Ray craters on Ganymede as time-stratigraphic markers. R. J. Wagner[1], N. Schmedemann[2], S. C. Werner[3], J. W. Head[4], K. Stephan[1], K. Krohn[1], R. Jaumann[1], T.Roatsch[1], H. Hoffmann[1], and P. Palumbo[5]. [1]Institute of Planetary Research, German Aerospace Center (DLR), Berlin, Germany (Email: roland.wagner@dlr.de); [2]Max Planck Institute for Solar System Research, Göttingen, Germany; [3]CEED, University of Oslo, Norway; [4]Dept. Earth, Environmental and Planetary Sciences, Brown University, Providence, R.I., USA; [5]Università degli Studi di Napoli Parthenope, Naples, Italy.

Introduction: The stratigraphic column of a planetary body and its geologic history is subdivided by distinct key events or processes recorded in its geologic units [1]. Such stratigraphic *marker horizons* in general are associated with major resurfacing events. On atmosphereless bodies, impact events, creating large basins and ray craters, are primarily used to establish their stratigraphic columns [1, and refs therein]. Other commonly used processes are volcanic or tectonic events.

On the largest Jovian satellite Ganymede which was imaged by the cameras aboard the Voyager and Galileo spacecraft [2], the geologic history was subdivided basically into three chronologic periods, marked by tectonism and by the formation of the basin Gilgamesh into the *Nicholsonian, Harpagian, and Gilgameshan Periods* [3]. Ganymede also features several large bright and also dark ray craters [3][4][5] which could serve as additional time-stratigraphic markers. Unfortunately, however, most of these large ray craters were not imaged at high resolution by the Galileo SSI camera. In this study, we use reprocessed Voyager and SSI data to define the stratigraphic positions of selected ray craters, e.g., ***Osiris*** and ***Achelous***, in the context of dark and bright materials, constrain their ages, and examine the size distribution of secondary craters created by these ray craters.

Procedure: ***(1)*** For this study, Voyager and Galileo SSI images (Voyager gap fills) were reprocessed and highpass-filtered to enhance contrast and detail. From this image data set a global basemap at a spatial resolution of 700 m/pxl was produced and subdivided into 15 quadrangle mosaics [5]. The global basemap and the quadrangle mosaics provide the context for Galileo SSI target areas imaged at higher resolution. ***(2)*** Geologic mapping is based on the units defined in the geologic map by [3]. Locally, these units were modified where it was necessary to account for requirements of crater counts. ***(3)*** We applied recent improvements in the method of crater size-frequency measurements to derive crater distributions and surface ages, such as the buffered non-sparseness correction [6][7]. The Poisson timing analysis is used to derive absolute model ages (AMAs) [8] of geologic units, based on two different cratering chronology models: (a) a lunar-derived time scale (termed LDM) [9], and a time-scale derived from impacts of Jupiter-family comets (termed JCM) [10].

Study areas: *Osiris* is a 107 km large crater, located at lat. 38˚ S, long. 193.69˚ E, imaged by Voyager-2 at a resolution of ~ 800 m/pxl. Osiris and part of its extended bright ray system is shown in *Fig. 1* (top). *Achelous* has a diameter of 40 km and is located at lat. 61.9˚ N, long. 348.22˚ E. Like Osiris, Achelous features bright rays in Voyager-1 images taken at ~ 2 km/pxl. The Galileo SSI camera captured Achelous (*Fig. 1* (bottom)) at low sun at a spatial resolution of 180 m/pxl.

Results: The stratigraphic positions of Osiris and Achelous are shown in a cumulative crater size-frequency diagram in *Fig. 2*, in context with the time-stratigraphic bases [3] of Nicholsonian, Harpagian, and Gilgameshan units (crater counts and statistical analysis carried out in this study). The curves in *Fig. 2* represent the Ganymede crater production function, derived from the lunar production function by crater scaling [11]. It could be shown that the transferred lunar production function is applicable to crater distributions on Ganymede, implying that the majority of craters on Ganymede were formed from members of a collisionaly evolved impactor family [11]. The *Nicholsonian base* features AMAs (with upper/lower uncertainties) of 4.07±0.02 Ga (LDM [9]) or 4.33 (4.56 / 2.89) Ga (JCM [10]). The AMAs of the *Harpagian base* are 3.84±0.06 Ga (LDM [9]) or 2.12 (3.94 / 0.91) Ga (JCM [1]). According to its AMAs the *Gilgamesh* impact basin was formed 3.75±0.5 Ga (LDM [9]) or 1.52 (3.21 / 0.58) Ga (JCM [10]) ago. The AMA of Osiris can be constrained in two ways: (1) by identifying a potential single small bright crater superimposed on Osiris' floor, and (2) by estimating an age from the area of bright ejecta deposits in the rays, assuming no superimposed craters can be identified at the given spatial resolution, as described in [8]. This latter method provides a maximum age of Osiris. The two Osiris data points (green symbols in *Fig. 2*) lie well on one curve, implying an AMA of 750±570 Ma (LDM [9]), or 84 (57 / 6) Ma (JCM [10]) of Osiris. The large area resurfaced by Osiris and its ejecta and the fact that Osiris' AMA can be constrained to some degree of certainty supports the recommendation to establish ***Osirian*** as the topmost time-stratigraphic system, or youngest chronologic period on Ganymede. The only fresh, young bright ray crater imaged by Galileo SSI at a spatial resolution of 180 m/pxl is Achelous (*Fig. 1*, bottom). No superimposed smaller craters are distinguishable on its floor and continuous ejecta. With the same method as for Osiris, a maximum AMA of 170±200 Ma (LDM [9]) or 19 (57 / 6) Ma (JCM [10]) can be estimated, placing Achelous into the Osirian Period.

Future work: The current Voyager and Galileo SSI image data base to define AMAs of Ganymede's ray craters is not sufficient. ESA is planning to launch the JUpiter ICy moons Explorer (JUICE) in 2022 which will reach Jupiter in 2030. After 2 years in Jupiter orbit with flybys at Europa, Ganymede and Callisto, JUICE will be inserted into an orbit about Ganymede in 2032 and orbit the largest Jovian moon for about a year. The JANUS camera aboard JUICE [12] will achieve global coverage of Ganymede at spatial resolutions on the order of 100 – 200 m/pxl in the panchromatic filter, with local high-resolution targets at << 100 m/pxl.

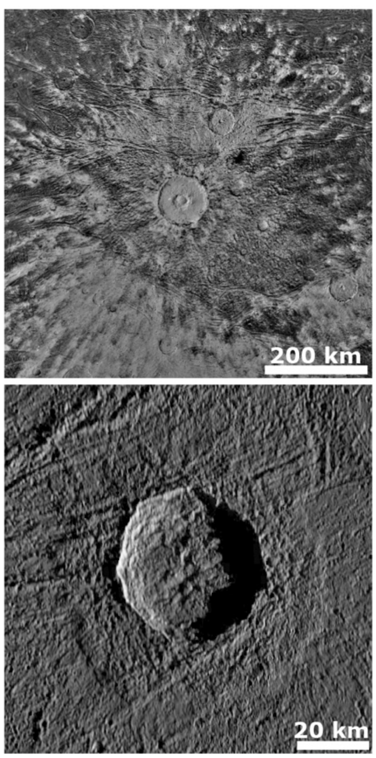

Figure 1. Study areas of Osiris (top) and Achelous (bottom). Osiris, covered by Voyager-2 is shown in a detail of a global Voyager-Galileo basemap (map scale: 700 m/pxl). Achelous was imaged by Galileo SSI (target area G7GSACHELS01, 180 m/pxl).

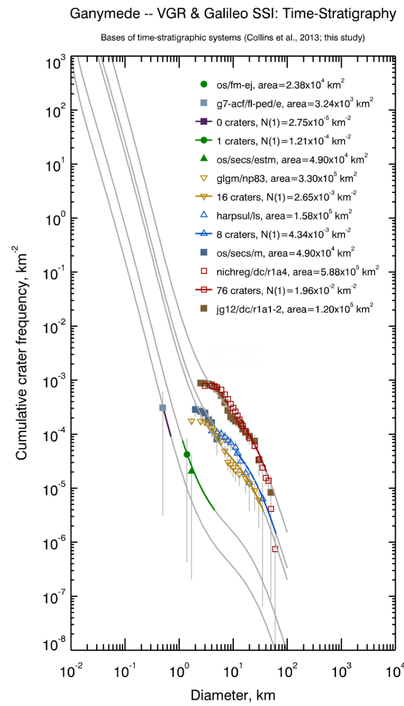

Figure 2: Cumulative crater size-frequency plot of the time-stratigraphic base units Nicholsonian (red/brown), Harpagian (blue) and Gilgameshan (dark yellow), and estimated crater frequencies on Osiris (green) and Achelous (dark blue). Further explanation given in text. Curves included are from [11].

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