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V. V. Vitkevich

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Abstract

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V. V. Vitkevich

THE STRUCTURE OF THE SOLAR SUPERCORONA

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1. Since 1951, when the author first discovered a new type of eclipse—the eclipse of discrete sources of radio emission by the solar corona—and detected the solar supercorona (^{1},^{2}), the "transillumination" method has undergone considerable development. By the present time extensive material has been accumulated from radio observations of the solar supercorona; in particular, there are many data on the scattering of radio waves as they propagate through it. Later, beginning in 1954, some optical studies of the supercorona were carried out. Work (^{3}) contains information on its mean electron concentration out to distances of $20R_{\odot}$, and work (^{4}) information on its inhomogeneity. The question now arises of jointly discussing the optical and radio data and of identifying the structure of the supercorona. Such attempts were made earlier (^{5},^{6}), but at that time there were few observational data, and the principal factor—the elongation of the inhomogeneities of the supercorona—was not taken into account.

Table 1

$r/R_{\odot}$	N_e	n_0
3	$3.4 \cdot 10^5$	3.23
5	$6.9 \cdot 10^4$	3.3
8	$1.8 \cdot 10^4$	2.56
12	$6.6 \cdot 10^3$	2
16	$3.7 \cdot 10^3$	1.63
18	$3.0 \cdot 10^3$	1.4

Let us compare the rate of change of the electron concentration as a function of distance from the center of the Sun according to optical and radio data.

Table 1 gives the values of the mean electron concentration N_e according to Blackwell (^{3}) and the exponent n_0 of the degree of decrease of the electron density; $r/R_{\odot}$ is the distance from the center of the Sun, expressed in solar radii; n_0 is determined by the expression

$$n_0(r) = n_0\left(\frac{r_1 + r_2}{2}\right) = \frac{\lg[N_e(r_2)/(N_e(r_1))]}{\lg(r_1/r_2)}; \tag{1}$$

r_1, r_2 are distances from the center of the Sun.

It is seen that the quantity n_0 decreases rapidly with increasing r, changing from 3.3 at $r \sim (5 \div 6)R_\odot$ to ~ 1.5 at $r \sim (16 \div 18)R_\odot$. Consequently, the rate of decrease of the mean electron concentration in the corona (measured from optical observations) sharply diminishes as the distance increases within the indicated limits. Let us recall that optical observations give the arithmetic mean value of the electron concentration.

2. Turning to radio observations, we shall analyze how the angle of scattering of radio waves in the supercorona, Φ_r, changes as a function of distance, and shall also find the quantity $n_\varphi(r)$—the exponent for the scattering angle Φ_r for the direction of the interferometer baselines east-west.

The 10 most reliable eclipse curves obtained over the entire period of studies of the solar supercorona by foreign authors (mainly English), as well as observational data from the Physi-

tical Institute named after P. N. Lebedev of the Academy of Sciences of the USSR (^{7,8})—16 eclipse curves in various years (1951-1958).

The calculation showed that the values of the quantity $n_\varphi(r)$, obtained from the two series of observations, lie comparatively close to one another ($n_\varphi = 1.9 \pm 0.6$) and do not vary with distance r. We shall be interested below in the radial component of the inhomogeneities, which produces scattering in the direction perpendicular to the radial one.

It is easy to establish a relation between Φ_r—the value of the scattering angle obtained from measurements on the east-west radio-interferometer baseline—and Φ_p—the scattering perpendicular to the radial direction with respect to the Sun; then from the value of n_φ one can obtain n_p; in the conversion, however, the ratio b/a of the semiaxes of the scattering ellipse enters.

The calculations performed lead to a value for the scattering angle $n_\mathrm{p} \sim 1.5$. However, as was shown in (^{9}), this same exponent is also retained for the electron concentration of the inhomogeneities producing the indicated scattering in the case where they have a conical form.

3. Comparing the values of n_p and n_0, we arrive at the following conclusion. At $r \approx (5 \div 10)R_\odot$, $n_0 > n_\mathrm{p}$. Then n_0 rapidly decreases with distance, and at $r = (15 \div 17)R_\odot$, to within the accuracy of the measurements and the uncertainty of the correction for the shape of the scattering ellipse b/a, n_φ coincides with n_p.

Let us represent the supercorona as consisting of two electron components. One component is diffuse, with a uniform distribution of electron concentration; as radio waves propagate through it, they undergo no scattering.

The second component is in the form of radial rays with an electron concentration exceeding the electron concentration of the diffuse medium; these radial inhomogeneities produce scattering.

The density of the diffuse component (d.c.) decreases rapidly as $r/R_\odot$ increases; the density of the radial (ray) component (r.c.) decreases slowly. The total number of electrons in the d.c. at $r \sim (5 \div 10)R_\odot$ is noticeably greater than in the r.c. Conversely, at $r \geq 12R_\odot$ the total number of electrons may be comparable or even greater in the r.c.

Thus, radial inhomogeneities permeating the diffuse component have a relatively small specific weight (in terms of the total number of electrons) in the inner regions of the supercorona, but as r increases their specific weight grows; it is quite probable that at $r \geq 15R_\odot$ the entire supercorona consists only of radial inhomogeneities.

The concrete numerical characteristics of both components cannot be determined unambiguously; nevertheless, various models can be constructed that satisfy the general scheme.

For example, let us assume that the inhomogeneities are conical and radial; let us assume that the electron concentration of the inhomogeneities at $r = 17R_\odot$ is 50 times higher than the diffuse one, and that the total number of electrons in the d.c. and r.c. at this distance is the same. Then the porosity coefficient $K = 50$, and the transverse linear size of an inhomogeneity is 7 times smaller than the distance between them. At $r = 5R_\odot$ the geometry is preserved; however, the complete mean number of electrons in the d.c. is 7 times greater than in the r.c., and the concentration ratio is about 7.

What is the physical nature of the two components, and is it different? Apparently, there must be a substantial difference between the components. The diffuse component, in view of the large values of n_0, is possibly on the whole in hydrostatic equilibrium. It is unlikely to be characterized by rapid motions. Conversely, the ray component of the plasma is, apparently, in continuous motion. This motion is predominantly radial. The indicated motion also creates the solar "wind," detected by direct rocket observations (^{10}).

The nature of the origin of the ray component has not been established. However, it is possible that at the basis of the origin of each inhomogeneity lies a spi-

a spicule—a microflare on the Sun; they are observed both during periods of maximum and minimum solar activity, and the supercorona of the Sun is observed in the same way.

In any case, individual streams of the solar "wind" are apparently associated with certain active formations on the Sun.

P. N. Lebedev Physical Institute
Academy of Sciences of the USSR

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REFERENCES

1. V. V. Vitkevich, DAN, 77, No. 4 (1951).
2. V. V. Vitkevich, Astr. zhurn., 32, No. 2 (1955).
3. D. E. Blacwell, Monthly Notices Roy Astr. Soc., 116, 56 (1956).
4. S. M. Poloskov, A. E. Mikirov, Report at the COSPAR symposium, Washington, 1963.
5. V. V. Vitkevich, Astr. zhurn., 35, No. 1 (1958).
6. H. Scheffler, Zs. Astrophys., 45, 113 (1958).
7. V. V. Vitkevich, Astr. zhurn., 37, 1 (1960).
8. V. V. Vitkevich, B. N. Panovkin, A. G. Sukhovei, Izv. vyssh. uchebn. zaved., Radiofizika, 2, No. 6 (1959).
9. V. V. Vitkevich, Izv. vyssh. uchebn. zaved., Radiofizika, 3, No. 4 (1960).
10. C. W. Cneyder, Report at the COSPAR symposium, Warsaw, 1963.

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