THE EVOLUTION OF PLASMA COMPOSITION DURING A SOLAR FLARE

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WHY METAL ABUNDANCES ON OUR SUN IS IMPORTANT?

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

Solar Photospheric Elemental Composition

Hydrogen	71.0%
Helium	27.1%
Metal	1.9%

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 solar atmosphere abundances to their photospheric abundances is called the FIP bias.

In this analysis, we use two pairs of emission lines, Si X/S X (~1.5 MK), and the ratio between Ca XIV/Ar XIV (~3.0MK). This is the first time of us having two pairs of emission lines at the same time!

ALFVÉN WAVES & PONDEROMOTIVE FORCE

Ponderomotive Force Equation

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

- Reconnections trigger alfvén waves to travel from the corona downward, which propagate along loops.
- Alfvén waves are reflected in the chromosphere
- Ponderomotive force thus pull ionised particle up

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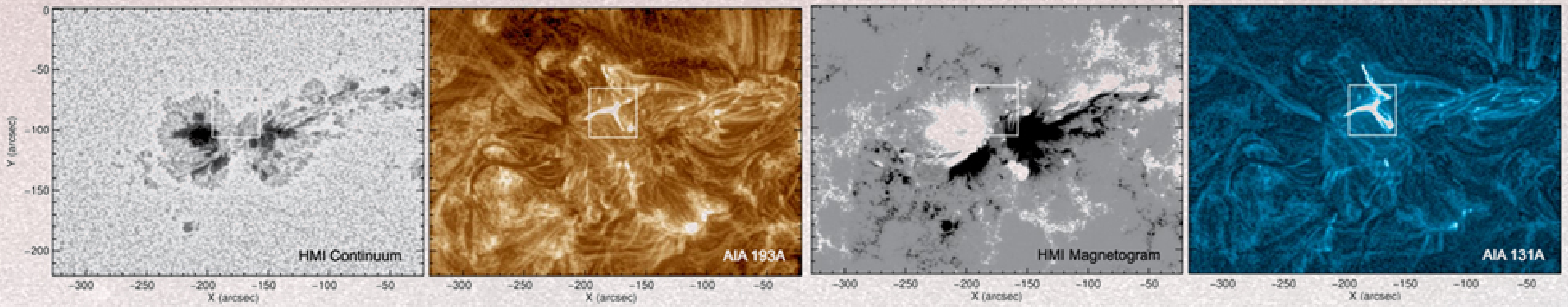
INTRUMENTS AND DATA

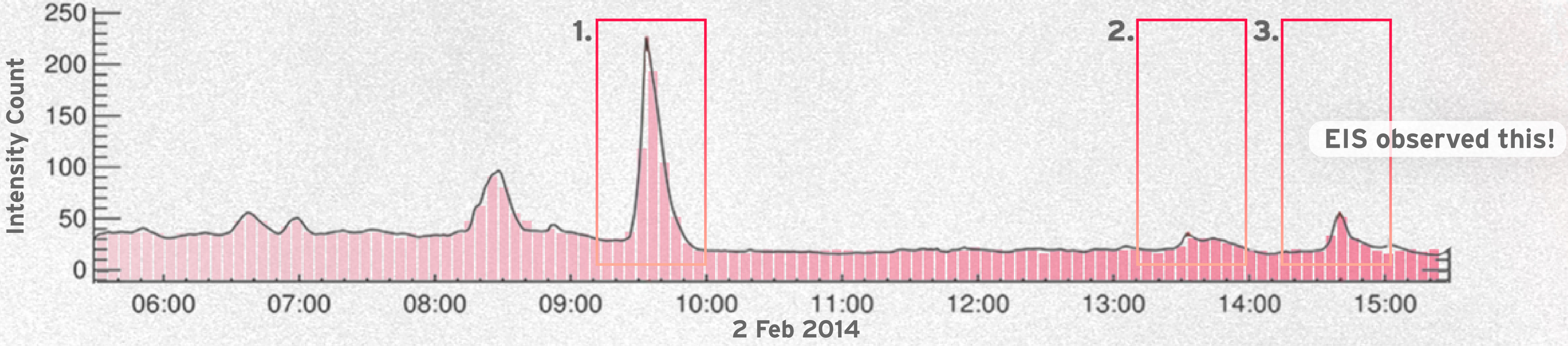
- Atmospheric Imaging Assembly (AIA/SDO)
- Helioseismic and Magnetic Imager (HMI/SDO)
- Extreme-Ultraviolet Imaging Spectrometer (EIS/Hinode)

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



In our paper, we looked into the composition of three flares that happened on 2 Feb 2014, indicated by the red boxes. Flare 1 was huge, whereas flare 2 & 3 were very small brightenings

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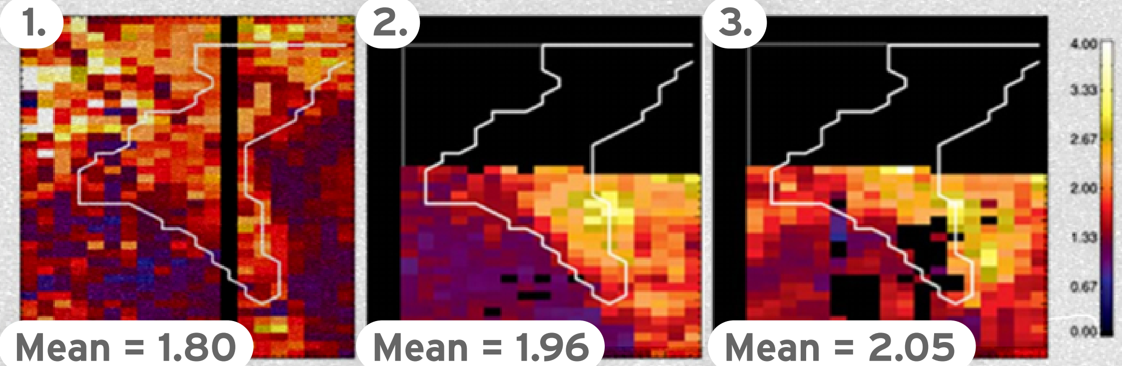
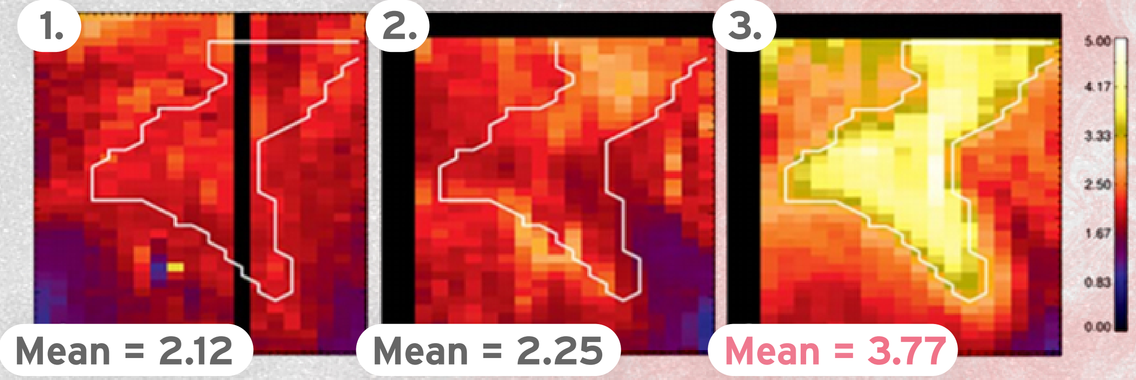
RESULT - DIFFERENT RESULTS USING TWO PAIRS OF ELEMENTS

- 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)

CONCLUSION - 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 a big heating like flare, it causes an unexpected ionisation of S, and the evaporation brought up Si/S in tandem, but Ar remained the same.

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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