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New estimates of the mass and density of asteroid (16) Psyche

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Abstract

We briefly detail our novel Markov-chain Monte Carlo algorithm for asteroid mass estimation based on asteroid-asteroid close encounters and present our latest results for the mass of asteroid (16) Psyche based on several different close encounters. We utilize our results alongside the latest literature values for the volume to compute the corresponding density for Psyche and compare our results to previous density and mass estimates for this asteroid.

1. Introduction

There is currently great interest in the asteroid (16) Psyche, as it is the target of NASA's upcoming eponymous Psyche mission [2]. Based on radar observations and its reportedly high density, Psyche is thought to be the exposed metallic core of a protoplanet [4]. Recently, we applied our Markov-chain Monte Carlo (MCMC) mass estimation algorithm to Psyche, among other asteroids, and obtained separate densities of $1.57^{+1.17}_{-0.70}$ g/cm^3 and $2.35^{+0.68}_{-0.98}$ g/cm^3 with two separate, independent sets of close encounters [6]. These results imply a density approximately half of the generally accepted literature values, casting some doubt upon previous theories regarding Psyche's composition. However, we could not entirely rule out previous density estimates as the accepted literature values remained barely within our 3σ boundaries. In addition, we predicted that high-precision astrometry taken during the summer of 2019 of (151878) 2003 PZ$_4$, one of the test asteroids considered in our previous work, may significantly reduce the uncertainties of mass estimates for Psyche based on this encounter.

Here we apply our MCMC-based mass estimation algorithm previously described in [6] to the case of Psyche while including the latest astrometry for each considered asteroid, including 2003 PZ$_4$. Where possible, we also seek to make use of astrometry from the second Gaia data release [3]. This allows us to test our previous prediction and potentially either confirm or refute Psyche's previously accepted mass and density values. We present our latest results for Psyche's mass and density utilizing this new astrometry and compare these values to previous literature values, including those of our own.

2. The MCMC algorithm

We utilize our previous robust adaptive Metropolis-based MCMC mass estimation algorithm [5, 6] which has been well tested and generally gives results consistent with previous literature values with wider and, possibly more realistic, uncertainties in comparison to previous studies using the least squares method. We use astrometry obtained from the Minor Planet Center for each object combined with an astrometric error model [1].

3. Previous predictions

Figure 1 shows our previous prediction of the behavior of (151878) 2003 PZ$_4$. a test asteroid which has a close gravitational encounter with (16) Psyche, in terms of right ascension (RA) as a function of time. This prediction was made by separately propagating each of our accepted MCMC proposals for a run including Psyche, 2003 PZ$_4$ and a third test asteroid, to 60 000 MJD. It can be seen that the range of possible RA values for (151878) 2003 PZ$_4$ is up to approximately 2 arcseconds wide during the summer of 2019. Figure 2 shows strong correlation between the RA of 2003 PZ$_4$ and the mass of Psyche at 58650 MJD, confirming that this wide range of possible values is due to the uncertainty of the mass of Psyche in the MCMC results. This, in turn, allows us to predict that high precision astrometry taken at this time may significantly reduce the range of possible masses for Psyche in this case.

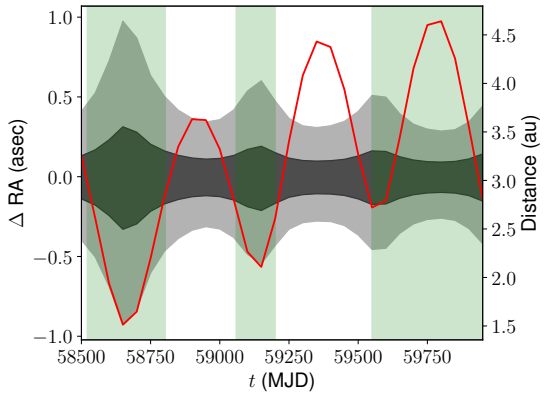

Figure 1: Ephemeris prediction for asteroid (151878) 2003 PZ_4 up to MJD 60000 in terms of RA relative to the best-fit value. The 1σ and 3σ confidence intervals are shown in darker and lighter gray, respectively. The red line shows the asteroid's topocentric distance as a function of time. The green color represents times when the asteroid is observable assuming a topocentric observer by requiring that the solar elongation is greater than 60 degrees and the apparent V magnitude is less than 21. [6]

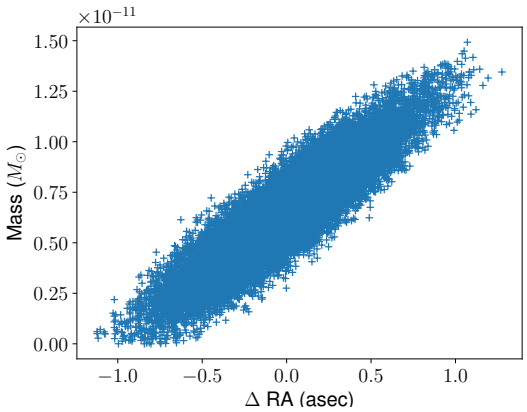

Figure 2: The mass of (16) Psyche versus the RA prediction for asteroid (151878) 2003 PZ_4 relative to the best-fit value at MJD 58650. [6]

4 Summary and Conclusions

We expect that new astrometry will enable us to obtain significantly improved mass and density estimates for (16) Psyche. The impact of these results on theories regarding Psyche's structure and composition remains to be seen.

Acknowledgements

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