(NASA-CR-134318) THE 90-DAY REPORT FOR SL4 EXPERIMENT S019: UV STELLAR ASTRONOMY (Texas Univ.) 17 p HC $4.00 CSCL 03A N74-29249 Unclas G3/30 42563

CR 134318

90 Day Report for SL4

Experiment S019 - UV Stellar Astronomy

Objectives and Description

The primary purpose of Experiment S019 is to obtain moderate dispersion stellar spectra extending down to 1300A with sufficient spectral resolution to permit the study of ultraviolet (UV) line spectra and of spectral energy distributions of early-type stars. The data obtained from this experiment should be of sufficient accuracy to permit detailed physical analysis of individual stars and nebulae, but an even more basic consideration is the expectation of obtaining spectra of a sufficient number of stars ($\sim$500) so that a statistically meaningful survey may be made of the UV spectra of a wide variety of star types. These should include all luminosity classes of spectral types O, B and A, as well as peculiar stars such as Wolf-Rayet stars and "Ap" or "Am" stars.

A secondary objective is to obtain, in the no-prism mode, low dispersion UV spectra in a number of Milky Way star fields and in nearby galaxies. This mode is also to be used in the three student investigations associated with S019--ED23, ED26 and ED75. The objective of ED23 is to photograph spectra of several Quasars and Seyfert galaxies in an effort to measure the amount of UV radiation emitted by these peculiar galaxies. The objectives of ED26 and ED75 are to obtain similar measurements of Pulsars and T Tauri stars respectively.

The equipment with which these observations are to be made consists of an f/3, six-inch aperture objective-prism spectrograph using a Ca F_2 prism with a 4° wedge angle. This instrument has a $4^\circ \times 5^\circ$ field of view and records the spectra of all stars of sufficient brightness occurring in that region. The spectrograph has a removable film canister containing approximately 164 frames of Kodak 101 film mounted on individual stainless steel plates.

During operation the spectrograph is mounted to an Articulated Mirror System (AMS) which in turn is mounted on the anti-solar scientific airlock. When the airlock is opened the mirror may be extended outside the spacecraft and is then pointed at various star fields by means of Rotation and Tilt motions. Widening of the spectra to eliminate photographic grain noise (smooth widening is highly desirable) is accomplished by a widening mechanism which slowly tilts the rear of the AMS canister (and the spectrograph) through an angle of 270 arcsec which amounts to a linear image motion of 0.6mm in the focal plane. Three exposure times, with corresponding widening rates, are available--270, 90 and 30 sec. The widening is affected by drift in the rate gyros but so long as this is smooth and gives a resultant vector of less than 1 arcsec/sec this is of

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little concern. However, widening is adversely affected by any "hunt" or "jitter" in spacecraft attitude with an amplitude exceeding ±10 arcsec.

The spectrograph may also be operated without spectral widening. In this case widening is caused by spacecraft motion. If the gyro drift is as small as 0.1 arcsec/sec it is possible to increase the limiting magnitude by at least 2 magnitudes. However, attitude jitter or gyro drift in the direction of dispersion can be expected to reduce the wavelength resolution of such spectra.

In the no-prism mode the prism is removed but wavelength dispersion is still evident in the images due to lateral chromatic aberration in the optics. The dispersion is very small but this allows spectral flux data of very faint stars to be recorded if spacecraft motion is small. The widening mechanism is not used in this mode.

The operation of the spectrograph is entirely mechanical and manual. The astronaut extends the mirror, sets the required Rotation and Tilt values, activates the widening mechanism, opens the shutter, times the exposure, closes the shutter, and advances film all in a manual mode. Knowing the spacecraft attitude accurate to ±0.5° is of particular importance since the Rotation and Tilt angles depend on having a known attitude. Rotation about the Z-axis is the least well determined quantity and observations with the ATM star tracker are required before each S019 pass to accurately define this attitude component. Corrections to Z-axis rotation affect only Rotation settings and are made by the astronauts who may determine such corrections by comparing the Orbit Plane Error with the assumed value of NUZ which is stated in each set of data.

Results and Performance Analysis

A tabulation of exposures made during SL4 is given in Appendix A. Table 1 gives an analysis of these data. A total of 138 exposures were obtained of which 14 were devoted to comet Kohoutek. Of these 138, four were blank for unknown reasons, two (both on comet Kohoutek) were fogged beyond use, 12 were taken 4° or more off center and 13 were taken with degraded (but still usable) focus. Thus 22% of the exposures were appreciably degraded. However only 4% (6 exposures) were completely unusable. These data do not include 15 exposures made with a jammed canister which was thought to be operating.

The following comments may be made concerning data degradation problems.

Film fog - Background fog is worse on SL4 films than on films from previous missions as might be expected from the longer duration of the mission. However the fog is not disastrous and constitutes mainly a moderate nuisance during the data reduction process. Four distinct fogging problems may now be distinguished on our plates. The first is a not previously noticed uniform fog on the areas of the film protected by the nylon retainers. This may be ascribed either to the effects of high energy particles in the space environment or to thermal fogging. The former is more probable since the resulting density is roughly proportional to the radiation dose incurred. The maximum value is 0.39 density units corresponding to a radiation dose of 1.91 rads during SL4.

The second effect is the physical interaction between the film and the stainless steel platens which produces a hole pattern on the area of the plate not protected by the nylon retainers. The attempt made to reduce this phenomenon by introducing spacecraft atmosphere into the film canisters during periods of storage was perhaps effective, as this type of fogging was only slightly stronger than on the SL3 film. The SL4 film was in vacuum for about one month before the back-filling procedure was implemented.

The third fogging effect is the random blotchiness of the background which is thought to be due to contamination on the steel platens. Although strenuous efforts were made during preparation and loading of the SL4 film to insure clean platens and to prevent finger grease from reaching the platens, many of the SL4 films still show this effect.

The fourth effect is fogging due to bright moonlight. This problem was avoided during SL4 by proper scheduling of the observations. However a related effect is noted on comet Kohoutek exposures - fogging due to the bright twilight conditions under which the comet was observed. Nearly all the Kohoutek exposures show appreciable fog due to this cause and two were completely fogged. It is presumed the complete fogging is due to the film hatch having been left open until after the sun rose.

Poor pointing - Improper pointing during SL4 was due mainly to crew error. In two cases tilt or rotation values were set in error and during one pass involving ten exposures the NUZ correction was made with reversed sign resulting in a 4° pointing error. However, these exposures have recorded data of some value even though they were not centered on the anticipated fields.

Poor stabilization - Streaky widening due to less than optimum spacecraft stabilization continued to be a minor problem during SL4. Pointing excursions in excess of 10 arcsec can produce these effects and it is felt that the effects observed are due to crew motion. The crew was constrained from riding the bicycle ergometer during S019 observations but it was not feasible to prohibit all three crew members from engaging in less energetic activities. It is expected that the streaky widening will degrade the data very little thanks to the sophisticated data reduction procedures available to us via the PDS Microdensitometer. Spectra in which these effects have been removed by computer processing are illustrated in figure 2.

Poor focus - The image quality produced by the S019 instrument has generally been excellent. However during SL4 two film canisters with differing focus positions were flown and in one instance a series of 13 exposures were made with an improper focus setting. The loss of resolution on these films is noticeable but not disastrous.

Equipment malfunctions included jamming of both film canisters, failure of the tens and hundreds positions of the rotation digital display of the AMS and shifting in the zero point of the rotation display of the AMS.

Film canister 002 jammed on 23 Dec. It was put into storage and canister 003 was used for subsequent observations. On 7 January canister 003 jammed. Ground analysis indicated the only hope of solving the problem was to apply force to the film advance lever in hopes of freeing the jam. An attempt to do so was successful and eight more exposures were obtained before a second jam occurred on 11 January. An attempt to free this jam by force was unsuccessful, resulting in a hard internal jam, loss of synchronism in the drive mechanism and free cycling of the film advance lever. An attempt to free up canister 002 was apparently successful and fifteen more exposures were made with this canister. However when the film was developed it was found that the film transport was not operative during these final fifteen exposures. A total of 55 frames were used in canister 002 and 83 were used in canister 003.

The partial failure of the rotation counter of the AMS provides an excellent example of man's ability to work around minor equipment failures. In the case of the failure of the tens and hundreds position of the counter, careful counting of revolutions of the drive wheel provided a setting accurate to ±3°. Finer setting was then achieved by use of the units and tenths digits of the counter. This change in operating procedures required a revision of the PAD format and a slight slowing of the operational time line but, in general, gave results of the same accuracy as had been previously achieved.

In the case of the shifting zero point, this was detected by the crewmen who noted shifts in the reading at which they could sight the discone antennae (which were used to confirm the rotational zero position at which the mirror could be retracted). They detected two such shifts and subsequent sightings on stars proved them correct. The cause of these shifts is believed to be wear in a bevel gear in the mirror drive system which allowed the gear to occasionally slip by one tooth. A similar malfunction had been noted in the training unit.

The crew also performed a major upgrading of equipment during this mission by replacing the mirror of the AMS. The UV reflectivity of this mirror had dropped by a factor of 2 to 3 in the course of the SL2 and 3 missions. The replacing of the mirror was accomplished with no difficulty and the SL4 spectra show a marked improvement in far-UV sensitivity.

Preliminary Analysis of Scientific Results

Little analysis has been made of SL4 data so far beyond initial inspection of the film and confirmation that excellent spectra were obtained of γ Velorum, ζ Puppis, and many other stars of special interest. Current efforts have been directed at solving the problems related to the spectraphotometric analysis of the spectra, at providing master positives of all frames for archive purposes, at producing working prints of all frames and at taking a field by field census of the stars measurable in each field. At this point it seems more appropriate to summarize the overall accomplishments of all three missions.

Figure 1 displays the distribution over the sky of the 173 fields in which useful spectra were obtained during all three missions. Those fields observed during SL4 are shown in black. With due allowance for overlaps, these fields cover a total area of slightly more than 3200 square degrees. As figure 1 shows, these fields are mostly situated in the Milky Way. Approximately 27% of the Milky Way band between ±15° galactic latitude has been surveyed.

As of 8 May 1974 a careful census of 54 fields has been completed. These fields contain 421 stars with measurable flux at 2000A or below. Of these, 110 show measurable fluxes at 1500A or below. If we extrapolate these numbers to the total 173 fields we may expect to find about 1350 stars with measurable fluxes at 2000A or below of which 350 stars will show measurable fluxes at 1500A or below.

In the 54 fields 101 stars show spectrum lines in the region below 2500A. Although only three or four strong lines are readily visible on the original plates, when the spectra are scanned and computer processed to remove the effects of contorted line shapes and irregular widening a number of fainter lines also become visible. Such computer processed spectra are illustrated in figure 2 which shows representive spectra of various spectral and luminosity classes. These spectra clearly illustrate the luminosity effects in CIV and SiIV lines mentioned in the SL3 90-day report.

The S019 plates show numerous stars of special interest including Wolf-Rayet stars, Am stars, shell stars, X-ray sources, Zeta Aurigae binary stars, etc. Table 2 gives an extensive list of scientific papers which has been formulated as a goal toward which our data analysis group will work.

During the SL4 mission one of the special objectives was spectroscopy of comet Kohoutek. Usable images of the comet were obtained on nine separate dates. Several of these are illustrated in figure 3. Although dispersion is evident in the nucleus of the comet it is disappointing to find that no data are visible shortward of 3000A. This is due primarily to the less than expected brightness of the comet. However, the nuclear images of 13 Dec., 16 Dec. and 7 Jan. show a distinct image at the position of OH λ3090 which should yield valuable data on the development of this emission band.

KGH
17 May 74

Table 1

Analysis of S019 Exposures Made During SL4

Program	Frames	Fields
S019	124[a]	60[b]
S019K	14[c]	
S183	0[d]	0
ED23	0	0
ED26	0	0

a - Of these exposures 3 were blank, 12 were taken 4° or more off center and 13 were taken with an improper focus setting.

b - Eight fields were covered only by data degraded by poor focus, or inaccurate pointing.

c - Of these exposures, one was blank and two were completely fogged.

d - Two exposures were taken for S183 on 25 Jan. but it was subsequently found that the film canister was not transporting film.

Table 2

List of Potential S019 Scientific Papers

Calibration and Reduction Methods for Data Obtained by Skylab Experiment S019

UV Luminosity Effects and Mass Ejection Rates for O- and Early B-type Stars

UV Line Spectra of Normal O and B Stars

An Analysis of the UV Fluxes of O and B Stars

The UV Spectra of Normal and Peculiar A Stars

The UV Spectra of Star Types Later than Class A

Catalogue of UV Fluxes Obtained by Skylab Experiment S019

UV Spectra of Eight Wolf-Rayet Stars

UV Spectra of Four X-ray Sources

UV Spectra of Ten Shell Stars

UV Spectra of Be Stars

UV Observations of Zeta Aurigae Binary Stars

UV Observations of Beta CMa Variable Stars

UV Flux Data for 200 Stars in the Eta Carinae Region

UV Flux Data for 120 Stars in the Region of P Cygni

UV Flux Data for 80 Stars in the Region of M8

UV Fluxes of Faint Stars in the Region of the Large Magellanic Cloud

UV Fluxes of Faint Stars in the Region of the Small Magellanic Cloud

A Study of the Distribution of Interstellar Scattering Material Based on UV Observations

A Note on the UV Spectrum of Eta Carina

The UV Spectra of Mars, Saturn and Venus

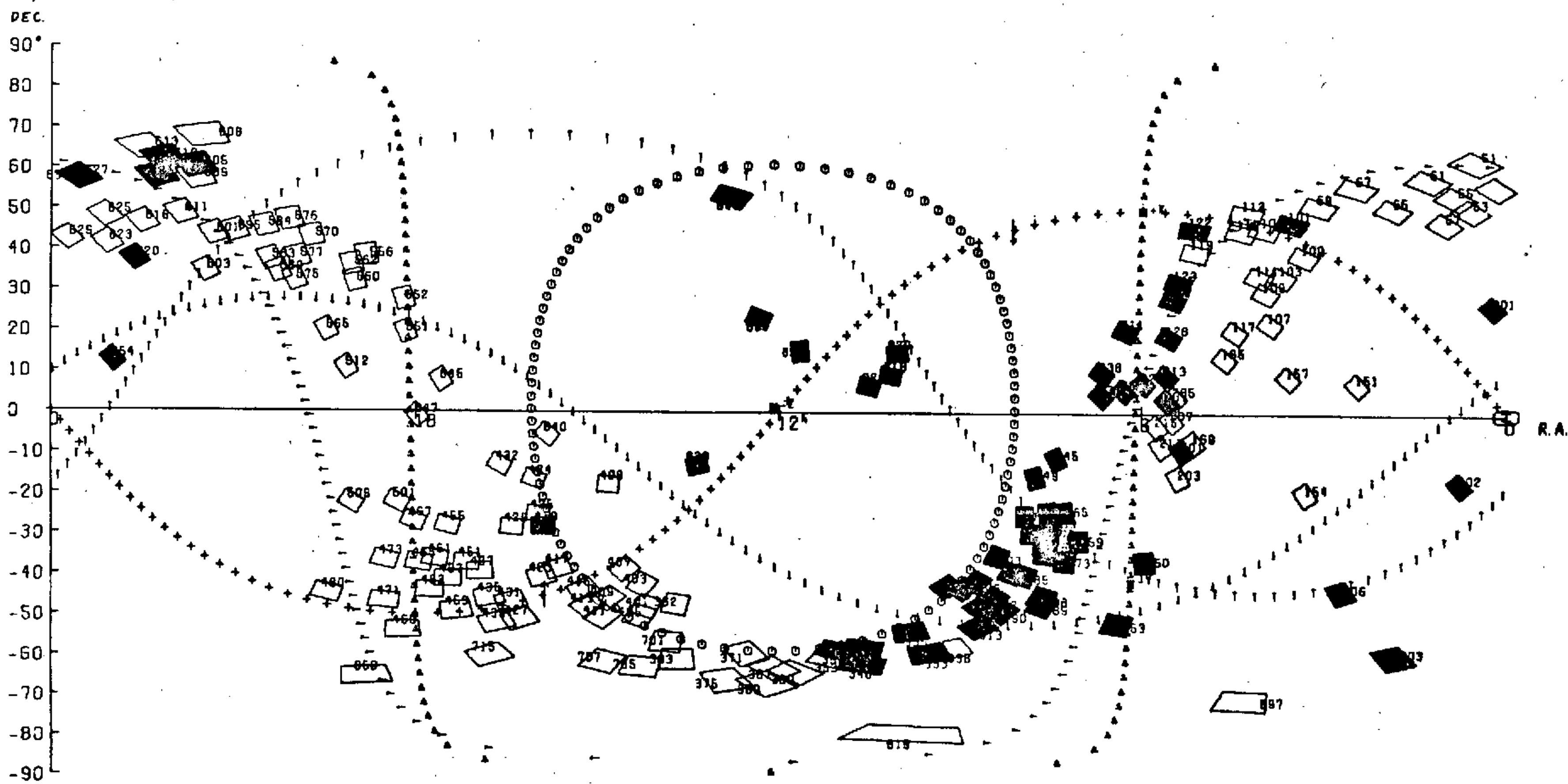
UV Observations of Comet Kohoutek

FIGURE CAPTIONS

Figure 1. SKY DISTRIBUTION OF ALL FIELDS PHOTOGRAPHED BY SKYLAB EXPERIMENT S019.

Figure 2. RECTIFIED UV SPECTRA OBTAINED BY SKYLAB EXPERIMENT S019. These representative spectra have been processed and rerecorded on photographic film using a PDS 1010 Microdensitometer operating with a PDP-8/e computer. Many, but not all, of the fainter lines are real.

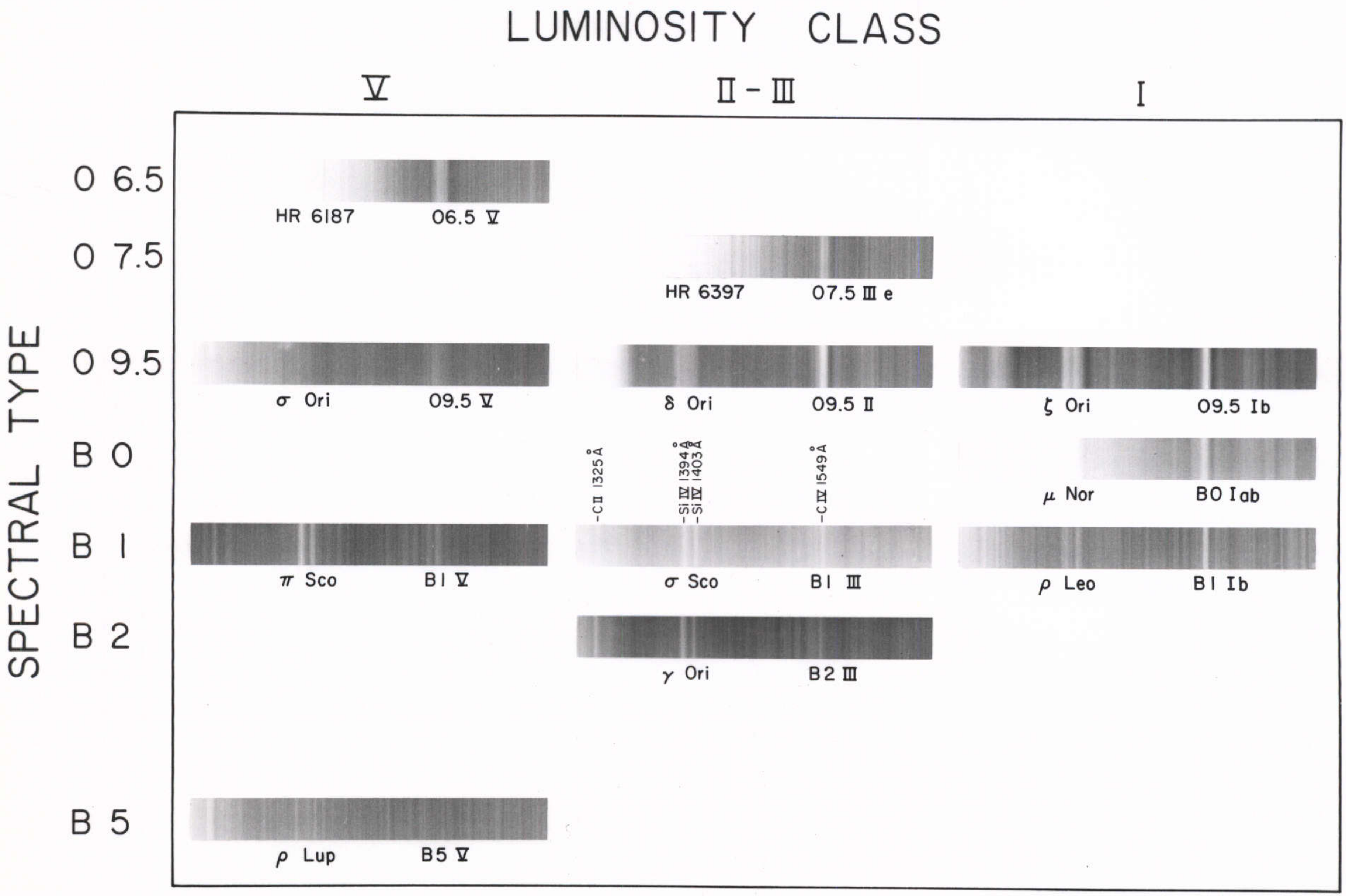
Figure 3. OBJECTIVE-PRISM IMAGES OF COMET KOHOUTEK OBTAINED BY SKYLAB EXPERIMENT S019.
From right to left the dates and exposure times are: 13 December (200 sec), 16 December (270 sec), 7 January (400 sec), 8 January (500 sec), and 11 January (720 sec). Several stellar spectra appear on the exposure taken on 16 December. The star directly below the comet, π Scorpio, was occulted by the comet five hours later. The double image of the nucleus on the first three dates is probably due to the separation of the OH λ3090 image from the remainder of the blue-violet radiation.

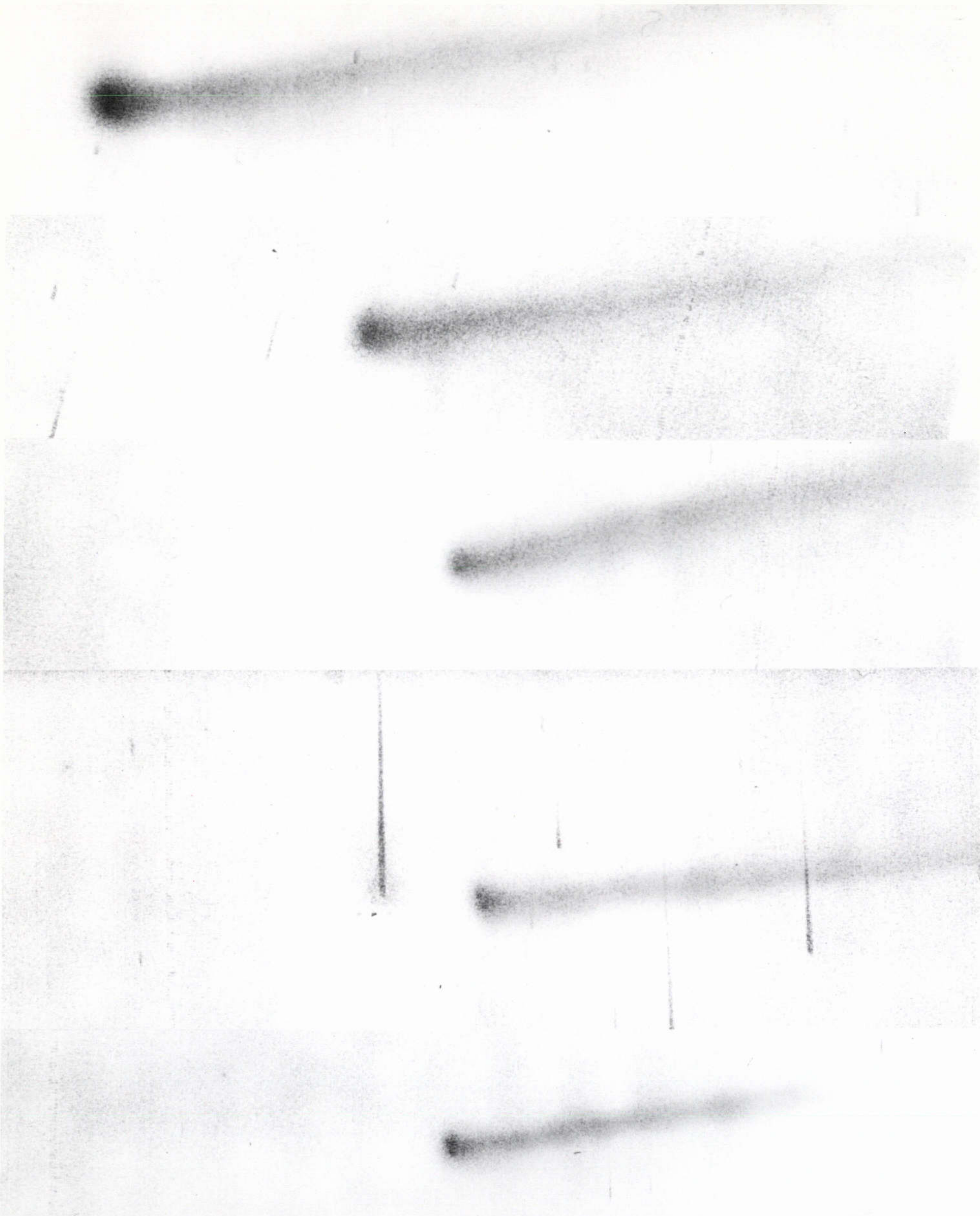


SKY DISTRIBUTION OF ALL FIELDS PHOTOGRAPHED BY SKYLAB EXPERIMENT S019

Fields photographed during SL4 are shown in black.

Fields are superposed on a sky visibility plot for 23 September. The zone between O's and Δ's is the zone observable with the Articulated Mirror System on that date. + indicates the orbit plane projected on the celestial sphere while ↓ ← ↑ denote the earth horizon at orbital sunset, midnight and sunrise respectively.


LUMINOSITY CLASS
V
II - III
I
SPECTRAL TYPE
O 6.5
O 7.5
O 9.5
B 0
B 1
B 2
B 5
HR 6187 O6.5 V
HR 6397 O7.5 III e
σ Ori O9.5 V
δ Ori O9.5 II
ζ Ori O9.5 Ib
μ Nor B0 Iab
-C II 1325 Å
-Si IV 1394 Å
-Si IV 1403 Å
-C IV 1549 Å
π Sco B1 V
σ Sco B1 III
ρ Leo B1 Ib
γ Ori B2 III
ρ Lup B5 V



Appendix A

Catalogue of S019 Exposures During SL4

Frame	Date	F.C.#	Field	Expo.	Measured Center (1950) α	δ	Remarks
001	11/25/73	003	122	270	5^h06^m	+ 47°.7	
002	"	003	"	90		"	smudge
003	"	003	101	270	3 12	+ 50.9	smudge
004	"	003	"	90		"	
005	"	003	KOH	900U	13 09	- 17.2	
005A	11/26/73	003	265	90	0 38	- 15.8	blank
006	"	003	265	270	0 38	- 15.8	smudge, ROT off +100°
007	"	003	249	270U	7 38	- 15.2	smudge
008	"	003	271	270	7 22	- 24.1	smudge
009	"	003	"	90	7 22	- 24.8	
009A	"	003					blank
010	12/4/73	003	302	90	8 22	- 47.7	
011	"	003	269	270	7 17	- 27.5	
012	"	003	"	90		"	
013	"	003	"	270U		"	
014	"	003	275	270	7 19	- 29.7	
015	"	003	"	90	7 19	- 29.7	
016	"	003	283	270	7 45	- 25.2	
017	"	003	"	90		"	
018	"	003	259	270	6 51	- 32.0	smudge
019	12/7/73	003	823	270	11 47	+ 15.2	smudge
020	"	003	830	90	13 22	- 10.7	atm. ext.
021	"	003	"	30		"	
022	"	003	KOH	300U	14 25	- 21.8	(fogged)
023	12/8/73	003	620	90	22 25	+ 38.0	(out of focus)
024	"	003	854	270	22 50	+ 13.8	"
025	"	003	"	90		"	"
026	"	003	803	270	1 33	- 58.9	"
027	"	003	"	90	1 33	- 58.9	"
028	"	003	"	30		"	"

Frame	Date	F.C.#	Field	Expo.	Center (1950) α h m	δ °	Remarks
029	"	003	281	270	7 41	- 29.6	"
030	"	003	"	90		"	"
031	"	003	820	270	10 05	+ 16.7	"
032	"	003	"	90		"	"
033	"	003	818	90	10 04	+ 12.2	"
034	"	003	"	270		"	"
035	"	003	"	30		"	"
036	12/12	002	620	270	22 26	+ 38.8	
037	"	002	"	90		"	
038	"	002	854	270	22 54	+ 14.3	
039	"	002	276	270	7 28	- 32.8	
040	"	002	"	270U		"	
041	"	002	281	270	7 38	- 30.1	
042	"	002	821	270	10 30	+ 8.7	
043	"	002	"	90		"	
044	"	002	818	90	10 07	+ 11.3	
045	"	002	"	30		"	
046	"	002	"	30		"	
047	12/13	002	213	270	5 30	+ 10.7	
048	"	002	"	90		"	
049	"	002	128	90	5 28	+ 20.6	
050	"	002	KOH	120U	15 20	- 24.3	fogged, started before comet ri: total 253 sec.
051	12/14	002	209	90	5 28	+ 4.5	
052	"	002	127	270	5 25	+ 30.5	
053	"	002	408	90	14 52	- 14.9	
054	"	002	KOH	180U	15 34	- 24.0	
055	"	002	"	30U		"	

Frame	Date	F.C.#	Field	Expo.	Center (1950) α	δ	Remarks
056	12/16	002	004=221	180U	5^h48^m	+ 9°.5	
057	"	002	KOH	270U	15 54	- 25.3	fogged
058	12/17	002	KOH	270	15 55	- 26.7	fogged
059	12/19	002	221	270	5 54	+ 9.0	
060	"	002	811	270	6 12	+ 22.6	Saturn
061	"	002	"	270U		"	
062	"	002	237	270	6 33	+ 6.4	
063	"	002	"	270U		"	
064	"	002	238	270	6 33	+ 11.6	
065	"	002	"	90		"	
066	"	002	KOH	230U	(16 30	- 26)	fogged
067	12/20	002	801	270	0 06	+ 27.8	
068	"	002	"	90		"	
069	"	002	"	30		"	
070	"	002	605	270	21 25	+ 60.7	smudge
071	"	002	"	90		"	
072	"	002	303	270	8 13	- 35.1	
073	"	002	302	270	8 16	- 46.6	
074	"	002	"	90		"	
075	"	002	"	30		"	
076	"	002	318	270	8 48	- 44.7	
077	"	002	"	270U		"	
078	12/20	002	614	270	22 00	+ 59.1	
079	"	002	"	90		"	
080	"	002	612	270	21 34	+ 63.4	
081	"	002	279	270	7 24	- 35.1	
082	"	002	273	270	7 04	- 37.2	
083	"	002	"	90		"	

Frame	Date	F.C.#	Field	Expo.	Center (1950) α	δ	Remarks
084	"	002	313	270	8^h31^m	- 54°.3	
085	"	002	"	90		"	
086	"	002	253	270	6 09	- 52.6	
087	"	002	"	90		"	
088	12/24	002	201	90	5 12	- 7.6	
089	"	002	"	30		"	
090	"	002	219	270*	6 12	+ 7.2	(fogged), TILT off +17°
091	12/30	003	627	270	23 19	+ 58.6	
092	"	003	"	90		"	
093	"	003	285	270	7 45	- 40.8	(fogged)
094	"	003	"	90		"	
095	"	003	328	270	9 04	- 43.9	
096	"	003	"	90		"	
097	"	003	335	270	9 45	- 56.1	
098	"	003	"	90		"	smudge
099	"	003	"	270U		"	
100	"	003	293	270	7 56	- 40.5	
101	"	003	"	30		"	
102	"	003	"	1/2)90		"	
102A	–	003	614	270U		—	blank
103	12/30	003	806	360U	2 29	- 42.6	
104	12/30	003	828	90	12 54	+ 51.3	all off ~4°
105	"	003	"	30		"	
106	"	003	827	270	12 24	+ 21.2	smudge (fogged)
107	"	003	"	270U		"	smudge
108	"	003	288	270	7 26	- 46.3	
109	"	003	"	90		"	
110	"	003	289	270	7 26	- 48.3	

* resembles very short U expo.; according to transcript, it may have been terminated after about 10 sec.

Frame	Date	F.C.#	Field	Expo.	Center (1950) α	δ	Remarks
111	"	003	289	90	7^h26^m	- 48°.3	
112	"	003	309	270U	8 08	- 50.2	(fogged)
113	"	003	319	270U	8 33	- 42.6	
114	1/5/74	003	KOH	270U	(20 20	- 16 :)	fogged
115	"	003	245	270	7 16	- 10.5	
116	"	003	"	270U		"	
117	"	003	265	270	7 06	- 24.0	
118	"	003	"	90		"	
119	"	003	"	270U		"	
120	"	003	270	90	7 19	- 25.7	
121	1/5	003	250	270U	5 45	- 36.5	
122	"	003	303	270U	8 12	- 36.9	
123	"	003	309	270U	8 29	- 49.1	
124	1/7	003	KOH	400U	20 58	- 14.0	fogged, Venus
124A	"	003	"	100U		—	blank
125	"	003	352	300U	11 05	- 60.6	fogged
126	"	003	"	30		"	
127	1/8	003	KOH	500U	21 04	- 13.4	fogged
128	"	003	"	70U		"	
129	"	003	333	270	9 25	- 61.4	
130	"	003	"	90		"	
131	"	003	352A =341	270U	10 45	- 60.3	
132	"	003	346	270	10 40	- 64.2	fogged
133	"	003	"	90		"	
134	1/11	003	KOH	720U	21 47	- 7.5	(fogged)

TsF 138

atm. ext. - indicates spectra are affected by atmospheric extinction

(fogged) - indicates plate has narrow streak of fog, or general fog greater than normal

fogged - indicates plate has heavy fog, but images usable

fogged - indicates plate has severe fog, images not usable