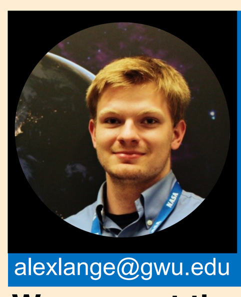

High-Mass Gamma-Ray Binary: J1405.1-6119

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We present the results of multi-wavelength observations of the High-Mass Gamma-Ray Binary 4FGL J1405.1-6119. XMM-Newton and NuSTAR observations taken in 2019 (sampling the gamma-ray maximum and minimum), constrain the emission of soft and hard X-rays, show variability of the hydrogen column density, n_H, and spectral index, Γ_X, and provide no evidence of short-term variability or pulsations. We also present the first orbital phase-resolved analysis of 15 years of Fermi-LAT data of 4FGL J1405.1-6119 and the evolution of the spectral shape as a function of orbital phase. Finally, the X-ray and Gamma-ray spectrum can be interpreted in the framework of the intra-binary shock model previously used within High-Mass Gamma-Ray binaries such as LS 5039.

Introduction

- **High-mass Gamma-ray Binaries (HMGBs) are a rare class of binaries observed in our Galaxy (differing from other binaries by a characteristic peak in the SED above a few hundred MeV), comprised of a massive O/Be/WR type companion and a NS/BH compact object. Most of (~ 11 HMGBs) are unclassified.**
- **High-energy emission models are either an intrabinary shock (pulsar wind interacting with companion wind) and microquasar (MQ) relativistic jet model.**

Previous Research/Discovery of 4FGL J1405.1-6119

- J1405 was discovered using a power spectrum analysis of Fermi-LAT data from aperture weighted photometry, finding a significant period of 13.7 days [1]
- Folding the light curve on the orbital period resulted in a double-peaked structure
- Limited spectral analysis, frozen to 4FGL values, (the basis for a microquasar emission model by [2])

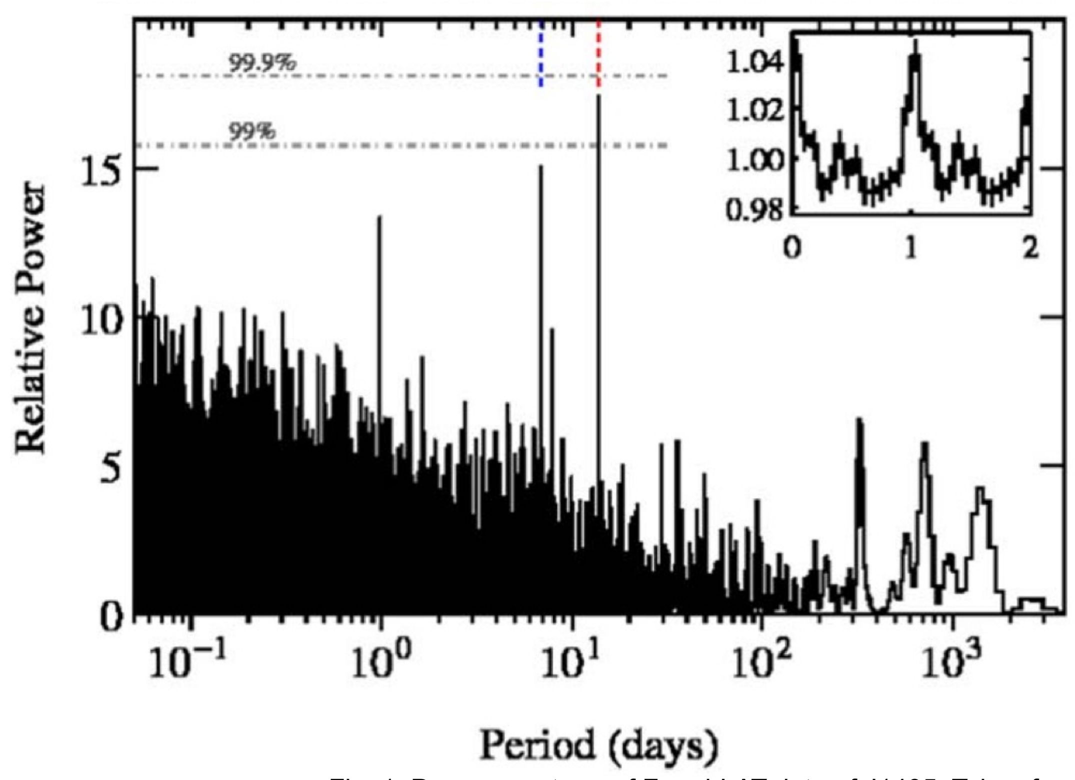


Fig. 1. Power spectrum of Fermi-LAT data of J1405. Taken from [1].

X-ray Analysis

- Two XMM-Newton and NuSTAR Observations are taken at orbital phase 0 and 0.5 (defined by the gamma-ray max and min)
- We find that absorbed power law models are the best fit (tested broken power laws, gaussian emission and absorption features) and no spectral break. X-ray and gamma-ray emission are anti-correlated
- χ^2_{red} values for Phase 0 and 0.5 are 1.03 and 1.15 respectively
- No pulsations from 10^{-5} to 10^{3} Hz found in XMM-PN or NuSTAR observations
- We find orbital variation in the n_H, and slight variation in the spectral index, Γ_X, suggesting a significant change in the binary's geometry

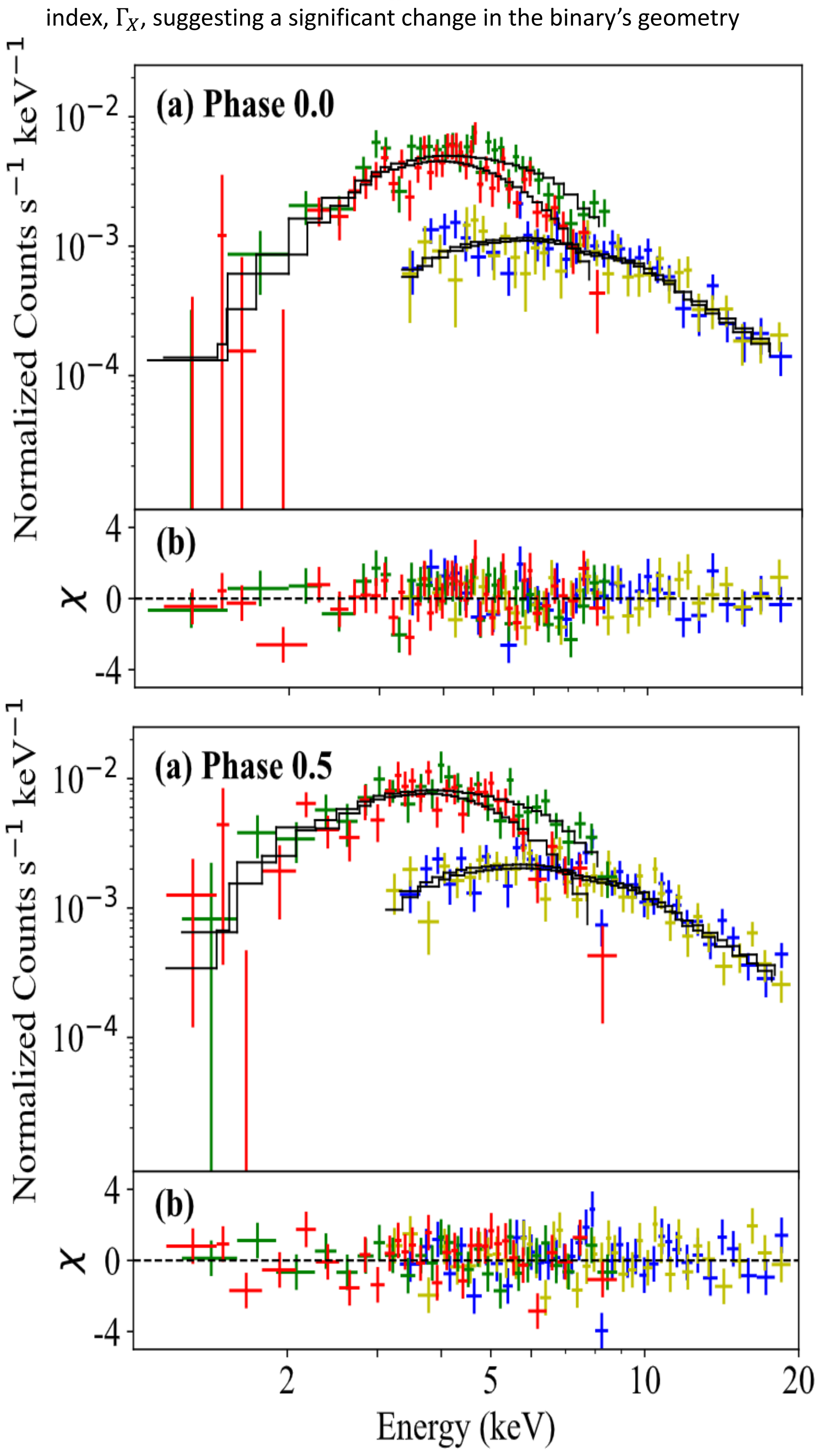


Fig. 2. Joint spectral fits and residuals of Phase 0 and 0.5 for XMM and NuSTAR observations.

Fermi-LAT Analysis

- Dynamic Lomb-Scargle Periodogram (LSP) with 750-day lightcurves (and a 100-day sliding window function) of the aperture photometry data shows the relative strength of the fundamental, 2nd and 3rd harmonics of the orbital period

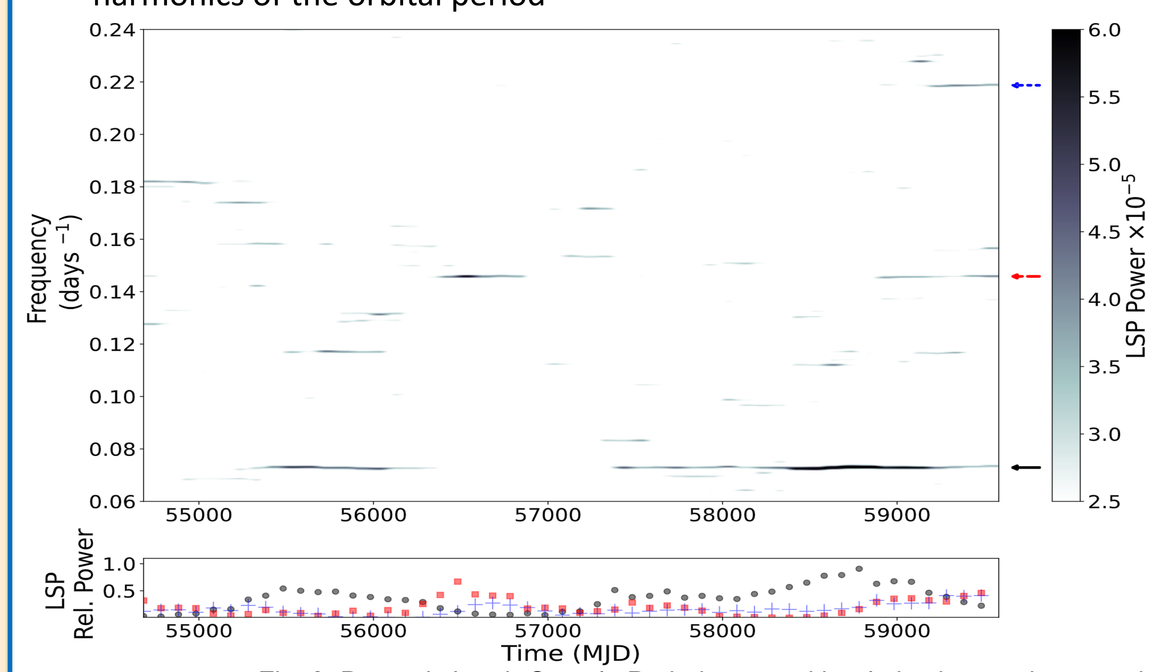


Fig. 3. Dynamic Lomb-Scargle Periodogram with relative harmonic strengths. Black, red and blue arrows point out the fundamental, 2nd and 3rd harmonics.

- In a binned likelihood analysis of 15 years of Fermi-LAT events, we fold the data onto the orbit and separate into 14 phase bins using the 4FGL-DR3 catalog [3] and FermiPy [4]
- Binned likelihood analysis confirms peaked structure [1] is less prominent at phase 0.5 and broadened at phase 0
- Spectral indices appear fairly flat

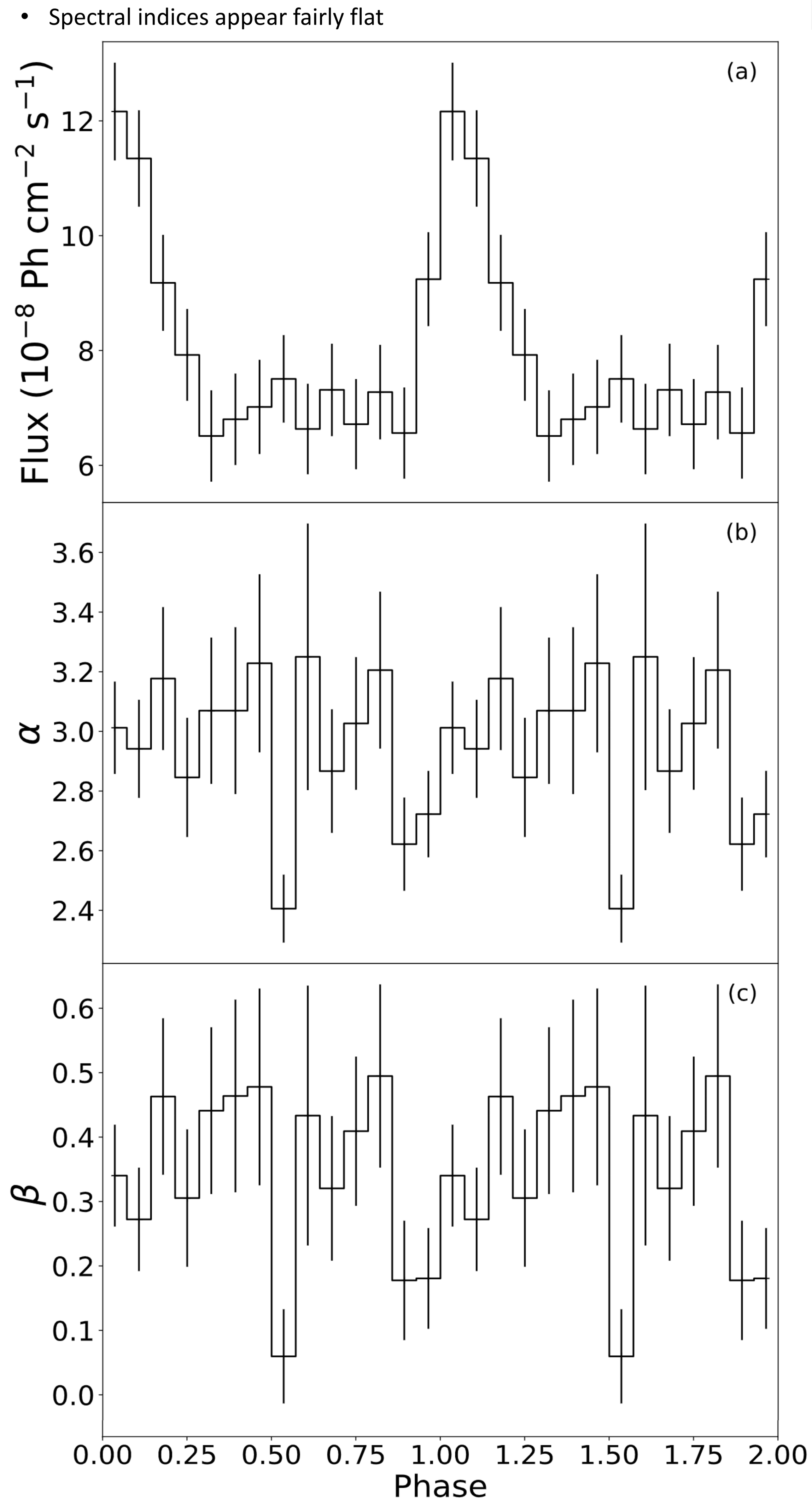


Fig. 4. Orbital phase-folded spectral fits from Fermi-LAT (200 MeV – 500 GeV). Panel (a) corresponds to flux, while (b) and (c) correspond to spectral indices α and β.

- Phase 0 and 0.5 SEDs are extracted and compared from 200 MeV – 500 GeV
- Similar SED spectral behavior, only difference is normalization

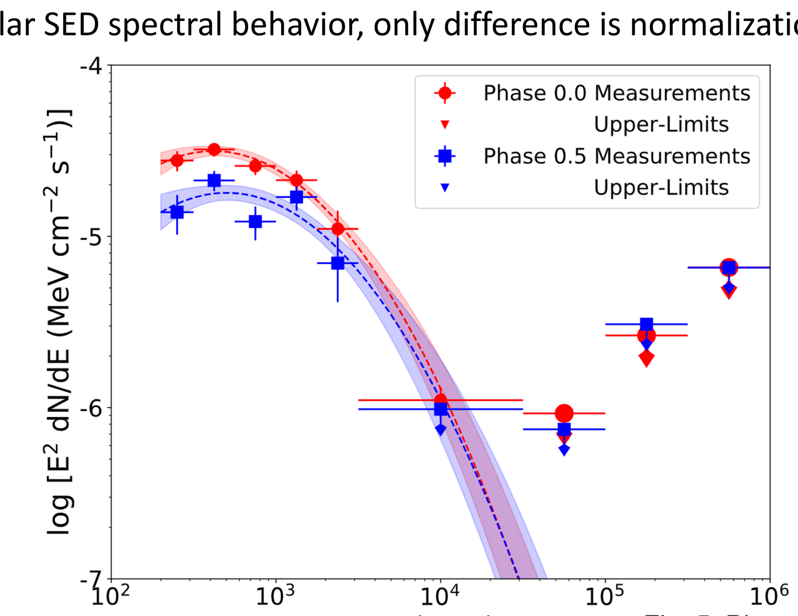
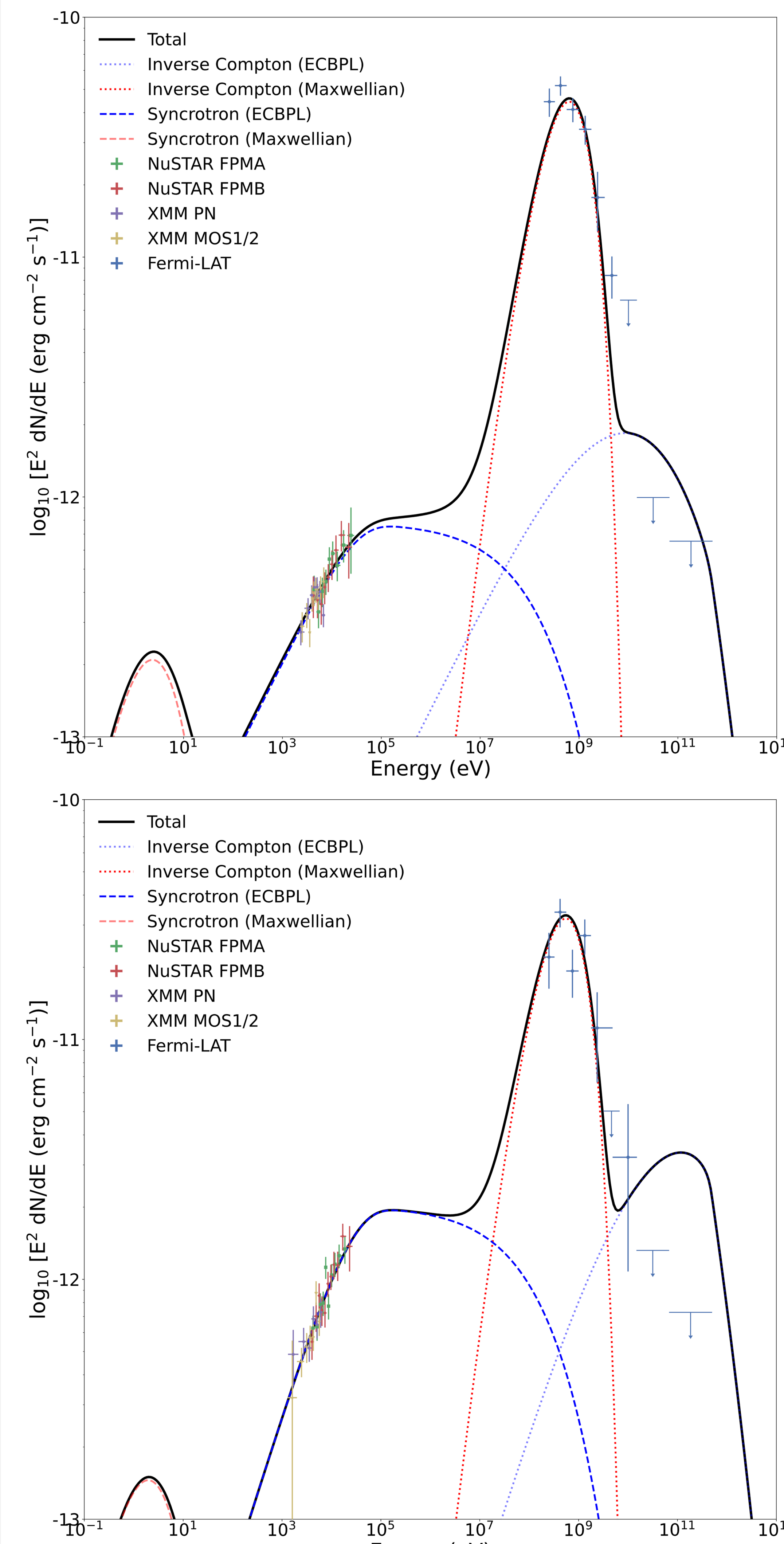


Fig. 5. Phase 0 and 0.5 SEDs.

Broadband Fitting

- We fit the broadband data with an IBS model, based off LS 5039 [5]
- Assuming the IBS is very close to the surface and the NS, and the associated magnetic field is ~ 3 G (due to no detected spectral breaks in X-ray modeling)
- Fit with inverse Compton and Synchrotron components from an Exponential Cutoff Broken power law (ECBPL; modeling the O type companion) and a Maxwellian Distribution (modeling the IBS)
- We find good agreement with these assumptions and only 5 fit parameters



Broadband SEDs fit with an IBS model. Top: Phase 0. Bottom: Phase 0.5.

- χ^2_{red} values for Phase 0 and 0.5 are 1.28 and 1.16 respectively
- Low number of free parameters (5), which is more favorable than the MQ broadband fit from [2]

Summary

- We analyze 2 XMM-Newton and NuSTAR observations taken during the gamma-ray maximum and minimum (defined as phase 0 and phase 0.5) and model the X-ray spectra and search for pulsations
- We find a simple absorbed power law provides the best fit and find no evidence for any other features
- We find no evidence of pulsations within the XMM-PN or NuSTAR data in a wide range of frequencies
- We find evidence that the previously reported 2nd peak in the gamma-rays at phase 0.5 has diminished in significance, and is only apparent during certain periods
- We provide the first gamma-ray phase-resolved spectral fits of J1405
- We model the broadband (X-ray and gamma-ray) data with Inverse Compton and synchrotron components with an exponential cutoff broken powerlaw distribution for the companion's stellar wind and a Maxwellian Distribution for the intrabinary shock
- We find the intrabinary shock model is in good agreement with the data and a significant improvement to the microquasar model presented in [2] with significantly fewer free parameters

Citations:
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[5] G. Dubus *et al* 2015 A&A **581**, A27