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Uticaj nisko-energetskih sudara na dinamičku evoluciju NEA objekata

U radu je analiziran uticaj nisko-energetskih sudara na dinamičku evoluciju NEA (Near earth asteroids) objekata, prilikom njihovog prolaska kroz asteroidni pojas. Napravljen je teorijski model asteroidnog pojasa i model sudara asteroida i NEA objekta.

Model asteroidnog pojasa podrazumeva vremenski nepromenljiv, polarno simetričan torus sa centrom u Suncu, nastanjen asteroidima. Za opis pojasa koriste se dve funkcije: gustina asteroidnog pojasa $n(\mathbf{r}, R)$ i Keplerovska brzina asteroida $\mathbf{u}(\mathbf{r})$, gde je $\mathbf{r}$ radijus-vektor (u heliocentričnom sistemu), a R poluprečnik asteroida, respektivno. Gustina asteroidnog pojasa je nađena kao proizvod tri komponente: broja asteroida po jedinici površine u heliocentričnoj ravni, broja asteroida po pravcu normalnom na heliocentričnu ravan i raspodele asteroida po radijusima. Za prve dve raspodele pretpostavljeno je da su Gausove a za treću da je inkrementalna. Keplerovska brzina asteroida se dobija na osnovu principa o centripetalnoj prirodi gravitacione sile. Empirijska osnova asteroidnog pojasa je baza podataka malih tela Sunčevog sistema The Asteroid Orbital Elements Database (http://www.naic.edu/~nolan/astorb.html) na osnovu koje su nađene numeričke vrednosti konstanti u funkcijama koje opisuju asteroidni pojas.

U modelu sudara je izveden izraz koji kumulativno računa verovatnoćnu sudara između NEA objekta i asteroida P_s po putanji NEA objekta a na osnovu funkcije gustine asteroidnog pojasa i kinematike NEA objekta. Ukoliko do sudara dođe, a to se određuje po tome da li slučajno izabran broj rand $\in [0, 1]$ zadovoljava rand $\leq P_s$, po principu slučajnosti se biraju koordinate tačke sudara na orbiti NEA objekta (jer do njega može doći bilo gde na orbiti) i prelazi se na pogodne transformacije koordinatnih sistema kako bi se sudar dve homogene sfere (asteroida i NEA objekta) u prostoru, matematički sveo na sudar dve materijalne tačke (njihovih centara) po pravoj, što je dalje rešeno primenom zakona održanja linearnog impulsa i mehaničke energije.

NEA objekat (homogena sfera poluprečnika R_{NEA} i gustine σ) se kreće po po heliocentričnoj orbiti opisanoj Keplerovskim orbitalnim elementima. Izbor NEA objekta mora da zadovolji da on prolazi kroz asteroidni pojas dovoljno dugo da račun verovatnoće sudara daje dovoljno veliku učestanost sudara. U tu svrhu je izabran pogodan objekat 2212 Hephaistos (1978 SB). U numeričkoj simulaciji su varirani poluprečnici posmatranog objekta, dok su ostali parametri (fizički i orbitalni) tabelarni. Za izabrani objekat praćena je njegova dinamička evolucija tokom 20 sudara.

Račun veronatnoće predviđa da će P_s po završetku jednog perioda stepeno opadati sa povećanjem poluprečnika NEA objekta. Zbog toga bi trebalo očekivati da će, u srednjem, za velike vremenske rezolucije broj sudara biti veći što NEA objekat ima manji poluprečnik. Naše numeričke simulacije su sa ovakvim očekivanjem u saglasju, što se može protumačiti kao indikator (delimične) valjanosti teorijskih modela.

Impact of Non-Destructive Collisions on the Dynamical Evolution of NEA Objects

The aim of this paper is to investigate the impact of non-destructive collisions on orbital parameters of NEA objects, during their movement through an asteroid belt. In this paper, a theoretical model of asteroid belt and a model of collisions of asteroids and NEA objects were made.

The model of the asteroid belt presumes temporaly fixed, polar symmetric torus centered at the Sun where asteroids reside. For a description of the

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asteroid belt two functions were used: the density of the asteroid belt $n(\mathbf{r}, R)$ and the Keplerian speed of asteroids $\mathbf{u}(\mathbf{r})$, where $\mathbf{r}$ and R are radius-vector (with respect to Sun) and the radius of the asteroid, respectively. The density of the asteroid belt was found as the product of three components: the number of asteroids per unit area in heliocentric plane, the number of asteroids in the direction perpendicular to the heliocentric plane and the distribution of asteroids in radius. First two distributions are assumed to be Gaussian and the third is asumed incremental. Keplerian asteroid speed was obtained via centripetal nature of gravitational force. Empirical base for asteroid belt, used for obtaining numerical constants in the functions that describe the asteroid belt, is a database of small solar system bodies The Asteroid Orbital Elements Database (http://www.naic.edu/~nolan/astorb.html).

In the collision model expression that cumulatively accounts probability of collision between the object and the NEA asteroid on the NEA object orbit P_s was derived. It is based on the asteroid belt density function and kinematics of the NEA object. If a collision occurs, and this is determined by whether the randomly chosen number rand $\in [0, 1]$ satisfies rand $\leq P_s$, then the coordinates of the point of collision at the NEA object orbit are randomly selected (because it can take place anywhere on the orbit) and appropriate transformation of the coordinate system is made. Coordinate system transformation is needed so the collision of two homogeneous spheres (asteroid and NEA object) in space is mathematically reduced to a collision of two points (their centers) at the line, which is further solved by applying the conservation laws of linear momentum and mechanical energy.

The NEA object (homogeneous sphere of radius R_{NEA} and density σ) moves on the heliocentric orbit described by Keplerian orbital elements. NEA object choice must ensure that he passes through the asteroid belt long enough so P_s provides a substantial frequency of collisions. The selected suitable object was 2212 Hephaistos (1978 SB). In the numerical simulation the radius of object was varied, while other parameters (physical and orbital) were tabular. Dynamical evolution was monitored during 20 collisons.

The model of collison predicts that during one period of NEA object P_s declines with the increasing of NEA object radius. Therefore, it is expected that, on average, for high temporal resolution the number of the collision will be higher if NEA object has a smaller radius. Our numerical simulations are in agreement with this expectation which could be interpreted as an indicator of (partial) validation of theoretical models in this paper.