Stellar Quasi-periodic Pulsations in Highly Active Low Mass Stars

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ABSTRACT

Stellar atmospheres encompass an abundance of waves and oscillations. This includes those associated with flares. Oscillatory and pulsating signatures, commonly known as quasi-periodic pulsations (QPPs), are observed at many wavelengths during both solar and stellar flares. These oscillatory phenomena travel on magnetic field lines in the star's atmosphere and can provide insight into the astrophysical processes of flares. We present a preliminary study of flare oscillations in a nearby, active M dwarf star. We use high cadence Swift (~1 sec, UV) data to measure QPP properties and place constraints on the fundamental processes driving flares at different layers of the stellar atmosphere. We present preliminary results to be incorporated with high-cadence TESS 20-second flare data for future studies.

Data

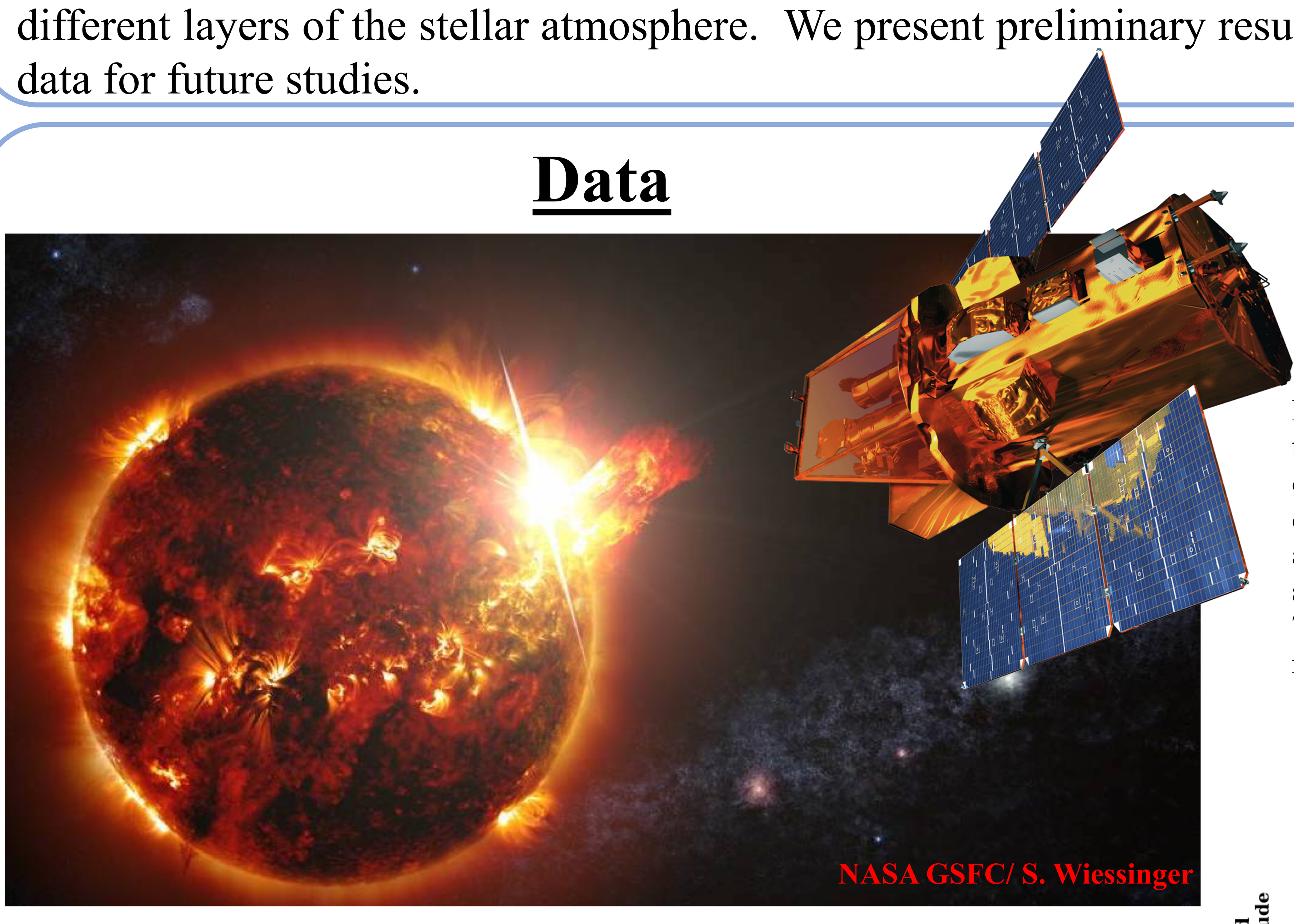

Figure 1 – Magnetic activity drives flares. We will study a sample of highly active flare stars with high-cadence Swift and TESS 20-second cadence data to search for QPPs. QPPs travel on magnetic field lines in the star's atmosphere providing insight into the flare mechanisms and the local flare plasma. NASA's Swift mission is a multi-wavelength observatory dedicated to the study of gamma-ray burst science, but can also study flaring stars. Swift has 3 telescopes, we focus on the UV/Optical Telescope (UVOT) for flares. Swift's filter is centered at 225 nm in the near UV, telescope FOV is 17 arcmins. Swift uses a photon counting detector, allows flexible binning as low as <1 s.

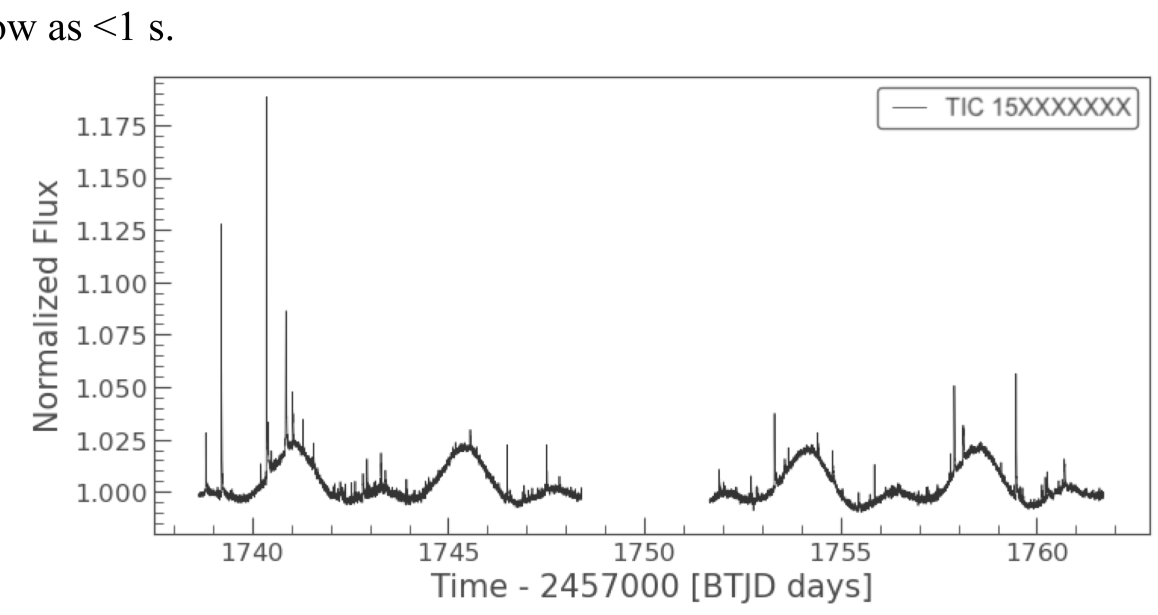

Figure 2 – TESS 2-minute light curve of TIC 15xxxxxxx showing that it is a highly active flare star. However, this low mass star was only observed in Sector 16 of the TESS mission and with 2-minute data.

QPPs in Flares in the UV

Swift is excellent for QPP science because it provides very high cadence time-domain observations at UV and optical wavelengths inaccessible from the ground and its flexible scheduling is ideal for coordinating simultaneous observations with other observatories. We studied QPPs in flares in the UV to place constraints on the fundamental processes governing flare emission at different layers in the stellar atmosphere. We utilized high cadence data from the Swift mission since QPPs are elusive in low cadence data (such as TESS 2-min and Kepler 30-min data); in Swift and TESS 20-sec high cadence data, flare morphology is very well resolved and reveals QPPs. Our study measured the broad-band frequency behavior, amplitudes, and periods of the QPPs (Figure 3) to compare flare energies and constrain physical processes such as flare emission mechanisms and the transfer of energy by QPPs to different layers of the stellar atmosphere.

Future Work

In this preliminary study of QPPs in flares we have modeled and calculated the periods of the QPPs in high cadence UV data with Swift. We are applying these techniques in future multi-wavelength observation campaigns with Swift and TESS 20-second data.

Preliminary Results

INTRODUCTION: Stellar atmospheres encompass an abundance of waves and oscillations, those driven by flares are commonly known as quasi-periodic pulsations (QPPs). QPPs are observed at many wavelengths in the decay branches of both solar and stellar flares. These oscillations travel on magnetic field lines in the star's atmosphere and provide insight on the astrophysical processes of flares (Nakaraikov, 2004). We present preliminary findings to study QPPs in high-cadence data. We studied a highly active flaring low mass M4 star, with a TESS magnitude of 7.73041, with Swift UVOT data binned at 1-second to resolve the morphology of the QPP within the flare.

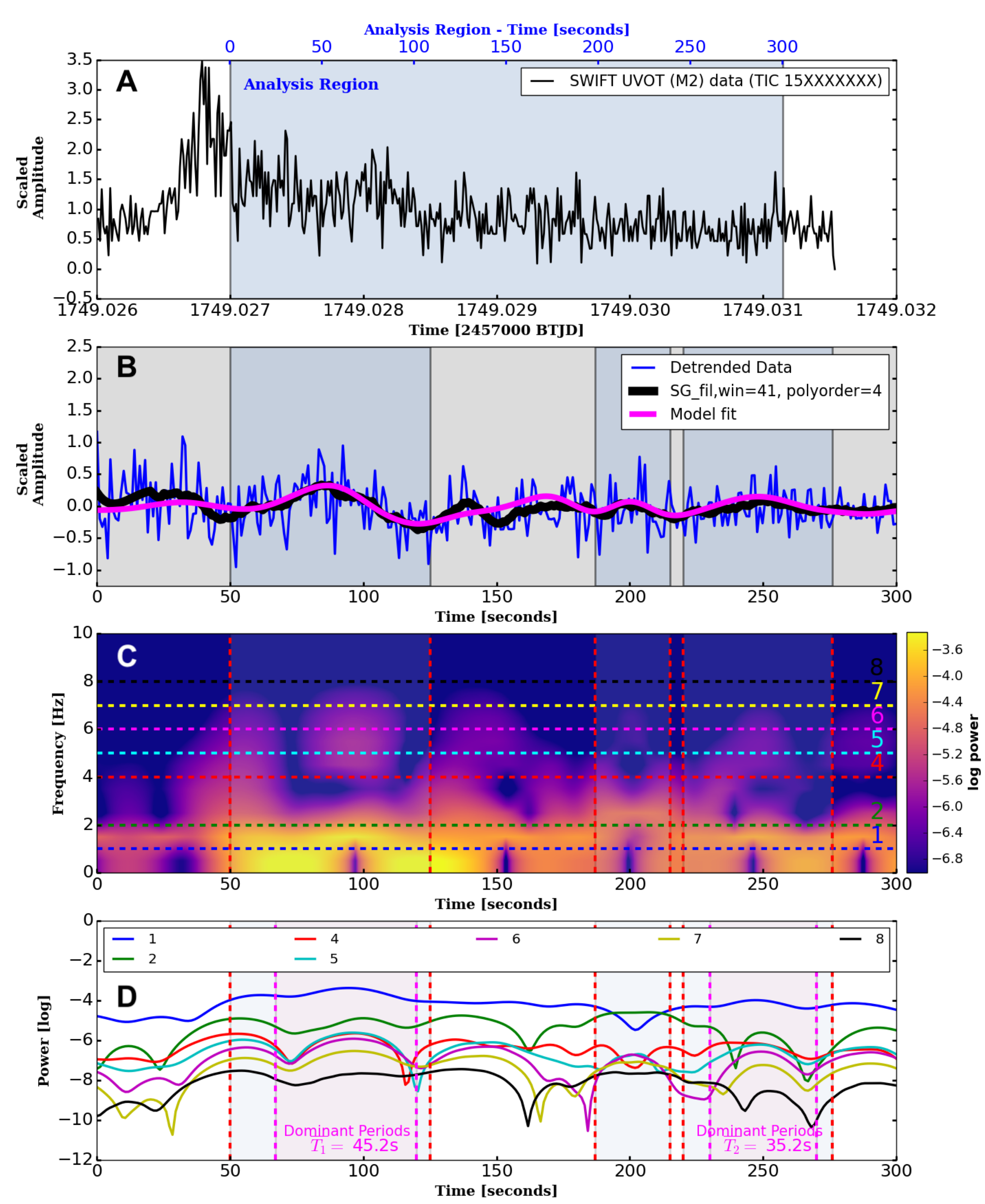

Figure 3 – **A study of oscillations in Swift high cadence data.** A) 1-sec high cadence UVOT data of a flare on TIC 15xxxxxxx. The analysis region is in the decay branch of the flare and is 300 seconds in length. B) The data (**blue solid line**) is detrended in the analysis region. The detrended data is then smoothed (**black dashed line**) with a smoothing filter of window size=41 and a polynomial order of 4. The QPP detrended data is then model fitted (**solid magenta line**) with Modal Decomposition (e.g. Jackman *et al.* 2019, Kolotkov *et al.* 2015). C) A time-frequency-power diagram is taken of the QPP region to analyze the detrended analysis region and to show the frequency behavior of the log power as time evolves. D) QPP periods are then found through samplings of spectra as a function of power through time.

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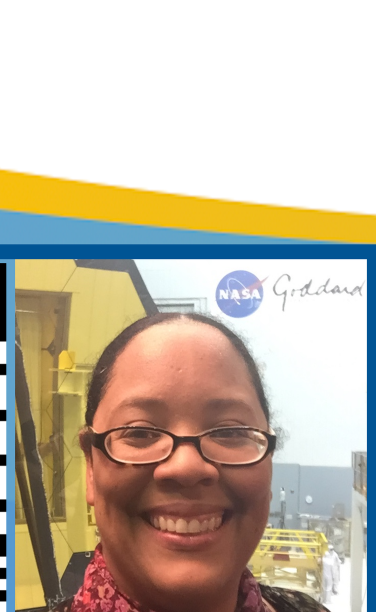

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