THE EVOLUTION OF PLASMA COMPOSITION DURING A SOLAR FLARE

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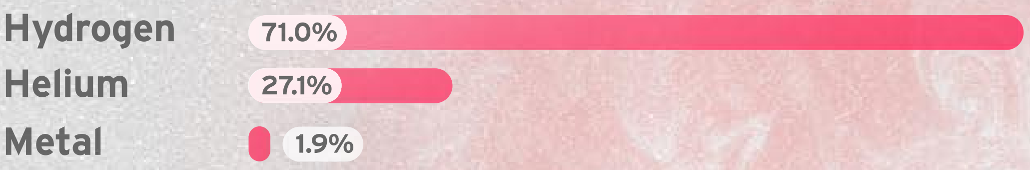
WHY ARE METAL ABUNDANCES ON OUR SUN IMPORTANT?

The trace amount of metal provides an indirect probe into the physical processes happening in the chromosphere and corona. As Martin Laming proposed, Alfvén waves travel from the corona to the chromosphere where they reflect, pulling up ionised plasma through the ponderomotive force.

Solar Photospheric Elemental Composition



CATEGORISING COMPOSITION - FIRST IONISATION POTENTIAL (FIP)

First Ionisation Potential (FIP)	
LOW-FIP (< 10eV)	HIGH-FIP (> 10eV)
Calcium | Silicon	Argon | Sulphur

High FIP and low FIP elements are separated at 10eV. In a developed active region, the low-FIP elements are usually more abundant than the high-FIP ones. The ratio between their coronal abundances to their photospheric abundances is called the FIP bias.

In this analysis, we use two pairs of Low FIP/High FIP emission lines, Si X/S X (~1.5 MK), and the ratio between Ca XIV/Ar XIV (~3.0MK). For the first time, we derive the FIP bias at two different temperatures!

ALFVÉN WAVES & PONDEROMOTIVE FORCE

Ponderomotive Force Equation

$$F_i = \frac{m_i c^2}{4} \frac{\mathrm{d}}{\mathrm{d}z} \left[\frac{\delta E_p (z_i)^2}{B (z_i)^2} \right],$$

- Magnetic reconnections trigger Alfvén waves to propagate from the corona downward along loops.
- Alfvén waves are reflected in the chromosphere
- Ponderomotive force (see left) pulls up particles, which are ionised in the chromosphere, fractionating the plasma.

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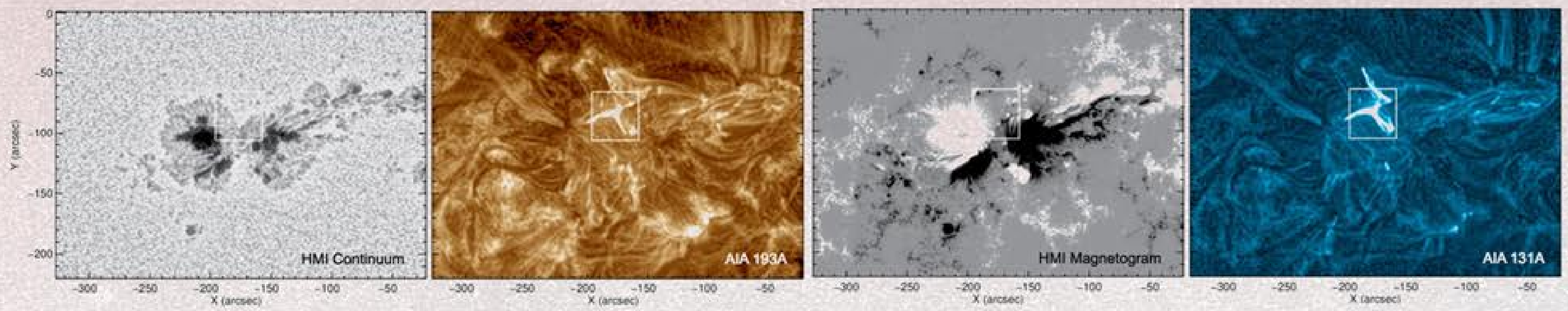
INTRUMENTS

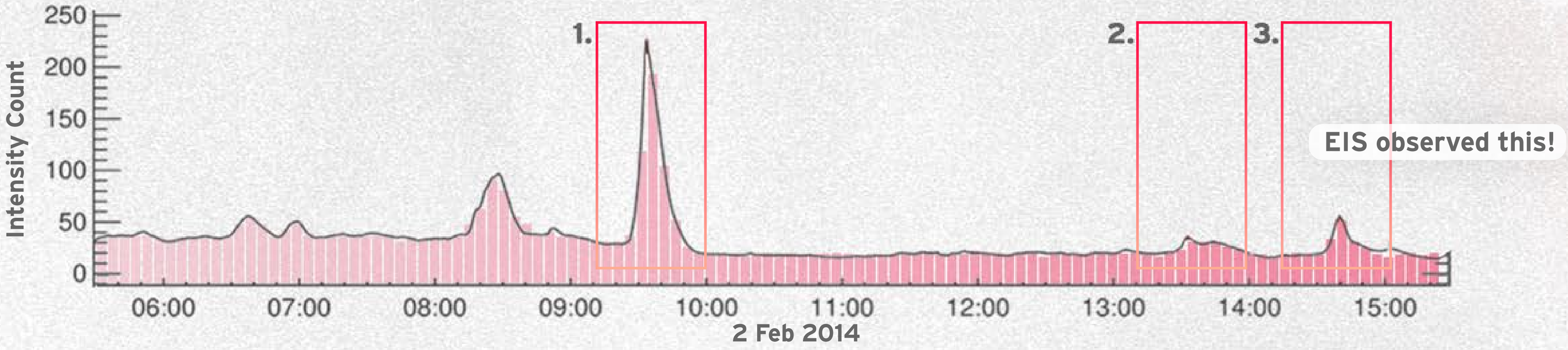
- Atmospheric Imaging Assembly (AIA/SDO)
- Helioseismic and Magnetic Imager (HMI/SDO)
- Extreme-Ultraviolet Imaging Spectrometer (EIS/Hinode)

FLARE HOSTING ACTIVE REGION (AR 11967)



- Constantly reconnecting
- 83 C-class flares, 28 M-class flares
- Perfect environment for Alfvén waves and fractionation

RESULT - CORONAL COMPOSITION DURING A FLARE



We looked into the composition of three flares that happened on 2 Feb 2014, indicated by the red boxes over the AIA light curve. Flare 1 was relatively large, whereas flare 2 & 3 were very small brightenings.

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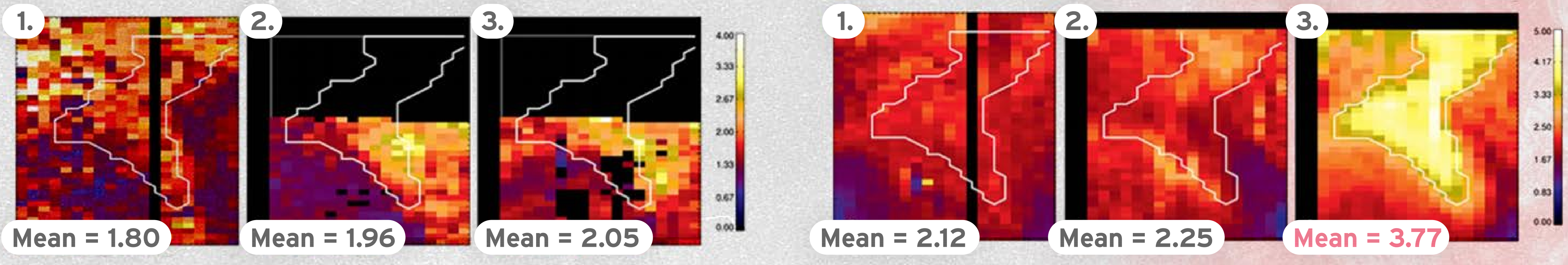
RESULT - DIFFERENT RESULTS USING TWO PAIRS OF ELEMENTS

- Si/S FIP bias maps indicates no change across the three observations
- Ca/Ar FIP bias maps indicates a big change in the last observation which caught the flare! What caused the discrepancy?



Si/S FIP Bias (1.5MK)	Ca/Ar FIP Bias (2.5MK)

CONCLUSIONS - TWO NEW INTERPRETATIONS FOR FLARES

1. Partial Ionization of Different Elements
2. Fractionation in the Low Chromosphere

First, while S is typically categorized as a high-FIP element, it has a relatively low FIP value of 10.36 eV, whereas Si, typically categorized as a low-FIP element, has a comparable FIP value of 8.15 eV. During the third event, flare heating ionised S, so Si and S were brought up in tandem, while it was not sufficient to ionise Ar.

Second, the flare studied here took place between very strong magnetic fields. This has the effect of lowering the plasma fractionation height of different elements. Under this condition, S also acts like low-FIP elements.

Laming, J. M. (2015). The FIP and Inverse FIP Effects in Solar and Stellar Coronae. Living Rev. Sol. Phys., 12(1), 1–76. doi: 10.1007/lrsp-2015-2

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