MINOR PLANETS AND RELATED OBJECTS. XXV. *UBV* PHOTOMETRY OF 145 FAINT ASTEROIDS

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ABSTRACT

Magnitudes and colors on the *UBV* system are presented for 145 minor planets, including 31 objects in the Eos family, 14 in the Koronis family, 6 in the Nysa family, 11 in the Themis family, 4 Hungarias, 7 Hildas, 8 Trojans, and several objects in unusual orbits. Clearly defined color groups for the Eos, Koronis, Nysa, and Themis family members are strongly suggestive of origin from discrete parent bodies. The Nysas apparently show large lightcurve amplitudes. The Mars-orbit-crossers 1977RA and 1980=1950LA,the Earth-orbit crosser 1976UA, and several mainbelt asteroids are found to show peculiar colors of unknown significance. The Mars-orbit crosser 1916=1953RA appears to be a typical *S* object, while 1474 Beira and 1977VA show neutral colors. Asteroids at semimajor axis $a > 4$ AU (Trojans preceding and following Jupiter, 279 Thule, and 944 Hidalgo) all belong to a color group centered at $B\text{-}V = 0.72$, $U\text{-}B = 0.24$.

I. INTRODUCTION

Photometric data on the *UBV* system were presented by Zellner *et al.* (1975) for 91 minor planets. They demonstrated that, although little compositional information can be directly extracted from $B - V$ and $U - B$ colors, it is usually possible to recognize the principal optical types identified by more sophisticated techniques (e.g., Chapman *et al.* 1975; Zellner and Gradie 1976; Morrison 1977; McCord and Gaffey 1974; Gaffey and McCord 1977; Bowell *et al.* 1978. Ferrosilicates generally have reddish colors in this spectral region due to the broad wings of ultraviolet charge-transfer absorptions; the colors are variously muted by components of spectrally neutral silicate, free metal, and opaques such as finely divided carbon. In *UBV* colors asteroids of type *S* (ferrosilicate plus metal) are well separated from other types, while the domains of type *C* (silicate plus opaques), *M* (metal, or metal plus neutral silicate), and *E* (neutral silicate) overlap somewhat. Objects of exceptional type usually stand out from the population in *UBV* colors.

The power of *UBV* photometry lies in its great sensitivity, which permits observations of almost any numbered asteroid at a 2-m telescope. Thus we can classify, at least provisionally, large numbers of small and distant objects for statistical studies of the distributions of types over diameter and heliocentric distance (Zellner and Bowell 1977). We can also study the smaller members of dynamical families, which are now showing indications of compositional homogeneity in accordance with old suggestions that they are fragmentation remnants of discrete parent bodies.

Zellner *et al.* (1977a) presented additional *UBV* data for 65 objects, with emphasis on the distant Hildas and Trojans and main-belt asteroids down to 6-km diameter. We here present new observations of 145 objects, most of which have not been previously observed by any compositionally sensitive technique.

Asteroids were selected according to (a) mean opposition blue magnitudes between 14.5 and 15.5, for improvement of the classification statistics in this poorly sampled magnitude range; (b) poorly-known absolute magnitudes as indicated by Gehrels and Gehrels (1978); and (c) membership among the Hungarias, Hildas, Trojans, and the dynamical families associated with 24 Themis, 44 Nysa, 158 Koronis, and 221 Eos (Arnold 1969; Williams 1978). The Nysa family appears to consist entirely of the very rare *E* type (Zellner *et al.* 1977b), while the large Eos, Koronis, and Themis groups are the subjects of continuing exploration by several techniques (Gradie and Zellner 1977; Gradie *et al.* 1977). Our program is complementary to the extensive *UBV* photometry of Bowell (1977) for the brighter asteroids.

II. OBSERVATIONS

Circumstances of the observing nights are given in Table I. With few exceptions as noted, the measurements were made with standard *UBV* filters and the computerized photon-counting polarimeter described by Frecker and Serkowski (1976). Standard stars exclusively from the list of Purgathofer (1969) were observed each night and the reductions were done by standard techniques (Hardie 1962; Zellner *et al.* 1977a). An analysis of the standard star measurements showed no indications of variability. Some checks for possible systematic deviations between our Purgathofer standards and primary *UBV* standards (Gehrels and Owings 1962) showed no indication for any significant deviation. For 12 objects

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TABLE I. Photometric quality of the observing nights.

Date UT	Observer[a]	Instrument[b]	Standard stars	N	Standard star observations[c] σ_V	σ_{B-V}	σ_{U-B}
1976 Oct 29	Z/D	M,154	SA94-16-18-29-30	8	0.011	0.020	0.028
Nov 26	G/D	M,154	SA71-7-11-14-17	14	0.006	0.015	0.018
Dec 21	G/L	M,228	SA51-11-19-20-21 SA71-7-11-14-17	16	0.016	0.010	0.017
Dec 22	G/L	M,228	SA51-11-20-21 SA71-7-11	10	0.007	0.008	0.011
Dec 27	Z/L	M,154	SA51-18-20-21-22	8	0.015	0.012	0.028
1977 Jan 16	G	M,154	SA51-7-11-14-17 SA71-7-11	9	0.020	0.011	0.006
Feb 20	Z/D	M,154	SA54-18-20-21-22 -24-26	9	0.011	0.041	0.016
Feb 21	D	M,154	SA54-18-20-24-26	9	0.009	0.012	0.017
Mar 21	G	M,154	SA51-19-20-21 SA57-15-18	10	0.027	0.019	0.036
Apr 13	D	M,154	SA54-18-20	4	0.006	0.004	0.012
Apr 14	D	M,154	SA54-18-20-24-26	6	0.011	0.003	0.016
May 15	D	M,154	SA54-18-20-24-26	12	0.007	0.007	0.026
May 16	D	M,154	SA54-18-20-14-26 AQUILA-15	8	0.040	0.035	0.044
Jun 12	D	M,154	SA54-18 AQUILA-8-14-15-24	12	0.015	0.020	0.029
Jun 13	D	M,154	SA54-18-20 AQUILA-8-14-15-24	13	0.019	0.024	0.025
Jun 14	D	*UBV*,154	SA54-18-20 AQUILA-8-14-15-24	10	0.026	0.041	0.030
Jun 15	D/G	*UBV*,154	AQUILA-8-14-15-24	11	0.027	0.017	0.045
Jun 16	G/D	*UBV*,154	SA54-15 AQUILA-8-14-15-24	10	0.024	0.010	0.040
Sep 18	D	M,154	AQUILA-15-24	5	0.004	0.013	0.011
Sep 19	D	M,154	AQUILA-15-24 SA71-14-17	10	0.008	0.020	0.025
Sep 20	G	M,152	AQUILA-7-16-20	6	0.012	0.004	0.008
Oct 16	D	M,152	SA71-14-17	4	0.010	0.010	0.010
Oct 17	D	M,152	SA71-14-17	4	0.040	0.007	0.008
Oct 19	D	M,154	AQUILA-15-24	4	0.002	0.006	0.008
Oct 20	D	M,154	AQUILA-14-15-24	6	0.018	0.010	0.032
Nov 3	G	M,154	SA94-16-18	4	0.000	0.002	0.006
Nov 16	D	M,154	SA71-14-17	4	0.004	0.021	0.016
Nov 17	D	M,154	SA71-14-17	16	0.004	0.009	0.012
Dec 16	Z	M,228	SA94-16-19-23-26	4	...	...	...
Dec 17	Z	M,228	SA94-16-19-23-26	6	...	...	...

[a] D: J. Degewij G: J. Gradie L: M. Leake Z: B. Zellner.
[b] M: Computerized photopolarimeter with *UBV* filters (Frecker and Serkowski 1976) *UBV*: *UBV*-photometer (Johnson 1962).
152: 152-cm Mt. Lemmon reflector of the Lunar and Planetary Laboratory.
154: 154-cm Catalina reflector of the Lunar and Planetary Laboratory.
228: 228-cm Kitt Peak reflector of Steward Observatory.
[c] Number of standards observed and standard deviation of the residuals.

we have measurements in common with E. Bowell. For both colors we found a mean for the residuals ("Tucson–Flagstaff") of $-0^{m}.01$ and an rms error of $0^{m}.03$.

For faint moving objects that are not always near the predicted positions, identification can be difficult. We make finding charts in the form of 35 mm negatives covering 55 × 35 arcmin from Palomar Observatory Sky Survey glass plates. Faint circles indicating the predicted position of the asteroid are superimposed on the negatives. At the telescope a 30X microfiche projector gives a scale and illumination close to that of the star background at the eyepiece. Recently we used at the 154-cm telescope a TV system with an intensified-silicon intensified-target vidicon, showing in some seconds objects down to visual magnitude 18 in a field of 5 arcmin diameter. This device was invaluable in locating the fainter objects. Asteroid motion is checked by plotting the position of the asteroid and nearby stars on a plastic overlay in front of the TV screen. The image scale (1 mm = 4 arcsec) allows motion to be visible in 5–10 min.

Table II lists the results. Generally we used filter sequence *VVBBUUUUBBVV* with integration time 20 s and a sky measurement at each filter, for a total integration time of 6 min per observation. Figure 1 illustrates the rms error of a tabulated observation expected from the internal noise level of our data. In some cases special efforts were made to achieve higher precision, as indicated in Table II.

Multiple observations in Table II give some indications of lightcurve variability. Measurements separated by an hour or more on a single night for 17 minor planets show mean magnitude difference $0^{m}.08$ and no differences exceeding $0^{m}.18$. Apparently many of these small objects are not very elongated, in agreement with the photographic lightcurve studies of Degewij (1977). An exception is asteroid 1595, for which a large-amplitude

TABLE II. Photometric observations of asteroids.

Asteroid	F[a]	Date	UT[b]	Phase (Deg.)	$B-V$[d]	$U-B$[d]	V[d]	$V(1,\alpha)$	$V(1,0)$
37 Fides		76 11	26.48	23.96	0.84	0.40	11.17	8.26	7.71
40 Harmonia		77 11	16.45 !	9.70	0.83	0.47	9.88	7.64	7.42
69 Hesperia		77 10	16.37 !	6.83	0.66	0.18	11.47	7.49	7.36
		77 10	16.39 !	6.83	0.65	0.20	11.45	7.47	7.34
89 Julia		77 10	16.43 !	23.85	0.83	0.46	11.48	7.78	7.23
		77 10	16.45 !	23.85	0.88	0.48	11.46	7.76	7.21
142 Polana	Ny	76 12	21.54	25.91	0.61	0.23	14.96	11.60	11.00
153 Hilda[c]	Hi	76 08	30.24	8.61	0.68	0.30	12.81	8.03	7.83
166 Rhodope		77 06	15.40 !	11.89	0.74	0.40	14.15	10.63	10.36
		77 06	15.45 !	11.87	0.71	0.45	14.09	10.57	10.30
167 Urda	Ko	77 09	20.18 !	18.09	0.81	0.41	13.93	10.11	9.69
184 Dejopeja	Th	77 09	18.22 !	0.20	0.66	0.21	12.95	8.32	8.70
		77 10	20.13 !	9.62	0.71	0.23[e]	13.68	8.92	8.70
		77 10	20.16 !	9.62	0.66	0.21	13.73	8.97	8.75
186 Celuta		77 10	16.34 !	11.47	0.71	0.35	11.39	9.72	9.46
		77 10	16.36 !	11.47	0.78	0.32	11.28	9.61	9.35
208 Lacrimosa	Ko	77 09	20.30 !	0.75	0.83	0.44	12.93	9.18	9.43
221 Eos	Eos	77 03	21.46 !	10.05	0.81	0.38	12.71	8.37	8.13
279 Thule		76 11	26.20	11.94	0.76	0.20	15.21	9.18	8.91
		76 11	26.22	11.96	0.73	0.25	15.25	9.22	8.95
		76 12	21.18 !	13.22	0.74	0.30[e]	15.56	9.32	9.02
311 Claudia	Ko	77 11	03.48 !	17.80	0.83	0.43	14.83	10.74	10.33
313 Chaldaea		76 11	26.42 !	16.19	0.70	0.35	11.78	9.85	9.48
321 Florentina	Ko	77 03	21.44 !	4.65	0.82	0.35	14.30	10.48	10.44
323 Brucia		77 02	21.47	11.40	0.90	0.43	13.80	10.43	10.18
339 Dorothea	Eos	76 12	22.13	16.03	0.79	0.43	14.20	10.12	9.76
413 Edburga		77 06	13.28 !	11.29	0.68	0.22	14.00	10.88	10.62
448 Natalie		77 11	17.18 !	8.40	0.65	0.32	14.63	10.87	10.68
		77 12	16.16	16.34	0.65	0.35[e]	15.17	11.04	10.67
		77 12	17.09	16.51	0.69	0.30[e]	15.48	11.35	10.97
		77 06	13.33	11.31	0.65	0.24	14.01	10.89	10.63
450 Brigitta	Eos	77 09	20.25 !	9.84	0.79	0.49	14.41	10.89	10.67
		77 09	20.28 !	9.85	0.78	0.46	14.50	10.97	10.75
461 Saskia	Th	77 10	17.46 !	3.21	0.59	0.32	14.87	11.18	11.22
		77 11	03.23 !	3.87	0.63	0.30	14.12	10.47	10.48
462 Eriphyla	Ko	77 06	15.36	7.49	0.74	0.41	13.35	9.81	9.65
		77 06	16.34 !	7.15	0.82	0.42	13.28	9.71	9.56
468 Lina	Th	77 10	16.51 !	11.46	0.64	0.32	13.59	10.11	9.85
		77 11	03.37 !	4.23	0.67	0.30	13.35	9.93	9.92
513 Centesima	Eos	77 11	03.36 !	8.15	0.81	0.44	13.73	10.22	10.04
522 Helga		77 09	18.21 !	6.82	0.66	0.24	14.13	9.64	9.48
525 Adelaide		77 04	14.36	14.76	0.95	0.56[e]	15.55	13.35	13.02
533 Sara		77 06	13.43	14.49	0.85	0.50	14.58	10.55	10.22
		77 06	13.45	14.48	0.86	0.40	14.51	10.48	10.15
534 Nassovia	Ko	77 03	21.38 !	5.30	0.80	0.36	14.24	10.48	10.41
542 Susanna		77 06	12.16	13.08	0.80	0.40	14.56	10.19	9.89
		77 06	12.26 !	13.10	0.79	0.36	14.44	10.07	9.77
546 Herodias		77 02	21.13 !	16.98	0.76	0.35	13.30	10.63	10.23
		77 02	21.35 !	16.98	0.79	0.36	13.32	10.65	10.25
562 Salome	Eos	76 12	21.44	4.97	0.79	0.39	14.54	10.28	10.22
		76 12	27.43	3.27	0.80	0.42	14.53	10.30	10.30
566 Stereoskopia		76 11	26.37 !	4.91	0.69	0.29	12.83	8.53	8.48
617 Patroclus	TF	77 09	19.39 !	8.65	0.68	0.26	15.04	8.79	8.59
		77 09	19.45 !	8.65	0.68	0.18	15.03	8.78	8.58
		77 10	20.25 !	2.53	0.68	0.18	14.80	8.65	8.73
		77 11	17.21 !	4.91	0.67	0.27	14.80	8.59	8.54
621 Werdandi	Th	77 11	03.09 !	13.58	0.66	0.28	15.53	11.26	10.95
		77 11	03.10 !	13.58	0.64	0.29	15.54	11.27	10.96
633 Zelima	Eos	77 11	03.40 !	9.93	0.79	0.42	14.38	10.43	10.20
639 Latona	Eos	76 11	26.30	8.41	0.84	0.47	12.42	8.76	8.58
643 Scheherezade		77 02	20.25 !	9.19	0.75	0.29	14.46	10.37	10.16
		77 02	21.24 !	9.46	0.74	0.29	14.45	10.35	10.13
651 Antikleia	Eos	76 12	22.32	8.98	0.82	0.45	14.47	10.61	10.40
		76 12	27.48	7.52	0.85	0.51	14.37	10.52	10.36
653 Berenike	Eos	77 03	21.30 !	12.78	0.83	0.40	13.83	9.93	9.64
661 Cloelia	Eos	77 06	15.21	11.72	0.79	0.29	14.42	10.40	10.13
		77 06	15.26	11.74	0.76	0.47	14.48	10.46	10.19
664 Judith		77 10	17.51 !	7.25	0.69	0.54	15.65	10.63	10.48
		77 10	19.26 !	6.79	0.67	0.23	15.47	10.46	10.32
		77 10	19.31 !	6.79	0.70	0.15[e]	15.55	10.54	10.40
669 Kypria	Eos	77 11	03.44 !	9.58	0.82	0.47	15.18	10.88	10.66
692 Hippodamia		77 02	20.32	13.89	0.88	0.41	13.46	9.81	9.49
		77 02	21.29	13.90	0.87	0.45	13.42	9.76	9.44
720 Bohlinia	Ko	77 01	16.42	4.13	0.82	0.44	13.78	10.14	10.14

TABLE II. (continued)

Asteroid	F[a]	Date	UT[b]	Phase (Deg.)	$B-V$[d]	$U-B$[d]	V[d]	$V(1,\alpha)$	$V(1,0)$
729 Watsonia		77 06	12.34 !	11.06	0.79	0.39	13.03	9.98	9.73
		77 06	12.39	11.05	0.77	0.36	13.06	10.01	9.76
742 Edisona	Eos	77 05	15.26 !	5.18	0.85	0.44	14.07	9.85	9.79
		77 05	16.21 !	5.49	0.85	0.37	14.37	10.15	10.07
750 Oskar	Ny	76 10	29.44 !	12.80	0.65	0.22[e]	15.49	12.77	12.48
		76 12	22.21	13.89	0.56	0.23[e]	15.57	13.02	12.70
754 Malabar		77 06	13.27	12.56	0.69	0.33	14.21	10.04	9.75
		77 06	13.32	12.57	0.70	0.34	14.05	9.88	9.59
807 Ceraskia	Eos	76 12	21.40	5.64	0.92	0.47	14.66	10.03	10.94
		76 12	27.40	3.84	0.84	0.45	14.62	11.00	11.01
		77 01	16.33 !	6.95	0.80	0.47	14.67	11.03	10.90
811 Nauheima	Ko	77 01	16.49	9.33	0.88	0.52	15.57	11.37	11.16
814 Tauris		77 11	16.53 !	15.96	0.69	0.36	12.55	9.63	9.27
		77 11	17.50 !	15.60	0.67	0.32	12.69	9.77	9.41
824 Anastasia		77 04	14.39	4.48	0.82	0.41	13.70	10.48	10.46
857 Glasenappia		77 02	21.38 !	11.46	0.63	0.14	14.75	12.04	11.77
876 Scott	Eos	76 12	21.34 !	8.26	0.83	0.54	15.36	11.58	11.39
		77 01	16.13 !	14.98	0.78	0.38	15.70	11.68	11.34
		77 01	16.15 !	14.98	0.81	0.37	15.72	11.69	11.35
883 Matterania		77 06	16.44 !	13.88	0.86	0.48	14.68	13.40	13.08
884 Priamus	TF	77 09	19.42 !	6.09	0.68	0.17	16.11	9.26	9.16
		77 10	19.21 !	2.28	0.74	0.12[e]	15.80	9.03	9.13
		77 10	19.23 !	2.28	0.76	0.23	15.85	9.08	9.18
		77 10	20.21 !	2.29	0.74	0.27[e]	15.75	8.93	9.03
		77 11	17.34 !	6.13	0.65	0.32[e]	16.13	9.22	9.12
887 Alinda	Z	77 10	17.42 !	44.61	0.94	0.42	14.95	15.62	14.59
		77 11	03.47 !	49.38	0.84	0.41	14.29	15.62	14.48
890 Waltraut	Eos	77 06	12.36 !	6.96	0.81	0.36	14.96	11.31	11.17
		77 06	12.42 !	6.95	0.69	0.31	14.80	11.15	11.01
		77 06	13.39 !	6.73	0.81	0.32	15.00	11.35	11.22
899 Jokaste		77 06	12.37 !	3.52	0.67	0.20	14.42	10.52	10.55
		77 06	12.43 !	3.50	0.65	0.26	14.24	10.34	10.37
		77 06	13.40 !	3.18	0.67	0.28	14.46	10.57	10.62
911 Agamemnon	TP	77 02	21.22	1.96	0.77	0.20	14.80	8.15	8.27
920 Rogeria		77 05	16.34 !	6.78	0.80	0.30[e]	15.16	11.71	11.58
944 Hidalgo	Z	76 10	29.14 !	7.34	0.74	0.23	13.57	11.18	11.02
		76 12	21.15 !	26.86	0.76	0.21	14.58	11.95	11.33
954 Li	Th	77 10	17.33 !	2.06	0.61	0.34	14.06	10.31	10.43
		77 11	03.22 !	8.43	0.64	0.28	14.27	10.40	10.21
966 Muschi		77 04	14.14	16.00	0.85	0.42	14.04	10.77	10.40
		77 04	14.23	16.00	0.87	0.43	14.00	10.73	10.36
975 Perseverantia	Ko	77 11	03.42 !	7.96	0.85	0.39	14.45	10.96	10.78
981 Martina	Th	77 11	03.12 !	13.76	0.62	0.33	14.63	11.37	11.05
991 McDonalda	Th	77 09	19.29	11.26	0.66	0.37	15.18	11.83	11.57
1004 Belopolskya		77 04	14.32	1.01	0.72	0.12	15.16	10.12	10.34
1012 Sarema	Ny	77 10	19.16 !	13.60	0.73	0.17[e]	15.72	12.81	12.49
		77 10	19.25 !	13.60	0.56	0.33[e]	16.49	13.58	13.26
1015 Christa		77 05	15.41 !	3.71	0.68	0.37	14.00	9.38	9.36
		77 06	12.24 !	8.37	0.71	0.30	14.31	9.64	9.45
		77 06	12.30 !	8.39	0.69	0.29	14.30	9.63	9.44
1019 Strackea	Hu	77 02	20.42 !	16.43	1.00	0.52[e]	15.00	13.54	13.16
		77 02	21.45	16.09	0.96	0.49[e]	15.01	13.56	13.19
		77 04	13.32	24.43	0.97	0.57[e]	15.27	13.76	13.19
1029 La Plata	Ko	76 12	22.47	12.60	0.79	0.41	15.42	11.62	11.33
		76 12	22.49	12.60	0.77	0.38	15.33	11.53	11.24
		77 01	16.39 !	3.30	0.80	0.38	14.84	11.21	11.25
1031 Arctica		77 06	13.29 !	7.85	0.68	0.30	14.05	10.10	9.93
		77 06	13.35	7.86	0.68	0.35	14.11	10.16	9.99
1075 Helina	Eos	77 05	15.37	5.37	0.79	0.37	14.67	10.61	10.54
		77 06	16.23	8.25	0.74	0.37	14.76	10.73	10.55
1076 Viola	Ny	77 11	17.51 !	16.97	0.67	0.34	15.18	13.03	12.69
		77 12	16.26 !	2.67	0.61	0.24	14.49	11.80	11.87
		77 12	16.29 !	2.67	0.60	0.26	14.45	11.76	11.83
1079 Mimosa	Ko	77 06	14.18	11.49	0.84	0.39	15.91	11.90	11.64
		77 06	16.19	12.08	0.75	0.41	16.10	12.07	11.79
1082 Pirola	Th	77 10	17.49 !	11.40	0.74	0.33	15.08	11.21	10.95
		77 11	03.31 !	5.26	0.67	0.30	14.59	10.77	10.71
1087 Arabis	Eos	77 03	21.42 !	3.02	0.81	0.43	14.11	9.95	10.00
		77 03	21.43 !	3.02	0.81	0.32	14.10	9.95	10.00
1093 Freda		77 11	16.52 !	10.77	0.70	0.30	14.55	9.43	9.19
		77 11	17.48 !	10.57	0.66	0.33	14.56	9.45	9.21
		77 11	17.52 !	10.57	0.65	0.42	14.57	9.46	9.22
1127 Mimi		77 06	13.41 !	11.06	0.73	0.30	15.48	11.70	11.45
		77 06	13.44 !	11.05	0.67	0.30	15.32	11.54	11.29

TABLE II. (continued)

Asteroid	F[a]	Date	UT[b]	Phase (Deg.)	$B-V$[d]	$U-B$[d]	V[d]	$V(1,\alpha)$	$V(1,0)$
1129 Neujmina	Eos	77 11	03.34 !	4.12	0.78	0.41	14.17	10.70	10.69
1143 Odysseus	TP	77 02	20.26	3.89	0.82	0.23	15.06	8.68	8.68
1148 Rarahu	Eos	77 11	03.24 !	6.74	0.88	0.46	14.48	10.75	10.62
1162 Larissa	Hi	77 02	20.19	8.13	0.80	0.40	15.71	9.49	9.76
1172 Aeneas	TF	77 10	19.19 !	3.01	0.78	0.27[e]	15.24	8.55	8.59
		77 10	19.22 !	3.01	0.71	0.28[e]	15.34	8.65	8.69
		77 10	20.23 !	2.88	0.67	0.22	15.27	8.59	8.64
		77 11	17.36 !	4.96	0.73	0.30[e]	15.38	8.64	8.59
1173 Anchises	TF	77 10	19.30 !	6.37	0.83	0.18[e]	16.10	9.32	9.20
		77 10	19.33 !	6.37	0.65	0.24	16.12	9.34	9.22
		77 11	17.46 !	1.26	0.74	0.29[e]	15.68	8.94	9.15
1186 Turnera	Eos	77 09	20.34 !	11.11	0.79	0.43	14.07	9.89	9.64
1199 Geldonia	Eos	77 06	15.30	5.06	0.76	0.33	14.72	10.81	10.75
1208 Troilus	TF	77 11	17.37 !	3.29	0.67	0.38[e]	15.61	9.18	9.21
1210 Morosovia	Eos	77 04	13.27	14.70	0.83		14.98	10.75	10.41
1223 Neckar	Ko	77 03	21.21 !	16.43	0.82	0.47	15.43	11.46	11.09
		77 03	21.23 !	16.43	0.86	0.34	15.44	11.48	11.11
1235 Schorria	Hu	76 10	29.40 !	30.14	0.75	0.33	14.61	13.98	13.29
1241 Dysona		77 02	21.43	2.11	0.75	0.29	14.26	9.68	9.80
1245 Calvinia	Ko	77 09	19.23 !	13.33	0.81	0.53	14.17	10.61	10.30
1247 Memoria	Th	77 10	17.47 !	5.64	0.68	0.24[e]	15.19	10.98	10.90
		77 11	03.31 !	0.94	0.68	0.34	14.85	10.63	10.87
1252 Celestia		77 02	21.14 !	13.97	0.89	0.40	14.63	11.67	11.30
		77 02	21.26 !	13.97	0.89	0.45	14.77	11.81	11.44
1286 Banachiewcza	Eos	77 01	16.18 !	13.37	0.85	0.43	16.16	11.66	11.36
1289 Kutaïssi	Ko	77 11	03.19 !	7.44	0.78	0.38	14.59	10.97	10.82
1317 Silvretta		77 02	21.50	5.05	0.74	0.34	15.10	10.40	10.35
1326 Losaka		77 06	13.30 !	5.72	0.79	0 43	15.16	11.40	11.31
		77 06	13.36 !	5.74	0.78	0.52	15.16	11.40	11.31
1328 Devota		77 10	20.11 !	8.12	0.64	0.12	15.03	11.04	10.86
		77 10	20.17 !	8.12	0.75	0.21	14.83	10.84	10.65
1330 Spiridonia		77 06	12.17 !	14.47	0.65	0.18	15.29	11.06	10.73
		77 06	12.28 !	14.79	0.69	0.16	15.19	10.96	10.63
1331 Solvejg	Th	77 11	03.14 !	11.55	0.64	0.35	14.67	10.87	10.60
1339 Desagneauxa	Eos	76 12	21.30 !	4.25	0.80	0.41	14.60	10.95	10.93
		77 01	16.35 !	12.97	0.78	0.44	15.61	11.80	11.51
1341 Edmee		77 05	15.39 !	7.58	0.71	0.22	14.22	11.23	11.06
		77 05	16.35 !	7.71	0.71	0.27	14.29	11.30	11.13
		77 06	12.19 !	15.12	0.68	0.28	14.57	11.44	11.09
		77 06	12.31 !	15.15	0.70	0.24	14.44	11.31	10.96
		77 06	14.25	15.71	0.63	0.30	14.51	11.36	11.00
1345 Potomac	Hi	77 11	17.39 !	4.70	0.73	0.32[e]	14.98	10.09	10.05
		77 12	17.11	10.82	0.69	0.27[e]	15.47	10.35	10.10
1359 Prieska		77 04	14.15	13.46	0.66	0.35[e]	15.94	11.35	11.04
		77 04	14.26	13.46	0.76	0.36[e]	15.91	11.32	11.01
1390 Abastumani		77 04	13.34	1.06	0.72	0.28[e]	14.32	9.54	9.75
		77 04	14.31	1.16	0.69	0.18	14.15	9.36	9.56
		77 05	16.18 !	10.21	0.80	0.19	14.40	9.48	9.24
1391 Carelia		77 05	15.23 !	18.37	0.92	0.45[e]	15.32	13.12	12.76
		77 05	16.22 !	18.37	0.91	0.69	15.39	13.19	12.80
1416 Renauxa	Eos	77 11	03.20 !	5.57	0.79	0.41	14.26	10.88	10.80
1434 Margot	Eos	77 01	16.37	2.81	0.81	0.41	14.84	10.54	10.61
1439 Vogtia	Hi	77 12	17.25	9.71	0.75	0.32[e]	16.67	11.02	10.81
1453 Fennia	Hu	77 02	20.39	16.08	0.91	0.56[e]	14.96	13.53	13.16
		77 02	21.39	16.02	0.98	0.52[e]	14.94	13.51	13.14
1456 1937 NG		77 06	14.44	15.37	0.69	0.34	15.22	11.78	11.43
1461 Jean-Jacques		77 02	21.16 !	5.10	0.72	0.21	14.58	10.43	10.37
		77 02	21.41 !	5.10	0.73	0.23	14.60	10.45	10.39
1474 Beira	MC	77 02	20.20 !	16.93	0.61	0.26	15.26	13.59	13.20
		77 02	21.20 !	17.22	0.63	0.23	15.26	13.56	13.16
1512 Oulu	Hi	77 02	20.22	3.30	0.70	0.16	15.45	9.95	10.00
1529 Oterma	Hi	76 10	29.35 !	8.25	0.76	0.17	15.06	10.61	10.42
		76 12	22.18	10.21	0.76	0.46	15.20	10.75	10.52
1532 Inari	Eos	77 01	16.45	9.32	0.84	0.36	15.93	12.13	11.92
1533 Saimaa	Eos	77 06	16.31 !	5.35	0.81	0.42	15.46	11.43	11.41
		77 06	16.32 !	5.34	0.78	0.54	15.39	11.41	11.34
1595 1930 ME		77 06	12.18 !	12.64	0.72	0.45	15.83	12.91	12.62
		77 06	12.29 !	12.68	0.59	0.51	15.48	12.56	12.27
1602 Indiana		77 05	16.28 !	10.73	0.93	0.55[e]	15.25	13.19	12.94
1604 1931 FH	Eos	76 12	22.28	2.80	0.77	0.35	14.86	10.80	10.86
1625 The NORC		77 11	17.44 !	5.09	0.69	0.28[e]	16.37	11.03	10.97
1650 Heckmann	Ny	76 12	22.38	9.47	0.65	0.14	15.88	12.37	12.15
		76 12	27.50	7.51	0.66	0.30	15.54	12.07	11.91

TABLE II. (continued)

Asteroid	F[a]	Date	UT[b]	Phase (Deg.)	$B-V$[d]	$U-B$[d]	V[d]	$V(1,\alpha)$	$V(1,0)$
1658 Innes		77 05	15.27 !	15.51	0.96	0.67[e]	15.03	12.34	11.99
		77 05	16.24 !	15.86	0.96	0.55	15.19	12.50	12.14
1669 Dagmar	Th	77 06	15.19	10.12	0.73	0.46	15.32	11.63	11.40
1693 Hertzsprung		77 04	13.46	7.75	0.76	0.41	14.52	11.35	11.18
		77 05	16.29 !	9.38	0.83	0.35	14.61	11.64	11.43
1702 1924 SH		77 06	15.42 !	12.06	0.72	0.27	14.99	11.75	11.47
		77 06	15.46 !	12.04	0.75	0.14	15.07	11.83	11.55
1723 1936 FX	Eos	76 12	22.24	7.52	0.76	0.44	14.52	10.59	10.43
1750 1950 NA1	Hu	77 12	16.23 !	12.66	0.87	0.50[e]	14.44	14.25	13.96
		77 12	17.18 !	13.09	0.90	0.50[e]	14.35	14.16	13.86
1754 Cunningham	Hi	77 09	18.20 !	6.01	0.62	0.26	15.15	10.30	10.20
1755 1936 VD		77 04	13.40	4.93	0.91	0.44[e]	15.34	11.31	11.26
		77 05	16.20 !	9.93	0.92	0.28	15.46	11.33	11.10
1765 Wrubel		77 05	15.35	7.00	0.73	0.26	14.81	10.41	10.27
		77 05	16.26 !	7.23	0.77	0.28	14.91	10.51	10.36
1767 Lampland	Eos	77 06	16.36	10.86	0.75	0.34	16.49	12.89	12.64
1830 1968 HA		76 10	29.50 !	14.92	0.91	0.50	15.39	13.28	12.94
1867 Deiphobus	TF	77 09	19.20 !	6.25	0.78	0.23	15.60	8.88	8.77
		77 09	19.32 !	6.25	0.71	0.29	15.64	8.92	8.81
		77 11	17.27 !	9.57	0.76	0.23[e]	15.93	9.05	8.83
1916 1953 RA	MC	77 09	19.24 !	12.7	0.86	0.48	14.39	15.83	15.54
		77 09	19.36 !	12.7	0.89	0.38	14.16	15.60	15.31
		77 10	17.37 !	19.19	0.82	0.36	15.53	15.97	15.53
		77 11	17.08 !	27.66	0.84		16.85	16.08	15.44
1980 1950 LA	MC	77 10	20.47 !	53.34	0.95	0.44	15.52	15.89	14.66
		77 10	20.49 !	53.34	0.96	0.47	15.21	15.58	14.35
1976 UA	EC	76 10	29.28 !	32.09	0.77	0.50[e]	15.85	21.62	20.88
1977 RA	MC	77 09	18.16 !	17.29	0.84	0.48	14.03	16.22	15.82
		77 09	19.25 !	17.26	0.83	0.56	14.28	16.45	16.05
		77 11	17.07 !	29.19	0.82		16.07	16.07	15.40
1977 VA	MC	77 11	16.37 !		0.78	0.19[e]	16.37		
		77 11	16.41 !		0.68	0.03[e]	16.05		
		77 11	17.28 !		0.65	0.22[e]	16.16		
		77 11	17.42 !		0.71	0.10[e]	16.04		
1977 VB	MC	77 11	17.14 !		0.96		15.91		
		77 11	17.32 !		0.69	0.35[e]	16.01		
1977 VC		77 11	16.39 !		0.83	0.40	14.16		
		77 11	17.16 !		0.80	0.43	14.21		

[a] Members of dynamical families or other orbital groups are designated by: Eos, 221 Eos family; Ko, 158 Koronis family; Ny, 44 Nysa family; Th, 24 Themis family; Hi, Hildas; Hu, Hungarias; TP, Trojans preceding Jupiter; TF, Trojans following Jupiter; EC, earth-crosser; MC, Mars-crosser; and Z, unique orbit.
[b] An exclamation mark indicates that the asteroid identification was confirmed by visible motion in the expected direction.
[c] The listed phase angle of 153 Hilda and hence its $B(1,0)$ and $V(1,0)$ in Zellner *et al.* (1977) were incorrect.
[d] The error indicated in Fig. 1 is to be divided by $\sqrt{3}$ for nights designated G in Table I.
[e] The error indicated in Fig. 1 for $U-B$ is to be divided by $\sqrt{2}$.

lightcurve was clearly demonstrated on June 12 and 13, 1977. Observations a few weeks apart suggest large-amplitude lightcurves for 1339 and 1390.

The standard correction to four degrees phase was done with the magnitude-phase relation adopted by Gehrels (1970). No corrections were applied for possible phase effects in the colors.

III. INTERPRETATIONS

The photoelectric observations reported here will be combined with other results in the TRIAD computer file (Bender *et al.* 1978) for further analysis. Interpretations in terms of the asteroid population statistics, with corrections for observational selection bias, will be the subject of future papers. Here we discuss only a few of the more significant results.

Asteroid colors from Table II are plotted in Figs. 2–4 together with the domains of the predominant *C* and *S* types as described by Bowell *et al.* (1978). The Eos and Koronis families are both located in the outer parts of the main belt, where the field population is ~90% of type *C* (Zellner and Bowell 1977). In Fig. 2 we note that members of the Koronis family seem to be all of the *S* type, a result confirmed in the thermal radiometry of Gradie *et al.* (1977). The Eos objects are more problematical, forming a color group not characteristic of any common type and with albedos near 0.08 according to Gradie *et al.* (1977). Such combinations of color and albedo are hardly if ever seen outside the Eos family. The Nysa objects also form a discrete unit, as plotted in Fig. 3 and discussed by Zellner *et al.* (1977b). The view that asteroid families are formed by collisional focussing of unrelated field objects (e.g., Alfvén 1969) is clearly inconsistent with the modern observational data.

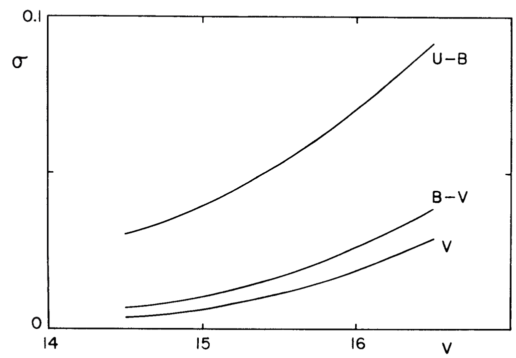

FIG. 1. Standard deviation of V, $B - V$, and $U - B$ measurements in the instrumental system. For observations with a higher precision see Footnotes to Table II.

Hansen (1977) noted that seven members of the 24 Themis family are classified as type *C*. In Table II we find *C*-type colors for 11 additional Themis members. It is unlikely (probability ~15%) that 18 out of 18 objects randomly picked from the Themis family would *all* be of the type *C* if this family were to follow the field population distribution of ~90% type *C* at 3.14 AU.

Morrison (1977) and Zellner *et al.* (1977b) have reported that asteroid 434 Hungaria at $a = 1.94$ is of the rare *E* type. Three Hungarias in Table II show colors that scatter widely (Fig. 3), but none of these are from the Hungaria dynamical family identified by Williams (personal communication). The other members of the true Hungaria family remain unsampled at this writing.

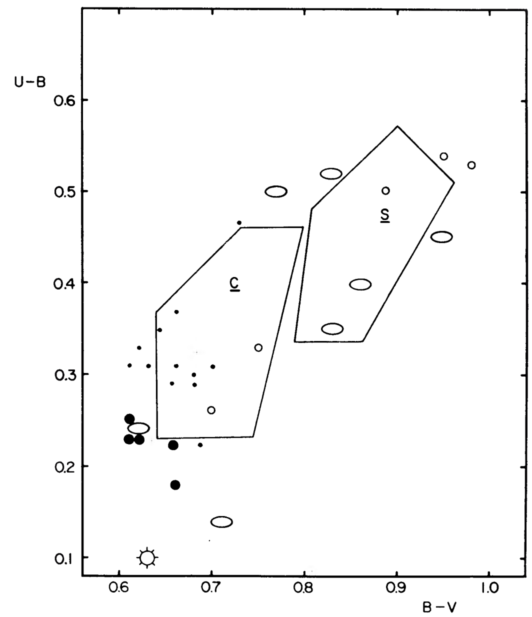

FIG. 3. $U - B$ vs $B - V$ colors for asteroids in the 434 Hungaria group (○), the Nysa family (●), the 24 Themis family (·) and Mars-orbit-crossers (⬭). Data from Table II, Zellner *et al.* (1975) and Zellner *et al.* (1977a).

Neither the Mars orbit-crossers 1474 Beira, 1977RA, 1980 = 1950LA, and 1977VA nor the Earth orbit-crosser 1976UA in Table II belong to any of the common mainbelt types. The latter is discussed by Helin *et al.* (1978), and shown to be similar to the sun grazer 1566

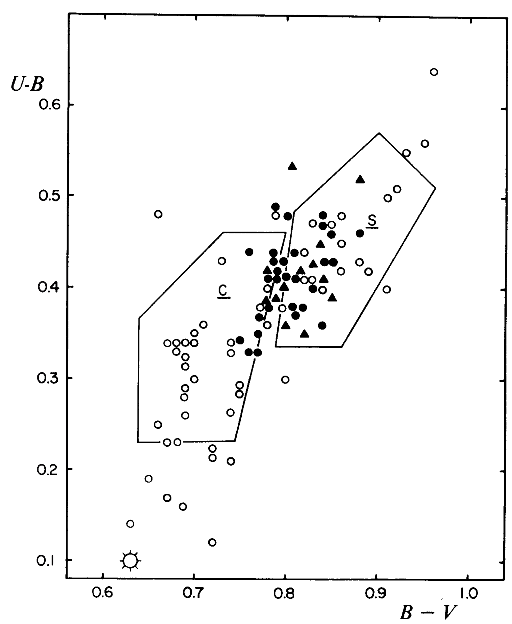

FIG. 2. $U - B$ *vs* $B - V$ colors for asteroids in the 221 Eos family (●), the 158 Koronis family (▲). The asteroids marked with open circles are field objects from Table II. Solar colors are indicated at $B - V = 0.63$ and $U - B = 0.10$. Domains for the S and C compositional types are as defined by Bowell *et al.* (1978).

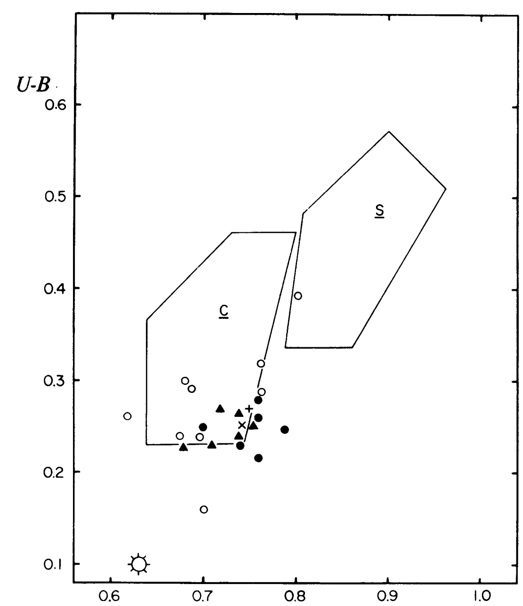

FIG. 4. $U - B$ vs $B - V$ colors for asteroids in the 153 Hilda group (○), the Trojan cloud preceding Jupiter (●) and following Jupiter (▲), 944 Hidalgo (+) and 279 Thule (×). Data from Table II. Zellner *et al.* (1975) and Zellner *et al.* (1977a).

Icarus. The Mars orbit-crossers 1953RA, 1977VB, and 1977VC appear to be typical *S* objects, like 433 Eros, 1036 Ganymed, and 1620 Geographos.

Figure 4 illustrates colors for the Hildas, Trojans, and other objects outside the main belt. Trojans in the preceding cloud were already known to form a spectral reflectivity group distinct from the mainbelt population (McCord and Chapman 1975; Zellner *et al.* 1977); we can now add to this group six Trojans following Jupiter. The distant orbitally unique objects 279 Thule and 944 Hidalgo show very much the same unusual colors. The Hildas also have generally weak *UBV* colors, but with wider scatter.

Finally, we note in Fig. 2 that the small mainbelt objects in our survey are not so closely confined to the typical *C* and *S* classes as are the larger asteroids initially surveyed; compare, for example, Fig. 2 of Zellner *et al.* (1975). Some of the scatter may be due to noise in the fainter observations, but we note well-established exceptional colors for 1330, 1595, and 1658. Doubtless the asteroid populations hold more variety than one would conclude from only the larger representatives.

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REFERENCES

Alfvén, H. (1969), Astrophys. Space Sci. **6**, 161.
Arnold, J. R. (1969). Astron. J. **74**, 1235.
Bender, E., Bowell, E., Chapman, C., Gaffey, M., Gehrels, T., Zellner, B., Morrison, D., and Tedesco, E. (1978). Icarus. *33*, 630.
Bowell, E. (1977). Bull. Am. Astron. Soc. **9**, 459.
Bowell, E., Chapman, C. R., Gradie, J., Morrison, D., and Zellner, B. (1978). Submitted to *Icarus*.
Brouwer, D. (1951). Astron. J. **56**, 9.
Chapman, C. R., Morrison, D., and Zellner, B. (1975). Icarus, **25**, 104.
Degewij, J. (1977). Proc. Lunar Sci. Conf. 8th, 145.
Degewij, J., Gradie, J., and Zellner, B. (1977). *Bull. Am. Astron. Soc.* **9**, 503.
Frecker, J. E., and Serkowski, K. (1976). *Appl. Opt.* **15**, 605.
Gaffey, M. J., and McCord, T. B. (1978). Space Sci. Rev. In press.
Gehrels, T. (1957). Astrophys. J. **125**, 550.
Gehrels, T., and Owings, D. (1962). Astrophys. J. **135**, 906.
Gehrels, T. (1970). In *Surfaces and Interiors of Planets and Satellites*, edited by A. Dollfus (Academic, New York), p. 317.
Gehrels, T., and Gehrels, N. (1978). To be published (Paper XXVI).
Gradie, J., and Zellner, B. (1977). Science **197**, 254.
Gradie, J., Rieke, G., and Zellner, B. (1977). Bull. Am. Astron. Soc. **9**, 503.
Hansen, O. L. 1977. Icarus **32**, 229.
Hardie, R. H. 1962. In *Astronomical Techniques*, edited by W. A. Hiltner (Univ Chicago P., Chicago), p. 178.
Helin *et al.* 1978. In preparation.
Johnson, H. L. (1962). Comm. Lunar and Planet. Lab. **1**, 73.
McCord, T. B., and Gaffey, M. J. (1974). Science *186*, 352.
McCord, T. B., and Chapman, C. R. (1975). Astrophys. J. **197**, 781.
Morrison, D. (1977). Icarus **31**, 185.
Purgathofer, A. T. (1969). *Lowell Obs. Bull.* **7**, 98.
Williams. J. (1978). In preparation.
Zellner, B., Wisniewski, W. Z., Andersson, L., and Bowell, E. (1975). Astron. J. **80**, 986 (Paper XVIII).
Zellner, B., and Gradie, J. (1976). Astron. J. **81**, 262 (Paper XX).
Zellner, B., and Bowell, E. (1977). In *The Interrelated Origin of Comets, Asteroids, and Meteorites*, (edited by A. H. Delsemme Univ. Toledo Pub., Toledo), p. 185.
Zellner, B., Andersson, L., and Gradie, J. (1977a). Icarus **31**, 447.
Zellner, B., Leake, M., Morrison, D., and Williams, J. G. (1977b). Geochim. et Cosmochim. Acta. To be published.