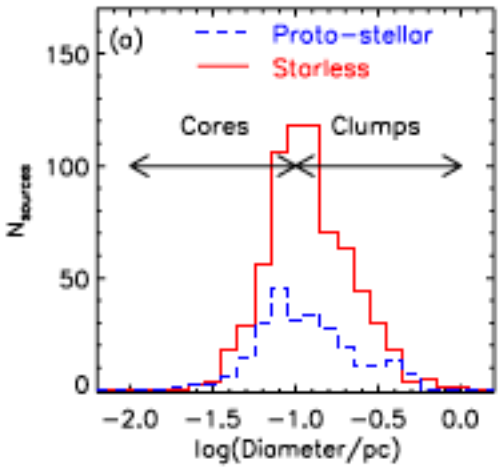


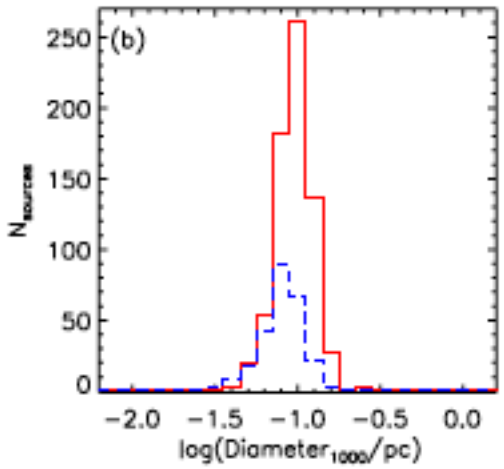
Schisano+ 201

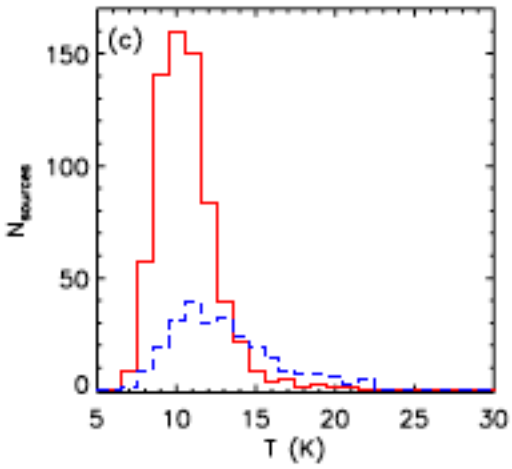
Distance determination

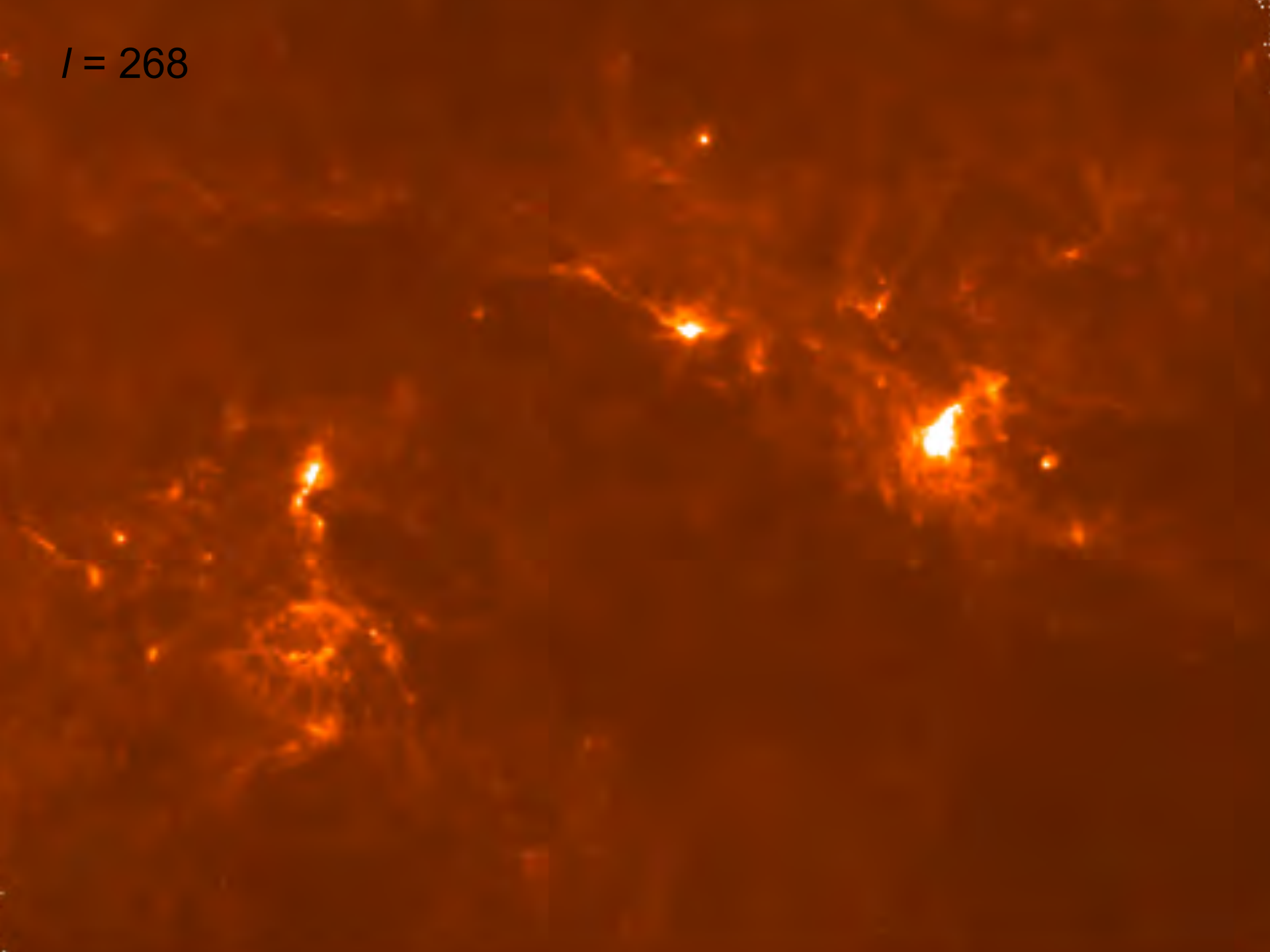




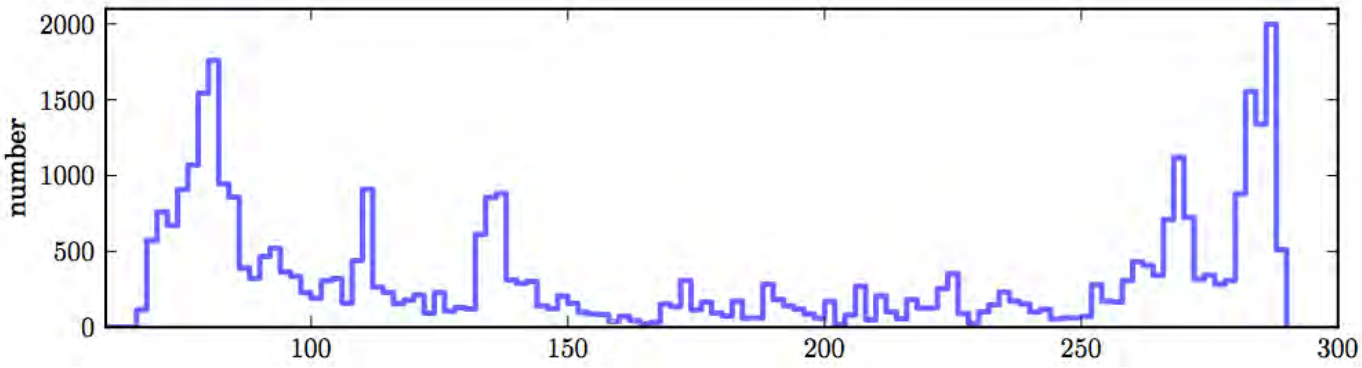




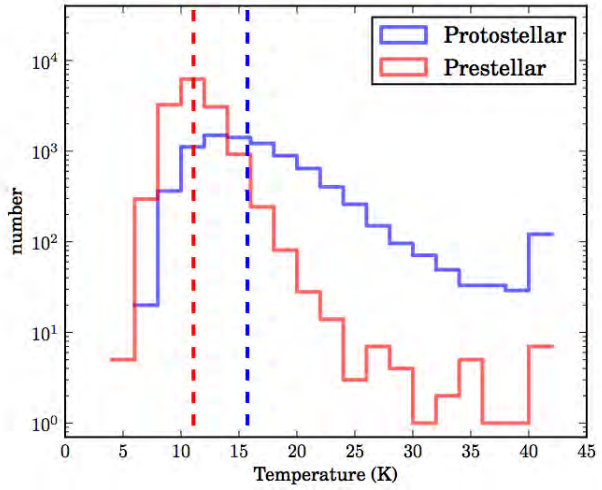


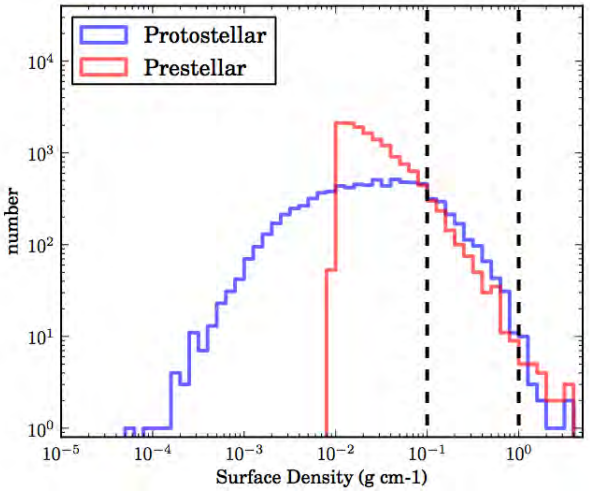

l = 268

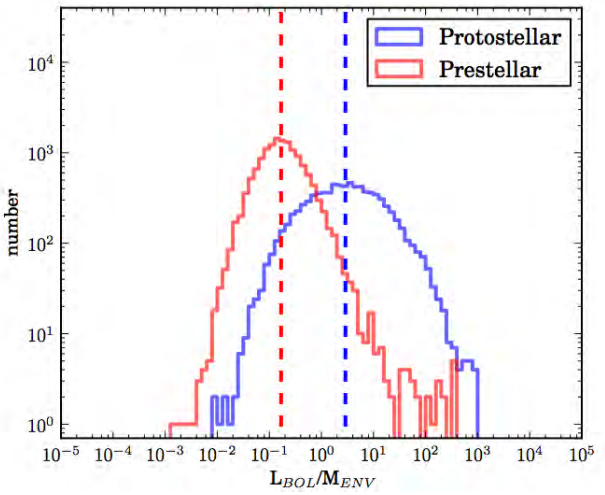
Large number of recovered sources on the outer Galaxy:
37995 with fitted SED.



Distance independent parameters:

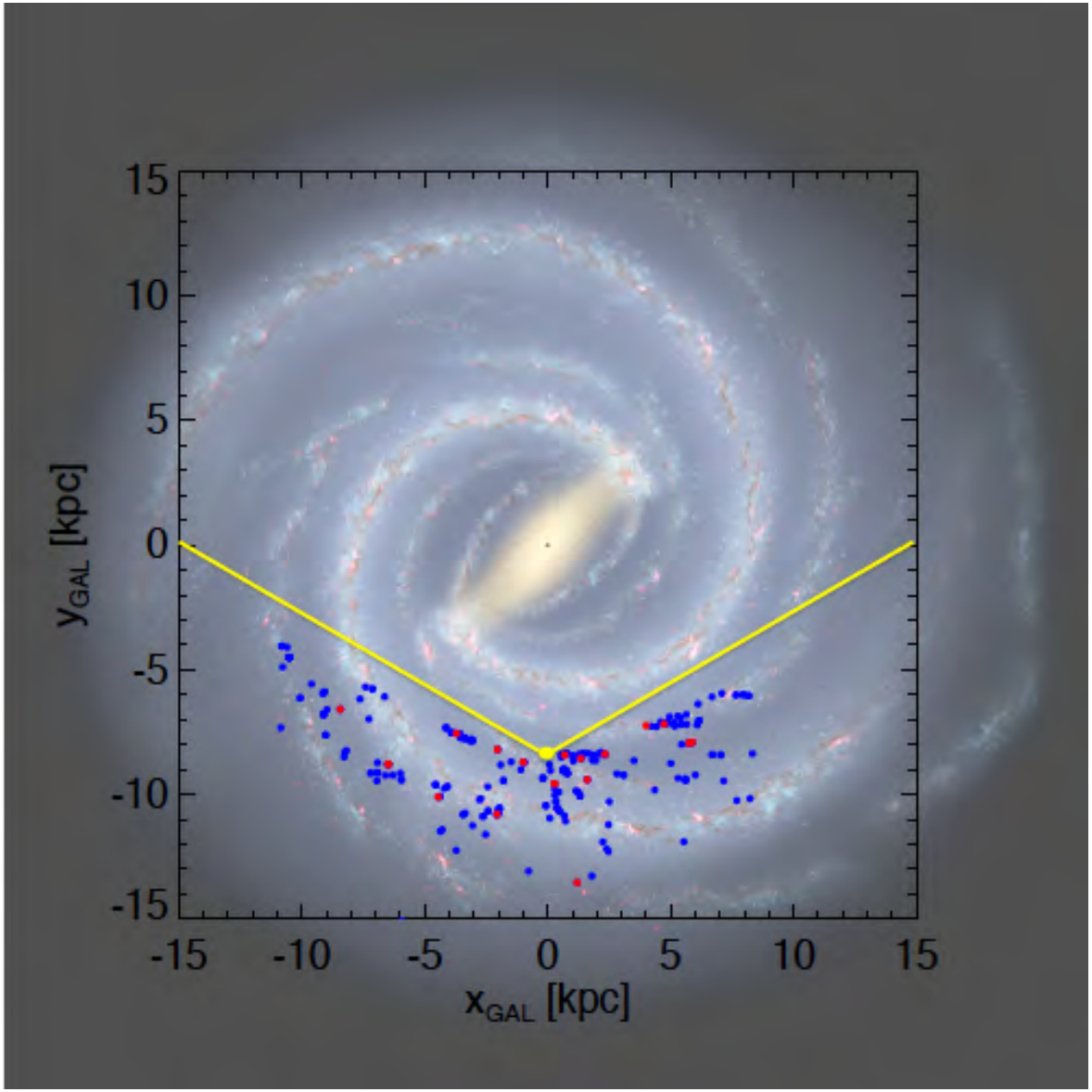






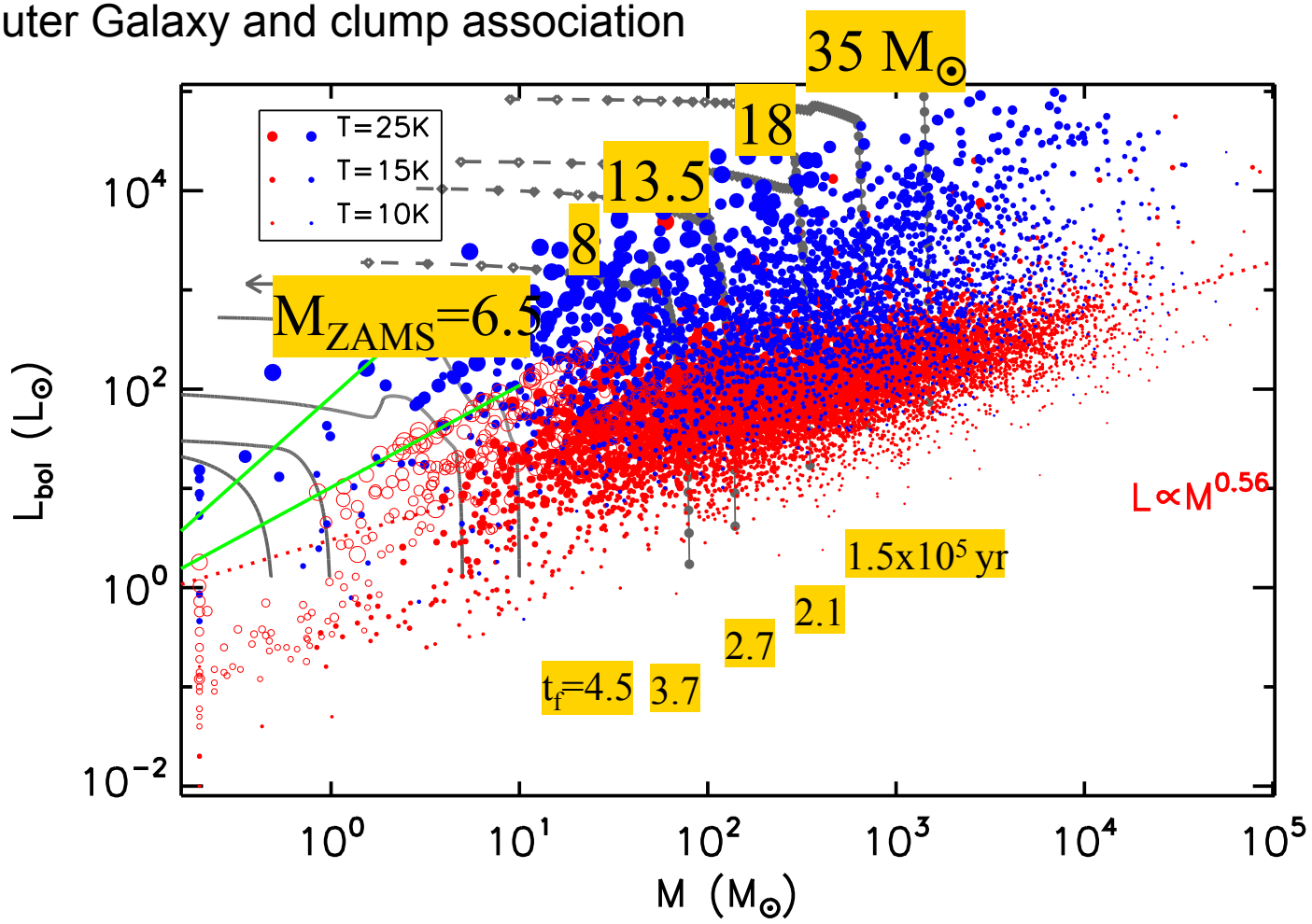
Cross-correlation with line surveys:

- Bronfman et al. 1996 CS(2-1) survey toward IRAS points with characteristic colors of UCHII regions
- New CS(2-1) data (Bronfman et al., in prep)
- 291 HiGAL sources with CS counterpart.



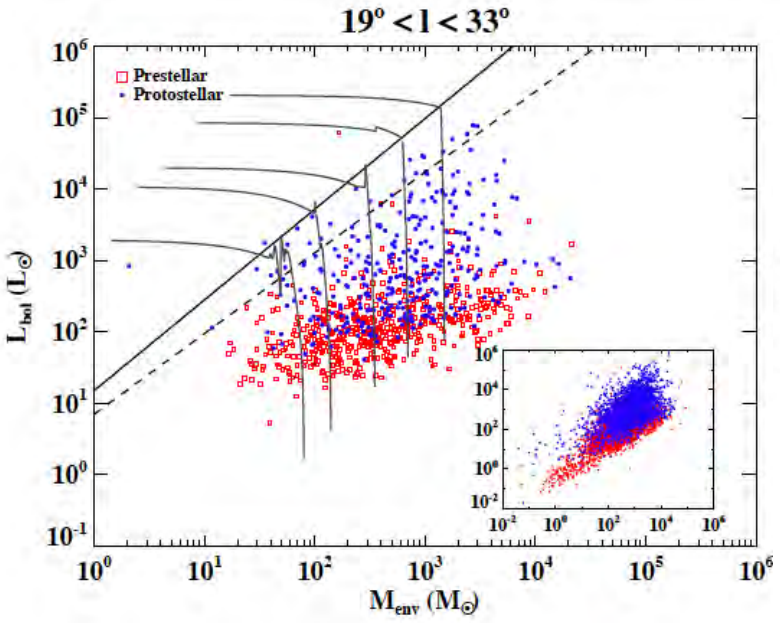
Lots of things to do:

- Estimation of distances using molecular line catalogs, and distance-dependent properties.
- Characterization of sources in the outer Galaxy, comparison with inner Galaxy.
- Evolutionary scenario for sources
- Filaments in the outer Galaxy and clump association

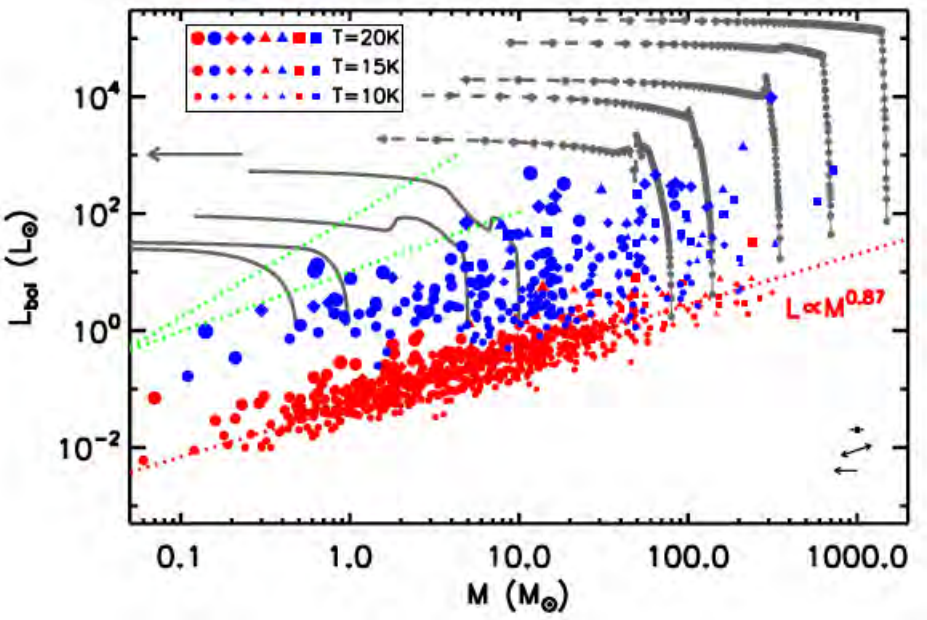


Lots of things to do:

- Estimation of distances using molecular line catalogs, and distance-dependent properties.
- Characterization of sources in the outer Galaxy, comparison with inner Galaxy.
- Evolutionary scenario for sources
- Filaments in the outer Galaxy and clump association



217 < *l* < 225



Summary

- Hi GAL provides a global picture of Galactic star formation
-
- Characterization of different evolutionary stages of clumps
  - yields insight on the massive star formation process

- Outer Galaxy maps show population of sources with conditions for massive star formation

- Significant differences between properties of inner and outer Galaxy sources

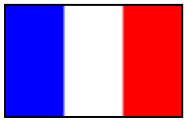
- Comparison with line surveys allows studies of large scale structure
-

VIALACTEA

an FP7-SPACE-2013 Collaborative Project

- ***IAPS-Rome***
- **Oss. Catania**
- **Oss. Capodimonte**
- **Oss. Trieste**

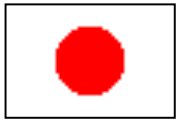
- **MPIA-Heidelberg**



- **LAM-Marseille**
- **Univ. Strasbourg**

- **Univ. Cardiff**
- **Univ. Leeds**
- **Univ. Exeter**

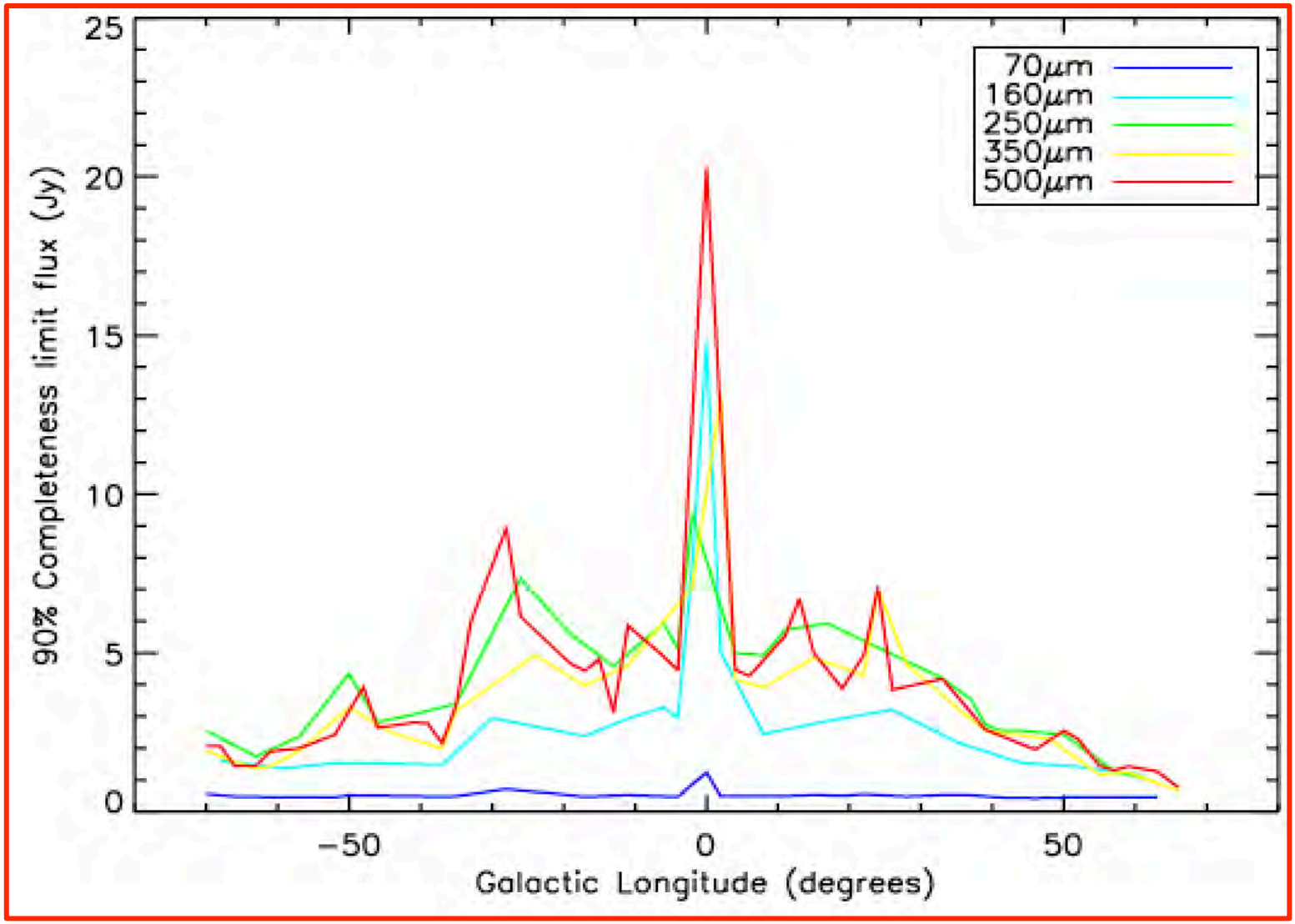
- **SZTAKI**



- **Nagoya Univ.**

The aim is to create a bottom-up model for Galactic star formation, also producing a portal for all community to access all GP Surveys in a unified framework of tools for visualization and science analysis

Thanks


70μm
160μm
250μm
350μm
500μm
90% Completeness limit flux (Jy)
25
20
15
10
5
0
−50
0
50
Galactic Longitude (degrees)

Comparing L/M