Observational Analysis of Line Formation Heights in the Flaring Chromosphere

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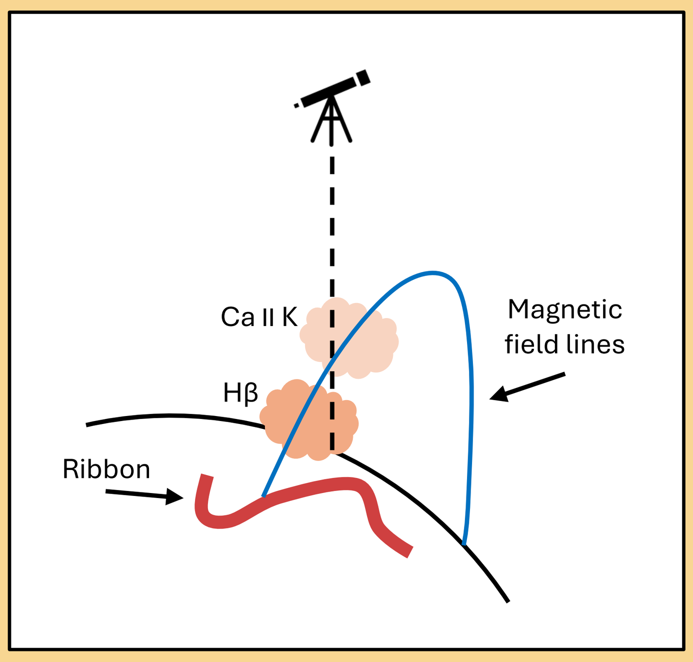
1. Introduction

- During solar flares, energy stored in the coronal magnetic field is transported down through magnetic field loops, heating lower layers of the atmosphere after magnetic reconnection
- A large fraction of this energy is deposited in the chromosphere, heating surrounding plasma and producing highly structured flare signatures such as ribbons (Forbes 1991)
- The energy transport mechanism through the solar atmosphere is not widely agreed upon, with the most cited method being the standard thick target model of an electron beam
- Different models and different parameters or initial conditions used in these models can result in distributions of source heights through the chromosphere

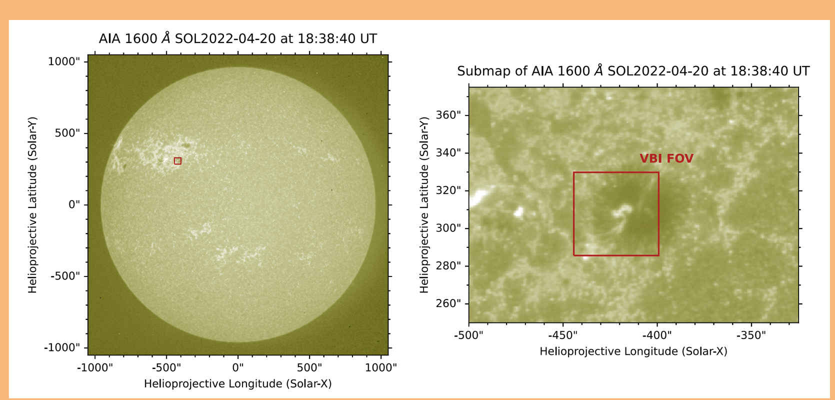
Overview of Results

- Flare energy is transported along the magnetic field to the chromosphere, but the transport mechanism is still uncertain
- Different mechanisms will produce different distributions of chromospheric source heights with wavelength
- Viewing the magnetic field at an angle should expose a spatial offset between different wavelengths
- Cross correlation was performed between images of a ribbon in Hβ and Ca II K, finding an offset of 0.32 ʺ or ~230 km projected distance
- This is broadly consistent with electron beam and Alfvén wave model predictions but further observations and model comparisons are needed

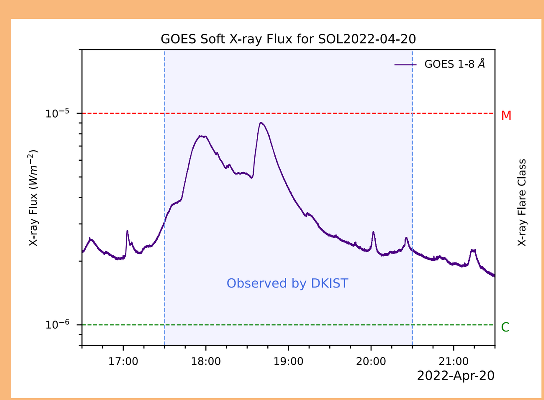


2. Motivation

- Flare chromospheric sources emitting in different wavelengths should appear at different heights, which should give an offset visible when viewed from an angle
- 1D electron-beam heated radiation hydrodynamics models predict a difference of ~400 km between Ca II K (formed in the upper chromosphere and Hβ (mid-chromosphere) (Kerr et al. 2016, Capparelli 2017)
- An observed spatial offset between Ca II K and Hβ can be compared with existing electron beam or other possible energy-transport mechanisms, e.g. Alfvén waves (Fletcher and Hudson, 2008)



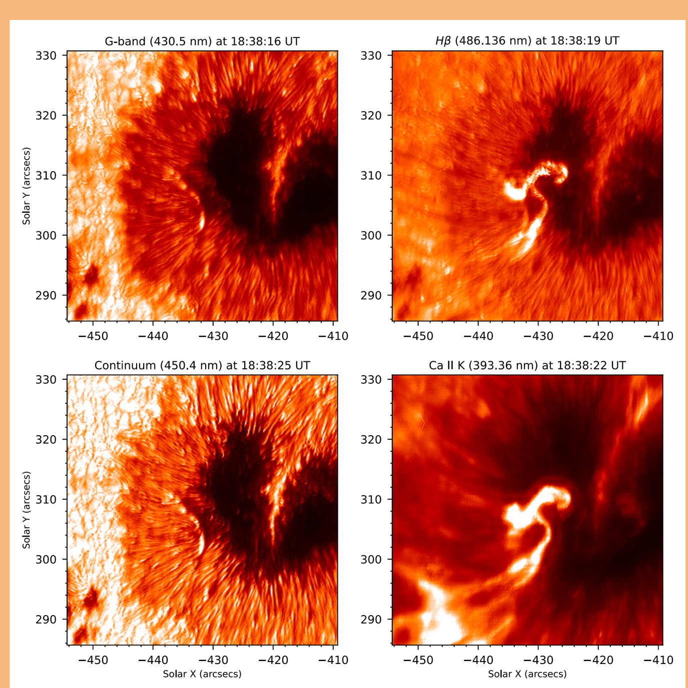
AIA 1600 Å data from the impulsive peak, showing a closer image of the sunspot located in the Northwest of the solar disk with DKIST's VBI field-of-view outlined in red.



GOES 1-8 Å channel, showing two C-class flare peaks

3. Observations

- The data used in this project are observations of a solar flare over a sunspot, taken with the Visual Broadband Imager's 'blue channel' (VBI) on the Daniel K. Inouye Solar Telescope (DKIST)
- The VBI has a 45 ʺ physical FOV, spatial sampling of 0.011 ʺ per pixel and spatial resolution of 0.022 ʺ
- DKIST implements adaptive optics and speckle interferometry before reconstructing images
- The overall cadence is 3.2 seconds, imaged through G-band, Hβ, Ca II K and continuum filters consecutively
- The event was a C-class flare on 20/04/2022 with two impulsive phase peaks at 17:47 UT and 18:35 UT
- A ribbon forms in the sunspot umbra in the Ca II K and Hβ bands at the second impulsive phase peak, reaching a maximum GOES flux of 2.3x10^{-4} Wm^{-2} in the 1-8 Å channel



VBI images across the 4 wavelengths at the time of the second impulsive phase peak.

4. Analysis

- The seeing of observations was very poor, with a maximum Fried Parameter value of 0.01±0.02 m
- Cross correlation was performed on the images of the ribbon in Hβ and Ca II K, using a frame with a suitable level of seeing
- Cross correlation of the full images showed no significant offset between the two, however cross correlation in thin segments along each axis showed the offset between the images increased only where the ribbon was located
- Restricting this calculation to only the ribbon itself in the image produced an offset of 0.32 ʺ or ~230 km projected distance
- No significant offset was found in any other set of images from the same time, suggesting it is not due to some effect such as atmospheric refraction

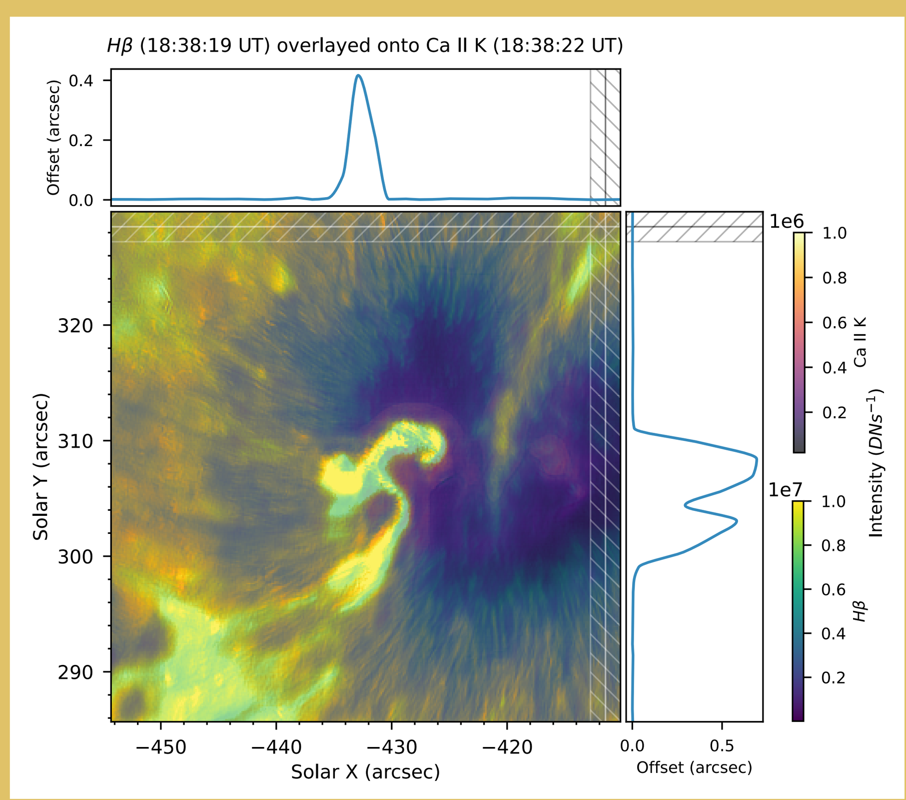


Image of Hβ overlayed onto an image of Ca II K in the same filter cycle, where cross correlation was performed over thin segments, showing significant offset between the images only where the ribbon was located.

5. Conclusions

- A spatial offset of 0.32 ʺ or ~230 km projected distance was found between line source heights of Ca II K and Hβ in a ribbon during a solar flare
- This offset could have implications for energy transportation theories from the corona to lower layers of the atmosphere
- This result and more observations in the future will be compared with radiation hydrodynamics models and simulations
- Currently spectropolarimetric data from this event is being studied to support the observations from the VBI

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