PG1159-035: A NEW, HOT, NON-DA PULSATING DEGENERATE

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Introduction

PG1159-035 was originally detected as a 14.5 mag. blue object in a survey for QSO candidates (Green 1977). An SIT spectrogram obtained at the Hale 5m telescope at 6Å resolution showed this star to have a very blue continuum with absorption features near λ4686 and λ4650 which were tentatively attributed to HeII and the CIII/CIV complex, respectively. Possible narrow emission components to these lines appear in Figure 1 which shows confirming spectra obtained with the IIDS (at 2.5Å resolution) on the Kitt Peak 2.1m telescope. The blue continuum and possible presence of HeII in emission suggested that this star was perhaps similar to the helium mass-transfer binary AM CVn (HZ 29). For this reason, we put PG1159-035 on our program of high-speed photometry, expecting the star to show "flickering" associated with mass transfer into an accretion disk and possible orbital modulation or eclipses in the period range 10-20 minutes--photometric characteristics similar to those observed in AM CVn.

Observations

On 29 April, 1979 UT, we observed PG1159-035 using the Steward Observatory computer-controlled high-speed photometer mounted on the Multiple Mirror Telescope on Mount Hopkins. The real-time display of the light curve, which is provided by the data acquisition system, showed PG1159-035 to have nearly sinusoidal variations with a period of about 8 minutes and a peak-to-peak amplitude of about 0.02 magnitude--variations totally unlike those we expected to see (McGraw et al., 1979). Figure 2 shows the light curve obtained on 29 April, corrected for extinction. No filter was used, therefore the response of the photometer

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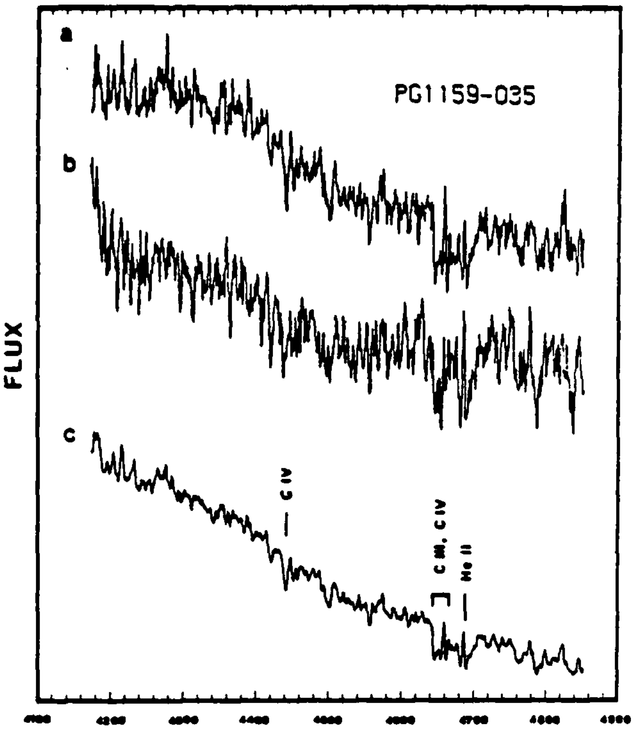

Fig. 1. IIDS spectra obtained on (a) 5 April 1979 UT, (b) 6 April, and (c) the smoothed sum of these two.

was that of our EMI 6256 photomultiplier. Observations of constant stars and variable stars with known periods were made to ensure that the variations seen in the light curve were definitely intrinsic to the star. Observations confirming the variability of this star were subsequently made by us using the MMT and the Steward Observatory 0.91m telescope and by R.E. Nather using the McDonald Observatory 2.08m telescope.

To investigate the period structure of PG1159-035 in more detail, power spectra of the light curves were calculated. Figure 3 (top panel) shows the power spectrum of the light curve obtained on 29 April. The power spectrum of the light curve of the known ZZ Ceti variable G117- B15A obtained on the same night is shown in the lower panel for comparison. The results for G117-B15A are completely consistent with earlier data obtained at McDonald Observatory (McGraw and Robinson 1976). The power spectrum for PG1159-035 shows two significant peaks at frequencies of about 1.86 and 2.17 milliherz, corresponding to periods of about 539 and 460 seconds, respectively. The width of each peak corresponds to the resolu-

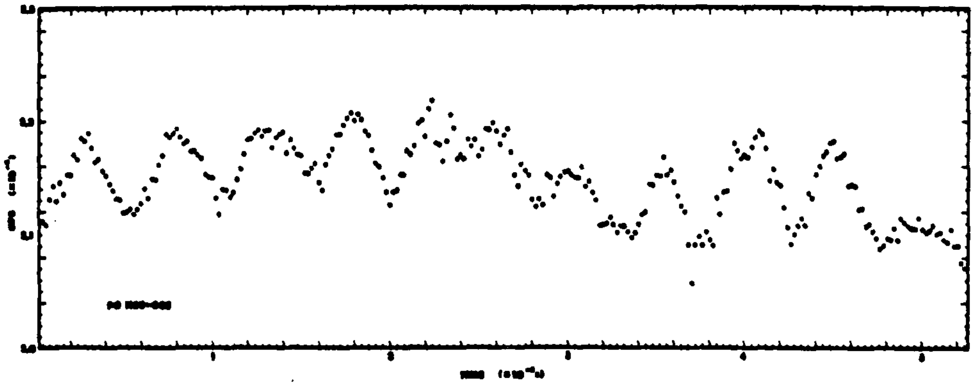

Fig. 2. "White" light curve of PG1159-035 obtained on 29 April. The abscissa is labelled every 1000 seconds. The ordinate is expressed as detected counts per second outside the atmosphere.

tion of the spectrum, which is determined by the length of the light curve. It appears that the light curve reflects the "mean" of these two periods and that the interference ("beating") seen in the light curve may be due to the presence of these two closely-spaced periods.

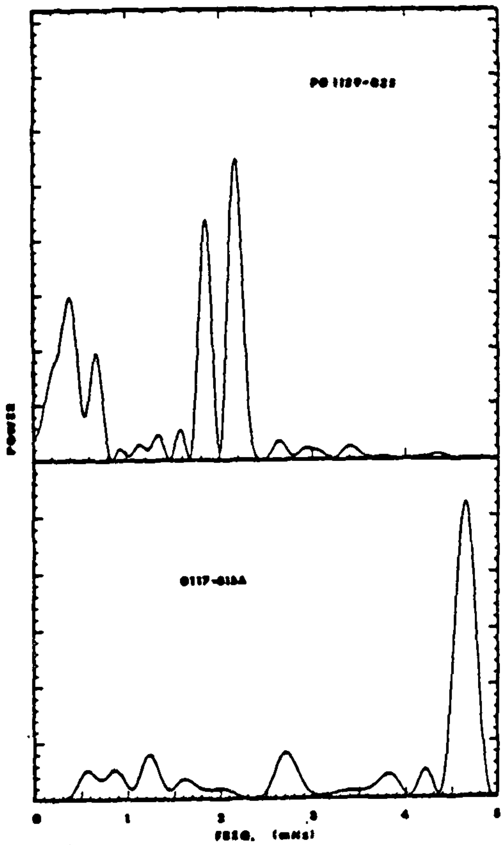

Fig. 3. Power spectra of the light curve shown in Fig. 2 (upper) and of the light curve of G117-B15A obtained the same night (lower).

We have obtained information on the physical properties of PG1159-035 by several techniques. Using plate material spanning a 13 year baseline, W.J. Luyten has measured a relative proper motion of 0.00 ± 0.10 arc sec/year. We have used the MMT to obtain Stromgren colors for the star. Wegner (1979, private communication) has also obtained Stromgren photometry. Because of the high airmass at which this very blue star was measured, the uncertainties on the colors are large, but they indicate that the effective temperature is greater than 50,000 K. Multi-channel scanner data (Oke 1979, private communication) confirms that to a wavelength of 3200Å, the energy distribution is characteristic of a Rayleigh-Jeans slope and the effective temperature exceeds 50,000 K. We have observed the star using the Angel (Angel and Landstreet, 1970) polarimeter and have found no circular polarization, indicating that it does not possess a large surface magnetic field. Finally, the Einstein satellite has observed the field of PG1159-035 and, on the basis of "quick-look" data, has made a marginal detection (Seward 1979, private communication).

Discussion

Using these data together, we find that this star is very hot, at least 50,000 K. The surface gravity is indeterminate, basically because at this high temperature there are no sensitive gravity discriminants from optical observations. The sharpness of the spectral features (Figure 1) and null proper motion favor a surface gravity somewhat lower than log g $\gtrsim$ 8. Again, because of the high temperature, at this time we can make no estimates of the abundances. It is possible, though not likely, that H is completely ionized and the surface abundances are normal. It is more likely that surface hydrogen is depleted and PG1159-035 is an evolved object. An analysis of the period structure of PG1159-035 can be made independant of its physical structure, however.

The power spectrum of the light curve of PG1159-035 indicates the presence of two closely spaced periods in the light curve which makes it unlikely that the variations are caused by either orbital motion or rotation, both of which are singly-periodic mechanisms. It is more likely that we are observing a pulsating star. The light curve and power spectrum of PG1159-035 are virtually identical to those of certain ZZ Ceti variables - known nonradially pulsating DA white dwarfs (cf. Robinson, this Colloquium). We stress, however, that because both the luminosity and effective temperature of PG1159-035 are much higher than for a ZZ Ceti variable and the surface composition is probably different, this star cannot be included in the ZZ Ceti class of variable stars. In particular, the excitation mechanism operative in PG1159-035 cannot be the same as that for the ZZ Ceti stars (cf. Dziembowski; Starrfield, Cox, and Hodson; Keeley, all in this Colloquium). In fact, until we more accurately determine the structure of PG1159-035, we cannot even identify the modes in which this star is pulsating-in fact, it is possible that this star is pulsating in radial modes rather than the nonradial modes characteristic of the ZZ Ceti variables. Whatever the pulsation mode, the presence of C IV in the optical spectrum suggests that the driving mechanism may be produced by a succeeding ionization of some highly ionized abundant element such as carbon. Pulsation analyses of hot, luminous stars should be performed to test this suggestion.

Finally, we point out that whatever the structure and evolutionary state of PG1159-035, it is likely to be changing rapidly. If, for example, this star is in the process of becoming a white dwarf, it will be cooling rapidly. The periods of the pulsations must then change to accomodate the changing structure of the star (McGraw 1977, and this Colloquium). Because we can measure the periods very accurately, over a sufficiently long time we will be able to infer much about the properties of the star by observing the light curve. The first steps toward implementing this technique for the stably pulsating ZZ Ceti variables have already been taken (Robinson et al. 1976, Stover et al. 1977, Stover et al. 1979). Because it is much hotter, the rate of cooling of PG1159-035 and, therefore, the rate of change of the pulsation periods, will be much faster in this variable than in a ZZ Ceti star. In particular, this type of analysis may allow us to determine the effect of neutrino cooling as a star becomes a white dwarf. Thus, it may be possible to observe a change in the internal structure of a star based only on observational data obtained during a human lifetime.

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