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Mass loss of Mira stars associated with a star formation field in the M16 and M17 region

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Abstract. We examine the possibility to obtain a reasonable limit for the stellar mass in a sample of Mira stars located in a star forming region, associated with the nebulosities M16 and M17. We use a set of historic photographic plates in I filter ($0.68 \div 0.88 \mu m$), together with more recent data from the IRAS (12, 25, $60 \mu m$ fluxes) and 2MASS (JHK magnitudes) missions. We estimate, through modeling a spherically symmetric circumstellar envelope with constant outflow, the $10 \mu m$ opacity, and this allows us to compute the mass loss rate in dust. By taking into account all photometric bands, as well as the spatial position of each star with respect to the nebula, we are able to compute the mass loss in gas and therefore the gas to dust ratio. The estimated value and analytic model suggest the presence of silicates in the dust, although uncertainties remain on the grain dimensions, which would decrease the ratio. The value for the ratio we estimate is typical of intermediate-mass stars ($2.5 \div 5\ M_{\odot}$). The stars in the sample are all O-rich, with light periods longer than 250-300 days, and this again agrees with their status of intermediate mass stars.

Key words. Mira Stars – mass loss – M16 and M17 region

1. Introduction

Our stars are LPVs located in a star forming region, associated with the nebulosities M16 and M17. The historic data (I filter) are correlated with the JHK and IRAS photometry, through the mean value $\overline{I}$ of the light curve (the $100 \mu m$ IRAS fluxes were not considered because of IR cyrrus contamination). Our sample includes 12 stars, which are subdivided, according to their spatial location, in three groups: A, B, and C.

2. Reddening

The region appears to be rich in dust, therefore the observational data are affect by extinction and reddening. In order to have an estimate of intrinsic magnitudes, we made use of a mean reddening. This

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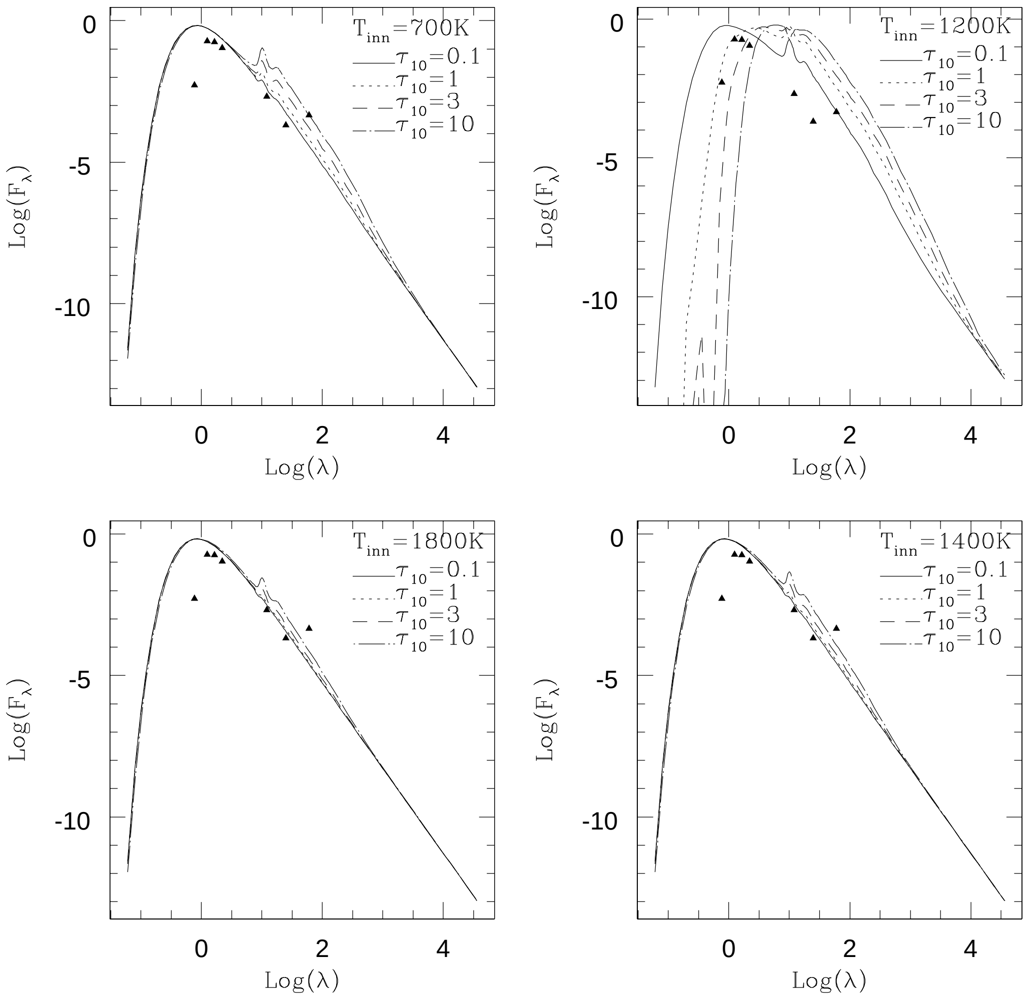

Fig. 1. V401 Sct flux compared with fits of DUSTY. T_{inn} is the temperature on the shell inner boundary.

procedure is of course not very accurate for any individual star, but it gives a reasonable first approximation for the physical parameters of the sample. From Chini & Krügel (1983) and Chini & Wargau (1990) we have R_{M16}=R=(A_V/E_{B-V})=4.8, and A_V=3.3 (extinction in front of M17); we can therefore deduce (for λ=I, J, H, K)

$$A_\lambda = \frac{A_V \cdot (R - \frac{E_{V-\lambda}}{E_{B-V}})}{R}$$

We obtain A_I=1.67, A_J=0.99, A_H= 0.65, A_K= 0.46.
The reddening is negligible for the 12, 25, 60μm band.

3. Physical parameters and models

Observational data are listed in table 1; the reddened IJHK magnitudes and I-K color, estimated by subtraction for each source the relevant A_λ, appear in table 2.
In order to interprete the physical charac-

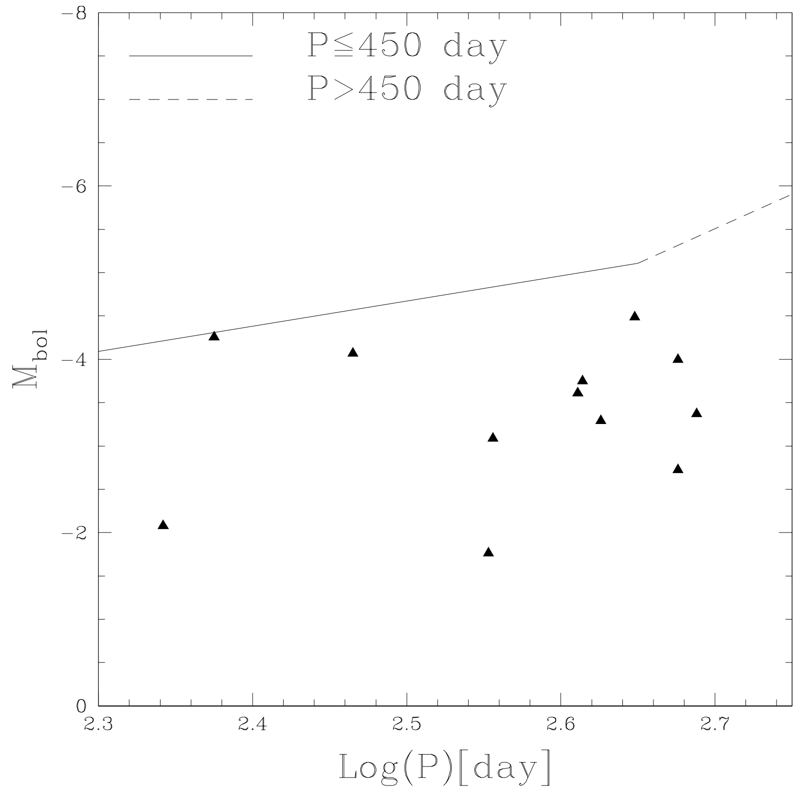

Fig. 2. M_{bol} vs Log(P) compared with fit to Hughes & Wood (1990)

teristics of our stars, we compared their I-K color with the models of Bessel et al. (1991) (our data cannot be compare with those of LMC variables because of the different metallicity).

Our stars in group A have all similar color, namely I-K≈7, to be compared with $5.2 < I - K < 5.7$ for Mira stars with $T_{eff} 2500 \div 2800$K and $2.5 \leq M/M_{\odot} \leq 5$, and solar metallicity, in the Bessel models; the stars in group A might therefore be typical Miras with the above mentioned parameters if they are affected by the same foreground extinction giving an additional color excess $\approx 1.5 \div 2$ in I-K.

The I-K colors of stars in groups B and C are appreciably different from each other, and this could be perhaps due to the presence of different mechanism of mass loss, and also to non-uniform extinction by foreground dust.

We notice that almost all stars (10 in 12) in our sample present a conspicuous excess at $60 \mu m$, which, according to Willson (2001), *"....is most readily interpreted as the result of the cessation or substantial reduction in the rate of mass loss, so that the expanding shell cools."*

These caracteristics cannot be accounted in detail by our analytic model (DUSTY code), which does not describe foreground dust.

Table 1. Observational data

Region	GCVS	$\bar{I}[mag]$	J[mag]	H[mag]	K[mag]	12[Jy]	25[Jy]	60[Jy]	P[day]
A	V401 SCT	13.6	7.55	6.22	5.42	3.9	1.68	21.4	474
A	V418 SCT	14.15	7.79	6.47	5.64	1.98	0.79	13.2	411
A	V412 SCT	14.25	8.09	6.61	5.77	1.9	1.04	18.1	408
B	GP SER	14.75	7.65	6.30	5.25	1.14	0.37	2.1	292
B	GR SER	11.75	6.88	5.82	5.21	1.41	0.61	3.55	237
B	GQ SER	15.5	8.59	7.03	5.98	2.86	1.66	1.36	488
B	FY SER	15.2	8.73	7.22	6.27	1.21	0.74	8.17	360
C	V405 SCT	15.25	9.79	8.64	7.91	1.51	1.9	18	357
C	V421 SCT	14.5	9.32	8.16	7.46	1.29	0.91	10.8	220
C	V424 SCT	12.75	9.48	7.87	6.77	4.74	3.55	5.2	474
C	V422 SCT	13.95	8.56	6.97	6.09	1.97	1.77	8.77	423
C	V425 SCT	14	7.08	5.66	4.89	2.83	1.35	8.23	445

Table 2. De-reddening data

Region	GCVS	$\bar{I}[mag]$	J[mag]	H[mag]	K[mag]	I-K[mag]
A	V401 SCT	11.92	6.56	5.58	4.96	6.96
A	V418 SCT	12.47	6.80	5.82	5.19	7.29
A	V412 SCT	12.57	7.11	5.96	5.32	7.26
B	GP SER	13.07	6.66	5.65	4.79	8.28
B	GR SER	10.07	5.89	5.17	4.76	5.32
B	GQ SER	13.82	7.61	6.38	5.52	8.30
B	FY SER	13.52	7.74	6.57	5.81	7.72
C	V405 SCT	13.57	8.80	7.99	7.45	6.12
C	V421 SCT	12.82	8.34	7.51	7.00	5.82
C	V424 SCT	11.07	8.49	7.23	6.31	4.76
C	V422 SCT	12.27	7.57	6.32	5.63	6.64
C	V425 SCT	12.32	6.09	5.01	4.44	7.89

4. Bolometric magnitudes and luminosities

We compare our data with the M_{bol} vs Log(P) plots of Hughes & Wood (1990): as can be seen in Fig. 2, the representative points fall below the fit, and this agrees with the idea that the sample is hightly reddened. The correspondent luminosities are, for the stars in group A and also for those in groups B and C (with a somewhat greater uncertainty) in the range $3 \leq Log(L/L_{\odot}) \leq 3.6$, which are representative values of intermediate mass.

In conclusion, we discovered the presence of a group of evolved stars of intermediate mass within a region of star formation.

5. Conclusions

In conclusion we found that the [8.8]-[12.5] color index, which can be obtained with simple photometric measurements, is related to the mass loss value only when one considers groups of sources which are homogeneous from an evolutionary point of view. The O-rich stars are further subdivided in two groups, which differ on the basis of both luminosity and wind velocity.

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