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Plasma dynamics in the polar coronal plumes

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Abstract. We use the spectral shapes of the EUV line profiles to study the plasma dynamics, acceleration and heating, in polar plumes (PP). We find that the observed profiles are reproduced fairly well when considering low plume wind speeds and velocity turbulence (α_S) at low altitudes followed by a rapid acceleration and heating of the plasma to reach the properties of inter-plumes (IP) by $\approx 3 - 4\ R_\odot$. We also find that plumes very close to the pole give narrow profiles at all heights that are not observed above $\approx 2.5\ R_\odot$. This suggests a tendency for plume footpoints to lie more than 10° away from the pole. High resolution magnetograms of SOLIS and EUV images support this hypothesis.

Keywords. Line: profiles, Plasmas, Sun: corona, Sun: solar wind, Sun: UV radiation

1. Introduction

The contribution of polar plumes to the fast solar wind recently became a subject of debate and controversy. EUV coronal emissions provide excellent diagnostics for the plasma dynamic properties in different coronal structures, in particular in polar plumes. We use the profile shapes, intensities, widths and intensity ratios of coronal lines to study the plasma dynamics (acceleration and heating) in polar plumes.

2. Emission properties and model of polar plumes

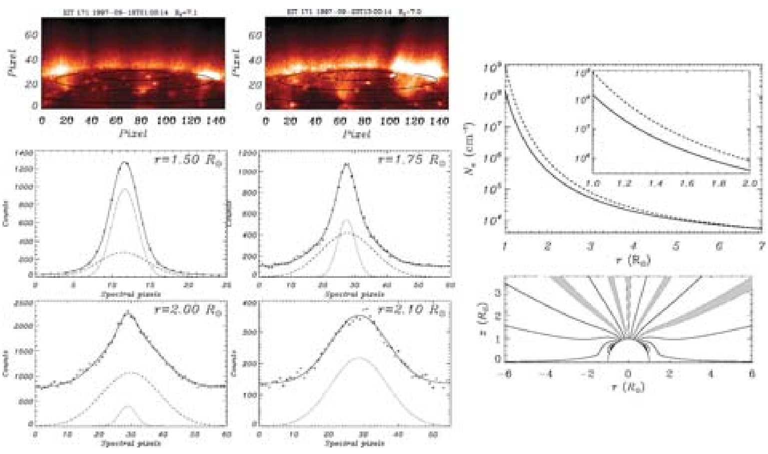

Figure 1. Left: EIT images of the north solar pole showing PP on September 19 and 23, 1997 and the O VI line profiles at the same period of time. Top-right: PP (dashed line) and IP (solid line) electron densities. Bottom-right: PP distribution used for the calculations of the coronal line profiles. PP footpoints are assumed to be $\approx 15 - 20$ Mm wide.

The main properties of the O VI profiles are (see figure 1): **1)** Up to $\sim 2.0\ R_\odot$ the profiles have two components; **2)** The narrow component dominates the profiles below $\sim 2.0\ R_\odot$ and decreases above that height; **3)** No narrow component beyond $\sim 2.5\ R_\odot$; **4)** No significant Doppler shifts for the narrow component.

For both plume and inter-plume regions, we assume simple Maxwellian velocity distributions with different velocity turbulences. The electron densities in both regions are given by the dashed and solid lines in figure 1, respectively. We also assume the same expansion factor for both PPs and IPs that is given by the model by Banaszkiewicz *et al.* (1998, A&A, 337, 940; same figure).

3. PP plasma dynamics: best fit case and PP footpoint distribution

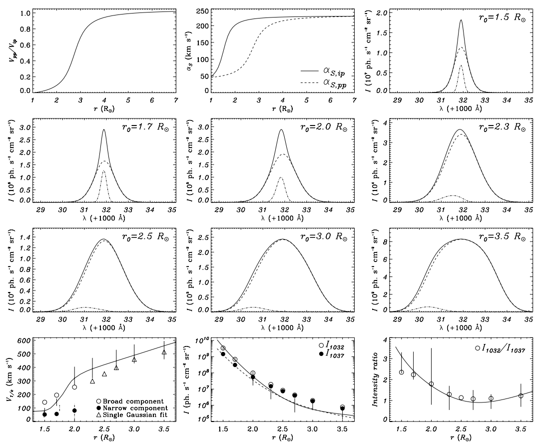

Figure 2. Left: V_{pp}/V_{ip} (top-left), $\alpha_{S,pp}$ and $\alpha_{S,ip}$ (top-middle) as a function of r and synthetic profiles of the O VI 1032 Å (next 7 panels). Bottom: Width, total intensity and intensity ratio of the O VI doublet as a function of height.

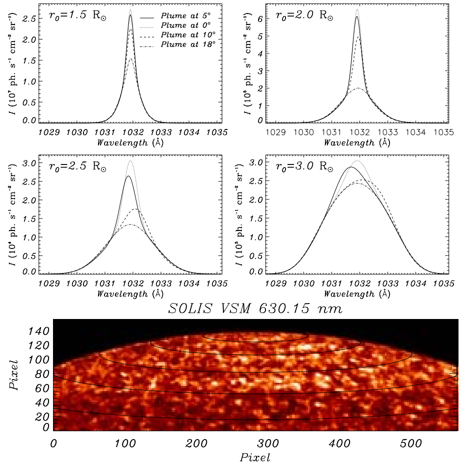

Figure 3. Top: profiles for the four right–hand PP in figure 2. Bottom: SOLIS magnetograms displaying the magnetic flux distribution around the north pole for Sep. 2005.

We consider the contribution from one PP at mid-altitudes (left-hand PP in figure 1). Profile shapes, widths of the narrow and broad components, total intensities and ratios of the O VI lines are in good agreement with the observed ones at all altitudes (figure 2). The present model suggests that the PP plasma remains much cooler and much slower than IP material up to $\approx 2\ R_\odot$. The PP speeds and velocity turbulence then increase rapidly to reach the IP properties by $\approx 3-4\ R_\odot$.

Contrary to the observations, narrow components from PPs close to the pole are present at most heights. This suggests that Pps preferentially originate away from the pole. EUV images and SOLIS magnetograms showing low flux concentrations near the solar pole and higher at lower altitudes and thus support this hypothesis (figure 3).

4. Conclusions

UVCS O VI profile data allowed us to constrain the height evolution of the plasma acceleration and heating inside polar plumes. We find that highly height-dependent plasma velocity broadening and outflow speed in plumes are needed. Low PP plasma temperature and outflow speeds up to $\approx 2\ R_\odot$ rapidly increase to reach IP values by $\approx 3-4\ R_\odot$. We also find a trend for PPs to be based more than 10° away from the pole. SOLIS high resolution magnetograms and EUV images tend to support this hypothesis. For more details see Raouafi *et al.* (2006; SOHO 17 proceedings).