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THE NATURE OF A NEBULOUS STELLAR OBJECT IN CENTAURUS[1] (Research Note)

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RESUMEN

Un objeto estelar nebuloso hallado por Vogt *et al.* (1981) fue estudiado con mayor profundidad para conocer su verdadera naturaleza. De este estudio concluímos que este objeto no es una estrella joven que se encuentre en una etapa previa a la secuencia principal, sino que es una estrella que evoluciona a partir de la secuencia principal, hacia la rama asintótica de las estrellas gigantes rojas.

ABSTRACT

A nebulous stellar object found by Vogt *et al.* (1981) has been studied further in order to determine its real nature. From our study we conclude that this object is not a young pre-main sequence star, but that it is a star evolving away from the main sequence probably towards the asymptotic giant branch region.

Key words: NEBULAR OBJECT – STARS-CIRCUMSTELLAR SHELLS

I. INTRODUCTION

Vogt *et al.* (1981; hereafter VWBS) found an extremely red stellar object in Centaurus accompanied by a faint reflection nebula extending to ≈ 50″ towards the NE and ≈ 20″ to the SW. From a low dispersion spectrum (124 A mm^{-1}) they derived an MK spectral type of G0 III-IV. From the visual magnitude $V = 12^m.92$, the color index $B-V = 1^m.97$, the intrinsic color index and the absolute visual magnitude for a G0 giant, and by adopting a ratio of total to selective extinction $R = 3.46$, they derived a distance in the range of 120 to 300 pc. It should be remarked here that the total extinction, $A_V = 4.5$, derived by VWBS is certainly not caused by foreground extinction material only. Therefore, VWBS assumed that this extinction is mainly caused by the nebulosity in the environment of the star.

As to its origin, VWBS suggest two possibilities. Firstly, the star and the nebula are at present together by a chance encounter, or secondly, star and nebula have a common origin. After discussing several evolutionary models VWBS conclude that it is not possible to discriminate among the following three interpretations: chance encounter, proto-planetary nebula or a late stage of stellar evolution, possibly in a common envelope binary phase.

From the *IRAS* point source catalogue we find the star to have a large flux at all IR pass-bands (10, 25, 60 and 100 μm). In order to better determine the nature of the VWBS object, we have made more photometric and spectroscopic observations. An analysis of the new data is given in the present paper.

1. Based on observations at the European Southern Observatory, La Silla, Chile.

II. THE OBSERVATIONS

In order to know whether the star is variable, P.S. Thé started *VRI*, later *UBVRI*, observations in 1983, and continued such observations every year up to 1986. These observations were made using the ESO 50-cm telescope with an RCA 31034A (Quantacon) PM tube as detector, through a diaphragm of 15″. Standard stars in the Johnson-Cousins system were chosen from a list by Menzies *et al.* (1980). The photometric results are given in Table 1. The accuracy of these measurements is typically $\pm 0^m.01$ from V, $V-R$, and $V-I$, $\pm 0^m.02$ for $B-V$ and $\pm 0^m.05$ for $U-B$. It should be noted that the star is too faint in U to measure it reliably with a 50-cm telescope.

TABLE 1

PHOTOMETRIC DATA OF THE VWBS OBJECT

Johnson-Cousins					
Date	*U–B*	*B–V*	*V*	*V–R*	*V–I*
12/6/83	....	....	12.687	1.269	2.488
01/3/84	....	....	12.732	1.292	2.524
01/3/84	....	....	12.724	1.268	2.508
03/3/84	....	....	12.715	1.254	2.470
12/7/85	0.913	2.099	12.673	1.236	2.401
13/7/85	0.800	2.017	12.653	1.239	2.570
18/7/85	0.904	1.953	12.521	1.249	2.533
05/8/86	....	1.995	12.692	1.271	2.514
Average	0.872	2.016	12.687	1.260	2.501
	±.036	±.031	±.013	±.007	±.018
Near IR					
Date	*J*	*H*	*K*	*L*	*M*
13/3/84	8.466	7.860	7.509	7.418	7.550
20/7/86	8.480	7.814	7.506	7.232	7.067
Average	8.443	7.837	7.508	7.325	7.309
IRAS					
Pass-band		12 μm	25 μm	60 μm	100 μm
Flux in Jansky		4.594	13.56	214.3	307.1
Quality		3	3	2	1
S/N		14.7	38.4	89.0	15.3

In 1984 and 1986 new near infrared *JHKLM* observations were made using the InSb photometer mounted at the ESO 1-m telescope. The diaphragm used was 15″. The standard stars used for this photometry were chosen from those of Koornneef (1983). The results are also given in Table 1. The uncertainties in the *L* and *M* measurements were caused by the fact that at these pass-bands, we were measuring above the accuracy limit of the employed photometer.

The *IRAS* data (in Jansky) are also listed in Table 1, together with their Quality (Q) and Signal to Noise ratio (S/N).

A spectrum with a dispersion of 172 A mm^{-1} was taken in June 1983 (exposure time 40 min) with the Image Dissector Scanner mounted at the Boller and Chivens spectrograph of the ESO 1.5-m telescope. This spectrum is shown in Figure 1.

III. DISCUSSION

UBV observations were made by VWBS in April 1976 and in March 1977. No significant variability has been detected during this epoch. Our observations in *VRI* and later in *UBVRI* were made between June 1983 and August 1986. Apart from the fact that the VWBS-object became somewhat fainter in 1984, it had an average visual magnitude $V = 12^{m}_{.}69$, significantly ($\sim 0^{m}_{.}23$) brighter than in 1976-1977. This leads us to believe that the star is slowly becoming brighter, or that the extinction due to the nebulosity surrounding the object is gradually becoming lower as a result of the expansion of the nebulosity.

The spectrum of the VWBS object shown in Figure 1 and the one published by VWBS do not show any emission lines of hydrogen or other atoms; this indicates that the star does not have an extended gaseous atmosphere. The spectra are entirely photospheric.

The satellite *IRAS* has detected this object as a point source in the 12 and 25 μm pass-bands, and with less certainty at the 60 μm pass-band. It is of interest to study the spectral energy distribution of this star including the *IRAS* spectral region. The observed and extinction-free spectral energy distribution is shown in Figure 2. Here we have assumed a ratio of total to selective extinction $R = 3.1$ to correct for extinction. Furthermore, we have taken the intrinsic $(B-V)_0 = 0.65$ for a G0 III-IV type star, given in the Landolt-Börnstein Catalogue (Schmidt-Kaler 1982). A Kurucz (1979) theoretical model for spectral energy distribution of $T_{eff} = 6000$ K and log g = 3 has been compared with the extinction-free one in Figure 2. The fit between the two spectral

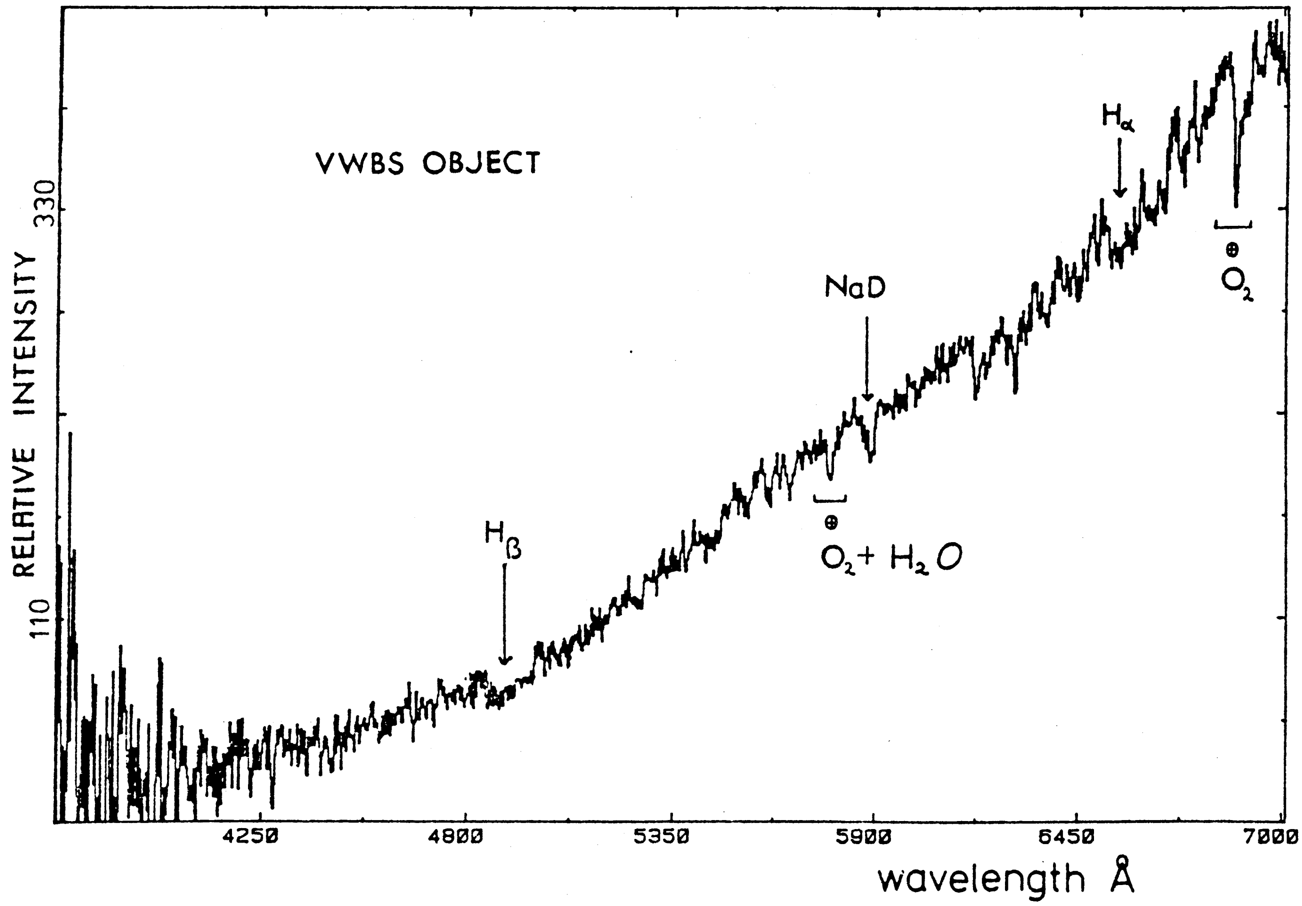

Fig. 1. An Image Dissector Scanner Spectrum of the VWBS object, obtained with the Boller and Chivens Spectrograph of the ESO 1.5-m telescope. The dispersion is 172 A mm^{-1}.

energy distributions in the visual, is quite good; which justifies our assumption of R = 3.1. However, above log λ = 0.5 the stellar spectral energy distribution clearly shows an enormous excess of infrared radiation, which we attribute primarily to thermal re-emission by one or more dust shells.

The difference curve, a plot of log ΔF_λ versus log λ, shown in Figure 3, can be fitted with two dust shells having temperatures of 215 and 46 K, respectively. Using simple methods it can be shown that the first shell is located at a distance of approximately 24 A.U., if we assume that the radius of the dust grains $r_d = \approx$ 1 μm, while the second one is at 524 A.U. These distances become 12 A.U. and 262 A.U., respectively if $r_d \approx 10$ μm is adopted. However, considering the quality of the fluxes measured by *IRAS* at the 60 and 100 μm pass-bands (see Table 1), we doubt whether the dust shell of 46 K is real. It might be that *IRAS*, with its very wide measuring slots, has measured the thermal flux of the reflection nebulosity surrounding the VWBS object. It is of interest to note that the first dust shell is located at a "planetary" distance.

It is important to estimate the total mass of the matter obscuring the star. As has been pointed out by VWBS, the distance of the star is small enough to assume that most of the extinction is due to this obscuring matter. Based on this assumption it is possible to make an estimate of the column density of obscuring matter and hence the total mass. We obtain for the latter 0.01 $M_\oplus$, which is approximately equal to the mass of the moon.

From the above discussion we conclude that the object is not a young pre-main sequence star which is evolving towards the main sequence. We arrive at this conclusion on the basis of the following arguments. The star does not show clear signs of variability, which one expects of pre-main sequence stars of this spectral type. Furthermore, it does not have an extended gaseous atmosphere, which young stars usually possess. The low temperature dust shell need not be a leftover of parental matter, because it can be formed gradually over several million years by a star losing mass at a high enough rate. Thus, although its position in a dusty environment could indicate an extreme youth, we nevertheless believe that the VWBS object is a star which is evolving away from

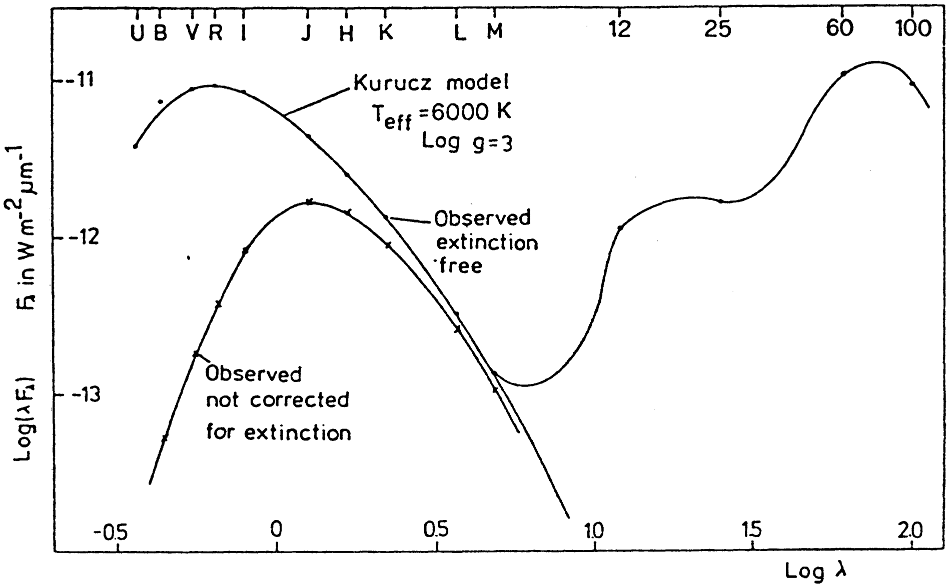

Fig. 2. The spectral energy distribution of the VWBS object, uncorrected and corrected for foreground extinction. The latter is compared with a Kurucz model energy distribution of $T_{eff} = 6000$ K and log g = 3.

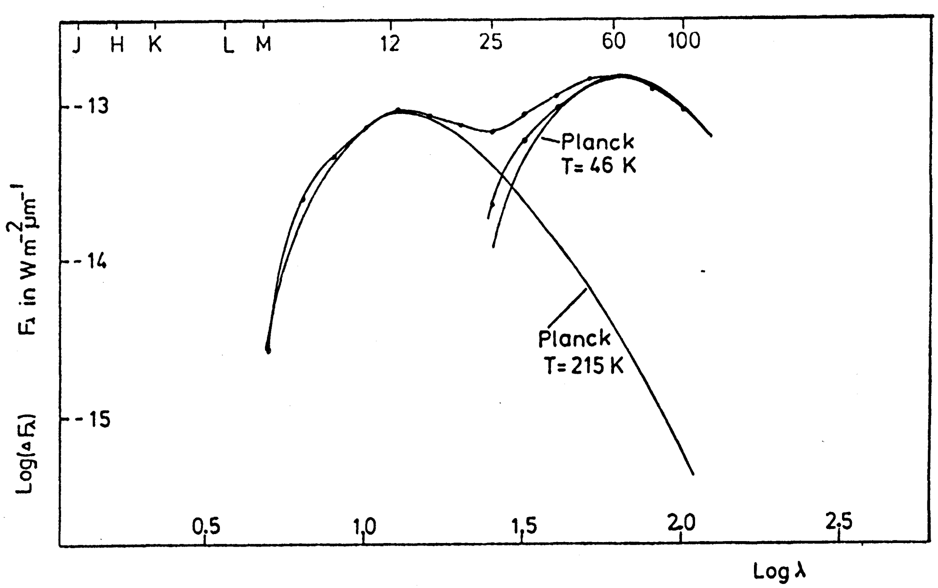

Fig. 3. The difference curve, log Δ Fλ plotted against log λ, shows two bumps, presumably caused by two circumstellar shells.

the main sequence. Finally the lack of other young pre-main sequence stars, such as T Tauri stars, indicates that the environment of this object is not a young star forming region.

REFERENCES

Koornneef, J. 1983, *Astr. and Ap. Suppl.*, **51**, 489.
Kurucz, R.L. 1979, *Ap. J. Suppl.*, **40**, 1.
Menzies, J.W. and Laing, J.D. 1980, *Circ. SAAO*, **1**, 5.
Schmidt-Kaler, Th. 1982, *Landolt Börnstein Catalogue*, **Vol. VI/2b.**
Vogt, N., Wamsteker, W., Breysacher, J., and Schuster, H.-E. 1981, *Astr. and Ap.*, **96**, 120.

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