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HOT DEGENERATES IN THE MCT SURVEY. I. MCT 0130−1937, A NEW, COLOR-SELECTED PG 1159 OBJECT

S. DEMERS,[1,2] F. WESEMAEL,[1,2,3] M. J. IRWIN,[1,4] G. FONTAINE,[1,2,3] R. LAMONTAGNE,[1,2,3]
S. O. KEPLER,[1,5] AND J. B. HOLBERG[6]

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ABSTRACT

We report the discovery, in the course of a survey for high-latitude, ultraviolet-excess objects in the southern hemisphere, of a new white dwarf star belonging to the PG 1159 spectroscopic class. A variety of spectroscopic observations show this object to be similar to the prototype PG 1159−035 in exhibiting He II, C IV, and O VI features in its optical spectrum, as well as a rich absorption spectrum in the ultraviolet. In addition, the slope of its energy distribution appears as steep as that of PG 1159−035 and is consistent with the Rayleigh-Jeans tail of a very hot ($T_e \geq 100{,}000$ K) star. White-light, high-speed photometry reveals that this object does not exhibit periodic variations in the range 10–2000 s with semiamplitudes larger than ~0.002 mag. The importance of such objects for current models of the spectral evolution of white dwarfs is emphasized.

Subject headings: stars: individual (MCT 0130−1937) — stars: white dwarfs — ultraviolet: spectra

I. INTRODUCTION

According to the classification scheme of Wesemael, Green, and Liebert (1985, hereafter referred to as WGL), the PG 1159 stars represent the hottest helium-rich white dwarfs known. This spectroscopic class is defined by the presence of a distinctive absorption trough in the 4640–4690 Å region, which is dominated by C IV λ4658 and He II λ4686. The λ4441 and other C IV lines also show up frequently, as well as O VI transitions below 4000 Å (Sion, Liebert, and Starrfield 1985). Several objects exhibit emission reversals in the cores of those lines. The ultraviolet spectra of a handful of stars observed with the *IUE* at low dispersion are quite rich as well, with He II λ1640 and several additional features detected. The nature of the latter has recently been established by Liebert *et al.* (1989) from high-dispersion, ultraviolet observations of the prototype PG 1159−035: they appear to be high-excitation, heavily broadened C IV lines. Weaker N V and O VI features appear as well in the high-resolution data.

In the context of their classification scheme, WGL assigned effective temperatures upward of 100,000 K and gravities of the order of $\sim 10^7$ cm s^{-2} to objects in the PG 1159 class. Effective temperature estimates for several objects obtained since indeed suggest that PG 1159 stars are found in the range 100,000–160,000 K. However, WGL discussed the observed properties of the PG 1159 class in terms of a helium-dominated atmosphere. This picture has been occasionally called into question (Nousek *et al.* 1986; Vennes, Fontaine, and Wesemael 1989; Barstow and Tweedy 1989); a detailed spectral analysis study by Werner, Heber, and Hunger (1989*b*) of four PG 1159 objects now suggests that carbon could be the dominant photospheric constituent in these stars.

Interestingly, six of the 13 such objects known are nonradial pulsators as well (McGraw *et al.* 1979; Bond *et al.* 1984; Grauer and Bond 1984; Bond and Grauer 1987; Bond and Ciardullo 1989), with periods in the range 330–2500 s. The pulsating members of the class are known as GW Vir stars, although current evidence suggests that their pulsational properties may not be as uniform as their spectroscopic similarities could have led us to believe (e.g., Winget 1988).

In this paper, we present data on a new PG 1159 object discovered in the course of a survey for ultraviolet-excess objects currently being carried out in the southern hemisphere. The general techniques used in this colorimetric search, designated as the Montreal-Cambridge-Tololo (MCT) Survey, are similar to those used in the earlier, highly successful survey of Green (Green, Schmidt, and Liebert 1986): the photographic part consists of a series of doubly exposed *U* and *B* Schmidt plates, with a usable field of 5° × 5°. The plates are scanned at the Automatic Plate Measuring System (APM) facility at Cambridge and are calibrated on the Johnson system. The sample of objects with $(U-B) \leq -0.4$ is then submitted to a visual inspection to weed out undesirable candidates, and a list of ultraviolet-excess candidates is then drawn up. Follow-up spectroscopy and narrow-band photometry is an integral part of this survey as well. Additional details on our techniques are provided by Demers *et al.* (1986). We have, by now, obtained a variety of spectroscopic and photometric observations on this new PG 1159 object, which allow us to confirm its nature, compare its properties to those of the prototype (PG 1159−035), and pave the way for future detailed model atmosphere studies.

II. OBSERVATIONS

MCT 0130−1937 was identified as an ultraviolet-excess object on doubly exposed *U* and *B* plates obtained at the CTIO Curtis Schmidt telescope in 1984. Its position, given in Table 1, is consistent with that of PHL 1025, a blue object

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[1] Visiting Astronomer, Cerro Tololo InterAmerican Observatory, National Optical Astronomical Observatories, which is operated by AURA, Inc., under contract with the National Science Foundation.

[2] Département de Physique, Université de Montréal.

[3] Guest Observer with the *International Ultraviolet Explorer* satellite, which is sponsored and operated by the National Aeronautics and Space Administration, by the Science Research Council of the United Kingdom, and by the European Space Agency.

[4] Institute of Astronomy, Cambridge University.

[5] Instituto de Fisica, Universidade Federal do Rio Grande do Sul.

[6] Lunar and Planetary Laboratory, University of Arizona.

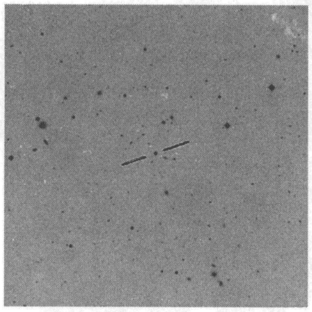

FIG. 1.—Finding chart for MCT 0130−1937, reproduced from the ESO Sky Survey J film. North is up, and east is left. The field is 15′ × 15′.

identified in the earlier three-color survey of Haro and Luyten (1962), and with that of GD 1088. It is included in the Lowell survey as a blue star with no definite motion (Giclas, Burnham, and Thomas 1975). A finding chart is given in Figure 1. An examination of the *J* film from the ESO Sky Survey reveals no obvious nebulosity around this object.

a) *Optical Spectrophotometry*

Follow-up optical spectrophotometry of MCT 0130−1937 was first obtained on 1985 September 4 at the CTIO 1.5 m telescope. This first scan, obtained with the UV SIT at 13.5 Å resolution, is shown in Figure 2. The spectrum clearly showed the 4650–4680 Å blend characteristic of the PG 1159 class, together with an additional feature near 4440 Å which we identified with C IV λ4441. Additional optical spectra at improved resolution were obtained with the same telescope and a GE CCD chip on 1987 August 17 (∼8 Å resolution), and with the Steward Observatory 2.1 m telescope and intensified blue-sensitive photon-counting Reticon at 2.5 Å resolution on 1987 October 29. Both spectra are displayed in Figure 2 as well. The higher resolution data clearly confirm the nature of this object. However, the Steward Observatory spectrum shows no evidence for emission reversals in the cores of the C IV and He II features, which are seen in data of comparable resolution on several members of this class. As such, the spectrum of MCT 0130−1937 is more reminiscent of that of PG 2131+066 (Bond *et al.* 1984) or PG 1424+535 (Grauer *et al.* 1987) than that of PG 1159−035 itself.

The earlier 1.5 m CCD data extended far enough in the blue to suggest the presence of at least some of the C IV transitions first reported below 4000 Å in several objects of that class by Sion, Liebert, and Starrfield (1985). MCT 0130−1937 was thus reobserved with a similar setup on 1988 October 2, at a comparable resolution. The resulting average blue spectrum is displayed in Figure 3. The presence of the suspected C IV λ3689 and λ3934 transitions is confirmed; the former is by far the strongest transition expected in that part of the spectrum (Sion, Liebert, and Starrfield 1985). The much weaker O VI transitions at 3811 Å and 3834 Å are not as conspicuous in our

TABLE 1

MISCELLANEOUS DATA ON MCT 0130−1937

Parameter	Value
α_{1950}	$01^{\rm h}30^{\rm m}14^{\rm s}.8$
δ_{1950}	$-19°37'03''.9$
V	15.84
$U-B$	−1.15
$B-V$	−0.29
y	15.85 ± 0.01
$u-b$	−0.504 ± 0.011
$b-y$	−0.150 ± 0.038

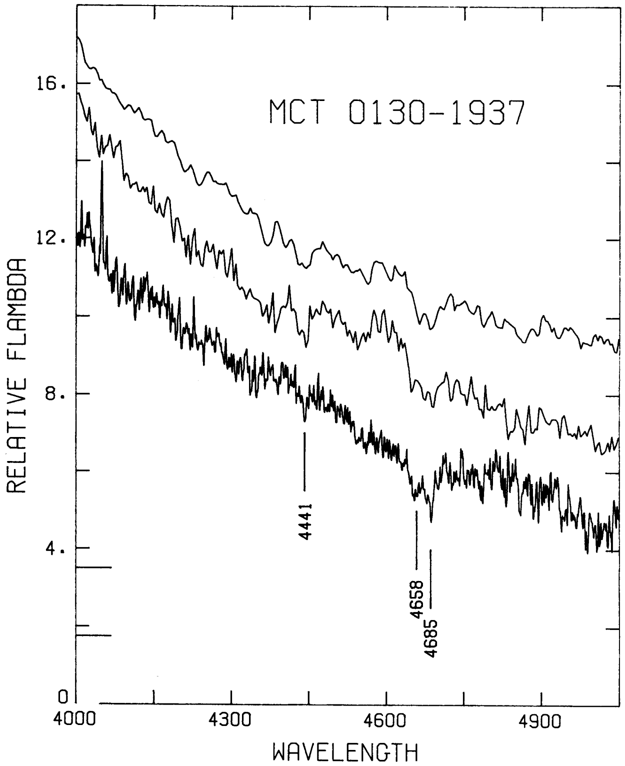

FIG. 2.—Optical spectra of MCT 0130−1937. These are, from top to bottom, our discovery SIT scan at 13.5 Å resolution; a CTIO 1.5 m spectrum at 8 Å resolution; and a Steward Observatory 2.3 m spectrum at 2.5 Å resolution. The C IV feature at 4441 Å and the characteristic C IV λ4658–He II λ4686 blend are indicated.

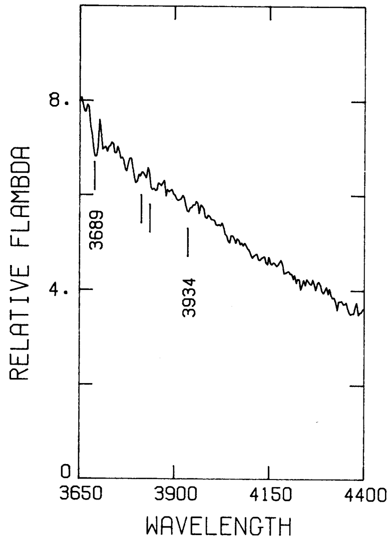

FIG. 3.—Average optical ultraviolet CCD spectrum of MCT 0130−1937 at ∼8 Å resolution. The observed C IV transitions at 3689 Å and 3934 Å are indicated, as well as the expected location of O VI features (3811 Å, 3834 Å) generally seen in higher resolution data on stars of this type.

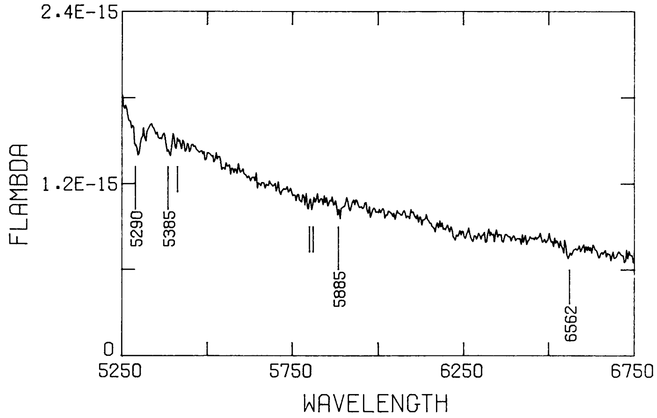

FIG. 4.—Red CCD spectrum of MCT 0130−1937 at 7 Å resolution. The strong O VI feature near 5290 Å and the He II λ6562 feature are indicated. The expected location of the He II λ5411 and of the C IV doublet λλ5801, 5812 are shown as well. The latter could be present, albeit weakly. The features at 5385 Å and 5885 Å are also labeled but remain unidentified. All lines present appear in absorption, and there is no evidence, at this resolution, for central emission reversals in any of them.

data, although the latter could be present as well. At our modest resolution (∼8 Å), these very narrow transitions could easily have escaped detection, especially if they exhibit the emission reversals observed in most members of that class.

MCT 0130−1937 was observed as well in the 5100–6700 Å region of the spectrum in the course of a backup program on the CTIO 4 m telescope on 1988 September 25. The resolution achieved was 7 Å. This red spectrum, shown in Figure 4, shows several features which we identify with transitions in the He II, C IV, and O VI ions. The strongest feature observed, the O VI λ5290 transition, is in absorption with little evidence—at our modest resolution—of a central reversal. Werner, Heber, and Hunger (1989*a*, *b*) report that feature with a strong central emission reversal in PG 1159−035, albeit at better resolution. Present as well in our data is the He II λ6562 (4–6) transition, but not the higher (4–7) λ5411 member of that series. In addition, two features are observed near 5385 Å and 5885 Å. While it may have been reasonable to suspect that these are related to the C IV and O VI transitions observed elsewhere in the spectrum, the recent lists of Husfeld and Butler (1989) and Werner (1989) provide no more convincing identification for these transitions than did the tabulations of Wiese, Smith, and Glennon (1966) or Moore (1972). Furthermore, these lines are not seen in the red spectrum of PG 1159−035. Also indicated in Figure 4 is the location of the C IV (3*s*–3*p*) doublet λλ5801, 5812 which appears in pure emission in PG 1159−035 (Werner, Heber, and Hunger 1989*a*, *b*), but which is at best weak in our lower resolution data on MCT 0130−1937. Not unexpectedly, the higher 6*s*–7*p* transition, near 6592 Å, does not show up in our scan either.

TABLE 2

LOG OF *IUE* OBSERVATIONS

Image Number	Date (1987)	$t_{\rm exp}$ (minutes)
SWP 31695	Sep 2	50
SWP 31696	Sep 3	70
SWP 32193	Oct 30	90
LWP 11558	Sep 3	100

b) *Ultraviolet Spectrophotometry*

MCT 0130−1937 was observed with the *IUE* satellite on two occasions in 1987. A complete log of these *IUE* observations is given in Table 2. All observations were obtained in the low-dispersion (∼7 Å) mode, through the large (10″ × 20″) aperture. The absolute flux recalibration for the SWP camera of Bohlin (1986) was used and was augmented with the correction suggested by Hackney, Hackney, and Kondo (1982) to account for exposure—and wavelength-dependent continuum distortions near 1600 Å; the resulting fluxes were further corrected for the time-dependent sensitivity loss of the camera, as described by Bohlin and Grillmair (1988). For the LWP camera data we used the absolute flux recalibration of Oliversen (1988); also, the sensitivity loss was taken into account as well, following Garhart and Teays (1988).

The low-dispersion, average spectrum of MCT 0130−1937 in the 1200–2000 Å range is displayed in Figure 5, together with that of PG 1159−035 (SWP 23031), which was recently rediscussed by Liebert *et al.* (1989). Prominent in the spectrum of MCT 0130−1937 is the He II λ1640 transition, of equivalent width ∼2.9 Å, as well as a broad absorption feature near 1351 Å. The existence of this feature in the spectrum of PG 1159−035 has been discussed at length by Liebert *et al.* (1989) and is attributed there to a blend of transitions between highly excited levels of C IV (4*d*–7*f* at 1351.2 Å and 4*f*–7*d*/*g* at 1352.9 Å. We find the same feature in MCT 0130−1937, albeit considerably stronger and more complex. Its width is ∼4.8 Å if the structure observed near 1340 Å and 1367 Å is included in the measurement, ∼2.3 Å otherwise. Additional transitions, noted by Liebert *et al.* in the low-dispersion spectrum of PG 1159−035 (see their Fig. 2 and Table I) and possibly present in MCT 0130−1937 are those at 1260 Å and 1587 Å, the latter associated with the C IV 4*p*–6*d* λ1586.1 transition. In addition, our data reveal at least three features near 1502 Å, 1550 Å, and 1620 Å which are not conspicuous in the particular scan of PG 1159−035 shown in Figure 5.[7] Note that the prototype, the brightest and best observed object of that class, tends to have the weakest lines among the objects discussed by WGL.

We also constructed ultraviolet energy distributions for both objects by first combining the long-wavelength and short-wavelength images, and binning the resulting spectrum. This procedure initially gave unsatisfactory results for MCT 0130−1936, as the three available SWP images matched unevenly, and generally poorly, with the single LWP image. After inspection of the photowrites provided by the *IUE Observatory*, we believe that this is due to the poor centering of our object in the *IUE* large aperture. This unfortunate occurrence makes impossible the placement of the *IUE* fluxes on an absolute scale. We have thus used the following procedure to generate an energy distribution for MCT 0130−1937: the *IUE* fluxes for the best exposed SWP images (31696 and 32193) were first normalized (near 1475 Å), and then averaged. This average SWP image was then scaled and tacked onto the end of the LWP image. Note that the LWP image also suffers from absolute calibration problems, just like its SWP counterparts. Indeed, SWP 31696 and LWP 11558, taken one after the other, do not match perfectly near 2000 Å. Clearly, minute tracking errors are sufficient, in that case, to

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[7] Two of these features, near 1504 Å and 1547 Å, had been reported in earlier low-dispersion images of PG 1159−035 (see Table I of Liebert *et al.* 1989). The high-dispersion spectrum of PG 1159−035 indeed shows two possible features at 1503.1, 1504.3 Å for an uncertain combined width of ∼310 mÅ, as well as the C IV λ1550 resonance doublet of width ∼1 Å (see Table III of Liebert *et al.* 1989).

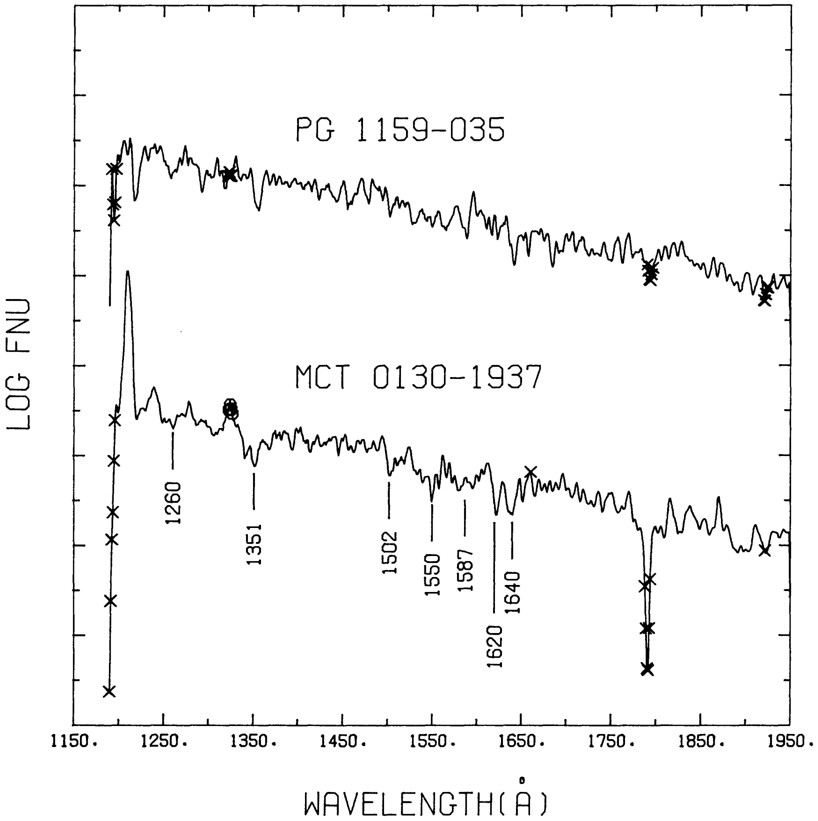

FIG. 5.—Average low-resolution SWP spectrum of MCT 0130−1937 (SWP 31696 and 32193) compared to that of PG 1159−035 (SWP 23031). Both spectra have been smoothed with a three-point filter. The characteristic C IV complex near 1351 Å, discussed by Liebert *et al.* (1989), the He II λ1640 transition, and several other features of interest are marked. Reseau marks and bright spots are indicated as well. Tick marks are separated by 0.125 dex.

cause noticeable offsets in the absolutely calibrated fluxes. The resulting energy distribution is compared to that of PG 1159−035 in Figure 6. For the latter, we combined a recent SWP image with the better exposed of the two existing long-wavelength images, LWR 6193. We have, for the latter, used the absolute recalibrations of Holm *et al.* (1982) and Bohlin (1986), as well as the corrections for the time-dependent sensitivity loss of Bohlin and Grillmair (1988).

Figure 6 confirms the high effective temperature of MCT 0130−1937, suspected from its belonging to the PG 1159 spectroscopic subclass. Its energy distribution is similar to that of the prototype, with a steep, steady rise toward the ultraviolet. It is entirely consistent with the ν^2 Rayleigh-Jeans tail of a high-temperature photosphere. In this respect, the energy distribution of MCT 0130−1937 is consistent with those published for other members of that class (WGL; Sion *et al.* 1984; Nousek *et al.* 1986).

We have also searched both the *Einstein* and *EXOSAT* observing logs for possible serendipitous soft X-ray observations of MCT 0130−1937, and found no fields which included this object. Of the known sample of 13 PG 1159–like objects, five have been observed at X-ray wavelengths by either *Einstein* or *EXOSAT*, and four have been detected (PG 1159−035, H1504+65, K1-16, and PG 1144+005). Soft X-ray observations, in addition to helping estimate effective temperatures in these objects, are proving as well extremely useful in constraining the atmospheric CNO abundances (Barstow and Tweedy 1989; Vennes, Fontaine, and Wesemael 1989; Barstow and Holberg 1989).

c) *Multicolor Photometry*

Single broad-band *U*, *B*, and *V* CCD frames were obtained for this star on 1987 November 5/6 with the CTIO 1.0 m telescope, using the RCA No. 5 CCD chip. The standard CTIO set of *UBV* filters was used, and extinction and transformation coefficients were determined from observations of several standard stars from the lists of Stobie, Sagar, and Gilmore (1985) and Graham (1982). In addition, photoelectric narrow-band Strömgren photometry was obtained on two nights in 1988 September on the CTIO 1.5 m and 1.0 m telescopes. The standard CTIO set of Strömgren filters was used here as well, and standard stars were selected from the lists of Crawford, Barnes, and Golson (1971) and Cousins (1987). The resulting magnitudes and colors are all listed in Table 1.

d) *High-Speed Photometry*

High-speed photometry was obtained for this object during two nights in 1988 September. On the first night, a single-channel photometer was attached to the Cerro Tololo Inter-

TABLE 3

HIGH-SPEED PHOTOMETRY LOG

Date (1988)	Telescope	Starting UT	Run Duration (hr)	Integration Time (s)
Sep 14..........	CTIO 1.0 m	05:40	3.1	5
Sep 19..........	CTIO 1.5 m	08:18	1.1	5

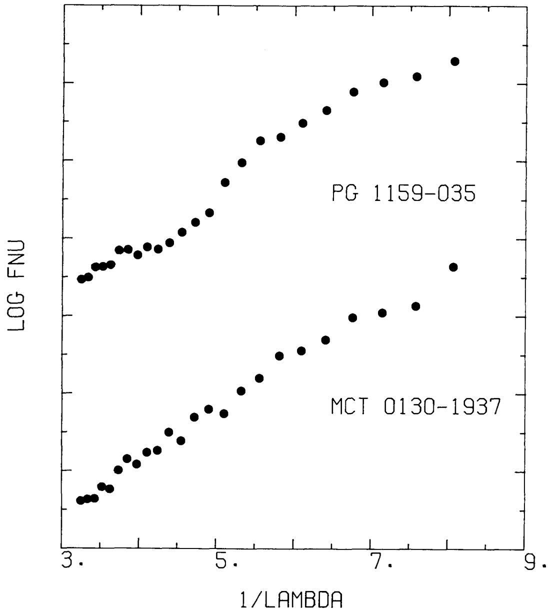

FIG. 6.—Ultraviolet energy distributions of PG 1159−035 (*top*) and MCT 0130−1937 (*bottom*). The abscissa is in μm^{-1}. The energy distributions are constructed by combining the following images: SWP 23031 and LWR 6193 for PG 1159−035; SWP 31696 and 32193 and LWP 11558 for MCT 0130−1937. The images of MCT 0130−1937 cannot be placed on an absolute scale because of uncertainties in the absolute calibration caused by the poor centering of the object in the *IUE* aperture. Each tick mark corresponds to 0.125 dex. The bin size is 80 Å, and the drop in flux near $1/\lambda = 7.4$ μm^{-1} in MCT 0130−1937 is due to the broad absorption feature near 1351 Å (see Fig. 5).

american Observatory 1.0 m telescope, while the CTIO 1.5 m telescope was used on the second run. The observing log is given in Table 3. In both cases, the slowly varying extinction was first removed by dividing each data string by a best-fit cubic polynomial.

Neither of the two light curves exhibited any obvious periodicities. This was later confirmed by the Fourier analysis of both runs. Figure 7 shows the complete power spectrum of our longest light curve (run 1). We have inserted an artificial signal of amplitude equal to 0.5% of the intensity of the star at 10 mHz. The tracer, with its normalized power equal to 1, dominates the power spectrum. The normalized power of the largest peaks is less than 0.1, meaning that the maximum semi-amplitudes of possible periodicities are less than 0.002 mag. The period interval covered ranges from about 10 s (set by the 5 s integration time) to about 2000 s (or roughly one-fifth of the length of the data string). Our limit on the maximal semi-amplitude compares favorably with those recently set by Grauer *et al.* (1987) on four objects in the PG 1159 spectroscopic class. The limits set by the shorter, second run are not as stringent ($\Delta m \leq 0.003$ mag); they suggest, nevertheless that the results of our first run are probably not due to a phase of relative quiescence due to the beating of closely spaced pulsation modes (Bond *et al.* 1984).

III. DISCUSSION

Our identification of the ultraviolet-excess object MCT 0130−1937 as a new member of the PG 1159 spectroscopic class brings the number of such stars to 13. The class appears particularly homogeneous from a spectroscopic point of view: the 4640–4690 Å complex in the optical is present in all members and is a reliable spectroscopic indicator of membership to that class, as that blend is recognized even at modest resolution. The 1350 Å trough, recently identified as heavily broadened C IV features (Liebert *et al.* 1989), appears to be another fairly common feature of all members observed in the ultraviolet and can, likewise, be detected at the modest resolution ($\sim$7 Å) of the low-dispersion mode of the *IUE*.

A very preliminary interpretation of the observed optical and ultraviolet spectra is possible on the basis of unpublished models calculated by Werner (1989). From those, it appears that the relative strengths of the optical C IV $\lambda\lambda$5801, 5812 doublet and of the strong ultraviolet C IV λ1351 feature can be reconciled for an effective temperature near 120,000 K, a result which is only weakly dependent on the carbon abundance. This temperature also appears to be consistent with the presence of O VI λ5290 in absorption rather than in emission, although the latter result does depend on the oxygen abun-

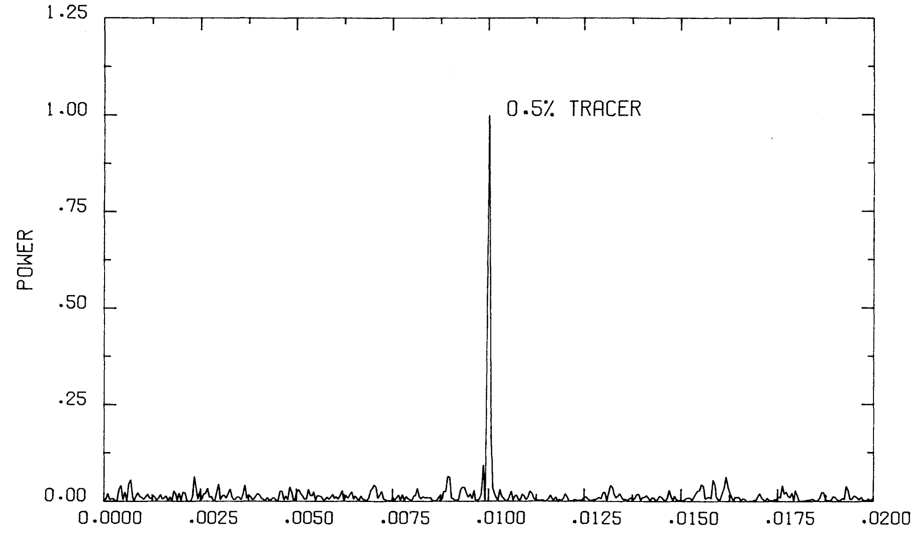

FIG. 7.—Power spectrum for our longest run (3.1 hr) of white-light, high-speed photometry on MCT 0130−1937. The peak at 10 mHz is an artificial tracer, of amplitude equivalent to 0.5% of the star's amplitude at that frequency. The limit on the semiamplitude of variation during that run is 0.002 mag.

1159 stars simply evolve into helium-rich white dwarfs while the more numerous hydrogen-rich PN nuclei would eventually evolve into DA white dwarfs. In contrast, Fontaine and Wesemael (1987) argue that a single channel, perhaps fed predomi-dance, which is not known. At these relatively low temperatures, however, the absence of He II $\lambda5411$ may be somewhat unexpected. Clearly this object, which thus appears somewhat cooler than PG 1159−035 ($T_e \sim 140{,}000$ K) itself, is deserving of its own detailed model atmosphere analysis.

Interestingly, of the 13 known PG 1159 objects, eight were first recognized in the Palomar-Green survey of ultraviolet-excess objects at high Galactic latitudes (Green, Schmidt, and Liebert 1986). The rich yield of these objects in colorimetric surveys, where completeness can in principle be controlled, suggests that an improved estimate of the space density of these objects will become available when the PG survey is fully extended to the southern hemisphere. The current estimate of $n_{1159} = 6 \times 10^{-8}$ pc^{-3} rests on the seven objects originally identified in the PG survey, and on an average M_v, assumed to be characteristic of the sample as a whole (WGL); this space density is uncertain by at least a factor of 3. Identifications of additional objects in ongoing searches for ultraviolet-excess objects, together with improved determinations of their basic stellar parameters, should help refine this number considerably.

These issues will, most likely, have a considerable impact on current models of the spectral evolution of white dwarf stars at lower luminosities. In Weidemann's (1987) scheme, the PG nantly by PG 1159 objects, might be a more satisfactory way to account for the interplay of spectral types observed on the white dwarf sequence. An improved knowledge of the space density of PG 1159 stars may thus well hold the key to further progress in these areas.

The frequency of GW Vir stars among the PG 1159 objects ($\sim 50\%$) also raises interesting questions concerning the pulsation properties of these objects: do the six known pulsators define an instability strip, similar to those observed among their cooler ZZ Ceti and V477 Her siblings? If so, is the effective temperature a unique predictor of variability, or do additional parameters (envelope abundances, layer masses, gravity, etc.) influence the stability of individual objects? Statistical studies of the GW Vir stars and the mapping of their instability strip (if one exists) will require a much larger sample of PG 1159 stars which will be most efficiently obtained from continuing searches for ultraviolet-excess objects at high Galactic latitudes.

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REFERENCES

Barstow, M. A., and Holberg, J. B. 1989, in *EUV Astronomy*, ed. R. F. Malina and C. S. Bowyer (Elmsford, N.Y.: Pergamon), in press.
Barstow, M. A., and Tweedy, R. W. 1989, *M.N.R.A.S.*, in press.
Bohlin, R. C. 1986, *Ap. J.*, **308**, 1001.
Bohlin, R. C., and Grillmair, C. J. 1988, *Ap. J. Suppl.*, **68**, 487.
Bond, H. E., and Ciardullo, R. 1989, in *IAU Colloquium 114, White Dwarfs*, ed. G. Wegner (New York: Springer), p. 473.
Bond, H. E., and Grauer, A. D. 1987, *Ap. J. (Letters)*, **321**, L123.
Bond, H. E., Grauer, A. D., Green, R. F., and Liebert, J. W. 1984, *Ap. J.*, **279**, 751.
Cousins, A. W. J. 1987, *South African Astr. Obs. Circ.*, No. 11, p. 93.
Crawford, D. L., Barnes, J. V., and Golson, J. C. 1971, *A.J.*, **76**, 1058.
Demers, S., Kibblewhite, E. J., Irwin, M. J., Nithakorn, D. S., Béland, S., Fontaine, G., and Wesemael, F. 1986, *A.J.*, **92**, 878.
Fontaine, G., and Wesemael, F. 1987, in *IAU Colloquium 95, The Second Conference on Faint Blue Stars*, ed. A. G. D. Philip, D. S. Hayes, and J. W. Liebert (Schenectady: L. Davis), p. 319.
Garhart, M. P., and Teays, T. J. 1988, *IUE Newsletter*, No. 35, p. 99.
Giclas, H. L., Burnham, R., Jr., and Thomas, N. G. 1975, *Lowell Observatory Bull.*, Vol. **8**, No. 2.
Graham, J. A. 1982, *Pub. A.S.P.*, **94**, 244.
Grauer, A. D., and Bond, H. E. 1984, *Ap. J.*, **277**, 211.
Grauer, A. D., Bond, H. E., Liebert, J., Fleming, T. A., and Green, R. F. 1987, *Ap. J.*, **323**, 271.
Green, R. F., Schmidt, M., and Liebert, J. 1986, *Ap. J. Suppl.*, **61**, 305.
Hackney, R. L., Hackney, K. R. H., and Kondo, Y. 1982, in *Advances in Ultraviolet Astronomy: Four Years of IUE Research*, ed. Y. Kondo, J. M. Mead, and R. D. Chapman (Washington, DC: NASA), p. 335.
Haro, G., and Luyten, W. J. 1962, *Boletin de los Observatorios Tonantzintla y Tacubaya*, Vol. **3**, No. 22.
Holm, A., Bohlin, R. C., Cassatella, A., Ponz, D. P., and Schiffer, F. H. 1982, *Astr. Ap.*, **112**, 341.
Husfeld, D., and Butler, K. 1989, private communication.
Liebert, J., Wesemael, F., Husfeld, D., Wehrse, R., Starrfield, S. G., and Sion, E. M. 1989, *A.J.*, **97**, 1440.
McGraw, J. T., Starrfield, S. G., Liebert, J., and Green, R. F. 1979, in *IAU Colloquium 53, White Dwarfs and Variable Degenerate Stars*, ed. H. M. Van Horn and V. Weidemann (Rochester: University of Rochester), p. 377.
Moore, C. E. 1972, *A Multiplet Table of Astrophysical Interest* (NSRDS-NBS 40) (Washington, DC: US Government Printing Office).
Nousek, J. A., Shipman, H. L., Holberg, J. B., Liebert, J., Pravdo, S. H., White, N. E., and Giommi, P. 1986, *Ap. J.*, **309**, 230.
Oliversen, N. A. 1988, *IUE Newsletter*, No. 35, p. 55.
Sion, E. M., Liebert, J., and Starrfield, S. G. 1985, *Ap. J.*, **292**, 471.
Sion, E. M., Liebert, J., Starrfield, S. G., and Wesemael, F. 1984, in *Future of Ultraviolet Astronomy Based on Six Years of IUE Research*, ed. Y. Kondo, R. D. Chapman, and J. M. Mead (Washington, DC: NASA), p. 273.
Stobie, R. S., Sagar, R., and Gilmore, G. 1985, *Astr. Ap. Suppl.*, **60**, 503.
Vennes, S., Fontaine, G., and Wesemael, F. 1989, in *IAU Colloquium 114, White Dwarfs*, ed. G. Wegner (New York: Springer), p. 363.
Weidemann, V. 1987, in *IAU Colloquium 95, The Second Conference on Faint Blue Stars*, ed. A. G. D. Philip, D. S. Hayes, and J. W. Liebert (Schenectady: L. Davis), p. 19.
Werner, K. 1989, private communication.
Werner, K., Heber, U., and Hunger, K. 1989*a*, in *IAU Colloquium 114, White Dwarfs*, ed. G. Wegner (New York: Springer), p. 194.
———. 1989*b*, in *Hot Star Workshop: Intrinsic Properties of Hot Luminous Stars*, in press.
Wesemael, F., Green, R. F., and Liebert, J. 1985, *Ap. J. Suppl.*, **58**, 379 (WGL).
Wiese, W. L., Smith, M. W., and Glennon, B. M. 1966, *Atomic Transition Probabilities*, Vol. **1** (NSRDS-NBS4) (Washington, DC: US Government Printing Office).
Winget, D. E. 1988, in *IAU Symposium 123, Advances in Helio- and Asteroseismology*, ed. J. Christensen-Dalsgaard and S. Frandsen (Dordrecht: Reidel), p. 305.

S. DEMERS, G. FONTAINE, R. LAMONTAGNE, and F. WESEMAEL: Département de Physique, Université de Montréal, C.P. 6128, Succ. A, Montréal, Québec, Canada H3C 3J7

J. B. HOLBERG: Lunar and Planetary Laboratory West, 9th Floor, Gould-Simpson Building, University of Arizona, Tucson, AZ 85721

M. J. IRWIN: Institute of Astronomy, Cambridge University, Madingley Road, Cambridge, CB3 0HA, UK

S. O. KEPLER: Instituto de Fisica, Universidade Federal do Rio Grande do Sul, 91500 Porto Alegre, RS, Brazil