Visible and Infrared Study of L.P.V. with the 1 m Telescope

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Introduction

Long-period variables (L.P.V.) are evolved stellar objects whose luminosity varies with period ranging from ~ 100 to ~ 2,000 days. The central stars are giants or supergiants with relatively low effective temperature (from 1,500 to 4,000°K). Depending on the abundance ratio (C/O), they are classified as carbon-rich (C/O >1) or oxygen-rich (C/O <1). Most of them

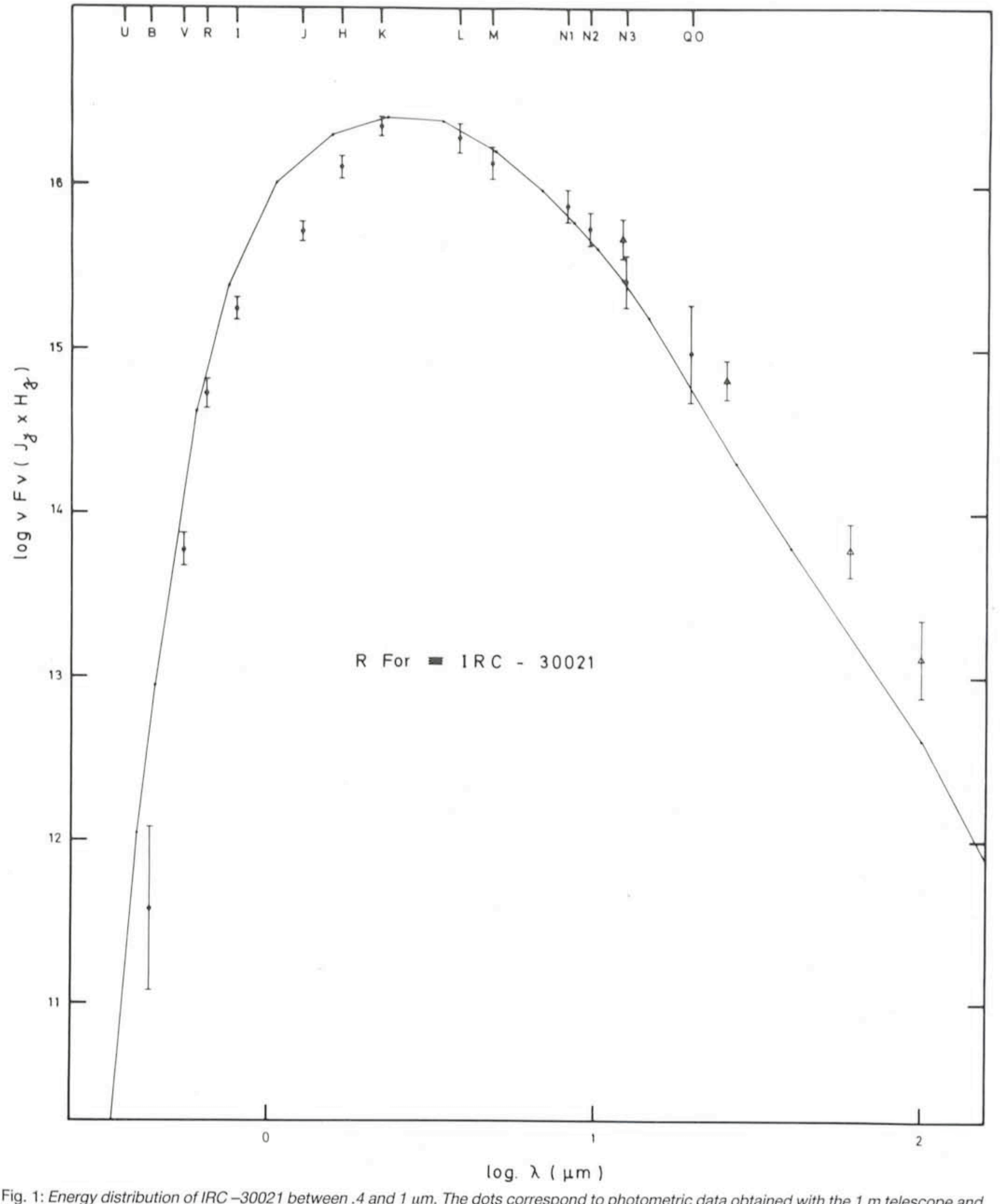

Fig. 1: *Energy distribution of IRC –30021 between .4 and 1 μm. The dots correspond to photometric data obtained with the 1 m telescope and the triangles to IRAS data. The solid curve represents a numerical adjustment using a model described in the text.*

are surrounded by a shell of gas and dust. When in the stellar atmosphere, carbon is more abundant than oxygen, all the oxygen is locked into carbon monoxyde (CO), and the most probable species to condense out of the gas are made of carbon; consequently, the dust in the circumstellar shell will be mainly silicon carbide and graphite (or amorphous carbon). But if the star is oxygen-rich, all the carbon will be bound into CO, and the dust in the shell will be made of silicate (Salpeter, 1974). This circumstellar dust absorbs the stellar flux, and re-emits it at longer wavelengths. The optical thickness of the shell may be very great, to the point that, in some cases, the star is completely hidden inside its envelope.

High spectral resolution in the visible has revealed that these shells are expanding (Deutsch, 1956). Part of this expansion may be due to radiation pressure on the grains: grains are expelled by the absorption of stellar light and drag with them the circumstellar gas. This shell expansion is the manifestation of a mass-loss phenomenon. The study of this phenomenon is of importance as it affects the evolution of the central star; also, through it, these objects may be a major source of matter for the interstellar medium. To tackle these questions and to get quantitative information, we have undertaken a photometric study of some L.P.V. We will illustrate this study with two objects that we are observing since October 1982, at La Silla, with the 1 m telescope.

R For:

This carbon star is a Mira of period ~ 400 days. When observed at the eyepiece, it presents a marvellous garnet colour due to the shape of its spectrum in the optical range (Fig. 1); the steepness in the blue is mainly due to absorption bands of C_2 and CN. Its infrared counterpart is a bright source discovered by Neugebauer and Leighton (1969) in their Two Micron Sky Survey (T.M.S.S.), where it is referred to as IRC –30021. Nevertheless, it has been little studied since that time.

We are obtaining (U,B,V,R,I) data using the 1 m ESO photometer equipped with the Quantacon, (J,H,K,L,M) data with the conventional 1 m infrared photometer and an InSb detector, and (M1, M2, M3 Q0) data with the same infrared photometer, but with a Ge-Ga bolometer. All our data presented in Fig. 1

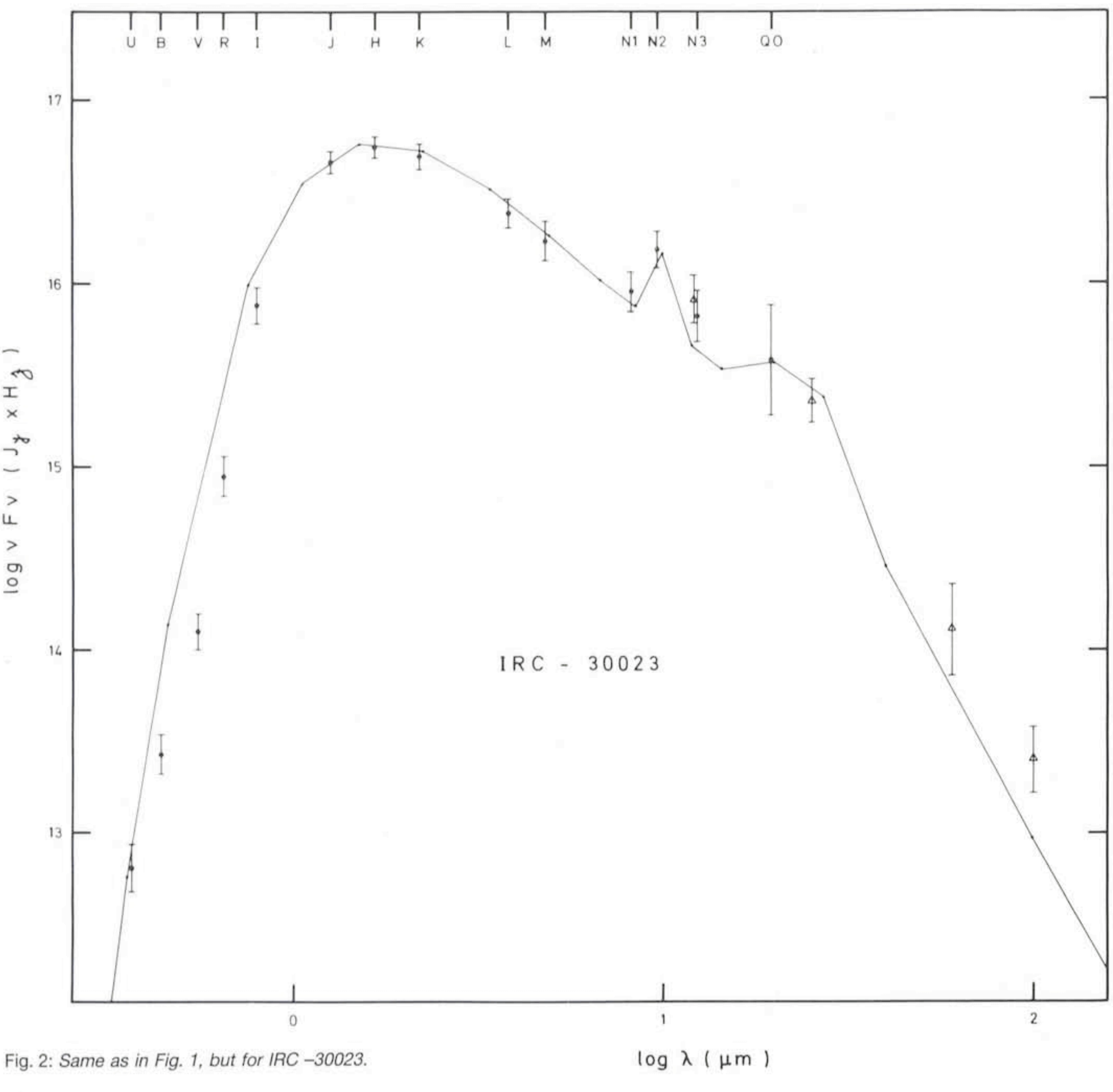

Fig. 2: *Same as in Fig. 1, but for IRC –30023.*

TABLE 1

Parameter \ Objects	C / O > 1		C / O < 1	
	IRC –30021	GL 3068	IRC –30023	OH 353.60–0.23
d (kpc)	0.5	1.2	0.5	9.9
V_e (km s^{-1})	10	15	10	18
T_* (K)	2900	2000–3000	2200	2000–3000
$\tau_{10\,\mu m}$	0.02	3.2	0.1	6.0
T_c (K)	1100	1600	750	900
$\dot{M}$ ($M_\odot$. yr^{-1})	1.4×10^{-7}	3×10^{-5}	1.7×10^{-7}	6×10^{-5}
L_* ($L_\odot$)	3.6×10^3	17×10^3	7.3×10^3	80×10^3

Star and shell parameters deduced from adjustments of broad-band photometric data.
"d" is the object distance; "V_e", the shell expansion velocity, "T_*", the central star effective temperature; "$\tau_{10\mu m}$", the optical depth of the dust shell at 10 μm; "T_c", the condensation temperature of the dust; "$\dot{M}$", the mass loss rate and "L_*", the total luminosity.

are obtained at about the same phase, around December 20, 1984. We have plotted also, for comparison, at 12 and 25 μm, and for complementarity, at 60 and 100 μm, the data obtained by the IRAS satellite through 1983. As these data are not obtained at the same phase, there is a possible slight shift between them and ours.

The broad-band spectrum of IRC –30021 is featureless and looks like the one of a blackbody of temperature ~ 1,200°K. Nevertheless, from its spectral type, the star effective temperature should be greater than 2,400 K. All this indicates the presence of carbon grains around R For; except for a resonance band around 11.5 μm which could be due to silicon carbide (SiC) these grains have optical characteristics which present no distinctive feature at $\lambda > .4$ μm.

We have developed a model of circumstellar dust shell based on the Leung (1975) radiative transfer method. Using the opacities derived by Jones and Merrill (1976) for graphite grains of radius ~ 0.05 μm, supposing that the central star radiates like a blackbody and assuming spherical symmetry and uniform expansion for the dust shell, we are able to adjust the observed data between .4 and 100 μm (solid line on Fig. 1). In this simplified model, we do not take into account photospheric bands due to CH, C_2, CN, CO, etc. and circumstellar bands mainly due to CO, in such a way that, in the observations, there is a strong deficit in B (CN and C_2), and also in J and H (CO,...), with respect to the simulation. From this adjustment, we derive for R For, at .5 kpc, a stellar luminosity of 3×10^3 $L_\odot$ and a dust mass loss rate of ~ 1.4×10^{-9} $M_\odot$/year (or, adopting a gas-to-dust mass ratio of 100, a total mass loss rate of ~ 1.4 10^{-7}) $M_\odot$/year).

IRC –30023:

Very near IRC –30021, there is another bright infrared source discovered during the T.M.S.S.: IRC –30023. Our photometric data show it to be variable with a period of ~ 500 days. Although it has an optical counterpart which may be quite bright (V ~ 10 near maximum), till now, it has not been catalogued as a variable star. Fig. 2 presents its broad band spectrum between .4 and 100 μm. A strong emission feature, visible at 10 μm, indicates the presence of silicate dust in a circumstellar shell. We infer from it that the central star is oxygen-rich.

As for IRC –30021, we performed the modeling of this dust shell, using now opacities of silicate grains of radius ~ .1 μm. The solid line in Fig. 2 presents our adjustment. Photospheric absorption bands (mainly due to TiO) are not taken into account in our model and their effects can be seen on the B, V, R fluxes. Our fit implies a total luminosity of ~ 7×10^3 $L_\odot$ and a total mass loss rate of ~ 1.7×10^{-7} $M_\odot$/year.

Conclusion

We are studying at the 1 m telescope a whole sample of evolved stars with luminosities ranging from ~ 10^3 to ~ 10^5 $L_\odot$ and mass loss rate from 0 to 10^{-4} $M_\odot$/year; a few results are given in Table 1. As these objects are variable, it is very important to monitor them for investigating their evolution, and for evaluating their importance in the replenishment of the interstellar medium.

As it is equipped with visible and infrared photometers, the 1 m telescope is very adequate for this kind of study. Its excellent pointing and tracking accuracy makes it particularly valuable for photometry, to the point that, as long as there is not too much turbulence, infrared observations can be performed even during the day. This quality is especially useful for monitoring variable objects of period ~ one year or more.

References

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STAFF MOVEMENTS

Arrivals

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SCHARRER, Rebekka (D), Laboratory Technician (Photography)
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