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Ray craters on the satellites of Jupiter and Saturn

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Abstract

Ray craters on the surfaces of planets and of their satellites are morphologically fresh impact features. They superimpose other geologic units which implies that they are stratigraphically young [1][2]. The preservation of craters with bright (or dark) rays is an indicator for the intensity of geological processes at more recent time, especially erosion and erosion rates. Rayed craters occur on terrestrial planets as well as on icy satellites in the outer solar system [1][2]. In this work we focus on bright rayed craters on icy satellites of Saturn and Jupiter in order (1) to date ray craters on high-resolution images by their superimposed crater frequencies and (2) to constrain stratigraphy and ages of older geologic units and more recent geological processes. (3) The morphology of ray craters and the possible occurrence of double or multiple impacts producing ray craters as discussed by, e.g., [3] infer impact conditions and impactor origins.

1. Introduction

Ganymede, Jupiter's largest satellite, shows the greatest number of bright ray craters of all icy satellites in the outer solar system [4]. Some of these craters (e.g., *Osiris*, *Hershef, Tashmetum*) have diameters larger than 100 km. Unfortunately, the SSI camera [5] aboard the Galileo Jupiter orbiter (1995 – 2003) could image only one of these ray craters, *Achelous*, at regional resolution (~180 m/pxl) usable for detailed mapping and age dating. No high-resolution images were taken of typical bright ray craters on Callisto. On sparsely cratered Europa, the ray crater *Pwyll* was imaged by Galileo SSI at high resolution [6]. On the satellites of Saturn which are imaged by the ISS cameras aboard the Cassini orbiter [7], some ray craters can only be distinguished by using color ratio images [8][9]. Large bright ray craters several tens of kilometer in diameter are only found on Dione and Rhea.

2. Cratering model ages

The age of ray craters on icy satellites can only be estimated with cratering chronology models [10]: (1) The Neukum lunar chronology [11] is based on impacts preferentially by asteroids. The cratering rate has decayed exponentially in the first 700 Ma of solar system history and has been constant since 3 – 3.3 Ga ago. (2) The cometary chronology by Zahnle and colleagues [12] is based on impacts primarily of cometary bodies with a constant or monotonically declining cratering rate. (3) In the Nice model [10, and ref.'s therein], migration of the large planets is assumed to have caused a solar-system wide intense flux of projectiles and a Late Heavy Bombardment around 3.9 Ga ago. Currently, ages from crater size distributions can only be derived using the lunar-like [11] and the cometary [12] cratering chronologies.

3. Ray craters on the Galilean satellites

For ray craters on the Galilean satellites of Jupiter, retention times on the order of 1–2 Ga were estimated [4]. The cratering model age of ray crater *Achelous* on Ganymede, based on crater counts in Galileo SSI data, is on the order of 410 Ma in the lunar chronology [11], versus 30 Ma in the cometary chronology [12]. Since no other ray crater was imaged at high resolution, the range of model ages and a possible maximum age for ray craters on Ganymede could not be determined. Ray craters on Ganymede are high-priority targets for a future mission to the Jovian satellites. Crater counts on the floor of *Pwyll* on Europa yielded an age of 50 Ma [11], versus 2.5 Ma [12]. On Callisto, two large basin-type impact structures with a bright ray system, *Lofn* and *Heimdall*, occur in the southern sub-jovian hemisphere. Only Lofn could be dated with model ages of 3.86 [11], versus 2.56 Ga [12]. With future higher resolution images obtained of Heimdall it will be possible to verify if Lofn and Heimdall are the result of a double impact.

4. Ray craters on Dione and Rhea

Dione's largest bright ray crater *Creusa* has a diameter of 36.2 kilometer. Its bright rays extend over several hundreds of kilometers almost across the entire sub-Saturnian hemisphere. Low-resolution VIMS data (orbit 043) showed an association of a strong H_2O spectral signal with the location of the crater and also revealed a significant influence of the extended ray system on the H_2O-dominated spectral properties of the leading hemisphere [8]. The morphologic freshness of Creusa and the pristine state of its rays infer that the crater is very young. Images of higher resolution are necessary for detailed geologic mapping and measurements of crater size-frequency distributions.

Rhea's largest bright ray crater *Inktomi* has a diameter of 47.2 km. Analysis of VIMS data revealed clean H_2O ice without impurities at the crater and in its ejecta [13]. Cassini ISS images from orbit 049 show a continuous ejecta blanket almost devoid of small craters. Cratering model ages are 280 Ma [11], versus 8 Ma [12]. Regular radial secondaries occur outside of the continuous ejecta blanket associated with the bright rays. In addition, clusters of numerous small craters were identified in the eastern part of the crater floor and in the continuous ejecta [14].

4. Summary

Of the nine major satellites of Saturn, only Dione and Rhea feature morphologically fresh craters several tens of kilometers across with extended bright ray systems. In Cassini VIMS data, these craters and their rays are associated with strong H_2O ice absorption bands [8][13]. Ray craters on these two satellites most likely are younger than 500 Ma [11], or much younger than 100 Ma [12]. On Ganymede, the range of cratering model ages of ray craters cannot be determined because of insufficient high-resolution image coverage, but the age of Achelous seems to provide a good estimation for average ages of ray craters. The far-reaching spatial extension of bright rays indicate high-velocity impacts, possibly from heliocentric cometary bodies. With the possible exception of Lofn/Heimdall on Callisto, double or multiple impacts observed especially on the satellites of Saturn [3] seem to be rare in the group of ray craters.

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