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Galileo PPR observations of Europa: Hotspot detection limits and surface thermal properties

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ABSTRACT

The Galileo photopolarimeter–radiometer (PPR) made over 100 observations of Europa's surface temperature. We have used these data to constrain a diurnal thermal model and, thus, map the thermal inertia and bolometric albedo over 20% of the surface. We find an increased thermal inertia at mid-latitudes that is widespread in longitude and does not appear to correlate with geology, albedo, or other observables. Our derived thermophysical properties can be used to predict volatile stability across the surface over the course of a day and in planning of infrared instruments on future missions. Furthermore, while observations in the thermal infrared can and have been used to find endogenic activity, no such activity was detected at Europa. We have calculated the detection limits of these PPR observations and find that 100 km^2 hotspots with temperatures of 116–1200 K could exist undetected on the surface, depending on the location.

1. Introduction

Europa, one of the Galilean satellites of Jupiter, is an intriguing world with a young surface (Zahnle et al., 1998; Pappalardo et al., 1999; Schenk et al., 2004). A global ocean has been inferred (Carr et al., 1998; Hoppa et al., 1999; Pappalardo et al., 1999) based on the young average surface age, the presence of surface features indicating a detached ice shell (Pappalardo et al., 1999), and the magnetic induction signature of Europa (Kivelson et al., 2000; Nico et al., 2007).

Models of the cooling history of extruded liquid water and warm ice onto an icy surface (Van Cleve et al., 1999; Abramov and Spencer, 2008) have found that the detectible lifetimes of such features can be up to thousands of years, and endogenic activity might therefore be detectable by its thermal signature longer than it might be seen directly by, for example, plume activity. Thermal observations were made by the Voyager spacecraft, but had limited coverage and low spatial resolution (Spencer, 1987).

Current active venting on Enceladus demonstrates that recent geology activity is possible on icy satellites and that the presence of impact craters on some parts of the surface does not preclude localized ongoing activity in other regions (Porco et al., 2006). Furthermore, the detection of endogenic thermal emission on Enceladus in the infrared (Spencer et al., 2006) directly demonstrates the value of thermal observations for detection of endogenic activity on icy satellites.

The photopolarimeter–radiometer (PPR) was the simplest remote sensing instrument (a single aperture photometer) on the Galileo spacecraft. It had the lowest spatial resolution of all Galileo's remote sensing instruments but was sensitive to wavelengths up to 100 μm (Russell et al., 1992). Thus, it was the only instrument capable of measuring the surface temperature of Europa. During Galileo flybys of Europa, PPR was used primarily in radiometry mode which measures the brightness temperature of the surface at various wavelengths through different narrow infrared bands. For some observations, it was used without a filter to measure the total thermal radiation and, thus, the effective temperature. Thermal radiation from Europa is close to a blackbody with an emissivity of 0.9, so kinetic temperatures are probably slightly higher than the infrared brightness temperatures measured by PPR (Spencer, 1987).

The PPR instrument obtained more than one hundred observations of Europa. Of these, 15 had high spatial resolution, low noise, and covered a large area (Table 1) and were thus most suitable for investigation of Europa's thermal properties. Each of the selected observations built up an image by scanning PPR's single aperture across the surface of Europa. In total, the 15 data sets cover approximately half of Europa's surface and include both daytime (7) and nighttime (8) observations. Six of these observations have been previously published (Spencer et al., 1999). Fig. 1 shows five of the best data sets and the general distribution in longitude and time of day.

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Table 1
List of the PPR data sets with high spatial resolution, low noise, and coverage of a large area. Time of day is given in degrees where 0 is midnight, 90 dawn, 180 noon, and 270 dusk.

Filename	Date of obs.	Filter	Latitude range		Longitude range		Resn. (km/pixel)	Time of day range	
E6EPDGTM_01	February 1997	27 μm	−80	80	140	310	130	70	220
G7EPDGTM_01	April 1997	27 μm	−80	80	100	270	180	90	240
E11EPHOTSPT 01	November 1997	17 μm	−40	50	230	310	120	40	100
E11EPHOTSPT 02	November 1997	17 μm	−10	30	0	170	80	190	340
E12EPHOTSPT 01	December 1997	17 μm	−20	20	290	360	100	40	90
E12PHOTSPT 02	December 1997	17 μm	−5	25	70	130	80	290	330
E14EPDGTMHR01	March 1998	27 μm	−80	80	80	230	120	190	320
E15EPDRTMHR01	May 1998	27 μm	−20	90	120	300	110	40	200
E17EPDARKHR01	September 1998	Open	−50	50	200	310	110	20	110
E17EPDARKHR02	September 1998	Open	−25	40	0	70	80	280	330
E17EPDRKMAP02	September 1998	Open	−70	70	0	70	180	280	330
E17EPDRKMAP03	September 1998	Open	−70	70	0	70	230	290	340
I25EPDGTM__01	November 1999	17 μm	−70	80	135	270	190	140	230
I25EPDRKMAP01	November 1999	Open	−80	90	0	110	210	-40	80
I25EPH2040_02	November 1999	17 μm	−10	50	0	110	280	140	230

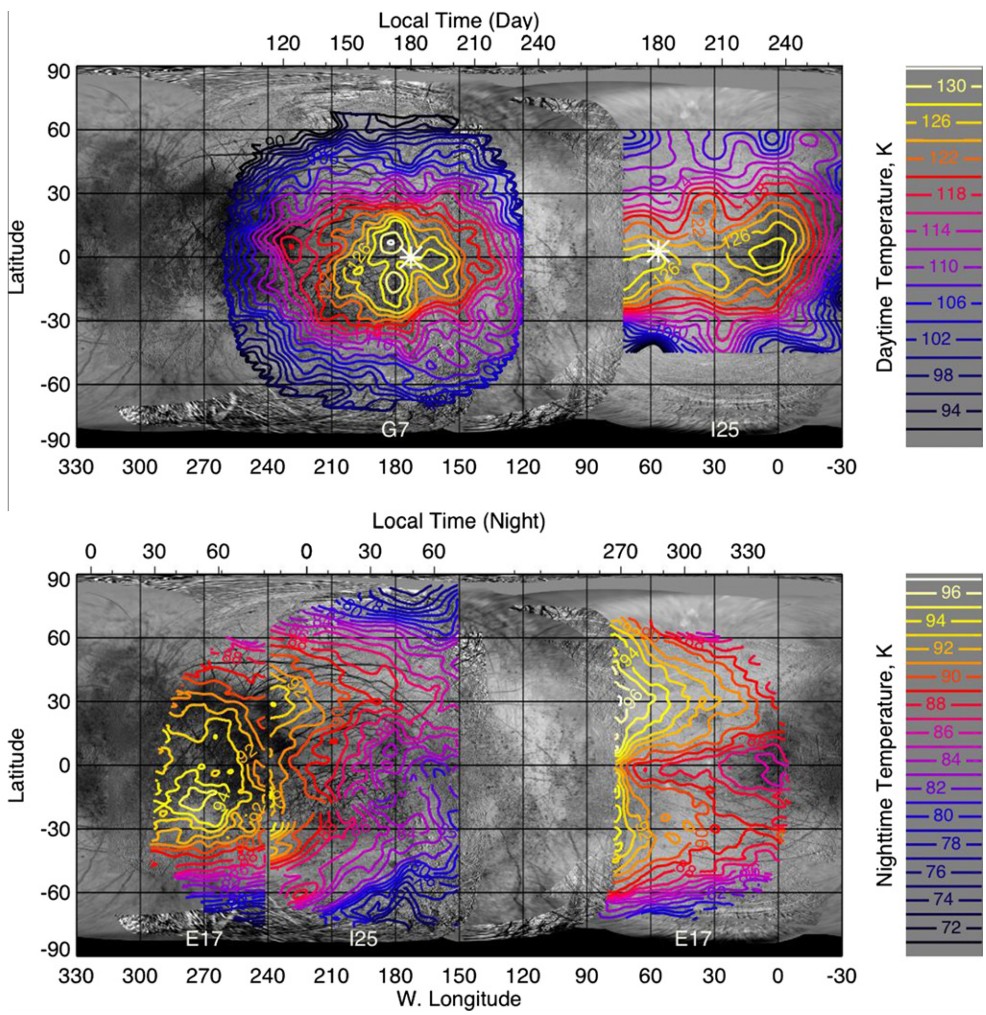

Fig. 1. Composite of five of the best PPR data sets. The daytime images are G7EPDGTM_01 and 25EPDGTM_01 while the nighttime images are E17DARKHR01, 25EPDRKMAP01, and E17EPDRKMAP02 (west to east).

In general, daytime temperatures behave as expected, with temperatures peaking at approximately 130 K near the subsolar point in all images covering a substantial portion of the disk and dropping off away from the subsolar point. Nighttime temperatures vary with location and local time, but are generally less than 100 K. One surprising feature in the nighttime data is in the region between 0 and 90 west longitude where the nighttime temperatures are highest at mid-latitudes and drop not only toward higher latitudes, but also toward the equator (Spencer et al., 1999). This change is not apparently correlated with any surface features or albedo. Spencer et al. (1999) suggested that thermal inertia variations could account for the observed temperature difference, but could not rule out warming of mid-latitude surfaces by widely-distributed endogenic heat as a possibility. They also fit a diurnal thermal