Magnetic Perturbation in a Sunspot Chromosphere linked to Plasma Fractionation in the Corona

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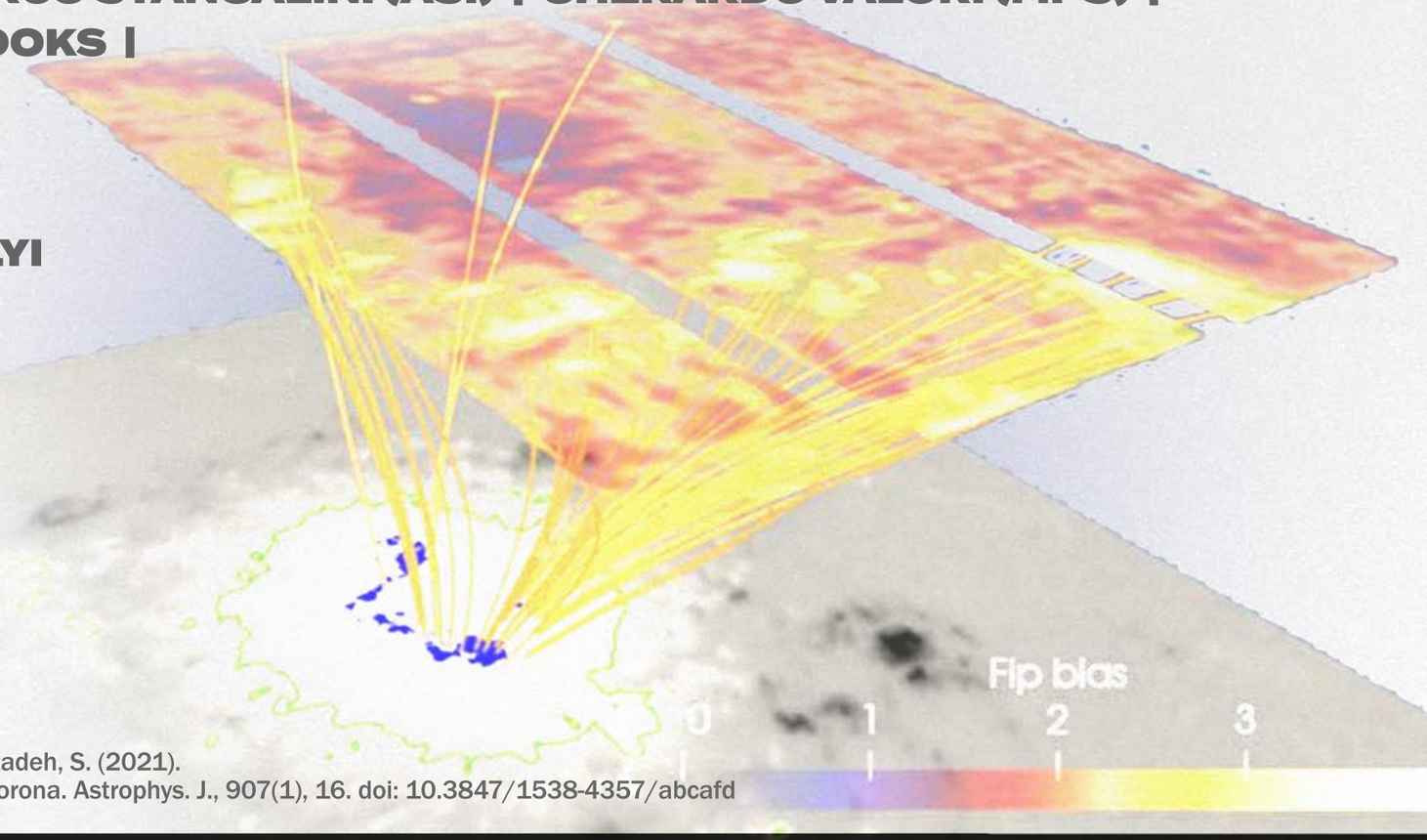

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WHY ARE METAL ABUNDANCES ON OUR SUN IMPORTANT?

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

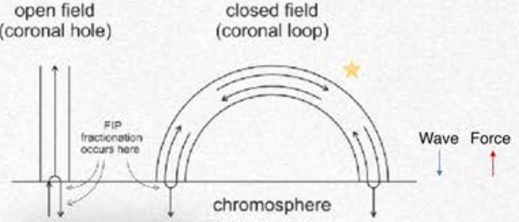
High FIP and low FIP elements are separated at 10eV.
In a developed active region, the low-FIP elements are usually more abundant than the high-FIP ones. The ratio between their solar atmosphere abundances to their photospheric abundances is called the FIP bias.

In this analysis, we use the emssion line Si X/S X (~1.5 MK) to form our composition map

ALFVÉN WAVES & PONDEROMOTIVE FORCE

Ponderomotive Force Equation

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



p-mode waves

- Fractionation occurs at the loop footpoints in the chromosphere
- Alfvén waves are reflected in the chromosphere
- Ponderomotive force thus pull ionised particle up

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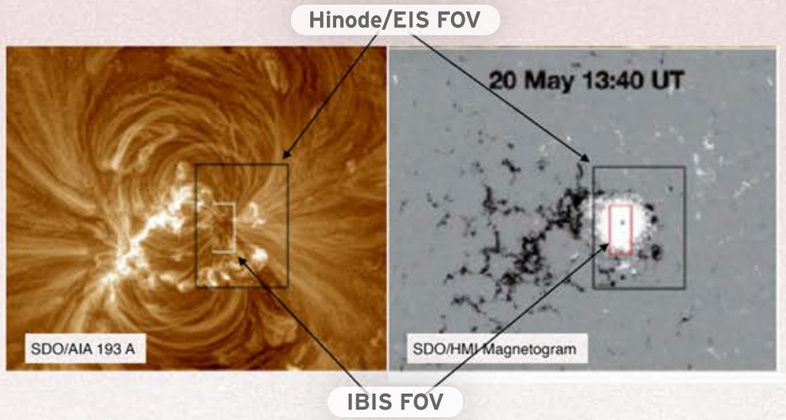
INTRUMENTS

Solar Dynamics Observatory (SDO)

Extreme-Ultraviolet Imaging Spectrometer (EIS/Hinode)

Interferometric BIdimensional Spectrometer (IBIS)

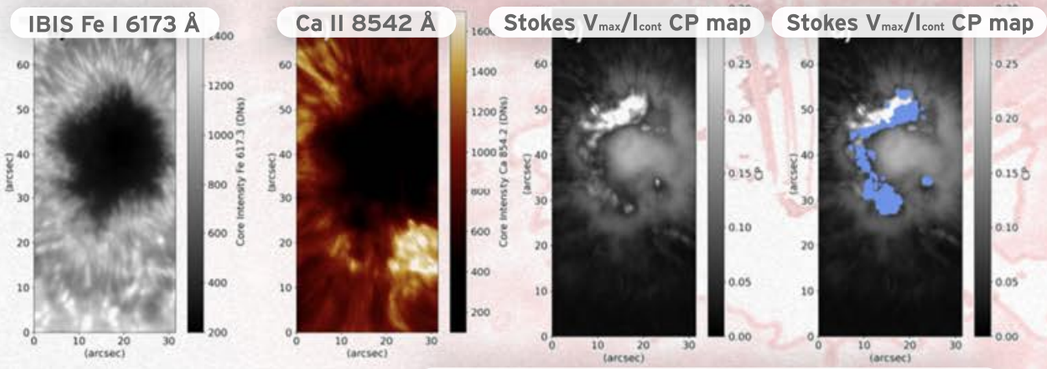
DATA OVERVIEW - SUNSPOT OF AR12546



- One of the largest sunspots of solar cycle 24
- Relatively simple, bipolar region
- Strong, coherent leading positive-polarity sunspot, >4000 Gauss
- Observations of the photosphere, chromosphere and corona were broght together with magnetic field modelling
- The simple topology makes it perfect to study wave and composition

IBIS CHROMOSPHERIC OBSERVATIONS

- High spatial and temporal resolution full SP scans
- Ca II 8542 A time series of 184 min
- Ca II 8542 A magnetically sensitive line at chromospheric heigth
- IBIS full Stokes spectropolarimetric scans were used to identify possible mangetic field oscillations signatures in CP measurements



Blue dots indicate the locations of magnetic waves!

Stangalini, M., Baker, D., Valori, G., Jess, D. B., Jafarzadeh, S., Murabito, M., ...MacBride, C. D. (2021). Spectropolarimetric fluctuations in a sunspot chromosphere. Phil. Trans. R. Soc. A., 379(2190), 20200216. doi: 10.1098/rsta.2020.0216

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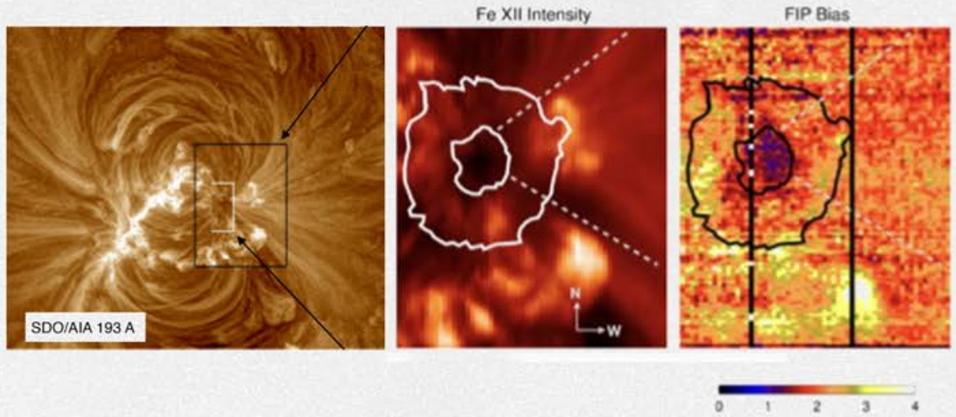
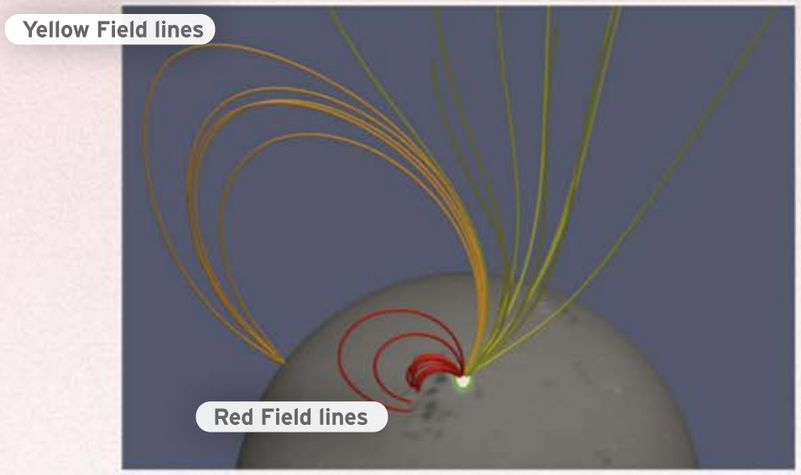
EIS CORONAL OBSERVATIONS



- On the very right, we have what we called a composition map, where we visualise the FIPbias of a solar structure. Bright and warm colours like yellow means that the coronal abundances of the low FIP elements are enhanced. Whereas colder colours like blue represents a photospheric abundance (unenhanced)
- Hinode/EIS observations revealed that compositional variation ranged from little or no fractionation in the corona above the core of the umbra to partially or highlyfractionated plasma in groups of coronal loops rooted in the surrounding penumbra.

CORONAL LOOP CONNECTIVITIES (PFSS)



- A Potential Field Source Surface (PFSS) extrapolation was computed to model the coronal loop system surrounding the sunspot. The rationale behind the use of the PFSS extrapolation is that this model captures the global field of the sunspot for comparison with theSDO/AIA coronal images
- Yellow field lines on the western side of the sunspot are long, extended loops that reach the source surface of the PFSS model (=2.5 RSun), therefore these field lines are considered to be open
- The red loops on the east and south of the sunspot are compact loops that connect mainly with the opposite polarity within the active region. Plasma is highly fractionated with FIP bias of 3-4.

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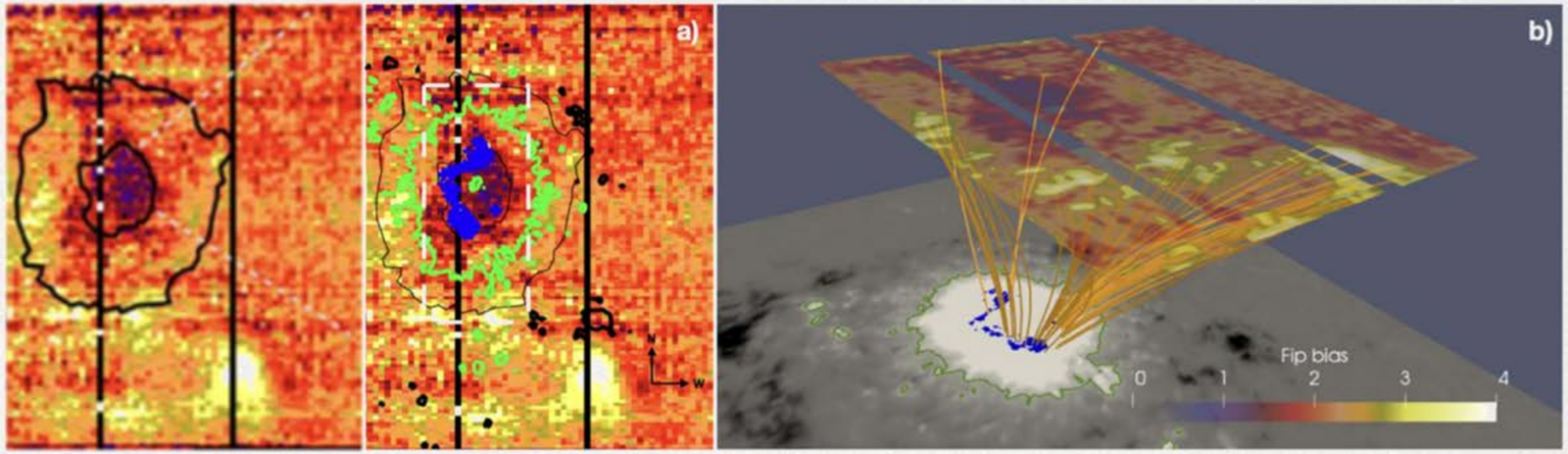
ALFVÉNIC PERTURBATIONS IN THE SUNSPOT CHROMOSPHERE



Coronal loops containing highly fractionated plasma are present with particularly high values both to the east and to the southwest of the sunspot.

Which matches the location of the Alfvénic perturbations in the sunspot chromosphere found in Stangalini et al. (2021)

CONCLUSIONS - TWO NEW INTERPRETATIONS FOR FLARES

A possible link between magnetic perturbations at chromospheric heights, and the locations of high FIP bias observed in the corona

This work represents a first attempt to investigate the role of magnetic fluctuations in plasma fractionation, made possible thanks to nearly simultaneous observations at chromospheric and coronal heights by IBIS and EIS, respectively. Our results demonstrate a possible link between magnetic perturbations, observed at chromospheric heights as small fluctuations of the spectropolarimetric quantities, and the locations of high FIP bias observed in the corona. They therefore observationally support a role for MHD waves in the generation of the FIP effect and wave-based theoretical models.

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