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G61−29, A HELIUM EMISSION-LINE STAR

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ABSTRACT

Spectrograms of G61−29 reveal that it is a helium emission-line star, probably a white dwarf. The spectrum is described, and possible interpretations are briefly discussed.

I. INTRODUCTION

The purpose of this communication is to report the discovery of a helium emission-line star, G61−29. Although many stars are known in which helium, but not hydrogen, appears in absorption, this is, so far as we are aware, the first time that helium alone has been discovered in emission.

The star in question, G61−29, was observed as part of a program aimed at discovering further DB white dwarfs. Candidate stars were selected from the *Lowell Proper Motion Survey* catalogs (Giclas, Burnham, and Thomas 1971, and references contained therein) with the additional criterion that their *UBV* color indices (Eggen 1968) should be in the neighborhood of $U - B \sim -1.0$, $B - V = -0.1$, a region of the two-color diagram in which practically all known DB stars appear to lie. The results of this program will be discussed elsewhere. Here we will confine ourselves to G61−29, giving a description of the observational results in § II and a brief discussion of their implications in § III.

II. OBSERVATIONAL RESULTS

The proper motion of G61−29 is given by Giclas *et al.* (1971) as $0''.35$ year^{-1}, a value confirmed by Klemola (private communication) from Lick astrograph plates. Eggen (1968) gives photometric data as follows: $V = 15.69$, $B - V = -0.10$, $U - B = -0.97$. Again, according to Klemola (private communication), photographic data from eight plates taken over a period of 23 years suggest that the luminosity of the star has remained essentially constant to within 0.1 mag during this time.

We have obtained three spectrograms of G61−29 at the Lick 120-inch telescope. Details are shown in Table 1, in which ES denotes plates obtained with the conventional prime-focus spectrograph and EI the Carnegie image-tube spectrograph. Reproductions of these spectrograms are shown in Figure 1 (Plate L3). The most prominent spectral features in the blue region are the He I triplet lines λλ4471, 4026, and 3889. The latter arises from the metastable 2 ^3S level and clearly contains a central absorption feature. Features corresponding to the singlet lines λλ4388 and 3964 and the triplets λλ3819 and 3705 are also discernible on the ES spectrograms. The image-tube data clearly show the presence of the triplet lines at λλ7065, 5876, 4922, 4713 and the singlet lines λλ6678, 5016. The latter arises from the metastable 2 ^1S level, but no evidence of central reversal is detectable on this low-resolution spectrogram. There is also a weak emission feature near the expected wavelength of He II λ4686 which we tentatively identify with this feature (see discussion below).

Wavelength measures of the He lines proved rather difficult because of their extreme broadness. From two spectrograms, EI 141 and ES 2078, we derived a formal radial velocity $v_r \sim -20 \pm 30$ km s^{-1}. In ES 2071, however, the helium lines were shifted systematically blueward, giving $v_r \sim -120 \pm 30$ km s^{-1}. This may be an indication of a true radial-velocity change and hence of binary motion. There are, however, a number of features of the measurements which cast some doubt on this interpretation. In

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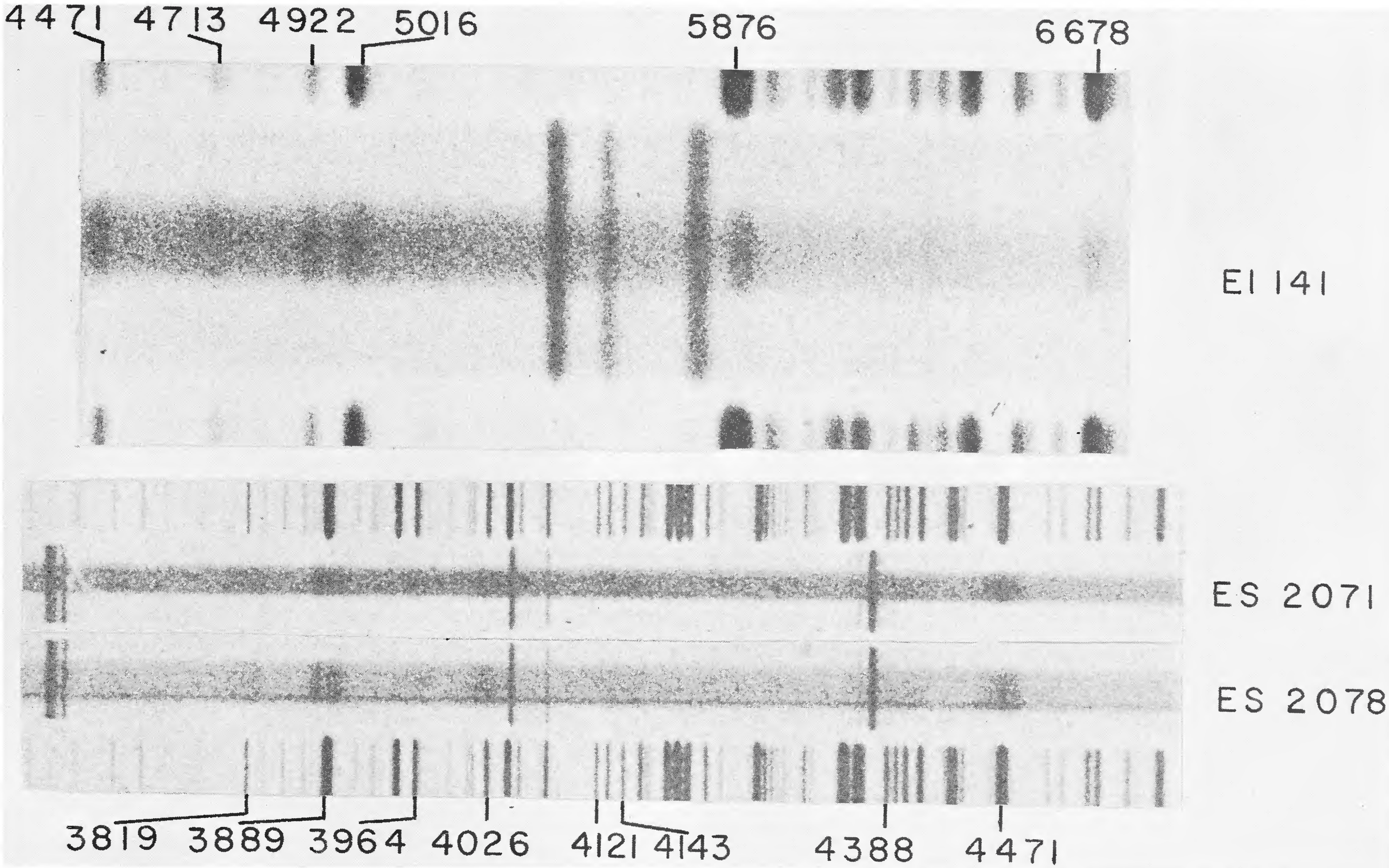

FIG. 1.—Spectrograms of G61−29 obtained at prime focus of the Lick 120-inch telescope, EI 141 with Carnegie image-tube spectrograph, ES 2071, 2078 with photographic spectrograph. Several He lines in the comparison spectra are marked where broad He emission lines can be seen in the star. Lines crossing the whole object window in each spectrogram are Hg lines from city lights and [O I] λ5577. Note structure in He I λλ3889 and 4471 in the star in ES 2071 and 2078.

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TABLE 1

DATA ON SPECTROGRAMS

Plate No.	Date UT	Dispersion (Å)	Range (Å)
EI 141........	1971 May 22.3	400	4000–7100
ES 2071........	1971 May 23.3	190	3600–4800
ES 2078........	1971 June 21.2	190	3600–4800

particular, we note (*a*) He I λ3889, although very broad, gives mean radial velocities of $v_r \sim -20$ and -120 km s^{-1} from ES 2071 and ES 2078, respectively, that is, precisely the reverse of the values derived from the other He I lines; (*b*) there is some evidence for slight but varying asymmetry in a number of lines; (*c*) the structure of He I λλ3889 and 3964 in particular seems to have changed (see Fig. 1); and (*d*) in both ES spectrograms the weak line associated with He II λ4686 appears ~3 Å to the red of its expected position based on the He I measurements.

In Figure 2 we present a microdensitometer tracing on an intensity scale of ES 2078; rest wavelengths of the He I lines are noted on this diagram. An inspection of the tracings suggests the existence of a number of weak but possibly real features. Further observational data are required to resolve this question. Two features, also noted in Figure 2, deserve further comment here, namely,

i) A possible emission feature at ~λ4133 which appears on both spectrograms

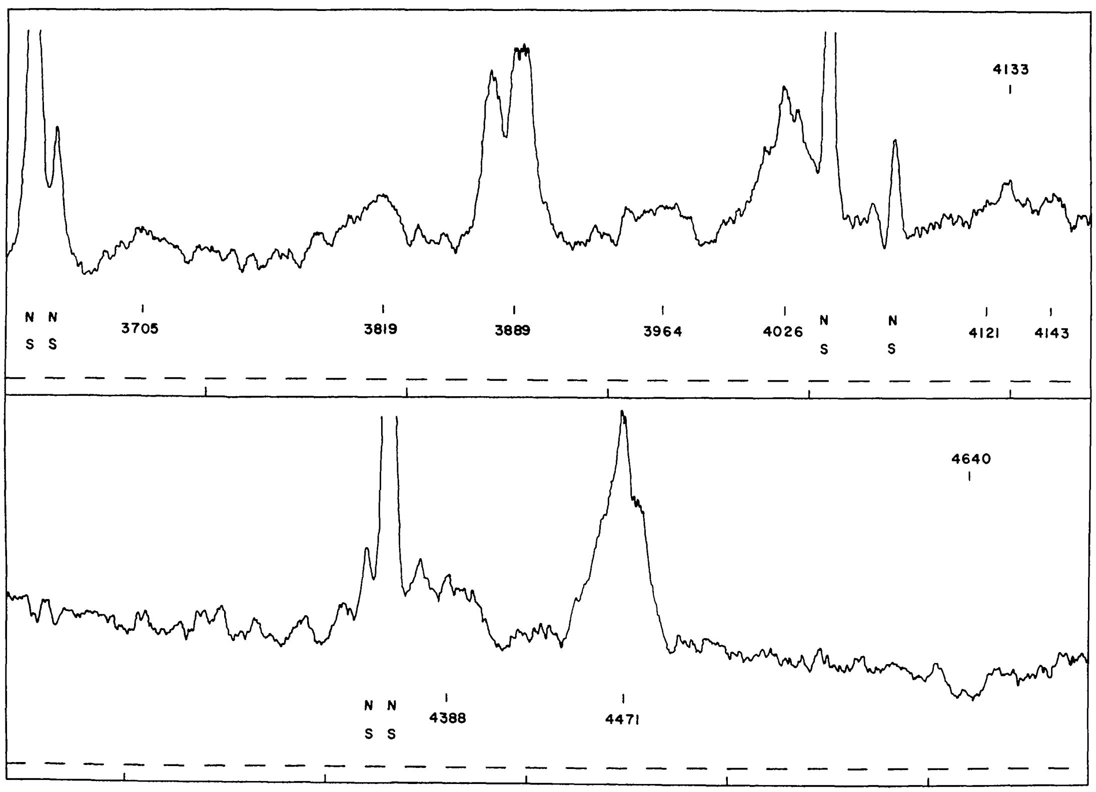

FIG. 2.—Intensity tracing of ES 2078. Rest wavelengths of the stronger He I lines are noted, together with approximate wavelengths of the two unidentified features at λλ4133 and 4640. The symbol NS denotes nightsky emission. Dashed line indicates the clear plate level.

but seems rather strong to be due to overlapping of λλ4121 and 4143 of He I. We note that this feature lies very close to the central wavelength of the broad λ4135 absorption in Grw 70°8247 (Greenstein 1960).

ii) A broad absorption feature at λ4638. Possible identification as O II λ4638 is ruled out by the absence of λ4415 which should be of comparable strength. The blend N II λλ4631, 4643 can likewise be rejected because of the absence of λ3995. With the poorer quality of these spectrograms and the great width of the observed emission lines, we wondered whether the apparent absorption feature might be due to the combination of a declining continuum superposed upon which appear highly broadened features of He II λ4686 and, subsequently, He I λ4713. Our impression, both from the tracings and from visual inspection of the spectrograms, is that this explanation is unlikely. The origin of this feature thus remains a mystery.

The spectrum is, however, equally remarkable for what it does not contain. Most obvious, of course, is the complete absence of hydrogen either in absorption or in emission. Second, there is no evidence for any He II lines either in absorption or in emission other than the weak emission feature near λ4686. This places a fairly good upper bound on the temperature of the star and suggests that for normal composition the lines of C II λ4267, Si II λ4129, Si III λ4552, and N II λ3995 should be seen in absorption. None of them is found.

Finally, we should comment on the He I lines themselves. All lines are extremely broad with typical widths at half-maximum of $w_{1/2} \sim 20$ Å corresponding to velocities in excess of 10^3 km s^{-1}. The lines at λλ4471 and 4026 are, however, remarkably sharp-peaked and are certainly not rounded or double as is usually the case for hydrogen lines in old novae (Greenstein 1960). The λ3889 line is clearly self-reversed, probably due to the metastability of its lower level; a true comparison of its emission profile with those of λ4471 or λ4026 is thus not possible. One comparison may, however, be made, namely, that of base widths, w_B. While the noise problem is nonnegligible, measurements of both spectrograms indicate that w_B decreases systematically by approximately 7 Å (~12%) from λ4026[1] through λ4471 to λ3889. Finally, we note that, while the triplets are clearly dominant in the photographic region, the singlet lines λλ5016, 4922, and 4388 are nonetheless of significant strength. Thus, while some weakening of singlet versus triplet lines may be present, the evidence is certainly not overwhelming.

III. DISCUSSION

The high proper motion of this star limits its maximum distance to $R \lesssim 200$ pc if it is gravitationally bound to the Galaxy. The apparent magnitude $m_v \sim 15.69$ then indicates that the star is a white dwarf (or possibly fainter). The breadths of the emission lines, whether interpreted as due to mass motions or to pressure broadening, add weight to this conclusion.

The colors of G61−29 coincide remarkably well with those of normal DB stars despite the emission spectrum. Since the absorption lines in normal DBs affect the color indices, especially $B - V$, significantly (Strittmatter and Wickramasinghe 1971), the discovery of G61−29 in this color range may at first sight appear to be an amazing coincidence. That this is not necessarily so can be seen at least qualitatively from the following general argument. The strength of emission lines increases strongly toward lower series numbers, that is, toward the red; in particular, the many He I lines in the ultraviolet will be very weak in emission. The opposite tendency, however, occurs among absorption lines where the effect of Stark broadening increases toward higher series members. Thus, both emission and absorption probably tend to make the stars appear redder; a quantitative analysis is clearly required to verify these points. In the meantime, we conclude tentatively that the effective temperature of G61−29 is probably not far

[1] λ4026 is complicated by the nightsky emission feature at λ4046; measures have therefore been made on the assumption of symmetry about the peak.

different from other DB stars and is probably in the neighborhood of $T_{\mathrm{eff}} \sim 20{,}000°$ K.

On the basis of the present data, two alternative explanations for the emission-line region still seem possible: (*a*) that the lines arise in the upper photosphere of the star due to an outward increase in temperature, or (*b*) that they arise from high-velocity gas clouds surrounding the star. We discuss these briefly in turn.

On hypothesis (*a*) the extreme breadth of the lines must be attributed to Stark broadening of the lines and requires densities of up to $\rho \sim 10^{-7}$ g cm^{-3}. The variation of w_B noted in § II would arise naturally from differential broadening between the lines—the highest lines being the most broadened. The profile of λλ4471 and 4026 would be generated naturally (in a slowly rotating star) from the general decrease of density with height. At sufficiently low density, the metastability of the 2 ^3S level becomes important and a central reversal in λ3889 is to be expected. The absence of any clear evidence for other elements is not surprising in view of the existing evidence for DBs. Only the origin of the reversed temperature gradient remains a puzzle, although the possibility of surface convection in the neighborhood of $T_{\mathrm{eff}} \sim 20{,}000°$ K (Wickramasinghe and Strittmatter 1970) suggests itself as a form of mechanical heating.

Hypothesis (*b*) is at once more exciting and more problematical. It is clear from the absence of hydrogen in the spectrum that the material must be ejected from the object itself. The idea that the gas is rotationally supported seems implausible in view of the He I line profiles, in particular the sharp cores to λλ4026 and 4471. A binary hypothesis requires (i) that the companion be a fainter white dwarf or neutron star and (ii) that the DB fill the appropriate Roche lobe. For typical white dwarfs this would require a very short-period ($\lesssim 10^2$ s) orbit[2] and hence a very high rate of gravitational radiation. Since, in addition, the radius of the white dwarf increases with decreasing mass, such a configuration would be unstable on a short time scale—on the order of a few years. Pulsational mass loss leading to the formation of gas clouds moving in the gravitational field of the star would seem the most likely possibility, although the variation in w_B would (if real) be difficult to account for in such a model. On the other hand, the apparent variation in the central reversal of λ3889 and the possible changes in detailed profiles of other He I lines would be expected in this case. The weakness of He II sets less stringent conditions on T_{eff} ($\lesssim 40{,}000°$ K) than those obtained from the photosphere. (In the absence of trapped Lα radiation, the usual resonance enhancement mechanism for He II λ4686 will not be operative.) Certainly, in any mass-loss model it becomes of vital interest to ascertain whether or not other elements are present in significant proportions since it is unlikely that effective element separation could occur in this case. The material in the envelope would then reflect closely the true abundance distribution in the star.

Further work, both theoretical and observational, is currently in progress to determine the origin of the emission lines.

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REFERENCES

Eggen, O. J. 1968, *Ap. J. Suppl.*, **16**, 97.

Giclas, H. L., Burnham, R. Jr., and Thomas, N. G. 1971, *Lowell Proper Motion Survey; The G Numbered Stars* (Flagstaff, Arizona: Lowell Observatory).

Greenstein, J. L. 1960, in *Stars and Stellar Systems*, Vol. **6**, ed. J. L. Greenstein (Chicago: University of Chicago Press), p. 676.

Strittmatter, P. A., and Wickramasinghe, D. T. 1971, *M.N.R.A.S.*, **152**, 47.

Wickramasinghe, D. T., and Strittmatter, P. A. 1970, *M.N.R.A.S.*, **150**, 435.

[2] The possible binary motion noted in § II would be associated with an orbital period in excess of our exposure time of ~90 min. For mass loss to occur, this demands a main-sequence companion which is extremely faint (and hence of low mass) and which also consists of pure helium. This hypothesis seems rather implausible to us.