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.

**SPACE RESEARCH FOR SOCIETY**

“TÄHT!”
(eng. “star”)

first word of Ellen, one year old daughter of an astronomer, looking at the evening sky.

**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.

“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

**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 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.
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?

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.

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.
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.


- 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)
TARTU OBSERVATORY IN THE SERVICE OF SOCIETY

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.

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

CALIBRATION LABORATORIES
- Calibration and characterisation of light sources and radiometric sensors

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

GROUND STATION AND ANTENNAS FOR SPACE COMMUNICATION

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

VISITOR CENTRE

TARTU OBSERVATORY 2016 AT YOUR FINGERTIPS

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