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IR observations of Am stars

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Abstract. The IR observations of chemically peculiar stars are carried out and compared with the previous data in IR and far IR from IRAS. The flux redistribution appears to be a common phenomenon in all the stars of this class. The observed energy distribution and a model fit based on effective temperature estimates show slight excess in the IR.

Keywords : Am stars - chemically peculiar stars - energy distribution - infrared fluxes

1. Introduction

Several features in the spectra that lead to chemical abundance anomalies characterize the chemically peculiar (CP) stars. The classification into various subgroups like CP1, CP2, CP3 and CP4 is based on the type of peculiarity. Among these stars, the CP1 group, which are also known as Am stars, generally have Mn, Sr, Ba, Eu and Hg as overabundant, while Mg, Ca, Sc & Y appear to be underabundant. Their spectral types derived on the basis of the CaII K line appear to be earlier compared to those derived by metallic line ratios, and their energy distributions clearly indicate that in the blue and UV regions, the continuum itself is suppressed because of the strong metallic lines.

There have been several attempts to obtain their IR spectral energy distributions. One of the earlier attempts (Babu & Shylaja, 1981, 1982) considered only the region longward of λ 500 nm to avoid line blanketing to derive the effective temperatures. The values of T_{eff} thus obtained are found to be systematically high, compared to other determinations, for example, Bohme-Vitense (1981), Lane & Lester (1984), Smalley & Dworetsky (1992), Meggesier & van't Veer (1992), van't Veer Minneret & Megessier (1996).

Therefore it is important to look at the infrared region (IR) to test the validity of the model fit. With this idea in mind, the present study is oriented to extend the energy distributions to the IR regions, with the help of ground based near IR data. The fluxes at 12 μ are obtained from the observations with the IRAS. The compilation of the data is described in Section 2, while in Section 3, the results are discussed with the idea of an overall energy distribution from UV to IR.

2. Data

We observed Am stars through the IR photometer at Gurushikhar at the 1.2 m telescope (the method of observations and calibration are described in Chandrasekhar et al., 1992). The estimated errors are of the order of 0.03 magnitudes. The near IR observations for other programme stars were compiled from Gezari et al. (1984, 87) and from subsequent reports available in literature. The magnitude estimates of Hipparcos are used for calibration of fluxes (Adelman, 1998).

The far IR data are collected from the IRAS observations, searching for the counterparts in the Point Source Catalogue (PSC), within positional accuracy of a few arcseconds. Further, the possible contamination because of contributions from nearby strong IR sources also were checked and only cases which are free of this are considered. The estimates at 12 μ generally are reliable, while at 25 μ the measurements are of good quality for a few stars only.

Table 1 gives a compilation of the IR data of the program stars. Most of the observations listed are from Gezari et al. (1987). Our observations at Gurushikhar are indicated by asterisk. For some stars, other observations also are available and these references are indicated in the Table. Thus some stars have multiple entries. The 12μ fluxes are generally reliable flux estimates and the values with 'L' suffix indicating upper limits are also included in the Table 1.

3. Results and Discussion

The JHKLM magnitudes are from various sources and therefore the heterogeneity of the data can lead to errors in the transformation to physical flux units. The sources referred to on the Morel-Magnetat catalogue are in the Johnson system. The more recent observations are in the ESO system. Koorneef (1983 a and b) who shows that this calibration makes a significant effect for spectral types near G, has discussed the differences between the various JHKLM systems. From the comparison of the various color indices, provided in this reference it appears that this effect may not be serious for the domain of Am stars. A difference of 1% is likely to lead to an error of 100K which is comparable to the accuracy of our method of estimates using the Rayleigh-Jeans tail of spectrum.

Table 1. Infra red Observations of Am Stars

HR	HD	IRAS	J	H	K	L	M	12µ Jy	25 µ Jy	Ref
395	8374	01208+3728						0.39	0.25L	
1139	23281	03411-1038	5.26	5.15	5.14	5.03	5.14	0.38	0.25L	
1368	27628	04192+1357	5.12	5.02	5.15			0.43	0.27L	
					5.15*					
1376	27749	04210+1637	5.09	5.00	4.98			0.27L	0.32L	
1389	27962	04228+1748	4.15		4.12			0.94	0.29L	
					4.30*					
1403	28226	04250+2130			5.23*			0.39	0.37	
1428	28546	04277+1534	5.02	4.95	4.95			0.47	0.31L	
1458	29140	04328+1003						1.22	0.42L	
1483	29573	04365-1213						0.54	0.25L	
1519	30210	04432+1136			5.15*			0.46	0.30L	
1672	33254	05065+0946	5.09	4.99	4.94	4.91	4.88	0.42	0.42L	
					5.07*					
2143	41357	06031+3829			4.90*			0.49	0.39L	
2291	44691	06222+5618			5.32*			0.41	0.38L	
3572	76756	08557+1203			3.97*			1.1	0.30L	
5531	130841	14481+1550	2.484	2.412	2.397	2.376		4.61	1.17	1
			2.52	2.45	2.41-44	2.35				
			2.499	2.448	2.411	2.393	2.419			2
5892	141795	15483+0437					1.76	0.59		
6129	148367	16250-0815					0.93	0.39L		
7056	173648	18430+3733			3.90	3.84	3.86	1.04	0.33L	
7431	184552	19332-2445					0.68	0.34		
7653	189849	19590+2736					0.66	0.22L		
7928	197461	20411+1453					1.36	0.42L		
8278	206088	21373-1653	3.203	3.059	3.043	3.032		2.65	0.67	1
			3.245	3.148	3.007	3.037				2
			3.22	3.15	3.06	3.03	3.04			3
			3.16-20	3.09	3.02-.06	2.8				
					3.097*					
8322	207098	21442-1621	2.34		2.14			6.24	1.50L	
8708	216608	22514+4429						0.41	0.25L	

Notes to Table 1:
Most of the observations are from Gezari et al, 1987
Observations at Gurushikhar 1.2m telescope are indicated by asterisk
Other sources are indicated as references :
1. Center, 1990
2. Bouchet et al., 1991
3. Groote and Kaufmann, 1983

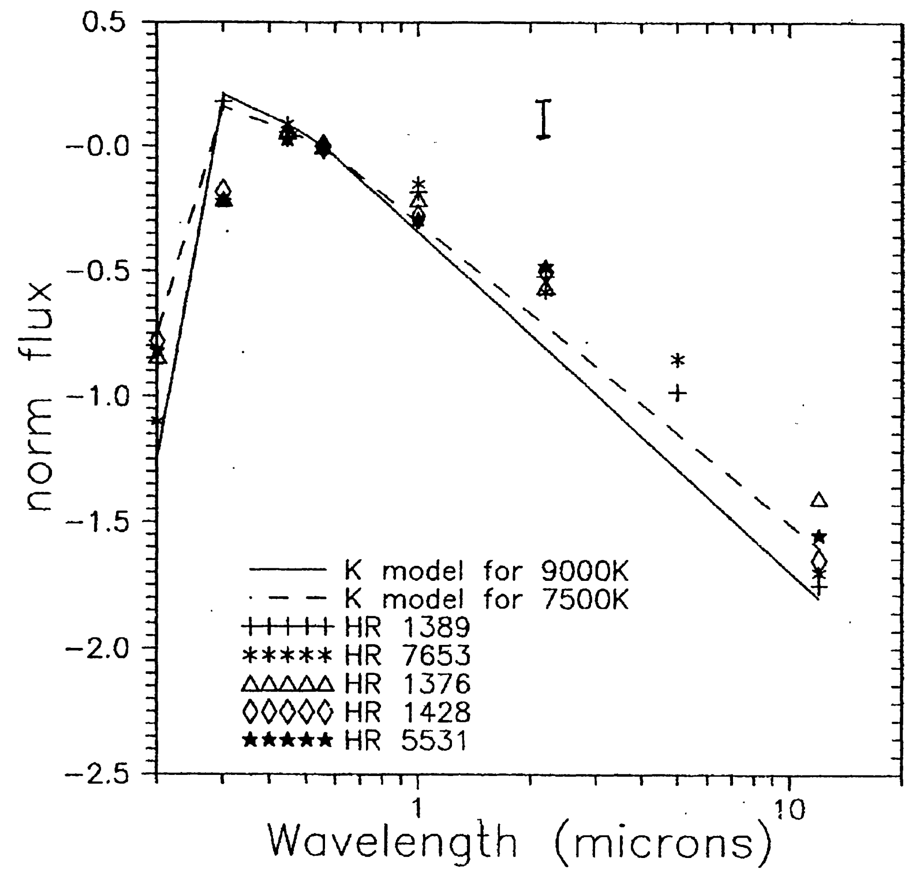

Figure 1. Energy distribution of some Am stars from optical to IR. The lines correspond to Kurucz models at the respective effective temperatures.

Figure 1 indicates the flux distribution from optical to 12 μ for some of the program stars, along with the model predictions. The models of Kurucz (1979) have been used for these estimates of T_{eff}. The method of least squares was used to compare with the models in steps of 100K of T_{eff} in the wavelength range 500-780 nm along with the near IR data, whenever they were available.

It is generally seen that almost in all cases, although the model agrees fairly well up to about the near IR, (there is a definite deviation beyond this). Therefore, this technique has been effectively used for the determination of the effective temperatures. Figure 2 gives the energy distribution of another set of program stars. Comparing Figures 1 and 2, the deviation from the models is striking. Most of the program stars show this kind of trend. Based on such a diagram, one is tempted to conclude that generally all the Am stars have IR excesses. It may be mentioned here that in other classes of CP stars, the possibilities of such excesses have been disputed (Kroll et al., 1987).

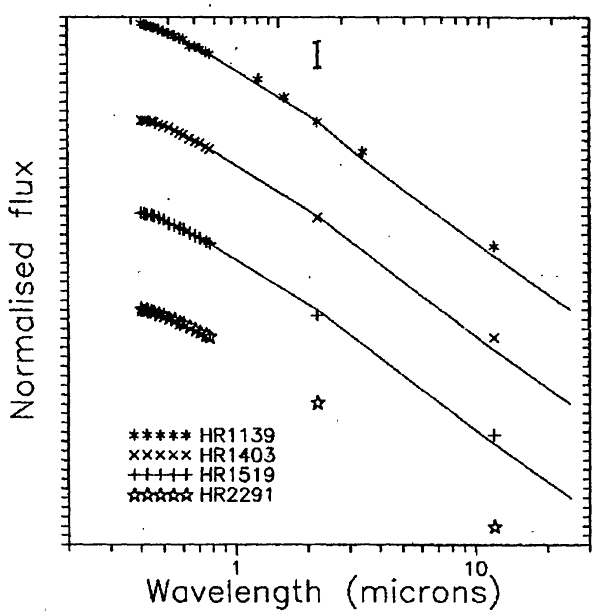

Figure 2. Energy distribution of some Am stars from optical to IR. The lines correspond to Kurucz models at the respective effective temperatures.

To avoid a direct deduction that all Am stars have IR excesses, an alternative choice may be to revise the effective temperature itself. This has been attempted in specimen cases of HR8278 and HR 8322. Figure 3 depicts the observations with the models for 8500K and 7500K. The lower value of T_{eff} seems to be in good agreement for HR 8322. However, the IR flux at 2.2 micron and 12 micron appear to be in excess. Another star HR1458 with similar T_{eff} (7800K) is included. The UV observations are available from Jamar et al. (1976) and are included in the figure. We may note that, although a lower effective temperature of 7500 K

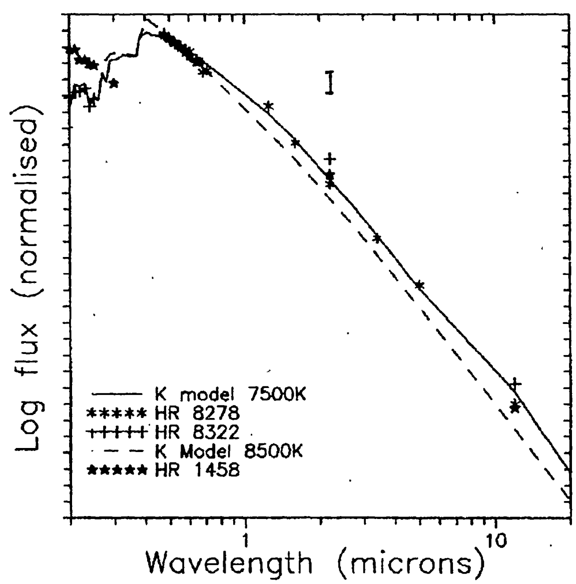

Figure 3. Normalised energy distribution for HR8322 and HR8278 from UV to IR. The lines correspond to Kurucz models at the respective effective temperatures.

agrees well in the IR for HR1458, the fit is not very impressive in UV. This type of ambiguity of results based on the UV and optical data has already been discussed in other cases (Lane and Lester, 1984). It is very clear from the figure that the observations of the stars in the IR are not very different and the difference in the T_{eff} would not have been noticeable but for the inclusion of the UV data.

The contribution from interstellar reddening has to be considered before considering other sources of reddening. This has been done in the following way. All the program stars have been catalogued by Hipparcos, thus the parallaxes are fairly well determined. The least value of parallax as seen from the compilation is 0.005 arcsec. The distances thus are less than 200pc. The following procedure was adapted to ensure that the interstellar reddening may not be operative at this distance. The colour excess $E_{(B-V)}$ was calculated for all the stars; it was found to have a range of 0.01 to 0.2 magnitudes. The extinction for V magnitude A_v was calculated as

$$A_v = R \times E_{(B-V)}$$

The extinction at the IR wavelengths for example, J, was calculated following the inverse wavelength variation. This works out to be having a range of .02 to 0.10 magnitudes. Only HR 5531 has a maximum value of 0.25 magnitudes. Thus at the IR wavelengths the effect of interestellar reddening may be neglected for most of the stars.

The other main source namely, the line blanketing may now be considered. In the continuum for $\lambda < 500$nm the (B–V) values of Am stars appear redder than their normal counterparts (Wolff, 1971; Wiertz and van Greden, 1983, Babu and Shylaja, 1982). This aspect helps us to think of the mechanism of flux redistribution itself as a suitable explanation.

From Figure 3, we may infer that the suppressed flux in the UV probably reappears at the IR wavelengths. This aspect can be verified with more number of stars. Jamar et al. (1976) provide the UV fluxes for six more stars of our list and the UV flux redistribution becomes evident in all the cases.

Thus it appears that

1. the phenomenon of flux redistribution is common amongst all the Am stars.
2. the redistributed flux makes its presence conspicuously felt from the near IR region onwards.

This discussion strongly suggests that the total flux from UV to IR should be considered for the determination of the T_{eff}. From a limited data in the near IR region it is not possible to quantitatively estimate the amount of redistributed flux. As has been pointed out by Lane and Lester (1980), many Am stars tend to show variation in the continuum itself over large time scales. It would be worth monitoring the IR variability of Am stars because, the flux redistribution appears to commence in the near IR itself. Recently, it has been found that the variability in IR follows that in optical. (Catalano et al., 1998)

There is yet another factor that contributes to the uncertainties in the near IR. Various investigators (Koorneef, 1983; Hayes, 1985; Glushneva, 1985) have pointed out the deficiency in the absolute calibration in the near IR. The models of Kurucz are also sparsely placed in this region so that a comparison as good as that in the optical or UV is not possible.

The reality of the excess at the 12 μ may be judged by comparing with the normal stars. Because of the ambiguity in the determination of the T_{eff}, it may be worth comparing the various color indices. As discussed above the interstellar reddening effect appears to be having little or no effect in the near IR regions and beyond. Therefore (R-I) was chosen for comparison, as it appears to be free of any blanketing effect (Shylaja & Babu, 1992) also, as far as comparison with normal stars are considered.

As can be seen from the Figures 1, 2 and 3, generally the 12 μ fluxes always tend to indicate some excess. It is known that early type stars show IR excess (Shylaja, 1994). Waters et al. (1986) have shown that the models predict systematically lower fluxes (up to about 12%) for normal stars as well. Considering this point, the excess at 12 μ as observed in all figures has to be reviewed. They appear to be realistic only in some cases. A better comparison is possible with the color index (R-I), which is shown in the Figure 4.

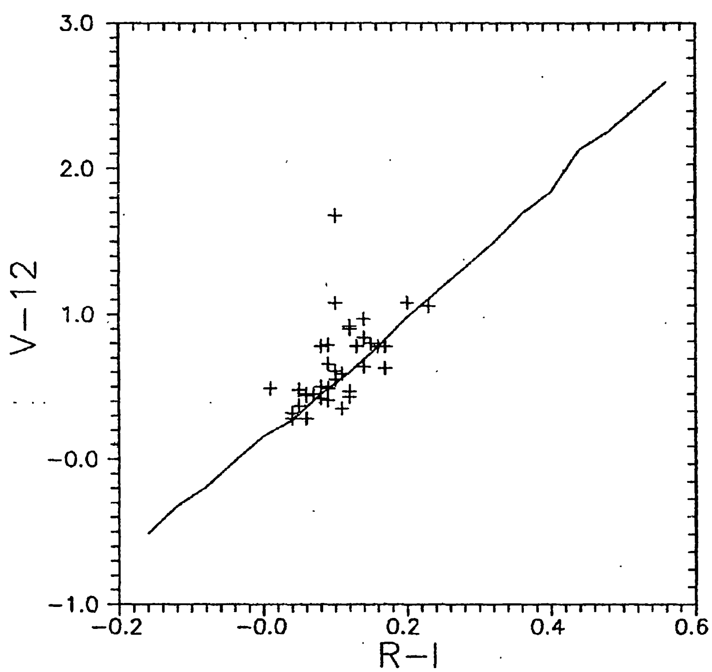

Figure 4. The variation of the (R-I) index of Am star as compared to the relation (line) of normal stars from Waters et al. (1987). Notice that the Am stars with large excess can be easily identified.

Extending the argument of interstellar reddening of the previous section, we can calculate the extinction in all the bands namely, R, I and [12μ]. This shows that the correction in the (R-I) index is about 0.04 magnitudes, while the same for the (V − 12μ) ranges from 0.04 to 0.15. These corrections have been applied to the Am stars as well as normal stars. The relation for normal stars (provided by Waters et al, 1984) is drawn as a line. The figure includes more stars than those in Table 1. This was a result of the availability of the counterparts in the IRAS PSC for the stars in the source list of Nicolet (1983) as well as the (R-I) indices (from the BS catalogue, Hoffleit & Jaschek, 1982). As can be seen the distribution of Am stars is generally scattered around the normal stars relation (from Waters et al., 1986). The exceptions have conspicuously larger excess and are listed in Table2.

Table 2. Stars with possible IR excess

Star#	R-I	V-12μ
395	0.12	0.8
1139	0.12	0.88
1368	0.17	1.13
1403	0.14	1.11
1458	0.05	0.58
1483	0.05	0.58
1519	0.08	0.86
2291	0.1	1.08
5892	0.01	0.51
6129	0.09	0.76
6486	0.12	1
6553	0.2	1.19
8708	0.14	0.93

It is also interesting to see that for some of these stars, the PSC indicates flags, which do not correspond to point objects. This may be explained by weak circumstellar dust emission. This emission cannot be ruled out completely, since it is possible to sustain grains at temperatures of 200 – 300 K at distances more than 1 – 1.5 AU (depending on the type of grains, like silicates or graphites) as shown by Leikners & Havnes (1984). For establishing this type of cooler circumstellar dust shells, more reliable measurements in the far IR are necessary.

The other possible contributor for the 25 & 60 μ fluxes is the free-free emission from the stellar wind. Havnes & Goertz, (1984) have studied the free-free emission from a plasma cloud surrounding a magnetic star and indicate that for lower plasma densities and temperatures (as in case of Am stars), the near IR excess may not be observable. Assuming T_{eff} of 8000K, R_* as 10 $R_\odot$ and a massloss rate of 10^{-8} $M_\odot$/year, terminal velocity of about 300 kms/s for the wind, we can calculate the excess in flux in IR (following Shylaja, 1994). However, this exercise shows that the excess in flux is not greater than the scatter observed in Figure 4. Extending this to the region beyond 25 μ the excess works out to be about 0.05 magnitude.

Although the discussion provides a general picture of the Am stars, it is very difficult to extend the arguments of one star to another. It appears as though each star needs to be treated with a separate model.

4. Conclusions

The energy distributions of 24 Am stars are studied from the available UV to IR data. The flux redistribution appears to be a common phenomenon in all the stars of this class. The mid IR fluxes measured from IRAS show excesses only in some cases. The various contributors for the IR excess, namely, interstellar, line blanketing, free-free emission from the wind and circumstellar dust, are considered and it appears that a general deduction for the Am stars as a class may not be possible. The (R-I) index appears to be an indicator of the IR excess. Each star may have to be modeled separately keeping in mind the chemical peculiarity to explain the observed disparity in the IR and mid IR regions.

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