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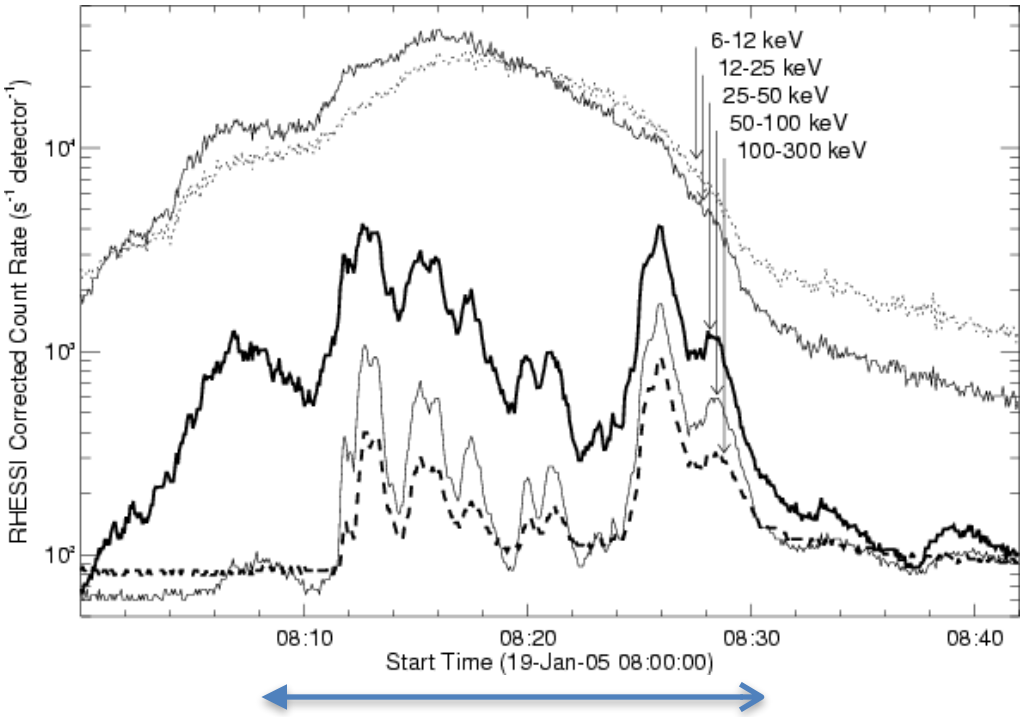
Quasi-Periodic Pulsations in Solar Flares

PROBA2/SWT

28 June 2016

Quasi-Periodic Pulsations in Solar Flares
Introduction

Nakariakov et al. 2006



Period of ~2-4 min

- Oscillatory signatures in emission
- Characteristic periods of 1s - several mins
- Majority of investigations focus on **non-thermal emissions**
- **Why interesting?**
  1. Fundamental physical processes in flares
  2. Coronal seismology
  3. Stellar flares

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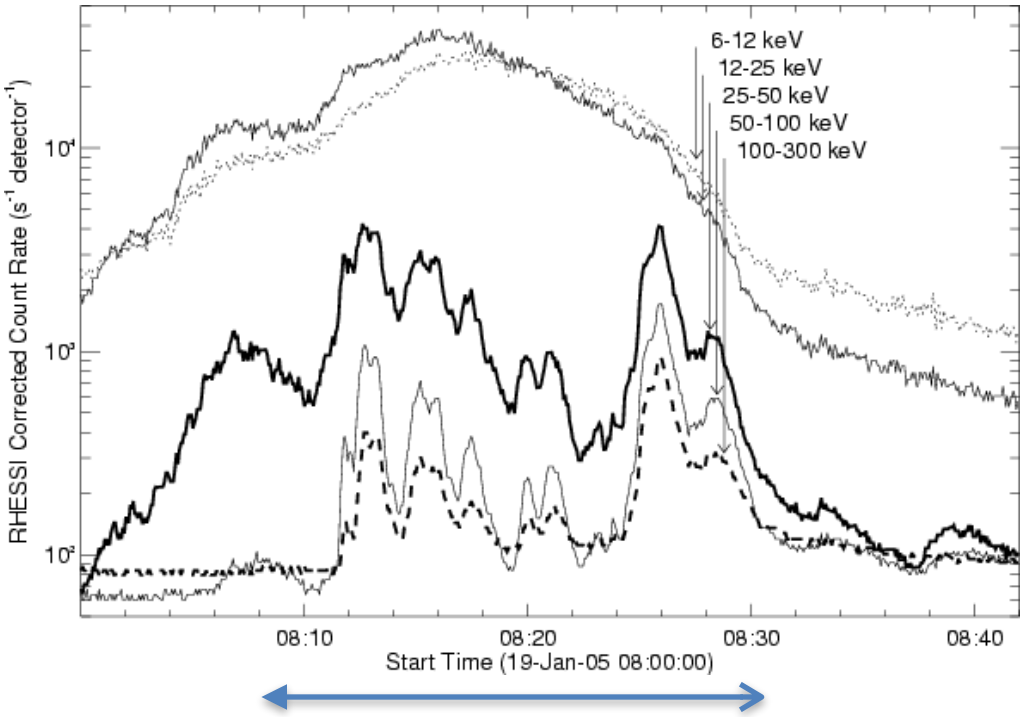

Period of ~2-4 min

- **Physical Origins?**

1. 'Bursty' Reconnection
2. MHD Wave Behavior

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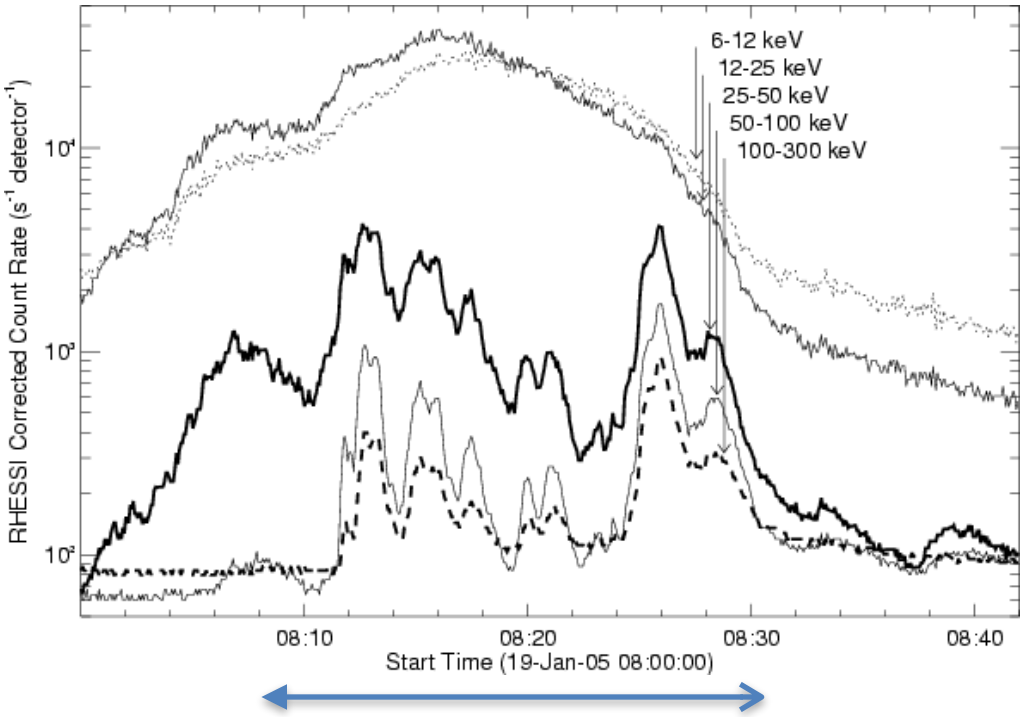


Period of ~2-4 min

- **Physical Origins?**

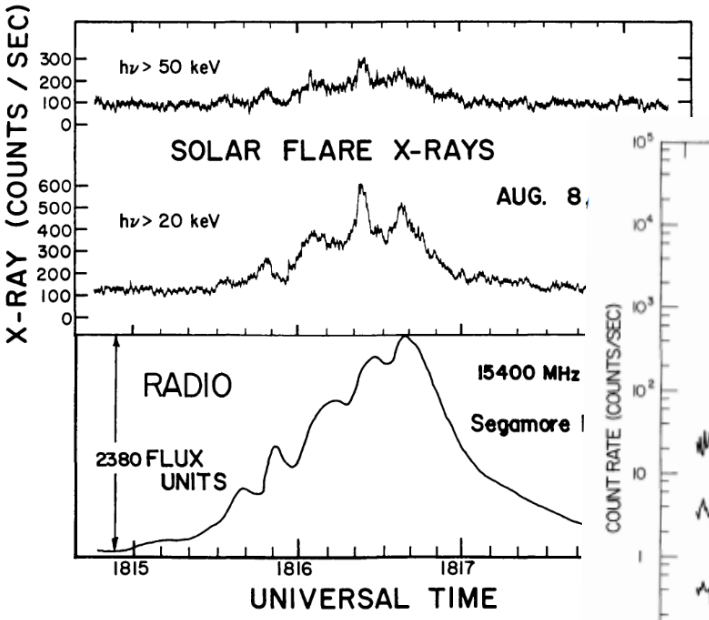
1. 'Bursty' Reconnection
2. MHD Wave Behavior

Yet still complete theory!

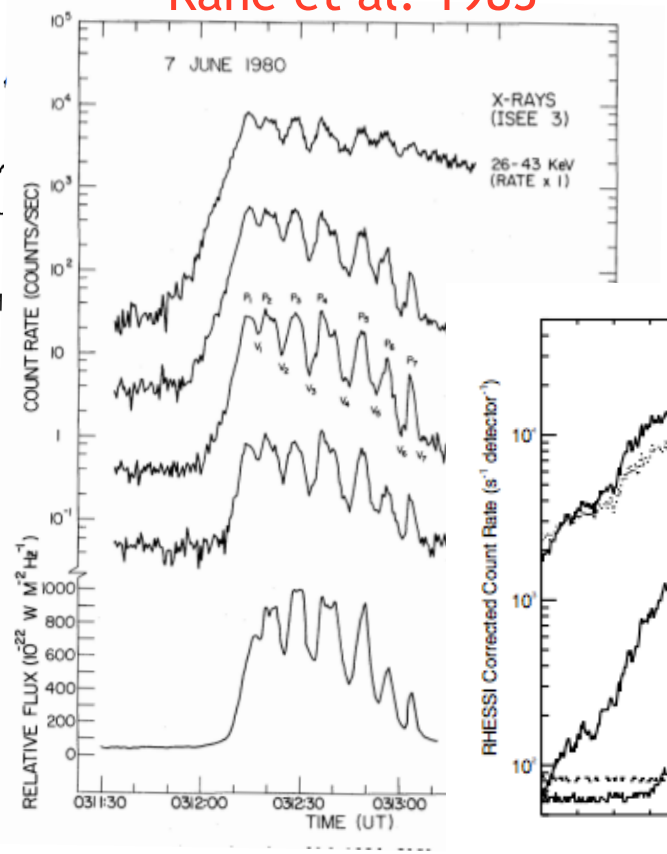
Quasi-Periodic Pulsations in Solar Flares

Previous Studies

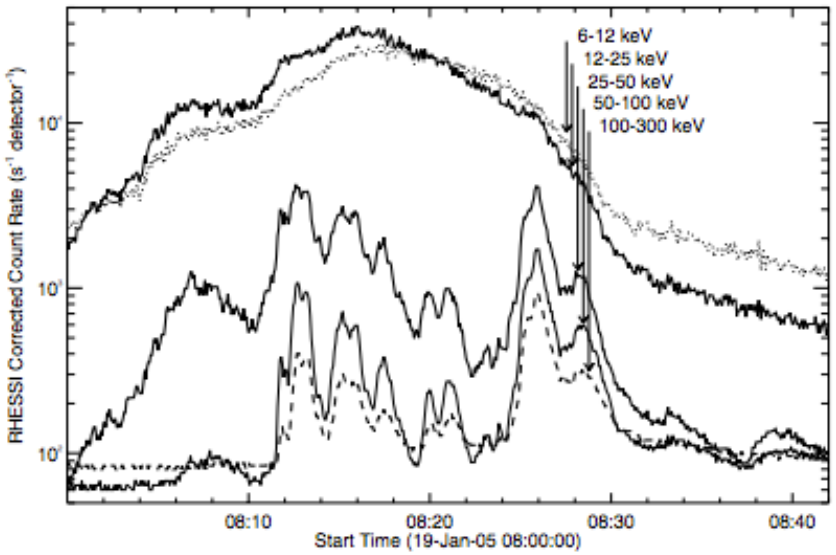
Parks and Winkler 1969



'Seven Sisters Flare'
Kane et al. 1983



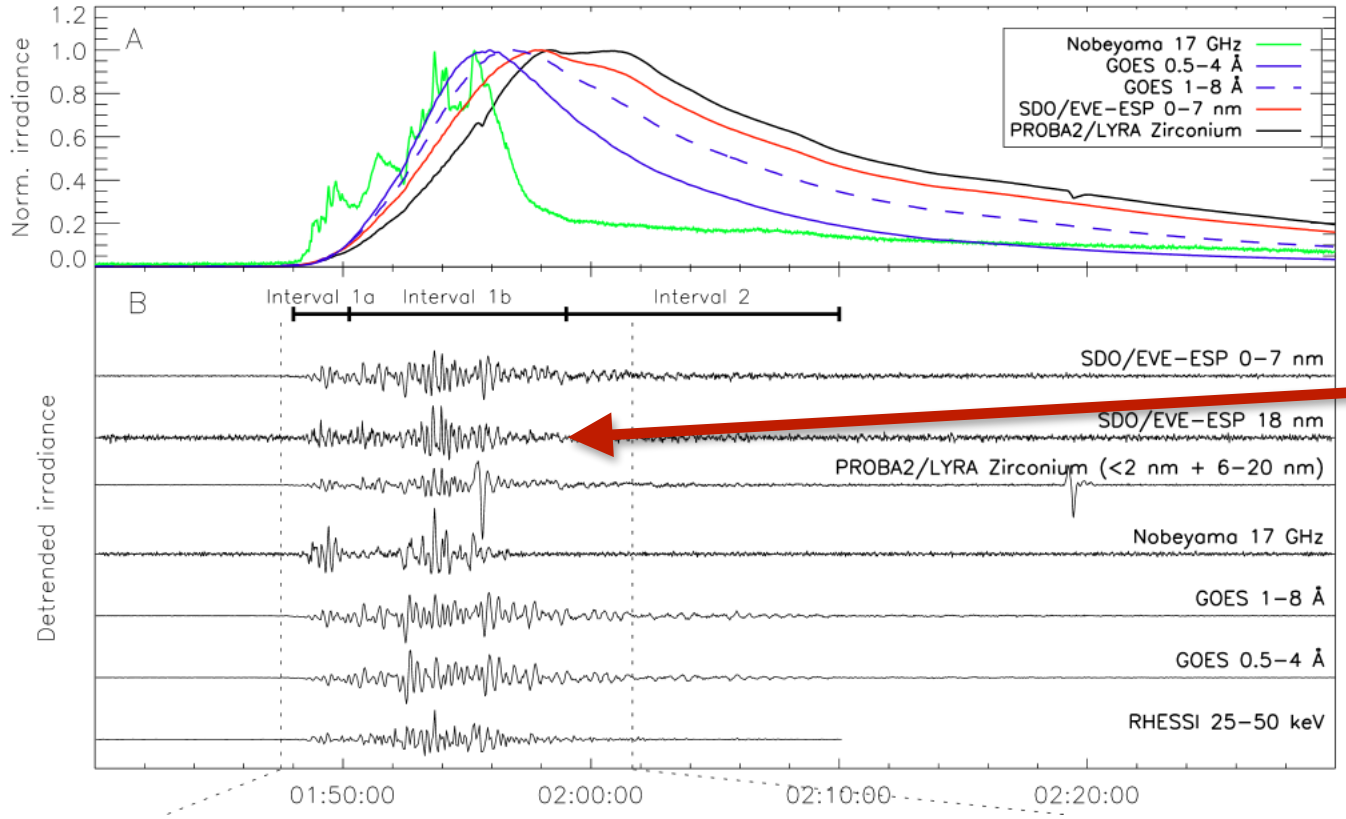
Nakariakov et al. 2006



Quasi-Periodic Pulsations in Solar Flares

Previous Studies Soft X-ray Contributions

Dolla et al. 2012

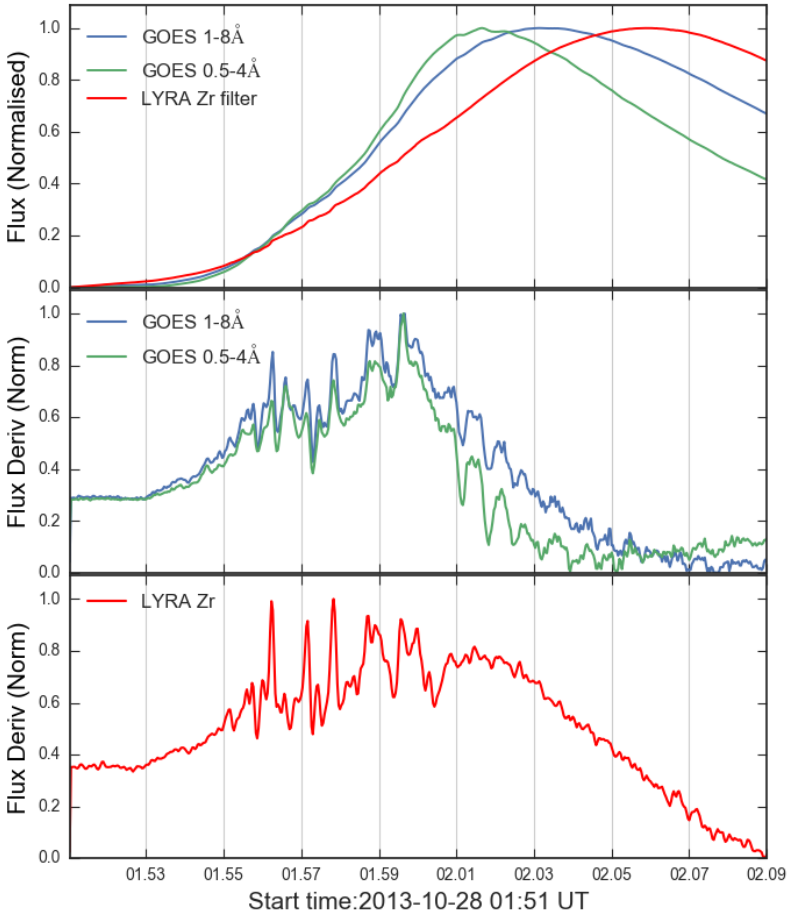


- Gradual trend removed highlights pulsations
- Pulsations observed across soft X-ray emissions from GOES, LYRA, EVE/ESP

Multi-wavelength detection of QPP

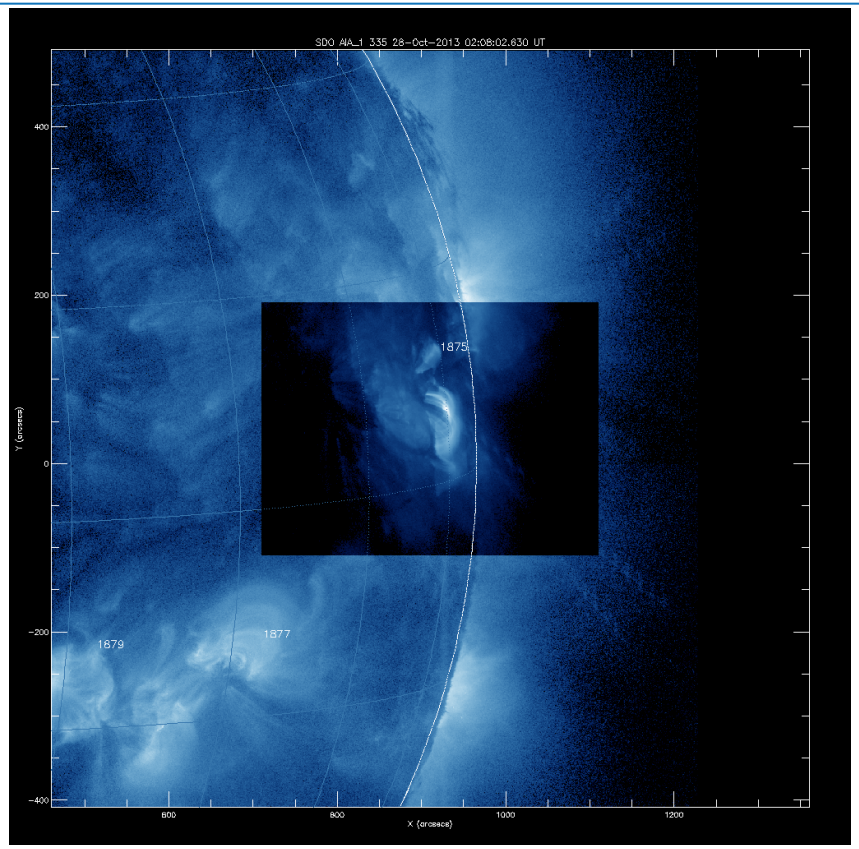
Key science goals

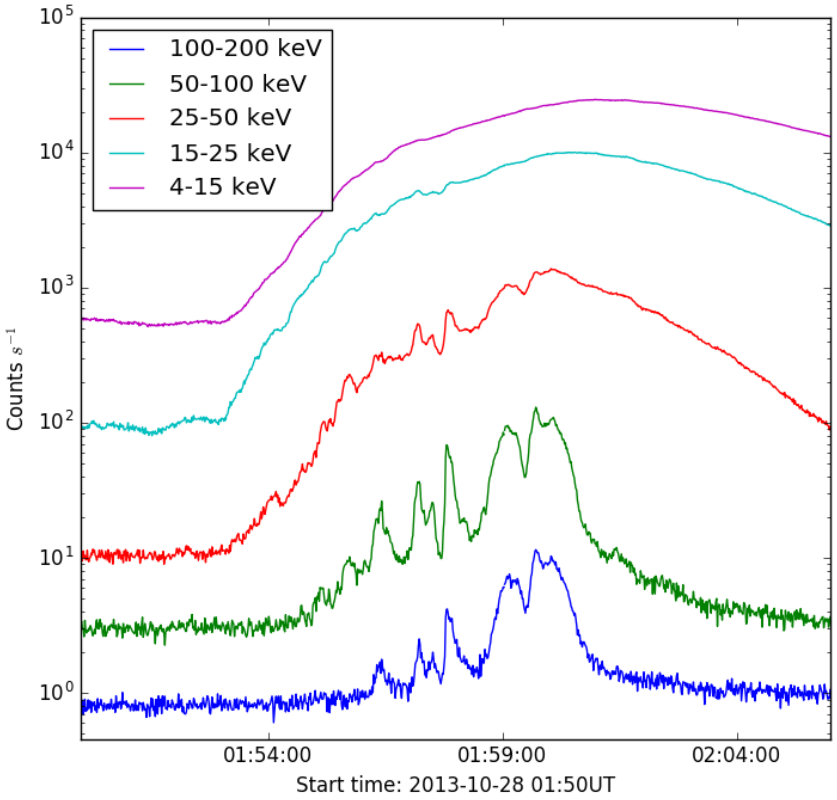
- **Perform a multi-instrument study focusing on fine structure recently identified in soft X-ray emissions.**
- Highlight pulsations using **time derivative** of soft X-ray time series
- Take advantage of **LYRA's** nominal cadence and use as a **GOES proxy** to highlight soft X-ray pulsations



Multi-wavelength detection of QPP

X1.0 GOES event





Multi-wavelength detection of QPP

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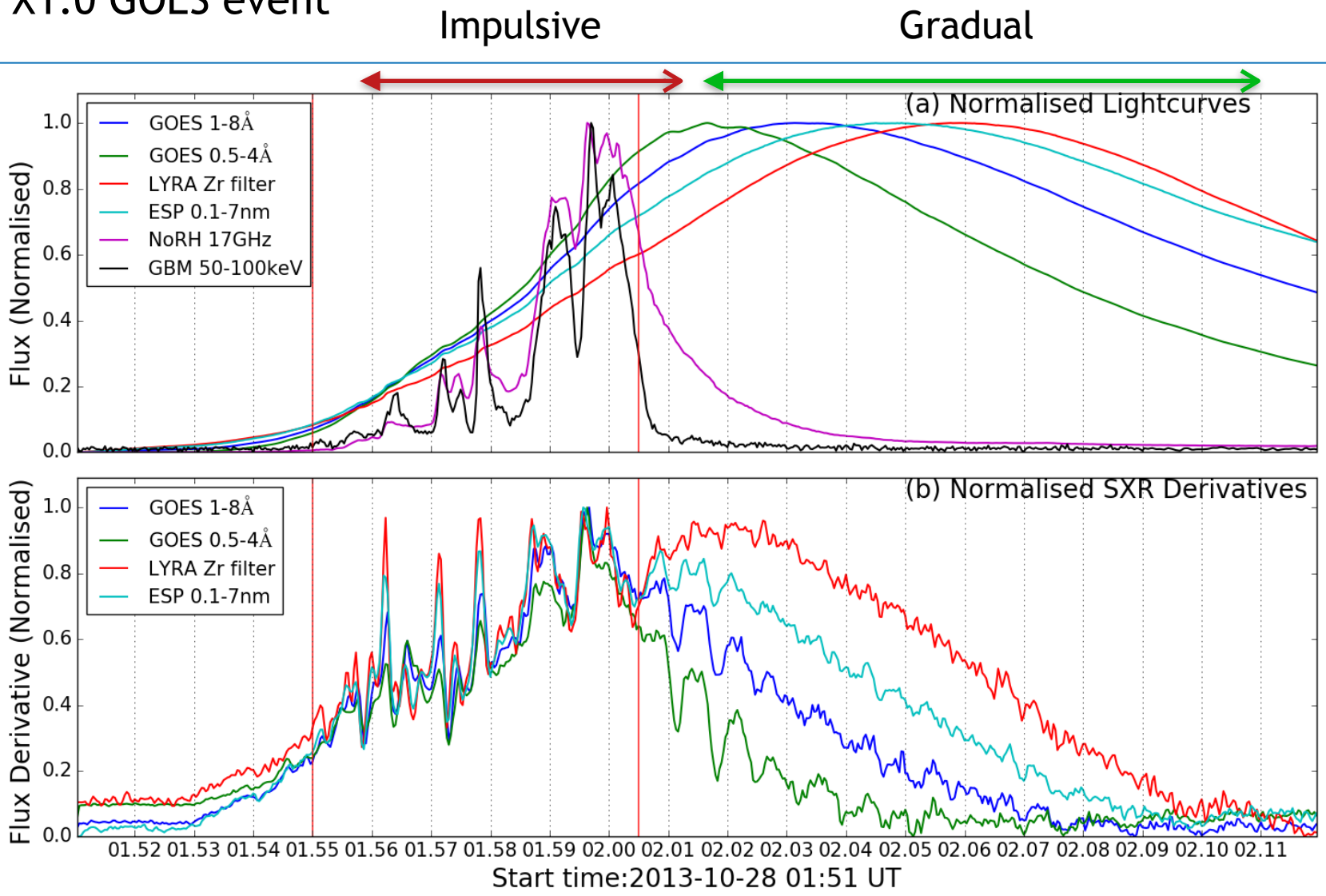
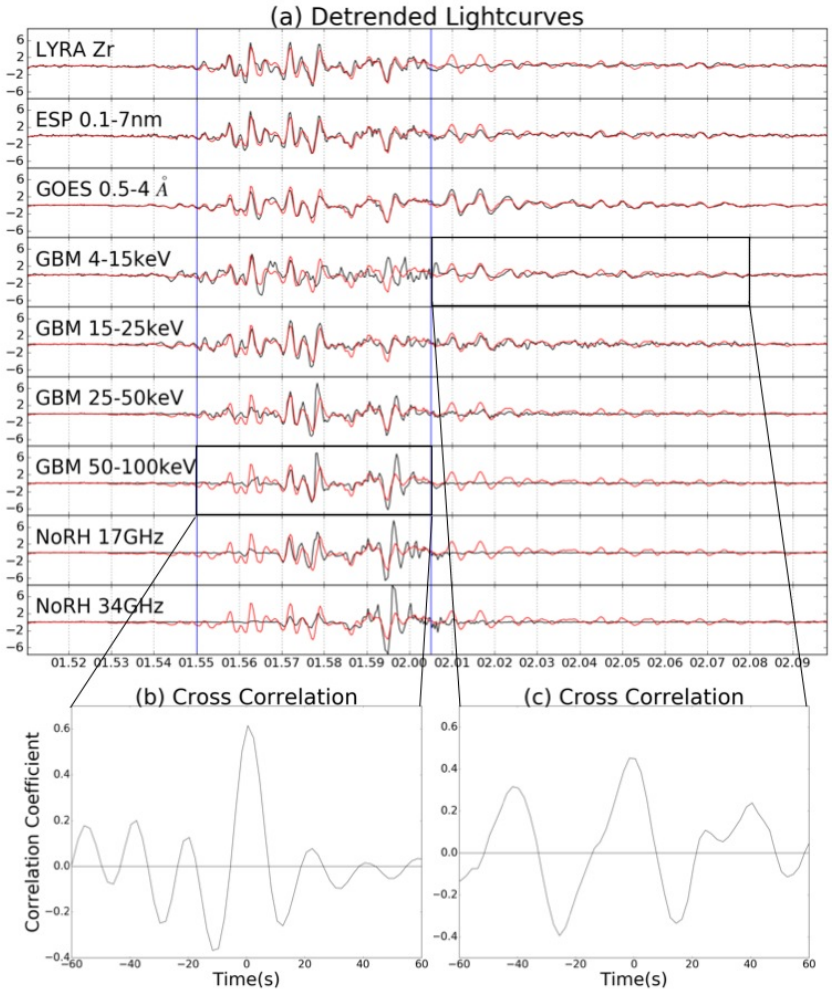


Multi-wavelength detection of QPP

X1.0 GOES event

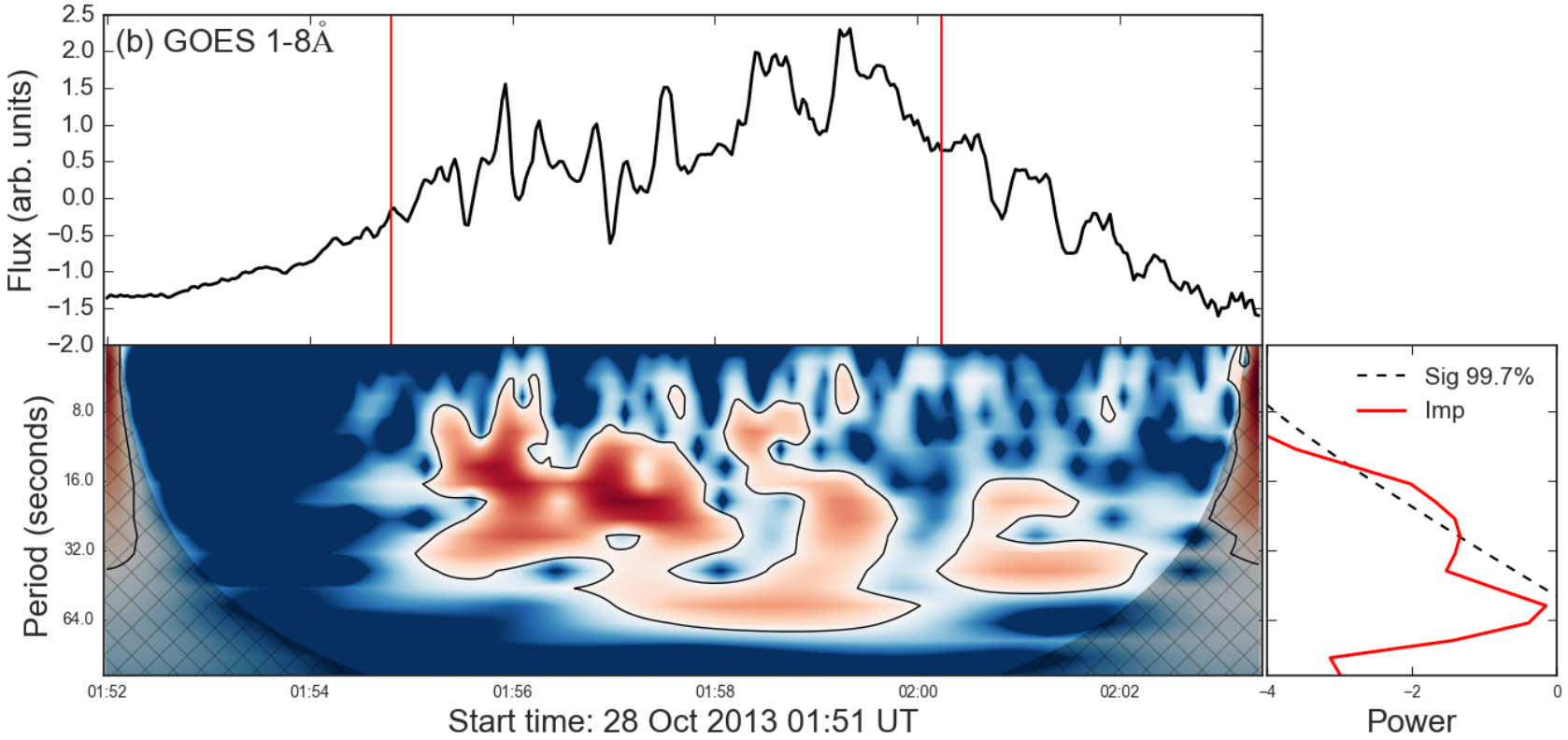
- Short time-scale fluctuations correlated across multiple energies
- Minimal time delay between peaks (<=2s)
- Pulsations persist in thermal channels



Multi-wavelength detection of QPP

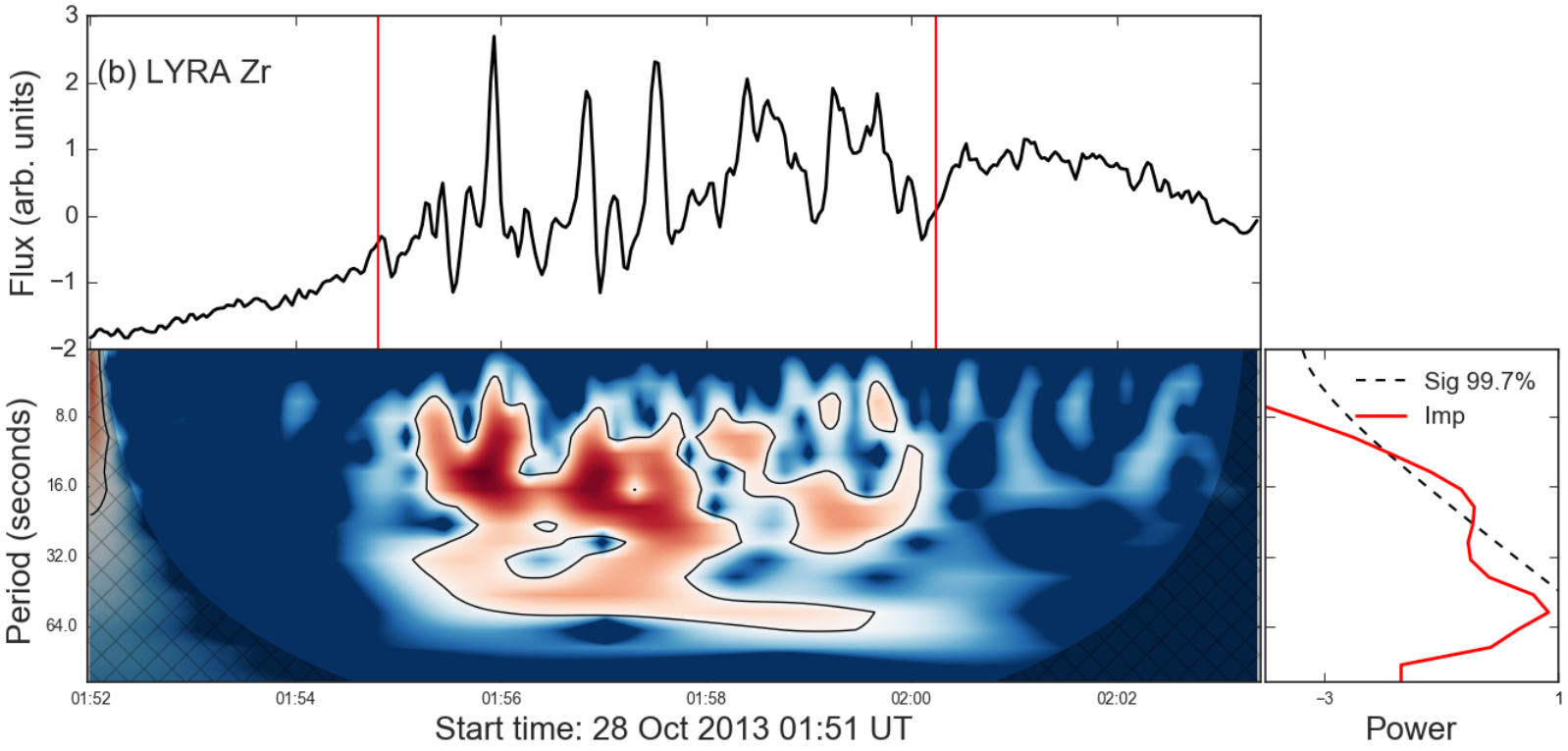
X1.0 GOES event GOES wavelet Analysis

Wavelet analysis taking into consideration red-noise distribution



Multi-wavelength detection of QPP

X1.0 GOES event LYRA Wavelet Analysis

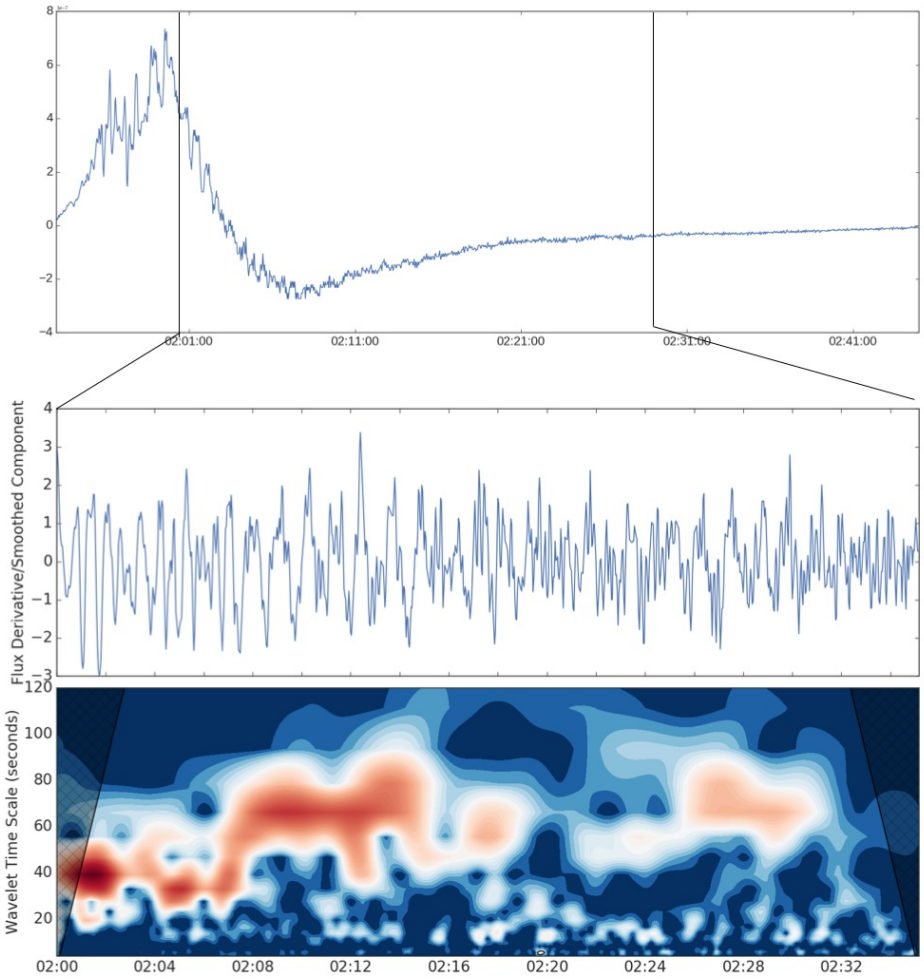


Multi-wavelength detection of QPP

X1.0 GOES event (persistent thermal pulsations)

- Thermal pulsations persist late into decay phase
- Timescale of pulsations tend towards longer timescales

  ~39s to ~70s
- Is this correlated with loops expanding over time?



Multi-wavelength detection of QPP

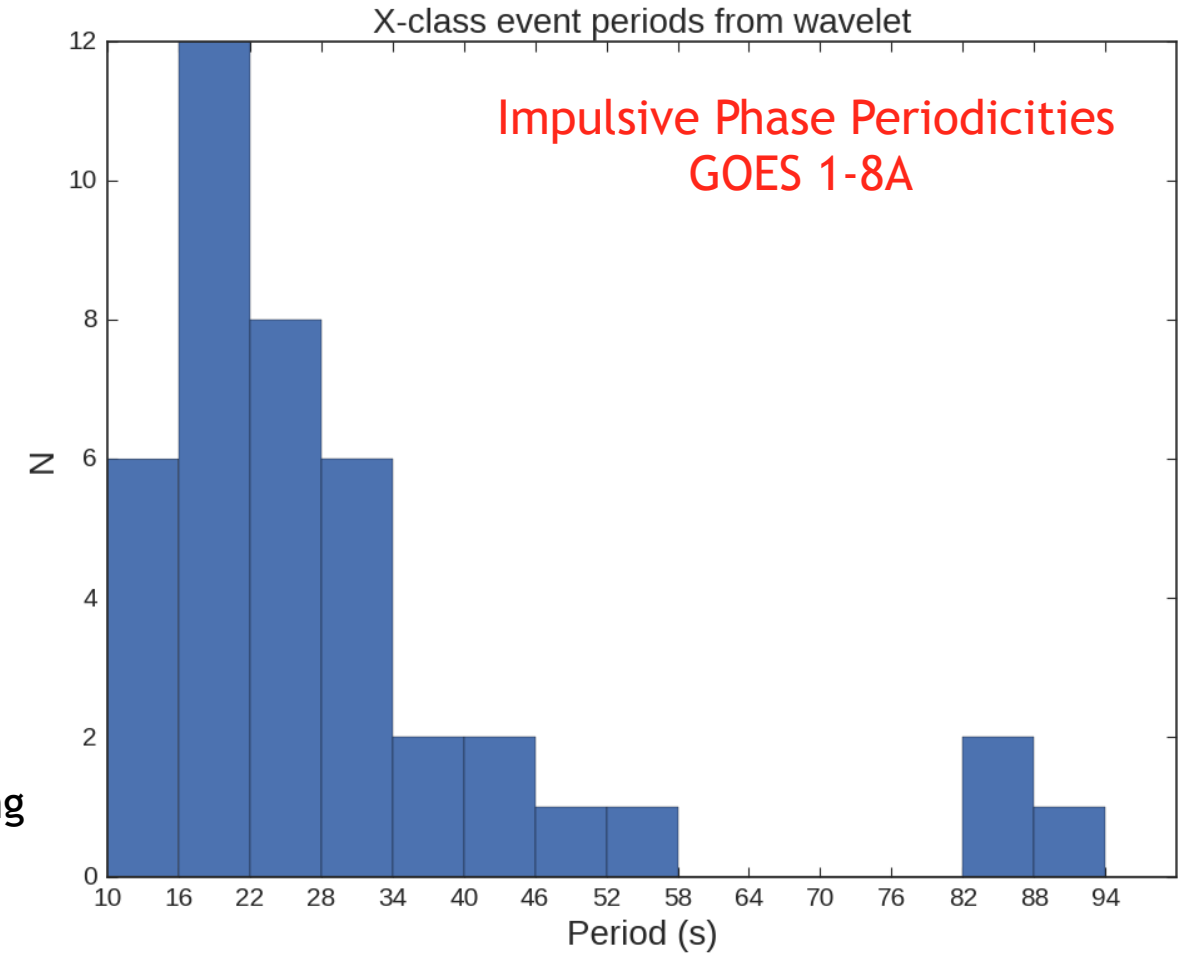
Conclusions of Single Study

- Co-existent QPP observed across **10 wavebands on 5 different instruments** with minimal time delay between energies.
- Characteristic timescales of **~20s above a 99.7% significance.** Second period of ~55s observed across all channels showing significance in non-thermal regime.
- Distinct **pulsations in the high temperature plasma persist** into decay phase with period of pulsations systematically increasing.
  - Why doesn't LYRA see these? Cooler plasma?

Hayes et al. *in prep*, ApJ Letters.

Future Work
QPP Statistical Analysis

- Preliminarily statistical analysis of periods observed with GOES
- Characteristic periods ~15-30s
- Does **LYRA** see that same?
- What about **gradual phase**?
- Thermal distribution of pulsating plasma possibly with LYRA?



Future Work
QPP

Future Work:

- Large scale multi-wavelength analysis of QPP with particular attention of soft X-ray thermal emissions with GOES/XRS & LYRA Zr throughout impulsive and decay phases of flares
- LYRA important as use for GOES proxy and correct identification of ‘real’ pulsations of solar origin
- Relate characteristic timescales to some physical parameters:
  - Higher altitude of energy release site?
  - Length of loops?
  - Other factors; length scales of reconnection?

Conclusions and Future Work
QPP Statistical Analysis

Conclusions:

- Soft Xray QPP are a common if not intrinsic feature of solar flares
- LYRA important as use for GOES proxy and correct identification of ‘real ’pulsations of solar origin

Proposed Work:

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