Long-period oscillation leakages from the chromosphere to the corona

D. Yuan, C. Foulon, N. Chorley, and V. Nakariakov

Centre for Fusion, Space and Astrophysics
University of Warwick
Coventry, UK
Ding.Yuan@warwick.ac.uk

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CFSA centre for fusion, space and astrophysics

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Observations of slow magnetoacoustic waves

Usually Observed as propogating intensity perterbation in:

- Polar plume (EIT 171Å, DeForest and Gurman (1998), Ofman et al. 1999)
- Coronal loops (EIT 195Å, Berghmans and Clette 1998)
- Large diffuse coronal structure (De Moortel 2000,2002, King et al. 2003)

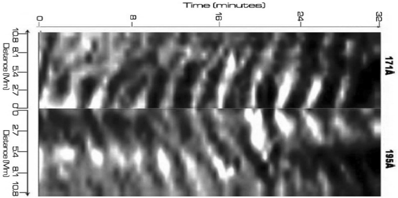

Figure: King et al. 2003

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Parameters of slow magnetoacoustic waves

Table: Adapted from Aschwanden, Physics of the Solar Corona, chapter 8, p.334 and De Moortel 2009

Observer	N	Wavelength(*s*)	Speed v[(km/s)]	Instrument
DeForest & Gurman (1998)	1	171Å	$\approx 75 - 150$	SoHO/EIT
Berghmans & Clette (1999)	3	195Å	$\approx 75 - 200$	SoHO/EIT
Nightingale (1999)	1	171Å, 195Å	$\approx 130 - 190$	TRACE
Schrijver (1999)	1	195Å	$\approx 70 - 100$	TRACE
De Moortel (2000)	1	171Å	$\approx 70 - 165$	TRACE
De Moortel (2002a)	38	171Å	122 ± 43	TRACE
De Moortel (2002b)	4	195Å	150 ± 25	TRACE
Robbrecht (2001)	4	171Å,195Å	$\approx 65 - 150$	EIT, TRACE
Berghmans (2001)	1	171Å,195Å	...	EIT, TRACE
Sakurai (2002)	1	5303Å	≈ 100	Norikura
King (2003)	1	171Å, 195Å	$\approx 150 - 190$	TRACE
Marsh (2003)	1	171Å, 368Å	$\approx 50 - 195$	CDS, TRACE
McEwan & De Moortel (2006)	25	171Å	98 ± 6	TRACE

The periods of slow magnetoacoustic waves

- Short periods: 2-7 mins (3 mins over sunspots, 5 mins off sunspots) (De Moortel 2002a,b)
- Long periods: 10-30 mins (Marsh et al 2003, Wang et al. 2009)

Leakage of sunspot oscillations

- 3 mins oscillation were found to leak from sunspot umbra to transition region (Shibasaki 2001)
- QPP in active region flaring were linked to 3 mins sunspot oscillation through slow magnetoacoustic wave leakage (Sych et al. 2009)
- 5 mins p-mode oscillations were reported to propagate to solar corona through inclined magnetic field lines (de Wijn et al. 2009)
- Long period sunspot oscillations (30-60 mins) were reported with possible source from solar interior, while leakage to upper solar atmosphere are not confidently investigated (Chorley et al. 2010)

NOAA AR8253

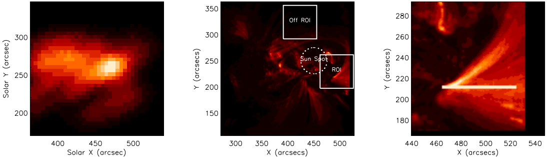

Figure: NOAA AR8253 observed by NoRH, TRACE 171 Å, and the ROI

Dataset

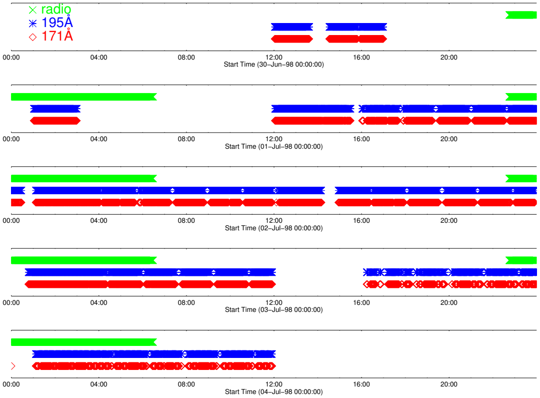

Figure: Daily Observation over AR8253 by TRACE and NoRH

Orbital Effect

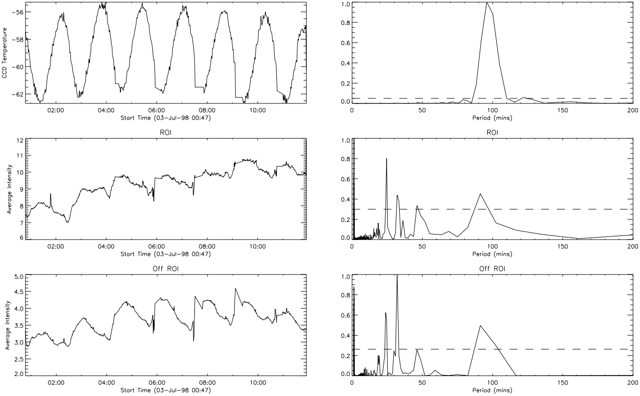

Figure: From top to bottom: CCD temperature, average intensity of ROI and OFF ROI, left colomn: time series; right colomn: power spectra

Explainations

- Assume CCD temperature $T = T_0 + \Delta T \cos(\frac{2\pi t}{P} + \phi)$, where $P = 96$ mins
- Average Intensity $I = F(T(t))$ is a non-linear mapping of $T(t)$, and expand it in Taylor series:

$$
\begin{aligned}
F(T) &= F(T_0) + \frac{dF}{dT}\delta T + \frac{d^2F}{2!dT^2}(\delta T)^2 + \dots \\
&= a_0 + a_1 \cos(\frac{2\pi t}{P} + \phi) + a_2 \cos^2(\frac{2\pi t}{P} + \phi) + \dots \\
&= b_0 + b_1 \cos(\frac{2\pi t}{P}) + b_2 \cos(\frac{2\pi t}{P/2}) + b_3 \cos(\frac{2\pi t}{P/3}) + \dots
\end{aligned}
$$

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Cross-correlation plots

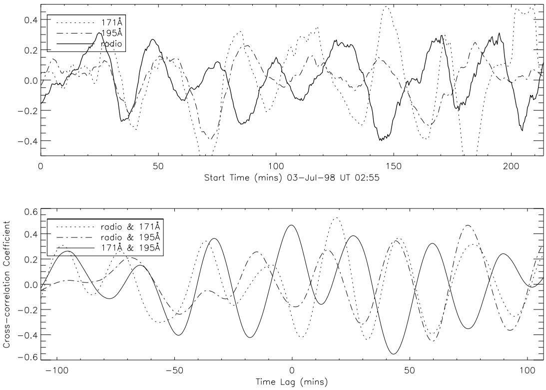

Figure: The time series of 17 GHz radion emission, 171 Å, and 195 Å EUV emission (top), the cross-correlation plots (bottom)

Power Spectra

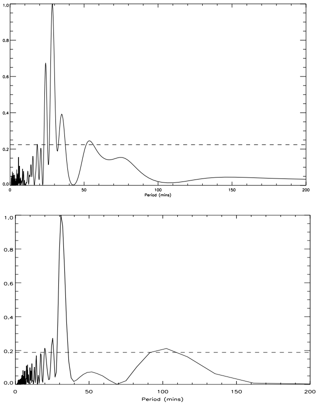

Figure: Power spectrum of average radio emission at 17 Ghz (NoRH, top) and 171 Å EUV emission (TRACE, bottom)

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Conclusions

1. The orbital period and its harmonics have strong impact on the intensity of EUV images, due to the non-linearity of orbital environment, detection effeciency, and complexity of telescope system.
2. The long period at $\sim$ 30 mins are both detected in TRACE EUV light curves and NoRH radio 17 GHz emission.
3. the oscilatory patterns in the correlation plot, with non-zero lag-0 coefficient, indicate the leakage of long-period sunspot oscillation into the corona.