MAIN FILE

60-31,211

JPRS: 3352

1 June 1960

INTERFEROMETER MEASUREMENT OF THE WIDTHS OF λ 6300 Å (OI) AND λ5198-5200 Å (NI) EMISSIONS IN AURORAS

- USSR -

By T. M. Mulyarchik

Distributed by:

OFFICE OF TECHNICAL SERVICES
U. S. DEPARTMENT OF COMMERCE
WASHINGTON 25, D. C.
([redacted])

U. S. JOINT PUBLICATIONS RESEARCH SERVICE
205 EAST 42ND STREET, SUITE 300
NEW YORK 17, N. Y.

F O R E W O R D

This publication was prepared under contract by the UNITED STATES JOINT PUBLICATIONS RESEARCH SERVICE, a federal government organization established to service the translation and research needs of the various government departments.

JPRS: 3352

CSO: 3648-D

INTERFEROMETER MEASUREMENT OF THE WIDTHS OF λ6300 Å (OI) AND λ5198-5200 Å (NI) EMISSIONS IN AURORAS

- USSR -

[Following is a translation of an article by T. M. Mulyarchik in Doklady Akademii nauk SSSR (Bulletin of the Academy of Sciences USSR), Vol. 130, No. 2, January 1960, Moscow, pages 303-306.]

The following was presented by academician V. G. Fesenkov on 11 July 1959.)

During the winter of 1958-1959, interferometer measurements were made of forbidden emissions from auroras: λ6300 Angstrom units (OI) and λ5198-5200 Angstrom units (NI) at the station of the Institute of Atmospheric Physics of the Academy of Sciences USSR at Loparskaya.

An apparatus equipped with a Fabry-Perot interferometer was used. Individual emissions were separated by interference filters with pass bands of 80-100 Angstrom units. Quartz spacer rings with a thickness of 8 and 10 mm were used in photographing the red oxygen line. The aperture ratio of the apparatus was 1:3, the focal length of the objective was 150 mm, and the coefficient of reflection of the dielectric coatings was 95%. An invar spacer ring with a thickness of 3 mm was used when photographing emissions of λ5200 Angstrom units. The aperture ratio of the apparatus was 1:1.3 (focal length of 65 mm). The coefficient of reflection was 85%.

In order to check the adjustment of the instrument prior to and after photography, photographs were made of the interference rings of a krypton gas-discharge tube. In addition, the yellow or green krypton line was printed on the very same frame as the lines from the aurora several times during exposure in order to determine the instrument contour. When photographing emissions of the λ5200 Angstrom unit nitrogen line, the instrumental contour was determined by the controu of the λ5577 Angstrom-unit line, which was photographed at the limb of the interference filter centered at λ5200 Angstrom units. The red oxygen line was photographed on Dn film which was sensitized by preliminary illumination while the emissions of the λ 5200 Angstrom-unit line were photographed on 0-α-D Kodak plates.

Photographs of the interference rings of the λ6300 Angstrom-unit line (OI) and the yellow krypton line are presented in Figures 1 and 2. A photometric section of the 6300 Angstrom-unit inner ring is given in Figure 3.

The width of the lines under study was completely determined by the Doppler effect, as the widening due to collisions under the conditions prevailing in the upper atmosphere could be neglected. Therefore measurements of the width of the spectral lines made it possible to judge the temperature in the luminescent regions. However, the kinetic temperatures can be determined by the width of the spectral lines only if the atoms under study maintain a Maxwell distribution of velocities. In certain mechanisms of excitation (fluorescence, electron impacts), the kinetic energy of the particles shows practically no change. In these cases, the temperature determined by the width of the spectral lines coincides with the kinetic temperature in the luminescent region.

If excitation occurs as a result of dissociation, dissociation recombination, charge-exchange, etc., it may be accompanied by changes in the kinetic energy of the excited atoms. In this case the temperatures as determined by the width of the lines can differ noticeably from the kinetic temperature of the medium. However, if an atom in an excited state undergoes several collisions, then the Maxwell distribution of velocities will be restored and the reliability of the determination of temperatures will not depend upon the mechanism of excitation. Therefore forbidden emissions are the most convenient for determining the temperatures of the upper atmosphere (particularly at great altitudes).

It can be calculated that the time required for establishing a Maxwell distribution for neutral atoms at an altitude of 150 km is less than 1 second, at an altitude of 300 km less than 100 seconds, and at an altitude of 600 km less than 10^5 seconds. It can be seen then that in the case of the λ5577 Angstrom-unit (OI) line temperature measurements make sense at least up to altitudes of 150 km, for the λ6300 Angstrom-unit line (OI) up to 300 km, and for emissions of the λ5200 Angstrom-unit line (NI) up to 600 km.

Since electron impacts [1, 2] constitute the most probable mechanism of excitation, the temperatures measured by the width of these emissions apparently coincide with the kinetic temperatures at all altitudes of interest to us.

The fundamental shortcoming of the interferometer method for determining temperatures of the upper atmosphere is the uncertainty of the altitude of the luminescent layer. The altitude of clear-cut forms of aurora borealis (basically the λ5577 Angstrom-unit line) can be measured by base photography, but it is very difficult to determine the altitude of the aurora in the case of the almost uniform diffuse luminescence from emissions of λ6300 Angstrom units and λ 5198-5200 Angstrom units. Such simultaneous measurements have not yet been made at the station at Loparskaya. Thus at present it is possible to obtain only approximate evaluations of altitudes at which the temperatures are measured by the interferometer. As shown by Chamberlain [3], there are grounds for believing that the altitude of luminescence from emissions of λ 6300 Angstrom units in the night sky is about 250-300 km. Interferometer photographs of the red line in auroras indicate high-altitude auroras: red patches, red rays which are usually located at altitudes of not less than 200 km [4]. It is very difficult to evaluate the altitude of emissions of λ 5200 Angstrom units in aurora borealis. If we take into consideration the exceedingly small probability of transition (equal to 1.06×10^{-5} cm^{-1} [5], and the correlation of the intensity of λ 5200 Angstrom units with the intensity of the red oxygen emission, we can conclude that the altitude of λ 5200 Angstrom-unit luminescence is scarcely less than 300 km.

Not all photometric sections of the λ 6300 Angstrom-unit ring can be represented by a simple Doppler contour. Apparently, the deviation from the Doppler contour is explained by the superposition of luminescence of layers with different temperatures.

The temperatures determined by the width of the red line were concluded to be between 1200 and 3400° Kelvin. The accuracy of the determinations was ±15% in all cases. Measurements made under the conditions of an almost clear night sky with three photographs yielded values of 1230, 1120, and 1280° Kelvin. Thus the mean temperature was 1210 ± 50° Kelvin. This value agrees better with the accepted altitude of luminescence of the red line than the $T < 450$-550° Kelvin as measured by Dufay [6].

A tendency has been observed in auroras to increase in temperature with an increase in the brightness of luminescence. In type A auroras a temperature of about 1500° Kelvin was obtained with an intensity of the λ 6300 Angstrom-unit line of 2-5 kilorayleighs and 1700-2000° Kelvin with intensities of 5-15 kilorayleighs. During exceedingly strong red type A auroras on 17-18 December 1958, when simultaneous electrophotometric measurements by N. V. Dzhrdzhio indicated an intensity in excess of 80 kilorayleighs at λ 6300 Angstrom units, a temperature of 3400° Kelvin was registered.

Two photographs of interference rings of the forbidden doublet of atomic nitrogen at λ 5198-5200 Angstrom units were obtained during high-altitude red type A auroras on 27-28 March and 28-29 March 1959 with exposures of 4 and 5 hours. Typical "atomic" spectra were obtained on an SP-48 spectrograph during these nights [7] with sharply weakened emission from the 1NG N_2^+ band, while the (0--3) 1NG N_2^+ band at λ 5228 Angstrom units was markedly weaker than λ 5200 Angstrom units. The λ 5577, 5200, and 5198 Angstrom interference rings are visible in both photographs (refer to Figure 4) while the λ 5577 Angstrom-unit line is greatly weakened in the limb of the transmission curve of the interference filter. Measurements of the lengths of the waves confirms the identity of the observed emissions with the forbidden nitrogen doublet. The measured ratio of the intensities of the components of the λ 5198-5200 Angstrom doublet is $I_{5200}/I_{5198} = 1.7 \pm 0.1$. The temperatures determined by the width of the λ 5200 Angstrom-unit line are $1850 \pm 250°$ Kelvin for the first photograph and $2000 \pm 3000°$ Kelvin for the second.

Institute of Atmospheric Physics,
Academy of Sciences USSR

Submitted 7 July 1959.

LITERARY REFERENCES

1. M. J. Seaton, J. Atmosph. Terr. Phys. Vol. 4, 1954, page 306.

2. R. A. Duncan, Planet, Space Sci. Pergamon Press, Vol. 1, 1959, page 112.

3. J. W. Chamberlain, Ap. J. Vol. 127, 1958, page 54.

4. C. Stoermer, The Polar Aurora, 1955, page 109.

5. R. H. Garstang, M. N., Vol. III, 1951, page 115; Ap. J., Vol. 115, 1952, page 506.

6. J. Cabannes, J. Dufay, The Airglow and the Aurorae, London--New York, 1955, page 73.

7. Yu. I. Gal'perin, Sborn. Spektral'nyye, elektrofotometricheskiye i radiolokatsionnyye issledovaniya polyarnykh siyaniy i svecheniya nochnogo neba [Symposium. Spectral, Electrophotometric, and Radar Investigations of Auroras and Airglow], No. 1, 1959, page 7.

FIGURE APPENDIX

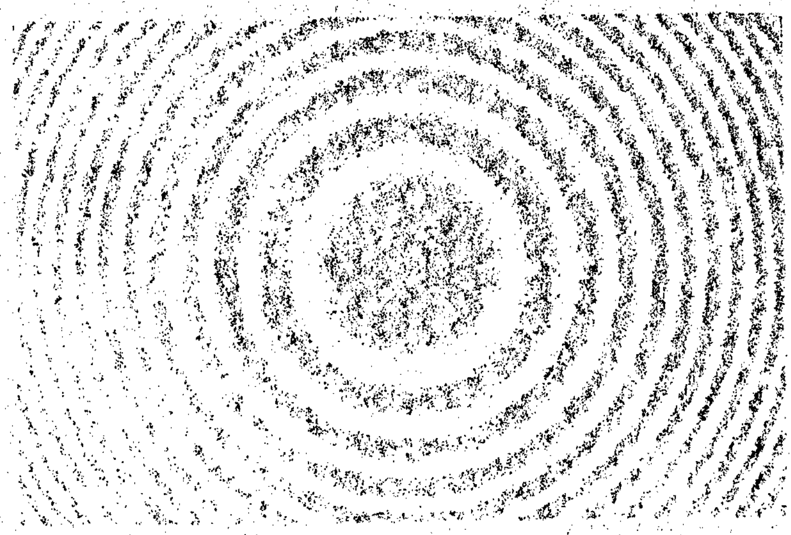

Figure 1. Interference rings of λ 6300 Å (OI). The photograph was taken during type A red luminescence with an exposure of one hour.

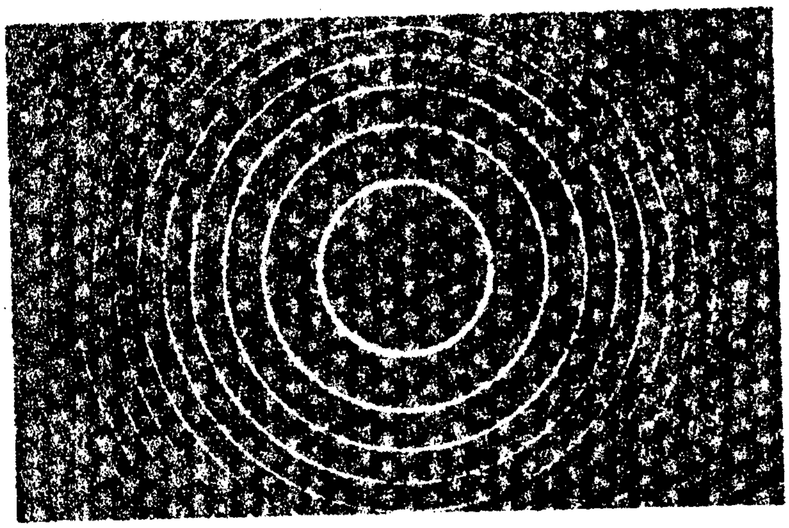

Figure 2. Interference rings of the yellow krypton line.

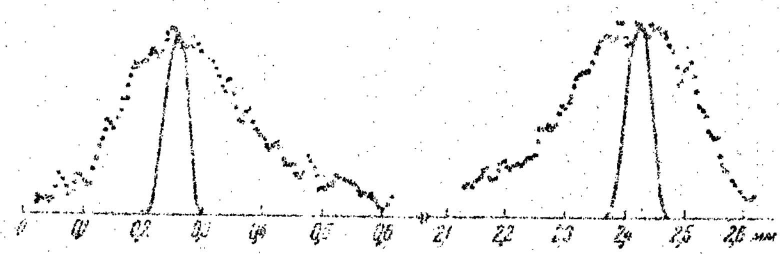

Figure 3. A photometric section of the inner ring of the λ 6300 Å line. The measurements were made with an MF-2 microphotometer. The apparent asymmetry of the contour is due to variable dispersion. The contour of the yellow krypton line (solid line) is shown for comparison.

5809

- END -