Investigation of Doublet Craters on Ceres as Evidence of Main Belt Asteroid Systems

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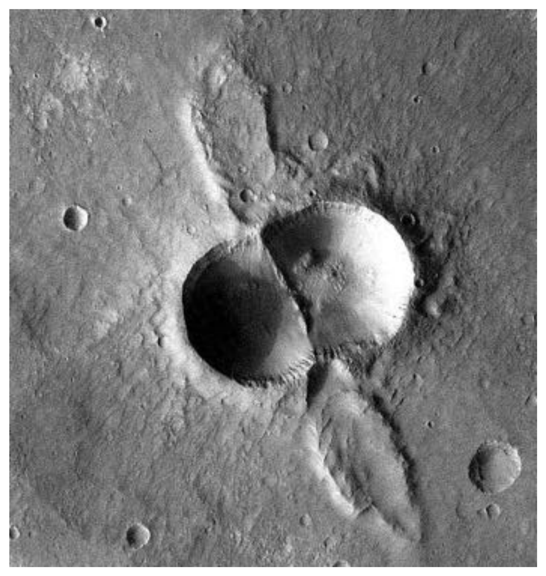
Abstract #2407

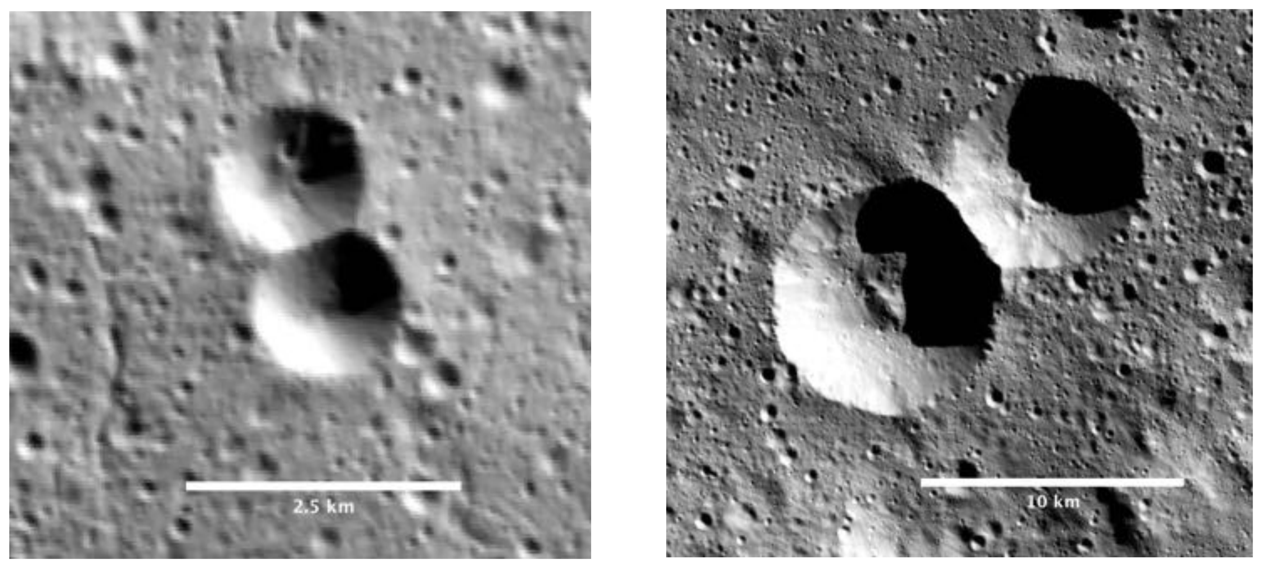
BACKGROUND



Doublet on Mars (NASA/JPL/ASU)

Doublet Crater: a pair of nearby impact craters that are created by the same primary impact event [1]. Doublets are observed on Earth, on Luna, on Mercury, on Venus, on Mars [2,3,4,5,6,7,8], and now on Ceres.

Formation: doublet crater formation had been attributed to a single impactor broken up by either atmospheric disruption [9] or tidal forces [1,10], but further studies showed these processes could not result in sufficient separation to create observed doublets [11][12]. It is now believed that **well-separated binary asteroids are the source of doublet craters** [12]. This makes doublets a source of evidence for the prevalence and nature of binary asteroid systems. The percentage of doublets in the inner solar would require ~15% of planet-crossing asteroids to be binaries [12]. 290 binary asteroids have been identified in the Earth-crossing, Main Belt, Trojan, and TNO populations [13,14,15].



Doublet craters on Ceres photographed by the Dawn Framing Camera [17]

OBJECTIVE

Use doublet craters on Ceres to constrain Main Belt binary asteroids

Images acquired recently from NASA's Dawn mission to Ceres [16,17] provide a new opportunity for using doublet craters to estimate the size of the binary asteroid population within the main belt, particularly for smaller asteroids that likely remain undetected at such a distance from Earth.

METHODS

We took an approach similar to Melosh et al. [8]:

Initial Study Area:

- Chose terrain near large craters *Urvala* and *Yalode* [18] for its lower crater density, to minimize randomly-adjacent craters
- Small sample area bounded by 250°E to 270°E and 10°S to 30°S (~28,000 km^2)

Visual Survey:

- Counted impact craters ≥ 3 km in Dawn Framing Camera images [17], using JMARS [19]
- Evaluated all unique crater pairs with separations < 20km using scoring system
- Points added for similar and lighter erosion, possible septum and/or ejecta lobes
- Points subtracted for superimposition, differing erosion (implies different ages) and heavy erosion

Monte Carlo Simulation:

- It creates an expected distribution of crater pair separations if all impact events are single asteroids, and compares with observed pairs.
- It will generate random impacts within the study area (the same number counted), and measure separations between all unique pairs
- Simulation will run 100 times, average results
- ***Actual doublets should cause excesses in comparison to the expected distribution.***

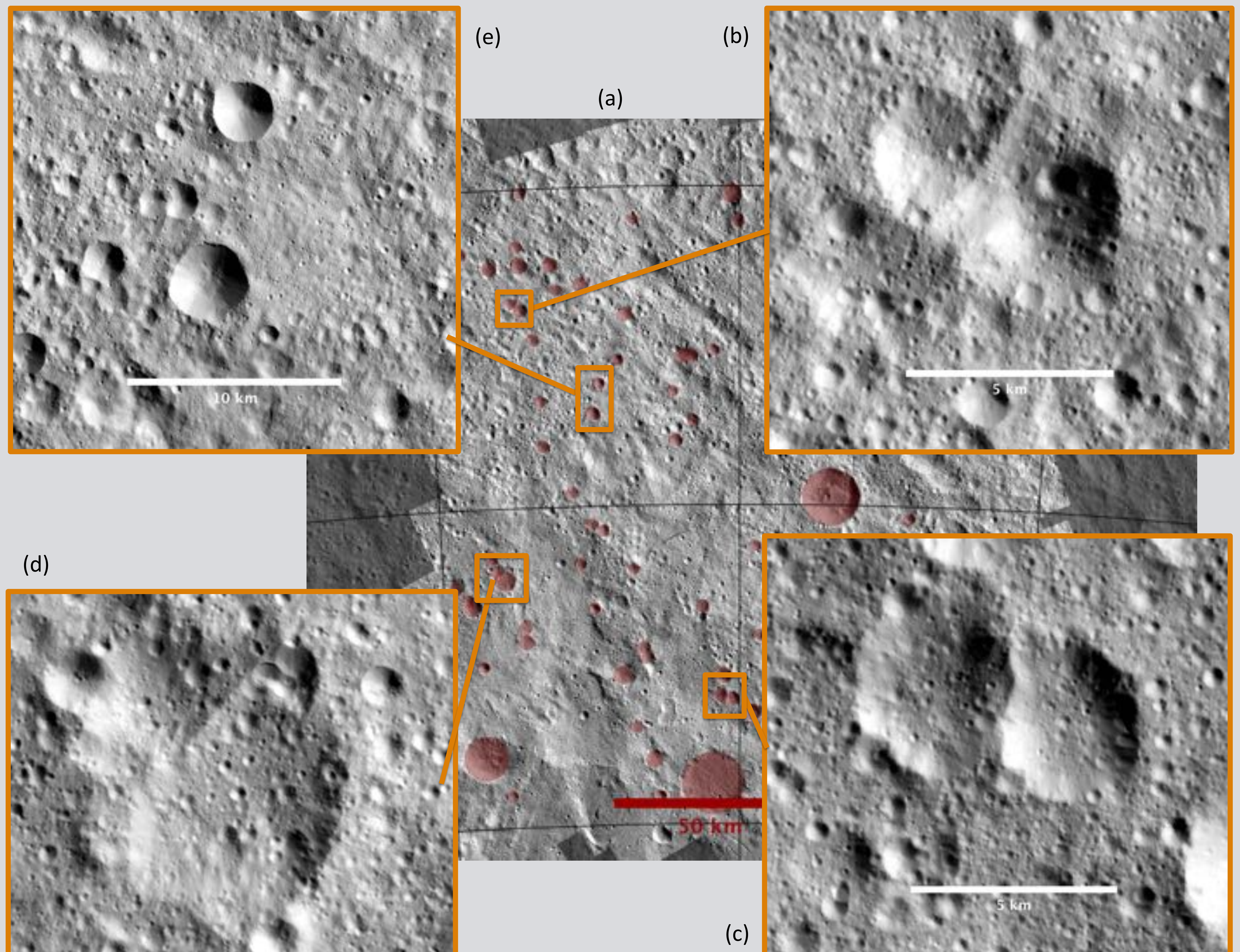


Figure 1: a) Crater counting on Ceres in JMARS [19]; b) "Pair 1" from Dawn FC image 0052195 [17]; c) "Pair 2" from Dawn FC image 0047316 [17]; d) "Pair 3" from Dawn FC image 0051873 [17]; e) "Pair 4" from Dawn FC image 0051871 [17].

Table 1. Candidates for doublet craters on Ceres in the study area.

Crater Pair	*Longitude*	*Latitude*	*Diameter (km)*	*Separation (km)*	*Doublet?*
Pair 1	252.679	-13.583	3.0	2.92	Likely
	252.938	-13.831	3.2		
Pair 2	259.332	-25.994	3.8	3.38	Likely
	259.771	-26.107	3.5		
Pair 3	251.772	-21.941	3.0	3.26	Possible
	252.024	-22.236	5.3		
Pair 4	255.199	-17.097	3.6	8.01	Possible
	255.426	-16.152	3.0		

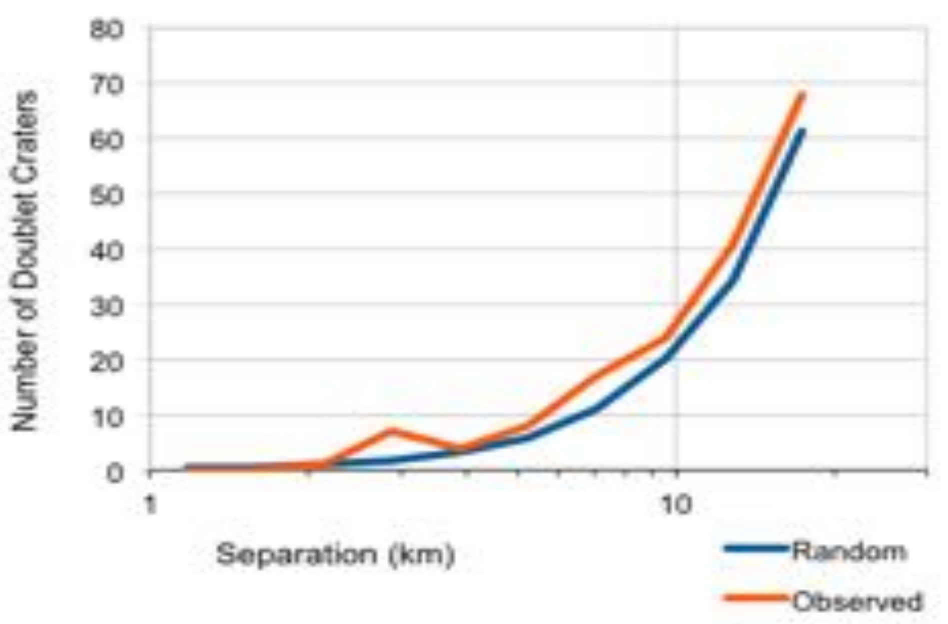


Figure 2: Observed counts of paired craters by separation, plotted against expected distribution from random impacts.

RESULTS

Visual Survey and Evaluation:

- Counted 80 craters ≥ 3 km (Figure 1a)
- 172 unique pairs separated by less than 20km
- 4 pairs received positive scores (Table 1)
- 63 pairs were inconclusive
- 105 pairs were eliminated for differing erosion, extreme erosion, or being superimposed.

Of the four high-scoring crater pairs, none were as convincing as the clear doublets shown above. Pair 1 (Figure 1b) may have a septum, and ejecta lobes may be present. Pair 2 (Figure 1c) seems to feature a septum. The craters of Pair 3 differ in size and depth, but a possible ejecta lobe holds promise. Pair 4's craters are separated more than the others, but are well-defined newer craters that appear to be roughly the same age.

Monte Carlo Simulation:

- 80 random lat/lon pairs within the sample region
- Separations < 20 km tallied into logarithmic bins
- Figure 2 shows expected distribution ("Random") along with observed crater pairs tallied into the same bins ("Observed")

There is a pronounced excess in the bin centered at 2.88 km separation, which is where Pairs 1-3 of the candidate double impacts in Table 1 are tallied. This supports the interpretation that the four candidate crater pairs are not due to random chance, but instead are the result of a double impact.

CONCLUSIONS

If Pairs 1 and 2 are true doublet craters:

- Our data place a lower bound of **2.6%** on impact events in study area that are doublets
- This is consistent with 2-3% for Earth & Mars [2]

If we apply previous experimental data showing 15% of binary impacts produce doublets [2]:

- Our initial study suggests **~17%** of main belt asteroids are binary
- Previous radar and photometric studies show ~15% of NEAs & MBAs < 10km are binary [2,20]

Our preliminary sample is small. We plan to expand the survey to other parts of Ceres, and work toward a model for estimating binaries in the Main Belt.

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