Herschel PACS photometry of 4-10 Myr old T Tauri stars in the Orion OB1b association

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SUMMARY

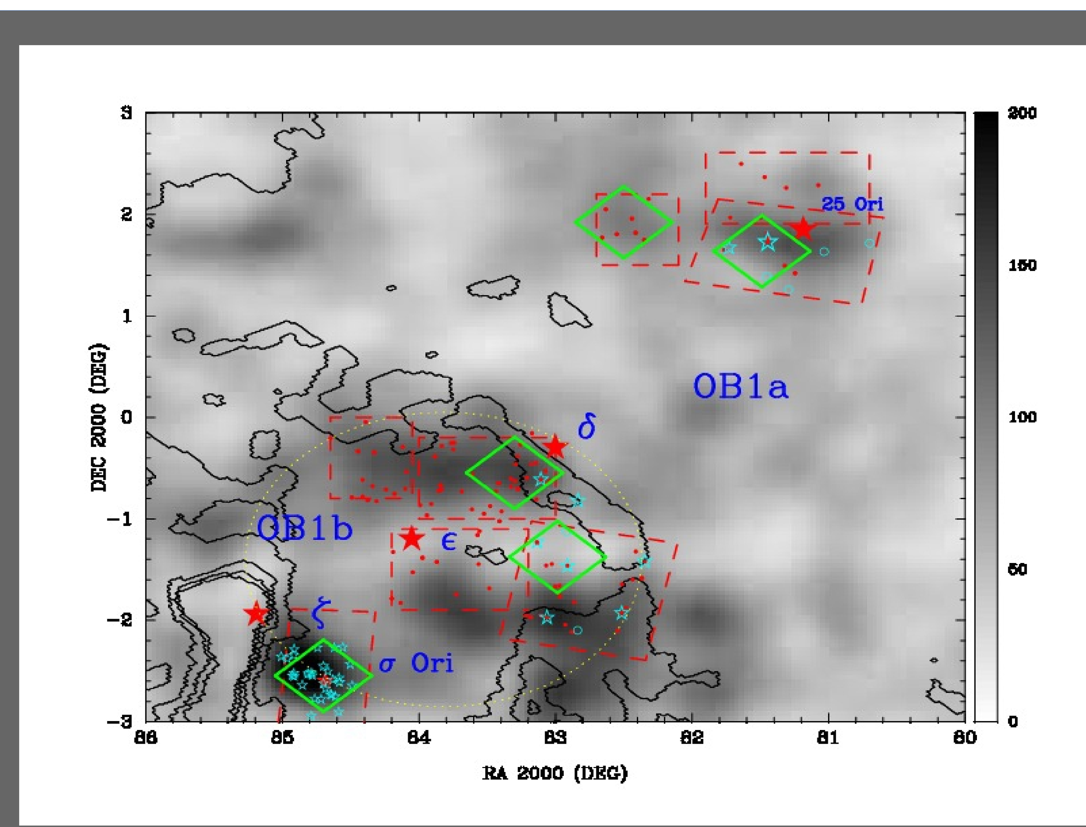
We present the first results of our Herschel PACS mapping at 70 and 160 microns, of 4 fields, each roughly 30 x 30 arcmin, located in the ~4 Myr old Orion OB1a and the ~10 Myr old Orion OB1b sub-associations. These regions contain 63 well characterized T Tauri stars (TTS), identified in the course of our large scale (~180 sq.deg.) optical multi-epoch survey of the Orion OB1 association. Sixteen stars have detections at both 70 and 160mm. The SEDs of our objects exhibit a variety of disk types, from optically thick disks similar to those in the younger Taurus star forming region, to transitional disks with gaps. Comparison of the Spitzer /Herschel SED slopes with our disk models suggest that many of these disks have experienced an important degree of dust settling, a telltale sign of a more evolved state.

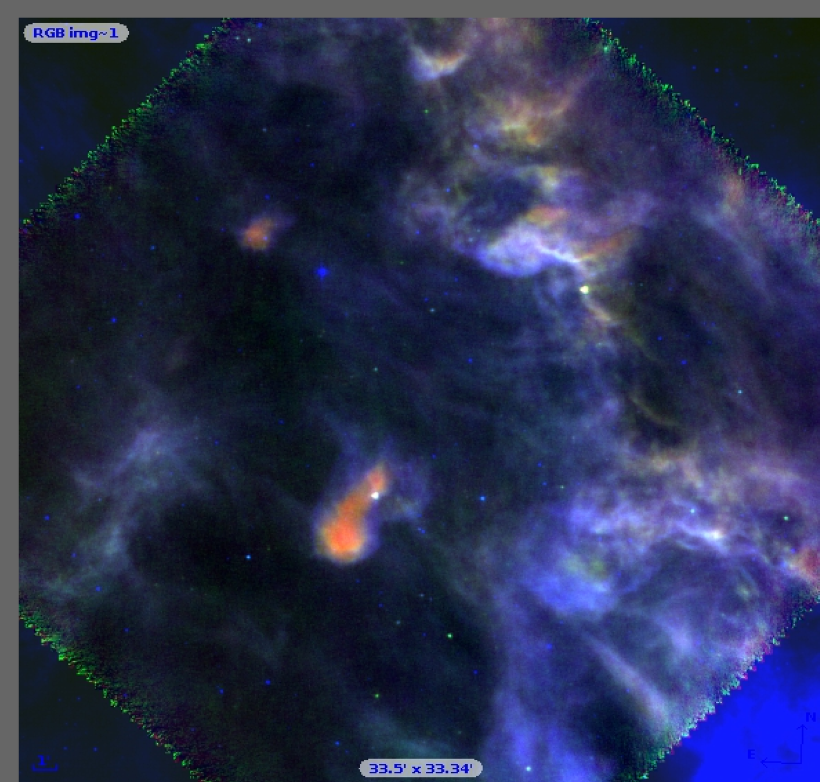
Observations and Data Reduction

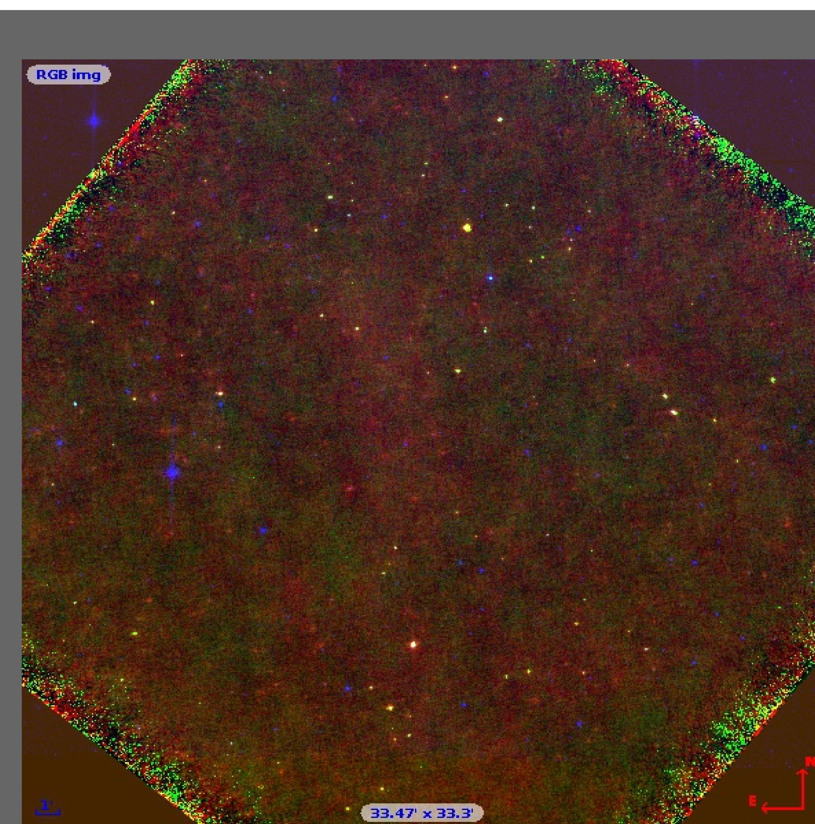
We obtained Herschel PACS 70 and 160µm maps in scan map mode at the medium rate (20"/s), repeated in orthogonal directions. This approach yields a high S/N and maximizes area coverage, hence including more stars. It also allows coping with the range in surface brightness across the various fields, while minimizing smearing of the PSF. The data were processed with HIPE V.9.0, and the final images produced with the *Scanamorphos* software (Roussel 2012), using the "galactic" option.

We performed aperture photometry with PHOT in IRAF, using apertures of 9.6" at 70µm and 12.8" at 160 µm, and sky annuli= 9.6-19.2" and 12.8-25.6", respectively. We then applied aperture corrections 0f 0.7331 (70µm) and 0.6602 (160µm; Stutz et al. 2013).

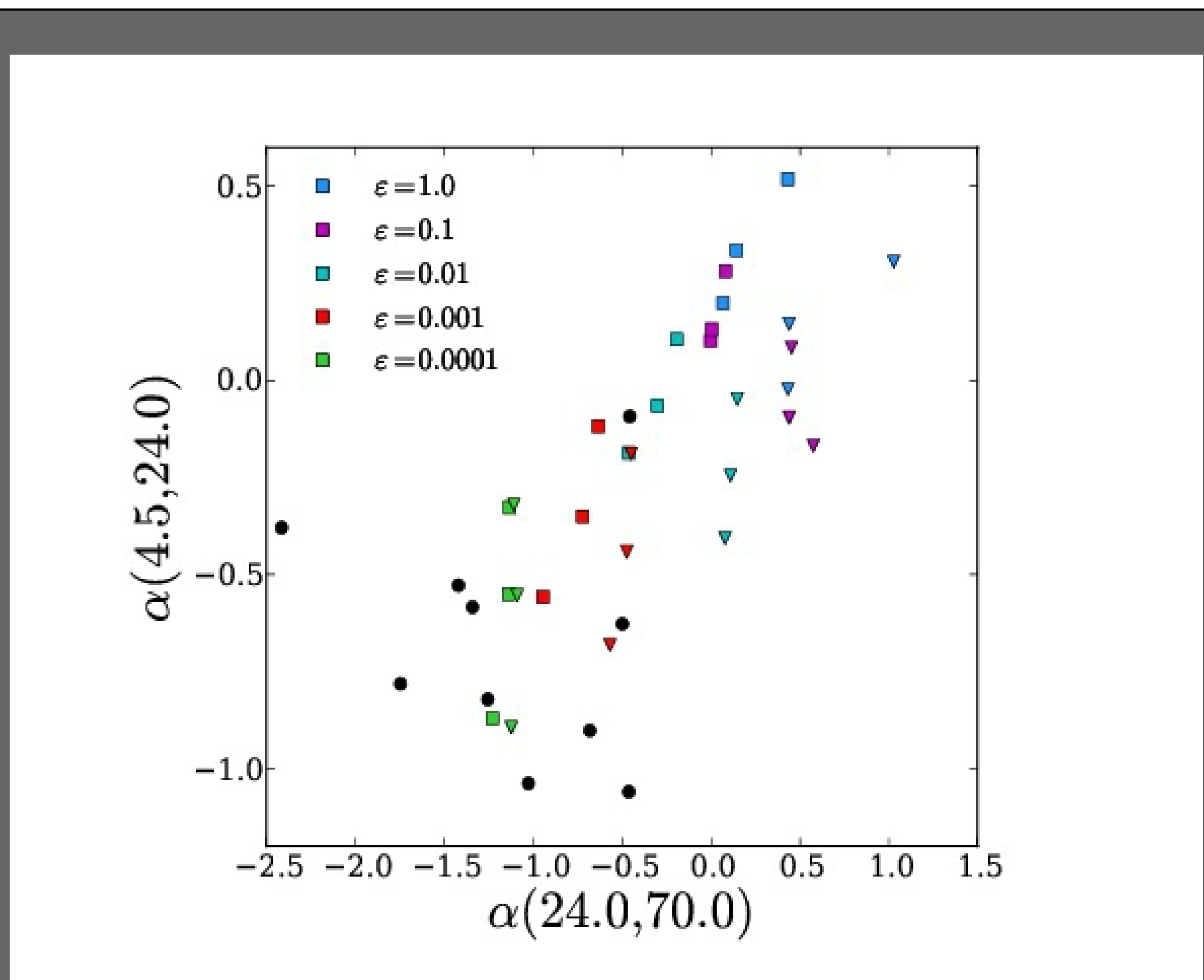
Location of our Herschel PACS fields (large green diamonds). The grey scale map is the surface density of pre-main sequence stars in the CIDA Variability Survey of Orion (CVSO). The ^{12}CO emission (black contours; Bally et al. 1987) outlines the molecular clouds. The ~10 Myr old 25 Ori cluster (Briceno et al. 2007) is indicated. Red dashed lined rectangles are our Spitzer IRAC/MIPS fields, and the red dots a subset of the ~2000 TTS we have identified in Orion OB1.







RGB images (Blue=IRAC 8mm, Green=PACS 70mm, Red=PACS 160mm) of the the Ori OB1b-1 field (left) and the 25 Ori field (right).

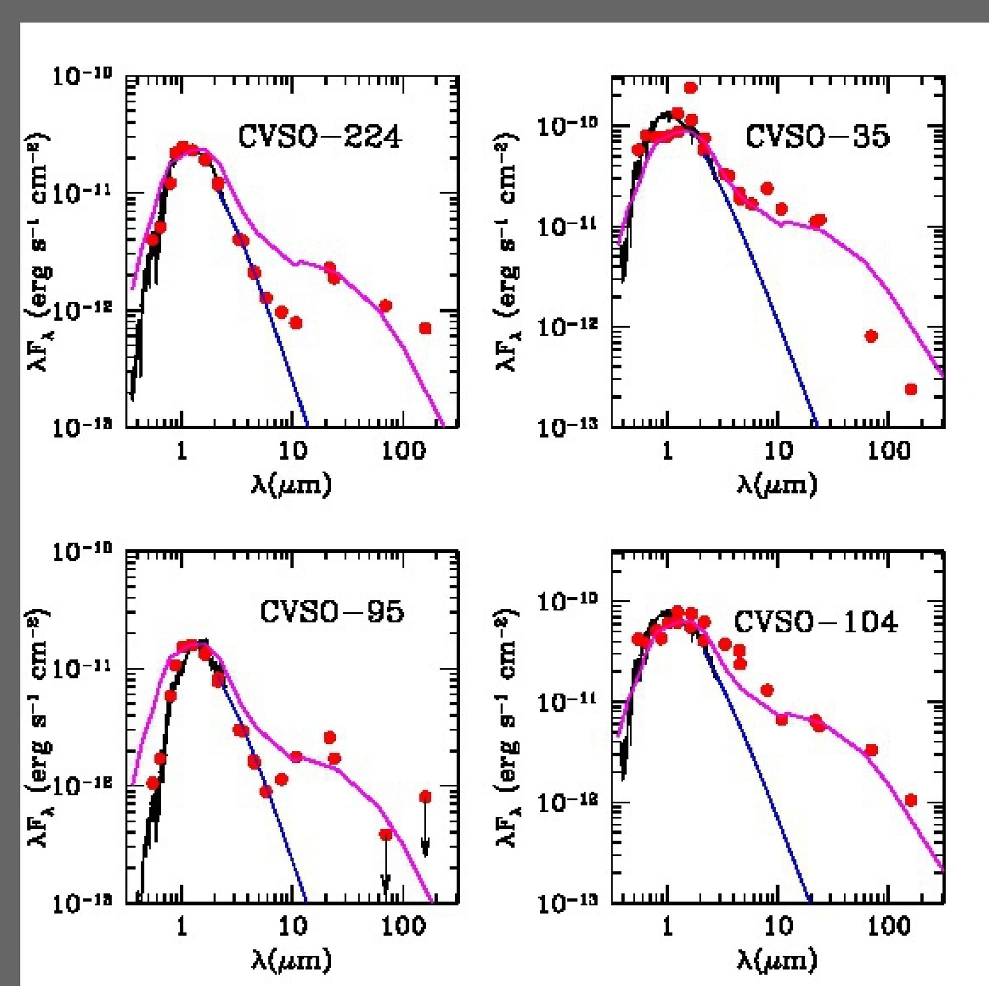


SED slopes (α) for disks in Ori 1a and 1b compared to predictions of irradiated accretion disk models including dust settling. The models have been calculated following the procedures of D'Alessio et al. (2006). The dust consists of two populations of small and large grains with size distribution **$1/a^{3.5}$** between **a_{min}** and **a_{max}**, with **a_{max} = 0.25mm** and **a_{max}=1 mm**, for the small and big dust populations, respectively. Dust settling is parametrized by **ε**, that measures the dust to gas mass ratio of the small grains in the upper layers of the disk relative to the standard dust to gas mass ratio. Dust removed from the upper layers adds to the large grains in the midplane. Dust consists of silicates, graphite, with mass abundances 0.004 and 0.0025 respectively, and water ice, with two abundances 10^{-5} (squares) and 0.002 (triangles). Comparison with observations indicates that disks are very settled, with depletions of 1% or less in the disk upper layers.

Other parameters are: Star: mass, radius, and effective temperature. We used M=0.5 Msun, R=2 Rsun, Teff = 4000 K. Disk mass accretion rate=10^{-8} Msun/yr, viscosity alpha parameter=0.01, radius=350 AU. SEDs were calculated for cos i =0.9, 0.6, 0.3, where **i** is the inclination.

SEDs of four CVSO TTS detected in our PACS fields. The data combines VRI from our large scale synoptic survey (Briceño et al. 2001, 2005), JHKs from 2MASS (Skrutskie et al. 2006), ZYJHKs from VISTA (Petr-Gotzens et al. 2011), 3.6, 4.5, 5.8, 8 and 24µm from our Spitzer program (Hernandez et al. 2007; Briceno et al. 2013b, in preparation), 3.4, 4.6, 12 and 22µm from WISE (Wright et al. 2010), and 70 and 160µm from Herschel PACS. Black line: photosphere of the same spectral type; blue line: blackbody at the same Teff, magenta line: median SED of Taurus (~2 Myr) TTS, scaled at J.

CVSO-104 is a Classical TTS (CTTS) with large W(Ha), indicative of strong ongoing accretion; its SEDs is similar to the Taurus median, which represents a primordial optically thick disk. Detections also include transitional disks, i.e., disks with inner cavities possibly carved by a planet, like CVSO 224 (Espaillat et al 2008) and CVSO-95.



CVSO	SpT	W(Hα) (Å)	TYPE
224	M3	-20.3	CTTS
35	K7	-13.0	CTTS
95	M5	-8.9	WTTS
104	K7	-62.9	CTTS

References

Bally et al. 1987, ApJL, 312, L45
Briceño et al. 2001 Sciencee, 291, 93
Briceño et al. 2005, AJ, 129, 907
Briceno et al. 2007, ApJ, 661, 1119
D'Alessio et al. 2006, ApJ, 638, 314
Espaillat et al. 2008, ApJL, 689, L145
Hernandez et al. 2007, 671, 1784
Petr-Gotzens et al. 2011, Messenger, 145, 29
Roussel, H. 2012, PASP, submitted (arXiv:1205.2576)
Skrutskie et al. 2006, AJ, 131, 1163
Stutz, et al. 2013, ApJ, 767, 36
Wright et al. 2010, AJ, 140, 1868