Active Regions as sources of slow solar wind

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September 17, 2013
Introduction

SOHO (Solar and Heliospheric Observatory): launched on December 2, 1995 to study the Sun; still operating.

The SOHO/UVCS experiment is a coronagraph spectrometer, designed for ultraviolet spectroscopy and visible light polarimetry, of the extended solar corona ($1.5-10 \ R_\odot$).

What we knew before SOHO

- Coronal holes: Fast wind
- Low latitude: Slow wind
The source of the fast solar wind has been identified about 40 years ago in the coronal holes.

Sources of the slow wind have not been unequivocally identified yet, although quite a good number of candidates have been suggested.

Radial plots of wind speed vs. latitude from Ulysses’ three polar orbits of the sun (blue: outward IMF; red: inward IMF). A graph showing sunspot frequency vs. time is shown at the bottom.
As possible sources of the slow wind quite a good number of candidates have been suggested (all of them associated with open magnetic field lines):

- Streamer cusps or flanks
- Equatorial holes
- Streamer coronal hole interface
- Active regions.

Questions:
- What happens over the first few solar radii?
- Where does slow wind originate?
Years ago, it was suggested that Active Regions (ARs) might contribute significantly to slow solar wind.

Evidences from:

- **Scintillation measurements** (e.g. Kojima et al., 1999, concluded that a slow-speed stream was emanating from one side of an active region.);
- **In situ data and remote EUV observations** (Brooks and Warren, 2011, established a wind-AR association, by comparison of the in situ slow-wind abundances).
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Recently, HINODE showed the occurrence of continuous and/or intermittent flows at the edge of Active Regions (AR), in the lower corona.

Sakao et al. (2007) identified outflowing plasma from the edge of AR by using HINODE/XRT data.
To ascertain whether those flows eventually contribute to the solar wind, evidence at larger heliocentric altitudes is needed. UVCS can contribute to this point but good quality and spatially resolved spectra are available only up to 2006.

We analyzed SOHO/UVCS data of different limb transits of AR 8100 (January 1998). The aim was to identify possible outflows from AR periphery, in the 1.5 to 2.5 \( R_\odot \) range.
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As we will see:

- High outflows originate in narrow lanes in between closed loop systems;
- In these regions, the outflow speed vs. height profile turns out to be steeper than typical profiles for the wind emerging from equatorial holes.
- At these positions, potential field extrapolations show bundles of open fieldlines.
Method and Data

**Doppler dimming technique has been used to infer outflow speeds:**

*it consists in the decrease of the coronal line intensities in moving plasma with respect to the static case.*

**UVCS observations of two transits of AR 8100.**

**Observation details.**

- January 2 and 29, 1998;
- Spectra from synoptics observations at altitudes from 1.5 to 2.5 solar radii;
- Slit normal to the radius of the Sun at a south latitude of 45 degrees, moved in steps from 1.5 to 2.5 solar radii;
- Spectra include H I Lyα 1216Å, and OVI doublet lines at 1032 and 1037 Å.
Magnetic configuration: based on potential field extrapolations.


First panel: EIT 195 Å wavelet enhanced image, showing AR crossing the West limb. Arrow: dark lane at the AR edge.

Second: Potential field extrapolation: open/closed fieldlines at the AR edge. Bundle of open fieldlines at 45 degree. Third panel: outflow speed map from Doppler dimming.
Let us examine the successive transit of the AR at the west limb. We focus on fieldlines originating in between two closed loops.

An enhanced speed lane, is present in the latitude interval between 20 and 30 degrees.
Conclusions

We will examine the other transits aiming at checking whether outflow speeds change over the lifetime of the AR: we will check what happens in the first and the last transit when the magnetic field may be more diffuse.

Given the low spectral resolution of the synoptic, we have to check whether we can infer temperatures from line profiles. If this can be done, we will check whether temperatures in the high speed lanes is different from temperatures in the nearby regions.

This may give us indications about the mechanism accelerating the wind. We know that in CHs the temperatures are very high (possibly because of ion-cyclotron heating): are temperatures in the high speed lanes as high as those in CHs?.

Thank you for your attention