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EXTREME ULTRAVIOLET EXPLORER OPTICAL IDENTIFICATION CAMPAIGN. IV. A NORTHERN HEMISPHERE SAMPLE OF ACTIVE LATE-TYPE STARS AND TYPICAL EUV SOURCES

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ABSTRACT

We present new optical identifications of previously unidentified faint extreme ultraviolet sources. Our total sample of 30 identified sources, of which 22 are new identifications, includes 24 late-type stars, three white dwarfs, two cataclysmic variables (CVs), and one active galactic nucleus. These sources are joint detections of the faint sources from the all-sky surveys of the *Extreme Ultraviolet Explorer* (*EUVE*) in the 58–174 Å (0.071–0.214 keV) EUV band and of the *ROSAT* Position Sensitive Proportional Counter in the 5–120 Å (0.1–2.4 keV) X-ray band. We obtained medium-resolution spectra of the possible optical counterparts with the Shane 3 m telescope at Lick Observatory using the Kast double spectrograph covering a bandpass of 3600–7500 Å. Our sample of active late-type stars is dominated by K and M stars showing strong Balmer and Ca II emission lines. The white dwarfs are fairly typical for those detected in the *EUVE* survey with $T_{\rm eff}$ and $\log g$ ranging from 35 to 53 kK and 7.6 to 8.7, respectively. We found strong H and He emission lines typical of cataclysmic variables (CVs) for EUVE J0854+390 and EUVE J1802+180. EUVE J0854+390 is a newly identified cataclysmic variable showing radial velocity shifts to the red as large as ≈400 km s^{-1}. We associate EUVE J1802+180 with the previously identified CV, V884 Her (RX J1802.1+1804). Including the present work (22 new identifications), *EUVE* optical identification campaigns have identified ≈28% of the presently cataloged NOID sources.

Key words: catalogs — stars: late-type — ultraviolet emission

1. INTRODUCTION

The *Extreme Ultraviolet Explorer* (*EUVE*) and *ROSAT* all-sky surveys conducted the first detailed studies in the EUV wave band region of the electromagnetic spectrum (Bowyer et al. 1996; Pye et al. 1995). *EUVE* provided the first complete look at EUV sources in the 70 to 700 Å region with an all-sky survey between 1992 June and 1993 January (Bowyer & Malina 1991). The resulting *EUVE* source catalog (Bowyer et al. 1996) contained 734 objects, 245 of which had no optical identification and were indicated as NOID. The *EUVE* source list has been expanded to over 900 sources by comparing marginal *EUVE* detections within 90″ from the *ROSAT* PSPC X-ray source list (Lampton et al. 1997), which raised the NOID count to 310. The *EUVE* source list has been further expanded from analysis of serendipitous data taken with the all-sky survey telescopes during the spectroscopic portion of the mission (the *EUVE* Right Angle Program, RAP). The RAP has brought the number of *EUVE* sources to over 1200 (Christian et al. 1999; Christian 2001) and the number of NOIDs to 340.

We have been conducting an optical identification campaign to find the optical counterparts to the *EUVE* NOID class. We selected sources from the NOID class from the second *EUVE* all-sky survey catalog (Bowyer et al. 1996), the *EUVE* faint-source list (Lampton et al. 1997), and the second RAP catalog (Christian et al. 1999). This study will help complete the fainter end of the *EUVE* source distribution and promises to provide insights into the physical nature of these unidentified sources where there is presently very little or no information available. Previous optical identification campaigns have primarily found the NOIDs to be late-type stars and fainter white dwarfs (Mathioudakis et al. 1995a; Craig et al. 1996; 1997, Polomski et al. 1997; Vennes, Korpela, & Bowyer 1997). However, there have been a few cataclysmic variables (Craig et al. 1996; Craig 1996) and about a dozen active galactic nuclei (AGNs; Craig & Fruscione 1997; Polomski et al. 1997). In this paper we present the results of a sample of active late-type stars (dKe and dMe), three white dwarfs, one AGN, and two CVs, selected from optical observations conducted between 1996 and 1998 from Lick Observatory. We observed over 60 fields (~20% of the combined NOID list) centered on NOID positions from the above-mentioned catalogs with one-half of these fields yielding the identifications presented. We present a brief description of the source selection criteria from which we derived our source list in § 2.1 and the *EUVE* and *ROSAT* properties. In § 2.2 we describe the optical identification procedure and observation setup. In § 3 we present ground-based optical spectroscopy for objects identified as the optical counterpart to the *EUVE* source, and we include measurements of Ca H and K and Balmer series emission for the CVs and late-type stars and derive temperatures and surface gravities for the white dwarfs. We discuss the current number of unidentified *EUVE* sources and implications for the *EUVE* source distribution in § 4. Lastly, we summarize our results in § 5.

2. OBSERVATIONS

2.1. *EUVE All-Sky and Deep Surveys*

During the *EUVE* all-sky survey, three co-aligned telescopes (the "scanners") scanned the sky over the EUV wavelength range in four bandpasses: Lexan/B (58–174 Å), Al/Ti/C (156–234 Å), Ti/Sb/Al or "dagwood" (345–605 Å), and Sn/SiO or "Tin" (500–740 Å). Simultaneously, a fourth telescope, the Deep Survey Instrument (DS), mapped a $2^\circ \times 180^\circ$ strip of sky along the ecliptic in the two shortest EUV bandpasses, DS Lexan/B (65–190 Å) and DS Al/C (167–364 Å), with an order of magnitude greater sensitivity than the all-sky survey. The effective areas for each telescope and filter combination are given in Bowyer et al. (1996), which also describes the all-sky survey data processing, analysis, and calibration. *EUVE* continued to obtain data with these all-sky survey telescope during the guest observer portion of what became known as the Right Angle Program (McDonald et al. 1994; Christian et al. 1999). Our source list also includes several late-type stars from these RAP catalogs.

We present the *EUVE* all-sky and pointed data for the NOID sources in Table 1, including: the *EUVE* positions, Lexan/B (100 Å) bandpass count rates and count-rate errors, and the detection significances. These values are derived from *EUVE* all-sky survey data (as described in Bowyer et al. 1996 or Lampton et al. 1997 as applicable). We obtained the *ROSAT* PSPC count rates, associated errors, detection significance in the *ROSAT* survey and the *ROSAT* source identification, where available, from the *ROSAT* All Sky Survey Bright Source Catalog (RASSBSC; Voges et al. 1999), and the *ROSAT* All Sky Survey Faint

TABLE 1

EUVE AND *ROSAT* DATA FOR THE NORTHERN SAMPLE OF SOURCES

EUVE						*ROSAT*	
Name (1)	R.A (2)	Decl. (3)	Count Rate[a] (counts s^{-1}) (4)	Signif.[b] (σ^2) (5)	Ang. Sep.[c] (arcsec) (6)	Count Rate[d] (counts s^{-1}) (7)	Name (8)
EUVE J0018+309...	00 18 17.5	+30 57 47	0.050 ± 0.010	48	51	1.507 ± 0.065	1RXS J001821.2+305723[e]
EUVE J0101+331...	01 01 08.8	+33 06 58	0.022 ± 0.009	13	...	...	...
EUVE J0224+373...	02 24 18.0	+37 25 06	0.007	...	...	...	...
EUVE J0331+269...	03 31 16.7	+27 00 23	0.022 ± 0.008	14	25	0.042 ± 0.012	1RXS J033114.9+270017
EUVE J0337−069...	03 37 42.1	−06 58 43	0.030 ± 0.009	17	42	0.27 ± 0.03	1RXS J033741.2−065921
EUVE J0559+086...	05 59 25.2	+08 40 25	0.023 ± 0.009	13	6	0.048 ± 0.013	1RXS J055924.4+084032
EUVE J0738+098...	07 38 08.0	+09 49 30	0.115 ± 0.032[f]	27	...	...	...
EUVE J0808+211...	08 08 16.0	+21 05 42	0.033 ± 0.011	17	56	0.77 ± 0.06	1RXS J080813.8+210612[e]
EUVE J0831+402...	08 31 05.6	+40 12 45	0.025 ± 0.009	12	56	0.12 ± 0.03	1RXS J083101.3+401217
EUVE J0854+390...	08 54 15.9	+39 05 56	0.030 ± 0.009	20	34	0.124 ± 0.020	1RXS J085413.1+390543
EUVE J1031+508...	10 31 18.0	+50 52 37	0.021 ± 0.008	12	64	4.46 ± 0.09	1RXS J103118.6+505341
EUVE J1206+701...	12 06 48.3	+70 06 58	0.021 ± 0.006	17	69	0.435 ± 0.026	1RXS J120656.2+700754
EUVE J1451+569...	14 51 29.9	+56 55 45	0.016 ± 0.005	14	40	0.028 ± 0.007	1RXS J145134.1+565605
EUVE J1603+052...	16 03 16.3	+05 17 55	<0.006[g]	...	...	...	...
EUVE J1716−231...	17 16 21.0	−23 10 06	0.003 ± 0.0006	...	58	0.13 ± 0.02	1RXS J171617.5−231038
EUVE J1725+021...	17 25 36.8	+02 08 07	0.051 ± 0.015	20	...	...	...
EUVE J1734+618...	17 35 02.6	+61 52 28	0.014 ± 0.003	42	35	0.345 ± 0.011	1RXS J173458.8+615227[e]
EUVE J1745+607...	17 45 47.5	+60 41 58	0.007 ± 0.002	14	51	0.96 ± 0.007	1RXS J174554.2+604211
EUVE J1802+180...	18 02 05.4	+18 04 06	0.021 ± 0.007	14	37	2.51 ± 0.16	1RXS J180206.7+180438
EUVE J1802+642...	18 02 09.4	+64 15 25	0.007 ± 0.001	39	50	0.143 ± 0.004	1RXS J180216.3+641546[e]
EUVE J1844+792...	18 44 53.1	+79 14 06	0.008 ± 0.003	11	62	0.011 ± 0.003	1RXS J184450.8+791303
EUVE J1932+696...	19 32 29.0	+69 39 25	0.009 ± 0.003	18	56	0.25 ± 0.014	1RXS J193220.4+693958
EUVE J1952+478...	19 52 47.3	+47 51 57	0.013 ± 0.004	14	84	0.014 ± 0.006	1RXS J195242.9+475308
EUVE J2030+798...	20 30 26.0	+79 51 20	0.015 ± 0.004	17	56	0.34 ± 0.06	1RXS J203011.0+795040
EUVE J2055+164...	20 55 27.0	+16 27 52	0.027 ± 0.007	24	...	...	...
EUVE J2124+284...	21 24 54.5	+28 26 29	0.030 ± 0.009	21	61	0.052 ± 0.01	1RXS J212458.2+282553[e]
EUVE J2156+052...	21 56 26.6	+05 15 31	0.033 ± 0.010	20	23	0.411 ± 0.037	1RXS J215627.3+051552
EUVE J2206+637...	22 06 43.9	+63 45 20	0.012 ± 0.004	13	52	0.551 ± 0.031	1RXS J220636.4+634515
EUVE J2223+253...	22 23 55.6	+25 23 35	0.028 ± 0.010	14	20	0.031 ± 0.009	1RXS J222357.1+252337
EUVE J2240+097...	22 40 22.0	+09 43 36	0.039 ± 0.012	11	...	...	...

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

[a] *EUVE* count rate in the Lexan/B band (58–174 Å or 0.075–0.21 keV).

[b] *EUVE* detection significance.

[c] Angular separation between the *EUVE* and the *ROSAT* source.

[d] *ROSAT* PSPC count rate in the 0.1–2.4 keV band or 5–124 Å (RASSBSC, Voges et al. 1999 and RASSFSC).

[e] Noted sources also have *ROSAT* WFC detections (Pye et al. 1995); namely: 2RE J0018+305, 2RE J0808+210, 2RE J1734+615, 2RE J1802+641, and 2RE J2125+282, respectively.

[f] Bowyer et al. 1996 "dagwood" detection.

[g] *EUVE* RAP source from Christian et al. 1999.

Source Catalog (RASSFSC).[1] These quantities, together with the calculated angular separation between the *EUVE* and *ROSAT* source positions, are also shown in Table 1.

2.2. *Optical Observations and Spectral Types*

Possible optical source counterparts were first identified from 6′ × 6′ Digitized Sky Survey Maps, centered on the *EUVE* J2000.0 positions from Lampton et al. 1997 and are presented in Figures 1*a*–1*d*. The figures include a circle with a radius of 30″ to represent typical positional uncertainties of identified sources. The formal positional uncertainty of *ROSAT* is 30″ (Voges et al. 1999), and that of *EUVE* is about twice as large (Bowyer et al. 1996). The selection criteria used to observe these candidates are discussed in a previous optical identification paper (Craig et al. 1995). We obtained spectra in 1996 May and September, 1997 February, May, August, and September, and 1998 July with the 3 m Shane Telescope at Lick Observatory. The Kast double spectrograph with a Reticon 1200 × 400 CCD was used at the Cassegrain focus. This setup yields a spectral resolution of 1.7 Å pixel^{-1} and covers the wavelength region of ≈3600–5250 Å on the blue side and ≈5500–7500 Å on the red side. The Lick data were reduced using standard IRAF software. Wavelength scales were derived from He-Hg-Cd and Ne-Ar lamps for the blue and red sides, respectively. Flux calibrations were derived from flux standards (Stone 1977) and include: HZ 15, Kopff 27, BD+40°4032, BD+28°4211, and θ Vir. The optical observation log for

[1] See HEASARC and http://www.xray.mpe.mpg.de/rosat/survey/rass-fsc.

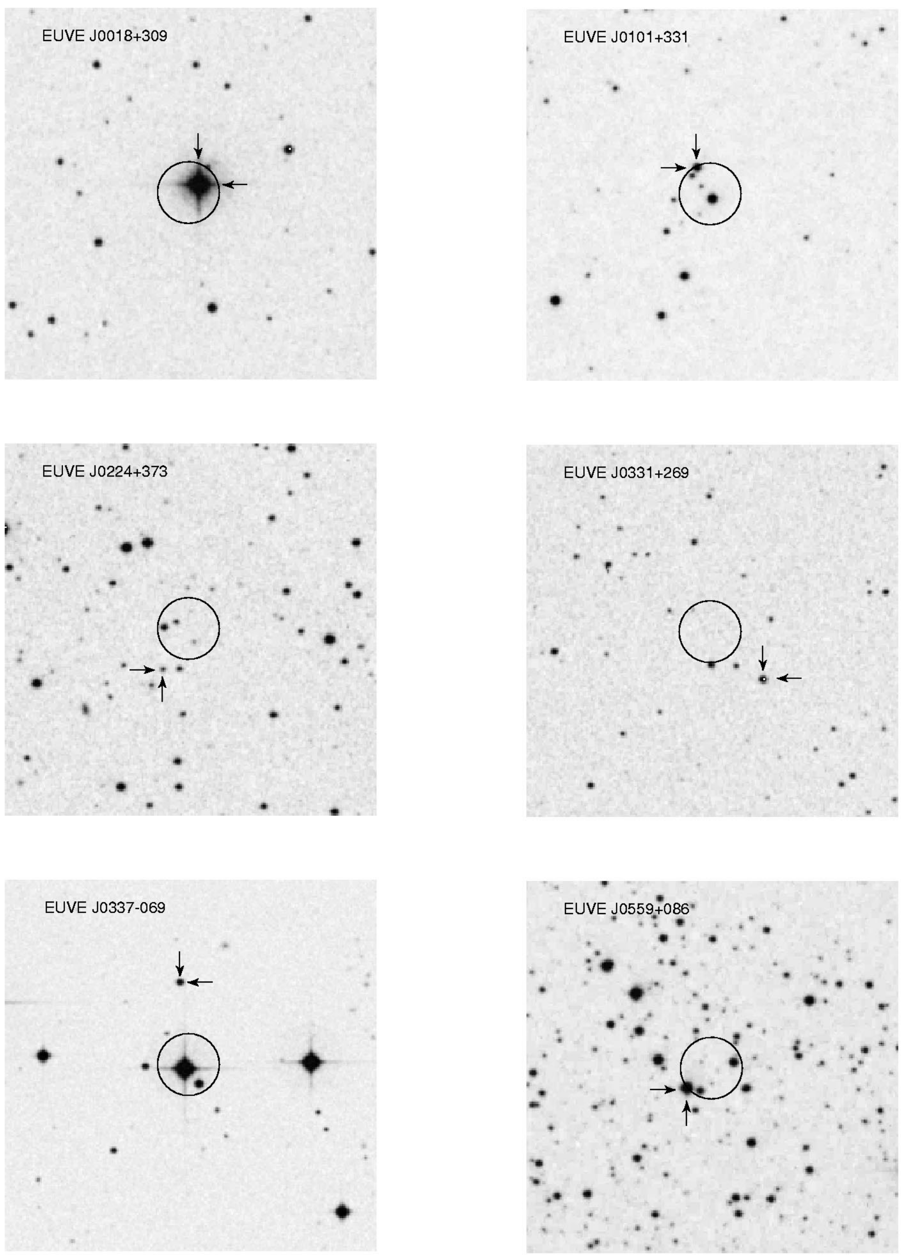

FIG. 1.—(*a–f*): Optical finding charts from the Digitized Sky Survey centered on the *EUVE* position from Lampton et al. (1997) or *EUVE* Second Catalog where applicable. Finding charts are 6′ × 6′ and labeled with the *EUVE* source name. Arrows indicate optical counterpart. Typical *EUVE*/*ROSAT* positional uncertainty is indicated with a circle of radius 30″. North is up, and east to the left.

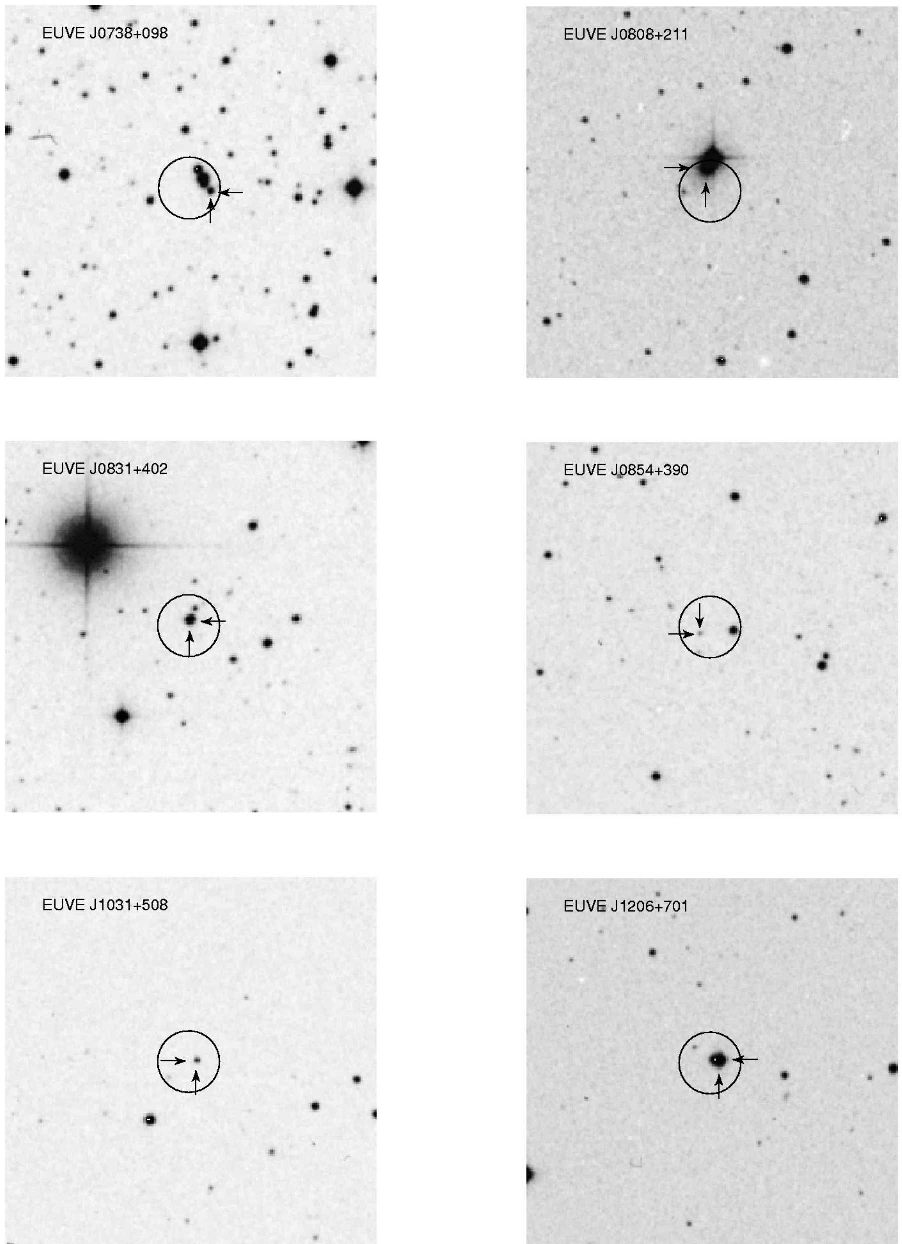

FIG. 1.—*Continued*

identified optical counterparts for the *EUVE* sources are tabulated in Table 2.

3. SOURCE IDENTIFICATIONS

3.1. *The K Stars and M Stars*

We derived general spectral types by comparing the observed spectra with several spectral atlases (e.g., Jacoby et al. 1984; Pettersen & Hawley 1989) and refined these types by using the strength of the titanium oxide (TiO) band. We used the 7050 Å band denoted as "TiO5" in the Reid, Hawley, & Gizis (1995) paper, with upper and lower wavelength ranges of 7042–7046 Å and 7126–7135 Å, respectively. We also include measurement of the 4760 Å TiO feature with its relationship to spectral type from Pettersen & Hawley (1989). It has been argued that this Peterson & Hawley relationship suffers from a nonuniform sample and is not as accurate as the Reid relations; we include the 4760 Å band for comparison with our previous work. In general absolute magnitudes (M_V) calculated from Reid et al. (1995) for the TiO5 band agreed with the derived spectral type, but in a few cases (EUVE J0331+269, EUVE J0831+402, and EUVE J1802+642) the derived M_V implied a later type than assigned from the Reid relation of type and TiO5 band. In these few cases we preferred the dM4–5 classification based on comparison with atlas standards.

3.1.1. *K and M Star Properties*

The majority of optical spectra show the characteristics of late-type stars with Ca H and K and the Balmer series in emission, and strong TiO bands. The M stars are easily recognizable by their strong TiO bands, and sample dMe stars (EUVE J0331+269, J0559+086, J0808+211, J0831+402, J1206+701, and J1802+642) are shown in Figures 2*a*–2*f*. The sample of dKe stars generally had weaker Balmer emission, but strong Ca H and K emission or core emission. EUVE J2206+637 and EUVE J2223+253 are shown in Figures 3*a* and 3*b* as representa-

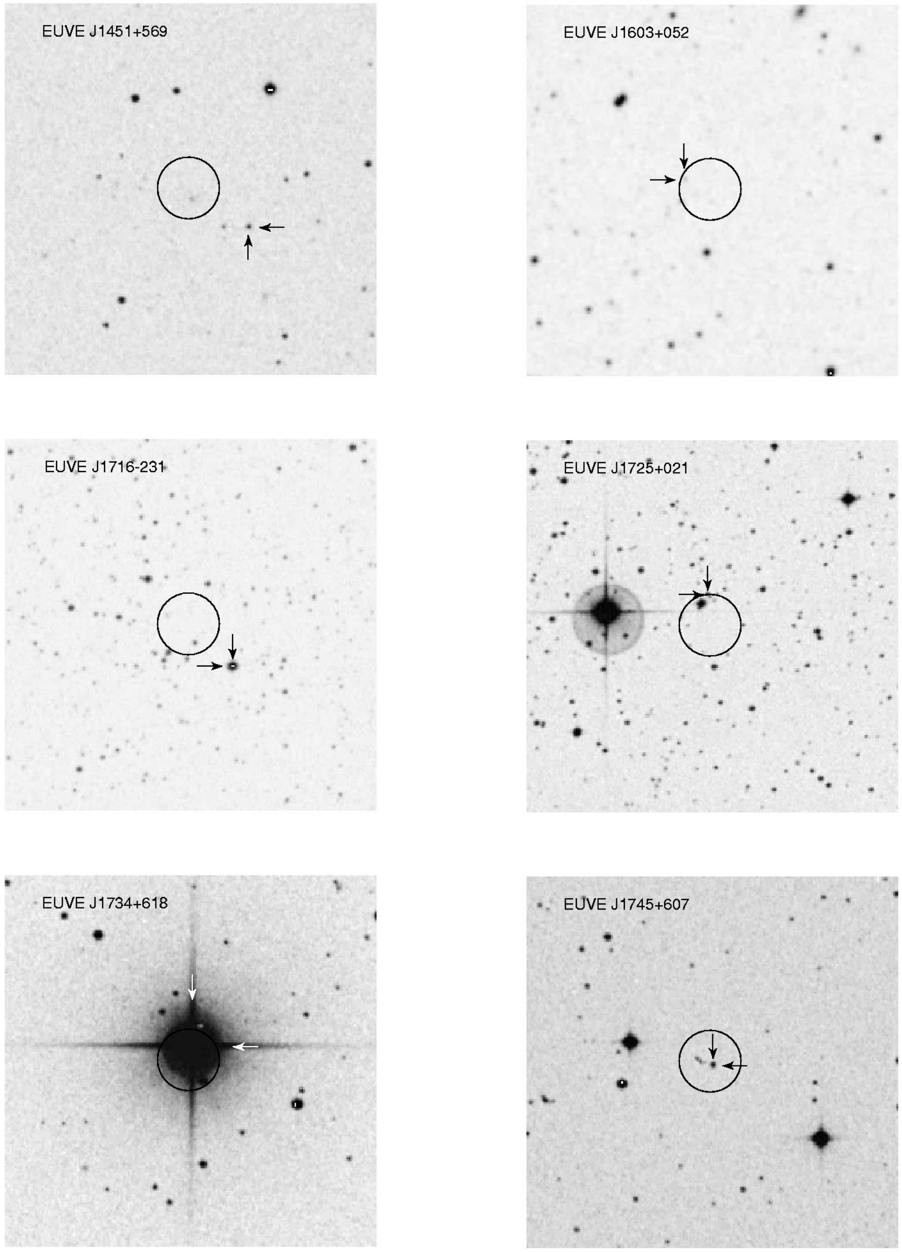

FIG. 1.—*Continued*

tive dKe stars. The Ca II H and K and Balmer line fluxes and equivalent widths for the optical counterparts of the *EUVE* late-type sources are presented in Table 3.

Spectrophotometric magnitudes m_b and m_v were derived by folding the measured absolute flux from the optical spectra of the bands (B, 4300 Å; V, 5500 Å) with the flux of a star with magnitude $m_b = 0$, using absolute calibration photometry of Bessell (1979), and is accurate to $\approx$0.5 mag. Once the absolute magnitude is obtained, the spectroscopic distance can be estimated from the distance modulus. For the *EUVE* candidates we estimated the neutral hydrogen column N(H) density along the line of sight using a three-dimensional interpolation method of P. Jelinsky (1996, private communication).[2] This model uses a large database of hydrogen column densities (Fruscione et al. 1994) from *EUVE* and N(H I) measurements for individual stars. Generally, derived interstellar column densities are consistent with the observed *EUVE* count rates.

[2] See http://archive.stsci.edu/euve/ism/ismform.html.

3.1.2. *EUV Fluxes and L_{euv}/L_{bol}*

We have calculated observed fluxes for our sample using the EUVE Lexan count rates, the coronal model of Monsignori-Fossi & Landini (1994) with $\log T = 6.8$, and the above derived column densities (see Mathioudakis et al. 1995b). In general the dependence of the fluxes on column density is small (50% changes in N(H) result in flux changes of $\leq$25%). We present the observed fluxes for the late-type stars, spectrophotometric magnitudes and derived distances in Table 4.

Studies of late-type stars have found the ratio of their X-ray to optical bolometric luminosities L_X/L_{bol} to span the range of $\sim 10^{-6}$ to 10^{-3} (Agrawal, Rao, & Sreekantan 1986; Fleming, Schmitt, & Giampapa 1995). Jeffries & Jewell (1993) found a similar range for the ratio of L_{euv}/L_{bol} for a sample of late-type stars observed with the *ROSAT*

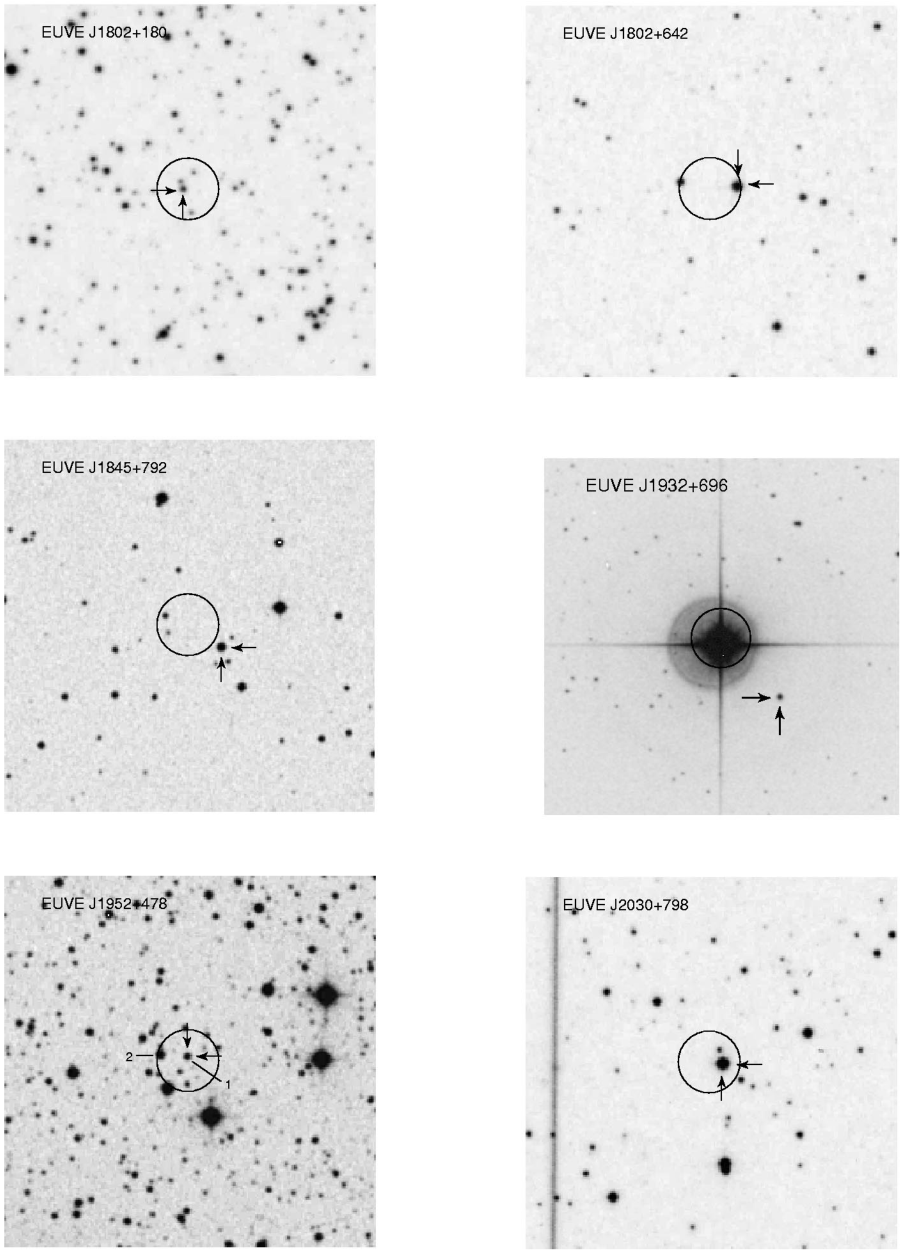

FIG. 1.—*Continued*

WFC. We calculated the ratio of L_{euv}/L_{bol} using the relation given by Jeffries & Jewell (1993) and our derived EUV fluxes and bolometric magnitudes. We find values for the majority of the sample in the previously observed range with the K stars clustering between $L_{euv}/L_{bol} \approx 10^{-5.5}$ to $10^{-3.5}$, and the M stars clustered around 10^{-3}. We plot the Hα equivalent width against L_{euv}/L_{bol} for those sources with measured Hα emission in Figure 4. This figure shows a trend, similar to the one found by Fleming et al. (1995), in which the sources with the strongest Hα emission are clustered near $L_{euv}/L_{bol} \approx 10^{-3}$.

3.1.3. *Notable Sources*

Several sources have other notable characteristics that we discuss presently.

EUVE J0018+309. Only 10″ from RS CVn PW And, but listed in Lampton as a NOID. This *EUVE* source is within ~1′ of 2RE J0018+305, which Pye et al. (1995) identify as PW And (BD +30°34). We also identify EUVE J0018+309 as PW And with dK0e spectral type.

EUVE J0738+098. Identified as a dM2.5e. This source is a long wavelength detection (dagwood; ~400 Å) in the Bowyer et al. (1996) catalog. The EUV flux derived from the dagwood detection gives an unreasonably large $\log(L_{euv}/L_{bol}) \approx -1.7$, and it is surprising there was no shorter wavelength detection. We derive an 90% confidence upper limit of 0.014 counts s^{-1} for a detection in the Lexan filter from the all-sky survey data. This converts into an $\log(L_{euv}/L_{bol}) \approx -2.6$ (shown in Fig. 4), and is reasonably close to the saturation limit. The strong long wavelength detection and lack of emission near 100 Å makes this an interesting source for future EUV and soft X-ray studies.

EUVE J0808+211. Showed the strong TiO absorption bands of a dM3e star and the Balmer series in emission (also shown in Fig. 2*b*). This is the field (centered on EUVE J0807+210) that Maoz, Ofek, & Shemi (1997) had searched

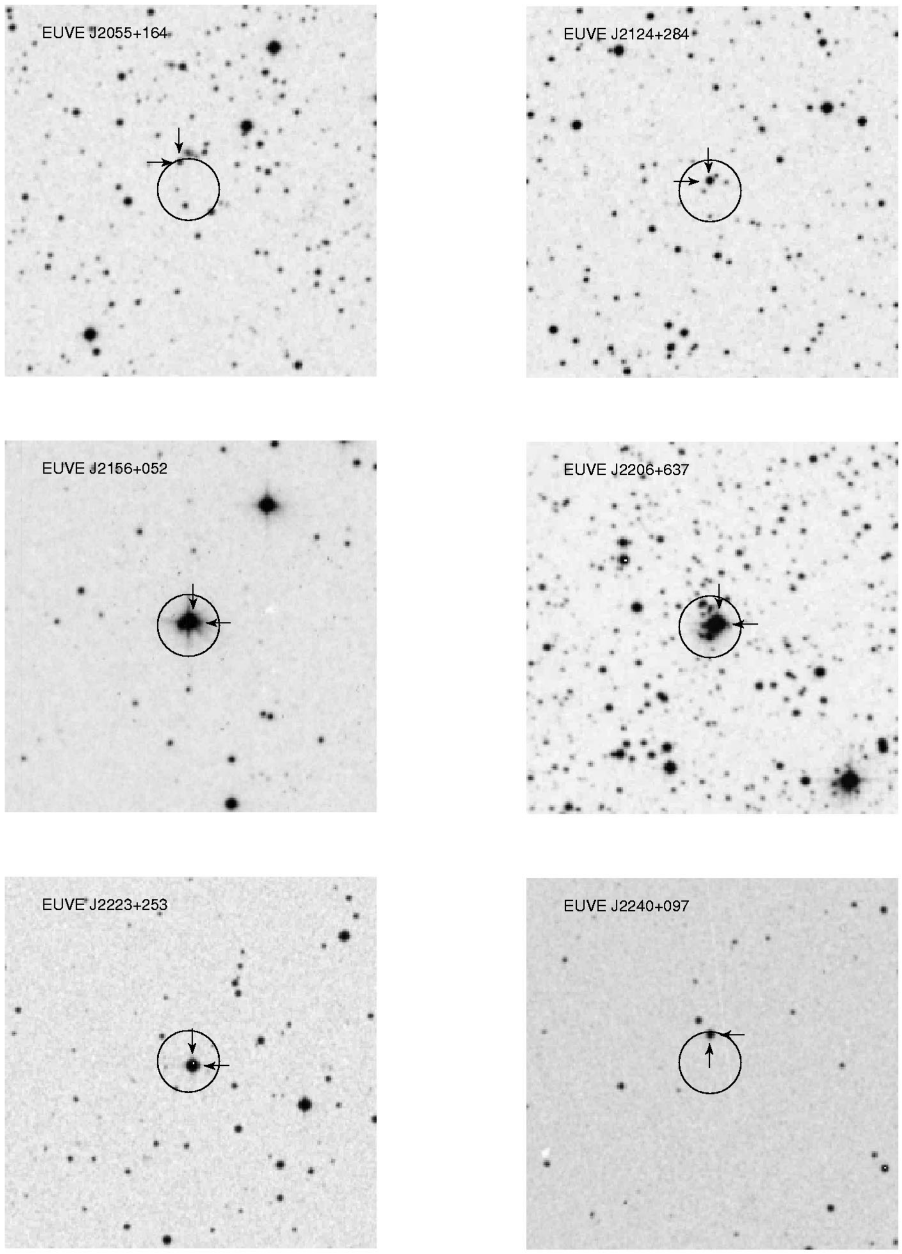

FIG. 1.—*Continued*

for possible isolated accreting neutron stars, and although the dM3e star is 50″ from the *EUVE* field center, it is a more likely candidate as the *EUVE* source. EUVE J0808+211 is also 63″ from 2RE J0808+210, which Pye et al. (1995) identify as the dK5e+dMe pair BD +21°1764A/B. We found no emission from the companion star and attribute the EUV emission to the active dM3e star.

EUVE 1206+701. Has a companion star only ≈5″ from it was also a dM2.5 star, but without Balmer series emission lines, and we chose the dM4e (with position listed in Table 2) as the optical counterpart. The dM4e star is 15″ from the *ROSAT* position.

EUVE J1734+618. Had no optical candidates within a few arcminutes of the *EUVE* position that had indicators of chromospheric activity. However, 5th magnitude dG0, 26 Dra is within ≈20″ of the *EUVE* position. The *EUVE* count rate of EUVE J1734+618 is similar to other G-type stars presented by Mathioudakis et al. (1995b) as having real EUV emission. Also 26 Dra has been identified as a main-sequence star with X-ray emission in the *ROSAT* all-sky survey (Hünsch, Schmitt, & Voges 1998) and has *ROSAT* counterparts (2RE J1734+615, 1RXS J173458.8+615227). For these reasons, we identified EUVE J1734+618 with 26 Dra, a 5th magnitude dG0 star.

EUVE J1952+478. Had two K stars within the *EUVE* pointing uncertainty showing Ca II H and K and Hα in emission. The second star (labeled "2" in the finding chart, Fig. 1*d*, *bottom left*), a dK3e with $V \approx 13$ is 26″ further east than the dK7e (labeled "1" in finding chart and $V \sim 14$) star, which is only a few arcseconds from the *EUVE*/*ROSAT* position. Although the dK7e stars is closer to the *EUVE*/*ROSAT* position both sources are within the *EUVE* positional uncertainty, and either source could be the optical counterpart. We give measured optical quantities for both source in Table 4.

EUVE J2206+637. Identified as a dK5e with V magnitude of 9.7, and we associate it with GSC 04271−00037. This magnitude is in good agreement with the results of

TABLE 2

OBSERVATION LOG

Name	$R.A._{opt}$	$Decl._{opt}$	Observation Date	Exposure (s)	Air Mass
EUVE J0018+309	00 18 20.4	+30 57 29	1996 Sep 26	60	1.12
EUVE J0101+331	01 01 09.3	+33 07 29	1997 Aug 23	900	1.00
EUVE J0224+373	02 24 20.3	+37 24 27	1996 Sep 23	900	1.05
EUVE J0331+269	03 31 13.1	+26 59 35	1997 Sep 12	300	1.02
EUVE J0337−069	03 37 41.8	−06 58 07	1997 Sep 12	490	1.40
EUVE J0559+086	05 59 24.7	+08 40 09	1997 Feb 18	900	1.32
EUVE J0738+098	07 38 06.7	+09 49 28	1997 Feb 18	1800	1.22
EUVE J0808+211	08 08 14.6	+21 06 28	1997 May 19	300	1.26
EUVE J0831+402	08 31 02.2	+40 12 17	1997 Feb 18	900	1.12
EUVE J0854+390	08 54 14.2	+39 05 39	1997 Feb 18	1500	1.21
			1997 Feb 18	3600	1.32
			1997 Feb 18	1800	1.68
EUVE J1031+508	10 31 18.4	+50 53 37	1997 Feb 18	1900	1.33
EUVE J1206+701	12 06 53.6	+70 07 48	1996 May 27	600	1.19
EUVE J1451+569	14 51 27.2	+56 55 24	1996 May 28	1200	1.06
EUVE J1603+052	16 03 17.8	+05 18 04	1998 Jul 17	1800	1.35
EUVE J1716−231	17 16 18.1	−23 10 46	1996 May 26	600	1.26
EUVE J1725+021	17 25 39.4	+02 07 20	1996 May 28	1200	1.22
EUVE J1734+618	17 34 57.6	+61 52 50	1996 May 28	3	1.12
EUVE J1745+607	17 45 53.9	+60 42 10	1997 May 19	1200	1.26
			1996 May 28	1200	1.11
EUVE J1802+180	18 02 06.5	+18 04 42	1997 Sep 12	900	1.07
EUVE J1802+642	18 02 15.2	+64 16 03	1996 May 27	700	1.16
EUVE J1844+792	18 44 56.8	+79 13 30	1997 Sep 12	900	1.39
EUVE J1932+696	19 32 11.0	+69 38 47	1997 Sep 12	600	1.38
EUVE J1952+478 (1)......	19 52 43.3	+47 53 03	1997 Sep 12	900	1.36
EUVE J1952+478 (2)......	19 52 45.9	+47 53 05	1997 Sep 12	600	1.52
EUVE J2030+798	20 30 05.4	+79 50 45	1997 Sep 12	900	1.51
EUVE J2055+164	20 55 28.8	+16 27 30	1996 Sep 23	900	1.98
EUVE J2124+284	21 24 58.3	+28 26 06	1996 Sep 23	900	1.01
EUVE J2156+052	21 56 27.0	+05 15 57	1996 Sep 25	600	1.33
EUVE J2206+637	22 06 35.5	+63 45 18	1996 Sep 25	300	1.12
EUVE J2223+253	22 23 56.0	+25 23 36	1996 Sep 25	900	1.13
EUVE J2240+097	22 40 22.2	+09 44 04	1996 Sep 25	900	1.48

NOTE.—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

Vennes, Korpela, & Bowyer (1997), who find $m_v = 9.8$. EUVE J2206+637 is 104″ from 2RE J2206+634, which Pye et al. (1995) identify as a GSC 04271−01011, a 14th magnitude star. This implies that the 2RE identification is wrong or that EUVE J2206+637 and 2RE J2206+634 are distinct objects.

3.2. *White Dwarfs*

Only three sources showed the strong blue continuum with Balmer lines in absorption indicative of a white dwarf star. We identified EUVE J1745+607, EUVE J2055+164, and EUVE J2124+284 as DA white dwarfs (WDs). We determined the atmospheric parameters by fitting the Balmer profiles with the theoretical line profiles of Wesemael at al. (1980), as done in our previous optical identification work described in Craig et al. (1997). We find these WDs to have fairly typical temperatures and surface gravities for white dwarfs observed with *EUVE*. EUVE J2124+284 is the hottest in the sample with a temperature of 53,000 K and surface gravity of $\log g = 7.6$. EUVE J2055+164 has a temperature of 38,000 K and $\log g = 8.4$. EUVE J2055+164 and EUVE J2124+284 have been previously presented as WDs by Vennes, Korpela, & Bowyer (1997), and our derived atmosphere parameters are consistent with theirs. EUVE J1745+607 has the highest surface gravity, 8.72 ± 0.05, on the high side for the *EUVE* sample, but in line with massive white dwarfs found with *EUVE* (Vennes et al. 1996; Dupuis & Vennes 1997). EUVE J1745+607 has also been identified as a DA by Homeier et al. (1998) in the Hamburg Quasar Study. Our value for the surface gravity is consistent with the value of $\log g = 8.68$ derived by Homeier et al. (1998). We derived a temperature for this source of 35,450 ± 250 K, which is also consistent with the Homeier et al. (1998) value. The optical spectrum of DA white dwarf EUVE J1745+607 is shown in Figure 5*a*, and the fits to the Balmer line profiles are shown in Figure 5*b*. White dwarf spectrophotometric magnitudes, H I columns and derived distances are also presented in Table 4.

3.3. *Cataclysmic Variables*

EUVE 1802+180. Shows the strong emission lines of a cataclysmic variable (see Fig. 6*a*) is ≈5″ from RX J1802.1+1804 (V884 Her). RX J1802.1+1804 was identified independently as a magnetic CV by Szkody et al. 1995 and Greiner et al. 1995. EUVE J1802+180 coincidentally had a serendipitous *EUVE* RAP observation in 1993 May 29 (MJD 49,136.59) with an exposure of ≈70 ks. We folded

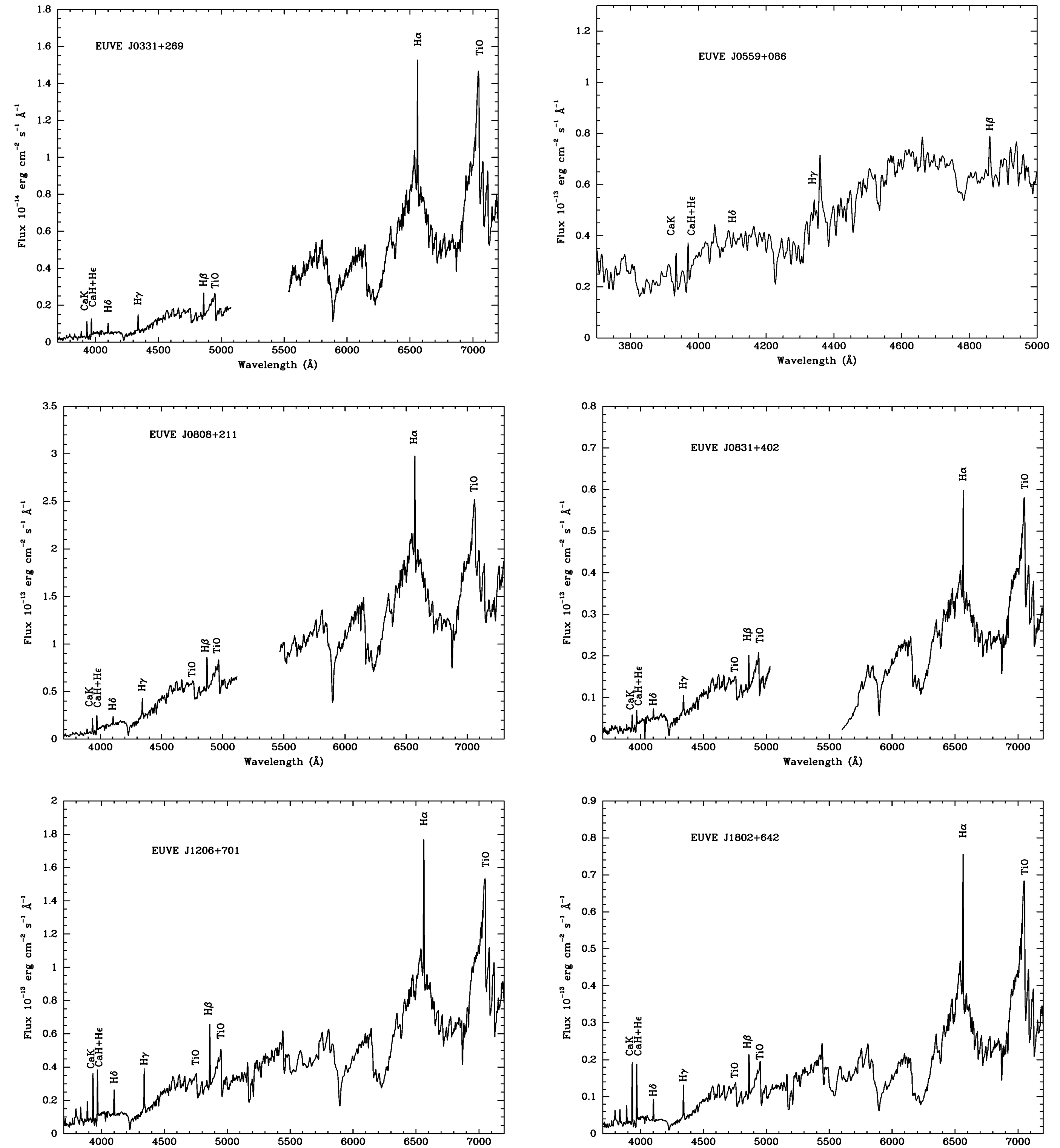

FIG. 2.—Sample optical spectra of the dMe stars

the *EUVE* scanner Lexan (100/AA) light curve on the 113.0 minute period of Szkody et al. (1995; see also Hastings et al. 1999), and we show this in Figure 6*b*.

EUVE J0854+390. Optical spectra showed Balmer, He I λλ4471, 5876, and He II λ4686 lines strongly in emission with the continuum increasing toward the blue and indicating the source is a CV, probably magnetic. There were three exposures of the CV, although in the two shorter exposures the CCD was centered on other stars in the field, although the CV was also in the slit. The first 25 minute exposure found the lines to be blueshifted by ≈2 Å or ≈200 km s^{-1} and was followed by a 60 minute exposure. This second observation found the source to be ≈2 times brighter and with the emission lines shifted to the red. The average line

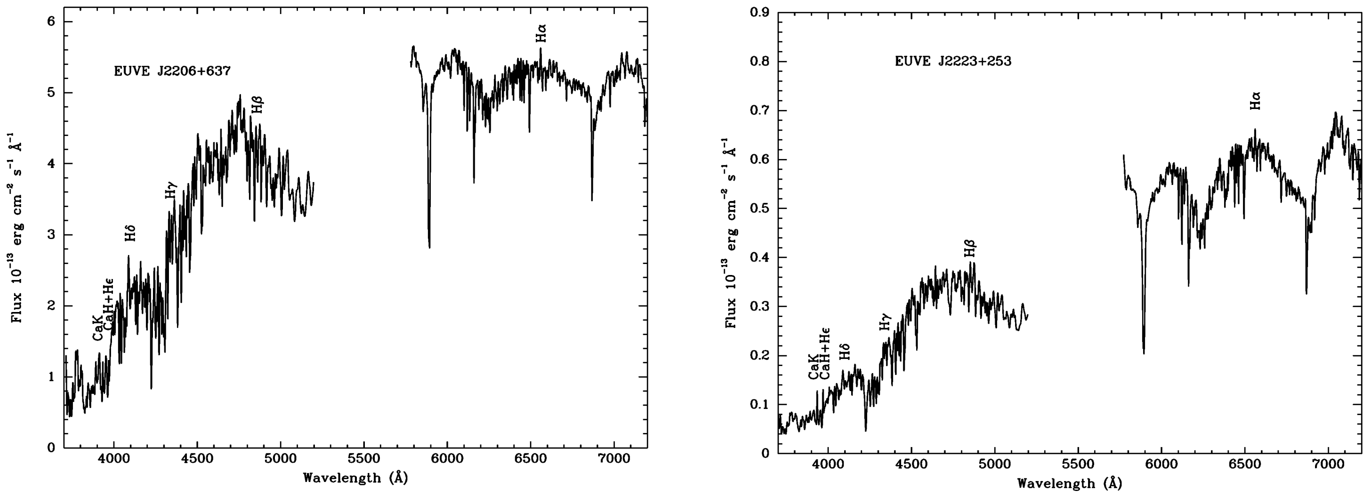

FIG. 3.—Sample optical spectra of dKe stars, EUVE J2206+637 (dK5e) and EUVE J2223+253 (dK7e)

shift was about ≈6 Å or 400 km s^{-1}. The third exposure, started at 11:45 UT, found the source to be ≈7 times fainter than the previous exposure with measurable lines redshifted by ∼100 km s^{-1}, although limited by low signal. The measured radial velocities suggest the source period is less than 2 hr, although the poor sampling is not definitive and further observations are needed. We show the two brightest optical spectra of EUVE J0854+390 from 1997 January in Figure 7. If we assume an intrinsic magnitude of ≈10 for the white dwarf in EUVE J0854+390 based on typical *EUVE*-selected WDs (Vennes et al. 1996), we derive a distance to the CV of 190–250 pc.

3.4. *Active Galactic Nuclei*

EUVE J1031+508 showed a featureless continuum rising toward the blue end of the spectrum. Polomski et al. (1997) identify this source as a BL Lac and measure a redshift of 0.361 from the Ca II lines. The redshifted Ca II lines

TABLE 3

RESULTS FOR EUVE LATE-TYPE STAR OPTICAL COUNTERPARTS

	LINE FLUXES[a]					EQ. WIDTHS[b]							
SOURCE	Ca K	Ca H	Hα	Hβ	Hγ	Ca K	Ca H	Hα	Hβ	Hγ	TiO BAND (λ4760)	TiO BAND (λ7050)	SP. TYPE
EUVE J0018+309	29.4	19.2	42.0	...	...	0.9	0.5	0.4	...	...	0.91	...	dK0e
EUVE J0101+331	0.3	0.4	1.3	...	...	5.0	4.6	2.3	...	...	0.84	...	dK5e
EUVE J0224+373	0.01	0.015	...	...	...	7.4	12.3	...	...	...	0.71	...	dM0e
EUVE J0331+269	0.3	0.4	3.4	0.65	0.36	12.0	12.4	4.3	4.8	5.6	0.71	0.36	dM4e
EUVE J0337−069	0.01	0.01	...	...	...	2.4	0.9	...	...	...	0.84	...	dK5e
EUVE J0559+086	6.5	6.0	20.2	9.8	2.5	3.7	2.9	2.5	1.6	0.5	0.81	0.71	dM0.5e
EUVE J0738+098[c]	...	...	0.9	...	...	...	...	2.7	...	...	...	0.51	dM2.5e
EUVE J0808+211	7.0	7.0	61.0	20.0	7.7	11.0	7.1	3.3	3.8	2.9	0.69	0.48	dM3e
EUVE J0831+402	1.6	1.9	9.3	3.8	1.7	6.1	6.2	2.7	3.1	2.5	0.62	0.38	dM4e
EUVE J1206+701	12.9	14.6	53.0	21.6	10.0	18.8	17.1	5.9	7.8	6.8	0.73	0.39	dM4e
EUVE J1451+569	0.003	0.005	0.004	...	...	0.6	0.9	1.6	...	...	0.85	...	dK4e
EUVE J1603+052	0.004	0.004	...	...	...	1.6	1.9	...	...	...	0.79	...	dK7e
EUVE J1716−231	1.1	1.1	2.6	...	...	3.2	2.9	0.3	...	...	0.92	...	dK0e
EUVE J1725+021	5.7	8.1	...	...	...	0.7	0.9	...	...	...	0.72	0.87	dM1e
EUVE J1802+642	7.7	7.8	19.0	6.5	3.7	36.6	27.7	5.3	6.4	7.8	0.52	0.31	dM5e
EUVE J1844+792	0.13	0.09	1.0	0.7	...	1.2	0.6	1.0	0.9	...	0.86	...	dK4e
EUVE J1932+696	0.06	0.07	...	...	...	0.4	0.4	...	...	...	0.93	...	dK1e
EUVE J1952+478 (1)......	0.15	0.17	0.9	...	...	1.8	1.8	1.3	...	...	0.83	...	dK7e
EUVE J1952+478 (2)......	0.4	0.2	0.6	...	...	0.8	0.3	0.2	...	...	0.89	...	dK3e
EUVE J2030+798	4.5	5.2	40.0	8.8	3.4	18.5	17.7	4.8	4.4	3.3	0.77	0.55	dM2e
EUVE J2156+052	3.1	2.5	...	...	...	0.5	0.3	...	...	...	0.93	...	dK0e
EUVE J2206+637	16.0	16.0	...	...	...	2.2	1.9	...	...	...	0.9	...	dK5e
EUVE J2223+253	3.0	2.8	3.9	...	...	4.8	3.9	0.6	...	...	...	0.83	dK7e
EUVE J2240+097	0.01	0.02	...	...	...	0.2	0.3	...	...	...	0.88	...	dK3e

[a] 10^{-14} ergs cm^{-2} s^{-1} $Å^{-1}$.
[b] Angstroms.
[c] No blue side spectrum for EUVE 0738+098.

TABLE 4

PHYSICAL PROPERTIES

Name	Mag[a] (m_b)	Mag[b] (m_v)	Spectral Type	Distance (pc)	log N_H (cm^{-2})	Obs. Flux[c] (10^{-13} ergs cm^{-2} s^{-1})	Ang. Sep.[d] (arcsec)	Ang. Sep.[e] (arcsec)	Comment
Late-Type Stars									
EUVE J0018+309	9.6	8.7	dK0e	36	18.3	14.2	41	12	PW And
EUVE J0101+331	15.9	14.4	dK5e	190	20.1	148.9	32	29[g]	GSC 02281-00797
EUVE J0224+373	19.2	17.9	dM0e	550	<20.6	264.4	48	...	
EUVE J0331+269	17.4	15.0	dM4e	48	18.9	8.1	68	49	GSC 01806-01541
EUVE J0337-069	17.1	15.8	dK5e	363	18.2	8.4	36	75	
EUVE J0559+086	12.9	11.8	dM0.5e	29	19.0	9.1	18	24	GSC 00716-01605
EUVE J0738+098	...	15.5	dM2.5e	91	18.1	290.0	19	...	
EUVE J0808+211	11.7	9.8	dM3e	6	18.3	9.4	50	19	GSC 01389-02023
EUVE J0831+402[f]	14.9	13.3	dM4e	22	17.3	6.5	47	10	GSC 02978-01686
EUVE J1206+701	14.0	12.4	dM4e	14	17.2	5.8	57	15	GSC 04396-01487
EUVE J1451+569	19.3	19.5	dK4e	~700[g]	20.3	226.0	31	70	
EUVE J1603+052	19.3	18.0	dK7e	692	20.3	226.6	24	...	
EUVE J1716-231	13.2	11.5	dK0e	132	20.0	6.8	57	11	GSC 06812-00348
EUVE J1725+021	18.0	17.3	dM1e	316	20.0	138.9	61	31[h]	
EUVE J1734+618[i]	5.9	5.3	dG0	14	17.4	37.0	42	25	GSC 04199-01513
EUVE J1802+642	15.3	13.5	dM5e	17	17.2	1.8	54	18	GSC 04209-01465
EUVE J1844+792	15.2	13.9	dK4e	182	18.1	2.7	37	31	GSC 04591-00057
EUVE J1932+696	15.0	14.3	dK1e	398	18.7	2.9	101	86	GSC 04448-00084
EUVE J1952+478 (1)	15.8	14.4	dK7e	132	19.6	14.2	26	7	
EUVE J1952+478 (2)	13.9	13.0	dK3e	150	19.6	14.2	44	30	
EUVE J2030+798	14.4	12.1	dM2e	22	17.5	3.9	65	15	GSC 04593-01344
EUVE J2156+052	11.0	...	dK0e	105	19.6	35.8	27	7	GSC 00553-00033
EUVE J2206+637	10.9	9.7	dK5e	22	19.3	6.9	56	6	GSC 04271-00037
EUVE J2223+253	13.7	12.2	dK7e	48	18.0	7.6	5	15	GSC 02222-00055
EUVE J2240+097	15.6	14.3	dK3e	275	19.9	113.2	28	...	GSC 01152-00010
White Dwarfs									
EUVE J1745+607	15.0	16.3	DA	138	19.1	...	48	2	
EUVE J2055+164	15.1	15.6	DA	120	18.9	...	34	...	
EUVE J2124+284	13.4	14.3	DA	115	19.1	...	55	13	
Cataclysmic Variables									
EUVE J0854+390	16.4	16.4	CV	190–250	18.5	...	26	14	
EUVE J1802+180	15.0	14.6	CV	100–200[j]	19.3	...	39	5	V884 Her
AGN									
EUVE J1031+508	16.7	...	BL Lac	2200[k]	20.1	...	60	4	

[a] From B bandpass spectrophotometry; the estimated error is 0.5 mag.
[b] From V bandpass spectrophotometry; the estimated error is 0.5 mag.
[c] The observed flux derived using N_H value and *EUVE* Lexan count rates from Table 1.
[d] Angular separation between the optical and the derived *EUVE* source position.
[e] Angular separation between the optical and the *ROSAT* source position (unless otherwise noted).
[f] Our recent observations resolved EUVE 0831+402 as a binary with a separation of $<1''$.
[g] Distance set from maximum column observable in the *EUVE* Lexan band.
[h] Separation between the optical source and the Lampton et al. 1997 position.
[i] Identified as 26 Dra; see § 3.1.
[j] Distance estimate from Greiner et al. 1998.
[k] Distance in megaparsecs from Polomski et al. 1997.

fell between our Kast blue and red setup, but our featureless continuum and B magnitude of 16.7 are the same as Polomski et al., and we also identify this source as a BL Lac.

4. DISCUSSION

The source distribution of the combined all-sky survey *EUVE* catalogs (Bowyer et al. 1996; Lampton et al. 1997) and RAP catalogs (McDonald et al. 1994; Christian et al. 1999) is dominated by late-type stars (nearly 40%). The second largest class of identified objects are the white dwarfs (~15%) followed by early-type stars, extragalactic objects, sources classified as "other," and cataclysmic variables, each contributing ~5%. However, the class of sources with no spectral types or other catalog information (NOIDs) accounts for more than 30% of the *EUVE* sources (340 by number). The contributions of the optical identification campaigns (Craig et al. 1995; 1996; Craig & Fruscione 1997; Polomski et al. 1997; Vennes et al. 1997) and this current work have identified ≈28% (94) of these 340 NOIDs. In light of the *EUVE* source distribution, it is not surprising that the majority of the sources identified by

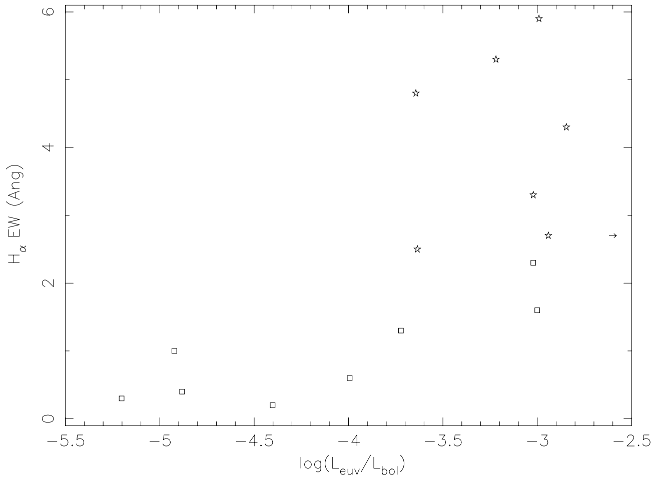

FIG. 4.—Hα equivalent width (EW) plotted against the log of the ratio of L_{euv}/L_{bol} for the K (*squares*) and M (*stars*) stars for sources with measured Hα emission. The arrow indicates a 90% confidence upper limit for EUVE J0738+098 (see § 3.1.3).

these campaigns were late-type stars and other emission line sources. Although this may also indicate the selection effect of optical observations being more sensitive to sources with strong emission lines.

Although *EUVE* optical identification campaigns have had some success, they have yet to identify nearly 250 fields. Our own optical observations of more than 120 fields (this work and Craig et al. 1995; 1997) found ≈50 fields for which no obvious EUV candidates were found, although the fields were extensively observed. Based on the all-sky survey source distribution, one is tempted to then predict that the majority of the remaining NOIDs are fainter active late-type stars, many of which may be high proper-motion objects and generally uncataloged, or fainter white dwarfs. However we can also speculate that there is a new class of faint EUV-emitting objects, such as, isolated nearby old neutrons stars (e.g., Geminga, Bignami et al. 1996). Maoz et al. (1997) predict a large number, $\sim 10^9$, of isolated old neutron stars, and several hundred of them are expected to be within 100 pc. Even though the optical spectra of such objects are not clearly known, Stocke et al. (1995) and Walter, Wolk, & Neuhauser (1996) found two X-ray sources that may be candidates for this class. Clearly this is an areas that merits further study. Photometric colors for many of the sources in these unidentified NOID fields will soon be available with the large all-sky optical surveys such as the Second Guide Star Catalog (McLean et al. 2001) and Sloan Digital Sky Survey (York et al. 2000). These surveys, combined with spectroscopic studies, promise to shed light on these remaining unidentified *EUVE* sources.

5. SUMMARY

We have presented optical identifications of previously unidentified faint extreme ultraviolet sources including ones selected from joint detections from the *EUVE* all-sky survey and *ROSAT* 0.25 keV band. Our sample includes: 24 late-type stars, three white dwarfs, two cataclysmic variables, and one AGN, of which 22 are new identifications. Our sample of active late-type stars is dominated by M stars showing strong Balmer and Ca II emission lines. The white dwarfs are fairly typical for those detected in the *EUVE* survey with T_{eff} and $\log g$ ranging from 35–53 kK and 7.6–8.7, respectively. We found strong H and He emission lines typical of cataclysmic variables for EUVE J0854+390 and EUVE J1802+180. EUVE J0854+390 is a new cataclysmic variable with strong Blamer and He I and He II emission lines with maximum radial velocity shifts observed to be ~ 400 km s^{-1}, and this source merits further

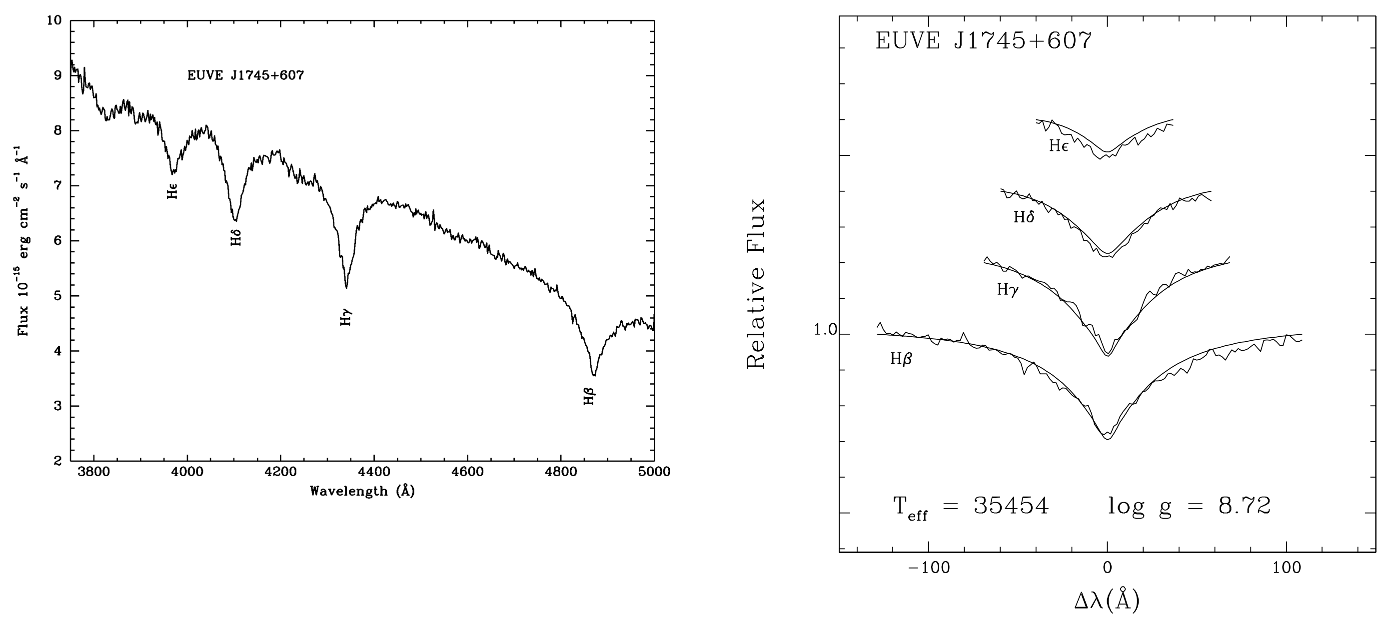

FIG. 5.—Blue-side optical spectrum of DA white dwarf EUVE J1745+607(*top*) and the fits to the Balmer line profiles (*bottom*; see text)

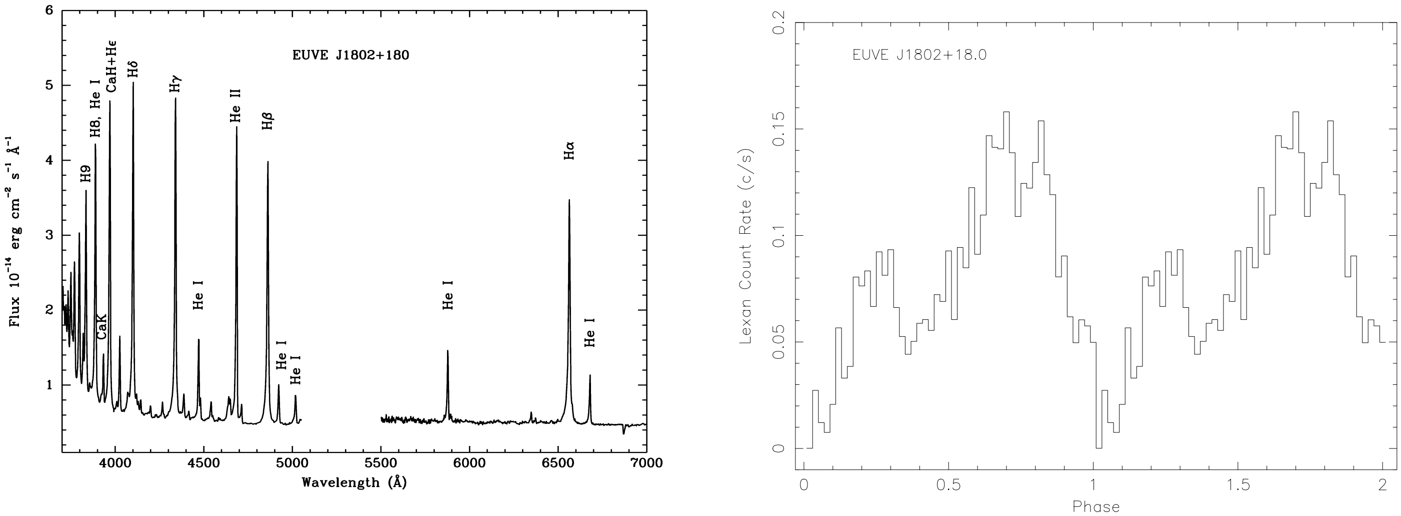

FIG. 6.—(*a*) Optical spectrum of CV EUVE J1802+180 and (*b*) EUVE Lexan (100 Å) light curve folded on the 113 minute period of Szkody et al. (1995) (see text).

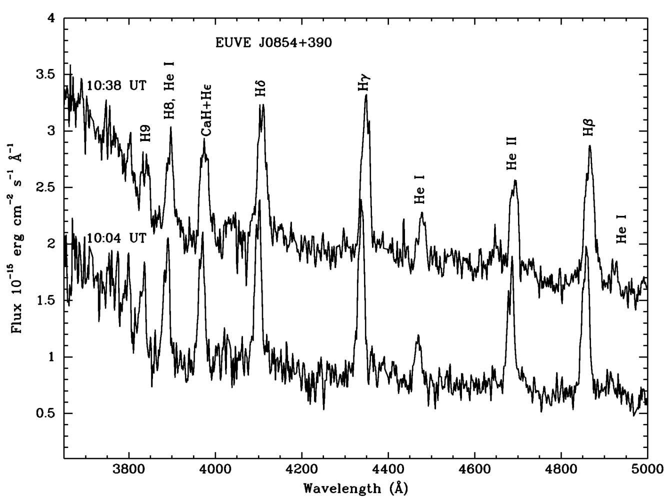

FIG. 7.—KAST blue-side spectra for CV EUVE J0854+390. The bottom spectrum was the first 30 minute exposure (10:04 UT) and was followed by an hour integration started 34 minutes later (10:38 UT). The second exposure found the source to be ≈ 2 times brighter with lines redshifted by ≈ 6 Å (see text).

study. We associate EUVE J1802+180 with previously identified CV, V884 Her (RX J1802.1+1804). We found *EUVE* RAP data consistent with the source's 113 minute optical period. *EUVE* optical identification campaigns have identified $\approx 28\%$ of the presently cataloged NOID sources.

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