Spectroscopic Investigation of Solar Filaments

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Abstract

Solar filaments are structures of cool and dense material suspended at coronal heights by the magnetic field. We present a detailed exploration of filament emission line characteristics using data from the Interface Region Imaging Spectrograph (IRIS). We investigate the temporal and spatial evolution of chromospheric and transition region emission lines characteristics in a number of filaments, identifying morphological and spectral signatures of their evolution. When seen at the limb as prominences, we further investigate their vertical structure and explore flows free from unwanted contributions. Multiple flow patterns can be identified within the larger structure as corresponding to individually evolving strands. Despite being long-lived structures in the solar atmosphere, changes in their confinement or anchoring can lead to their destabilization and to total or partial eruption as Coronal Mass Ejections (CME).

Observational Data

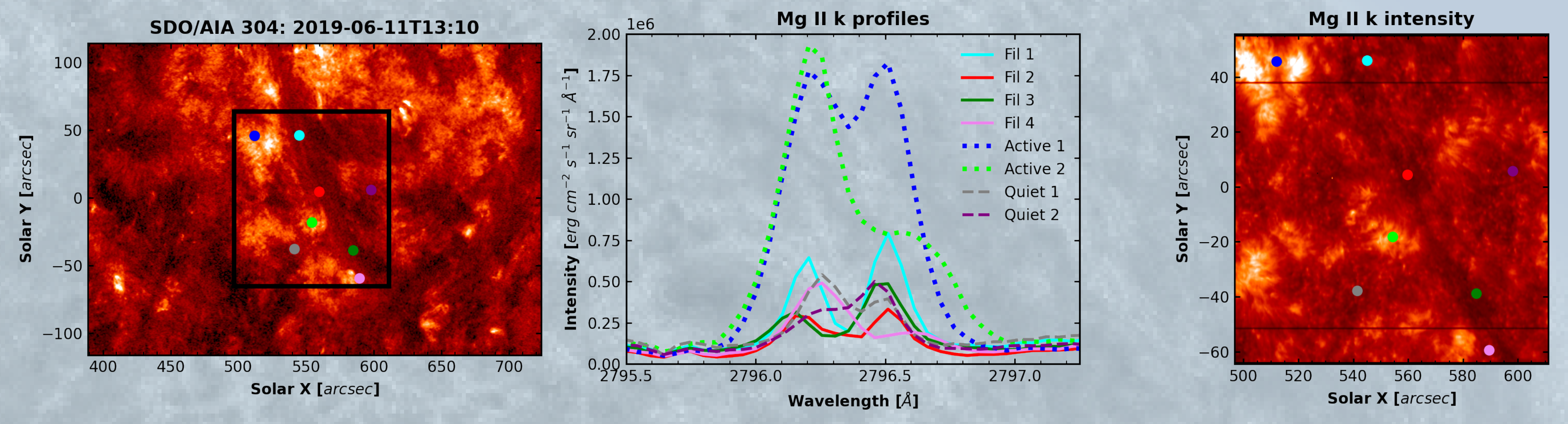
We were interested in the evolution of solar filaments (and their limb counterparts, prominences), their morphology, and spectral line emission. We focus on the NUV emission as captured by the Mg II resonance lines. A number filaments were investigated, but here we show the results from the most intriguing one.

A large reversed C-shaped filament transited the disk in June 2019 and was located between two active regions during its transit. IRIS[1] data was taken between 2019-06-08 and 2019-06-14, from after the meridian crossing to close to the limb, in various observing modes, and probing different parts of the filament. In addition to the large scanning rasters, a large 2-step raster was also taken during its passage, enabling detailed analysis of the filament strands.

SDO/AIA[4] data was used for context and for following the large scale evolution, as well as to explore the surrounding coronal emission.

Data analysis

The calibrated IRIS level 2 data was used and the *iris_orbitvar_corr_l2s.pro* routine was further applied to remove any residual orbital variations. The absolute intensity $I(\lambda, t)$ in $erg \cdot s^{-1} \cdot cm^{-2} \cdot sr^{-1} \cdot Å^{-1}$ was then computed[6]. We then identified the location of the features of the Mg II profiles[3]. The separation of the emission peaks, their ratio, and depth of the central reversal were thus computed. If both resonance lines were present in the dataset, their ratio was also computed. Moment analysis (i.e. moment i is $\int_{\Delta v} I_v v^i dv$) was used to find the integrated intensity of the line, the Doppler shift, and the wavelength dispersion (line width).

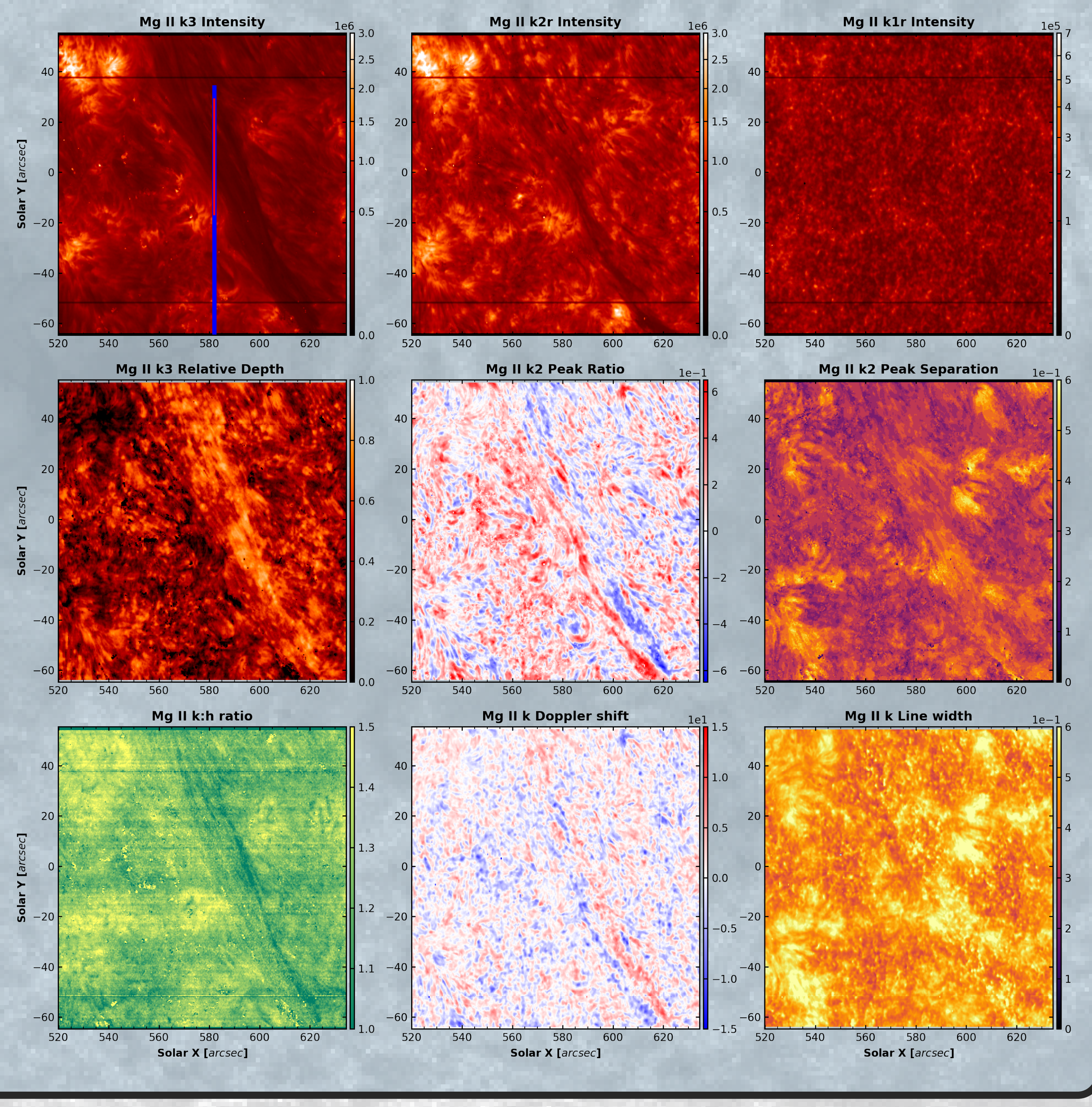


Left: *Context SDO/AIA 304 Å with the black rectangle showing the IRIS FOV. The coloured dots correspond to the profiles included in the middle panel.* **Middle**: *Typical Mg II k profiles of chromospheric structures in the FOV.* **Right**: *Mg II k integrated intensity.*

Mg II resonance lines characteristics

Understanding the temporal and spatial evolution filaments and their relation to the surrounding structures can provide new insights into their long term stability and reveal precursors of destabilisation and eruption[7, 2]. Their detailed morphology is highly dynamic, with strands showing flows and oscillations during their lifetime[5], despite being long lived structures in the solar atmosphere.

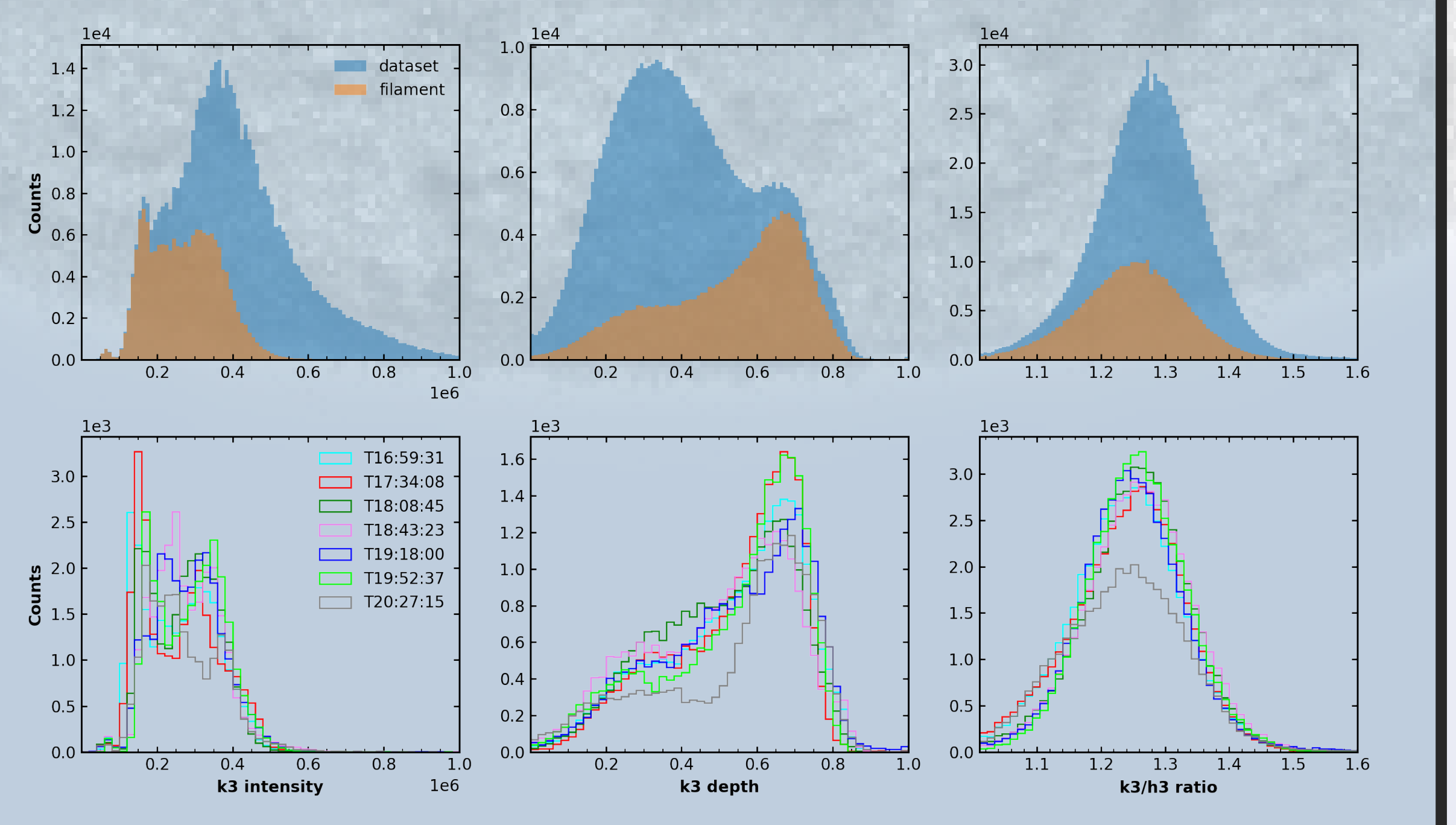
We identified the profile characteristics that best capture an evolving quiescent filaments and used them to follow its transit across the disk. We show the derived characteristics for the raster scan on June 11, 2019. The line core of Mg II best captures the bulk structure. The relative depth of the core reversal as well as the ratio of the reversal cores are markers of its presence. Subtle signs can be seen in the peak separation, which has higher values in the filament. The peak ratio and the Doppler shift are complementary as they both highlight flow patterns along the filament.



Top: *Mg II k3, Mg II k2r, and Mg II k1r intensities;* **Middle**: *Relative depth of the central reversal; relative intensity of the emission peaks, and k2 peaks separation;* **Bottom**: *Integrated intensity, Doppler shift, and Line width.*

Filament evolution

Using the extended 2-step scan following the filament spine on June 11th (blue line in above figure), we explore the change in the identified filament markers in the region marked by the red line, over time, as the filament evolves under the SG slit. Namely we are interested in the k3 intensity, the relative depth of k3, and the k3:h3 ratio. The observed variation is a result of changes in the strands captured by the slit, representing both changes in the local structure and the effect of flows moving filamentary material in and out of the FOV.



Top: *Variation of best filament indicators for the whole dataset vs. the filament region.* **Bottom**: *Temporal evolution of main filament markers, in ~30-min bins.*

Discussion and Conclusions

We aimed to identify the profile characteristics that best pinpoint the presence and structure of filaments by using a custom profile feature identification algorithm to locate important positions in the profile shapes of the Mg II resonance lines.

- The central reversal intensity is the most sensitive, as the filament material is denser and cooler than the surrounding atmosphere, the emission originating from a thin layer along the line-of-sight.
- While the core intensity reveals the bulk of the structure, the relative depth of the central reversal highlights the strands within the larger structure.
- The ratio of the h and k line cores captures the details of individual strands and is great proxy for variation of optical thickness within the emitting plasma.
- Hints of the filament's presence are also seen in the separation of the emission peaks and very faintly in the line width values.
- In the case when flows are present these are distinguishable in the relative peak intensity and in the Doppler signal; however, this effect can not fully disentangle real motions within the filament from evolution as the raster scan is recorded.
- Based on rapid scans of a single location across the filament, the evolution details and slow decay of the filament as the strands become tenuous are captured.

We are developing an automated selection tool based on these markers in order to follow the evolution of filaments up to their destabilisation and eruption. In a previous study, we found that the onset of a slow rise phase proceeds the eruption in active region filaments. We will identify any significant changes of spectral properties that can be used to pinpoint the onset of destabilisation of the structure and identify its cause.

References

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