Research project objectives Brightest Star Explorer (BRITE) is the first Polish astronomical satellite mission carried out by Polish-Austrian-Canadian consortium. The constellation of 5 nano-satellites has been created and lunched to observe micro variabilities of intensity of the brightest stars. Each satellite has a CCD sensor installed onboard which is employed to observe the objects through either red or blue filter. The lack of atmosphere allows for unprecedented high photometric precision, not achievable from the ground.

Unfortunately, due to the weight and on-board space constraints, the installation of heavy shielding and employing strong sensor cooling was impossible. Thereby, shortly after the lunch, the radiation defects appeared in CCDs, making the image analysis a challenging task. The defects are visible as significantly brighter pixels, column intensity offsets and regions corrupted by charge transfer inefficiency. These problems not only affected the scientific camera, but also the star tracker sensor. As a result, the satellite suffers from temporal instabilities and the images are occasionally blurred as the objects are randlomly shifted within the CCD plane from frame to frame.

The leader of proposed project developed currently the most efficient algorithm for BRITE data photometry. In his method, the image rasters are processed in several steps, which include: column intensity compensation, defective pixels selection and interpolation, centroid estimation and finally, flux measurement utilizing circular aperture photometry. Now, when the current pipeline is well-established and with much experience gained, it seems to be the most appropriate time for starting the research toward the new algorithm which, by employing more complex routines, will allow for reducing the noise floor in future data releases.

Research methodology In the proposed project, Adam Popowicz plans to investigate and develop several sophisticated solutions for the BRITE images processing. First, the model of satellite rotations is going to be implemented to retrieve the objects centroids globally, instead of independent analysis in each image raster. For this purpose, the positions of each star in the field will be estimated and then the weighted least mean square algorithm will be used to obtain three satellite rotation angles (roll, pitch and yaw) in a robust way.

Another new approach will be used for the restoration of blurred images. In current method, such frames are rejected from the analysis, therefore the overall quality of photometry decreases due to the lower number of observations. In future pipeline, the blurred images will be compared with a database of possible blur effects, to assess direction and strength of satellite motion during exposure. By such precise characterization of blurred images, the adaptive aperture will be created to identify the pixels with the registered star flux.

Another important part of proposed project will be the evaluation of effectiveness of various impulsive noise reduction routines. In current pipeline, the median filtering schema is frequently utilized. The project leader, by his extensive literature search, has selected a large set of the most prominent algorithms which are widely used for reduction of such a noise. All the methods will be implemented and their accuracy evaluated. For this purpose a model of stellar profile will be created, which will account for the variability of profiles shape due to the temperature and position within CCD plane.

The last of most vital elements of the new pipeline will be the utilization of the photometry based not on the charge counting (as it is now) but on the stellar profile fitting. This kind of flux assessment was not applicable in current algorithm due to the high level of noise, problem of precise centroid estimation and because of the profile fluctuations with temperature. With the new solutions proposed in this project, especially robust estimation of centroid and new image filtering techniques, the profile photometry will become possible again. The leader will also propose a novel weighted least-mean-squares approach which will allow for robust profile fitting, in which defective pixels will be gradually excluded from the analysis. The saturated images, the dimmest objects and the most disturbed data sets will be the main beneficiaries of this new approach.

Research impact The precise photometry of objects was the main goal of the BRITE nanosatellites constellation. Unfortunately, the radiation-induced defects in CCDs complicated the mission and made the image processing a difficult task. The established pipeline allowed for the astronomical evaluation of light curves and made possible presentation of the first scientific results produced by the mission. However, there is a strong requirement for starting the research toward the new pipeline which will further decrease the noise level of observations. It is currently one of the the most important technical issue as it affects directly the mission success and the range of possible discoveries based on the BRITE data.