Newton Susceptometer first prototypes development and results

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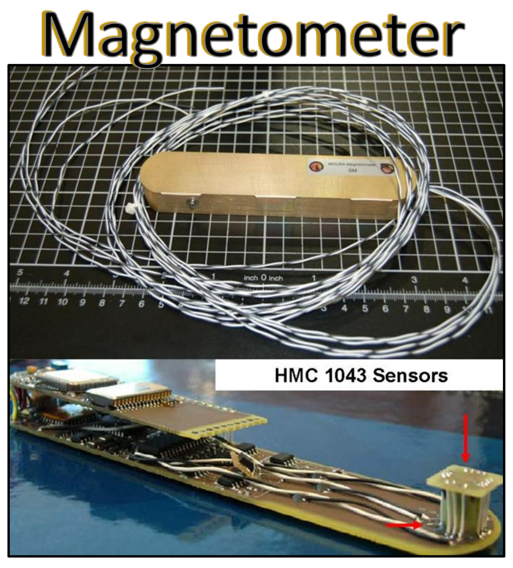
In-situ Magnetic Characterization

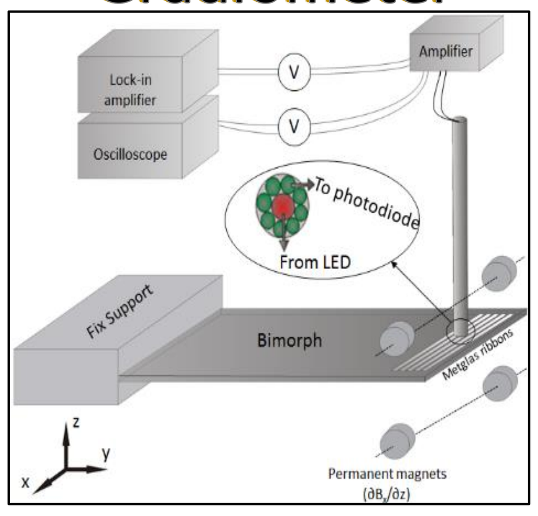
The characterization of magnetic signature and magnetic properties of natural samples includes:

$$\text{Magnetic Characterization} \rightarrow \begin{pmatrix} B_x \\ B_y \\ B_z \end{pmatrix} + \begin{pmatrix} \bar{\nabla} B_x \\ \bar{\nabla} B_y \\ \bar{\nabla} B_z \end{pmatrix} + \chi$$

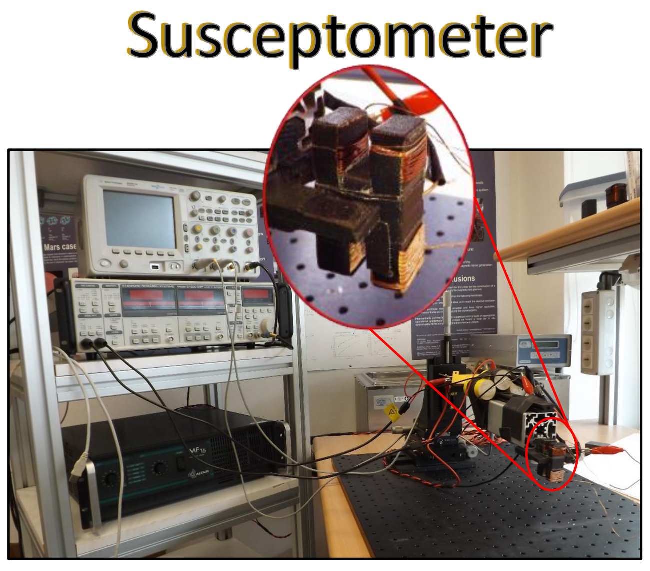
Magnetometer



Gradiometer



Susceptometer

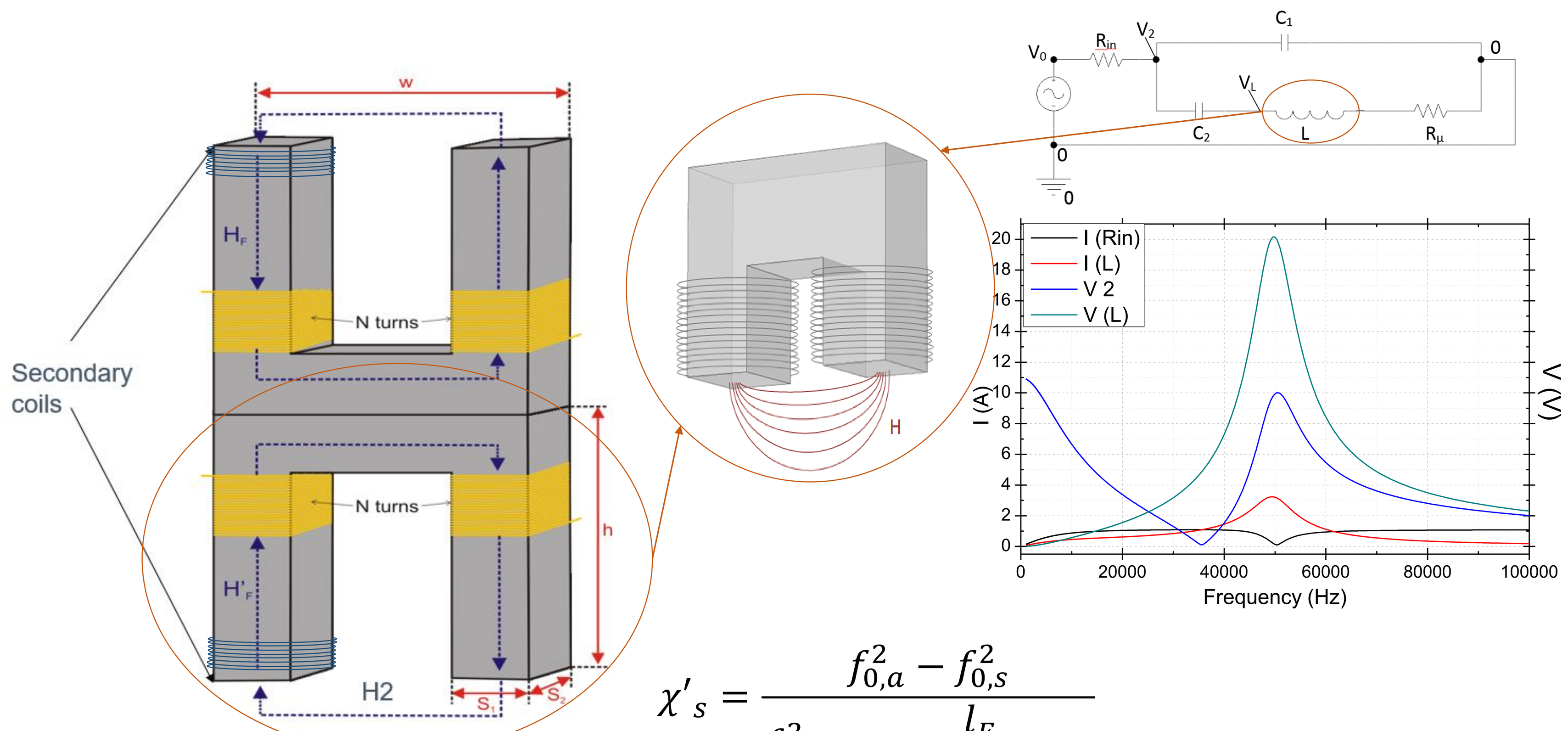


Magnetic susceptibility:

$$\chi = \frac{dM}{dH} \rightarrow \chi = \chi' + i\chi'' \qquad \begin{cases} \chi' = \frac{|M|}{|H|} \\ \chi'' \rightarrow \text{Dissipative processes} \end{cases}$$

The characterization of magnetic signature and magnetic properties of natural samples is a useful tool not only to understand the composition and structure of the rock but also its geological history, which can have important implication on paleomagnetic information and the magnetic fields involved in the early history of the planets [1, 2]. For a complete magnetic characterization of natural samples it is important to measure the magnetic field and the magnetic dipolar structure by means of magnetometers, and complementary other magnetic properties, such as the field gradient and the magnetic susceptibility.

Newton Magnetic Susceptometer Prototypes 1 and 2



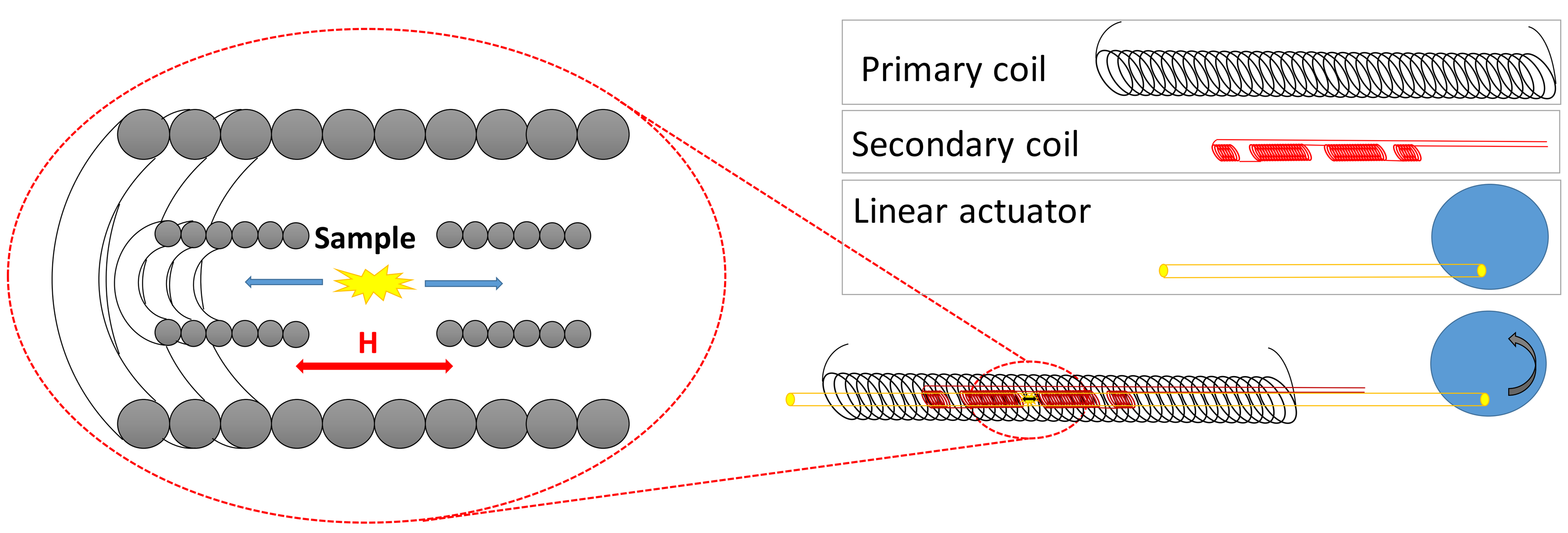
$$\chi'_s = \frac{f_{0,a}^2 - f_{0,s}^2}{f_{0,s}^2 - \frac{l_F}{2\pi^2 N^2 C S_F \mu_F}}$$

Within the frame of Newton project, the development of three different prototypes with different application scenarios is proposed, from a large laboratory device for a complete paleomagnetic characterization (**Fixed Susceptometer - FS)** to a portable device for in-situ measurement of terrestrial and space applications (**Portable Susceptometer - PS**).

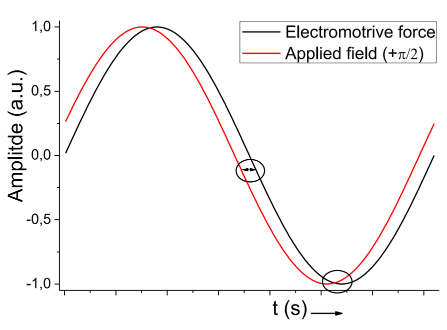
Prototypes 1 and 2 are based on a H-shaped ferrite core. They are devoted to in-situ measurement of magnetic susceptibility. Real and imaginary components can be determined by means of the measurement of the changes in the resonance frequency of the electric circuit coupled to the ferrite core and the electromotive force induced in the secondary coils.

Newton Magnetic Susceptometer Prototype 3

A. Small samples



EMF = 0 in equilibrium; EMF ≠0 due to the magnetization of the sample



Real part

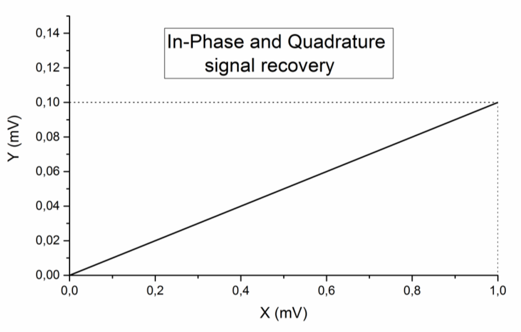
$$\varepsilon_x = \frac{d\phi}{dt} = \omega NSB_{sample}$$

$$B_{sample} = H \cdot Vol \cdot \mu_{sample}$$

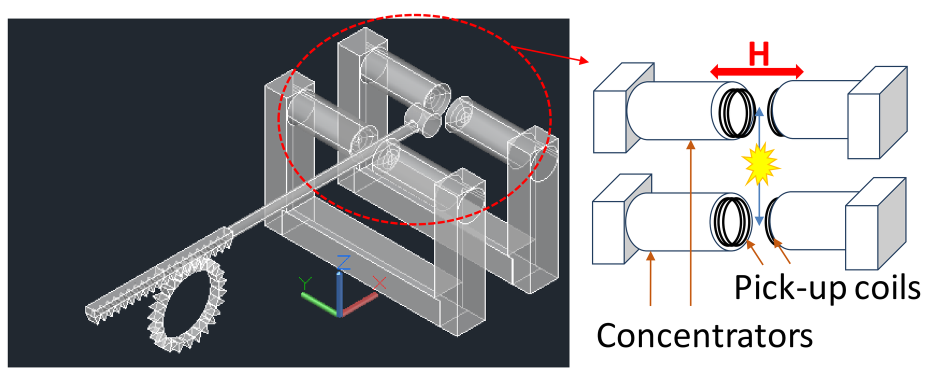
$$\mu' = \alpha\frac{\varepsilon_x}{V} \rightarrow \mu' = \alpha\frac{\varepsilon_x}{mass}$$

Imaginary part

$$\mu'' = \beta\frac{\varepsilon_y}{mass}$$



B. For larger samples



Susceptometer based on VSM principle. The sample moves linearly between a set of magnetic concentrators by means of a linear actuator. A high AC field magnetizes the sample while the pick-up coils collect the state of the magnetization of the sample.

Prototype 3 A and B are designed to form part of the laboratory instrumentation needed for a complete magnetic characterization. Prototype 3 A have been developed and calibrated as part of the work done in the calibration of prototype 2, based on our previous experience on a similar devices developed to measure hyperthermia on magnetic nanoparticles [3].

Calibration and Results

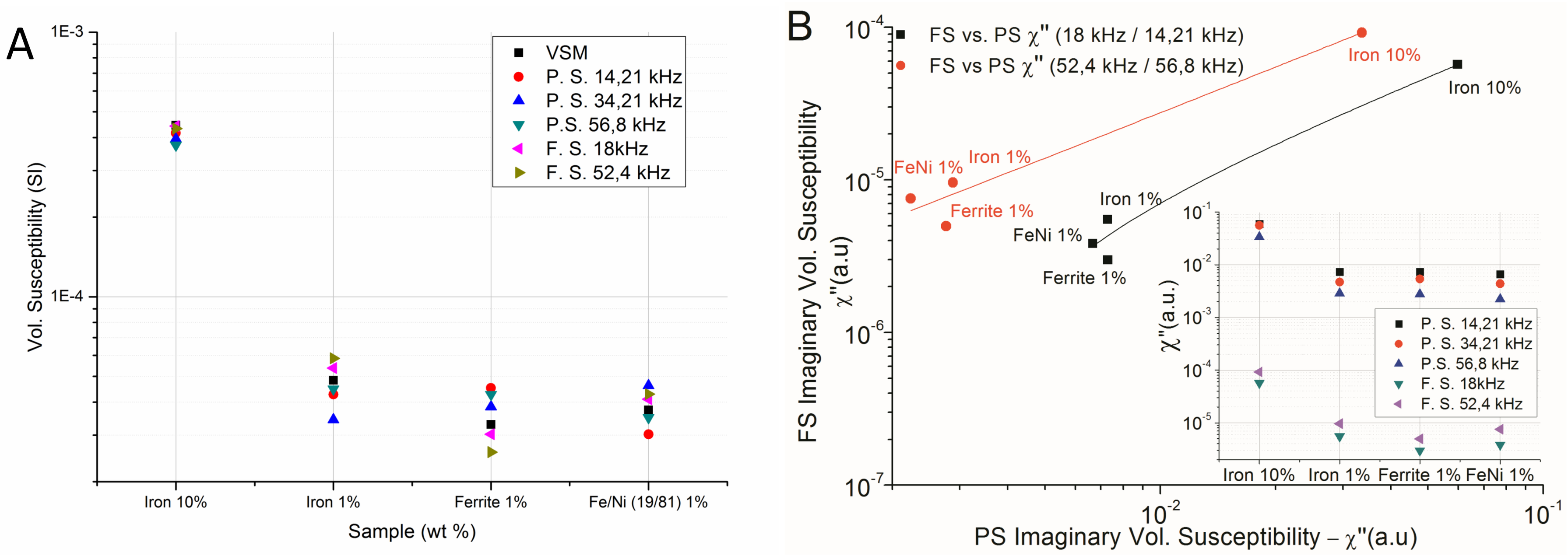


FIG. 1. A: Calibration of χ' vs. the reference samples. B: Linear regression of the results for FS vs PS for the imaginary susceptibility in arbitrary units. Inset: Calibration of χ'' vs. the reference samples in the PS and the FS.

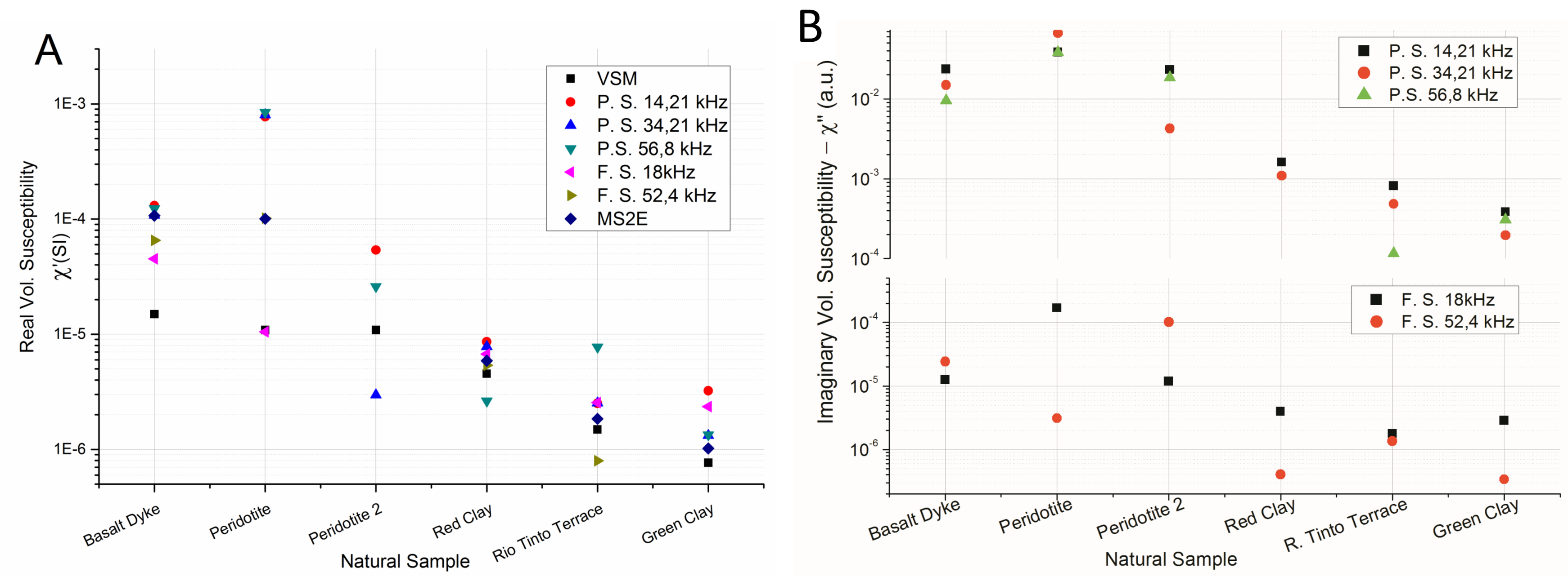


FIG. 2. A: Measurement of χ' of natural samples. There are two results representations for the peridotite, given that this sample presents a intrusion of high susceptibility material. B: Measurement of χ'' of natural samples.

Results show good resolution, repeatability and very high stability. Regarding the real part of the susceptibility, values of VSM and the PS are in very good correlation for the calibration samples as it is shown in Fig. 1 A.

In comparison, the results of the measurement of natural samples show a higher dispersion of values with the two devices: PS and FS. This is attributed to the heterogeneity of natural samples, which shows measurable deviations in susceptibility when sweeping their areas. These inhomogeneities are specially remarkable in the case of the peridotite.

The low contrast observed in the imaginary part in all samples, with content of magnetic material lower than the 10% in the calibration samples, is directly related to the low magnitude of μ'' in these samples, and the low expected imaginary component in the natural samples.

References:
[1] Díaz Michelena, M., Kilian, R.. Phys Earth Space Env 248 (2015) 35–54).
[2] Clark, A., “Seeing Beneath the Soil”, Bats-ford, London (1990).
[3] Cobos, P., Maicas, M., Sanz, M., Aroca, C.. IEEE T Magn. Vol. 47, 10 (2011).

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