Optical Variability of "Light-weight" Supermassive Black Holes at a Few Percent Level from ZTF Forced-Photometry Light Curves

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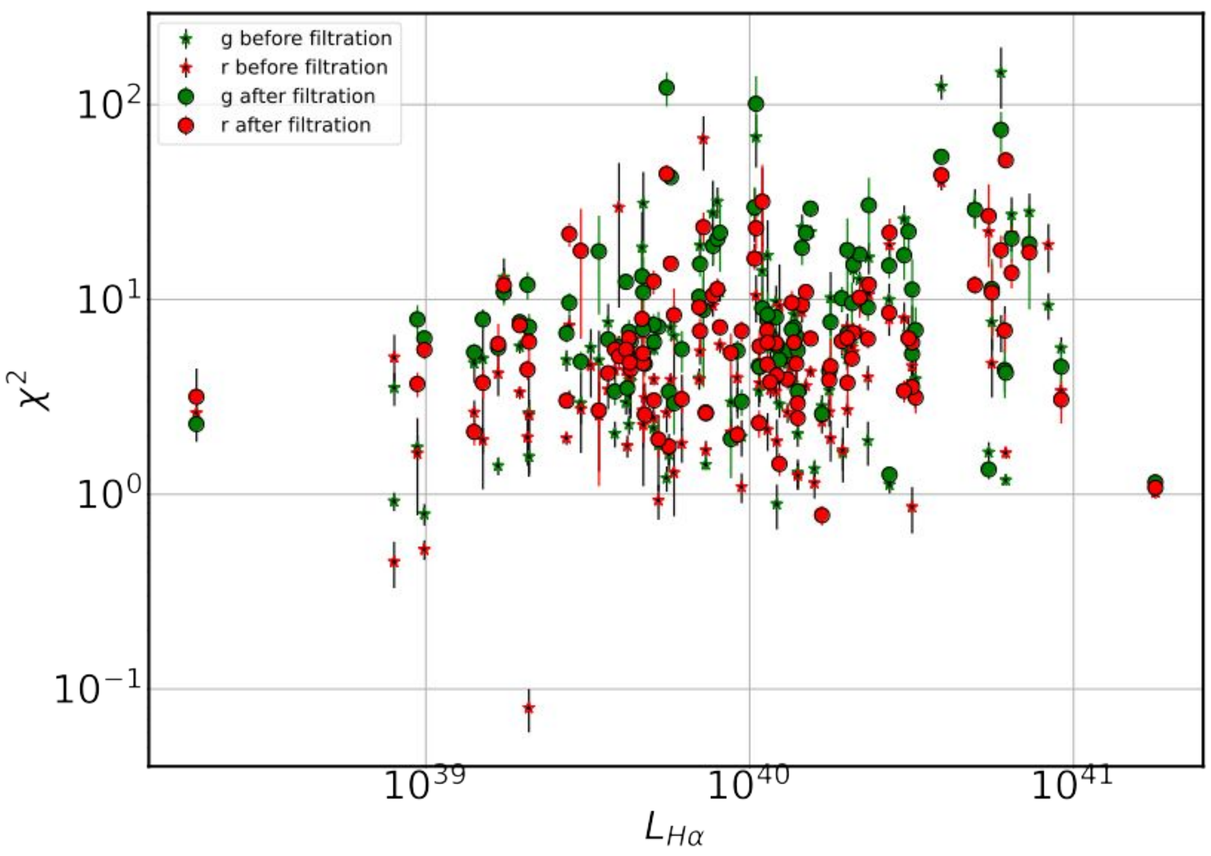
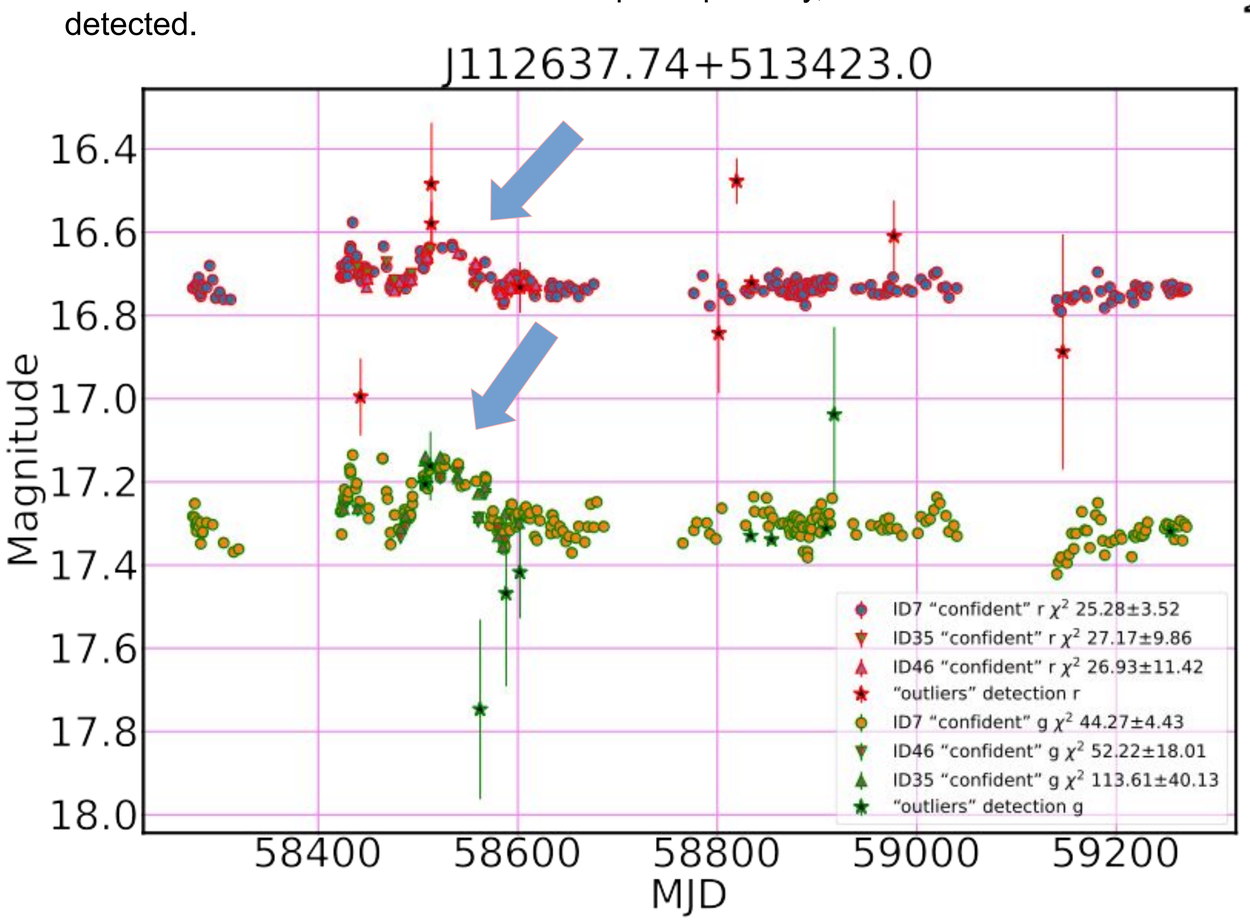
Active galactic nuclei (AGN) are variable on different timescales which scale linearly with the mass of the central black hole. ZTF Data Release aperture light curves cannot be used for unobscured AGN confirmation because of the systematic errors reaching 15-20% making detection of weak variability AGN powered by "light-weight" SMBH (2e6 M⊙) on top of bright host galaxies unfeasible. We build reliable light curves from difference images using the ZTF Forced-Photometry service to detect optical variability at a few percent level from a large sample weak AGN selected from archival X-ray observations and Hα broad line width.



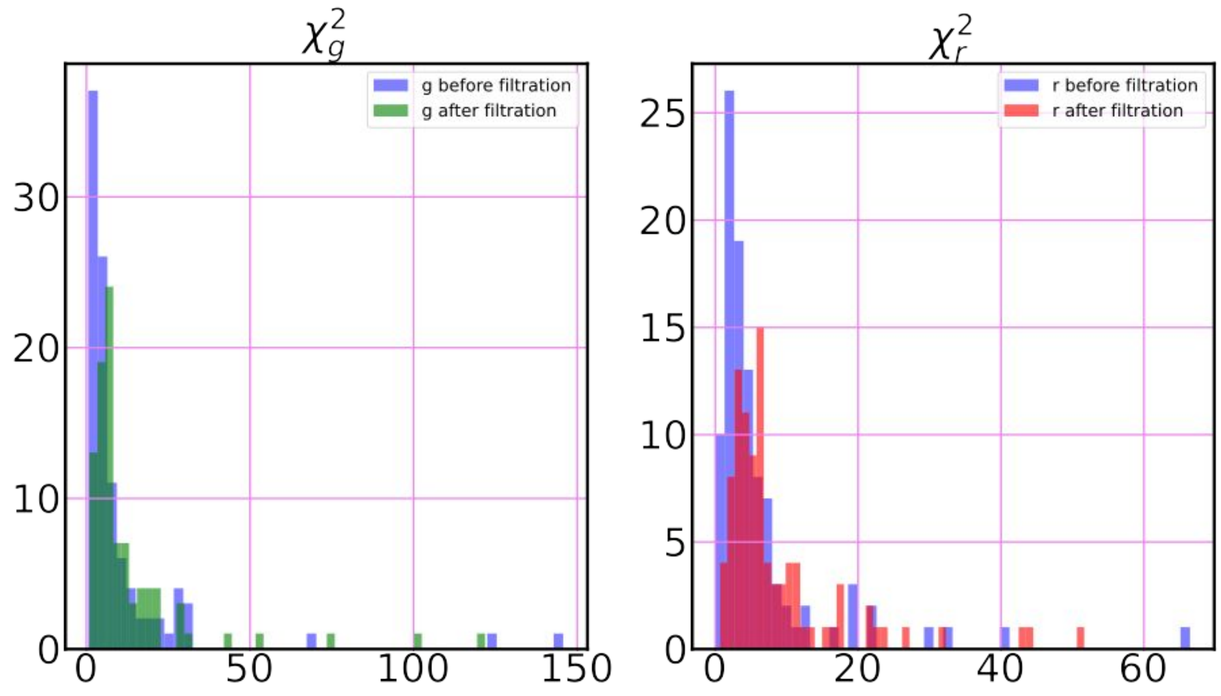
Also, we found a strong flare in J112637.74+513423.0, which can be a star ruptured by tidal forces in the SMBH potential (tidal disruption event) or a changing look AGN or an under-luminous supernova. Even when looking at observations from different CCD chips separately, the transient can still be detected.



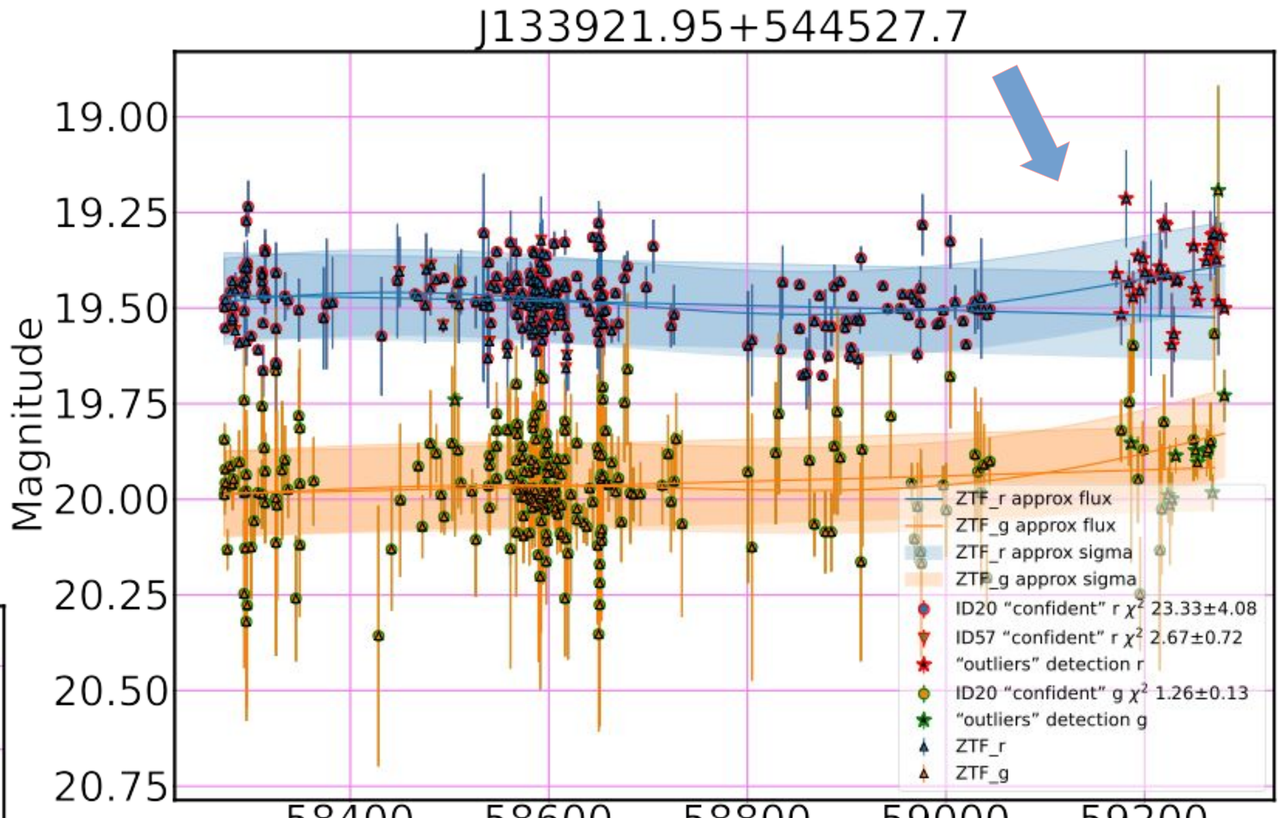
We use the instruction from the Forced Photometry Service to filter by criteria SNR, distance to the nearest reference, pixel quality indicators for filtering observation with uncorrected cosmic ray hits and hot pixels in scientific images, sharp value and chi parameter of the reference source for avoiding spikes or hard edges because of extended reference sources.

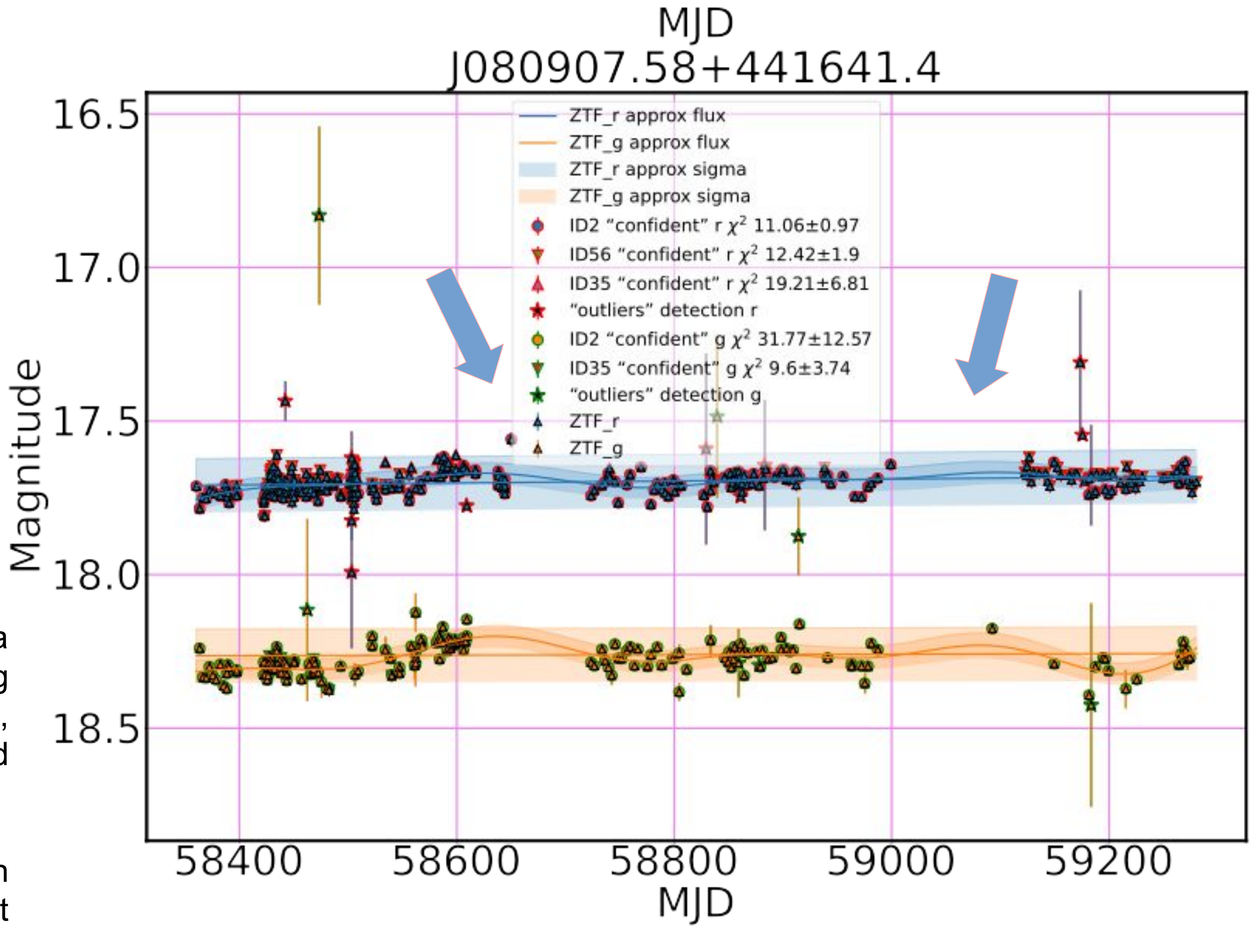
Filtering from ZTF explanatory supplements was used according to the criterion number of PS1 calibrators used in initial calibration of scientific image, zero point and airmass, based on the CCD quadrant. A color correction was made using the zero color from the Pan-STARRS1 photometric system.

We defined the level of significance according to the chi-square criterion at which the light curve is not consistent with white noise on top of a constant. Many of the studied objects showed statistically significant variability on the timescales from dozens days to months.



We want to emphasize the importance of filtering before using the curve. When approximated by Gaussian processes, for example, to estimate the reverberation in the quasar light curve using JAVELIN code, or approximated using the FULU library on the light curves below, the results before and after filtering may be different.





The reference image averages observations from the scientific image on a time scale sometimes larger than the expected variability of "light-weight" SMBH. Filtered light curves help to precisely exclude SMBH, quasars and transients from the sample selected using the broad lines. The bottleneck limiting the scalability of our analysis is that the ZTF Forced-Photometry Service can process up to 100 objects at a time and it takes hours to weeks to process the data.

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The code for your experiments will appear here: https://github.com/masha-astro/optical_variability_ztf