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An Chomhairle um Thaighde in Éirinn

Impulsive and Decay Phase Quasi-Periodic Pulsations

ISSI Workshop 2

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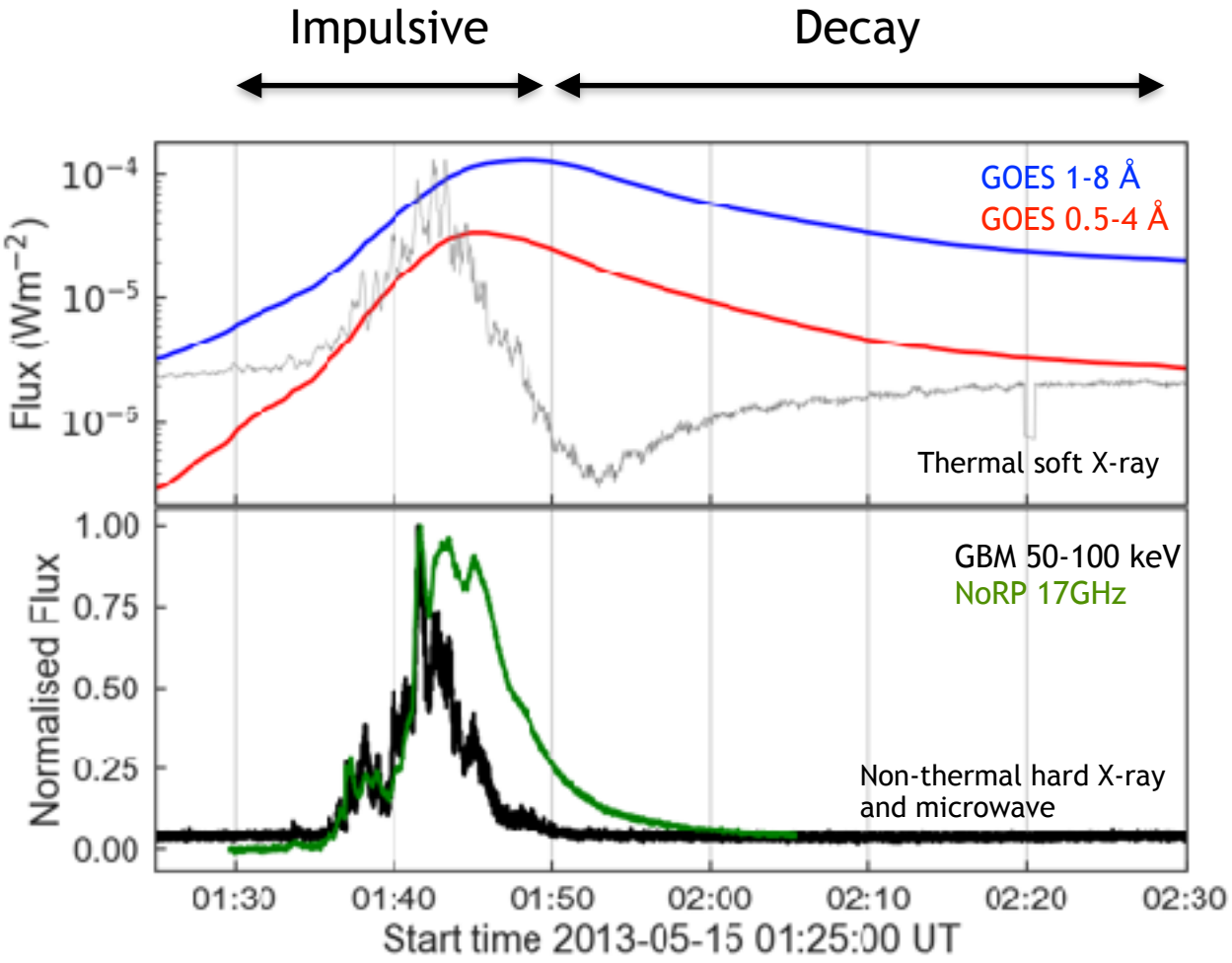
Outline

Impulsive vs decay phase (preliminary results and discussion)

- **What do we mean by Impulsive Vs Decay Phase?**
- **Soft X-ray Quasi-Periodic Pulsations & Statistics from AFINO**
- **Impulsive Vs Decay Phase Properties**
- **Examples of long duration events**

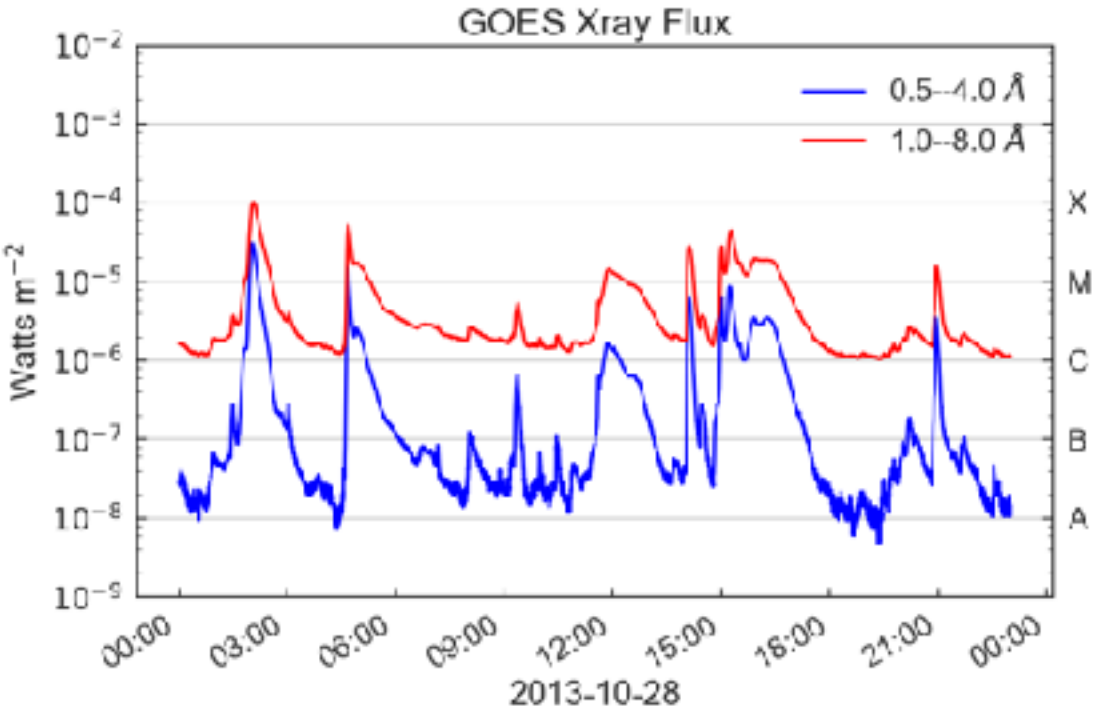
Solar Flares

Impulsive vs decay phase



- *Impulsive phase* dominated by impulsive energy release - accelerated electrons upto MeV
- *Decay phase* build up and subsequent decay of soft x-ray emission - thermal
- Are QPP in different phases different?

Solar Flares
Impulsive vs decay phase

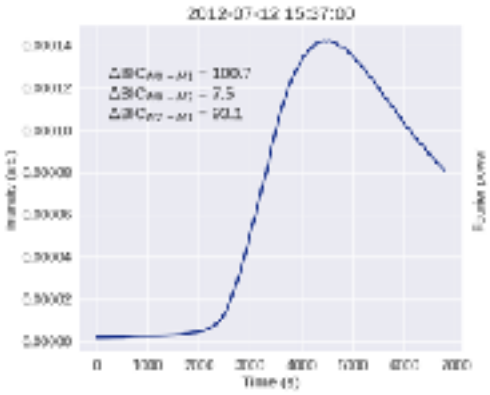


- Lets look at statistics from GOES/XRS channel.
- Thermal plasma in 1-8 Å channel
- Geosynchronous orbit - continuous coverage

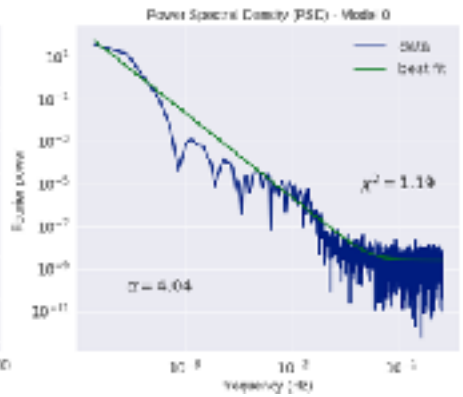
AFINO Analysis

Inglis et al., 2016

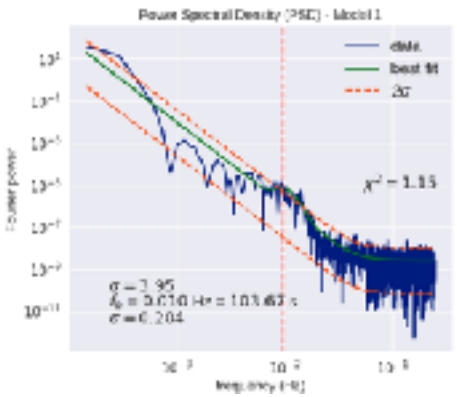
Signal



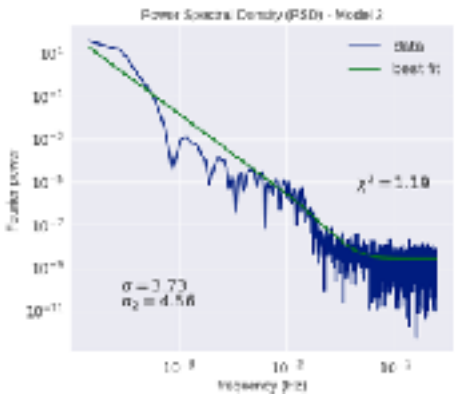
Single Power Law



QPP model

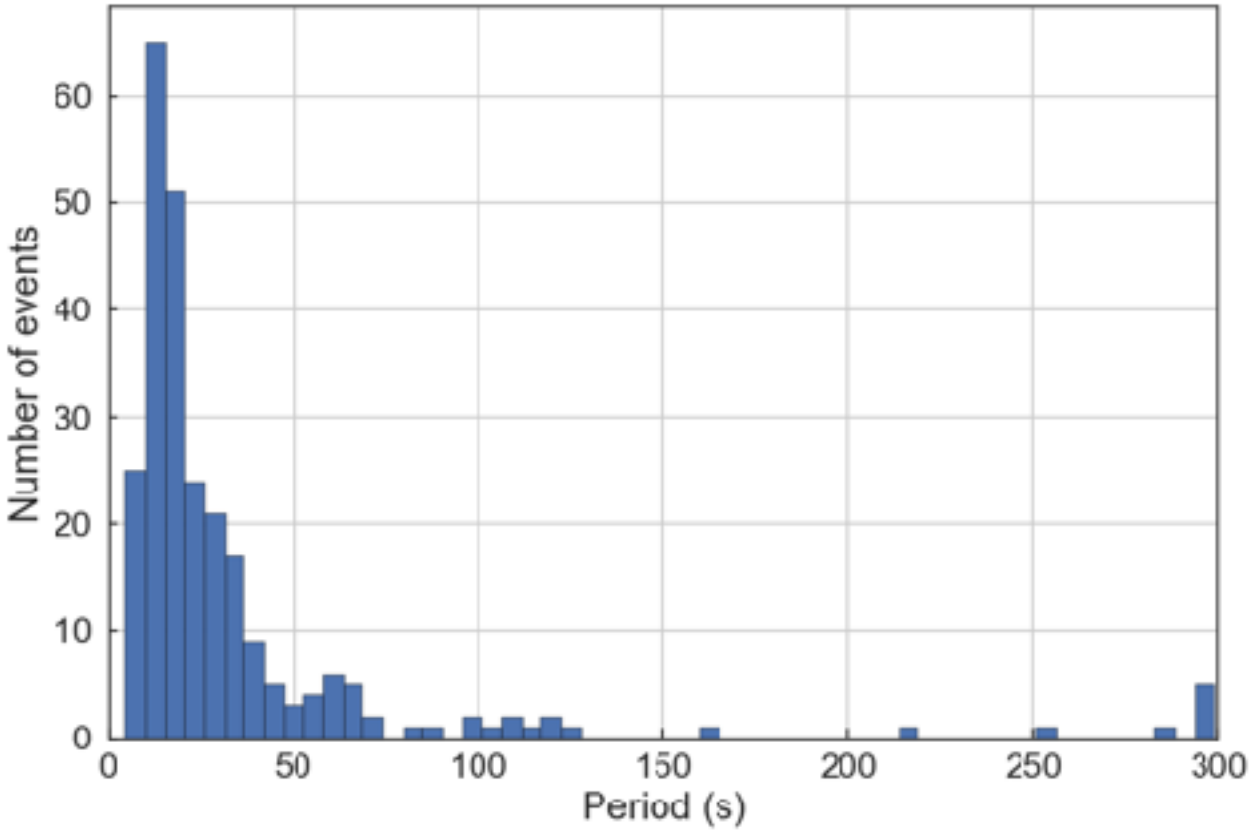


Broken Power Law



- Model comparison test to find significant periodic signatures
- Inglis et al., 2016 - all X and M class flares from 2011-2016 (2017)
- Analyzed all X and M class flares 2011-2016.
- ~30% show significant QPP signatures, preferred timescales 5-30s

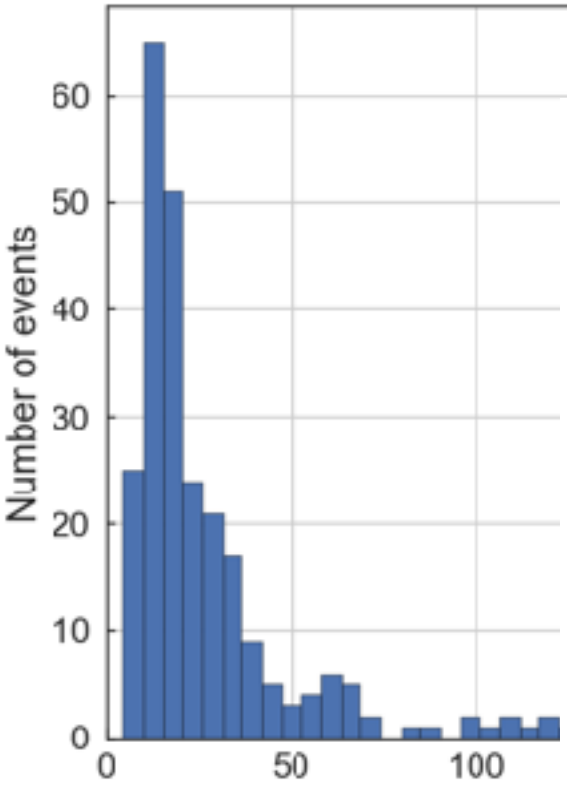
Large Scale Study
Properties of QPP results

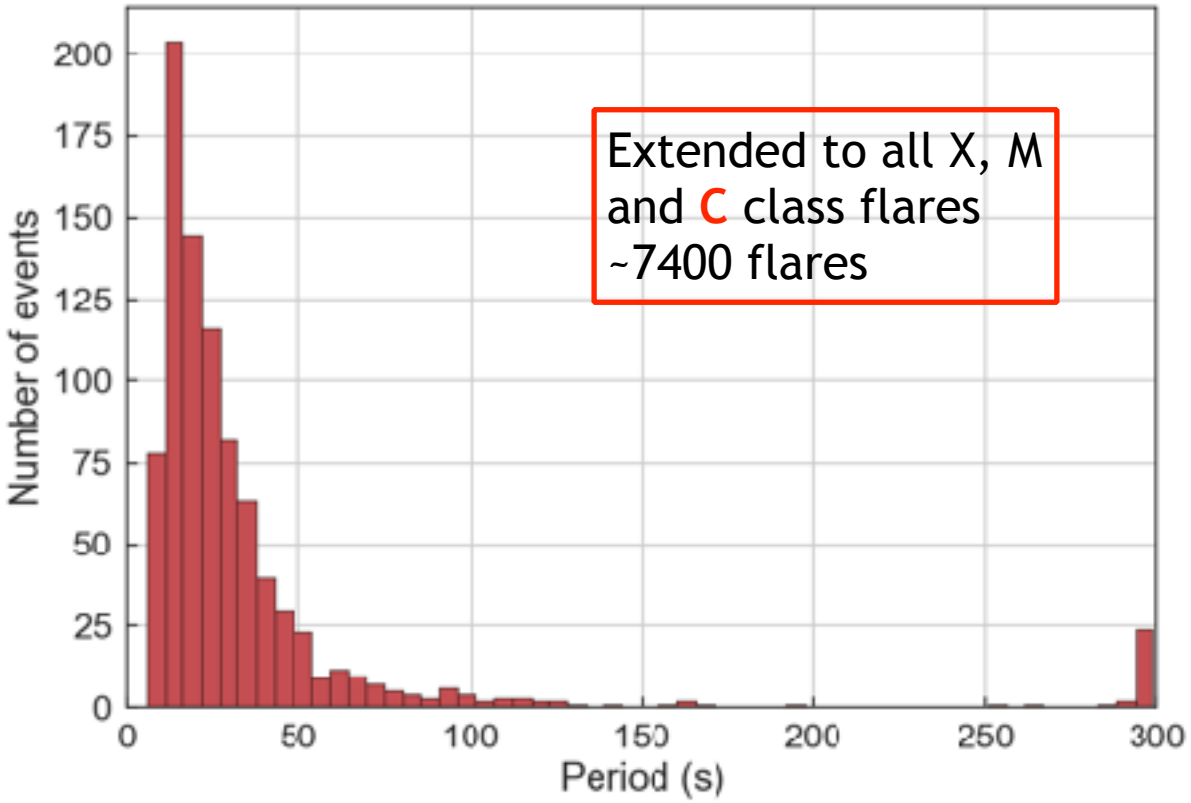


- Analyzed all X and M class flares 2011-2016.
- ~30% show significant QPP signatures, preferred timescales 5-30s
- Other correlations?

Large Scale Study

Properties of QPP results

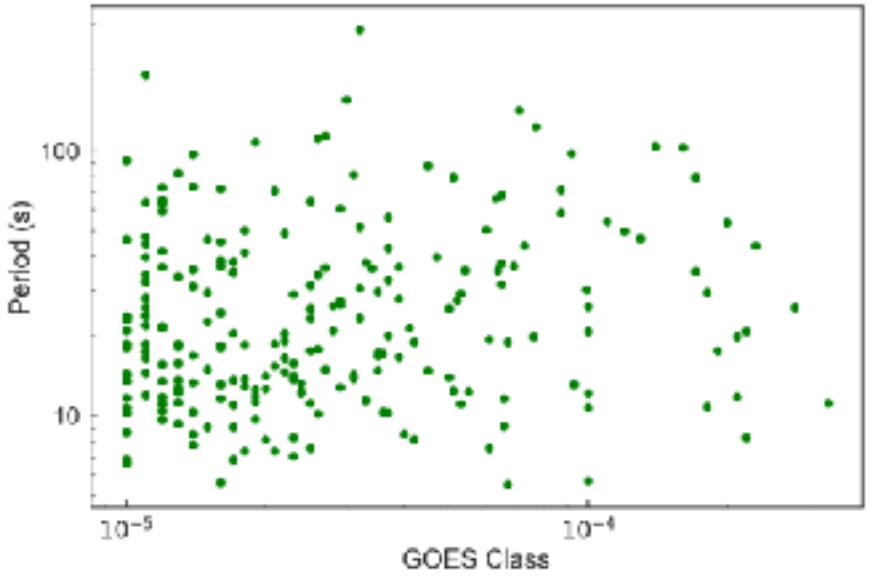


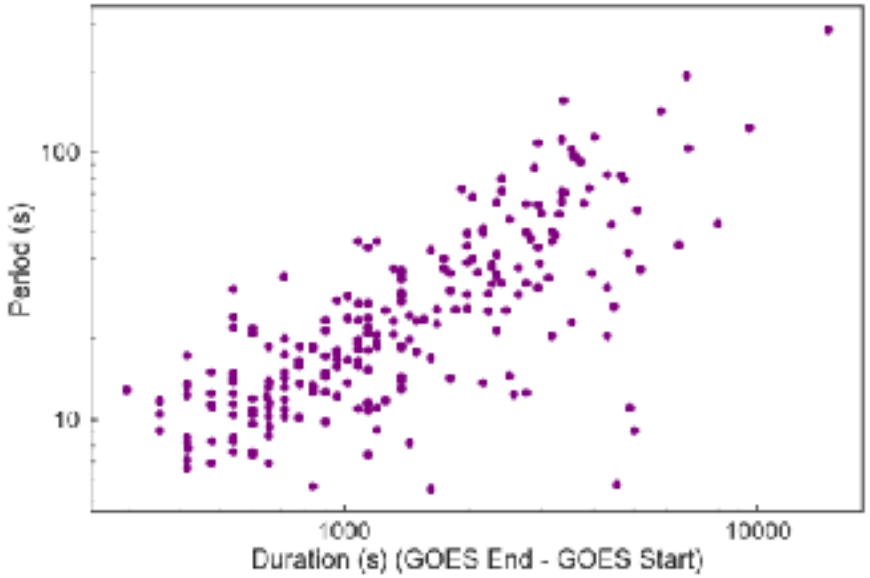


Extended to all X, M and C class flares
~7400 flares

Large Scale Study

GOES SXR Pulsations Inglis et al. 2016

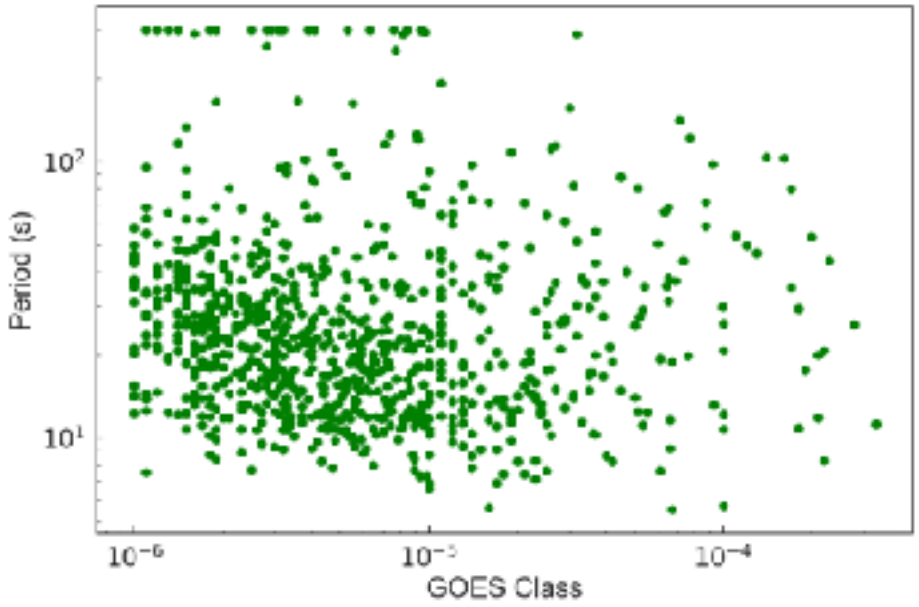


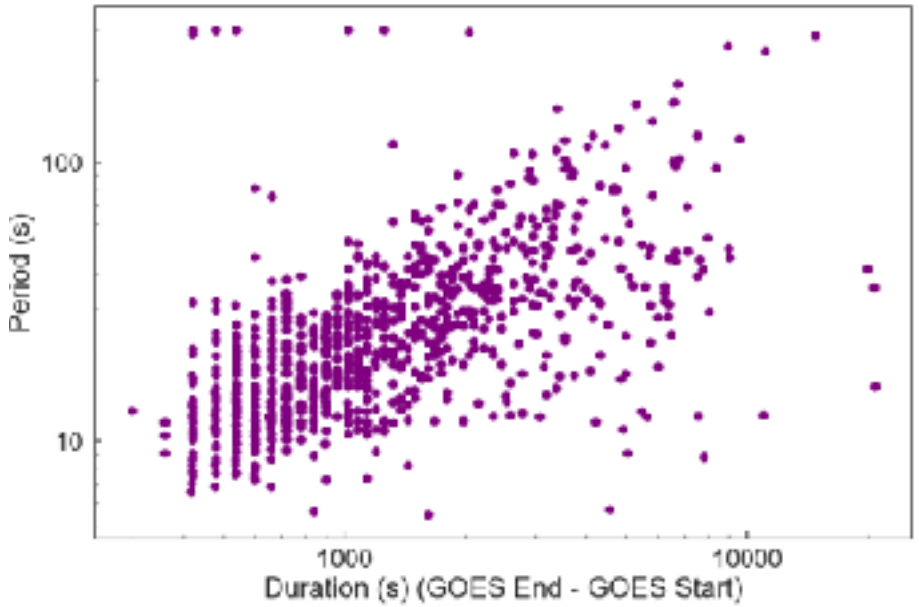


- **No correlation with GOES class (ie energetic size of flare)**
- **Duration of flare well correlated with period - longer loops? Larger flare arcade?**

Large Scale Study

Extended Inglis et al., 2016 All X, M and C class flares

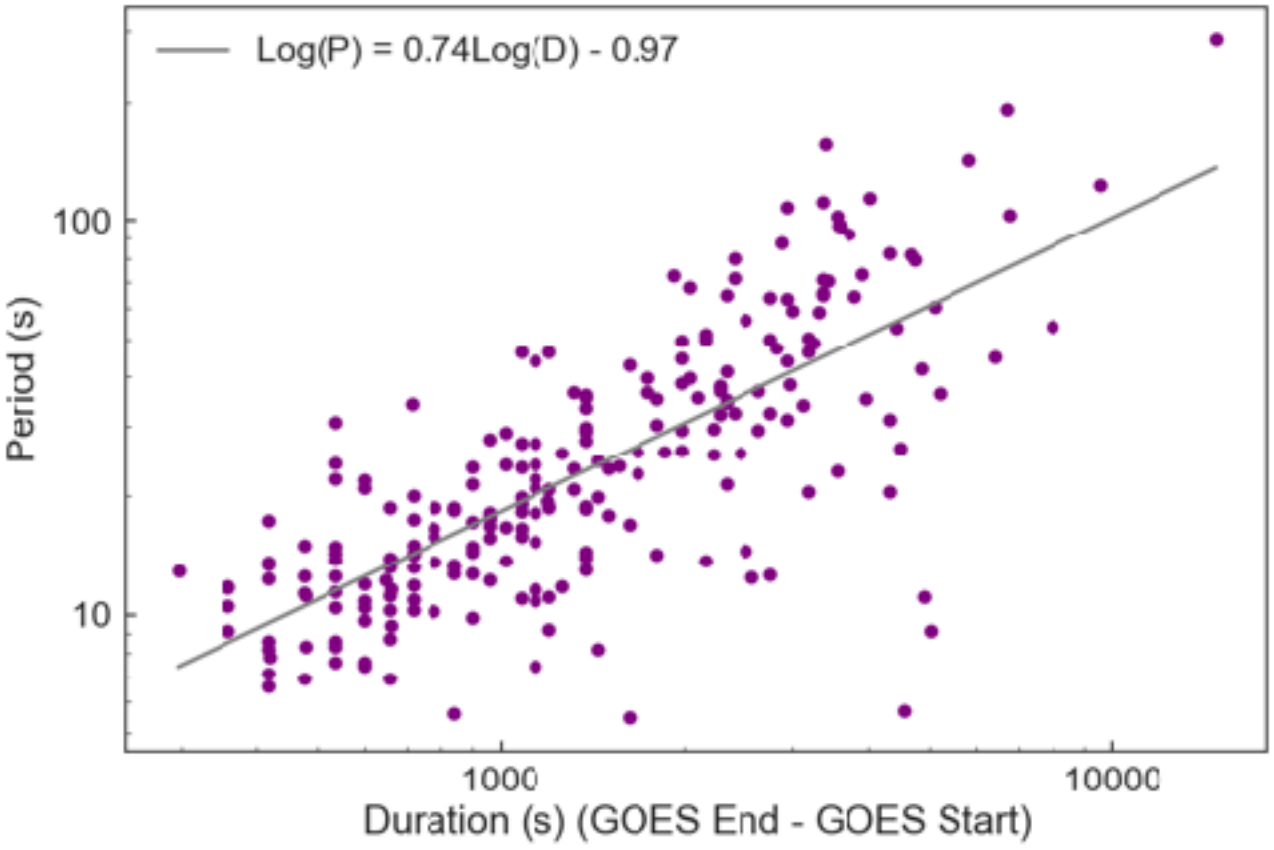




- **No correlation with GOES class (ie energetic size of flare)**
- **Duration of flare well correlated with period - longer loops? Larger flare arcade?**

Large Scale Study

Longer flares - Longer Periods? - Decay phase pulsations?!

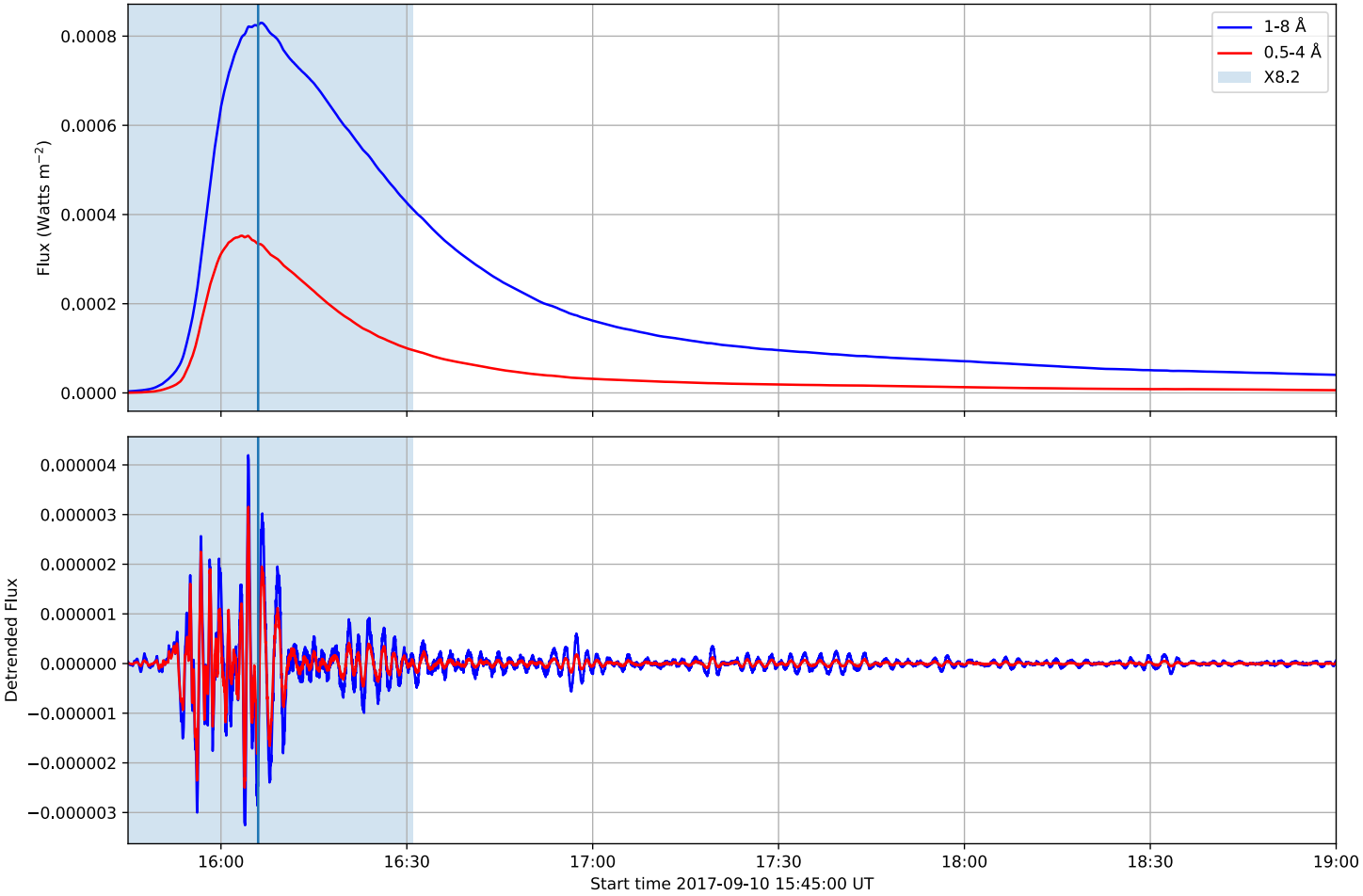


- Very similar to Pugh et al., 2017!
- Correlation Coeff .77
- Somewhat of an observational bias
- Longer flares - larger flare arcades, more time for timescale to evolve?

Lets look at a long duration flare example

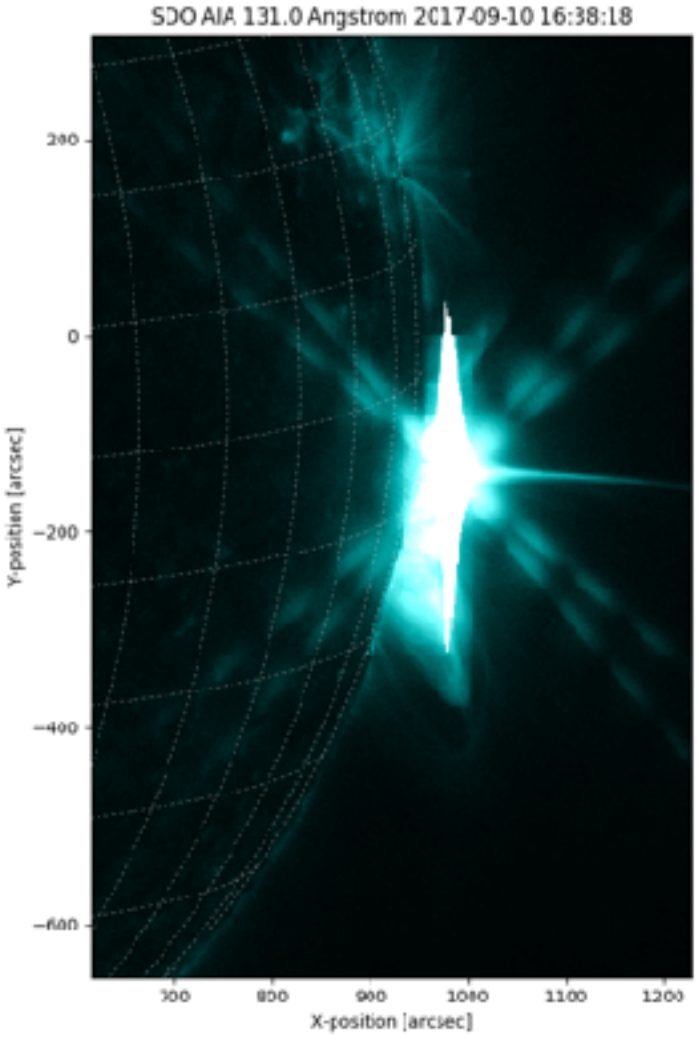
Longer Duration - Longer Period?

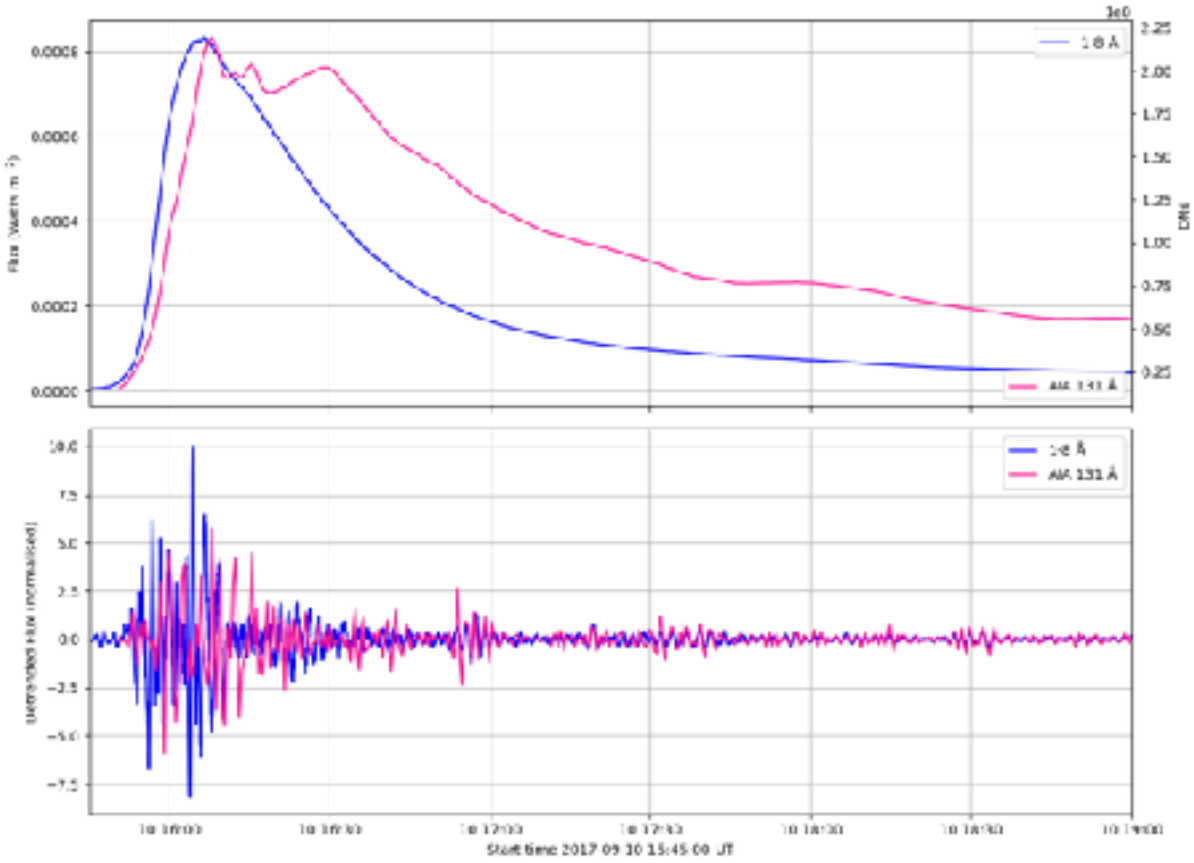
Investigate Events - 2017-09-10 X8 class flare



Longer Duration - Longer Period?

Investigate Events - 2017-09-10 X8 class flare

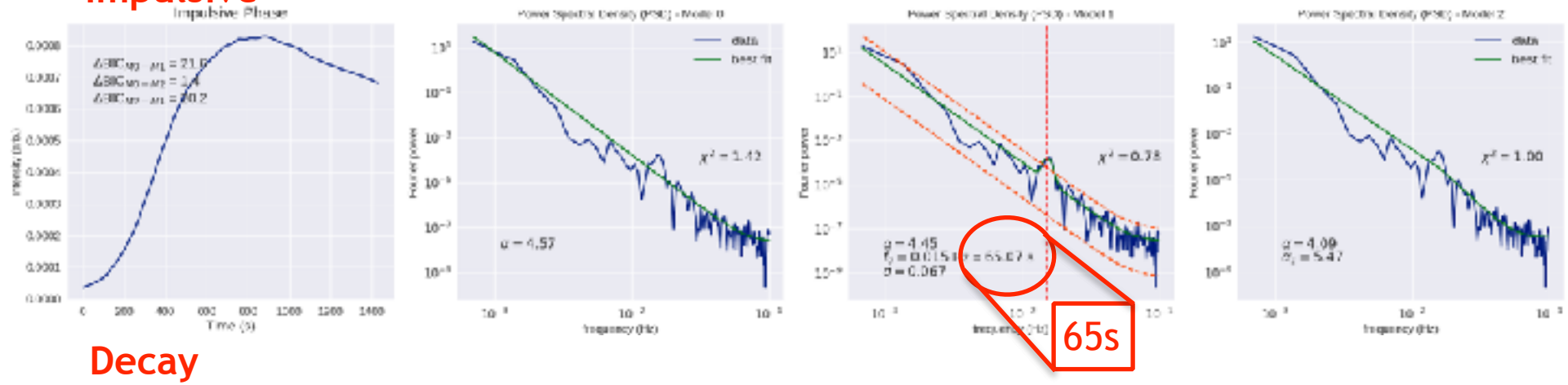




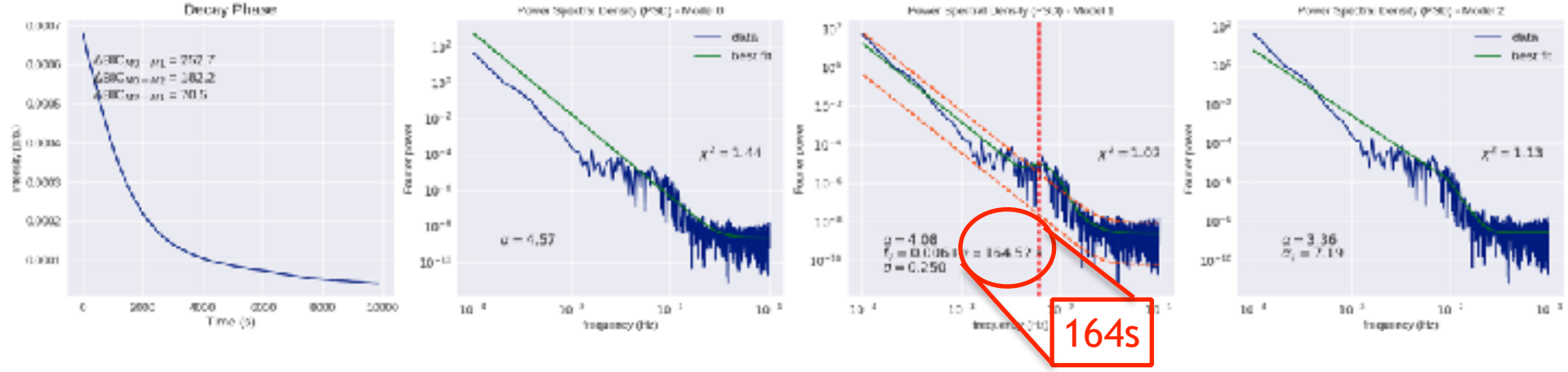
Longer Duration - Longer Period?

Investigate Events - 2017-09-10 X8 class flare

Impulsive

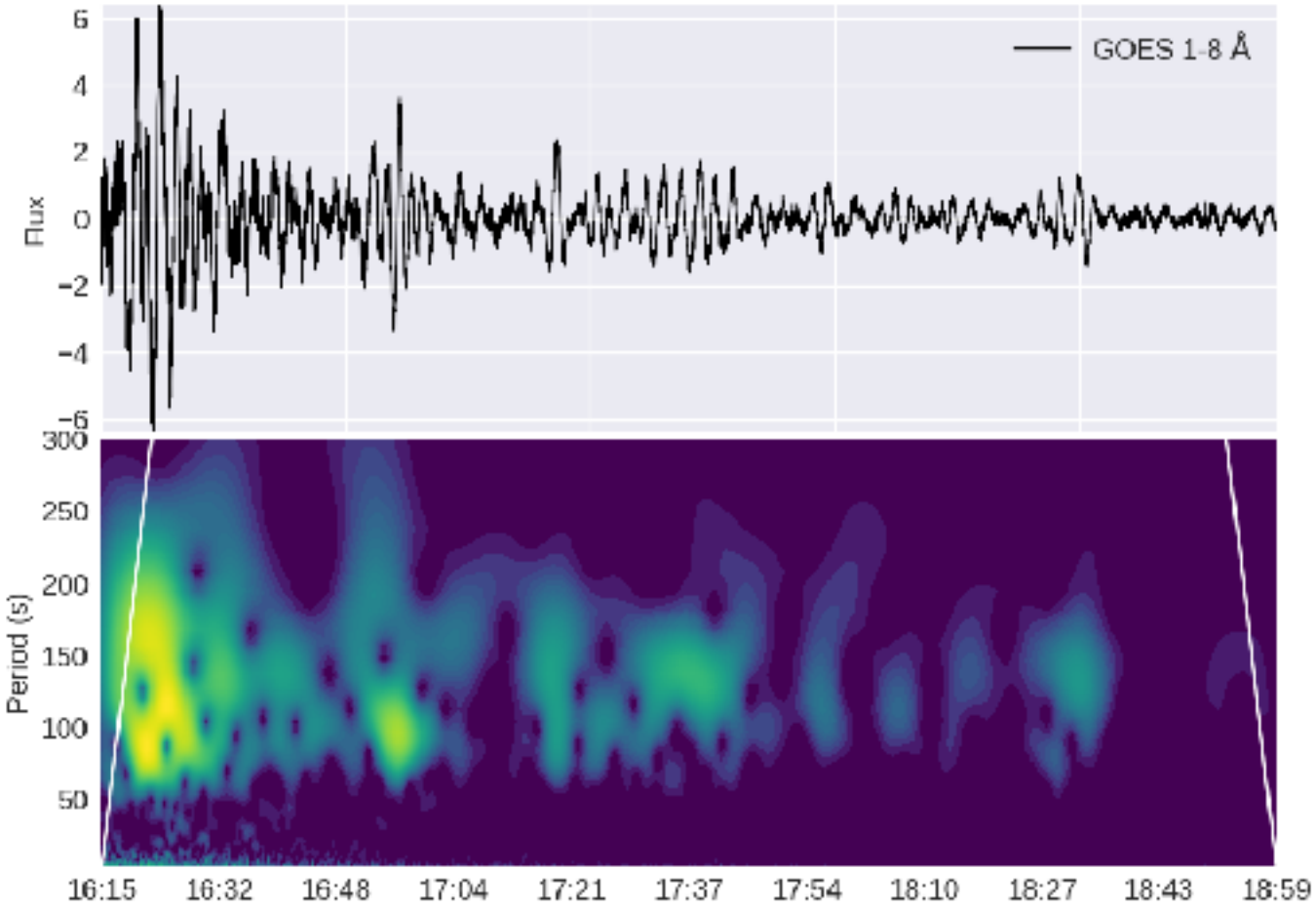


Decay



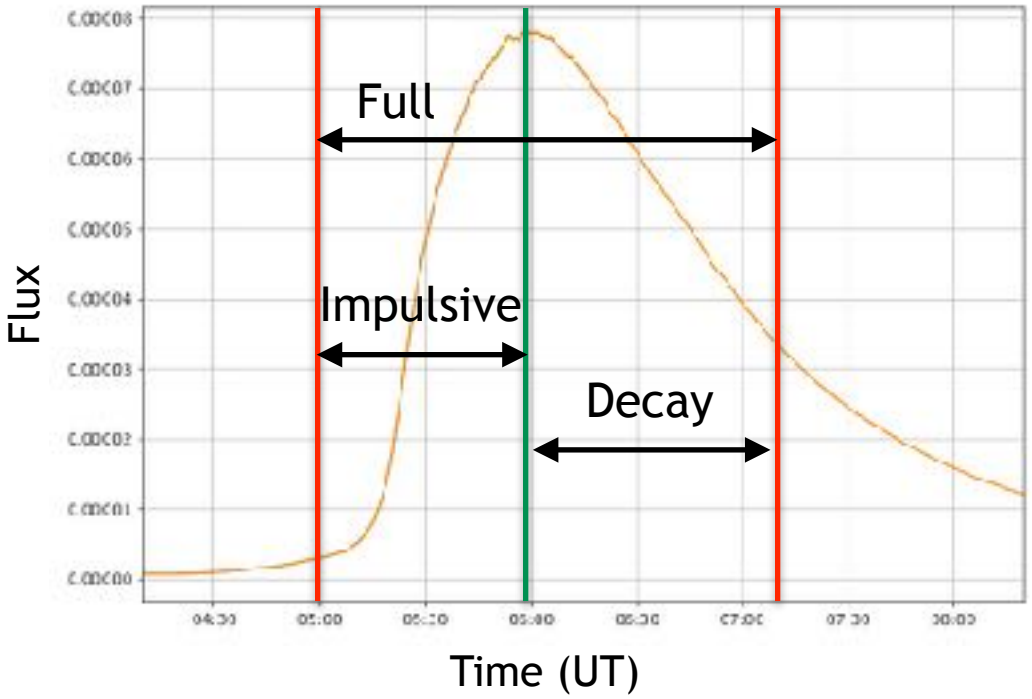
Longer Duration - Longer Period?

Decay phase - 2017-09-10 X8 class flare



Impulsive Vs Decay Study (Preliminary Results)

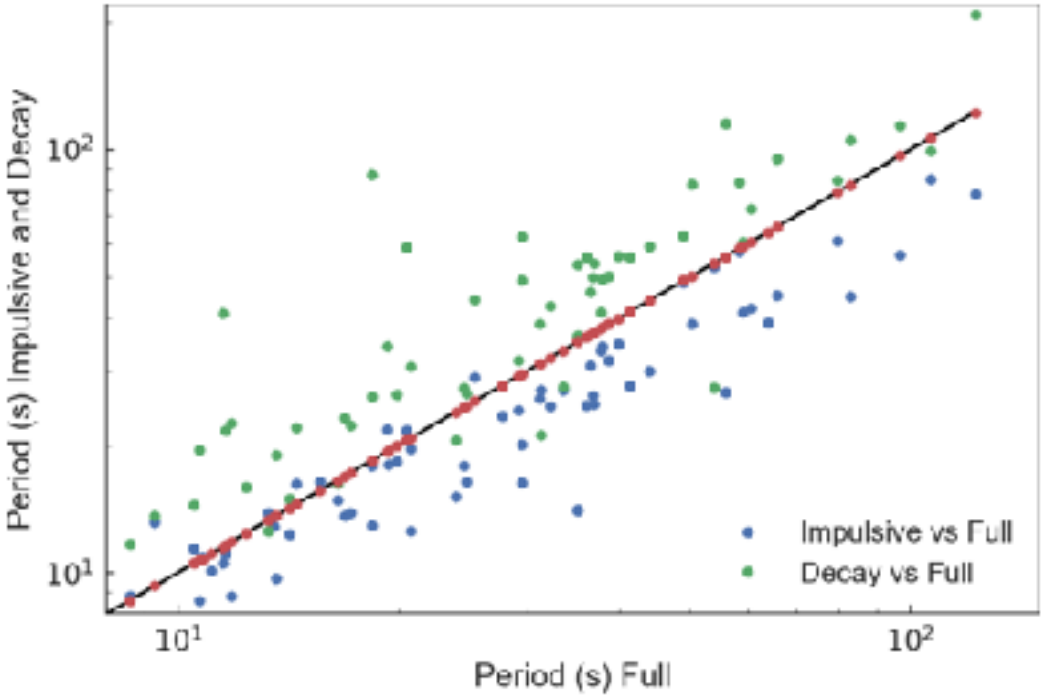
Windowing AFINO



- **Use GOES Start, Peak and End times to define impulsive vs decay.**
- **Perform AFINO on full flare, impulsive and decay separately.**

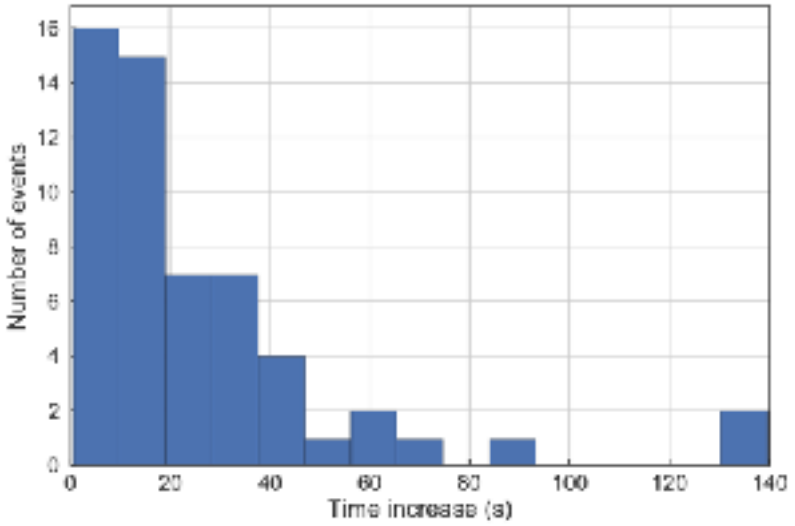
Impulsive Vs Decay Study (Preliminary Results)

Windowing AFINO



- Increased period in decay phase in 85% events

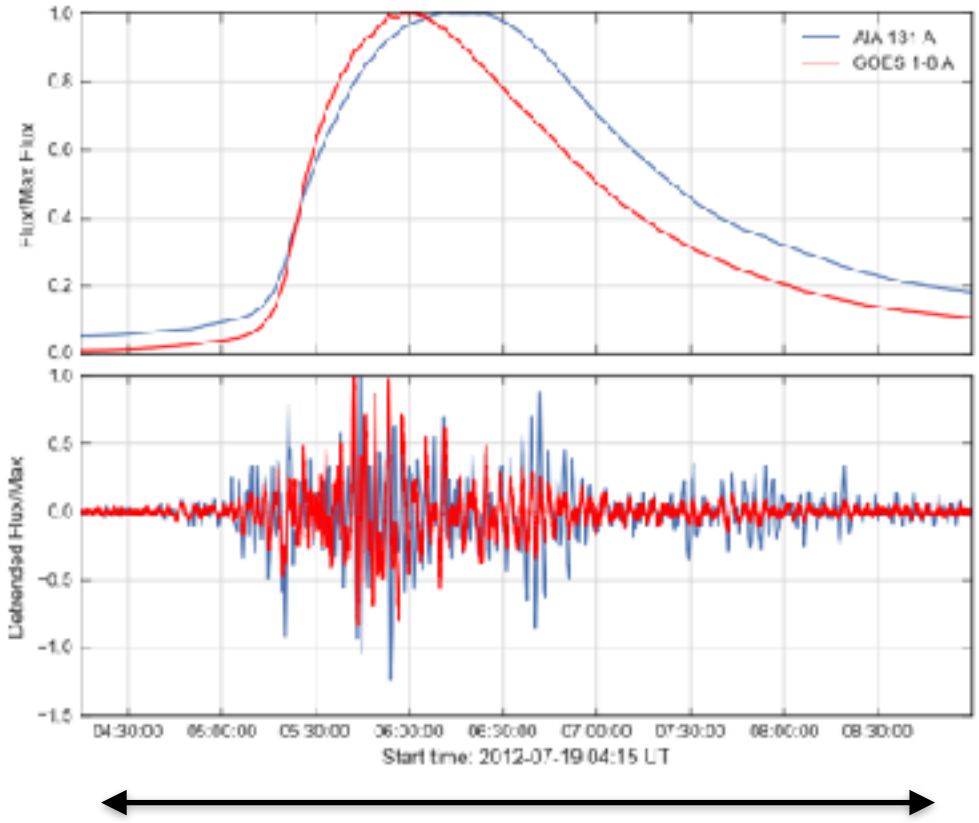
- Out of ~700 flares, 69 show significant period in full, impulsive and decay phases.



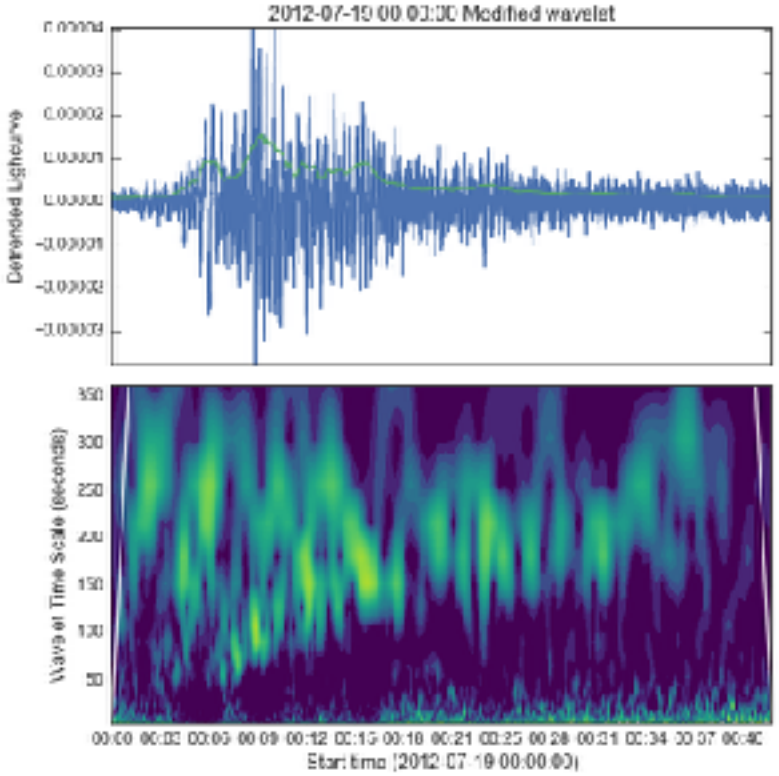
Crude first step - need windowed analysis …

Longer Duration - Longer Period?

Investigate Events - 2012-07-19 M7 class flare



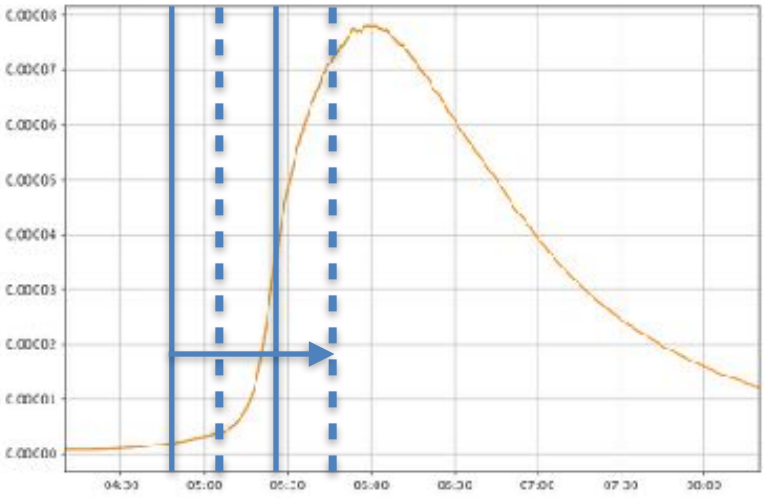
Long duration ~ 4 hours



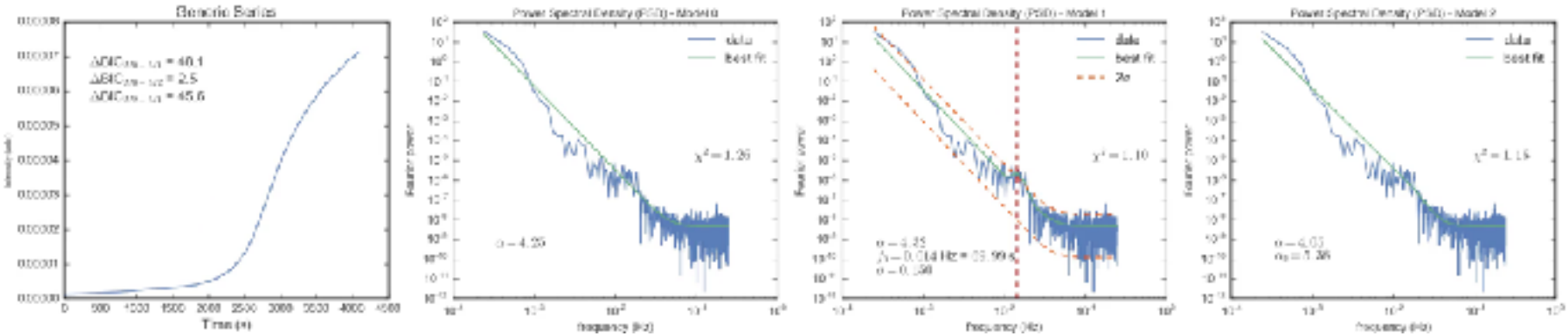
Wavelet analysis - increasing period

Longer Duration - Longer Period?

Investigate Events - 2012-07-19 M7 class flare



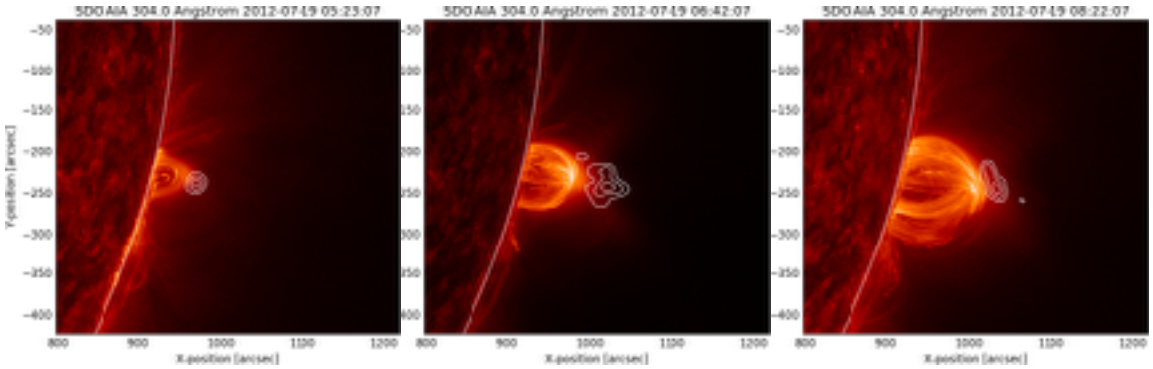
- Windowed AFINO - take overlapping windows and find significant periods in each.
- Results promising

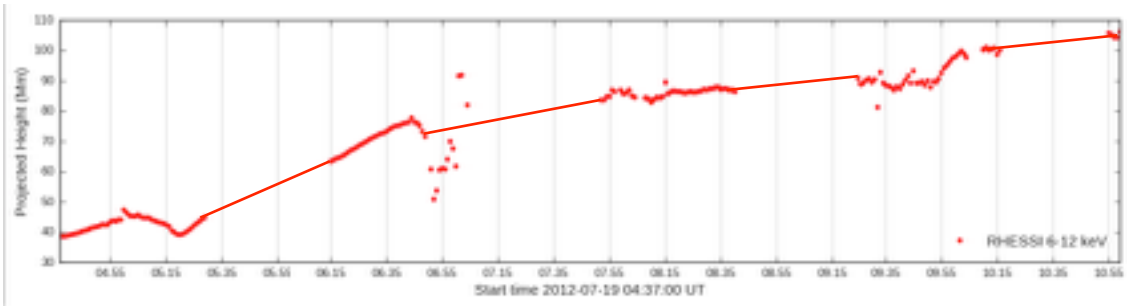


(Movie)

Longer Duration - Longer Period?

Investigate Events - 2012-07-19 M7 class flare





- The increased timescale must have some dependence on physical properties of flare
- Here example of loop length increase - continued reconnection at higher and higher altitudes

Altitude increase as function of time
Longer loops - longer period - MHD processes?

Duration - period plot then makes sense

Conclusions

- Preliminary analysis and observations show that decay phase pulsations tend towards longer timescales and more coherent compared to impulsive phase
- Is there an average growth rate of QPP in flares?
- Perhaps connected with continued reconnection at higher and higher altitudes? Longer loop lengths - MHD processes?
- What is needed to be done:
  - Detailed statistical analysis to take into account evolving period of pulsations
  - Directly link timescale to loop length via X-ray imaging