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"SPICULES, JETS AND POLAR PLUMES: ORIGIN AND DYNAMICS"

by

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Abstract: ***We discuss what we recently got from the analysis of SOT Hinode time sequences of high resolution limb spicules observed at broad band in the cool CaII H line emission. Images were processed to minimize the overlapping effects using the Madmax algorithm before extracting time slice diagrams to discuss the coherent behavior of multiple components spicules (Fig. 1, 2). It suggests the flows (Fig. 3) are determined by the properties of a dynamic surrounding magnetic flux tube. Both kink and Alfven waves are identified at short periods near 100s (Fig. 4). Examining the best resolution coronal filtergrams (ex. 171A; 192A) from the AIA experiment of the SDO mission we were not capable to find any counterpart of ordinary spicules at coronal temperature, even in polar regions; they are seen just in absorption (Fig. 7), confirming results deduced from SXR (Daw , De Luca and Golub 1995).***

Giant spicules and/or macro- spicules as observed in TR emission lines show an "Eiffel tower" (or inverse Y) structure in the corona). Eclipse observations confirm the importance of these small scale eruptive mixed temperature structures for feeding the corona and presumably heating the low corona with the released free energy. Short time sub-microflares in network regions are proposed to explain the occurrence of tiny and less tiny SXR jets (Fig. 5, 6) possibly evolving along magnetic separatrices and resulting from the interaction with the background field. Polar plumes observed in W-L (Fig. 8) at solar eclipses and with space-borne coronagraphs confirm the occurrence of a global magnetic field most of the time of the cycle but outside the solar maximum. A careful differential analysis of dynamical polar plumes imaged with the 171 channel of the AIA (SDO) at high rate (Fig. 9) convincingly shows propagating perturbations resulting from waves launched from the underlying layers and seemingly giving a global coherent picture of the origin of both the heating and of the acceleration of the plasma in coronal holes.

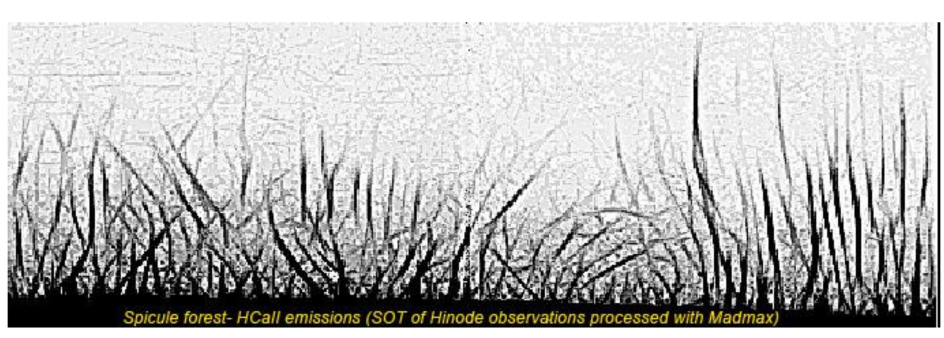

Fig. 1-Example of a Mad-Maxed image from the Hinode/SOT HCaII line observations of 17 June 2011 at 9:13:42.4 UT, in negative display. To the left of the multi-thread, long twisted spicule, a loop can be noticed.

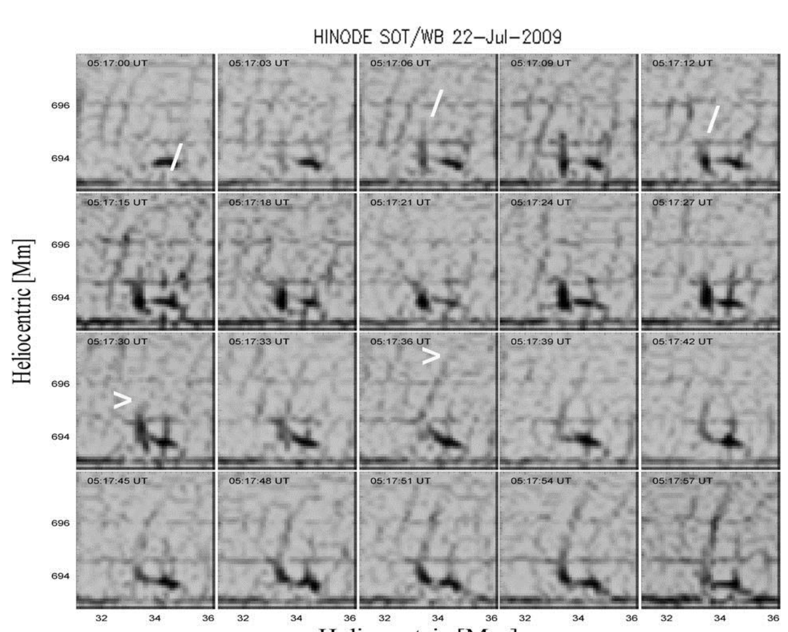

Fig. 2- Example of rapidly moving features at the ultimate SOT resolution, after using the Madmax processing and a negative display of the results. Only the first 5 Mm heights above the limb are shown. Variations are extremely fast. The frames are separated by only 3 sec and the field covers just 5x5 Mm². The neo- spicule feature (shown with a white bar /) at 05:17:00 is rapidly rising vertically until 05:17:06 UT and then seems to slowly fall during at least the 6 following sec. The second neo- spicule feature (shown with a white >) at 05:17:30 rises rapidly with a small angle to the vertical until 05:17:36 and fades after and then reinforces at 05:17: 51 with a small evidence of twist 6 sec later at 05:17:57 UT. The apparent associated upwards velocities are typically 350 +/- 50 km/sec in both cases, taking into account the scale (given in Mm) and the px size of 0.1 arcsec or 74 km in July.

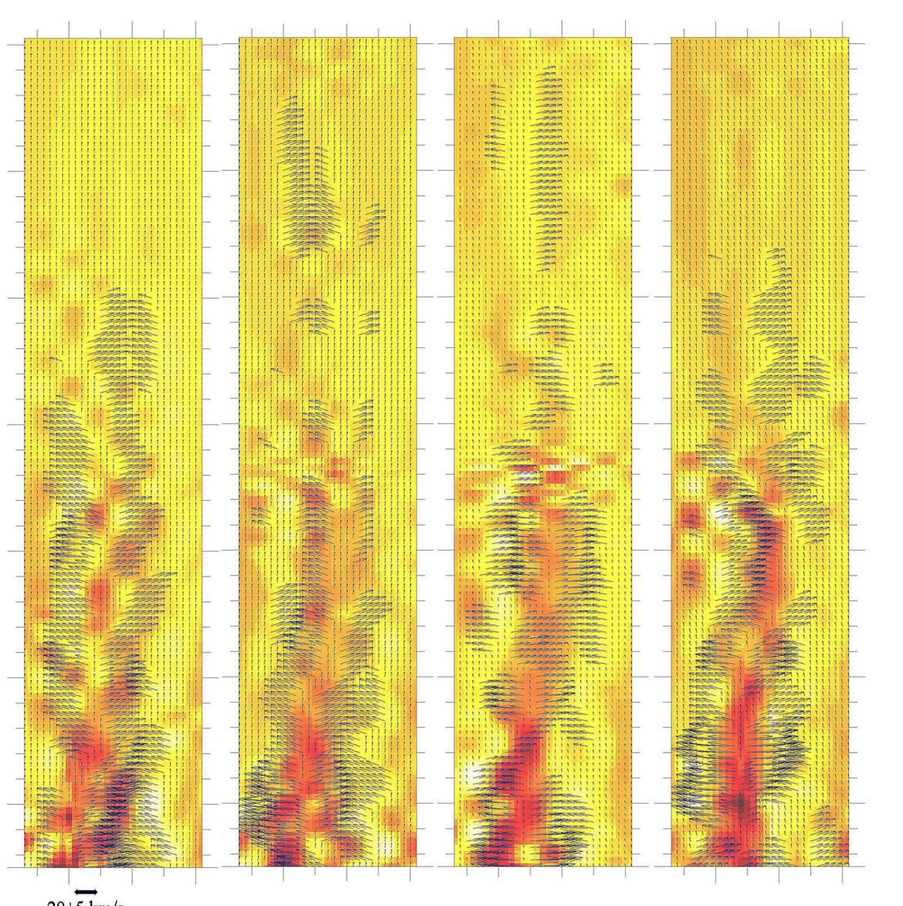

Fig. 3- Velocity maps obtained using the FLCT algorithm for showing the 2D velocity variations from successive frames with a corresponding remarkable structure (result for the largest spicule which was seen in figure 1); spatial units used in the display are 0.1 arcsec (corresponds to pixel size), and the cadence is 1.6 sec. Intensities are reproduced in red color. Note the large magnification needed to clearly evaluate the results, see Fig. 2b for an evaluation.

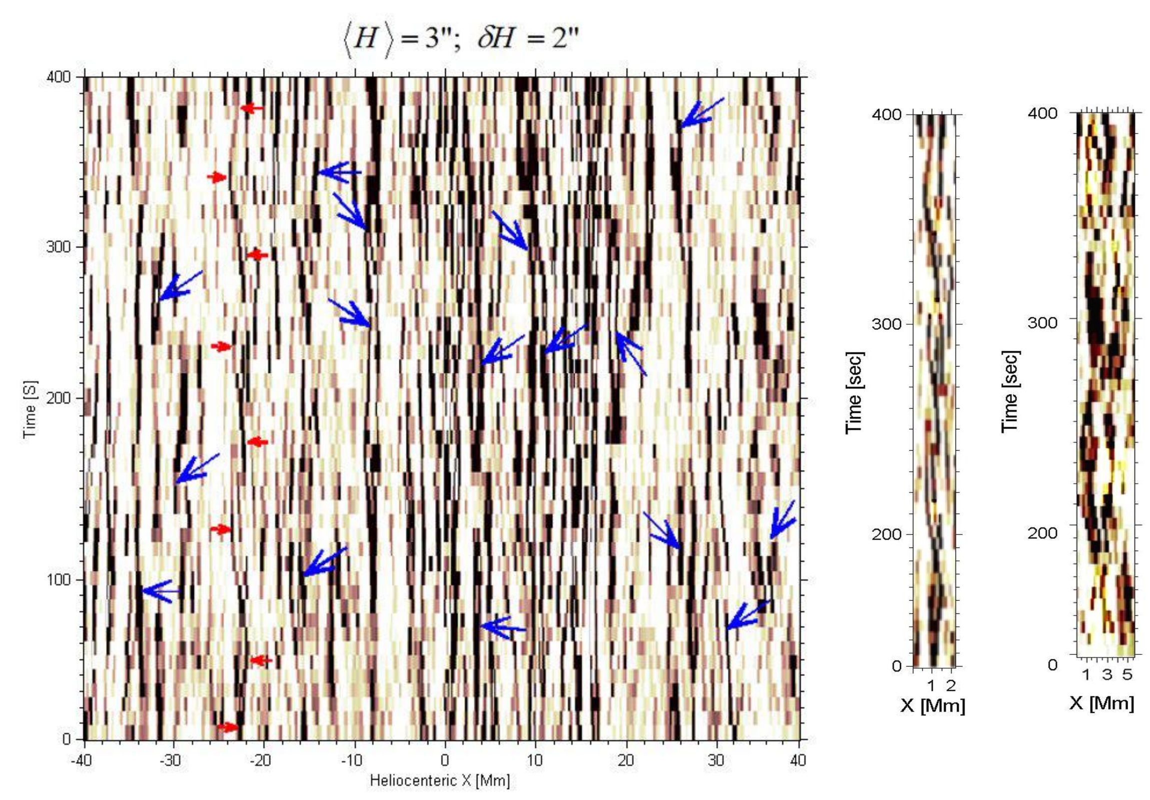

Fig. 4- "Time slice" image which are located at 3 arcsec height above the limb. In order to improve the time slice result, we computed the average intensity along the y-axis direction over 2 arcsec (20 pixels) interval. Red arrows in this image show a typical transverse motion and the doublet threads are marked using blue large arrows. This diagram suggests that spicules are multi- components with a coherent behavior and transverse motions due to waves of 100 s. periods.

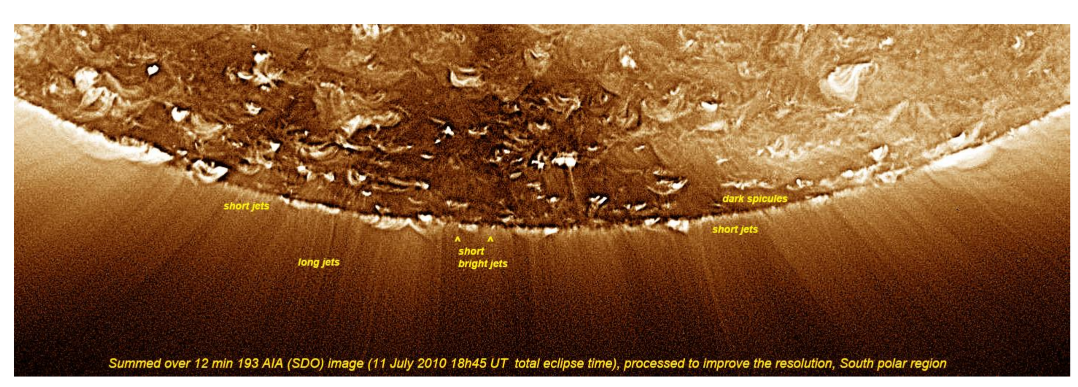

*Fig. 7- Near limb **polar summed for 12 min coronal images** from AIA (SDO) dramatically illustrate the variations with heights of the impulsive events observed inside the inner corona at > 1MK temperature (positive display- 193A emissions). Note spicules observed in absorption (in dark) near the surface , short jets, loops and polar plumes in emissions. In the background (see Fig. 8 for the dynamics)*

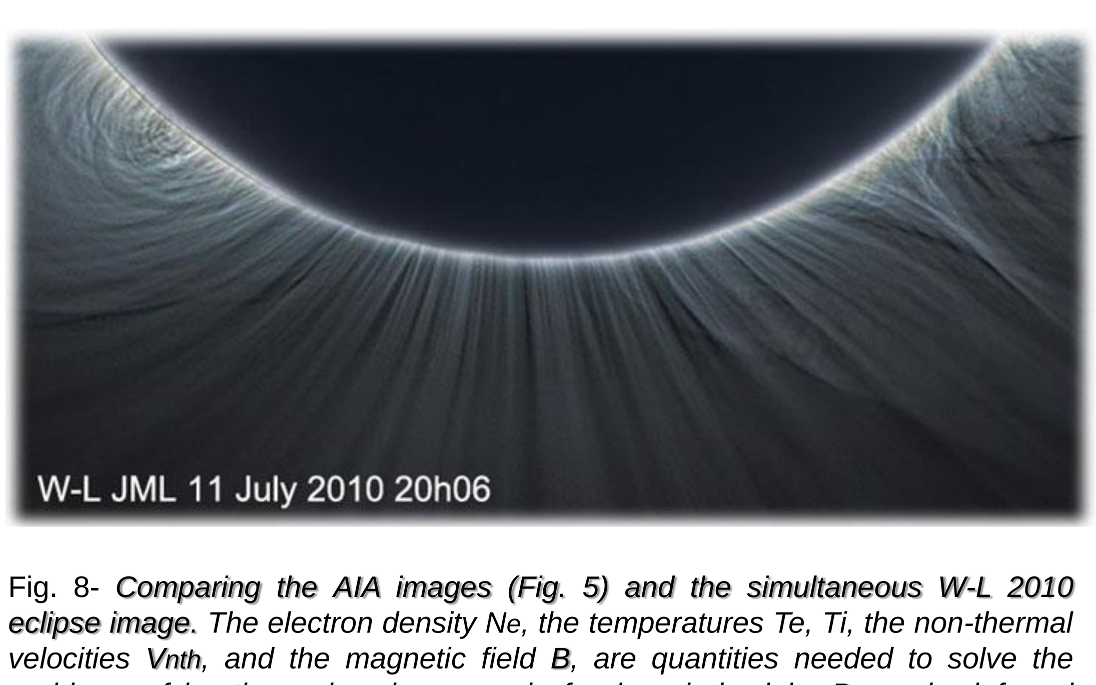

Fig. 8- ***Comparing the AIA images (Fig. 5) and the simultaneous W-L 2010 eclipse image.*** *The electron density N_e, the temperatures T_e, T_i, the non-thermal velocities **V_{nth}**, and the magnetic field **B**, are quantities needed to solve the problems of heating polar plumes and of solar wind origin. **B** can be inferred from structures inside the large-scale 3D corona and/or from interpolations of surface measurements; N_e is deduced from the analysis of the W-L corona (for decades); the radial gradient of N_e gives $T_{hydrostatic}$ via the scale height. T_i can better be analyzed using the emission measures EM of X and EUV emissions, provided the line emissions are identified. EM (and DEM) are proportional to (N_e x N_i) # N_e^2 in a collisionally dominated plasma; V_{nth} non thermal velocities are finally evaluated from time sequences, using proper motion analysis (or better, using line profiles analysis)…*

Higher: Jet-like events are indeed observed on different scales in the solar corona in EUV and X-rays

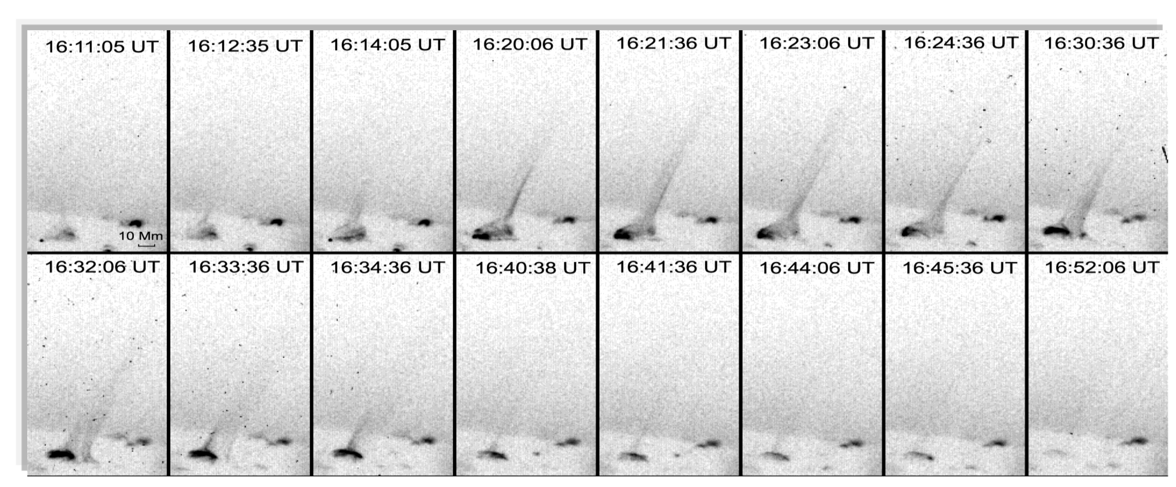

Fig. 5- Negative X-ray images showing the jet evolution on 09 January 2007

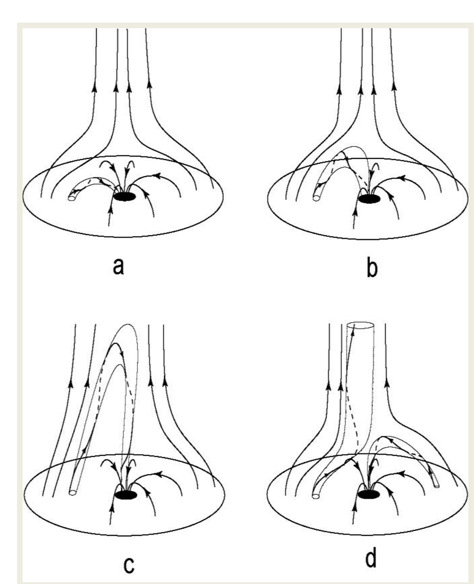

*Fig. 6- Scheme of possible scenario of ejection of a small twisted flux tube within dome-like magnetic configuration. (a) and (b) show the growth of an emerging bipole into the assumed unipolar field; (c) and (d) show two alternate possibilities. In (c) the loop moves upward through the null point region, while in (d) it reconnects with the ambient field and one leg opens out. A quite similar scenario and numerical model was recently proposed by Patsourakos, S., Pariat, E., Vourlidas, A., Antiochos, S. K., Wuelser, J. P.: 2008, Astrophys. J. **680**, L73, from a STEREO observation. Of a polar jet.*

From Filippov, Golub and Koutchmy (SP 2009)

Polar plumes dynamics in 193 (AIA)

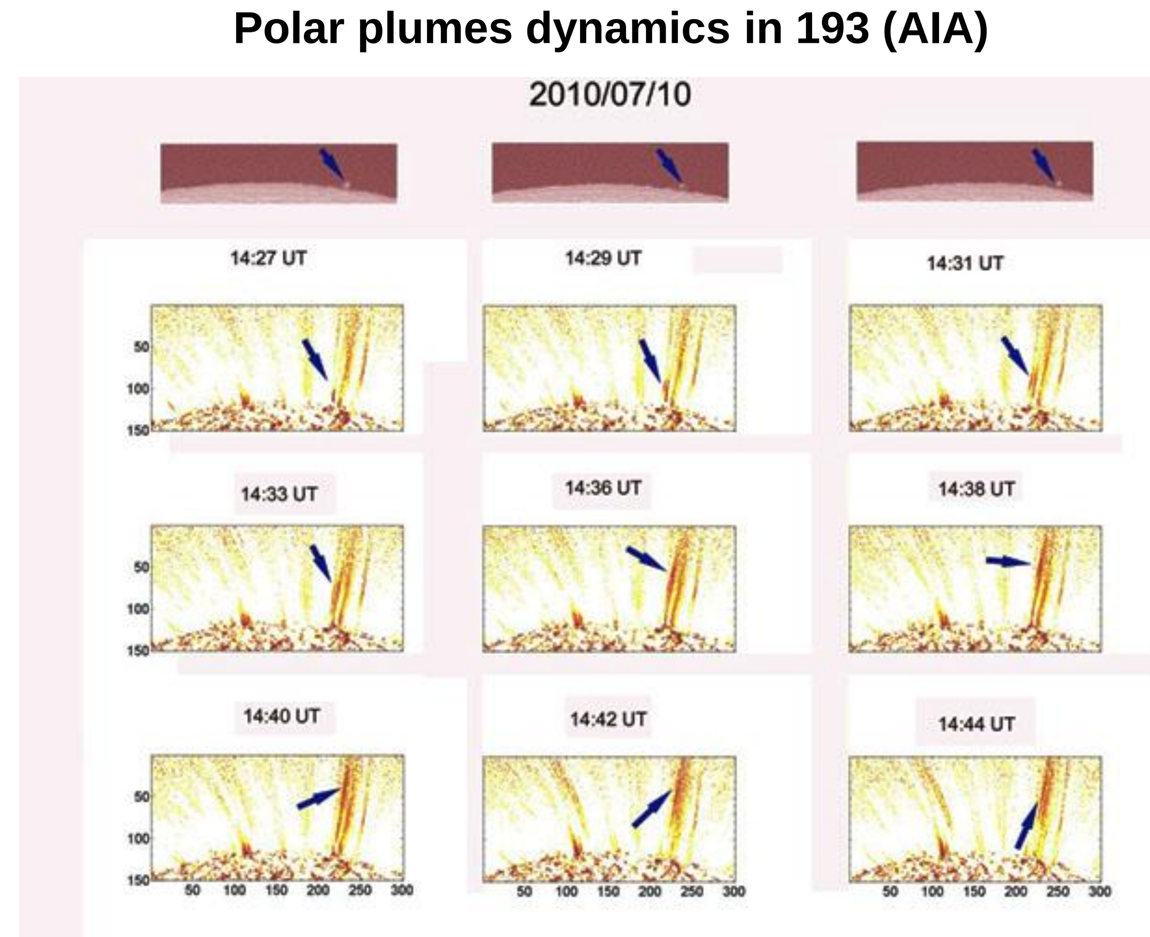

Fig. 9- Successive frames taken from a processed movie made of 193 AIA filtergrams to demonstrate the fast variations observed inside a polar plume dynamical system (only # 2 min between 2 successive frames).
Note the occurrence of multiple components.
At top, 3 selected Hα partial frames taken from the Kanzelholm Observatory routine movies.
*At the foot of this event, 304 AIA movie made for the same time interval covering shows a **tornado** type event suggesting Alfven waves are also produced. The proper motion measured along the main component is up to 200 km/s and transverse motion is 1 order of magnitude smaller.*

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