Exploring EUV Spicules Using 304 Angstrom HI II Data from SDO/AIA

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Abstract

We present results from a statistical study of HI 304 Å EUV spicules at the limb of the Sun. We also measured properties of one macropulse; macropulses are longer than most spicules, and much broader in width than spicules. We use high-cadence (12 sec) and high-resolution (0.6 arcsec pixels) resolution data from the Atmospheric Imaging Array (AIA) spacecraft on the Solar Dynamic Observatory (SDO). All of the observed events occurred near the solar north pole, where quiet Sun or coronal hole environments prevail. We examined the maximum lengths, maximum rise velocities, and lifetimes of 33 EUV spicules and the macropulse. For the bulk of the EUV spicules these quantities are, respectively, 10,000–40,000 km, 20–100 km/s, and 100–1000 s. For the macropulse the corresponding quantities were 60,000 km, 130 km/s, 1800 sec, which is typical of macropulse measured by other workers. Therefore macropulses are taller, longer-lived, and faster than most EUV spicules. The rise profiles of both the spicules and the macropulse match well a second-order ("parabolic") trajectory, although the acceleration was often weaker than that of solar gravity in the profiles fitted to the trajectories. Our macropulse also had an obvious brightness at its base at birth, while such brightening was not apparent for the EUV spicules. Most of the EUV spicules remained visible during their descent back to the solar surface, although a small percentage of the spicules and the macropulse faded before falling back to the surface. Our sample of macropulses is not yet large enough to determine whether their initiation mechanism is identical to that of EUV spicules.

Introduction

Various jet-like phenomena occur in the Sun's atmosphere. In the chromosphere, spicules are ever-present, with about a million of these "chromospheric spicules" on the Sun at any time; they shoot up to heights of ~5000 km above the photosphere (e.g., Beckers 1968, 1972; Sterling 2000; De Pontieu et al. 2007; Tsikoura et al. 2012). In the hotter atmosphere, X-ray jets occur at a rate of 60/day and extend to ~5 x 10^4 km (e.g., Shibata et al. 1992, Shimajo et al. 1996, Sasaviche et al. 2009, Cabin et al. 2007, Moore et al. 2013). Other coronal jets, similar to the X-ray jets, are visible in relatively "hot" EUV images (e.g., in lines formed by Fe I at wavelengths of 193 and 195 Å; Wang et al. 1998, Nistico et al. 2009).

Here we study jets seen at cooler temperatures than the coronal jets but hotter than the spicules. These jets are seen in EUV II 304 Å images, which show emissions of the chromosphere and transition region of temperature ~10^5 K. Data are from the Solar Dynamic Observatory (SDO) Atmospheric Imaging Array (AIA) (Lemen et al. 2012). The "304 Å EUV spicules" dominate the limb in close-up view of AIA 304 Å images, with about two dozen distinct spicule-like features being discernible in 100'' spans of the polar limb regions at any given time. Most of these images show the 304 Å spicules to be highly dynamic, similar to the chromospheric spicules. Here we concentrate on these common EUV III 304 Å features that set up "10'' above the limb seen in the 304 Å images. Much less frequently there are larger jets visible in the 304 Å images, of size similar to the X-ray jets ("10's/100'' km); we refer to these larger jets as "macropulses." We examined directly only macropulse in this work, and we compare its properties with that of the 304 Å spicules. Two questions of interest are: (1) What are the properties of spicules seen at this wavelength, and (2) are macropulses large-scale versions of the 304 Å spicules?

Data Sets

We examined AIA 304 Å channel data three different time periods. For each data set, we restricted our field of view to about 100'' spans of the limb in the north polar region. Table 1 lists the observation details. These times and observation fields of view were selected to coincide with Hinode SOT observations of the same regions. [SOT data were not examined in this study). All of the data were of 12 sec cadence and at the full AIA resolution of 6''/pixel. Data set 0 is from a polar coronal hole region. Data sets 1–3 were of the polar region, but during a period of the solar cycle when the polar coronal holes were not present, and thus they are polar quiet Sun regions.

Table 1: EUV Spicule and Macropulse Observations

<table>
<thead>
<tr>
<th>Data Set</th>
<th>Start Time (UT)</th>
<th>End Time (UT)</th>
<th>Range (arcsec)</th>
<th>Range (arcsec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2011 Sep 09:58</td>
<td>2011 Sep 15:11:00</td>
<td>50–500</td>
<td>935–1085</td>
</tr>
<tr>
<td>2</td>
<td>2014 Apr 23:04:45</td>
<td>2014 Apr 15:00:75</td>
<td>75–450</td>
<td>935–1085</td>
</tr>
</tbody>
</table>

Procedure

We examined the AIA 304 Å movies over the regions and times of Table 1. For looked for spicules that were isolated enough to follow their entire evolution, from emergence above the limb "surface" in the 304 Å images until they returned to that surface or faded from view. From each of the data sets 0–2 we were able to identify 10 spicules that satisfied these criteria. From movie 3 we only identified 4 spicules, because much of the time a large, wide macropulse dominates that movie, obscuring the smaller spicules along the same line-of-sight.

For each selected spicule, we measured the projected length from the photospheric limb, with the white-light limb being calculated from the Sun-earth distance at the times of the observations. Typically the limb in 304 Å images is ~15–15 above the photospheric limb, and so the minimum-observable length (height) for the 304 Å spicule is ~7000 km. We measured the top of the spicule visually, after verifying that the apparent top location of the features was not significantly influenced by the intensity scaling of the displayed images. We derived velocities from the derivative of the length-time trajectories (after applying a running box-car smoothing to the trajectories), and fit first- and second-order polynomials to the trajectories. From the second-order fits we could obtain an acceleration term, which we could compare with the solar gravitational acceleration.

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