ProtoPlanetary Discs as **Planetary Factories***

H. Cánovas, U. Lammers, A. Mora

Abstract

Protoplanetary discs (disc-like structures roughly composed by 99% of gas and 1% of dust) around young (<10 Myr) stars are a natural product of stellar formation. As the birthplaces of planets, their study is key to understand the first steps of planet formation. Observations in the optical/near infrared with high-contrast imaging instruments such as SPHERE/NACO (VLT) and in the sub-millimeter range with ALMA have revealed morphological features like spiral arms, narrow rings, and/or dust depleted inner cavities in a selected, *small*, sample of discs. These complex structures are better explained by (giant) planet-disc interactions. While those disks are prime targets to search for recently formed planets, the high detection rate of (mature) exo-planetary systems indicate that, in practice, the majority of protoplanetary disks will eventually form a planet. Combining Gaia observations with (on-going) ALMA surveys will offer the first opportunity to study the properties (age, temperature, mass, size) of *large* samples of disks in different star forming regions. This will help to connect the observed properties of mature exo-planetary systems with what happens at the initial stages of planet formation.

Exo-Planets

There are more than 3000 exoplanets detected to date [1]. The dominant detection methods are 1) radial velocities (measuring the periodic Doppler shift in the stellar spectra caused by the planet -star interactions) and 2) transits (measuring the periodic drop in stellar flux created as the planet passes in front of the star). The statistics of this planet population show that planet formation is a robust process, and that nearly every star in our Galaxy should host at least one planet [2, 3]. Young (<10 Myr), pre-main sequence stars are very active and detecting forming planets using the previous methods is currently unfeasible. However, the signatures of planet-disc interactions are observed in a selected sample of protoplanetary discs.

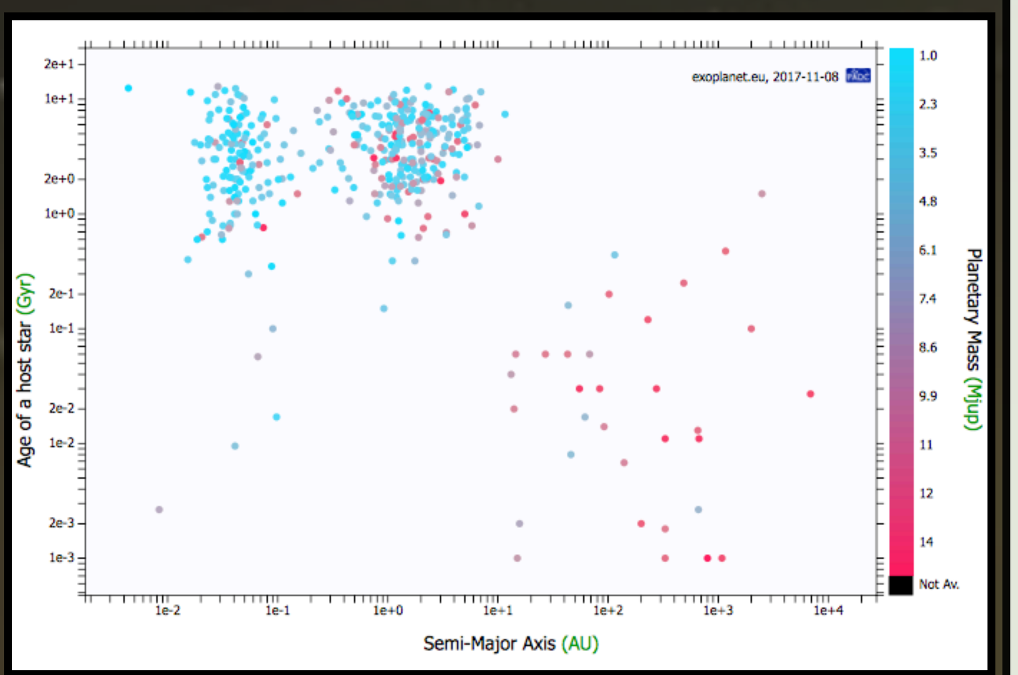

Fig. 1: Planetary population as a function of host stellar age (Y-axis) and planet orbital radius (X-axis)

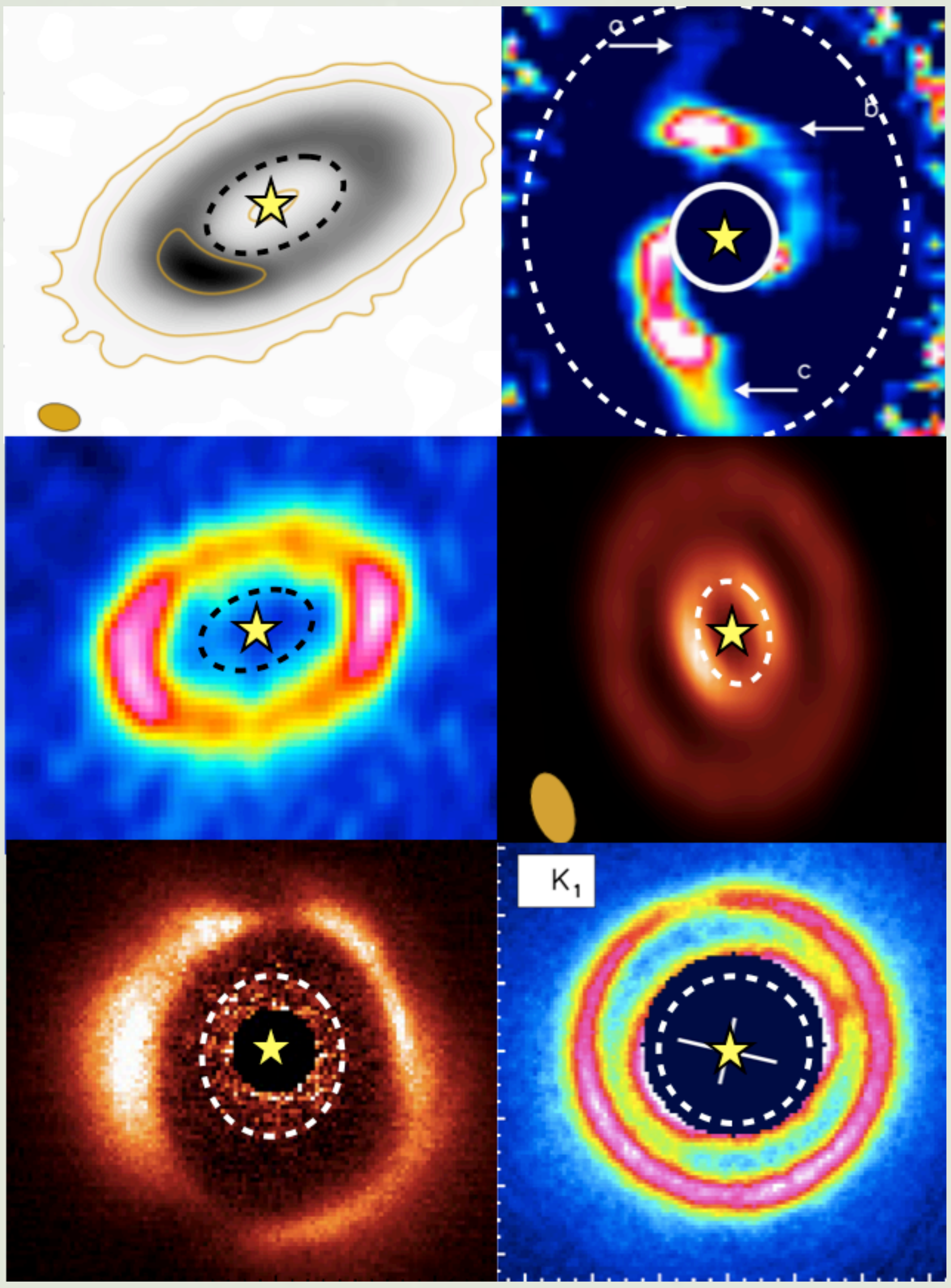

Fig. 3: Scattered light and thermal emission images of discs with evidences of planet-disc interactions in the form of large dust-depleted inner cavities, narrow rings, and spiral arms. This sample encompasses Herbig Ae/Be and T Tauri stars. For reference, the dashed line shows the average radius of Neptune's orbit (30 AU) [7,8,9,10,11]

ProtoPlanetary Discs

Nearby (<300 pc from Earth), young (<10 Myr) star forming regions offer the opportunity to study protoplanetary discs in detail. Measuring their age, temperature, total (gas and dust) mass, and their radial density distribution, is necessary to constraint the initial conditions of planet formation. Sensitive and spatially resolved observations with the ALMA interferometer are the best (and only) option to measure these quantities. Current surveys are showing tentative trends between host stellar and disc properties [4, 5]. However, the large error bars caused by the uncertainties on the distance to the individual discs supposes a major problem for these studies, as it translates into uncertainties on the stellar ages, disk sizes, and disk masses.

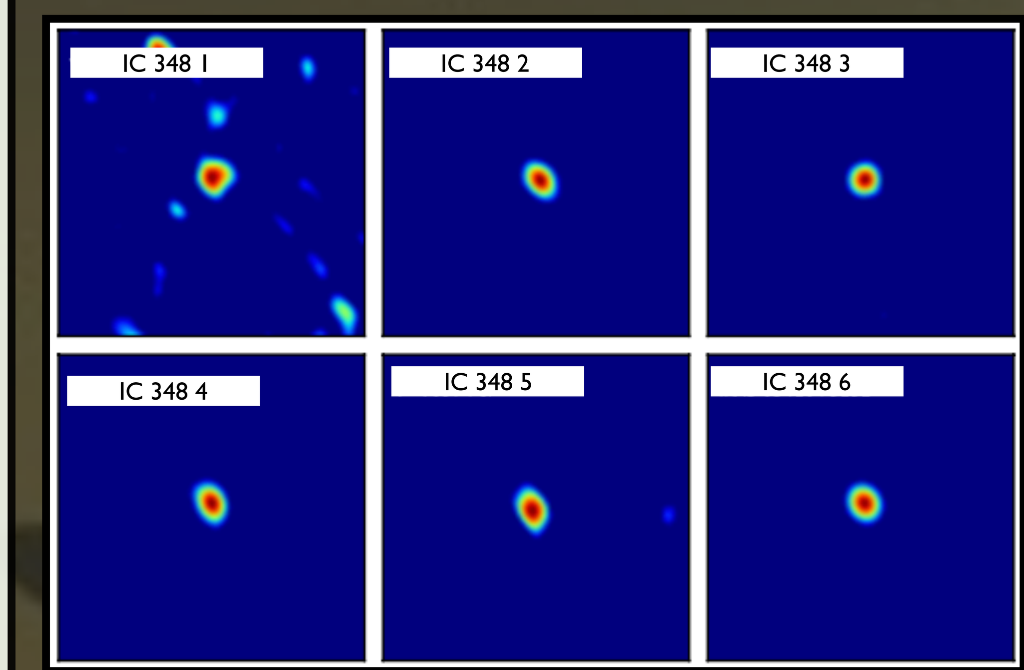

Fig. 2: First results form our ALMA survey on the star-forming region IC 348 [6]. Continuum (dust) images of different protoplanetary discs.

ALMA: Disc Observations

- Total Dust Mass
- Total Gas Mass
- Surface Density distribution

PPDISC ⟷ **PLANET**

Unveiling the link?

Gaia: Host-Star Observations

- Distances
- Stellar Ages
- Metallicity & Variability

References

[1] exoplanets.eu
[2] Cassan et al. 2012
[3] Borucki et al. 2011
[4] Andrews et al. 2013
[5] Pascucci et al. 2016
[6] Rodriguez et al. 2017 (in prep)
[7] Canovas et al. 2013
[8] Canovas et al. 2015
[9] Canovas et al. 2016
[10] Canovas et al. 2017 (in press)
[11,12] Van de Plas et al. 2017a,b

* The images here presented are based on my previous research (i.e. before starting the Research Fellowship)