New WWW Database of Self-Consistent Physical Disk Models for SED Analysis

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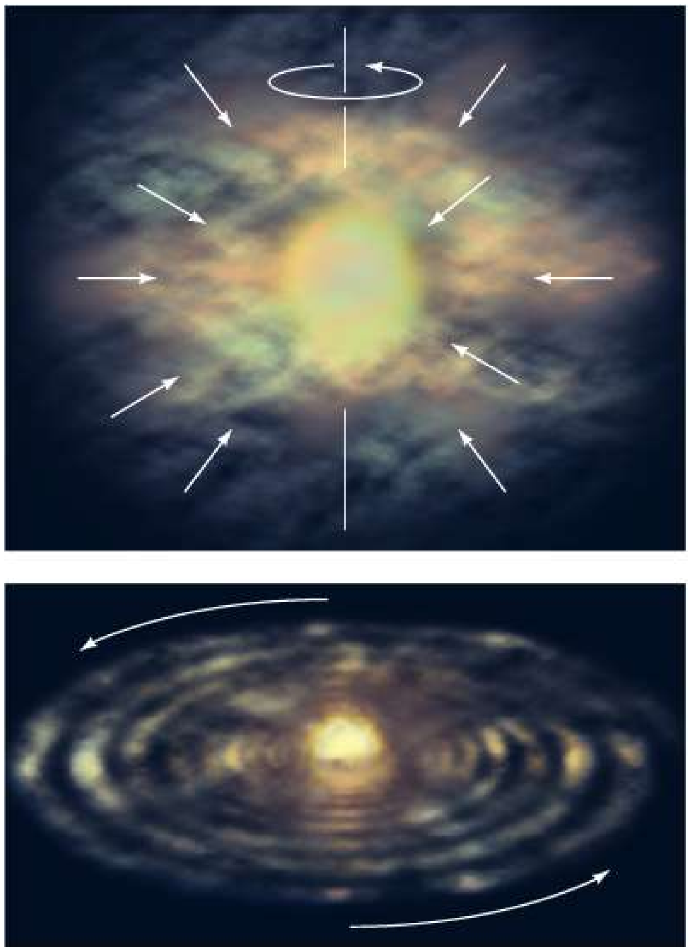
Abstract

We announce the release of a catalog of models of irradiated accretion disks around young stars based on the modelling techniques by D'Alessio et al. The model includes the disk heating by stellar radiation (considered in a shorter wavelength regime with respect to the disk own radiation field), viscous dissipation due to accretion (described using the alpha prescription) and ionization by energetic particles (cosmic rays and radioactive decay). The energy in the disk model is transported by radiation, convection and a turbulent alpha-flux. The disk is assumed axisymmetric, with gas and dust well mixed. The opacity is calculated taking into account both dust and gas. For the gas, the populations of selected molecules are calculated assuming LTE. For the dust, we explore different grain size distributions.

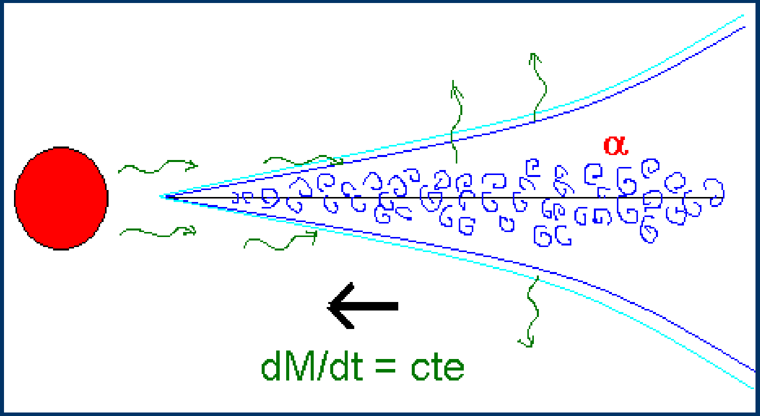
The WWW catalog includes disk models for different central stars, disk sizes, inclinations, dust contents and mass accretion rates. We show how IRAC synthetic colors from the models reproduce new Spitzer data of young star-forming clusters, hence allowing for a detailed physical characterization of their protoplanetary disks, and demonstrate how to use the library to get the most of newly-observed Spitzer SEDs of young stars. An interesting results concerning the SEDs of two HaeBe stars, also obtained making use of the models, is shown.

Introduction



The protoplanetary disks where planets may form are the result from the gravitational collapse of the primordial cloud. The presence of these protoplanetary disks has been established by the characterization of IR excesses in the Spectral Energy Distributions (SEDs) of young stars and by direct IR and millimeter imaging. The models from D'Alessio et al. (1998, 1999, 2001) compute in a self-consistent way the detailed vertical and azimutal structure of temperature, pressure and density of these disks by solving the physical equations of hydrostatic equilibrium, local thermodinamical equilibrium and radiative transfer. Once these models are computed, thermal and scattering emission maps at any wavelength can be obtained by solving the radiative transfer equation in rays parallel to the line of sight. Adding up the emission at each wavelength it is also possible to trace the synthetic SED to compare with the observations.

Disk Models



Energy transported by radiation, convection and turbulent flux.

Heating due to viscous dissipation and stellar flux irradiation.

Self consistent irradiation surface with hydrostatic solution to the disk structure.

The models assume the following:

Steady state, dM/dt = cte

Geometrically thin, H/R << 1

α viscosity $\nu = \alpha H c_s$

Dust and gas well mixed in the whole disk

The radiation field is supposed to have two main regimes:

- Star radiation (opt. - UV)
- Disk radiation (IR - cm)

Radiative transfer by solving the two first moments of the equations.

Behavior of disk emission related with central star and disk parameters.

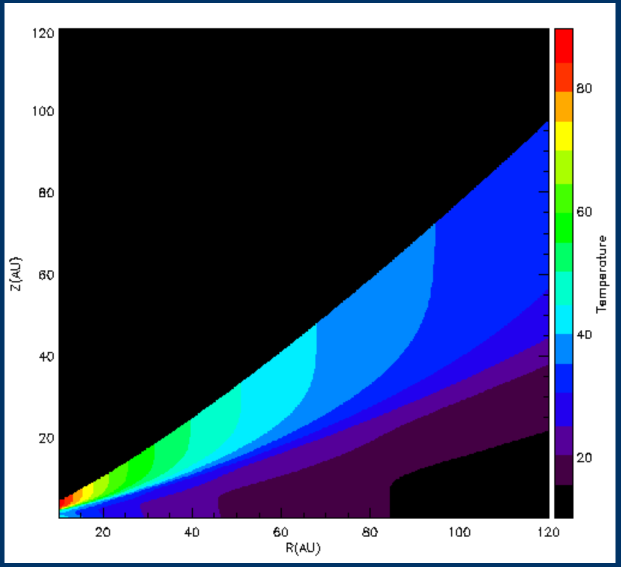
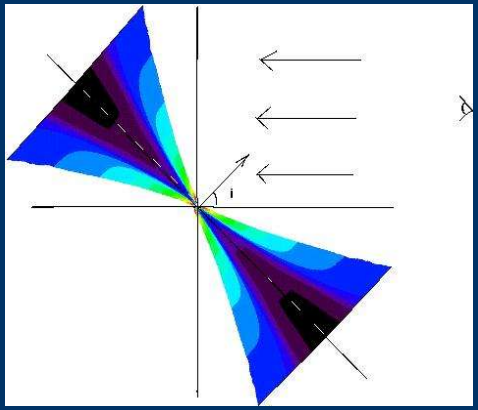
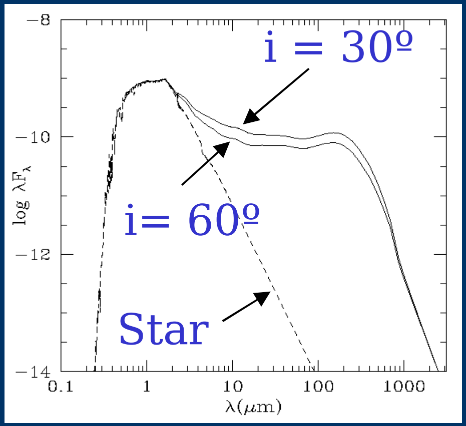


Figure : Vertical cut of a disk model showing the temperature distribution with height and radius. In this model the central star has T_{eff}= 4000 K and M_* = 2.0 M_{sun}. The disk model has accretion rate = 10^{-8} M/yr, viscosity parameter α=0.01, R_{disk}= 120 AU, p= 3.5 and a_{max}= 1 micron.

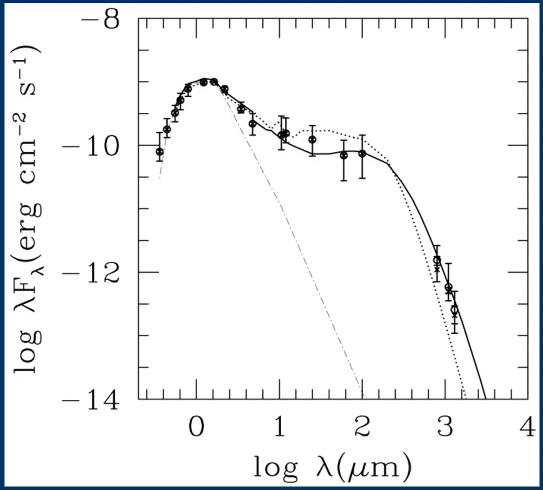
Spectral Energy Distributions

Once we have a model we can calculate the emission of the disk in any specific wavelength and for any inclination angle i. The aspect of the IR excess in the SED will depend on the stellar parameters, the disk mass accretion rate, the maximun and minimum radii, the maximum grain size a_{max}, p, α, and the inclination angle i.





Taurus Median SED



The models from D'Alessio et al. are able to fit the median Spectral Energy Distribution of the Taurus Molecular Cloud. (D'Alessio et al. 2001)

This allows to confirm important average values:

- Slope in mm -> grain growth in protoplanetary disks
- Maximum grain size a_{max}= 1 mm
- Median accretion rate of $3x10^{-8}$ M_{sun} / yr (from Gullbring et al. 1998 and Hartmann et al. 1998)
- p= 3.5, M_{disk}=0.046 M_{sun}
- i= 50º

Web-Based Model Library

We have computed a grid of model results for different central stars and a large range of physical values for the parameters of the star, the disk and the dust. This library of models will be a very valuable tool for analyzing the SEDs of young stars with protoplanetary disks and will be published on a web page soon (D'Alessio et al. 2004).

Central star

- Stars parameters from Siess et al. PMS tracks
- T_{eff}= 4000 - 10000 K (K7V - B9 V)
- Ages= 1, 10 Myr (Siess et al. 2000)

Disk

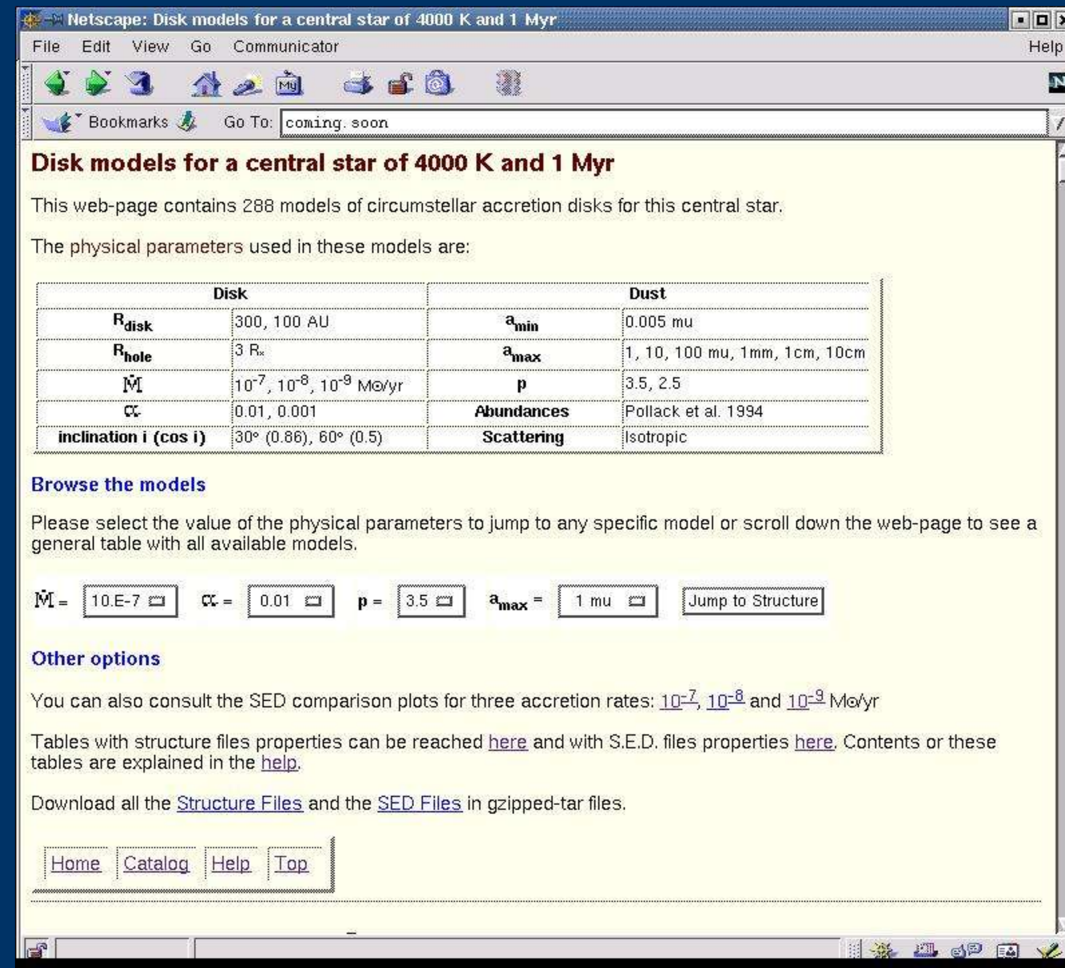
- dM/dt= 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9} M_{sun}/yr
- α = 0.01
- R_{disk} = 800, 300, 100 AU
- inclination angle i= 30, 60°

Dust

- Pollack et al 1994 abundances
- n(a) ~ a^{-p} , p= 3.5, 2.5
- a_{max}= 1, 10, 100 µm, 1mm, 1cm, 10cm

Inner irradiated wall

- T_{wall} = 1400 K (Muzerolle et al. 2003)



Netscape: Disk models for a central star of 4000 K and 1 Myr

File Edit View Go Communicator Help

Bookmarks Go To: coming. soon

Disk models for a central star of 4000 K and 1 Myr

This web-page contains 288 models of circumstellar accretion disks for this central star.

The physical parameters used in these models are:

Disk		Dust	
R_{disk}	300, 100 AU	a_{min}	0.005 mu
R_{hole}	3 R_*	a_{max}	1, 10, 100 mu, 1mm, 1cm, 10cm
$\dot{M}$	10^{-7}, 10^{-8}, 10^{-9} M⊙/yr	p	3.5, 2.5
α	0.01, 0.001	Abundances	Pollack et al. 1994
inclination i (cos i)	30° (0.86), 60° (0.5)	Scattering	Isotropic

Browse the models

Please select the value of the physical parameters to jump to any specific model or scroll down the web-page to see a general table with all available models.

$\dot{M}$ = 10.E-7 α = 0.01 p = 3.5 a_{max} = 1 mu Jump to Structure

Other options

You can also consult the SED comparison plots for three accretion rates: 10^{-7}, 10^{-8} and 10^{-9} M⊙/yr

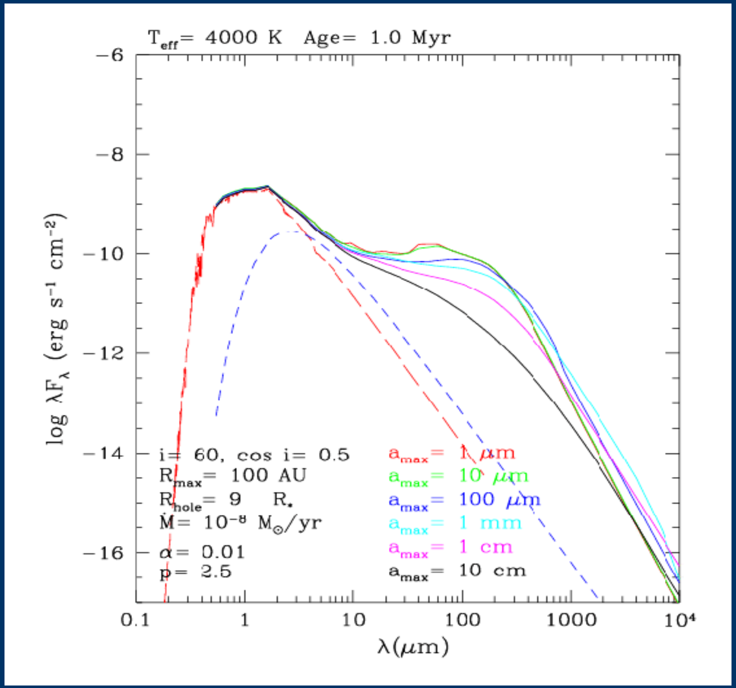
Tables with structure files properties can be reached here and with S.E.D. files properties here. Contents or these tables are explained in the help.

Download all the Structure Files and the SED Files in gzipped-tar files.

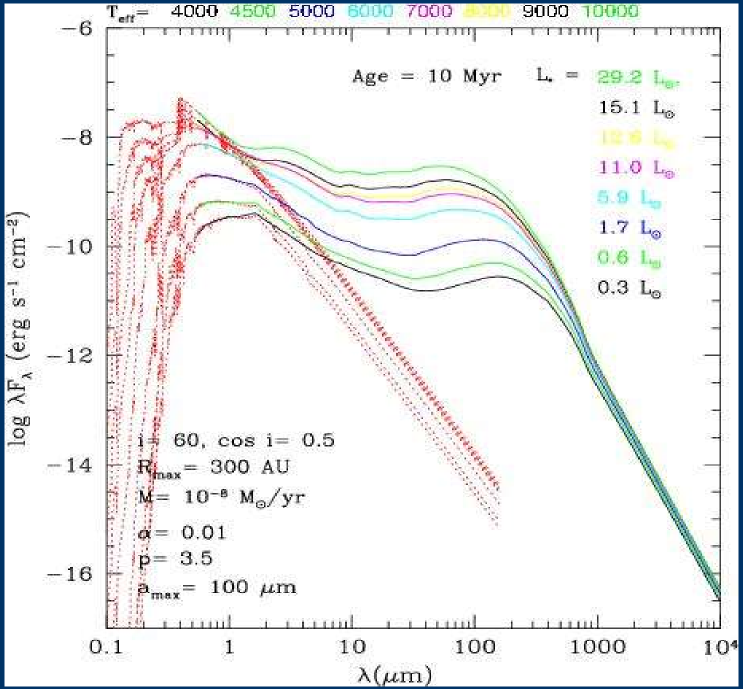
Home Catalog Help Top

Web page containing all the available models for any specific central star. The structure results from the model calculations and the model SEDs can be browsed and downloaded from the corresponding web pages.

Result #1: self consistent calculation of the emission from the inner wall explains the 3 μm bump in HAeBes.



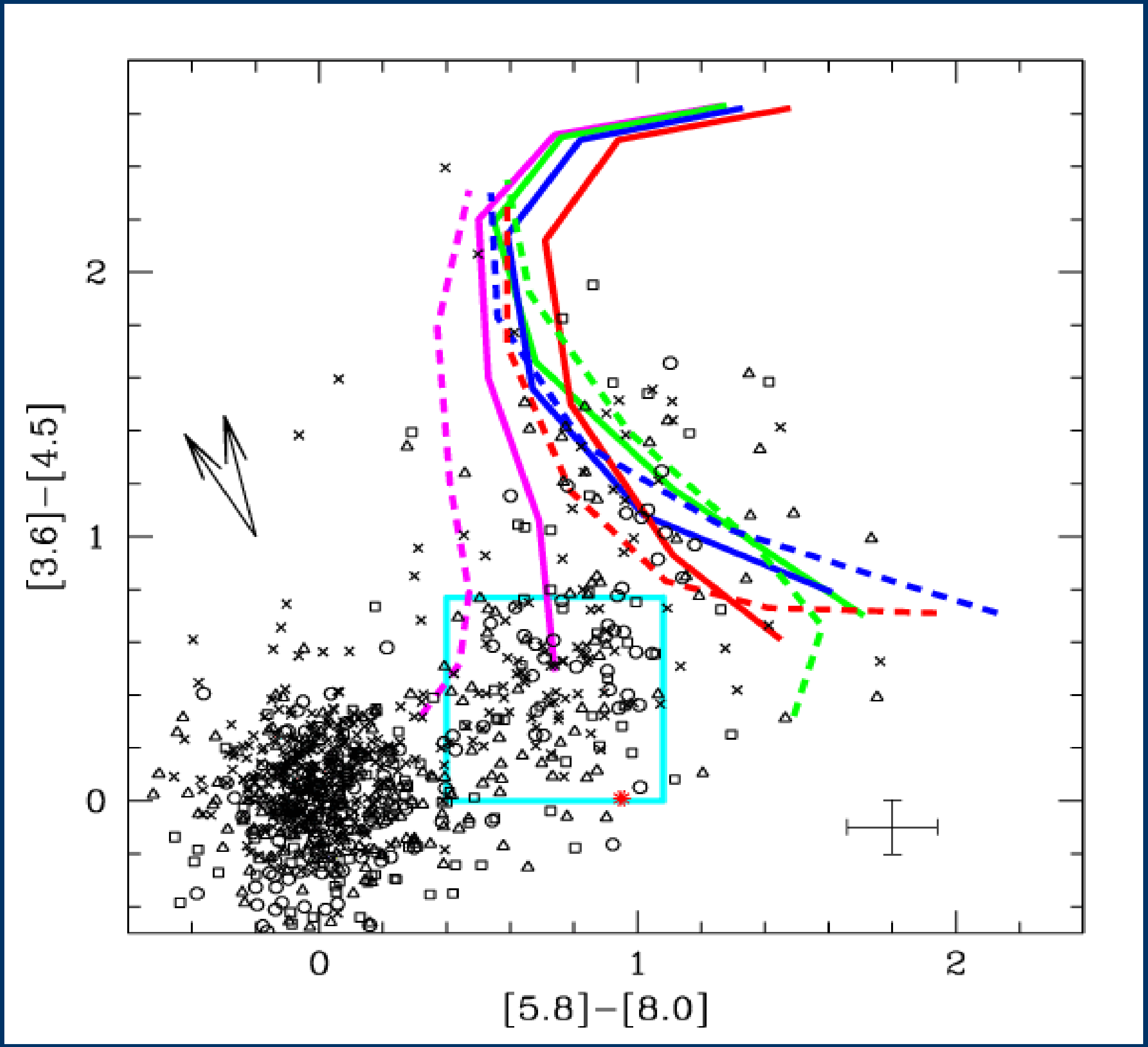
Comparison plot of SEDs in which we only changed the maximum grain size. The dashed red line is the emision from the central star, the colored lines are the emission from the disk models for different values for the grain size distribution upper cut-off, the blue-dashed line is the 1400 K blackbody emission coming from the inner irradiated wall normalized as in Muzerolle et al. (2003). The values of all parameters are quoted in the plot.



Comparison plot of SEDs in which we only changed the central star. From top to bottom the effective temperature of the central stars range from 10000 K (top) to 4000 K (bottom). The disk models plus black body fluxes (colored lines) where computed with the same parameters in all cases. The self-consistent addition of the black-body emission from the disk inner wall only modifies noticeably the total spectrum for the hotter Herbig AeBe-like stars on the top of the plot.

D'Alessio et al. (2004)
Merín et al. (2004a)

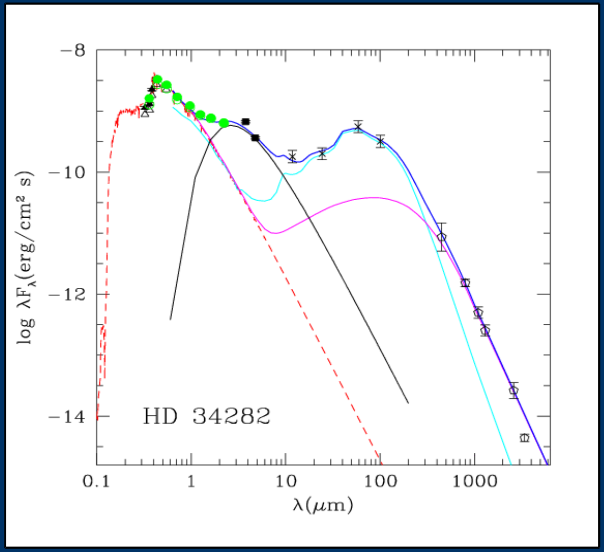
Result #2: IRAC IR synthetic colors computed with the grid of disk models match first Spitzer observations of young stellar clusters.

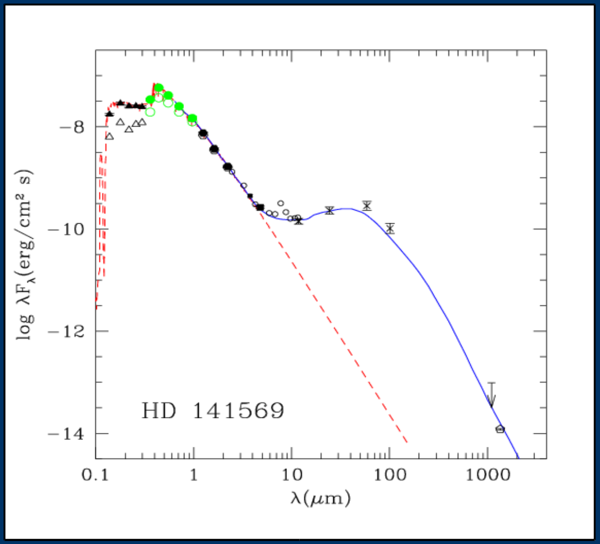


Color-color diagram comparing GTO Spitzer IRAC observations of four young stellar clusters (namely S140 -squares-, S171 -circles-, NGC 7129 -triangles- and Cep C -crosses-) with the predicted emission from D'Alessio et al. self-consistent disk models from the model library (blue squared area) and self-consistent envelope models from Calvet et al. (thick continuous and dashed colored lines). The disk models used for this plot were computed for stellar parameters of the central star typical of a T Tauri star (T_{eff} = 4000 K, age = 1 Myr). The comparison shows that, out of the stars with IR excesses, some embedded Class I objects in the clusters can be fitted with envelope models and many Class II objects can be explained with the physical disk models.

Allen et al. (2004)

Result #3: Does the metallicity affect the evolutionary status of CS disks? A test case: HD 34282 and HD 141569





HD 34282 **[Fe/H] = -0.8**

- Star: A3 V, photometric variable.
- Age = 6 ± 3 Ma.
- Weak Hα emission.

From SED fitting with disk models:

- Vertical segregation of dust grains.
- Active accretion towards the star.
- Truncated disk with irradiated wall.
- $M_{disc} = 0.70\ M_{sun}$, $R_{disc} = 700$ AU

HD 141569 **[Fe/H] = -0.5**

- Star: B9.5 V, photometric stable.
- Age = 5 ± 1 Ma.
- Intense Hα emission plus wind.

From SED fitting with disk models:

- Large dust grains in the mid-plane.
- No accretion.
- Not truncated disk.
- $M_{disc} = 0.07\ M_{sun}$, $R_{disc} = 400$ AU

We computed physical disk models from D'Alessio et al to fit their multiwavelength SEDs (with simultaneous EXPORT data in the optical and near-IR plus photometry from the literature and from satellite data archives) after determining the stellar parameters for the central stars. The comparison between these two stellar systems with similar mass, effective temperature and age but very different IR excesses and (with the aid of physical disk models) very different circumstellar (CS) disks hint to a possible influence of the metallicity (low in both cases) to the evolutionary status of their CS disks: if the amount of metals in the CS disk affects the sticking probability of the grains (and hence also the growth speed), then the lower the metallicity of an object, the slower the evolution of its CS disk. This may explain why HD 34282, with lower metallicity, has a less evolved disk than HD 141569 having both systems similar ages.

Merín et al. (2004b)

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Acknowledgments

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