EPSC Abstracts
Vol. 11, EPSC2017-504, 2017
European Planetary Science Congress 2017

Sunspot as the source of slow solar wind

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Abstract

The coronal and microwave observations are analysed along with the Potential Field Source Surface (PFSS) model simulations of the coronal magnetic fields to verify that the isolated sunspot in the solar active region NOAA 8535 is the source of slow solar wind.

1. Introduction

The local plasma outflows at the periphery of some bipolar active regions (ARs) have proven to be the origin of slow solar wind [1]. Such outflows persist for days over the confined areas of one magnetic polarity with reduced coronal emission. The outflows occur along the quasi-separatrix layers (QSLs), where the magnetic connectivity is high.

This work presents the analyses of the reduced emission and the magnetic structure of the sunspot NOAA 8535. The aim is to test the analogy between the plasma outflows in the bipolar ARs and in this isolated sunspot.

2. Reduced emission

Two regions of the reduced soft X-ray emission near the sunspot overlap two open-field regions simulated with the PFSS model [2]. These depressed regions correspond to the location of relatively weak absorption in the He 10830Å line. This correspondence confirms the comparison made in [3].

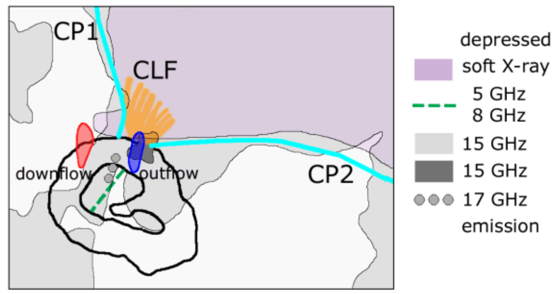

Figure 1: The schematic picture of the reduced emission and two coronal partings near the sunspot (the black thick contours are of the sunspot umbra and penumbra).

The maximum depression at 15 GHz in the north-west region of the sunspot penumbra corresponds to the location of the Doppler blue shifts in the EUV line OV 629 Å (Doppler velocities up to 52 km s^{-1} [4]).

3. Boundaries between open and closed field lines

[1] The areas, which underlie the depressed regions, are the unipolar areas with the footprints of coronal loops connected to the different regions of opposite magnetic polarity (so called coronal partings [5]). To reveal the preferential location for magnetic reconnection - the QSL [6] - the lines of the squashing factor $Q > 10^8$ are drawn. The northern QSL marks the western boundary between the open and closed field lines. Another extended QSL traces the south-west coronal parting and crosses the region of the Doppler blue shifts observed in the EUV line.

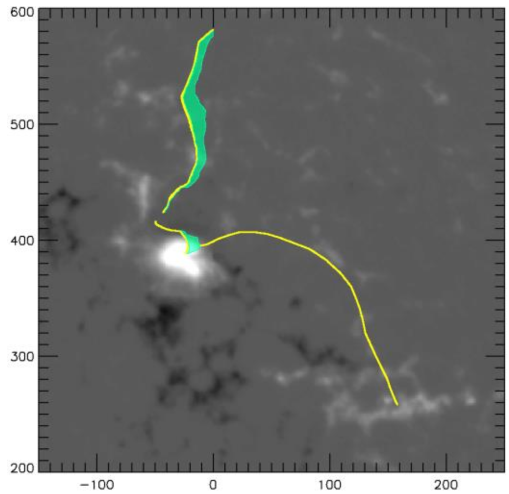

Figure 2: Calculated QSLs (yellow lines) and open-field regions (azure colour) overlaid on the SOHO MDI map of the Br magnetic component.

4. Summary and conclusions

The observational and topological features of the isolated sunspot NOAA 8535 are similar to those of the bipolar ARs with a coronal parting. The essential difference is that the sunspot magnetic fields in the region of the plasma outflow are stronger than the magnetic fields at the outer edges of the bipolar ARs by two orders of magnitude.

The simulated open field lines, which connect the sunspot with the heliospheric current sheet, give evidence of the long duration connectivity. Two-step mapping and the ballistic model [7] led to the solar wind speed of 370 – 400 km s^{-1}.

One might conclude that the isolated sunspot NOAA 8535 is associated with the source of slow solar wind. The maximum depression of 15 GHz emission in ordinary electromagnetic mode can indicate the location of the plasma outflow [2].

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