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The Photocenter-Barycenter Effect in Gaia astrometry and its Impact on Asteroid Orbit Determination (online)

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The recent advancement of observational capabilities, particularly with the addition of Gaia observations, has brought significant improvements in the determination of orbital parameters for Small Solar System bodies. In this study, we investigate the impact of incorporating Gaia Data Release 3 (DR3) into the orbit determination process, with a specific focus on the photocenter-barycenter effect.

By combining ground-based and satellite observations obtained from the Minor Planet Center (MPC) with available radar data, we compare the results obtained with and without the utilization of Gaia DR3. Figure 1 presents the relationship between the semimajor axes and their associated uncertainties for 446 Near Earth asteroids in Gaia. The green data points represent semimajor axis values determined solely using ground-based and satellite observations available in the MPC, along with radar observations, if available. The blue data points depict semimajor axis values obtained when Gaia DR3 data is incorporated. We further analyze the covariance confidence ellipses to assess the impact of Gaia DR3 on the overall precision of the orbit determination. The green ellipsoids represent the confidence ellipses calculated solely using MPC data, while the blue ellipsoids include Gaia DR3 data. The inclusion of Gaia observations results in more tightly constrained confidence ellipses, validating the enhanced precision achieved through Gaia data. Gaia DR3 significantly reduces uncertainties for the semimajor axes and other orbital parameters.

To obtain the best possible orbital fit and minimize observation residuals, we integrate the photocenter-barycenter effect into Gaia observations for selected objects. This offset represents the difference between the measured photocenter and the true center of mass of an object. The magnitude of the photocenter-barycenter offset can be significant, reaching up to 10-20% of the asteroid's apparent diameter. By accounting for this offset, we further enhance the precision and reliability of Gaia astrometric measurements, contributing to the improved accuracy of orbital parameters.

This study highlights the substantial contributions of Gaia observations in improving the determination of orbital parameters, with a specific focus on the photocenter-barycenter effect.

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