Letter of Intent

To: EGO Director - EGO Council Chair - Virgo Spokesperson

Date: 10 May 2025

From: BelGrav Group
Prof. Hans Van Haevermaet
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Subject: Expression of Interest to join VirgoLab

Dear Sir/Madam,

This letter serves as a formal expression of interest by the BelGrav group representing three universities in the Flemish region of Belgium (hereinafter referred to as "BelGrav") to join the VirgoLab, as described in VIR-1025B-24. We understand that VirgoLab operates, commissions, and upgrades the Virgo interferometer, and we are willing to contribute to its mission and to the achievement of its goals.

1. Introduction

The BelGrav group is composed of three universities in Belgium, on the Flemish side (funded by the FWO), namely Universiteit Antwerpen (UAntwerpen), Universiteit Gent (UGent), and Vrije Universiteit Brussel (VUB). The PIs in these universities have expertise in instrumentation as well as GW data analysis and have over the years been involved in several Virgo service tasks and outreach activities in relation to Virgo. Nick van Remortel (UAntwerpen) carries out data analysis as well as instrumentation for Virgo. He serves as the chair of the stochastic data analysis group and leads and coordinates several stochastic group projects and activities. He also leads the UAntwerpen activities on Post-O5 R&D towards improved seismic isolation techniques. Hans Van Haevermaet (UAntwerpen) carries out research in the field of GW instrumentation (seismic isolation sensing and control) and contributes to the calibration activities of Virgo where he is deliverable manager of the Advanced Virgo+ Phase 2 Calibrators based on end-bench scattered light (CAL.03) upgrade project. Archisman Ghosh (UGent) is an expert on CBC data analysis and observational science, in particular, fundamental physics and cosmology implications of CBC observations. He also manages the GW instrumentation activity in UGent set up by Daniela Pascucci. Daniela Pascucci (UGent) has years of experience in GW instrumentation in the context of LIGO, LISA, Virgo, and now also the Einstein Telescope and ETpathfinder, with a focus on Optics. Pascucci is also involved in the development of calibrators based on end-bench scattered light (deliverable CAL.03 of Advanced Virgo+ Phase 2). Christophe Detavernier (UGent) specializes in thin film research and the atomic layer deposition (ALD) technique and his group is involved with the development and testing of alternate mirror coatings for Post-O5 R&D, as well as in the characterization of mirror coatings for O5 R&D. Alex Sevrin (VUB) and his group are involved in modeling cosmological sources of the stochastic GW background and developing searches for topological defects. Alberto Mariotti (VUB) is leading a group working on stochastic searches. Michael Vervaeke (VUB) and the B-PHOT group are involved in extreme fabrication technologies for optics including advanced metrology. Nathalie Vermeulen and Tatevik Chalyan carry out research on quantum squeezing.

Our expertise and ongoing research activities are highly relevant to the operation, commissioning, and potential upgrades of gravitational wave interferometers. We believe that our participation in VirgoLab would be mutually beneficial, allowing us to contribute our knowledge and resources to the advancement of gravitational wave science in Europe and beyond, while also providing our members with valuable experience and opportunities within a leading international collaboration.

This letter outlines our main areas of interest and potential contributions to VirgoLab.

2. Scientific / Technological Case or Context of Opportunity

Our group has a strong background in:

- UAntwerpen and UGent are contributing to Virgo calibration, in particular, they are further developing a new calibration technique using end-bench scattered light. This is a AdV+ Phase II upgrade project for O5 included in the TDR as CAL.03 deliverable. The BelGrav group is responsible for the upgrade deliverable for O5 and it is coordinated by Hans Van Haevermaet (deliverable responsible, VMD activity responsible). The hardware development will be done at the local BelGrav labs and/or the ETpathfinder R&D facility in Maastricht, the Netherlands. This new calibration technique uses scattered light from the end benches in a controlled way to reconstruct a calibrated detector strain equivalent signal. This can be used to obtain an independent validation of *h(t)* as this method does not rely on induced physical mirror motion. In addition, it allows calibrated strain data at higher frequencies (up to 2 kHz) which is not feasible with Ncal or Pcal injections. We also have obtained experience in VIM and DMS monitoring of the Virgo calibration systems.
- UAntwerpen obtained experience in the construction and commissioning of GW suspension systems, in particular the sensors, actuators, HRTS, and DAQ systems involved. We developed optimised LVDT position sensors and voice coil actuators, and contributed to the commissioning of the ETpathfinder bench suspension sensing and control. We also studied a new type of accelerometer, combining the Rasnik and Watt's linkage concepts, and studied seismic noise background at the LSBB site. This expertise could be useful for the O5 detector upgrade projects and detector characterization.
- At UGent, Daniela Pascucci is working on the development of optical devices for 2 μm optics. The UGent optical lab, currently specialised in 2 μm optics, is planned to be upgraded and 1064 nm optical research will be also carried out.
- At UGent, Christophe Detavernier and Jorden De Bolle are involved in a crystallisation study of Ti:GeO_2 mirror coatings for O5, employing in-situ X-ray diffraction. The group has a long track-record in thin film research for various applications and has ample expertise in X-ray diffraction, scanning electron microscopy, X-ray photoelectron spectroscopy, spectroscopic ellipsometry and various synchrotron-based techniques such as GIWAXS, GISAXS, XAS and PDF.
- Brussels Photonics Team (B-PHOT) from VUB has experience in Frequency Dependent Squeezing (FDS) activities, and Michael Vervaeke and his team on extreme optics have expertise in optics fabrication and metrology with laser-assisted diamond turning, corrective bonnet polishing and ion beam figuring.
- Elise Van den Bossche (VUB, Universiteit Maastricht) is contributing to the

commissioning of Virgo. In particular, she is characterizing the coating of the signal recycling baffle and assisting in the upgrading of the frequency-dependent squeezing subsystem.

3. Description of the Proposed Contribution

Our proposed involvement in VirgoLab would encompass the following potential contributions:

- **Technical Development:** Lead the AdV+ Phase 2 CAL.03 upgrade project. Contributing to the design, development, testing, installation, and commissioning of the new method within the Detector Upgrades project and the Calibration team. This will involve dedicated hardware tests at local BelGrav labs, simulations, (analysis) software development.
- **Technical Development:** Contribute to the commissioning, testing, and operation of the O5 stable signal recycling cavity suspensions within the Detector Upgrades project and the Suspensions Technical Team. This would involve providing person power to help with the commissioning of the new hardware, setting up the control, potentially contributing with optimised sensors and actuators.
- **Instrumentation Support:** Contributing to the monitoring and mitigation of seismic noise within the Detector Commissioning project and relevant Technical Teams (Suspensions, Sensing and Control). This could involve developing monitoring systems (VIM, DMS), and implementing noise reduction strategies.
- **Detector characterization:** Contribution to metrology and qualification of optical elements (B-PHOT) including sub-nanometer roughness evaluation, shape error characterisation with full-field interferometry, evaluation of absorption coatings.
- **Technical Development:** Contribution to FDS activities (B-PHOT, Tatevik Chalyan) by involvement in the subcarrier laser source upgrades, such as the addition of a modulator and other components to optimize the laser source control. Moreover, we will be involved in SQB1 and EQB1 bench upgrades, characterization, and maintenance.
- **Detector characterization:** Contributions to the commissioning of Virgo (Elise Van den Bossche (VUB, Universiteit Maastricht)), in particular to characterize the coating of the signal recycling baffle and assist in the upgrade of the frequency-dependent squeezing subsystem. Experience will be further obtained by participating in commissioning training(s).
- **Technical Development:** Contributing to the design, development, and testing of Ti:GeO_2 and Ti:SiO_2 mirror coatings (UGent) within the Detector Upgrades project and the Optics & Light sources Technical Team. This would involve crystallisation studies with in-situ X-ray diffraction, surface morphology studies with scanning electron microscopy and structural analysis on the atomic level with total X-ray scattering at synchrotron facilities (if beamtime is granted).

We are also open to contributing to other areas based on the evolving needs of VirgoLab and the expertise within our group. We are keen to engage with the existing VirgoLab Technical Teams and Projects to identify areas where our skills and resources can be most effectively utilized.

4. Costs, Calendar and Resources

Initially, our contribution would primarily involve the effort of our existing personnel currently consisting of 11 researchers and 4 engineers with an expected commitment of 4.1 FTE.

We understand that the successful accomplishment of VirgoLab tasks, particularly the timely installation and commissioning of the O5 upgrade, will demand strong and continual presence at EGO site. Our group commits to support that effort as much as reasonably possible.

We anticipate the need for:

- Regular travel to EGO to participate in installation and commissioning activities.
- Access to raw Virgo data to commission and analyse detector performance.
- Local BelGrav infrastructure to conduct dedicated hardware tests.
- Resources to complete the AdV+ Phase 2 CAL.03 upgrade.

We understand that Member Labs are in charge of maintaining and operating the equipment they provide, and we are prepared to discuss the provision of:

- Resources available at B-PHOT to perform optics fabrication and metrology.
- Small optical laboratory in UGent with plans of expansion (subject to funding).
- (In-situ) X-ray diffraction (XRD) for characterisation of mirror coating crystallisation
- X-ray photoelectron spectroscopy (XPS) for chemical analysis of mirror coatings
- Scanning electron microscope (SEM) with energy-dispersive X-ray spectroscopy (EDX) capabilities for analysis of the surface morphology and composition of mirror coatings
- Atomic force microscope (AFM) for microroughness measurements
- Spectroscopic ellipsometry (SE) for wavelengths between 300 nm and 1600 nm for characterisation of refractive index and thickness of mirror coatings.
- Future infrastructure (cleanroom lab) at UAntwerpen with equipment to clean and measure components to study their UHV compatibility, or to host future local experiments that need UHV environments (subject to funding).

as part of a Memorandum of Agreement (MoA).

We are aware that financial resources are allocated by EGO Council, national funding agencies, or research organizations. We will explore potential funding opportunities through our institution and national agencies to support our involvement in VirgoLab.

We are prepared to work towards the establishment of a MoA with EGO should our application be successful.

5. Stakeholders and Requirements

Our primary stakeholders are Universiteit Antwerpen, Universiteit Gent, Vrije Universiteit Brussel and the Flemish funding agency FWO (Fonds Wetenschappelijk Onderzoek).

We understand that as a contributing group, our main requirements would be to have effective communication channels within VirgoLab, opportunities for our members to actively participate in relevant projects and technical teams, and recognition for our contributions to the scientific and technical advancements of Virgo.

We are committed to adhering to the policies and procedures of VirgoLab, including those related to resource allocation and publications.

We are ready to discuss our potential participation further and provide any additional information that may be required. We look forward to the possibility of joining the VirgoLab and contributing to its continued success.

Sincerely,

Prof. Hans Van Haevermaet, Universiteit Antwerpen
On behalf of BelGrav
10 May 2025