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Constraints on the Rotation State of Comet 103P/Hartley 2

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Abstract

A number of rotation states have been proposed for EPOXI mission target comet 103P/Hartley 2. While the EPOXI flyby provides the precise shape and orientation of the comet at a specific time, radar observations of the comet from Arecibo Observatory over a timebase of one week provide more rotational information. We will combine the EPOXI shape model with radar images to constrain the viable rotation states, exploring both simple and complex rotation.

1. Observations

Prior to the EPOXI spacecraft flyby, comet 103P/Hartley 2 was observed daily with the Arecibo S-band (12.6-cm, 2380-MHz) radar system from 2010 October 24-31 (except October 28) providing valuable astrometry, a rotation period estimate, and a basic shape model reminiscent of a bowling pin [1] (see Fig. 1). The EPOXI encounter with comet 103P/Hartley 2 on November 4 at ∼14:00 UT provided an excellent snapshot of the target body from a range of viewing geometries. However, because the flyby was so short compared to the rotation of the comet (a few minutes versus ∼18 hours), EPOXI provided the shape and orientation to high precision, but essentially at only one instant in time.

2. Rotation states

Rather than a photograph that collapses an illuminated three-dimensional object to an image with two spatial dimensions, the radar echo of an object collapses the three-dimensional object to an image with one spatial dimension (the echo depth) and one frequency dimension (the Doppler broadening) that is dependent upon the shape, rotation rate, and orientation of the spin axis with respect to the line of sight. By combining the known shape and orientation of the comet from the EPOXI flyby with the radar images, we will explore the proposed rotation states for comet 103P/Hartley 2, assuming simple (principal axis) and complex (non-principal axis) rotation as necessary, to determine the range of rotation states that are consistent with the observed echo depth and Doppler broadening of the radar images. The rotation state is also relevant to the interpretation of the observed coma jet morphology, providing a consistency check for our results.

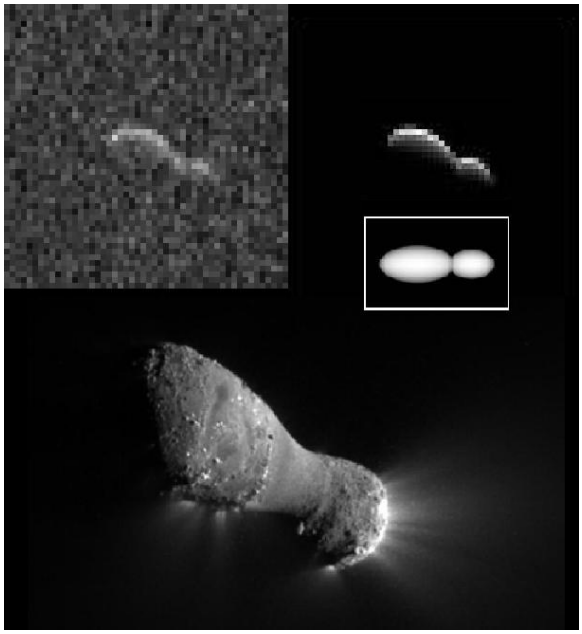

Figure 1: Clockwise from upper left: Arecibo S-band radar echo of comet 103P/Hartley 2, synthetic radar image based on the inset basic shape model, and the comet as imaged by EPOXI near close approach. The radar image, taken 2010 October 25, is the sum of about 15 minutes of data with range increasing downward at 75 m/pixel and Doppler frequency increasing to the left with 0.18-Hz resolution. The simple inset shape model of two prolate spheroids squashed together provides a solid match to the radar data and is a good first approximation of the actual shape found by EPOXI. The EPOXI image was taken by the Medium-Resolution Instrument from a distance of 849 km on 2010 November 4 at 14:00 UT. EPOXI image credit: NASA/JPL-Caltech/UMD.

3. Spin-down

Lightcurves and observations of coma jet morphology between August and December 2010 [2, 3, 4, 5] revealed a clear, consistent lengthening of the synodic rotation period of comet 103P/Hartley 2 from 16.6 to 19 hours at a rate of more than 0.02 hours per day. Over the course of the radar observations, such spin-down would cause a shift in the rotational phase of about 15 degrees compared to using a constant rotation rate. However, using the implied spin-down with the simple shape model of Fig. 1 does not improve the fit to the radar data [1]. In addition, preliminary analysis using the EPOXI spacecraft model finds that spin-down is not necessary to fit the radar data alone despite the clear evidence of spin-down on longer timescales from other types of observations.

4. Summary

Analysis of the rotation state of comet 103P/Hartley 2 is underway, applying the spacecraft model from the EPOXI flyby to S-band radar images collected at Arecibo Observatory. Simple and complex rotation states will be explored to determine the range of states that are consistent with the observed radar echoes. The observed spin-down of the comet will also be examined further as the implied rotational phase shift, compared to a constant spin rate, of 15 degrees over the timebase of the radar observations could be visible.

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