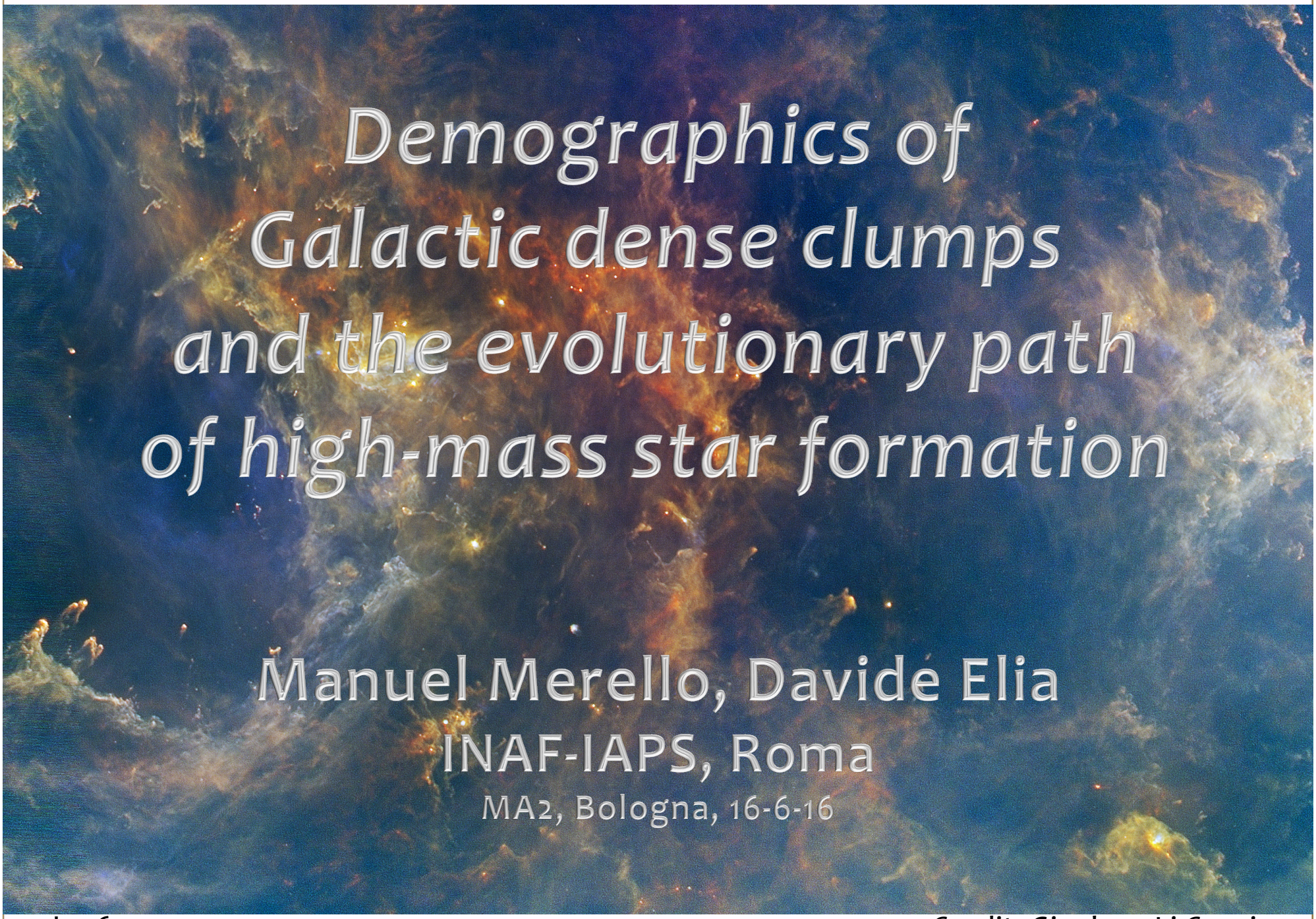


L136

Credit: Gianluca Li Causi

Study of star formation through large data sets:

open issues

1. Large Infrared/sub-mm photometric surveys of the Milky Way: toward a combined use.
2. Follow-up observations of clumps detected in such surveys

3. Elaborating an evolutionary scenario for quiescent and star-forming clumps

Hi-GAL… and its analogues

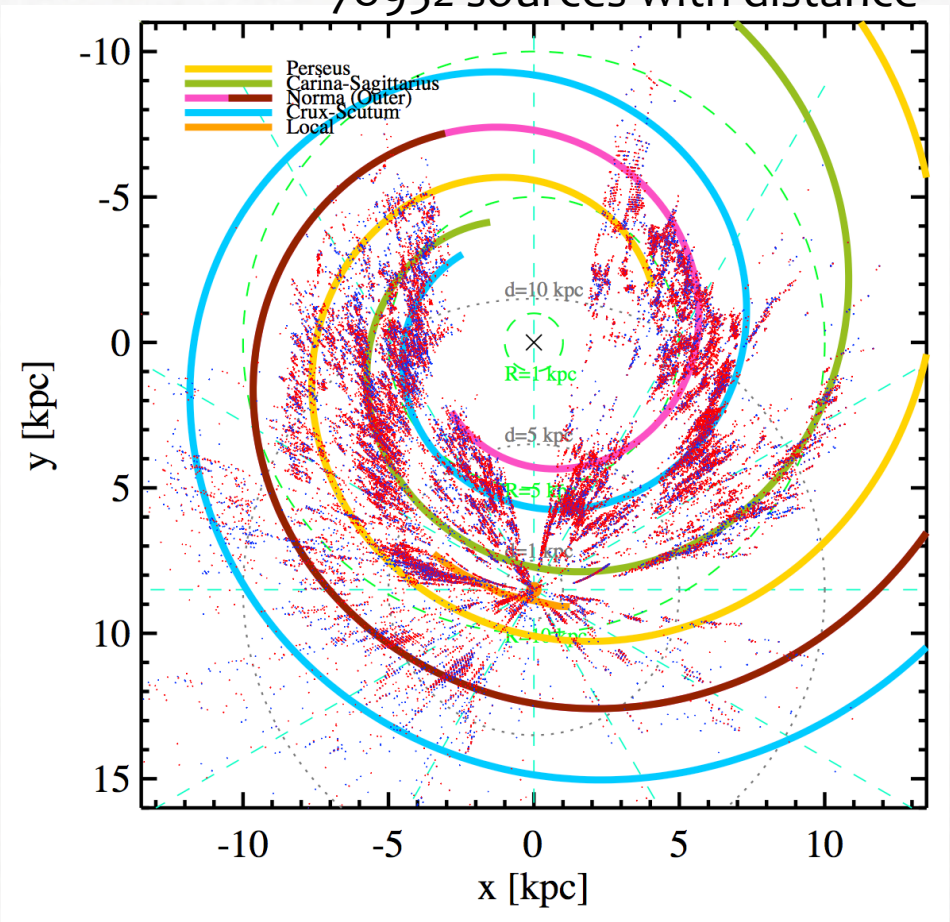
Hi-GAL, P.I. Sergio Molinari, INAF-IAPS, Italy

Simultaneous 5-bands (70-160-250-350-500 μm) continuum mapping of 720 deg² of the Galactic Plane (|b|≤1°)

Hi-GAL Photometry of clumps
Combined with:
21 μm (MSX)
22 μm (WISE)
24 μm (MIPSGAL)
870 μm (ATLASGAL)
1100 μm (BGPS)

150223 **reliable Hi-GAL SEDs**
35412 **protostellar**
80554 **pre-stellar**
34257 starless unbound

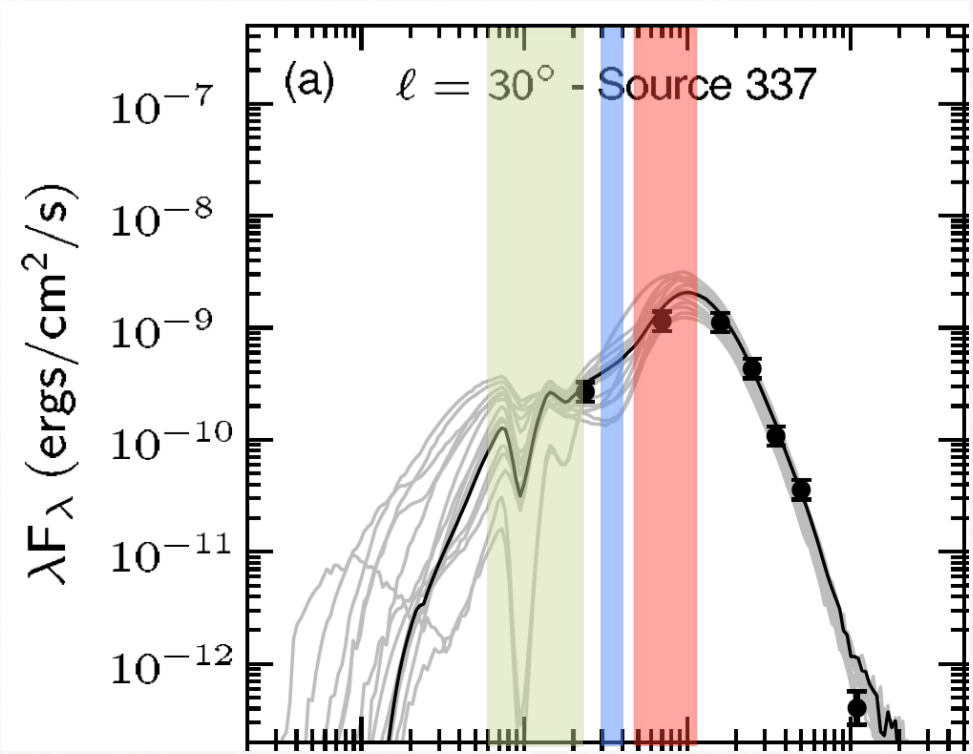
78952 sources with distance



SED fitting and near/mid-IR bands

SOFIA

FORCAST: 31.6, 33.6, 34.8, 37.1 μm
HAWC+: 53, 63, 89, 154, 214 μm:
Ideal to fit a second component (warmer) to the SED and/or to remove degeneracy from the results of more complex fitting procedures.



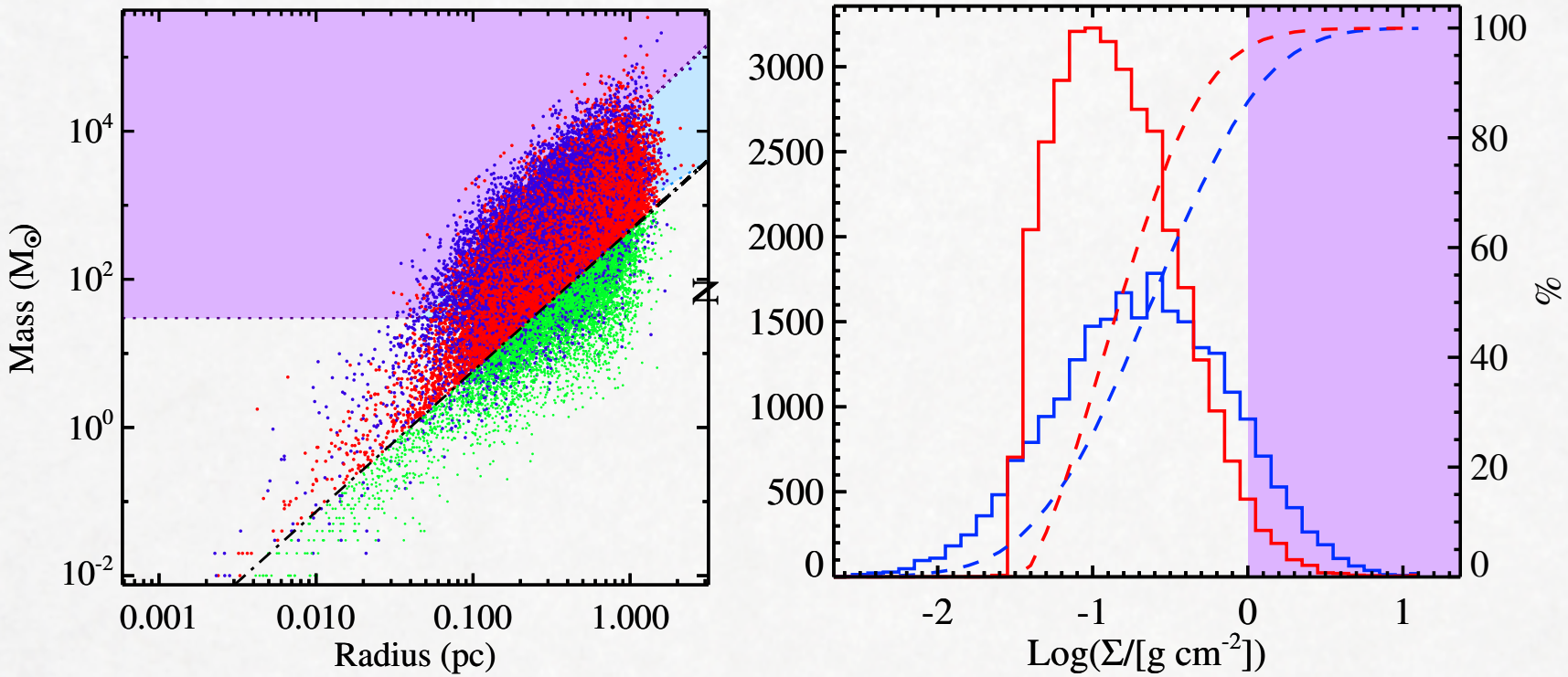
JWST

MIRI: 5.6 to 25.5 μm (10 filters):
MID-IR counterparts of Spitzer-IRAC YSOs

Conditions for massive star formation?

Krumholz & McKee (2008): $\Sigma > 1$ g cm^{-2}

Kauffmann & Pillai (2010): $M > 870\ M_\odot\ (r/pc)^{1.33}$



Proto-stellar

Starless unbound

Starless Unbound

High surface density is only a necessary condition for MSF…

How does clump fragmentation proceed?

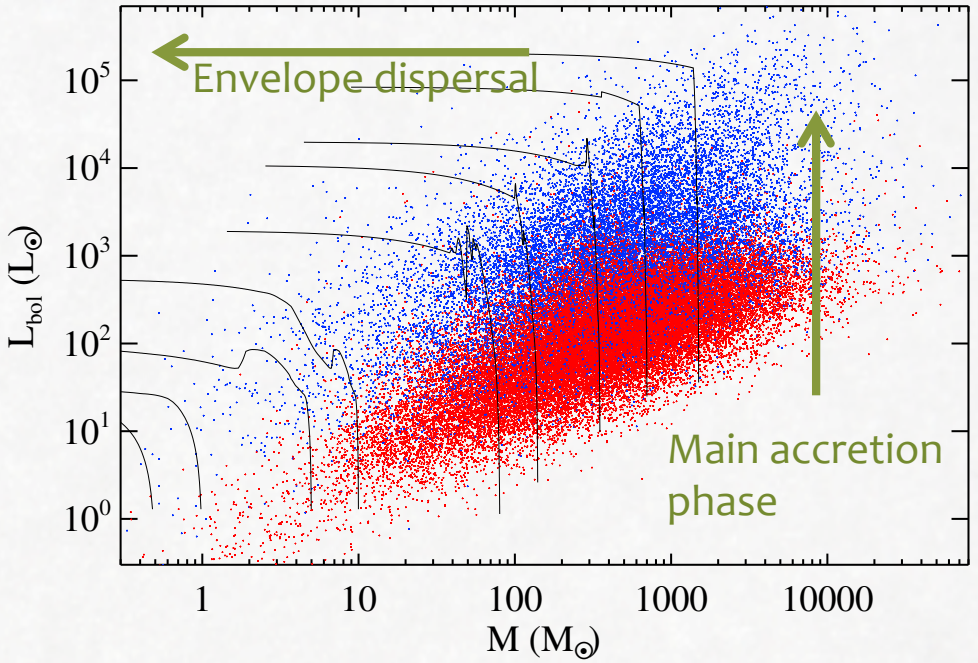
Submitted:

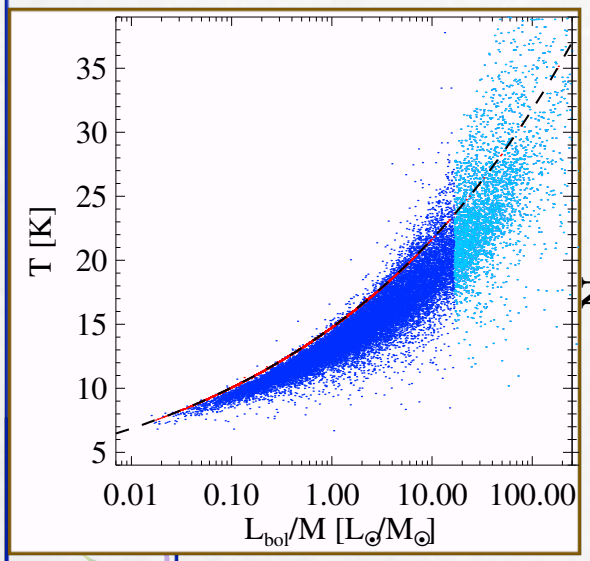
ALMAGAL - ALMA Evolutionary study of high-mass star formation in the Galaxy.

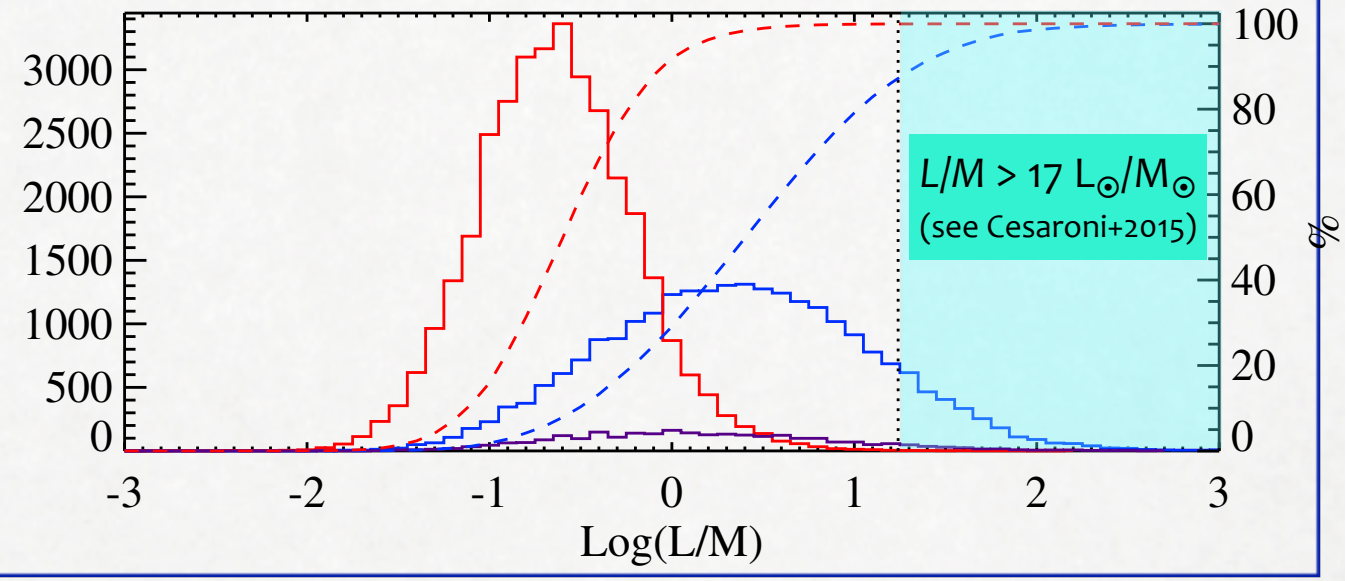
1000 Hi-GAL sources to be observed in the continuum in Band 6, to study the degree of fragmentation with a resolution of 1000 AU (or better).

Clump evolution

Ratio between the bolometric luminosity and clump mass, as a tool for characterizing the ongoing star formation (e.g. Molinari+ 2008)

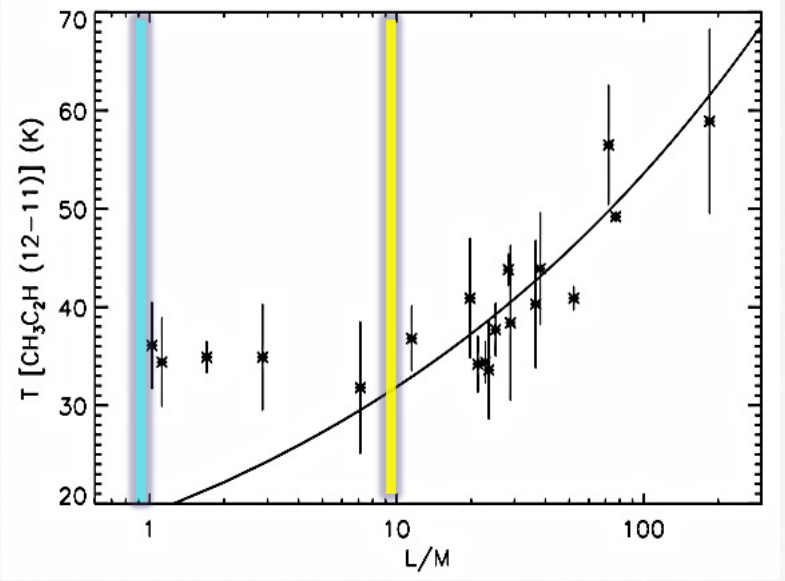


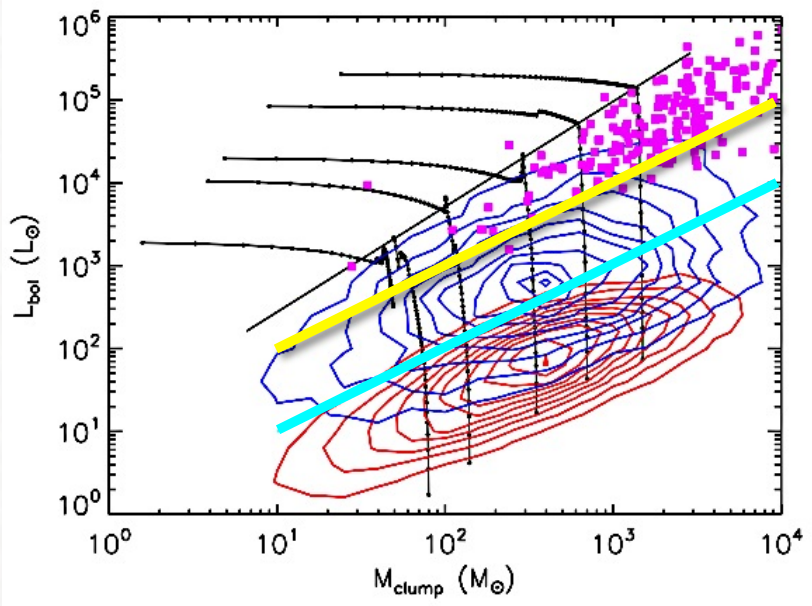




APEX observations of warm, inner dense gas of Hi-GAL clumps

- Observations of CH_3C_2H (J=12-11) towards 51 protostellar massive clumps from Hi-GAL catalog.
- L/M parameter used as a diagnostic of the star formation evolutionary stage.
- Three ranges defined:
  - **L/M < 1**, very early stages, or low mass YSO formation.
  - **1 < L/M < 10**, build luminosity and temperature due to ongoing evolution of relatively low-mass protostars.
  - **L/M > 10**, raise of inner clump gas temperature, first appearance of intermediate/high-mass ZAMS star.



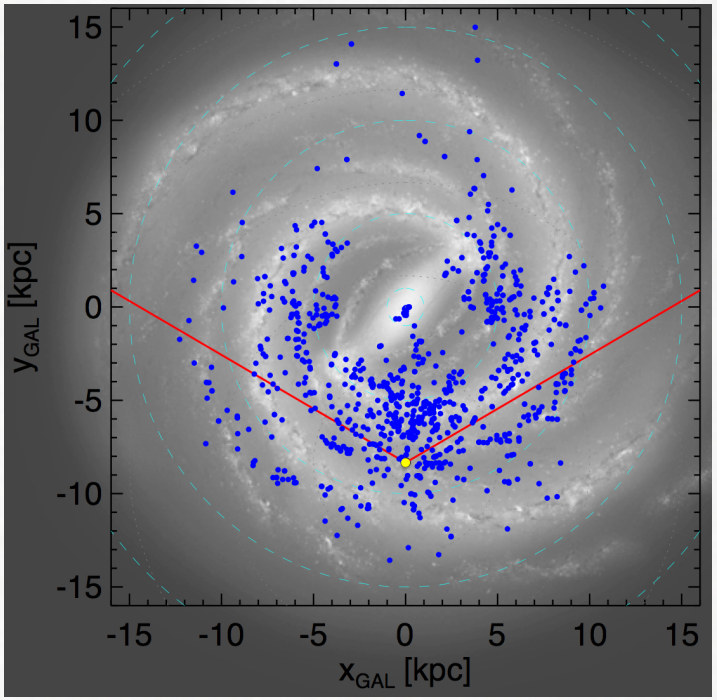


Hi-GAL clumps associated with CS observations.

- CS(2-1) data from Bronfman et al. (1996,2016)
- IRAS point sources with IRAC colors characteristics of UCHII regions (Wood & Churchwell 1989)

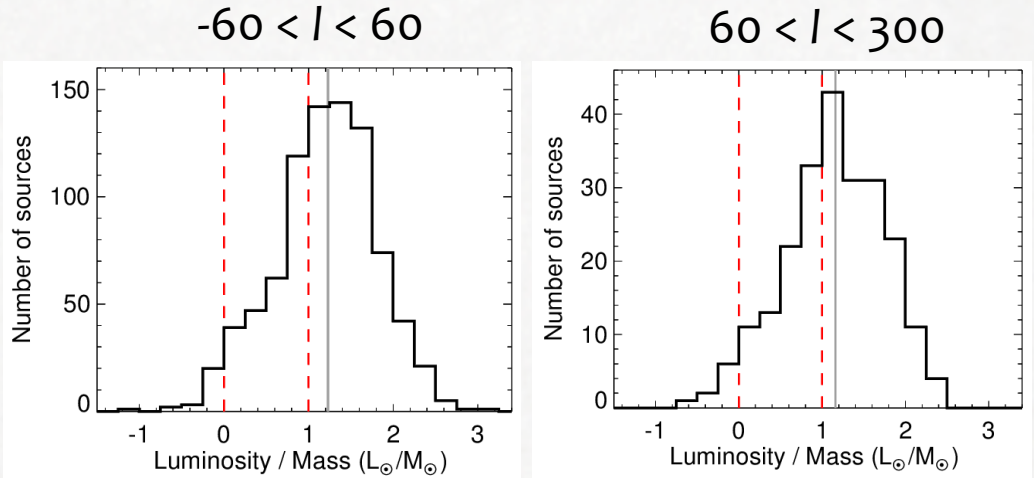
  852 CS observations, associated with ~1000 dust clumps from catalogue

- The L/M parameter works as an independent diagnostic of the evolutive stage of clumps.



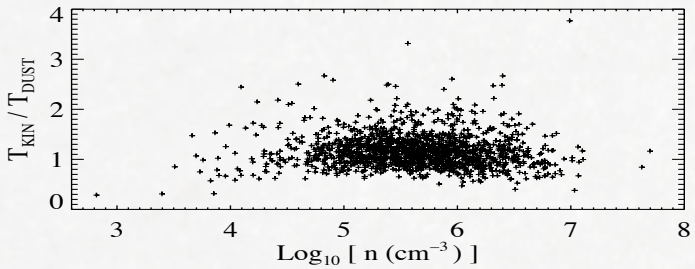
Follow up projects: molecular line observations with APEX:

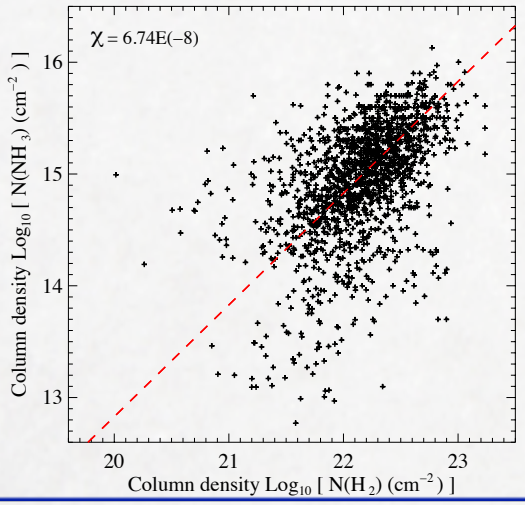
- Characterization of dense gas
- Indicators of evolution

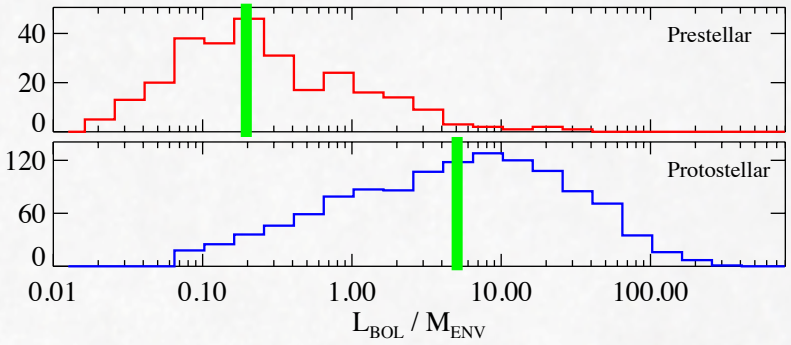


Association between Hi-GAL and NH3 surveys

- Catalogs of ammonia inverted transitions toward selected sample of sources at different stages.
- Comparison between dust and cold gas properties on a sample of ~1100 clumps





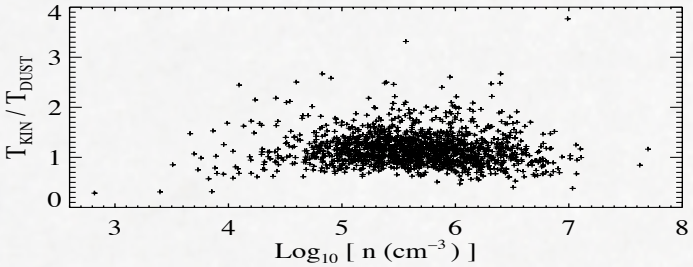


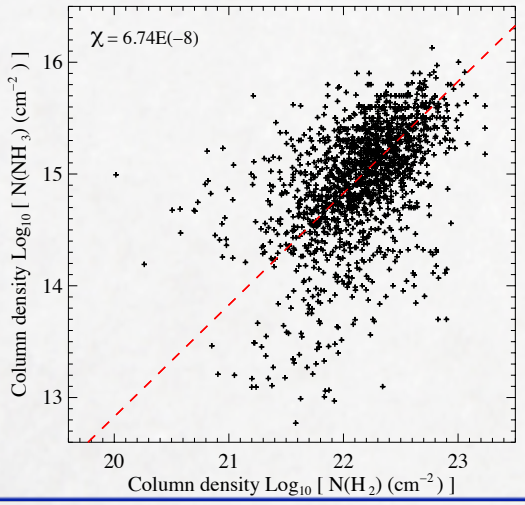
Ammonia surveys includes sources:

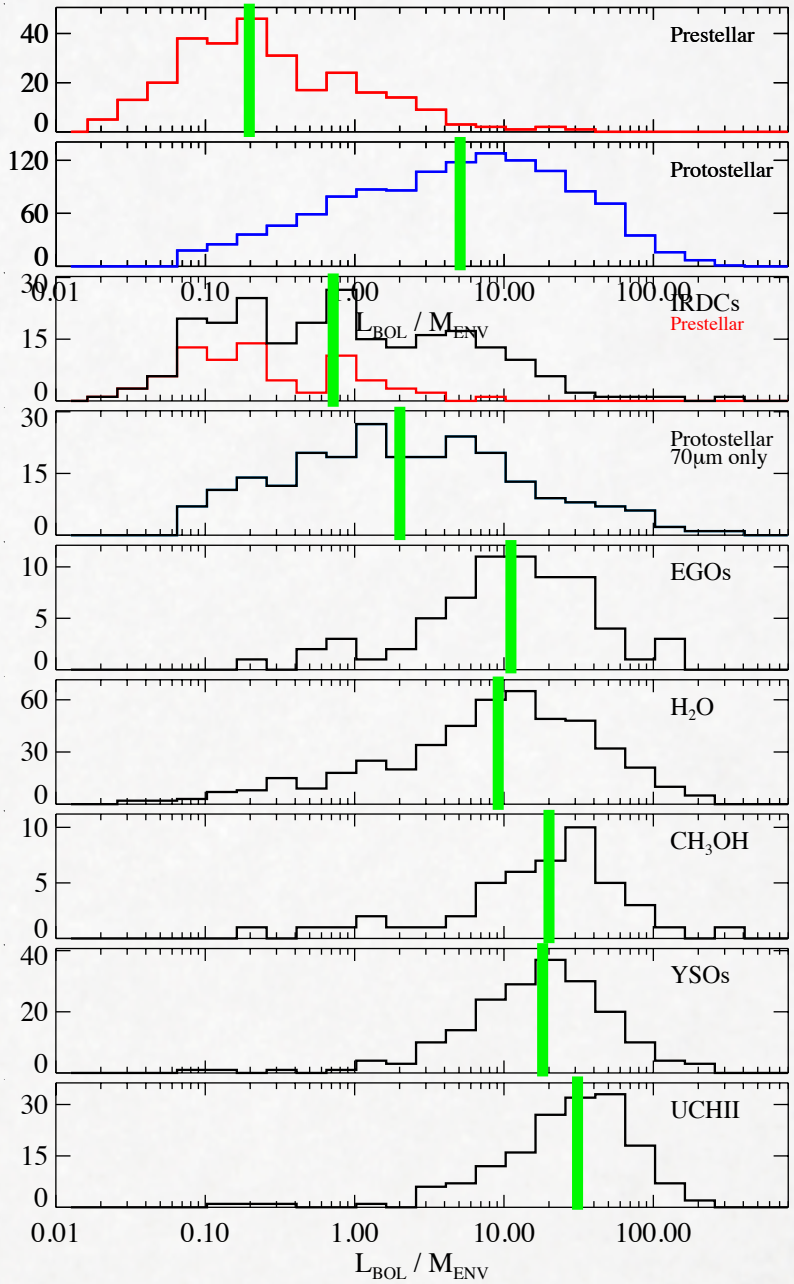
- IRDCs
- Maser associations
- Young Stellar Objects
- UCHII region candidates.

Association between Hi-GAL and NH3 surveys

- Catalogs of ammonia inverted transitions toward selected sample of sources at different stages.
- Comparison between dust and cold gas properties on a sample of ~1100 clumps

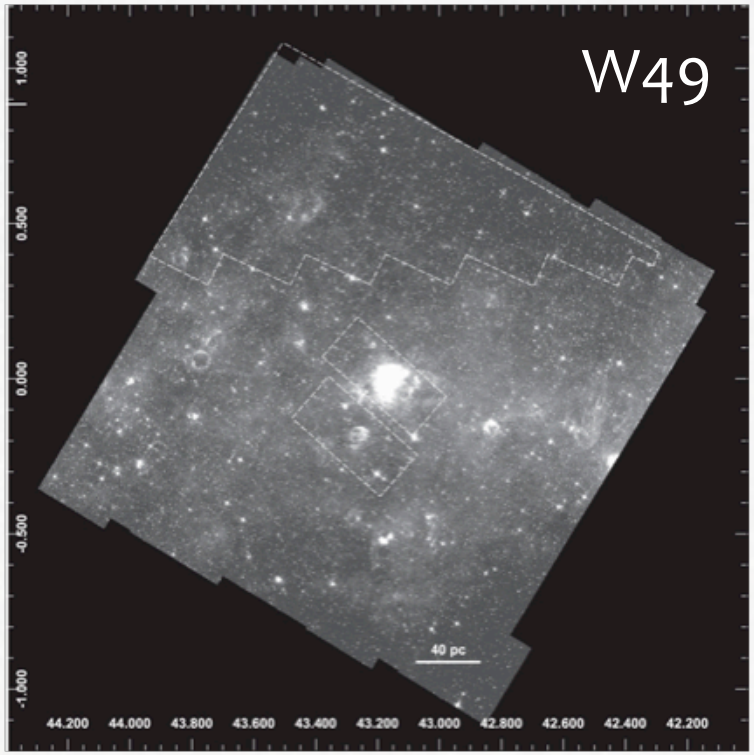






Association between Young Stellar Objects and parental clumps

- Mid and Near Infrared catalogues of Galactic point sources are considered:
  GLIMPSE
  MIPSGAL (2439865 sources)
  WISE (8225860 sources)
  2MASS
  UKIDSS
- Classification of sources done with color-color criteria for YSO from literature (e.g., Gutermuth+09, Robitaille+08)



Example: W49

- Saral et al. (2015), identification of YSO class I and II from IRAC+NIR colors

Design of a data mining approach for source classification

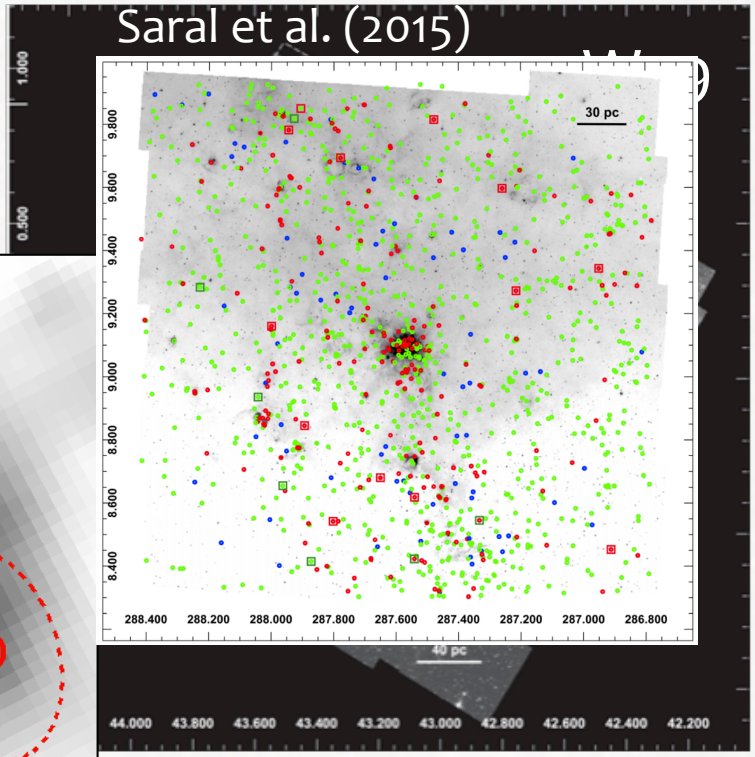
VIALACTEA

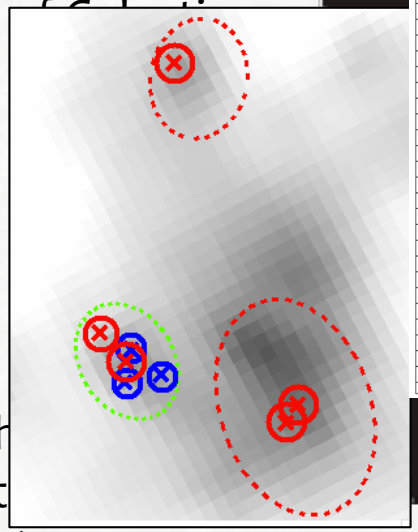
Association between Young Stellar Objects and parental clumps

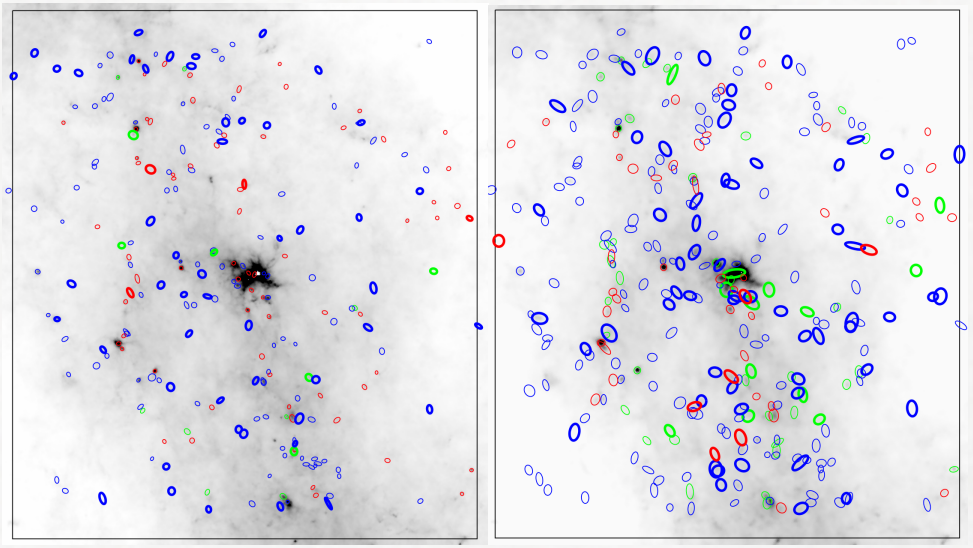
- Mid and Near Infrared catalogues of Galactic point sources are considered:
  - GLIMPSE
  - MIPSGAL (2439865 sources)
  - WISE (8225860 sources)
  - 2MASS
  - UKIDSS
- Classification of sources done with color-color criteria for YSO from lit (e.g., Gutermuth+09, Robitaille+08)

Example: W49

- Identification of YSO class I and II from IRAC+NIR colors







Design of a data mining approach for source classification

IN CONCLUSION…

Plans and needs for the future

To collect all the present information useful to reconstruct the evolutionary path of star-forming clumps

To propose and carry out medium and large observing programs, both spectroscopic and photometric, at both single-dish and interferometric facilities

To deal with managing and combining large amounts of data