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A NEW LIST OF 52 DEGENERATE STARS. VII.

JESSE L. GREENSTEIN
Hale Observatories, California Institute of Technology, Carnegie Institution of Washington
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ABSTRACT

Conclusion of observations with the prime-focus spectrograph of the Hale reflector leads to a list of 20 white dwarfs confirmed spectroscopically. An additional 32 white and yellow degenerates are included in another table; these stars were observed with the multichannel spectrophotometer. Degenerate stars are recognized by narrow-band colors, and by hydrogen and helium lines. Some 10 stars are classified as free of lines, DC, or are known to be circularly polarized.

Subject headings: white dwarf stars — spectrophotometry

I. PHOTOGRAPHIC SPECTROSCOPY

Late-type and circularly polarized white dwarfs have been of special interest; their discovery requires extensive search among proper-motion stars of suitable color. In a later section we list results of a colorimetric survey carried out with the multichannel spectrophotometer. In this section we describe 20 additional spectra of white dwarfs found with the prime-focus (A = 90 Å mm^{-1}, B = 190 Å mm^{-1}, C = 380 Å mm^{-1}) or Cassegrain image-tube (Q = 90 Å mm^{-1}) spectrographs of the 5-m Hale reflector. The median magnitude was 15.5, approaching the effective limit for widened spectra with the prime-focus spectrograph, except on dark nights. Some were taken on an experimental basis with a single-stage ITT fiber-optics image tube at the Cassegrain. Since the latter has a skylight eliminator, for use with widening, it will be useful for extensive search among fainter objects. In table 1 are listed objects Gr 285–304, together with a few additional spectra for already published EG or Gr objects.

Giclas, Burnham, and Thomas (1972) have introduced a survey listing of red proper-motion stars called by GR numbers. I have therefore changed from GR to Gr notation. (The polarized star G99-47, here called Gr 290, was called GR 289 in Greenstein, Gunn, and Kristian (1971).) For bibliographic purposes, lists of the EG stars are in Eggen and Greenstein for EG 1–165 (1965*a*); EG 166–178 (1965*b*); EG 172–202 (1967*); EG 203–266 are in Greenstein (1969*a*) with further notes in Greenstein (1969*b*); GR 267–284 in Greenstein (1970), and Gr 285–304 in this publication. Many of the colors used in Papers IV–VII are by Eggen (1968). In addition to the degenerate stars listed in table 1, spectra of 23 additional stars were obtained, which were neither white nor yellow degenerates. Most were horizontal-branch B, A, or F, subdwarf O, and sdG–sdK (among the redder stars). The percentage of red degenerates found among suspected candidates remains low. A few of the new hot white dwarfs are included in the Greenstein and Sargent (1974) FB lists, and studied in more detail.

It should be noted that the yield of DC or carbon-rich (λ4670) stars is low in table 1. The spectra become poorer for fainter stars, and weak features like the C_2 bands, or the λ4135 band, as in EG 129, become less visible. In consequence, if any DC star in table 1 should show polarization, it is possible that better spectra could show lines. The cooler DA stars (sharp lines, DAs) are candidates for light variability. Only one known polarized star is included, Gr 290; it has an essentially continuous spectrum (see below). This set of observations concludes my use of the prime-focus spectrograph with which the stars EG 1–284 were observed.

II. SPECTROPHOTOMETRIC WHITE DWARFS

An extensive series of multichannel observations provide data on 32 new degenerate stars. Details will be discussed in a forthcoming paper on the use of narrow-band colors for identification of degenerate stars. The new degenerate stars are listed with Gr numbers, names, positions, $m_{1.85}$, a magnitude at λ5400, close to the m_V of the three-color broad-band system, an estimated $B - V = m_{2.35} - m_{1.85} + 0.15$, where broad-band colors were unavailable, and the type of spectrum deduced from the multichannel observations. Identification of the spectral type of a white dwarf from its continuum is assisted by the strong Balmer lines present in DA stars, and the He I lines in DB, which also lack the Balmer discontinuity. The DC stars, spectrophotometrically defined, have no recognizable features at 40 or 80 Å bandwidth, deeper than 10 percent on one night, with a typical photon counting accuracy of 3 percent, from λ3500 to λ8200. Very broad features seen in the λ4135 and λ4670 circularly polarized white dwarfs with magnetic fields were searched for in any suspected DC. The known polarized stars are here classified as DP. Included is an apparently new type Gr 329 = GD 356, which has a single dip at λ3830, near the Mg I line which is seen in a few cool degenerate stars. In addition, before publication Gr 333 = GD 229 was reported by John Swedlund, to whom I am grateful, as having circular polarization. A few cool stars have colors which are barely distinguishable from those of extremely weak-lined subdwarf G stars of the halo population. Among the stars in table 1 there are three, and in table 2,

TABLE 1

SPECTRA OF NEW WHITE DWARFS

Gr	Name	1950 α	1950 δ	V	B-V	U-B	Type	Qual.	μ	Remarks
285	LTT 329	00 34.9	-21 09	14.53	+0.45	-0.57	DAn	B	0.32	L651-29
269	GD 279	01 48.9	+46 45	12.44	+0.06	-0.53	DAs	A	μ_2	Added spectra; sharp cores
286	TS 243	02 12.1	-23 08	(15.6)	...	...	DA	C	...	
287	GD 38	02 59.4	+37 49	15.55	-0.03	-1.06	DA	B	μ_2	
288	GD 50	03 46.3	-01 07	13.98	-0.16	-1.16	DAwk	A	μ_2	sdOp?
289	GD 257	05 48.1	+00 05	15.10	-0.30	-1.21	DAwk	B	μ_1	Very hot
290	G99-47	05 53.8	+05 22	14.12	+0.62	-0.12	DP	B	1.07	Circularly polarized; called GR 289 in VI
291	TN 10	08 41.0	+26 14	14.78	-0.10	-1.01	DB	B	...	FB 51
85	Ll261-24	11 54.2	+18 39	15.54	+0.30	-0.60	DFs	C	0.31	G57-29; new spectra
292	GD 479	12 41.2	+65 09	(16)	(-2)	...	DBp	C	μ_2	
293	GD 267	12 57.3	+04 48	15.05	-0.09	-0.88	DA	C	μ_1	
294	BPM 89123	13 30.8	+03 36	15.86	+0.01	-0.79	DA	C	0.17	GD 269
295	G200-39	14 26.0	+54 02	(15.7)	(-1)	...	DBp	C	0.37	cpm sdM; He star?
296	TN 210	14 34.5	+28 57	(14.8)	...	...	DAn	B	...	
297	GD 173	14 51.3	+00 38	15.29	-0.14	-0.96	DA	B	μ_2	
298	G166-58	14 56.0	+29 50	15.61	+0.31	-0.59	DA,F	C	0.69	
299	GD 203	16 55.0	+21 01	16.60	-0.21	-1.18	DA	Q	μ_3	
262	LTT 16151	20 59.7	+31 37	15.04	+0.07	-0.75	DC	Q	0.50	G187-15; new spectra
300	GD 547	21 16.5	+67 32	(16)	(-1)	...	DAs	Q	μ_2	
301	GD 548	21 19.3	+58 07	(16)	(-1)	...	DA	Q	μ_2	
302	G18-34	22 07.3	+14 15	15.61	+0.32	-0.58	DC	Q	0.43	
303	GD 559	23 19.2	+69 10	(14.5)	(-1)	...	DAs	Q	μ_1	
304	GD 561	23 42.9	+80 40	14.52	-0.33	...	DA	Q	μ_0	

10 objects classified as DP or DC. Some of the DC may, in fact, show weak lines; others have colors like the extremely weak-lined, cool DAs, i.e., yellow degenerates. But, a few DC remain candidates for tests for circular polarization.

For those stars for which proper motions were available, the reduced proper motions yield an estimate of luminosity from $M_{1.85} = m_{1.85} + 5 \log \mu + 8.39 - 5 \log V_T$. Assuming, for convenience, a typical tangential velocity $5 \log V_T = 8.39$, i.e., 48 km s^{-1}, we have $M_{1.85} = m_{1.85} + 5 \log \mu$. Inspection shows that all stars except Gr 308, 309, 313, 316 (if a Hyades member, $M_V = +12$), 319, 333, 335 have $M_{1.85} > +10$. For the hot stars the confusion would be with sdO; for the cool, with extremely weak-lined sdG. Of course, for Population I, the condition on $m + 5 \log \mu$ is needlessly stringent, and for the sdG, too loose; for the latter $M_{1.85} \approx m_{1.85} + 5 \log \mu - 3.13$, at $V_T = 200$ km s^{-1}. Of the stars in table 1, Gr 269, 288, 289, 303 have $H < 10$, but some of these are very hot and could have $M_{1.85}$ approaching those of sdO.

In resumé, we provide a list of 52 additional degenerate stars observed spectroscopically or spectrophotometrically. Most have finding charts in the *Lowell Observatory Bulletin* series (which gives more details), or the two Tonantzintla polar caps. Some lack accurate proper motions: the Tonantzintla stars and the GD series for which only estimates exist. The LTT catalogs (Luyten 1957, 1961) also give estimated colors and measured proper motions. One DB star, LP 475-242, is listed as Gr 316; Luyten (1971) gives it as a possible Hyades member. Eggen (1968) called it 475-42, and also listed it as a possible member, with $M_V \approx +12$. It is the only DB (i.e., helium star) among cluster white dwarfs. A possible Pleiades member, LB 1497 (EG 25), was noted by Luyten and Herbig (1960) and shows the spectrophotometric properties as well as the spectrum (Eggen and Greenstein 1965*a*) of a weak-lined white dwarf. On the average for the entire group, the reduced proper motion yields $\langle M_{1.85} \rangle = +11.8$ with a dispersion of ± 1.8, typical for a group consisting largely of DA stars. There are six DB as compared to 34 DA stars, a slightly high ratio; six stars are of later types.

I am indebted to John Swedlund for the information prior to publication that GD 229 (Gr 333) was circularly polarized, and to J. B. Oke for guidance on the use of the multichannel spectrophotometer.

TABLE 2

WHITE DWARFS IDENTIFIED FROM SPECTROPHOTOMETRY

Gr	Name	1950 α	1950 δ	$m_{1.85}$	B-V	Type	Qual.	μ	Remarks
305	GD 408	00 02.9	+72 56	14.30	-0.04	DB	B	μ_3	Possibly helium star
306	G172-4	00 30.3	+44 28	16.5	+0.16	DA	C	0.27	cpm(?) of W3
307	LTT 784	01 23.0	-26 14	14.94	+0.40	DF-DG	C	0.51	
308	GD 419	01 34.9	+83 20	13.06	-0.23	DA	A	μ_2	LP2-534; strange colors
309	PHL 3802	01 46.4	-26 52	12.35	-0.05	DC:	B	0.09	V. wk. H and He?; sd?
310	GD 421	01 47.4	+67 25	14.40	-0.31	DAwk	B	μ_2	
311	G71-41	01 51.6	+01 47	14.88	+0.02	DA	A	0.36	
312	GD 35	02 13.2	+39 38	14.80	+0.23	DA	B	μ_2	
313	GD 26	02 14.2	+38 36	14.35	+0.50	DG:	B	μ_1	Probably extra wk sdG
314	G174-5	02 32.8	+52 31	13.73	-0.09	DA	A	0.28	
25	LB 1497	03 49.1	+24 47	16.55	-0.20	DAwk	C	0.06	Luyten & Herbig; Eggen; possibly in Pleiades
315	GD 61	04 35.2	+41 04	14.90	-0.09	DB	C	μ_2	
316	LP475-242	04 37.6	+13 53	14.83	-0.09	DB	A	0.10	Luyten; Eggen; possibly in Hyades
317	G175-46	04 40.1	+51 01	15.95	+0.24	DA	B	0.51	
318	G191-16	04 55.3	+55 21	15.98	+0.03	DA	B	0.30	
319	GD 69	05 32.8	+41 28	14.64	+0.32	DAs	B	μ_1	
320	LTT 2437	05 59.4	-12 30	14.29	+0.65	DG	C	0.26	Probably extra wk sdG
321	G234-4	07 28.8	+64 16	16.33	+0.91	DK-DC	B	0.29	
322	G193-78	07 51.9	+57 50	15.06	+0.12	DC	A	0.49	
323	TN 953	08 46.0	+34 41	15.70	+0.28	DAs	B	μ_2	GD 96
324	G117-25	09 30.8	+29 25	15.89	+0.25	DA	B	0.28	
	-7°3007*	10 18.6	-08 34	10.65	0.00	DAe	A	<0.10	Probably composite interacting
325	G119-47	10 56.7	+34 31	15.93	-0.08	DC:	C	0.33	
326	LTT 14182	14 13.4	+23 11	16.41	-0.10	DA	B	0.27	G166-14
112	LP135-154	15 10.6	+56 36	16.26	+0.23	DA	B	0.36	G201-39;cpm LP135-155 dM
327	G138-31	16 25.5	+09 19	16.16	+0.39	DC	A	0.53	Possible very wk H
328	G138-49	16 36.5	+05 47	16.5	+0.26:	DAs:	C	0.59	Possibly DC; UBV discrepant
329	GD 356	16 39.8	+53 47	15.07	+0.33	DP	A	μ_3	Peculiar spectrum; λ3830
330	G206-18	18 11.8	+32 48	17.05	+0.49	DC	C	0.27	Q spectrogram DC:
331	GD 533	19 18.9	+72 32	15.12	-0.27	DA	A	μ_2	Possibly hot sdB
332	GD 543	20 10.0	+62 17	15.15	-0.18	DA	A	μ_2	Close companion
333	GD 229	20 10.4	+31 05	14.70	+0.47:	DP	A	μ_1	Q spectrogram DP; circularly polarized
334	G212B1A	21 08.0	+42 45	15.9	+0.05	DC	C	0.20	cpm dM
335	GD 248	23 23.6	+15 44	15.09	+0.12	DC:	A	μ_1	
336	Green 165-20	23 37.3	+12 21	13.08	+0.03	DAs	B	...	

*-7°3007 is a rapid variable, probably double. May not be DA.

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