Memorandum of Understanding
for the Giant Radio Array for Neutrino Detection (GRAND) Collaboration

amended ***

1. **Parties** *(listed in alphabetical order)*

committing themselves to the agreement including the full names, the names of their organisations, and their addresses

A. **Institut d'Astrophysique de Paris (IAP)**
CNRS/INSU et Sorbonne Université, 98 bis boulevard Arago, 75014 Paris, France

B. **Hellenic Open University (HOU)**
Parodos Aristotelous 18, 26335 Patras, Greece

C. **Inter-University Institute For High Energies at the Vrije Universiteit Brussel (IIHE-VUB)**
Vrije Universiteit Brussel, Pleinlaan 2, 1050 Brussels, Belgium

D. **Laboratoire de Physique Nucléaire et des Hautes Énergies (LPNHE)**
CNRS/IN2P3, Sorbonne Université, Université de Paris, 4 place Jussieu 75005 Paris, France

E. **Nanjing University**
163 Xianlin Avenue, 210023, Nanjing, Jiangsu, China

F. **National Astronomical Observatories, Chinese Academy of Sciences (NAOC)**
20A Datun Road, Chaoyang District, Beijing 100101, China

G. **Pennsylvania State University**
Center for Particle and Gravitational Astrophysics, Pennsylvania State University, University Park, PA 16802, USA

H. **Purple Mountain Observatory (PMO)**
Chinese Academy of Sciences (CAS), No.10 Yuanhua Road, Qixia District, Nanjing 210023, China

I. **Radboud University**
Faculty of Science, P.O. Box 9010, 6500 GL Nijmegen, Netherlands

J. **Universidade Federal do Rio de Janeiro**
Av. Pedro Calmon, 550 - Cidade Universitária, Rio de Janeiro - RJ, 21941-901, Brazil

K. **University of Warsaw**
Krakowskie Przedmieście 26/28, 00-927 Warsaw, Poland

L. **Xidian University**
No. 2 South Taibai Road, Xi'an, Shaanxi 710071, China

2. **Preamble**

2.1 A group of institutes known as the GRAND Collaboration, listed in Section 1, are committed to carry out a cooperative effort to develop the GRAND project, a staged approach to realize a next-generation detector primarily designed to detect ultrahigh-energy astroparticles, using a large array of radio antennas.
2.2 The purpose of this Memorandum of Understanding (MoU) is to define the program of work and the distribution of charges and responsibilities between the parties, the organizational and managerial guidelines, and the operation of the experiment.
2.3 While all parties have the firm intention to adhere to the terms of this MoU, it is understood that this document has no legal implications.
2.4 The articles of the MoU cover agreements which are expected to remain valid throughout during the duration of the project. Information which might require more frequent updates is summarized in the Addendum.
2.5 It is understood that the anticipated contributions of each party may be modified, or that additional responsibilities may be taken on by those described in the Addendum.

3. **Contact persons** *(listed in alphabetical order)*

Reference persons from each party committed to the GRAND project are expected to be:

Name	**Institute**	**Position**
Sijbrand de Jong	Radboud University, IMAPP	Professor
João Torres de Mello Neto	Universidade Federal do Rio de Janeiro	Professor
Krijn de Vries	IIHE-VUB	Professor
Kumiko Kotera	IAP	Researcher
Antonios Leisos	HOU	Professor
Olivier Martineau	LPNHE	Professor
Miguel Mostafa	Penn State University	Professor
Lech Wiktor Piotrowski	University of Warsaw	Researcher
Xiangyu Wang	Nanjing University	Professor
Xiang-Ping Wu	CAS, NAOC	Professor
Pengfei Zhang	Xidian University	Professor
Yi Zhang	CAS, Purple Mountain Observatory	Professor

New participants may become Party to this MoU by consensual agreement by the MoU Parties and after signing of this MoU. MoU Parties may leave the GRAND Collaboration at any time without any legal or financial penalty.

4. **Data use and access**

The data resulting from the common efforts of the Parties in this MoU are available to all Parties and will be made available in open access at a date or dates to be determined by the Parties. The collected data will be used for scientific and educational purposes only.

5. **Terms**

The Memorandum of Understanding is effective upon being signed by the Parties. Its duration is set to five years. The Parties may, by amendment, choose (i) to extend the Understanding at any time during the term or (ii) no later than one year prior to the end of its duration, to shorten the duration.

This MoU does not constitute a legal contractual obligation for either of the parties. It reflects an arrangement that is currently satisfactory to the parties involved. The parties agree to negotiate additional amendments to this memorandum as required to meet the evolving nature of the R&D program and GRAND.

Signatures

The following persons concur in the terms of this Memorandum of Understanding. These terms will be updated as appropriate in Amendments to this Memorandum.

For Hellenic Open University

Ioannis Kalavrouziotis, President of the Governing Committee — date

For Institut d'Astrophysique de Paris (INSU/CNRS)

François Bouchet, Director — Jan 28th 2023 — date

For Inter-University Institute for High Energies at the Vrije Universiteit Brussel

Jorgen D'Hondt, Director — 07/02/2023 — date

For Laboratoire de Physique Nucléaire et des Hautes Énergies (IN2P3/CNRS)

Marco Zito, Director — 10/2/2023 — date

For Nanjing University

Xiangdong Li, Director — date

For National Astronomical Observatories, Chinese Academy of Sciences

Jin Chang, Director — date

For Pennsylvania State University

Tracy Langkilde, Verne M. Willaman Dean of the Eberly College of Science — date

For Purple Mountain Observatory

Changyin Zhao, Director — date

For Radboud University

Eric Cator, Chair of IMAPP — date

For Universidade Federal do Rio de Janeiro

Amaury Fernandes da Silva Junior

Assinado de forma digital por Amaury Fernandes da Silva Junior
Dados: 2023.01.19 15:47:03 -03'00'

Denise Carvalho, Rectrix — date

For University of Warsaw

PROREKTOR
UNIWERSYTETU WARSZAWSKIEGO
prof. dr hab. Sambor Grucza

31 STY. 2023

Sambor Grucza, Vice-Rector for Cooperation and Human Resources — date

For Xidian University

Zongkai Yang, President — date

Addendum

1. **The GRAND Project**

a. Roadmap

A staged construction plan ensures that key techniques are progressively validated, while simultaneously achieving important science goals in astroparticle physics, radioastronomy, and cosmology, early during construction. We highlight below some of the key steps that will lead to the completion of the GRAND project.

Protyping: GRANDProto300 will be an array of 300 antennas deployed over 200 km^2, which should trigger on radio signals independently from any other technique. The radio array will be complemented by a ground array of muon detectors. The hybrid measurements will enable to get novel information on cosmic rays and associated air-shower physics in the $10^{16.5\text{-}18}$ eV energy range. It will also search for radio-transient sources, such as Giant Radio Pulses from pulsars.

First sub-array: GRAND10k will be the first hotspot of 10000 antennas of GRAND, which will serve as a testbench for all challenges related to very large arrays, including communication, data transfer, maintenance etc. It will be in good position to detect the first ultra-high-energy neutrinos.

Full array: About 20 sub-arrays of 10k antennas will be deployed worldwide to constitute the full 200'000-antenna GRAND. All the hotspots are foreseen to be replicas of the optimized setup of GRAND10k, with an industrial approach for the production of all units. This stage should enable to reach adequate sensitivity to perform neutrino astronomy in the 2030s.

b. Agreed activities that each party intends to contribute to the project:

Hellenic Open University (HOU) : The Physics Laboratory of HOU has long experience in neutrino telescopes (NESTOR, KM3NeT) and cosmic ray physics (ASTRONEU). The group members will contribute to the data analysis pipeline development, including simulation libraries and undertaking data challenges for software development. The related infrastructure and especially the computing power of the Physics Laboratory will be used primarily by the GRAND collaboration for simulation studies and data analysis.

Institut d'Astrophysique de Paris (IAP) : The institute has played a key role in the definition and development of the GRAND project. It hosts a large team for simulation, reconstruction and data analysis. Crucial elements of the data analysis software have been developed at IAP, including fast radio-signal calculation and event reconstruction methods. IAP will continue to play a major role in these aspects. The institute also hosts Science Case expertise on high-energy astroparticles and has a leading role in the organization and construction of the collaboration.

Inter-University Institute For High Energies at Vrije Universiteit Brussels (IIHE-VUB) : The VUB group of the IIHE has a strong experience in radio signal simulations and reconstruction. The group will work on simulations of radio signals from very inclined air-

showers and understanding these signals. This can subsequently be applied to the development of advanced reconstruction algorithms that can be tested and optimized using both trigger-level as well as higher level data. A good and fast reconstruction is also crucial for sending out alerts to the community for the most interesting neutrino events. Therefore once GRAND is in neutrino detection mode, the IIHE-VUB group will also be involved in setting up an automated alert system to inform the community of the most promising neutrino events.

Laboratoire de Physique Nucléaire et des Hautes Énergies (LPNHE): LPNHE has played a key role in the development of the GRAND project, through its participation in the seed experiment TREND, and the definition of the GRAND project. It has played a key role in the development of methods for the identification of radio signals from air showers and event reconstruction. LPNHE will maintain its implication in these fields and will work at developing advanced methods for trigger and online signal identification.

Nanjing University: The group has experience in astroparticle physics theory and gamma-/X-ray data analysis (Fermi, Swift, etc.). The group will work on air-shower simulations to optimize the detector configuration and phenomenological studies on the science case. The group has internal funding for post-docs and graduate students to work on GRAND.

Nationaal Instituut voor Kernfysica en Hoge Energie Fysica (Nikhef)/Radboud University: Nikhef and the Radboud University have a long history in the hardware development and analysis of radio detection of cosmic rays. The institutes are leading in the AERA experiment as well as in the ongoing radio upgrade of the Pierre Auger Observatory. The group is leading the electronics development of GRANDProto300 and are involved in the surveys of possible sites for GRAND hotspots. In addition, the team takes a leading role in the management of GRAND.

National Astronomical Observatories, Chinese Academy of Sciences (NAOC): The institute has successfully operated the largest low-frequency radio array in China, 21CMA, for 17 years and hosted the GRAND pathfinders, TREND and GRANDProto35, in past years. NAOC has constructed and also operates a wide variety of major astronomical facilities in China such as LAMOST and FAST, and is one of the world-leading institutes in astrophysics research. The institute has been actively involved in the site selection and pre-construction of GRANDProto300 and will play essential roles in coordination of site management and government support during GRANDProto300.

Pennsylvania State University: The Penn State group has both theory and experimental faculty. The group will work on air-shower simulations to optimize the detector configuration and phenomenological studies on the science case. The latter includes the demonstration of expected signals and the feasibility of discriminating among theoretical models for astrophysical neutrinos and UHECRs. The group will also take leadership of the surface detector for GRANDProto300. This includes the design, construction, deployment, and operation of muon counters. The group has experience in astroparticle physics theory and experiment (Auger, HAWC, CREAM, etc.).

Purple Mountain Observatory (PMO): The PMO group has long history in the hardware development and data analysis in the cosmic ray experiments (ATIC, DAMPE, LHAASO), and has both theoretical and experimental expertise. PMO will be the host institute of GRANDProto300 in China. The group is leading the surveys of possible sites of

GRANDProto300, and will lead the design, deployment and operation of the GRANDProto300 array. The group will play major role in the design and deployment of the DAQ system for GRANDProto300. The group will also work on simulations to optimize the detector configuration, reconstruction for air-showers and on the science case.

Universidade Federal do Rio de Janeiro: The Physics Institute group and collaborators from the State of Rio de Janeiro institutions will provide manpower for simulation of the experiment, data analysis techniques and phenomenology studies. The group members have considerable expertise in astroparticle physics from previous experiments. Two supercomputing centers in Rio de Janeiro can be used in shared basis by the GRAND collaboration. The group has funding for post-docs and graduate students to work in GRAND.

University of Warsaw: The University of Warsaw has a long history of research in particle and astroparticle physics. The group will focus on event selection, reconstruction of air-shower parameters and software for the GRAND experiment. The group has external funding for post-docs.

Xidian University: The National Key Laboratory of Science and Technology on Antenna and Microwave at Xidian University has a long-standing history and expertise in antenna and radio-frequency (RF) system design and electromagnetic radiation and propagation analysis, and is one of the important parties of the FAST experiment. Researchers in Xidian University will play a major role in the RF system design and hardware construction of GRANDProto300, in particular the antenna design and the RF chain simulation and calibration. The group is also involved in the surveys of possible sites for GP300 and GRAND in China.

There are no penalties or repercussions for any of these groups in the case(s) where -for any reason(s)- they are not able to contribute to the tasks described above.

1. **GRAND management and organisation**

    a. Global organization

The Collaboration Board is the oversight body concerned with scientific and technical aspects of the Collaboration and the GRAND project. It deals with issues including governance of the Collaboration, scientific policy, new members and institutions, publication policy and monitoring the operation of each of the stages of GRAND to ensure that the scientific objectives are being met. The members of the Collaboration Board are appointed by their home institutions among the scientists participating in GRAND. The number of appointed representatives should reflect the number of members in the collaboration belonging to each institute. Decisions will be made by consensus or by vote. Before the signing of this International Agreement, the GRAND Core Team has prepared the collaboration forming process and has served as the Collaboration Board.

The Financial board will oversee the budget and expenses of the collaboration. It will be constituted of representatives of the funding entities.

The GRAND Collaboration is represented by 3 co-Spokespersons: Kumiko Kotera (IAP), Olivier Martineau (LPNHE, France) and Xiang-Ping Wu (NAOC).

Project Manager. The GRAND project is managed by the Project Manager: Charles Timmermans (Nikhef).

Tasks Groups and Coordinators. The design, construction and operation of the detector and the analysis of data shall be divided into tasks, which are to a significant extent self-contained. The Collaboration Board will establish Task Groups (TGs) to handle these tasks, and appoint a Coordinator for each of these TG in agreement with the Spokespersons, the Project Manager, and the representatives of the institutes involved in the TG.

The Site manager is elected by the Collaboration board. He is responsible for status of GRAND site infrastructure, habitation of participance and transports.

b. Meetings

The Board holds meeting calls every one or two months to discuss strategical steps and take decisions.

General GRAND meeting calls are held regularly (typically monthly). Updates are made on progress on the project from scientific, technical, communication, administrative and political aspects. Working groups present results and on-going work.

The Collaboration holds meetings once or twice per year in order to discuss the progress and assess the next steps to undertake.

c. Equipment Installation and Coordination

The installation of equipment on a GRAND-site is coordinated by the host institute. The host institute will deal with legal matters concerning land access and import and output of equipment.

c. Software and Data

Collaborative software developed within GRAND, and for GRAND, will be publicly distributed under an OSI approved license with "the GRAND collaboration" as copyright owner, i.e. the Institutes of the MoU parties. Affiliated software development will be licensed according to the authors wills and usual rights. A software can be considered to be "Collaborative" if and only if all of its authors agree.

Experimental data as well as collaborative utilities are available without restrictions to all participating institutes and members of the collaboration. It is expected that institutes providing a detector component will also provide the necessary software tools to format, calibrate, monitor and analyze the data from this component, unless otherwise agreed upon.

d. Results and Publications

Physics results presented in papers, conference contributions, seminars, and contacts with the media need to be presented to, and agreed upon by the collaboration prior to public presentation. Publications including unpublished results of the experiment have to be made available to all collaboration members well before submission. A Publication Committee has been established which (i) accompanies the preparation of publications and which needs to approve the submission of papers and (ii) coordinates the presentation of results at Conferences etc.

Prior to the first publications concerning instrumental or scientific results, the collaboration board will define a policy concerning authorship. Apart from waiting periods for new members, all active collaboration members should be entitled for authorship on publications presenting physics results.

Any collaborator(s) will be able to publish their own work if for any reason(s) the Publication Committee does not approve their study. In those situations the following language must be included in the publication: “Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not reflect the views of the GRAND Collaboration.”

e. Carbon Code of Conduct

The Collaboration will endeavor to minimize its impact on the environment by setting up a GRAND Green Policy. A committee will evaluate the impact of GRAND's collaboration meetings, hardware, computing resources, buildings etc. on the environment. It will work on establishing a set of policies that enable efficient scientific collaboration while reducing the impact on the planet.