Universiteit Antwerpen

Belgium in gravitational waves

Hans Van Haevermaet

RECFA visit to Belgium – 12/9/2025

GHENT UNIVERSITY · VUB VRIJE UNIVERSITEIT BRUSSEL · ULB UNIVERSITÉ LIBRE DE BRUXELLES · KU LEUVEN · UHASSELT · UCLouvain · LIÈGE université · UNIVERSITÉ DE NAMUR · UMONS

Gravitational waves (GW) research in Belgium

Research field expanded significantly in last 8 years:

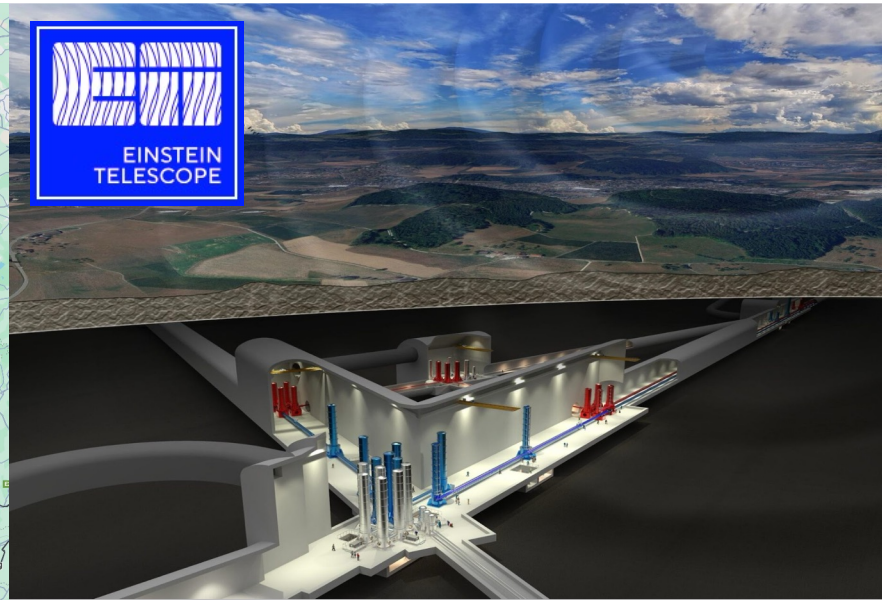
- 170 researchers (including theory, EMR site preparations)
- 10 universities (all Belgian universities!)
- 5 experiments (Virgo, ET, LISA, ETpathfinder, ET-CRISTAL)
- Theory, data analysis, instrumentation, outreach
- Several new permanent staff members
- Formation of new groups/institutes
  e.g. Leuven Gravity Institute (2024, T. Hertog)
- Valorization, projects with industry.

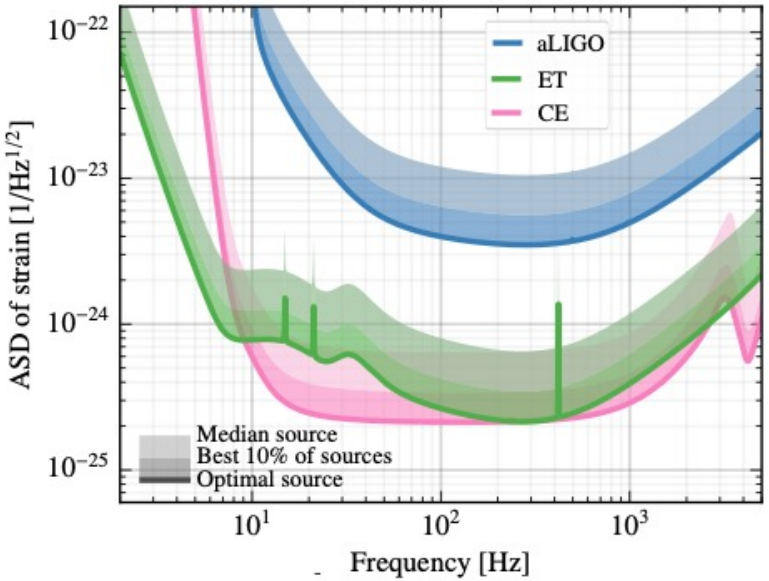
Close collaboration with HEP community

Einstein Telescope

Third-generation GW observatory in Europe, with the Euregio Meuse-Rhine (EMR) region as site candidate.

- Included in ESFRI Roadmap (2021), formal creation of ET Collaboration (2022).





- Single-site triangular geometry (3 nested detectors),
  or network of 2 identical L-shaped detectors in two distant sites

Design report: https://apps.et-gw.eu/tds/?r=18715
Blue Book: https://arxiv.org/abs/2503.12263

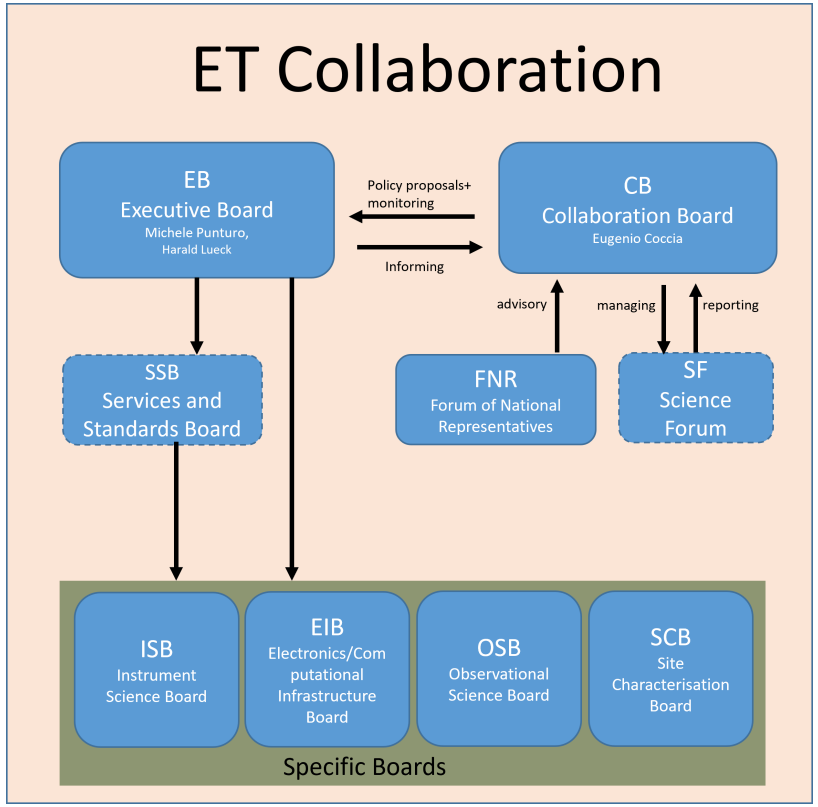
Einstein Telescope

The ET Collaboration: 1800 members, representing 264 Institutions in 31 different countries.

➔ Belgium: 110 researchers from 8 institutes

Several key scientific contributions/roles of Belgian researchers:

- Instrument Science Board (ISB):
  WP I.5 Seismic Isolation Platform: C. Collette (ULiège)
  WP II.4 Input and Output Optics: D. Pascucci (UGent)
  WP IV.2 Pipe Arm Vacuum: N. van Remortel (UAntwerpen)
  WP V.1 Newtonian Noise: S. Koley (ULiège)
- Co-chair of Observational Science Board (OSB): A. Ghosh (UGent)
- Site Characterization Board (SCB):
  WD3: Geological & Geotechnical Evaluation : F. Nguyen (ULiège)
- e-Infrastructure Board (eIB) division 1 Chair: A. Tanasijcsuk (UCLouvain)



Einstein Telescope

ET Organization (ETO) coordinates the ET Project's preparatory phase (conclude with selection of the site, decision on the configuration of the detector): B. Tuybens (KULeuven)

ET-PP (Einstein Telescope Preparatory Phase): EU-funded project (HORIZON-INFRADEV) to address fundamental prerequisites for the approval, construction and operation of the Einstein Telescope.

➔ UCLouvain, UAntwerpen

Strong support from Belgian federal, Flemish, and Walloon governments:

- 4M euro funding from federal government for ET-PP and ETO
- Flanders (government, FWO): 34M euro funding for ET-PP, EMR site studies, scientific research.
- Wallonia region: 10M euro for 4 research projects (2024):
  E-TEST CRISTAL laboratory at CSL (ULiège)
  ET-GEO EMR site characterization (ULiège)
  ET-OPT Laser and optics (UCLouvain)
  ET-LOG Software and computing (ULB, UMons, UCLouvain)
- Flanders & Wallonia: each 200M euro funding reservation for ET in EMR region

Einstein Telescope

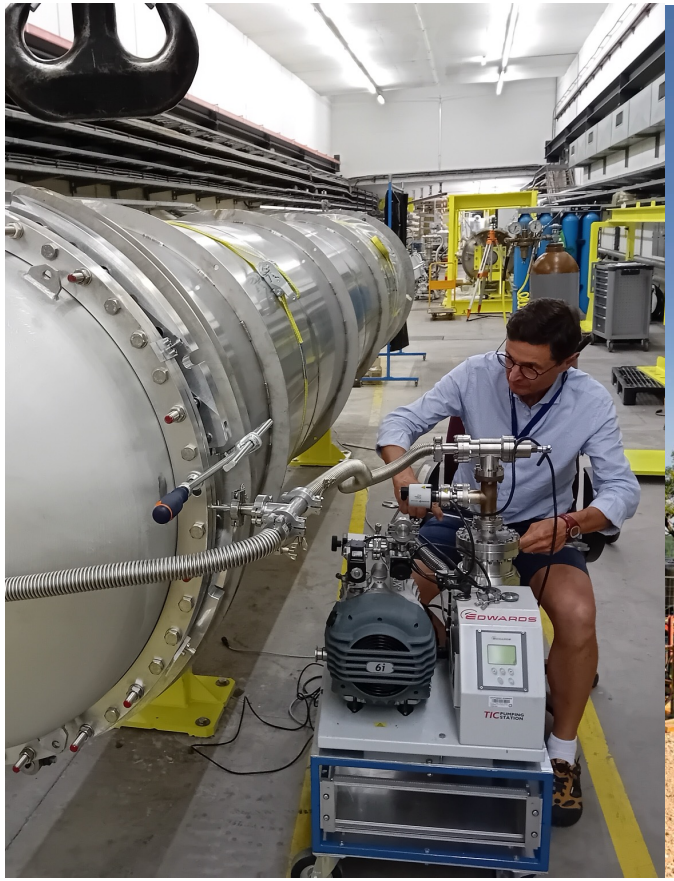
Dedicated teams and committees from governments and funding agencies (FWO, FNRS) integrated in EMR project office to support bid book

- Large drilling campaigns ongoing for geological & environmental site studies
  ➔ KULeuven, ULiège, UNamur, UCLouvain

- Projects to actively involve Belgian industry & valorization opportunities

Close collaboration with CERN

- Vacuum beampipe development (UAntwerpen, UGent, UHasselt) e.g. BeamPipes4ET Interreg project

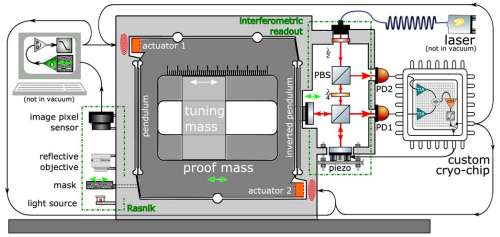


Einstein Telescope

Broad research landscape towards next-gen GW detectors: on instrumentation, data analysis techniques, simulations, modelling, theory.

Mirror coatings (both crystalline, amorphous), polishing
Laser & optics: e.g. IMC, freeform OMC designs, phase cameras
Quantum sensors & Squeezed vacuum
(KULeuven, UCLouvain, UGent, VUB, ULiège, UNamur, UHasselt)

Cryogenic (inertial) sensors (KULeuven, UCLouvain)
Radiative cooling strategies (UNamur)
Vacuum beampipes (UAntwerpen, UGent, UHasselt)
Mirror suspension & seismic isolation (KULeuven, UCLouvain, UAntwerpen)
Newtonian noise cancellation (KULeuven, ULiège, UAntwerpen)

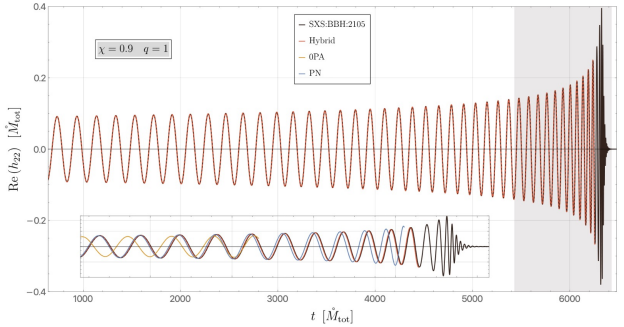


Computing, software and data analysis tools

state-of-the-art simulations of physical phenomena behind gravitational waves (KULeuven)
novel signal processing algorithms for detection & reconstruction of GW (KULeuven, UAntwerpen, UGent)
overlapping BBH signal detection, BNS early detection with ML, null stream glitch mitigation (UCLouvain)

Astrophysical and theoretical modelling

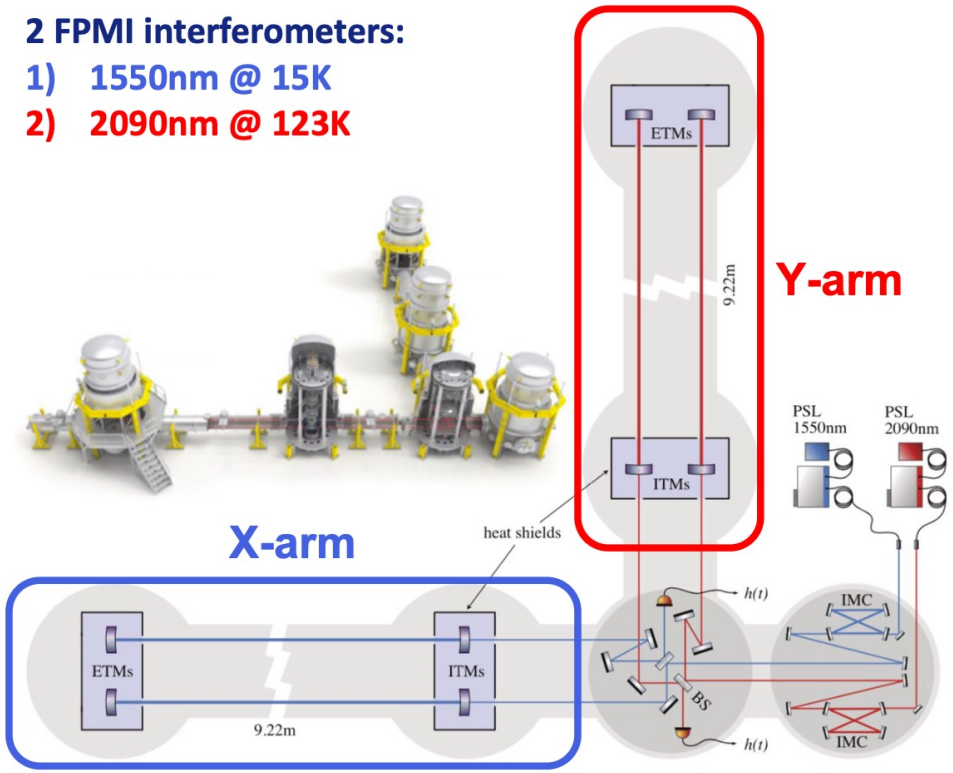
waveform modelling for CBC, EMRI (ULB, UMons, KULeuven)
parameter estimation (ULB)
burst detection methods, population studies (ULiège, UAntwerpen)
modelling GW signals of cosmic, HEP origin (VUB)



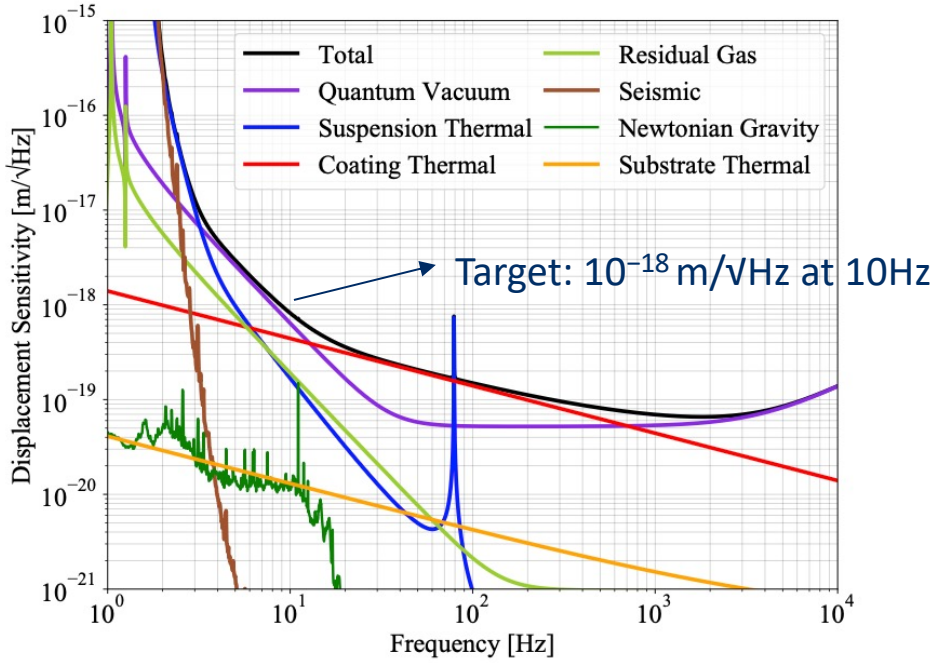
ETpathfinder

R&D infrastructure for testing new ET technologies in a low noise full interferometer environment

Located in In Maastricht (NL)



- Cryogenic temperatures: 15K & 123K
- New Mirror Material: Silicon
- New Wavelengths: 1550nm & 2090nm
- Advanced Quantum Noise Reduction Techniques



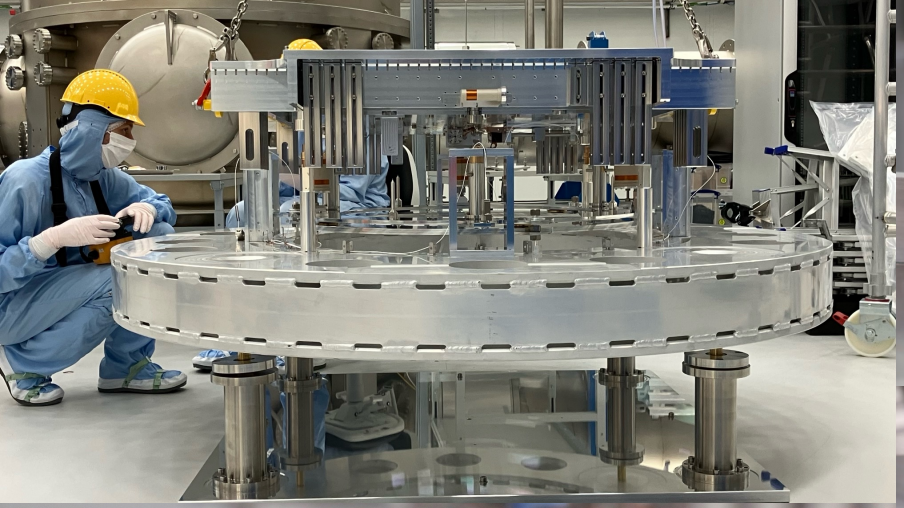
[Class. Quantum Grav. 39 (2022) 215008]

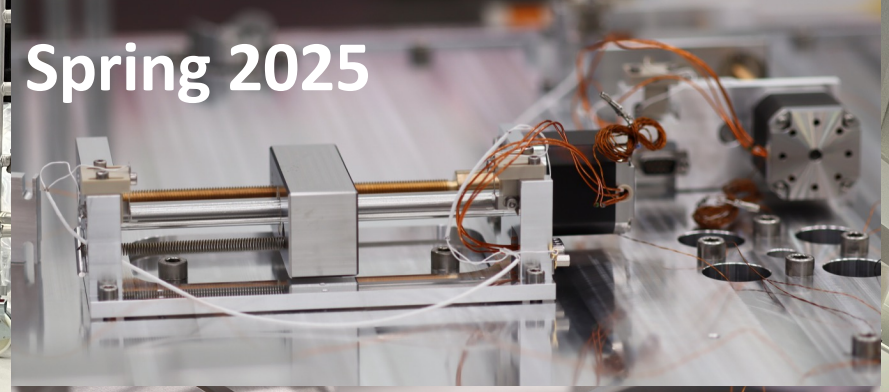
Deputy project leader: N. van Remortel
https://www.etpathfinder.eu

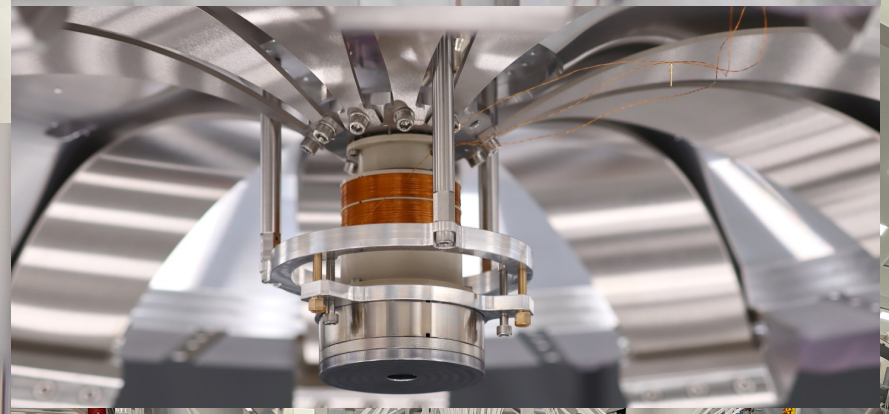
ETpathfinder partners

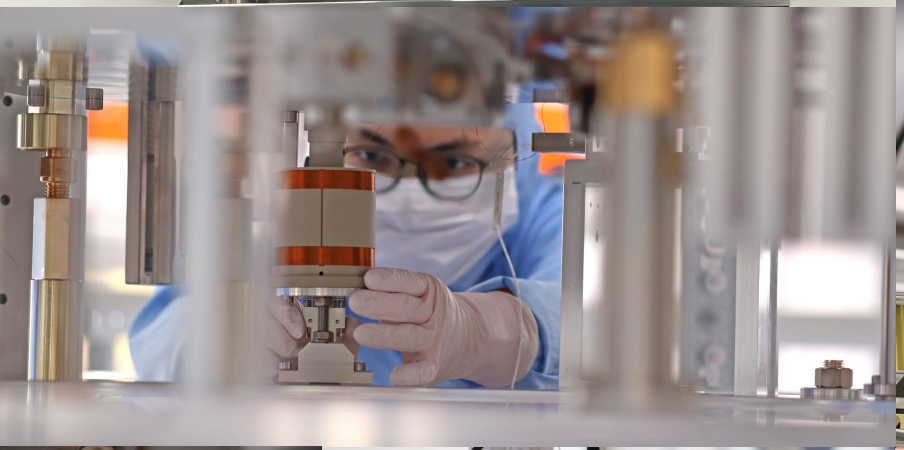
Initial funding of 14.5M euro of Interreg Vlaanderen-Nederland for construction of the experiment.

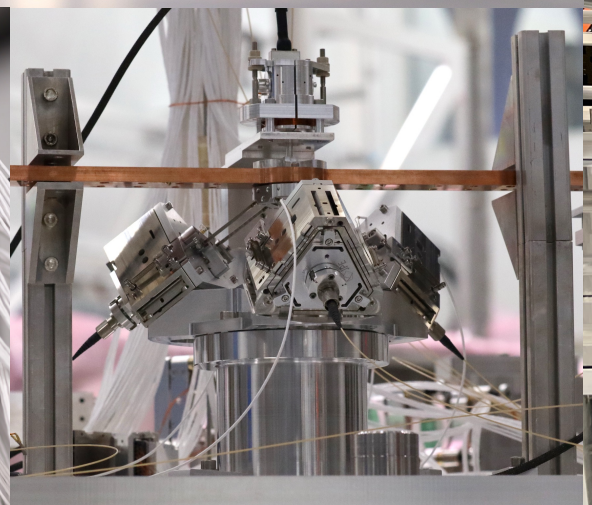
- Continued support in Belgium through research infrastructure funding projects (FWO, FNRS)
- New Interreg funding 2025: ETpathfinder Smart Skills Lab (2.2M euro)

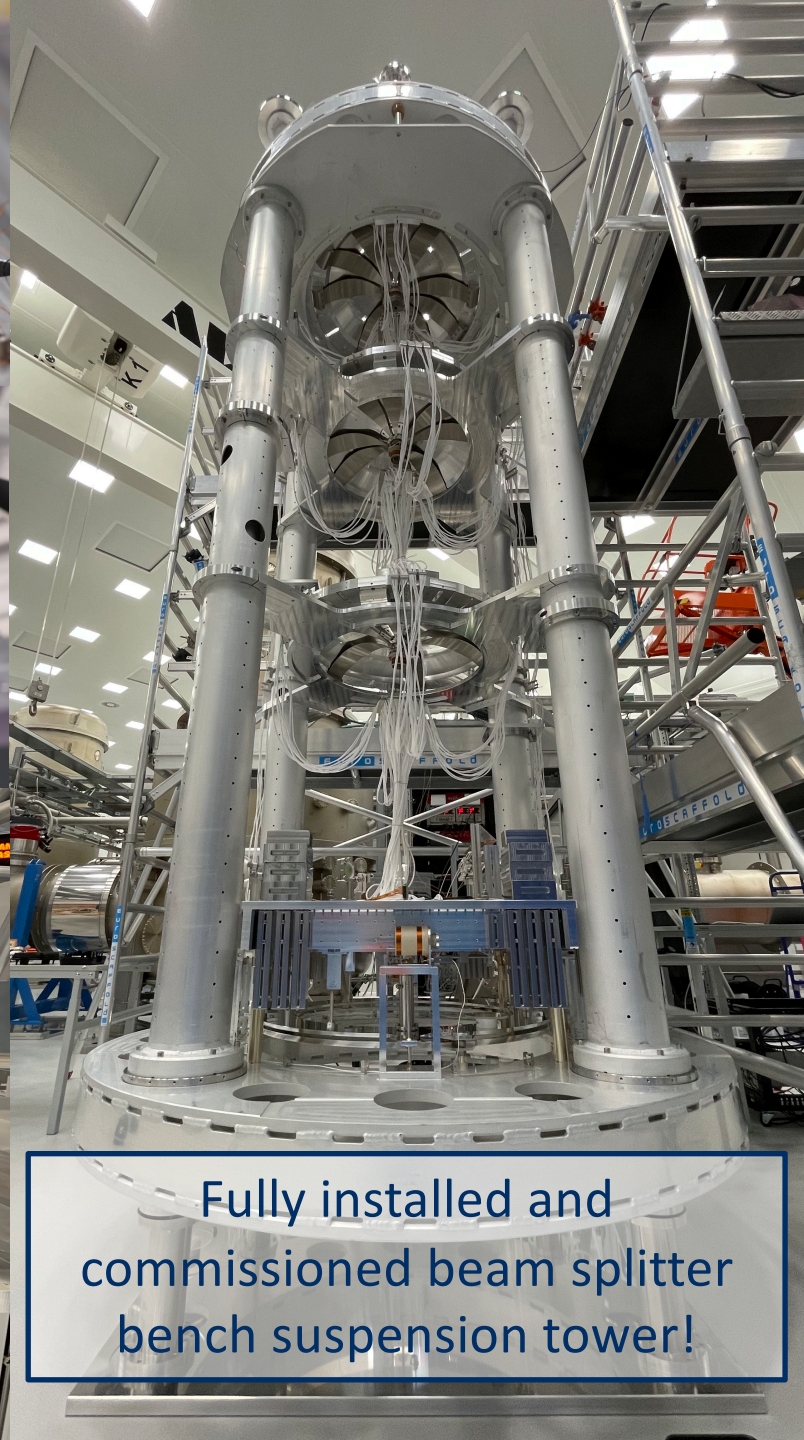












Fully installed and commissioned beam splitter bench suspension tower!

E-TEST

Make substantive improvements in the Einstein Telescope Site and Technologies:

- Development of a new mirror prototype under cryogenic conditions ➔ ET-CRISTAL
- Validation of cutting-edge technologies
- Defining the optimal location of ET in Euregio Meuse-Rhine

16.2M euro funding of Interreg Euregio Meuse-Rhine
(€ 8.11M from European Regional Development Fund (ERDF))

www.etest-emr.eu

Co-financers:

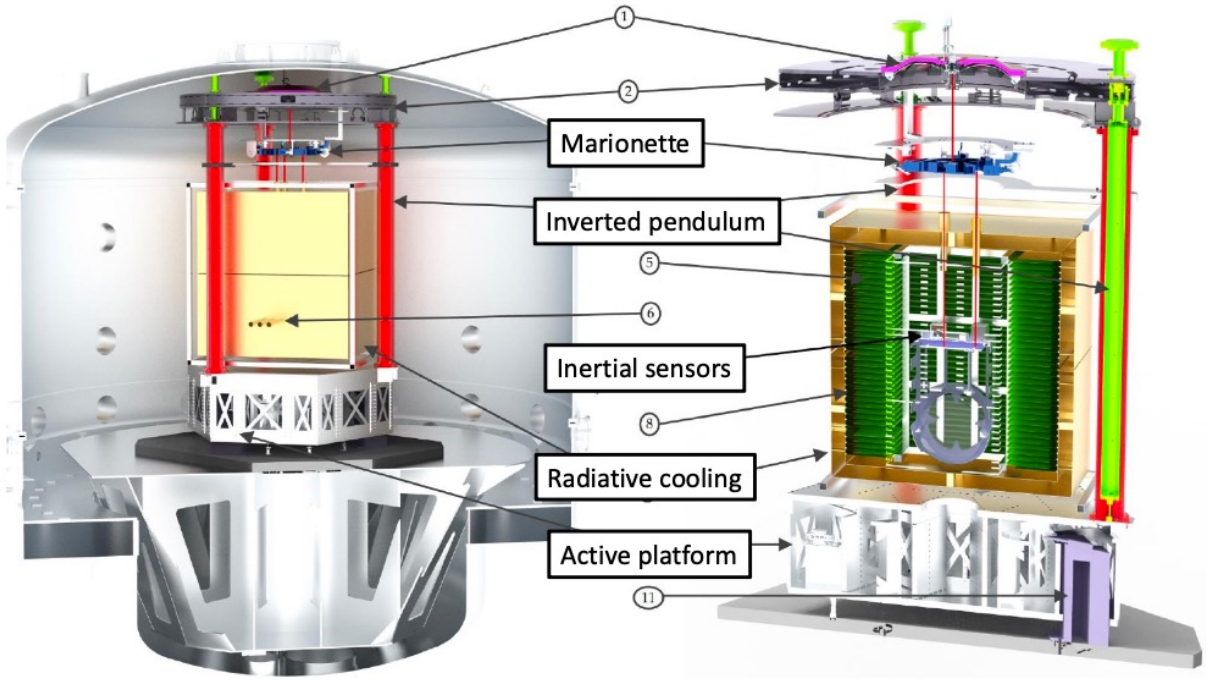
Interreg Euregio Meuse-Rhine European Regional Development Fund
EUROPEAN UNION
Wallonie
provincie Limburg
VLAAMS-BRABANT
provincie limburg
Ministerium für Wirtschaft, Innovation, Digitalisierung und Energie des Landes Nordrhein-Westfalen
Ministerie van Economische Zaken en Klimaat
AGENTSCHAP INNOVEREN & ONDERNEMEN
Vlaanderen is ondernemen

Partners:

LIÈGE université
Fraunhofer ILT
RWTH AACHEN UNIVERSITY
UHASSELT
KU LEUVEN
Nikhef
UNIVERSITÄT BONN
NMWP. The Innovation Engineers.
Royal Netherlands Meteorological Institute Ministry of Infrastructure and Water Management
Maastricht University
UCLouvain

ET-CRISTAL (CRyogenics & Inertial STAbility Lab)

Full scale prototype of a large cryogenic silicon mirror located at Liège Space Center.



- Low frequency seismic isolation at full scale
- Newtonian noise estimation and experimental validation
- Heavy mirror silicon suspension
- Mono-cristalline full scale silicon mirror production
- Cryogenic inertial sensors
- Radiative cooling strategy
- Low noise electronics

Design report: https://arxiv.org/abs/2212.10083

Project lead: C. Collette (ULiège)

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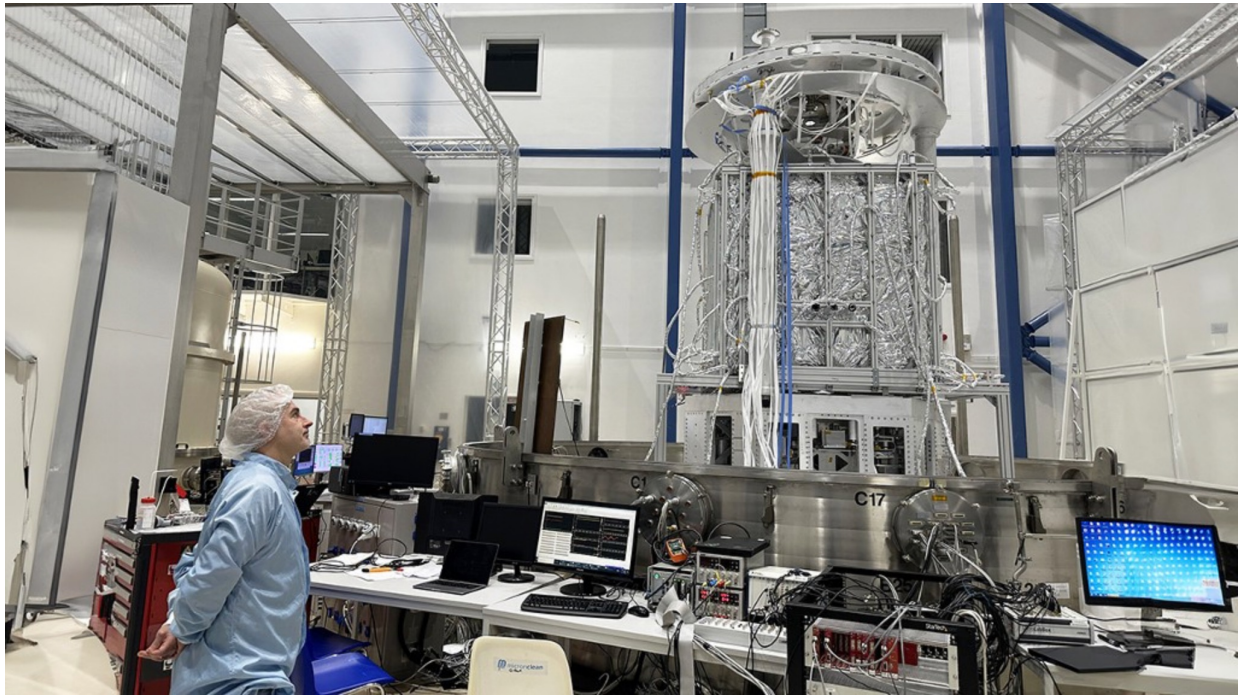
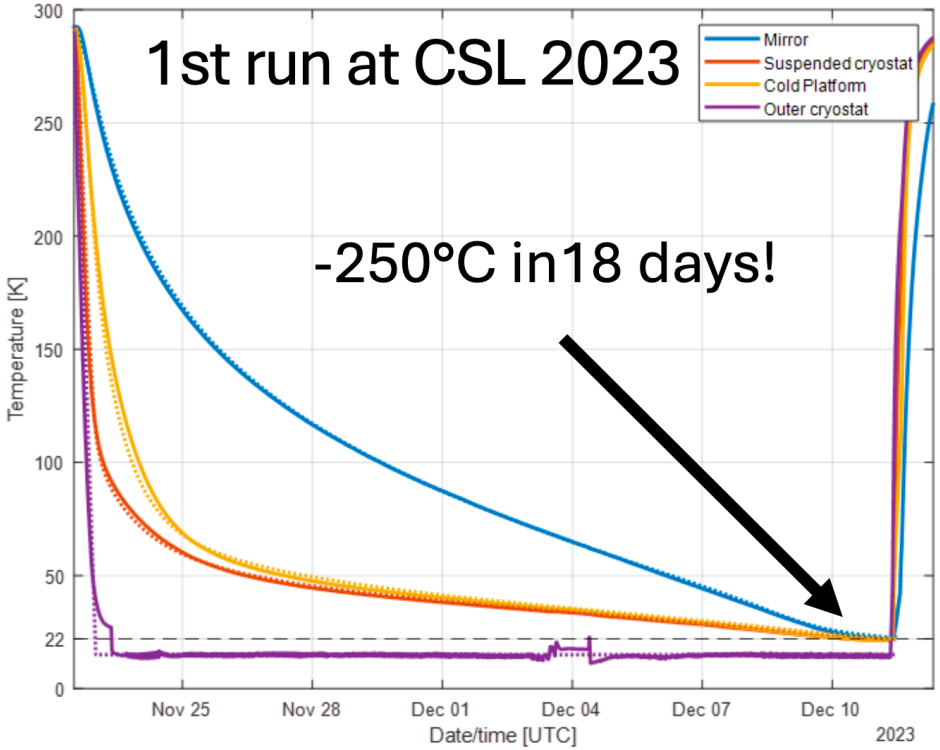




Continue R&D through additional funding from FNRS, Walloon region.

Virgo

FNRS and FWO join EGO council in 2025 (300 k€ yearly financial contribution)

Belgium in Virgo Collaboration:

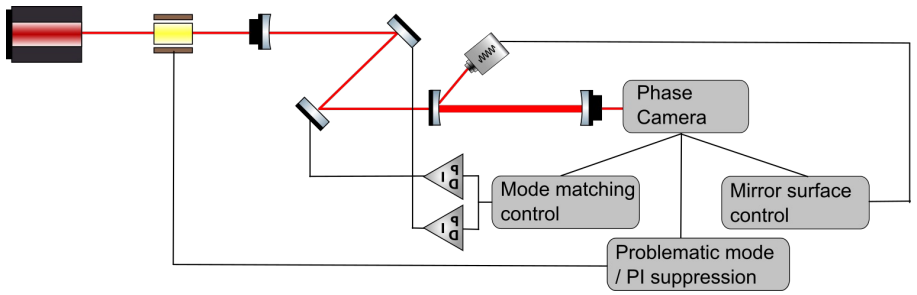
- 87 researchers from 7 universities
- Leading contributions to key GW paper publications
- Several positions in editorial boards & review committees; Virgo Evolution Forum/ EGO-Virgo Reorganisation Committee (T. Li)
- Current/past working group conveners:
  - stochastic GW background (N. van Remortel)
  - multi-messenger physics (M. Vereecken)
  - GW lensing (J. Janquart)
  - CBC cosmology (initiated by A. Ghosh)
  - CBC testing GR (T. Li)
  - Long-duration burst (M. Fays)

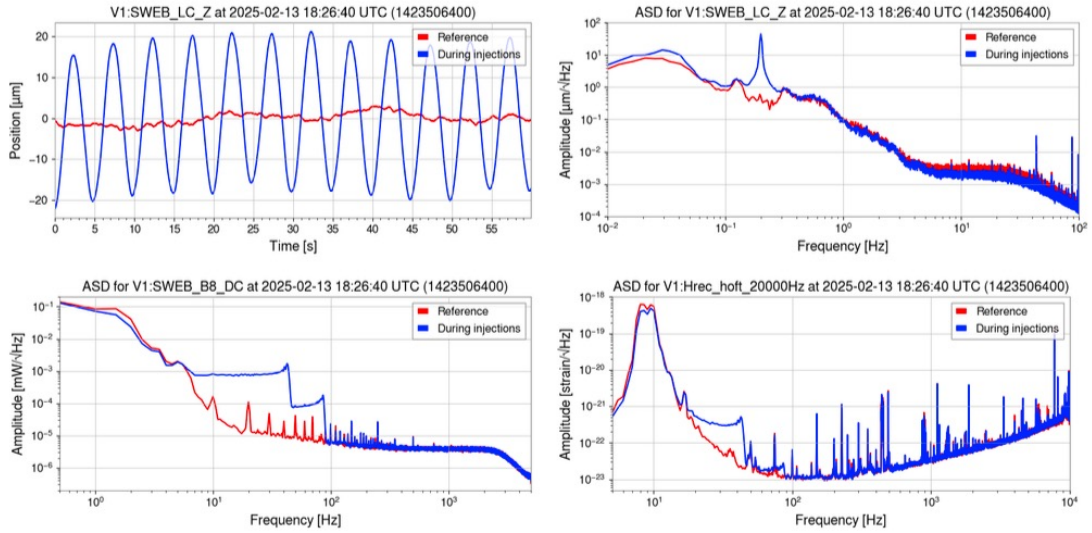
- Computing WLCG cluster at UCLouvain integrated in LVK computing system since 2019
  3000 cores (37 kHEPscore) and 2400 TB - 10% are Virgo specific resources
  ➔ Tier2 cluster in Brussels to be extended for LVK in 2025.

Virgo instrumentation

Large increase in Virgo instrumentation and commissioning activities for O4 and O5
➔ investment from funding agencies (e.g. through FWO IRI)

- Detector calibration AdV+ Phase 2 upgrade project for O5 (UAntwerpen, UGent)
  ➔ with BelGrav group in leading role (H. Van Haevermaet)
- Contributions to seismic isolation (suspensions recycling cavities) for O5 (UAntwerpen, KULeuven)
- Optics, coating research towards (post-)O5 (VUB, KULeuven)
- Phase cameras for mode mismatch mitigation (UCLouvain)
- Optical simulations (UCLouvain)
- On-site commissioning activities for O4 & O5 (UCLouvain, VUB)

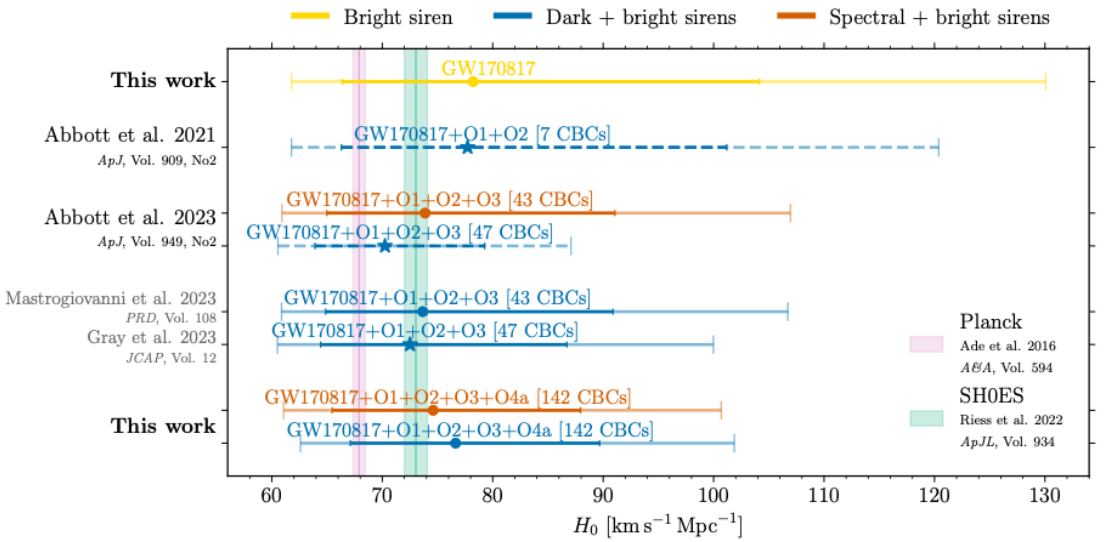




LVK data analysis

Broad GW physics research program with existing LIGO, Virgo, Kagra (LVK) data:

- Stochastic GW background: searches, analysis techniques (UAntwerpen, VUB, UCLouvain, UNamur)
- CBC Cosmology (major contributions to GWTC-4.0 cosmology paper) (UGent)
- Multi-messenger physics: low-latency alerts and neutrino-triggered GW searches (UCLouvain, UGent)
- Continuous waves, fundamental physics with CBC (UCLouvain)
- Detection & characterization of GW signals with ML (UCLouvain, KULeuven)
- Primordial black holes (ULB)
- Strongly lensed GW physics (UCLouvain, KULeuven, ULiège)
- Search for GW from core-collapse supernova & tests of GR (KULeuven)

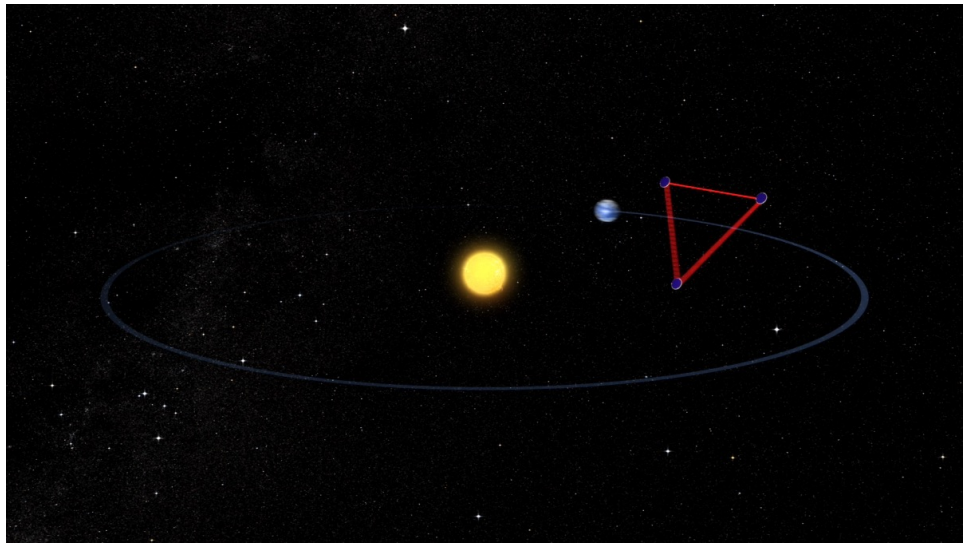


[arXiv:2509.04348]

LISA (Laser Interferometer Space Antenna)

First GW observatory in space, providing new observational window in the long wavelength GW spectrum. Detect e.g. Supermassive black holes, Gravitational wave background.

Adopted by ESA as flagship "Large" mission (2024), currently planned to be launched in 2035.



KU LEUVEN ULB

Key involvements:

- Instrument Development: design, construction of interferometric detection system and modeling LISA data.
- Data Analysis: build LISA simulator to study complex data extraction from millions of GW sources.
- Multi-messenger Astrophysics: connect different disciplines like astronomy and particle physics
- Coordination of the primordial black hole group (ULB)

https://www.kuleuven.be/lgi/Home

Outreach

Several projects ongoing and starting up in Belgium and EMR region for Einstein Telescope:

- Presence at events with exhibitions, talks: e.g. Dag van de Wetenschap, Nerdland Festival,…
- ET Roadshow: touring all Flemish provinces and Brussels. Contains interactive exhibition, an extensive school program and activities for young and old.
  (https://www.etforbusiness.be/etroadshow/)
- Build links and initiatives with ETEC center in Maastricht (ULB)
- Project with GRE ULiège and Euro Space Center (UNamur)

Summary

Gravitational wave physics in Belgium has become a large research field, spanning multiple experiments, and many theoretical & data analysis topics. Providing key contributions and leading positions within international collaborations.

With the Einstein Telescope being a major future project for Belgium and EMR region (decision on location in 2027) these will be exciting times…

Important to maintain & possibly extend our existing collaborations with CERN and the HEP community.

Thank you to all my colleagues for their input!

My apologies if I missed specific topics, due to the huge growth of our research field…

And thank you for your attention!