

Nikhef

# GRAVITATIONAL WAVE PROGRAM

S.Hild for the Nikhef GW team

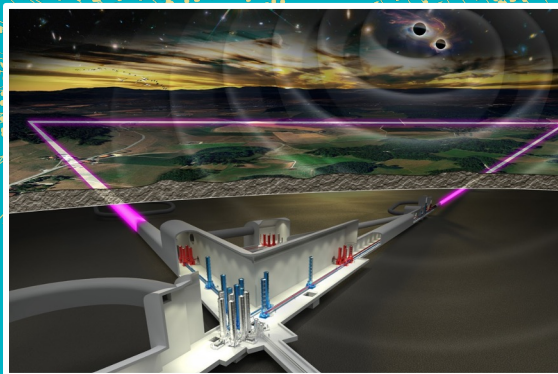
LIGO/VIRGO/KAGRA



ETPATHFINDER



EINSTEIN TELESCOPE



LISA\*



ET-EMR  
@NIKHEF\*\*



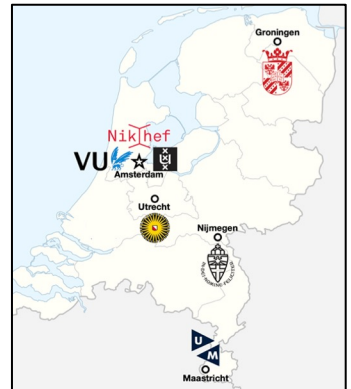
ETO  
@NIKHEF\*\*



# OVERVIEW OF THE GW PROGRAM

Key Mission: To detect and study gravitational waves (ripples in the fabric of space-time) that are produced by cataclysmic events in the universe.

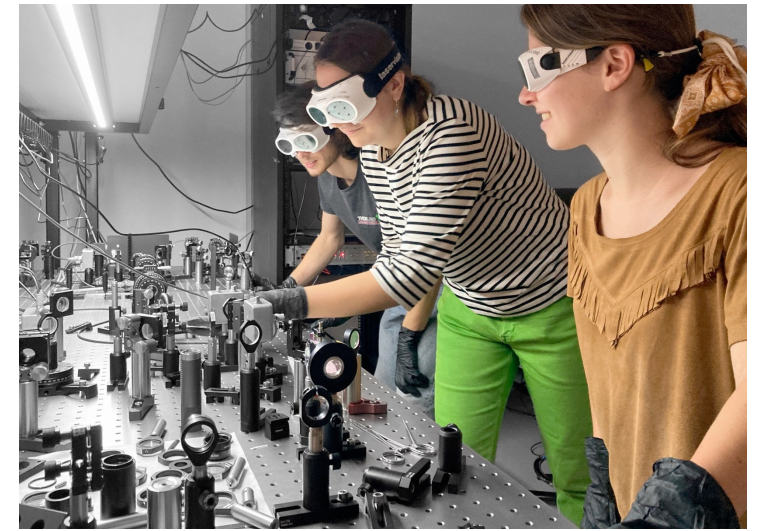
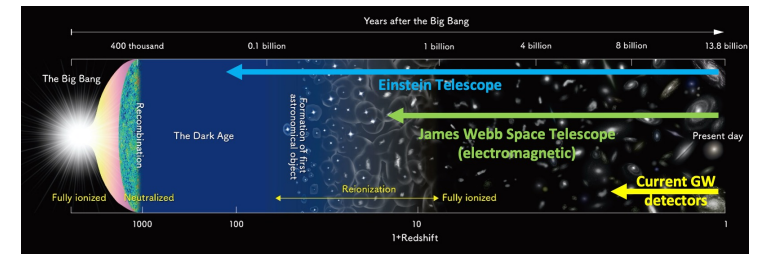
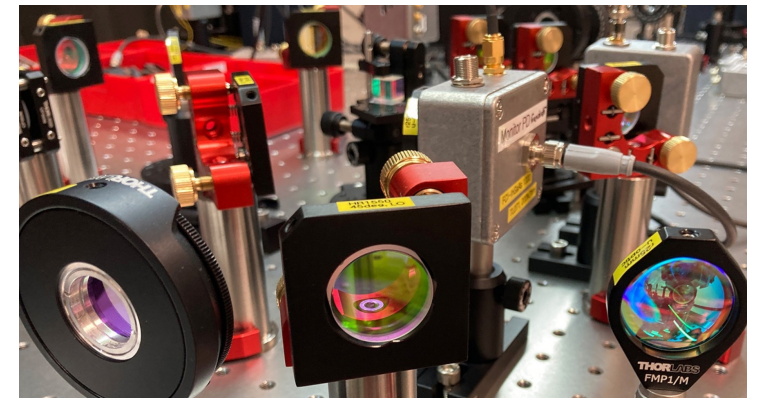
- **70 scientist:** ~20 academics, ~20 postdocs and ~30 PhD students. (EMR team and Nikhef ETO staff is not part of the GW program)
- **Large portfolio of grants including:**
  - Personal grants (ERC Adv, ERC Consolidator, ERC starter, NWO Vici, NWO Vidi (2x), NWO Veni, Humboldt etc)
  - Consortium grants (NWO Infrastructure for Virgo, NWO XL – ET, Dutch Black Hole Consortium, ET-PP, LISA/ET roadmap etc)
  - 6x Industry Consortia for developing ET technologies
  - Specials: ET NGF (42 + 870), ETnext (Prinsjesdag announcement)





# STRATEGY OF GW PROGRAM

- **Upgrade Advanced Virgo** and **run jointly with Advanced LIGO** providing observational data of unprecedented reach and pointing accuracy.
- **Study gravitational waves** from compact binary mergers, and extract knowledge about black-hole and neutron star populations, their formation channels, the equation of state of neutron stars and the expansion rate of the universe.
- Develop strategies to probe the **nature of black holes** and the **fundamental physics of gravity** and shed light on the nature of **dark matter** and **dark energy**.
- Develop new **data-analysis techniques** and consolidate innovative **instrumentation R&D** for **Virgo**, **ETpathfinder**, **ET** and **LISA**.
- Support the Consolidation of the Dutch co-leadership of the Einstein Telescope and **prepare a strong bid for hosting the Einstein Telescope in Euregio Meuse-Rhine\*\***.



# EVOLUTION OF THE GROUP

- GW one of the younger programs in Nikhef
- Strong Growth over the past years

## From previous SAC meeting: Permanent staff & leadership positions



## Recent new hires of permanent staff

### Marco Vardaro

Hired by Nikhef as ETpathfinder Technical Coordinator



### Anna Green

Hired by Maastricht (UD) Expert in Optical Simulations and Interferometry



### Alex Amato

Hired by Maastricht (UD) Expert in Materials and optical Coatings





# RUNNING SCIENCE PROJECTS

- **Currently in the fourth LIGO-Virgo-KAGRA observing run**
  - **200+ detections**
  - **First release of comprehensive results around August**
  - **Special event: Neutron star + very light black hole (?)**
    - Further evidence for compact objects in the purported “lower mass gap”
- **Pipelines in O4:**
  - Searches for lensed GWs
  - Testing GR:
    - TIGER: test of the inspiral-merger-ringdown dynamics
    - MDR: test of GW propagation looking for anomalous dispersion
    - Unmodeled searches for echoes from black hole mimickers
- **Waveform modeling: eccentricity**

OPEN ACCESS

## Observation of Gravitational Waves from the Coalescence of a 2.5–4.5 $M_{\odot}$ Compact Object and a Neutron Star

A. G. Abac, R. Abbott, I. Abouelfettouh, F. Acernese, K. Ackley, S. Adhicary, N. Adhikari, R. X. Adhikari, V. K. Adkins, D. Agarwal ▾ Show full author list

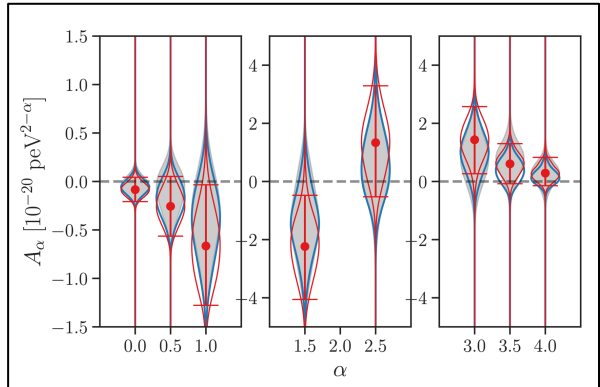
Published 2024 July 26 • © 2024. The Author(s). Published by the American Astronomical Society.

*The Astrophysical Journal Letters*, Volume 970, Number 2

**Citation** A. G. Abac et al/ 2024 *ApJL* **970** L34

**DOI** 10.3847/2041-8213/ad5beb

LVK, *Tests of general relativity with GWTC-3*, arXiv:2112.06861



**Stringent constraints on anomalous dispersion**

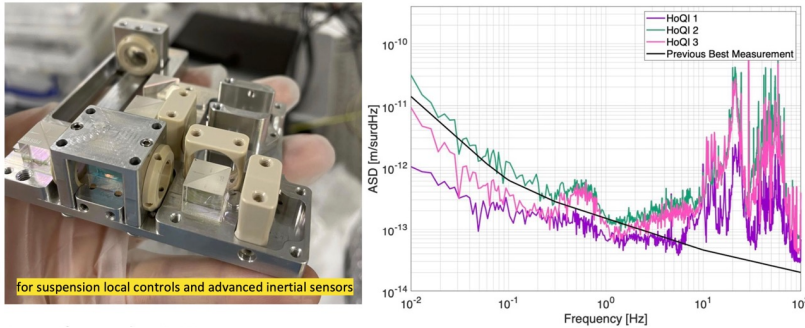
$$E^2 = p^2 c^2 + A_{\alpha} p^{\alpha} c^{\alpha}$$

	kWh	CO <sub>2</sub> [kg]	Trees <sup>†</sup>
JIM	34	11	0.55
pBILBY	3599	1180	59.02

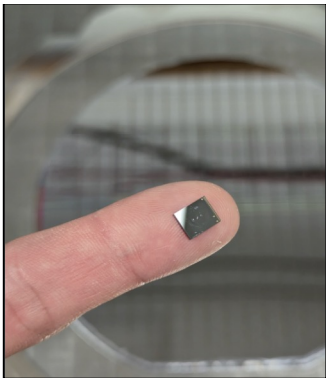
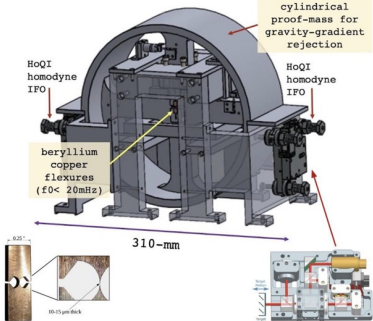
WOUTERS, PANG, DIETRICH, VAN DEN BROECK, PRD 110, 083033

# RUNNING TECHNOLOGY PROJECTS

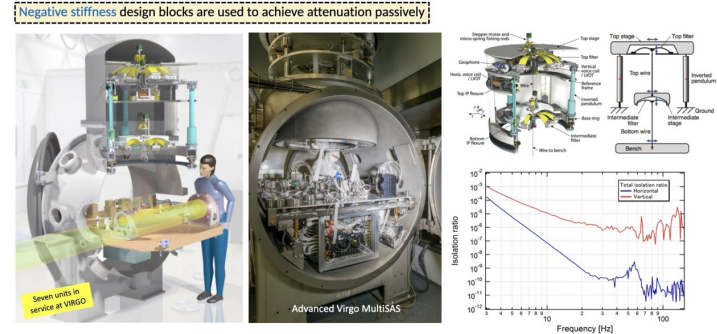
## Homodyne Quadrature Interferometer (HoQI) displacement sensors



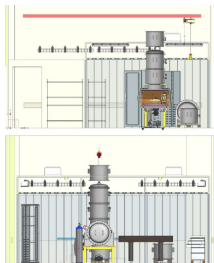
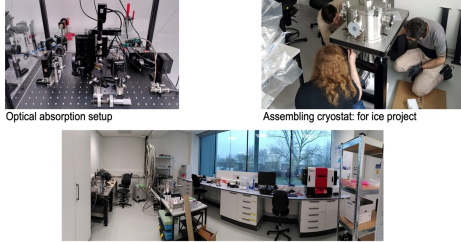
## Tackling ground rotation noise



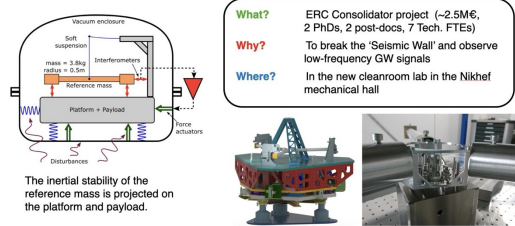
## Vibration isolation for ET / VIRGO legacy



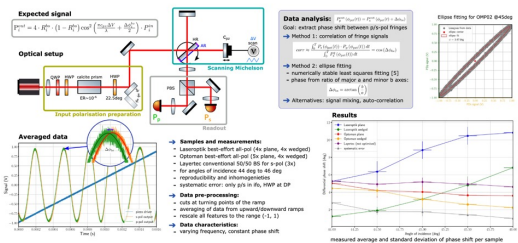
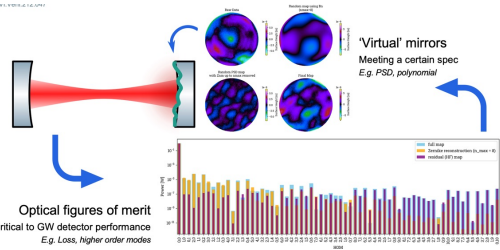
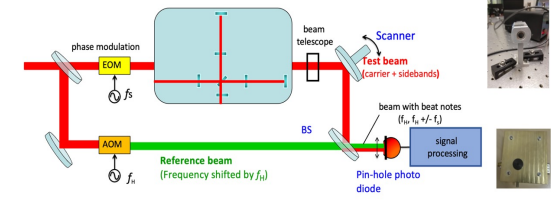
## The Maastricht Materials Lab



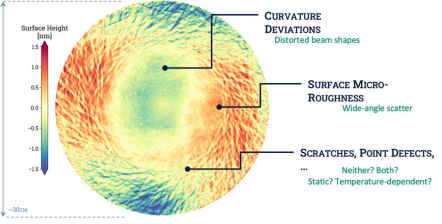
## OmniSense pre-isolation technology demonstrator



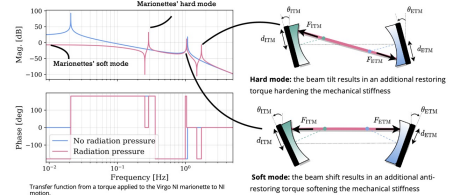
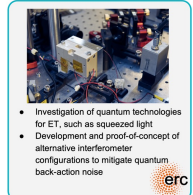
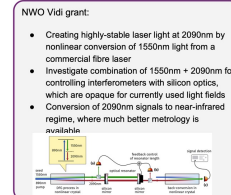
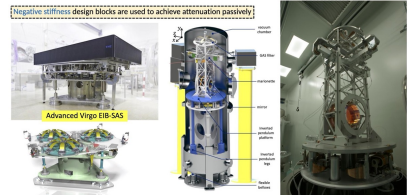
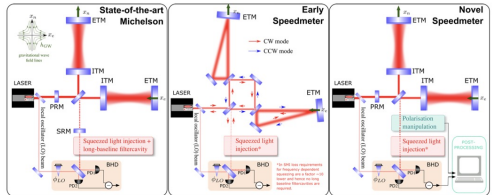
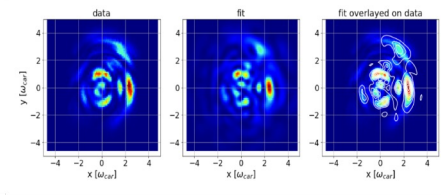
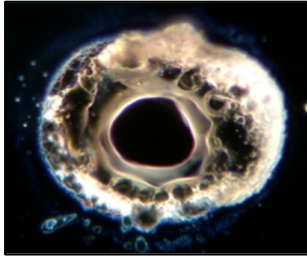
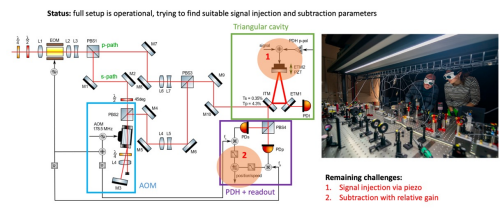
## Phase Camera



## ANATOMY OF A MIRROR SURFACE

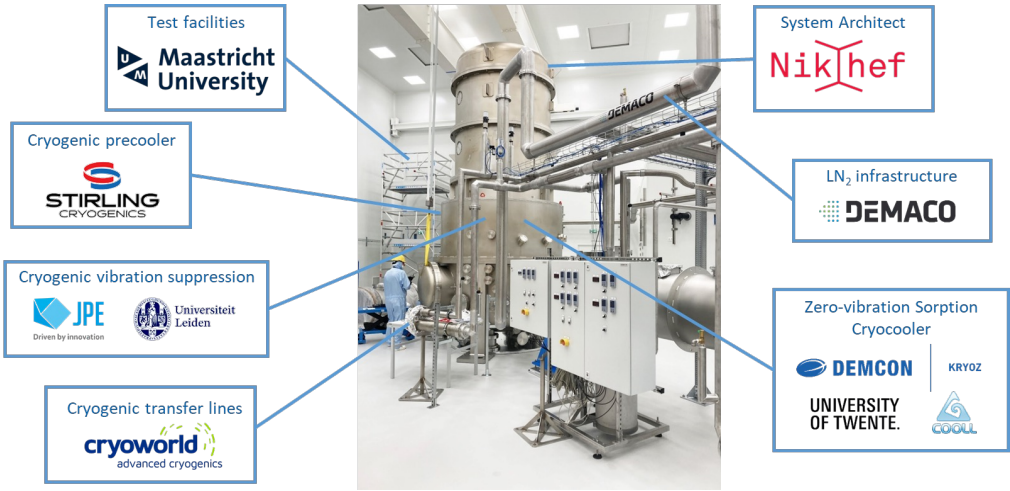


## EPR Speedmeter Proof of Concept experiment





# RUNNING COLLABORATIONS WITH INDUSTRY



Einstein Telescoop - 10 Kelvin trillingsvrije cryokoeling

Life-sciences & materiaal onderzoek

(bio)sample onderzoek bij extreem lage temperaturen

Halfgeleider industrie

supergeleidende lineaire motoren voor wafer steppers

Ruimtevaart

cryogeen gekoelde optische sensoren in ruimtevaart satellieten

Quantum computing

(kosten) efficiënte Qubit cryokoeling voor quantum computers



Call 1 Vibration free cooling	Call 2 Vibration damping	Call 3 Optics	Call 4 - Thermal deformations	Call 5 Vacuum
<p>DEMCON KRYOZ</p> <p>UNIVERSITY OF TWENTE.</p> <p>COOL</p> <p>STIRLING CRYOGENICS</p> <p>cryoworld advanced cryogenics</p> <p>mat-tech innovative solidifying &amp; freezing</p> <p>ASTRON</p> <p>Universiteit Leiden</p>	<p>Onnes Technologies</p> <p>JPE Driven by innovation</p> <p>Universiteit Leiden</p> <p>SRON</p> <p>Nikhef</p> <p>MAGNETIC INNOVATIONS the cryogenic motor company</p> <p>PIAK</p> <p>SAFELY</p>	<p>lionite</p> <p>cosine </p> <p>VSL</p> <p>SRON</p> <p>TNO</p> <p>Maastricht University</p> <p>micronit microtechnologies</p> <p>UNIVERSITY OF TWENTE.</p>	<p>TNO</p> <p>DEMCON FOCAL</p> <p>ATG europe</p> <p>SILOUX TECHNOLOGIES</p> <p>hour sec</p> <p>Nikhef</p>	<p>TNO</p> <p>VDL VDL ETG</p> <p>VDL VDL KTI</p> <p>SBE Piping Machine-Apparatenbouw</p> <p>settels savenije group of companies</p> <p>Nikhef</p>

SIX CONSORTIA NOW IN OPERATION


# RUNNING EDUCATION/OUTREACH

## Einstein Telescope Education Center


➤ for school classes

## MAGIC

➔ for high-school teachers

 Maastricht University

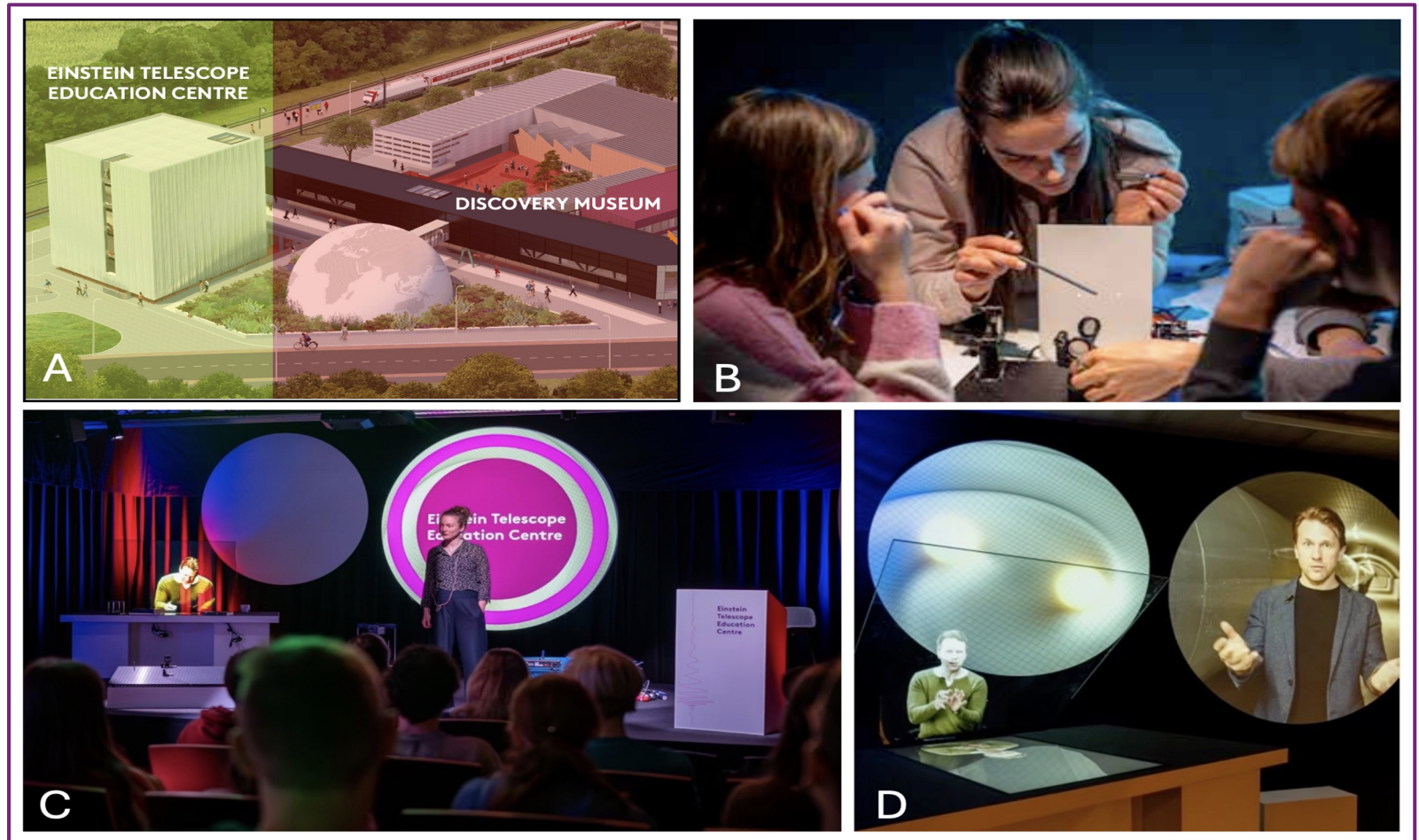
Einstein Telescope Education Centre

provincie limburg 

# MAGIC

**MAASTRICHT GRAVITATIONAL INSPIRATION CURRICULUM**  
17 - 23 AUGUST 2025 | MAASTRICHT, THE NETHERLANDS

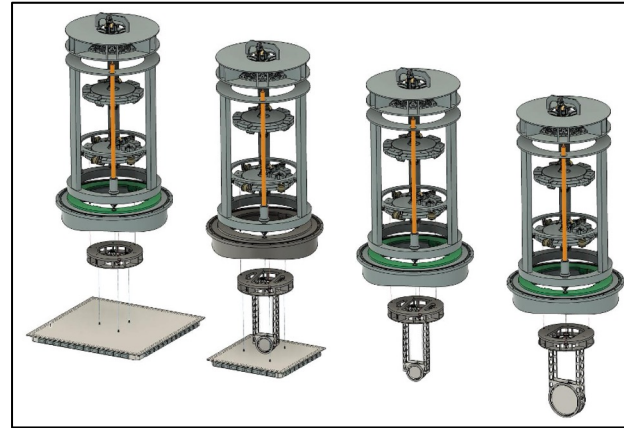
An all-in summer course for teachers, on the physics of the Einstein Telescope and how to effectively teach this in upper high school physics classes.





# FUTURE PLANS/AMBITIONS --- VIRGO

Virgo is in a critical phase ...



Advanced Virgo Plus for O5

Technical Design Report

The Virgo Collaboration

VIR - 0499A - 25

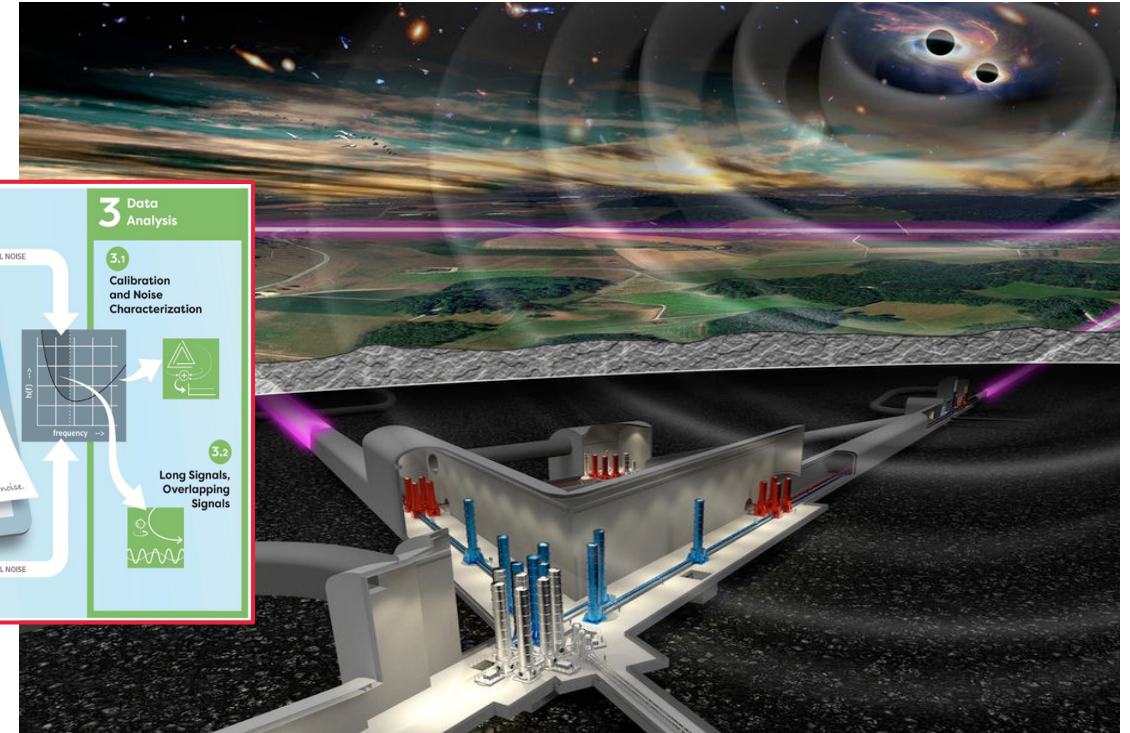
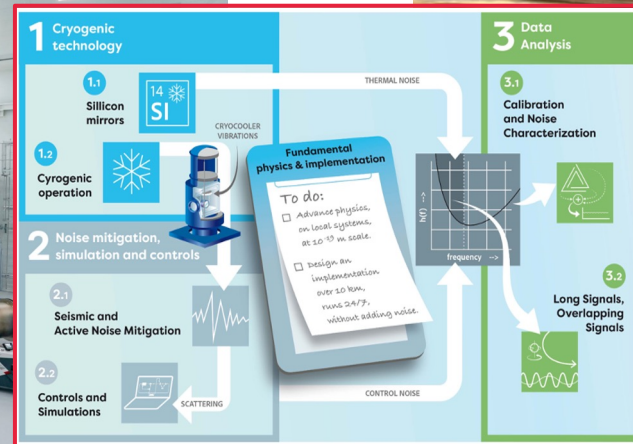
5 May 2025

- **Completion of O4 observation run.**
- Ramp-up of data analysis **R&D to cope with O5** and beyond; machine learning (and other) techniques as a pathway towards ET.
- **Enable a functional and effective Virgo organisation, as prerequisite for a successful Virgo upgrade.**

# FUTURE PLANS/AMBITIONS --- ETPATHFINDER & ET



ETpathfinder R&D lab



Enabling Science in ET



# SYNNERIES WITH OTHER NIKHEF PROGRAMS

## PARTICLE PHYSICS:

NEUTRON STAR  
EQUATION OF  
STATE -- ALICE



## ASTRO PARTICLE PHYSICS:

MULTIMESSENGER  
ASTRONOMY  
-- KM3NET, AUGER, ...

# CHALLENGES

- Significant and rapid change in organisational Aspects and Boundaries (e.g. Virgo lab, IGWN, ET bootstrapping)
- NL GW is expected by some stakeholders to be able to “punch at the same level” as much larger communities abroad (e.g. INFN).
- Interactions with ETO@Nikhef and ET-EMR

# OPPORTUNITIES

- **Amazing Science!**
- Steer Virgo lab and IGWN in the right direction and support their start;
- Upgrade Virgo and increase its impact in the LVK network;
- High impact, leadership in international GW community;
- Connect Industry to our effort. Benefit for us + showcasing valorisation and societal impact.
- (co)-leadership in ET (european aspects ETO and ETC).
- Bringing a multi-billion Euro facility to EMR
- Expanding ETpathfinder to Low-Frequency integration facility for ET.





WE HAVE QUITE SOME  
CHALLENGES AND TASKS AHEAD  
OF US ....

... BUT WE HAVE A FANTASTIC  
TEAM TO TACKLE THEM. LETS GO!

