Study of periodicity in Blazar light curves observed by Fermi LAT

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γ 2022
7th Heidelberg International Symposium on
High Energy Gamma-Ray Astronomy
Barcelona, July 4-8 2022

Abstract

Long term periodicity in gamma-ray Blazar light curves could be linked to the innermost zone of the complex structure of AGN, like possible presence of binary system of supermassive black holes [1], or it could shed light on the origin of gamma-rays emission.

The work analyses 1525 sources, whose 14 years light curves come from the Fermi LAT Repository[1] (LCR), making use of Lomb-Scargle Periodogram (LSP) [2][3] and wavelet weighted Z transform (WWZ) [4].

All the available possibilities for the light curves in the LCR, such as different temporal samplings and the use of photon flux and energy flux, are taken into account in order to ensure more reliable results.

We found out high significance periodicity in less than 1% of the sources considered, and in few other sources hints of possible periodicity.

Our results are compliant with the findings of recent literature [5][6] focused on searches of periodic modulation in AGNs.

[1] https://fermi.gsfc.nasa.gov/ssc/data/access/lat/LightCurveRepository/

Analysis

The first method used is the LSP, in addition to the changes introduced by Scargle [2] for the classical periodogram, we included some practical consideration of Vanderplas [3] related to significance and uncertainty. The second method used is a wavelet transform for discrete and uneven spaced time series [4], this one allows the study of temporal evolution of periodicity. These methods were validated through periodic light curve simulations.

Neither method allows finding uncertainty, because it is proportional to period, or direct significance of the periodicity found. For this reason, we use the False Alarm Probability (FAP): the probability that data consisting in pure noise will lead to a peak of a similar magnitude.

The most reliable method for the FAP is Bootstrap, based on randomization of the time series, but it has a high computational cost. The Naive method underestimates the FAP. In the analysis of the entire catalog, we chose Baluev method, in that overestimates the FAP, as it is shown in Figure 1, and it is faster.
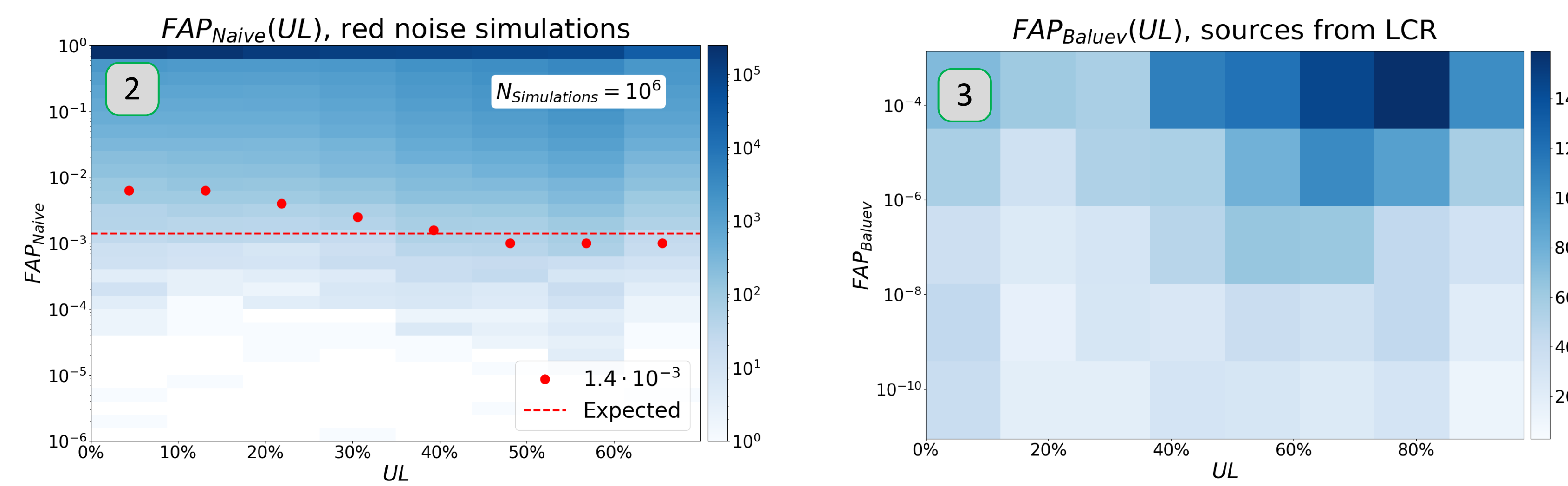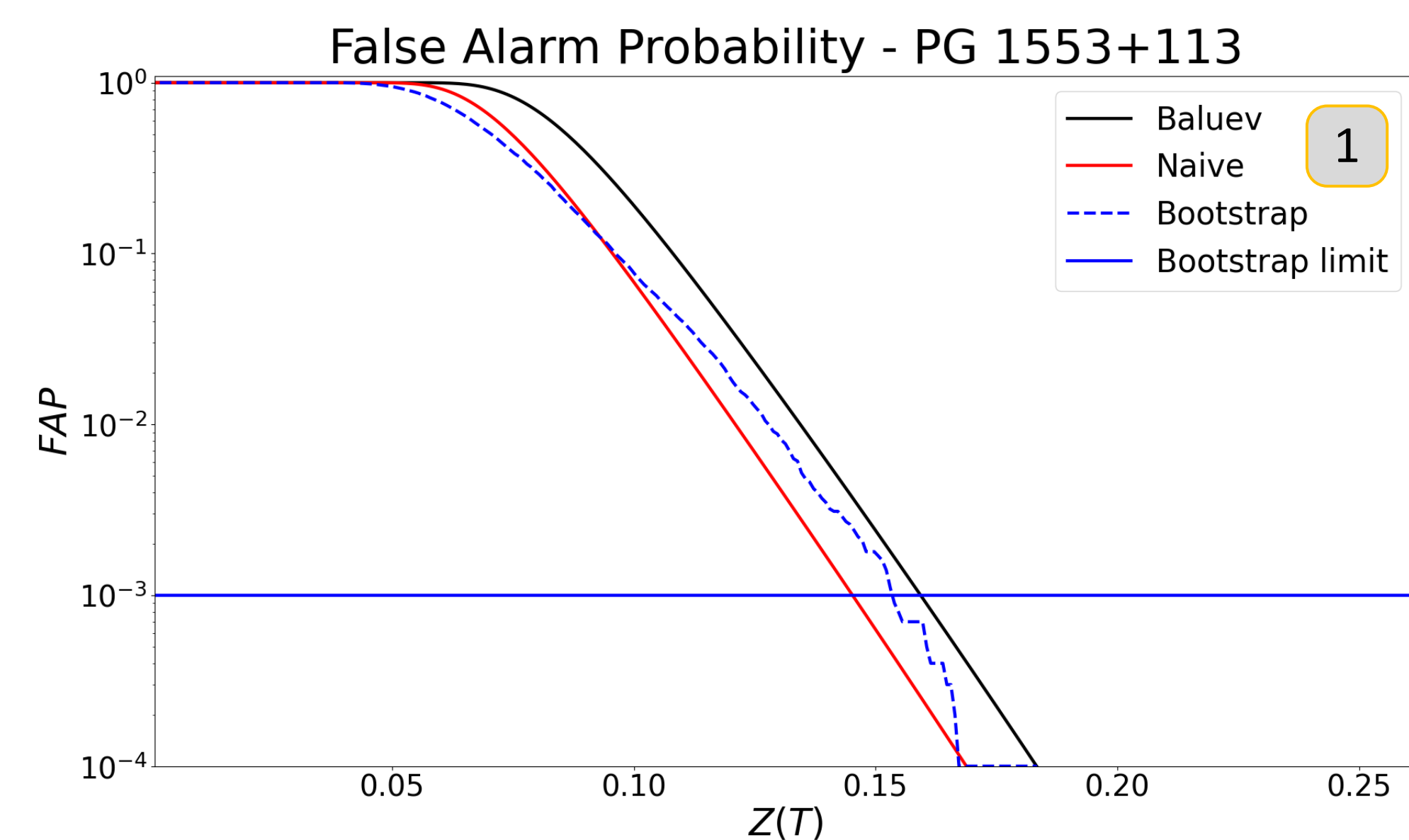

Results

For a simpler rapresentation of the significance we associate the FAP with number of σ.

With preliminary analysis performed on red noise simulations we made some assumptions about the light curves and the data types. When the UpperLimit (UL) percentage exceeds the 40% the significance increases above the expected value in the case of red noise, Figure 2; for LCR sources we can see the same effect, Figure 3.

Figure 4 is the summary graph of the analysis of the entire catalog, we identified a sample of **25 sources**, in **the green box**, with: significance above 3.5σ, Normalized Root-Mean-Square Deviation (NRMSD) <3% and periodicity found with more than 2 data types. In Figure 5, the best example of periodicity in blazar: PG 1553+113 with a period of 2.2 yr, monthly light curve of energy flux, on the left the wavelet local spectrum and on the right the global spectrum in black and the LSP in blue.
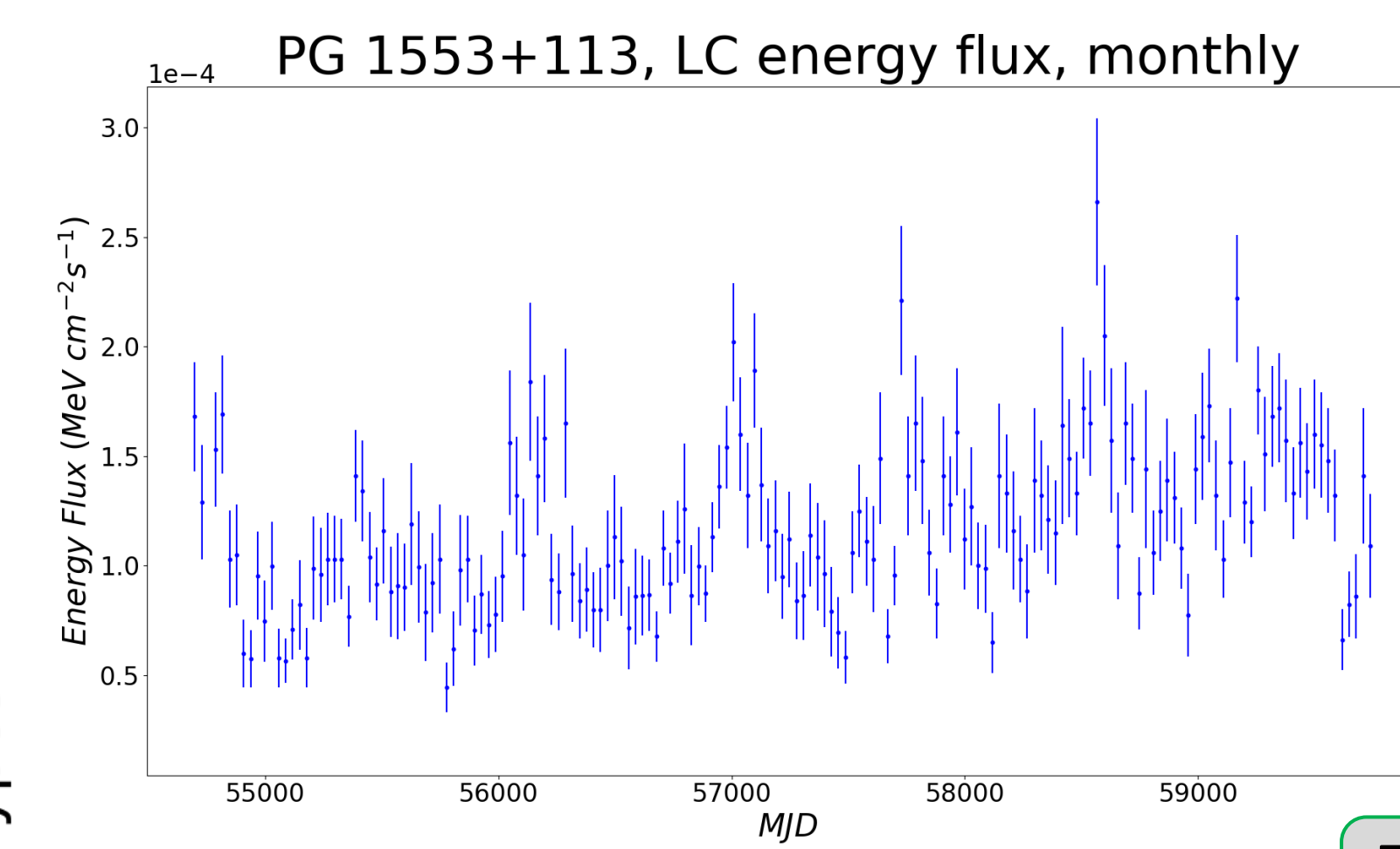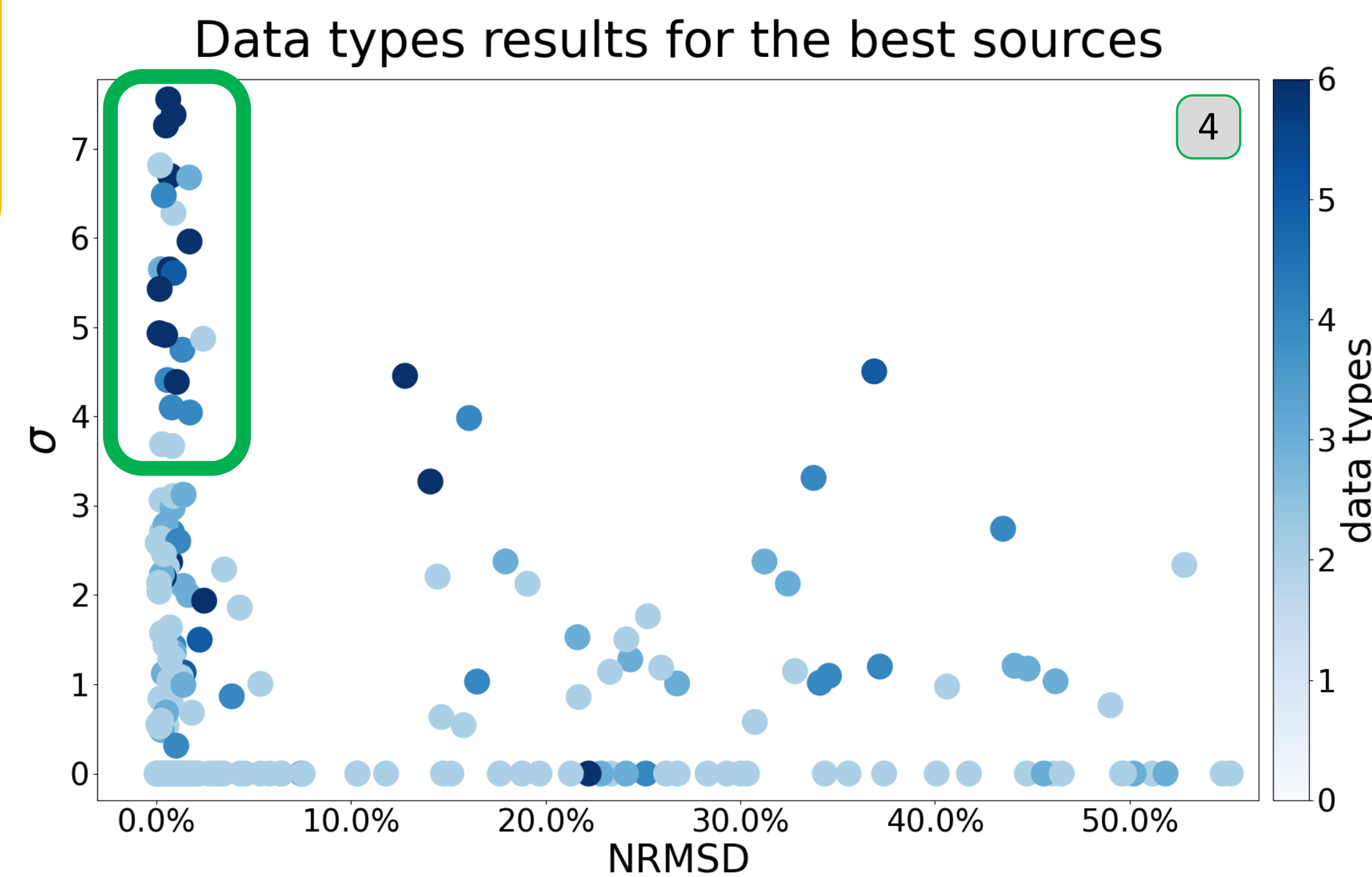
Conclusions

The analysis methods: LSP and WWZ, were validated through periodic light curve simulations, while with red noise simulations we verified the goodness of FAP as a significance estimation method.

Among the 1525 sources in the LCR, a significant periodicity was found in 25 blazars: 15 Flat Spectrum Radio Quasars (fsrq) and 10 BL-Lac objects (bll).

We identified a golden sample of 6 sources with very high significance, shown in the table; three of these sources with light curves, local and global spectrum and periodogram are shown in Figure 6.
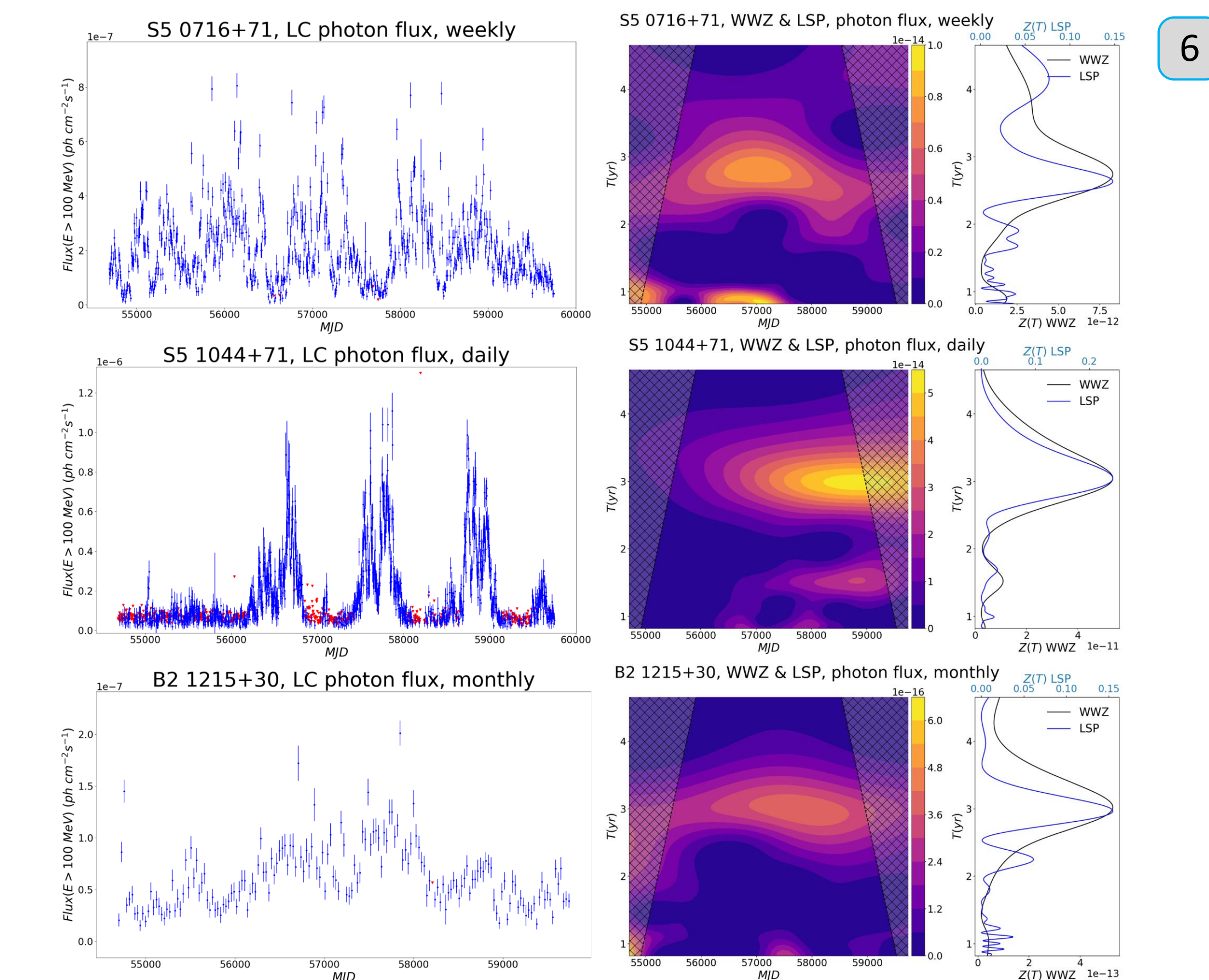
Source Name	RA J2000	Dec J2000	Type	Best T (yr)	Nσ
PKS 0426-380	67.173	-37.941	bll	3.5	>5σ
PKS 0454-234	74.261	-23.414	fsrq	3.5	>5σ
S5 0716+71	110.489	71.341	bll	2.6	>5σ
S5 1044+71	162.107	71.730	fsrq	3.0	>5σ
B2 1215+30	184.476	30.118	bll	3.0	>5σ
PG 1553+113	238.932	11.188	bll	2.2	>5σ

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