A far-infrared catalogs of dense cores and protostars in the Lupus complex

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Submitted to A&A

Protoplanery disks seen through the eyes of new-generation high-resolution instruments
INAF – AOR 25-28 Jume 2018

Herschel Gould Belt Survey

http://gouldbelt-herschel.cea.fr

Main aim: to study the process of protostars formation from diffuse ISM, through complete census of prestellar cores and young, embedded protostars in nearby (d<500 pc) star-forming regions.

Observations: large maps at 70, 160, 250, 350 and 500 µm with Herschel photometers.

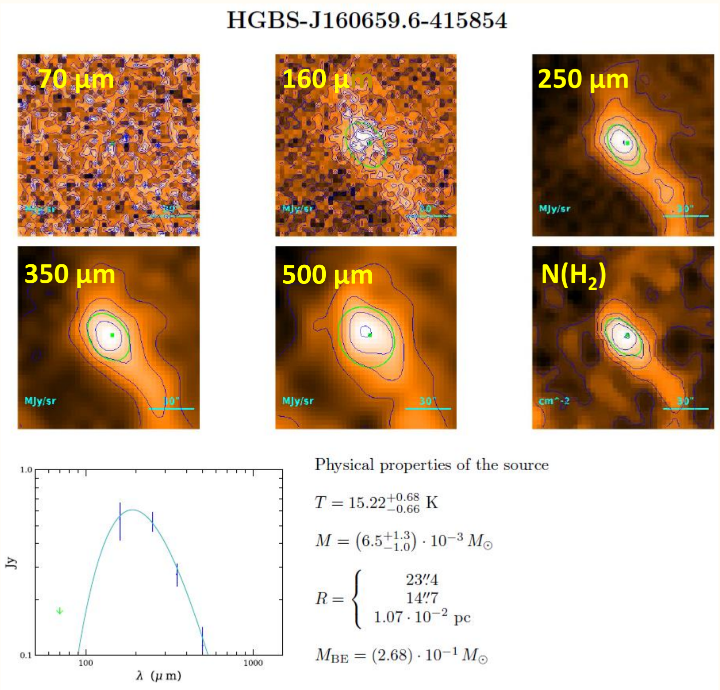
Products:

Calibrated photometric maps, N(H_2) column density and temperature maps
Catalogues of dense cores with their measured and physical properties
Catalogues of protostars/YSOs with their measured and physical properties

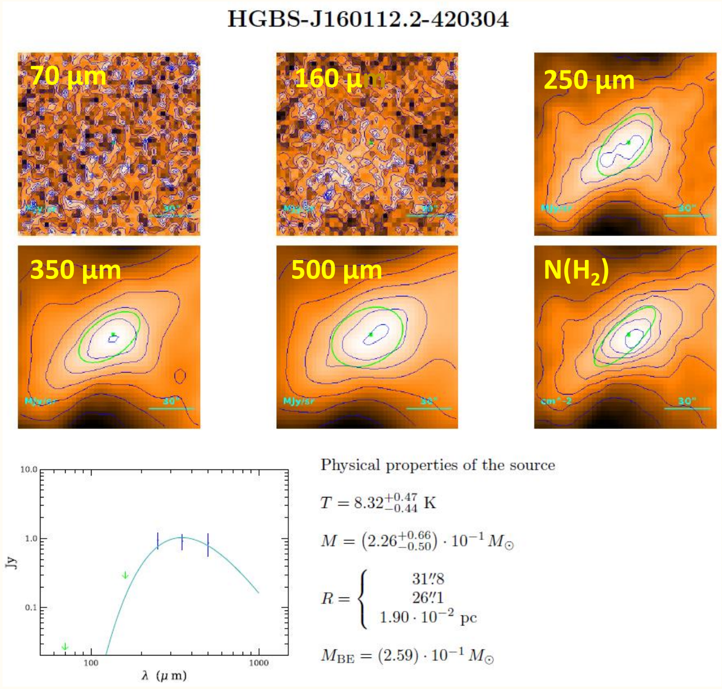
Compact source detection and classification

Starless dense core
without 70 μm detection

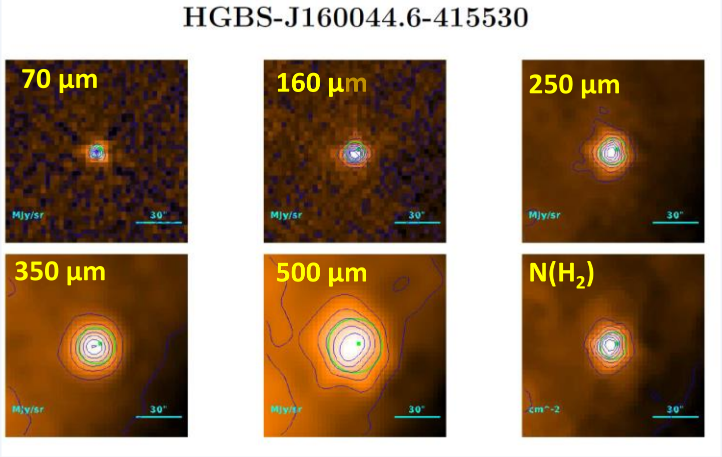
Unbound core
$M_{BE}/M_{obs} > 2$

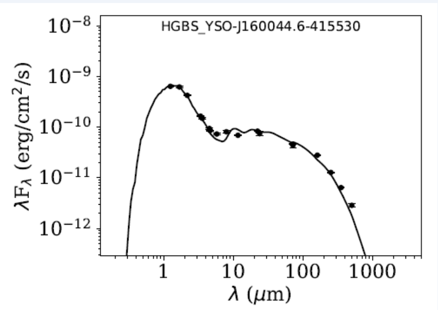


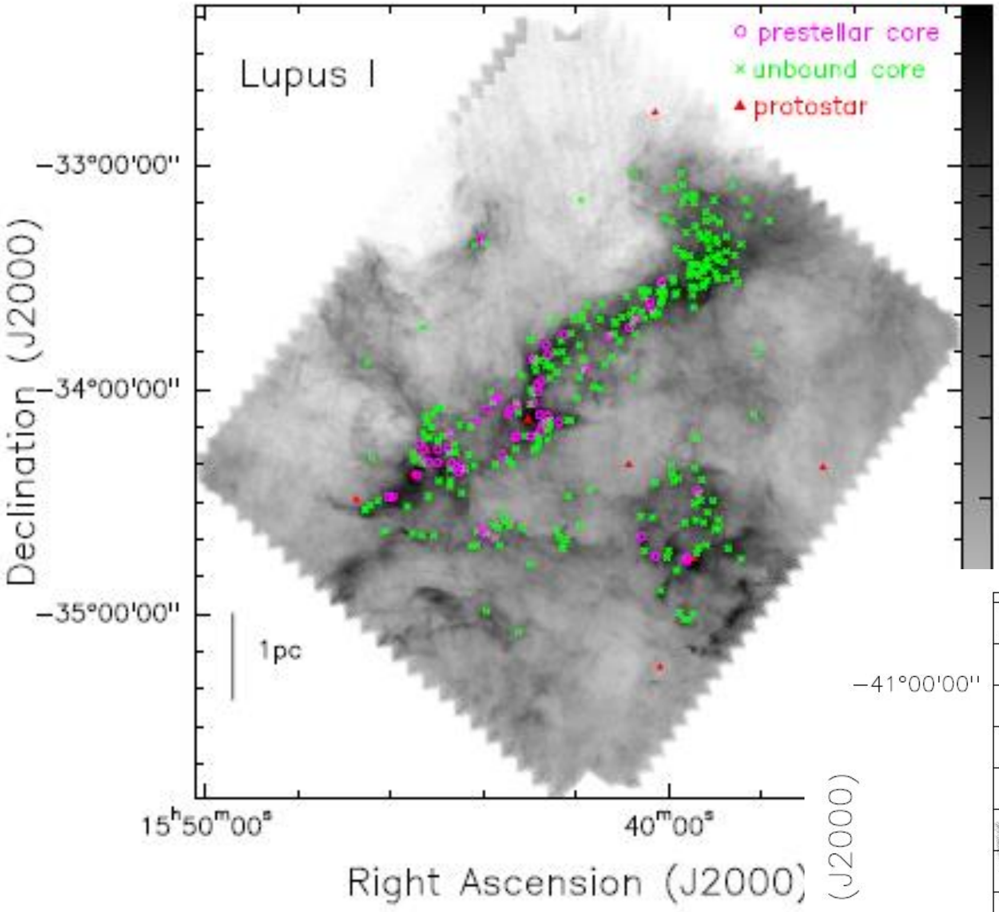
Candidate pre-stellar core
$M_{BE}/M_{obs} \leq 2$

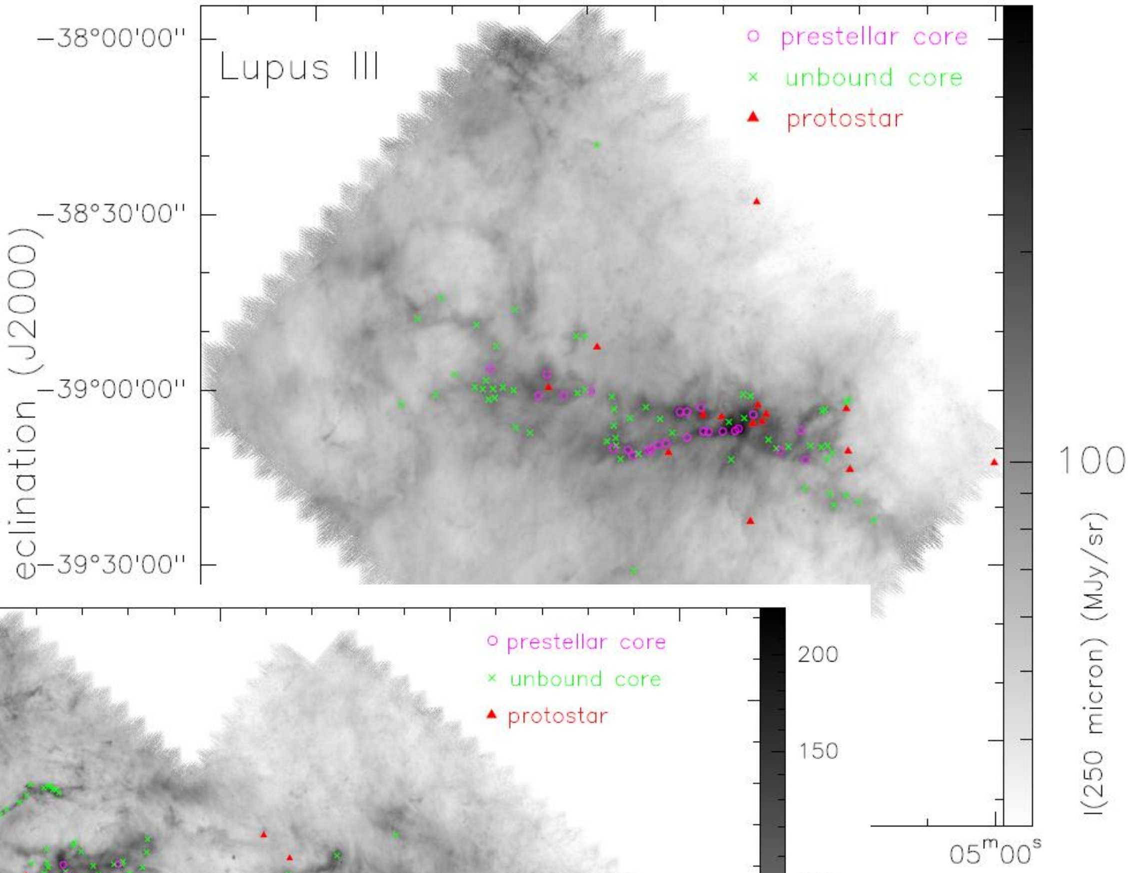


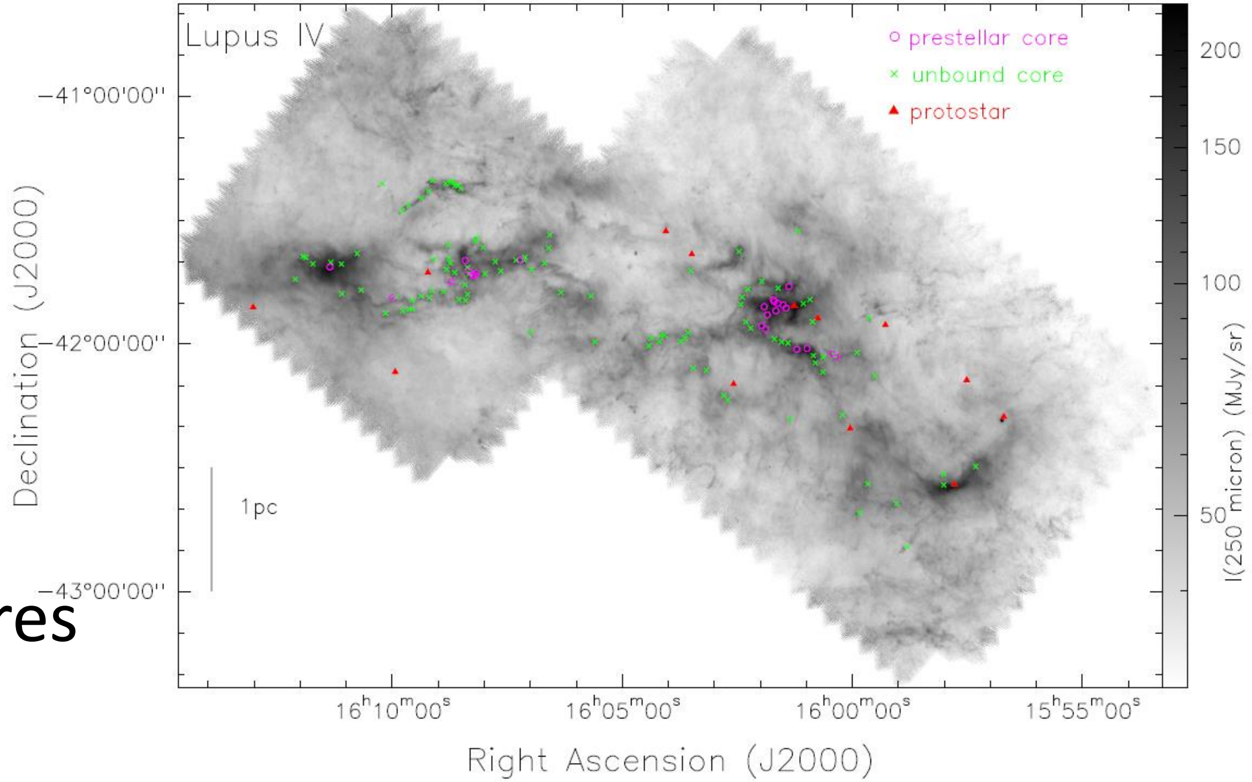
Protostar / YSO
with 70 μm detection











Lupux complex

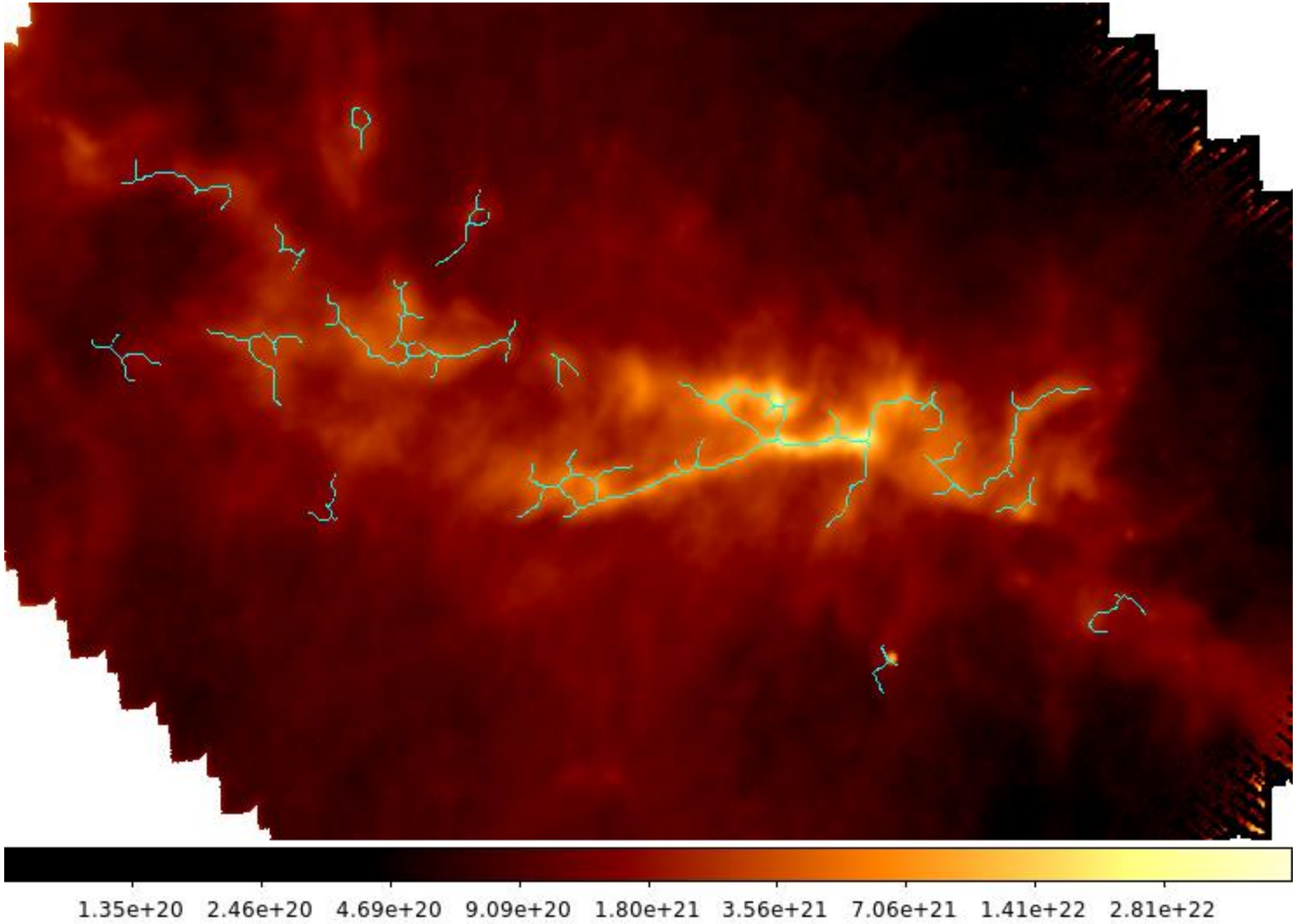
429 unbound starless cores

103 candidate prestellar cores

38 protostars / YSOs

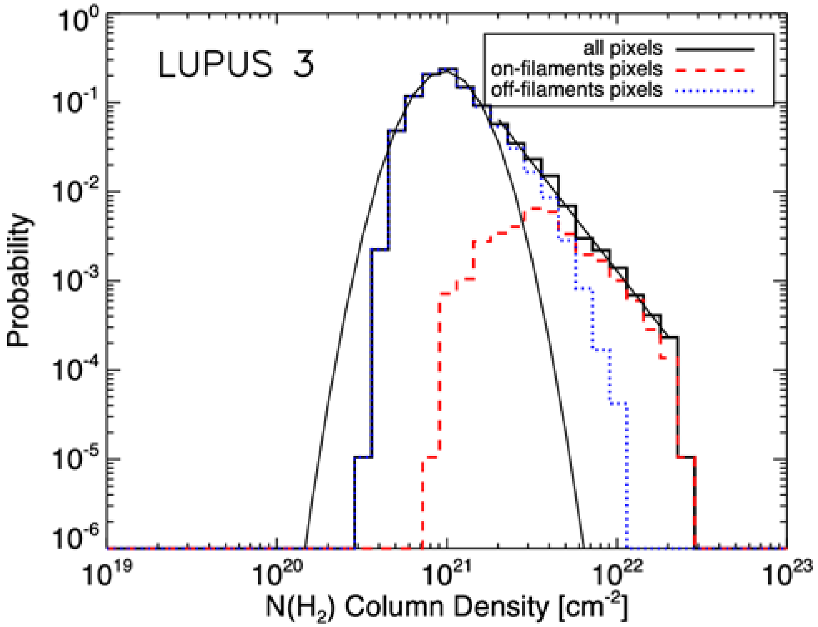
Benedettini et al, submitted

ISM of GMC is structured in filaments



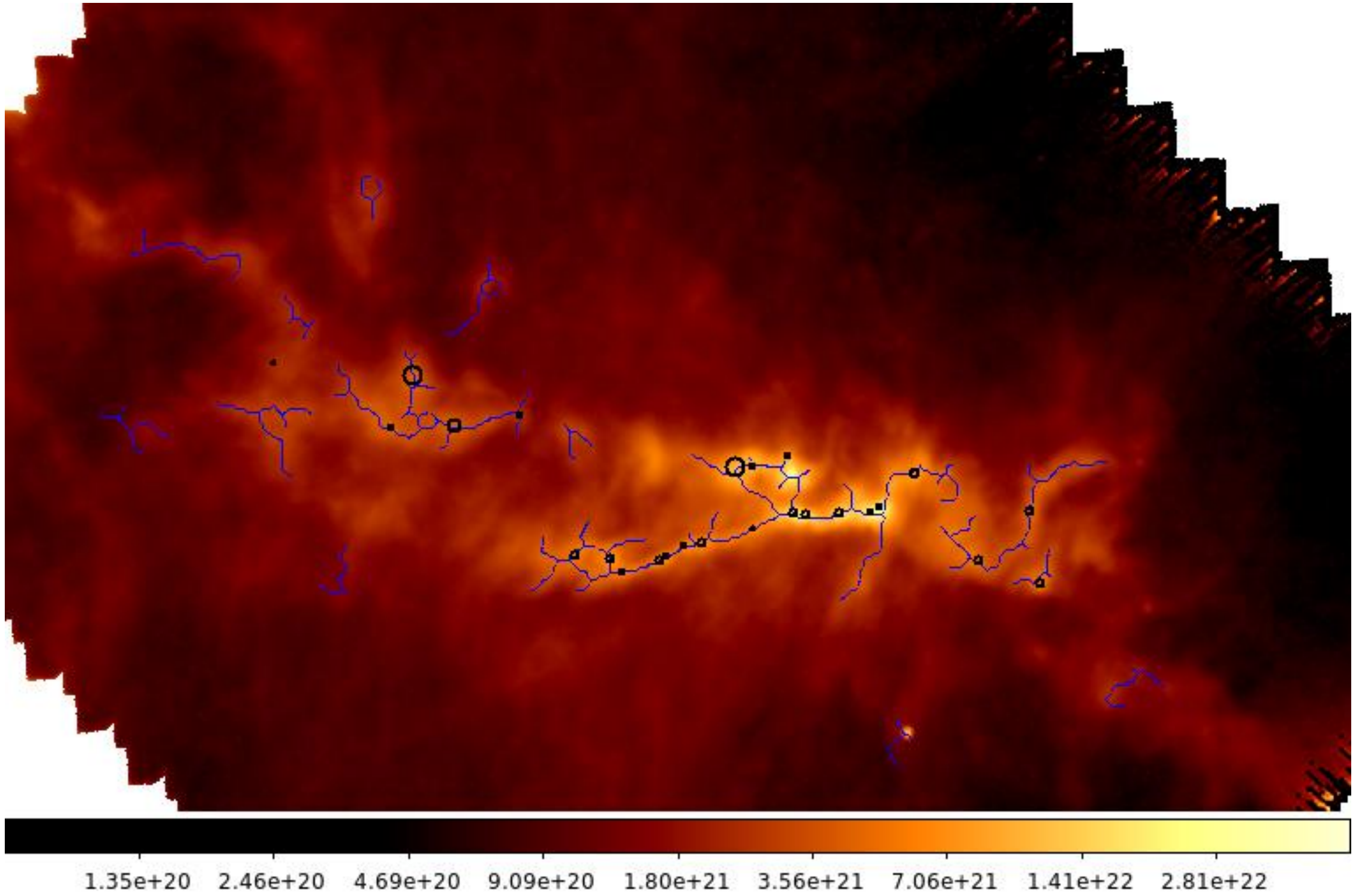
Lupus III $N(H_2)$ map

Probability Distribution Function (PDF) of $N(H_2)$



Benedettini et al. 2015

ISM of GMC is structured in filaments

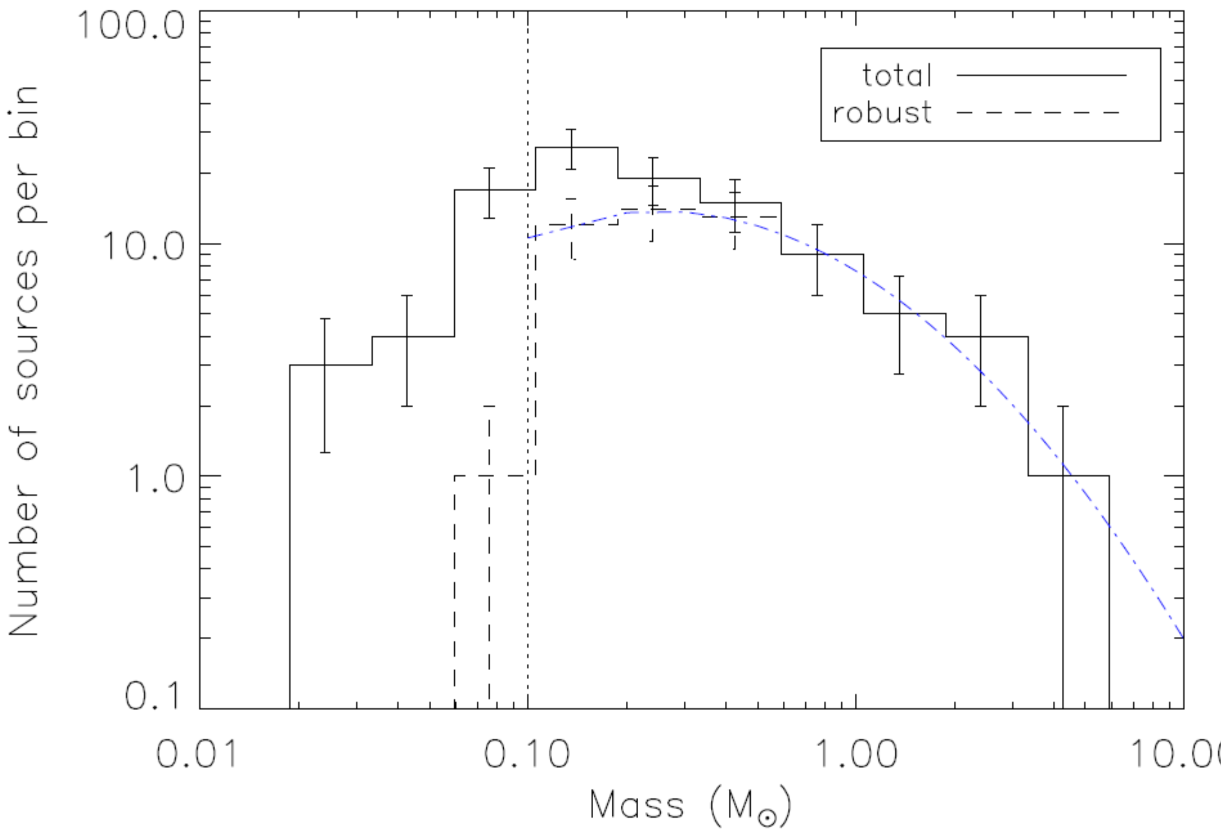


Lupus III $N(H_2)$ map
Benedettini et al. 2015

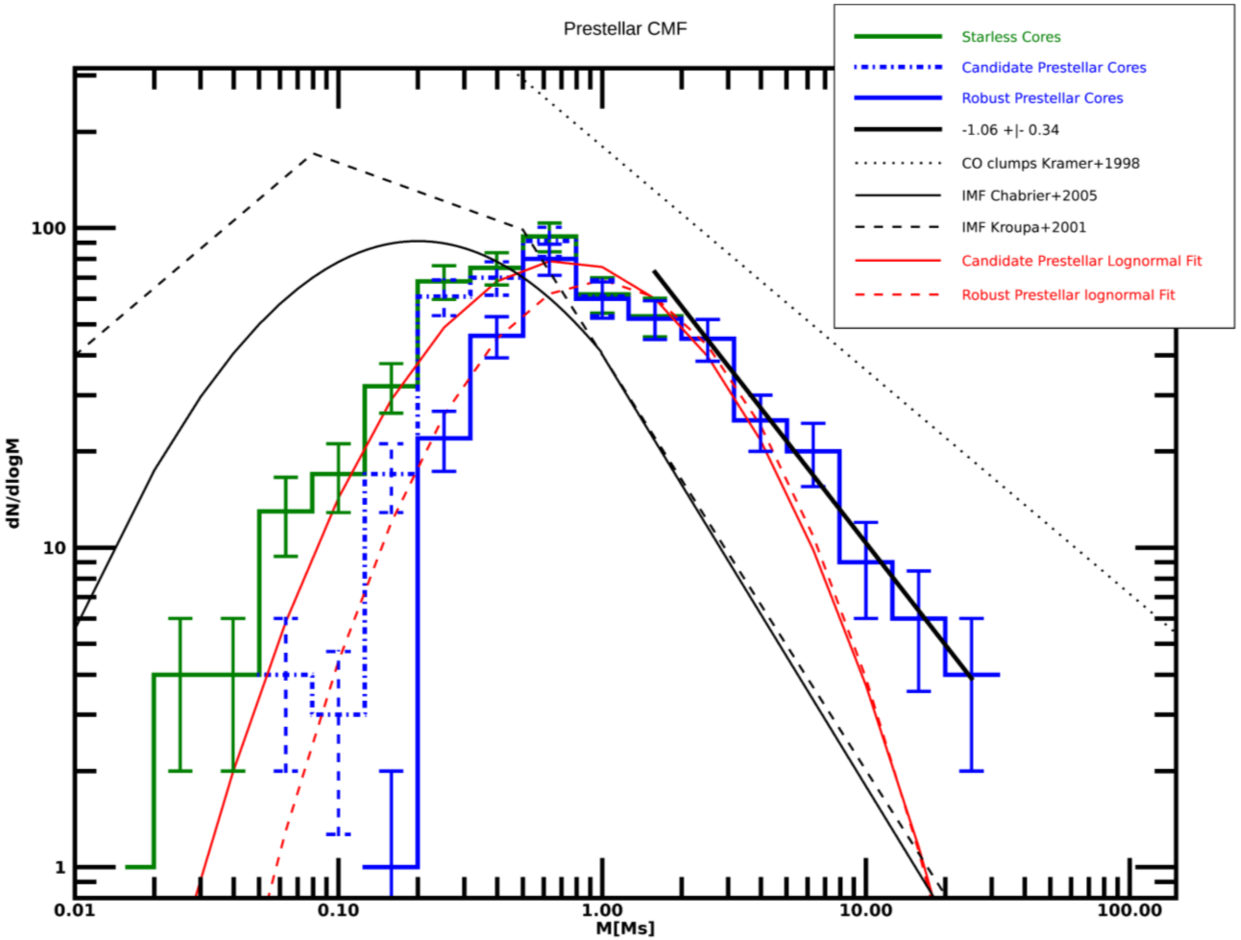
The large majority of candidated pre-stellar cores (94% in Lupus) are found ON FILAMENTS.

Filaments are the prefered place where the pre-stellar condensations are formed.

Core Mass Functions of candidate pre-stellar cores



Lupus (Benedettini et al., submitted)



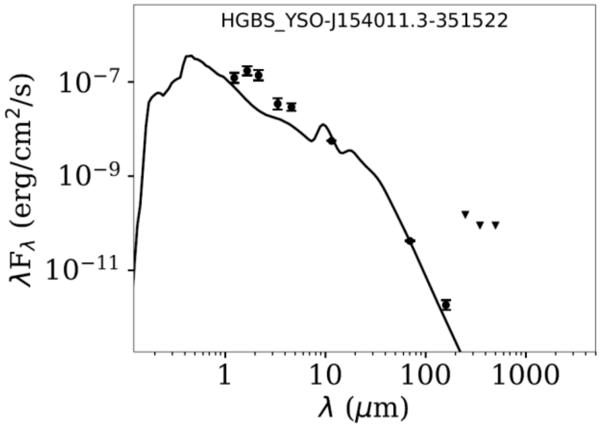
Serpens (Fiorellino et al. in prep)

Lupus YSOs/protostars catalog

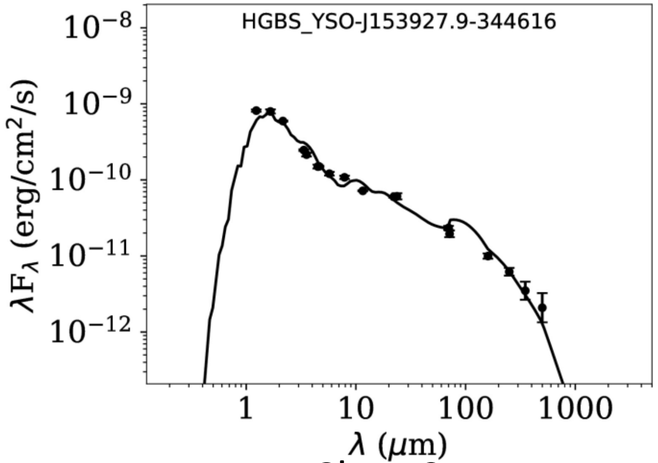
Herschel found sources not present in previuos catalogs.

Association with Spitzer, WISE and 2Mass ➡ SED from 1.2 μm to 500 μm

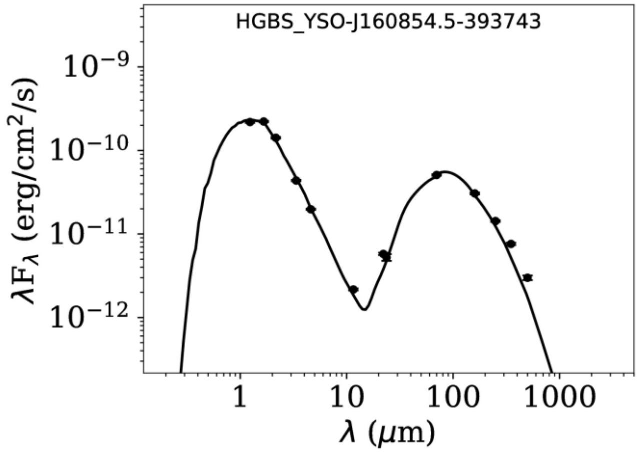
Class III



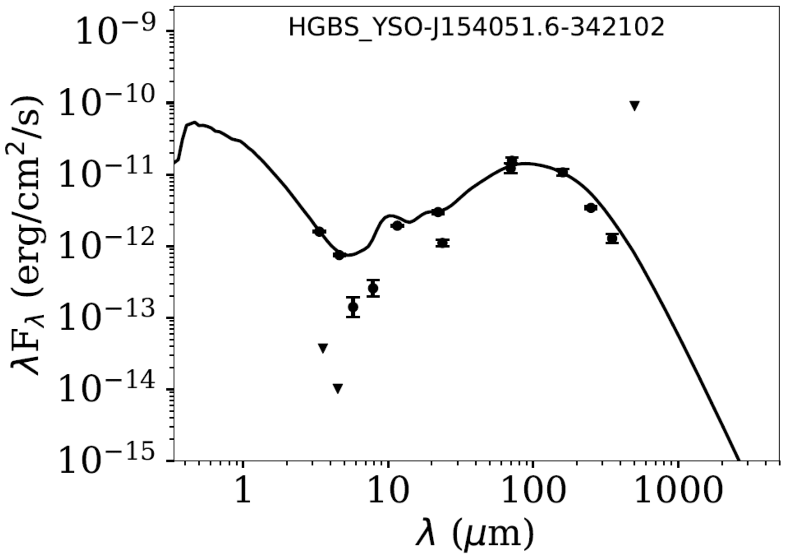
Class II



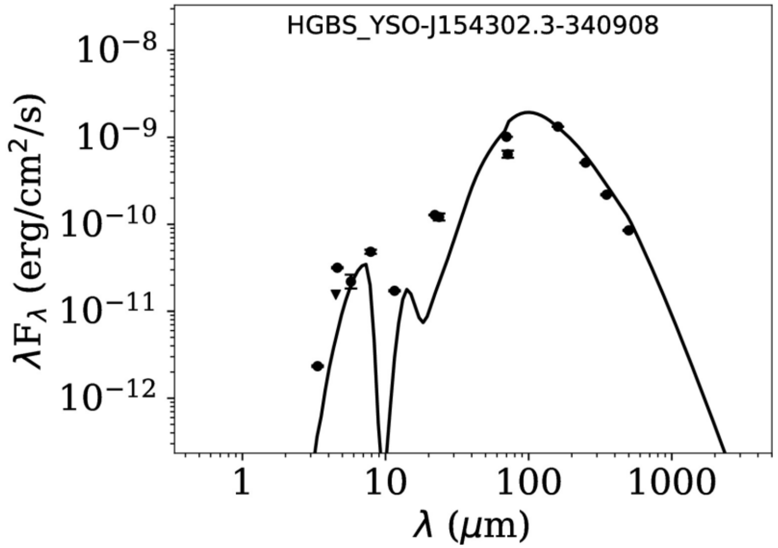
Class II with transitional disk



Class I



Class 0



Herschel catalog is complete for Class 0 and I

Evolutionary classification based on two indicators:

- α spectral index between 2.2 μm and 24 μm $\alpha = \frac{d[\log(\lambda F\lambda)]}{d(log\lambda)}$

  spectral Class I, Flat, II, III (as Spitzer c2d)

  + $L_{submm}/L_{bol}>0.01$ for Class 0

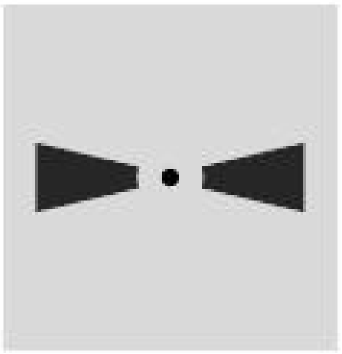
- SED modeling with radiative transfer models

In general we find good agreement between the two methods

SED modeling

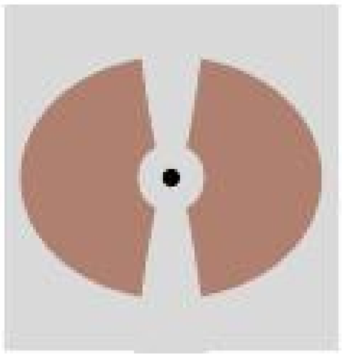
Different sets of models (Robitaille 2017) with different combination of 5 key elements: star, disk, envelope, outflow cavity + ambient medium.

disk

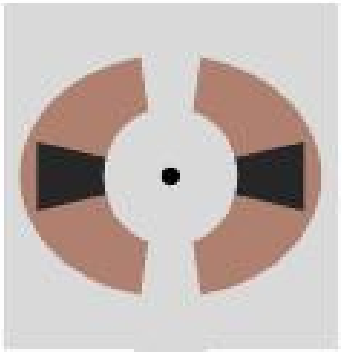


envelope

envelope + cavity



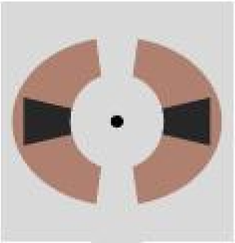
envelope + cavity + disk



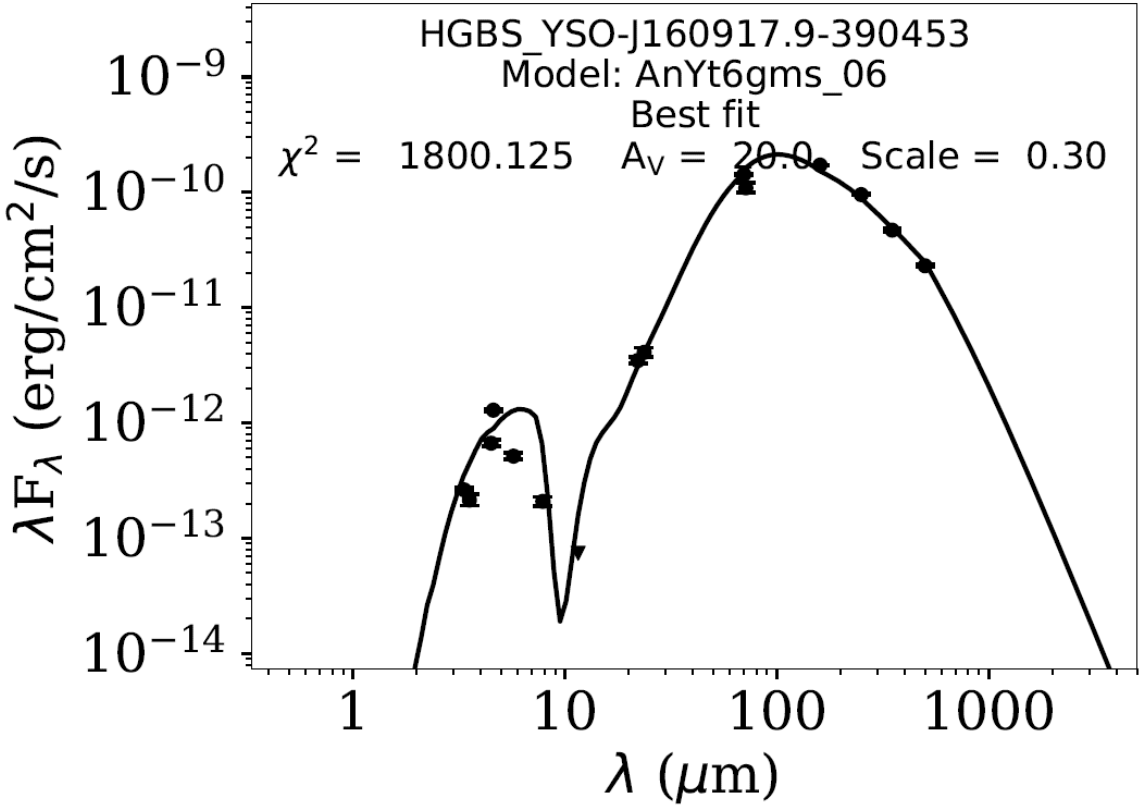
In Benedettini et al. submitted, we provide tables with the range of the input parameters for best fit model.

It is possible to define the presence/absence of disk/envelope/outflow cavity.

Best Fit
Model with envelope + cavity + disk

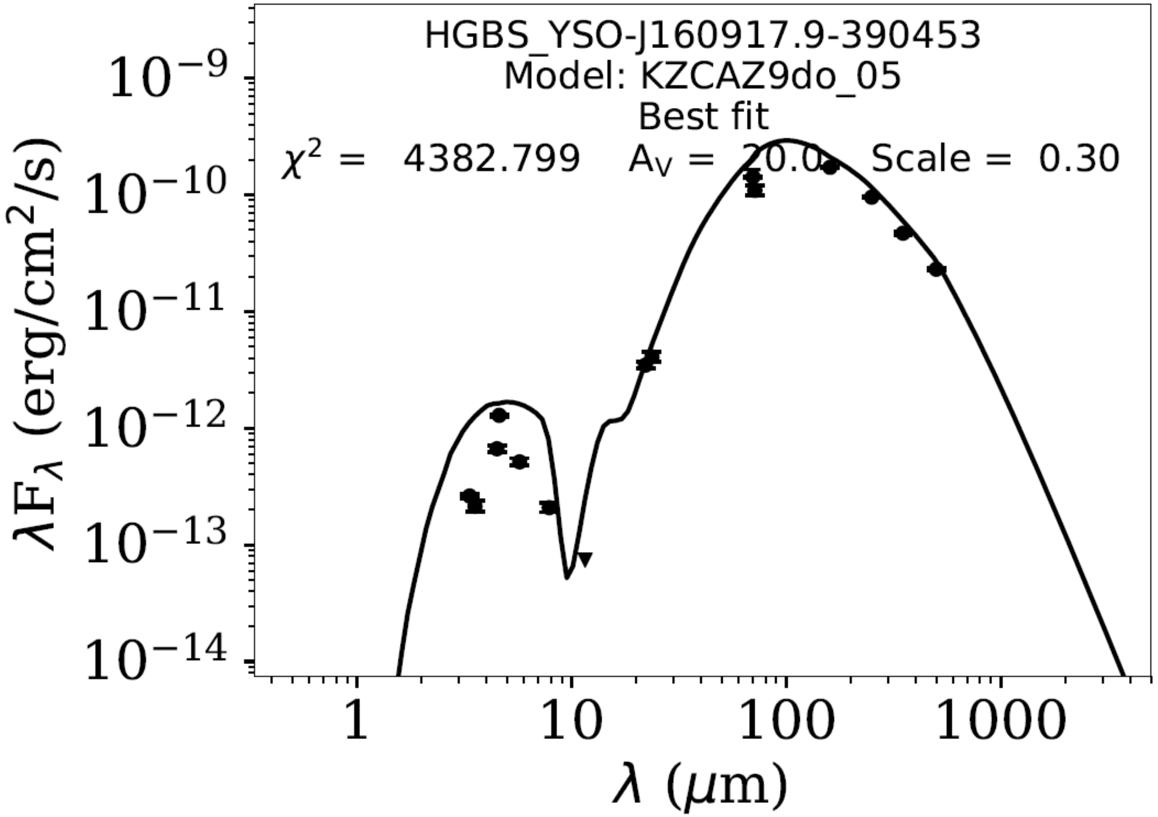


ρ_0=1.2x10^{-19} g/cm^3 , M_{disk}=4.8x10^{-6} M⊙



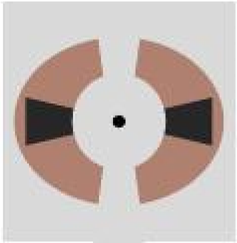
Model with envelope + cavity

ρ_0=1.5x10^{-18} g/cm^3

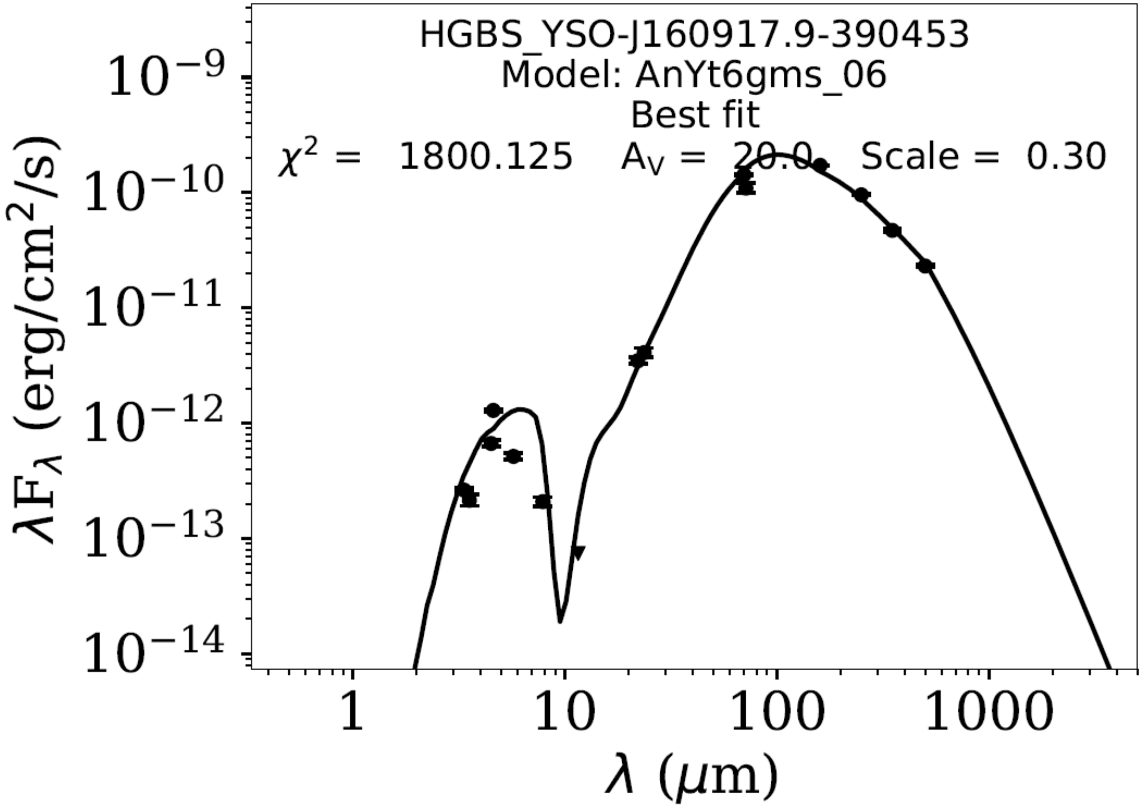


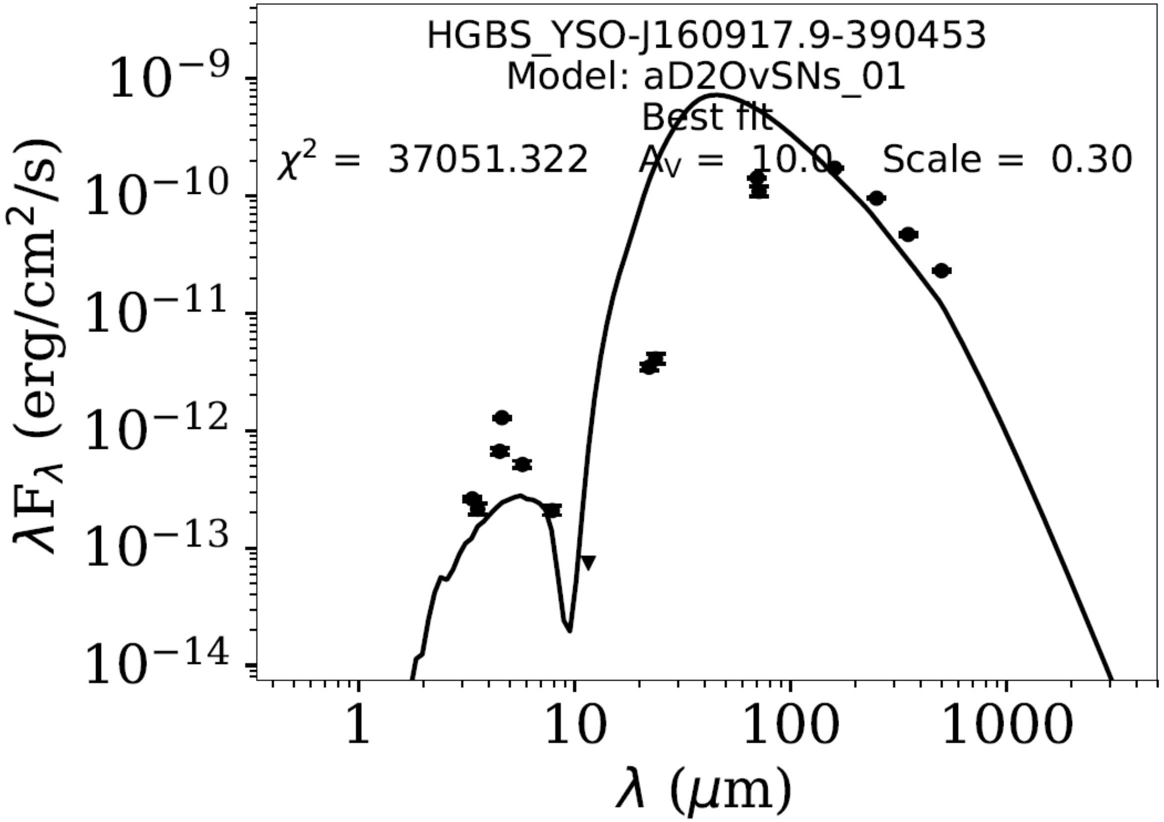
It is possible to define the presence/absence of disk/envelope/outflow cavity.

Best Fit
Model with envelope + cavity + disk



Model with only envelope

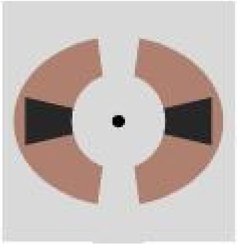




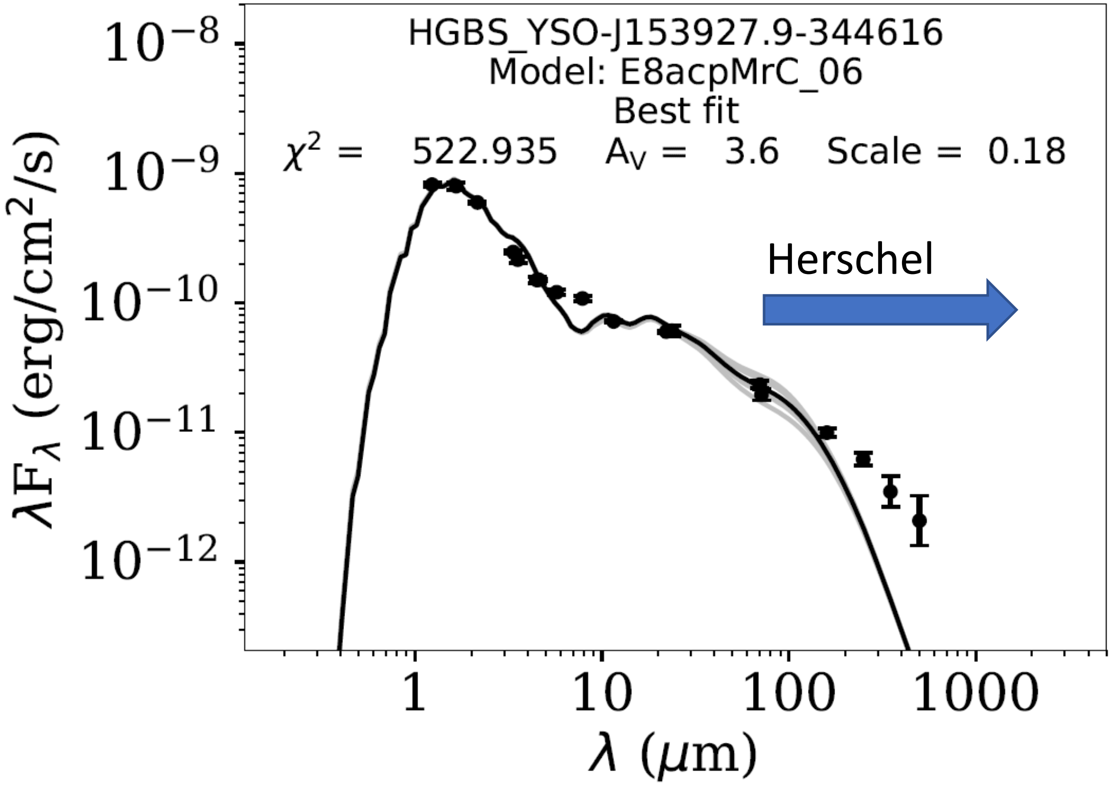
It is possible to define the presence/absence of disk/envelope/outflow cavity.

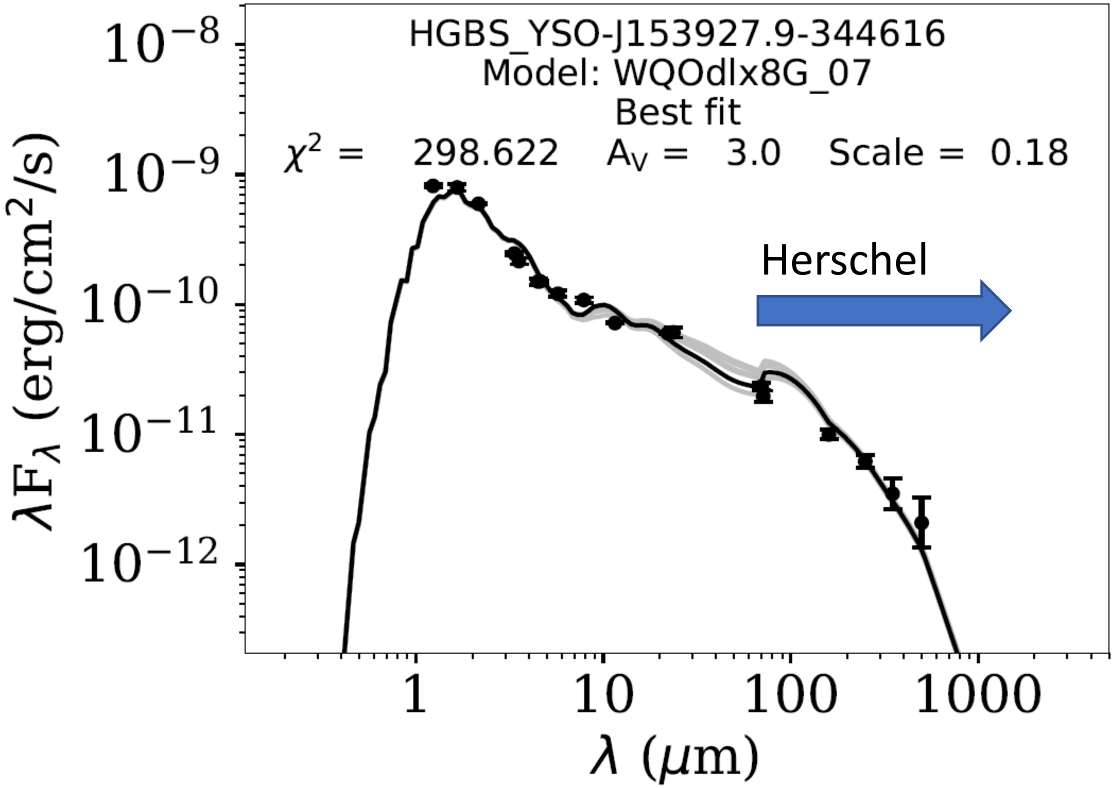
Model with only disk

Best fit
Model with disk + envelope + cavity



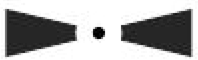
ρ_0=5x10^{-23} g/cm^3 , θ_{cav}=57°



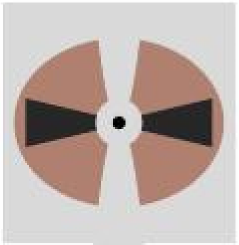


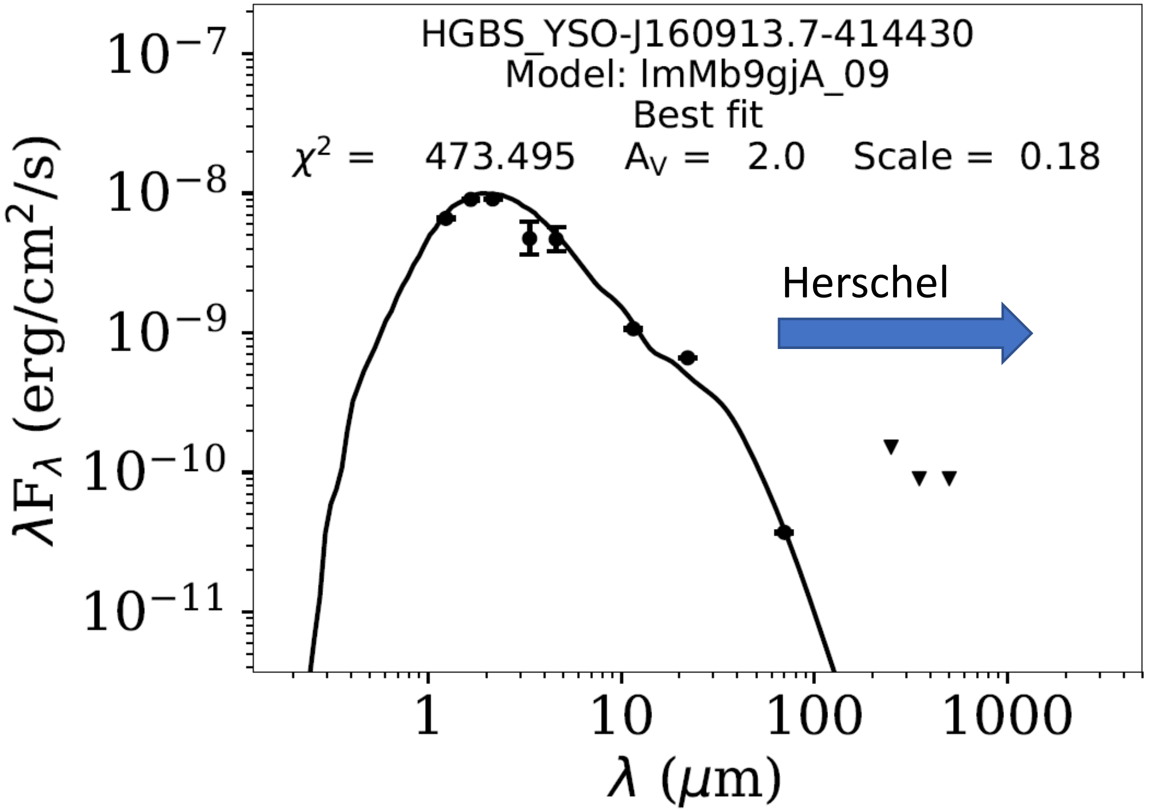
It is possible to define the presence/absence of disk/envelope/outflow cavity.

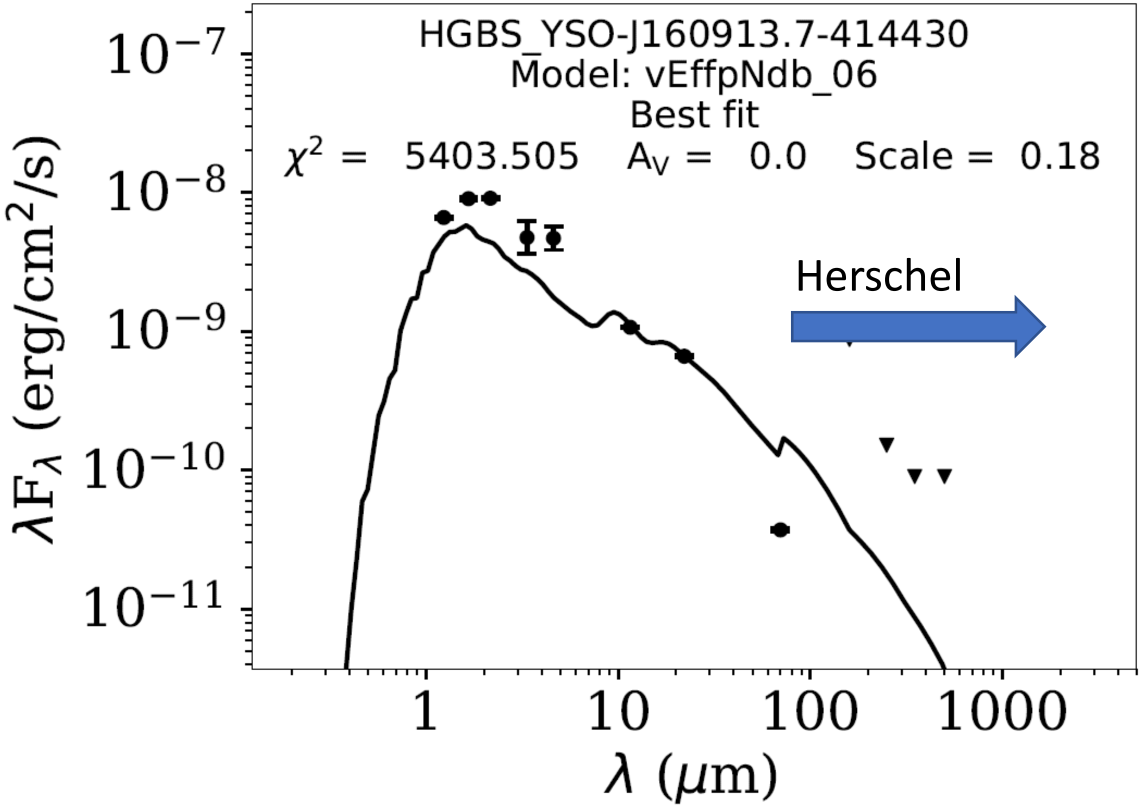
Best fit
Model with only disk



Model with disk + envelope + cavity







CONCLUSIONS

- HGBS provides catalogs of starless dense core (unbound and prestellar) and young, embedded protostars for nearby (d<500 pc) star forming regions.
- The densest ISM in molecular clouds is arranged in filaments.
- The large majority of pre-stellar cores are associated to filaments.
- CMFs (complete down to ~0.1 $M_{\odot}$) have log-normal shape for $M \leq 1\ M_{\odot}$ and power law tail for $M > 1\ M_{\odot}$, similar to IMF.
- HGBS data are a vital complement of previuos YSOs catalogs based on NIR-MIR data.
- HGBS data allow the correct evolutionary classification of the youngest protostars and the detection/measurement of the possible residual envelope around more evolved YSOs.