Search for periodicities in High Energy AGNs with a time-domain approach

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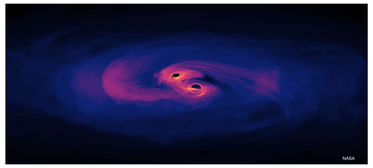
Introduction

· Binary black holes (BH) and super-massive black holes (SMBH) could be responsible for the apparent precession of radio jets and would have detectable periodic modulation of their fluxes.



· Binary BH has become a hot topic due to the detection of gravitational waves from merger events by LIGO and VIRGO and expected future detection of binary SMBH.

· These sources are well identified through their High Energy (HE) emission by detecting periodicities on their light curves. Then, it is necessary to separate the true period from the stochastic noise.

Methodology

Object Selection and Data Analysis

· Sources selected compose a AGN population sub-sample of the 4FGL Fermi-LAT 12 year catalog.

→ Data sub-sample of 27 sources motivated from existing literature on Fermi-LAT periodicities.

· Light curve computation based on a binned likelihood LAT analysis using *enrico* software.

→ Only continuously sampled light curves are considered.

MCMC - Time Series Models

· Different MCMC models are fitted by composition of the following terms.

→ Stochastic noise components:

Auto-Regressive AR(N) + White Noise

$$\phi(t_n) = \bar{\phi} + \sum_k \beta_k \phi(t_{n-k}) + N(0, \sigma)$$

→ Deterministic component: Linear, Sinusoidal, Harmonic

Results

Full Light-Curve *example*: PG 1553+113

· The observed data is the Fermi-LAT logarithmic light curve with systematic 1σ error.

· The fit shows a stochastic noise term, a linear term and a sinusoidal term with a 774 days periodicity.

→ Spectral cross-check: Bayes Factor Periodogram (BFP) computed from Agatha software.

→ The result is compatible with the spectral analysis and with previous literature.

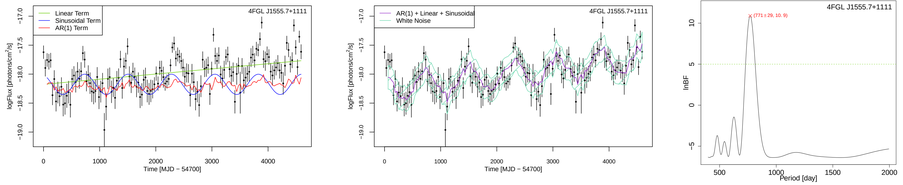


Fig. 2: **MCMC fit components (left); MCMC fit global (center); BFP (right).**

Harmonics *example*: PKS 0301-243

· PKS 0301-243 shows a principal periodic component of 821 days with a second harmonic.

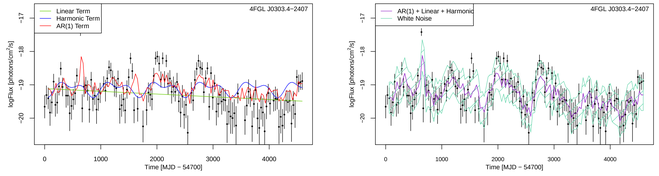


Fig. 3: **MCMC fit components (left); MCMC fit global (right)**

Time-Windows *example*: PKS 2155-304

· The observed data is divided into 5 equally spaced and overlapped time windows.

· To analyze the period change with time and the variation of the sinusoidal amplitude with period.

→ Useful for understanding the physical mechanisms of periodicity in HE emission.

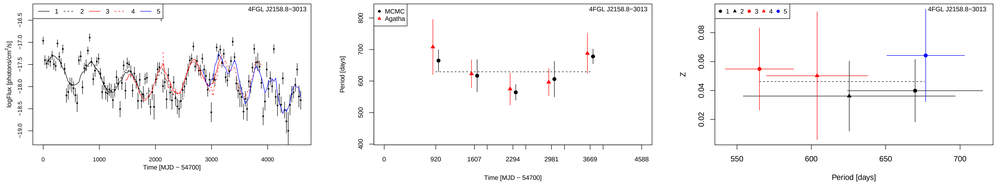


Fig. 4: **For each time window: MCMC fit (left); MCMC and BFP period value (center); MCMC physical amplitude Z value vs period (right).**

Conclusion

1. 14 high-energy source periodicities from 4FGL have been found by a novel method which separates the stochastic and the periodic component.
2. Adding a periodic component can improve significantly the fit to the data compared to an AR noise only model.
3. Adding a AR component can improve significantly the fit to the data compared to white noise models.
4. Time-domain approach is able to analyse harmonics and the evolution in time of periods and amplitudes.
5. All this knowledge helps to better understand the physical mechanism models on the AGN HE emission.

→ **Accepted for publication by *The Astrophysical Journal***

Ongoing Work

Irregularly Spaced Data

· Some sources present irregularly sampled light-curves.

→ Few data points and important time gaps. Problematic for period detection and for Time-Series algorithms.

· New algorithms developed giving good preliminary results.

→ **Paper in preparation.**

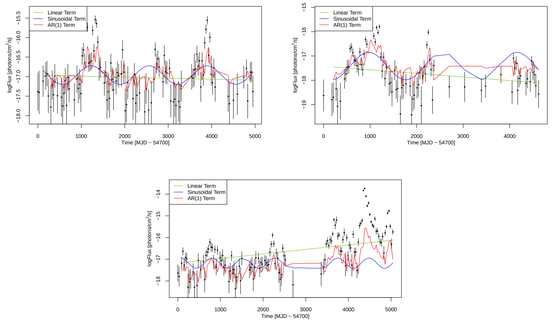


Fig. 5: **MCMC fit components for three irregularly sampled 4FGL sources**