

Linking characteristic timescales and spatial scales for quasi-periodic pulsations in solar flares

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Supervisors:

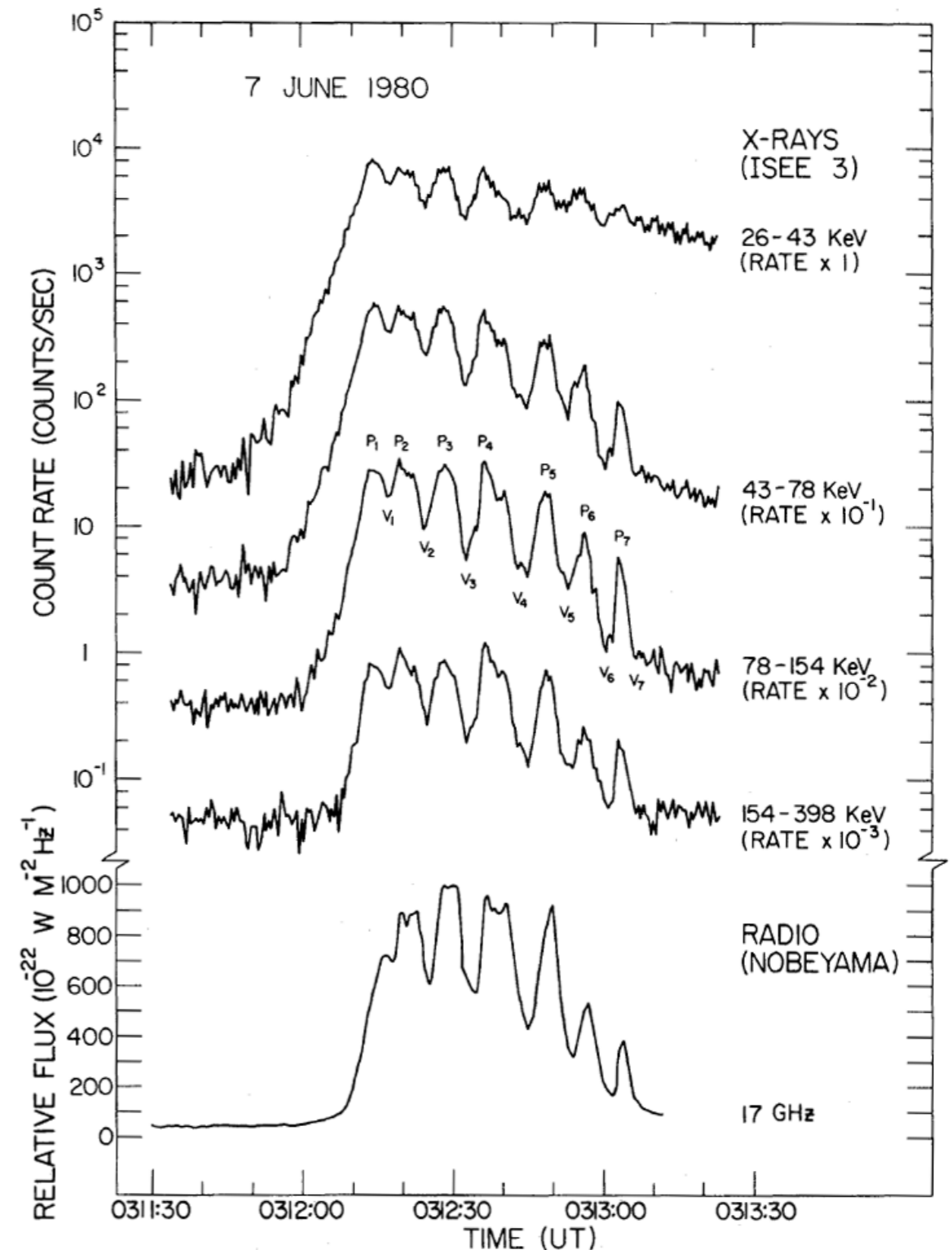
Valery M. Nakariakov, Anne-Marie Broomhall



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Quasi-periodic pulsations (QPPs)

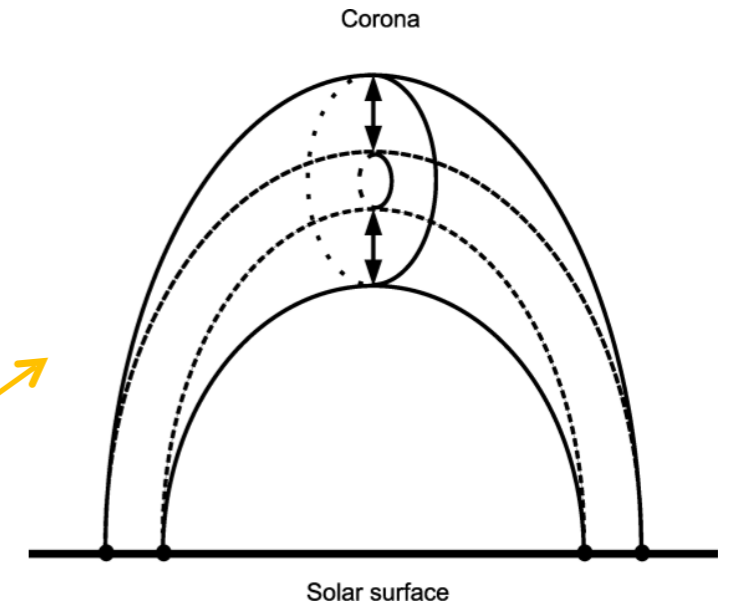
- ▶ Time-variations of the intensity of light emitted by a flare
- ▶ First observed in solar flares by Parks & Winckler (1969)
- ▶ Example of QPPs in a solar flare: The Seven Sisters Flare, observed by Kane et al. (1983)
- ▶ Seem to be a fairly common feature of flares



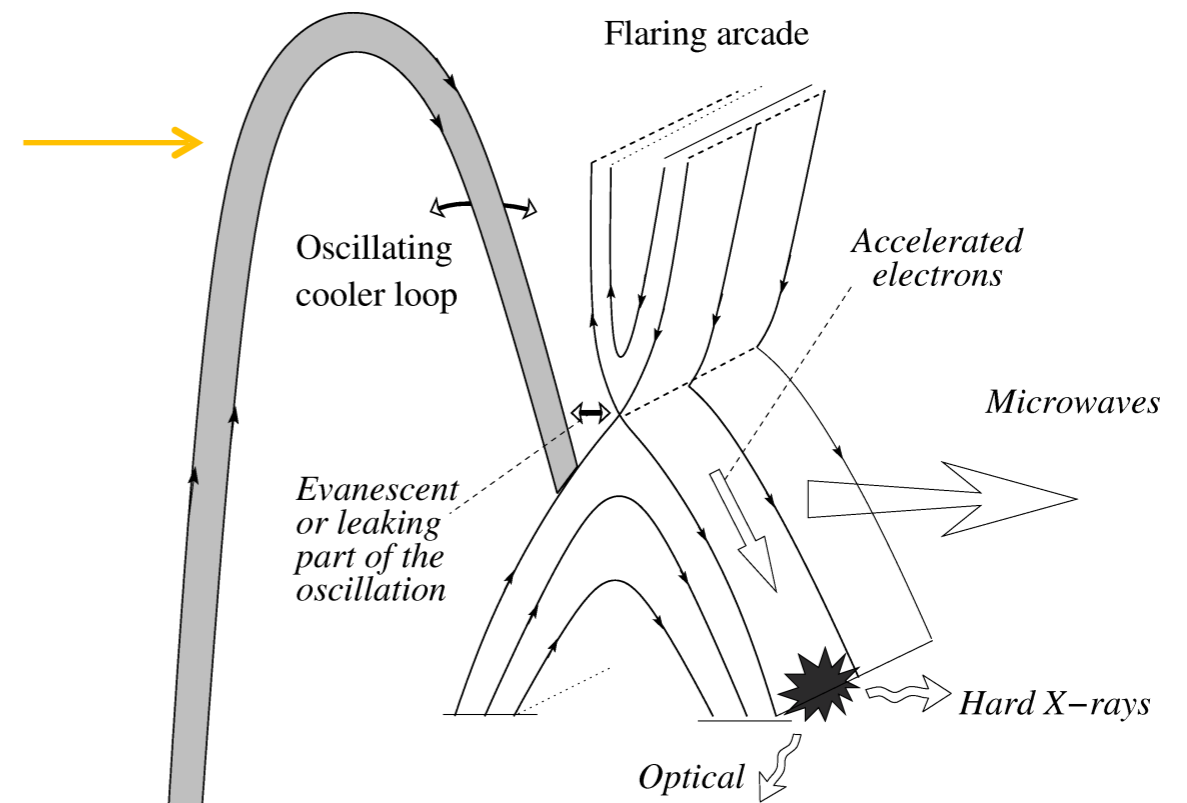
Quasi-periodic pulsations

Two groups of possible mechanisms:

- ▶ Magnetohydrodynamic (MHD) oscillations ...
 - ..of the flaring structure
 - ..of a nearby structure
- ▶ Load/unload or 'magnetic dripping' mechanisms of energy release (periodically induced reconnection)



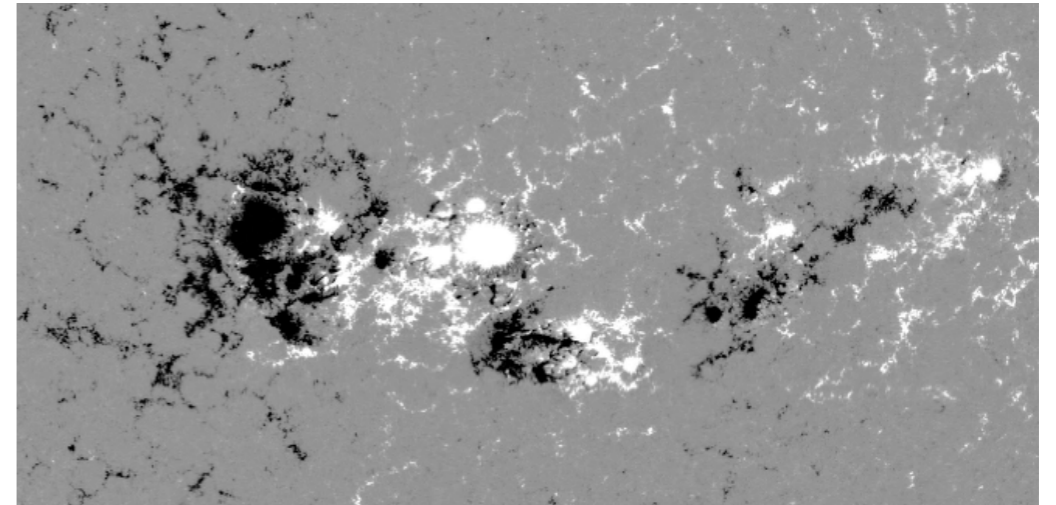
Pascoe et al., 2007



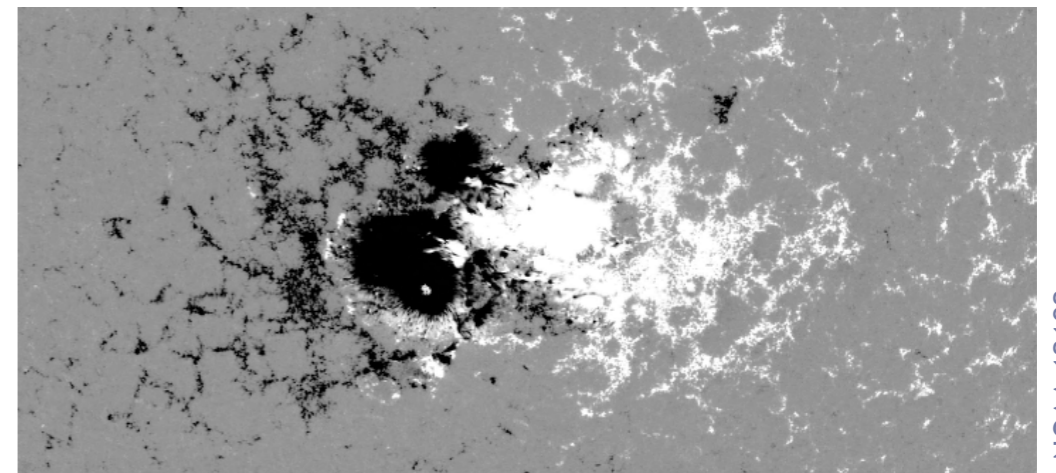
Nakariakov et al., 2006

Solar flare QPP statistical study

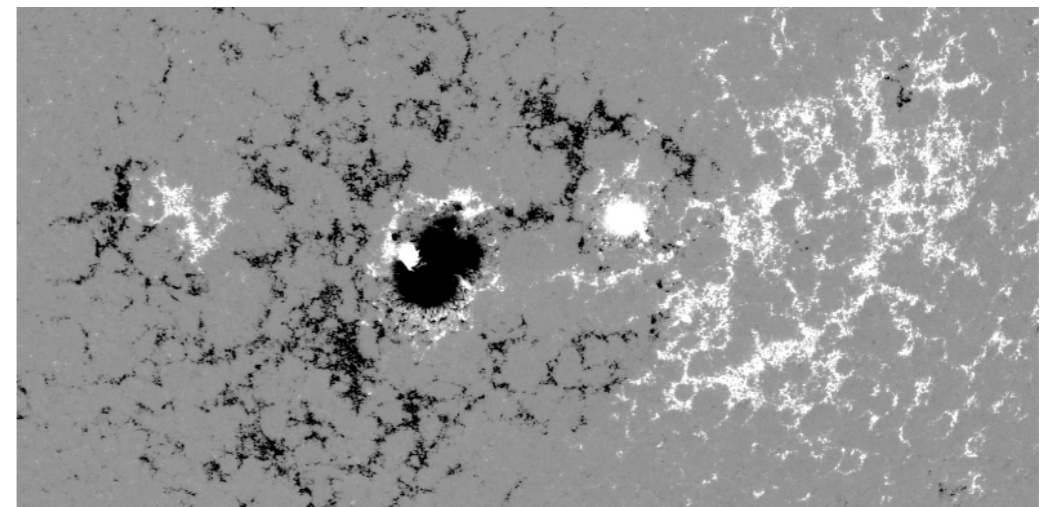
- ▶ 181 GOES class flares from a single (very) active region
- ▶ 137 C-class, 38 M-class, 6 X-class
- ▶ Observations from GOES, EVE, Fermi, Vernov, NoRH
- ▶ Do QPP properties relate to properties of the flares or flaring region?



NOAA 12172, 12173, 12171



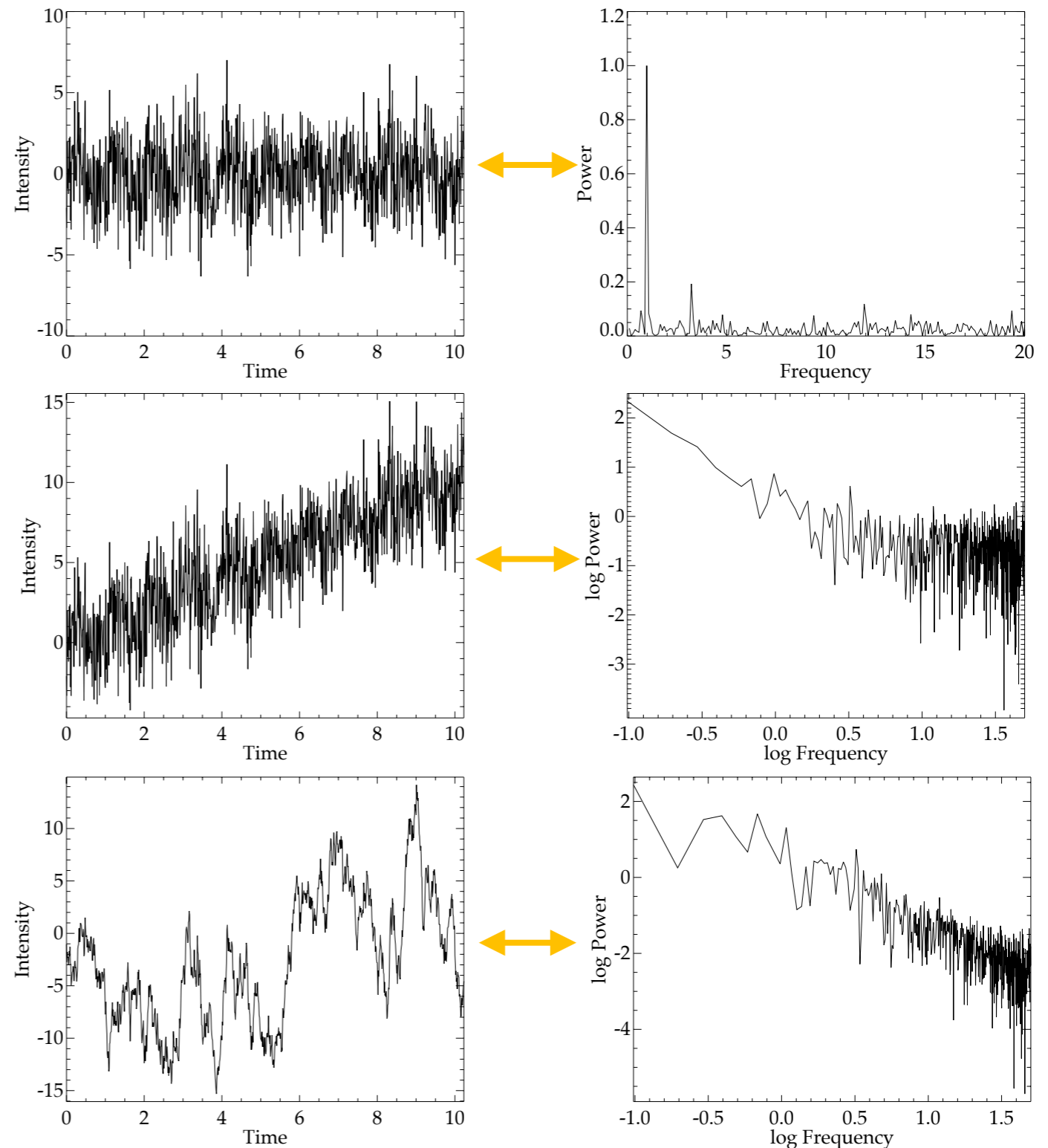
NOAA 12192



NOAA 12209

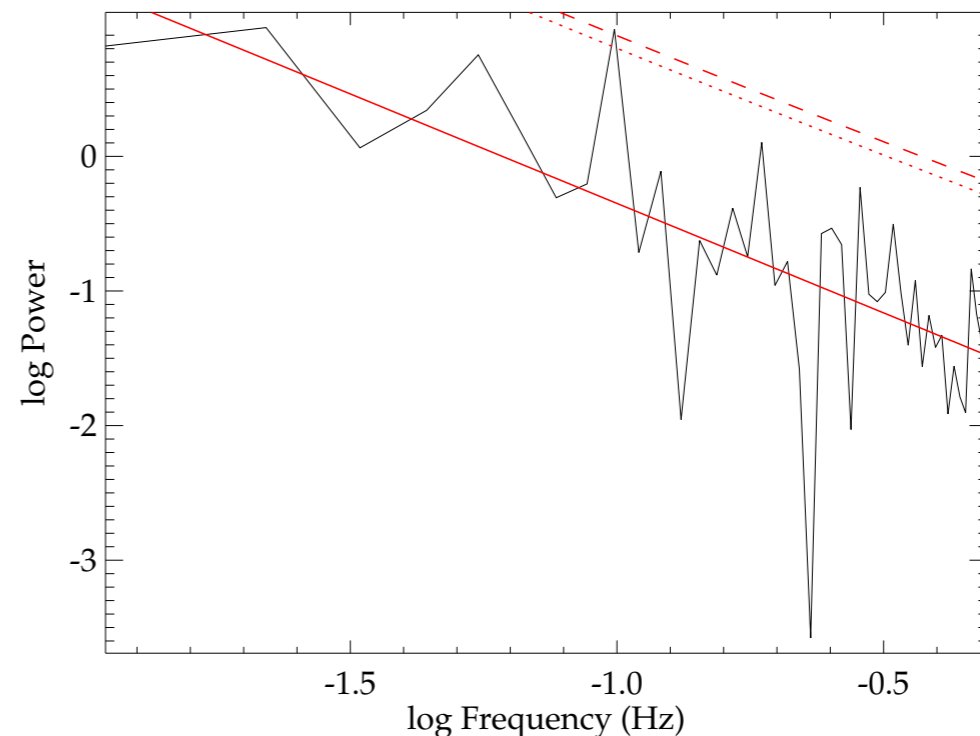
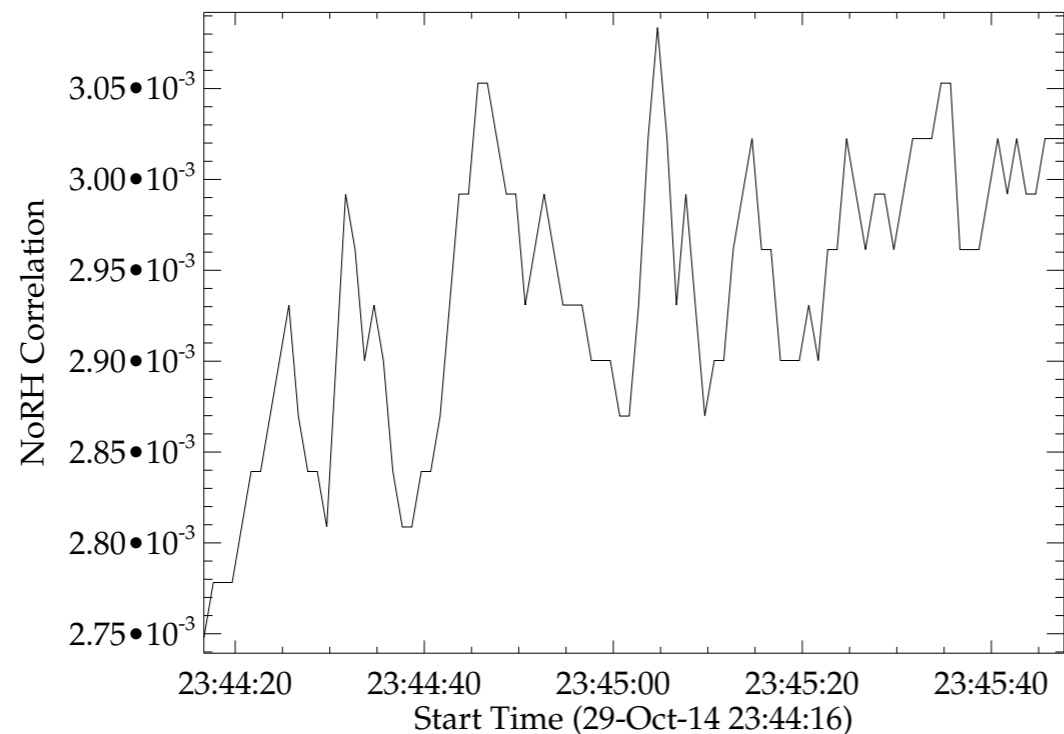
Detecting the QPPs

- ▶ Flare time series have power-law power spectra, due to trends and correlated noise
- ▶ Need to account for this dependence when searching for peaks
- ▶ Eg. Vaughan 2005, Inglis et al. 2016, Auchère et al. 2016, Pugh et al. 2017a



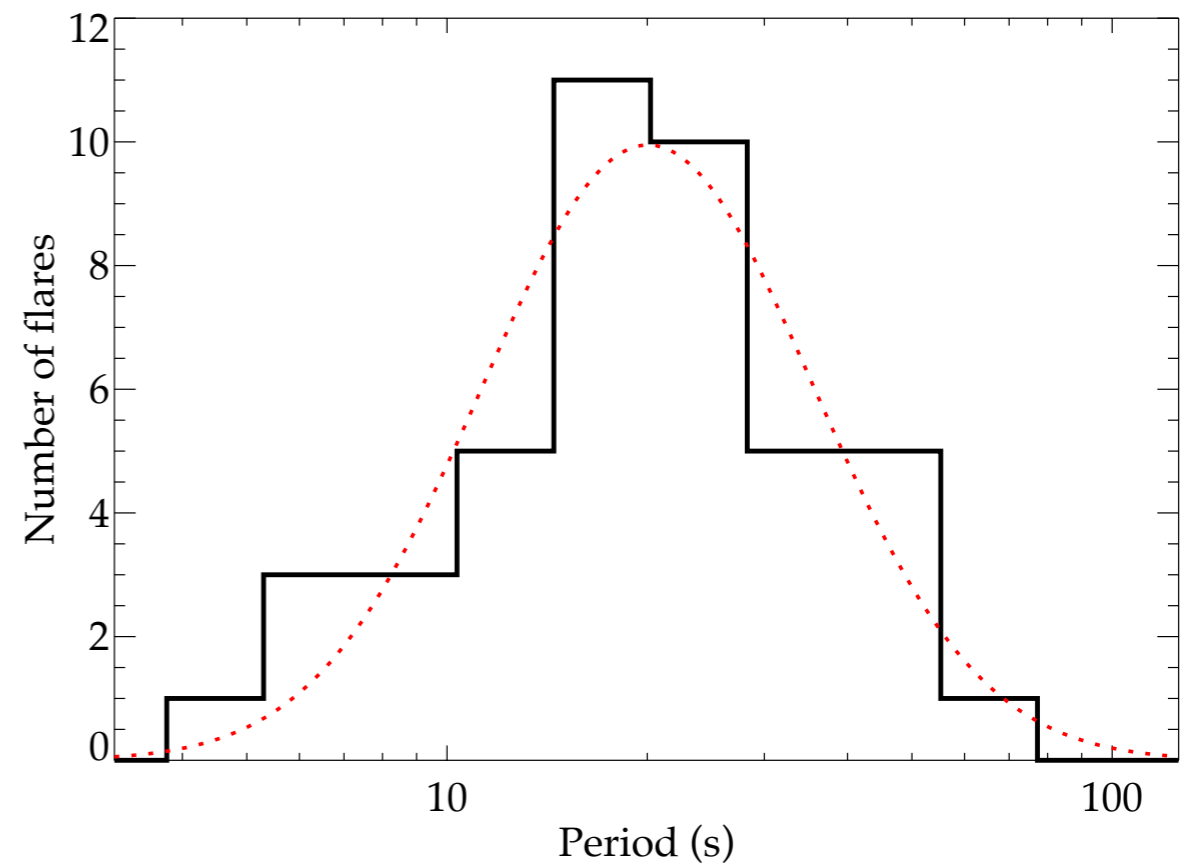
Detecting the QPPs

- ▶ Example solar flare observed by Nobeyama Radioheliograph
- ▶ Power spectrum confidence levels calculated according to Pugh et al. 2017a/b
- ▶ *Left:* Correlation time series of part of a flare
- ▶ *Right:* Periodogram with a peak above 99% confidence level, at a period of ~ 10 seconds



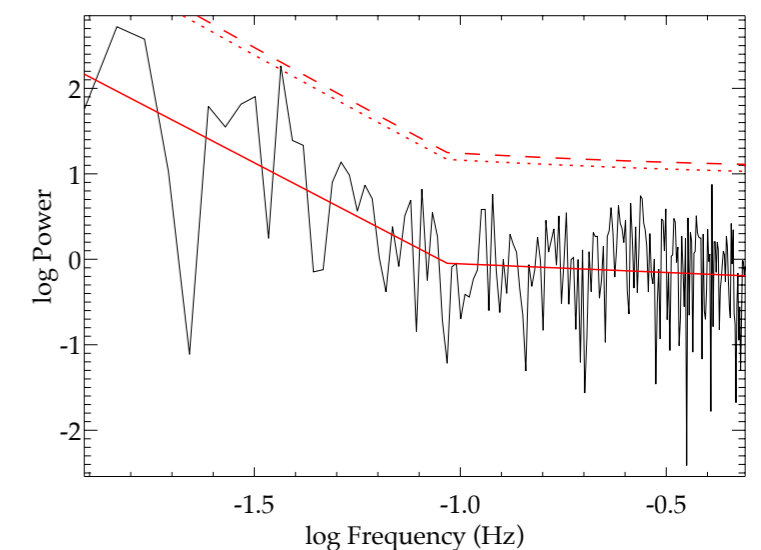
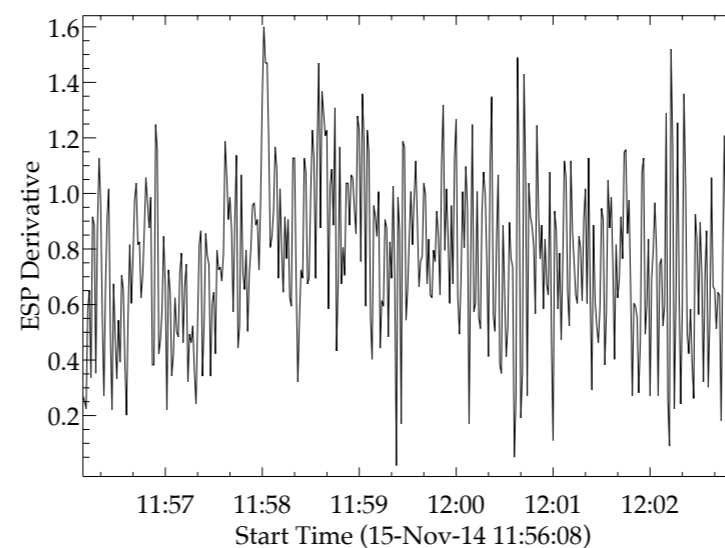
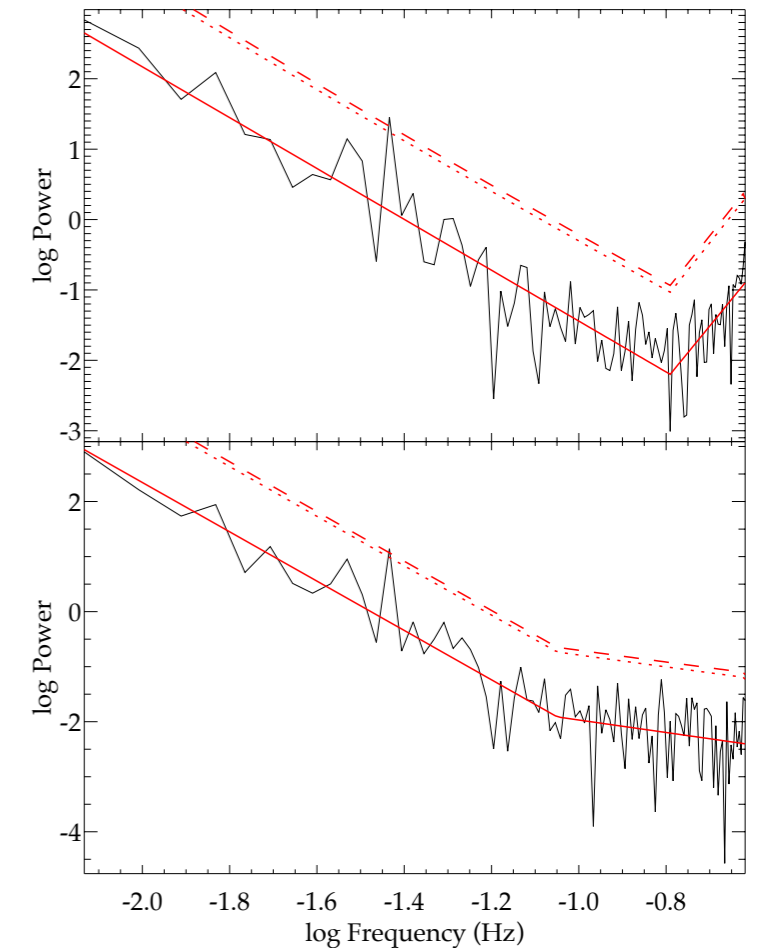
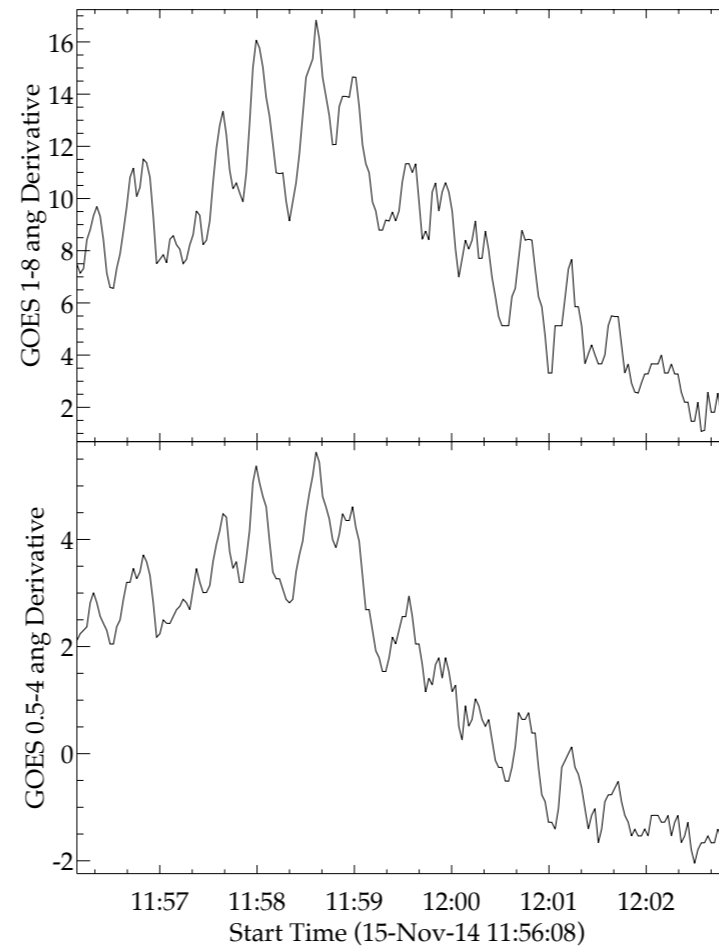
The set of flares with significant QPPs

- ▶ Out of 181 flares: 37 with periodic signal above 95% global confidence level (20% of sample)
- ▶ *Right:* histogram of QPP periods, with mean period of 20^{+16}_{-9} seconds
- ▶ Pugh et al. 2017b



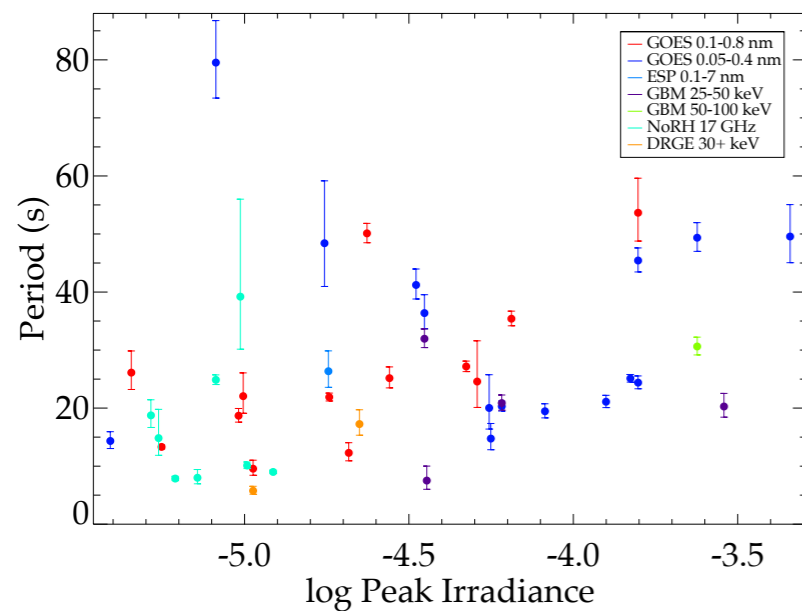
The set of flares with significant QPPs

- ▶ Seven of these flares have the same QPP signal detected above the 95% confidence level in data from two different instruments
- ▶ *Right: 27 s period detected in both GOES/XRS and EVE/ESP light curves*

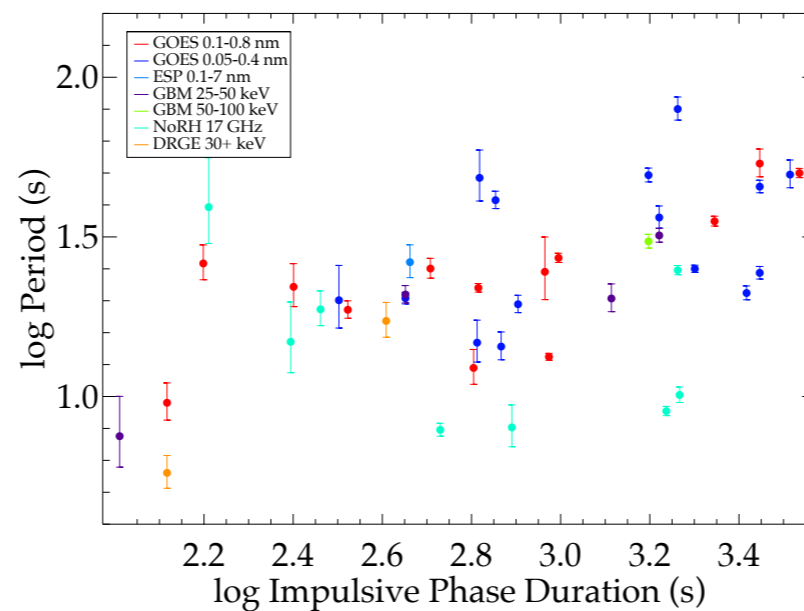


Relation to flare properties?

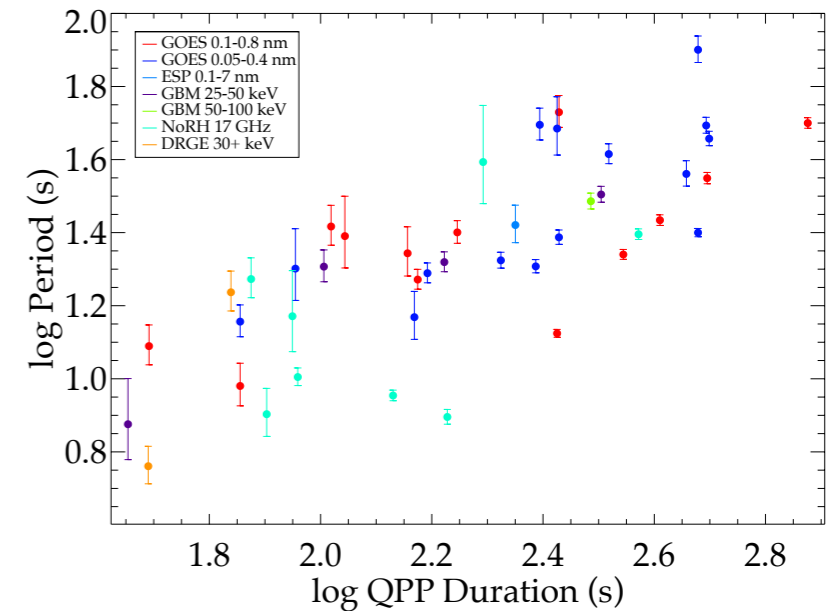
- ▶ QPP periods plotted against flare amplitude, flare duration (impulsive phase), and the duration of the QPP signal
- ▶ Period vs flare/QPP duration: can't detect long-period short-duration QPP signals, but should be able to detect short-period long-duration signals



$cc = 0.39$



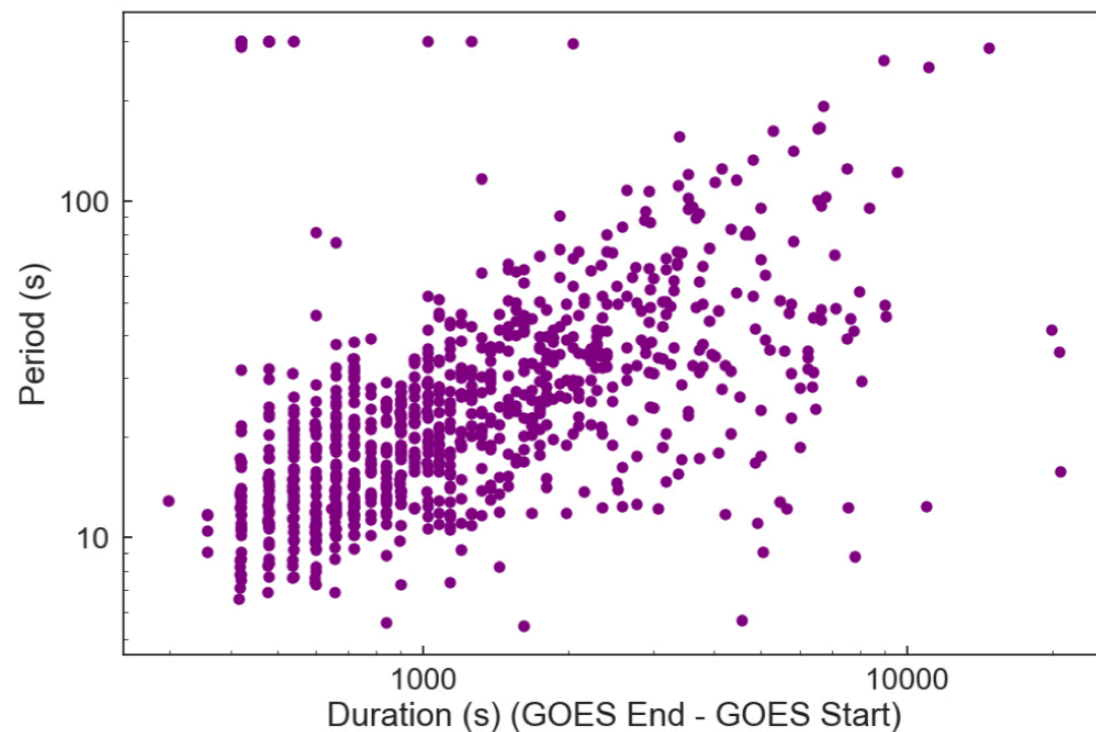
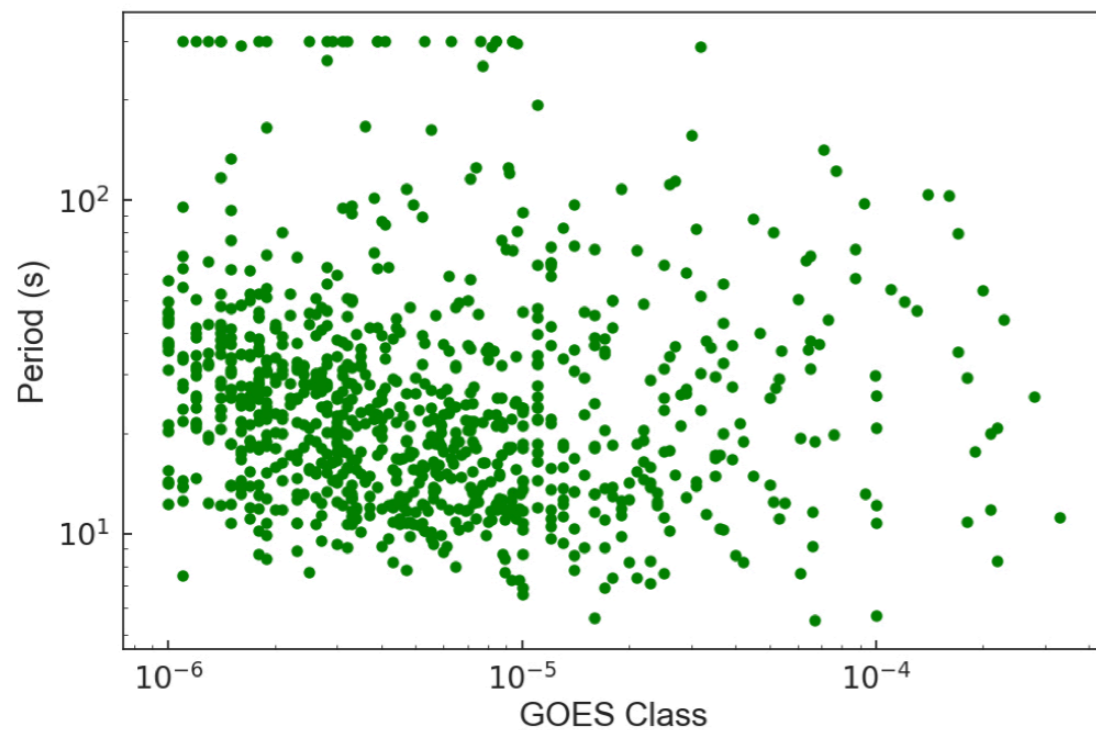
$cc = 0.50$



$cc = 0.79$

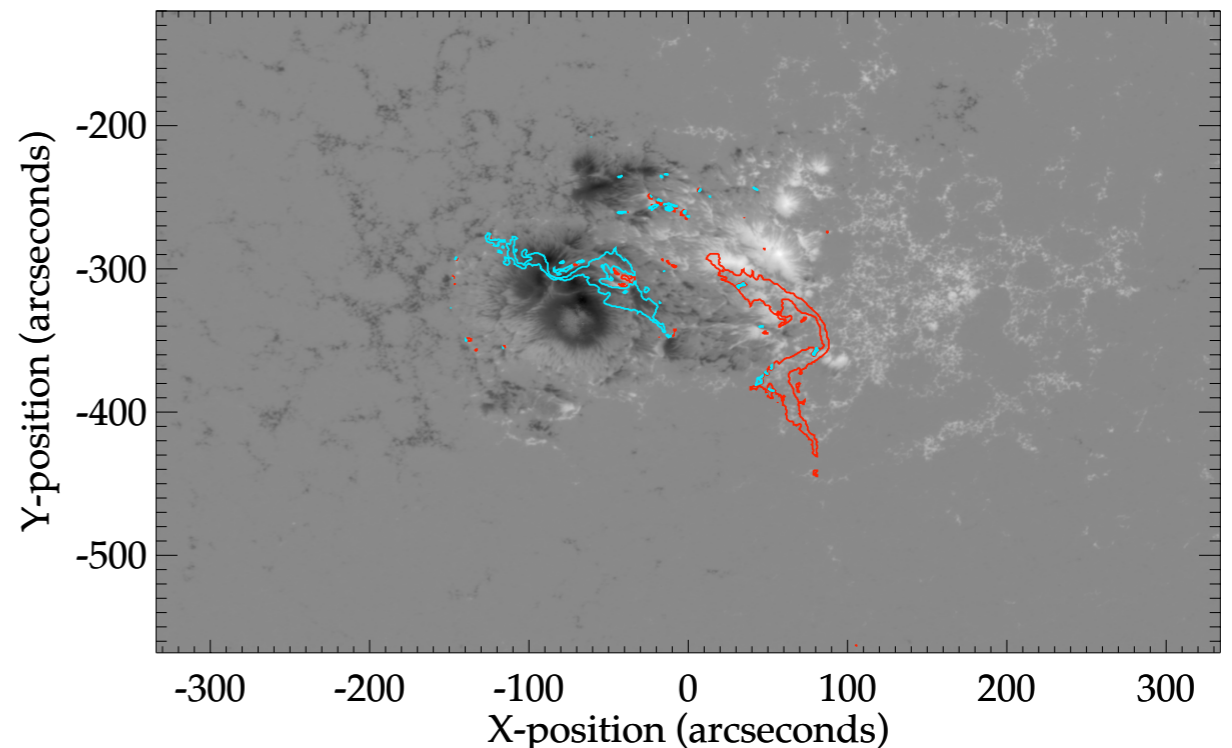
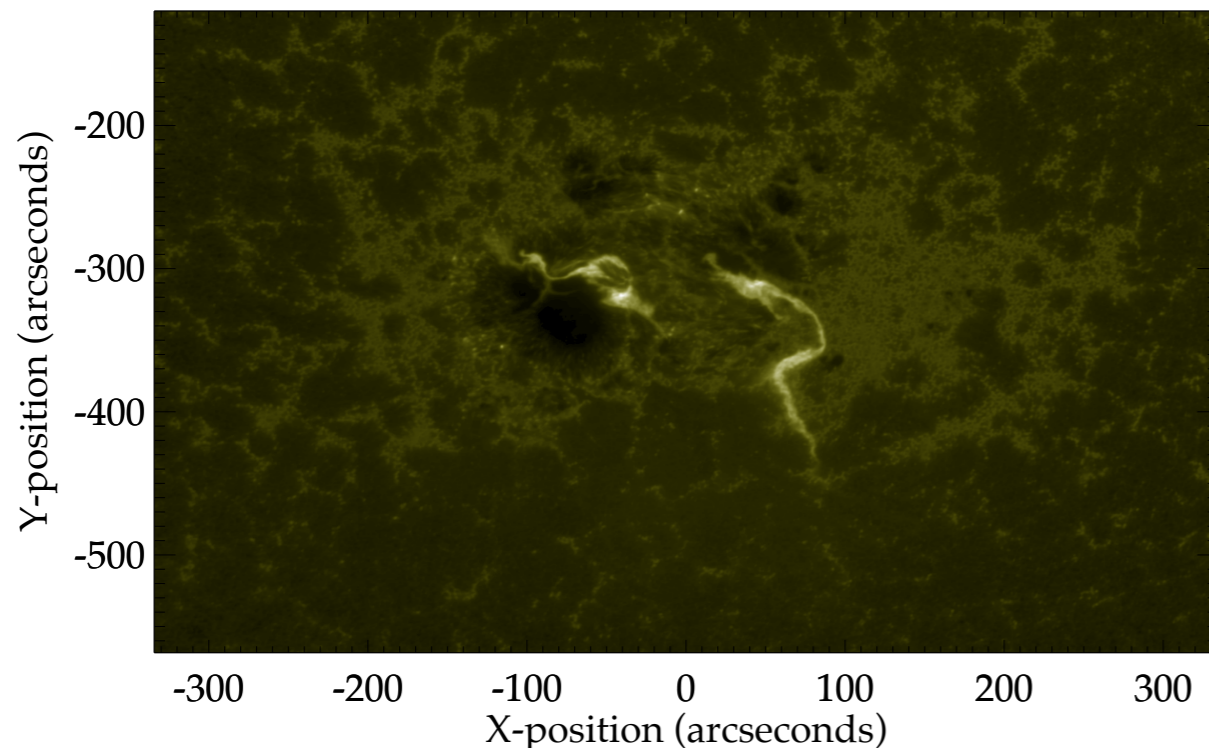
Relation to flare properties?

- ▶ Extension of Inglis et al. 2016 by Laura Hayes - includes all X, M, C class flares 2011-2016
- ▶ They also find no correlation with GOES class
- ▶ and a significant correlation with flare duration



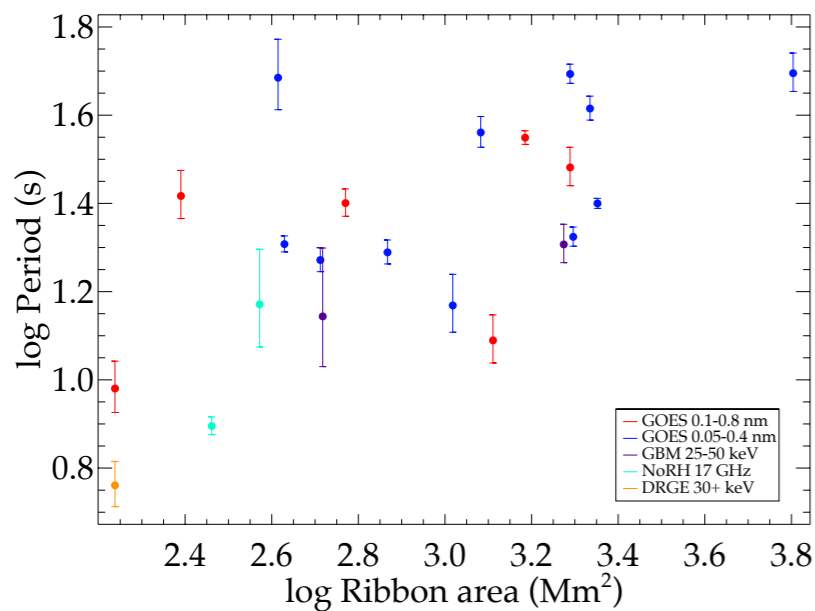
Determining flare ribbon properties

- ▶ Only including flares where the AR was within $\pm 60^\circ$ of disk centre, so line of sight effects can be accounted for
- ▶ Follow approach of Toriumi et al. 2017 — combine AIA 1600Å and HMI data to determine spatial scales and magnetic field strength of flare ribbons

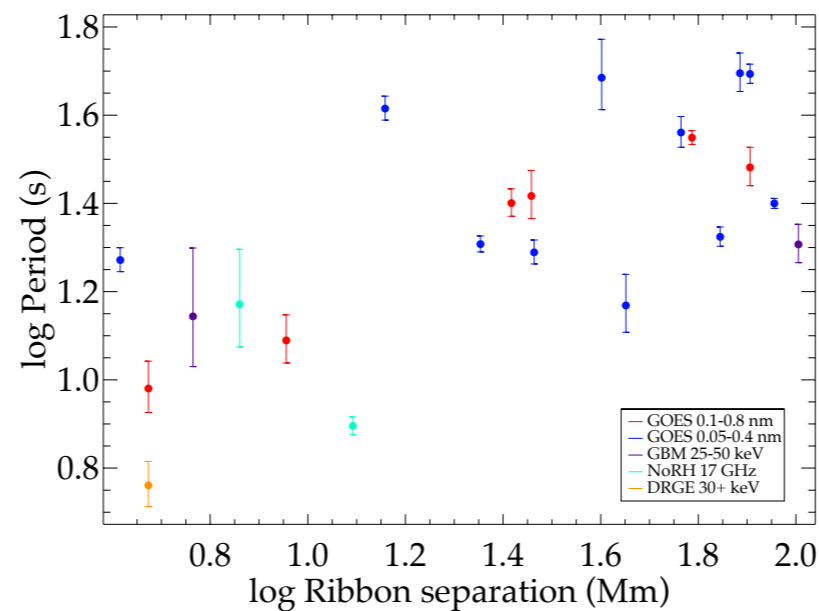


Relation to flare ribbon properties?

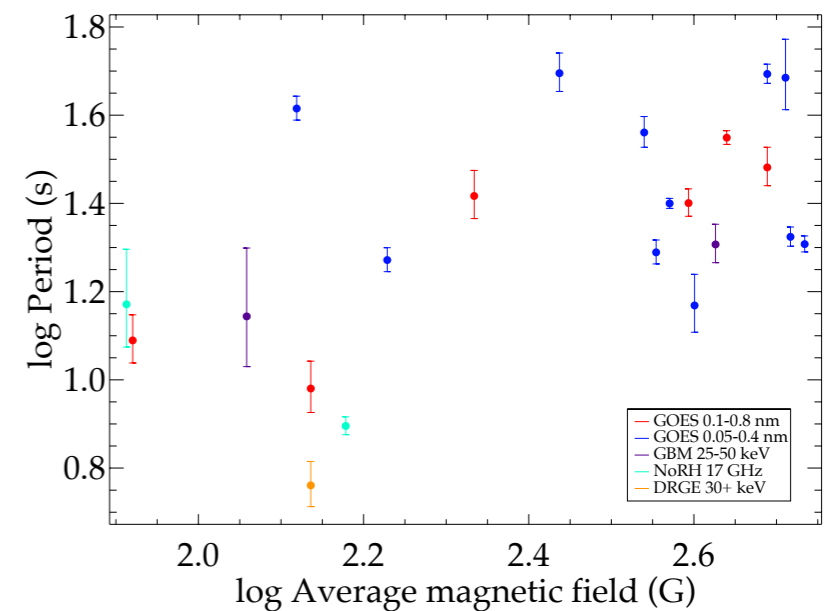
- ▶ QPP period correlates with flare ribbon area (*left*), separation distance (*middle*), and average magnetic field strength (*right*)
- ▶ Strongest correlation with ribbon separation distance



cc = 0.59



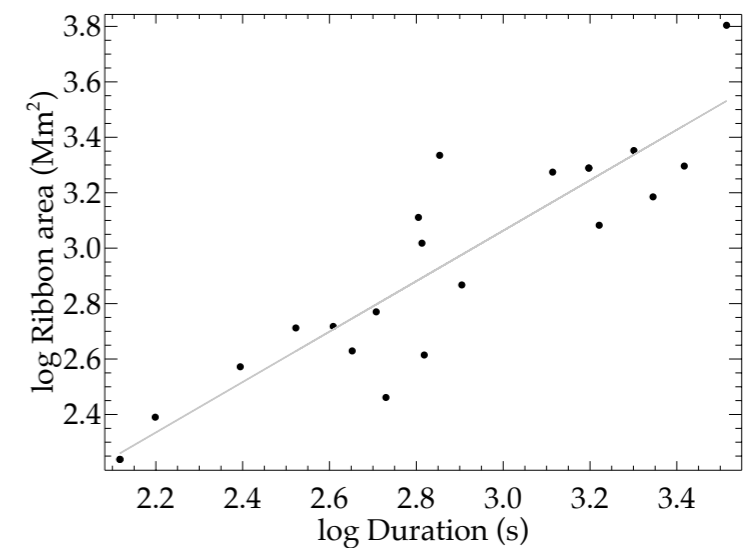
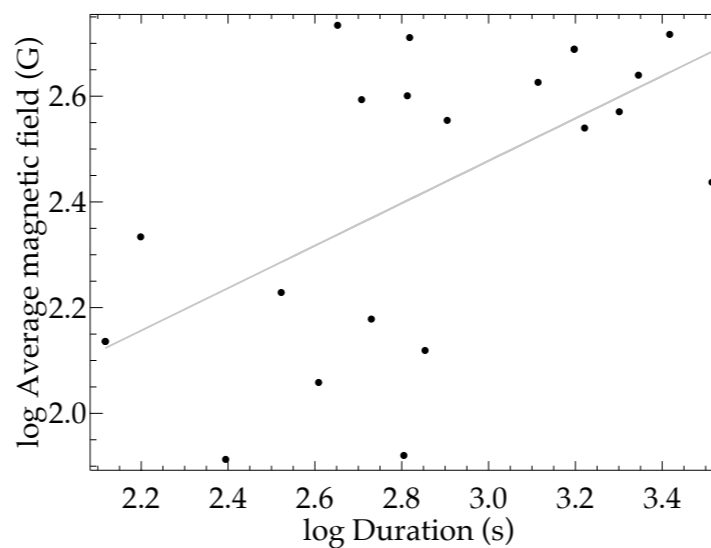
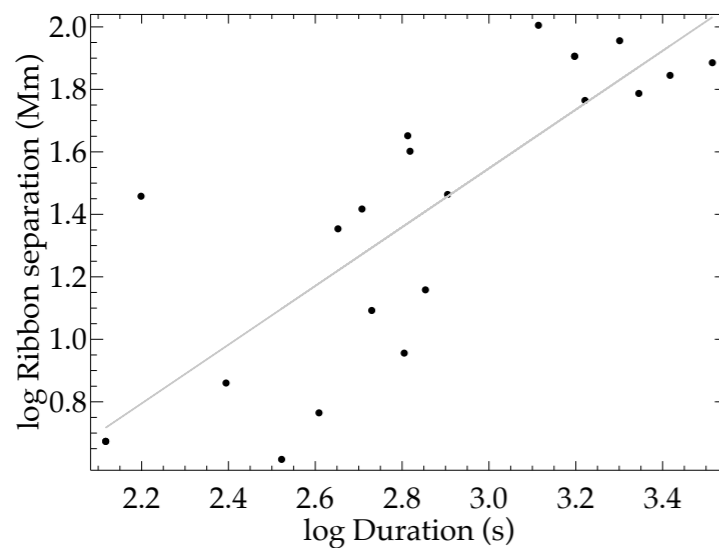
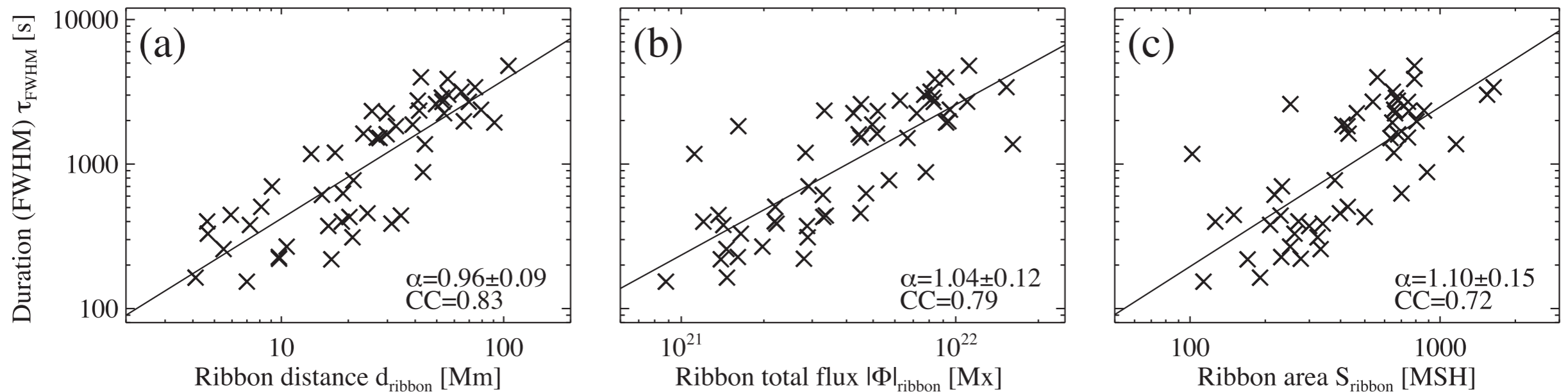
cc = 0.64



cc = 0.50

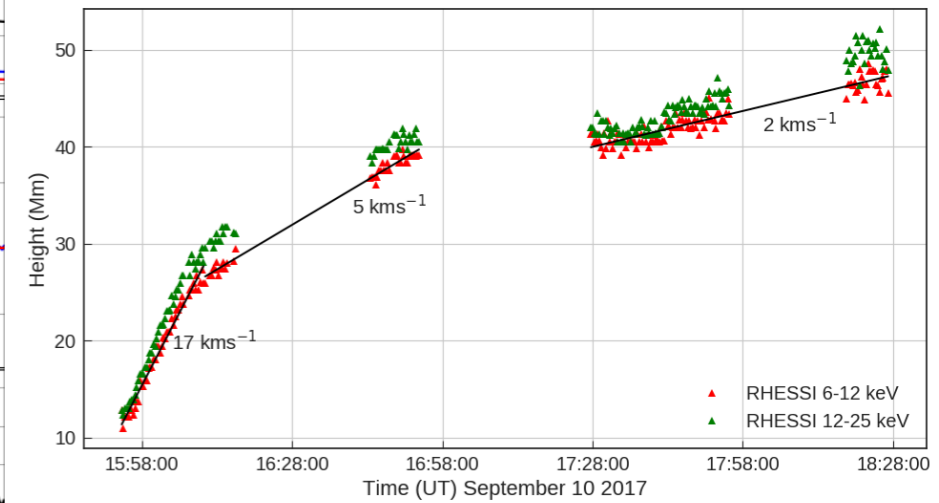
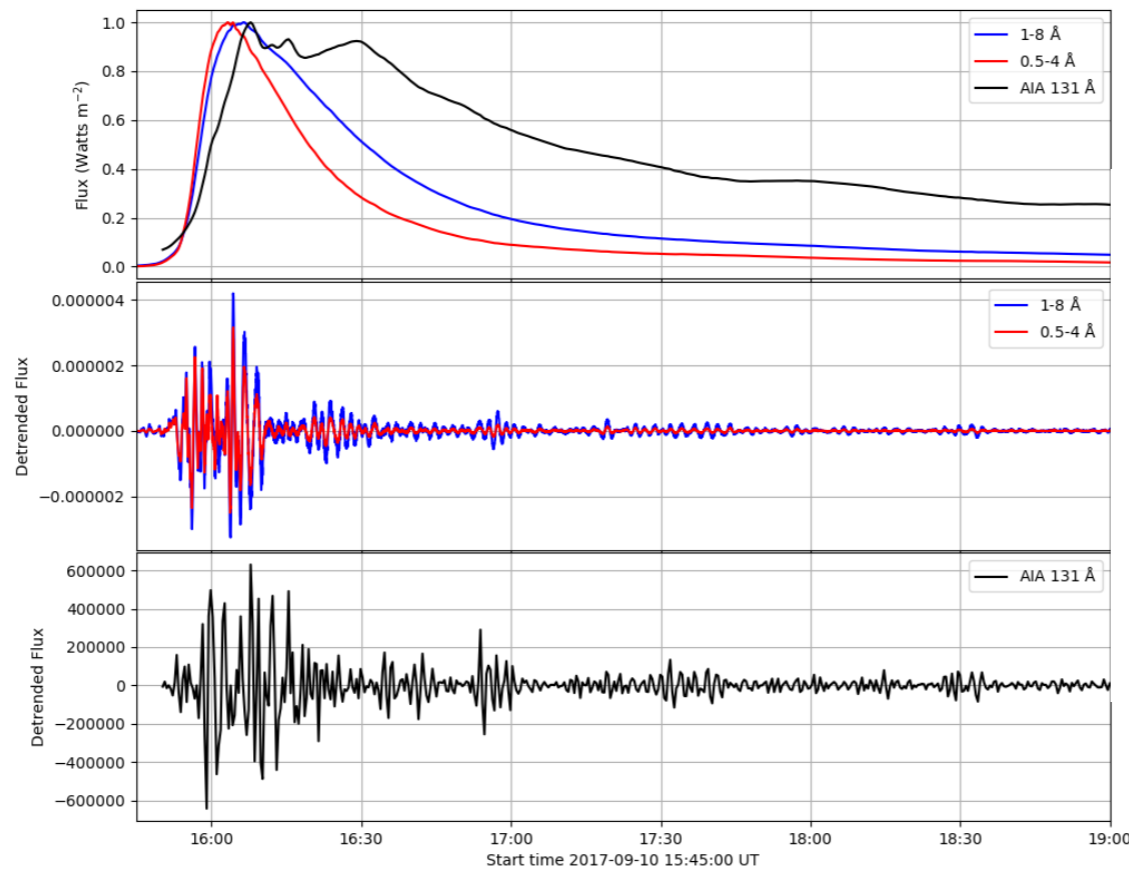
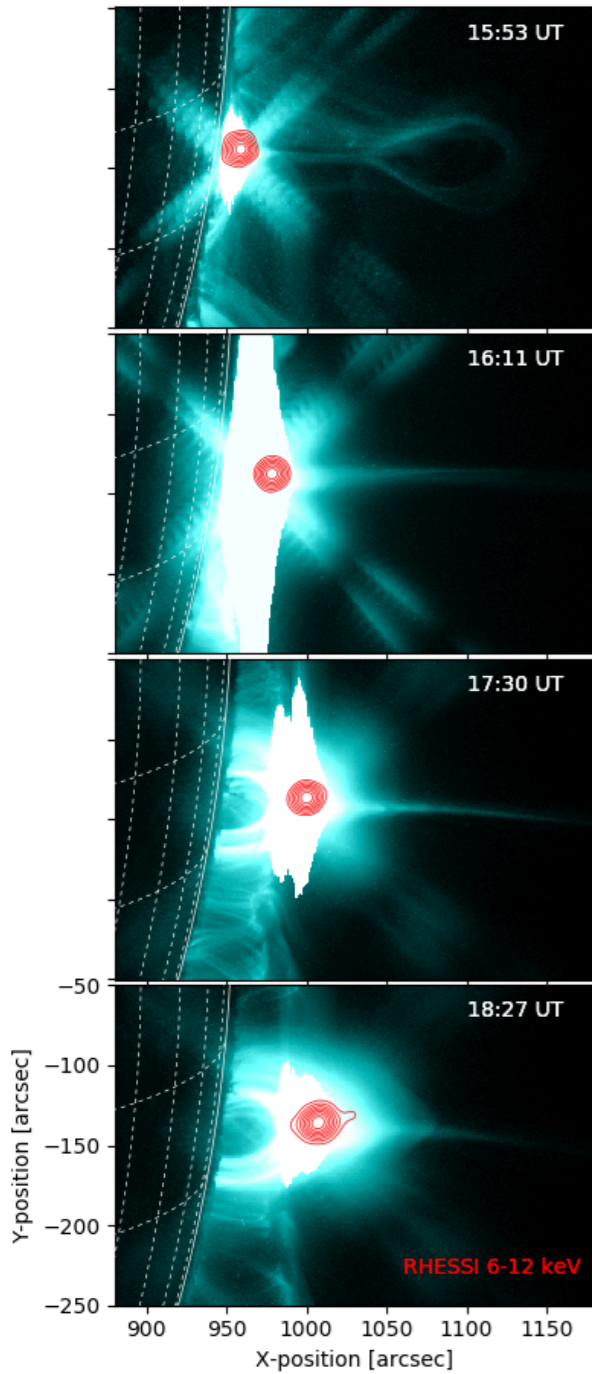
Relation to flare ribbon properties?

- ▶ Toriumi et al. 2017 showed that these ribbon properties correlate with the flare duration



Relation to flare properties?

- ▶ Hayes et al. 2018 (in prep) shows a long-lasting QPP signal with an increasing period (~ 65 - 164 s)
- ▶ Could be linked to the expansion of the flare loop structure



Summary

- ▶ Using a sample of solar flares from a single active region
- ▶ 20% of flares have a periodic signal above the 95% global confidence level in the power spectra
- ▶ Correlations between QPP period and flare ribbon properties
- ▶ Preliminary results of [Hayes et al. 2018 \(in prep\)](#) also suggest a link between the QPP period and the size of the flaring loop structure
- ▶ This could be used as a constraint for QPP models
- ▶ Further work: assessment of potential of observational bias to affect QPP period vs flare duration relationship, using simulated data