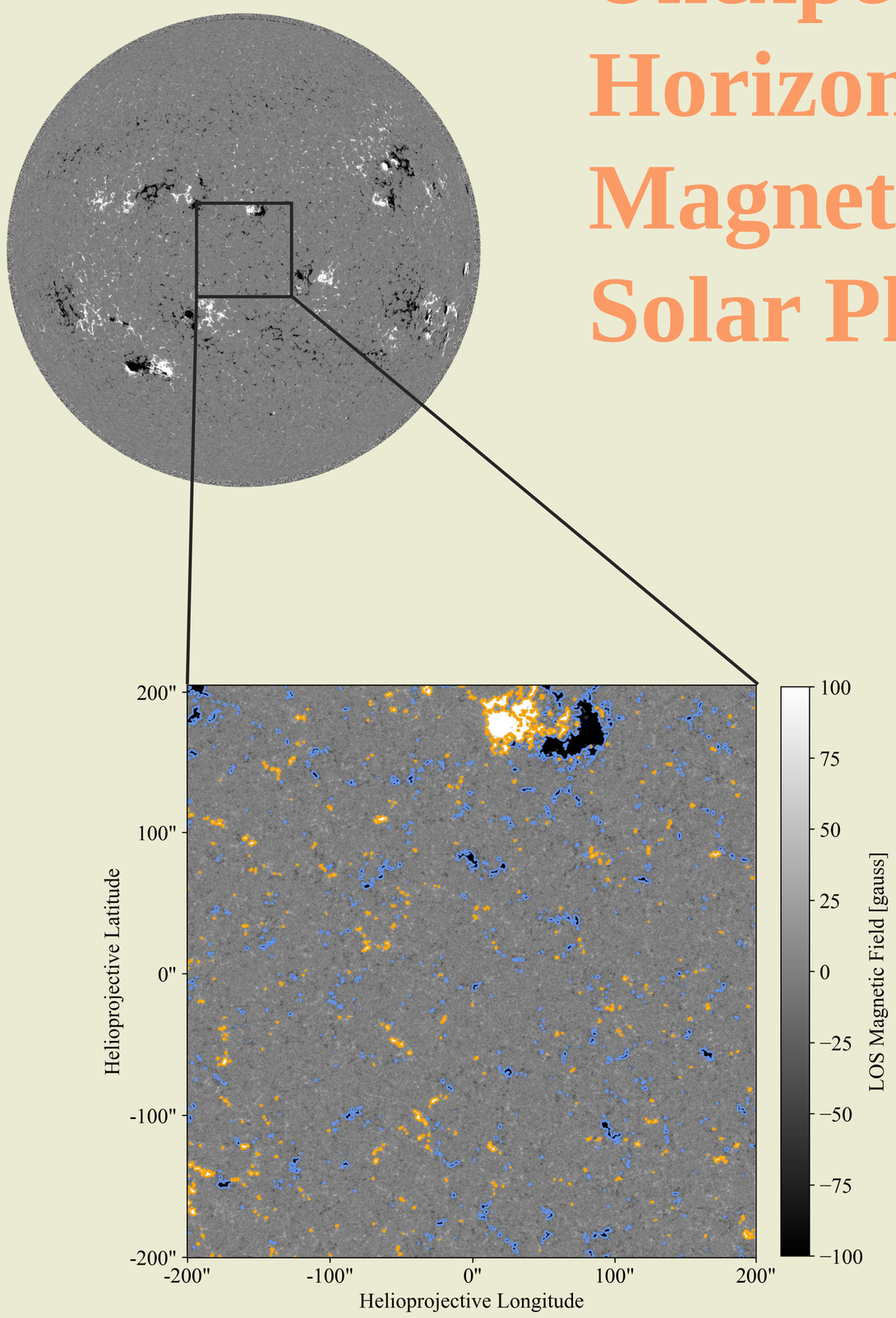
Unexpected Frequency of Horizontal Oscillations of Magnetic Structures in the Solar Photosphere 236

M. Berretti[1,2], M. Stangalini[3], G. Verth[4], S. Jafarzadeh[5,6], D. B. Jess[7,8], F. Berrilli[2], S. D. T. Grant[7], T. Duckenfield[7], V. Fedun[9]



ABSTRACT

It is well known that the **dominant frequency of oscillations in the solar photosphere is at 3 mHz**, which is the result of global resonant modes pertaining to the whole stellar structure. However, analyses of the **horizontal motions of nearly 1 million photospheric magnetic elements** spanning the entirety of solar cycle 24 has revealed an **unexpected dominant frequency of 5 mHz**, i.e., a frequency typically synonymous with the chromosphere.

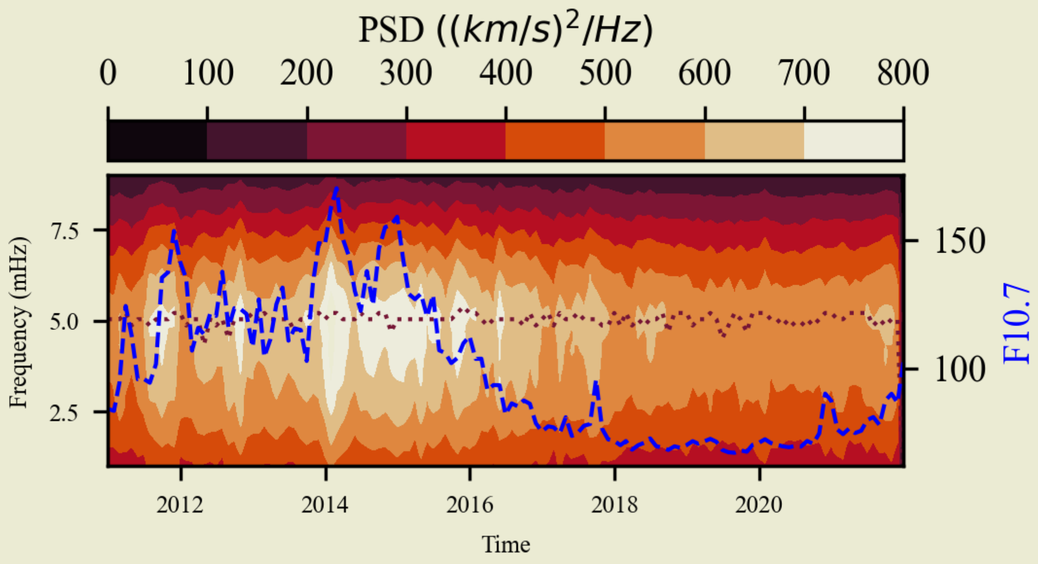
This novel result was obtained by exploiting the **unmatched spatial and temporal coverage** of magnetograms acquired by the Helioseismic and Magnetic Imager (HMI), onboard NASA's Solar Dynamics Observatory (SDO). Our findings provide a timely avenue for future exploration to **better understand the magnetic connectivity between sub-photospheric, photospheric, and chromospheric layers of the Sun's dynamic atmosphere**.

DATASET

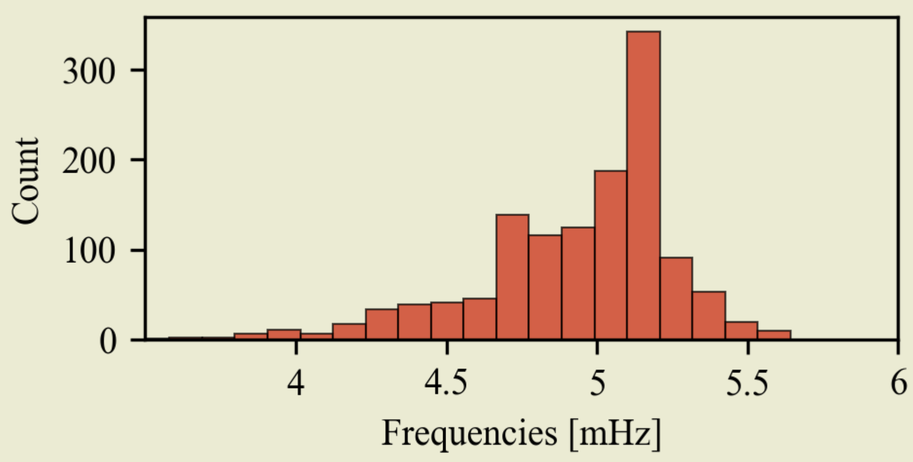
We analyzed magnetograms acquired with SDO/HMI in the Fe I 617.3 nm absorption line, with a cadence of 45 seconds, in observational windows of 40 minutes each, every three days, starting from 2011-01-01 to 2021-11-29. This dataset consists of around **11 years of observations of the line-of-sight component of the photospheric magnetic fields** spanning the full solar cycle 24 over a 400x400 arcsec patch located at the center of the solar disk.

RESULTS

Here, we show the time-frequency diagram of the horizontal velocity oscillation. Inspired by the B-ω diagram introduced in Stangalini et al. (2021), it shows the average spectral density of the observed features over each month. It reveals a **frequency band with dominant power centered between 2-6 mHz.** Furthermore, it shows a clear **correlation between the width and power of the frequency band and the solar activity cycle**.



Below, we show the histogram of the dominant frequency of the horizontal velocities in each observational window. It can be seen that there is a **clear peak centered at 5 mHz**.



CONCLUSIONS

Understanding the nature of the observed 5 mHz frequency is a challenging task. Indeed, this frequency is not in agreement with two typical timescales in the photosphere; namely the global p-modes (i.e., 3 mHz), and the typical lifetime of granules (i.e., 1.6-2 mHz). However, since the 5 mHz oscillation is found in a sample of different (in size and flux) magnetic elements, we argue that **this can be the result of a global process** (i.e. not linked to the local environmental conditions of the plasma). On the other hand, a **5mHz dominant frequency is more commonly found in the chromosphere**. Therefore, our next goal would be to investigate the **magnetic link between the photosphere and the chromosphere**, as well as **understanding the origin of such frequency at photospheric heights**.

1: Department of Physics, University of Trento
2: Department of Physics, Univeristy of Rome "Tor Vergata"
3: ASI Italian Space Agency
4: Plasma Dynamics Group, School of Mathematics and Statistics, University of Sheffield
5: Max Planck Institute for Solar System Research
6: Niels Bohr International Academy, Niels Bohr Institute
7: Astrophysics Research Centre, School of Mathematics and Physics, Queen's Univeristy Belfast
8: Department of Physics and Astronomy, California State University Northridge
9: Plasma Dynamics Group, Department of Automatic Control and System Engineering, University of Sheffield

We wish to acknowledge scientific discussions with the Waves in the Lower Solar Atmosphere (WaLSA) team, which has been supported by the Research Council of Norway (project no. 262622), The Royal Society (award no. Hooke18b/SCTM), and the International Space Science Institute (ISSI Team 502). MB acknowledges that this publication (communication/thesis/article, etc.) was produced while attending the PhD program in Space Science and Technology at the University of Trento, Cycle XXXIX, with the support of a scholarship financed by the Ministerial Decree no. 118 of 2nd March 2023, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 "Education and Research", Component 1 "Enhancement of the offer of educational services: from nurseries to universities" - Investment 4.1 “Extension of the number of research doctorates and innovative doctorates for public administration and cultural heritage”. MB also acknowledges the valuable discussions held with S. Mestici.SJ acknowledges support from the Rosseland Centre for Solar Physics (RoCS), University of Oslo, Norway. DBJ and TD acknowledge support from the Leverhulme Trust via the Research Project Grant RPG-2019-371. DBJ and SDTG wish to thank the UK Science and Technology Facilities Council (STFC) for the consolidated grants ST/T000021X/1 and ST/X000923/1. DBJ and SDTG also acknowledge funding from the UK Space Agency via the National Space Technology Programme (grant SSc-009). VF and GV are grateful to the Science and Technology Facilities Council (STFC) grants ST/V000977/1 and ST/Y001532/1. They also thank the Institute for Space-Earth Environmental Research (ISEE, International Joint Research Program, Nagoya University, Japan), the Royal Society, International Exchanges Scheme, collaboration with Greece (IES/R1/221095), India (IES/R1/211123) and Australia (IES/R3/213012) for the support provided.