UNIVERSITY OF OSLO

Rosseland Centre for Solar Physics

Annual report 2023

Norwegian Centre of Excellence

UNIVERSITAS OSLOENSIS MDCCCXI

Contents
Annual report 2023

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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 retreat at Støtvig hotel. Credit: Reetika Joshi

From the Director

This is the sixth annual report of the Rosseland Centre for Solar Physics (RoCS). The centre is one of the 10 centres of excellence selected by the Research Council of Norway in the fourth round of the centres of excellence scheme.

Activity has been high throughout 2023 with a record number of PhD candidates finishing and a record number of refereed papers. The group of doctoral and post-doctoral research fellows has been very active in organising the retreats, seminars, workshops, and short presentations at the monthly solar-stellar lunches, in addition to many social activities. These activities are at the heart of a well-functioning research environment and a sample of these activities are featured in this annual report.

The ongoing NASA mission IRIS and the new mission MUSE are central for realizing the RoCS vision. In February/March 2023 we organized an international scientific meeting in Longyearbyen, Svalbard. The RoCS/MUSE/IRIS meeting (dubbed RoCMI) gathered 100 eminent scientists for one week of intense discussions with both northern lights and a visit to SvalSat – the downlink station for data from IRIS and MUSE. Read more about MUSE on page 38 and more about this biggest scientific in-person meeting so far organized by RoCS on page 34.

We finally managed to book the hotel early enough to have a retreat along the Oslo fjord, at Støtvig hotel, in May 2023. For the first time, there was no principal investigator in the organising committee and the retreat was widely regarded as the best ever (up to the reader to attribute that to the location or the composition of the organising committee). Between games, hikes, and other social activities we got to know the research interests of each other better in poster sessions. In addition, we had several talks on other aspects, like how to write applications

In 2023 we were a total of 61 persons of 19 nationalities from three continents at RoCS.

for external funding and perspectives on career development. And of course, we got to see the very competitive side of some members in the evening bowling session. A big thanks goes to the organising committee (Carlos, Eilif, Elias, Heidi, Maryam, Petra, and Sondre).

In November we had our second gathering, now in our own premises. We had talks focusing on activities, methodology and possibilities at RoCS with titles like "Photon Chronicles: Observing Our Star" (Luc and Reetika), "Bridging Simulations and Observations" (Tiago and Carlos), "Simulation Odyssey" (Mats), and "Tech Trek: Navigating Astrophysical Networks" (Torben and Mikolaj, which included a much-appreciated visit to the new server room). Between these talks with active group discussions, we also had games "Solar Pictionary", "Blindfolded observations", "Construction constellations", and "RoCS anthem" and poster sessions. Again very successful, thanks to a hard working committee (Aditi, Benedikte, Fan, George, Jonas and Quentin).

RoCS is like a big family but in constant change: new people come and some leave. One postdoc started in 2023: Fan Zhang on a general RoCS grant. Three new PhD students started, Sascha Ornig and Mats Kirkaune with RoCS funding and Elisabeth Enerhaug on a shared PhD degree with University of St.Andrews (where she spent the first two years). As well as many new coming in we also have people moving out. Atul Mohan finished his postdoc period in February and moved to NASA Goddard Space Flight Center, Chandrashekhar Kalugodu finished in February and moved to Belgium. We had a record number of thesis defences: Helle Bakke, Thore Espedal Moe, Sneha Pandit and Rebecca Robinson all finished in 2023. Stian Aannerud, Edvarda Harnes, Mats Kirkaune, and Jonas Ringdalen Thrane finished their Master's. A hearty welcome to newcomers and best wishes in their new careers to the ones leaving.

The activity has been high in 2023 and reports, organised by theme, are given in Section 2. A list of talks and presentations is given in Appendix 1 and a full list of the 64 papers published in refereed journals in 2023 in Appendix 2.

Research results are important, but it is also essential to communicate these results to both the scientific world and the society at large. Our full-time communication advisor, Eyrun Thune, has been very active in promoting solar physics together with the RoCS crowd. RoCS, in collaboration with MUNCH, had the honor of opening the National Science Week of 2023 at the University of Oslo in the Aula in front of Edvard Munch's painting of the Sun. Doctoral research fellow Mats Ola Sand won the competition of the first project in an artist-in-residence initiative hosted by the Faculty of Mathematics and Natural Sciences with a project in collaboration with artist Laila Kongsvold. You can read more about the important outreach activities on page 26.

The International Rosseland Visitor Programme is covered in Section 3 and we continue the tradition from the last years with some glimpses from the life at RoCS in Section 4.

As the most important part of a centre is people, we have short presentations of all the members in Section 5. In 2023 we were a total of 61 persons of 19 nationalities from three continents at RoCS. I feel the environment gets better and better for every year so I can't wait to see the further development in 2024!

February 2024

Mats Carlsson,
Director of RoCS

2023 Activities by theme

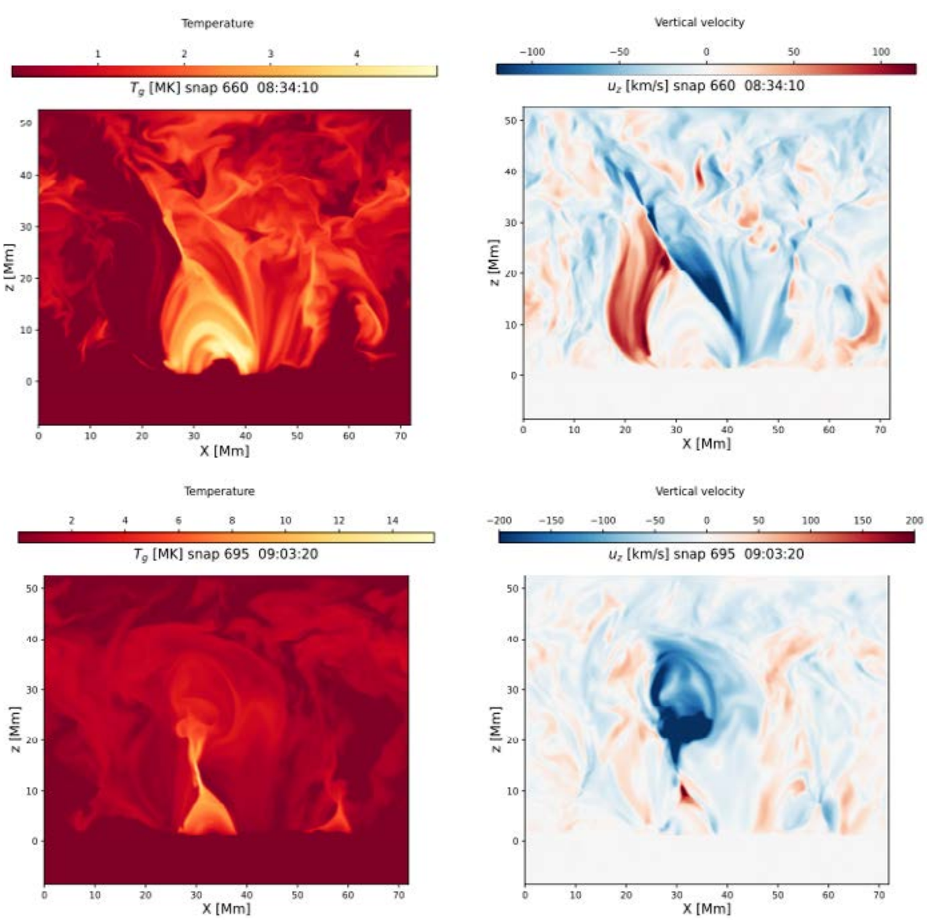
Credit: Aditi Bhatnagar

Simulations

In RoCS we have spent considerable energy understanding the solar magnetic field and its interaction with the plasma that comprises the Sun's outer atmosphere. Our goal has been to model the processes that drive "space weather"; flares, coronal mass ejections, jets and surges, filaments and prominences, and a host of smaller phenomena that characterise the active energetic Sun.

We don't have full knowledge of how, or even exactly where and in what form, the magnetic field is generated, nor how it is transported from the solar interior to the surface. Therefore, educated guesses must be made when setting up numerical experiments in the hope that these will lead to deeper insights into the workings of the Sun. In 2023 our guesses bore fruition: models in which a coronal bright point (see p. 47), a C-class flare, and even some quiet Sun runs producing small episodic events were produced.

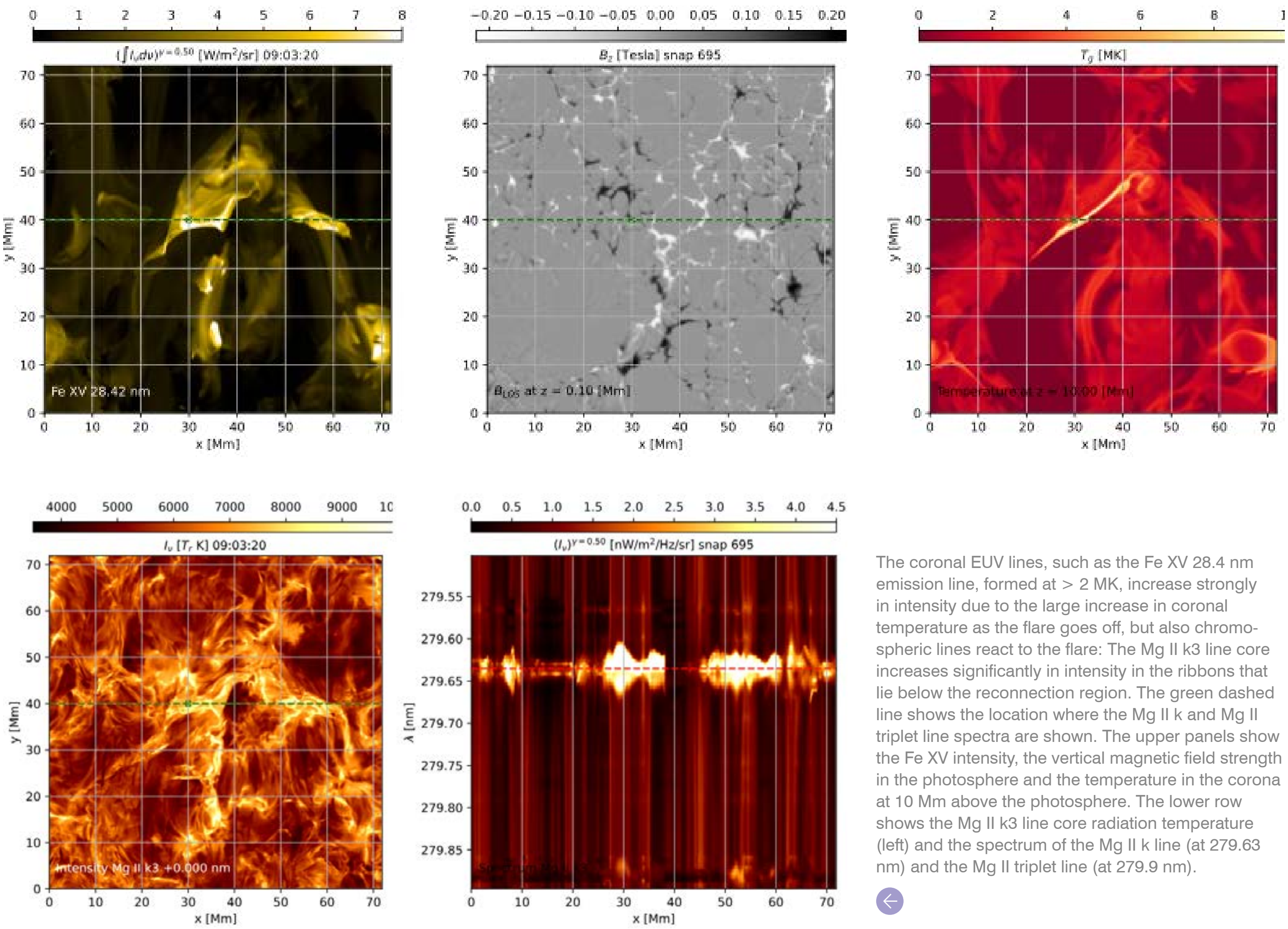
The simplest magnetic field configuration imaginable is possibly that of a unidirectional constant amplitude "sheet" of field introduced at the bottom boundary of our computational box, several thousand kilometers below the solar surface.



In this sub-surface region of the Sun, which stretches more than 200,000 km towards the core, energy is transported via convective motions, hot gas rises slowly while cool gas descends in plumes. The questions then become: How much complexity can the workings of these motions impart on the field that is rising with the hot gas? And what impact does the complex field that emerges from the photosphere and interacts with the pre-existing ambient field have on the outer atmosphere, namely the chromosphere, transition region, corona and solar wind? And on what time-scale do these processes occur?

A simulation covering more than 10 hours of solar time shows that the resulting coronal topology, even from such a simple starting point, is quite complex indeed. Typically, "Eiffel Tower", or inverted Y-shaped structures are formed, with footpoints in strong flux regions of opposite polarity, and the upper part of which often are the sites of magnetic field reconnection. These structures have extended lifetimes and are associated

«Eiffel Tower» structure of coronal structure before and during the C-class flare that occurs 9 hours after a flat, constant magnetic flux sheet is injected into the convection zone 8000 km below the photosphere. Temperatures reach > 15 million degrees, while vertical velocities are > 400 km/s just above the reconnecting apex of the flare.



The coronal EUV lines, such as the Fe XV 28.4 nm emission line, formed at > 2 MK, increase strongly in intensity due to the large increase in coronal temperature as the flare goes off, but also chromospheric lines react to the flare: The Mg II k3 line core increases significantly in intensity in the ribbons that lie below the reconnection region. The green dashed line shows the location where the Mg II k and Mg II triplet line spectra are shown. The upper panels show the Fe XV intensity, the vertical magnetic field strength in the photosphere and the temperature in the corona at 10 Mm above the photosphere. The lower row shows the Mg II k3 line core radiation temperature (left) and the spectrum of the Mg II k line (at 279.63 nm) and the Mg II triplet line (at 279.9 nm).

with continual and dynamic episodic heating. And in the example shown, perhaps triggered by newly emerging flux from below, a larger inverted Y explodes in a flare-like explosion that raises the near lying coronal temperatures to in excess of 15 million degrees. The basic outline of this simulated flare is remarkably like the (quite complex) cartoons drawn on the basis of observed flares, but has arisen naturally, without any prompting other than the introduction of a flat unidirectional constant amplitude sheet at depth in the convection zone.

Does the model give a reasonable representation of a real solar flare? A detailed comparison of synthetic observables generated from the model with observations taken from the Swedish 1-metre Solar Telescope, IRIS, SDO/AIA, currently underway, is required to answer that question, but initial glimpses seem quite promising.

In regions of the Sun where the Solar Wind is formed our "guess" is that the magnetic field is (slightly) unbalanced, resulting in vertical or nearly vertical field lines that eventually stretch into interplanetary space, allowing hot solar plasma to accelerate to supersonic velocities and escape the Sun's gravitational pull. The driving force behind this acceleration could be small-scale dynamics within the solar atmosphere; these are likely important in shaping the emerging wave-turbulence spectrum that ultimately heats and accelerates the coronal plasma. Models in which vortex motions are produced in the photosphere and chromosphere, the base of the solar wind, have been constructed to study the possible generation of Alfvénic waves and the resulting heating and acceleration of the coronal plasma. The twisting of the coronal magnetic field by photospheric flows efficiently injects energy into the low corona. Torsional Alfvén waves are favourably transmitted along these structures, and subsequently escape where they could play an important role in accelerating the wind to high velocities.

Viggo Hansteen

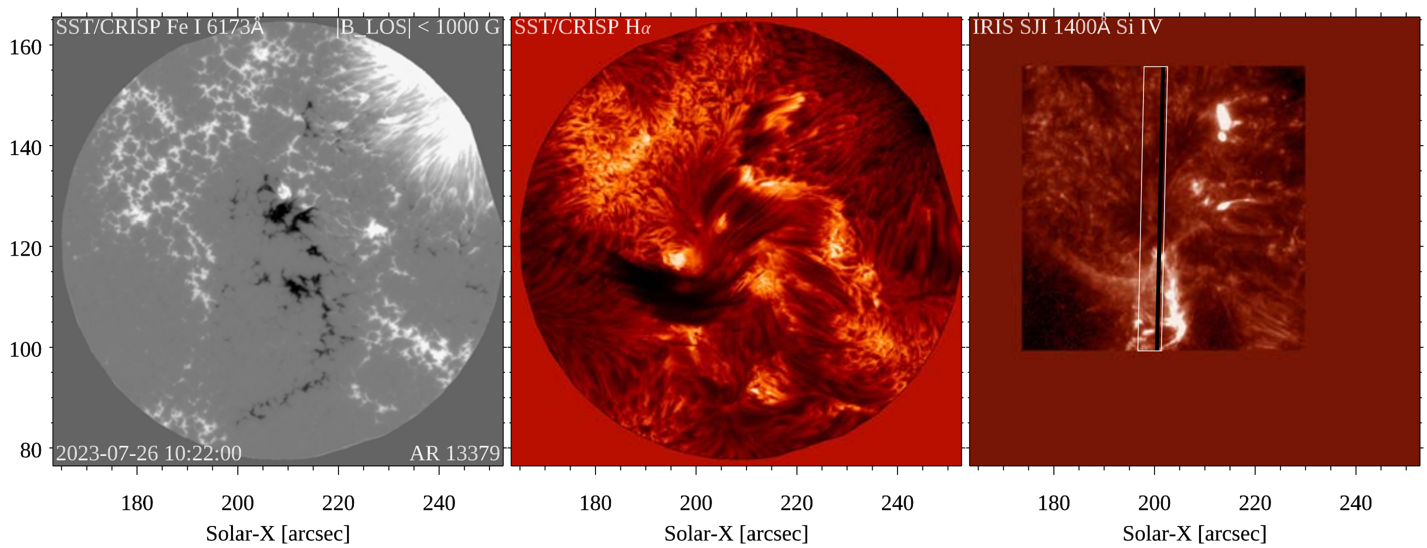
Observations with SST and IRIS

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 so that we have dense coverage of the solar atmosphere from the photosphere up through the chromosphere and transition region into the corona.

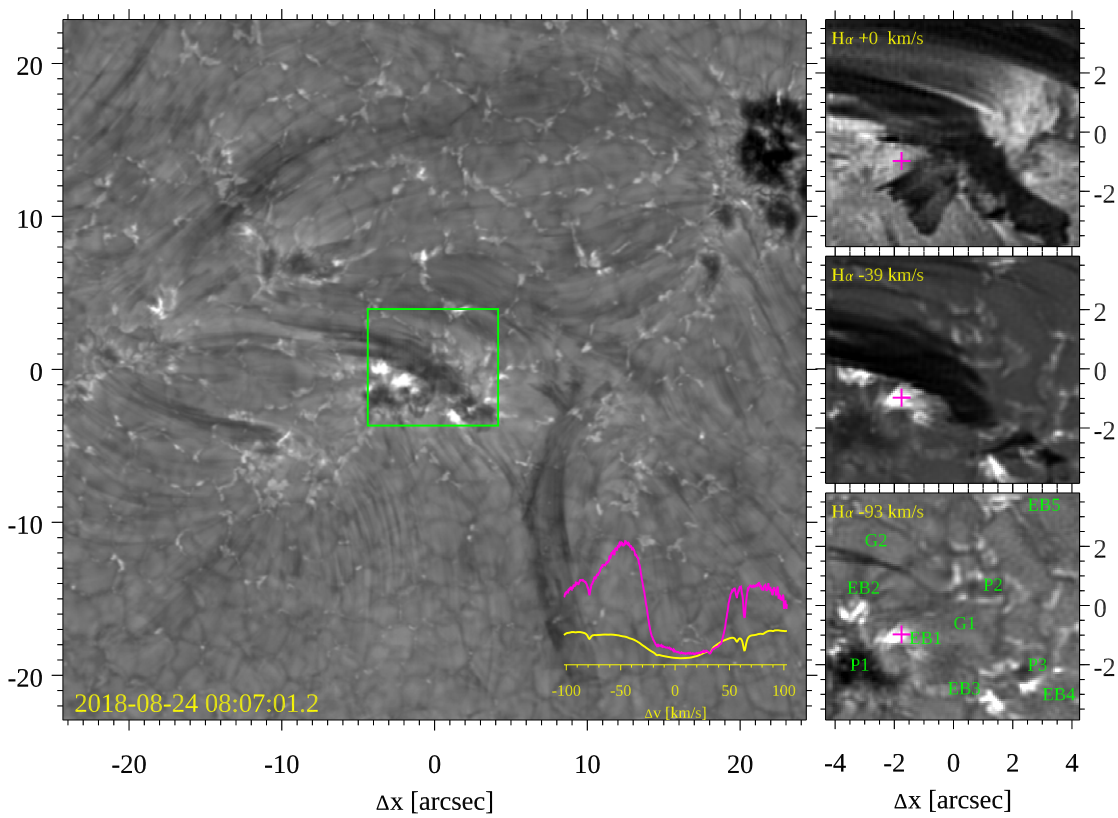
For many years we have had an agreement with the Institute for Solar Physics in Stockholm which gives us observing time at the SST. The observing time is usually divided over three campaigns spread over the observing season. In 2023 these campaigns were in July, August, and September/October. In total there were 12 RoCS members participating in the three campaigns, including two Master students. The photos on pages 50-51 give an impression.

Flare alert system

The Sun is now close to its maximum in the 11-year activity cycle and is producing more flares and energetic events than in previous observing seasons. It is not trivial to observe a flare with SST since the field of view is limited and it is practically impossible to predict where and when a flare will occur. A flare alert system was installed this season which is based on rapid changes in the full disk images of the SST H-alpha finderscope. This allows to precisely locate the onset of bigger flares (C class and stronger). Upon request of the July observers, this flare warning system also comes with a sound alarm, and they managed to catch a few C and M class flares. One exciting observation was acquired on July 26th, when a filament eruption occurred in the center of the SST field of view. The onset of the eruption was also covered well by the IRIS spectrograph raster. The figure below shows CRISP and IRIS images from the observation.



Filament eruption observed with SST and IRIS on July 26th, 2023. The black line in the IRIS Si IV image marks the location of the spectrograph slit in this exposure. The white rectangle marks the area of the spectrograph raster covering a large fraction of the base of the eruption.



MiHI H-alpha observation of the heart of a young emerging active region on August 24th, 2018. The large image is taken with the wideband H-alpha context imager. The green square in the center marks the 8"x8" area where MiHI acquires spatially resolved H-alpha spectra every 1.33 s. A full MiHI spectrum of an Ellerman bomb is shown in the lower right corner. The three small images in the right column show the region covered by MiHI in three selected wavelengths. From Rouppe van der Voort et al. 2023.

Large field of view with CRISP

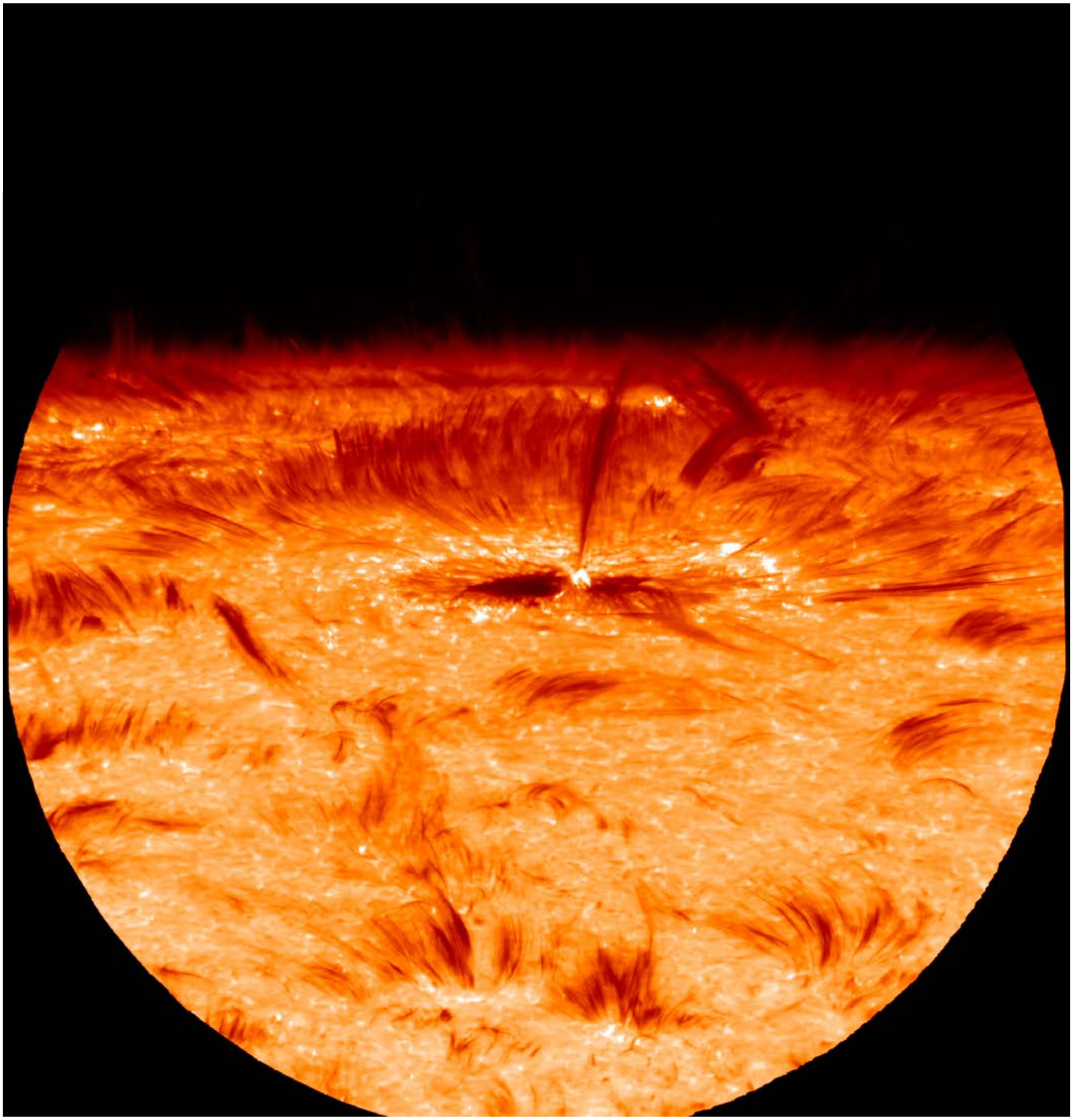
The CRISP images of the July 26th eruption observation show the large field of view after the installation of the new cameras at the end of last season. The CRISP instrument has now a circular field of view of 87 arcseconds diameter which means an area increase of a factor of about 1.5. This allows better coverage of large-scale structures and activity events. We can also now quickly cover full active regions with their surroundings in mosaic mode. This observing mode can cover an extended area by moving over a grid of different telescope pointings. A nice example of a mosaic of a large active region from the September campaign is shown on page 15. Here we also show the same area observed with the Solar Dynamics Observatory which can be used to study the magnetic connectivity through loops in the corona.

The MiHI integral field spectrograph

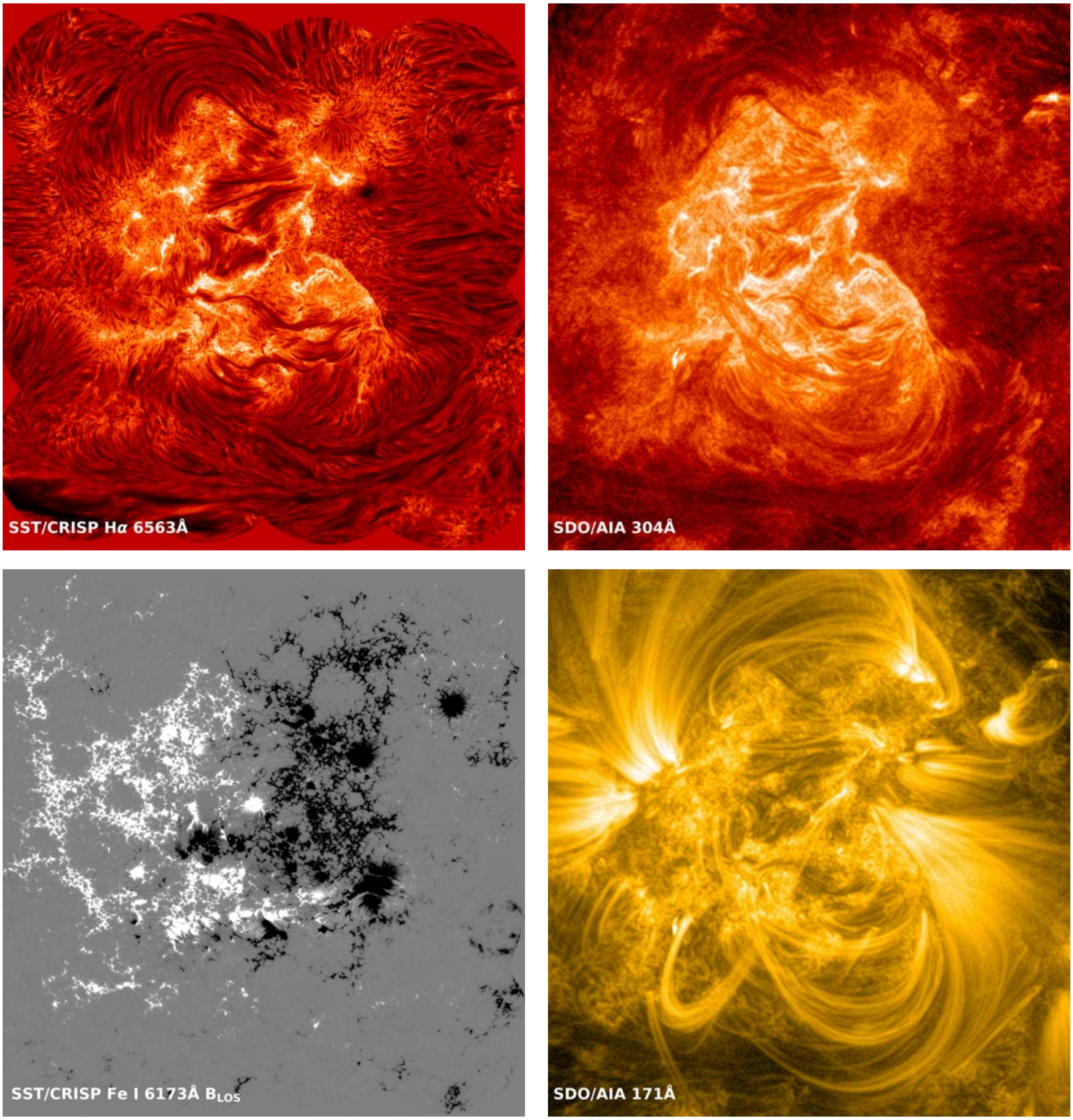
This year we published a study based on unique H-alpha observations with the prototype of a Microlensed Hyperspectral Imager (MiHI) developed by Michiel van Noort (MPS Göttingen). The MiHI instrument provides integral field spectroscopy and delivers simultaneous ultra-high resolution in the spatial, spectral, and temporal domains. For the 2018 H-alpha observations, that means 4.5 Å spectral coverage (456 spectral pixels) with diffraction limited spatial resolution over an 8.6" x 7.7" area at a temporal cadence of 1.33 seconds. The observation was centered on an area with the emergence of magnetic fields and there were a few sites with strong Ellerman bomb activity. The MiHI observations showed in fine detail the rapid evolution of plasmoid-like features that emerged from the magnetic reconnection site in the Ellerman bombs.

The figure above shows some aspects of the multi-dimensional dataset. The MiHI prototype has proven the potential of this concept of integral field spectroscopy. It is implemented in HeSP, the new instrument for the He I 10830 Å line that is being commissioned at SST. It is also proposed as an instrument for the European Solar Telescope (EST).

Luc Rouppe van der Voort



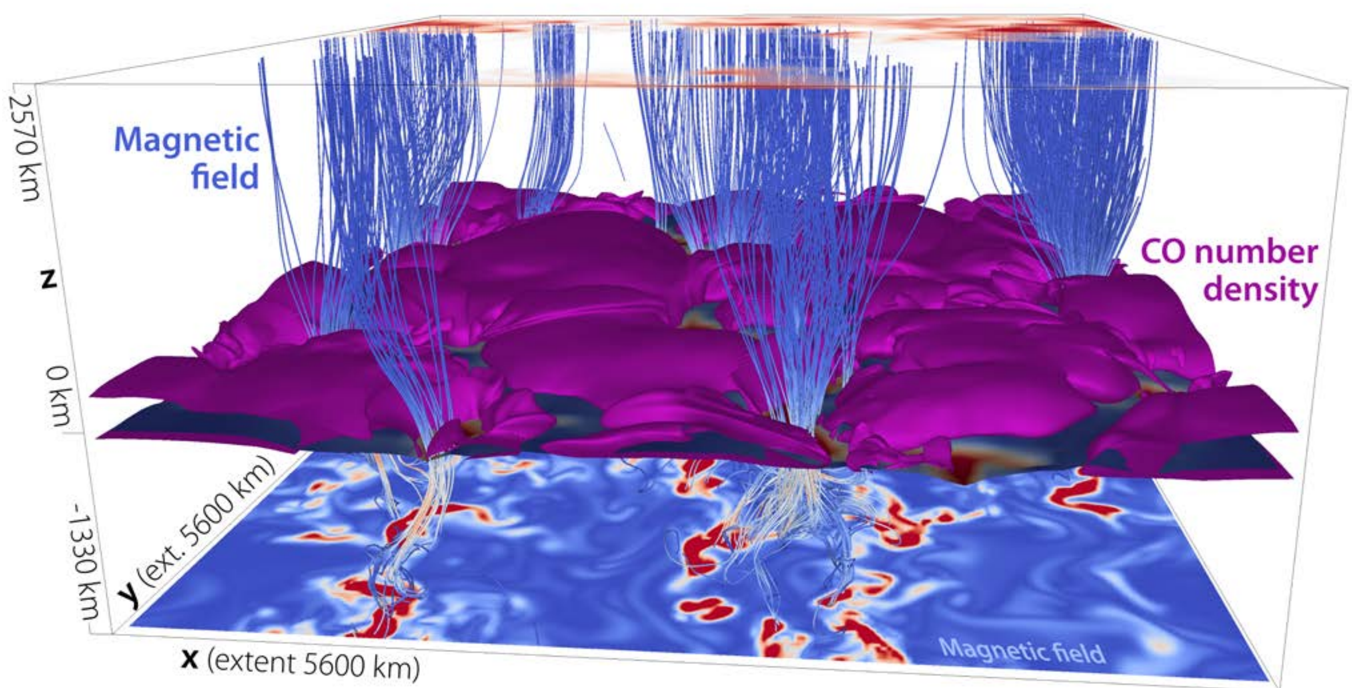
Sunspot near the limb in H-beta wing observed with SST on 28 Aug 2023.
The new CRISP cameras increase the field of view to 87 arcsec diameter.



4x4 mosaic of AR13445 taken with SST/CRISP on 25 Sep 2023. The top image shows the chromospheric H-alpha line core, and the bottom image shows the line-of-sight magnetic field as measured from the photospheric iron 6173 Å line. Images of AR13445 taken by SDO/AIA. 304 Å shows the chromosphere and transition region, while 171 Å shows the loops in the hot corona. The images have been processed with Wavelet-Optimized Whitening (WOW; Auchère et al., 2023).

Science at Long Wavelengths – ALMA and beyond

In 2023, several projects were concluded, and one Ph.D. and two M.Sc. theses were successfully defended. The activities ranged from the further development of ALMA post-processing and future observing capabilities with ALMA and AtLAST to studies of solar and stellar activity at millimeter and radio wavelengths.



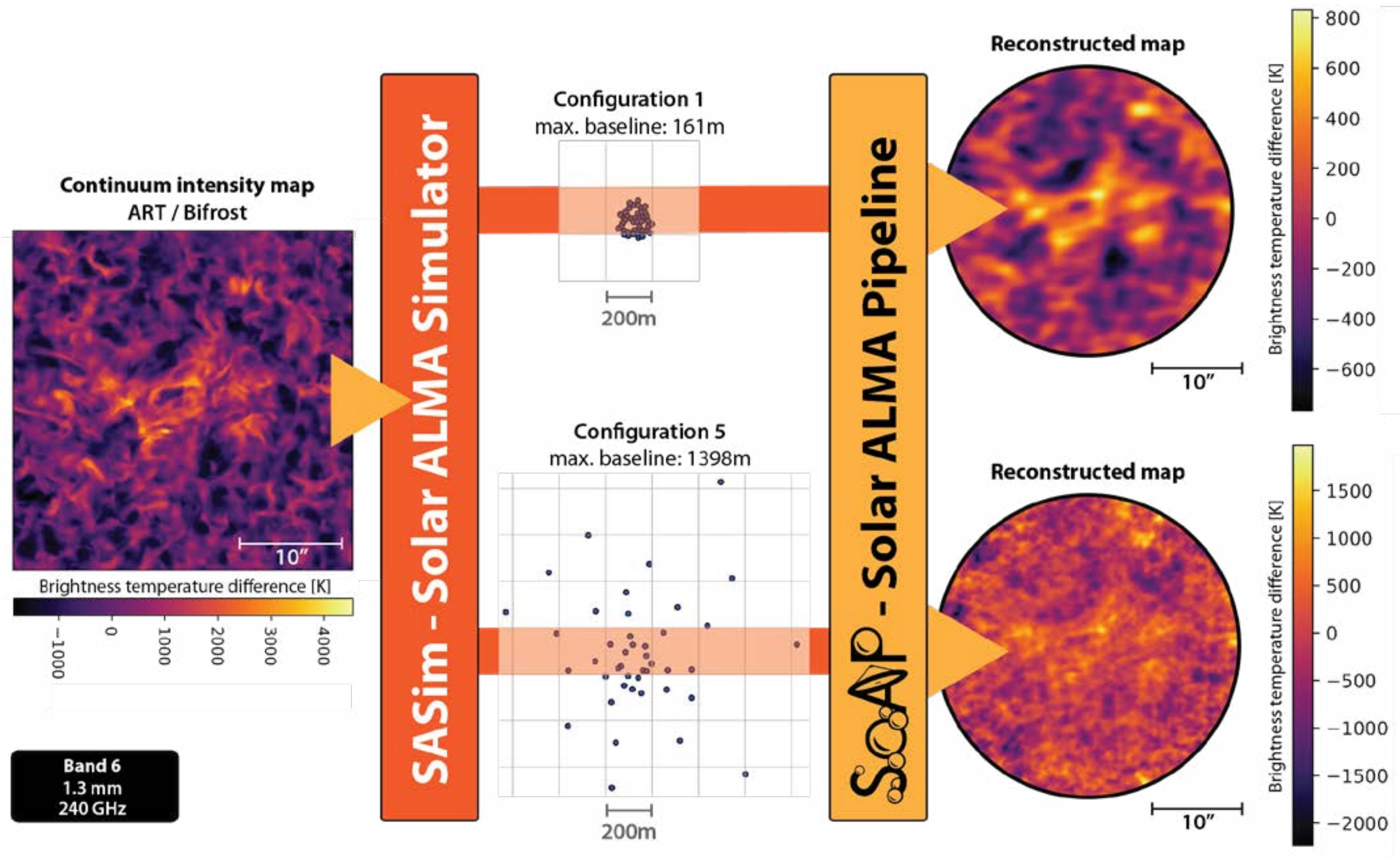
A numerical 3D magnetohydrodynamic simulation with a chemical reaction network including the top of the convection zone, the photosphere, and the chromosphere as computed with CO5BOLD. The illustration was produced with VAPOR and includes the surface of optical depth unity (plane in the middle), an isocontour enclosing higher concentrations of carbon monoxide, and the magnetic field (top and bottom layer and field lines). Credit: S. Wedemeyer

Carbon monoxide in the Sun

Supported by a grant from the Rosseland Visitor Program, Johnathan Stauffer visited RoCS from March to August 2023 and started to study the impact of magnetic fields on the abundance of carbon monoxide (CO) in the solar atmosphere. For this purpose, a set of 3D CO5BOLD simulations with a CO chemical reaction network with different magnetic field strengths was produced. Brightness temperatures, as measured with ALMA, helped to characterize the thermal environment for the formation of CO.

Waves and oscillations

As part of his M.Sc. thesis project at the National University of Colombia, Francisco Javier Ordonez Araujo visited RoCS to extend the study of waves and oscillations as seen with ALMA. His comprehensive analysis integrates data from



ALMA, SDO, and IRIS. By estimating the differences in formation height of the radiation observed by these telescopes and by accounting for the dynamic behavior of post-shock regions, his work produced valuable insights into the thermal dynamics of the solar chromosphere.

Optimising the imaging procedure

The ALMA development study "High-cadence Imaging of the Sun" was concluded with recommendations for optimizing the imaging process for solar ALMA observations for a range of observational conditions. In addition, a potential new observing mode at a cadence of only 0.1s was explored (Wedemeyer & Szydlarski et al). The study was based on image sequences computed with the Advanced Radiative Transfer (ART) code from Bifrost 3D simulations. A major product of the study is the Solar ALMA Simulator (SASim).

New observing capabilities for ALMA

The SASim tool forms the basis for the M.Sc. project of Eloi Martaille Richard which started in August 2023 by exploring wider array configurations with the antennae spread over wider distances. While wide configurations would enable higher spatial resolution, producing images from such sparsely sampled observations is challenging – an effect that can be evaluated with SASim. The tentative results point to a maximum distance of antennae that would increase the achievable resolution beyond what is currently implemented for ALMA.

AtLAST – A future solar observatory

Leading the international working group for solar science with the future Atacama Large Aperture Submillimeter Telescope (AtLAST), a 50-m single-dish telescope currently in its initial design phase, led

Simulating extended array configurations for ALMA. The antennae can be arranged in different ways, forming very compact configurations or extended configurations. Larger antenna distances (baselines) result in a higher angular resolution of the interferometric array but also pose challenges for reconstructing solar images from the resulting measurement sets. Experiments with the Solar ALMA Simulator (SASim) and the Solar ALMA Pipeline (SoAP) are used to explore how the resolution can be increased while maintaining sufficient imaging quality. Credits: Eloi Martaille Richard, Mikolaj Szydlarski & Sven Wedemeyer.

> The key solar science cases (for AtLAST) include flare detections and long-term monitoring of solar activity.

to the preparation of a White Paper (to be published in 2024) that summarises the scientific potential and instrumental requirements. The key solar science cases, as presented at the AtLAST consortium meeting at ESO HQ, include flare detections and long-term monitoring of solar activity. A crucial technological requirement would be the use of novel multi-pixel multi-frequency detectors. The optimal setup of such a solar instrument for AtLAST is the topic of the first part of the Ph.D. thesis project of Mats Kirkaune, which he started in 2023. As the simulation package maria is used for this purpose, Mats Kirkaune and Eloi Martaille Richard visited the developers at ESO HQ in 12/2023.

Solar activity indicators

As part of the Ph.D. thesis of Sneha Pandit, which she defended in 12/2023, millimeter continuum data was compared to other chromospheric diagnostics and solar activity indicators including the width of the Hα spectral line (Pandit et al. 2023) and indicators based on the Ca II spectral lines. The studies were mostly based on a 3D Bifrost model of the Sun (Pandit et al., under review).

EMISSA – The solar-stellar connection

In connection with the EMISSA project, which concluded at the end of 2023, two M.Sc. theses were successfully defended. Jonas Ringdalen Thrane calculated continuum intensity maps at millimeter wavelengths for a grid of 3D CO5BOLD simulations of cool main sequence stars including the Sun. The models started with different magnetic field strengths, thus representing a sequence increasing in activity level. Different radiative transfer codes were used for this purpose (ART, Linfor3D, MULTI, RH), which enabled cross-checking and thus improved the reliability of the results. The resulting grid of synthetic observables will be useful for future comparisons with observations.

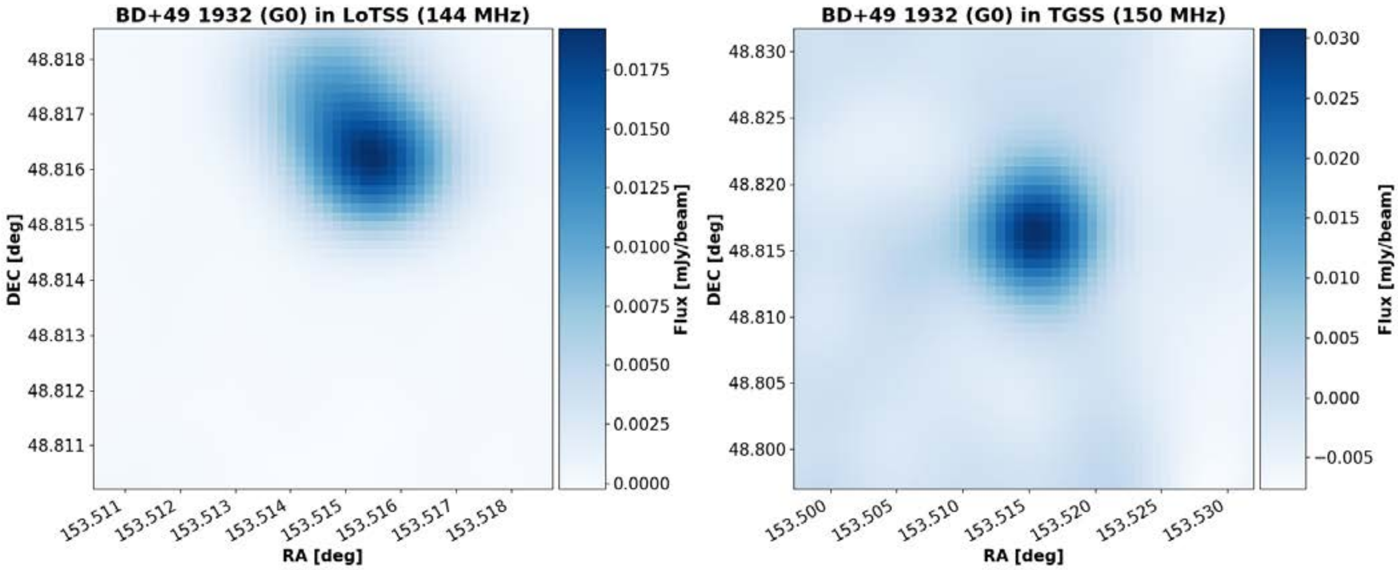
Mats Kirkaune assembled a catalog of stellar observations at radio wavelengths by intensively searching for serendipitous (background) detections of stars in five major radio surveys for different frequencies. This sub-project, titled Stellar Emission in Blind Radio All-sky surveys (SEBRA) resulted in a catalog of more than 600 main sequence stars that will be published in 2024 (Kirkaune et al., in prep).

Type-IV radio bursts associated with coronal mass ejections (CMEs) are clearly detected for our Sun but have been elusive in young active M-dwarfs despite targeted long-term radio observation campaigns. Our team led by Atul Mohan discovered the first metrewave type-IV radio burst in a young M dwarf, AD Leo (~250 Myr; M4V (Mohan et al., 2024 accepted for publication in A&A).

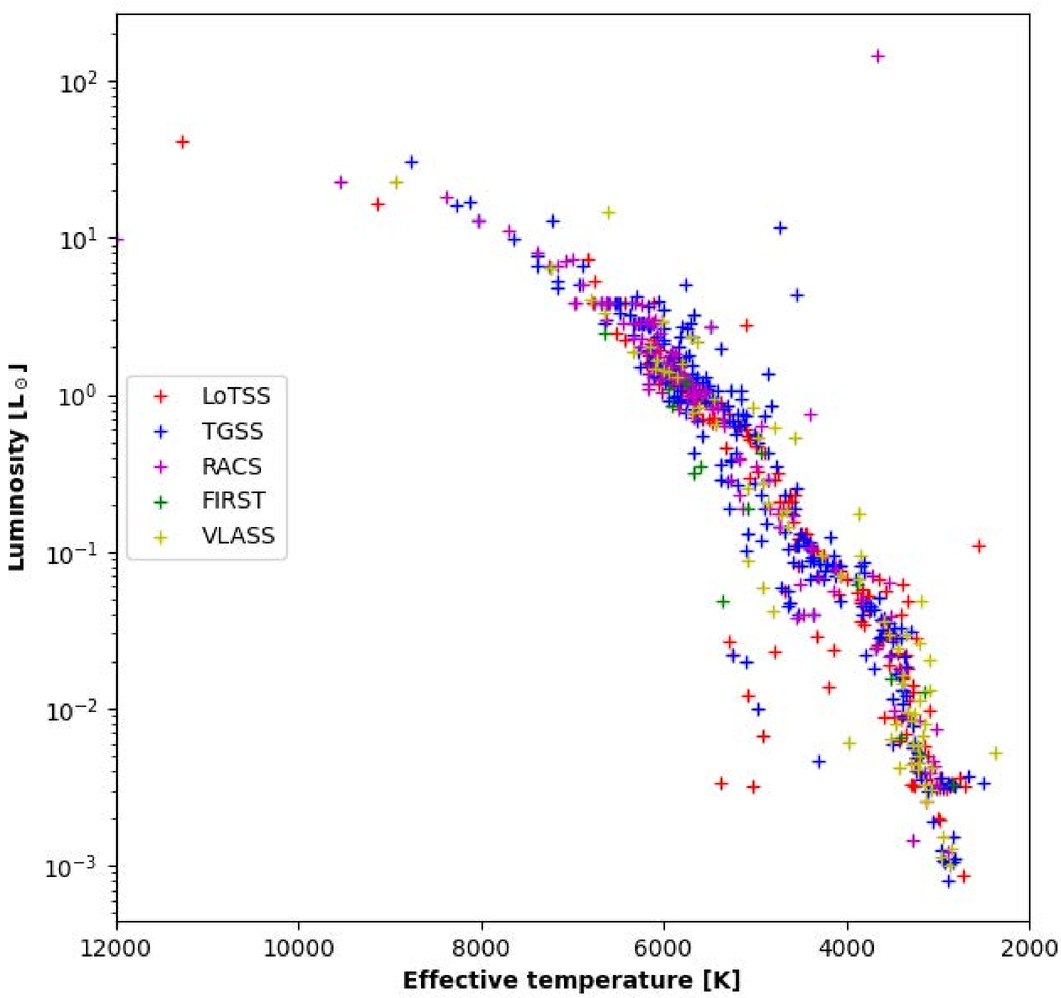
Evolved stars

Maryam Saberi was granted a Young Research Talent project titled “Tracing the impact of Evolved Stars on the Galactic Chemical enrichment (ESGC)”, which started in 2/2023. The project aims to understand the cosmic origin of the element fluorine (F) using high spectral resolution ALMA observations towards various types of evolved stars in addition to understanding the impact of stellar chromospheric activity on the recycled materials from evolved stars. The initial analysis of ALMA observations focused on aluminum fluoride (AlF) lines observed towards the Asymptotic Giant Branch (AGB) star χ Cyg (Saberi et al. in prep.). It was followed by a proposal for spectral observations of a selected group of AGB stars using the FIES spectrograph at the Nordic Optical Telescope (NOT). The NOT observations aim to identify the third dredge-up (3DUP) indicator technetium (Tc) in a sample of AGB stars to support the interpretation of the ALMA observations and for the sample selection of upcoming ALMA observations.

Sven Wedemeyer



Radio observations of the Sun-like star BD+49 1932. The star of spectral type G0 at a distance of 90pc was observed with the Low Frequency Array (LOFAR) at 144 MHz (left) and with the Giant Metrewave Radio Telescope (GMRT) at 150 MHz (right). Credits: Mats Kirkaune & Atul Mohan.



The Hertzsprung-Russell diagram for the SEBRA sample of main sequence stars. A search across five radio surveys resulted in over 600 detections of stellar emission. Credits: Mats Kirkaune & Atul Mohan.

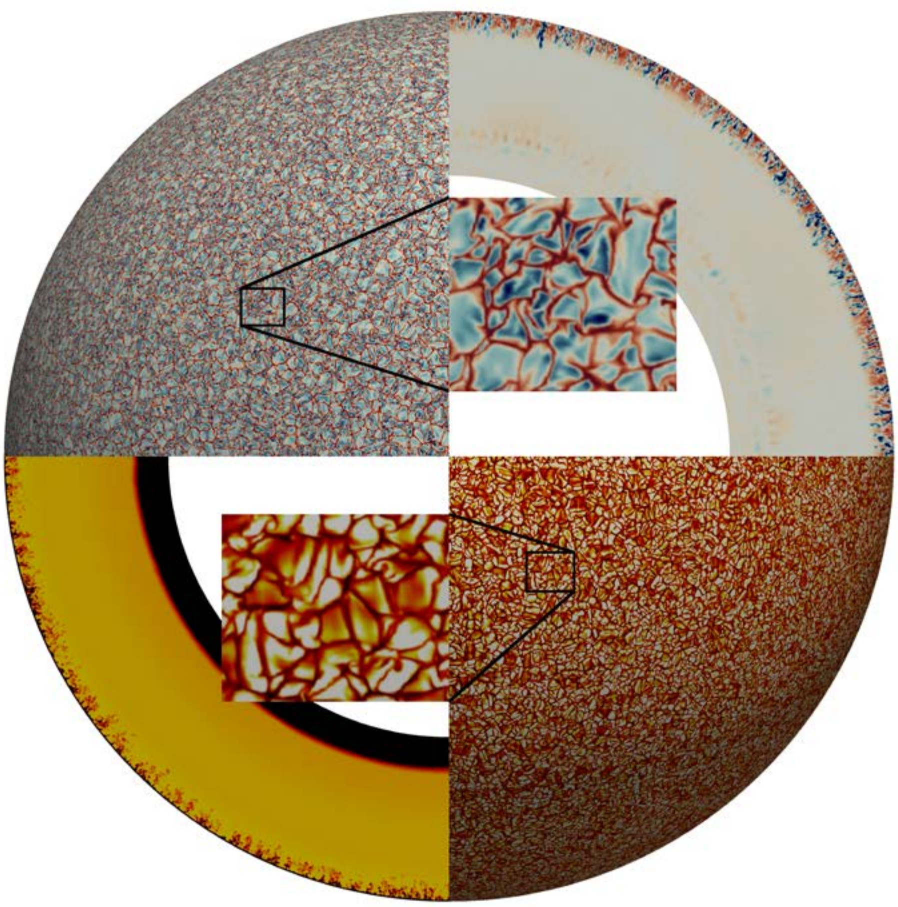
> To the eyes of the beholder,
> Sun is the magnificent light!
> To every earth dweller,
> Sun is the power of might.

Geeta Radhakrishna Menon

Credits: NCRA-TIFR

Code Development

This year has primarily centered around enhancing the multi-physics and multi-scale functionalities of our code base. In 2022, we succeeded in demonstrating the capacity to conduct a simulation of the entire Sun. We have continued our efforts on this type of simulation, which was recognized with an allocation of 167 million CPU-hours through the Euro-HPC Extreme Scale program. The substantial length and time scales required for such simulation necessitate an extended simulation period to stabilize the system and ensure that the results aren't skewed by initial conditions.



Simulating the entire Sun is very different from modeling the tiny scales needed to mimic the core of a solar flare. The development of the Particle-In-Cell code is nearing completion with some optimization already achieved. In simple terms, the code is designed to compute the behavior of individual charged particles or clusters of particles and their associated magnetic and electric fields. These fields emerge from the movement and electrical charge of the particles, and the dynamic interaction between the fields and these particles is incredibly complex. The rate of energy release is a crucial signature of a solar flare, which has an energy release rate much higher than one would think based on a macroscopic description of the energy release mechanism. Results from a double current sheet experiment and the development of electric current channels are shown in Figure 2.

Fig 1 Different cuts through the latest data snapshot from the simulation of the whole sun.

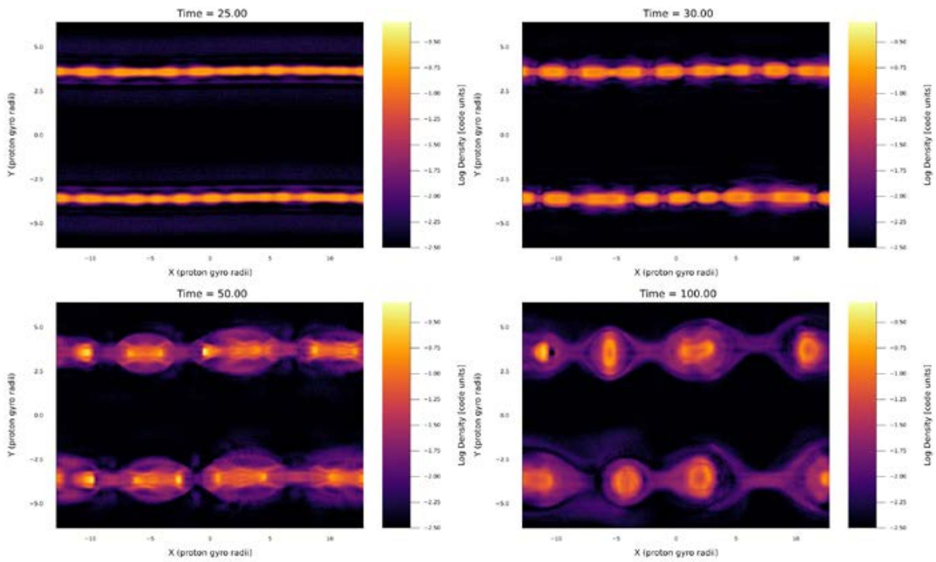
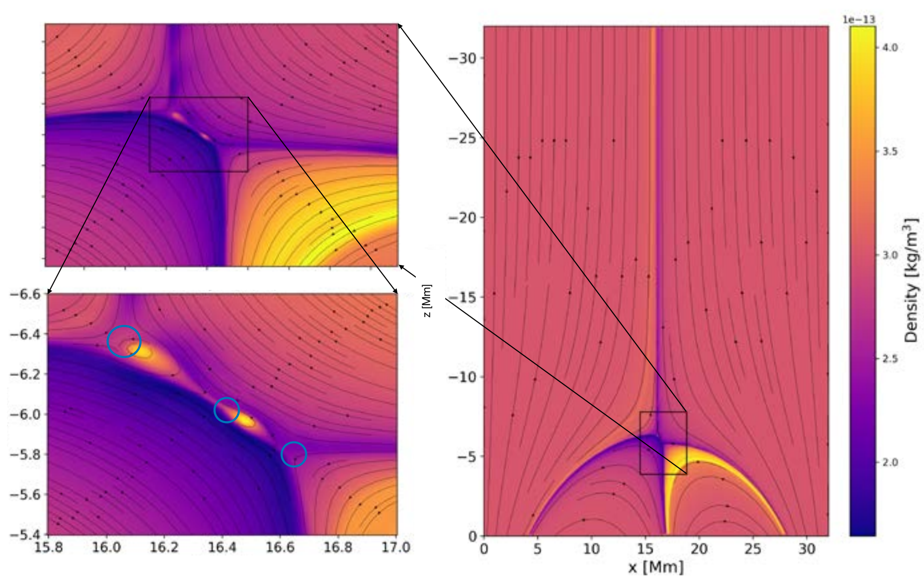


Fig 2 Electric current developing in a simulation of two electric current concentrations, and becoming unstable as time progresses. This instability can increase the energy release rate – maybe to levels like a solar flare.

Solar flares are recognized for generating highly accelerated particles. A Particle-In-Cell (PIC) simulation cannot model these particles, as they are a minor subset of the overall particle count, necessitating an alternative approach. This year, the initial promising results have sprung from the ongoing development of our Trace-Particle(TP) code, which is capable of modeling these highly accelerated particles. The acceleration process and ultimate speed of these particles can now be simulated by the TP code. The location of significant acceleration was identified in a simulation of a simplified solar atmosphere, and work has begun on repeating the identification for more complex scenarios.



Post processing tools have been a focus again in 2023. Especially the very complicated geometry and very large data volumes from the whole sun simulation have been a center of intense work. The large data volumes have made the Python version of our post-processing tools cumbersome, and work has started to port some of the post processing tools into Julia, which is inherently multithreaded and much faster. The workhorse code Bifrost has also seen some attention, with detailed testing of implementation methods taking place.

Boris Gudiksen

Fig 3 Three different zoom levels of the particle acceleration sites in a simplified simulation of the solar atmosphere showing mass density in color, and magnetic field direction in black lines. Identified acceleration sites are circled.

Ongoing projects at RoCS in 2023

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.

ALMA Development Study "High cadence imaging of the Sun" (2019-2023), supported by ESO and RoCS, in cooperation with the Nordic ALMA Regional Center node at Onsala Space Observatory and Stockholm University, Sweden. Aim: Optimisation of solar observations with ALMA.

EMISSA ("Exploring Millimeter Indicators of Solar-Stellar Activity", 2019-2023), funded by the Research Council of Norway. Aim: Re-evaluation of stellar activity as observed with ALMA.

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.

Preparatory Phase of the European Solar Telescope (2017-2023), funded by the European Union Horizon's 2020 programme. The principal objective of the present Preparatory Phase is to provide both the EST international consortium and the funding agencies with a detailed plan regarding the implementation of EST.

SOLARNET (2019-2023), funded by the European Union's Horizon 2020 programme. The main objectives are to foster networking activities and mobility programmes, conduct joint research activities and ensure access to research infrastructures and databases in the field of high-resolution solar physics. There are 35 partners in 16 countries.

SOLDYN (2016-2023), funded by the Research Council of Norway. Aim is to advance our understanding of the complex dynamics of the solar atmosphere through the combination of high-quality observations from both ground-based and space-born instruments.

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.

"
The Sun is new each day.

Heraclitus

Credit: Aditi Bhatnagar

Outreach

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

From Monday, March 20th, to Friday, March 24th, ITA and RoCS collaborated to organize the training week and finals of **the Norwegian Olympiad on Astronomy and Astrophysics**, during which top candidates were selected to represent Norway at the International Olympiad on Astronomy and Astrophysics.

Throughout the week, 18 students from upper secondary schools engaged in lectures and training sessions held at the Institute for Theoretical Astrophysics. **RoCS played a significant role in the Astronomy Olympiad Team**, with members Sneha Pandit, Reetika Joshi, Tiago Pereira, Luc Rouppe van der Voort, Mats Ola Sand, and Eilif Sommer Øyre. They made significant contributions to the organization of the qualifying rounds.

Ignasi Poquet delivered insightful lectures on observations. Sven Wedemeyer, alongside Mats Ola Sand and Eilif Sommer Øyre, conducted an engaging workshop for students participating in the "Astronomy Olympiad". A diverse group of students delved into the fascinating realm of exoplanets. After an introduction to exoplanets, the students actively engaged in an experiment demonstrating the transit method, an observational technique used in exoplanets discovery. Following this, they embarked on a virtual journey through the galaxy using NASA's interactive web-app, "Exoplanet Exploration", allowing them to explore properties of both exotic and neighboring planetary systems. The workshop concluded with an interactive Kahoot session covering the learning objectives, adding an element of fun and competition.

Credit: Martina D'Angelo

Mats Ola Sand captivating the audience during a workshop at the Astronomy Olympiad week.

Credit: Private

General Assembly of Universum Panton. Ignasi gave an introductory course to observational astronomy.

Astronomy Club

Ignasi Poquet became a member of the board of Universum Panton, the student astronomy club at the UiO. The main objective of this student association is to disseminate and popularize astronomy for all audiences, based on its main activity which consists of night-time observations with telescopes. **Ignasi is the head of the scientific committee**, responsible for all the activities related to science and the observation nights.

Poster made by Maria Hammerstrøm.

Opening of the National Science Week

The National Science Week, known as Forskningsdagene, is an annual nationwide event aimed at making science and research accessible to the public. Institutions across Norway participate, offering various events to provide insight into their work. Forskningsdagene offers diverse activities such as science expos, demonstrations, lectures, performances, exhibits, discussions, tours, and hands-on activities, held in unconventional venues. These events are free and open to people of all ages, providing a unique opportunity to engage with science in accessible and interactive ways.

RoCS had the honor of opening the week on 20th of September at the University of Oslo with a talk about the Sun from two different perspectives: Art and astrophysics. The event took place in the Aula in front of Edvard Munch's painting of the Sun.

Art Mediator Sivert Thue from MUNCH and Professor Mats Carlsson from RoCS entertained the audience by addressing questions such as: 'Why did Munch choose the Sun as his main motif, and what do we know about the Sun today?' Charlotte Wiik, Art Curator at UiO, initiated the discussion.

From left: Mats Carlsson and Sivert Thue at the general rehearsal for the talk "Art and Astrophysics Meet: The Sun and Its Energy". The event was part of The National Science Week. Credit: Eyrun Thune

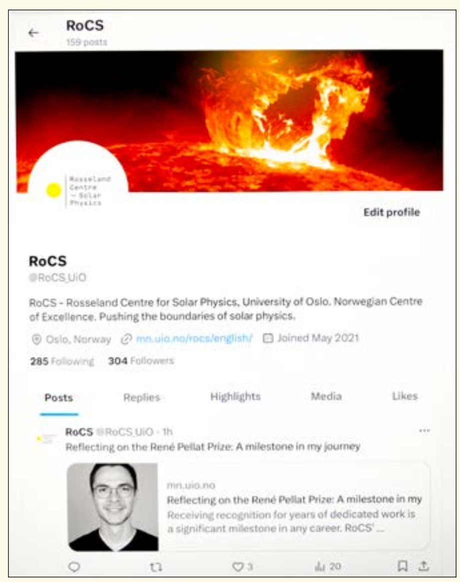
School visits

Sondre Vik Furuseth visited Sandvika High School on Thursday, December 7th, 2023. He talked to a Physics 2 class and their parents about higher education and **the application of physics, including NTNU, CERN and RoCS.**

Michaela Brchnelova, a visiting Ph.D. student at RoCS in autumn 2023, conducted a series of lectures across various locations in Norway, including Andøya, Tromsø, Trondheim, Tønsberg, and Oslo. Her presentations, delivered to both high school students and staff at The Norwegian Mapping Authority, focused on the subject of space weather.

Social media

RoCS maintains an active Twitter account (@RoCS_UiO) with 304 followers and regularly shares content related to solar physics. Additionally, RoCS delivers content to social media platforms affiliated with the Institute of Theoretical Astrophysics, UiO.



Screenshot of RoCS' Twitter account.

Personal Outreach

Adjunct Professor Lyndsay Fletcher **delivered a Christmas Lecture** on December 9th in London to the British Astronomical Association **titled "Exploring the Solar Atmosphere: A Journey through the Sun's Spectrum".** The lecture was attended by an audience of about 90 people.

Adjunct Professor **Guillaume Aulanier gave a TEDx talk in Caen, France,** in October. The talk can be seen on TedX Talks and has the title "Faites de Laplace aux creux de vos mains". Aulanier asks the questions "What if the Sun wasn't just a calm and luminous star? But also the scene of violent phenomena, causing disturbances at the Earth's level?

Guillaume Aulanier gave a 13 minute Tedx Talk in October to an audience in Caen, France.


Laila Kongevold and Mats Ola Sand visited La Palma and the Swedish Solar 1-m Telescope (SST) for a science and artist residency. Photo: Laila Kongevold.

REAL Art

The artist Laila Kongevold has achieved a significant milestone by becoming the first participant in the REAL Art Program, an artist-in-residence initiative hosted by the Faculty of Mathematics and Natural Sciences. This program promotes collaboration between artists and researchers, providing a platform for interdisciplinary exploration.

With her captivating project titled 'The Sun in the Sun', Kongevold is collaborating with doctoral research fellow Mats Ola Sand at RoCS. In addition to her artistic pursuits, Kongevold delivered a compelling lecture in the autumn to the faculty staff, delving into her past and present artistic endeavors. She clearly explained how she uses ideas from different fields, highlighting how she integrates insights from the natural sciences into her artistic process.

Scheduled for completion in 2024, Kongevold's artwork promises to be a testament to her innovative vision and collaborative spirit. Furthermore, Mats Ola Sand and Laila Kongevold are poised to host an exclusive Real Art workshop in March 2024, further showcasing their dedication to fostering creativity and interdisciplinary dialogue.

Media highlights

Forskning.no
"Det er få steder i verden som dette", by journalist Lasse Bjørnstad who visited the Swedish Solar Telescope (SST) at La Palma. He wrote about the work being done by RoCS's scientists at SST and interviewed Luc Rouppe van der Voort. The article was published 10th of December.


Turister reiser til La Palma for å bade og sole seg på øya som har en årlig snitt-temperatur på 20 grader.

"Gigantisk «hull» på sola kan gi mer nordlys i dagene som kommer", interview with Luc Rouppe van der Voort, 8th of November.

"Europa samarbeider om solteleskop til to milliarder kroner", an interview with Mats Carlsson, 24th of March.

Sigma2 Website
"Successful pilot phase for Norwegian LUMI projects", an interview with Mikolaj Szydlarski 13th of January.

Astronomi
"Hva stjernene er lagd av", by Tiago Pereira 1st of February.

"Den mest energirike strålingen fra Sola", an interview with Luc Rouppe van der Voort, 29th of November.

Teknisk Ukeblad
"Nordlys: Dette er vitenskapen bak lyset" by Aditi Bhatnagar, 5th of February.

Science Norway
"A strong solar storm will probably increase northern lights in the near future", an interview with Mats Carlsson, 21st of February.

NRK Finnmark and Nordland: Radio and web
Mats Carlsson was interviewed about increased solar activity "Dette kan du se mer av i årene som kommer – reiselivet jubler" and "Mer Nordlys aktivitet fremover" 16th of February 2023.

NRK EKKO
"Hva har skjedd med Nordlyset?", Terje Fredvik was interviewed on EKKO 16th of November.

NRK Østfold Radio
"En billedkunstner og en astrofysiker samarbeider om sola", Laila Kongevold and Mats Ola Sand are interviewed on the morning show 23rd of November.

L'Astronomie
"Rotation et magnétisme : Passé, Présent & Futur des étoiles de type solaire" by Quentin Noraz, Sacha Brun & Antoine Strugarek, June 2023.

Fladseth podcast
"Gammel venn og fysiker er innom for å snakke om kosmos", an interview with Mats Ola Sand, 17th of November.

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 is our programme for international exchange, including funds for visits by researchers at professor, post-doctoral and PhD level for shorter or longer visits to RoCS.

The visitor programme has finally started to normalize after Covid, as we have had several visitors in 2023.

Diego Prado Barroso from the Brazilian National Institute for Space Research visited from December 2022 to March 2023 to work with Shahin Jafarzadeh and Luc Rouppe van der Voort on waves in the atmosphere of a sunspot.

Jayant Joshi from the Indian Institute of Astrophysics visited for one month in February-March. During his visit, he collaborated with Luc Rouppe van der Voort on observations of Ellerman bombs in the quiet Sun

Shahin Jafarzadeh, researcher from the Max Planck Institute for Solar System Research, visited in February to collaborate with Luc Rouppe van der Voort and Diego Prado Barroso.

Souvik Bose from Lockheed Martin Solar and Astrophysics Lab visited in March to work with Luc Rouppe van der Voort on SST and IRIS observations of jets.

From July to October, **Francisco Javier Ordonez Araujo** worked with Juan Camilo Guevara Gomez and Sven Wedemeyer on waves and oscillations as seen in ALMA observations of the Sun, using the Solar ALMA Archive for this purpose. This work is part of his M.Sc. thesis project at the National University of Colombia.

Paola Testa, researcher at the Smithsonian Astrophysical Observatory, visited in February and July/August to work with Luc Rouppe van der Voort and Helle Bakke on SST, IRIS, and SDO observations of a micro-flare. She also worked with Mats Carlsson and other members of RoCS on several projects.

Michaela Brchnelova, PhD-student from KU Leuven visited for three months in August-November. She worked with Mats Carlsson and Boris Gudiksen on improving boundary conditions for space weather simulations using Bifrost simulations.

Johnathan Stauffer, Ph.D. student at the University of Colorado, Boulder, USA, visited RoCS from March to August. He worked with Sven Wedemeyer on observations and simulations of carbon monoxide (CO) in the solar atmosphere, which also involved ALMA observations to evaluate the formation conditions for CO.

Hugh Hudson from the University of Glasgow visited for two weeks in November-December. He discussed flare physics and the interpretation of flare observations with several members of RoCS.

Glimpses from the life at RoCS

Credit: Luc Rouppe van der Voort


Credit: Tiago Pereira

RoCMI: the workshop a stone's throw from the North Pole

In February 2023, RoCS organised a large scientific workshop in Longyearbyen, the world's northernmost town, in the Svalbard archipelago, Norway. Besides the many scientific talks and lively discussions, participants also visited the SvalSat ground station, saw northern lights, and explored the polar landscape.

Credit: Tiago Pereira

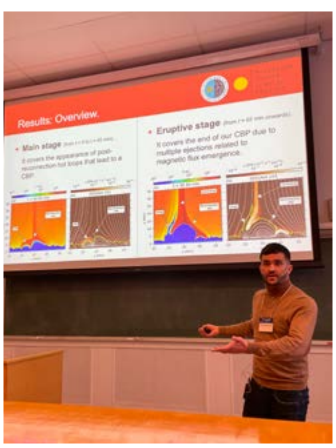
RoCMI is not only the coolest name for a conference, it was possibly the coolest solar physics conference ever. As frigid Longyearbyen was waking up from the long polar night, it hosted about 100 solar physicists that came from 15 countries spread over four continents.

At RoCMI, the future of solar observations and modelling was discussed. It was the first conference dedicated to the confrontation between simulations and future observatories such as MUSE and SOLAR-C. Despite its relatively narrow focus, it was extremely popular with participants, and a resounding success.

Logistically, it was a challenge to ensure everyone had a bed. We maxed out our accommodation and the auditorium at UNIS was nearly full to capacity. RoCS organised the conference with the help of the Norwegian Space Agency and UNIS. We also supplied the largest contingent of any institute, and many PhD students, postdocs, research software engineers, and PIs contributed enthusiastically with many talks and posters.

Despite the dark days and not seeing the Sun over the horizon, RoCMI led to fruitful discussions and social interactions. We had a guided tour of the SvalSat ground station, which is essential to download data from solar telescopes we use. Even in the dark, the Sun did not disappoint, and gave us a memorable northern light show. Many participants braved the Svalbard outdoors, whether dog sledding, looking for polar bears, or exploring mines.

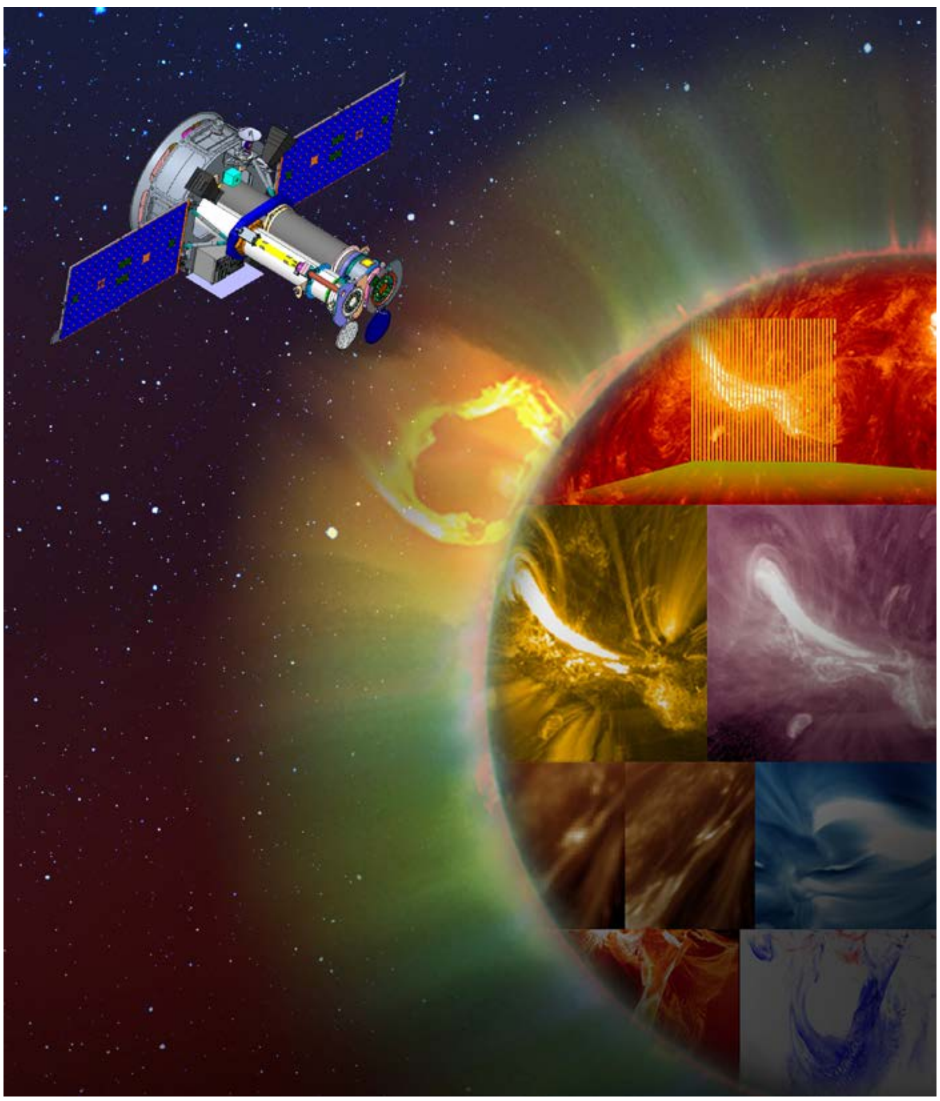
Tiago Pereira


Results: Overview.
Main stage
It covers the appearance of post-reconnection hot loops that lead to a CBP.
Eruptive stage
It covers the end of our CBP due to multiple ejections related to magnetic flux emergence.


Welcome to
The University Centre in Svalbard
UNIS

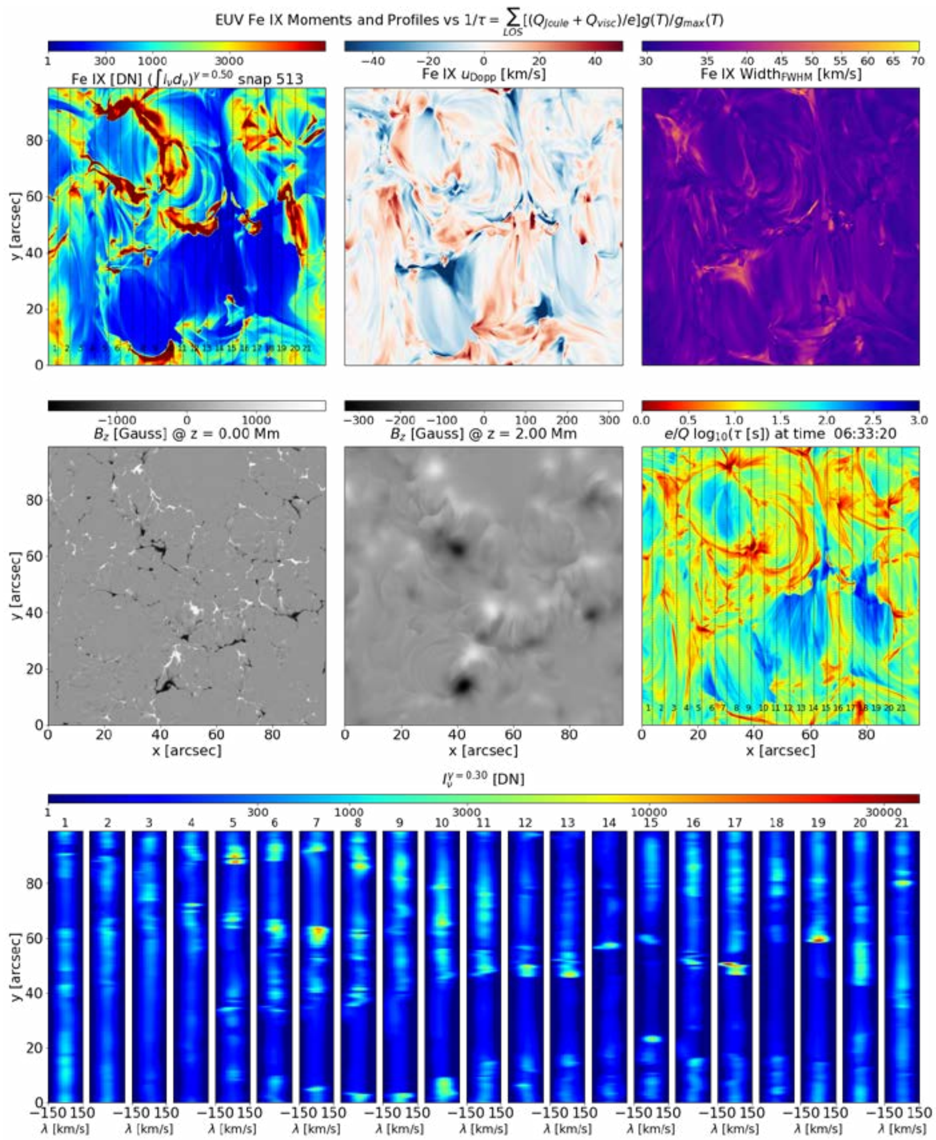
MUSE Mission: Advancing solar exploration for deeper understanding

NASA and RoCS are collaborating on a groundbreaking solar project, the Multi-slit Solar Explorer (MUSE). MUSE aims to illuminate the mysteries of the solar corona, which in addition to being extremely interesting scientifically, will offer vital insights for astronaut safety, satellite operations, and communication infrastructure like GPS.



Credit: Lockheed Martin Solar and Astrophysics Laboratory

With its array of slits, MUSE will probe energetic eruptions like flares and jets at unprecedented high spatial and temporal resolution.



MUSE synthetic observables from a Bifrost 3D MHD simulation depict heating signatures via magnetic field line braiding in the corona. Panels display Fe XV 284 Å line intensity, shift, and width, alongside photospheric magnetic field, heating rate, and MUSE slit locations. Fe XV 284 Å spectral profiles along 21 MUSE slits are shown in the bottom row. Braiding events driven by photospheric motions lead to strong heating, particularly in a defined region and along a diagonal current sheet. Fe XV line width responds notably to these heating events. Nano-jets resulting from reconnection are also evident.

RoCS team on board

MUSE was chosen by NASA in 2022 and is currently facing a preliminary design review planned for March 2024. If all goes well it is scheduled for launch in June 2027. MUSE has a $192 million budget and is headed by project manager Bart De Pontieu, an adjunct professor at RoCS working at the Lockheed Martin Advanced Technology Center. MUSE assembles a team of RoCS' researchers, including Professors Mats Carlsson, Viggo Hansteen, and adjunct professor Juan Martinez Sykora, who serve as Co-Investigators.

Unprecedented solar observations

MUSE's core strength will be in measuring solar spectral data from corona processes at an unprecedented pace, surpassing all previous coronal spectrometers, including NASA's IRIS. Its instruments will capture solar explosions swiftly over a large field of view, providing invaluable data for a nuanced understanding of solar phenomena.

NASA underscores MUSE's potential to unlock cosmic secrets, offering crucial insights for astronaut safety and space weather challenges. The mission serves as a foundation for future space exploration.

MUSE will provide a unique opportunity to study rapid changes in the solar corona on a large spatial scale. It is the key to unraveling the puzzle of the solar atmosphere's outer layers and their unexpected heating to several million degrees.

Armed with a potent multi-slit spectrometer, MUSE captures the highest-resolution images of the solar transition region and corona, complemented by data from other heliophysical research instruments.

The project is right on track and with that a launch in 2027 is within reach.

Viggo Haraldsen Hansteen

Captivating Northern Lights in Oslo

In 2023, Oslo witnessed an exceptional year for Northern Lights observation, with more frequent and vibrant displays compared to previous years. These images, captured at Sognsvann, a lake near the University of Oslo, fully displays this mesmerizing phenomenon.

Photos: Aditi Bhatnagar, taken with Canon EOS 6D Mark II








Summer interns and supervisors in front of the Rosseland building. First row from left: Karl, Delfine, Rebecca, Carlos. Second row from left: Semya, Eloi, Ana, Quentin in front of Eilif, Christophe in front of Aline. Last row from the left: Magnus, Michael, Nicolas, Sondre, Luc. Missing: Olav, Reetika, Avijeet. Photo: Ola Gamst Sæther

Summer Internship Highlights 2023

At RoCS, we are committed to nurturing the next generation of researchers in Solar physics, recognizing both the necessity and benefits of this endeavor. This past summer, we welcomed Nine interns who spent six weeks with us. The experience exceeded our expectations in fostering learning and collaboration.

The diversity of projects undertaken during the program showcased the breadth of talent and interests among our interns and supervisors, including simulations, observations, machine learning, and ChatGPT. Regardless of the project they worked on, the interns were able to enhance their scientific skills and knowledge.

"For me, the project was a success ... The most interesting part was seeing how [neural networks] could be applied in completely different ways than I could expect."

Magnus Axelsen

"I learned a new computer language and gained a deeper understanding on High-performance computing"

Eloi Martaillé Richard

"I have gained insight into the everyday life of researchers and the forefront of solar physics research"

Delfine Vågenes

"This will definitely come in handy when I am working on my Master's thesis."

Aline Rangøy Brunvoll

Fostering a culture

Beyond the independent work, the social aspect of the program played a pivotal role. Informal gatherings served as catalysts for forging connections, while scientific meetings provided opportunities for students to discuss their own work as well as that of their peers. An unexpected yet welcomed outcome was a new connection and collaboration between supervisors.

"I gained insight within the field through discussion with my supervisor and fellow students."

Rebecca Nguyen

"We developed a proof of concept with promising results ... This has opened the possibility for a collaborative project and paper."

Nicolas Poirier & Carlos José Díaz Baso, Supervisors

The success of our summer intern program lies not only in the projects accomplished, but also in the relationships built and the knowledge exchanged. As we look to the future, we remain committed to fostering a culture of collaboration and discovery.

Sondre Vik Furuseth

Oscillations in the Realistic Corona of the Sun

Project Update

The ORCS project is funded by the Research Council of Norway and is focused on investigating the characteristics of oscillations in the realistic solar atmosphere, while relaxing numerous assumptions made by previously used models.

Excitation and damping of coronal oscillations

The observations of the solar corona suggest that persistent coronal oscillations are extremely common, but their drivers are unknown. To tackle this question, we combine coronal and photospheric/chromospheric diagnostics together, and use coordinated high-resolution observations taken by the Swedish 1-meter Solar Telescope, the Solar Dynamics Observatory and the Solar Orbiter mission to analyse the flows at the base of the coronal loops. We find velocities sufficient to initiate transverse kink oscillations through the self-oscillation mechanism (e.g. Karampelas & Van Doorsselaere 2020).

To model the damping of coronal oscillations, we used self-consistent convection-zone-to-corona simulations to answer the following questions: Do the oscillating coronal loops in the realistic models of solar atmosphere damp on timescales comparable to observations? What processes are responsible for the oscillation damping and dissipation in such a setup? We have found that the oscillations damp within 3 oscillation periods. The shear flows induced by these oscillatory motions trigger the formation of Kelvin-Helmoltz vortices, which contribute to dissipation of the oscillations. This manifests by an increase in the vorticity, volumetric heating rates, and in the temperature in the vicinity of the oscillating loops.

Coronal veil and structure of coronal waveguides

Convection-zone-to-corona models predict a coronal structure (so-called 'coronal veil', e.g. Malanushenko et al. 2022) which is at odds with our traditional picture of coronal loops as hot cylinders of plasma clearly distinct from the surroundings. In addition, it is commonly assumed that the loop properties derived from extreme-ultraviolet observations such as loop diameter or transverse profile are representative of those of the actual waveguide – a coherent structure trapping magnetohydrodynamic waves and oscillating as a whole. To put this assumption to the test, we have analysed the variability of the Alfvén speed to identify waveguides in the simulated corona and compared these to the apparent loops visible in synthetic Fe IX emission. We find that the three-dimensional shape of the waveguides is very different from the assumptions we might be tempted to make based on the line-of-sight integrated coronal emission alone.

Petra Kohutova

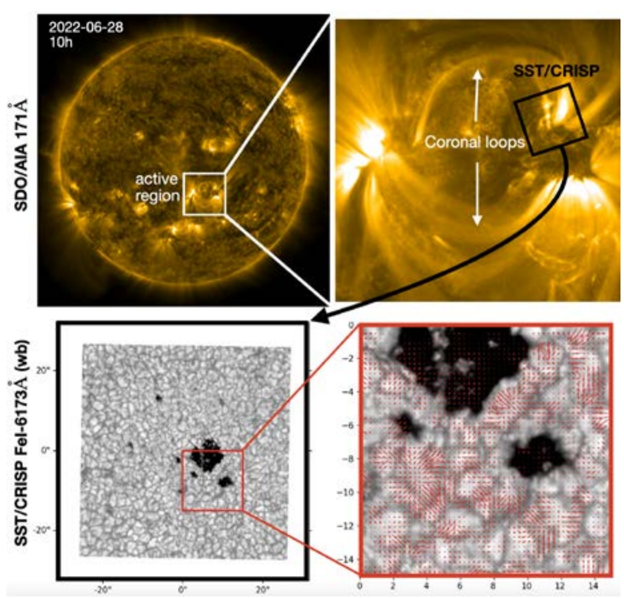


Fig. 1: Active region coronal loops and horizontal flows at their base as observed by the Solar Dynamics Observatory and the Swedish Solar Telescope. (credit: N. Poirier)

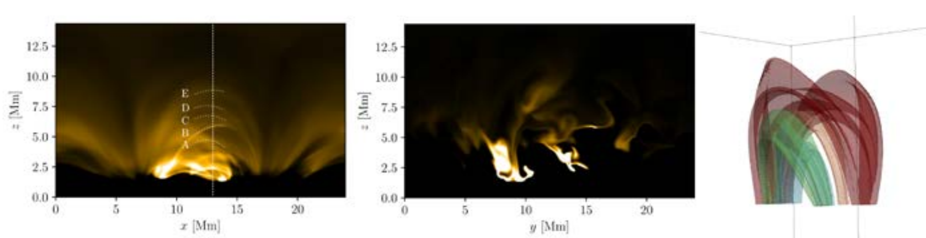


Fig. 2: Synthetic coronal emission, volumetric emissivity along the coronal loop cross-sections and coronal waveguides in a convection-zone-to-corona simulation. (credit: P. Kohutova)

Unraveling Solar Storms: Sun's Explosive Impact on Earth

Solar storms were recorded for the first time when the British amateur astronomers Richard Christopher Carrington and Richard Hodgson independently observed powerful flares associated with a large sunspot in 1859. The solar storm destroyed telegraph lines across the United States and was followed by unusually long-lasting, power-full northern lights.

Carrington realized that there had to be a connection between the rare solar flare and the recorded geomagnetic disturbances.

Solar storms today and in the past

Fortunately, the very strong solar storms of the “Carrington” type do not hit the Earth often, but ultraviolet radiation, X-ray radiation and CMEs ((coronal mass ejections) from less dramatic eruptions can still cause significant damage to modern navigation systems, power grids and satellites. A US communications satellite was destroyed by a solar storm in January 1997.

In March 1989, the entire Quebec area in Canada lost power for more than nine hours due to a severe solar storm. A Carrington-type solar storm was recorded on July 23, 2012, but it avoided our globe. If that storm had hit the Earth, it would certainly have caused major problems for today's internet dependent society.

Numerous solar storms yearly

About 20 solar storms hit the Earth every year, but they rarely cause problems. Internet management of vital global activities is today based on more than 7,000 satellites in space that can be affected and disrupted by reasonably powerful solar storms. Damage on sensitive satellite instruments is reduced or even avoided by turning them off before they are hit by particle streams from an eruption.

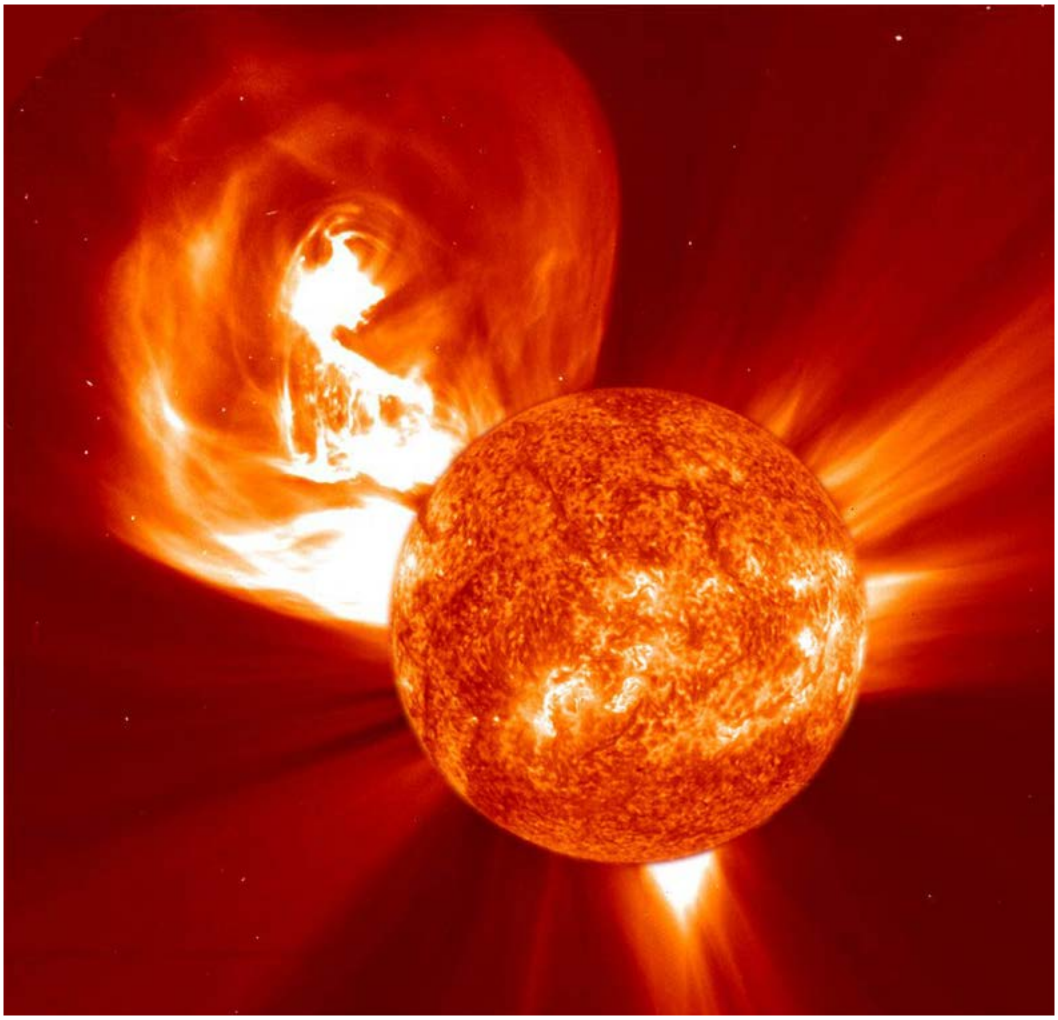
Warning of solar storms

Imbalance in local concentrations of magnetic fields on the solar surface leads to explosive heating and radiation (flares), which are followed by strong CMEs. Such solar storms will be able to reach and hit the earth two to three days later and create disruptive electrical currents in the ionosphere layer, which affect navigation and communication systems and the electrical power supply over large regions.

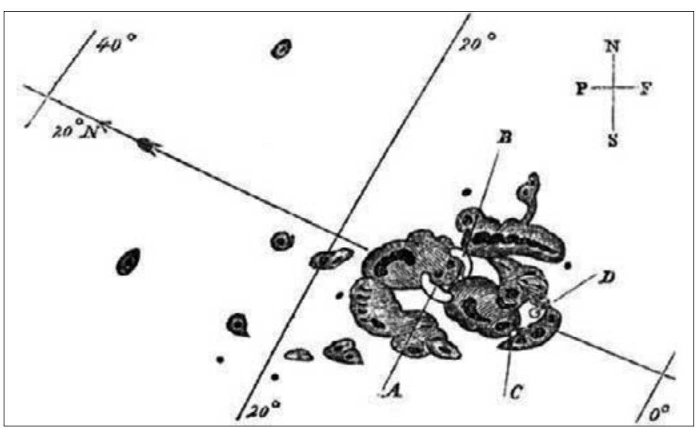
The Carrington-type solar storms recorded to date have all occurred near maxima in the sunspot cycles. This fact links them to high solar magnetic activity, as confirmed from recent studies of extremely magnetic active solar-like young stars.

Protections against potentially destructive solar storms are important and challenging. A gradually expanding, satellite based monitoring system provides timely warning and possibilities for appropriate actions.

Oddbjørn Engvold



Solar storm outbreak on 4 January 2002, taken with LASCO (Large Angle and Spectrometric COronagraph) on board the SoHO space observatory. (SoHO ESA/NASA)



Richard Carrington's drawing of a large sunspot observed on 1 September 1859. A and B mark where increased radiation occurred, which within five minutes spread to C and D and then quickly disappeared.

The audience at the Greveskogen high school in Tønsberg during the lecture. The lectures were mostly aimed at high school students in the last two years of their studies, covering topics such as radiation, gravity and electromagnetism.

Introducing the topic of space weather to the high school students studying at the Andenes high school. Especially in the north of Norway, the increased solar activity now that the Sun has reached its maximum is easily noticeable for the pupils thanks to the aurora.

Michaela Brchnelova was a visiting ph.d. student at RoCS in the autumn of 2023. She holds Bsc and MSc degrees in Aerospace Engineering from TU Delft, the Netherlands, and is currently finishing her PhD at KU Leuven, Belgium in space weather modeling.

Exploring Space Weather

The solar cycle is currently at its peak, causing various space weather-related phenomena.

This includes radio bursts, communication blackouts, and vivid auroras observed as far south as Greece. Countries at high latitudes, like Norway, frequently experience space weather effects. Consequently, educating the younger generation about space weather and solar physics is crucial.

Recognizing that some schools, particularly in remote areas, struggle to cover space-related topics in Physics 2 classes, we initiated outreach activities to raise awareness. As part of this effort, we offered physics teachers across Norway the opportunity for a visit to discuss the Sun's impact on technology and society. The response exceeded expectations, leading to invitations from high schools across the country, spanning from Tønsberg to Tromsø.

The presentation's final segment focused on current solar physics and space weather modeling efforts, along with opportunities for studying these subjects in Norway and Europe, including RoCS. The teachers received the presentation slides for future use.

The experience was fantastic, with positive feedback from teachers and even inspiring one student to choose space weather as her yearly project. Overall, the outreach activities successfully increased awareness and interest in space weather among the younger population.

Michaela Brchnelova

Deciphering solar coronal heating

Magnetic field loops are one of the most fundamental structures in Astrophysics. A recent paper provides answers to the question about the heating in small-scale magnetic loops in the solar atmosphere, known as Coronal Bright Points (CBPs).

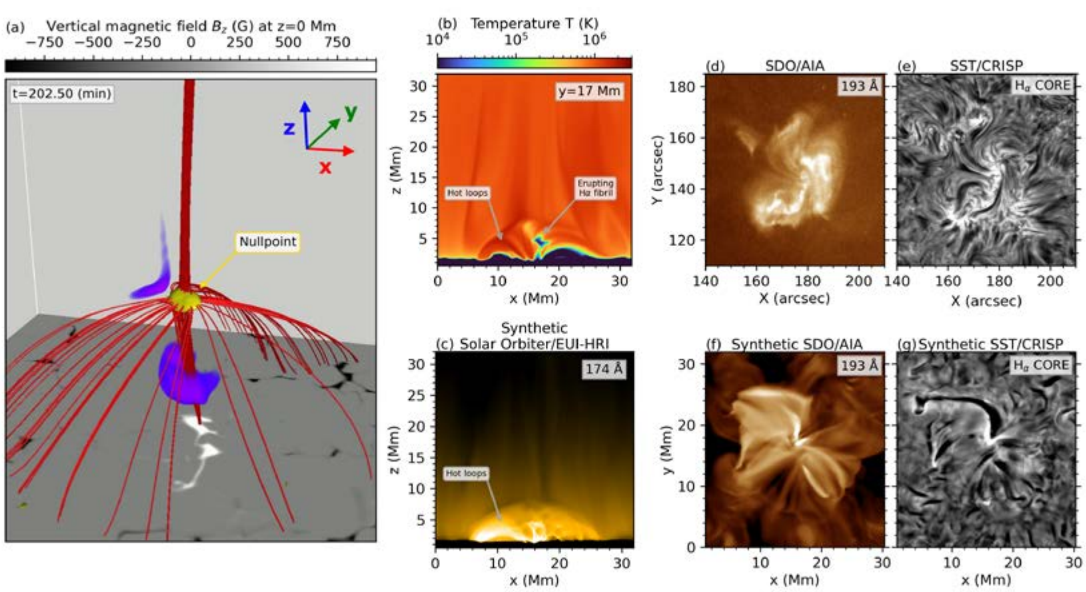
CBPs are ubiquitous phenomena that stand out in the Sun by their enhanced X-ray and/or extreme-ultraviolet (EUV) emission for hours to days. Through state-of-the-art radiation-magnetohydrodynamics 3D numerical simulations performed using the Bifrost code, we explain how these magnetic loop structures can be energized and emit enormous amounts of energy for hours, as observed on the Sun, based solely on their energization through surface convective motion. This implies a major change in paradigm compared to the current explanations obtained through idealized models. Thus, our research has important implications for the longstanding question of the solar coronal heating problem in astrophysics.

The manuscript also includes (1) new CBP observations from space, using the Solar Dynamics Observatory (SDO), and from the ground, through the Swedish 1-m Solar Telescope (SST); and (2) detailed diagnostics calculated from the numerical data for EUV wavelengths as well as for the H-alpha line using the Multi3D synthesis code. The similarities between the synthetic observables from the model and the observations are striking, even reproducing the most complex features in the chromosphere, thus confirming the adequacy of the presented 3D model of CBPs across different atmospheric layers.

This work has required millions of hours of computing time in two of the most advanced supercomputing facilities in Europe: Betzy (in Norway) and MareNostrum (in Spain). Access to these facilities was provided through the "Whole Sun" project, a program funded by the European Research Council (ERC). RoCS and the IAC in Tenerife are partners in the Whole Sun project together with three other European institutions.

The paper by Nóbrega-Siverio et al. 2023, ApJ Letters is an effort between international researchers, including members of RoCS.

Daniel Nobréga-Siverio (IAC and RoCS)



Comparison between the numerical model and observations. (a) magnetic nullpoint topology (red lines), (b) temperature in the middle of the 3D model, (c) synthetic side view of the model to mimic observation by Solar Orbiter, (d) and (e) observations of a CBP from SDO and SST which can be compared with the synthetic top view of the model in (f) and (g).

Social life at RoCS

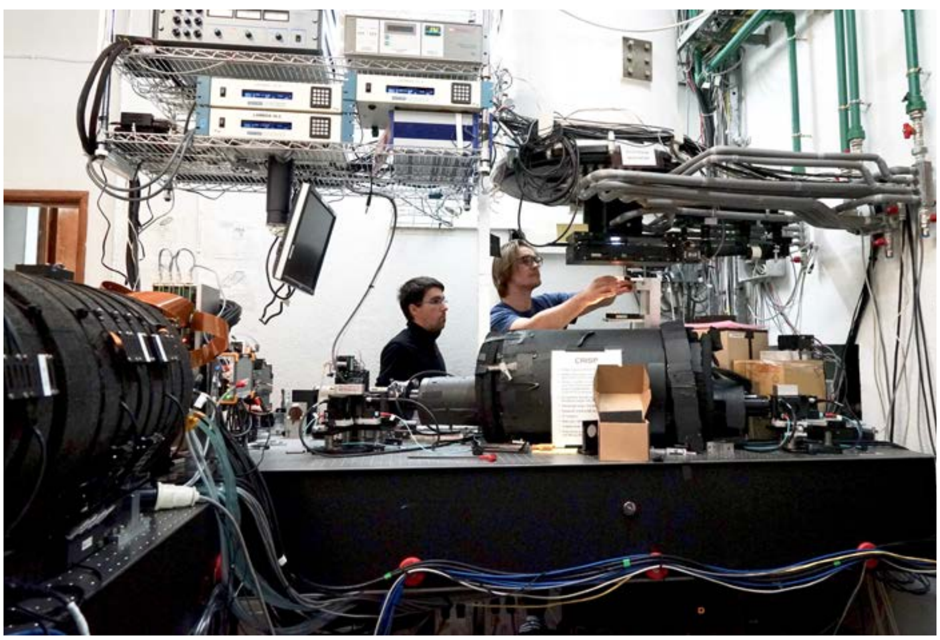
Short and long-distance journeys showcase the vibrant community at RoCS, thriving with a seamless blend of work and leisure.

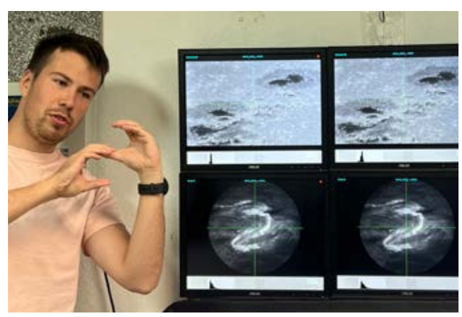

5399


TEORETISK ASTROFYSIKK

Life at the SST

In 2023, we conducted three two-week observation periods in July, August/September, and September/October. Twelve participants, involved in research spanning from master's theses to four-year research projects, actively contributed to the observations.





Members of the centre

Credit: Aditi Bhatnagar

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 because of their excellent qualifications and expertise. During 2023 we had five master students, 18 doctoral research fellows, 14 postdocs and researchers, three research software engineers, one associate professor, five professors, one centre coordinator and one communication adviser. In addition, we had seven adjunct professors, as well as six associated members in the administrative and technical staff, and five emeriti. Our Scientific Advisory Committee consisted of four members. Owing to our privileged position as a centre of excellence, we are able to grow in numbers, hiring talented and exceptional researchers of a large number of nationalities (currently 19 nationalities from three continents). All our members are putting their best efforts into strengthening our scientific achievements, setting forward new goals and reaching even higher standards for our research.

Phd

Helle Bakke

Helle Bakke, doctoral research fellow, defended her thesis "Impact of nanoflare heating in the lower solar atmosphere" for the degree of Philosophiae Doctor in October 2023.

Aditi Bhatnagar

Aditi Bhatnagar, 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.

George Cherry

George Cherry, doctoral research fellow, is a member of the CompSci PhD programme, which contributes to intensive training in computational and data science. George is working to develop the heat conductivity functions within Bifrost, and is also looking at the detection of wave propagation through Bifrost simulations. She is also active in outreach activities, aurora chasing and enjoys communicating science to the public.

Phd

Elisabeth Enerhaug

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

Jonas Thoen Faber

Jonas Thoen Faber, doctoral research fellow, analyzes observations of a solar flare. The flare is well-observed with multiple instruments which covers the photosphere, chromosphere and corona. The chromosphere is considered as an important part of the interpretation of the flare and so high-resolution observations from the Swedish 1-m Solar Telescope are used. The aim is to use the coaligned datasets and study the dynamics at different formation heights with an emphasis on the chromosphere.

Lars Frogner

Lars Frogner, doctoral research fellow, does research in fields mainly concerned with numerical modeling of the solar atmosphere, in particular the origin, behavior and effect of accelerated particles. He is generally interested in a range of topics in software development, including numerical simulations and computer graphics.

Øystein Håvard Færder

Øystein Håvard Færder, doctoral research fellow, is part of the Whole Sun team. His research is focused on numerical simulations. His first two papers deal with reconnection simulated with different resistivity models with a major focus on plasmoid instability. In his third paper, he applies forward modeling to determine how small-scale plasmoids in the corona can be detected with the upcoming MUSE and Solar-C missions.

Michael Haahr

Michael Haahr, doctoral research fellow, is part of the newly formed 'particle group' that tries 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 modeling and high performance computing.

Mats Kirkaune

Mats Kirkaune, doctoral research fellow, is going to search for signatures of nanoflares in solar observations obtained with the Atacama Large Millimeter/submillimeter Array (ALMA), and is currently exploring the prospects for extending this search with the future Atacama Large Aperture Submillimeter Telescope (AtLAST). This is done by putting realistic high-resolution mock-up observations through an atmospheric simulator tool that simulates single-dish observations, and exploring the impacts of the instrumental properties on the resulting image.

Phd

Kilian Krikova

Kilian Krikova, 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 get a better understanding of small-scale energetic phenomena at the Sun.

Thore Espedal Moe

Thore Espedal Moe, doctoral research fellow, defended his thesis "Line formation in the magnetized solar chromosphere"for the degree of Philosophiae Doctor in October 2023.

Sascha Ornig

Sascha Ornig, doctoral research fellow, will investigate solar flares with emissions in optical wavelengths (“white-light”) to try to understand which conditions facilitate those emissions as well as the underlying formation mechanisms. He will use high-resolution observations from the Swedish 1-m Solar Telescope (SST) combined with state-of-the-art simulations using the RADYN code.

Sneha Pandit

Sneha Pandit, doctoral research fellow, defended her thesis "A new look at Solar-Stellar Activity with the Atacama Large Millimeter/submillimeter Array" for the degree of Philosophiae Doctor in December 2023.

Ignasi J. Soler Poquet

Ignasi J. Soler Poquet, 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. The plan is to find and classify them by exploring large observational datasets. Ignasi applies Deep Learning techniques to detect these events automatically. He uses solar observations from both ground-based and space-borne telescopes such as the SST and SDO.

Rebecca Robinson

Rebecca Robinson, doctoral research fellow, defended her thesis "Magnetic characteristics of quiet Sun nanoflares" for the degree of Philosophiae Doctor in September 2023.

Phd

Mats Ola Sand

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

Elias Roland Udnæs

Elias Roland Udnæs, doctoral research fellow, will in his research project combine high-resolution observations, magnetohydrodynamic (MHD) simulations, and machine learning techniques to identify and quantify heating mechanisms in the solar chromosphere. He hopes that his time at RoCS will lead to a tool that, with innovative methods, associates complex spectral data from current and future solar telescopes with heating signatures.

Eilif Sommer Øyre

Eilif Sommer Øyre, doctoral research fellow, will use simulations to study how particles are accelerated in the solar atmosphere. In particular, he is developing a trace-particle code to follow particles embedded in MHD-simulations. This will provide the opportunity to better understand the physical processes at play in solar flare kernels. In general, Eilif is interested in plasma physics, numerical analysis, and high performance computing, as well as rock climbing and the outdoors.

Postdocs and researchers

Souvik Bose

Souvik Bose, affiliated researcher, completed his PhD at RoCS in 2021. Souvik's research mainly focuses on unraveling the dynamics of the solar atmosphere with coordinated high-resolution ground and space based observations. He also works on computing synthetic observations from high-resolution MHD simulation snapshots using a variety of radiative transfer codes. His main 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, postdoctoral research fellow, whose general areas of interest are 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 with novel deep learning and Bayesian inference techniques, and comparing them with numerical models of the solar atmosphere.

Sondre Vik Furuseth

Sondre Vik Furuseth, postdoctoral research fellow, did his PhD in accelerator physics at CERN, focused on beam stability and high-performance computing. Now, he brings his experience to studying the Sun. In particular, he is interested in understanding the formation of active regions and eruptions. He approaches these challenging questions of the active Sun by simulating pre-eruptive magnetic dynamics in the upper convection zone and atmosphere of the Sun.

Postdocs and researchers

Ana Belén Griñón-Marín

Ana Belén Griñón-Marín, postdoctoral research fellow, focuses on the long-term evolution of active regions. She has studied the evolution of the magnetic field topology in the solar photosphere of active regions of type alpha. The study of light bridges by means of ground-based telescopes and space-borne missions is also a research field. Her current interest aims at the characterization of light bridges through the whole solar atmosphere, from the photosphere to the corona.

Shahin Jafarzadeh

Shahin Jafarzadeh, affiliated researcher, is primarily employed by the Max Planck Institute for Solar System Research, Germany. He is predominantly interested in characterisation of wave activity in the lower solar atmosphere, and he 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.

Reetika Joshi

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

Petra Kohutova

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

Atul Mohan

Atul Mohan is a postdoctoral research fellow at RoCS. He studies the physics of frequent weak emissions omnipresent in the solar atmosphere analysing big datasets from modern radio telescopes. He works for the EMISSA project to understand the nature of atmospheric activity in different types of stars, including our Sun, using data from modern radio telescopes, mainly ALMA. The radio observations will be supplemented by high energy data and atmospheric models to understand the structure and dynamics of stellar atmospheres. The study will compare and contrast the Sun against similar stars.

Quentin Noraz

Quentin Noraz, 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, delving into its thermodynamics, incorporating new magnetic constraints from global MHD models, and aiming to venture into local simulations of stellar atmospheres.

Postdocs and researchers

Nicolas Poirier

Nicolas Poirier, 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, affiliated researcher, is an earlier postdoctoral researcher. He now works at Instituto de Astrofísica de Canarias (IAC) in Tenerife. Daniel´s research is mainly focused on chromospheric surges and Coronal Bright Points from a theoretical and observational perspective.

Avijeet Prasad

Avijeet Prasad, postdoctoral research fellow, is part of the Whole Sun project team. Avijeet's research is mainly focused on coronal magnetic field extrapolations derived from photospheric vector magnetograms and data-constrained magnetohydrodynamics simulations of high-energetic events in the corona like solar flares and coronal mass ejections.

Maryam Saberi

Maryam Saberi, researcher, is studying the impact of evolved stars on the Galactic chemical composition. She is also interested in studying the solar and stellar chromospheric activity and its variation throughout stellar evolution. She mainly uses observational data at mm/sub-mm wavelengths observed with ALMA and APEX telescopes. She is also experienced in radiative transfer and chemical modeling of the outflow around evolved stars.

Fan Zhang

Fan Zhang, postdoctoral fellow, is primarily interested in developing numerical techniques for studying fluid & plasma dynamics that are typically described by nonlinear hyperbolic partial differential equations. In particular, he is now striving 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

Maria Guadalupe Barrios Sazo

Maria Guadalupe Barrios Sazo, research software engineer, worked at RoCS from Autumn 2020 until June 2023.

Andrius Popovas

Andrius Popovas, research software engineer, works with developing next generation global magnetohydrodynamic simulations of the convective regions of the Sun and other stars. It will enable running experiments on an unprecedented scale and complexity, bridging the 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, research software engineer, is a physicist and mathematician by education, but computer scientist by 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, adjunct professor, develops 3D MHD models for flares, prominences, magnetic field topology and reconnection. He is a member of the science teams of SDO and Solar Orbiter. His home institution is the Laboratory for Plasma Physics in Paris. He is deputy-director of the astrophysics graduate school of Université PSL, chair of the Sun-Earth programme of CNRS, and policy officer for HPC at the ministry of research.

Ineke De Moortel

Ineke De Moortel, adjunct professor, has a research focus on coronal heating, in particular the efficiency of heating by MHD waves, using a combination of numerical simulations and observational data analysis. Her home institute is the University of St Andrews (UK). From September 2021, one of her PhD students, Elisabeth Enerhaug, has started a joint PhD between the Universities of St Andrews and Oslo.

Bart De Pontieu

Bart De Pontieu, 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.

Adjunct professors

Lyndsay Fletcher

Lyndsay Fletcher, 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 fraction of women and girls participating in physics and astronomy.

Juan Martínez-Sykora

Juan Martínez-Sykora, adjunct associate professor, is based at LMSAL and BAERI. He is deputy science lead of MUSE (NASA MIDEX program) and EUVST Co-I. His major contributions are on numerical modeling of the solar atmosphere. His main interest is chromospheric heating and dynamics, and multi-fluids, using and developing state of the art 3D radiative MHD codes and comparing the models with ground-based and space-based observations.

Åke Nordlund

Åke Nordlund, adjunct professor, works at the Astrophysics and Planetary Sciences group at the Niels Bohr Institute and STARPLAN at 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, adjunct associate professor, works with R&D in the Norwegian Defence Estate Agency. Her field of interest is shock and blast waves, both experimentally and numerically, using the numerical code Multi-Phase Regularized Smoothed Particle Hydrodynamics (MP-RSPH). The experimental work includes sensors and visualization techniques such as Schlieren and Shadowgraph.

> The sun burnt every day.
> It burnt time.
>
> Ray Bradbury

Principal investigators

Mats Carlsson

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

Boris Gudiksen

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

Viggo Hansteen

Viggo Hansteen, senior researcher at Bay Area Environmental Research Institute and part time professor and PI, works both on 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. Flux emergence, coronal heating and chromospheric dynamics and energetics are keywords.

Tiago M. D. Pereira

Tiago M. D. Pereira, associate professor, studies dynamic processes in stellar atmospheres. In particular, he is working 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 visualization, he works with high-performance computing and big data problems.

Luc Rouppe van der Voort

Luc Rouppe van der Voort, 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 observing campaigns with the SST and space-borne telescopes, such as IRIS and Hinode, and earlier TRACE and SOHO.

Sven Wedemeyer

Sven Wedemeyer, professor and PI, coordinates the research activities related to solar and stellar observations with ALMA and supporting simulations. He led the EMISSA project (RCN), and an ESO-funded ALMA development study, which concluded in 2023. His research mostly focuses on the small-structure, dynamics and energy balance of the solar atmosphere with implications for other stellar types.

Centre administration

Benedikte Fagerli Karlsen

Benedikte Fagerli Karlsen, centre coordinator, was on maternity leave until May 2023. She is responsible for the administration of the centre and takes care of all practical tasks related to the centre's activity. Among her tasks are new employment, visitors, contracts, reporting and logistics at events.

Heidi Haugsand

Heidi Haugsand, centre coordinator, worked temporarily at RoCS from August 2022 to June 2023.

Eyrun Thune

Eyrun Thune, 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 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, engineer in the institute's Project Related IT Services (PRITS) group, is the lead of the development of the data pipeline for the Solar Orbiter SPICE instrument. He is also a contributor to the operations of the Hinode Science Data Centre Europe, 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, 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 is the lead for 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, Head of Office at the Institute of Theoretical Astrophysics (ITA), is the head of ITA's administration, and cooperates closely with both the scientific, technical and administrative staff at RoCS and the Institute.

Torben Leifsen

Torben Leifsen, 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, and is doing research in helioseismology in his spare time.

Martin Wiesmann

Martin Wiesmann, engineer in the institute's Project Related IT Services (PRITS) Group, is responsible for part 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, computational plasma physicist, has an interest that spans 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, professor of Solar Physics at UCL's Mullard Space Science Laboratory, has an interest in energy storage and release in magnetised plasmas. In particular solar eruptive events and space weather. Her work is mainly observational, but she also works in collaboration 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 PI.

Oskar Steiner

Oskar Steiner, senior researcher at the Leibniz-Institut für Sonnenphysik (KIS) in Freiburg, Germany and at the Istituto Ricerche Solari Locarno (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.

Scientific Advisory Committee

Francesca Zuccarello

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

Emiriti

Oddbjørn Engvold

Oddbjørn Engvold, emeritus professor, focuses on areas of 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, of 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, 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, 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, emeritus professor, focuses on research in plasma physics, turbulence phenomena in ionized and neutral media, numerical simulations.

Master students

Tor-Andreas S. Bjone

Tor-Andreas S. Bjone, second-year master student, will in his thesis create a 3D MHD model of the convection zone to explore super granulations and effects between the magnetic field and plasma. He started his work in autumn 2023 under the supervision of B. Gudiksen and S.V. Furuseth.

Christophe K. Blomsen

Christophe K. Blomsen, second-year master student, will in his thesis study non-LTE radiative transfer, using GPU. He started on his thesis autumn 2022 under the supervision of Tiago M. D. Pereira.

Aline R. Brunvoll

Aline R. Brunvoll, second-year master student, is under the supervision of Luc Rouppe van der Voort. She will compare high-resolution H alpha and H beta observations from the SST, aiming to learn how recent observations from the CHROMIS instrument can advance our understanding of the solar chromosphere.

Eloi Martaillé Richard

Eloi Martaillé Richard, second-year master student, will in his project simulate new capabilities of ALMA for observing the Sun. With Sven Wedemeyer as his supervisor, he will finish his thesis in 2024.

Semya Amouche Tønnessen

Semya A. Tønnessen, second-year master student, has a master project with the working title “Making sense of the solar chromosphere – investigations of the diagnostic power of various spectral lines” with Mats Carlsson as supervisor.

> The Sun is such a lonely star. Whenever he comes out to see his friends, they all disappear.

Joseph Gordon-Levitt

Credit: Aditi Bhatnagar

Talks and presentations 2023

Bhatnagar, Aditi. Chromosphere and Transition region response to Quiet Sun Ellerman Bombs. Hinode-16/IRIS-13 meeting; 2023-09-25 - 2023-09-29

Carlsson, Mats. Kunst og astrofysikk møtes: Solen og dens energi. Forskningsdagene; 2023-09-20

Carlsson, Mats. Solar Physics in Norway. Status and Prospects. Norwegian-American Space Seminar; Washington DC, 2023-11-14 - 2023-11-16

Carlsson, Mats. Understanding the workings of the energetic Sun. Seminar at Hylleraas Centre of Excellence for Quantum Molecular Sciences; 2023-05-12

De Pontieu, Bart. Future high-resolution observations of the low solar atmosphere from space. RoCMI 2023; 2023-02-27 - 2023-03-02

De Pontieu, Bart. MUSE. seminar at National Solar Observatory; 2023-04-12

De Pontieu, Bart. MUSE science. MUSE workshop; 2023-10-02

De Pontieu, Bart. MUSE science. PUNCH Winter telecon 2023; 2023-01-23

De Pontieu, Bart. The Mulit-Slit Solar Explorer (MUSE). Hinode-16/IRIS-13 meeting; 2023-09-25 - 2023-09-29

Díaz Baso, Carlos José. Deep Learning 2.0: Combining physics-based models with data-driven solutions. Solar seminar at Instituto de Astrofisica de Canarias (IAC); 2023-10-15

Díaz Baso, Carlos José. Deep Learning 2.0: Combining physics-based models with data-driven solutions. Solar Seminar at Leibniz-Institut für Sonnenphysik (KIS); 2023- 06-05

Díaz Baso, Carlos José. Differentiable programming for spectra modeling and inference. RoCMI 2023; 2023-02-26 - 2023-03-02

Díaz Baso, Carlos José. Unleashing the Potential of Machine Learning for Efficient Analysis of Solar Observations. Universitat de les Illes Balears; 2023-02-17

Frogner, Lars; Gudiksen, Boris. Accelerated particles in the solar atmosphere. New generation multidimensional (2D/3D) and multi-scale modelling of solar flares; from reconnection to particle energisation and beyond; 2023-01-13

Furuseth, Sondre Vik. Fra Sandvika til CERN og Sola - Med alle muligheter åpne. Fysikkkveld - Motivasjonsforedrag til elever ved en videregående skole; 2023-12-07

Furuseth, Sondre Vik. Pre-eruptive shearing and convection-driven reconnection in Bifrost. Solarnet School; 2023-06-26 - 2023-06-30

Færder, Øystein Håvard. Modelling the resistivity for magnetic reconnection on the Sun – a comparative study of anomalous resistivity models. Institute Colloquium; 2023- 05-05

Færder, Øystein Håvard; Nóbrega-Siverio, Daniel; Carlsson, Mats. Magnetic Reconnection Signatures in the Corona through MUSE Forward Modelling. AGU 2023; 2023-12-11 - 2023-12-15

Grinon Marin, Ana Belen. A light bridge crossing the atmosphere. RoCMI 2023 Svalbard; 2023-02-27 - 2023-03-02

Grinon Marin, Ana Belen. Caracterización de un puente de luz y su contribución a las pérdidas radiativas. VIII Reunión Española de Física Solar y Heliosférica; 2023-07-11 - 2023-07-13

Grinon Marin, Ana Belen. Conversando con jóvenes científicos aragoneses. V Curso de Periodismo Especializado de Alcañiz 2023: 'Comunicación y ciencia. Los divulgadores esenciales'; 2023-08-31 - 2023-09-01

Grinon Marin, Ana Belen. El Sol. Curso de Monitores Astronómicos Starlight comarca Andorra Sierra de Arcos; 2023-05-15 - 2023-05-20

Joshi, Reetika. Understanding the Physics of solar coronal jets and surges. RoCMI Meeting; 2023-02-26 - 2023-03-03

Joshi, Reetika. Lower atmospheric evidence of swirled-anemone solar jets. Royal Astronomical Society, London 2023-11-10.

Joshi, Reetika. Synergy of High Resolution Observations and Theoretical Model. Hinode-16/IRIS-13 meeting; 2023-09-25 - 2023-09-29

Joshi, Reetika. Probing Solar Jets. National Astronomical Meeting; 2023-07-03 - 2023-07-07

Joshi, Reetika. Probing Solar Jets: Synergy of High Resolution Observations and Theoretical Model. Department of Astronomy of Kyoto University.; 2023-09-19

Joshi, Reetika. Interaction of solar jets with filaments: Triggering of large-amplitude filament oscillations. Yearly meeting of the ERC Synergy Grant "The Whole Sun".; 2023-03-06 - 2023-03-24

Wedemeyer, Sven; Kirkaune, Mats. Observing the Sun with AtLAST - Prospects and Challenges. AtLAST Consortium Meeting 2023; 2023-10-10 - 2023-10-12

Kohutova, Petra. What can coronal rain tell us about coronal heating mechanisms and the structure of the corona?National Astronomy Meeting; 2023-07-03 - 2023-07-07

Kohutova, Petra; Antolin, Patrick; Szydlarski, Mikolaj; Carlsson, Mats. Damping of Coronal Oscillations in Self-Consistent 3D Radiative MHD Simulations of the Solar Atmosphere. AGU Chapman Conference on Advances in Understanding Alfvén Waves in the Sun and the Heliosphere; 2023-05-28 - 2023-06-02

Kohutova, Petra; Antolin, Patrick; Szydlarski, Mikolaj; Carlsson, Mats. Damping of coronal oscillations in self-consistent 3D radiative MHD simulations of the solar atmosphere. Hinode-16 / IRIS-13 meeting; 2023-09- 25 - 2023-09-29

Krikova, Kilian. H a new spectral line to detect small-scale reconnection phenomena in the solar photosphere. The Next Frontier - Linking Simulations with Observations of the Solar Atmosphere; 2023-06-05 - 2023-06-09

Nóbrega Siverio, Daniel. An observational study of magnetic flux emergence leading to a dark bubble, EB, surge, and a UV burst reaching 1 MK.. Flux Emergence Workshop (FEW, 2023).; 2023-06-05 - 2023-06-09

Nóbrega Siverio, Daniel. An overview of numerical experiments about ephemeral magnetic flux emergence: comparison with observations.. Department of Astronomy of Kyoto University.; 2023-10-09 - 2023-10-10

Nóbrega Siverio, Daniel. Deciphering the solar coronal heating: Energizing small-scale loops through surface convection. CLASP 2.1 Science Meeting; 2023-10-16 - 2023- 10-19

Nóbrega Siverio, Daniel. Modeling Coronal Bright Points. Rocmi. Confronting numerical models of the solar chromosphere and corona with high resolution observations - a RoCS/MUSE/IRIS workshop.; 2023-02-27 - 2023-03-01

Nóbrega Siverio, Daniel. Modeling Coronal Bright Points.. Yearly meeting of the ERC Synergy Grant "The Whole Sun".; 2023-03-06 - 2023-03-24

Nóbrega Siverio, Daniel. Unraveling the heating of Coronal Bright Points: a fundamental block in the solar atmosphere. HINODE-16/IRIS-13.; 2023-09-25 - 2023-09-29

Nóbrega Siverio, Daniel. Unraveling the heating of Coronal Bright Points: a fundamental block in the solar atmosphere. Reunión Española de Física Solar y Heliosférica (REFSH, 2023).; 2023-07-10 - 2023-07-14

Noraz, Quentin. Impact of the Nusselt number on the energy distribution among solar convection scales. IAU Symposium 365; 2023-08-21 - 2023-08-25

Noraz, Quentin. New insight about magneto~rotational evolution of solar-type stars. 2023 International Conference of Deep Space Sciences; 2023-04-22 - 2023- 04-27

Noraz, Quentin. Power supply and evolution of the solar dynamo. SOLARNET Conference: The Many Scales of the Magnetic Sun; 2023-05-08 - 2023-05-12

Noraz, Quentin. Quantifying Rossby numbers in the Kepler field: Promising candidates for anti-solar differential rotation. PLATO Stellar Science Conference; 2023-06-26 - 2023-06-30

Noraz, Quentin. Role of Poynting flux injection by magneto-convection on the chromospheric energy balance. Hinode-16 / IRIS-13 meeting; 2023-09-25 - 2023- 09-29

Pandit, Sneha; Wedemeyer, Sven; Carlsson, Mats. Comparison of activity indicators in a 3D model atmosphere. RoCMI 2023; 2023-02-27 - 2024-02-02

Pandit, Sneha; Wedemeyer, Sven; Carlsson, Mats. Comparison of activity indicators in a 3D model atmosphere. RoCMI workshop; 2023-02-27 - 2023-03-02

Pereira, Tiago. Fast 3D non-LTE spectral synthesis with neural networks. Seminar Plasma Dynamics Group University of Sheffield; 2023-05-05

Pereira, Tiago. Uncovering chromospheric secrets with forward modelling. Colloquium Centre for mathematical Plasma-Astrophysics KU Leuven; 2023-03-16

Pereira, Tiago. 3D NLTE radiative transfer in stellar atmospheres. Solarnet Sun in Science and Society; 2023-09-11 - 2023-09-15

Poirier, Nicolas. On the modelling of multi-specie plasmas: theory and challenges for the solar atmosphere. Institute colloquium; 2023-03-31

Poirier, Nicolas; Kohutova, Petra; Joshi, Reetika; Rouppe van der Voort, Luc. About the source of sustained kink oscillations in coronal loops: what do we know and what do we need from future observation campaigns?. Hinode/IRIS-13 meeting; 2023-09-25 - 2023-09-29

Poirier, Nicolas; Lavarra, Michael; Rouillard, Alexis Paul; Blelly, P.-L.; Indurain, Mikel; Réville, Victor. Investigating the role of diffusion effects in the fractionation of minor elements in solar loops, using a multi-specie high-order 1-D model. Hinode/IRIS-13 meeting; 2023-09-25 - 2023-09-29

Poirier, Nicolas; Rouillard, Alexis Paul; Kouloumvakos, Athanasios; Réville, Victor; Valette, Emeline. On the variability of the slow solar wind: New insights from the modelling and PSP-WISPR observations. PSP-WISPR Consortium meeting - virtual; 2023-07-24

Poirier, Nicolas; Rouillard, Alexis Paul; Lavarra, Michael; Blelly, P.-L.; Indurain, Mikel; Réville, Victor; Lomazzi, Paul; Thomas, Simon; Marchaudon, Aurélie; Pinto, Rui F. On the modelling of multi-specie plasmas: theory and challenges for the solar atmosphere. European Space Weather Week (ESWW) 2023; 2023-11-20 - 2023-11-24

Poirier, Nicolas; Rouillard, Alexis Paul; Réville, Victor; Indurain, Mikel; Alexandre, Matthieu.Tutorial on Connectivity Science using the Connectivity-Tool. PSP Scholars Fifth meeting - virtual; 2023-05-02 - 2023-05-03

Popovas, Andrius; Nordlund, Åke; Szydlarski, Mikolaj; Kohutova, Petra; Hansteen, Viggo; Noraz, Quentin; Zhou, Yixiao. Global MHD simulation of the solar convective region. EuroHPC User Day; 2023-12-11

Popovas, Andrius; Nordlund, Åke; Szydlarski, Mikolaj; Kohutova, Petra; Hansteen, Viggo; Noraz, Quentin; Zhou, Yixiao. Update on global MHD simulations of the solar convective region. Hinode-16/IRIS-13 symposium; 2023-09-25 - 2023-09-29

Popovas, Andrius; Nordlund, Åke; Szydlarski, Mikolaj; Kohutova, Petra; Noraz, Quentin Global MHD simulations of the solar convective zone using a volleyball mesh decomposition: Pilot. Whole Sun meeting 2023; 2023-03-06 - 2024- 03-24

Prasad, Avijeet. Data-constrained magnetohydrodynamics simulations of the solar atmosphere using the Bifrost code. RoCMI 2023; 2023-02-27 - 2023-03-02

Robinson, Rebecca. Evolution of a nanoflare-scale reconnection event in the quiet Sun. IAU Symposium 365: Dynamics of Solar and Stellar Convection Zones and Atmospheres; 2023-08-21 - 2023-08-25

Robinson, Rebecca. Signatures of Drama in the (not so) Quiet Sun. RoCMI Meeting 2023; 2023-02-27 - 2023-03-02

Robinson, Rebecca. Signatures of Drama in the not-so-quiet Sun. Whole Sun gathering March 2023; 2023-03-06 - 2023-03-17

Robinson, Rebecca. We Accidentally Simulated a Nanoflare. Northumbria University Seminar; 2023-01-31 - 2023-02-02

Rouppe van der Voort, Luc. High-resolution observations of chromospheric dynamics. RoCMI workshop Svalbard; 2023-02-27 - 2023-03-02

Sand, Mats Ola. Åpen dag: Et glimt fra solfysikken. Åpen dag ved Universitetet i Oslo; 2023-03-07

Soler Poquet, Ignasi J.; Rouppe van der Voort, Luc.; Díaz Baso, Carlos José. Interpretación de observaciones solares usando redes neuronales. VIII REFSH; 2023-07-11 - 2023-07-13

Soler Poquet, Ignasi J.; Rouppe van der Voort, Luc; Díaz Baso, Carlos José. Interpretation of Solar Observations with Deep Learning. The Next Frontier - Interpretation of Solar Observations with Deep Learning; 2023-06-05 - 2023-06-09

Wedemeyer, Sven. Radio and millimeter observations of the Sun - Recent advances and future opportunities. IUGG 28th General Assembly; 2023-07-11 - 2023-07- 20

Wedemeyer, Sven; Szydlarski, Mikolaj. Artificial observations of the Sun – The scientific potential of optimizing future solar observatories. RoCMI 2023; 2023-02-27 - 2023-03-02

Papers in refereed journals 2023

Abdollahi, Hedieh; Javadi, Atefeh; Mirtorabi, Mohammad Taghi; Saremi, Elham; van Loon, Jacco Th.; Khosroshahi, Habib G.; McDonald, Iain; Khalouei, Elahe; Mahani, Hamidreza; Aghdam, Sima Taefi; **Saberi, Maryam**; and Torki, Maryam: 2023, The Astrophysical Journal, 948, 63, The Isaac Newton Telescope Monitoring Survey of Local Group Dwarf Galaxies. VI. The Star Formation History and Dust Production in Andromeda IX

Antolin, P., and 36 colleagues (among them **Aulanier, G.)**: 2023, Astronomy and Astrophysics, 676, A112, Extreme-ultraviolet fine structure and variability associated with coronal rain revealed by Solar Orbiter/EUI HRI$_{EUV}$ and SPICE

Bakke, H.; Frogner, L.; Rouppe van der Voort, L.; Gudiksen, B. V.; and **Carlsson, M.**: 2023, Astronomy and Astrophysics, 675, A103, Accelerated particle beams in a 3D simulation of the quiet Sun. Lower atmospheric spectral diagnostics

Berghmans, D., and 37 colleagues (among them **Aulanier, G.)**: 2023, Astronomy and Astrophysics, 675, A110, First perihelion of EUI on the Solar Orbiter mission

Bose, Souvik; Nóbrega-Siverio, Daniel; De Pontieu, Bart; and Rouppe van der Voort, Luc: 2023, The Astrophysical Journal, 944, 171, The Chromosphere Underneath a Coronal Bright Point

Calchetti, D., Stangalini, M., **Jafarzadeh, S.**, and 31 colleagues: 2023, Astronomy and Astrophysics, 674, A109, Spectropolarimetric investigation of magnetohydrodynamic wave modes in the photosphere: First results from PHI on board Solar Orbiter

Carlsson, Mats and **De Pontieu, Bart**: 2023, The Astrophysical Journal, 959, 87, An Optically Thin View of the Solar Chromosphere from Observations of the O I 1355 Å Spectral Line

Carlsson, Mats; Fletcher, Lyndsay; Allred, Joel; Heinzel, Petr; Kašparová, Jana; Kowalski, Adam; Mathioudakis, Mihalis; Reid, Aaron; and Simões, Paulo J. A.: 2023, Astronomy and Astrophysics, 673, A150, The F-CHROMA grid of 1D RADYN flare models

Cheng, X.; Xing, C.; **Aulanier, G.**; Solanki, S. K.; Peter, H.; and Ding, M. D.: 2023, The Astrophysical Journal, 954, L47, Deciphering the Slow-rise Precursor of a Major Coronal Mass Ejection

Cheng, X.; Priest, E. R.; Li, H. T.; Chen, J.; **Aulanier, G.**; Chitta, L. P.; Wang, Y. L.; Peter, H.; Zhu, X. S.; Xing, C.; Ding, M. D.; Solanki, S. K.; Berghmans, D.; Teriaca, L.; Aznar Cuadrado, R.; Zhukov, A. N.; Guo, Y.; Long, D.; Harra, L.; Smith, P. J.; Rodriguez, L.; Verbeeck, C.; Barczynski, K.; and Parenti, S.: 2023, Nature Communications, 14, 2107, Ultra-high-resolution observations of persistent null-point reconnection in the solar corona

Cho, Kyuhyoun; Testa, Paola; **De Pontieu, Bart;** and Polito, Vanessa: 2023, The Astrophysical Journal, 945, 143, A Statistical Study of IRIS Observational Signatures of Nanoflares and Nonthermal Particles

da Silva, Douglas Félix; Hui, Li; Simões, Paulo J. A.; Valio, Adriana; Costa, Joaquim E. R.; Hudson, Hugh S.; **Fletcher, Lyndsay**; Hayes, Laura A.; and Hannah, Iain G.: 2023, Monthly Notices of the Royal Astronomical Society, 525, 4143, Statistical analysis of the onset temperature of solar flares in 2010-2011

Díaz Baso, C. J.; Rouppe van der Voort, L.; de la Cruz Rodríguez, J.; and Leenaarts, J.: 2023, Astronomy and Astrophysics, 673, A35, Designing wavelength sampling for Fabry-P{\'e}rot observations. Information-based spectral sampling

Eklund, Henrik; Szydlarski, Mikołaj; and **Wedemeyer, Sven**: 2023, Astronomy and Astrophysics, 669, A105, Using the slope of the brightness temperature continuum as a diagnostic tool for solar ALMA observations

Eklund, Henrik: 2023, Astronomy and Astrophysics, 669, A106, Deep solar ALMA neural network estimator for image refinement and estimates of small-scale dynamics

Evans, Samuel; Oppenheim, Meers; **Martínez-Sykora, Juan**; Dimant, Yakov; and Xiao, Richard: 2023, The Astrophysical Journal, 949, 59, Multifluid Simulation of Solar Chromospheric Turbulence and Heating Due to Thermal Farley-Buneman Instability

Fremstad, D.; **Guevara Gómez, J. C.**; Hudson, H.; and Martínez Oliveros, J. C.: 2023, Astronomy and Astrophysics, 672, A32, An overview of HMI off-disk flare observations

Færder, Ø. H.; Nóbrega-Siverio, D.; and **Carlsson, M.**: 2023, Astronomy and Astrophysics, 675, A97, A comparative study of resistivity models for simulations of magnetic reconnection in the solar atmosphere

Guevara Gómez, Juan Camilo; Jafarzadeh, Shahin; Wedemeyer, Sven; Grant, Samuel D. T.; **Eklund, Henrik;** and **Szydlarski, Mikołaj**: 2023, Astronomy and Astrophysics, 671, A69, The Sun at millimeter wavelengths. IV. Magnetohydrodynamic waves in small-scale bright features

Hansteen, Viggo H.; Martinez-Sykora, Juan; Carlsson, Mats; De Pontieu, Bart; Gošić, Milan; and **Bose, Souvik**: 2023, The Astrophysical Journal, 944, 131, Numerical Simulations and Observations of Mg II in the Solar Chromosphere

He, Wen; Jing, Ju; Wang, Haimin; Nayak, Sushree S.; and **Prasad, Avijeet**: 2023, The Astrophysical Journal, 958, 90, Coronal Magnetic Field Extrapolation and Topological Analysis of Fine-scale Structures during Solar Flare Precursors

Herde, Vicki L.; Chamberlin, Phillip C.; Schmit, Don; **Bose, Souvik**; Daw, Adrian; Milligan, Ryan O.; and Polito, Vanessa: 2023, The Astrophysical Journal, 946, 103, Spicules in IRIS Mg II Observations: Automated Identification

Hotta, Hideyuki; Bekki, Yuto; Gizon, Laurent; **Noraz, Quentin**; and Rast, Mark: 2023, Space Science Reviews, 219, 77, Dynamics of Large-Scale Solar Flows

Howson, Thomas and **De Moortel, Ineke**: 2023, Physics, 5, 140, Heating and Cooling in Transversely Oscillating Coronal Loops Powered by Broadband, Multi-Directional Wave Drivers

Huang, Ziwen; Teriaca, L.; Aznar Cuadrado, R.; Chitta, L. P.; Mandal, S.; Peter, H.; Schühle, U.; Solanki, S. K.; Auchère, F.; Berghmans, D.; Buchlin, É.; **Carlsson, M.**; Fludra, A.; Fredvik, T.; Giunta, A.; Grundy, T.; Hassler, D.; Parenti, S.; and Plaschke, F.: 2023, Astronomy and Astrophysics, 673, A82, Imaging and spectroscopic observations of extreme-ultraviolet brightenings using EUI and SPICE on board Solar Orbiter

Janvier, M., and 58 colleagues (among them **Carlsson, M.** and **Fredvik, T**): 2023, Astronomy and Astrophysics, 677, A130, A multiple spacecraft detection of the 2 April 2022 M-class flare and filament eruption during the first close Solar Orbiter perihelion

Jess, David B.; Grant, Samuel D. T.; Bate, William; Liu, Jiajia; **Jafarzadeh, Shahin**; Keys, Peter H.; Vieira, Luís E. A.; Dal Lago, Alisson; Guarnieri, Fernando L.; Christian, Damian J.; Gilliam, Doug; and Banerjee, Dipankar: 2023, Solar Physics, 298, 146, The Fibre Resolved OpticAl and Near-Ultraviolet Czerny-Turner Imaging Spectropolarimeter (FRANCIS)

Jess, David B.; **Jafarzadeh, Shahin**; Keys, Peter H.; Stangalini, Marco; Verth, Gary; and Grant, Samuel D. T.: 2023, Living Reviews in Solar Physics, 20, 1, Waves in the lower solar atmosphere: the dawn of next-generation solar telescopes

Joshi, Reetika; Luna, Manuel; Schmieder, Brigitte; Moreno-Insertis, Fernando; and Chandra, Ramesh: 2023, Astronomy and Astrophysics, 672, A15, Interaction of solar jets with filaments: Triggering of large-amplitude filament oscillations

Kohutova, P.; Antolin, P.; Szydlarski, M.; and Carlsson, M.: 2023, Astronomy and Astrophysics, 676, A32, Damping of coronal oscillations in self-consistent 3D radiative magnetohydrodynamics simulations of the solar atmosphere

Krikova, K.; Pereira, T. M. D.; and **Rouppe van der Voort, L. H. M.**: 2023, Astronomy and Astrophysics, 677, A52, Formation of H-epsilon in the solar atmosphere

Kumar, Sanjay; **Prasad, Avijeet**; Nayak, Sushree S.; Agarwal, Satyam; and Bhattacharyya, R.: 2023, Plasma Physics and Controlled Fusion, 65, 085008, Magnetohydrodynamics simulation of magnetic flux rope formation in a quadrupolar magnetic field configuration

Kuznetsov, A. A.; Karakotov, R. R.; **Chandrashekhar, K.**; and Banerjee, D.: 2023, Research in Astronomy and Astrophysics, 23, 015006, X-Ray and Ultraviolet Flares on AT Microscopii Observed by AstroSat

Martínez-Sykora, Juan; de la Cruz Rodríguez, Jaime; Gošić, Milan; Sainz Dalda, Alberto; **Hansteen, Viggo H.**; and **De Pontieu, Bart**: 2023, The Astrophysical Journal, 943, L14, Chromospheric Heating from Local Magnetic Growth and Ambipolar Diffusion under Nonequilibrium Conditions

Martínez-Sykora, Juan; De Pontieu, Bart; Hansteen, Viggo H.; Testa, Paola; Wargnier, Q. M.; and **Szydlarski, Mikolaj**: 2023, The Astrophysical Journal, 949, 112, The Impact of Multifluid Effects in the Solar Chromosphere on the Ponderomotive Force under SE and NEQ Ionization Conditions

Millar, David C. L.; **Fletcher, Lyndsay**; and Joshi, Jayant: 2023, Monthly Notices of the Royal Astronomical Society, Intensity and velocity oscillations in a flaring active region

Moe, Thore E.; Pereira, Tiago M. D.; Calvo, Flavio; and Leenaarts, Jorrit: 2023, Astronomy and Astrophysics, 675, A130, Shape-based clustering of synthetic Stokes profiles using k-means and k-Shape

Mulay, Sargam M.; **Fletcher, Lyndsay**; Hudson, Hugh; and Labrosse, Nicolas: 2023, Monthly Notices of the Royal Astronomical Society, 526, 4755, Behaviour of molecular hydrogen emission in three solar flares

Murabito, M.; Ermolli, I.; Chatzistergos, T.; **Jafarzadeh, S.**; Giorgi, F.; and **Rouppe van der Voort, L.**: 2023, The Astrophysical Journal, 947, 18, Investigating the Effect of Solar Ambient and Data Characteristics on Ca II K Observations and Line Profile Measurements

Nóbrega-Siverio, D.; Moreno-Insertis, F.; Galsgaard, K.; Krikova, K.; **Rouppe van der Voort, L.; Joshi, R.**; and Madjarska, M. S.: 2023, The Astrophysical Journal, 958, L38, Deciphering Solar Coronal Heating: Energizing Small-scale Loops through Surface Convection

Oberoi, Divya; Bisoi, Susanta Kumar; Sasikumar Raja, K.; Kansabanik, Devojyoti; **Mohan, Atul**; Mondal, Surajit; and Sharma, Rohit: 2023, Journal of Astrophysics and Astronomy, 44, 40, Preparing for solar and heliospheric science with the SKAO: An Indian perspective

Omang, M.; Hauge, K. O.; and **Trulsen, J. K.**: 2023, Shock Waves, Combustion models for shock-induced cloud ignition of aluminium particles using smoothed particle hydrodynamics

Pandit, Sneha; Wedemeyer, Sven; Carlsson, Mats; and **Szydlarski, Mikołaj**: 2023, Astronomy and Astrophysics, 673, A137, Comparison of chromospheric diagnostics in a 3D model atmosphere. H{\ensuremath{\alpha}} linewidth and millimetre continua

Panesar, Navdeep K.; **Hansteen, Viggo H.**; Tiwari, Sanjiv K.; Cheung, Mark C. M.; Berghmans, David; and Müller, Daniel: 2023, The Astrophysical Journal, 943, 24, Solar Orbiter and SDO Observations, and a Bifrost Magnetohydrodynamic Simulation of Small-scale Coronal Jets

Parto, Tahere; Dehghani, Shahrzad; Javadi, Atefeh; Saremi, Elham; van Loon, Jacco Th.; Khosroshahi, Habib G.; McDonald, Iain; Mirtorabi, Mohammad T.; Navabi, Mahdieh; and **Saberi, Maryam**: 2023, The Astrophysical Journal, 942, 33, The Isaac Newton Telescope Monitoring Survey of Local Group Dwarf Galaxies. V. The Star Formation History of Sagittarius Dwarf Irregular Galaxy Derived from Long-period Variable Stars

Pietrow, A. G. M.; Kiselman, D.; Andriienko, O.; Petit dit de la Roche, D. J. M.; **Díaz Baso, C. J.**; and Calvo, F.: 2023, Astronomy and Astrophysics, 671, A130, Center-to-limb variation of spectral lines and continua observed with SST/CRISP and SST/CHROMIS

Poirier, Nicolas; Réville, Victor; Rouillard, Alexis P.; Kouloumvakos, Athanasios; and Valette, Emeline: 2023, Astronomy and Astrophysics, 677, A108, Variability of the slow solar wind: New insights from modelling and PSP-WISPR observations

Prasad, A.; Kumar, S.; Sterling, A. C.; Moore, R. L.; **Aulanier, G.**; Bhattacharyya, R.; and Hu, Q.: 2023, Astronomy and Astrophysics, 677, A43, Formation of an observed eruptive flux rope above the torus instability threshold through tether-cutting magnetic reconnection

Rackham, Benjamin V., and 60 colleagues (among them **Wedemeyer, Sven**): 2023, RAS Techniques and Instruments, 2, 148, The effect of stellar contamination on low-resolution transmission spectroscopy: needs identified by NASA's Exoplanet Exploration Program Study Analysis Group 21

Reid, Hamish A. S., and 59 colleagues (among them **Fletcher, Lyndsay**): 2023, Aerospace, 10, 1034, The Solar Particle Acceleration Radiation and Kinetics (SPARK) Mission Concept

Réville, Victor; **Poirier, Nicolas**; Kouloumvakos, Athanasios; Rouillard, Alexis Paul; Ferreira Pinto, Rui; Fargette, Naïs; Indurain, Mikel; Fournon, Raphaël; James, Théo; Pobeda, Raphaël; and Scoul, Cyril: 2023, Journal of Space Weather and Space Climate, 13, 11, HelioCast: heliospheric forecasting based on white-light observations of the solar corona

Robinson, Rebecca A.; Aulanier, Guillaume; and **Carlsson, Mats**: 2023, Astronomy and Astrophysics, 673, A79, Quiet Sun flux rope formation via incomplete Taylor relaxation

Robinson, Rebecca A. and **Carlsson, Mats**: 2023, Astronomy and Astrophysics, 677, A36, Tracing the signatures of a quiet Sun nanoflare

Rouppe van der Voort, Luc H. M.; van Noort, Michiel; and de la Cruz Rodríguez, Jaime: 2023, Astronomy and Astrophysics, 673, A11, Ultra-high-resolution observations of plasmoid-mediated magnetic reconnection in the deep solar atmosphere

Sahu, Suraj; Joshi, Bhuwan; **Prasad, Avijeet**; and Cho, Kyung-Suk: 2023, The Astrophysical Journal, 943, 70, Evolution of Magnetic Fields and Energy Release Processes during Homologous Eruptive Flares

Sainz Dalda, Alberto and **De Pontieu, Bart**: 2023, Frontiers in Astronomy and Space Sciences, 10, 1133429, Chromospheric thermodynamic conditions from inversions of complex Mg II h & k profiles observed in flares

Sainz Dalda, Alberto and **De Pontieu, Bart**: 2023, The Astrophysical Journal, 944, 118, Recovering Thermodynamics from Spectral Profiles Observed by IRIS. (II). Improved Calculation of the Uncertainties Based on Monte Carlo Experiments

Sowmya, K.; Shapiro, A. I.; **Rouppe van der Voort, L. H. M.**; Krivova, N. A.; and Solanki, S. K.: 2023, The Astrophysical Journal, 956, L10, Modeling Stellar Ca II H and K Emission Variations: Spot Contribution to the S-index

Testa, Paola; **Martínez-Sykora, Juan**; and **De Pontieu, Bart**: 2023, The Astrophysical Journal, 944, 117, Coronal Abundances in an Active Region: Evolution and Underlying Chromospheric and Transition Region Properties

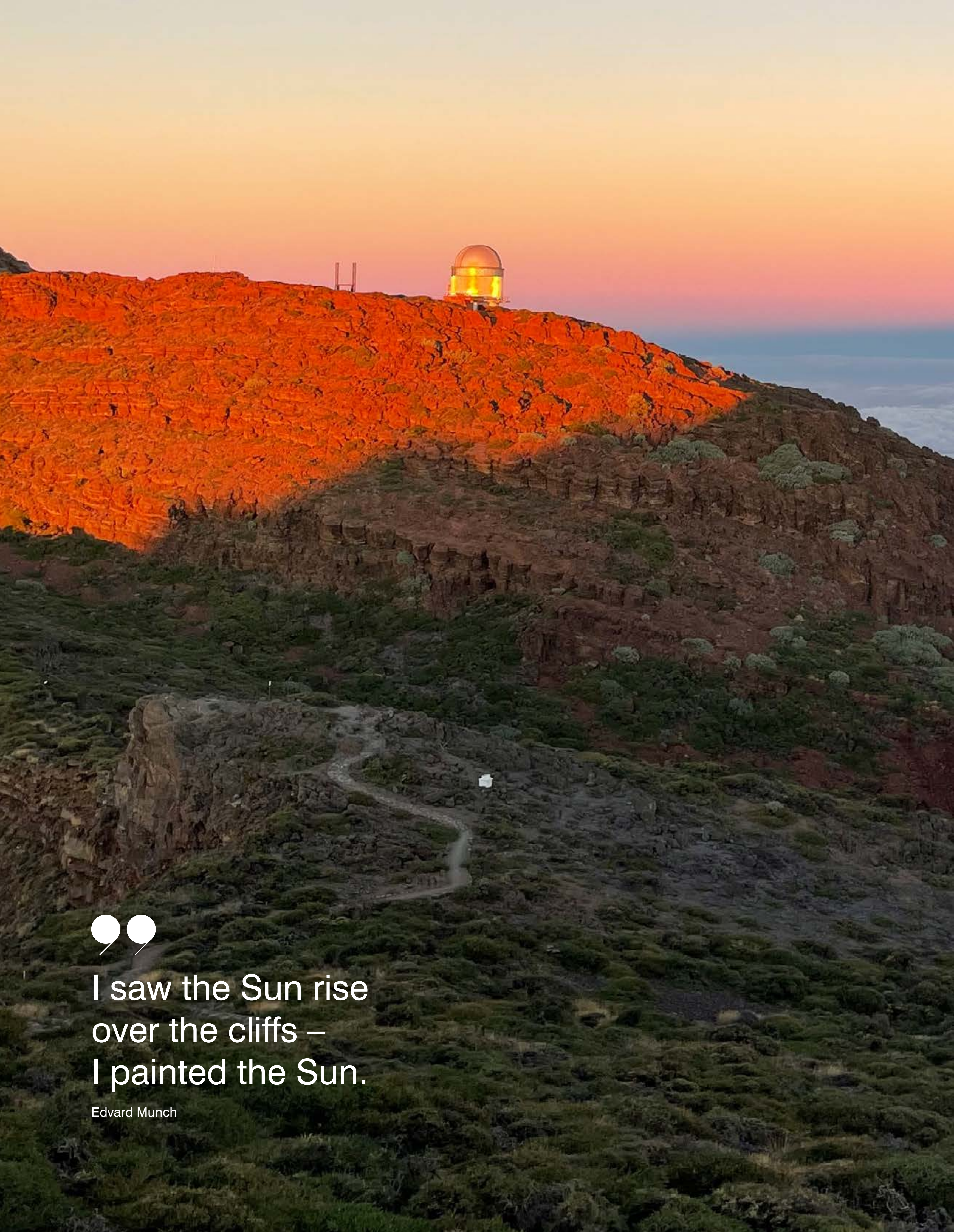
Testa, Paola; **Bakke, Helle; Rouppe van der Voort, Luc**; and **De Pontieu, Bart**: 2023, The Astrophysical Journal, 956, 85, High-resolution Observations of the Low Atmospheric Response to Small Coronal Heating Events in an Active Region Core

Tziotziou, K.; Scullion, E.; Shelyag, S.; Steiner, O.; Khomenko, E.; Tsiropoula, G.; Canivete Cuissa, J. R.; **Wedemeyer, S.**; Kontogiannis, I.; Yadav, N.; Kitiashvili, I. N.; Skirvin, S. J.; Dakanalis, I.; Kosovichev, A. G.; and Fedun, V.: 2023, Space Science Reviews, 219, 1, Vortex Motions in the Solar Atmosphere

Udnæs, Elias R. and **Pereira, Tiago M. D.**: 2023, Astronomy and Astrophysics, 675, A127, Irregular grids for 3D NLTE radiative transfer in stellar atmospheres

Wargnier, Q. M.; **Martínez-Sykora, J.; Hansteen, V. H.**; and **De Pontieu, B.**: 2023, The Astrophysical Journal, 946, 115, Multi-fluid Simulations of Upper-chromospheric Magnetic Reconnection with Helium-Hydrogen Mixture

Yardley, Stephanie L., and 78 colleagues (among them **Carlsson, Mats, Fredvik, Terje**): 2023, The Astrophysical Journal Supplement Series, 267, 11, Slow Solar Wind Connection Science during Solar Orbiter's First Close Perihelion Passage



> I saw the Sun rise
> over the cliffs –
> I painted the Sun.

Edvard Munch

Credit: Aditi Bhatnagar