SOLAR CORONAL LINE PROFILES IN THE EXTREME-ULTRAVIOLET

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ABSTRACT

We report here the first direct measurements of the widths of the lines emitted by the solar corona from 170 to 370 Å. The transitions 1s-2p and 1s-4p in He \textsuperscript{i} are wider than 0.1 Å, perhaps showing the effect of optical depth. The lines of highly ionized O, Mg, Si, S, and Fe have widths which may be ascribed to a mean random turbulent velocity of about 30 km s\textsuperscript{-1} in addition to thermal Doppler broadening.

Subject headings: corona, solar — line profiles — ultraviolet

I. INTRODUCTION

A rocket spectrograph with a wavelength resolution better than 0.03 Å in the wavelength region 170-370 Å was flown aboard an Aerobee 150 rocket from White Sands Missile Range, New Mexico. The rocket was launched at 20:20 UT on 1969 May 16, and reached a peak altitude of 202 km. The spectrograph employed a concave gold replica grating (Bausch and Lomb) of 3-meter radius ruled with 1200 grooves mm\textsuperscript{-1} and blazed at an angle of 4°8'. The angle of incidence was 88°. The fixed entrance slit was 3 X 10\textsuperscript{-3} mm wide. The spectra were recorded on 101-05 Kodak glass plates. The wavelength analysis and line identifications of the spectra obtained from the flight were published by Behring, Cohen, and Feldman (1972). These papers include reproductions of the spectra.

In this Letter, we report measurements of the profiles of lines in the 170-370 Å wavelength region.

II. OBSERVATIONS AND RESULTS

The intrinsic line widths of nonflare coronal emission lines are due almost entirely to thermal Doppler effects and turbulent broadening (at least in the line core) because of the low density of the corona. For the permitted lines originating from highly ionized ions heavier than He, we can also assume that the corona is optically thin. Consequently, these line profiles may be approximated by a Gaussian with a full width at half-maximum (FWHM) of \( \Delta \lambda \), where

\[
\Delta \lambda / \lambda = [(\Delta \lambda \textsubscript{T} / \lambda)^2 + 4 \ln 2 (2kT / m + \bar{\sigma}^2 / \bar{\sigma}^2)]^{1/2}.
\]

Here \( \Delta \lambda \textsubscript{T} \) is the instrumental broadening, \( T \) is the ion temperature, \( m \) is the mass of the ion, and \( \bar{\sigma} \) is a mean random velocity for a turbulent structure with Gaussian velocity distribution. The factor \( (4 \ln 2)^{1/2} \) is required to change from \( \Delta \lambda \textsubscript{T} \) as usually defined (e.g., Gibson 1973) to the FWHM.

Laboratory spectra taken before and after the rocket flight showed instrumental broadening \( \Delta \lambda \textsubscript{T} \) less than 0.030 Å (FWHM). Since the solar lines were much wider, we considered whether any temperature changes, rocket vibrations, or grating aberrations could have broadened them during exposure, and we are unable to identify any such effect that would be sufficiently large.

The spectrum plates were traced on a Grant microdensitometer. A sensitometric curve was constructed by plotting the peak density against the flux using lines from 170 Å to 220 Å. The line fluxes were taken from a rocket experiment reported by Malinovsky and Heroux (1973). Our points fitted very smoothly to a single curve. This shows that in both flights the solar lines used had nearly the same relative intensities. The X-ray flux measured by SOLRAD 9 was nearly the same for both flights. This same characteristic curve was used for the longer wavelengths on the assumption that its shape does not change much over our wavelength range. The emission producing the line profiles discussed here comes from the entire Sun, except in the case of 304 Å. This line was measured on another spectrum taken with a very short entrance slit which gave an angular discrimination of 3' arc along an axis parallel to the horizon.

Figure 1 shows the first and third members of the resonance series, 1s-2p, of ionized helium. The other members are either weak or contaminated with other lines. For the L\( \alpha \) line at 304 Å, the dashed line profile (FWHM = 0.112 Å, after removing instrumental broadening) arising from the center of the Sun is significantly narrower than the solid line profile (FWHM = 0.125 Å) arising from the eastern quarter of the disk, showing perhaps the effect of increased optical depth. The active...
regions were all on the western half of the disk. For the Ly line at 243 Å the FWHM = 0.102 Å.

For the ions of the heavier elements O, Mg, Si, S, and Fe, the ion temperatures were approximated by taking the ionization equilibrium temperatures given by Jordan (1969). Using these in the above equation along with Δλ_γ = 0.025 Å, we obtained a mean random velocity for each line. The range of velocities from 25 to 40 km s\(^{-1}\) may represent the experimental accuracy. The average for 35 lines is a little over 30 km s\(^{-1}\).

Figure 2 shows two examples of line profiles, each compared with a Gaussian profile. The two lines for which good profiles are available in both first and second order (177.2 and 182.1 Å) give good agreement for a mean random velocity of 34 km s\(^{-1}\) provided we take Δλ_γ = 0.025 Å for the instrumental line width.

The forbidden coronal lines in the visible wavelength range do not indicate such a high turbulent velocity (Billings 1966). This is not necessarily in contradiction to our result because most of the extreme-ultraviolet flux comes from the portion of the corona below the lowest level at which visible observations have been made.

We are preparing a more detailed discussion of the rocket experiment data, including the results from a flight on 1973 September 21 which recorded lines up to 770 Å.

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REFERENCES