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LONG-TERM ORBITAL LIFETIME PREDICTION OF HIGHLY ECCENTRIC ORBITS

Abstract

Highly eccentric orbits (HEOs) are perturbed by the combined effect of the Earth's oblateness, luni-solar third-body gravity, atmospheric drag and solar radiation pressure. Particularly, HEOs may be subject to various orbital resonances, such as the solar apsidal resonance and secular luni-solar resonances. Consequently, the orbital evolution and lifetime of space objects in HEOs are sensitive to initial conditions and to the parameters of the dynamical model. The long-term orbital lifetime prediction for the HEOs is still a quite challenging subject, and the prediction accuracy is not satisfactory. Therefore, the long-term orbital lifetime prediction of HEOs is well worth further studies.

Generally, long-term orbital lifetime prediction is done by propagating an object until it reaches the altitude of about 100 km or 80 km. For long-term predictions, the orbit has a relatively long residue lifetime, and then a semi-analytical dynamical model is usually used for orbital propagation. The main difficulties for HEOs are handling large uncertainties of the publicly available Two Line Elements set (TLEs) and the high dynamical sensitivity of the orbital evolution, as well as estimating the area-to-mass ratio (AMR) of the object.

In this study, we will concentrate on the long-term orbital lifetime prediction of HEOs based on TLEs. Firstly, for the TLEs data, we do a pre-processing by filtering their outliers. Meanwhile, according to the decay of semi-major axis and the variation of eccentricity, two AMRs corresponding to the drag and solar radiation pressure are estimated, respectively, based on a weighted least-squares algorithm by taking the TLE states as input pseudo-observations. Then, a singly-averaged, semi-analytical orbital model is established to propagate the HEO until its re-entry. However, due to the high dynamical sensitivity of orbital evolution induced by the perturbation coupling and orbital resonances, a single extrapolation may be not reliable for the HEO. Therefore, we will adopt statistical methods to calculate the probability distribution of orbital lifetime by slightly changing the initial conditions and the parameters of the dynamical model. The sensitivity of orbital lifetime will be analyzed based on its probability distribution. Further, the performance of the method is assessed by the accuracy of orbital lifetime prediction of space objects, which re-entered from HEOs in the past 50 years. Finally, based on the prediction accuracy of past re-entries, the effects of orbital resonances on lifetime prediction are analyzed specially.