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Proposed Scientific Research Programme Planning Group

Antarctic Geospace and ATmosphere reseArch AGATA

Report Authors

Lucilla Alfonsi (Italy), Nicolas Bergeot (Belgium), core membership

Summary

This document outlines the proposal for establishing a Programme Planning Group for developing a SCAR Scientific Research Programme (SRP) provisionally entitled “Antarctic Geospace and ATmosphere reseArch” (AGATA). The proposed SRP will contribute to answering the outstanding scientific questions within atmospheric and space physics, namely:

(i) How are different atmospheric layers coupled in the polar regions?

(ii) How does the upper polar atmosphere respond to increased geomagnetic activity, including energy transfer from space into the ionosphere?

(iii) How can we improve the understanding of the Antarctic atmosphere by radio signals from the GNSS or other satellites, and from ground based radars?

Answering these questions will not only have implications on the understanding of processes in the polar atmosphere, but it will also greatly improve our understanding of the global atmospheric dynamics, thus contributing to the development of large-scale whole atmosphere and climate models.

The proposed SRP will bring together communities that investigate the polar atmosphere and geospace, with a particular focus on Antarctica, but also with a bi-polar perspective. AGATA will be a coordinated, worldwide effort to monitor, investigate and better understand the physics of the polar atmosphere and the impact of the Sun-Earth interactions on the polar regions. AGATA will take advantage of existing and planned instrumentation in Antarctica, but also in the Arctic and satellite-based observations, and it will aim for coordinated research efforts and data exchange. A bi-polar perspective will allow to study significant interhemispheric asymmetries in the atmospheric response observed in the polar regions. Finally, AGATA will also be important for sciences that depend on the removal and mitigation of negative effects of the atmosphere on their observations (such as astrophysics). It will also be important for science activities and logistic operations that rely on precise positioning and satellite navigation, because radio signals, such as GPS, Galileo, GLONASS, or BeiDou can be severely impacted by structures in the ionosphere (i.e., ionised part of the atmosphere).

It is worth emphasizing that the objectives of the proposed SRP are directly relevant to the following open questions identified by *1st SCAR Antarctic and Southern Ocean Science Horizon Scan*:

- *Open Question # 71 "What are the differences in the inter-hemispheric conjugacy between the ionosphere and that in the lower, middle and upper atmospheres, and what causes those differences?"*
- *Open Question # 72 "How does space weather influence the polar ionosphere and what are the wider implications for the global atmosphere?".*
- *Open Question # 73 "How do the generation, propagation, variability and climatology of atmospheric waves affect atmospheric processes over Antarctica and the Southern Ocean?".*

AGATA objectives also address the priorities identified by Kennicut et al. (2014) and the concluding statement of the SCAR Strategic Plan 2017-2022.

SCAR is the most suitable platform to establish the necessary environment to assess the current understanding of the Antarctic atmosphere and geospace, and to initiate coordinated efforts to fill the knowledge gaps. AGATA would also support other communities, such as astronomers and geodesists, providing competencies of mutual benefit to conduct the respective research. AGATA SRP aims to take advantage of the experience of the SCAR Expert Group GRAPE (GNSS Research and Application for Polar Environment) that successfully experienced the exploitation of a multidisciplinary environment. AGATA will build upon the legacy of GRAPE by enhancing the interactions between the scientists who study the atmosphere, ionosphere (i.e., the ionized part of the upper atmosphere), solid earth, and outer space. It also refers to the ICESTAR (previous SCAR SRP) heritage. AGATA aims to bring the **AAA** EG (past SRP) close to the Physical Sciences Group to facilitate the interaction between researchers in the fields of Astronomy, Astrophysics, Atmosphere and Ionosphere. Moreover, as AGATA includes the investigation of the coupling between the neutral and ionized atmosphere, its outcomes could be of interest also for other SRPs, like AntClimNow. In this context of vertical coupling, the ANGWIN Action Group is also of strong relevance for AGATA.

AGATA will fill the current gap of SRPs dedicated to the study of the whole polar atmosphere, including the upper atmosphere and the solar-terrestrial relationships.

As the **multidisciplinary** and **multi-instrumental** nature of the proposed SRP, AGATA is a **joint Physical Sciences and Geosciences initiative**. This is reflected in the Core Membership composition.

The Core Membership includes early career scientists and sees a good gender balance (women scientists about 40%). The Planning Group will pose particular attention to attract young scientists and to endorsing inclusivity and diversity in its composition.

For the Research Programme Planning Group, the initial Chief Officers will be Lucilla Alfonsi (Italy) and Nicolas Bergeot (Belgium). Proposed initial core membership includes 29 members from 18 countries, representing physical sciences and geosciences.

During the pandemic period, this community, even if not officially recognised by SCAR, started a fruitful collaboration, also taking the opportunity offered by the GRAPE workshop, held fully online, in July 2020 (http://www.grape.scar.org/index.php/conferences/16-conference-grape). From the collaboration was born the initiative to publish a white paper on polar atmosphere and geospace (http://www.grape.scar.org/index.php/conferences/16-conference-grape) and the submission of a review paper authored by about 40 scientists and titled "Review of environmental monitoring by means of radio waves in the (Ant)Arctic:

from atmosphere to geospace", currently under minor revisions for publication on *Survey in Geophysics*.

Recommendation

Delegates are asked to consider the proposal and decide whether to approve the Programme Planning Group Proposal.

Summary Budget 2022-2024

	2022	2023	2024
	Request	Request	Request
US $	5000	10000	10000

Summary of funds usage and desired results

Requested funds will be used to support travel and subsistence expenses of early-stage researchers.

2022: Establish work plan among Chief Officers and core group meeting.

2023: Meeting to finalise the draft of the SRP Science and Implementation Plan and to partially support the dissemination of the proposed SRP to attract new members.

2024: Meeting at SCAR OSC 2024 to initiate the SRP and draw in additional members.

Scientific Research Programme Title

Antarctic Geospace and ATmosphere reseArch

Scientific Research Programme Acronym

AGATA

Proposed Scientific Research Programme Outline

The AGATA SRP aims to significantly advance the current knowledge of the Antarctic atmosphere and geospace, also in the bi-polar, interhemispheric context. AGATA SRP will contribute to answering the outstanding scientific questions within atmospheric and space physics:

(i) How are different atmospheric layers coupled in the polar regions?

(ii) How does the upper polar atmosphere respond to increased geomagnetic activity, including energy transfer from space into the ionosphere?

(iii) How can we improve the understanding of the Antarctic atmosphere by radio signals from the GNSS or other satellites, and from ground-based radars?

These questions will be addressed with a multi-disciplinary and multi-instruments approach, and by bringing together communities that investigate the polar atmosphere and geospace. AGATA will take advantage of existing and planned instrumentation in Antarctica, but also in the Arctic and satellite-based observations, and it will aim for coordinated research efforts and data exchange. While the understanding of physics of the neutral and ionized atmosphere has been significantly improved using both ground-based and space-based radio soundings, the questions that remain open, need to be addressed with a synergistic approach. This requires active involvement of various research groups in the field.

Since 2012, the GRAPE Expert Group has been an example of how a synergy among the Antarctic sciences can be applied to gathering important scientific data for several applications from GNSS measurements. AGATA aims to further extend the actions of the GRAPE Expert Group to a broader community that interacts not only with experts dealing with the neutral atmosphere, the ionized atmosphere and the plasmasphere, but also with astronomers and astrophysicists in a common framework. This framework would facilitate a fruitful exchange on what they consider atmospheric noise and what the AGATA proposers consider atmospheric information. Such ambition is also in agreement with the AAA objective that reads “Improved coordination with atmospheric and ionospheric researchers”. Another aspect would be a contribution to all other sciences and field operations that rely on the quality of radio signals, such as GNSS for navigation and precise positioning (systems such as GPS, Galileo, GLONASS, or BeiDou can be affected by the irregularities in the ionosphere). Coordinated network of GNSS measurements would contribute to future space weather forecasting services in the polar regions.

AGATA aspires to such common goal and addresses the outstanding questions by pursuing three main scientific objectives:

- To monitor and investigate the polar atmosphere, in order to better understand the governing physical processes including the coupling between different atmospheric layers and to the magnetosphere;
- To contribute to the understanding of the Sun-Earth interactions and the energy transfer into the upper polar atmosphere (i.e., ionosphere) through these interactions;

- To support the sciences interested in removing or mitigating the atmospheric contribution negatively affecting their observations and provide information on disturbances in received radio signals due to ionospheric structuring.

These objectives address the following open questions identified by *1st SCAR Antarctic and Southern Ocean Science Horizon Scan*:

- *Open Question # 71 "What are the differences in the inter-hemispheric conjugacy between the ionosphere and that in the lower, middle and upper atmospheres, and what causes those differences?"*
- *Open Question # 72 "How does space weather influence the polar ionosphere and what are the wider implications for the global atmosphere?".*
- *Open Question # 73 "How do the generation, propagation, variability and climatology of atmospheric waves affect atmospheric processes over Antarctica and the Southern Ocean?".*

AGATA objectives address also the priorities identified by Kennicut et al. (2014) and the concluding statement of the SCAR Strategic Plan 2017-2022.

In this framework AGATA can provide valuable results to advance the current state of the art. To better explain how the AGATA community can contribute to address the aforementioned questions, here follows a schematic, not exhaustive but illustrative, description of the advantages offered by AGATA.

Open questions and priorities	**AGATA contribution**
What are the differences in the inter-hemispheric conjugacy between the ionosphere and that in the lower, middle and upper atmospheres, and what causes those differences? *Horizon Scan #71*	AGATA includes competencies of the lower and upper atmosphere with a bipolar perspective, with a number of observatories and experiments taking place in the Arctic and in Antarctica, and with expertise on satellite data.
"How does space weather influence the polar ionosphere and what are the wider implications for the global atmosphere?" *Horizon Scan # 72*	AGATA includes outstanding competencies on forecasting and nowcasting modelling based on ground- and space-based observations of the space weather effects on the polar ionosphere. The high latitude ionosphere is considered a sentinel of the impact at global scale.
"How do the generation, propagation, variability and climatology of atmospheric waves affect atmospheric processes over Antarctica and the Southern Ocean?" *Horizon Scan # 73*	AGATA gathers specialists on lower and upper atmosphere making easier to work in synergy on the assessment of the regional variability and climatology of the different layers, including the coupling among the ionized and the neutral atmosphere.
"International collaboration is essential to expanding our understanding of these linkages, as well as to our use of Antarctica as a platform for astronomy and for observing Earth's outer atmosphere, the behaviour of the magnetosphere, outer space, and sun-earth	AGATA gathers the excellence of the space weather specialists operating in Antarctica with a deep knowledge of the solar wind-magnetosphere-ionosphere-thermosphere coupling. Such expertise is a valuable support for radioastronomers, providing them a regional

interactions." (SCAR Strategic Plan 2017-2022) «*Work together […] Coordinated international efforts that engage diverse stakeholders will be crucial."* (Kennicut et al., 2014)	assessment of the ionospheric noise disturbing their measurements, and for researchers operating their experiments in the radio spectrum (e.g. Synthetic Aperture Radars, GNSS reflectometry, etc,). AGATA includes also lower atmosphere scientists, experts on water vapour regional modelling, another potential benefit to minimise the atmospheric noise to astronomy observations. The multidisciplinary composition of AGATA facilitates the collaborations. AGATA can facilitate the interaction among these communities and can contribute to promote common initiative for multi-disciplinary exploitation of the data.

To achieve these aims AGATA will:

- Invite scientists working on the study of the atmosphere, the plasmasphere and the geospace at polar latitudes to join the programme. Special attention will be extended to scientists coming from countries that currently have low or nonexistent activity in SCAR;
- Encourage the interaction between different scientific communities, e.g., between astronomers, geodesists and atmospheric scientists to share needs, strategies,
- competencies and data;
- Coordinate common actions to identify best practices to maximize the exchange of data, information, models, algorithms and other resources among the represented communities;
- Facilitate the mobility and the sharing of students and early-career scientists by offering them a stimulating multidisciplinary environment in which to train;
- Stimulate joint initiatives aimed at setting up international collaborative projects;
- Propose activities for capacity building, outreach, training and dissemination activities of information about Antarctic Science.

Background - foundational knowledge

The idea to create AGATA as a focused programme was born within the GRAPE (GNSS Research and Application for Polar Environment) community. GRAPE is an on-going joint GeoSciences and Physical Sciences SCAR Expert Group established in 2012. The International Polar Year (IPY) and International Heliophysical Year (IHY) initiatives left an important heritage in terms of data sharing, expertise exchange and increasing awareness of the current scientific capabilities in the physical sciences and in geosciences. In particular, the GPS for Weather and Space Weather Forecast (GWSWF) SCAR Action Group took advantage of the Interhemispheric Conjugacy Effects in Solar-Terrestrial and Aeronomy Research (ICESTAR) and the Polar Earth Observing Network (POLENET) experiences that led to the creation of working groups on specific themes, such as the use of geodetic data to study weather and space weather events. The GRAPE Expert group continued the initiative of the Action Group GWSWF, intensifying the efforts to build a robust network of collaborations in order to answer a variety of space weather related needs through ad hoc data sharing and model development. In this framework, GRAPE has been successful in creating and maintaining distributed networks of specialized GPS/GNSS (Global Navigation

Satellite Systems) Ionospheric Scintillation and TEC Monitors at high latitudes, and in enhancing the interaction between GeoSciences and Physical Sciences to optimize the scientific use of GNSS at polar latitudes. Thanks to GRAPE, the space weather and the tropospheric communities established contacts to share expertise and data. Another significant goal achieved by GRAPE has been the interaction with the SERCE SRP to exploit the POLENET data, for their mutual benefit.

The efforts of GRAPE and the results obtained have also been acknowledged by URSI (International Union on Radio Science) through the appointing of the GRAPE coordinator, Dr. Giorgiana De Franceschi, in 2014 as the URSI delegate to SCAR. This endorses the need to further strengthen the link between URSI and SCAR that could be fostered by AGATA **extending collaborations across a wide field of disciplines**.

Hence, the need to propose AGATA is a natural consequence of the progress GRAPE has made and derives from the **urgent need for a SCAR SRP dedicated to the study of the ionized and neutral atmosphere and the Sun-Earth relationship, for which Antarctica provides a unique vantage point.**

Synergies with other Programmes

The AGATA SRP is proposed by the teams involved in the GRAPE Expert Group, inheriting the GRAPE links with SERCE SRP. The AGATA proposers are also involved in the activities of the AAA (Astronomy & Astrophysics from Antarctica) EG (past SRP). Other SCAR initiatives, such as ANGWIN AG or AntClimNow SRP would also benefit from the activities within AGATA SRP.

As the URSI (International Union on Radio Science) endorsement of GRAPE, AGATA will act as a link with the radio science communities at large, also thanks to the URSI delegate to SCAR that is part of the AGATA core group. In the AGATA core group there is a SCAR representative at SCOSTEP Bureau (Scientific Committee on Solar-Terrestrial Physics) and there are members of SCOSTEP and IAG (International Association of Geodesy) who can facilitate the interactions with these interdisciplinary bodies. Moreover, SCAR recently appointed its representative to COSPAR (Committee on Space Research) who is also involved in the AGATA core group, facilitating the communications and interaction between the two communities regarding the Earth's outer space.

The objectives of AGATA could contribute to the action of the AntClim SRP by providing the evaluation of the atmospheric impact on measurements that derive information such as the glacier displacement or the water vapour atmospheric content. Both these factors contribute to the assessment of climate change (also reported at official level as, for instance, in the case of IPCC). At the same time, the rigorous monitoring and study of the ionosphere-magnetosphere-solar wind coupling that is crucial to developing reliable space weather services, are required by modern society (COSPAR and ILWS road map). At high latitudes, the ionospheric response to geospace perturbation is considered a sentinel of the global space weather effects and some peculiar perturbations can significantly affect the communication and navigation systems and thus field operations. In this frame, the AGATA actions and expected outcomes will also benefit the WMO Operating Plan to address enhanced capabilities to observe, monitor, exchange data, produce and disseminate high-quality information and use integrated and interoperable surface and space-based observation systems for weather, climate and space weather observations.

Capacity building, education, and training plan

The AGATA's proposers have a wide experience in education and public outreach of polar sciences. This will guarantee a proper dissemination of the project to attract both the public and students to pay attention to the AGATA topics.

AGATA will liaise with National Antarctic Programmes to promote outreach initiatives, endorsing didactic labs and theses. The SRP will also encourage the academic entities to include the AGATA themes in their courses.

AGATA will support the next generation of Antarctic scientists by encouraging young researchers to participate in AGATA meetings and workshops by offering, within the constraints of budget limitations, bursaries for travel and subsistence. The condition of each bursary will be a report by the bursary holder about their research and workshop experiences, which will be posted on the AGATA website.

AGATA will collaborate with young students (18-25 years) and with the Association of Polar Early Career Scientists (APECS) to create and manage, under its supervision, the link to the most popular social networks.

The AGATA initiatives in dissemination, capacity building and training will endorse inclusivity and diversity.

Proposed (Initial) Chief Officers

Lucilla Alfonsi (Italy), Nicolas Bergeot (Belgium)

Proposed Core Membership

The Core membership attempts to cover the broad variety of expertise needed to accomplish the AGATA expected results. We are fully aware that further engagement is required with a broader range of researchers to ensure the adequate representation of SCAR member countries and to address a gender balance. In that context, the core members, from now on and during the Planning Group lifetime will disseminate the proposal to maximize participation. In this context, we rely also on SCAR Delegates to disseminate this proposal among their relevant networks and ask anyone interested in participating to contact any member of the AGATA Programme Planning Group. The current Core Members who have expressed their commitment to join the Programme Planning Group through their expression of interest letters (accessible here) are listed in the table below.

Proposed Core Membership of the AGATA Project Planning Group			
Name	**Country**	**Discipline**	**Institution**
Adriana Gulisano	Argentina	Cosmic Rays	National Scientific and Technical Research Council - Universidad de Buenos Aires
Fabien Darrouzet	Belgium	Plasmasphere physics	Royal Belgian Institute for Space Aeronomy (BIRA-IASB)
Eric Pottiaux	Belgium	Atmosphere Physics	Royal Observatory of Belgium
Roeland Van Malderen	Belgium	Atmosphere Physics	Royal Meteorological Institute
Emilia Correia	Brazil	Upper Atmosphere Physics/Space Weather	Instituto Nacional de Pesquisas Espaciais, Universidade Presbiteriana Mackenzie
P. T. Jayachandran	Canada	Upper Atmosphere Physics/Space Weather	University of New Brunswick
Guozhu Li	China	Upper Atmosphere Physics	Institute of Geology and Geophysics, Chinese Academy of Sciences
PR Shreedevi*	Japan	Upper Atmosphere Physics/Space Weather	Institute of Space Earth Environment Research, Nagoya University
Kirsti Kauristie	Finland	Middle-upper atmosphere Physics	Finnish Meteorological Institute
Liliana Macotela*	UK	Upper Atmosphere Physics	University of Bath
Jean Lilensten	France	Middle-upper atmosphere physics	IPAG/CNRS/UGA
Georg Heygster	Germany	Atmosphere Physics	University of Bremen
Tanja Fromm	Germany	Geomagnetism	Alfred Wegener Institut
Janos Lichtenberger	Hungary	Plasma physics	Eötvös University
Giorgiana De Franceschi	Italy	Upper Atmosphere Physics/Space Weather	Istituto Nazionale di Geofisica e Vulcanologia
Federica Marcucci	Italy	Upper Atmosphere Physics	Istituto Nazionale di Astrofisica
Monia Negusini	Italy	Atmosphere Physics	Istituto Nazionale di Astrofisica
Changsup Lee*	Korea	Upper Atmosphere Physics	Korean Polar Research Institute
Wojciech J. Miloch	Norway	Upper Atmosphere Physics/Space Weather	University of Oslo
Irina Zakharenkova	Russia	Upper Atmosphere Physics/Space Weather	Russian Academy of Sciences
Pierre Cilliers	South Africa	Space Weather/Geomagnetism	South African National Space Agency
Michael Kosch	South Africa	Middle-upper atmosphere Physics	South Africa National Space Agency
Stefan Lotz*	South Africa	Middle-upper atmosphere Physics/Space Weather	South African National Space Agency

Carl-Fredrik Enell	Sweden	Upper Atmosphere Physics	EISCAT Scientific Association
Mark Clilverd	UK	Upper Atmosphere	British Antarctic Survey
Andriy Zalizovski	Ukraine	Upper Atmosphere	Institute of Radio Astronomy, National Academy of Sciences
Iurii Cherniak	USA	Upper Atmosphere Physics/Space Weather	University Corporation for Atmospheric Research
Jade Morton	USA	Upper Atmosphere Physics	University of Colorado
Shasha Zou	USA	Upper Atmosphere Physics	University of Michigan

* Early Stage Researcher