THE K-CORONA UNDER HYDROSTATIC DENSITY DISTRIBUTION; RELEVANCE TO SOLAR WIND

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ABSTRACT. The comparison of the observed surface brightness of the solar corona with the theoretical curves has corfirmed the conclusion about the hydrostatic density distribution at heliocentric distance smaller than 2.5 $R_{\odot}$.

К-КОРОНА С ГИДРОСТАТИЧЕСКИМ РАСПРЕДЕЛЕНИЕМ ПЛОТНОСТИ, ЗНАЧЕНИЕ ДЛЯ СОЛНЕЧНОГО ВЕТРА: Сравнение наблюдательных данных об яркости короны Солнца с теоретическими кривыми привело к заключению о гидростатическом распределении плотности в короне до гелиоцентрического расстояния меньшего чем 2.5 $R_{\odot}$.

K-KORÓNA S HYDROSTATICKÝM ROZDELENÍM HUSTOTY, VÝZNAM PRE SLNEČNÝ VIETOR: Porovnanie pozorovacích údajov o jasnosti koróny s teoretickými krivkami potvrdilo závery o hydrostatickom rozdelení hustoty do heliocentrických vzdialeností menších ako 2,5 $R_{\odot}$.

The surface brightness B depending on the distance from the disc center ρ is the observable in studying the physical conditions in solar corona. Ordinarely, the distribution of density n as a function of heliocentric distance r is inferred from the observed trend of $B(\rho)$ and, after that, one can draw relevant conclusion concerning the physical model of the corona from the dependence n(r) [1, 2, 3] . We proposed a different approach to the problem [4, 5]. Physical considerations are used a priori to specify a model for density distribution in the corona; this model is used to calculate the expected dependence $B(\rho)$ which is then compared with observational data. The approach makes it possible not only to arrive at definite conclusions concerning the adoptability of the model assumed, but also readily obtain the parameters describing the coronal plasma.

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To calculate $B(\varrho)$ the following assumptions have been adopted:

1/ the corona is homogeneous,

2/ T = const

3/ the density distribution is described by the hydrostatic law

$$n(r) = n(R_{\bullet})\exp\left[-\frac{\mu m_H g_{\bullet} R_{\bullet}^2}{k\,T}\left(\frac{1}{R_{\bullet}} - \frac{1}{r}\right)\right] = a\ e^{b/r} \qquad (1)$$

The third assumption is founded on the following considerations. First, gravitation and gas pressure are the main factors specifying the density distribution in the middle corona, and the influence of forces, which may have seriously violated the hydrostatic distribution, seems to be small. Second, the variation n(r), obtained in [2, 3] and in other papers, as soon as the empirical formula by Newkirk

$$n(r) = 4.2 \times 10^4 \times 10^{4.32\ R_{\bullet}/r} = 4.2 \times 10^4 \times e^{9.95\ R_{\bullet}/r} \qquad (2)$$

show that at least to $2\ R_{\odot} - 2.5\ R_{\odot}$ the density distribution may be considered as hydrostatic. Certainly, it does not mean, that the corona is completely static in these layers. It is quite possible that there exist the motion of the whole coronal plasma with small velocities, or the high-speed streams is small volumes, that do not affect the observed distribution of brightness.

As it was shown in [4, 5] , at $r > 1.2\ R_{\odot}$, the dilution factor being expanded in series, we get the expression for $B(\varrho)$ as as following

$$B(\varrho) \sim a \int_{\varrho}^{\infty} \frac{e^{b/r}\ dr}{r\sqrt{r^2 - \varrho^2}} \qquad (3)$$

(r is heliocentric distance, ϱ is the distance from disc center in the picture plane). The integral in Eq. (3) may be expressed anaôytically, which gives

$$B(\varrho) \sim \frac{n(R_{\bullet})}{\varrho}\ I_0\ (b/\varrho) \qquad (4)$$

where $I_0(b/\varrho)$ is the zero-order modified Bessel function of a pure imaginary argument. As it follows from Eqs. (1) and (2), $b/R_{\odot} \sim 10$ for the Sun, therefore

$$B(\varrho) \sim \frac{n(R_{\odot})}{\sqrt{\varrho}}\ e^{b/\varrho} \qquad (5)$$

This means (see [4, 5]) that the dependence of ln B on $1/\varrho$ is in practice linear for the middle corona at $1.2\ R_{\odot} < \varrho < 2.5\ R_{\odot}$, and the inclination angle of the straight line ln B makes it possible to define the coronal plasma temperature. The comparison with observations carried out in [4, 5] has shown that thus obtained temperature coincides with the T-values defined by the standard methods.

Thus,

1. The $B(\varrho)$ curve shape is a consequence of the fact that density distribution in layers $r < 2.5\ R_{\odot}$ is hydrostatic. In contrast to the Baumbach treatment, $B(\varrho)$ is expressed by the parameters describing the coronal plasma.

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2. The deviation of ln B from the straight line may have been used as a measure of the difference between the real and hydrostatic density distributions, which may be most naturally attributed to coronal plasma outflow of solar wind type. The $B(\rho)$ shape may be used to verify the theoretical models for solar wind source.

Further, the following questions were considered:

1. Calculation of polarization emission characteristics [7]. The use of the polarization brightness allows, first, to obtain the observational data not spoiled by the F-component effect, and second, the treatment makes allowance for the anisotropy of the photospheric emission scattering. The comparison of the observed data with the theoretical curves carried out in [7], has confirmed the conclusion about the hydrostatic density distribution at $r < 2.5\ R_\odot$.
2. The models for hydrodynamic coronal expansion of Parker solution type. The main conclusion [8, 9] is that the deviation of observed values of ln pB at $R_\odot/\rho < 0.4$ from theoretical curve calculated under asumption of hydrostatic density distribution may probably indicate the existence of the plasma outflow of solar wind type, the velocity of this outflow is in excess of sonic velocity at about $5\ R_\odot$.
3. The plasma outflow from the coronal hole areas [10]. The character of variance of $B(\rho)$ for the coronal holes has been found the same as for the quiet corona. It was obtained that for coronal holes $n(R_\odot) \approx 7 \times 10^7\ cm^{-3}$ and the outflow velocity v is about 100 km s^{-1} at $r \sim 4\ R_\odot$.

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DISCUSSION

J. Sýkora
Ваше первое предположение говорит о том что корона однородная. Мы все знаем что в действительности она совершенно структуральна. Как Ваше настолько противоречимое предположение влияет на полученные выводы и результаты ?

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Yes, that's right. The corona consists of the structural elements. The effect of these elements was discussed in (Badalyan and Livshits, Astron. Zh. 1985, 62, 132). The main conclusion we have arrived at is that the linear dependence of ln B on $1/\rho$ does not violate if the temperatures and densities of the structural element are not too far from their mean values. Of course, in defining the density distribution we get some mean value of n. But it should be emphasised that we deal with the emission integrated over the line of sight (that is the inverse problem is solving), and therefore to determine the structural element characteristics is not easy at any approach to the problem.

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