FRB121102 repeating radio burster

Fast radio bursts (FRBs) are bright and very short flashes of radio waves of yet unknown physical origin, first discovered back in 2007. They typically last less than a few milliseconds, and display a large dispersion measure, suggesting compact size and extra-galactic origin. However, to date no counterparts have ever been detected in other wavebands, and no energetic transient events (GRBs, supernovae, AGNs) have been associated with FRBs.

The discovery of a repeating source FRB121102 opened unprecedented possibilities for an accurate determination of its position and for initiating massive multi-wavelength observational campaigns aimed to detect the source and uncover its nature.

To date, the only attempt for an optical monitoring of FRB121102 position with high temporal resolution and synchronous with radio observations was published in [1], where authors did not detect any flashes brighter than 1.2 mJy in 70.7 ms frames coincident with the radio bursts from the source.

We observed the position of FRB121102 synchronous with a dedicated radio monitoring run on a 100-m Effelsberg radio telescope. Unfortunately, there were no radio detections of a bursts from the object during that run [2], so we are unable to characterize the brightness of their simultaneous optical components. However, we may still place an upper limit on a rapid optical activity of the source during its radio quiet phase, as well as to characterize the performance of a 50-cm telescope with fast CCD camera for such a task.

Search for optical flashes

We performed an aperture photometry with 2 pixels radius at a target position of FRB121102 and a background position close to it, and compared their statistical properties looking for any outliers. All of a few statistically significant deviations of target flux were visually inspected and found to be non-astrophysical, related to either detector read-out anomalies, cosmic ray hits or meteors.

To define the upper limit for a single-frame optical flashes detectable in our observations, we computed a running variances estimation for a target and background fluxes, and computed a survival functions (which are practically identical) for both fluxes divided by their standard deviations (i.e. "numbers of sigmas"). We then extrapolated them (using two possible slope models) to get the flux level corresponding to a $10^{-5}$ probability (5 sigmas) for a number of trials corresponding to the one of acquired frames.

Non-detection of significant flashes on any of acquired frames places the following upper limits for a brightness of possible events on the time scale of single exposure:

<table>
<thead>
<tr>
<th>Regime</th>
<th>Optical Limit</th>
<th>Pessimistic Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02 σ / filter I</td>
<td>12.9σ ± 18.2 mJy</td>
<td>12.8σ ± 20 mJy</td>
</tr>
<tr>
<td>0.02 σ / filter N</td>
<td>14.0σ ± 9.5 mJy</td>
<td>13.8σ ± 11.4 mJy</td>
</tr>
<tr>
<td>0.01 σ / filter N</td>
<td>13.8σ ± 11.4 mJy</td>
<td>13.6σ ± 13.7 mJy</td>
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</table>

Observations and data reduction

We observed the field of FRB121102 for a three nights with 50-cm D50 telescope of ASU AV ČR, located in Ondrejov. The telescope was equipped with Andor Ikon DU-888 EMCCD, operated in an electron-multiplying regime with full amplification (300x). We used 2x2 binning for the whole run, and either full-frame or half-frame readouts (which gives either 47 or 86 FPS frame rate).

The telescope is driven by RTS2 robotic observational control software. However, RTS2 architecture does not support taking continuous sequences of images and working with high frame rate sensors. Thus, during the observations the camera was controlled by a dedicated FAST data acquisition software [3], which is specifically designed for such scenarios. Using it, we acquired 2.5 millions of science frames in various regimes:

All the frames were dark subtracted using masterarkds acquired with the same gain and exposure settings of the camera, and then flatfield corrected using evening sky flats acquired in a normal manner. Every 30 consecutive frames were co-added and astronomically calibrated using local Astrometry.Net [4] installation to account for a tracking instabilities of the telescope mount and atmospheric variations.

Due to non-normal nature of a noise that is dominant on short exposures (read-out and electron multiplication noises, clock-induced charges), an accurate background estimation on a single frame is problematic. Therefore, we derived the background map by employing a clipped mean algorithm (which is the fastest in convergence) on co-added images (30 frames long), and using this estimation for analyzing individual frames.

To derive the photometric zero point, we used the stars from APASS DR9 [5] catalogue.

Photometric stability

We performed a forced aperture photometry of all non-blended catalogue stars on every single frame, and constructed the scatter-magnitude diagram in order to check how precise are the individual measures and what one may expect from a high temporal resolution observations on a such telescope. About 5% accuracy is achievable for brighter objects on a time scale of 10-20 ms.

References

2. A. Shearer, private communication 2017
5. A. Heniden et al. APASS - The Latest Data Release, AAS Meeting #225, 2015, d.336.16