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AN ATTEMPTED MEASUREMENT OF AN $O_2\left({}^1\Delta_g - {}^3\Sigma_g^-\right)$ NIGHTTIME EMISSION PROFILE IN A ZERO DEGREE LATITUDE REGION

JEAN EDWARD WELKER

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CONTENTS

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INTRODUCTION

In the last few years the $O_2\left({}^1\Delta_g - {}^3\Sigma_g^-\right)$ transition centered at 1.268μ, the (O, O) band of the infrared atmospheric system of O_2, has caused some interest [1-4]. The source of production of the daytime peak radiation intensity from this O_2 transition, which occurs in the vicinity of 50 km altitude, is believed to be the photolysis of ozone by the radiation in the 2000 to 3000 Å region of the spectrum, the region known as the Hartley continuum and the value for the maximum zenith intensity for this O_2 transition at 50 km is 20 to 25 MR[2]. With the onset of twilight, this O_2 emission begins to decay and the expected nighttime intensity is reduced some two orders of magnitude, to approximately 100 to 500 kR. Although some measurements have been made in twilight[3], no known previous attempt has been made to measure the nighttime altitude profile of O_2 emission in situ. An assumption has been advanced that the $O_2\left({}^1\Delta_g - {}^3\Sigma_g^-\right)$ transition behaves at night in the same way as the 5577 Å transition of atomic oxygen, which is caused by the recombination of oxygen atoms[2]. This assumption, if correct, would indicate that the most likely altitude to observe the maximum emission at night would be around 100 km. A radiometer was designed with the intent of observing a nighttime profile through 100 km, in conjunction with an additional daytime profile measurement with another radiometer, both in a zero degree latitude region. The nighttime radiometer had two channels, one which observed a spectral region representative of the background radiation intensity, the other which observed the spectral region in which the O_2 emission was expected. The radiometer looked out the side of the rocket in a direction perpendicular to the cylindrical axis and the radiometer was built with a rapid response time to allow measurements with this viewing configuration. No O_2 emission radiation was seen; the minimum detectable signal level of the radiometer was 1 MR.

FLIGHT HISTORY

A series of experiments on a number of different rockets flown from Thumba, India in March 1970 presented the opportunity to investigate the behavior of the D and E regions of the atmosphere. A limited amount of space was available on two of the payloads and IR radiometers sensitive to the 1.268μ centered band of the $O_2\left({}^1\Delta_g - {}^3\Sigma_g^-\right)$ transition were flown. One rocket containing an IR radiometer was flown in the afternoon of 19 March 1970 at 78 days 10 hours 59 seconds GMT or 3 hours 30 minutes 59 seconds local time, and the results are now being prepared for publication. The radiometer being discussed was flown at night on 10 March 1970 (68 days, 20 hours, 34 minutes and 59.245 seconds GMT) on a Nike-Tomahawk rocket which was launched at a zenith angle of 4 degrees. After both stages of rocket burnout the zenith angle was closer to 11 degrees. The latitude of the launch site was 8.540° and the launch azimuth angle was 180° or due South. The flight lasted 253 seconds and the maximum altitude achieved by the rocket was 264 km. In the altitude region of interest for airglow observation, namely, from 50 to 150 km, the rocket gained altitude at close to 2 km/sec from 50 through 90 km and at a rate close to 1.5 km/sec from 90 through 150 km. The spin rate maintained through most of the flight was 5 Hz. The trajectory was computed from tone ranging data taken at the site.

INSTRUMENTATION

The radiometer consisted of two optical channels each with a Ge PIN diode detector with an active area of 5 mm diameter which was thermoelectrically cooled. The detectors were located behind the periphery of a mechanical chopping wheel which caused the radiation emerging from the optical channels to be chopped at a frequency of 1 kHz. The optical channels consisted of non-reflecting metal cylinders, each of which contained an interference filter and an f/1 lens with a focal of one inch. In the cylinder containing the signal channel optics the interference filter had a half width of 100 Å centered at 1.268μ and in the other cylinder containing the background channel optics the interference filter was a half width of 100 Å centered at 1.23μ. The cylinders containing the optics for both the signal and background channels lay side by side in a parallel configuration on a shelf perpendicular to the cylindrical axis of the rocket. The 100 Å half width centered at 1.23μ was chosen as the optical pass band of the background channel since it was felt that this region was relatively free of any strong molecular resonances and would provide a representative background signal.

One telemetry channel recorded the difference between the signal from the 1.268μ centered pass band and the signal from the 1.23μ centered pass band while a second telemetry channel recorded the signal from the 1.23μ centered channel alone. A detailed description of the method of construction of the radiometer will be published shortly by William H. Jones of the Goddard Space Flight Center.

DISCUSSION

The viewing direction of this radiometer was unusual for an experiment of this type, with a recent exception[5]. Most radiometers are mounted in the nose of the rocket payload and look forward along the cylindrical axis of the rocket. Since this radiometer was pointed out the side in a direction perpendicular to the cylindrical axis of the rocket, more stringent requirements were placed on the response time characteristics of the radiometer. This radiometer accompanied a number of other experiments on the payload and payload space considerations alone dictated this viewing configuration. If the instrumental obstacles in the construction of the radiometer can be overcome, this unusual viewing direction presents some advantages. For example, in this flight the spin rate was 5 Hz and an average climb rate was not greater than 2 km/sec. Therefore, the time taken for one spin rotation of 360° was 200 milliseconds and a spin occurred every 0.4 kilometers. The pass band of the radiometer that was flown was 100 Hz which makes the response time of the radiometer some order of magnitude faster than the spin rotation. Altitude resolution better than 0.4 km can produce a finely resolved altitude profile. Also, for regions of low radiation extinction, a layer of gases of a dimension of a few kilometers altitude which is emitting radiation would be more easily detected by the side viewing configuration. There are also many disadvantages in the side viewing configuration in addition to the difficulty in the radiometer construction. For example, if the radiometer looks back toward the earth or along the limb of the earth, intensity of radiation in the optical pass band centered at 1.23μ, the so-called background channel, can be greater than the intensity of radiation in the optical pass band centered at 1.268μ, the signal plus background channel. The radiometer was allowed to show a negative deflection on the telemetry to indicate greater 1.23μ intensity if that were the case. This possible negative deflection combined with the independent monitoring and calibration of the 1.23μ centered optical pass band and the fast response time of the radiometer were considered sufficient to handle most contingencies.

CALIBRATION

Calibration of the radiometer was accomplished with the use of a Barnes Engineering Company Blackbody Model No. 11-200T in conjunction with an Off-Axis Collimator Model No. 6-101 equipped with a variable speed chopper attachment. The blackbody has a variety of constricting apertures and a temperature range of 200 to 1000°C. The collimator has a 4.8 inch diameter exit port and the radiation from the blackbody into the collimator's entrance port can be chopped by the variable speed chopper in the range from 30 to 3000 Hz. The frequency modulation function of the radiometer was tested with this chopper and showed that a decrease in the gain of a factor of two occurred when the radiation was chopped at the rate of 100 Hz. Since the radiometer would not be required to mechanically scan radiation any faster than the 5 Hz spin rotation frequency although the variation in the sky background scanned would cause a fluctuation at a greater rate, it appears that the radiometer design had been provided sufficient leeway. The responsivity of the radiometer was determined and the ability of the radiometer to maintain this responsivity was investigated. This investigation consisted of thermal testing as well as a test of the linearity of the instrument. Thermal testing was conducted on the radiometer since it was critical that the thermoelectrically cooled detectors rigidly maintained their preset temperature for a correct gain assessment and accurate calibration. The detectors were unable to maintain their preset temperature when the ambient temperature rose above 104° F. This temperature was not critical even for Thumba, India within an hour or two of midnight. The test for linearity showed that the radiometer diverged from a linear performance only with the very highest intensity signal levels. Since these high intensity levels did not appear in flight, it is assumed that the radiometer flight data is linear in its entirety.

RESULTS

The radiometer, although not calibrated in flight, demonstrated both its speed and sensitivity during the flight. In particular, there was a large and rapid decrease in the radiation intensity to the background channel centered at 1.23μ, which is a familiar occurrence having been observed on two other similar flights in the daytime. One flight was the previously mentioned flight from Thumba, India; the other was an earlier flight from Wallops Island, Virginia.

This radiometer reacted analogously to the radiometers on the other two flights although it was designed and functions differently from the other two radiometers. The telemetry record itself showed the reaction time of the radiometer to be as fast as expected. Radiometer sensitivity, however, presented a problem and the original goal of a minimum detectable signal of 200 to 500 kR or some two orders of magnitude below the daytime maximum zenith intensity measured at the 50 kilometer peak at 20 MR was not achieved. Rather, the minimum sensitivity was for an intensity only one order of magnitude below the 50 kilometer peak or the equivalent of 1 MR with the radiometer operating in a photovoltaic mode. Although this was a disappointment, the potential for an airglow observation such as this was great and the side viewing configuration increased the possibility of observing an intensity within the sensitivity of the radiometer. However, no detectable level of intensity was observed in the 1.268μ pass band.

CONCLUSION

The radiometer did not register a signal in the 100 Å pass band centered at 1.268μ within the range of sensitivity discussed, that is, with an intensity of 1 MR above the background signal assumed to be the intensity in the 1.23μ centered channel. The signal data did not show any major fluctuations due to the spin rotation of the rocket although the radiometer was fast enough to record any such fluctuations as previously stated. The data indicated that the background radiation centered in the 1.23μ pass band which was monitored independently, decreased noticeably above 63 km and then maintained a relatively constant, if not slightly decreasing, va'ue of intensity as the flight progressed. It became apparent that the scheme for looking at the intensity of the background radiation at the 1.23μ centered pass band and assuming that it was approximately the same background intensity for the 1.268μ centered band did not seem to be necessarily correct while scanning the night sky, although it appears to work for the daytime airglow. Although the monitored background channel indicated a near constant intensity above 63 km as expected, this intensity seemed to be greater than the intensity which entered through the signal channel centered at 1.268μ. This situation was not the case in the two daytime flights which will be reported shortly. Precaution had been taken in the design of the radiometer to allow for this condition and, although it was undesirable, the radiometer was still functional with the described sensitivity.

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