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ISOPHOT Observations of a Selected Sample of Flare Stars

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Abstract.
A selected sample of UV Cet-type stars were photometrically observed by ISOPHOT on ISO to trace their spectral energy distribution in the 2-200 μm spectral range. We report on our data analysis which confirms the presence of an IR excess for some of the observed sources, as already suggested by IRAS data. The nature of this IR excess is under investigation.

1. The Data and Data Reduction

We selected a sample of dMe sources to be observed by ISO (Kessler et al. 1996), following the indication given by IRAS on the presence of IR excess. In this paper we report on preliminary data obtained by the ISOPHOT instrument (Lemke et al. 1996) for 8 over 12 dMe stars in our target list.

The P1 and P2 detectors were used to perform photometry at 3.6, 4.85, 7.3, 10, 12.8, 16.0, and 25 μm using the PHT03 AOT. Far infrared photometry using the C100 and C200 bidimensional detectors at 60, 100, 135, and 200 μm was obtained using the PHT22 AOT. We observed the following stars: FF And, UV Cet, BY Dra, Gl 781, Gl 852, EV Lac, GT Peg, and EQ Peg. For Gl 781, only the PHT03 AOT was done.

The results of automatic processing of multi-filter photometry made by ISO in chopped mode are are not scientifically validated yet (current reduction pipeline: OLP_9.0). Therefore we have performed our own reduction by using the Interactive Analysis Software Package (PIA, V7.3) starting from Edited Raw Data (ERD) level. The standard reduction path was followed, i.e. correction for non linearity, deglitching, and dark current subtraction. The triangular chopping enabled us to get an interpolated background to be subtracted from the on source measurement at SCP (Signal per Chopper Plateau) reduction level. The calibration to flux unit was done by using FCS (Fine Calibration Source) data taken during the observations as well as the standard CAL-G data which give the default response. We have found that the results are not affected by the calibration choice, at least qualitatively. The data here shown are those

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obtained using default responses. Details on the reduction of each source will be given by Leto et al. (2002).

2. Results

In Figure 1 we present the spectral energy distributions (SEDs) of our sample of dMe stars derived from ISOPHOT photometric data and from UBVJHK(-L) measurements given in the literature. IRAS fluxes and upper limits from Mathioudakis and Doyle (1993), black body (BB) emission curves at the photospheric temperature(s) and the M dwarf atmospheric by Hauschildt et al. (1999) are also plotted. The ISO measurements obtained with PHT03 AOT have been scaled according to the L band ground based flux, or to the flux computed by the model photophere at 3.6 μm. The plotted errorbars give our estimated uncertainty on the measurements. These are in good agreement with the uncertainties linked to the flux reproducibility as estimated by Klaas et al. (2000), that are equal to 10% for P1, P2, and C200 detectors, and 20% for the C100 detector.

Gl 29.1 shows an excess of emission between 4.85 and 16 μm. We find upper limits for the 25, 60, 100, and 200 μm measurements, and a detection at 150 μm that indicates a flux close to the cirrus and galaxy confusion noise.

Gl 65AB was undetected at almost all wavelengths. Data are noisy, in fact the uncertainties are typically twice with respect to the other sources.

Gl 719 shows emission excess from 4.85 to 25 μm, with a maximum of displacement from the photospheric emission at 12-16 μm. The measurements at wavelength greater than 60 μm give only upper limits.

Gl 781 was detected only till 7.3 μm, and shows emission excess at 4.85 and 7.3 μm.

Gl 852AB was detected from 3.6 to 7.3 μm, undetected from 10 to 100 μm and detected again at 150 and 200 μm. The flux exceeds the photospheric expected contribution at 4.85, 7.3, 150 and 200 μm. The flux value at 150 μm, but not at 200 μm, is greater than the cirrus and galaxy confusion noise level.

Gl 873 was detected from 3.6 to 25 μm, with clear excess from 7.3 to 16 μm. We have no clear detection with the C100 detector, while we have huge FIR fluxes at 150, and 200 μm, both well above the cirrus and galaxy confusion noise.

Gl 875.1 was detected from 3.6 to 10 μm, undetected from 12 to 60 μm, again detected from 100 to 200 μm. No significative excesses were found for this source.

Gl 896AB was detected at all waveleghts, except at 60 μm. Its emission exceeds that expected from the photoshere from 7.3 to 12.8 μm, and is significatively above the cirrus and galaxy confusion noise at 150 and 200 μm.

3. Conclusions

We have found that excess emission at infrared wavelengths in the range 4.8 - 12 μm is almost common in flare stars (6 over 8 stars). We have also found clear

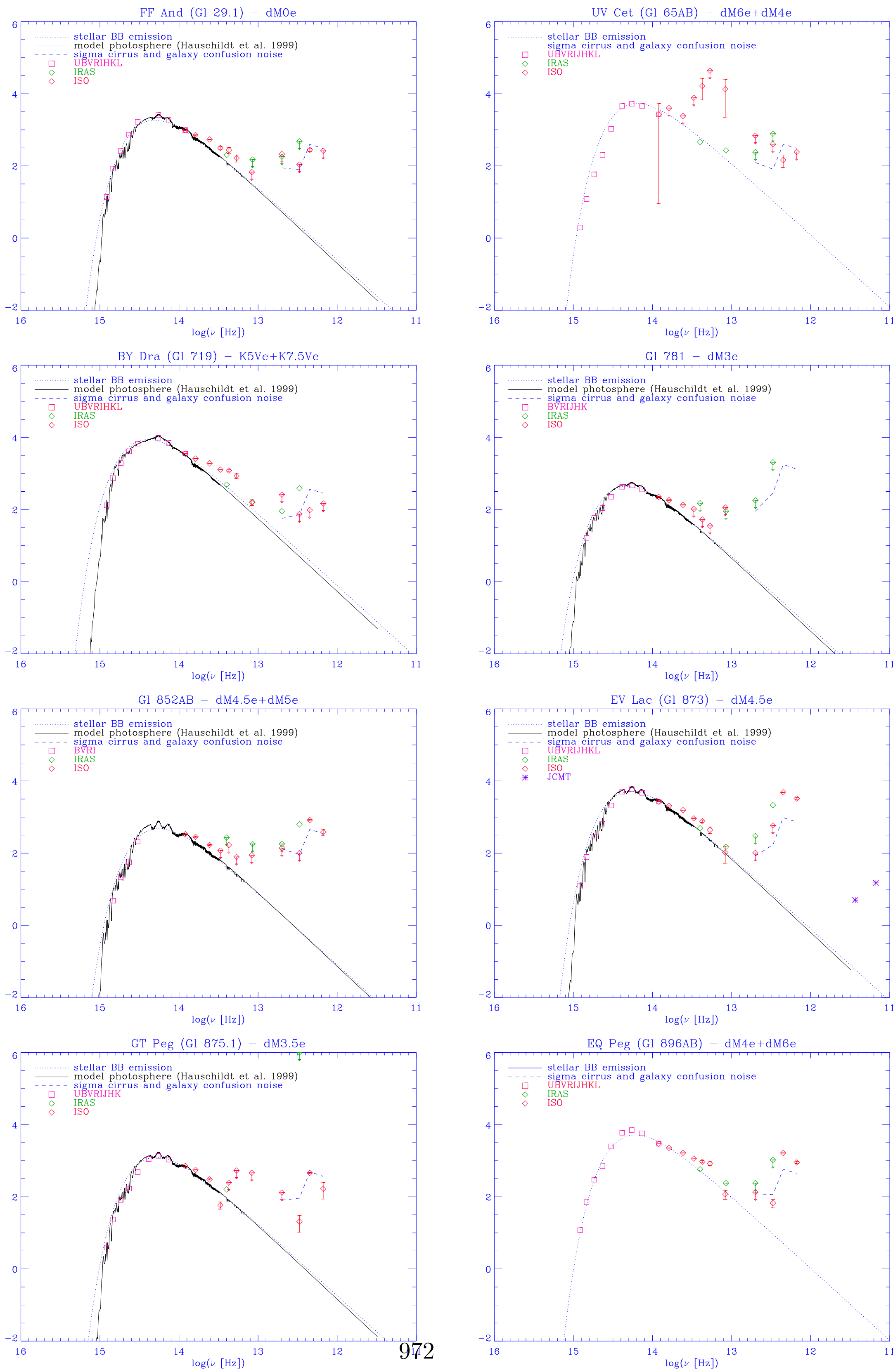

Figure 1. Spectral Energy Distributions (SEDs) of the dMe stars observed by ISO with ISOPHOT.

excess emissions at 150 μm and 200 μm for 2 over 8 stars, and excess emission only at 150 μm for another star. Although the found excesses at 150 and 200 μm are well above the cirrus and galaxy confusion noise, we cannot definitively attribute their origin to the observed stars, because a detailed analysis of the four pixels of the C200 detector shows a behavior that is not easily attributable to a point-like source.

What is the nature of the 4.8-12 μm excess? Possible interpretations include: *i)* synchrotron radiation of relativistic electrons produced during flare and microflare activity; *ii)* emission from a stellar wind; *iii)* thermal emission from dust grains. The synchrotron model implies that the energy distribution increases towards long wavelengths, but it is ruled out by the fact that at 60 μm the flux would be much larger than observed. The free-free emission from a stellar wind has been definitively ruled out as mechanism responsible for the IR excess by van den Oord & Doyle (1997), who demonstrated that the maximum allowable mass loss rate from dMe stars is at most a few times 10^{-12} $M_{\odot}$ yr^{-1}, i.e., too low to account for the observed IR and millimetric fluxes. The thermal emission from dust grains remains the only plausible explanation of the IR excess and an observational support to this hypothesis would be given by fluxes of order of 1 Jy at 200 μm. Actually, this is what we find for a few sources (Gl 873, Gl 852AB, Gl 896AB). It is worth noting that a relevant infrared excess was found also for two RS CVn-type stars, HR 7428 (Rodonò et al. 1998b) and II Peg (Rodonò et al. 1998a, Leto et al. 2001) by ISO measurements. The dMe stars here studied share with RS CVn's a high regime of flare activity, and, therefore may experience mass loss episodes, such as coronal mass ejections, that occur during the cause of the strongest flares. Can the IR excess be due to dust formed by the remnants of those ejecta? Our investigation is still preliminary and need modelling and interpretation effort.

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References

Doyle, J.G., & Mathioudakis, M., 1991, A&A, 241, L41.

Hauschildt, P., Allard, F., & Baron, E., 1999, ApJ, 512, 377.

Kessler, M.F., Steinz, J.A., Anderegg, M.E., et al., 1996, A&A, 315, L27.

Klaas, U., et al., 2000, ISOPHOT Calibration Accuracy, SAI/1998-092/Dc

Lemke, D., Klaas, U., Abolins, J. et al., 1996, A&A, 315, L64.

Leto, G. et al., 2001, ISOPHOT measurements of II Peg, in preparation

Leto, G. et al., 2002, ISOPHOT measurements of dMe stars, in preparation

Mathioudakis, M., & Doyle, J.G., 1993, A&A, 280, 181.

Rodonò, M., Pagano, I., Leto, G., et al., 1998a, Ap&SS, 255, 237

Rodonò, M., Pagano, I., Leto, G., et al., 1998b, ASP Conf. Ser. 154, p. 1446.

van den Oord, G.H.J., & Doyle, J.G., 1997, A&A, 319, 578.