ROYAL BELGIAN INSTITUTE FOR SPACE AERONOMY (BIRA-IASB)

ANNUAL REPORT 2019-2020

"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."

Louis Pasteur

COLOPHON

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MARTINE DE MAZIÈRE
DIRECTOR GENERAL A.I.

“It is important that we continue to offer our staff favourable and enriching perspectives in the future and that the conditions are created to efficiently attract and use additional people and resources to respond to the scientific challenges.”

Preface

It will not come as a surprise if a retrospective of the years 2019 and 2020 seems overshadowed by the corona pandemic that struck Belgium from mid-February 2020, and which we are still suffering from in 2021. This global crisis has left deep wounds in the lives of some of us, it has shown our vulnerability, but also our resilience and the importance of scientific knowledge in supporting political decisions, among others. It will also influence our way of working and living in the future.

The Royal Belgian Institute for Space Aeronomy has dealt with the crisis by adapting to a more digital and remote working environment, with its advantages and disadvantages. I think we have also realised how important it is to meet colleagues at the office, and to be able to talk to each other freely and casually. Going digital and teleworking may be goals for the future, but they must not come at the expense of the social contacts we need as human beings.

On the scientific front, BIRA-IASB has performed wonderfully over the past two years, despite the corona pandemic in 2020. Ongoing space missions and research projects continued, and new initiatives were launched; the Benelux network for the radio detection of meteors, BRAMS, was further renewed and expanded, and a new associated STEM project with a Citizen Science component (MOMSTER) was started. It is mainly the ground experiments abroad that have suffered from the travelling ban, as it prevented us from installing, maintaining or repairing instruments.

The crisis also brought about a global experiment for the environment and the atmosphere: just as human activities have a footprint on our environment, including the atmosphere, so the variety of lockdown measures in different countries has left its mark on the atmosphere. BIRA-IASB scientists investigated the impact of the crisis on the atmosphere and the climate, and were able to observe a temporary reduction in man-made pollutants, as well as a bluer sky due, among other things, to the reduction in air traffic.

While air traffic decreased significantly, internet traffic increased enormously: how both influence CO_2 emissions and other climate variables is a fascinating subject for research.

The scientific contributions to the corona policy, the development of

vaccines and the rapid pace of research into the impact of the lockdown measures on our living environment once again demonstrate the importance of fundamental research: it is thanks to continuous investment in fundamental research that an unexpected crisis such as the one we are currently experiencing can quickly count on scientifically substantiated answers.

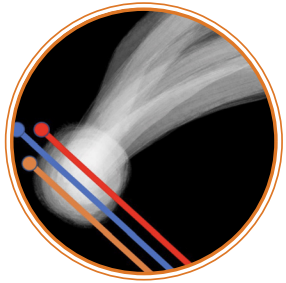
Thanks to the continuity and even slight growth in BIRA-IASB's scientific activities, we can fortunately also state that BIRA-IASB's staff numbers have not decreased in the last two years: our external income has guaranteed this. Nevertheless, it is regrettable that the structural financing by the federal government is evolving in the opposite direction.

But there are hopeful signs that a new wind is blowing in the policy towards federal scientific institutions, which should allow us to gain autonomy and efficiency in the management of our budgets and investments, as well as of our staff, and supports the further development of a digital structure and which pays more attention to climate research and services on an inter-federal level. In any case, we are well armed to face the future with hope, with important scientific challenges in the field of aeronomy, including participation in new satellite missions to Venus, Jupiter, and comets, and the further development of the ESA Earth Watch mission ALTIUS "made in Belgium".

Now that teleconferencing is well established, we will probably move towards a hybrid conference culture, with partly face-to-face and partly 'remote' meetings, and a larger share of teleworking in our daily work. But the most important pillar of a fruitful future remains our staff. We currently have motivated and competent people: I would like to thank them explicitly for their continued commitment, even in the difficult circumstances of 2020 and today. It is important that we continue to offer them favourable and enriching perspectives in the future and that the conditions are created to efficiently attract and use additional people and resources to respond to the scientific challenges.

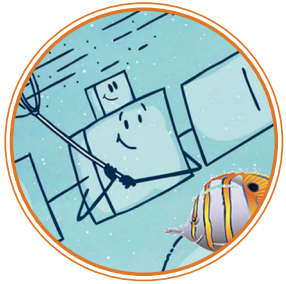
Martine De Mazière
Director General a.i.
14 April 2021

SPACE PHYSICS



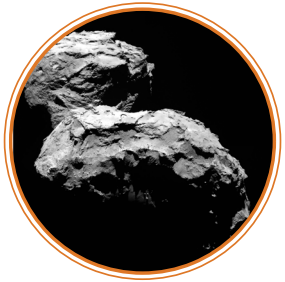
Prepare to be hit ... at 70 km/s

BIRA-IASB is building the electric field sensors for ESA's Comet Interceptor mission that will visit a fresh comet entering the inner solar system for the first time. These sensors are a delicate piece of equipment. They are very lightweight, built with Aluminum walls that are only 0.3 mm thick in order to comply with the mass limitations on the spacecraft. However, there is one major question: will the probes survive the comet flyby as it zaps through the cloud of dust particles ejected by the comet, at speeds that may reach up to 70 km/s?



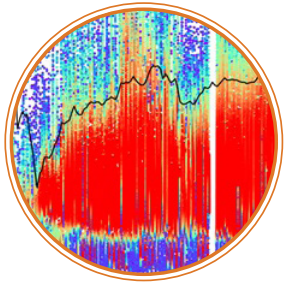
The riddle of the halogens

In the zoo of neutral gases discovered by Rosetta at comet 67P/Churyumov-Gerasimenko, the group of halogen-containing species represented by the saltwater fish grows. The ROSINA-DFMS instrument discovered ammonium chloride (NH_4Cl) in a dust grain from the comet and a careful analysis of data from the complete mission revealed that chlorine exists in at least one other form different from HCl or NH_4Cl.



The ageing effect of cosmic rays on comets

Comets consist of relatively small aggregates of cold ice and dust formed in the outer Solar System. They remain unaltered by gravity or heating contrary to other bodies. They are thus thought to contain the best samples of pristine early Solar System materials. However, we were able to show that they age as Galactic Cosmic Rays penetrate into the outer parts of the nucleus and change the composition and structure of cometary ice, which can no longer be considered as pristine. This has strong implications on the interpretation of cometary measurements.



Radiation belts during geomagnetic storms observed by EPT

The Energetic Particle Telescope (EPT), launched on the satellite PROBA-V in May 2013, provides flux measurements at 820 km hoogte for more than 7 years. They allow us to determine the strong flux variations associated to the geomagnetic storms observed since 2013. Storms are characterized by dropouts followed by flux enhancements, with injections in the slot region, located between the inner and the outer belt, for the strongest events. Altitudes of impenetrable barriers for the dropouts and the injections have been statistically determined for different energy ranges of electrons.

Solar wind particles organized by the flow speed

Two new solar missions, Parker Solar Probe (NASA) launched in 2018 and Solar Orbiter (ESA) launched in February 2020, are taking the closest ever images of the Sun, observing the particles of the solar wind and the Sun's polar regions like never before. Combined with previous observations, they allow us to determine the presence of very energetic (suprathermal) particles close to the Sun at the origin of the acceleration of the solar wind and possibly the heating of the corona.

Cluster of new BRAMS stations in Limburg

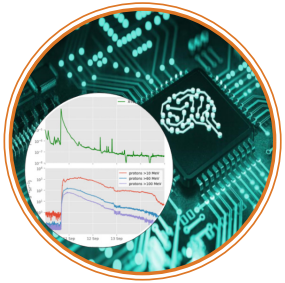
Seven BRAMS receiving stations 2.0 were installed in Limburg in addition of the 3 existing ones. They include new material (receivers, Raspberry Pi, GPSDO) with the aim to increase the quality of BRAMS data and to guarantee the long-term activities of the project. The goal of creating a cluster of BRAMS receiving stations geographically close to each other is to detect a lot of common meteor echoes, and to use time delays between their appearances at six (or more) stations in order to retrieve the trajectory of the corresponding meteoroid.

Radiation pattern of the BRAMS transmitter using a weather balloon

Knowing the radiation pattern of the BRAMS transmitter is paramount for many studies using BRAMS data. Using a dedicated payload located on a small platform below a captive weather balloon, we carried out in-situ measurements, which revealed that the transmitted signal was not truly circularly polarized as expected and that the beam was not pointing at the zenith but ~10° westwards. The transmitter has been adapted accordingly in the months that followed, and the technique will be further improved to work even in light winds.

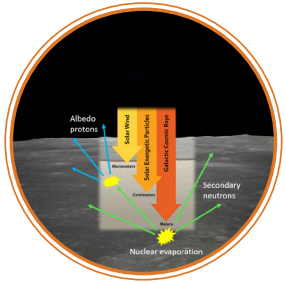
Multi-wavelength observations and modelling of aurora

Despite different atmospheres and magnetospheres, aurora are observed on all magnetized bodies in the solar system. Within the BRAIN-Be project MOMA (Multi-wavelength Observations and Modelling of Aurora) we study the ultraviolet, visible, and radio emissions of aurora on Earth, through both observations and modelling, to shed some light on the physical processes at play in the formation of aurora. More generally, this project allows to better understand the near-Earth space within the space weather context.



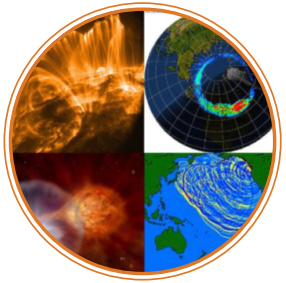
Improving Solar Energetic Particles Forecasts

Strong solar eruptions can accelerate particles like electrons, protons and heavier ions to high energies. These particles might cause disturbances in electronics on board satellites and are a health concern for astronauts and even aircrew and passengers on polar routes. The SAWS-ASPECS project provides warnings by following the evolution of active regions and eruptions on the Sun. The DENSER project recently started to investigate how to employ machine-learning techniques to improve these predictions that still pose many challenges.



Lunar radiation environment specification and analysis

The last years have seen a renewed interest in the exploration of the Moon and the possibility for commercial exploitation of its resources. The modelling of the lunar radiation environment and its effects is an important element for designing and protecting lunar-based assets. We have used ESA's SPace ENvironment Information System (SPENVIS, https://www.spenvis.oma.be) developed at BIRA-IASB, to support the design of a miniature X-Ray Fluorescence (XRF) spectrometer for a future ESA mission to the Moon.



Mechanisms for Extreme Event Generation (MEEG)

It still remains to be fully understood why extreme events in complex systems in fields as diverse as space plasma physics, geophysics, to finance and economics, sometimes deviate from power law behaviour. Observations suggest that an inter-disciplinary approach could further advance the understanding of the mechanisms that generate extreme events and their relationship with the rest of the statistics.

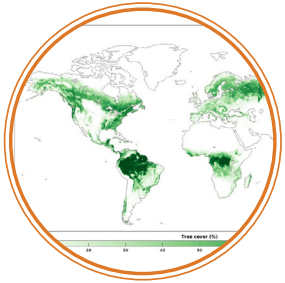
CHEMICAL COMPOSITION AND CLIMATE

Aerosol data for better climate modelling

Climate modelling requires high-quality data for every aspect of the Earth system (atmosphere, oceans, cryosphere, etc.). Long time series, global datasets, or more detailed local data form a gigantic set of data that can be centralised in international databases after precise and detailed characterisation. As such, BIRA-IASB provides atmospheric data to the European Copernicus programme for various atmospheric species, including stratospheric aerosols.

Stratospheric aerosols: a key player in climate change

Aerosols are an important player in the Earth's climate: they diffuse sunlight and modify the physico-chemical, thermal and dynamic properties of the atmosphere as well as the radiation received at ground level. The origin of stratospheric aerosols is mainly volcanic, but increasingly, other actors such as forest and bush fires are taking their place in this theatre. Understanding the composition and microphysical characteristics of aerosols, and in particular the particle size, is a major issue for the study and modelling of climate change.

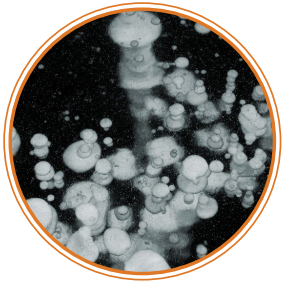


Better quantify isoprene emissions using remotely sensed land cover data

Isoprene is primarily emitted from plant foliage and about 80% of its global emissions occur in the Tropics where warm temperatures, high radiation fluxes and broadleaf trees favour its release. Current isoprene inventories are usually based on vegetation maps that are either modelled and dynamic or satellite-based and static. But high pressure on land use over the last decades leads to severe losses, especially in tropical forests, that are not considered in models. We provide the first isoprene inventories based on spaceborne land covers.

African biomass burning plumes detected at La Réunion

Biomass burning is a major source of volatile organic compounds (VOCs), key ingredients in the formation of surface level ozone and secondary organic aerosols. Characterisation of sources and sinks of these VOCs in the atmosphere supports research on both climate change and air quality. Researchers at BIRA-IASB used VOC measurements at the high-altitude Maïdo observatory at La Réunion, a remote island in the Indian Ocean, to search for clues on missing sources of VOCs in biomass burning plumes from Africa.

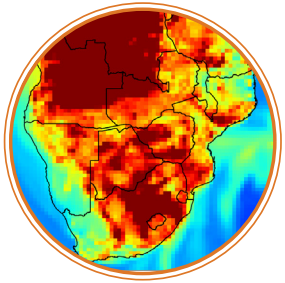


The challenges of atmospheric methane monitoring

Methane (CH_4) is an important greenhouse gas in the Earth's atmosphere. Since a few years, CH_4 concentrations are increasing very fast again and our current understanding about its sources and sinks is still inadequate. To improve our understanding, the "Infrared observations" team at BIRA-IASB is involved in 3 critical activities: retrieving CH_4 concentrations from the space-borne IASI instrument, using ground-based FTIR instruments to produce highly accurate reference measurements, and performing extensive satellite retrieval quality control studies.

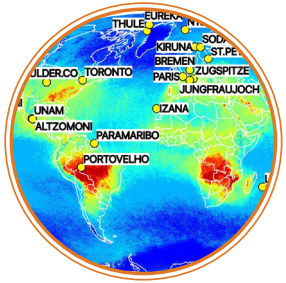
Growing involvement in ICOS and ACTRIS research infrastructures

European research infrastructures such as ICOS and ACTRIS are quickly becoming fundamental components of the scientific atmospheric monitoring landscape as they ensure long-term state-of the-art measurements of atmospheric constituents from ground-based instruments (be it in situ or remote sensing), backed by centralized quality control and harmonization. BIRA-IASB takes on an important role within these infrastructures, both as a data provider and as a central facility operator.



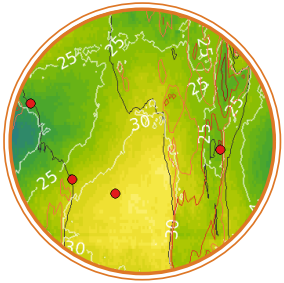
Interpretation of time series of key gases in the carbon cycle

BIRA-IASB is contributing to international initiatives for long-term monitoring of the atmospheric composition, by delivering measurements of CO_2, CH_4, and CO, gases that play an important role in the carbon cycle, at Ile de La Réunion. The collected time series show variations of the concentrations at different time scales: from daily to seasonal to interannual. In order to understand the origin of these variations, BIRA-IASB implemented the WRF-GHG model to simulate the transport and surface fluxes of CO_2, CH_4, and CO with a spatial resolution up to 1 km^2.



Ground-based data network: a key tool for satellite validation

A homogenized formaldehyde (HCHO) data set from FTIR measurements has been developed including more than 25 stations over the world, covering clean air regions (Arctic or oceanic sites) and high emissions source regions (cities and forests). This enabled a thorough assessment of the quality of TROPOMI satellite data: TROPOMI is overestimating the HCHO amounts under clean conditions while underestimating them over polluted sites. Such specific results can only be obtained by using a harmonized data set from international networks like NDACC.

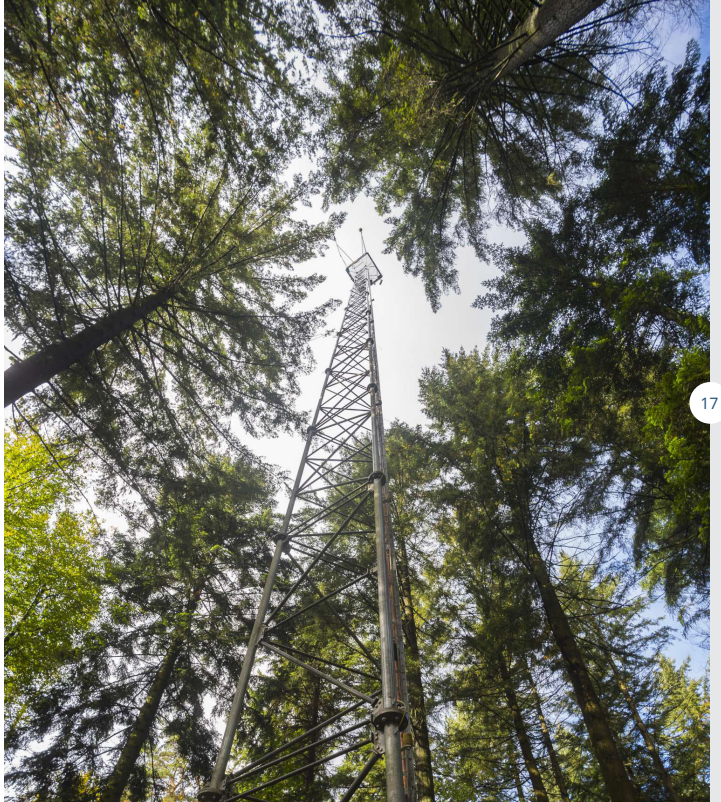


Geophysical assessment of tropical tropospheric ozone

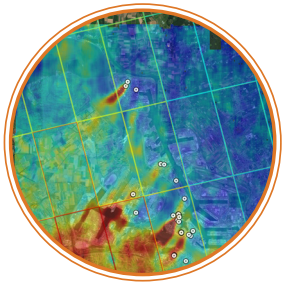
Although a technical and scientific challenge, monitoring ozone in the global troposphere is crucial to verify whether environmental policies work efficiently to protect public health and ecosystems. Designed with high-resolution capabilities for tropospheric monitoring, the Sentinel-5P TROPOMI instrument has been acquiring since 2017 a valuable Climate Data Record. BIRA-IASB researchers have demonstrated the unprecedented accuracy of the TROPOMI data, and its value for international scientific assessments like IGAC TOAR-II.

Evaluating stratospheric circulation in climate models

The Brewer-Dobson Circulation (BDC) is the global system of atmospheric currents in the stratosphere and mesosphere. It transports air masses upwards in the tropics, then poleward and downward in the middle and high latitudes. It is well known that the BDC has a big impact on the ozone layer but the details of this mechanism are not yet fully understood and its representation in climate models requires further research. We addressed this issue through a study of the mean impact of the BDC on the long-lived tracer nitrous oxide (N_2O) in the stratosphere by comparing a variety of datasets.



AIR QUALITY



Sentinel-5P TROPOMI validation campaigns

The new sensor technology and retrieval approaches of S-5p/TROPOMI, launched in October 2017, introduce many opportunities and challenges. This requires to carefully assess the quality and validity of the generated data products by comparison with independent airborne and ground-based reference observations. The UV-Visible DOAS group is coordinating a series of international validation campaigns (s5pcampaigns.aeronomie.be), including the S5PVAL-BE airborne campaign over Brussels and Antwerp, Belgium.

Tailoring Sentinel data to inform Belgian air quality policies

LEGO-BEL-AQ, a new activity initiated by BIRA-IASB in partnership with the Interregional Environment Agency IRCEL-CELINE, aims at tailoring atmospheric observations from the Copernicus constellation of Sentinel satellites to support air quality policies in Belgium. LEGO-BEL-AQ integrates daily global data from the polar orbiting Sentinel-5(p) series with hourly data over Europe from the upcoming geostationary Sentinel-4, to generate maps of nitrogen dioxide (NO_2) at sub-city resolution and to elaborate synergies with regional surface pollution analyses.

Exploiting the full capability of Sentinel-5P TROPOMI

TROPOMI delivers since May 2018 high quality operational measurements for key atmospheric trace gases. To make the most of its outstanding instrumental performances, new tools and atmospheric products are being developed to further contribute to the air quality monitoring. Scientists at BIRA-IASB have developed an innovative algorithm leading to a tremendous step forward in the detection of weak sulphur dioxide sources. Similarly, important information on emissions of volatile organic compounds is gained with the new TROPOMI glyoxal product.

Wildfire plumes detection from Sentinel-5P TROPOMI

Increasingly devastating wildfires have recently raised international concerns about their impacts on air quality and climate. The "UV-visible observations" group is exploiting the high resolution Sentinel-5P TROPOMI instrument which holds the potential to provide valuable insights into trace gas emissions from fires. For the first time, nitrous acid (HONO) from fires was detected from space. Research focuses also on formaldehyde (HCHO) and glyoxal (CHOCHO), important indicators of biomass burning hydrocarbons emissions.

Measuring NO_2 in two dimensions from the ground for satellite validation

Two-dimensional MAX-DOAS observations of nitrogen dioxide (NO_2) are known to contribute to the better characterization of the horizontal distribution of this key air pollutant. The "UV-visible observations" group has developed a new strategy for the retrieval of near-surface NO_2 concentrations and tropospheric NO_2 vertical column densities in different azimuthal directions and applied it at the Uccle station. This research contributes to improve the interpretation of NO_2 column observations by satellite nadir air quality instruments over urban areas.

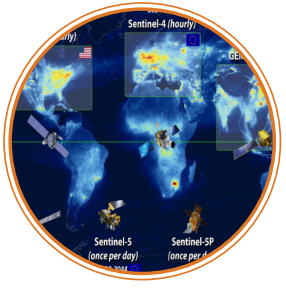
Sharp changes in NO_2 observed by TROPOMI during lockdowns

Since the start of the COVID-19 pandemic, we have tracked closely the evolution of NO_2 abundances observed by the TROPOMI sensor. Due to lockdown measures, unprecedented decreases were observed in China, where COVID-19 was first identified. As the pandemic spread around the world, more cities and countries declared lockdown measures. This resulted in a drastic decrease in transportation and industrial activities and led to substantial NO_2 reductions ranging between 20% and 50% in many large cities around the world.

Satellites reveal changes in the NO_2 weekly cycle over cities

Human activities, the dominant source of NO_x into the atmosphere, induce a weekly cycle of NO_2 abundances over cities. Comprehensive analysis of NO_2 observations from two satellite sensors (OMI and TROPOMI) reveals significant weekly cycles in 115 of the 274 cities considered. The data show a clear weakening of the weekly cycle over European and U.S. cities, whereas the opposite tendency is observed in regions undergoing rapid emission growth. Models capture the observed weekly cycles as well as their trends over large cities.

The SACS early warning system of natural hazard

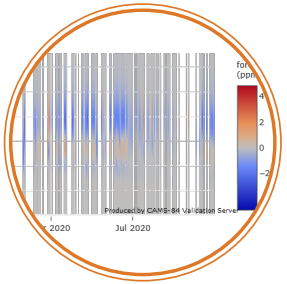


Operational quality assurance for Sentinel-5P TROPOMI atmospheric composition data

The Support to Aviation Control Service (SACS), hosted by BIRA-IASB, provides near real-time information on natural airborne hazards, such as volcanic ash and SO_2, dust from sandstorms, or smoke from wildfires, to key users from the aviation sector. As a contribution to the EUNADICS-AV H2020 and OPAS Engage–KTN projects, the "UV-visible observations" research team has upgraded its early warning system with new observations and event detections.

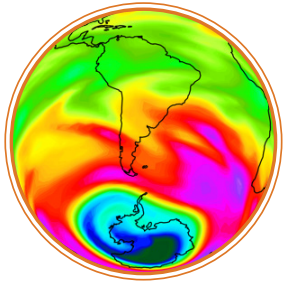
Since its launch in 2017, Sentinel-5P TROPOMI pioneers the emerging constellation of Copernicus Sentinel satellites for the global monitoring of air quality, climate forcing, ozone, and atmospheric hazards. Part of this programme, the Validation Data Analysis Facility (VDAF) hosted at BIRA-IASB delivers the operational validation service required to assure routinely the quality and fitness-for-purpose of the TROPOMI data procured to the Copernicus information services, and to ensure interoperability with other instruments of the Sentinel constellation.

STRATOSPHERIC OZONE MONITORING



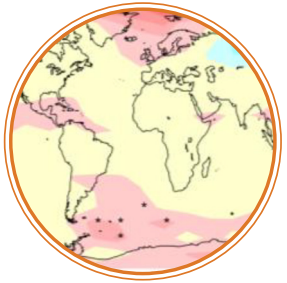
Copernicus monitors exceptional ozone holes in 2019 and 2020

Three record-breaking ozone holes happened consecutively and were monitored in real-time by the Copernicus Atmosphere Monitoring Service (CAMS) with key contributions from BIRA-IASB. From September to November 2019 the Antarctic ozone hole was exceptionally weak and short-lived; in 2020 it was exceptionally strong and lasted much longer than usual; and in February-April 2020 an ozone hole appeared above the Arctic while no such event had been observed since 2011. These extreme events were due to exceptional meteorology above the poles.



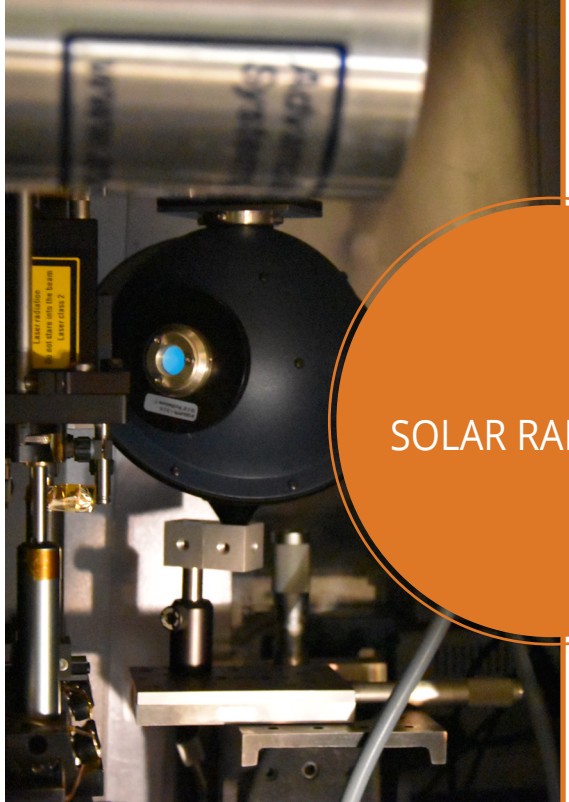
Evaluation of future ALTIUS stratospheric ozone observations

ALTIUS is an ESA Earth Watch microsatellite mission, initiated by BIRA-IASB and dedicated to the monitoring of the ozone layer. Microsatellite means that the mission will be much more cost-effective than most previous ozone missions. In order to prove the scientific potential of the ALTIUS measurements, we simulated ALTIUS data and measured how they could constrain a model of the ozone layer. Comparing these results with those obtained by the state-of-the-art NASA MLS satellite instrument, we were able to confirm the value of this budget instrument.



LOTUS refines assessments of long-term changes in stratospheric ozone

Signed in 1987, the Montreal Protocol bans the production and use of chemical substances responsible for the dramatic depletion of the ozone layer. To monitor long-term effects of this international treaty, BIRA-IASB coordinates LOTUS, a community-wide assessment of stratospheric ozone changes under the auspices of the World Climate Research Programme. LOTUS confirms the long-awaited slow rise of ozone in the upper stratosphere. In the lower stratosphere declining ozone levels are still the subject of heated debates. The recent enhancement of resolution of trend estimates has improved our understanding of the long-term processes controlling ozone.



SOLAR RADIATION

From a dark lab to the sky and space

All experimental setups in aeronomy require the characterization of instrumentation. It allows converting instrument raw signals into useful scientific data, with optimal control of instrumental effects and uncertainties. The solar irradiance measurement or the use of its flux as a reference light source is a key point for measurements in aeronomy. The radiometry laboratories at BIRA-IASB are equipped accordingly, with recent involvement in projects such as MAJIS, ALTIUS, and PLIP.

PLANETARY AERONOMY

First detection of the oxygen green line dayglow emission on Mars

The NOMAD/UVIS spectrometer has detected, for the first time in a planetary atmosphere outside the Earth, the oxygen green line emission around 80 km altitude in the Martian atmosphere. The green line at 557.7 nm is emitted by the de-excitation of oxygen atoms, produced by the photolysis of CO_2, the major constituent of the Martian atmosphere. The simultaneous measurement of the green line and another oxygen emission at 297.2 nm also allowed solving an old discrepancy between ab initio calculation and terrestrial measurements.

Global dust storms on Mars inject water high into atmosphere

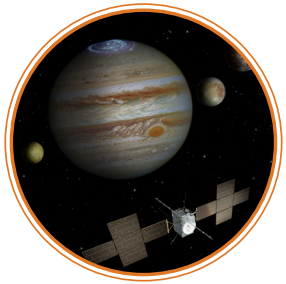
One of the most striking phenomena on Mars is a planet-encircling storm or "global dust storm". Once it starts, the dust suspended in the atmosphere covers the whole globe for several weeks. Mid 2018, one of these storms occurred and measurements from the Nadir and Occultation for Mars Discovery (NOMAD) instrument on the ExoMars Trace Gas Orbiter (TGO) showed elevated water vapour in the upper atmosphere connected to the storm. We use a 3D numerical model of the Mars atmosphere to help explore the mechanisms during this event.

Modelling space radiation effects in space and on Mars

The influence of space radiation, as a limiting factor for survival of future crewed missions in Space, human explorers on Mars, and in general of life outside our biosphere, is wide-ranging and profound. The H2020 project ESC2RAD studies habitability conditions under space radiation, by modelling radiation effects in different targets, from water to biomolecules to the materials needed for radiation-protection and enhanced assets performance, merging chemical-physics models with Monte Carlo particle transport approaches.

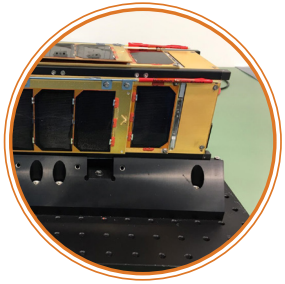
The Benelux hub of the Europlanet Society

The Europlanet Society promotes the advancement of planetary science and all related disciplines in Europe, with the aim to expand and support the planetary community in the different countries. To facilitate this, “regional” hubs have been created, such as the Europlanet Benelux hub (https://www.europlanet-benelux.org/) in which BIRA-IASB is strongly involved. Ever since its creation, the Benelux hub has been actively contributing to outreach, education and policy activities, as proven by the long list of activities highlighted in the online activity report.



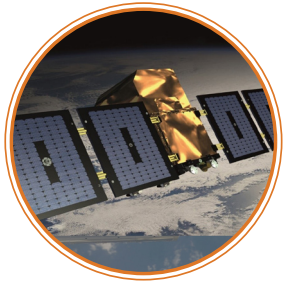
Exploring Jupiter and its icy moons with MAJIS

ESA's JUICE satellite will be launched in 2022 with the Franco-Italian MAJIS instrument on board: a hyperspectral imager optimized for the study of Jupiter and its moons. BIRA-IASB was in charge of the electro-optical characterization of the MAJIS flight model detector, which extends to the visible and near-infrared (VIS-NIR) channel. A dedicated facility in thermal vacuum and radiometry was designed and developed, extensively tested and validated, to finally being used in 2020 during the characterization campaign. Its performances are fully determined.



PICASSO: the Golden Satellite

Led by the Royal Belgian Institute for Space Aeronomy, the ESA-backed mission PICASSO (PICo-Satellite for Atmospheric and Space Science Observations) successfully launched its gold-plated satellite on an Arianespace Vega rocket in September 2020. The two onboard instruments serve as successful proofs-of-concept for providing scientific measurements delivered using CubeSat technology.

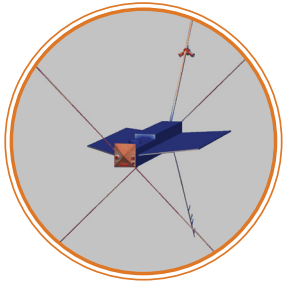


ALTIUS team succeeds at mission preparatory phase activity

The ALTIUS mission, initiated by the Royal Belgian Institute for Space Aeronomy and currently an element of the ESA Earth Watch programme, aims to develop a microsatellite dedicated to the monitoring of stratospheric ozone and other atmospheric trace gases that affect air quality and climate. The ALTIUS team at BIRA-IASB has just completed a successful mission preparatory activity and will now begin advanced development with the kick-off of the B2CD phase, culminating with the satellite launch in 2024.

A combined electric and magnetic field sensor

In the context of ESA's Comet Interceptor mission aiming at a comet flyby, BIRA-IASB has designed and built a combined electric and magnetic field sensor. Combining these two types of instruments required special precautions to avoid that both sensors interfere with each other. As is typical for space applications, the combined instrument had to be lightweight. This offered our engineers a challenging mechanical design problem … but the job was completed successfully!



Daedalus: dealing with frictional heating during atmosphere dive

The Daedalus mission intends to study the Earth's upper atmosphere and lower ionosphere. It will do so by diving deep into the atmosphere at the perigee of its orbit and regularly reboosting itself to make up for the frictional losses. BIRA-IASB is studying an instrument for this mission: the neutral cross-track wind sensor (CWS). The challenge for the mission and this instrument in particular is to deal with the frictional heating at low altitude. Intelligent thermal engineering helps to keep instrument temperatures under control.

Space plasma physics instrumentation on the Lunar Gateway

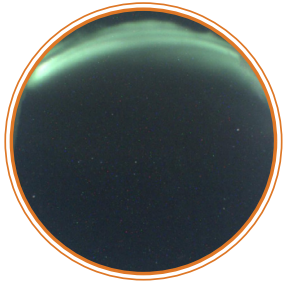
In the recent rush to the Moon, NASA, ESA, and other space agencies plan to build a small space station in lunar orbit to facilitate excursions to the lunar surface. Because of its interesting position in a wide orbit around the Moon, ESA asked an industrial team to examine whether this would be a good place to host scientific instruments for space plasma physics on the Lunar Gateway and how this could be optimally accommodated. The answer is a resounding "yes!". BIRA-IASB was among the parties participating in this study..

SUPPORTING SERVICES

EnVision, maybe back to Venus

ENGINEERING

Fifteen years ago, BIRA-IASB sent its first instrument to Venus. SOIR was an infrared spectrometer performing exceptionally well during the ESA Venus Express mission. A consortium of European and American research institutes has now proposed a new mission to Venus in the framework of ESA's M5 medium size mission call: EnVision. VenSpec-H is the name of a Belgian instrument that could become the successor of the SOIR instrument. As with SOIR, the Engineering department of BIRA-IASB is heavily involved in the design of VenSpec-H.



Aurora Borealis brought to light

ENGINEERING

At the poles of the Earth, the magnetic field curves down to the ground. At these locations wonderful phenomena can be observed, the so called Northern Lights or Aurora Borealis (North Pole) and the Southern Lights or Aurora Australis (South Pole). Research of this phenomenon is done amongst others by means of polarization research of the observed light. For this purpose, the Engineering department developed, in collaboration with the “Limb Remote Sounding” division, a polarimeter instrument, called ASPA.

The challenge of optimizing the use of scientific data storage

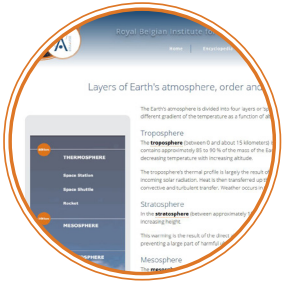
IT

Our institute continuously collects measurements made by more and more numerous and precise instruments, which are used by our scientists to produce increasingly detailed and voluminous analyses. To enable the continuous management of data flows, growing storage (equivalent to more than five times the Netflix catalogue and +10%/year) and data mining (300,000,000 objects), an arsenal of techniques and technologies must be exploited. This is a real challenge!

Sharing knowledge, sharing passion

COMMUNICATION

BIRA-IASB offers numerous educational activities (student internships, study visits, etc.) and also participates in various events to promote science on the initiative of communities, local authorities or the academic world. Recently, researchers have been collaborating in the Prometeruse project aimed at raising awareness of climate change among students. Presentations, workshops and exchanges with a foreign class are the ingredients of this project in which BIRA-IASB collaborates with several schools in Brussels and Flanders.



New website attains wide international audience

COMMUNICATION

In December 2019, BIRA-IASB published a new website on www.aeronomie.be with an important focus on education (explaining our research topics), but also on regular reporting of important findings of our science and engineering teams. Given the (inter)national character of our partnerships, every page is available in English, French and Dutch. We are writing, building, hosting and maintaining the site completely in-house.

All about the Institute of Aeronomy in less than seven minutes!

COMMUNICATION

In 2019, BIRA-IASB's Communication Cell took up the challenge to create an appealing and dynamic presentation film. This film had to summarize, in less than 7 minutes, the work accomplished by all our researchers and support services. A year later, we are proud to announce that this challenge has been brilliantly achieved, thanks to the contribution of the firm Zen-it. As a picture (and in this case a movie) is better than a long presentation, we invite you to watch this movie: https://www.youtube.com/watch?v=Z3dnJRWtPhY

Digit-04: a plunge into BIRA-IASB history

COMMUNICATION

As part of the federal Digit-04 project, the communication department is digitizing all visual material inherited from the generations of scientists that have worked at the Institute since its earliest days. Over 4100 photographs and slides of scientific missions and instruments of the past - ranging from the 1960's until the early 2000's - have been recovered, catalogued and scanned in order to safeguard both the scientific and human heritage from loss or degradation, and with the aim to make it available to the public in the future.

BELGIAN USER SUPPORT AND OPERATIONS CENTRE

Observing thunderstorms from above for more than 2,5 years

Since April 2018, the ASIM payload is monitoring almost non-stop thunderstorms from the International Space Station, to catch rapid luminous events happening in the upper atmosphere; auroras and other light phenomena are also analysed. After two and a half years of continuous operations, the mission that was supposed to last 2 years, will probably go on until end of 2022. The observations and data collected by the two instruments onboard allowed the science team to already publish significant scientific papers, which made it to the front page of the Science and Nature magazines.

Boiling in microgravity with a high-tech kettle

On September 9, 2019, after two separate days of work by Luca Parmitano, the Fluid Science Laboratory on board the International Space Station was activated again. From this moment on, it was time for the Reference mUltiscale Boiling Investigation (RUBI) to heat up. The experiment was used to address the basic phenomena of boiling heat transfer processes on a heater surface. At B.USOC, the operators worked tirelessly to perform more than 2100 runs over the course of 6 months, each with different settings.

Seven months to shake samples and make foam on board the ISS

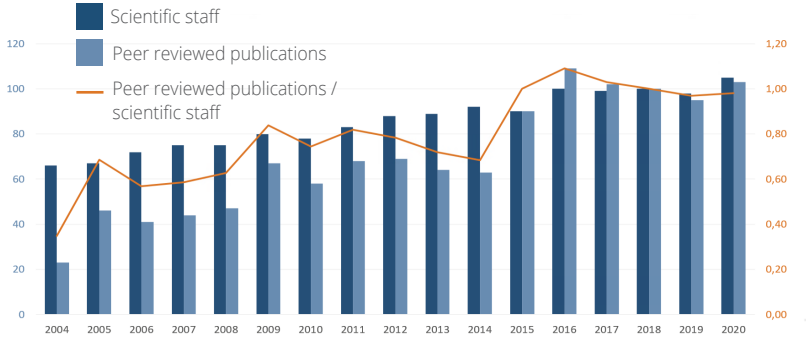
From March 9 until October 13, 2020, the B.USOC operated the Foam Coarsening experiment devoted to the study of the properties of wet foams in microgravity inside the Fluid Science Laboratory onboard the International Space Station. The microgravity environment allowed to study the poorly known physics of “wet foams" without the draining effect of gravity, which, on Earth, pulls the liquid between the foam bubbles downward.

PUBLICATIONS

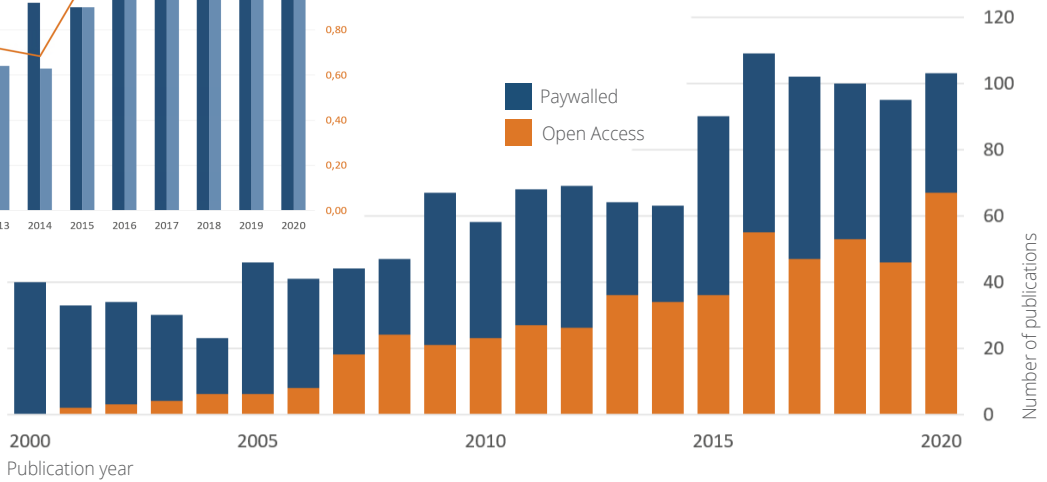
One of the main tasks of BIRA-IASB's Documentation Center is to ensure that the institute's scientists have prompt access to publications supporting ongoing research. This is maintained through the acquisition of licenses with academic publishers and through book and article purchases.
On the other hand, the Documentation Center is responsible for the dissemination of the institute's research by archiving the scientists' publications in the federal institutional Open Access (OA) repository Orfeo: https://orfeo.kbr.be/. Research data created by BIRA-IASB are provided with digital object identifiers and propagated in the institute's Data Repository (https://repository.aeronomie.be/), thus supporting the Open Data principles. The increasing number of OA peer-reviewed publications, reaching 65% in 2020, also reflects BIRA-IASB's engagement in Open Science.

Over the period 2019-2020, BIRA-IASB published almost 200 peer-reviewed articles. This word cloud is created based on their titles, with the size of the words corresponding to the number of times they appear.

Peer-reviewed publications per scientific staff member



Evolution of peer-reviewed publications and publications in Open Access



PEOPLE AND FIGURES

The previous chapters of this activity report illustrate the large variety of results obtained by the scientists at BIRA-IASB. Their activities strongly rely on the support of services such as engineering, IT, communication, administration and infrastructure. While the total number of employees has remained unchanged since 2018, the proportion of scientists has increased, while the support staff (mainly in the engineering and IT departments) has proportionally decreased. This is easy to explain. On the one hand, these are professions in short supply which, even if the need is great and even if we can afford it, are very difficult to fill. On the other hand, the long SELOR procedures for these non-scientific profiles also play a role.

In the right-hand figure on page 42, you can see that the share of contractual employees among scientists (72%) is much higher than in support services (47% in IT, 61% in administration and 64% in engineering/technical staff). This is due to the fact that many scientists are paid on externally funded projects.

All statistics in this activity report are calculated on 31 December of the year concerned and are based on staff numbers, not on FTE's (full time equivalents).

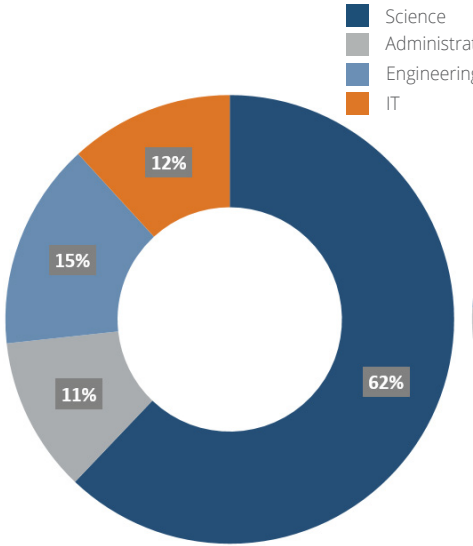
IT staff: In 2020, only 47% of the IT staff is found within the IT department, which provides support to the whole institute in areas such as IT infrastructure, networking, high-performance computing, data management and storage. The remaining 53% are paid on a project basis and work within a specific department or project.

Staff on external contracts: For the sake of completeness, we would like to mention that the workforce at BIRA-IASB was supplemented by 3 staff members with an external contract, both in 2018 and 2020. In 2018, this concerned two persons with an egov contract and one person who was employed by the Royal Observatory of Belgium but put at the disposal of the B.USOC; in 2020, this concerns one person with an egov contract and two persons with an FNRS contract. These people were not included in our graphs.

Doctor of Science: The BIRA-IASB staff is characterised by a high percentage of doctors. At the end of 2020, no less than 81 of the 161 staff members (50%) had a PhD. The vast majority of them are scientists. Indeed, 78% of the 104 scientists have obtained a doctorate and 4% are currently preparing a doctoral thesis.

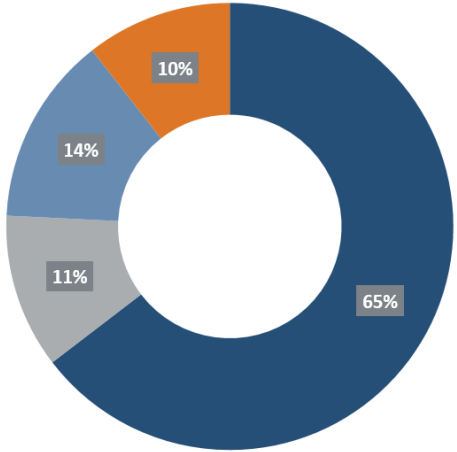
WORKFORCE 2018

100% = 161



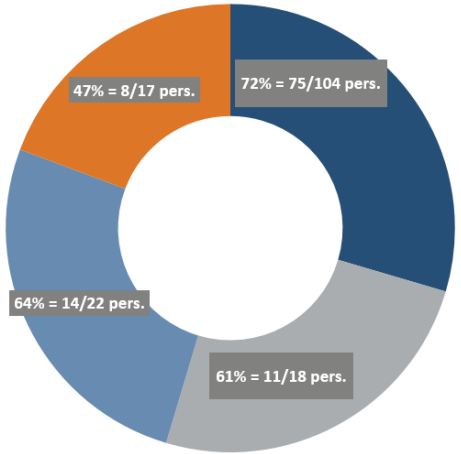
WORKFORCE 2020

100% = 161



WORKFORCE 2020

Percentage of contractual staff by category



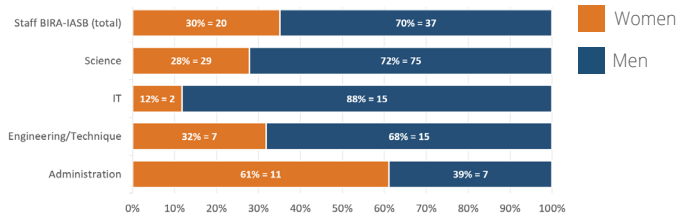
PROMOTING WOMEN IN THE (GEO) SCIENCES: OBSERVING, ANALYSING, ACTING

Although their number is growing, women are still under-represented in STEM research and their potential is not sufficiently recognised and taken into account. However studies show that diversity enhances the dynamism of research and is essential to properly address societal challenges such as climate change. BIRA-IASB is committed to promoting women in science and some of its employees are involved in diversity research in the geo-sciences. The goal is to achieve a better balance and an inclusive practice of science in all its richness.

GENDER DISTRIBUTION IN THE WORK-PLACE

By category

In 2020, 30% of the institute's staff are women. The following figures illustrate that STEM scientists are still predominantly men. Only 28% of the scientists is female, 12% of the IT people and 32% of the engineering and technical staff. It should be noted that 4 out of the 7 female persons in the latter group are cleaning ladies, who should not be counted in the category of STEM jobs. On the other hand, women make up the majority in the administration.



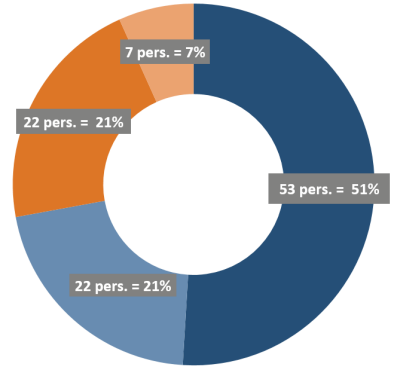
At leadership level

When trying to promote gender equality, it is important to take a look at the position of women in leadership positions. At the end of 2020, across the different levels of the hierarchy in our institute, 9 out of 31 leadership positions (or 29%) are held by women. Consult our online activity report for the institute's organisational chart and more details on gender distribution.

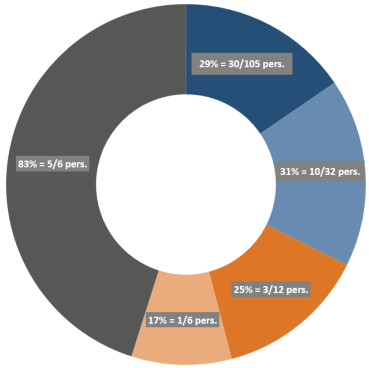
By statute and level

More than half of the Institute's scientists are contractual men. When we look at the level (SW, A, B, C, D), we find the highest percentage of women in level D. They are mainly cleaning ladies. In level C, we find mainly male technical and administrative assistants. In the higher levels (SW, A and B) the percentages of women vary between 25 and 31%.

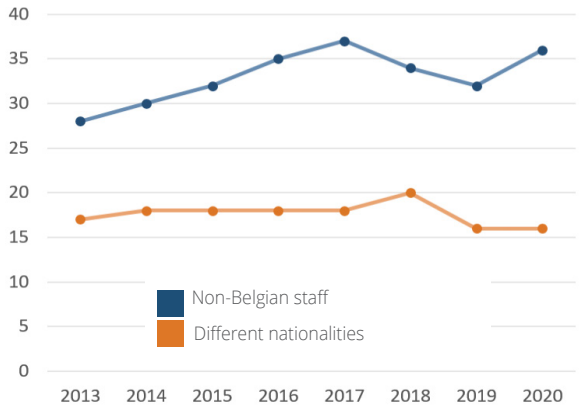
Distribution of scientists by statute and gender, in 2020



Percentage of women/total by level in 2020



DISTRIBUTION BY NATIONALITY



BIRA-IASB is proud of its international recognition and working environment. By the end of 2020, 36 people of foreign nationality (22% of staff) work at the Institute. The Institute has 16 different nationalities (including Belgian). With the exception of two American and two Chinese colleagues, all staff members have European nationality.

Nationality of staff in 2020

Belgium
Greece
Germany
China

France
Spain
Czech Republic
Cyprus

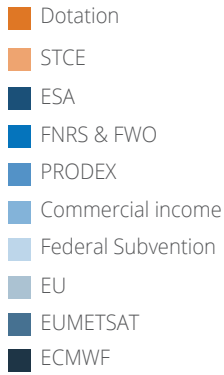
Netherlands
Portugal
Romania
United States

Italy
United Kingdom
Ukraine
Denmark

ACCOUNTING AND CONTRACT MANAGEMENT

Of all the Federal Scientific Institutes, BIRA-IASB has the highest proportion of its budget coming from external competitive projects (63%). These are projects funded by organisations such as ESA, EUMETSAT, the European Commission and (to a lesser extent) national research funds. With a contribution of 42% and 28% of external project funding respectively, ESA and PRODEX (ESA) are the most important sources of income for the institute, followed by the EU funding (essentially H2020) with 19%.

ONGOING PROJECTS BY SOURCE OF FUNDING

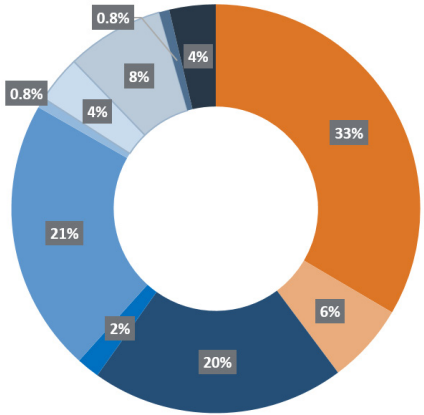


	2018	2019	2020
Dotation			
STCE			
ESA	27	28	32
FNRS & FWO	4	4	3
PRODEX	11	9	11
Commercial income			
Federal Subvention	21	22	16
EU	13	7	10
EUMETSAT	2	2	2
ECMWF	6	6	5

REVENUE BY SOURCE

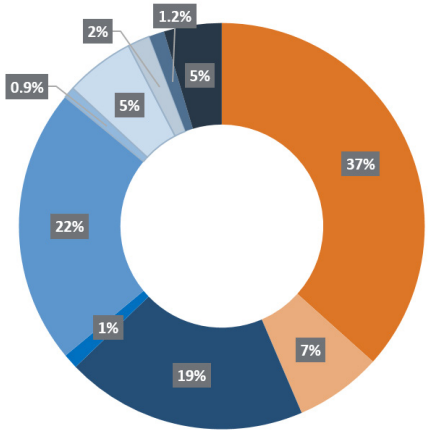
2018

100% = € 14 773 390



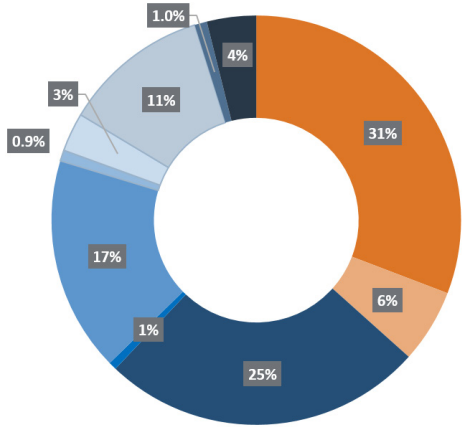
2019

100% = € 13 499 762



2020

100% = € 16 255 094



INTERNATIONAL PROGRAMMES AND PROJECTS

Recognition of the expertise of BIRA-IASB scientists is expressed through staff representation on international programme committees, scientific advisory committees, evaluation panels and expert groups.

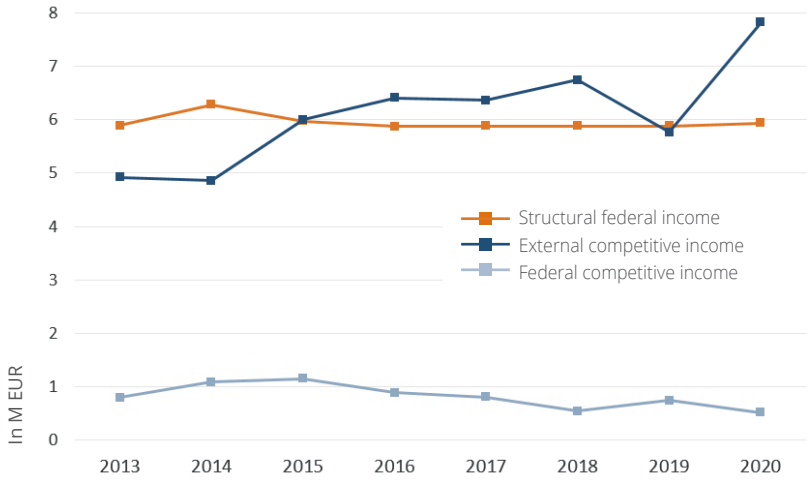
BIRA- IASB is also a partner in, and even coordinator of, many international projects. For example, BIRA-IASB had a total of 78 ongoing projects in 2019 and 79 in 2020. The Contract Management department, a two-person team, is responsible for the financial, contractual and administrative management of all these projects, in consultation with the scientific leaders, of course.

In the word clouds opposite, it is obvious that we have the most partnerships with our neighbouring countries: Germany, the Netherlands, France and the United Kingdom. Our frequent international partners are KNMI in the Netherlands, DLR and IUP-UB in Germany, and IMF in Finland. Also our national partners are clearly visible: universities like UGent, KU Leuven, ULB, ULiège (formerly ULg), UCL, as well as our neighbours on the Space Pole: the Royal Observatory of Belgium (ROB) and the Royal Meteorological Institute of Belgium (RMI).

These word clouds show the countries and partners with whom we cooperate in projects, with the size of the words indicating the number of partnerships (up to 75 partnerships with German partners, and up to 15 partnerships with KNMI).

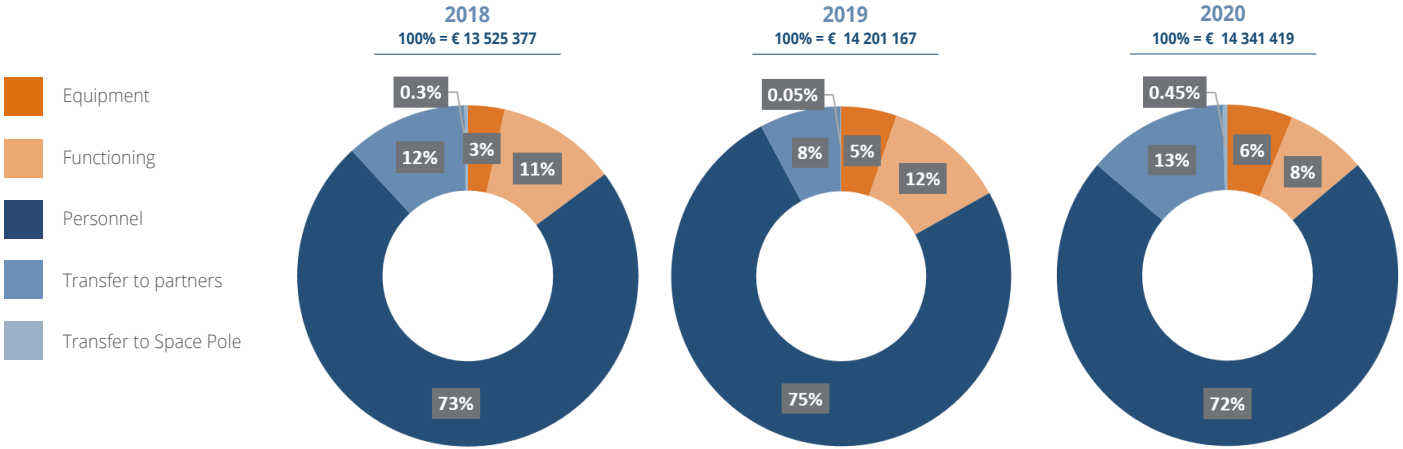
EVOLUTION OF THE DIFFERENT TYPES OF INCOME

BIRA-IASB is supported on a structural basis by the Federal Science Policy through the dotation and the Solar-Terrestrial Centre of Excellence (STCE). Since 2018, the personnel envelope is part of the overall dotation. Since then, cuts in operating funds have increased in order to maintain the current level of statutory staff. Federal non-structural, competitive, revenues (e.g. BRAIN, FED-tWIN, ...), despite a slight increase in 2019, have steadily decreasing since 2015, as there are fewer and fewer opportunities. However, we note a strong increase in income from external competitive projects, indicating an active commitment within the Institute to compensate for the decrease in national resources by seeking external funding with intensive competition.



EXPENSES PER CATEGORY

The following figures show immediately that the vast majority of our expenditure (>70%) is on staff. BIRA-IASB staff is increasingly financed by external projects. As a result of the COVID-19 crisis, which greatly reduced travel, we were able to save some budget on general operating funds to invest in scientific equipment.



THANK YOU

Our sources of income:
Belspo, ESA, EU, EUMETSAT, ECMWF, FWO&FNRS, PRODEX.

And all of our colleagues who worked at BIRA-IASB during 2019-2020:

Amelynck Crist
Anciaux Michel
Aoki Shohei
Arijs Yenn
Aubry Aurélien
Baker Noel Catherine
Bauwens Maite
Beeckman Bram
Berkenbosch Sophie
Berthelot Antonin
Bevernaegie Jessica
Bingen Christine
Boca Gheorghina
Bogaerts Brigitte
Bolsée David
Bonnewijn Sabrina
Botek Edith
Brenot Hugues
Brouckmans Kristien
Brun Nicolas
Bulcke Johan
Calders Stijn
Calegaro Antoine
Callewaert Sieglinde
Cambier Pascale
Cardoen Pepijn
Cessateur Gael
Chabanski Sophie
Chabrillat Simon
Christophe Yves
Cierkens Jana
Cisneros Miriam
Clairquin Roland
Compernolle Steven
Counerotte Frédéric
Crosby Norma
Da Pieve Fabiana
Daerden Frank
Darrouzet Fabien
De Brouwer Benedicte
De Donder Erwin
De Grave Charlotte
de Harenne Christina
De Keyser Johan
De Mazière Martine
De Pauw Samuel
De Ridder Sven
De Rudder Anne
De Smedt Isabelle
Debosscher Jonas
Dekemper Emmanuel
Demoulin Philippe

Meetings in COVID-periode

Depiesse Cédric
Dhooghe Frederik
Dierckxsens Mark
Dils Bart
Dimitropoulou Ermioni
Dohogne Yves
Echim Marius
Egerickx Tom
Errera Quentin
Erwin Justin Tyler
Fayt Caroline
Fedullo Leonardo
Ferriere Olivier
Fonteyn Dominique
Franssens Ghislain
Fratta Stéphanie
Friedrich Martina
Fussen Didier
Gaffé Dominique
Gerard Pierre
Geunes Yves
Granville José
Gunell Karl Nils Herbert
Hamdaoui Mohamed
Haumont Etienne
Helderweirt Anuschka
Hemerijckx Geert
Hendrick François
Hermans Christian
Heymans Carine
Hrsak Dalibor
Hubert Daan
Iterbeke Philippe
Jacobs Lars
Kalb Nathalie
Keppens Arno
Kruglanski Michel
Kumps Nicolas
Lambert Jean-Christopher
Lamort Lucie
Lamy Hervé
Langerock Bavo
Leclere Fabienne
Lefebvre Arnaud
Lefever Karolien
Lerot Christophe
Letocart Vincent
Liber Corentin
Litefti Karim
Maes Jeroen
Maggiolo Romain
Mahieux Arnaud
Marcourt Loïck
Martinez Ana
Massano Cristina
Mateshvili Nina
Merlaud Alexis
Messios Neophytos
Michel Alice
Middernacht Michael
Minganti Daniele
Minion Jean Louis
Moreau Didier
Muller Alexis
Müller Jean-François
Nay Maïté
Neary Lori
Neefs Eduard
Nerovali Cüneyt
Noel Christian
Ooms Tim
Opacka Beata
Pauwels Dirk
Pawlak Jordan
Pereira Nuno
Piccialli Arianna
Pieck Gerry
Piens Matthias
Pieroux Didier
Pierrard Viviane
Pinardi Gaia
Poraicu Catalina
Queirolo Claudio
Ranvier Sylvain
Rasoanaivo Aina
Rasson Olivier
Ristic Bojan
Robert Charles
Robert Séverine
Santos Branca Claudia
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