A two dimensional view of spicules from He 1083nm triplet observations

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**Solar Spicules**

**What are they?**

- Very thin and very dynamic jet-like structures seen at the solar limb.

- Basic properties of spicules from the classical review of Beckers, 1968, SoPh, 3, 367:
  - Very thin diameters: $[100-2500]$ km (see table 1 in Tavari et al. 2011, NewA, 16, 296)
  - There is a clear dependence of diameters with height
  - Maximum height of 12000 km although there is no clear boundary (sensitivity)
  - Lifetime: 2.2 - 6.3 minutes and velocity: $[20-70]$ km
  - Range of inclinations: **20 degree** from the local vertical
  - **Two types** of spicules

- Spicules are very demanding in terms of resolution. To spatially resolve them we need resolutions below one arcsecond and fast cadence. Thus, most properties have not been well defined yet since we have likely been observing time averaged, bundles of spicules.

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Spicules seen in Halpha (taken from Beckers 1968, SoPh, 3, 367)
**Solar Spicules**

**What are they?**

HIGH temporal and spatial resolution observations of Active Region Spicules

Chromospheric (Ca II H 3968Å) spicules observed with the Solar Optical Telescope aboard the Japanese Hinode satellite

Do spicules exist in other stars?

How would they look like?

Any chance to have a glance at them?

Lifetime: 3-10 min
Velocities: 10-50 km/s
Length: ~3,000 km
Solar Spicules (Sun’s case)  
Magnetic Configuration

  - Single slit observations in He I 1083.0 nm. TIP@VTT. Data with 2 minutes integration.

  - Spectropolarimetric observations of spicules in the He I D3 (587.6 nm) line with the ASP at the DST of the Sacramento Peak Observatory. (resolution ~ 3"), no profiles shown in the paper, unknown integration time.

- **Ramelli et al. 2006, ASPC, 358, 448**
  - Spectropolarimetric observations of spicules in the He I D3 (587.6 nm) line, ZIMPOL. Exposure times for each measurement ranged from 10 minutes to about 1 hour.

  - Spectropolarimetric observations taken in the He I 1083.0 nm triplet of spicules at two distances from the limb with the TIP at the VTT on Tenerife. They carried out a 45 minute long (averaged) time series in sit-and-stare mode, with a cadence of 56 s. Resolution is 2".
Near Infrared observation in the He 1083.0 nm triplet

- **Instrument**: Tenerife Infrared Polarimeter installed at the German Vacuum Tower Telescope at the Observatorio del Teide (Tenerife, Spain).
- **Data**: We measure the four Stokes parameters (I,Q,U,V) with a spectral sampling of 1.1 pm with adaptive optics system at work and good seeing conditions.
- The total **integration time is 10 seconds for each slit step** with a spatial sampling of 0.17” along the spectrograph slit and and 0.36” slit step size = **5.5 minutes per map**
- **Spatial resolution** [0.7” - 1”]
Stokes I shows He 1083 nm emission and some spicule structure -> good resolution
Stokes I, Q, U, and V spectra extend up to 8 Mm above the limb.
There are clear Stokes Q and U signals => joint action of atomic level polarization and the Hanle effect
Stokes U changes sign -> change in field orientation with height
Clear Stokes V signals due to the Zeeman effect

(1) High speed flows (I)
(2) Selective absorption mechanism (II)
  ‣ Stokes Q shows tiny negative signal around the blue component
(3) Stokes I shows absorption in the red component
High speed flows (I)

- Which is the origin of high Doppler shifted signals?
- Velocities of about 30 km/s (line of sight). Clear Stokes V signals. Unclear Stokes Q and U.
The data show seizable linear polarization signals in the blue component.

The blue linear polarization signal is due to atomic level polarization of the lower level $J_L = 1$.

It is the observational signature of the selective absorption of polarization components of the lower level.
Radiative transfer (III)

- Many profiles also show a small absorption in the line peak meaning that the optical thickness may be considerably large.
- Radiative transfer effects

![Prototypical profile](image)

Atomic polarization of the lower level $J_L = 1$
**Slab-model**

- We assume a slab of constant physical properties and thickness $\Delta \tau$.
- The slab atoms are equally illuminated from below by the photospheric solar continuum radiation, producing atomic level polarization.

\[
I = e^{-K^*\tau}I_{\text{sun}} + (K^*)^{-1}(I - e^{-K^*\tau})S
\]

\[
S = \frac{\epsilon}{\eta_I}
\]

\[
K^* = K/\eta_I
\]

- In off limb observations: $I_{\text{sun}} = 0$

- The slab model takes into account the selective absorption mechanism
- It also allows for the use of two components.
- We neglecting radiative transfer effects inside the slab.

Prototypical fits

- “Normal” profiles are fit successfully
- In this case: \( B = [34, 29] \) gauss, Inclination = [43, 90] deg, Azimuth = [34, 137] deg
- The optical thickness at the position of the red component is 1.3
- The two solutions correspond to the 90 degree ambiguity of the Hanle effect
Prototypical fits

- Slab-model is not sufficient to interpret profiles with a self-absorption in Stokes I
- The optical thickness is 6.4
- How much affect to the determination of the magnetic field vector?
- Need to include radiative transfer effects. Firsts test indicate that the inferred magnetic field vector does not change
“Two components” profiles

If we do not take into account a second component, then:

- \( B = [48, 41], \) Inclination = [43, 98], Azimuth = [16, 37]

- The optical thickness is 2.7

- We are trying to fit a second component to infer the field vector in the “jet”
**Inversion results**

- Optical thickness vs. Height (Mm)
- Doppler width vs. Height (Mm)
- LOS velocity vs. Height (Mm)
- Field strength vs. Height (gauss)
- Field inclination vs. Height (degrees)
- Field azimuth vs. Height (degrees)
\[ B(z) = B(0)e^{\int_0^z \frac{dz}{2H(T)}} \]
Spicules up to 8 Mm in the four Stokes parameters (in He 1083 nm).

Clear linear polarization signals in the blue component of the line as well as tiny absorptions at the peak => optically thick spicules (selective absorption mechanism) and radiative transfer effects are important

Detection of high speed flows

Field strength decreasing from 80 gauss to 30 gauss and then showing a large scatter probably due to noise in the data and averaging along the LOS.

No strong variations of field orientation although the field is clearly more vertical at low heights and then goes close to 50 degree at 2 Mm (~3”).

Observationally the structures (spicules) are 20 degrees inclined, on average (from imaging observations), in agreement with our results.

Thanks for your attention