MNRAS **000**, 1–1 (2015) Preprint 28 April 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 VARIABILITY

Many lightcurves display intrinsic variability, in addition to the error-induced noise. A lightcurve consists of a set of N measurements of the object brightness x_i and associated errors e_i. In this analysis we assume that x_i are drawn from a Gaussian distribution $\mathcal{N}(\mu,\sigma)$, and that errors e_i are homoscedastic, so that the distribution of measurements is a Gaussian. In this framework μ describes the median brightness, which for non-variable objects is the true brightness. Using the Bayesian approach, we find μ by maximizing the posterior probability distribution function (pdf) of μ given x_i and e_i : $p(\mu|x_i,\sigma_i)$. We can proceed analoguously to find the width of the distribution, σ, which describes the departure from the mean.

To find μ and σ, we follow Ivezic+2014, with the two-step approach. First, we find approximate values of μ_0 and σ_0, and then we evaluate the full logarithm of the posterior pdf in the vicinity of the approximate solution. The maximum of the 2D likelihood becomes our full solution - σ_{full} and μ_{full}, as shown on Fig. 1 (see Appendix B for the detailed calculation).

For each lightcurve, we also calculate mean-based χ^2_{DOF} and median-based χ^2_R (the latter is more robust against any outliers in the distribution) :

$$\chi^2_{dof} = \frac{1}{N-1}\sum\left(\frac{x_i - <x_i>}{e_i}\right)^2 \tag{1}$$

and

$$\chi^2_R = 0.7414(Z_{75\%} - Z_{25\%}) \tag{2}$$

with $Z = (x_i - median(x_i))/e_i$.

Initially, we evaluate μ_{full}, σ_{full}, χ^2_{dof}, and χ^2_R for the entire lightcurve. Then, only if either $\sigma_{full} > 0$ or $\chi^2 > 1$, which hints some intrinsic variability, we also calculate mu_{full}, σ_{full}, and χ^2 for the seasonally-binned portions of the lightcurve.

On Fig. 1 we plot the stages of calculating μ and σ. Left and middle panels compare two methods of calculating our variability parameters. The initial approximation (dashed) is based on bootstrapped resampling of x_i, e_i points from the lightcurve. With bootstrapping we resample the lightcurve M times, so that instead of a single sample with $N \approx 10-70$ points we have M samples. Random resampling means that points may be chosen multiple times in a random fashion. This allows us to calculate M approximate values of μ,σ. Dashed lines trace the histogram for $M = 1000$ resamples of our variability parameters. The approximate values are in turn used to provide bounds for the 200*x*70 grid of μ, σ on which we evaluate the full posterior likelihood density function (right panel). This ensures that we are sampling the peak of the underlying distribution.

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

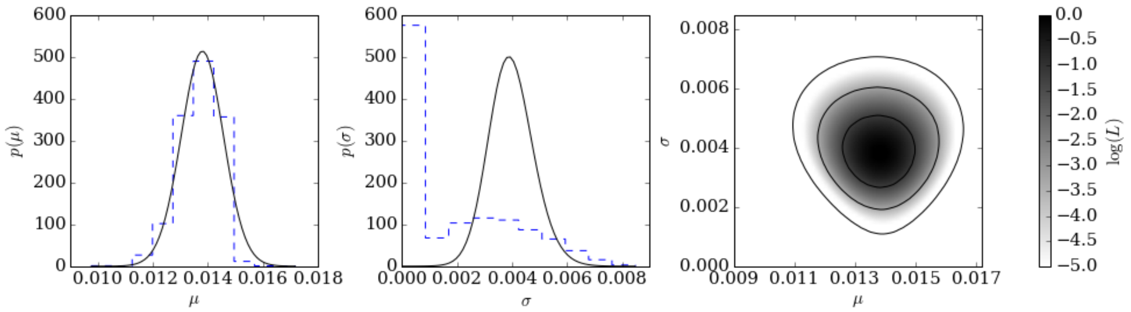

Figure 1. Two-step approach to finding μ and σ via μ_0 and σ_0 for an object 2177208948883346446. In this calculation we use raw psf flux, before employing the faint source treatment outlined in Section **??**. On the left and middle panels, solid lines trace marginalized posterior pdfs for μ and σ , while dashed lines depict histogram distributions of 10,000 bootstrap resamples for μ_0 and σ_0. The right panel shows the logarithm of the posterior probability density function for μ and σ.