Herschel PACS and SPIRE colors of Young Stellar Objects

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Photometry at mid-infrared and sub-millimeter wavelengths has proven to be a very efficient and important technique for the search and study of young stellar objects as the emission of circumstellar material peaks at these wavelengths.

With its unprecedented sensitivity between 70 and 500 µm, the recently launched Herschel Space Observatory offers a unique opportunity to detect and study the properties of deeply embedded young stellar objects.

We investigate how PACS and SPIRE luminosities and colors can be used to study the properties of young stellar objects. We use the mid-infrared and sub-millimeter photometry and colors predicted by theoretical models of various classes of young stellar objects. The PACS/SPIRE color-color diagram ([250]-[500] vs [70]-[160]) is a useful tool to estimate the maximum grain size of the dust in the cirmcustellar disk. The disk dust mass can be inferred complementing Herschel colors with optical colors.

Disk models

Synthetic photometry of YSO was obtained using the 3D radiative transfer code MCFOST (Pinte et al. 2006), which includes multiple scattering, passive dust heating assuming radiative equilibrium and continuum thermal reemission. Table1 summarizes the model parameters and the values used in our grid. The synthetic photometry was computed for Herschel PACS and SPIRE central wavelengths (70, 100, 160 µm for PACS and 320, 250, 500 µm for SPIRE) as well as for Cousin V, R, I, 2MASS J, H and K and Spitzer IRAC and MIPS1 central wavelengths. In the present poster we restrict the study to a typical T_{eff}=4000K TTauri star. The results for cooler/hotter stars show similar trends.

Parameter	Values/Range
$T^{\star}$ [K]	1500 to 6000, 8 values
a_{min} [µm]	0.005 to 1.0, 3 values in log. scale
a_{max} [µm]	1 to 1000, 5 values in log. scale
r_{out} [AU]	100, 400
r_{in}[AU]	0.5 to 40, 6 values in log. scale
β	1.05, 1.20, 1.35
M_{dust} [$M_{\odot}$]	10^{-4} to 10^{-7}, 5 values in log. scale
log(g)	3.5, 4.0
i [deg]	0 to 90, 5 values in cos. scale
h0 [AU]	5, 15, 25, 35

Table 1: Parameter space used in our grid

Physical properties

Disk Mass

Physical properties of the YSOs can be inferred with Herschel colors, in particular the disk dust mass. The mass of the disk is one of the most important parameter which define a disk and the evolution of the central star and its eventual planets. As seen in Figure 1 for a given photospheric flux PACS and SPIRE fluxes increases with increasing disk mass. The R band luminosity mostly originates from the photosphere while the 500µm luminosity mostly originates from the disk. To take advantage of this property we use the [R]-[500] color to illustrate the direct dependence of this color on the disk dust mass, as shown in Figure 2 for a typical T_{eff}=4000K TTauri star. We find that disks with the same mass and similar optical colors show different [R]-[500] colors depending on a combination of the size of the external disk radius and the maximum grain size.

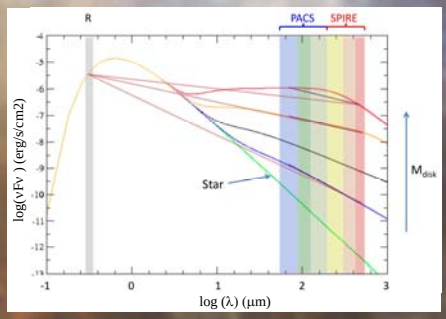

Fig. 1: Sample SEDs for a 4000K star with disks of increasing masses (all other disk parameters fixed).

Maximum Grain Size

We find that in the Herschel PACS/SPIRE color diagram YSOs are clustered in 4 main regions corresponding to the different maximum grain sizes of the disk material. The interpretation of this diagram, and similar ones, is still on-going, but Figure 3 shows that SPIRE [250]-[500] colors might be readily translated into a rough estimate of the size of the large grains present in the circumstellar disk.

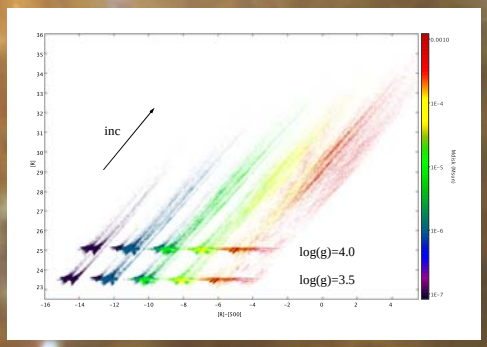

Fig. 2: [R] vs [R]-[500] color diagram for a 4000K star

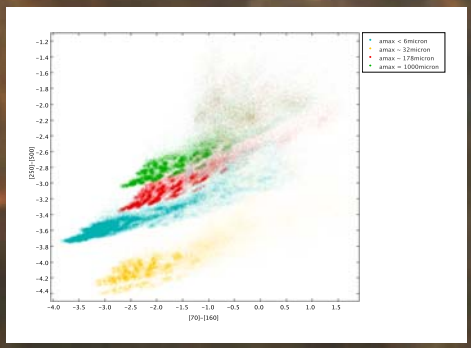

Fig. 3: [250]-[500] vs [70]-[160] color diagram for a 4000K star

Conclusions and future prospects:

★ Our preliminary investigations show that Herschel colors can be used to characterize the disk dust mass and the maximum grain size of YSOs.

★ We will extend the study:

- to even younger objects with envelopes
- new colors including Spitzer, near-IR, optical luminosities.
- compare the results with real data