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Title: Recent Radar Astrometry of Asteroid 2004 MN4

Authors: [Giorgini, J. D.](#); [Benner, L. A. M.](#); [Nolan, M. C.](#); [Ostro, S. J.](#)

Affiliation: AA(JPL/Caltech), AB(JPL/Caltech), AC(Arecibo Observatory), AD(JPL/Caltech)

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Abstract

Arecibo (2380-MHz) delay-Doppler radar astrometry obtained in late January of 2005 significantly corrected 2004 MN4's orbit. Doppler-shifted echoes were acquired 4.8-sigma away from the predicted frequency on Jan 27, while range to the object on Jan 29 was found to be 747 km (2.8-sigma) closer to Earth than the pre-radar orbit solution predicted. Incorporation of these radar measurements into least-squares orbit solution #82 resulted in a new predicted Earth encounter on 2029-Apr-13 of 36000 +/- 9900 km (3-sigma formal uncertainties), or 5.6 +/- 1.6 Earth radii, from Earth's center. This is inside geosynchronous orbit and 27700 km (4.3 Earth radii) closer to Earth than predicted by the pre-radar ephemeris -- a 5-sigma change compared to the pre-radar orbit solution, illustrating the problematic nature of prediction and statistical analysis when only single-apparition optical data-sets are available. The current data-set does not permit reliable trajectory propagation to encounters later than 2029; this may not be possible until data from 2012-2013 are available. The corrected nominal approach distance in 2029 is approximately twice the classical Roche limit and closer than any known past or future approach by a natural object larger than 10 m, other than those detected after already impacting the Earth or it's atmosphere. Such close approaches by objects as large as 2004 MN4 ($D \gtrsim 0.3$ km) are currently thought to occur at $\gtrsim 1000$ -year intervals on average. 2004 MN4 is expected to reach 3rd magnitude for observers in Europe, western Asia, and Africa, and thus be visible to the unaided eye. The asteroid's disk will be 2-4 arcseconds across and potentially resolvable with small ground-based telescopes.

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