Massive star formation properties in the Galactic disk

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Galaxies2015, Santiago, Chile

Overview

- Possible sites of massive star formation
- Source sample:
  - Planck catalog
  - ECC clumps in the Hi-GAL region
- Physical parameters of the clumps:
  - T, N
  - D
  - M, d
- Follow-up studies

Possible sites of HMSF - IRDCs

Infrared Dark Clouds:

- significant mid-IR opacity

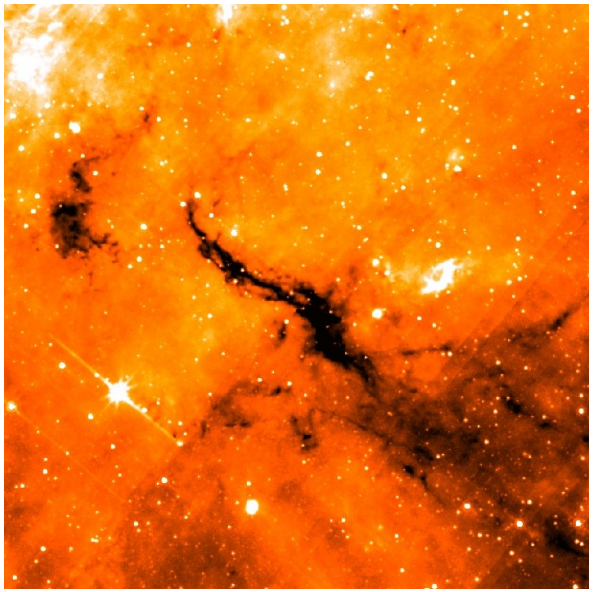
- cold (<20 K), dense (>10^4 cm^{-3}) with high column densities (>10^{23} – 10^{25} cm^{-2})

- dark at 100 um

Sizes (few pc) and masses (few 1000 $M_\odot$) comparable

to warm, cluster-forming molecular clumps

-> Colder and with little obvious star formation

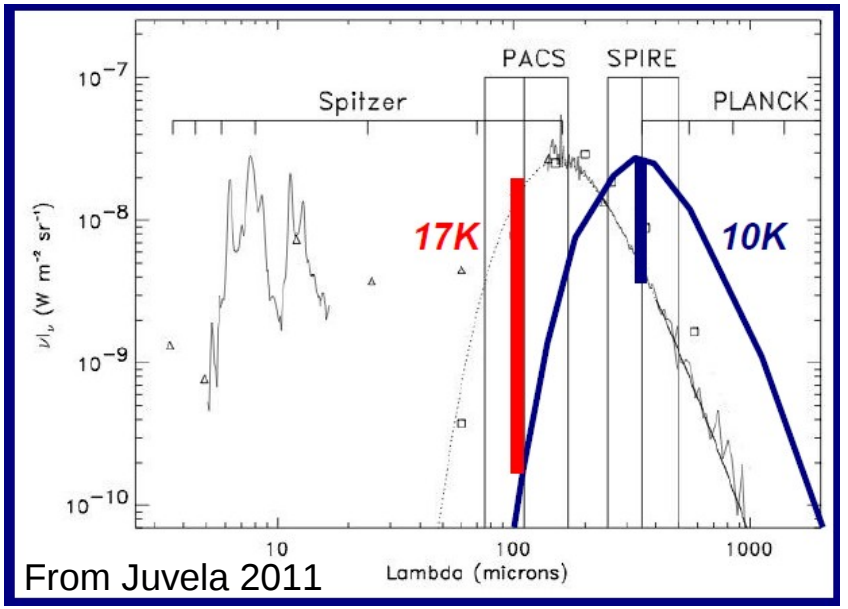


Spitzer GLIMPSE 8um image

Perault et al. 1996; Egan et al. 1998; Carey et al. 1998, 2000; Hennebelle et al. 2001; Simon et al. 2006; Rathborne et al. 2006

Planck all sky survey

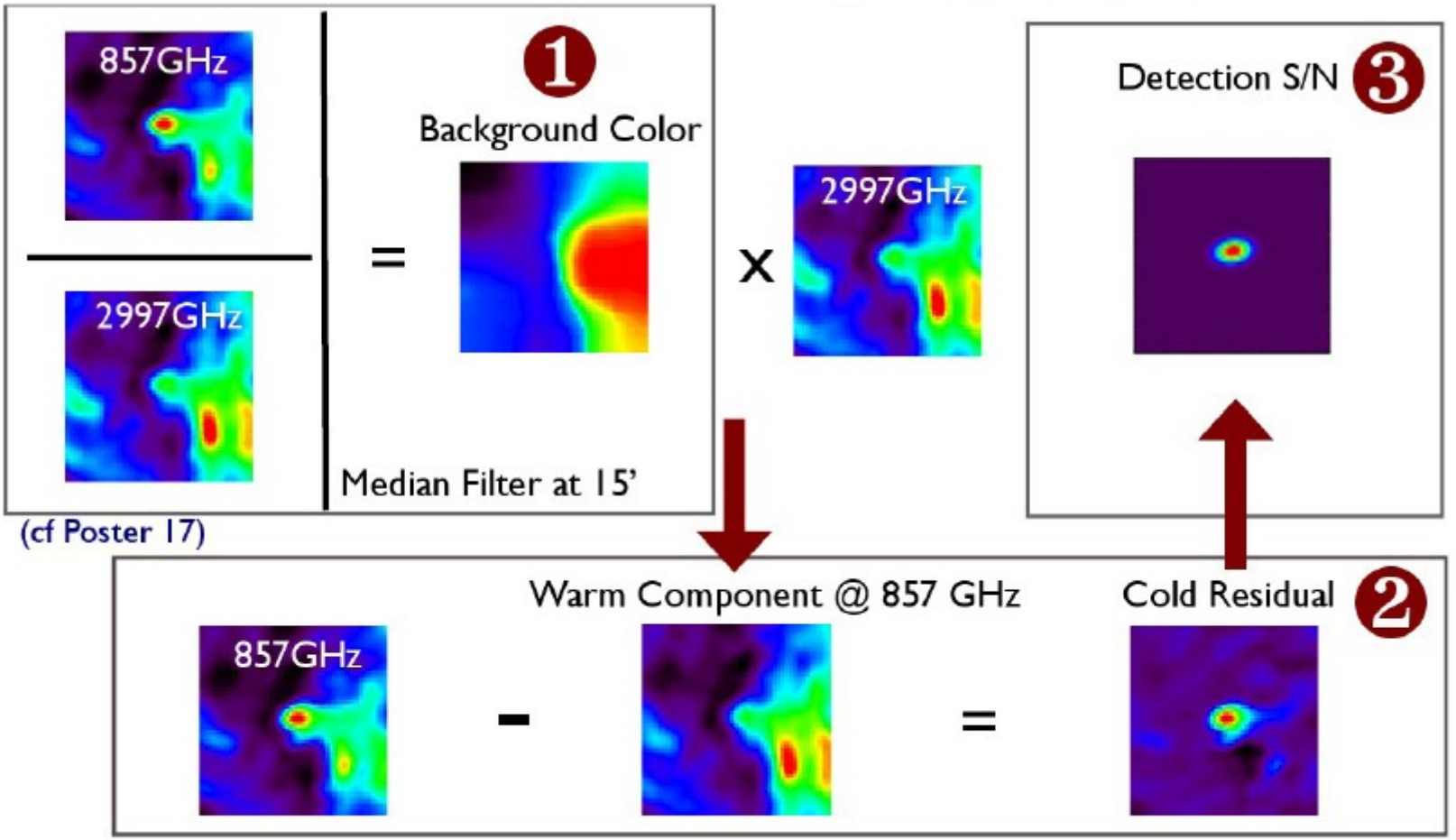
- Mapped the sky at 9 frequencies between 857 GHz and 30 GHz (350, 550, 850, ... 10000 um)
- Better than 5' resolution in the submm



From Juvela 2011

Detection of cold clumps is possible

Detection method



Planck Collaboration, 2011, A&A, 536, 23 + Planck Collaboration 2015

C3PO, ECC, PGCC

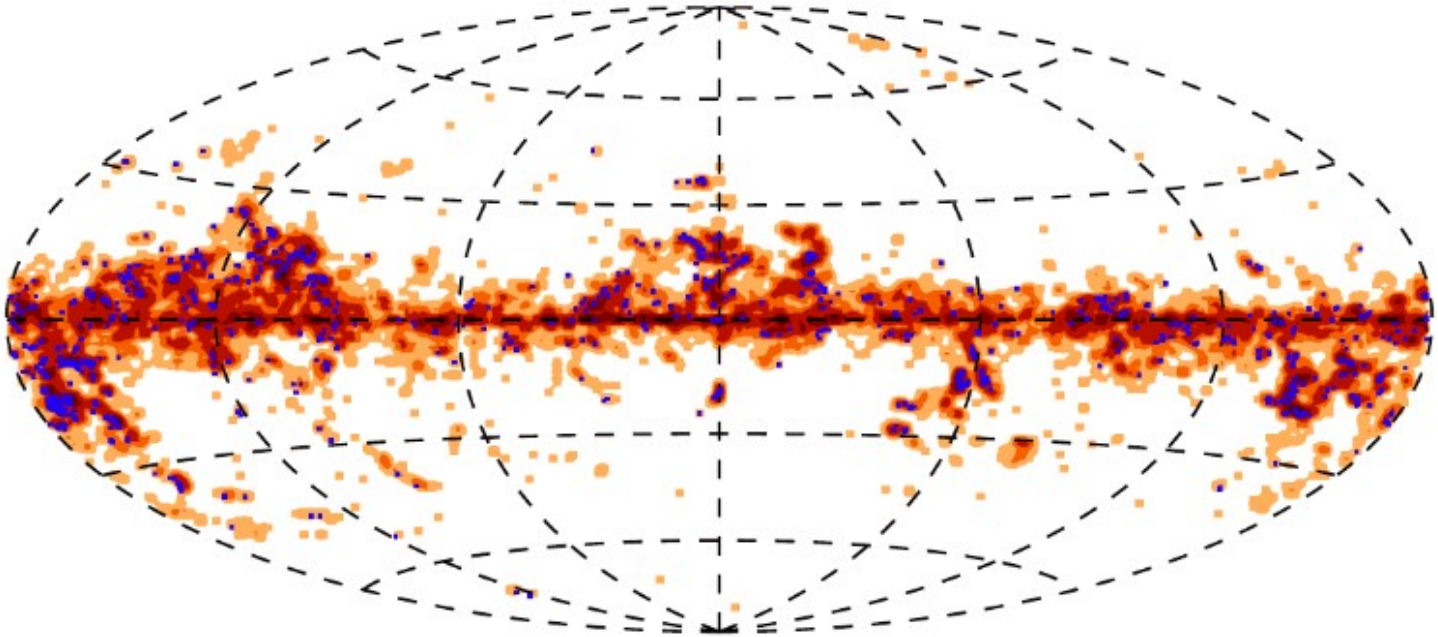
C3PO: Preliminary catalog ~10000 sources

Early Cold Core selection(**ECC**)

Most reliable sources ~ 900

S/N > 15

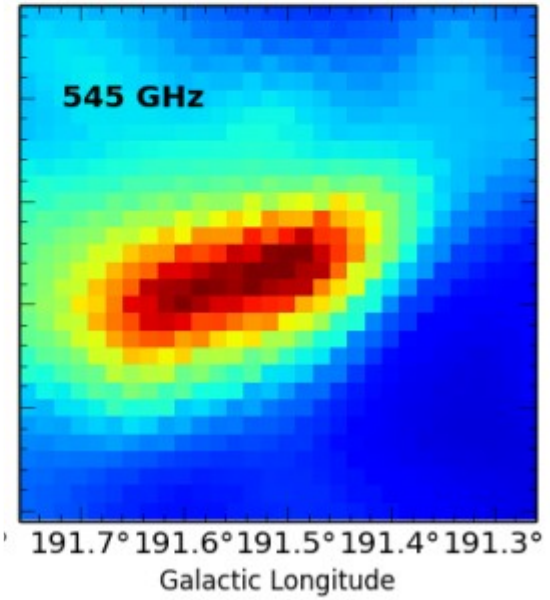
T < 14 K



PGCC: Final catalog ~13000 sources

Planck Collaboration, 2011, A&A, 536, 23 + Planck Collaboration 2015

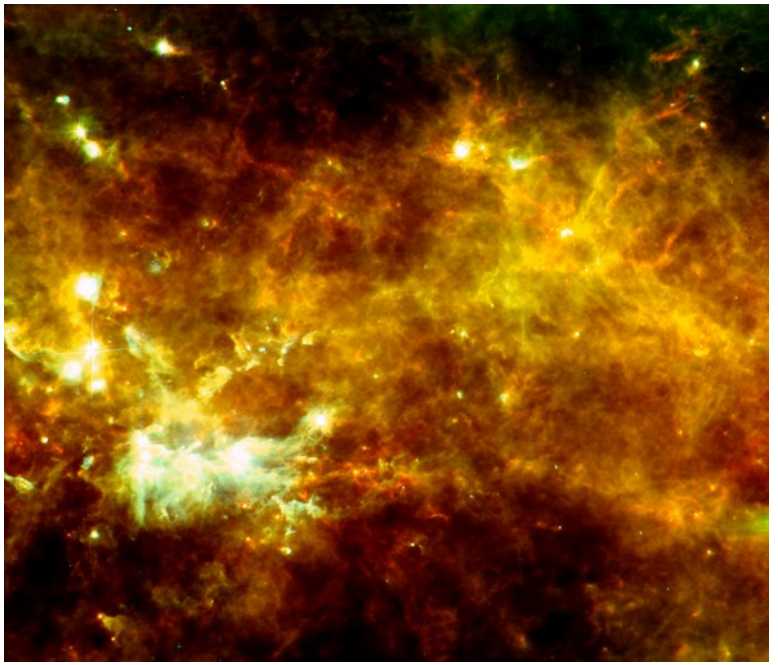
Planck view of an ECC



Hi-GAL survey

- Herschel Infrared Galactic Plane Survey, Open Time KP
- Herschel PACS (70-160 um) and SPIRE (250-500 um) survey of the Galactic Plane of the Milky Way
- -1 deg < b < 1 deg
- Resolution: 5”, 13”, 18”, 25”, 36”

https://hi-gal.ifsi-roma.inaf.it/higal



Composite image (70-160-350) of the Galactic Plane in the Vulpecula region

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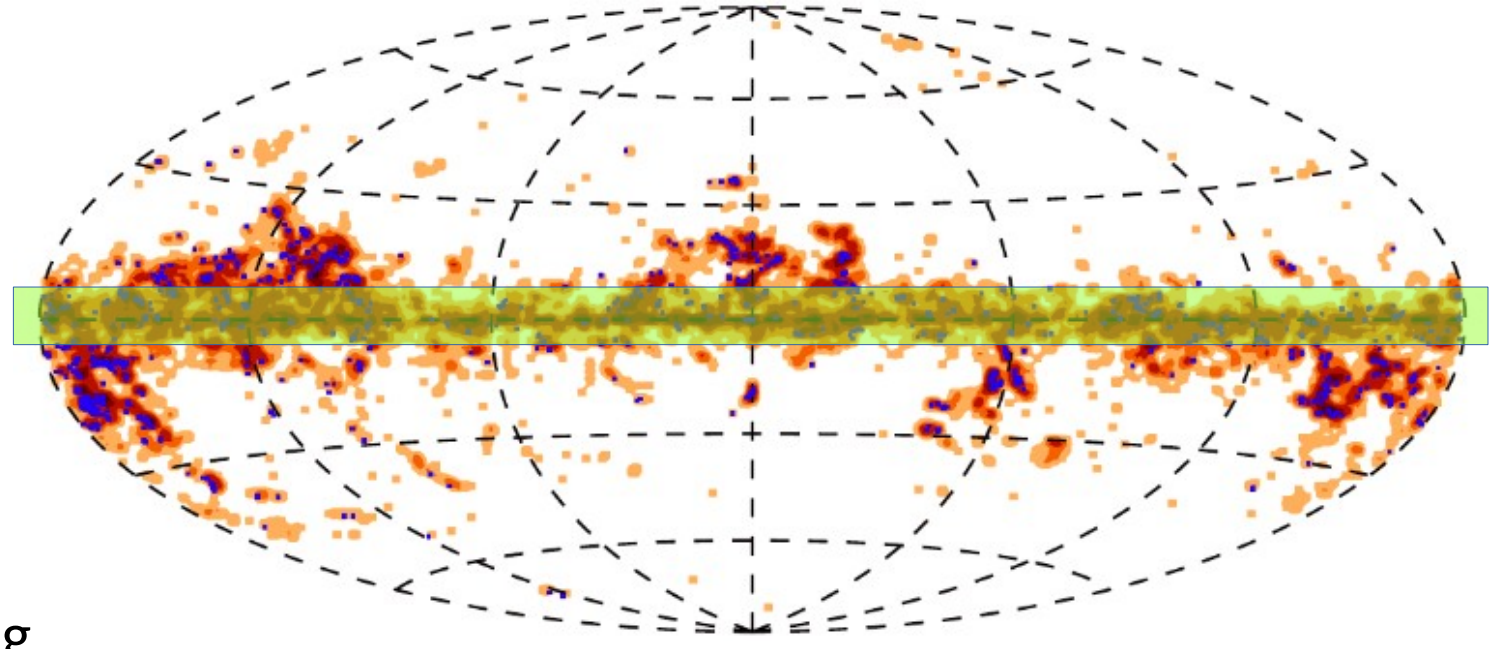
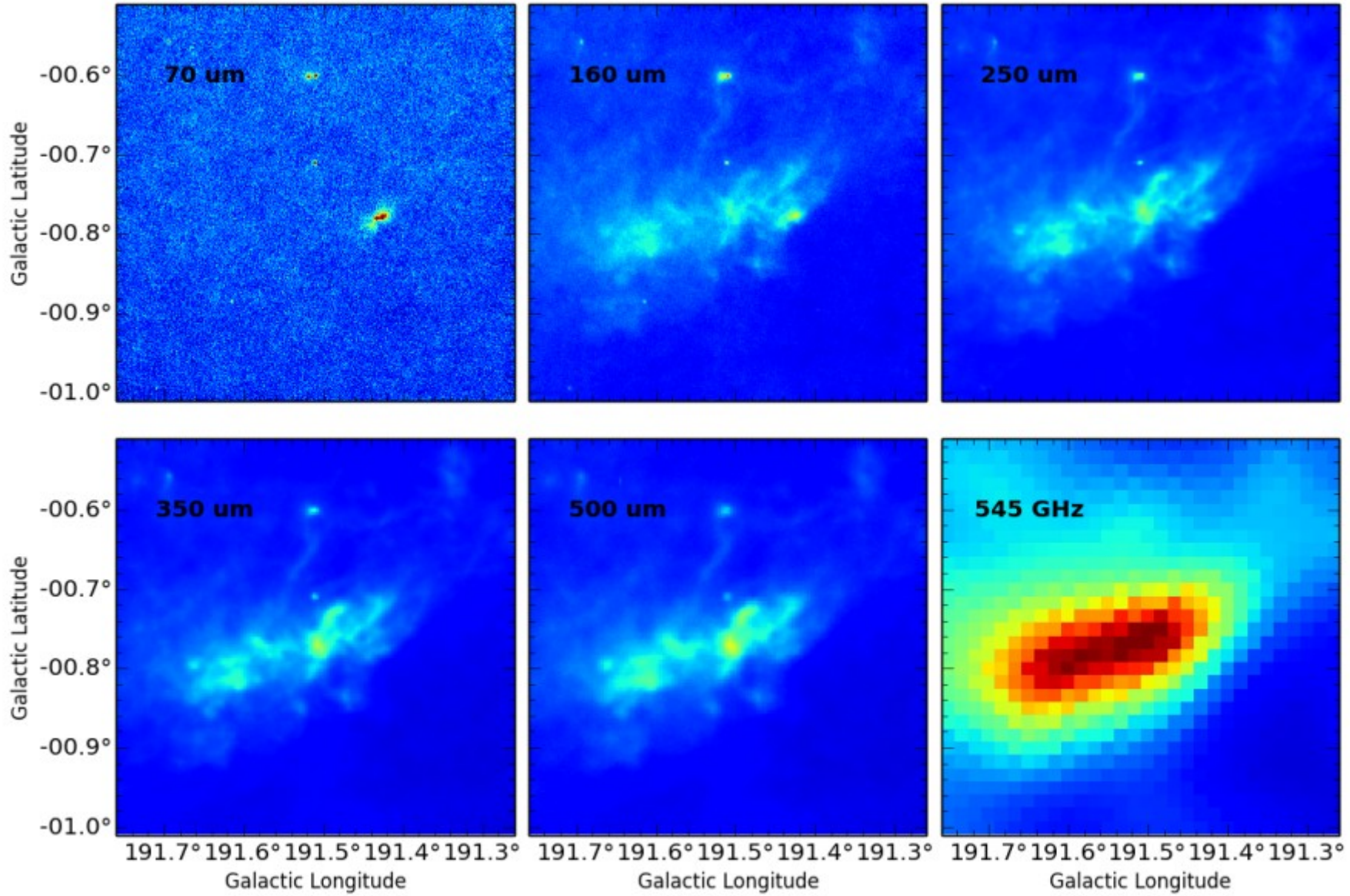


48 ECCs covered by Hi-GAL (https://hi-gal.ifsi-roma.inaf.it/higal/)

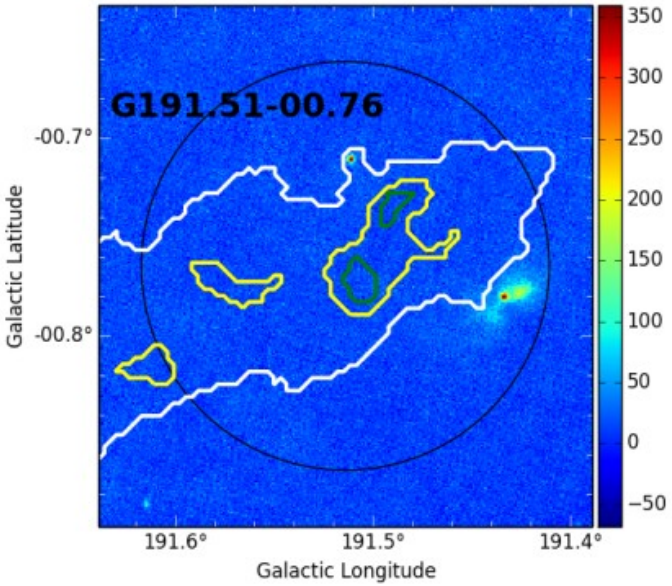
Planck Collaboration, 2011, A&A, 536, 23 + Planck Collaboration 2015

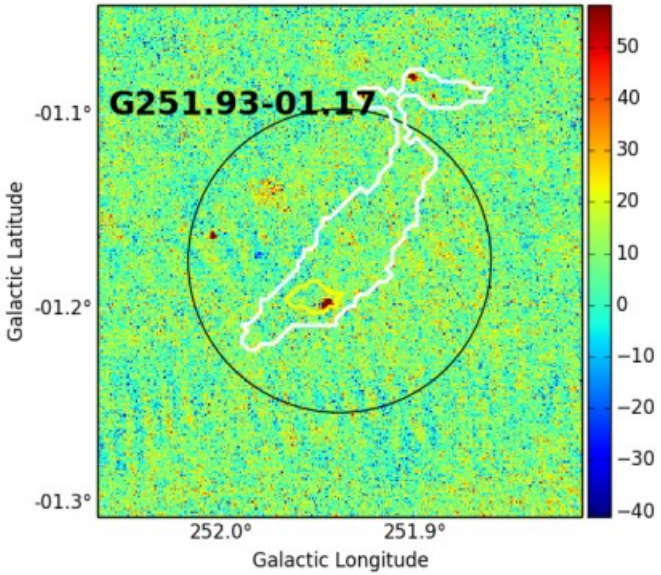
The role of Hi-GAL data

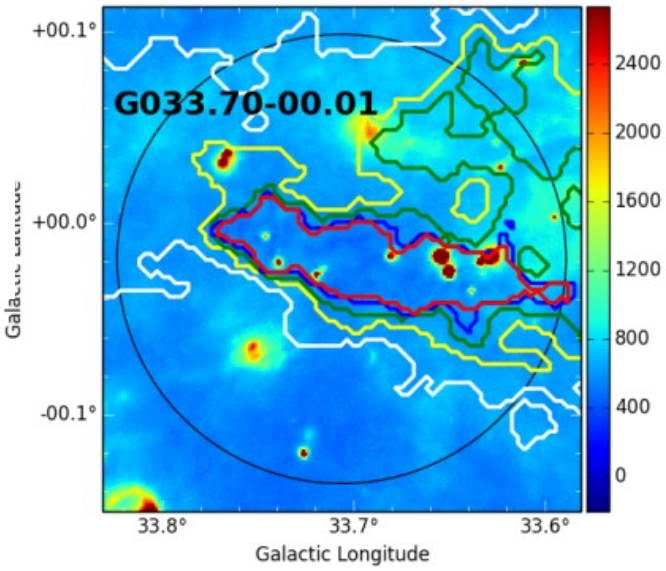


Star formation properties of ECCs

- 24 / 70 um images

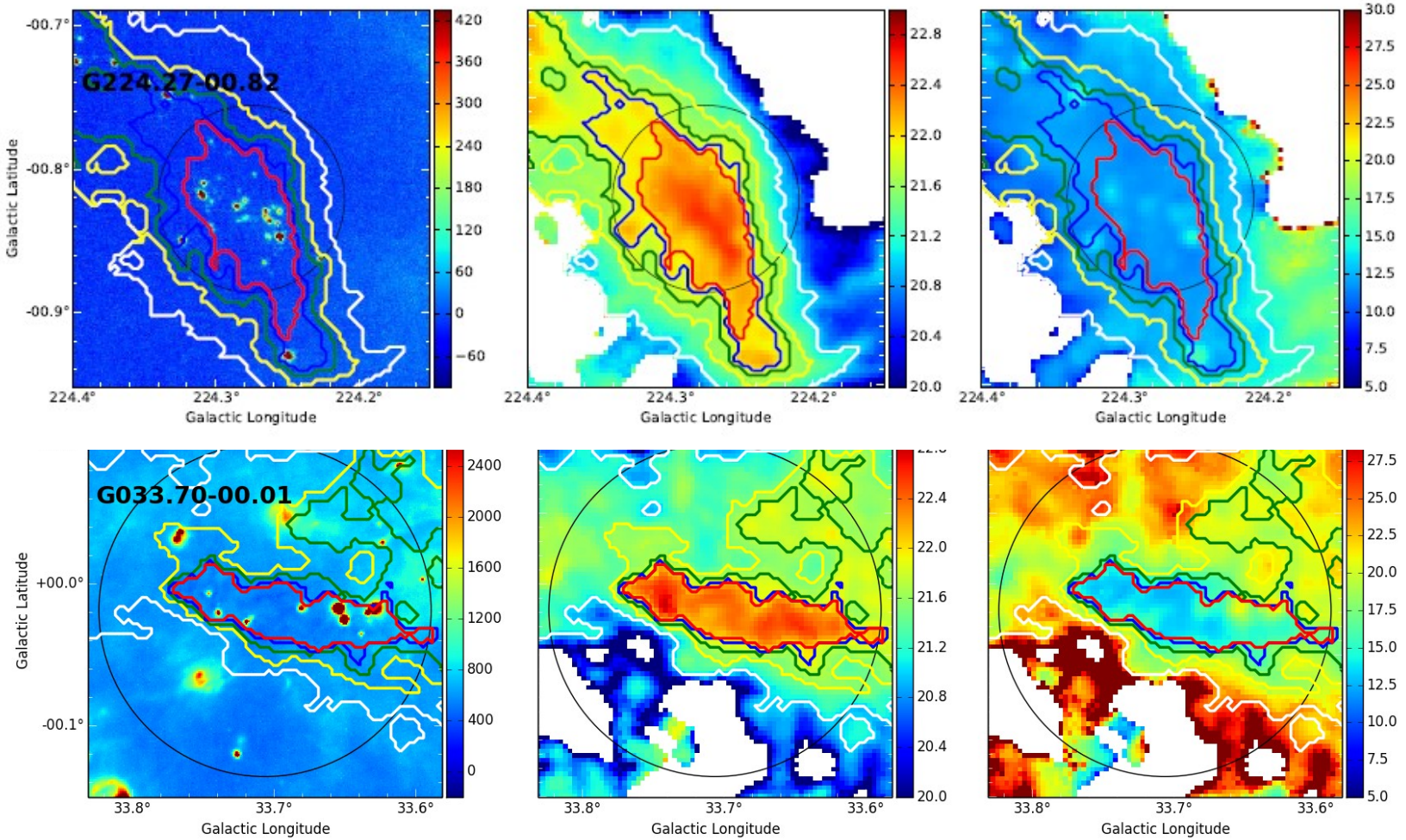




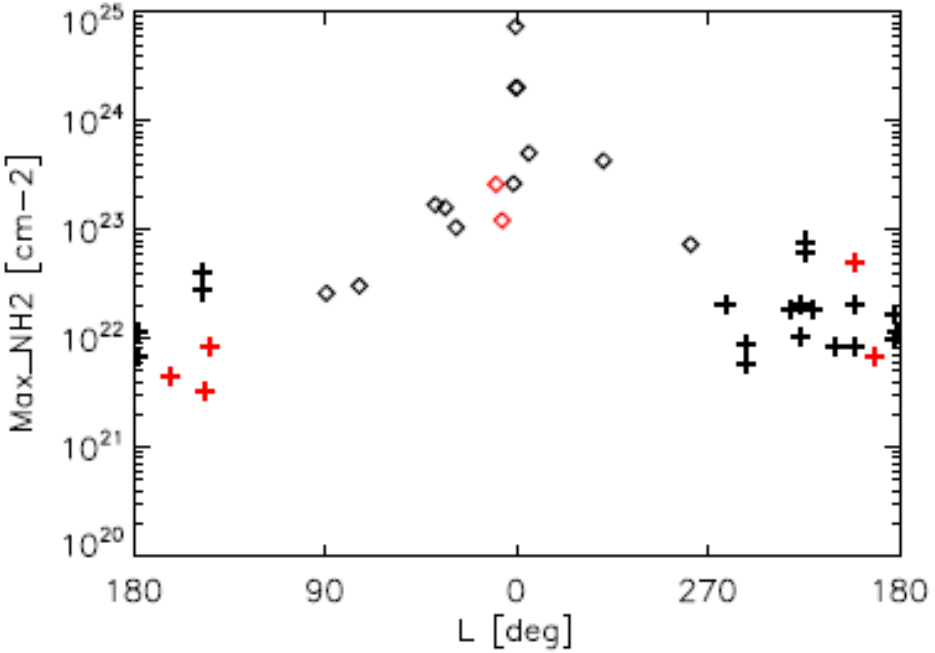


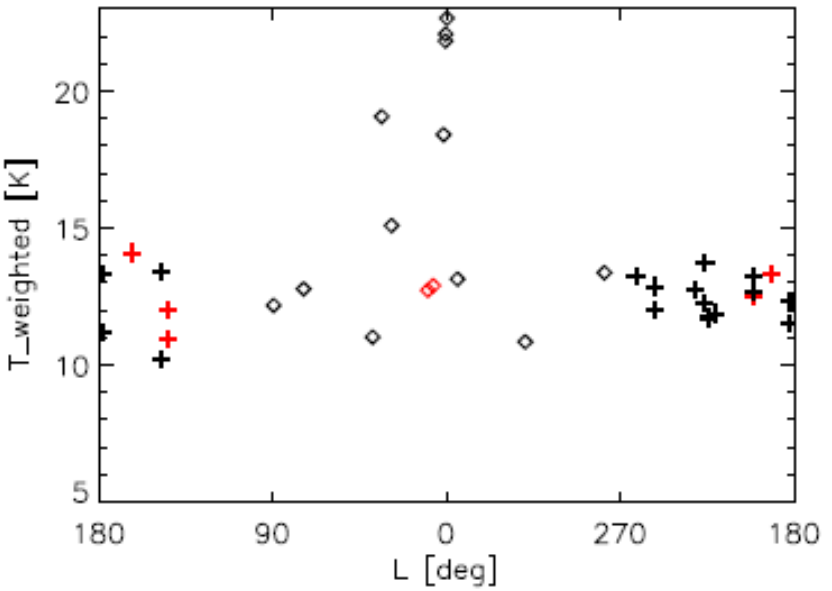
Physical properties of ECCs

- T, $N(H_2)$: 160 - 500 um images



Difference in the inner and outer galaxy?





Physical properties of ECCs

- size, mass determination:

  -> distance estimation needed:

  Wu et al. 2012 – Purple Mountain Obs., Galactic Plane line surveys, CfA CO survey, APEX observations, ...)

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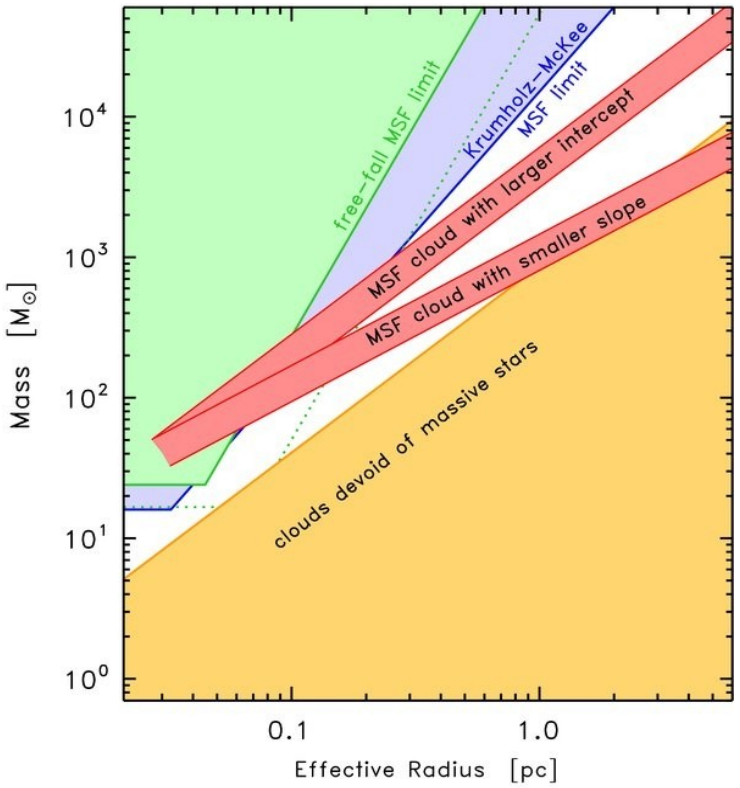
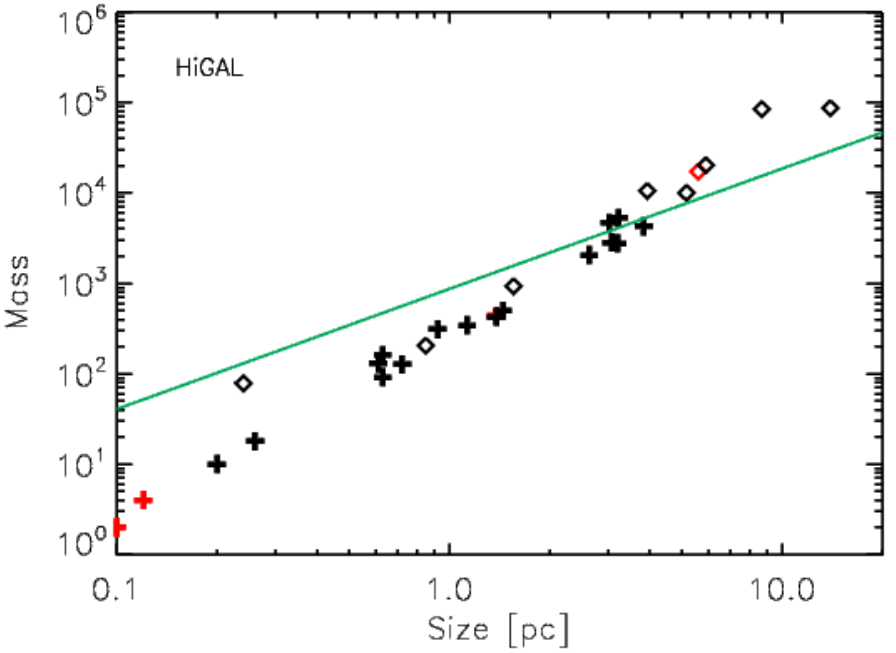


Figure 1 from Kauffmann & Pillai, 2010, ApJ, 723, L7

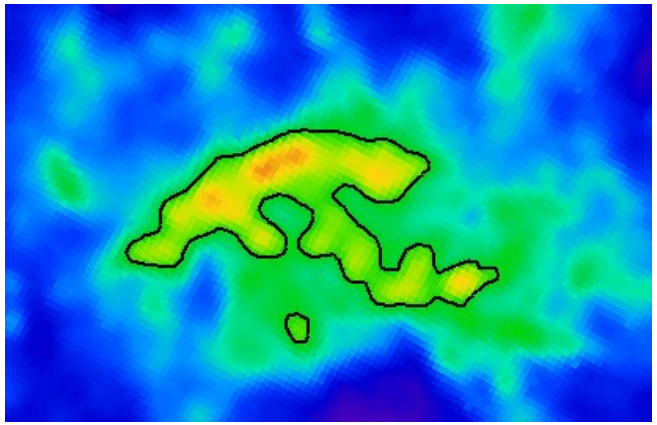
Mass – size limit for HMSF



Importance of follow-up studies

Most massive, cold sources in their early phases

Molecular line follow-up: APEX, ALMA, eVLA



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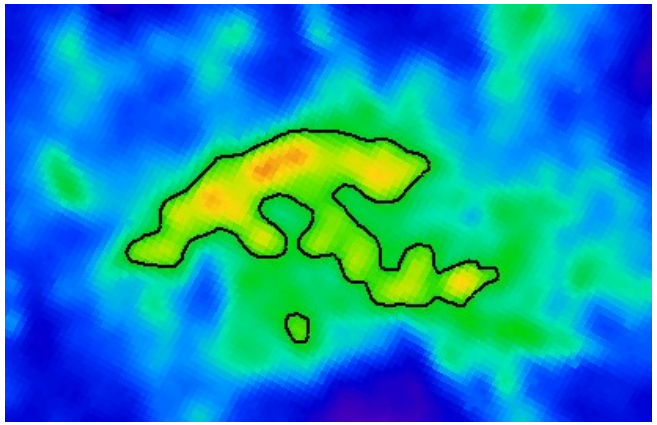

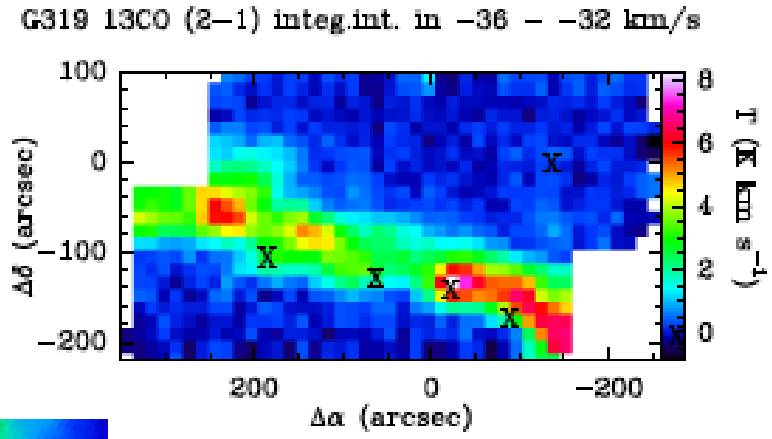

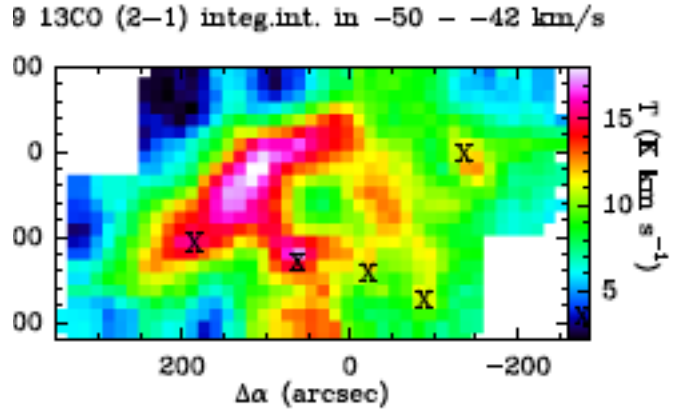

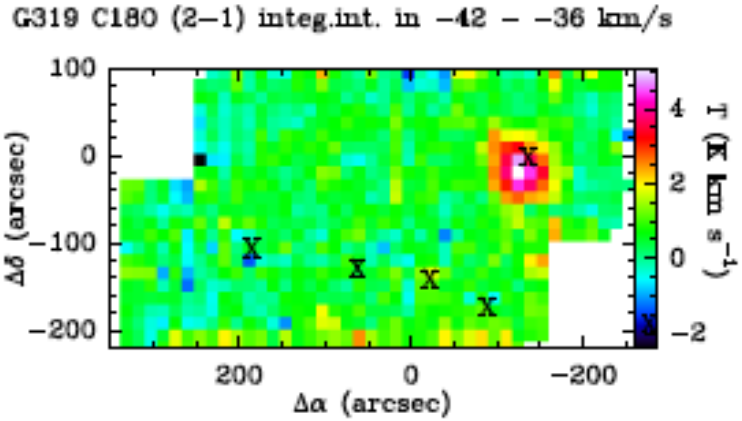

Summary

- 48 ECCs in the Galactic plane
- D ~ 0.5 kpc to 8 kpc
- M ~ few M_S to 10^5 M_S
- ~60 % in the outer part of the Galaxy
- 23 % “starless”
- 10 objects are above the mass – size limit for massive star formation

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ALMA Cycle 2 – G191.51-0.76, Band 3, 4” ~ 0.03 pc :)