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# PROPER-MOTION SURVEY. I. COMMON-PROPER-MOTION SYSTEMS IN ESO AREAS 439 AND 440

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## ABSTRACT

Spectra and *BVRI* CCD photometry of stars members of 15 common-proper-motion systems, found in red ESO Schmidt plates (areas 439 and 440) were used to derive their spectral types and distances. The sample contains two emission-line red dwarfs, one double degenerate pair, and three systems with one degenerate component, one of which is a spectroscopic binary.

## I. INTRODUCTION

In a search program for large proper-motion stars in two ESO Schmidt plates (5°×5°), Area 439 and Area 440, we have found several hundred new proper-motion stars. Among them we identified 14 common-proper-motion (cpm) pairs plus one system of four stars sharing a common proper motion.

The present sample includes only those pairs that are close enough in angular separation as to be projected near the center of the field at the blink comparator during the search process. We also excluded stars with proper motions less than 0.1″ yr$^{-1}$. Seven out of 15 systems found had been already cataloged by Luyten (1957, 1978).

Given that cpm systems can provide important information about stellar evolution, masses, and other basic stellar parameters, we decided to obtain spectra and photometry of the stars in our sample.

## II. OBSERVATIONS

### *a) Search and Proper Motions*

Search plates were obtained with the ESO Schmidt Camera at La Silla, using a IIIa-F emulsion and an RG630 filter. With an exposure time of 2 hr the plate limit is at $m_R \simeq 21$. The time base for proper motions was 7 yr for area 439 and 9 yr for area 440. The procedure used to calculate them was described by Ruiz *et al.* (1988). Figures 1(a)–1(m) [Plate 38] are finding charts for the objects [finding charts for objects 439-162/163 and 440-55A/55B have already been published by Ruiz and Maza (1988a,b)].

### *b) Spectroscopy*

Spectra of the program stars were obtained in April 1989, with the 4 m telescope at CTIO, using an R-C spectrograph and a CCD detector, and with the 3.6 m ESO telescope at La Silla equipped with EFOSC (B300 grism) and a CCD detector. Table I gives a summary of the observations. The spectrograms start at about 3600 Å and extend up to about 7000 Å with a resolution of 15 Å. The spectra are shown in Fig. 2, they were flux and wavelength calibrated using IRAF packages at CTIO computing facilities at La Serena. Given that we used a slit only 2″ wide which did not include all of the light from the stars (especially from the brightest stars), the fluxes in Fig. 2 should not be considered absolute fluxes.

### *c) CCD Photometry*

During the nights of 30 and 31 March 1989 we used the 1.5 m telescope at CTIO in order to obtain *BVRI* CCD photometry of our proper-motion stars. The detector was an RCA chip. The filters were Johnson's *B*, *V* and *R*, *I* of Kron–Cousins. During each night we observed Graham's E field standards for calibration (Graham 1982). The photometry was reduced using DAOPHOT on a Microvax II at our institution.

Colors and magnitudes are summarized in Table II (colors have an average precision of 7%), where we also give proper motions ($\mu$), position angles of proper motions ($\theta$), angular distances between the members of each cpm pair (s), and spectral types deduced from their observed spectra in Fig. 2.

## III. RESULTS AND DISCUSSION

A spectral type has been assigned to each star based upon their absorption spectra. For this purpose we observed several previously classified stars with the same instrumentation used for the observation of program stars. The spectral types are listed in Table II.

Wing and Dean (1983), calibrated the strength of TiO bands (spectral types) in nearby K and M stars, with their absolute visual magnitudes. Making use of such calibration, we obtained an absolute visual magnitude for every star in our sample, which together with their observed apparent visual magnitudes (Table II), define a distance to each star. On the other hand, we know that members of a given cpm pair or group must be at the same distance from us, therefore we averaged the distances obtained for each individual component (they never differed by more than 30%), and used the mean distances to get new values for their absolute visual magnitudes and spectral types. The results are summarized in Table III.

Figure 3 shows the observed $R-I$ color as a function of spectral type (Table III). A line has been drawn joining members of a given pair. It is a very tight relation, which was first found by Kron *et al.* (1957) in the development of Kron's *R*, *I* system of photometry and later by Eggen and Greenstein (1965). The fact that the sample as a whole and members of individual pairs fit well in such tight relation provides a check upon our distances and spectral types. We estimate that distances in Table III, have uncertainties of 25% or less.

Among the cpm pairs, we found two emission-line M dwarfs (439-182 and 440-490) showing lines of Ca II (H and K) and Balmer lines. The presence of an active chromo-

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TABLE I. Log of spectroscopic observations.

| Object | Other name | $\alpha(1950)^1$ h m s | $\delta(1950)^1$ ° ' " | Date | Telesc. | Integr. time |
|---|---|---|---|---|---|---|
| 439-162/163 | – | 11 27 25.0 | -31 06 17 | 3/15/88 | ESO 3.6m | 10800 s |
| 439-178N/S | LDS853 | 11 27 06.9 | -31 16 54 | 4/17/89 | CTIO 4m | 15 s |
| 439-70/71 | LDS4089 | 11 19 18.7 | -29 19 06 | – | – | – |
| 439-229/230 | LDS4092 | 11 20 56.0 | -32 06 36 | 4/11/89 | ESO 3.6m | 1920 s |
| 439-9A/B | LDS4126 | 11 36 39.6 | -28 13 49 | 4/15/89 | CTIO 4m | 1500 s |
| 439-96A | | 11 32 53.0 | -29 52 46 | 4/15/89 | CTIO 4m | 240 s |
| 439-96B | LDS4119 | 11 32 52.9 | -29 52 42 | 4/15/89 | CTIO 4m | 600 s |
| 439-95a/b | | 11 32 52.6 | -29 53 37 | 4/15/89 | CTIO 4m | 3600 s |
| 439-181/182 | – | 11 30 41.3 | -31 21 36 | 4/11/89 | ESO 3.6m | 2700 s |
| 439-136/137 | – | 11 21 35.3 | -30 28 57 | 4/12/89 | ESO 3.6m | 1500 s |
| 440-152/153 | LTT4451/2 | 11 55 34.8 | -29 14 33 | 4/15/89 | CTIO 4m | 180 s |
| 440-55A/B | – | 12 04 03.2 | -31 20 27 | 3/15/88 | ESO 3.6m | 7200 s |
| 440-489/490 | – | 11 58 10.6 | -32 30 41 | 4/15/89 | CTIO 4m | 1200 s |
| 440-132/133 | LDS4157 | 11 51 53.3 | -29 01 04 | 4/11/89 | ESO 3.6m | 1200 s |
| 440-178/179 | – | 12 00 18.4 | -29 30 00 | 4/11/89 | ESO 3.6m | 600 s |
| 440-29/30 | – | 12 01 30.6 | -28 04 53 | 4/12/89 | ESO 3.6m | 1200 s |
| 440-386/387 | – | 11 50 04.5 | -31 11 53 | 4/15/89 | CTIO 4m | 600 s |

(1) For objects in area 439 the coordinates epoch is 1986.1 and 1988.5 for those in area 440.

sphere in these stars can imply the existence of a blue continuum which would obliterate the relation between color and spectral type as well as the spectral type itself (based on the depths of TiO bands). In consequence we did not include these stars in the distance calculations, instead we deduced their distances from the spectral types of their nonactive M dwarfs companions. However, the absolute magnitudes (spectral types) thus obtained seem to follow the same $R-I$ vs ST relation as their nonactive counterparts.

We also found a cpm pair formed by a magnetic DQ white dwarf with Swan bands of $C_2$ shifted by a strong magnetic field and a DC9 white dwarf (439-162/163), a description of this cpm pair has been published by Ruiz and Maza (1988a).

Three other systems were found to contain one degenerate component:

(a) **440-55A/55B**, consist of a red dwarf M5.1 and a DZ 7 metallic white dwarf. This pair was discussed by Ruiz and Maza (1988b).

(b) **439-229/230**, formed by an M4.1 red dwarf and a DA 7 white dwarf. The distance to this pair was estimated from the spectral type of the M star. With an absolute visual magnitude $M_V = 14.84$, the DA star (439-229) is two magnitudes fainter than its main-sequence companion. The continuum of 439-229 can be fitted with a 7000 K blackbody. Applying a bolometric correction BC = $-0.35$ (Liebert *et al.* 1988), we get a bolometric magnitude $M_B = 14.49$, indicative of a very small radius and large mass (Weidemann 1978). The equivalent widths (EW) of the most prominent Balmer lines in the spectrum of 439-229 are: $\mathrm{EW}(\mathrm{H}_\gamma) = 6.58$, $\mathrm{EW}(\mathrm{H}_\beta) = 8.45$, and $\mathrm{EW}(\mathrm{H}_\alpha) = 7.08$.

(c) **439-96A/96B/95a/95b** was recognized as a triple cpm system by Luyten (1978). Stars 96A and 96B are normal M dwarfs, but star 95 is a spectroscopic binary with a spectrum composed by a DA type white dwarf (95b) plus an M dwarf (96a). From the red part of the spectrum [see Fig. 2(e)] we classified the M star as an M4. With that information we drew the zero-continuum level for the red dwarf, considering the appropriate depths for the TiO and CaOH bands, corresponding to an M4 star. In Fig. 2(e) we have indicated the zero-continuum level for the M star, which in turn corresponds to the DA star continuum level. From the above argument we conclude that the ratio of fluxes in the visual ($\lambda_{\mathrm{eff}} = 5500$ Å) is $f(\mathrm{M4})/f(\mathrm{DA}) = 2.89$. On the other hand, the total $V$ magnitude (CCD) in Table II is

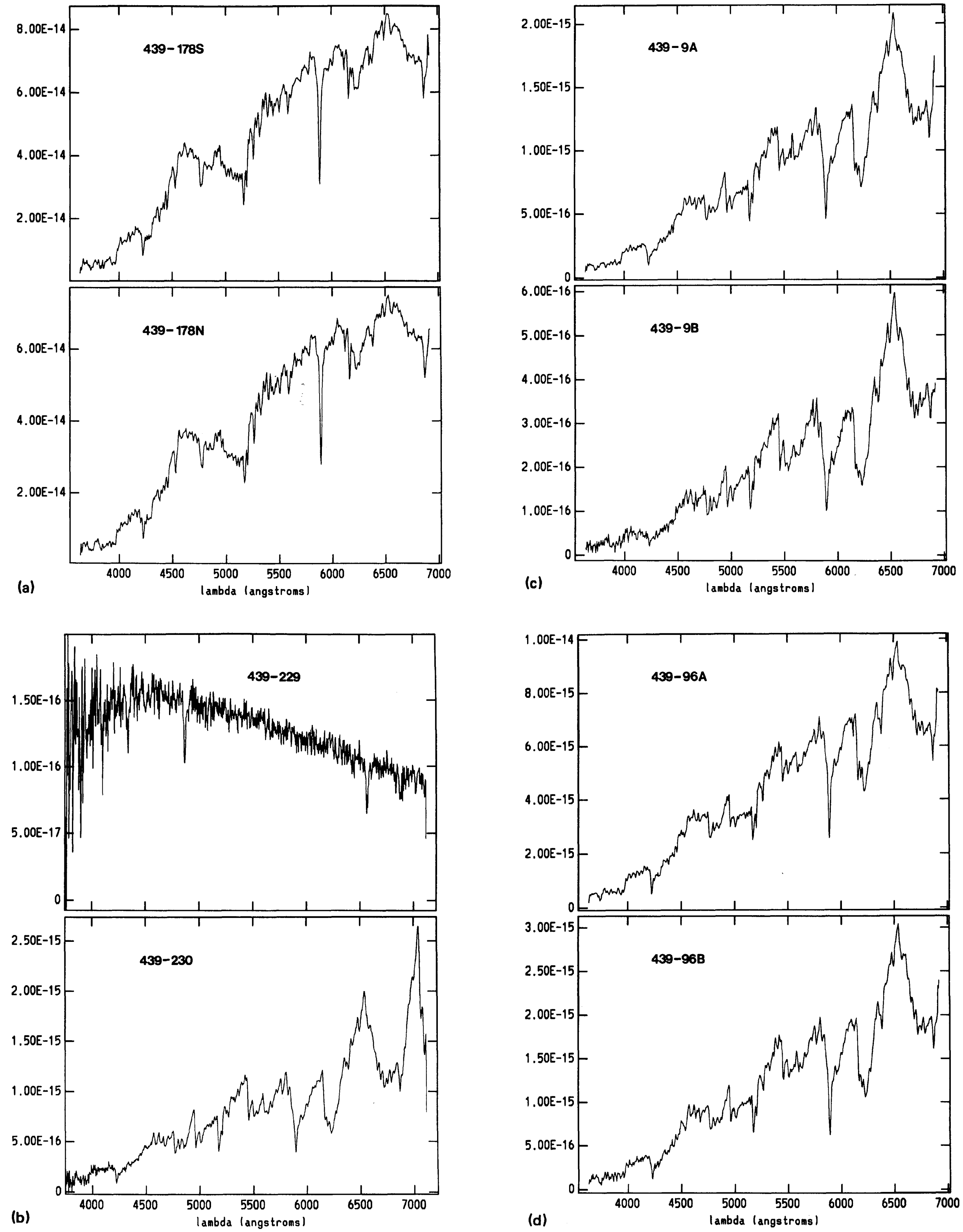

FIG. 2. Spectra of the cpm stars obtained with the instruments and integration times given in Table I. Fluxes ($F_\lambda$) are in units of ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$ and wavelengths in Ångstroms.

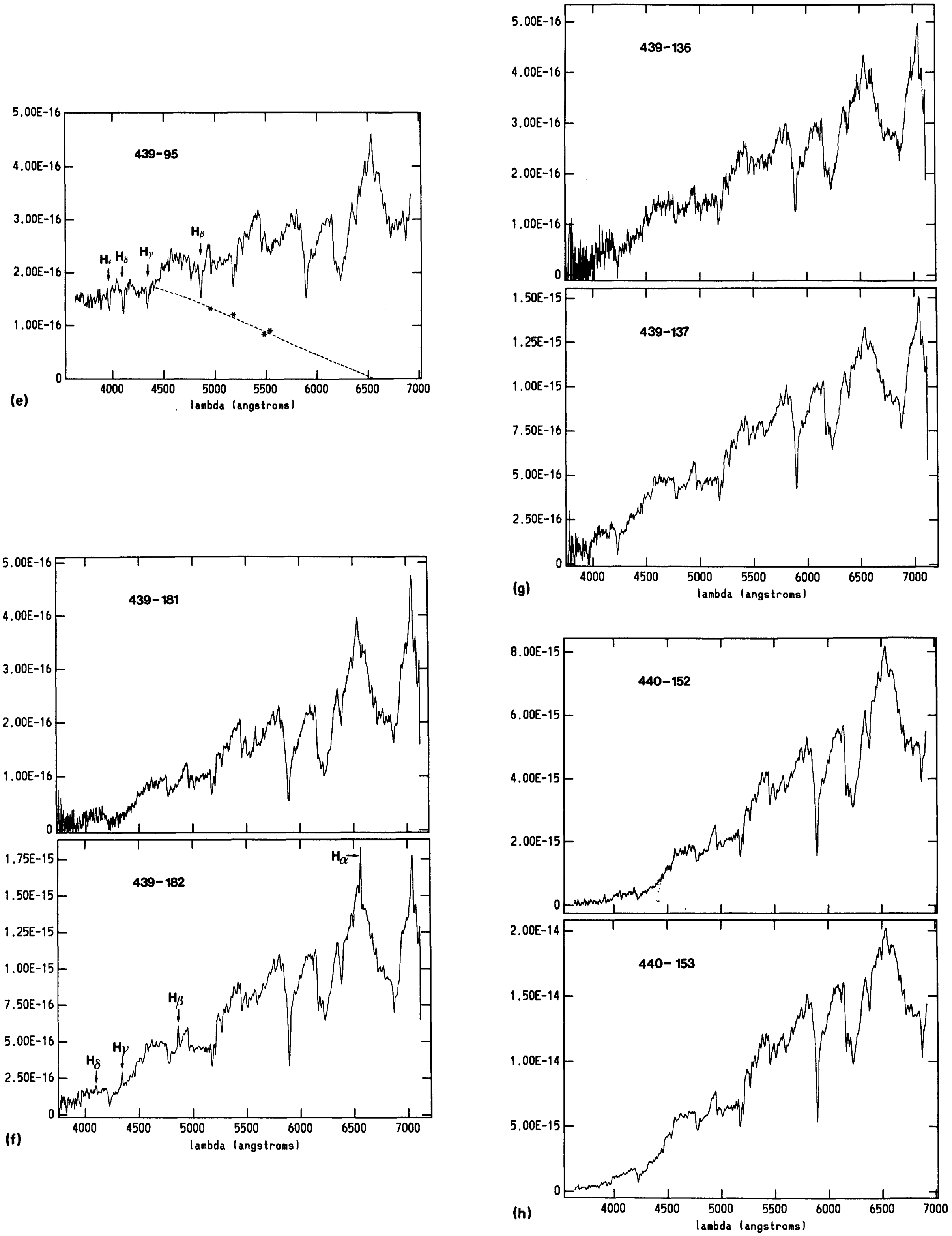

FIG. 2. (continued)

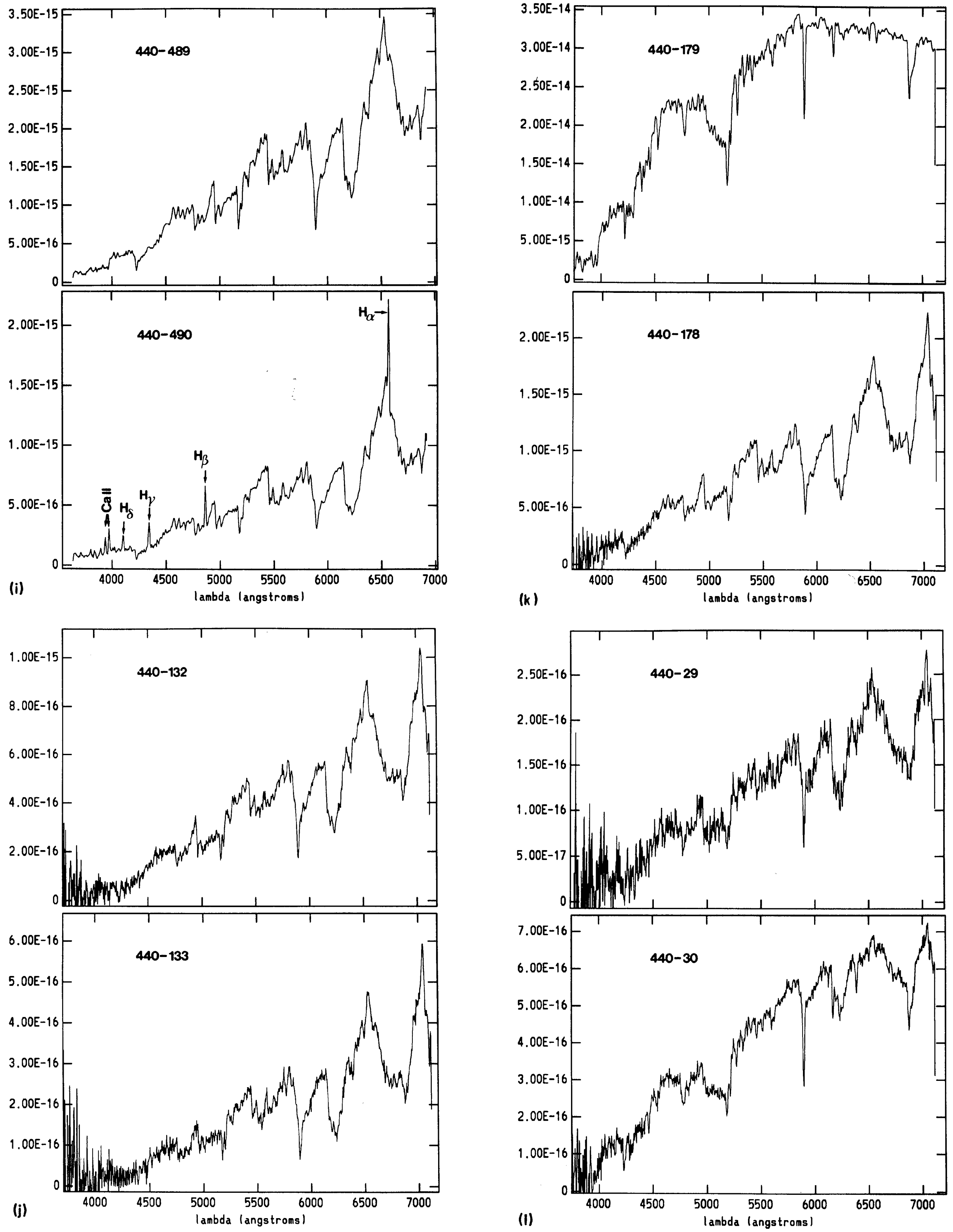

FIG. 2. (continued)

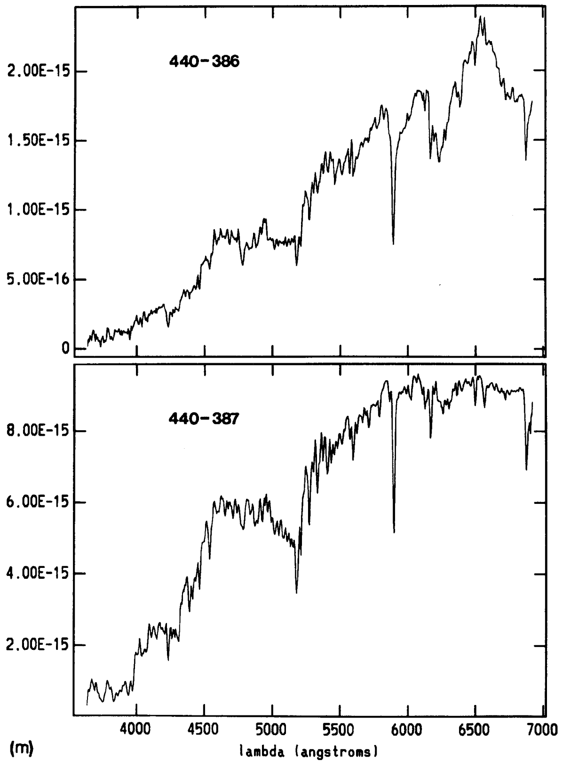

FIG. 2. (continued)

TABLE II. Proper motion, CCD photometry, and spectral types.

| Object | $\mu$ ("/yr) | $\theta$ (°) | s (") | V | B-V | V-R | R-I | ST |
|---|---|---|---|---|---|---|---|---|
| 439-162 | 0.38 | 306 | 23 | 18.77 | 0.82 | 0.53 | 0.31 | DQ |
| 439-163 | | | | 19.84 | 1.14 | 0.80 | 0.13 | DC9 |
| 439-178N | 0.32 | 254 | 3 | (13.1)$^1$ | – | – | – | K7 |
| 439-178S | | | | (13.0)$^1$ | – | – | – | K7 |
| 439-70 | 0.21 | 253 | 23 | 15.07 | 1.42 | 0.88 | 1.10 | (M1.2)$^2$ |
| 439-71 | | | | 16.63 | 1.50 | 0.93 | 1.40 | (M2.8)$^2$ |
| 439-9A | 0.17 | 128 | 20 | 16.08 | 1.53 | 0.95 | 1.44 | M3.1 |
| 439-9B | | | | 17.32 | 1.61 | 1.02 | 1.64 | M4.3 |
| 439-95 | 0.16 | 226 | 53 | 17.37 | 0.79 | 0.89 | 1.20 | M4+DA |
| 439-96A | | | 4 | 14.40 | 1.59 | 0.93 | 1.25 | M2.0 |
| 439-96B | | | | 15.54 | 1.66 | 0.96 | 1.44 | M3.0 |
| 439-181 | 0.12 | 287 | 9 | 18.07 | 2.14 | 0.97 | 1.55 | M3.8 |
| 439-182 | | | | 16.54 | 1.59 | 0.96 | 1.25 | M1.8e |
| 439-136 | 0.1 | 280 | 7 | 16.37 | 1.62 | 0.96 | 1.11 | M1.4 |
| 439-137 | | | | 16.23 | 1.59 | 0.94 | 1.11 | M1.1 |

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TABLE II. (continued)

| Object | μ ("/yr) | θ (°) | s (") | V | B-V | V-R | R-I | ST |
|---|---|---|---|---|---|---|---|---|
| 440-152 | 0.42 | 107 | 9 | 14.33 | 1.80 | 0.93 | 1.28 | M2.1 |
| 440-153 | | | | 13.29 | 1.67 | 0.92 | 1.14 | M1.2 |
| 440-55A | 0.22 | 280 | 5 | 19.20 | 0.61 | 0.38 | 0.76 | DZ7 |
| 440-55B | | | | 19.65 | 1.60 | 0.86 | 1.88 | M5.1 |
| 440-489 | 0.16 | 285 | 9 | 15.31 | 1.77 | 0.97 | 1.49 | M3.7 |
| 440-490 | | | | 16.01 | 1.75 | 0.97 | 1.69 | M4.3e |
| 440-132 | 0.16 | 289 | 15 | 17.15 | 1.54 | 0.94 | 1.43 | M3.5 |
| 440-133 | | | | 17.90 | 1.56 | 0.97 | 1.55 | M4.0 |
| 440-178 | 0.14 | 241 | 85 | 16.32 | 1.33 | 0.89 | 1.37 | M3.0 |
| 440-179 | | | | 12.66 | 1.08 | 0.67 | 0.59 | M4.0 |
| 440-29 | 0.10 | 264 | 4 | 18.24 | 1.61 | 0.88 | 1.2 | M2.0 |
| 440-30 | | | | 16.99 | 1.54 | 0.87 | 0.89 | M0.1 |
| 440-386 | 0.10 | 120 | 14 | 15.54 | 1.65 | 0.92 | 1.03 | M1.0 |
| 440-387 | | | | 13.70 | 1.14 | 0.70 | 0.63 | K4.2 |

(1) m(ph) from Luyten (1978).
(2) From Fig. 3; no spectra were obtained for this pair.

TABLE III. Derived parameters.

| Object | d pc | $M_V$ | Revised ST | s AU | $v_t$ km $s^{-1}$ |
|---|---|---|---|---|---|
| 439-70 | 126 | 9.57 | M1.0 | 2898 | 125 |
| 439-71 | | 11.13 | M3.0 | | |
| 439-229 | $52^{(1)}$ | 14.84 | DA7 | 988 | 42 |
| 439-230 | | 12.85 | M4.1 | | |
| 439-9A | 80 | 11.56 | M3.2 | 1600 | 64 |
| 439-9B | | 12.80 | M4.1 | | |
| 439-95a | $70^{(1)}$ | 13.5 | M4.3 | 35 | 53 |
| 439-95b | | 14.4 | DA7 | 3710 | |
| 439-96A | | 10.17 | M1.8 | 280 | |
| 439-96B | | 11.31 | M3.1 | | |
| 439-181 | $143^{(2)}$ | 12.30 | M3.8 | 1287 | 81 |
| 439-182 | | 10.76 | M2.5e | | |
| 439-136 | 204 | 9.82 | M1.3 | 1428 | 97 |
| 439-137 | | 9.68 | M1.1 | | |
| 440-152 | 58 | 10.51 | M2.3 | 522 | 115 |
| 440-153 | | 9.47 | M1.0 | | |

TABLE III. (continued)

| Object | d<br>pc | $M_V$ | Revised<br>ST | s<br>AU | $v_t$<br>km s$^{-1}$ |
|---|---|---|---|---|---|
| 440-55A | 91$^{(1)}$ | 14.40 | DZ7 | 491 | 95 |
| 440-55B |  | 14.85 | M5.1 |  |  |
| 440-489 | 46$^{(2)}$ | 12.0 | M3.7 | 414 | 35 |
| 440-490 |  | 12.70 | M4.0e |  |  |
| 440-132 | 112 | 11.90 | M3.5 | 1680 | 85 |
| 440-133 |  | 12.65 | M4.0 |  |  |
| 440-178 | 96 | 11.41 | M3.2 | 8160 | 64 |
| 440-179 |  | 7.75 | K4.0 |  |  |
| 440-29 | 379 | 10.35 | M2.1 | 1516 | 180 |
| 440-30 |  | 9.10 | M0.0 |  |  |
| 440-386 | 146 | 9.72 | M1.0 | 2044 | 69 |
| 440-387 |  | 7.88 | K4.5 |  |  |

(1) In these cases the distances have been derived from the magnitudes and spectral types of the nondegenerate components.
(2) The emission-line component of these systems have not been considered for distance calculations (see text).

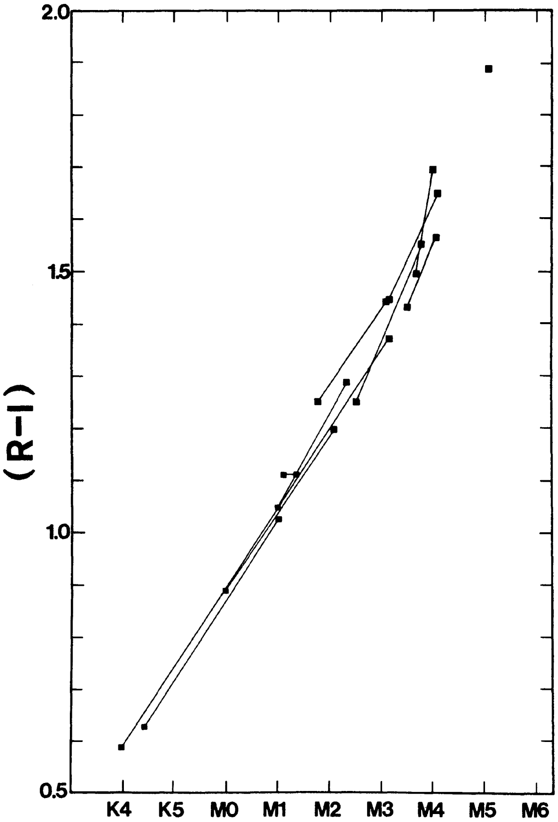

FIG. 3. Observed $(R-I)$ colors, from Table II, as a function of spectral types, from Fig. 2, after taking into account that members of a given cpm system should be at the same common distance from us.

17.37, implying that $f(\mathrm{M4}) + f(\mathrm{DA}) = 4.18 \times 10^{-16}$ ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$. Thus obtaining apparent visual magnitudes for both components $m_V(\mathrm{M4}) = 17.70$ and $m_V(\mathrm{DA}) = 18.85$. From stars 96A and 96B and 95a we derive a distance to the group of 70 pc, hence the absolute visual magnitude of the components of the spectroscopic binary are $M_V(\mathrm{M4}) = 13.5$ and $M_V(\mathrm{DA}) = 14.4$. The shape of the DA continuum and line strengths are similar to those of 439-229, therefore we may assume the same blackbody temperature (7000 K) and bolometric correction (BC = 0.35), in this way we derive an absolute bolometric magnitude for the DA star $M_B(439\text{-}95\mathrm{b}) = 14.05$, which according to Weldemann (1978) should indicate a radius of $R(\mathrm{DA}) = 0.01 R_\odot$. A monitoring of this binary is certainly worth while, it might turn out the necessary information to calculate the masses of the two components.

With the exception of the spectroscopic binary 439-95a/95b, the distances between the different members of the cpm systems included in this list are large enough to guarantee that no strong interaction between them has taken place during their lifetime, which could modify their evolution and invalidate the use of relations and calibrations ($M_V$ vs ST) derived from single stars. Tangential velocities in Table III are consistent with most of the stars being members of the old disk population.

Even in our small sample of cpm systems with one degenerate component, we confirm the finding by Sion and Oswalt (1988) that, contrary to what happens with single degenerates, the ratio of "non-DA" to DA white dwarfs among members of cpm systems is $\sim 1$. The reason for this anomaly is still a puzzle whose solution hides important clues about the origin of the bifurcation of the white dwarf cooling sequence in DA and "non-DA" stars (Shipman 1988).

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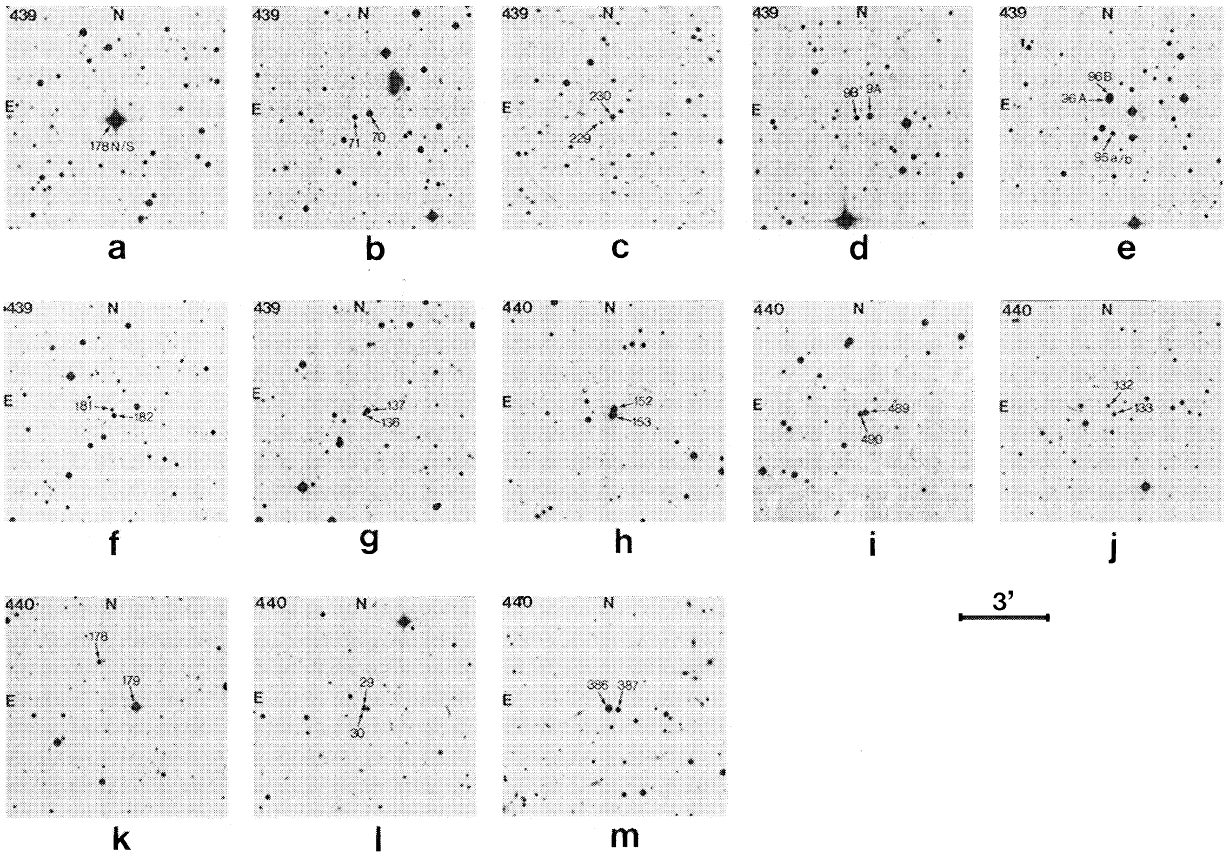

FIG. 1. The cpm stars are indicated on a reproduction of the ESO R Sky Survey charts. (a) 439-178N/S, (b) 439-70/71, (c) 439-229/230, (d) 439-9A/B, (e) 439-96A/B-95, (f) 439-181/182, (g) 439-136/137, (h) 440-152/153, (i) 440-489/490, (j) 440-132/133, (k) 440-178/179, (l) 440-29/30, (m) 440-386/387.

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