

# The propagation of acoustic wave energy in magnetic atmospheres

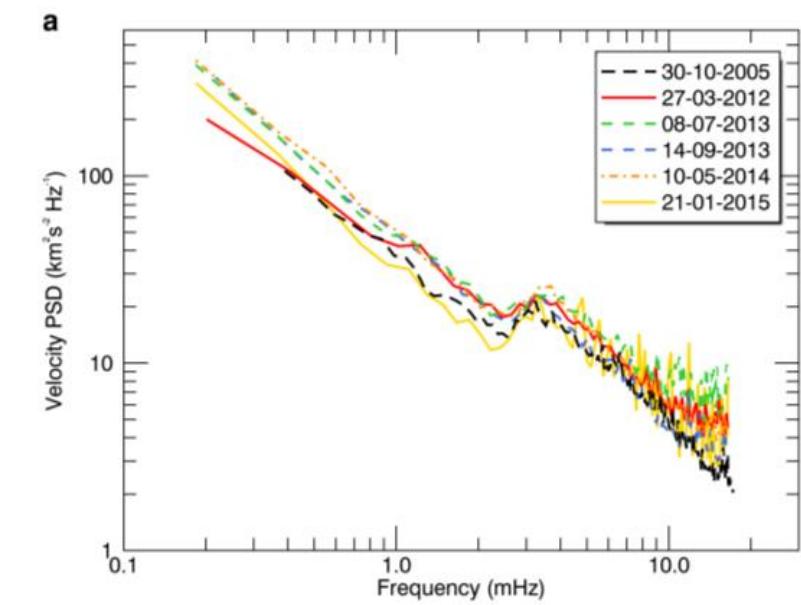
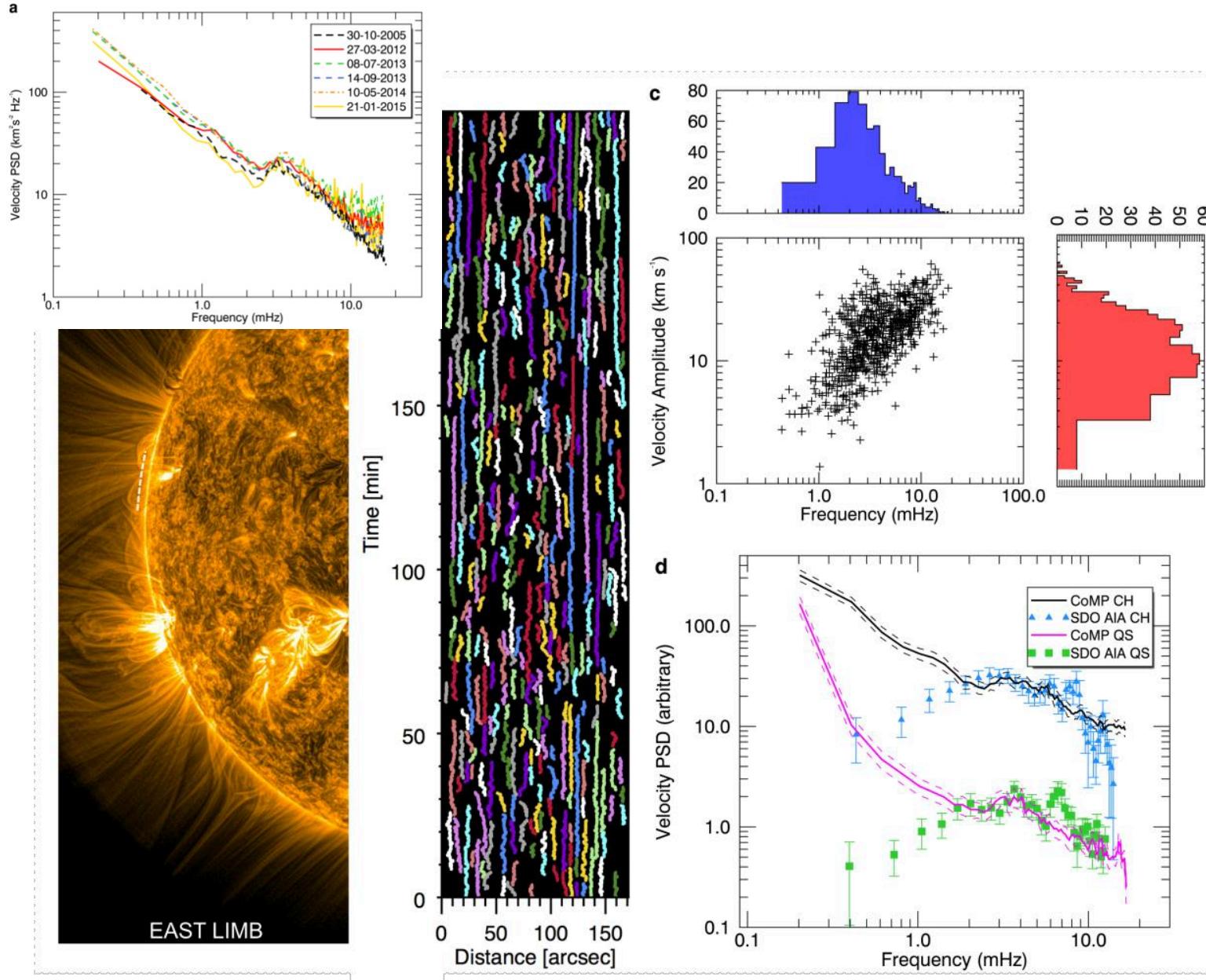
S. Krishna Prasad

Postdoctoral Research Fellow



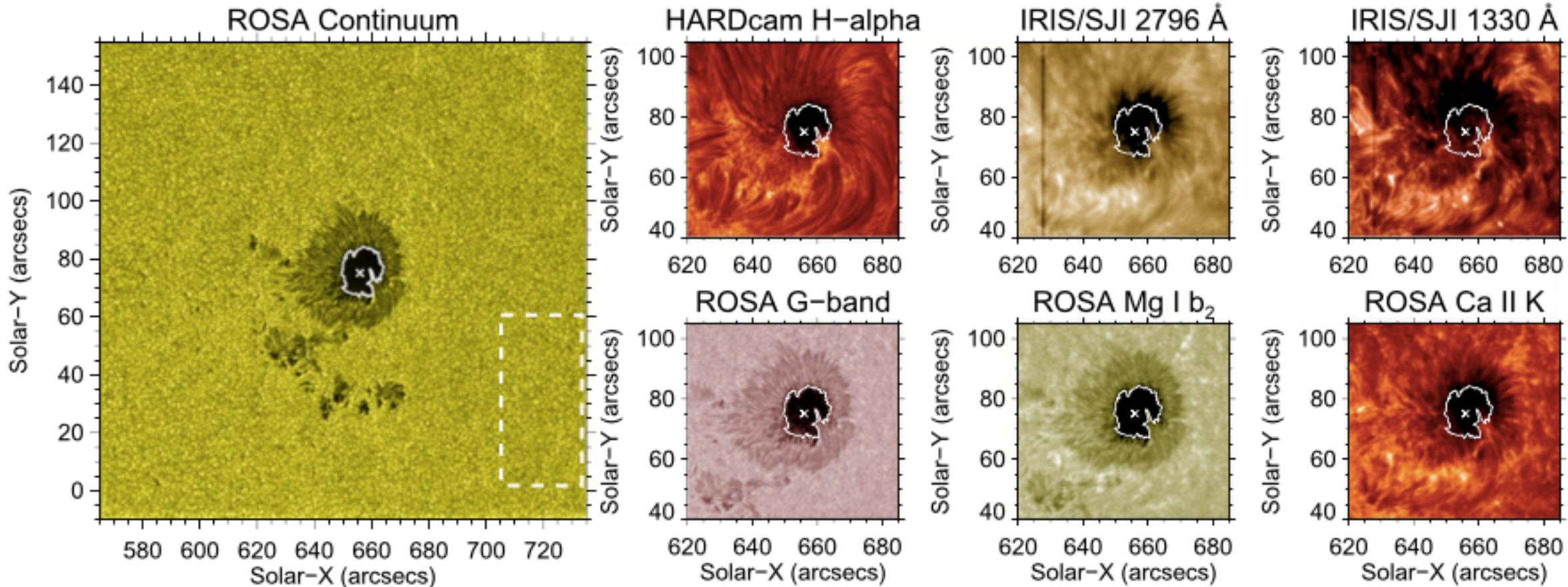
# Introduction

- The available energy flux in the compressive slow waves detected in the solar corona is on the order of a few hundred to a few thousand  $\text{erg cm}^{-2}\text{s}^{-1}$ , which is much less than the required value for heating the active corona (e.g., McEwan & De Moortel 2006, Wang+ 2009)
- There was also a debate on whether or not the compressive waves carry enough energy to heat the quiet chromosphere (see Fossum & Carlsson 2005, Carlsson+ 2007, Wedemeyer-Bohm+ 2007, Bello Gonzalez+ 2009, 2010)
- The contribution of acoustic waves in magnetized atmospheres is relatively less studied. Recent studies provide mixed results (Felipe+ 2011, Kanoh+ 2016, Chae+ 2017)



There has been renewed interest in acoustic waves because of their potential to drive the recently discovered ubiquitous Alfvénic waves (Tomczyk+ 2007, Morton+ 2015, 2016, 2019)

# ROSA and IRIS observations of a sunspot



## ROSA

AR12149 observed on 30 August 2014

Filters: Continuum, Gband, Mg I  $b_2$ , CaK, Halpha

Scale: 0.185" & Cadence: 0.99 – 4.22 s

Duration: 3 hours

## IRIS

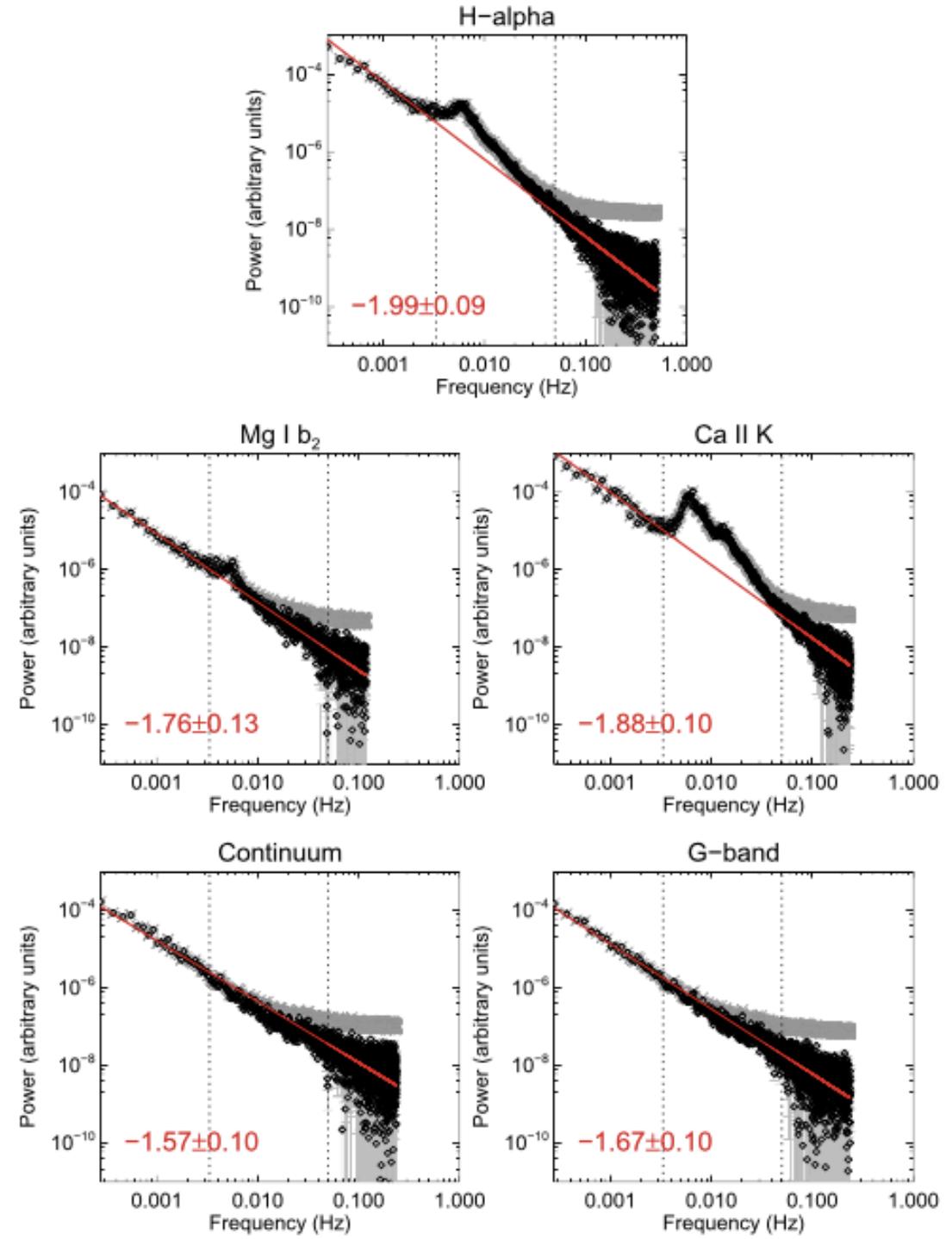
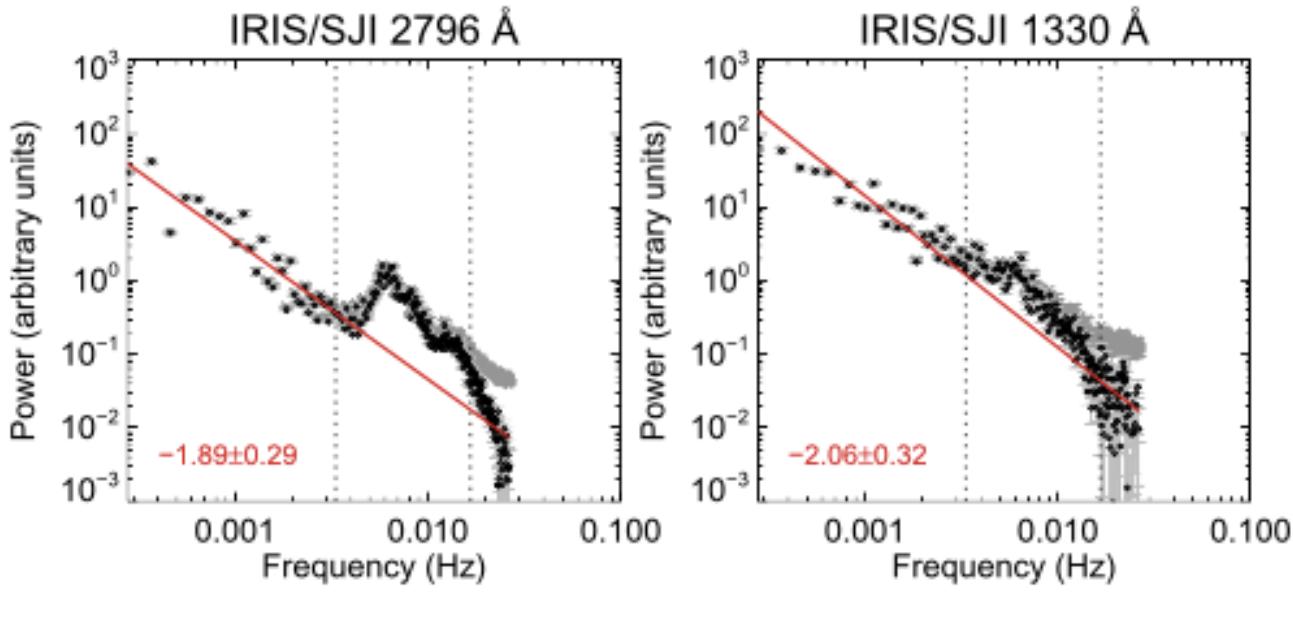
Co-temporal SJI data (slit was outside umbra)

Filters: 2796, 1330 slit jaw images

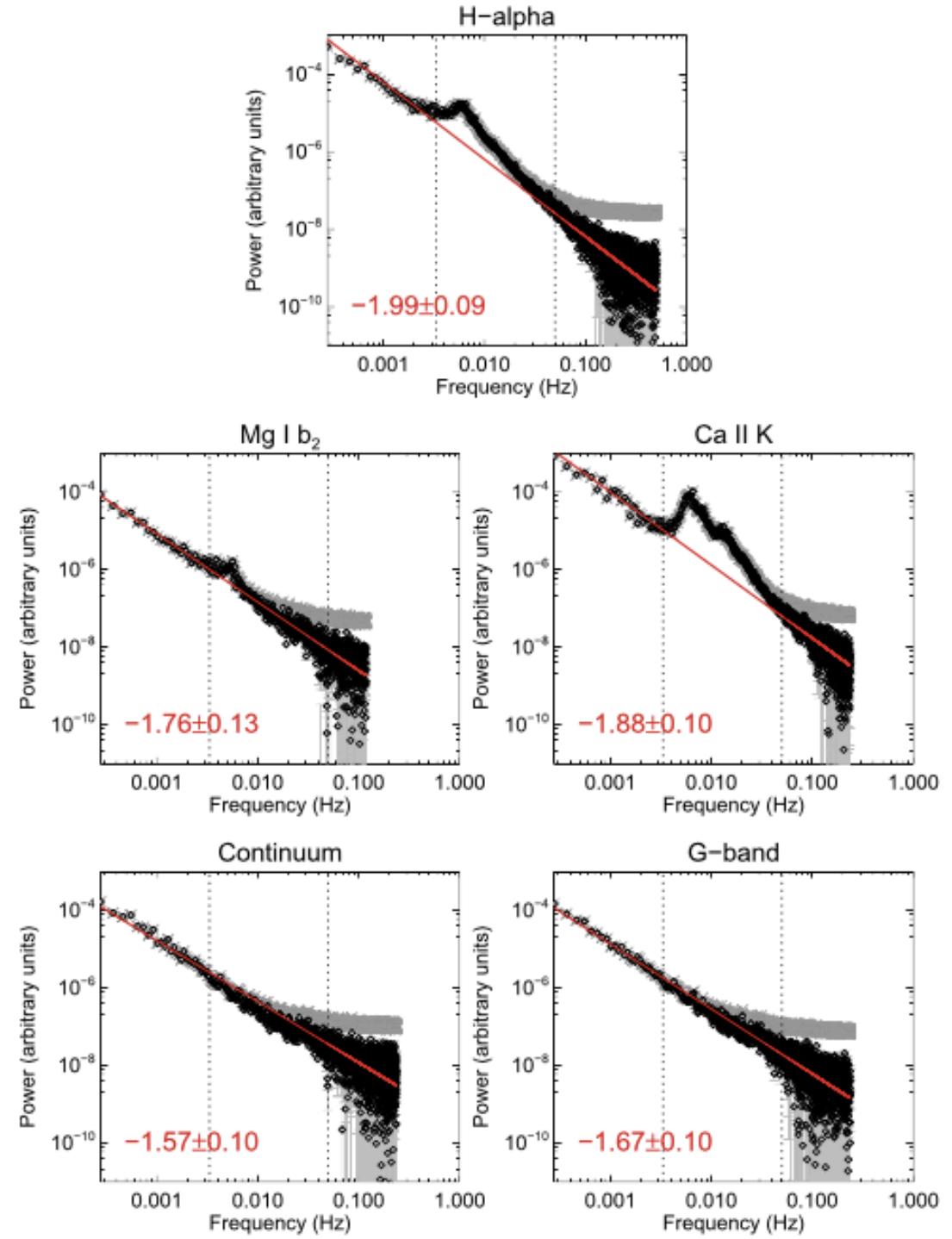
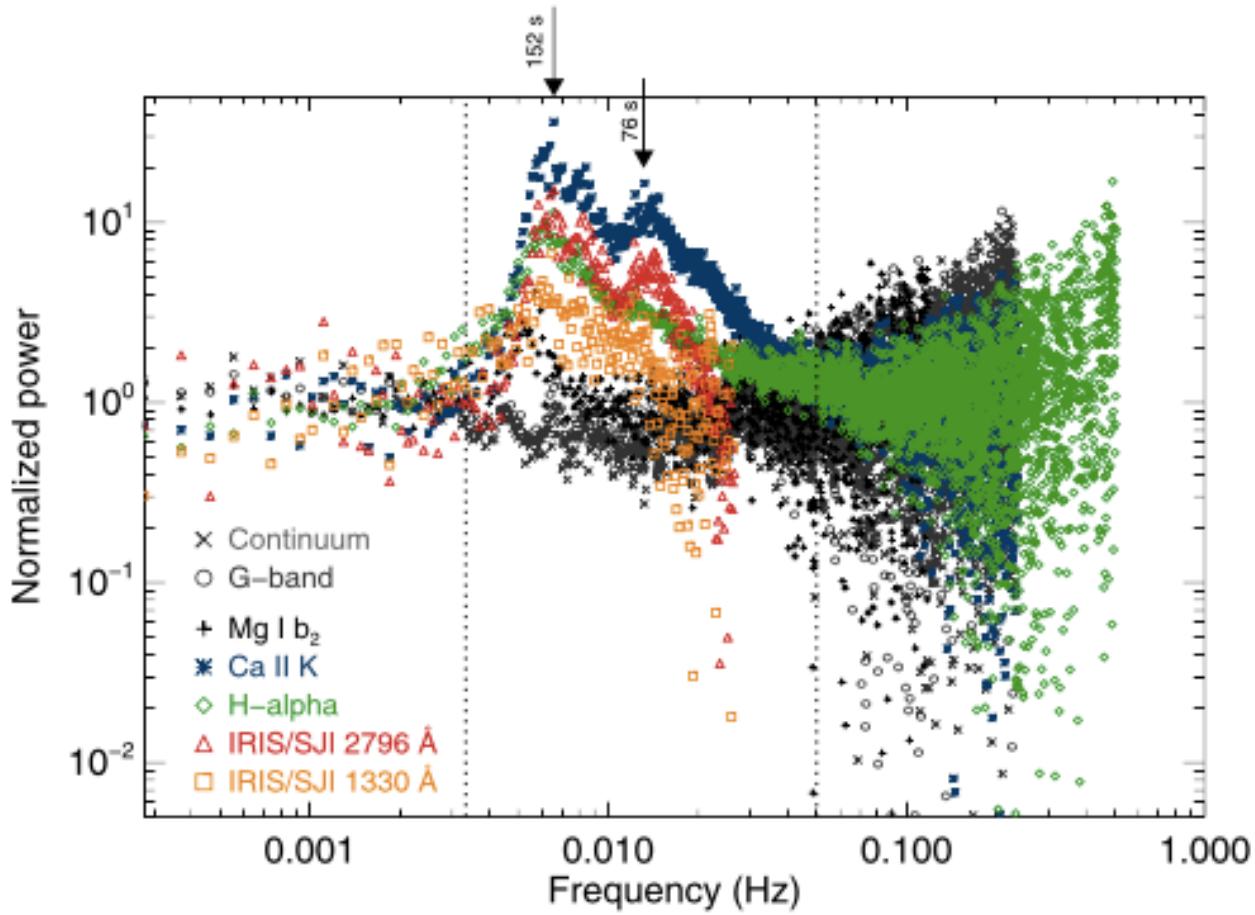
Scale: 0.166" & Cadence: 19 s

Duration: 3 hours

- Original power spectra
- White noise subtracted
- Power-law fits



# Normalized power spectra



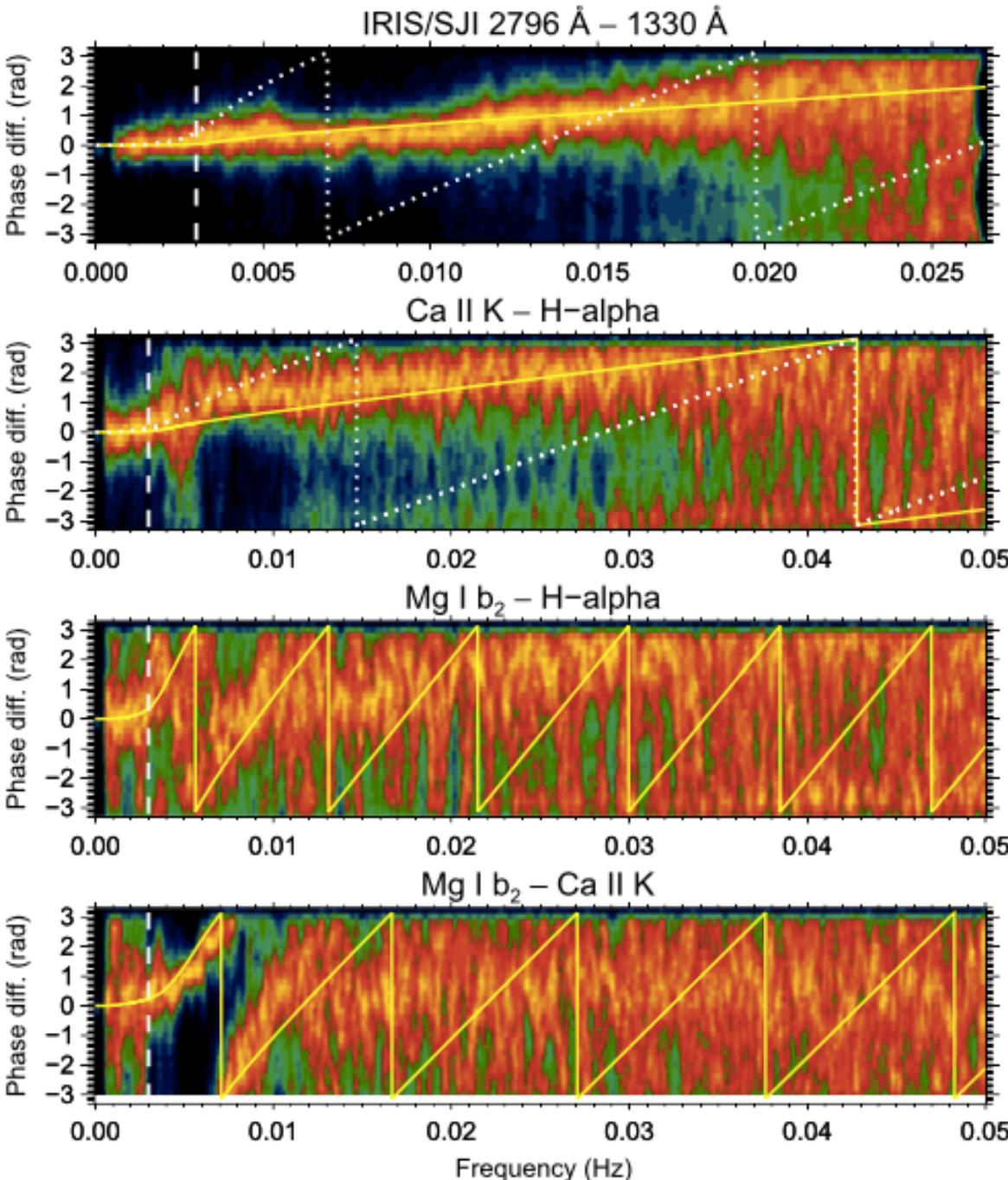
# Phase difference spectra

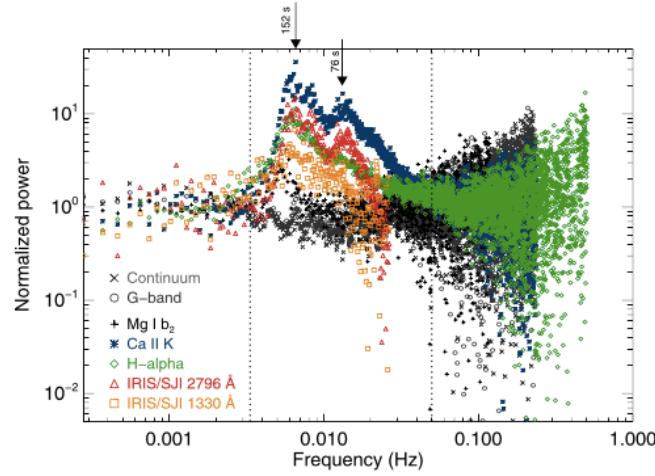
- Phase difference spectra are computed between different channel pairs using the pixel-to-pixel phase difference values.
- Theoretical phase curves are computed assuming wave propagation in a stratified isothermal atmosphere with radiative cooling (Centeno et al. 2006).
- H-alpha and IRIS 1330 channels show lower height difference (< 100 km) w.r.t Ca II K and IRIS 2796 channels, respectively.

Typical Formation Heights of Different ROSA/HARDcam Channels above the Photosphere

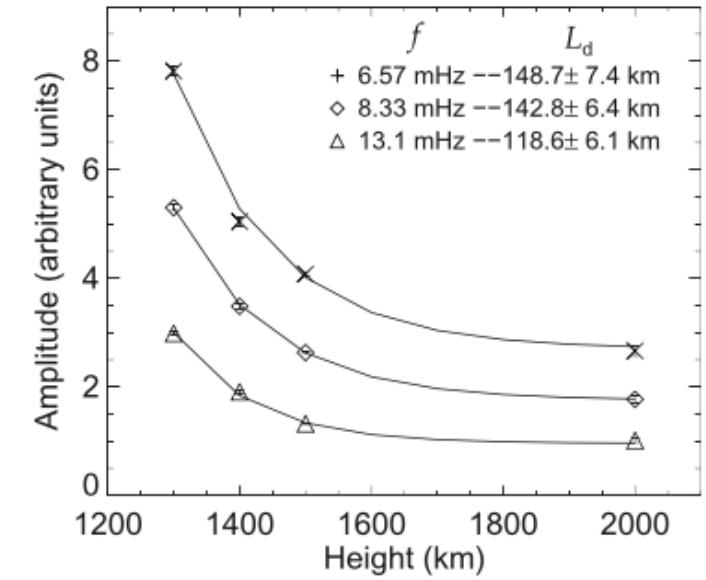
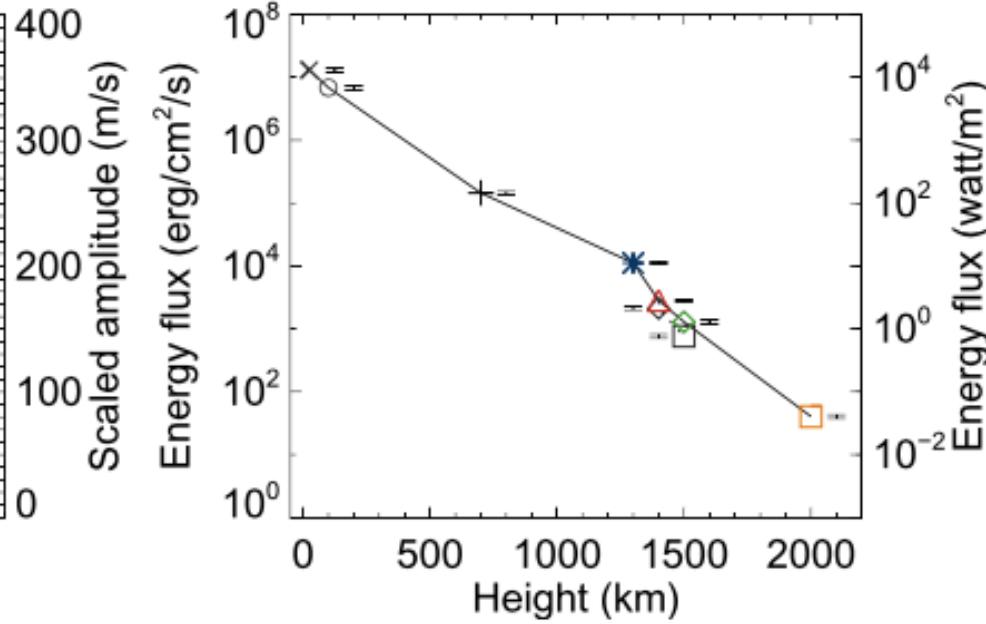
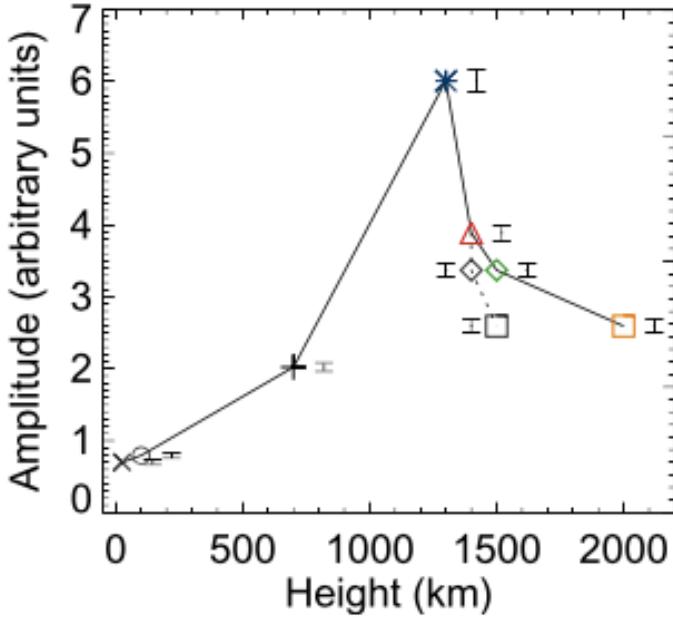
Channel Name	Formation Height
Blue continuum (4170 Å)	25 km (1)
G-band	100 km (1)
Mg I b <sub>2</sub>	700 km (2)
Ca II K	1300 km (3)
H $\alpha$	1500 km (4)

References. (1) Jess et al. (2012b), (2) Schmieder (1979), (3) Beebe & Johnson (1969), (4) Vernazza et al. (1981).

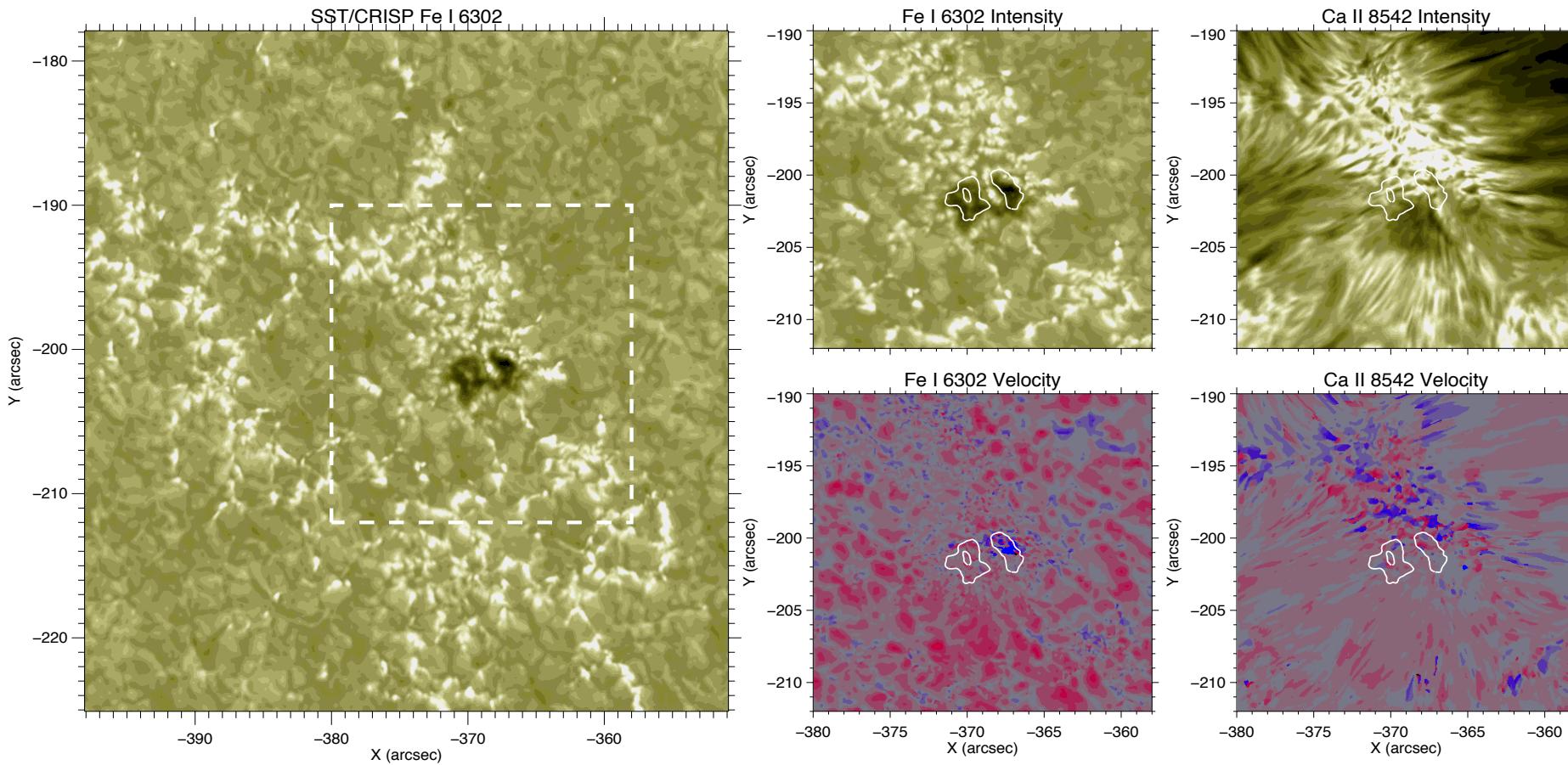




- Relative amplitudes of three-minute (5.5 mHz) oscillations gradually increase up to about Ca II K height and then decrease rapidly thereafter.
- Photospheric amplitudes are scaled to 40 m/s (Thomas & Weiss 1992, Chae et al. 2017). Temperature and density values are taken from umbral core 'M' model of Maltby et al. (1986)
- Energy flux steadily decreases right from the photosphere from about  $1.3 \times 10^7$  erg/cm<sup>2</sup>/s to 40 erg/cm<sup>2</sup>/s (800 erg/cm<sup>2</sup>/s if alternate height is chosen for H-alpha and IRIS 1330 channels).

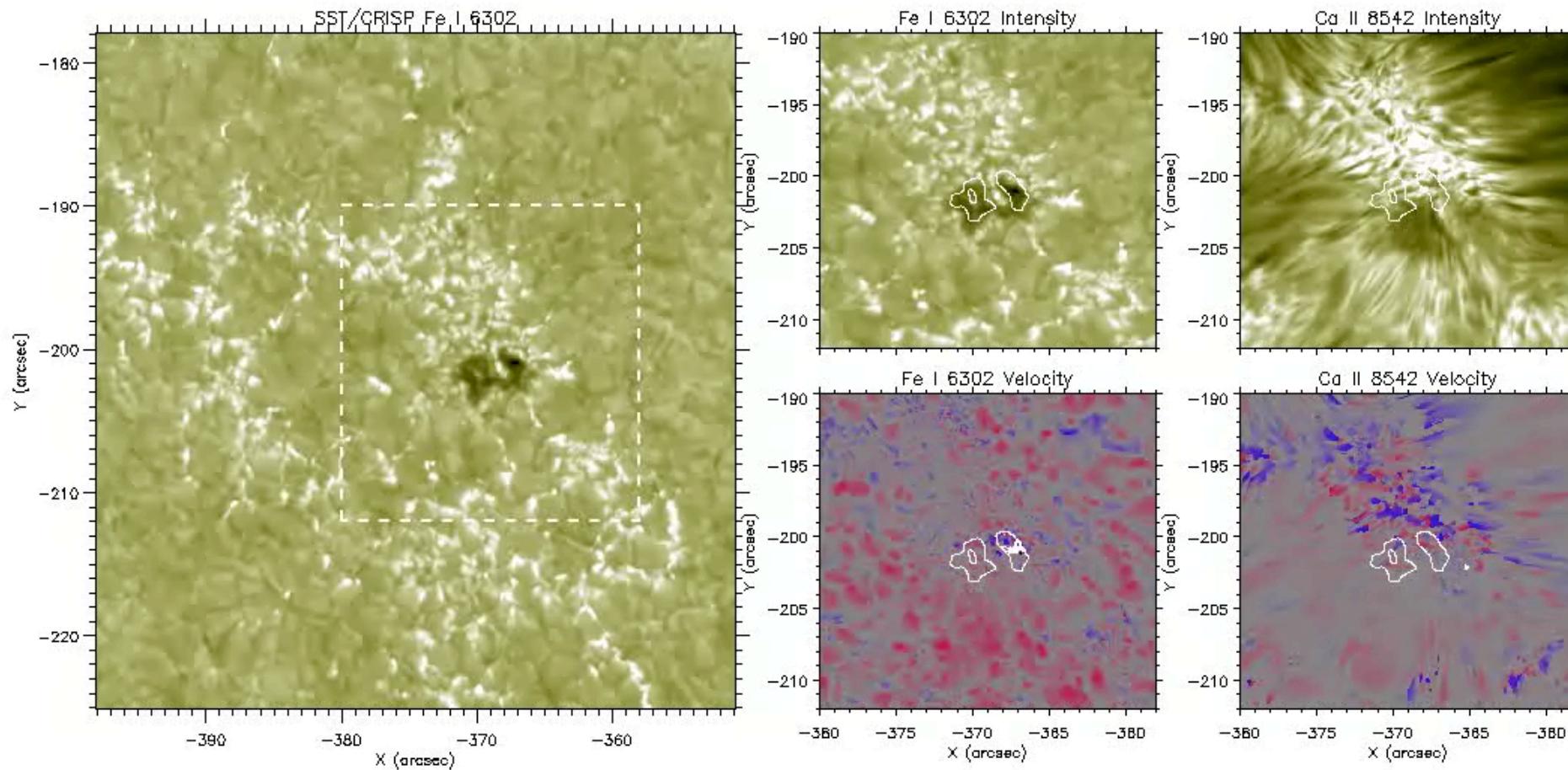


# SST observations of a pore



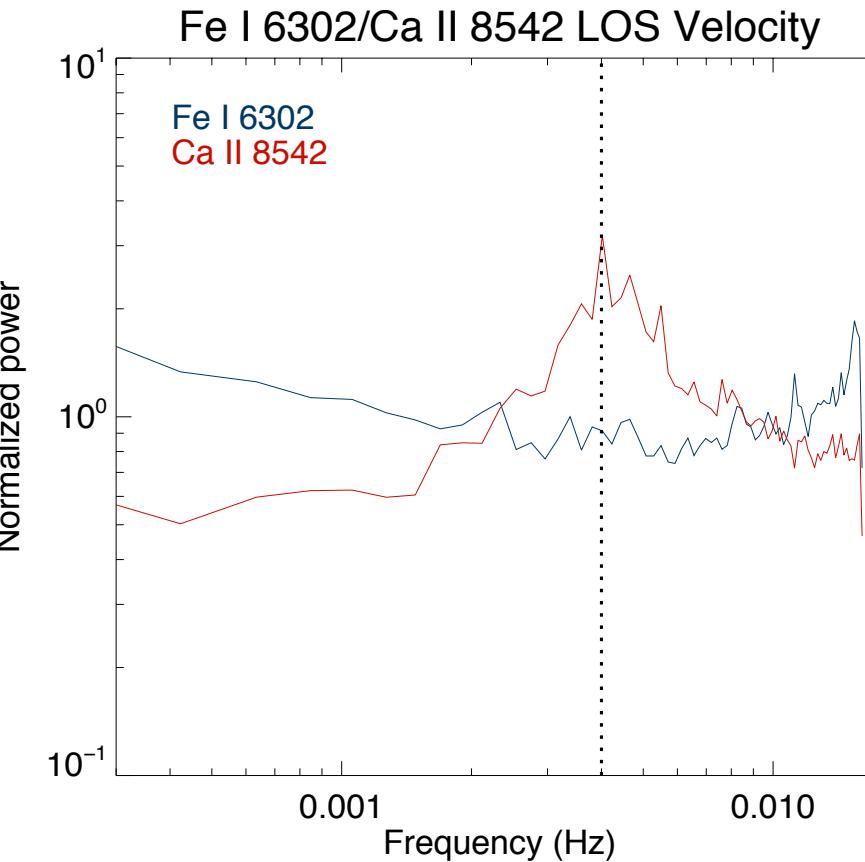
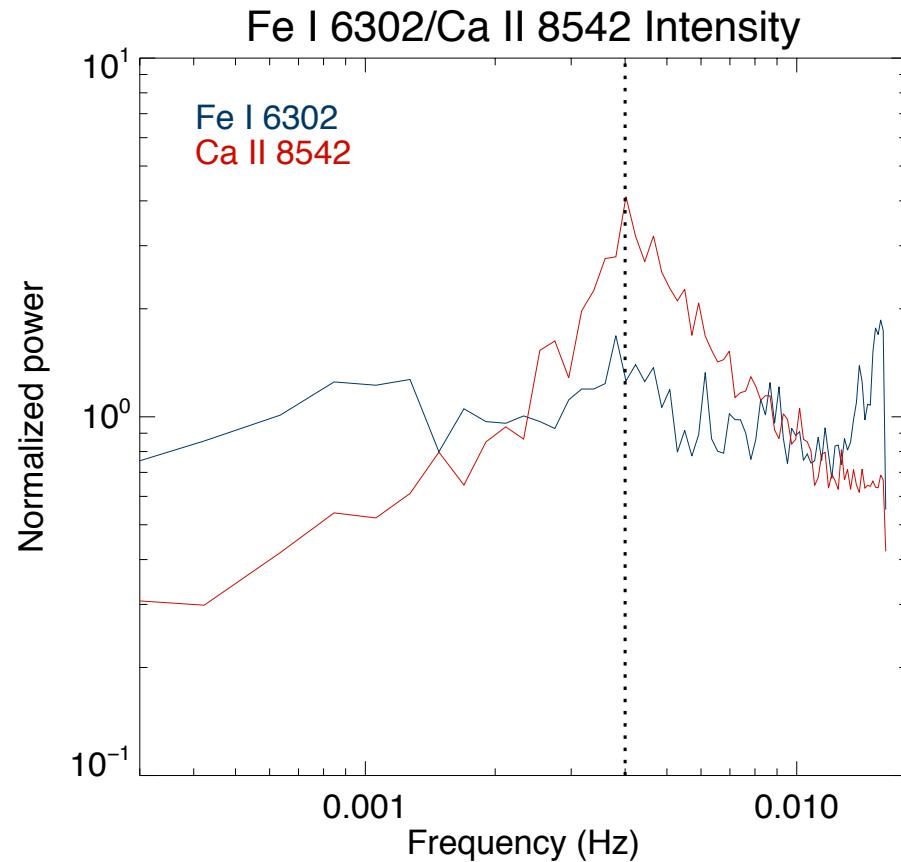
Spectropolarimetric observations in Fe I 6302 and Ca II 8542 lines.  
Cadence:  $\sim 31$  s, Pixel scale:  $\sim 0.06''$ . Duration:  $\sim 75$  min.

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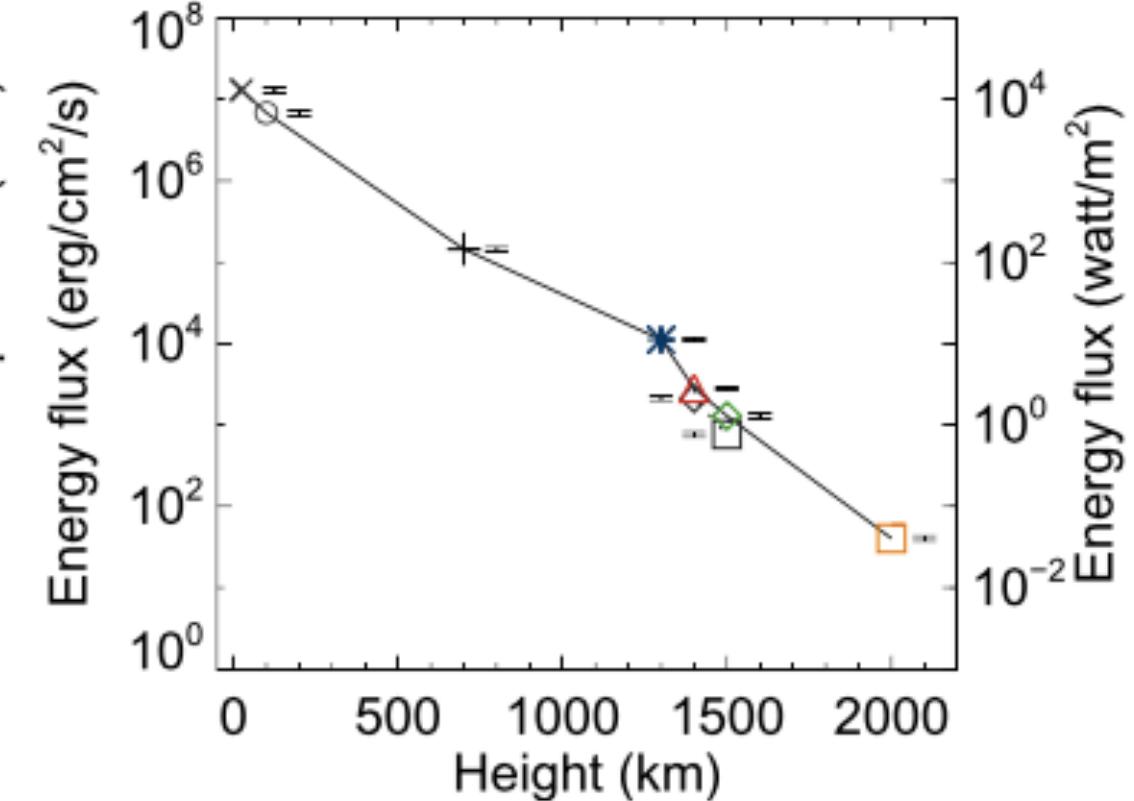
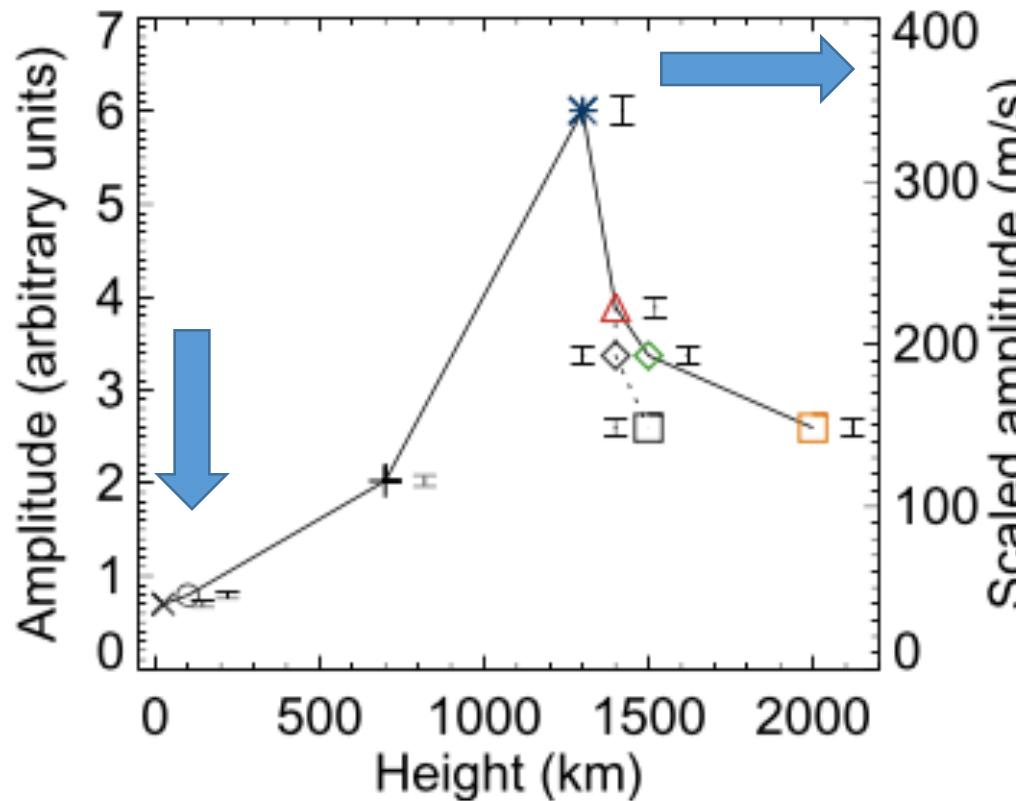


Spectropolarimetric observations in Fe I 6302 and Ca II 8542 lines.  
Cadence: ~31 s, Pixel scale: ~0.06". Duration: ~75 min.

# Mean umbral power spectra

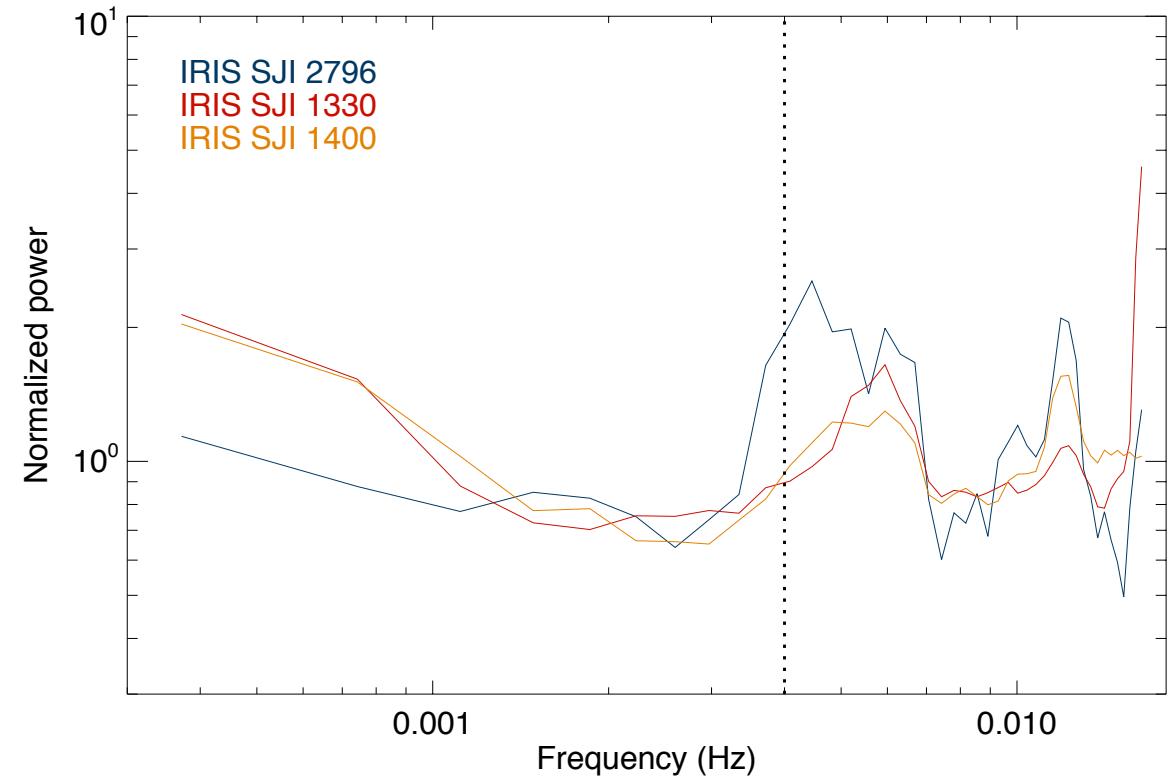
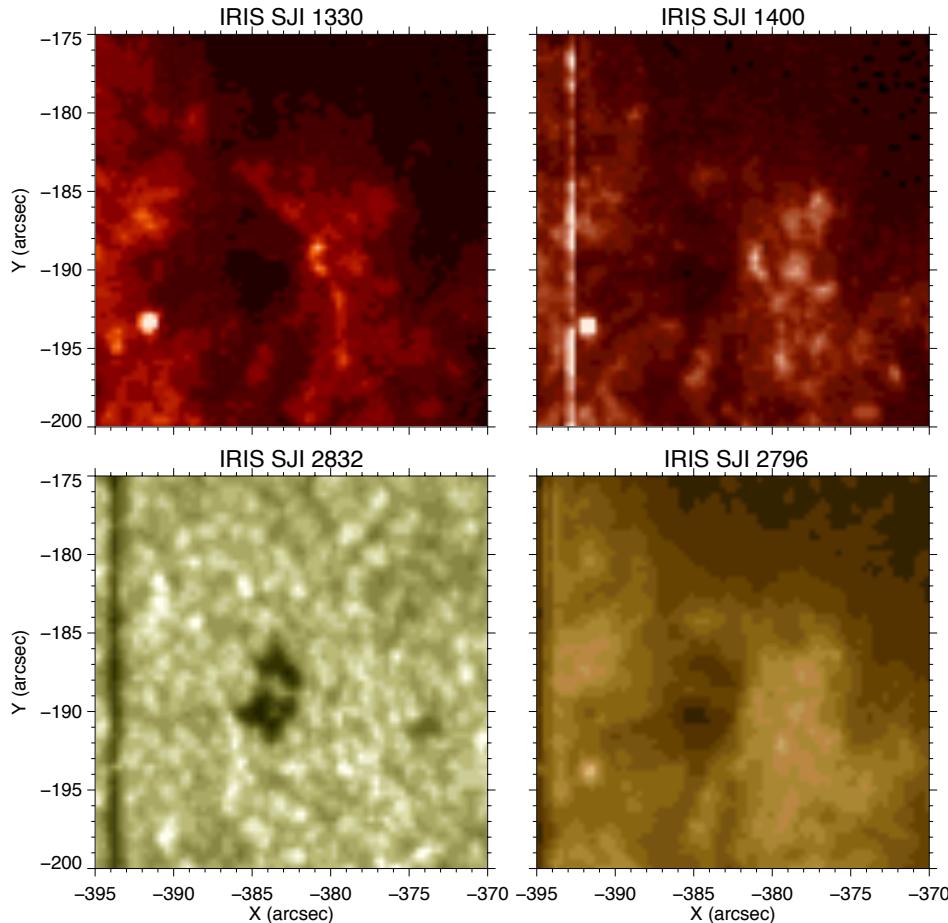


Velocity amplitudes on the order of  $\sim 285$  m/s in the Fe I line and  $1.3$  km/s in Ca II line!



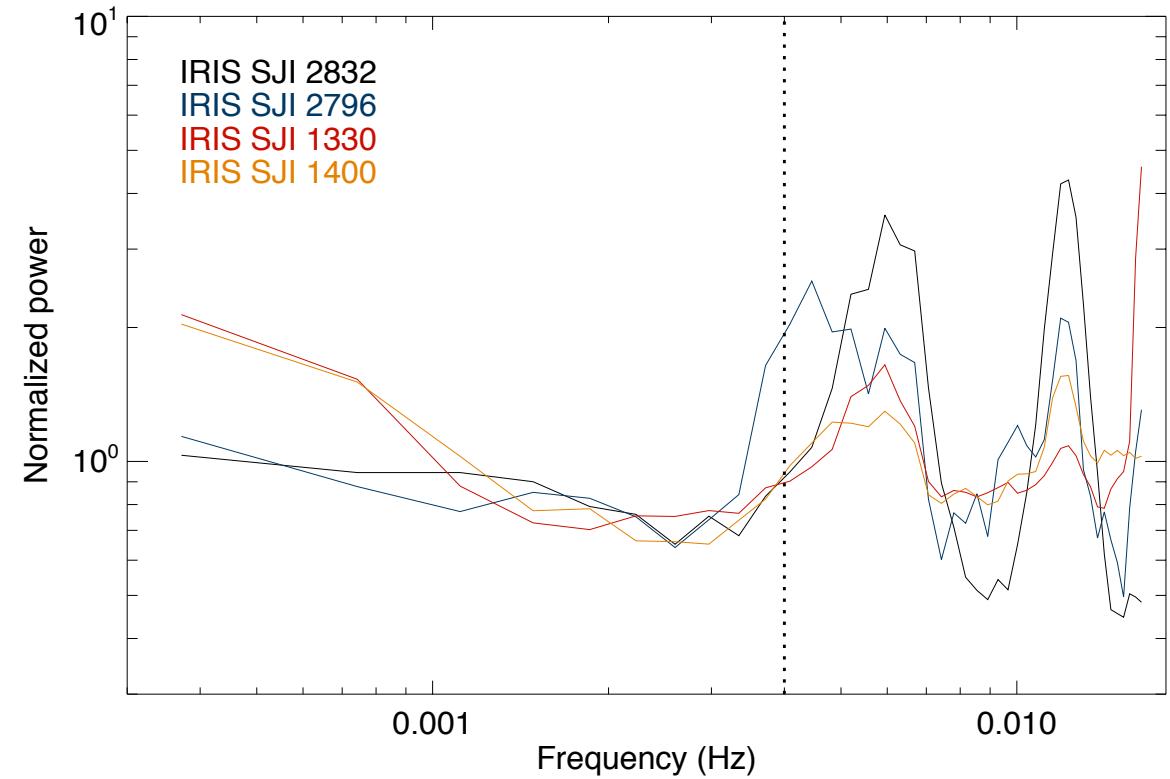
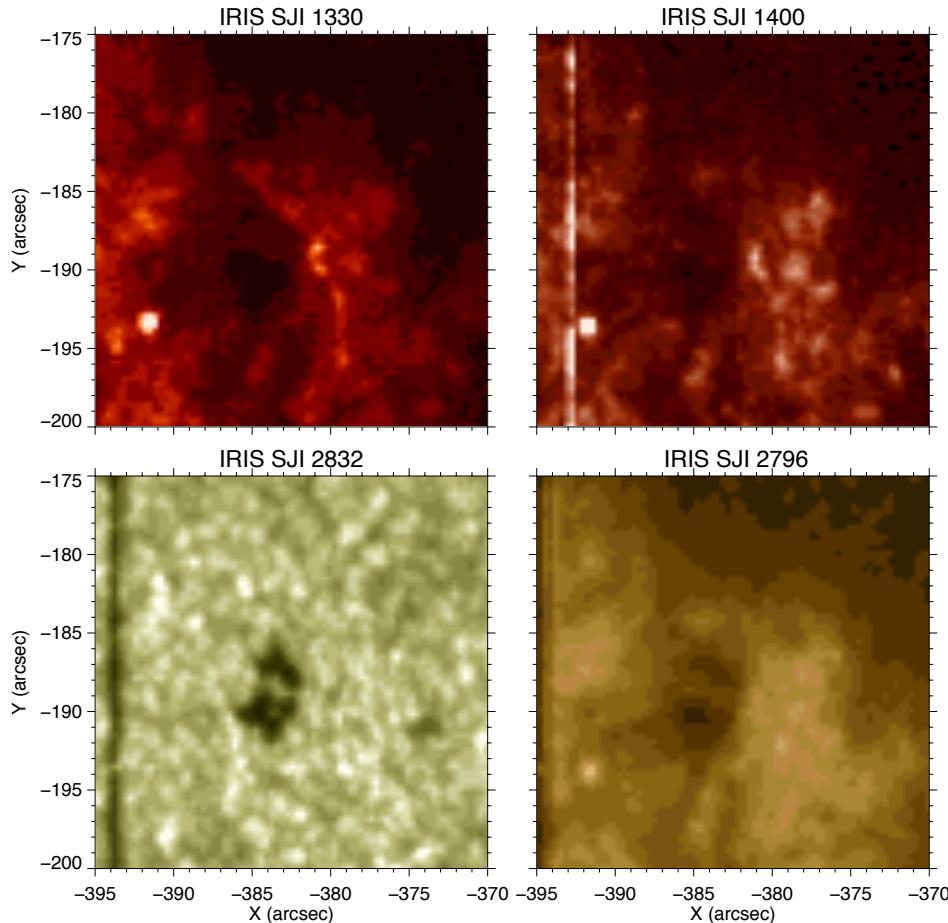
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# Corresponding IRIS data



Slit was outside the umbra. All 4 SJIs available. Cadence:  $\sim 21$  s,  
Pixel scale:  $\sim 0.33''$ . Duration:  $\sim 55$  min.

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## Summary & Conclusions

- Significant damping of acoustic waves has been observed in the lower atmospheric layers of a sunspot. The damping is frequency-dependent with higher frequencies damping faster.
- The energy loss could be due to greater radiative losses for high frequency waves (Carlsson & Stein, 2002), followed by shock dissipation in the chromosphere although dissipationless effects such as mode conversion are quite possible.
- Analysis of oscillations in a pore shows availability of up to an order of magnitude higher energy.
- Harmonics in the power spectra peaks are seen especially in the IRIS data. Could be related to sausage oscillations of pore(?)

Thanks for your attention!