United by Space!

Aalto University
Finnish Meteorological Institute (FMI)
The Finnish Environment Institute (SYKE)
University of Turku, Tuorla Observatory
University of Helsinki
Univerisity of Jyväskylä
Iceye

Ventspils University College
University of Latvia
Deep Space Industries Latvia

NanoAvionics
Vilnius University

Vrije Universiteit Brussel
Royal Observatory of Belgium, Brussels
Royal Belgian Institute of Natural Sciences

National Physical Laboratory (NPL)
Plymouth Marine Institute (PLM)
Argans Ltd

Centre National d'Etudes Spatiales (CNES), Toulouse
Centre de Recherches d'Avignon (INRA), Avignon
Université de Lorraine
ACRI-ST

Uppsala University Ångström Space Technology Centre
Stockholm University, Department of Systems Ecology
NanoSpace AB
Royal Institute of Technology

Forschungszentrum Geesthacht GmbH (GKSS)
Max-Planck- Institute for Extraterrestrial Physics
Max Planck Institute for Solar System Research, Göttingen
University of Hannover, Institute of Meteorology and Climatology
Brockmann Consult
Leibniz Institute for Astrophysics Potsdam (AIP)
German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR)

Water Insight
Vrije Universiteit Amsterdam
Delft University of Technology

Universität Wien

Oslo University
Norwegian Water Research Institute
Integrated Detector Electronics AS

Instituto de Astrofisica de Canarias
Nordic Optical Telescope Scientific Association
Centro de Estudios de Física del Cosmos de Aragón
Universitat de València

International Centre for Relativistic Astrophysics
University of Pisa
Alta S.p.A.

EC Joint Research Centre Marine Environment Unit

esa European Space Agency

Polish Academy of Sciences
Toruń Centre for Astronomy
Wroclaw University

Virginia Polytechnic Institute and State University
Boston University, Geography and Environment Department
University of California, Scripps Institution of Oceanography, San Diego
University of Maryland
University of Memphis
University of Chicago
NASA's Ames Research Center

Universidad Nacional de La Plata

Observatorio Nacional, Rio de Janeiro

Astronomical Institute Ondřejov

Universidad de Valparaiso

Institute of Astronomy of the Slovak Academy of Sciences, Tatranska Lomnica
P.J. Šafarik University, Košice

Special Astrophysical Observatory, Nizhnij Arkhyz

University of Tartu
Estonian University of Life Sciences
Tallinn University of Technology
National Institute of Chemical Physics and Biophysics
Estonian Environment Agency
Estonian Ministry of Education and Research
Estonian Ministry of Environment
Estonian Agricultural Registers and Information Board
Estonian Research Agency
Enterprise Estonia
Archimedes
Interspectrum AS
Hohenheide AS
Metrosert AS

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TARTU OBSERVATORY
space research centre

SPACE RESEARCH FOR SUSTAINABLE LIFE

Research Priorities 2016 - 2020

"TÄHT!"
(eng. "star")
first word of Ellen, one year old daughter of an astronomer, looking at the evening sky.

"In order to contribute effectively
to the better future of the entire mankind,
one has to dare to dream big,
then get up early every day and go for the dream".

Jan Wörner
ESA Director General in Estonia in Sept 2016

SPACE RESEARCH FOR SOCIETY

Life is rare in the Universe — it may be that it has occurred only once within detectable distance, on Earth or in the Solar System. **Life is precious**, and it is up to us to preserve it.

The Earth's population and the use of resources have reached a point where we have to consider carefully the sustainability of society and life. **Global challenges** such as the changing environment, overconsumption, socio-geopolitical crises, artificial intelligence, possible pandemics, etc. require global actions based on information about our planet. **Space-based solutions for acquiring such information are often the easiest and the most efficient ones.**

Space-based capabilities play a key role in the context of European security and defence, but also provide our citizens with services in many other areas: maritime security, agriculture, the environment, responding to climate change, energy security, disaster management, humanitarian aid and transport, as well as promoting scientific and technical progress and industrial competitiveness.

Space research is widely acknowledged as one of the most innovative fields of science, and an important driver of technology development. Through collaboration and technology transfer, space researchers contribute to the increase of the innovation capacity of entrepreneurs. The development of space science and technology enables space exploration, and improves our understanding of the nature of the Universe.

Knowledge and communication is the key to building a sustainable society. There is a need to be more aware of space benefits, to support the training of space-specialists and -officers, to generate synergy between engineers and researchers; these actions will help to increase the added value of technology and research for society.

As a member of ESA and EU, we have a responsibility and an opportunity to contribute to space affairs.

MISSION

The mission of Tartu Observatory as Estonia's space research centre is to implement cutting-edge scientific research and technology in the interests of Estonia's development.

VISION

Tartu Observatory is a recognised partner in the international sectors of scientific research and technological development. Its established research competence is applied to the promotion of science education, supporting entrepreneurship, and expanding the scientific understanding of the world, thus helping to find solutions for the challenges facing society.

200+ YEARS OF SPACE RESEARCH EXCELLENCE IN ESTONIA

Tartu Observatory is the leading centre of space research and technology in Estonia. With over 200 years of experience in space research, Estonia is well known all over the world in this field. The development of space applications and their downstream services is seen as the basis for future competitiveness and economic growth of the country.

In 2015, Estonia became a full member of the European Space Agency; it has been active in European space policy since 2004. With strong competence in ICT and digitalisation, Estonia can help to increase awareness of space benefits, support the education of specialists and officers, and generate the synergy between engineers and researchers to create higher added value for European society.

Tartu Observatory's research priorities for 2016-2020 have been developed in synergy with the outstanding competence of the University of Tartu in the field of education, and bring together scientific and public goals. Their implementation is based on the existing scientific excellence in specific topics at Tartu Observatory, identified as most relevant for collaboration with the European Research Area and the European Space Agency.

"Estonian space researchers have shown
that they can aim high
and expand our knowledge
about planet Earth and the Universe."

Kersti Kaljulaid
President of Estonia

TARTU OBSERVATORY
space research centre

RESEARCH

- Earth Observations
- Space Technology
- Cosmology
- Stellar Physics

APPLICATIONS

- Environmental monitoring
- Satellite imagery processing
- Big Data computation software
- Partner in the ESA Business Incubation Centre
- Testing and verification for nanosatellites
- Optical calibration and radiometry
- Electromagnetic compatibility
- Experts in EC and ESA committees

EDUCATION

- Doctoral, master and bachelor degree in
  - Space and military technology
  - Environmental physics and EO technology
  - Astrophysics - theory and observation
- Popularisation of science in partnership with ESA ESERO and the ESO educational offices
- Active learning programmes and excursions for schools
- High-tech entrepreneurship

TARTU OBSERVATORY CONTRIBUTION TO ESA MISSIONS AND INITIATIVES

- Refinement of data algorithms (Gaia, Planck, Euclid)
- Input to mission design (Athena, PLATO)
- Participation in mission predefinition (Arago)
- Development of miniature camera systems (ESEO)
- Participation in validation teams (ENVISAT, SENTINELS)
- Quality assurance of measurements (FRM4SOC)

THE UNIVERSE IS OUR HOME

What can we learn from it?

The Earth is part of the cosmos. Life is a result of cosmic evolution. Our environment, our long-term past and future are shaped by the cosmos. We share the physics and the chemistry of the cosmos. Thus, by studying the cosmos, we also get a better idea of ourselves, our place in the Universe, and the fundamental laws of nature that frame our everyday life.

Astrophysics is the science that studies the cosmos. It is driven by observations and is linked to physics, mathematics, chemistry, computer science, geophysics, material science, and biology. Among the biggest unanswered questions in astrophysics, Tartu Observatory scientists are currently focusing on the following:

- What is the nature of the dominant constituents of the Universe: dark matter and dark energy?
- How do different cosmic structures (planets, stars, galaxies, the large-scale structure of the Universe) form and evolve?
- What are the cosmic requirements for the formation of life? Are there other habitable planets?
- What new physics can be learned from extremes of the cosmos (neutron stars, black holes, early Universe, gravitational waves, high-energy cosmic rays)?

Research and development priorities at Tartu Observatory

- We study the properties, formation and evolution of the **largest structures of the Universe: galaxies, galaxy clusters,** and the **large-scale network that they form**. We use the gained information to untangle the fundamental issues of **dark matter**, **dark energy** and gravity.
- We use state-of-the-art observational data, novel methods, and complex mathematical algorithms to understand the **dynamics of stars in galaxies**, as well as the evolution of galaxies and its relationship with the large-scale environment.
- **Massive stars** play a crucial role in the Universe: they drive the evolution of galaxies and are the source of important chemical elements necessary for life. We study the physics of massive stars to unravel their evolution from the cradle to the grave, using modern observing facilities at Tartu Observatory, as well as large observatories worldwide.
- **Planet formation and astrobiology**. We evaluate the applicability of CubeSat-class or smaller satellites for autonomous mapping of an asteroid and for navigation around it.
- Compact astrophysical objects such **as neutron stars** and **black holes** constitute natural laboratories that probe matter in extreme conditions impossible to replicate on Earth. We develop the theoretical tools necessary to "operate" those laboratories by connecting their various observational manifestations to their physical properties.
- Our priority is to further increase the visibility and impact of our work via **partnership in big scientific collaborations** for building and using state-of-the-art space research instrumentation.

SPACE EVOLUTION

What's next after the industrial and digital revolutions?

HIGHLIGHTS

- May 7, 2013: Estonia became a space country by launching its first satellite, **ESTCube-1**.
- The first Estonian instrument on board an ESA satellite – **a camera system for the European Student Earth Orbiter** (ESEO).
- **Modern laboratories** at Tartu Observatory provide access to top-level technology and competence in the space industry.

Space technology is the most effective way to monitor the environment globally, and the best way to explore the Solar System and beyond. Satellites orbiting from Pole to Pole, with the Earth rotating below, can observe the whole planet. While it is truly magnificent how space technology has changed our lives, orbits around the Earth are a limited resource that we have to monitor and maintain. The Kessler syndrome is a scenario in which ever-increasing objects in Earth's orbit will collide, starting a cascade effect and limiting access to space.

We pursue, develop, and promote technology for unprecedented space missions that will enable novel fundamental scientific discoveries and address environmental and global challenges. Our vision is to be the leading hub for space technology in the region, and to be competitive worldwide, via excellent engineering, science, education, international cooperation, outreach, and commercialisation.

Research and development priorities at Tartu Observatory

- Environment monitoring missions, such as Envisat and Sentinels, have provided and continue to provide detailed information about our planet on a weekly basis. **By miniaturising satellites and new instruments,** we can afford to have more of them in orbit, increasing the revisit frequency and providing closely spaced measurement points.
- In 2009, the Iridium 33 and Kosmos-2251 satellites collided; in 2016, Sentinel-1A was hit by space debris. This suggests that Kessler syndrome has already started. The concept of the **plasma brake** has to be implemented – a charged tether dragged by the Coulomb force in the ionosphere can deorbit satellites in the most populated orbits an order of magnitude faster than would happen naturally by aerodynamic drag.
- The Solar System still poses a surprising number of open questions. A mission to any object in the Solar System costs between 100 million and 3 billion euros. By using miniature satellites and the **electric solar sail**, the cost of interplanetary missions can be decreased. This makes it possible to launch tens of self-propelled satellites that will return data about hundreds of objects, increasing the science output by an order of magnitude.

PALE BLUE DOT

How to maintain life on Earth?

Studies about the Earth have been raised to a new level thanks to **observations uniquely available from satellites**. Images of the changing planet are improving the understanding of the Earth's dynamic processes, and helping society to manage its limited resources. Earth Observation (EO) has become **technologically** more and more sophisticated – the number of satellites is increasing, the spectral range of passive and active sensors has been extended from UV to microwave, and spatial resolution has decreased to centimetres.

The European Commission and ESA are developing the **Copernicus programme**, as more accurate, timely and easily accessible information is needed to improve our knowledge about the Earth. The Copernicus Sentinel-1, Sentinel-2 and Sentinel-3 systems are operational as of 2016, and new satellites will be launched in the coming years. TO plays an important role in the quality management and smart application of these data.

Research and development priorities at Tartu Observatory

- Development of **metrology for Earth Observation**, design and characterisation of instrumentation. Contribution to the **EU Copernicus programme**. Participation in the work of the Estonian Environmental Observatory and the SMEAR station at Järvselja.
- Combining optical and radar data for **terrestrial remote sensing**. Improving and developing methodologies for grasslands mowing detection and identification of built-up areas.
- Estimation of **important water parameters** for the EU Water Framework Directive via satellite data. Development of EO algorithms for water transparency, sediment load, phenology of phytoplankton and toxic Cyanobacteria, and carbon fluxes in water bodies.
- Studying **variations in UV radiation** from the data continuously collected at Tõravere. Estimating the variability of the factors influencing optical properties of the atmosphere in the Baltic Sea region.
- Studying **climatological teleconnections between the Arctic and Europe**. Investigating absorption of Earth radiation in the atmosphere for different greenhouse gas conditions.

TARTU OBSERVATORY IN EUROPEAN FRAMEWORKS

- Capacity building and opening up to international collaboration (AHEAD, ESTSPACE, WATERS)
- Innovation in the development of space technology (ESAIL, NANOSAT)
- Applications of Earth Observation for forests, water bodies, and atmosphere (EOMORES, FORMIT, GLASS, MULTIPLY, COST Actions)
- Metrology for Earth Observation and Climate (METEOC-3)
- Chemical Evolution of the Universe (COST Action)

GOALS

TARTU OBSERVATORY
is an effective base for space research, and for the development of innovative space technology applications.

The laboratories for space technology development and environmental testing are a reliable partner for small and medium sized enterprises.

TARTU OBSERVATORY IN THE SERVICE OF SOCIETY

SCIENTIFIC RESEARCH * APPLICATIONS * TEHCNOLOGY DEVELOPMENT * CONSULTING * PUBLIC OUTREACH * EDUCATION

TELESCOPES

- The largest 1.5 m diameter mirror telescope in the Nordic Countries
- Spectrometry and photometry of variable stars
- Training of observers

VISITOR CENTRE

- Modern conference facilities for seminars
- Active learning programmes
- Cultural events, excursions
- Summer Academy
- Hands-on training

CALIBRATION LABORATORIES

- Calibration and characterisation of light sources and radiometric sensors

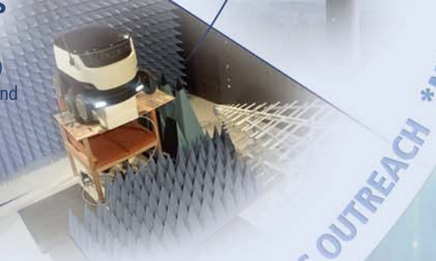
GROUND STATION AND ANTENNAS FOR SPACE COMMUNICATION

SPACE TECHNOLOGY LABORATORIES

- Designing, assembling and prototyping of electronic devices
- Electrostatic discharge (ESD) protected areas
- Cleanrooms

TESTING LABORATORIES

- Electromagnetic Compatibility (EMC)
- Mechanical shock and vibration
- Thermal and humid environment
- Thermal-vacuum



93 members of staff
(77 researchers, 16 other)
40 Summer Academy interns and guest researchers
7 international collaboration projects (FP7, H2020, ESA)
120 publications, 4 defended PhD theses
9300 visitors, over 60 public lectures at schools

TARTY OBSERVATORY 2016 AT YOUR FINGERTIPS