

AD-752 228

OAO, A-2 (ORBITING ASTRONOMICAL OBSERVATORY  
A-2) MEASUREMENTS OF THE ULTRAVIOLET AIR-  
GLOW

Edward S. Fishburne, et al

Grumman Aerospace Corporation

Prepared for:

Air Force Cambridge Research Laboratories  
Advanced Research Projects Agency

30 September 1972

DISTRIBUTED BY:

**NTIS**

National Technical Information Service  
U. S. DEPARTMENT OF COMMERCE  
5285 Port Royal Road, Springfield Va. 22151

**BEST  
AVAILABLE COPY**

AFCRL-72-0318

OAD, A-2, MEASUREMENTS  
OF THE ULTRAVIOLET AIRGLOW

by

Edward S. Fishburne      Charles R. Waters  
Donald L. Moyer          Barnett S. Green

Grumman Aerospace Corporation  
Bethpage, New York 11714

Contract No. F19628-71-C-0129  
Project No. 8692

FINAL REPORT  
March 1971 - September 1972

30 September 1972

Contract Monitor: Arthur K. Holmes  
Optical Physics Laboratory

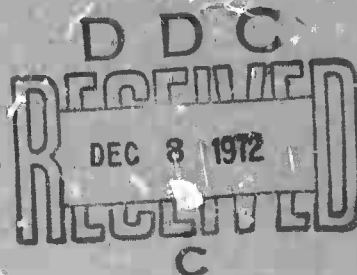
Reproduced by  
NATIONAL TECHNICAL  
INFORMATION SERVICE  
U S Department of Commerce  
Springfield VA 22151

Approved for Public Release; Distribution Unlimited

Sponsored by  
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY  
ARPA Order No. 1366

Monitored by  
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
BEDFORD, MASSACHUSETTS 01730

Details of illustrations in  
this document may be better  
studied on microfiche





## DOCUMENT CONTROL DATA - R&amp;D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

|                                                                                                         |                                                    |
|---------------------------------------------------------------------------------------------------------|----------------------------------------------------|
| 1. ORIGINATING ACTIVITY (Corporate author)<br>Grumman Aerospace Corporation<br>Bethpage, New York 11714 | 2a. REPORT SECURITY CLASSIFICATION<br>Unclassified |
|                                                                                                         | 2b. GROUP                                          |

|                                                                      |
|----------------------------------------------------------------------|
| 3. REPORT TITLE<br>OAO, A-2, MEASUREMENTS OF THE ULTRAVIOLET AIRGLOW |
|----------------------------------------------------------------------|

|                                                                                                         |                            |
|---------------------------------------------------------------------------------------------------------|----------------------------|
| 4. DESCRIPTIVE NOTES (Type of report and inclusive dates)<br>Scientific Final March 1971-September 1972 | Approved:<br>25 Sept. 1972 |
|---------------------------------------------------------------------------------------------------------|----------------------------|

|                                                                                                |                                       |
|------------------------------------------------------------------------------------------------|---------------------------------------|
| 5. AUTHOR(S) (First name, middle initial, last name)<br>Edward S. Fishburne<br>Donald L. Moyer | Charles R. Waters<br>Barnett S. Green |
|------------------------------------------------------------------------------------------------|---------------------------------------|

|                                                  |                                                                             |                       |
|--------------------------------------------------|-----------------------------------------------------------------------------|-----------------------|
| 6. REPORT DATE<br>30 September 1972              | 7a. TOTAL NO. OF PAGES<br>71                                                | 7b. NO. OF REFS<br>21 |
| 8a. CONTRACT OR GRANT NO.<br>F19628-71-C-0129    | 9a. ORIGINATOR'S REPORT NUMBER(S)                                           |                       |
| b. PROJECT, TASK, WORK UNIT NOS.<br>8629 n/a n/a |                                                                             |                       |
| c. DOD ELEMENT<br>62301D                         | 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) |                       |
| d. DOD SUBELEMENT<br>n/a                         | AFCRL-72-0318                                                               |                       |

|                                                                                    |
|------------------------------------------------------------------------------------|
| 10. DISTRIBUTION STATEMENT<br>Approved for Public Release; distribution unlimited. |
|------------------------------------------------------------------------------------|

|                                                                                                                |                                                                                                                                           |
|----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| 11. SUPPLEMENTARY NOTES<br>Details of illustrations in<br>this document may be better<br>studied on microfiche | 12. SPONSORING MILITARY ACTIVITY<br>Air Force Cambridge Research<br>Laboratory (OP)<br>L.G. Hanscom Field<br>Bedford, Massachusetts 01730 |
|----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13. ABSTRACT<br>The term airglow is commonly used to describe nonthermal emissions not correlated with magnetic disturbances in the upper atmosphere. The study of this radiation provides information on the nature of the upper atmosphere, as well as clues to the physical processes occurring at very high altitudes. The spectral region below 3000 A is one of the most informative wavelength intervals, but the opacity of the atmosphere in this part of the spectrum prevents adequate measurement of ultraviolet emissions except by rockets and satellites. To obtain more information, we undertook an investigation to measure the dark and sunlit earth using the Wisconsin Experiment Package (WEP) photometers of the Orbiting Astronomical Observatory A-2. The first series of measurements were concerned with the magnitude of the emitted radiation. Based on findings indicated by these measurements, we began concentrating on measurements of the earth limb. We used the 2980, 2460, 2380, 1920, 1500, 1380, and 1250A filters of the WEP stellar photometers. Our experimental results tend support the theory that dayglow in the 1300-1800A region is due primarily to photoelectron excitation of molecular nitrogen. The measurements obtained on the earth's limb represent the most complete coverage known to the authors. |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

14.

## KEY WORDS

Airglow  
Earth Limb  
Nonthermal emissions  
Ultraviolet  
Atmosphere  
Radiation

ib

~~Unclassified~~

**Security Classification**

DAO, A-2, MEASUREMENTS  
OF THE ULTRAVIOLET AIRGLOW

by

Edward S. Fishburne      Charles R. Waters  
Donald L. Moyer          Barnett S. Green

Grumman Aerospace Corporation  
Bethpage, New York 11714

Contract No. F19628-71-C-0129  
Project No. 8692

FINAL REPORT  
March 1971 - September 1972

30 September 1972

Contract Monitor: Arthur K. Holmes  
Optical Physics Laboratory

Approved for Public Release; Distribution Unlimited

Sponsored by  
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY  
ARPA Order No. 1366

Monitored by  
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
BEDFORD, MASSACHUSETTS 01730

jc

## ABSTRACT

The term airglow is commonly used to describe nonthermal emissions not correlated with magnetic disturbances in the upper atmosphere. The study of this radiation provides information on the nature of the upper atmosphere, as well as clues to the physical processes occurring at very high altitudes. The spectral region below  $3000\text{\AA}$  is one of the most informative wavelength intervals, but the opacity of the atmosphere in this part of the spectrum prevents adequate measurement of ultraviolet emissions except by rocket and satellites. Until recently, most measurements were restricted to rocket flights at high altitudes, although a limited amount of information was obtained by several satellites in the OGO series, in particular, OGO-4 (Refs. 1-5).

To obtain more information about the earth's ultraviolet airglow, we undertook an investigation to measure the dark and sunlit earth using the Wisconsin Experiment Package (WEP) photometers of the Orbiting Astronomical Observatory A-2. The first series of measurements were concerned with the magnitude of the emitted radiation. Based on findings indicated by these measurements, we began concentrating on measurements of the earth limb. The small field of view of the WEP package has a fine spatial resolution, providing a detailed picture of the ultraviolet radiation in the earth's limb. Our measurements used the 2980, 2460, 2380, 1920, 1500, 1380, and  $1250\text{\AA}$  filters of the WEP stellar photometers.

The measurements obtained on the earth's limb represent the most complete coverage known to the authors. In addition, measurements in selected spectral regions provide the first information available on these regions and confirm observations by previous investigators. Finally, our experimental results tend to substantiate the theory that the dayglow in the  $1300\text{-}1800\text{\AA}$  region is primarily due to photoelectron excitation of molecular nitrogen.

## TABLE OF CONTENTS

| <u>Item</u>                                     | <u>Page</u> |
|-------------------------------------------------|-------------|
| Introduction .....                              | 1           |
| The Orbiting Astronomical Observatory A-2 ..... | 8           |
| Data Reduction .....                            | 15          |
| Data Analysis .....                             | 37          |
| Summary and Conclusions .....                   | 59          |
| References .....                                | 61          |

## LIST OF ILLUSTRATIONS

| <u>Figure</u> |                                                                                                                                                                                                                              | <u>Page</u> |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| 1             | Various Experimental Measurements of the Earth's Radiance and the Theoretical Values Based on Rayleigh Scattering .....                                                                                                      | 6           |
| 2             | Relative Response of WEP Filters .....                                                                                                                                                                                       | 9           |
| 3             | Relative Position of Earth and OAO during Typical Measurement Sequence .....                                                                                                                                                 | 12          |
| 4             | Ground Track of OAO Field of View during Measurement Sequence Depicted in Fig. 3 .....                                                                                                                                       | 14          |
| 5             | Received Radiation Measured with 1250Å Filter ....                                                                                                                                                                           | 16          |
| 6             | Received Radiation Measured with 1920Å Filter ....                                                                                                                                                                           | 17          |
| 7             | Received Radiation Measured with 1500Å Filter ....                                                                                                                                                                           | 18          |
| 8             | Typical Viewing Geometry .....                                                                                                                                                                                               | 20          |
| 9             | Variation of Angles for Orbit 7903 .....                                                                                                                                                                                     | 45          |
| 10            | Comparison of OAO Measurements with Other Experimental Measurements. Values are for 1380Å, 1500Å, and 1920Å Filters. Lower line represents the measured value minus the expected contribution of the 1304Å oxygen line. .... | 46          |
| 11            | 1500Å Limb Measurement .....                                                                                                                                                                                                 | 48          |
| 12            | Altitude Profile of 1500Å Radiation .....                                                                                                                                                                                    | 49          |
| 13            | Altitude Profile of 1500Å Radiation .....                                                                                                                                                                                    | 50          |
| 14            | Altitude Profile of 1500Å Radiation .....                                                                                                                                                                                    | 51          |
| 15            | Altitude Profile of 1920Å Radiation .....                                                                                                                                                                                    | 52          |
| 16            | Altitude Profile of 1250Å Radiation .....                                                                                                                                                                                    | 53          |

| <u>Figure</u> |                                               | <u>Page</u> |
|---------------|-----------------------------------------------|-------------|
| 17            | Altitude Profile of the 1920Å Nightglow ..... | 55          |
| 18            | Altitude Profile of the 2980Å Nightglow ..... | 56          |
| 19            | Altitude Profile of 2380Å Nightglow .....     | 57          |
| 20            | Altitude Profile of the 2460Å Nightglow ..... | 58          |

## INTRODUCTION

Airglow and auroras have been subjects of considerable research during the past century. The most comprehensive analysis is that given by Chamberlain (Ref. 6), which contains more than 1600 references, compiled through 1959, to the literature. Most of these references concern ground observations of the visible airglow. Due to atmospheric absorption, however, measurements of ultraviolet emissions of the upper atmosphere have been limited to rocket and satellite observations. Tables 1-3 summarize the important ultraviolet experiments flown since 1963.

The most important features of the earth's airglow below 2000Å are the Lyman alpha emissions of atomic hydrogen at 1216Å and the emissions from the 1302, 1305, and 1306Å triplet of atomic oxygen. The Lyman alpha emission is produced by the resonance scattering of the Sun's Lyman alpha line, the strongest emission line in the solar spectrum. Most of the early rocket measurements (Ref. 7) concentrated on this particular feature. A long term study of the Lyman alpha corona was made by the Naval Research Laboratory Experiment, using OGO-4 (Ref. 4). From these measurements, Meier developed a detailed description and theory of the Lyman alpha geo-corona. The atomic oxygen lines, including the 1356Å line, have been studied thoroughly in the past few years (Refs. 8-10). It appears that these emissions of atomic oxygen are produced by photoelectron excitation. This mechanism also appears to produce the weaker emissions from atomic nitrogen at 1200, 1493, and 1744Å.

Barth (Ref. 2) has shown that the dominant radiation between 1358 and 1700Å is that due to the Lyman-Birge-Hopfield, the Birge-Hopfield, and the Vergard-Kaplin bands of molecular nitrogen. Theoretical investigations by Barth and by Green (Ref. 9) indicate that the emissions from these bands appear to be produced also by photoelectron excitation. The other major feature of the ultraviolet dayglow is the gamma bands of nitric oxide that are observed in resonance fluorescence (Ref. 11).

Measurements of the earth's dayglow (between 1700 and 3000Å) agree very well with calculations based on Rayleigh scattering, including absorption by ozone and absorption by molecular oxygen. We have indicated in Fig. 1 our calculation of the earth dayglow, which would result from first order Rayleigh scattering for a spherical atmosphere in the region between 1000 and 2000Å. The actual magnitude of the earth's dayglow will depend on the values

Table 1

## OBSERVATIONS OF THE ULTRAVIOLET DAYGLOW

| Reference                             | Wavelength<br>Region       | Quoted<br>Measurement                                             | Earth Radiance<br>$\text{W/cm}^2 \text{ - Ster - u}$                   | Comments                                                                                                                                                                                                       |
|---------------------------------------|----------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Friedman, Rawcliffe<br>& Meloy - 1963 | 2450 - 2850 Å              | $2 \times 10^{-5}$<br>$\text{W/cm}^2 \text{ - Ster - u}$          | $\approx 10^{-5}$                                                      | Satellite measurement Radiometer with<br>$\lambda_c = 2550 \text{ Å}$ solar angle = $49^\circ$<br>FOV = $1.2 \times 10^{-4}$ Ster = $.7^\circ$<br>Sens. = $5 \times 10^{-6} \text{ W/cm}^2 \text{ - Ster - u}$ |
| Hunter, Fowler<br>Dunkelman<br>1964   | 2000 - 2700 Å              | $(.4-.2) \text{ erg/sec-cm}^2 \text{ - ster}$<br>$-100 \text{ Å}$ | $(.4-.2) \times 10^{-4}$                                               | Rocket flight<br>2 photometers<br>$\lambda_c = 2200 \text{ Å}$<br>$\Delta\lambda = 230 \text{ Å}$<br>$\lambda_c = 2600 \text{ Å}$<br>$\Delta\lambda = 100 \text{ Å}$<br>Solar angle = $22^\circ$               |
| Barth<br>1964                         | 1500-3200 Å                | 2 KR at 2155 Å                                                    | $1.47 \times 10^{-7}$                                                  | Aerobee - Spectrometer<br>Altitude = $75 - 114 \text{ Km}$<br>Sun angle = $60^\circ$<br>Resolution = $10 \text{ Å}$<br>2 bands of NO most prominent feature -<br>Produced by resonant Scatt.                   |
| Pastie Crosswhite<br>& Heath<br>1964  | 1216 Å<br>1304 Å<br>1356 Å | 13 Kr<br>7 Kr<br>.4 Kr                                            | $100 \times 10^{-6}$<br>$5.03 \times 10^{-7}$<br>$2.76 \times 10^{-8}$ | Aerobee<br>Attitude - 210 km max.<br>Resolution = $17 \text{ Å}$<br>Peak in 1304 at 190 km<br>Peak in 1356 at 135 km                                                                                           |
| Rawcliffe &<br>Elliott<br>1966        | 2000 - 3200 Å              | $(.2 - 9.5) \times 10^{-10} \text{ W/cm}^2 \text{ - ster-Å}$      | $(.2 - 9.5) \times 10^{-6}$                                            |                                                                                                                                                                                                                |
| Moos & Pastie<br>1967                 | 1216 Å<br>1304             | 3.6 Kr at 152 km<br>110 R                                         | $3.14 \times 10^{-7}$<br>$8.95 \times 10^{-9}$                         | Rocket observation<br>Sun elevation = $-14^\circ$<br>Twilight condition                                                                                                                                        |
| Pearce<br>1969                        | 2070 - 2370 Å              | 2155 Å<br>10 KR at 60 km<br>1 KR at 95 km                         | $6.15 \times 10^{-7}$<br>$6.15 \times 10^{-8}$                         | Rocket observation<br>Altitude - 60-95 km<br>Twilight condition<br>Sun zenith = $92^\circ$<br>Resolution = $12 \text{ Å}$<br>(1.0) band of NO<br>Most prominent                                                |

Table 1

## OBSERVATIONS OF THE ULTRAVIOLET DAYGLOW - (Continued)

| Reference                 | Wavelength<br>Region           | Quoted<br>Measurement                                                                   | Particle<br>Flux<br>$\mu/\text{cm}^2 \cdot \text{day} \cdot \text{sr}$                           | Comments                                                       |
|---------------------------|--------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|----------------------------------------------------------------|
| Barth & Mackey<br>1969    | 1150 - 3350 Å                  | 1216 Å = 30 KR/20 Å<br>1304 Å = 20 KR/20 Å<br>1356 Å = 2 KR/20 Å<br>2550 Å = 30 KR/20 Å | $1.96 \times 10^{-6}$<br>$1.26 \times 10^{-6}$<br>$1.17 \times 10^{-7}$<br>$9.36 \times 10^{-7}$ | OGO IV - Spectrometer<br>Sun zenith = 0°<br>Resolution = 20 Å  |
| Chubb & Hicks<br>1970     | 1050 - 1350 Å<br>1350 - 1550 Å | 1216 Å = 26 KR<br>1304 Å = 15 KR<br>2.5 KR                                              | $2.27 \times 10^{-6}$<br>$1.22 \times 10^{-6}$<br>$1.37 \times 10^{-8}$                          | OGO IV - No protoionization<br>Chamber<br>FOV = 65° 40'        |
| Barth & Schaffner<br>1970 | 1150 - 3350 Å                  | 1304 Å - 36.2 KR<br>1356 Å - 2 KR<br>1384 Å - 1.2 KR                                    | $2.21 \times 10^{-6}$<br>$1.17 \times 10^{-7}$<br>$6.90 \times 10^{-8}$                          | OGO IV - Spectrometer<br>Resolution = 20 Å<br>Sun zenith = 31° |

## OBSERVATIONS OF THE ULTRAVIOLET NIGERINLOW

| Reference              | Wavelength<br>Region       | Quoted<br>Measurement                                        | Earth Radiation<br>$\mu/\text{cm}^2 - \text{Ster} - \mu$                | Comments                                                                                                                                                 |
|------------------------|----------------------------|--------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Stecher<br>1965        | 1500 - 3500                | 20-100 R/Å                                                   | $(1.27 - 5.3) \times 10^{-5}$                                           | Aerobee 4 spectrometers<br>Resolution = 50 Å<br>Max. radiation received at 92.7 km<br>at 3000 Å through horizon.                                         |
| Hermes                 | 2300 - 3800                | Avg. = .75 R/Å                                               | $3.975 \times 10^{-7}$                                                  | Rocket observation<br>spectrometer - 12 Å Res.<br>FOV = 2°<br>Altitude = 184 km<br>Zenith measurement<br>Radiation due to Herzberg bands of $\text{O}_2$ |
| Winter & Chubb         | 1216 Å                     | $(1.1 - 12) \times 10^{-3}$<br>ery/cm <sup>2</sup> -sec-ster | $(1.1 - 12) \times 10^{-6}$                                             |                                                                                                                                                          |
| Chubbs & Hicks<br>1970 | 1050 - 1350 Å              | 1.2 KR                                                       | $5.3 \times 10^{-9}$                                                    | OGO IV - NO photoionization<br>Chambers<br>Zenith Measurements<br>FOV = 6° 40'                                                                           |
| Barth & Schaffner      | 1216 Å<br>1304 Å<br>1556 Å | 2.5 KR<br>1.7 KR<br>1.4 KR                                   | $1.64 \times 10^{-7}$<br>$1.04 \times 10^{-7}$<br>$5.22 \times 10^{-8}$ | OGO IV - Spectrometer<br>Equatorial Nightglow<br>Resolution = 20 Å<br>Zenith Measurements                                                                |
| Prinz & Meirer<br>1970 | 1304 Å<br>1350 - 1600      | 4-6 KR<br>25 R                                               | $(3.25-4.88) \times 10^{-7}$<br>$1.1 \times 10^{-10}$                   | OGO IV - NO photoionization<br>Chambers<br>Zenith Measurements                                                                                           |

-4-

Table 3

## OBSERVATIONS OF THE ULTRAVIOLET AURORA

| Reference                          | Wavelength<br>Region                                                             | Quoted<br>Measurement                                                                            | Earth Distance<br>$\text{m/cm}^2 \cdot \text{liter} \cdot \text{u}$                             | Comments                                                                       |
|------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Teller & Fastie<br>1965            | 1412 - 2110                                                                      | AV. = 2.25 MB                                                                                    | $9.95 \times 10^{-7}$                                                                           | Rocket Observation and Spectrometer<br>Resolution = 2 Å<br>Sensitivity = .5 MB |
| Murphy                             | 2000 - 1450 Å<br>1450 - 1350 Å                                                   | $.08 \times 10^{-3} \text{ erg/cm}^2 \cdot \text{sec} \cdot \text{liter}$<br>$.2 \times 10^{-3}$ | $5 \times 10^{-3}$<br>$\pm 10^{-3}$                                                             | Rocket observation<br>NO photoionization Chamber<br>FOV = 140°                 |
| Miller, Fastie<br>& Teller<br>1968 | 1150 - 1530 Å<br>1200 Å (NI)<br>1300 Å (OI)<br>LM                                | 1.1 MB<br>15.4 MB<br>3.50 MB                                                                     | $1.06 \times 10^{-7}$<br>$1.17 \times 10^{-7}$<br>$2.75 \times 10^{-7}$                         | Rocket observation<br>Spectrometer<br>Altitude 90-160 km                       |
| Charles & Hinks<br>1970            | Day<br>1050 - 1350 Å<br>1350 - 1550 Å<br>Night<br>1050 - 1350 Å<br>1350 - 1550 Å | 1.4 MB<br>.27 MB<br>2.6 MB<br>1.0 MB                                                             | $1.14 \times 10^{-7}$<br>$4.17 \times 10^{-8}$<br>$2.11 \times 10^{-7}$<br>$7.3 \times 10^{-8}$ | OSO IV - NO Photoionization<br>Chambers<br>Zenith Measurements                 |
| Burth & Schaffner<br>1970          | 1304 Å<br>1356 Å<br>1384 Å (He)                                                  | 16.2 MB<br>3 MB<br>1.4 MB                                                                        | $9.89 \times 10^{-7}$<br>$1.76 \times 10^{-7}$<br>$8.05 \times 10^{-8}$                         | OSO IV - Spectrometer<br>Zenith Measurements<br>Resolution = 20 Å              |

-5-

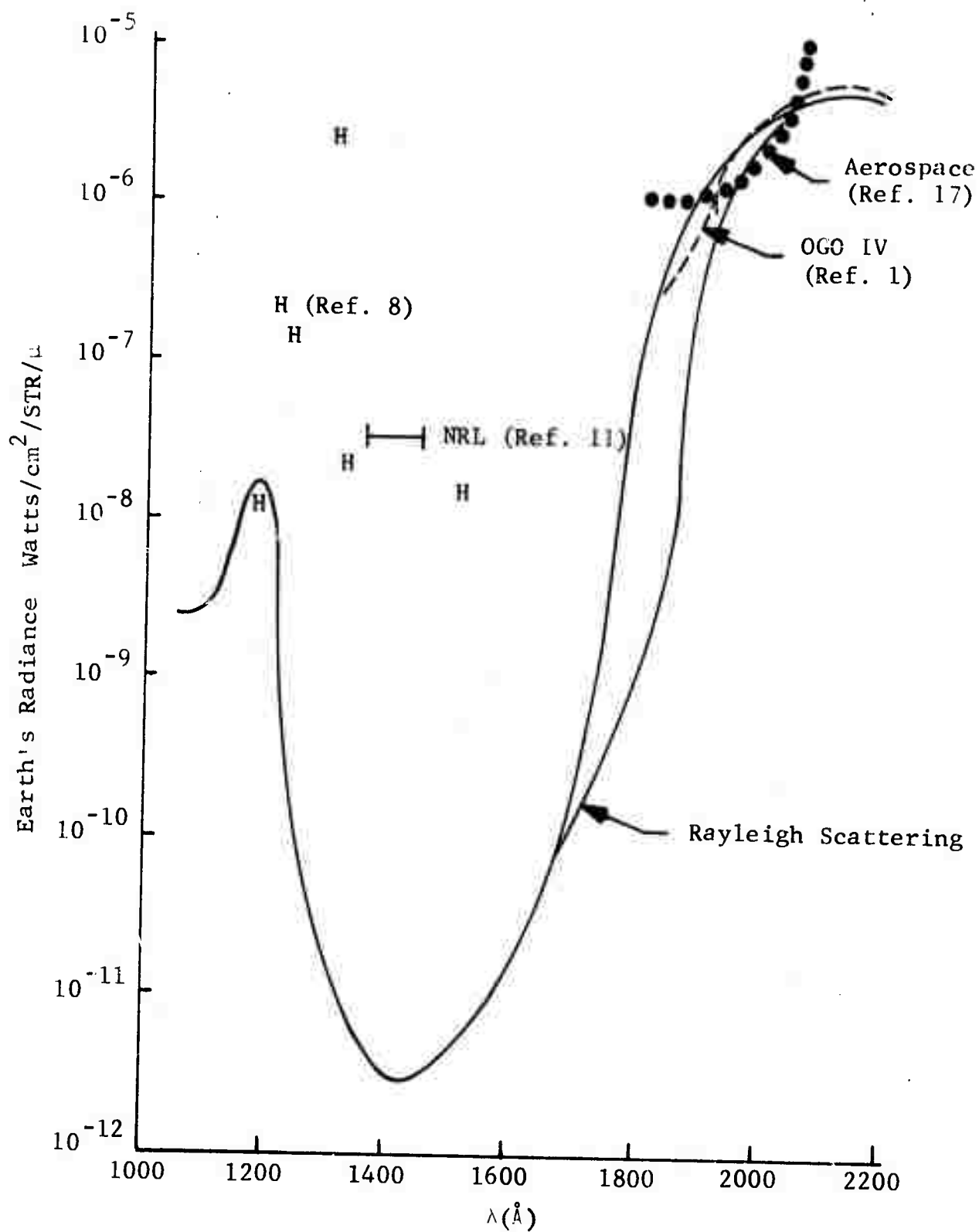


Fig. 1 Various Experimental Measurements of the Earth's Radiance and the Theoretical Values Based on Rayleigh Scattering

chosen for the absorption cross section of molecular oxygen. In addition, it is necessary that a molecular oxygen altitude profile be used in the calculation. For the calculation presented in Fig. 1, we used the ultraviolet flux from the sun as determined by Hinteregger (Ref. 12), the absorption coefficients from Ditchburn (Ref. 13), and the standard atmosphere for the molecular oxygen distribution. The selection of other values for the solar flux and the absorption coefficients or the choice of a different molecular oxygen distribution will tend to shift the curve slightly higher or slightly lower but not by a considerable amount.

The nightglow below  $3000\text{\AA}$  consists mainly of the Herzberg band of molecular oxygen that occurs primarily between  $2500$  and  $3500\text{\AA}$  (Refs. 14,15). The  $2972\text{\AA}$  line of atomic oxygen is also present. Below  $2000\text{\AA}$ , the only major radiation is that due to the Lyman alpha line (Refs. 2,7) and the  $1304\text{\AA}$  triplet of atomic oxygen (Refs. 3,5).

In a search of the literature for previous measurements of the earth's dayglow and nightglow, we have been unable to find any detailed spatial measurements of the earth's limb in the ultraviolet region below  $3000\text{\AA}$ . Some mention has been made of an apparent brightening effect, but no quantitative measurements were reported. Quantitative measurements are presented in this report.

## THE ORBITING ASTRONOMICAL OBSERVATORY A-2

The NASA-Goddard/Grumman Orbiting Astronomical Observatory A-2 was launched 7 December 1968, its mission to make detailed ultraviolet measurements of stars, galaxies, and other heavenly bodies. A set of six-gimbal star trackers and a system of gyros enable the OAO to be pointed with an accuracy of 1 minute of arc and to hold a pointing  $\pm 15$  arc seconds once it has been stabilized. The A-2 is equipped with the Smithsonian Astrophysical Observatory (SAO) package and the Wisconsin Experiment Package (WEP). The SAO package is designed to make large field sky maps in the ultraviolet, and the WEP obtains precise photometric measurements of individual celestial objects.

The Wisconsin Experiment Package consists of seven instruments designed to make ultraviolet measurements of selected celestial objects. The package includes four 8-inch telescopes incorporating photoelectric photometers, two scanning objective grating spectrometers, and a 16-inch photometer that unfortunately failed after two months of operation.

Each 8-inch telescope has a five-position filter wheel that contains three different interference filters, dark slide, and a calibration source. Each is an off-axis paraboloid with a focal length of 81 cm and an effective collecting area of 325 cm<sup>2</sup>. The two field stops available at the focal plane have angle diameters of 2 and 10 arc minutes. Stellar photometers 1 and 2 operate at above 1700Å, while stellar photometers 3 and 4 cover the spectral region between 1200 and 2700Å. The response curves for the given filter combinations utilized in the ultraviolet measurements reported in this investigation are shown in Fig. 2. Photometer 1, which contains the 2980Å filter, employs EM 6256B photomultipliers. Photometer 3, which contains the 2460 and 1920Å filters, utilizes an EMR 541F photomultiplier, while Photometer 4, which has the 1250, 1380, and 1500Å filters, employs an EMR 541G photomultiplier.

The photomultiplier signal is processed by a pulse counter and a d.c. amplifier, providing a digital and analog output, both of which are stored after each exposure. Exposure times of 1/8, 1, 8, or 64-second duration are available by command.

Several modes of operation are available to the experimenter, the choice depending on the type of investigation being conducted. The mode used for most of the airglow measurements was one in which the data sampling was controlled by the scanning spectrometers.

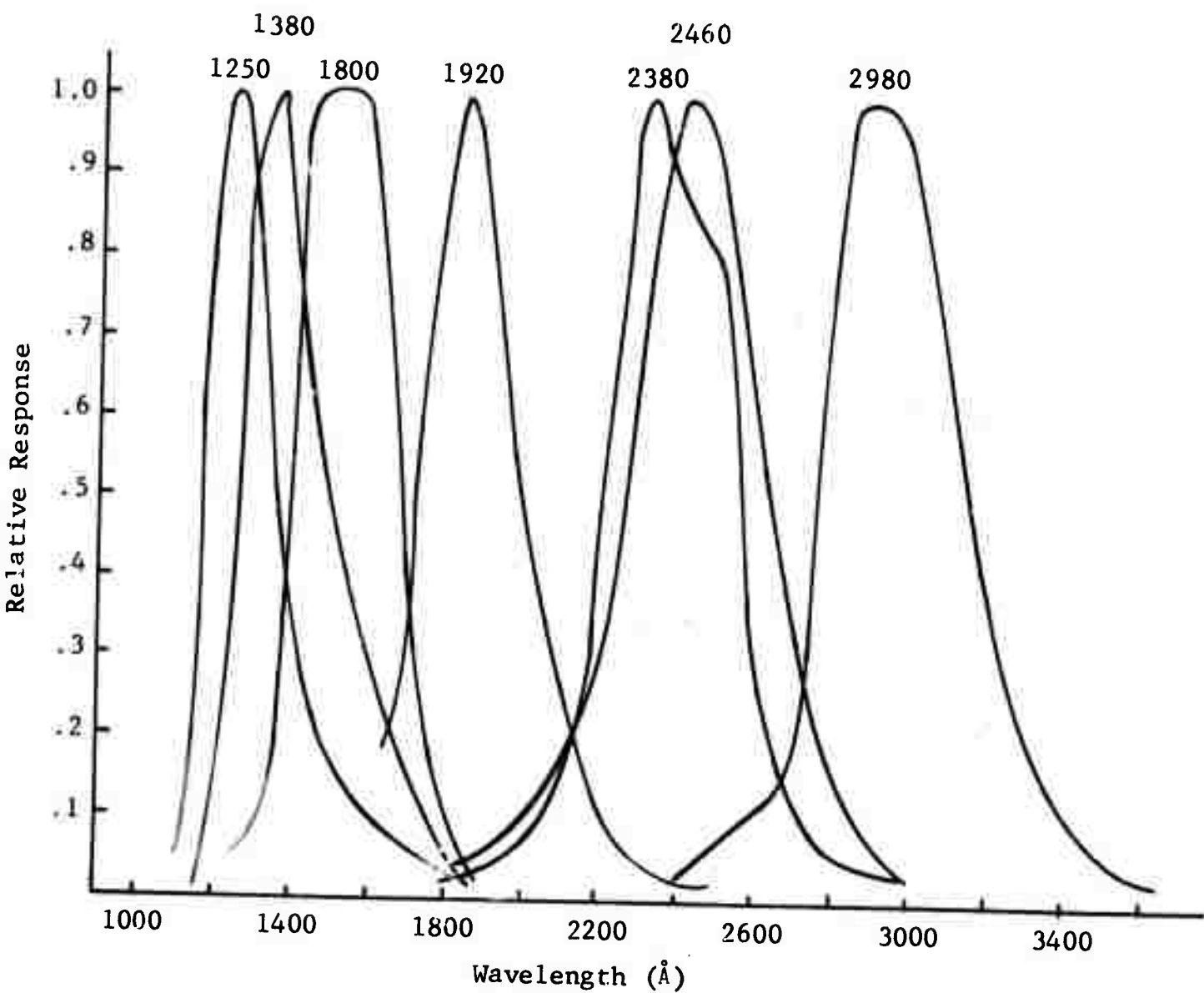


Fig. 2 Relative Response of WEP Filters

Table 4

CALIBRATION FACTORS

EQUIVALENT RADIANCE

$(\omega/\text{cm}^2\text{-ster-}\mu\text{-count})$

| Filter | 1/8 Sec<br>Exposure    | 1/2 Sec<br>Exposure    | 1 Sec<br>Exposure      | 8 Sec<br>Exposure      | 64 Sec<br>Exposure     |
|--------|------------------------|------------------------|------------------------|------------------------|------------------------|
| 1250Å  | $1.25 \times 10^{-7}$  | $3.14 \times 10^{-8}$  | $1.57 \times 10^{-8}$  | $1.96 \times 10^{-9}$  | $2.5 \times 10^{-10}$  |
| 1380Å  | $6.04 \times 10^{-8}$  | $1.5 \times 10^{-8}$   | $7.55 \times 10^{-9}$  | $9.40 \times 10^{-10}$ | $1.2 \times 10^{-10}$  |
| 1500Å  | $2.89 \times 10^{-8}$  | $7.24 \times 10^{-9}$  | $3.63 \times 10^{-9}$  | $4.5 \times 10^{-10}$  | $5.82 \times 10^{-11}$ |
| 1920Å  | $7.73 \times 10^{-10}$ | $1.94 \times 10^{-10}$ | $9.71 \times 10^{-11}$ | $1.22 \times 10^{-11}$ | $1.56 \times 10^{-12}$ |
| 2380Å  | $4.03 \times 10^{-10}$ | $1.02 \times 10^{-10}$ | $5.07 \times 10^{-11}$ | $6.32 \times 10^{-12}$ | $7.94 \times 10^{-13}$ |
| 2460Å  | $2.96 \times 10^{-10}$ | $7.42 \times 10^{-11}$ | $3.70 \times 10^{-11}$ | $4.63 \times 10^{-12}$ | $5.79 \times 10^{-13}$ |
| 2980Å  | $7.4 \times 10^{-11}$  | $1.87 \times 10^{-11}$ | $9.46 \times 10^{-12}$ | $1.16 \times 10^{-12}$ | $1.45 \times 10^{-13}$ |

DEGRADATION FACTOR FOR PHOTOMETER 4

$(I_{\text{actual}} = k I_{\text{measured}})$

| Filter \ Time | D 161-165<br>1970 | D 268<br>1970 | D 83<br>1971 | D 148<br>1971 | D 215<br>1971 | D 225<br>1971 |
|---------------|-------------------|---------------|--------------|---------------|---------------|---------------|
| 1250Å         | 1.58              | 2.51          | 8.32         | 9.12          | 10.0          | 10.0          |
| 1380Å         | 1.15              | 1.45          | 4.37         | 5.25          | 5.75          | 5.75          |
| 1500Å         | 1.10              | 1.20          | 1.58         | 1.74          | 2.09          | 2.09          |

-9B-

One spectrometer was commanded to perform two consecutive 94-step scans. An 8-second exposure period exists between the completion of one step and the initiation of the next step. After the exposure, the data from all instruments are sampled. The actual time to perform a step is approximately 1 second. The exposure times of the photometers can be selected to be 1/8, 1, or 8 seconds and are initiated at the beginning of an 8-second spectrometer exposure.

Another mode of operation was employed for the detailed measurements of the earth's limb. In this mode, the exposure time for all instruments was set at 64 seconds. However, each instrument was sampled at 0.524 second intervals. A total of about  $2\frac{1}{2}$  minutes of data can be stored in the spacecraft's data processing system using this mode. When the OAO is in real time contact with a ground station, this mode can provide up to 10 minutes of continuous data.

To obtain measurements of the earth's nightglow, we found it necessary to employ the 64-second exposure mode. This particular mode is the most sensitive, since the signals are integrated over the entire 64-second period. It cannot be used during daylight hours since the photometers would saturate.

The calibration factors for the various filters and modes of operation are given in Table 4. These factors were obtained from calibration tests made prior to launch. Other tests have been conducted in space to validate the factors.

To appreciate the data and the manner in which they were obtained, it is necessary that the reader fully understand the relation between the OAO line of sight (LOS) and the relative position of the earth. All observations were made by inertially fixing the OAO LOS in terms of right ascension and declination. This means that the OAO points at a particular spot on the celestial sphere. The OAO is inertially stabilized such that it will continue pointing at that spot until commanded to another position. Thus, we cannot command the OAO to look at a particular point on the surface of the earth and to follow that point since this was not the original intent of the OAO. Once the OAO is pointed at a particular spot on the celestial sphere, we can obtain measurements of the earth's dayglow, nightglow, and limb by exposing during the time the desired portion of the earth moves through the field of view of the OAO. The position of the OAO relative to the earth during a typical measurement sequence is depicted in Fig. 3. The three positions of the OAO shown in the illustration correspond

## GEOMETRY OF OAO, ORBIT 7903

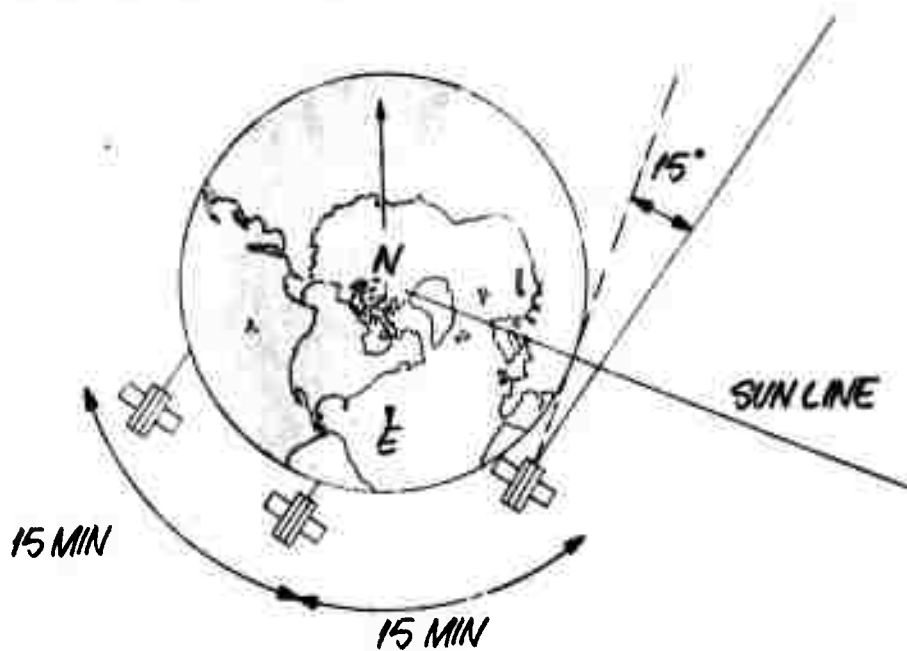
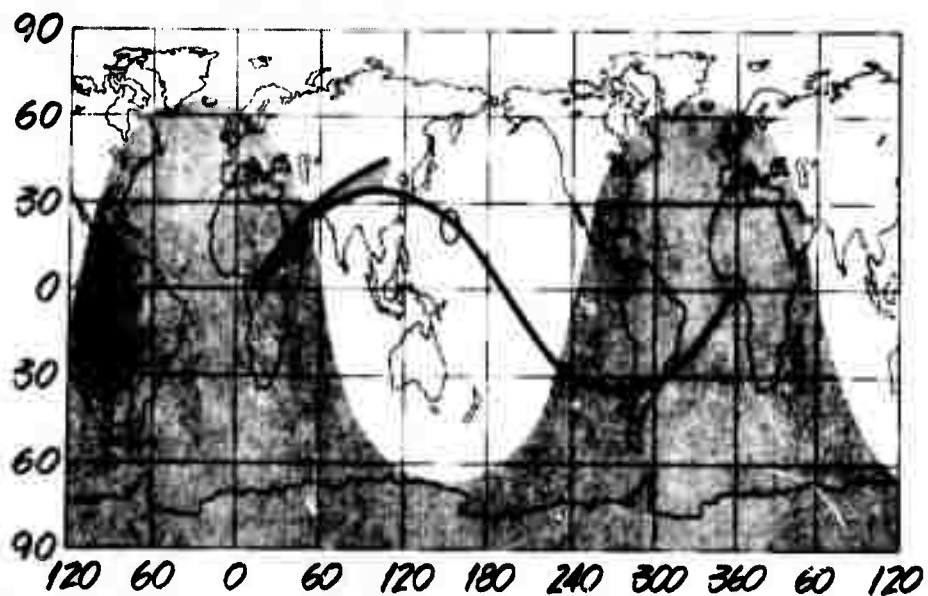


Fig. 3 Relative Position of Earth and OAO during Typical Measurement Sequence

to the position at the beginning, middle, and end of a half-hour measurement sequence. Note in the illustration that the measurements were initially made of the dark earth, then the sunlit portion of the earth, and finally the sunlit limb. Also note that the total amount of sunlit atmosphere in the field of view increases as the earth moves through the field of view. Figure 4 indicates the ground track of the OAO field of view during the measurements period. The viewing situation is typical of those made during the first set of observations and characterizes the manner in which all measurements were made.

## QAO MEASUREMENTS

• QAO ORBIT 7903: 10 JUNE 1970



Reproduced from  
best available copy.

Fig. 4 Ground Track of QAO Field of View  
during Measurement Sequence Depicted  
in Fig. 3

## DATA REDUCTION

Wisconsin Experiment Package measurements of the earth airglow were made at several different times during 1970-1971. The bulk of the measurements were made over a four-day period (June 10 through June 13, 1970) on 27 different orbits. This set of observations was obtained by programming the OAO to view a star, Alpha-Leo, and to expose during the time this star was occulted by the earth. Each measurement period was approximately 30 minutes long and consisted of a series of 188 exposures of either 1/8, 1, or 8 seconds duration. The experiment was operated in the mode in which the scanning spectrometer controlled the sampling period. Figure 4 indicates the ground track of orbit 7903 during the measurement period.

The variation of the received radiation as the viewing area scans across the earth is indicated in Figs. 5-7. The received radiation is given in terms of the original digital counts or voltage as transmitted from the OAO. Figures 5 and 6 represent data obtained during orbit 7903. Figure 5 indicates the radiation received by the 1250Å photometer and Fig. 6 represents that received by the 1920Å photometer. An interesting feature is apparent on examining these two curves: radiation in the 1250Å regions appears to reach a maximum value after the field of view has left the surface of the earth. This maximum occurs at a tangent altitude of about 175 kilometers. On the other hand, the 1920Å photometer indicates that as the field of view moves off the earth's surface, the radiation begins to decrease rapidly. Figure 7 depicts the radiation received by the 1500Å photometer during a later orbit. This radiation also peaks at a tangent altitude of about 175 kilometers.

The presence of the peak in the radiation indicates that the source of radiation in the 1200-1600Å region is different from that in the 1900Å region. The explanation and theoretical models for these two sources of radiation are given later. Also discussed in a later section is the method of reducing the data to some common basis such that comparisons to other experimental results can be made.

A considerable amount of data was obtained on the earth dayglow, nightglow, sunlit limb, and nighttime limb. Samples of the data are presented later in reduced form. At this point, it is important that the reader understand the geometry and the method of converting the raw data into a measure of the earth's radiance.

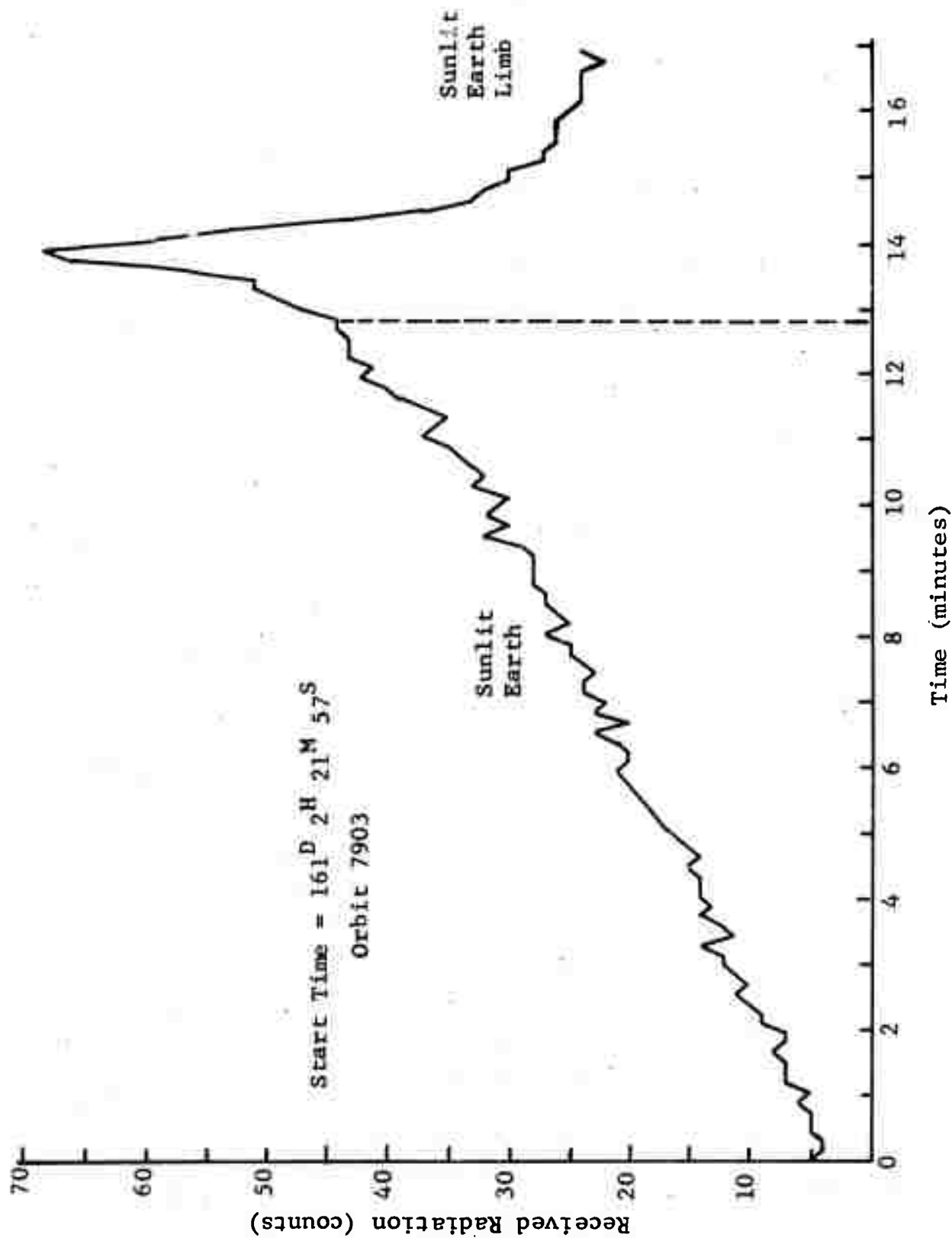


Fig. 5 Received Radiation Measured with 1250 $\text{\AA}$  Filter

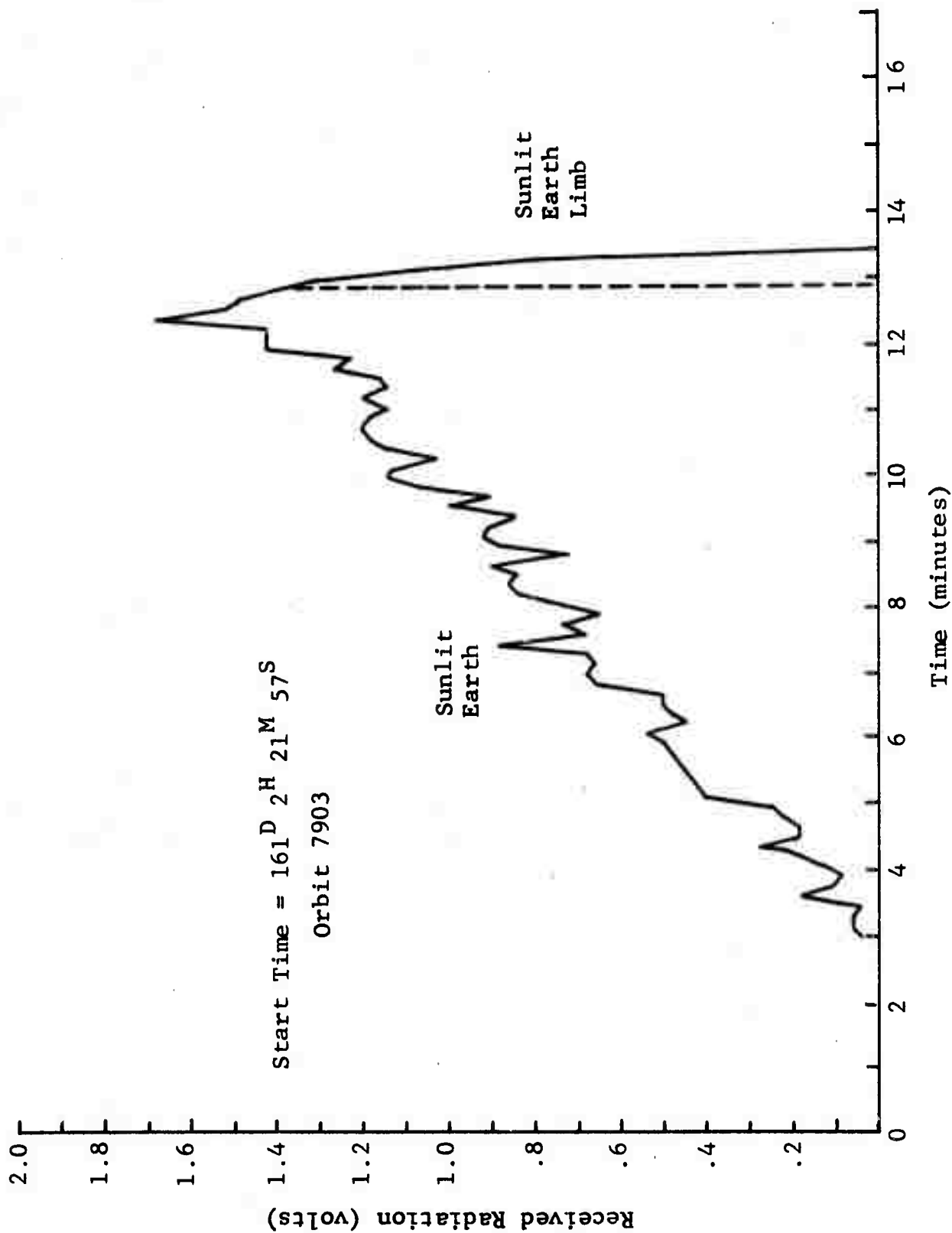


Fig. 6 Received Radiation Measured with 1920 Å Filter

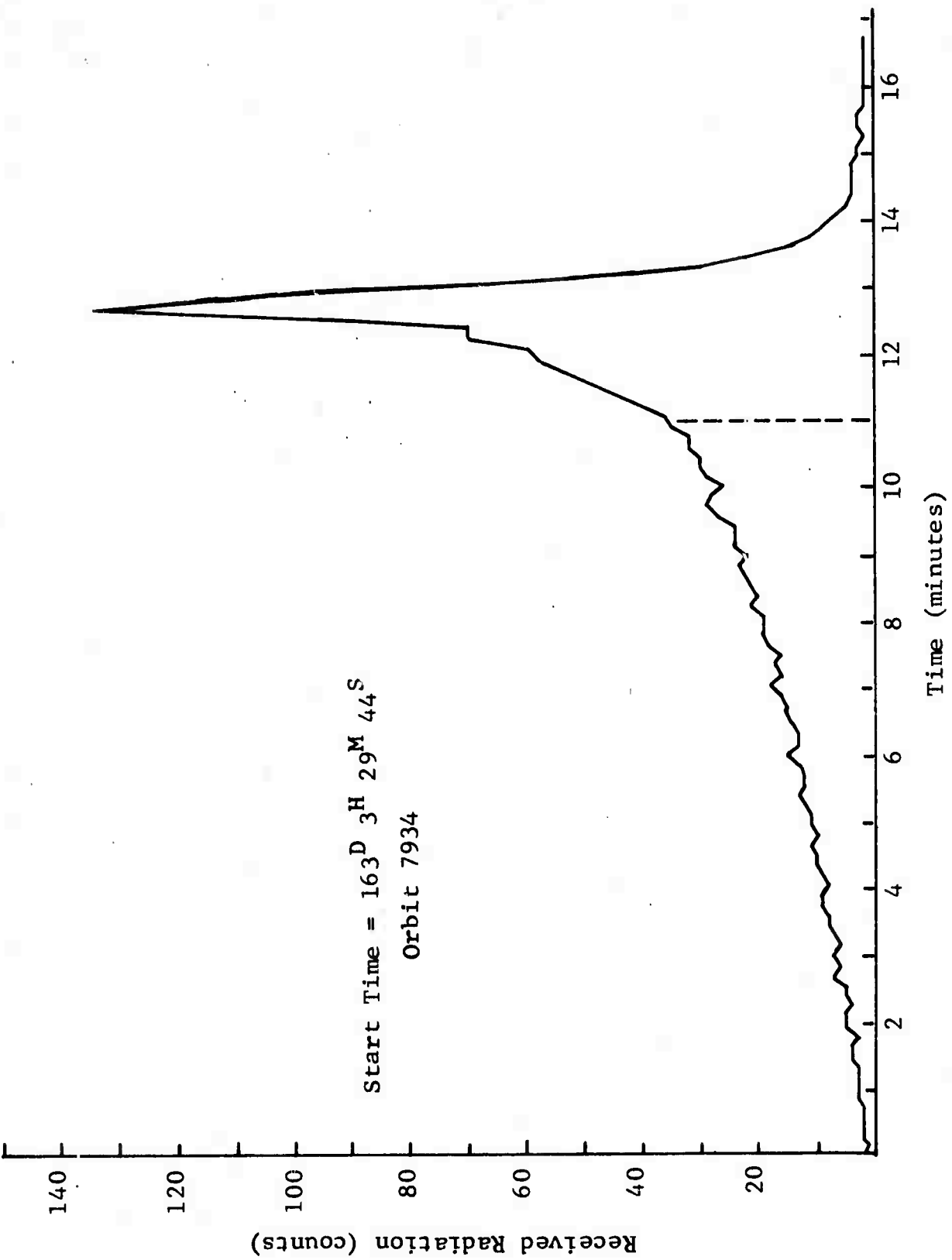


Fig. 7 Received Radiation Measured with 1500Å Filter

Consider a typical viewing situation such as shown in Fig. 8. The total received radiation is the sum of the contributions from each portion of the atmosphere along the line of sight vector,  $s$ , that is

$$I_T(s) = \int_{I_r(s=0)}^{I_r(s=\infty)} dI_r(s) \quad (1)$$

where  $s = 0$  is the point of intersection with the earth's surface and the upper limit is at  $s = \infty$  if the detector is outside the atmosphere. The increment  $dI_r(s)$  is the radiation received from emissions originating at a distance,  $s$ , from a layer of atmosphere of thickness,  $ds$ . Assuming that the source of radiation fills the field of view, we have

$$A_o dI_r(s) = A_e(s) B(s) I(s) T(s) ds \quad (2)$$

$A_o$  = collecting area of the optics ( $\text{cm}^2$ )

$A_e(s)$  = the area of atmosphere at a distance  $(s)$ ,  
that contributes to the received radiation  
( $\text{cm}^2$ )

$B(s)$  = the solid angle subtended by the detector  
at a distance  $s$  (steradians)

$T(s)$  = the transmission of the atmosphere from  $s$   
to the detector

$I(s)$  = atmospheric radiance at  $s$  ( $\text{w/cm}^3\text{-ster}$ )

Now, by definition

$$A_e(s) B(s) = A_o \alpha \quad (3)$$

where

$\alpha$  = field of view of the detector (steradians)

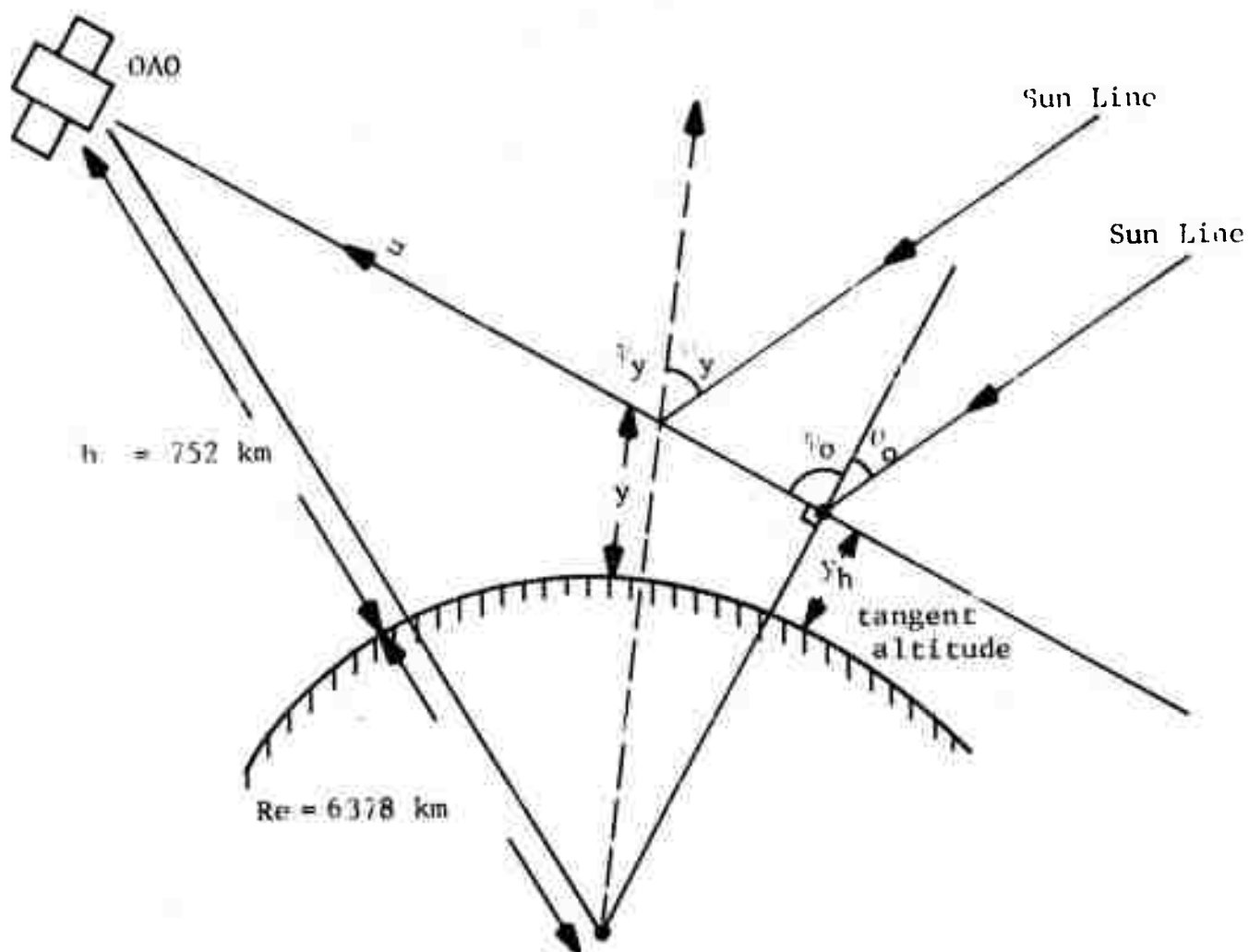


Fig. 8 Typical Viewing Geometry

Hence the radiation received by the detector from a source at a distance  $s$ , is

$$dI_r(s) = \alpha I(s)T(s)ds \quad (4)$$

Integrating along the line of sight, the total received radiation is

$$I_T = \alpha \int_{s=0}^{\infty} I(s)T(s)ds \quad (5)$$

$$= \alpha I_B \quad (6)$$

$I_B$  is the equivalent radiance of the earth in  $w/cm^2$ -ster. It is dependent on the angle between the LOS and the local zenith and also the position of the sun. The earth's radiance normally is defined by the situation when both the LOS and the sun line lie along the local spacecraft zenith. A method for obtaining this particular value of the radiance from the measured intensities is discussed in the next section, together with some results of this reduction.

The equivalent radiance can be calculated from the measured irradiance values and gives a good indication of the magnitude of the true radiance. Therefore, all measurements have been reduced to their equivalent radiance. The viewing geometry and equivalent radiance for each data sample have been placed on computer cards and tape. Each line of the printout from the cards and tape contains

- 1) the run number
- 2) a day or night designation (D or N) to indicate the condition of the area on the earth viewed at the time of the sample
- 3) the GMT time of the measurement in days, hours, minutes, and seconds
- 4) the tangent altitude (TAN.ALT) given in kilometers

- 5) the solar-zenith angle (SUN.ANG), which is the angle between the sun line and the local vertical through the earth at either the intersection point of the LOS with the earth's surface or the tangent altitude point
- 6) the line-of-sight/zenith angle (OBS ANG), which is the angle between the line of sight and the local vertical at the point indicated in 5)
- 7) the Rayleigh scattering angle (SCAT ANG), which is the angle between the LOS vector and the sun line
- 8) the longitude (LON) and latitude (LAT) of either the intersection point of the LOS with the earth's surface or the tangent altitude point
- 9) the equivalent radiance values from the 1250, 1380, 1920, 2380, 2460, and 2980Å filter photometers of the WEP.

The data samples are given at 3-minute intervals when the dark earth is being observed, at 1-minute intervals for sunlit observations, and every 10 seconds for measurements of the earth limb when the viewing does not intersect the earth's surface. The reduced data for all meaningful observations are given in Table 5. This table represents a computer printout of the data stored on magnetic tape.

TABLE 5

PRINTOUT OF REDUCED DAO DATA

THIS TAPE CONTAINS A SUMMARY OF THE ULTRAVIOLET EARTH BACKGROUND MEASUREMENTS THAT WERE MADE BY THE GRUMMAN AEROSPACE CORPORATION USING THE WISCONSIN EXPERIMENT PACKAGE OF DAO A-2. INFORMATION ON THE VIEWING GEOMETRY AND THE MEASURED RADIANCE VALUES FOR THE PHOTOMETERS ARE GIVEN FOR EACH DATA SAMPLE. THE MEASUREMENTS WERE OBTAINED DURING THE GMT DAYS 161-164 AND 268 OF 1970 AND FOR DAYS 83-146, 215 AND 225 OF 1971.

EACH LINE OF PRINTOUT CONTAINS

- (1) THE RUN NUMBER
- (2) A DAY OR NIGHT DESIGNATION (D OR N) TO INDICATE THE CONDITION OF THE AREA ON THE EARTH VIEWED AT THE TIME OF THE RUN.
- (3) THE GMT TIME OF THE MEASUREMENT IN DAYS, HOURS, MINUTES AND SECONDS.
- (4) THE TANGENT ALTITUDE (TAN.ALT) GIVEN IN KILOMETERS WHICH IS THE MINIMUM HEIGHT THAT THE LINE OF SIGHT MAKES WITH THE EARTH'S SURFACE.
- (5) THE SOLAR-ZENITH ANGLE (SUN ANG) WHICH IS THE ANGLE BETWEEN THE SUN LINE AND THE LOCAL VERTICAL THROUGH THE EARTH AT EITHER THE INTERSECTION POINT OF THE LOS WITH THE EARTH'S SURFACE OR THE TANGENT ALTITUDE POINT.
- (6) THE LINE OF SIGHT-ZENITH ANGLE (OBS ANG) WHICH IS THE ANGLE BETWEEN THE LINE OF SIGHT AND THE LOCAL VERTICAL AT THAT POINT.
- (7) THE RAYLEIGH SCATTERING ANGLE (SCAT ANG) WHICH IS THE ANGLE BETWEEN THE LINE OF SIGHT VECTOR AND THE SUN LINE.
- (8) THE LONGITUDE (LON) AND LATITUDE (LAT) OF THE DAO POSITION.
- (9) THE LONGITUDE (LON) AND LATITUDE (LAT) OF EITHER THE INTERSECTION POINT OF THE LOS WITH THE EARTH'S SURFACE OR THE TANGENT ALTITUDE POINT.
- (10) THE MEASURED RADIANCE VALUES FROM THE 1250A, 1380A, 1500A, 1920A, 2380A, 2460A AND 2930A FILTER PHOTOMETERS OF THE WISCONSIN EXPERIMENT PACKAGE. THESE VALUES WERE OBTAINED BY DIVIDING THE MEASURED IRRADIANCE BY THE FIELD OF VIEW OF THE WEP PHOTOMETERS (6.646X10 TO THE -6 STEPADIONS). THEY ARE THEREFORE EQUIVALENT RADIANCE VALUES.

| RUN | NO. | DAY | GMT | Y  | S  | TAN   | SUN  | OBS   | SCAT | DAD | LON | LAT | CBS      | 1250A  | 138CA  | 150CA  | 192CA  | 238CA  | 2460A  | 290CA  |
|-----|-----|-----|-----|----|----|-------|------|-------|------|-----|-----|-----|----------|--------|--------|--------|--------|--------|--------|--------|
|     |     |     |     |    |    |       |      |       |      |     |     |     |          |        |        |        |        |        |        |        |
| 14  | A2  | 14  | 17  | 12 | 13 | 14    | F5.1 | F5.1  | F5.1 | 13  | 14  | 14  | 14       | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 |
| 10  | 161 | 1   | 12  | 57 | 0  | 134.3 | 36.0 | 77.7  | 25   | -1  | 21  | 1   | 4.99E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 15  | 57 | 0  | 127.1 | 30.8 | 87.7  | 34   | 6   | 31  | 8   | 4.99E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 18  | 57 | 0  | 110.1 | 29.5 | 55.3  | 42   | 12  | 40  | 15  | 4.99E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 21  | 57 | 0  | 97.9  | 33.5 | 112.7 | 51   | 17  | 50  | 21  | 1.09E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 24  | 57 | 0  | 93.9  | 35.6 | 116.3 | 54   | 19  | 54  | 23  | 1.55E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 27  | 57 | 0  | 89.8  | 37.9 | 121.1 | 57   | 21  | 57  | 25  | 2.14E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 30  | 57 | 0  | 85.7  | 40.4 | 125.0 | 60   | 23  | 61  | 28  | 2.85E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 33  | 57 | 0  | 81.5  | 43.5 | 128.7 | 63   | 24  | 65  | 30  | 3.57E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 36  | 57 | 0  | 77.3  | 46.7 | 131.9 | 66   | 26  | 69  | 31  | 3.92E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 39  | 57 | 0  | 73.0  | 50.1 | 134.6 | 70   | 27  | 74  | 33  | 5.23E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 42  | 57 | 0  | 68.7  | 53.7 | 136.5 | 73   | 29  | 78  | 35  | 5.71E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 45  | 57 | 0  | 64.2  | 57.5 | 137.4 | 77   | 30  | 83  | 37  | 6.18E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 48  | 57 | 0  | 59.5  | 61.7 | 137.3 | 81   | 32  | 94  | 40  | 7.85E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 51  | 57 | 0  | 55.0  | 65.7 | 135.9 | 84   | 33  | 101 | 42  | 8.80E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 54  | 57 | 0  | 49.6  | 71.1 | 132.0 | 88   | 33  | 110 | 44  | 9.98E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 57  | 57 | 0  | 43.3  | 77.7 | 127.7 | 92   | 33  | 110 | 44  | 9.98E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 60  | 57 | 0  | 33.5  | 92.0 | 116.2 | 96   | 34  | 127 | 46  | 1.21E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 63  | 57 | 0  | 33.3  | 90.0 | 115.7 | 97   | 34  | 127 | 46  | 1.21E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 66  | 57 | 0  | 33.0  | 90.0 | 115.4 | 97   | 34  | 127 | 46  | 1.25E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 69  | 57 | 0  | 32.8  | 90.0 | 115.1 | 98   | 34  | 127 | 46  | 1.26E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 72  | 57 | 0  | 32.5  | 90.0 | 114.3 | 99   | 34  | 127 | 46  | 1.04E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 75  | 57 | 0  | 32.3  | 90.0 | 114.5 | 99   | 34  | 127 | 46  | 1.68E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 78  | 57 | 0  | 32.0  | 90.0 | 114.2 | 100  | 35  | 127 | 46  | 1.43E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 81  | 57 | 0  | 31.9  | 90.0 | 113.9 | 101  | 35  | 127 | 46  | 1.26E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 84  | 57 | 0  | 31.5  | 90.0 | 113.7 | 101  | 35  | 127 | 44  | 1.07E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 87  | 57 | 0  | 31.3  | 90.0 | 113.4 | 102  | 35  | 127 | 44  | 9.27E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 90  | 57 | 0  | 31.1  | 90.0 | 113.1 | 103  | 35  | 127 | 44  | 8.08E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 93  | 57 | 0  | 30.8  | 90.0 | 112.8 | 104  | 35  | 126 | 43  | 7.85E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 96  | 57 | 0  | 30.6  | 90.0 | 112.5 | 104  | 35  | 129 | 43  | 7.61E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 99  | 57 | 0  | 30.3  | 90.0 | 112.2 | 104  | 35  | 128 | 41  | 6.18E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 10  | 161 | 1   | 102 | 57 | 0  | 29.7  | 90.0 | 110.9 | 109  | 35  | 128 | 41  | 6.18E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 51  | 46 | 0  | 140.1 | 39.7 | 74.3  | 356  | -3  | 352 | -2  | 4.99E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 54  | 46 | 0  | 127.9 | 33.0 | 82.9  | 5    | 3   | 1   | 5   | 4.99E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 57  | 46 | 0  | 115.8 | 30.0 | 94.1  | 13   | 9   | 11  | 12  | 6.89E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 60  | 46 | 0  | 103.7 | 31.5 | 106.3 | 21   | 15  | 20  | 18  | 9.27E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 63  | 46 | 0  | 99.6  | 33.0 | 111.1 | 24   | 17  | 24  | 21  | 1.05E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 66  | 46 | 0  | 95.6  | 34.9 | 115.4 | 27   | 19  | 27  | 23  | 1.24E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 69  | 46 | 0  | 91.5  | 37.1 | 119.5 | 30   | 20  | 31  | 25  | 1.90E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 72  | 46 | 0  | 87.4  | 39.7 | 123.6 | 33   | 22  | 34  | 27  | 2.62E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 75  | 46 | 0  | 83.3  | 42.5 | 127.3 | 37   | 24  | 38  | 29  | 3.33E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 78  | 46 | 0  | 78.2  | 46.2 | 131.4 | 41   | 26  | 43  | 31  | 4.40E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 81  | 46 | 0  | 73.9  | 49.5 | 134.2 | 44   | 27  | 48  | 33  | 4.99E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 84  | 46 | 0  | 69.6  | 53.1 | 136.2 | 48   | 28  | 52  | 35  | 5.47E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 87  | 46 | 0  | 65.1  | 56.9 | 137.4 | 51   | 30  | 57  | 37  | 5.94E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 90  | 46 | 0  | 60.5  | 61.0 | 137.4 | 55   | 31  | 62  | 38  | 6.66E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 93  | 46 | 0  | 55.6  | 65.4 | 136.2 | 59   | 32  | 68  | 40  | 7.85E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 96  | 46 | 0  | 50.3  | 70.5 | 132.4 | 62   | 33  | 75  | 42  | 9.56E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 99  | 46 | 0  | 44.2  | 76.9 | 128.5 | 66   | 33  | 83  | 43  | 9.98E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 102 | 46 | 0  | 33.8  | 90.0 | 116.3 | 70   | 34  | 101 | 47  | 1.12E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 105 | 46 | 0  | 33.5  | 90.0 | 116.0 | 71   | 34  | 101 | 47  | 1.18E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 20  | 161 | 2   | 108 | 46 | 0  | 33.3  | 90.0 | 115.7 | 72   | 34  | 102 | 46  | 1.26E-06 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |

| NO. | DAY | M  | S  | ALT | SUN   | OBS  | SCAT  | DAO   | CBS | 1250A | 1300A | 1500A    | 1920A    | 2300A | 2400A | 2900A |     |
|-----|-----|----|----|-----|-------|------|-------|-------|-----|-------|-------|----------|----------|-------|-------|-------|-----|
| 14  | 42  | 14 | 13 | 13  | 14    | F6.1 | ANG   | ANG   | LOX | LAT   | 1250A | 1300A    | 1500A    | 1920A | 2300A | 2900A |     |
| 20  | 161 | 3  | 15 | 29  | 131   | 33.0 | 92.0  | 115.4 | 72  | 34    | 102   | 46       | 1.37E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 15 | 30  | 123   | 32.8 | 90.0  | 115.1 | 73  | 34    | 102   | 46       | 1.45E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 15 | 49  | 155   | 32.5 | 90.0  | 114.9 | 74  | 34    | 102   | 45       | 1.59E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 15 | 54  | 181   | 32.3 | 92.0  | 114.5 | 74  | 35    | 102   | 45       | 1.71E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 15 | 59  | 217   | 32.0 | 90.0  | 114.2 | 75  | 35    | 102   | 45       | 1.59E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 16 | 19  | 232   | 31.8 | 90.0  | 113.2 | 76  | 35    | 102   | 45       | 1.30E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 16 | 29  | 267   | 31.5 | 90.0  | 113.5 | 77  | 35    | 102   | 44       | 1.15E-06 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 16 | 39  | 281   | 31.3 | 90.0  | 113.3 | 77  | 35    | 102   | 44       | 5.75E-07 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 16 | 49  | 304   | 31.1 | 90.0  | 113.0 | 78  | 35    | 102   | 44       | 8.80E-07 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 16 | 59  | 327   | 30.8 | 90.0  | 112.7 | 79  | 35    | 102   | 43       | 7.85E-07 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 17 | 59  | 454   | 29.5 | 90.0  | 111.1 | 93  | 35    | 103   | 42       | 6.18E-07 | 0.0   | 0.0   | 0.0   |     |
| 20  | 161 | 3  | 16 | 59  | 561   | 28.3 | 90.0  | 109.5 | 87  | 35    | 103   | 40       | 5.71E-07 | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 40 | 4   | 177.5 | 30.8 | 113.0 | 353   | 13  | 152   | 17    | 7.37E-08 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 43 | 4   | 95.3  | 35.2 | 115.8 | 2     | 19  | 2     | 23    | 1.29E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 44 | 4   | 91.2  | 37.5 | 120.0 | 5     | 21  | 6     | 25    | 1.78E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 45 | 4   | 47.1  | 40.0 | 124.0 | 8     | 22  | 9     | 27    | 2.73E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 46 | 4   | 43.0  | 42.9 | 127.7 | 12    | 24  | 13    | 29    | 3.33E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 47 | 4   | 34.8  | 45.9 | 131.1 | 15    | 26  | 17    | 31    | 3.90E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 48 | 4   | 24.6  | 49.2 | 133.9 | 18    | 27  | 22    | 33    | 4.28E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 49 | 1   | 20.4  | 52.5 | 136.0 | 22    | 28  | 26    | 35    | 5.17E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 50 | 1   | 26.0  | 56.2 | 137.3 | 25    | 30  | 31    | 36    | 5.94E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 51 | 1   | 31.4  | 60.3 | 137.6 | 29    | 31  | 36    | 38    | 6.42E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 52 | 1   | 36.6  | 64.6 | 136.5 | 33    | 32  | 42    | 40    | 7.37E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 53 | 1   | 41.4  | 69.0 | 134.1 | 37    | 33  | 49    | 41    | 8.32E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 54 | 1   | 45.5  | 75.6 | 129.6 | 41    | 33  | 57    | 43    | 9.27E-07 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 55 | 1   | 49.7  | 86.0 | 120.3 | 45    | 34  | 71    | 46    | 1.07E-06 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 56 | 1   | 53.9  | 90.0 | 114.9 | 49    | 34  | 77    | 45    | 1.59E-06 | 0.0      | 0.0   | 0.0   | 0.0   |     |
| 30  | 161 | 4  | 56 | 11  | 173   | 32.4 | 90.0  | 114.5 | 49  | 35    | 77    | 45       | 1.69E-06 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 56 | 21  | 204   | 32.1 | 90.0  | 114.2 | 50  | 35    | 77    | 45       | 1.40E-06 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 56 | 31  | 223   | 31.9 | 90.0  | 113.9 | 51  | 35    | 77    | 45       | 1.14E-06 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 56 | 41  | 254   | 31.6 | 90.0  | 113.6 | 51  | 35    | 77    | 44       | 9.98E-07 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 56 | 51  | 273   | 31.4 | 90.0  | 113.4 | 52  | 35    | 77    | 44       | 9.03E-07 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 57 | 1   | 302   | 31.2 | 90.0  | 113.1 | 53  | 35    | 77    | 44       | 9.09E-07 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 58 | 1   | 332   | 25.8 | 90.0  | 111.4 | 57  | 35    | 78    | 42       | 6.18E-07 | 0.0   | 0.0   | 0.0   | 0.0 |
| 30  | 161 | 4  | 59 | 1   | 362   | 28.5 | 90.0  | 109.7 | 51  | 35    | 78    | 40       | 5.71E-07 | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 12 | 54  | 113.1 | 30.4 | 97.3  | 324   | 11  | 322   | 14    | 6.66E-08 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 21 | 54  | 121.0 | 32.9 | 110.0 | 333   | 17  | 332   | 20    | 5.27E-08 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 22 | 54  | 97.0  | 34.6 | 114.3 | 336   | 18  | 336   | 23    | 1.07E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 23 | 54  | 92.9  | 36.7 | 118.5 | 339   | 20  | 339   | 25    | 2.00E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 24 | 54  | 89.8  | 39.2 | 122.6 | 342   | 22  | 343   | 27    | 2.85E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 25 | 54  | 94.7  | 41.9 | 126.4 | 345   | 24  | 347   | 29    | 3.33E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 26 | 54  | 90.5  | 44.8 | 129.9 | 348   | 25  | 351   | 31    | 3.80E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 27 | 50  | 76.6  | 47.4 | 132.3 | 352   | 26  | 355   | 32    | 4.75E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 28 | 50  | 72.3  | 51.2 | 135.3 | 355   | 28  | 359   | 34    | 5.47E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 29 | 50  | 67.9  | 54.8 | 136.9 | 359   | 29  | 4     | 36    | 6.18E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 30 | 50  | 63.4  | 58.7 | 137.6 | 2     | 30  | 9     | 38    | 6.66E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 31 | 50  | 58.6  | 62.9 | 137.1 | 6     | 31  | 14    | 39    | 7.61E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 32 | 50  | 53.6  | 67.6 | 135.3 | 10    | 32  | 21    | 41    | 8.56E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 33 | 50  | 48.1  | 73.0 | 131.7 | 14    | 33  | 28    | 42    | 9.51E-07 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |
| 40  | 161 | 6  | 34 | 50  | 41.1  | 80.5 | 125.4 | 18    | 34  | 38    | 45    | 1.05E-06 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0 |

| RUN | NO. | DAY | GMT | M   | S    | LAT  | SUN  | OBS   | SCAT | DAD | CBS |      |          |     |     |     | 125CA | 1360A | 150CA | 192CA | 238JA | 2460A | 2900A |
|-----|-----|-----|-----|-----|------|------|------|-------|------|-----|-----|------|----------|-----|-----|-----|-------|-------|-------|-------|-------|-------|-------|
|     |     |     |     |     |      |      |      |       |      |     | ANG | F6.1 | LON      | LAT | LON | LAT |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 35  | 57  |      | 33.2 | 90.C | 115.6 | 22   | 34  | 51  | 45   | 1.28E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 36  | 0   | 115  | 33.2 | 90.C | 115.3 | 22   | 34  | 51  | 45   | 1.43E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 36  | 10  | 142  | 32.8 | 90.C | 115.0 | 23   | 34  | 52  | 45   | 1.55E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 36  | 20  | 169  | 32.5 | 90.C | 114.7 | 24   | 35  | 52  | 45   | 1.74E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 36  | 30  | 194  | 32.3 | 90.C | 114.4 | 25   | 35  | 52  | 45   | 1.62E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 36  | 40  | 219  | 32.0 | 90.C | 114.1 | 25   | 35  | 52  | 45   | 1.43E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 37  | 0   | 244  | 31.8 | 90.C | 113.8 | 26   | 35  | 52  | 44   | 1.28E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 37  | 10  | 269  | 31.5 | 90.C | 113.5 | 27   | 35  | 52  | 44   | 1.14E-06 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 37  | 20  | 292  | 31.3 | 90.C | 113.2 | 27   | 35  | 52  | 44   | 9.93E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 37  | 30  | 318  | 31.1 | 90.C | 112.9 | 28   | 35  | 52  | 44   | 9.03E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 37  | 40  | 343  | 30.8 | 90.C | 112.6 | 29   | 35  | 52  | 43   | 8.03E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 37  | 50  | 367  | 30.5 | 90.C | 112.3 | 29   | 35  | 52  | 43   | 7.61E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 38  | 0   | 392  | 30.4 | 90.C | 112.1 | 30   | 35  | 52  | 43   | 7.13E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 38  | 10  | 417  | 29.9 | 90.C | 111.8 | 30   | 35  | 53  | 41   | 6.42E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 38  | 20  | 442  | 29.4 | 90.C | 111.5 | 31   | 35  | 53  | 39   | 5.94E-07 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 38  | 30  | 467  | 28.9 | 90.C | 109.9 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 38  | 40  | 492  | 28.4 | 90.C | 109.6 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 38  | 50  | 517  | 27.9 | 90.C | 109.3 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 39  | 0   | 542  | 27.4 | 90.C | 109.0 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 39  | 10  | 567  | 26.9 | 90.C | 108.7 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 39  | 20  | 592  | 26.4 | 90.C | 108.4 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 39  | 30  | 617  | 26.1 | 90.C | 108.1 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 39  | 40  | 642  | 25.8 | 90.C | 107.8 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 39  | 50  | 667  | 25.5 | 90.C | 107.5 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 0   | 692  | 25.2 | 90.C | 107.2 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 10  | 717  | 24.9 | 90.C | 106.9 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 20  | 742  | 24.6 | 90.C | 106.6 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 30  | 767  | 24.3 | 90.C | 106.3 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 40  | 792  | 24.0 | 90.C | 106.0 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 50  | 817  | 23.7 | 90.C | 105.7 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 60  | 842  | 23.4 | 90.C | 105.4 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 70  | 867  | 23.1 | 90.C | 105.1 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 80  | 892  | 22.8 | 90.C | 104.8 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 90  | 917  | 22.5 | 90.C | 104.5 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 100 | 942  | 22.2 | 90.C | 104.2 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 110 | 967  | 21.9 | 90.C | 103.9 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 120 | 992  | 21.6 | 90.C | 103.6 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 130 | 1017 | 21.3 | 90.C | 103.3 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 140 | 1042 | 21.0 | 90.C | 103.0 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 150 | 1067 | 20.7 | 90.C | 102.7 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 160 | 1092 | 20.4 | 90.C | 102.4 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 170 | 1117 | 20.1 | 90.C | 102.1 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 180 | 1142 | 19.8 | 90.C | 101.8 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 190 | 1167 | 19.5 | 90.C | 101.5 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 200 | 1192 | 19.2 | 90.C | 101.2 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 210 | 1217 | 18.9 | 90.C | 100.9 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 220 | 1242 | 18.6 | 90.C | 100.6 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 230 | 1267 | 18.3 | 90.C | 100.3 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 240 | 1292 | 18.0 | 90.C | 100.0 | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 250 | 1317 | 17.7 | 90.C | 99.7  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 260 | 1342 | 17.4 | 90.C | 99.4  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 270 | 1367 | 17.1 | 90.C | 99.1  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 280 | 1392 | 16.8 | 90.C | 98.8  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 290 | 1417 | 16.5 | 90.C | 98.5  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 300 | 1442 | 16.2 | 90.C | 98.2  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 310 | 1467 | 15.9 | 90.C | 97.9  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 320 | 1492 | 15.6 | 90.C | 97.6  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 330 | 1517 | 15.3 | 90.C | 97.3  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 340 | 1542 | 15.0 | 90.C | 97.0  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 350 | 1567 | 14.7 | 90.C | 96.7  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 360 | 1592 | 14.4 | 90.C | 96.4  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 370 | 1617 | 14.1 | 90.C | 96.1  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 380 | 1642 | 13.8 | 90.C | 95.8  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 390 | 1667 | 13.5 | 90.C | 95.5  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 400 | 1692 | 13.2 | 90.C | 95.2  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 410 | 1717 | 12.9 | 90.C | 94.9  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 420 | 1742 | 12.6 | 90.C | 94.6  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 430 | 1767 | 12.3 | 90.C | 94.3  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 440 | 1792 | 12.0 | 90.C | 94.0  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 450 | 1817 | 11.7 | 90.C | 93.7  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 460 | 1842 | 11.4 | 90.C | 93.4  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 470 | 1867 | 11.1 | 90.C | 93.1  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 480 | 1892 | 10.8 | 90.C | 92.8  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 490 | 1917 | 10.5 | 90.C | 92.5  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 500 | 1942 | 10.2 | 90.C | 92.2  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 510 | 1967 | 9.9  | 90.C | 91.9  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 520 | 1992 | 9.6  | 90.C | 91.6  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |
| 4D  | 151 | 6   | 40  | 530 | 2017 | 9.3  | 90.C | 91.3  | 38   | 35  | 53  | 29   | 3.83E-08 | 0.0 |     |     |       |       |       |       |       |       |       |

[illegible]

| DUN D | W DAY | GMT | M  | S  | TAN | SUN   | DBS  | SCAT  | DAO | LON | LAT | LCN | LAT | CDS      | 125CA  | 138CA    | 150CA  | 1920A  | 2380A  | 2450A  | 2900A  |
|-------|-------|-----|----|----|-----|-------|------|-------|-----|-----|-----|-----|-----|----------|--------|----------|--------|--------|--------|--------|--------|
|       |       |     |    |    |     |       |      |       |     |     |     |     |     |          |        |          |        |        |        |        |        |
| 14    | A2    | 14  | 13 | 13 | 14  | F6.1  | F6.1 | F6.1  | 14  | 14  | 14  | 14  | 14  | F6.1     | 1PE9.2 | 1PE9.2   | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 |
| 90    | 161   | 23  | 10 | 57 | 3   | 73.5  | 51.6 | 135.4 | 103 | 29  | 107 | 35  | 0.0 | 2.62E-C7 | 0.0    | 2.62E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 11 | 57 | 3   | 52.1  | 55.0 | 137.1 | 106 | 30  | 111 | 37  | 0.0 | 2.94E-C7 | 0.0    | 2.94E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 12 | 57 | 3   | 54.5  | 59.8 | 137.9 | 110 | 31  | 117 | 38  | 0.0 | 3.46E-C7 | 0.0    | 3.46E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 13 | 57 | 3   | 59.9  | 62.9 | 137.5 | 114 | 32  | 122 | 40  | 0.0 | 3.98E-C7 | 0.0    | 3.98E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 14 | 57 | 3   | 54.9  | 67.4 | 135.7 | 118 | 33  | 128 | 41  | 0.0 | 4.33E-C7 | 0.0    | 4.33E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 15 | 57 | 3   | 49.4  | 72.7 | 132.3 | 122 | 34  | 136 | 43  | 0.0 | 5.02E-C7 | 0.0    | 5.02E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 16 | 57 | 3   | 42.7  | 79.7 | 126.4 | 126 | 34  | 145 | 45  | 0.0 | 5.88E-C7 | 0.0    | 5.88E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 90    | 161   | 23  | 17 | 57 | 3   | 34.1  | 90.0 | 116.3 | 130 | 35  | 160 | 47  | 0.0 | 6.92E-C7 | 0.0    | 6.92E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 43 | 3  | 3   | 137.1 | 33.5 | 125.8 | 51  | 16  | 50  | 19  | 0.0 | 1.21E-C8 | 0.0    | 1.21E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 44 | 3  | 3   | 123.0 | 34.5 | 129.9 | 54  | 17  | 53  | 22  | 0.0 | 1.21E-C8 | 0.0    | 1.21E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 45 | 3  | 3   | 99.0  | 36.2 | 114.1 | 57  | 19  | 57  | 24  | 0.0 | 2.62E-C8 | 0.0    | 2.62E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 46 | 3  | 3   | 94.9  | 37.8 | 118.2 | 60  | 21  | 60  | 26  | 0.0 | 6.58E-C8 | 0.0    | 6.58E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 47 | 3  | 3   | 90.8  | 39.9 | 122.2 | 64  | 23  | 64  | 29  | 0.0 | 1.02E-C7 | 0.0    | 1.02E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 48 | 3  | 3   | 96.7  | 42.4 | 126.3 | 67  | 24  | 68  | 30  | 0.0 | 1.56E-C7 | 0.0    | 1.56E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 49 | 3  | 3   | 82.5  | 45.1 | 129.6 | 70  | 26  | 72  | 32  | 0.0 | 1.90E-C7 | 0.0    | 1.90E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 50 | 3  | 3   | 74.0  | 49.1 | 132.7 | 74  | 27  | 76  | 33  | 0.0 | 2.42E-C7 | 0.0    | 2.42E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 51 | 3  | 3   | 69.7  | 54.7 | 137.0 | 81  | 30  | 86  | 37  | 0.0 | 2.77E-C7 | 0.0    | 2.77E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 52 | 3  | 3   | 65.2  | 59.4 | 137.9 | 85  | 31  | 91  | 38  | 0.0 | 3.29E-C7 | 0.0    | 3.29E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 53 | 3  | 3   | 60.5  | 62.4 | 137.6 | 88  | 32  | 96  | 40  | 0.0 | 3.81E-C7 | 0.0    | 3.81E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 54 | 3  | 3   | 55.6  | 65.9 | 136.3 | 92  | 33  | 102 | 41  | 0.0 | 4.33E-C7 | 0.0    | 4.33E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 55 | 3  | 3   | 52.2  | 72.0 | 132.3 | 96  | 34  | 110 | 43  | 0.0 | 4.67E-C7 | 0.0    | 4.67E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 56 | 3  | 3   | 43.7  | 78.7 | 127.3 | 100 | 34  | 119 | 45  | 0.0 | 5.36E-C7 | 0.0    | 5.36E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 100   | 162   | 4   | 57 | 3  | 3   | 104.4 | 34.4 | 108.8 | 28  | 17  | 27  | 21  | 0.0 | 1.21E-C8 | 0.0    | 1.21E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 23 | 57 | 3   | 100.3 | 35.7 | 112.9 | 31  | 19  | 30  | 23  | 0.0 | 1.38E-C8 | 0.0    | 1.38E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 24 | 57 | 3   | 96.3  | 37.3 | 117.0 | 34  | 21  | 34  | 25  | 0.0 | 2.77E-C8 | 0.0    | 2.77E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 25 | 57 | 3   | 92.2  | 39.4 | 121.1 | 37  | 22  | 38  | 27  | 0.0 | 6.40E-C8 | 0.0    | 6.40E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 26 | 57 | 3   | 99.1  | 41.7 | 124.9 | 41  | 24  | 42  | 29  | 0.0 | 1.02E-C7 | 0.0    | 1.02E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 27 | 57 | 3   | 93.9  | 44.3 | 128.6 | 44  | 26  | 46  | 31  | 0.0 | 1.44E-C7 | 0.0    | 1.44E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 28 | 57 | 3   | 79.7  | 47.2 | 131.8 | 47  | 27  | 50  | 33  | 0.0 | 1.90E-C7 | 0.0    | 1.90E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 29 | 57 | 3   | 75.5  | 50.3 | 134.5 | 51  | 28  | 54  | 35  | 0.0 | 2.25E-C7 | 0.0    | 2.25E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 30 | 57 | 3   | 71.1  | 53.7 | 136.6 | 54  | 30  | 59  | 36  | 0.0 | 2.60E-C7 | 0.0    | 2.60E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 31 | 57 | 3   | 66.7  | 57.3 | 137.7 | 58  | 31  | 64  | 38  | 0.0 | 2.94E-C7 | 0.0    | 2.94E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 32 | 57 | 3   | 62.1  | 61.2 | 137.8 | 62  | 32  | 69  | 39  | 0.0 | 3.63E-C7 | 0.0    | 3.63E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 33 | 57 | 3   | 57.2  | 65.5 | 136.7 | 66  | 33  | 75  | 41  | 0.0 | 4.15E-C7 | 0.0    | 4.15E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 34 | 57 | 3   | 52.0  | 70.3 | 134.0 | 70  | 33  | 82  | 42  | 0.0 | 4.67E-C7 | 0.0    | 4.67E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 35 | 57 | 3   | 46.0  | 76.4 | 129.5 | 74  | 34  | 90  | 44  | 0.0 | 5.19E-C7 | 0.0    | 5.19E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 36 | 57 | 3   | 36.0  | 88.4 | 118.4 | 78  | 35  | 107 | 47  | 0.0 | 6.40E-C7 | 0.0    | 6.40E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 110   | 162   | 2   | 37 | 57 | 3   | 101.6 | 35.4 | 111.3 | 5   | 19  | 4   | 23  | 0.0 | 1.21E-C8 | 0.0    | 1.21E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 4  | 53 | 3   | 97.5  | 37.0 | 116.0 | 8   | 20  | 8   | 25  | 0.0 | 2.25E-C8 | 0.0    | 2.25E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 5  | 53 | 3   | 93.4  | 39.9 | 120.0 | 11  | 22  | 11  | 27  | 0.0 | 6.56E-C8 | 0.0    | 6.56E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 6  | 53 | 3   | 89.3  | 41.2 | 124.0 | 14  | 24  | 15  | 29  | 0.0 | 9.00E-C8 | 0.0    | 9.00E-C8 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 7  | 53 | 3   | 85.2  | 43.7 | 127.6 | 18  | 25  | 19  | 31  | 0.0 | 1.33E-C7 | 0.0    | 1.33E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 8  | 53 | 3   | 81.0  | 46.5 | 131.0 | 21  | 27  | 23  | 33  | 0.0 | 1.73E-C7 | 0.0    | 1.73E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 9  | 53 | 3   | 76.8  | 49.5 | 133.3 | 25  | 28  | 28  | 34  | 0.0 | 2.25E-C7 | 0.0    | 2.25E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 10 | 53 | 3   | 72.4  | 52.8 | 136.1 | 28  | 29  | 32  | 36  | 0.0 | 2.77E-C7 | 0.0    | 2.77E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 11 | 53 | 3   | 68.0  | 56.3 | 137.3 | 32  | 31  | 37  | 38  | 0.0 | 2.94E-C7 | 0.0    | 2.94E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 12 | 53 | 3   | 63.5  | 60.1 | 137.9 | 36  | 32  | 43  | 39  | 0.0 | 3.63E-C7 | 0.0    | 3.63E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 13 | 53 | 3   | 58.7  | 64.3 | 137.2 | 40  | 33  | 48  | 41  | 0.0 | 3.98E-C7 | 0.0    | 3.98E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 14 | 53 | 3   | 53.6  | 68.9 | 135.0 | 43  | 33  | 55  | 42  | 0.0 | 4.85E-C7 | 0.0    | 4.85E-C7 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 120   | 162   | 4   | 15 | 53 | 3   |       |      |       |     |     |     |     |     |          |        |          |        |        |        |        |        |

| SUN D | GMT | W  | M  | S  | ALT | TAN   | SUN  | CBS   | SCAT | OAD | LCN | LAT | CBS | 1250A    | 1330A | 1500A | 1920A | 2330A | 2450A | 2900A |
|-------|-----|----|----|----|-----|-------|------|-------|------|-----|-----|-----|-----|----------|-------|-------|-------|-------|-------|-------|
| 14    | A2  | 14 | 13 | 13 | 17  | 14    | F6.1 | F6.1  | F6.1 | 14  | 14  | 14  | 14  | 14       | 14    | 14    | 14    | 14    | 14    | 14    |
| 120   | 162 | 4  | 16 | 53 | 0   | 47.9  | 74.5 | 121.0 | 47   | 34  | 63  | 44  | 0.0 | 5.19E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 120   | 162 | 4  | 17 | 53 | 0   | 47.9  | 82.0 | 123.7 | 51   | 34  | 74  | 46  | 0.0 | 5.40E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 120   | 162 | 4  | 18 | 53 | 115 | 37.9  | 90.0 | 115.5 | 56   | 35  | 85  | 46  | 0.0 | 7.96E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 44 | 55 | 0   | 122.4 | 35.0 | 111.2 | 339  | 18  | 338 | 23  | 0.0 | 1.35E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 45 | 55 | 0   | 92.7  | 35.0 | 115.4 | 342  | 20  | 342 | 25  | 0.0 | 1.35E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 46 | 55 | 0   | 94.2  | 32.7 | 119.4 | 345  | 22  | 345 | 27  | 0.0 | 4.33E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 47 | 55 | 0   | 92.1  | 40.9 | 123.3 | 349  | 24  | 349 | 29  | 0.0 | 5.65E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 48 | 55 | 0   | 95.0  | 42.7 | 127.1 | 352  | 25  | 353 | 31  | 0.0 | 1.32E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 49 | 55 | 0   | 91.0  | 45.1 | 130.6 | 355  | 27  | 357 | 32  | 0.0 | 1.73E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 50 | 55 | 0   | 77.0  | 49.0 | 133.4 | 359  | 28  | 2   | 34  | 0.0 | 2.25E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 51 | 55 | 0   | 73.3  | 52.3 | 135.8 | 2    | 29  | 6   | 36  | 0.0 | 2.60E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 52 | 55 | 0   | 69.9  | 55.7 | 137.4 | 6    | 30  | 11  | 37  | 0.0 | 3.11E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 53 | 55 | 0   | 64.4  | 59.4 | 139.0 | 10   | 31  | 16  | 39  | 0.0 | 3.46E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 54 | 55 | 0   | 59.7  | 63.6 | 137.4 | 14   | 32  | 22  | 40  | 0.0 | 3.98E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 55 | 55 | 0   | 54.6  | 68.1 | 135.5 | 18   | 33  | 28  | 42  | 0.0 | 4.50E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 56 | 55 | 0   | 49.1  | 73.4 | 131.3 | 22   | 34  | 36  | 43  | 0.0 | 5.19E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 57 | 55 | 0   | 42.1  | 80.8 | 125.6 | 26   | 34  | 46  | 45  | 0.0 | 5.23E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 130   | 162 | 5  | 58 | 55 | 86  | 34.2  | 90.0 | 115.9 | 30   | 35  | 59  | 47  | 0.0 | 7.79E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 24 | 48 | 0   | 103.4 | 35.2 | 110.0 | 313  | 18  | 312 | 22  | 0.0 | 1.21E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 25 | 48 | 0   | 99.7  | 35.5 | 114.1 | 310  | 20  | 315 | 24  | 0.0 | 1.73E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 26 | 48 | 0   | 95.7  | 34.2 | 118.2 | 319  | 21  | 319 | 26  | 0.0 | 2.94E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 27 | 48 | 0   | 91.6  | 40.3 | 122.2 | 322  | 23  | 323 | 29  | 0.0 | 1.12E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 28 | 48 | 0   | 87.5  | 42.6 | 125.3 | 326  | 25  | 327 | 30  | 0.0 | 1.47E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 29 | 48 | 0   | 83.3  | 45.2 | 129.5 | 329  | 26  | 331 | 32  | 0.0 | 1.90E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 30 | 48 | 0   | 79.1  | 49.1 | 132.6 | 332  | 28  | 335 | 34  | 0.0 | 2.25E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 31 | 48 | 0   | 74.8  | 51.2 | 135.1 | 336  | 29  | 340 | 35  | 0.0 | 2.77E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 32 | 48 | 0   | 70.5  | 54.6 | 137.0 | 340  | 30  | 344 | 37  | 0.0 | 3.29E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 33 | 48 | 0   | 66.0  | 58.2 | 137.9 | 343  | 31  | 349 | 39  | 0.0 | 3.91E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 34 | 48 | 0   | 61.3  | 62.2 | 137.8 | 347  | 32  | 355 | 43  | 0.0 | 4.15E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 35 | 48 | 0   | 56.4  | 65.5 | 136.3 | 351  | 33  | 1   | 41  | 0.0 | 4.35E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 36 | 48 | 0   | 51.1  | 71.5 | 133.3 | 355  | 34  | 8   | 43  | 0.0 | 5.71E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 37 | 48 | 0   | 44.8  | 77.9 | 128.2 | 359  | 34  | 17  | 45  | 0.0 | 5.92E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 140   | 162 | 7  | 38 | 48 | 32  | 34.9  | 90.0 | 116.6 | 3    | 35  | 34  | 48  | 0.0 | 1.21E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 8  | 59 | 0  | 0   | 128.1 | 36.7 | 37.5  | 271  | 6   | 267 | 16  | 0.0 | 1.21E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 2  | 0  | 0   | 116.0 | 34.1 | 98.1  | 279  | 12  | 277 | 16  | 0.0 | 1.21E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 5  | 0  | 0   | 103.9 | 35.4 | 110.1 | 288  | 18  | 287 | 22  | 0.0 | 1.21E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 6  | 0  | 0   | 99.9  | 36.7 | 114.2 | 291  | 20  | 290 | 24  | 0.0 | 2.08E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 7  | 0  | 0   | 95.9  | 38.4 | 118.2 | 294  | 22  | 294 | 26  | 0.0 | 5.06E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 8  | 0  | 0   | 91.7  | 40.4 | 122.2 | 297  | 23  | 297 | 28  | 0.0 | 9.52E-08 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 9  | 0  | 0   | 87.6  | 42.7 | 126.0 | 300  | 25  | 301 | 30  | 0.0 | 1.45E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 10 | 0  | 0   | 83.4  | 45.3 | 129.5 | 304  | 26  | 305 | 32  | 0.0 | 2.08E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 11 | 0  | 0   | 79.2  | 48.2 | 132.6 | 307  | 28  | 310 | 34  | 0.0 | 2.42E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 12 | 0  | 0   | 75.0  | 51.3 | 135.2 | 311  | 29  | 314 | 36  | 0.0 | 2.60E-07 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 9  | 13 | 0  | 0   | 70.6  | 54.6 | 137.0 | 314  | 30  | 319 | 37  | 0.0 | 3.97E-09 | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 18 | 59 | 0  | 0   | 133.7 | 42.4 | 85.1  | 116  | 5   | 111 | 7   | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 19 | 2  | 0  | 0   | 121.6 | 34.2 | 94.4  | 124  | 11  | 121 | 14  | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 19 | 5  | 0  | 0   | 109.5 | 35.6 | 105.7 | 132  | 17  | 131 | 20  | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 19 | 8  | 0  | 0   | 97.4  | 38.9 | 117.7 | 142  | 22  | 141 | 27  | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 19 | 9  | 0  | 0   | 93.3  | 40.7 | 121.6 | 145  | 24  | 145 | 29  | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 19 | 10 | 0  | 0   | 89.2  | 42.8 | 125.4 | 148  | 25  | 149 | 31  | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |
| 150   | 162 | 19 | 10 | 0  | 0   | 89.2  | 42.8 | 125.4 | 148  | 25  | 149 | 31  | 0.0 | 0.0      | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   | 0.0   |

| RUN | DAY | H  | M  | S  | TAN | SUN   | ORS  | SCAT  | DAD | LON | LAT | CDS | 125CA  | 138CA  | 150CA    | 1020A    | 2380A  | 246CA  | 2900A  |
|-----|-----|----|----|----|-----|-------|------|-------|-----|-----|-----|-----|--------|--------|----------|----------|--------|--------|--------|
|     |     |    |    |    |     |       |      |       |     |     |     |     |        |        |          |          |        |        |        |
| 14  | 42  | 14 | 13 | 13 | 14  | 14    | F5.1 | F5.1  | 14  | 14  | 14  | 14  | 1PE9.2 | 1PE9.2 | 1PE9.2   | 1PE9.2   | 1PE9.2 | 1PE9.2 | 1PE9.2 |
| 160 | 162 | 19 | 11 | 0  | 0   | 35.1  | 45.3 | 126.9 | 152 | 27  | 153 | 32  | C.C    | 0.0    | 2.15E-08 | C.C      | 0.0    | 0.0    | 0.0    |
| 160 | 162 | 19 | 12 | 0  | 0   | 40.9  | 49.0 | 132.1 | 155 | 28  | 157 | 34  | 0.0    | 0.0    | 3.14E-08 | 5.82E-07 | 0.0    | 0.0    | 0.0    |
| 160 | 162 | 19 | 13 | 0  | 0   | 76.6  | 50.9 | 134.7 | 159 | 29  | 162 | 36  | 0.0    | 0.0    | 3.64E-08 | 1.05E-06 | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 35 | 27 | 0   | 147.0 | 48.6 | 78.9  | 82  | -2  | 75  | 0   | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 39 | 57 | 0   | 134.9 | 41.2 | 84.7  | 90  | 4   | 85  | 7   | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 41 | 57 | 0   | 122.7 | 36.7 | 93.7  | 98  | 10  | 95  | 13  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 44 | 57 | 0   | 110.6 | 35.6 | 104.3 | 106 | 16  | 104 | 20  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 47 | 57 | 0   | 94.5  | 38.6 | 116.7 | 116 | 22  | 115 | 26  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 48 | 57 | 0   | 94.5  | 40.3 | 120.7 | 119 | 23  | 119 | 29  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 49 | 57 | 0   | 90.4  | 42.4 | 124.5 | 122 | 25  | 123 | 30  | 0.0    | 0.0    | 1.09E-08 | 0.0      | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 50 | 57 | 0   | 86.2  | 44.7 | 128.1 | 125 | 26  | 127 | 32  | 0.0    | 0.0    | 1.82E-08 | 5.82E-08 | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 51 | 57 | 0   | 82.1  | 47.3 | 131.3 | 129 | 28  | 131 | 34  | 0.0    | 0.0    | 2.48E-08 | 5.82E-07 | 0.0    | 0.0    | 0.0    |
| 170 | 162 | 20 | 52 | 57 | 0   | 77.8  | 50.2 | 134.1 | 132 | 29  | 135 | 35  | 0.0    | 0.0    | 3.64E-08 | 1.19E-06 | 0.0    | 0.0    | 0.0    |
| 180 | 162 | 22 | 17 | 42 | 0   | 140.7 | 44.7 | 81.5  | 60  | 1   | 55  | 4   | 0.0    | 0.0    | 3.57E-09 | C.C      | 0.0    | 0.0    | 0.0    |
| 190 | 162 | 22 | 20 | 42 | 0   | 128.6 | 38.7 | 89.2  | 69  | 8   | 65  | 10  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 180 | 162 | 22 | 23 | 42 | 0   | 116.6 | 36.0 | 99.4  | 77  | 14  | 74  | 17  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 180 | 162 | 22 | 26 | 42 | 0   | 104.5 | 37.0 | 111.0 | 86  | 19  | 84  | 23  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 180 | 162 | 22 | 27 | 42 | 0   | 100.5 | 38.1 | 115.0 | 92  | 21  | 88  | 26  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 180 | 162 | 22 | 28 | 42 | 0   | 96.4  | 39.7 | 118.9 | 92  | 23  | 92  | 28  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 162 | 22 | 29 | 42 | 0   | 92.3  | 41.6 | 122.9 | 95  | 24  | 95  | 29  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 180 | 162 | 22 | 30 | 42 | 0   | 88.2  | 43.7 | 126.5 | 99  | 26  | 99  | 31  | 0.0    | 0.0    | 7.94E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 162 | 22 | 31 | 42 | 0   | 84.1  | 46.2 | 129.9 | 102 | 27  | 104 | 33  | 0.0    | 0.0    | 1.21E-08 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 4  | 54 | 0   | 112.7 | 36.1 | 103.2 | 55  | 16  | 52  | 19  | 0.0    | 0.0    | 2.65E-08 | 2.62E-07 | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 7  | 54 | 0   | 100.6 | 38.3 | 115.0 | 64  | 21  | 63  | 26  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 8  | 54 | 0   | 96.5  | 39.6 | 119.0 | 67  | 23  | 66  | 28  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 9  | 54 | 0   | 92.5  | 41.7 | 122.9 | 70  | 24  | 70  | 30  | 0.0    | 0.0    | 6.62E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 10 | 54 | 0   | 88.3  | 43.8 | 126.5 | 73  | 26  | 74  | 31  | 0.0    | 0.0    | 7.78E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 11 | 54 | 0   | 84.2  | 46.3 | 129.9 | 77  | 27  | 78  | 33  | 0.0    | 0.0    | 1.26E-08 | 0.0      | 0.0    | 0.0    | 0.0    |
| 190 | 163 | 0  | 12 | 54 | 0   | 80.0  | 49.0 | 133.0 | 80  | 29  | 83  | 35  | 0.0    | 0.0    | 2.65E-08 | 1.75E-07 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 48 | 49 | 0   | 97.4  | 39.5 | 117.9 | 41  | 22  | 40  | 27  | 0.0    | 0.0    | 3.14E-08 | 5.82E-07 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 49 | 49 | 0   | 93.7  | 41.2 | 121.3 | 44  | 24  | 44  | 29  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 50 | 49 | 0   | 89.6  | 43.3 | 125.5 | 47  | 26  | 48  | 31  | 0.0    | 0.0    | 8.28E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 51 | 49 | 0   | 85.5  | 45.6 | 129.0 | 51  | 27  | 52  | 33  | 0.0    | 0.0    | 1.21E-08 | 0.0      | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 52 | 49 | 0   | 81.3  | 48.3 | 132.2 | 54  | 28  | 56  | 35  | 0.0    | 0.0    | 2.48E-08 | 2.51E-07 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 53 | 49 | 0   | 77.1  | 51.1 | 134.8 | 58  | 30  | 61  | 36  | 0.0    | 0.0    | 3.31E-08 | 6.40E-07 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 54 | 49 | 0   | 72.8  | 54.3 | 136.4 | 61  | 31  | 66  | 38  | 0.0    | 0.0    | 3.97E-08 | 9.89E-07 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 55 | 49 | 0   | 68.3  | 57.6 | 138.0 | 65  | 32  | 71  | 39  | 0.0    | 0.0    | 4.80E-08 | 1.34E-06 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 56 | 49 | 0   | 63.7  | 61.3 | 138.1 | 69  | 33  | 76  | 41  | 0.0    | 0.0    | 5.56E-08 | 2.04E-06 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 57 | 49 | 0   | 59.9  | 65.4 | 137.1 | 73  | 33  | 82  | 42  | 0.0    | 0.0    | 7.28E-08 | 2.76E-06 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 58 | 49 | 0   | 53.9  | 70.0 | 134.6 | 77  | 34  | 89  | 43  | 0.0    | 0.0    | 7.94E-08 | 3.17E-06 | 0.0    | 0.0    | 0.0    |
| 200 | 163 | 1  | 59 | 49 | 0   | 47.9  | 75.6 | 130.4 | 81  | 34  | 97  | 44  | 0.0    | 0.0    | 9.93E-08 | 3.78E-06 | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 26 | 44 | 0   | 107.2 | 37.1 | 105.0 | 11  | 20  | 10  | 25  | 0.0    | 0.0    | 1.16E-07 | 3.78E-06 | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 27 | 44 | 0   | 103.1 | 38.0 | 112.9 | 11  | 20  | 10  | 25  | 0.0    | 0.0    | 3.97E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 28 | 44 | 0   | 99.1  | 39.2 | 116.9 | 14  | 22  | 14  | 27  | 0.0    | 0.0    | 3.57E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 29 | 44 | 0   | 95.0  | 40.8 | 120.7 | 18  | 24  | 17  | 29  | 0.0    | 0.0    | 5.79E-09 | 0.0      | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 30 | 44 | 0   | 90.9  | 42.8 | 124.5 | 21  | 25  | 21  | 31  | 0.0    | 0.0    | 1.18E-08 | 0.0      | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 31 | 44 | 0   | 86.8  | 45.0 | 128.1 | 24  | 27  | 25  | 32  | 0.0    | 0.0    | 1.82E-08 | 2.91E-07 | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 32 | 44 | 0   | 82.6  | 47.6 | 131.3 | 28  | 28  | 30  | 34  | 0.0    | 0.0    | 2.48E-08 | 5.24E-07 | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 33 | 44 | 0   | 78.4  | 50.3 | 134.1 | 31  | 29  | 34  | 36  | 0.0    | 0.0    | 3.31E-08 | 1.02E-06 | 0.0    | 0.0    | 0.0    |
| 210 | 163 | 3  | 34 | 44 | 0   | 74.1  | 53.4 | 136.3 | 35  | 31  | 39  | 37  | 0.0    | 0.0    | 4.47E-08 | 1.31E-06 | 0.0    | 0.0    | 0.0    |



[illegible]

| RUN |  | C |  | GMT |  | TAN |  | SUN |  | DBS |  | SCAT |  | QAD |  | DBS |  | LAT |  | LON |  | LAT |  | LON |  | 125CA |  | 1390A |  | 1500A |  | 192CA |  | 238CA |  | 2460A |  | 2900A |  |  |  |
|-----|--|---|--|-----|--|-----|--|-----|--|-----|--|------|--|-----|--|-----|--|-----|--|-----|--|-----|--|-----|--|-------|--|-------|--|-------|--|-------|--|-------|--|-------|--|-------|--|--|--|
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |
|     |  |   |  |     |  |     |  |     |  |     |  |      |  |     |  |     |  |     |  |     |  |     |  |     |  |       |  |       |  |       |  |       |  |       |  |       |  |       |  |  |  |

| QJN | D  | GMT | M  | S   | TAN   | SUN   | OBS  | SCAT  | D40 |    |     | LAT | LON | CBS |     |     | 1250A  | 1300A  | 1500A  | 1920A  | 2300A  | 2400A  | 2900A  |
|-----|----|-----|----|-----|-------|-------|------|-------|-----|----|-----|-----|-----|-----|-----|-----|--------|--------|--------|--------|--------|--------|--------|
|     |    |     |    |     |       |       |      |       |     |    |     |     |     |     |     |     |        |        |        |        |        |        |        |
| 14  | A2 | 14  | 13 | 13  | 14    | F6.1  | F5.1 | F6.1  | 14  | 14 | 14  | 14  | 14  | 14  | 14  | 14  | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 |
| 31N | 83 | 1   | 41 | 48  |       | 176.8 | 55.4 | 109.1 | 234 | 27 | 225 | 36  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 38 | 35  | 153.2 |       | 90.0 | 101.8 | 179 | 11 | 160 | 18  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 48 | 301 | 152.9 |       | 90.0 | 102.3 | 180 | 11 | 160 | 19  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 58 | 295 | 152.7 |       | 90.0 | 102.8 | 190 | 12 | 160 | 19  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 13 | 8   | 271   | 152.4 | 90.0 | 103.2 | 191 | 12 | 160 | 20  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 18 | 256 | 152.2 |       | 90.0 | 103.7 | 191 | 12 | 160 | 20  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 28 | 240 | 151.9 |       | 90.0 | 104.2 | 192 | 13 | 160 | 21  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 38 | 225 | 151.6 |       | 90.0 | 104.7 | 192 | 13 | 160 | 21  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 48 | 219 | 151.3 |       | 90.0 | 105.2 | 193 | 13 | 161 | 22  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 58 | 193 | 151.0 |       | 90.0 | 105.7 | 193 | 14 | 161 | 22  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 14 | 8   | 130   | 150.5 | 90.0 | 106.5 | 194 | 14 | 161 | 23  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 14 | 12  | 164   | 150.2 | 90.0 | 107.0 | 194 | 15 | 161 | 24  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 14 | 28  | 149   | 149.9 | 90.0 | 107.5 | 195 | 15 | 161 | 24  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 14 | 38  | 131   | 149.5 | 90.0 | 108.0 | 195 | 15 | 161 | 25  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 14 | 48  | 115   | 149.2 | 90.0 | 108.5 | 196 | 16 | 162 | 25  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 14 | 58  | 92    | 148.8 | 90.0 | 109.0 | 196 | 16 | 162 | 26  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 15 | 8   | 66    | 148.4 | 90.0 | 109.5 | 197 | 16 | 162 | 26  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 15 | 18  | 55    | 148.1 | 90.0 | 110.0 | 197 | 17 | 162 | 27  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 15 | 28  | 43    | 147.7 | 90.0 | 110.6 | 199 | 17 | 162 | 27  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 15 | 38  | 33    | 147.3 | 90.0 | 111.1 | 198 | 17 | 162 | 28  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 15 | 48  | 16    | 146.9 | 90.0 | 111.6 | 199 | 18 | 163 | 29  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 15 | 58  | 0     | 147.0 | 89.3 | 111.6 | 199 | 18 | 163 | 29  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 18 | 58  | 0     | 146.5 | 72.4 | 104.6 | 199 | 23 | 196 | 31  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 32N | 83 | 12  | 21 | 58  | 0     | 136.9 | 65.6 | 108.3 | 209 | 28 | 200 | 36  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 53 | 43  | 244   | 151.7 | 90.0 | 104.4 | 157 | 13 | 135 | 21  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 53 | 53  | 223   | 151.4 | 90.0 | 104.9 | 157 | 13 | 135 | 21  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 54 | 3   | 213   | 151.1 | 90.0 | 105.4 | 158 | 14 | 135 | 22  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 54 | 13  | 198   | 150.8 | 90.0 | 105.9 | 158 | 14 | 136 | 22  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 54 | 23  | 182   | 150.5 | 90.0 | 106.4 | 159 | 14 | 136 | 23  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 54 | 33  | 163   | 150.2 | 90.0 | 107.2 | 159 | 15 | 136 | 24  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 54 | 43  | 152   | 149.6 | 90.0 | 107.7 | 160 | 15 | 136 | 24  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 54 | 53  | 126   | 149.3 | 90.0 | 108.2 | 160 | 16 | 136 | 25  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 55 | 3   | 120   | 149.0 | 90.0 | 108.8 | 161 | 16 | 136 | 25  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 55 | 13  | 104   | 148.6 | 90.0 | 109.3 | 161 | 16 | 137 | 26  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 55 | 23  | 87    | 148.2 | 90.0 | 109.8 | 162 | 16 | 137 | 26  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 55 | 33  | 71    | 147.9 | 90.0 | 110.3 | 162 | 17 | 137 | 27  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 55 | 43  | 54    | 147.5 | 90.0 | 110.8 | 163 | 17 | 137 | 28  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 55 | 53  | 35    | 147.1 | 90.0 | 111.3 | 163 | 17 | 137 | 29  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 56 | 3   | 21    | 146.7 | 90.0 | 111.8 | 164 | 18 | 137 | 29  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 56 | 13  | 5     | 146.3 | 90.0 | 112.4 | 164 | 18 | 138 | 29  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 56 | 23  | 0     | 148.4 | 86.5 | 109.6 | 155 | 18 | 142 | 29  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 33N | 83 | 13  | 56 | 33  | 0     | 145.7 | 72.1 | 105.1 | 174 | 23 | 161 | 32  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 32 | 55  | 253   | 151.6 | 90.0 | 104.5 | 131 | 13 | 110 | 21  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 34 | 5   | 239   | 151.3 | 90.0 | 105.0 | 132 | 13 | 110 | 21  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 34 | 15  | 222   | 151.0 | 90.0 | 105.5 | 132 | 14 | 110 | 22  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 34 | 25  | 217   | 150.7 | 90.0 | 106.0 | 133 | 14 | 111 | 23  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 34 | 35  | 191   | 150.4 | 90.0 | 106.5 | 133 | 14 | 111 | 23  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 34 | 45  | 177   | 149.9 | 90.0 | 107.3 | 134 | 15 | 111 | 24  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 34 | 55  | 161   | 149.5 | 90.0 | 107.8 | 134 | 15 | 111 | 24  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83 | 15  | 35 | 5   | 145   | 149.2 | 90.0 | 108.3 | 135 | 16 | 111 | 25  | 0.0 | 0.0 | 0.0 | 0.0 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |

| RUN | C   | DAY | T  | H  | S   | ALT   | TAN  | SUN   | OBS  | SCAT | ANG  | LON | LAT | LON | LAT | CBS | 1257A    | 136CA    | 150CA  | 192CA  | 2380A  | 2462A  | 290CA  |
|-----|-----|-----|----|----|-----|-------|------|-------|------|------|------|-----|-----|-----|-----|-----|----------|----------|--------|--------|--------|--------|--------|
|     |     |     |    |    |     |       |      |       |      |      |      |     |     |     |     |     |          |          |        |        |        |        |        |
| 14  | A2  | 14  | 13 | 13 | 13  | 14    | F6.1 | F6.1  | F6.1 | F6.1 | F6.1 | 14  | 14  | 14  | 14  | 14  | 1PE9.2   | 1PE9.2   | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 | 1PE9.2 |
| 34N | 83  | 15  | 35 | 15 | 129 | 143.9 | 90.0 | 108.3 | 135  | 16   | 111  | 25  | C.0 | C.0 | C.0 | C.0 | 2.06E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 35 | 25 | 113 | 145.5 | 90.0 | 109.3 | 136  | 16   | 112  | 26  | C.0 | C.0 | C.0 | C.0 | 1.94E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 35 | 35 | 97  | 148.1 | 90.0 | 109.8 | 136  | 17   | 112  | 27  | C.0 | C.0 | C.0 | C.0 | 1.57E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 35 | 45 | 21  | 147.8 | 90.0 | 110.3 | 137  | 17   | 112  | 27  | C.0 | C.0 | C.0 | C.0 | 1.45E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 35 | 55 | 64  | 147.4 | 90.0 | 110.9 | 137  | 17   | 112  | 28  | C.0 | C.0 | C.0 | C.0 | 1.57E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 36 | 5  | 43  | 147.0 | 90.0 | 111.4 | 139  | 18   | 112  | 29  | C.0 | C.0 | C.0 | C.0 | 1.09E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 36 | 15 | 31  | 146.6 | 90.0 | 111.9 | 139  | 18   | 112  | 29  | C.0 | C.0 | C.0 | C.0 | 6.05E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 36 | 25 | 15  | 145.2 | 90.0 | 112.4 | 139  | 18   | 112  | 29  | C.0 | C.0 | C.0 | C.0 | 3.63E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 36 | 35 | 0   | 146.9 | 90.0 | 111.6 | 139  | 18   | 114  | 29  | C.0 | C.0 | C.0 | C.0 | 2.42E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 39 | 35 | 0   | 145.6 | 72.4 | 105.4 | 149  | 28   | 136  | 32  | C.0 | C.0 | C.0 | C.0 | 0.0      | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 34N | 83  | 15  | 42 | 35 | 0   | 136.0 | 65.7 | 109.1 | 159  | 28   | 150  | 36  | C.0 | C.0 | C.0 | C.0 | 0.0      | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 13 | 56 | 279 | 151.9 | 90.0 | 104.1 | 106  | 13   | 85   | 20  | C.0 | C.0 | C.0 | C.0 | 0.0      | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 14 | 6  | 254 | 151.6 | 90.0 | 104.5 | 106  | 13   | 85   | 21  | C.0 | C.0 | C.0 | C.0 | 0.0      | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 14 | 16 | 242 | 151.2 | 90.0 | 105.0 | 107  | 14   | 85   | 21  | C.0 | C.0 | C.0 | C.0 | 1.21E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 14 | 26 | 233 | 150.9 | 90.0 | 105.5 | 107  | 14   | 85   | 22  | C.0 | C.0 | C.0 | C.0 | 1.21E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 14 | 36 | 217 | 150.6 | 90.0 | 106.2 | 108  | 14   | 85   | 23  | C.0 | C.0 | C.0 | C.0 | 3.63E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 14 | 46 | 202 | 150.3 | 90.0 | 106.5 | 109  | 15   | 86   | 23  | C.0 | C.0 | C.0 | C.0 | 6.05E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 14 | 56 | 186 | 150.0 | 90.0 | 107.0 | 109  | 15   | 86   | 24  | C.0 | C.0 | C.0 | C.0 | 7.26E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 15 | 6  | 172 | 145.5 | 90.0 | 107.8 | 109  | 15   | 86   | 24  | C.0 | C.0 | C.0 | C.0 | 1.09E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 15 | 16 | 155 | 149.1 | 90.0 | 108.3 | 110  | 16   | 86   | 25  | C.0 | C.0 | C.0 | C.0 | 1.94E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 15 | 26 | 142 | 148.8 | 90.0 | 108.8 | 110  | 16   | 86   | 25  | C.0 | C.0 | C.0 | C.0 | 2.18E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 15 | 36 | 124 | 148.4 | 90.0 | 108.3 | 111  | 16   | 86   | 26  | C.0 | C.0 | C.0 | C.0 | 2.18E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 15 | 46 | 109 | 149.1 | 90.0 | 109.8 | 111  | 17   | 87   | 27  | C.0 | C.0 | C.0 | C.0 | 1.69E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 15 | 56 | 92  | 147.7 | 90.0 | 110.4 | 112  | 17   | 87   | 27  | C.0 | C.0 | C.0 | C.0 | 1.61E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 16 | 6  | 75  | 147.3 | 90.0 | 110.9 | 112  | 17   | 87   | 28  | C.0 | C.0 | C.0 | C.0 | 1.33E-10 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 16 | 16 | 59  | 147.0 | 90.0 | 111.4 | 113  | 18   | 87   | 29  | C.0 | C.0 | C.0 | C.0 | 8.47E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 16 | 26 | 43  | 146.6 | 90.0 | 111.9 | 113  | 18   | 87   | 29  | C.0 | C.0 | C.0 | C.0 | 6.05E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 16 | 36 | 26  | 146.2 | 90.0 | 112.4 | 114  | 18   | 87   | 29  | C.0 | C.0 | C.0 | C.0 | 3.63E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 16 | 46 | 10  | 145.9 | 90.0 | 112.9 | 114  | 19   | 88   | 30  | C.0 | C.0 | C.0 | C.0 | 3.63E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 16 | 56 | 0   | 147.2 | 90.0 | 111.0 | 115  | 19   | 91   | 29  | C.0 | C.0 | C.0 | C.0 | 2.42E-11 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 19 | 56 | 0   | 145.1 | 72.2 | 105.8 | 124  | 24   | 111  | 32  | C.0 | C.0 | C.0 | C.0 | 0.0      | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 35N | 83  | 17  | 22 | 56 | 0   | 135.5 | 65.6 | 109.6 | 134  | 28   | 126  | 37  | C.0 | C.0 | C.0 | C.0 | 0.0      | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 18 | 57 | 230 | 28.7  | 90.0 | 109.6 | 224  | 34   | 206  | 19  | C.0 | C.0 | C.0 | C.0 | 9.03E-08 | 7.18E-09 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 19 | 7  | 206 | 29.0  | 90.0 | 109.9 | 225  | 35   | 207  | 19  | C.0 | C.0 | C.0 | C.0 | 1.35E-07 | 1.11E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 19 | 17 | 191 | 29.2  | 90.0 | 110.2 | 226  | 35   | 207  | 19  | C.0 | C.0 | C.0 | C.0 | 2.26E-07 | 1.90E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 15 | 27 | 156 | 29.5  | 90.0 | 110.6 | 227  | 35   | 207  | 19  | C.0 | C.0 | C.0 | C.0 | 3.46E-07 | 3.69E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 19 | 37 | 130 | 29.7  | 90.0 | 110.3 | 227  | 35   | 207  | 19  | C.0 | C.0 | C.0 | C.0 | 2.71E-07 | 7.27E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 19 | 47 | 104 | 30.0  | 90.0 | 111.2 | 228  | 35   | 207  | 19  | C.0 | C.0 | C.0 | C.0 | 1.50E-07 | 1.00E-07 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 19 | 57 | 77  | 30.3  | 90.0 | 111.6 | 229  | 35   | 208  | 17  | C.0 | C.0 | C.0 | C.0 | 1.66E-07 | 9.99E-08 | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 20 | 7  | 50  | 30.5  | 90.0 | 111.9 | 229  | 35   | 208  | 17  | C.0 | C.0 | C.0 | C.0 | 1.66E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 20 | 17 | 23  | 30.8  | 90.0 | 112.3 | 230  | 35   | 208  | 17  | C.0 | C.0 | C.0 | C.0 | 1.66E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 20 | 27 | 0   | 32.6  | 87.8 | 114.6 | 231  | 35   | 210  | 18  | C.0 | C.0 | C.0 | C.0 | 1.66E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 36D | 225 | C   | 20 | 37 | 0   | 35.5  | 94.2 | 118.1 | 231  | 35   | 213  | 21  | C.0 | C.0 | C.0 | C.0 | 1.66E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 38 | 53 | 296 | 27.9  | 90.0 | 109.4 | 172  | 34   | 155  | 20  | C.0 | C.0 | C.0 | C.0 | 1.72E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 39 | 3  | 273 | 28.1  | 90.0 | 108.9 | 173  | 34   | 156  | 19  | C.0 | C.0 | C.0 | C.0 | 1.72E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 39 | 13 | 250 | 28.3  | 90.0 | 109.1 | 174  | 34   | 156  | 19  | C.0 | C.0 | C.0 | C.0 | 1.72E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 39 | 23 | 226 | 28.6  | 90.0 | 109.4 | 174  | 35   | 156  | 19  | C.0 | C.0 | C.0 | C.0 | 2.59E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 39 | 33 | 202 | 28.8  | 90.0 | 109.8 | 175  | 35   | 156  | 19  | C.0 | C.0 | C.0 | C.0 | 4.31E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 39 | 43 | 177 | 29.1  | 90.0 | 110.1 | 176  | 35   | 156  | 18  | C.0 | C.0 | C.0 | C.0 | 5.17E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |
| 37D | 225 | C   | 39 | 53 | 152 | 25.3  | 90.0 | 110.4 | 176  | 35   | 157  | 18  | C.0 | C.0 | C.0 | C.0 | 7.76E-07 | 0.0      | 0.0    | 0.0    | 0.0    | 0.0    | 0.0    |

| SUN | DAY | GMT | YAW | SUN | JBS | SCAT  | DAD  |       |     | CBS |     |     | 12SDA  | 13SDA    | 15SDA  | 192DA    | 23SDA  | 24SDA  | 290DA    |
|-----|-----|-----|-----|-----|-----|-------|------|-------|-----|-----|-----|-----|--------|----------|--------|----------|--------|--------|----------|
|     |     |     |     |     |     |       | ANG  | LOW   | LAT | LOW | LAT | LOW |        |          |        |          |        |        |          |
| 14  | 42  | 14  | 17  | 13  | 13  | 14    | F6.1 | F6.1  | 14  | 14  | 14  | 14  | 1DE9.2 | 1DE9.2   | 1DE9.2 | 1DE9.2   | 1DE9.2 | 1DE9.2 | 1PE5.2   |
| 37D | 225 | 7   | 4C  | 3   | 126 | 29.6  | 90.0 | 110.3 | 177 | 35  | 157 | 13  | C.0    | 7.76E-07 | C.0    | C.0      | C.0    | 0.0    | 0.0      |
| 37D | 225 | 7   | 4C  | 13  | 122 | 29.9  | 90.0 | 111.1 | 178 | 35  | 157 | 18  | 0.0    | 6.04E-07 | C.0    | C.0      | 0.0    | 0.0    | 0.0      |
| 37D | 225 | 7   | 4C  | 23  | 74  | 30.1  | 90.0 | 111.4 | 175 | 35  | 157 | 17  | 0.0    | 5.17E-07 | 0.0    | C.0      | 0.0    | 0.0    | 0.0      |
| 37D | 225 | 7   | 4C  | 33  | 47  | 30.4  | 90.0 | 111.5 | 179 | 35  | 158 | 17  | 0.0    | 5.17E-07 | 0.0    | C.0      | 0.0    | 0.0    | 0.0      |
| 37D | 225 | 7   | 4C  | 43  | 2   | 30.7  | 90.0 | 112.1 | 181 | 35  | 158 | 17  | 0.0    | 5.17E-07 | 0.0    | C.0      | 0.0    | 0.0    | 0.0      |
| 37D | 225 | 7   | 4C  | 53  | 5   | 31.0  | 87.1 | 115.1 | 190 | 35  | 160 | 17  | 0.0    | 5.17E-07 | 0.0    | C.0      | 0.0    | 0.0    | 0.0      |
| 38N | 148 | 7   | 34  | 15  | 23  | 124.0 | 90.0 | 144.7 | 212 | 23  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 1.59E-09 |
| 38N | 148 | 7   | 34  | 16  | 25  | 124.1 | 90.0 | 144.7 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 1.68E-09 |
| 38N | 148 | 7   | 34  | 17  | 23  | 124.1 | 90.0 | 144.7 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | C.0    | 0.0    | 1.79E-09 |
| 38N | 148 | 7   | 34  | 18  | 32  | 124.1 | 90.0 | 144.7 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 1.93E-09 |
| 38N | 148 | 7   | 34  | 19  | 35  | 124.1 | 90.0 | 144.7 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 2.21E-09 |
| 38N | 148 | 7   | 34  | 20  | 34  | 124.1 | 90.0 | 144.5 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 2.52E-09 |
| 38N | 148 | 7   | 34  | 21  | 41  | 124.1 | 90.0 | 144.5 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 2.80E-09 |
| 38N | 148 | 7   | 34  | 22  | 45  | 124.1 | 90.0 | 144.5 | 212 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 3.09E-09 |
| 38N | 148 | 7   | 34  | 23  | 49  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 3.46E-09 |
| 38N | 148 | 7   | 34  | 24  | 51  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 3.83E-09 |
| 38N | 148 | 7   | 34  | 25  | 55  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 4.30E-09 |
| 38N | 148 | 7   | 34  | 26  | 59  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 4.96E-09 |
| 38N | 148 | 7   | 34  | 27  | 61  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 5.42E-09 |
| 38N | 148 | 7   | 34  | 28  | 64  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 5.95E-09 |
| 38N | 148 | 7   | 34  | 29  | 67  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 3.88E-10 | C.0    | 0.0    | 6.83E-09 |
| 38N | 148 | 7   | 34  | 30  | 71  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 8.70E-09 |
| 38N | 148 | 7   | 34  | 31  | 74  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 3.88E-10 | C.0    | 0.0    | 1.05E-08 |
| 38N | 148 | 7   | 34  | 32  | 77  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 1.08E-08 |
| 38N | 148 | 7   | 34  | 33  | 80  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 9.16E-09 |
| 38N | 148 | 7   | 34  | 34  | 83  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 5.98E-09 |
| 38N | 148 | 7   | 34  | 35  | 87  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 3.46E-09 |
| 38N | 148 | 7   | 34  | 36  | 90  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 1.40E-09 |
| 38N | 148 | 7   | 34  | 37  | 93  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 8.04E-10 |
| 38N | 148 | 7   | 34  | 38  | 96  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 5.98E-10 |
| 38N | 148 | 7   | 34  | 39  | 99  | 124.1 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 4.67E-10 |
| 38N | 148 | 7   | 34  | 40  | 102 | 124.2 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 4.30E-10 |
| 38N | 148 | 7   | 34  | 41  | 106 | 124.2 | 90.0 | 144.5 | 213 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 4.30E-10 |
| 38N | 148 | 7   | 34  | 42  | 109 | 124.2 | 90.0 | 144.5 | 214 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 0.0      | 0.0    | 0.0    | 4.30E-10 |
| 38N | 148 | 7   | 34  | 43  | 112 | 124.2 | 90.0 | 144.5 | 214 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.26E-08 | C.0    | 0.0    | 4.30E-10 |
| 38N | 148 | 7   | 34  | 44  | 115 | 124.2 | 90.0 | 144.5 | 214 | 24  | 245 | 34  | C.0    | 0.0      | C.0    | 1.94E-10 | C.0    | 0.0    | 4.30E-10 |

## DATA ANALYSIS

A major problem in comparing various airglow measurements is that of reducing the results to some common basis by eliminating the angular dependence of the measurements. The angles on which these measurements depend are the solar zenith angle,  $\theta$ , and the line of sight zenith angle,  $\psi$ . The common basis usually chosen for comparison is the case in which both of these angles are zero. It was shown in Eq. (5) that the total received radiation is given by

$$I_T = \alpha \int_{s=0}^{\infty} I(s)T(s)ds \quad (5)$$

According to Beer's law, the atmospheric transmission,  $T(s)$ , can be expressed as

$$T(s) = \exp \left[ - \sum_i \sigma_i N_i(s) \right] \quad (7)$$

where

$\sigma_i$  = absorption cross section of the  $i^{\text{th}}$  atmospheric constituent

$N_i(s)$  = total number of particles per unit area of the  $i^{\text{th}}$  constituent between the point  $s$  and the detector

By definition,

$$N_i(s) = \int_{t=s}^{\infty} n_i(t) dt \quad (8)$$

where  $n_i(t)$  is the number density of the  $i^{\text{th}}$  constituent along the line of sight vector.

Since most atmospheric quantities are expressed as functions of altitude along the local vertical, we make the transformation

$$ds = dy \sec \varphi_y \quad (9)$$

where  $\varphi_y$  is the angle between the line of sight and the local vertical at an altitude of  $y$  kilometers. The total received radiation is given by

$$I_T = \alpha \int_{y=0}^{\infty} I(y) \exp \left[ - \sum_i \sigma_i \int_{t=y}^{\infty} n_i(t) \sec \varphi_t dt \right] \sec \varphi_y dy \quad (10)$$

From Fig. 8 it can be seen that

$$\sec \varphi_y = \left[ 1 - \left( \frac{R_e}{R_e + y} \right)^2 \sin^2 \varphi_0 \right]^{-\frac{1}{2}} \quad (11)$$

When the line of sight does not intersect the earth, the  $s = 0$  location is taken to be the tangent altitude point. This point indicates where the line of sight vector makes its closest approach to the earth. In this case, the total received radiation can be expressed as

$$I_T = \int_{y_h}^{\infty} [\cdot] T(y, \infty) dy + \int_{y_h}^{\infty} [\cdot] \left[ T'(y_h, y) + T'(y_h, \infty) \right] dy \quad (12)$$

where

$$[\cdot] = \alpha I(y) \sec \varphi_y$$

$$y_h = \text{tangent altitude}$$

$$T'(a, b) = \text{transmission of solar energy from point } a \text{ to point } b$$

and  $T'(A, b)$  has the same definition except that  $\varphi_t$  is always greater than 90 degrees.

In the expressions given above,  $I(y)$  is the volume emission rate of the atmosphere at the height  $y$ . This volume emission rate can be produced by several phenomena. For the analysis of our data, however, we believe that only two sources of radiation are important — Rayleigh scattering and photoelectron excitation.

For a Rayleigh scattering atmosphere, the theory is well known (Ref. 6) and we have

$$I(y, \lambda) = \frac{3}{16\pi} k_s (1 + \cos^2 \psi) \rho(y) H(\lambda) T(y, \theta_y) \quad (13)$$

where

- $k_s$  = Rayleigh scattering coefficient ( $\text{cm}^{-1}$ )
- $\psi$  = Rayleigh scattering angle
- $\theta_y$  = angle between the sun line and the local vertical at the altitude  $y$
- $\rho(y)$  = total atmospheric number density at an altitude  $h(\text{cm}^{-3})$
- $H(\lambda)$  = solar irradiance at the top of the atmosphere at the wavelength  $\lambda(\text{w/cm}^2)$
- $T(y, \theta_y)$  = transmission of the solar energy from the top of the atmosphere to the altitude  $y$

The term  $H(\lambda)T(y, \theta_y)$  is the amount of solar energy of wavelength  $\lambda$  that reaches an altitude  $y$  along the slant path described by  $\theta_y$ . The other term,  $\frac{3}{16\pi} k_s (1 + \cos^2 \psi) \rho(y)$ , describes how much of this transmitted energy is electromagnetically scattered along the line of sight vector.

When the radiation is the result of photoelectron excitation, the volume emission rate is theoretically given by (Refs. 9,10)

$$I(y, \lambda) = \sum_{\ell} \sum_j \beta_{kj} r_{j\ell} f_j \quad (14)$$

where

- $k$  = the electronic state from which the transition to the ground state produces radiation of wavelength  $\lambda$
- $\beta_{kj}$  = branching ratio or probability of a transition from the state  $j$  to the state  $k$
- $f_j$  = the fraction of depopulations of the state  $j$  that produces radiation
- $r_{j\ell}(y, \theta)$  = the rate of population of the  $j^{\text{th}}$  state of the  $\ell^{\text{th}}$  species

The rate of population of the  $j^{\text{th}}$  state is proportional to the amount of energy lost during a collision with a photoelectron of energy  $E_p$ , and, therefore, is also proportional to the number of such photoelectrons produced by solar ionization. Thus, we have

$$r_{j\ell} = \int_{E_p > E_j} Q_p \times E_{j\ell} \quad (15)$$

where

$Q_p(y, \theta)$  = production rate of photoelectrons with energy  $E_p$

$E_{j\ell}$  = energy deposited in the  $j^{\text{th}}$  state through a collision with an electron of energy  $E_p$

The production rate of photoelectrons can be given as

$$Q_p(y, \theta) = \sum_i \sum_{\ell} \sigma_{i\ell}(\lambda_p) n_{\ell}(y) H(\lambda_p) \exp \left[ - \sum_m \sigma_m \int_y^{\infty} n_m(t) \sec \theta_t dt \right] \quad (16)$$

where

$\sigma_{i\ell}$  = cross section for the  $i^{\text{th}}$  ionization  
state of the  $\ell^{\text{th}}$  species

$n_{\ell}$  = particle density of the  $\ell^{\text{th}}$  species

Obviously this relationship is complicated and many of the variables, such as the absorption and collision cross sections, are not known precisely. A complete investigation at this level is beyond the scope of this study. From the limb measurements, we have found that the emission rate follows an altitude profile with a peak near 175 kilometers. Therefore,  $I(y)$  can be approximated by a general distribution function of the form

$$I(y) = I_p \frac{(1 + a^2) e^{(y-y_p)/h}}{\left( a + e^{(y-y_p)/h} \right)^2} \quad (17)$$

The parameters  $a$ ,  $h$ ,  $y_p$  and  $I_p$  must be adjusted so that the predicted irradiance matches the measured values.

The practical application of the theories given above can only be accomplished with the assistance of high speed electronic computers. For this reason, several computer programs were devised in 1970 to allow us adequate flexibility in the data analysis. In these computer programs, we only consider atmospheric absorption by ozone and molecular oxygen. Table 6 gives the parameters for the various distributions (concentrations versus altitude, etc.) used in the programs. These distributions represent a 600°K model atmosphere that matched the density measurements obtained by Hayes and Robles (Ref. 16) using the WEP. The values of the absorption coefficients and the solar flux used in the programs were obtained from published data (Refs. 12,13,16). All wavelength dependent parameters are averaged over 50 $\text{\AA}$  intervals. The spectral shapes of the WEP are also incorporated into the program.

Using the WEP filter curves, the expected outputs of the photometers are calculated by averaging over the effective half bandwidths of the filters. Thus, if  $S_{ij}(\lambda)$  is the filter shape of the  $j^{\text{th}}$  filter on photometer  $i$ , then

Table 6

DISTRIBUTION PARAMETERS

General Distribution Function

$$x(y) = \frac{(1 + a)e^{(y-y_p)/h_a}}{(a + e^{(y-y_p)/h_a})^2}$$

Distributions

LBH Radiation

$a = 1.0$

$y_p = 175 \text{ km}$

$h = 25 \text{ km}$

O<sub>2</sub> Density

$y < 163 \text{ km}$

$a = .3594$

$y_p = 0$

$h = - 5.9 \text{ km}$

$y > 163 \text{ km}$

$a = - .9999469$

$y_p = 0$

$h = - 31$

O<sub>3</sub> Density

$a = 0$

$y_p = 23.5 \text{ km}$

$h = - 4.63$

$y < 23.5 \text{ km}$

$+ 4.63$

$y > 23.5 \text{ km}$

Total Atmosphere

$y < 150 \text{ km}$

$a = 5.0$

$y_p = 0$

$h = - 7.057$

$y > 150 \text{ km}$

$a = - .99992$

$y_p = 0$

$h = - 62.04$

$$I_{ij} = \frac{1}{B_{ij}} \int_{\lambda=0}^{\infty} S_{ij}(\lambda) I_T(\lambda) d\lambda \quad (18)$$

$$= \frac{1}{B_{ij}} \left[ 50\text{\AA} \times \sum_k S_{ij}(\Delta_k + 1000\text{\AA}) I_T(\Delta_k + 1000\text{\AA}) \right] \quad (19)$$

where

$B_{ij}$  = the effective half bandwidth of the  $j^{\text{th}}$  filter of photometer  $i$

$\Delta_k$  = 50\text{\AA} intervals

The inputs to this particular program are the tangent altitude and the three angles  $\phi_0$  (line of sight zenith angle),  $\theta_0$  (sun zenith angle), and  $\psi$  (scattering angle) all measured at the earth's surface or at the tangent altitude point. These quantities are provided by another Grumman program that gives a complete analysis of the OAO viewing geometry during the observation periods. The output of the program is the expected irradiance at 50\text{\AA} intervals produced by both Rayleigh scattering and photoelectron excitation. Also given are the irradiance values expected to be obtained from the WEP filter photometers.

For each measurement sequence, a series of theoretical irradiance values was calculated. Parameters in the program were then varied until the theoretically predicted sequence matched the measured values. The irradiance was then calculated using these parameters for the case when both the viewing and the solar zenith angles were zero. This zero-zero case is used to compare the results of other experimenters.

The variation of the received radiation as the viewing area scans across the earth during a typical measurement sequence is shown in Figs. 5-7. In each of these sequences, the OAO field of view initially moves across the dark earth onto the sunlit earth and then through the sunlit limb and onto the star. The radiation increases rather sharply as the viewing moves across the sunlit earth. This is the result of the particular viewing geometry

associated with all these observations. During this portion of the scan, the solar zenith angle,  $\theta$ , was decreasing and the line of sight zenith angle,  $\varphi$ , was increasing as shown in Fig. 9. The first effect means that less solar radiation is absorbed by higher altitude constituents. The second effect results in measurements of greater amounts of sunlit atmosphere as the viewing moves across the earth. Measurements during this same sequence of the dayglow in the  $1920\text{\AA}$  region are shown in Fig. 6. Notice that these measurements do not show the sharp maximum in received radiation.

These measurements have been reduced to the case when both the sun and the line of sight lie along the local zenith ( $\theta = 0^\circ$ ,  $\varphi = 0^\circ$ ). This provides a common basis from which the WEP measurements can be compared to theoretical predictions and results of other experiments. The radiances for this case, averaged over five orbits, are plotted in Fig. 10 for each filter. Also shown are the radiance values predicted by the Rayleigh scattering calculation. Note that only the values in the vacuum ultraviolet are shown since the dayglow saturated all WEP photometers using filters above  $2000\text{\AA}$ . Figure 10 shows that the only measurements that agree with the Rayleigh scattering prediction are those in the  $1920\text{\AA}$  spectral band. These measurements also agree with the results of Barth and Mackey (Ref. 1) and Elliott et al. (Ref. 17).

The spectral region covered by the  $1500\text{\AA}$  photometer is of particular interest. The measurements in this region agree with the data from the NRL experiment on OGO-4 and clearly indicate that the very low estimate of the earth's radiance predicted by Rayleigh scattering does not exist. The high level of radiation in the  $1500\text{\AA}$  region is believed to be the result of electronic excitation of molecular nitrogen by high energy photoelectrons ( $> 7\text{ eV}$ ). These photoelectrons are produced from the ionization of high altitude atmospheric constituents by the extreme ultraviolet solar radiation. The principal emissions are from the Lyman-Birge-Hopfield ( $a'\pi_g - x'\Sigma_g^+$ ), Birge Hopfield ( $b'\pi_u - x'\Sigma_g^+$ ) and Vegard-Kaplan ( $A^3\Sigma_u^+ - x'\Sigma_g^+$ ) bands of molecular nitrogen. These transitions produce radiation in the  $1350$  to  $1800\text{\AA}$  spectral region. This mechanism was first considered theoretically by Barth and Green (Ref. 9) and later by Dalgarno et al. (Ref. 10). Prinz and Meier (Ref. 11) of NRL have used some of the more recent measurements of ionization cross sections, photoelectron collision cross sections, and quenching coefficients in determining the expected emissions from this mechanism. Their calculation

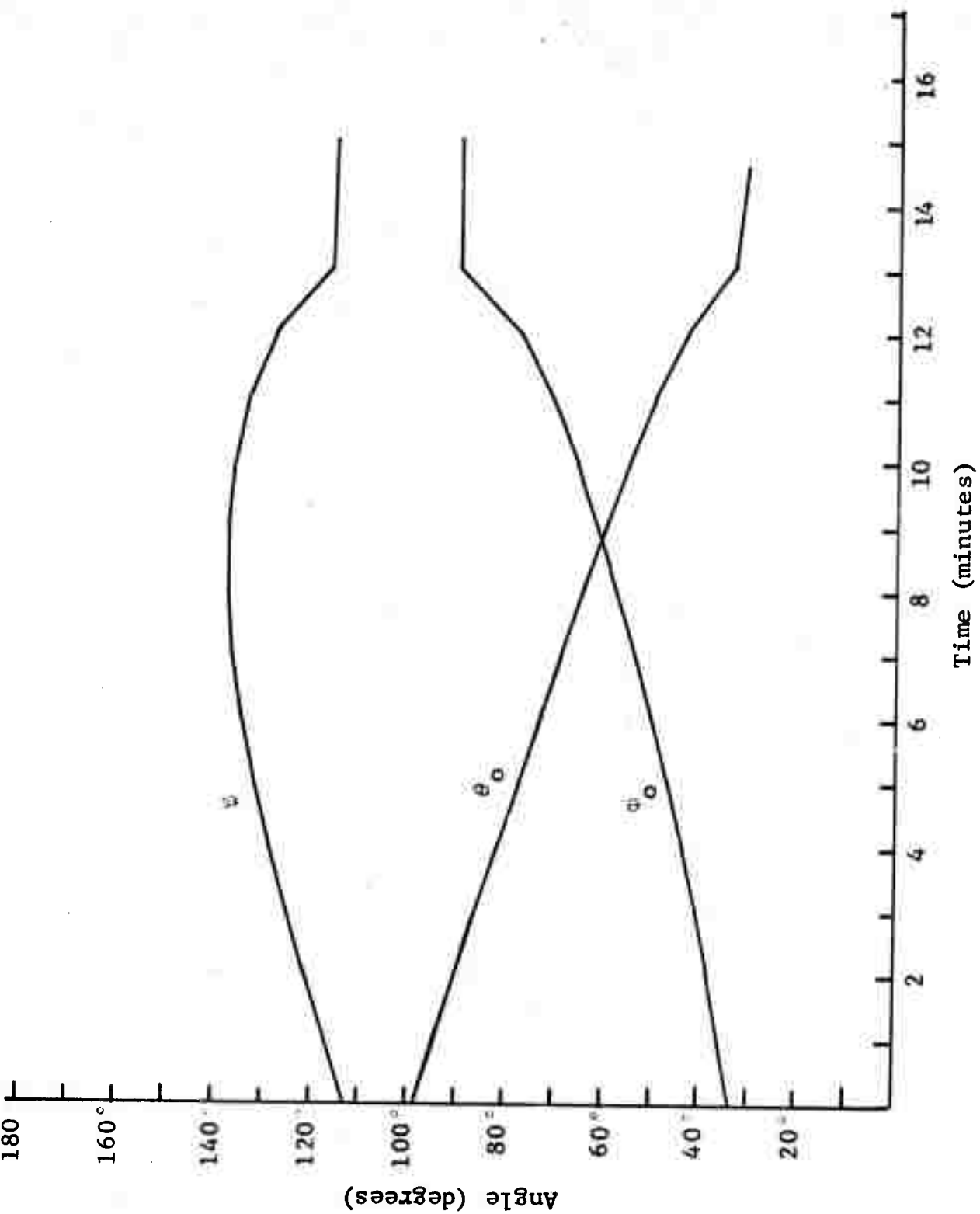


Fig. 9 Variation of Angles for Orbit 7903

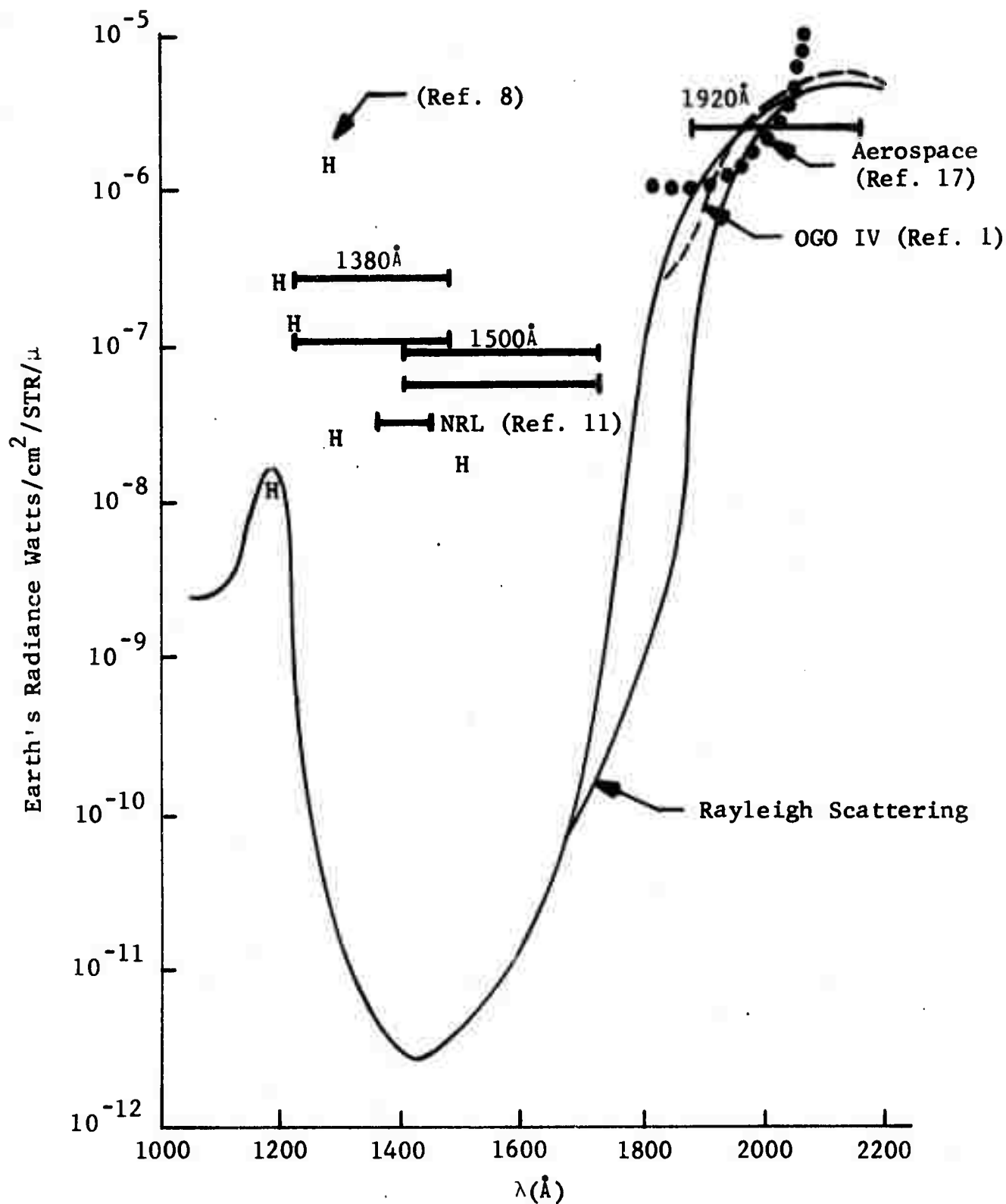


Fig. 10 Comparison of OAO Measurements with Other Experimental Measurements. Values are for 1380Å, 1500Å, and 1920Å Filters. Lower line represents the measured value minus the expected contribution of the 1304Å oxygen line.

predicts that the columnar emission rate from this system should be 6.5 kR or  $3.3 \times 10^{-8}$  w/cm<sup>2</sup>-ster-μ between 1350 and 1800Å. They also indicate that a peak in the emission rate should exist near 180 kilometers.

Detailed measurements of the sunlit limb with the 1500Å filter and using the half second sampling mode of the WEP, are shown in Fig. 11. These measurements show a sharp peak in the received radiation near a tangent altitude of 175 kilometers. Because of the small field of view of the WEP photometers, it is reasonable to assume that the volume emission rate also has a maximum near 175 kilometers. The gaps in measurements, as shown in Fig. 11, are due to the delay in the issuance of new exposure commands. It should be noted that part of the radiation measured by the 1500Å filter is due to the emission from the 1304Å triplet of atomic oxygen. Assuming that the strength of this line is approximately  $4 \times 10^{-9}$  w/cm<sup>2</sup>-ster as measured by Barth and Schaffner (Ref. 2), then this represents only 4 percent of the measured energy. Because of the near zero transmission of the 1500Å filter at 1200Å, the Lyman alpha emission of atomic hydrogen also does not contribute to radiation measured by this filter. Therefore, the only radiation of significance is that produced by the LBH bands of N<sub>2</sub>. The variation of the 1500Å radiation with tangent altitude is shown in Figs. 12-14. It also should be noted that the radiance value given in Fig. 10 for the 1500Å measurements is an approximate value since the model chosen for the nitrogen emissions did not include the effects of the solar angle.

The measurements with the 1920Å filter, as mentioned, agree very well with values predicted by the Rayleigh scattering model. Results of the measurements of the sunlit limb using this filter are shown in Fig. 15. It can be seen that no large peak in the received radiation occurs as a function of tangent altitude in this wavelength region.

The radiation measured by the 1250Å filter is almost entirely due to the Lyman alpha emissions of atomic hydrogen at 1216Å. Part of the radiation can be attributed to the 1304 and 1356Å lines of atomic OI and also to the 1358Å LBH band of N<sub>2</sub>. Although no detailed measurements, using half second sampling, of the sunlit limb were made at 1250Å, a good picture of the limb was obtained with the Mode C measurements. As shown in Fig. 16, the 1250Å radiation also shows a peak in the received radiation near 175 kilometers. It should be noted that radiation in this spectral region is very dependent on solar activity, explaining the spread in measured values.

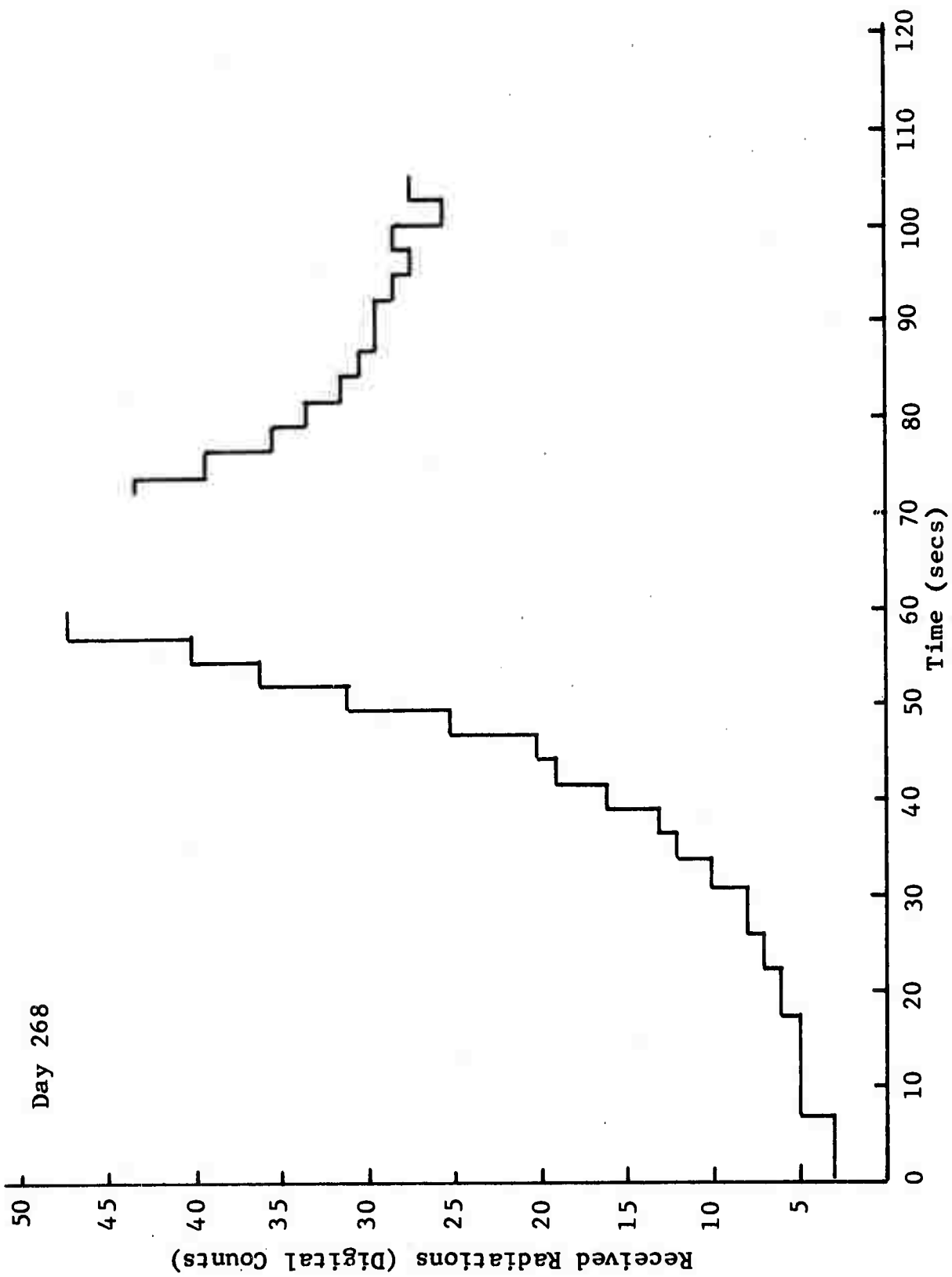


Fig. 11 1500Å Limb Measurement

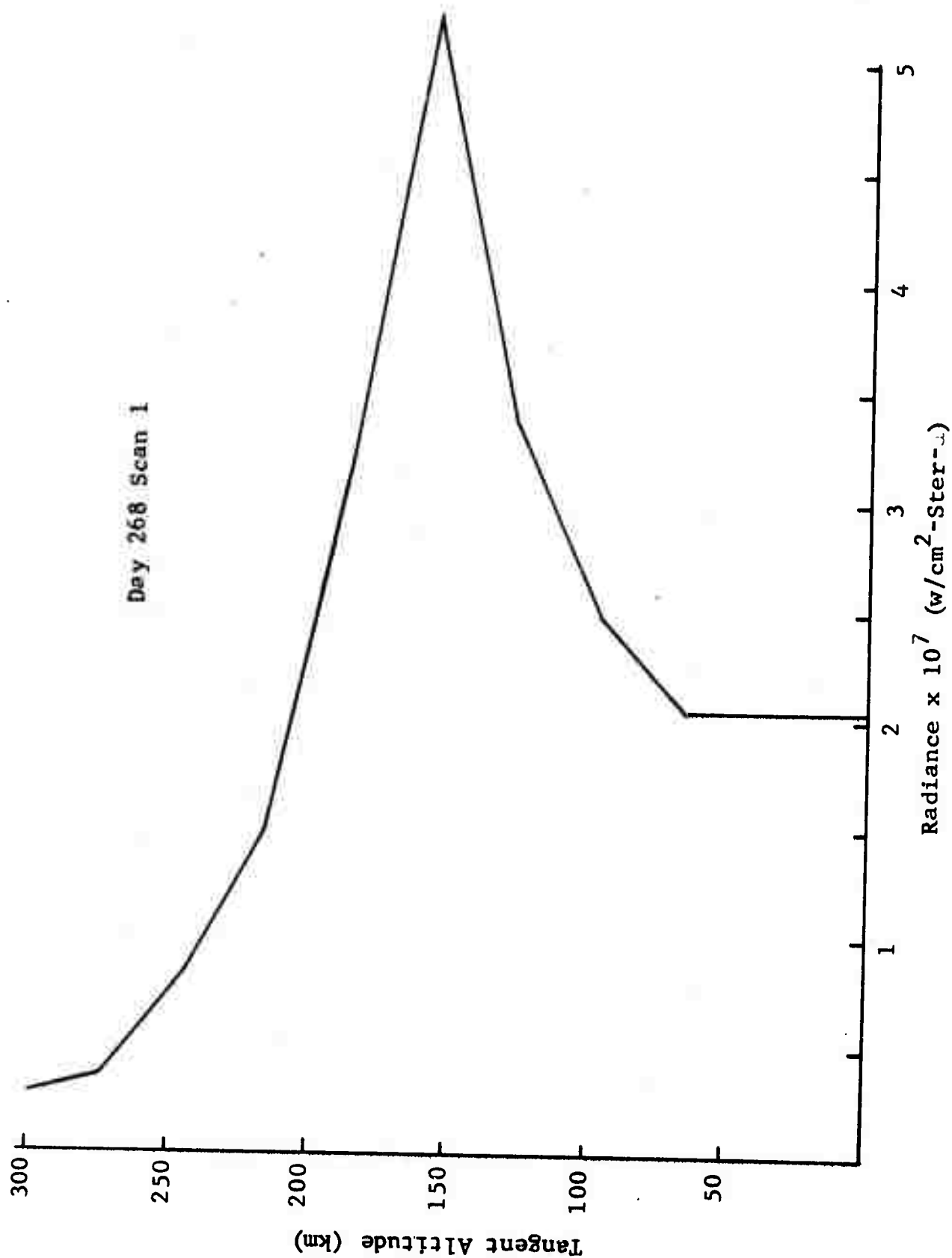


Fig. 12 Altitude Profile of 1500Å Radiation

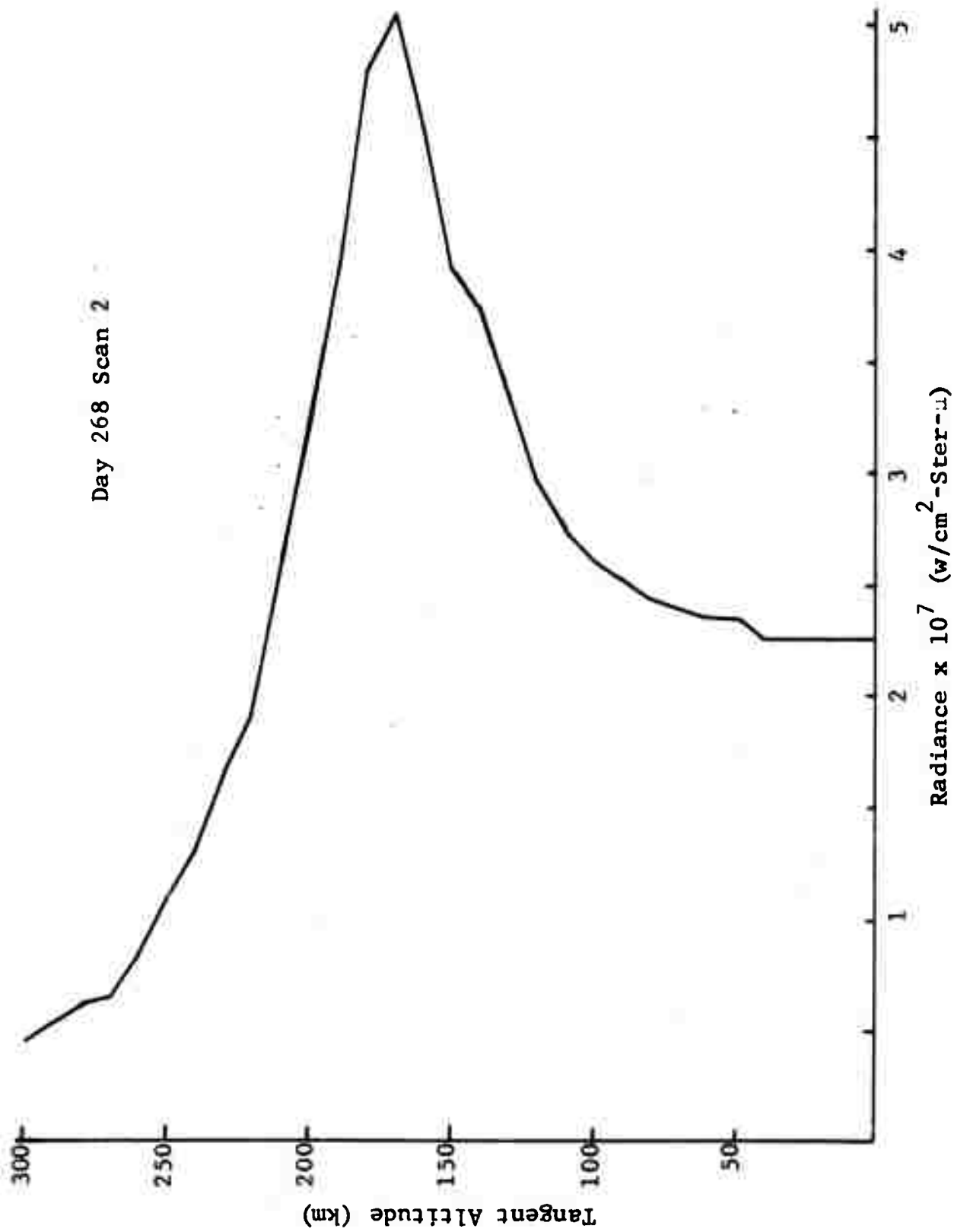


Fig. 13 Altitude Profile of 1500Å Radiation

Day 225

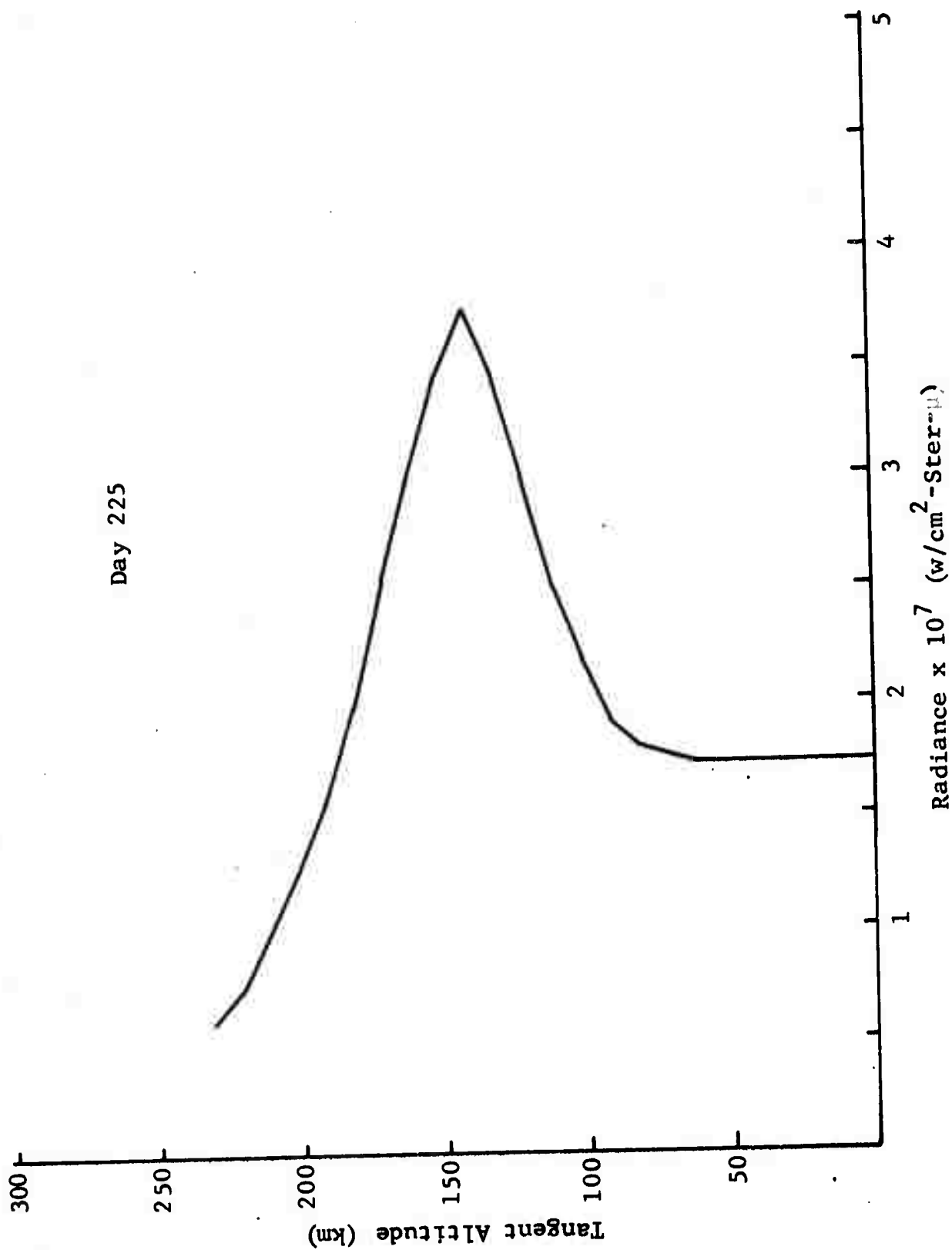


Fig. 14 Altitude Profile of 1500Å Radiation

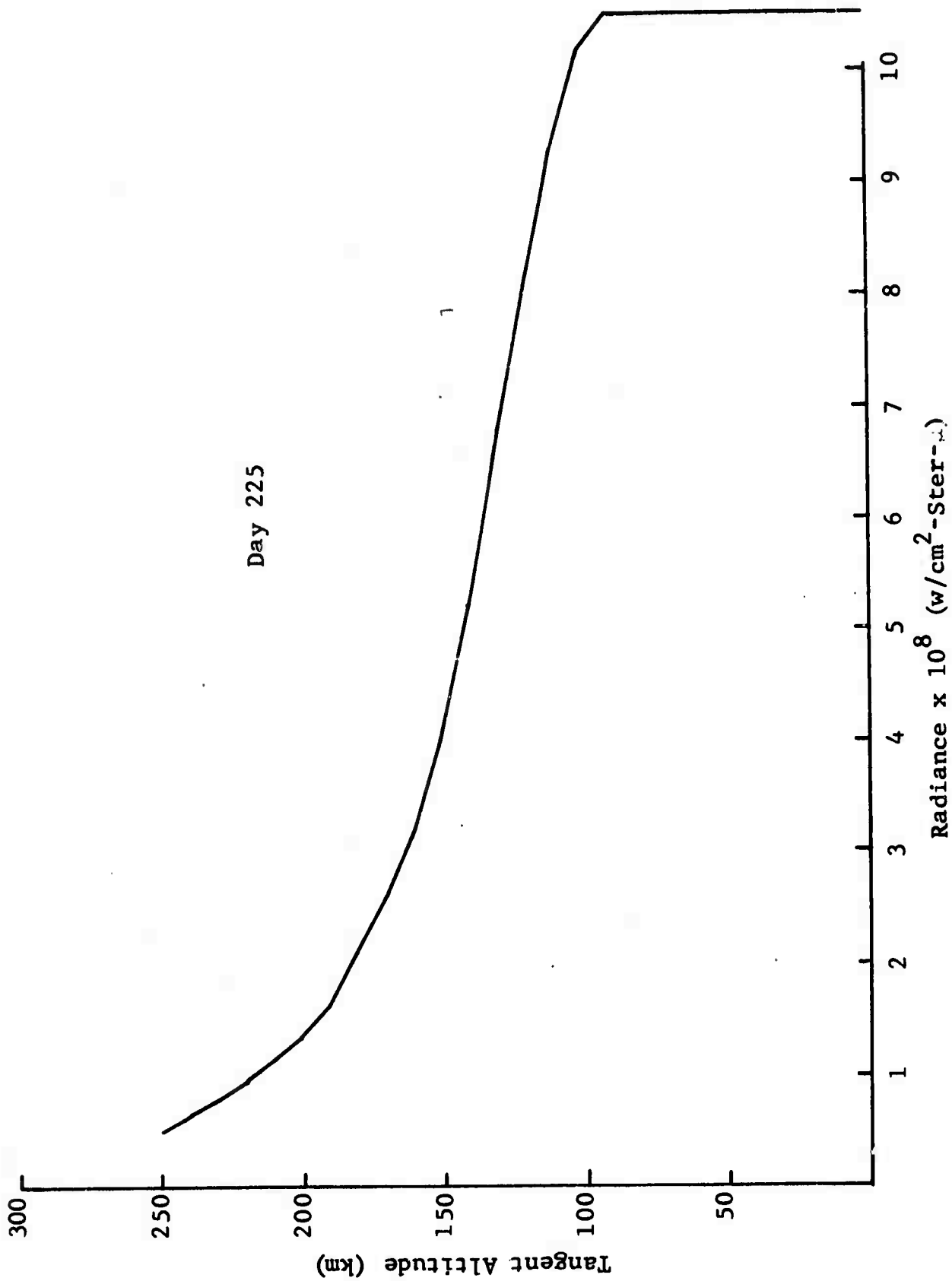


Fig. 15 Altitude Profile of 1920i Radiation

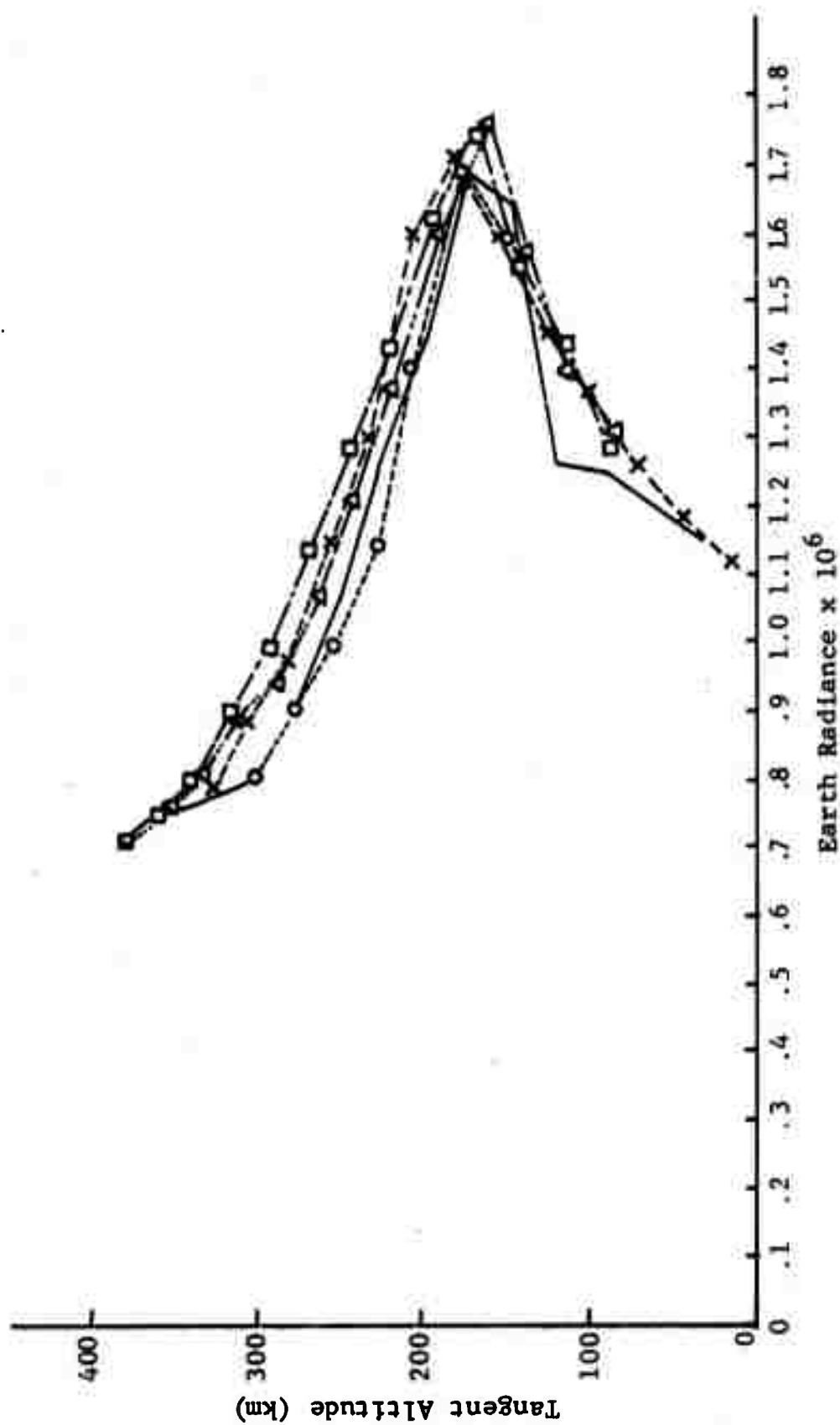


Fig. 16 Altitude Profile of 1250Å Radiation

The vacuum ultraviolet nightglow is barely a measurable feature. The measurements, using the 1250Å filter, show the radiance to be independent of altitude with a magnitude of about  $10^{-8}$  w/cm<sup>2</sup> ster-μ, which is slightly above the noise level of the photometer. The source of this radiation was postulated by Meier (Ref. 4) to be scattered Lyman alpha emission from the sunlit portions of the upper atmosphere. The output from the 1500Å filter was at the noise level of the photometer for all nightglow measurements. This noise level is equivalent to an irradiance of  $4.8 \times 10^{-14}$  w/cm<sup>2</sup>-μ. In the 1920Å region, the nightglow was measurable. The limb measurements showed a distinct altitude profile to the emission, as is shown in Fig. 17, with a peak in the received radiation occurring at a tangent altitude of about 70 kilometers. A similar spike in the nightglow was measured by Stecher (Ref. 15) at 1800Å. At present, the source of this radiation has not been identified. The prominent features of the ultraviolet nightglow occurred in the spectral region measured by the 2380 and 2980Å filters. The emissions measured by the 2980Å filter show a sharp peak occurring near 110 kilometers (Fig. 18). This maximum was also observed by Stecher (Ref. 15) and later by Hennes (Ref. 14). Their rocket spectrometers show the peak occurring near 97 kilometers. The spectrum obtained by both experiments indicate that the source of the radiation are the Herzberg bands of molecular oxygen. This band system produces emissions between 2500 and 3500Å. The most prominent feature of the spectrum is the large maximum near 3000Å produced by the Herzberg (7,4) and (5,3) bands at 2976 and 2945Å and by the 2972Å line of atomic oxygen. Figure 19 shows the altitude profile of the received radiation from the 2380Å filter and Fig. 20 shows the radiation measured by the 2460Å filter. These measurements also show a peak near 110 kilometers and, therefore, are probably measuring some of the lower wavelength bands of the Herzberg system.

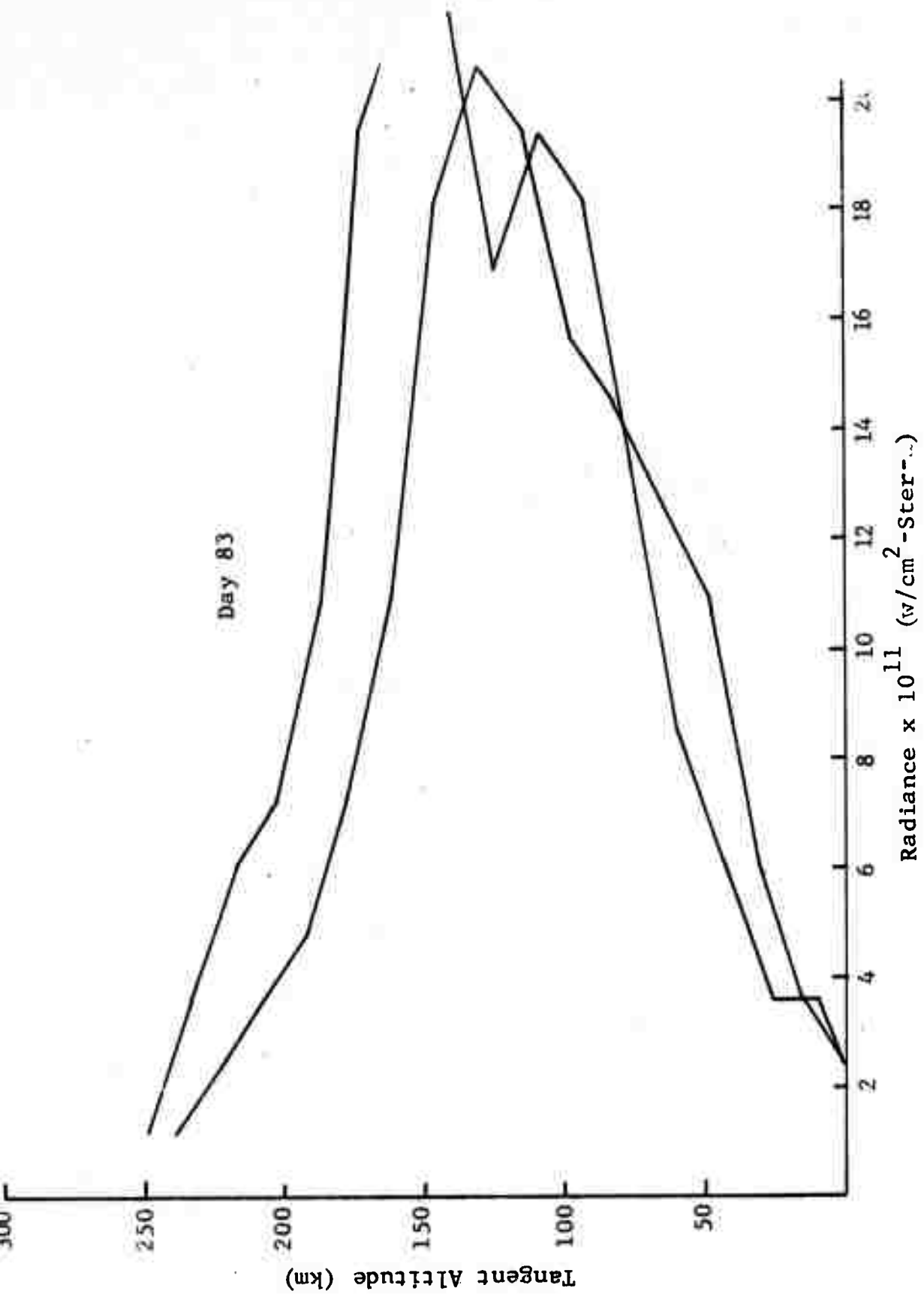


Fig. 17 Altitude Profile of the 1920Å Nightglow

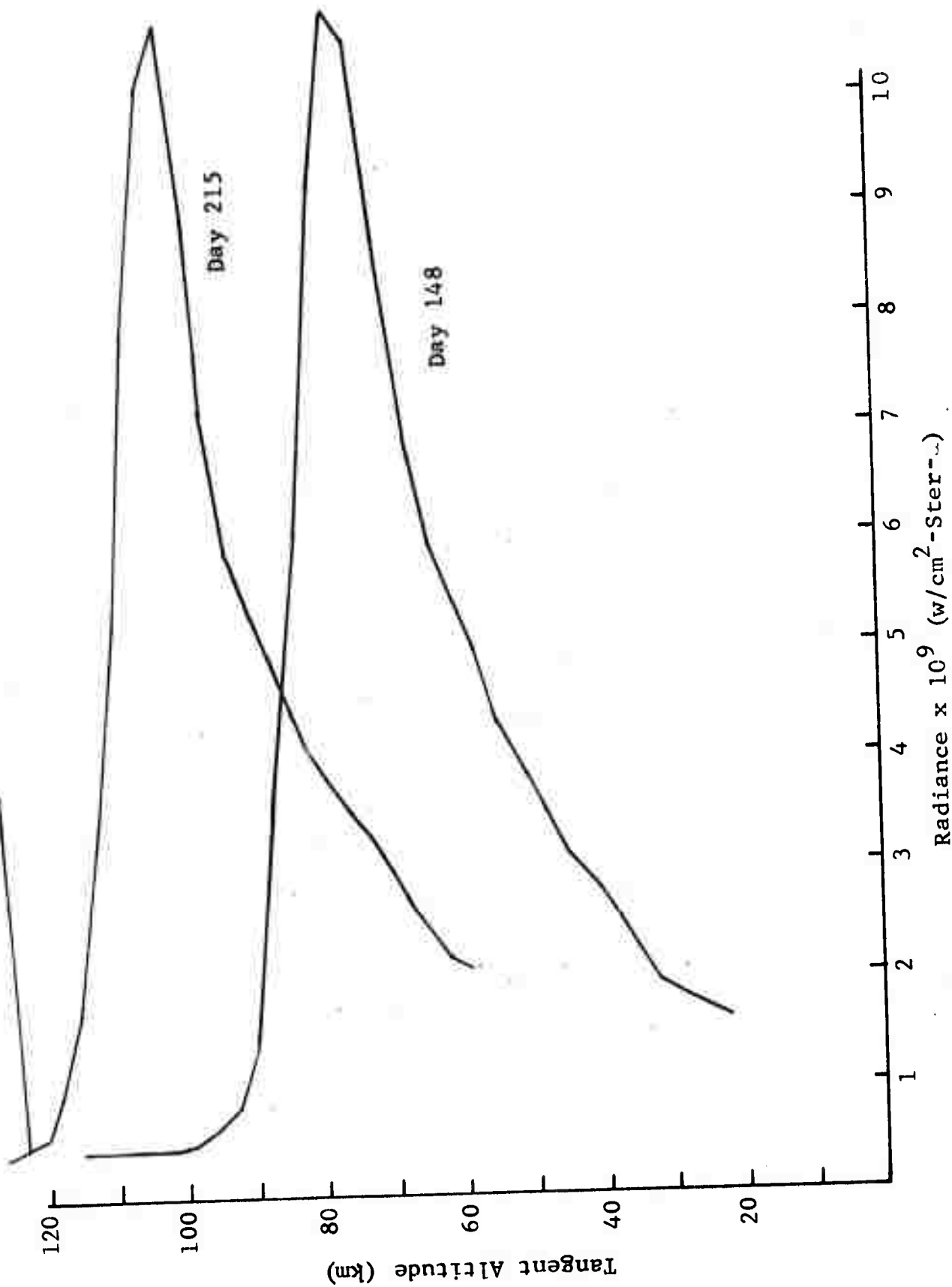


Fig. 18 Altitude Profile of the 2980Å Nightglow

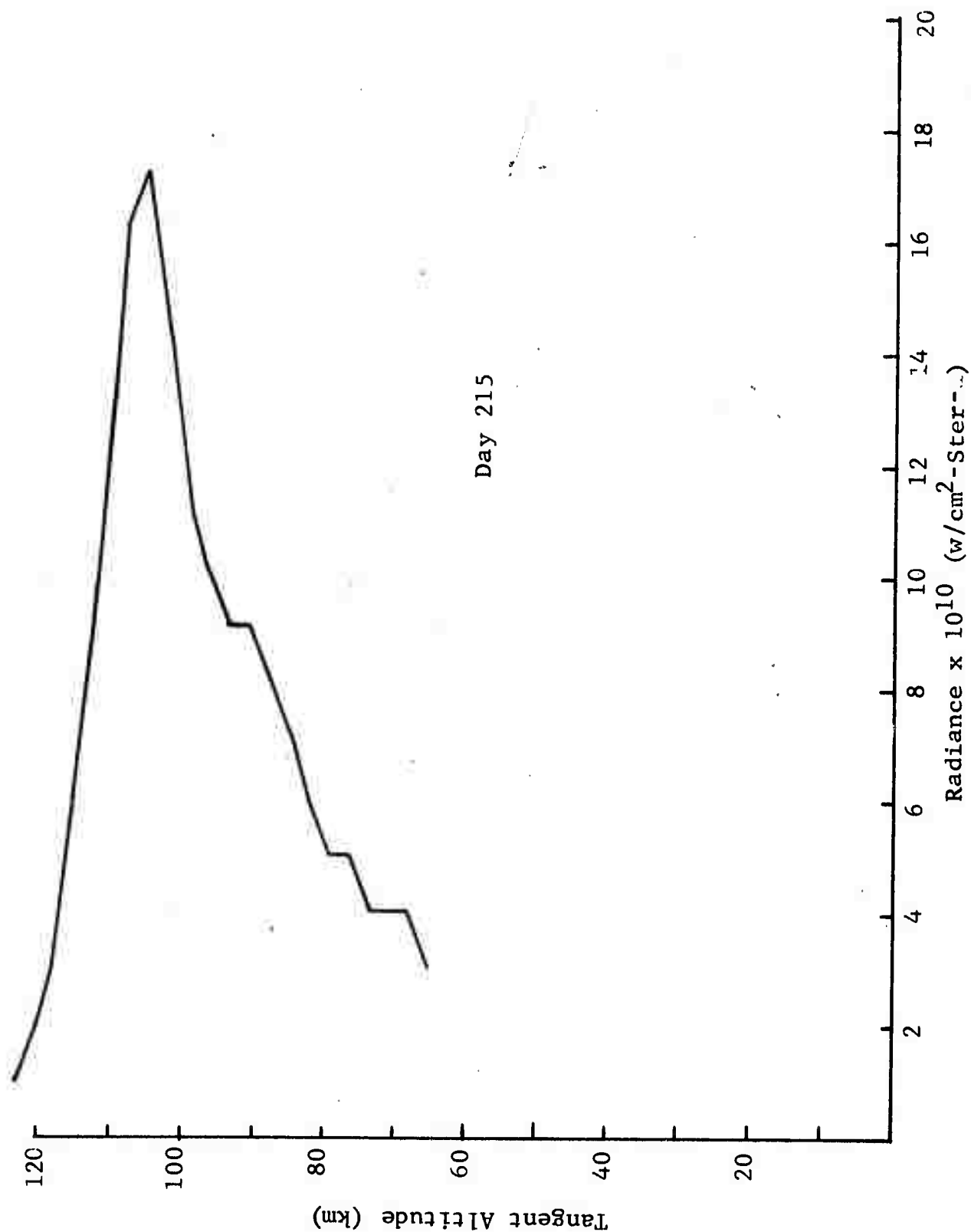


Fig. 19 Altitude Profile of 2380 Å Nightglow

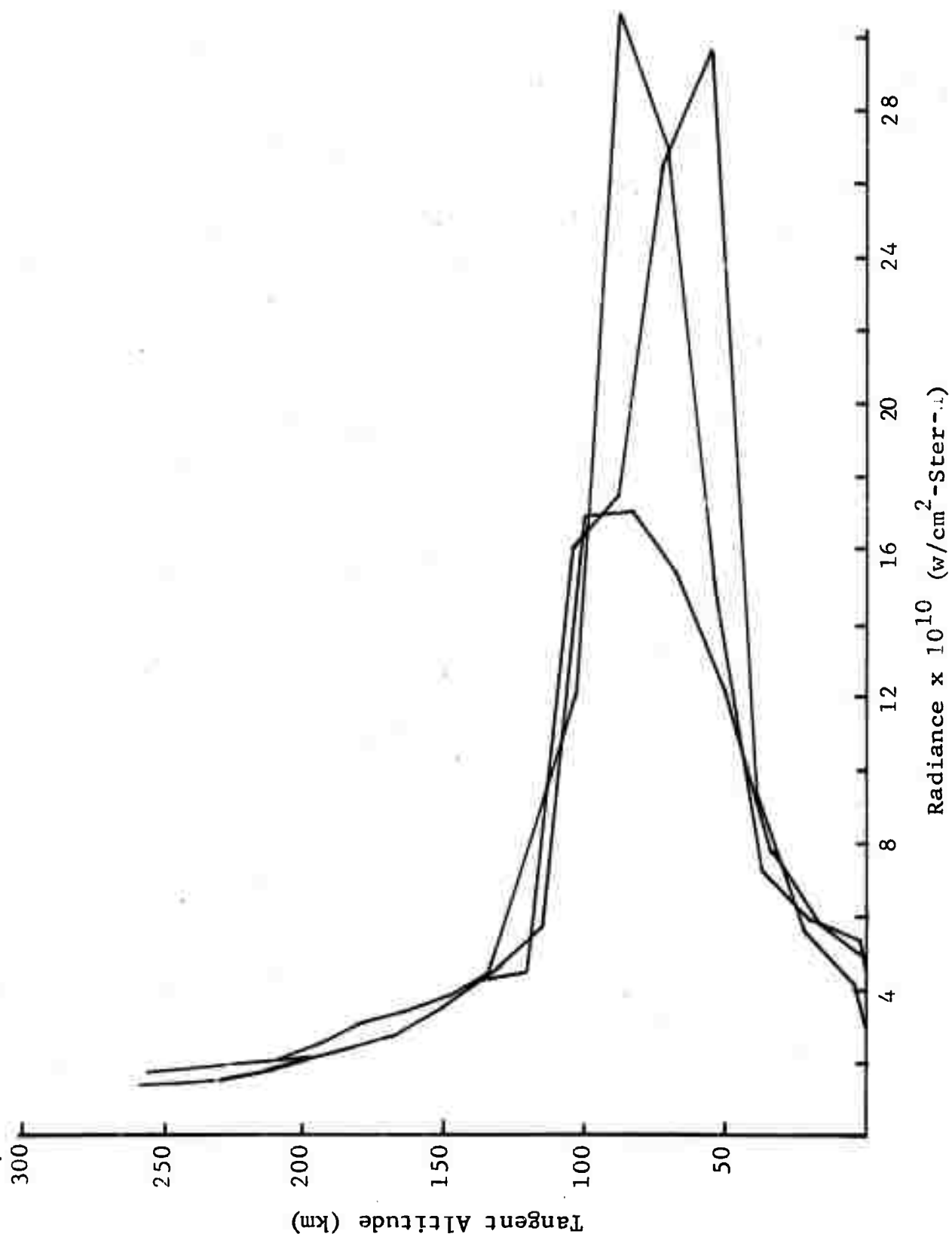


Fig. 20 Altitude Profile of the 2460 Å Nightglow

## SUMMARY AND CONCLUSIONS

All earth background measurements made with the OAO A-2's Wisconsin Experiment Package have been analyzed in terms of viewing geometry, and have been converted to equivalent earth's radiance. This information has been summarized and placed on a computer tape, the printout of which is given in Table 5.

Samples of the measurements were analyzed every three minutes when observing the dark earth, every minute for sunlit observations, and every 10 seconds for measurements of the earth's limb. The GMT time of the measurements, the tangent altitude, the solar viewing, and scattering angles, the OAO and viewing intersection longitude and latitude, as well as the reduced radiance for seven of the filter combinations, are given for each point analyzed.

An analysis of the reduced data has provided the following conclusions:

- 1) The dayglow in the  $1920\text{\AA}$  spectral region is produced by the Rayleigh scattering of solar radiation. No significant radiation is produced above 100 kilometers.
- 2) In the  $1300\text{-}1700\text{\AA}$  region, the measurements support the theory that the radiation is produced by photoelectron excitation of nitrogen ( $\text{N}_2$ ). This radiation has a peak in the emission rate near 175 kilometers.
- 3) The nightglow below  $1700\text{\AA}$  is quite low, less than  $1.5 \times 10^{-8} \text{ w/cm}^2\text{-ster-}\mu$ . There is some radiation produced by an unknown source, present in the  $1920\text{\AA}$  region. This radiation has a peak intensity near 70 kilometers.
- 4) The prominent feature of the UV nightglow is the radiation between  $2500$  and  $3000\text{\AA}$  that is thought to be the emissions from the Herzberg bands of molecular oxygen. This radiation shows a very sharp peak near 110 kilometers.

To complete the interpretation of these data, all measurements should be reduced into volume emission rates, and a detailed model of the radiation mechanisms should be developed. The reduction of

the nightglow measurements should be the simplest of these tasks. This involves inverting the limb measurements in a manner similar to that used by Robles and Hayes (Ref. 16). Reduction of the dayglow measurements is more complicated since the volume emission rates are dependent on the sun's position. The inversion is, therefore, not straightforward. A detailed model for the radiation mechanism, such as given by Eq. (13) for photoelectron excitation, is also required for a complete analysis of the measurements. Also needed are limb measurements at 1250, 1380, and 2380Å to complete the spectral picture of the ultraviolet earth background. Complete sets of measurements should be made at various times during the year to obtain seasonal variations in atmospheric emissions. Most observations made thus far with the OAO have been in the northern hemisphere. Therefore, additional measurements are required over various portions of the earth to obtain a global picture of the UV emissions. It appears that the best experiment for such measurements would be an imaging system with a large field of view and the comparable resolution of the WEP. This would provide significant information about local and global variations of the background.

## REFERENCES

1. Barth, C. and Mackey, E., IEEE Trans. Geo. Elec., Vol. GE-7, No. 2, 1969, p. 114.
2. Barth, C. and Schaffner, S. J. Geophys. Res., Vol. 75, No. 22, 1970, p. 4299.
3. Chubb, T. and Hicks, G., J. Geophys. Res., Vol. 75, No. 7, 1970, p. 1290.
4. Meier, R. and Mange, P., Planet. Space Sci., Vol. 18, 1970, p. 803.
5. Prinz, D. and Meier, R., J. Geophys. Res., Vol. 76, No. 19, 1971, p. 4608.
6. Chamberlain, J., Physics of the Aurora and Airglow, 1961, Academic Press, New York.
7. Winter, W. and Chubb, T., J. Geophys. Res., Vol. 72, No. 21, 1967, p. 4405.
8. Fastie, W., Crosswhite, H., and Heath, D., J. Geophys. Res., Vol. 69, No. 19, 1964, p. 4129.
9. Green, A. and Barth, C., J. Geophys. Res., Vol. 72, No. 15, 1967, p. 3975.
10. Dalgarno, A., McElroy, M., and Stewart, A., J. Astron. Sci., Vol. 26, 1969, p. 753.
11. Barth, C., J. Geophys. Res., Vol. 69, No. 15, 1964, p. 3301.
12. Hinteregger, H., J. Geophys. Res., Vol. 66, 1961, p. 2367.
13. Ditchburn, R. and Young, P., J. Atmos. Terr. Phys., Vol. 24, 1962, p. 127.
14. Hennes, J., J. Geophys. Res., Vol. 71, No. 3, 1966, p. 763.
15. Stecher, T., J. Geophys. Res., Vol. 70, No. 9, 1965, p. 2209.

16. Hays, P. and Roble, R., Report 08953-1-T, University of Michigan, 1967.
17. Elliott, D., Clark, M., and Hudson, R., Aerospace Report No. TR-1058 (3260-10), 1967.
18. Craig, R., The Upper Atmosphere, Academic Press, New York, 1965.
19. Green, A., The Middle Ultraviolet; Its Science and Technology, J. Wiley, New York, 1967.
20. Green, A. and Wyatt, P., Atomic and Space Physics, 1965.
21. Prinz, D. and Meier, R., Private Communication, 1971.