Finding oscillatory regions in SDO/AIA EUV data

J. Ireland, C.A. Young
ADNET Systems, Inc. at NASA GSFC

Funded by a NASA ROSES 2008 HGI award.
Solar structures oscillate

- many different oscillation periods have been identified - lots of frequency space to examine.
- concentrate on 3 and 5 minute wavebands.
Scientific return

• Diagnostic potential: if you are sure that the oscillation can be identified with a predicted wave mode, then observations can be used to measure coronal properties, e.g. coronal field strength.

• Potential energy source that heats the corona.
Measurements

- Frequencies.
- Occurrence locations, longevity, recurrence rate at a given location, conditions for required for an oscillation to occur.
SDO/AIA data

• 16 Mpx/image.
• 10 wavebands.
• One image in each waveband every 12 seconds continuously. Overlapping time-ranges imply $\approx 24$ analyses per active region.
• $\sim 4 \times 10^9$ FFTs per day.
• Identify oscillating structures.
Approach

• Look for 3 and 5 minute period oscillations only.
• Examine active regions only (smaller number of time-series examined).
• Identification of oscillating individual pixels, then segmentation into significant groups
Data

• Use SPoCA active region detections.
• Download cutouts from AIA cutout service in 171 Å and 193 Å.
• Remove solar rotation, sum $2 \times 2$.
• One hour duration = 300 samples.
Analysis

• Oscillation model in each pixel \[ d_j = A \cos(\omega t_j) + B \sin(\omega t_j) \]

• Calculate (Bayesian) probability \( p(\omega) \) that the time-series \( d_j \) observed at times \( t_j = j.\delta t \) (\( l \leq j \leq N \)) supports a frequency \( \omega \).

\[
p(\omega) \propto \left[ 1 - \frac{2C(\omega)}{Nd^2} \right]^{1-N/2} \quad C(\omega) = \frac{1}{N} \left| \sum_{j=1}^{N} d_j e^{i\omega t_j} \right|^2
\]

• Integrate over pre-defined frequency ranges.

• Use the Fourier frequencies \( \omega_k = k.2\pi/(N.\delta t) \).
Analysis

• Group together pixels that have a high probability of oscillating within the frequency range.

• Measure local coherence properties of these groups.

• Keep groups of highly coherent pixels.
Analysis

• Active region size ~ 240 x 240 arcsec$^2$ with 2×2 spatial summing, ~ $10^{4-5}$ px.

• Approximately 1-10 active regions per day.

• Analyze durations of 1 hour of data only.

• Two wave bands analyzed (out of a possible 6).
Results

distributions: fraction of AR area with prob(oscillation) > 0

solid, red = 171, 5-minute

dashed, red = 193, 5-minute

solid, black = 171, 3-minute

dashed, black = 193, 3-minute
Results

distributions: fraction of AR area with \( \text{prob(oscillation)} > 95\% \)

- solid, red = 171, 5-minute
- dashed, red = 193, 5-minute
- solid, black = 171, 3-minute
- dashed, black = 193, 3-minute
Results

distributions: ratio total coherent group area to total HPG area per AR

- solid, red = 171, 5-minute
- dashed, red = 193, 5-minute
- solid, black = 171, 3-minute
- dashed, black = 193, 3-minute
Conclusions

• Not many coherently oscillating groups of pixels in 171 Å and 193 Å.

• Consistent with the suggestion most oscillatory signals are not wave-like.

• But....
  
  – need knowledge of the underlying physical structure (where are the loops? where is the moss?) to give a definitive answer.