GANYMEDE IN THE THERMAL INFRARED: PRELIMINARY ANALYSIS OF VOYAGER IRIS DATA

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This abstract describes a preliminary analysis of Voyager 2 IRIS observations of Ganymede, and provides an indication of the potential of similar data from other Voyager satellite flybys.

A uniform unit emissivity surface will exhibit brightness temperature (T_B) equal to the actual surface temperature at all thermal wavelengths. Spatial temperature variations within the field of view, or an emissivity less than one, will produce a wavelength dependance to T_B that can be used to constrain surface characteristics. Figure 1 shows the difference in T_B at 225, 405 and 602 cm^{-1}, plotted for 43 spectra covering Galileo Regio and surrounding areas of grooved terrain. Actual values of T_B for these spectra vary over more than 20°K (see below), but the wavelength-dependance of T_B is remarkably constant between spectra. Except at very large solar incidence angle, when the wavelength dependance of T_B is also large, position of fig. 1 does not correlate well with either terrain type or local sun angle.

Fig. 1 also shows the expected location of various theoretical surfaces, all with a mean temperature of 130°K. The three lowest points are single-temperature surfaces with the given emissivities, and fall well below the observed spectra. The diagonal line shows a unit-emissivity surface with two components of different temperature and equal areal extent, the temperature difference between components being as shown. It appears that this model, with thermal contrasts of about 40°K within each IRIS field of view, is fairly consistent with the data. 2-temperature models in which the warmer component occupies much more than 50% of the field of view can be ruled out by the IRIS data. The fact that, except near the terminator, the inferred temperature contrasts are independant of local time-of-day suggests that they are not due to shadowing, or to thermal inertia variations. Small-scale albedo contrasts are a more likely explanation. All 2-temperature models consistent with the data appear to require thermal contrasts larger than 30°K, and emissivities larger than 95%. More extensive modelling is in progress.

Fig. 2 shows T_B at 225 cm^{-1} for 113 IRIS spectra of in the afternoon region of Ganymede's anti-Jupiter hemisphere. Spectrum location is determined by referring to the near-simultaneous imaging data, resulting in positional errors generally much smaller than the IRIS field of view (shown). To first order, T_B is a simple decreasing function of distance from the subsolar point (shown), as expected for a slowly-rotating body. Superimposed on this sun-angle dependance are several thermal "anomalies". The most dramatic co-incides with the very bright ray crater Osiris. T_B in this region is depressed by up to 15°K below that at similar solar incidence angles elsewhere, presumably due to the high albedo. Albedo control probably also explains the thermal 'highs' in the northern hemisphere and near the centre of the disk, which correspond to the dark regions Galileo Regio and Marius Regio respectively.

Fig. 3 compares the observed T_B distribution with that expected according to a simple thermal model. This assumes a 2-component surface with the observed mean albedo, and albedo contrasts between the 2 components sufficient to account for the observed wavelength dependance to T_B, if instantaneous equilibrium with sunlight is assumed for each component individually. For Ganymede cratered terrain, for instance, a 2-component surface with 34% having 0.76 albedo, and 66% having 0.01 albedo, provides a reasonable, though not unique, fit to the observed wavelength-dependance of T_B over a wide range of solar incidence angles. On this model, T_B at 225 cm^{-1} is always about 4°K below the equilibrium surface temperature for a 1-component surface with the same mean albedo. Figure 3 shows the variation of T_B across the surface of Ganymede expected on this model. Grooved terrain and cratered terrain are each assumed to have everywhere the albedos determined by (1) as averages for these terrain types, and small bright craters are ignored, as are the polar caps. The crater Osiris and its bright ejecta is shown by the stippled region.

Fig. 3 shows that actual subsolar temperatures are depressed about 10° below equilibrium values. This is probably due to the conduction of heat into the subsurface during the day, and is consistent with the modelling of (1). In contrast, temperatures near the evening terminator are greater than equilibrium values, due to re-radiation of the heat absorbed earlier in the day. Even away from Osiris, temperatures at high southern latitudes are lower than those at low latitudes and the same sun angle, probably due either to the bright polar cap or the lower mean insolation at high latitudes. Both theory and observations show an approximate 5°K temperature variation between grooved and cratered terrain at a given sun angle.

Summary of Preliminary Conclusions

1) The emissivity of Ganymede's surface in the thermal infrared is larger than 0.95.
2) The surface shows small-scale temperature variations of greater than 30°K, independant of terrain type. These are probably due to albedo variations.
3) Surface temperature shows the expected variation with large-scale albedo.
4) Subsolar temperatures are about 10°K below equilibrium values, and temperatures close to the terminator are elevated above equilibrium values, as expected.

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Reference

(1) Squyres S.W. (1980) Icarus 44 502

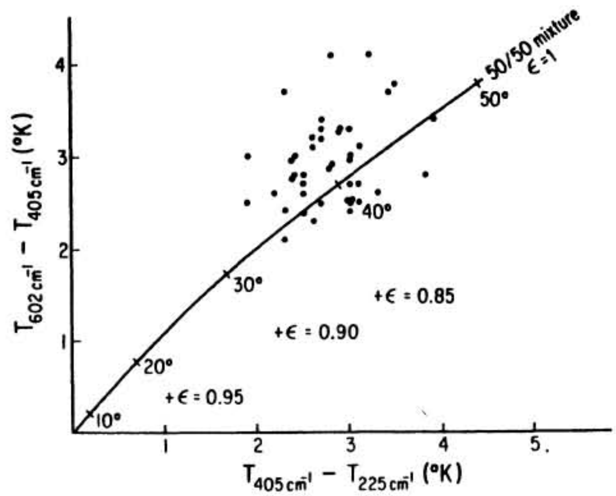
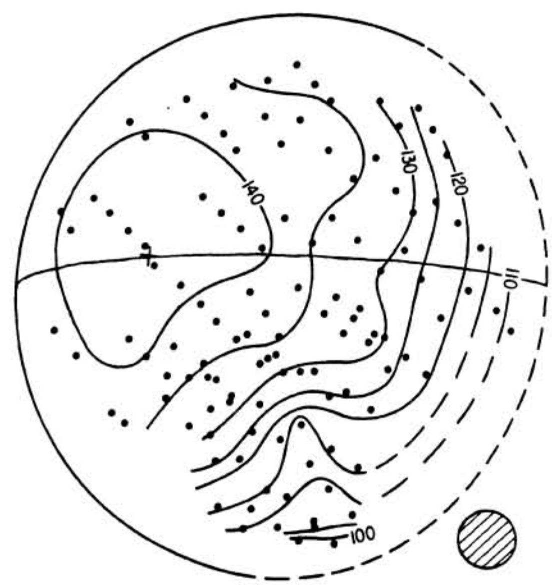


Figure 1 Brightness temperature differences between 225 and 405cm^{-1}, and 405 and 602cm^{-1}, for 43 Ganymede IRIS spectra covering Galileo Regio and surrounding grooved terrain. Expected values for various theoretical surfaces, all with mean temperature of 130°K, also shown (see text). Emissivity assumed to be independant of wavelength.

Figure 2 Brightness temperature distribution at 225cm^{-1} on the anti-Jovian, afternoon, hemisphere of Ganymede. Temperatures in °K. Dots indicate the locations of the 113 IRIS observations used to construct the contours. Representative size of the IRIS field of view shown by hatched circle. The equator is shown, as is the subsolar point (indicated by a cross). Based on wide-angle Voyager 2 image FDS 20635.51, central longitude 167°, taken during this IRIS sequence.



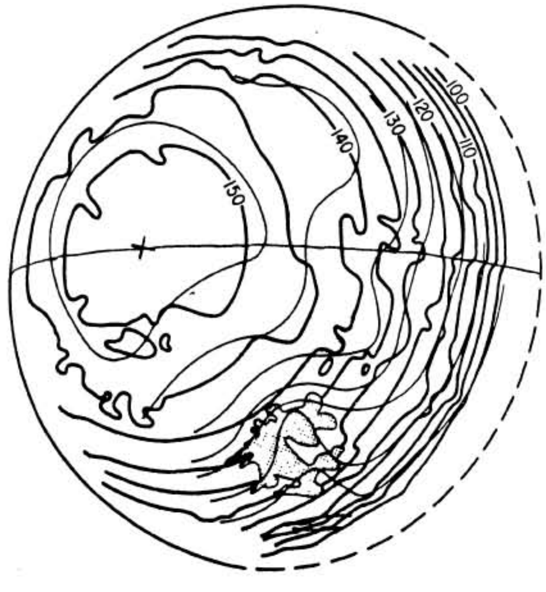


Figure 3 Theoretical brightness temperature distribution at 225cm^{-1}, assuming equilibrium with sunlight and a 2-component surface consistent with the IRIS spectra. Uniform, but different, albedos assumed for the grooved and cratered terrains, polar caps ignored. Contours have been hand-smoothed but still have higher resolution than the IRIS data, which is also shown, using thinner contours. Bright ejecta blanket of Osiris shown stippled. Geometry same as figure 2.