# AIRGLOW EMISSION AS A TEMPERATURE PROBE IN EARTH'S ATMOSPHERE

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THE earth's atmosphere during the day, as well as at night, emits radiations in the visible and near infrared regions of the electromagnetic spectrum characteristic of the emitting species of the upper atmosphere. Favourable conditions of atomic and molecular emissions existing in the atmosphere between 50 and 500 km altitudes and the intensity of emission, primarily depend on the density, the rates of reaction for emission, quenching, etc. Day-time airglow emissions are predominantly governed by the solar flux incident on the atmosphere and are difficult to detect from the ground due to the large amounts of scattered sunlight ($\sim 10^6$ Rayleighs/Å)[1] in the lower atmosphere. Most of the night airglow emissions are weaker compared to their day-time counterparts but are relatively easy to measure due to the absence of scattered sunlight from the earth's lower atmosphere.

The fact that airglow emissions arise under specific conditions and therefore confine themselves to narrow or broad layers of emission in the atmosphere can be used to estimate specific parameters of the emission regions. One such parameter is temperature and one of the many emissions from the atmosphere is due to the OH radical. It has been known for some time[2,3] that the OH radical emits an extended system of bands from the violet to the near infrared in the 90 km altitude region of the earth's atmosphere. The primary reaction for the night time emission[4] is:

$$H + O_3 \rightarrow OH^* + O_2 + 3.3\,\mathrm{eV}, \qquad (1)$$

where $OH^*$ is the excited OH radical capable of giving the vibrational rotational band system by radiative de-excitation.

Other reactions[5,6], $O + HO_2$ and $O_2^* + H$ for the production of excited OH have been suggested but are shown to be less important. The relative contributions due to these reactions are not precisely known. In the 90 km region of the upper atmosphere, it is estimated that before radiative de-excitation, the excited OH radical undergoes about 250 collisions and attains the ambient neutral temperature. This fact is also established by high resolution spectroscopic measurements[7].

The basic concept used for temperature determination by ground-based observations is that the relative emission intensities of the rotational lines in the vibrational rotational bands, given by the excited OH molecule vary with temperature according to the equation:

$$I_J = C\nu_J^4\, S_J \exp\,(-F(J)hc/kT). \qquad (2)$$

where $I_J$ is the intensity of the rotational line corresponding to the line given by the particular rotational quantum number $J$. Once $I_J$ is experimentally measured, a value of the temperature $T$ can be computed.

The classic spectroscopic work for measuring the OH band intensities is due to Kvifte[8,9]. By plotting the rotational quantum number $J$ against the intensity $I$, the temperature was determined by matching the calculated $I$-$J$ profile with the one obtained by spectroscopic measurements. Such measurements can also give the temperature by plotting $\ln(I/S_J\nu^4)$ against energy $E(J) \propto F(J)$ and by determining the slope of the straight line. The OH rotational-variational system gives $P$, $Q$ and $R$ branches for each vibrationally excited band, and further, each branch is split into $P_1\,P_2$, $Q_1Q_2$ and $R_1R_2$ due to $\Lambda$ type doubling. Hence, by yet another method, by measuring total $P$, $R$ and $Q$ branch intensities, the temperature has been determined[10,11] by taking the ratios of the $P/Q$ and $R/Q$ branches.

Some of the vibrational rotational bands of OH are either contaminated by other airglow emissions or overlap on each other or are so

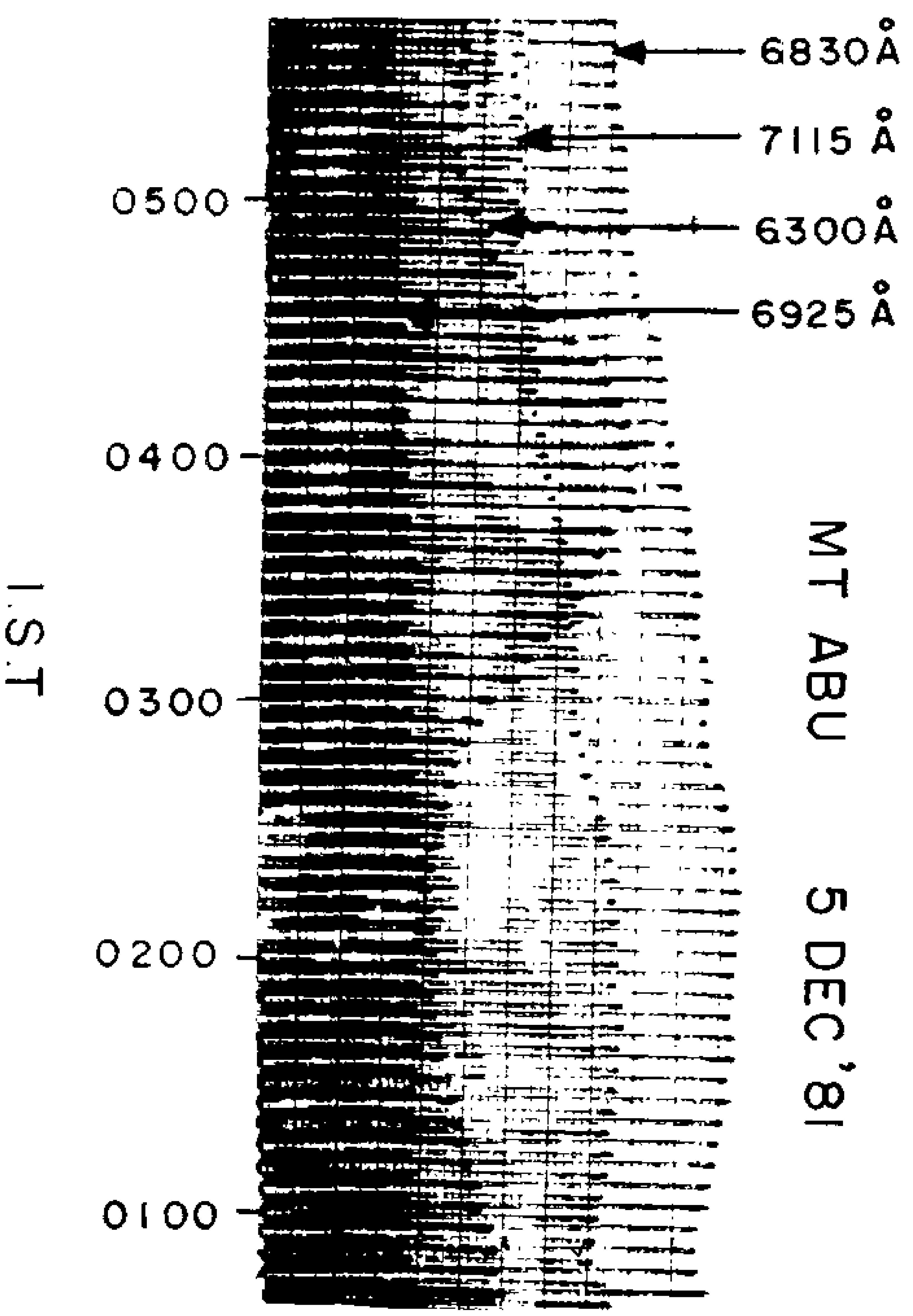


**Figure 1.** Actual photometric record of the airglow emissions. The $X$ axis shows time, $Y$ axis shows deflections proportional to the respective intensities of airglow emissions. 6925 Å deflection is due to the $P_1(3)$ rotational line intensity and 6830 Å deflection is due to the integrated intensity or $R$ branch of the OH (7–2) band. 7115 Å measures the background continuum. 6300 Å emission is due to the atomic oxygen.

crowded that the measurement of the intensity of an individual line becomes difficult. However, by choosing an appropriate band, it is possible to isolate a rotational line with moderately narrow (H.W ~ 10 A) filters. Majumdar and Kulkarni[12] used a new method for temperature determination by measuring the ratio $X$ of the intensity of a rotational line of one branch ($P$) to the total intensity of the other branch ($R$) of the same band, by photoelectric photometry. Observations are quicker and much less laborious than spectroscopic methods. A typical record from the photoelectric photometer is given in figure 1. From equation (2), for a single value of temperature $T$, the corresponding value of $X$ can be determined. The ratio is chosen to eliminate errors in calibration and instrumental errors which could be quite large. Theoretically, only one intensity measurement is enough. A theoretical curve of $X$ against $T$ can be drawn for a number of values of $T$ and this is used to determine $T$ from the observed ratio $X$. Several values of temperature during a night can be obtained by monitoring the nocturnal variation in OH intensities at the mesospheric height, though the method has its limitations. *In situ* measurements could be done with rockets and for a limited time by satellites. The measurement of mesospheric temperature is important because this is the intermediate region in which the chemistry as well as the dynamics of the upper atmosphere changes.

The upper atmospheric models show[13] that the region between 84 and 94 km has a minimum temperature and that this region is stable. Except for satellite measurements, most of the ground-based measurements have been carried out in the middle and high latitudes. There are very scanty measurements in low latitudes. Long-term consistent measurements do not exist at low latitudes except at Mt. Abu (India)[14].

Observations over a few years have revealed that the 90 km altitutde region of our atmosphere is not as steady as it was thought. Measurements during a night show that even during the same night, there are different kinds of variations.

The study over a number of nights shows that about a fifth of the nights do show that the temperature is steady during the night, while a third of the nights show fluctuations in temperature with time. There are some nights on which the temperature steadily increases by as much as 40° K within a few hours in this region. Some nights also show a steady decreae in temperature. While the constant temperature conditions can be attributed to the static conditions in the mesosphere, fluctuations or monotonous changes in temperature are difficult to interpret.

The changes in temperature inferred from OH intensity measurements could be mainly due to two reasons: (1) a change in the heights of the emission layer of OH or (2) a change in the intrinsic temperature of the emission layer due to the absorption or emission of heat. In his classic papers on internal gravity waves, Hines[15,16] has shown that in the 90 km region of the atmosphere reversible adiabetic heating is produced due to these waves and the heating could manifest itself as fluctuations in the temperatures and that the periods of such fluctuations could be between 10 to 200 minutes. On many nights, fluctuations in temperature were observed by Majmudar and Kulkarni[17] at Mt. Abu which are of the same order as those predicted above and considering the present trend in the various theories about mesosphere, these fluctuations in temperature could be attributed to internal gravity waves. However, this suggestion must be taken with caution because simultaneous height measurements of the emission region have not been made.

In a technique recently developed by Peterson and Kieffaber[18] and extensively used by Moreels and Herse[19], the OH emission in the near infrared (7580–9850 Å wavelength) region is photographed, with a fast camera on an IR sensitive film, the exposure being of the order of 10 to 15 minutes. Extensive observations show that on many occasions the OH emission shows wave like patterns. One of the important results obtained with these photographs was the determination of the height of the OH emission layer which was fixed at 84 ± 2 km. The wavelength of the wavy structure is not very constant but varies and the approximate value is of the order of a few tens of kilometres. The wave velocity is of the order of $15\,ms^{-1}$ per hour, again with a wide variation. From the wave system observed on some of the photographs, a period of 50 minutes is deduced by Moreels and Herse which again fits into the theoretically derived period range, for gravity waves.

The structures shown in the near infrared photographs due to OH emission support independantly the presence of gravity waves in the atmosphere in the 80 to 90 km region.

If techniques are developed to measure OH emission intensities and emission height simultaneously, and temporal changes in the OH emission are found to be not due to changes in the emission height of the OH layer, the OH emission probe would be a very powerful tool to determining many basic features of the occurrence of the internal gravity waves. Alternatively, if the movement of the emission layer is detected, the observations could be useful in studying the dynamics of the mesosphere from night airglow measurements.


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