Multi-wavelength study of an X9.3-class chromospheric flare ribbon

& the overlooked line profiles it contains

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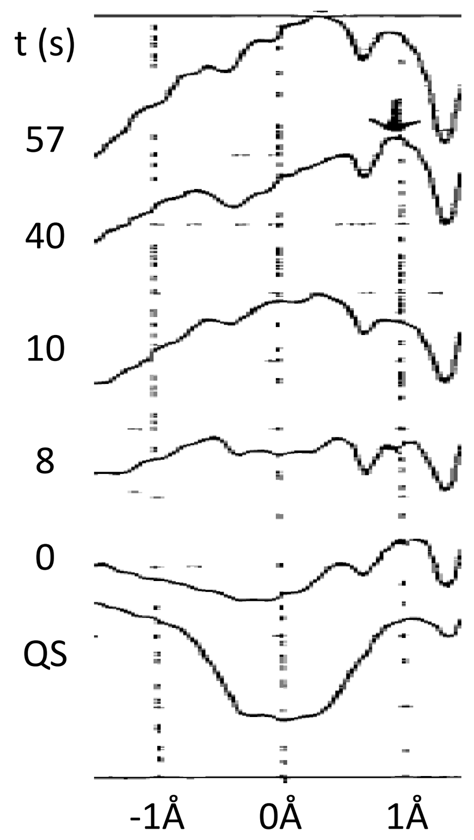
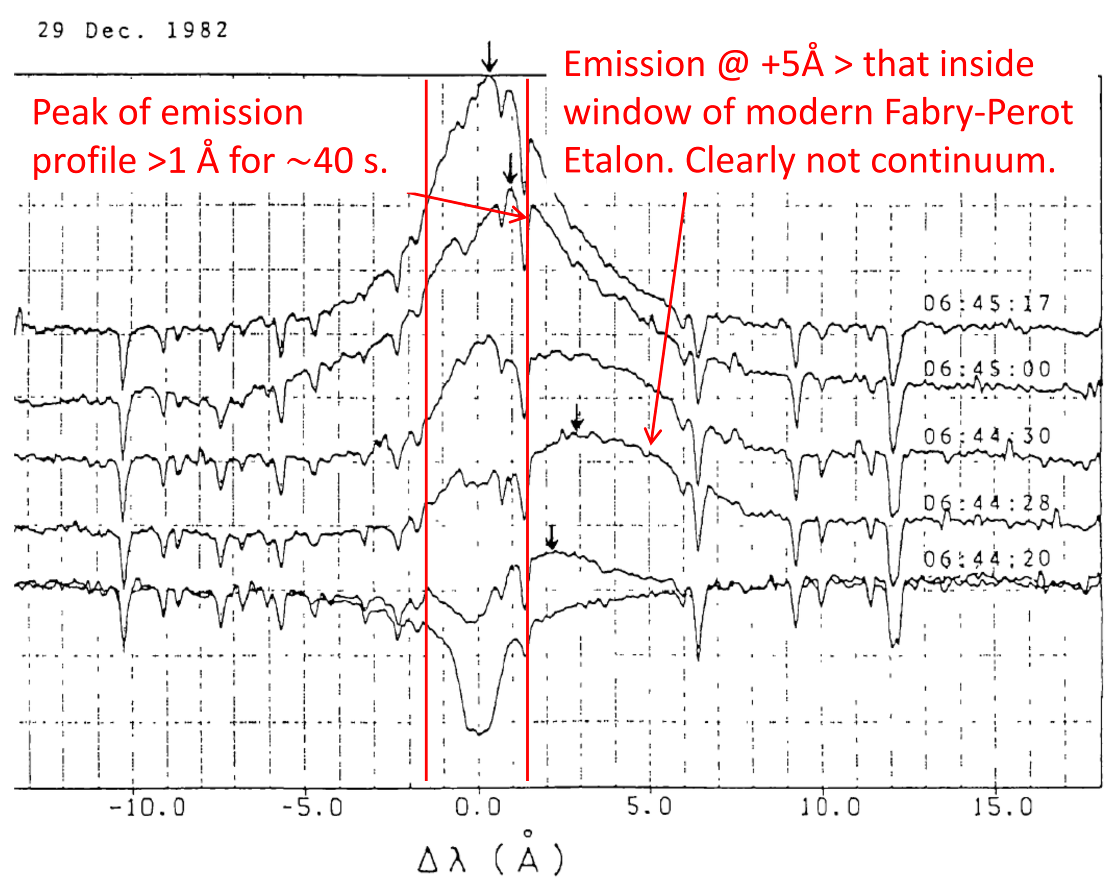
(1) Introduction



You are analysing the time sequence (bottom to top) of Hα profiles in a flare (image left)

"The flare converts Hα from an absorption profile into emission, with a slightly asymmetric enhancement at around +1Å (46km/s Doppler Velocity) and opacity effects dominating the shape of the line core."

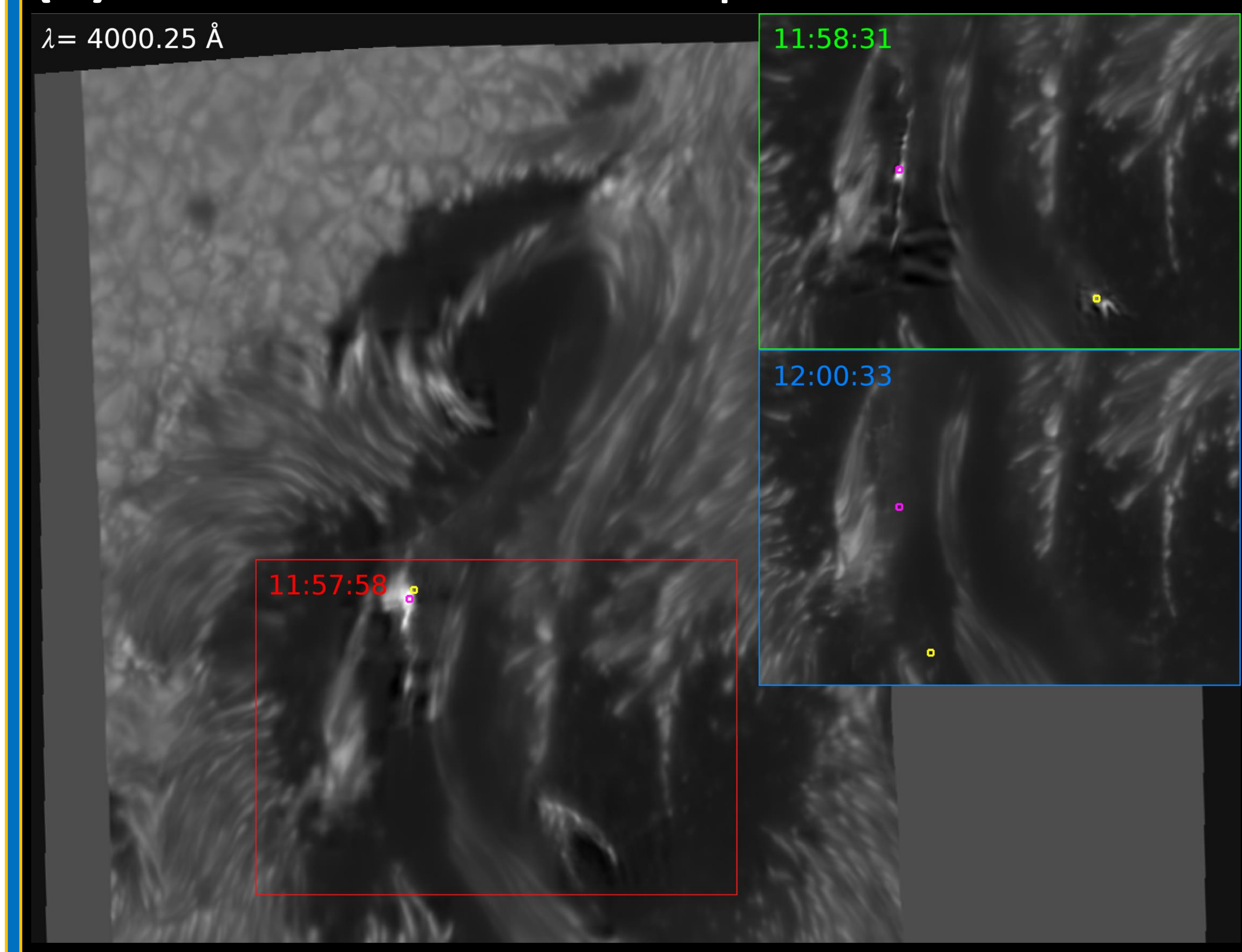
This is a typical interpretation, with such asymmetries frequently described as "strong" and widths as "broad".



However, the full profiles from this observation are shown left. (Ichimoto and Kurokawa 1984)

Vertical lines show CRISP instrument wavelength window. CRISP (Scharmer et al 2007) @ SST is one of the most successful instruments of this generation for flare observations. Other modern imaging instrumentation has similar window widths.

(2) Observations: 6th Sept 2017 11:56UT

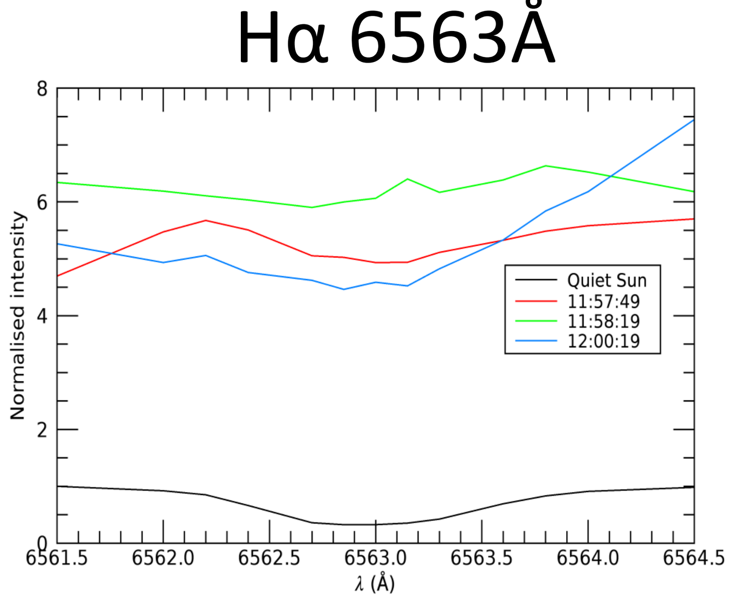


- Taken using CRISP and CHROMIS instruments at the SST.
- Above: image of photosphere via Ca II K 3934Å continuum point at 4000.25Å,
- Red area repeated in green/blue at later times. Hα line profiles taken from locations in yellow, Ca II 8542Å in purple.

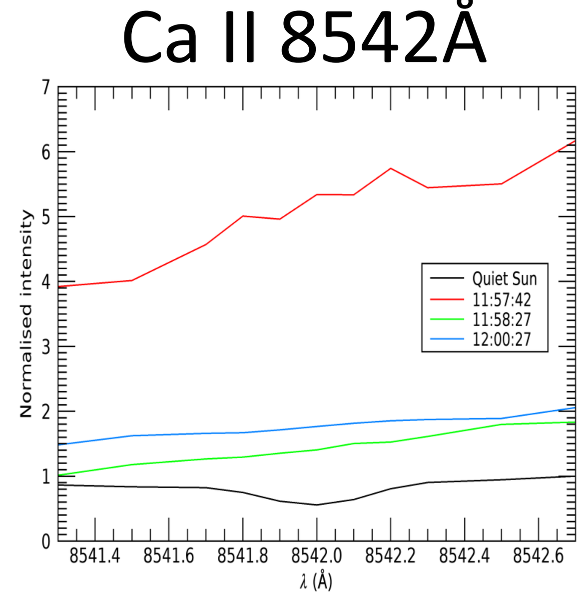
(3) Results

- Easy to find profiles strongly suggesting similar forms to past observations by e.g. Ichimoto and Kurokawa (1984) Wulser and Marti (1989) Zarro et al (1993)
- Common above areas of white light enhancement in impulsive phase.
- These sites are strongly suspected to be the footpoints of reconnecting loops.
- Present both in Hα and Ca 8542, examples below.

Hα 6563Å

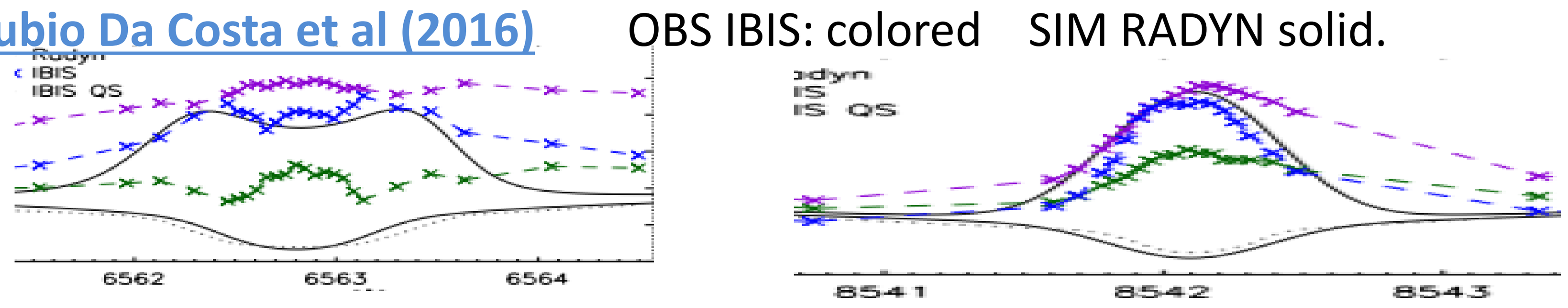


Ca II 8542Å

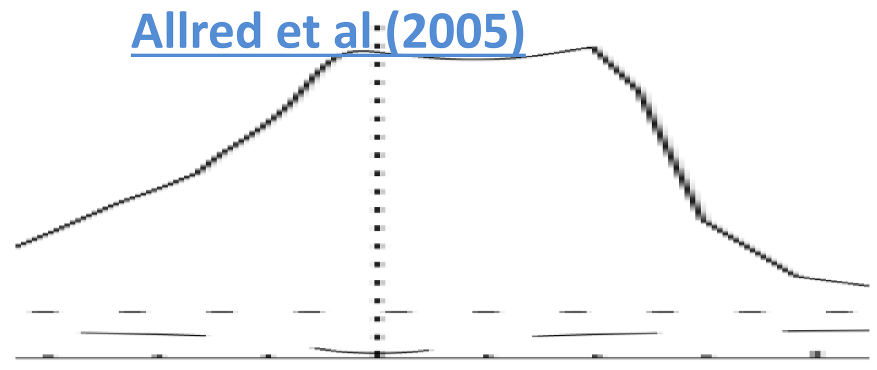


- However, it is very hard to analyse profiles that are not fully captured.
- Simulations, perhaps unsurprisingly focus on narrower flare profiles with small Doppler shifts. Examples are shown below.

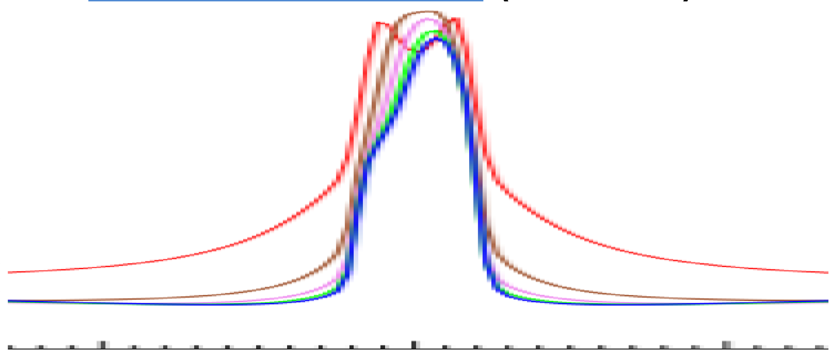
Rubio Da Costa et al (2016) OBS IBIS: colored SIM RADYN solid.



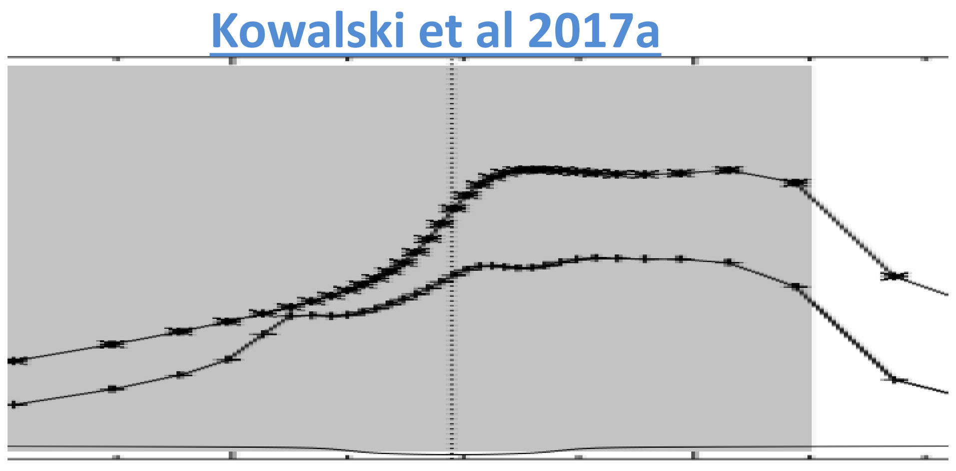
Allred et al (2005)



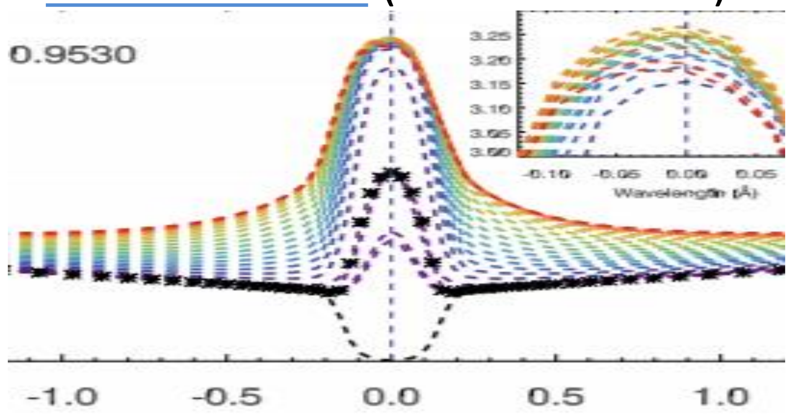
Kuridze et al 2020 (off limb)



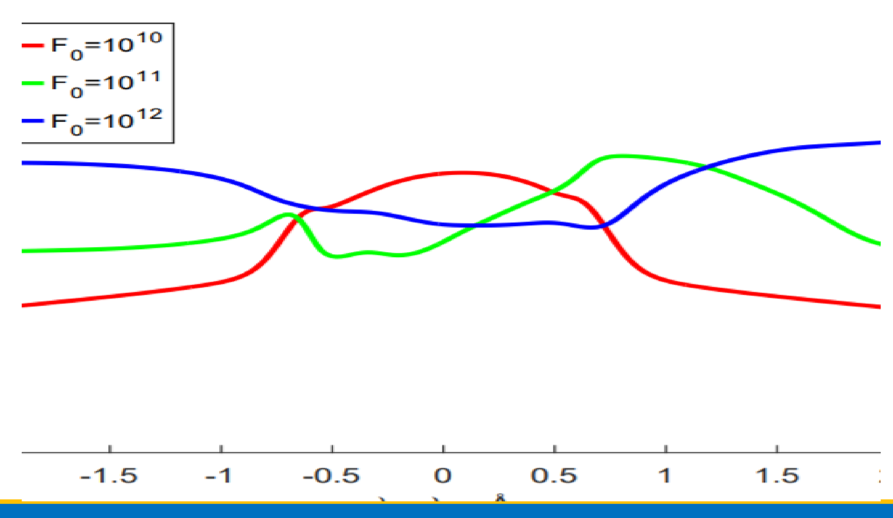
Kowalski et al 2017a



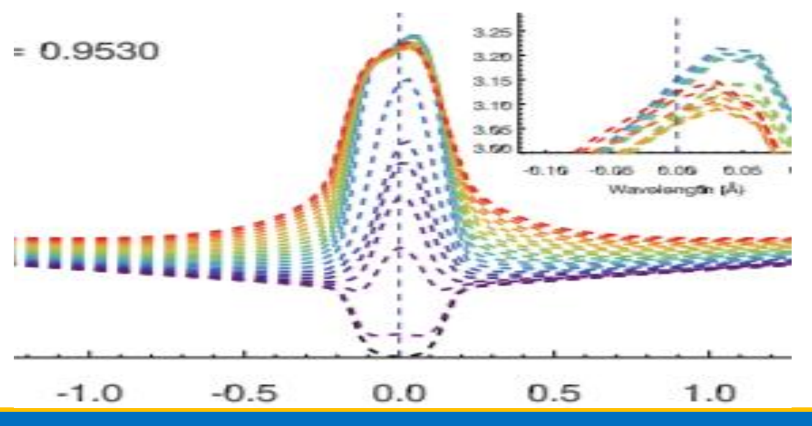
Kerr et al 2016 (Electron Beam)



Druett & Zharkova (2018)



Kerr et al 2016 (Alfven Wave)



(4) Conclusions

- Instrumentation of recent generations is designed with the wider solar community in mind. Therefore do not have large enough wavelength windows to understand flare kernel chromospheric dynamics.
- Solar flare papers this millennium rarely give direct comparisons between such observations and the simulated profiles. Rubio Da Costa et al (2016) and Zharkova et al (2020) are the exceptions to this.
- DKIST provides the opportunity to once more draw back the curtains and see the wider picture in chromospheric lines in flares. SUC 195 by Gerry Doyle is a perfect example of this, placing the 3 ViSP tuneable filter wavelength windows side-by-side.
- This will provide opportunities for models that predict large broadenings and shifts to evaluate these scenarios and potential drivers, including energetic proton beams, wave propagation, formation at higher than expected kinetic temperatures, additional atomic physics, etc. More recently Kowalski et al 2017a Kowalski et al. 2017b have looked into including electric pressure broadening / Stark effect into hydrogen line profiles. We encourage similar endeavours and publishing flare profiles in common observational lines.

3 point summary

(1) We encourage flare observers to present the broad, shifted, challenging chromospheric line profiles in their work more often.

(2) We encourage early "on-boarding" of modelling to provide physical mechanisms that can broaden out lines to the degree seen in suggested by these profiles and studies from the 80s and 90s.

(3) We strongly encourage flare-watch observations using DKIST (Rast et al 2021) to make use of ViSP's 3 tunable bands to observe wider spectral windows in such chromospheric lines, see Science Use Case 195.

References

Allred et al (2005) https://arxiv.org/abs/astro-ph/0507335 Doyle SUC 195 https://nso.edu/telescopes/dkist/csp/dkist-final-science-use-cases/ Druett & Zharkova (2018) https://doi.org/10.1051/0004-6361/201731053 Ichimoto & Kurokawa (1984) https://ui.adsabs.harvard.edu/abs/1984SoPh...93..105I/abstract
Kerr et al (2016) https://arxiv.org/abs/1605.05888 Kowalski et al 2017a https://arxiv.org/abs/1609.07390
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Zharkova et al (2020) http://doi.org/10.1051/0004-6361/202037885