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INTERFEROMETRIC MEASUREMENT OF THE WIDTHS OF THE EMISSIONS λ6300 Å [O I] AND λ5198–5200 Å [N I] IN AURORAE

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During the winter of 1958–1959, at the station of the Institute of Atmospheric Physics of the Academy of Sciences of the USSR in Loparskaya, interferometric measurements were made of the widths of the forbidden auroral emissions: λ6300 Å [O I] and λ5198–5200 Å [N I].

An apparatus with a Fabry–Perot interferometer was used. The individual emissions were isolated by interference filters with passbands of 80–100 Å. When photographing the red oxygen line, quartz spacer rings 8 and 10 mm thick were used. The aperture ratio of the apparatus was 1 : 3, the focal length of the objective was 150 mm, and the reflection coefficient of the dielectric coatings was 95%. When photographing the emission λ5200 Å, an invar spacer ring 3 mm thick was used. The aperture ratio of the apparatus was 1 : 1.3 ($f = 65$ mm). The reflection coefficient was 85%.

The interferometer was placed in an airtight chamber. The change in ambient temperature during the night reached 20°, and therefore it proved necessary to use double thermostating: the airtight chamber with the interferometer was placed in a heat-insulated box, in which the temperature was maintained constant to within $\pm 0.5°$; the chamber itself, by means of a TS-15 water thermostat, was thermostated to an accuracy of $\pm 0.05°$.

To check the adjustment, before the start of photographing and after its completion photographs were taken of the interference rings of a krypton gas-discharge tube. In addition, several times during an exposure the yellow or green line of krypton was recorded on the same frame as the auroral line, in order to determine the instrumental contour. In the case of photographing the nitrogen emission λ5200 Å, the instrumental contour was determined from the contour of the line λ5577 Å, which was photographed in the wing of the interference filter centered at λ5200 Å. The red oxygen line was photographed on Dn film, made sensitive by preliminary flashing; the emission λ5200 Å was photographed on Kodak 0-α-D plates.

Figures 1 and 2 show photographs of the interference rings of the line λ6300 Å [O I] and the yellow krypton line. Figure 3 shows a photometric section of the

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

inner ring at 6300 Å.

The width of the lines under investigation is completely determined by the Doppler effect, since broadening due to collisions under upper-atmosphere conditions may be neglected. Therefore, measurement of the width of spectral lines makes it possible to judge the temperature in the region of luminescence. However, determination of the kinetic temperature from the width of spectral lines is possible only if the emitting atoms retain a Maxwellian velocity distribution. Under some excitation mechanisms (fluorescence, electron impact) the kinetic energy of the particles practically does not

changes. In these cases the temperature determined from the width of a spectral line coincides with the kinetic temperature in the region of emission.

If excitation occurs as a result of dissociation, dissociative recombination, charge exchange, etc., then it may be accompanied

Fig. 1. Interference rings of λ6300 Å [OI]. The photograph was obtained during a red aurora of "type A" with an exposure of 1 hour

by a change in the kinetic energy of the excited atoms. In such a case the temperature determined from the line width may differ appreciably from the kinetic temperature of the medium. However, if the atom, while in the excited

Fig. 2. Interference rings of the yellow krypton line

state, has time to undergo several collisions, then the Maxwellian velocity distribution will be restored and the reliability of the temperature determination will not depend on the excitation mechanism. Therefore, for determining the temperature of the upper atmosphere (especially at great altitude), forbidden emissions are the most convenient.

It may be estimated that the time required for the establishment of a Maxwellian distribution for neutral atoms at an altitude of 150 km is less than 1 sec, at an altitude of 300 km less than 100 sec, and at an altitude of 600 km less than 10^5 sec. It follows from this that, for the λ5577 Å [OI] line, temperature measurement is meaningful at least up to an altitude of 150 km; for the λ6300 Å [OI] line, up to 300 km; and for the λ5200 Å [NI] emission, up to 600 km.

Since the most probable excitation mechanism of λ6300 Å [OI] and λ5200 Å [NI] is electron impact ([1], [2]), the temperatures measured from the widths of these

Fig. 3. Photometric cross section of the inner ring $\lambda 6300$ Å. Measurements were made with an MF-2 microphotometer. Each asymmetric contour is the result of a variable dispersion. For comparison, the contour of the yellow krypton line is shown (solid line).

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emissions apparently coincide with the kinetic temperature at all altitudes of interest to us.

Fig. 3. Photometric cross section of the inner ring $\lambda 6300$ Å. Measurements were made with an MF-2 microphotometer. Each asymmetric contour is the result of a variable dispersion. For comparison, the contour of the yellow krypton line is shown (solid line).

A fundamental drawback of the interferometric method for determining the temperature of the upper atmosphere is the uncertainty in the altitude of the emitting layer. The altitude of sharply delineated auroral forms (mainly the $\lambda 5577$ Å line) can be measured by baseline photography, but in the case of the nearly homogeneous diffuse glow of the $\lambda 6300$ Å and $\lambda 5198$–5200 Å emissions, it is very difficult to determine the altitude of the glow in this way. Such simultaneous determinations at the station in Loparskaya have not yet been made. Therefore at present only approximate estimates are possible of the altitude at which the temperature has been measured interferometrically. As Chamberlain ([3]) has shown, there are grounds for believing that the altitude of the $\lambda 6300$ Å emission in the night sky is about 250–300 km. Interferometric photographs of the red line in aurorae refer to high-altitude aurorae: red patches and red rays, which are usually located at altitudes not lower than 200 km ([4]). It is very difficult to estimate the altitude of the $\lambda 5200$ Å emission in aurorae. Taking into account the extremely small transition probability (equal to $1.06 \cdot 10^{-5}$ cm^{-1}) ([5]) and the correlation of the $\lambda 5200$ Å intensity with the intensity of the red oxygen emission, one may conclude that the altitude of the $\lambda 5200$ Å glow is hardly less than 300 km.

Not all photometric cross sections of the $\lambda 6300$ Å rings can be represented by a simple Doppler contour. Apparently, the deviation from the Doppler contour is explained by the superposition of the glow of layers with different temperatures.

The temperatures determined from the width of the red line lie between 1200 and 3400°K. The accuracy of determination in all cases is $\pm 15\%$. Measurements under conditions of an almost undisturbed night sky from three photographs give 1230, 1120, and 1280°K. Thus, the mean temperature is 1210 ± 50°K. This value agrees better with the accepted altitude of the red-line glow than $T < 450$ –550°K, measured by Dufay ([6]).

Fig. 4. Photograph of the forbidden nitrogen doublet λ5198-5200 Å. The first ring, counting from the center of the system, belongs to λ5198 Å, the second to λ5200 Å, and the third to λ5577 Å [OI]

Figure 4: Fig. 4. Photograph of the forbidden nitrogen doublet λ5198-5200 Å. The first ring, counting from the center of the system, belongs to λ5198 Å, the second to λ5200 Å, and the third to λ5577 Å [OI]

In aurorae there is a tendency for the temperature to increase with increasing brightness of the glow. In type A aurorae, a temperature of about 1500°K was obtained at a λ6300 Å line intensity of 2–5 kilorayleighs, and 1700–2000°K at an intensity of 5–15 kilorayleighs. During the exceptionally strong red type-A aurora of 17–18 XII 1958, when, according to simultaneous electrophotometric measurements by N. V. Giorgio

intensity of λ6300 Å exceeded 80 kilorayleighs, and a temperature of 3400° K was recorded.

Two photographs of the interference rings of the forbidden doublet of atomic nitrogen λ5198-5200 Å were obtained during high-altitude red auroras of type A on 27-28 III and 28-29 III 1959, with exposures of 4 and 5 hours. On the SP-48 spectrograph, on these nights, typical "atomic" spectra were obtained

Fig. 4. Photograph of the forbidden nitrogen doublet λ5198-5200 Å. The first ring, counting from the center of the system, belongs to λ5198 Å, the second to λ5200 Å, and the third to λ5577 Å [OI].

(7) with sharply weakened emission of the bands 1NG N_2^+, the band (0—3) 1NG N_2^+ λ5228 Å being considerably weaker than λ5200 Å. In both photographs (see Fig. 4) the interference rings λ5577, 5200, and 5198 Å are visible; the line λ5577 Å is strongly weakened in the wing of the transmission curve of the interference filter. Measurements of the wavelengths confirm the identification of the observed emission with the forbidden nitrogen doublet. The measured intensity ratio of the components of the doublet λ5198-5200 Å is

$$I_{5200}/I_{5198} = 1.7 \pm 0.1.$$

The temperatures determined from the width of λ5200 Å are $1850 \pm 250°$ K for the first photograph and $2000 \pm 300°$ K for the second.

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Note: Figure translations are in progress. See original paper for figures.