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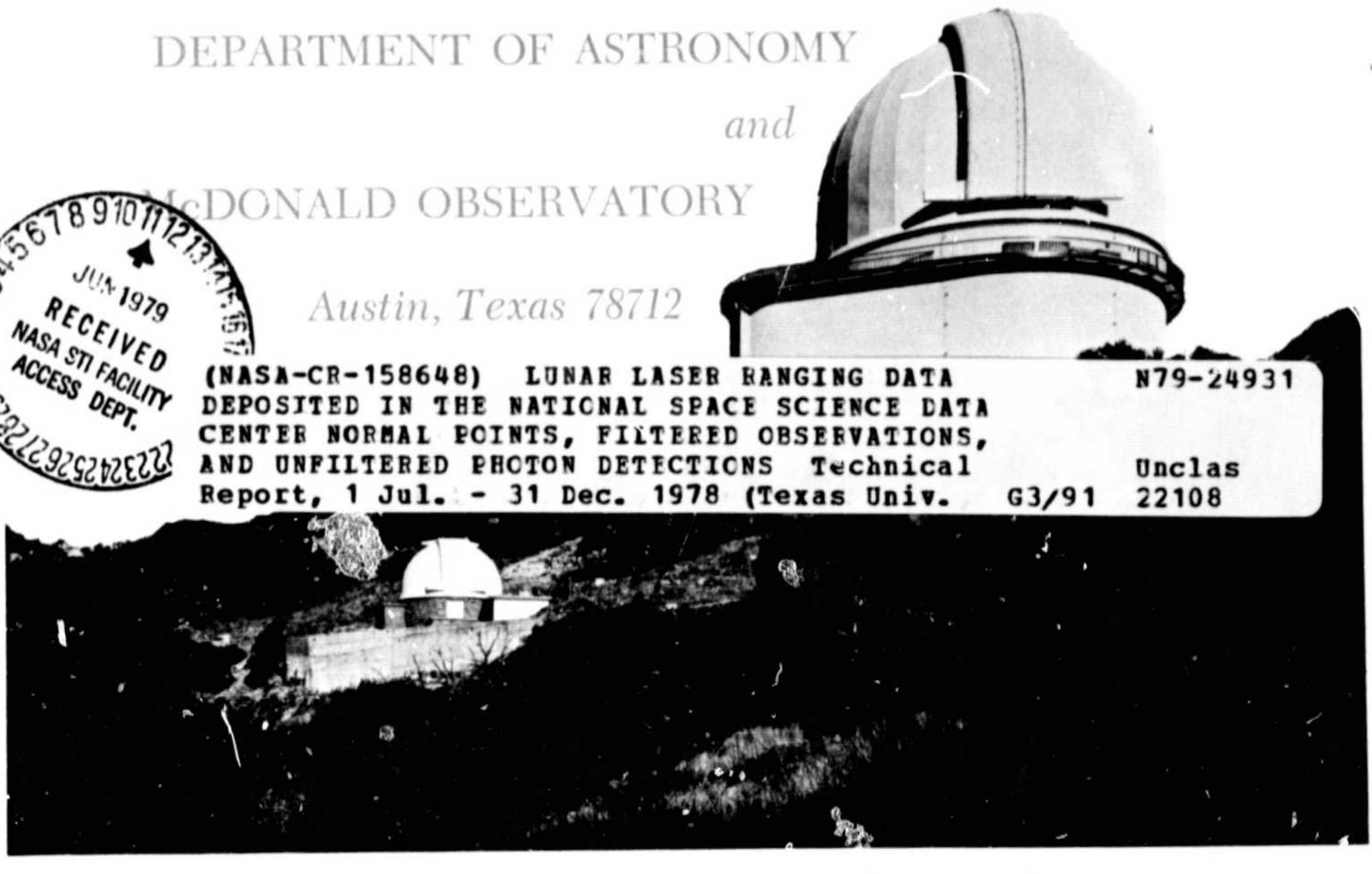

(NASA-CR-158648) LUNAR LASER RANGING DATA DEPOSITED IN THE NATIONAL SPACE SCIENCE DATA CENTER NORMAL POINTS, FILTERED OBSERVATIONS, AND UNFILTERED PHOTON DETECTIONS Technical Report, 1 Jul. - 31 Dec. 1978 (Texas Univ. G3/91

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Lunar Laser Ranging Data Deposited in the National Space Science Data Center Normal Points, Filtered Observations, and Unfiltered Photon Detections for 1 July 1978 through 31 December 1978

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I. Introduction

The lunar laser ranging project at McDonald Observatory provides beyond a doubt the unique opportunity to acquire successfully precise range data for the Earth-moon system. From the experiment's inception, the obligation has been recognized to make these data available to the general scientific community in a reasonably useable form and in a realistic time frame. The present report is the documentation to be used in conjunction with the 1979 April deposit into the National Space Science Data Center which contains normal points, filtered observations and unfiltered photon stops for the months July through December, 1978. Note that deposits in this series are now being made semi-annually on or about 1 April and 1 October and consist of 6-month blocks of data which end three months before the deposit date, i.e., January-June or July-December.

This deposit contains observations from lunar laser ranging operations at McDonald Observatory, Fort Davis, Texas. The observing equipment is mounted on the 2.7m reflector (Silverberg, 1974). The nominal coordinates for this instrument, based on lunar ranging data, are available from Bender et al (1973); the precise role played by the telescope mirror geometry is discussed by Shelus et al (1975). The nominal coordinates for the lunar surface retroreflectors 0, 2, and 3 are available from Bender et al (1973); data for retroreflector 4 is available from Barker et al (1974).

II. Observational Statistics

The 119 McDonald Observatory normal points contained in this data deposit represent some 1208 photons. The distribution of the data with respect to month and reflector is presented in Table I.

	REFLECTOR 0		REFLECTOR 2		REFLECTOR 3		REFLECTOR 4		TOTALS	
1978	Normal points	# of photons	Normal points	# of photons	Normal points	# of photons	Normal points	# of photons	Normal points	# of photons
Jul	0	0	2	34	10	108	3	32	15	174
Aug	0	0	3	46	18	234	0	0	21	280
Sep	0	0	1	10	2	15	0	0	3	25
Oct	2	19	5	54	20	182	2	29	29	284
Nov	6	55	4	44	18	145	1	13	29	257
Dec	1	6	2	21	16	136	3	25	22	188
TTL	9	80	17	209	84	820	9	99	119	1208

Table I. Summary of filtered observations by month and by reflector.

A histogram providing the distribution of photons per normal point for this deposit can be found in Figure 1. Figure 2 presents histograms of the distribution of the McDonald normal points contained in this deposit with respect to the classical fundamental arguments of the lunar motion. Figure 3 gives histograms of the same data with respect to the lunar declination and the local hour angle. It should be noted that the various distributions of the present data are essentially identical to earlier deposits in this series.

III. Data Description

The data are contained on three files of a binary magnetic tape written in card-image format, using a CDC 6400/6600 computer. It is written with odd parity at 800 bpi. Three types of cards are present, distinguished by an alphabet character in column 1. The letter "Z" designates a "RUN" card, giving environmental and operational parameters for a series of shots. Except for clock epoch offset, these will not customarily be required for application of the range data, but serve to provide information on the observing conditions and the state of the equipment. The letter "P" in column 1 represents a "SHOT" card, containing the result of a single laser firing. The letter "N" in column 1 represents a "NORMAL POINT" card containing the information compressed from an entire "RUN". A word of warning is in order to the unwary user. Some of the specified data may not be available. In the card images, a blank field is a "no information" indicator. Actual null values will be represented by zero punches. The complete "Z", "P", and "N" card formats are as follows:

```
  INTEGER ZIN(23)
  READ(5,1)ZIN
1 FORMAT(A1,I3,I10,I8,I3,3I2,A1,2X,I3,I5,5I3,A5,2I3,2I4,2I2)
```

where ZIN(1) = Card identifier (=Z)
(2) = Observatory code* (=711)
(3) = Julian date x 1000
(4) = Clock epoch offset (microseconds)
(5) = Atmospheric temperature (Celsius)
(6) = Humidity (% saturation)
(7) = Wind speed (km/hr)
(8) = Seeing (0.1 arc sec)
(9) = Electronic calibration accuracy code (see Appendix A)
(10) = Energy (0.1 joule)
(11) = Laser Frequency (10 gigahertz)
(12) = Pulse length (100 picoseconds)
(13) = Shot-by-shot resolution (100 picoseconds)
(14) = Dark count (kHz)
(15) = Moon count (kHz)
(16) = Star count (kHz)
(17) = Star identification
(18) = Spectral filter width (nanometers)
(19) = Spatial filter width (0.1 arc sec)
(20) = Number of shots in run
(21) = Calendar year
(22) = Month
(23) = Day

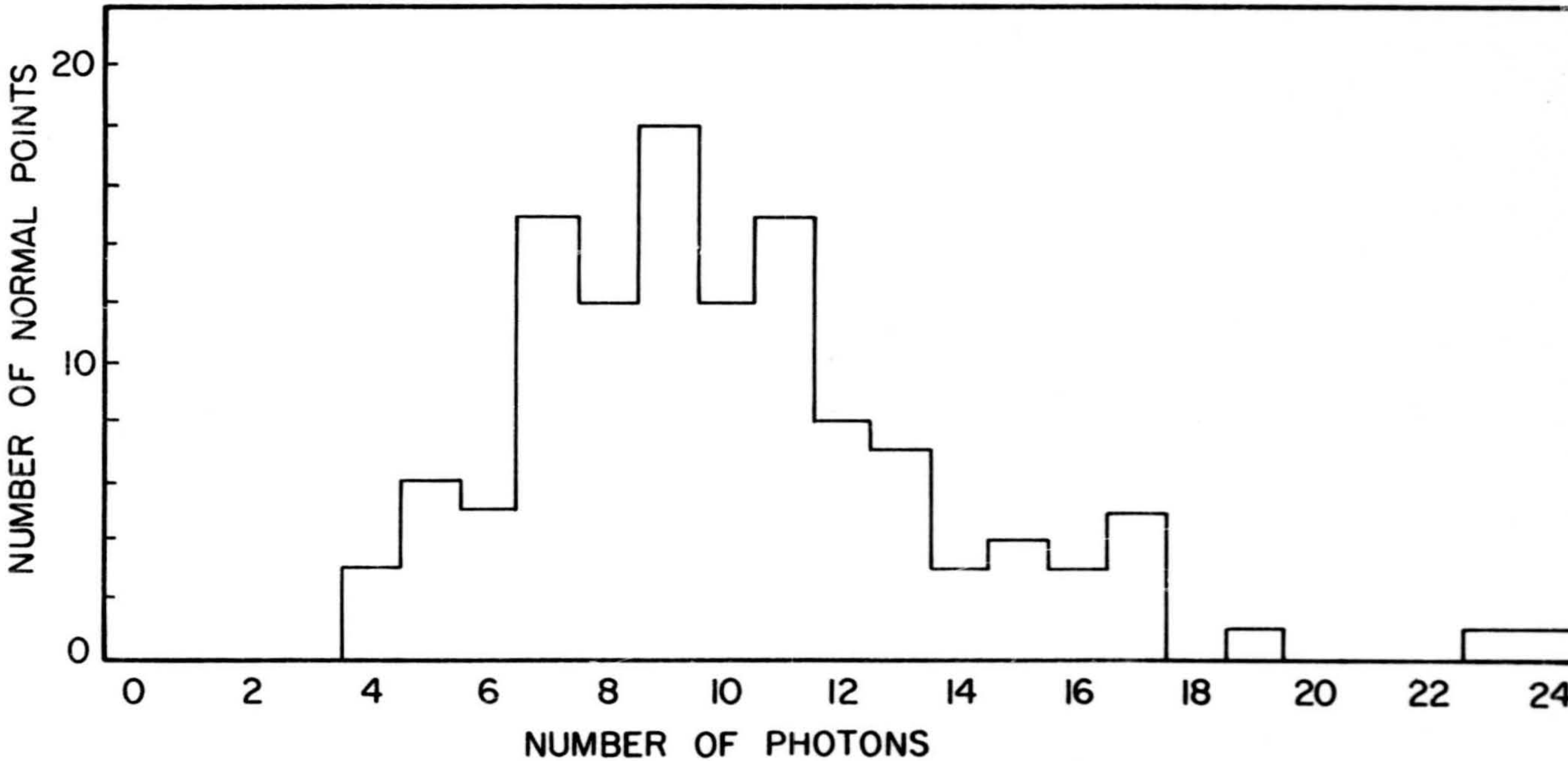

Figure 1. Distribution of signal photons per normal point.

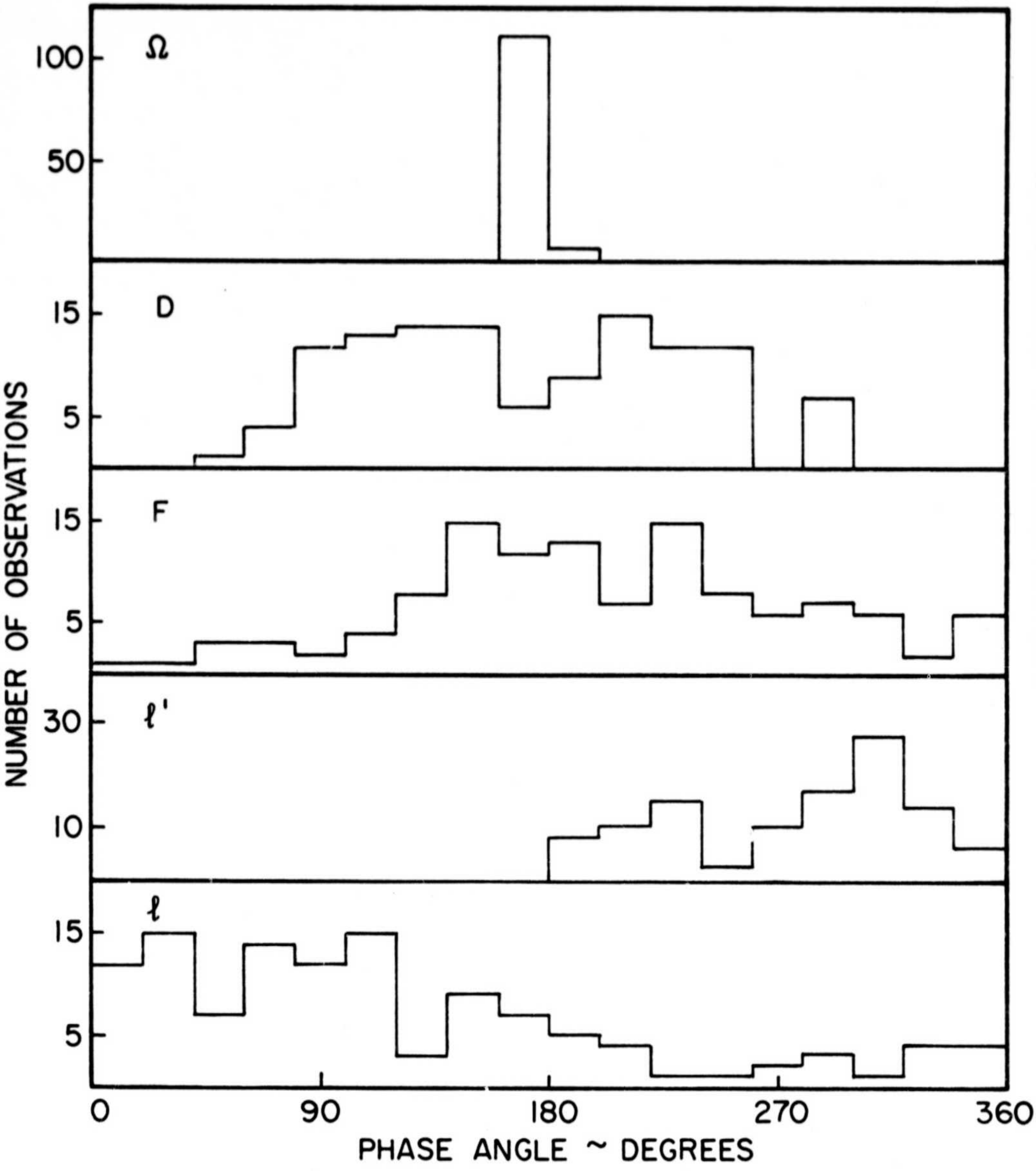

Figure 2. Histograms of the 1978.5-1979.0 observation distributions with respect to the phase of each of the fundamental arguments of the lunar orbit motion. The sampling interval is 20°.

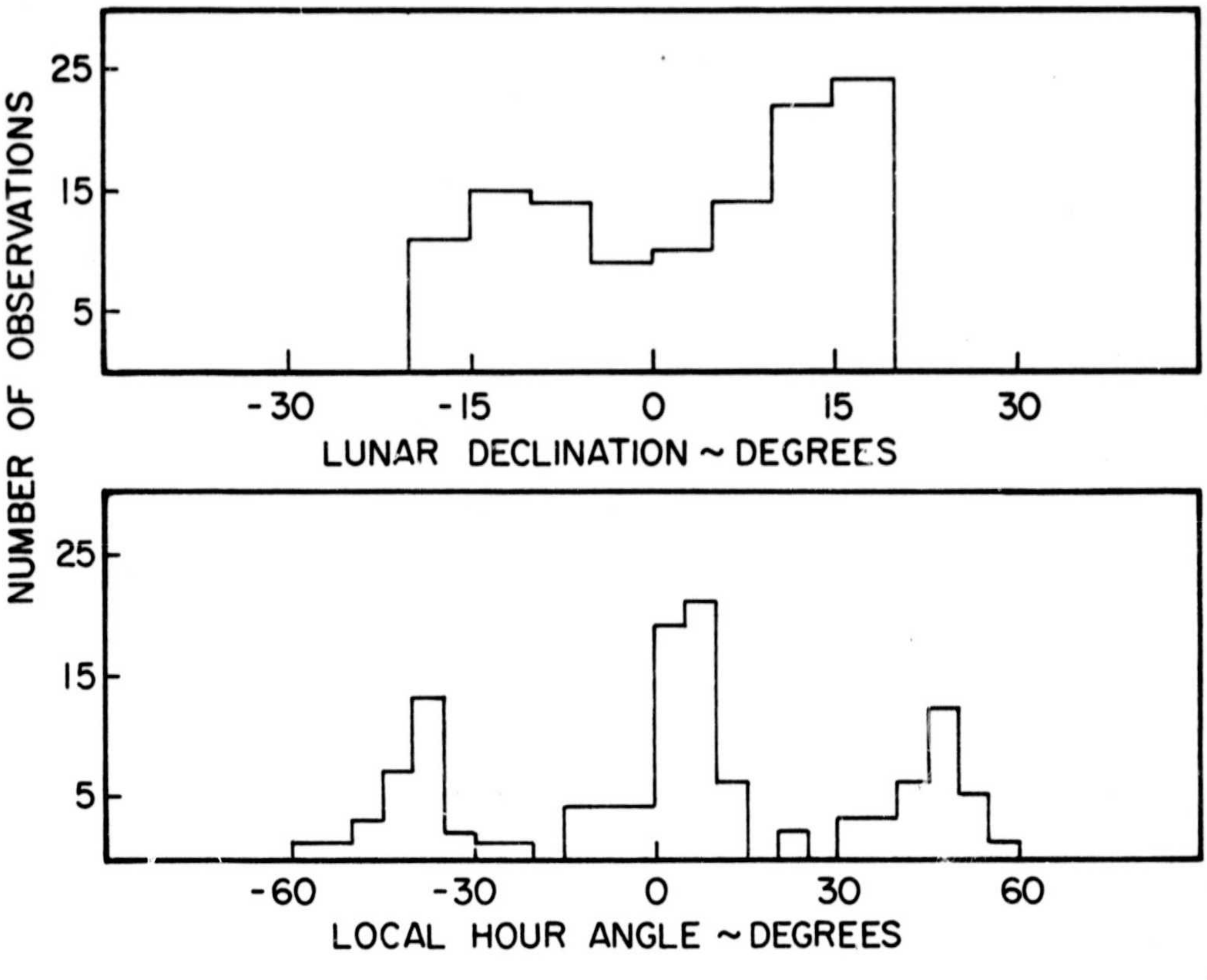

Figure 3. Histograms of the 1978.5-1979.0 observation distributions with respect to the lunar declination and the local hour angle of the Moon. The sampling interval is 5°.

```
  INTEGER PIN(17)
  READ(5,2)PIN
2 FORMAT(A1,I3,I17,I5,I2,A1,I1,I12,I5,I6,I5,3X,I5,I1,I5,I4,2I2)
```

where: PIN(1) = Card identifier (=P)
(2) = Body identifier (Moon = 011)
(3) = Observation epoch
(4) = Observatory code* (=71110)
(5) = Reflector code*
(6) = Observation type (=L)
(7) = Epoch time base*
(8) = Observed time delay (100 psec)
(9) = Uncertainty estimate (100 psec)
(10) = Electronic delay (100 psec)
(11) = Geometric delay (100 psec)
(12) = Frequency offset (parts in 10**11), subtract effect from range
(13) = Delay time base*
(14) = Atmospheric pressure (0.1 mb)
(15) = Calendar year
(16) = Month
(17) = Day

(*) For additional explanation see also Mulholland (1972).

```
  INTEGER NIN(18)
  READ(5,3)NIN
3 FORMAT(A1,I3,I17,I5,I2,A1,I1,I12,I5,I6,I5,I3,I5,I1,I5,I4,2I2)
```

where: NIN(1) = Card identifier (=N)
(i) = PIN(I) for I=2,3,...,11 (see P-card above)
(12) = Number of photon stops in normal point
(J) = PIN(J-1) for J=13,14,...,18 (see P-card above)

The first data file contains the signal photon detections which have been compressed into normal points by a procedure developed at the University of Texas at Austin (Abbot et al, 1973). Under the current mode of operation, the McDonald laser operates at a repetition rate of one shot every three seconds. To be sure, the vast majority of shots do not result in true reflection photon events. Nonetheless, the sheer bulk of observation events increases quite rapidly. The nature of the observing process, which requires a number of observations distributed over only a few minutes in time, makes it quite natural to compress the data into normal points. Each normal point represents the information content of an entire run where, in this context, a run is defined to be a continuous series of shots at a given reflector, terminated by either (a.) moving to another reflector, or (b.) the lapse of an extended period of time (15-60 minutes) between successive shots at the same reflector. Such a normal point observation is comprised of a single pair of "Z" and "N" punched cards.

The second data file contains the photon detections which have been obtained by a data filtering procedure also developed at the University of Texas at Austin (Abbot et al, 1973). This process is based on the assumption of the linearity of (O-C) residuals over a relatively short interval of time and relies on Poisson statistics for establishing a level of confidence in a collection identified by the filter. Application of the process results in the identification of the observations during the subject interval. The potential user should be aware that the laser cannot be relied upon to produce a simple pulse shape. There sometimes is a complex and/or biased structure within the pulse. Therefore, residuals derived from the signal photons are not necessarily expected to show a Gaussian distribution. The uncertainties assigned are based on the sum of the 1-sigma pulse-width and the measured uncertainty in calibrating the electronic system. Beginning with the April-May, 1972 lunation, a letter code appears in collumn 32 (formerly unused) of the "Z" card image which provides an estimate for the accuracy of the electronic calibration correction (see Appendix A).

The third data file contains the unfiltered photon stops. It is most important that the potential user observe the desigantion "unfiltered". By this, we mean that the real data are heavily interspersed with noise photons from any of the various sources of stray light. Any attempt to use these data in a simple Gaussian application would probably result in a solution closely adhering to the prediction ephemeris which was used to control the detector range gating. Some filtering process needs to be applied to these data before effective use can be made of them. The unfiltered data may be of direct utility or interest to those potential users who may wish to replace our filter criteria with their own.

IV. Acknowledgements

This report and the data tape described herein were prepared at the University of Texas at Austin under NASA Grant NSF 7162. The observations are obtained at McDonald Observatory under the direction of E. C. Silverberg using predictions computed at the Jet Propulsion Laboratory by J. G. Williams.

V. References

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APPENDIX A

Code for the accuracy of the McDonald Observatory electronic calibration correction:

A - better than (+/-)200 picoseconds
B - (+/-)200 to (+/-)400 picoseconds
C - (+/-)400 to (+/-)600 picoseconds
D - (+/-)600 to (+/-)1000 picoseconds
E - (+/-)1.0 to (+/-)1.5 nanoseconds
F - (+/-)1.5 to (+/-)2.0 nanoseconds
G - (+/-)2.0 to (+/-)4.0 nanoseconds
H - worse than (+/-)4.0 nanoseconds

These calibration codes were established by E. C. Silverberg.