A New Technique for Precise Stellar Photometry: Application to Small-Scale Activity of EV Lacertae

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Abstract: A new prefiltering technique (PFT) for precise stellar photometry is described. It has been proved that the prefiltered and added high-time resolution data provide an increase in S/N ratio by factors $1.3 - 1.7$ in comparison with simple integration. The PFT allows to detect event amplitudes which are comparable to that caused by counting statistics. Adopting the PFT, our observations reveal small-scale flare events in the subsecond range in EV Lac.

1 Brief sketch of the PFT algorithm

For lack of space consider a specific application of the method. Let readings x_i be mutually independent random variables, i.e. $\mathrm{cov}(x_i, x_j) = s^2\delta_{ij}$. Let us denote initial values of the mean count rate and the variance as $\bar{x}$ and s^2. Let the variation coefficient be $V_0 = s/\bar{x}$. Then the S/N ratio in the light curve is $S/N = 1/V_0$. Consider in addition raw readings x_i in groups of three points, and readings $\tilde{x}_i$, smoothed by a moving-average three-point filter. Let us denote by M and D the expectation and the variance operators of the random variable. It is easy to show for raw and prefiltered data that

$$y_i = x_{i-1} + x_i + x_{i+1}, M[y] = 3\bar{x}, D[y] = 3s^2, V_3 = 0.577V_0$$

and

$$\tilde{y}_i = \tilde{x}_{i-1} + \tilde{x}_i + \tilde{x}_{i+1}, M[\tilde{y}] = 3\bar{x}, D[\tilde{y}] = 19/9s^2, \tilde{V}_3 = 0.484V_0\,.$$

Applying the PFT, the gain in S/N is equal to 1.192. As shown in detail by Zhilyaev et al. (1994), in the common case of an arbitrary l-point moving-average filter and an m-point addition, the gain is equal to

$$\frac{V_m}{\tilde{V}_{l,m}} = \left(\frac{m}{\sum_{i=1}^{m} \sum_{j=1}^{m} r(i-j)} \right)^{1/2}$$

with

$$r(k) = \frac{l-k}{k}, \qquad |\, k \,| \leq l-1\,,$$

where $r(k)$ is the autocorrelation function of prefiltered data. The gain can reach a value of $1.3 - 1.7$ for appropriate values of l and m. In this case, the radius of correlation of modified data is no more than $l - m + 1$ points.

https://doi.org/10.1017/S0252921100034862 Published online by Cambridge University Press

2 Application of the PFT to EV Lacertae

High-time resolution observations were obtained with 0.01 s integration time in B-band with a high-speed photometer. The advantage of the PFT is shown in Fig. 1. The first panel shows a simple 5-point addition of readings, the second one is obtained by adoption of the PFT with $l = 11$, $m = 5$. The outburst seen in Fig. 1 is significant at the $> 4\sigma$ confidence level. Miscellaneous features of the flare-shaped event can be deduced from the PFT light curve. One can see a short-lived flare with an amplitude of $-0\overset{m}{.}4$, superimposed on an intensity drop of longer duration with an amplitude of $+2\overset{m}{.}2$. Significant intervals of the flare and of the drop are of the order of 1.5 and 3.5 s, respectively. The paper attempts to describe the principle of operation of the prefiltering technique, and this example is a typical demonstration. Note that a reference star showed no presence of flare events at such a high confidence level during an overall observing run of half an hour.

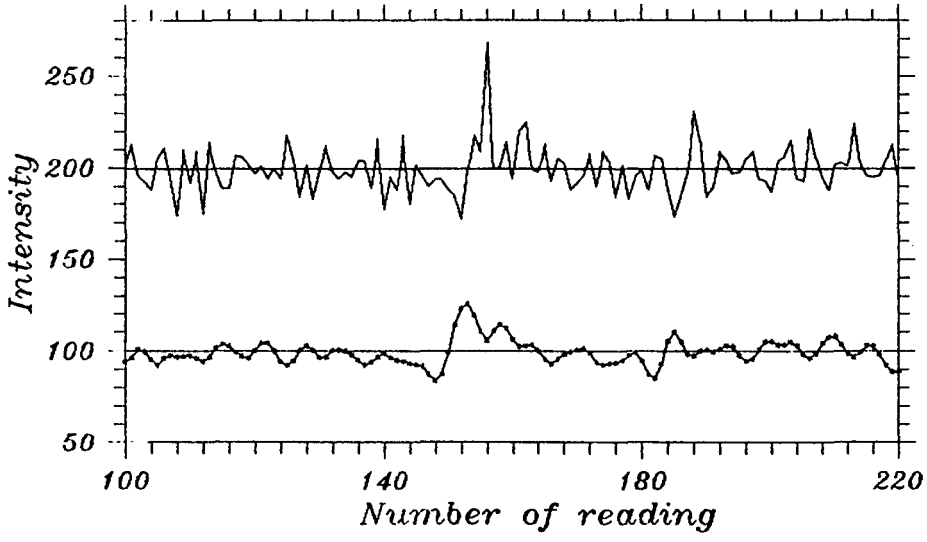

Fig. 1. EV Lac on 1992, Sept. 5, 22:05 UT, B-band. Time resolution is 0.05 s. Upper curve – raw data, lower curve – PFT light curve.

Acknowledgement: The research described in this publication was made possible in part by Grant No UCBOOO from the International Science Foundation.

References

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