Searching for satellites of Ceres

B. Schmidt[1], J. Li[2], L. McFadden[3], M. Mutchler[4], B. McLean[4], and C. Russell[5]

[1]Georgia Institute of Technology
[2]PSI
[3]Goddard
[4]STSCI
[5]UCLA

The existence of satellites, or lack thereof, around Ceres is of great interest to the Dawn mission, which is currently en route to Ceres and will arrive in February 2015. The Dawn spacecraft will orbit Ceres at altitudes of 1180 to 6400 km, well within the satellite stability region. The final opportunity for observations of Ceres with HST prior to Dawn's arrival occurred in April 2014, when Ceres will make a close pass at opposition to Earth. In addition to providing additional targets for exciting physical studies by the Dawn instruments, satellites, if there were any, would substantially affect Dawn's orbit planning in order to accommodate observations and ensure spacecraft safety. For example, detection of satellites would allow this program to derive a more accurate measurement of the mass of Ceres, which is important for the mission planners to determine the orbit of the spacecraft. With the observation planning process already underway, early detection of satellites will provide sufficient time to adapt mission plans to be able to observe any satellites on ingress or during the mapping orbits. The timing is particularly important, since the spacecraft now has use of only two reaction wheels, which is already impacting mission design, and which prevents Dawn from conducting its own deep satellite search as was accomplished prior to arrival at Vesta. Because of this, an HST survey is critical for Dawn operations at Ceres. Since satellite detection could require a change to the mission's nominal orbital strategy and present risk from dust associated with any satellites, it is crucial to put Dawn in the best position to succeed. HST observed Ceres using the High Resolution Channel (HRC) of the Advanced Camera for Surveys (ACS) to study the physical properties of Ceres and carried out surface mapping (Parker et al. 2004, Thomas et al. 2005, Li et al. 2006). Several "long-V" (F555W filter) exposures were taken using the full field of view of the ACS-HRC to search for possible satellites of Ceres, and no satellite of Ceres' albedo or higher larger than 2 km in diameter was found (Bieryla et al. 2011). However, these HST images only covered ∼6 % of Ceres' Hill sphere, considerably smaller than the stability region, so ground-based surveys filled in the Hill sphere to about a 2-km size limit. Also, the region within 480 km above the surface of Ceres, inside of Dawn's planned High-Altitude Mapping Orbit (HAMO) and Low-Altitude Mapping Orbits (LAMO), could not be searched because of the saturation of the wing of the PSF. Director's discretionary time with WFPC2 was granted to the Dawn team in 2009 for a similar search, which also did not detect any satellites down to about 1km in size outside of 4000 km of the asteroid's surface. However, closer in, the limit is closer to 10 km. Another ground-based program carried out with the Large Format Camera on the Hale 5-m telescope at Palomar Observatory using an occulting disk and PSF removal techniques to enhance the contrast, covered the whole stability region. Again, no satellite above 1 km in diameter was discovered. Although these results are reasonably robust, there is still the possibility that satellites above the detection limit exist. They could have escaped detection by being too close along the line of sight with Ceres during the observations. This is more likely for any satellites located in the ground-based images obscured by the over-exposed image of Ceres, but still outside of the HST FOV (since those data covered multiple epochs), and in a high-inclination, nearly edge-on orbit. Also, a satellite larger than 2 km would not have been detected if it has an albedo sufficiently smaller than that of Ceres, which has a visual geometric albedo of 0.07–0.10 (Millis et al. 1987; Tedesco 1989; Li et al. 2006). We report initial results of our 2014 HST observations of Ceres to search for any satellites. In April 2014, Ceres will be at opposition and close to the Earth with a range of ∼1.65 au, spanning ∼0.8". Its Hill sphere has a radius of ∼434 Ceres radii, or ∼350" in diameter. As discussed by Toth (1999), the stability region is about 1/3 of the classic Hill sphere, consistent with all binary systems reviewed in Richardson and Walsh (2006, their Fig. 2). Therefore, the search within the stability region will be emphasized while most of the Hill sphere will be thoroughly searched.

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