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LIGHT CURVE INVERSION FOR ATTITUDE RECONSTRUCTION OF TUMBLING SPACE DEBRIS

Abstract

In recent years, the problem of space pollution has become more and more important in the space field. Space debris monitoring and tracking is fundamental to keeping space accessible for human operations. Within the SST framework, observations through optical telescopes allow space agencies to directly observe an orbiting object and study the corresponding trail (streak or tracklet) it leaves on the detector. From these streaks, a post-processing phase extracts the in-time light variation reflected by the object (light curve). Light curves embed key features such as the debris orbital parameters and attitude state. Particularly, the information about the latter is crucial when it comes to actively removing the debris or predicting how it will behave when/if it will re-enter the atmosphere. In the literature, attitude motion estimation relies on methods developed for the determination of asteroids and variable stars rotational period (period finding algorithms). More complex approaches, such as light curve inversion, allow to reconstructing the attitude state by simulating the dynamics of a geometry-defined object and the way it reflects the light coming from the Sun. In this work, a variation of the latter is used to extract the angular velocity of a generic tumbling object approximated by a simplified geometry. Its dynamics evolution is leveraged to build synthetic light curves through a basic reflection model. They are used to fit the real ones extracted from FITS images solving an optimization problem that outputs the attitude state of the target. Moreover, synthetic images containing streaks are generated to validate the pipeline with the same simulation process. Considering the results, the algorithm correctly extracts and analyses streaks from both real and synthetic images. For moderate rotational regimes, the object angular velocity norm and out-of-plane component are accurately retrieved. On the other hand, the in-plane components are sometimes inverted and, in general, their optimization is less accurate. Furthermore, the relative error between optimized and simulated angular velocity norm is computed for multiple runs of the algorithm on the same image. For simulated angular velocities less than 10 deg/s, the error is kept below 5% in 80% of the cases, whereas with faster rotations (angular velocities above 90 deg/s), its magnitude and statistical behaviour worsen. In general, for high rotational regimes, the overall validity of the results slightly decreases, albeit remaining acceptable for a preliminary analysis of the target tumbling motion.