Comet Ephemerides for the EPOXI and Stardust-NExT Flybys

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Abstract

The recently successful flybys of Comet 103P/Hartley 2 by the Deep Impact spacecraft and Comet 9P/Tempel 1 by the Stardust spacecraft each presented different challenges from the perspective of comet ephemeris prediction and spacecraft targeting. Hartley 2 is a small, highly active comet, with nongravitational accelerations that proved very difficult to model, requiring some amount of "comet-chasing" by the spacecraft navigators. In contrast, Tempel 1 is a far larger and less active comet. It showed very stable ephemeris behavior and at flyby was within 1-sigma of predictions issued more than a year prior to encounter. This happenstance was fortuitous because the Stardust spacecraft had very little fuel margin available for comet ephemeris errors.

1. 9P/Tempel 1

Tempel 1 was well-observed prior to and during the 2005 Deep Impact encounter, and proved to be a cooperative comet in terms of ephemeris prediction for that mission. Continuing astrometric observations though June 2010 showed that the standard nongravitational acceleration model [1] continued to perform well. The comet was recovered on January 4, 2011, at Magdalena Ridge Observatory, New Mexico, under very difficult observing circumstances due to solar elongation less than 25 degrees. Continuing observations up to encounter on Feb. 15, 2011 showed the comet staying very close to the prediction based on only data from Jan. 1993 through Jan. 2010. From a mission operations point of view, this meant that very little fuel was expended to correct for comet ephemeris errors.

2. 103P/Hartley 2

Comet Hartley 2 was positively unruly when compared to Tempel 1. It's small size, high levels of activity, and (later discerned) complex rotation made the standard nongravitational acceleration model completely inadequate for the task of predicting the comet's position for the EPOXI flyby. The Rotating Jet Model or RJM [2] eventually proved to be dramatically more effective at fitting the existing data and predicting the comet's path. The difficulty at the time was that the rotation pole was unknown and published pole orientations [3] were discordant with each other, as well as with the RJM. A grid search of all possible pole orientations reveals an optimal pole orientation of (RA, DEC) = (140°, -7°), with formal uncertainties of 2°, although more credible uncertainties are likely in the range of 5-10°. While the RJM does not account for non-principal axis rotation, it does seem to model the comet's orbital path very well. The presumed interpretation of the above pole estimate is that it reflects the orientation of the comet's angular momentum vector.

References

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