EPSC Abstracts
Vol. 7 EPSC2012-803-3 2012
European Planetary Science Congress 2012

Europa Subsurface Science from Mutli-Flyby Missions

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Abstract

Both ESA's selected JUICE mission and NASA's proposed Europa Clipper missions will provide high-value, lower-cost science at Europa by implementing a novel approach to maximizing science return from flyby missions. A decade or more of Europa mission proposals have focused on Europa-orbiting platforms; recent analysis suggests however that, at least for the as-yet uncharacterized subsurface, flyby missions provide far greater science return than their orbital cousins. Future Europa exploration will seek to characterize the distribution of shallow subsurface water and understand the three dimensional nature of geological features and ice dynamics through radar sounding. As the only instrumentation that may unequivocally image subsurface water and habitats, radar investigations should be of primary interest to the astrobiology community for understanding how and where life might arise on Europa. Here we discuss the leverage of creative approaches to flyby planning and processing techniques, as well as the value of terrestrial analogues to maximizing science return from Europa flybys.

1. Introduction

Orbiting platforms at Europa are data-limited, both by downlink and by the need for radiation hardened memory. Thus, from the perspective of data volume-intensive instruments such as radar sounders and imaging spectrometers, orbiter-based science at Europa is scientifically limiting, requiring on-board processing via a priori assumptions about surface and subsurface characteristics. Radar sounding of the cryospheres of both Earth and Mars has benefited from the return of raw data to the science teams and a posteriori processing that can be tuned to the data set and observational circumstances. We consider how best to leverage existing capability and planning to achieve multiple high-value flybys. These strategies are frequency, velocity, and memory dependent. ESA's JUICE mission includes an HF frequency radar, while the NASA Europa Clipper mission carries both HF and VHF sounder capabilities.

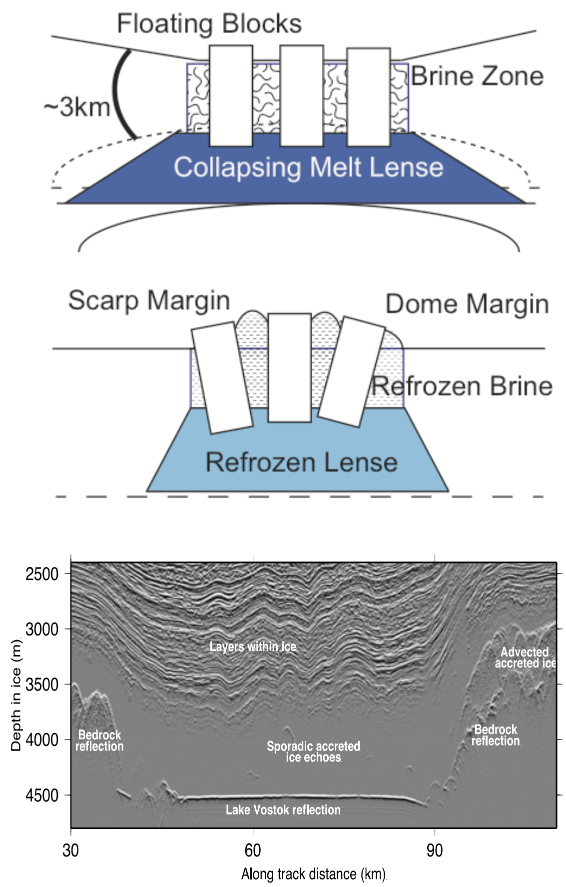

Figure 1: Example of how radar sounding observations may contribute to our understanding of Europa's subsurface, highlighting the value of regional context. Hypothesis for an actively forming chaos feature [Top, 1] and for a frozen chaos feature [middle, 1]. Bottom: University of Texas, Austin HiCARS radargram of a terrestrial subglacial water lens--Lake Vostok, Antarctica. The deformation of the ice water interface in response to the changes in surface slope and accreted basal ice are observed [2]. The ice-water interface can be imaged by both JUICE and Europa Clipper. The accreted ice and detailed structure, will likely only be detected by properly focused VHF imaging, proposed for Europa Clipper [2].

2. Subsurface Targets

2.1 Water Lenses

Recent work has shown that Europa's chaos terrain may be formed by the production of large subsurface lakes by rising diapirs [1]. This analysis also indicates that *water survives today* within 3 km of the surface, and in some regions is still forming the chaos terrain that covers ~50% of Europa's surface [2]. Similar water lenses – subglacial lakes – shaped by analogous surface-driven hydraulic gradients are routinely explored by radar on Earth. Both JUICE and Europa Clipper are capable of detecting these subsurface lenses with focused or unfocused radar.

2.2 Ridges and Fractures

Ridges and fractures dominate Europa's surface. Whether they form by injection of water, or water is formed within them by frictional heat, it will be vital to measure the distribution of fluid in fractures as a test of their formation and activity. Rupturing water-filled fractures above melt lenses may be indicative of active chaos formation [1].

2.3 Brine Zones

Brine rich ice may exist at the base of the ice shell, or within shallow ice above and surrounding melt lenses [1]. Such ice will have increased absorption, similar to terrestrial brine-laden layers and accreted marine ice. Both Thera and Thrace Macula show evidence for near-surface brine mobility that might be detected by radar sounding. Both JUICE and Europa Clipper can investigate these features. However, the higher resolution of the Europa Clipper VHF channel is optimized for imaging complex interfaces, where the HF frequency may not resolve a brine front.

3. The Value of Flyby Missions

One of the great advantages of the JUICE and Europa Clipper missions is that they provide more context for radar observations than do orbital platforms. Because of the selection of Thera and Thrace Macula as probably flyby targets, JUICE will be able to test the major hypotheses for formation of chaos terrain and potentially fractures, and revolutionize our understanding of Europa's subsurface. It may also detect the ice-ocean interface. However exciting, important regional and global context will be missing. The likely high velocity of the flybys and HF frequency limit the return of high-resolution data.

From orbit, raw data footprints for the planned JEO mission would only have been 30km long; the large chaos features are typically 50-150 km long, such that no data would return an image where the structure of these features as well as their effects on the surrounding terrain could be imaged. This would preclude the detection of brine infiltration in the surrounding terrain in the context of its source, for instance. The longer flyby groundtracks of both JUICE and the Europa Clipper missions solve this issue of context.

The Europa Clipper mission would conduct flybys of multiple examples of each of Europa's terrain. The global network of flybys allows for comprehensive coverage and rigorous tests of the hypotheses for formation of Europa's geology by imaging the subsurface in high resolution down to 5km depth with the VHF sounder. In addition, the flyby mission architecture increases the potential to detect the ice-ocean interface from multiple flybys with both the HF and VHF sounders on both sides of Europa. This networked flyby mission returns to Earth a significantly richer data volume than does an orbiter, since considerably longer raw data profiles, facilitating high-resolution regional context in a global framework across Europa.

References

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[2] Blankenship, D. D., Young, D. A., Moore, W. B., Moore, J. C. "Radar sounding of Europa's subsurface properties and processes: the view from Earth. In *Europa*. The Univ. of Arizona Press, 631-695. 2009.