Mapping Europa's Thermal Properties with ALMA.

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Introduction:

The surface of Jupiter's fourth-largest moon, Europa, is comprised of various terrain units (e.g. chaos, linea, regiones) that imply a relatively young (~40–90 Myr) and active ice shell above a sub-surface ocean [1]. Although measurements by the Galileo, Voyager, and Juno spacecraft (among others) have revealed the extent, color, and composition of the surface features (see, for example, [2,3,4]), the thermophysical sub-surface properties at mm-m depths can only be ascertained through (sub)millimeter and longer wavelength observations. The depth and variability of the surface terrain alteration provides insight into the exo- and endogenic processes that shape natural satellites in dynamic environments, exhibited prominently by those in the Jovian system.

We have determined thermal properties from the leading and trailing hemispheres of Europa at multiple near-surface depths using observations with the Atacama Large Millimeter/submillimeter Array (ALMA). Observations at (sub)millimeter wavelengths are sensitive to emission from potentially 10s of cm or deeper, depending on the composition and structure of the ice beneath Europa's surface. The comparison of temperature anomalies at various depths with previously observed thermal and albedo maps (e.g. [5,6,7]) and retrieval of surface porosity and thermal emissivity [8] allows for an assessment of the influence of external (e.g. Jupiter's radiation environment, meteorite gardening) and internal (e.g. tidal heating, resurfacing) processes on the manifested geographic units of Europa's hemispherically asymmetric surface.

Observations:

Europa was observed during 2016 and 2017 with ALMA at 3, 1.3 and 0.87 mm (~100, 230, and 345 GHz, respectively). Multiple observations were executed in each wavelength band to observe longitudes near Europa's leading and trailing hemisphere.

From the ALMA data, high signal-to-noise images of the brightness temperature distribution across Europa's surface were constructed. The resulting synthesized beam sizes (i.e. the ALMA image point-spread-functions) were on the order of 1/5–1/8 Europa's angular diameter (average beam size ~0.090 x 0.145'', corresponding to ~390 x 625 km on Europa).

Results:

Brightness temperature maps of Europa's leading and trailing hemispheres are presented in 3 wavelengths, sensitive to above and below the solar skin depth. Fig. 1 shows the brightness temperature distribution of Europa's leading and trailing hemispheres at 0.87 mm, which probes the shallowest sub-surface layer. We compare the temperature distribution to visible albedo maps to determine the importance of co-located surface features (e.g. pure water ice, chaos terrain and impact craters) and their material properties. We discuss regional and hemispheric temperature distribution and compare to previous spacecraft observations, and present preliminary retrieved surface properties following the methodology detailed in [8].

Acknowledgments:

This paper makes use of the following ALMA data: ADS/JAO.ALMA#2016.1.00691.S ALMA is a partnership of ESO (representing its member states), NSF (USA) and NINS (Japan), together with NRC (Canada), MOST and ASIAA (Taiwan), and KASI (Republic of Korea), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ. In addition, publications from NA authors must include the standard NRAO acknowledgement: The National Radio Astronomy Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

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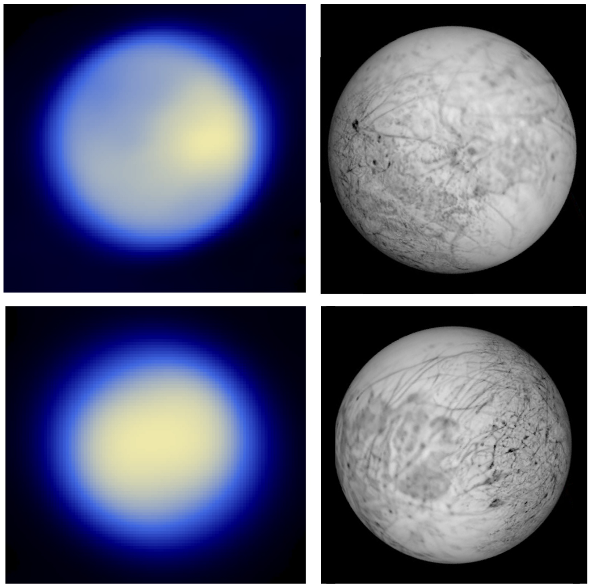

Figure 1: Thermal Maps of Europa: Thermal images of Europa's leading (top left) and trailing (bottom left) hemispheres from ALMA 0.87 mm (345 GHz) observations. Light yellow emission corresponds warmer surface features, while darker blue corresponds to cooler features. Images were not rotated to correct for Europa's north polar offset. Galileo SSI Global Mosaic projections corresponding to each ALMA observation are shown on the right.