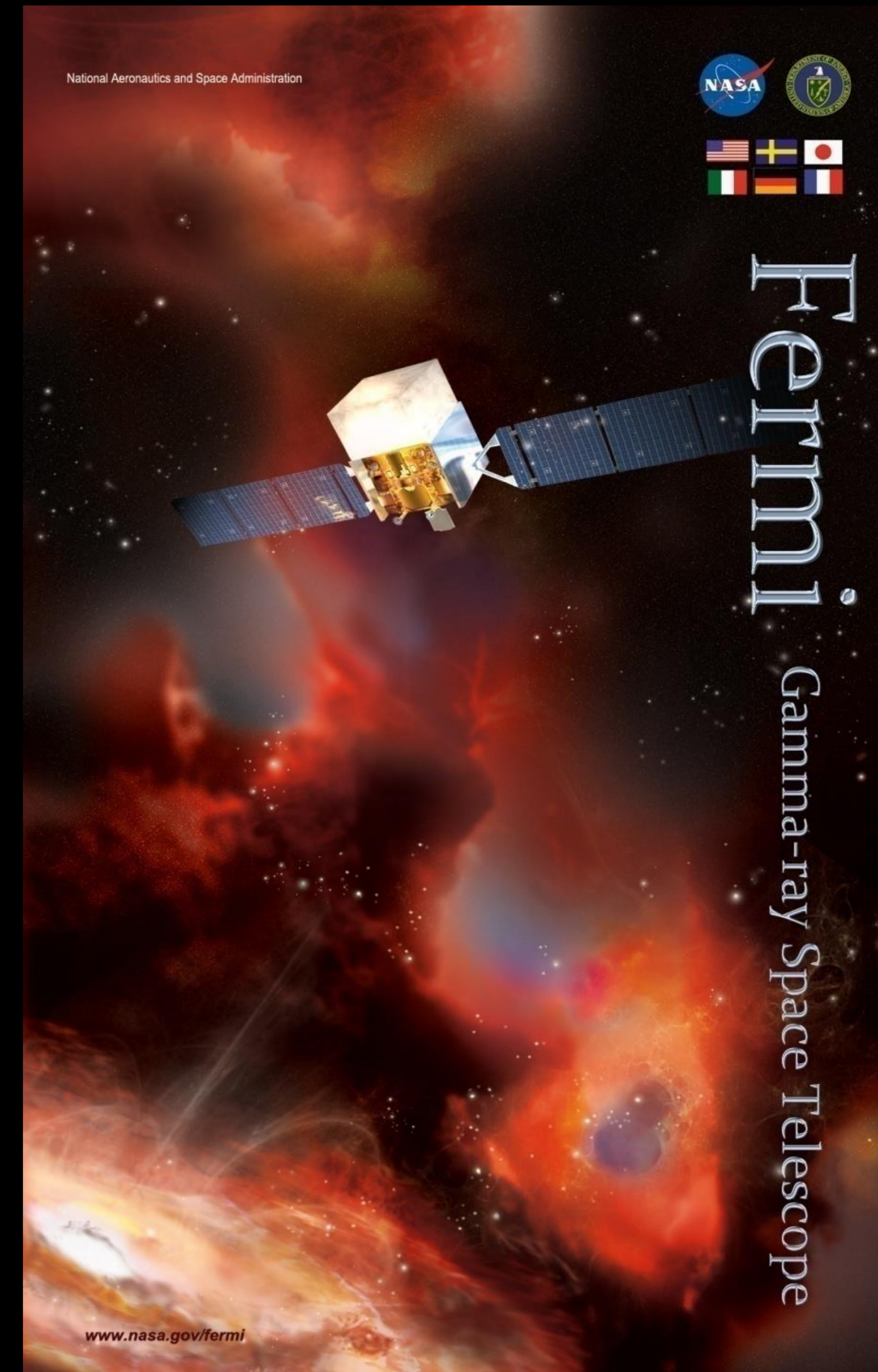


# Systematic search for $\gamma$ -ray periodicity in active galactic nuclei detected by the *Fermi*-Large Area Telescope

P. Peñil<sup>1</sup>, A. Domínguez<sup>1</sup>, M. Ajello, S. Buson, J. Otero, J.A. Barrio<sup>1</sup>, R. Nemmen, S. Cutini, B. Rani, A. Franckowiak, E. Cavazzuti

<sup>1</sup>: IPARCOS and Department of EMFTEL, Universidad Complutense de Madrid, Spain



## ABSTRACT

Active galactic nuclei (AGN) emissions present an intrinsic variability that cover the entire range of wavelengths. Understanding the processes behind this phenomenon will provide a better view about the astrophysical nature of these extragalactic sources. However, the observation of periodicities in  $\gamma$ -ray light curves of AGN is still challenging. Despite the fact that there have been efforts on characterizing the temporal emission of some individual sources, a systematic search that considers large populations is still missing. We use nine years of  $\gamma$ -ray data provided by the *Fermi* Large Area Telescope (LAT) to systematically study the light curves of more than two thousand AGN included in *Fermi*-LAT catalogs. We use several techniques, that are organized in an automatic periodicity-search flow, in order to find evidence of periodic emission in  $\gamma$ -rays. Our analysis results in 23 AGN with evidence of periodicity, of which 18 are new candidates.



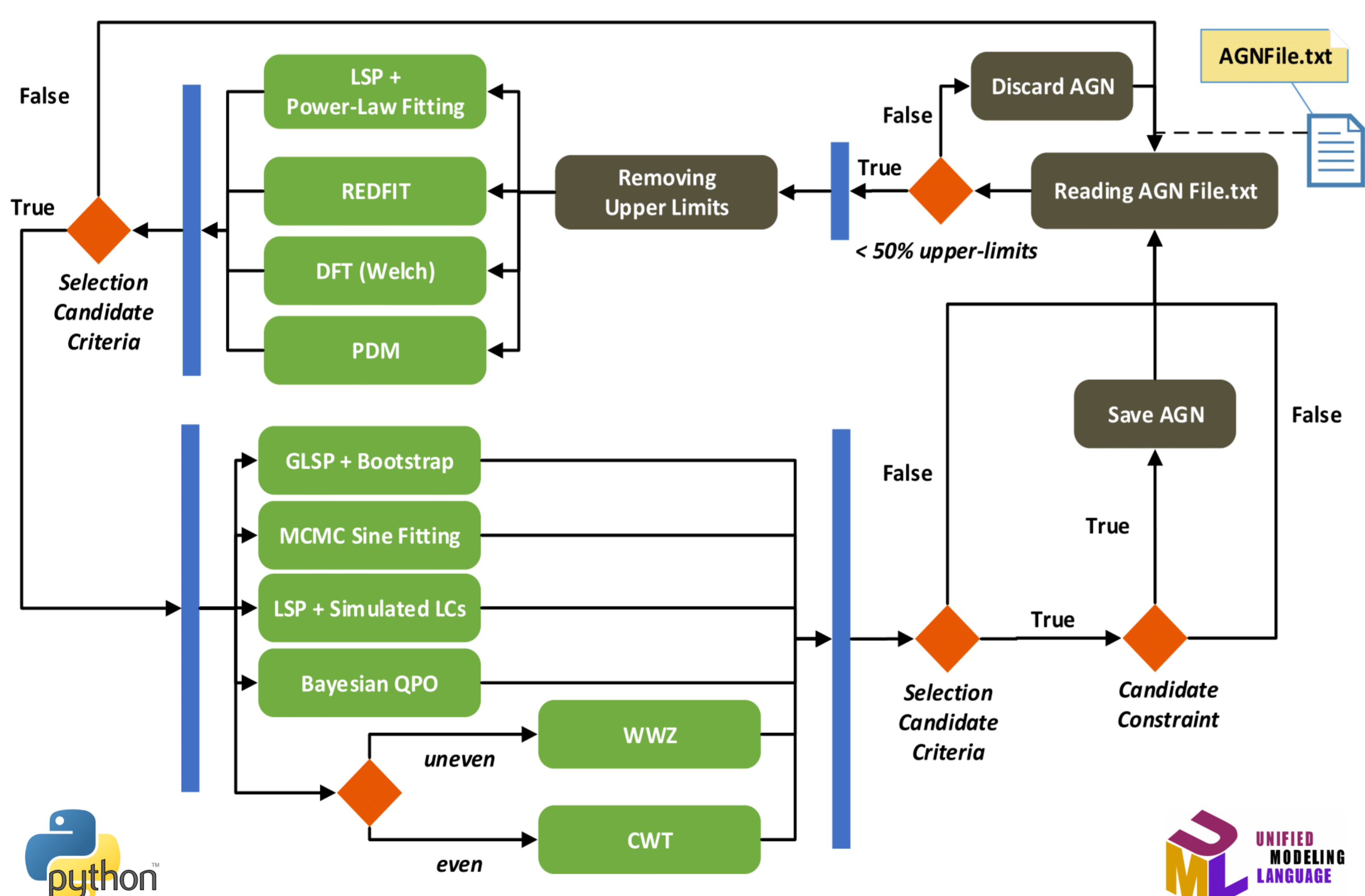
## Introduction

One conclusion after decades of multiwavelength observations is that supermassive black holes (SMBHs) are present at the center of most galaxies. A fraction of these galactic centers have the environmental conditions in terms of a dense accretion disk to feed the SMBH, transforming such objects in powerful emitters known as AGN. These emissions, that tend to be directional in the form of relativistic jets, are characterized by variability at different time scales. The light curves of these sources (a graph of light intensity as a function of time) show temporal behavior, which may or may not display a specific pattern. Possible explanations of periodic behavior in AGN emissions are the existence of binary SMBH, lighthouse effects or modulations in the accretion flow in the jet among others. Different strategies have been employed to detect periodicities in the  $\gamma$ -ray light curves of AGN. The typical approach in the literature consists in analyzing one object by means of applying a few time series algorithms, with a minimum of two for cross-checking. Employing data taken by *Fermi*-LAT, we perform a systematic search for detecting  $\gamma$ -ray periodic emissions in a sample composed of approximately 2300  $\gamma$ -ray sources.

## Pre-Conditions

- 2274 AGN of different types (BL Lac, Flat Spectrum Radio Quasar ...)
- *Fermi*-LAT observations: September 2008-September 2017 and between 20 MeV -  $\approx$ 300 GeV
- Automatic, systematic search
- Target: detect periodic  $\gamma$ -ray emitters

## Periodicity-Search Flow

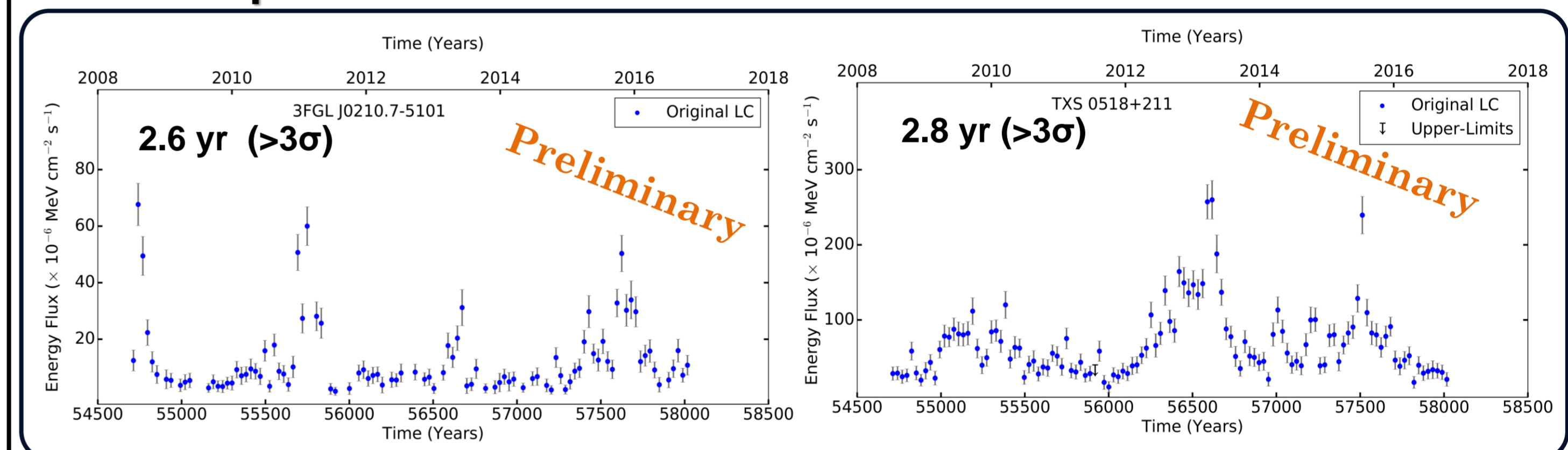


## Complementary Procedures

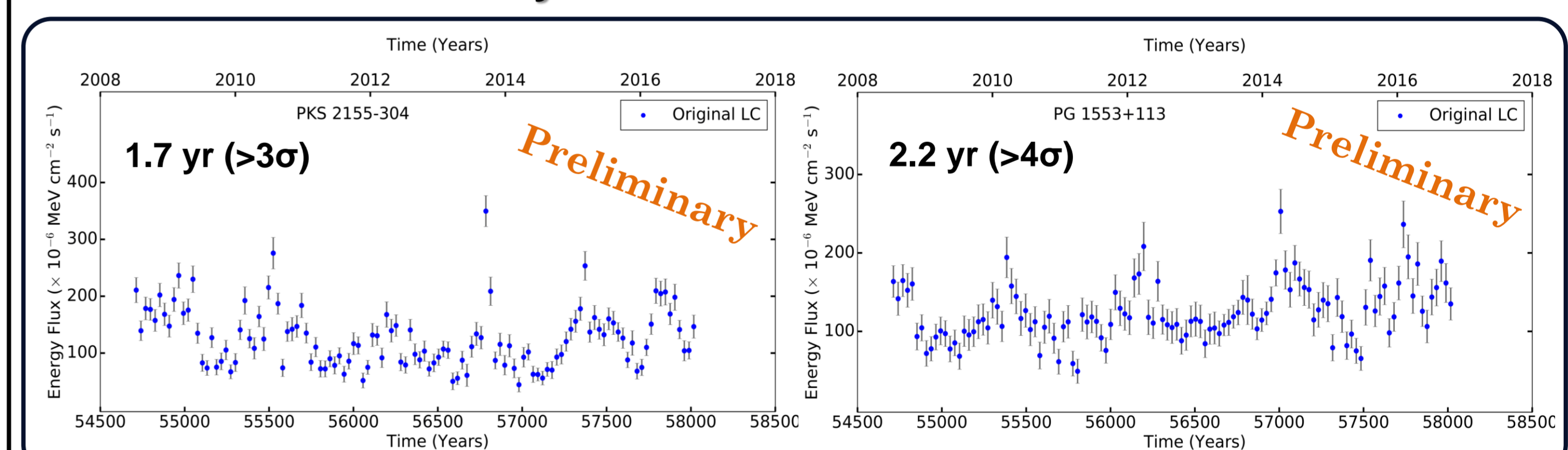
- **False Positive Detection Rate:** infers whether the detection of the periodic-emission candidates is resulting from a random process.
- **$5\sigma$  *Fermi*-LAT observations:** estimates the number of years required to obtain a significance of  $\geq 5\sigma$  for the period detection of each periodic-emission candidate.
- **Flares Detection:** evaluate the impact of the flares in our periodic-emission candidates, we defined a selection criterion to detect those that have high activity states.
- **Upper-Limits Removing Impact:** evaluate the impact in the sensibility after removing the upper-limits in the light curves.

## Results

- ❑ 23 AGN with high evidence of periodic  $\gamma$ -ray emissions
- ❑ 18 new periodic-emission candidates

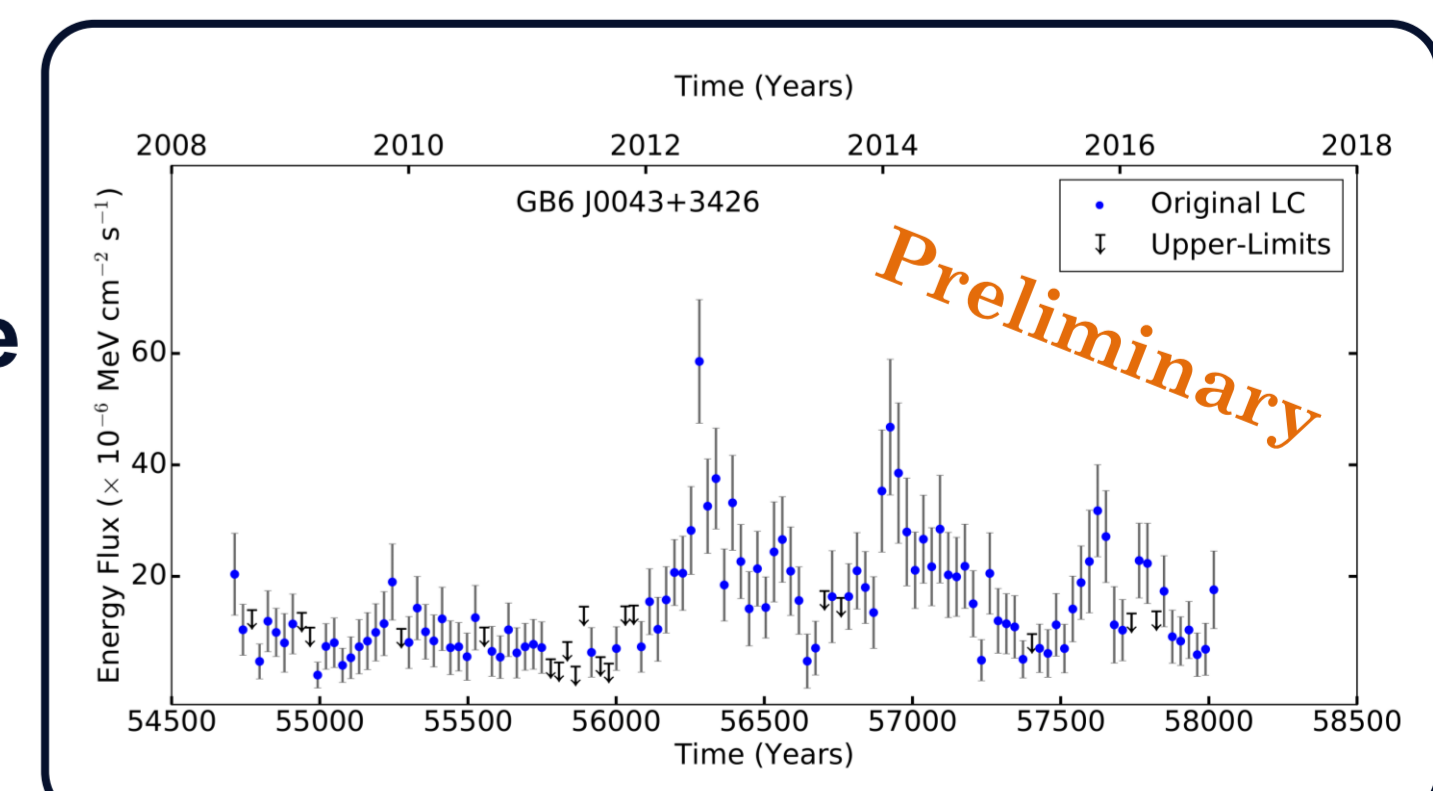


- ❑ 5 previously reported in the literature
- ❑ Different result for S5 0716+71 :
  - ✓ My result  $\rightarrow$  2.8 yr ( $>2.5\sigma$ )
  - ✓ Literature  $\rightarrow$  1 yr



## Complementary Results

- ❑ False Positive Detection Rate  $\rightarrow$  0.15%
  - ❑ 3 detections are false
- ❑  $5\sigma$  *Fermi*-LAT observations
  - ❑ Range 2.5-5 yr
- ❑ Flare Detection: 3 objects whose detection is questionable
- ❑ Upper-Limits Removing Impact
  - ❑ Loss of sensitivity:
    - ✓ significance: 10%-40%
    - ✓ period: 5%-30%
- ❑ Asymmetric light curves



## Summary and Conclusions

We have systematically studied  $\approx$ 2300  $\gamma$ -ray AGN with *Fermi*-LAT data. The result is the detection of 23 candidates with periodic behavior thanks to an original search flow we developed. Only 5 of these sources were previously found to have periodic emissions.