Looking for Acoustic Precursor Signals of Solar Eruptive Events with a new Helium D3 Instrument

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Introduction

- Helium D3 (587.6 nm) is a transition of ortho-helium between the orbitals $1s2p^3P_{0,1,2}$ and $1s3d^3D_{1,2,3}$. It is formed in the upper chromosphere (2,000 m).
- In the interior of the Sun, low frequency acoustic waves can propagate, but high frequency waves cannot overcome the potential barrier of the magnetic fields in the solar atmosphere. Magnetic breaking (caused by high energy events like solar flares) can lower the acoustic cutoff frequency so that acoustic waves of lower frequencies can propagate outwards.
- Measuring the velocity fields at multiple heights in the solar atmosphere allows us to calculate acoustic wave travel times (Figure 1) and determine the acoustic cutoff frequency and its potential correlation to solar eruptive events.

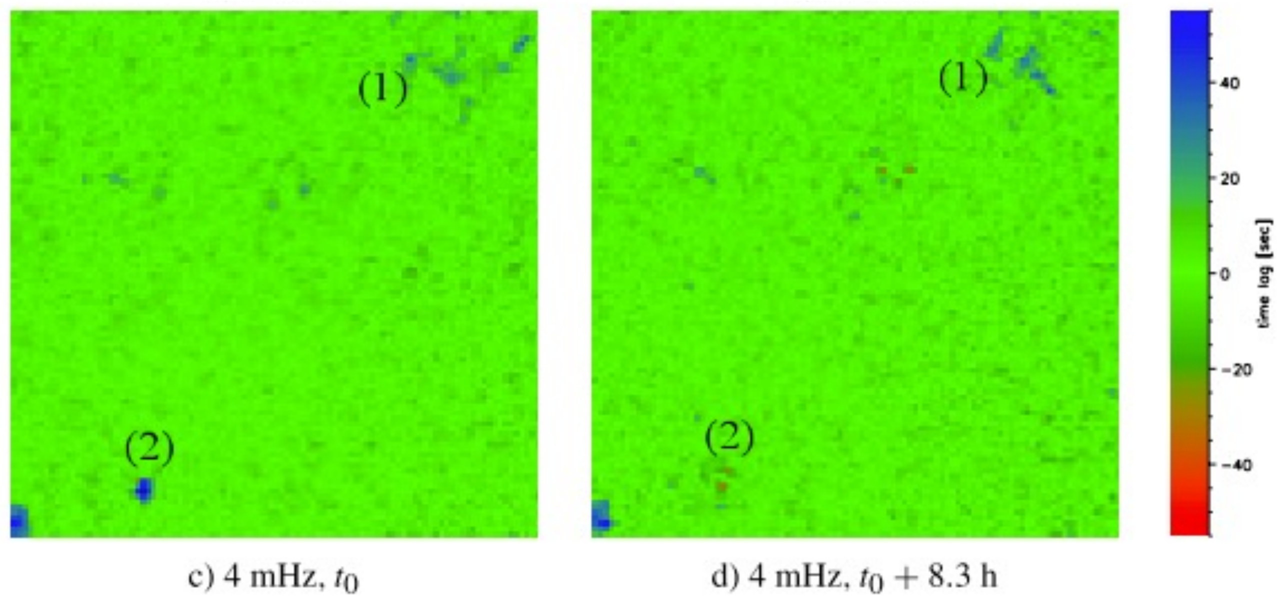


Figure 1: Phase travel time maps from Finsterle et al. 2004. Green shows evanescent waves, blue indicates upward propagating waves while red indicates downward propagating waves. Region (2) depicts the rapid change in wave travel time and therefore acoustic cutoff frequency.

Magneto Optical Filters (MOF)

- MOFs consist of a cell filled with a gaseous ion of choice (He for this study) situated in a longitudinal magnetic field and placed between two crossed polarizers (Figure 5 parts 3-7).
- Within the cell, the Zeeman (Figure 2) and Macaluso-Corbino effects occur, splitting the wings of the observed spectral line and causing a 90° polarization change. This allows for extremely narrow passbands (≈60 mÅ) to be achieved.
- The data-products of MOFs are Dopplergrams and magnetograms (Figure 3) which show the vector fields of velocity and magnetic field (respectively) at a particular height in the solar atmosphere.

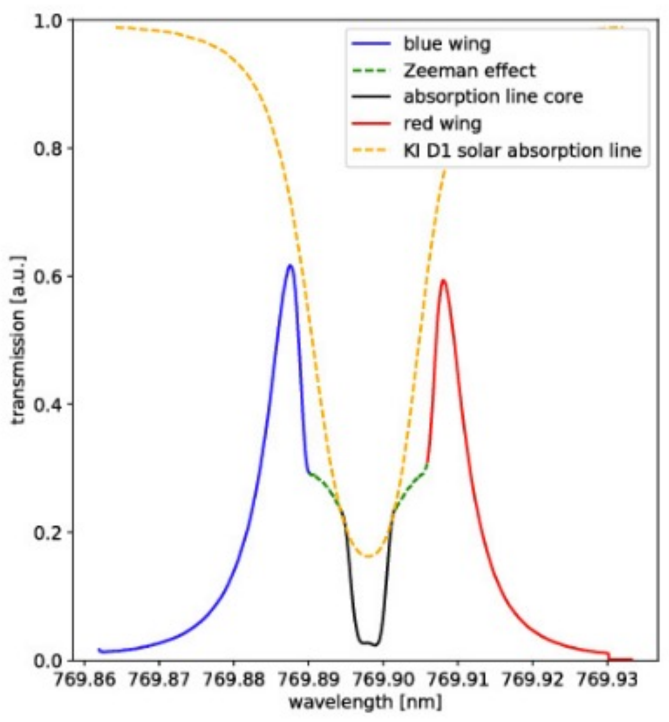


Figure 2: Depiction of the Zeeman effect within a K D1 MOF cell from Calchetti et al. 2020. The Zeeman effect splits the spectral absorption feature into its central core and component wings; additionally, it causes the wings to go into emission.

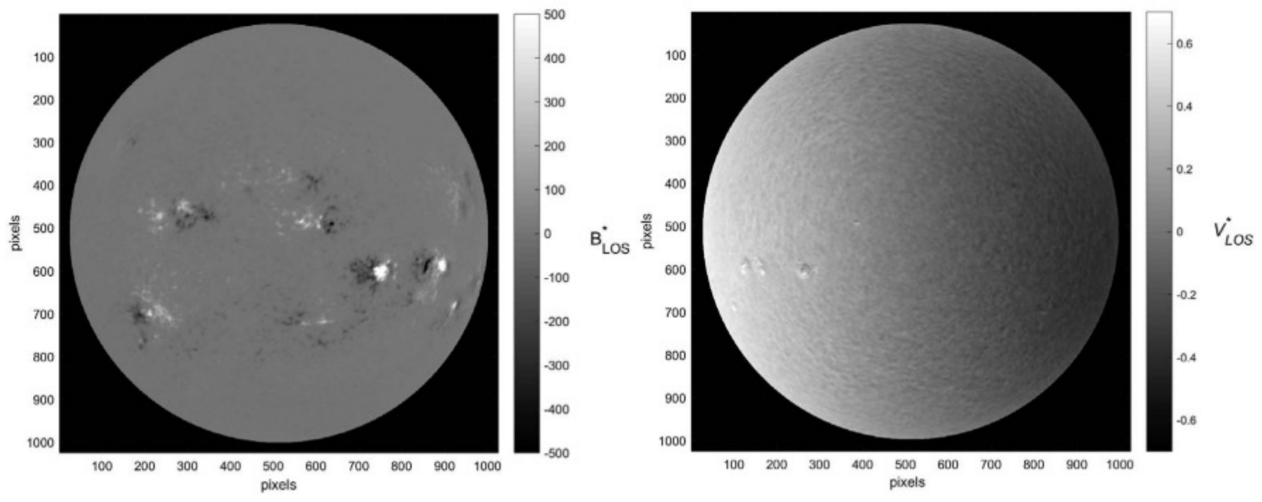


Figure 3: Magnetogram (left) and Dopplergram (right) obtained using a Potassium (K D1 769.9 nm) MOF by Forte et al. 2020. K D1 is formed in the photosphere of the Sun. Note the solar rotation obvious in the Dopplergram.

Development/Testing Techniques

- We are developing a new He D3 MOF which requires the population of metastable He within our cell.
- We have built a magnetron (Figure 4) to clean the glass cell of impurities and simulate observational conditions.
- Our MOF testbed (Figure 5) allows us to detect the presence of Faraday rotated light by measuring the light that transits through the two crossed polarizers.

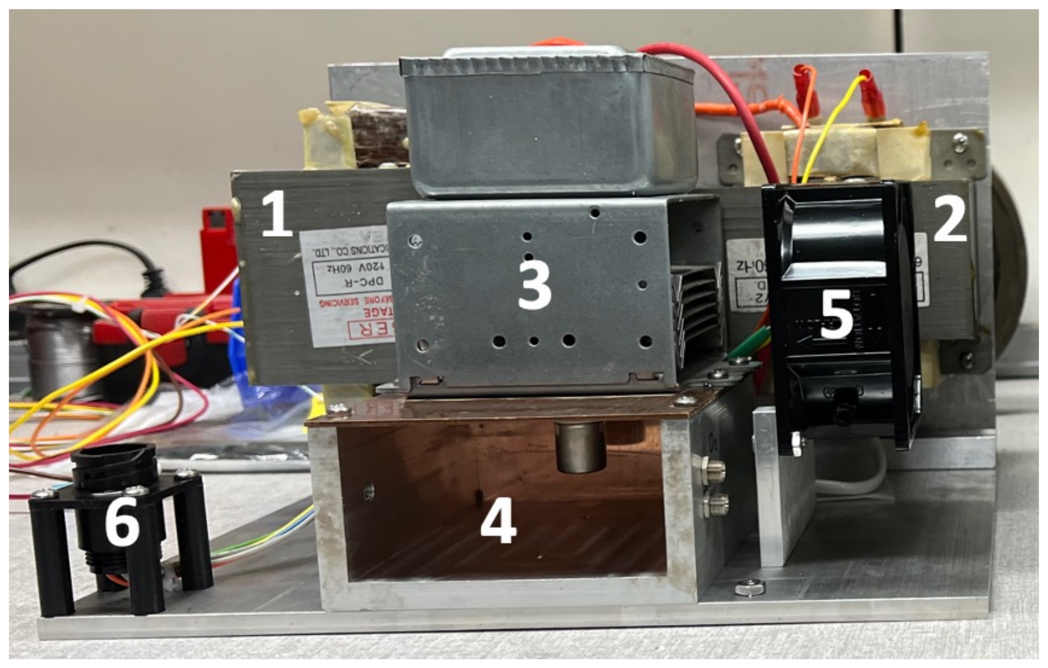
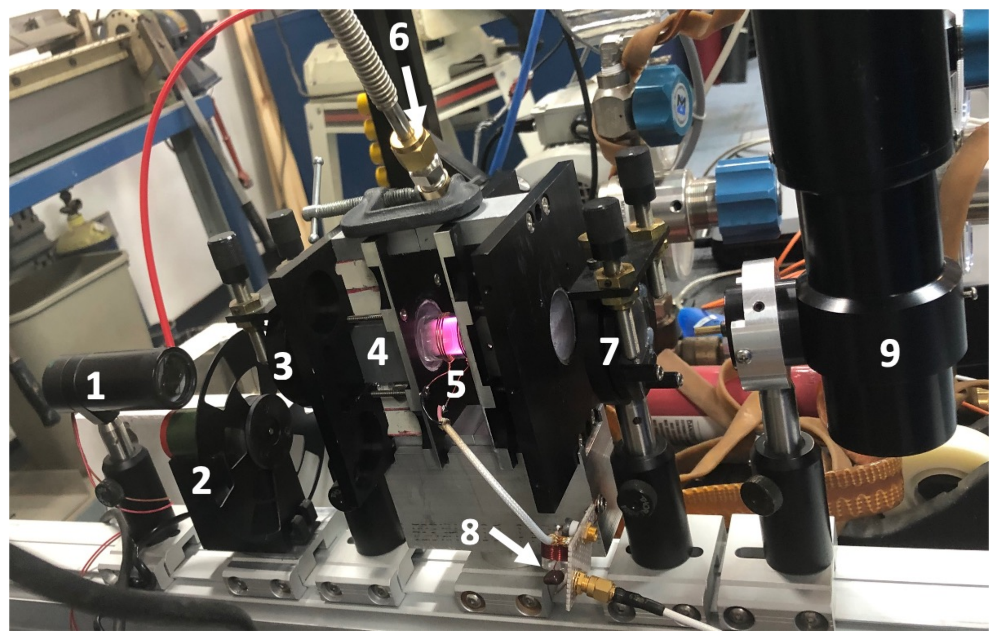


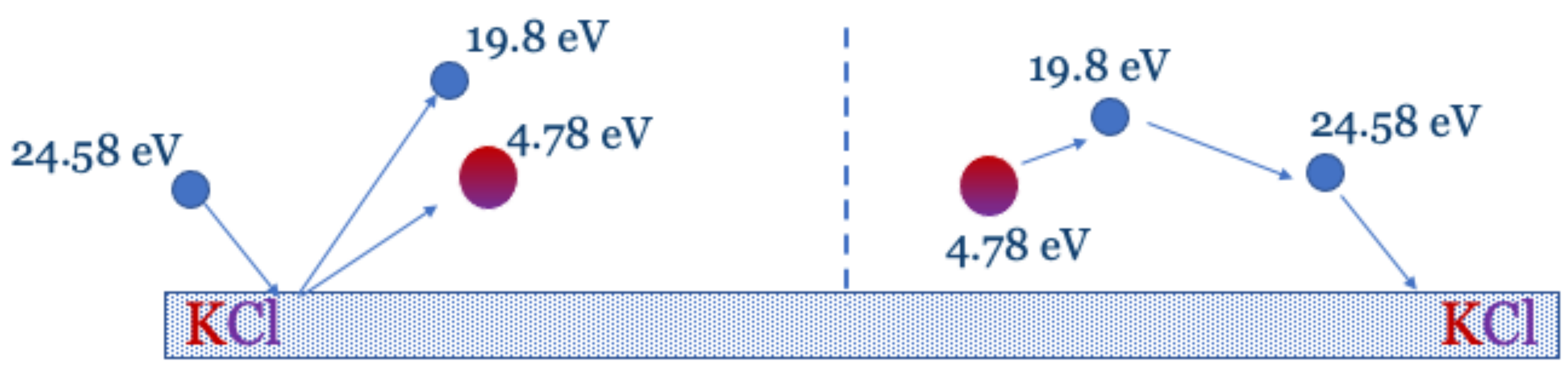
Figure 4 (left): Image of the newly designed and built magnetron-based microwave oven consisting of transformers (1 & 2), magnetron (3), oven cavity (4), fan (5), and pin adapter (6).

Figure 5 (right): Image of the MOF testing set-up containing Na 589.0 nm hallow cathode (1), lock-in amplifier's chopper (2), colorPol polarizers (3 & 7), longitudinal magnets (4), MOF cell (5), tube to vacuum system (6), RF circuit (8), and detector (9).



Future Work

- To increase the population of metastable He within our cell, we will be attempting a sputtering technique (schematic on right) using KCl. The binding energy of KCl is very similar to the difference in energy between the metastable ground state of the D3 line and fully ionize He. Ionized He collides with the KCl, releasing a K or Cl atom while dropping the He atom down to the metastable state necessary to populate the D3 line.
- Once our He cell shows MOF functionality in the lab, we will mount it at the Mojave Solar Observatory in Apple Valley, CA. We will observe in conjunction with a previously developed Na D1 (589.0 nm) MOF to observe two heights in the solar atmosphere, obtain Doppler- and magnetograms, and subsequently analyze the acoustic wavefield of the chromosphere.



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