Highlights of Astronomy, Vol. 13
International Astronomical Union, 2003
O. Engvold, ed.

Is Amalthea a Captured Trojan Asteroid of Jupiter?

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Abstract. The Galileo spacecraft has found Jupiter's inner regular moon Amalthea to be a porous assemblage of rock and ice. This and other factors point to Amalthea having first condensed in a solar orbit.

In 2002, the Galileo spacecraft discovered that Amalthea has an unexpectedly low mean density $\overline{\rho} \sim 0.9$ g/cm^3. This value is much less than the value ~ 3.87 g/cm^3 expected at Amalthea's orbital distance, namely $2.539R_{\rm J}$ ($R_{\rm J} = 71492$ km), had this body formed as a native Jovian satellite. The latter density follows from a gas ring condensation model which successfully accounts both for the broad distributions of mass and orbital radius, and the bulk chemical compositions of the four large Galilean moons (Prentice & ter Haar 1979, Prentice 2001a). This model provides a condensation temperature and gas pressure at Amalthea's orbit of ~ 880 K and ~ 45 bar, respectively. It produces a condensate that is 32% metal and 68% rock, and has mass that is $\sim 10^4$ larger than that of Amalthea. The absence of another native satellite at $\sim 3.5R_{\rm J}$ thus makes it much more likely that Amalthea formed outside the Jupiter system. Prentice & ter Haar (1979) had predicted Amalthea to be a C-type asteroid. Main belt stony asteroids have a predicted zero-porosity density ~ 3.67 g/cm^3 (Prentice 2001b). Galileo has found Amalthea to be less dense than the highly porous, ice-free, main belt asteroid Mathilde ($\overline{\rho} = 1.3 \pm 0.2$ g/cm^3), despite being ~ 30 times more massive. This suggests the presence of some ice, as well as rock. Most likely, therefore, Amalthea originally condensed as a planetesimal from the gas ring shed by the proto-Solar cloud at Jupiter's orbit, prior to dynamical capture by this planet. The predicted bulk chemical composition, by mass, of such condensate is asteroidal rock (65%), graphite (1%), and water ice (34%) (Prentice 2001b) . The zero-porosity density is 1.83 g/cm^3. Amalthea is simply a first cousin of the Trojan asteroids of Jupiter. This interpretation is consistent with the Galileo spacecraft findings and implies a porosity of 50%.
I thank John D. Anderson [NASA/JPL] and David Warren [Hobart] for support.

References

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