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Spectroscopic observations of first ISOGAL sources

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Abstract. Infrared Space Observatory Galactic (ISOGAL) survey at 7 and 15 μm of ~ 22 deg^2 of the inner galactic disk and bulge, has detected several hundred thousand sources. Combining ISOGAL survey with I, J, H, K_s data of DENIS (Deep Near Infrared Survey of the Southern Sky) and 2MASS (The Two Micron All Sky Survey), has provided a completely new insight of infrared galactic stars. We have proposed a limited preliminary program of low resolution spectroscopy with the 2.3-meter telescope of VBO (Vainu Bappu Observatory, Kavalur, India) on ISOGAL sources, with the double purpose : i) confirm or help to establish the criteria of identification from ISOGAL+DENIS/2MASS data of a few classes of important sources (subclasses of dusty AGB stars, dusty young stars, extreme red giants, supergiants, etc). ii) observe a number of stars which look peculiar. In this paper, we present the spectra of a few sources observed in 6 ISOGAL fields.

Key Words : stars : red giants and AGB–Galaxy : center – infrared : stars

1. Introduction

ISOGAL is a survey at 7 and 15 μm with Infrared Space Observatory Camera (ISOCAM) of ~ 22 deg^2 of the inner galactic disk and bulge. Combined with the near infrared (K_s,J,H,I) data of the DENIS and 2MASS survey, it is mainly aimed at the study of the cold stellar populations of the most obscured regions of the inner Galaxy and the corresponding galactic structures. The main classes of detected stars are cold red giants, dusty AGB stars and dusty young stars of intermediate mass, detectable up to the galactic center. However, ISOGAL is also detecting a variety of other stars including supergiants, planetary nebulae, symbiotic stars, high and low mass young stars and various other foreground stars.

The scientific results of the analysis of the first ISOGAL field are detailed in Pérault et al. (1996). The analysis of a small field in the inner bulge ($l = 0^o$, $b = +1^o$) (Omont et al. 1999) confirms the importance of combining 7 and 15 μm data. It shows the remarkable capability of ISOGAL to detect and characterize mass-losing AGB and RGB tip stars. Glass et al. (1999) analysed the ISOGAL fields near Baade's Windows of low obscuration towards the inner parts of the bulge. Most of the detected objects towards Baade's Windows are late-type M stars, with a cut-off for those earlier than about M3-M4. The ISOGAL results are also summarized in Omont et al. (2000) and Ojha et al. (2000).

These analyses have also proved that the combination of ISOGAL and DENIS/2MASS data is quite powerful to identify the nature of the ISOGAL sources even in regions of high extinction (A_V up to 20-30). For the ISOGAL + DENIS/2MASS detected sources, the various color-color and color-magnitude diagrams available with the 5 bands provide a rich information on the extinction, the distance, the intrinsic colors and the absolute magnitude. There is thus little uncertainty about the nature of most sources, mainly M6-M9 red giants at several kpc including a large proportion of dusty AGB stars. However, it is clear that it is not always easy to disentangle the effect of these different parameters, especially for peculiar sources, and complementary spectroscopic information can be quite important. Therefore we have proposed a limited preliminary program of low resolution spectroscopy with the 2.3m telescope of VBO with a double purpose :

i) Confirm or help to establish the criteria of identification from ISOGAL + DENIS/2MASS data a few classes of important sources (subclasses of dusty AGB stars, dusty young stars, supergiants, planetary nebulae, etc);

ii) Observe a number of stars which look peculiar in order to start and prepare a general program on really peculiar, and even weird, ISOGAL sources with the hope to identify interesting and possibly exceptional objects in the ISOGAL data bank.

2. Observation

We have selected the sources from 6 ISOGAL fields already analysed. The spectra have been obtained with OMR spectrograph - short camera attached to the 2.3-meter telescope at VBO during the period of March - May, 1998-99 and October - December, 1998. The detector is Tektronix 1K CCD with 24 μm pixels. The objects were observed with 300 lines/mm grating, which gives a resolution of 5 Å pixel at 5000 Å. Two wavelength comparison sources (Fe-Ne and Fe-Ar Hollow Cathode sources) are also taken during the observing nights.

Since most of the observed stars are surrounded by a thick dust shell, their optical counterparts are in most cases very faint in blue and spectroscopic measurement can be done only in the red (~ 5500 - 8500 Å). Only stars with I mag brighter than ~ 11 can be measured. The total exposure time was 30 min per source for I~11. Low resolution spectra of 16 stars from 6 ISOGAL fields are presented in Figure la,b.

3. Data reduction

The CCD data has been bias-subtracted and flat-fielded using the IRAF-CCDPROC task. The wavelength and flux calibration has also been done using IRAF-specred task. The continuum normalisation is done using a cubic spline of order 3. The spectral classification is done by comparing the normalised spectra with the Jacoby standards which is slightly better than our resolution. Table 1 shows the final spectral types of ISOGAL sources derived from VBO optical spectra. Because of low resolution, the spectral types can be uncertain by about 1 or 2 sub types. The luminosity classes are also given in the table.

4. Optical spectra of ISOGAL sources

The prominent lines seen in our optical spectra (Figures 1a & b) of ISOGAL sources are : 5698Å (FeI), 5780Å (FeI) 5889Å & 5896Å (NaI D lines), 6267Å (TiO), 6493Å (CaI) and 6563Å (Hα). Below 5000Å the flux is very low as most of the sources are of later spectral types and they may be reddened by the interstellar and circumstellar reddening.

There are strong lines of TiO seen in the stars classified as M type. TiO bands are seen in the spectra of our ISOGAL sources, which we find to be the M type. The wavelengths of TiO bands seen in the spectra of these stars are : 5003Å, 5240Å, 5497Å, 5862Å, 6159Å, 6715Å, 7126Å and 7589Å.

Most of the other lines which are seen in the spectra of ISOGAL sources beyond 6700Å are telluric lines which we have not removed. The stellar lines beyond 6700Å are blended with

Table 1. Final spectral types derived from the Kavalur observatory spectra of ISOGAL sources. The resolution is 5 Å/pixel. Because of low resolution, the spectral types can be uncertain by about 1 or 2 sub types. The luminosity classes are also given. In some cases, we designate the luminosity class as III-II, II-I and V-IV

Id	ra (2000)	dec (2000)	K_s	J-K_s	[15]	[7]-[15]	Sp. Type
Field l = 45°; b = 0°							
ISO 429	14:31:00.93	-60:18:09.6	8.72	0.88	8.98	0.09	K3 III-II
ISO 438	14:31:09.07	-60:16:09.3	7.90	0.79	8.41	-0.04	K2 III-IV
ISO 337	14:31:41.33	-60:15:55.5	8.93	0.71	7.76	0.23	K2 III
ISO 260	14:31:55.70	-60:32:39.2	8.00	0.90	8.15	0.17	K2 I
ISO 224	14:32:17.97	-60:28:42.0	9.61	0.22	-	-	A1V
ISO 218	14:32:20.27	-60:29:16.8	8.04	0.87	8.25	0.08	K2 I-II
ISO 158	14:32:32.02	-60:31:05.5	9.11	0.78	-	-	K2 III
ISO 154	14:32:32.60	-60:29:50.7	8.00	1.30	8.07	0.01	K5 I
Field l = 0°; b = + 1°							
ISO 19	17:41:30.53	-28:32:25.9	6.15	0.93	6.60	0.14	M2 I
ISO 80	17:41:51.59	-28:24:54.6	5.83	-	4.71	-0.09	K5 III
Field l = -0.3; b = -2.2°							
ISO 129c	17:54:53.00	-29:45:35.0	6.21	-	3.95	0.08	M6 III-II
Field l = +97.5°; b = +0.0°							
src094	21:45:40.57	+53:32:46.9	-	-	8.48	0.02	K2 I
src469	21:46:27.26	+53:36:01.4	-	-	5.20	-0.15	K4 III
src572	21:46:35.96	+53:38:54.9	-	-	7.31	0.16	K2 III
src613	21:46:39.97	+53:18:01.1	-	-	7.99	0.02	K4 III
src1022	21:47:27.05	+53:23:07.9	-	-	6.55	-0.13	K3 III
src 1078	21:47:37.74	+53:25:07.8	-	-	7.69	0.08	K0 III-II
Field l = +105.0°; b = +0.0°							
src033	22:28:40.53	+57:56:24.1	-	-	7.86	0.25	K7 III
src 188	22:29:11.56	+57.53:40.3	-	-	5.73	-0.07	K2 III
Field l = +135.9°; b = -0.6°							
src020	02:35:51.37	+59:39:58.8	-	-	7.78	0.52	K7 III
src284	02:36:55.15	+59:33:11.0	-	-	6.65	0.03	K4 III

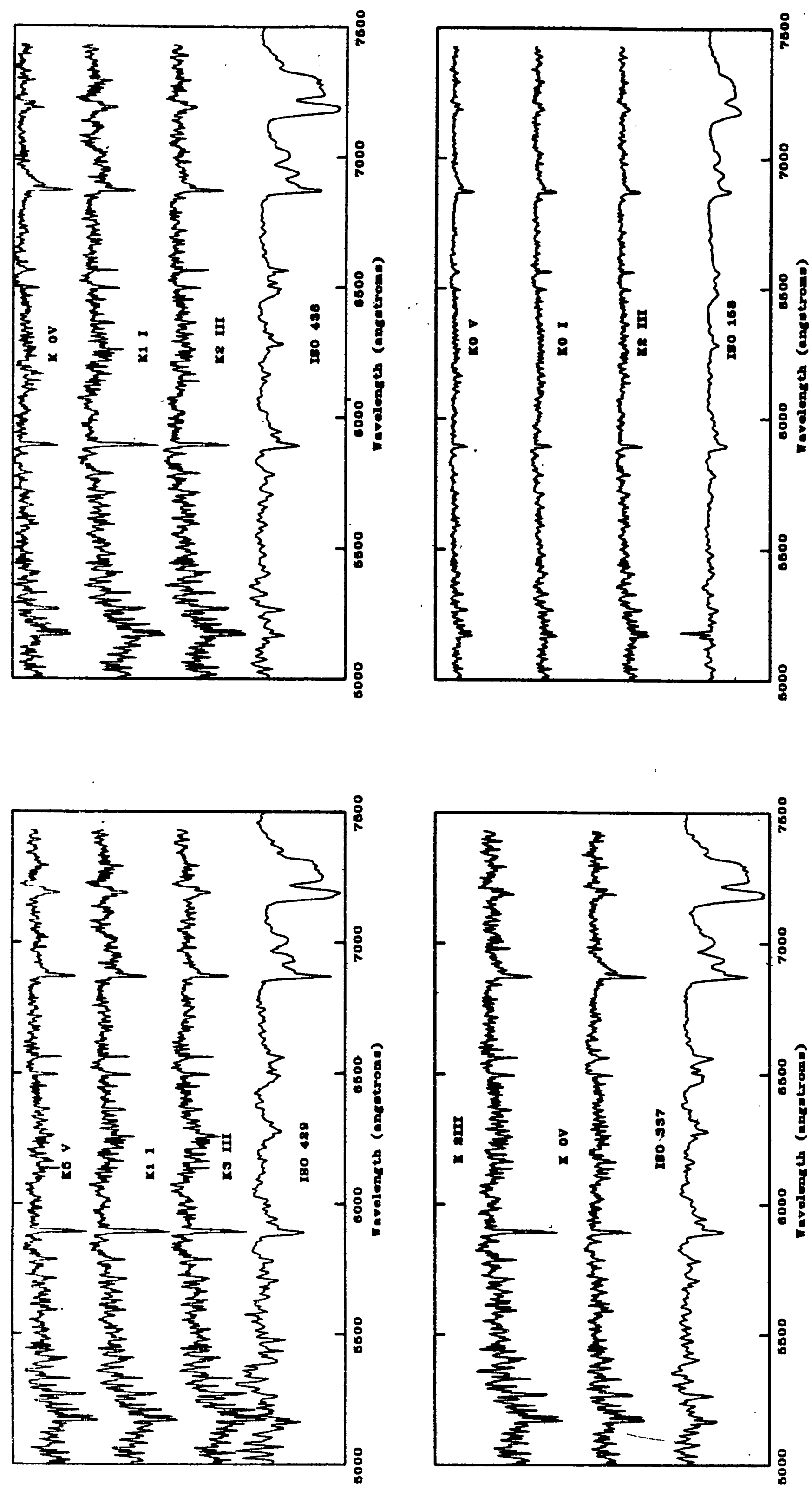

Figure 1a. VBO spectra of ISOGAL sources. Each figure contains the spectrum of the programme star at the bottom and above that the spectra of standard stars of similar spectral type are plotted.

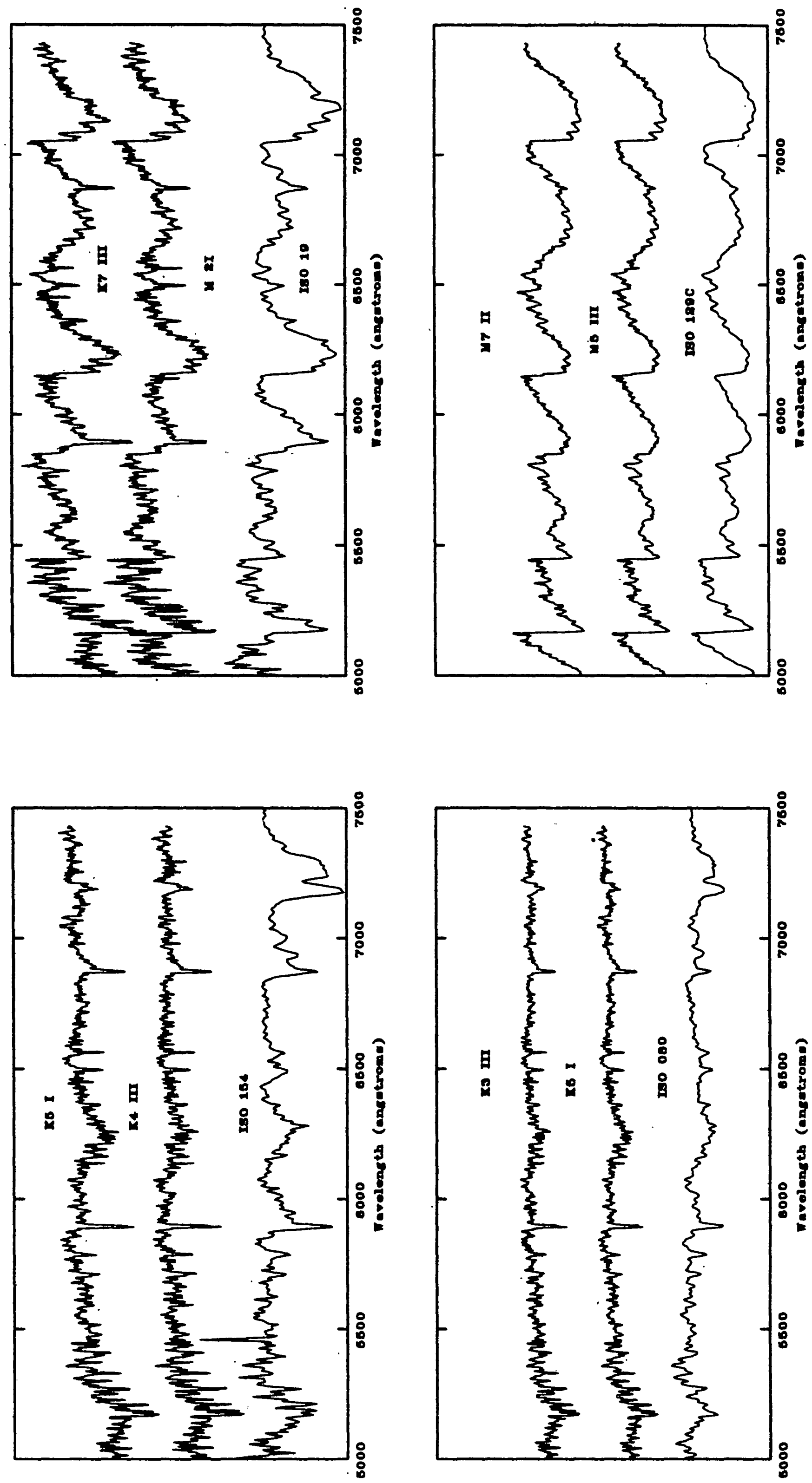

Figure 1a. Continued.

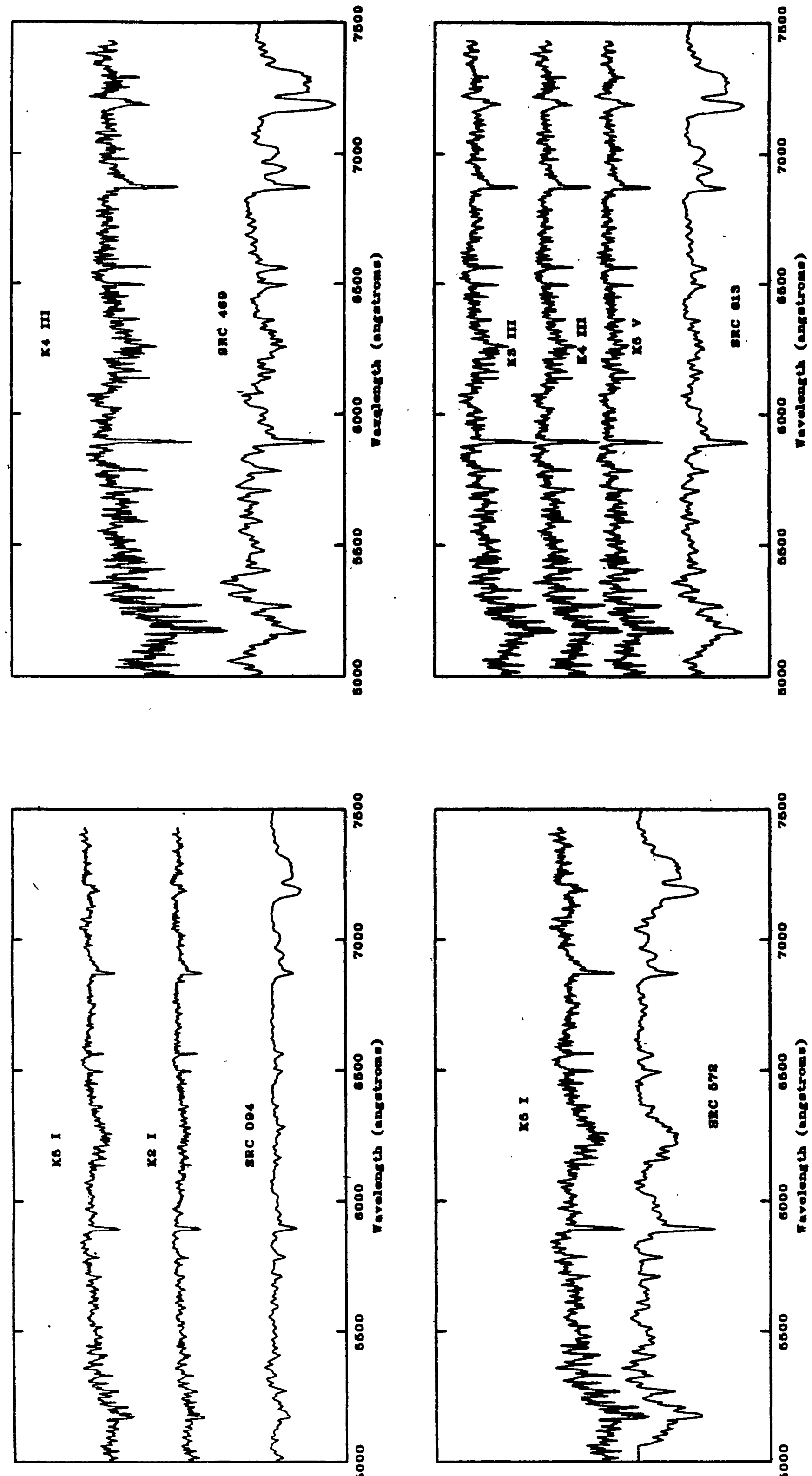

Figure 1b. VBO spectra of ISOGAL sources. Each figure contains the spectrum of the programme star at the bottom and above that the spectra of standard stars of similar spectral type are plotted.

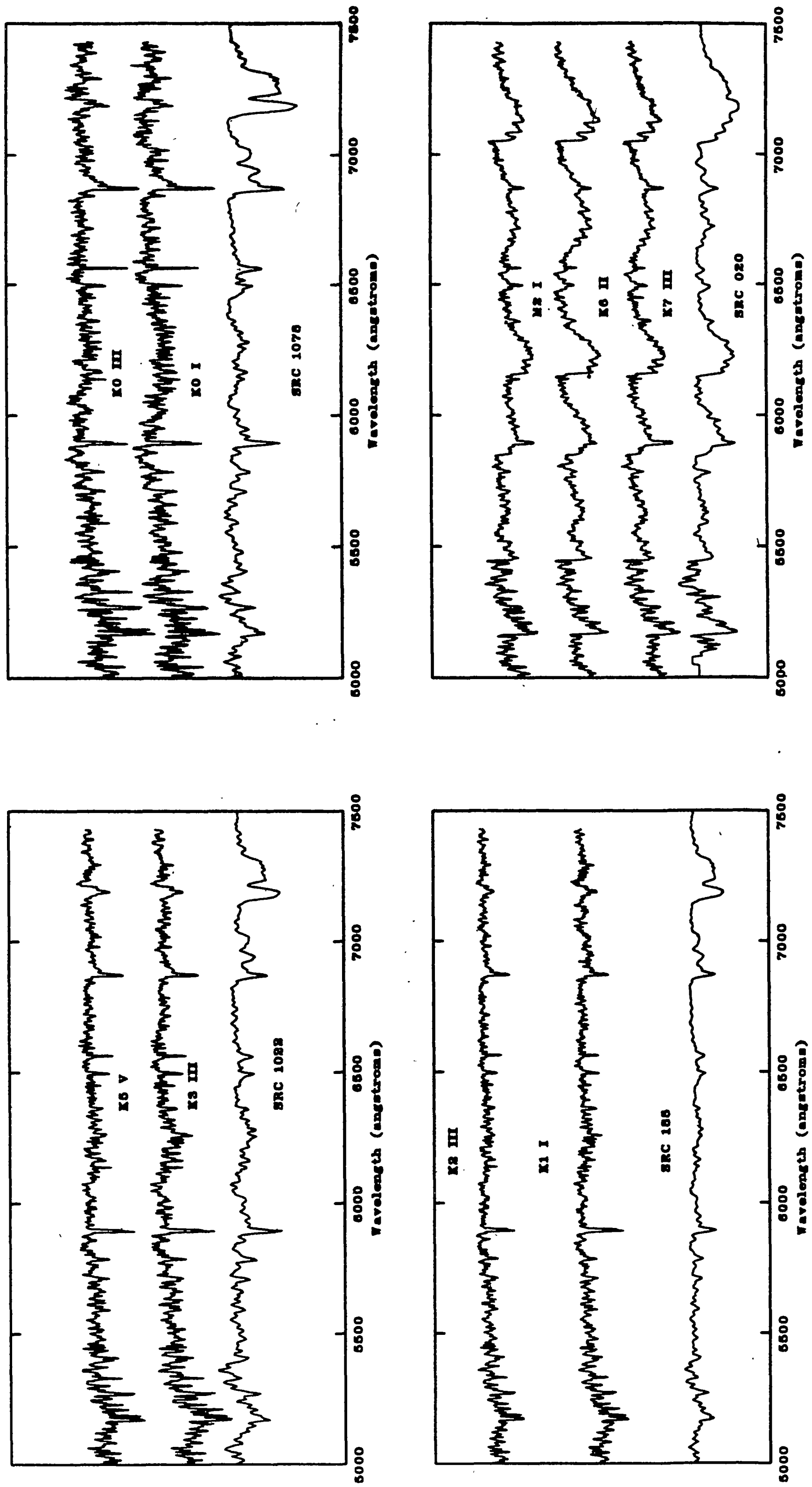

Figure 1b. Continued.

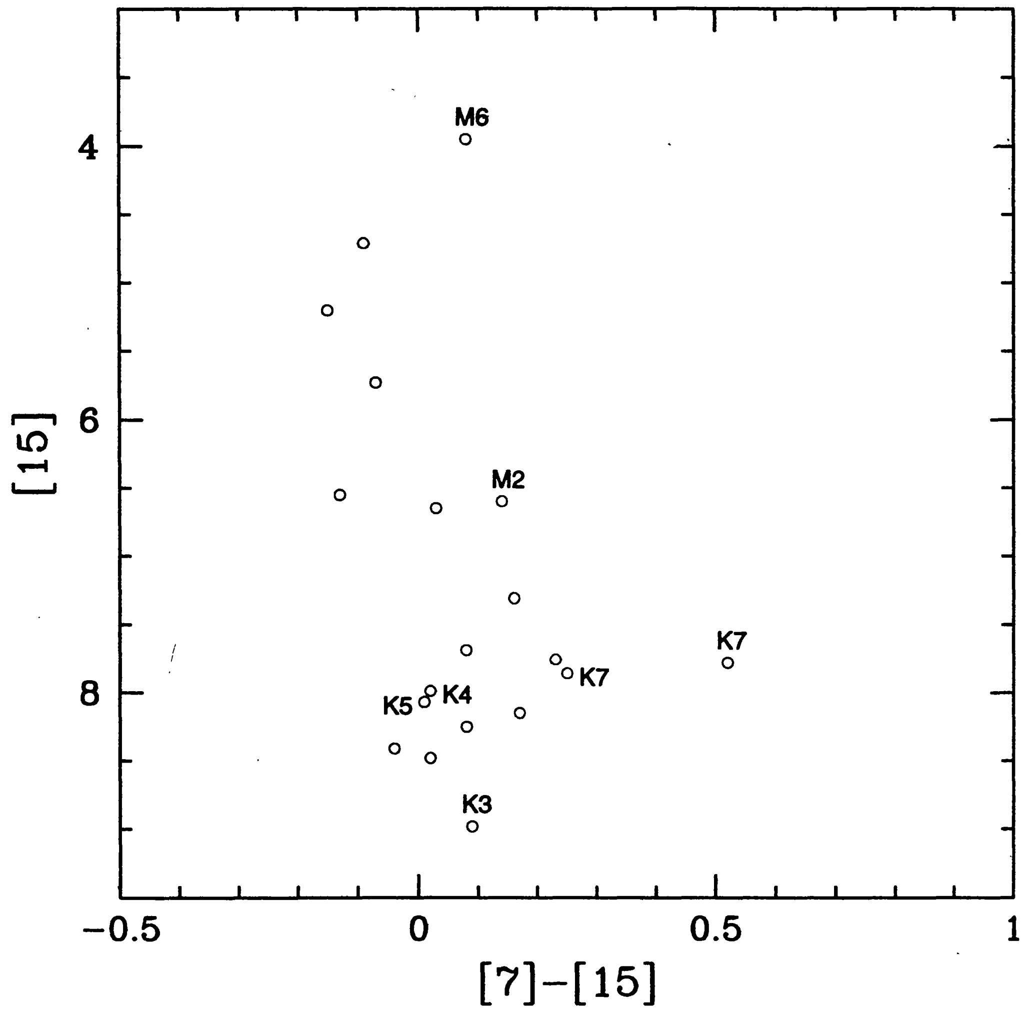

Figure 2. [15] vs [7]-[15] diagram of the ISO sources from 6 ISOGAL fields.

the telluric lines. Since our spectra are of very low resolution, we are not able to detect and resolve the spectral features due to circumstellar dust and gas.

5. Stellar sources

Figure 2 shows the color-magnitude [7]-[15]/[15] diagram of ISOGAL sources in 6 fields in the galactic disk and bulge. This provides a straightforward view of the nature and the amount of dusty sources of various classes. The sources at the beginning of the sequence, with small 15 μm excess, have the luminosity expected for red giants at the tip of the red giant branch (RGB). They are weak mass-loss AGB stars ($M_{gas} \sim 10^{-9} - 10^{-7}\ M_{\odot}$/yr). A few foreground stars (brighter in 15 μm wth [7]-[15] ≤ 0), are also visible in the diagram, left of and above the low mass-loss AGB sequence. The observed spectra of the red giant stars above the RGB tip detected with ISO, show a sequence of increasing 15 μm dust emission which commences with K giants of late sub-type. The results also show that there is a continuous sequence of increasingly mass-losing objects from the earlier-K-type giants to the late-M-type giants.

6. Conclusion

We have presented the spectra of a few ISOGAL sources obtained with OMR spectrograph attached to the 2.3 meter telescope of VBO. With the help of the spectral classification of the ISOGAL sources, the nature of the ISOGAL sources is discussed. The spectra of the sources confirm that most of the ISOGAL sources observed so far from VBO are K and M giants. The near- and mid-infrared colors of these sources suggest that these are mass-losing stars.

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