**Thermal Properties of the Icy Galilean Satellites from Millimeter ALMA Observations.** K. de Kleer[1] B. Butler[2], I. de Pater[3], M. Gurwell[4], R. Moreno[5], A. Moullet[6]. [1]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA (dekleer@caltech.edu), [2]National Radio Astronomy Observatory (NRAO), Socorro, NM, [3]The University of California at Berkeley, Berkeley, CA, [4]Smithsonian Astrophysical Observatory, Cambridge, MA [5]Observatoire de Paris-Meudon, Meudon, France, [6]National Radio Astronomy Observatory, Charlottesville, VA.

**Introduction:** The surfaces of icy worlds encode information about the exogenic and endogenic processes that alter these bodies' surface environments and sub-surface conditions. Observations at millimeter wavelengths probe the very shallow sub-surface (~cm depths), and provide information on thermal properties such as emissivity and thermal inertia. Observations at multiple frequencies can also establish the depth of diurnal temperature fluctuations, which depends on the density, heat capacity, and thermal conductivity of the material [1].

The leading and trailing hemispheres of the galilean satellites are subject to different external processes, with fast-moving particles in the Jupiter system incident on the trailing sides. Both Ganymede and Europa show strong hemispheric differences in surface albedos, with large regions of warmer, darker terrain as well as cooler, ice-rich regions [2,3,4,5]. Measurements of the sub-surface properties of both hemispheres can determine how deep these asymmetries go and whether they extend beneath the solar skin depth.

**Observations:** We observed the leading and trailing hemispheres of Europa, Ganymede, Callisto in 2016-2017 with the Atacama Large Millimeter Array (ALMA). Continuum observations were made at frequencies of 100, 230, and 345 GHz (Bands 3, 6, and 7 respectively); these frequencies were chosen to bracket the solar skin depth, as coarsely constrained by past observations [6]. The calibrated visibility data provided by ALMA were phase-calibrated using self-calibration procedures and imaged using the Common Astronomy Software Applications (CASA) package, resulting in improved signal-to-noise and reduced image artifacts over the standard calibration.

**Results:** We present brightness temperature maps of the leading and trailing hemispheres of Europa, Callisto, and Ganymede. With a spatial resolution of ~1/10$^{th}$ the diameter of each satellite, the maps are sensitive to prominent localized thermal features in addition to large-scale asymmetries between the hemispheres. Figure 1 shows Band 6 (230 GHz) images of Ganymede's leading and trailing hemispheres; the comparison with optical spacecraft images demonstrates that large optically-bright regions are resolved by our observations and appear as anomalously cool areas, as expected. Thermal models that take into account the optical albedo maps will reveal whether albedo alone can account for these brightness temperature variations, or whether the material properties of these regions also differ from surrounding terrain as in recent work on Europa [7]. Preliminary results from this modeling will be presented, including the vertical structure of thermal properties for each hemisphere as a whole, as well as for individual regions of interest.

**References:** [1] Wesselink 1948. BAI Neth. [2] 10, 351. [2] Schenk et al. 2001. Nature 410, 57. [3] Greeley et al. 2004. In: Jupiter, Cambridge Press. [4] Shirley and Carlson, 2000. Eos, 81, F793. [5] McCord et al. 1999. JGR 104, 11827. [6] Muhleman and Berge, 1991. Icarus 92, 263. [7] Trumbo et al. 2017. AJ 154, 148.

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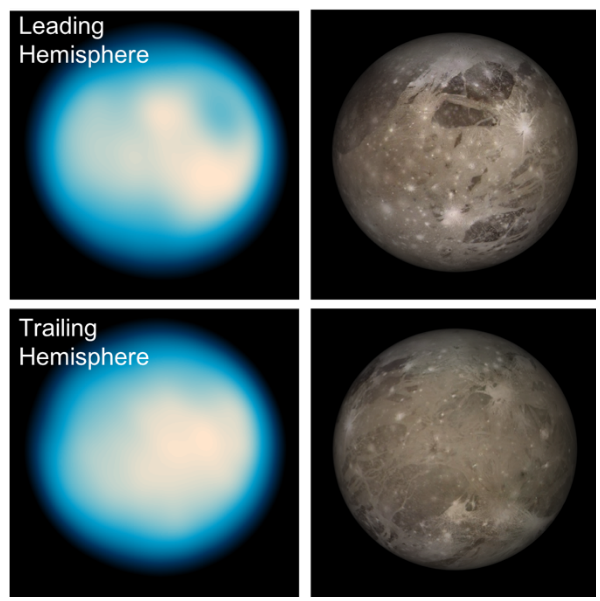


**Figure 1: Ganymede's Leading and Trailing Hemispheres:** (Left) ALMA Band 6 Observations: white regions represent higher brightness temperatures and blue regions lower; (Right) Mosaic of *Galileo/Voyager* optical images projected to the corresponding geometry [mosaic by Bjorn Jonsson]. A comparison between the columns demonstrates that the bright, reflective regions at optical wavelengths correspond to lower brightness temperatures at millimeter wavelengths.