The different paths of disk dispersal and evolution: A Herschel view of two regions

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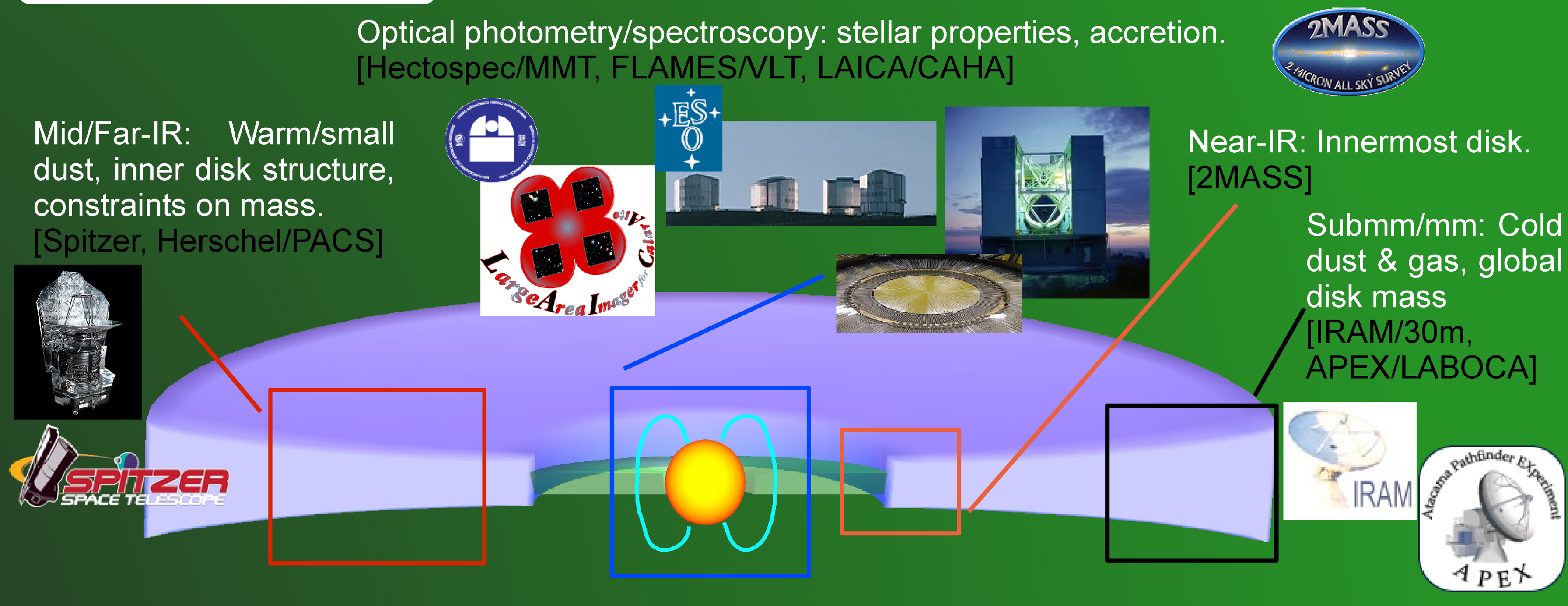
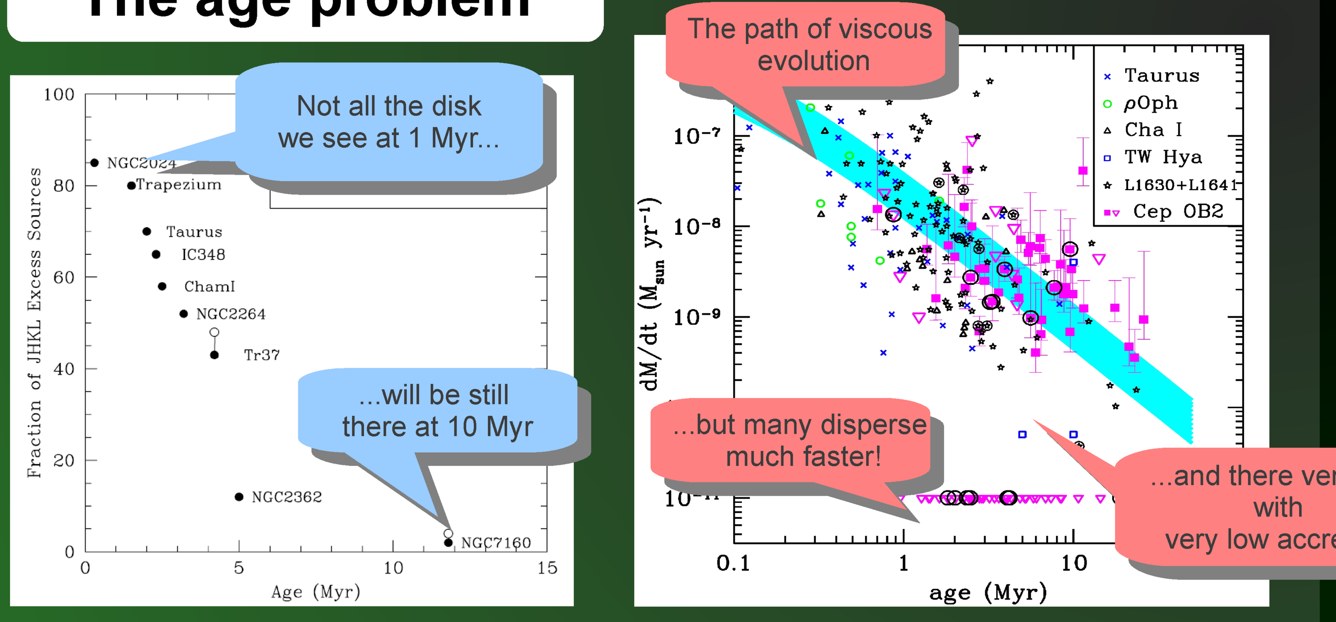
The paths of disk evolution

Cluster studies reveal that signs of disk evolution (inner holes or gaps, small dust depletion, low accretion rates) are common, even in regions with young ages. First Spitzer, and now also Herschel, combined with ground-based observations, show that not all disks follow the same evolutionary paths, suggesting an interplay of different effects in disk dispersal. In particular, the different properties of transition disks (presence of accretion, global dust mass) can give valuable information to the processes acting on disk dispersal. The differences in the typical disk structures observed from region to region also suggest that the system's initial conditions and environment probably play an important role. We present multiwavelength data, including new Herschel/PACS observations, of two very different regions, the young, sparse Coronet cluster, and the older, more populous Cep OB2 region, with the clusters Tr37 and NGC7160. The new Herschel data helps to constrain disk masses and global properties, while our previous Spitzer and ground-based observations provide us information on the presence of gas accretion. The diversity of disks observed shows us the different ways disk dispersal can operate, and what consequences this may have for the outcome of protoplanetary disk evolution.

Observations

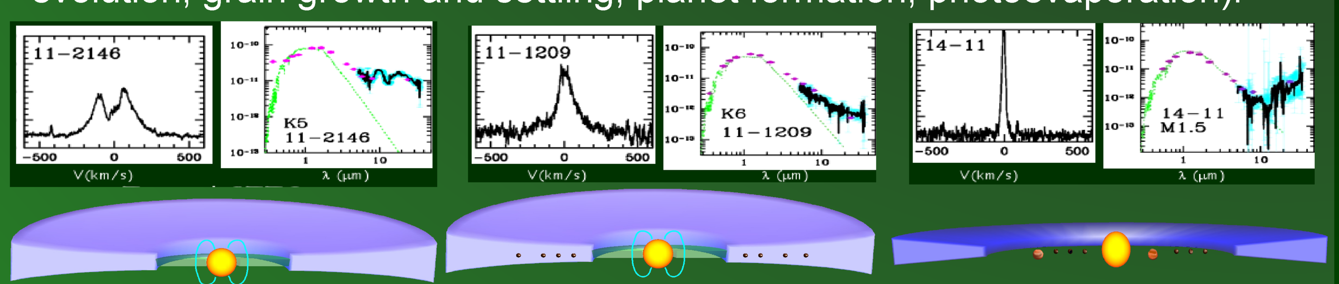


The age problem



Disk fraction plot (left) and mass accretion vs age (right). Sicilia-Aguilar et al. 2006, ApJ 638, 897; 2010 ApJ 710, 597.

Objects from the same cluster, same age, and similar spectral types can have very different disks. Age alone cannot be the only parameter that controls disk evolution. Not all the disks seen at 1 Myr will be still there at 10 Myr, suggesting different initial conditions, disk dispersal timescales, and various physical processes involved in the disk removal (e.g. viscous evolution, grain growth and settling, planet formation, photoevaporation).



Typical flared accreting disk

Settled disk with large grains and low accretion rate.

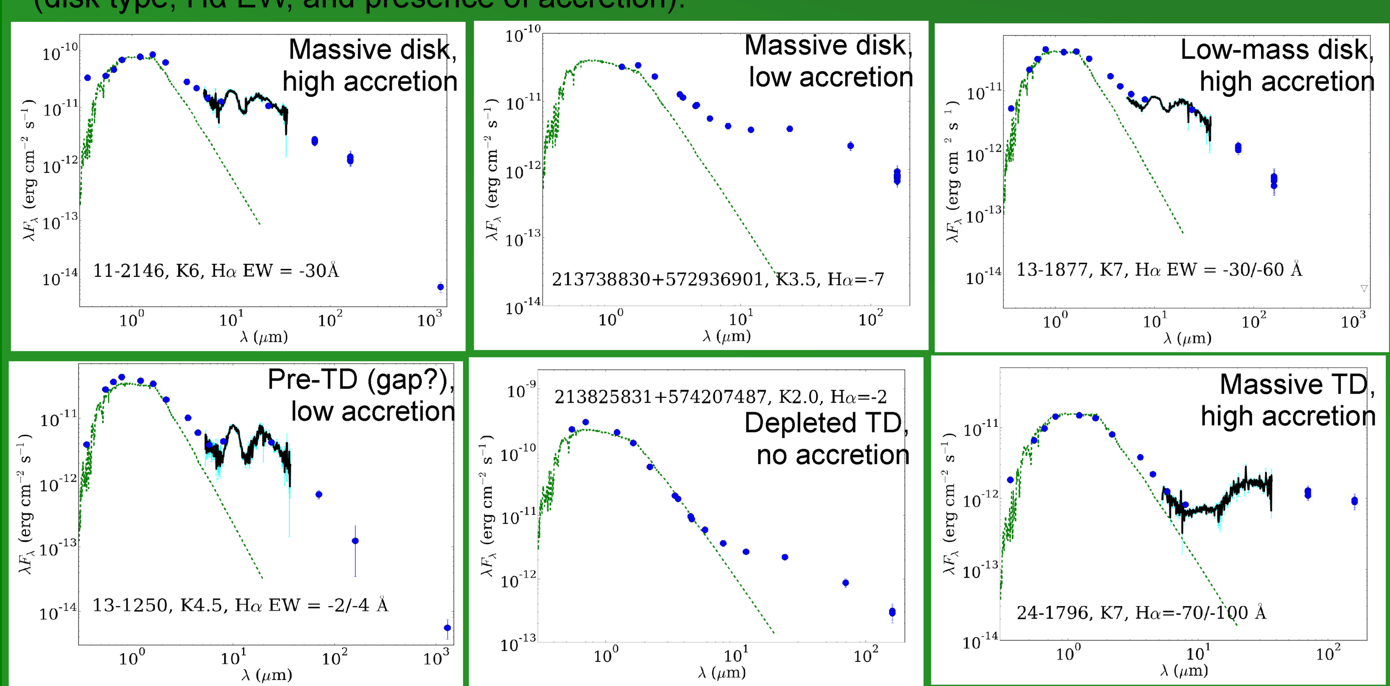
Non-accreting transition disk, candidate for inner holes

Hα profiles and SEDs of disks with different morphologies in Tr37 and cartoons of the likely disk structures. All of them have the same isochronal age (2-3 Myr) and similar spectral types (K6-M1).

Witnessing disk evolution in Tr 37 (4 Myr)

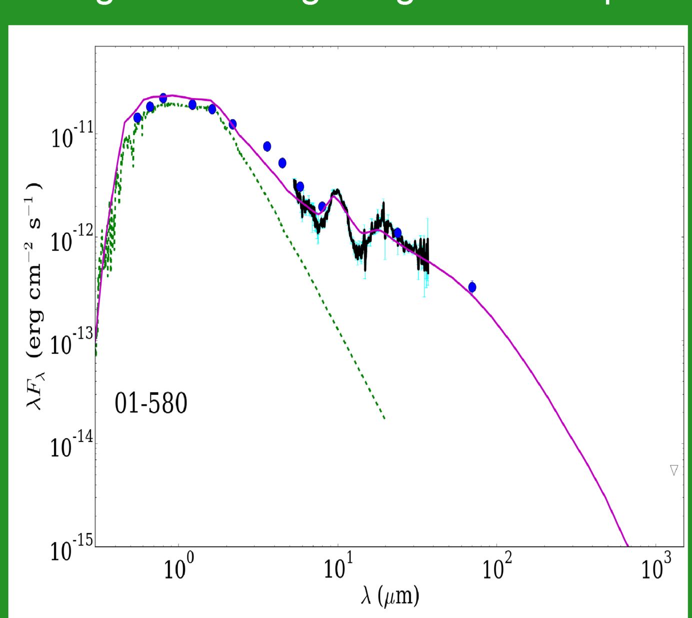
Tr37 (d=870 pc, 4Myr) has a disk fraction ~45%. Optical, Spitzer, Herschel (P.I. Sicilia-Aguilar), and IRAM observations reveal a large variety of disks, ranging from massive, primordial systems with high accretion rates, to transitional disks with or without accretion, pre-transitional disks candidates to host gaps, and small-dust-depleted disks (or disks suffering strong grain growth). About 30% of the disks show evidence of inside-out evolution, and the object diversity suggests that several disk dispersal processes are at work.

Below: SEDs of different types of disks observed with Herschel in Tr 37, and their properties (disk type, Hα EW, and presence of accretion).

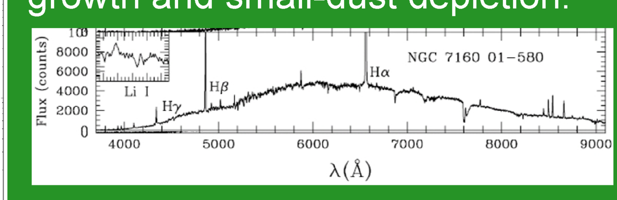


The rare suvivors: NGC 7160

Only one object is accreting in the 12 Myr-old NGC7160. From optical observations, 01-580 was dubbed the *"Peter Pan"* disk as it refused to get old, with an accretion rate of 2-4 10^{-8} M_{sun}/yr. From IRAM 30m 1.3mm non-detection and Herschel 70μm photometry, the estimated dust mass is so low, that generalized grain growth is required to explain the observed accretion.

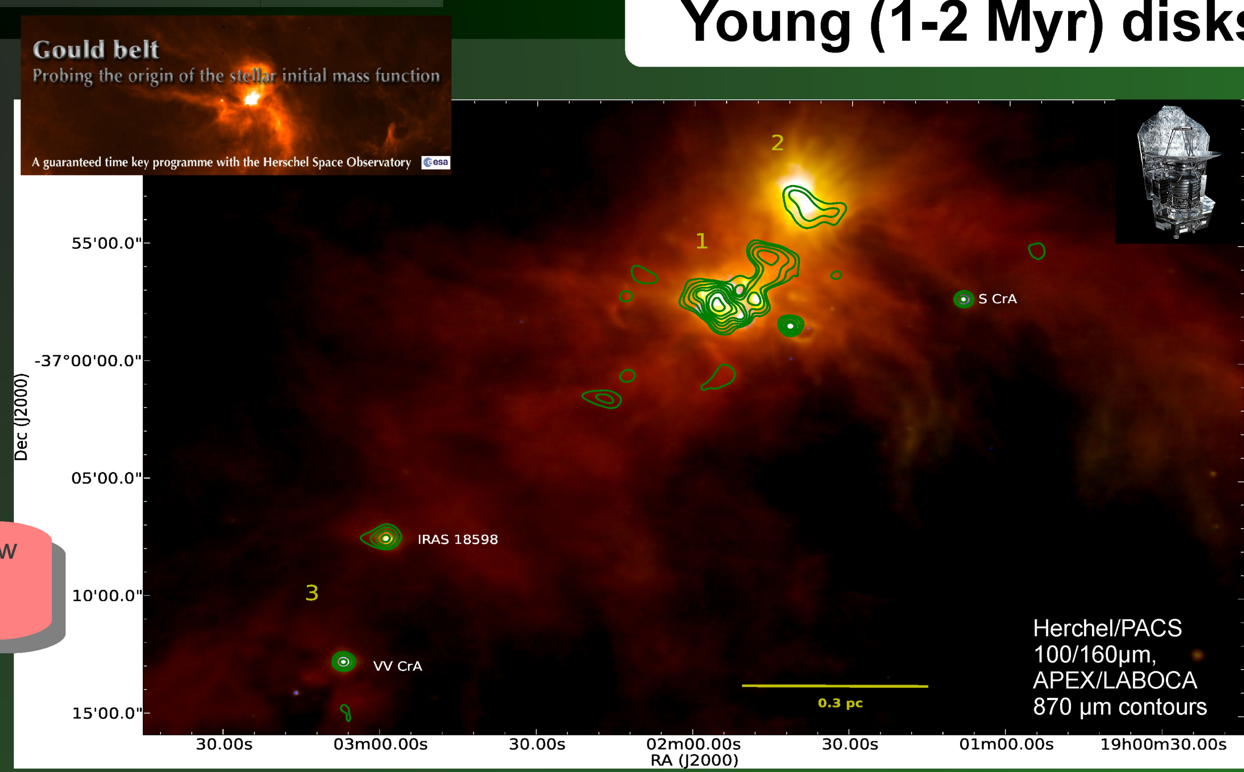


The disk is thus a *"Dorian Gray"* system, appearing very young and primordial in the optical, while the depths of its midplane hide the signs of time evolution in the form of grain growth and small-dust depletion.



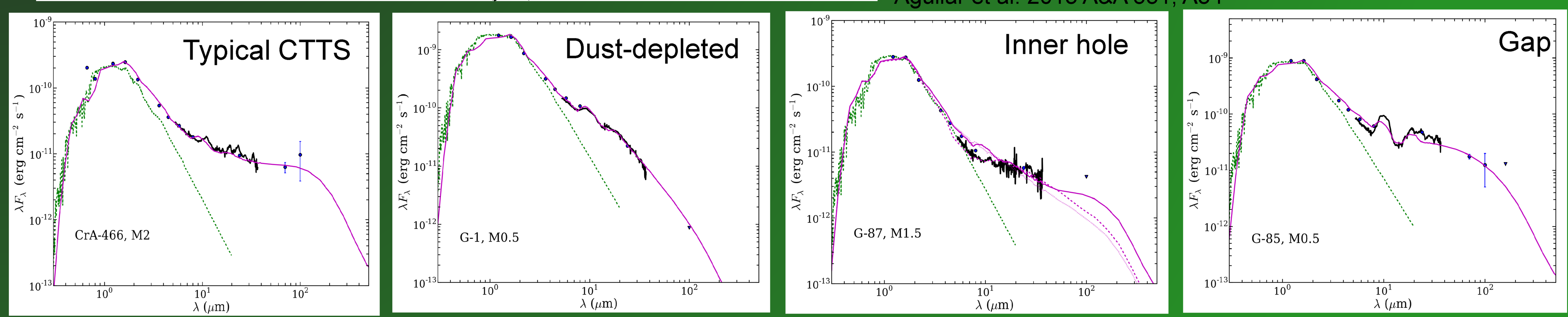
SED, RADMC model, and optical spectrum of 01-580. The strong accretion suggest a large gas mass, the strong silicate is a sign of small grains in the inner disk, but low global small-dust mass suggests strong grain growth.

Young (1-2 Myr) disks in the Coronet Cluster



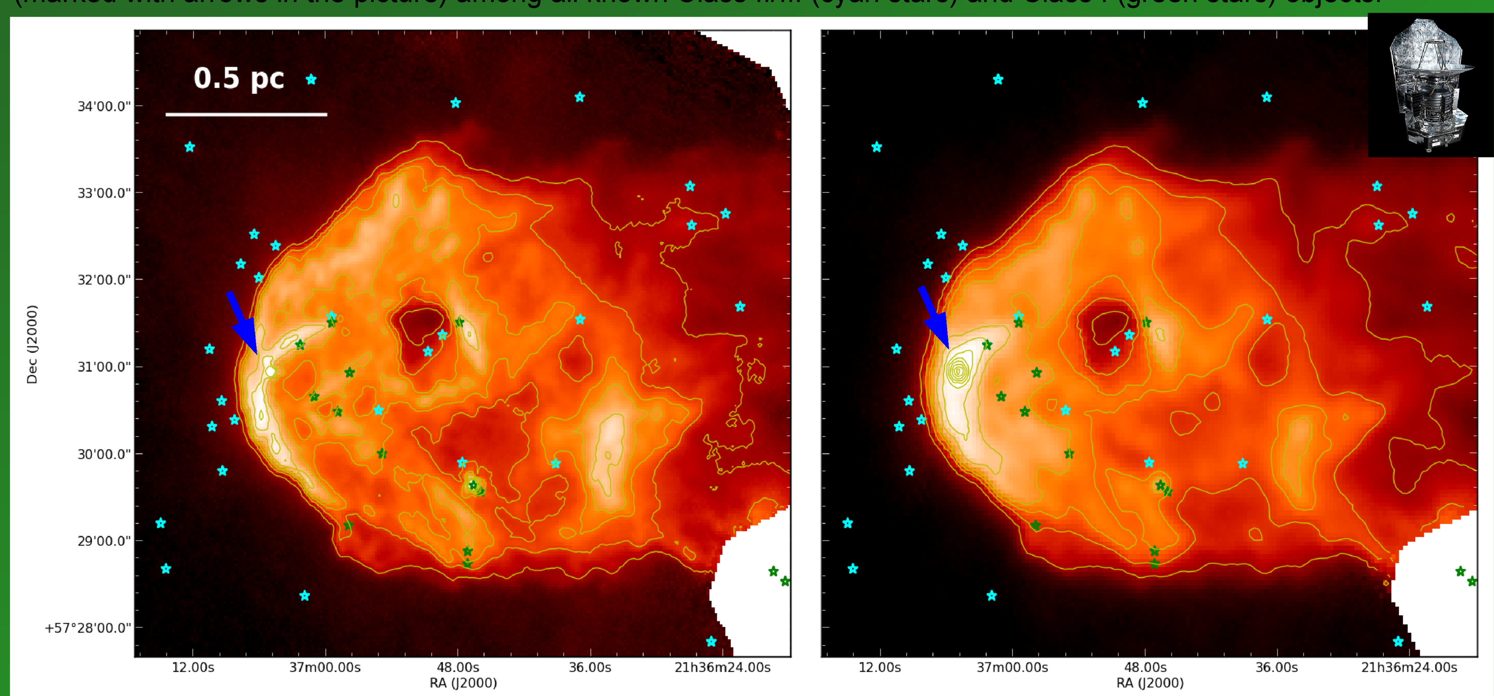
The Coronet cluster, at 130 pc distance, is a sparse, presumably coeval SF region. It was observed with Herschel/PACS at 100 and 160 μm as part of the Gould Belt Survey (PI Ph. André). Despite its age and compactness, the disks around M-type stars range from typical CTTS disks, to disks with inner holes, globally depleted objects, and potentially truncated disks. The disk fraction is also slightly lower than expected for its age (50-60%), in the line of what is observed in other sparse associations (Fang et al. 2013, A&A 549, A15). A zoom in the cluster center reveals that the region is not as quiescent as previously thought, but shows strong signs of interaction between stars and clouds, which may contribute to shaping the disks.

Below: SEDs of some M-type CTTS in the Coronet cluster (including Optical, 2MASS, Spitzer, and Herschel/PACS data). Radiative transfer disk models using RADMC (Dullemond & Dominik 2004 A&A 417, 159). Photospheric MARCS models used for comparison (Gustafsson et al. 2008; A&A 486, 951). Sicilia-Aguilar et al. 2013 A&A 551, A34

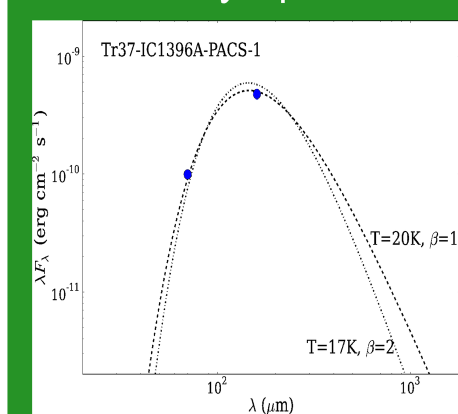


Looking into the clouds: IC1396 A

Below: Herschel/PACS 70μm (left) and 160μm (right) maps of IC 1396A, to the west of Tr37. The globule is illuminated by the O6 star HD206267 (~4 pc away). Herschel reveals a bright, massive, previously unknown object (marked with arrows in the picture) among all known Class II/III (cyan stars) and Class I (green stars) objects.



Herschel can probe the cloud content and ongoing star formation. The Herschel maps of IC1396A near Tr37, reveal a new very embedded, massive object, probably an intermediate stage Class 0/I. The source may have X-ray emission (Getman et al. 2012), but it was not detected by Spitzer nor CO surveys.

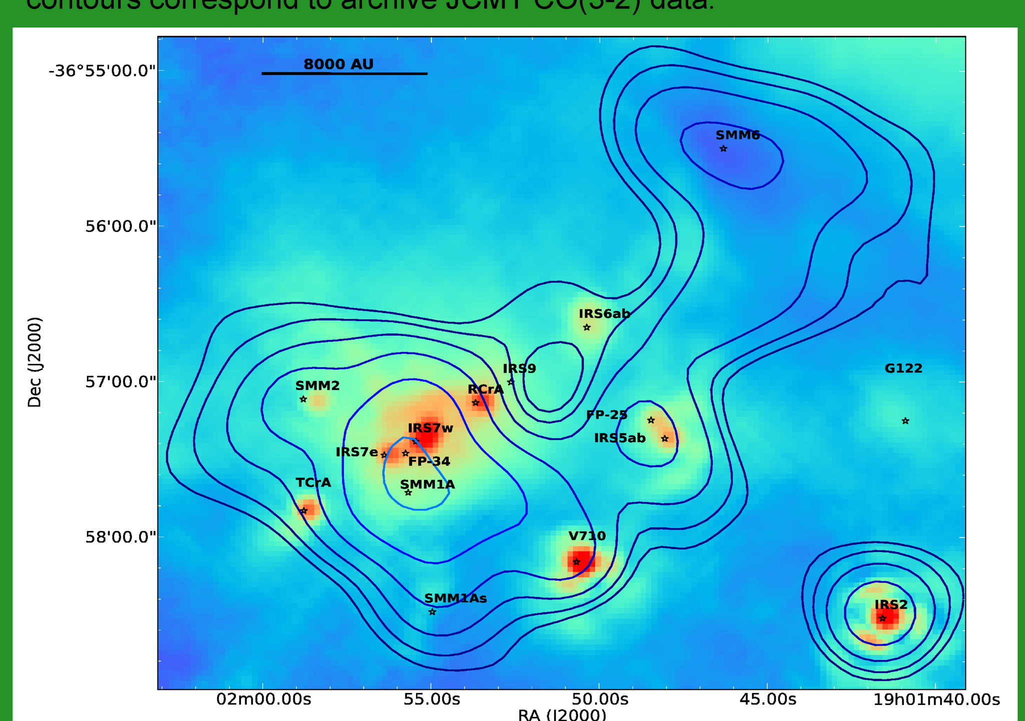


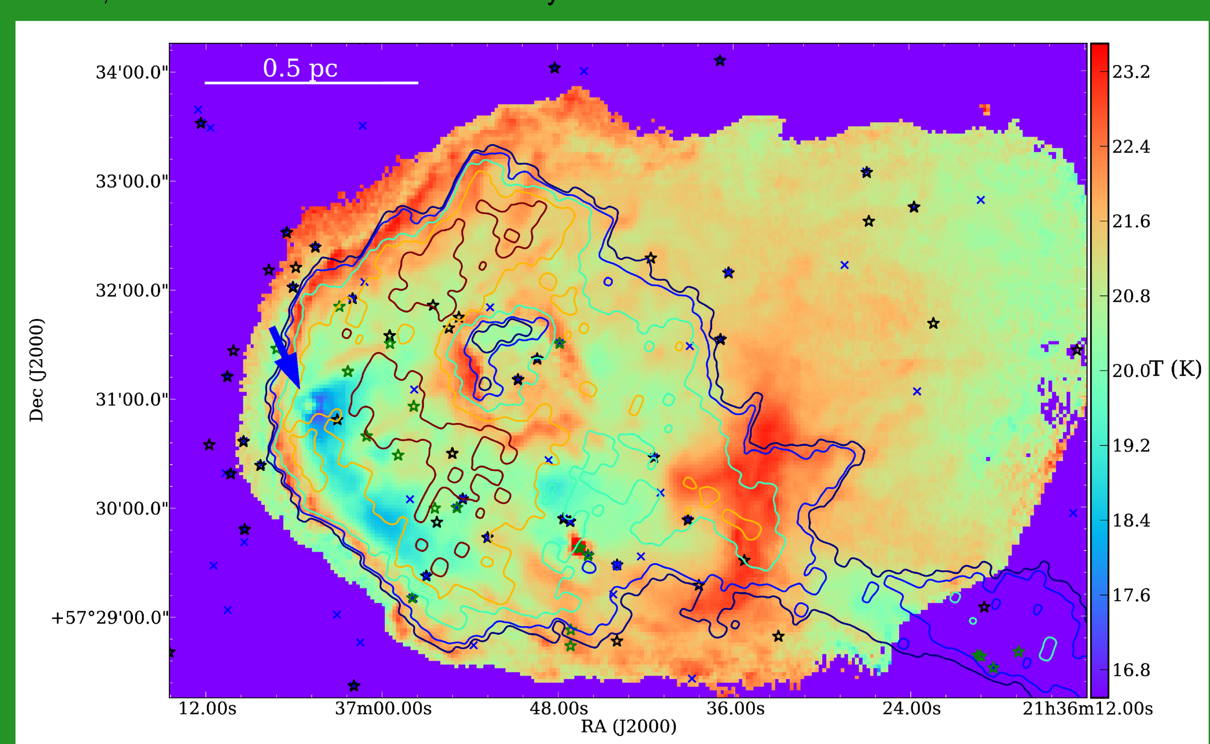
SED and modified blackbody models for the new source, which is also a tentative X-ray source.

Environment and interactions

An approximate temperature map can be derived from the ratioed images 100μm/160μm and 70μm/160μm, respectively.
The presumably quiescent Coronet cluster appears as a very active and interactive star-forming region. The cluster center has numerous low-mass stars in multiple systems and a stellar number density of ~2000/3000 stars/pc^3. It also contains cold and dense regions without evidence of star formation (SMM6). The number of stars packed within a small region suggest a high degree of interactions from a very early stage on, that could compromise disk formation and evolution.
IC1396A has a stellar density 2 to 3 orders of magnitude lower than the Coronet cluster (correcting for completeness, distance, and unresolved multiplicity, and including the YSO candidate population revealed by X ray imaging; Getman et al. 2012 MNRAS 426, 2917). There is also evidence of cloud heating by both the O6 star HD206267, that gives the globule its blown-away appearance, and by the embedded YSO, mostly intermediate-mass and low-mass Class I/II objects.

Below: Approximate temperature maps for the center of the Coronet cluster (left) and IC1396A, in Tr37 (right). Temperature scales vary due to the different wavelengths observed in both clusters. In the Coronet map, we mark the APEX/LABOCA 870μm contours and known objects are marked by stars. In IC1396A, green stars mark known Class I sources, black stars mark known ClassII/III sources, and blue crosses mark the X ray YSO candidates from Getman et al. 2012. The contours correspond to archive JCMT CO(3-2) data.





Read more: Sicilia-Aguilar et al. 2011, ApJ 736, 137; Sicilia-Aguilar et al. 2011, ApJ 742, 39; Sicilia-Aguilar et al. 2013 A&A 551, A34; Sicilia-Aguilar et al. 2013 submitted to A&A; SA et al. in prep.