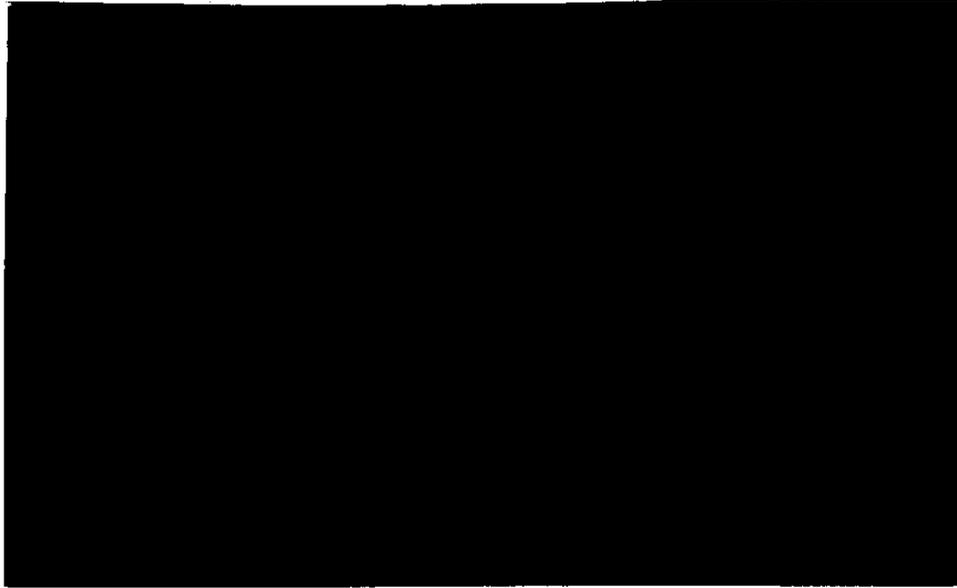


THE UNIVERSITY OF TEXAS AT AUSTIN



(NASA-CR-138486) LUNAR LASER RANGING
DATA DEPOSITED IN THE NATIONAL SPACE
SCIENCE DATA CENTER: FILTERED
OBSERVATIONS FOR JULY THROUGH DECEMBER
(Texas Univ.) 8 P HC \$4.00 CSCL 03B

63/30 Unclas
42473

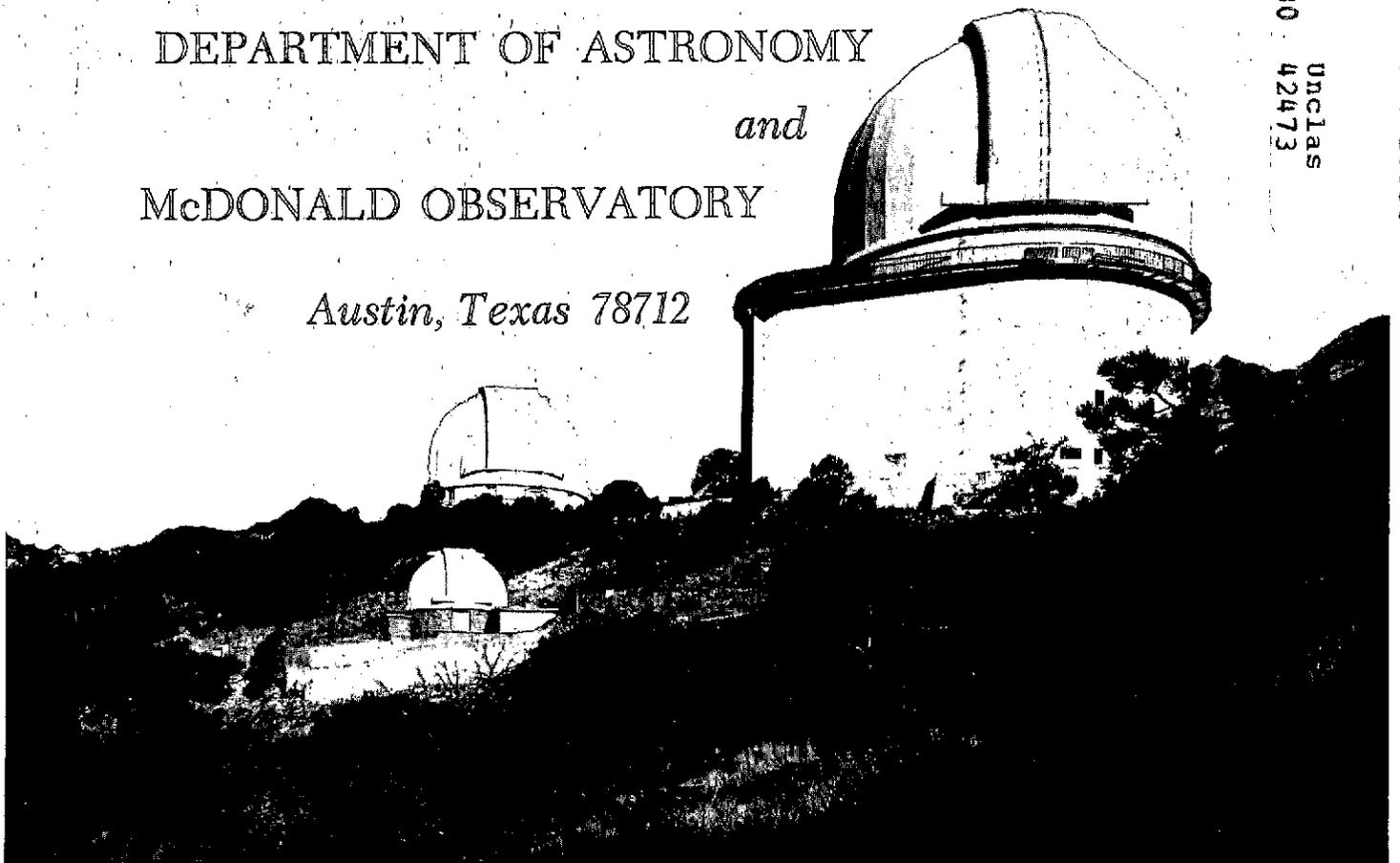
M74-28300

DEPARTMENT OF ASTRONOMY

and

McDONALD OBSERVATORY

Austin, Texas 78712



Lunar Laser Ranging Data Deposited in the
National Space Science Data Center:

Filtered Observations for
1972 July through 1972 December

and

Unfiltered Photon Detections
for 1973 January through 1973 July

J. Derral Mulholland
Peter J. Shelus

University of Texas at Austin
Research Memorandum in Astronomy

1974 July

/

I. Introduction

The lunar laser ranging experiment (LURE) project at McDonald Observatory has been active for almost five years, providing beyond a doubt the unique opportunity to acquire successfully precise ranging data for the earth-moon system.

From the experiment's inception, the LURE Team has recognized the obligation to make these data available to the scientific community in a reasonably usable form, and we have agreed upon a time-schedule that strives for a fair compromise between timely release and priority of the members of the LURE Team. This report is the documentation to be used in conjunction with the deposition in the National Space Science Data Center (NSSDC) of the filtered data obtained during lunar laser ranging operations at McDonald Observatory for the six months ending 1972 December 31 and the unfiltered photon detections for the succeeding six months.

The laser ranging equipment is mounted on the 272 cm (107-inch) reflector at the McDonald Observatory, Fort Davis, Texas. The physical installation has been so thoroughly described in the literature (e.g. Silverberg and Currie 1972, Silverberg 1974) that it seems unnecessary to dwell on it here. The nominal coordinates for this instrument, based on high-order land survey ties to the SAO Organ Pass Tracking Station, are

geocentric radius	$\rho = 6374.665$ km
east longitude	$\lambda = +255.97779$ degrees
geocentric latitude	$\varphi' = +30.50320$ degrees

These refer to the intersection of the polar and transverse axes of the telescope. The center of the primary mirror, as the telescope

tracks across the sky, describes a circle of radius 305 cm whose plane is normal to the polar axis.

The nominal coordinates for the reflectors are

	Tranquility	Fra Mauro	Hadley
selenocentric radius	$\rho=1735.730$ km	1736.680	1735.64
east longitude	$\lambda=+23.485$ degrees	-17.4628	+3.673
latitude	$\beta=+0.642$ degrees	-3.6680	+26.094

based on data supplied by NASA/MSO during tracking operations during the Apollo missions. Improved telescope and reflector coordinates are available, see Bender, et al (1973).

The second of two French retroreflector arrays was deployed on the lunar surface on the Soviet roving vehicle Lunakhod 2, landed by the Luna 21 spacecraft in January, 1973. Shortly after, it was observed by a Franco-American effort at the McDonald Observatory (Abalakin et al 1973). A second series of McDonald observations was obtained a month later, after a considerable traverse by the rover. Due to the motion, these observations are of no practical value beyond giving assurance that the reflector array was usable and permitting some very tenuous discussion of the use of very short data arcs for determining reflector coordinates (Mulholland, et al 1973). These observations (together with the unsuccessful attempts at this reflector) made at McDonald have been included in the unfiltered observations for this semi-annual data deposition under the reflector identifier 4.

II. Data Description

The data are contained on two 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. Two types of cards are present, distinguished by an alphabet character in column 1 (Mulholland, 1971). The letter Z designates a "run" card, giving environmental and operational parameters for a series of shots. Except for clock epoch error, 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. Most users will find them helpful only as separators between observing sessions. The letter P in column 1 represents a "shot" card, containing the result of a single laser firing. A word of warning is in order to the unwary users. Some of the specified data items 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 first data file contains the photon detections which have been obtained by a data filtering procedure developed at the University of Texas (Abbot, et al; 1973). This process is based on the assumption of the linearity of θ -C residuals over a relatively short time interval 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 signal photons are not necessarily expected to show a Gaussian distribution. The uncertainties assigned are based on the sum of the pulse half-width and the measured uncertainty in calibrating the electronic system. Beginning with the April-May, 1972 lunation, a letter code appears in column 32 (formerly unused) of the "Z" card image, which provides an estimate for the accuracy of the electronic calibration correction. The following code is used:

- 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

The calibrations were performed by E. C. Silverberg.

The second data file contains the unfiltered photon stops. It is most important that the potential user observe the designation "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 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.

III. Acknowledgements

The data described herein were generated at the McDonald Observatory through the collective efforts of the LURE Team and numerous supporting personnel at their several institutions. The team is composed of C. O. Alley and D. G. Currie (U. of Md.), P. L. Bender and J. E. Faller (JILA), R. H. Dicke (Princeton U.), D. H. Eckhardt (AFCRL), W. M. Kaula (UCLA), J. D. Mulholland and E. C. Silverberg (McDonald Obs. and U. of Tex.), H. H. Plotkin (NASA/GSFC), J. G. Williams (JPL). Executive Secretary is A. T. Strickland (NASA HQTRS). This report and the data tapes described herein were prepared under NASA Grant NGR 44-012-219.

- Abalakin, V. K., Calame, O., Kokurin, Y. L., Mulholland, J. D., Orszag, A., and Silverberg, E. C., C. R. Acad. Sci. Paris 276 B, 673 (1973).
- Abbot, R. I., Shelus, P. J., Mulholland, J. D., and Silverberg, E. C. 1973, "Laser Observations of the Moon: Identification and Construction of Normal Points for 1969-1971" Astron. J., 78, 784.
- Bender, P. L., Currie, D. G., Dicke, R. H., Eckhardt, D. H., Faller, J. E., Kaula, W. M., Mulholland, J. D., Plotkin, H. H., Poultney, S. K., Silverberg, E. C., Wilkinson, D. T., Williams J. G. and Alley, C. O. 1973, "The Lunar Laser Ranging Experiment," Science 182, 229.
- Mulholland, J. D. 1971, "Proposed Standards for Distribution and Documentation of Lunar Laser Ranging Data" COSPAR Bulletin, No. 61 (March).
- Mulholland, J. D., Shelus, P. J., and Silverberg, E. C. 1973, COSPAR Bull. 68, 27.
- Silverberg, E. C., 1974. "Operation and Performance of a Lunar Laser Ranging Station," Applied Optics, 13, 565.
- Silverberg, E. C., and Currie, D. G. 1972, "A Description of the Lunar Ranging Station at McDonald Observatory" Space Research XII (Akademie-Verlag, Berlin).