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Preliminary report

# ON INTERACTIONS BETWEEN (1) CERES AND (2) PALLAS

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**SUMMARY: Mutual perturbing effects between (1) Ceres and (2) Pallas are presented by using differences in their right ascensions and declinations. These differences are obtained as the result of two integrations–with and without the mass of the perturbing body. For each body are performed two backward and two forward integrations and obtained results are analysed.**

## 1. INTRODUCTION

As is well known (1) Ceres and (2) Pallas are in a 1:1 temporary resonance and every 4.6 years these two largest asteroids mutually approach. Between 1802 and 1839 all close encounters were within 0.25 AU ( the closest encounter, 0.18 AU, was in 1820). As can be seen from Fig.1, the last close encounter between these two objects was in 1996, but at the minimum distance of 1.38 AU, when the mutual influences are practically neglegible.

From the consideration of the perturbations on Pallas by Ceres, Schubart (1970) derived the mass of Ceres and found the value $(6.7\pm0.4)10^{-10}M_{\odot}$. By using a slightly different set of Pallas observations, Schubart (1974) obtained a new value for mass of Ceres, $M_C$=$(5.9\pm0.3)10^{-10}M_{\odot}$. From the observations of Ceres in the period 1801–1970, Schubart (1974, 1975) determined the mass of Pallas and found the value $(1.14\pm0.22)10^{-10}M_{\odot}$. Later, again considering perturbations by Ceres on Pallas, Landgraf (1988) obtained a new value for the mass of Ceres: $(5.0\pm0.3)10^{-10}M_{\odot}$. The last determination of the mass of Ceres from Pallas observations was done by Viateau and Rapaport (1995). The obtained value is $(5.0\pm0.2)10^{-10}M_{\odot}$.

## 2. RESULTS

It is well known that the mutual perturbing effects between (1) Ceres and (2) Pallas are not negligible, and this fact is used for the determination of their masses. It is also obvious that perturbing interactions between these two asteroids exist during the close approaches only, when their orbits slightly change. Having in mind the 1:1 resonance in the mean motions of (1) Ceres and (2) Pallas, the changes increase due to the cumulative effect. But, the changes of their orbits constantly increase due to the perturbing effects by major planets, which act in a different way. On account of this fact, very important is the procedure of the numerical integration. In this case it is best to start with a forward integration from the epoch prior to the closest encounter.

Asteroids (1) Ceres and (2) Pallas are the most observed– the interval of about 200 years is covered by observations, so we would expect their orbits to be known with a high precision. Their orbital elements are determined by using observations from 1839. In our calculus used were the orbital elements published in EMP by ITA in Sankt-Peterburg. By the use of a Radau integrator of order 15 developed by Everhart (1985), the orbital elements were calculated for two epochs: JD 2451500.5 for backward integration and JD 2378500.5 for forward integration.

Further we have calculated the residuals in the geocentric right ascensions and declinations, as inferred from two numerical integrations, one with and the other without taking into account the effects of the perturbing asteroid, by using convential masses– $5.9 \times 10^{-10} M_\odot$ for Ceres and $1.1 \times 10^{-10} M_\odot$ for Pallas.

In Figs 2-3 are given so obtained residuals in right ascension and declination of Pallas, as result from two backward integrations. The corresponding residuals for Ceres are given in Figs 4-5 (here Pallas is the perturbing body).

The same residuals, but as the result of two forward inegrations are presented in Figs 6-7 (for Pallas) and Figs 8-9 (for Ceres).

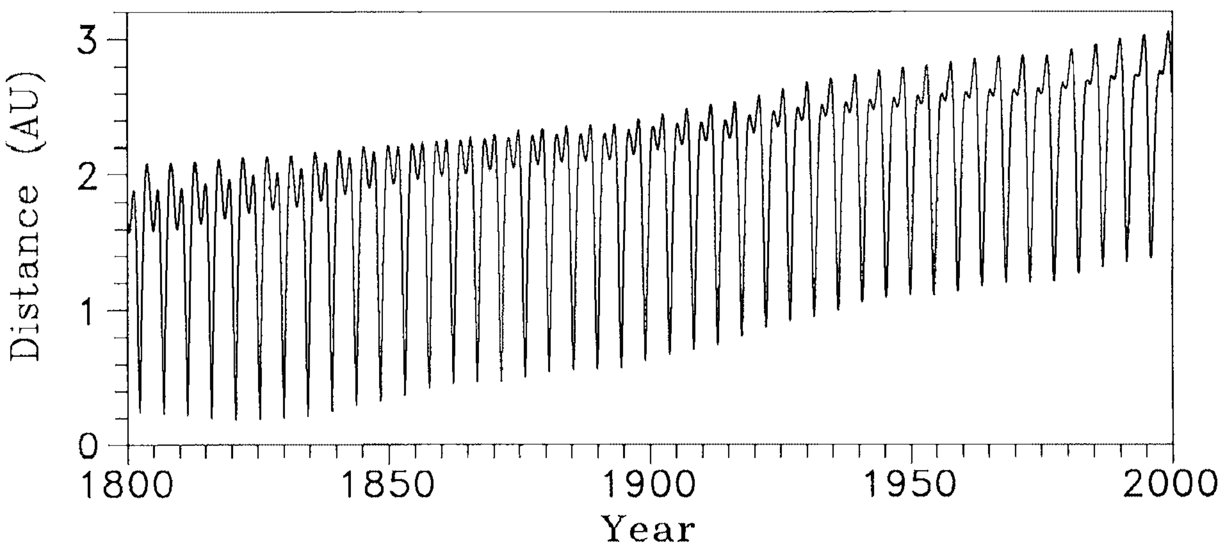


**Fig. 1.** *Mutual distance between (1) Ceres and (2) Pallas from 1800 to 2000.*

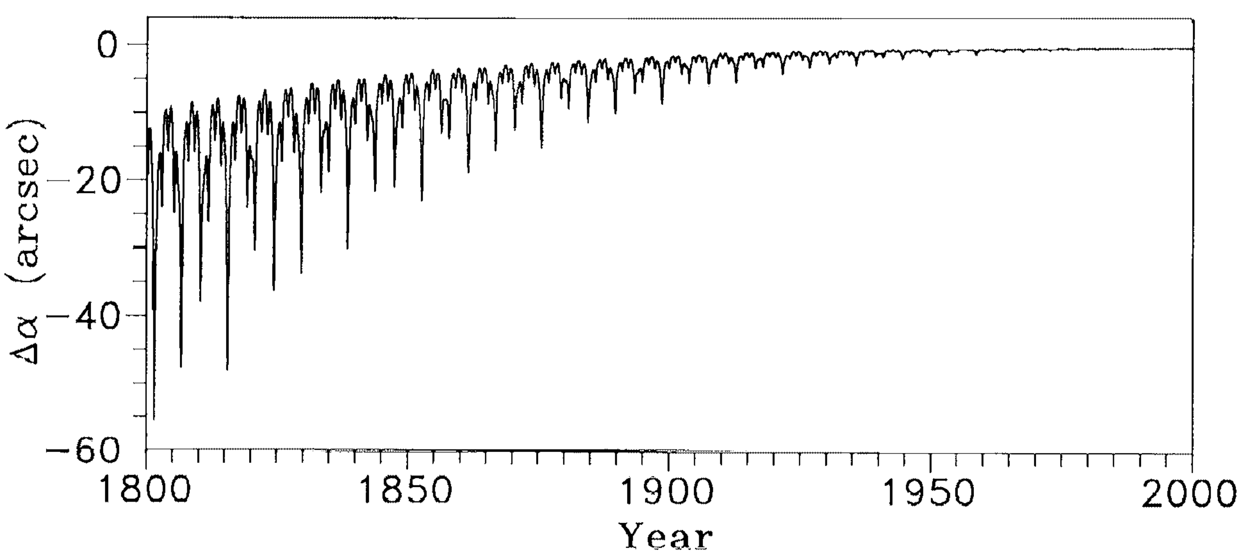


**Fig. 2.** *Differences of the geocentric right ascensions of the perturbed body (2) Pallas, as inferred from two backward numerical integrations, one with and the other without taking into account the effects of the perturbing body (1) Ceres.*

Having in mind that such residuals in right ascensions and declinations of Ceres and Pallas have to be used as a tool for mass determinations, one can conclude that by the procedure with forward integration a better result will be obtained. By backward integrations, the results are based on old observations; all observations after 1950 practically are not influential. Cenversely, by forward integrations, the results will be based on the observations after 1900, as can be seen in Figs 6-9. Further, all future observations also can be included for new determinations of the masses of (1) Ceres and (2) Pallas.

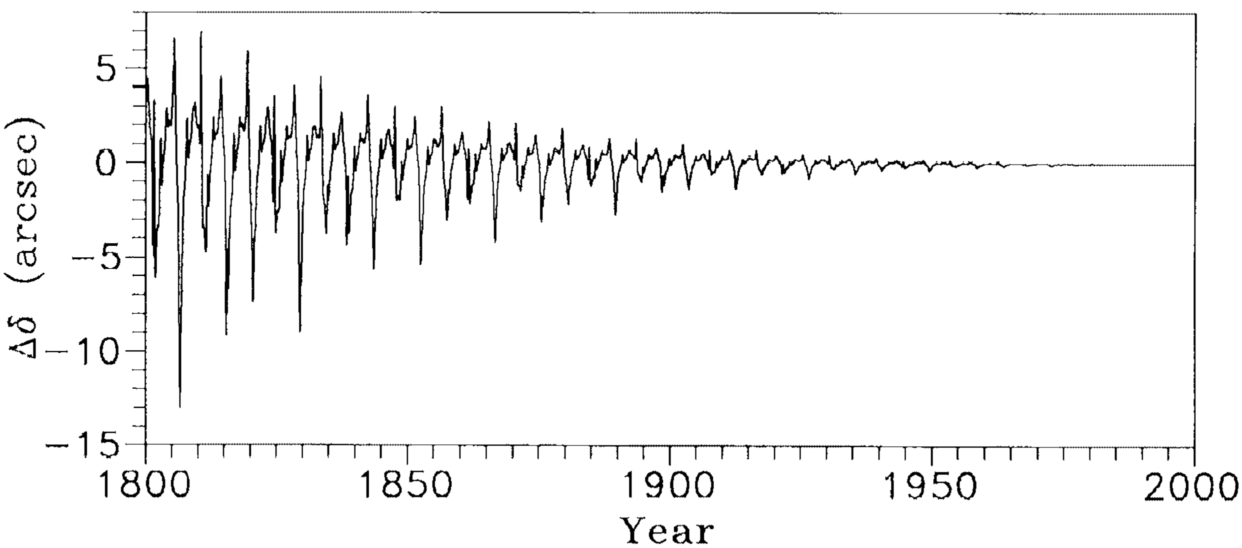


**Fig. 3.** *Differences of the geocentric declinations of the perturbed body (2) Pallas, as inferred from two backward numerical integrations, one with and the other without taking into account the effects of the perturbing body (1) Ceres.*

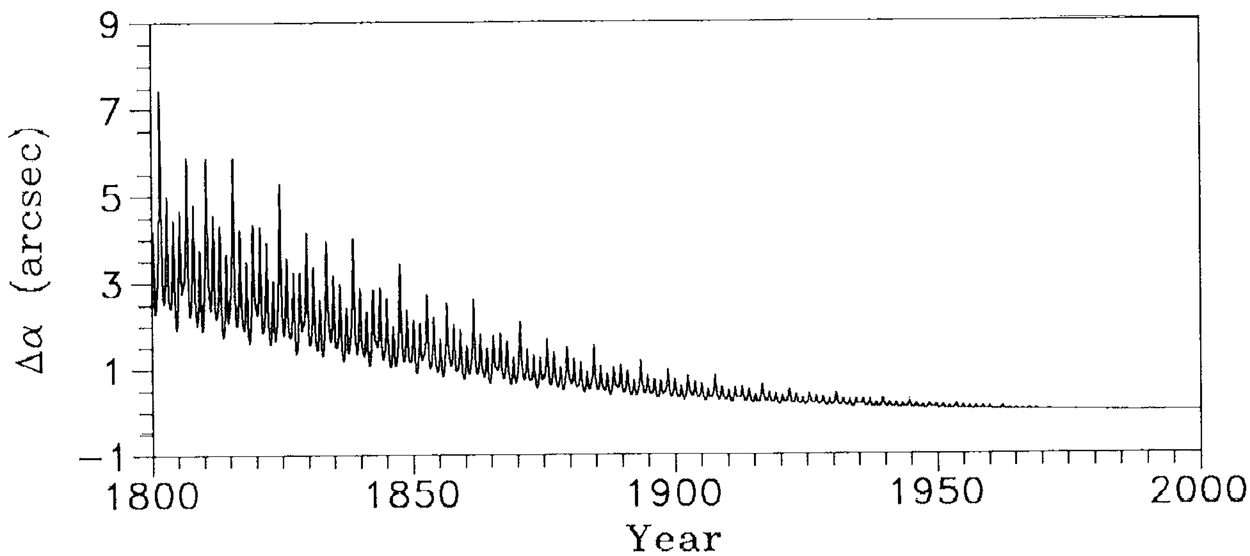


**Fig. 4.** *Differences of the geocentric right ascensions of the perturbed body (1) Ceres, as inferred from two backward numerical integrations, one with and the other without taking into account the effects of the perturbing body (2) Pallas.*

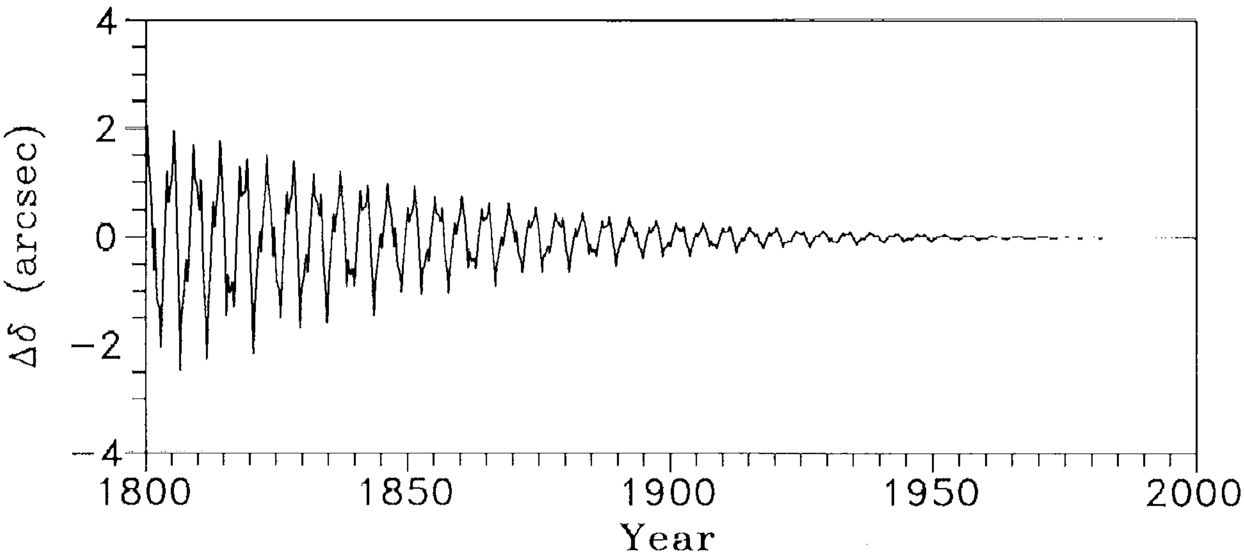


**Fig. 5.** *Differences of the geocentric declinations of the perturbed body (1) Ceres, as inferred from two backward numerical integrations, one with and the other without taking into account the effects of the perturbing body (2) Pallas.*

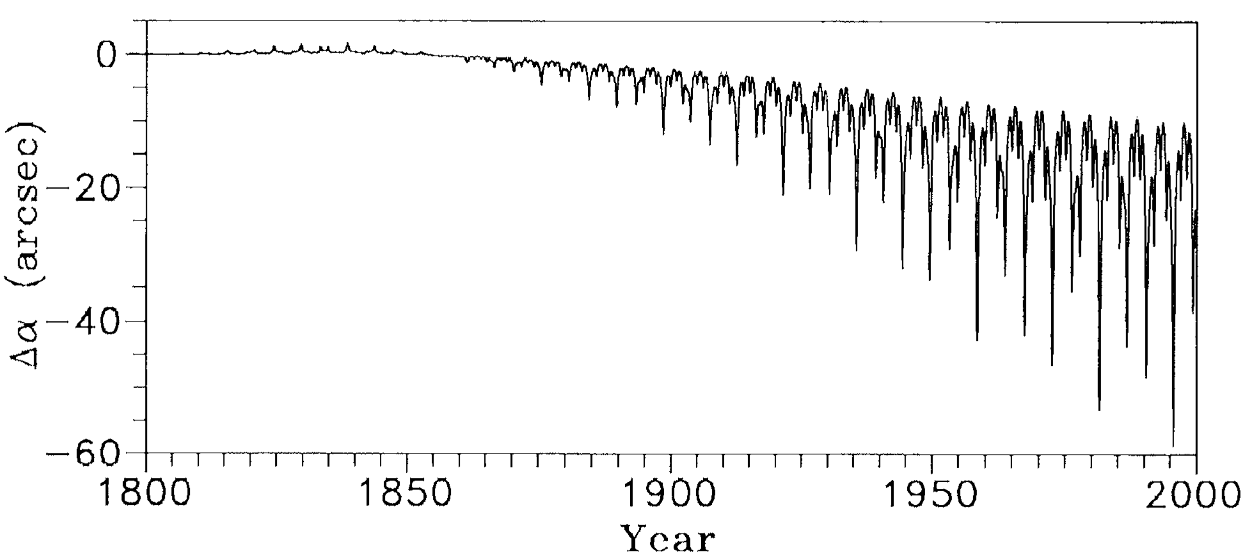


**Fig. 6.** *Same as Fig. 2., but from two forward integrations.*

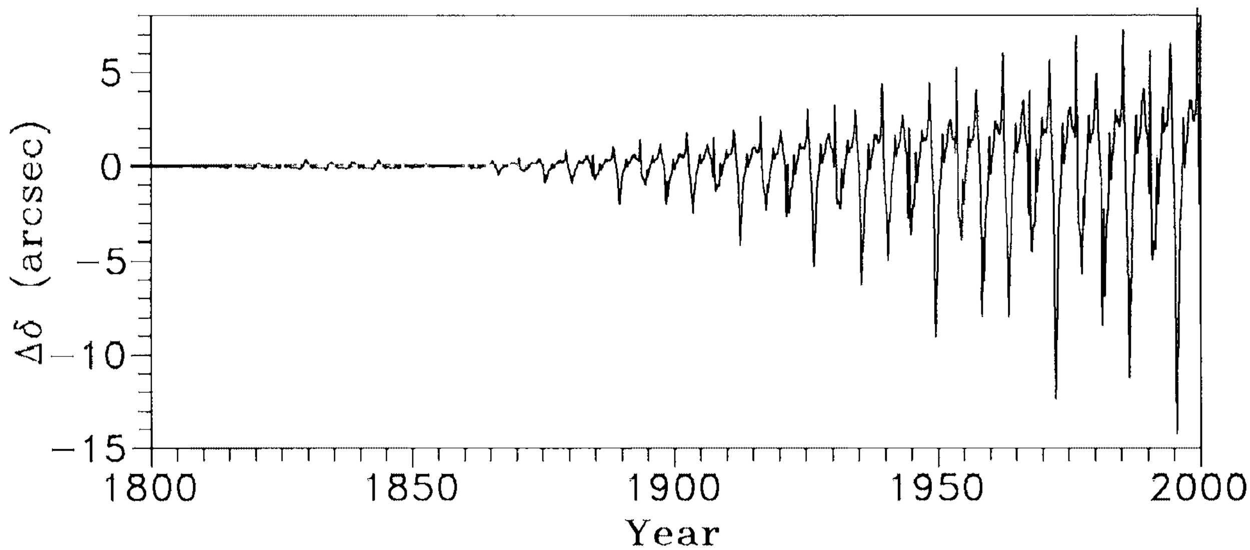


**Fig. 7.** *Same as Fig. 3., but from two forward integrations.*

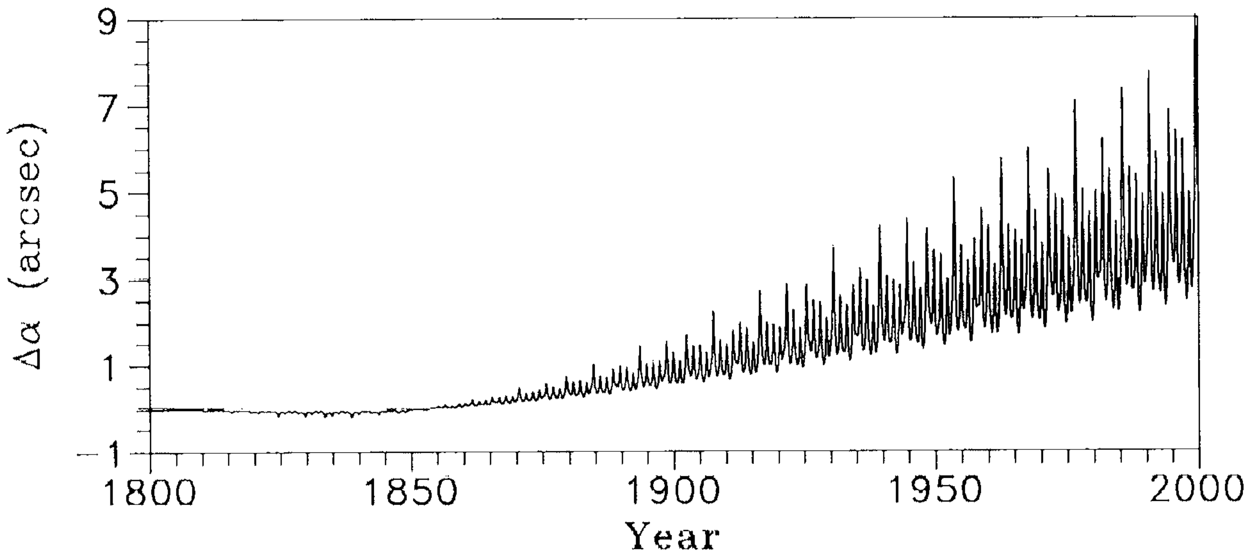


**Fig. 8.** *Same as Fig. 4., but from two forward integrations.*

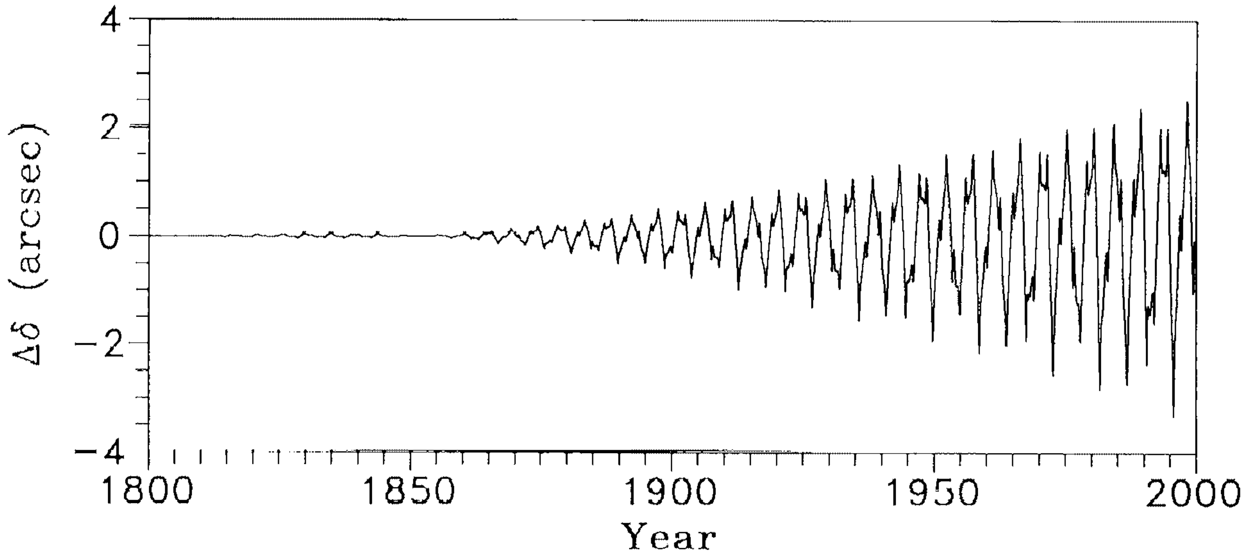


**Fig. 9.** *Same as Fig. 5., but from two forward integrations.*

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## О ИНТЕРАКЦИЈАМА ИЗМЕЂУ (1) ЦЕРЕСА И (2) ПАЛАСА

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*Претходно саопштење*

Презентирани су међусобни поремећајни ефекти између (1) Цереса и (2) Паласа коришћењем разлика у њиховим ректасцензијама и деклинацијама. Ове разлике добијене су као резултат две интеграције – са и без масе поремећајног тела. За свако тело извршене су по две интеграције уназад и две интеграције унапред и анализирани су добијени резултати.