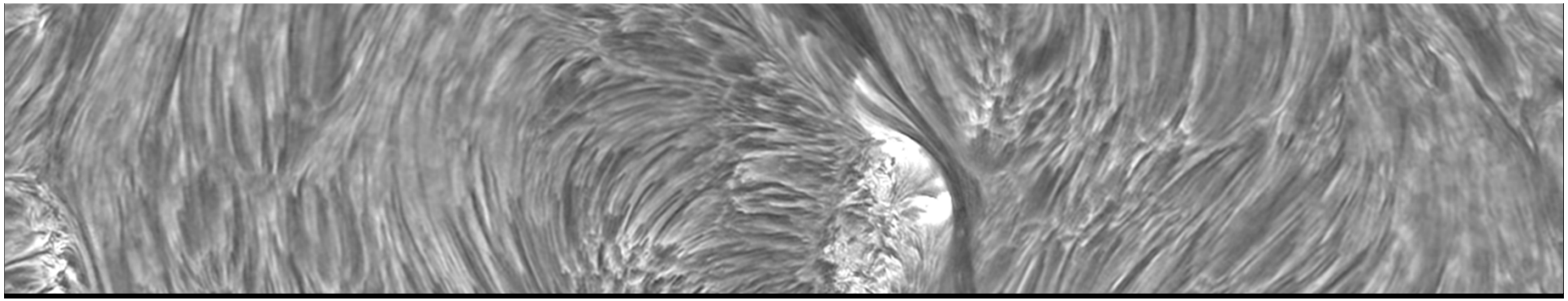

High Cadence Spectroscopy of Prominence Dynamics

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Introduction

- One clear deviation from MHD would be the presence of a drift velocity between neutrals and ions.
- Simultaneous measurements of proxies for these quantities measured in other contexts (sunspots), but interpretation may prove difficult for the different formation regions of the lines.
- However, prominences are an excellent target:
  - Plasma conditions suitable for the coexistence of ions and neutrals (ionization fraction around 50%),
  - Complex plasma dynamics, but easy to observe!
  - Line formation in small regions (which share the same macroscopic parameters).

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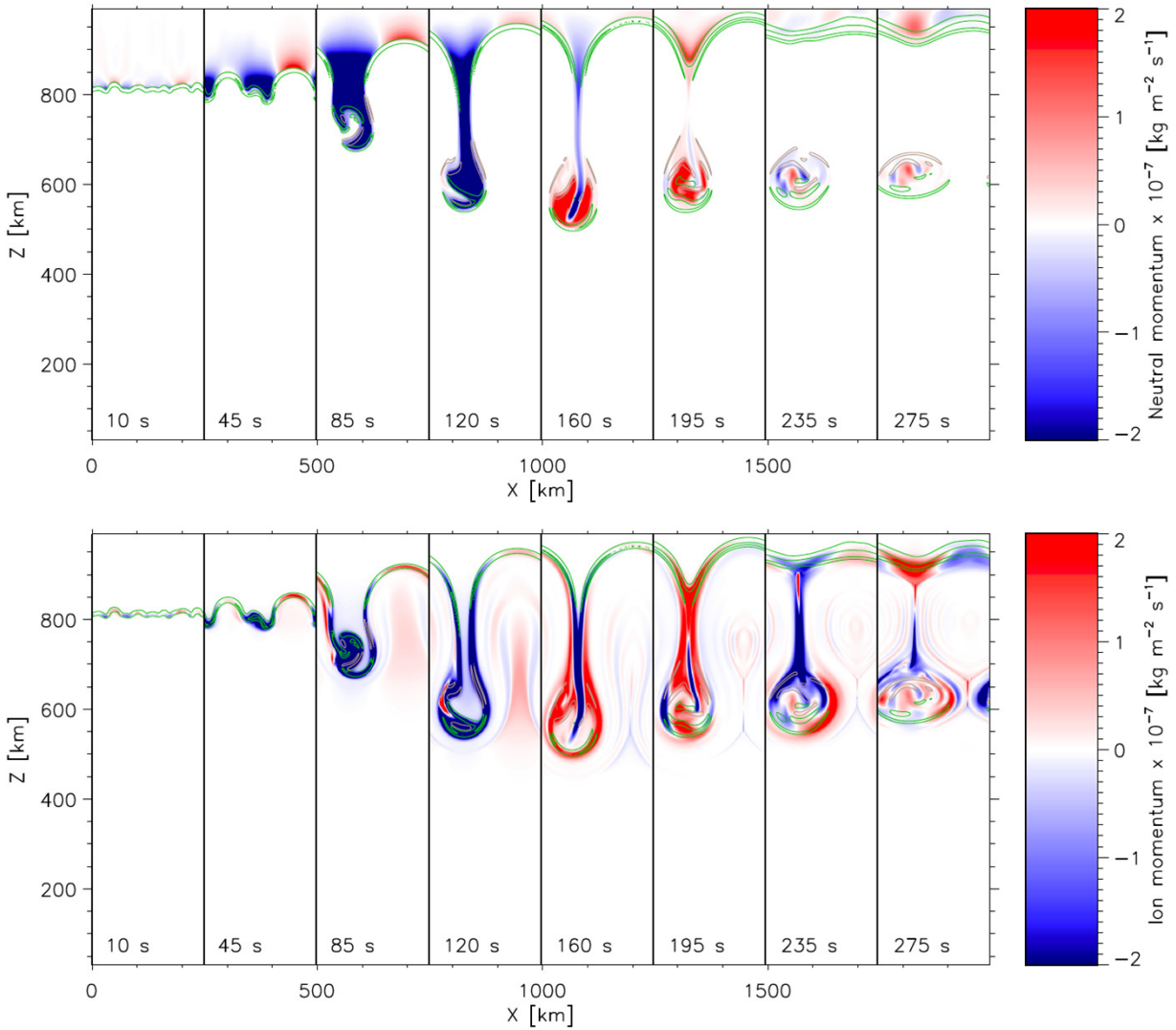
Single fluid description

Combining the momentum equations of the species and neglecting electron inertia we obtain an expression for the drift velocity:

$$\boldsymbol{w} = \boldsymbol{u}_i - \boldsymbol{u}_n = \frac{\xi_n}{\alpha_n}\left[\boldsymbol{J} \times \boldsymbol{B}\right] - \frac{\boldsymbol{G}}{\alpha_n} + \epsilon\frac{\boldsymbol{J}}{e n_e} + \frac{\xi_n \rho_e}{\alpha_n}\boldsymbol{g}$$

Ambipolar term

- Start with the ambipolar term only
- The drift velocity can be calculated afterwards.
- Simulations of RTI report drift velocities on the order of 1 km/s

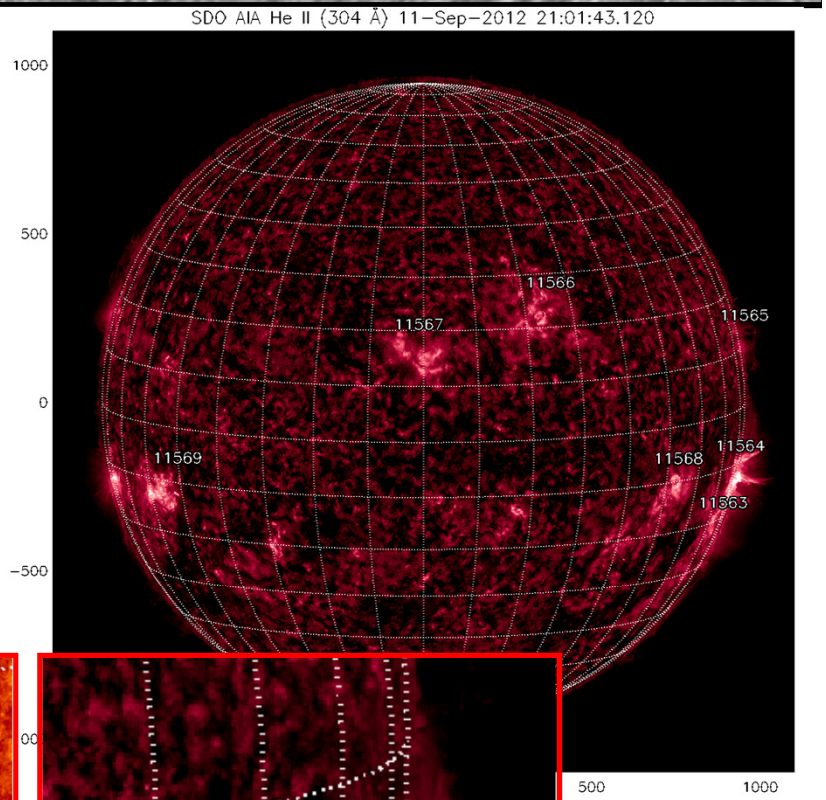


Observational campaign

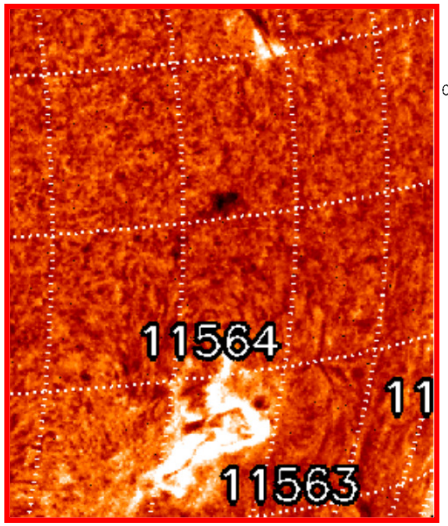
- Two campaigns in the VTT (September 12 and May 13; one in THEMIS (June 13) with different lines.
- Setup: high cadence (around 1.5 s) two simultaneous spectral regions, without spectropolarimetry. This setup also allow us to have more counts. Small scans.
- Two different lines: one for a ionized element and one for a neutral one (at least). The most suitable candidates are both in the infrared (CaII 8524 and HeI 10380).

Observational target (11 sep 2012)

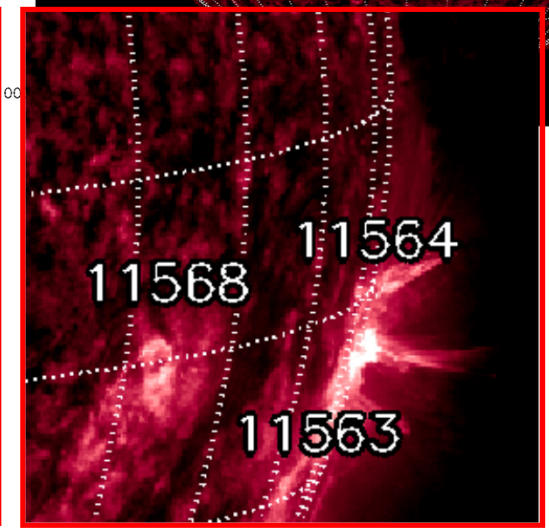
- Target: prominence near AAR11564, observed from 08:49UT continuously for almost 30 min with only one AO jump. R0=6-8.
- Slit along the limb in this series (prominence and surges). 10 steps in scan (so image at a fixed position every 15 seconds).
- Quiescent prominence.



SDO AIA HeII 304



Hα, 2 days before



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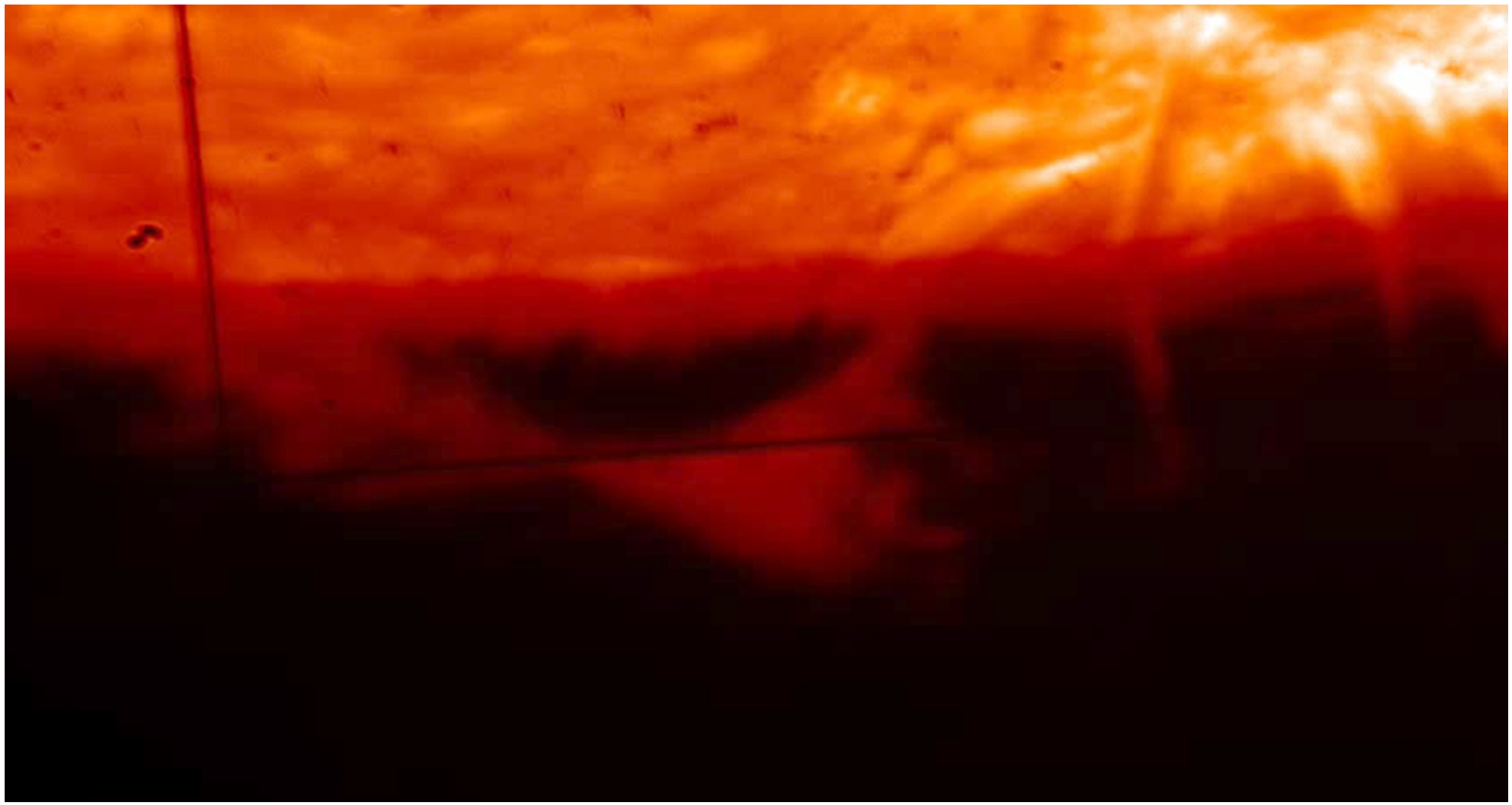
Hα slitjaw images

No flat or dark processing in this movie, raw images. FOV much larger. Slit scan can be seen (1200 images, 1.5 cadence).



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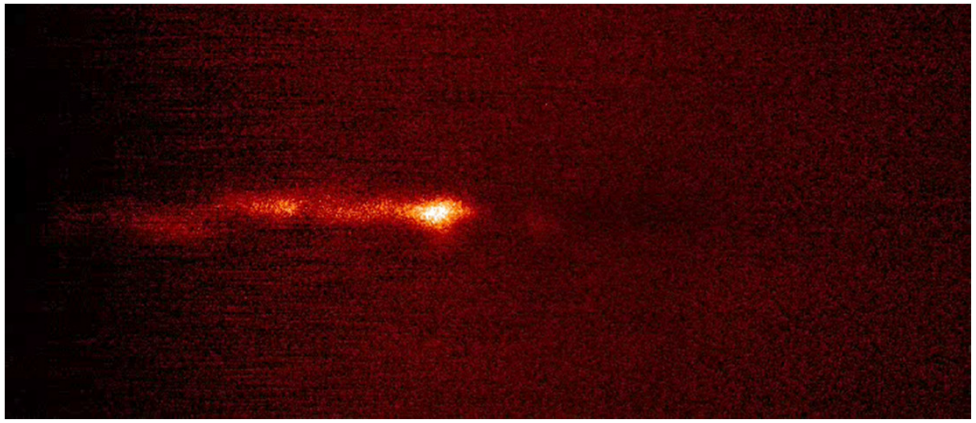
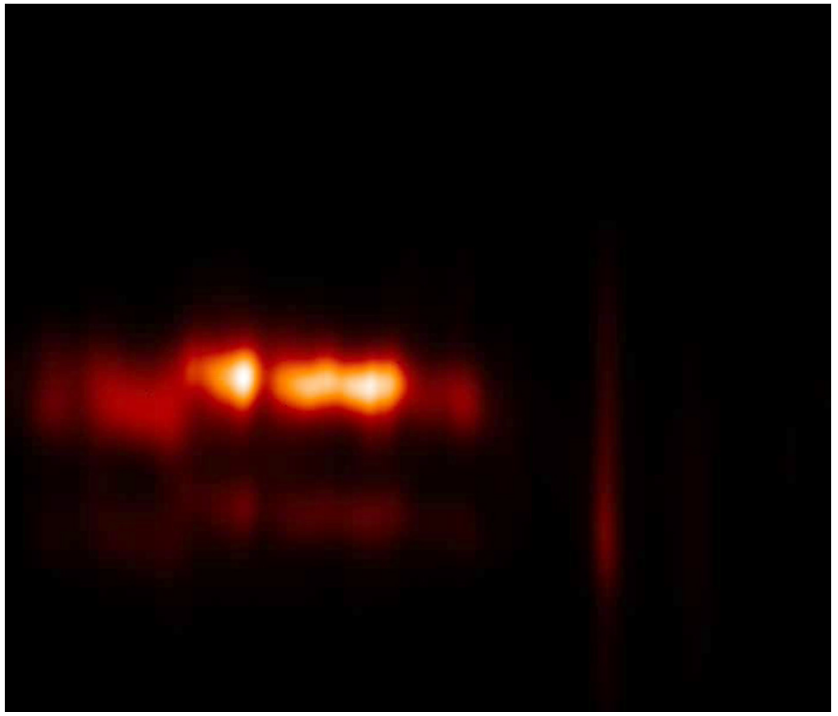
Ca II and He I data

- Spectral data (I) Δλ=0.011 A/pixel
- Dark and flat reduction, realignment of AO jump.
- Ca images much noisier, pca decomposition to filter it.



CaII 8542



HeI 10830

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Ca II and He I fitting

- Ca II: one component, single gaussian. Outputs are amplitude (counts), Doppler displacement and width.

$$f(x) = a_0 \exp\left[\frac{-(x - a_1)}{2a_2}\right]$$

- He I: pattern (triplet), fixed amplitude and distance between components (Wiehr et al. 03), baseline set to 0 and no opacity taken into account. Same outputs than CaII fitting.

$$f(x) = r_2 a_0 \exp\left[\frac{-(x - a_1 - \Delta_1)}{2a_2}\right] + r_1 a_0 \exp\left[\frac{-(x - a_1)}{2a_2}\right] + a_0 \exp\left[\frac{-(x - a_1 - \Delta_2)}{2a_2}\right] + a_3.$$

- Only a single component (more on this later).

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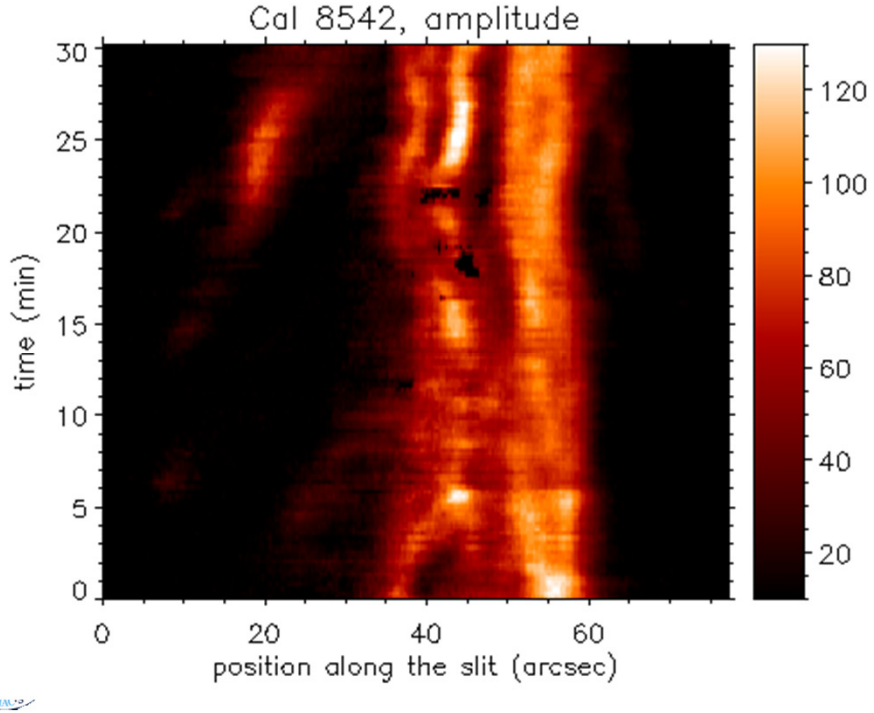
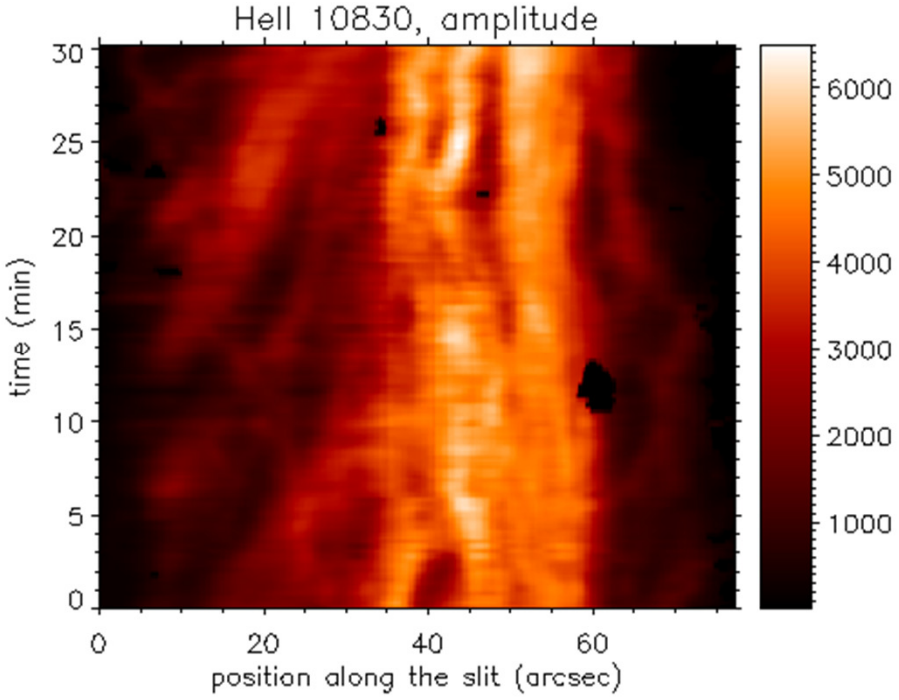
Ca II and He I amplitude

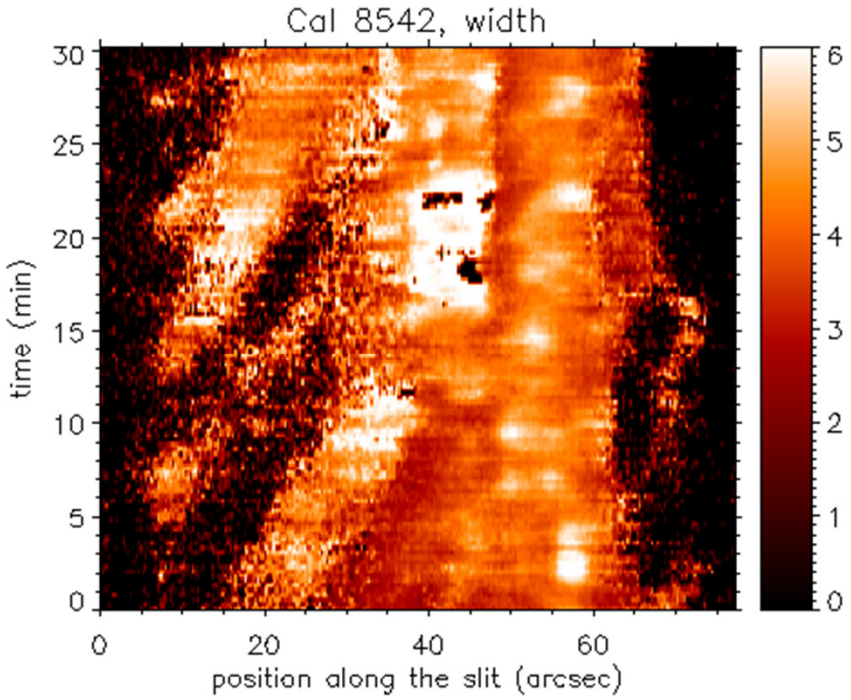
- Good correlation between images (similarity with Hα too).
- Some of the CaII signal lost in the noise level.
- Regions where fitting does not meet the requirements.
- Differences between consecutive images (seeing not good enough)

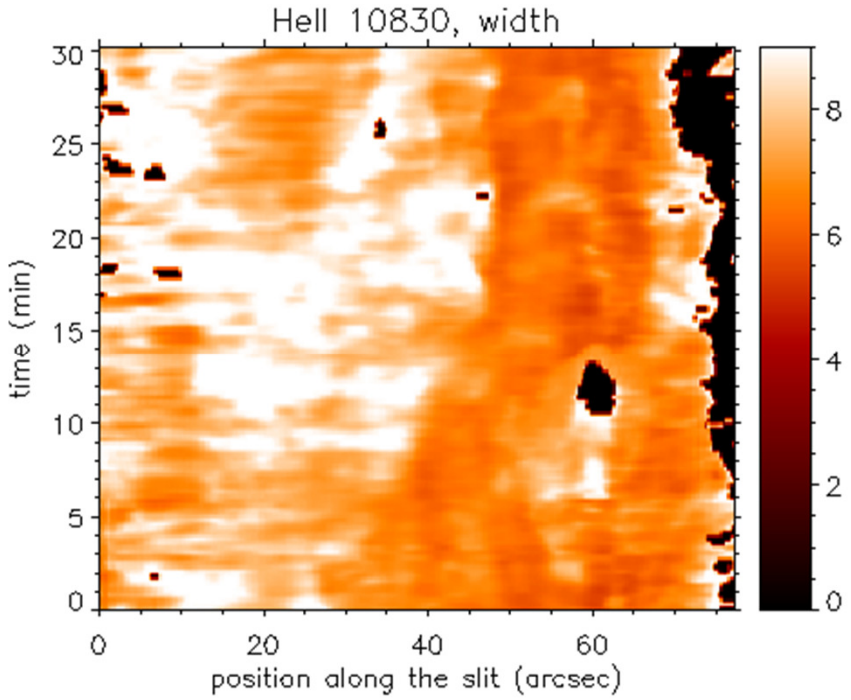




Ca II and He I width

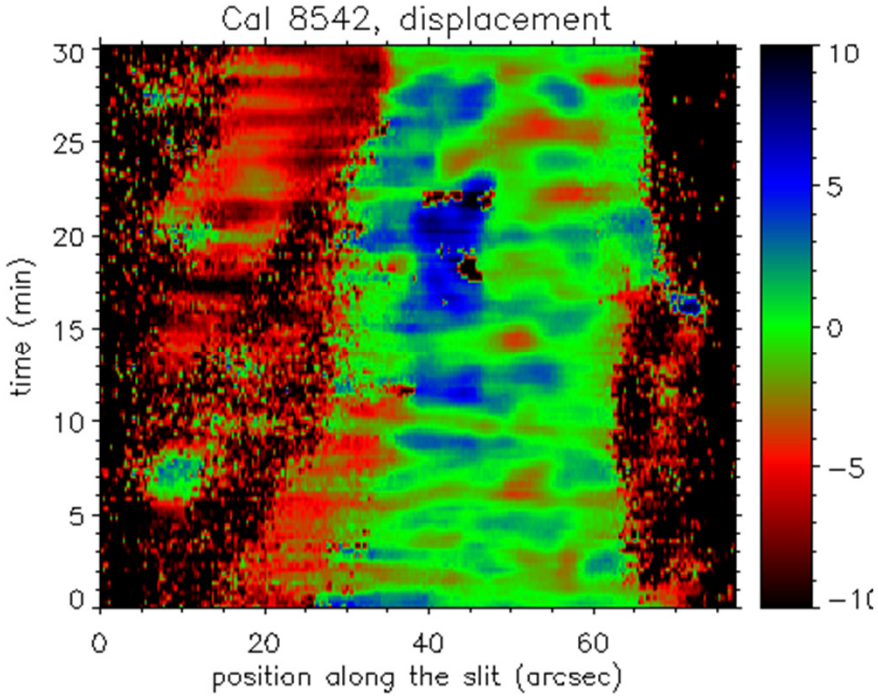
- Related to temperature.
- Serves as an indication of the points where two components are required.
- Again remarkable correlation between the lines.

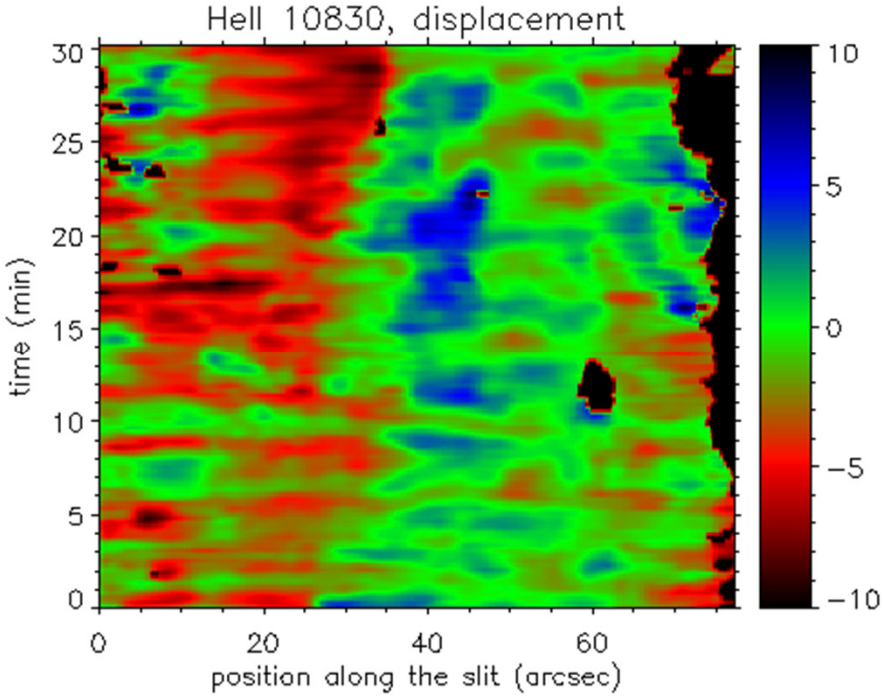




Ca II and He I displacement

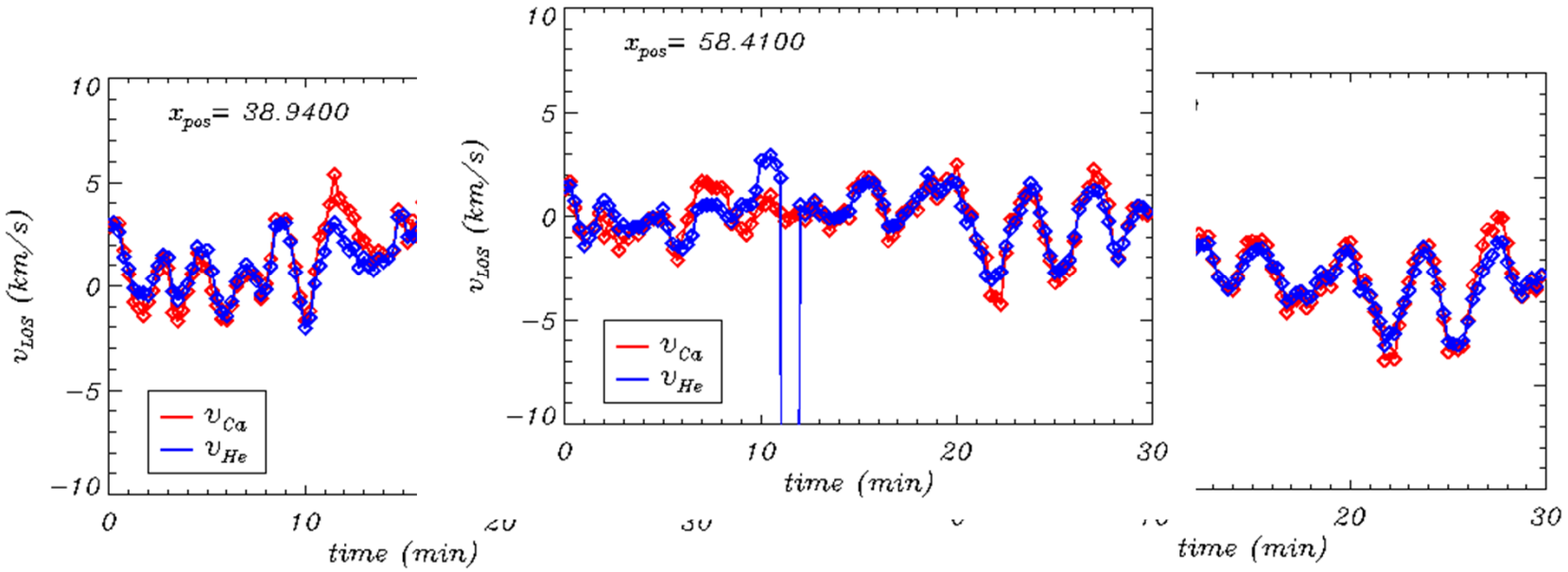
- Measure of LOS velocity (Doppler velocity)
- Striking similarity between the images! Confirms we are looking to plasma with same dynamics.
- Velocities in the expected range (around 5 km/s)





Ca II and He I velocity correlation

- Cuts for a fixed position.
- Same signal, well above the noise level. Extremely well correlated (correlation coefficient above 95%), except in very few places. Confirms visual impression.



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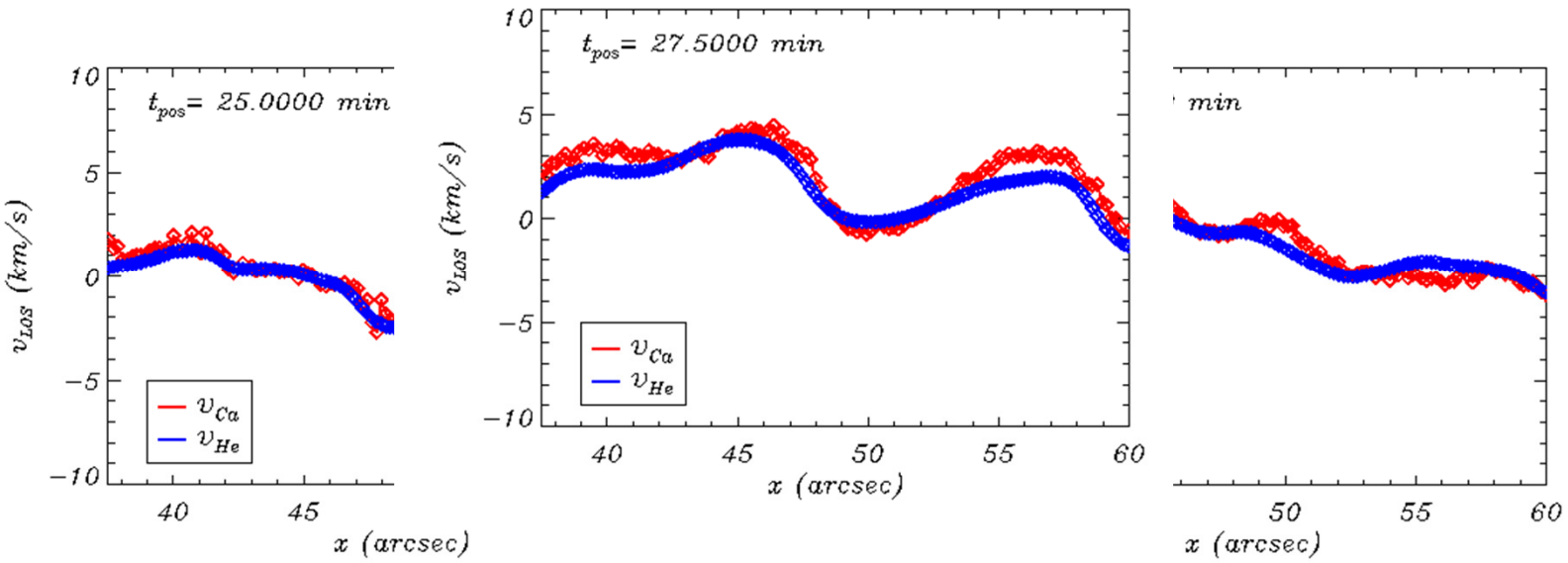
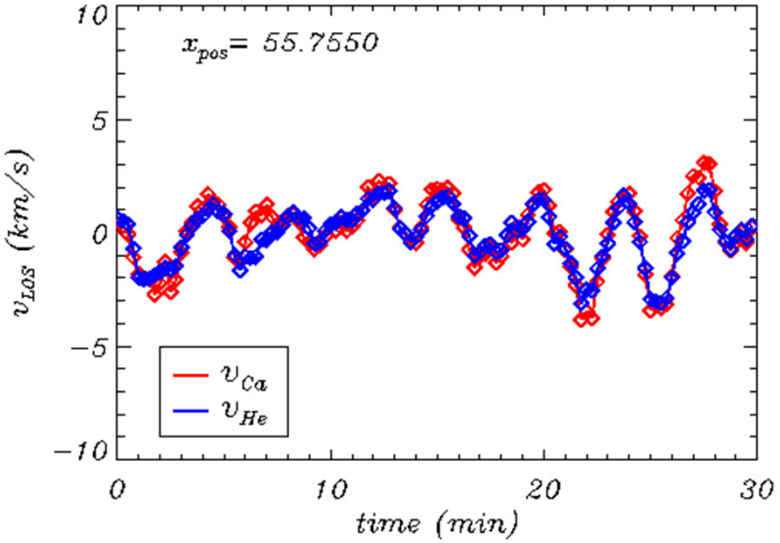
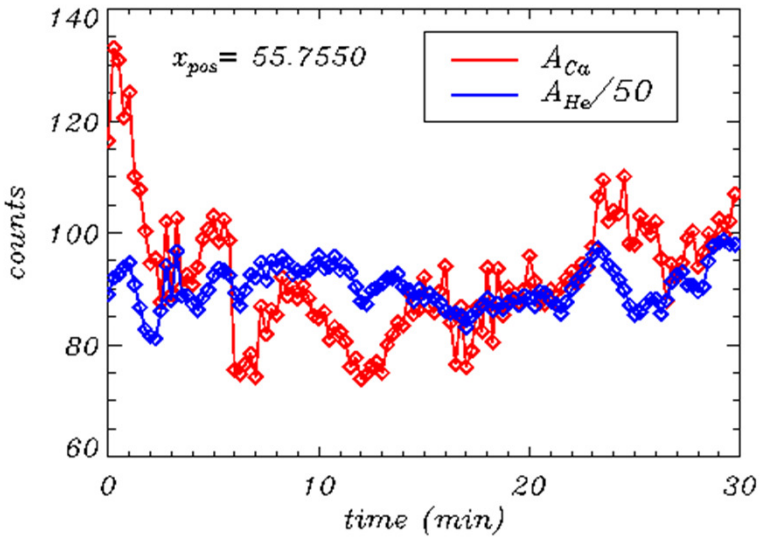
Ca II and He I velocity correlation

- Cuts for a fixed time.
- Wave front almost parallel to the slit?
- Ca and He seem to be out of phase at some instants (related to theoretical predictions, Soler et al. 13, work in progress)

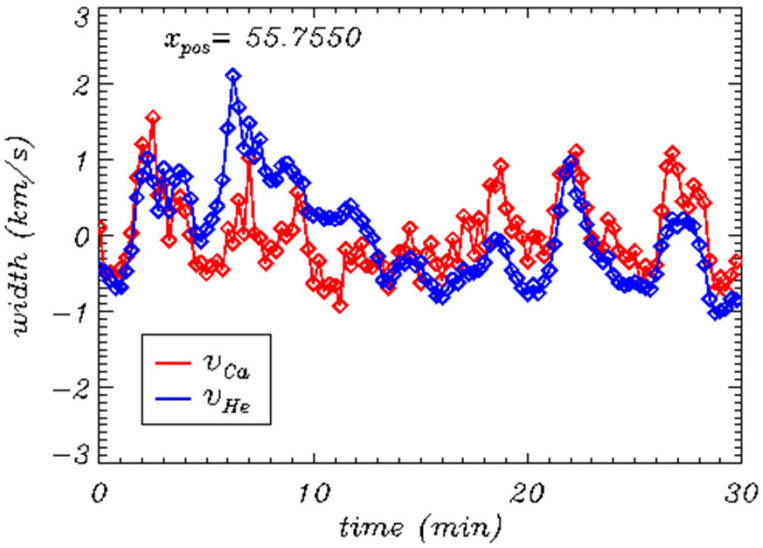


Ca II and He I parameter correlation





- Amplitudes, displacements and widths are apparently not correlated.



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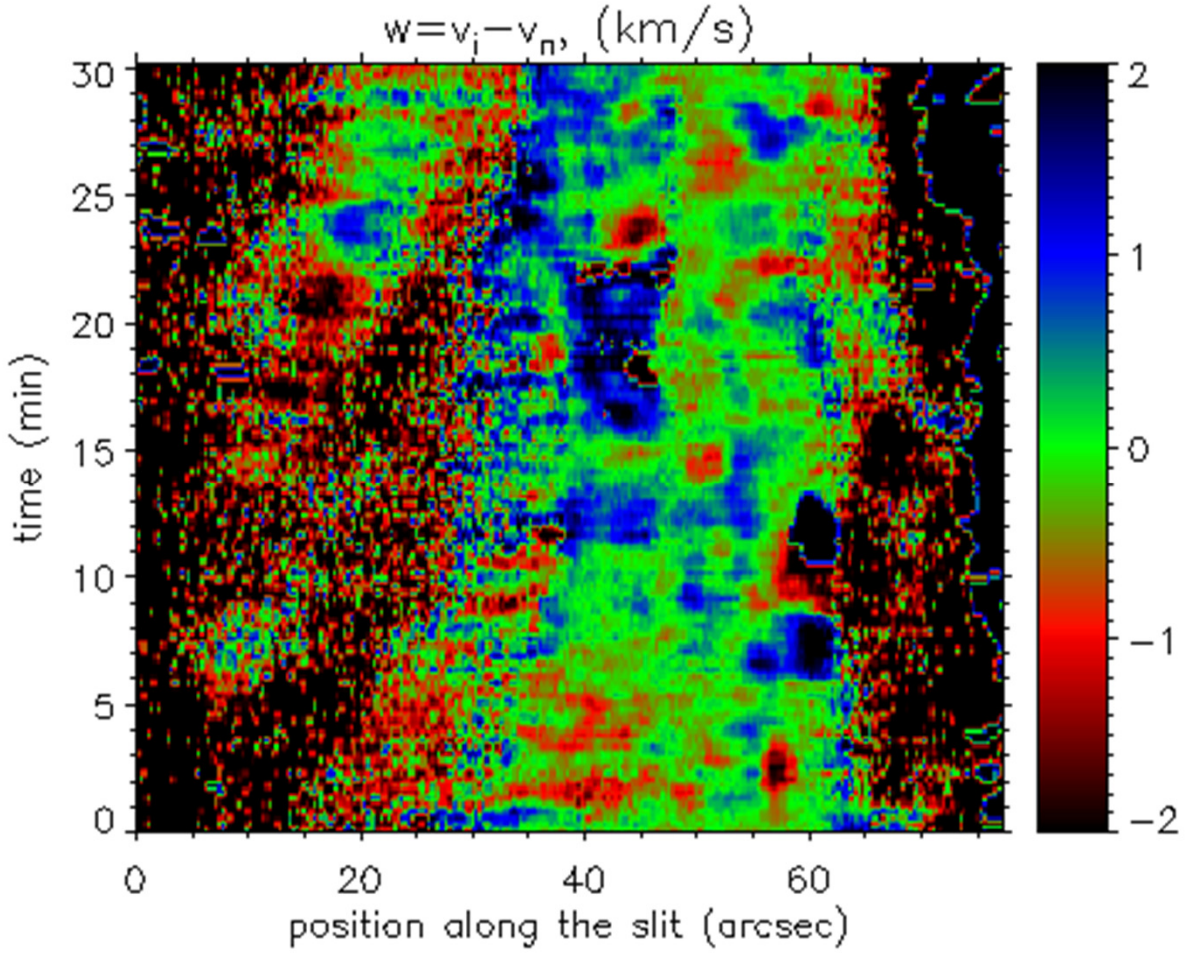
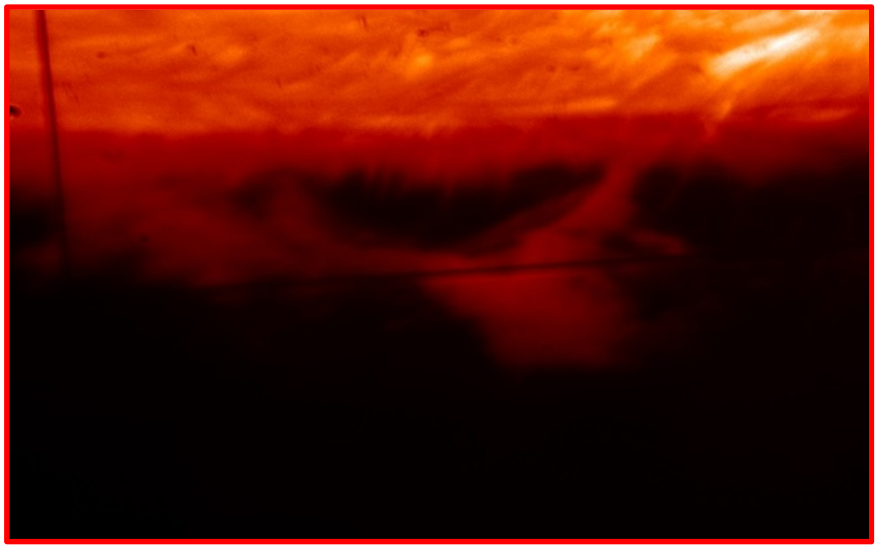
Drift velocities

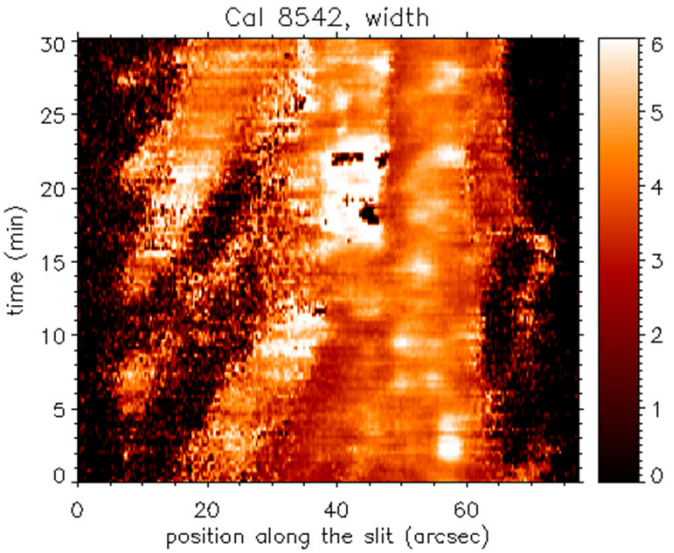
- Assuming that the LOS velocity of HeI and CaII is a proxy of the velocity of neutrals and ions, respectively, we can measure the drift velocity w between ions and neutrals.



Multicomponent profiles

- Only one gaussian has been adjusted so far, but some of the profiles show clear asymmetries between the wings, or even two clear peaks.
- At some points it can be attibuted to surges from the nearby AR, but in other cases it seems to be intrinsic (subresolution elements).





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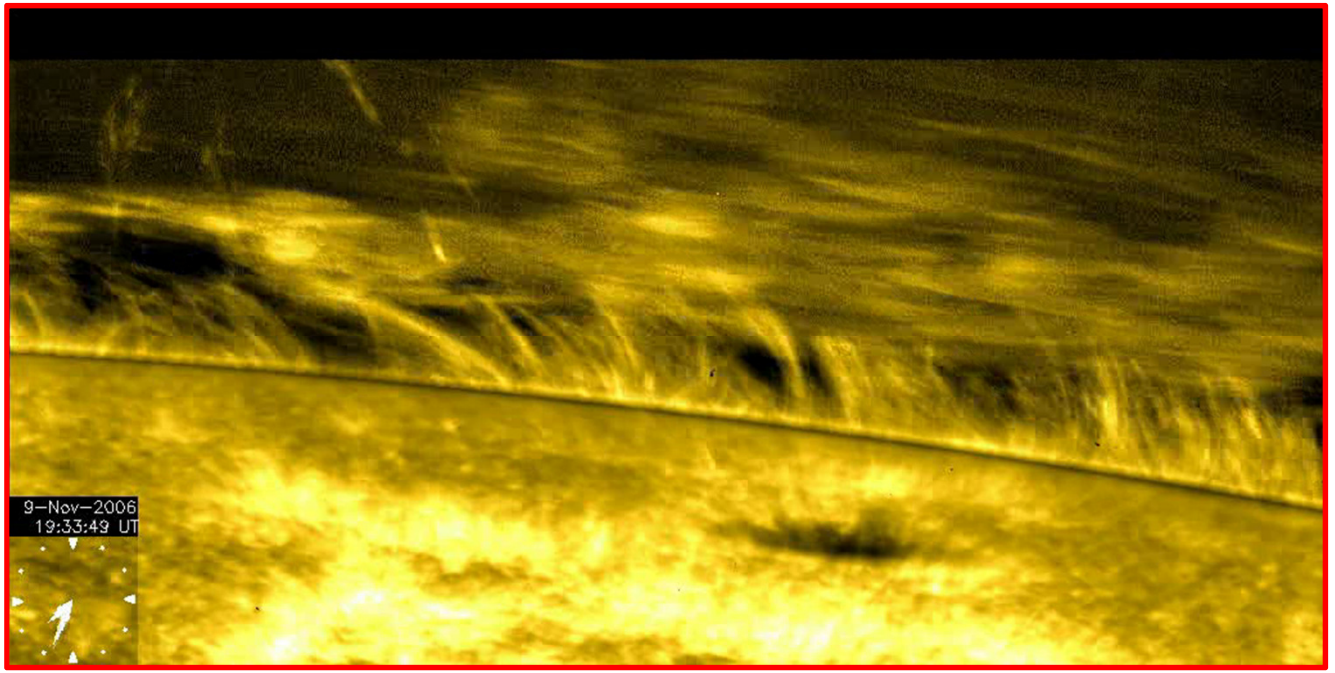
Open questions

- Data fitting needs to be refined to avoid doubts with the analysis.
- Error estimates: do not seem to be a problem checking the variations in the time series, but some estimate is necessary to constrain the range of w.
- Differences in intensity: He and Ca have different formation temperatures (Ca closer to the cooler core of the threads), so this can be expected.
- Wave analysis and interpretation. Relation with other observations and theoretical models.
- Ca and He formation is similar?

Open questions

- If PI effect is confirmed, some estimates about the local conditions of the plasma (and the amount of energy dissipated by the process) need to be computed.
- Relation with other observations: type of prominence, counterstreaming & swaying threads…



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Conclusions

- Prominences are highly dynamical, with short living structures. Observational challenge (no spectropolarimetry with these constraints).
- Observing simultaneously a neutral (HeI 10830) and ionized line (CaII 8542) might provide clues on the PI effects.
- Preliminary results show an excellent correlation in Doppler displacement between the lines. Only in a few regions differences are significant (and also maybe some hints of phase delay).
- Drift velocity in the expected range. Theoretical models and simulations necessary to asses these conclusions and extract potentially more information from this type of observations (ionization fraction at least).