MNRAS 000, 1–2 (2016) Preprint 20 May 2016 Compiled using MNRAS LaTeX style file v3.0

SDSS Stripe 82 : quasar variability from forced photometry

Krzysztof Suberlak,[1]* Željko Ivezić, [1] Yusra AlSayyad,[1]
[1]Department of Astronomy, University of Washington, Seattle, WA, United States

Accepted XXX. Received YYY; in original form ZZZ

ABSTRACT

1 ASSIGNMENT 6 PARAGRAPH

1.1 before

Each measurement of flux is affected by the background noise. The bright optical background can have two contributions to faint source detection. First, the oscillation of background around the mean may lead to spurious detections. We can understand it by modelling the distribution of background counts as a Gaussian centered around the mean value $B_0 : B - B_0 \sim \mathcal{N}(0, \sigma_B)$. The noise itself is Poissonian, and for a large number of photons hitting the detector the width of the distribution σ_B is proportional to the square-root of counts: $\sqrt{B}$. Thus on a 4kx4k CCD, similar to those used by SDSS, we would expect about 1 false detection in a million at 5σ level - 16 per CCD. Second contribution of background variation is the unphysically low flux at source location. Since the background oscillates around a mean value, an individual epoch may have a lower-than-average background value which after mean background subtraction yields a negative value of flux at source location. Thus especially for variable sources, the location where it was detected in coadds may have a negative flux value because if the source is below detection threshold in an individual epoch, we are measuring the background noise oscillation. The background noise can significantly affect the measurement if it is as strong as the flux of a source in some epochs.

1.2 after

Forced photometry in a background-subtracted epoch may yield unphysical, negative values. Such negative pixel value may originate from the variation of background across the image. If we model the background counts as a Gaussian centered around the mean $B_0 : B - B_0 \sim \mathcal{N}(0, \sigma_B)$, then background in some parts of the image will be above, and in other parts below the mean value. After subtraction of the mean background value, regions with previously lower than average background will have negative pixel value. This means that a forced photometry on a location where an object is undetected in single epoch may be measuring the background noise. Apart from creating low pixel values, background oscillation may also cause spurious detections where it is above the mean. For a large number of photons hitting the detector the width of the background noise distribution is proportional to the square-root of counts: $\sigma_B \propto \sqrt{B}$. This yields a 1 in a million chance that a pixel has a background value larger than $5\sigma_B$. Thus on a 16 megapixel CCD, like those used in SDSS, we anticipate about 16 spuriously bright pixels per CCD. Therefore, since forced photometry is affected by the background noise, a special care must be taken of faint, noise-dominated measurements.

2 ASSIGNMENT 5 PARAGRAPH

2.1 before

Forced photometry measurement in a single epoch is in fact the mean of a likelihood for the observed flux. We can think of each source as being represented by a Gaussian likelihood centered on the measured flux F_i, with a widh corresponding to the measurement error σ_i. Thus in the flux likelihood space bright sources have very narrow Gaussians, with a width on the level of $1-2\% \approx 0.01-0.02$ mag, whereas faint sources with larger uncertainties have very wide Gaussian tails, that can extend below zero. Such nonzero likelihood for a negative flux measurement is unphysical, given that we know that no source can in reality have a negative flux. Any negative portion of the likelihood stems from the background fluctuation, as described in previous section, or from very large measurement error. We address the issue of negative tails of Gaussian flux likelihood by recalculating the measurement of flux for all sources with less than $'2\sigma'$ detection, i.e. $\langle F_L \rangle < k\sigma$, with $k=2$. This corresponds to the 2% probability of $F_L < 0$ (in a Gaussian likelihood).

2.2 after Ass 6 corrections

We remedy the unphysically low, even negative measurements for all 'faint' ($< 2\sigma$) sources and recalculate their fluxes. Each flux measurement can be thought of as a mean of the 'intrinsic' flux likelihood function $L(F)$. L determines the probability that the flux has a value F. In our treatment we assume that L is a Gaussian, and therefore its width corresponds to the measurement error : $L(F) \sim \mathcal{N}(F, \sigma_F)$. This means that bright sources with high signal-to-noise ratio have very narrow L, and faint sources, dominated by noise, have L with very wide tails. Only for faint sources a significant portion of L may be negative, corresponding to non-zero likelihood of flux being negative. This stands in conflict with our prior knowledge that no physical flux can be negative. We resolve this problem by recalculating single-epoch flux for all sources where $F < 2\sigma_F$. We calculate for each epoch the mean of the truncated L, such that $L(F) = 0$ for $F < 0$. This shifts upward all measurements for faint epochs, and remedies the unphysicality of faint forced photometry fluxes.

This paper has been typeset from a TEX/LATEX file prepared by the author.