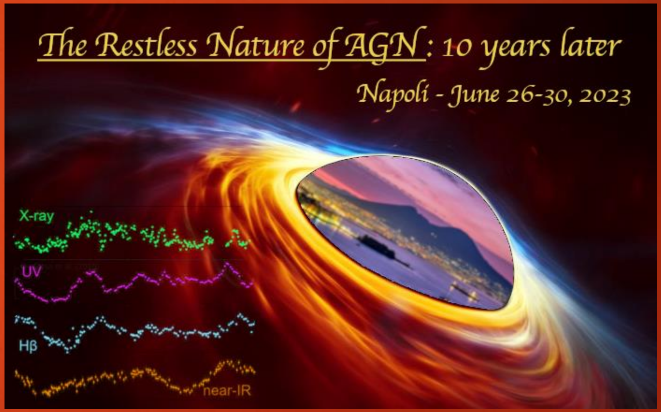
UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

INAF ISTITUTO NAZIONALE DI ASTROFISICA

The Restless Nature of AGN: 10 years later

Napoli – June 26-30, 2023

Centro Congressi Federico II



Unveiling the periodic variability patterns of the multiwavelength light emission from the blazar PG 1553+113

by Tommaso Aniello

Colls: L. A. Antonelli (supervisor), F. Tombesi (University supervisor), F. G. Saturni, A. Lamastra, A. Stamerra, F. Verrecchia, M. Perri, R. Middei and OAR VHE Team

What are Blazars?

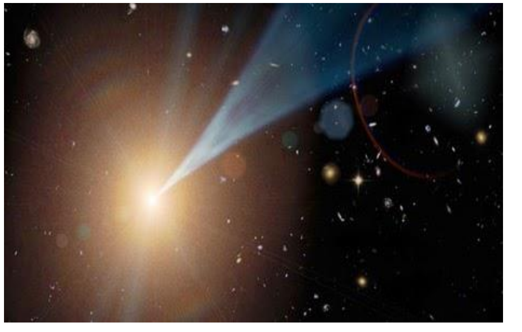
✓Powerful extragalactic sources with emission across the entire electromagnetic spectrum

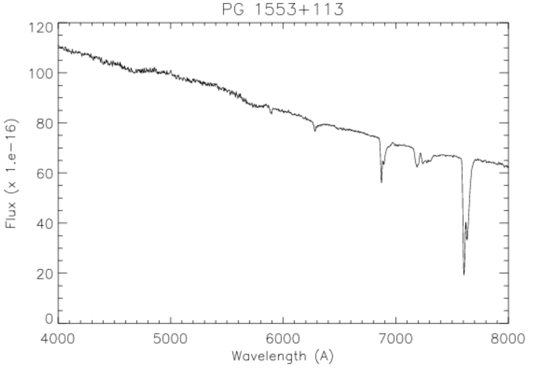
✓Highly variable sources, often with rapid fluctuations in brightness on short timescales (even less than 1 day), and usually from hours to a few months

✓Optical spectra almost without emission lines

✓Polarized emission and highly variable polarization

✓Presence of a relativistic jet pointed almost directly towards Earth

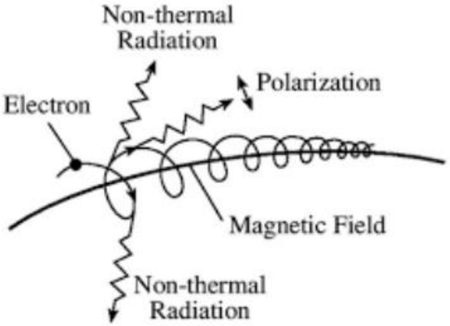


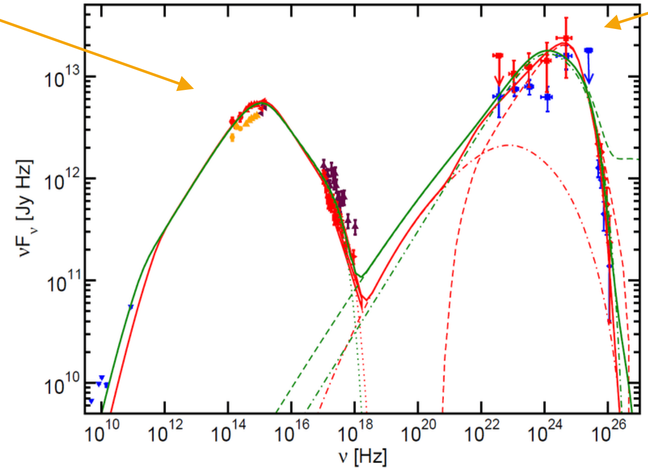


What are Blazars?

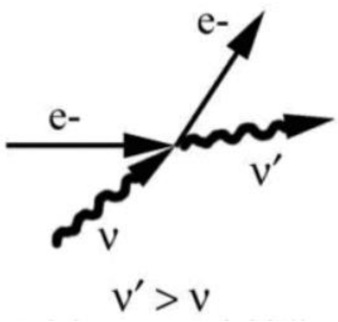
Synchrotron emission

Inverse Compton effect



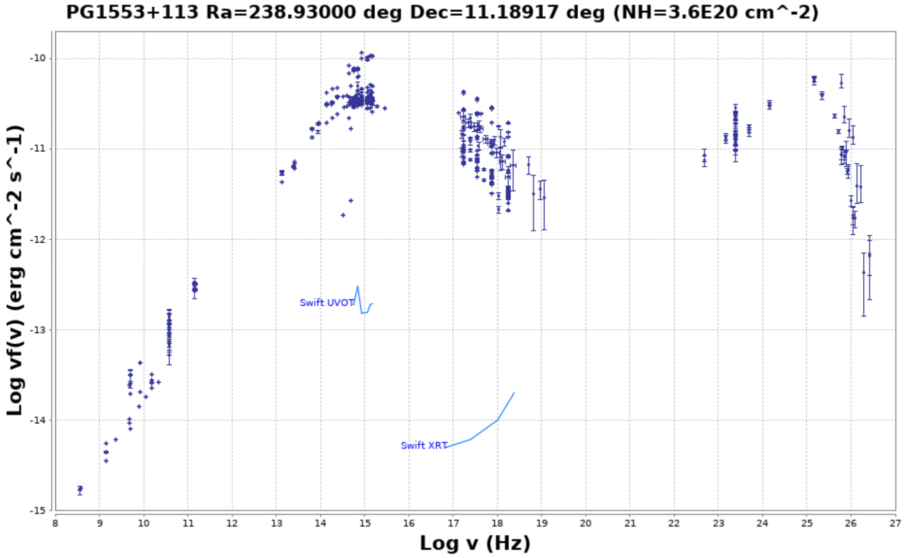


Typical spectral energy distribution (SED) of Blazars



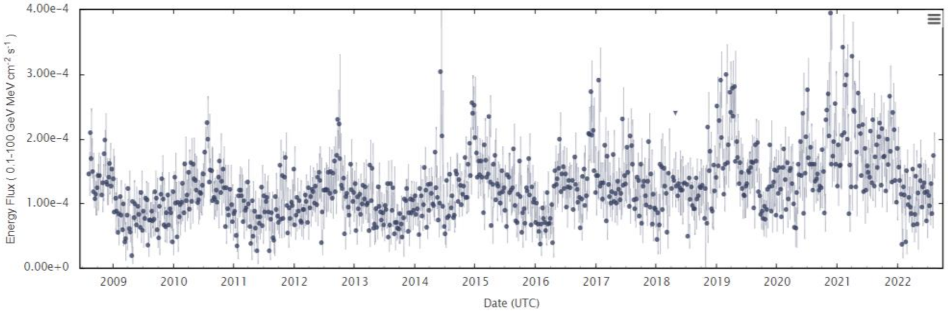
PG 1553+113

- ✓ PG 1553 + 113
  - blazar (optical magnitude V ~ 14.5)
  - HBL (High-energy peaked BL Lac)
  - redshift z ~ 0.4-0.5 (Danforth+ 2010)



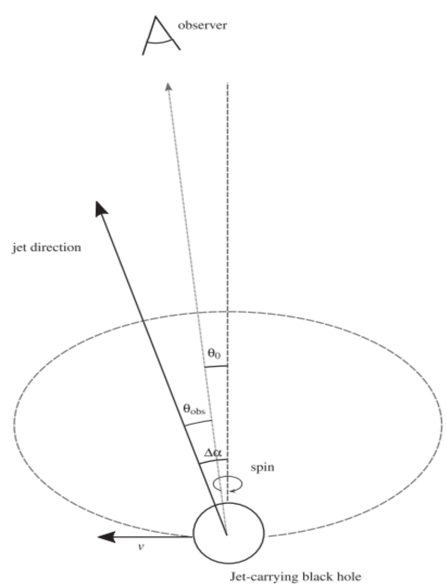
  - evidence of periodicity of ~2.2 years at different wavelengths (Fermi-LAT 2015, Sobacchi+ 2017)

(https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/source.html?source_name=4FGL_J1555.7+1111)



PG1553+113 periodicity scenarios

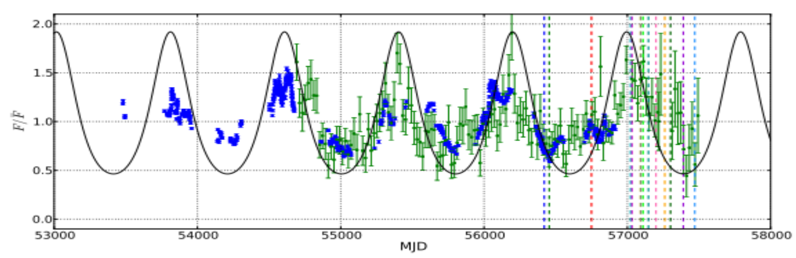
- ✓ **jet precession, helical jet or gravitationally affected jet (Sobacchi et al. 2017)**



To fit the gamma-ray and optical light curves the **jet precession model (Sobacchi et al. 2017)** is considered.

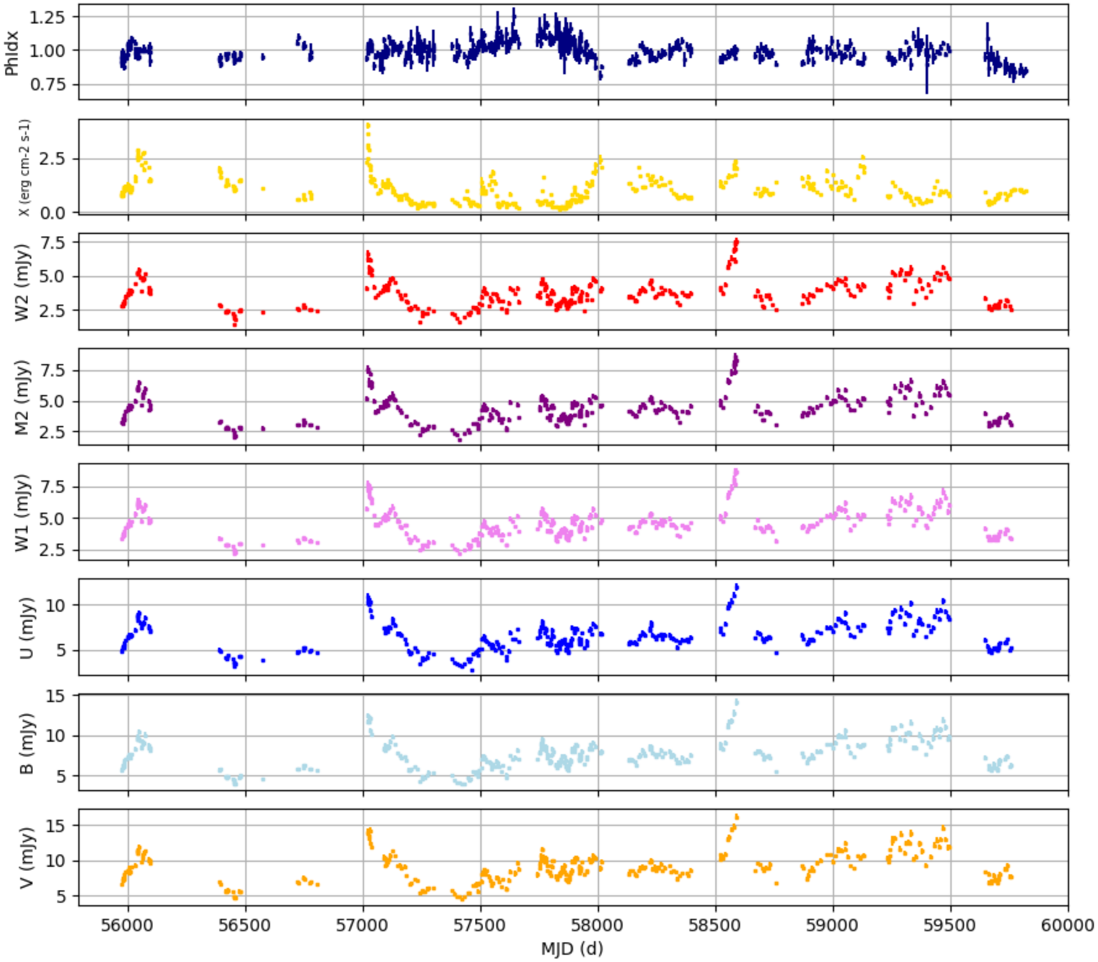
This scenario is based on a binary super-massive black hole system in which one of the two SMBHs produces a jet.

T~2.2 years



X-ray analysis of PG 1553+113

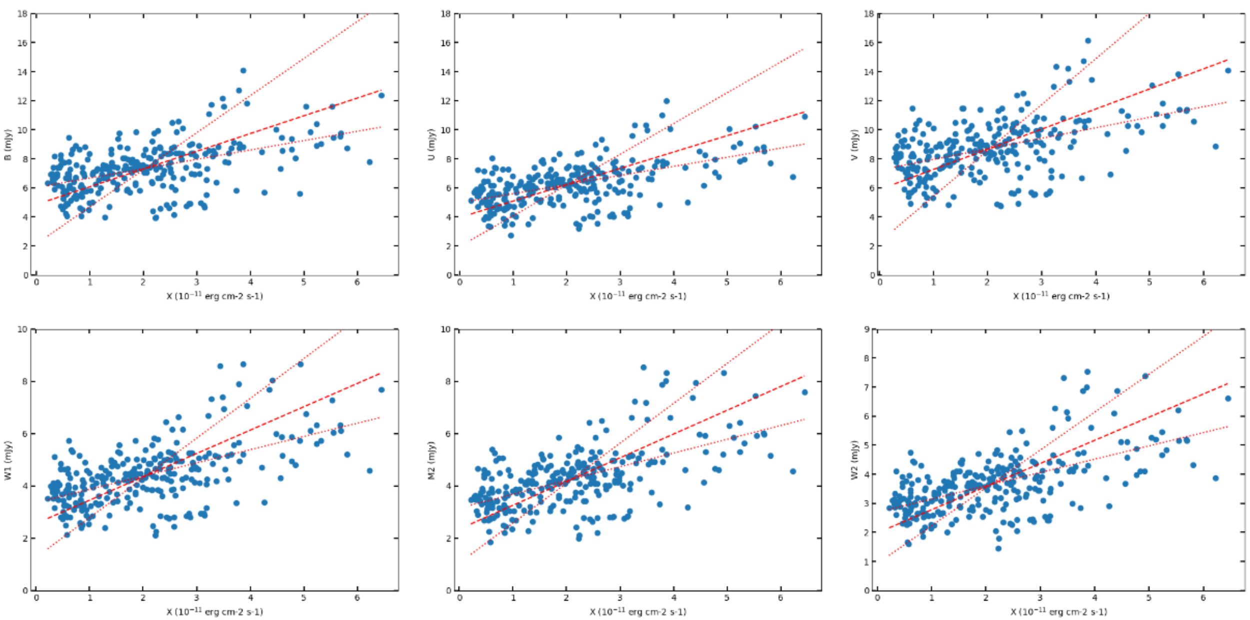
- ✓ The Swift satellite, which was launched in 2004 carries the X-ray telescope (XRT; sensitive 0.2-10 keV) and the UV/Optical Telescope (UVOT; sensitive 170-600 nm)



X-ray light curve - data from Swift X-Ray Telescope (XRT) from 2012 to 2022, obtained both from ASI-SSDC and by running SWIFT XRT pipeline from HEASARC software Xspec; there is considerable variability and a possible periodicity that we studied in last months.

X-ray/UV-optical correlation

Optical-X



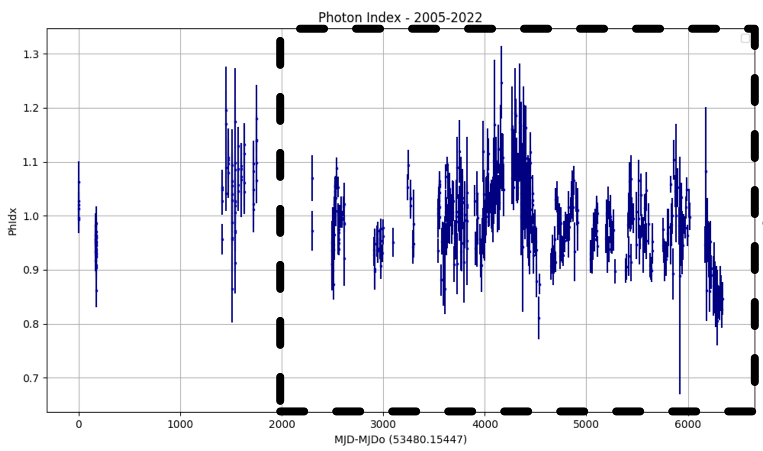
UV-X

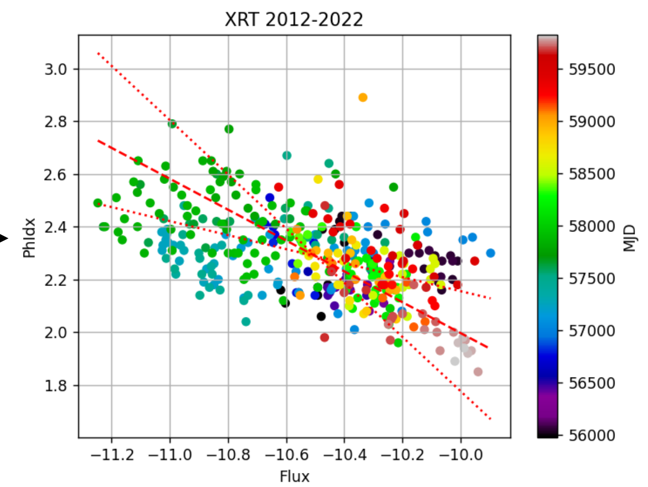
We used the ASI-SSDC Swift UVOT data, comparing them with the XRT data (0.5-10 keV). We found moderate correlations among the different bands.

Correlation	Pearson coeff.	Degrees of freedom
U/X	0.54	265
B/X	0.50	264
V/X	0.48	254
W1/X	0.57	279
M2/X	0.58	269
W2/X	0.60	278
X PhIdx/flux	0.51	303

X-ray Photon Index – Flux ratio of PG 1553+113

- ✓ The photon index is slightly variable and there is evidence of an anticorrelation beetween the photon index and X-ray flux (Pearson index r=-0.51 with p(>r)=3.6e-24) → "harder when brighter" behavior common in Blazars.
- ✓ This behaviour is associated to a shift to high energy of the synchrotron peak during flares, meaning that more energetic electrons are responsible for the bulk of the emission

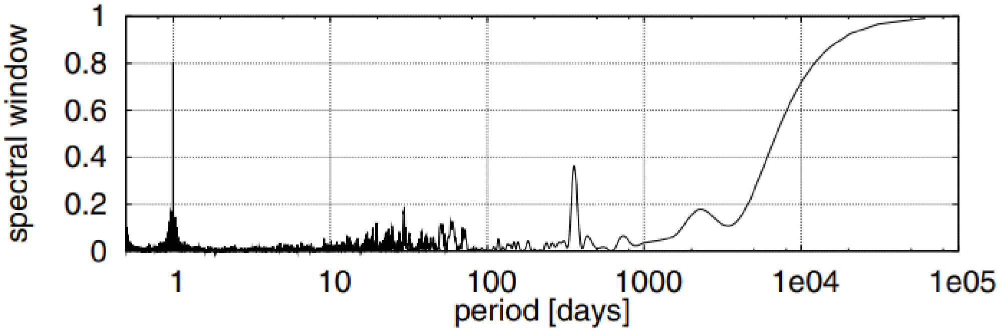


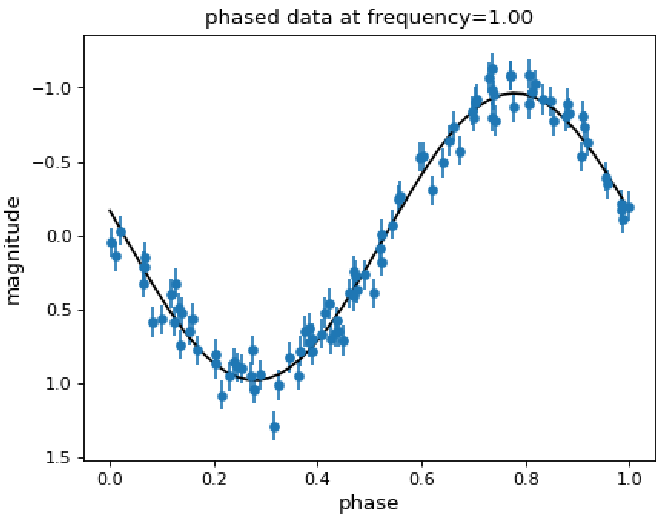


Lomb-Scargle analysis

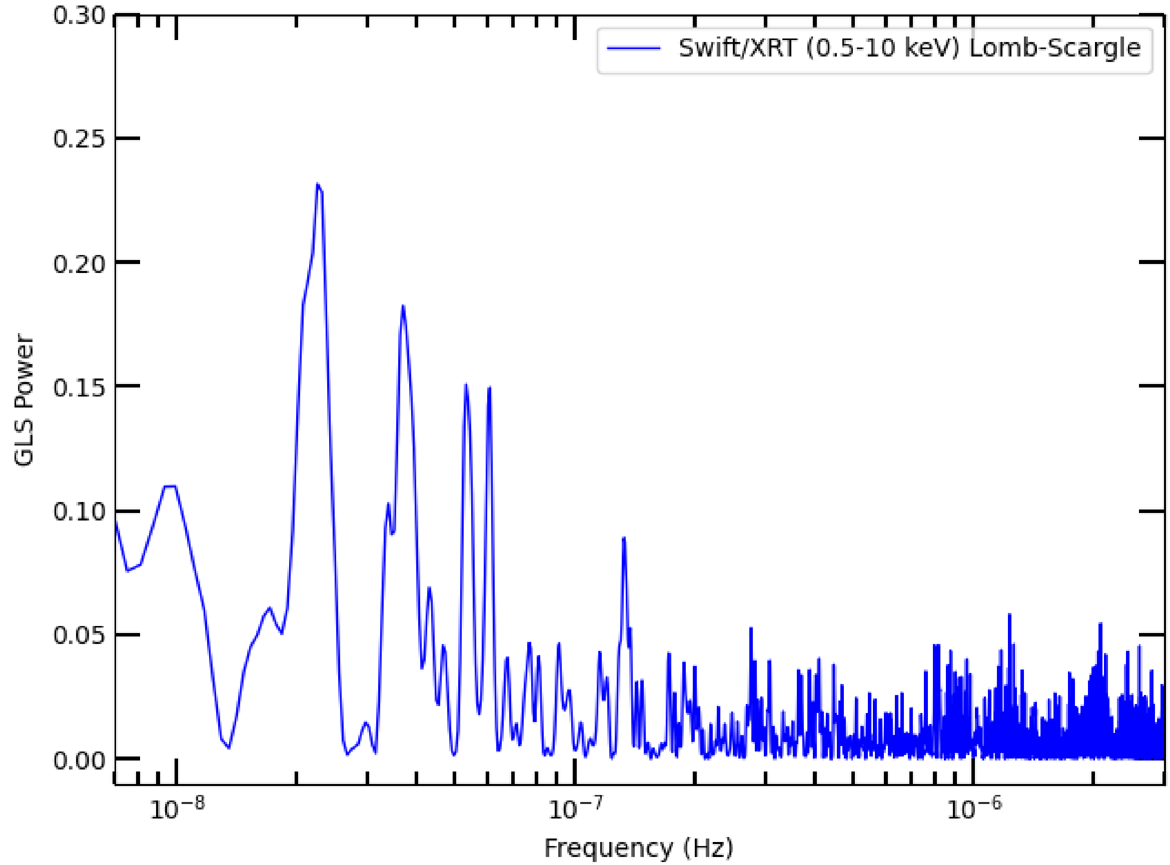
To investigate the possible periodic behavior of the X-ray, UV and optical emissions in PG1553+113, we employed the Lomb-Scargle method (Lomb 1976; Scargle 1982).

The Lomb-Scargle periodogram is a widely used technique for analyzing irregularly sampled time-series data and searching for periodic signals. It provides a powerful tool to identify and characterize periodic variations in astronomical datasets, even in the presence of unevenly spaced or gaped observations (Baluev 2008).



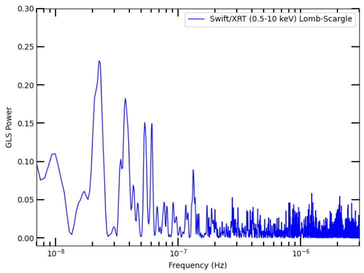


Lomb-Scargle analysis



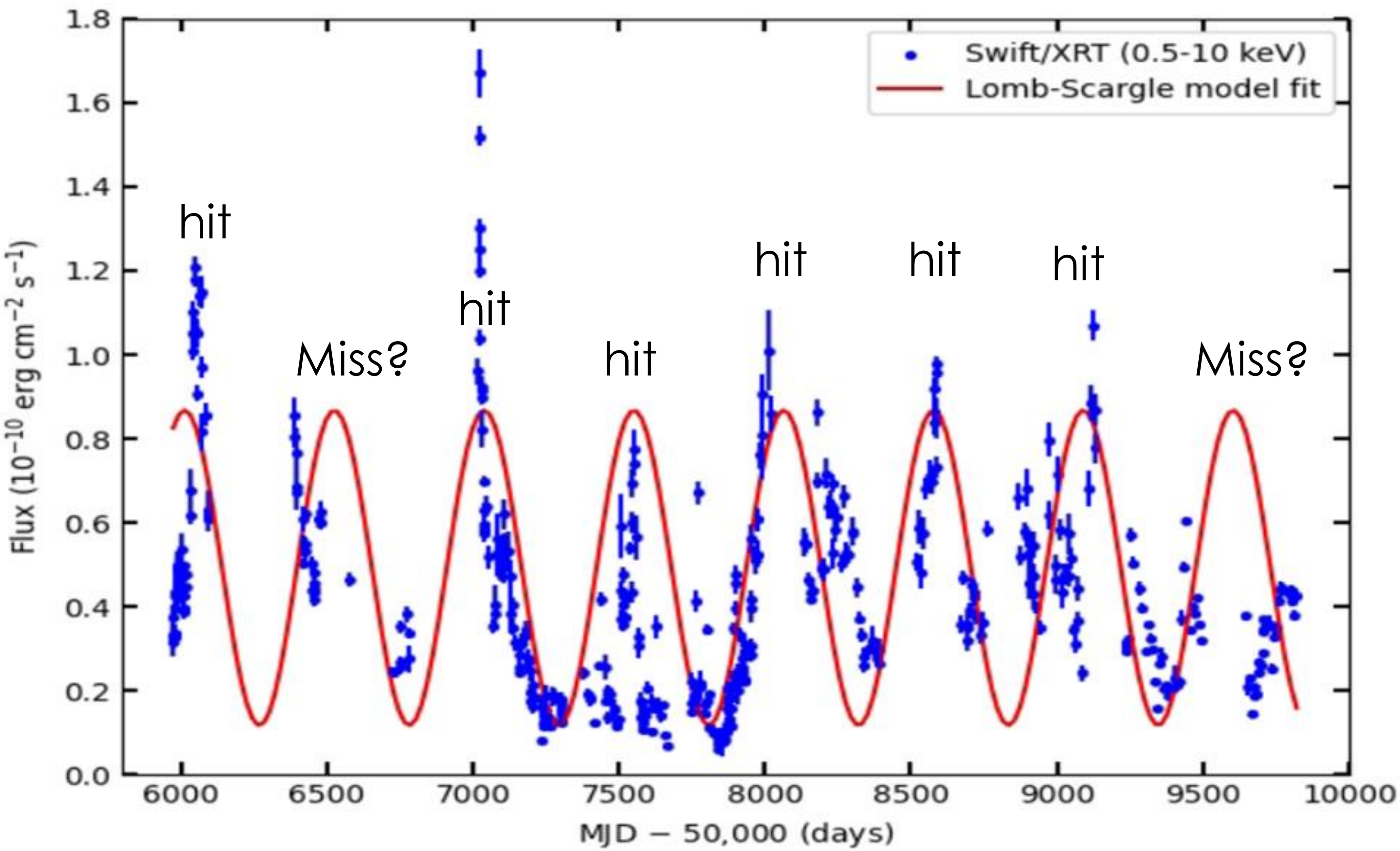
peakfrequency: 2.3e-08 Hz
1.4 years
significance: 5.1

Lomb-Scargle analysis

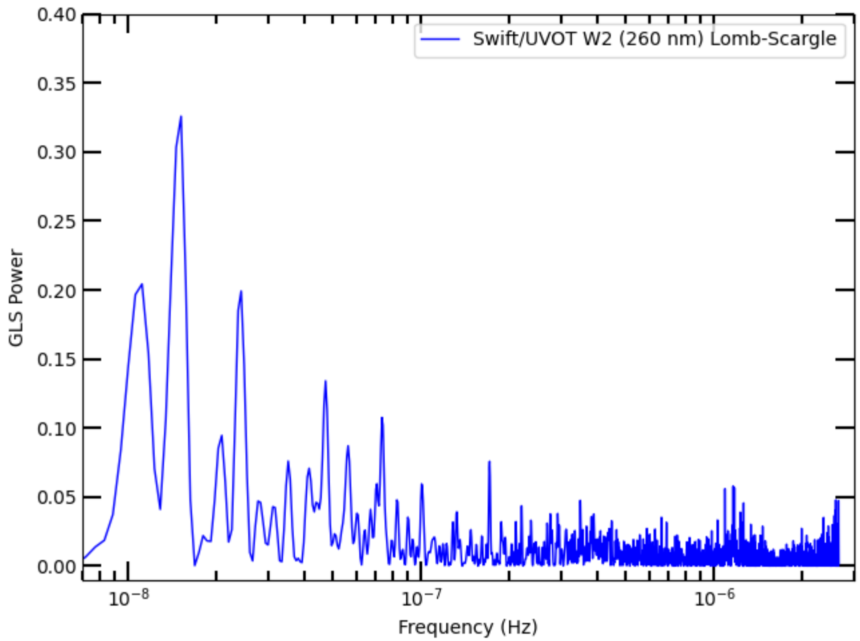


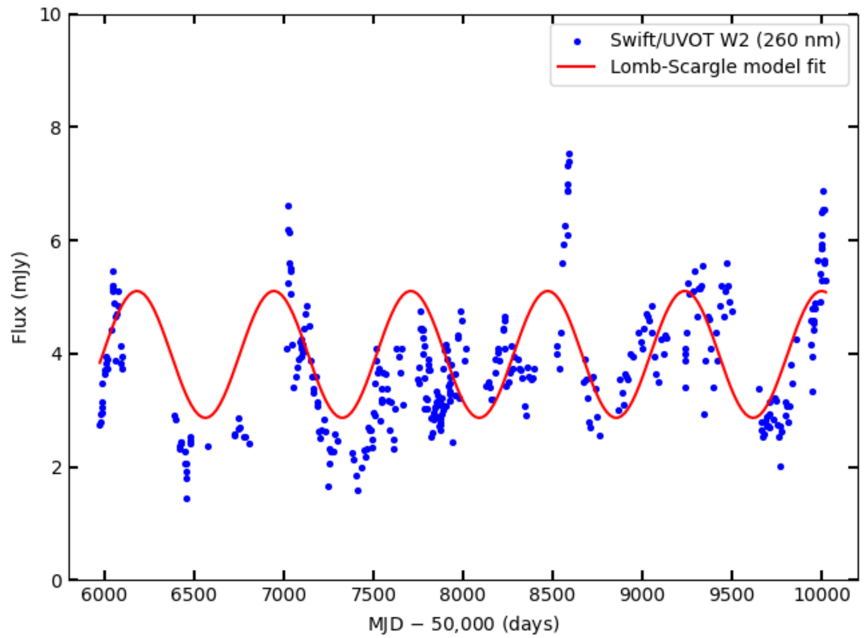
peakfrequency: 2.3e-08 Hz
1.4 years
significance: 5.1

Sine peaks compatible with flares of the source



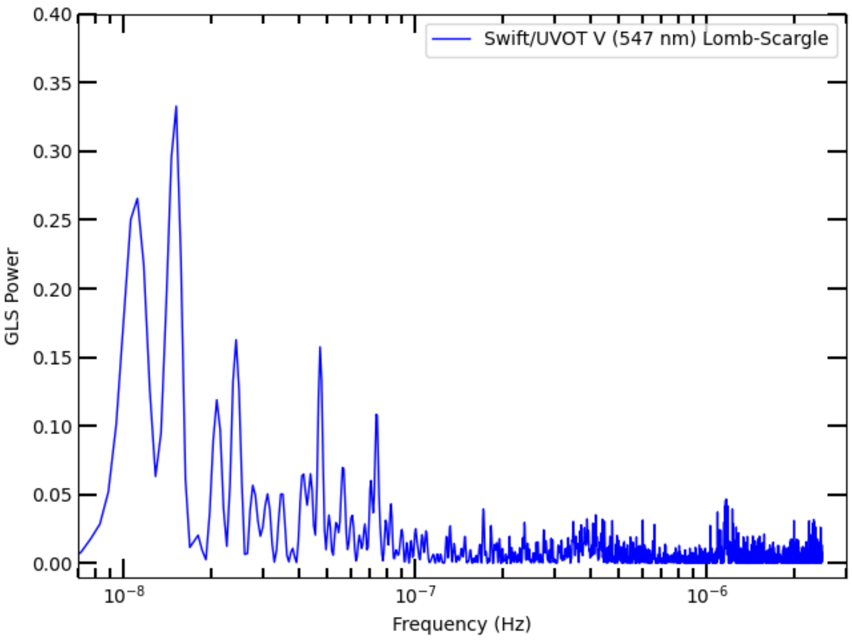
Lomb-Scargle analysis

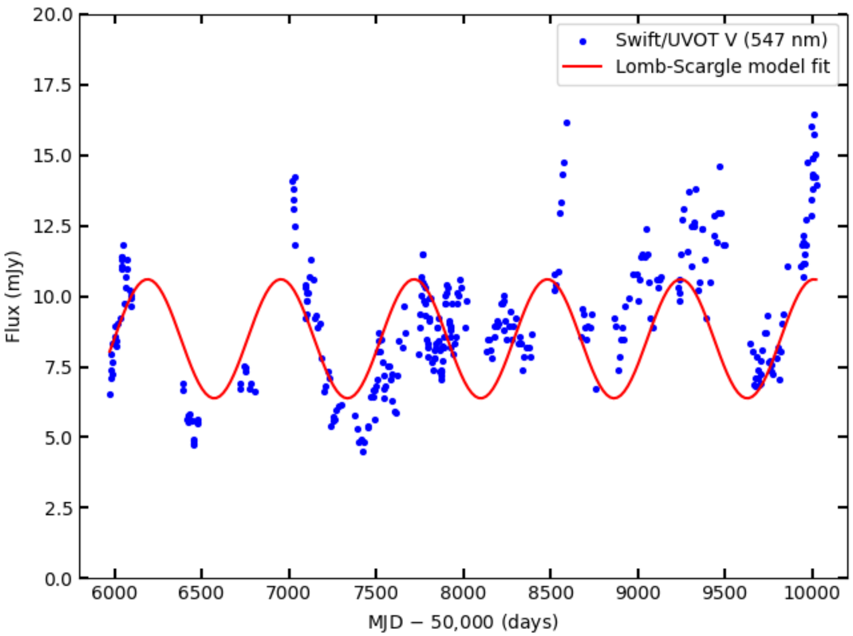




peakfrequency: 1.5e-08 Hz
2.1 years
significance: 5.8

Lomb-Scargle analysis





peakfrequency: 1.5e-08 Hz
2.1 years
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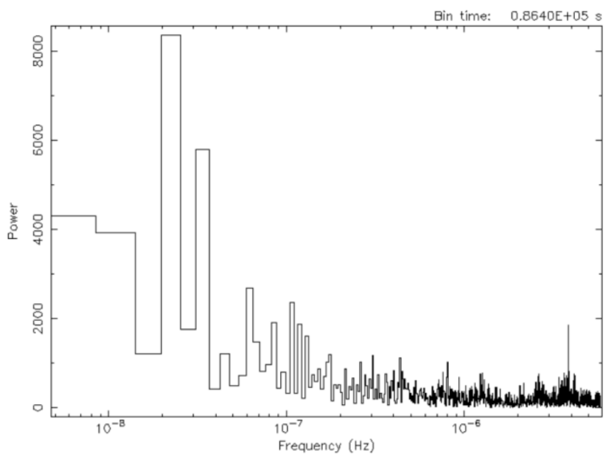
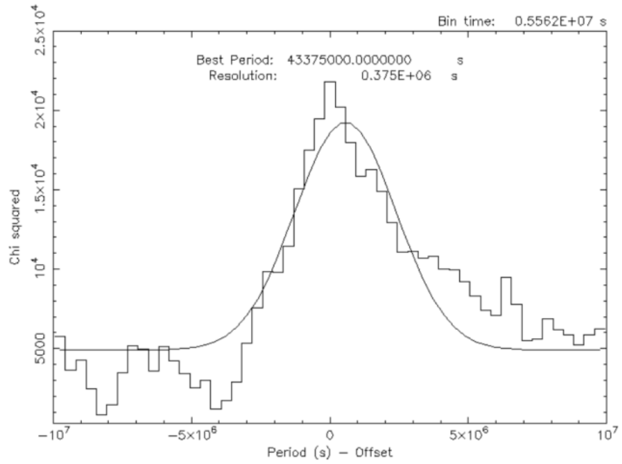
Xronos analysis





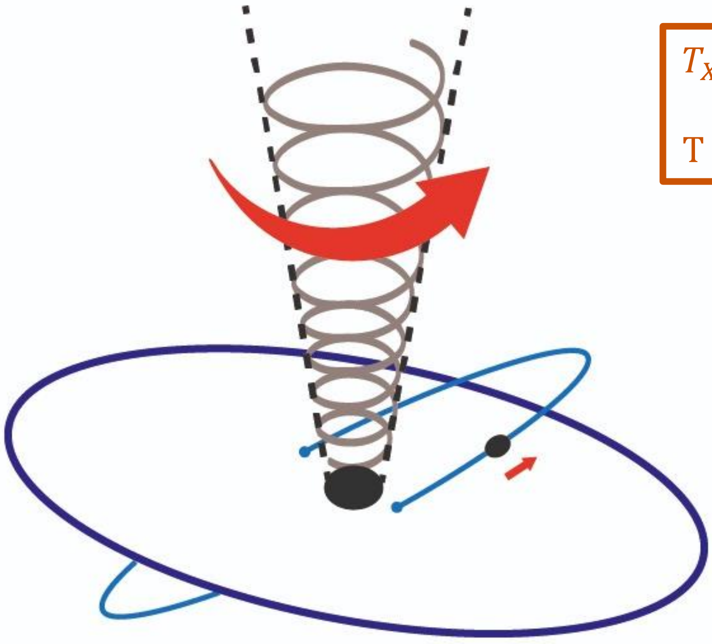
- ✓ Xronos:
  - software package created by NASA-HEASARC
  - designed for the analysis of high-energy astrophysics data
- ✓ powspec (power spectrum) method:
  - analysis tool to analyze spectrum and time-series data
  - measures the distribution of frequencies in a dataset
- ✓ Application to the optical and UV bands:
  - returns the results already found by previous researches at these wavelengths

- ✓ Application to X-rays:
  - confirms the results of the Lomb-Scargle analysis
- ✓ the width of the peak of the efsearch method gives us the uncertainty on the period of about 0.2 years

Proposed scenario

- the secondary BH orbits around the main central engine, perturbing the X-ray emitting region with a 1.4-yr period

- The jet is carried by the main BH, and precedes with a 2.2-yr period



$T_X \sim 1.4 \pm 0{,}2$ yr

$\mathrm{T}_{\gamma UVopt} \sim 2.2$ yr

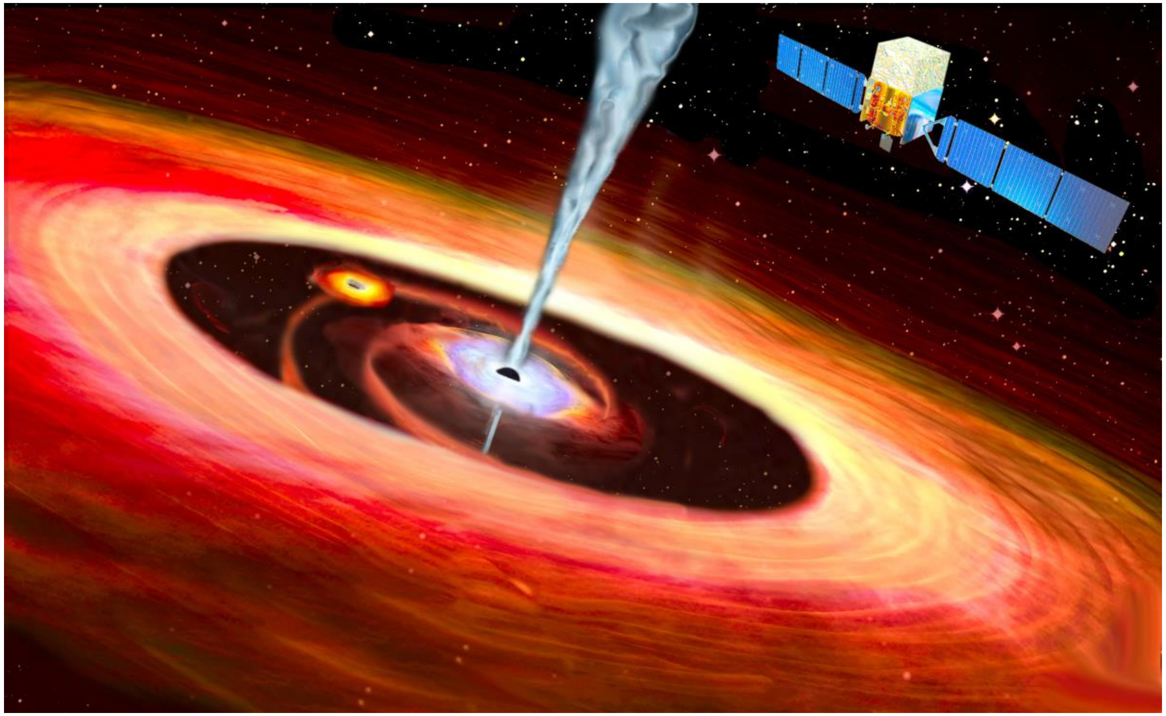
Conclusions

PG 1553+113

- ✓ XRT and UVOT data analysis
- ✓ The X-ray light-curve shows a different period from that found in optical/UV and gamma-ray bands
- ✓ Current scenarios do not properly explain the periodicity of the X-ray emission
- ✓ the difference in period could be due to different emission zones in the internal regions of the SMBH which are not completely superimposed and therefore behave differently or to a second BH which somehow influences the central zone of the first giving rise to an emission X with a different period
- ✓ Future polarimetric studies should ideally be carried out as well (e.g. using IXPE data).

T_X~1.4 +- 0,2 yr
$T_{\gamma UVopt}$~2.2 yr

Thank you for the attention



Credits: NASA's Goddard Space Flight Center/CI Lab