(NASA-CR-142555) ASTROMETRIC OBSERVATIONS OF SATURN'S SATELLITES FROM MCDONALD OBSERVATORY, 1972 (Texas Univ.) 27 p HC $3.75 CSCL 03A
N75-21177
Unclas
G3/89 14761

Astrometric Observations of Saturn's Satellites from McDonald Observatory, 1972.

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Abstract

Observations of Saturn's satellites have been reduced by means of secondary reference stars obtained by reduction of Palomar Sky Survey plates. This involved the use of 39 SAO stars and plate overlap technique to determine the coordinates of 59 fainter stars in the satellite field. Fourteen plate constants were determined for each of the two PSS plates. Comparison of two plate measurement and reduction techniques on the satellite measures demonstrate the existence of a serious background gradient effect and the utility of microdensitometry to eliminate this error source in positional determinations of close satellites.

I. INTRODUCTION

The physical nature of the natural satellites of the solar system is an increasingly interesting question, moreso with the approaching possibilities for closeup observations. The possibilities for direct near-field measurements will depend, however, on the precision with which the satellites can be located. Astrometric observations of these objects are vitally needed for the construction of new orbital theories, but such activity has been very limited in recent years (cf. Pierce 1974). In 1972, one of us initiated a resumption of the satellite astrometry program at McDonald Observatory, dormant for two decades. We present here the first results from the program.

Our goal is to produce celestial positions and intersatellary distances as accurately as our capacities and facilities will permit. Consequently, we are studying several innovative techniques, both at the telescope and in the reduction process, in attempts to overcome some of the problems inherent in the observation of satellites. In the case of the Saturn system, excluding Saturn IX (Phoebe), the overriding problem is the proximity of the satellites to the planet and its ring system, creating a serious background gradient on the plate. This background sometimes obscures the closest satellites and, as was discovered in the course of this work, affects the apparent position of the image centroid, thus degrading the astrometric positions unless countermeasures are taken. This problem can be combatted at the telescope by the use of spot filters (Pascu 1968) and in the reduction process by modelling the field gradient. Although we have begun using such filters for some observations, the 1972 plates were taken in the conventional way. Thus, we have used these plates to investigate the effectiveness of computerized post-processing.

II. OBSERVATIONS

The observations were taken with the 2.1 meter Otto Struve reflector and the 76 cm reflector of the McDonald Observatory on 1972 December 27-31, approximately three weeks after Saturn opposition. All exposures were taken on Kodak IIaD plates, with no filters or other magnitude compensation; most of the plates contained either four or six exposures. The plate scale at Cassegrain focus is 7.7"/mm on the 2.1 m instrument and 20"/mm on the 76 cm, giving 8x10 fields of about $0^\circ\!.4 \times 0^\circ\!.5$ and $1^\circ\!.1 \times 1^\circ\!.4$, respectively. The true effective field of the smaller instrument was reduced by about one-third by vignetting. The interval between the first and last plates was sufficiently short that a large fraction of the background star field was common to all plates.

III. REDUCTION AND RESULTS

In principle, the large plate scale available from either of the two instruments is an astrometric advantage. One tends to find, however, that this advantage is somewhat tarnished when one looks for standard reference stars. The field of the present observations falls in the Paris zone of the Astrographic Catalogue (plate 2249), and many of the field stars are given there. This is, however, an unreduced section of the AC with (x,y) measures only. Also, the epoch of the AC plate is 1909, and no proper motions are available. The use of the AC was abandoned. It was not possible to use the Smithsonian Astrophysical Observatory (SAO) Catalogue directly, since no plate contained more than two SAO stars. In the light of reports (e.g. Humstead 1974, Douglas 1974) that accuracies of 0"3-0"5 could be obtained by such a method, a multistep reduction using the National Geographic-Palomar Sky Survey (PSS) plates was adopted.

The observation field was located on the copies of both E and O plates available at the University of Texas at Austin. The glass copies were used because of better dimensional stability than can be obtained with the paper copies. The E plates appeared to have better quality stellar images in this particular field, and were selected for our use on that basis. A two degree square concentric with the observation field was selected as having enough SAO stars to provide a good reference net to control the statistical errors in the determination of astrometric coordinates of fainter stars to be used as reference points in the reduction of the Saturn field. Conformable to Evans' law*, this square is divided between two of the PSS plates (E1461, E1481). Sufficient overlap exists between these two to permit a combined plate reduction using the techniques developed by Eichhorn (1959) to strengthen the solution. The reduction used 24 SAO stars from plate E1461 and 21 from E1481, with six common to the two plates. These were used to determine the coordinates of 59 stars in the Saturn

*"The place that you're looking for is always on the fold of the map."
D. S. Evans

field, 30 of which were common to the two PSS plates. The equations of condition for the plate constants are of the form

$$\xi_i = Ax_i + By_i + Cx_iy_i + Dx_i^2 + Ey_i^2 + Fx_i(x_i^2 + y_i^2) + G$$

$$\eta_i = A'x_i + B'y_i + C'x_iy_i + D'x_i^2 + E'y_i^2 + F'y_i(x_i^2 + y_i^2) + G'$$

where (ξ_i, η_i) represent standard coordinates and (x_i, y_i) are the plate measures. The measures were obtained by means of a manual two-screw Mann engine. Each plate was measured in both direct and reverse orientation, three measures on each image each direction. Since the plates were taken in 1955 and the SAO stars were referred to the 1950.0 epoch, proper motion corrections were omitted as being too small to affect the uncertainties in the reduction, especially in view of the large number of stars being used. The SAO identification numbers are listed in Table 1, the resulting plate constants in Table 2, and the coordinates of the satellite field stars in Table 3.

The satellite plates have been measured in two different ways. First, the same regimen was followed on the manual Mann engine as was used on the PSS plates. Subsequently, they have been remeasured on the NASA/Skylab PDS microdensitometer at the University of Texas at Austin (Abbot, Benedict and Shelus 1974). The nature of the problem that led to the use of the microdensitometer can be explained with the aid of figure 1. When multiple exposures are taken on a single plate, the declination screw on the camera is offset before each additional exposure except the last. The last is offset in right ascension to establish the time sequence of the images. It is often the case that a given satellite will be so positioned that some of the exposures will be relatively distant from the overexposed part of the field (e.g. positions 5 and 6 in figure 1, showing one possible configuration) some will be deeper into this area but still measurable (1, 2, 4), and some will be lost totally (position 3) in the planet image. The purpose of multiple exposures is to provide a $\sqrt{n}$ statistical improvement in deduced positions, but this assumes that the images are consistent. To examine the internal consistency of the positions obtained from the measures of such a configuration, it is first necessary to account for the motion of the satellite system through the star field between individual exposures. In the present instance, the motion in right ascension was significant (0.″2/min), but that in declination negligible. After this was taken into account, there was evidence in the hand measures of a serious effect due to the background gradient. It is not certain to what degree this is physiological or psychological in the measurer's response to the gradient surrounding the planet image.

The reduction procedure used on the microdensitometer measures, yet unpublished, is based on a technique developed by W. van Altena (1974). It uses two-dimensional density scanning and digital background gradient modelling to define the effective centroid of the image with zero background. After accounting for system motion, the PDS measures within a given plate are found to be consistent to within 0.″1 in both coordinates. The same agreement was found between PDS measures and Mann measures of images that are outside the region of strong gradient (e.g. images 5 and 6). The error in the hand measures of images inside the overexposed region (e.g. images 1, 2, 4) is a progressive function of closeness to the planetary image, typically attaining 0.3-0.″5 and sometimes 0.″8.

Due to the very restricted region near the plate center occupied by the satellites and to the number and distribution of the reference stars, only linear plate constants were used in the reduction of the satellite measures from both techniques. No magnitude effect has been applied, although the microdensitometer modelling process does provide magnitude-dependent information for each image. Each plate was used to produce a single normal point observation for each satellite. For the manual measures, the normal position is the unweighted mean of the individual exposures for that plate. Greater discrimination was possible for the microdensitometer measures. The computer processing of the density scans includes an inexpensive but invaluable line printer plot of the density distribution for each image, permitting a direct evaluation of the image quality. On this basis, we assigned admittedly subjective weights (0.25, 0.5, 0.75 or 1.0) to each satellite and reference star image in the construction of the mean observations.

Uncertainties in the final coordinates arise from measurement error, systematic errors in the SAO catalog, and the lack of proper motions in the secondary reference stars. Given the relatively small interval (1955-1972) between the PSS plate epoch and the observations, we estimate that the contribution from proper motions is negligible, at least being averaged out by the relatively large sample of reference stars, unless there are non-isotropic effects. The uncertainty estimates given are based on a quadratic sum of statistical scatter and an estimate of catalogue systematics. The reduced observations, corrected for the E-terms of aberration, are tabulated in Tables 4 (Mann measures) and 5 (PDS measures); the latter are recommended as being the more reliable. Refraction has been effectively accounted for by the plate reduction process. In addition to absolute coordinates, the tables give intersatellary distances relative to Saturn VI; these should be much more reliable, being affected only by the measurement errors.

It seems worthwhile to comment on both the format and content of Tables 4 and 5. Two features of the format are at variance with customary practice, but both are based on the realities of the current use of such observations. First, we have chosen to abandon calendar dates in the tabulation, in favor of the more immediately usable Julian date; it is expressed in UTC, since that is the measure of time available to the observer. Second, all angular quantities are expressed in decimal degrees; we feel that the sexigesimal system has outlived its usefulness in such matters. Those readers who still wish to visualize in arc seconds may still do so by noting that $0\overset{\circ}{.}0003$ is approximately equal to one second. Both of these changes have a common justification: adoption of a sexigesimal (or calendric) system either for time or angular measure requires a supplementary (and non-trivial!) conversion computation before preparation of the table, which must be reversed as the first step in any serious application of the measures. The sole effect that this would have accomplished would be to increase the difficulty and expense of typesetting. We urge the system used here upon other authors.

A comparison of the two tables reveals that the changes in the formal uncertainties are not spectacular, as indeed one would expect from normal point reductions. In general, the differences in the measures themselves are larger. Even in the normal points, one can find differences of $0\overset{''}{.}7$ in the absolute positions and $0\overset{''}{.}4$ in the differential positions. These are rare, to be sure, but significant deviations of smaller size between the Mann and PDS reductions are not. We conclude that, for satellite measures in the presence of a strong background gradient due to the presence of the primary on the same plate, the use of a two-coordinate microdensitometer is necessary for obtaining results of the highest quality.

IV. ACKNOWLEDGEMENTS

We are grateful to William van Altena for providing, prior to publication, the basic concepts for the microdensitometer data reduction program, to Burton Jones for assistance in developing this program, to Vasso Tsikoudi for assistance in making the PDS measures. Access to and operation of the PDS equipment would have been impossible without the collaboration and good will of James G. Wray and G. F. Benedict. The observations were taken with the collaboration of David S. Evans. This work was partially supported by the National Aeronautics and Space Administration under grant ~~NSG~~ NGR 44-012-282.

V. REFERENCES

Abbot, R. I., Benedict, G. F., and Shelus, P. J. (1974) Bull. AAS 6, 439.

Douglas, J. N. (1974) in New Problems in Astrometry, edited by W. Gliese, C. A. Murray and R. H. Tucker (Reidel, Dordrecht), p. 141.

Eichhorn, H. K. (1959) Astr. Nach. 285, 16.

Humstead, R. W. (1974) in New Problems in Astrometry, edited by W. Gliese, C. A. Murray and R. H. Tucker (Reidel, Dordrecht), p. 175.

Pascu, D. (1968) in Trans. IAU XIIIB, edited by L. Perek (Reidel, Dordrecht), p. 118.

Pierce, D. A. (1974) Publ. Astr. Soc. Pacific, 86, 998.

van Altena (1974) private communication.

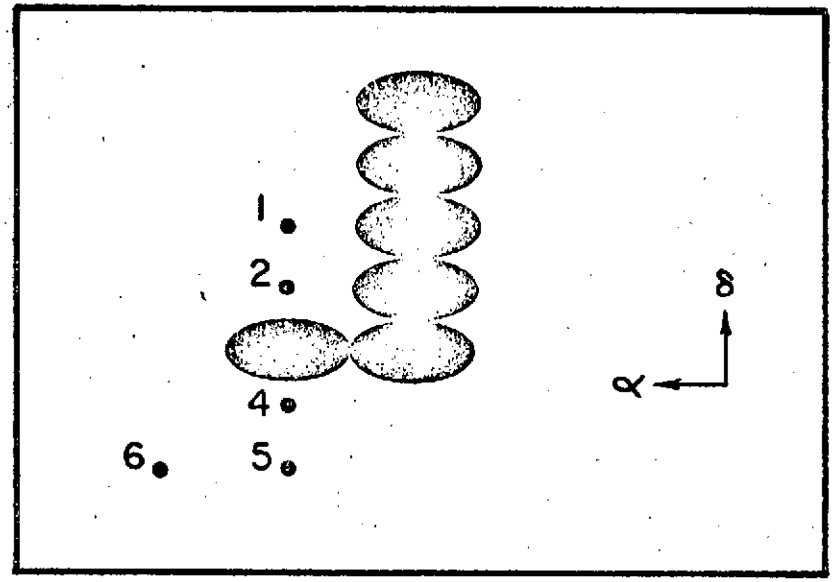

Figure 1: Example configuration for multiple images of Saturn satellite system.

Table 1: Identification of SAO stars used in reduction of secondary reference stars. (No asterisk = plate E1461, * = plate E1481, ** = both).

76817*	76846	76905*	76969
76828**	76850	76907**	76971*
76829**	76863*	76923*	76975
76830	76870	76932	94210*
76831*	76872	76939**	94243*
76832	76873*	76940	94264*
76836*	76882	76956	94273*
76837	76884*	76962	94282*
76842	76888	76966	94306*
76844	76891**	76968**	

Table 2: Plate constants determined for the 2° region centered at about $\alpha = 4^h 57^m 46^s$, $\delta = +21°9'$. (These are presented only to show the degree of non-linearity in this region of PSS plates E1461 and E1481). These are presented in the form $M \cdot 10^{-N}$.

E1461	M	N		M	N
A	-3.3527	7	A'	6.264	9
B	-2.786	9	B'	3.3545	7
C	9.31	15	C'	-9.77	15
D	1.34	14	D'	-4.09	15
E	3.77	15	E'	-1.33	14
F	-8.34	21	F'	8.42	21
G	1.6652	1	G'	-1.6877	1
E1481					
A	-3.3430	7	A'	2.019	8
B	-8.654	10	B'	3.6735	7
C	7.83	15	C'	-3.22	14
D	1.24	14	D'	-1.91	14
E	2.81	15	E'	-5.78	14
F	-7.69	21	F'	3.31	20
G	1.6514	1	G'	-1.7517	1

Table 3: Secondary reference star coordinates deduced from PSS plates, in order of increasing right ascension. Astrographic catalogue (Paris zone, plate 2249) identifications are included as appropriate, asterisk code as for table 1.

★	α_{1950}	δ_{1950}	AC #
1	$4^h\ 53^m\ 58^s.69$	+21° 04' 51".9	82 **
2	4 54 25.86	20 49 05.2	301 *
3	4 54 27.71	20 56 06.8	302 *
4	4 54 30.42	21 19 04.9	97 **
5	4 54 32.54	21 16 42.7	99 **
6	4 54 40.78	20 56 36.6	307 *
7	4 54 48.54	21 27 06.5	106
8	4 54 56.73	21 24 45.9	110
9	4 55 03.45	21 06 29.9	115 **
10	4 55 08.73	20 48 38.0	319 *
11	4 55 20.85	20 48 15.9	322 *
12	4 55 32.66	20 48 05.7	326 *
13	4 55 36.81	21 15 48.1	121 **
14	4 55 41.61	20 42 13.9	330 *
15	4 55 42.12	21 02 36.6	329 **
16	4 55 43.15	20 47 51.6	331 *
17	4 55 48.01	21 09 08.4	123 **
18	4 55 49.37	21 07 59.4	125 **
19	4 55 50.07	21 07 00.3	126
20	4 55 50.10	20 58 07.3	--- *
21	4 55 55.47	20 54 55.3	--- *
22	4 56 00.69	21 21 41.7	130
23	4 56 01.84	21 06 19.2	--- **
24	4 56 02.32	21 20 23.7	132
25	4 56 06.35	21 11 22.4	134 **
26	4 56 06.97	20 46 10.6	333 *
27	4 56 07.76	21 05 13.3	--- **
28	4 56 08.10	21 18 14.2	135 **
29	4 56 10.45	21 15 57.4	138 **
30	4 56 11.25	21 23 33.5	139
31	4 56 11.59	20 44 44.5	335 *
32	4 56 13.13	21 07 24.8	--- **
33	4 56 14.63	20 55 52.2	--- *
34	4 56 20.82	20 58 38.5	336 **
35	4 56 28.49	21 08 10.8	---
36	4 56 33.04	20 45 17.1	341 *
37	4 56 36.34	21 02 16.1	342 **
38	4 56 38.60	20 52 28.2	--- *
39	4 56 38.77	21 10 57.9	--- **
40	4 56 44.15	21 10 44.3	--- **
41	4 56 48.69	21 01 31.1	--- **
42	4 56 55.12	21 16 22.2	148 **

Continued.........................

Table 3 (Continued)

★	α_{1950}	δ_{1950}	AC #
43	4^h 56^m $58^s.03$	+20° 57' 39".9	346 *
44	4 57 01.10	20 44 51.1	347 *
45	4 57 03.46	21 00 45.1	348 **
46	4 57 13.48	21 04 55.7	--- **
47	4 57 15.56	20 51 16.2	351 *
48	4 57 18.28	21 02 44.6	--- **
49	4 57 21.70	20 59 31.5	--- **
50	4 57 25.46	21 03 13.8	--- **
51	4 57 26.29	20 57 18.6	--- *
52	4 57 28.91	21 09 34.6	153 **
53	4 57 31.30	20 59 57.9	--- **
54	4 57 33.37	20 56 51.0	--- *
55	4 57 36.13	21 11 08.1	157 **
56	4 57 40.00	20 55 39.1	354 *
57	4 57 42.78	21 01 18.6	--- **
58	4 57 45.54	21 09 04.5	161 **
59	4 58 09.62	20 57 55.0	356 *

Table 4: Satellite positions based on Mann measures. Asterisks indicate 76 cm reflector observations, all others 2.1 meter Struve reflector.
Observer: Mulholland; Measurer: Abbot

Satellite	Julian Date (UTC) -2441600	Right ascension α_{1950} degrees	Declination δ_{1950} degrees	Uncertainty ϵ 10^{-5} deg	$\Delta\alpha_{S-VI}$ 10^{-5} deg	$\Delta\delta_{S-VI}$ 10^{-5} deg	Uncertainty ϵ_{Δ} 10^{-5} deg	# images	# stars
I	80.890799	74°.06920	+21°.01088	15	+996	-2425	9	1	13
II	78.801649	74.25378	21.02198	13	-2040	-2580	4	4	10
	78.835035	74.25193	21.02253	13	-1882	-2519	3	5	10
	78.868368	74.24969	21.02312	13	-1760	-2451	4	5	11
	80.890799	74.06699	21.01366	15	+775	-2147	9	1	13
	81.694792*	74.02839	21.01016	14	+4879	-1581	7	2	11
	82.658623*	73.94124	20.99852	13	+5083	-1419	5	3	22
III	78.696354	74.26584	21.02757	13	-1912	-2044	3	6	10
	78.733073	74.26205	21.02805	12	-1918	-1989	3	6	9
	78.801753	74.25445	21.02873	13	-1971	-1906	3	5	10
	78.835243	74.25056	21.02899	13	-2017	-1874	3	4	10
	78.868576	74.24658	21.02919	13	-2070	-1844	5	4	11
	80.570544	74.11786	21.01717	12	+2546	-2100	3	6	9
	80.816204	74.09022	21.01923	13	+2331	-1668	5	2	10
	80.887326	74.08124	21.01909	13	+2165	-1606	5	2	11
	80.890799	74.08078	21.01908	15	+2154	-1606	9	1	13
	81.694097*	74.00748	21.00272	14	+2775	-2331	6	3	11
	82.658854*	73.95041	21.00943	13	+6003	-326	4	4	22
IV	78.696354	74.23298	21.02428	13	-5198	-2373	3	6	10
	78.733073	74.22990	+21.02340	13	-5133	-2454	3	6	9

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 4 (Continued)

IV	78.801823	74.22443	+21.02176	12	-4972	-2603	3	6	10
	78.835243	74.22196	21.02098	12	-4876	-2674	3	6	10
	78.868576	74.21960	21.02023	13	-4767	-2740	4	6	11
	80.570255	74.11345	21.02171	13	+2102	-1646	4	5	9
	80.816204	74.08351	21.02092	13	+1660	-1499	5	2	10
	80.887326	74.07476	21.02019	13	+1517	-1496	5	2	11
	80.890799	74.07433	21.02013	15	+1508	-1500	9	1	13
	81.694792*	73.99957	21.00374	13	+1993	-2226	5	4	11
	82.659086	73.95961	21.00119	13	+6925	-1150	5	3	22
V	78.696354	74.27835	21.02762	13	-662	-2038	3	6	10
	78.733073	74.27515	21.02795	12	-608	-1999	3	6	9
	78.801823	74.26892	21.02855	12	-523	-1924	3	6	10
	78.835243	74.26585	21.02883	12	-487	-1890	3	6	10
	78.868576	74.26270	21.02906	13	-457	-1857	4	6	11
	80.570544	74.07924	21.01699	12	-1315	-2118	3	6	9
	80.815336	74.05778	21.01194	13	-921	-2397	4	4	10
	80.886632	74.05215	21.01046	13	-752	-2470	4	4	11
	80.890799	74.05183	21.01035	15	-742	-2478	9	1	13
	81.694097*	74.00613	20.99771	13	+2640	-2831	6	3	11
	82.658854*	73.96406	20.99853	13	+7367	-1417	4	4	22
VI	78.696354	74.28496	21.04801	13	--	--	--	6	9
	78.733073	74.28123	21.04794	12	--	--	--	6	9
	78.801823	74.27415	21.04778	12	--	--	--	6	10
	78.835243	74.27072	21.04772	12	--	--	--	6	10
	78.868576	74.26727	+21.04763	13	--	--	--	6	11

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Table 4 (Continued)

VI	80.570544	74.09240	+21.03816	12	--	--	--	6	9
	80.815336	74.06699	21.03590	13	--	--	--	4	10
	80.886632	74.05967	21.03516	13	--	--	--	4	11
	80.890799	74.05924	21.03513	15	--	--	--	1	13
	81.694792*	73.97964	21.02601	13	--	--	--	4	11
	82.658854*	73.89038	21.01269	13	--	--	--	4	22
VII	78.696354	74.32023	21.02486	13	+3527	-2314	3	6	10
	78.733073	74.31736	21.02500	12	+3612	-2294	3	6	9
	78.834549	74.30941	21.02543	13	+3861	-2229	4	4	10
	80.815336	74.14353	21.03291	13	+7653	-299	4	4	10
	80.886285	74.13708	21.03305	14	+7737	-211	4	1	11
	82.658854*	73.97140	21.03342	13	+8102	+2072	4	4	22
VIII	78.696354	74.29458	20.99286	13	+962	-5514	3	6	10
	78.733073	74.29208	20.99281	12	+1085	-5512	3	6	9
	78.801823	74.28742	20.99266	12	+1327	-5512	3	6	10
	78.835243	74.28517	20.99261	12	+1445	-5511	3	6	10
	78.868576	74.28296	20.99255	13	+1569	-5508	4	6	11
	80.570544	74.17164	20.99006	12	+7924	-4810	3	6	9
	80.815336	74.15533	20.98979	13	+8833	-4611	4	4	10
	80.886632	74.15060	20.98968	13	+9092	-4548	4	4	11
	80.890799	74.15037	20.98969	15	+9112	-4544	9	1	13
	81.694792*	74.09861	20.98892	13	+11897	-3709	5	4	11
	82.658854*	74.03643	+20.98814	13	+14605	-2455	4	4	22

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 5: Satellite positions based on PDS measures. Asterisks indicate 76 cm reflector observations, all others 2.1 m Struve reflector. Observer: Mulholland; Measurer: Abbot.

Satellite	Julian Date (UTC) -2441600	Right ascension α_{1950} degrees	Declination δ_{1950} degrees	Uncertainty ϵ 10^{-5} deg	$\Delta\alpha_{S-IV}$ 10^{-5} deg	$\Delta\delta_{S-VI}$ 10^{-5} deg	Uncertainty ϵ_{Δ} 10^{-5} deg	# images	# stars
I	80.890799	74.06916	+21.01091	14	+992	-2422	7	1	11
II	78.801649	74.25380	21.02194	13	-2033	-2581	4	4	12
	78.835035	74.25189	21.02246	12	-1882	-2519	3	5	20
	78.868229	74.24972	21.02301	13	-1756	-2458	4	4	18
	80.890799	74.06708	21.01369	14	+783	-2144	7	1	11
III	78.696354	74.26581	21.02753	12	-1917	-2044	3	6	21
	78.733003	74.26202	21.02802	13	-1920	-1990	3	5	15
	78.802170	74.25440	21.02870	13	-1967	-1905	4	4	12
	78.835174	74.25055	21.02893	12	-2014	-1874	3	5	20
	78.868576	74.24666	21.02917	13	-2058	-1841	4	4	18
	80.570544	74.11786	21.01715	12	+2545	-2099	3	6	18
	80.816204	74.09024	21.01921	13	+2333	-1665	5	2	18
	80.887326	74.08124	21.01908	13	+2167	-1604	5	2	21
	80.890799	74.08083	21.01910	14	+2158	-1603	7	1	11
	82.658854*	73.95041	21.00946	12	+6002	-324	4	4	22
IV	78.696354	74.23298	21.02423	12	-5200	-2373	3	6	21
	78.733073	74.22987	21.02339	12	-5135	-2453	3	6	15
	78.801823	74.22440	21.02173	12	-4972	-2602	3	6	12
	78.835243	74.22193	21.02093	12	-4876	-2673	3	6	20
	78.868576	74.21959	21.02018	12	-4767	-2739	3	6	18
	80.816204	74.08353	+21.02091	13	+1662	-1496	5	2	18

FOLDOUT FRAME 1

FOLDOUT FRAME 3

Table 5 (Continued)

IV	80.887326	74.07478	+21.02016	13	+1521	-1496	5	2	21
	80.890799	74.07441	21.02016	14	+1517	-1497	7	1	11
	81.695023*	73.99942	21.00376	13	+1972	-2224	6	3	11
	82.658854*	73.95962	21.00117	13	+6923	-1153	5	2	22
V	78.696354	74.27835	21.02758	12	-663	-2038	3	6	21
	78.733073	74.27513	21.02794	12	-608	-1998	3	6	15
	78.801823	74.26891	21.02851	12	-521	-1924	3	6	12
	78.835243	74.26582	21.02878	12	-487	-1888	3	6	20
	78.868576	74.26270	21.02904	12	-455	-1854	3	6	18
	80.570544	74.07924	21.01697	12	-1317	-2117	3	6	18
	80.815336	74.05780	21.01193	12	-920	-2395	3	4	21
	80.886632	74.05215	21.01043	12	-751	-2469	3	4	11
	80.890799	74.05187	21.01038	14	-737	-2475	7	1	11
	82.658854*	73.96406	20.99855	12	+7367	-1415	4	4	22
VI	78.696354	74.28498	21.04796	12	--	--	--	6	21
	78.733073	74.28121	21.04792	12	--	--	--	6	15
	78.801823	74.27412	21.04775	12	--	--	--	6	12
	78.835243	74.27069	21.04766	12	--	--	--	6	20
	78.868576	74.26726	21.04758	12	--	--	--	6	18
	80.570544	74.09241	21.03814	12	--	--	--	6	18
	80.815336	74.06699	21.03588	12	--	--	--	4	18
	80.886632	74.05966	21.03512	12	--	--	--	4	21
	80.890799	74.05924	21.03513	14	--	--	--	1	11
	81.694792*	73.97973	21.02600	13	--	--	--	4	11
	82.658854*	73.89039	+21.01269	12	--	--	--	4	22

FOLDOUT FRAME

FOLDOUT FRAME

Table 5 (Continued)

VII	78.696146	74.32026	+21.02481	12	+3526	-2316	3	5	21
	78.733073	74.31740	21.02500	12	+3618	-2292	3	6	15
	80.570810	74.16567	21.03221	12	+7328	-593	3	5	18
	80.815336	74.14353	21.03286	12	+7654	-302	3	4	18
	80.886632	74.13708	21.03299	12	+7742	-213	3	4	21
	82.658854*	73.97138	21.03339	12	+8099	+2070	4	4	22
VIII	78.733073	74.29209	20.99279	12	+1088	-5513	3	6	15
	78.801823	74.28743	20.99264	12	+1331	-5511	3	6	12
	78.835243	74.28517	20.99258	12	+1448	-5508	3	6	20
	78.868576	74.28294	20.99253	12	+1568	-5505	3	6	18
	80.570544	74.17162	20.99003	12	+7921	-4812	3	6	18
	80.815336	74.15534	20.98976	12	+8835	-4612	3	4	18
	80.886632	74.15062	20.98964	12	+9096	-4547	3	4	21
	80.890799	74.15037	20.98969	14	+9112	-4544	7	1	11
	81.694792*	74.09851	20.98892	13	+11877	-3709	4	4	11
	82.658854*	74.03642	+20.98816	12	+14603	-2454	4	4	22

FOLDOUT FRAME

FOLDOUT FRAME