THE ASTROPHYSICAL JOURNAL, 304:L25-L28, 1986 May 1

ER 8: A VERY LOW LUMINOSITY DEGENERATE STAR

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Received 1985 November 4; accepted 1986 January 31

ABSTRACT

In a search for faint, high proper motion stars, a very cold ($T_{BB} = 3500 \pm 100$ K) degenerate star with a featureless spectra has been found. Its proper motion is $\mu = 2.128 \pm 0.008$ arcsec yr^{-1}, and its apparent visual magnitude is $m_v = 17.2 \pm 0.1$. Available data suggest that ER 8 is a possible member of the Hyades Supercluster implying a distance $d \leq 4.5$ pc, a luminosity $L \leq 5.9 \times 10^{-6}$ $L_\odot$, and an age less than 10^9 yr.

Subject headings: photometry — spectrophotometry — stars: individual — stars: proper-motion — stars: white dwarfs

I. INTRODUCTION

The study of cold degenerate stars provides a way of testing the validity of available cooling theories for white dwarfs (Böhm *et al.* 1977). Current ideas about the luminosity function and equations of state for white dwarfs will also depend on the detailed characteristics and numbers of cold degenerate stars (Shaviv and Kovetz 1976).

In spite of the fact that theoretical cooling curves calculated by Shaviv and Kovetz (1976) show that rapid cooling does not occur (for a 0.6 $M_\odot$ star) at luminosities above 10^{-5} $L_\odot$ and thus their number should not be negligible, searches for these very low luminosity degenerates (VLLD) with $M_{bol} > 16$ have been unsuccessful so far (Liebert *et al.* 1979*b*; Liebert 1979, 1980).

There is a significant discrepancy between the number of VLLD predicted by current theories, about 46 within 10 pc (see Table 2 of Liebert *et al.* 1979*b*), and the number of VLLD actually found, possibly only one, LP 131 − 66 (Liebert *et al.* 1979*a*). The corresponding prediction for the number of VLLD within 5 pc is $6 \pm \sqrt{6}$, they are expected to be found as stars of $m_v > 18$ and with a $\mu > 2''$ yr^{-1}. Liebert *et al.* (1979*b*) report that after a careful search for them, in areas north of $\delta = -20°$, none have been found within 5 pc.

In this *Letter* we communicate the discovery of a star which could belong to the VLLD class and be located at a distance of 4.5 pc.

II. OBSERVATIONS

For almost 6 yr a supernova search program has been carried out at the Astronomy Department of the University of Chile using a 70/100/210 cm Maksutov Camera located at the Cerro El Roble Astronomical Station (Maza *et al.* 1981; Maza, González, and Wischnjewsky 1986). Besides the supernovae, a large number of other types of objects were discovered during the blinking process of the monthly plate material. Among the most interesting of them are the faint ($m_B > 14$) large proper motion ($\mu > 1''$ yr^{-1}) stars. Most of these stars had not been found before.

With the purpose of learning more about these stars we started a spectroscopic study of them using the facilities of the Cerro Tololo Inter-American Observatory. Spectroscopy and proper motions for the first group of these stars will be given elsewhere (Ruiz *et al.* 1986).

ER 8 stood out from the beginning as an object of particular interest due to its large proper motion ($\mu = 2''.128$ yr^{-1}) and its faint apparent magnitude ($m_B = 18.8$) on the supernova survey plates. Figure 1 is a finding chart for this object.

ER 8 was found comparing plates taken only 3 yr apart (1979–1982), but we were fortunate to have plates of the same area taken with the same telescope during 1969 and 1970. In §III we give a detailed description of the method and the material we used to calculate the proper motion.

Spectrophotometry of ER 8 was done at the 4 m telescope of CTIO, equipped with a Ritchey-Chrétien spectrograph and a two-dimensional Frutti detector. The 1 hr spectrum in Figure 2 was obtained in 1985 April, through a slit 1000 μm (8″) wide, the seeing was about 1″.5. During the night three flux standards as well as a He-Ne-Ar lamp were observed in order to flux and wavelength calibrate the spectra. The calibrations were performed at the CTIO La Serena Computing Facilities.

A second spectrum of ER 8 was secured on 1986 January 4 with the same telescope and equipment used to obtain the spectrum in Figure 2. The night was photometric with a 1″.0 seeing. The color ($B - V$) obtained from the new spectrum is the same as the one from Figure 2, but the star appeared to be 0.1 mag brighter. As we believe that the night in 1985 April was not photometric, we have used for our discussion of the ER 8 parameters the m_v obtained from the new spectrum.

III. PROPER MOTION DETERMINATION

In order to get the proper motion of ER 8 we measured six plates taken with the Maksutov Telescope at Cerro El Roble (see Table 1). All plates were measured using a Zeiss-Jena x-y

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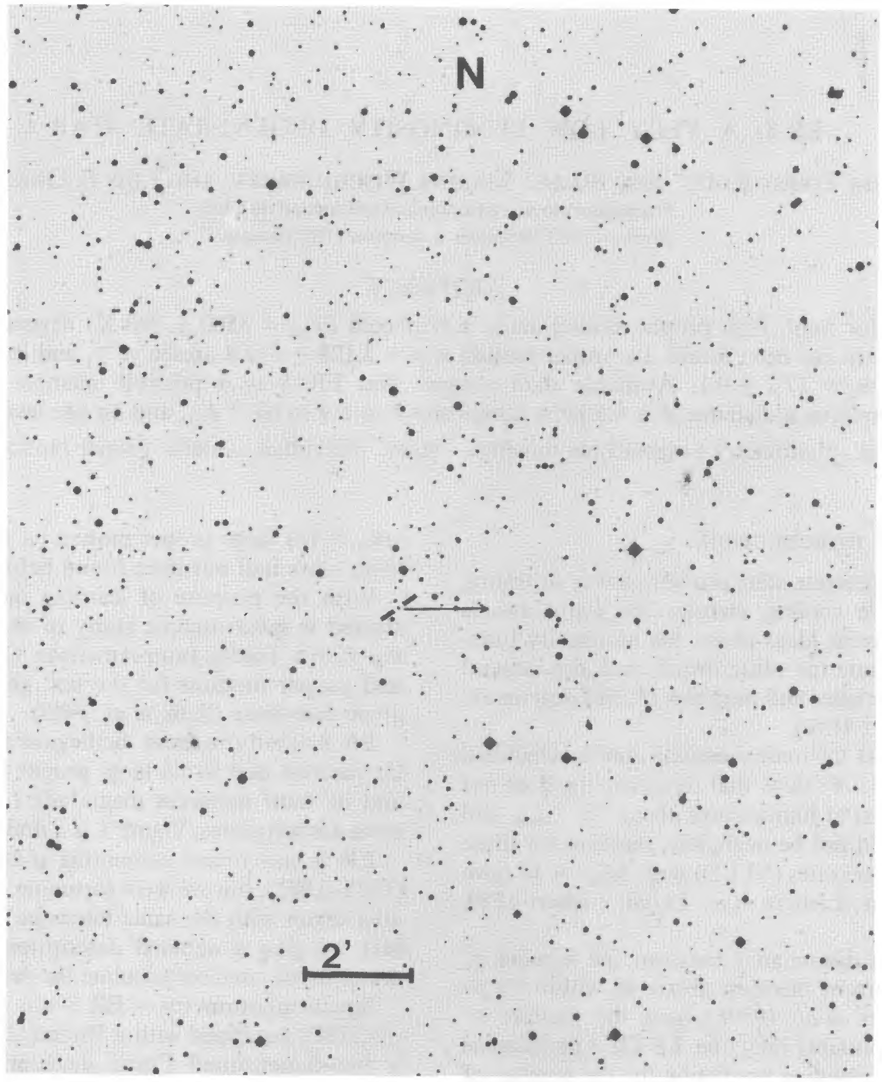

FIG. 1.—The position of ER 8 and the direction of its proper motion is indicated on a reproduction of the ESO (B) Survey

measuring engine at Cerro Calán in Santiago, digitalized and connected to a microcomputer. ER 8 was measured on each plate along with 28 reference stars from the *Perth* 70 *Catalogue*, 20 stars within 30′ of ER 8 (of roughly the same magnitude as ER 8) and 28 faint galaxies.

On a first iteration the (α, δ) coordinates for all 28 galaxies and 20 faint reference stars were obtained for the six plates. A small systematic apparent proper motion was detected for both the galaxies and the 20 reference stars. We obtained the average (α, δ) for each of these 48 objects and reprocessed the coordinate computations for ER 8, using the averaged positions as reference.

Once the final celestial coordinates for ER 8 were obtained, for the epoch of each plate, a least-squares fit was performed to get the proper motion in both coordinates. The final values are:

$$\mu_\alpha = -2''127 \pm 0''008 \text{ yr}^{-1}$$

$$\mu_\delta = -0''58 \pm 0''008 \text{ yr}^{-1},$$

and then the proper motion is $\mu = 2''128 \pm 0''008 \text{ yr}^{-1}$. The 1985.0 coordinates for ER 8 for the equinox 1950.0 are: $\alpha = 13^h10^m3^s663$ and $\delta = -47°12'12''58$.

IV. RESULTS AND DISCUSSION

The visual and blue magnitudes of ER 8 have been obtained using the spectrum in Figure 2. We found a visual magnitude $m_v = 17.2 \pm 0.1$ ($\lambda_v = 5500$ Å) and a blue magnitude $m_B = 18.8 \pm 0.1$ ($\lambda_B = 4400$ Å) implying a color $B - V = 1.6 \pm 0.1$.

In Figure 2 we show blackbody curves at 3400 K and 3600 K. Although it is clear that ER 8 cannot be fitted by a single blackbody, we estimate that the best fit is obtained for $T_{\rm BB} = 3500 \pm 100$ K. The bolometric correction for a blackbody at $T_{\rm BB} = 3500 \pm 100$ K is BC = 1.07 ± 0.1; if we apply this BC to ER 8 we obtain an apparent bolometric magnitude $m_{\rm bol} = 16.1 \pm 0.2$. The errors in $m_{\rm bol}$ due to the estimate of the BC, considering ER 8 to be a blackbody, can

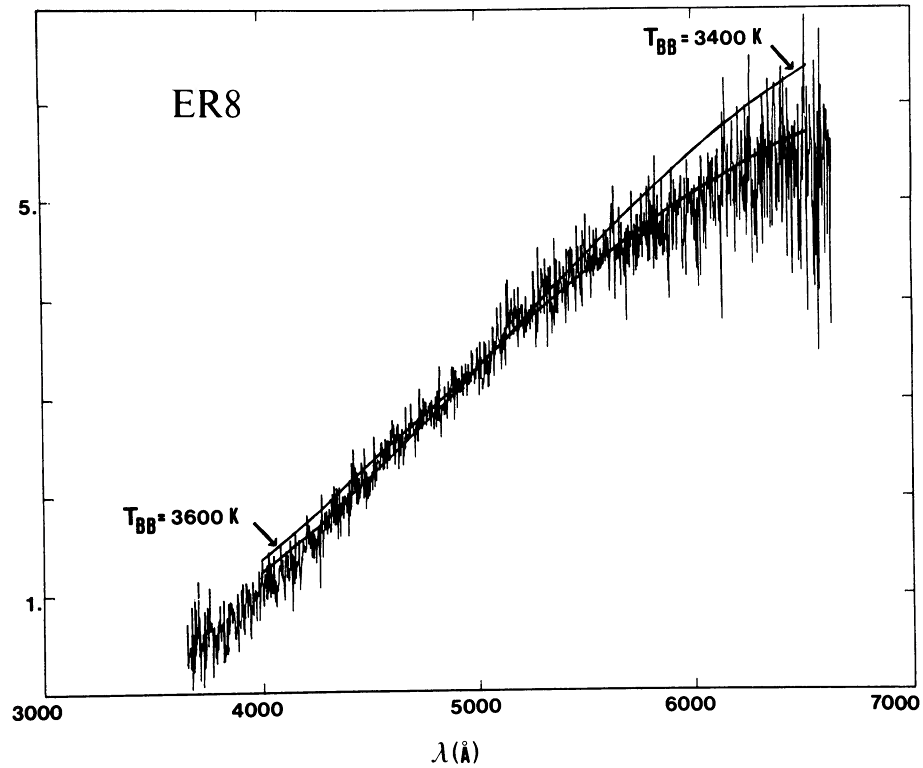

FIG. 2.—Spectrogram of ER 8 obtained with the 4 m telescope at CTIO equipped with an RC spectrograph and a 2D-Frutti system. The integration time for it was 1 hr. Blackbodies at 3400 K and 3600 K are shown in solid lines.

TABLE 1
PLATES USED FOR PROPER MOTION

Plate Number	Emulsion	Exposure Time (minutes)	Epoch
283	103a−O	30	1969.367
1465	103a−O	30	1970.334
1983	103a−O	30	1971.170
7822	IIa−O	20	1983.186
8865	IIa−O	20	1984.241
9002	IIa−O	20	1984.342

be quite large. For instance if we apply to ER 8 the BC corresponding to a main sequence star of $B - V = 1.6$ we get an apparent bolometric magnitude of $m_{\rm bol} = 15.2$.

The large proper motion, faint apparent magnitude, and red colors of ER 8, suggest that is a very nearby object. An attempt to measure its trigonometric parallax is presently under way using a CCD detector (by Anguita and Ruiz). Meanwhile an estimate for its distance can be obtained if we realize the fact that the proper motion of ER 8 is almost exactly toward the convergent point of the Hyades Supercluster ($A = 6^{\rm h}42$; $D = +7°27$) with a very small peculiar velocity P.V. = -0.8 km s^{-1} (Eggen 1984*a*, *b*). The Hyades Supercluster, in which the Sun is immersed, has a total space motion $V = 45.5$ km s^{-1} (Eggen 1984*b*). The two criteria adopted by Eggen (1984*a*) to consider a white dwarf as a member of the Hyades Supercluster are as follows:

1. The peculiar velocity (P.V.) has to be less than 10% the total space motion $V = 45.5$ km s^{-1}, that is P.V. $\leq$ 4.5 km s^{-1}. This first criterion is easily met by ER 8 with a P.V. = -0.8 km s^{-1}.

2. The second criterion concerns a relation found by Graham (1972) between the luminosities of white dwarfs and their intermediate-band colors $(b - y)$. The criterion for membership says that the M_v given by the astrometric modulus obtained from the cluster parallax should not be off by more than 0.5 mag from the magnitude found with the relation $M_v = 11.5$ mag $+ 7.5\ (b - y)$ (Eggen and Bessell 1978). Intermediate photometry for ER 8 is not yet available, but the $(B - V)$ colors also correlate with M_v for white dwarfs (Fig. 2 of Eggen 1984*a*). Considering the fact that the $(B - V) = 1.6$ of ER 8 implies a gross extrapolation in Figure 2 of Eggen (1984*a*) we found a good agreement between the $m - M = -1.3$ found from such magnitude-color relation and the modulus of -0.94 obtained using the cluster parallax (π_c).

It seems that ER 8 satisfies the criteria for being a member of the Hyades Supercluster, which implies a distance to ER 8 $d \leq 4.5$ pc (Eggen 1985). At such distance its absolute visual magnitude would be $M_v \geq 18.9$ with an absolute bolometric magnitude $M_{\rm Bol} \geq 17.8$ and a luminosity $L \leq 5.9 \times 10^{-6}\ L_\odot$.

In spite of the uncertainties involved in the estimates made to calculate the luminosity of ER 8 we believe that the evidence strongly suggest that ER 8 is a nearby ($d \leq 5$ pc)

VLLD, whose existence has been predicted for so long by theories. Given the small numbers expected, ER 8 could be the only VLLD within 5 pc.

The possible membership of ER 8 in the Hyades Supercluster poses some questions upon the current cooling theories for white dwarfs, because although ER 8 is the coldest degenerate known, and thus, according to cooling theories should be one of the oldest stars in the Galaxy, its actual age cannot exceed 10^9 yr, the age of the Hyades Supercluster.

We want to thank Dr. G. Wegner for a stimulating conversation and Dr. S. Heatcote for his help with the data reduction. We are specially thankful to Dr. O. Eggen who pointed out to us the possible membership of ER 8 to the Hyades Supercluster, a fact that together with the very relevant referee's comments helped us improve the original version of this paper.

This research was partially financed by a grant from Fondo Nacional de Ciencias 1135.

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