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ISO-SWS observations of EXPORT targets

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EXPORT

Abstract. We present a first analysis of the ISO-SWS spectra of the pre-main sequence and Vega-type stars observed during the 1998 La Palma International Observing time. PMS stars generally show excesses in the whole SWS spectral range, while the excess in Vega-type stars normally appears at wavelengths longer than 10 μm. PMS stars normally show silicate emission, while most of the Vega-type stars do not. The observed silicate profiles is similar to those observed in cometary silicates. The SWS results together with EXPORT ground-based data could reflect the evolution of circumstellar disks from PMS to Vega-type stars.

1. Introduction

Most of the EXPORT 1998 International Time of the Canary Island Observatories was devoted to optical spectroscopy and near-IR and optical photopolarimetry of a large sample of main sequence (MS) and pre-main sequence (PMS) objects. Such observations are very suitable to study physical properties of the protoplanetary gaseous and dusty disks around those stars. In addition, the mid-IR provides a lot of information on the dusty component of the disks, due to the expected grain temperatures and to the solid state spectral features found in this wavelength regime. In this respect, the Short Wavelength Spectrometer (SWS, de Graauw et al., 1996) onboard on the Infrared Spatial Observatory (ISO[1], Kessler et al., 1996) has obtained very interesting results. Thus, in order to complement the EXPORT ground-based data we decided to analyse the available SWS spectra of the EXPORT targets.

Among the several solid state features present in the SWS spectral range, the 10 μm silicate band is one of the best studied and it appears in many different astrophysical scenarios. It is also known that the band profile allows to

[1]Based on observations with ISO, an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA.

determine the degree of processing of the dust particles. Thus, the comparison of silicate features observed towards young stars with those observed in solar system comets is very useful to study the dust properties in young protoplanetary systems, because comets are supposed to have a chemical composition very close to that of the primitive protosolar nebula. In fact, the discovery of comet-like silicate emission around some young stars (Telesco and Knacke, 1991) is a major support to argue on the existence of stellar systems where the very first steps of planet formation are likely taking place. The coincidence of these features with optical transient spectroscopic events, which have been interpreted as due to the evaporation of solid bodies around Vega-type and some PMS stars (e.g. Grady et al., 1999) can lead to new insights into the formation and evolution of protoplanetary disks.

2. Available data and reduction

The ISO post mission archive was surveyed for SWS spectra of the EXPORT targets. Only SWS01 observations have been considered in our first approach. This observing mode provides a spectrum for the full grating instrumental setup, designed to produce a spectra for the whole wavelength range covered by the SWS detectors (3 to 45 μm) at a nominal resolution of around 1000.

Table 1. Individual ISO-SWS observations of stars included in the EXPORT ground-based programme.

Object		Sp. Type	Type	TDT number
HR 10		A2V	Vega	37802001
BD+31°643		B5	Vega	65201414
HD 31293	AB Aur	A0V	HAeBe/ZAMS	68001206
MWC 480	HD 31648	A3	HAeBe/ZAMS	83501201
HD 34282		A0	HAeBe/ZAMS	83301240
HD 34700		G0V	Vega	66302638
HD 109085	GL 9411	F2V	Vega	24002304
λ Boo	HD 125162	A0V	Vega?	35101303
HD 141569		A0V	HAeBe/ZAMS	62802937
HD 142666		A7Ve	HAeBe/ZAMS	10402952
				44901283
HD 144432		A5V	HAeBe/ZAMS	45000284
HD 150193	MWC 863	A1Ve	HAeBe	8200444
51 Oph	HR 6519	B9Ve	Vega	10703103
HD 163296		A1Ve	HAeBe/ZAMS	32901191
MWC 297		O9	HAeBe/ZAMS	70800234
HD 179218		B9e	HAeBe/ZAMS	32301321
WW Vul		A0e	HAeBe	17600305
V 1686 Cyg	LkH$_\alpha$ 224	G2V		85800502
SV Cep		A0e	HAeBe	28800703
HR 9043		A5V	Vega	40400904

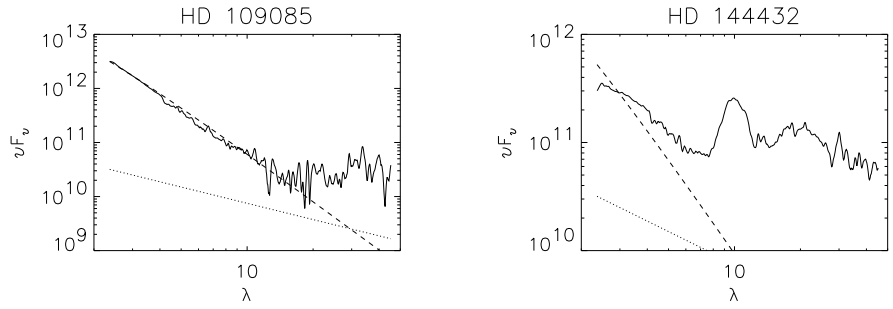

Figure 1. SWS Spectral Energy Distributions for two sample object: a Vega-type star (left) and a PMS object (right). The dashed line represents a blackbody fitted to the $3\mu m$ flux. The dotted line marks a 0.25 Jy flux level.

The retrieved datasets are shown in Table 1. One third of the stars is classified as Vega-type stars in the literature, and most of the PMS stars are HAeBe stars close to the ZAMS (van den Ancker et al., 1997, van den Ancker et al., 1998).

The reduction of the SWS spectra was performed using the SWS Interactive Analysis package (IA3[2]). Special attention was devoted to dark current calculation and subtraction due to the low flux levels of many of the objects. A description of the reduction procedure, close to the standard one, is detailed by Palacios et al. (Palacios et al., 2000).

3. The mid-IR spectra

The SWS spectral energy distribution of each star in Table 1 has been compared with a blackbody with the effective temperature of the star and normalized to the observed flux around 3 μm. Two distinct behaviours are observed. Most of the Vega-type stars show SEDs compatible with a photosphere in the shorter SWS spectral range ($\sim 10\,\mu m$), and the Vega excess typically appears beyond 20-30 μm. SEDs of the PMS stars are flatter than blackbodies and their slopes are not compatible with a photosphere even at 3 μm. Considering the SWS SED, the Vega-type stars 51 Oph and HD 34700 should be classified as PMS objects, since both stars show a remarkable excess at the shorter wavelengths. On the other hand, the star HD 141569, which is among the oldest HAeBe stars according to Hipparcos data (van den Ancker et al., 1997), could be classified as a possible Vega star, since the SWS SED at wavelengths shorter than 10 μm is practically photospheric; this likely is also the case of HD 34282, though this star is too faint to make a reliable classification.

With respect to the presence of the silicate feature, the band is not observed in any of the objects in Table 1 with a photospheric SWS SED, i.e. the Vega-

[2]IA3 is a joint development of the SWS consortium. Contributing institutes are SRON, MPE, KUL and the ESA Astrophysics Division.

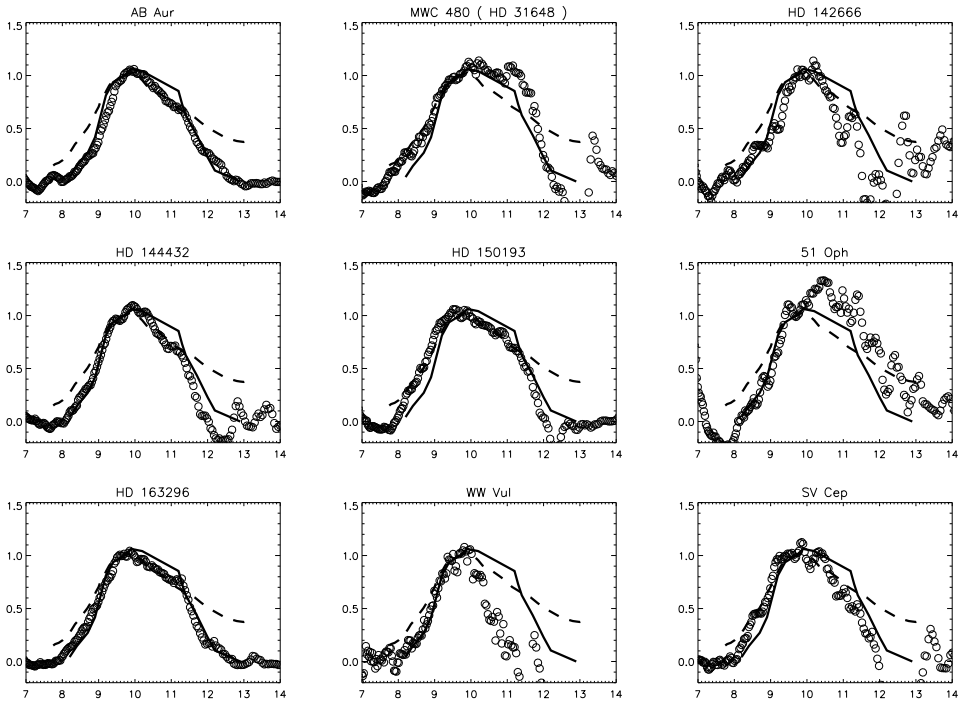

Figure 2. Normalized 7 to 14μm spectra of the objects with silicate emission feature. The Trapezium (dashed line) and comet Kohoutek silicates (continuous line) are superimposed.

type stars. The opposite is true for the PMS objects, where the feature appears in emission in most of the cases. In this group, MWC 297 shows the silicate band in absorption, while no feature is observed in V 1686 Cyg, whose SED shows increasing flux densities with wavelength. This star is located inside an active young stellar cluster(van den Ancker, 1999).

We have made a first comparison of the silicate emission observed towards the stars in our sample and other astronomical silicates. Figure 1 shows the normalized SWS 7 - 14 μm spectra of our objects and the Trapezium (Hanner et al., 1995) and comet Kohoutek (Merrill, 1974) silicates. The emission in the Trapezium is believed to be characteristic of amorphous silicates in a dense interstellar environment, as that found in the direction of the Orion molecular cloud, while the comet emission is an example of crystalline silicates and should be a good sample of dust material processed while the central object evolves. For comparison, we have removed the underlying dust emission in our stars and all spectra have been normalized at 9.7 μm. The agreement is very poor for the Trapezium silicates; on the other hand, it is in general very satisfactory in the case of the cometary silicates. In particular, the observed silicate emissions of AB Aur and HD 163296 are quite similar to cometary silicates.

4. Comparison with EXPORT ground-based results

The EXPORT ground-based data contain optical spectroscopic and photopolarimetric information on the gas and dust properties of the circumstellar environment. It is an interesting exercise to compare those results with the SWS data, in order to see if any kind of general trend or relationship exists.

Table 2. Properties derived from EXPORT ground-based and SWS observations. See description in text.

Star	Pol	Near-IR	Spectra	SWS-SED	SWS-Silicates
HR 10	○	○	●	○	○
HD 109085	○		○	○	○
λ Boo	○	○	○	○	○
HR 9043	○	○	●	○	○
BD+31°643	●	reddened	○	?	○
HD 34700	●	●	●	●	○
51 Oph	●	●	●	●	●
HD 34282	●	●	○	?	○
HD 141569	●	○	●	○	○
AB Aur			●	●	●
MWC 480	●	●	●	●	●
HD 142666	●	●	●	●	●
HD 144432	●	●	●	●	●
HD 150193	●	●	●	●	●
HD 163296	?	●	●	●	●
MWC 297	●	●	●	●	abs
HD 179218	?	●	●	●	●
WW Vul	●	●	●	●	●
V 1686 Cyg	●	●	●	●	○
SV Cep	●		●	●	●

The ground-based results for the sample of SWS stars are summarized in Table 2. A blank in any of the columns 2 to 6 means that there is no information on the corresponding star, while an open circle means that the behaviour of the star is apparently normal, i.e. unpolarized, photospheric near-IR colours and SWS-SED up to $\sim 10\,\mu m$, photospheric spectra, and no silicate feature. The second column indicates if the object is polarized in the UBVRI bands (black dot); a question mark in this column means that the object is probably polarized, with a very low polarization degree[3]. Infrared photometry is shown in the third column; black dots mean a near-IR excess. The near-IR colours of BD +31°643 are compatible with a reddened star of its spectral type. Black dots in the fourth

[3]HD 163296 could show variable polarization at very low levels

column identify non photospheric spectra with spectral lines indicating gaseous circumstellar activity. The last two columns indicate the presence of a SWS excess at wavelengths shorter than ~ 10 μm and of a silicate feature.

The results in Table 2 suggest an evolution from the PMS objects to Vega-type stars. As expected, most of the PMS stars have a circumstellar component as shown by the gas and dust signatures in the columns of Table 2. On the opposite, Vega-type stars usually do not show any observational property revealing the presence of dust around the stars. However, in at least two cases, HR 10 and HR 9043, the optical spectra indicate circumstellar gas. Five objects likely are in intermediate evolution phases, three Vega-type stars - BD $+31°643$, HD 34700 and 51 Oph - and two HAeBe/ZAMS stars - HD 34282 and HD 141569. All these stars are polarized and show some of the properties of PMS objects in Table 2.

5. Conclusions

The ISO-SWS data of the PMS and MS stars studied by EXPORT show a good correlation with the results obtained from the ground and well indicate the presence of dust. It is interesting to point out that the observed silicate profiles in the sample of stars are similar to the profiles observed in solar system comets. Apparently, dust particles in the protoplanetary disks around young stars experience similar physical processes as those prevailing in the formation phase of the solar system.

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