Possible Nature and Detectability of Endogenic Thermal Anomalies on Europa

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BACKGROUND/MOTIVATION:

How active is Europa at the present time?

What types of thermal anomalies do models of Europa’s ice shell and interior predict?

Previous Work:

Endogenic activity is rarely seen in Earth’s oceanic crust. Thermal anomalies have been inferred to the oceanic crust by seismic studies of the oceanic floor [8, 9]. In contrast, Europa’s thermal anomalies are much more pervasive and could be associated with various processes such as tectonics, plumes, ridges, and basins.

The European Thermal Emission Imaging System (E-THEMIS) is a multi-wavelength infrared instrument designed to search for thermal anomalies in part of NASA’s planned Europa Clipper (EP 10.1) mission. It is based on the highly successful THEMIS observations at Mars [9].

METHODS:

We ran Monte Carlo simulations using a discrete probabilistic model for resurfacing, incorporating temperatures and lifetimes based on numerical thermal models for four feature types: Ridges, Bands, Chaos, Lenticulae.

Temperature and Melting:

- Buried liquid layer with temperature T, produces surface anomaly:
  - Temperature range: 0 – 1 km
  - Shear heating [13] (upper figure): detectable lifetime M = 10 kyr, 8F
  - Freezing and cooling of liquid water: 10 – 100 m thick, detectable lifetime M = 0.1 – 1 kyr [6]
  - Chaos model: At = 1 – 10 kyr, 8F

METHODS:

Likelihood of hot spot occurrence:

- Global average resurfacing rate:
  \[ A = A_{surf} \times 1 \text{ km}^2 \text{ yr}^{-1} \]
  - Average occurrence rate for feature i with area A_i = L^2 whose total population occupies a fraction of Europa’s surface f_i:
    \[ f_i = \frac{A_i}{A_{surf}} \]
  - Average time between events i:
    \[ t_i = \frac{A_{surf}}{A_i} \]
  - Probability of N events during interval Δt, assuming events are independent:
    \[ P(N|Δt) = \frac{Δt^N}{N!} \left( \frac{A_{surf}}{N} \right)^N \]

FIGURES:

- Figure (top): Probability of at least one event occurring by any given time for a total area A_{surf} = 10^6 km^2.
- Figure (middle): Detection limits for different feature types (e.g., liquid water).

RESULTS:

Panels at right show example simulation using model parameters above, for a total duration 200 Myr.

The surface temperature “snapshot” is the initial mean temperature map at an arbitrary instant in time.

Predictions for E-THEMIS:

- Thermal anomalies expected for modeled styles of resurfacing: replacement of warm ice or liquid water, or shear heating on faults with sufficient dissipation [13]
- Resurfacing heat sources (e.g., liquid water) detectable within ~100 m to 1 km
- Daytime and nighttime measurements needed; also visible albedos [right figure]
- Background heat flow could be measured if >100 mW m^-2 at the equator, or >100 mW m^-2 at the pole

CONCLUSIONS:

Models of Europa’s ice shell and interior can be tested by the presence or absence of thermal anomalies:

1. Thermal anomalies are likely to be present on Europa today, if resurfacing occurs via warm ice or liquid water, and is either continuous or episodic with recurrence interval < 10 kyr.
2. Expected thermal anomalies are detectable by E-THEMIS with >99% likelihood for the model above
3. Smaller, more frequent thermal anomalies are more likely to be detected, even if they are sub-pixel hot spots

Detection depends critically on accurate measurements of both daytime and nighttime temperature, and visible albedo. NASA’s planned Europa Clipper mission and E-THEMIS are being designed to achieve these objectives.

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References: