



GINGER: prospettive e collaborazioni (in atto e future)

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Dipartimento di Fisica - Università di Pisa

Workshop sulla Gravitazione Sperimentale:
Misure laser, fisica fondamentale e applicazioni in INFN-CSN2
12-13 Novembre 2020

Esperimento G-GranSasso

- INFN - Sez. di Pisa & Dipartimento di Fisica - Univ. di Pisa
 - coordinamento, hardware sperimentale, analisi dati
 - Il Dip. di Fisica ha dato un contributo sostanziale scientifico e finanziario per sostenere il technical design, le strutture e le apparecchiature
- INFN - Sez. di Napoli & Dipartimento di Fisica - Univ. di Napoli
 - teorie relativistiche, logistica, ottica
 - Il Dip. di fisica sta sostenendo al 50% un PhD per il nostro esperimento
- INFN - Lab. Nazionale di Legnaro
 - teoria e analisi dati

INFN - Pisa

- [Angela Di Virgilio](#)
- Andreino Simonelli
- Umberto Giacomelli
- Filippo Bosi
- Andrea Basti
- Giuseppe Terreni

Università di Pisa

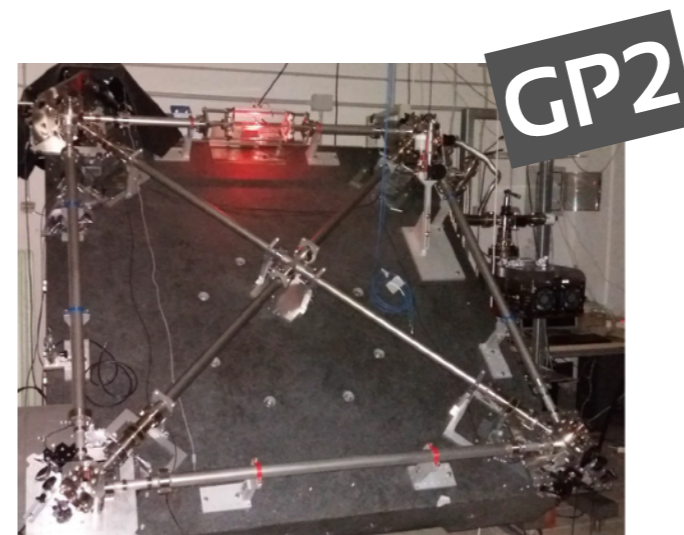
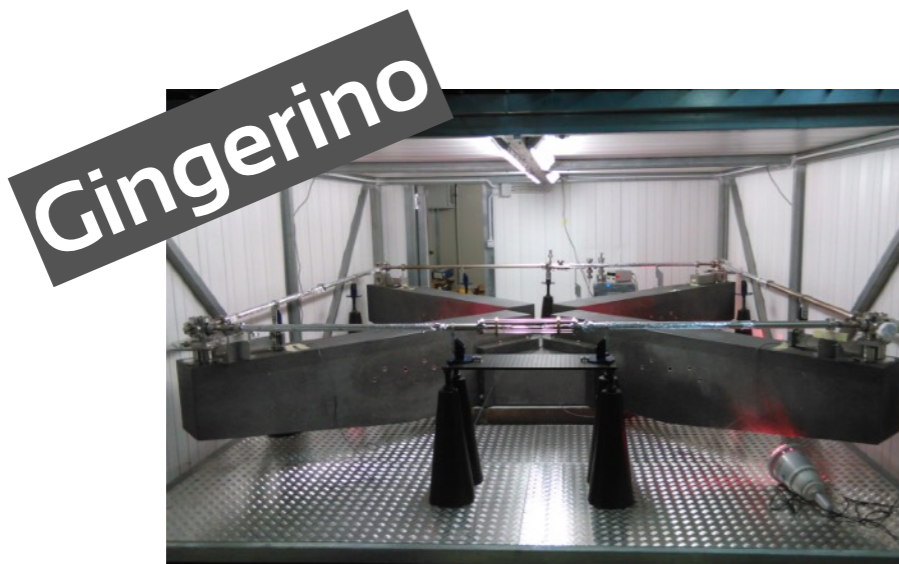
- Nicolò Beverini
- Giorgio Carelli
- Enrico Maccioni
- Paolo Marsili
- Francesco Fuso
- Donatella Ciampini

INFN & University - Napoli

- Alberto Porzio
- Salvatore Capozziello
- Carlo Altucci
- Raffaele Velotta
- Pino Passeggio
- Francesco Bajardi

Lab. INFN di Legnaro

- Antonello Ortolan



Collaborazione con INGV

- Attività scientifica e applicativa:

- ✓ Dislocazione di strumentazione sismometrica presso Gingerino

- ✓ Interpretazione dati per studi di sismologia e geofisica

Vari articoli pubblicati in collaborazione

- ✓ Inserimento a partire da Febbraio 2020 dei dati di rotazione su Orpheus-EIDA [IV.GIGS.HJZ](#)

ORFEUS is the non-profit foundation to coordinate and promote digital, broadband seismology in the European-Mediterranean area.

EIDA is the **European Integrated Data Archive** infrastructure within ORFEUS to provide access to seismic waveform data in European archives.

- *Gaetano de Luca*
- *Aladino Govoni*
- *Roberto Devoti*
- *Giuseppe di Stefano*
- *Andrea Morelli*
- *Gilberto Saccorotti*

- Progetti preparati e presentati insieme

- ✓ FISR 2019

*PRECURSORI SISMICI E GIROSCOPI DI SAGNAC:
SUPERARE LE ATTUALI FRONTIERE DELLA SISMOLOGIA*

(selezione non ancora terminata)

- ✓ Altri progetti applicativi:

- RLG trasportabile,
- dati Open Access,
- edge computing per produrre in real time i dati rotazionali

Collaborazione con INGV

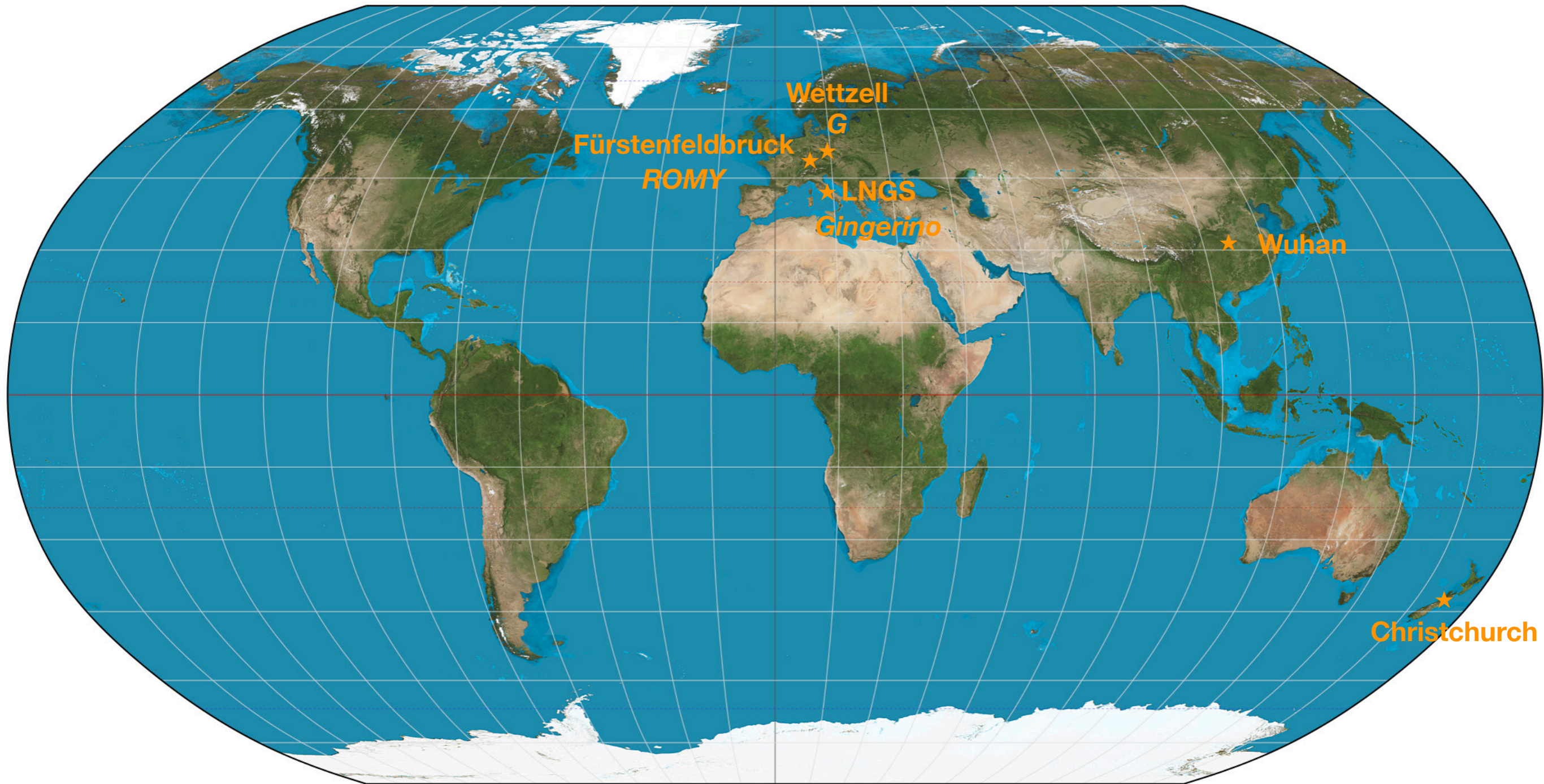
Geodetic-Geophysical topics in INFN-INGV cooperation

1. Study of high frequency variations of Earth Rotation Parameters
 - ✓ *Tidal variations of polar motion*
 - ✓ *High frequency UT1 variations (Oceans & Atmosphere tides)*
2. Study of high frequency Earth's axis nutation
 - ✓ *Forced nutations*
 - ✓ *Free core nutation*
3. Monitoring high frequency local tilt and Solid Earth Tides
4. Rotational seismology

Possibili contributi al progetto GINGER:

- *Gestione della strumentazione sismologica*
- *Acquisizione dati*
- *Elettronica di controllo*
- *Gestione sensori ambientali*

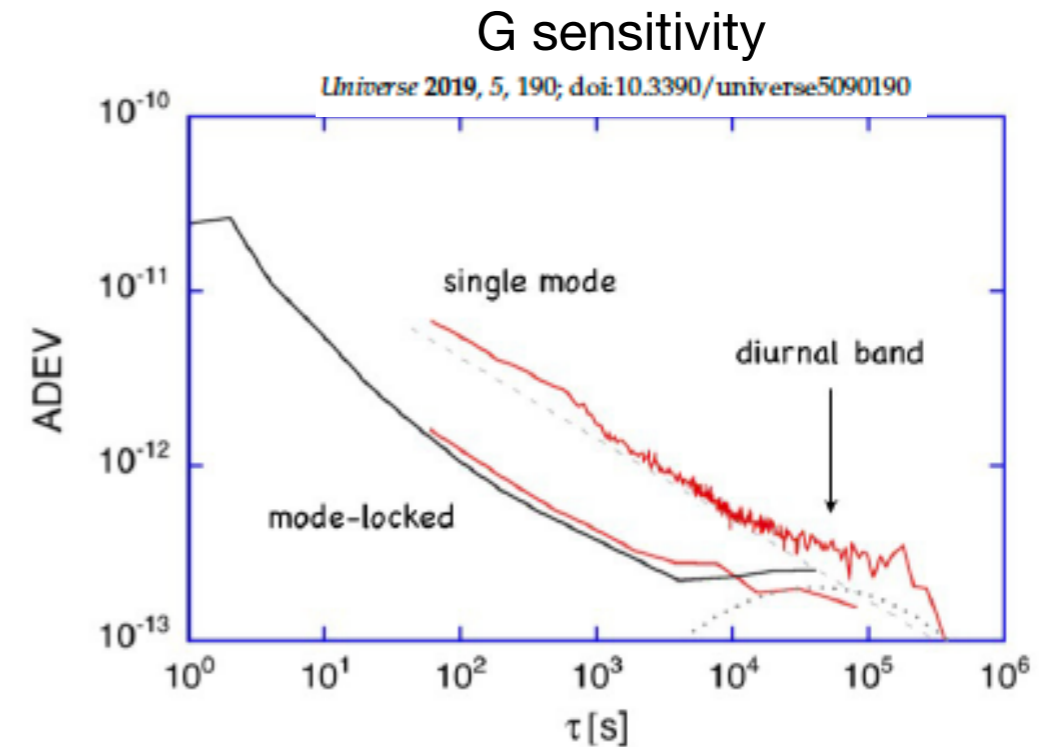
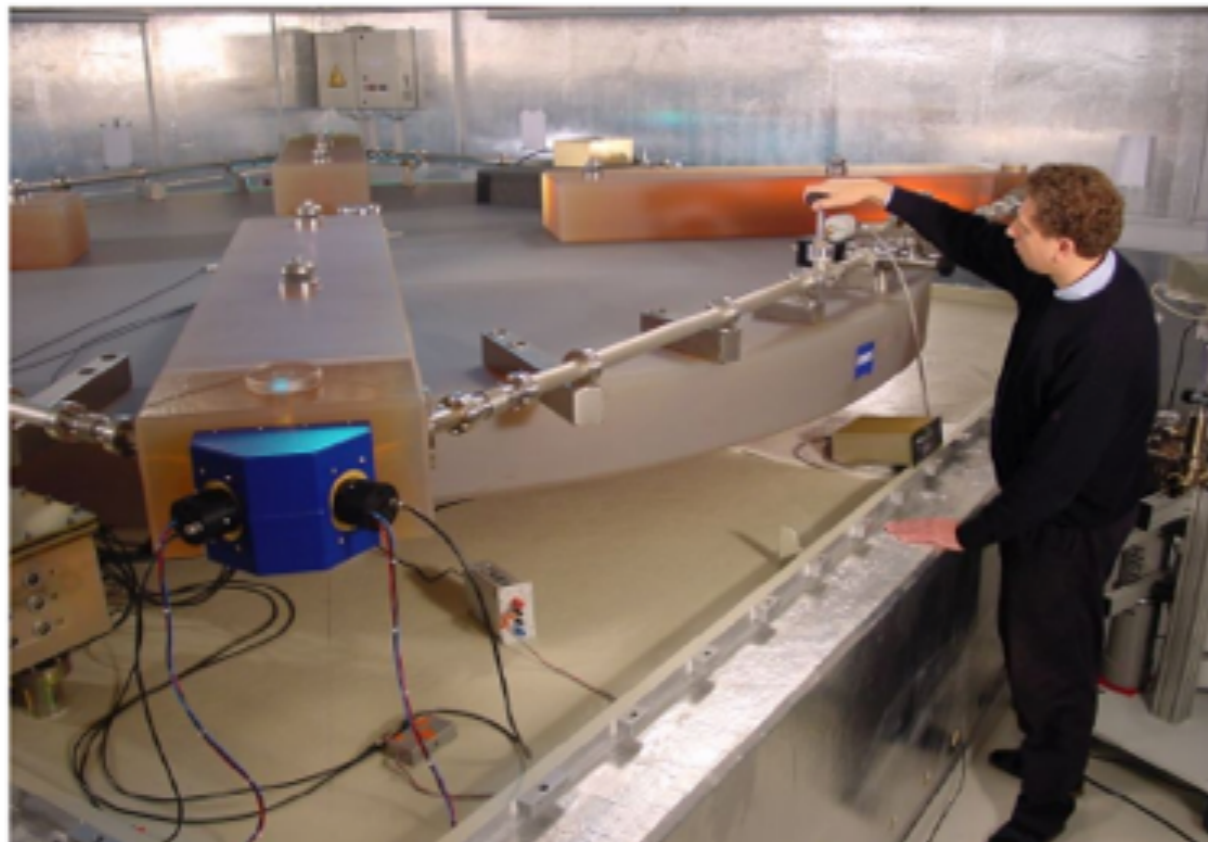
Large-frame optical gyroscopes in the world



G (*Großer Ring*)

Geodätisches Observatorium Wettzell

- Giroscopio laser con lato di 4 m su struttura portante monolitica in Zerodur
- Osservazione di segnali geofisici e geodetici
 - *Microsisma*
 - *Maree terrestri*
 - *Chandler and Annual Wobbles*
 - *Osservazione del polar motion*
- Raggiunge una stabilità di 0.4 prad/s ($3.5 \times 10^{-8} \Omega_{\oplus}$) su una banda di un giorno



G and VLBI (*Measuring the Length Of the Day*)

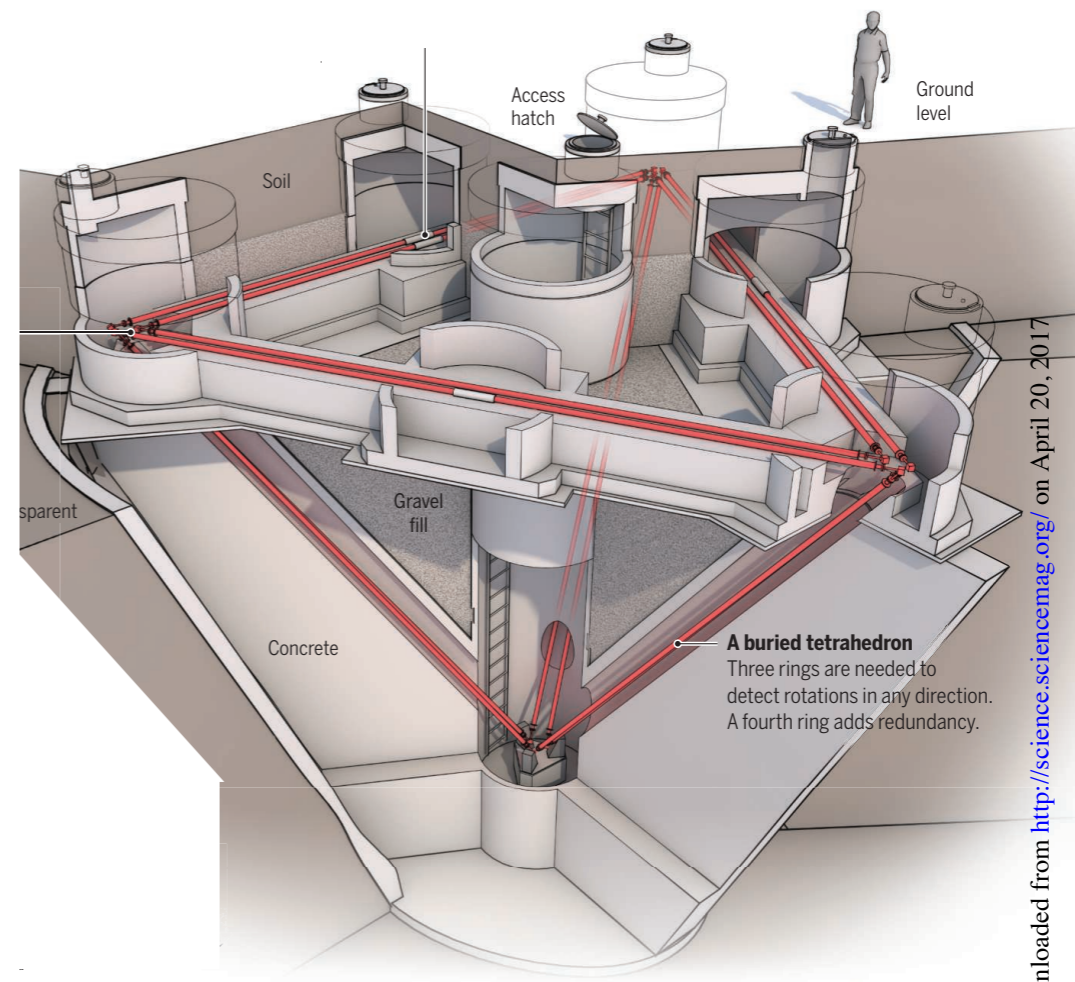
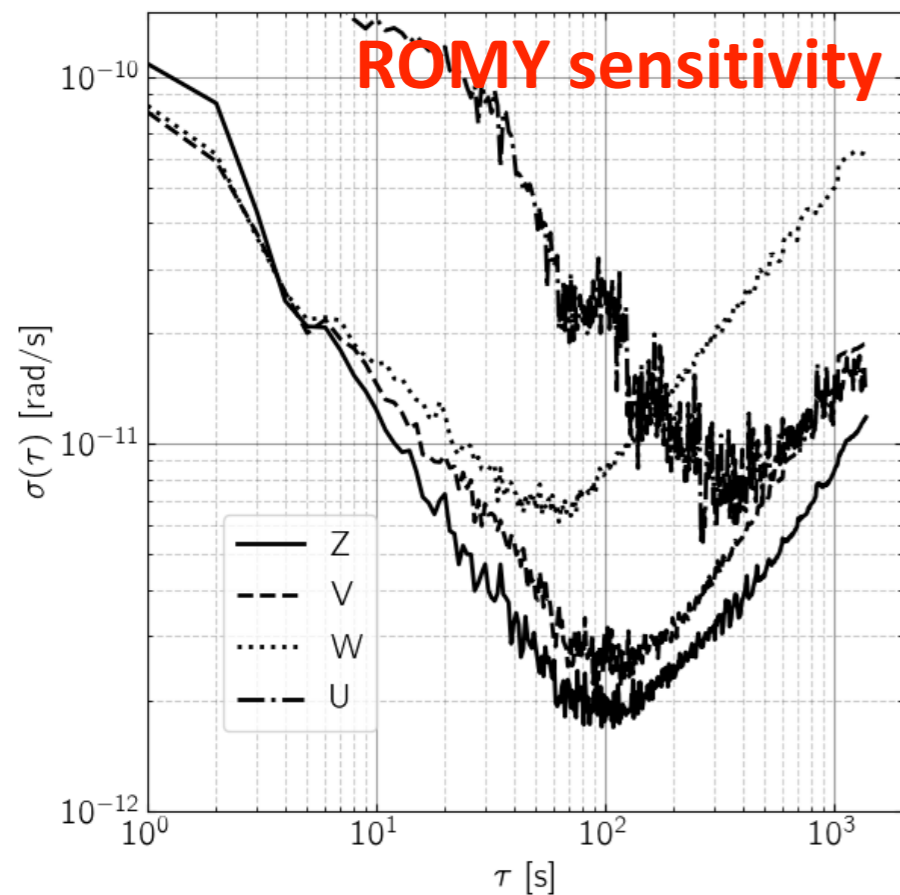
“We conclude that the potential of the ring laser to effectively complement the VLBI technique is there, albeit not very distinct at present. Naturally, the impact shown here is also a consequence of the design of the reduced VLBI networks. With weaker geometry and less stations the ring laser influence would be more visible, while it would be less pronounced or even vanish with more stations. The advantage of a combined evaluation will become obvious, as soon as the accuracy differences between both techniques are further decreased. The physical limits of ring lasers are not yet fully exploited. (.....) **The vision of an optimal sensor fusion incorporates a network of high resolution Sagnac interferometers** to bridge the gaps between successive VLBI sessions and to extrapolate the Earth rotation variations until the next session is correlated and analyzed. In this way the high temporal resolution and continuous observing mode of the ring laser and the accuracy and long term stability of VLBI can be merged to ideally exploit the strength of each system.”

from Böhm et al,
Adv. Geosci., 50, 9–15, 2019 **Earth rotation variations observed by VLBI and the Wettzell “G”ring laser during the CONT17 campaign**



3-dimensional rotational seismometer in Fürstenfeldbruck (Munich)

Underground array of 4 triangular large gyroscopes 12-meter of side in tetrahedral configuration



**Long term orientation stability:
 better than 0.5 arcsec (2.5 μ rad) over 47 days**

Gebauer et al., PHYSICAL REVIEW LETTERS 125, 033605 (2020)

HUST-1

Wuhan

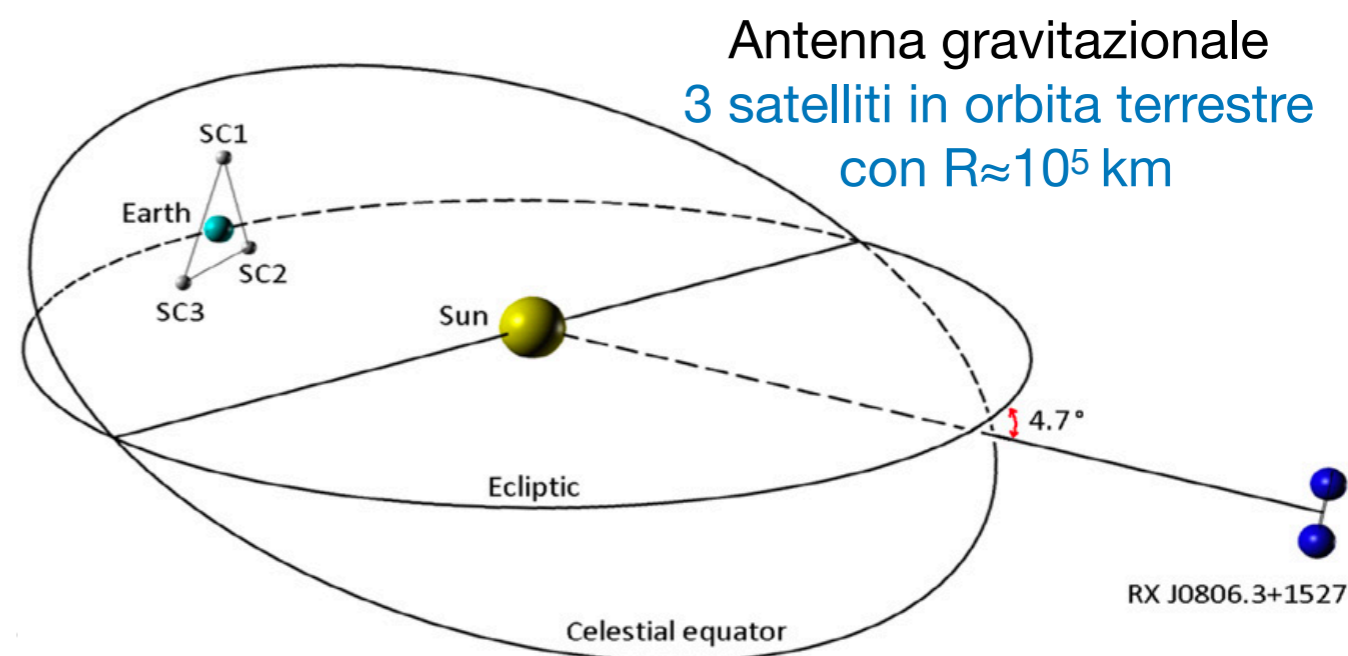
Fenglei Zhang et al.

Class. Quantum Grav. 37 (2020) 215008

“The main development goal of HUST-1 is the support of the space-borne gravitational waves detector (TianQin) by linking the celestial reference frame of the satellites to the terrestrial body fixed reference frame with high-time-resolution Earth rotation measurements”

- Giroscopio eterolitico passivo
- Cavità quadrata di lato 3 m con controllo attivo della geometria
- I due fasci contropropaganti sono agganciati a modi longitudinali della cavità ottica differenti
- Rotation sensitivity:
 - $1.6 \times 10^{-9} \text{ rad s}^{-1} \text{ Hz}^{-1/2}$ beyond 1 Hz
 - $1.7 \times 10^{-7} \text{ rad s}^{-1} \text{ Hz}^{-1/2}$ at 0.01 mHz

天琴计划



MEMORANDUM OF UNDERSTANDING

between

Istituto Nazionale di Fisica Nucleare (INFN), Italy

and

**the College of Science
University of Canterbury, New Zealand**

Jon-Paul Wells

and

the Technische Universität München (TUM), Germany

acting through the

Research Facility Satellite Geodesy (FESG)

*Ulrich Schreiber
Urs Hugentobler*

and

**the Department for Earth Sciences of the
Ludwig Maximilians Universität (LMU), Germany**

Heiner Igel

concerning

“the development of high sensitivity and accuracy ring lasers in underground laboratory with the long term purpose of a General Relativity test (GINGER, Gyroscope IN GEneral Relativity, an experiment to measure the gravito-magnetic effect of the Earth with an array of ring lasers) and the short term purpose of measuring the Length Of the Day (LOD)”

Memorandum Of Understanding

Article 2 – Fields of cooperation

It is agreed that the Parties intend to undertake collaborative activities that may be implemented through :

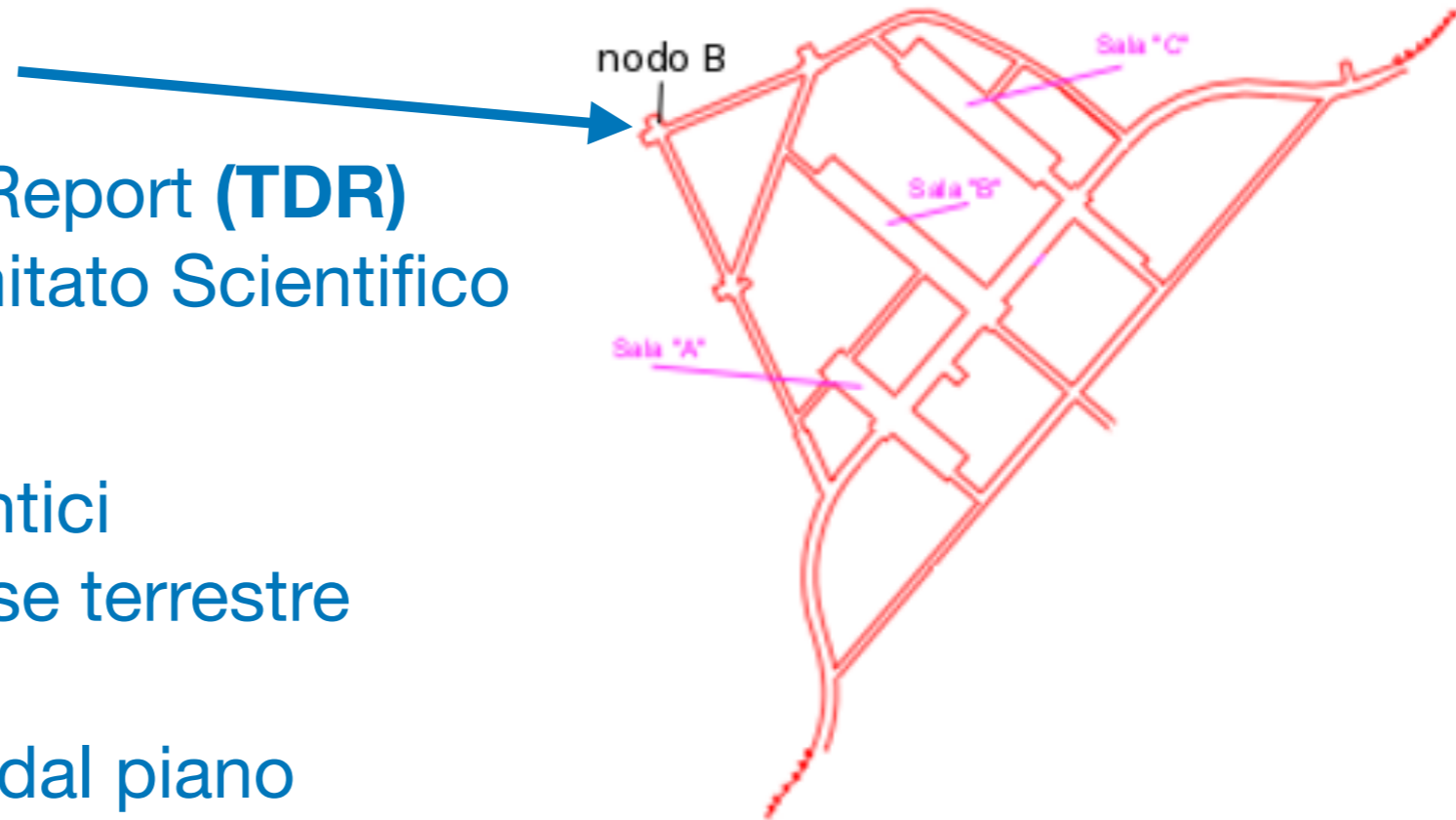
1. Joint meetings;
2. Exchange of scientific and/or technical personnel;
3. Development of joint research projects/activities;
4. Exchange of information and publications in the fields of interest to the Parties;
5. jointly work towards the establishment of a platform for cooperation in areas of mutual interest, which involve several disciplines as fundamental physics, geodesy and seismology.
6. Jointly operate in order to build a ring laser inside LNGS to measure the length of the Day (LOD GINGERino phase II).
7. Compare the results of the different ring lasers owned by the groups for geodetics and geophysics studies.

Contributo previsto da parte tedesca alla costruzione ed al funzionamento di GINGER:

- Contributo ingegneristico alla progettazione e alla costruzione di GINGER
- Modellizzazione dati geofisici e geodetici
- Calibrazione strumentale

GINGER Technical Design Report

- LNGS - Nodo B
- Technical Design Report (**TDR**) sottoposto al Comitato Scientifico del LNGS.
- Array di 3 ring identici
 - parallelo all'asse terrestre
 - orizzontale
 - orientato fuori dal piano meridiano
- L'apparato sperimentale è facilmente scalabile ed adattabile anche ad altri siti.
- Il TDR è stato elaborato per il nodo B del LNGS, ma è valido anche per altre locazioni entro i LNGS o anche in altri siti (per es. [Sos Enattos](#)).



Grazie

per l'attenzione