Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA

Project ***E.T. Start-up*** (F25F21002720001) D.M. 737/2021 - Linea d'intervento Iniziative di ricerca interdisciplinare su temi di rilievo trasversale per il PNR

E.T. Start-up

Andrea Sanna
Giuseppe Muscas
Pierluigi Bortignon
Elena Codazzo

ET Sardegna Kickoff meeting

24/06/2024

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E.T. Start-up: a “multidisciplinary” project

Financed by University of Cagliari (PNR DM 737/2021)

The project aims to collect specific competencies and skills from different fields and connect them to provide unconventional approach to solve the unique scientific challenges arising from to the extraordinary framework of the ET activities.
Timeframe 2024-2025

Principal investigator

Prof. Andrea Sanna
(Astrophysics)

Prof. Pierluigi Bortignon
(High-energy Physics)

Dr. Giuseppe Muscas
(Solid state Physics)

Post doc

Dr. Elena Codazzo

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WP1

Search algorithms for continuous GW from spinning neutron stars in binary systems.

WP2

Large data handling and new search algorithms (Machine Learning architecture).

WP3

Investigation of materials for GW mirror coatings.

Investigating robust and reliable data analysis methods for the detection of continuous gravitational waves that could be applicable to datasets collected with new-generation GW observers.

Interconnected development

Implementing large machine learning skills to build a Deep Neural Network (DNN) to extract NS signals using ET simulated data.

Exploring candidate materials for next-generation coatings: magneto-electric characterization and micromagnetic modeling.

Feeding new level of S/N performance

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Impact of coalescence signals on the search for continuous waves

Aim of the study: To quantify the influence of a spectrum of GW signals from coalescing binaries on the search for CWs in ET and Virgo O5.

- Simulate the *spectrum of coalescence signals*, focusing on the low-frequency range of 1-20 Hz.
- Construction of the *background* for the CW analysis accounting for CBC spectrum.
- Improve CW detection methods.

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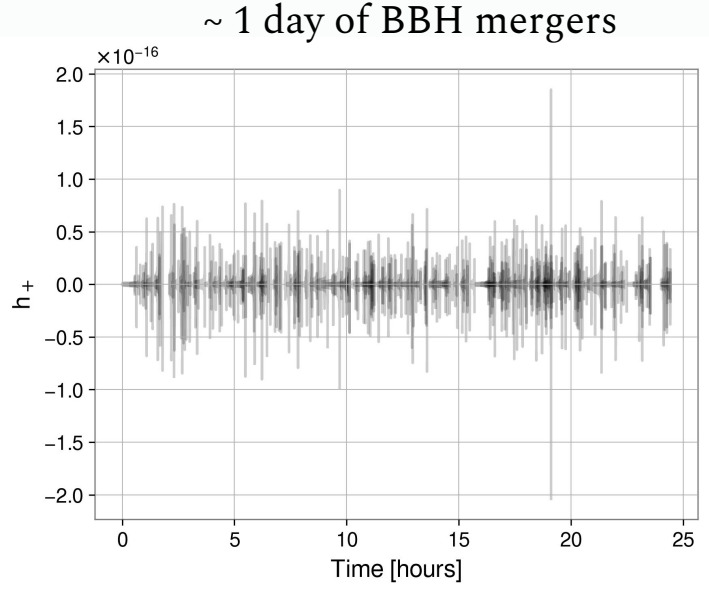
Spectrum of coalescence signals

- BBH ~10^5 /yr,
  BNS ~ $7 \cdot 10^5$ /yr
  projected into the detectors
- Simulation of detector noise
- Signals injection into the noise



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Activities in the collaborations

ET:

- OSB / div 7: Stellar collapse and spinning neutron stars.

Virgo:

- Continuous waves group.
- Rapid Response Team - Level 0.

Collaborators: M. Di Giovanni, P. Astone, C. Palomba, L. Mirasola

Hardware for data analysis and ML

- Scientific computing GPU server already present
  - Epyc 2 (7452). 64 core. 512 GB RAM. 8TB Nmve. 10TB SSD.
- A new powerful GPU for scientific computing and machine learning has been ordered (NVidia A100 40GB)

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WP3
Investigation of materials for GW mirror coatings

Framework

- Maximize reflectivity employing dielectric materials and multilayer coating (e.g., SiO_2 + doped-Ta_2O_5)
- Minimization of the thermal motion noise (critical region 30-300 Hz).

Scientific questions

- HfO_2-based coatings offer 100X sensitivity gain at ~10 Hz. Anomalous FM? Emerging FE?
- New coatings such as Nb_2O_5 or TiO_2 doped with Nd, Fe, and Co. Emerging magnetic order?
- Superparamagnetic behavior in nanostructured doped-Ta_2O_5 .

Aim

- Investigate the magnetic properties of the most promising coatings.
- Explore the role of the nanostructure and multilayered form.
- Magneto-electric characterization of prototypes and micromagnetic modeling.

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Amorphous HfO_2

Collaboration

Dr. Massimo GRANATA
Laboratoire des Matériaux Avancés - IP2I

Dr. Annalisa Paolone

Istituto dei Sistemi Complessi
Consiglio Nazionale delle Ricerche

Prof. Ernesto Placidi

Sapienza Università di Roma

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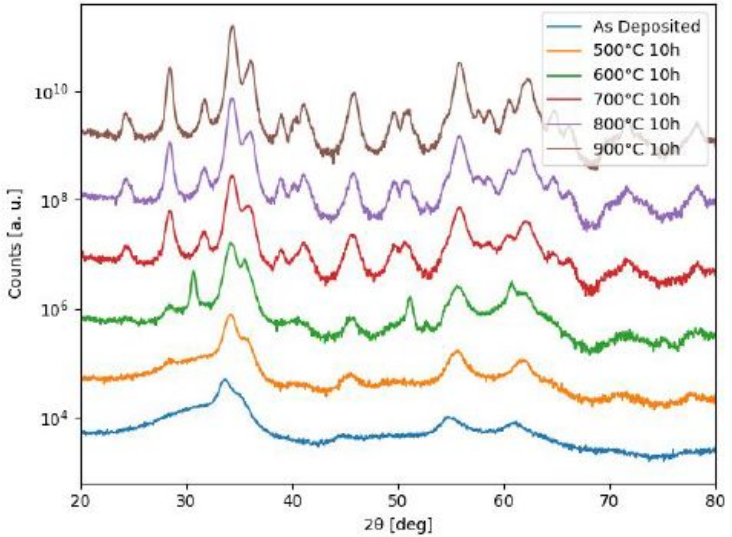
ET Einstein Telescope

Sample	Hf (At %)	O (At %)	Ta (At %)	Ar (At %)	Hf/(Hf+Ta) (%)	HfO2 (mol %)
As dep	27.3 ± 0.4	66 ± 2	2.7 ± 0.5	4.4 ± 0.3	91 ± 2	95 ± 2
900°C 10h	29.3 ± 0.4	66 ± 3	2.8 ± 0.4	2.0 ± 0.4	91 ± 1	95 ± 1

- Crystallization temperature: some peaks present already as dep.
- Phase: monoclinic HfO_2 (PDF 00-078-0049)



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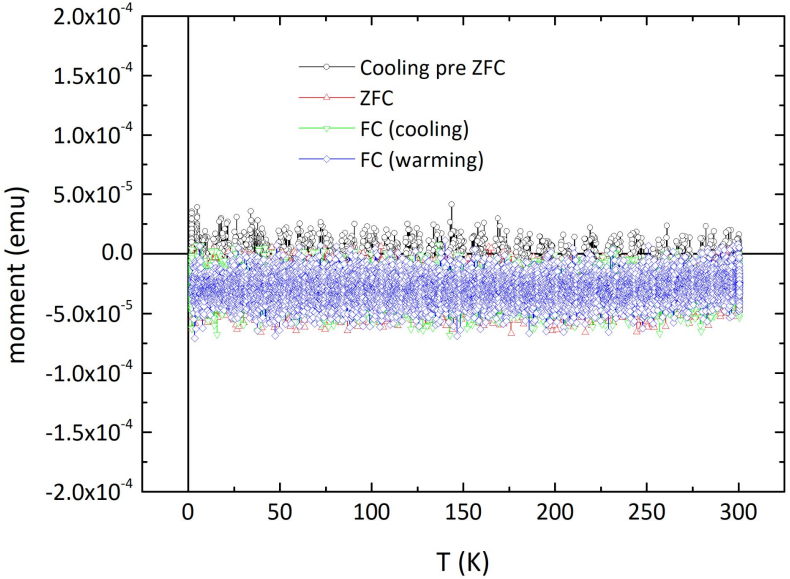
DC Magnetization vs Temperature curves



Temperature independent magnetic signal

Negative signal, compatible with a diamagnetic background, probably provided by the Si substrate.

No evidence of magnetic ordering in the temperature range (2 – 300 K).

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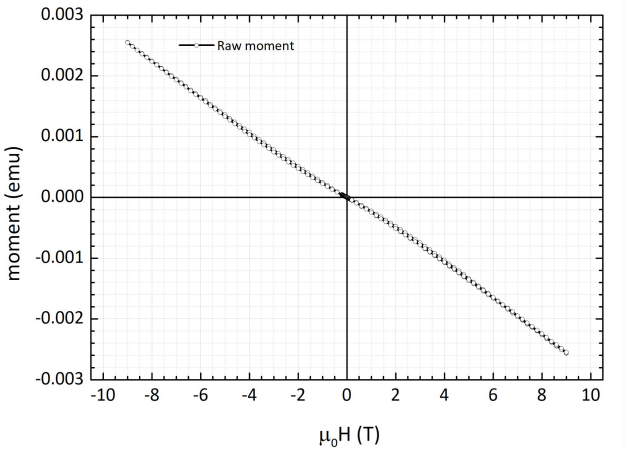
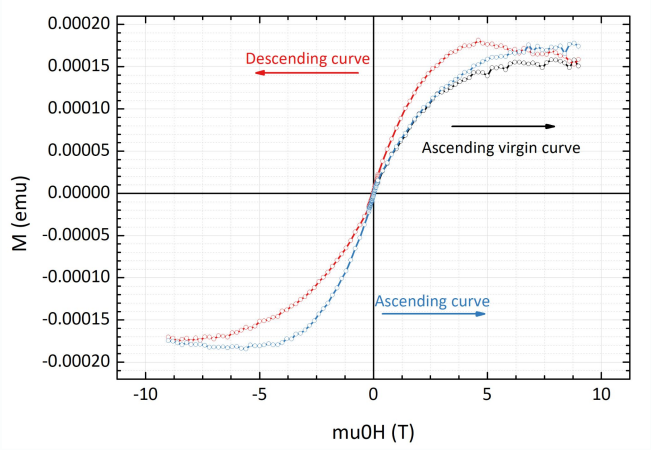
Magnetization vs Field curves (2 K)



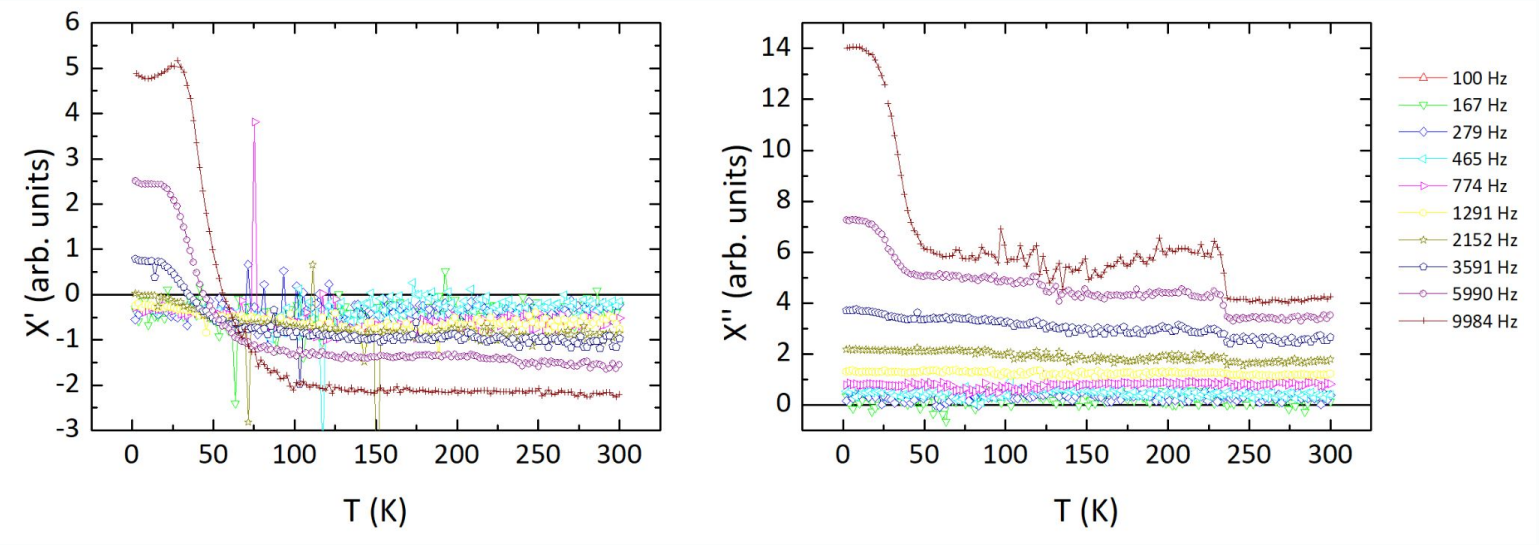


Strong diamagnetic background, typical of Si substrate.

Once the linear diamagnetic background is removed, a hysteretic behavior emerges.

Anomalous bottleneck effect. Impurities? Anomalous FM-AFM order?

AC Magnetization vs Temperature curves



- General temperature independent negative signal (diamagnetic background)
- Emergent positive signal below about 50 K

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Conclusions...

- “Mixed results”
- Signature of anomalous FM ordering
- Possible FM order induced by impurities and/or defects?
- Lack of long range ordering and limited FM Clusters?

...and next steps

- Refined low-T measurements with updated setup
- Identify thermal treatment effects
- Analyze Ta doping

Thank you all!

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