

ORIGINAL ARTICLE

Influence of projection effects on the observed differential rotation rate in the UV corona

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Abstract Following previous investigations by Giordano and Mancuso [1] and Mancuso and Giordano [2,3] on the differential rotation of the solar corona as obtained through the analysis of the intensity time series of the O VI 1032 Å spectral line observed by the UVCS/SOHO telescope during solar cycle 23, we analysed the possible influence of projection effects of extended coronal structures on the observed differential rotation rate in the ultraviolet corona. Through a simple geometrical model, we found that, especially at higher latitudes, the differential rotation may be less rigid than observed, since features at higher latitudes could be actually linked to much lower coronal structures due to projection effects. At solar maximum, the latitudinal rigidity of the UV corona, with respect to the differential rotating photosphere, has thus to be considered as an upper limit of the possible rigidity. At solar minimum and near the equatorial region throughout the solar cycle, projection effects are negligible.

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Introduction

The coronal rotation rate and its variation as a function of height and heliographic latitude remains as yet a poorly understood and debated topic. In fact, quantifying the coronal rotation rate critically depends upon both the applied methods of data reduction and the type of analysed data. The rotation rate in the solar corona has been studied by means of different

coronal tracers over an extended set of wavelengths, covering the range from radio to X-rays. In the past few years, the analysis of a full decade of data obtained by telescopes aboard the Solar and Heliospheric Observatory (SOHO; [4]) spacecraft, has allowed to study the temporal variation in the coronal rotation rate for the whole solar cycle 23. In particular, time-series observations of the coronal O VI 1032 Å spectral line intensity provided by the UltraViolet Coronagraph Spectrometer (UVCS/SOHO; [5]) telescope on board SOHO have been effectively used to study the differential rotation of the solar corona during minimum [1] and maximum [2] solar activity and throughout the whole solar cycle [3]. The work of Giordano and Mancuso [1] confirmed the already established result that the corona, during minimum activity, tends to rotate with a less pronounced differential rotation than the plasma of the photosphere. The estimated equatorial synodic rotation period of the corona was ~ 27.5 days. Mancuso and

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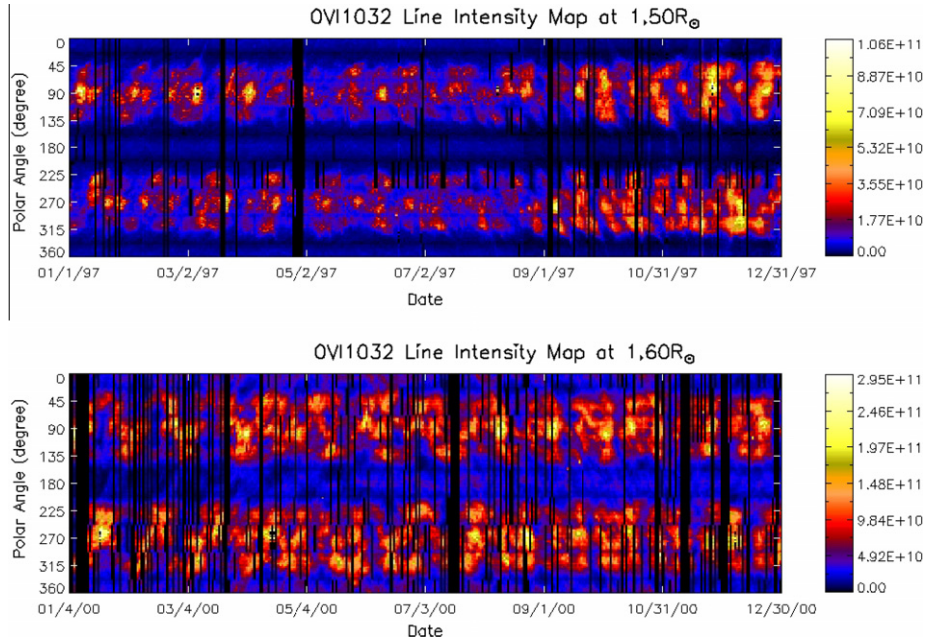


Fig. 1 Upper panel: O VI 1032 intensity synoptic map at $1.5R_{\odot}$ for year 1997 (solar minimum). Lower panel: O VI 1032 intensity synoptic map at $1.6R_{\odot}$ for year 2000 (solar maximum). Intensities are measured in units of photons $\text{cm}^{-2} \text{s}^{-1} \text{sr}^{-1}$. Position angles, measured counterclockwise (i.e., N–E–S–W–N) from the north pole, increase from top to bottom and cover all latitudes from 0° to 360° .

Giordano [2] in a similar study carried out during a 4-year period around solar maximum, showed that the coronal rotation differential profile tends to be less rigid, that is, more differential, during enhanced solar activity. In general, during solar maximum, the coronal magnetic structures were observed to rotate much faster at all latitudes, and less differentially, than the underlying small-scale magnetic structures linked to the photospheric plasma. A striking significant positive correlation was finally discovered by Mancuso and Giordano [3] between the variations in the residual rotation rates of the coronal and sub-photospheric equatorial plasma, suggesting that the observed variations in the coronal rotation rate reflect the dynamic changes inferred within the near-surface shear layer, where the tracer structures responsible for the observed coronal emission are thus most probably anchored. Projection effects could certainly play a major role in the interpretation of the results presented in the previous works.

In this paper, we analyse the possible influence of projection effects of extended coronal structures on the observed differential rotation rate in the ultraviolet corona.

Data reduction and analysis

The data analyzed by Giordano and Mancuso [1] and Mancuso and Giordano [2,3] were collected in a time interval from April 1996 to May 2007 from observations of the coronal O VI 1032 Å spectral line, which is routinely observed by the UVCS/SOHO instrument. UVCS is an internally and externally occulted coronagraph consisting of two spectrometric channels for the observation of spectral lines in the UV range and a visible light channel for polarimetric measurements of the extended solar corona. The UVCS slit, parallel to a tangent to the solar limb on the plane of the sky, can be moved along

the radial direction, thus being able to yield raster observations of the solar corona between 1.4 and $10R_{\odot}$ with a field of view of $40'$. To cover all possible position angles, the slit can be rotated by 360° about an axis pointing to the Sun's center. For a complete description of the UVCS instrument, see [5]. The periodicity analysis was restricted to periods on time scales near the 27-day solar rotation period and was obtained by combining results from the east and west hemispheres. Fig. 1 shows an O VI 1032 intensity synoptic map at $1.6R_{\odot}$ in the time interval from March 1999 to December 2002. The lower panels show O VI 1032 intensity synoptic maps for each single year. Indeed, the intensity maps of Fig. 1 show a clear modulation, which can be readily attributed to the rotation of persistent features through several consecutive rotations. Results can be found in papers [1–3].

Results and discussion

During solar minimum, the global, dipolar-like magnetic field of the Sun is the dominant factor in determining the structure of the UV coronal tracers, strictly linked to a longitudinally modulated streamer belt [6]. However, during the maximum phase, multipolar components become predominant and active regions tend to dominate the magnetic flux up to a factor of three. A major caveat in the analysis proposed in the papers of Giordano and Mancuso [1] and Mancuso and Giordano [2,3] is the possibility that different structures along the line of sight, rooted at different latitudes over the solar surface, might contribute to the observed periodicity due to projection effects of lower latitude features that can contaminate the coronal signal observed at higher latitudes [7]. These projection effects might create an unwanted bias and difficulties in confirming the exact degree of rigidity in the corona. In other

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