ON THE 3D SOLAR CORONA STRUCTURE

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Abstract. We consider the 3D structure of the solar corona using eclipse observations. We use a pseudostereoscopic effect of the rigidly rotating corona to determine the true position of the main coronal structures: broad threads, rays and streamers. We find that observations collected by the “Multi-station International Coronal Experiment” are well suited for solving this problem. Formula and error estimation are given to demonstrate the feasibility of the method. An example of stereo-view deduced from a simple analysis of results coming from the 1991 eclipse is given. The observed apparent shifts allow for the first time to apprehend the true 3D structure of the corona. The structure of streamers was compared with the peculiarities (pleats and cusps) of the solar heliosphere current sheet, deduced from the source surface. The positions of the two main streamers systems rays (near the N-E and S-limb) coincide with the pleats of the current heliosphere layer. We conclude that large helmet streamers are composed by the pleats of the heliosphere current sheet projected on the plane of the sky.

Key words: Corona – Eclipse – Helio-Sheet

1. Introduction

There is a general consensus for considering that the solar corona is structured and that structures are due to the solar magnetic fields induced from currents at the surface of the Sun and, possibly, in situ in the corona (Priest, 1982). Coronal inhomogeneities are well observed on radially compensated eclipse pictures (Koutchmy, 1977) taken in white-light or in coronal emission lines (Allen, 1975). Reminding that the plasma is fully ionized, the rather large density inhomogeneities are evidenced on eclipse white-light (WL) pictures thanks to the Thomson scattering of the solar light on free electrons. At equal radial distances, pressure differences observed at the edges of a structure are obviously balanced by the local magnetic field pressure; the field is not yet carried out by the wind in the intermediate corona. The origin of the coronal magnetic field is not well understood.


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Indeed, multiple attempts have been made to infer the structure of coronal magnetic field lines from the observed line of sight component of the magnetic field in photospheric layers (Ambrož, 1989). Currents are ignored, although twisted structures are observed everywhere, and more importantly, the canopy field observed below the corona is also fully ignored. Further, it is not clear what fields in the photosphere or the chromosphere are important when comparing coronal structures: those from sunspots (Altschuler, 1971), those from coronal holes edges (Levine et al., 1977) or those associated with prominences and filaments (Sturrock et al., 1968, Koutchmy et al., 1984, 1985). A fundamental result which emerged from more than 2 decades of efforts is the importance of coronal holes (with no photospheric counterparts) especially in polar regions, and of the equatorial “belt of magnetic activity” which seems well representative of the coronal structure responsible for the 3D-helio-sheet (Hoeksema, 1968).

When a detailed analysis of coronal structure is made one is immediately faced with the question of interpreting a 3D-distribution of structures projected on the plane of the sky, which is what we observe in white-light during eclipses. The WL corona is obviously optically thin and polarized. The use of the polarization ratio should be helpful but far from being sufficient and is even ambiguous (Saito, 1972). With the use of externally occulted space-borne coronographs, the corona has been pictured many times during its rotation and an attempt was made to use the rotation for analysing the 3D structure of the June 1973 corona (Wilson, 1977). It did not work well for several reasons: i) the lack of a spatial resolution good enough to measure small shifts, ii) the shadow of the pylons supporting occulting discs, iii) the intrinsic coronal changes due to dynamical effects in the corona when day-to-day observations are used, iv) the absence of data in the most interesting region situated between the surface and 1 solar radii ($R_\odot$) from the surface, due to the externally occulting out-of-focus discs. We note that snapshots taken during total eclipses avoid these defects, although data covering a rather limited time lapse can be collected only during the crossing of the Earth by the shadow of the Moon (typically a few hours). A last objection, related to point iii), could be put forward: what about the flow responsible for the solar wind? We think that this objection falls down when numbers are considered: the flow is mainly along the structure and we consider here effects produced by the quasi-rigid rotation and moreover, it is not demonstrated that the solar wind flow occurs in dense coronal structures; downflows cannot be totally excluded. In this respect, our approach could also be considered as a possible way to get some insight in the problem of the source of the solar wind.

2. The Pleats of the Heliospheric Current Sheet

Koutchmy (1972) mentioned for the first time that the edges of ray structures coincide with filaments, i.e., the so called neutral line $B_r = 0$ on the surface of the Sun. On
the other hand at the distance $h > 5R_\odot$ the current heliospheric sheet has a relatively high density of plasma. And this sheet is located at the surface $B_r = 0$.

It is possible to construct this surface, assuming that it is pulled on two lines, one of them is the neutral line on the source surface and the other - is the magnetic equator of the Sun at $r \to \infty$. In Fig. 1 the map of the magnetic field on the source surface is shown for July 1991 (taken from Solar Geophysical Data). In spherical coordinates $\theta, \varphi$ the equation of the equatorial plane of the dipole is $\theta = -\arctg\left(\frac{m_x}{m_z}\sin \varphi + \frac{m_y}{m_z}\cos \varphi\right)$, where $m$ is the dipole moment ($m^2 = 1$). The minimal deviation of $\theta$ from the line $B_r = 0$ of Fig. 1 corresponds to $m_x/m_z = 0.1$, $m_y = 0$ and these parameters determine the magnetic equator. Than we assume that the surface consists of the straight lines. This surface is shown on (stereo-picture) Fig. 2. One sees two pleats arising as a result of the projection of the surface on the plane of the sky. The positions of these pleats correspond to the main helmet streamers on 11.07.91.

3. Conclusions

a/ The limited resolution that we reach in the analysis of the July 11, 1991 eclipse corona is enough to demonstrate the 3D structure of the corona.

b/ Large coronal helmet streamers can be interpreted as pleats of the heliospheric current sheet.

c/ To look more carefully at the 3D structure of the corona, several improvements could be made in the future. First, data on polarization ratio of structure's WL brightness should be used (Saito, 1972). It is well known that the polarization ratio is a function of $z$ and $r$. Furthermore, properties resulting from the theory of continuous mapping of surfaces (theory of “catastrophes”) could be introduced. Such improve-
ments in the simple theory will greatly improve the precision of the analysis and possibly fully resolve the old problem of knowing the 3D structures of the corona.

References

*Solar Geophysical Data*: 1991

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