FRACTAL ANALYSIS ON GANYMEDE GROOVES: INSIGTHS INTO THE ICY SHELL THICKNESS OF THE SATELLITE. A. Lucchetti[1], R. Pozzobon[2,1], M. Pajola[1], F.Mazzarini[3], G. Cremonese[1], M. Massironi[2,1]. [1]INAF-OAPD Astronomical Observatory of Padova, Italy (alice.lucchetti@inaf.it), [2]Dept. of Geosciences, University of Padova, Italy, [3]INGV, Istituto Nazionale di Geofisica e Vulcanologia, Pisa, Italy.

Introduction: The analysis of icy satellites surfaces provides hints regarding their interiors, as well as their ice shell's mechanical behavior. Indeed, faults distribution and fault populations on the icy satellite can reveal insights into the evolution of its surface that cannot be gained with other techniques. Statistical characterization of fault-population attributes, such as length and clustering, are fundamental means to explore deformation rates, stress transmission modes, rheology of the medium, and mechanical stratification [e.g. 1,2,3,4,5]. Fractal analysis has been used in terrestrial studies to determine the thickness of the fractured (brittle) crust [e.g., 6,7,2,8,9,10]. In the same fashion, on icy satellites we can constrain the depth at which fractures penetrate the brittle ice layer exploring some of the main characteristics of fault populations, such as length size-distribution and clustering. A previous work [11] has validated the use of this technique on Enceladus fractures estimating the depth of the mechanical discontinuity of the ice shell in five different regions. Such discontinuity is the depth to which fractures penetrate the brittle ice layer above the ductile one [11]. In this work, we analyze the grooves' spatial distribution on the surface of Ganymede to provide an estimate of the thickness of the brittle icy crust.

Geological context: The surface of Ganymede is subdivided into two main terrains: dark and light terrains. The dark terrain covers 35% of the surface and it is characterized by large-scale, arcuate fracture systems termed furrows, that have been hypothesized to be impact-related. The other 65% of the satellite surface is covered by the light terrain showing the presence of numerous morphotectonic lineated landforms, termed grooves. The light grooved terrain of Ganymede [12] represents one of the most tectonically disrupted surfaces of the Solar System. Grooves are organized in systems that crosscut or intersect with each other [12, 13]. They are interpreted as extensional fractures and/or faults, whose origin is still debated. In this context, grooves play a key role in the possible connection between surface and the subsurface ocean and represent the evidence of tectonic activity that deformed the satellite surface during its geologic evolution. In this work, we mapped grooves in well-defined geological units, such as light grooved units, light irregular units and light subdued units, related to tectonic deformation, as reported in the Ganymede geological map [14]. The mapped grooves will be then investigated with the fractal analysis explained below.

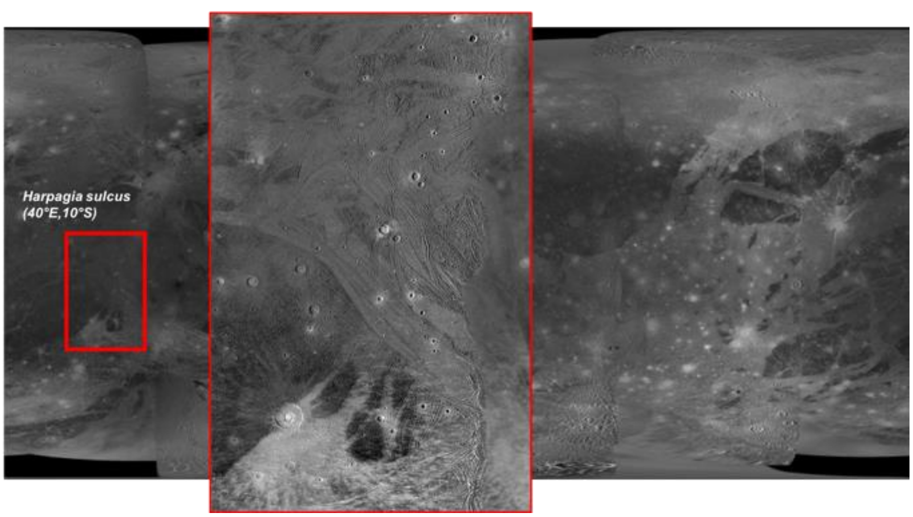

Figure 1: The Ganymede Voyager and Galileo Global Mosaic released by USGS. It is outlined in red the Harpagia Sulcus (40°E, 10°S), i.e. the grooved area on which we applied the fractal analysis.

Method: A robust way to define how fractures fill space (i.e. fracture spatial distribution) is to analyze their self-similar clustering [15]. The self-similar clustering of fractures is performed for a range of lengths (the size range) between a lower and an upper cutoff by applying the two-point correlation function method to measure the fractal dimension of the fracture population. For a population of N points (fracture's trace barycenter) the correlation integral C(l) is defined as the correlation sum that accounts for all the points at a distance of less than a given length l. If scaling holds, $C(l) \sim l^D$ (where D is the fractal exponent). Within this size range, the linear fit of the curve is well defined and the angular coefficient of the straight line is the fractal exponent D. The derivation of the cut-offs defining the size range is not trivial, especially when the local slope does not show a regular and wide plateau. The cut-offs are defined according to the method described in [7] by selecting the wider length range for which the correlation between log(C(l)) and log(l) is greatest. The cutoffs are considered directly linked to the mechanical layering of the medium [8] and, hence, in our case the upper cutoff reflects the thickness of the fractured layer and/or the depth at which a liquid or frozen reservoir should be.

Results and Future Works: We mapped grooves located on the Harpagia Sulcus region. The mapping was performed on the monochrome base map of the satellite released by the USGS (available on http://astrogeology.usgs.gov), the Ganymede Voyager and Galileo Global Mosaic (Fig. 1, [16]). The area is located at 40°E, 10°S on which we identified about 830 grooves. The grooves are located in those well-defined geological units related to tectonic deformation.

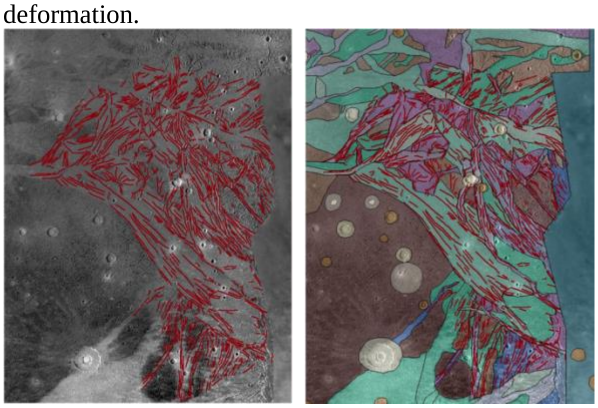

Figure 2: The 830 mapped grooves on Harpagia Sulcus identified on light grooved units (blue), light irregular units (pink) and light subdued units (green) of the geological map (right panel, [12]).

We applied the fractal analysis on the mapped grooves finding: i) the prevalence of fractal populations of grooves and ii) a depth to which fracture penetrate the icy crust of about 90 km. This preliminary analysis seems to infer that the brittle ice shell thickness of Ganymede could be 90 km. Previous estimation on the icy shell thickness of Ganymede reported (i) an internal ocean at depths of 150–200km but possibly shallower from Galileo magnetometer observations [17], (ii) the detection of an ocean at least at 80 km from crater shapes analysis [18] and (iii) the presence of an ocean assumed to be located between 150 and 250 km revealed by HST observation for the monitoring of the variability of the location of aurora ovals [19].

We will extend our analysis also to other regions of Ganymede to globally investigate the behavior of the ice shell thickness of the satellite.

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