

ULTRAVIOLET PHOTOMETRY OF STARS OBTAINED WITH THE CELESCOPE EXPERIMENT IN THE ORBITING ASTRONOMICAL OBSERVATORY

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Abstract. We have used the television photometers in the Telescope OAO experiment to measure the far ultraviolet brightnesses of several thousand stars, including parts of the constellations Draco, Lyra, Puppis, Vela, Taurus, and Orion; and the Moon. As of this date (22 July 1969), three of our four cameras continue to operate satisfactorily, and we are making measurements in additional star fields distributed throughout the sky. Our shortest wavelength band, which includes the Lyman α line of atomic hydrogen, provides information on the Earth's outer atmosphere, as well as on star brightnesses. The intensity of the Lyman α radiation from the geocorona is a maximum when the Sun is near the horizon as seen by the OAO, and a minimum when the Sun is in the nadir. The direction that the telescope points does not much affect the measured intensities.

Because of the heavy logistic problems of identification, calibration, and measurement for so many stars and because of the survey character of the program, the scientific interpretation of the results is, as expected, lagging the measurement program. However, one consistent picture beginning to emerge from our data is that our observed stars are about equally divided between those that fall within 0.5 magnitude of the predicted ultraviolet brightnesses and those that are significantly fainter than predicted. Most of the giant stars we observe exhibit these ultraviolet deficiencies. Since some of these giants are stars for which little or no interstellar reddening is predicted, we attribute the observed deficiencies to the stars themselves.

Many of the objects we observe do not have accurate ground-based published data regarding magnitude, color, and spectral type; new ground-based observations of these objects are required to ensure satisfactory interpretation of our results.

1. Introduction

The Telescope experiment consists of four ultraviolet television photometers, each with an aperture of 31 cm, mounted in the Orbiting Astronomical Observatory (OAO). These cameras produce pictures, 3° square, in four spectral regions: U1, extending from 2200 to 3200 Å; U2, 1600 to 3200 Å; U3, 1350 to 2000 Å; and U4, 1050 to 2000 Å. A complete description of the instrumentation appears in Smithsonian Astrophysical Observatory Special Report No. 282, 18 July 1968.

Since launch on 7 December 1968, the Telescope experiment has taken 3652 pictures, in 1276 different directions, covering approximately 6% of the sky. Most of these observations are within 20° of the galactic plane; however, we have taken enough pictures at high galactic latitude to confirm our expectation that very few objects at high latitudes are brighter than our limit of 9th magnitude at spectral type A0. Near the north galactic pole, we detected about 1 star for every 3 sets of pictures (1 star per 12 square degrees), whereas near the Orion nebula, we measured 20 stars per picture, and in the galactic plane in Vela, we measured 50.

Each Telescope picture consists of 256 lines, each of which contains 251 picture elements. The Telescope instrumentation encodes the signal amplitude in each ele-

ment to 7-bit accuracy. Although Telescope is capable of other modes of picture transmission, these modes have not yet been used for the collection of scientific data. These pictures, recorded on magnetic tape at both the data-acquisition station and the central control center, are re-formatted by NASA's data-analysis center and processed on Smithsonian Astrophysical Observatory's CDC-6400 computer to provide identification and ultraviolet magnitudes for the stars observed. A detailed description of these analysis techniques will appear in Smithsonian Astrophysical Observatory Special Report No. 310, scheduled for publication later this year.

We will publish these Telescope observational results in a series of Telescope Observational Data Reports, which will be regularly distributed to all institutions and individual scientists who request them from the Publications Division, Distribution Section, Smithsonian Astrophysical Observatory, Cambridge, Mass. 02138. Our preliminary review of the pictures and of the resultant data indicates that for nearly every object we have observed, the ultraviolet brightness can be reasonably explained on the basis of atmospheric theory and interstellar reddening. We have, therefore, concentrated our attention on compiling and refining our observational results, postponing the scientific interpretation to a later date. The remainder of this paper is an example of one set of Telescope pictures, typical of the more than one thousand such sets obtained to date.

2. Sample Telescope Observational Data Report

Telescope observations are obtained only by live video transmission from the OAO to one of five ground stations: Madagascar (M); Orroral, Australia (O); Quito, Ecuador (Q); Rosman, North Carolina (R); and Santiago, Chile (S). Such transmission can occur only during a 'contact' or 'pass' of the satellite over the station. Contacts are identified by a letter designating the station and a number indicating the number of times the satellite has crossed the ascending node of its orbit. During a contact, the Telescope experiment may transmit video data of one or more exposures. The first of these exposures may precede arrival of the OAO over the station.

The reports are divided into sections, one for each contact. The first page of each section is a 'data sheet' listing the conditions under which the exposures were made. If there are more than three exposures, subsequent exposures are listed on a second page. On this data sheet, right ascension and declination are given for the Telescope optic axis in current-epoch coordinates. Magnetic coordinates are based on an approximate magnetic coordinate system whose north pole is at geographic latitude $78^{\circ}3$ N and longitude $69^{\circ}0$ W; magnetic hour angle is measured eastward from the sun; beta angle is the distance of the target from the Sun. Roll (direction to the north celestial pole) is measured clockwise from the left end of the filter split line. The directions to zenith, magnetic pole, and Sun are measured counterclockwise from the left end of the filter split line, as indicated by the horizontal lines in the plots and pictures.

The most important parameters of Telescope operation are exposure time and

operating mode, which control sensitivity and noise level, respectively. Normally, the exposure time is set at 60 sec and the operating mode is set at pulse code modulation (PCM). Blank entries indicate which, if any, cameras were not used.

Status at estimated time of arrival (ETA) lists the less important parameters of operation. Special Report 310 describes these entries in full.

Following the data sheet for each contact are charts, pictures, and numerical data for each exposure. The picture presents the video data exactly as recorded on the magnetic data tape, free from any processing other than that necessary to convert the magnetic data into printed picture. It can thus be used both to assess image quality and to serve as orientation while the numerical data are studied. The small plot, to the same scale as the picture, indicates rough brightnesses and positions for all stars found in the picture and the position of the filter split line. Star-like objects evident in the picture but missing from the small plot include noise pulses, the signal from the calibrator lamp, permanent target blemishes, and stars too near the edge of the field to allow proper analysis of the data. These objects are indicated on the large plot, as described in the paragraph below.

The large plot identifies the star-like images in the picture and cross references them to the data listing. Numbers refer to stars; letters refer to other star-like objects in the picture: C for calibrator lamp; G for ghosts of the calibrator lamp; F for target blemishes ('false stars'); N for noise pulses; and X for objects more than $1\frac{1}{4}$ from the optical axis. Asterisks refer to merged images for double stars that are seen as separate objects on some, but not all, cameras. These reports list numerical data only for the numbered objects and for those represented by asterisks.

Ultraviolet brightnesses and identifications are presented in the observational data listing following the pictures and identification charts for each exposure. Objects are listed and assigned identification numbers in order of increasing right ascension. For each object, the first line summarizes ground-based data, and subsequent lines list the Telescope observational data, one line per camera. If the Telescope identification catalog contains more than 10 literature references for an object, a second line is used for printing additional reference numbers.

The information is listed as follows:

ID	Identification number.
HD	<i>Henry Draper Catalogue</i> number, or variable star name.
DM	Durchmusterung number or IC/NGC number.
R.A.	Right ascension (1950.0).
DEC.	Declination (1950. 0).
MAGNITUDES AND MCODE	Magnitudes (M1, M2, M3), and magnitude code describing same. The preferred set of magnitudes (V , $B-V$, $U-B$) is assigned a magnitude code of 1. Refer to CDL-100 for other code assignments.
SP	Spectral type.
L	Luminosity class.

Station ID Ororal		Orbit No. 692	Date 24 January 1969	First Exposure	Second Exposure	Third Exposure
Target	Universal time	12 : 60				H, M
Target	Right ascension	5 : 30 : 25		0 : 0	0 : 0 : 0	H, M, S
	Declination	-5 : 16 : 45		0 : 0 : 0	0 : 0 : 0	DEG, M, S
Target	Roll	283		0	0	DEG
Target	Zenith distance	33		0	0	DEG
Target	Azimuth	325		0	0	DEG
	Direction to zenith	255		0	0	DEG
Target	Magnetic polar distance	106		0	0	DEG
Target	Magnetic hour angle	9 : 17		0 : 0	0 : 0	H, M
	Direction to magnetic pole	106		0	0	DEG
	Beta angle	130		0	0	DEG
Solar	Zenith distance	122		0	0	DEG
Solar	Azimuth	209		0	0	DEG
	Direction to sun	343		0	0	DEG
Satellite	Latitude	-33		0	0	DEG
Satellite	Longitude	142		0	0	DEG
Satellite	Magnetic latitude	-43		0	0	DEG
Satellite	Magnetic hour angle	10 : 48		0 : 0	0 : 0	H, M
	Distance to illumination	528		0	0	KM
	Height of illumination	1223		0	0	KM
Camera 1	Exposure time	5				SEC
	OP mode	PCM				
Camera 2	Exposure time					SEC
	OP mode					
Camera 3	Exposure time	5				SEC
	OP mode	PCM				
Camera 4	Exposure time	5				SEC
	OP mode	PCM				

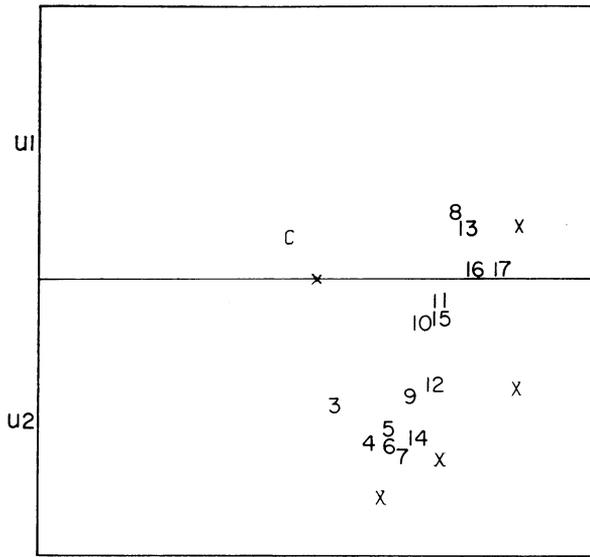
Status at E.T.A.

Bay E-4	OP Mode	Thresh	Temp	+6V	+18V	-12V	+28V	ADC	HBC	VBC	HO	VO
	OFF	6	+28.6	A +6.10	A +18.0	A -12.2	+28.0	A	A	A	A	A
Temperature												
	CAM	UVICON	CAL	SWP	LAMP	FIL	EXP	MODE	FOCUS	BEAM	ASTIG	
Camera 1				A	OF	ON	OF	HV	2	2	4	
Camera 2	-35.1		-43.0	A	OF	ON	OF	HV	2	1	4	
Camera 3		-17.3		A	OF	ON	OF	HV	2	3	4	
Camera 4	-31.3	-16.6	-42.1	A	OF	ON	OF	HV	2	1	4	

Comments

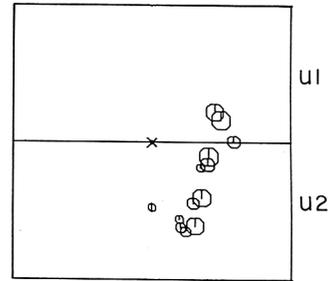
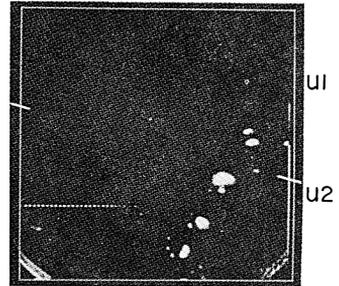
- (1) On camera 4, the over-exposed image of object no. 11 is merged with the images of object no. 10 and object no. 15, and exceeds the brightness range of accurate calibration. This image appears through the U4 filter. The combined light of these objects exceeds a U_4 magnitude of -2.5 .
- (2) Object no. 18 appears in the extreme right-hand edges on cameras no. 1 and 3, but its image is truncated by the scanning raster so that no accurate brightness could be determined.

RIGHT ASCENSION: 05^h 30^m 25^s
DECLINATION : -05° 16' 45"
ROLL : 283°

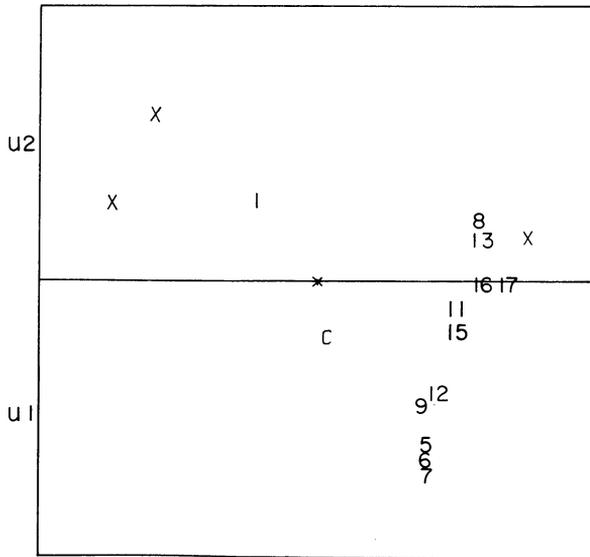


A097- 3 , 0 692

CAMERA 1

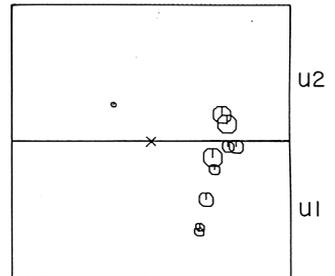
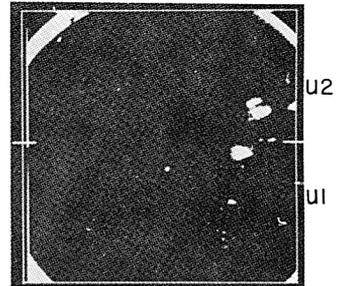


A097- 3 , 0 692



A097- 4 , 0 692

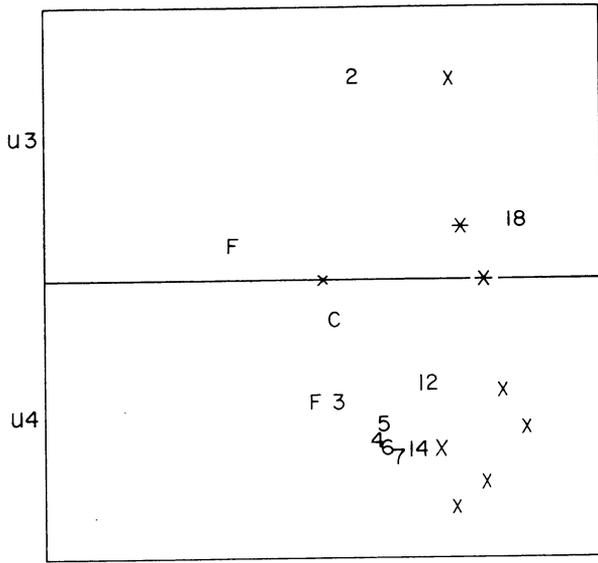
CAMERA 3



A097- 4 , 0 692

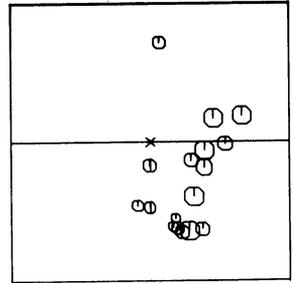
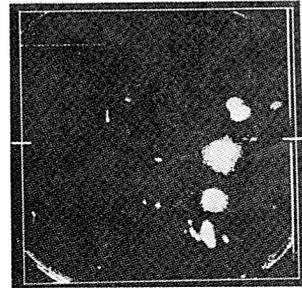
Fig. 1.

RIGHT ASCENSION: $05^{\text{h}} 30^{\text{m}} 25^{\text{s}}$
 DECLINATION : $-05^{\circ} 16' 45''$
 ROLL : 283°



A097- 5 , 0 692

CAMERA 4



A097- 5 , 0 692

Fig. 2.

1950.0			MAGNITUDES			REFERENCES/					
ID HD	DM	R.A.	DEC.	SP L	6-----7-----8	CAM U	FIL NUM	CODES	TAPE	FM	CON
			AND MCODE								
1	36120	--5 1269 5	26 42 --5 49.8	7.96	--.03 --.36 1 B8	A	R A19 897 898				
1		5 26 42	--5 49.8				3P 11.94 2 3	00 0A	A097	4	0 692
2	36430	--6 1207 5	28 55 --6 44.7	6.22	--.17 --.74 1 B2V	S	R A19 840 898 20	36	259	901 884 2 13	
2		5 28 55	--6 44.7				897 4P 10.56 3 19	00 0A	A097	5	0 692
3	36629	--4 1164 5	30 29 --4 36.0	7.65	.02 --.66 1 B2V	P	R A19 A 7 2 898	36	340	897	
3		5 30 29	--4 36.0				1P 9.73 2 9	00 0A	A097	3	0 692
3		5 30 29	--4 36.0				4P 10.88 4 8	00 0A	A097	5	0 692
4	36842	--4 1168 5	31 57 --4 23.6	8.09	--.11 --.51 1 B9	A	R A19 404 898 897	756			
4		5 31 57	--4 23.6				1P 10.62 2 5	00 0A	A097	3	0 692
4		5 31 57	--4 23.6				4P 11.58 4 22	01 0A	A097	5	0 692
5	36865	--4 1171 5	32 3 --4 31.2	7.40	--.07 --.43 1 B9	A	R A19 404 898 897				
5		5 32 3	--4 31.2				3P 10.32 1 13	00 0A	A097	4	0 692
5		5 32 3	--4 31.2				1P 9.49 2 7	00 0A	A097	3	0 692
5		5 32 3	--4 31.2				4P 11.90 4 23	01 0A	A097	5	0 692
6	36883	--4 1172 5	32 15 --4 25.5	7.22	--.08 --.47 1 B8		A19 897				
6		5 32 15	--4 25.5				3P 10.02 1 14	00 0A	A097	4	0 692
6		5 32 15	--4 25.5				1P 8.61 2 18	01 0A	A097	3	0 692
6		5 32 15	--4 25.5				4P 10.49 4 21	01 0A	A097	5	0 692
7	36936	--4 1176 5	32 30 --4 23.2	7.52	--.11 --.58 1 B8		A19 897				
7		5 32 30	--4 23.2				3P 9.94 1 15	00 0A	A097	4	0 692
7		5 32 30	--4 23.2				1P 8.52 2 4	01 0A	A097	3	0 692
7		5 32 30	--4 23.2				4P 10.06 4 20	01 0A	A097	5	0 692
8	36959	--6 1233 5	32 34 --6 2.5	5.67	--.22 --.90 1 B1V	V	R A19 12 897 884	898	259	629 20 756 158	
							699 783 36 921 2				

950.0	MAGNITUDES				REFERENCES/															
	D HD	DM	R.A.	DEC.	SP L	6-----7-----8	P	R	CAM U	FIL NUM CODES	TAPE	FM	CON							
8	36960	-6 1234 5	32 36	-6 2.0	4.78	-0.25	-1.01	1	B0V	P S	V	P	R	A19	12	897 884	898 259	629	158 699	20
8		5 32 36	36	-6 2.1									IP	36	756	921 13	2			
8		5 32 36	36	-6 2.1									3P	IP	5.17	1 16	00 0A	A097	3	0 692
8	also	5 32 36	36	-6 2.1									4P	3P	5.96	2 4	01 0A	A097	4	0 692
9	KX ORI	-4 1179 5	32 37	-4 45.8	7.40				3 B3V			P	2	A 7	898 259	340 B97				
9		5 32 37	37	-4 45.8									3P	10.54	1 12	00 0A	A097	4	0 692	
9		5 32 37	37	-4 45.8									1P	7.87	2 19	01 0A	A097	3	0 692	
10	36981	-5 1311 5	32 38	-5 14.3	7.82	-0.11	-0.59	1	B8	P S	V	A	897	314	898 A19	36				
10		5 32 38	38	-5 14.3									1P	9.62	2 11	00 0A	A097	3	0 692	
11	37020	-5 1315 5	32 49	-5 25.3	6.73	.02	-0.88	1	B0V		V	P	P	A19	2	884 901				
11	37021	-5 1315 5	32 49	-5 25.3	8.10			6	B3		V	Y	884	901						
11	37022	-5 1315 5	32 49	-5 25.3	5.13	.02	-0.95	1	O6	P	V	P	P	A R	A19 901	897 884	898 350	474	12	13
11	37023	-5 1315 5	32 49	-5 25.3	6.70	.09	-0.71	1	B0V		V	P	883	2	895 314	883 756	895			314
11	Theta	-1 5 32 49	49	-5 25.3	4.60	.02	-0.90	1	O8		V		A19							
11	IC/NGC1976	5 32 52	52	-5 25.0	4.00			6			E		R	A09	975	695 940				
11	37041	-5 1319 5	32 56	-5 26.8	5.07	-0.09	-0.94	1	O9V	P	V	Y	P	R	A19 895	699 921	756 884	897	898 340	350
11	37042	-5 1319 5	32 56	-5 26.8	6.38	-0.09	-0.93	1	B1V	P	V	Y	P	R	A19 895	699 921	756 884	897	898 340	350
11		5 32 52	52	-5 25.1									629	901	764 2	12 13	336			
11		5 32 52	52	-5 25.1									3P	2.50	1 8	00 0A	A097	4	0 692	
11		5 32 52	52	-5 25.1									1P	2.40	2 20	01 0A	A097	3	0 692	
12	37018	-4 1185 5	32 55	-4 52.2	4.59	-0.20	-0.93	1	B2III	S	V	Y	P	R	A19 783	897 756	921 898	36	377 785	2
12		5 32 55	55	-4 52.2									884	12	901 13	212 158				
12		5 32 55	55	-4 52.2									3P	7.55	1 11	00 0A	A097	4	0 692	
12		5 32 55	55	-4 52.2									1P	4.96	2 8	01 0A	A097	3	0 692	

1950.0		MAGNITUDES AND MCODE										REFERENCES/				
ID HD	DM	R.A.	DEC.	MAGNITUDE	MCODE	SP L	6-----7-----8	ES	USV	P	CAM U	FIL NUM	CODES	TAPE	FM	CON
12		5 32 55	-4 52.2								4P	7.07	4 7 10 0A	A097	5	o 692
13	37043	-6 1241 5	32 59 -5 56.5	2.76	-.25-1.07	I	o9III			P	A19	699	158 793 7 921	891	934 10	2
13		5 32 59	-5 56.5								9	12 13 336	377 765	766	785 882	895
13		5 32 59	-5 56.5								1P	4.19	1 15 00 0A	A097	3	o 692
13		5 32 59	-5 56.5								3P	4.38	2 16 01 0A	A097	4	o 692
13	also	5 32 36	-6 2.1								4P	4.80	3 15 00 0A	A097	5	o 692
14	37017	-4 1183 5	32 53 -4 31.5	6.54	-.14-.78	I	B1V			P	R A19	12 897 756	898 36	901	2 884	13
14	37016	-4 1184 5	32 54 -4 27.3	6.23	-.16-.68	I	B3V	S	V	P	A19	897 901 2 13 884	839	839	756	
14	37040	-4 1186 5	33 2 -4 23.7	6.30	-.15-.68	I	B3		V	P	R A19	13 897 36 2 901	840	884 898		
14		5 33 2	-4 23.8								1P	5.31	2 3 00 0A	A097	3	o 692
14		5 33 2	-4 23.7								4P	6.15	4 3 01 0A	A097	5	o 692
15	NU ORI	5 33 4	-5 11.0							J	969					
15		5 33 4	-5 11.4								3P	9.22	1 9 00 0A	A097	4	o 692
15		5 33 4	-5 11.4								1P	6.90	2 10 01 0A	A097	3	o 692
16	37115	-5 1330 5	33 26 -5 38.9	7.06	-.08-.57	I	B6V	EN			314	342 898 260	A 7 A19			
16		5 33 26	-5 38.9								1P	9.36	1 13 00 0A	A097	3	o 692
16		5 33 26	-5 38.9								3P	8.79	2 6 00 0A	A097	4	o 692
16	ALSO	5 33 48	-5 40.8								4P	9.59	3 14 00 0A	A097	5	o 692
17	37150	-5 1334 5	33 48 -5 40.7	6.54	-.19-.80	I	B3V			P	A19	13 898 756	897 901	835	884 2	
17		5 33 48	-5 40.7								1P	7.45	1 12 00 0A	A097	3	o 692
17		5 33 48	-5 40.7								3P	7.67	2 7 00 0A	A097	4	o 629
17	ALSO	5 33 48	-5 40.8								4P	9.59	3 14 00 0A	A097	5	o 692
18	37209	-6 1255 5	34 9 -6 5.7	5.70	-.24-.91	I	B1V	S	V	P	R A19	897 756 898	259 36	901	884 13	2
18		5 34 9	-6 5.7								839					
18		5 34 9	-6 5.7								4P	7.62	3 17 00 0A	A097	5	o 692

6...7...8	Special characteristics and peculiarities. Refer to CDL-100 for code assignments.
REFERENCES/	References to original publications of the data. CDL-100 contains the bibliography. References are listed in the same columns used to report the Telescope observational results.
CAM	Camera number and operation mode; P is for direct PCM mode, A for analog mode, and S for store mode.
U	Ultraviolet magnitude: $U = -2.5 \log I$, where I is the measured intensity in MKS units (watts m^{-3}).
FIL	Filter number.
NUM	An identification number by which the computation for each object can be traced and verified.
CODES	Five columns describing the quality of the data. The first column describes the background in the vicinity of the object: codes 0 and 2 are normal background; 1 and 3 indicate unreliable data because of high background surrounding the object. The second column describes the relationship of the object to the filter split line; codes greater than or equal to 2 indicate unreliable data because of proximity to the filter split line. The third and fourth columns indicate general picture quality, larger numbers indicating poorer quality. The fifth column is a letter indicating which calibration table was used for data reduction. Special Report 310 includes a complete description of these quality codes.
TAPE, FM	Tape number and frame number by which the supporting data can be located in the Telescope files.
CON	Contact designation.

Discussion

Henize: I understand that you find the excess UV radiation of θ Ori to originate, at least partially, in the Orion nebula. Could you say whether your observation of η Car relates to the star itself or to its surrounding nebula?

Davis: The observation of η Car does not have sufficient resolution to determine definitely whether the observed UV comes only from the star, or partly from the nebula. However, I believe it is best interpreted as including an important contribution from the nebula.

Morton: Does the Orion nebula appear bright in all your wavelength bands?

Davis: Yes.

Malaise: When will Telescope data be released and how will it be made available?

Davis: Telescope data will be released in regular reports (Telescope Observational Data Reports), beginning in about two months. Any scientist wishing to receive these reports should write to the Publications Division, Distribution Section, Smithsonian Astrophysical Observatory, Cambridge, Mass. 02138, USA, requesting that he be placed on the mailing list.