An active Seismic experiment on Bepi-Colombo

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• **The objective of the seismic experiment** is to determine the propagation properties in the crust and upper mantle of Mercury and the thickness of the crust by using an active source (the SEPM of the spacecraft), natural quakes triggered by the Sun tidal forces and micro-meteorites impacts

. The primary objective of the experiment are therefore:

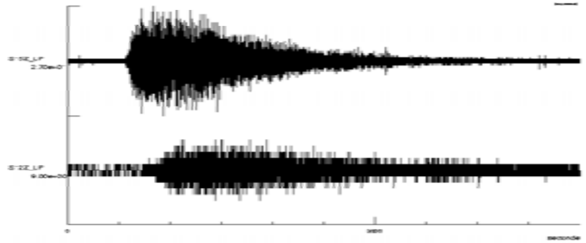
-to detect the impact of the MSE SEPM

- to detect mercury tide

-to detect quakes and meteorites impacts

-to detect thermal cracks in the upper most layers just after sunrise

-to determine with these records a model of Mercury interior



Example of two seismic measurements on the Moon performed by the impact of the LEM module (2400 kg, 1.70 km/s), ar recorded at distances of [illegible] km and of 1750 respectively (up and down). SEPM mass and velocity will be 365 kg and 4.4 km/s (Impulse 2.5 smaller). On Digital Unit represent 5 10^{-10} ms^{-2} in acceleration.

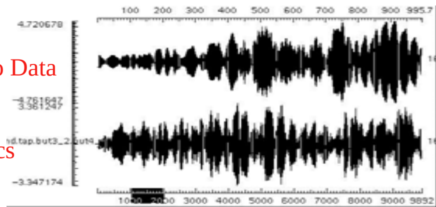
• **What can be achieved with a single seismometer?** It is well known that detailed seismic studies need at least 3 seismic stations, recording at least the P and S arrivals (6 data) in order to locate the seismic source and to determine the occurrence time (4 unknown) and to determine the Vp and Vs interior model (2 unknown depending on depth). The resolution in depth coverage of the model is then related to the number of events successfully recorded at the 3 stations. In the case of Bepi-Colombo, it is necessary :

-either to use known sources (the impact of SEPM, the tidal forces of the Sun)

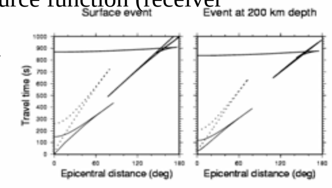
- or to use technics able to cancel most of the source effects, for example by using the spectral ratio between two independent seismic record, which are both proportional to the source function (receiver function technics)

Apollo Data

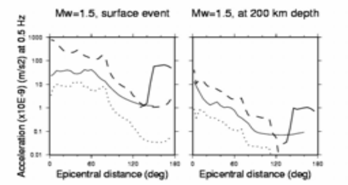
Apollo synthetics Data



Impact calibration: In order to perform a good estimate of the signal impact generated by S/C impacts, we have calibrated synthetics seismograms with the Moon Apollo Saturn and LEM impacts.

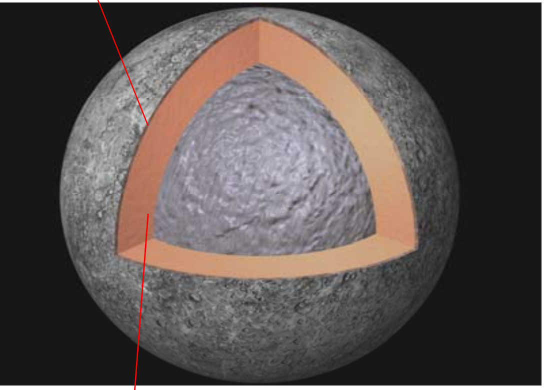


Hodochrone: Thin line P+PcP, Large line PKP, doted line S+ScS



Amplitude: Thin line P Vertical, Large line PKP Vertical, Doted line S Vertical, Dashed S radial

Scientific objective one: what is the crustal thickness below the landing site?



Scientific objective two: seismic informations on the core

• **Why is the crustal thickness important?** The effect of the crust thickness on the determination of the mass and size of the mantle and core is probably small, to the level of 1% in the mantle and core density and core radius. However, because the crust is representing about 15% of the bulk mantle, it will be very important for determining the amount of bulk silicate, U, Th and other core incompatible elements. While mineralogical instruments onboard the Messenger and Bepi-Colombo orbiters, as well as the mineralogical sensors onboard the MSE will allow to determine the mineralogical composition of the crust, the crustal volume will be necessary:

-for providing an estimate on the bulk composition of Mars, especially for chemical species enriched in the crust, like U, Th and possibly Ca, Al for which the crust might represent more than 50% of the bulk amount if enriched by a factor of 3

-for providing an estimate on the thickness of the primordial magma ocean produced after impacts

-For a separation of the core/mantle heat flux from heat flux generated in the crust and therefore of the source of mantle and core convection

Only seismic data can constrain the mean crustal thickness!

Geodesy data are limited (mean mass, mean inertia and possibly density Jump at the core from libration) and will constrain mainly the core density and size and the mantle density. Gravity data will constrain the crustal thickness variation but not the mean crust. In contrary to the Earth, the small radius of the planet and the possible cold mantle temperature is freezing lithospheric relaxation processes and prevent to use joint gravity/topography data for estimating the crust thickness precisely.

How to perform the impact?

The possibilities for the SEPM's impact need a detailed mission analysis for a mission already not so clear for MSE. However, possibilities exist by releasing the SEPM prior MSE on a very elliptical SEPM impact trajectory with a minimum ΔV. A crude control module of the SEPM might be however necessary for some DV and for positioning and timing the impact.

Instrument description

Instrument	Seismometer
Acronym:	SI2NIR
Characteristics	very broad band measurements of acceleration from 10^{-5} to 10 Hz by two outputs Tide outputs, flat in acceleration up to $3x10^{-3}$ Hz Seismic output, flat in velocity from $3x10^{-3}$ Hz to 10 Hz
Resolution	LSB = 10^{-11} m/s for velocity (seismic) output, 10^{-11} ms-2 for acceleration(tide) output
Noise	$2.5x10^{-10}$ $ms^{-2}/Hz^{1/2}$ in seismic band, $<10^{-8}$ $ms^{-2}/Hz^{1/2}$ in tidal band
Range(s):	± 10^{-3} ms^{-2} for acceleration measurments
Resolution(s):	$2.5x10^{-10}$ $ms^{-2}/Hz^{1/2}$ in seismic band, $<10^{-8}$ $ms^{-2}/Hz^{1/2}$ in tidal band
Pointing direction	± 35° (self leveling device enclosed) No pointing direction request for horizontal
Desirable accuracy about pointing knowledge :	
Mass:	instrument: sensor and electronics: 1 400 gr for one axis, 800 gr for two axis
Dimensions :	Instrument: diameter 5 cm x height 15 cm equivalent volume per axis
Supply voltages:	±5 V DC, 3.3 V digital
Preferred mounting location(s):	Inside the lander, assuming a direct contact of the lander on the ground, or inside penetrator
Preferred altitude with respect to ground surface:	None if rigidly connected to the landing footpads, either on the ground ± 35° with respect to local vertical
Power during operation:	<200 mW for each axis
Minimum time of operation:	- A few hours with impact of Electrical Propulsion module inside for active seismology - a substential fraction of the Mercurian day around maximum tidal stress release for passive seismology
Minimum data volume:	1 Mbits / day of operation
Mechanism(s):	None
Temperature ranges:	Available now: MILITARY temperature range Possible: -100°C / + 100
Maximum tolerable shock:	250 g - 20 ms

• A single seismic station can add information on the core size, by determining the epicentral distance of appearance of PKP waves and of S shadow zone of the core. Epicentral can be crudely determined by the S-P travel time of mantle body wave before the S shadow zone. As for the Moon, we can expect tidal triggered quakes, occurring with a orbital periodicity. If the seismometer is operational during a significant fraction of the orbital period (e.g. a full night), we can expect the detection of such quakes, from different location. In addition, the measurement of the Solar tide on the ground, in addition to the measurement of its gravity effect by the orbiter will provide two Love numbers constraining the mean mantle shear modulus, the depth of the core mantle boundary and the mantle density, in addition to the other geodetic data..