AN ATLAS OF *HUBBLE SPACE TELESCOPE* PHOTOMETRIC, SPECTROPHOTOMETRIC, AND POLARIMETRIC CALIBRATION OBJECTS[a)]

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ABSTRACT

The *Hubble Space Telescope* (*HST*) has capabilities for direct imaging, photometry, spectrophotometry, polarimetry, and astrometry. The combined scientific instruments cover the wavelength range from ~1150 to 11 000 Å. This paper presents an overview of the standard astronomical sources, referred to here as calibration targets, which will be used to calibrate *HST* images, photometry, spectrophotometry, and polarimetry in the UV and optical wavelength regions. Finding charts, accurate coordinates, and other details are presented. References to documents with more detail on *HST* calibration requirements, calibration targets, and calibration plans are included.

I. INTRODUCTION

HST requires calibration targets with well-defined magnitudes, fluxes, polarizations, and positions, to achieve and maintain a proper standardization. The goals of the *HST* calibration program are: (1) to derive the required calibrations with a reliable set of calibration targets and optimize the use of *HST* observing time, (2) to calibrate all *HST* science instruments on the same photometric, spectrophotometric, and polarimetric systems so that magnitudes, fluxes, or polarizations measured by one instrument can easily be compared to those measured by another instrument at a known level of accuracy, (3) to provide tie-ins to established ground-based photometric and spectrophotometric systems and polarimetric reference data, and (4) to be consistent with the Science Verification plans of the Investigation Definition Teams, which have chosen the initial *HST* calibration targets from the findings of *HST* Calibration Target Working Groups.

A set of six Space Telescope Science Institute (STScI) internal documents provides more details on calibration requirements, assignment of calibration targets, and calibration plans. Six different types of calibration targets exist: (1) UV spectrophotometric calibration targets (Bohlin *et al.* 1987), (2) optical spectrophotometric and photometric calibration targets (Turnshek *et al.* 1989), (3) wavelength calibration targets (Ford *et al.* 1984), (4) astrometric calibration targets (Fresneau *et al.* 1986), (5) polarimetric calibration targets (Lupie *et al.* 1985), and (6) targets for spatial flatfields (Cox *et al.* 1987). These targets are used to quantify the calibration of the scattered light, the linearity, the spectral flatfield, the sensitivity of photometric and spectrophotometric modes, the point-spread function, the wavelength scale, the plate scale, the polarimetric modes, and spatially flatfields for all *HST* scientific instruments.

The photometric, spectrophotometric, and polarimetric calibration targets discussed in Bohlin *et al.* (1987), Turnshek *et al.* (1989), and Lupie *et al.* (1985) can be grouped into a category of targets for which very accurate flux measurements are necessary. Appropriate flux measurements for these calibration targets either exist or will exist. The calibration targets are not only needed for the calibration of *HST* but are useful for ground-based calibrations or other space-based calibrations, as well. Therefore, the STScI will aid in making the appropriate data available to the astronomical community, once the data are in proper form. As a first step in providing the astronomical community with this information, we present here an atlas of finding charts for *HST* photometric, spectrophotometric, and polarimetric calibration targets. Section II describes the use of each target and contains coordinates, magnitudes, colors, and spectral types. In Sec. III we discuss the *HST* photometric system and polarimetric calibrations which will establish the physical basis of *HST* flux measurements. In Sec. IV the types of measurements are outlined for each calibration target. *While data are being collected for all of the listed targets, some may never be an actual HST calibration target. Operational problems or unforseen difficulties with the astronomical information currently being analyzed may prevent a particular object from becoming a calibration target. The final set of HST calibration targets that are actually observed with HST on a regular basis is likely to be a small subset of the targets presented here.* However, current plans (Sec. V) call for making all data on calibration targets internally consistent and referenced to a single photometric-spectrophotometric system, i.e., the "*HST* photometric system."

II. *HST* CALIBRATION OBJECTS

Tables I–VI present the *HST* calibration targets which can be either single, isolated stars, a field of stars, or a diffuse source. Table VII lists the alias names in alphabetical-numerical order and the corresponding *HST* standard name, which should be used for all *HST* applications. If the single *HST* calibration targets are fainter than $V \sim 6$, finding charts have been prepared. Finding charts for the photometric and spectrophotometric calibration stars are presented in Fig. 1 [Plates 45–57]. Finding charts for the photometric calibration target fields are presented in Fig. 2 [Plates 58–68]. Finding charts for the polarimetric calibration stars are presented in Fig. 3 [Plates 69–72]. Finding charts for the polarimetric calibration target fields from Table V are presented in Fig. 4 [Plates 73–78]. Finding charts are not needed for the globular clusters or elliptical galaxies that are the unpo-

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TABLE I. Photometric and spectrophotometric calibration stars.

Name	α (2000)			δ (2000)			V	$B-V$	Spectral Type	Standard Type[a]
β Hyi	0h	25m	45s38	−77°	15′	15″5	2.80	+0.62	G2IV	1
G158–100	0	33	54.32	−12	07	57.1	14.89	+0.69	DK-G	2,3
ζ Cas	0	36	58.30	+53	53	48.9	3.66	−0.19	B2IV	1
BPM 16274	0	50	03.18	−52	08	17.4	14.20	−0.05	DA2	1,3
Feige 11	1	04	21.64	+4	13	37.7	12.07	−0.23	sdB	2,3
Feige 16	1	54	08.03	−6	42	53.6	12.41	−0.02	A0	3
ξ² Cet	2	28	09.53	+8	27	36.3	4.29	−0.06	B9III	1
Feige 22	2	30	16.55	+5	15	51.6	12.80	−0.07	DA3	3
Feige 24	2	35	07.51	+3	43	56.6	12.42	−0.19	DA1	3
GD50	3	48	50.06	−0	58	30.4	14.06	−0.28	DA2	1,2,3
SA95–301	3	52	41.21	+0	31	20.8	11.22	+1.30	G8III	3
SA95–302	3	52	42.08	+0	31	18.0	11.71	+0.84	G7	3
SA95–190	3	53	13.23	+0	16	22.0	12.62	+0.28		3
SA95–42	3	53	43.67	−0	04	33.0	15.61	−0.22		2,3
SA95–317	3	53	44.16	+0	29	50.0	13.45	+1.32		3
SA95–330	3	54	30.74	+0	29	05.1	12.18	+1.98		3
SA95–275	3	54	44.23	+0	27	19.9	13.48	+1.75		3
SA95–218	3	54	49.93	+0	10	07.9	12.09	+0.71	G2V	3
SA95–132	3	54	51.67	+0	05	21.1	12.06	+0.44	A4	3
HZ 4	3	55	21.70	+9	47	18.7	14.52	+0.08	DA4	1,2,3
LB227	4	09	28.76	+17	07	54.4	15.34	+0.05	DA4	1,2,3
HZ 2	4	12	43.51	+11	51	50.4	13.86	−0.05	DA3	1,2
HD27836	4	24	12.33	+14	45	30.7	7.62	+0.60	G1V	1
G191B2B	5	05	30.62	+52	49	54.0	11.78	−0.32	DA0	1,2,3
μ Col	5	45	59.92	−32	18	23.4	5.17	−0.28	O9V	1
GD71	5	52	27.51	+15	53	16.6	13.04	−0.24	DA1	3
HD44498	6	22	22.56	+8	19	36.3	8.83	−0.08	B2.5V	3
HD49798	6	48	04.64	−44	18	59.3	8.30	−0.29	O6	1,3
HD50583	6	53	54.24	−0	18	50.9	8.29	−0.04	B9	3
HD52533	7	01	27.05	−3	07	04.1	7.70	−0.09	O9V	3
Rubin 149	7	24	14.31	−0	33	05.0	13.86	−0.14	O9–B2p	3
Rubin 152	7	29	59.29	−2	05	59.5	13.01	−0.20	O5V	3
HD60753	7	33	27.26	−50	35	03.7	6.70	−0.09	B3IV	1
G193–74	7	53	27.40	+52	29	35.7	15.70	+0.24	DA0	2,3
HD64854	7	55	54.24	−0	16	49.7	9.40	−0.16	B2III	3
ζ Pup	8	03	35.06	−40	00	11.6	2.25	−0.27	O4If	1
BD +75° 325	8	10	49.31	+74	57	57.5	9.54	−0.32	O5p	1,2,3
AGK +81° 266	9	21	19.06	+81	43	28.6	11.92	−0.33	sdO	1,2,3
PG 0918+029	9	21	28.24	+2	46	02.2	13.32	−0.28		2,3
SA101–327	9	56	08.81	−0	25	53.9	13.44	+1.16		3
SA101–330	9	56	20.55	−0	27	22.9	13.71	+0.58		3
SA101–429	9	57	31.71	−0	18	16.8	13.49	+1.00		3
SA101–431	9	57	37.25	−0	17	54.2	13.68	+1.25		3
SA101–207	9	57	52.45	−0	47	37.2	12.41	+0.52	F8	3
GD108	10	00	47.33	−7	33	31.2	13.56	−0.22	sdB?	1,2,3

TABLE I. (continued)

Name	α (2000)			δ (2000)			V	$B-V$	Spectral Type	Standard Type
α Leo	10^h	08^m	$22^s.32$	$+11^\circ$	$58'$	$02''.0$	1.35	−0.11	B7V	1
G162–66	10	33	43.12	−11	41	38.4	13.01	−0.15	DA2	3
PG 1034+001	10	37	3.86	−0	08	20.2	13.22	−0.37	DO hot	2,3
Feige 34	10	39	36.71	+43	06	10.1	11.18	−0.34	DO	1,2,3
HD93521	10	48	23.51	+37	34	12.8	7.04	−0.27	O9Vp	1,2
G163-27	10	57	36.01	−7	31	24.8	14.33	+0.29	DA6	3
G163-50	11	07	59.97	−5	09	19.7	13.08	+0.02	DA4	3
G163-51	11	08	06.56	−5	13	40.6	12.57	+1.49	M6V	3
θ Crt	11	36	40.90	−9	48	08.2	4.70	−0.08	B9.5Vn	1
γ UMa	11	53	49.83	+53	41	41.1	2.44	0.00	A0V	1
HZ 21	12	13	56.42	+32	56	30.8	14.68	−0.33	DO2	1,2,3
Feige 66	12	37	23.55	+25	04	00.3	10.50	−0.28	sdO	2,3
Feige 67	12	41	51.83	+17	31	20.5	11.81	−0.33	sdO	2,3
G60–54	13	00	09.53	+3	28	55.7	15.81	+0.65	DC	3
HZ 44	13	23	35.37	+36	08	00.0	11.66	−0.29	sdO	1,2,3
PG 1323-085	13	25	39.47	−8	49	19.4	13.48	−0.14	sdB-O	2,3
Grw +70° 5824	13	38	51.77	+70	17	08.5	12.77	−0.09	DA3	1,2,3
η UMa	13	47	32.44	+49	18	48.0	1.86	−0.19	B3V	1
β Cen	14	03	49.51	−60	22	22.8	0.61	−0.22	B1III	1
GD337	14	34	43.49	+53	35	20.9	16.09	−0.03	DA	3
HD129956	14	45	30.26	−0	43	02.8	5.69	−0.03	B9.5V	3
HD130557	14	48	54.05	−0	50	52.1	6.13	−0.04	B9V	3
ι Dra	15	24	55.74	+58	57	57.7	3.29	+1.16	K2III	1
SA107–568	15	37	52.71	−0	17	17.9	13.04	+1.15		3
SA107–456	15	38	42.77	−0	19	47.8	12.91	+0.93		3
SA107–351	15	38	45.77	−0	32	06.8	12.34	+0.56	F8	3
SA107–601	15	39	13.81	−0	13	27.3	14.64	+1.36		3
SA107–602	15	39	18.87	−0	15	30.4	12.12	+1.00	F8	3
SA107–626	15	40	05.31	−0	17	29.2	13.47	+1.00		3
SA107–627	15	40	07.45	−0	17	23.0	13.34	+0.78		3
BD +33° 2642	15	51	59.86	+32	56	54.8	10.81	−0.17	B2IV	1,2
G153–41	16	17	55.43	−15	35	49.3	13.42	−0.22	DA2	1,2,3
G138–31	16	27	53.59	+9	12	24.5	16.14	+0.34	DC	2,3
ζ Oph	16	37	09.54	−10	34	01.7	2.56	+0.02	O9.5V	1
γ Dra	17	56	30.39	+51	29	19.8	2.22	+1.52	K5III	1
G21–15	18	27	13.51	+4	03	10.1	13.89	+0.09	DA:	3
α Lyr	18	36	56.33	+38	47	01.1	0.03	0.00	A0V	1
16 Cyg B	19	41	51.96	+50	31	02.9	6.20	+0.66	G5V	1
G24–9[b]	20	13	56.05	+6	42	55.2	15.72	+0.40	DC	2,3
Mark A	20	43	59.21	−10	47	41.8	13.26	−0.25		3
LDS749B	21	32	15.75	+0	15	13.6	14.67	−0.04	DB4	1,2,3
SA113–221	21	40	36.52	+0	21	03.2	12.09	+1.03		3
SA113–339	21	40	55.64	+0	27	57.9	12.25	+0.57	F8	3
SA113–241	21	41	09.17	+0	25	48.7	14.39	+1.37		3
SA113–260	21	41	48.05	+0	23	52.7	12.41	+0.51		3

TABLE I. (continued)

Name	α (2000)	δ (2000)	V	$B-V$	Spectral Type	Standard Type
BD +28° 4211	21^h 51^m $11\overset{s}{.}07$	+28° 51′ 51″.8	10.51	−0.34	Op	1,2,3
G93–48	21 52 25.33	+2 23 24.3	12.74	−0.01	DA3	1,2,3
NGC 7293	22 29 38.46	−20 50 13.3	13.51	−0.35	V. Hot	1,2,3
ζ Peg	22 41 27.74	+10 49 52.9	3.40	−0.09	B8V	1
G28–27	22 57 26.31	+7 55 45.6	17.24	−0.04	DQ5	3
GD246	23 12 35.30	+10 50 27.2	13.10	−0.32	DA1	3
Feige 108	23 16 12.42	−1 50 35.3	12.96	−0.23	DAs	3
LTT 9491	23 19 34.98	−17 05 29.8	14.12	+.01	DC	2,3
Feige 110	23 19 58.39	−5 09 56.1	11.82	−0.29	DOp	1,2,3
GD248	23 26 06.69	+16 00 21.4	15.09	+0.09	DC	2,3

[a] For this column, the codes are as follows:
1 = UV Spectrophotometric Standard
2 = Optical Spectrophotometric Standard
3 = Optical Photometric Standard

[b] This star is an apparent eclipsing binary with eclipses observed 1985 October 7.4 and 1988 July 15.3. See IAU Circular No. 4648 for more information.

TABLE II. *HST* photometric calibration target fields.

Name	Approximate α (2000)	Approximate δ (2000)	Field Size (arcmin)	Standard Type[a]
47 Tuc F1	0^h 19^m $39\overset{s}{.}9$	−72° 01′ 03″	2.8 × 4.8	3
χ Per	2 22 00.0	+57 11 36	8 × 8	2
SA 95 Field 2	3 37 51.7	+0 34 19	(5.8 × 5.8)	4
SA 95 Field 1	3 40 05.1	+1 47 01	(5.8 × 5.8)	4
SA 95 Field 4	3 41 49.0	+1 38 26	(5.8 × 5.8)	4
SA 95 Field 3	3 46 51.8	−0 37 37	(5.8 × 5.8)	4
M36	5 36 20.5	+34 07 48	8 × 8	2
M67	8 51 26.9	+11 48 45	8 × 8	2
SA 101 Field 1	9 57 33.8	−0 22 29	(5.8 × 5.8)	4
SA 57 Field	13 09 13.1	+29 23 18	(2.5 × 4)	3
ω Cen	13 25 27.0	−47 35 54	8 × 8	1
SA 107 Field 1	15 35 28.4	+0 03 08	(5.8 × 5.8)	4
SA 107 Field 2	15 44 18.8	+0 17 36	(5.8 × 5.8)	4
M11	18 50 56.8	−6 16 31	8 × 8	1
NGC 6752	19 10 08.2	−59 50 24	8 × 8	1
SA 113 Field 1	21 36 06.7	−0 29 41	(5.8 × 5.8)	4
SA 113 Field 3	21 40 02.4	+1 32 58	(5.8 × 5.8)	4
NGC 7789	23 59 15.2	+56 43 29	8 × 8	2

[a] For this column, the codes are as follows:
1 = WFPC rich field to be observed on-orbit
2 = WFPC rich field not to be observed on-orbit
3 = FOC faint photometric field
4 = FOC faint photometric candidate field

TABLE III. *HST* polarimetric calibration targets—polarized stars.

Name	α (2000)			δ (2000)			V	B − V	Spectral Type	%P_V(*Err*)[a]	θ_V[b]	N[c]
BD+64° 106	0h	57m	36s71	+64°	51′	35″1	10.34	+0.69	B1V	5.65(.053)	96°8	2
BD+59° 389	2	02	42.06	+60	15	26.5	9.07	+1.01	F0Ib	6.69(.027)	98.2	4
HD19820	3	14	05.35	+59	33	47.7	7.11	+0.51	O9IV	4.81(.047)	114.9	4
HD25443	4	06	08.07	+62	06	07.0	6.78	+0.29	B0III	5.13(.061)	134.2	1
BD+25° 727	4	44	24.90	+25	31	42.7	9.50	+0.72	A2III	4.27(.012)	33.8	1
HD251204	6	05	05.67	+23	23	38.9	10.28	+0.28	B0IV	4.04(.066)	147	1
HD298383	9	22	29.76	−52	28	57.4	9.68	+0.88	A0Ib	5.23(.009)	148.6	12
HD110984	12	46	44.91	−61	11	11.7	8.95	+0.44	B0IV	5.70(.007)	91.6	20
HD111579	12	51	03.61	−61	14	37.8	9.50	+0.78	B2Ib/II	6.46(.014)	103.1	6
HD126593	14	28	51.06	−60	32	24.8	8.50	+0.49	B0.5IV	5.02(.012)	75.2	6
o Sco	16	20	38.20	−24	10	10.3	4.57	+0.84	A5II	4.17(.008)	32.9	6
HD154445	17	05	32.24	−0	53	31.7	5.61	+0.12	B1V	3.80(.075)	88.03	4[d]
HD155197	17	10	15.62	−4	50	03.1	9.20		A0	4.38(.030)	103.2	4
HD161056	17	43	47.03	−7	04	46.2	6.32	+0.36	B1.5V	4.035(.038)	67.01	4[d]
HD204827	21	28	57.70	+58	44	24.0	7.93	+0.82	B0V	5.36(.025)	58.6	5

[a] %P_V(*Err*) is the percent polarization in the *V* filter with the uncertainty in parentheses.
[b] θ_V is the equatorial position angle in the *V* filter.
[c] Number of observations by Tapia or Schmidt
[d] Possibly variable

TABLE IV. *HST* polarimetric calibration targets—unpolarized stars.

Name	α (2000)			δ (2000)			V	B − V	Spectral Type	%P_B(*Err*)[a]
β Cas	0h	09m	10s72	+59°	08′	59″1	2.27	+0.34	F2III	0.015(.027)
HD12021	1	57	56.11	−2	05	58.2	8.86	−0.10	B7	0.112(.025)
HD14069	2	16	45.16	+7	41	11.1	9.00		A0	0.111(.036)
ξ^2 Cet	2	28	09.53	+8	27	36.3	4.29	−0.06	B9III	0.092(.024)
HD21447	3	30	00.21	+55	27	07.0	5.10	+0.04	A1IV	0.017(.030)
G191B2B	5	05	30.62	+52	49	54.0	11.78	−0.30	DA1	0.090(.048)
β Tau	5	26	17.52	+28	36	26.7	1.65	−0.13	B7III	0.073(.025)
γ Gem	6	37	42.73	+16	23	57.3	1.92	0.00	A0V	0.076(.020)
HD64299	7	52	25.55	−23	17	45.9	10.15	+0.09	A2V	0.151(.032)
θ UMa	9	32	51.41	+51	40	38.4	3.18	+0.46	F6IV	0.072(.015)
HD94851	10	56	44.17	−20	39	51.6	9.10		B9	0.057(.018)
β UMa	11	01	50.47	+56	22	56.6	2.37	−0.02	A1V	0.023(.017)
HD98161	11	17	11.84	−38	00	52.0	6.27	+0.10	A3V	0.017(.006)
GD319	12	50	04.49	+55	06	02.5	12.32	+0.04	DA	0.045(.047)
γ Boo	14	32	04.68	+38	18	29.7	3.02	+0.19	A7III	0.002(.018)
BD+33° 2642	15	51	59.86	+32	56	54.8	10.84	−0.17	B2IV	0.145(.029)
HD154892	17	07	41.38	+15	12	37.6	8.00		F8V	0.050(.030)
HD176425	19	02	08.66	−41	54	36.3	6.23	0.00	A0V	0.020(.009)
BD +32° 3739	20	12	02.11	+32	47	43.5	9.31	+0.20	A6V	0.039(.021)
BD +28° 4211	21	51	11.07	+28	51	51.8	10.53	−0.34	Op	0.063(.023)
HD212311	22	21	58.55	+56	31	52.8	8.10	+0.08	A0V	0.028(.025)
ζ Peg	22	41	27.74	+10	49	52.9	3.40	−0.09	B8III	0.028(.019)

[a] %P_B(*Err*) is the percent polarization in the *B* filter with the uncertainty in parentheses.

TABLE V. *HST* polarimetric calibration targets—polarized resolved fields.

Name	α (2000)			δ (2000)			V^a	Spectral[b] Type	$\%P_V(Err)$	θ_V	Aper. Size	$V/\square''^c$
				Primary Standards								
R Mon – 4[d,e]	6h	39m	09.s98	+8°	44′	11″.4	13.1	A0	...	...	...	...
R Mon – 1	6	39	09.98	+8	44	41.4	16.1		14.52(.47)	89°.9	5″.3	19.4
R Mon – 2	6	39	10.75	+8	44	27.7	15.8		13.78(.45)	118.1	5.3	19.1
R Mon – 3	6	39	09.98	+8	44	23.7	15.3		11.90(.47)	87.7	5.3	18.6
ESO–172 – 3[d,f]	12	44	46.2	−54	31	15	13.3	G0	16.5(0.1)	78.2	5.3	...
ESO–172 – 1	12	44	45.5	−54	30	55.4	17.8		37.0(1.2)	84.5	5.3	21.1
ESO–172 – 2	12	44	45.9	−54	31	04.8	16.6		43.2(1.3)	97.9	5.3	19.9
ESO–172 – 4	12	44	46.5	−54	31	25.5	16.5		31.2(1.3)	93.6	5.3	19.9
ESO–172 – 5	12	44	46.8	−54	31	36.6	17.4		33.2(2.1)	83.8	5.3	20.8
CRL2688 – offset star[g]	21	02	16.75	+36	41	29.6	...		...	...	...	...
CRL2688 – 1	21	02	19.02	+36	41	49.5	16.7	F2	59.55(.76)	106.6	5.3	20.0
CRL2688 – 2	21	02	18.84	+36	41	41.1	12.7		49.74(.26)	100.7	5.3	16.1
CRL2688 – 3	21	02	18.59	+36	41	33.8	14.0		55.19(.26)	105.0	5.3	17.4
LK Hα 233 – 2[d,h]	22	34	41.01	+40	40	03.6	14.1	A7	10.34(.23)	152.7	5.3	17.5
LK Hα 233 – 1	22	34	40.06	+40	40	05.9	16.6		33.38(.96)	1.0	5.3	20.0
LK Hα 233 – 3	22	34	38.73	+40	39	40.3	16.7		44.97(.91)	137.3	5.3	20.1
				Secondary Standards								
Crab Nebula – Pulsar[i]	5h	34m	31.s96	+22°	00′	52″.0	...		...	...	...	...
Crab Nebula – 1	5	34	33.01	+22	00	40.0	16.2		21.45(.50)	160°.7	5″.3	19.6
Crab Nebula – 2	5	34	33.14	+22	00	13.5	16.5		29.68(.61)	170.6	5.3	19.9
NGC6823 – 2[j]	19	42	58.39	+23	20	15.9	11.6		2.67(.11)	13.0	...	...
NGC6823 – 6[j]	19	43	04.43	+23	18	49.4	12.1		3.23(.13)	9.0	...	...
NGC6823 – 7[j]	19	43	01.94	+23	17	31.4	12.1		3.74(.13)	6.9	...	...
NGC6823 – 10[j]	19	43	13.56	+23	19	06.2	11.9		4.55(.13)	7.2	...	...
NGC6823 – 12[k]	19	43	10.93	+23	18	04.0	10.8		3.74(.05)	5.0	...	...
NGC6823 – 13[k]	19	43	09.96	+23	17	54.7	11.1		3.48(.06)	3.0	...	...

[a] Integrated Magnitude–Includes all stars and nebulosity within aperture. When no aperture size is specified, the magnitude is for the star alone.

[b] Spectral type of central illuminating star

[c] Surface Brightness–Derived from the integrated magnitude and the aperture diameter using the relation: surface brightness = integrated magnitude + $2.5\log_{10}(\pi(\text{aperture size}/2)^2)$

[d] Central Star

[e] Coordinates from the Guide Star Catalog. Epoch=1982.9, mean error = 0.3 arcsec. R Mon is a known photometric variable (Bellingham and Rossano 1980), but there is no evidence for variabililty of the polarization. The photometry quoted here was obtained in 86 Nov.

[f] Coordinates hand measured from Guide Star image. Epoch=1983.6, mean error = 1 arcsec

[g] Coordinates hand measured from Guide Star image. Epoch=1983.6, mean error = 0.4 arcsec

[h] Coordinates from the Guide Star Catalog. Epoch=1983.7, mean error = 0.3 arcsec

[i] Coordinates from McNamara (1971), precessed from Equinox=1950, Epoch=1970.3 to Equinox=J2000, Epoch=2000.0, using proper motions from the reference.

[j] Coordinates from the Guide Star Catalog. Epoch=1982.6, mean error = 0.3 arcsec

[k] Coordinates hand measured from Guide Star image. Epoch=1982.6, mean error = 0.4 arcsec

TABLE VI. *HST* polarimetric calibration targets—unpolarized clusters/galaxies.

Name	α (2000)[a]	δ (2000)[a]	V^b	%P(Err)	Filter	Aper. Size	$V/\square''^c$
NGC4147[d]	12h 10m 06s.3	+18° 32′ 30″	11.2	0.24(.10)	*B*	32″.3	18.5
NGC4478[e]	12 30 17.5	+12 19 42	13.4	0.17(.05)	Open[f]	8.0	17.7
NGC4552[e]	12 35 39.9	+12 33 20	12.4	0.29(.03)	Open[f]	8.0	16.6
NGC5272 (M3)[d]	13 42 11.4	+28 22 38	10.1	0.11(.04)	*B*	16.4	16.0
NGC6205 (M13)[d]	16 41 41.6	+36 27 27	9.1	0.13(.05)	*B*	32.3	16.4

[a] Coordinates are of the cluster/galaxy center and are derived from GS images using the Center of Gravity centroiding method, mean error 1″

[b] Integrated Magnitude

[c] Surface Brightness—This can be derived from the integrated magnitude and the aperture diameter using the relation: surface brightness = integrated magnitude $+2.5\log_{10}(\pi(\text{aperture size}/2)^2)$

[d] Globular Cluster

[e] High galactic latitude elliptical galaxy

[f] Unfiltered

larized standards in Table VI, because identification of the target is unambiguous and a large aperture was centered on the target for the polarimetric measurements.

a) Spectrophotometric and Photometric Standards

Based on the calibration requirements of *HST* scientific instruments, spectrophotometric and photometric calibration targets have been selected by *HST* Calibration Target Working Groups. Based on its primary use, a target can be classified as either a UV or optical spectrophotometric standard star, a Johnson–Cousins *UBVRI* optical photometric standard star, a Wide Field Planetary Camera (WFPC) optical photometric standard field, or a Faint Object Camera (FOC) faint optical photometric standard field.

Table I contains the *HST* photometric and spectrophotometric calibration stars. Specified in the columns of Table I are: (1) the calibration target name, (2) the equinox 2000 coordinates deduced from the *HST* Guide Star Catalog, (3) the *V* magnitude, (4) the $B-V$ color, (5) the spectral type, if available, and (6) the type of calibration target. A few of these entries deserve additional explanation, which are generally applicable to the other tables, as well. All equinox 2000 coordinates for stellar targets fainter than $V\simeq 6$ mag have been derived from the *HST* Guide Star Catalog and have relative accuracies of a fraction of an arcsecond with respect to the nearby stars within about 30 arcmin. Absolute errors range up to about 2 arcsec. The coordinates for the brighter stars are from the SAO catalog and are precessed to equinox 2000. The cataloged proper motion is applied for SAO coordinates, while the epoch of the Guide Star coordinates is the date of the Guide Star plate (1975–1985). Information on the calibration targets' proper motions is compiled in the STScI internal documents discussed earlier. When possible, the *V* magnitude and the $B-V$ color were taken from Landolt (1973, 1983, and private communication). A complete set of recent references for the *HST* calibration targets can normally be found in the STScI internal documents. Some of the most useful references for these targets are Landolt (1973, 1983), Drilling and Landolt (1979), and McCook and Sion (1987). When the final data for these calibration targets become available, fitted synthetic energy distributions will be generated, if empirical energy distributions do not exist (see Secs. III and IV).

Table II contains the *HST* photometric calibration target fields. Specified in the columns of Table II are: (1) the calibration target field name, (2) the approximate equinox 2000 coordinates of the field center, (3) the approximate size of the field in arcminutes, and (4) the type of calibration field. The field centers are chosen to maximize the number and color range of 15–17 mag stars in the 2.6 arcmin WFPC field of view. Stars of 14 mag and brighter are avoided, in order to minimize saturation in the WFPC CCDs. When the field size is in parentheses, standard star quality observations of the field do not yet exist (see Sec. IV*d*). The field size is that of the ground-based data, while the field of view of the *HST* Wide Field Camera is 2.6 arcmin, the field of view of the *HST* Planetary Camera is 1.1 arcmin, and the field of view of the *HST* FOC is 44 arcsec or less. Observations of these fields with *HST* will not usually be positioned exactly on the field centers listed in Table II. The categories of calibration fields are: (1) a WFPC on-orbit calibration field on the outskirts of a cluster, (2) a WFPC calibration field on the outskirts of a cluster which *will not be observed on-orbit*, (3) a FOC faint photometric calibration field which contains a faint ($V>20$ mag) blue–yellow star pair, and (4) a FOC faint photometric *candidate* calibration field which contains a faint ($V>20$ mag) blue–yellow star pair. The WFPC on-orbit calibration fields have been selected to have stars with a range of colors fainter than $V=13$ mag. There can be problems with crowding in the ground-based images of these fields, but not in the *HST* images. The WFPC calibration fields which *will not be observed on-orbit* can contain stars brighter than $V=13$ mag. These fields were observed from the ground with filters that closely replicate the WFPC flight filters in order to explore metallicity effects (see Sec. IV*d*). Some useful general references for the WFPC fields are Alter, Ruprecht, and Vanysek (1970) and Ruprecht, Balazs, and White (1981). The FOC will generally observe subfields containing faint ($V>20$ mag) blue–yellow star pairs in the FOC calibration fields. However, the ground-based data on these fields will have a much larger field of view and will usually contain some stars as bright as $V=16$ mag. So far, precise photometry is available for only two of the FOC fields (see Sec. IV*d*). More detailed information on the characteristics of all of the standard fields can be obtained from the STScI internal documents.

TABLE VII. Alias names and corresponding standard names.

Alias	Standard Name	Alias	Standard Name
27 Boo	γ Boo	3 Lyr	α Lyr
11 Cas	β Cas	13 Oph	ζ Oph
17 Cas	ζ Cas	19 Sco	o Sco
34 Cas	ϕ Cas	25 UMa	θ UMa
5 Cep	α Cep	48 UMa	β UMa
21 Crt	θ Crt	112 Tau	β Tau
12 Dra	ι Dra	64 UMa	γ UMa
33 Dra	γ Dra	85 UMa	η UMa
24 Gem	γ Gem	108 Vir	HD129956
32 Leo	α Leo		
Agena	β Cen		
AGK−00° 1119	HD64854	AGK+42° 1953	BD +42° 3914
AGK−00° 1954	HD130557	AGK+49° 1116	η UMa
AGK−00° 2173	HD154445	AGK+50° 1408	16 Cyg B
AGK−00° 887	HD50583	AGK+51° 1174	γ Dra
AGK+00° 1775	HD129956	AGK+51° 758	θ UMa
AGK+07° 247	HD14069	AGK+53° 54	ζ Cas
AGK+08° 747	HD44498	AGK+53° 826	γ UMa
AGK+12° 2095	HD182900	AGK+55° 344	HD21447
AGK+14° 2017	HD231195	AGK+56° 1570	HD212311
AGK+14° 395	HD27836	AGK+56° 832	β UMa
AGK+16° 1838	HD170878	AGK+57° 146	ϕ Cas
AGK+23° 1951	BD +23° 3745	AGK+58° 1354	HD204827
AGK+23° 598	HD251204	AGK+58° 16	β Cas
AGK+25° 1350	Feige 66	AGK+59° 326	HD19820
AGK+25° 440	BD +25° 727	AGK+59° 999	ι Dra
AGK+28° 516	β Tau	AGK+60° 126	HD236633
AGK+32° 1897	HD191082	AGK+60° 232	BD +59° 389
AGK+32° 1910	BD +32° 3739	AGK+61° 364	HD25443
AGK+37° 1080	HD93521	AGK+62° 1226	α Cep
AGK+38° 1345	γ Boo	AGK+75° 374	BD +75° 325
AGK+38° 1711	α Lyr		
Alcaid	η UMa		
Alderamin	α Cep		
Alhena	γ Gem		
BD −00° 1479	HD50583	BD +10° 4797	ζ Peg
BD −00° 2886	HD130557	BD +12° 2149	α Leo
BD −00° 3224	HD154445	BD +12° 3907	HD182900
BD −02° 1885	HD52533	BD +14° 3881	HD231195
BD −02° 329	HD12021	BD +14° 693	HD27836
BD −04° 4239	HD155197	BD +16° 1223	γ Gem
BD −07° 4487	HD161056	BD +16° 3529	HD170878
BD −08° 3202	θ Crt	BD +18° 2647	Feige 67
BD −10° 4350	ζ Oph	BD +23° 1179	HD251204
BD −19° 3140	HD94851	BD +25° 2534	Feige 66
BD +00° 2129	HD64854	BD +26° 741	HD283805
BD +01° 2972	HD129956	BD +28° 795	β Tau
BD +07° 357	HD14069	BD +32° 3707	HD191082
BD +07° 388	ξ^2 Cet	BD +38° 2179	HD93521
BD +08° 1296	HD44498	BD +38° 2565	γ Boo

TABLE VII. (continued)

Alias	Standard Name	Alias	Standard Name
BD +38° 3238	α Lyr	BD +57° 1302	β UMa
BD +50° 2027	η UMa	BD +57° 260	ϕ Cas
BD +50° 2848	16 Cyg B	BD +58° 2272	HD204827
BD +51° 2282	γ Dra	BD +58° 3	β Cas
BD +52° 1401	θ UMa	BD +59° 1654	ι Dra
BD +53° 105	ζ Cas	BD +59° 191	HD236633
BD +54° 1475	γ UMa	BD +59° 609	HD19820
BD +54° 684	HD21447	BD +61° 2111	α Cep
BD +55° 2731	HD212311	BD +61° 669	HD25443
BPM 97859	GD246		
CD −22° 5281	HD64299	CD −42° 13839	HD176425
CD −23° 12849	o Sco	CD −44° 2920	HD49798
CD −32° 17672	HD223184	CD −50° 2835	HD60753
CD −32° 2538	μCol	CD −60° 4358	HD110984
CD −37° 7146	HD98161	CD −60° 4390	HD111579
CD −39° 3939	ζ Pup	CD −77° 15	β Hyi
Caph	β Cas		
EGGR 19	Feige 22	EGGR 145	LDS749B
EGGR 20	Feige 24	EGGR 150	G93–48
EGGR 26	HZ 4	EGGR 156	G28–27
EGGR 29	LB227	EGGR 157	Feige 108
EGGR 31	HZ 2	EGGR 158	Feige 110
EGGR 70	G162–66	EGGR 210	GD71
EGGR 71	Feige 34	EGGR 233	GD246
EGGR 74	G163–27	EGGR 247	G191B2B
EGGR 76	G163–50	EGGR 264	LTT9491
EGGR 86	HZ 21	EGGR 288	GD50
EGGR 95	G60–54	EGGR 327	G138–31
EGGR 102	Grw +70° 5824	EGGR 335	GD248
EGGR 118	G153–41	EGGR 344	G193–74
EGGR 125	G21–15	EGGR 363	GD337
EGGR 138	G24–9	EGGR 382	G158–100
Etamin	γ Dra		
G62–3	G60–54	G238–44	Grw +70° 5824
G141–11	G21–15		
HD432	β Cas	HD122451	β Cen
HD2151	β Hyi	HD127762	γ Boo
HD3360	ζ Cas	HD137759	ι Dra
HD7927	ϕ Cas	HD147084	o Sco
HD15318	ξ^2 Cet	HD149757	ζ Oph
HD35497	β Tau	HD164058	γ Dra
HD38666	μCol	HD172167	α Lyr
HD47105	γ Gem	HD186427	16 Cyg B
HD66811	ζ Pup	HD203280	α Cep
HD82328	θ UMa	HD214923	ζ Peg
HD87901	α Leo	HD236928	BD +59° 389
HD95418	β UMa	HD283808	BD +25° 724
HD100889	θ Crt	HD283812	BD +25° 727
HD103287	γ UMa	HD331891	BD +32° 3739
HD120315	η UMa	HD344776	BD +23° 3745

TABLE VII. (continued)

Alias	Standard Name	Alias	Standard Name
HELIX NEBULA	NGC 7293		
HR 21	β Cas	HR 5267	β Cen
HR 98	β Hyi	HR 5435	γ Boo
HR 153	ζ Cas	HR 5501	HD129956
HR 382	ϕ Cas	HR 5522	HD130557
HR 718	ξ^2 Cet	HR 5744	ι Dra
HR 1046	HD21447	HR 6081	o Sco
HR 1791	β Tau	HR 6175	ζ Oph
HR 1996	μCol	HR 6353	HD154445
HR 2421	γ Gem	HR 6601	HD161056
HR 3165	ζ Pup	HR 6705	γ Dra
HR 3775	θ UMa	HR 6955	HD170878
HR 3982	α Leo	HR 7001	α Lyr
HR 4295	β UMa	HR 7177	HD176425
HR 4372	HD98161	HR 7389	HD182900
HR 4468	θ Crt	HR 7504	16 Cyg B
HR 4554	γ UMa	HR 8162	α Cep
HR 5191	η UMa	HR 8634	ζ Peg
Hilt 80	BD +64° 106	Hilt 514	HD251204
Hilt 103	HD236633	Hilt 815	BD +23° 3745
Hilt 379	HD19820	Hilt 1027	BD +42° 3914
Hilt 423	HD25443	Hilt 1049	HD204827
L219–48	BPM 16274	L898–25	G163–27
L770–3	G153–41	L970–30	G163–50
L791–40	LTT9491	L1002–16	LDS749B
L825–14	G162–66		
LFT 15	β Cas	LFT 753	G163–27
LFT 43	β Hyi	LFT 960	G60–54
LFT 658	θ UMa		
LHS 6	β Hyi	LHS 2661	G60–54
LHS 270	θ UMa	LHS 3532	G24–9
LHS 1027	β Cas	LHS 6305	G138–31
LHS 2333	G163–27		
LP 414–10	LB227	LP 822– 50	LTT9491
LP 671–11	G163–27		
LPM 364	G163–27		
LTT 226	β Hyi	LTT 12716	α Leo
LTT 3870	G162–66	LTT 13746	G60–54
LTT 4020	G163–27	LTT 15456	G21–15
LTT 4099	G163–50	LTT 15486	α Lyr
LTT 4100	G163–51	LTT 15751	16 Cyg B
LTT 6497	G153–41	LTT 15921	G24–9
LTT 10046	β Cas	LTT 16749	G28–27
LTT 11733	GD71	LTT 18341	Grw +70° 5824
LTT 12519	θ UMa	LTT 18548	G93–48
Merak	β UMa		
PG1433 +53.8	GD337		

TABLE VII. (continued)

Alias	Standard Name	Alias	Standard Name
Phecda	γ UMa		
Regulus	α Leo		
SAO 6435	BD +75° 325	SAO 104744	HD231195
SAO 11597	HD236633	SAO 104832	HD182900
SAO 12096	BD +59° 389	SAO 108103	ζ Peg
SAO 13012	HD25443	SAO 110446	HD14069
SAO 19302	α Cep	SAO 110543	ξ^2 Cet
SAO 21133	β Cas	SAO 113777	HD44498
SAO 21566	ζ Cas	SAO 120642	HD129956
SAO 22191	ϕ Cas	SAO 129586	HD12021
SAO 23886	HD19820	SAO 133839	HD50583
SAO 24064	HD21447	SAO 134061	HD52533
SAO 27289	θ UMa	SAO 135266	HD64854
SAO 27876	β UMa	SAO 138296	θ Crt
SAO 28179	γ UMa	SAO 140152	HD130557
SAO 29520	ι Dra	SAO 141513	HD154445
SAO 30653	γ Dra	SAO 141543	HD155197
SAO 31899	16 Cyg B	SAO 141832	HD161056
SAO 33461	HD204827	SAO 160006	ζ Oph
SAO 34361	HD212311	SAO 174702	HD64299
SAO 44752	η UMa	SAO 179363	HD94851
SAO 50259	BD +42° 3914	SAO 184329	o Sco
SAO 62257	HD93521	SAO 196149	μCol
SAO 64203	γ Boo	SAO 198752	ζ Pup
SAO 67174	α Lyr	SAO 202283	HD98161
SAO 69429	HD191082	SAO 214775	HD223184
SAO 76732	BD +25° 727	SAO 218207	HD49798
SAO 77168	β Tau	SAO 229446	HD176425
SAO 87608	BD +23° 3745	SAO 235291	HD60753
SAO 93910	HD27836	SAO 252025	HD110984
SAO 95912	γ Gem	SAO 252052	HD111579
SAO 98967	α Leo	SAO 252582	β Cen
SAO 103800	HD170878	SAO 255670	β Hyi
Vega	α Lyr		
WD 0047 -52	BPM 16274	WD 1321 +36	HZ 44
WD 0227 +05	Feige 22	WD 1337 +70	Grw +70° 5824
WD 0232 +03.5	Feige 24	WD 1433 +53	GD337
WD 0352 +09	HZ 4	WD 1615 -15	G153–41
WD 0406 +16	LB227	WD 1625 +09	G138–31
WD 0410 +11	HZ 2	WD 1824 +04	G21–15
WD 0501 +52.7	G191B2B	WD 2011 +06	G24–9
WD 0549 +15	GD71	WD 2129 +00	LDS749B
WD 0749 +52	G193–74	WD 2149 +02	G93–48
WD 1031 -11	G162–66	WD 2201 -21.1	NGC 7293
WD 1036 +43	Feige 34	WD 2254 +07	G28–27
WD 1055 -07	G163–27	WD 2309 +10.5	GD246
WD 1105 -04	G163–50	WD 2313 -02	Feige 108
WD 1211 +33.2	HZ 21	WD 2317 -05	Feige 110
WD 1247 +55.1	GD 319	WD 2317 -17	LTT9491
WD 1257 +03	G60–54	WD 2323 +15	GD248

b) Polarimetric Standards

The diversity in design, performance, and goals of the *HST* polarization modes necessitates a set of standard targets which encompass a wide range in brightness, polarization properties, and wavelength coverage. The wavelength ranges accessible to the *HST* polarimeters are: High Speed Photometer (HSP) (2100–3400 Å), FOC (2800–6000 Å), WFPC (4500–6000 Å), and Faint Object Spectrograph (FOS) (1200–6000 Å). The HSP is *best* suited for broadband UV polarimetry of point sources, the FOC for UV and optical imaging polarimetry of faint sources, WFPC for optical imaging polarimetry, and the FOS for UV and optical spectropolarimetry of point sources.

The selection of an appropriate set of standards for *HST* polarimetry is not straightforward: the UV polarization of any potential standard target is unknown; there is a lack of *faint* time-tested standards; and the pool of well-understood, continuously monitored polarization standards is poor, in general. To improve the latter two conditions, two ground-based programs were initiated to acquire repeated measurements on a number of potentially acceptable targets (see Sec. IV*e*).

Polarized and unpolarized single stars are the logical choice of calibration sources for the HSP and the FOS. An effort was made to select stars with polarization data histories and fairly well-understood polarizing mechanisms. The fainter the target, however, the less information is available and the less credible an object is as a standard target. When possible, targets which will be used for other *HST* calibrations are incorporated into the list to promote observing efficiency and a more complete understanding of target physics and behavior.

In order to study any spatially dependent effects in the WFPC and FOC, resolved sources are selected as the most efficient targets. Large polarization standards include bipolar reflection nebulae and highly polarized galactic clusters. Galactic globular clusters and elliptical galaxies are used as null extended standard fields. The bipolar reflection nebula are extremely advantageous because of their extent, the smooth radial dependence of the polarization (10%–50%), and symmetric position angle about the central illuminating star. However, the targets are not *ideal* because of potential variability of the lobe structure over timescales of several months, lack of UV polarization measurements, and difficulties in predicting the UV polarization without extensive modeling and large amounts of data.

Tables III–VI contain the *HST* polarization standard targets. Tables III and IV contain the polarized and unpolarized stars. In Tables III and IV, columns 1–5 contain: (1) the calibration target name, (2) the equinox 2000 coordinates deduced from the *HST* Guide Star Catalogue, (3) the V magnitude, (4) the $B-V$ color, and (5) the spectral type, if available. Columns 6 and 7 in Table III list the visual polarization and error and the position angle in equatorial coordinates and error, respectively. Column 6 in Table IV contains the polarization in the B band and error for the unpolarized stars. These polarization data are from Schmidt or Tapia (see Sec. IV*e*).

The polarized standard fields, reflection nebulae and galactic clusters, are listed in Table V. For each reflection nebulae, the aperture size is indicated. In all but CRL 2688 the coordinates are computed from offsets measured with respect to the stellar component of the nebula. The offset star for CRL 2688 is indicated on the finder chart. Individual stars that are measured in the NGC 6823 cluster are identified in the finder charts and listed in Table V. The Crab Nebula is a secondary standard, because there may be structure within the 5.3 arcsec aperture used to obtain the data. The stars in the NGC 6823 open cluster are secondry standards, because only a few observations are available.

The unpolarized standard field, i.e., globular clusters and elliptical galaxies, are listed in Table VI, along with the polarization error in the B band and the aperture size. In all cases, the aperture was centered on the cluster or galaxy.

III. PHOTOMETRIC AND POLARIMETRIC CALIBRATIONS

a) The HST Photometric System

Two different types of sensitivity calibrations are normally used in astronomy. When standards of known absolute flux are observed, a sensitivity calibration is achieved by deriving a transformation between instrumental output and some measure of absolute flux. An example at optical wavelengths is the "AB79" spectrophotometric system (Oke and Gunn 1983). In other cases, a sensitivity calibration is achieved by deriving a transformation between instrumental output and some traditional photometric system such as Johnson–Cousins *UBVRI*. In these cases, measurements are normally reported in magnitudes and absolute physical units are eschewed. These two different approaches each have advantages and can be related, if an appropriate set of measurements of the stars which define the photometric or spectrophotometric systems in question are available. For *HST* the goal is to achieve an absolute sensitivity calibration of all photometric and spectrophotometric modes on "the *HST* photometric system." Another goal is to achieve the ability to transform between the *HST* photometric system and traditional photometric or spectrophotometric systems. The approaches that will be used to do this will be based on synthetic photometry techniques (e.g., Buser 1986; Horne 1988; Edvardsson and Bell 1989).

The first step in establishing a stable *HST* photometric system was to develop a formalism which can be the basis for reporting photometric and spectrophotometric measurements. This formalism has been discussed by Koornneef *et al.* (1986). The second step in establishing a stable system is to provide a set of standards that have been accurately measured on the *HST* photometric system, as discussed in Sec. IV.

b) The HST Polarimetric Calibration

The goals of a polarimetric calibration program are to: (1) remove systematic polarization effects introduced by instrumentation, (2) relate the polarization direction to an absolute reference frame, namely the equatorial reference system, and (3) characterize the uncertainties of polarization measurements. Since there are no 100% polarized calibration sources onboard *HST*, external astronomical targets must be used to characterize the efficiency and calibrate the position angle offsets. The targets with near-zero polarizations will be used to measure instrument-induced polarization components.

In-orbit calibration procedures are necessary in order to confirm the suitability of the standards selected from ground-based results. Since the HSP has the largest dynamic range of all the instruments onboard *HST* ($V\simeq 0$–24 mag), the HSP will be used to provide initial UV data on the faint polarization standards for the FOC, FOS, and WFPC. The HSP is linked to the ground-based reference data via observations in the *N* band at 3400 Å. The HSP can observe the brightest and most well-studied ground calibration standards. We intend to cross-calibrate the *HST* polarimeters and, at the appropriate time, to cross-calibrate the HSP and FOS with the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), which will be onboard the ASTRO-1 shuttle payload. The calibration methods for each of the *HST* Science Instruments are described in internal *HST* documentation (Lupie *et al.* 1985) and briefly in Lupie and Stockman (1989). If the roll capability of the spacecraft can be used without great impact to the power and thermal requirements (this is under review), the polarization calibrations would be greatly facilitated and null polarization standards easily verified.

In preparation for the initial on-orbit calibrations, a dataset of polarization and position angle as a function of wavelength for each calibration target is being prepared using the recently collected ground-based data of Schmidt and Tapia (see Sec. IV*e*) and appropriate data from the literature. These datasets are derived from the ground-based data using fitting procedures, interpolation, and extrapolation. The standard stars with large polarization are fit with interstellar polarization laws, and their position angles are fit with constant or linear functions of wavelength. The small but significant polarizations observed in some of the null polarization standards are fit with appropriate linear or low-order polynomials. In the case of more complex objects such as bipolar reflection nebulae, extrapolation into the UV is based upon trends in the usual regions but will be inaccurate. The initial on-orbit measurements by HSP and FOS will be used to determine the UV wavelength dependencies of these objects.

IV. PRELAUNCH CALIBRATION DATABASE

The STScI has coordinated and sponsored a number of observational programs for *HST* calibration targets, if the data available in the literature was judged insufficient. The programs that have been initiated to obtain space-based and ground-based observations of *HST* photometric, spectrophotometric, and polarimetric calibration targets are briefly reviewed below. The current status of the photometric and spectrophotometric observations of *HST* calibration targets is summarized in Table VIII.

a) UV Spectrophotometry

UV spectrophotometry of *HST* calibration targets is obtained with *Voyager* by J. Holberg and R. Polidan and with the *International Ultraviolet Explorer* (*IUE*) by Bohlin *et al.* (1989). The *Voyager* data cover the wavelength region from ~900 to 1600 Å, while the *IUE* data cover the wavelength region from ~ 1150 to 3200 Å. In the UV wavelength region, absolute fluxes measured on the *HST* photometric system will be traceable to *IUE*'s UV spectrophotometric system defined by Bohlin *et al.* (1989).

b) Optical Spectrophotometry

J. B. Oke is establishing a new set of optical spectrophotometric calibration standards for *HST* (Oke 1988). In the optical wavelength region, his work will be the basis for the *HST* photometric system (see Sec. III*a*) and will be traceable to the AB79 spectrophotometric system (Oke and Gunn 1983). The ideal *HST* spectrophotometric calibration target has a completely measured flux distribution from 0.1–1.0 μm. Therefore, optical spectrophotometry has been obtained for many of the UV spectrophotometric calibration targets. In addition, a number of cool white dwarfs have been identified and observed by Oke. Because of their relatively featureless optical continuua, these stars make good optical calibration targets; but their UV fluxes are too low for good spectrophotometry with *IUE*.

As noted in Sec. III*a*, part of the calibration strategy for *HST* will be based on synthetic photometry techniques. Therefore, R. Stone and S. Tapia have also separately undertaken a program to obtain optical spectrophotometry of calibration targets. A large number of the calibration targets observed by Stone and Tapia are primarily photometric standards, but some of the Oke spectrophotometric standards are also in their programs. These observations could be used to define transformations between the *HST* photometric system and more traditional photometric systems. Stone is also determining the relationship between the AB79 spectrophotometric system and Lick's spectrophotometric system.

c) Optical Photoelectric Photometry

A. Landolt and collaborators, R. Light and A. Uomoto, have sought to extend Landolt's previous work (Landolt 1973, 1983) on establishing Johnson–Cousins *UBVRI* sequences (Johnson and Morgan 1953; Cousins 1976) near zero declination by providing more accurate photometry and faint extensions to existing sequences. In addition, Landolt and collaborators have obtained Johnson–Cousins *UBVRI* photometry of many of the calibration targets that are primarily UV or optical spectrophotometric standards and have begun optical monitoring of selected *HST* standards that have not been observed over a long-time baseline. Since none of the *HST* passbands are identical to Johnson–Cousins *UBVRI*, transformations or synthetic photometry techniques must be utilized in order to fully profit from Landolt's *UBVRI* database. The plans for utilizing the *UBVRI* database are twofold. First, the *UBVRI* data can be used to aid in transforming from measurements made on the *HST* photometric system to Johnson–Cousins *UBVRI*. This transfer will be direct for the case where an *HST* science instrument (e.g., the HSP) observes Landolt's *UBVRI* standards. For science instruments that will not normally observe Landolt *UBVRI* standards (e.g., the WFPC and to FOC) the transfer must be indirect. The second reason for utilizing *UBVRI* photometry is for an internal consistency check. Using synthetic photometry techniques, Landolt's photometry of spectrophotometric calibration targets can be compared with the absolute spectrophotometric measurements. Systematic errors in absolute flux measurements may be identified and corrected as a result of these comparisons. In the final analysis, all objects with optical spectrophotometry and Johnson–Cousins *UBVRI* measurements may be adjusted to an accurate and consistent scale, if any significant inconsistency is found.

Using the same principles discussed above, a database of Strömgren photometry (Strömgren 1963) collected from the literature and a database of Walraven photometry (DeRuiter and Lub 1986) provided by T. Courvoisier and J. Lub may also be utilized.

TABLE VIII. Status of data collection for *HST* optical or UV calibration targets.

Name	α (2000)	δ (2000)	V	B−V	Data Available (see Column Headings Below) 1	2	3	4	5	6	7	8	9	10	11‡	12	13	14	15
47 Tuc Field	0^h 19^m	−72° 01′	—	—	—	—	—	—	—	—	—	—	—	—		—	O	—	—
β Hyi	0 25	−77 15	2.80	+0.62	—	P	—	—	—	P†	—	P	P	—	—	—	—	—	—
G158-100	0 33	−12 07	14.89	+0.69	—	—	O	—	O	P	O	P†	P	—		—	—	—	—
ζ Cas	0 36	+53 53	3.66	−0.19	O	P	—	O	—	P†	—	P	P	—	—	—	—	—	—
BPM 16274	0 50	−52 08	14.20	−0.05	—	P	—	—	—	—	O	P	P	—		—	—	—	O
Feige 11	1 04	+4 13	12.07	−0.23	—	—	—	O	O†	P	O	P	P	—		—	—	—	—
Feige 16	1 54	−6 42	12.41	−0.02	—	—	—	—	O†	—	O	P	P	—		—	—	—	—
χ Per Field	2 22	+57 11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—
ξ^2 Cet	2 28	+8 27	4.29	−0.06	—	P	—	O	—	P	—	P	P	—	—	—	—	—	—
Feige 22	2 30	+5 15	12.80	−0.07	—	—	—	—	—	—	O	P	P	—		—	—	—	—
Feige 24	2 35	+3 43	12.42	−0.19	—	—	—	—	—	P	O	P	P	—		—	—	—	—
GD50	3 48	−0 58	14.06	−0.28	—	P	O	O	O	—	O	P†	—	—		—	—	—	—
SA95-301	3 52	+0 31	11.22	+1.30	—	—	—	O	O	—	O	P	—	—		—	—	O†	—
SA95-302	3 52	+0 31	11.71	+0.84	—	—	—	O	O	—	O	P†	—	—		—	—	O†	—
SA95-190	3 53	+0 16	12.62	+0.28	—	—	—	O†	O	—	O	—	—	—		—	—	—	—
SA95-42	3 53	−0° 04′	15.61	−0.22	—	—	O	—	O	—	O	—	—	—		—	—	—	—
SA95-317	3 53	+0 29	13.45	+1.32	—	—	—	O†	O	—	O	—	—	—		—	—	—	—
SA95-330	3 54	+0 29	12.18	+1.98	—	—	—	O†	O	—	O	—	—	—		—	—	—	—
SA95-275	3 54	+0 27	13.48	+1.75	—	—	—	O†	O	—	O	—	—	—		—	—	—	—
SA95-218	3 54	+0 10	12.09	+0.71	—	—	—	O	O	—	O	P†	—	—		—	—	—	—
SA95-132	3 54	+0 05	12.06	+0.44	—	—	—	O	O	—	O	P	—	—		—	—	—	—
SA95 Fields 1,2,3,4	3 41	+0 56	—	—	—	—	—	—	—	—	—	—	—	—	O†	—	—	—	—
HZ 4	3 55	+9 47	14.52	+0.08	—	P	O	O†	O	P	O	—	P	—		—	—	—	—
LB227	4 09	+17 07	15.34	+0.05	—	P	O	—	—	P	O	P†	—	—		—	—	—	—
HZ 2	4 12	+11 51	13.86	−0.05	—	P	O	—	—	P	T	P†	P	—		—	—	—	—
HD27836	4 24	+14 45	7.62	+0.60	—	P	—	O†	—	P	—	P	P	—	—	—	—	—	—
G191B2B	5 05	+52 49	11.78	−0.32	O	P	O	O†	O	P	O	P†	—	—		—	—	—	—
M36 Field	5 36	+34 07	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—
μ Col	5 46	−32 18	5.17	−0.28	O	P	—	—	—	P†	—	P	P	—	—	—	—	—	—
GD71	5 52	+15 33	13.04	−0.24	—	—	—	—	O	—	O	P	P†	—		—	—	—	—
HD44498	6 22	+8 19	8.83	−0.08	—	—	—	—	—	—	—	P†	—	—	—	—	—	—	—
HD49798	6 48	−44 18	8.30	−0.29	O	P	—	—	—	—	O	P†	P	—	—	—	—	—	—
HD50583	6 53	−0 18	8.29	−0.04	—	—	—	—	—	—	—	P†	—	—	—	—	—	—	—
HD52533	7 01	−3 07	7.70	−0.09	—	—	—	—	—	—	—	P†	P	—	—	—	—	—	—
Rubin 149	7 24	−0 33	13.86	−0.14	—	—	—	—	O	—	O	P†	—	—		—	—	—	—
Rubin 152	7 29	−2° 05′	13.01	−0.20	—	—	—	—	O	—	O	P†	—	—		—	—	—	—
HD60753	7 33	−50 35	6.70	−0.09	—	P	—	—	—	—	—	P†	—	—	—	—	—	—	—
G193-74	7 53	+52 29	15.70	+0.24	—	—	O	—	O	P	O	—	P†	—		—	—	—	—
HD64854	7 55	+0 16	9.40	−0.16	—	—	—	—	—	—	—	P	—	—	—	—	—	—	—
ζ Pup	8 03	−40 00	2.25	−0.27	O	P	—	—	—	P	—	P	P	—	—	—	—	—	—
BD+75°325	8 10	+74 57	9.54	−0.32	O	P	O	—	—	—	O	P†	P	—		—	—	—	—
M67 Field	8 51	+11 49	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—
AGK+81°266	9 21	+81 43	11.92	−0.33	O	P	O	—	O	—	O	P†	—	—		—	—	—	—
PG 0918+029	9 21	+2 46	13.32	−0.28	—	—	—	O†	O	—	O	P†	—	—		—	—	—	—
SA101-327	9 56	−0 25	13.44	+1.16	—	—	—	O†	O	—	O	—	—	—		—	—	O	—
SA101-330	9 56	−0 27	13.71	+0.58	—	—	—	O†	—	—	O	—	—	—		—	—	O	—
SA101-429	9 57	−0 18	13.49	+1.00	—	—	—	O†	O	—	O	—	—	—		—	—	O†	—
SA101-431	9 57	−0 17	13.68	+1.25	—	—	—	O†	O	—	O	—	—	—		—	—	O†	—
SA101-207	9 57	−0 47	12.41	+0.52	—	—	—	O†	—	—	O	P†	—	—		—	—	O†	—
SA101 Field 1	9 57	−0 22	—	—	—	—	—	—	—	—	—	—	—	—	O†	—	—	—	—
GD108	10 00	−7 33	13.56	−0.22	—	P	O	O†	—	—	O	P†	—	—		—	—	O†	—
α Leo	10 08	+11 58	1.35	−0.11	O	P	—	—	—	P	—	P	P	—	—	—	—	—	—
G162-66	10 33	−11 41	13.01	−0.15	—	—	—	O†	O†	—	O	P	—	—		—	—	—	—
PG 1034+001	10 37	−0 07	13.22	−0.37	—	—	—	O†	O†	—	O	—	—	—		—	—	—	—
Feige 34	10 39	+43 06	11.18	−0.34	O	P	O	O†	O†	P	O	P†	P	—		—	—	—	—

TABLE VIII. (continued)

Name	α (2000)	δ (2000)	V	B−V	Data Available 1	2	3	4	5	6	7	8	9	10	11‡	12	13	14	15
HD93521	10^h 48^m	+37° 34′	7.04	−0.27	O	P	O	O†	O†	—	—	P†	—	—	—	—	—	—	—
G163–27	10 57	−7 31	14.33	+0.29	—	—	—	—	O†	—	O	P†	P	—		—	—	—	—
G163–50	11 07	−5 09	13.08	+0.02	—	—	—	O†	—	P	O	P	P	—		—	—	O†	—
G163–51	11 08	−5 13	12.57	+1.49	—	—	—	O†	—	—	O	P†	—	—		—	—	O†	—
θ Crt	11 36	−9 48	4.70	−0.08	—	—	—	O†	—	P	—	P	P	—	—	—	—	—	—
γ UMa	11 53	+53 41	2.44	+0.00	—	P	—	—	—	P	—	P	P	—	—	—	—	—	—
HZ 21	12 13	+32 56	14.68	−0.33	—	P	O	O†	O†	P	O	P†	P	—		—	—	—	—
Feige 66	12 37	+25 04	10.50	−0.28	—	—	O	O†	O†	—	O	P	P	—		—	—	—	—
Feige 67	12 41	+17 31	11.81	−0.33	—	—	O	O†	O†	—	O	P†	P	—		—	—	O†	—
G60–54	13 00	+3 28	15.81	+0.65	—	—	O	—	O†	P	O	P†	P†	—		—	—	O†	—
SA 57 Field	13 09	+29 23	21.9	0.1	—	—	—	—	—	—	—	—	—	—	—	O	—	—	—
HZ 44	13 23	+36 08	11.66	−0.29	O	P	O	O†	O†	P	O	P†	P	—		—	—	—	—
PG 1323-086	13 25	−8 49	13.48	−0.14	—	—	—	O†	O†	—	O	P†	—	—		—	—	—	—
ω Cen Field	13 25	−47 35	—	—	—	—	—	—	—	—	—	—	—	O		—	—	O	—
Grw 70°5824	13 38	+70 17	12.77	−0.09	—	P	O	—	O†	P	O	P†	P	—		—	—	—	—
η UMa	13 47	+49 18	1.86	−0.19	O	P	—	—	—	P	—	P	P	—	—	—	—	—	—
β Cen	14 03	−60 22	0.61	−0.22	O	P	—	—	—	P	—	P†	P	—	—	—	—	—	—
GD337	14 34	+55 35	16.09	−0.03	—	—	—	—	—	—	—	P†	—	—	—	—	—	—	—
HD129956	14 45	+0 43	5.69	−0.03	—	—	—	—	—	—	—	P†	P	—	—	—	—	—	—
HD130557	14 48	−0 50	6.13	−0.04	—	—	—	—	—	—	—	P†	P	—	—	—	—	—	—
ι Dra	15 24	+58 57	3.29	+1.16	—	O†	—	O†	—	—	—	P	P	—	—	—	—	—	—
SA107–568	15 37	−0 17	13.04	+1.15	—	—	—	O	O†	—	O	—	—	—		—	—	O†	—
SA107–456	15 38	−0 19	12.91	+0.93	—	—	—	O	O†	—	O	P†	—	—		—	—	—	—
SA107–351	15 38	−0 32	12.34	+0.56	—	—	—	O	O†	—	O	P†	—	—		—	—	—	—
SA107 Fields 1,2	15 39	+0 10	—	—	—	—	—	—	—	—	—	—	—	—	O†	—	—	—	—
SA107–601	15 39	−0 13	14.64	+1.36	—	—	—	O	O†	—	O	—	—	—		—	—	O†	—
SA107–602	15 39	−0 15	12.12	+1.00	—	—	—	O	O†	—	O	P†	—	—		—	—	O†	—
SA107–626	15 40	−0 17	13.47	+1.00	—	—	—	O	O†	—	O	—	—	—		—	—	O†	—
SA107–627	15 40	−0 17	13.34	+0.78	—	—	—	O	O†	—	O	—	—	—		—	—	O†	—
BD+33°2642	15 51	+32 56	10.81	−0.17	—	P	O	O	O†	P	O	P†	P	—		—	—	—	—
G153–41	16 17	−15 35	13.42	−0.22	O	O†	T	O	O†	—	O	P†	P†	—		—	—	—	—
G138–31	16 27	+9 12	16.14	+0.34	—	—	O	—	O†	P	O	P†	—	—		—	—	—	—
ζ Oph	16 37	−10 34	2.56	+0.02	O	P	—	O	—	P	—	P	P	—	—	—	—	—	—
γ Dra	17 56	+51 29	2.22	+1.52	—	—	—	—	—	P	P	—	P	—	—	—	—	—	—
G21–15	18 27	+4 03	13.89	+0.09	—	—	—	—	O†	—	O	P†	—	—		—	—	—	—
α Lyr	18 36	+38 47	0.03	+0.00	O	P	P	—	—	P	—	P	P	—	—	—	—	—	—
M11 Field	18 51	−6 17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—
NGC 6752 Field	19 10	−59 50	—	—	—	—	—	—	—	—	—	—	—	—		—	—	O	—
16 Cyg B	19 41	+50 31	6.20	+0.66	—	P	—	O	—	P	—	P	P	—	—	—	—	—	—
G24–9[a]	20 13	+6 42	15.72	+0.40	—	—	O	—	O†	P	O	P†	P†	—		—	—	O†	—
Mark A	20 43	−10 47	13.26	−0.25	—	—	—	—	O†	—	O	—	—	—		—	—	—	—
LDS749B	21 32	+0 15	14.67	−0.04	—	P	O	—	O†	—	O	P†	P	—		—	—	—	O
SA113–221	21 40	+0 21	12.09	+1.03	—	—	—	O	—	—	O	—	—	—		—	—	—	O
SA113–339	21 40	+0 27	12.25	+0.57	—	—	—	O	O†	—	O	P†	—	—		—	—	O†	O
SA113–241	21 41	+0 25	14.39	+1.37	—	—	—	O	—	—	O	—	—	—		—	—	O†	O
SA113–260	21 41	+0 23	12.41	+0.51	—	—	—	O	—	—	O	—	—	—		—	—	—	O
SA113 Fields 1,3	21 38	+0 30	—	—	—	—	—	—	—	—	—	—	—	—	O†	—	—	—	—
BD+28°4211	21 51	+28 51	10.51	−0.34	O	P	O	O	O†	P	O	P	P	—		—	—	—	—
G93–48	21 52	+2 23	12.74	−0.01	—	P	O	O	O†	—	O	P	P	—		—	—	O†	O
NGC 7293	22 29	−20 50	13.51	−0.35	O	P	O	—	—	—	O	P†	P†	—		—	—	—	O
ζ Peg	22 41	+10 49	3.40	−0.09	—	P	—	O	—	P	—	P	P	—	—	—	—	—	—
G28-27	22 57	+7 42	17.24	−0.04	—	—	—	—	—	—	—	P†	—	—	—	—	—	—	—
GD246	23 12	+10 50	13.10	−0.32	—	—	—	—	O	—	O	P	P	—		—	—	—	—
Feige 108	23 16	−1 50	12.96	−0.23	—	—	—	—	O	—	O	P	P	—		—	—	—	—
LTT 9491	23 19	−17 05	14.12	+.01	—	—	O	—	—	P	O	P†	P	—		—	—	O†	—
Feige 110	23 19	−5 19	11.82	−0.29	O	P	O	O	O†	P	O	P†	P	—		—	—	—	P
GD248	23 26	+16 00	15.09	+0.09	—	—	O	—	O	P	O	P†	P	—		—	—	—	—
NGC 7789 Field	23 59	+56 43	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	O	—

[a] This star is an apparent eclipsing binary with eclipses observed 1985 October 7.4 and 1988 July 15.3. See IAU Circular No. 4648 for more information.

TABLE VIII. (continued)

Column Headings for Table
1= UV Voyager Absolute Spectrophotometry (Holberg) λλ 900,1600
2= UV (IUE or OAO) Absolute Spectrophotometry (Bohlin *et al.*) λλ 1150, 3200
3=Absolute Spectrophotometry (Oke) λλ 3200-9900
4=Spectrophotometry (Stone) λλ 4000-8800
5=Spectrophotometry (Tapia) λλ 3200-7000
6=Absolute Optical Spectrophotometry (Literature)
7=UBVRI Photoelectric Photometry (Landolt)
8=UBVRI Photoelectric Photometry (Literature)
9=Stromgren Photoelectric Photometry (Literature)
10=UBVRI CCD Photometry (Walker)
11=UBVRI CCD Photometry (Landolt ;Oke)
12=UBVRI CCD Photometry (Koo and Kron)
13=BV CCD Photometry (Hesser)
14=WFPC-15 Filter CCD Photometry (Baum)
15=Walraven Photometry (Courvoisier or Lub)

The entries in the Table are as follows:
P=Published in the literature
O=Observed, but not yet published
T=To be observed
—=No data expected
* Indicates measurements are absolute, not relative.
† Indicates this is a partial dataset (For Stone, partial data set means only blue, i.e., 4000-6700 Å, or only red, i.e., 6100–8800 Å. For Tapia, partial data means CCD spectra that have not been fully reduced. The other Tapia entries are Reticon data. For Baum, Landolt ,Oke or the Literature, partial data set means only a fraction of the complete filter set was used).
‡ Blanks indicate that these objects may be observed; a fair number certainly will.

d) Optical CCD Photometry

Calibration of WFPC can be done efficiently only if rich fields are used. Therefore, W. A. Baum and collaborators, H. Harris, D. Hunter, and T. Kreidl, set out to establish the WFPC calibration fields presented in Table II (Harris and Baum 1985; Harris, Hunter, and Baum 1987). They identified appropriate WFPC calibration fields and then obtained ground-based measurements of the rich fields using a set of 15 filters which closely replicate the WFPC filter set. Baum and collaborators have observed most of Landolt's *UBVRI* standards and a few of Oke's spectrophotometric standards. Synthetic absolute spectrophotometry for the stars in these fields can be derived by fitting an appropriately reddened spectrum from a grid of stellar energy distributions to the photometric data for each star. These synthetic spectra could be used to derive traditional transformations between Johnson–Cousins *UBVRI* and WFPC *UBVRI*, as measured on the *HST* photometric system. A. Walker has made additional CCD *UBVRI* measurements of ω Cen, which should aid in this task.

A remaining problem is identifying and measuring faint photometric sequences. Faint standard stars are required, because the linear count rate limit for the FOC is very low. Two of the faint fields in Table II are based on existing data: J. Hesser provided data on 47 Tuc (Hesser *et al.* 1987) and D. Koo provided data on SA 57 (cf. Koo, Kron, and Cudsworth 1986 for the preliminary study). The SA 57 field now has a complete set of *UBVRI* CCD measurements available from ground-based work, but 47 Tuc has only *BV* CCD measurements. However, two faint photometric fields are an insufficient number for *HST*. To identify the required, supplemental faint fields, deep IIIa-J and IIIa-F UK Schmidt plates were obtained by the UK Schmidt Telescope Unit in four selected areas that Landolt has studied (SA 95, SA 101, SA 107, and SA 113). One of us, D.M., used the COSMOS machine at the Royal Observatory in Edinburgh to provide the STScI with a catalog of relative photographic magnitudes and colors of faint objects in the fields. Using these catalogs of magnitudes and colors, FOC faint photometric *candidate* subfields have been identified and included in Table II. Preliminary CCD photometry of some of the candidate fields by Landolt and collaborators suggests that the fields will be useful, once the required accuracy is obtained. Considerable work remains in this area. Oke is making deep measurements with a CCD on the Palomar 5 m. Finally, G. Wlérick and collaborators have obtained some *electronographic camera* data of a few of the faint photometric fields. STScI encourages the astronomical community to study these fields so that the best fields can be selected for use by *HST*.

e) Polarimetry

Two ground-based programs have collected data on *HST* polarization calibration targets. Aperture photopolarimetry of targets was obtained in multiple passbands. Repeated measurements were taken during 3 or 4 one week observing runs in each hemisphere over the course of 2 years. In a future publication, some of these results will be given (Schmidt *et al.*, in preparation). Tapia's results have been described in Tapia (1988). We briefly describe the programs here. G. Schmidt has obtained data on northern hemisphere targets using the "two-holer" polarimeter, primarily on the University of Minnesota/UCSD 1.5 m telescope and the Steward Observatory 2.3 m telescope. S. Tapia has acquired data in the southern hemisphere using the "Minipol" polarimeter, primarily with the Las Campanas 1.0 and 2.5 m telescopes. These instruments are Serkowski-type polarimeters employing rapidly rotating achromatic half-wave plates. Both investigators have made extensive studies to thoroughly characterize instrumental effects, determine effective wavelengths, and understand limitations in accuracy.

The initial statistical studies have resulted in the flagging of some of the initial set of targets as unsuitable due to variability, peculiar wavelength dependence, or excessive polarization in "null" targets. Tables III through VI do not include the targets which are not suitable standard targets. We have retained some additional targets which have been recently listed as variable (Bastien *et al.* 1988) but show no evidence of variability in Schmidt's observations. These possible variables are indicated in the comments in the last column of Table III. These targets should be investigated more thoroughly.

The globular clusters are not ideal null standards, because significant polarizations are found in many of them. The seven globular clusters that were observed are NGC 1261, NGC 6752, NGC 5139 (ω Cen), NGC 2419, NGC 4147, M3, and M13. The three clusters with polarizations of less

TABLE IX. FOC faint photometric sequence fields.

Name	α (2000)			δ (2000)			V	$B-V$	Ecl. Lat.	Comment
47 Tuc F1	0^h	19^m	$39^s.9$	−72°	01′	03″			−62°.0	Optimal[a] Field Center
	0	19	25.62	−72	01	21.4	21.60	+0.30	−62.0	Blue Star 1
	0	19	26.91	−72	01	20.8	21.82	+0.35	−62.0	Blue Star 2
	0	19	25.30	−72	01	17.9	23.47	+1.02	−62.0	Yellow Star 1
	0	19	25.70	−72	01	16.5	22.99	+1.36	−62.0	Yellow Star 2
	0	19	26.30	−72	01	18.2	20.19	+0.83	−62.0	Yellow Star 3
	0	19	26.36	−72	01	19.4	22.82	+0.82	−62.0	Yellow Star 4
	0	19	26.51	−72	01	22.1	20.56	+1.00	−62.0	Yellow Star 5
SA 95*										
Field 1	3	40	05.1	+1	47	01			−17.8	Optimal Field Center
	3	40	04.0	+1	46	38			−17.3	Blue Star
	3	40	03.1	+1	46	30			−17.3	Yellow Star
Field 2	3	37	51.7	+0	34	19			−18.3	Optimal Field Center
	3	37	54.6	+0	33	54			−18.3	Blue Star
	3	37	53.6	+0	33	47			−18.3	Yellow Star 1 (Galaxy)
	3	37	55.0	+0	34	01			−18.3	Yellow Star 2
Field 3	3	46	51.8	−0	37	37			−20.0	Optimal Field Center
	3	46	51.8	−0	36	32			−20.0	Blue Star
	3	46	50.8	−0	36	28			−20.0	Yellow Star
Field 4	3	41	49.0	+1	38	26			−17.5	Optimal Field Center
	3	41	45.5	+1	38	42			−17.5	Blue Star
	3	41	46.4	+1	38	52			−17.5	Yellow Star
SA 101*										
Field 1	9	57	33.8	−0	22	29			−12°.0	Optimal Field Center
	9	57	37.0	−0	22	34			−12.0	Blue Star
	9	57	37.5	−0	22	22			−12.0	Yellow Star
SA 57										Koo and Kron UBVRI data
	13	09	13.1	+29	23	18			33.6	Optimal Field Center
	13	09	13.18	+29	23	17.2	21.90	+0.10	33.2	White Dwarf
	13	09	13.84	+29	23	00.8	22.40	+1.60	33.2	M Dwarf
SA 107*										
Field 1	15	35	28.4	+0	03	08			18.8	Optimal Field Center
	15	35	32.0	+0	04	13			18.8	Blue Star
	15	35	31.4	+0	04	03			18.8	Yellow Star
Field 2	15	44	18.8	+0	17	36			19.6	Optimal Field Center
	15	44	18.9	+0	17	07			19.6	Blue Star
	15	44	17.9	+0	17	19			19.6	Yellow Star 1
	15	44	18.1	+0	17	03			19.6	Yellow Star 2
SA 113*										
Field 1	21	36	06.7	−0	29	41			13.0	Optimal Field Center
	21	36	10.2	−0	30	39			13.0	Blue Star
	21	36	09.8	−0	30	23			13.0	Yellow Star
Field 3	21	40	02.4	+1	32	58			14.6	Optimal Field Center
	21	40	06.4	+1	33	38			14.6	Blue Star
	21	40	06.2	+1	33	56			14.6	Yellow Star

* Identification based on UK Schmidt Plates.

[a] The optimal field center is the best field center for observations from the ground (~ 3 × 3 arcmin) or with WFPC.

than 0.25% are listed in Table VI. Two elliptical galaxies, NGC 4478 and NGC 4552, are included with polarizations of $<0.3\%$. Taking into account the limitations of the WFPC and FOC as polarimeters, and the accuracies with which the ground measures were made, some of these targets will still be suitable initial null standards for the *HST* cameras.

V. CHANGES AND ERRORS

Since the publication of STScI document No. 2 "Optical Calibration Targets" in January 1989 (Turnshek *et al.* 1989), several changes are required and a few errors have been discovered.

a) Changes

The 47 Tuc field, F2 of Hesser *et al.* 1987, was found to be deficient for FOC calibration (I. King, private communication). The blue star has a companion 0.5 arcsec away; one of the yellow stars is on a bad CCD column; and the other yellow star is somewhat too bright at $V=19$. The F2 field is replaced by the F1 field of Hesser *et al.* (1987), even though the bluest star is only $B-V=0.3$. The selection criterion for the other blue stars is $B-V<0.1$.

The field SA113-2 is dropped as a candidate, since initial CCD photometry from Landolt demonstrates that the blue star is not as blue as the photographic photometry suggested.

One yellow star (No. 1) in SA 95-2 turned out to be a galaxy; but the field is retained, since a valid blue–yellow pair remains.

b) Errors

The coordinates for yellow star 2 in SA 95-2 were wrong. The identification of the blue and the yellow stars in the finding chart for SA 95-3 are reversed in Turnshek *et al.* (1989). The finding chart is correct here. The coordinates for the star identified as yellow in SA 107-2 were wrong. A second yellow star is added in SA 107-2 and the finding chart is corrected. The coordinates for PG 1034 + 001 were in error, as pointed out by R. Downes, and are now correct in Table I here. A. Landolt noted that the coordinates for PG 0918 + 029 and the photometry for LTT 9491 are wrong in Turnshek *et al.* (1989). The coordinates for GD 71 are wrong in Turnshek *et al.* (1989) and STScI Preprint No. 397.

Because of the number of revisions and errors for the FOC Faint Photometric Sequence Fields, Table IV from Turnshek *et al.* (1989) is updated here as Table IX.

VI. CURRENT AND FUTURE PLANS

For spectrophotometric and photometric standards, the work in progress includes: (1) publication of the data obtained by the workers observing the standards, (2) evaluation of the systematic differences between measurements made by different observers, (3) adjustment of the data to account for any systematic differences, if a consensus on a procedure to adjust data can be reached, and (4) preparation and publication of the actual data and errors that will be used to calibrate *HST* observations on the "*HST* photometric system."

For polarimetric standards, the current and future work planned may be summarized as follows: (1) complete the variability studies, (2) prepare the recent ground-based data for publication, (3) interpolate and extrapolate (e.g., into the UV) the polarization and position angle data as required, and (4) prepare the actual dataset of polarization, position angle, and estimated errors over the full wavelength range of the *HST* polarizers that will be used to calibrate *HST* polarimetric observations.

Much of this paper was based on recommendations made by the *HST* Calibration Target Working Groups, and we acknowledge the large number of individuals from the general astronomical community who provided important inputs since 1983. Also, many individuals in the astronomical community have directly contributed to the *HST* calibration target effort through the work they have done setting up *HST* optical calibration targets. In particular, we thank R. G. Allen, W. Baum, A. Bijaoui, J. C. Blades, R. Cannon, A. Code, T. Courvoisier, J. Dolan, C. Grady, C. Gry, A. Harris, H. Harris, J. Hesser, J. Holberg, A. Holm, K. Horne, D. Hunter, J. Hsu, J. Jones, D. Koo, T. Kreidl, A. Landolt, G. Leliévre, J. Liebert, J. Lub, R. Light, I. McLean, J. B. Oke, B. Savage, H. S. Stockman, G. Schmidt, R. Stone, S. Tapia, A. Uomoto, A. Walker, R. White, G. Wlérick, C. Wu, the UK Schmidt Telescopy Unit, and the COSMOS group for their efforts.

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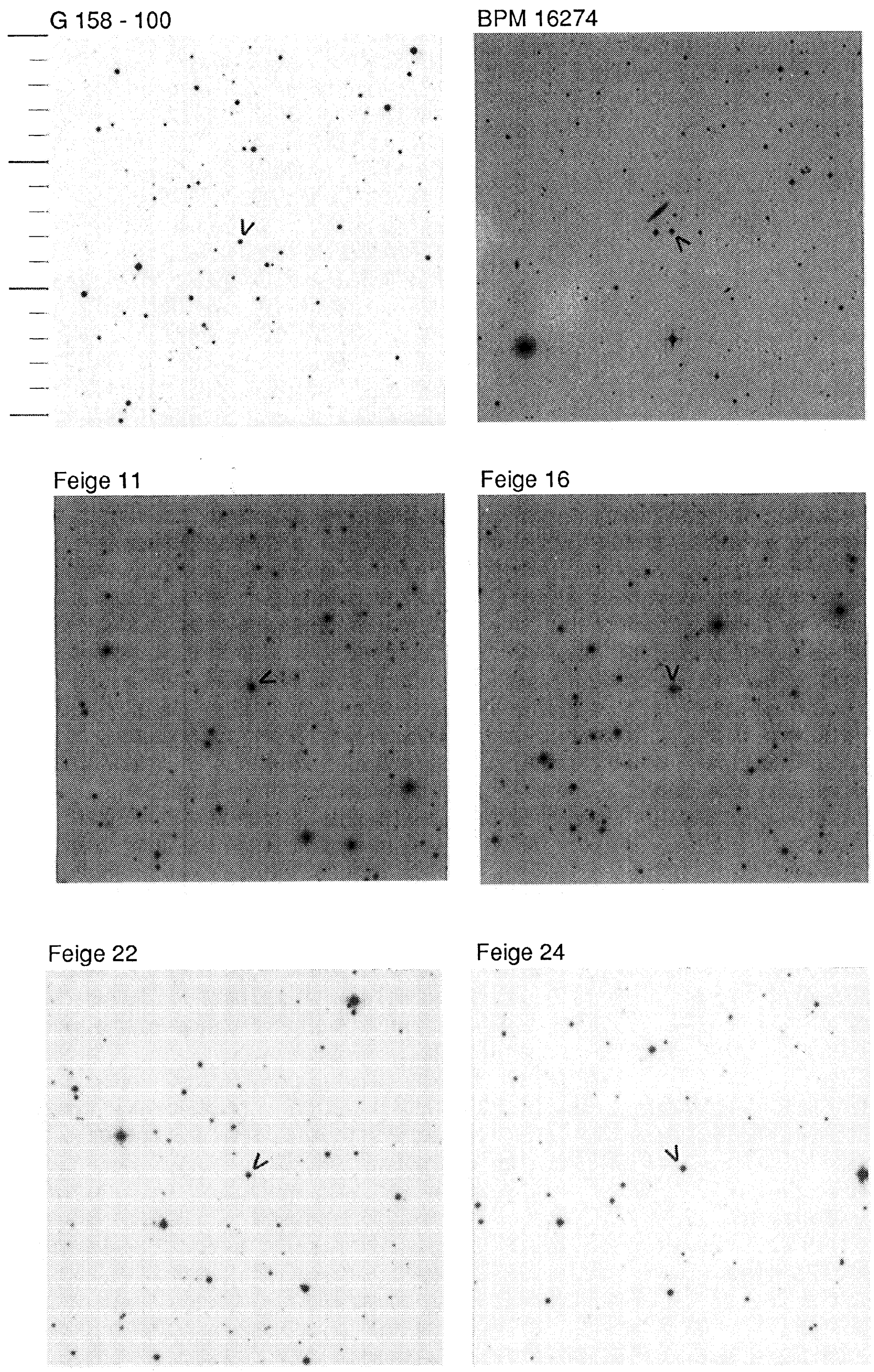

FIG. 1. Finding charts for single *HST* photometric and spectrophotometric calibration stars listed in Table I which are fainter than 6th magnitude. All 19 plates are to the same scale, which is indicated on the first field for G158-100. Each small tick mark is one arcminute and each field is about 15 × 15 arcmin. North is at the top and east is at the left, except for AGK + 81° 266, where north is about 20° from the top toward east. Reproduced from the blue Palomar Sky Survey Prints.

Turnshek *et al.* (see page 1243)

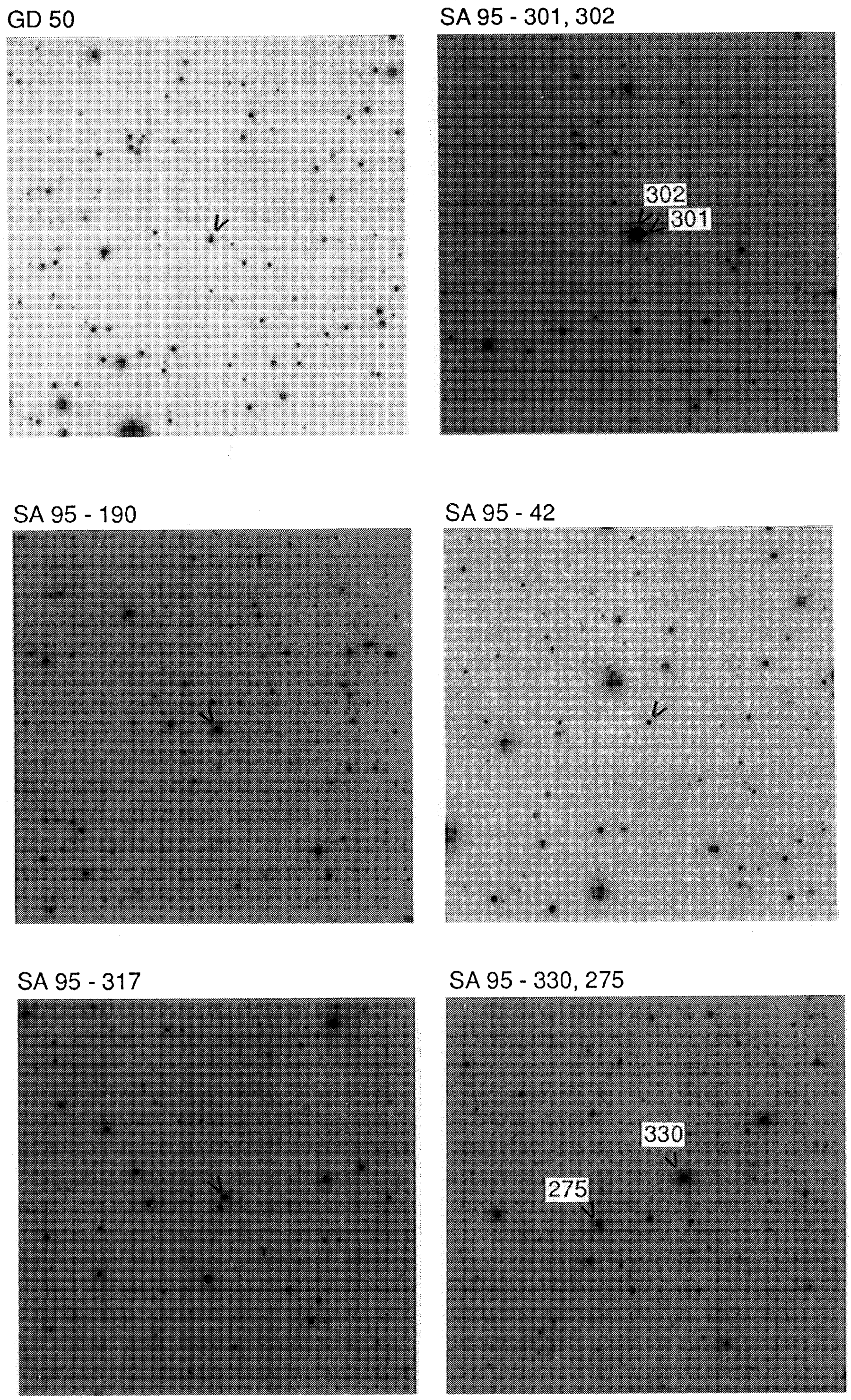

FIG. 1. (continued)

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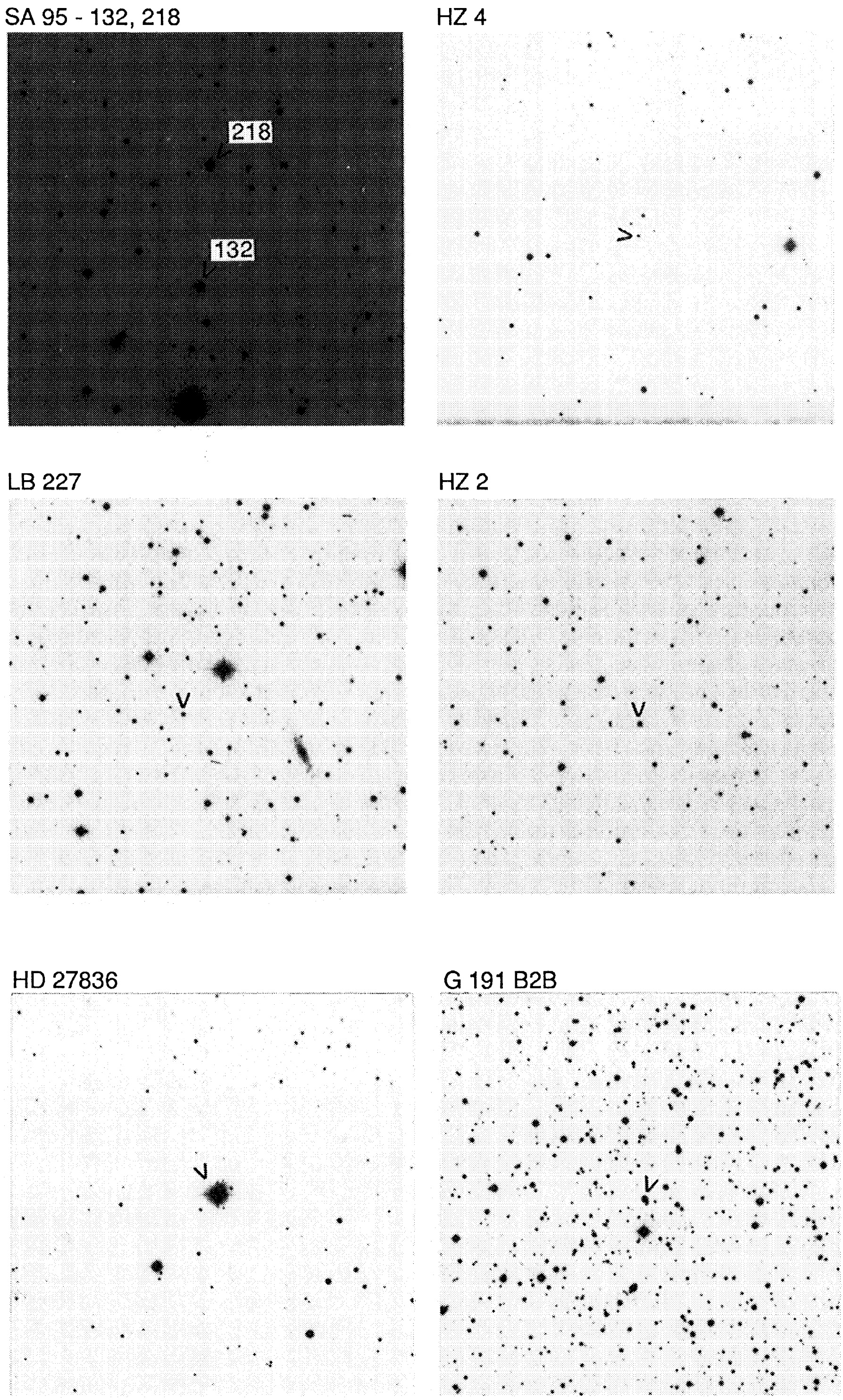

FIG. 1. (continued)

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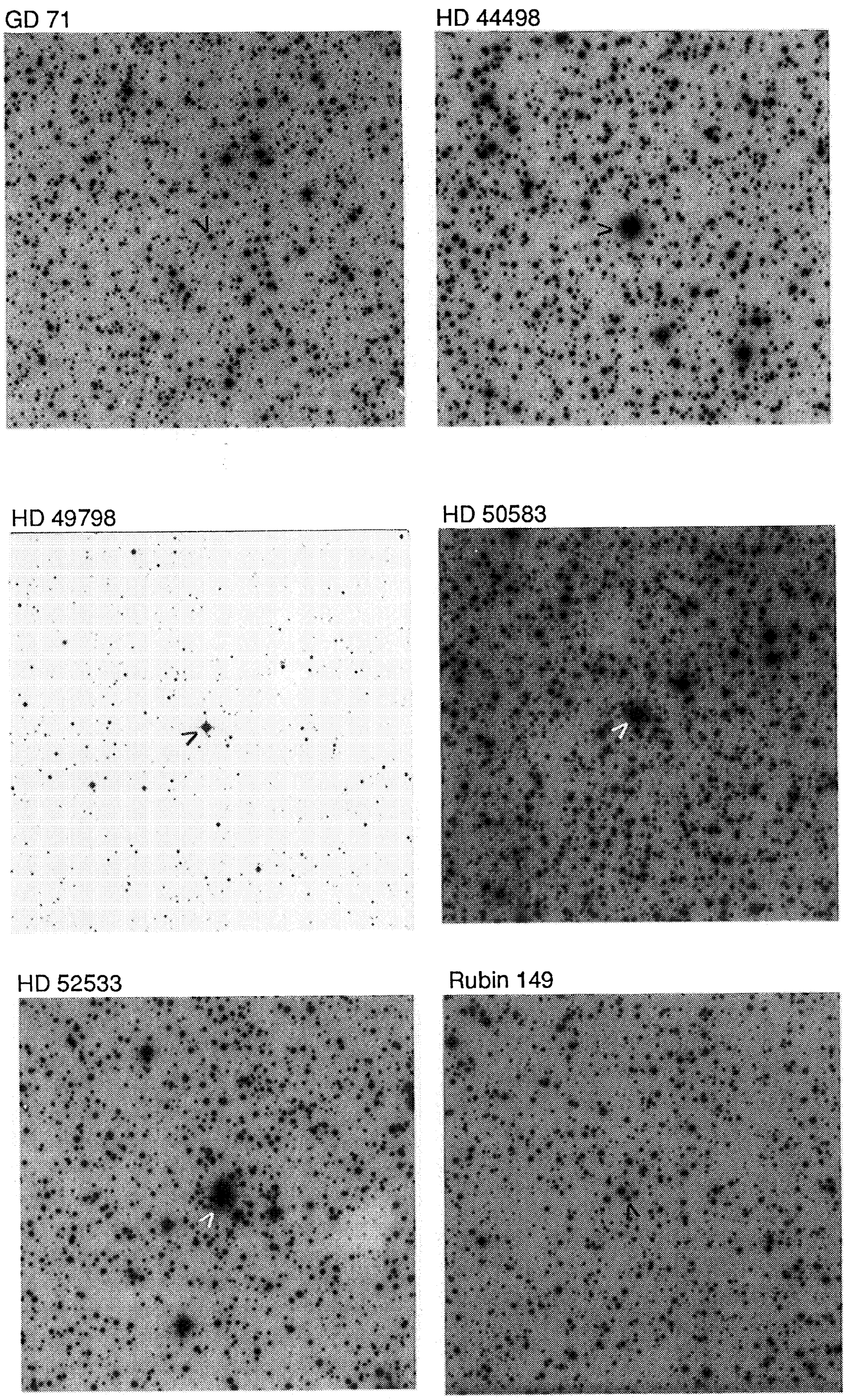

FIG. 1. (continued)

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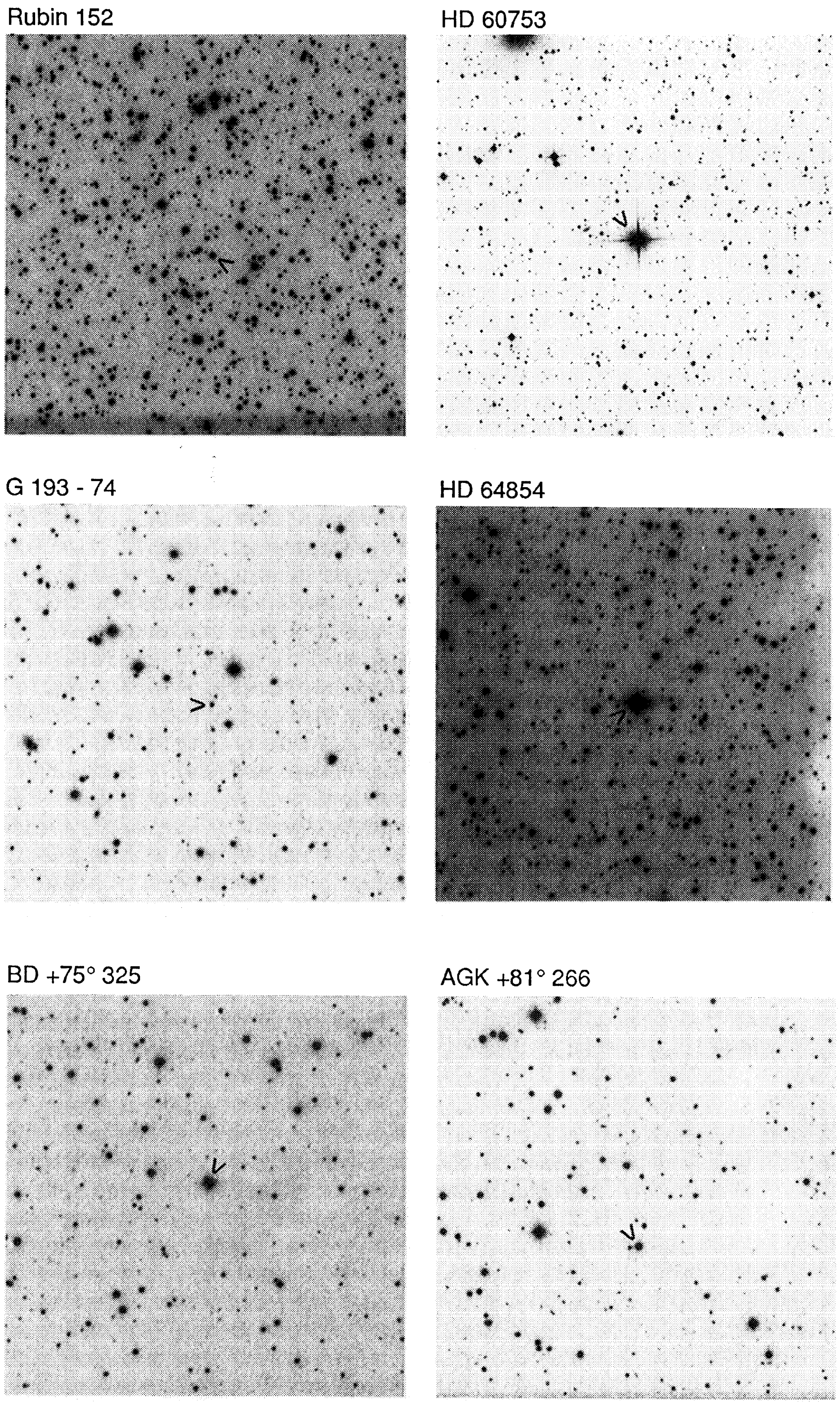

FIG. 1. (continued)

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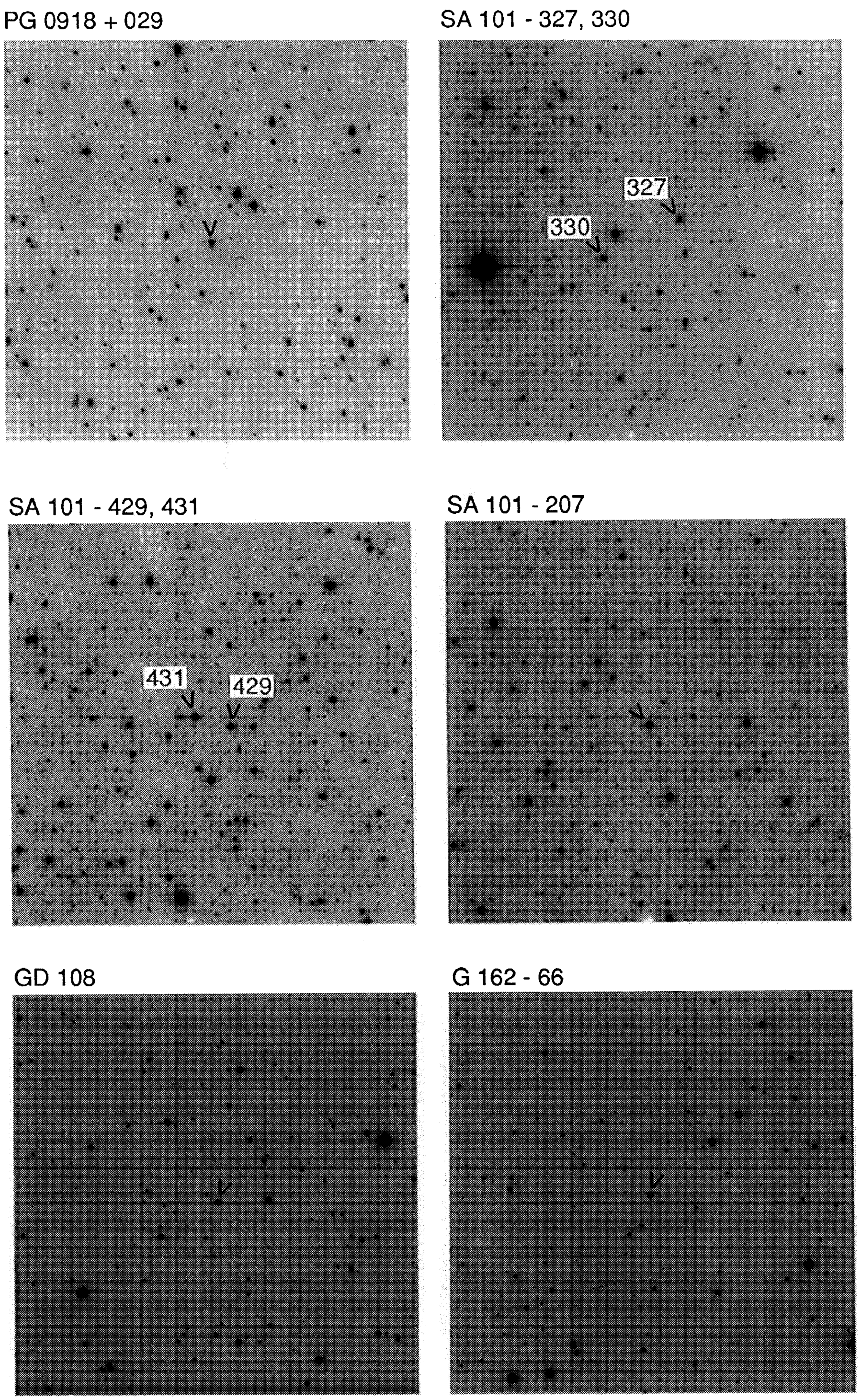

FIG. 1. (continued)

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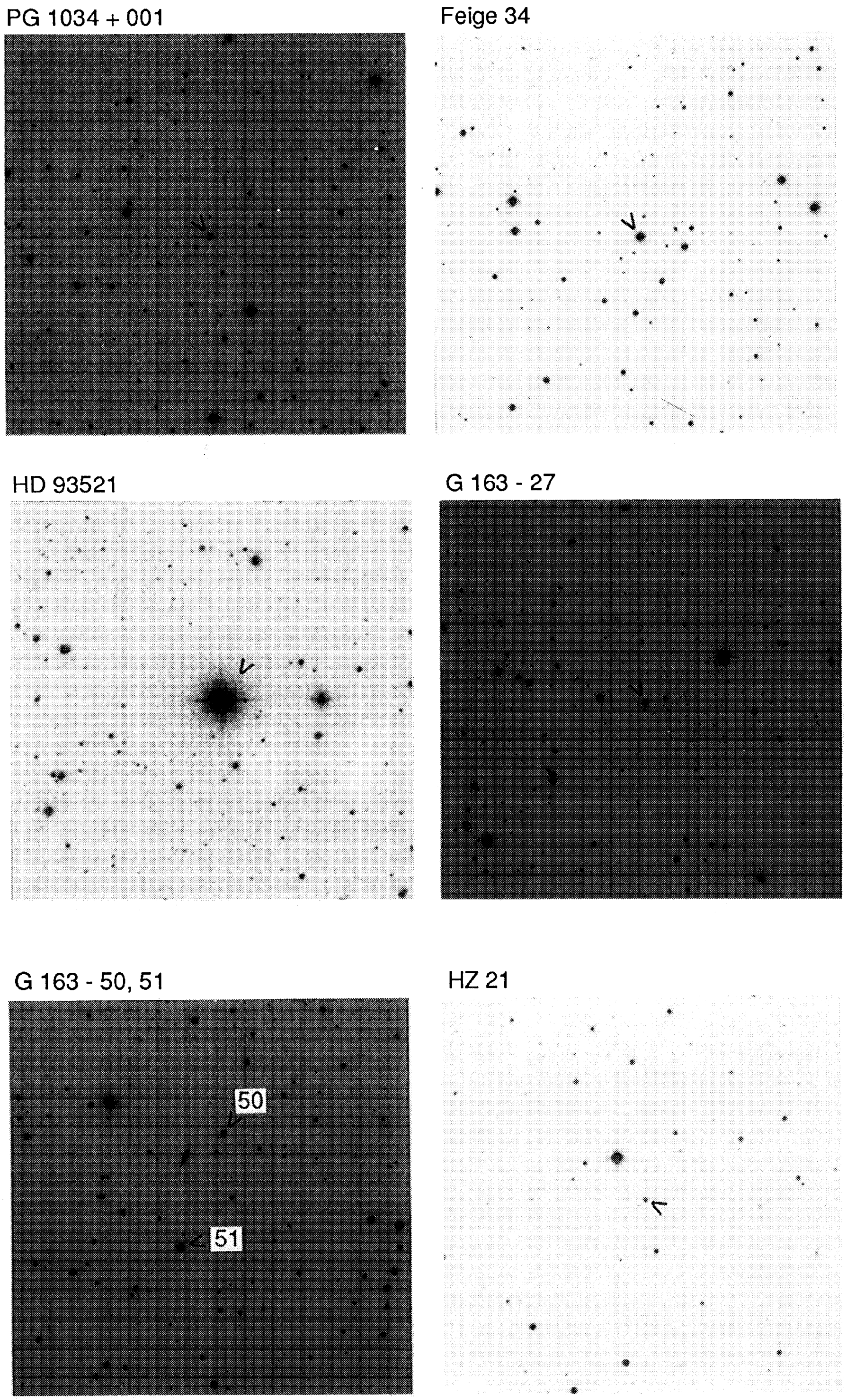

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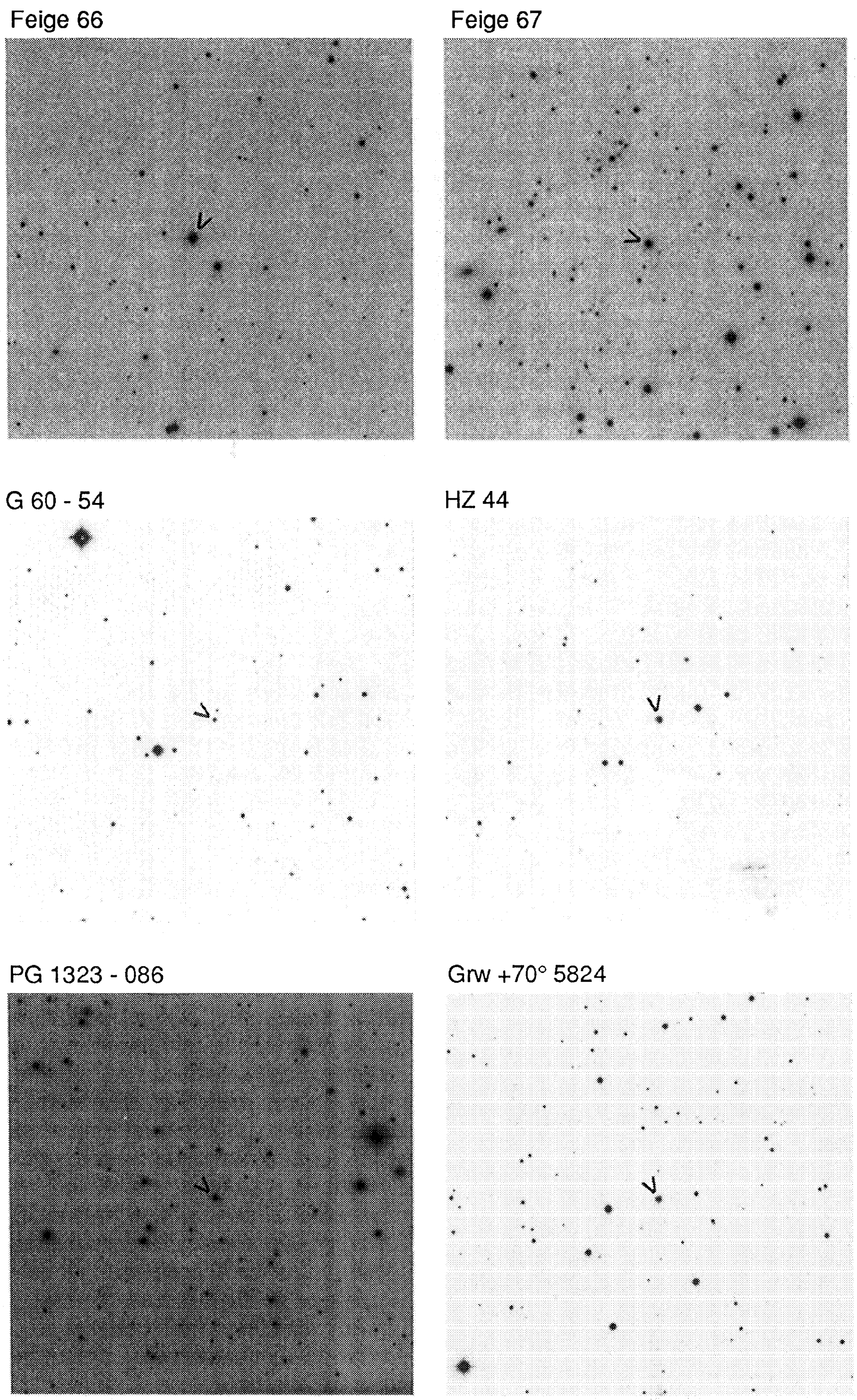

FIG. 1. (continued)

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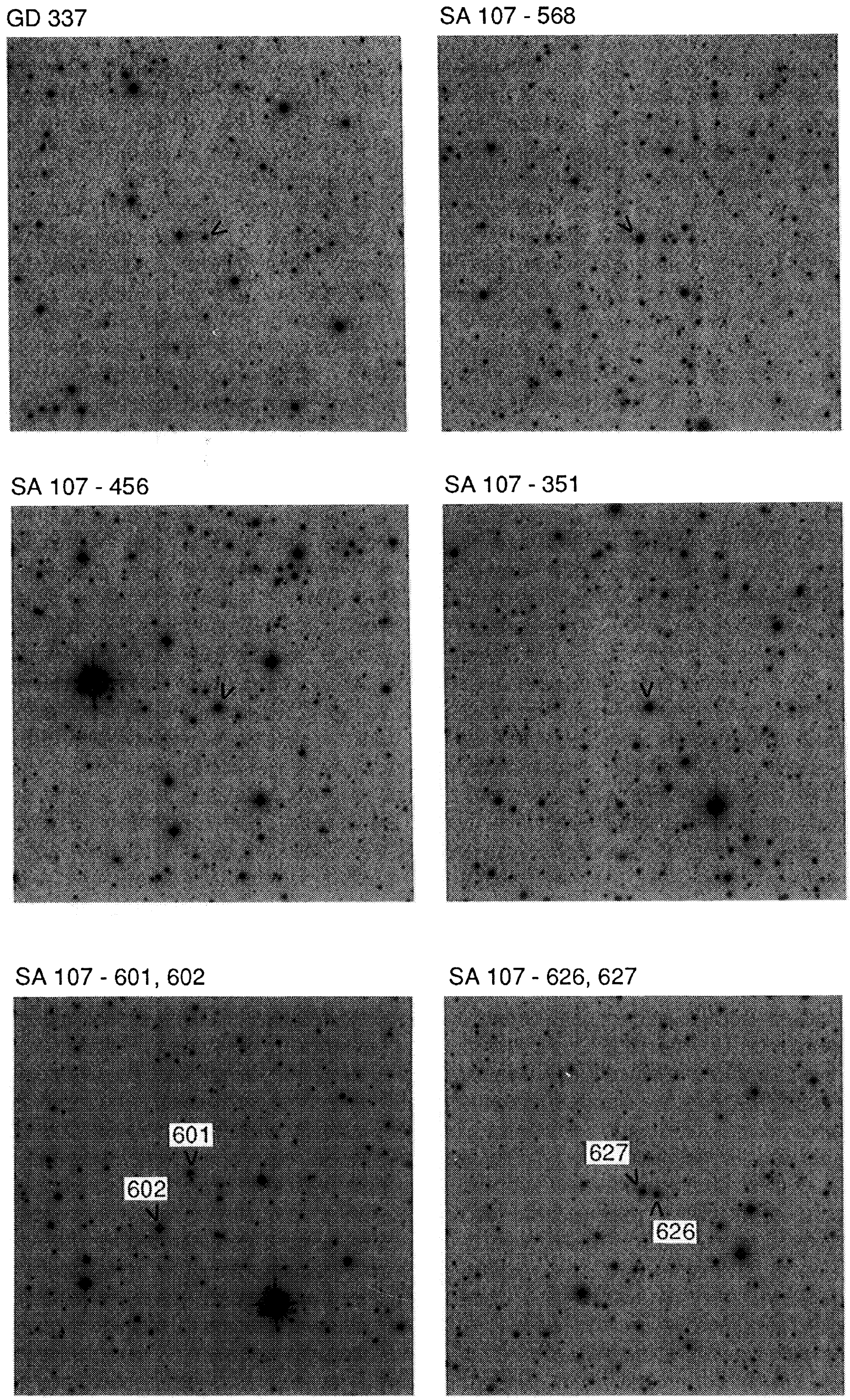

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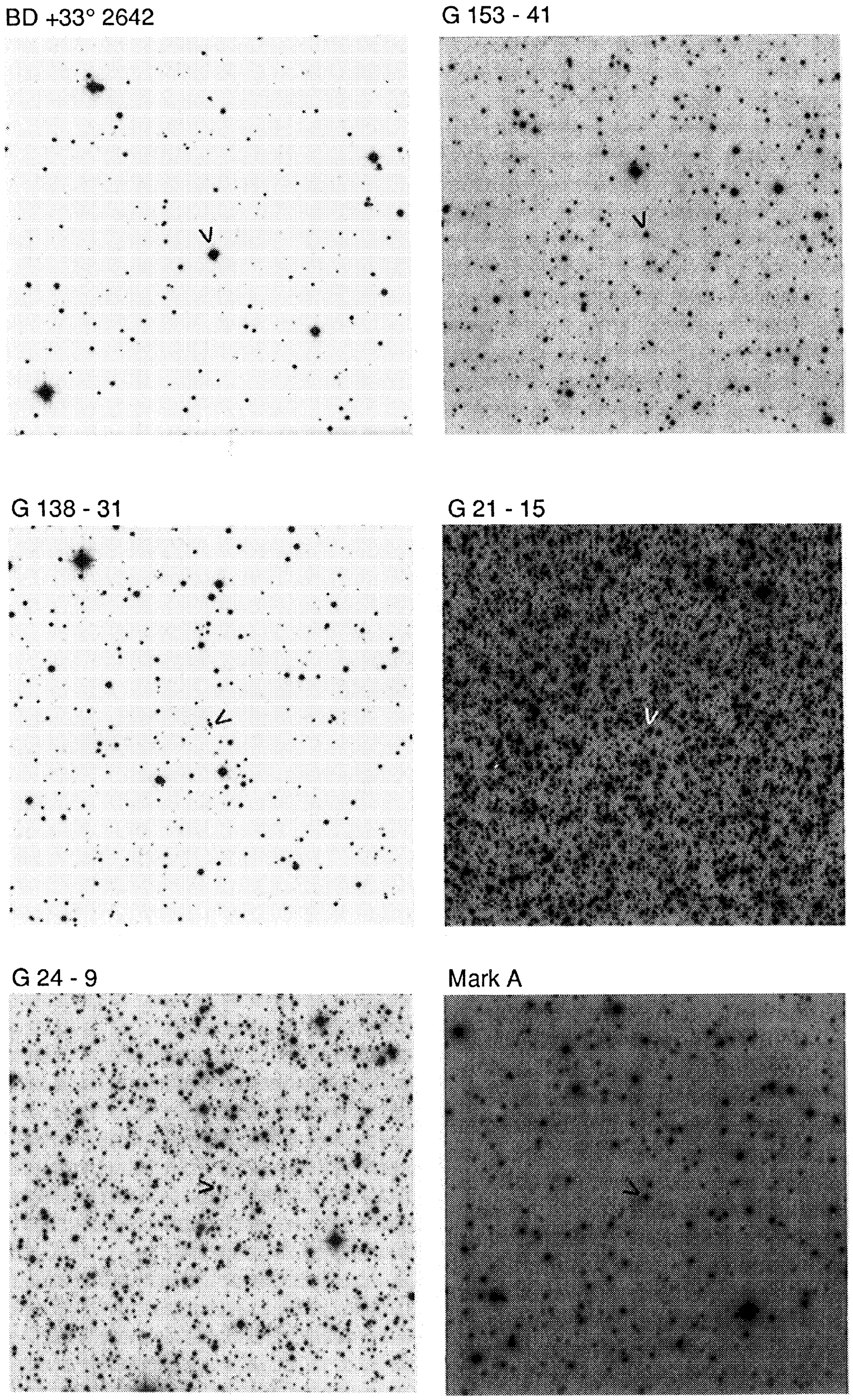

FIG. 1. (continued)

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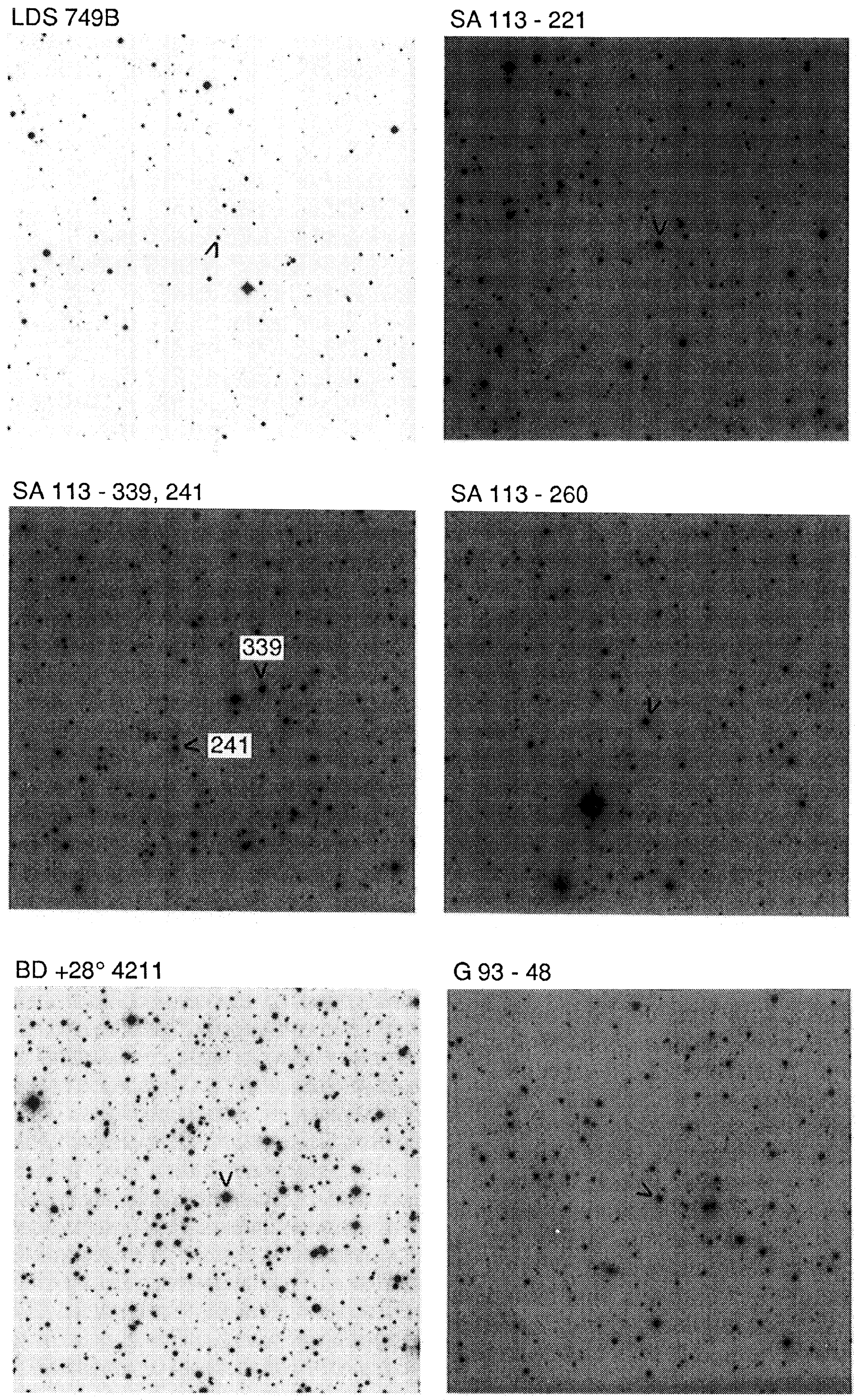

FIG. 1. (continued)

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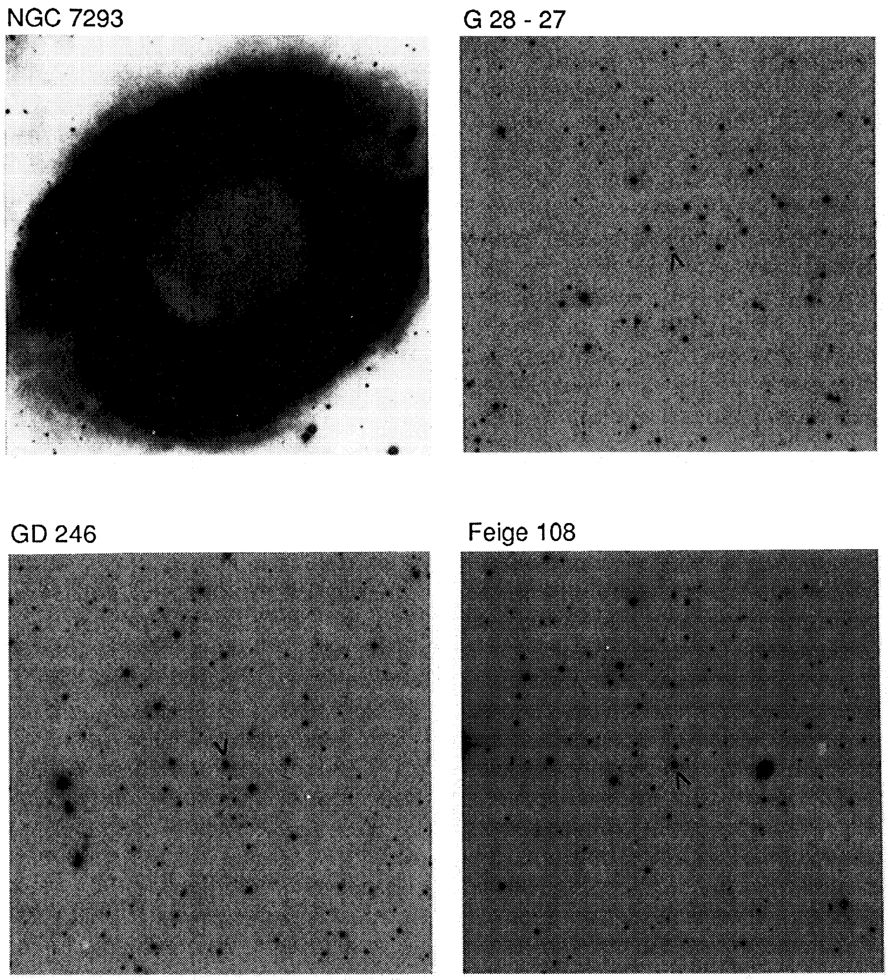

FIG. 1. (continued)

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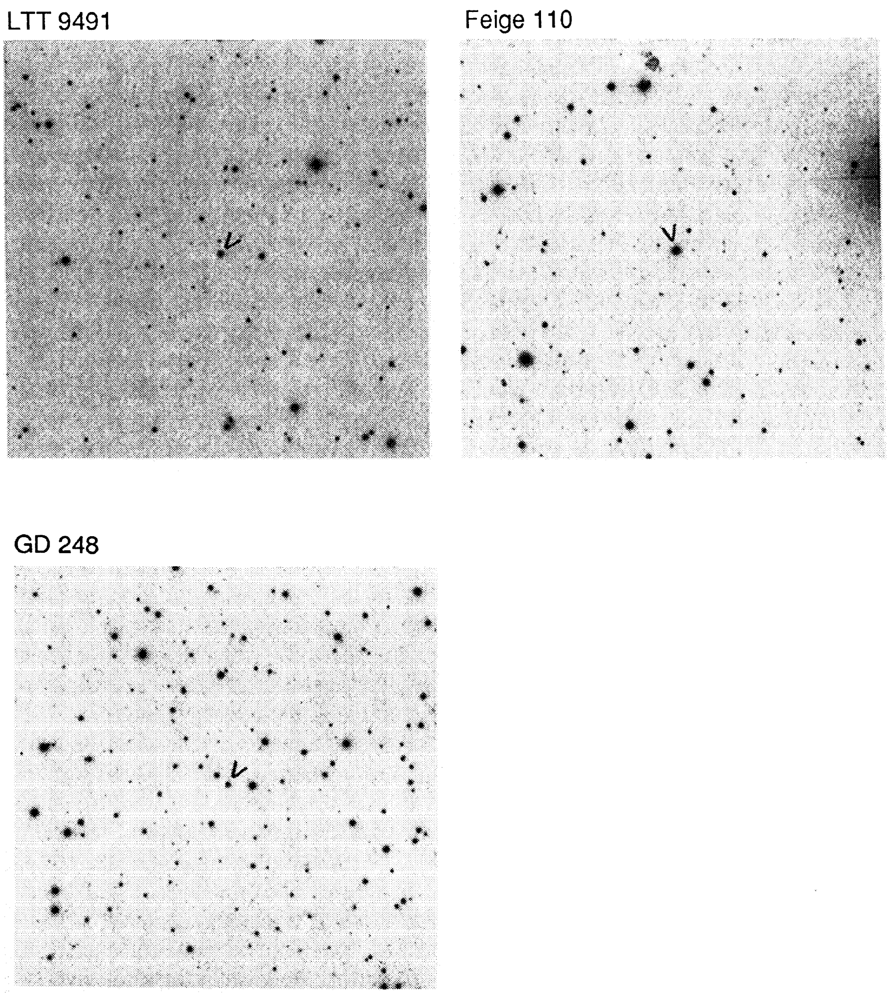

FIG. 1. (continued)

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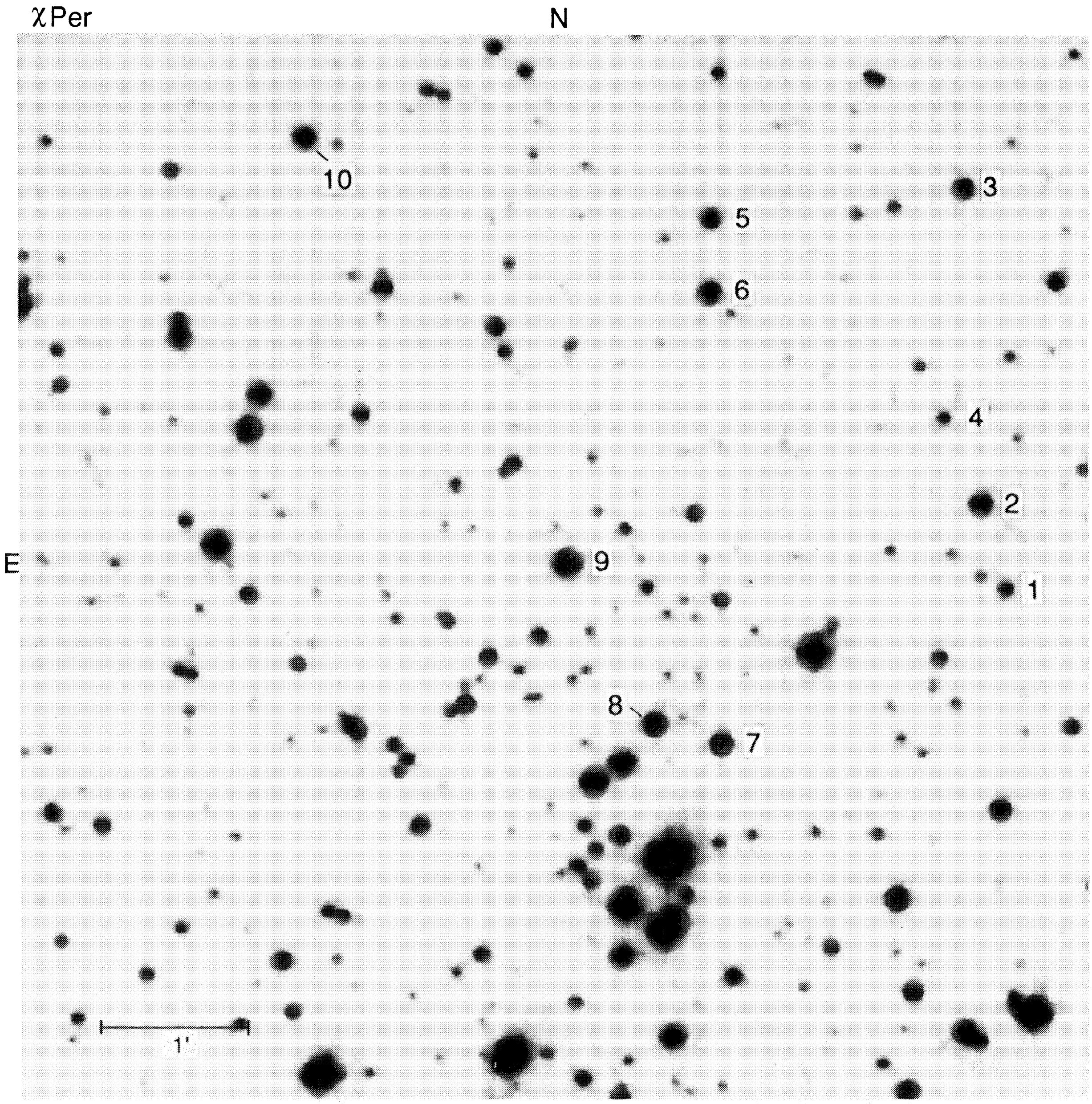

FIG. 2. Finding charts for *HST* calibration target fields that are in Table II. The first seven fields are the WFPC clusters and are about 8×8 arcmin. The numbered stars have coordinates that are in the Space Telescope Guide Star Catalog. The numbering corresponds to Table 7B of Turnshek *et al.* (1989). The remaining 11 fields contain the candidate FOC faint photometric sequences from Table IX. The scale of one arcminute per tick mark is indicated on SA 95 Field 1 and 47 Tuc F1. The arrow points to a blue star in each field, while the yellow stars are identified by a bar. The 9 finding charts for SA 95, SA 101, SA 107, or SA 113 are made from the UKST EJ (blue) Equatorial Sky Survey, while the finding charts for 47 Tuc F1 and SA 57 are from 4 m CCD images.

Turnshek *et al.* (see page 1243)

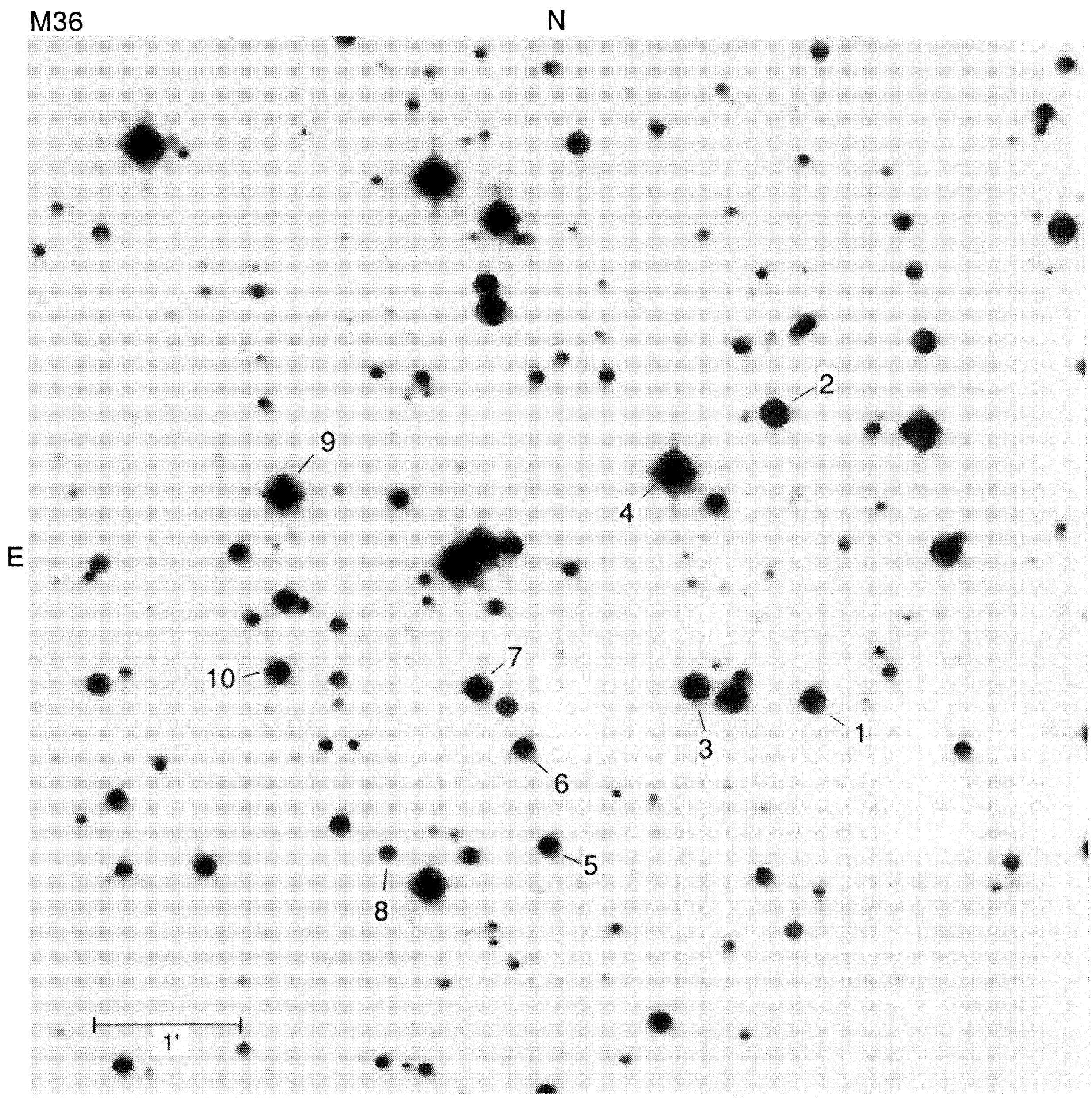

FIG. 2. (continued)

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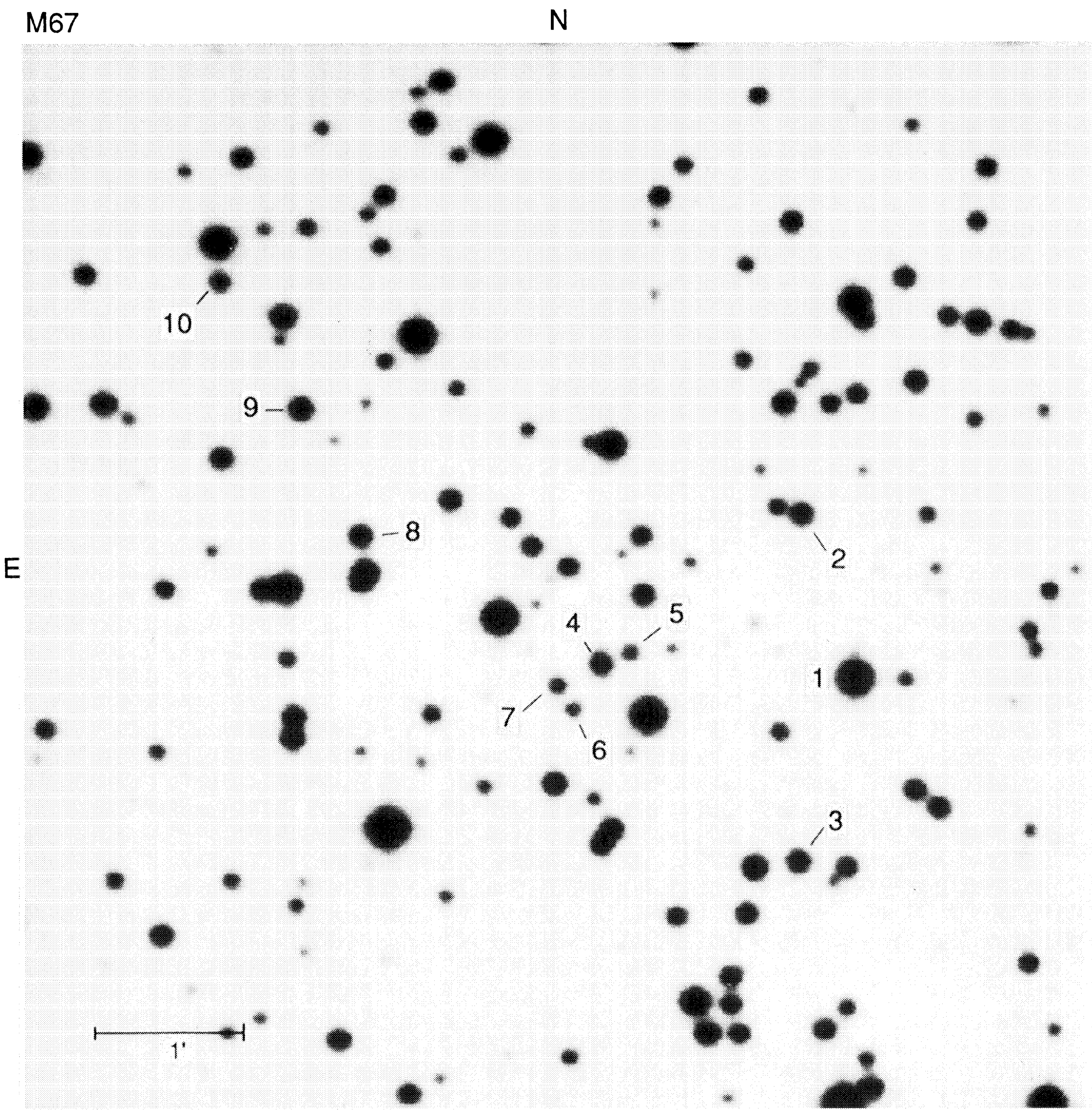

FIG. 2. (continued)

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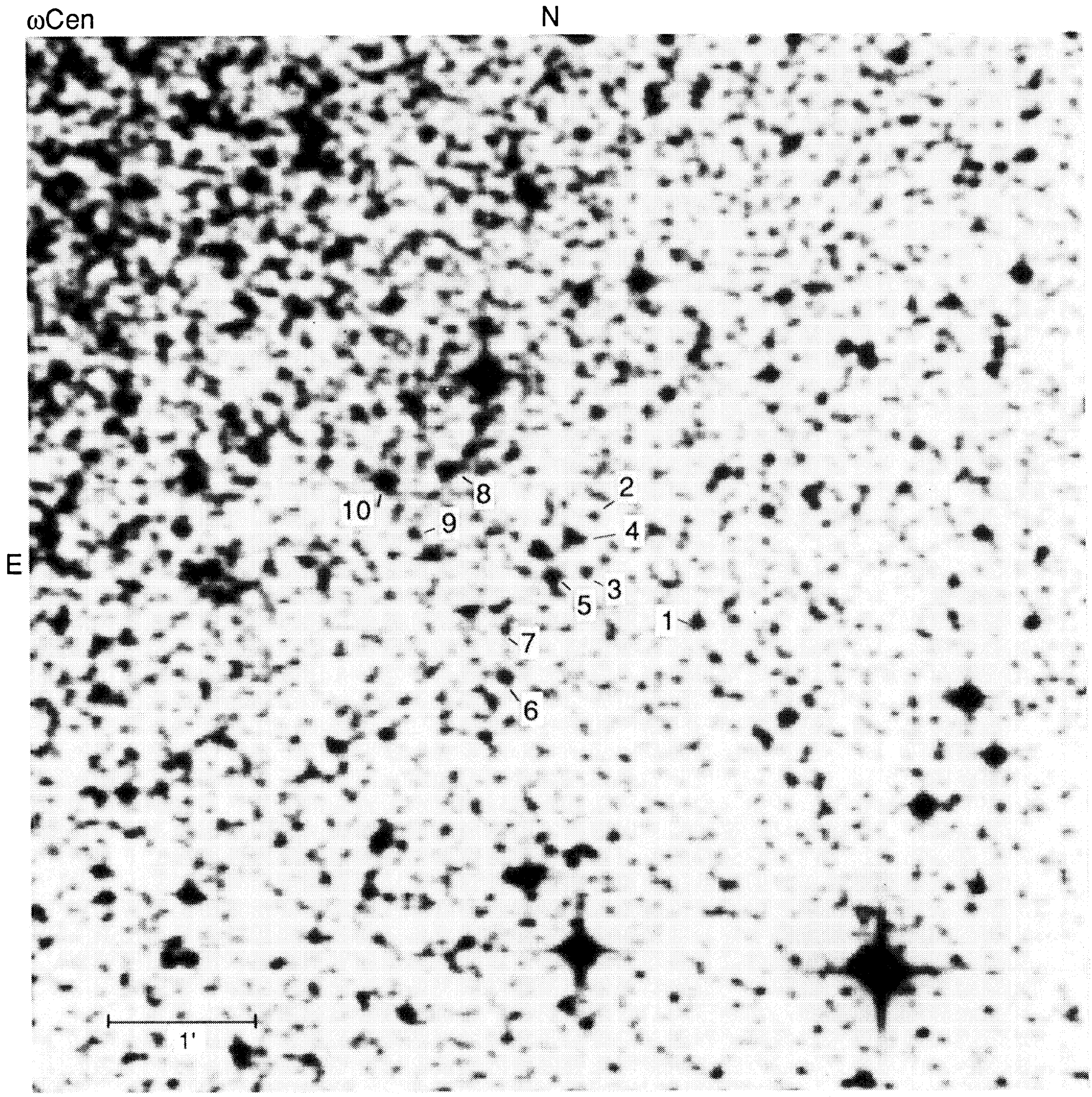

FIG. 2. (continued)

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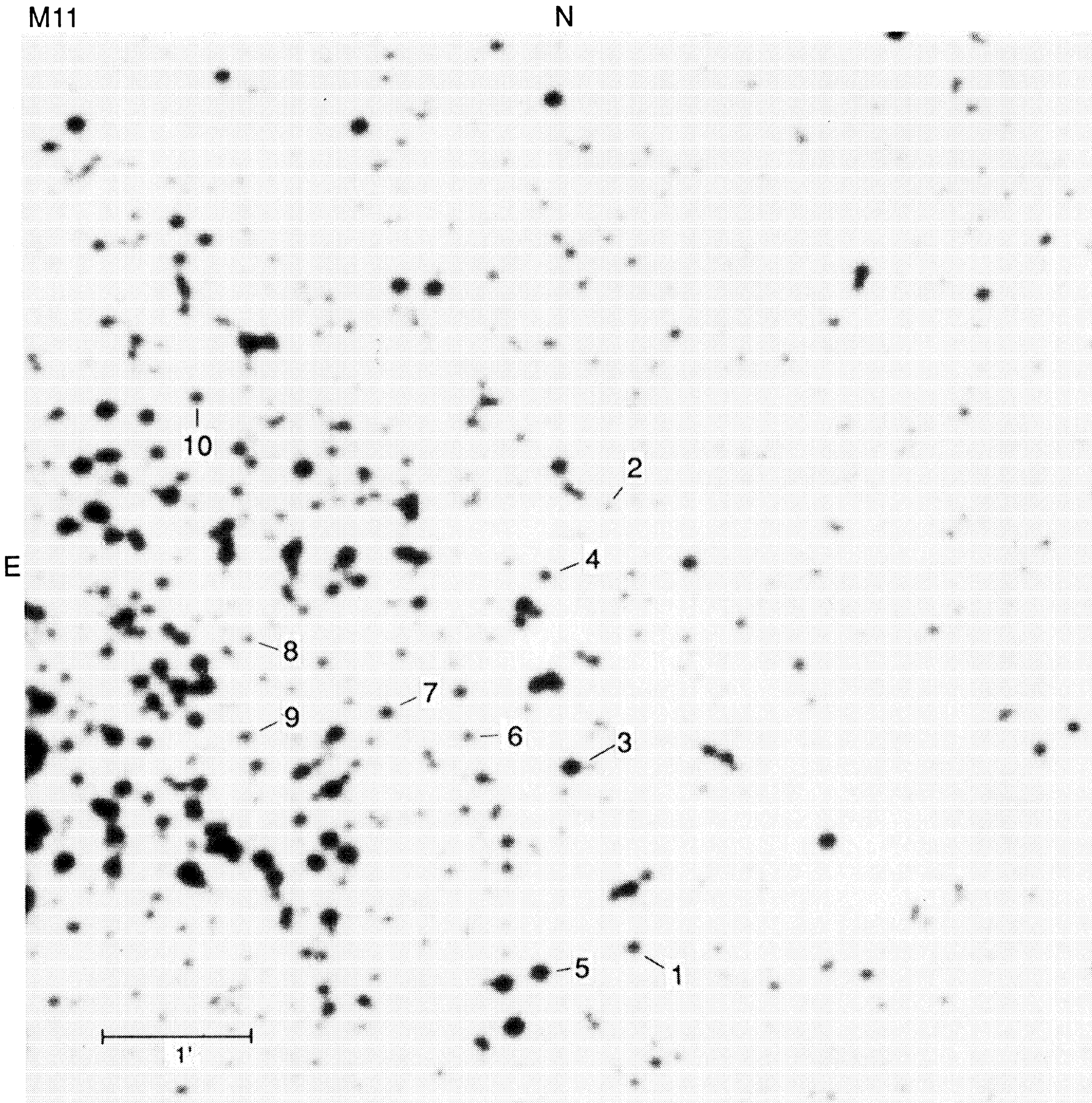

FIG. 2. (continued)

Turnshek *et al.* (see page 1243)

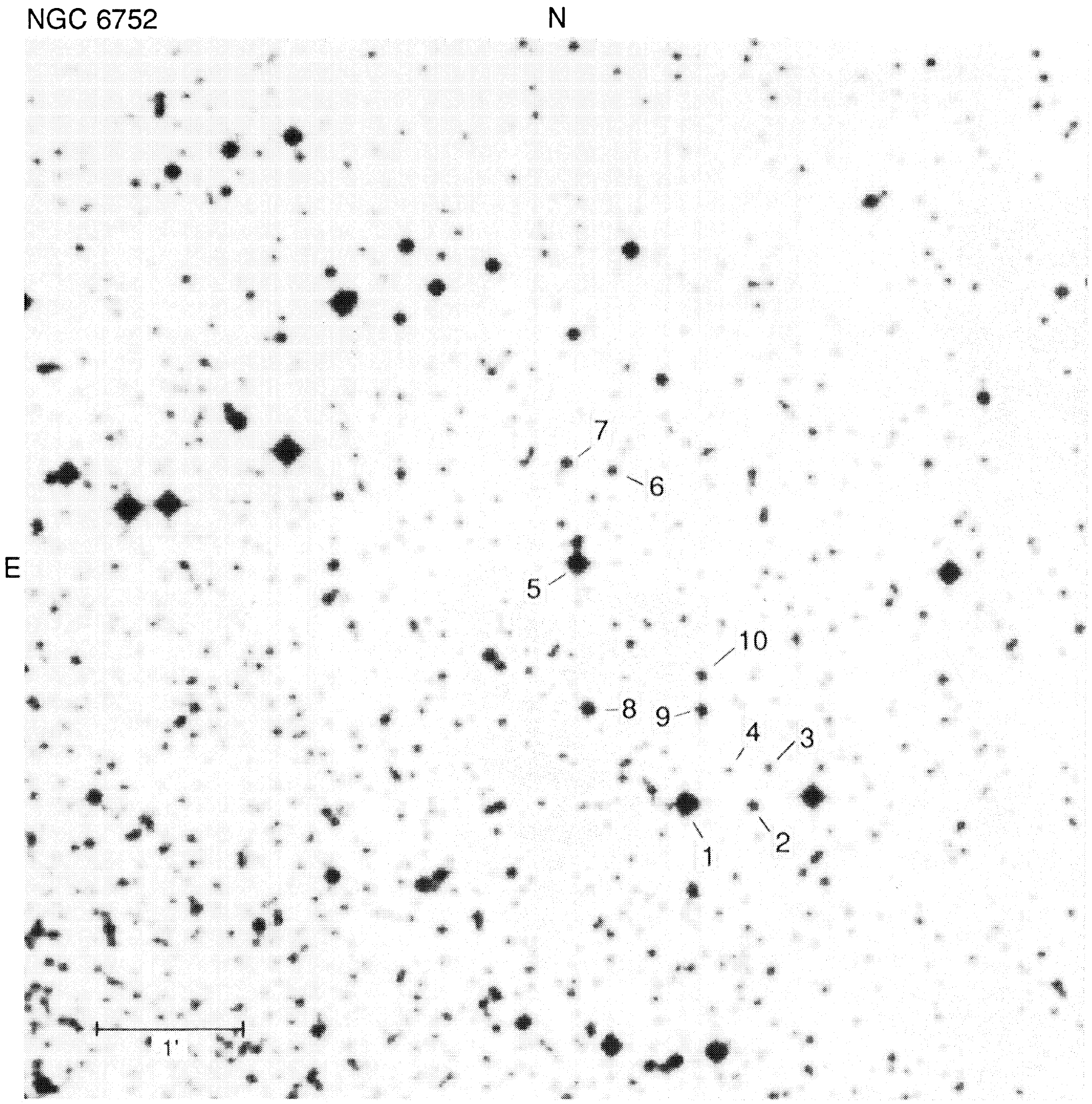

FIG. 2. (continued)

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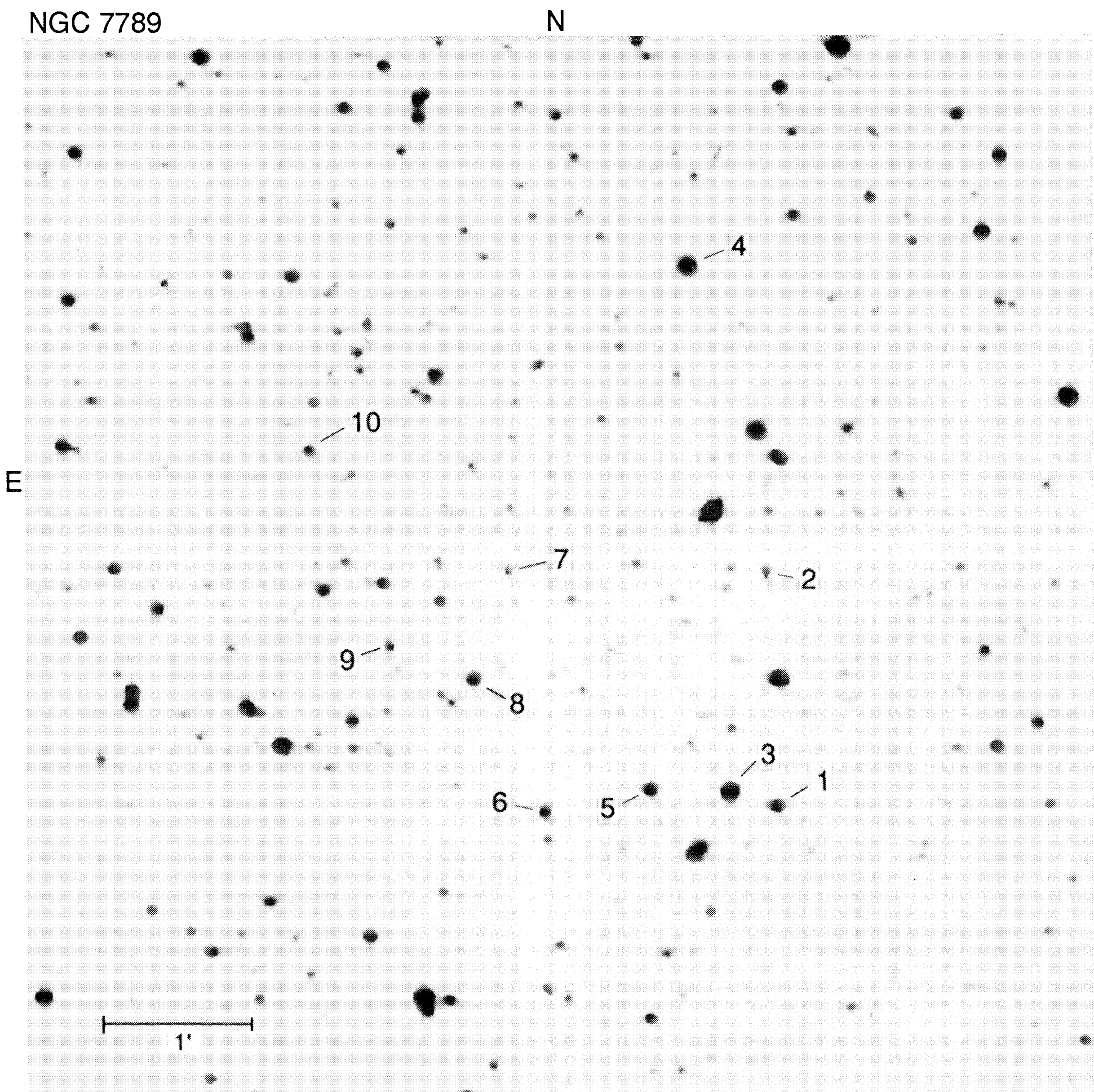

FIG. 2. (continued)

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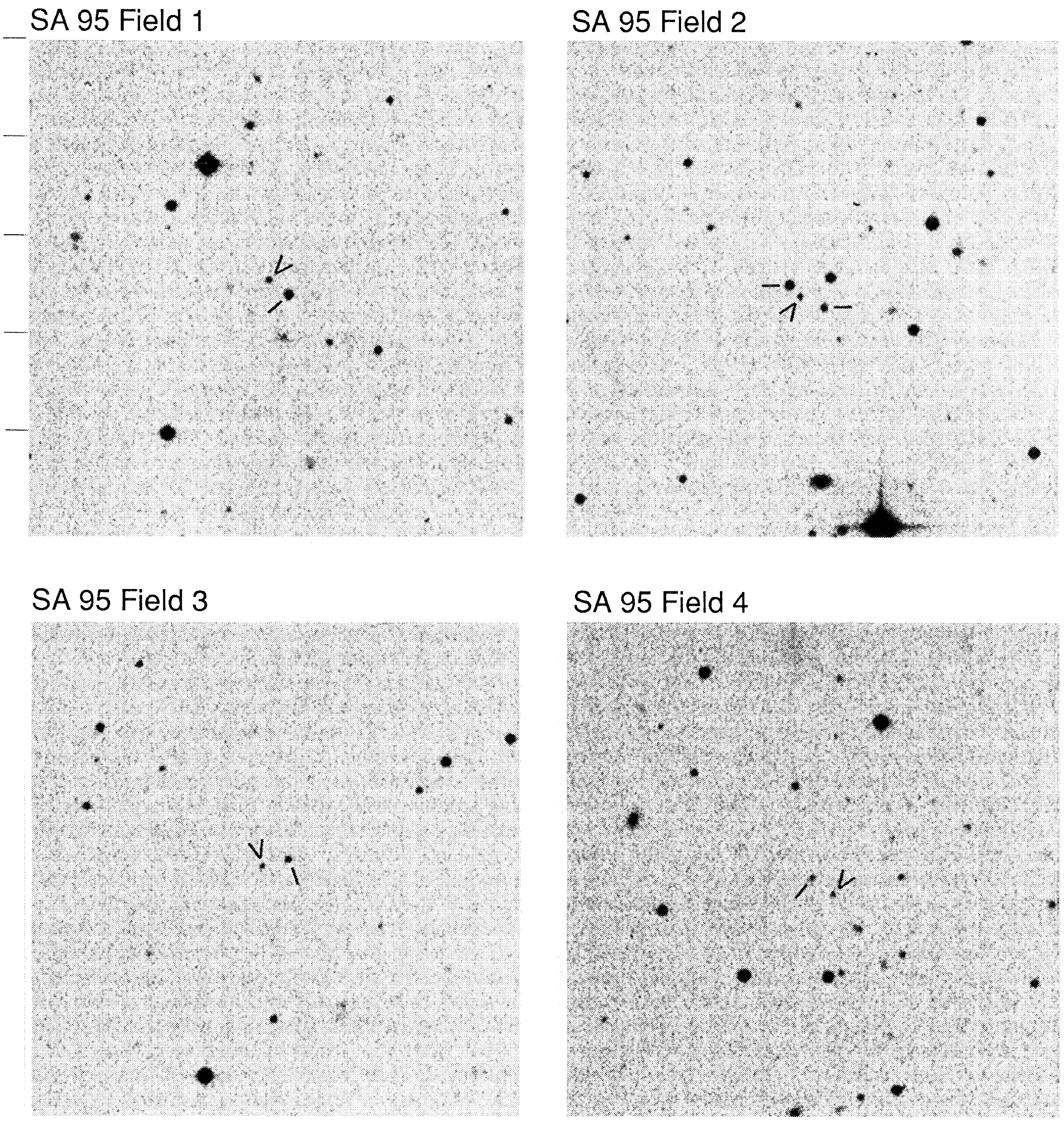

FIG. 2. (continued)

Turnshek *et al.* (see page 1243)

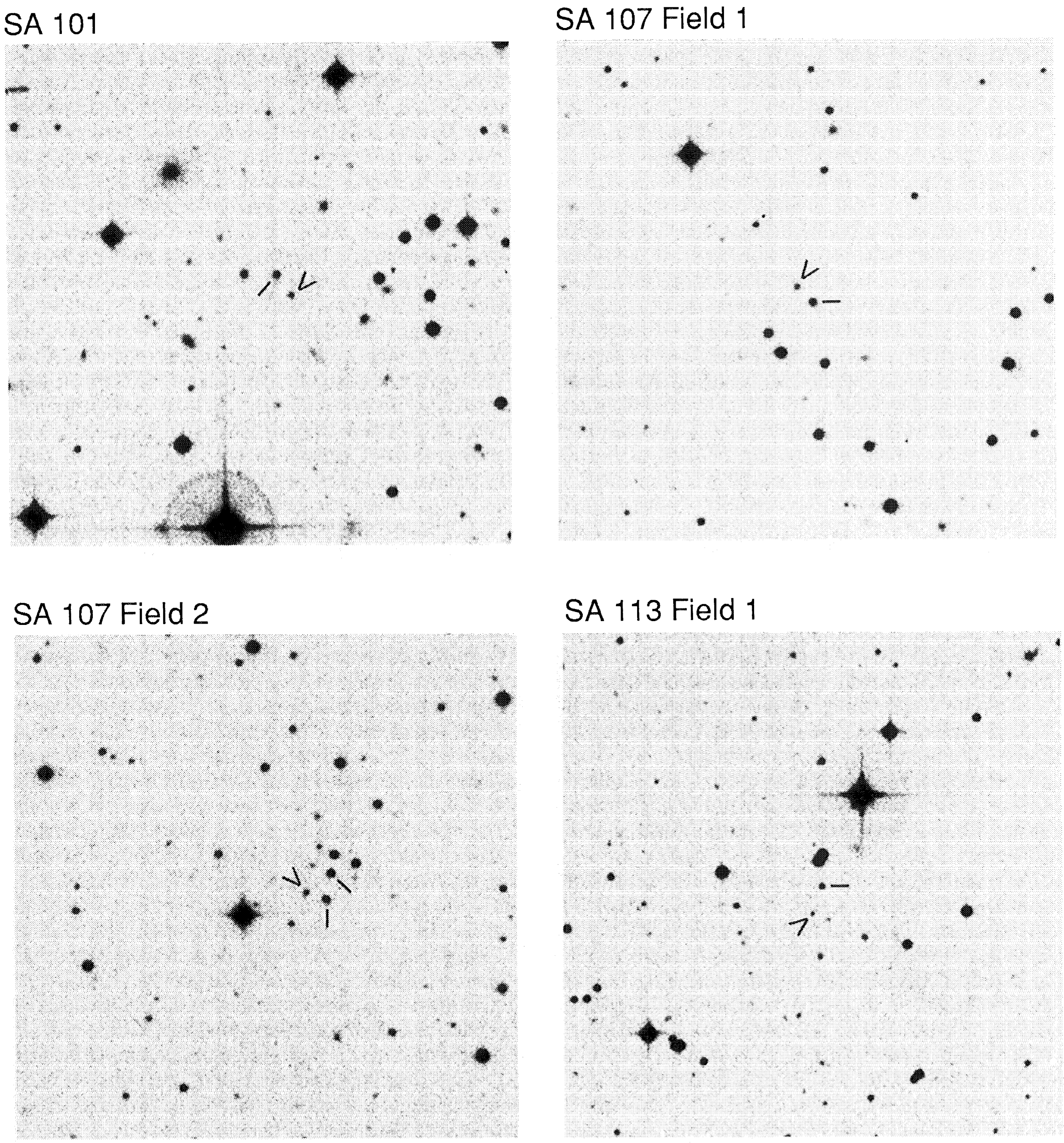

FIG. 2. (continued)

Turnshek *et al.* (see page 1243)

SA 113 Field 3

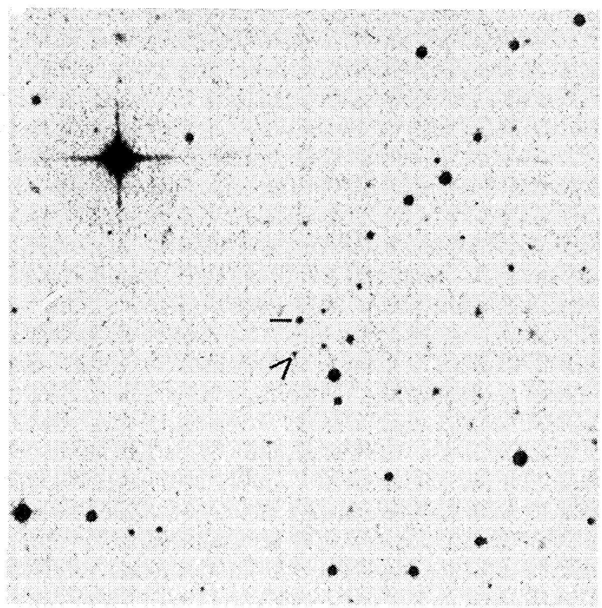

FIG. 2. (continued)

Turnshek *et al.* (see page 1243)

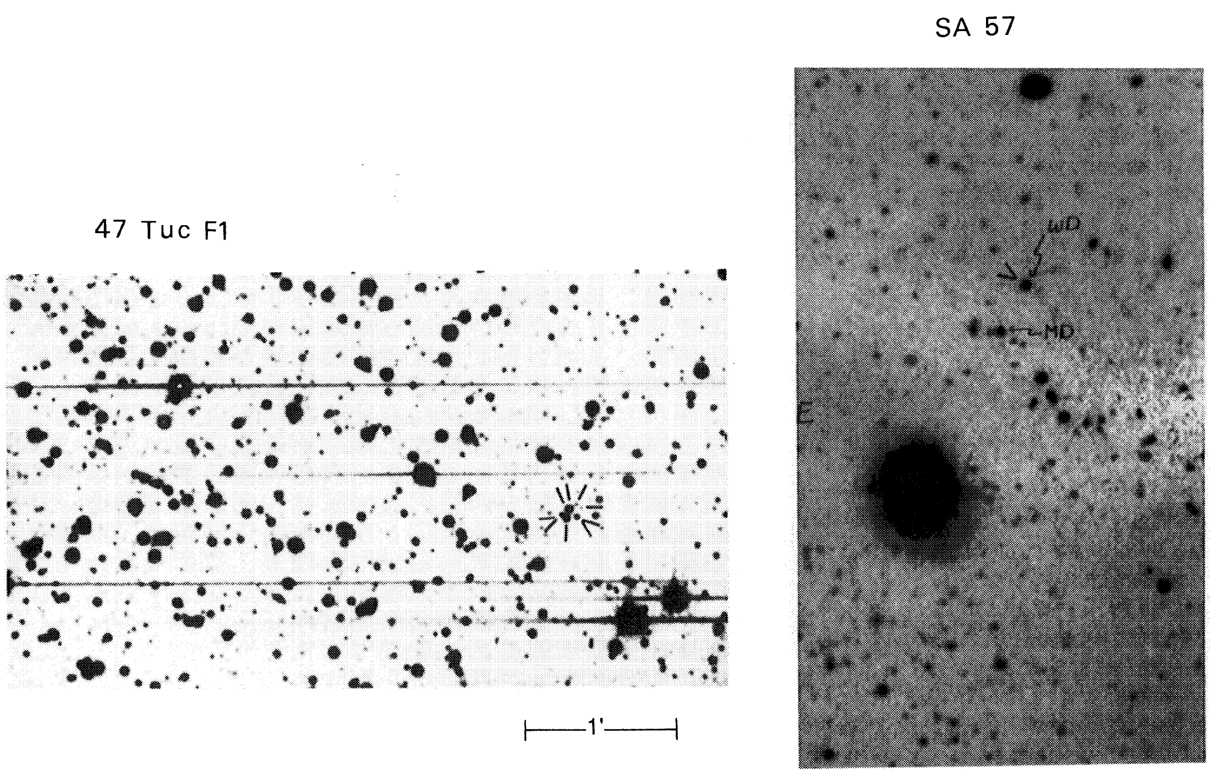

FIG. 2. (continued)

Turnshek *et al.* (see page 1243)

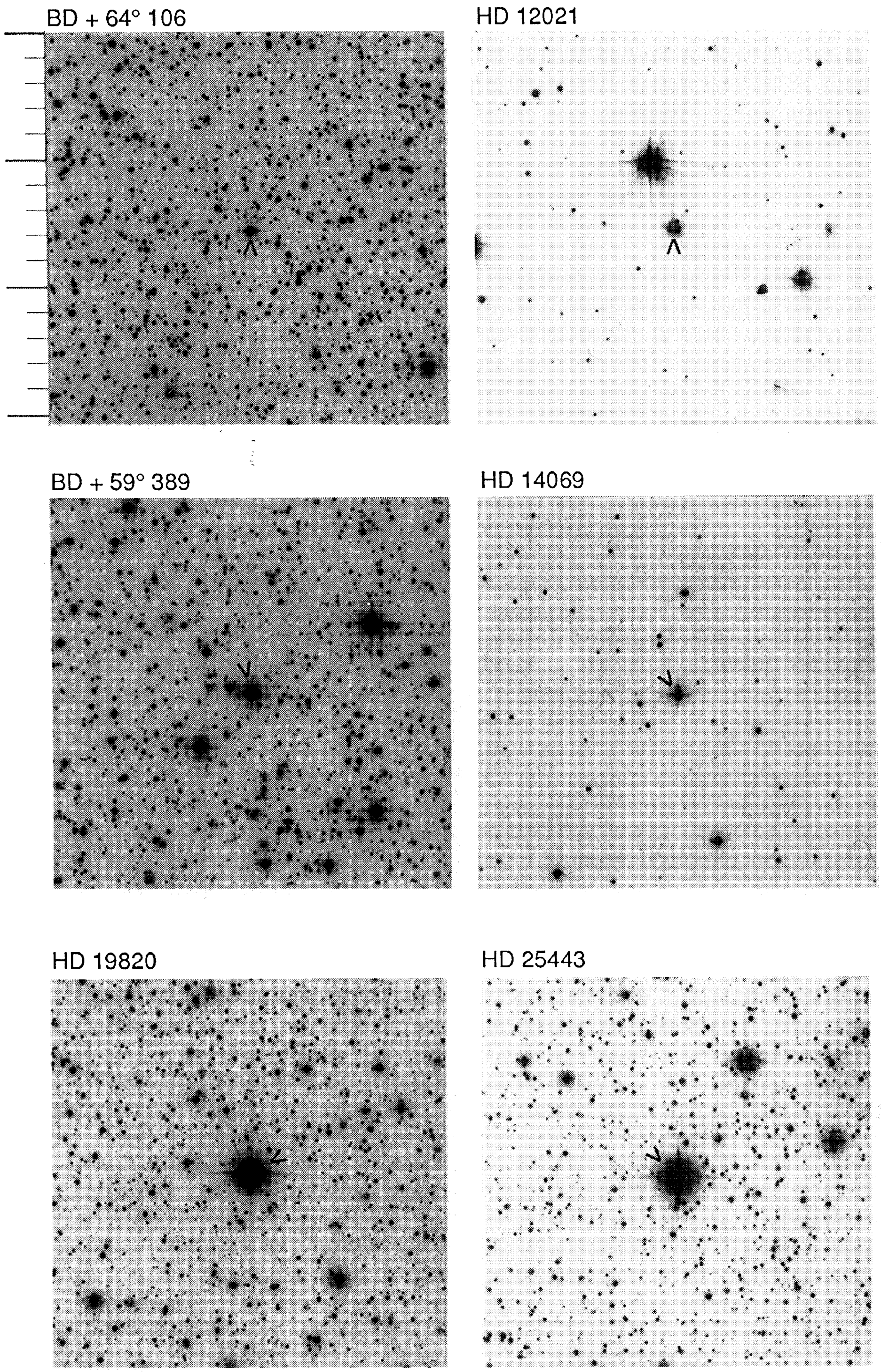

FIG. 3. Finding charts for single *HST* polarimetric calibration stars from Tables III and IV (see Fig. 1 caption).

Turnshek *et al.* (see page 1243)

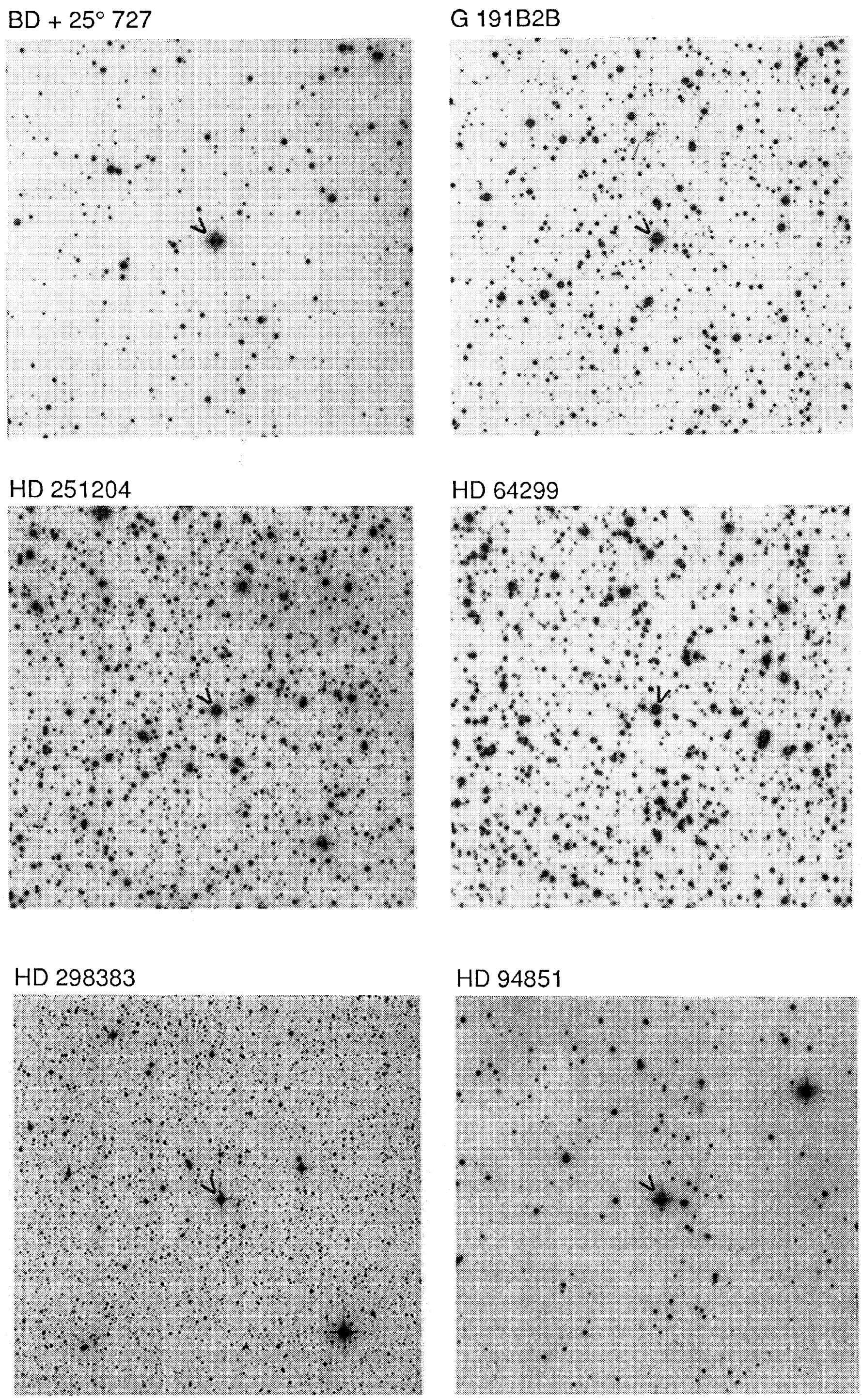

FIG. 3. (continued)

Turnshek *et al.* (see page 1243)

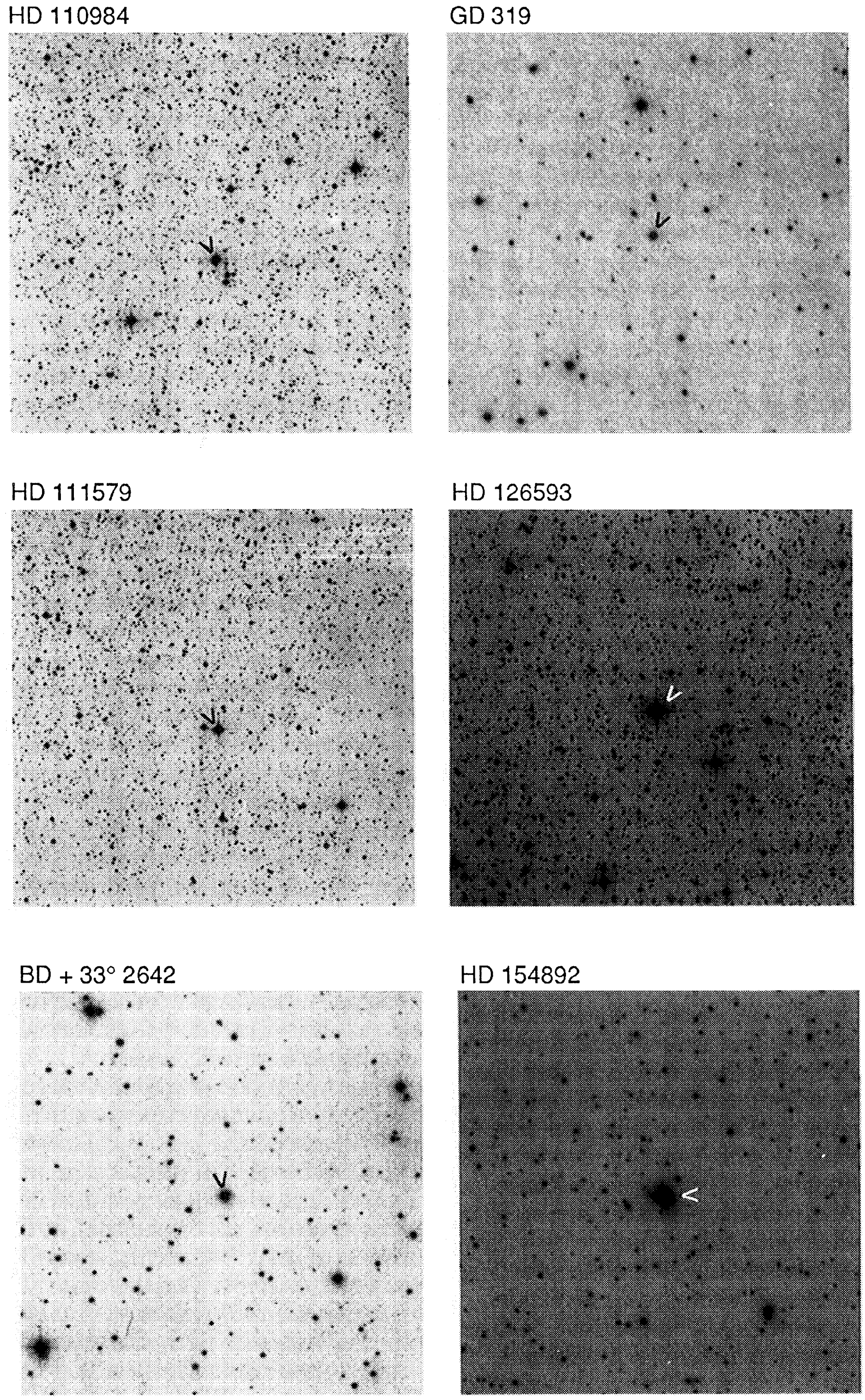

FIG. 3. (continued)

Turnshek *et al.* (see page 1243)

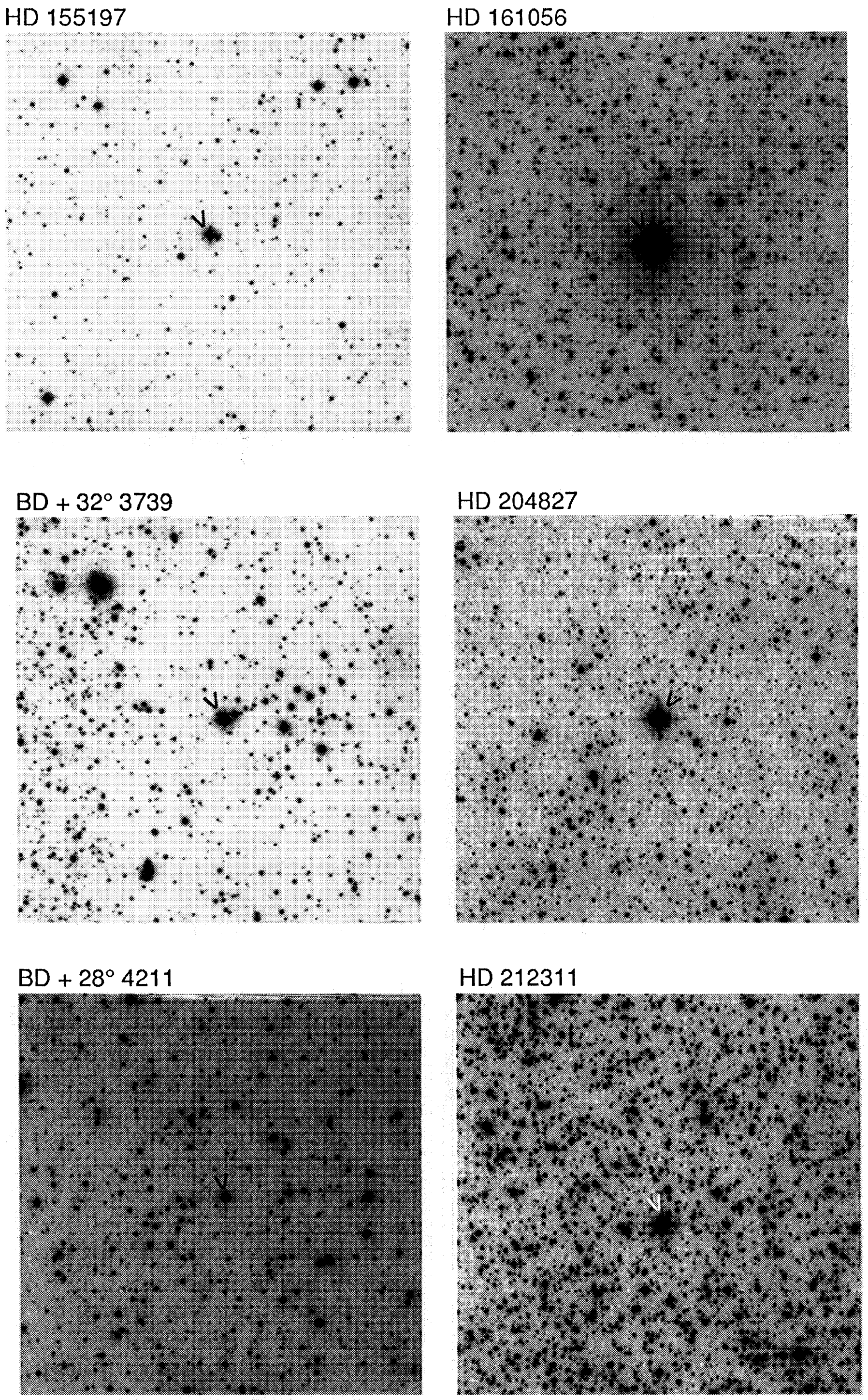

FIG. 3. (continued)

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R Mon

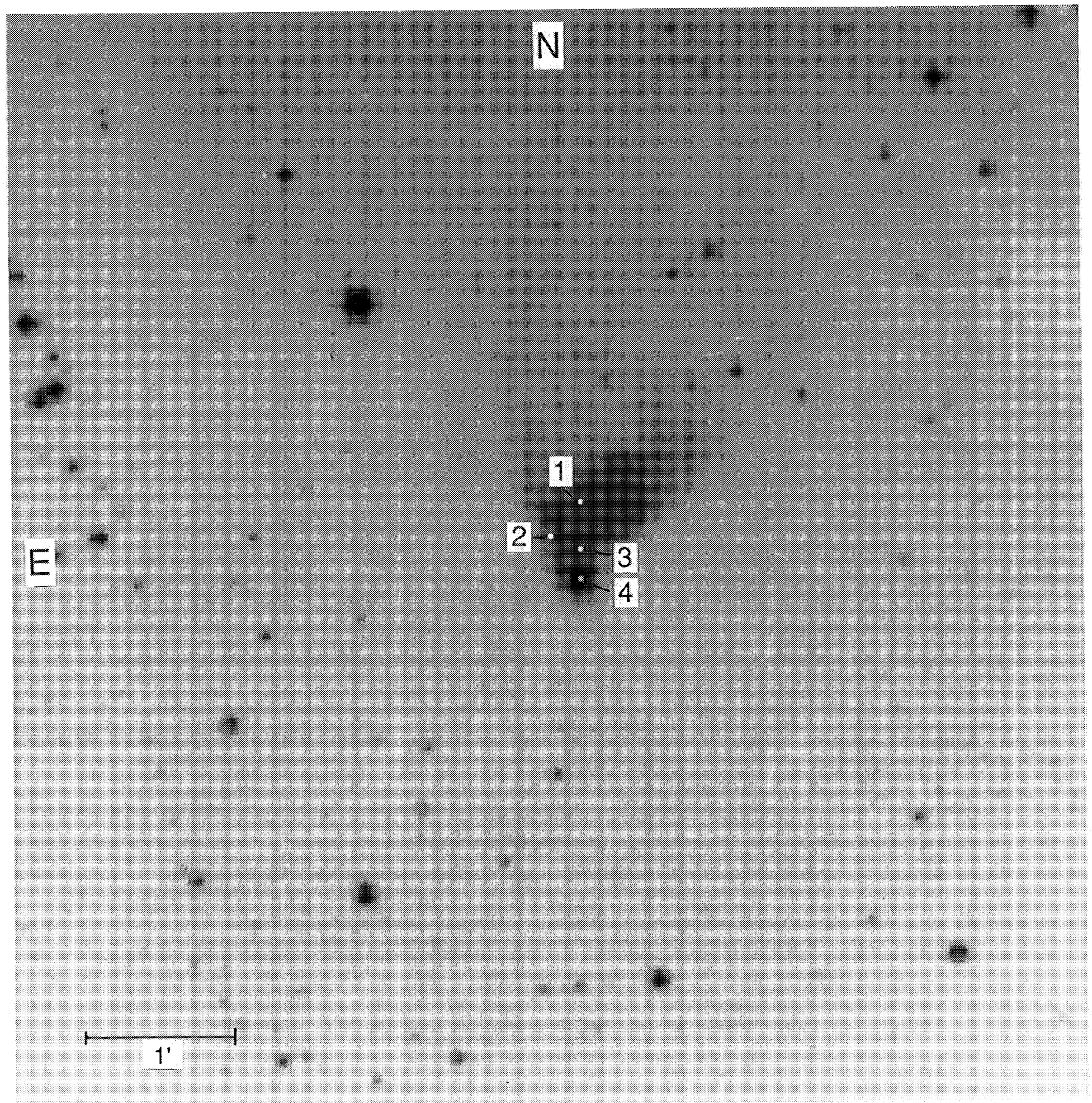

FIG. 4. Finding charts for *HST* polarimetric calibration target fields from Table V. In the reflection nebulae, the observed positions are flagged with a white pixel and numbered according to Table V. In the CRL 2688 field, the "a" is the nearest star in the STScI Guide Star system. All target coordinates are defined on this GS system. For NGC 6823, the stellar targets are numbered.

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ESO - 172

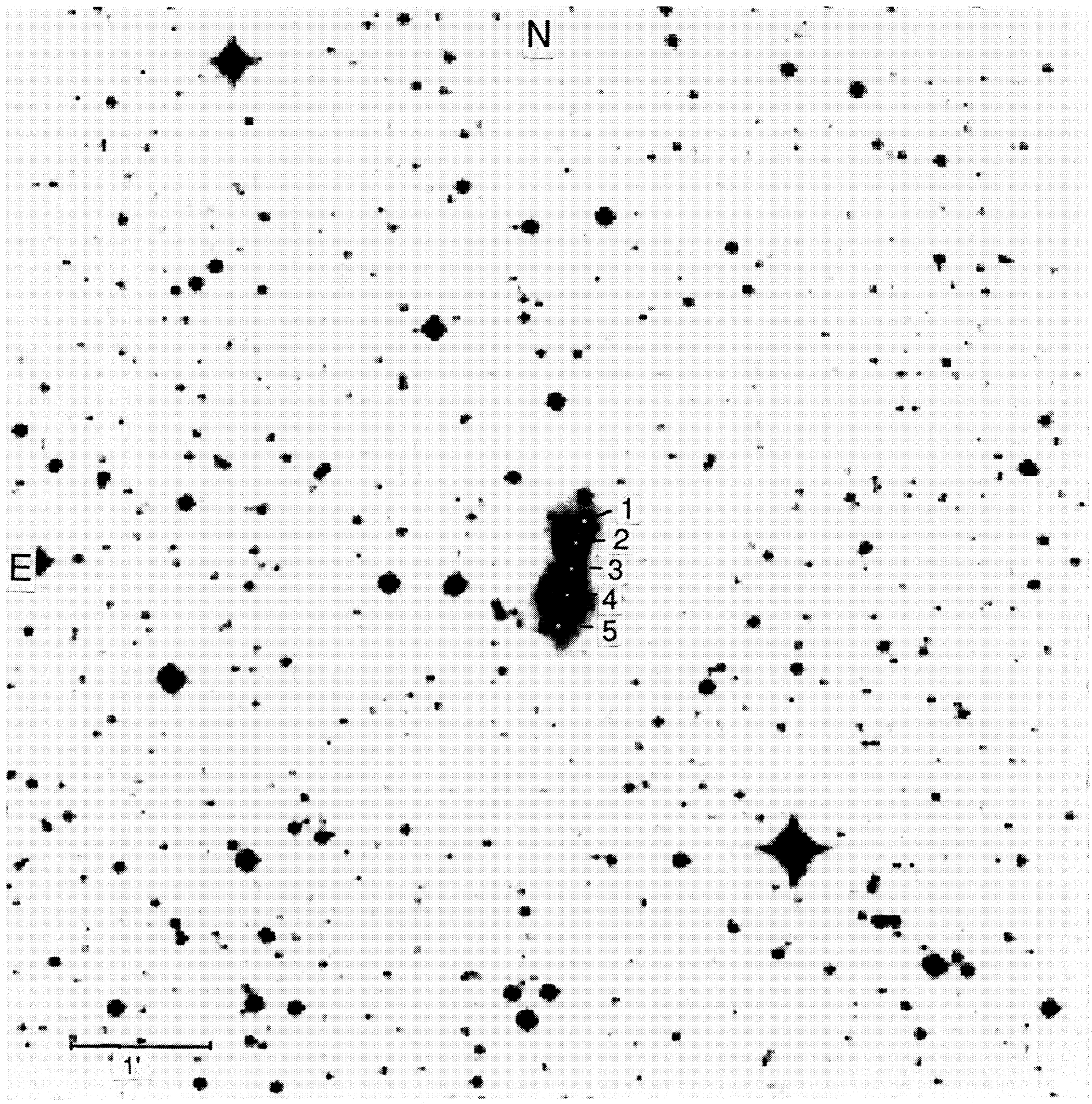

FIG. 4. (continued)

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CRL - 2688

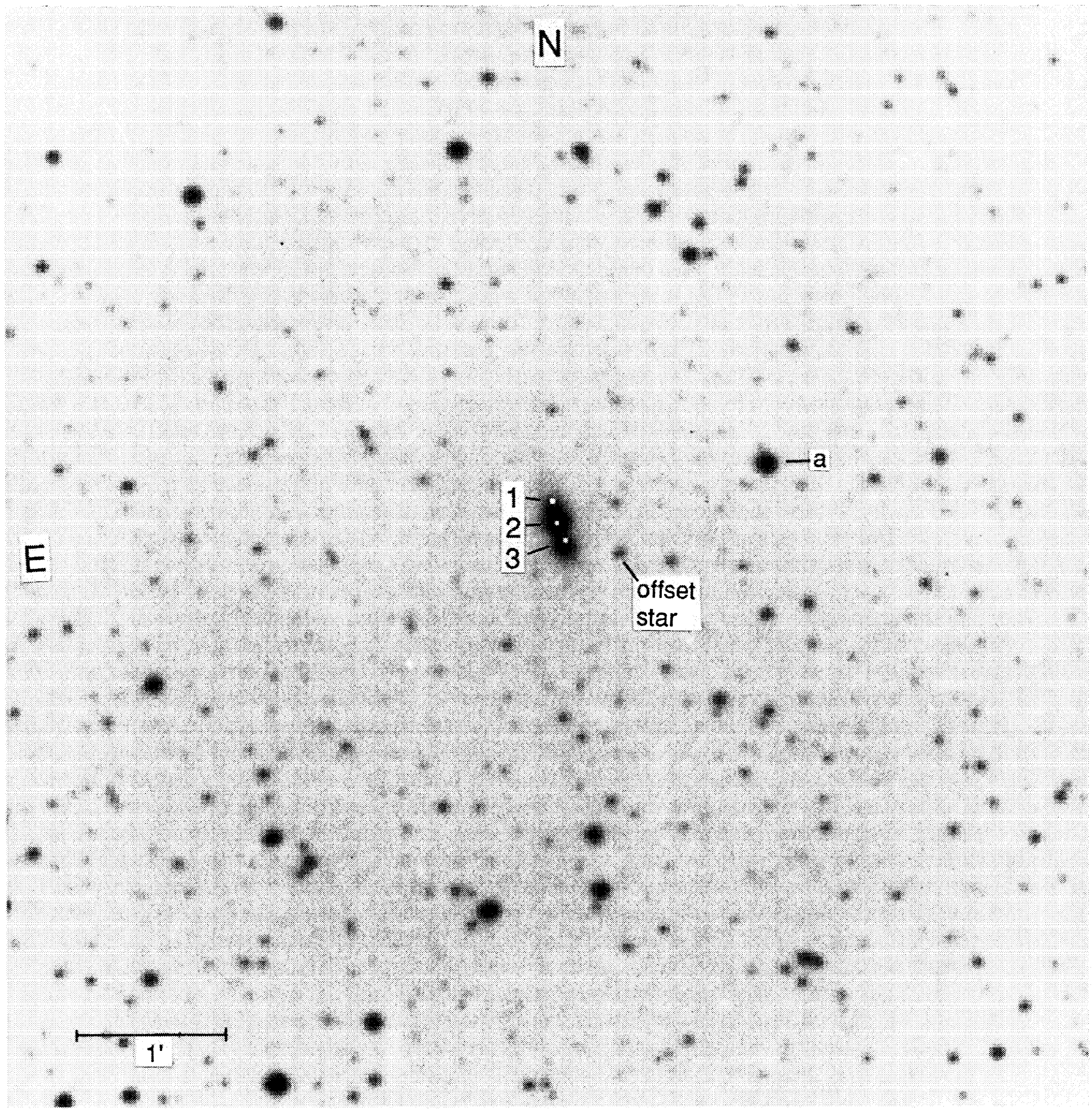

FIG. 4. (continued)

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LK Hα 233

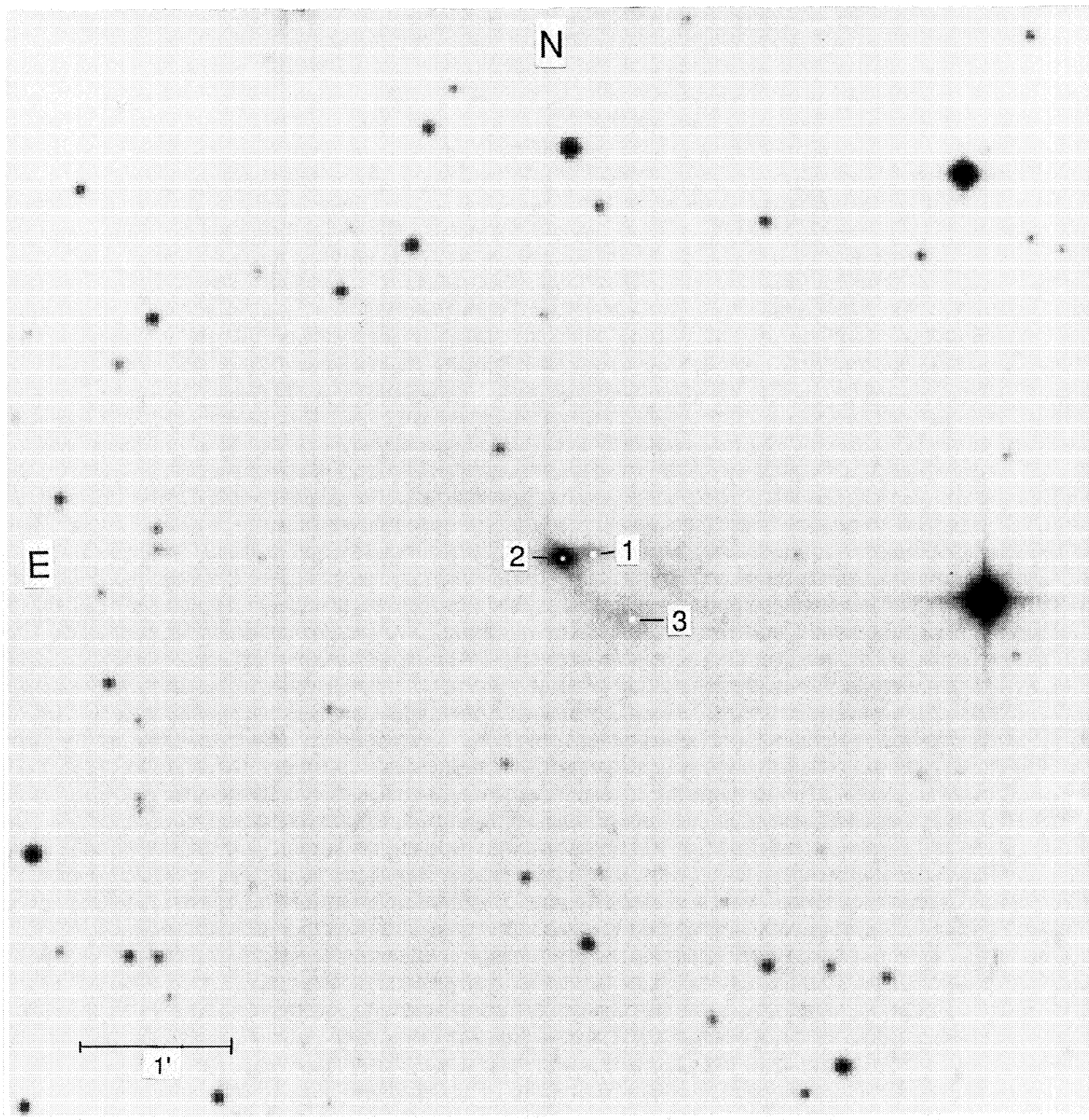

FIG. 4. (continued)

Turnshek *et al.* (see page 1243)

Crab Nebula

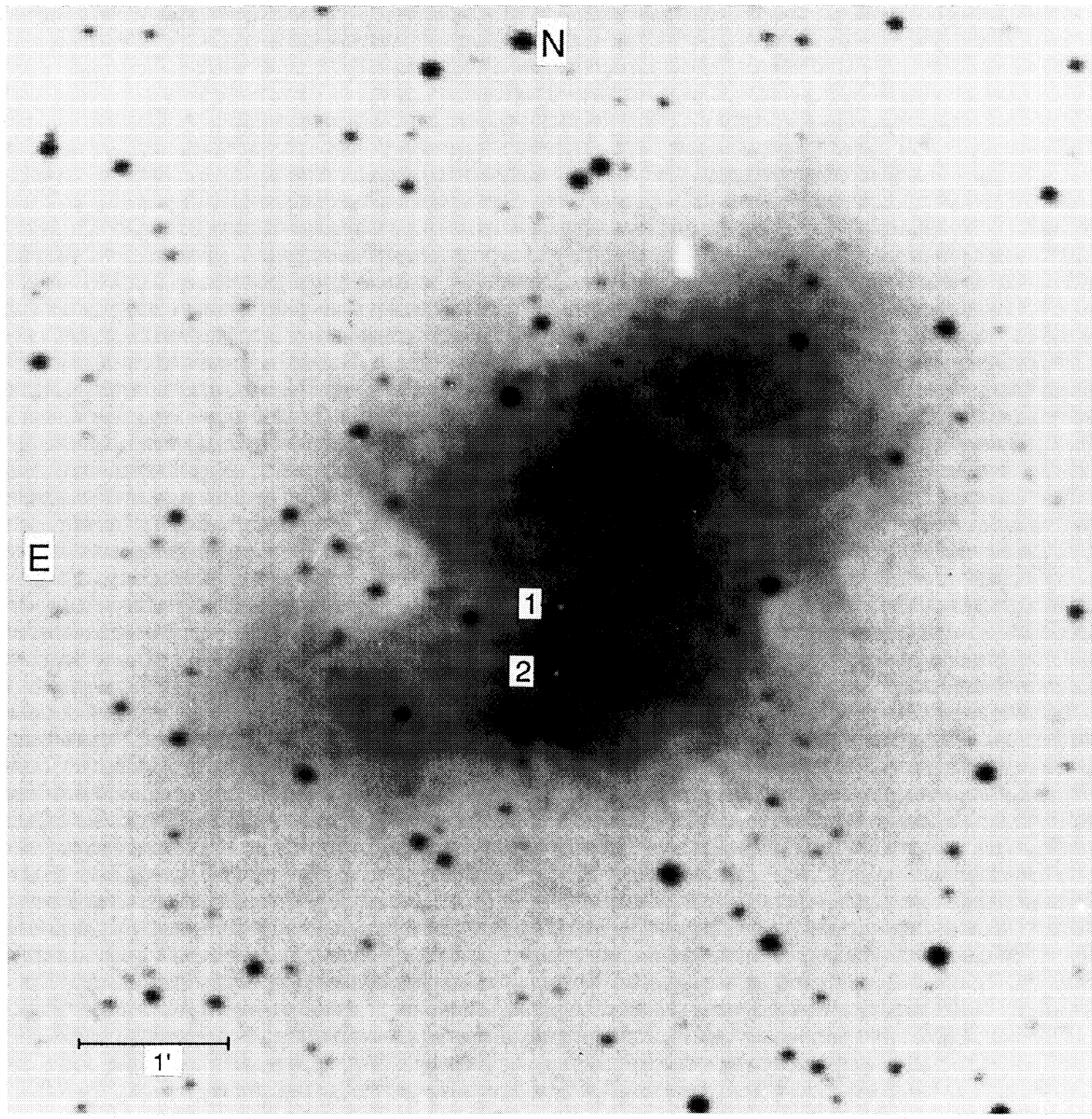

FIG. 4. (continued)

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NGC 6823

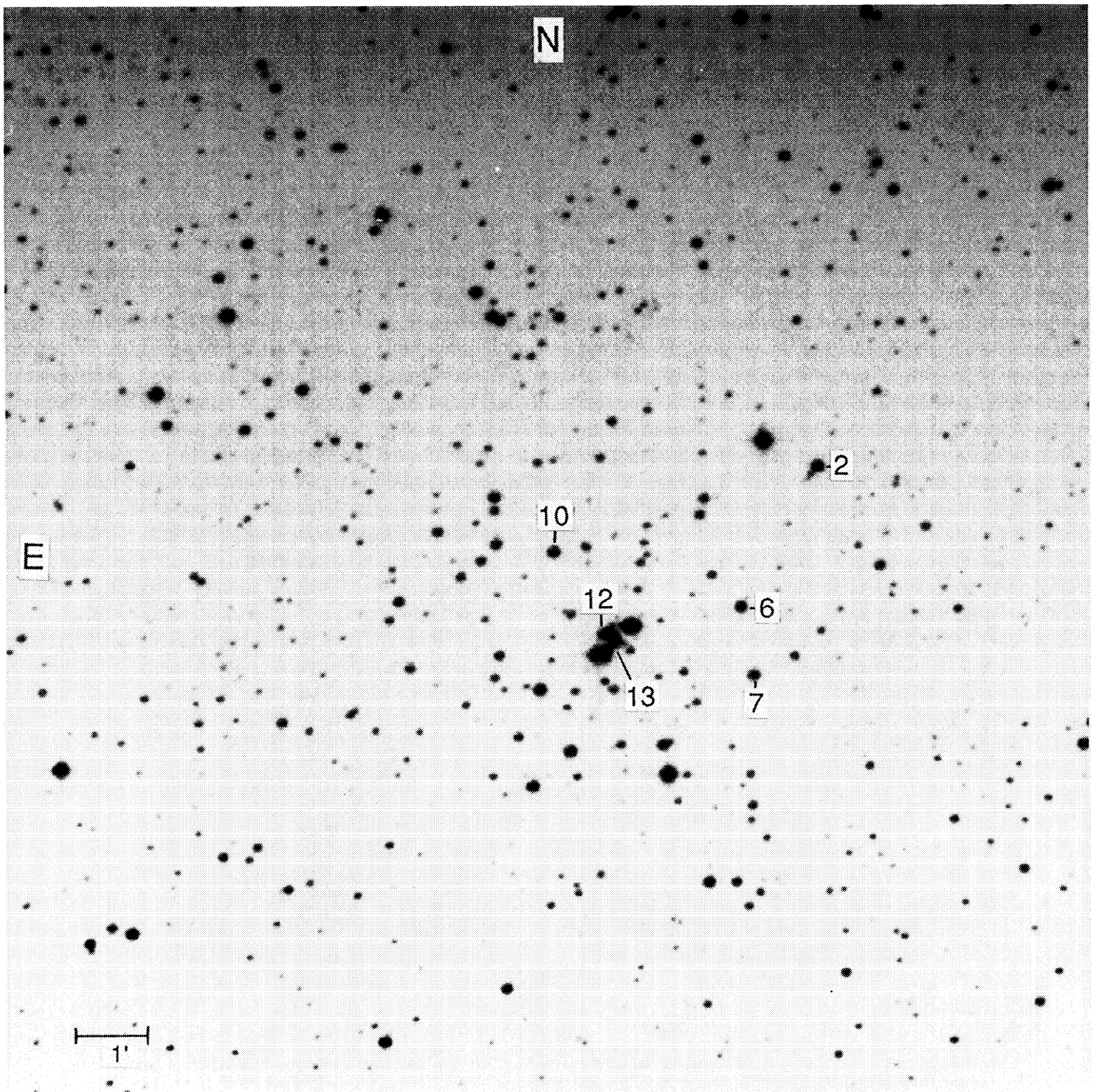

FIG. 4. (continued)

Turnshek *et al.* (see page 1243)