Letter of Intent

To: EGO Director - EGO Council Chair - Virgo Spokesperson

Date: 15th of May, 2025

From: Sapienza-Roma group, Piazzale A. Moro 2 , 00185 Roma

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Subject: Expression of Interest to join VirgoLab

Dear Sir/Madam,

This letter serves as a formal expression of interest by Sapienza-Roma group, 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

Sapienza-Roma is a research group of researchers belonging to INFN Sezione di Roma and to Sapienza University of Rome specialized in the construction, operation, data characterization and analysis of Gravitational Wave detectors. In particular the group has expertise in the domain of vacuum and cryogenics, suspensions, vibration isolation technologies and control strategies as well as on the development of data analysis algorithms. Our expertise and ongoing research activities are highly relevant to the operation, commissioning, and potential upgrades of gravitational wave interferometers.

We think there are details about the VirgoLab organization that still need to be completely defined and clarified, and we stress that this letter does not imply any formal commitment.

Nevertheless, we believe that our participation in VirgoLab could 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

Test Mass Suspensions: The development and implementation of the new last stage of the mirror suspension has a great relevance for keeping the thermal noise limit of the Virgo interferometer well below its target sensitivity. This activity primarily aligns with the Mechanics & Vacuum Technical Team.

Suspension Thermal Noise: The suspension thermal noise characterization and optimization is crucial for improving the sensitivity of Virgo in the low frequency range. We have developed and improved our expertise on this item, and we believe it will be useful both for characterizing

the present and the future detectors. This activity is aligned within the frames of the Controls & Simulation Technical Team.

Control: Since the beginning of the scientific adventure of Virgo, we designed and installed the local position control system of the test masses that plays a crucial role in the alignment and operation of the interferometer. This activity aligns with the Sensing & Actuation Technical Team.

Parametric Instabilities: Our research on the mitigation of parametric instabilities is crucial in the context of the Virgo program to increase the light power into the interferometer: in absence of an effective mitigation strategy of this effect the detector would be unstable. The design and implementation of the hardware tools to mitigate the parametric instabilities can be placed in the Optics & Light sources Technical Teams.

Squeezing: We contribute to the development and operation of the squeezing system installed in Virgo: in particular, we have the responsibility of the development and operation of the diagnostic homodyne detector installed in the Frequency Dependent Squeezing system. We are also involved in the upgrades of this system and, in addition, in the R&D activities devoted to developing alternative ways to produce frequency dependent squeezing in absence of additional filter cavities. This activity aligns with the Optics & Light sources Technical Teams. We also contribute to the assembly of the FDS and commissioning for O4.

Coatings: we have expertise in the characterization of coatings. Specifically, recently we have done preliminary AFM and XPS investigation of amorphous GaP samples deposited on silica/silicon deposited by sputtering. XPS measurements of amorphous SiNx coating deposited by LMA were performed. Thermal desorption measurements have also been performed on Ti:GeO2 samples produced by LMA. This activity aligns with the Optics & Light sources Technical Teams.

All these experimental activities fit in the VirgoLab Detector Commissioning and upgrades projects. In addition, we have significant expertise on:

Low latency: we are the main developers of the coherent WaveBurst pipeline for the low-latency analysis. The algorithm has been in place since O1, and since the beginning of O3 it was installed in the Cascina cluster, and then run in online mode for the analysis of real data including the Virgo detector. The analysis generated alerts which have been submitted to GraceDB since O1. This activity fits in the Detector Operations and Maintenance project, in connection with the Computing & Software TT.

Detector characterization: development of algorithms for the characterization of noise in the interferometer's data stream. We have expertise in the identification of noise lines affecting the spectral output of the interferometer. Several years ago we conceived the framework NOEMI, a software originally developed for this purpose and, since that time, we continued contributing to detector characterization activities, especially in relation to noise lines. This activity fits in the Detector Operations and Maintenance project.

Noise hunting: we have started contributing to noise hunting activities during the commissioning of the O4 run, with a particular focus on technical noises from the interferometer infrastructure and environmental noises. As Virgo will progressively reduce its fundamental noises in future upgrades, technical noises will become more and more limiting and more effort

will be needed in this field. This activity fits with the Detector Commissioning project, in connection with the Infrastructure TT.

3. Description of the Proposed Contribution

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

- **[Specify the area of contribution clearly, linking it to VirgoLab Projects and Technical Teams. Examples:]**
    - **Technical Development:** In the context of the Detector Upgrades project, we propose to contribute to the design, development, and testing of:
        - new payloads and their controls, in connection with Mechanics & Vacuum and Sensing & Actuation Technical Teams;
        - parametric instabilities damping system to be integrated in the last stage of mirror suspension, in connection with Optics & Light sources TT;
        - balanced low-noise homodyne detectors for diagnostic control of the squeezed light source and contribution to the R&D on alternative squeezing techniques. In connection with the Optics & Light sources Technical Team.
        - Low-loss Faraday Isolators, already developed, assembled, characterized, and installed on the squeezing FDS system for O4, we will continue with the necessary upgrade for O5.
        - new coating solutions among amorphous oxides, nitrides, semiconductors and multi-materials based on mixtures of these. In connection with Optics & Light sources Technical Team

          All these contributions would involve activities, such as simulation, prototyping, testing at our facilities.
    - **Detector characterization:** contribution to data quality characterization activities in the context of the Detector Operations and Maintenance project. Specifically, contribution to noise line identification effort, development of suitable software tools (upgrades of NoEMi), review of the DQR.
    - **Noise hunting:** contribution, in the context of the Detector Commissioning project, to noise hunting for technical and environmental noises during future commissioning periods, in particular vibrational, acoustic and electromagnetic noises from HVAC devices. In connection with the Infrastructure TT.
    - **Low latency:** contribution to development of coherent WaveBurst-Online, and implementation of the analysis in real time in the Cascina cluster, including the data of all available detectors, to generate alerts which will be submitted to GraceDB. This activity will be carried on in the context of the Detector Operations and Maintenance project, in connection with the Computing & Software TT..

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 10 researchers of our group, with an expected commitment of about 4.8 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, for the people working on payloads and SQZ light, the need of accessing all the laboratories of the Virgo site. In particular we need to access laboratories used for preparation and installations of the payloads and their equipment, placed in the central building, the end and middle arms laboratories, as well as to the towers and the rooms below them. The detection and injection labs access is also requested. The access to the control room is also important. We also need access to the SQZ laboratory in the clean room at 1500W, where we are taking care of the installation of the test facility for an alternative technique to produce frequency-dependent squeezing without the need for additional filter cavities. This facility can also be used for training the new generations that will work on the FDS of VIrgo, as done in the past 10 years.

From the logistic point of view, needing these activities for several days of work, involved people will need an office, with 5 desks at least, and the possibility to access with their own cars on the site. Also the use of the EGO cars to reach the middle and end labs is requested.

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 **payloads, homodyne detectors and related equipment**, 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 INFN - Sezione di Roma and the Department of Physics of Sapienza University of Rome

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,

Dr. Cristiano Palomba

On behalf of Sapienza-Roma group

15th of May, 2025