EPSC Abstracts
Vol. 10, EPSC2015-198, 2015
European Planetary Science Congress 2015

Fragment dynamics in disintegrating asteroid P/2013 R3

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Abstract

We study the relative motion of fragments of the disintergrating asteroid P/2013 R3 in a series of Hubble Space Telescope and Keck images, to reconstruct the temporal sequence of the fragmentation process and the separation velocities of the fragments.

P/2013 R3 (Catalina-PanSTARRS) was discovered in 2013, September, due to an extended dust coma and tail (Hill et al., 2013). The combination of its asteroidal orbit and comet-like appearance classified it as a member of the recently identified class of active asteroids (Jewitt, 2012, Jewitt et al., 2015). P/2013 R3 is unique among the active asteroids in that its nucleus catastrophically disintegrated into at least 10 distinct components $<$200 m in size, while all other known active asteroids have kept an intact primary nucleus. At discovery, the components were too far apart to be gravitationally bound.

We obtained a series of five high-resolution images with the Hubble Space Telescope separated in time by about one month, and additional images with the W. M. Keck observatory, which documented the gradual disintegration of the larger fragments into smaller ones as an on-going process (Jewitt et al., 1014). We argued that an impact was an unlikely cause for such a gradual process, and that also internal gas pressure was not sufficient to cause the disruption, concluding that super-critical rotation, probably under the influence of the YORP effect, was a likely cause for the disruption. This was in agreement with rough estimates of the fragment separation velocities being comparable to the gravitational escape speeds of the fragments. Hirabayashi et al. (2014) support this hypothesis and derived physical properties of the precursor body.

We here report of a detailed study of the relative motion of the fragments in order to derive their separation velocities and times. We calculate the motion of test fragments separated at various times and with various velocities and compare their relative motions to that of the observed fragments, similar to the approach we used to reconstruct the fragmentation of active asteroid P/2010 A2 (Agarwal et al., 2013). While A2 underwent a single disruption event at a well-constrained time, the disintegration of R3 requires individual reconstructions for each fragment pair. We discuss our results and their implications for the nature of the disruption process.

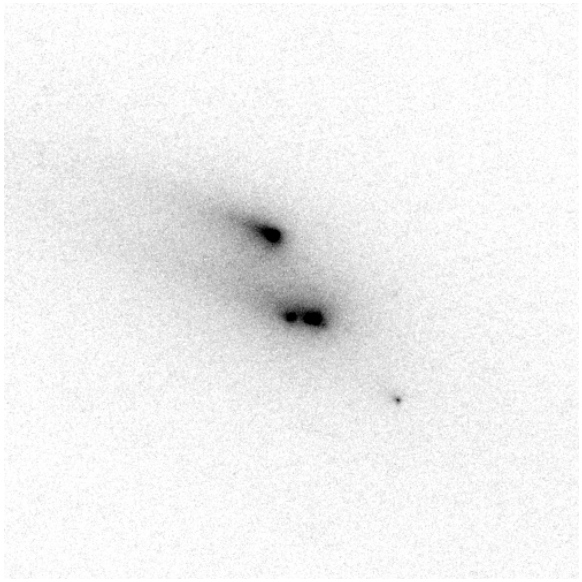

Figure 1: Fragments of P/2013 R3 on 2013 October 29, observed with the Hubble Space Telescope and Wide Field Camera 3.

Acknowledgements

Based in part on observations made with the NASA/ESA Hubble Space Telescope, with data obtained at the Space Telescope Science Institute (STScI). Some of the data presented herein were obtained at the W. M. Keck Observatory, operated as a scientific partnership among Caltech, the University of California and NASA. The Observatory was made

possible by the generous financial support of the W. M. Keck Foundation.

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