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Rosseland
Centre
for Solar
Physics

Annual report
2024

Norwegian
Centre of
Excellence

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Annual report 2024

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Rosseland Centre for Solar Physics (RoCS)

Our vision is understanding the workings of the energetic Sun.

1. To understand the origin and evolution of the solar magnetic field on spatial scales ranging from the smallest observable (<100 km) to the size of active regions (100,000 km).

2. To understand the dynamic structuring and mass and energy transfer in the solar atmosphere from the relatively cool (6,000 K) surface to the multi-million degree corona.

3. To understand which configurations of the magnetic field, ambient and emerging, lead to the development of dynamic phenomena such as surges, jets and flares of all sizes that permeate the active solar atmosphere.

4. To go beyond the single-fluid magnetohydrodynamic (MHD) paradigm, which breaks down in the nearly neutral chromosphere and the almost collisionless coronal plasma. We will do this by applying multi-fluid and particle-in-cell techniques, providing new understanding of heating and particle acceleration in both quiet and active solar environments.

From the autumn retreat at the Norwegian Academy of Science and Letters. Credit: Private

From the Director

This is the seventh annual report of the Rosseland Centre for Solar Physics (RoCS), one of the 10 centers of excellence selected by the Research Council of Norway in the fourth round of the centers of excellence scheme.

Activity has been high throughout 2024. The doctoral and postdoctoral research fellows have been very active in organising retreats, seminars, workshops, short presentations at the monthly solar-stellar lunches, and many other social activities. These activities are at the heart of a well-functioning research environment, and this annual report illustrates some of them.

The external retreat was in 2024 close to Kongsberg. The deep forest replaced the fjord setting of 2023. We had scientific presentations as the theme, and two external talks gave lots of ideas and inspiration. Before the retreat, all participants had suggested themes in solar physics that they would like to hear presented in a flash talk. We could then choose a theme from this list to make a five-minute presentation in a small group setting with feedback followed by a repeat in another group. Very successful. Thanks to the organising committee (Benedikte, Elias, Elisabeth, Luc, Sascha, and Quentin).

The internal retreat was this time half external, with the first day at the Norwegian Academy of Science and Letters. A very fitting frame around the theme – the historical development of current tools in solar physics. Talks were given on the history of solar atmospheric models, solar/stellar atmospheric simulations, solar telescopes and IT at ITA. A piano concert with George Cherry was a highlight. The second day was followed by discussions on the science at RoCS and the situation for doctoral research fellows. These discussions had been in various groups before the retreat with a follow-up during the second day with group discussions, reports and panel discussions. Again, it was very successful, thanks to a

> In 2024 we were a total of 63 persons of 20 nationalities from three continents at RoCS.

hard-working committee (Benedikte, Eilif, Elisabeth, Eyrun, Ignasi, and Mikolaj).

RoCS is like a big family but constantly changing: new people come, and some leave. One postdoc started in 2024: Valeriia Liakh on the DSTrain Cofund program. Two new PhD students, Semya Amouche Tønnessen and Aline Rangøy Brunvoll, also joined. As well as many new people coming in, we also have people moving out. Ana Belén Griñon Marín finished her postdoc period in September and moved to the Institute for Solar Physics in Stockholm, Sondre Vik Furuseth left us in August for the private sector, and Avijeet Prasad finished in August. We had two PhD thesis defences in 2024: Øystein Færder and Lars Frogner. Tor-Andreas Bjone, Christophe K. Blomsen, Aline Rangøy Brunvoll, Eloi Martaillé Richard and Semya Amouche Tønnessen finished their Master's. A hearty welcome to the newcomers and best wishes for their new careers to the ones leaving.

The activity was high in 2024, and reports organised by theme are given in Section 2. As a new feature this year, Appendix 1 provides summaries of all Master's and PhD theses. Appendix 2 lists talks and presentations, and Appendix 3 provides a full list of the 62 papers published in refereed journals in 2024.

Research results are important, but it is also essential to communicate these results to both the scientific world and society at large. Our full-time communication advisor, Eyrun Thune, has actively promoted solar physics together with the RoCS crowd. Many venues were used: Domus Bibliotheca, Ungforsk, the Astronomy Olympiad, Ted talk, newspapers, podcasts, TV, radio, social media – we were active everywhere. You can read more about the important outreach activities on page 22.

Several persons from RoCS participated in the third workshop on Career Development for Young Researchers, a series of workshops initiated by the Hylleraas Center of Excellence. As during the previous editions, we were inspired to work further on improving the career development at RoCS. One very popular activity is career talks by previous alumni – the presentations show that the skills you develop at RoCS can also be very valuable for a career outside academia.

Another popular monthly series of talks is "Passion pursuit," which covers interests outside work. Mountaineering, terrain biking, knitting, and wine are some of the hobbies covered.

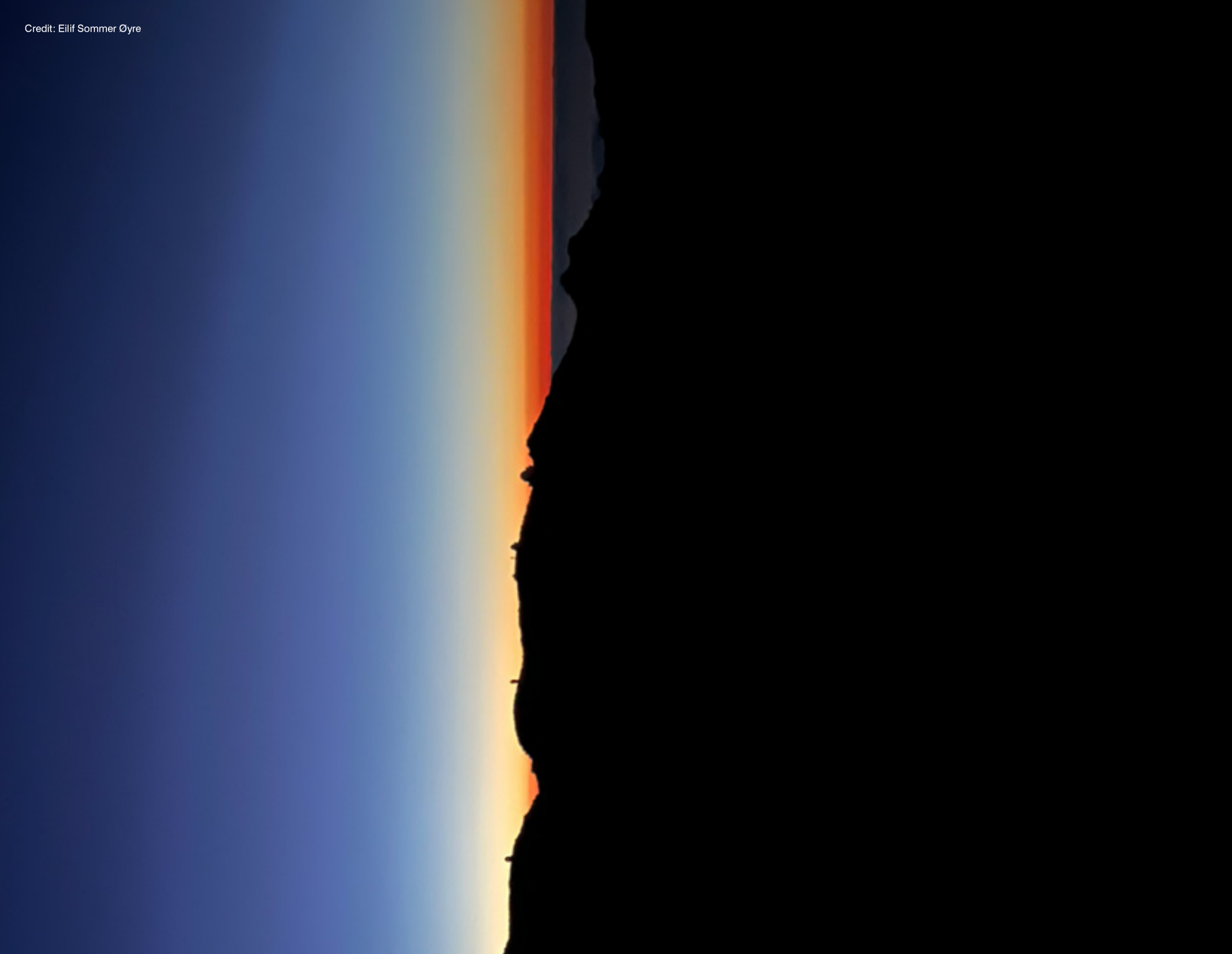
The International Rosseland Visitor Programme is covered in Section 3, and we continue the tradition with some glimpses from the life at RoCS in Section 4. Among other topics, you can there read about teaching solar physics in Africa, Engagement with the solar physics community in Europe, Observing flares with SST, Engaging with solar orbiter observations, Chromospheric heating, a Deep Learning workshop at RoCS, Real art, a Career at NASA, Summer projects at RoCS and the Northern lights. Life at RoCS is certainly varied, productive and rewarding.

As the most important part of a centre is people, we have short presentations of all the members in Section 5. In 2024, we were a total of 63 persons of 20 nationalities from three continents at RoCS. We have seen major progress towards the goals of RoCS, and we are looking forward to 2025, which promises a record number of PhD defences.

March 2025

Mats Carlsson,
Director of RoCS

2024 Activities by theme



Credit: Eilif Sommer Øyre

Simulations

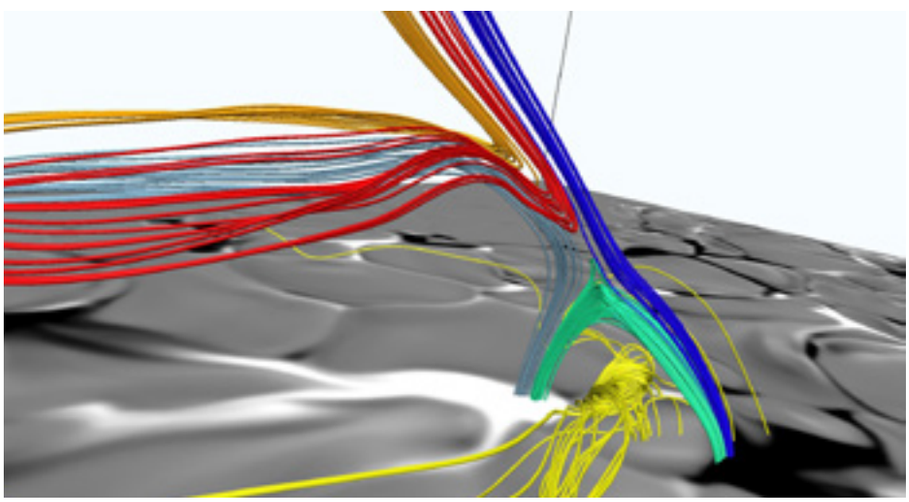
Simulations of the solar atmosphere can serve many purposes; from investigating fundamental physical problems such as reconnection, understanding the structure and dynamics of the solar atmosphere, to preparing the best possible observing sequences for new or existing instruments. The past year has seen progress in all these endeavours.

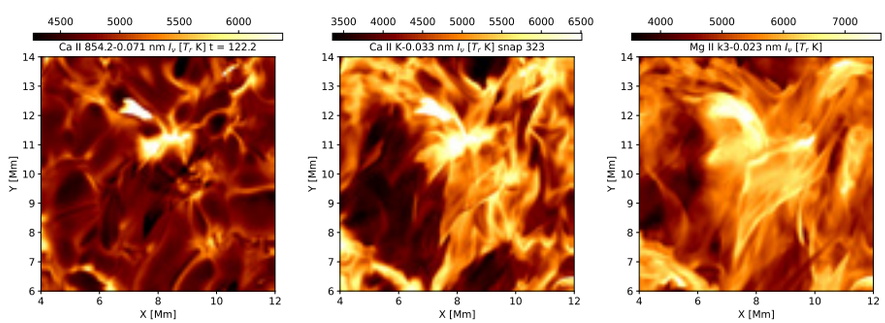
Cancellation

The source of solar activity lies in the interaction between photospheric and convection zone dynamics and the magnetic field. The plasma of the photosphere dominates and distorts magnetic field elements, and thereby sends an energy flux towards the outer atmosphere above where it is dissipated. In addition to heating the outer atmosphere of the Sun, the interaction between photospheric dynamics and the magnetic field plays an important role in the generation of the magnetic field itself: a local dynamo presumably operates independent of the larger scale global dynamo that is responsible for sunspots. Photospheric or near photospheric reconnection is involved, often leading to 'cancellation'; the observed disappearance or strong reduction of magnetic flux as magnetic elements of opposite polarity interact. High resolution observations indicate that the density of mixed magnetic polarity near the footpoints of hot magnetic loops may be large and that flux cancellation therefore could be a source of energy injection into the chromosphere and corona. But the case is far from closed, models are fully capable of producing coronal heating without any cancellation events, so the questions become: Can cancellation heat the solar plasma to coronal temperatures and are such events important in building the structure of the outer solar atmosphere?

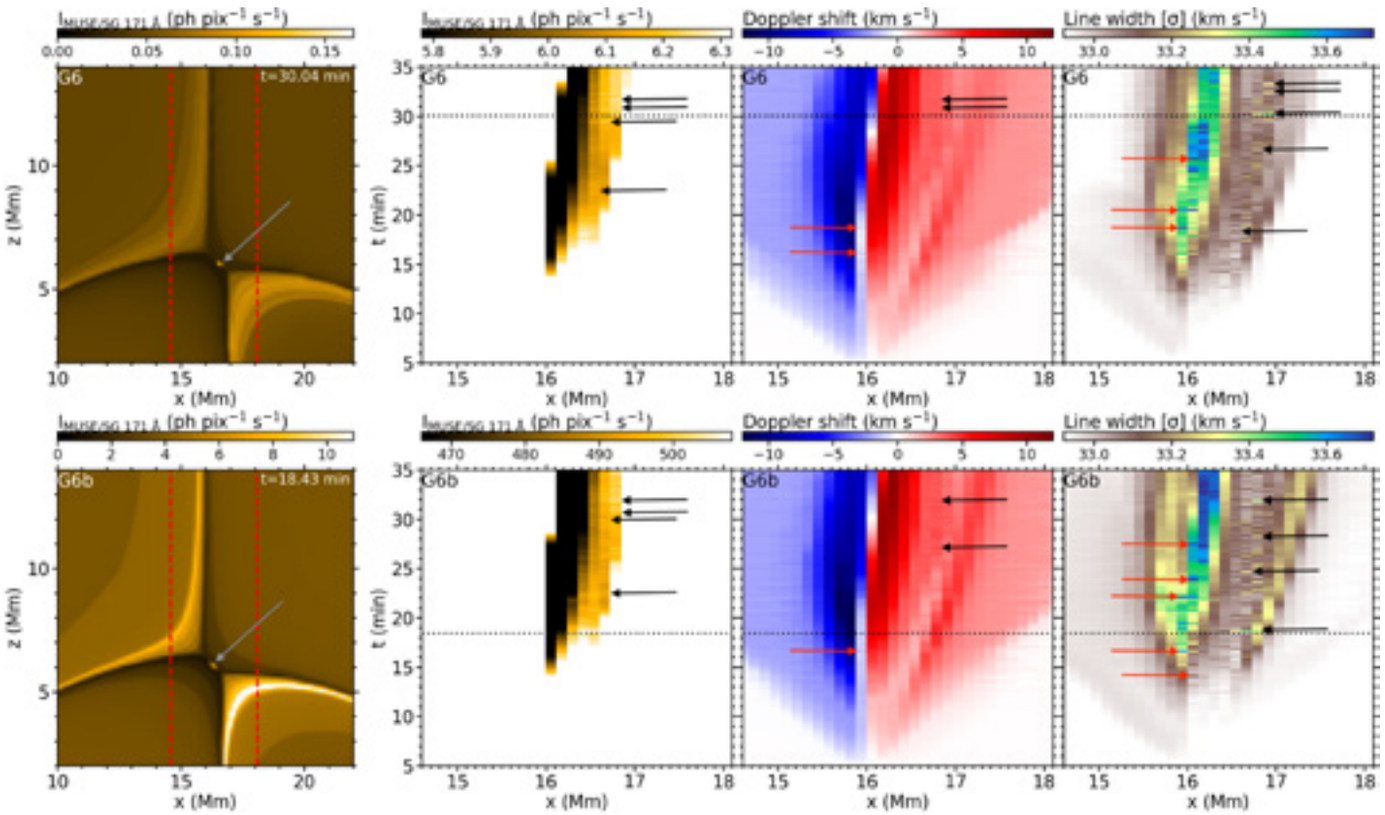
Plasmoids

As noted above, reconnection is an extremely important process in channeling magnetic energy into the Sun's outer atmosphere. This is also true in coronal structures where we find fan-spine structures (such magnetic structures are typically located below coronal bright points) as seen through strong emission from multiple ionised iron, like the Fe IX 17.1 nm and Fe X 17.4 nm lines. Simulations of these structures with varying assumed densities have been carried out. These simulations show that the "plasmoids" – small rapidly moving bundles of magnetic field – are formed during the reconnection process and appear brighter than the surroundings. When taking instrumental broadening into account the simulations show that the plasmoids are resolvable with MUSE and appear bright enough to be detected, especially in high-density cases.





Positive and negative magnetic polarities approaching each other prior to cancellation with associated magnetic reconnection occurring in the atmosphere above (left). Observational signatures of this cancellation is seen in the three important chromospheric lines of Ca II 854.2 nm, Ca II K and the Mg II k, which all show the formation of a jet (Moreno Insertis et al. 2025).



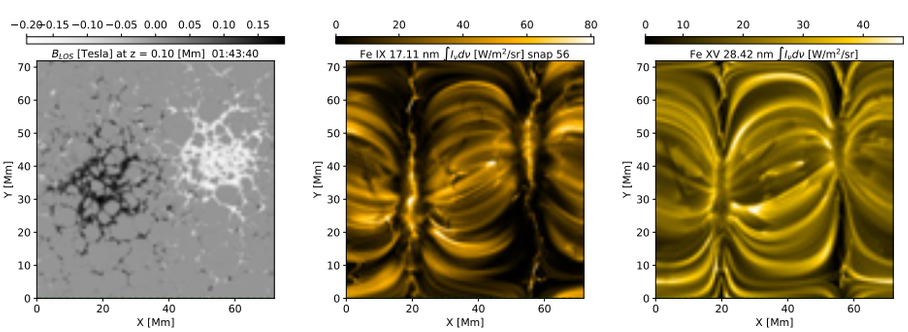
Synthetic spectral moments of the Fe IX 17.1 nm line, relevant to Solar Orbiter (and MUSE) observations. Note the bright plasmoid situated in the current sheet between the interacting magnetic flux systems. Such plasmoids are highly dynamic consequences of reconnection and are evidence of magnetic energy being converted to heat and motion (Færder et al. 2024).

While reconnection in the corona may produce large amounts of plasmoids that are too small to be studied by the majority of today's telescopes and spectrographs, MUSE, along with Solar-C, should be capable of detecting several, as well as being able to perform spectral analysis, mapping their densities, temperatures, and velocities, and hence potentially revealing crucial details about the physical process that drive coronal heating and triggers explosive events such as flares.

Preparation for MUSE

MUSE is a multi-slit instrument slated for launch in 2027 designed to observe the hot corona at unsurpassed temporal and spatial resolution. The multiple-slits ensure high quality, but complexity comes at a price, and particular attention must be paid to the planning of observing modes and the design of the data reduction pipeline. This effort is helped enormously by the use of synthetic models which can provide answers to these challenges. Of course, to be of use, the models need to replicate the real Sun sufficiently closely to accurately predict expected count rates. Bifrost simulations of the quiet Sun, of plage, and of small flares are currently being vetted – by stringent comparisons with SDO/AIA, Hinode/EIS and IRIS data. When validated these models will be of great value to the MUSE team, but will also give us deep insight into the physics of the solar atmosphere and its complex magnetic field.

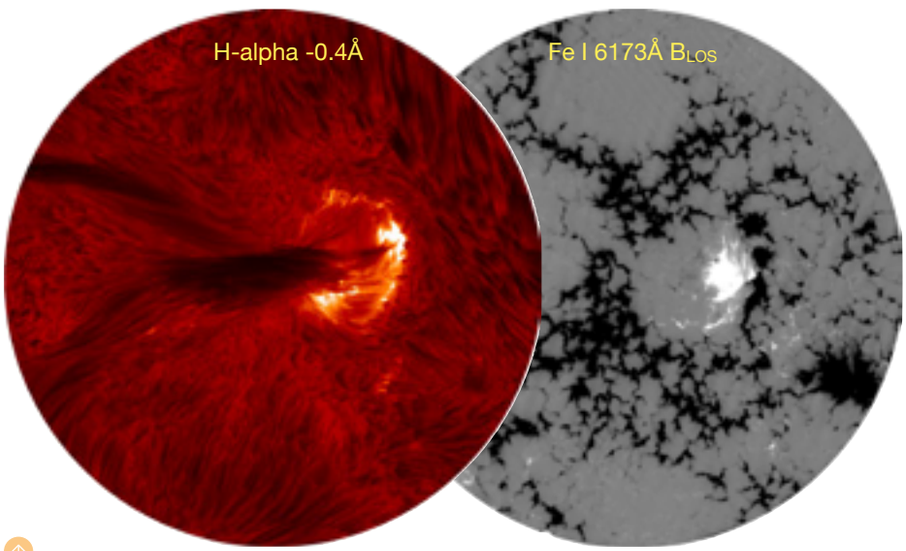
Author: Viggo Hansteen



Photospheric magnetic field and synthetic Fe IX 17.1 nm and Fe XV 28.4 nm intensities. This is a plage model used to investigate possible observing modes of the MUSE telescope, but has also been used to investigate possible modes of chromospheric and coronal heating in a solar plage like environment (Bose et al. 2024).

Observations with SST and IRIS

RoCS is the largest external user of the Swedish 1-m Solar Telescope (SST) at La Palma in the Canary Islands. All observations are coordinated with the IRIS satellite to have dense coverage of the solar atmosphere from the photosphere up through the chromosphere and transition region into the corona. This year we also coordinated with ESA's Solar Orbiter spacecraft.



Jet eruption from an anemone magnetic topology observed on 21 May 2024. The positive magnetic polarity patch (white) is surrounded by a ring of negative polarity (black) magnetic fields. This results in a so-called fan-spine magnetic topology that resembles an anemone at the base. This magnetic topology can lead to large-scale jet eruptions like observed here in H-alpha (see another example of an anemone jet observed with SST and IRIS in Joshi et al. 2024 A&A 687).

For many years we have had an agreement with the Institute for Solar Physics in Stockholm which gives us observing time at the SST. The observing time is usually divided over three campaigns spread over the observing season. In 2024 these campaigns were in May, September, and October. In total there were 9 RoCS members participating in the three campaigns. The photos on page 48 give an impression.

Long campaign in May 2024

With 3 weeks, the campaign in May was longer than usual. In combination with a number of good seeing days, this campaign produced a record amount of data: almost 140 TB of raw data was transferred to Oslo. The Sun was very active and we acquired several time series of flares, jets, and eruptions. An example of a jet observed on 21 May is shown in the image above. With the CRISP instrument, we observed the cooler parts of the jet in H-alpha, and also measured the magnetic field in the photosphere. This is a beautiful example of a jet eruption from a fan-spine magnetic topology. This jet was also well covered by the IRIS spectrograph. On 24 May, the seeing was excellent and stable for a long time. This resulted in a more than 2 hour long time series of a complex active region near the limb. The image on the right shows the region in the wing of the H-beta spectral line. A large number of Ellerman bombs can be seen as bright flames that stick out vertically from the granulation. Ellerman bombs are caused by magnetic reconnection in the deepest parts of the solar atmosphere.

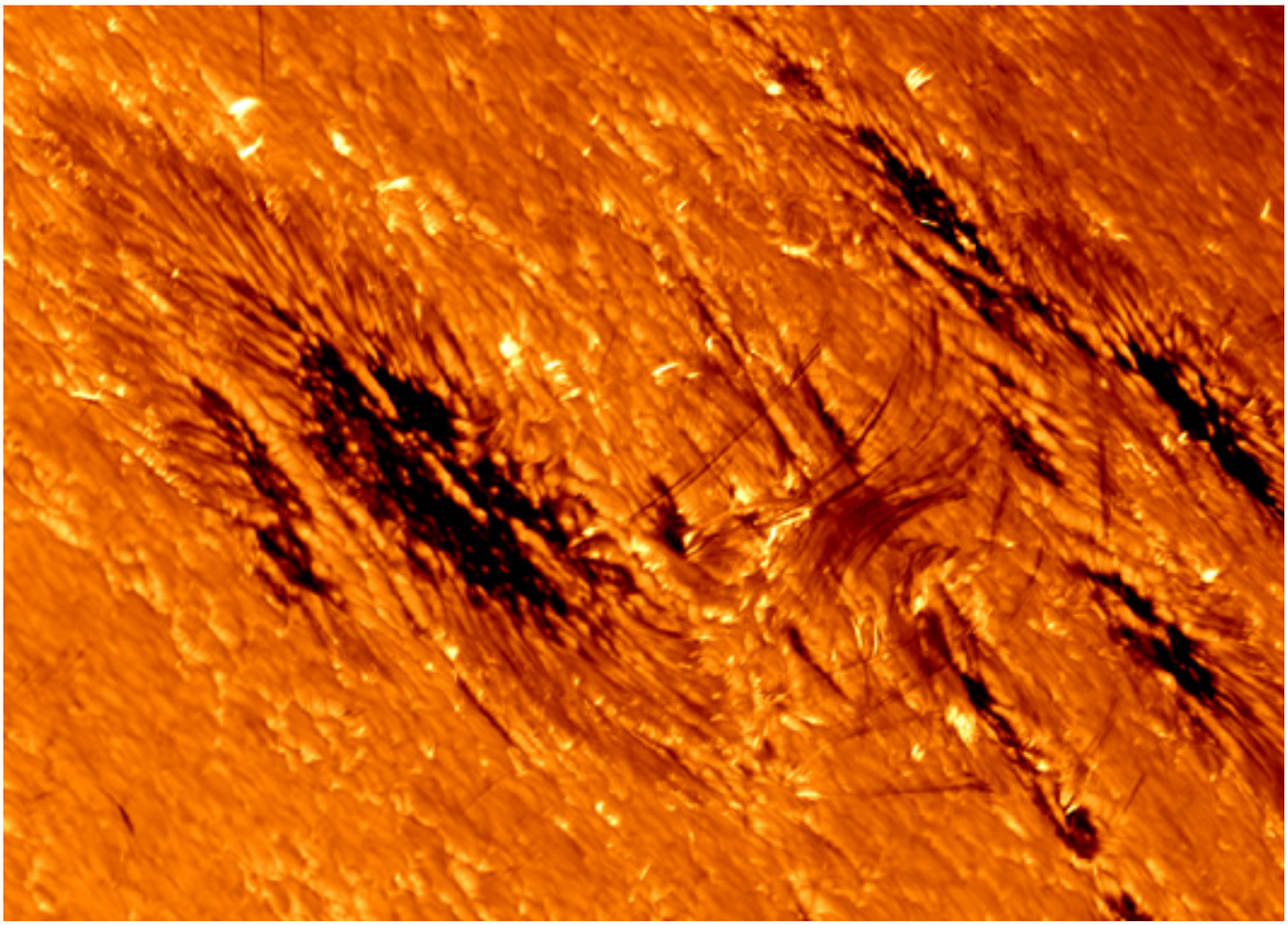
M2 flare

The September campaign was not as productive as in May but we were fortunate to have good seeing during a rather strong flare. We managed to observe the full evolution of the M2 class flare. The observations were started just before the flare onset so that we got data to study the impulsive early phase of the flare. On page 43 we describe the flare alert system that is operational at the SST. The flare alert system enabled us to observe multiple flares.

Coordination with Solar Orbiter

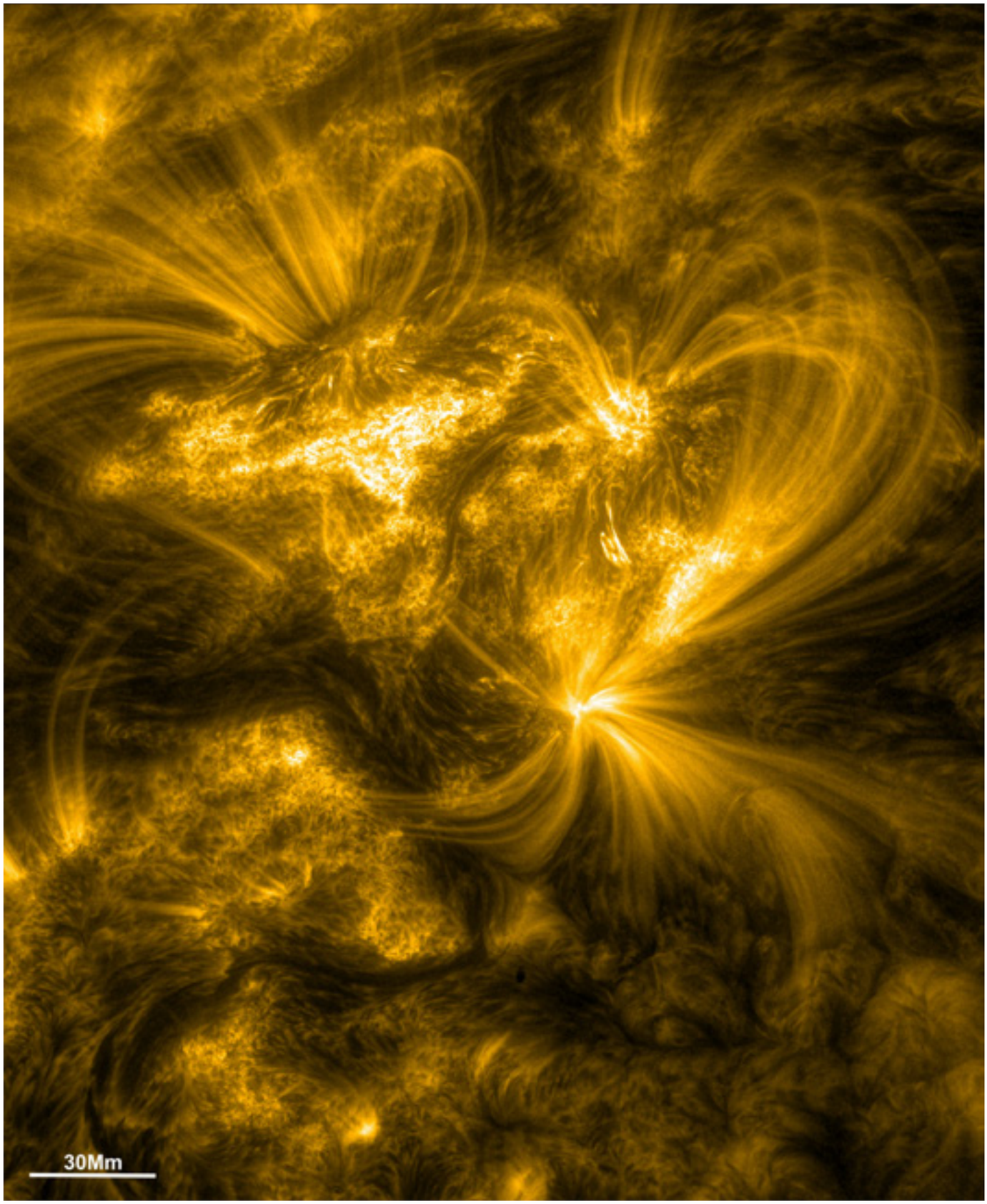
In October, we participated in a coordinated campaign with several instruments on the Solar Orbiter spacecraft. We joined the long-term active region Solar Orbiter observing program (SOOP) organised by former RoCS member Clara Froment (now at CNRS in Orléans, France), former RoCS PhD Henrik Eklund (now at ESA/ESTEC in the Netherlands) and Li Xiaohong (MPS Göttingen, Germany). During this SOOP, the aim was to follow an active region for as long as possible. We joined the campaign during the last week of the coordination window when the target active region was visible both from Solar Orbiter and from SST at Earth. The observing conditions at La Palma are often challenging in October but we were lucky to be able to acquire data for 5 days during the week-long campaign. Of particular interest are the observations that were taken during the 60 min high-resolution window of the EUI instrument when coronal images were taken at a cadence of 6 s and a spatial resolution that is more than 4 times better than the images from the AIA instrument at the Solar Dynamics Observatory. An example EUI image with the corresponding SST H-alpha mosaic are shown on pages 14 and 15.

Author: Luc Rouppe van der Voort

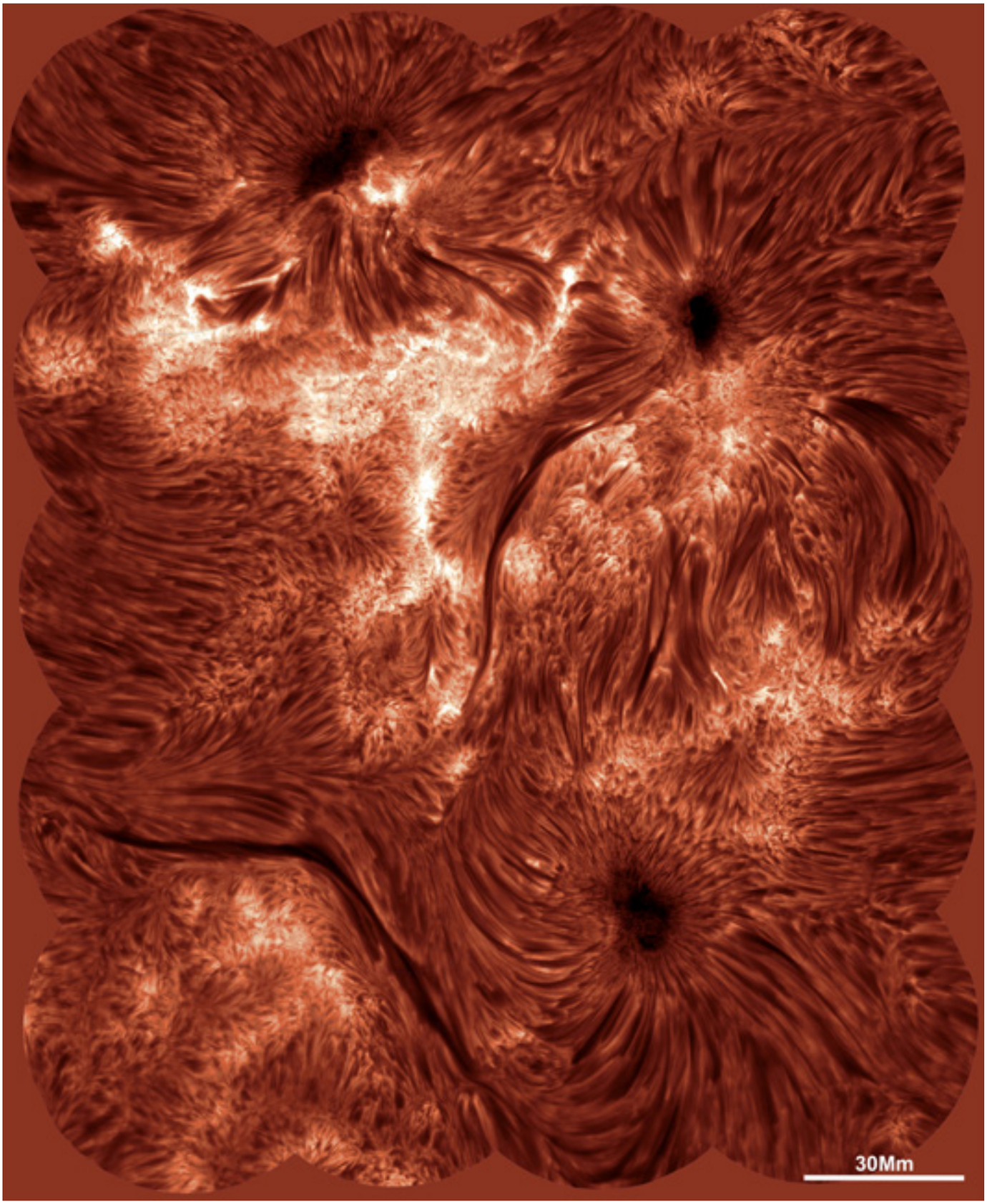


H-beta wing image (at -700 mÅ offset from line core) of a large active region close to the solar limb, observed with the CHROMIS instrument on 24 May 2024. There are many examples of both very tall and smaller Ellerman bombs, visible as narrow, elongated brightenings.

Coordinated Solar Orbiter & SST observations: active regions



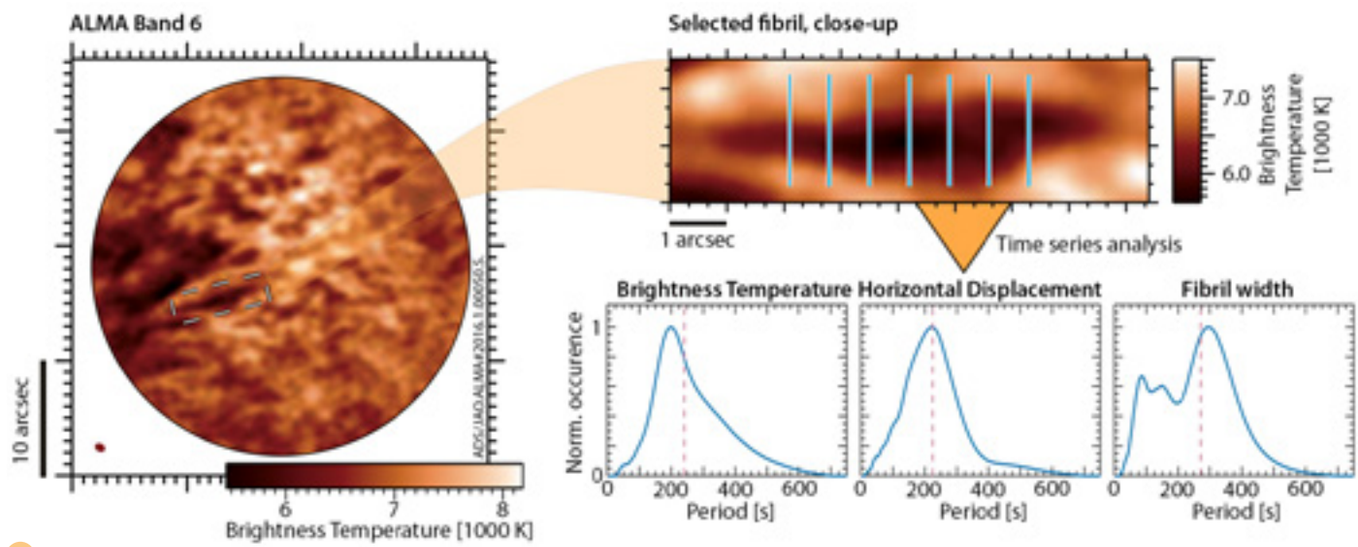
Coronal image in extreme UV (174Å) of active region 13852/4 observed on 14 Oct 2024 10:07UT by the EUI/HRI instrument on Solar Orbiter. Image processed with the Wavelet-Optimized Whitening method (WOW; Auchère et al., 2023).



Coordinated observation of the same active region in the chromosphere by SST/CRISP in the H-alpha line core. The mosaic was constructed from a 5x4 grid of pointings. Solar Orbiter was separated by 35 degrees from the Sun-Earth line, giving a different viewing perspective.

Science at long wavelengths – ALMA, AtLAST, and beyond

In 2024, future observing capabilities with the Atacama Large Millimeter/submillimeter Array (ALMA) and the Atacama Large Aperture Submillimeter Telescope (AtLAST) were explored, promising new insights into solar and stellar activity at millimeter wavelengths.



Brightness temperature map from the ALMA Band 6 observation of a plage region (left) featuring a fibril (outlined by the dashed white rectangle). The beam size is indicated in the bottom-left corner and the long-lived fibril of interest. The time-dependent variation across artificial slits across the fibril (top right) was analysed in detail, providing insights into the oscillatory behaviour of properties such as temperature variation, horizontal (lateral) displacement, and width of the fibril. The figure was adapted from Saberi et al. (2025).

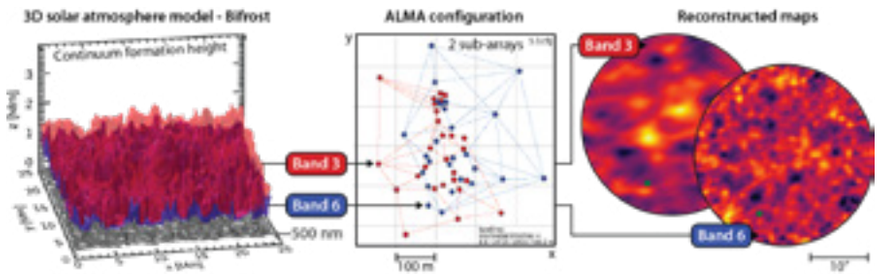
ALMA observation of a fibril

Magnetohydrodynamic (MHD) waves, critical for energy transport in the solar atmosphere, were studied in a long-lasting dark fibril using high-cadence (2 s) ALMA Band 6 observations. Oscillations in brightness temperature, horizontal displacement, and width revealed median periods of approximately 240 s, with wavelet analysis identifying a combination of standing and propagating waves, indicative of MHD kink and sausage modes. Propagating waves, less dominant than standing waves, exhibited median phase speeds below 100 km/s. This study highlights ALMA's effectiveness in capturing dynamic fibrillar structures, offering valuable insights into chromospheric wave dynamics (Saberi et al.).

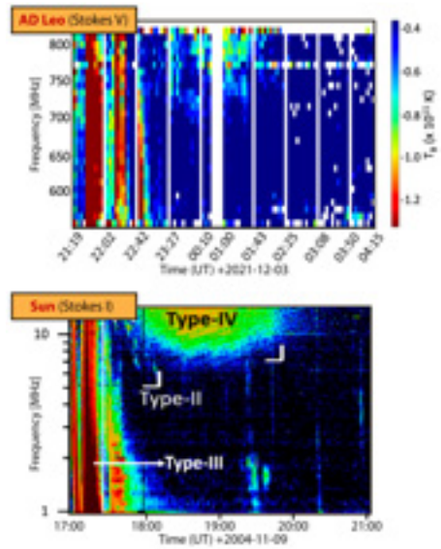
New observing capabilities for ALMA

The successfully concluded M.Sc. project of Eloi Martaille Richard investigated the scientific potential of a sub-array observing mode for ALMA. Splitting ALMA into two sub-arrays would enable strictly simultaneous observations in two receiver bands and, thus, two frequency (or wavelength) bands, corresponding to different height ranges in the solar atmosphere. This capability would unlock new diagnostic possibilities for tracking waves and probing the solar chromosphere's height-dependent structure. Each sub-array would have only half the number of antennae and thus a much lower number of baselines connecting these antennae. The latter is critical for reconstructing reliable images of the solar target. Using the Solar ALMA Simulator (SASim), the project explored if reliable imaging could be done with sub-arrays and how such a setup could be designed. The conclusion is that decent imaging seems possible with sub-arrays in compact configurations.

While it is not clear yet if or when a sub-array mode will be implemented, ALMA's Wideband and Sensitivity Upgrade (WSU)



Simulations of ALMA dual-sub-array observations with one sub-array observing in Band 6 (3.0 mm) and the other simultaneously in Band 3 (1.3 mm). Left: Formation heights of the Band 3 and Band 6 continuum. Middle: ALMA configuration with some of the possible baselines connecting the antennae in the respective sub-arrays. Right: Reconstructed brightness temperature maps. These results are part of the concluded M.Sc. thesis project of E. Martaillé Richard.



Comparison between the observed radio burst on AD Leo (top) and a typical event for the Sun connected to a CME (bottom, observed with the Wind/WAVES instrument). The AD Leo spectrum shows features similar to the solar type-IV and type-III features. Figure adapted from Mohan et al. (2024). Solar data credit: CDAW data centre.

is progressing. A wider frequency range per band and possible multi-band receivers would increase the simultaneously covered height range in the solar atmosphere with direct diagnostic advantages. Simulation results for the sub-array mode and wide-band extension were presented at an international workshop at ESO headquarters in June 2024.

Solar science with AtLAST

2024 was a pivotal year for AtLAST with the first design study concluded and the second phase being approved. The international working group for solar/stellar science with AtLAST produced an overview article that explores the scientific potential and instrumental requirements and also points out the complementarity to other observatories such as ALMA. The now-published article (Wedemeyer et al.) describes the following key solar science cases for AtLAST: The thermal structure and the atmospheric heating problem, solar flares, prominences, long-term monitoring of the solar activity cycle, and the solar-stellar connection in particular concerning solar/stellar activity. The content of this article was presented at the AtLAST conference in Mainz, Germany, in May 2024, and at the Annual Meeting of the European Astronomical Society in Padua, Italy, in July 2024.

A solar observing mode for AtLAST

As multi-pixel detectors are on the verge of becoming the new technological standard for mm-wavelength astronomy, AtLAST promises observational capabilities that make this telescope, despite its limited angular resolution, highly compelling for the above-mentioned science cases. The technical requirements and possible scan strategies for providing full-disk images of the Sun at high cadence were explored as part of the Ph.D. thesis project of Mats Kirkaune, using the simulation package maria. The publication of the study results is foreseen for 2025.

Stellar activity

Type-IV radio bursts, as observed for our Sun, are generated by flare-accelerated electrons trapped in post-flare loops or moving magnetic structures associated with coronal mass ejections (CMEs). These bursts are key tracers of space weather events. The first detection of a solar-like type-IV burst on AD Leo, a young, active M dwarf, was reported in 2024 (Mohan et al.). The observation with the upgraded Giant Metrewave Radio Telescope (uGMRT) at >700 MHz revealed a burst characterized by high brightness temperature and nearly 100% circular polarization, suggesting a CME origin. This discovery highlights the potential of type-IV bursts as markers of stellar CMEs and offers insights into particle acceleration mechanisms and magnetic field structures in stellar coronae, revealing similarities and differences with solar cases.

Evolved stars

Observations of the ejected material from evolved solar-type stars at mm/sub-mm wavelengths trace the origin and evolution of various chemical elements. In 2024, we have conducted new observations of aluminium fluoride in the outflow of three asymptotic giant branch (AGB) stars using the IRAM 30 m telescope to study their contribution to the Galactic fluorine budget (Gorai et al. in prep). Moreover, using ALMA high spectral resolution observations towards the AGB star, Mira, we studied the role of the S-process on the Titanium (Ti) isotopic ratio (Saberi et al. in prep). Additionally, we studied the density, temperature, and velocity distributions of the gas in the atmosphere of the AGB star, R Dor using ALMA observations and 3D radiative transfer models (Khouri et al. 2024).

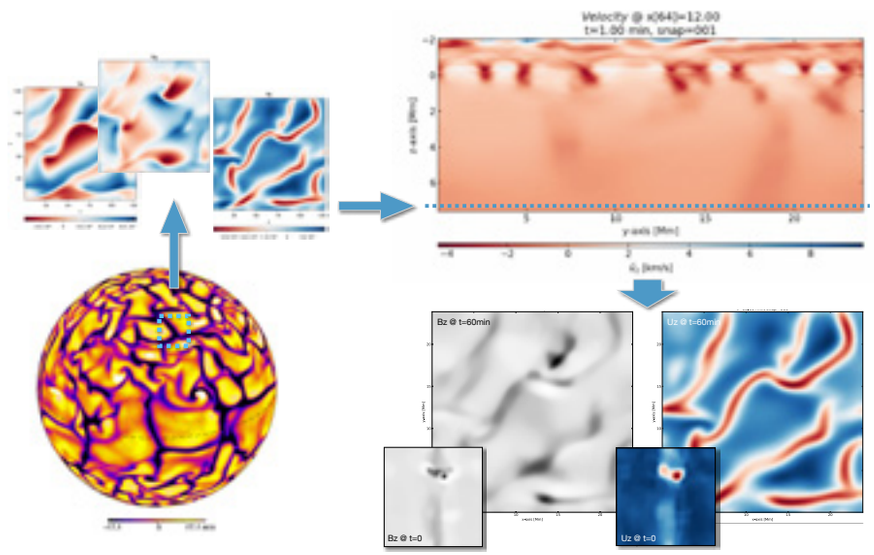
Author: Sven Wedemeyer

New code developments

Several goals have been the focus for code development throughout the existence of RoCS. We are getting tantalizingly close to reaching them after taking significant steps forward during 2024.

Free magnetic parameter

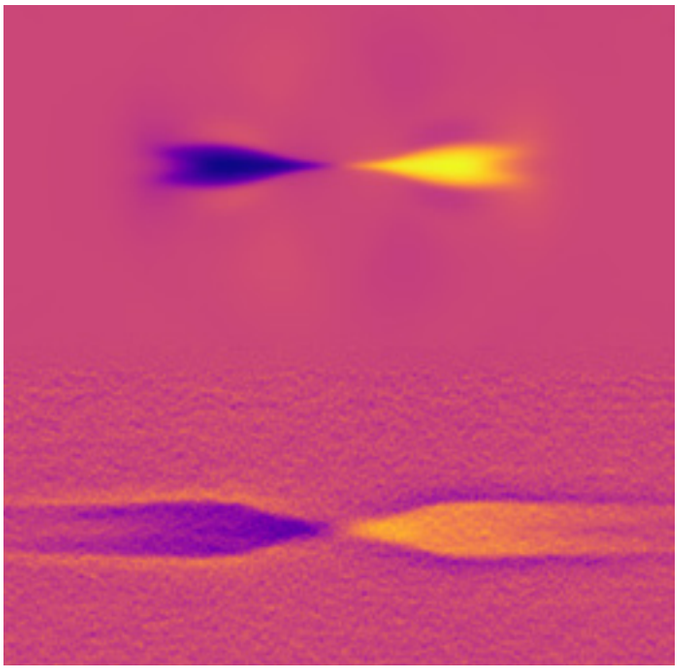
Our large-scale simulations of the solar surface, produced with the Bifrost code, have one major free parameter that remains unconstrained: the structure of the magnetic field generated in the Sun's interior. Thus far, simulations of the solar surface and atmosphere have relied on either an initial field or one produced through the injection of magnetic flux at the lower boundary beneath the solar photosphere. The initial field structure can either be based on an analytical expression or be an approximation based on the observation of the field's imprint on the solar photosphere. An ad-hoc injection of magnetic flux at the base is fundamentally uncertain in both structure and magnitude. Through the ERC Synergy grant WholeSun, we have been collaborating with other research groups that conduct simulations of the solar interior, including the solar dynamo. In these simulations, the magnetic flux reaches the edge of their simulation domain, which is near the bottom of our solar surface simulation domains. Thus, throughout 2024, we have been working on employing the time-dependent data from the solar dynamo simulation as the lower boundary for a Bifrost simulation. We now have a test case where this merging remains stable over extended periods, paving the way for such a groundbreaking simulation to become a reality.



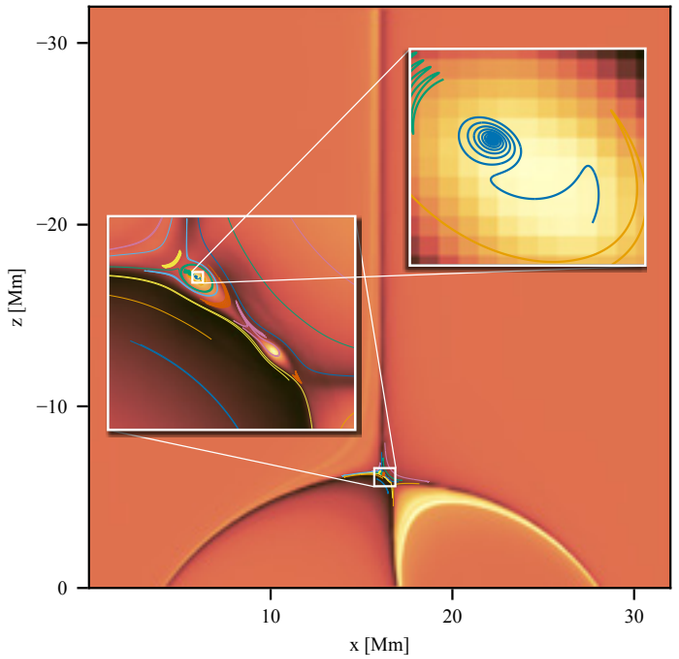
A section of a simulation of the whole Sun interior is used as the input to one of our Bifrost simulations. The velocity and magnetic field at the top of the whole Sun simulation being passed smoothly into our Bifrost simulation. (M. Szydlarski)

Bifrost & Dispatch & PIC

After securing the magnetic field through collaboration on the WholeSun project, attention has shifted to reproducing the dynamics at the smallest scales within the violent solar flares caused by explosions in the solar atmosphere. Here, vast amounts of energy are released when the



The momentum in two flare kernels simulated with MHD (top) and PIC (bottom) in one simulation, showing the almost seamless interface and the difference between the two approximations (M. Haahr, 2024)



Paths of accelerated electrons inside an evolved flare kernel simulated with MHD (E.S. Øyre, 2024)

magnetic field emerging from below the surface becomes unstable and rearranges itself. The generally reliable assumption employed to simulate the solar atmosphere falters in the inner cores of the solar flares. Incorrectly modelling this region raises doubts about whether the speed of energy release, field rearrangement, and observational imprint can be trusted. The RoCS goal of investigating the active Sun and the main strength of RoCS in comparing observations with model output therefore necessitate accurate modelling of these regions. The preferred method is Particle-in-Cell (PIC) simulations, where the fluid approach typically used is replaced by tracking numerous pseudo-particles that represent individual small ensembles of protons, electrons, and possibly heavier nuclei. This offers a new level of detail, and the coupling of these two modelling approaches is highly complex. In 2024, we successfully completed the implementation of a PIC solver into DISPATCH, allowing us to run simultaneously with the fluid Bifrost solver and manage the intricate boundary between the two approaches in real time. We can now effectively run a simulation in which part of the volume is modelled with a pseudo-particle approach, and another part with a fluid approach. A simulation of a solar flare using such an approach has not been conducted before and will be a groundbreaking endeavour.

Flare kernel fingerprints

One of the observational fingerprints of flare kernels is the accelerated electrons that are almost always observed emanating from the flare kernels. Observations have shown hard X-rays emitted by these electrons and the effect they have when they impact the dense surface of the Sun, heating the plasma to tens of millions of degrees. The observations show very different distributions of electron energy in individual flares. Why that is, is presently unknown and at least partially an effect of our limited knowledge of what happens inside the inner flare kernel. To continue along the trajectory RoCS is known for, the successful interplay between models and observations, we are developing the tools to investigate the ability of flare kernels to accelerate electrons to super high energies. We have now developed a tool to follow single electron trajectories inside the kernels for a large number of electrons, producing information on which electrons can be accelerated, how they are accelerated and why the total energy spectrum looks the way it does. The first results show that the shortcut usually used to do similar investigations is, for a large fraction of the accelerated electrons, a bad approximation and might mean that the results will be modified. A more complete approximation has been developed and is being implemented in our code.

Author: Boris V. Gudiksen

Ongoing projects at RoCS in 2024

A number of externally funded projects exist as part of RoCS, in addition to the basic funding of RoCS from the Research Council of Norway and the University of Oslo.

Hinode Science Data Centre Europe (2004-2025), funded by the European Space Agency through a contract with the Norwegian Space Agency and the European Union through the SOLARNET project. The data centre hosts all data from the Japanese Hinode and the NASA Interface Region Imaging Spectrograph (IRIS) solar satellites and a number of Bifrost simulations.

ISSRESS ("Impact of small-scale reconnection events on the solar atmosphere", 2021-2025), funded by the Research Council of Norway. Aim: To understand the origin and formation of small-scale magnetic reconnection events in the lower solar atmosphere and explore their role in the energy and mass transport from the lower to the upper solar atmosphere.

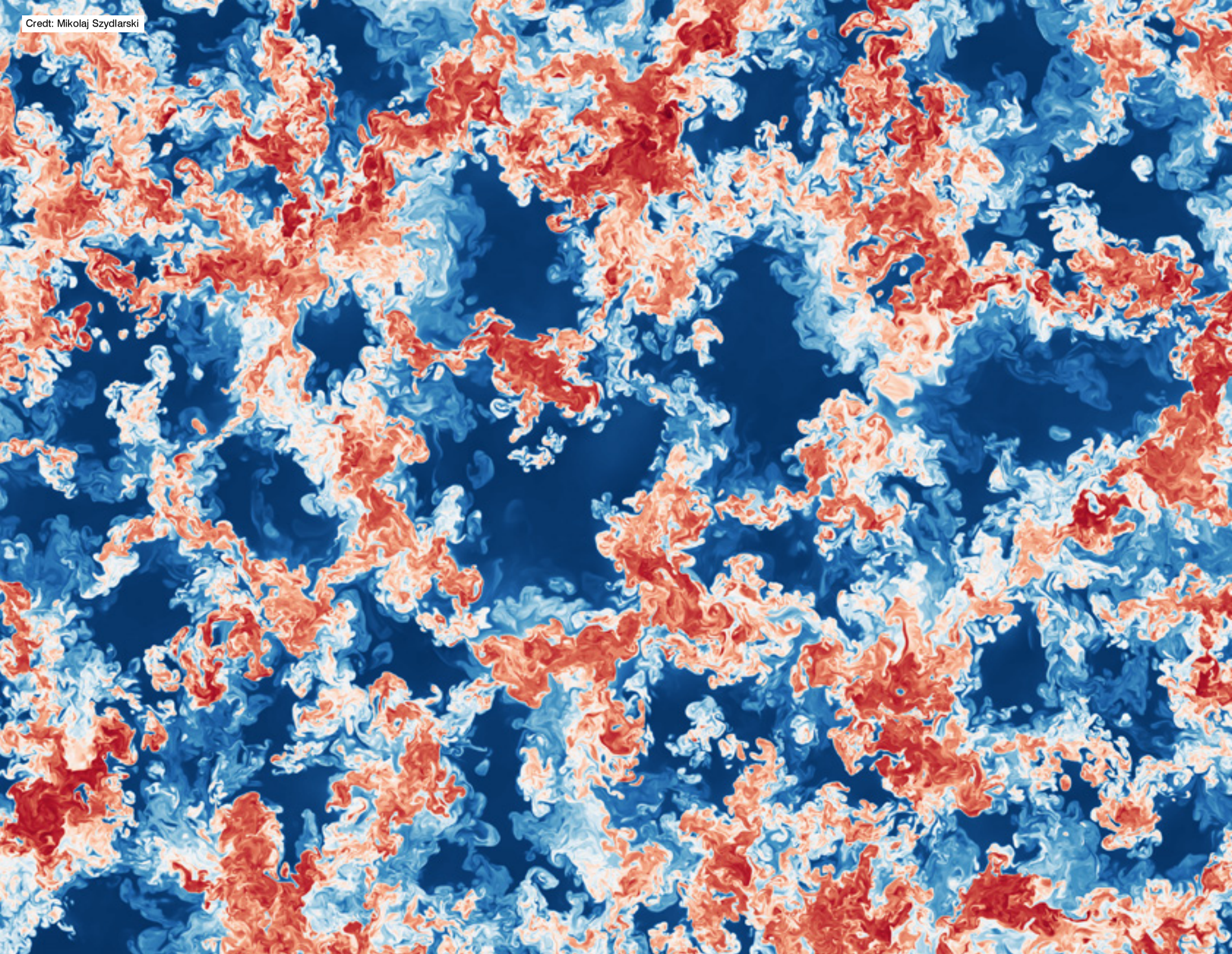
ORCS ("Oscillations in the Realistic Corona of the Sun", 2021-2025), funded by the Research Council of Norway. Aim: To combine the self-consistent numerical simulations of the solar atmosphere and high-resolution solar observations to understand the generation, evolution and dissipation of MHD oscillations in the structured and dynamical solar atmosphere.

OSCARS, (2024-2026) funded by the EU. Aim: Federation of solar data to make them more accessible by the solar physics community. There are eight partner institutions. The UiO part is to implement recommendations from the International Virtual Observatory Alliance in the SOLARNET metadata recommendations for solar data and convert three data-formats to be compliant with the new recommendations.

SPICE on Solar Orbiter (2016-2026), funded by the PRODEX programme. Finances the Norwegian contribution to the SPICE instrument on-board Solar Orbiter: the software that transforms the raw binary data from the remote-sensing instrument SPICE into a format that can be analyzed by scientists.

ESGC ("Tracing the impact of Evolved Stars on the Galactic Chemical enrichment", 2023-2027), funded by the Research Council of Norway. Aim: (A) Understand how fluorine, an element found in our bones and teeth as fluoride, is forming in the Galaxy; (B) Assess the impact of internal UV radiation on the efficiency of the stellar dust formation in oxygen-rich AGB stars; (C) Investigate the effect of internal UV radiation on the elemental isotopic ratios derived from observations of molecular lines.

Whole Sun (2019-2026), funded by an ERC Synergy grant. How does the Sun work? Why does it possess a magnetic cycle, dark spots and a dynamic hot atmosphere? In the "Whole Sun" project, we aim at tackling these key questions as a coherent whole for the first time.


Credt: Mikolaj Szydlarski

Outreach 2024

Outreach is a valued part of our work at RoCS, and we participate in a variety of activities in order to promote science education, knowledge, and accessibility.

Astronomy Olympiad

The National Astronomy Olympiad for 2023/2024 highlighted the remarkable talents of students passionate about astronomy and astrophysics. The event, held in week 11, included four days of training, culminating in the finals on the last day. It was organized by the Institute for Theoretical Astrophysics (ITA) and RoCS – Rosseland Centre for Solar Physics. **The competition showcased several impressive students, with six students being named winners of the Norwegian Astronomy and Astrophysics Olympiad.**

Various topics were covered during the week, where 20 upper secondary school students attended lectures and practical sessions to enhance their understanding and skills. **Nicolas Poirier and Ignasi Poquet from RoCS contributed to the organizing committee and taught alongside RoCS scientists, including Aditi Bhatnagar, Tiago Pereira, Luc Rouppe van der Voort, Sven Wedemeyer, and Eilif Sommer Øyre**.

Five participants advanced to the IOAA (International Olympiad on Astronomy and Astrophysics) 2024 in Vassouras, Brazil,where they competed in astronomy and astrophysics challenges against high school students from around the world.

Ignasi J. Soler Poquet from RoCS presented an introductory lecture on observational astronomy, focusing on the basics of telescope technology and its applications. Credit: Martina D'Angelo

Twenty students underwent four days of extensive training and lectures before taking their final exams on the last day, where six winners were announced. Credit: Martina D'Angelo

The photo by Aditi Bhatnagar, a doctoral research fellow at RoCS, capturing Sognsvann at midnight on March 15, 2023, served as the centerpiece for the event at Domus Bibliotheca.

Domus Bibliotheca talks

January

Exploring the Sun and northern lights

On January 18th, 2024, RoCS hosted an event titled “The Sun and the northern lights: The explosions that hit us.” Set during solar cycle 25, the event offered attendees a glimpse into the spectacular winter skies. Held on a cold evening at Domus Bibliotheca, it drew an enthusiastic audience eager to learn about the dynamic interactions between the Sun and earth's atmosphere.

Experts from the University of Oslo, Professors Wojciech J. Miloch from the Department of Physics and Mats Carlsson from RoCS, shared their knowledge, providing captivating insights. Professor Miloch explored solar events and their impact on the polar ionosphere, while Professor Carlsson discussed the sun's magnetic fields and their potential to cause powerful explosions.

The event featured an interactive discussion that highlighted the public's interest in space weather and underscored the importance of educational initiatives in enhancing public knowledge of space physics.

From left: Speakers Professors Wojciech J. Miloch and Mats Carlsson, with Sondre Vik Furuseth, a postdoctoral research fellow at RoCS, as the moderator in the middle. Credit: Eyrun Thune

April

Botany and solar physics meet under the spring Sun

On April 16, 2024, Domus Bibliotheca hosted an engaging event uniting botany and solar physics enthusiasts for the session titled “Botany and solar physics meet under the spring Sun,” **featuring talks by Charlotte Sletten Bjorå and Mats Ola Sand. Elisabeth Enerhaug served as the evening's moderator.**

Charlotte Sletten Bjorå, a professor at the University of Oslo's Natural History Museum, shared insights into the resilience of spring flowers and highlighted the ecological significance of the snowdrop amid climate change.

Mats Ola Sand, a doctoral research fellow at RoCS, explored solar phenomena with vivid imagery. He discussed observing the Sun from La Palma, compared solar telescopes with other tools, described life in solar observation amidst volcanic challenges, and provided glimpses into the Sun's tranquil and active phases.

Following the presentations, a lively discussion allowed participants to reflect on the interplay between botany and astrophysics. The evening highlighted how these two diverse scientific disciplines can illuminate the wonders of nature and the cosmos.

From left: Speakers Mats Ola Sand and Charlotte Sletten Bjorå, with Elisabeth Enerhaug, a doctoral research fellow at RoCS, as the moderator in the middle. Credit: Eyrun Thune

Poster made by Maria Hammerstrøm

The Sun is the giver of life

Ramses II

Credit: Nicolas Poirier

School visits

Reetika Joshi visited Moss International School on March 20th as a judge for their science fair.

Quentin Noraz and Nicolas Poirier, both postdoctoral fellows, delivered an engaging introductory lecture on solar physics to around 35 students from the French Lyceum of Oslo on April 15th at the Institute of Theoretical Astrophysics. The session provided valuable insights into solar phenomena, enriching the students' scientific understanding and sparking their interest in astronomy.

Reetika Joshi carefully evaluated the various projects during her judging round at the exhibition. Credit: Private

Personal outreach

Reetika Joshi was a TED speaker in June 2024, discussing 'The World of Tomorrow: The Essence of Basic Science in Shaping Our Future' at Chateau Neuf in Oslo.

Adjunct Professor **Lyndsay Fletcher** has made significant contributions to community engagement in Scotland through various outreach activities. She has shared her expertise and passion for science by delivering presentations and participating in interviews and discussions. Her efforts have reached diverse audiences, including school students, astronomy clubs, scientific societies, and listeners of educational podcasts. Through her talks and written contributions, she has engaged and inspired approximately 185 individuals across these events, further promoting the visibility and importance of women in physics and science in general.

Reetika Joshi at the TED Talk in Oslo. Credit: Private

In September, **Mats Ola Sand** served as an expert for the pilot episode of the children's TV series “Måneland,” a potential new Norwegian series. The show emphasizes the use of TellusTube, an educational platform for engaging children in scientific exploration.

Jonas Thoen Faber delivered a captivating talk on solar science research on the 17th of October at the conference hosted by the Naturfagsenteret at the University of Oslo. Addressing an audience of teachers from elementary to high school levels, he shared insights into the scientific work conducted at RoCS and introduced tools that teachers can use to engage their students in solar science.

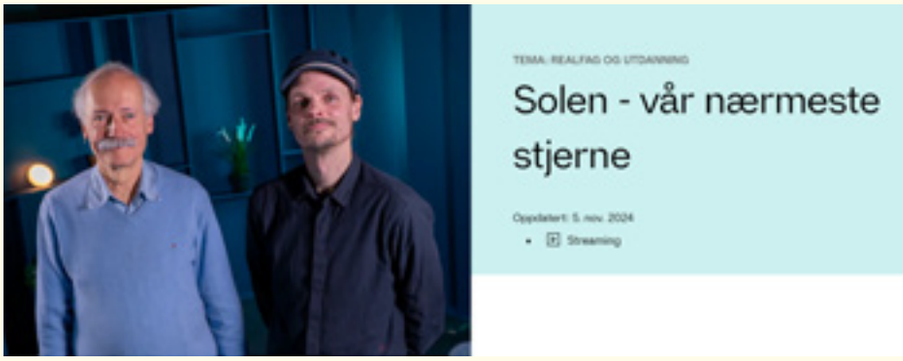
Mats Ola Sand actively engaged with the astronomy community by delivering talks on the topic of the Sun. He presented at the “Astronomikonferansen 2024 – Norsk Astronomisk Selskap” at the Teknisk Museum and later gave a lecture titled “Our star” for the Astronomy Association in Agder. Through these events, Sand contributed to the dissemination of knowledge about solar science to interested audiences.

Mats Ola Sand on solar storms in UiO’s #vitenstyrke. Credit: Screenshot UiO’s social media.

Mats Ola Sand discussed how solar storms can affect people on Earth in UiO’s TikTok/Instagram video #vitenstyrke on the 20th of November.

Adjunct professor Lyndsay Fletcher. Credit: Private

TEKNA talk



Mats Carlsson with science teacher Fredrik Gade, who moderated the evening's talk. The audience, consisting of hundreds of science teachers, was captivated, resulting in a lively session filled with numerous questions after the presentation. Credit: Screenshot from Tekna's website.

On November 5th, professor **Mats Carlsson** from RoCS delivered a lecture titled "The Sun, our nearest star" for Tekna Realfagslærerne, a network for science teachers. He explored the enduring mysteries of the Sun, such as why its corona is so hot, and provided insights into how solar physicists are tackling these challenges by focusing on the Sun's magnetic fields and their impact on solar activity and the atmosphere. Professor Carlsson also highlighted findings from observatories and spectrographs that enhance our understanding of the Sun's dynamics.

The lecture is available for streaming on TEKNA's website, providing wider access to these insights.

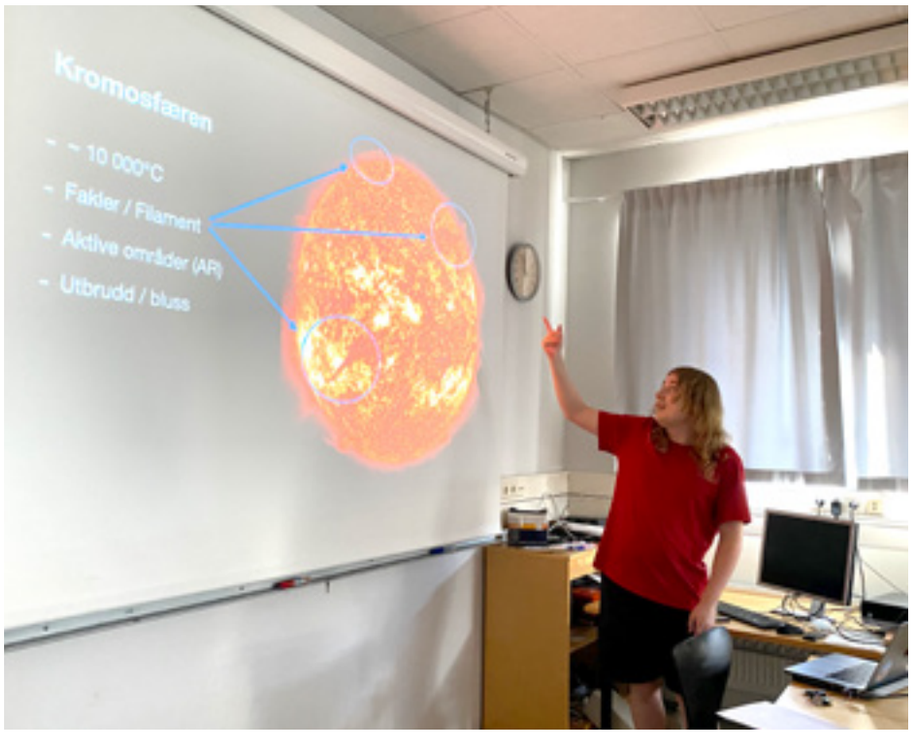
Inspiring future scientists: Ungforsk

Ungforsk aims to inspire students to pursue science by sparking curiosity and offering hands-on research experiences. Targeted at young high school students from Oslo and the surrounding areas, Ungforsk is part of the national Research Days celebrated every fall.

On September 18th, doctoral research fellows **Mats Kirkaune** and **Aline Rangøy Brunvoll**, along with Researcher **Maryam Saberi**, led an exciting workshop on solar science during the Ungforsk event at the University of Oslo.

The workshop offered students an opportunity to delve into the fascinating world of solar physics. Participants first gained foundational knowledge about the sun, learning about its structure and the methods used to observe it at RoCS. Following the introductory session, students had the chance to step into the shoes of solar researchers. Engaging with Helioviewer, they explored the different layers of the sun's atmosphere, simulating the work of real scientists.

Elisabeth Enerhaug, delivered an exciting talk to high school students at the event. Titled "How do we know how hot the sun is?" She started by explaining how we look for cosmic "fingerprints" in space. From there she told the story of how this was used in the discovery of an element which didn't actually exist and the unveiling of one of the longest unanswered mysteries in modern astrophysics: The coronal heating problem.



Mats Kirkaune in action at Ungforsk 2024. Credit: Eyrun Thune

Elisabeth Enerhaug captivates students with her lecture on the Sun. Credit: Eyrun Thune

Media highlights

Apollon

“Ildsjeler redder flere tusen historiske bilder av solflekker”: The article dated January 23rd features comments from Mats Carlsson.

NRK.no

“Total solformørkelse i USA over – neste sjanse om 20 År”: An article featuring insights from Luc Rouppe van der Voort, discussing the solar eclipse on April 8th.

Mats Carlsson was interviewed about the Sun in the NRK article “Her gikk sola ned to ganger på samme dag: – Det er litt spesielt for oss” on the 28th of July.

Har skjedd tidligere

Ifølge Mats Carlsson, professor ved Rosseland senter for solfysikk, er ikke dette første gangen fenomenet oppstår, men det er litt spesielt.

- Det er spesielt ved at du må være på ett spesielt sted. Det kan jo bare skje hvis en er nord for polsirkelen.

Ifølge Carlsson oppstår akkurat denne syklusen hvert fjende år. Spoler man tilbake til denne dagen for fire år siden, og var i Finnmarksområdet, har man opplevd dette før. Men nå finnes denne typen informasjon lettere tilgjengelig for folk flest.

For eksempel gjennom vær-apper.

Mats Carlsson, professor ved Rosseland senter for solfysikk.
FOTO: UNIVERSITETET I OSLO

Bilde tatt tidligere i juli i Kåfjord, Alta.
FOTO: KRISTINA BREKKE / NRK

Mats Carlsson is a regular in articles about the Sun on NRK.no. Credit: Screenshot from NRK.no

Titan.uio.no

Oddbjørn Engvold published the article “Solstormer gir vakkert nordlys, men er også en potensiell trussel in Titan on the 23rd of May.

Eyrun Thune wrote the article “Hvorfor er det ytterste laget av solens atmosfære varmere enn alle de andre lagene til sammen?” which was published on Titan on the 26th of August.

VGTV

In an engaging live broadcast titled “Derfor er denne solformørkelsen spesiell”, Sondre Vik Furuseth captivated audiences on April 8th from the VGTV studios. Over three hours, he provided expert commentary on the total Solar eclipse in North America, which several RoCS staff members also watched live from the USA. Furuseth skillfully addressed questions from the hosting VG journalist and responded to numerous inquiries from the audience. The broadcast reached approximately 40,000 viewers, highlighting the widespread interest and impact of this celestial event.

Sondre Vik Furuseth providing live commentary on the solar eclipse from the VGTV studio. Credit: Screenshot VGTV.

VG.no

The article “Fest og unntakstilstand for himmelsk skue”, from April 8th explains the solar eclipse and includes an interview with Luc Rouppe van der Voort.Vårt Oslo

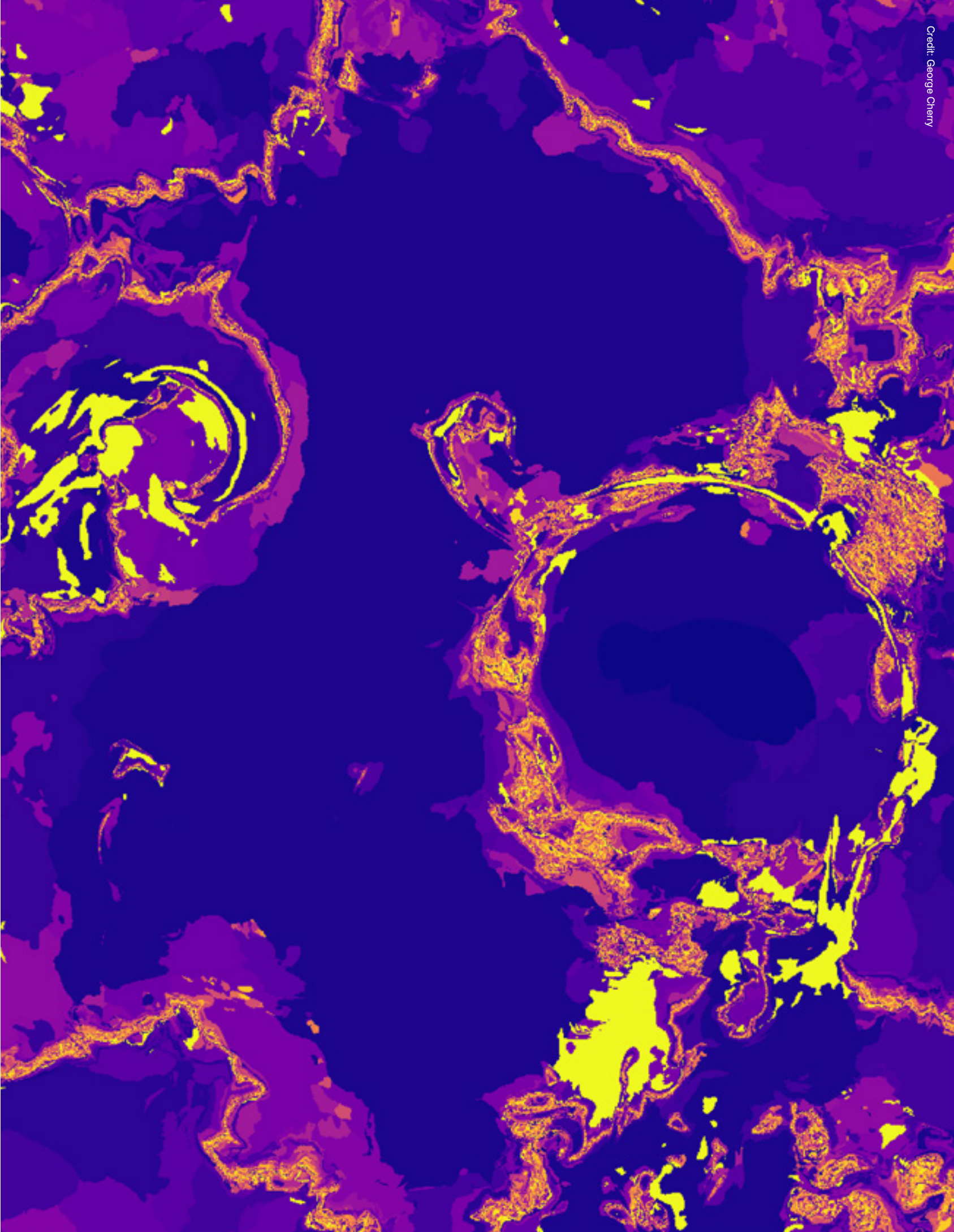
Luc Rouppe van der Voort commented on the solar eclipse in both VG and NRK. Here, he is seen in an article on VG.no. Credit: Screenshot from VG.no.

Aditi Bhatnagar had photos of the Northern Lights over Sognsvann published in the newspaper “Vårt Oslo” on the 13th of September, with the title “Se de fargerike bildene av nordlyset over Oslo.”

Aditi Bhatnagar explained to readers how they can spot the comet in Oslo in the article titled “Her fanget Aditi kometen over hovedstaden – nå røper eksperten hvor i Oslo du har best sjanse for å se den de kommende dagene.” The piece could be read in the newspaper “Vårt Oslo”, October 17th.”

Author: Eyrun Thune

Aditi captured the stunning comet over Oslo on October 15th. Credit: Screenshot from “Vårt Oslo”.



Credit: George Cherry

Credit: Aditi Bhatnagar

International Rosseland Visitor Programme

Visits from internationally leading scientists are very important for the success of RoCS. The International Rosseland Visitor Programme facilitates international exchange by providing funds for researchers at the professor, post-doctoral, and PhD levels for short or extended visits at RoCS.

2024 has been a busy year with several events and visitors, contributing to important scientific collaboration and progress.

In January **Tim Duckenfield** (Queen's University Belfast), **Elena Khomenko** (Instituto de Astrofísica de Canarias), **Daniele Calchetti** (Max Planck Institute for Solar System Research), **Luiz Schiavo** (Northumbria University), **Viktor Fedun** (University of Sheffield), **Stuart Jefferies** (Georgia State University), **Oskar Steiner** (Istituto Ricerche Solari Locarno/KIS), **Shahin Jafarzadeh** (Max Planck Institute for Solar System Research), **Gary Verth** (University of Sheffield), **Matías Kill Pistarini** (Instituto de Astrofísica de Canarias) and **Marco Stangalini** (ASI – Italian Space Agency) visited to attend the Waves in the Lower Solar Atmosphere (WaLSA) workshop hosted by RoCS.

Eduard Kontar from the University of Glasgow visited Boris Gudiksen in April. Eduard was invited to serve on the PhD committee of Lars Frogner. He is an expert on particle acceleration and deceleration in the solar atmosphere and using analytically derived expressions to arrive at fundamentals of these processes. He has also used these expressions to understand the complex changes in energy spectra of particles and which physical effects they are subjected to and what observables it produces.

Thomas Neukirch from the University of St. Andrews visited in April to have a scientific talk and to collaborate with Boris Gudiksen. He is an expert on the structure and forces provided by a magnetic field and the equilibria of plasma systems. The stability of magneto-plasma equilibria can bring important knowledge of the type and violence of the instability that might be triggered in these systems.

Daniel Nóbrega-Siverio from IAC came to attend Øystein Færder´s thesis defense as his co-supervisor. He visited us in May, and also got to attend our retreat at Søstrene Storaas. Daniel has a number of different collaborative projects with RoCS members, including studies of jets and coronal bright points with Reetika Joshi and Luc Rouppe van der Voort.

Jorrit Leenaarts and **Jaime de la Cruz Rodríguez** from the Institute for Solar Physics in Stockholm visited in June to serve in Master exam committees. They further discussed instrument developments at the SST on La Palma and modelling of the solar atmosphere with several members at RoCS.

Jayant Joshi from the Indian Institute of Astrophysics in Bengaluru, India, visited from September to October to work with Luc Rouppe van der Voort. Jayant is involved in the supervision of PhD students Aditi Bhatnagar and Mats Ola Sand. He also attended the Deep learning workshop arranged at RoCS in September.

In September **Robert Jarolim** (High Altitude Observatory, NCAR), **Vishal Upendran** (Bay Area environmental research institute), **Ivan Milic** (Institute for Solar Physics KIS), **Andrés Asensio Ramos** (Instituto de Astrofísica de Canarias) and **Benoit Tremblay** (High Altitude Observatory) came to attend our Deep learning workshop.

Hugh Hudson from the University of Glasgow visited for ten days in december. He discussed flare physics and the interpretation of flare observations with several members of RoCS.

Author: Benedikte Fagerli Karlsen

Glimpses from the life at RoCS

Credit: Aditi Bhatnagar

Carlos José Díaz Baso visited Instituto de Astrofísica de Canarias in Tenerife, Spain. Credit: Private

Collaboration at the Instituto de Astrofísica de Canarias

Carlos José Díaz Baso was awarded with the **Visiting Researchers Occident Foundation** grant, allowing him to work at Instituto de Astrofísica de Canarias. This opportunity provided a one-month stay, enabling him to collaborate with Dr. Asensio Ramos' research team to advance spectropolarimetric inversions and corrections for atmospheric aberrations, contributing to the development of next-generation diagnostic tools for solar physics.

Under Díaz Baso's leadership, a new code based on Physics-Informed Neural Networks was implemented to integrate observations from various facilities, including the Hinode space telescope and ESA's Solar Orbiter mission, to refine solar magnetic field estimates using two different viewpoints – a first of its kind.

Concurrently, Dr. Andrés Asensio Ramos led the development of an innovative method to deconvolve observational data, significantly reducing the impact of Earth's atmosphere. This technique ensures exceptionally sharp imaging, overcoming limitations of conventional methods – a timely innovation given the instrument upgrades at the Swedish 1-m Solar Telescope.

These projects have the potential to make substantial contributions to Solar Physics while benefiting other research groups within the IAC. A prime example is the anomaly detection method developed by Dr. Díaz Baso, which aids IAC researchers like Dr. Christoph Kuckein in identifying previously undetected exciting features within large datasets.

Author: Carlos José Díaz Baso

An early approach to solar research

Supervisors and summer students in front of the Institute for Theoretical Astrophysics. From the left: Elias Roland Udnæs, Rebecca Nguyen, Yaroslav Divin, Ignasi Solar Poquet. Credit: Private

In the summer of 2024, the bachelor students Rebecca Nguyen and Yaroslav Divin worked together with the PhD students Ignasi Soler Poquet and Elias Roland Udnæs towards new insights of small-scale energetic events on the sun, known as Ellerman bombs. For this purpose, they analysed high-resolution observations taken by RoCS at the Swedish 1-m Solar Telescope (SST) on La Palma.

The project was divided into two parts, combining both practical skills and theoretical insight.

Practical skills: Developing a tracking code for Ellerman bombs

In the practical part of the project, the summer students developed a code to track Ellerman bombs in the observations, allowing for a comprehensive statistical analysis of their properties. The coding and interaction with the observational data reflected genuine scientific processes.

Theoretical insights: Understanding Ellerman bombs

The theoretical part of the project aimed to develop the student's physical understanding of Ellerman bombs. Both the physical processes leading to the energy release in the lower solar atmosphere, and the theory behind the formation of the spectral line that is seen in observations, were emphasised.

Student experience and future endeavors

"I found the study of Ellerman Bombs and magnetic reconnection to be really interesting and hope to possibly further develop this summer project to a master thesis," Rebecca said. After the summer project ended, Rebecca started a master thesis at RoCS, where she will continue to work with solar observations.

Supervisory perspectives: Learning through engagement

As well as giving the summer students tangible science experience, the summer project also gave the supervisors Ignasi and Elias an invaluable opportunity to supervise:

"The summer project proved itself to be a great opportunity for me to get supervision experience, and I really liked the interaction with the students," Elias summarized.

Presenting results: Key findings on Ellerman bombs

At the end of the project, Rebecca and Yaroslav got the opportunity to present their project to the rest of the group at RoCS, gathering the interest from several in the group. In their results, they presented several key features of Ellerman bomb evolution inferred from the observational data. In their conclusion, they linked formation of Ellerman bombs to radiative transfer theory, and compared their statistical properties to previous studies.

Author: Elias Roland Udnæs

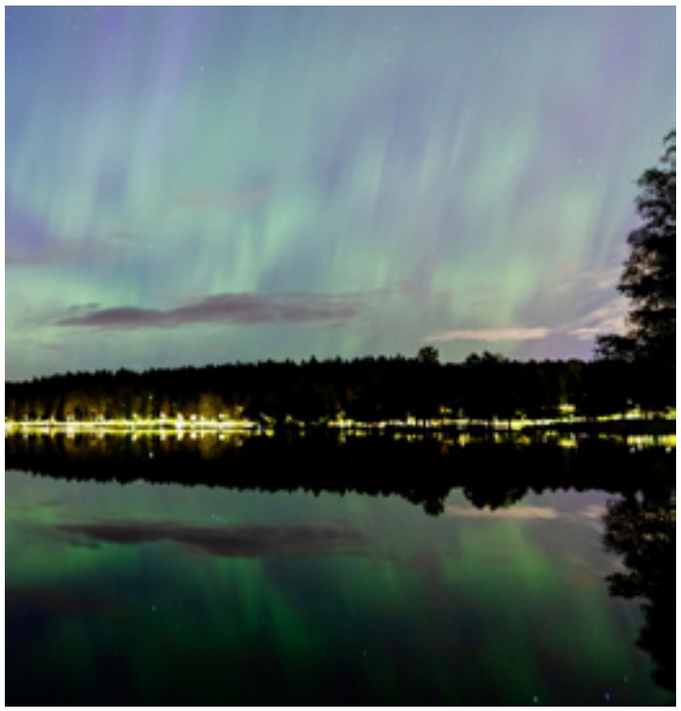
Mesmerising aurora illuminates autumn skies

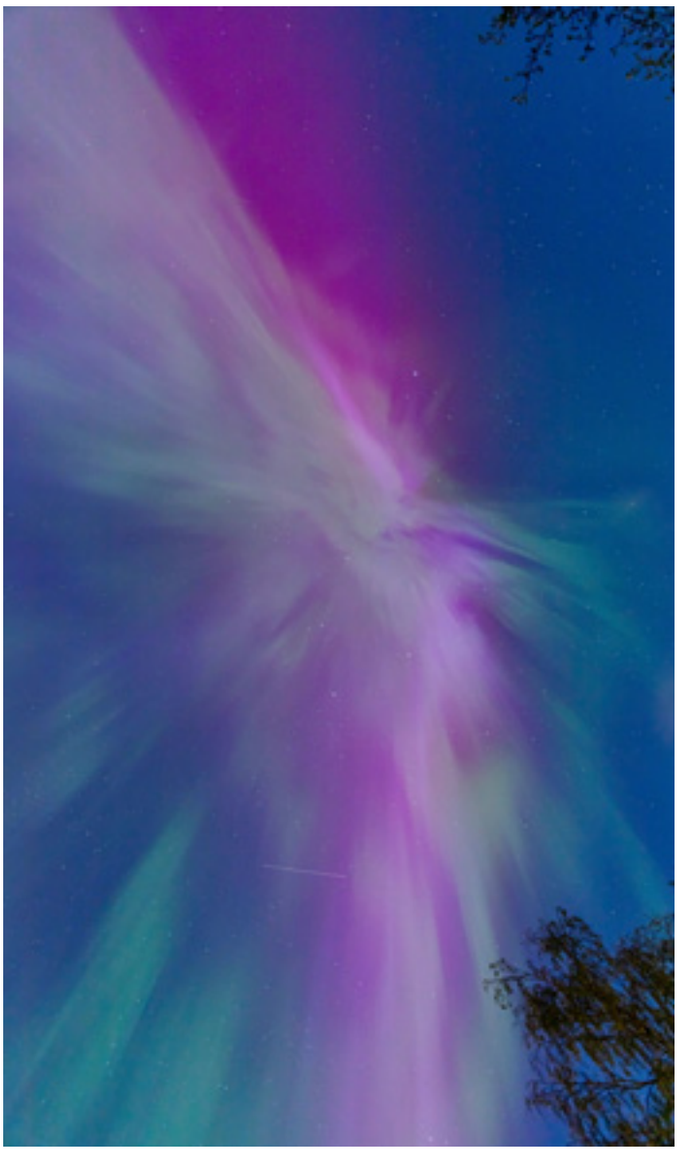
The auroral display on September 12 was truly stunning. The lights became visible immediately upon exiting the T-bane station at Sognsvann, despite the presence of streetlights. It was an impressive display of greens, pinks, and purples dancing in the sky above Sognsvann lake.

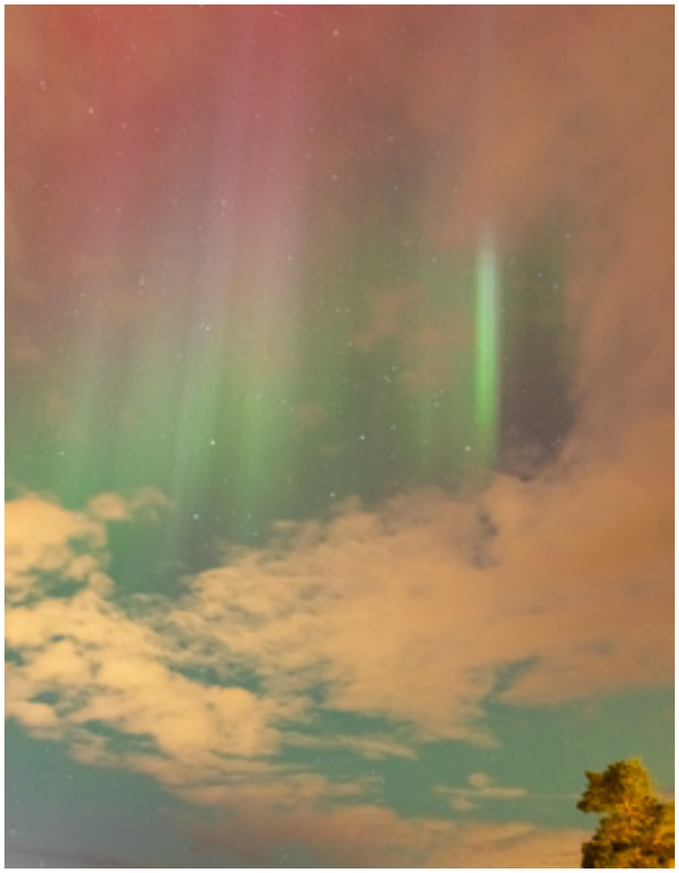
On October 10, the weather in Oslo was quite cloudy, so we traveled about 45 minutes outside the city to Sundvollen. There, we were treated to beautiful Auroras with striking hues of red and green illuminating the night. However, the clouds soon rolled in, prompting our return to Oslo. Unexpectedly, the skies cleared, and the auroras were visible even from the city centre.

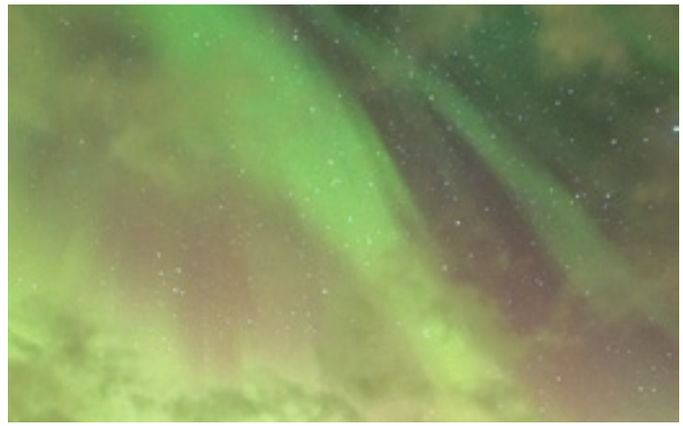
Author: Aditi Bhatnagar

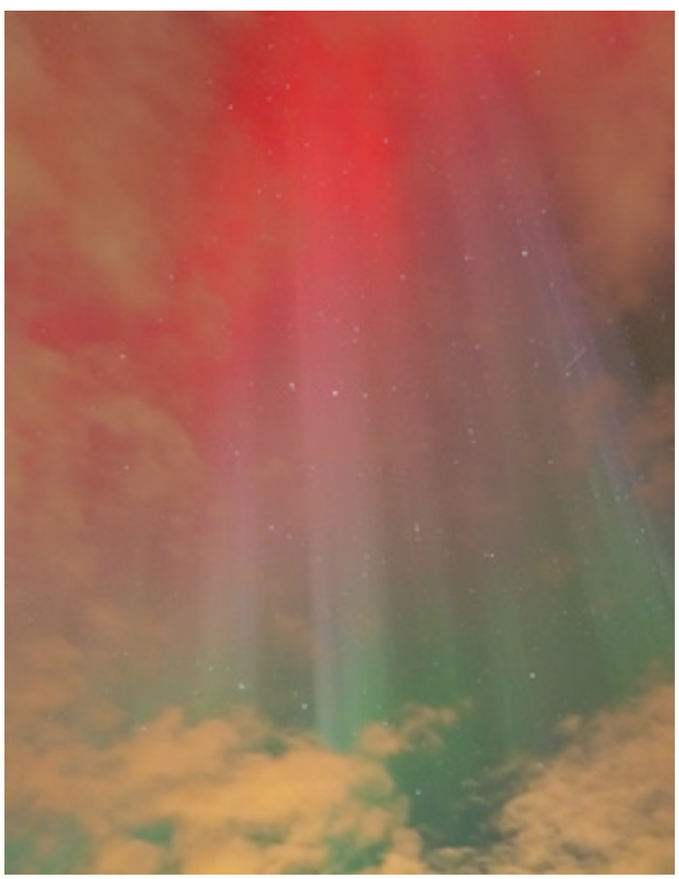
Photo credits: Aditi Bhatnagar, taken with Canon EOS 6D Mark II and an iPhone 12 pro.

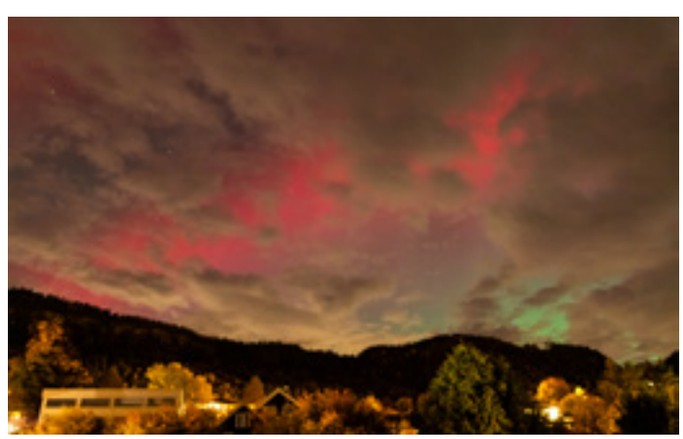






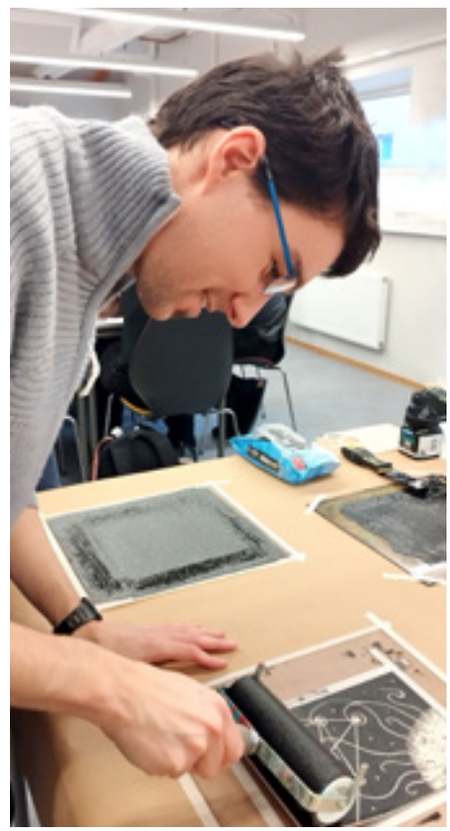




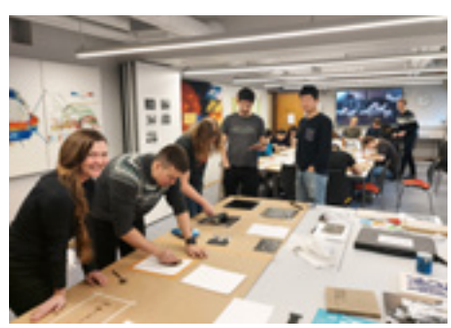


First guest artist in the REAL art program: Connecting art and science

In 2024, doctoral research fellow Mats Ola Sand from the Rosseland Centre for Solar Physics (RoCS) played a key role in launching a special initiative at the University of Oslo's Faculty of Mathematics and Natural Sciences. He helped secure the first guest artist grant, awarded to Laila Kongevold for her project, "The Sun in the Sun." The initiative set a new standard for merging art with science.



Credit: Laila Kongevold



Credit: Henrik Hovland Svensen

Fostering creative synergy

Throughout 2023 and 2024, the collaboration flourished. Kongevold and Sand collaborated on a creative journey, including a residency in La Palma, known for its stellar solar views. They also conducted two engaging lectures and a workshop for RoCS staff, blending scientific knowledge with artistic creativity.

Sand shared: "We hope to use our striking solar observations and simulations to inspire Laila's art and exchange fresh perspectives in both fields."

Kongevold, who worked closely with RoCS for 18 months, expressed: "The 'REAL Art – The Sun in the Sun' project let me discover the sun in a new light. I wanted to share its brilliance and mystery with the curious."

Workshop highlights

A standout moment was the workshop in March 2024 "Art Meets Science: A Creative Workshop on Solar Physics," which brought together 15 young astrophysicists and guests from geology and neuroscience to explore scientific ideas through lino cutting. This approach allowed participants to express complex scientific concepts in simple, tangible forms.

Facilitators like Kongevold, Sand, and geologist Henrik H. Svensen fostered a creative environment where art and science complemented each other beautifully.

A model for future initiatives

The first guest artist project in the REAL Art program demonstrated how art can enhance the understanding of science. Through collaboration with Laila Kongevold and Mats Ola Sand, it expanded the view of solar physics and emphasized creativity in learning about our world. This effort stands as a model for future initiatives, promising enriching blends of art and science.

Author: Eyrun Thune

Kongevold and Sand collaborated on a creative journey, including a residency at SST in La Palma in 2023. Credit: Laila Kongevolda

The REAL Art Program workshop, led by guest artist Laila Kongevold and project organizer Mats Ola Sand, showcased a dynamic fusion of art and science. Participants engaged in creative processes, guided by Kongevold, Sand, and geologist Henrik H. Svensen, exploring lino cutting. Credit: Private

"Sun in the Sun" was also to be seen at the 2024 Summer Exhibition at Østfold Kunstsenter. Kongevold used photogravure with images from the SST at the Roque de los Muchachos Observatory on La Palma. Credit: Henrik Hovland Svensen

Becca's path: From Ph.D. at RoCS to NASA

In a remarkable leap from completing her Ph.D. in 2023 to becoming the Outreach Lead for NASA's MUSE satellite (Multi-slit Solar Explorer, designed to study the Sun's atmosphere) in 2024, Becca Robinson has embarked on an exciting journey that bridges cutting-edge solar physics and public engagement.

Embracing new challenges

"Being selected for this role was wildly unexpected and immediately exciting," Becca shares, reflecting on the moment she learned of her selection. Though thrilled, she faced challenges due to her recent residency in Norway and new personal commitments. Thankfully, with support from the MUSE team and her wife, Becca was able to embrace this unique position with enthusiasm.

Translating science for the public

As Outreach Lead, Becca is responsible for translating complex scientific concepts into accessible content. Her background in conducting research across various cultures, teaching diverse students, and curating outreach in unique venues has prepared her well for this task. "My intuition for outreach is natural to me", she explains, "and I love using it alongside research to solve problems and improve public understanding."

Life in the Bay area

Relocating to the vibrant San Francisco Bay Area to work with the SETI Institute ("Search for Extraterrestrial Intelligence") and the Lockheed Martin Solar Astrophysics Lab, Becca finds bliss in both professional and personal realms. While the area is known for technological innovation, she cherishes the opportunity to explore California's renowned redwood forests on weekends, echoing her Norwegian lifestyle. Professionally, she learns from experts developing pioneering technologies for MUSE as well as those plugged into the greater outreach community, gaining insights into the intricate workings of NASA missions.

A unique focus on outreach

What sets Becca's role apart is her singular focus on outreach, a rarity within science missions. "Typically, outreach is a secondary duty for scientists," she remarks, "but I can dedicate all my energy to it, boosting the MUSE program." This dedicated approach is poised to amplify public engagement and foster excitement, particularly as the satellite's 2027 launch approaches.

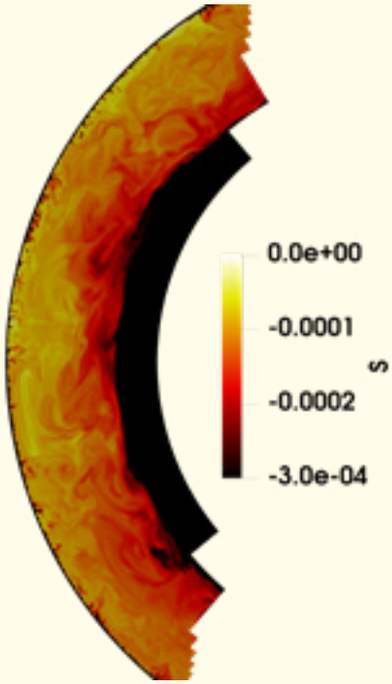
Stepping into greater roles

Looking forward, Becca's primary goal is to be an effective leader, forging robust partnerships. Through these collaborations, she aims to deliver engaging content on fundamental scientific concepts key to the MUSE mission.

Becca and wife Renate Robinson-Hellerud enjoying Pu'uhonua O Honaunau National Historical Park in Hawaii, where Becca attended the Cosmovisions II Gathering in January 2025. Cosmovisions is a collection of non-indigenous and indigenous knowledge-holders who are committed to exploring the intersections between western science and indigenous ways of knowing. Credit: Becca Robinson

This new chapter promises substantial responsibilities and opportunities for growth. By embracing these challenges, Becca is set to make a meaningful impact on both the outreach community and her career. "I tend to mature fastest when given significant responsibility," she notes. "This project allows me to grow and adapt, leveraging the flexibility to navigate my path."

Author: Eyrun Thune



Volleyball/entropy: Entropy per unit mass near the surface of the global simulation of the solar convection zone (model R998-nw96). Credit: Andrius Popovas

Volleyball/entropy-side: Radial cut of entropy per unit mass in the global simulation of the solar convection zone (model R998-nw96). Credit: Andrius Popovas

The global simulation of the entire convection zone of the Sun. It extends from 0.655 to 0.998 of the radius of the Sun (thus ends about 1.5 Megameters below the surface of the Sun). Here we see entropy per unit mass in a radial cut through the simulation domain (Figure on the left). The down-flows penetrate deep into the atmosphere, where the entropy per unit mass is otherwise nearly constant. At the surface (Figure below), the entropy flows give the very recognizable convection granular structure of the Sun. In the simulation, the typical upflow velocities near the surface of the domain are around 300 m/s, downflow velocities of the order of 1-3 km/s. Typical cell size is around 2-3Mm. All these numbers correspond very well to values seen in local simulations at the corresponding depths. This simulation is now being analyzed and is expected to provide numerous insights into the convection morphology of the Sun.

DLRoCS: a deep learning workshop at RoCS

This group photo from the workshop captures all the participants. From left to right and top to bottom, we have: Momchil Molnar (UCAR/Boulder), Andrés Asensio Ramos (IAC/Tenerife), Ivan Milic (KIS/Freiburg), Elias Roland (RoCS/UiO), Robert Jarolim (UCAR/Boulder), Luc Rouppe van der Voort (RoCS/UiO), Tiago Pereira (RoCS/UiO), Vishal Upendran (LMSAL/Baeri Palo Alto), Carlos J. Díaz Baso (RoCS/UiO), Benoit Tremblay (UCAR/Boulder), Ignasi J. Soler Poquet (RoCS/UiO), and Jayant Joshi (IIA/Bengaluru). It was truly an international gathering! Credit: Eilif Sommer Øyre

In September 2024, RoCS organized a one-week workshop focused on the application of deep learning and machine learning to solar physics. This in-person meeting brought together 12 experts from around the world to discuss the current state-of-the-art, possible advances in the field, and opportunities for new collaborations.

Deep Learning and solar physics

Deep learning is a key paradigm within artificial intelligence that has gained significant relevance over the past decade due to its ability to solve complex tasks that are unaffordable or very hard to handle for traditional methods.

On the other hand, solar research is advancing by leaps and bounds. This progress is driven by new observational and computational facilities, along with the development of new models that explain the workings of the Sun. However, we are starting to encounter the limitations of traditional methods in some aspects of solar physics, demanding new approaches.

This is where Deep Learning and solar physics converge, forming a powerful synergy that enhances our capabilities in the field.

Discussions of DLRoCS:

Throughout the workshop, participants engaged in a series of talks, discussions, and hands-on sessions on the application of deep learning techniques to solar physics.

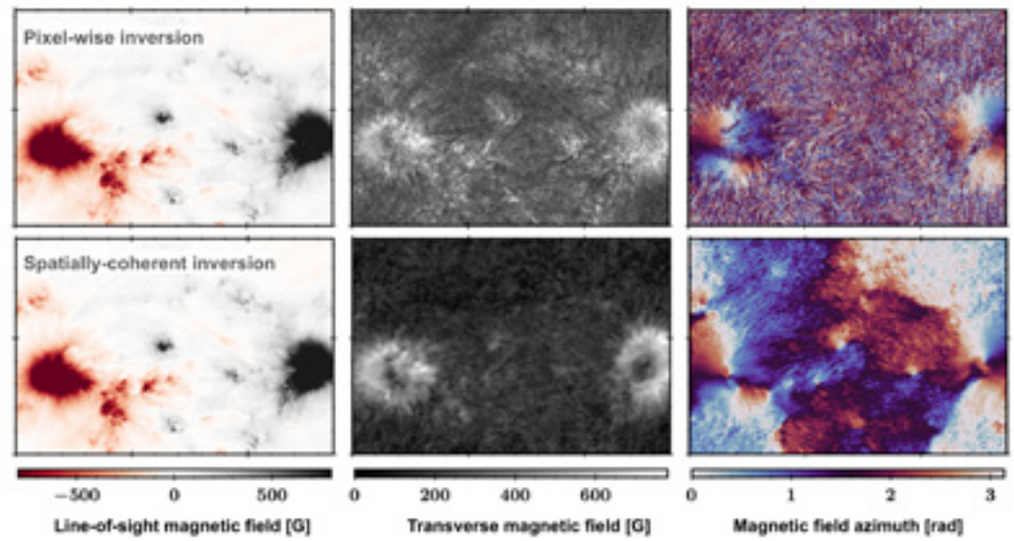


Figure 2. Comparison of magnetic field estimation using the classic pixel-wise approach (top row) and the newly developed spatially coherent approach (bottom row). The new method leverages all available information and the interrelationships between pixels to achieve a more accurate estimation of the magnetic field.

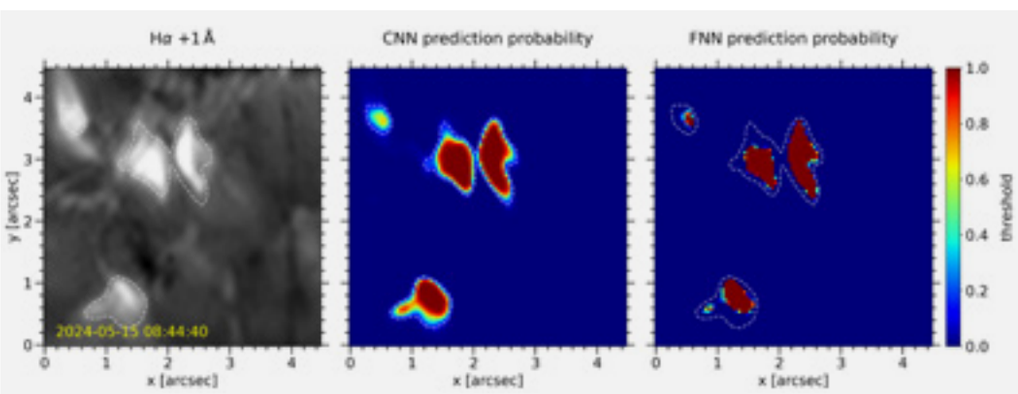


Figure 3. Examples of Ellerman Bomb predictions by the models trained by Ignasi. The left image shows a cut out of an observation of the Sun, with Ellerman bombs seen as brightenings surrounded by white-dashed lines. The middle and left panels show the classification made by the models. The colour of each pixel represents the probability of it being an Ellerman bomb, with dark red a very high probability near 100% and blue indicating almost 0%.

A wide range of topics was covered, including magnetic field extrapolations using neural fields, 3D reconstruction of the solar corona, artificial intelligence explainability, and feature detection in solar observations with convolutional neural networks. There was a strong emphasis on discussing past, present and future radiative transfer and inference techniques based on deep learning. Key questions included: How can we make these techniques more efficient, reliable, and fast?

Contributions from RoCS

RoCS made significant contributions, with presentations by Carlos J. Díaz Baso, Tiago M. D. Pereira, Luc Rouppe van der Voort, Elias Roland Udnæs, and Ignasi J. Soler Poquet. In particular, Carlos Díaz and Ignasi Poquet, postdoctoral and doctoral researchers at RoCS, had the opportunity to present their latest work during the workshop. Figure 2 shows an image from Carlos's recent research, showing an exciting new method that exploits the previously unexplored spatial coherence in spectropolarimetric inversion, aimed at estimating the magnetic field from solar observations.

In addition, Figure 3 showcases an image from Ignasi's latest research. In this study, he employs convolutional and fully-connected neural networks to identify a phenomenon known as the Ellerman bomb in solar observations. Ellerman bombs highlight regions in the solar atmosphere where a significant amount of energy is released over a short period.

Authors: Ignasi J. Soler Poquet and Carlos J. Díaz Baso

Teaching solar physics in Africa

Impressions from an ISYA school in Algeria

The International Astronomical Union (IAU), sponsored by the Norwegian Academy of Sciences and Letters, organises every year an International School for Young Astronomers (ISYA). This takes place in regions that typically do not have a strong astronomical community and is meant to foster interest in astronomy by providing students with a solid theoretical and practical knowledge across different fields in astronomy.

In 2024, the 45th ISYA took place in Algiers, Algeria. There was strong competition to attend: out of more than 200 applications, only 30 students managed to secure a spot. The selected finalists came from 12 different countries, mostly in Africa, and with a strong contingent from Algeria. The lectures spanned 11 topics, and were given by 14 lecturers, most coming from Africa or Europe.

I was privileged to teach the solar physics lectures at ISYA. Covering many topics from the solar interior to space weather and everything in between, I gave the students a taste of what solar research is about, how it relates to other fields in astronomy, and to life on our own planet.

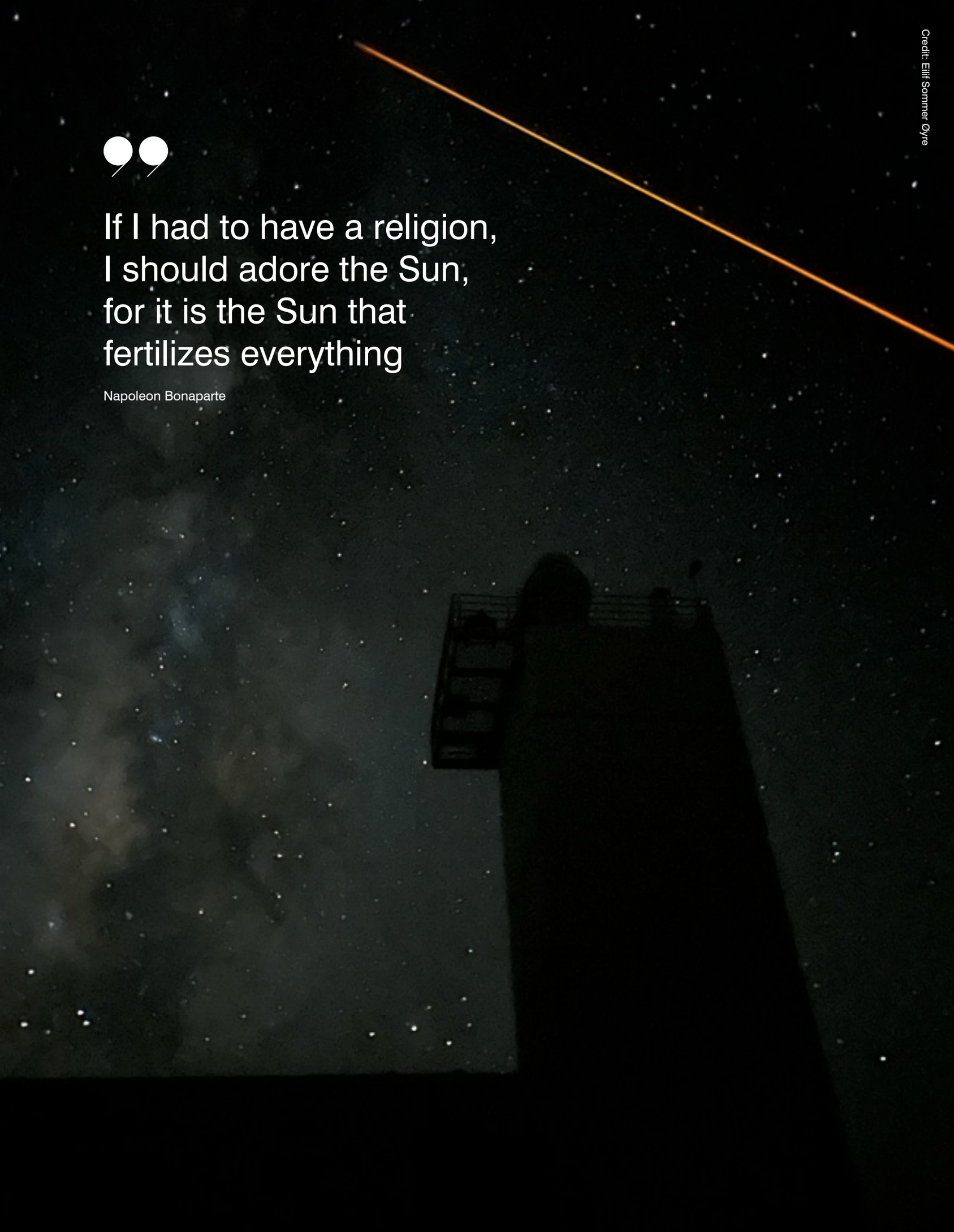
The days were intense and filled with lectures. Still, the organisers managed to pack another intense social and cultural programme, with visits to the sights in Algiers and the highlight of the school–a weekend trip to the town of Ghardaïa, a world-heritage gem in the Sahara desert. Overall, it was a uniquely rewarding experience to bring solar physics to students that otherwise wouldn't have it in their curricula.

Author: Tiago Pereira

Tiago lecturing at the school. Credit: Abdallah Ghebriout

Central square in Algiers during a day trip. Credit: Tiago Pereira

In a traditional house in Ghardaïa. Credit: Abdallah Ghebriout



Credit: Elif Sommer Øyre

If I had to have a religion, I should adore the Sun, for it is the Sun that fertilizes everything

Napoleon Bonaparte

Engaging with Solar Orbiter observations

I was awarded a guest investigator grant in 2024, along with Daniel Nóbrega Siverio (former postdoctoral researcher at RoCS, now working at IAC Spain), to collaborate on Solar Orbiter observations at the Royal Observatory of Belgium (ROB).

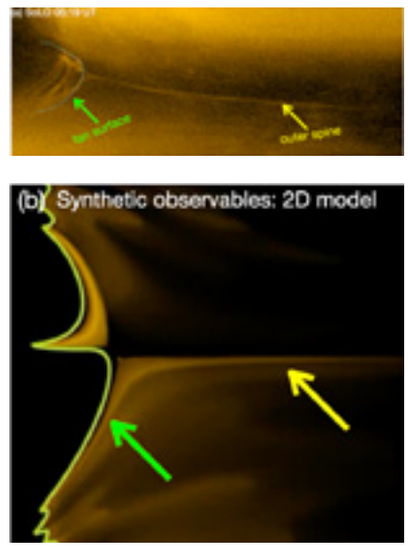


Fig. 1: An example of a standard solar jet (panel a) featuring a thin spine and fan surface, closely resembling the synthetic observable (panel b) from the 2D model by Nóbrega-Siverio & Moreno-Insertis (2022).

Exploring Solar Orbiter observations

In 2024, we spent a total of three weeks at ROB, analyzing high-resolution coronal observations of solar jets and coronal bright points using data from the Extreme Ultraviolet Imager (EUI) onboard Solar Orbiter. Our work focused on the elongated spines of thin solar jets observed with the EUI instrument, exploring the potential for multi-view perspectives through both observational data and simulations. The exceptional spatial resolution of EUI has been particularly valuable in revealing the extended spines of standard solar jets, which were previously challenging to observe due to resolution constraints.

As an early career researcher, it was a valuable experience to collaborate with experts from the EUI data analysis team in Brussels. Together with Daniel, I explored a vast set of observations from EUI, applied specific selection criteria, and narrowed our focus to a list of 10 solar jets.

Highlights of the visit

By traveling close to the Sun–down to 0.3 AU–EUI is providing a new perspective on the solar atmosphere, uncovering a diverse range of transient small-scale events and resolving the fine structure of the corona with unprecedented spatial and temporal detail. Our research focuses on the evolution of hot solar jets mainly originating from coronal bright points (CBP) highlighting the significance of these previously unresolved jets in understanding the dynamics of upflows in the solar corona. In our preliminary analysis, these observations show strong similarities with recent CBP models, motivating us to further investigate the physical properties of these jets (see Fig. 1).

This was a fantastic opportunity to focus on scientific research with Solar Orbiter, while discussions with EUI experts further enriched our expertise. During our visit, we delivered two talks to present our findings and look forward to continuing our work with Solar Orbiter, with hopes of future visits under a new fellowship grant.

Author: Reetika Joshi

The two of us, visiting researchers, standing at the gate of ROB, unexpectedly enjoying the first snowfall of winter 2024 in Brussels in November. Credit: Daniel Nóbrega Siverio

Observing flares with SST

In 2024, the Sun was at its maximum in the 11-year activity cycle, producing a large number of flares and energetic events.

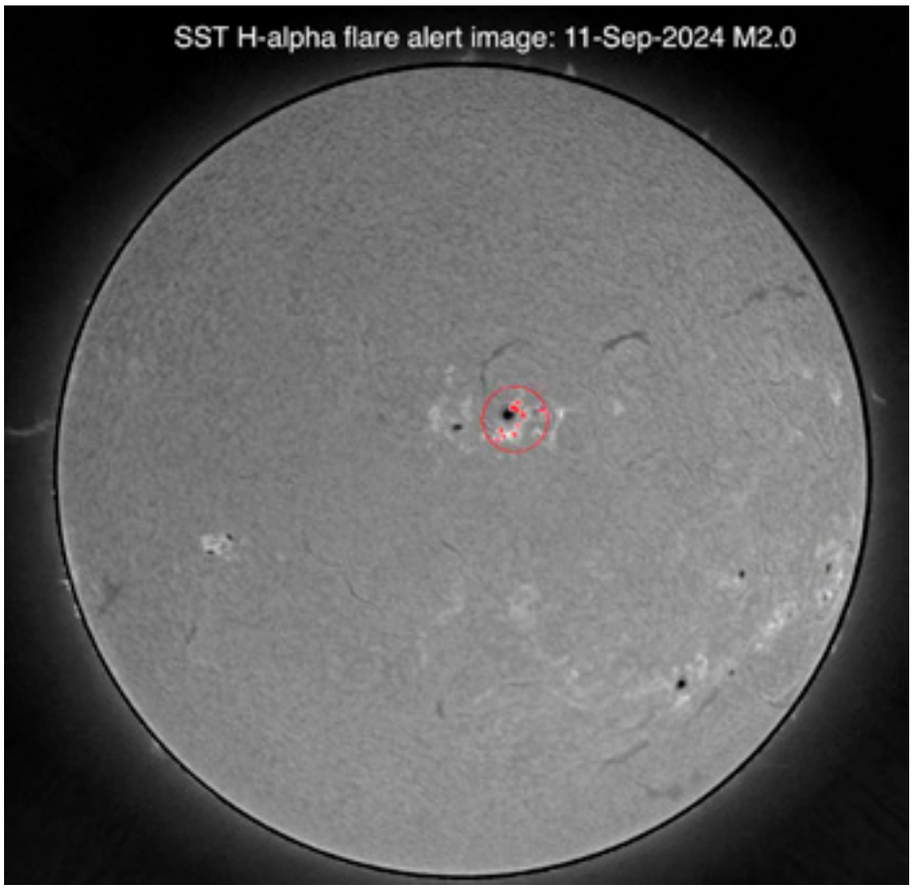
Challenges of observing Solar flares

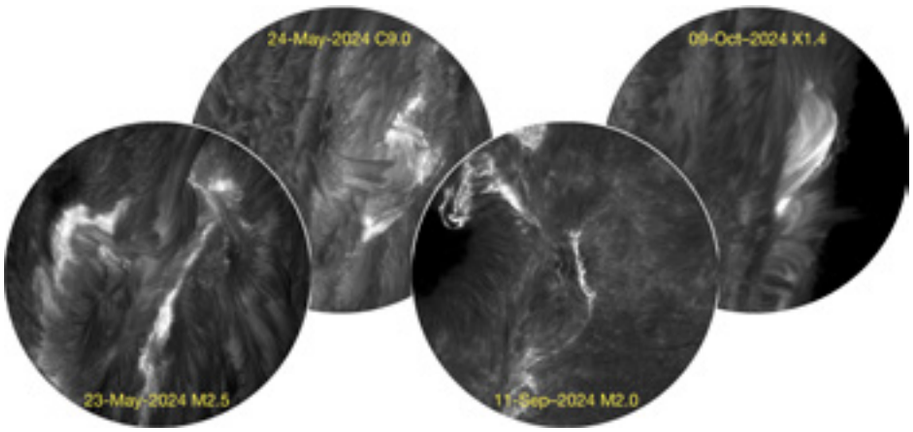
It is not trivial to observe a solar flare with SST since the field of view is limited and it is practically impossible to predict where and when a flare will occur in the various active regions. The SST has a flare alert system based on rapid changes in the full-disk images of the SST H-alpha finderscope. This allows observers to precisely locate the onset of bigger flares (C class and stronger).

Observation success

The flare warning system can also trigger a sound alarm, ensuring observers do not miss the start of a flare. The image on the right shows the H-alpha finderscope image with the M2 flare on September 11, 2024, marked with a red circle. The flare produced several intense localised brightenings in the H-alpha spectral line, detected and marked in red. The flare alert allowed us to quickly point the telescope at the right location and start observing. This was one of the four excellent flare observations that we acquired this season.

Authors: Reetika Joshi and
Luc Rouppe van der Voort





Shocks and reconnection: Probing chromospheric heating through simulations

The chromosphere is a dynamic layer of the solar atmosphere located between the relatively cool surface (photosphere) and the extremely hot surrounding corona. Its rising temperature can be attributed to various processes, that cross this layer while depositing material and energy, making it a key region for understanding the Sun's connection to its close environment.

Observational insights

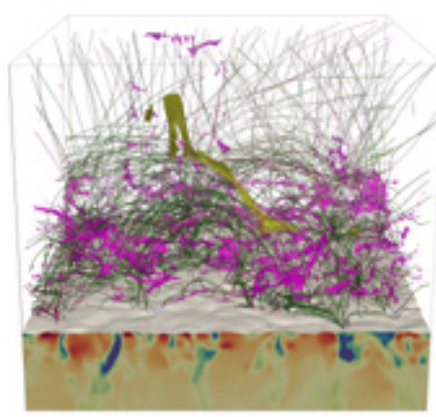
Recent high-resolution observations of the solar surface and of distant solar-type stars, point to a multi-scale, multi-physics origin of chromospheric heating. Surface convection especially plays a key role, first by producing rising acoustic waves that transform into shocks and dissipate energy in the chromosphere, but also by braiding magnetic field lines in complex structures, which then reconnect and release energy in a broad spectrum of flaring events.

Outstanding questions

However, questions persist about the relative importance of these chromospheric mechanisms, but also about the exact impact of constantly emerging magnetic flux from the convective surface into the atmosphere. The support and synergy of numerical simulations is then crucial alongside observations, which are both forefront expertises of RoCS.

Cutting-edge simulations

Using the state-of-the-art Bifrost code, newly developed 3D rMHD simulations have achieved unprecedented resolution in chromospheric models. These simulations enable exploration of how different processes behave under varying magnetic conditions in quiet-Sun regions. Our team has developed methods to trace shocks and reconnection sites, and we are now quantifying the energy they deposit. Notably, at least half of the energy deposition in the chromosphere occurs in current sheets, where magnetic reconnection is expected. Meanwhile, shocks from acoustic waves make a significant contribution to heating, accounting for about one-third of the heating over the whole chromospheric extent. The next step will involve generating synthetic images from these models, allowing direct comparisons with recent observations. Such comparisons will help in interpreting observations and refining the simulations themselves.



Visualization of a 3D solar simulation using *Bifrost*, showing the intricate network of magnetic field lines (colored lines) above the convective surface (red/blue for rising/sinking cells). Shock fronts (shown in magenta) propagate along these canopied-field lines, which act as waveguides. The yellow volume marks a magnetic current sheet formed by small-scale plasma emergence interacting with the ambient magnetic field. Magnetic reconnection is expected here, producing intense heating up to coronal temperatures and triggering a “pico”-flaring event.

These models have required millions of computing hours at Betzy, one of Europe's most advanced supercomputing facilities, located in Norway. Subsequent investigations are part of the “Whole Sun” project, funded by the European Research Council (ERC).

Author: Quentin Noraz

Engagement with the European solar physics and astronomy community

RoCS continues to play a pivotal role in the advancement of solar physics through its active participation in leading scientific organizations. As a hub for solar research, RoCS is deeply involved in the European Solar Physics Division (ESPD) of the European Physical Society (EPS).

Collaborative leadership in solar physics

The actions organised by the ESPD, which includes the European Solar Physics Meeting (ESPM) in Turin, Italy, in September 2024, foster collaboration and innovation among solar physicists across Europe. Members of RoCS are actively engaged in the division, contributing to its mission of promoting solar physics research and strengthening networks within the scientific community.

Key roles and future initiatives

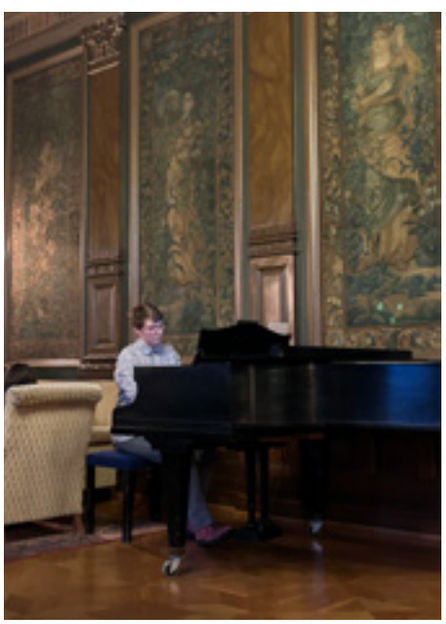
Following the terms of Tiago Pereira (2017-2021, as secretary), and Sven Wedemeyer (2021-2024, as vice-president), Reetika Joshi joined the ESPD board in 2024. Mats Carlsson, in his role as president of the European Association for Solar Telescopes (EAST) from 2013 to 2024, served as co-opted EAST representative on the ESPD board (2017-2024). After being elected councilor of the European Astronomical Society (EAS) in 2024 with the mission to strengthen the ties between the solar physics and the astronomy communities in Europe, Sven Wedemeyer will continue to engage with the ESPD as co-opted representative of the EAS. He will also represent the EAS in ASTRONET, the European network aimed at coordinating and strategizing astronomical research and infrastructure across Europe to address scientific and societal challenges in astronomy.

Author: Sven Wedemeyer

Caption: Jonas Thoen Faber presenting his work at the European Solar Physics Meeting (ESPM) in Turin (September 2024). The tri-annual ESPM meetings are a core activity of the European Solar Physics Division and aim to gather the European solar physics community. Credit: Elias Roland Udnæs

Social life at RoCS

A vibrant, thriving community emerges through a blend of work, leisure, connection, and enjoyment. These moments capture the essence of RoCS.



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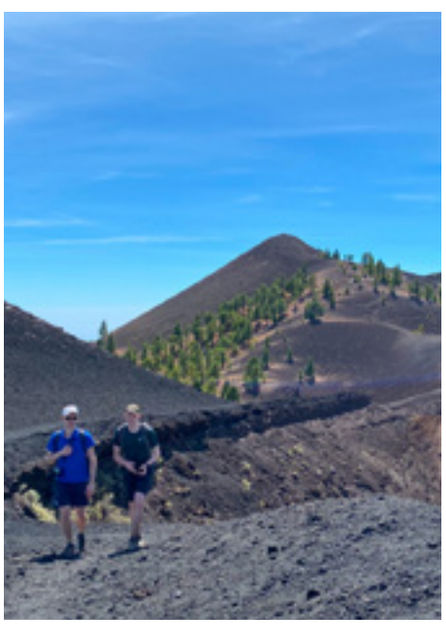
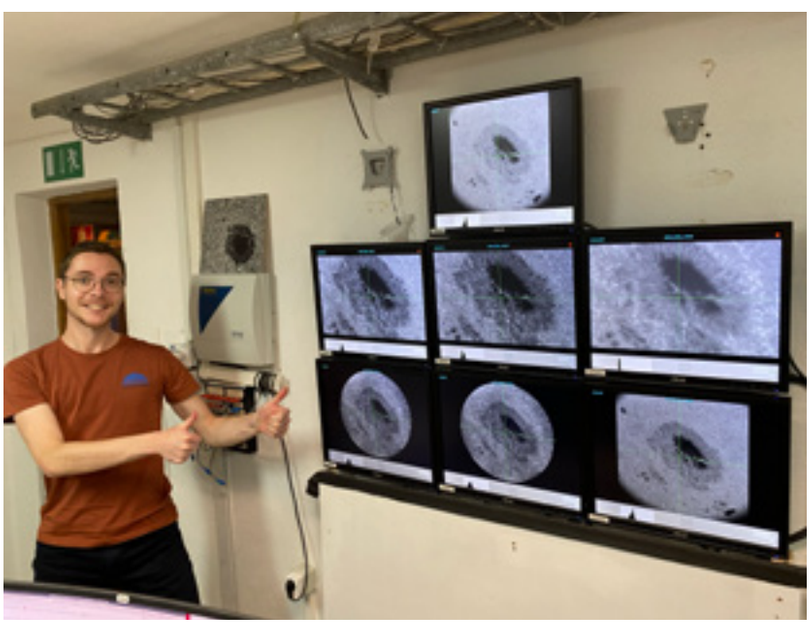
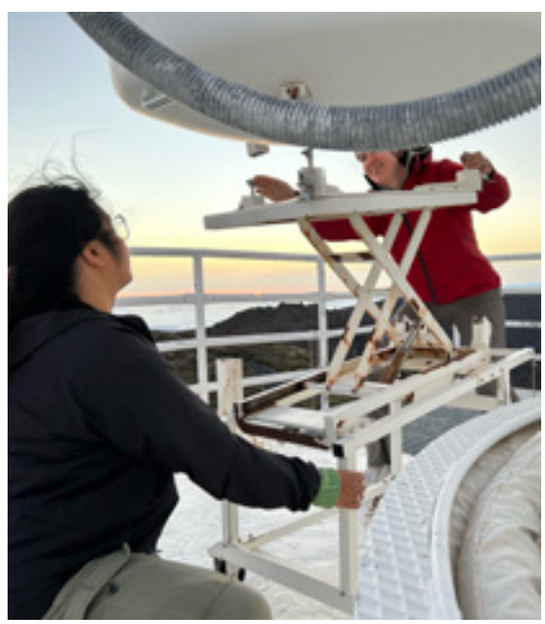
Life at the SST

In 2024, we conducted three observation campaigns in May, September and October. Nine RoCS members participated, including PhD students, postdocs, and PIs.







Members of the centre

Credit: Nicolas Poirier

Members of the centre

The main resource of RoCS and its most important contributor is our staff. Everyone at our centre – scientific, administrative, and technical – is handpicked for their excellent qualifications and expertise. During 2024, we had five master's students, 16 doctoral research fellows, 14 postdocs and researchers, two research software engineers, one associate professor, five professors, one centre coordinator, and one communication adviser. In addition, we had seven adjunct professors, six associated members in the administrative and technical staff, and four emeriti. Our Scientific Advisory Committee consisted of four members.

Thanks to our privileged position as a centre of excellence, we are able to grow by hiring talented and exceptional researchers from a wide range of nationalities (currently representing 20 nationalities from three continents). From a small group, RoCS has grown into a thriving international community with 47 employees from: Norway, Sweden, Denmark, Lithuania, Poland, Italy, Spain, United Kingdom, China, Ukraine, Belgium, France, Slovakia, Austria, India, Portugal, Iran, Switzerland, the Netherlands and Germany.

All our members are dedicated to strengthening our scientific achievements, setting forward new goals, and raising the standards for our research.

> Every morning, the rising Sun invites and inspires us to begin again.
>
> Debasish Mridha

Phd

Aditi Bhatnagar

Aditi Bhatnagar, a doctoral research fellow, studies the origin and impact of small-scale energetic phenomena in the solar atmosphere, focusing on Ellerman Bombs in the quiet Sun (QSEBs). This is done by combining observations from the lower atmosphere with IRIS observations from the higher layers, to obtain a more complete view of the impact of QSEBs on the solar atmosphere. She is also active in outreach activities, aurora chasing and enjoys communicating science to the public.

Aline R. Brunvoll

Aline R. Brunvoll, a doctoral research fellow, studies micro- and nanoflares on the Sun. Her work involves developing a machine-learning model to detect micro-and nanoflares in chromospheric observations captured by the Swedish 1-m Solar Telescope (SST).

George Cherry

George Cherry, a doctoral research fellow, is part of the CompSci PhD programme, which provides intensive training in computational and data science. Georges' work focuses on developing heat conductivity functions within Bifrost, and examining the detection of wave propagation through Bifrost simulations.

Elisabeth Enerhaug

Elisabeth Enerhaug, a doctoral research fellow, is in her fourth year of a joint PhD between the University of St Andrews and the University of Oslo. She is researching methods for identifying MHD wave modes in the solar atmosphere.

Jonas Thoen Faber

Jonas Thoen Faber, a doctoral research fellow, analyses observations of solar flares. He studies small-scale features associated with flares, mainly utilising the Swedish 1-m Solar Telescope (SST) on La Palma, covering the photosphere and the chromosphere.

Lars Frogner

Lars Frogner, a doctoral research fellow, defended his thesis "Modelling accelerated particles in the solar atmosphere" for the degree of Philosophiae Doctor in April 2024.

Phd

Øystein Håvard Færder

Øystein Håvard Færder, a doctoral research fellow, defended his thesis "The role of resistivity in plasmoid-mediated reconnection in the solar corona and its observational imprints" for the degree of Philosophiae Doctor in May 2024.

Michael Haahr

Michael Haahr, a doctoral research fellow, is part of the newly formed ‘particle group’ that aims to understand how particle acceleration occurs in the solar atmosphere. As a tool for this, he is working on a new particle-in-cell (PIC) code to model the internals of solar flares. His main interests lie in simulations, numerical modelling and high performance computing.

Mats Kirkaune

Mats Kirkaune, a doctoral research fellow, currently investigates the solar observing capabilities of various instruments considered for the future Atacama Large Aperture Submillimeter Telescope (AtLAST). This is done by utilising the general (sub-)millimetre telescope simulator, maria. Afterwards, he will search for signatures of nanoflares in solar observations obtained with the Atacama Large Millimeter/submillimeter Array (ALMA).

Kilian Krikova

Kilian Krikova, a doctoral research fellow, focuses on studying the impact and origin of small-scale energetic phenomena in the lower solar atmosphere. His work is especially focused on Ellerman “bombs”(EB), which could play a significant role in heating the lower solar atmosphere and the reconfiguration of photospheric magnetic fields. Therefore, he combines state-of-the-art observations, simulations, and radiative transfer tools to gain a better understanding.

Semya Amouche Tønnessen

Semya Amouche Tønnessen, a doctoral research fellow, investigates the diagnostic potential of spectral lines to be observed by the upcoming EUVST telescope onboard the Solar-C satellite. She will use dynamic simulations of the solar atmosphere and develop new techniques to efficiently include all physics that are important for the synthesis of optically thick line profiles. Using synthetic line profiles from a variety of 3D simulations, she will study their potential to diagnose dynamic events.

Sascha Ornig

Sascha Ornig, a doctoral research fellow, investigates solar flares with emissions in optical wavelengths (“white-light”) to understand the conditions that facilitate these emissions and identify the underlying formation mechanisms. He uses high-resolution observations from the Swedish 1-m Solar Telescope (SST) combined with state-of-the-art simulations using the RADYN code

Phd

Ignasi J. Soler Poquet

Ignasi J. Soler Poquet, a doctoral research fellow, is a member of the CompSci PhD programme. The main goal of his thesis is to study small-scale events of magnetic reconnection in the solar atmosphere. He plans to find and classify them by exploring large observational datasets. Ignasi applies Deep Learning techniques to automatically detect these events. He uses solar observations from different solar observatories such as SST, SDO, or IRIS.

Mats Ola Sand

Mats Ola Sand, a doctoral research fellow, focuses his research on the origin of jets in the solar atmosphere, commonly known as spicules on smaller scales and surges on larger scales. His project will compare these jets on different scales by studying high-quality observations from both ground-based and space-borne telescopes, particularly examining the connection between Ellerman Bomb-like features in the quiet Sun (QSEBs) and spicules.

Elias Roland Udnæs

Elias Roland Udnæs, a doctoral research fellow, is conducting a research project that combines high-resolution observations, magnetohydrodynamic (MHD) simulations, and machine learning techniques to identify and quantify wave heating in the solar chromosphere. He aims for his work at RoCS to result in an innovative tool that links complex spectral data from current and future solar telescopes with wave heating signatures.

Eilif Sommer Øyre

Eilif Sommer Øyre, a doctoral research fellow, uses simulations to study how particles are accelerated in the solar atmosphere. This research provides an opportunity to better understand the physical processes at play in solar flare kernels.

Postdocs and researchers

Souvik Bose

Souvik Bose, an affiliated researcher, completed his PhD at RoCS in 2021. His research mainly focuses on unravelling the dynamics of the solar atmosphere through coordinated high-resolution ground and space based observations. He also works on computing synthetic observations from high-resolution MHD simulation snapshots using various radiative transfer codes. His primary affiliation is with Lockheed Martin Solar and Astrophysics Laboratory (LMSAL) where he is involved in the upcoming NASA MUSE mission.

Carlos José Díaz Baso

Carlos José Díaz Baso, a postdoctoral research fellow, has general areas of interest in Bayesian statistics, deep learning, and solar physics. His research focuses on understanding solar chromospheric phenomena (from quiet solar filaments to explosive events) and their magnetic origin. He plans to achieve this goal by investigating high-quality space and ground-based spectropolarimetric observations using novel deep learning and Bayesian inference techniques, and comparing them with numerical models of the solar atmosphere.

Sondre Vik Furuseth

Sondre Vik Furuseth, a postdoctoral research fellow, worked at RoCS from August 2021 to July 2024. In August 2024, he started a new position at DNV as a Senior Energy Modeler.

Prasanta Gorai

Prasanta Gorai, a postdoctoral research fellow, focuses his research on the millimeter/submillimeter wavelength observations of asymptotic giant branches (AGBs) and young stellar objects (YSOs) using ground-based radio telescopes. Currently, he is working on imaging and spectral analysis of a sample of AGB stars.

Ana Belén Griñón-Marín

Ana Belén Griñón-Marín, a postdoctoral research fellow, worked at RoCS from December 2020 to September 2024. In October 2024, she began her position as a Scientific Researcher at the Institute of Solar Physics at Stockholm University with funding from the Swedish National Space Agency.

Shahin Jafarzadeh

Shahin Jafarzadeh, an affiliated researcher, is primarily employed by the Max Planck Institute for Solar System Research in Germany. He is predominantly interested in characterisation of wave activity in the lower solar atmosphere, and is a founding member of the WaLSA international science team. Shahin is an experienced observer, particularly with SST, and passionately engages in public outreach activities.

Postdocs and researchers

Reetika Joshi

Reetika Joshi, a postdoctoral research fellow, focuses her research on the multi-wavelength study of solar jets using ground based telescopes and space-borne satellites. Currently she is working on the imaging and spectroscopy analysis of solar jets and surges with NASA's IRIS instrument and SST observations.

Petra Kohutova

Petra Kohutova, a researcher, is the PI of the RCN-funded ORCS project, which focuses on oscillations in realistic models of the solar atmosphere. She combines high resolution solar observations and numerical simulations.

Valeriia Liakh

Valeriia Liakh, a postdoctoral research fellow, started working at RoCS on December 1, 2024. She comes from KU Leuven and is funded by the MSCA COFUND DSTrain program, which supports postdocs in computational and data sciences. Her research mainly focuses on the numerical modeling of solar prominences, with an emphasis on their formation, dynamics, and eruptions.

Quentin Noraz

Quentin Noraz, a postdoctoral research fellow, is involved in the WholeSun ERC project. During his PhD, he primarily investigated the dynamics and magnetism of the Sun and solar-type stars, using global numerical models. He now contributes to local numerical models of the lower solar atmosphere, exploring its thermodynamics, incorporating new magnetic constraints from global MHD models, and aiming to venture into local simulations of stellar atmospheres.

Nicolas Poirier

Nicolas Poirier, a postdoctoral research fellow, is a contributor to the ORCS project. During his PhD he explored various topics such as solar eruptions, the solar wind and coronal loops. He is involved in the Parker Solar Probe and Solar Orbiter missions and now brings his expertise to RoCS, and specifically to the ORCS project for which he studies coronal oscillations using high-resolution observations and advanced methods.

Daniel Nóbrega Siverio

Daniel Nóbrega Siverio, an affiliated researcher and former postdoctoral researcher, now works at the Instituto de Astrofísica de Canarias (IAC) in Tenerife. Daniel´s research primarily focuses on chromospheric surges and coronal bright points from both theoretical and observational perspectives.

Postdocs and researchers

Avijeet Prasad

Avijeet Prasad, a postdoctoral research fellow, worked at RoCS from August 2021 to September 2024.

Maryam Saberi

Maryam Saberi, a researcher, is the PI of the ESGC project funded by the RCN, which focuses on studying the impact of evolved stars on the Galactic chemical composition. She is also interested in studying solar and stellar chromospheric activity and its variation throughout stellar evolution. She has expertise in radiative transfer and chemical modelling of outflows around evolved stars.

Fan Zhang

Fan Zhang, a postdoctoral fellow, is primarily interested in developing numerical techniques for studying fluid & plasma dynamics, typically described by nonlinear hyperbolic partial differential equations. He is currently working to improve the modeling of the solar atmosphere by (1) further exploring fundamental dynamics in the lower solar atmosphere and (2) using advanced numerical techniques such as model order reduction and uncertainty quantification.

Research Software Engineers

Andrius Popovas

Andrius Popovas, a research software engineer, is developing next-generation global magnetohydrodynamic simulations of the convective regions of the Sun and other stars. This work will enable experiments on an unprecedented scale and complexity, bridging internal dynamo simulations to the surface of the Sun and stars on a global scale. These simulations are run on the LUMI supercomputer located in Finland.

Mikolaj Szydlarski

Mikolaj Szydlarski, a research software engineer, is a physicist and mathematician by education, but a computer scientist at heart. Mikolaj is interested in the application of high-performance computing (HPC) to challenging problems in solar astrophysics. His fields of expertise include MHD simulations and Solar ALMA data reduction.

Adjunct professors

Guillaume Aulanier

Guillaume Aulanier, an adjunct professor, develops 3D MHD models for flares, prominences, magnetic field topology and reconnection. He is a member of the science teams for SDO and Solar Orbiter. His home institution is the Laboratory for Plasma Physics in Paris. He is the deputy director of the astrophysics graduate school at Université PSL, chair of the Sun-Earth programme of CNRS, and policy officer for HPC at the ministry of research.

Adjunct professors

Ineke De Moortel

Ineke De Moortel, an adjunct professor, focuses her research on coronal heating, particularly the efficiency of heating by MHD waves, using a combination of numerical simulations and observational data analysis. Her home institution is the University of St Andrews (UK). Since September 2021, one of her PhD students, Elisabeth Enerhaug, has been pursuing a joint PhD program between the Universities of St Andrews and Oslo.

Bart De Pontieu

Bart De Pontieu, an adjunct professor, focuses on understanding how the Sun's magnetic field energizes the coupled solar atmosphere from the photosphere into the corona and heliosphere. He combines high resolution space-based and ground-based multi-wavelength observations with advanced numerical modeling. He is the PI of NASA's IRIS and MUSE satellite projects and manages the research team at Lockheed Martin Solar & Astrophysics Laboratory (LMSAL). He is also the PI of the JAXA/NASA EUVST project at LMSAL.

Lyndsay Fletcher

Lyndsay Fletcher, an adjunct professor, focuses on solar flares, specifically the transport of energy through the flare atmosphere, the energisation of the chromosphere, and the interpretation of radiation signatures. She uses data analysis to confront data with flare models. She also teaches astrophysics at her home institute (University of Glasgow, UK) and leads efforts to increase the participation of women and girls in physics and astronomy.

Juan Martínez-Sykora

Juan Martínez-Sykora, an adjunct associate professor, is based at LMSAL and SETI. He is the deputy science lead of MUSE (NASA MIDEX program) and EUVST Co-I. His major contributions are in the numerical modeling of the solar atmosphere. His main interests include chromospheric heating and dynamics, as well as multi-fluids. He uses and develops state of the art 3D radiative MHD codes and compares the models with ground-based and space-based observations.

Åke Nordlund

Åke Nordlund, an adjunct professor, works at the Astrophysics and Planetary Sciences group at the Niels Bohr Institute and STARPLAN at the University of Copenhagen. He is a member of the Niels Bohr International Academy, the Norwegian Academy of Sciences and Letters, and the Royal Swedish Academy of Science.

Marianne G. Omang

Marianne G. Omang, an adjunct associate professor, also works for the Norwegian Defence Estate Agency. Her fields of interest are shock and blast waves, with a focus on the effects of using reactive particles as additives. Her work combines experiments with numerical simulations using a Multi-Phase Smoothed Particle Hydrodynamics method (MP-RSPH).

Principal investigators

Mats Carlsson

Mats Carlsson is a professor and the director of RoCS. His main interests include chromospheric physics and radiation MHD. He works with both large-scale simulations and observations from ground and from space.

Boris Gudiksen

Boris Gudiksen, a professor and PI, focuses on the development of numerical codes for simulations of the solar atmosphere. His main interest is the solar corona and understanding how it maintains its high temperature.

Viggo Hansteen

Viggo Hansteen, a senior researcher at Bay Area Environmental Research Institute and a part time professor and PI, works on both simulations and observations, from the ground and from space. He is interested in how the magnetic field is formed in the deep convection zone, how it rises to the photosphere, and how it forms the outer solar atmosphere. Key areas of his research include flux emergence, coronal heating and chromospheric dynamics and energetics.

Tiago M. D. Pereira

Tiago M. D. Pereira, an associate professor and PI, studies dynamic processes in stellar atmospheres. He is particularly focused on the solar chromosphere, the interface between the hot corona and the dense surface. Tiago leverages space and ground-based observations with detailed radiative transfer calculations from 3D models. With an interest in computational astrophysics, data analysis and visualisation, he works with high-performance computing and big data problems.

Luc Rouppe van der Voort

Luc Rouppe van der Voort, a professor and PI, focuses on the research area of high-resolution observations of the Sun. He is a veteran observer at the Swedish 1-m Solar Telescope on the island of La Palma. For many years, he has been running coordinated observation campaigns with the SST and space-borne telescopes, such as Solar Orbiter, IRIS, Hinode, and previously TRACE and SOHO.

Sven Wedemeyer

Sven Wedemeyer, a professor and PI, coordinates research activities related to solar and stellar observations at mm/radio wavelengths with ALMA and AtLAST as well as supporting simulations. His research primarily focuses on the small-scale structure, dynamics, and energy balance of the solar atmosphere, with implications for other stellar types.

Centre administration

Benedikte Fagerli Karlsen

Benedikte Fagerli Karlsen, the centre coordinator, is responsible for the administration of the centre and manages all practical tasks related to its activities. Her responsibilities include new employment, visitor arrangements, contracts, reporting and logistics for events.

Eyrun Thune

Eyrun Thune, the communication adviser, is responsible for communication and outreach activities at RoCS.

Technical and administrative associated staff

Martina D'Angelo

Martina D'Angelo, communication advisor at the Institute of Theoretical Astrophysics (ITA), follows up on science communication, outreach activities, and promotion on social media channels. She is the web editor for the ITA website and coordinator for the Norwegian Olympiad on Astronomy and Astrophysics.

Terje Fredvik

Terje Fredvik, an engineer in the institute's Project Related IT Services (PRITS) group, leads the development of the data pipeline for the Solar Orbiter SPICE instrument. He also contributes to the operations of the Hinode Science Data Centre Europe, is a member of the ITA FITS Working Group, and assists in the adaptation of the SOLARNET2 FITS mechanisms for both observational and simulated data.

Stein Vidar Hagfors Haugan

Stein Vidar Haugan, the technical lead for the Project Related IT Services (PRITS) group, is responsible for the Hinode Science Data Centre Europe, serving data from the Hinode and IRIS missions and from SPICE on Solar Orbiter. He leads the ITA FITS Working Group, acts as a liaison between RoCS and the SOLARNET2 project, and contributes to the data pipeline and quicklook software for Solar Orbiter SPICE.

Technical and administrative associated staff

Kristine Aa. S. Knudsen

Kristine Aa. S. Knudsen, the Head of Office at the Institute of Theoretical Astrophysics (ITA) cooperates closely with both the scientific, technical, and administrative staff at RoCS and the Institute.

Torben Leifsen

Torben Leifsen, the head of IT at the institute, is responsible for planning, building and running the IT systems together with the IT-group at the institute. A second server room was added in 2020 to accommodate the needs of RoCS and other projects. Torben has a background in solar physics and is a member of the Virgo team on the ESA spacecraft SOHO. He also conducts research in helioseismology in his spare time.

Martin Wiesmann

Martin Wiesmann, an engineer in the institute's Project Related IT Services (PRITS) Group, is responsible for parts of the IRIS pipeline as well as the adaptation of AIA and Hinode data to IRIS data. Martin also contributes to the Solar Orbiter SPICE pipeline and quicklook software. He is mainly a programmer, implementing requests and wishes from various scientists into the pipeline or as separate programs.

Scientific Advisory Committee

Tony Arber

Tony Arber, a computational plasma physicist, has interests that span solar physics, space weather, laser-plasmas and QED-plasmas. He has been responsible for developing MHD codes for both solar physics and laser-driven fusion as well as kinetic codes for high-power plasma interactions. For all codes, he is interested in software development methods and uncertainty quantification.

Sarah Matthews

Sarah Matthews, a professor of solar physics at UCL's Mullard Space Science Laboratory, has an interest in energy storage and release in magnetised plasmas, particularly in solar eruptive events and space weather. Her work is mainly observational, but she also collaborates with magnetic field modelers to interpret the observations in the context of current models. She also has an interest in instrumentation and is currently the Hinode EIS Principal Investigator (PI).

Oskar Steiner

Oskar Steiner, a senior researcher at the Kiepenheuer-Institut für Sonnenphysik (KIS) in Freiburg, Germany and at the Istituto ricerche Solari Aldo e Cele Daccò (IRSOL) in Switzerland, focuses his research on the numerical simulation of magnetohydrodynamic processes in the solar and stellar atmospheres. He is also interested in polarimetry and numerical methods of radiative transfer.

Emiriti

Oddbjørn Engvold

Oddbjørn Engvold, an emeritus professor, focuses on the structure and dynamics of solar prominences. He is a veteran user of the Swedish 1-m Solar Telescope on the island of La Palma, as well as the solar telescopes of the US National Solar Observatory (NSO) and solar telescopes in space. He has edited and contributed to two books related to solar activity.

Olav Kjeldseth-Moe

Olav Kjeldseth-Moe, an emeritus professor, has a special interest in the transition region into the corona. He contributed to the development of instruments and observing procedures designed to map conditions in the corona. He participated in NASAs Skylab Observatory in 1973-74, was a co-investigator on the HRTS instrument on Spacelab 2 (1985), and served for 20 years as the Norwegian co-investigator for the CDS spectrometer on SOHO.

Egil Leer

Egil Leer, an emeritus professor, has the corona, the solar wind, and the interaction of the solar wind with the local interstellar medium as his areas of interest.

Jan Trulsen

Jan Trulsen, an emeritus professor, focuses on research in plasma physics, turbulence phenomena in ionized and neutral media, and numerical simulations.

Scientific Advisory Committee

Francesca Zuccarello

Francesca Zuccarello, an associate professor at the University of Catania in Italy, is involved in the study of the emergence, evolution and decay of solar active regions, as well as research related to solar eruptive events. Francesca is mainly an observer and has participated in several Coordinated Observational Campaigns.

Master students

Isak Aaby

Isak Aaby, a first-year master student, is working on a master project with the working title “Hypercadence, hyperspectral: a new look at synthetic spectra” supervised by Tiago Pereira.

Tor-Andreas S. Bjone

Tor-Andreas S. Bjone completed his master’s studies at RoCS in 2024.

Christophe K. Blomsen

Christophe K. Blomsen completed his master’s studies at RoCS in 2024.

Rebecca Nguyen

Rebecca Nguyen, a first-year master student, is working on a master project with the working title “Detection of Ellerman bombs in the solar atmosphere” supervised by Luc Rouppe van der Voort.

Eloi Martaillé Richard

Eloi Martaillé Richard completed his master’s studies at RoCS in 2024.

Credit: Eilif Sommer Øyre

PhD og master graduates overview 2024

Master's thesis

Tor-Andreas S. Bjone

"A numerical code for solving the convection zone of the sun using the anelastic approximation"

Summary: Modelling the internal structure of the Sun is numerically very difficult. The variables that describe the conditions change by many orders of magnitude as a function of depth, while the local variations are very small. To solve this problem, the anelastic approximation is often used, and is here used to model the whole convection zone and has been augmented with stable and physically sound boundary conditions. The implementation is tested and shown to provide consistent results and the code provides a good foundation for further exploration of the structure of the convection zone.

Christophe Kristian Blomsen

"Accelerating 3D non-LTE radiative transfer with GPUs "

Summary: This thesis addresses the radiative transfer problem outside local thermodynamical equilibrium (non-LTE) in stellar atmospheres by using Graphics Processing Units (GPUs) to accelerate calculations. It focuses on optimizing ray tracing on GPUs and comparing them with traditional CPU methods. Results show significant speedups, up to 82.7 times faster on certain GPUs, and around 50 times faster on others, with added energy efficiency benefits. These findings highlight the potential of GPUs for faster, more efficient solutions to non-LTE problems, advancing solar physics research with improved computational techniques.

Aline Rangøy Brunvoll

"A Co-Spatial, Co-Temporal View of the Solar Chromosphere in the Balmer Hα and Hβ Spectral Lines "

Summary: The thesis examines high-resolution observations from the Swedish Solar Telescope (SST) of the chromosphere in an active region. First, various methods of constructing "mosaic" images are explored and it is concluded that observing with high temporal cadence is of the highest priority when capturing each image. Secondly, co-temporal and co-spatial observations of the chromospheric H-alpha 6563 Å and H-beta 4861 Å spectral lines are compared pixel-to-pixel in order to determine how the chromospheric fibrils affect the line formation, and it is found that in the areas corresponding to the most optically thick fibril structures, the H-alpha and H-beta spectral lines both exhibit line broadening according to the curve of growth.

Eloi Martaille

"Simulating new capabilities of interferometric arrays for observing the Sun "

Summary: The thesis explores the scientific potential of a sub-array observing mode for the Atacama Large Millimeter/submillimeter Array (ALMA). By dividing ALMA into two sub-arrays, co-simultaneous observations in two different frequency bands corresponding to two different height ranges in the solar atmosphere would be possible. Utilizing the Solar ALMA Simulator (SASim), the study demonstrated that reliable imaging is achievable with sub-arrays in a compact configuration.

Semya Amouche Tønnessen

"Making Sense of the Solar Chromosphere – Investigations of the Diagnostic Power of Various Spectral Lines"

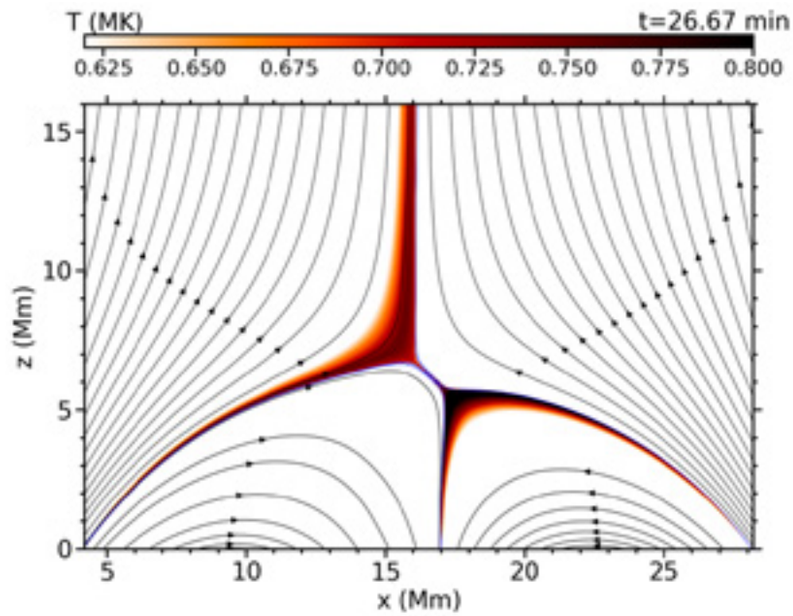
Summary: The thesis explores the EUVST observational capabilities for chromospheric lines, investigating the diagnostic power of the O I 1152 Å spectral line as a potential line that can be used to help understand the properties of the chromosphere. In addition, we study the O I 1039, 1040, and 1041 Å spectral line transitions, and give a comprehensive overview of the background processes that affect the continuum around the lines. The O I 1152 line was found to be optically thick with a formation that covers much of the chromosphere. However, the synthesized lines are weaker than what is observed, for which we found that a possible explanation could be a lack of coupling between energy levels in the oxygen atom.

Dissertations for the degree of Philosophiae Doctor

Øystein Færder

"The role of resistivity in plasmoid-mediated reconnection in the solar corona and its observational imprints".

Summary: Numerical simulations of magnetic field reconnection on the Sun demonstrate that different models for magnetic energy dissipation reproduce the same phenomena, though some models more accurately capture small-scale structures. The study indicates that such fine structures can be observed with satellites like the Multi-slit Solar Explorer, potentially enhancing our understanding of solar atmospheric heating and the causes of solar flares.

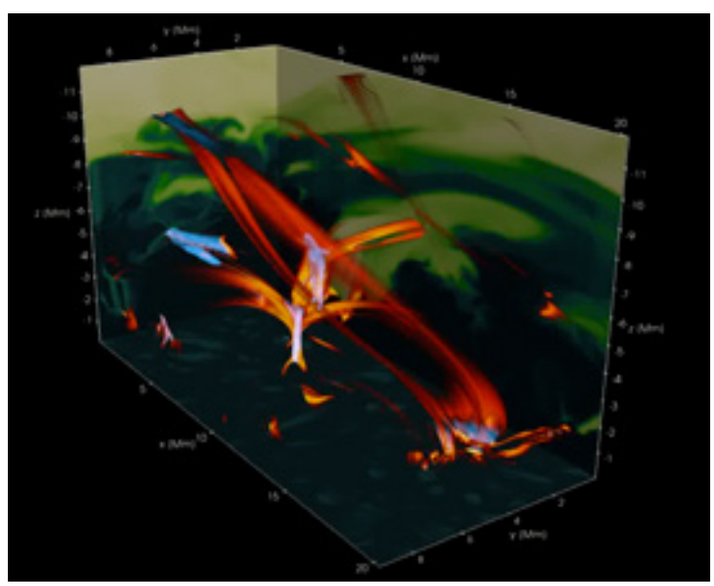


Temperature and magnetic field configuration for one of the simulations in Øystein Færder's PhD thesis.

Lars Frogner

"Modelling accelerated particles in the solar atmosphere"

Summary: The thesis explores particles accelerated in the Sun's atmosphere that form high-energy beams. Using a three-dimensional simulation, we modeled the formation and behavior of these beams in a more realistic environment than previously done. We found that the Sun's intricate magnetic field can influence the energy transport of the beams, providing new insights into the role of accelerated particles in the solar atmosphere.



Results from the PhD work of Lars Frogner showing 3D traces of accelerated particles in a Bifrost simulation.

Talks and presentations 2024

Carlsson, Mats. Sola og nordlyset: eksplosjonene som treffer oss. Offentlig foredrag; 2024-01-18

Carlsson, Mats. Understanding the Workings of the Energetic Sun. Sigma2 board meeting; 2024-06-10

Cherry, George; Gudiksen, Boris Vilhelm; Finley, Adam J. Detecting waves in non-idealised quiet-sun simulations. European Space Weather Week ESWW2024; 2024-11-04 - 2024-11-08

Cherry, George; Gudiksen, Boris Vilhelm; Szydlarski, Mikolaj. Implementation of thermal conduction energy transfer codes in the Bifrost Solar atmosphere MHD solver. ESPM-17; 2024-09-12

De Pontieu, Bart. MUSE science. Seminar University of Palermo; 2024-07-02

De Pontieu, Bart. MUSE status. EUVST science working group meeting; 2024-03-01

De Pontieu, Bart. MUSE status at Hinode/IRIS meeting. MUSE status at Hinode/IRIS meeting; 2024-07-01

Díaz Baso, Carlos José. Advances in machine learning applications on photospheric and chromospheric studies. 45th COSPAR Scientific Assembly, Busan, South Korea; 2024-07-13 - 2024-07-21

Díaz Baso, Carlos José. Chromospheric Magnetic Field Reconstruction through Neural Field Assisted Spectropolarimetric Inversions. 17th European Solar Physics Meeting; 2024-09-09 - 2024-09-13

Díaz Baso, Carlos José. Deep Learning 2.0: Combining physics-based models with data-driven solutions. Lockheed Martin Solar and Astrophysics Laboratory (LMSAL), California; 2024-05-16

Díaz Baso, Carlos José. Information content of solar spectra: Insights from numerical simulations and neural field inversion techniques. Solar seminar at Instituto de Astrofisica de Canarias (IAC); 2024-11-27

Díaz Baso, Carlos José. The Force Awakens: Unleashing Deep Learning in Solar Physics. Oslo AI Product Lab, Oslo; 2024-05-25

Enerhaug, Elisabeth. Hvordan vet vi hvor varm sola er?. UngForsk; 2024-09-18

Enerhaug, Elisabeth. Identifying Alfvén Wave Modes in the Solar Corona. 17th European Solar Physics Meeting; 2024-09-09 – 2024-09-13

Faber, Jonas Thoen. Analysis of flare ribbon fine structures using high-resolution observations. European Solar Physics Meeting 17; 2024-09-09 - 2024-09-13

Furuseth, Sondre Vik; Aulanier, Guillaume. Prominence formation through flux-cancellation of coronal arcades - A non-symmetric convective 3D R-MHD simulation. COSPAR 2024; 2024- 07-13 - 2024-07-20

Furuseth, Sondre Vik; Cherry, George; Martinez-Sykora, Juan. Benchmarking Astrophysical Simulations: An Analytical Solution for Non-Linear Diffusivity. ASTRONUM 2024; 2024-06-30 - 2024-07-05

Furuseth, Sondre Vik; Cherry, George; Martinez-Sykora, Juan. Benchmarking Solar Simulations: An Analytical Solution for Non-Linear Diffusivity. 17th European Solar Physics Meeting ESPM-17; 2024-09-13 - 2024-09-17

Haahr, Michael. Towards Realistic Solar Flare Models: A PIC-MHD hybrid code in DISPATCH. ASTRONUM 2024; 2024-06-01 – 2024-06-05

Joshi, Reetika. Anemone Solar Jets: Breakthroughs from SST Observations and Numerical Simulations. Seminar in the Solar Physics and Plasma Dynamics group in University of Sheield; 2024-10-03

Joshi, Reetika. Large Amplitude Oscillations in Solar Filaments. COSPAR 2024; 2024-07-13 - 2024-07-21

Joshi, Reetika. Solar Jets: Observations and MHD modelling. COSPAR 2024; 2024-07-13 – 2024-07-21

Joshi, Reetika. The World of Tomorrow: The Essence of Basic Science in Shaping Our Future. TED Talk; 2024-06-15

Kirkaune, Mats; Brunvoll, Aline Rangøy; Saberi, Maryam. Avsløring av solas hemmeligheter. UNGFORSK; 2024-09-18 - 2024-09-19

Kirkaune, Mats; Wedemeyer, Sven; Van Marrewijk, Joshiwa; Mroczkowski, Tony. Fast On-the-Fly Scanning of the Solar Disk with AtLAST. The Atacama Large Aperture Submillimeter Telescope (AtLAST) design study: results, science, and next steps; 2024-05-21 - 2024-05-24

Kirkaune, Mats; Wedemeyer, Sven; Van Marrewijk, Joshiwa; Mroczkowski, Tony; Morris, Thomas W. Simulating fast on-the-fly observations of the Sun with AtLAST. 17th European Solar Physics Meeting; 2024-09-09 - 2024-09-14

Kohutova, Petra; Antolin, Patrick; Szydlarski, Mikolaj; Poirier, Nicolas. Can we rely on EUV emission to identify coronal waveguides?. 11th Coronal loops workshop; 2024-06-24 - 2024-06-28

Kohutova, Petra; Antolin, Patrick; Szydlarski, Mikolaj; Poirier, Nicolas. Can we rely on EUV emission to identify coronal waveguides?. 11th Coronal loops workshop; 2024-06-24 - 2024-06-28

Noraz, Quentin. Chromospheric heating and flux emergence: from Bifrost to observations. Wholesun IAC; 2024-10-21 - 2024-10-25

Noraz, Quentin; Brun, Allan Sacha; Strugarek, Antoine. Dynamo of the solar interior: Powering the decadal cycle and Its comparison to stellar magnetic cycles. ESPM17; 2024-09-09 - 2024-09-13

Noraz, Quentin; Brun, Allan Sacha; Strugarek, Antoine. Impact of the Nusselt number in gl obal models of solar turbulent convection. Colloque PNST 2024; 2024-01-08 - 2024-01-12

Noraz, Quentin; Brun, Allan Sacha; Strugarek, Antoine. Magnetochronology of solar-type stars dynamos. NORDITA Stellar Convection; 2024-08-26 - 2024-08-30

Noraz, Quentin; Brun, Allan Sacha; Strugarek, Antoine. The Sun in Time: Evolution of cool-stars rotation and magnetism. EAS2024; 2024-07-01 - 2024-07-05

Noraz, Quentin; Carlsson, Mats; Aulanier, Guillaume. What is heating the chromosphere of Bifrost simulations?. Wholesun IPA; 2024-03-04 - 2024-04-22

Pereira, Tiago. Machine learning on observations and simulations. Solar MHD 2024; 2024-09-02 - 2024-09-05

Pereira, Tiago. Machine learning on observations and simulations. RoCS Deep Learning Workshop; 2024-09-16 - 2024-09-20

Pereira, Tiago. Solar Astrophysics. IAU School for Young Astronomers; 2024-08-23 - 2024-08-27

Pereira, Tiago. SOLAR-C EUVST Status Report on Modelling. University of Sydney seminar; 2024-08-12

Pereira, Tiago. Testing inversions at high spatial resolution: the case of Ca II 854.2 nm. Joint Solar Orbiter, Parker Solar Probe, and DKIST Meeting; 2024-04-08 - 2024-04-11

Pereira, Tiago; Martinez-Sykora, Juan. MUSE synthesis tools. SOLAR-C Workshop Nagoya 2024; 2024-03-05 - 2024-03-07

Poirier, Nicolas. About the enigmatic origin of the (slow) solar wind. Congress of the French Society of Physics (SFP) - Plasma Division; 2024-05-14 - 2024-05-16

Poirier, Nicolas. Challenges in modelling (coronal) abundances and observational needs. Solar Orbiter SPICE consortium meeting; 2024-06-11 - 2024-06-12

Poirier, Nicolas; Kohutova, Petra; Rouppe van der Voort, Luc; Danilovic, Sanja. About the source of sustained kink oscillations in coronal loops. Joint Solar Orbiter, Parker Solar Probe, and DKIST Meeting; 2024-04-08 - 2024-04-12

Poirier, Nicolas; Kohutova, Petra; Rouppe van der Voort, Luc; Danilovic, Sanja. About the source of sustained kink oscillations in coronal loops. 11th Coronal Loops Workshop; 2024-06-25 - 2024-06-28

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