Rocket observation of the near infrared airglow emissions in the auroral region

H.Yamamoto[1], Y.Matsuo[1], H.Sekiguchi[1] , T.Makino[1] and H.Takahashi[2]

Department of Physics, Rikkyo University, Tokyo, Japan

[2]Instituto Nacional de Pesquisas Espaciais, INPE, Sao Jose dos Campos, SP, Brasil

ABSTRACT

The rocket observation to measure the near infrared airglow emissions of N_2^+, O_2 and OH by using the filter radiometer was done at Andoya rocket range (69.5°N) on Dec. 1, 1994. The airglow radiometer worked well enough to get the airglow emission profiles under the active aurora. The periods of spin and precession of the rocket were about 10 s and 20 s, respectively, because of unknown trouble of the rocket body. Then the radiometers could get the airglow information every 10 s during the upleg and downleg observations on the airglow emission layers. Although it is hard to get the detailed information under such an observational condition, we got rough altitude information on the emission layers for N_2^+ and O_2 airglows. The peak height of the N_2^+ emission is 85 ~ 90 km and its layer is not expressed by a Gaussian profile. On the other hand, the emission profile of the O_2 is represented as a Gaussian profile whose peak is around 92 km and the width is 15 km. It is very similar to the profiles observed under the normal airglow conditions.

INTRODUCTION

N_2^+ Meinel band is the electronic energy transition between the exited state of A and the ground state of X of ionized N_2. The band around 1110 nm is the transition between v'=0 in the upper state and v"=0 in the ground state, and those around 1520 nm is it between v'=1 and v"=2. Gattinger and Vallance Jones (1981) reported the ground-based observation of the airglow emissions up to 1650 nm by using the interferometric technique. They compare the emissions under normal airglow condition and those under the active auroral one. It is clear from their results that N_2^+ Meinel (0,0) emission around 1110 nm has no emission feature under the normal airglow condition. The emission process of the N_2^+ Meinel band is considered as through the direct electron excitation of N_2, that is

$$N_2 + e \rightarrow N_2^+ (X, B, A) + 2e$$

The cross section of the above process has its peak around the electron energy of 100 eV. The branching ratio between the three states are X : A : B = 5 : 4 : 1 (Itikawa, 1994). The transition between the excited state of B and the ground one emits the first negative bands around 391.4 nm and 427.8 nm. As the first negative band emission is used as the index of the auroral activity, it is expected that the emission intensity of the N_2^+ Meinel band has strong correlation with the auroral activity or the emission intensity of the first negative band. As no rocket observation of the band has been done under the active auroral condition, we have had no information on the altitude distribution of the N_2^+ Meinel band.

The O_2 infrared atmospheric band around 1270 nm is one of the strongest nightglow emissions in the near infrared region. Some rocket observations were done in the middle and high latitude regions (for example, Thomas and Young, 1981 and Yamamoto et al., 1992). The altitude distribution of the 1270 nm emission is represented as nearly Gaussian distribution whose peak is around 92 km and half width of 10-15 km. The emission mechanism of the band is as follows.

$$O + O + M \rightarrow O_2 (A, A', C) + M$$

$$O_2 (C) + O_2 \rightarrow O_2 (a) + O_2 \quad \text{or} \quad O_2 (b) + O_2$$

$$O_2 (a) \rightarrow O_2 (X) + h\nu \quad (\lambda = 1270 \text{ nm}, 1580 \text{ nm})$$

Additional excitation mechanism is suggested as

$$O_2 + e \rightarrow O_2 (a) + e$$

under auroral condition (Cartwright et al., 1972). In this process, the most reactive energy of electron is around 8 eV (Itikawa, 1994). We have had no direct observational data for the altitude distribution of the O_2 1270 nm band under auroral condition.

The rocket observation to measure the airglow emissions in the near infrared region was made at Andoya rocket range in Norway under the active auroral condition. We got some information on the altitude distributions of the N_2^+ 1110 nm and O_2 1270 nm bands, and on the correlation between the auroral activities and the intensities of these emission bands. The data on the altitude distributions of the N_2^+ 1110 nm and O_2 1270 nm emissions will be presented in this paper.

FILTER RADIOMETER AND ROCKET OBSERVATION

The filter radiometer to measure the airglow emissions in the near infrared wavelength region consists of an entrance hood, a rotating chopper an interference filter, an optical lens and a sensor. An InGaAs photo-diode whose diameter is 2 mm is used as the sensor and is cooled at –20ºC by a thermo-electric cooling whose power is 1 V, 0.7 A. The output signal from the pre-amplifier is fed to a lock-in amplifier whose electronic time constant is 10 ms, and the final output voltage is converted to 14 bits digital signal. We arranged three radiometers, one for N_2^+ 1110 nm, one for O_2 1270 nm and the last for OH 1380 nm emissions. All the radiometers are combined as one radiometer. It mounted on the rocket as its field of view is perpendicular to the rocket spin axis.

The rocket S-520-21 had the following scientific purposes, those are (1) to solve the problem of emission mechanisms of the auroral emissions in relation to auroral particles and plasma instability and (2) to solve the auroral dynamics in relation to auroral particles, current systems and the structure of the electric field. It was launched at 21:39 UT on Dec. 1, 1994 at Andoya rocket range (69.5ºN, 16ºE) in Norway under active auroral condition. The rocket attitude was very complicated because of unknown trouble of the rocket body. The periods of rocket spin and precession were about 10 s and 20 s. Furthermore the angles of the rocket precession axis were 50º in elevation and 264º in direction. Then the radiometer got the airglow data every 10 s. On the other hand, it could observe the horizontal structure of the emission layers that were near 100 km when the rocket was above 100 km. The rocket reached the apogee of 343.3 km at 293 s after launch and arrived at the sea level at about 600 s. The radiometer worked well during the rocket flight.

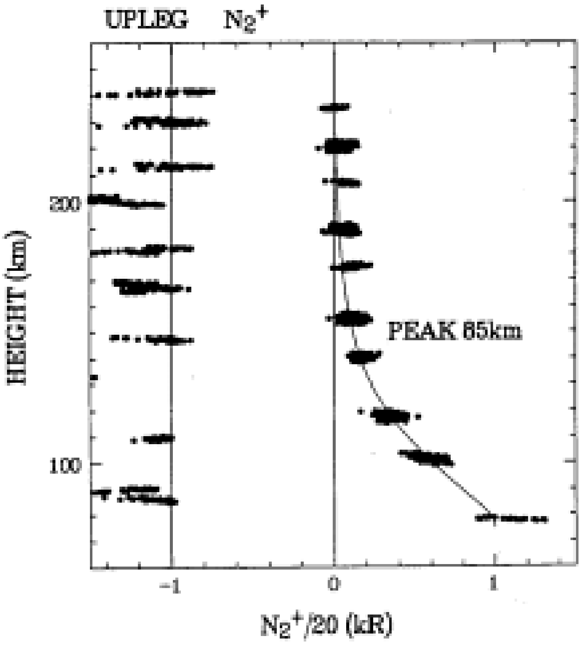

Figure 1. Altitude distribution of noramlaized zenith radiance of N_2^+ 1110 nm emission observed in upleg measurement. Solid curve represents calsulated one by using the assumed volume emission profile shown in Figure 2 (see text).

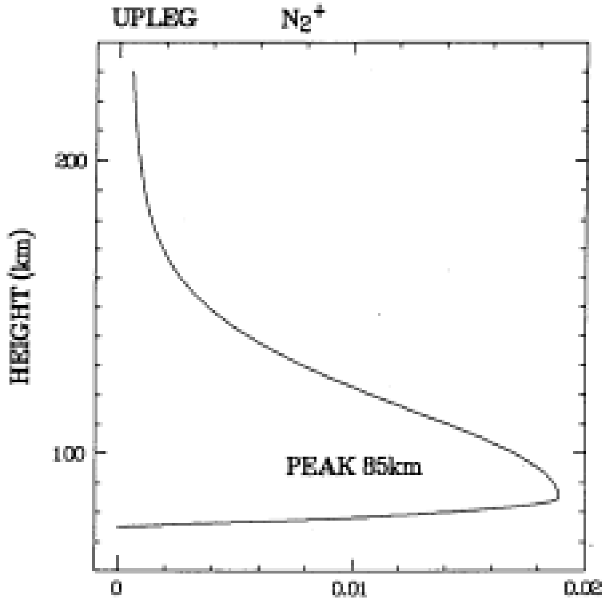

Figure 2. Assumed altitude distribution of volume emission rate of N_2^+ 1110 nm emission for the upleg mesurement.

ALTITUDE DISTRIBUTIONS OF N_2^+ AND O_2 AIRGLOW EMISSIONS

The radiometer measureed the airglow radiation every 10 s. We plotted radiance data referenced to the zenith direction, that is obtained by using the correction of cos ζ where ζ represents the zenith angle of the radiometer. When the rocket is under the emission layer, the zenith radiance is signed as plus. On the other hand, the zenith radiance that is signed as minus represents the emission that is observed from the rocket that is over the emission layer. As the rocket is over the emission layer, we get zero radiance in case that the radiometer observes to zenith and minus radiance when it measures the emission layer. Figure 1 shows the altitude distribution of the N_2^+ 1110 nm zenith radiance normalized to the total zenith radiance observed in upleg measurement, that is 20 kR. The groups of the data points near center region represent the radiance observed to the direction of the zenith. Those near the left side represent one observed to the direction to the earth. As the radiance closes to zero at the altitude of 200 km, we can decide that the emission layer is below this height. Taking into the condition that N_2^+ (A) is produced by the collision with electron, we assume the altitude distribution of the volume emission rate of the radiation as one shown in Figure 2. The solid curve in Figure 1 is obtained by integration of the volume emission rate curve shown in Figure 2. As it is very similar to the observed one, the peak height of the N_2^+ 1110 nm emission was around 85 km in the upleg measurement. We got nearly the same altitude distribution of the zenith radiance in the downleg measurement except for the total radiance of 27.5 kR. The observed data told us that the altitude distribution of the N_2^+ 1110 nm emission has its peak at

85 – 90 km and is similar to one shown in Figure 2. Figure 3 illustrates the distribution for the O_2 1270 nm. The solid line also represents the integral intensity distribution obtained from the assumed profile of the volume emission rates for the O_2 1270 nm. In this case we assume that the altitude distribution of the volume emission rate has the Gaussian distribution whose peak is at 92 km and the half width (FWHM) is 15 km. As the curve reproduces the observed data well, the emission profile of the O_2 1270 nm under the auroral condition is nearly the same as one observed in middle and high latitudes. The total radiance was 125 kR in the upleg and 160 kR in the downleg measurements.

CONCLUSIONS

This work presents the first observed profiles for the N_2^+ 1110 nm and O_2 1270 nm airglow bands under the active auroral condition. The emission layer of the N_2^+ 1110 nm has its peak at 85 – 90 km and is not represented as a Gaussian distribution. The total radiance was around 25 kR. In case of O_2 1270 nm bands, the total radiance was around 150 kR and the emission layer has nearly the same structure observed under the normal airglow condition, that is, its peak around 92 km and the half width (FWHM) is 15 km.

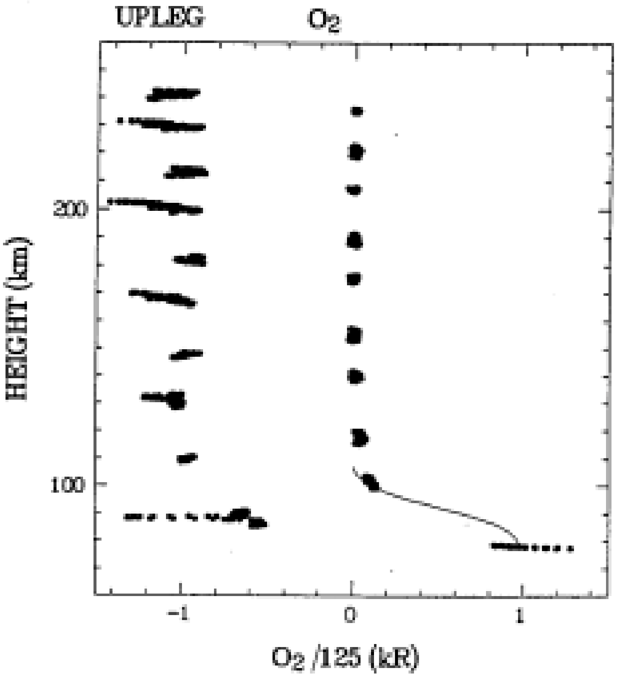

Figure 3. Same as Figure 1, but for O_2 1270 nm emission. Solid curve represents the calculated one. In this case, assumed volume emission rate profile is a Gaussian distribution whose peak at 92 km and half width of 15 km.

REFERENCES

Cartwright, D.C., Trajmar, S. and Williams, W., 1972, The excitation mechanisms in auroras, Ann. Geophys., 28, 397.

Gattinger, R.L. and Vallance Jones, A., 1981, Quantitative spectroscopy of the aurora. V. The spectrum of strong aurora between 10000and 16000 Å, Can. J. Phys., 59, 480.

Itikawa, Y., 1994, Electron collisions with N_2, O_2 and O : What we do and do not know, Advances in atomic, molecular and optical physics, 33, 253.

Thomas, R.J. and Young, R.A., 1981, Measurement of atomic oxygen and related airglows in the lower thermosphere, J. Geophys. Res., 86, 7389.

Yamamoto, H., Naito, I., Makino, T. and Sekiguchi, H., 1992, Altitude distribution of O_2 1.27 μm nightglow emission observed by a rocket-borne radiometer, J. Geomag. Geoelectr., 44, 207.

ACKNOWLEDGMENTS

The rocket S-520-21 was operated at Andoya rocket range in Norway. We thank to the staff at Andoya rocket range and the rocket launching crew of ISAS for the successful operation.