Project funded by H2020,
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(Grant Agreement No 801221)

The NEWTON-g "gravity imager": a new window into processes involving subsurface fluids

EGU General Assembly 2020
G4.4 - New tools for terrain gravimetry

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The strength of gravimetry

The transport and storage of **fluids in the subsurface** (water, hydrocarbons, magma…) is critically important for both **resource management and risk reduction**.

Surface deformation provides a method for investigating volumetric changes linked to subsurface fluid transport/storage, but it cannot (i) detect variations that do not produce volume changes, or (ii) supply information on the density, and thus on the nature, of the subsurface fluid.

In contrast, **gravimetry** can identify subsurface mass changes and can thus detect variations in the physical state or migration of subsurface fluids over time.

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Commercially available gravimeters

Relative instruments

Spring gravimeters

Superconducting gravimeter

Absolute instruments

«Free fall» gravimeters

Gravimeters measure the vertical component of the gravity acceleration. **Relative gravimeters** only measure gravity differences over space or time. Conversely, using **absolute gravimeters**, it is possible to measure the actual value of the gravitational acceleration at the observation point.

Commercially available gravimeters

Comparison table

Manufacturer	Model	Tipe	Abs/Rel	Cont/Discr meas	Resolution μGal	Precision μGal	Drift μGal/mo	Weight kg	Occup. area m^2	Power req W
Scintrex	CG-6	Spring (quartz)	Relative	Discrete	0.1	~5	<600	5	< 1	5.2
Micro g-LaCoste	gPhoneX	Spring (metal)	Relative	Continuous	0.1	1	<500	58	> 1	100-330
ZLS	Burris	Spring (metal)	Relative	Contin./Discrete	1	10	300	6	< 1	~ 5
GWR	iGrav	Superconducting	Relative	Continuous	< 0.001	0.05	< 1	> 100	2 - 3	1400
Micro g-LaCoste	FG5-X	Falling Corner cube	Absolute	Discrete	1	1 - 2	n/a	320	3	500
Micro g-LaCoste	A-10	Falling Corner cube	Absolute	Discrete	1	10	n/a	105	> 1	200 - 300

100-250 k€ (Scintrex CG-6, gPhoneX, Burris, iGrav)

~500 k€ (FG5-X, A-10)

None of the currently available gravimeters is well-suited for use in harsh conditions (e.g., the active zone of a tall volcano).

Furthermore, due to the **high cost** of these instruments (if compared with other geophysical equipment), the installation of an extended array cannot be afforded by research and monitoring institutions

NEWTON-g

Project ID: 801221
Funded under: H2020-EU.1.2.1. - FET Open
Topic: FETOPEN-01-2016-2017 - FET-Open research and innovation actions

New tools for terrain gravimetry

From 2018-06-01 **to** 2022-05-31

Project facts

Start date: **1 June 2018**	Number of partners: **6**
Project duration: **48 months**	Project coordinator **INGV**

Main objective:

NEWTON-g aims at overcoming the instrumental limits of terrain gravimetry, through the development of a *gravity imager* including MEMS pixels, anchored to a reference absolute gravimeter, the latter based on quantum technology. Once developed, this system for dense gravity measurements will be field-tested at Mt. Etna volcano.

Consortium of NEWTON-g

Coordinator

Istituto Nazionale di Geofisica e Vulcanologia	Italy

Participants

MUQUANS	France
University of Glasgow	United Kingdom
Koninklijk Nederlands Meteorologisch Instituut	Netherlands
Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum	Germany
Université de Genève	Switzerland

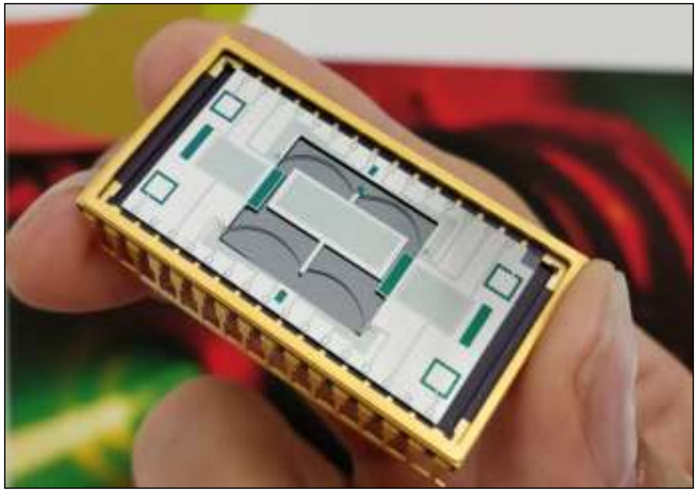
Project objectives

- To overcome the current **limits of terrain gravimetry**, that are imposed by the **high cost** and by the **characteristics** of currently available gravimeters
- To design and produce a new "**gravity imager**", including an **absolute quantum gravimeter** and an array of low-cost gravimeters based on **MEMS** technology
- To **field-test** the newly-developed "gravity imager" at **Mt. Etna volcano**, where a 30-year history of gravity measurements will provide context for NEWTON-g deployments
- To deploy strategies for **incorporating the data** produced by the new measurament system into **early warning** systems, **hazard reporting** and **crisis management** plans
- To shift the **center of production** of gravimeters from North America to **Europe**

Project objectives

NEWTON-g aims at designing and producing a new "**gravity imager**", including an absolute quantum gravimeter and an array of low-cost gravimeters based on MEMS technology

MEMS gravimeter



Possibility to deploy (for the first time!) a dense array of continuously running gravimeters.

High spatio-temporal resolution

Absolute quantum gravimeter

Possibility to have an absolute reference that can be used for continuous and discrete measures.

Moveable absolute reference

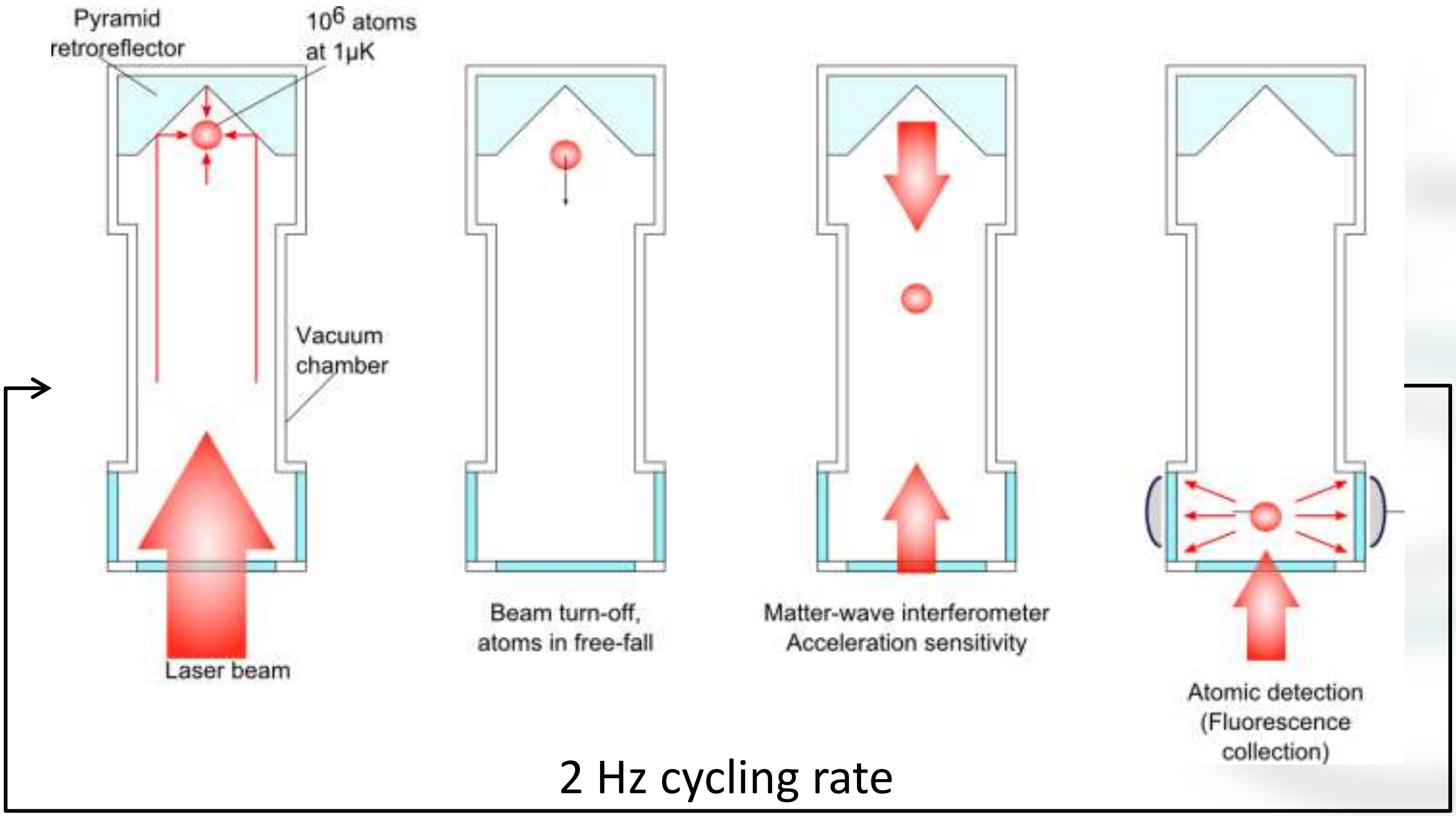
AQG: Absolute Quantum Gravimeter

Control Unit :
. Lasers
. Drive electronics
. Power supply
. On-board computer

Sensor head :
. Dropping chamber
. Tilt-meters
. Accelerometer
. Pressure Gauge
. GPS receiver

Ménoret et al., « *Gravity measurements below 10−9 g with a transportable absolute quantum gravimeter* » Nature Sci. Rep. 8, 12300 (2018)

AQG: a free fall gravimeter with "on-demand" test mass

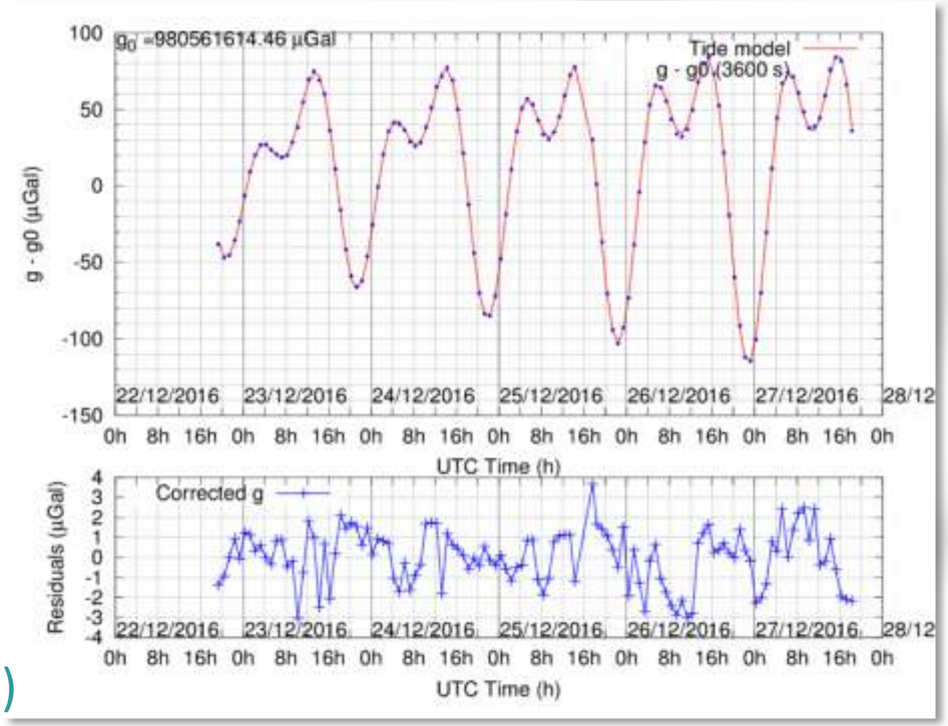


No moving parts:
once a set of atoms has fallen,
a new test mass is built up with new atoms for the next drop, etc…

AQG: short-term sensitivity of AQG#A01
Mobile and precise absolute gravimeter

- High performance absolute gravity measurements:
  - 5 µGal in 1'30
  - 2 µGal in 10'
  - 1 µGal in 40' (quiet site)
- Strong robustness w.r.t ground vibrations even in noisy environment

AQG data recorded in urban environment, 2nd floor of a building



σ_g = 1 µGal (1 hour averaging time)

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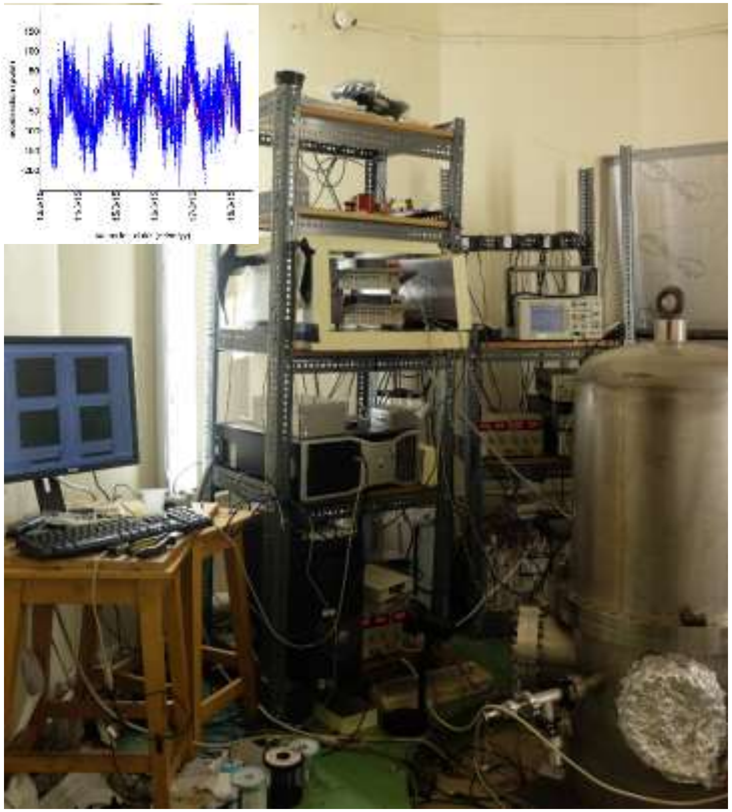
MEMS gravimeter: development of a field unit

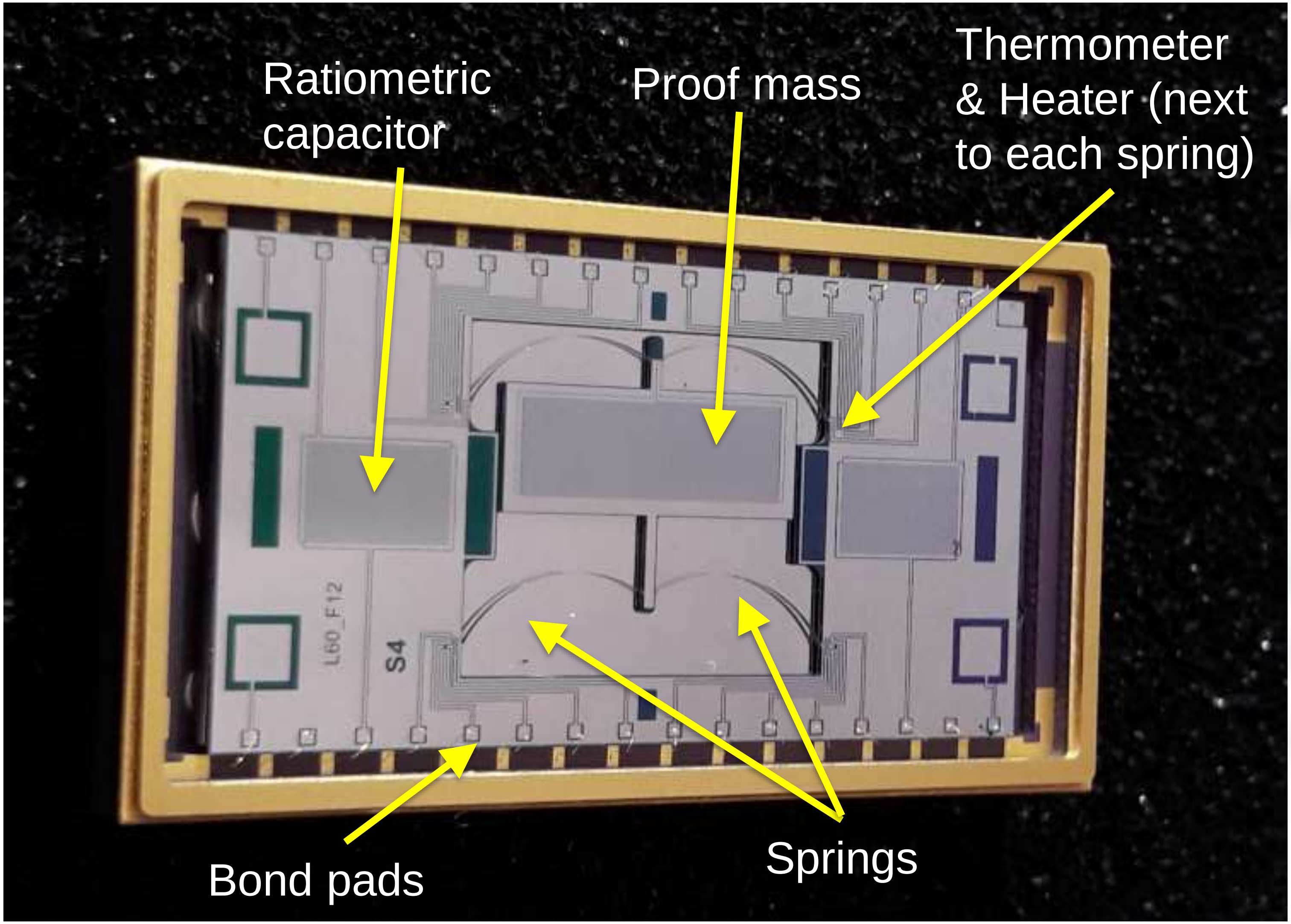


2015: lab based system with mains power, rack mount electronics

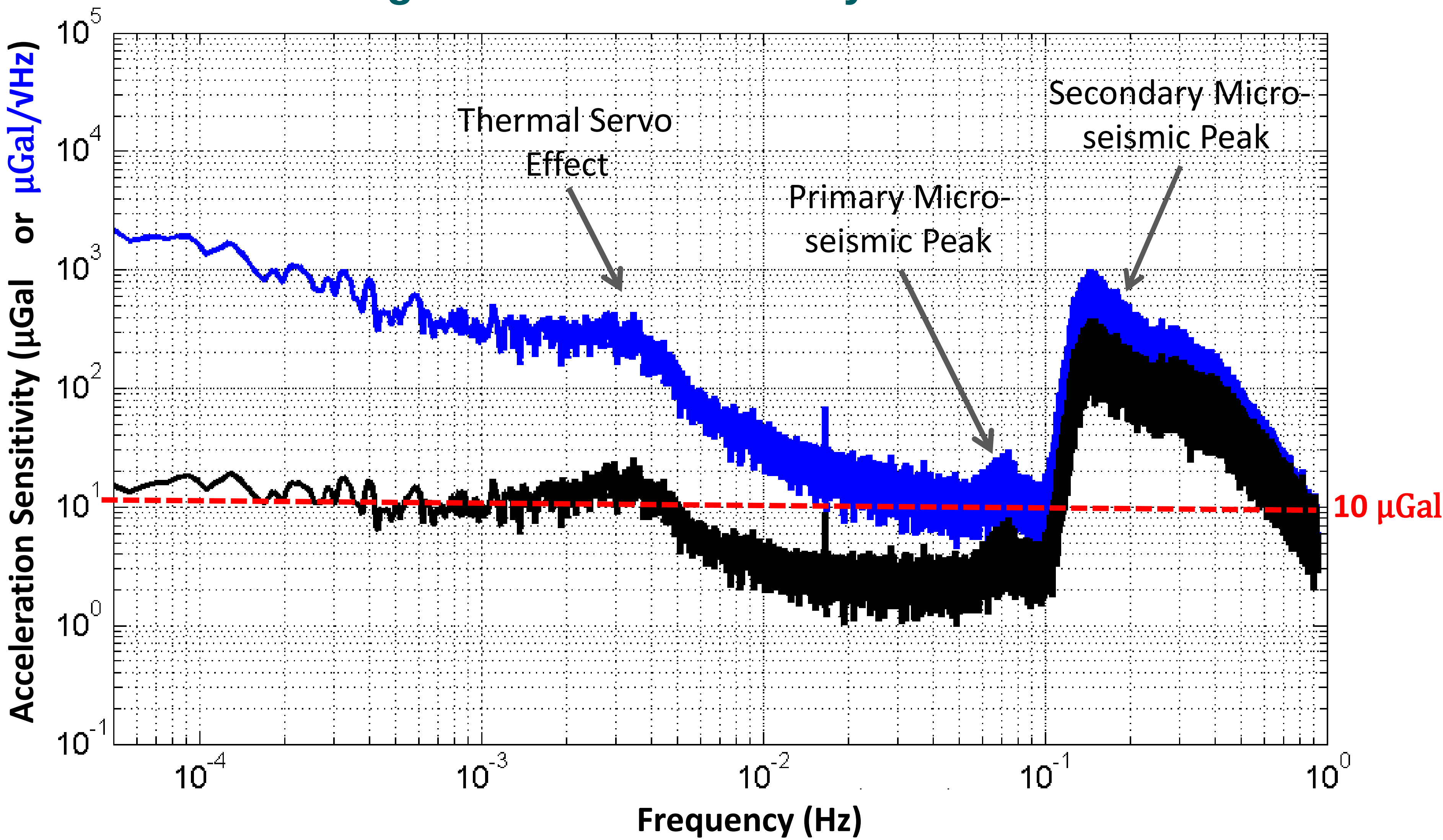
2016: shoebox sized field demonstrator, battery power

2018/19: packaged device with FPGA readout

MEMS gravimeter: the NEWTON-g device

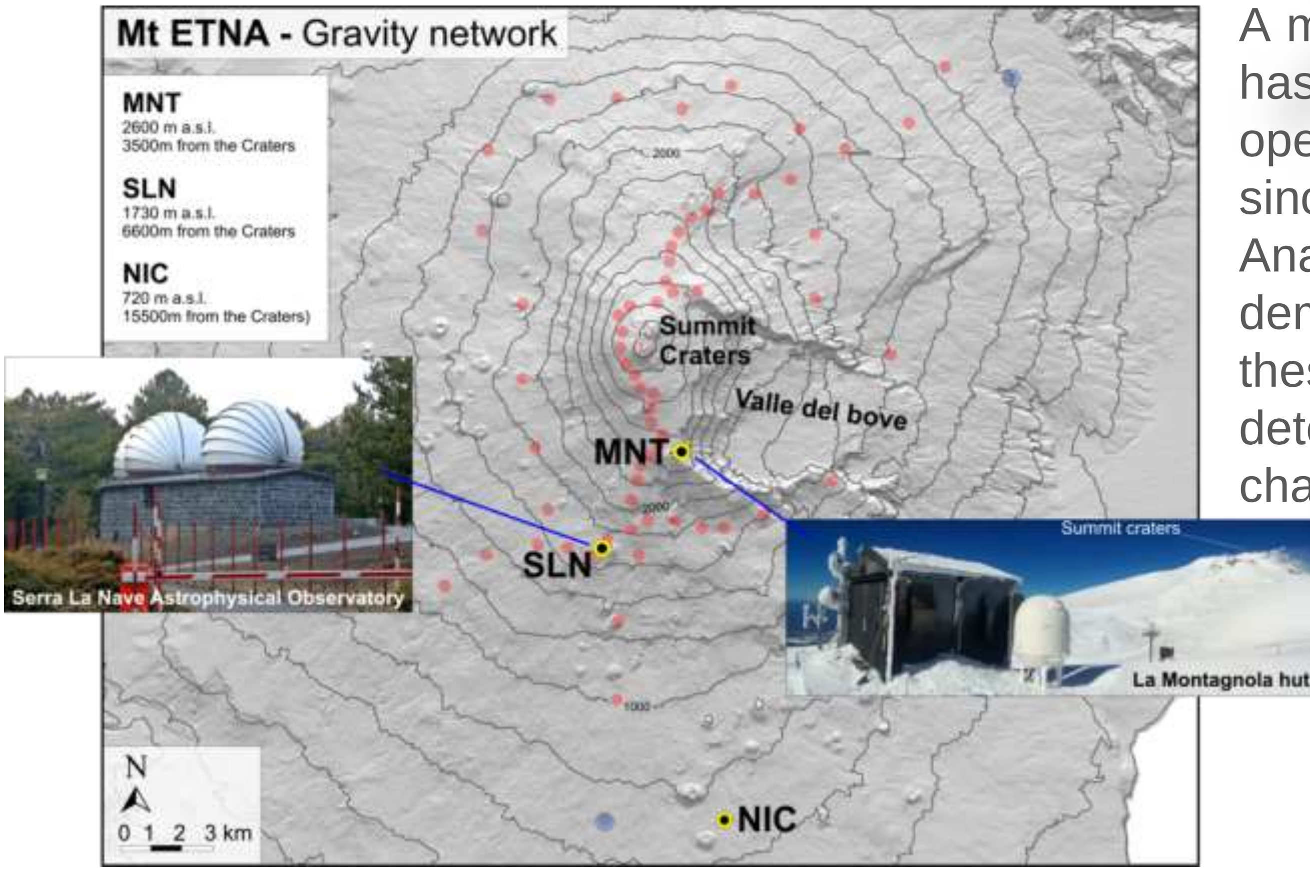


MEMS gravimeter: Sensitivity Measurement



Field-test of the gravity imager

During the last two years of NEWTON-g the newly developed "**gravity imager**", will be **field-tested at Mt. Etna**, where a 30-year history of gravity measurements will provide context for the deployment



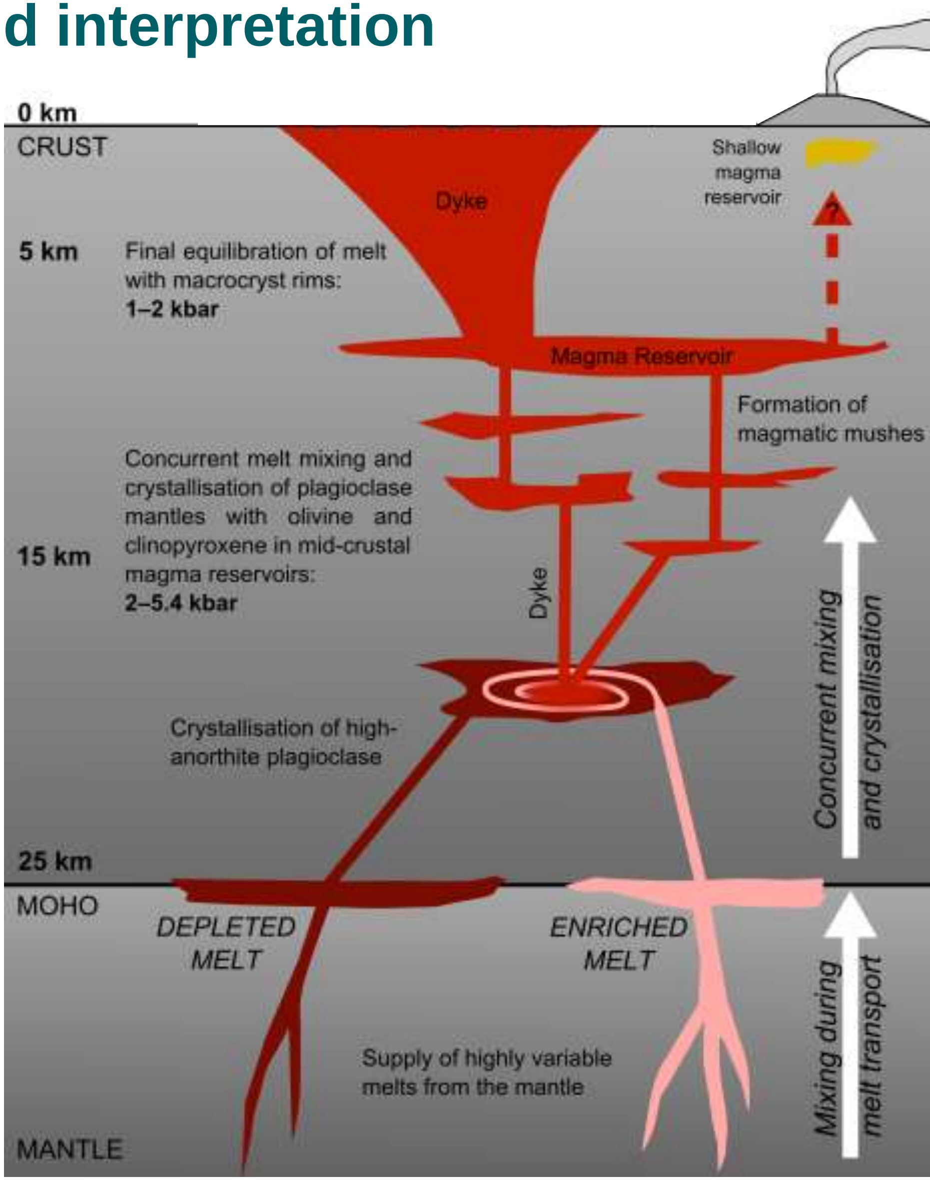
A mini-array of **three SGs** has been in continuous operation at Mount Etna since the summer of 2016. Analyses of these data demonstrate the ability of these instruments to detect even small gravity changes due to volcanic processes that occur over a **wide range of time-scales** (minutes to months).

Carbone et al., 2019, JGR, 123

Data modelling and interpretation

Forward **modelling** of relevant processes will **inform the interpretation** of the data produced by the new measuring system.

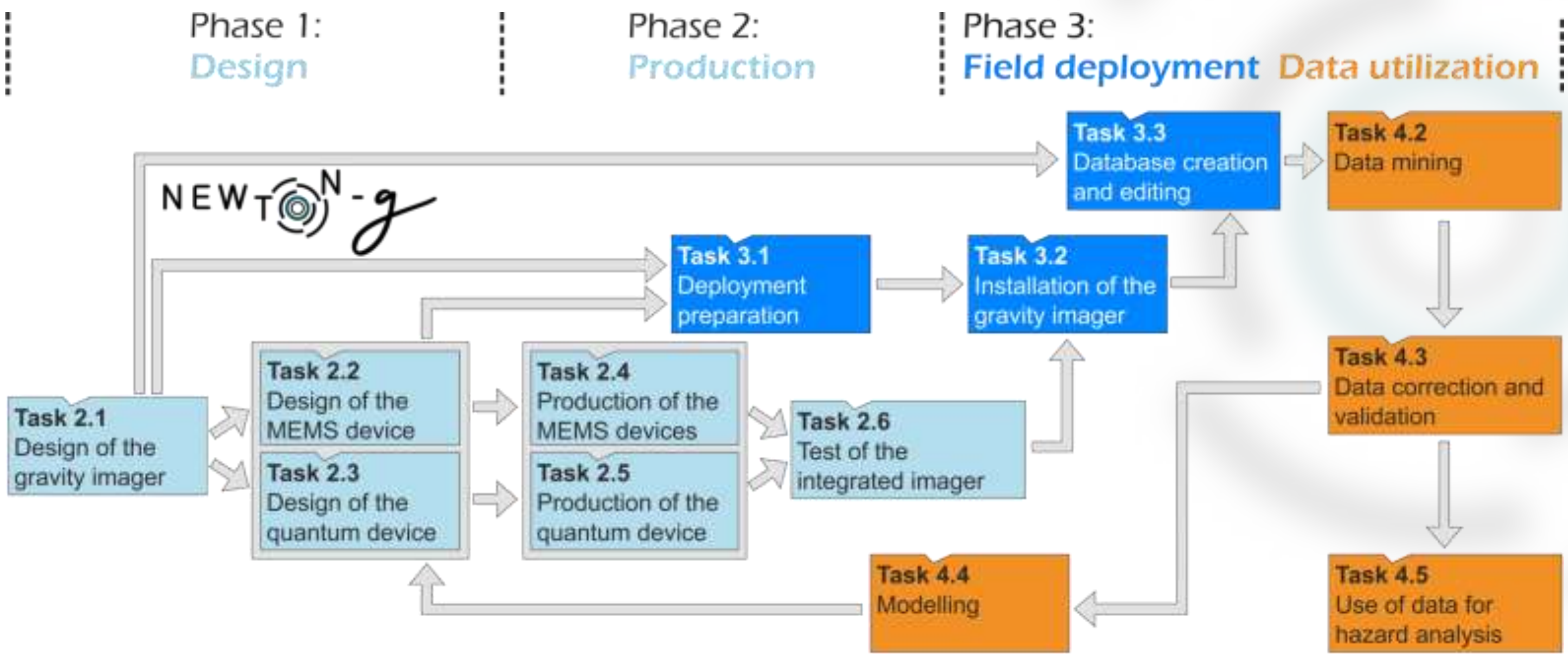
A comprehensive study will be carried out to understand how the new information can be best exploited for **volcanic hazard monitoring and assessment**.



Overview of NEWTON-g

The implementation of NEWTON-g involves three main phases:

- phase 1: **DESIGN** (year 1)
- phase 2: **PRODUCTION** (year 2)
- phase 3: **FIELD DEPLOYMENT AND DATA UTILIZATION** (year 3 and 4)



Pert chart of NEWTON-g

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For more info on NEWTON-g, please visit

our website at: www.newton-g.eu

and

our youtube channel: youtube.com/channel/UCxit8apmLkAN7psH0AoI8FA