Review on magnetic devices development for terrestrial and planetary magnetic surveys

J.L. Mesa Uña (1), M. Díaz Michelena (1) ,M. Pérez Jimenez (2), M. C. Maicas Ramos (2), P. Cobos Arribas (2), C. Aroca Hernandez-Ros (2)

(1) Payloads and Space Sciences Dept., Instituto Nacional de Técnica Aeroespacial, Torrejón de Ardoz, Madrid, Spain.

(2) ETSIT-ISOM, Universidad Politécnica de Madrid, Madrid, Spain.

3RD SOFT MAGNETIC MATERIALS CONFERENCE - O-46 Wednesday 4:45 PM

Earth Magnetic Surveys

Orbit measurements

(2000km – 100km)

- Magnetic field intensity and direction

(Absolute magnetometry, vector magnetometry)

- Magnetic field gradient (gradiometry)
- Rock susceptibility (susceptometry)

Medium height measurements (10km – 2m)

- Magnetic field intensity and direction

(Absolute magnetometry, vector magnetometry)

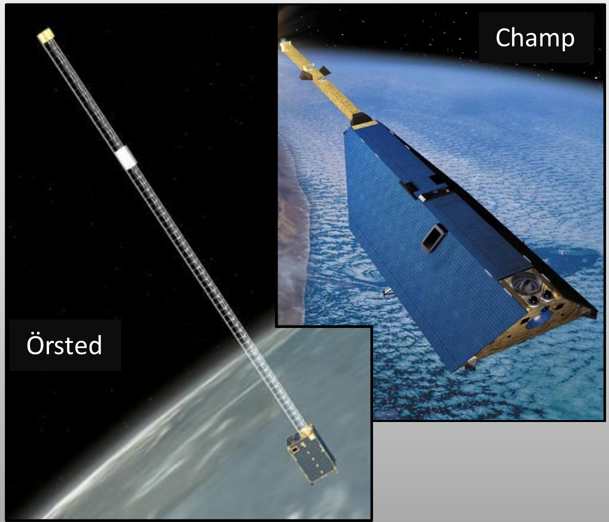
- Magnetic field gradient (gradiometry)
- Rock susceptibility (susceptometry)

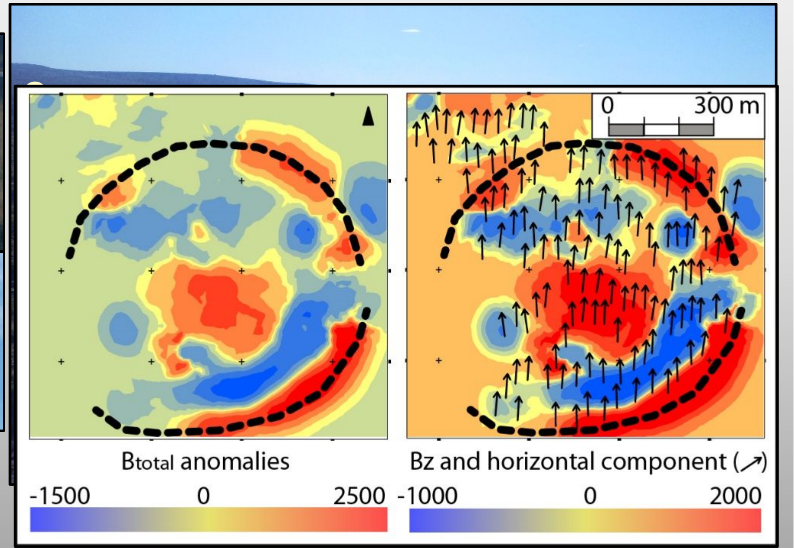
On ground and laboratory measurements (1m - contact):

- Magnetic field intensity and direction

(Absolute magnetometry, vector magnetometry)

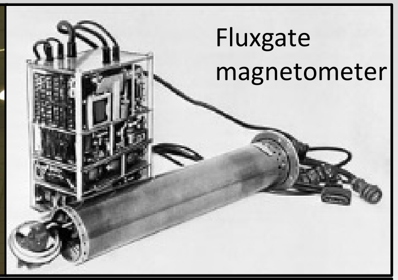
- Magnetic field gradient (gradiometry)
- Rock susceptibility (susceptometry)

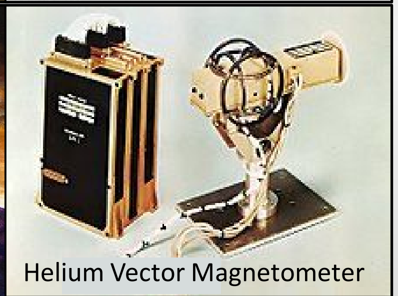




Space Magnetic Exploration

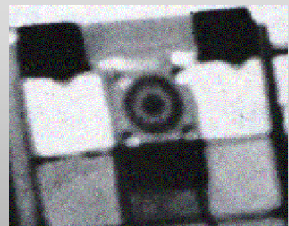
Orbital and fly-by



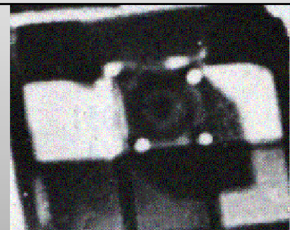


Ring core fluxgate magnetometer

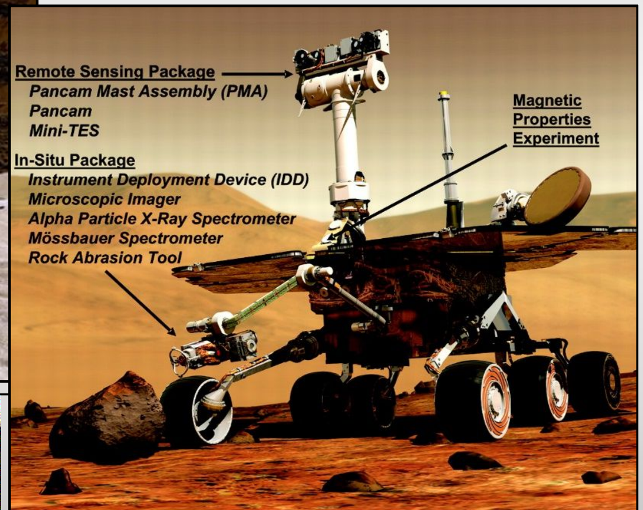
In situ magnetic exploration



Reference test chart magnet image for VL-1 on sol 31.



Reference test chart magnet image for VL-2 on sol 42.



State of the art

Space

Orbit

- Ørsted mission (1999-2014): Overhauser and Fluxgate Magnetometer.
- Champ mission (2000-2010): Overhauser and Fluxgate Magnetometer.
- Swarm mission (2013 – still flying): ASM Helium 4 Optical Pumping and Compact Spherical Coil (CSC) with a 3-axis Compact Detector Coil (CDC) inside.
- Exomars (planned for 2020-2022): lander deployable AMR magnetometer.

In situ

- Magnets (Viking) and Mossbauer spectrometer (Pathfinder) .

Terrestrial prospections

Field and laboratory measurements:

- Absolute magnetometers (SQUID, Protons, Overhauser).
- Vector magnetometer (Fluxgate, AMR, Hall Effect, Search Coils, etc.)
- Gradiometer (differential measurement)
- Susceptometer
- Field susceptometer (In situ, high spatial resolution, low sensitivity)
- Laboratory (need sampling, high sensitivity).

Airborne

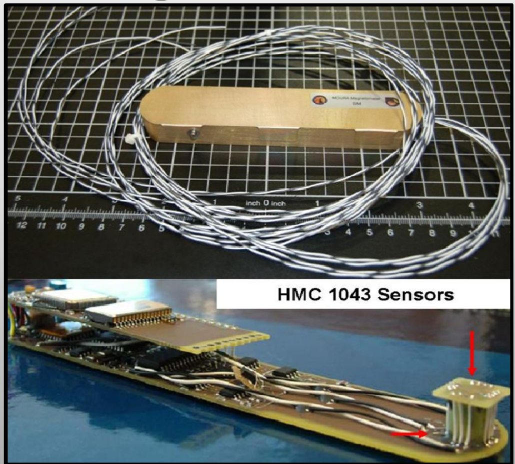
- Absolute magnetometers
- Vector magnetometers

New instrument concept of INTA Space Magnetism Laboratory

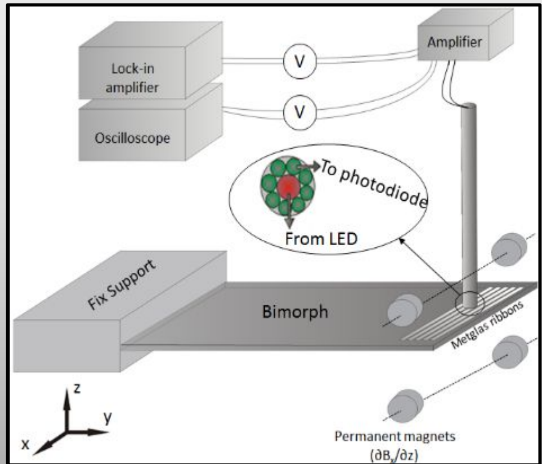
Objectives

- Complete magnetic characterization
- Distinguish materials by means of magnetic measurements
- Technological challenge: High maturity level
- Robust, miniaturizable and low-power consumption
- Designs compatible with rover architectures for planetary exploration

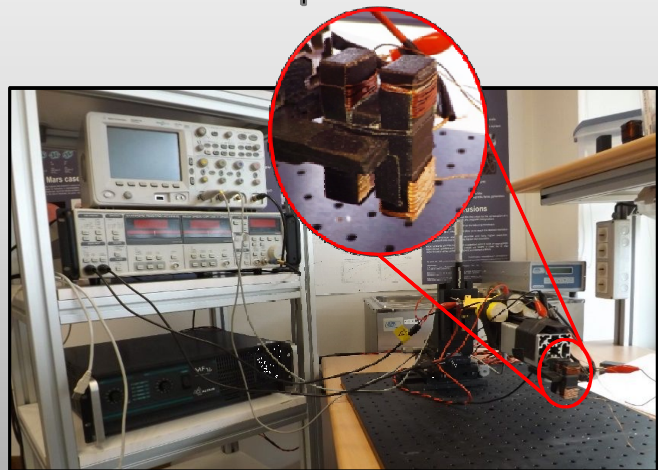
Magnetometer



Gradiometer



Susceptometer



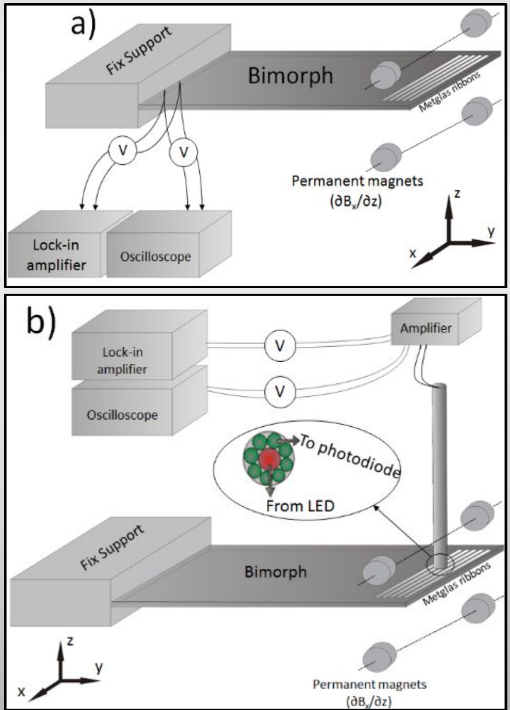
- Complete Magnetic Characterization

$$\begin{pmatrix} H_x \\ H_y \\ H_z \end{pmatrix} + \begin{pmatrix} \bar{\nabla} H_x \\ \bar{\nabla} H_y \\ \bar{\nabla} H_z \end{pmatrix} + \chi$$

- Technological challenge
- New concept
- Distinguish magnetic field sources

New instrument concept of INTA Space Magnetism Laboratory for in-situ measurements.

MEMS Gradiometer



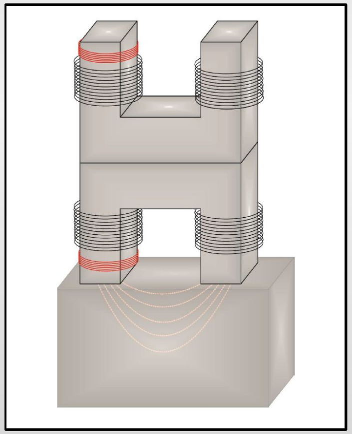
Based on the mechanical oscillation of a cantilever vibrating at its mechanical resonance frequency.

Direct and punctual measurement of the magnetic field gradient.

Miniaturizable and adaptable for the 9 components of the gradient tensor.

Designs compatible with rover architectures for planetary exploration.

Susceptometer



Based on inductive principles.

Direct measurement of the complex magnetic susceptibility.

Capability to determine the complex susceptibility.

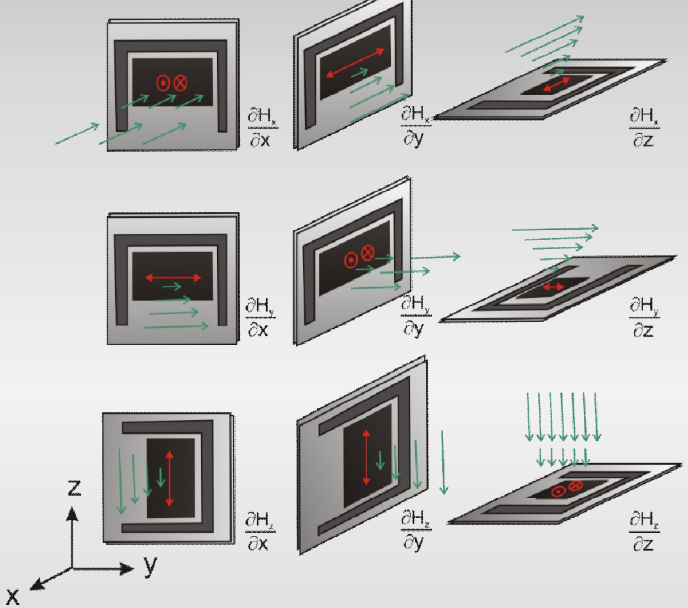
Capability to operate at different frequencies.

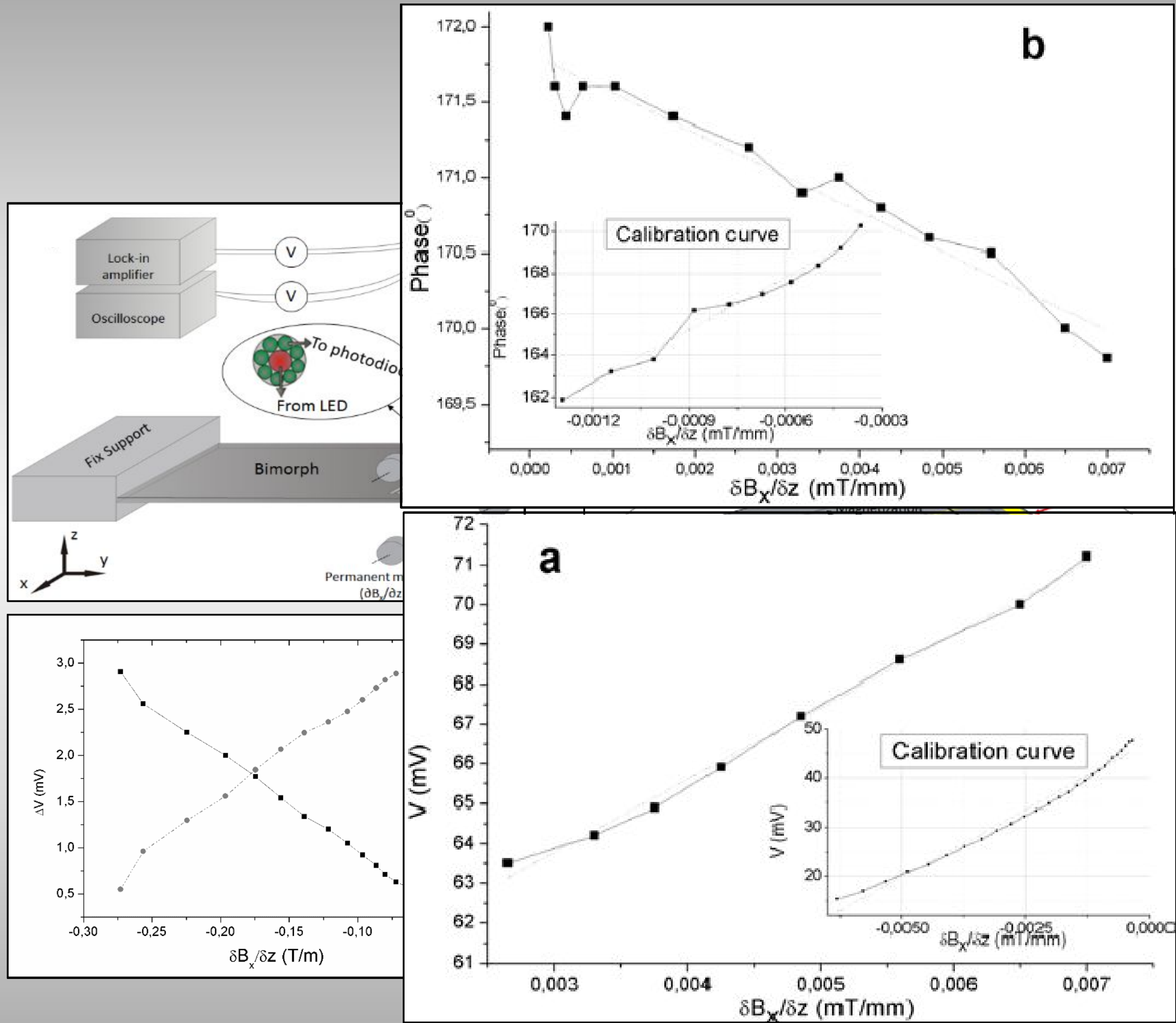
Designs compatible with rover architectures for planetary exploration.

No need for sampling.

"Single point gradiometer for planetary applications". IEEE Magnetics Letters, vol. 6, no. , pp. 1-4, 2015. Doi: 10.1109/LMAG.2015.2411576W.

MEMS Gradiometer





Complete Magnetic Characterization

$$\begin{pmatrix} H_x \\ H_y \\ H_z \end{pmatrix} + \begin{pmatrix} \overline{\nabla} \mathbf{H}_x \\ \overline{\nabla} \mathbf{H}_y \\ \overline{\nabla} \mathbf{H}_z \end{pmatrix} + \chi$$

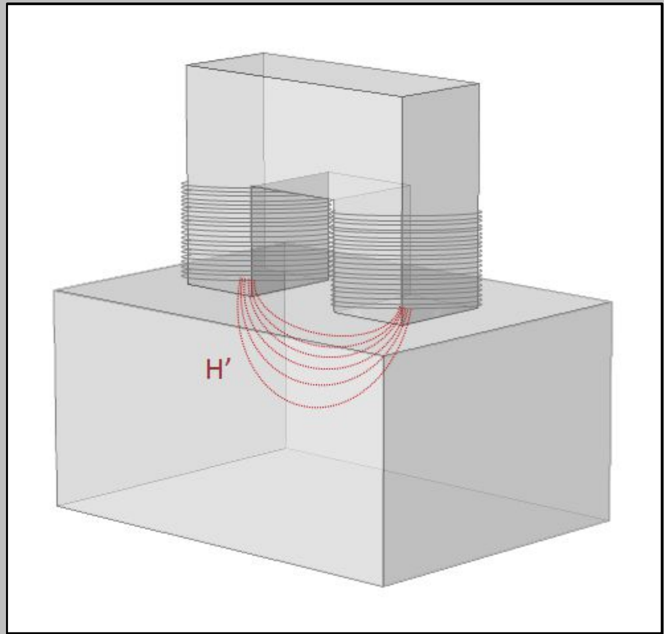
"Single point gradiometer for planetary applications". IEEE Magnetics Letters, vol. 6, no. , pp. 1-4, 2015. Doi: 10.1109/LMAG.2015.2411576W.

Susceptomter

Commercial devices

- VSM or Squids (MPMS).
- Few portable instruments.
- MS2E Surface scanning sensor.
- Working frequency from 1.36 to 2 kHz.
- Only real component.

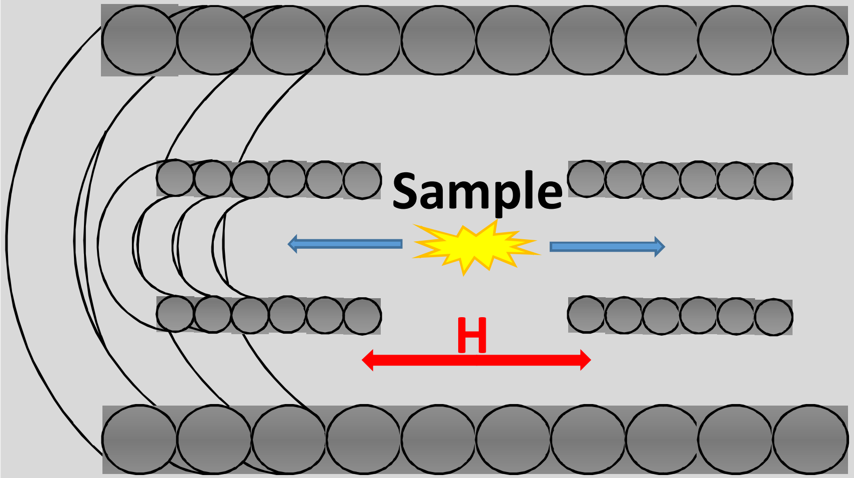
Portable susceptometer



Complete Magnetic Characterization

$$\begin{pmatrix} H_x \\ H_y \\ H_z \end{pmatrix} + \begin{pmatrix} \overline{\nabla} H_x \\ \overline{\nabla} H_y \\ \overline{\nabla} H_z \end{pmatrix} + \chi$$

Fixed susceptometer



Phase and quadrature analysis of the EMF

$$\mu' = \alpha \frac{\varepsilon_x}{mass} \qquad \mu'' = \beta \frac{\varepsilon_Y}{mass}$$

"A novel induction-based device for the measurement of the complex magnetic susceptibility". Sensor Actuat A-Phys 263 (2017) 471–479.

"High Resolution System for Nanoparticles Hyperthermia Efficiency Evaluation". IEEE Transactions on magnetics, vol. 47, No. 10, October 2011.

Results for the susceptometer

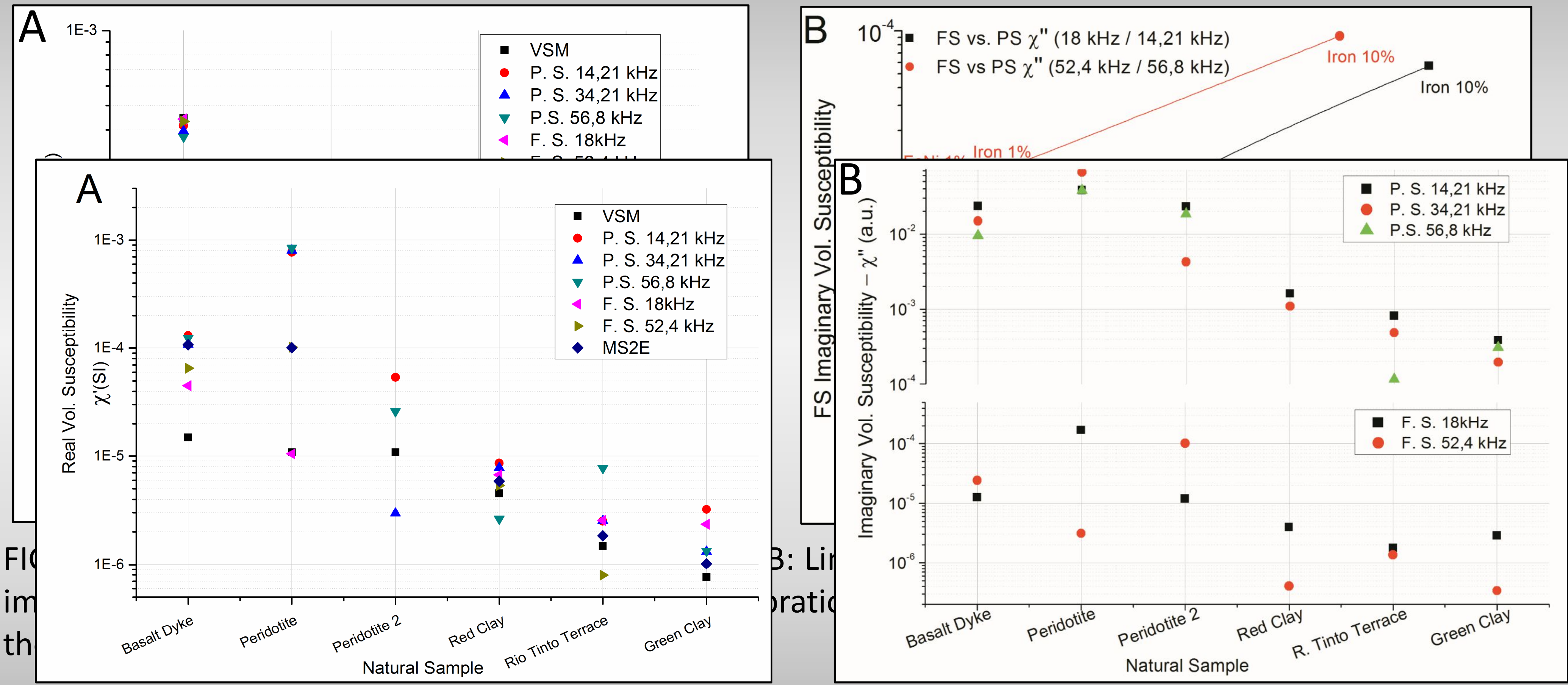
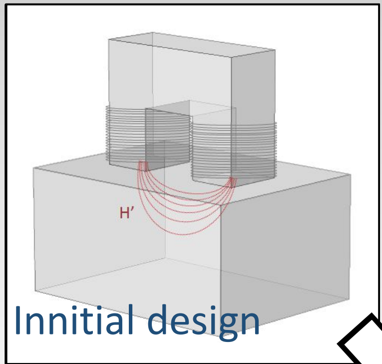
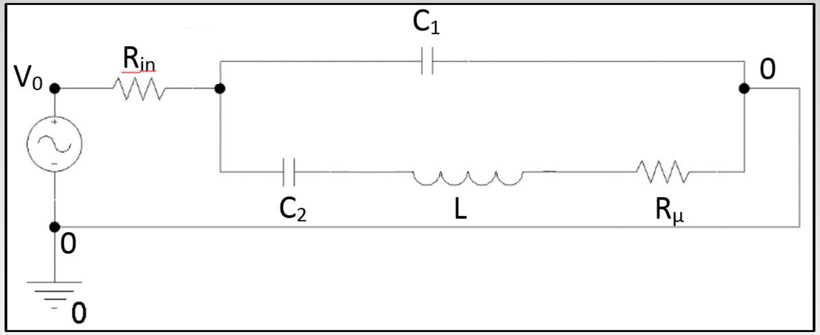


FIG. 2. A: Measurement of χ’ of natural samples. There are two results representations for the peridotite, given that this sample presents a intrusion of high susceptibility material. B: Measurement of χ” of natural samples.

Evolution of the NEWTON Susceptomter

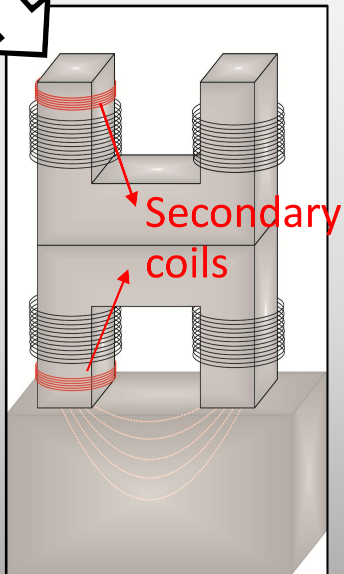


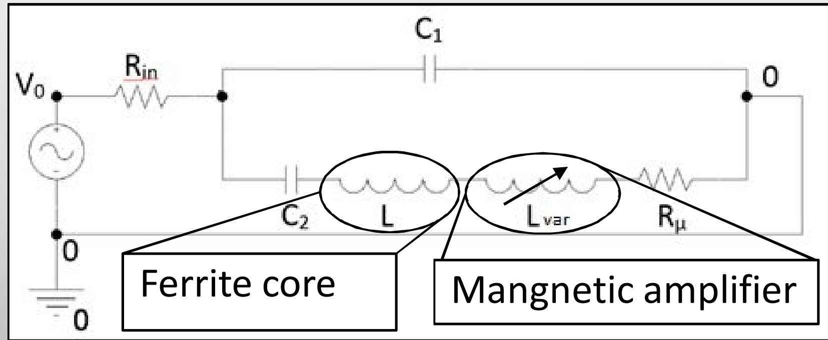
U-shape ferrite core which approaches to the sample.



The different working frequencies are reached by changing the capacitor values.

Improved design, which allows differential measurements.

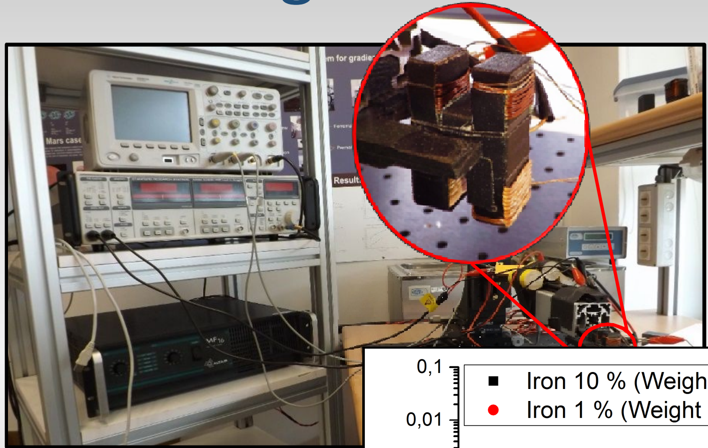


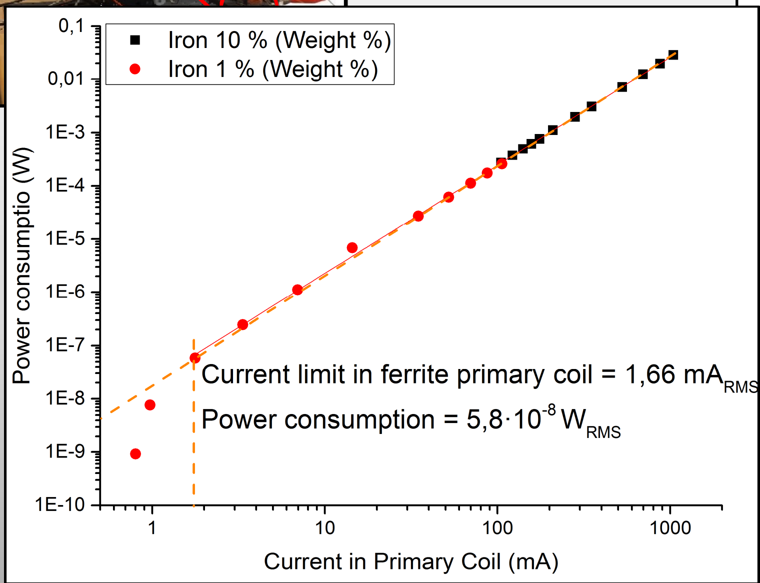


The electric circuit is being adapted to include magnetic amplifiers, which allows to modify the resonant frequency.

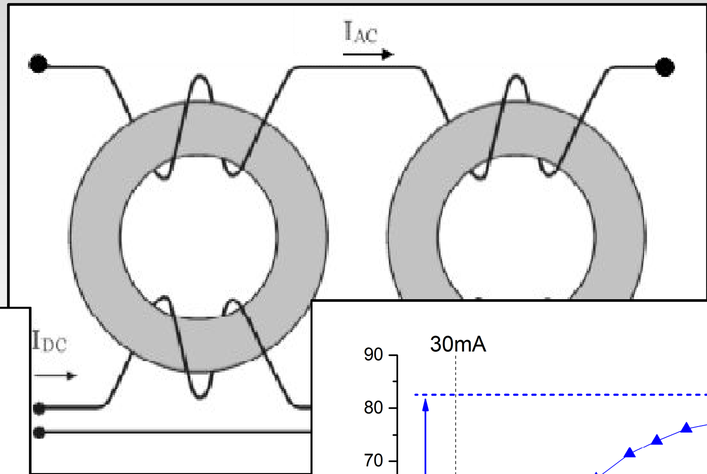
Current and future work

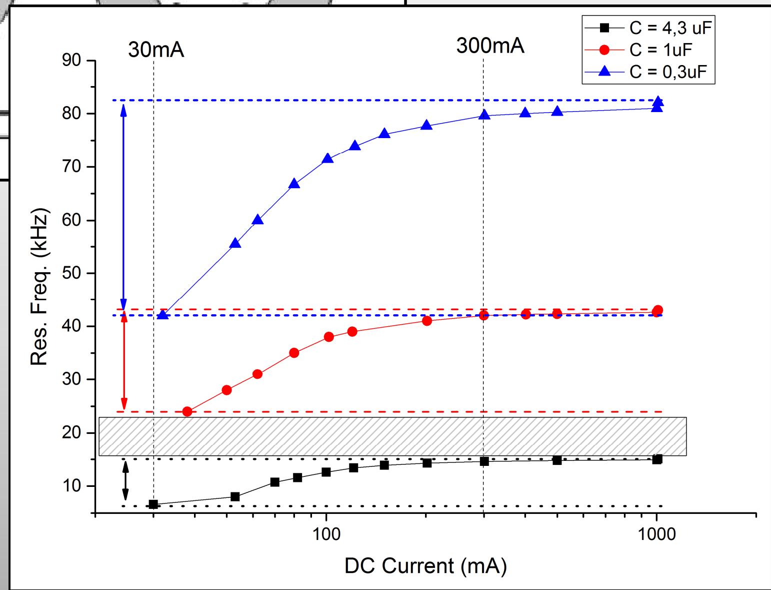
Defining limitations





Integration of magnetic amplifiers





2020: Exomars 2020 - AMR magnetometer in the meteorological module.

202?: Mars and its moons in situ exploration mission- Magnetometer, Susceptomter and Gradiometer

Thank you for your kind attention!