ОДИННАДЦАТЫЙ МОСКОВСКИЙ СИМПОЗИУМ ПО ИССЛЕДОВАНИЯМ СОЛНЕЧНОЙ СИСТЕМЫ 11M-S^3

октябрь 5-9, 2020
ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК
МОСКВА, РОССИЯ

THE ELEVENTH MOSCOW SOLAR SYSTEM SYMPOSIUM 11M-S^3

october 5-9, 2020
SPACE RESEARCH INSTITUTE OF RUSSIAN ACADEMY OF SCIENCES
MOSCOW, RUSSIA

спонсоры:
- Российский Фонд Фундаментальных Исследований (РФФИ)
- Институт Космических Исследований РАН

sponsored by:
- Russian Foundation for Basic Research (RFBR)
- Space Research Institute RAS

ISBN- 978-5-00015-050-4
DOI: 0.21046/11MS3-2020
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ИНСТИТУТ КОСМИЧЕСКИХ ИССЛЕДОВАНИЙ РОССИЙСКОЙ АКАДЕМИИ НАУК (ИКИ РАН)
2020

STUDY OF THE DYNAMIC STRUCTURE OF THE NEAR–LUNAR ORBITAL SPACE

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KEYWORDS:
Near–Lunar orbital space, dynamic structure, numerical modeling, lunar satellite lifetime

INTRODUCTION:

The knowledge of the dynamic features of the near-lunar space is necessary for its optimal mastering. This work is devoted to a study of the special features of the dynamics of the artificial Moon satellites (AMS) with intermediate and high orbits in the range of semimajor axes from 2500 to 26000 km.

RESULTS:

The AMS motion was predicted for a 10-year period using the program "Numerical Simulation of AMS Motion" developed by the authors of the report. In the process of research, the following perturbing factors were taken into account: the influence of the selenopotential up to harmonics of the 50^{th} order and degree and the attraction of the Sun and the Earth.

The results shown in Figure 1 illustrate the main feature of the dynamics of near-lunar objects in the intermediate and high orbits. The dependences of the AMS eccentricity and lifetime increase on the semimajor axis and the inclination of the orbits are well traced. These features of the dynamics of near-lunar satellites were also emphasized by other authors [1–4]. As can be seen, the increase in the eccentricity is accompanied by the drastically reduced lifetimes of satellites in the orbits.

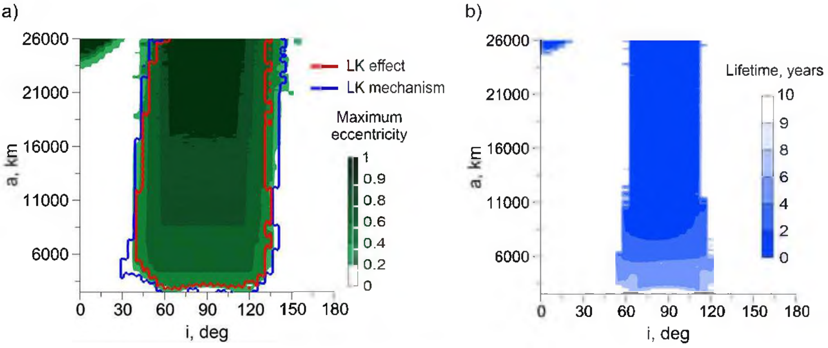

Fig. 1. Estimates of the satellite eccentricity (a) and lifetime in the orbit (b) depending on the initial values of the inclination and semimajor axis of the objects

Such increase in the eccentricity in the near-polar orbits, as a rule, is a consequence of the action of the Lidov – Kozai mechanism [5–8]; therefore, we studied this problem in more detail. This mechanism is manifested in the Lidov–Kozai resonance and effect.

The analytical method of revealing the action of secular resonances on the orbital dynamics of objects was described in detail in our work [9]. The Lidov–Kozai effect was estimated by the presence of the energy transfer between the eccentricity and the inclination while maintaining the integral $c_1 = \sqrt{1-e^2}\cdot\cos i$, and the presence of the sharp Lidov – Kozai resonance was judged by the proximity to zero of the Lidov – Kozai integral for a negative value of the Lidov integral $c_2 = \left(2/5 - \sin^2\omega\cdot\sin^2 i\right)e^2$.

Figure 1a shows contours of regions affected by the Lidov – Kozai mechanism (in dark blue color) and effect (in red color) according to our estimates.

An analysis of the results shown in Figure 1a demonstrates that the main source of the eccentricity growth in the intermediate and high orbits is the influence of the Lidov – Kozai mechanism on the AMS dynamics.

It can be clearly seen that the region of manifestation of the Lidov – Kozai effect covers the most part of the region in which the Lidov – Kozai mechanism acts on the orbital evolution of objects.

Our investigations showed that in the dynamics of objects with intermediate orbits, the Lidov – Kozai effect will be manifested through its overlap with the field action. Moreover, from our analysis of the results obtained it follows that the gravitational field of the Moon accelerates the manifestation of the Lidov – Kozai effect. The given effect is illustrated by Figure 2. Our studies showed that the higher the orbit, the smaller the manifestation of the field-induced Lidov – Kozai effect. Moreover, for objects in high orbits, the effect will be manifested practically in its pure form.

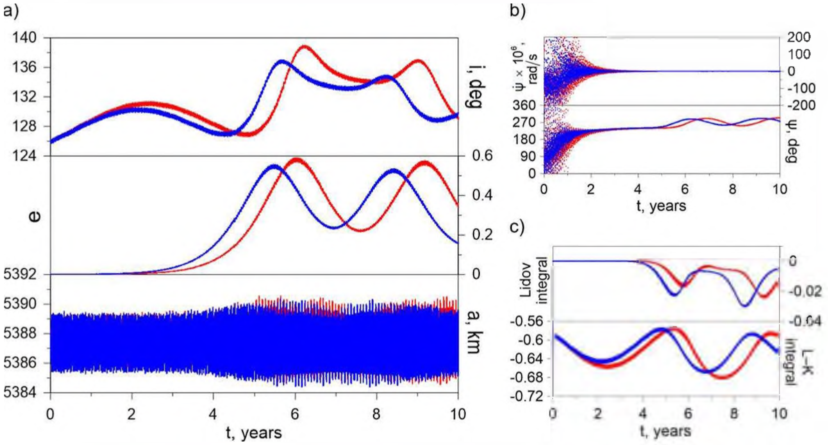

Fig. 2. Manifestation of the Lidov – Kozai effect for the object with semimajor axis less than 8500 km with allowance for perturbations from the total gravitational field of the Moon and the attraction of the Earth and the Sun (in dark blue color) and only from the Earth and the Sun (in red color): a) evolution of the orbit elements: b) resonant characteristics: c) time variations of the Lidov integral and the Lidov – Kozai integral

As to the growth of the orbit eccentricities for near-equatorial objects with semimajor axes in the vicinity of 26000 km, it is caused by the direct effect of the Earth.

CONCLUSIONS

Thus, our studies have shown that a part of the near-lunar objects has a short lifetime in the orbit, which is explained by the growth of the eccentricities of their orbits. Analyzing the results obtained, we can state that for the near-polar objects this phenomenon is caused by the influence of the Lidov – Kozai mechanism, and for the near-equatorial objects, it is caused by the direct influence of the Earth.

ACKNOWLEDGEMENTS

This work was supported by the Russian Science Foundation (Scientific Project No. 19-72-10022).

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