Relationship between high FIP bias and magnetic wave power

Mariarita Murabito (INAF/OACN)

Collaborators: M. Stangalini (ASI), D. Baker (UCL/MSSL), G. Valori (MPS), D. B. Jess (QUB), S. Jafarzadeh (MPS,ROCS), D. H. Brooks (GMU), I. Ermolli (INAF/OAR), F. Giorgi (INAF/OAR), S. D. T. Grant (QUB), D. M. Long (UCL), L. van Driel-Gesztelyi (UCL, LESIA)

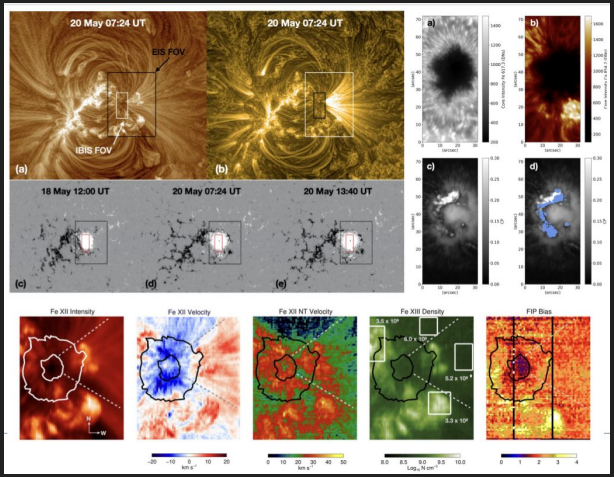
HINODE-15 / IRIS-12 Prague 22 September 2022

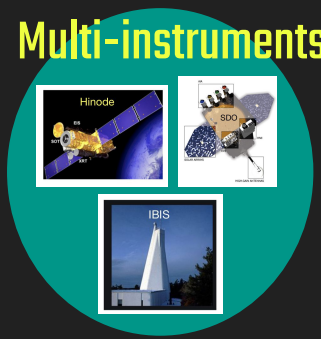
It was demonstrated the link between waves and FIP

The Astrophysical Journal, 907:16 (11pp), 2021 January 20 https://doi.org/10.3847/1538-4357/abcafd

Alfvénic Perturbations in a Sunspot Chromosphere Linked to Fractionated Plasma in the Corona

Deborah Baker[1], Marco Stangalini[2], Gherardo Valori[1], David H. Brooks[3], Andy S. H. To[1], Lidia van Driel-Gesztelyi[1,4,5], Pascal Démoulin[4], David Stansby[1], David B. Jess[6,7], and Shahin Jafarzadeh[8,9]
[1] University College London, Mullard Space Science Laboratory, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK
[2] ASI Italian Space Agency, Via del Politecnico, s.n.c I-00133—Roma, Italia
[3] College of Science, George Mason University, 4400 University Drive, Fairfax, VA 22030, USA
[4] LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Univ. Paris Diderot, Sorbonne Paris Cité, 5 place Jules Janssen, F-92195 Meudon, France
[5] Konkoly Observatory, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Konkoly Thege út 15-17., H-1121, Budapest, Hungary
[6] Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast, BT7 1NN, UK
[7] Department of Physics and Astronomy, California State University Northridge, Northridge, CA 91330, USA
[8] Rosseland Centre for Solar Physics, University of Oslo, P.O. Box 1029 Blindern, NO-0315 Oslo, Norway
[9] Institute of Theoretical Astrophysics, University of Oslo, P.O. Box 1029 Blindern, NO-0315 Oslo, Norway
Received 2020 September 9; revised 2020 November 9; accepted 2020 November 15; published 2021 January 21



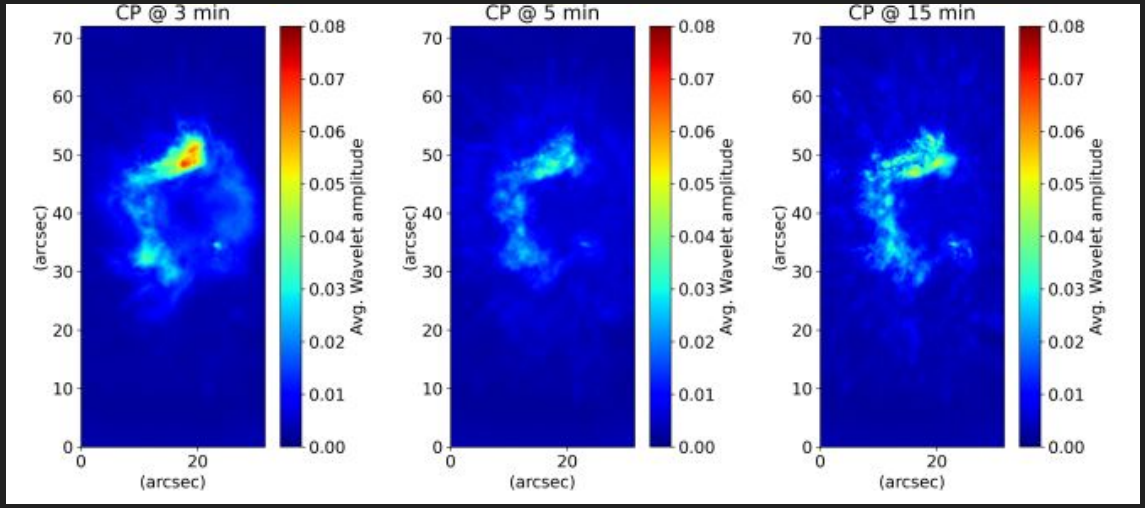


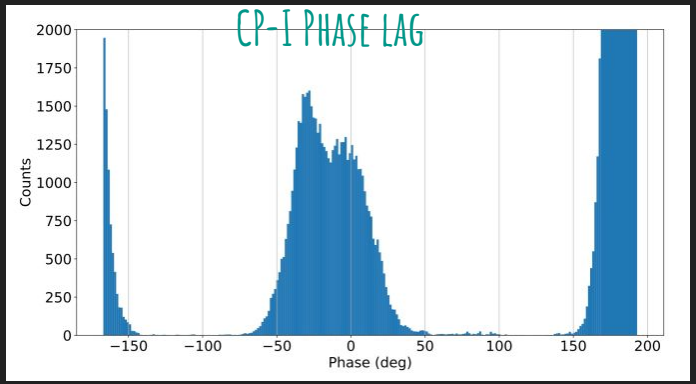
PHILOSOPHICAL TRANSACTIONS A
rsta.royalsocietypublishing.org
Research
Article submitted to journal
Subject Areas:
astrophysics, solar physics, MHD waves
Keywords:
Solar Spectropolarimetry, Solar MHD waves, Chromospheric dynamics
Author for correspondence:
Marco Stangalini
e-mail: marco.stangalini@asi.it

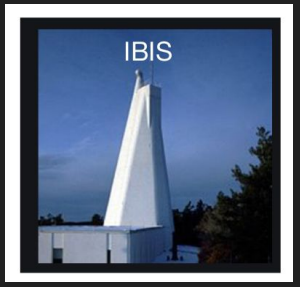
Spectropolarimetric Fluctuations in a Sunspot Chromosphere

M. Stangalini[1,2], D. Baker[3], G. Valori[3], D.B. Jess[4,5], S. Jafarzadeh[6,7], M. Murabito[2], A.S.H. To[3], D.H. Brooks[8], I. Ermolli[2], F. Giorgi[2], C.D. MacBride[4]
[1] ASI, Italian Space Agency, Via del Politecnico snc, 00133 Rome, Italy
[2] INAF-OAR National Institute for Astrophysics, 00078 Monte Porzio Catone (RM), Italy
[3] University College London, Mullard Space Science Laboratory, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK
[4] Astrophysics Research Centre, School of Mathematics and Physics, Queen's University Belfast, Belfast, BT7 1NN, U.K.
[5] Department of Physics and Astronomy, California State University Northridge, Northridge, CA 91330, U.S.A.
[6] Rosseland Centre for Solar Physics, University of Oslo, P.O. Box 1029 Blindern, NO-0315 Oslo, Norway
[7] Institute of Theoretical Astrophysics, University of Oslo, P.O. Box 1029 Blindern, NO-0315 Oslo, Norway
[8] College of Science, George Mason University, 4400 University Drive, Fairfax, VA 22030, USA

Let's go to two steps before: Stangalini et al. 2020







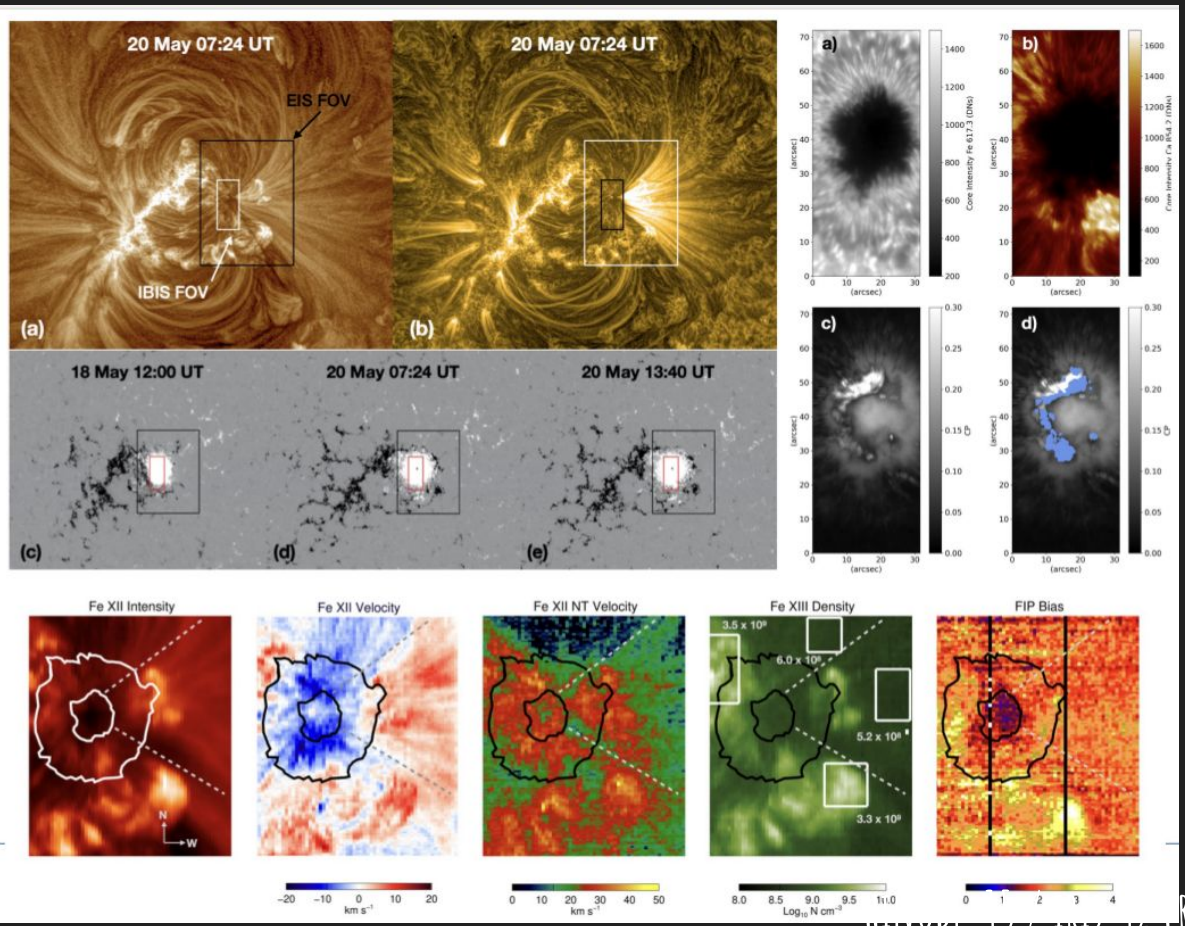
- IBIS (2016)
- Fe I 617.3 nm and Ca II 854.2 nm full stokes

- The magnetic oscillations could be enhanced for **opacity effects**
- look for specific **phase relations** between different diagnostics

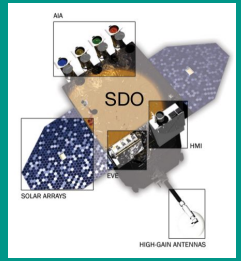
Three components:

- 0 and 180 degree → opacity effects
- -35 degree → not consistent with opacity

ONE STEP FURTHER: BAKER ET AL. 2021



Multi-instruments



Starting from….

- ➔ the magnetic field geometry or connectivity with the outside diffuse fields could play a role in the wave excitation and propagation (Stangalini et al. 2020 & Baker et al. 2021).
- ➔ a possible role between the mode conversion and the detected magnetic disturbances could exist if one takes into account the asymmetry of the distribution of the magnetic fluctuations (Baker et al. 2021)
- ➔ the wave activity found could be due to the magnetic field geometry, through the mode conversion mechanism which converts MHD waves in different modes with an efficiency depending on the magnetic field inclination with respect the wavevector (Houston et al. 2020)

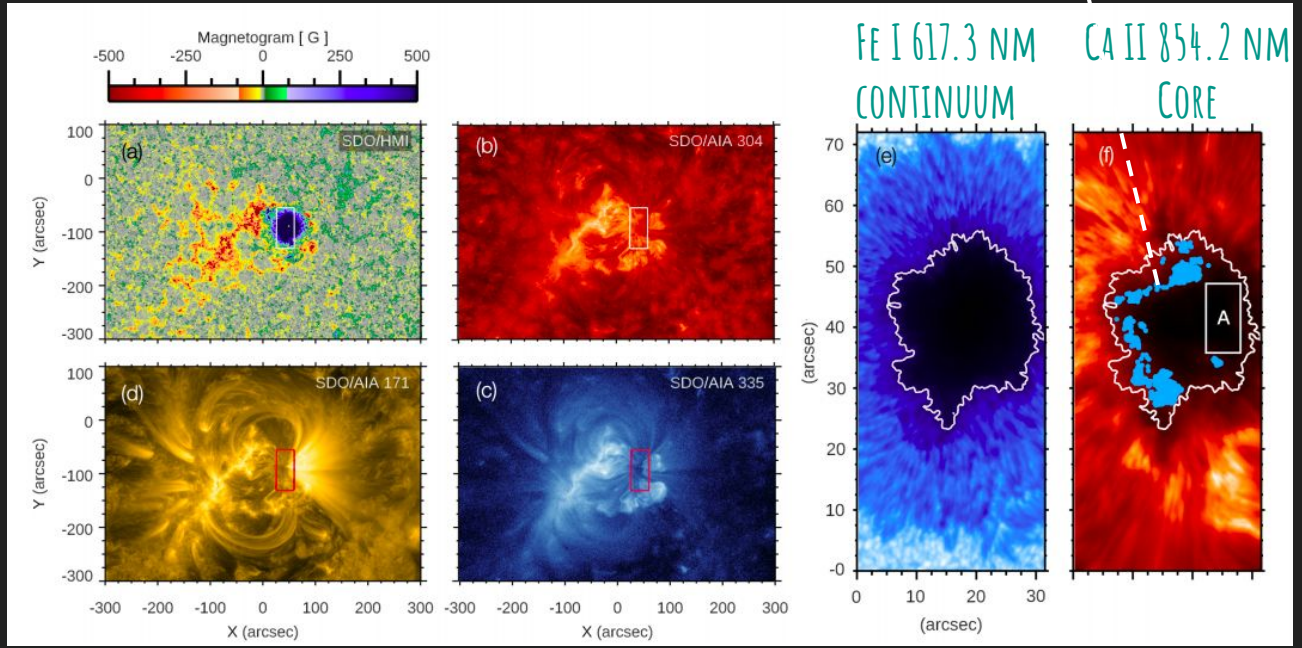
$$T + |C| = 1.$$

$$T = e^{-\pi k h_s \sin^2(\alpha)}$$

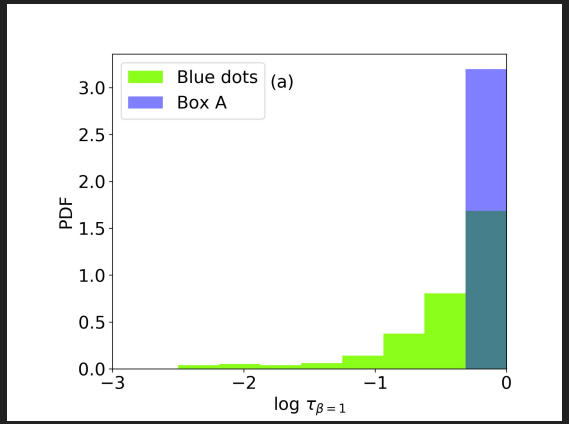
Data used in Murabito et al. 2021

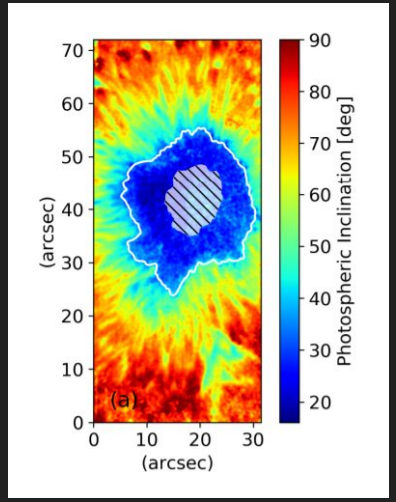
- Multi-height, multi-line NLTE inversion of IBIS photospheric Fe I at 617.3 nm and chromospheric Ca II at 854.2 nm observations
- SDO/AIA filtergrams
- SDO/HMI Dopplergrams

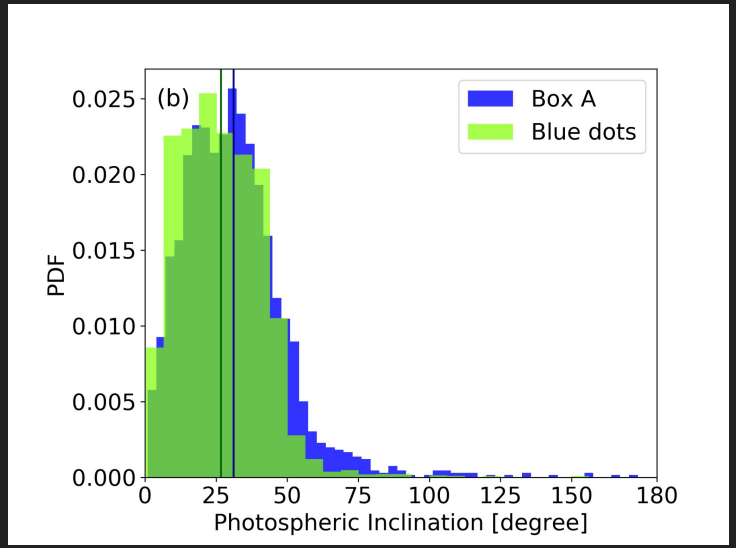
Blue dots
(Stangalini et al. 2020)



Analysis of the NLTE inversions



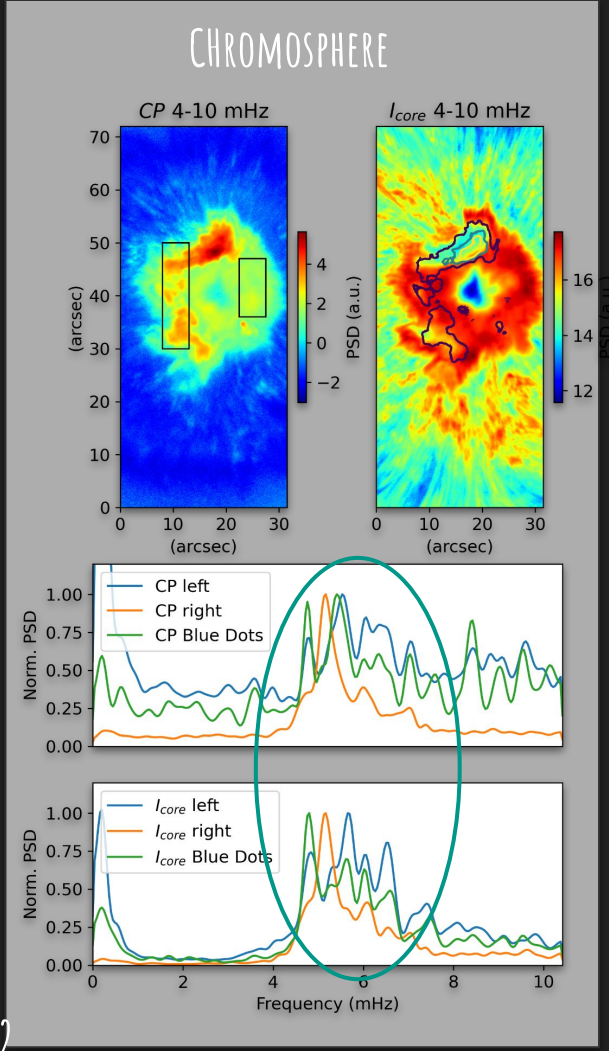




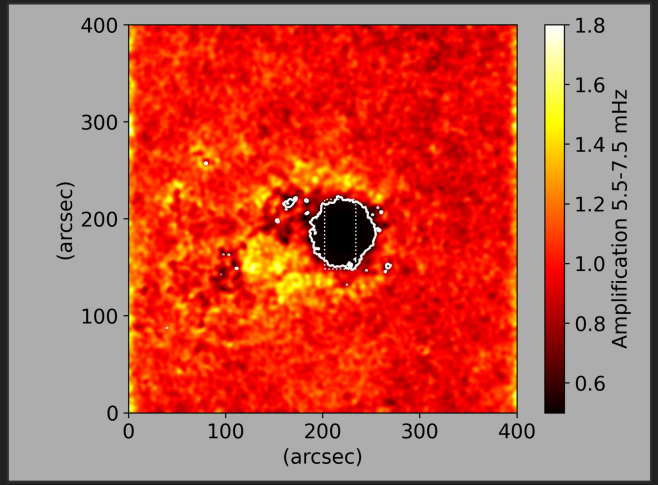
➔ The magnetic field inclination is not significantly different on the two opposite sides of the sunspot.

➔ Waves travelling in all directions (e.g. p-modes) would experience the same conditions (i.e. attack angle) and therefore their conversion can not justify the asymmetric wave power observed on the left side of the sunspot (i.e. blue dots)

➔ the study of the power spectrum at high frequencies suggests an asymmetric photospheric driver.

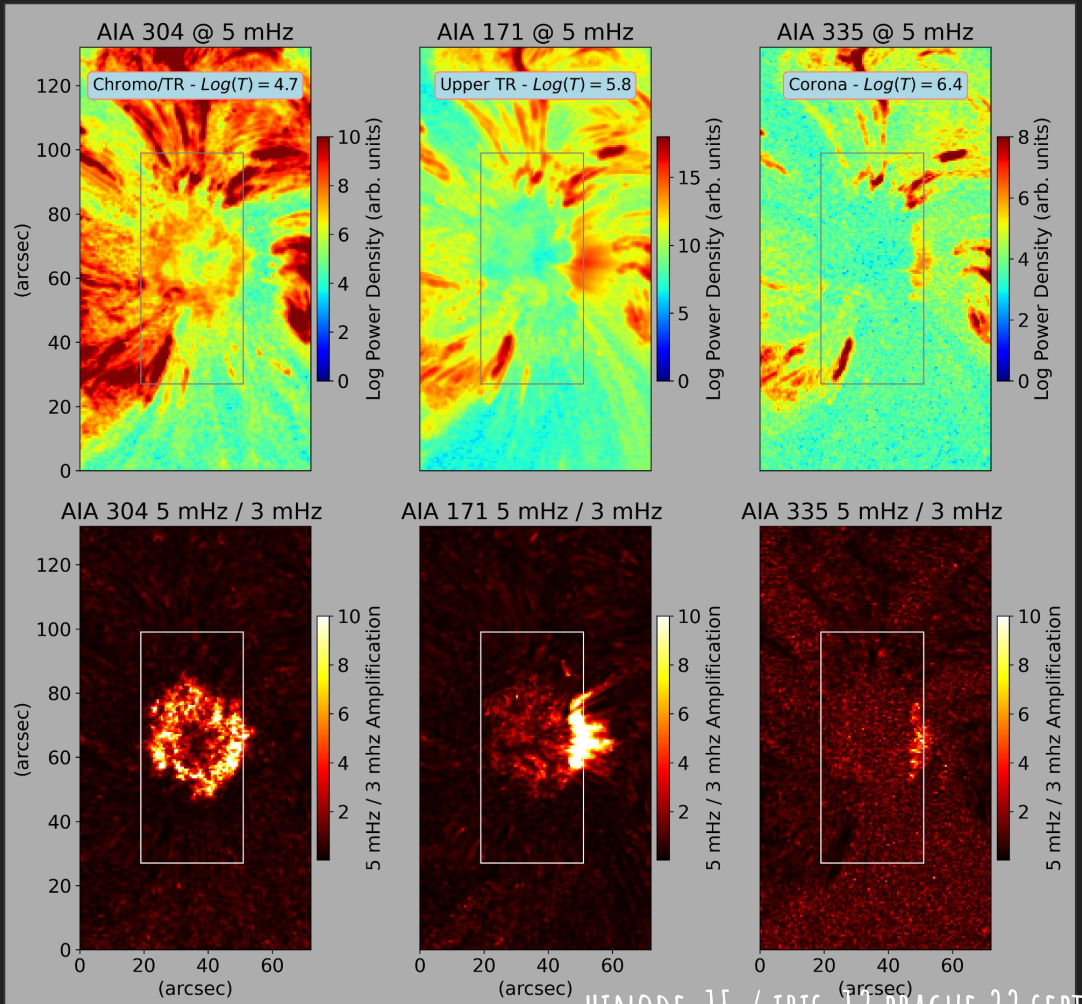


SDO/HMI VLOS power maps @5.5-7.5 mHz



➔ **Imbalanced** LOS velocity power flux detected in the left side of the whole AR. A broadening of the power spectrum, referred as **acoustic halo** (Brown et al. 1992, Hindman & Brown 1998, Khomenko & Collados 2009), with respect to that of a quiet sun area (where the contribution comes from the p-modes only).

➔ the halo is **asymmetric** and cospatial with the locations of the BD inside the umbra.



★ Acoustic flux **imbalance**

★ The coronal channels (171 Å and 335 Å) exhibit a 5 mHz power **excess**, towards the opposite side of the BD locations

★ The lower 304 Å map displays an almost homogeneous ring of oscillatory power.

➔ A power **deficit** at coronal heights cospatial with the locations displaying the enhanced FIP effect

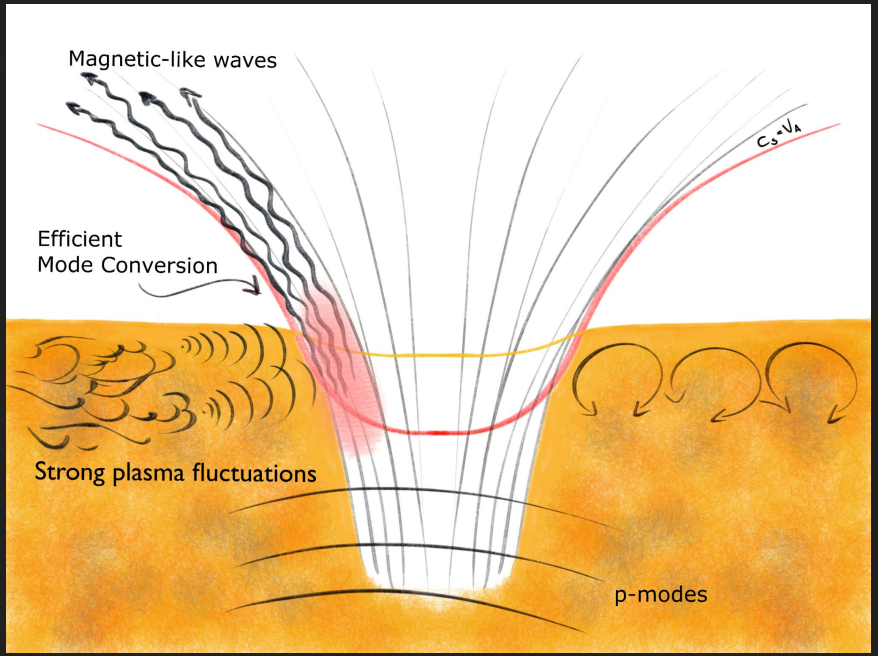
➔ high-frequency acoustic flux is unable to penetrate the upper layers

➔ clear deficit of power in the BD location

➔ The wave energy is **blocked/lost** at some point in the lower atmosphere, suggesting that the umbral magneto-acoustic waves (BD) are unable to reach coronal heights.

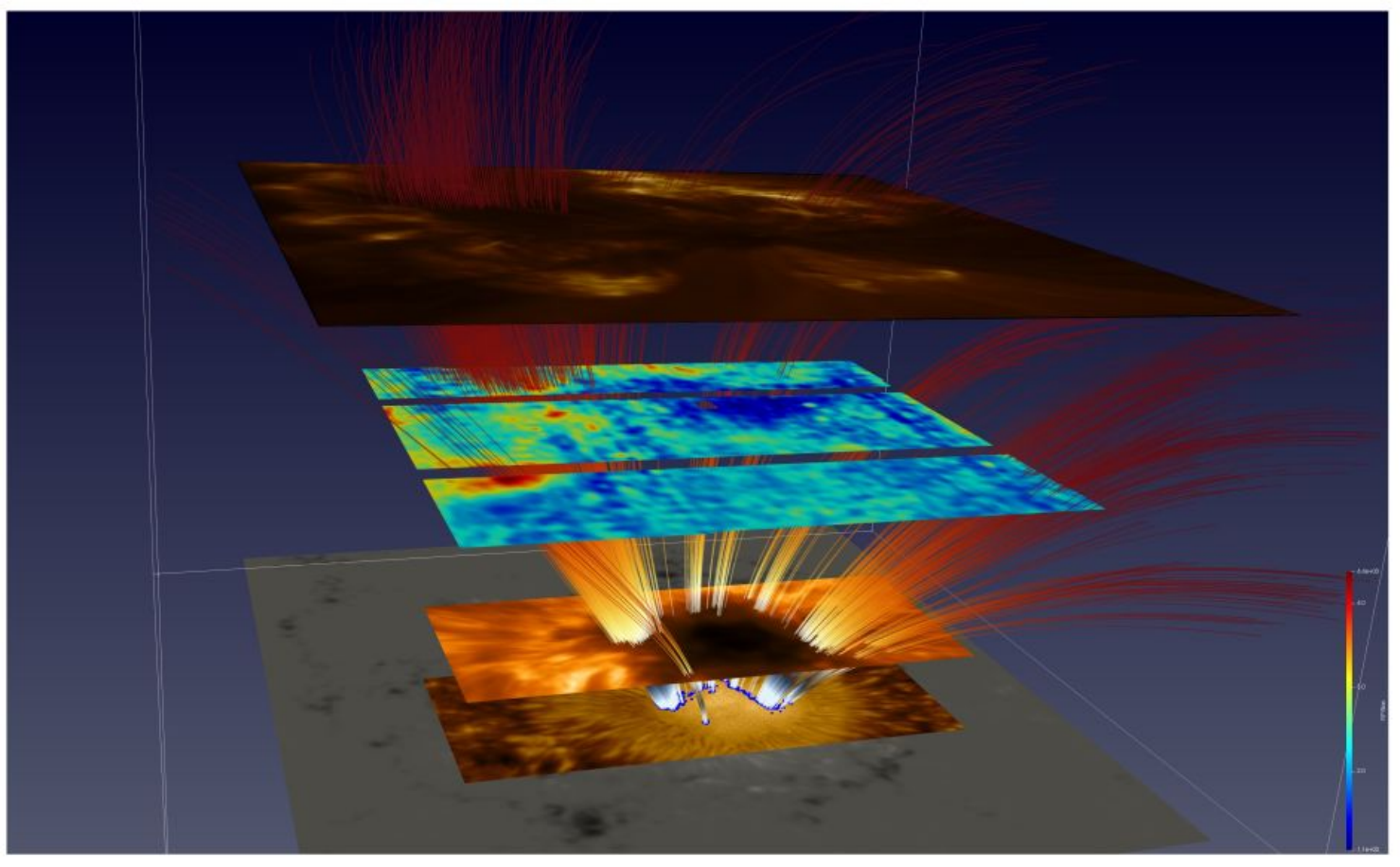
Our scenario:

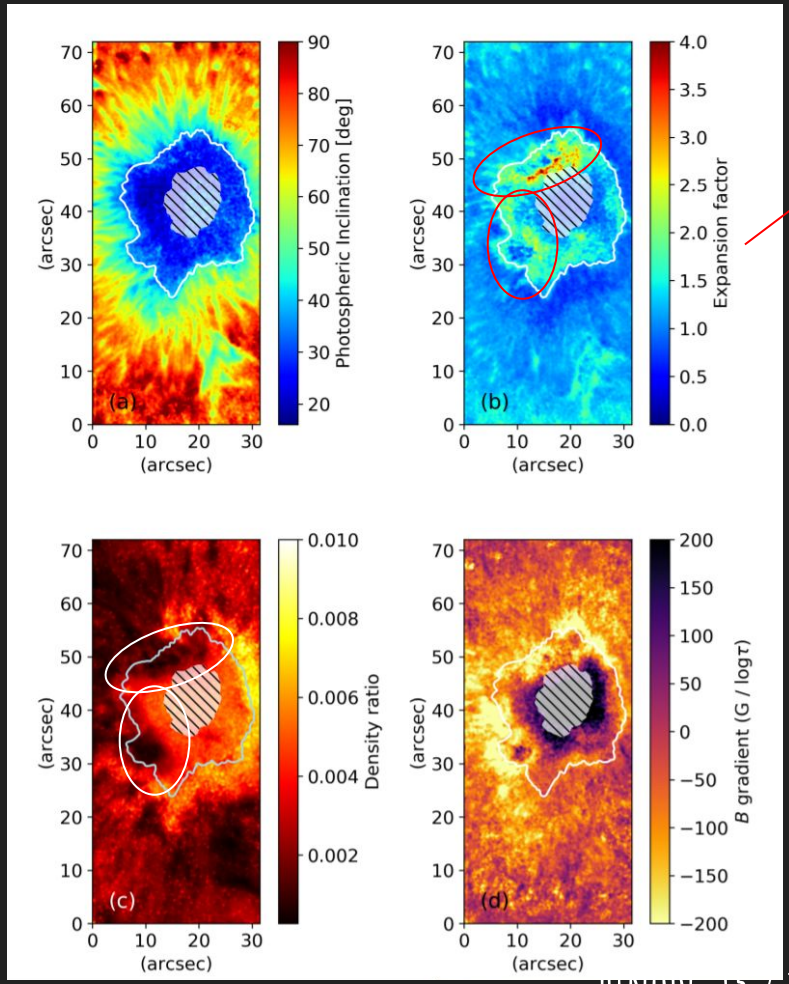
- ➔ An excess of acoustic wave power in between the two polarities, due to strong photospheric plasma fluctuations, could result in an excess of incident wave power on the left side of the sunspot.
- ➔ an excess of MMFs in between the two polarities is seen in HMI image covering the same observing window



➔ This provides further evidence of an high level of small scale plasma dynamics and perturbations that may result in a variation of the acoustic field and power

Thank you



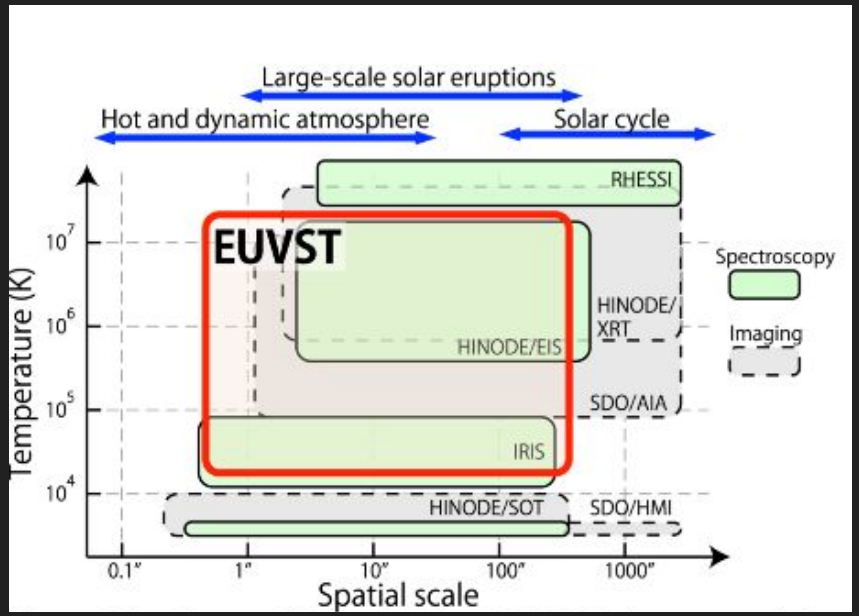


Chromospheric magnetic field inclination over the photospheric one.

- ❑ Chromospheric magnetic field inclination at the BD locations 3-4 times more inclined than the other side.
- ➔ expansion of the field lines about 2 times faster than the opposite side
- ➔ stronger decrease of plasma density with height

ideal condition for development of magneto-acoustic shocks at low atmospheric heights

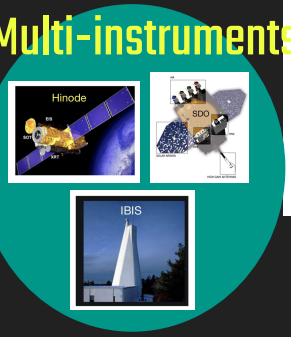
What's next



- ★ Solar-c will allow precise measurements of velocity fluctuations
- ★ Solar-C will provide unmatched temperature coverage
- ★ Combined with high-resolution of magnetic field from ground

It was demonstrated the link between waves and FIP

Multi-instruments



The Astrophysical Journal, 907:16 (11pp), 2021 January 20 https://doi.org/10.3847/1538-4357/abcafd

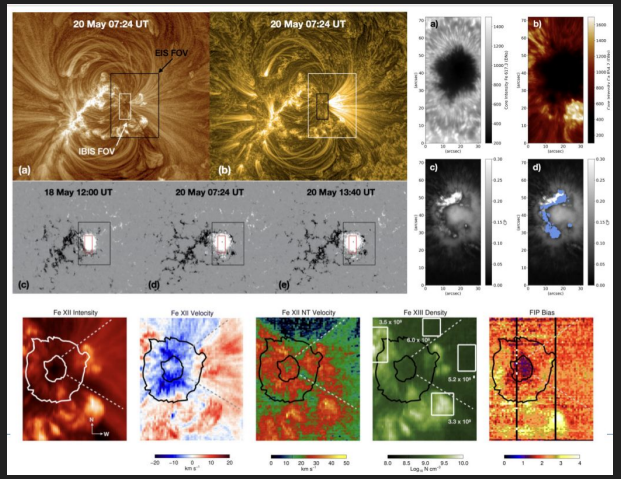
Alfvénic Perturbations in a Sunspot Chromosphere Linked to Fractionated Plasma in the Corona

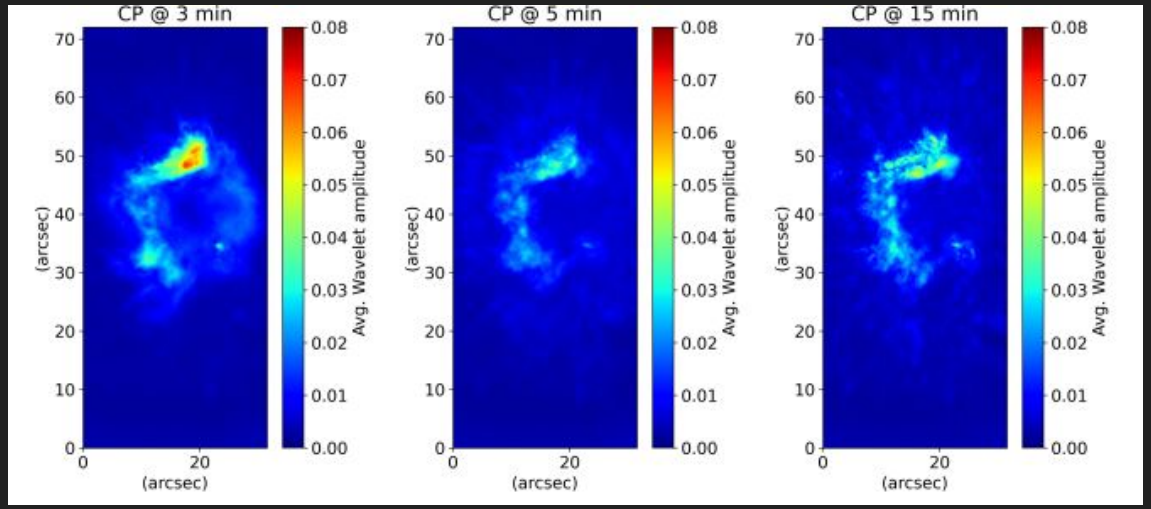
Deborah Baker[1], Marco Stangalini[2], Gherardo Valori[1], David H. Brooks[3], Andy S. H. To[1], Lidia van Driel-Gesztelyi[1,4,5], Pascal Démoulin[4], David Stansby[1], David B. Jess[6,7], and Shahin Jafarzadeh[8,9]
[1] University College London, Mullard Space Science Laboratory, Holmbury St. Mary, Dorking, Surrey, RH5 6NT, UK

PHILOSOPHICAL TRANSACTIONS A
rsta.royalsocietypublishing.org
Research
Article submitted to journal

Spectropolarimetric Fluctuations in a Sunspot Chromosphere

M. Stangalini[1,2], D. Baker[3], G. Valori[3], D.B. Jess[4,5], S. Jafarzadeh[6,7], M. Murabito[2], A.S.H. To[3], D.H. Brooks[8], I. Ermolli[2], F. Giorgi[2], C.D. MacBride[4]





AR12456 - GENERAL OVERVIEW

High-resolution IBIS data

Murabito et al 2020, ApJ, 890, 96

Penumbral Brightening Events

Observed in AR NOAA 12546

Stangalini et al 2018, ApJ, 869, 110

Propagating Spectropolarimetric Disturbances in a Large Sunspot

Murabito et al 2019, ApJ, 873,126

Height Dependence of the Penumbral Fine-scale Structure in the Inner Solar Atmosphere

Houston et al 2021, ApJ, 872, 49

Magnetohydrodynamic Nonlinearities in Sunspot Atmospheres: Chromospheric Detections of Intermediate Shocks

Stangalini et al 2020, RSPTA, 379, 20200216

Spectropolarimetric fluctuations in a sunspot chromosphere

Baker et al 2021, ApJ, 907, 16

Alfvénic Perturbations in a Sunspot Chromosphere Linked to Fractionated Plasma in the Corona

Murabito et al 2021, A&A, 656, A87

On the Origin of Magnetic Perturbations at the Base of the FIP Effect