

Department of Solar Physics

Solar research from ground & space



Overview

- ❑ Overview of current R&D in the Dept. of Solar physics
 - ◆ Basic research / Science (briefly)
 - ◆ Development: Instrumentation, services, infrastructures
 - ◆ Closer to applications: Space safety
- ❑ Instrumentation, infrastructures, development
 - ◆ Local instrumentation & observing programmes
 - ◆ Involvement in large ground-based infrastructures
 - ◆ Involvement in international space projects
- ❑ Space safety
 - ◆ ESA SWESNET programme (S2P)
 - ◆ GNSS & solar radio bursts
- ❑ Plans & perspectives
- ❑ Summary

Current research & development: An overview

R&D activities 2015 – 2022

□ 1. Basic research in solar & heliospheric physics

- ♦ Magnetic reconnection: 3D aspects, multi-scale nature, kinetic physics – theory, modelling and observed-data analysis with applications to ultimate understanding to solar flares and CMEs as main drivers of the space-weather disturbances.
- ♦ Particle energization & non-Maxwellian distributions: Key to understanding non-equilibrium physics of the solar atmosphere.
- ♦ Radiative transfer, radiation hydrodynamics, and spectroscopic and spectro-polarimetric (SP) inversions: Applications to chromospheric and flare heating, to investigation of magnetic structure of the sunspots, and for revealing true nature of prominences.
- ♦ Pulsations, oscillations and waves in the solar atmosphere as an excellent diagnostic tool.
- ♦ Kinetic-scale space plasma physics: Simulations and observations in the corona and solar wind.

□ 2. Development, services, user-support infrastructures

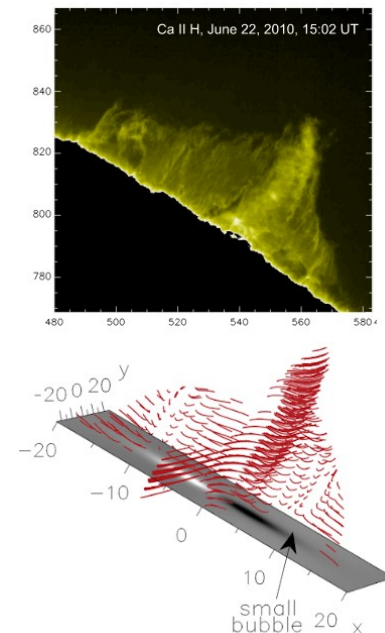
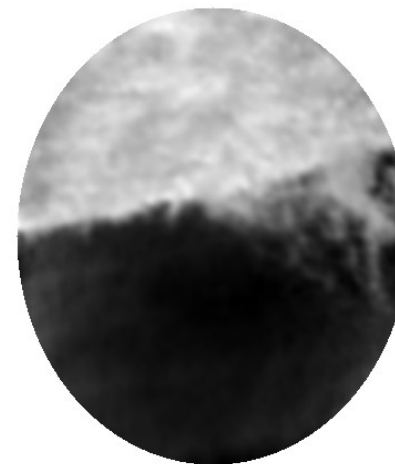
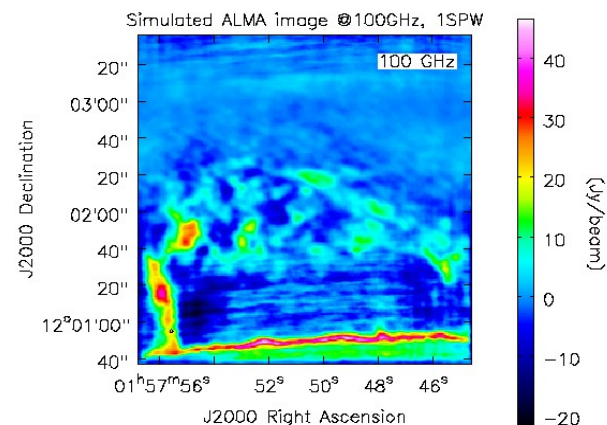
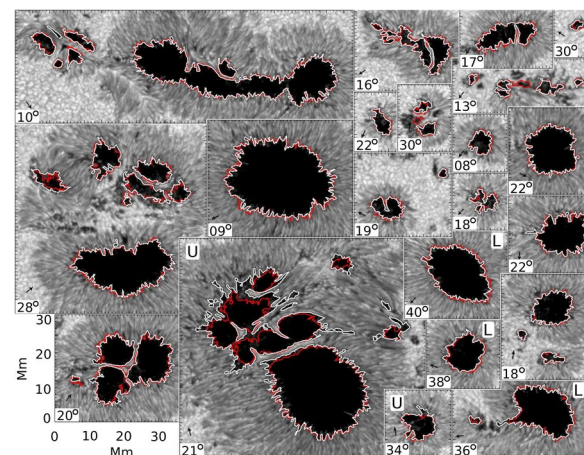
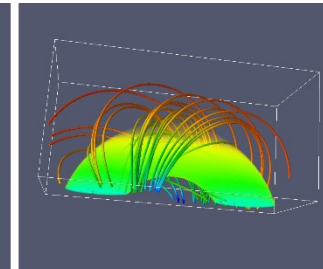
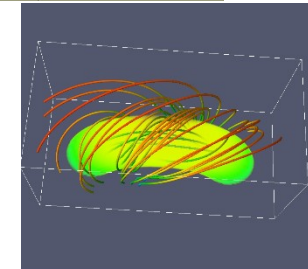
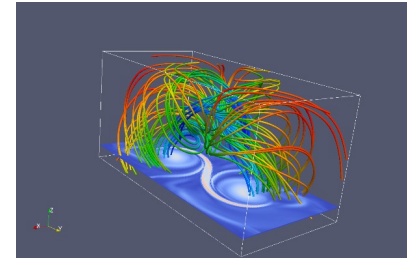
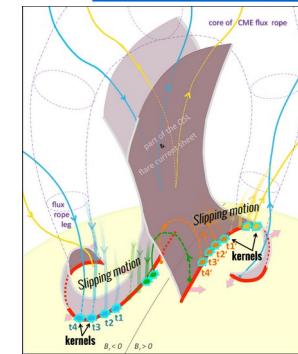
- ♦ Upgrade & development of our own observing & computing infrastructure (optical and radio spectrographs, HPC cluster, robotized telescopes, specific SW packages).
- ♦ Design definition and scientific lead for components of space-born missions (e.g. Solar Orbiter, Proba-3) and large international ground-based facilities (Gregor, EST).
- ♦ Solar ALMA Observing mode: Development, user services (EU lead).

□ 3. Closer to applications – Space safety

- ♦ Space weather predictions (Solar Patrol Service) as a part of international networks (e.g., ISES/RWC).
 - ♦ Risk assessment of major solar events; evaluation of long-term cumulative impact on the power grids.
 - ♦ Direct impact of solar radio bursts to GNSS.
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Results 2015 – 2022: A few selected nuggets

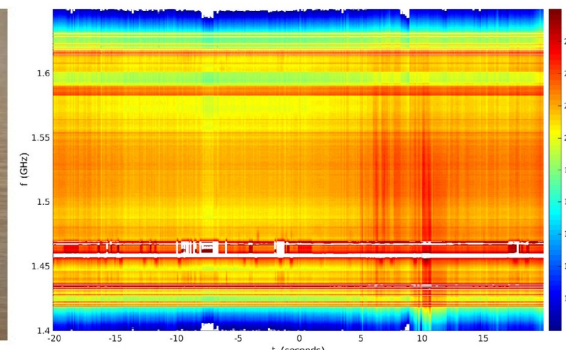
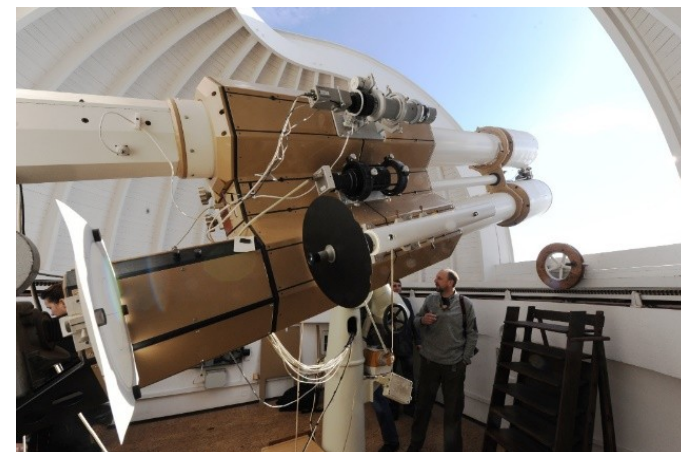
- 3D nature of magnetic reconnection: Many key features predicted by the 3D numerical models found in detailed analyses of high-quality (space-born missions) observed data – slipping reconnection, CME-flank vortices, etc.
- Fine structure of the solar prominence modelled successfully by magnetic-field extrapolation combined with non-LTE radiative transfer. Moreover, for the first time a prediction on how this structure transforms into ALMA interferometric images has been calculated and compared with real ALMA observations.
- Mysterious sharp boundary between sunspot umbra and penumbra was found to be determined by a vertical component of the magnetic field – the critical value is an empirical universal constant for all sunspots in an equilibrium and likely has a deep connection to bifurcation of magneto-convection regimes.



2. Infrastructure / instrumentation / development

In-house infrastructure

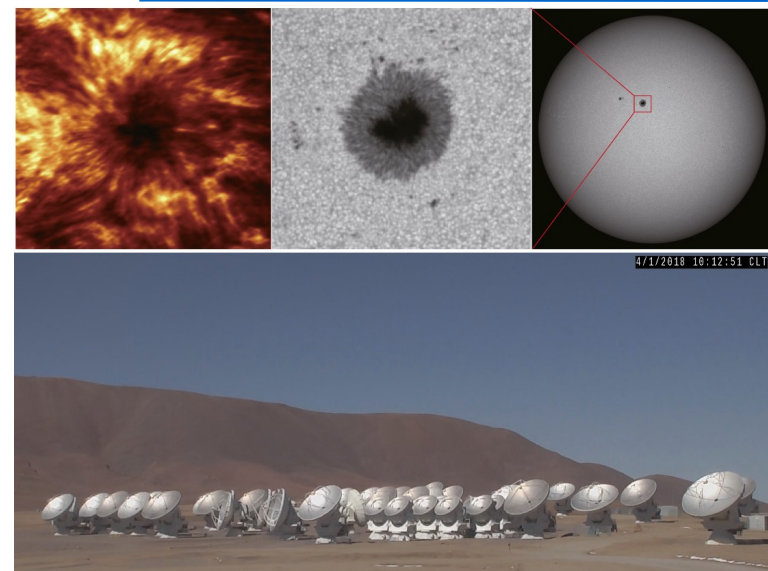
- ❑ **Solar Patrol Service:** Regular monitoring of solar activity with a set of imaging telescopes. Daily and weekly solar activity forecasts. Part of European networks for space-weather monitoring and forecasting.
- ❑ **Horizontal solar optical spectrograph HSFA-2:** Observations of solar flares and prominences with a multichannel slit spectrograph.
- ❑ **Low-dispersion broad-band flare spectrograph FICUS:** Research of solar-stellar connections and (simulated) stellar flares.
- ❑ **Radio telescopes:** Currently, 4 antennas are used to observe solar radio flux and spectra 0.8 – 4.5 GHz. Newly developed OSCARS (*Ondrejov Solar hi-Cadence Automated Spectrograph*) – software-defined-radio digital receiver.
- ❑ **HPC clusters OCAS and OASA (shared):** Demanding numerical simulations and ALMA data processing.



2. Infrastructure / instrumentation / development

Large ground-based infrastructures

- Czech node of the European ALMA Regional center (EU ARC) – *Large National Research Infrastructure* (shared with GPS dept.)
 - ♦ Unique expertise in solar research – **European leader** in this direction. All EU solar data processed by our group.
 - ♦ Development of Solar ALMA Observing Mode (2014-17) in frame of ESO Development Study.
 - ♦ World-wide responsibility for coordination of data-processing routines across the ARCs.
 - ♦ *New ALMA Devel Study*: Solar research with extended array (2022 -)



eso1703 — Photo Release

ALMA Starts Observing the Sun

17 January 2017

SPACE SCOOP

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About the Release

Release No.: eso1703
Name: Sun, Sun spot
Type: Solar System : Star : Feature : Photosphere : Sunspot
Facility: Atacama Large Millimeter/submillimeter Array

Science User Portal (en)

New Images taken with the Atacama Large Millimeter/submillimeter / invisible details of our Sun, including a new view of the dark, contour diameter of the Earth. The images are the first ever made of the Sun

Notes

[1] The ALMA Solar Campaign team includes: Shin'ichiro Asayama, East Asia ALMA Support Center, Tokyo, Japan; Miroslav Barta, Astronomical Institute of the Czech Academy of Sciences, Ondrejov, Czech Republic; Tim Bastian, National Radio Astronomy Observatory, USA; Roman Brajsa, Hvar Observatory, Faculty of Geodesy, University of Zagreb, Croatia; Bin Chen, New Jersey Institute of Technology, USA; Bart De Pontieu, LMSAL, USA; Gregory Fleishman, New Jersey Institute of Technology, USA; Dale Gary, New Jersey Institute of Technology, USA; Antonio Hales, Joint ALMA Observatory, Chile; Akihiko Hirota, Joint ALMA Observatory, Chile; Hugh Hudson, School of Physics and Astronomy, University of Glasgow, UK; Richard Hills, Cavendish Laboratory, Cambridge, UK; Kazumasa Iwai, National Institute of Information and Communications Technology, Japan; Sujin Kim, Korea Astronomy and Space Science Institute, Daejeon, Republic of Korea; Neil Philips, Joint ALMA Observatory, Chile; Tsuyoshi Sawada, Joint ALMA Observatory, Chile; Masumi Shimojo (interferometry lead), NAOJ, Tokyo, Japan; Giorgio Siringo, Joint ALMA Observatory, Chile; Ivica Skokic, Astronomical Institute of the Czech Academy of Sciences, Ondrejov, Czech Republic; Sven Wedemeyer, Institute of Theoretical Astrophysics, University of Oslo, Norway; Stephen White (single dish lead), AFRL, USA; Pavel Yagoubov, ESO, Garching, Germany and Yihua Yan, NAO, Chinese Academy of Sciences, Beijing, China.

European ARC nodes

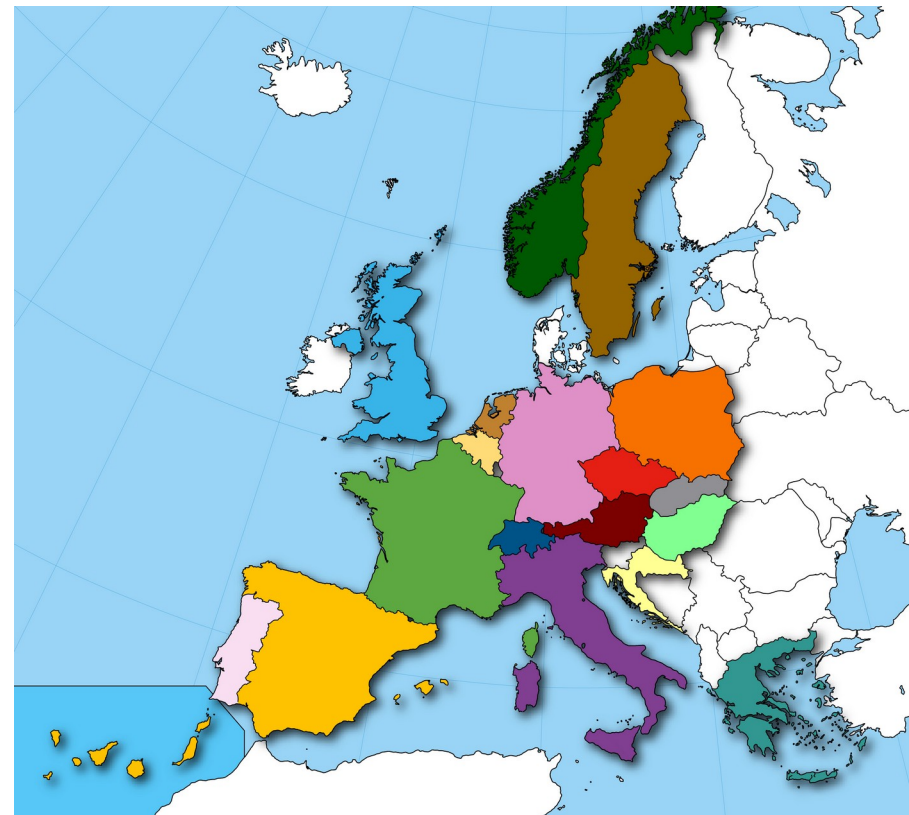


EUROPEAN ARC
ALMA Regional Centre Czech



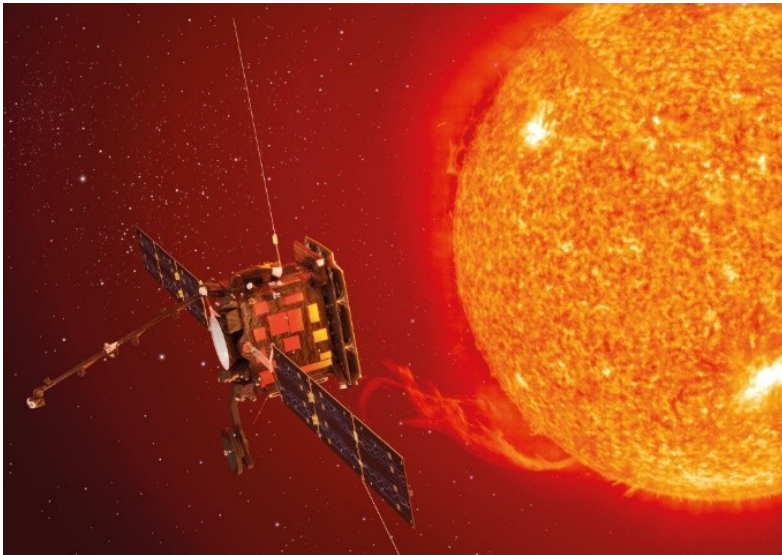
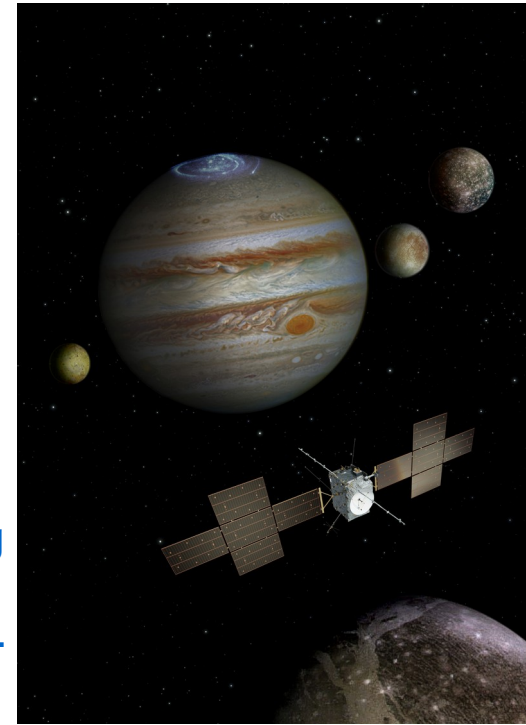
Large ground-based infrastructures

- Gregor & EST – *Large National Research Infrastructure* (EST.CZ)
 - ◆ Design and science-goal definitions for the instruments.
 - ◆ Participation in development of *Integral* field units based on *microlens arrays*
 - ◆ Development of data processing SW (SP inversions).
 - ◆ Observing campaigns.



Recent and near-future ESA space missions

- ❑ Solar Orbiter (close approaches to the Sun): Development and realization of power supplies and flight software for on-board instruments *STIX* (X-ray spectrometer and imager) and *RPW* (in-situ measurements of solar wind). Design definition of optical components for the coronagraph *METIS*, manufacturing at TOPTEC (IPP CAS) and in collaboration with industrial partners. Instrument Co-PI: Petr Heinzl – launched 2020.
- ❑ JUICE (a mission to Jupiter and its moons): Development and realization of power supply for the instrument *RPWI* (in-situ measurements in the magnetosphere of Jupiter) and on-board software (exp. launch 2022).
- ❑ PROBA-3 (space flight in a formation): Development, manufacturing and testing of optical components and front door of the coronagraph *ASPIICS* in collaboration with industrial partners. Co-I Stano Gunar (expected launch 2022).



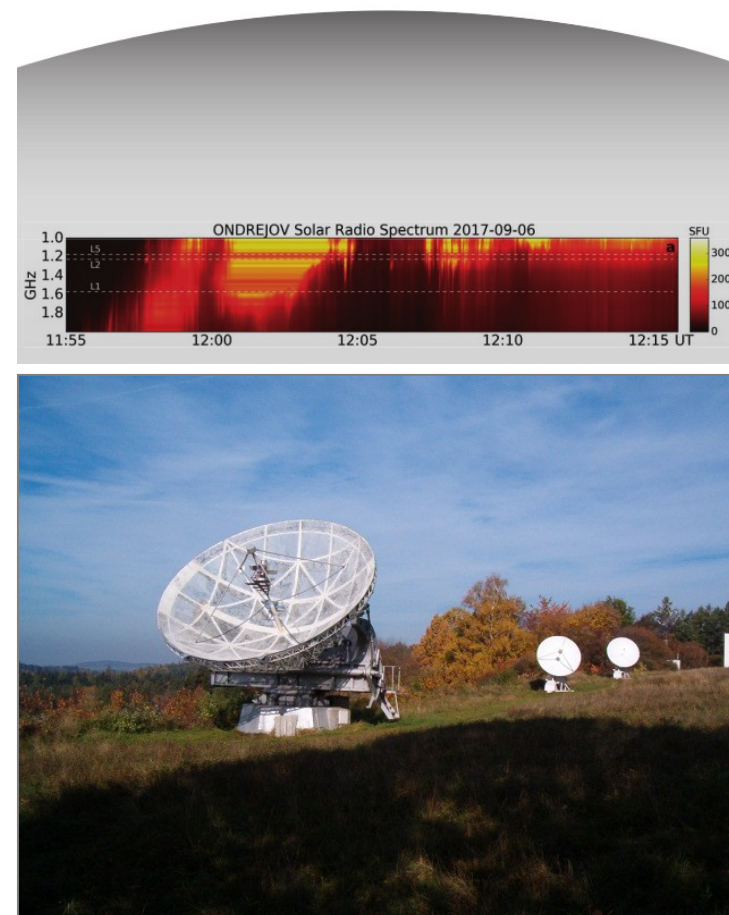
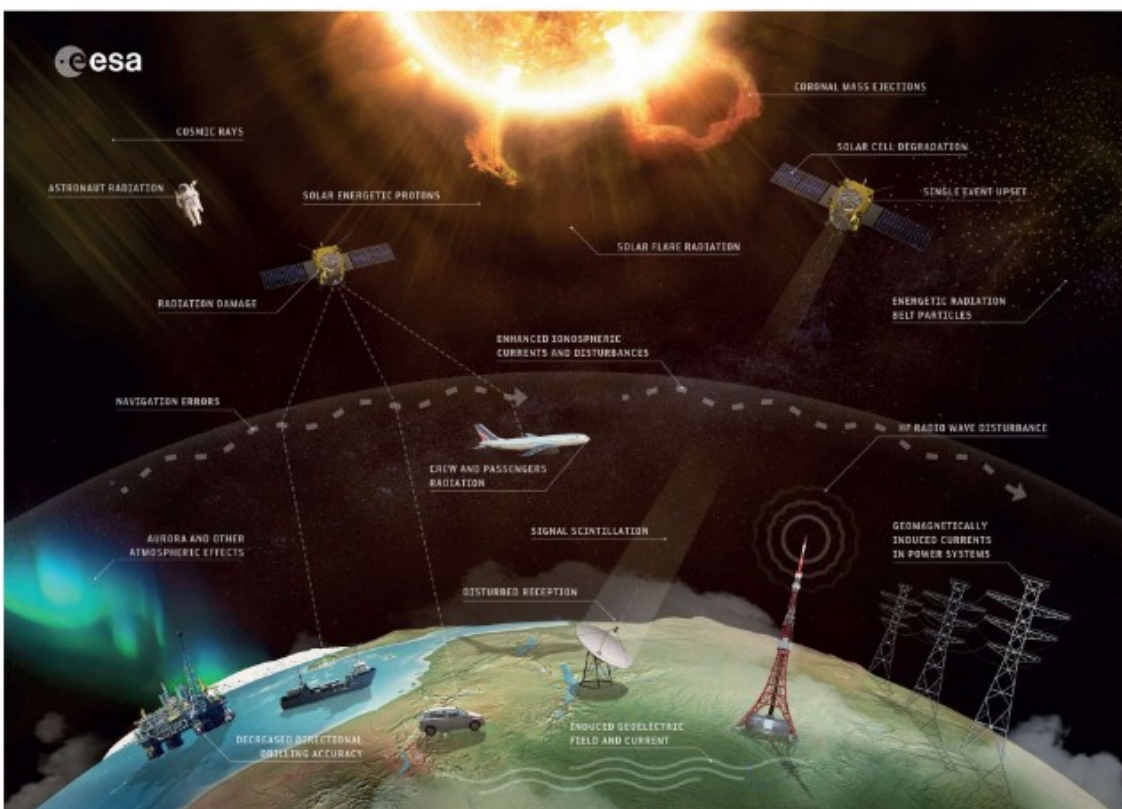
3. Closer to applications: Space safety

- ❑ ESA-SWESNET: Regular monitoring of solar activity with a set of imaging telescopes. Daily and weekly solar activity forecasts. Part of European networks for space-weather monitoring and forecasting – under [ESA S2P](#) programme.
- ❑ Solar radio bursts as an interference to GNSS
- ❑ Research on a long-term GIC effects to Czech power grid

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SPACE SCIENCE

Space Weather

June 2019 • Volume 17 • Issue 6



Plans, trends & perspectives

- ❑ Focus on our strong research topics and methods
 - ◆ Magnetic reconnection: FEM-MHD & PIC simulations, advanced data analysis aiming at connecting the 3D and multi-scale pictures of solar flares.
 - ◆ RHD simulations, radiative transfer (RT), and spectroscopic/SP diagnostics: 3D full-Stokes non-LTE RT, SP inversions – application to the high-quality data available in a near future (e.g., DKIST, EST, Solar Orbiter)
 - ◆ Radio, incl. sub-THz diagnostics of solar plasmas: Models & modern observations (LOFAR, OSCARS, ALMA).
 - ◆ Solar wind turbulence: Numerical simulations and data-analysis from recent space missions (SPP, Solar Orbiter).
- ❑ Sustainable development of our own infrastructure
 - ◆ 2nd phase of upgrade of our radio spectrographs (OSCARS, unique observing band in Europe).
 - ◆ Modernization and automation/robotization of our optical observing facilities (SPS, spectrographs).
- ❑ Strengthening our involvement in the large international cooperations: Ground-based & space
 - ◆ ALMA: New ESO Development Study – expected execution Oct 2022 – Dec 2024. Focus on longer-baseline solar observations.
 - ◆ Extending our solar radio-interferometry expertise: Ambition to become a **EU solar interferometry expert center** (ALMA, **LOFAR**, SKA).
 - ◆ Continuing effort in building European large optical solar facilities (EAST, SolarNet II, EST) – involvement in the **“Microlense arrays”** development (search for industrial partners).
 - ◆ Space activities: Continuing our participation on the running **ESA projects** (JUICE, PROBA-3), involvement in the future missions.
- ❑ “Applied” research
 - ◆ ESA-SWESNET network (**ESA S2P**): Finalizing development of our products, start of standard operations.
 - ◆ Interference of solar radio bursts to GNSS – a joint project with Faculty of Transportation TU Prague + industrial partners.
 - ◆ Potential applications in space-weather risk management: Solar-hazard assessment, so-far omitted cumulative effects of mid-size solar activity events on infrastructure.

Department of Solar Physics @ASU

- is pursuing high-quality basic research in solar & heliospheric physics,
- is involved in large international ground-based (ALMA, EST) and space (various ESA missions) projects, instrumental infrastructures, & services including development (SW, HW),
- develops an effort in applicability of its research namely in the area of space safety (ESA S2P).

There is clear perspective of future development in all these areas.