POLAR JETS AND PLASMOIDS: PRELIMINARY RESULTS FROM JOP 57

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ABSTRACT

Small eruptive and impulsive events were observed in December, 96 using both SoHO EUV experiments and ground-based facilities in the vicinity of the North pole. EIT sub-field images obtained at a cadence of 1 minute with the 30.4 nm filter were evaluated to identify different phases of the events. A special attention was paid to the analysis of the rising and disappearing detached part. A comparison is attempted with the simultaneously observed in Ha line macro-spicule ejection. At least 1 event was also well observed on a SUMER time series using several Lyman lines and the 'hot' SVI lines. We discuss the possible implications for the physics of plasmooids.

Key words: macro-spicules; jets; plasmoid; corona

1. INTRODUCTION

Plasmooids are plasma clouds. They can be observed in the solar corona. Plasmooids of all scales exist. The biggest are seen as a Coronal Mass Ejection. In this case their dimensions are about 1R☉ and their lifetime is about a few days. They can reach the magnetosphere. LASCO observes many plasmooids.

The smallest are seen at the limit of the time and spatial resolution, which means scales of about few 100 km and lifetime of about few minutes. They are detectable at the poles, in coronal holes. Here we study some small plasmooids observed with SoHO. We present the possible pattern of their formation and discuss their stability and their dynamics.

Let us notice that small scale impulsive events originating at the chromospheric level and propagating toward the corona are known since a long time. Both ground-based coronographic observations, see Koutchmy et al. 1991, and solar disc EUV spectroscopic observations, see Dere et al. 1989, did confirm this importance in the mass balance and energetic balance of the transition region. The new observational facilities flown on SoHO are used here in conjunction with more classical ground-based methods, to go further in the study of these important processes.

2. JOINT OBSERVING PROGRAM 57

![Figure 1. Sample of a sequence taken with EIT over the North pole. The time goes from the left to the right and from the top to the bottom. The time difference between two images is around 2 min. There are many brightenings and a big macro-spicule with a bright bottom.](image)

We observed the North pole in December from the 10th to the 17th 1996. The aim was to correlate the SXR brightenings often observed with Yohkoh and the macro-spicules observed in Ha and in HeII. We used several instruments. The observation in Ha was obtained in Sacramento Peak, with the Vacuum Tower Telescope. The UBF filter, working on the Ha line to analyze some Doppler shifts around this line, was used. SXR observation was obtain using Yohkoh. On EIT, we observed with the filter at 304 Å. SUMER took spectra of the North pole in Lyman6, Lyman7 and two SVI lines. Spectra of the region using some hot lines was also obtained by CDS.

Many observations were collected, but the different instruments worked strictly at the same time during only 8 min. At Sacramento Peak, the seeing was...
variable. Observations taken in Hα are not yet fully evaluated. Yokoh observations will not be considered here. CDS did not get some macro-spicules observations, essentially because their typical lifetime is about few minutes and CDS got an image of the region every twenty minutes. Probability to observe a macro-spicule was very low.

3. OBSERVATION WITH EIT

Many jets, spicule-like or macro-spicule-like, were observed, see figure 1. We analysed the macro-spicule case related to an impulsive event. We defined them as an ejection reaching a height of more than $10^4$ km. They are frequent and recurrent with a frequency of about $5$--$40$ minutes. Their feet are bright in about $50\%$ of cases, which leads us to conclude that in the other $50\%$ cases we do not see their feet because they are behind the solar limb. The EIT $304$ Å filter has two spectral components, HeII and SIII lines. The first one is formed at a low relatively temperature, around $20000$ K, with the chromospheric density. The second line is formed at a higher temperature of order of $1.5$ MK in the corona. If the brightening at the foot of the jets is due to the high temperature which is supposed to produce the ejection, then it could be detectable in SXR.

Small clouds are formed at the macro-spicules top in many cases. They are formed before the jets reach its highest point or when the jets begin to fall down. They are pushed up, they travel for few minutes in the corona, then they stay at a height or begin to fall back to the photosphere and disappear while continue their trajectory. We studied two of these clouds. Their dimension was about $1$ to $4$ Mm. They reach the maximal altitude of $60$ Mm. Their velocity is about $80$--$130$ km s$^{-1}$ and their lifetime is about $3$ min, see figure 3.

We could not get a definite correlation between these events and observations in Hα because the instruments worked few time simultaneously. Some previous analysis of Hα macro-spicules can be found in the literature suggesting that they could be quite similar. Clouds were observed in Hα formed at the top of macro-spicules. They have the same behavior than the ones described previously. Their physical parameters were: dimensions $5$ Mm, altitude $\approx 20$ Mm, velocity $\approx 100$ km s$^{-1}$, lifetime $\approx 5$ min.

Some authors tried to correlate the Hα spicules with the HeII ones. They found that there is no correlation between them (Kjeldseth et al 1975). In fact, we found very few cases for which we are sure of the correlation between the two wavelengths, see figure 7. In this figure the upper part show two images taken in Hα and two others, in the lower part, is the images of the same region taken at the same time in HeII. The disk darkening and the background chromosphere is removed from the images in Hα. The two images on left do not present correlation. Surprisingly enough, we found at the location of the $304$ spike or macro-spicule extending rather radially too a height of more than $20$ Mm, a bright Hα limb structure inside the chromospheric fringe up to $6$ Mm. This bright structure looks like a micro flare. No extension upward
4. OBSERVATION WITH SUMER

Radial fine jets should coincide with the position of the slit of 1 arcsec width put exactly above the North pole, so there was a low probability to see some of them. Two macro-spicules were however observed during the run. They present clouds at their top. Jets and clouds were observed in the four wavelengths, which means that different temperatures exist within the plasma forming the phenomenon. The typical ionization temperature of the SVI is $2 \times 10^5 \text{ K}$ and the one of the Lyman lines is $10^4 \text{ K}$. In the SVI lines, the clouds are not well defined. The maximal height reached by the jet is the same in Lyman and in SVI. One of these structures presents a maximal Doppler shift of order of 20 km s$^{-1}$. This shift is large at the beginning of the ejection, becomes zero at the maximal height and takes an opposite sign reaching again the maximal value. This can be interpreted as a jet situated on the pole axis but going toward us when going up and forward us when going back to the photosphere. So the ejection is evolving inside a tube, and moves in it.

In fact it is difficult to interpret the light flux of the plasma filling a structure of unknown geometry. Perhaps the jet presents some relative enhancement emitting in some lines without having a real cloud at its top. The only way to know if they are real clouds is to compare with 2D images. It is not excluded that a relative intensity enhancement propagating upward in a rather high temperature line (SVI) reveals the impulsively heating process in the corona.

5. SIMULTANEOUS OBSERVATION WITH EIT AND SUMER

A jet was observed simultaneously with EIT and SUMER on 12/17/96. SUMER images show a jet with the formation of 2 clouds at its top. The clouds are formed one by one and go up. We analyze only the spectra in Lyman lines because the signal obtained in SVI is too noisy, see figure 4.

The results in the Ly$\beta$ and Ly$\gamma$ lines are very close. The maximal altitude reached is for the first cloud 16 Mm and for the second cloud 10 Mm, see fig. 5. Their mean velocities are respectively, 49 and 44 km s$^{-1}$, see fig. 6. Finally their mean dimensions are 3 Mm and 2.5 Mm. These clouds seen moving slower are smaller than those studied previously with EIT. We tried to see where these clouds are on EIT 304 images. A jet is present at the pole. No cloud is visible at its top. We made a cut of the image at the presumable location of the slit on the field of view. The stability of the space probe is good enough to accurately localize both fields of view. The slit is situated at the boundary of the jet. This jet reach higher altitude than the clouds observed with SUMER. The spatial resolution of EIT is approximately half the one of SUMER (on EIT 1 px $\approx 1.87 \times 10^3 \text{ km}$ and on
SUMER, 1 px \(\approx 0.75 \times 10^3\) km). The clouds have dimension of about 4 px with SUMER, their dimension on EIT is less than 2 px. Their signal is comparable to the noise. Their shape can not be studied. In the following section we propose a possible scenario of their evolution.

6. THEORY

6.1. FORMATION

It exists many possible ways to form a plasmoid. The most probable origin is based on the reconnection of the magnetic field lines. An abnormal viscosity placed in a point can produce current and reconnection of lines. An other possibility is to make some motion in the material which is followed by the magnetic field. The lines go close to each other and reconnect with the production of high local currents.

For example, a magnetic arcade can merge from the photosphere and can reconnect with the surrounding magnetic field. In the case of the pole, the external magnetic field is vertical. Above the point of reconnection, a magnetic island is formed and goes up. The plasma is concentrated in or after the passage of the magnetic island. These results are present in many numerical and analytical simulations (Ugai 1995, Shibata et al. 1995, Magara et al. 1996, Karpen et al. 1996, Wang et al. 1994).

6.2. STABILITY

The magnetic island produced by the 2D simulation of the magnetic reconnection phenomenon has enough stability to explain the clouds observed during this run, but this configuration is unrealistic. The classical configuration in 3D of a plasmoid is a toroidal vortex one which could be produced by internal ring current. This structure is very unstable (Rosenbluth & Bussac 1979, Moffatt 1969). Any other possibility is to create a second ring current to maintain the plasmoid (Koutchmy et al. 1995), but this calculation is made without taking into account its velocity. The neutrals can also contribute to the stabilization of the structure (Drake et al. 1988) but it would only work at low temperature.

6.3. DYNAMICS

The plasmoid is expelled from the location of its formation due to the magnetic field restructuration. In each simulation of reconnection the simulation box is limited, so it is very difficult to follow the dynamics of the plasmoid. The model of the melon seed effect can explain the dynamics of the clouds (Schluter 1957, Pneuman 1983). It is pushed by the tension of the external magnetic field lines, deformed by its presence. This theory computes forces due to surface currents, but some internal currents certainly exists. In this case, they feel the external magnetic field and follow it with magnetic forces of more significant magnitude.

7. CONCLUSIONS

During the JOP 57, we observed jets, spicules like ejections, macro-spicules, and clouds (plasmoids) formed at the North pole of the Sun. Macro-spicules are frequent and show a brightening at their feet bright bases and clouds formation at their tops. Two macro-spicules were seen simultaneously in SVI and in Lyman lines which means that different temperatures exist inside. We studied the small clouds formed at their top. They are slow and small. Their lifetime is short. We tried to understand how they are formed, and how they can move inside the corona. The formation is probably due to the emergence of a magnetic loop and the reconnection with the surrounding magnetic field. Simulations of this phenomenon exist. They give different conclusions. The stability and the dynamics are difficult to understand for the moment and need a more careful analysis.

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