MEASUREMENTS OF THE EARTH'S AIRGLOW IN THE VACUUM ULTRAVIOLET

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ABSTRACT

A valuable by-product of the OAO-2 Astronomy Mission has been the first extensive set of measurements of the earth's airglow between 1000 and 3000 Å. These measurements, made with the Wisconsin Experiment Package, provide clues to the structure and chemistry of the upper atmosphere. The most significant results from these observations are (1) the detailed altitude profile of the emissions from the dark and sunlit earth limb and (2) the confirmation of recent theories concerning the source of the dayglow radiation between 1350 and 1700 Å.

I. INTRODUCTION

The term "airglow" has commonly been used to describe the non-thermal upper atmospheric emissions not correlated with magnetic disturbances. The study of this radiation provides information on the nature of the upper atmosphere and gives clues to the physical processes occurring there. The spectral region below 3000 Å is one of the most informative wavelength intervals, but because of the opacity of the atmosphere in this part of the spectrum, knowledge of these ultraviolet emissions can only be obtained by rocket and satellite observations. To obtain more information about the earth's airglow in the ultraviolet, measurements were made of the dark and sunlit earth using the photometers of the OAO-2's Wisconsin Experiment Package (WEP). These measurements used the 2980, 2380, 1920, 1500, 1380 and 1250 Å filters of WEP Stellar Photometers 3 and 4. The highly accurate pointing capability and the small field of view of the WEP photometers have made it possible to define precisely the measurement geometries. This unique capability has produced a set of unique measurements of the earth limb.

This paper describes how the measurements were made and gives some of the reduced results in terms of the earth's radiance and emission profiles for both the sunlit and dark atmosphere. These results are shown to be in good agreement with other experiments and help to substantiate recent theories on the sources of the ultraviolet airglow.

II. VIEWING GEOMETRY AND INSTRUMENTATION

WEP measurements of the earth's airglow were made at several different times during the 1970-1971 year. The bulk of the measurements were made over a three day period (June 10 through June 13, 1970) on 27 different orbits. Additional measurements were made whenever possible during times when the astronomy mission would not be impacted. The experiment was operated in two basic modes. In Mode C, used in most of the observations, the scanning spectrometer controlled the data sampling interval, 9 seconds, and enabled us to make a series of 188 exposures which covered a time period of approximately one half hour. The exposures were of either 1/8, 1 or 8 second duration. The EDHE Cyclic Store Mode was used to obtain detailed measurements of the earth limb. In this mode, the data is sampled every 1/2 second and up to 2-1/2 minutes of continuous measurements can be stored.

All observations were made by inertially fixing the OAO pointing and exposing during the time the desired portion of the earth moved through the field of view. The position of the OAO relative to the earth during a typical measurement sequence is depicted in Figure 1. The three positions of the OAO shown in the figure correspond to the position at the beginning, middle and end of a half hour measurement sequence. Note that the measurements are initially of the dark earth, then the sunlit earth and finally of the sunlit limb. Also note that the amount of sunlit atmosphere being viewed increases as the earth moves across the field of view. Figure 2 indicates the ground track for this same orbit. The shaded area indicates the portion of the earth in darkness. The short dark path across the terminator indicates the ground track of the OAO field of view during the measurement period. This viewing situation is typical of those made during the first set of observations.

III. DATA ANALYSIS

The variation of the received radiation as the viewing area scans across the earth during a typical measurement sequence is shown in Figures 3-5. In each of these sequences, the OAO field of view initially moves across the dark earth onto the

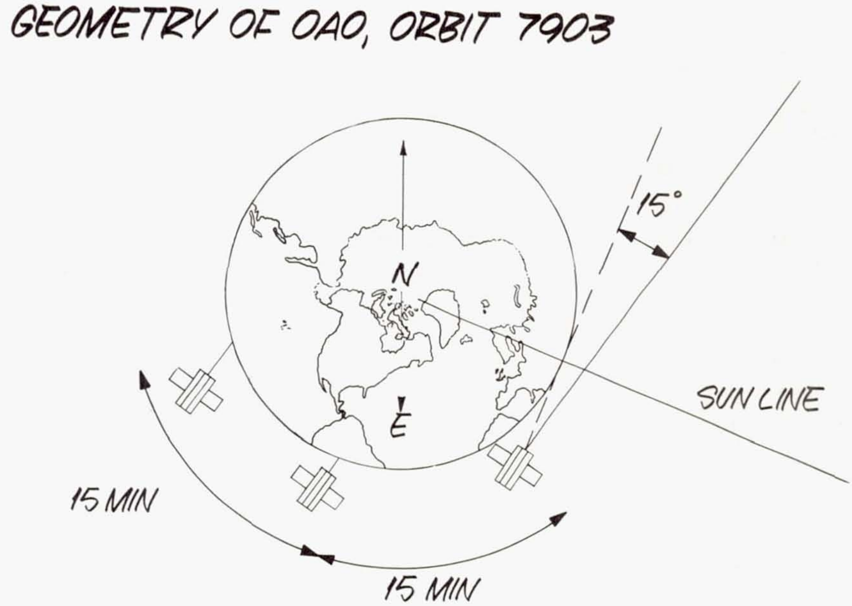

Figure 1.

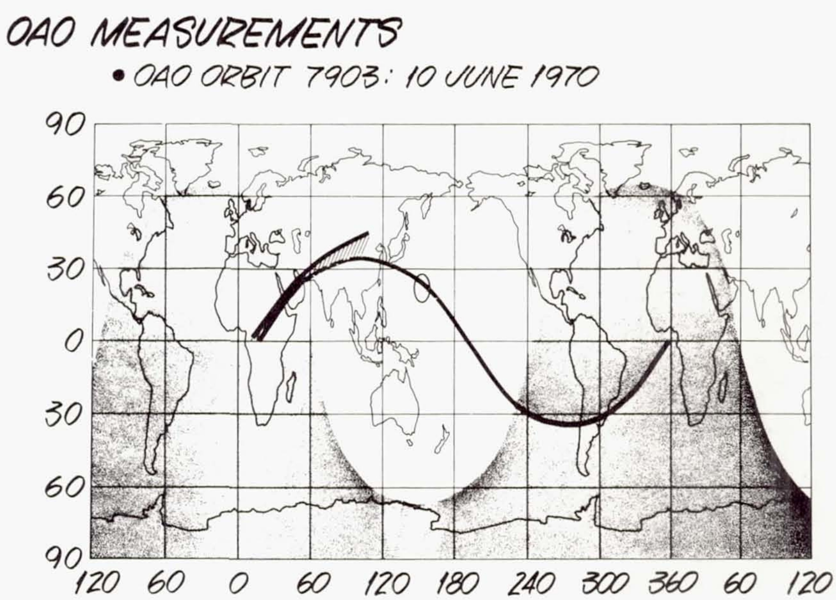

Figure 2.

sunlit earth and then off the earth through the sunlit limb and onto the star. Figure 3 indicates the radiation received by the 1250 Å photometer and Figure 4 represents that received by the 1920 Å photometer during the measurement sequence. These two curves provide an interesting comparison. Radiation in the 1250 Å region appears to reach a maximum value after the field of view has left the surface of the earth. This peak occurs at a tangent altitude of about 210 kilometers. On the other hand, the 1920 Å photometer indicates that as the field of view moves away from the earth's surface, the radiation begins to decrease rapidly. Figure 5 shows the radiation received by the 1500 Å photometer during a later orbit. This radiation also peaks at a tangent altitude of about 210 km.

These measurements have been reduced to the case where both the viewing and the sun lie along the local zenith. Figure 6 shows this reduced data in terms of earth's radiance as well as the results of other experiments. Also shown is our calculation of the expected radiance based on a Rayleigh scattering model. Obviously, the only measurements that agree with the Rayleigh scattering prediction are those in the 1920 Å spectral band which also agree with earlier measurements by others (Barth and Mackey 1969, Elliott _et al_. 1967). Of particular interest is the spectral region covered by the 1500 Å filter. The measurements in this spectral region agree with the data from the NRL experiment on OGO IV and clearly indicate that the "large dip" in the earth's radiance predicted by Rayleigh scattering does not exist.

The high level of radiation in the 1500 Å region is believed to be the result of electronic excitation of molecular nitrogen by high energy photoelectrons. 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, Birge-Hopfield and Vegard-Kaplan bands of N_2 and cover the spectral region from 1350-1800 Å. This mechanism was first considered theoretically by Barth and Green (1964), Dalgarno _et al_. (1969) and later refined by Prinz and Meirer (1971) of NRL. Their calculations predict radiation levels that are in general agreement with the data. They also indicate that a peak in the volume emission rate of the atmosphere should exist near 180 km. Results of the detailed measurements of the sunlit limb, shown in Figure 7, indicate that the received radiation in the 1500 Å wavelength region reached a maximum value when the tangent altitude was approximately 210 km. This implies that the volume emission rate also peaks at about 210 km. Note also in this figure that the radiation in the 1900 Å region shows no peak as a function of tangent altitude. The 1250 Å filter also shows a peak at 210 km which may partially be caused by the molecular nitrogen emissions. At present

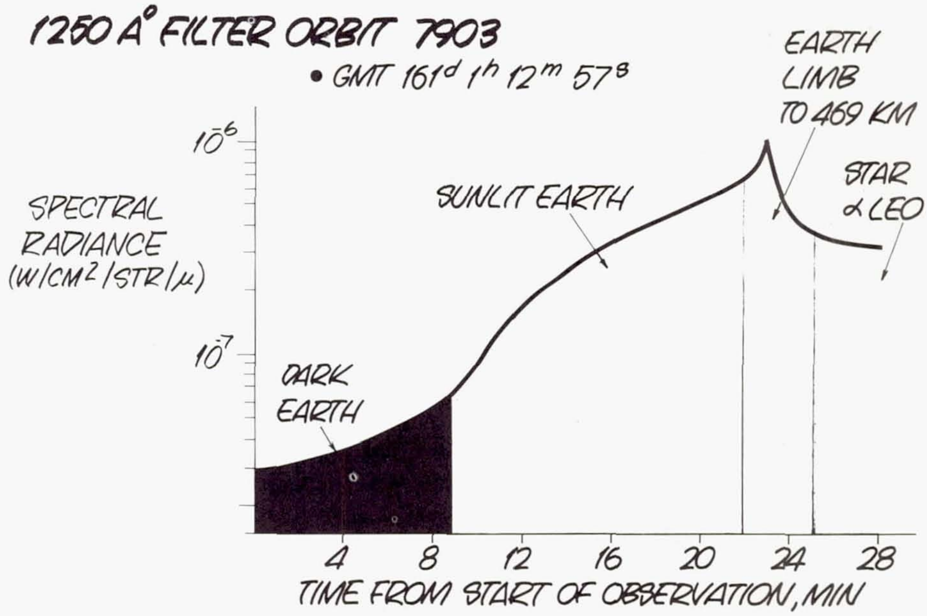

Figure 3.

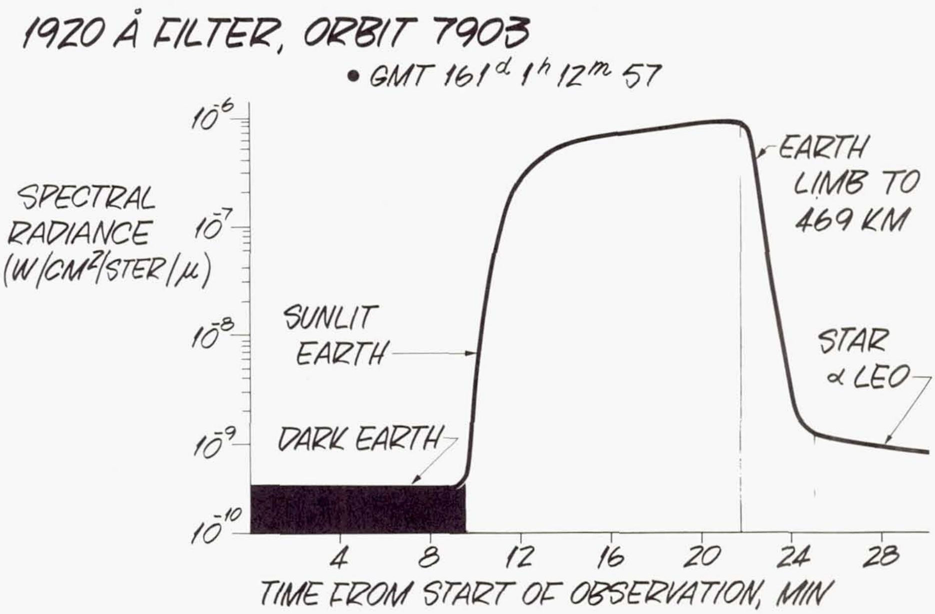

Figure 4.

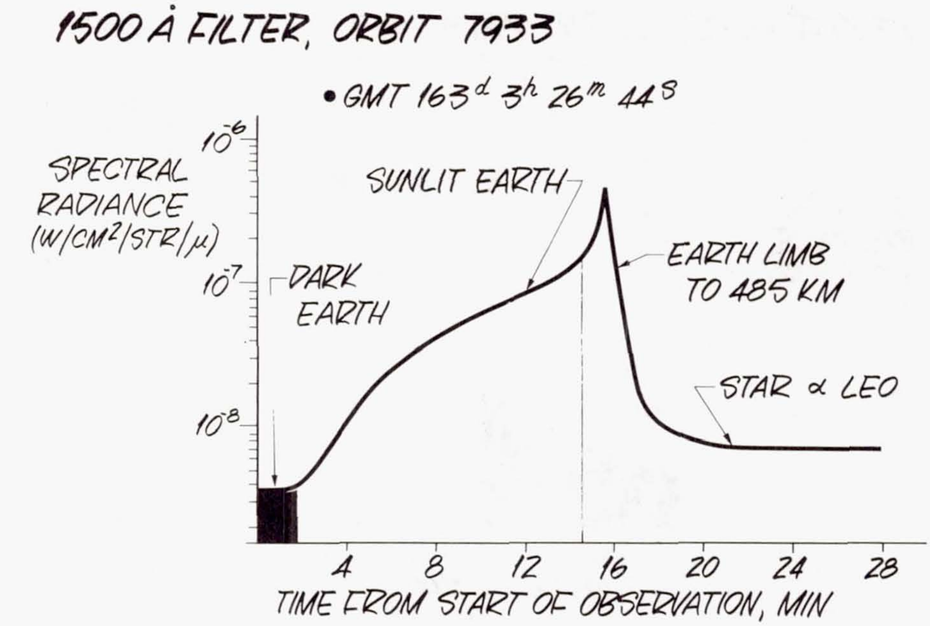

Figure 5.

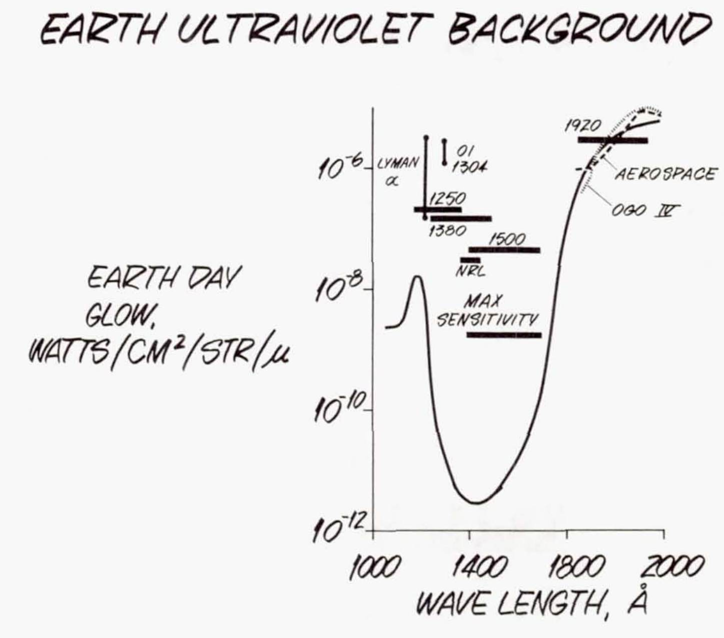

Figure 6.

these measurements are being reduced to terms of volume emission rates. Also being investigated are the implications of the emission peak being at an altitude that is higher than expected.

The tangent altitude profiles of the received radiation from the dark limb are shown in Figure 8. The radiation measured by the 2980 Å filter shows a sharp peak in emission at an altitude of approximately 100 km. The level and peak of the radiation agrees well with that measured by Stecher (1965) and Hennes (1966) and can be attributed to the Herzberg band system of molecular oxygen and the trans-auroral line of O I at 2972 Å. The 2380 Å filter also shows the peak occurring in the same region and is therefore probably measuring the same emissions from O_2. From this figure we also see that the radiation in the 1900 Å region peaks near 70 km. The source of this radiation is currently being investigated.

The radiation measured by the 1250 Å filter shows no variation with altitude and has an equivalent earth's radiance of approximately 10^{-8}w/cm^2-ster-μ. The radiation in the 1500 Å region was at or below the noise level of the detector.

IV. CONCLUSIONS

The OAO measurements indicate the magnitude and altitude profile of dayglow emissions between 1000 and 2000 Å. These measurements tend to support the theory that the radiation between 1300 and 1700 Å is produced by photoelectron excited molecular nitrogen. The nightglow measurements show no detectable emissions between 1700 and 1300 Å and a low level intensity at 1200 Å which is independent of altitude. The prominent feature in the ultraviolet nightglow appears to be the emissions of the Herzberg bands of O_2 in the 2000-3000 Å region.

The OAO results provide a unique part of the picture that describes the earth's ultraviolet airglow. The accurate pointing capability of the OAO spacecraft and the small field of view of the WEP provide the detailed resolution previously not available. The small field of view limits the size of the atmospheric area from which radiation is being received. The diameter of this area is 8 km at the 200 km tangent altitude point and decreases in size the closer the line of sight is to the local zenith. Thus it is possible to measure the spatial variations of the atmospheric emissions with a resolution far better than any previous experiment. The accurate pointing capability of the OAO results in an uncertainty in the tangent altitude of less than 1 km. This pointing capability, in addition to the small FOV, makes it possible to obtain volume emission rates from scans of the earth limb. Other experimenters could not do this confidently. It is hoped that further measurements can be made that will give information on the effects

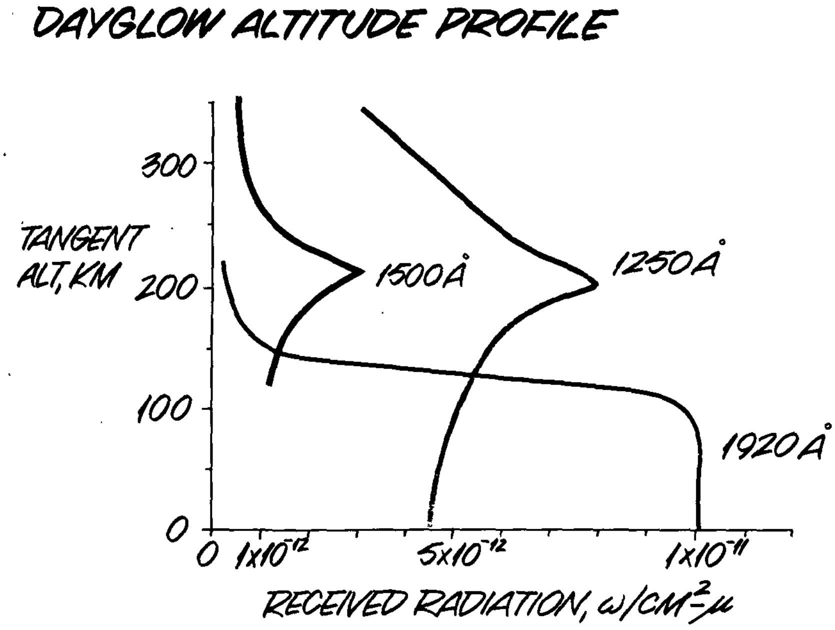

Figure 7.

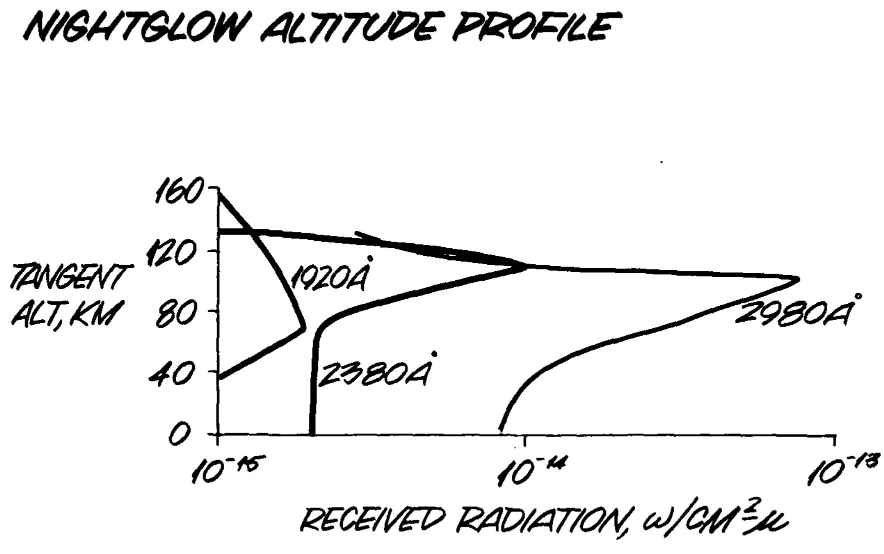

Figure 8.

of solar activity and seasonal variations.

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