THE EFFECT OF CORONAL EXPANSION ON THE SHAPE OF THE 530.3 nm CORONAL LINE

E. Dzifčáková, M. Rybanský
Astronomical Institute, Slovak Academy of Sciences,
059 60 Tatranská Lomnica, Czechoslovakia

ABSTRACT. The dynamical effect of the expansion corona on the coronal emission line profile 530.3 nm is examined. The magnitude of this effect is calculated as the function of the expansion velocity. It is showed, the broadening of the line profile is possible explained also the radial expansion of the solar corona. This hypothesis need a comparsion and a verification with the experimental data.

ВЛИЯНИЕ ЭКСПАНСИИ КОРОНЫ НА ФОРМУ КОНТУРА КОРОНАЛЬНОЙ ЛИНИИ 530.3 нм: В статье исследуется влияние экспансии короны на контур корональной эмиссионной линии 530 .3 нм. Величина этого эффекта определяется в зависимости от скорости экспансии. Показано, что уширение контура спектральной линии можно обяснить тоже радиальной экспансией солнечной короны. Гипотеза требует экспериментального потверждения.

VPLYV EXPANZIE KORÓNY NA TVAR PROFILU KORONÁLNEJ ČIARY 530.3 nm: V článku je skúmaný vplyv expanzie koróny na profil koronálnej emisnej čiary 530.3 nm. Veľkosť tohoto efektu je vyjadrená v závislosti na rýchlosti rozpínania a je ukázané, že rozšírenie profilu spektrálnej čiary je možné vysvetliť aj radiálnou expanziou slnečnej koróny. Hypotéza potrebuje experimentálne overenie.

According to Billings (1966), as early as in 1938 Waldmeier put forward the hypothesis that the broadening of coronal emission lines can be explained as due to the radial expansion of coronal matter, i.e. even before coronal lines had been identified. Since the time it was discovered that coronal lines originate in ions with a high degree of ionization, it has been generally accepted that coronal matter has a high temperature, of the order of 10^6 K. After the expansion of the corona had been discovered, no attention was paid to the shape of coronal lines.

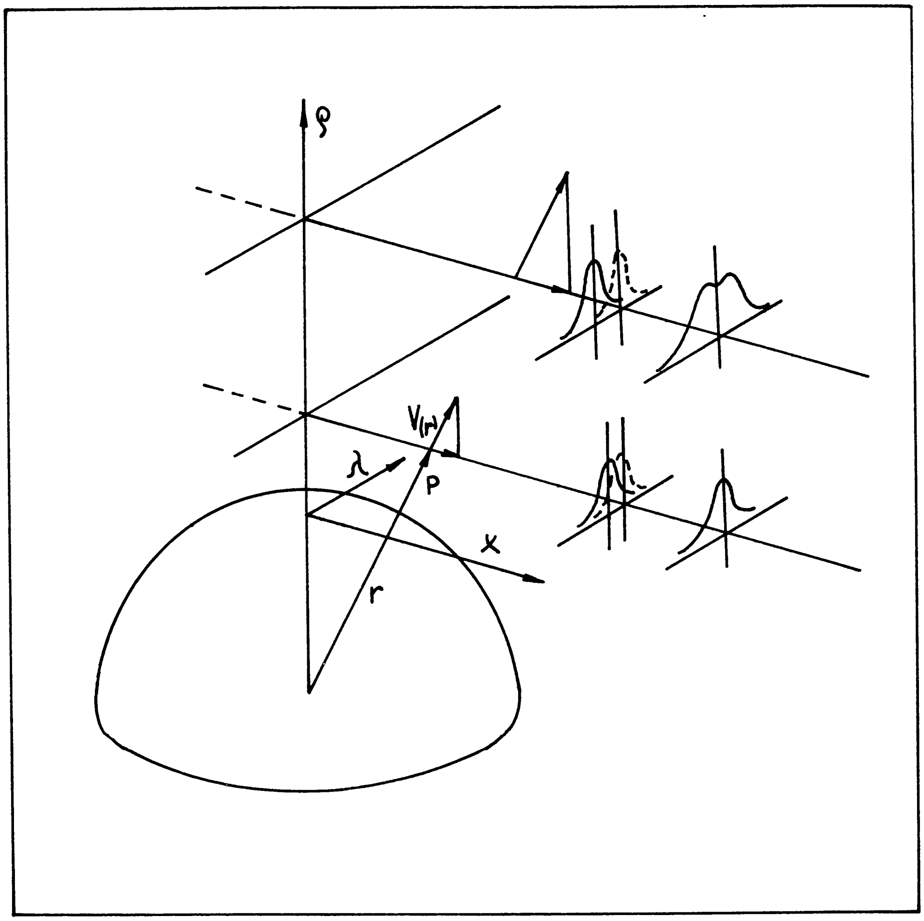

Fig. 1: The shape of the coronal emission line profile as a function of high (for details refer to text).

In the present paper, the authors have developed the idea od Dr. V.E. Stepanov according to which it is possible to determine the rate of expansion of coronal matter as a function of high above the photosphere by measuring the changes of the shape of emission lines with high, provided certain conditions are satisfied.

Measurements have proved that the shape of coronal emission lines can be approximated by Gauss' function, which is interpreted as a thermal expansion of the profile with the Doppler halfwidth δ . By Doppler halfwidth we understand half the width of the spectral line at the point where its intensity is e^{-1}-times that in the line's maximum. In all of our further deliberations, we shall assume that the ion temperature in the corona remains constant with high, i.e. that the profile halfwidth δ is constant and independent of high in

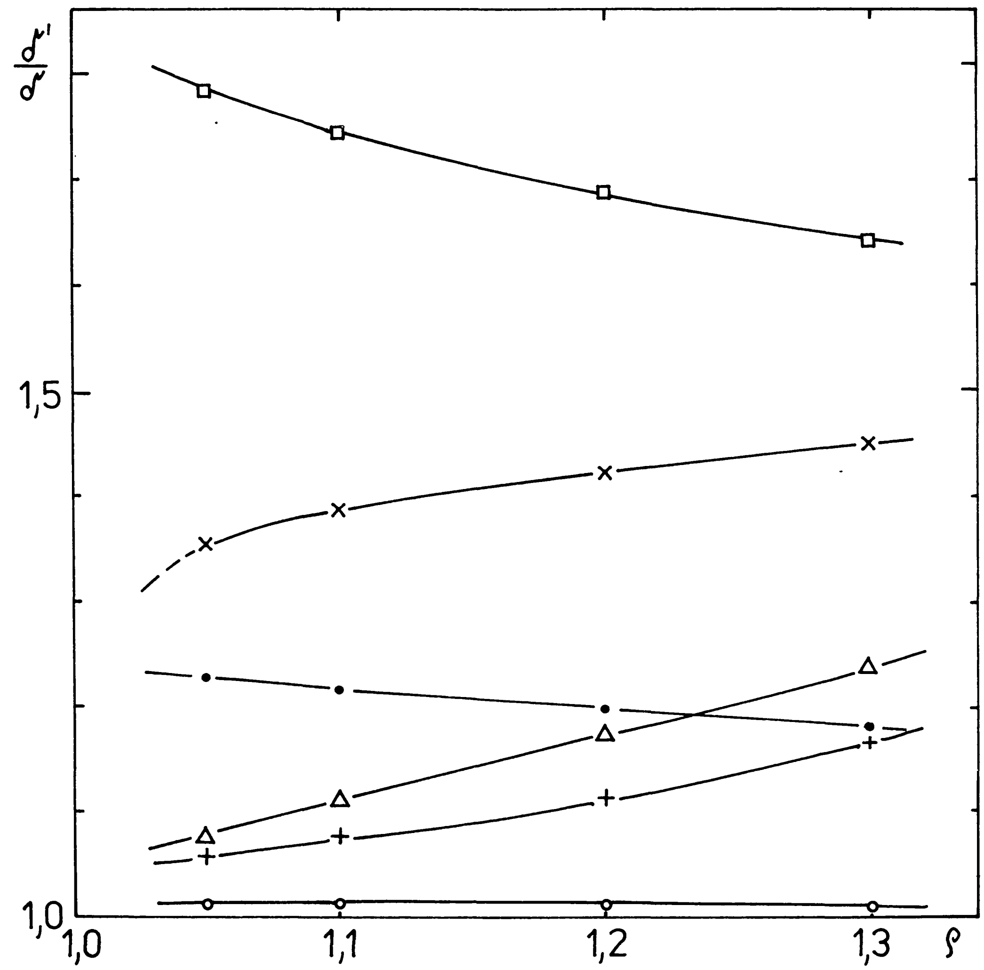

Fig. 2: Change in the halfwidth of the coronal emission line for δ = 0.05, v(r) = 10 km s^{-1} (o); 50 km s^{-1} (o); 100 km s^{-1} (●); v(r) = kr + q, v(1 R_0) = 10 km s^{-1}, v(4 R_0) = 300 km s^{-1} (+); v(r) = kr + q, v(1 R_0) = 10 km s^{-1}, v(10 R_0) = 300 km s^{-1} (Δ); v(r) = k 1 - exp(qr) , v(10 R_0) = 0.9 v , v = 300 km s^{-1} (x).

a static corona.

Assume that the matter in a volume elemnt at point P is moving at velocity v(r). The x-direction is that towards the observer. Then, as a result of the Doppler effect, the emitted spectral line will be displaced by

$$\Delta\lambda = -(v_x/c)\lambda_0 = c^{-1} v(r)\, x\, (\rho^2 + x^2)^{-\frac{1}{2}} \lambda_0, \qquad (1)$$

where r and ρ are distance from the Sun's centre in units of the solar radius.

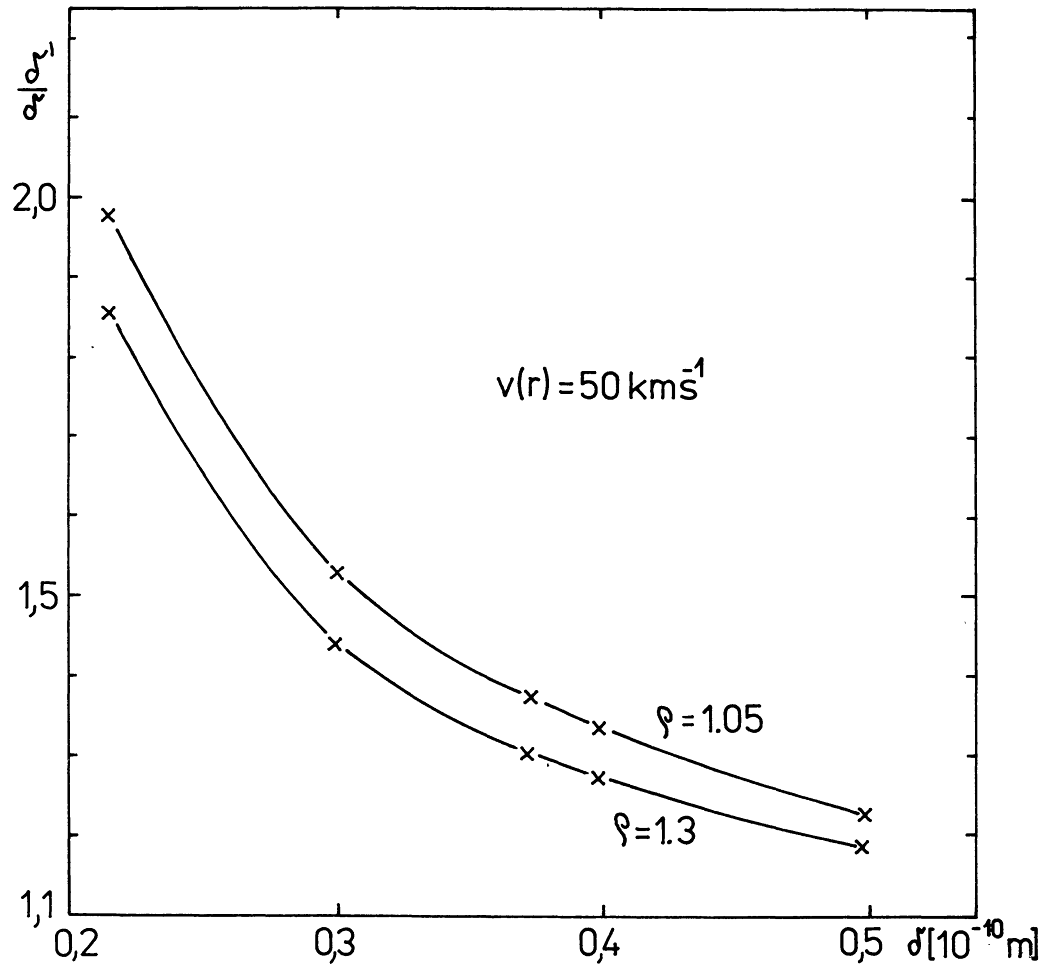

Fig. 3: Changes of the ratio δ'/δ for various values of δ when the corona is expanding at a constant rate of v = 50 km s^{-1}.

The emissivity at the given point for a line with a Gauss profile is

$$\varepsilon(r) = i_0(r) \int_{-\infty}^{\infty} \exp\{-[\delta^{-1}(\lambda - (\lambda_0 + \Delta\lambda))]^2\} \, d\lambda = i_0(r)\,\delta\sqrt{\pi}, \quad (2)$$

where $i_0(r)$ is the intensity in the maximum of the spectral line at distance r, and its total intensity above the limb (determined by integrating along the line of sight) is

$$J(\varrho) = \int_{-\infty}^{\infty} \varepsilon(r)\,dx = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} i_0(r) \exp\{-(\delta^{-1}(\lambda - [\lambda_0 + \Delta\lambda]))^2\} \, d\lambda \, dx \quad (3)$$

However, the emissivity can also be determined from the intensity of the coronal line measured above the limb and from its gradient $dJ(\varrho)/d\varrho$ (Rybanský 1975):

$$\mathcal{E}(r) = -(J_0/\pi) \int_r^{\infty} [dJ(\rho)/d\rho] \ (\rho^2 - r^2)^{-\frac{1}{2}} d\rho \ . \tag{4}$$

Function $J(\rho)$ can be approximated well by the exponential function (Rušin 1973)

$$J\ (\rho) = J_0 \alpha \ \exp(-\beta \rho\ ), \tag{5}$$

where J_0 is the intensity of the coronal line at the reference distance. The emissivity then reads

$$\mathcal{E}(r) = (J_0/\pi\ )\alpha \beta \ \exp(-\beta r) \int_0^{\infty} \exp(-\beta x) [x(x + 2r)]^{-\frac{1}{2}} dx \doteq \doteq J_0 \alpha \sqrt{\beta} \ \exp(-\beta r)\ (2\pi r)^{-\frac{1}{2}} \ . \tag{6}$$

By combining (2) and (6), Eq. (3) will the yield

$$i(\lambda, \rho\ ) = A \int_{-\infty}^{\infty} \exp[-\beta \sqrt{(\ ^2 + x^2)}] (\rho^2 + x^2)^{-\frac{1}{4}} \exp\{-([(\lambda - \lambda_0)/\delta] + + v(r) \lambda_0 x \delta^{-1} c^{-1} (\rho^2 + x^2)^{-\frac{1}{2}})^2\} \, dx. \tag{7}$$

Equation (7) implies that, for an isothermal, spherically symetrical corona and the given (measured) gradient of the intensity of the coronal line with a Gauss profile above the solar limb, the spectral distribution of the intensity in the line depends only on the form of function $v(r)$.

Measurements of the Doppler shifts of spectral lines in the lower corona indicate rates of expansion of the order of 10 km s^{-1}. Close to the Earth, under quiescent conditions, the solar wind velocity is between 300 and 400 km s^{-1} (Brandt, 1970). This is what we based the mathematical form of function $v(r)$ on. The computations were made for the green coronal line. The gradient of intensity of the green line has been given by Rušin (1973). The mean values of the coefficients are $\alpha = 6.33 \times 10^4$, $\beta = 11.05$, provided the distance is expressed in solar radii. The results are illustrated in Fig. 2. The horizontal axis gives the distance from the solar centre in solar adii, the vertical axis the increase in Doppler width δ' relative to Doppler width δ of profile, broadened only thermally. If $v(r)$ is an increasing function, also increases. It is interesting to note that, if the corona expands at a constant rate, δ' decreases with increasing distance in spite of δ being constant.

Figure 3 demonstrates the effect of the change in δ on the ratio δ'/δ as the corona expands at a constant rate. The figure shows that the ratio δ'/δ increases rapidly as δ (temperature) decreases.

The results of the computations indicate that the radial expansion of coronal matter also contributes to broadening the coronal emission lines, the amout of this contribution increasing with the rate of expansion and with decreasing ion temperature. At high rates, the observed halfwidth δ' depends but little on the original δ .

According to (7), the shape of the coronal emission line profile differs only little from the Gaussian (less than 5%). The largest deviations are in the line wings. Consequently, if the measurements of the coronal line profile and its changes were measured with greater accuracy even at large distances from the limb, it would be possible to determine the rate of radial expansion of the corona. However, observations are lacking. Only profiles measured up to a maximum high of 1.2 R_o with insufficient accuracy are available, and thesecannot be used to determine whether the halfwidth increases or decreases with high.

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