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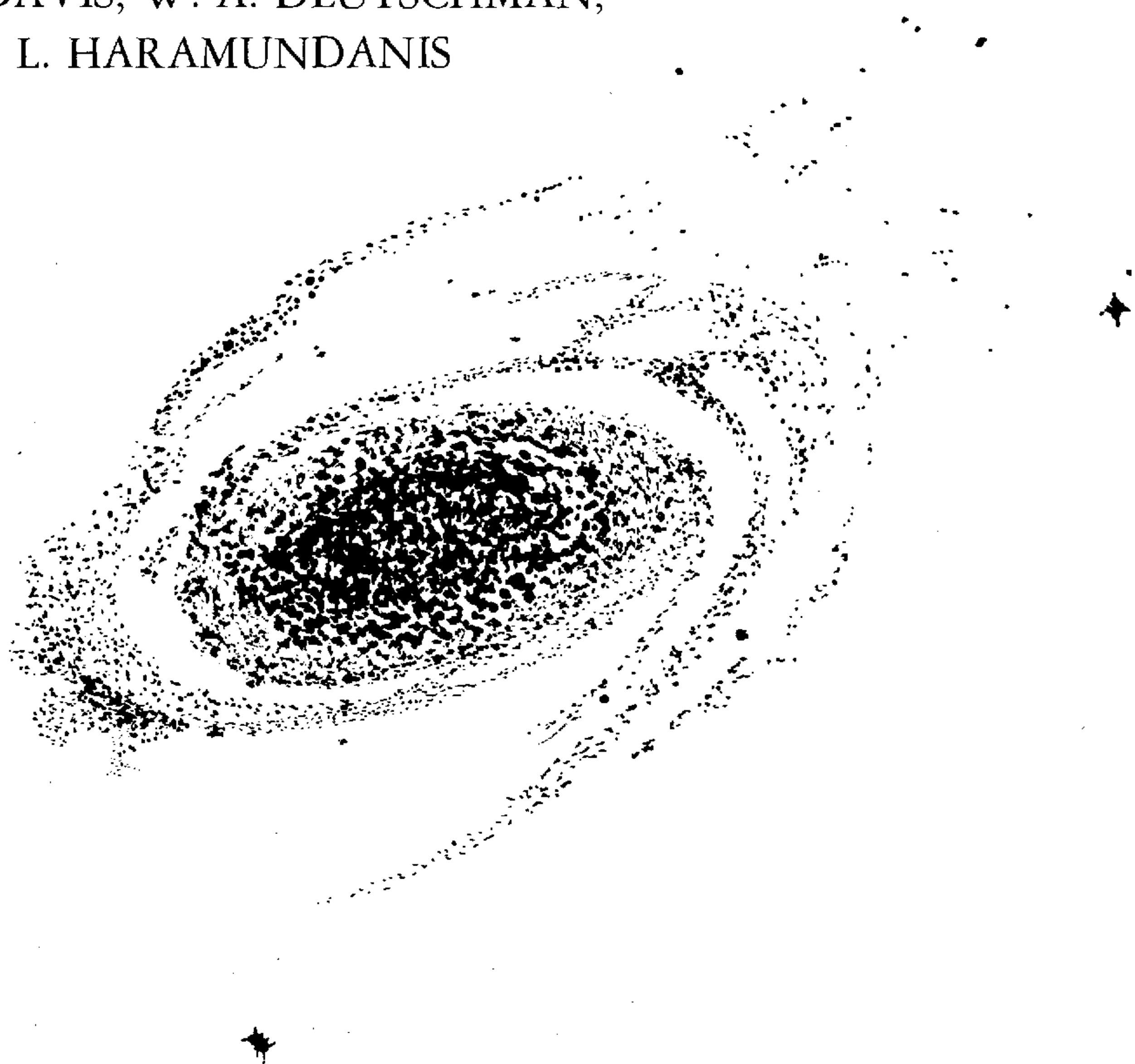
CELESCOPE CATALOG OF ULTRAVIOLET STELLAR OBSERVATIONS

MAGNETIC TAPE VERSION

R. J. DAVIS, W. A. DEUTSCHMAN,
and K. L. HARAMUNDANIS



Smithsonian Astrophysical Observatory
SPECIAL REPORT 350

Research in Space Science
SAO Special Report No. 350

MAGNETIC TAPE VERSION

CELESCOPE CATALOG OF ULTRAVIOLET STELLAR OBSERVATIONS

5068 Objects Measured by the Smithsonian Experiment
Aboard the Orbiting Astronomical Observatory (OAO-2)

Robert J. Davis, William A. Deutschman, and Katherine L. Haramundanis

May 3, 1973

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FOREWORD

This Special Report is being issued for use in conjunction with the magnetic-tape version of the Celescope Catalog of Ultraviolet Observations. It contains the same information about the experiment as does the printed version of the Catalog, published by the Smithsonian Institution Press (1973); in addition, it describes the magnetic-tape format (Section 7) and a collection of programs (Sections 8 and 9) written to manipulate the data on the magnetic tape. These programs, available with the tape, provide an easy method for extracting data from the tape.

The tape version of the Catalog is issued to make the Celescope data readily available for computer analysis. It contains all the data included in the printed version as well as all the individual measurements of each star. We hope that this introductory material and program descriptions will facilitate the use of the magnetic-tape version of the Celescope Catalog of Ultraviolet Observations.

PREFACE

This volume represents another step in man's long journey to the stars. It is the first catalog of the heavens as they appear in ultraviolet light – a catalog that would have been impossible 15 years ago, for the data contained here were gathered by a satellite in space above the restricting limits of the earth's atmosphere.

This Catalog is based on more than 8000 ultraviolet television pictures taken by the special Uvicon cameras of Project Celescope, the Smithsonian Astrophysical Observatory's experiment aboard the extraordinarily successful Orbiting Astronomical Observatory (OAO-2) launched by the National Aeronautics and Space Administration on December 7, 1968. During 16 months of routine operation, Celescope observed approximately 10% of the entire sky, including 20% of the region near the Milky Way, where the majority of ultraviolet stars are found. The final Catalog created from this mass of raw data lists, for each of 5068 stars, the ultraviolet magnitude, as well as the position, spectral type, and other astrophysical information, including cross references to ground-based literature.

The evolution of Project Celescope from its initial conception in the early years of the Space Age to the launching in 1968 and the subsequent publication of this Catalog is long and arduous. The original plan for Celescope was formally proposed to the National Academy of Sciences in 1958, even before the establishment of NASA. The concept called for an ultraviolet-sensitive television tube to be used in conjunction with an optical system operating in the very far ultraviolet. The telescope would be mounted in a relatively simple satellite, and its pictures would be telemetered to ground-based astronomers. Even with the simplicity of the original idea, Celescope still required several advances in state-of-the-art technology, such as the development of an image tube sensitive from the near ultraviolet to the lithium fluoride transmission limit at 1050 Å.

In addition, the project demanded high-quality ultraviolet filters for this wavelength and the nearer regions of the ultraviolet, advanced guidance and control systems only then becoming available for rockets, the creation of short-term memory units so that the telemetered data could be read out conveniently at ground stations, and elaborate data-processing techniques for assimilating the vast numbers of data gathered by this satellite.

The unusual requirements at the start of the Project only increased with time. The growth of the Celescope Project from one to four telescopes and the increasing need for more refined techniques throughout all phases created a demand for engineering innovation far beyond the scope of the original concept. For example, as ultraviolet stellar observations from rocket-borne telescopes were analyzed, it became clear that the hot stars were generally an order of magnitude less luminous in the very far ultraviolet than had been anticipated from earlier theory. This meant that the tube manufacturer had to increase image sensitivity so that the final system would (and did!) match early expectations regarding the number of stars observable. At the same time, the increased number of camera tubes required for both testing and operation necessitated a complete change in the method of tube production. All these technical changes and developments were matched by rapid administrative and operational changes in NASA, reflecting in part the great public interest and the support of the national space program.

The Smithsonian's concept of a single telescope and simple spacecraft evolved into the Orbiting Astronomical Observatory program — a series of increasingly sophisticated platforms for space astronomy. Thus, when Celescope finally rocketed above the atmosphere on December 7, 1968, it was aboard the largest, heaviest, and most highly instrumented unmanned spacecraft launched until that time.

Of course, the end results of this often frustrating, sometimes heartbreaking, and always challenging adventure make it all — even the frustrations — seem worthwhile. The combined Smithsonian Celescope Project and Wisconsin Experiment Package on OAO-2, and the Princeton Experiment on board OAO-3, have created a new field: ultraviolet astronomy. The Celescope Catalog of Ultraviolet Stellar Observations is destined to be a valuable tool for future research in this field, both from space and from the ground. Naturally, the Catalog will be used as a finding source for objects of especial interest to observers. Already, Celescope data have helped identify a group of stars in the constellation Orion that are anomalously bright in the ultraviolet; and ground-based observations of these same stars have both confirmed the space observations and helped revise old estimates of stellar temperatures.

The data contained in these pages will be particularly useful to theoreticians constructing models of the hot, rapidly evolving stars that seem to emit most of their light in the ultraviolet band of the spectrum. A companion volume, Blanketed Model Atmospheres for Early-Type Stars, presents, in both tabular and graphical form, theoretical flux distributions as well as visual and ultraviolet magnitudes for stars of given effective temperature and surface gravity. These theoretical models are the most realistic ever produced, incorporating the statistical effects of over one million spectral lines. The calculated magnitudes can be used in a number of ways to interpret the Celescope Catalog data and to determine the physical properties of observed stars.

The Celescope Catalog of Ultraviolet Stellar Observations is helping to open a new window on the universe.

Cambridge, Massachusetts
October 4, 1972

Fred L. Whipple
Director
Smithsonian Astrophysical Observatory

ABSTRACT

During the 16 months that the Celescope Experiment operated, it took 8000 frames of data. This report describes the experiment, the data it gathered, the format of the magnetic tape containing the data, and a number of programs that were written to read and manipulate the tape. The tape version of the Catalog contains data on 5068 stars and is available from the National Space Sciences Data Center.

RESUME

Pendant les seize mois que dura l'expérience Célescope 8.000 images de données ont été prises. Ce rapport décrit l'expérience, les données rassemblées, la structure de la bande magnétique contenant les données et un nombre de programmes qui furent écrits pour lire et manipuler la bande. Le catalogue sous forme de bande magnétique contient des données sur 5068 étoiles et peut être obtenu au Centre National de l'Information pour la Science Spatiale.

КОНСПЕКТ

За последние 16 месяцев работы опыта Селескоп им было получено 8000 кадров данных. Этот доклад описывает опыт, полученные данные, формат записи на магнитную ленту содержущую данные и число программ которые были составлены для считывания данных и манипуляций ленты. Записанный на магнитную ленту вариант каталога содержит данные о 5068 звездах и может быть получен от Государственного центра данных космических наук.

CELESCOPE CATALOG OF ULTRAVIOLET STELLAR OBSERVATIONS

R. J. Davis, W. A. Deutschman, and K. Haramundanis

1. INTRODUCTION

This Catalog contains the observational results obtained by the Celescope Experiment during the first 16 months of operation of NASA's Orbiting Astronomical Observatory (OAO-2). It lists the results of the stellar observations, along with selected ground-based information obtained from the available literature. Lunar observations (Ahmad and Deutschman, 1972), as well as other analyses of the data, are being published as separate papers.

These data are available in three forms:

A. This magnetic tape and the necessary utility programs for reading and printing the contents of the tapes.

B. A printed catalog transcribed from the magnetic-tape catalog: It is available from the Government Printing Office.

C. A microfilm of the Catalog printed in each of five different sorts with the standard printing package.

This magnetic-tape version contains not only the compiled results as printed here but also the results of the individual observations from which these averaged data were compiled.

2. THE INSTRUMENTATION

Since detailed descriptions of the OAO and Celescope instrumentation are available elsewhere (e.g., Davis et al., 1972), we include here only information directly relevant to the user of this Catalog.

The Orbiting Astronomical Observatory (OAO-2) containing the Celescope Experiment was launched 7 December 1968 into a nearly circular orbit, 800 km above the earth's surface, with a 35° inclination. The Observatory (Figure 1) is octagonal in shape (2 m across, 3 m high) and weighs 2000 kg. The OAO allows us to point the Celescope photometers in the desired direction to an accuracy of 1 arcmin with a stability of 15 arcsec. The Celescope Experiment by the Smithsonian Astrophysical Observatory (SAO) and the Wisconsin Experiment Package by the University of Wisconsin make up this Observatory.

Celescope consists of two major integrated units: the Optical Package and the Bay E-4 electronic module assembly. The Celescope Optical Package contains four 12-inch Schwarzschild telescopes, each of which images a star field onto the ultraviolet-sensitive photocathode of a television image tube (Uvicon). Figure 1 shows how these telescopes and the electronic system are mounted. The field of view of each photometer is determined by the active area of the image-tube photocathodes and the area of the target scanned by the readout beam. The projected

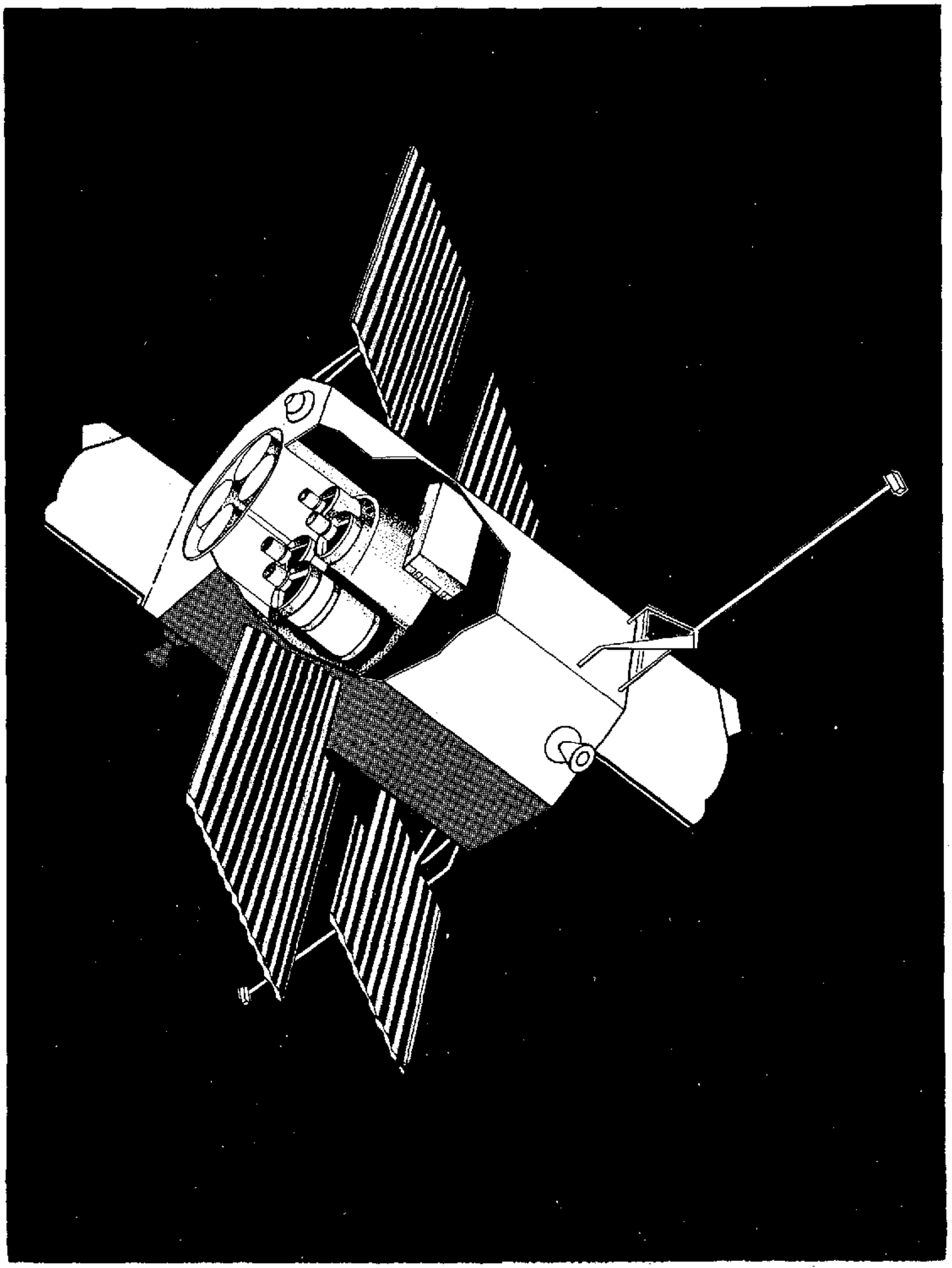

Figure 1. OAO spacecraft with cutaway showing the Celescope Experiment.

angular area is 2°8 × 2°8. Each field is optically split into two areas of different spectral sensitivity by mounting two different semicircular filters in front of each Uvicon. Further spectral selectivity is achieved by using two types of Uvicons, each with a different photocathode material. The resulting spectral responses are shown in Figure 2 and summarized in Table 1. The video signal developed by the readout of these tubes is amplified and supplied to an electronic data-processing system (Bay E-4 module assembly), which encodes the television pictures into a digital pulse train that indicates signal amplitude as a function of television line and element number for each of the four cameras. These digitized television pictures are transmitted via the OAO communications system to a receiving station in NASA's Satellite Tracking and Data Acquisition Network and eventually sent on magnetic tapes to SAO in Cambridge, Massachusetts.

3. THE DATA-PROCESSING SYSTEM

Each frame of data that arrives at SAO is first checked for quality and then sent through the automatic data-processing system. That system is divided into four basic sections: In the first, a program separates the star from the background signals in the frame and computes each star's frame coordinates and amplitude. The second section uses the final calibration data to calculate the observed magnitude for each star in the picture. The third identifies the stars in a frame or frames by matching them with a positional catalog of early-type stars prepared before launch.

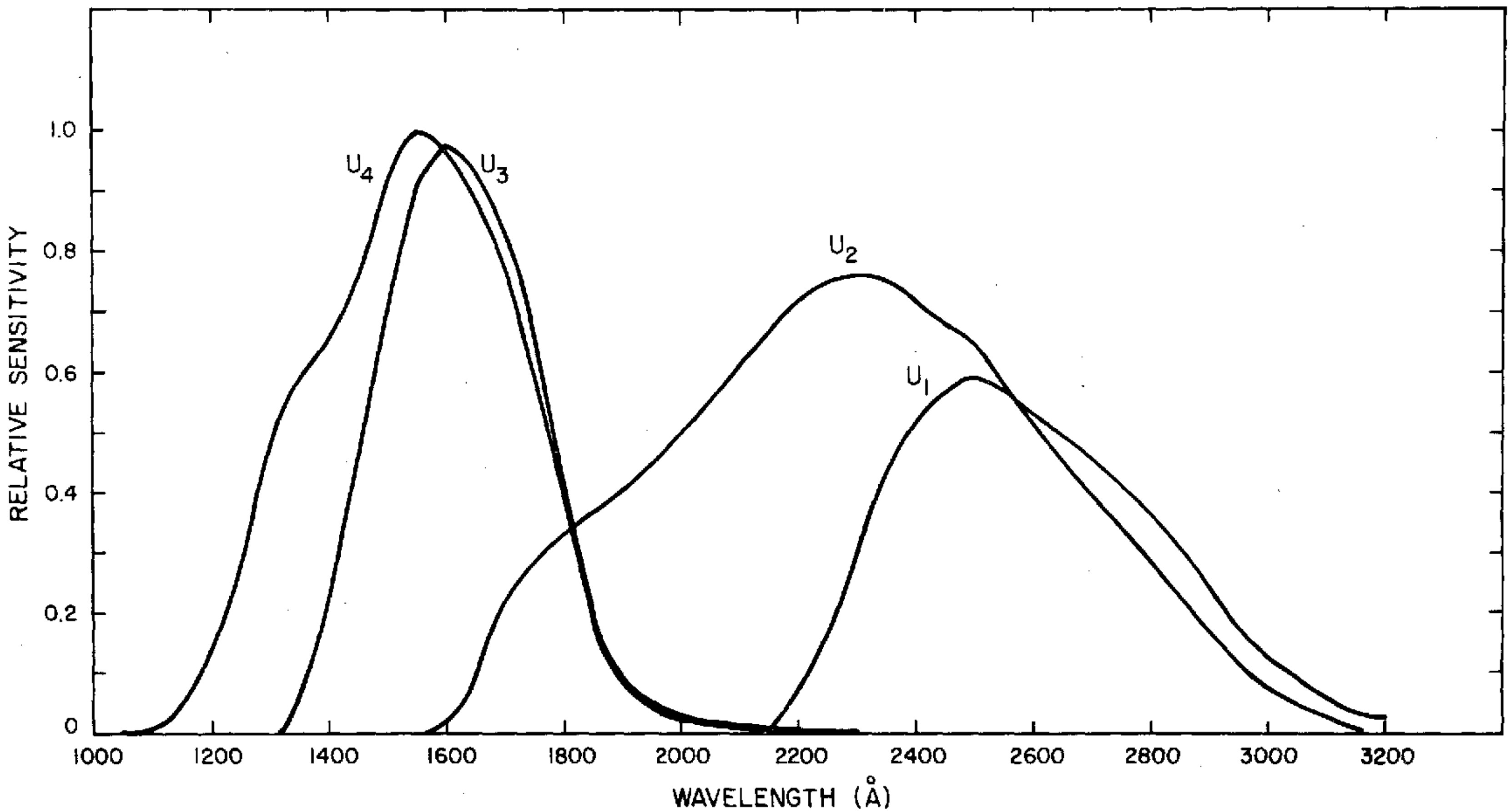

Figure 2. Relative spectral response of the filters.

Table 1. Relative sensitivity of the filters for each wavelength. *

Wavelength (Å)	Relative sensitivity			
	U1	U2	U3	U4
1050				1.455 -3
1100				1.018 -2
1150				5.081 -2
1200				1.463 -1
1250				2.779 -1
1300				4.765 -1
1350			6.879 -2	5.925 -1
1400			2.328 -1	6.555 -1
1450			4.565 -1	7.644 -1
1500			6.951 -1	9.151 -1
1550		8.979 -4	9.177 -1	1.000
1600		1.670 -2	9.760 -1	9.646 -1
1650		9.984 -2	9.390 -1	8.848 -1
1700		2.188 -1	8.327 -1	7.566 -1
1750		2.806 -1	6.535 -1	5.769 -1
1800		3.313 -1	4.053 -1	3.753 -1
1850		3.719 -1	1.941 -1	1.924 -1
1900		4.103 -1	8.114 -2	8.306 -2
1950		4.497 -1	5.051 -2	4.453 -2
2000		4.956 -1	3.329 -2	2.817 -2
2050		5.571 -1	2.201 -2	1.853 -2
2100		6.170 -1	1.451 -2	1.261 -2
2150	1.649 -2	6.608 -1	9.328 -3	7.968 -3
2200	6.748 -2	7.191 -1	5.878 -3	5.122 -3
2250	1.792 -1	7.452 -1	3.441 -3	2.788 -3
2300	3.028 -1	7.592 -1	1.610 -3	1.428 -3
2350	4.305 -1	7.509 -1		
2400	5.161 -1	7.165 -1		
2450	5.675 -1	6.769 -1		
2500	5.946 -1	6.472 -1		
2550	5.633 -1	5.789 -1		
2600	5.300 -1	5.227 -1		
2650	4.973 -1	4.690 -1		
2700	4.538 -1	4.106 -1		
2750	4.095 -1	3.615 -1		
2800	3.650 -1	3.194 -1		
2850	3.046 -1	2.563 -1		
2900	2.378 -1	1.928 -1		
2950	1.763 -1	1.329 -1		
3000	1.300 -1	9.145 -2		
3050	9.255 -2	6.222 -2		
3100	6.394 -2	4.085 -2		
3150	3.887 -2	2.335 -2		
3200	2.772 -2			

*The negative integers indicate the power of 10.

The last section adds further information, such as UBV magnitudes from the Naval Observatory Photoelectric Catalogue (Blanco et al., 1968), and checks the internal consistency of the data. These sections are described below.

In the first section, we assume that the stars are relatively sharp spikes on a smooth background and that any group of intensity points significantly above the background represents a star. The program (Deutschman, 1970) computes a "significance level" for each filter half of the frame, first by using a least-squares technique to fit the background equation $I.B. = A + Bk^4 + Ck^2 + Dk + Ek^2\ell + Fk\ell + Gk\ell^2 + H\ell + I\ell^2 + J\ell^4$ to every fifth intensity point k on every fifth line ℓ and then by adding 2.5 times the standard deviation of the fit to the background equation at each raster point. All intensities greater than or equal to the significance level are signal; all others are background noise. Then all contiguous points greater than or equal to the significance level are grouped into objects. Finally, the program calculates the center of intensity of the star, subtracts the calculated background from the individual points, and adds the results. On the basis of the shape of the object and the density of points in it, the program then decides whether it is a star, an object that may be either a star or noise, or merely noise.

Some objects contain more than 4000 points or are large and amorphous with $n < (\Delta k \, \Delta\ell)/c$, where n is the number of points in the object, Δk and $\Delta\ell$ are the maximum vertical and horizontal dimensions of the object, and c is an empirical constant (=3). These are flagged as questionable and require manual review. Any object that has less than four contiguous points in one of the configurations

```
XX    XX      X
XX     XX    XXX
              X
```

or a rotational permutation of these is classified as noise and automatically rejected. Objects that have a net intensity less than 25 in camera 1, 22 in camera 3, or 19 in camera 4 are also classified as noise. (Camera 2 was damaged before orbit number 400 and provided no data for this Catalog.)

The second section of the data-processing system calculates observed magnitudes by using the calibration parameters for each camera/filter combination, the frame position and intensity calculated by the first section, and pertinent satellite data (e.g., temperature and exposure time). The calibration model is described elsewhere (Deutschman, 1972a) and will not be discussed further here. The actual calibration parameters are described in this and other reports.

The third section matches the stars observed by Celescope with known catalog stars, using a configuration-matching program to compute the right ascensions and declinations of the stars. A number of contiguous pictures may be matched at the same time to improve reliability. Using this program, we were able to identify automatically about 60% of our observations. Visual matching of the BD, CD, or CPD charts with plots of our observations allowed us to identify the remaining objects.

We reconstructed the television image as a picture and produced a small plot to the scale of the Durchmusterung charts – which is the same as that of the Bečvář Atlases (Bečvář, 1962) – to facilitate this matching step. Figure 3 (not to scale) shows

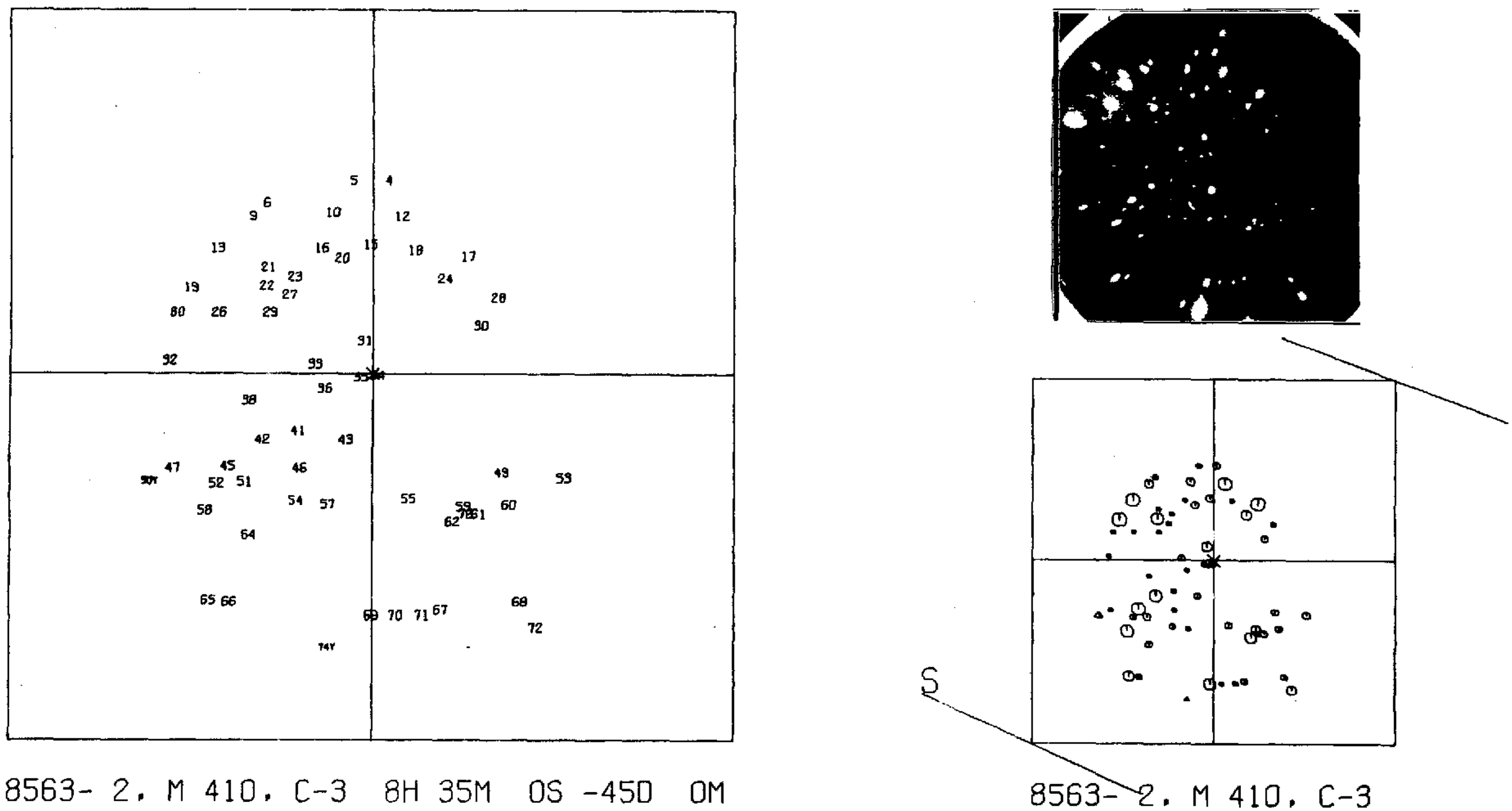

Figure 3. A sample identification plot and picture.

these plots and pictures of one Celescope data frame. The large-scale plot was used to identify the objects by the numbers assigned them by our signal-processing program. The results of the computer program were in most cases verified by our manual procedure of overlaying these plots on the appropriate Durchmusterung charts, with additional reference to the Bečvář Atlases where necessary.

The final stage of our system adds further ground-based data and checks our data for internal consistency. All the Celescope magnitudes of a star were compared, and any large discrepancies were manually checked. Configurations of stars were checked for consistency, and all manually separated stars were reexamined. Finally, the individual observations were compiled in the Celescope Catalog of Ultraviolet Stellar Observations.

4. EXPERIMENT CALIBRATION

Extensive prelaunch calibration procedures determined the basic transfer function of the experiment. These procedures are fully documented by Davis (1968) and Green (1970). In brief, a calibrated artificial star field established the positional sensitivity of the Uvicons. The filters were calibrated separately, and the results were mathematically combined with the gains of the amplifiers in Bay E-4 into the total system calibration. The experiment was then routinely monitored with nearly monochromatic calibration lamps to detect any changes before launch.

Before we launched the experiment, we realized the need for in-orbit calibration and planned to take data for it. The least we could expect was a decay in sensitivity with time; but because of the 2 years between the component calibration and the launch, we also made plans to check the positional calibration in orbit. After the first month of operational checkout, we began systematically to gather data for this task. The data gathered and their use are described by Deutschman (1972b); only the time-decay analysis of the experiment will be repeated here.

The time decay of the system would be most easily determined if the same stars were observed at the same positions on the target at regular intervals. Because of sun, power, and thermal constraints, this was impossible with our experiment, but we did observe a number of standard star fields as often as practical. Three star fields were used as primary calibration areas; one of the three fields was observed at least once during every operating period.

We determined the time-decay history of each camera/filter combination by requiring that each star have a unique magnitude at time zero. Its magnitude calculated from data at any later time will increase if the system decays. (Magnitudes are defined as -2.5 log (power); hence, lower power signals have larger magnitudes.) We therefore assumed that

$$M(t{=}0) = M(t_1) - \sum_{1}^{n} A_n t_1^n \quad ,$$

where $\sum A_n t_1^n$ is the camera sensitivity function in magnitudes. Because the corrected magnitude for each star is required to be invariant, observations at times t_1 and t_2 give the following:

$$M(t{=}0) = M(t_1) - \sum_{1}^{n} A_n t_1^n = M(t_2) - \sum_{1}^{n} A_n t_2^n \quad ,$$

and hence,

$$M(t_1) - M(t_2) = \sum_{1}^{n} A_n\left(t_1^n - t_2^n\right) .$$

When solved with a least-squares technique for all pairs of stars, this set of equations defines the coefficients A in the decay equation for the system.

The standard calibration-area data and all chance repeats greater than 20 orbits apart were used in these fits. Other data were not used, because they reflect area sensitivity changes and isolated frame shifts rather than time decays.

Figure 4 shows the resulting curves for the three cameras that we used for acquiring scientific data. The amount of correction in magnitudes is plotted versus the orbit number. The orbit numbers are discontinuous because we shared experiment time with the University of Wisconsin.

We defined the zero point for the Celescope ultraviolet magnitude system by specifying the values of U1, U2, and U3 to be assigned as the mean observed Celescope magnitudes for one star selected specifically for this purpose. The relationship between U3 and U4 was based on our prelaunch calibration of the Celescope Experiment against laboratory standards. We were unable to use the prelaunch calibration data to establish the relationships between the other Celescope colors, or between the Celescope magnitude system and absolute physical units, because the sensitivity of each camera changed rapidly during the first 700 orbits.

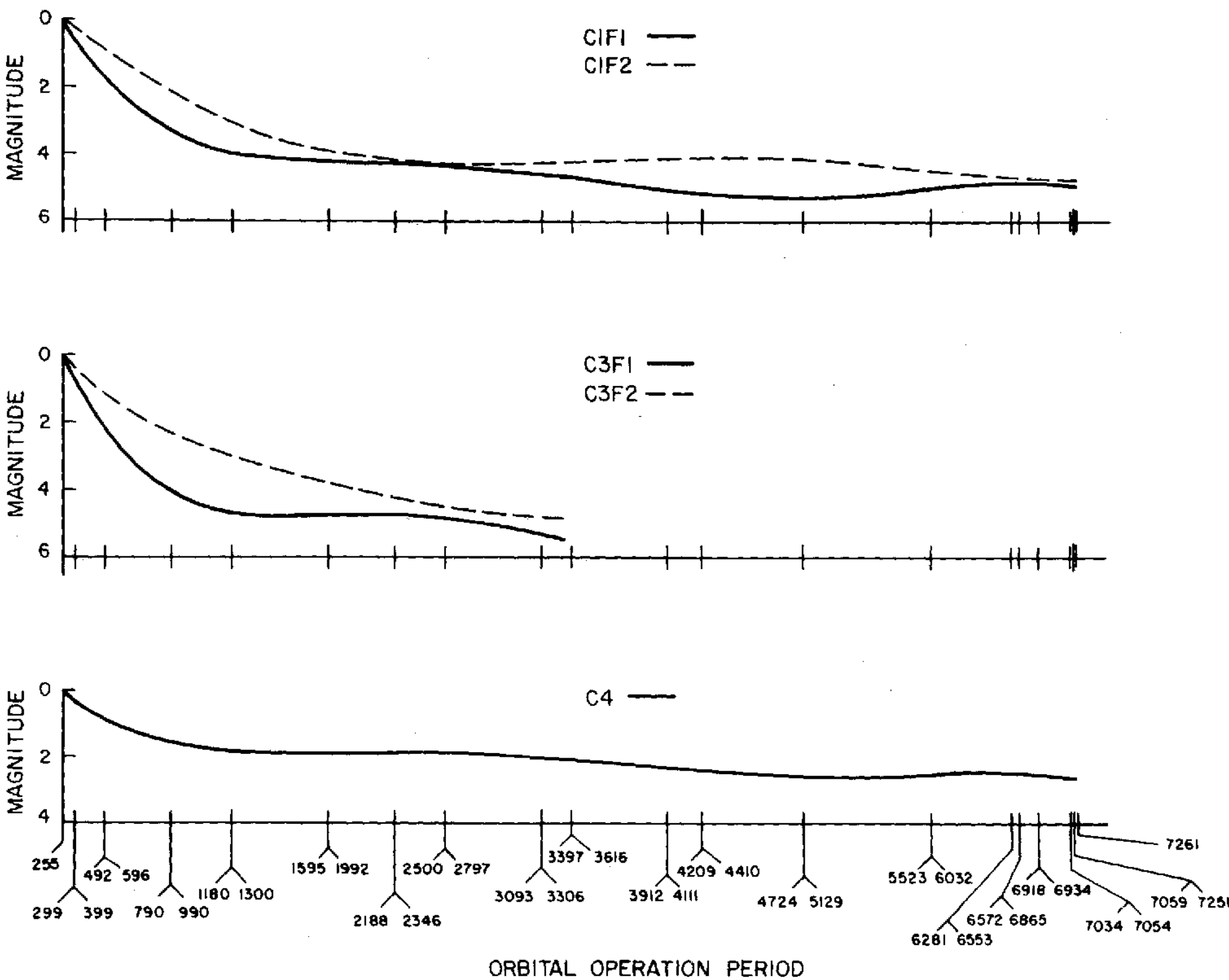

Figure 4. Relative sensitivity of the cameras vs. orbital operation period.

We chose CD -44°4704 and assigned the following magnitudes to it:

U1 = 9.44

U2 = 9.19

U3 = 9.56 .

This star was selected since it had been observed repeatedly by Celescope from orbits 400 to 6233 and also by the Wisconsin OAO experiment. The magnitudes assigned were originally determined by comparing preliminary Celescope data for several slightly reddened stars of luminosity classes III, IV, and V with theoretical values based on the Smithsonian grid of model atmospheres and preliminary Celescope reddening parameters. Our later decision to use a single star as a calibration standard eliminated the problem of reproducing and intercomparing our standard with those of other observers.

5. STATISTICAL SUMMARY

The Celescope Catalog of Ultraviolet Stellar Observations has been compiled from 13,646 observations of 5068 stars. Their areal distribution in equatorial and galactic coordinates is illustrated in Figures 5 and 6. Ultraviolet magnitudes in the U1 passband are available for 17% of the stars, in the U2 passband for 60%, in the U3 passband for 66%, and in the U4 passband for 6%. Figure 7 shows the distribution in magnitude for each of the magnitude types. The root-mean-square difference for all observations in each filter is as follows:

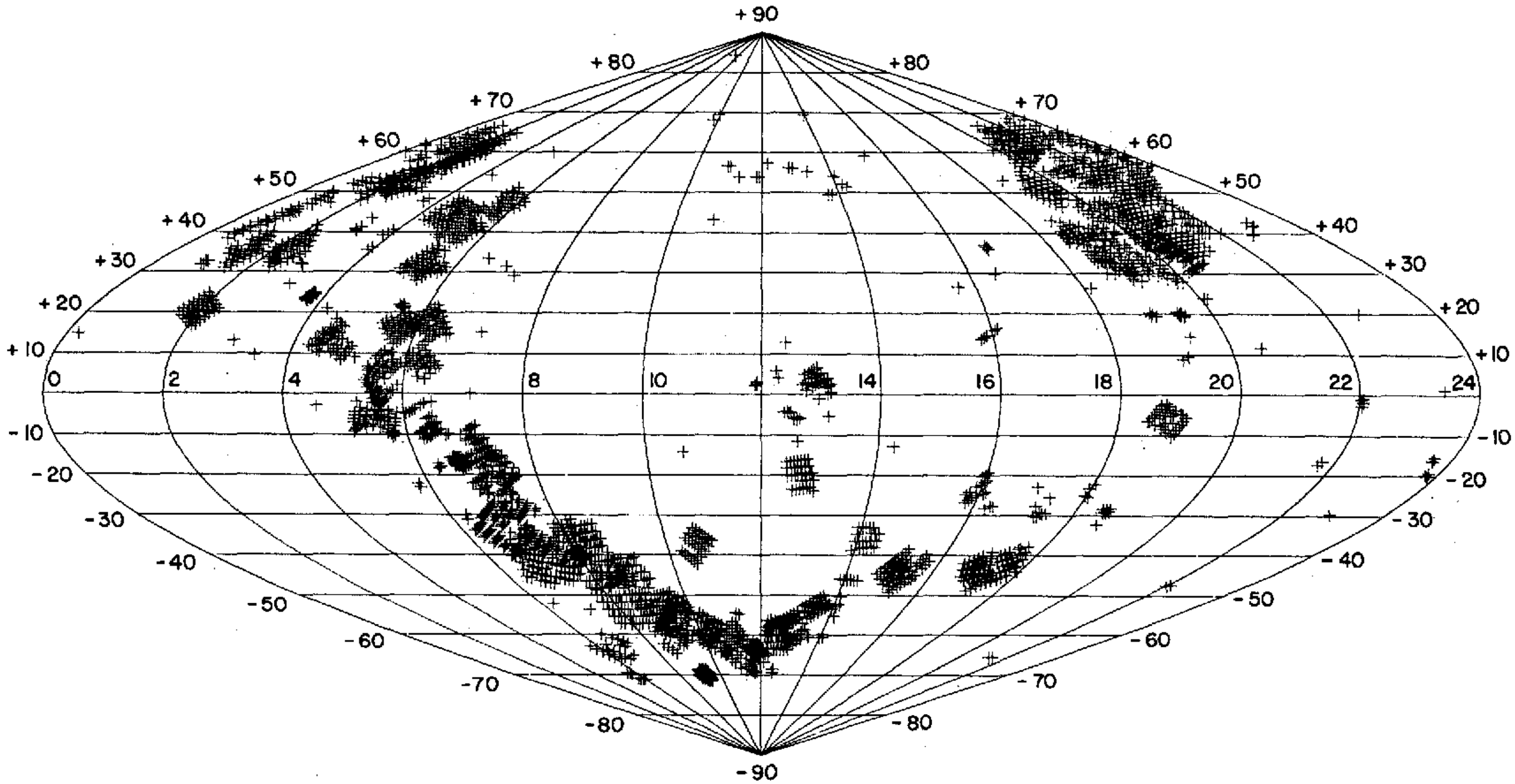

Figure 5. Plot in right ascension and declination of the exposures taken by Celescope.

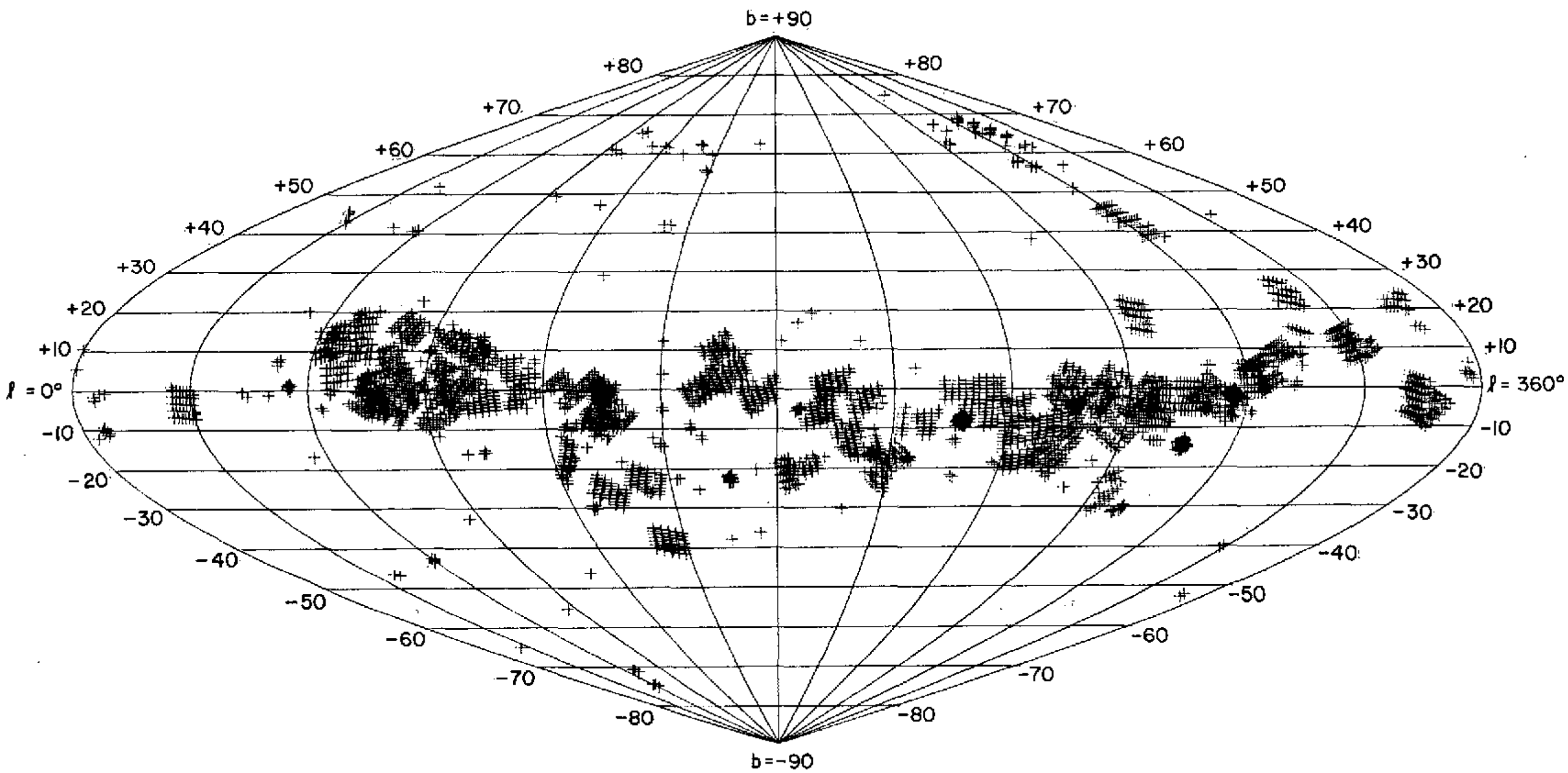

Figure 6. Plot in galactic coordinates of the exposures taken by Celescope.

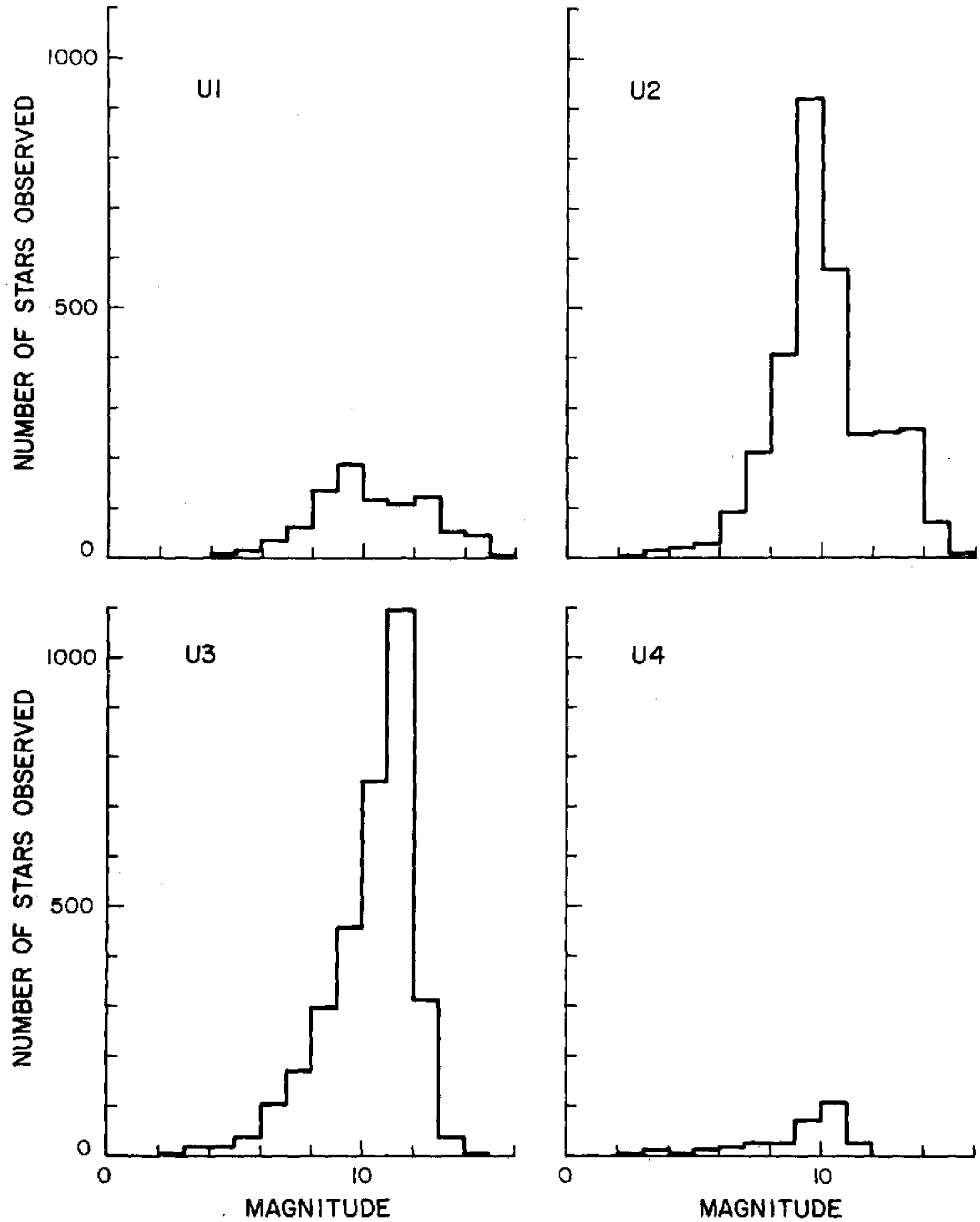

Figure 7. Distribution of Celescope magnitudes in each filter.

Filter	RMS difference
U1	0.24
U2	0.19
U3	0.20
U4	0.26

Figure 8 shows the number of stars in each visual magnitude range. Visual magnitude as used here means V, m_v, or m_{pg} and is intended to show the general magnitude distribution of Celescope observations. The V magnitudes on the UBV system are available for 36% of the stars, B-V colors for 37%, U-B colors for 27%, and $(U-B)_c$ colors for 6% of the stars. Spectral classifications in the MK system are given for 32% of the stars, and non-MK spectra for 62%. Figure 9 shows the number of Celescope observations in each spectral class, while Figure 10 displays the number of stars in each luminosity class. Of the observed stars, 1.4% are known to be variable in the visual; 56% of these variables are eclipsing binaries. Three percent of our observed stars are suspected variables. Nine percent of the stars are known binaries, and 8% are within 3 arcmin of other identified stars that may contribute some of the observed ultraviolet light. Finally, 0.3% of the stars have been classified as Wolf-Rayet stars, 1.5% as Ap stars, and 0.4% as Am stars.

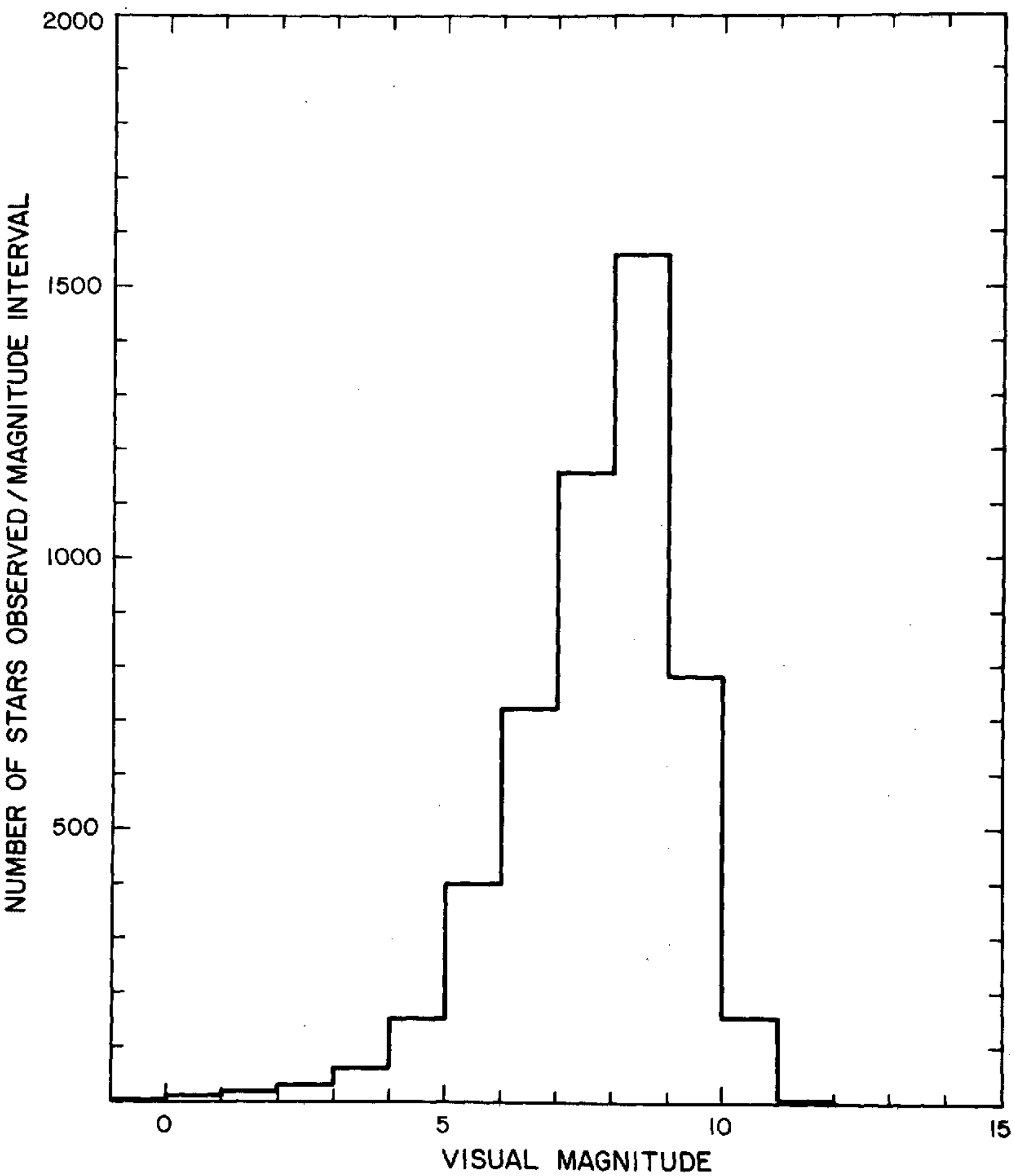

Figure 8. Distribution in visual magnitude of stars observed by Celescope.

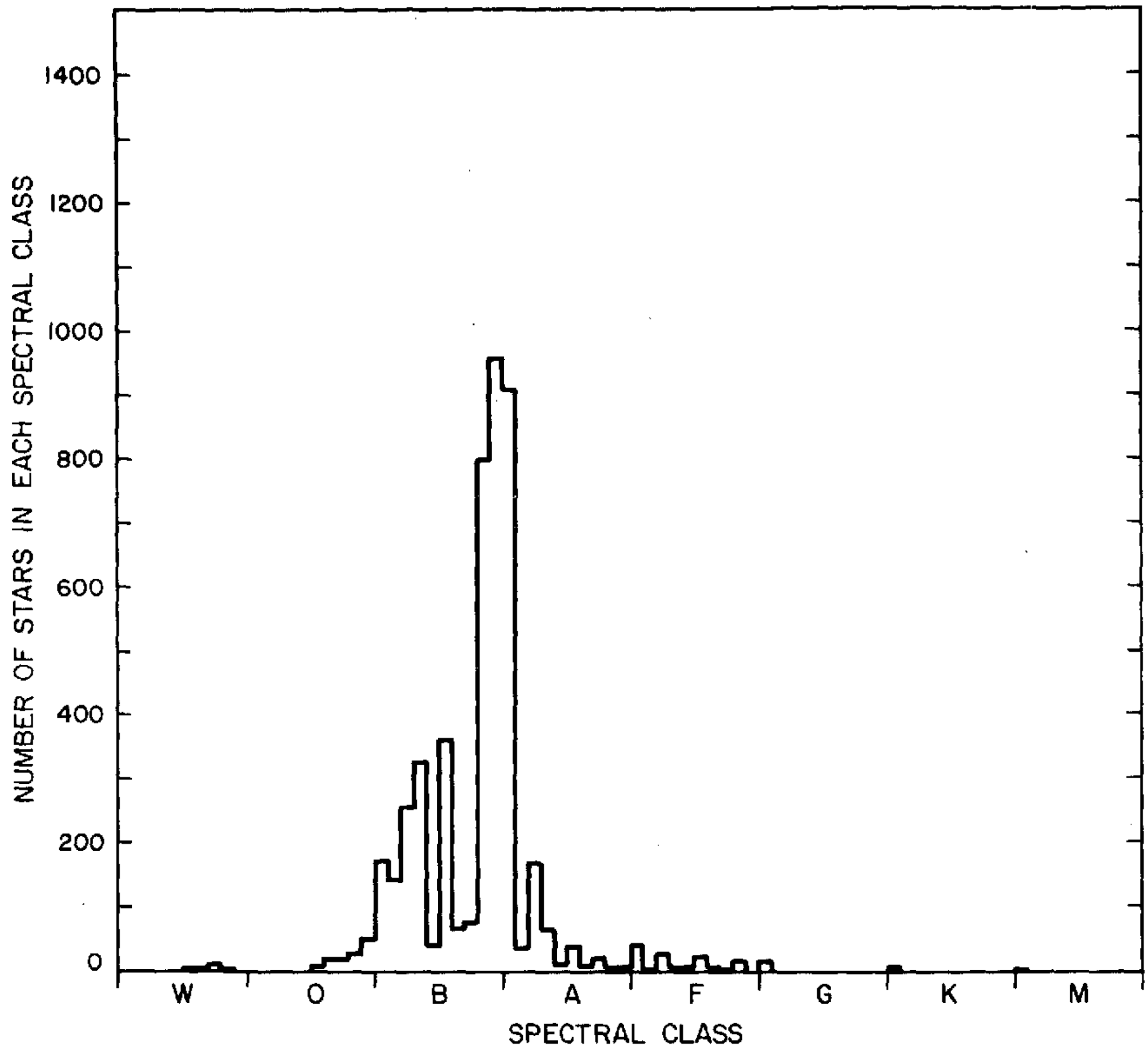

Figure 9. Distribution of stars by spectral class.

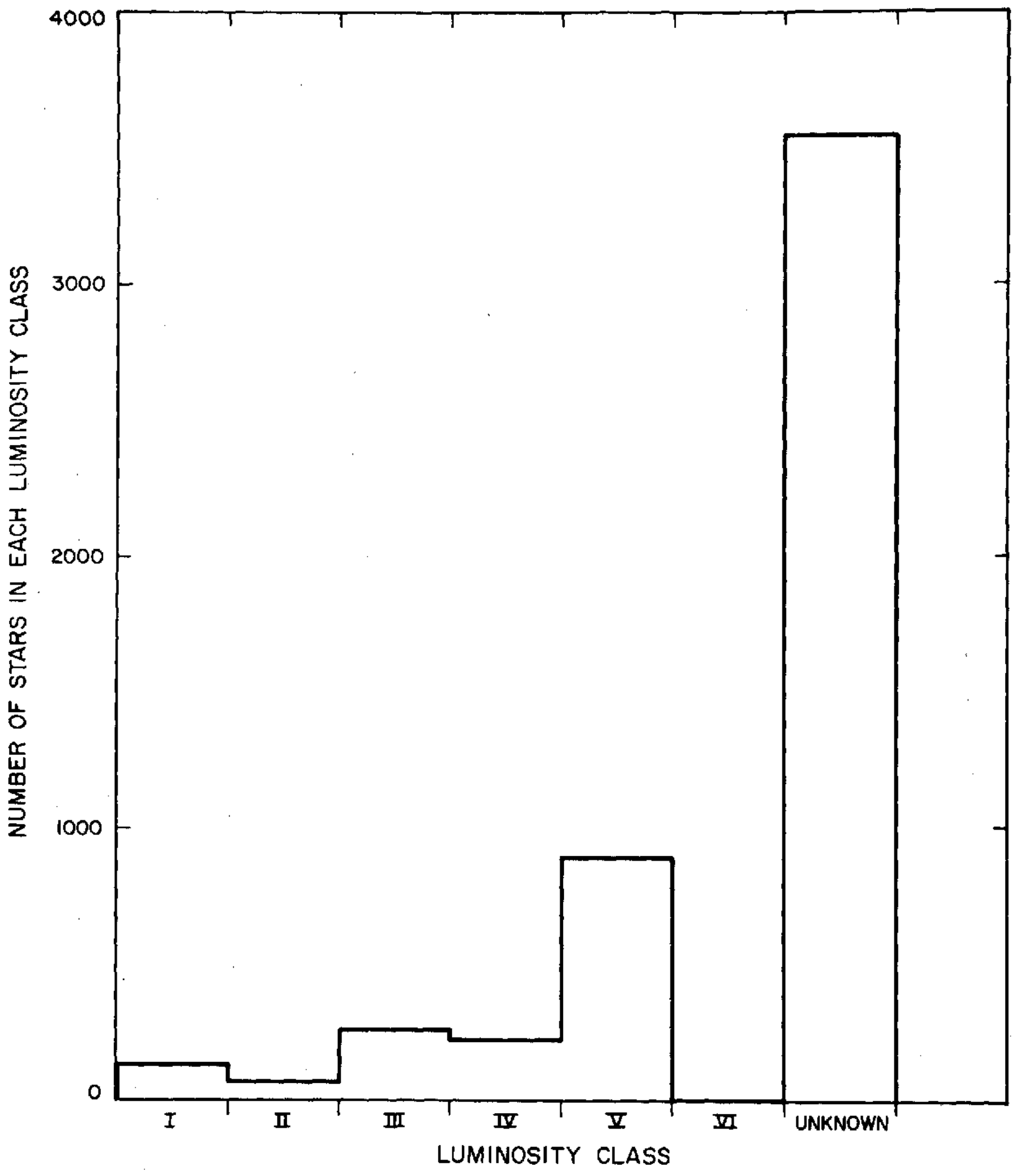

Figure 10. Distribution of stars by luminosity.

6. DRAMATIS PERSONAE

The general scientific planning that became the basis for Project Celescope originated in a series of meetings of the scientific staffs of the Smithsonian Astrophysical Observatory and Harvard College Observatory in February 1958. Following these meetings, a committee consisting of Dr. R. J. Davis, Dr. K. G. Henize, Dr. R. E. McCrosky, Dr. G. F. Schilling, and Dr. C. A. Whitney made more detailed plans and wrote a proposal that eventually became the basis for the NASA grants and contracts that supported Project Celescope. Dr. F. L. Whipple and Dr. Davis were SAO's delegates to NASA's Working Group on Orbiting Astronomical Observatories, which developed the relative roles of spacecraft and experiments in the OAO. Celescope became an official project of SAO in 1959. The name was suggested by Dr. D. H. Menzel in 1960 as the winning entry in an informal contest for naming the project; the name implies that the Smithsonian experiment is one of the first truly Celestial telescopes.

Since the beginning, Dr. Whipple has been Principal Investigator and Dr. Davis has been Coinvestigator and Project Scientist. From 1959 to 1961, engineering and administration were coordinated by Mr. F. R. Nitchie, Jr., Engineer-Administrator. In 1962, the title of this position was changed to Project Manager. Mr. G. K. Megerian served as Project Manager in 1962; Dr. C. A. Lundquist, as Acting Project Manager in 1963; Mr. J. J. Burke, as Project Manager in 1964-1968; Mr. J. J. Ainley, 1968-1970; Mr. R. T. Ayer, 1970-present. While Acting Project Manager, Dr. Lundquist was assisted for several months each by project administrators: Mr. L. McGrath, Mr. H. Rosenthal, and Mr. E. Kohn.

For the first few years, the major effort in Celescope was devoted to engineering. From 1959-1964, our engineering staff consisted of Dr. M. D. Grossi, Electronics Engineer; Mr. S. Sydor, Optical Specialist; and Mr. J. M. Franklin, Mechanical Specialist. From 1959-1962, Mr. H. Cobb served as Mechanical Engineer. From 1964-1972, Dr. Y. Nozawa was Electronics Engineer, and special engineering needs have been covered by Mr. T. E. Hoffman and others from SAO's Engineering Department. In 1966, the post of Project Engineer was filled by Dr. Nozawa. A critical activity of the engineering section from 1965-1969 was field engineering during subsystem and system testing, launch preparation, and orbital operations. Dr. Nozawa was SAO's field engineer during that time.

Members of the SAO Field Engineering Team, which performed engineering tests, system acceptance tests, and launch preparation, were as follows: Mr. J. Peters (Manager, 1967-1968), Mr. J. Munier (Assistant Manager, 1964-1965), Mr. B. A. McLean (Supervisor from EMR, 1964), Mr. J. W. Kennedy (Supervisor from EMR, 1965), Mr. D. R. Nelson (Supervisor from EMR, 1967-1968), Mr. J. Brown (Member from EMR, 1964-1965), Mr. J. Faso (Member from EMR, 1964-1965), Mr. G. Komen (Member from EMR, 1964-1965), and others who became members of the Orbital Operation Group. The successful completion of acceptance tests and launch preparation of the Celescope Experiment is heavily credited to the leadership, cooperation, and creativity of Mr. J. Peters, Mr. D. Nelson, and Mr. L. Koschmeder from the Test and Integration Division of Goddard Space Flight Center, and Mr. R. A. White from the OAO project office.

During 1968, 1969, and 1970, the major effort in Celescope was orbital operations; Dr. W. A. Deutschman was in charge of that activity. The success of the Celescope mission during orbital operations was in large measure the result of the efforts by him and his team in planning, computer programing, controlling, and reviewing the operating requirements and procedures. Special recognition is due Mr. J. Thorp and Mr. J. Latimer for representing Celescope as Field Managers during this round-the-clock operation; Mr. J. Block, as EMR Field Manager; and Mr. T. Omara and Mr. D. Moyer of Grumman Aircraft Corp., who acted as Project Operations Controllers for the OAO satellite.

During the summer and fall of 1970, a data-processing-improvement group consisting of Dr. C. Lundquist, Dr. R. Davis, Dr. W. Deutschman, Dr. E. Avrett, Dr. E. Gaposchkin, Dr. S. Ross, Dr. E. Young, Dr. C. Payne-Gaposchkin, Dr. Y. Nozawa, Mrs. K. Haramundanis, Mr. R. Ayer, Mr. J. Thorp, and Mr. R. Loeser met every week to discuss the best way to use the calibration data. Many other individuals in the Observatory also contributed to this effort.

Since 1969, a major effort in Celescope has been data reduction, of which Mrs. K. L. Haramundanis has been in charge. Her data-reduction section was responsible not only for handling the vast amount of data involved in analyzing over 8000 Celescope pictures but also for keeping track of the source, location, and status of the individual data items.

During the entire life of the project, computer programing support has been important. From 1959-1963, Mr. G. Szabo was in charge of that activity. Since then, the programing effort has been headed by Mrs. M. Havelock (1963-1964), Mrs. B. (Feit) Nair (1964-1965), Mr. P. Conklin (1965), Mr. J. D. de Clercq Zubli (1966-1970), Mr. R. Loeser (1970), and Mrs. L. Kirschner (1966-present).

Since 1970, Dr. Deutschman has been Deputy Project Scientist, in charge of coordinating the activities of the various sections in Celescope. He has overall responsibility for Celescope data processing.

From 1959-1969, Celescope maintained a spectrophotometric standards laboratory for calibrating the optical and spectrophotometric characteristics of Celescope's optical elements, calibration lamps, and Uvicons. From 1959-1960, Dr. A. V. Baez headed this laboratory; from 1960-1962, Dr. O. P. Rustgi. In 1963, and other times on a temporary basis, Mr. C. Miles was in charge.

In 1964, scientific activities of the laboratory were supervised by Dr. J. Marsh and Dr. I. Simon under subcontract to A. D. Little, Inc. From 1965-1969, Mr. H. O'Brien was manager of the spectrophotometric standards laboratory; he had been one of the laboratory assistants during 1963-1964. In 1966, under subcontract again, A. D. Little, Inc., furnished the services of Dr. P. von Thüna for scientific supervision of the activity required for recalibrating the primary laboratory standards against a black thermocouple standard. During the entire lifetime of the laboratory, 1959-1969, Mr. P. J. Hofmann performed competently as a physical-science aide.

During the 14 years that Project Celescope has operated, the above Project Staff has been ably supported by a number of devoted employees, as follows:

Physical-Science Aides: Mrs. G. Wald, Dr. E. Godfredsen, Mr. F. Ahern, Mrs. A. Renshaw, Mr. J. Gallagher, Miss M. Drugan, Mr. J. Black, Mr. I. A. Ahmad, Mrs. E. Green, Dr. S. Strom, Dr. D. Cunnold, Mr. E. Gerard, Dr. D. J. Malaise, and Dr. N. Raghavan.

Programers: Miss V. Kan, Mr. R. Taylor, Mr. M. Patenaude, Mr. P. Collins, Mrs. D. Hills, Mrs. O. Johonnot, Mr. G. Bullock, and Mr. B. Welch.

Assisting Engineers: Mr. E. Arazi, Mr. S. Asano, Mr. W. Ng, Mr. A. Goldstein, Mr. W. Grim, and Mr. S. Shell.

Laboratory Technicians: Mr. R. Beckett, Mr. F. Licata, Mr. M. Kalish, Mr. T. Lee, Mr. P. Griffiths, Mr. A. Bardos, Mr. D. Frost, Mr. E. A. Monash, and Mr. J. Munier.

Data-Analyst Clerks: Mr. P. Sylvester, Mr. G. Westgate, Mrs. L. Cannell, Mr. R. Jarvis, Mr. R. van der Ley, Mr. W. Persons, Miss A. Ballard, Miss C. Jones, Mr. A. Kallai, Miss A. Brownlee, Mrs. S. Yeh, Mrs. Z. Gallagher, Mr. R. Palleschi, Mr. C. Sprangers, Mr. J. Orman, and Mr. A. Girnius.

Astronomers: Prof. C. Payne-Gaposchkin and Mrs. K. (Hebb) O'Neill.

Administrative Assistants: Mr. J. Taylor and Mr. E. Shenton.

Orbital Operations, SAO: Mr. J. Thorp (Field Manager), Mr. J. Latimer, Mr. J. Luce, Mr. L. Greenhouse, Mr. T. Cram, Mr. A. Oakes, and Mr. W. Munn; EMR: Mr. J. Block, Mr. L. O'Connor, Mr. O. Brown, Mr. P. Scoles, Mr. C. Sloan, Mr. K. Leilich, and Mr. T. Dennison.

Secretaries: Mrs. H. M. Beattie, Mrs. B. Hicks, Mrs. P. (Kluge) McMullen, Mrs. P. Januszkiewicz, Mrs. M. deJoie, Mrs. A. Green, Mrs. B. Millar, Mrs. M. V. Flaherty, Mrs. C. Williams, Miss E. Shipe, and Mrs. L. (Poireir) Jordan.

Assistance from other departments: Mr. M. N. Malec (Contracts), Dr. E. M. Gaposchkin (Satellite Geodesy), Mr. C. Tillinghast (Administration), Mr. L. Campbell (Administration), Mr. G. Woron (Contracts), Miss E. Collins (Ed. & Pub.), Mr. E. N. Hayes (Ed. & Pub.), Mrs. A. Omundsen (Ed. & Pub.), Mrs. C. Wong (Ed. & Pub.), Mr. C. Hanson (Ed. & Pub.), Mr. J. Cornell (Ed. & Pub.), and Mr. R. Martin (Computations Center).

Scientific advice and interpretation were provided by many other members of the Observatory staff, including the following: Dr. E. H. Avrett, Dr. J. G. Baker, Dr. D. F. Carbon, Dr. N. P. Carleton, Dr. G. G. Fazio, Dr. F. A. Franklin, Dr. O. J. Gingerich, Dr. P. W. Hodge, Dr. W. Kalkofen, Mr. R. L. Kurucz, Dr. D. W. Latham, Dr. R. W. Noyes, Dr. E. Peytremann, Dr. W. W. Salisbury, and Dr. R. E. Schild.

In addition to the above employees of the Smithsonian Astrophysical Observatory, we wish to acknowledge the support of many staff members at the Smithsonian Institution in Washington, D.C. Especially important were the support and encouragement given by Dr. Leonard Carmichael, Secretary of the Smithsonian Institution until 1964, and by Dr. S. Dillon Ripley, Secretary since that time. Mr. James Bradley, Assistant Secretary, helped in a number of ways, especially in negotiating contracts between the Smithsonian Institution and EMR, Westinghouse, and the National Aeronautics and Space Administration.

Almost all the detailed design, fabrication, and testing of the Celescope hardware were performed by subcontractors. Among the most important were the EMR Telemetry Division of Weston Instruments, Inc. (formerly known as Electro-Mechanical Research, Inc.); the Research Laboratories of the Westinghouse Electric Corp.; the Harshaw Chemical Co.; Astro-Data, Inc.; and A. D. Little, Inc. EMR was prime contractor to SAO for the payload and ground-support systems; they had important subcontracts with Westinghouse, Harshaw, and the Ferson Optical Co. Westinghouse was responsible to SAO for development and fabrication of the Uvicon camera tubes; later that responsibility was changed to become a subcontract through EMR, and in 1965 the effort was transferred from the Research Laboratories to the Tube Division. The raw

materials for all the barium fluoride and lithium fluoride optical elements used in the Celescope payload were provided by the Harshaw Chemical Company – some directly under contract to SAO, some under subcontract to EMR, and some under subcontract to Westinghouse. The Ferson Optical Co. fabricated the Schwarzschild telescopes and the Corning and Suprasil filters. They had an important subcontract with Saffran Engineering Company for manufacture of the titanium structural components of these telescopes. Astro-Data designed and fabricated the data-handling equipment that Celescope used to record selected television pictures at Goddard Space Flight Center and to reformat those pictures for analysis on the CDC 6400 computer at SAO. In addition to the spectrophotometric assistance described above, A. D. Little, Inc., performed a number of special engineering analyses for Celescope, including thermal and vibration analyses.

Key subcontractor personnel involved in the Celescope effort were Mr. S. D. Bass, Project Manager for Celescope at EMR; Mr. B. J. Tucker, Project Engineer for Celescope at EMR; Dr. J. P. Magnin, first as head of the Advanced Development Department at EMR, later as General Manager of the Telemetry Division, and finally as President of EMR; Dr. G. Goetze, Mr. R. Schneeberger, Mr. A. E. Anderson, Mr. D. D. Doughty, and Mr. H. Alting-Mees of Westinghouse; Mr. F. Ferson and Dr. A. Schatzel of Ferson.

The Orbiting Astronomical Observatory Project was operated by the Goddard Space Flight Center of the National Aeronautics and Space Administration. The most important single factor contributing to the success of the OAO and its experiments was the support provided by GSFC. The OAO Program Office provided the money for the Celescope Project at SAO, the spacecraft, the test facilities, and the guidance necessary

for SAO to produce a reliable experiment. The Data and Analysis Branch transformed the raw data received from the tracking stations into magnetic tapes that could be processed by SAO's CDC 6400 computer. The Tracking and Data Acquisition Branch provided the logistic support required for communicating with the OAO and with the Celescope experiment. Key personnel included Mr. R. Ziemer, Project Manager of the OAO Project, 1961-1965; Mr. J. Purcell, Project Manager since 1965; Mr. R. Stroup, Experiment Systems Manager; Mr. J. J. Ainley, Assistant Experiment Systems Manager; Mr. R. White, SAO Experiment Coordinator; Mr. W. White, Experiment Systems Manager since 1967; Mr. D. Parker, Data-Processing Engineer; Dr. J. E. Kupperian, Project Scientist for OAO; Mr. S. Osler, Mission Operations Manager; Mr. T. Omara of Grumman Aircraft Corp., Project Operations Controller; Mr. D. Moyer of GAC, Project Operations Controller; Mr. E. Light of GAC, and the other members of the Grumman Operations Crew; Mr. L. Koschmeder, Experiment Test Manager; Mr. J. Stucker, Experiment Coordinator; and Mr. S. Socia, SCPS Manager.

The Celescope Project was supported by Contract NAS 5-1535 from the National Aeronautics and Space Administration, and we appreciate both their monetary and their technical support.

The OAO Program Office at NASA Headquarters provided financial, administrative, policy, and scientific support to Goddard Space Flight Center, without which the OAO Project could not have occurred. Especially helpful in supporting the OAO and Project Celescope were Dr. N. G. Roman, Head of Astronomy; Mr. C. D. Ashworth; and Mr. E. Ott.

7. TAPE FORMAT OF THE CELESCOPE CATALOG

The Celescope Catalog tape was written on a Control Data 6400 at SAO. The tape is a binary, 7-track tape with 556 bpi and variable-length records. Each record contains the data for all observations of a given star, with the length of the record depending on the number of observations. Each record is written with a FORTRAN binary BUFFER OUT statement. The content of each record is given in Table 2.

In the format description of the tape records, a "word" consists of 60 bits of information, numbered 59–0 from left to right:

59	0

All values on the tape are either alphanumeric or integer. Decimal values such as ultraviolet magnitudes, standard deviations, and composite weights have been multiplied by 100 and rounded in order to obtain integers. Alphanumeric quantities such as spectral type and ground-based magnitudes are given in CDC 6400 console display code (see Table 5 for the octal equivalents). Since a character occupies 6 bits, there is a maximum of 10 characters per 60-bit word.

The sign of whole-word, signed-integer (and rounded-decimal) quantities is given in bit 59, and the absolute value right-justified appears in bits 58–0. The following sign convention is used:

Bit 59	Sign of quantity
0	+
1	–

Table 2. Contents of the records in the Celescope Catalog.

Word	Contents			Bits
1	CHECKSUM	UNSIGNED	INTEGER	59–00
2	R. A. (1950) IN SECONDS OF TIME	UNSIGNED	INTEGER	59–00
3	DEC. (1950) IN TENTHS OF MIN. OF ARC	SIGNED	INTEGER	59–00
4	R. A. (2000) IN SECONDS OF TIME	UNSIGNED	INTEGER	59–00
5	DEC. (2000) IN TENTHS OF MIN. OF ARC	SIGNED	INTEGER	59–00
6	DM ZONE SIGN	UNSIGNED	INTEGER	59
6	DM ZONE ABSOLUTE VALUE	UNSIGNED	INTEGER	47–24
6	DM NUMBER	UNSIGNED	INTEGER	23–00
7	AMBIGUOUS I. D. FLAG (1 CHARACTER)	UNSIGNED	ALPHA	16–11
7	MERGED IMAGE FLAG (1 CHARACTER)	UNSIGNED	ALPHA	10–05
7	DM CODE	UNSIGNED	INTEGER	04–01
7	NON-STAR CODE	UNSIGNED	INTEGER	00–00
8	NGC-IC DESIGNATION (4 CHARACTERS)	UNSIGNED	ALPHA	43–20
8	HD NUMBER	UNSIGNED	INTEGER	19–00
9	PECULIARITY CODES 1–10	UNSIGNED	ALPHA	59–00
10	PECULIARITY CODES 11–20 Table 3	UNSIGNED	ALPHA	59–00
11	PECULIARITY CODE 21	UNSIGNED	ALPHA	53–48
11	M1 × 100 (4 CHARACTERS)	SIGNED	ALPHA	47–24
11	M2 × 100 (4 CHARACTERS)	SIGNED	ALPHA	23–00
12	M3 × 100 (4 CHARACTERS)	SIGNED	ALPHA	48–25
12	MAGNITUDE CODE FOR M1, M2, M3 (Table 4)	UNSIGNED	INTEGER	24–18
12	SPECTRAL CLASS AND SUBCLASS (2 CHAR.)	UNSIGNED	ALPHA	17–06
12	LUMINOSITY (1 CHARACTER)	UNSIGNED	ALPHA	05–00
13	REFERENCE 1 (3 CHARACTERS)	UNSIGNED	ALPHA	53–36
13	REFERENCE 2 (3 CHARACTERS)	UNSIGNED	ALPHA	35–18
13	REFERENCE 3 (3 CHARACTERS)	UNSIGNED	ALPHA	17–00
14	REFERENCES 4–6 SAME AS REF. 1–3			
15	REFERENCES 7–9 SAME AS REF. 1–3			
16	REFERENCES 10–12 SAME AS REF. 1–3			
17	REFERENCES 13–15 SAME AS REF. 1–3			
18	REFERENCES 16–18 SAME AS REF. 1–3			
19	REFERENCE 19 (3 CHARACTERS)	UNSIGNED	ALPHA	53–36
19	REFERENCE 20 (3 CHARACTERS)	UNSIGNED	ALPHA	35–18
20	NAME OR COMMENT (CHARACTERS 1–10)	UNSIGNED	ALPHA	59–00
21	NAME OR COMMENT (CHARACTERS 11–20)	UNSIGNED	ALPHA	59–00

Table 2 (Cont.)

Word	Contents			Bits
22	U1 AVERAGE × 100	SIGNED	INTEGER	59–00
23	(COMPOSITE WEIGHT OF U1) × 100	SIGNED	INTEGER	59–00
24	(RMS DEVIATION OF U1) × 100	SIGNED	INTEGER	59–00
25	U2 AVERAGE × 100	SIGNED	INTEGER	59–00
26	(COMPOSITE WEIGHT OF U2) × 100	SIGNED	INTEGER	59–00
27	(RMS DEVIATION OF U2) × 100	SIGNED	INTEGER	59–00
28	U3 AVERAGE × 100	SIGNED	INTEGER	59–00
29	(COMPOSITE WEIGHT OF U3) × 100	SIGNED	INTEGER	59–00
30	(RMS DEVIATION OF U3) × 100	SIGNED	INTEGER	59–00
31	U4 AVERAGE × 100	SIGNED	INTEGER	59–00
32	(COMPOSITE WEIGHT OF U4) × 100	SIGNED	INTEGER	59–00
33	(RMS DEVIATION OF U4) × 100	SIGNED	INTEGER	59–00
34	NUMBER OF U1 MAGNITUDES TO FOLLOW	UNSIGNED	INTEGER	59–00
35	(FIRST U1 MAG.) × 100	SIGNED	INTEGER	59–00
36	IDENTIFIER OF FIRST U1 MAG.			
36	STATION (1 CHARACTER)	UNSIGNED	ALPHA	59–54
36	ORBIT	UNSIGNED	INTEGER	53–40
36	TAPE (4 CHARACTERS)	UNSIGNED	ALPHA	39–16
36	FRAME	UNSIGNED	INTEGER	15–09
36	OBJECT NUMBER	UNSIGNED	INTEGER	08–00
37	WEIGHT OF FIRST U1 MAG.	UNSIGNED	INTEGER	59–00
38-I	SAME AS 35–37 FOR OTHER U1 MAGNITUDES			
I+1	NUMBER OF U2 MAGNITUDES TO FOLLOW			
(I +2)-J	SAME AS 35–37 FOR U2 MAGNITUDES			
J+1	NUMBER OF U3 MAGNITUDES TO FOLLOW			
(J+2)-K	SAME AS 35–37 FOR U3 MAGNITUDES			
(K+1)	NUMBER OF U4 MAGNITUDES TO FOLLOW			
(K+2)-L	SAME AS 35–37 FOR U4 MAGNITUDES			
L+1	NUMBER OF U1 MAGS. IN FILTER PROXIMITY TO FOLLOW			SEE 34
L+2	(FIRST U1 MAG. IN FILTER PROX.) × 100			SEE 35
L+3	IDENTIFIER OF FIRST U1 MAG. IN FILTER PROX.			SEE 36
L+4	WEIGHT OF FIRST U1 MAG. IN FILTER PROX.			SEE 37
L+5	(ETA OF FIRST U1 MAG. IN FILT. PROX.) × 100	SIGNED	INTEGER	59–00
(L+6)-M	SAME AS (L+2) - (L+5) FOR OTHER U1 MAGS. IN FILTER PROX.			
M+1	NUMBER OF U2 MAGS. IN FILTER PROX. TO FOLLOW			
(M+2)-N	SAME AS (L+2) - (L+5) FOR U2 MAGS. IN FILTER PROX.			
N+1	NUMBER OF U3 MAGS. IN FILTER PROX. TO FOLLOW			
(N+2)-R	SAME AS (L+2) - (L+5) FOR U3 MAGS. IN FILTER PROX.			
R+1	NUMBER OF U4 MAGS. IN FILTER PROX. TO FOLLOW			
(R+2)-S	SAME AS (L+2) - (L+5) FOR U4 MAGS. IN FILTER PROX.			

Table 3. Peculiarity codes.

Column	Information	Comment
1	P	Peculiar spectrum
2	E	Any type of emission
3	N	Nebulous lines
	S	Sharp lines
4	A	Peculiar A-type stars
5	M	Metallic-line stars
6	S	Shell spectrum
7	U	Observed in the ultraviolet below 3000 Å
8	S	Standard on MK or UBV system
9	V	Visual binary
	S	Spectroscopic binary
	E	Eclipsing binary
	C	Composite spectrum
	M	Multiple star
10	E	Emission nebula
	O	Object surrounded by or associated with nebulosity
11	G	Galactic cluster
12		Not used
13	A	α Canum Venaticorum variable
	B	β Canis Majoris variable
	C	Classical Cepheid variable
	G	Eclipsing variable
	H	Suspected variable
	I	Irregular variable other than Ia of Kurkakin et al. (1971)
	L	RR Lyrae variable
	N	Nova-like variable
	P	Peculiar variable
	V	RV Tauri variable
	X	Early-type irregular variable (type Ia of Kurkakin et al., 1971)
	Y	Unspecified variable

Table 3 (Cont.)

Column	Information	Comment
14	P	Polarization data given
15	C	Interstellar lines of calcium II, H and K
16	S	Interstellar lines of sodium D
17	A	Interstellar 4430 Å absorption band
18	R	Radio source
19	H	High velocity
20	R	Measured axial rotation
21	M	Magnetic field

Table 4. Magnitude code for m_1, m_2, m_3.

Column	Code	Designation		
		m_1	m_2	m_3
52–53	1	V	B–V	U–B
	2	V	B–V	
	3	V		
	4	m_v	m_{pg}	
	5		m_{pg}	
	6	m_v		
	11	V	B–V	$(U–B)_c$
	17	V	m_{pg}	U–B
	19	m_v	B–V	U–B
	21	m_v	B–V	$(U–B)_c$
	28	m_v	B–V	
	36	V	B–V	U–V

Table 5. CDC 6400 FORTRAN character codes.

Source language character	Console display code
A	01
B	02
C	03
D	04
E	05
F	06
G	07
H	10
I	11
J	12
K	13
L	14
M	15
N	16
O	17
P	20
Q	21
R	22
S	23
T	24
U	25
V	26
W	27
X	30
Y	31
Z	32
0	33
1	34
2	35
3	36
4	37
5	40
6	41
7	42
8	43
9	44
+	45
-	46
*	47
/	50
(	51
)	52
$	53
=	54
blank (space)	55
, (comma)	56
. (period)	57

Unsigned quantities are always right-justified in the allocated bits. Although we have allotted 60 bits for many items on the tape for ease of programing, the absolute value never occupies more than the right-most 24 bits of the word.

The checksum in word 1 of the record is the EXCLUSIVE OR of the words in the record. It is useful only for reading the tape on a CDC 6400 machine.

8. PRINTING PACKAGE FOR THE CELESCOPE CATALOG

8.1 Introduction

The printing package for the Celescope Catalog is a computer program intended to allow users of the Catalog to access the magnetic tape with a minimum of programing effort. In the interest of making it as general as possible, we have sacrificed efficiency for generality. Therefore, users who will be reading and printing the tape repeatedly would do well to revise the routines appropriately. All routines have been written in USASI FORTRAN except where otherwise noted. Two versions of the reading and unpacking routines have been supplied with this package. One is a special version corresponding to a 60-bit word size; the other is a general version for a machine of variable word size.

This printing package consists of a driver subroutine (DRIVE) to be called by the user, plus several printing and processing subroutines optionally called by the driver for each star (USER, PRINT, VARPR, and SELCT, as specified on data cards). If the user elects to call PRINT, he will obtain the information for each star, and the information will be printed in the standard Celescope Catalog format (described in Section 10). If he specifies a call to VARPR, the printout for each star will include only those items he has selected; they will be close-packed on one or more lines. By specifying a call to USER, he can write his own print or processing routine. In this case, USER will be called by the driver once for each star. The unpacked version of the record (see UNPAK, Section 9.6) is passed to USER, allowing the routine to print or otherwise access the data as desired.

The following options are available for printing the Catalog with routine PRINT:

1. All odd pages on one unit; all even pages on another.
2. All pages printed sequentially on one unit, alternating odd and even pages.
3. Only even or only odd pages printed.

Options 1 and 2 require a printer and a tape drive for the Catalog plus two scratch files (either magnetic tape drives or disk files). Option 3 requires a printer and a tape drive for the Catalog plus only one scratch file (either magnetic tape drive or disk).

In addition, when using PRINT, the user can specify if he wants galactic coordinates or right ascension and declination, printed on the even pages, given in an epoch other than the one (2000) normally given there. Note that precession and galactic-coordinate routines are included with this package.

Finally, the package can optionally call subroutine SELCT, which selects stars on the basis of right ascension and declination, HD number, or DM number. This allows the user to print or process only those records (stars) he wishes to see when using PRINT, VARPR, or USER.

8.2 Use of the Printing Package

Unless the user is working with a CDC 6400 series machine, he must supply a main program to call the driver subroutine DRIVE to set up the input/output logical unit numbers. DRIVE is called as follows:

CALL DRIVE (I1, I2, I3, I4, I5)

I1 – Card reader unit.
I2 – Printer unit.
I3 – Tape drive unit containing the Catalog to be read.
I4 – Scratch file unit or another printer unit.
I5 – Scratch file unit.

The following examples and Data Section 3 (in Section 8.3) give more details on I2, I4, and I5.

Example 1

a. The card reader is logical unit 5.
b. The printer is logical unit 6.
c. The tape drive with the Catalog is logical unit 10.
d. The user has a disk on which he defines a scratch file, logical unit 99.
e. The user has a tape drive (logical unit 11) on which he writes even-numbered Catalog pages to be copied later to the printer (default option in Data Section 3).

CALL DRIVE (5, 6, 10, 11, 99)

Example 2

a. Same as above.
b. Same as above.
c. Same as above.
d. The user has a disk or two extra tape drives on which he can define two scratch files, logical units 98 and 99, and he wishes the Catalog printed directly in odd/even, odd/even page order (DOUBLE option in Data Section 3).

CALL DRIVE (5, 6, 10, 98, 99)

Example 3

a. Same as above.
b. Same as above.
c. Same as above.
d. The user has only one scratch unit available (logical unit 40) and wishes to print only odd pages (option SINGLE ODD in Data Section 3).

CALL DRIVE (5, 6, 10, 0, 40)

Note that I4 = 0, but that I5 must always be defined when subroutine PRINT is called.

Example 4

a. Same as above.
b. Same as above.
c. Same as above.
d. The user wishes to print out selected Catalog information using the VARPR routine instead of PRINT. No scratch files are necessary.

CALL DRIVE (5, 6, 10, 0, 0)

8.3 Description of the Data

Input data for the package consist of several "sections," any of which may be omitted except the last. Each section has a default value that the program will use if no data card is encountered. If the user specifies more than one option card in a section, the last one encountered is used. All option cards begin in column 1 and must not have embedded blanks. All integer quantities must be right-justified in the columns provided.

Data Section 1, Card 1

a. USER – Call user-supplied routine USER.
or
b. VARPR – Call variable print routine VARPR.
c. Default – Call standard Celescope Catalog print routine PRINT.

If option b. is chosen, the following cards are required after the VARPR card:

Card	Columns	Contents
2	1–5	Number of items to be printed by VARPR
3–N+2	1–5	First item number
	6–10	Second item number
	.	.
	.	.
	.	.
	76–80	Nth item number

See Table 7 of subroutine VARP (Section 9. 12) for the correspondence between the list of item numbers and the items in the Catalog.

Ordinarily, VARPR does not separate items in the printout by blanks. However, a facility does exist by which this can be done. If VARPR encounters a negative number in the list of item numbers, it prints as many blanks as the absolute value of the number in that position in the list. A zero is considered equal to -1 for this purpose. For example, the list below will produce the result shown:

List: 6 -1 4 -2 5 0 9

Result: Item 6, one blank, item 4, two blanks, item 5, one blank, item 9.

If the user wishes to print more than one line of information, he should insert item number 999 in his list at appropriate points. For each such occurrence, a new line will be started with the succeeding item number.

Data Section 2 (used only if PRINT is called), Card 1

a. GALACT – Print galactic coordinates on even pages.

or

b. PRECESS – Print precessed right ascension and declination on even pages.
c. Default is right ascension and declination for epoch 2000 on even pages.

If option b. is chosen, the following card is required after the PRECESS card:

Card	Columns	Contents
2	1–4	Epoch for precession (e.g., 1975)

Data Section 3 (used only if PRINT is called), Card 1

a. DOUBLE – Write the two pages of Catalog information on unit I2 in odd/even, odd/even order. I4 and I5 are used for scratch.

or

b. SINGLE – Write only even or only odd pages on unit I2, with unit I5 used for scratch (I4, not used, = 0).
c. Default is to write all even pages on unit I4 and all odd pages on I2, with I5 used as scratch. I2 cannot equal I4. Note: Unless I4 is a printer unit, user must copy its contents to the printer.

If option b. is chosen, card 1 of this section must contain EVEN or ODD, beginning in column 8, to specify whether even or odd pages are desired. The odd pages contain the ultraviolet magnitudes and most other "vital" information.

I1, I2, I3, I4, and I5 must be defined in the user-supplied main program, which calls our driver subroutine DRIVE.

Data Section 4, Card 1

a. SELECT – Call routine SELCT to select certain stars to be printed or processed; ignore all other stars. Selection is done by HD, DM, and/or R.A., Dec. An HD number occupies one selection word, while DM and R.A., Dec. each occupy two. The total number of selection words allowed per run is 297.
b. Default is no selection.

If option a. is chosen, at least one of the following subsections is required after the SELECT card. The subsections must be in the order shown.

Subsection 1

Card	Columns	Contents
1	1–2	HD
	11–13	Number of HD numbers to follow
2–N	1–6	HD number

Subsection 2

Card	Columns	Contents
1	1–2	DM
	11–13	Number of DM numbers to follow
2–N	1–9	DM zone and number as ±ZZbNNNNN

Subsection 3

Card	Columns	Contents
1	1–5	RADEC
	11–13	Number of R.A., Dec. pairs to follow
2–N	1–8	R.A. in hours, minutes, and seconds of time (1950) HHbMMbSS
	11–18	Dec. in degrees, minutes, and tenths of minutes of arc (1950) ±DDbMM.M

Data Section 4 must terminate with a card with FIN in columns 1–3.

Data Section 5, Card 1

a. END
b. No default – the END card must be present even if no other data cards are included. It must be the last data card.

8.4 Sample Data Setups

A. To print in Catalog format the whole tape with odd pages on one unit and even pages on another:

No data necessary except END card

B. To print in Catalog format the whole tape with odd/even, odd/even pages on one unit:

```
DOUBLE
END
```

C. To print in Catalog format the whole tape as in B. above, with even-page positions precessed to 1975:

```
DOUBLE
PRECESS
1975
END
```

D. To print in Catalog format as in B. above, selecting only stars with particular HD or DM numbers and printing even-page positions in galactic coordinates:

```
DOUBLE
GALACT
SELECT
HDbbbbbbbbb3
234567
234568
234569
DMbbbbbbbbb2
-12b34567
-12b34568
FIN
END
```

E. To print using VARPR R.A., Dec., and HD for all stars:

```
VARPR
bbbb3
bbbb2bbbb3bbb12
```

9. DESCRIPTION OF THE ROUTINES IN THE PRINTING PACKAGE

9.1 Introduction

The Celescope Catalog printing package allows the user to access the Catalog tape. It consists of a driver (DRIVE), initializer (INIT), finalizer (FINAL), reader (IREAD), unpackers (UNPAK or UNPAK2), selector (SELCT), and processors (PRINT, VARPR, or USER).

Unpacking the Catalog Tape

There are two versions of the reading and unpacking routines. The first (IREAD and UNPAK) is written for a CDC 6400 and assumes a 60-bit machine word. The second (IREAD and UNPAK2) is written for use on a machine with a word size of N bits, where N is specified by the user.

Treatment of DM Zones of -0

Since some machines do not distinguish between +0 and -0, the Catalog printing package uses the following convention:

Subroutines UNPAK and UNPAK2 convert -0 DM zones on the Catalog tape to -666 DM zones in storage.

When reading data cards to select DM numbers from the Catalog, subroutine INIT converts -0 DM zones to -666 DM zones in storage.

Subroutines PRINT and VARPR will print a DM zone of -666 as a DM zone of -0. A DM zone of -0 will be printed as +0.

Users who write their own UNPAK2 or USER routines should follow this convention.

9.2 Sample Program T (Diane Hills)

Program T is an example of a FORTRAN calling routine for DRIVE (see Section 9.3). Its purpose is to set up the I/O units used in the printing package.

```
PROGRAM T (INPUT, OUTPUT, TAPE1=INPUT, TAPE2=OUTPUT, TAPE3,
    TAPE4, TAPE5)
```

where

TAPE1 (logical unit 1) = card reader.
TAPE2 (logical unit 2) = printer.
TAPE3 (logical unit 3) = catalog tape.
TAPE4 (logical unit 4) = disk file.
TAPE5 (logical unit 5) = disk file.

Program T calls DRIVE with

```
CALL DRIVE(1, 2, 3, 4, 5)
```

Note that unless PRINT is being called, units 4 and 5 can be accessed by the user.

9.3 DRIVE (Diane Hills)

Purpose

DRIVE is the main driver subroutine for the Celescope Catalog printing package. Its purpose is to call any of several subroutines to process or print information for stars on the Catalog tape.

Calling Sequence

DRIVE is called by a user-supplied program or routine, which must pass to it in the calling sequence the logical unit numbers of all I/O units involved:

DRIVE(I1, I2, I3, I4, I5)

where

I1 = card reader unit.
I2 = printer unit.
I3 = catalog tape unit.
I4 = scratch unit or another printer unit or 0.
I5 = scratch unit.

Method

All subroutines called by DRIVE have the following calling sequence:

(IØ, IBUF, IFLAG)

where IØ is the array of logical unit numbers for all I/O involved, as defined by the user in his call to DRIVE IØ is dimensioned 5:

IØ(1) = card reader unit.
IØ(2) = printer unit.
IØ(3) = catalog tape unit.
IØ(4) = scratch unit or another printer unit or 0.
IØ(5) = scratch unit or 0.

Note that while IØ(1), IØ(2), and IØ(3) are standard, IØ(4) and IØ(5) may vary, depending on the printout desired. For example, if VARPR is being called, IØ(4) and IØ(5) are never accessed and thus may be 0. However, if PRINT is being called, IØ(5) must always exist, while IØ(4) may or may not, depending on the page-ordering option.

IBUF is the array of unpacked Catalog items for a star with one integer (right-justified) or one character (left-justified with blank fill) per element. It is returned from routine IREAD. IBUF is dimensioned 3000.

IFLAG is the array of flags determining the purpose of the DRIVE routine. IFLAG is initially defined in INIT and subsequently altered by routines IREAD, SELCT, and FINAL. IFLAG is dimensioned 10. Default values for IFLAG are 0.

IFLAG(1) = 0 if PRINT is to be called.
= 1 if VARPR is to be called.
= 2 if USER is to be called.

IFLAG(2) = 0 if SELCT is not to be called.
= 1 if SELCT is to be called for every record read.

IFLAG(3) = 0 if even-page positions are to be R. A. and Dec. at epoch 2000.
= 1 if even-page positions are to be galactic coordinates.
= epoch, if even-page positions are to be precessed (e. g., 1975).

IFLAG(4) = 0 if all odd pages are to be printed on unit IØ(2) and all even pages on unit IØ(4), with unit IØ(5) used as scratch. IØ(4) ≠ IØ(2). (Default.)
= 1 if all pages are to be printed on unit IØ(2) in odd/even, odd/even order, with IØ(4) and IØ(5) used as scratch. IØ(4) ≠ IØ(2). (DOUBLE option.)
= 2 if only even pages are to be printed on unit IØ(2), with unit IØ(5) used as scratch. (SINGLE EVEN option.)
= 3 if only odd pages are to be printed on unit IØ(2), with unit IØ(5) used as scratch. IØ(4) not used. (SINGLE ODD option.)

IFLAG(5) = 0 throughout run.
= 1. This is set by routine FINAL for the final call to PRINT or USER, depending on which was called. Note that there is no final call to VARPR.
Note: IFLAG(3)–(5) are used only if PRINT is being called.

IFLAG(6) = 0 throughout the run if SELCT is not called.
= 0 if the SELCT routine rejects the record.
= 1 if the SELCT routine accepts the record.

IFLAG(7)–(9), not defined.

IFLAG(10) = 0 throughout the run.
= 1 when IREAD encounters an end of file on unit IØ(3).

Subroutines

The following routines are called by DRIVE:

1) INIT initializes the program by reading data cards from unit IØ(1) to set up the array IFLAG. INIT is called only once, before any records are read.

2) FINAL makes final calls to PRINT or USER and rewinds the Catalog tape. FINAL is called only once, after an end of file is encountered on the Catalog tape.

3) IREAD reads a record from the Catalog tape and returns it in unpacked form in buffer IBUF. The unpacked format is defined in Table 6 of UNPAK (Section 9.6). IREAD is called once for every record on the tape.

4) SELCT selects only certain records from the tape, when specified to do so by the data cards in INIT. Selection can be made on HD, DM, and/or R. A., Dec.

5) PRINT prints a record in standard Catalog format.

6) VARPR prints a record in variable close-packed format on one or more lines.

7) USER, a user-supplied routine, prints or processes a record according to the user's specifications.

Data cards read by INIT determine which one of the three subroutines 5), 6), or 7) is to be called. PRINT, VARPR, and USER are each called once for every record read (unless the record is not selected by SELCT)

FORTRAN

DRIVE is written in USASI FORTRAN.

9.4 INIT (Diane Hills)

Purpose

Subroutine INIT is a Celescope Catalog subroutine called by the routine DRIVE (Section 9.3) to read data cards and initialize arrays (see Section 8). The purpose of INIT is to determine:

1) Which of the following subroutines is to be called:
   a. PRINT (default),
   b. USER, or
   c. VARPR.

2) Whether or not routine SELCT is to be called. If SELCT is to be called, INIT also reads data cards specifying which Catalog items are to be selected. Default is not to call SELCT.

3) Whether galactic coordinates or precessed positions are to be printed on even pages (if PRINT is being called).

4) Which page-ordering option is to be used (if PRINT is being called).

Calling Sequence

```
INIT(IØ, IBUF, IFLAG)
```

where

IØ = array of logical unit numbers.

IBUF = array of unpacked Catalog items. IBUF is not used by INIT.

IFLAG = array of option flags to be defined by INIT. See DRIVE (Section 9.3) for details of IFLAG array items.

Data Defined

INIT sets up the following data:

1) Array IFLAG
IFLAG(1)–(4), as determined by data cards.
IFLAG(5)–(10) = 0.

2) IØ(4) = IØ(2) if IFLAG(4) = 2 (SINGLE EVEN option).

3) Array LIST, as determined by data cards only if VARPR is to be called. See VARPR (Section 9.11) for further details.

4) Item NUM, as determined by data cards only if VARPR is to be called (see Section 9.11).

5) Array ISEL, as determined by data cards only if routine SELCT is to be called. See SELCT (Section 9.9) for further details.

6) Item MSEL, the maximum dimension of ISEL array (= 300).

Items 3–6 above are in the following common blocks in INIT:

```
COMMON/LDATA/NUM, LIST(200)
COMMON/SEL/ISEL(300), MSEL
```

FORTRAN

INIT is written in USASI FORTRAN.

9.5 IREAD (Diane Hills)

Purpose

Subroutine IREAD, a Celescope Catalog routine, is called by subroutine DRIVE (see Section 9.3). It reads one record (a star) from the Catalog tape and returns it to DRIVE in unpacked form (see UNPAK, Section 9.6).

Calling Sequence

```
IREAD(IØ, IBUF, IFLAG)
```

where

IØ = an array of logical unit numbers. Note that the Catalog tape is on unit IØ(3). See DRIVE, Section 9.3.

IBUF = the unpacked array of Catalog items to be returned to DRIVE for further processing.

IFLAG = an array of flags. IREAD returns IFLAG(10) = 1 if an end of file is encountered on the Catalog tape. No other IFLAG elements are accessed.

Method

IREAD, written for the CDC 6400, uses a non-USASI FORTRAN BUFFER IN statement to obtain one record from the Catalog tape. IREAD then calls routine UNPAK to "unpack" the record into the format necessary for all further processing (the unpacked array IBUF).

If IREAD encounters an end of file on unit IØ(3), the flag IFLAG(10) is set to 1.

Comments

If a user wishes to write his own IREAD routine, he should note that the unpacked array has one character, or integer, per element. Since characters are in CDC display code on the tape, the routine CONVT should be used to convert to hollerith equivalents.

Also, the user must remember to return the end-of-file flag IFLAG(10) when necessary.

FORTRAN

IREAD is not written in USASI FORTRAN.

9.6 UNPAK (Diane Hills)

Purpose

Subroutine UNPAK is called by the read routine IREAD. It unpacks the Catalog record into an array containing one character (left-justified with blank fill) or one integer (right-justified) per element.

Calling Sequence

UNPAK(IAREA, IBUF)

where

IAREA = the packed array of Catalog tape items as read by IREAD (dimensioned 1000). See Table 2, Section 7, for a description of IAREA.

IBUF = the unpacked array of Catalog tape items to be returned to DRIVE (dimensioned 3000). See Table 6.

Table 6. Format of unpacked array items.

Unpacked word	Tape word	Contents of unpacked word
1	1	CHECKSUM (+ONLY) INTEGER
2	2	R.A. (1950) SECONDS OF TIME (+OR-) INTEGER
3	3	DEC (1950) 10THS OF MINUTES OF ARC (+OR-) INTEGER
4	4	R.A. (2000) SECONDS OF TIME (+OR-) INTEGER
5	5	DEC (2000) 10THS OF MINUTES OF ARC (+OR-) INTEGER
6	6	DM ZONE (+OR=) INTEGER
7	6	DM NUMBER (+ONLY) INTEGER
8	7	AMBIGUOUS I.D. FLAG LEFT JUST. ALPHANUMERIC CHAR.
9	7	MERGED IMAGE FLAG LEFT JUST. ALPHANUMERIC CHAR.
10	7	DM CODE (+ONLY) INTEGER
11	7	NONSTAR CODE (+ONLY) INTEGER
12	8	FIRST CHAR. OF NGC-IC DESIG. LEFT JUST. ALPHANUMERIC
13	8	SECOND CHAR. OF NGC-IC DESIG. LEFT JUST. ALPHANUMERIC
14	8	THIRD CHAR. OF NGC-IC DESIG. LEFT JUST. ALPHANUMERIC
15	8	FOURTH CHAR. OF NGC-IC DESIG. LEFT JUST. ALPHANUMERIC
16	8	HD NUMBER (+ONLY) INTEGER
17	9	PECULIARITY CODE1 LEFT JUST. ALPHA. CHAR.
.	.	
.	.	
.	.	
37	11	PECULIARITY CODE21 LEFT JUST. ALPHA. CHAR.
38	11	FIRST CHAR. OF M1 × 100 LEFT JUST. ALPHANUMERIC
39	11	SECOND CHAR. M1 × 100 LEFT JUST. ALPHANUMERIC
40	11	THIRD CHAR. M1 × 100 LEFT JUST. ALPHANUMERIC
41	11	FOURTH CHAR. M1 × 100 LEFT JUST. ALPHANUMERIC
42	11	FIRST CHAR. M2 × 100 LEFT JUST. ALPHANUMERIC
43	11	SECOND CHAR. M2 × 100 LEFT JUST. ALPHANUMERIC
44	11	THIRD CHAR. M2 × 100 LEFT JUST. ALPHANUMERIC
45	11	FOURTH CHAR. M2 × 100 LEFT JUST. ALPHANUMERIC
46	12	FIRST CHAR. M3 × 100 LEFT JUST. ALPHANUMERIC
47	12	SECOND CHAR. M3 × 100 LEFT JUST. ALPHANUMERIC
48	12	THIRD CHAR. M3 × 100 LEFT JUST. ALPHANUMERIC
49	12	FOURTH CHAR. M3 × 100 LEFT JUST. ALPHANUMERIC
50	12	MAGNITUDE CODE (+ONLY) INTEGER
51	12	SPECTRAL CLASS LEFT JUST. ALPHA. CHAR.
52	12	SPECTRAL SUBCLASS LEFT JUST. ALPHANUMERIC CHAR.
53	12	LUMINOSITY LEFT JUST. ALPHANUMERIC CHAR.
54	13	FIRST CHAR. OF REF1 LEFT JUST. ALPHANUMERIC
55	13	SECOND CHAR. OF REF1 LEFT JUST. ALPHANUMERIC
56	13	THIRD CHAR. OF REF1 LEFT JUST. ALPHANUMERIC
.	.	
.	.	
.	.	

Table 6 (Cont.)

Unpacked word	Tape word	Contents of unpacked word
111	19	FIRST CHAR. OF REF20 LEFT JUST. ALPHANUMERIC
112	19	SECOND CHAR. OF REF20 LEFT JUST. ALPHANUMERIC
113	19	THIRD CHAR. OF REF20 LEFT JUST. ALPHANUMERIC
114	20	FIRST CHAR. OF COMMENT LEFT JUST. ALPHANUMERIC
.	.	
.	.	
.	.	
133	21	TWENTIETH CHAR. COMMENT LEFT JUST. ALPHANUMERIC
134	22	U1 AVERAGE × 100 (+OR-) INTEGER
135	23	WT U1 × 100 (+ONLY) INTEGER
136	24	RMS DEV U1 × 100 (+ONLY)
.	.	
.	.	
.	.	
143	31	U4 AVERAGE × 100 (+OR-) INTEGER
144	32	WT U4 × 100 (+ONLY) INTEGER
145	33	RMS DEV U4 × 100 (+ONLY) INTEGER
146	34	NUMBER OF U1 MAGNITUDES
147	35	U1(I) × 100 (+OR-) INTEGER
148	36	STATION LEFT JUST. ALPHA.
149	36	ORBIT (+ONLY) INTEGER
150	36	FIRST CHAR. OF TAPE LEFT JUST. ALPHANUMERIC
151	36	SECOND CHAR. OF TAPE LEFT JUST. ALPHANUMERIC
152	36	THIRD CHAR. OF TAPE LEFT JUST. ALPHANUMERIC
153	36	FOURTH CHAR. OF TAPE LEFT JUST. ALPHANUMERIC
154	36	FRAME (+ONLY) INTEGER
155	36	OBJECT NUMBER (+ONLY) INTEGER
156	37	WEIGHT U1(I) (+ONLY) INTEGER
.	.	
.	.	
.	.	
N	I+1	NUMBER U2 MAGNITUDES
.	.	
.	.	
.	.	
NN	J+1	NUMBER U3 MAGNITUDES
.	.	
.	.	
.	.	
M	K+1	NUMBER U4 MAGNITUDES
.	.	
.	.	
.	.	
MM	L+1	NUMBER OF U1 MAGNITUDES IN FILTER PROXIMITY
.	.	
.	.	
.	.	
MM+4	L+5	ETA OF U1(I) × 100 (+OR-) INTEGER

Method

UNPAK can be used only on CDC 6400 machines. It assumes a 60-bit word size and utilizes the Celescope packing routine RUBY (Section 9.7). UNPAK also calls routine CONVT to convert alphanumeric items from CDC console display code to their hollerith equivalent.

If a user writes his own unpacking routine, he should follow this convention if he wishes to use either PRINT or VARPR.

FORTRAN

UNPAK is not written in USASI FORTRAN.

9.7 RUBY (Peter Collins)

Purpose

RUBY is a general-purpose packing and unpacking routine called by the Celescope Catalog printing package subroutine UNPAK (see Section 9.6). Its purpose is to unpack information in a Catalog record.

Method

RUBY was written for a CDC 6400 machine and assumes a 60-bit word. Given a starting bit position in a word, a number of bits N, and a flag as to whether an item is signed, RUBY returns the N bits in a word, right-justified, with extended sign bit if appropriate. RUBY will unpack any number of words at a time.

Calling Sequence

There are two calls necessary for each unpack or pack to be done. One initializes arrays and the other does the packing or unpacking.

1) To initialize,

```
ASSIGN N TO NCALL
CALL RUBY(IBLØCK, NBLØCK, NCALL, IARAY, NUSED)
```

where

N = statement number of PCK or UNPCK call.

IBLØCK = array of storage of length NBLOCK.

$$NBLØCK \geq 61 + \sum_{i=1}^{n} (1 + 1.6 * L_i)$$, where L_i is the length of the ith descriptor array and n is the number of calls to RUBY.

IARAY = descriptor array of pointers to bits within words (see below).

NUSED = last position in IBLØCK not in use.

2) To pack or unpack

```
N CALL UNPCK(IREC, IBUF)
          or
N CALL PCK(IREC, IBUF)
```

where

N = statement label, assigned to NCALL in call to RUBY.

IREC = array of packed items.

IBUF = array of unpacked items (always hollerith or integer).

Descriptor Array IARAY

All the description is done by assigning values to elements of an array called IARAY. IARAY's length is 1 greater than the sum of the lengths of IREC and IBUF. The first element gives n_p, the length of IREC. The rest of IARAY is divided into n_p groups, each corresponding to a successive word of IREC. Each group contains, in turn, $(n_L + 1)$ elements, where n_L is the number of fields in that word of IREC. The first element gives n_L; if n_L is 0, the IREC word has no fields and it will be the only element in the group. Otherwise, the remainder of the group will describe the n_L fields in the IREC word, with successive elements corresponding to the successive elements of IBUF that are matched with the IREC word's fields. The field description consists of three components: the left-most bit number K, the right-most bit number r, and a flag s (see page 30 for the description of the CDC 6400 bit structure). This last component is 0 if the field is unsigned and 1 if it is signed. The IARAY element is formed by

$$IELMNT = K*1000 + r*10 + s$$

Thus, a field occupying an entire word would have an IARAY descriptor value of either 59000 or 59001; a left-justified, signed, 3-bit field would be written as 59571.

Subroutines

The following subroutines are part of the RUBY package:

1) UNPCK provides a dummy entry point for the user unpack processing call. It provides a real entry point for RUBY to generate the unpacking code and link it with the processing call.

2) INST assembles instructions, transmitted one per call, in a storage block with no-ops as needed. This subroutine is used by PCK and UNPCK.

3) FINST terminates the INST assembly.

4) PCK provides a dummy entry point for the user pack processing call and a real entry point for RUBY to generate the packing code and link it with the processing call.

5) EQUARAY is a utility routine to set two arrays equal to each other.

6) CLEAR is a utility routine to set an array to a single value.

7) BADGER is a utility routine to write an absolute address from FORTRAN.

8) ABTRACE is a utility routine that puts an error message in the dayfile and an error traceback with relative addresses on OUTPUT and then aborts.

9) TRACE, an entry to ABTRACE, provides traceback only, followed by normal return.

10) CONT is a utility routine to read an absolute address from FORTRAN.

FORTRAN

RUBY is not written in USASI FORTRAN.

9.8 CONVT (Diane Hills)

Purpose

CONVT is a subroutine called by UNPAK. Its purpose is to convert alphanumeric characters from CDC display code (on tape) to their hollerith equivalents (for printing).

Calling Sequence

CONVT(ID)

where

ID = input with the character in CDC display code right-justified with zero fill in the word.

ID = output with the character left-justified with blank fill in the word.

Method

CONVT is independent of word size. It utilizes the numeric correspondence between the CDC display codes on the tape (octal 01–57) and the characters A–Z, 0–9, +, -, *, /, (,), $, =, blank, comma, and period.

It assumes a binary machine.

See Table 5, Section 7, for a listing of the console display codes.

FORTRAN

CONVT is written in USASI FORTRAN.

9.9 SELCT (Linda Kirschner)

Purpose

Subroutine SELCT is the star-selection routine for the Celescope Catalog printing package. It selects stars on the basis of HD number, DM zone and number, and/or R. A. and Dec.

Calling Sequence

SELCT(IØ, IBUF, IFLAG)

where

IØ = an array containing the I/O unit numbers. It is not used by SELCT.

IBUF = the unpacked array of Catalog items. See UNPAK writeup, Section 9.6.

IFLAG = an array of various flags. Only IFLAG(6) is used by SELCT.

Method

SELCT is called once by the driver subroutine DRIVE for each record (star). If the star satisfies any of the conditions specified on the selection data cards, SELCT returns with IFLAG(6) = 1 (accept star). Otherwise, IFLAG(6) = 0 (reject star).

COMMON Statements

SELCT contains a labeled common block

COMMON/ISEL/ISEL(300), MSEL

ISEL contains the selection information and is set up by subroutine INIT from the selection data cards. It is described in comment cards at the beginning of SELCT. The size of ISEL can be changed simply by changing its dimension and the value of variable MSEL to correspond to its length. Increasing the size of ISEL will allow more selection data cards.

Comments

Note that selection depends on an exact equality of the quantities.

Also note that R.A. and Dec. are stored in ISEL in seconds of time and tenths of a minute of arc, respectively (although they are specified on data cards in hours, minutes, and seconds and degrees and minutes). The epoch is 1950.0.

FORTRAN

SELCT is written in USASI FORTRAN.

9.10 PRINT (Peter Collins)

Purpose

Subroutine PRINT is called by the driver routine DRIVE (see Section 9.3). It prints, in standard Catalog format, information for stars on the Catalog tape.

Calling Sequence

PRINT(IØ, IBUF, IFLAG)

where IØ is an array of logical unit numbers:

IØ(1) = card reader (not used by PRINT).
IØ(2) = printer (always used by PRINT).
IØ(3) = Catalog tape (not used by PRINT).
IØ(4) = 0 if only odd pages are being printed by PRINT on unit IØ(2) (SINGLE ODD option in data) (i.e., IØ(4) not accessed).

IØ(4) = IØ(2) if only even pages are being printed by PRINT on unit IØ(4) (= printer)
(cont.) (SINGLE EVEN option in data). Note that subroutine INIT sets IØ(4) = IØ(2) in this case.

= scratch-unit number or another printer if all even pages are to follow all odd pages in the printout. In this case, IØ(4) will contain all the even pages, and if it is a scratch unit, it must be copied to the printer after job termination in order to obtain the even-page printouts (default option in data). Note: IØ(4) cannot equal IØ(2).

= scratch-unit number if odd/even, odd/even page ordering is desired. In this case, IØ(4) is used as scratch (DOUBLE option in data).

IØ(5) = scratch-unit number. PRINT always accesses this scratch file, regardless of which page-ordering option is used.

IBUF is the unpacked array of Catalog items to be printed.

IFLAG is an array of flags.

Method

PRINT is called once for every star. It stores information for five stars at a time before printing, ensuring a multiple of five stars per page, except on the last. Each page is printed with headings.

FORTRAN

PRINT is written in USASI FORTRAN.

9.11 VARPR (Diane Hills)

Purpose

Subroutine VARPR is called by the driver routine DRIVE (see Section 9.3) to call subroutine VARP to print, in user-supplied variable order, a number of items from the Catalog tape (see VARP, Section 9.12).

Calling Sequence

(IØ, IBUF, IFLAG)

where

IØ = an array of logical units used by DRIVE (IØ(2) is the printer).

IBUF = an array of unpacked Catalog items returned from routine IREAD.

IFLAG = an array of flags used by DRIVE.

COMMON Statements

VARPR contains a labeled common block:

COMMON/LDATA/NUM, LIST(200)

set up in routine INIT, also called by DRIVE.

FORTRAN

VARPR is written in USASI FORTRAN.

9.12 VARP (Diane Hills)

Purpose

VARP prints, in close-packed format with no labels, any number of Celescope Catalog tape items, on one or more lines, using a variable format.

Method

VARP obtains the unpacked record items in the array IBUF, with one character (left-justified) or integer per element in the array. See Table 6, Section 9.6, for a description of the IBUF array.

A set of NUM pointers to the particular items to be printed is obtained in a list LIST. See Table 7 for a description of valid pointers and the items to which they refer. The order of item numbers in LIST determines the order of the printed output.

VARP sets up one line of information to be printed at a time. If the user attempts to print more items than will fit on a line (119 characters), the overflow items will appear on a subsequent line of print. See Table 7 for the individual formats associated with each item to be printed.

Owing to their special nature, items 74–109 automatically print at the beginning of a new line. However, if no value exists for a particular item 74–109 and an attempt is made to print it, no line is printed.

If a particular item 2–73 is nonexistent in a record and an attempt is made to print it, blanks are printed in the space available.

Table 7. Pointers and format of VARP items.

Item	Description	Format
1	Checksum	Not to be printed. Will result in one blank
2	R. A. (1950)	I6 (HHMMSS)
3	Dec. (1950)	I6 (±DDMMM)
4	R. A. (2000)	I6 (HHMMSS)
5	Dec. (2000)	I6 (±DDMMM)
6	DM number	I3, I5 (±ZZNNNNN)
7	Ambiguous I. D.	A1
8	Merged image	A1
9	DM code	I1
10	NONSTAR code	I1
11	NGC–IC designation	4A1
12	HD number	I6
13	Peculiarity code 1	A1
.	.	.
.	.	.
.	.	.
33	Peculiarity code 21	A1
34	M1	5A1 (MM. MM)
35	M2	5A1 (MM. MM)
36	M3	5A1 (MM. MM)
37	Magnitude code	I1
38	Spectrum	2A1
39	Luminosity	A1
40	Reference 1	3A1
.	.	.
.	.	.
.	.	.
59	Reference 20	3A1
60–61	Comment	20A1
62	U_1 average	F6. 2 (±XX. XX)
63	Composite weight of U_1	F6. 2 (XXX. XX)

Table 7 (Cont.)

Item	Description	Format
64	RMS deviation of U_1	F6.2 (+XX.XX)
65	U_2 average	F6.2 (±XX.XX)
66	Composite weight of U_2	F6.2 (XXX.XX)
67	RMS deviation of U_2	F6.2 (+XX.XX)
68	U_3 average	F6.2 (±XX.XX)
69	Composite weight of U_3	F6.2 (XXX.XX)
70	RMS deviation of U_3	F6.2 (+XX.XX)
71	U_4 average	F6.2 (±XX.XX)
72	Composite weight of U_4	F6.2 (XXX.XX)
73	RMS deviation of U_4	F6.2 (+XX.XX)
74	Number of U_1 magnitudes	I3
75	All U_1(I)	F6.2 (±XX.XX)
76	All ID U_1(I)	1X, A1, I4, 4A1, I2, I3
77	All WT U_1(I)	I6
78	Number of U_2 magnitudes	I3
. . .	. . .	. . .
90	Number of U_1 magnitudes in filter proximity	I3
. . .	. . .	. . .
94	All eta U_1(I)	F6.2 (±XX.XX)
. . .	. . .	. . .
109	All eta U_4(I)	F6.2 (±XX.XX)

Comments on Format

The user may determine his output format to a certain extent by means of the following:

1) The appearance of a negative number in LIST will cause that (absolute) number of blanks to be printed at that point. For example, to insert three spaces between HD number (pointer 16) and DM number (pointer 6), LIST would contain the elements 16 -3 6. Item number 0 will give one blank space.

2) The appearance of item number 999 in LIST will cause a new line to be started at that point.

Calling Sequence

VARP is called with

(IPR, IBUF, LIST, NUM)

where

IPR = the logical unit number of the printer or file on which all printed output appears.

IBUF = the array of unpacked Catalog items. Each element in the array contains either a single hollerith character, left-justified with blank fill, or a right-justified integer.

LIST = an array of pointers to the items to be printed. Item pointers may be positive numbers from 1 to 109 (see Table 7), negative numbers, or 999.

NUM = the number of pointers appearing in LIST, i.e., the number of items to be printed.

Special Comments on FORTRAN

VARP is written in USASI FORTRAN and assumes that the user's system has capabilities for:

1) Printing with variable format (non-USASI).

2) Equivalencing an integer and a real array.

3) Printing an integer variable with an F-format conversion as long as the contents of the integer variable are real (obtained through 2) above).

Example

The following DRIVE output gives a data-card setup for VARP, showing the 73 LIST elements.

```
DATA CARDS READ

VARPR
  74
   2   3   4   5   6   0   9   0  12   0  34  35  36   0  37   0
   0  38  39   0  40  41  42 999  60  61  62  63  64  65  66  67
  68  69  70  71  72  73  74  75  76  77  78  79  80  81  82  83
  84  85  86  87  88  89  90  91  92  93  94  95  96  97  98  99
 100 101 102 103 104 105 106 107 108 109
END
```

It would produce the following printout for the first star on the Catalog tape.

```
   9 59410   243 59577+59 2819 1        9.4  9.5        4  A0  897A20A23
W/59 2819 FØLL.                       14.63  1.00  0.00
0
1
 14.63
R 2698551 3 14
     0
0
0
0
0
0
0
```

9.13 USER (Diane Hills)

Purpose

USER is a user-supplied subroutine called by the Celescope Catalog printing package driver routine DRIVE (Section 9.3). Its purpose is to process a record from the Catalog tape.

Calling Sequence

USER is called with

(IØ, IBUF, IFLAG)

where

IØ = an array of logical unit numbers.

IBUF = the unpacked array of Catalog items.

IFLAG = an array of flags.

Comments

The user should note the following when writing his own routine USER:

1) IFLAG(5) = 0 every time USER is called by DRIVE. When an end of file is encountered on the Catalog tape, USER is called one last time from FINAL with IFLAG(5) = 1. On each call to USER but the last, IBUF contains information about one star in the Catalog. The last call allows printing of totals and other such final processing.

2) Any initializing necessary can be done on the first call to USER, as follows:

```
      SUB USER(IØ, IBUF, IFLAG)
          .
          .
          .
      DATA IFIRST/0/
          .
          .
          .
      IF(IFIRST. EQ. 1) GØ TØ 30
          .
          .
          .
      initializing (print headings, etc.)
          .
          .
          .
      IFIRST=1
   30 CONTINUE
          .
          .
          .
```

3) The user may call routine VARPR (or VARP) from USER if the proper LIST elements are defined. Calls to PRINT, however, may be hazardous if other printing is done within routine USER. Calling PRINT from USER is not recommended.

Example of USER

The following example of the USER subroutine will count the number of A0 stars in the Celescope Catalog and print the total.

```
                     SUBROUTINE USER(IO, IBUF, IFLAG)
        C
        C    USER ROUTINE TO COUNT THE NUMBER OF A0 STARS IN THE CATALOG
        C
000006          DIMENSION IO(5), IBUF(3000), IFLAG(10)
000006          DATA IA, IZERO/1HA, 1H0/
000006          DATA IK0/0/
        C
        C    CHECK FOR FINAL CALL
        C    (FROM FINAL)
        C
000006          IF(IFLAG(5).NE.0) GOTO900
        C
        C    CHECK FOR A0 STAR
        C
        C    SPECTRAL CLASS
000007          IF(IBUF(51).NE.IA) RETURN
        C    SPECTRAL SUB CLASS
000011          IF(IBUF(52).NE.IZERO) RETURN
000014          IK0=IK0+1
000016          RETURN
        C
        C    FINALIZE
        C    PRINT TOTAL
        C
000016       900 CONTINUE
000016          LUPR=IO(2)
000020          WRITE(LUPR, 905) IK0
000025       905 FORMAT(1H1, 5HFOUND, I5, 9H A0 STARS)
000025          RETURN
000026          END
```

9.14 FINAL (Diane Hills)

Purpose

Subroutine FINAL is a Celescope Catalog routine called by the driver routine DRIVE (see Section 9.3). Its purpose is to rewind the Catalog tape and, if necessary, to make a final call to routine PRINT or USER.

FINAL is called only once, after an end of file has been encountered on the Catalog tape.

Calling Sequence

FINAL (IØ, IBUF, IFLAG)

where

IØ = an array of logical unit numbers.

IBUF = an array of unpacked Catalog items.

IFLAG = an array of flags.

Comments

FINAL sets IFLAG(5) = 1 and makes a final call to PRINT if PRINT has been called throughout the run or to USER if USER has been called throughout the run.

FORTRAN

FINAL is written in USASI FORTRAN.

9.15 UNPAK2 (Diane Hills)

Purpose

Subroutine UNPAK2 is a Celescope Catalog routine called by the Catalog tape-reading routine IREAD. It unpacks a Catalog record into an array containing one character (left-justified with blank fill) or one integer (right-justified) per element.. UNPAK2 utilizes the user's machine word size (in bits) as a variable and thus will work on any machine.* Since it is a generalized routine, it takes approximately twice as long as the original unpacking routine UNPAK (which works only on machines with a 60-bit word) (see Section 9.6).

Those who wish to utilize UNPAK2, instead of UNPAK or their own unpacking routine, will have to supply an IREAD routine that calls UNPAK2 appropriately.

Calling Sequence

UNPAK2(LEN, IBUF, IARAY)

where

LEN = the word length, in bits, of the machine being used to read the Catalog tape (e.g., LEN = 60 if the tape is being read by a CDC 6400 machine).

*UNPAK2 assumes a machine word ≥ 24 bits.

IBUF = the variable-length buffer containing one Catalog record as read by IREAD. IBUF consists of words of bit size LEN; the number of words in IBUF varies according to the number of observations in the record (dimensioned 1000).

IARAY = the variable-length array of unpacked Catalog items returned to DRIVE. IARAY consists of words of bit size LEN. See Table 6 for a description of this array.

Method

UNPAK2 utilizes the machine word size LEN and the known Catalog-item bit positions per 60-bit word on the tape to obtain bit positions per LEN-bit word in IBUF. With this information and the length, in bits, of each Catalog item, UNPAK unpacks IBUF into IARAY.

UNPAK2 calls routines GETBIT to obtain item bit positions per LEN-bit word, IBITS to obtain the actual bits per Catalog item right-justified in a word, and CONVT to convert characters from CDC display code on tape to hollerith equivalents.

Note that UNPAK2 assumes the significance of only the right-most 24 bits of any 60-bit word containing a single item (e. g., declination). The sign bit, if present, is considered separately.

Signed Catalog Items

UNPAK unpacks signed quantities by obtaining first the absolute value of the item (in general, the right-most 24 bits of the 60-bit word) and then the sign bit (in general, the left-most bit of the 60-bit word).

FORTRAN

UNPAK2 is written in USASI FORTRAN.

9.16 GETBIT (Diane Hills)

Purpose

GETBIT is a general-purpose bit-conversion routine called by the Celescope Catalog printing package routine UNPAK2 (see Section 9. 15). It has the following purpose:

Given

IWD = a word count in terms of 60-bit words

IBIT = a bit position in word number IWD (1–60, L–R)

LEN = a word length in bits (≤60),

GETBIT returns

JWD = a word count in terms of LEN-bit words

JBIT = a bit position in word number JWD (1–LEN, L–R) corresponding to bit-position IBIT in word number IWD.

COMMON

GETBIT has no arguments in its calling sequence. All values are transferred to and from GETBIT via a labeled common block:

COMMON/BITS/IWD, IBIT, JWD, JBIT, IDUM, LEN

where IWD, IBIT, JWD, JBIT, and LEN are described above and IDUM is a dummy variable not used by GETBIT.

FORTRAN

GETBIT is written in USASI FORTRAN.

9.17 IBITS (Diane Hills)

Purpose

Function IBITS is a general-purpose bit-shifting routine called by the Celescope Catalog printing package routine UNPAK2 (see Section 9.15). It has the following purpose:

Given

JBUF = an array of LEN-bit words

JWD = a word position in IBUF

JBIT = a starting bit-position in JBUF (JWD) (≤ LEN)

JLEN = a length, in bits (≤ LEN)

LEN = the machine word lengths, in bits, IBITS is returned as a word containing the JLEN bits that start in bit-position JBIT of JBUF(JWD) and continue to the right for JLEN - 1 bits, right-justified with zero fill.

Arguments and COMMON

IBITS has the calling sequence

```
FUNCTION IBITS(JBUF)
```

All other values are transferred to the function via the labeled common block

```
COMMON/BITS/IDUM1, IDUM2, JWD, JBIT, JLEN, LEN
```

IDUM1 and IDUM2 are dummy arguments not used by IBITS. JWD, JBIT, JLEN, LEN, and JBUF are described above.

Method

IBITS calls two bit-shifting functions IRSHFT and ILSHFT, where

I = IRSHFT(I1, N) returns I as the word I1 shifted N bits to the right
and
I = ILSHFT(I1, N) returns I as the word I1 shifted N bits to the left

IRSHFT and ILSHFT are independent of machine word size and may produce either end-off or end-around shifts because IBITS always masks the shifted word I according to the significant bits desired.

The user must supply IRSHFT and ILSHFT. Presumably, comparable routines exist on the user's system.

FORTRAN

IBITS is written in USASI FORTRAN.

10. EXPLANATION OF THE CATALOG COLUMNS

The contents of the Catalog are printed in a two-page format. The first, or odd-numbered, pages include the primary data, identification, position, UBV, and ultraviolet magnitudes. The second, or even-numbered, pages contain the known peculiarities, remarks about the object, including the DM numbers of stars that may be merged with it, and a list of references used to compile the ground-based data on the star. The following gives a detailed explanation of each column in the Catalog. The number following a catalog name refers to its number in the Reference List. Sample pages are shown in Figure 11.

ODD-NUMBERED PAGES

Column Heading	Contents
–	Sequence number from 1-90 to permit identification of the star on the even-numbered page.
HD	Henry Draper Catalogue number (922) or Henry Draper Extension number (A23, A24).
DM	Durchmusterung number: B BD, Bonner Durchmusterung (898) C CD, or CoD, Cordoba Durschmusterung (899) P CPD, Cape Photographic Durchmusterung (900). The Henry Draper Catalogue convention was used in the selection of the DM number for a star.

I	HD	DM	R.A.(1950)	DEC	V	B-V	U-B	S-L	U1	SD1	U2	SD2	U3	SD3	U4	SD4
1	29082	B- 2 942	4 32 4	- 2 11.1	8.2 M	8.2 G		A0	11.15		11.41					
2	29226	B- 2 952	4 33 31	- 2 19.9	8.1 M	8.1 G		B9	10.00		9.96					
3		B- 3 832	4 33 45	- 3 38.2	8.3 M			B9			11.83					
4	33069	B- 8 1035	5 5 3	- 8 43.1	6.88M			B8 /			8.91					
5	33316	B- 6 1094	5 6 42	- 6 30.1	8.5 M			B9			10.34		11.03			
6	33370	B- 5 1172	5 7 11	- 5 36.9	8.8 M			A0			12.26					
7	33547	B- 5 1178	5 8 20	- 5 13.8	8.5 M			B9			10.75	.01				
8	33590	B- 5 1179	5 8 37	- 5 39.7	9.0 M			B9			11.67					
9	33610	B- 6 1104	5 8 42	- 6 5.0	8.3 M			A0			11.41	.25	12.83			
10		B- 8 1057	5 10 34	- 8 7.4	8.0 M			A0			11.21					
11	33902	B- 5 1191	5 10 52	- 5 1.9	9.40M			A0			12.52	.55				
12	33918	B- 4 1073	5 11 0	- 4 42.6	8.0 M			A0			12.06	.42				
13	33928	B- 3 1042	5 11 9	- 3 40.6	7.6 M	7.6 G		B8 /	9.47							
14	33994	B- 6 1112	5 11 22	- 6 48.3	8.0 M			B8	9.63	.06	9.23	.49	9.40		9.92	.26
15		B- 7 1009	5 12 4	- 7 20.3	8.5 M			A0			10.86	.20	11.92			
16	34164	B- 5 1204	5 12 37	- 5 18.5	9.0 M			A0			12.12					
17	34280	B- 3 1051	5 13 45	- 3 32.3	8.6 M	8.6 G		B9			11.35					
18	34342	B- 5 1208	5 14 6	- 5 6.9	8.8 M	8.9 G		A2			12.25	.20				
19	34417	B- 7 1024	5 14 31	- 6 59.4	8.0 M	8.0 G		A0			10.89	.06			11.77	
20	34481	B- 4 1090	5 15 8	- 4 46.9	8.85M	8.85G		A0			12.12					
21	34639	B- 9 1119	5 16 23	- 9 5.8	9.2 M	9.2 G		B9			12.32					
22	34686	B- 5 1219	5 16 39	- 5 .6	8.55M	8.55G		A0			12.19	.34				
23	34736	B- 7 1036	5 16 56	- 7 23.9	8.0 M			B9	10.56		10.18	.15	11.12			
24	34734	B- 4 1102	5 17 2	- 4 23.5	8.6 M	8.6 G		A0			12.57					
25	34774	B- 5 1221	5 17 14	- 4 55.6	7.35M	7.35G		A0			11.37					
26	34814	B- 7 1042	5 17 26	- 7 10.9	8.8 M			A0			11.79		12.84			
27	34813	B- 7 1041	5 17 26	- 6 58.9	8.8 M			A0			11.76		12.66			
28	34827	B- 5 1223	5 17 35	- 5 15.5	7.09M			B9	10.24	.36	10.07	.21	11.05		10.49	
29	34835	B- 6 1141	5 17 41	- 5 53.7	8.6 M			B8	11.10		10.65					
30	34861	B- 7 1043	5 17 47	- 7 9.2	8.8 M			A0			11.93		12.89			
31	34892	B- 8 1092	5 18 0	- 8 4.7	8.0 M	8.3 G		F2 /			12.02					
32	34890	B- 5 1226	5 18 2	- 5 51.7	9.2 M			A0			11.72					
33	34889	B- 5 1227	5 18 5	- 5 20.2	9.2 M			B9			11.20	.05	11.69			
34	35178	B- 7 1054	5 20 10	- 7 38.4	8.0 M	8.0 G		A0			12.15					
35	35225	B- 8 1103	5 20 28	- 8 8.0	9.0 M	9.0 G		A0			12.54					
36	35223	B- 6 1158	5 20 32	- 6 45.8	8.7 M			A2			12.37					
37	35261	B- 8 1105	5 20 40	- 8 9.1	8.5 M			A0 $	10.57	.42	10.15					
38	35353	B- 8 1109	5 21 20	- 8 20.1	8.6 M	8.6 G		A0			11.81					
39	35659	B- 7 1075	5 23 34	- 7 .3	8.5 M			A3			12.08					
40	36695	B- 1 943	5 30 59	- 1 11.4	5.34	-0.18	-1.09V	B15*	6.76		6.21	.22	6.74	.22	6.33	.52

Figure 11a. Sample odd-numbered page of the Catalog.

2 NS	R.A.(2000)	DEC	WT1	WT2	WT3	WT4	OBJ	PHOT	S-PEC	------REMARKS-------	------------REFERENCES------------------
1	4 34 35	- 2 4.9	1.0	1.0							897 922
2	4 36 2	- 2 13.8	1.0	1.0							897 922
3	4 36 15	- 3 32.1		1.0							897
4	5 7 27	- 8 39.2		1.0				0			897 922 969
5	5 9 8	- 6 26.3		1.0	1.0						897 922
6	5 9 38	- 5 33.2		1.0							897 922
7	5 10 48	- 5 10.2		2.0							897 922
8	5 11 4	- 5 36.1		1.0							897 922
9	5 11 9	- 6 1.4		3.0	1.0						897 922
10	5 12 58	- 8 3.9		1.0							897
11	5 13 20	- 4 58.4		2.0							897 922 A07
12	5 13 28	- 4 39.1		3.0							897 922
13	5 13 38	- 3 37.4	1.0					U			897 922 A26
14	5 13 48	- 6 44.9	2.0	4.0	1.0	2.0					897 922
15	5 14 29	- 7 16.9		2.3	1.0						897
16	5 15 5	- 5 15.2		1.0							897 922
17	5 16 15	- 3 29.0		1.0							897 922
18	5 16 34	- 5 3.7		2.0							897 922
19	5 16 57	- 6 56.2		2.0		1.0					897 922
20	5 17 36	- 4 43.7		1.0							897 922
21	5 18 46	- 9 2.7		1.0							897 922
22	5 19 7	- 4 57.5		2.0							897 922
23	5 19 21	- 7 20.9	1.0	2.0	1.0						897 922
24	5 19 31	- 4 20.5		1.0							897 922
25	5 19 42	- 4 52.6		1.0							897 922
26	5 19 51	- 7 7.9		1.0	1.0						897 922
27	5 19 52	- 6 55.9		1.0	1.0						897 922
28	5 20 3	- 5 12.5	3.0	3.0	1.0	1.0					897 922
29	5 20 8	- 5 50.7	1.0	1.0							897 922
30	5 20 12	- 7 6.2		1.0	1.0						897 922
31	5 20 24	- 8 1.7		1.0				0			897 922 969
32	5 20 29	- 5 48.7		1.0							897 922
33	5 20 33	- 5 17.3		2.0	.3						897 922
34	5 22 35	- 7 35.6		1.0							897 922
35	5 22 52	- 8 5.2		1.0							897 922
36	5 22 58	- 6 43.0		1.0							897 922
37	5 23 4	- 8 6.3	2.0	1.0						W/ -8 1103	897 922
38	5 23 44	- 8 17.4		1.0							897 922
39	5 26 0	- 6 57.7		1.0							897 922
40	5 33 31	- 1 9.4	1.0	15.0	2.0	6.0		U2P	NR	VV ORI, 5B	897 002 012 013 020 036 259 377 756 884 901 921 922 969 A26 A42 A48 A54 A55 A59

Figure 11b. Sample even-numbered page of the Catalog.

Column Heading	Contents
R.A. (1950)DEC	Positions. The position is taken from the SAO Star Catalog if the first reference number is 897. The position is the DM position precessed to 1950.0 if the star was not in the SAO catalog and if one of the DM catalogs (898, 899, 900) is the first reference number. The position is the average of all positions given by the references after they were precessed to 1950.0 if neither the SAO nor the DM positions are available. If the star was not identified with a known object, the position was determined from the Celescope data and has an accuracy of about 1 arcmin. If the "star" is the merged image of two stars and is merged in all observations, then the more probable star is used. Average positions are used to distinguish among unique combinations if the images are merged differently on different frames.
V	The photoelectric V magnitude of the UBV system, when available; otherwise, in order of preference, m_v, m_{pv}, m_{pg}. To distinguish among these possibilities, the magnitude given may be followed by M(m_v), P(m_{pv}), or G(m_{pg}). If, when these data were compiled, different sources agreed to within $0^{m}.10$, the arithmetic mean is given. If the star has any type of magnitudes listed in the Naval Observatory Catalogue

Column Heading	Contents
V (cont.)	(reference A19 is always the first or second entry in the reference list), then that datum is used in preference to any other. Magnitudes given to one decimal place required a consistency of $\pm 0\overset{m}{.}5$ in the source material. Magnitudes given to two decimal places required a consistency of $\pm 0\overset{m}{.}05$ from those sources reporting the magnitude to two decimal places.
B-V	The photoelectric B-V color of the UBV system; otherwise, the magnitude m_{pg} (followed by a G) if available. The same conventions used in the V column with regard to accuracy and the use of reference A19 apply.
U-B	The photoelectric U-B color of the UBV system, when available; otherwise, in order of preference, U-V followed by a V or $(U-B)_c$ followed by a C. The same conventions for accuracy and use of A19 apply as in the V column.
S-L	Spectrum and luminosity. If different sources agreed to within ± 2 subclasses, the arithmetic mean was taken; otherwise, a decision was made on which spectrum to use. Intermediate spectral subclasses and luminosities have been truncated, and luminosities decimalized; i.e., a star of spectral type B0.5II-III is listed as B02.

Column Heading	Contents
S-L (cont.)	Peculiarity flag. One of the following symbols may follow the spectrum and luminosity, indicating that the even-numbered page contains information affecting the spectrum:

+	A spectral peculiarity exists
/	A photometric peculiarity exists
$	A comment exists
*	More than one of the above exists.

U1

U1 magnitude, the weighted mean of the Celescope observational results in the U1 color band (2100 to 3200 Å). Celescope magnitudes are based on spectral irradiance in MKS units: $U_n = -2.5 \log I$, where I is the spectral irradiance from the observed star at the effective wavelength of the color band, in units of watts per square meter per meter of wavelength. The U1 magnitude is derived from the formula

$$U1 = \frac{\sum [1/(1+w_i)]\ U1_i}{\sum [1/(1+w_i)]} \quad ,$$

where $U1_i$ is the ith observation of the U1 magnitude, and w_i is the weighting factor, equal to zero except:

w = 3 if the object could not be separated from a neighboring object by our standard computer program and was separated manually,

or

Column Heading	Contents
U1 (cont.)	if the object was within 15 arcmin of the line through the center of the field separating the two different optical filters, which were rigidly mounted in front of each television camera.
	$w = 6$ if the object was both manually split and near the filter split line.
	$w = \infty$ if the object was within 5 arcmin of the filter split line, or if the object was in a part of the picture having a bright background, or if the object touched the edge of the picture.
SD1	The root-mean-square (RMS) deviation of the observations used to compute U1, based on the formula $$SD1 = \left\{ \frac{\sum [1/(1+w_i)] \ (U1_i - U1)^2}{\sum [1/(1+w_i)]} \right\}^{1/2} .$$ If U1 is based on a single observation, the standard deviation is blank.
U2	U2 magnitude, the weighted mean of the Celescope observational results in the U2 color band (1550 to 3200 Å), calculated the same way as U1.
SD2	The RMS deviation of U2, computed in the same way as SD1.
U3	U3 magnitude, the weighted mean of the Celescope observational results in the U3 color band (1350 to 2150 Å), calculated the same way as U1.

Column Heading	Contents
SD3	The RMS deviation of U3, computed in the same way as SD1.
U4	U4 magnitude, the weighted mean of the Celescope observational results in the U4 color band (1050 to 2150 Å), calculated the same way as U1. Very few U4 magnitudes are given, because of interference from the bright Lyman-alpha background of the geocorona.
SD4	The RMS deviation of U4, computed in the same way as SD1.

EVEN-NUMBERED PAGES

Column Heading	Contents
–	Sequence number (the same number as on the matching odd-numbered page).
NS	The NGC, IC, 3C number or other designation for the object. Association names also appear in these columns.
R. A. (2000)DEC	The star's right ascension and declination precessed to epoch 2000.
WT1	The composite weight of the observations of the object in filter 1, calculated with the equation $WT1 = \sum [1/(1 + w_i)]$, where w_i is as defined in the U1 column.
WT2	The composite weight of the observations of the object in filter 2, calculated in the same manner as WT1.

Column Heading	Contents
WT3	The composite weight of the observations of the object in filter 3, calculated in the same manner as WT1.
WT4	The composite weight of the observations of the object in filter 4, calculated in the same manner as WT1.
OBJ	Codes referring to the general type of object, primarily to nonstellar objects. More than one of the following letters may apply, and the printed order is not significant: D Diffuse emission nebula G Galactic cluster O Object surrounded by or associated with nebulosity R Radio source.
PHOT	One-letter codes designating known photometric properties of the star, and a number code designating variability. More than one of the following letters or numbers may apply, and the order is not significant: B Visual binary H High-velocity star M Multiple star P Polarization data available S Standard on MK or UBV system U Observed in the ultraviolet below 3000 Å 0 Suspected variable 2 Eclipsing variable 3 Early-type irregular variable (type Ia of Kukarkin *et al.*, 1971)

Column Heading	Contents
PHOT (cont.)	4 Variable star of unspecified type
	5 Beta Canis Majoris variable
	6 Alpha Canum Venaticorum variable
	9 Peculiar variable
	10 Classical Cepheid variable
	12 Irregular variable other than type Ia of Kukarkin *et al*. (1971)
	14 RR Lyrae variable
	16 Nova-like variable
	22 RV Tauri variable.
S-PEC	One-column codes referring to the spectral characteristics of the star. One or more of the following may apply; their printed order is not significant:
	A Peculiar A-type star
	B Spectroscopic binary
	C Composite spectrum
	D Interstellar D lines of sodium
	E Any type of emission
	G Magnetic field
	H Interstellar H and K lines of calcium II
	M Metallic-line star
	N Nebulous lines
	P Peculiar spectrum
	R Measured axial rotation

Column Heading	Contents
S-PEC (cont.)	S Sharp lines
	Y Shell spectrum
	4 Interstellar 4430 Å absorption band.
REMARKS	Comments about a star when applicable. Occasionally, more than one star has been included in the mean ultraviolet magnitude reported. Such cases are described as fully as possible. A primary identification has been assigned to the observations, given in the HD and/or DM columns, and the ground-based data only for that star have been reported. Normally, DM numbers in the Remarks column are from the same catalog as the primary number. Additional stars in the observed image are given in the Remarks, e.g., W/P-45 3137 indicates a secondary component of the observation having a CPD number of -45 3137. Ground-based data are not reported for secondary components, except for the spectral classifications for components of known binaries. Where more information than could be reported in the S-PEC column was deemed important, it has been included here. In addition to identifications of secondaries, spectral classes for binaries, and variable star names, the following abbreviations are used:
	SB Spectroscopic binary
	EB Eclipsing binary
	CS Composite spectrum
	PREC. Preceding in right ascension
	FOLL. Following in right ascension.

Column Heading	Contents
REFERENCES	The identification numbers of the references used in compiling the ground-based astrophysical information about the star. They are arranged in numerical and then alphabetical order, except for the following: The SAO Star Catalog reference number (897) is always first if it appears. If 897 is absent, the reference number of the DM catalog (898, BD; 899, CD; 900, CPD) will be first if it is given. The second reference is the Naval Observatory Photoelectric Catalogue (A19) if it appears.

11. DESCRIPTION OF THE MICROFILM CATALOG

The National Space Sciences Data Center (NSSDC) has sorted the Celescope data into five different sorts and printed them on microfilm.

Each version was printed with the standard printing package, and all items appear in their usual columns (e.g., the datum used in the sort has not been moved to a position of prominence). All sorts have R.A./Dec as the final parameter, so that stars that are otherwise identical will be arranged in order of increasing right ascension, and within right ascension, by decreasing declination.

The five versions of the tape are as follows:

A. Right ascension, declination; the data are sorted by increasing right ascension (1950 epoch) and by decreasing declination if two or more stars have the same right ascension.

B. Henry Draper number; the data are sorted by increasing HD number. Stars that have no HD number follow those that do.

C. Durchmusterung number; the data are sorted by decreasing DM zone number, and within a zone, by increasing star number.

D. Magnitude; the data are sorted by increasing value (-1 to +11) of M1 (V, m_v, or m_{pg}).

E. Spectral class–luminosity; the data are sorted by spectral class, and within spectral class, by luminosity. Stars without a spectral subclass follow all the stars with the same class. Stars without a spectral class follow the stars with spectral classes.

This film is available from the NSSDC, Code 601, National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland 20771. The data should be requested by the designation "68-110A-01 (Smithsonian OAO Data)."

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520. BRAES, L. L. E. 1962
185. BRANDT, J. C. 1960
660. BRAUDE, S. YA., MEN', A. V., ZHUK, I. N., AND BABENKOV, K. A. 1962
132. BRETZ, M. C. 1961
954. BRODSKAYA, E. S. 1966
154. BROTEN, N. W., AND MEDD, W. J. 1960
469. BROWN, R. HANBURY, AND HAZARD, C. 1961
484. BROWN, R. HANBURY, AND HAZARD, C. 1959
496. BROWN, R. HANBURY, PALMER, H. P., AND THOMPSON, A. R. 1955
017. BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H. 1962
033. BURBIDGE, E. M., AND BURBIDGE, G. R. 1962
042. BURBIDGE, E. M., AND BURBIDGE, G. R. 1962

063.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1961
093.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1961
094.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1961
095.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1961
096.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1961
097.	BURBIDGE, E. M., BURBIDGE, G. R., AND FISH, R. A.	1961
101.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1961
111.	BURBIDGE, E. M., BURBIDGE, G. R., AND FISH, R. A.	1961
125.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1961
146.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1960
147.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1960
148.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1960
164.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1960
177.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1960
184.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1960
215.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1959
239.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1959
332.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1956
346.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1956
386.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1955
394.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1963
407.	BURBIDGE, E. M., AND BURBIDGE, G. R.	1955
711.	BURBIDGE, E. M., BURBIDGE, G. R., AND PRENDERGAST, K. H.	1963
751.	BURBIDGE, E. M., BURBIDGE, G. R., AND RUBIN, V. C.	1964
907.	BURBIDGE, E. M., LYNDS, C. R., AND BURBIDGE, G. R.	1966
230.	BURBIDGE, G. R.	1959
298.	BURBIDGE, G. R.	1958
301.	BURBIDGE, G. R., AND BURBIDGE, E. M.	1955
325.	BURBIDGE, G. R., AND BURBIDGE, E. M.	1957
347.	BURBIDGE, G. R., AND BURBIDGE, E. M.	1956
375.	BURGESS, A., AND SEATON, M. J.	1960
007.	BUSCOMBE, W.	1959
008.	BUSCOMBE, W.	1962
352.	BUSCOMBE, W.	1962
353.	BUSCOMBE, W., AND KENNEDY, P. M.	1962
468.	BUSCOMBE, W., AND MORRIS, P. M.	1961
499.	BUSCOMBE, W.	1956
526.	BUSCOMBE, W., AND KENNEDY, P. M.	1962
854.	BUSCOMBE, W.	1965
504.	BUTLER, H. E., AND SEDDON, H.	1960
511.	BUTLER, H. E., AND SEDDON, H.	1958
512.	BUTLER, H. E., AND THOMPSON, G. I.	1961
892.	BYRAM, E. T., CHUBB, T. A., AND WERNER, M. W.	1965
A49.	CAMPBELL, J. W.	1970
A66.	CAMPBELL, J. W.	1971
922.	CANNON, A. J., AND PICKERING, E. C.	1918
A23.	CANNON, A. J.	1925
A24.	CANNON, A. J., AND MAYALL, M. W.	1949
149.	CAPRIOTTI, E. R., AND DAUB, C. T.	1960
A47.	CARRUTHERS, G. R.	1969

A56.	CARRUTHERS, G. R.	1971
A69.	CARTER, B. S., CORBEN, P. M., AND HARVEY, G. M.	1971
395.	CAYREL, R., AND CAYREL, G.	1963
715.	CAYREL, R.	1958
712.	CHADEAU, C.	1955
335.	CHAMBERLAIN, J. W.	1956
547.	CHAMBERLIN, C., AND MCNAMARA, D. H.	1957
449.	CHOL CHOU, K.	1959
721.	CHOPINET, M.	1963
488.	CHUBB, T. A., AND BYRAM, E. T.	1963
998.	CLARKE, D., AND GRAINGER, J. F.	1966
797.	CODE, A. D., AND BLESS, R. C.	1964
901.	CODE, A. D.	1966
116.	COLLINS, G. W., II, DAUB, C.T., AND O'DELL, C. R.	1961
A58.	CONTI, P. S., AND ALSCHULER, W. R.	1971
A64.	CONTI, P. S., AND SMITH, L. F.	1972
493.	CONWAY, R. G.	1957
A68.	CORBEN, P. M.	1971
A71.	CORBEN, P. M.	1971
A72.	CORBEN, P. M., AND STOY, R.H.	1968
708.	COURTES, G.	1960
158.	COUSINS, A. W. J., AND STOY, R. H.	1963
832.	COUSINS, A. W. J.	1963
833.	COUSINS, A. W. J.	1964
835.	COUSINS, A. W. J.	1963
838.	COUSINS, A. W. J.	1963
839.	COUSINS, A. W. J.	1962
840.	COUSINS, A. W. J.	1962
A50.	COUSINS, A. W. J.	1970
A51.	COUSINS, A. W. J., AND STOY, R. H.	1970
A75.	COUSINS, A. W. J., LAKE, R., AND STOY, R. H.	1966
894.	COWLEY, A. P., AND COWLEY, C. R.	1965
464.	COWLEY, C. R.	1958
475.	CRAMPIN, J., AND HOYLE, F.	1960
103.	CRAWFORD, D. L.	1961
169.	CRAWFORD, D. L.	1960
259.	CRAWFORD, D. L.	1958
396.	CRAWFORD, D. L.	1963
397.	CRAWFORD, D. L.	1963
A59.	CRAWFORD, D. L., BARNES, J. V., AND GOLSON, J. C.	1971
492.	DAVIES, R. D.	1957
860.	DE GROOT, M., AND UNDERHILL, A. B.	1964
638.	DE JAGER, C.	1956
869.	DE JAGER, C.	1964
756.	DELHAYE, J.	1959
576.	DEUTSCH, A. J.	1956
624.	DEUTSCH, A. J.	1955
508.	DE VAUCOULEURS, A.	1957
030.	DE VAUCOULEURS, G., AND PAGE, J.	1962
112.	DE VAUCOULEURS, G.	1961

150.	DE VAUCOULEURS, G.	1960
178.	DE VAUCOULEURS, G.	1960
183.	DE VAUCOULEURS, G.	1960
197.	DE VAUCOULEURS, G.	1959
198.	DE VAUCOULEURS, G.	1959
255.	DE VAUCOULEURS, G.	1958
261.	DE VAUCOULEURS, G.	1961
393.	DE VAUCOULEURS, G., AND DE VAUCOULEURS, A.	1963
405.	DE VAUCOULEURS, G.	1963
435.	DE VAUCOULEURS, G.	1963
641.	DE VAUCOULEURS, G., AND DE VAUCOULEURS, A.	1959
642.	DE VAUCOULEURS, G.	1959
776.	DE VAUCOULEURS, G.	1963
801.	DE VAUCOULEURS, G.	1964
A04.	DE VAUCOULEURS, G., AND DE VAUCOULEURS, A.	1964
691.	DIBAI, E. A.	1960
958.	DIBAI, E. A.	1967
985.	DIBAI, E. A., AND ESIPOV, V. F.	1967
990.	DIBAI, E. A., AND SHAKHOVSKOI, N. M.	1967
943.	DICKENS, R. J.	1967
167.	DIETER, N. H.	1960
422.	DIETER, N. H.	1962
423.	DIETER, N. H.	1962
891.	DIVAN, L.	1965
675.	DOKUCHAEVA, O. D.	1959
680.	DOMBROVSKII, V. A.	1958
980.	DRAGOMIRETSKAYA, B. A.	1965
240.	EATON, J. J., AND KRAUS, J. D.	1959
331.	EBBIGHAUSEN, E. G., AND STRUVE, O.	1956
601.	EBBIGHAUSEN, E. G., AND STRUVE, O.	1959
731.	EBBIGHAUSEN, E. G.	1960
732.	EBBIGHAUSEN, E. G.	1960
733.	EBBIGHAUSEN, E. G., AND PETRIE, R. M.	1960
734.	EBBIGHAUSEN, E. G.	1960
066.	EDGE, D. O., SHAKESHAFT, J. R., MCADAM, W. B., ET AL.	1959
674.	EFIMOV, YU. S.	1959
580.	EGGEN, O. J.	1956
589.	EGGEN, O. J.	1956
781.	EGGEN, O. J.	1963
877.	EGGEN, O. J.	1965
A65.	EGGEN, O. J.	1972
690.	EGOROVA, T. M.	1963
929.	EKERS, R. D., AND BOLTON, J. G.	1965
194.	ELSMORE, B., RYLE, M., AND LESLIE, P. R. R.	1959
572.	ELSTE, G., JUGAKU, J., AND ALLER, L. H.	1956
702.	ELVIUS, A.	1962
482.	EVANS, D. S.	1959
487.	EVANS, D. S., MENZIES, A., AND STOY, R. H.	1959
500.	EVANS, D. S.	1956
503.	EVANS, D. S.	1956

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Before joining the staff at Smithsonian Astrophysical Observatory in 1956, Dr. Davis was an astrophysicist at Varo Manufacturing Company, Garland, Texas. He also held a teaching fellowship at Harvard College Observatory from 1955 to 1958.

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NOTICE

This series of Special Reports was instituted under the supervision of Dr. F. L. Whipple, Director of the Astrophysical Observatory of the Smithsonian Institution, shortly after the launching of the first artificial earth satellite on October 4, 1957. Contributions come from the Staff of the Observatory.

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