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Estimation of masses of some minor planets from observations of perturbed bodies

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The most straightforward method of mass determination of minor planets is the dynamical one which uses the gravitational perturbations produced by minor planet in the motion of other bodies. Its disadvantage consists in large relative errors of mass determination which are common for this method. They arise from insufficient accuracy of observations of 'test bodies' (minor planets) and deficient number of close approaches resulted in perceptible perturbations in the motion of small bodies. The merit of this method is its independence of any a priori suppositions concerning internal structure of a minor planet, its mineralogical composition and correspondingly assigned mean density what is essential for determining value of the 'photometric mass'.

As was shown in [1], the number of perturbed minor planets used as "test particles" can be substantially enlarged by considering bodies moving in the vicinity of commensurability of mean motions with a chosen minor planet. In the present paper one more attempt has been made to estimate masses of some minor planets with as high precision as possible.

The work was done in several steps. At first, the perturbed minor planets having a single close approach to the perturbing planet up to 0.05 a.u. or less as well as perturbed minor planets close to the commensurability with the perturbing planet and having several approaches to it up to 0.1 a.u. or less have been selected. Then, several determinations of the perturbing mass have been fulfilled using observations of each perturbed body separately. The results were separated by the value of the error of mass determination. Those bodies with a single approach that gave error greater than $0.5 \cdot 10^{-10} M_{Sun}$ as well as those with several approaches that gave error greater than $1 \cdot 10^{-10} M_{Sun}$ were eliminated from the subsequent consideration.

After that, the general solution was found for each perturbing planet. This solution provides the best fit to observed positions of all perturbed minor planets used in solution and of the perturbing mass. When finding general solution the positions of perturbed minor planets were determined with accounting for

perturbations from nine major planets in correspondence with DE403. Besides, the perturbations from 300 minor planets (including the minor planet with the mass to be improved) were taken into account. Masses of these 300 minor planets were taken in conformity with DE403, but their coordinates were obtained by numerical integration starting from the osculating elements published in [3]. The relativistic terms due to the Sun were included in the equations of motion. The observations were corrected for gravitational deflection of light and for phase effect by Lommel–Zeeliger law of scattering.

Some results of the work are presented in the table. The values of the masses of corresponding planets, found in [2] from their IRAS diameters and the mean densities assigned in conformity with their conventional taxonomic classes, are given for comparison.

The values of the masses of minor planets (15), (29) and (65) appear to be rather close in both papers. In contrast to it, there is still a difference in values for planet (7) obtained in various ways.

Perturbing minor planet	Number of perturbed minor planets	Mass in $10^{-11}\ M_{Sun}$	Mass from [2] in $10^{-11}\ M_{Sun}$
(7) Iris	4 (1:1)	1.5 ± 0.6	
	26 (close approaches)	1.4 ± 0.2	
	30 (total)	1.4 ± 0.1	0.6 ± 0.1
(15) Eunomia	14 (total)	1.2 ± 0.2	1.4 ± 0.2
(29) Amphitrite	15 (total)	0.77 ± 0.12	0.74 ± 0.1
(65) Cybele	25 (total)	0.58 ± 0.15	0.52 ± 0.03

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