EPSC Abstracts
Vol. 11, EPSC2017-241, 2017
European Planetary Science Congress 2017
© Author(s) 2017

Using passive seismology to study the sub-surface and internal structure of Didymoon

N. Murdoch[1], S. Hempel[1], L. Pou[1], A. Cadu[1], R. F. Garcia[1], D. Mimoun[1], L. Margerin[2] and O. Karatekin[3]

[1]Institut Supérieur de l'Aéronautique et de l'Espace (ISAE-SUPAERO), Université de Toulouse, 31055 Toulouse, France (naomi.murdoch@isae.fr). [2]IRAP-CNRS, Université Toulouse 3, 31400 Toulouse, France. [3]Royal Observatory of Belgium, Brussels, Belgium.

Abstract

As there is evidence to suggest that asteroids are seismically active, passive rather than active seismology could be performed thus simplifying the mission design. Here we discuss the possibility of performing a passive seismic experiment on Didymoon; the secondary component of asteroid (65803) Didymos and the target of the joint ESA-NASA mission AIDA [1,2].

1. Introduction

Understanding the internal structure of an asteroid has important implications for interpreting its evolutionary history, for understanding its continuing geological evolution, and also for asteroid deflection and in-situ space resource utilisation. Given the strong evidence that asteroids are seismically active, an in-situ passive seismic experiment could provide information about the asteroid surface and interior properties. Didymos is characterised as an S-type object [3]. Following [4] we assume that Didymain (the primary) and Didymoon (the secondary) both have a bulk density of 2146 kg/m^3 [5]. The mean diameter of Didymain is 775 m, and the mean distance between the center of the primary and the centre of the secondary is 1180 m. Didymoon has a mean diameter of 163 m and a likely retrograde orbit around Didymain with a rotation period of 11.9 h and an eccentricity of, at most, 0.03 [5].

2. Didymoon seismicitiy

Although meteoroid impacts are rare on an asteroid as small as Didymoon, thermal cracks and tidal stresses are expected to produce seismic signals. Based on our detailed tidal stress calculations, it is very likely that quakes occur on and in Didymoon due to failure from tidal stress if Didymoon has an eccentric orbit. In both the homogeneous and the layered internal structure models that we have considered, failure is found to be reached first at the poles, and to occur close to the asteroid's surface (Fig. 1).

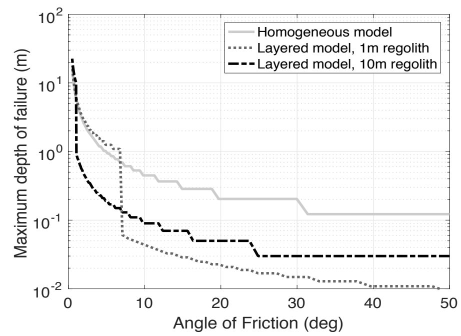

Figure 1. Maximum depth of failure due to tidal stresses versus the angle of friction. Results are shown for the homogeneous model (light grey solid line), the layered model with a 1 m regolith (darker grey dotted line), and the layered model with a 10 m regolith (black dashed line). The regular discontinuities are due to the quantification of the body into sub-layers of equal size. The spatial resolution varies between the models, however, the depth of failure for large angles of friction always occurs between the upper two sub-layers in our models. See [6] for details.

3. Seismic wave propagation in Didymoon

Our simulations of seismic wave propagation in a homogeneous Didymoon show that the seismic moment of even small meteoroid impacts can generate clearly observable body and surface waves that can travel several times around the tiny asteroid due to the low seismic attenuation. When a regolith layer is included, the seismic energy can become trapped in the regolith layer due to the strong impedance contrast at the regolith-core boundary. With macro-porosity (voids) included, the wavefield becomes more complex and the onsets of seismic waves become less clear due to increased scattering.

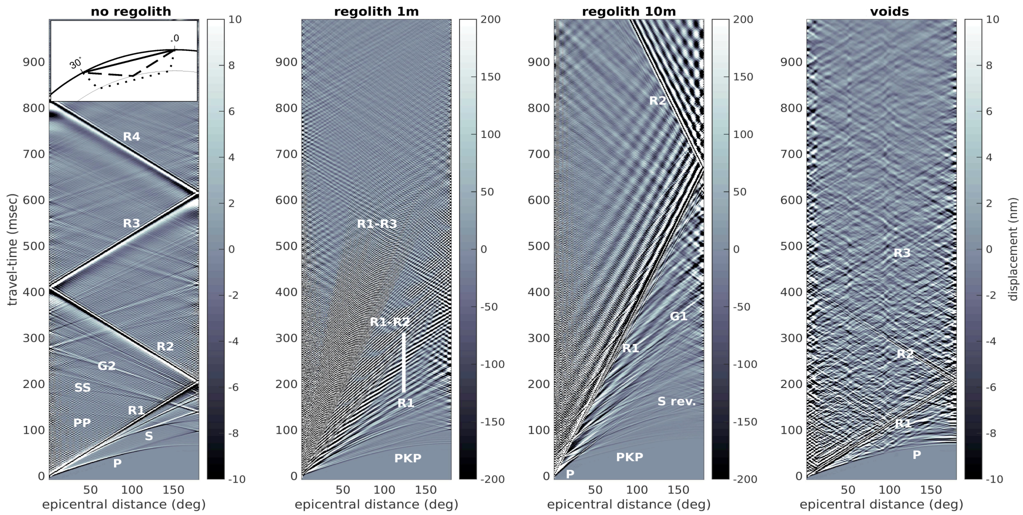

Figure 2. Didymoon seismic wavefields - The vertical seismic wavefield for models with regolith thicknesses of a) 0, b) 1 and c) 10 m as well as d) an asteroid containing voids of 5 m average diameter. Marked phases include the body waves P and S, their multiples PP and SS, the core phase PKP, as well as the surface waves. See [6] for details.

Nonetheless, the most prominent waves remain those traveling along the surface of the asteroid and those focusing in the antipodal point of the seismic source (Fig. 2).

4. Determining the internal structure of Didymoon

Both the direct waves and signals in transmission, and the diffuse wave field can be exploited to study the sub-surface and internal structure of the asteroid using in-situ seismic instrumentation. Our simulations show the strong effect interior structure such as layering or random heterogeneities of length-scales between centimeters and meters have on the seismic amplitudes as well as the frequencies, and on the types of seismic phases that can be observed. If the first arrival is strong enough to be detected, it gives the average P wave velocity of the interior. The arrivals with the strongest amplitude, however, characterise the S wave properties of the uppermost layer. In the case where the asteroid can be simplified as an asteroid-core covered with a regolith layer, these measurements will allow the computation of seismic velocities as well as regolith thickness. Strong resonance frequencies or long coda will indicate either trapped waves or strong heterogeneity.

5. Conclusions

Although the science return will be enhanced by having multiple seismic stations, one single seismic station can already vastly improve our knowledge about the seismic environment and sub-surface structure of an asteroid. In addition to performing the first surface-based geophysical investigation of an asteroid, a seismic experiment on Didymoon could lead to very unexpected and exciting scientific discoveries.

Acknowledgements

We gratefully acknowledge financial support from the French space agency (CNES), the European space agency (ESA), and the French national research agency (ANR).

References

[1] Cheng et al., (2016), PSS; [2] Michel et al., (2016), ASR; [3] deLeon et al., (2010), A&A; [4] ‘AIM-A Team’, (2016), ESA reference document; [5] Scheirich and Pravec (2009), Icarus; [6] Murdoch et al., (2017) PSS.