Correlation and evolution of the blazar S5 1803+784 short-term variability properties during 01.2022 – 01.2023

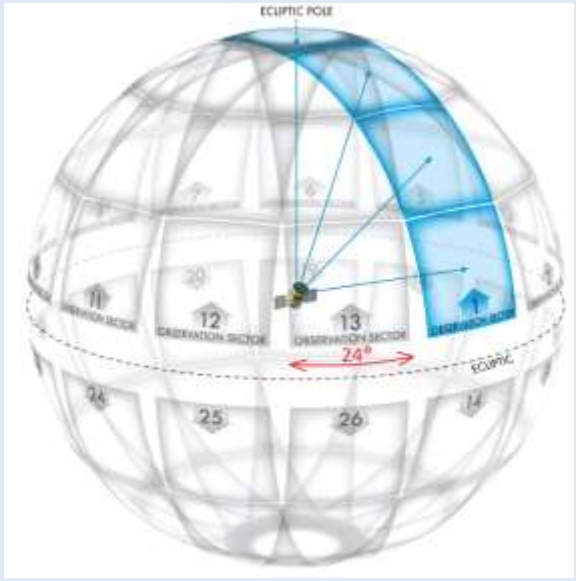
Butuzova M.S., Gorbachev M.A., Guseva V.A., Zhovtan A.V., Nazarov S.V., Baida G.V., Krivenko A.S.

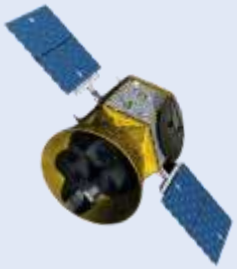
Crimean Astrophysical Observatory of RAS

Partially supported by
RSF №24-22-0034

Active galaxies at different scales and wavelengths,
SAO, Nizhny Arkhyz, October 14-17, 2024

TESS: a new era of short-term variability research



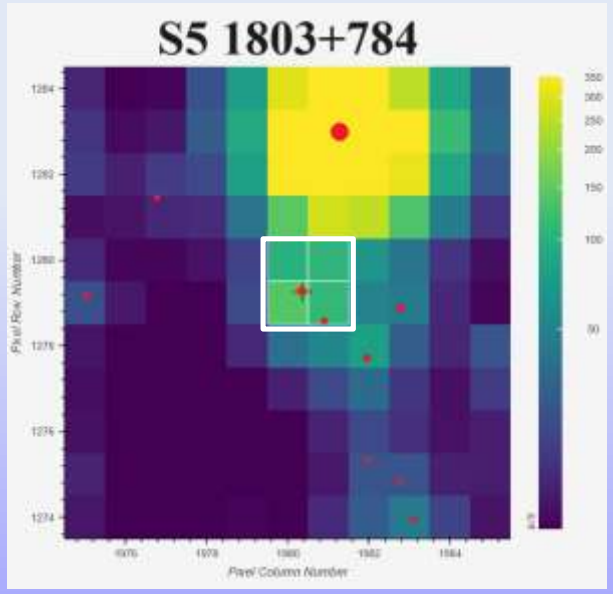


Data product

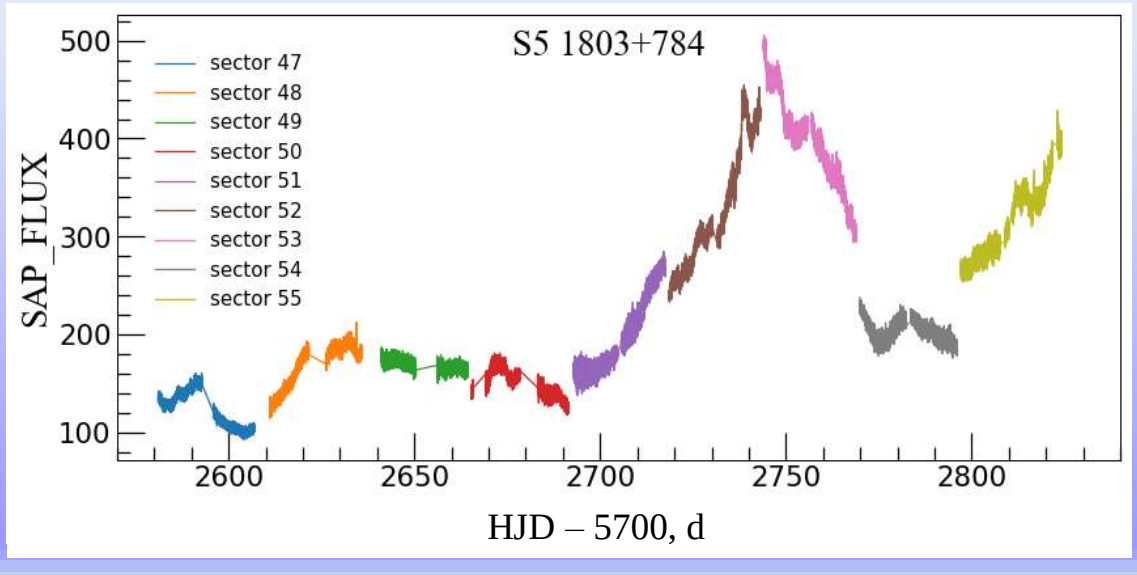
SAP-flux
is initial instrumental flux.

PDCSAP-flux
is flux after elimination a systematic trends common for all objects in the field of view.

Full Frame Image
and cuts from it.

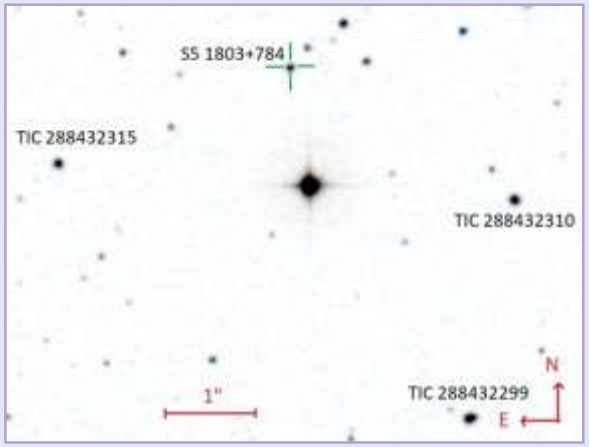


1 pixel corresponds to 21”,
Red circles mark objects from Gaia DR3.

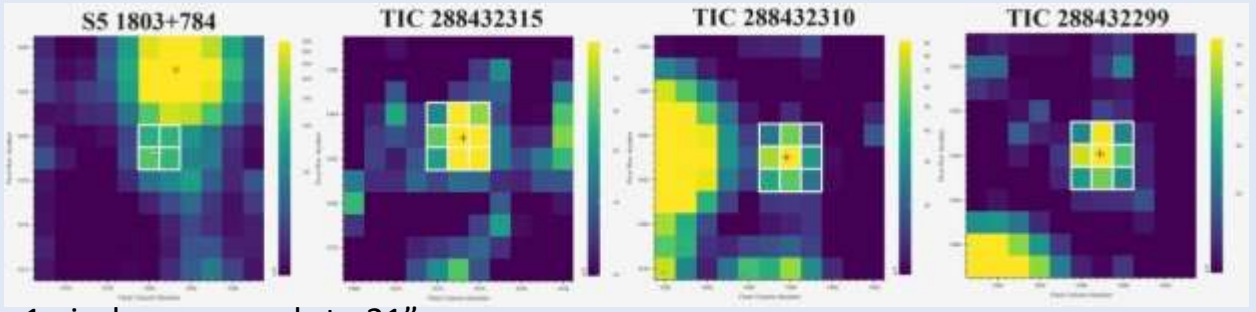


Aperture photometry

Object's research chart

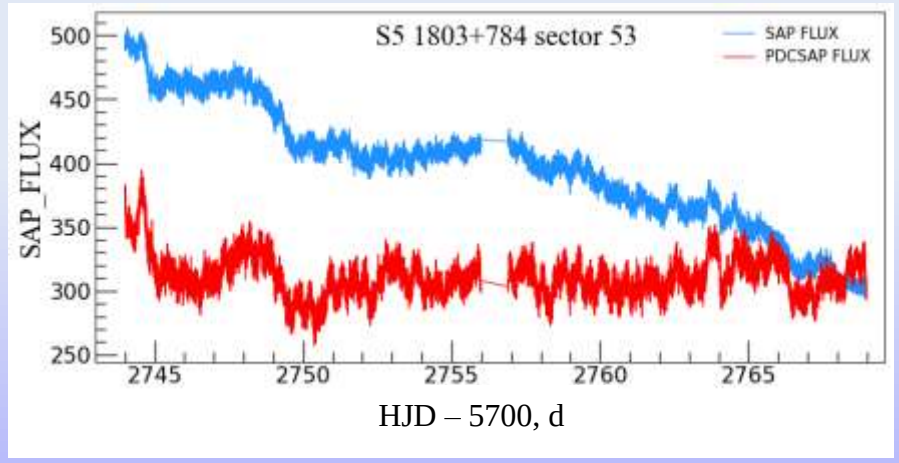


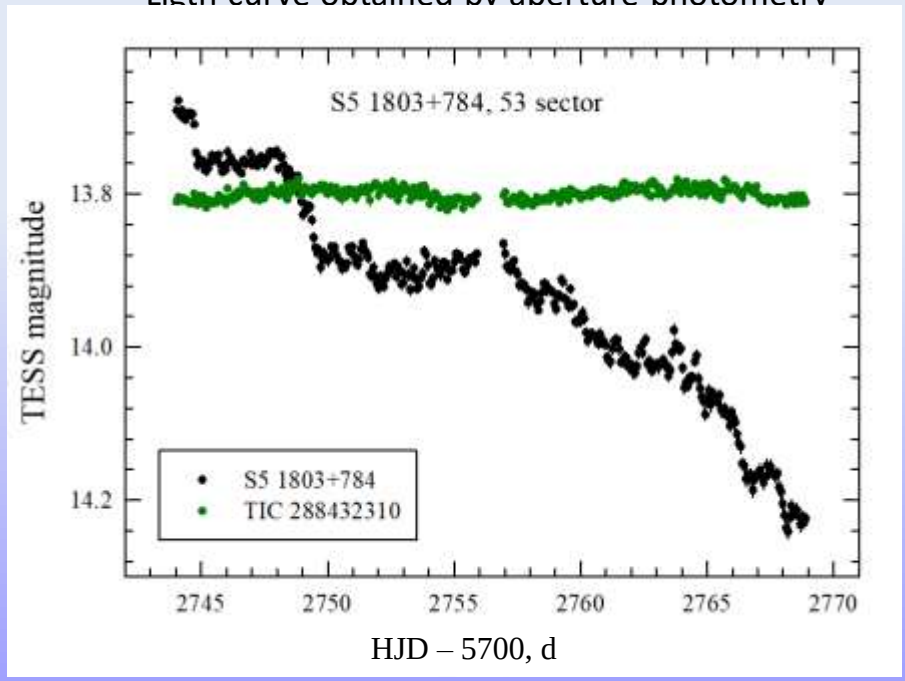
TESS cuts from full frame images for 53 sector



1 pixel corresponds to 21"

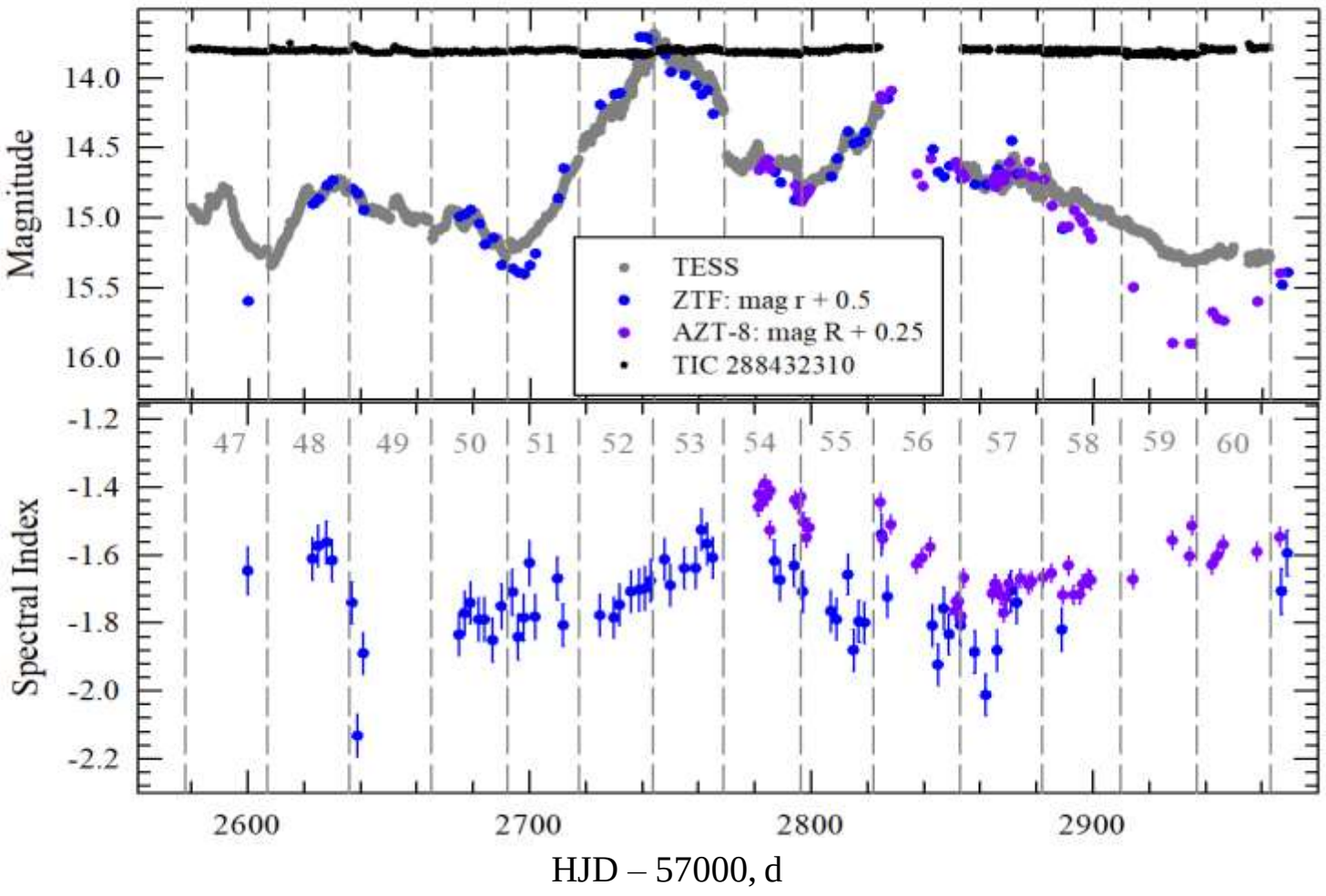
Ligth curve obtained by aperture photometry





There is good correspondence between SAP-fluxes and aperture photometry.
The astrophysical signal have been removed in PDCSAP-flux data.

Light curve and spectral index variations



Differences between TESS and ground-base observation amplitude caused by pixel large size of TESS CCD and redundant light of near stars falling into aperture.

Measurement errors in spectral index were obtained according to Gorbachev+ 2024.

Shortest variability timescale

Structure function *(Simonetti+ 1985):*

$$\mathrm{SF}(\tau) = \frac{1}{N(\tau)} \sum_{i}^{N} [X(i+\tau) - X(\tau)]^2 ,$$

where τ is time between two measurements,

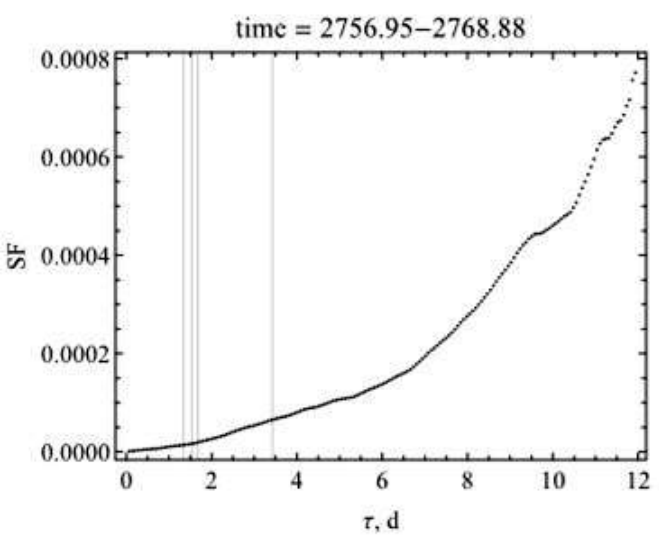
$N(\tau) = \sum [\omega(i)\omega(i+\tau)]$,

if measurement exist, then $\omega = 1$, else – $\omega = 0$.

1. We calculate SF for first 20 data points of the light curve.
2. Identification of an extremum, i.e. a maximum with value **≥ 0.0025**.
3. If there is no maximum, a point is added to the original dataset, and SF calculations; the maximum determination are performed again.
4. Maximum is detected: τ_V is a characteristic time of variability, SF_{max} is a the ***square of the average variability amplitude***.
5. The next 20 points on the light curve are taken and the algorithm is repeated.

Illustration of the method's operation

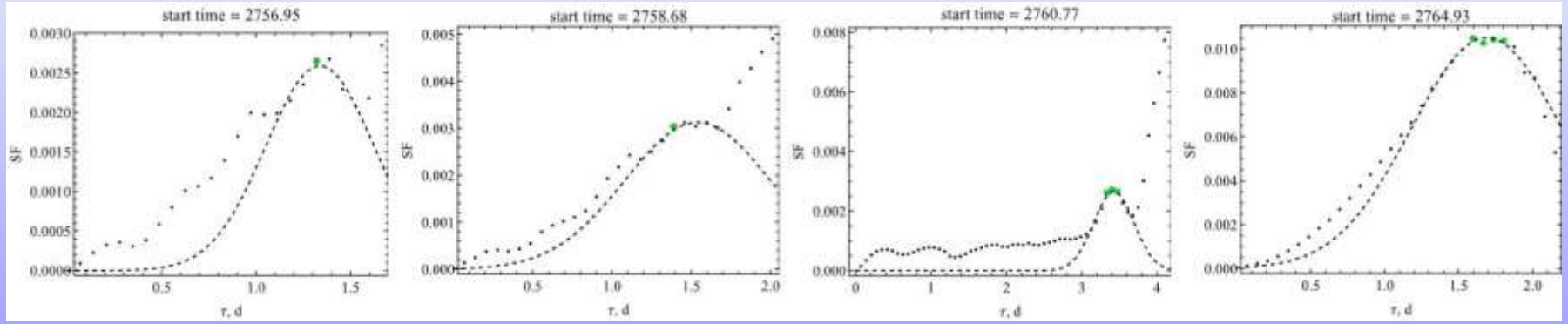
The structure function for the second part of the light curve for the 53rd sector



SF << 0.0025

Vertical lines mark the shortest characteristic times of variability found by the proposed method.

Structure functions for consecutive intervals of the light curve

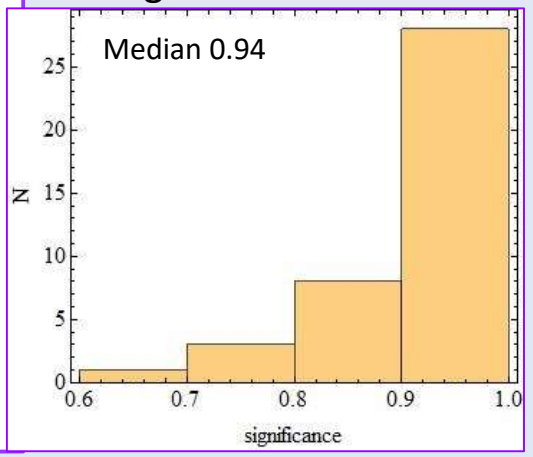


In the most cases, SF errors lie inside symbols.

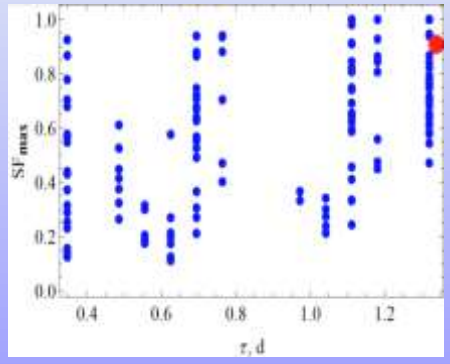
Significance levels of SF peaks

1. For each selected interval, we determined the parameters of the light curve as a random process.
2. 1000 model curves were generated.
3. The SFs was calculated for them.
4. Normalization was carried out for the maximum value of SF for observational data and model light curves.
5. We calculated the N number of those SF maxima which exceed the peak value of the SF plotted from observational data and are in the interval $\tau_v \pm 0.05\,\tau_{max}$.
6. Significance level is $p = 1 - N/1000$.

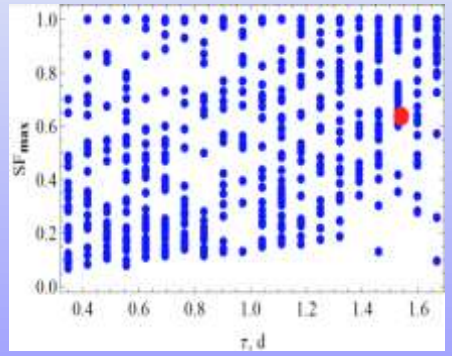
Distribution of significance levels



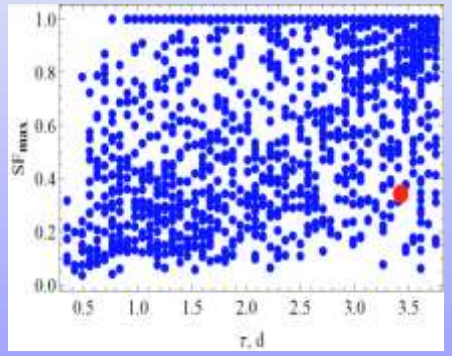
Significance levels for shown above structure functions



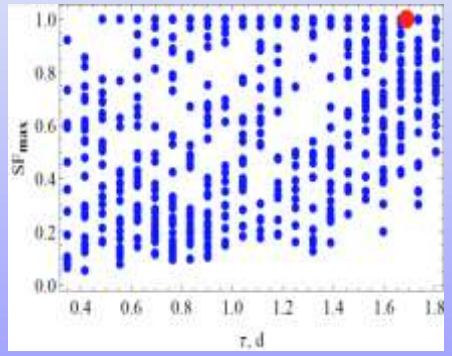
p = 0.99



p = 0.90

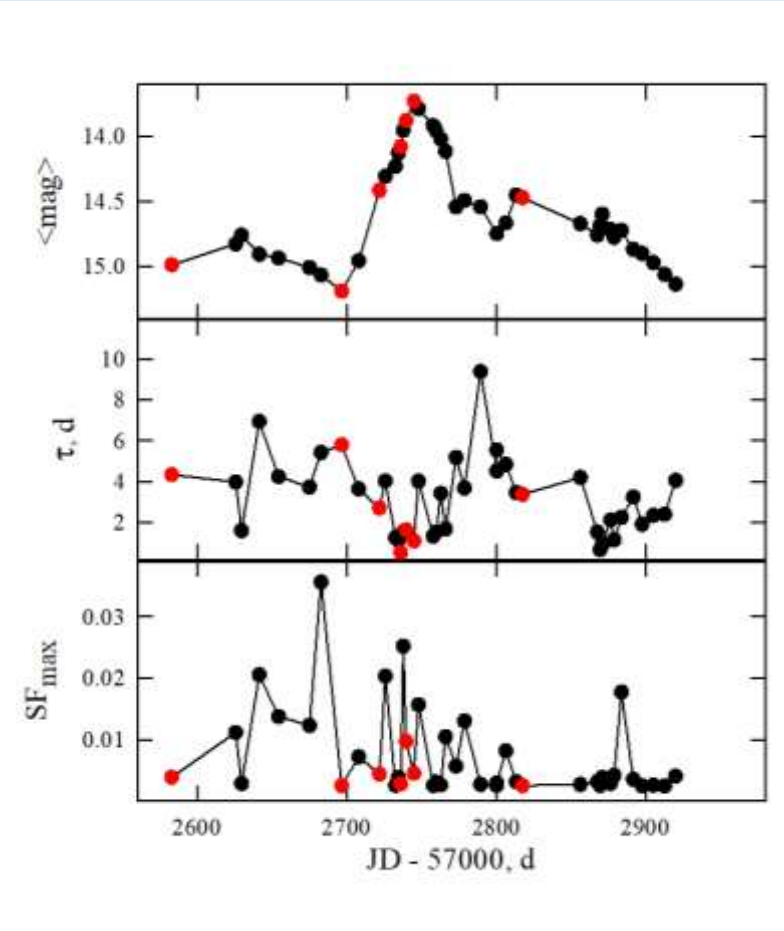


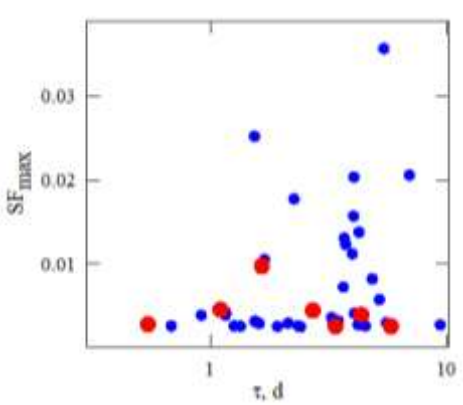
p = 0.75

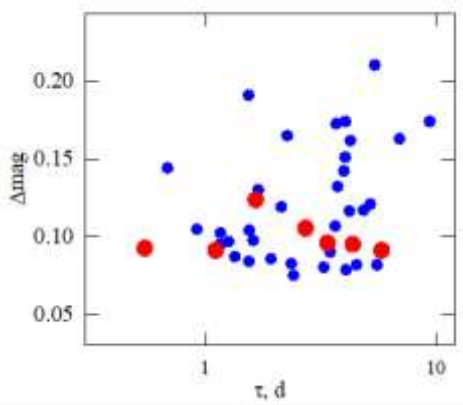


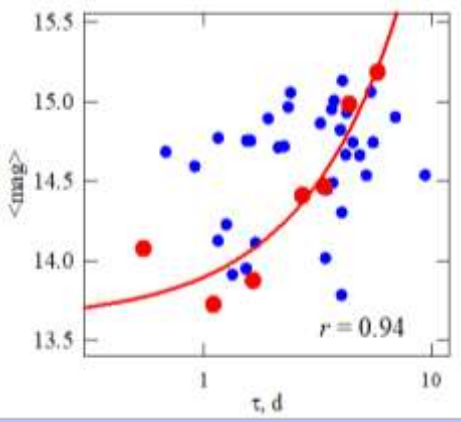
p = 0.93

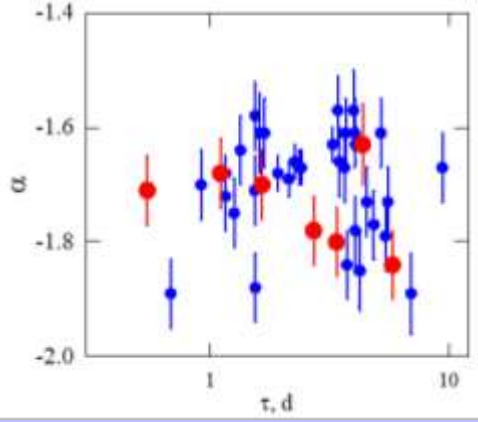
Results











Points with a significance level ≥ 0.95 are highlighted in red.

Conclusions

1. The blazar S5 1803+784 has brightness variations within **2** magnitudes, the spectral index variation in the range from **-2.2** to **-1.4** for the period from 01.2022 to 01.2023.

2. Using the new method, the shortest characteristic variability times for consecutive intervals of the light curve are determined. These times ranged **from 0.5 to 9.5 days** with an average variability **amplitude from 0.05 to 0.19 magnitude**.

3. No connection was found between the temporal and spectral characteristics of the variability.

4. The most likely mechanism of short–term variability is the presence of components in the jet, which have a Doppler factor differs from the Doppler factor of the general flow.

Thank you for your attention!