Disc population of Free Floating Planets in Taurus

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Credit: ESO/M. Kornmesser/S. Guisard

Credit: Peter Shah

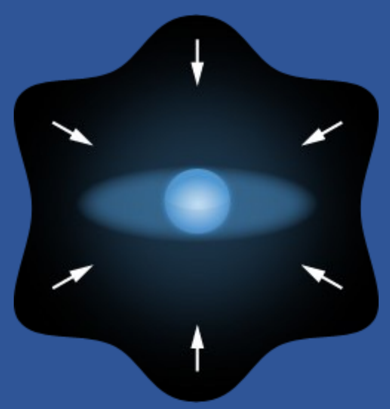
Free-floating planets (FFPs) are planetary-mass objects (< 13 M_{Jup}) that do not orbit a star but roam the galaxy isolated. The origin and the formation of these exotic objects is still largely an open question. A major key diagnostic of FFP formation and evolution is the occurrence and properties of discs.

Scenarios of their origin

- Planet-like formation: within a proto-planetary disc, either like gas-giant planets through core accretion [1] or like companions through gravitational fragmentation of massive extended discs [2], followed by ejection by dynamical scattering between planets [3]

Credit: T. Schindler

- Star-like formation: collapse and turbulent fragmentation of a tiny gas cloud [4, 5]



  - Embryos ejection: as aborted stellar embryos ejected from a stellar nursery before the hydrostatic cores could build up enough mass to become a star [6]
  - Photo-erosion: of a pre-stellar core by stellar winds from a nearby OB star before it can accrete enough mass to become a star [7].

We still do not understand their relative contributions

Different disc fractions & properties

A major method to constrain these theorie of formation

The occurrence and properties of discs: what fraction of FFPs harbors a disc ?

- Disc fragmentation scenario: FFPs form with discs which are disrupted when leaving their parent system. Some of the discs survive the ejection, however the disc frequency is expected to be lower [8]
- Core-collapse scenario: FFPs always form with discs [9] with a disc frequency and distributions of size and mass following the trends of more massive objects and decreasing with decreasing primary mass
- Embryo ejection scenario: simulations show that a significant number of discs should survive the ejection, with generally reduced sizes and masses [10].

SExtractor processing of SPITZER images

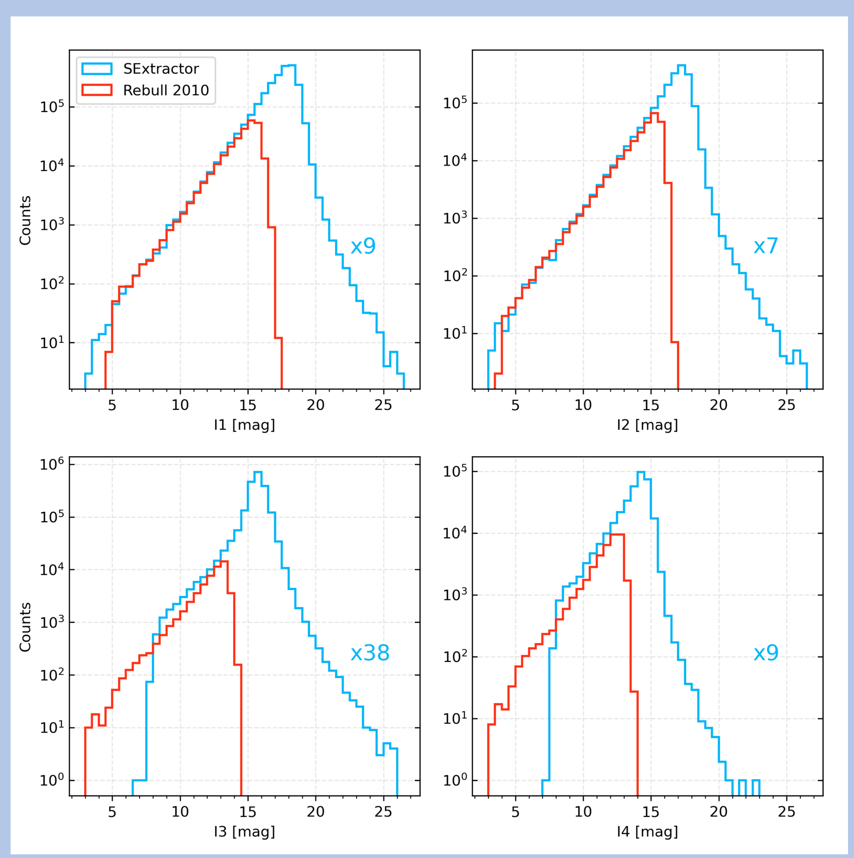


Fig 1: Magnitude distribution for objects in Taurus region for the filters IRAC1 (3.6 µm), IRAC2 (4.5 µm), IRAC3 (5.8 µm), and IRAC4(8 µm)

- Reprocessed archival Spitzer data: source detection and extraction on IRAC (I1, I2, I3, I4) and MIPS (M1) images
- Flux calibration of new datas using Rebull et al. 2010 [11] as reference (ODR linear regression ax+b combined with a sigma clipping procedure)
- 3 - 4 mag deeper than Rebull et al. 2010 [11] photometry
- Extraction of many more sources !

mid-IR photometry for the faintest objects

A new sample of FFPs in Taurus

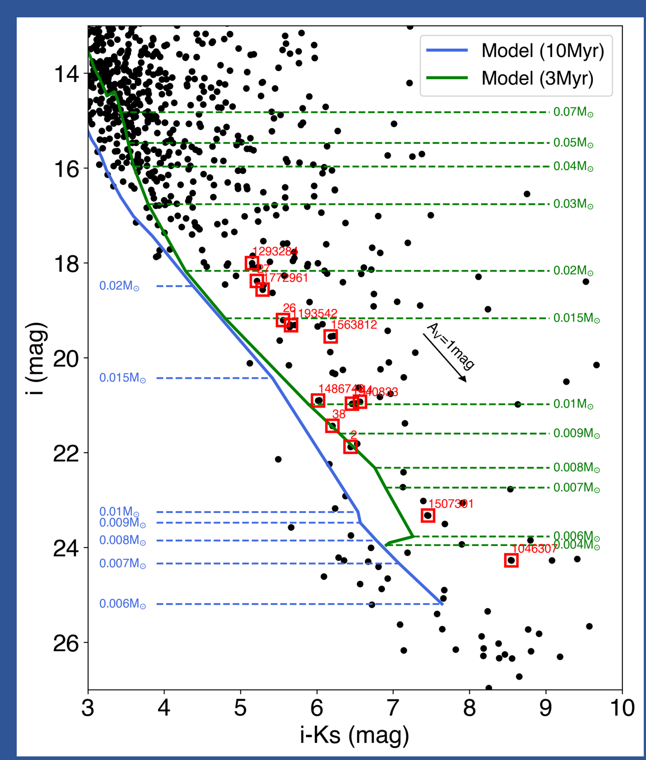
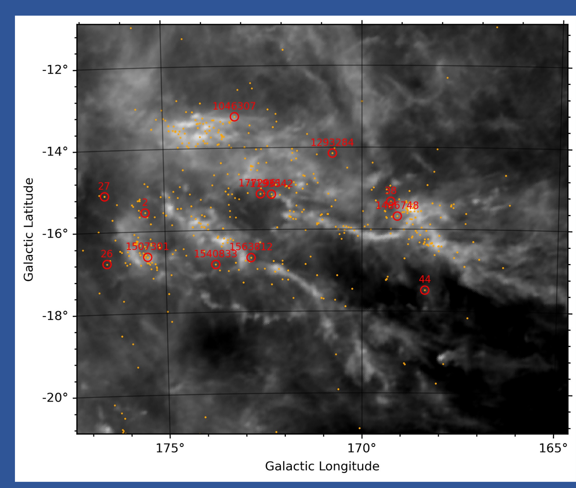


Fig 2: (i, i-Ks) diagram of Taurus members. [12] isochrone at 3 and 10 Myr and 140pc

Fig 3: Spatial distribution of Taurus members. Background image credit: PLANCK.



Taurus molecular cloud

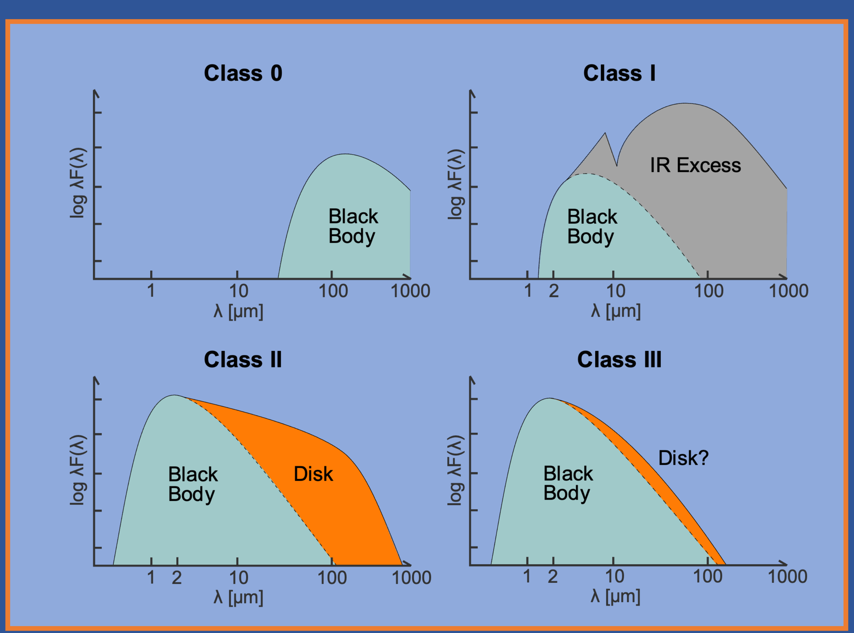
Low mass T association
DANCe & Gaia membership analyses
~100 FFPs / 900 members (Bouy et al., in prep [13])

Nearby : ~140 pc
Young star forming region : 1-3 Myr
⇒ Most still harbor a proto-planetary discs

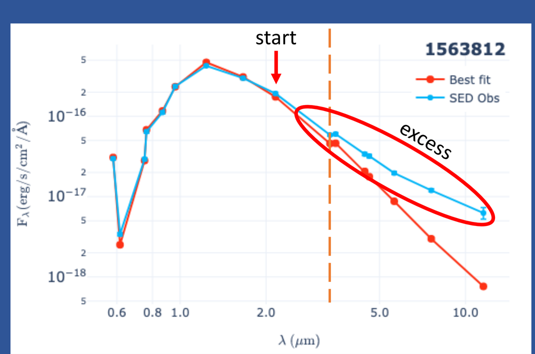
IR excess detection

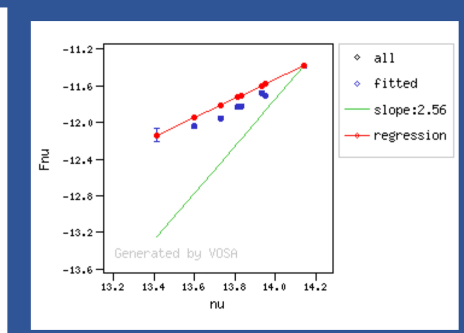
How to dectect a disk ?

Spectral Energy Distribution (SED) : Flux vs Wavelength
➔ Circumplanetary disk emission is detectable



- More complete than CMD detection (the entire SED is used)
- SVO tool VOSA (SED analyser, Bayo et al. 2008 [14]) provides an automatic IR excess calculation point by point (λ>2.15µm):





- The regression slope (y = log(νF_ν) as a function of x = log(ν)): b + σ(b) < 2.56 (Lada et al. 2006 [15])
- The observed value y_{obs} and y_L the predicted by the line with slope 2.56: $(y_{obs} - y_L) > 3\,\sigma(y)$
- Fit refinement: $\frac{F_{obs} - F_{mod}}{\Delta F_{obs}} > 3$ & $\frac{F_{obs} - F_{mod}}{F_{mod}} > 0.2$

Interesting objects

13 FFPs display robust mid-IR excess in WISE and/or Spitzer images
➔ Presence of circumplanetary material

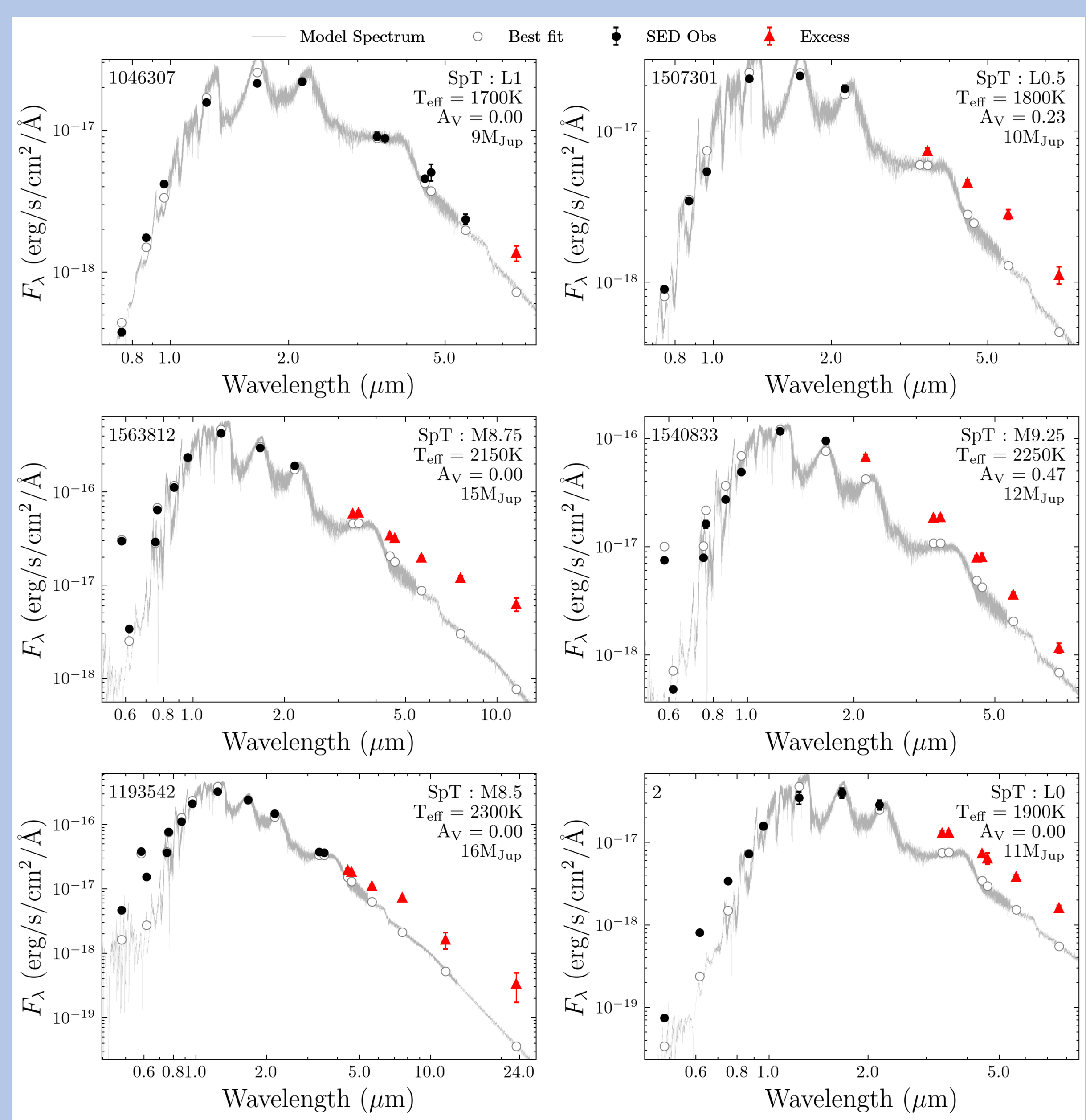


Fig 4: Spectral energy distribution (SEDs) of 6 of our planetary mass objects displaying mid-IR excess. Synthetic spectra and photometry of the best fitted BT-Settl model are represented.

Photometry:
GAIA: G, G_{BP}, G_{RP}
PAN-STARRs: g, r, i, z, y
2MASS: J, H, Ks
WISE: W1, W2, W3, W4
Spitzer: I1, I2, I3, I4, M1

Photospheric model:
BT-Settl
logg = 3.5
meta = 0
T_{eff} estimation

Chi-Square Fit

- Limited by the lack of photometry for many FFPs
- Model limit: Temperature - extinction degeneracy (possible source of contamination)
  ➔ when available, Spectral Type (Esplin & Luhman, 2019 [16]): more reliable T_{eff} estimation
- SpT/T_{eff} relation for young dwarfs reported in Faherty et al. 2016 [17]
- Mass estimation at 3Myr between 9 – 16 M_{Jup} (BD evolutionary model [18])

Preliminary disk fraction in Taurus for <50 M_{Jup} objects down to planetary mass : 33 / 85 ➔ 38.8 % (possible contamination and few planetary mass objects)

Conclusions

- Distributions of disc frequency are fundamental to test the predictions of the various formation mechanisms
- Reprocessed archival Spitzer data: IR photometry for the faintest objects in Taurus
- New sample of FFPs in Taurus to investigate
- Detection of disk emission using the Spectral Energy Distribution : 13 FFPs display mid-IR excess

Perspectives

- Caracterize the disc population (size and mass) around FFPs in Taurus : follow-up observations with NOEMA interferometer ?
- Detect disks in other FFP population: Upper Sco & Ophiucus (Miret Roig et al., 2022 [19])
- Compare the FFP disk fraction of different regions to understand how the environment and initial conditions influence their formation
- Improve the preliminary disk fraction in Taurus for very low mass objects
- Additional key diagnostic : occurrence and properties of multiple systems

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