Star formation in Infrared Dark Clouds

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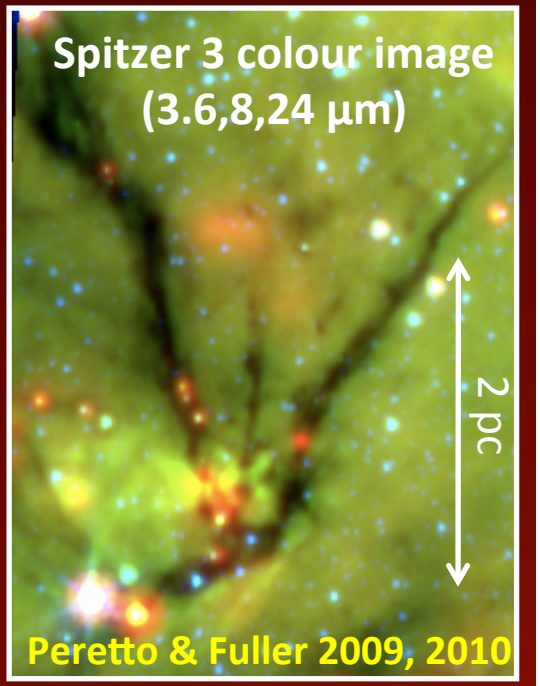
I. Infrared Dark Clouds: What are they ?

- Infrared Dark Clouds (IRDCs) are molecular clouds seen in silhouette against the mid infrared background of the galactic plane, first detected with ISO (Pérault et al. 1996)

- IRDCs are common objects in the Galaxy (e.g. Hennebelle et al. 2001; Simon et al. 2006a) and their physical properties are not different from standard molecular clouds (Simon et al. 2006b)

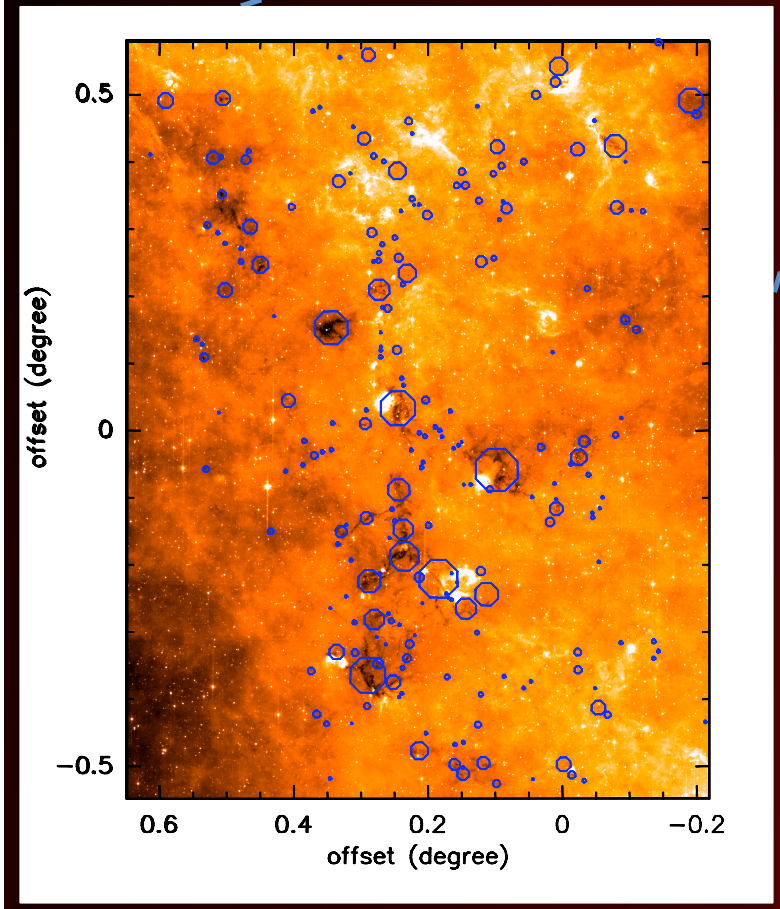
- IRDCs are claimed to be the place where massive stars form (e.g. Carey et al. 2000; Ragan et al. 2006; Rathborne et al. 2006; Vasyunina et al. 2009), and some indeed form massive stars (e.g. Zhang et al. 2009; Rathborne et al. 2011)



- By nature, IRDCs are pristine dense clouds in which the initial conditions for star formation are still imprinted, they are crucial targets to study through the Galaxy

Goal is to construct an unbiased catalogue of IRDCs in the inner galactic plane using Spitzer GLIMPSE/MIPSGAL data (Churchwell et al. 2009; Carey et al. 2009) and build a unique database of dense clouds in the Galaxy

II. A Spitzer survey of IRDCs in the Galaxy with Herschel/HiGAL follow-up



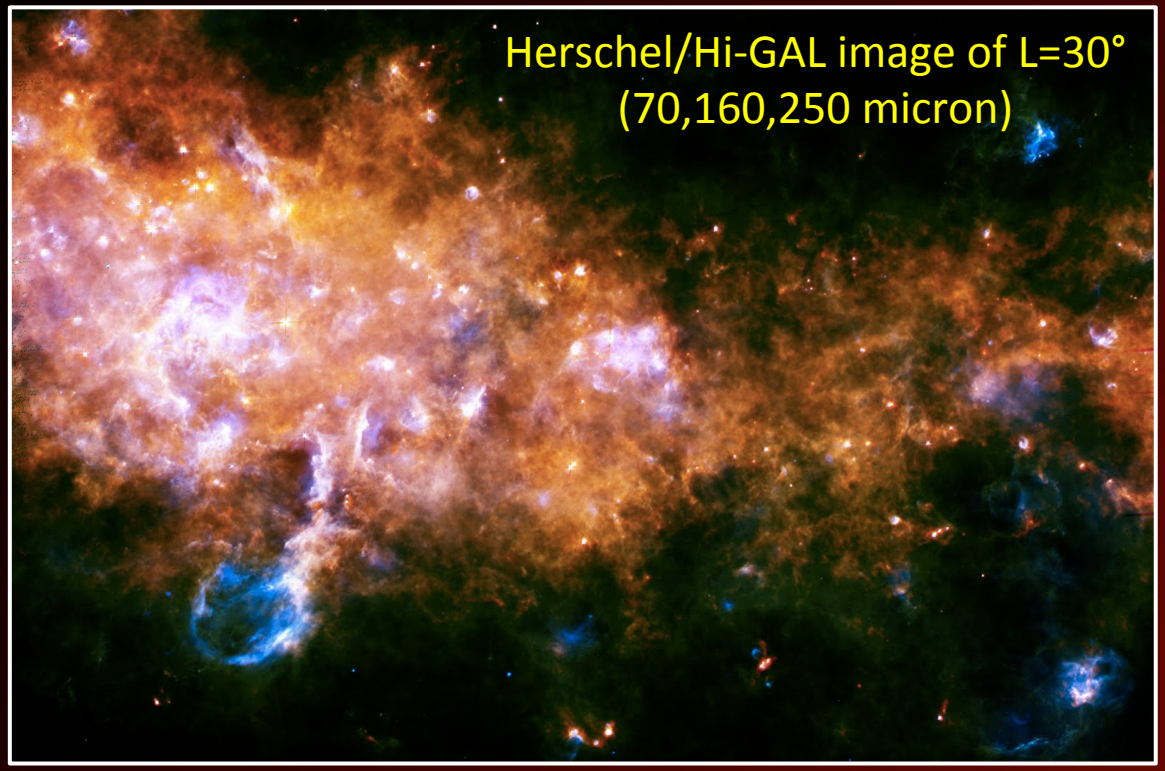
- Systematic detection of IRDCs in GLIMPSE 8μm data 0˚<|l|<65˚ and 0˚<|b|<1˚ with H_2 column density > $1x10^{22}cm^{-2}$ (A_v=10) and size > 4”
- A total of ~15000 IRDCs have been identified 80% of which were unknown
- More than just a catalog of IRDC positions we constructed column density map for each IRDC

  -> Online database: **www.irdarkclouds.org**

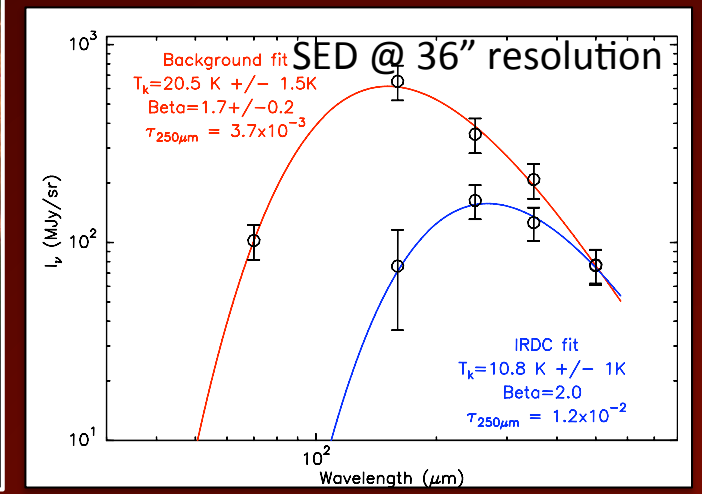
Peretto & Fuller 2009; Lenfestey, Peretto, Fuller, in prep

Issue: Some IRDCs might be just ”holes” of emission, not extinction

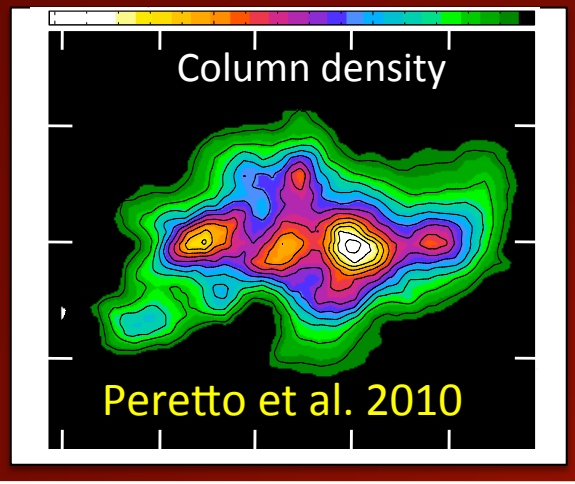
II. A Spitzer survey of IRDCs in the Galaxy with Herschel/HiGAL follow-up



The Hi-GAL survey covers all the IRDCs from our catalogue:
We can search for column density peaks in each IRDC



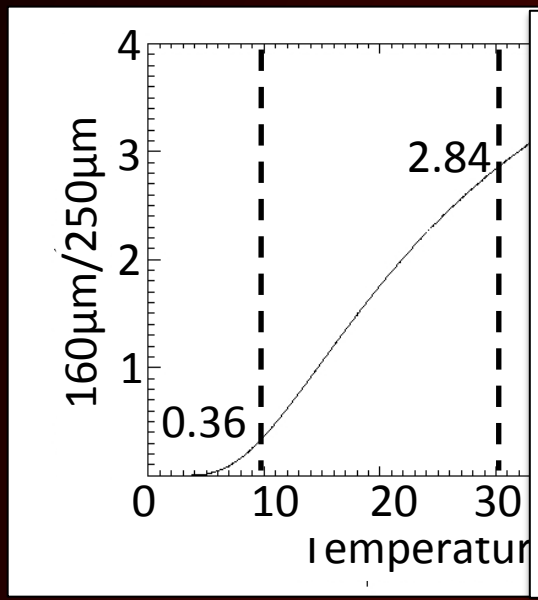
- Herschel ***Hi-GAL*** program (Molinari et al. 2010; Traficante et a. 2011)
- Parallel mode observations at 70, 160, 250, 350, 500 µm of the galactic plane -65° < l < 65° and -1° < b < 1°
- Reconstruction of column density and temperature structure by pixel by pixel SED fitting (e.g. Peretto et al. 2010, Battersby et al. 2011, Wilcock et al. 2011, Molinari et al. 2011)

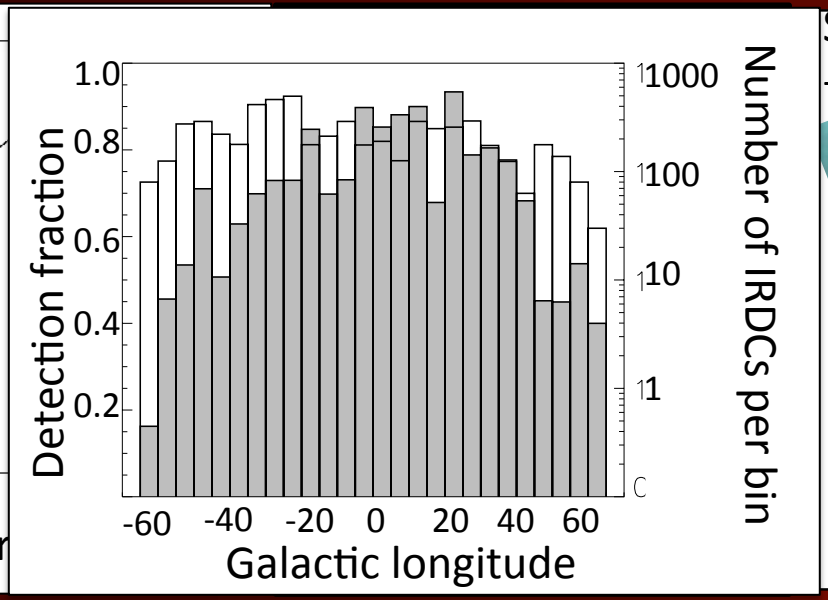


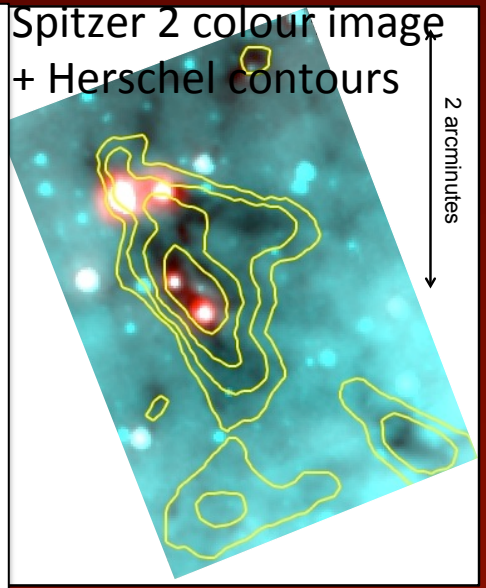
II. A Spitzer survey of IRDCs in the Galaxy with Herschel/HiGAL follow-up

Wilcock et al. 2011 looked at 250µm Herschel images (18" res.) toward a sample of ~3000 `IRDCs from the Peretto & Fuller catalogue between l=300˚ and l=330˚
-> 38% of "Herschel bright"

But column density is definitely a better tracer (250µm traces column density and temperature) -> need for a high resolution column density method







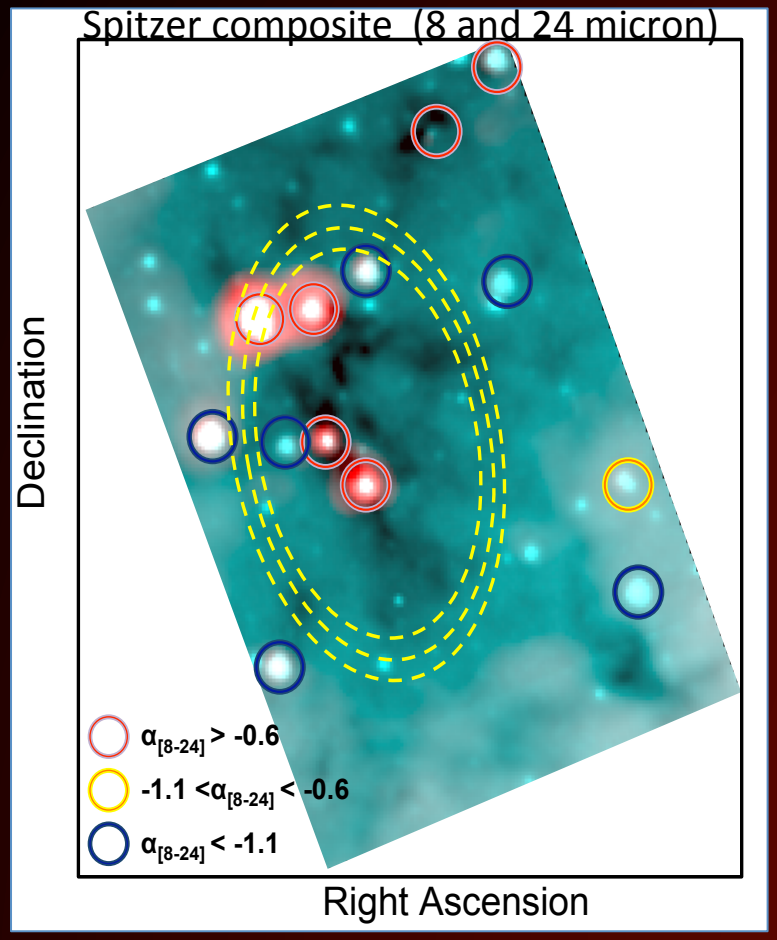
~ 70% of real IRDCs above 20'' size, percentage varying across the galactic plane

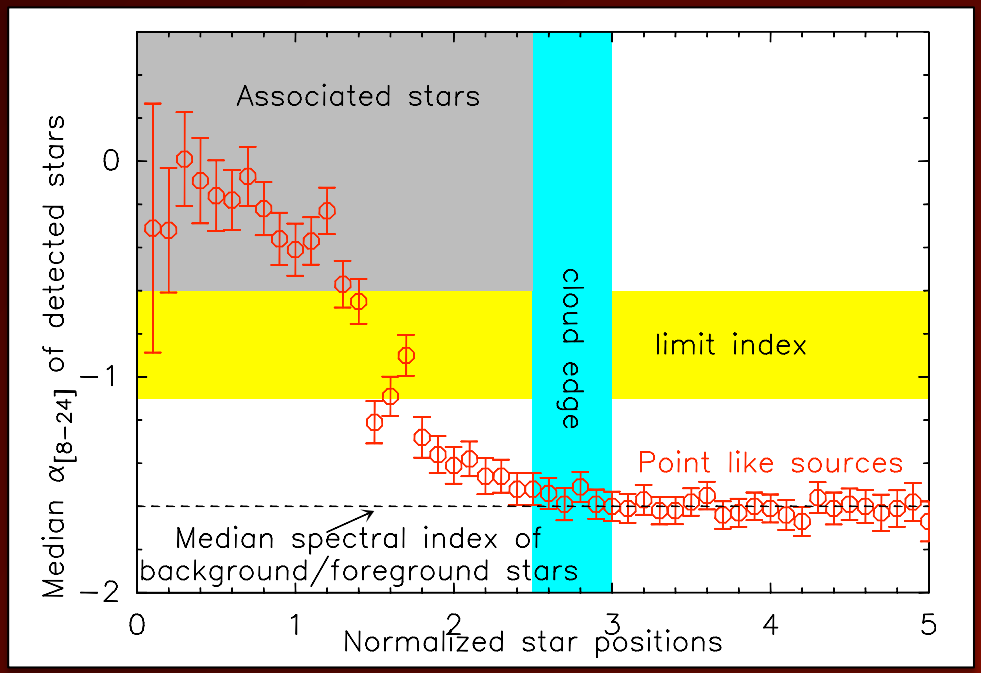
Lenfestey, Peretto, Fuller , 2012, in prep.

III. IRDCs: Nature and star formation activity

- Extract all 8 and 24micron sources in IRDC fields
- Spectral index between 8 and 24micron

$$\alpha_{[8-24]} = \frac{d\log(\lambda F_\lambda)}{d\log(\lambda)}$$



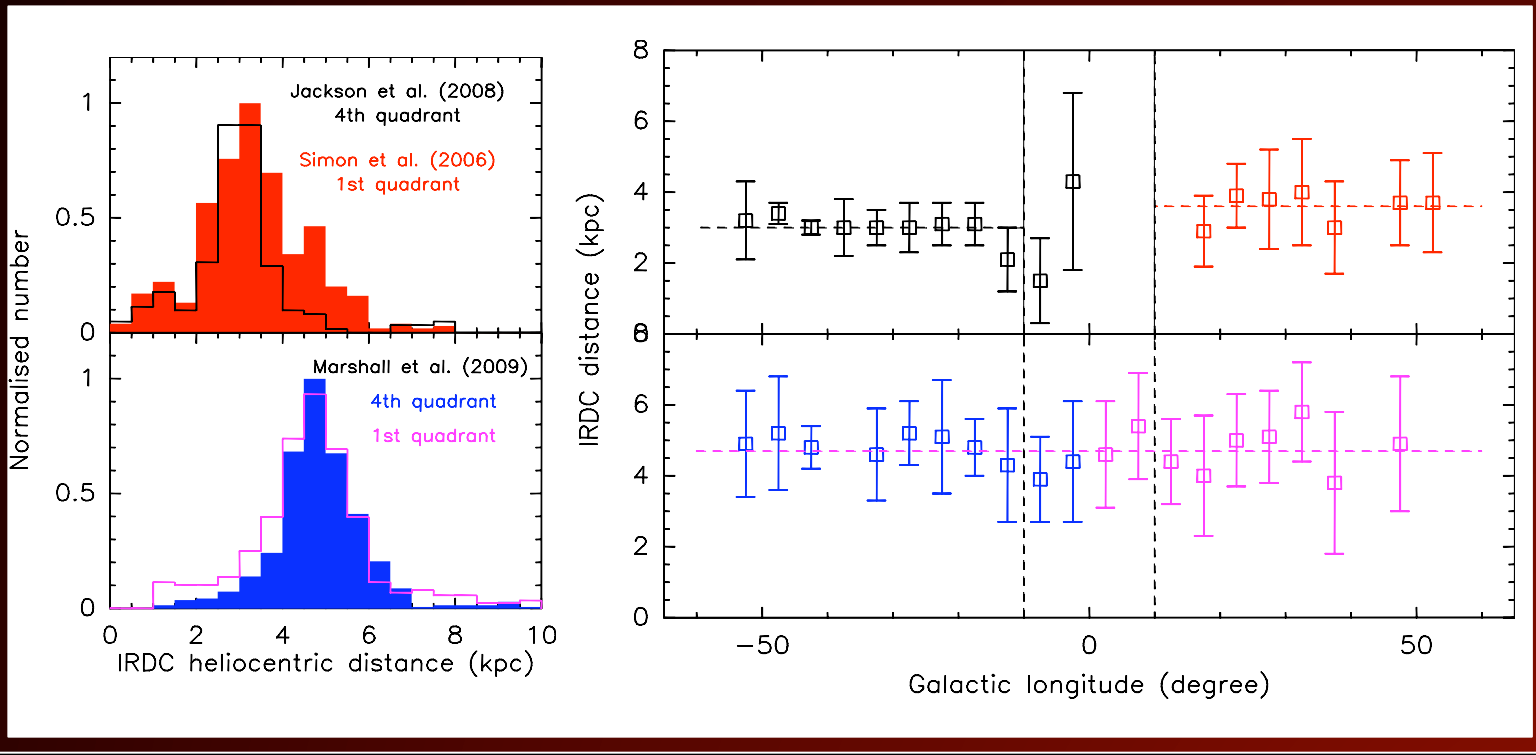


- 36% of IRDCs show star association, 64% do not
- Star association increases with column density

Peretto & Fuller, 2012, in prep

III. IRDCs: Nature and star formation activity

We are working on determining kinematic distances for all IRDCs of our sample, but not there yet….

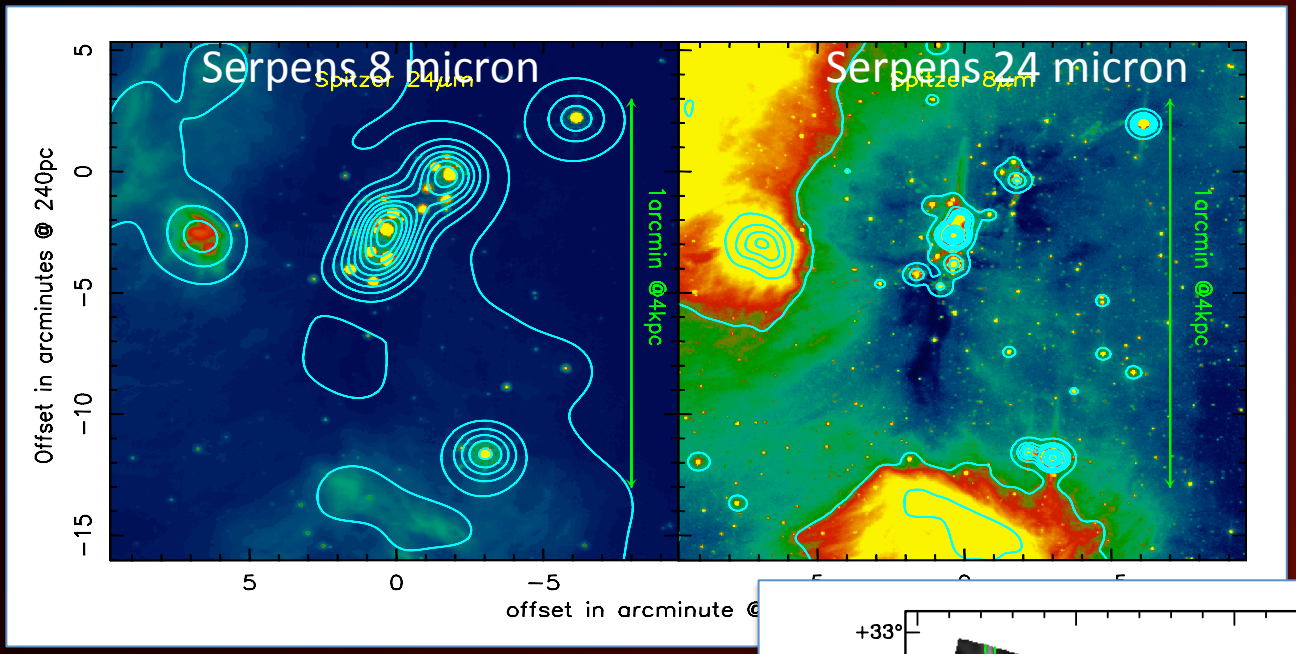


- Gaussian-like IRDC distance distribution peaking around **4kpc**
- No distance bias with galactic longitude
- There is no size bias either

Peretto & Fuller, 2010

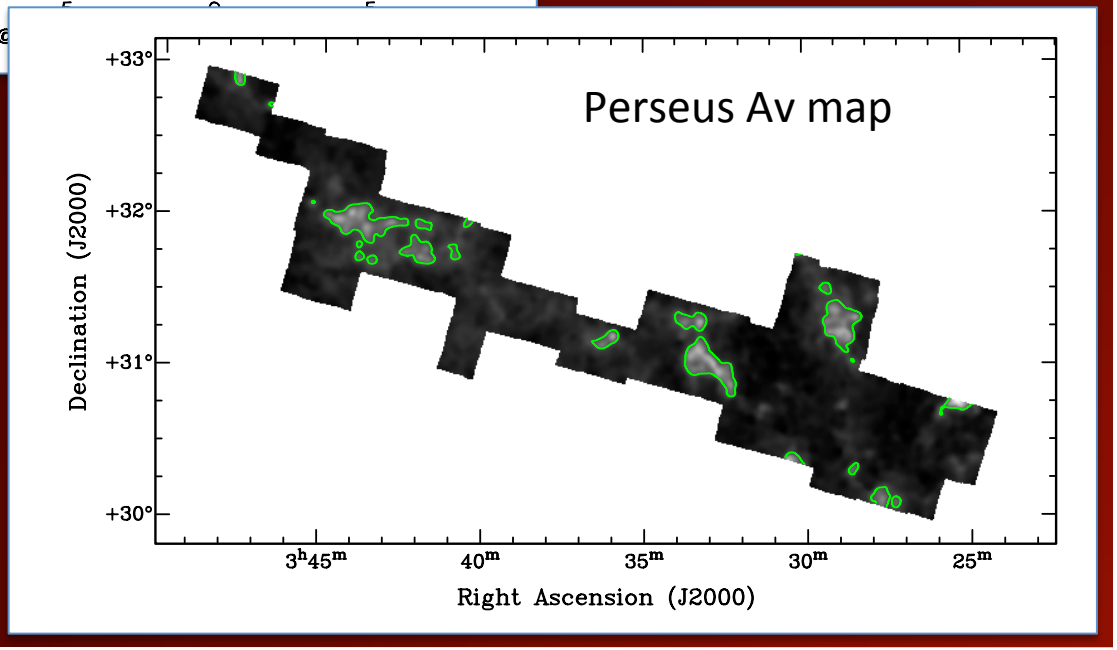
III. IRDCs: Nature and star formation activity

Use nearby star forming regions as templates (e.g. Evans et al. 2009)



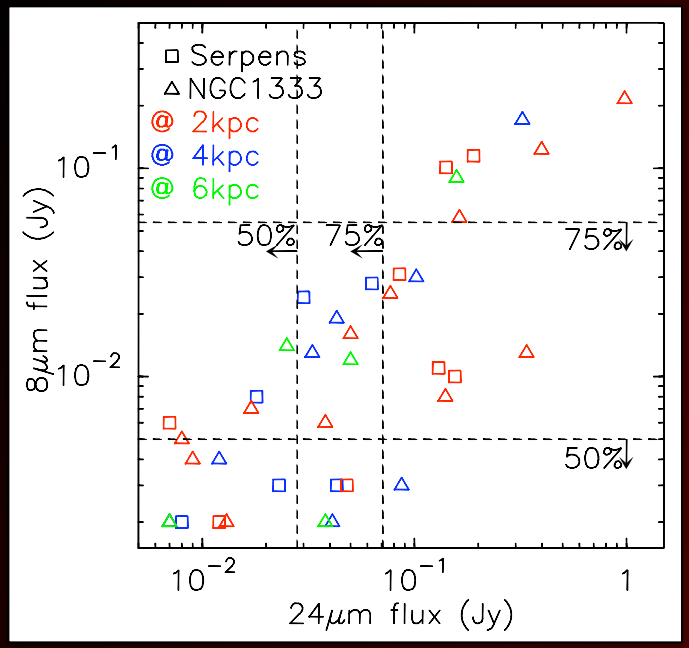
Compute protostar identification and fluxes as seen at 4pkc

Compute cloud identification and masses as seen at 4pkc

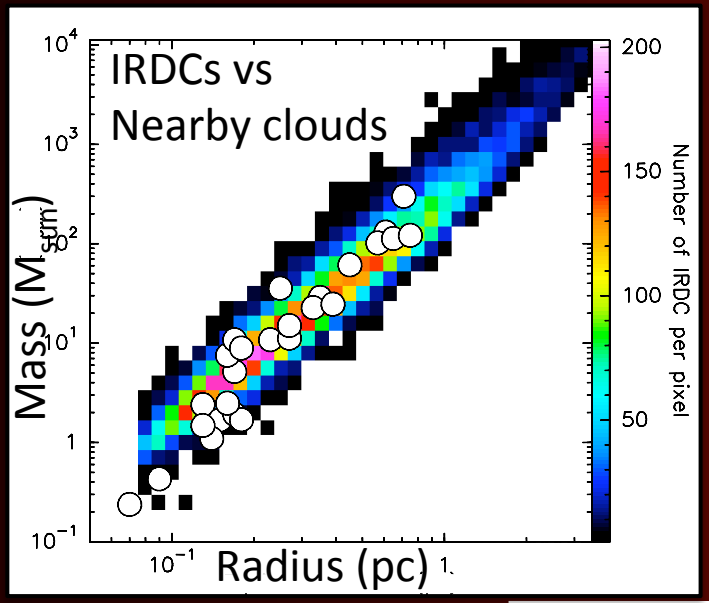


Peretto & Fuller, 2012, in prep

III. IRDCs: Nature and star formation activity



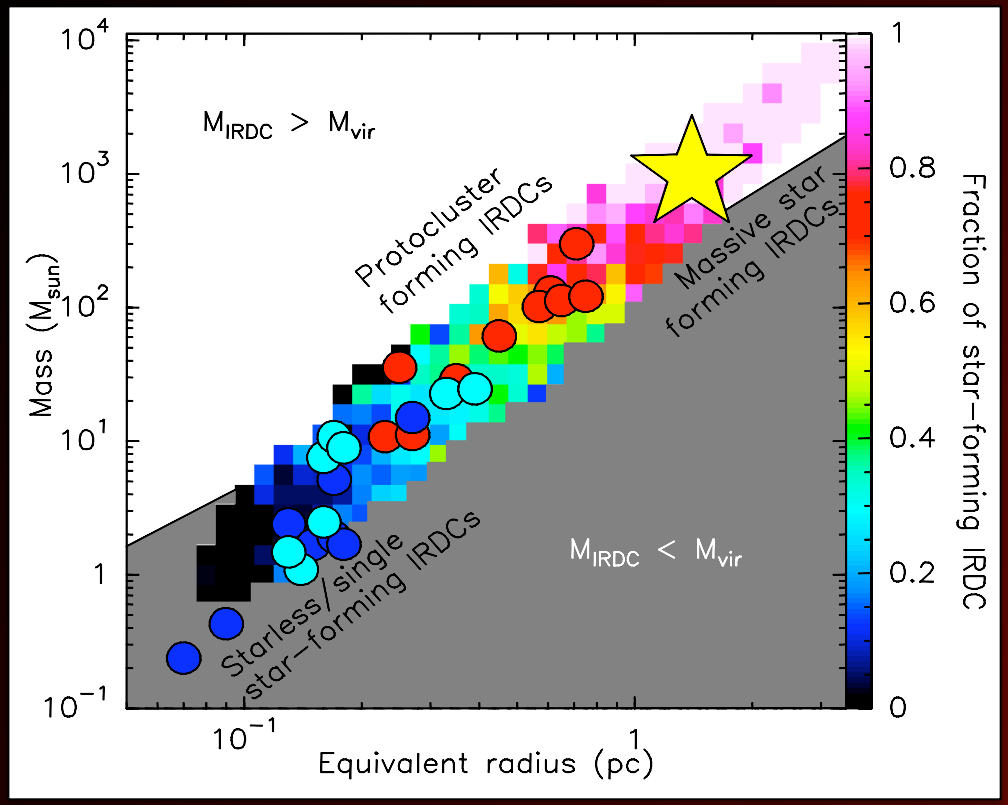
- Star fluxes in IRDCs are similar to the ones of nearby protoclusters
- IRDC stars have luminosities down to 10 L_{sun}
- IRDC stars are typically small clusters of unresolved protostars



- Size-Mass relation for IRDCs is similar to the one of nearby clouds – Star fluxes are compatible with the ones of nearby proto-clusters
- IRDCs are in all aspects similar to nearby star-forming clumps but they extend to high mass end

Peretto & Fuller, 2012, in prep.

III. IRDCs: Nature and star formation activity



- Nearby star forming clouds with L > 10 L_{sun}
- Nearby star forming clouds with 0 > L > 10 L_{sun}
- Nearby starless clouds

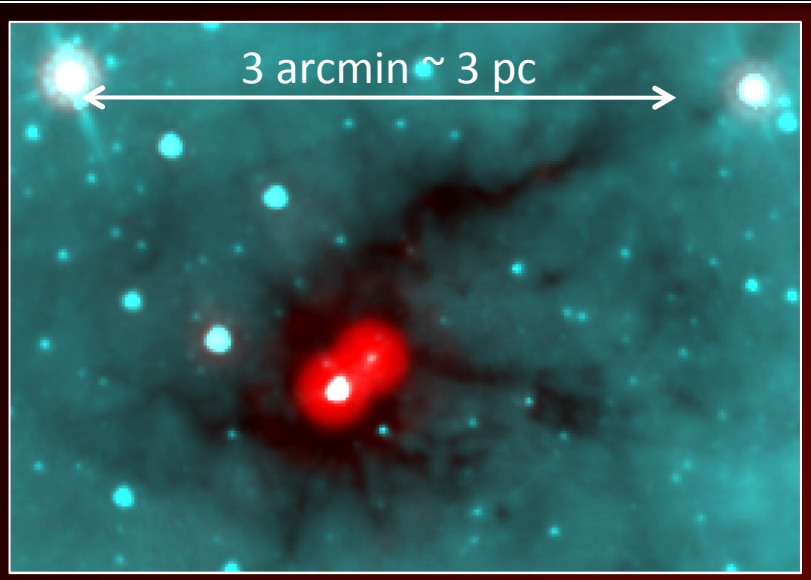
- Fraction of active IRDCs increases with cloud mass/size:

- Evolution of starless IRDC lifetimes as a function of mass/size
- Evolution of the fraction of gravitationally bound IRDCs as a function of mass/size
- **Time evolutionary sequence from low-mass IRDCs to high-mass IRDCs: Molecular cloud accretion**

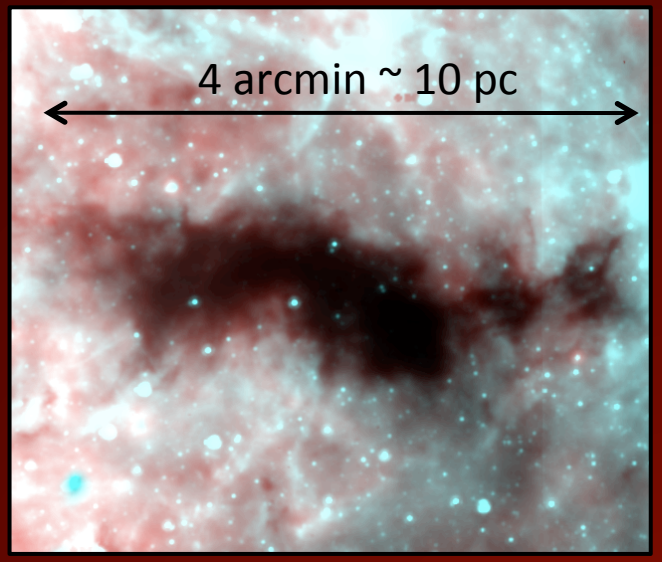
Peretto & Fuller, 2012, in prep.

IV. Extreme cases: ALMA Cycle 0 follow-up of a very bright IRDC

SDC335 , 5000 M_{sun}, two of the brighest massive YSOs observed within HiGAL



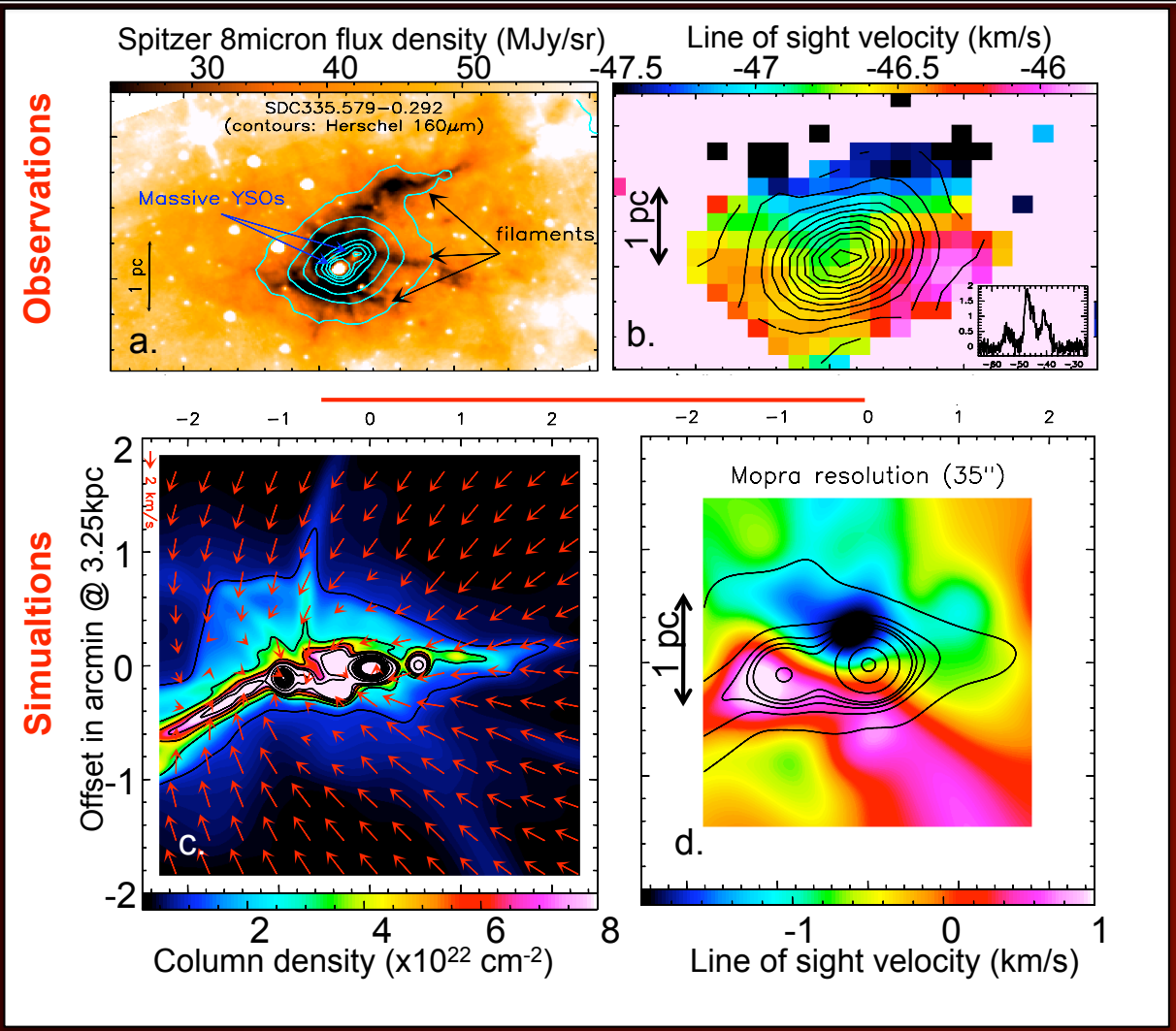
SDC0.341, or The Brick (Longmore et al. 2011), 1.4×10^5 M_{sun}, starless IRDC!!



Both sources have been / will be observed for ALMA Cycle 0:
SDC335 - Peretto et al. ; The brick - Rathborne et al.

IV. Extreme cases: ALMA Cycle 0 follow-up of a very bright IRDC

Comparison of single dish observations with MHD numerical simulations of a massive globally collapsing cloud (simulations from P. Hennebelle published in Schneider et al. 2010)



Summary

- We built a sample of 15000 Spitzer of IRDCs in |l| < 65 deg |b| < 1deg
- We showed that 70% detected in emission with Herschel
- We showed that IRDCs are, in all aspects, similar to nearby star-forming clumps
- We showed that star formation activity as a function of IRDC mass/size could be explain by cloud accretion
- Extreme objects can be found in our sample: follow-up observations with ALMA
- Many more studies on the earliest stages of star formation can be performed using our IRDC database (See Lenfestey's poster # 24)