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Elastic Wave Measurements with the CASSE triangle geometry

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1. Introduction

The Mission Rosetta is on its way to the comet 67P/Churyumov-Gerasimenko since 2004. During its journey Rosetta has completed three swing-by maneuvers at the Earth and one at Mars, in which the gravitational attraction was used to accelerate the spacecraft. These swing-by maneuvers also were opportunities to conduct calibration measurements with several instruments [1]. Rosetta crossed the asteroid belt two times on its way and had close flybys at the asteroids Steins (2008) [2] and Lutetia (2010) [3], which were used to determine the size, shape and density of the asteroids. In July 2011, Rosetta will enter a hibernation phase of two and a half years. After the hibernation phase the spacecraft will finally reach the comet and will deliver the Lander Philae at the surface of the nucleus in November 2014.

The Lander carries nine experiments, one of which is the Surface Electrical, Seismic and Acoustic Monitoring Experiment (SESAME). Part of this experiment is the Comet Acoustic Surface Sounding Experiment (CASSE) housed in the three feet of the lander, which will be used to study the properties of the comet nucleus surface material. The primary goal is to determine the elastic parameters of the surface material, like the Young's modulus and the Poisson ratio. Beside this, an additional goal is the localization of activity spots and thermally and impact caused cometary activity. Also, the macro structure of the surface and the layering of the upper regions and possible inhomogeneities will be investigated [4]. During the active phase of the comet, recording of particles ejected by the comet and falling back to its surface near the receivers will support the determination of the particle flux and the particle size frequency distribution.

At the beginning of the long term science phase of 13 months (November 2014-December 2015) the comet will be at a distance of 4 AU from the sun. In this distance the comet will still be inactive, and the temperatures Rosetta is exposed to are about –180° Celsius. In August of 2014 during the perihelion passage, the comet will come as close as 1.29 AU to the sun, the temperature will increase to up to 50° Celsius, and the comet will be in its most active phase. With the increasing temperature the mechanical properties of the nucleus material are likely to change, because of the sublimating ices.

The goal of this study is to estimate the precision and accuracy of elastic wave propagation velocities that can be achieved with the special triangle geometry of the CASSE experiment with varying ground properties. We conduct repeating measurements on a meadow in Berlin Adlershof at a fixed place but different humidity and temperature using the same accelerometers and the same geometry as will be used at the comet.

2. The experiment

The lander Philae has three legs, which will unfold at the time of the landing. The feet of the legs mark the angles of a nearly equilateral triangle. Every foot is build up of two soles in which the transmitters and receivers are fixed. Looking from the outside the left sole of each foot contains the transmitter and the right sole contains the receiver. The transmitters are made of stacked piezoceramics that also can be used as receivers. The receivers are Brüel & Kjaer Triaxial Piezoelectric Accelerometers. The distance between transmitters and receivers is 15 centimeters within one foot and about 2.5 meters between different feet [3].

In our experiments we apply identical Triaxial Piezoelectric Accelerometers like that used at the comet. As source we use a rubber mallet with a head radius of 2.25 centimeters. All measurements take place at a meadow near the DLR in Berlin Adlershof, to test the special array of the sensors used at the mission. The soil at the meadow is very loose and porous sand with a high air content. We use plastic plumbing tubes to reproduce the formation of the legs of the lander, so that we measure with the same distances of the transmitters and receivers as will be done later at the comet. During the measurements, after all accelerometers are at their place, the tubes will be removed. The frequencies that can be detected by the receivers lie between 100 Hertz and a few kHertz. To test, whether the accelerometers also record airborne sound, there were earlier tests, where an accelerometer was hold up in the air while hammering [5]. During these tests the accelerometer did not record any signal, so we can be sure that the signals we record represent ground waves. Most of the measurements are done at the same place on different days to examine the influence of humidity and temperature on the wave velocity. During our tests we measured a broad humidity range and the temperatures had values between slightly below 0° Celsius and over 20° Celsius. As reference, we use velocities determined with densely sampled linear profiles. Other experiments with linear arrays will be done to test if the wave velocity is isotropic at the meadow we choose for our measurements, because earlier experiments gave indications that the waves do not propagate with the same velocity in all directions [5]. The results for the wave velocity of the linear profiles are also used as reference values to assess the accuracy of the velocities obtained with the sensor triangle. For measurements at different places at the meadow, to determine the spatial variation of the wave velocity, we establish a coordinate system from the distances to several solar panels, which are permanently installed at the meadow. For the measurements a sampling rate of 16283 Hertz is used and the record length amounts 0.25 seconds, including a delay of 0.06 seconds before the trigger. For every source position we hammer 20 times, so we can stack these 20 time series after the measurement. Also we process the data with a band-pass filter after we detrended, synchronized, stacked and normalized it.

3. Results

Till now in large part measurements have been made to study the influence of humidity and temperature on the velocity. The preliminary results show that we can measure different wave velocities for differences in the humidity. Like expected, the velocity increases with higher humidity, because the air content decreases while the water content increases, and the wave velocity in water is higher than in air. We also observe a strong velocity increase if $T < 0°C$, which can be explained by the water-ice transition that welds the otherwise loose grains of the soil. The velocities for the humidity and temperature ranges we studied lie between 200 m/s and 500 m/s with an error up to 100 m/s.

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