



Annual report 2021

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2021

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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 Hadeland hotel
November 25-26 2021. Credit: Private

From the Director

This is the fourth 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.

The Covid-19 pandemic affected all our lives also in 2021. For the activities at RoCS, the pandemic had a strong influence – we had practically no international visitors and all conference attendances were through digital means. Default was working from home office, but we were also allowed to come to the University premises for parts of the working week. During the summer, we got more and more optimistic with vaccinations reaching more than 90% of the adult population and Norway reopened completely on September 25th. We were able to welcome new people, also from

abroad, and managed to organise a retreat in a hotel outside Oslo, November 24-25. Hopes were of course crushed with the new omicron variant hitting the country early December, resulting in a new lockdown and home-office. At the time of writing, Norway has just opened up again since the omicron variant has turned out to be less serious (especially when the vaccination level is high) – hospitalization levels have not gone up in spite of a very large increase in infections. We are slowly moving back to pre-Covid conditions and are very optimistic (again).

The topic of this year's retreat was “Working culture” and thus less focused on science than previous retreats. We had professional leadership from Mobilize Strategy Consulting through Marcus Trøite Amundsen and Are Syversen, who composed a two-day program with emphasis on group discussions but also with lectures giving background information, food for thought and research results. Topics ranged from “Psychological Safety” and “Organisational culture” to “Mastery and Cooperative Culture” and had been preceded by in-depth interviews of ten RoCS members. Quite unknown



This is for the people of the Sun.

Zack de la Rocha (Rage Against the Machine, 1996)

territory for most of us but the discussions were very vivid and participation wholehearted. Unfortunately, the follow-up has been difficult with the lock-down that happened almost immediately after the retreat. We are not giving up and many processes have been started to build on the momentum such a retreat gives.

RoCS has more or less reached a balance between new people moving in and people finishing their contracts. In 2021 we welcomed Guillaume Aulanier as new adjunct professor, two new postdocs on the WholeSun project (Sondre Vik Furuset and Avijeet Prasad) three new PhD students (Michael Haahr, Mats Ola Sand and Eilif Sommer Øyre) and five new master students (Isak Aaby, Stian Aanerud, Edvarda Harnes, Mats Kirkaune and Jonas Ringdalen Thrane). We also got a new collaboration established with the University of St. Andrews with a contract signed for shared PhD students. The first out is Elisabeth Enerhaug who will spend two years at St. Andrews before coming to Oslo for the last 1.5 years. As well as some new coming in we also have people moving out. Daniel Nóbrega Siverio moved to the IAC on Tenerife, Petra Kohutova got a prestigious “Researcher project for young talents” from the Research Council of Norway and will stay with RoCS for four more years. Vasco

Henriques and Shahin Jafarzadeh finished their researcher contracts as Sven Wedemeyer's ERC consolidator grant finished in 2021. Henrik Eklund, Souvik Bose and Ainar Drews defended their PhD theses and Bruce Arnold Chappell, Ida Risnes Hansen and Mats Ola Sand finished their Master's.

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. You can read more about this important activity on page 24.

The activity has been high in 2021 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 papers published in refereed journals in Appendix 2. We published 50 papers in refereed journals in 2021¹.

The International Rosseland Visitor Programme, amputated as it was in 2021, is covered in Section 3 and we continue the tradition from 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 2021 we were a total of 65 persons of 21 nationalities from four continents at RoCS.

At the time of writing, we are back in the offices and infection rates have started to go down. All covid restrictions have been lifted and international travel has started. We have an international group working on simulations and 3D radiative transfer in the RoCS meeting rooms and the Multi-slit Solar Explorer (MUSE) has just been selected as NASA's first solar medium class explorer mission. Launch is planned in 2026. MUSE has a strong RoCS involvement with Bart De Pontieu as principal investigator and three more RoCS members as co-investigators. The future may look bright after all. Stay safe and hope to meet you all in person soon.

March 2022

Mats Carlsson,
Director of RoCS

1) Following the reporting practice in the Norwegian University system, we report by year of the first publication of the paper (which may be on-line by the journal). Some papers with publication year of the journal issue in early 2021 were thus listed in the previous annual report.

A night sky with the Milky Way galaxy visible, a tall observation tower, and two people standing in a doorway.

2021 Activities by theme

Simulations

The year 2021 saw strides in the “development” and “cleaning up” of the Bifrost, Ebysus, RH, and Dispatch codes, but also and not least in their utilization to produce new simulations. The major aim of these simulations has been to produce exciting science, but they have also been a vital factor in making synthetic data used to model how the MUSE mission data can be utilized to understand the workings of the Sun.

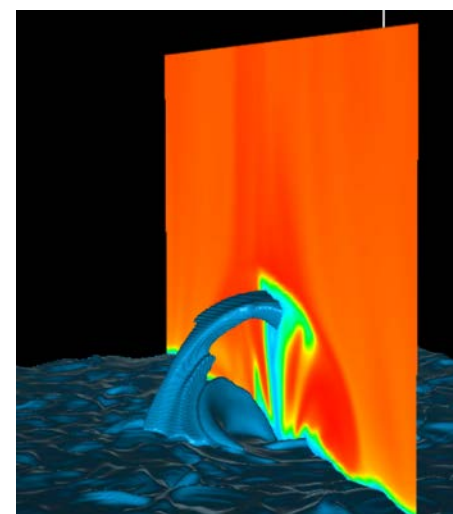
The use of “forward modeling” to test various physical scenarios and then producing synthetic observables such as spectral line intensities, Doppler velocities and line widths, as well as the detailed shapes of the line profiles, and this as would be seen by a given telescope is an extremely useful technique. These “observations” can be used to plan how observations will be carried out, how data are to be handled and viewed, but also when proposing new instrumentation. The latter to answer questions such as “Can the proposed instruments data actually be used as promised?”

A vivid example is found in the Multi-slit Solar Explorer (MUSE), a mission proposed to NASA as a Medium-class Explorer, that aims to overcome shortcomings of single-slit spectrometers. MUSE applies an innovative approach using multiple slits and several different and narrow EUV spectral bands in order to cover a large spatial area at high cadence. This will offer novel observations of the solar corona, and when coupled with state-of-the-art numerical modeling, will provide unprecedented constraints on the physical mechanisms driving coronal heating and space weather events. The science goals of MUSE are to determine the mechanisms that heat the corona and drive the solar wind and to understand the origin and evolution of the unstable solar atmosphere, while also investigating fundamental physical plasma processes

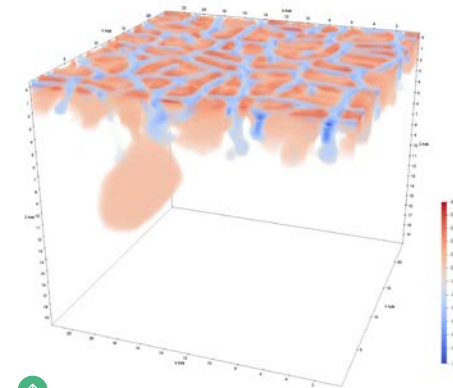
such as magnetic reconnection. Bifrost numerical models will be a great asset in understanding the data produced, but in 2021 they were also instrumental in winning the selection of MUSE by NASA, which now is scheduled for launch in 2026. In the paper “Probing the physics of the solar atmosphere with the Multi-slit Solar Explorer (MUSE): I. Coronal Heating” by the MUSE team (2021, accepted by ApJ) several possible coronal heating mechanisms were modeled using Bifrost and other codes and then examined as if observed by MUSE. One example, investigating the observational signature of coronal heating through the braiding of magnetic field lines is shown here. Such braiding leads to small scale heating events known as “nanoflares”, that have been quite difficult to find observationally with instruments currently in use. However, the numerical work done convinced the NASA review panel and was an important factor leading to MUSE being chosen as the first solar MidEx (“Medium Explorer”) project.

It is the interplay of coronal plasma with the magnetic field that presents the biggest challenges to our understanding of the outer layers of the Sun. Amongst coronal structures that are not well understood are Coronal Bright Points (CBPs), which appear as a fundamental building block in the solar atmosphere. Since the 90s, they have been considered to be at the large-end of coronal heating events.

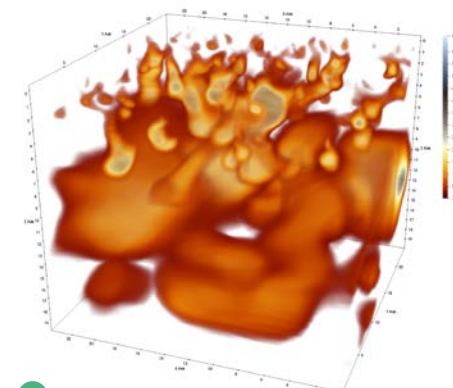
CBPs are scattered over the entire solar disc and consist of small-scale loops that confine plasma heated up to several million degrees, with conspicuous emission in extreme ultraviolet and X-rays, and that are even present when the Sun is at its minimum of activity. From the theoretical perspective, CBPs have so far been studied from analytical or idealized numerical models, thus lacking physical mechanisms such as radiation transfer or optically thin losses, which are indispensable to understand and explain the emission at different wavelengths, and, moreover, not reflecting new observational findings, such as the appearance



Visualization of a 3D Coronal Bright Point simulation. The figure contains a 2D cut of the temperature together with an isosurface of chromospheric density, showing the rise of a filament within the CBP.



Visualization of a 3D Coronal. Bright Point simulation. The figure contains a 2D cut of the temperature together with an isosurface of chromospheric density, showing the rise of a filament within the Coronal Bright Point.



Surface velocities (left panel) and kinetic energy density (density times velocity squared) for a of a “deep run” extending to 20 Mm below the solar surface. In the outer solar envelope just below the surface energy is carried by convection; hot bubbles of gas rise to the surface, release their energy as radiation and then fall again. The goal of the models shown here is to introduce magnetic fields of various configurations at the bottom boundary, at 20 Mm depth, and follow their interactions with convection and their emergence into the corona.

of CBPs during the emergence of magnetized plasma from the solar interior. Our current focus is modeling CBPs using the Bifrost code. This

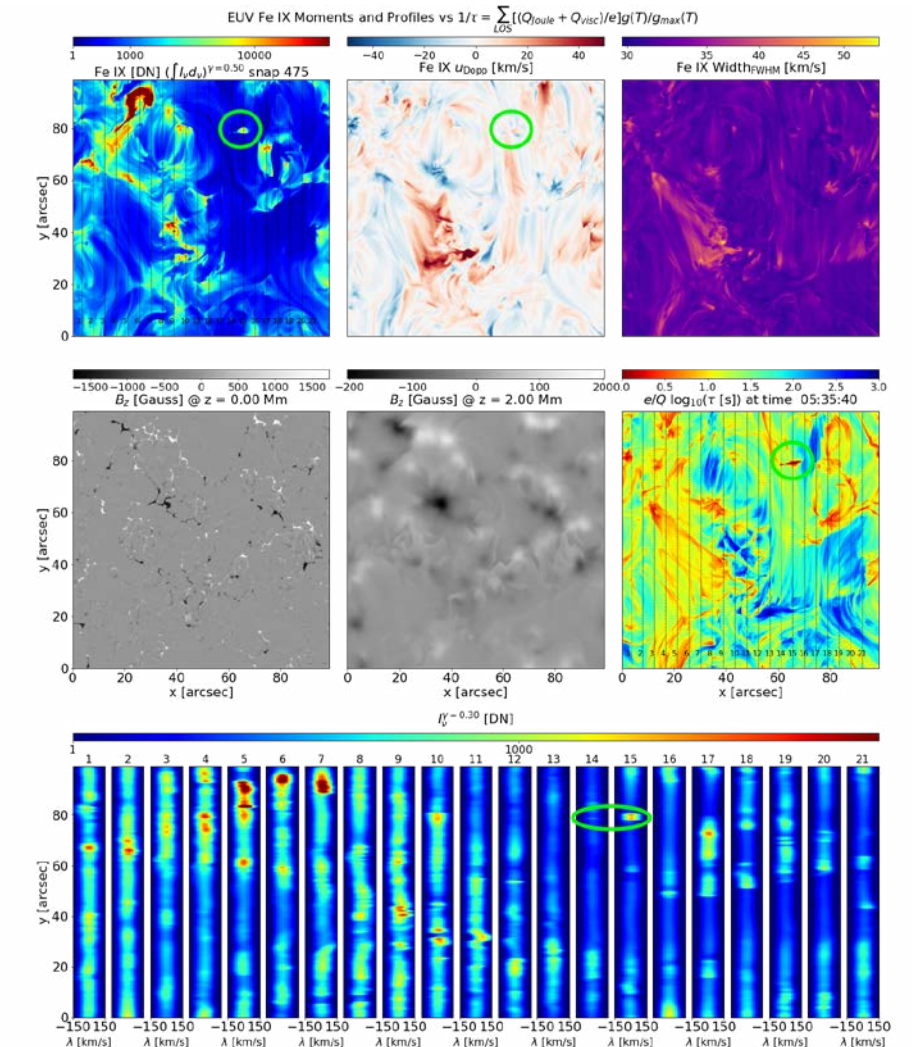
way, we can be in the unique position to self-consistently couple the different layers of the solar atmosphere, coping with several physical mechanisms that have not been previously included to study CBPs.

Flux emergence is another topic that has received much attention and will continue to receive attention in the near future. In

previous years, Bifrost models have been utilized to study the details of small-scale interactions of newly-emerging fields with the already-present ambient coronal magnetic field. But there are also important questions related to the geometry of the field before it rises. Not least how the workings of the solar dynamo, both the global dynamo that produces the 22-year cycle and is responsible for sunspots, and the smaller-scale local, or surface, dynamo impact coronal heating and topology. In order to address such questions some connection must be made between global

“sun in a box” dynamo models that cover the entire solar sphere, but at the cost of low resolution and inability to correctly model surface effects, and local detailed “box in the sun” models that faithfully reproduce the physics of the solar surface and outer atmosphere. There is a gap between these that needs to be filled, and in 2021 work has proceeded to extend Bifrost’s “box in the sun” models to 20 Mm below the solar surface, some 10 Mm more than has been achieved before.

Viggo Hansteen



MUSE synthetic observables, from a Bifrost 3D MHD model diagnosing heating through braiding. The upper three panels show the intensity, line shift, line width of the Fe XV 284 Å line, while the second row of panels shows the photospheric field, the field 2 Mm above the photosphere, and a measure of the heating rate in the temperature range where this line is formed. The upper left and lower right panels also show the potential location of 21 of the 37 MUSE slits for a “sit and stare” observation: The bottom row of panels show the line profiles of the Fe XV line at these locations. Taken from “Probing the physics of the solar atmosphere with the Multi-slit Solar Explorer (MUSE): I. Coronal Heating” by the MUSE team (2021, accepted by ApJ).

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 that gives us observing time at the SST. The observing time is usually divided over three campaigns spread over the observing season. In 2021, these campaigns were in May, July/August, and September. Travel for the first campaign was still impossible for us due to Covid travel restrictions. Fortunately, we could still have our observations done through service mode observations by Oleksii Andriienko from Stockholm. Coordination with IRIS and target selection could be done from our home offices and thanks to the excellent internet connection to the observatory, we managed to make basic assessments of the data quality and refine our observing strategy.

Back at the SST again

For the three-week campaign that started in July, we could finally travel again to the observatory and conduct the observations ourselves. Ana Belén Grifón Marín and Souvik Bose were joined at the SST by Daniel Nóbrega Siverio, who is now a postdoc at the IAC in Tenerife and still a guest researcher at RoCS. The Sun is

clearly getting more active again after the solar minimum of 2019/2020 and we get more opportunities to observe active regions and sunspots. A particularly nice observation of a complex active region is shown in the figure at right which was recorded during a brief moment of extremely good seeing conditions. The Fried parameter r_0 , a statistical measure of the seeing quality, was measured to be almost 70 cm. This is just short of the 1-meter SST aperture, and indicative of the extremely good conditions. We are normally already very happy when we measure Fried parameter values around 20 cm. The amount of fine detail in and around the pore is striking and this image certainly ranks among the sharpest images of the solar atmosphere.

We further managed to acquire a good time series of observations of Ellerman bombs in a quiet Sun region in coordination with IRIS, and an 11-min sequence of a coronal bright point during very good seeing conditions. The coronal bright point was first identified in near-real-time coronal images from SDO before it could be targeted with SST. We acquired data

at the root of the coronal bright point: from CRISP magnetic field data in the photosphere and from CHROMIS H-beta spectral line scans to study spicule dynamics in the chromosphere.

Volcanic eruption

The campaign in September turned out very different from what we had imagined. The day after our arrival, the Cumbre Vieja volcano, located in the Southern part of La Palma, started to erupt. A new volcanic mouth opened in the Aridane valley, about 7 km from the city of Los Llanos, and about 16 km from the observatory. There was some geological unrest in the days before the eruption, but we were still surprised that a volcanic eruption would actually happen and be visible from the site where we were working. During the first days, the wind blew from the north and basically prevented the volcanic ashes from reaching the observatory. However, when the wind turned to come from the south a few days later, the air around the telescopes got filled with ash particles and it became clear that we could not continue observing. It was better to stop the campaign and leave the



Photo: Luc Rouppe van der Voort

Postdoctoral researcher Chandrashekhhar Kalugodu watching the volcanic plume from the platform on the SST tower in the morning after the start of the eruption.

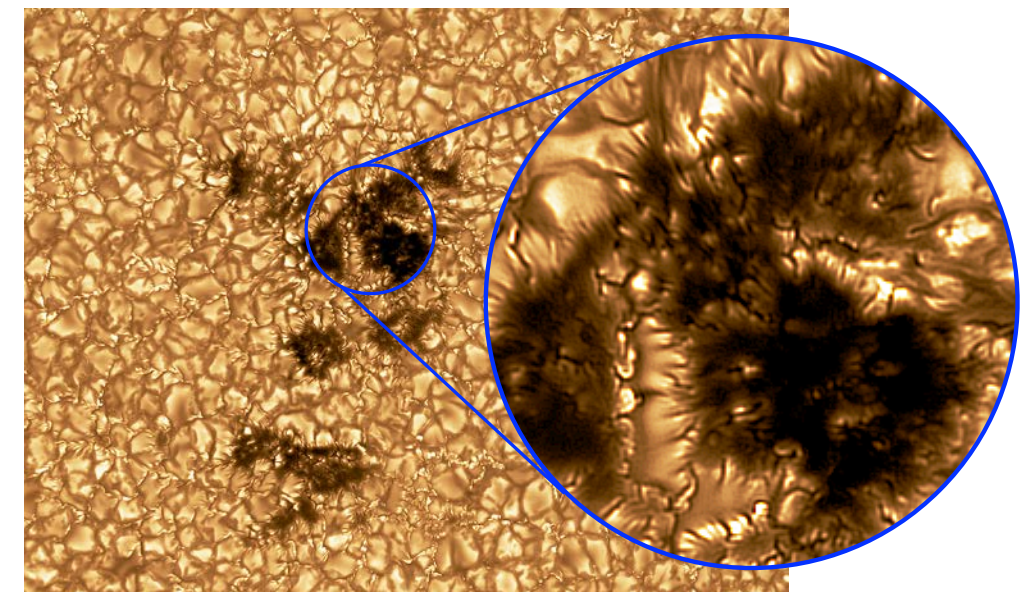


island. The eruption lasted for almost 3 months and ended just before Christmas. It broke many records of historic eruptions on La Palma, for example in terms of duration, lava and ash production and damage to properties and infrastructure. It has become a disaster with enormous impact on the island.

Two PhD theses

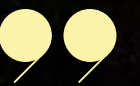
This year we celebrated the successful completion and defense of the PhD theses of Ainar Drews and Souvik Bose. Ainar worked on microjets in the penumbrae of sunspots and Souvik worked on the dynamics of spicules and mass flows in the solar atmosphere. Both PhD theses were based on analysis of co-aligned data sets from SST and IRIS.

Luc Rouppe van der Voort



Active region 12846 observed in the CHROMIS wideband channel on 25 July 2021. The image resolves small details down to the diffraction limit of the SST, which is close to 60 km for the wavelength of 395 nm.





The sun has body, form,
motion, radiance, heat,
and procreative power,
and these things flow
from the sun without
diminishing it.

Leonardo da Vinci

Science with ALMA

In 2021, both the Solar ALMA Science Archive (SALSA) and the first EMISSA stellar catalogue were produced, providing access to science-ready data for scientists interested in solar and stellar observations with ALMA.

Overview

While the pandemic still impacted observations with ALMA in 2021, new results were obtained based on archival data and numerical simulations. Major milestones of 2021 were the end of the ERC-funded SolarALMA¹ project with the release of the Solar ALMA Science Archive (SALSA) as a major product and the first EMISSA stellar catalogue. Also, Henrik Eklund successfully defended his PhD thesis with the title “*Investigating dynamic small-scale events in the Sun with the Atacama Large Millimeter/sub-millimeter Array*”.

The Solar ALMA project

After a final review of the Solar ALMA Pipeline (SoAP), resulting in the first complete version 1.0 (Szydlarski), the systematic processing of data sets obtained from ALMA observations of the Sun was continued. A new standard for the resulting science-ready time series of ALMA maps including a careful design of the FITS headers and extension data was produced with the aim to make it compatible with other current and future solar data products. A final number of 26 data sets with corresponding single-dish images of the whole Sun were collected in the first complete version of the Solar ALMA Science Archive (SALSA, Henriques et al. 2021). SALSA was made public online (<http://sdc.uio.no/salsa/>) and announced on various channels and

conferences, including the European Solar Physics Meeting in September 2021. SALSA is accompanied by the Solar ALMA Library of Auxiliary Tools (SALAT), which makes working with SALSA data straightforward.

Impact of instrumental and seeing effects

Adequately accounting for the influence of instrumental properties and observing conditions is essential for the detailed interpretation of an observation, especially when done in comparison with numerical simulations. For that reason, the instrumental properties of ALMA were simulated and applied to the millimetre maps produced for a Bifrost simulation of an enhanced network region at high cadence. The resulting data allowed for studying which properties of the small-scale structure of the solar chromosphere can be recovered in view of instrumental limitations. In particular, it was investigated how to correct for instrumental effects in order to derive more precise amplitudes of propagating shock waves, which is essential for determining the carried energy and thus the potential contributions to heating the solar chromosphere (Eklund et al. 2021).

The development of the Solar ALMA Simulator as part of the ongoing ALMA development study continued. A major

result in 2021 was the insight that day-time observing conditions are not well characterised by the precipitable water vapour (PWV), which is otherwise used as a key indicator, but rather by the more complex properties of phase variations across the antenna array.

Small-scale dynamics of the solar chromosphere

Solar ALMA observations have been analysed in comparison to data from the Solar Dynamics Observatory (SDO) and a 3D MHD simulation with Bifrost. A particular focus was on waves and oscillations as they are among the prime candidates for the transport of energy and momentum to the upper solar atmosphere. Automatic feature-detection algorithms resulted in a large number of detected (brightening) events, for which lifetimes, velocities and sizes and their temporal variations were determined. Next to the detection of propagating (non-magnetic) shock waves, indications of several other wave modes were found. As expected, the mix of events that seem to carry enough energy to heat the solar chromosphere, varies between different types of regions with different magnetic environments on the Sun (Jafarzadeh et al. 2021). Enhanced power in the frequency range 3-5 mHz was found for the most magnetically-quietest datasets, whereas it was suppressed in data sets for regions



Main results of the SolarALMA project: SoAP - SALSA - SALAT with a screenshot of the SALSA webpage.
Background: ALMA on the Chajnantor plateau (ESO/B. Tafreshi)



with stronger magnetic fields. These findings also have important implications for the formation-height ranges of the different ALMA bands in the solar atmosphere. In addition, transverse MHD waves were detected in fibrillar structures. Here, ALMA high temporal resolution enables estimates of the energy that can be carried by transverse oscillations.

The solar-stellar connection

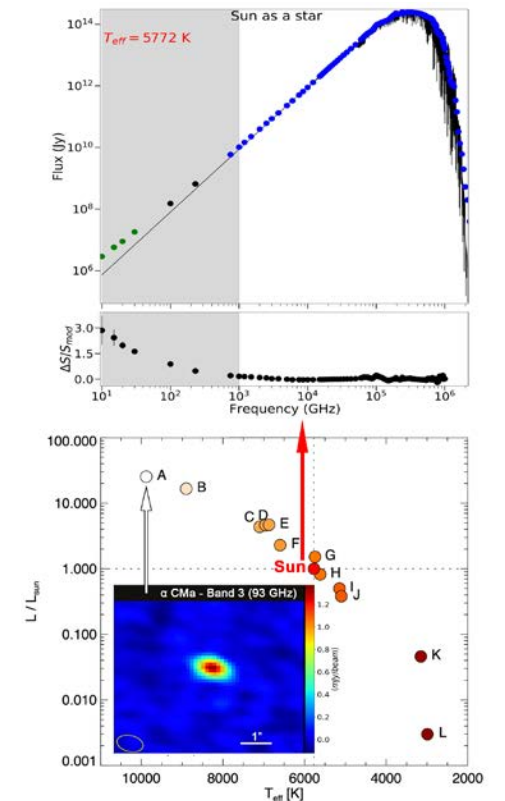
A major milestone of the EMISSA project was the compilation of the first sample of multi-wavelength observations that cover an extended wavelength range from the radio to the ultraviolet range, including the millimetre range as a novel tool for probing stellar chromospheres. As there are only a few ALMA observations of main-sequence stars available so far, the initial catalogue comprises twelve stars plus the Sun-as-a-star as a fundamental reference. The observationally-derived spectral energy distributions were then compared to photospheric 1D models produced with the PHOENIX code. The brightness temperature excess that was found for the solar-like and cooler stars in the sample provides convincing evidence for the existence of hot chromospheres

in these stars, whereas no signs of a chromosphere were found for the hotter stars. These first results, which have been summarised in a publication (Mohan et al. 2021), lay the foundation for future observations with the aim of extending the stellar sample.

In December, an observation of an active M-type dwarf star was successfully carried out with the Giant Metrewave Radio Telescope (GMRT). Any detected flare, should it be revealed during the ongoing data analysis, would provide a complementary view on flares on the Sun.

ALMA observations of asymptotic giant branch (AGB) stars were analysed regarding the contribution of evolved stars on the Galactic fluorine budget, for which follow-up observations in ALMA Cycle 8 in 2022 were granted. In parallel, the role of internal UV radiation on the HCN isotopologue ratio was investigated using ALMA and APEX observations of H12CN and H13CN lines for two UV active AGB stars.

Sven Wedemeyer



First results of the EMISSA project (Mohan et al. 2021): Top: The spectral energy distribution of the Sun as a star and the chromospheric excess, indicating the presence of a chromosphere. Bottom: Hertzsprung-Russell Diagram for the stellar sample including the Sun. The inset shows a millimetre map of a CMa observed with ALMA in Band 3.



¹) The SolarALMA project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (grant agreement No. 682462).

Code Development

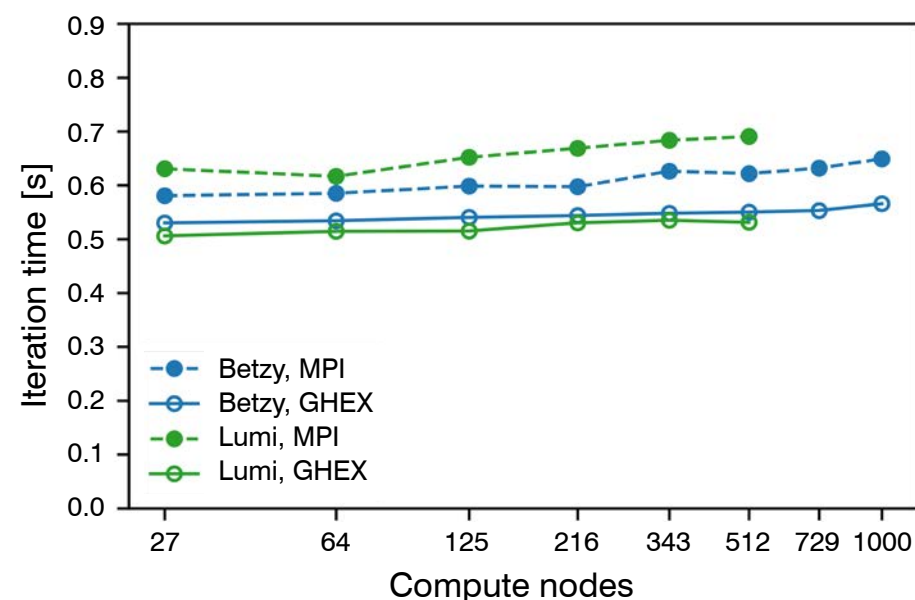
The work effort initiated in 2020 on the architecture for the stable and safe code development has come to fruition in 2021. Continuous integration is now an integral part of the code development at RoCS and has saved significant time and frustration. In 2021, we have had the stable base to accelerate the development of much more ambitious projects within RoCS and WholeSun.

New architectures and accelerators

Bifrost is still the workhorse for our simulations of the solar atmosphere. Therefore, there has been a large effort on running Bifrost as efficiently as possible on new architectures.

Bifrost and Dispatch have been tested on the new Lumi-C machine installed in Finland. Lumi-C is funded by the pan-European EuroHPC and is a pre-exascale machine, eventually having a peak performance of half an exaflop when fully installed. We were part of the pre-launch phase that gave us a possibility to evolve both Bifrost and Dispatch to work as efficiently as possible. This early access made it possible to work with

experts on the necessary modifications to reach the full performance. We have been collaborating with experts porting Bifrost and Dispatch to utilise the Generic exascale-ready library for halo-exchange (GHEX), available both on LUMI-C and the Norwegian HPC machine Betzy. On both machines, we reach a 20% speedup with the new GHEX implementation because there is now almost perfect weak scaling, which is not possible using pure MPI for communication. The weak scaling is close to perfect even up to roughly 30% of the present size of LUMI-C and the full size of Betzy. The full size of Betzy is 1024 nodes, corresponding to more than 128000 compute cores.



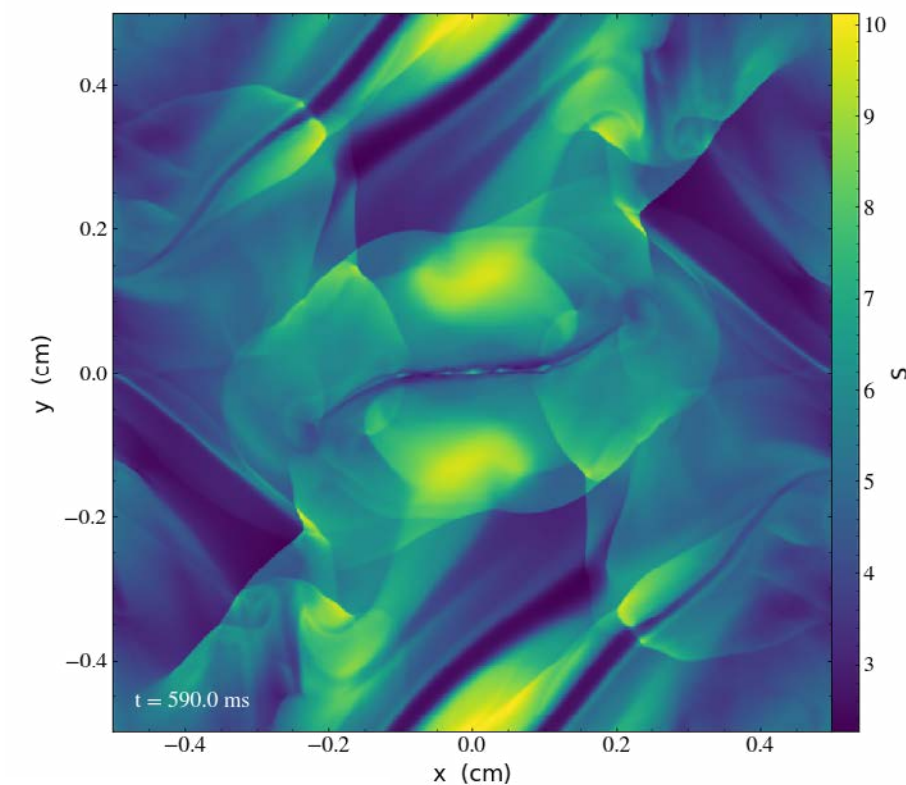
Expansion and stability of Bifrost

Not all of our physics modules have been ported from Bifrost to DISPATCH, we are still developing Bifrost to cope with the extreme conditions present in simulations of the active Sun. The developments during 2021 have been to improve our implementation of a hydrostatic boundary condition and a condition at the coronal boundary of our computational boxes, where large amplitude waves produced by the active Sun should be able to pass out of the box without reflecting back into the computational volume. The boundary conditions at the convection zone boundary are now able to handle conditions at much greater depth, so we can run simulation boxes that can handle super granular scales.

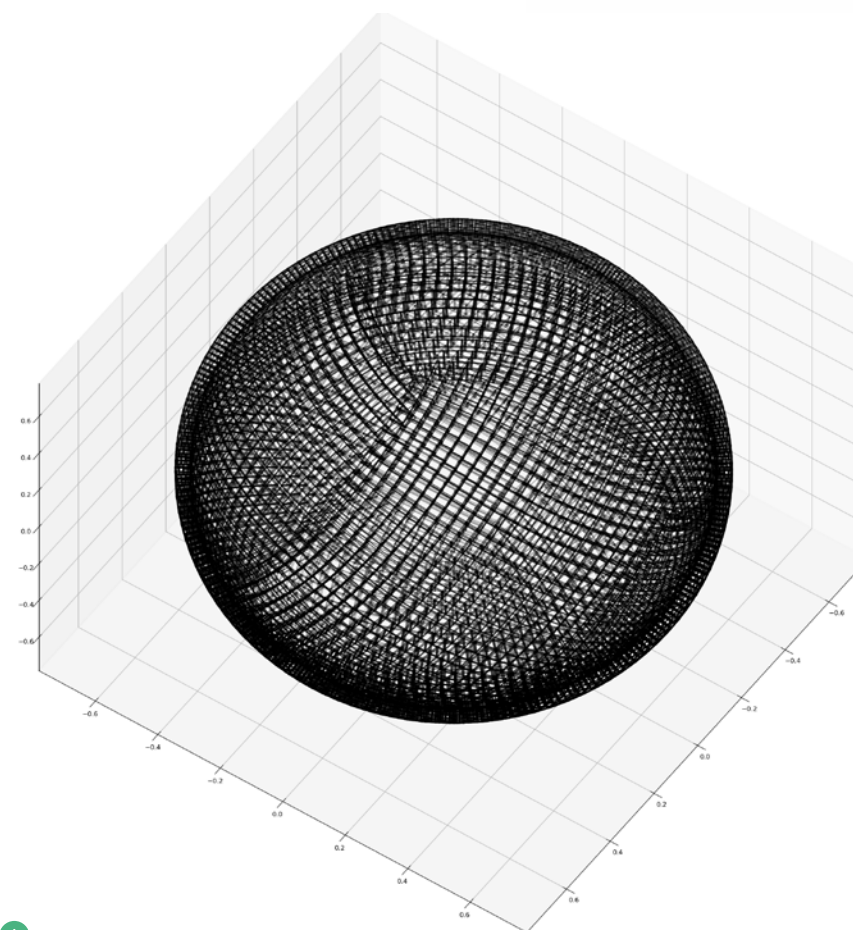
The EU-funded project 'The whole Sun' has the aim of developing a code that can simulate the solar dynamo and interface with codes being able to simulate the solar atmosphere. The physics that are important in the deep convection zone are very different from the physics which are important at the solar surface layers. So far, these codes have been quite far apart, and one of the steps in the Whole Sun project is to provide results from a benchmark simulation of the solar convection zone. This benchmark has been produced by both Bifrost and Dispatch and the comparisons between them have been interesting and highlighted the differences between the solvers employed.

Dispatch conserving entropy

The deep Sun is not well represented by using the internal energy of the plasma, because the contrast between the different flows in the Sun is very low. Often, the errors in the numerical solvers produce problems with representing the physics correctly. 2021 has been the year where significant steps have been made in producing a Riemann-solver which uses entropy instead of internal energy as one of the primary variables. This change makes the contrast between the flows much more obvious and easier for the code to handle. The results are so far very encouraging, and it has passed the tests that it has been subjected to.



Entropy in the Orzag-Tang test performed with the new Dispatch solver using entropy as primary variable. (Credit: Andrius Popovas)



The placement of Cartesian sub-grids to simulate the whole Sun in one simulation with Dispatch (Credit: Andrius Popovas)

Dispatch and a volleyball Sun

The ambitious project of including the whole Sun in one simulation is taking shape. The computational grid is one of the main problems in this type of simulation. Dispatch is ideally poised to handle this project. A spherical grid has the disadvantage that the resolution drops with radius, which is the opposite of what is necessary. The development has been to use a large number of small cartesian boxes to model the sun. If they are placed in a volleyball like pattern, they will have a small overlap which is taken into account when communicating boundaries, but the local cartesian boxes are much faster to solve making such a simulation achievable.

Boris Gudiksen

Accelerated Particles in solar flares

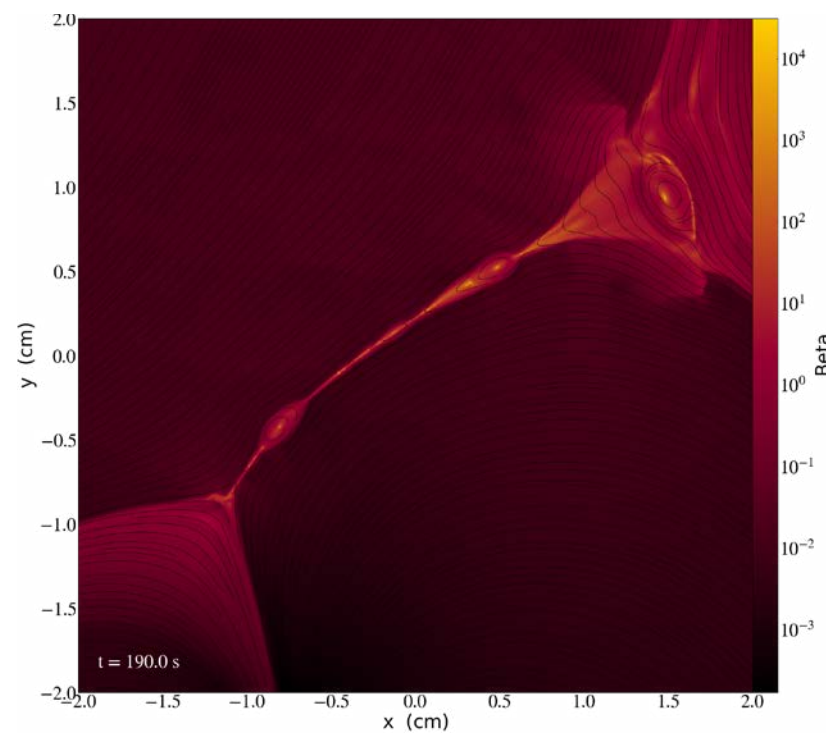
Understanding solar flares is a crucial component of the main goal of RoCS; to understand the active Sun. Solar flares are able to accelerate electrons to very high velocities. The acceleration itself, the distribution of particles with energy and the total number of accelerated particles are tightly connected to the process that drives the energy release process in solar flares and the characteristics of the accelerated particles can therefore be used to probe the innermost flaring region.

In 2021, RoCS undertook a concerted effort to evolve methods and develop software that can be used to investigate the acceleration process of particles in flares. The effort is multifaceted and attacks the problem from many sides.

The flare mechanism

Solar flares are caused by a violent and sudden release of energy. In the flare kernel, the otherwise unbreakable magnetic field lines are broken and reconnected, releasing stored energy. The released energy has been injected slowly into the magnetic field configuration by motions in the solar photosphere. The convective motions in the photosphere are able to advect the magnetic field footpoints. This relatively slow driving of the magnetic field forces the field to continuously find a new equilibrium. The sudden release of energy, instead of a prolonged release, points towards some instability limit being passed leading to a non-linear evolution. The instability limit can be set either by a large-scale instability such as the kink-instability or by a small-scale limit, where for instance the gradients in the magnetic field are transferred to smaller and smaller distances, that the particle behaviour suddenly allows

non-standard behaviour. Most likely both of these mechanisms can occur but in any case, it seems that a significant part of the released magnetic energy is being used to accelerate particles out of the thermal distribution. These particles are the source of radiation in the full range of the electro-magnetic spectrum from



The resolved details of reconnection in a numerical model of a solar flare (Credit: Frederik Clemmensen)

radio waves to X-rays. The emission in the different bands is produced by different effects and together they set very tight boundaries for the number, energy spectrum and focusing of the particles.

Modelling

At RoCS, we are following a number of paths to model the acceleration of energetic particles. As the codes and methods develop we will be able to merge these different approaches into a full model of a solar flare happening in an active region, one of the main goals of RoCS.

The effort started with the hiring of Lars Frogner, Helle Bakke and Frederik Clemmensen in 2018. From the large-scale perspective, Lars Frogner is investigating the effect on the large-scale corona when accelerated particles are carrying a significant fraction of the released energy in solar flares, down along the magnetic field into the lower atmosphere instead of heating the local plasma. Here, the assumption is that we can prescribe the spectrum of the particles and total fraction of the released energy used to accelerate the particles. Removing energy from the flaring region will have an impact on the flaring process itself and first results were published in 2020. The impact of accelerated particles on

the lower atmosphere is being investigated in detail by Helle Bakke, in order to transfer the effect of the particles into true observables that are measurable by for instance the Interface Region Imaging Spectrograph (IRIS).

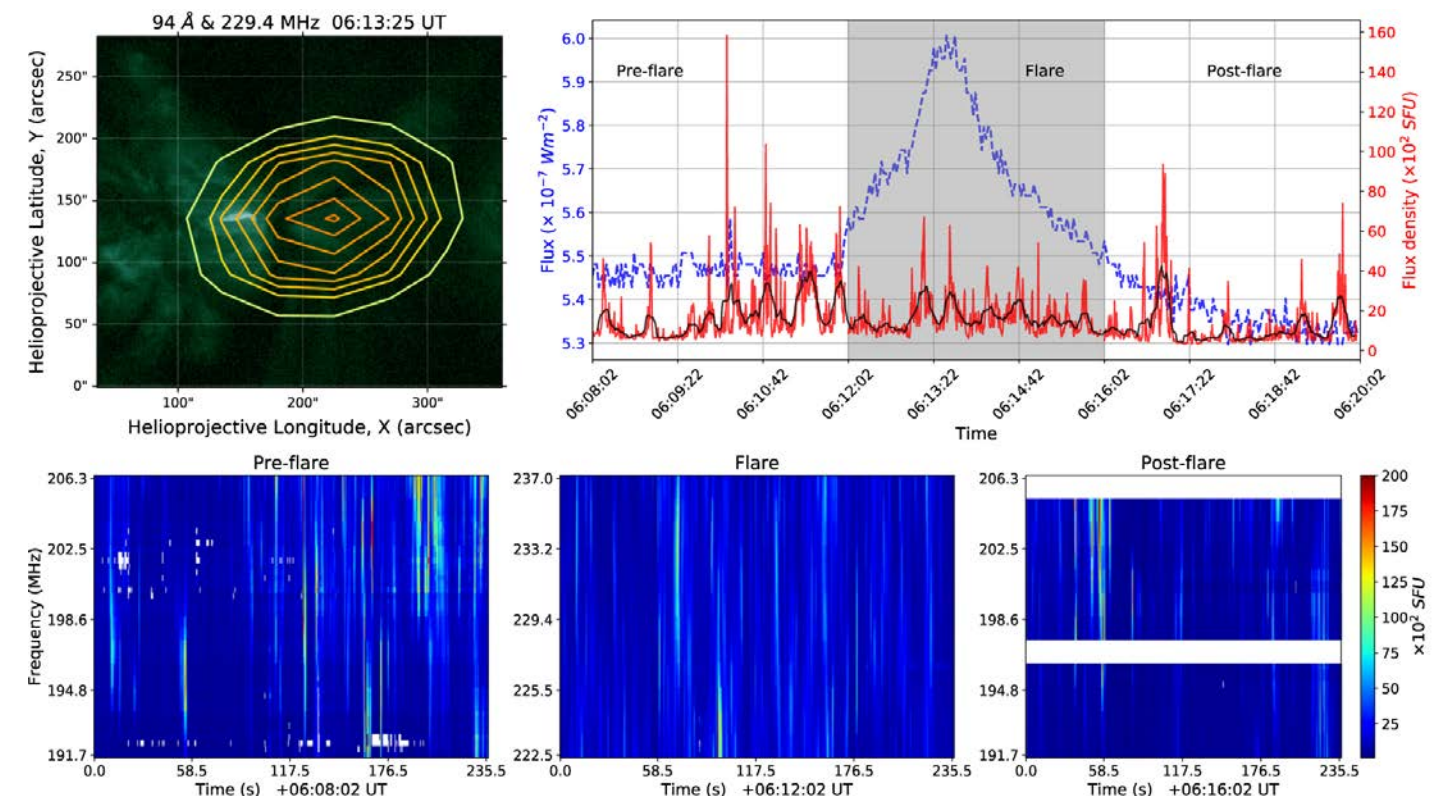
Modelling the flaring region itself is inherently a multiscale problem. The small scales of the reconnection region combined with the large-scale magnetic configuration results in a problem which is difficult to model. It turns out that resolution plays an important role because the resolution is necessary for small-scale instabilities to develop in the flare. If these are not resolved, the flare will not be as effective in converting energy, and will not be as violent. Above a certain resolution limit, the conversion seems to stagnate, but we do not know if the energy split into flows and heat are still the same or if there is still an effect of the resolution. The details of the energy balance in the reconnection region are being investigated by Frederik Clemmensen. In 2021, Michael Haahr and Eilif Sommer

Øyre were hired to write their PhDs on the details of the flaring process itself, and are working on significant code development efforts to make our modelling capabilities even better. Michael Haahr is developing the DISPATCH code to be able to model particles instead of fluids so we can model the inner parts of flares with particle dynamics instead of with a fluid approach. Eilif Sommer Øyre will be developing a code to follow individual particles as they are accelerated in the flaring region and answer the problem of the acceleration mechanism at work.

Observations

A number of experts are already a part of RoCS, with expertise in accelerated particles and flare observations. Comparing the models with observations relies on the correct synthesis of observables from the models, but also on the detailed knowledge of how these should be interpreted and compared with observations. We expect new results on this aspect of solar flares in the years to come.

Boris Gudiksen



An example of the observations possible with modern radio arrays such as the Murchinson Widefield Array used here. Shown is the time and spectrally resolved spectra of a very weak micro flare. (Credit: Atul Mohan, ApJL 909, L1)



Ongoing projects at RoCS

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” (2019-2022), 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 in comparison to the Sun as a fundamental reference star.

Hinode Science Data Centre Europe (2004-2023), 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 (2017-2022), 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.

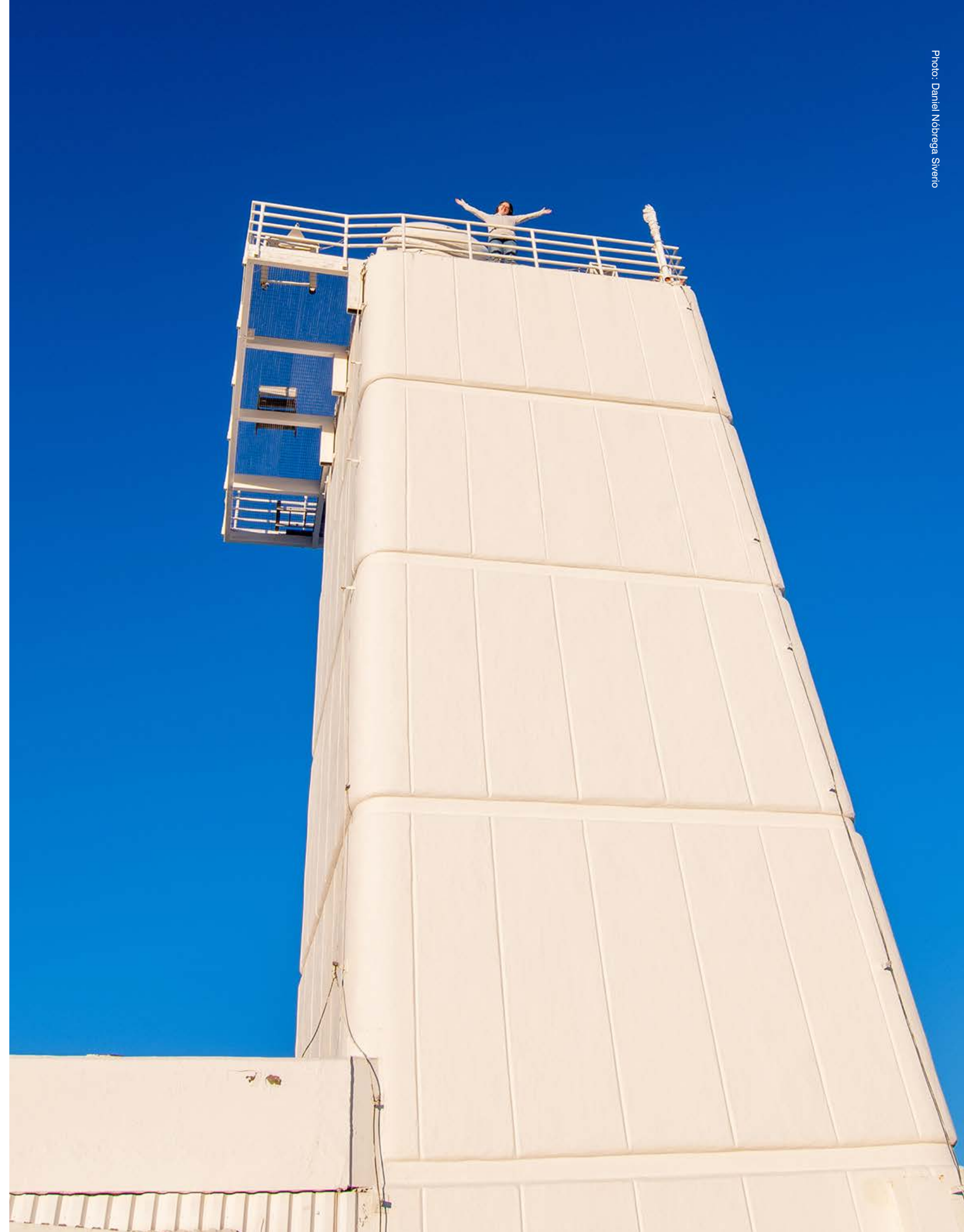
SolarALMA (2016-2021), funded by the European Research Council (ERC). Aim: Develop and exploit ALMA's diagnostic potential for studying the Sun's small-scale dynamics and constraining heating processes in the solar atmosphere.

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 (2016-2023), 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.

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.



Outreach

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



Becca Robinson onboard MS Otto Sverdrup with the solar telescope which she uses to take pictures and show the passengers what is happening on the Sun. (Credit: Private)



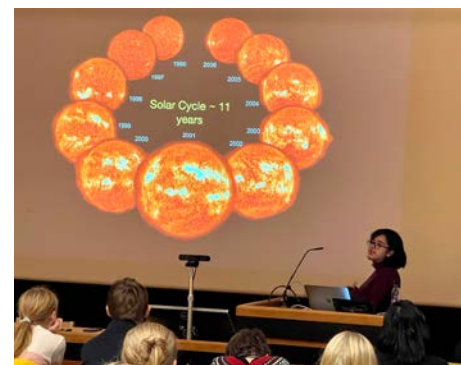
European Solar Telescope

RoCS is one of the institutions working towards building the European Solar Telescope (EST). The European Association for Solar Telescopes (EAST), the organization behind this effort, consists of 26 research institutions from 18 European countries. RoCS director Mats Carlsson is the current president of EAST.

RoCS follows up on different activities done by EAST to promote the European Solar Telescope and we were therefore part of this year's **EST calendar**. The photo was taken by Aditi Bhatnagar at RoCS and is featured in the month of November.

EST also organized a competition for school students to make Infographics on different topics related to the Sun. These

infographics will become part of an **EST Solarpedia** and the two winning teams will get an opportunity to travel to the island of Tenerife and visit the solar telescopes there. In preparation for this competition, students of Norwegian schools attended lectures on various topics of the Sun by Aditi Bhatnagar to prepare them for the infographics competition. Four such lectures were given in total, both at the University of Oslo to schools in Asker and Sandvika and via Zoom to schools in Tromsø and Tønsberg. Two Norwegian teams that were guided by RoCS finished in the top ten finalists of the competition, securing 4th and 5th positions from a total of 561 infographics which were submitted by students from 16 countries in Europe.



Aditi Bhatnagar teaches about the Sun to the students participating in the EST competition for making Infographics. (Credit: Avijeet Prasad)



Maria Guadalupe Barrios Sazo in front of the computer Tsubame at the Tokyo Institute of Technology. Tsubame was #1 in the list green500 in 2017 (Credit: Private).



Women in Astrophysics Blog

The women at RoCS were quite active last year, despite working from home. As it was difficult to have in-person outreach events they resorted to expressing their views by writing. The major contributions from RoCS were:

Thinking about stars... in the light of supercomputers

Do you know how scientists use supercomputers? Maria Guadalupe Barrios Sazo describes what it's like to work with these cool machines using experiences from her PhD.

Why Scientists Don't Always Read Pop Science Journalism

Are you an avid reader of pop science journalism? Becca Robinson explains how these articles at times are misleading from the scientific truths, and hence it's better to check the actual sources and ongoing research.

Celebrating Women and Girls in Astronomy

Becca Robinson makes an amazing collection of profiles of all the women at RoCS and ITA, describing their backgrounds, research interests and the adventures they like to do in their free time.



Luc Rouppe van der Voort teaches the Norwegian team for IOAA about our dynamic sun and the phenomenon of sunspots. (Credit: Oskar Hafstad)



Astronomy Olympiad

The Norwegian Astronomy Olympiad is organized jointly by RoCS and ITA and its main goal is to increase the interests of students in Physics and Astronomy from the school level. The Norwegian team is selected after a nationwide Olympiad for students at upper secondary schools who are interested in physics & astronomy. Five top students were selected in March 2021 to participate at the International Olympiad on Astronomy and Astrophysics (IOAA) in autumn. The students were invited for a training week at the University in June 2021. They attended lectures on various topics such as cosmology, stellar structure & evolution, different types of telescopes & how to navigate the skies.

They also went on an excursion to the Harestua solar observatory which is Northern Europe's largest astronomical facility. There they were given a guided tour of the facility, where they saw everything from radio telescopes, the solar observatory, cameras hunting for meteors, to an observation post that was used to find and track Russian satellites during the Cold War. The 2021 IOAA was originally scheduled to take place in Bogotá, Columbia, but was held online due to the pandemic.

Astronomy on Tap

Following last year's tradition, the AoT's (Astronomy on Tap) had to be done online because of the COVID pandemic. Still, it was quite a success and included informative talks, interesting discussions and prize-winning quizzes.

- **Hosts:** Becca Robinson and Mathew Galloway
- **Speakers:** Maria Guadalupe Barrios Sazo "Musings on the modeling of white dwarf mergers", Renate Mauland-Hus "You don't look like an Astrophysicist", Stian Hartman "Guide to building a lightsaber" and Vegard Lundby Rekaa "Why it's important to preserve our dark skies"
- **Social media and marketing:** Becca Robinson and Martina d'Angelo
- **Quizzes:** Petra Kohutova, Andrius Popovas and Frederik Clemmensen

Personal outreach - highlights

Talks & articles

● How do we understand habitability?

Sneha Pandit talks about the processes inside the Sun and how they affect the habitability in the heliosphere as a part of a series called 'Astrophysics home delivered talk' of IISER Bhopal Astronomy club.

● Analysis of ALMA full disk maps of the Sun

Sneha Pandit presents a poster at the PhD Day 2021 organized by the Faculty of Mathematics and Natural Sciences at University of Oslo.

● Sun and Solar system

Aditi Bhatnagar talks to class five students about "Sun and the Solar system" at Lycée Français René Cassin d'Oslo.

● The life cycle of a star from radio window

In a talk at the Faglig Pedagogisk dag held at UiO, Maryam Saberi gives an overview of the new generation radio telescopes and how they can be used to study evolution and chemical composition of stars.

● To the stars: Guatemala in space

Maria Guadalupe Barrios Sazo contributes to the book which highlights the stories of 23 Guatemalans (including her) working in engineering and space science careers.

● Becca's dream job

Becca Robinson goes on a six-week voyage from Hamburg to Nordkapp with "Hurtigruten" on the ship MS Otto Sverdrup, where she works as an Expedition lecturer. She gives lectures about the science behind Northern lights to the passengers and also shares her research on the Sun. Becca will go three times with the "Hurtigruten" through the winter 21/22.

● Torsdag og fredag kan det bli muligheter for å se nordlyset

Øystein Håvard Færder explains in an article to a local newspaper about the mythical and scientific aspects of Northern Lights, and notifies people the possibility of seeing auroras in the near future.

● OL-landslaget i astronomi trenes opp av Norges eksperter

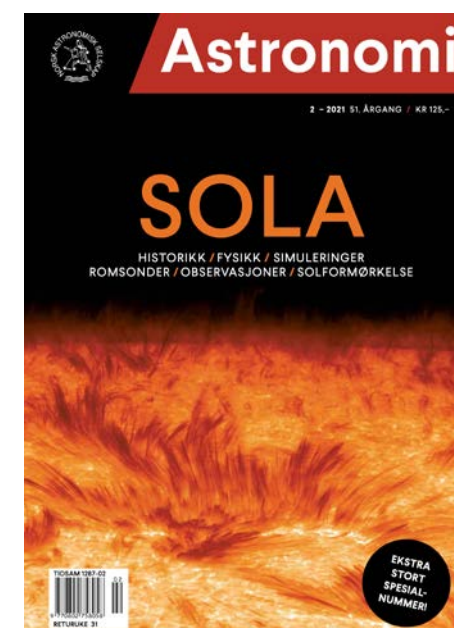
Summer job student Oskar Hafstad describes the journey of the Norwegian team participating in the International Olympiad of Astronomy and Astrophysics (IOAA).

● Teleskopet som skal hjelpe oss å løse solens mysterier

Oskar Hafstad gives an insight into the history of solar research in Norway, the present research the scientists here are focusing on and the need for the European Solar Telescope.

● Articles to Titan.uio.no

1) *Slik pynter Hollywood på sannheten om verdensrommet* Petra talks about the scientific mistakes made by the directors of Hollywood movies to exaggerate things in space and make them more dramatic. 2) Aditi Bhatnagar writes two articles about Solar Orbiter titled *Planetary rendezvous of Solar Orbiter* and *Space mission images its first coronal mass ejection*.



Astronomi: The special Sun edition of the Norwegian Astronomy magazine published in February 2021 which has articles by many members of RoCS. (Credit: Astronomi)

Media - highlights

Astronomi "Sola"

RoCS contributed to a special Sun edition of the Norwegian Astronomy magazine. Major articles were written by Mats Carlsson "Vår nærmeste stjerne", Boris Gudiksen "Hvorfor er koronaen så varm?", Viggo Hansteen "En kunstig sol", Tiago M.D. Pereira "Solens hete hemmeligheter", Luc Rouppe van der Voort "Sola på nært hold", Sven Wedemeyer "Sola over Atacama-ørkenen" and Terje Fredvik "Nærkontakt med Sola".

Apollon "Skal avsløre solens tre gåter"

Mats Carlsson and Viggo Hansteen were interviewed about the research project Whole Sun in the University of Oslo's research magazine Apollon.

NRK EKKO "Solens tre store mysterier"

Mats Carlsson highlights the topics 1) Chromosphere and corona heating, 2) Solar wind, 3) Formation of the magnetic field and the WholeSun project in a 15 minute long radio interview.

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. It includes funds for visits by researchers at professor, post-doctoral and PhD level for shorter or longer visits to RoCS.

The visitor programme has been severely affected by the Covid pandemic. Because of the uncertainties, visits were cancelled or not even planned. Even when Norway dropped all restrictions in the end of September, other countries had travel restrictions and by the time we were planning more international exchange, the omicron variant struck, and restrictions came back in December. The only visits we had in 2021 were by our adjunct professors Guillaume Aulanier and Åke Nordlund

in November/December and by two long time collaborators from Stockholm:

Senior researcher *Jaime de la Cruz Rodriguez* and professor *Jorrit Leenaarts*, from the Institute for Solar Physics, Stockholm University, visited in October to discuss multidimensional radiative transfer, MHD simulations, synthetic observables and observations with the Swedish 1-m Solar Telescope.

Imaging the Sun with ALMA

RoCS hosted the second international workshop on solar imaging with ALMA but this time as a hybrid meeting.

Due to the ongoing pandemic, the second workshop was held as a virtual meeting in November 2021, although participants from RoCS were able to attend in person in the RoCS meeting room. In total, up to 42 participants from around the globe were following the presentations and discussions that were scheduled over the course of three days.

Among the topics discussed in the workshop were best practices in data calibration, the combination of single dish and interferometric data, problems raised by the use of a heterogeneous array, observations of the solar limb, and time-domain challenges. While the workshop was primarily directed towards experienced users who have actively worked on processing and analysing solar observations with

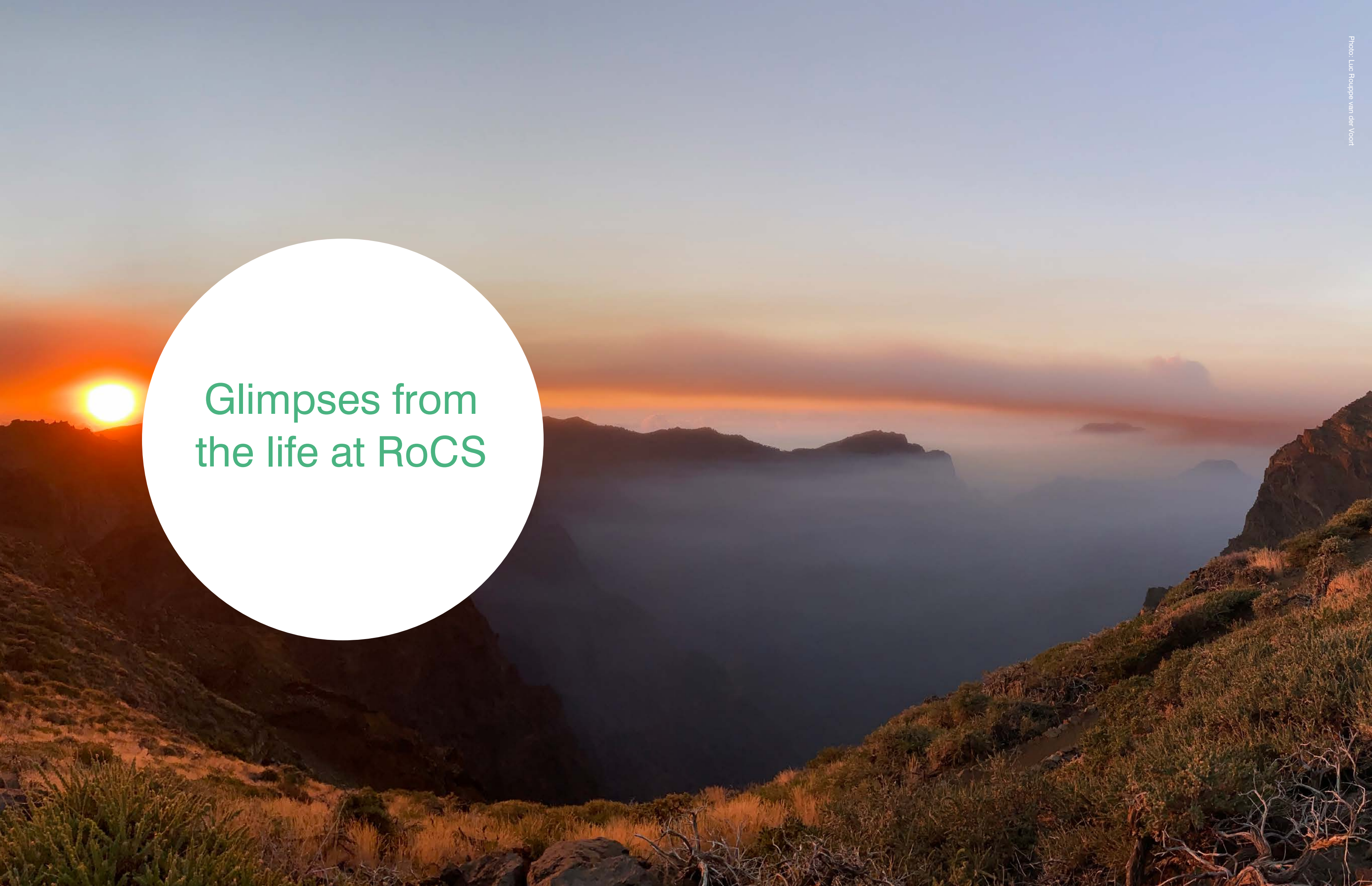


ALMA, a larger number of solar physicists also joined to learn about ALMA's diagnostic potential for the Sun.

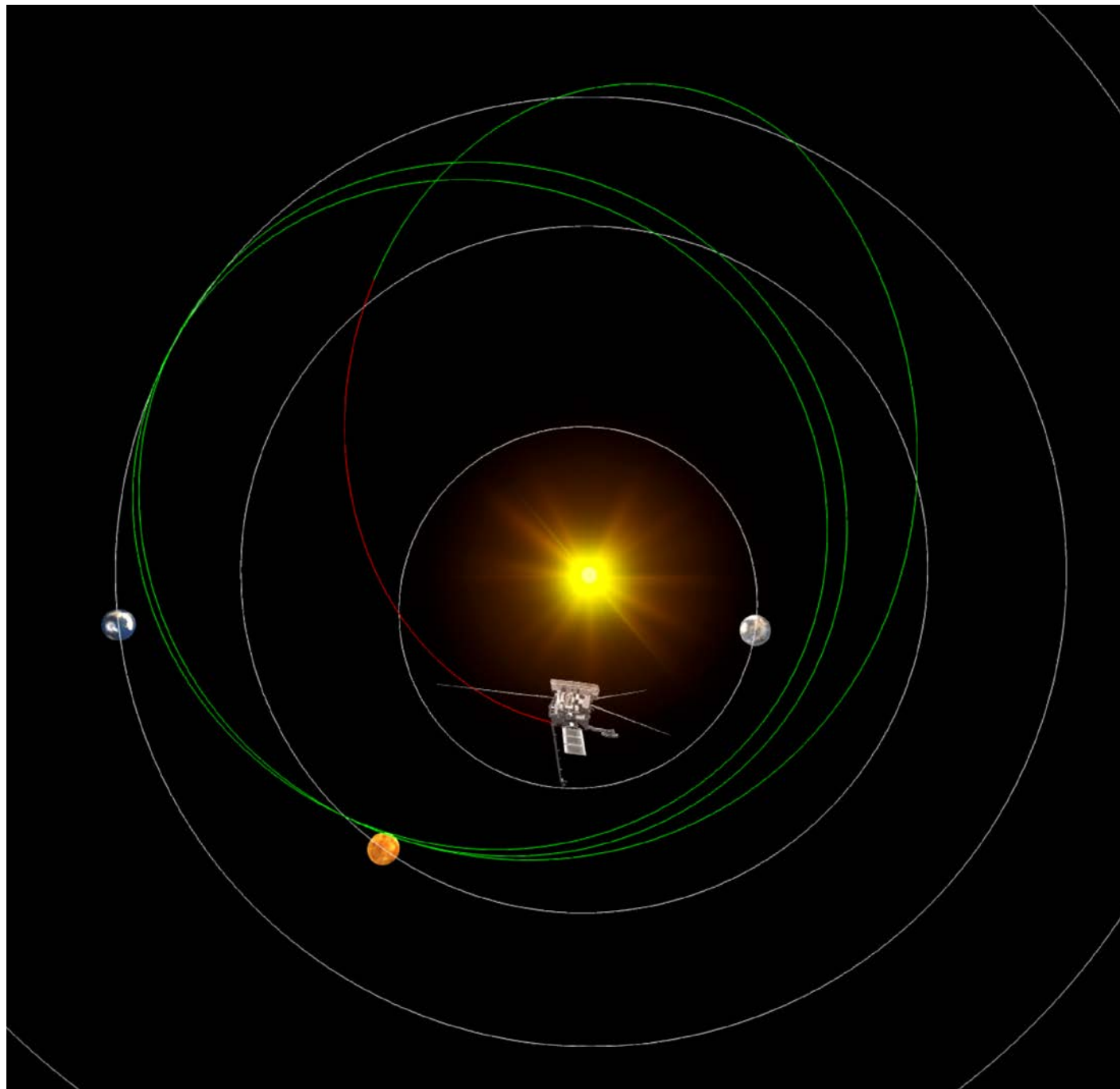
We may have raised more questions than we have found answers for during these three intense days, but the large number of participants shows the unbroken

interest in solar observations with ALMA. I am happy we organised this workshop despite the pandemic. The workshop was hosted with help of the ALMA team at RoCS and the international organising committee.

Sven Wedemeyer

A wide-angle landscape photograph of a mountain valley at sunset. The sun is a bright orange orb on the left horizon, casting a warm glow across the sky and the silhouetted mountain ranges. The foreground shows a grassy slope with some dry, brownish vegetation. A large white circle is overlaid on the left side of the image, containing the text 'Glimpses from the life at RoCS' in a green, sans-serif font.

Glimpses from the life at RoCS



SPICE on Solar Orbiter

In our quest to understand the fundamental physics of the Sun, we are now beginning to study our star from yet another vantage point: up close.

When a RoCS solar physicist leaves home in the morning, she first needs to know the outdoor temperature. Not much science can be done with frozen fingers or an overheated brain. Luckily, measuring the temperature is an easy task. A simple thermometer handles all conditions that the Oslo climate can throw at it. Even if warm summer days may feel far away at midwinter, the range of temperatures throughout the year is quite limited. The physical properties of the Solar atmosphere, on the other hand, vary enormously. No single instrument can investigate the entire atmosphere, ranging from the cool and dense photosphere to the hot and thin corona. Different types of observations and instruments are required for understanding the different regimes of different physical quantities.

Some types of observations may even require special observation sites. If you want to study the very hottest plasma of the Sun you need to observe extreme ultraviolet and X-ray emission, but this energetic radiation is effectively stopped by the Earth's protective atmosphere. You therefore need to place your telescope in space. At RoCS we have been using observations from space-borne observatories for years. However, ESA's Solar Orbiter stands out from the crowd. What makes this space probe special is the unique orbit it follows around the Sun.

With a little help from my planets

Solar Orbiter was launched from Cape Canaveral in the direction of the Sun on the 10th of February 2020. Four months later the probe was half-way to the Sun!

The instruments onboard had the opportunity to take images of the Sun from a closer distance than has ever been done before.

In order to get even closer to the Sun without spending too much fuel, Solar Orbiter makes close encounters with Venus and Earth. In November last year, Solar Orbiter raced past the Earth at a mere 466 km distance above the surface. That is closer than the distance between Oslo and Bergen! This controlled near-miss caused the space probe to radically change its orbit and to fall towards the Sun. In the coming years, Solar Orbiter is going to make several Venus flybys which will decrease the minimum distance to the Sun to no more than 0.284 AU. This will make it possible for the instruments to observe unprecedented fine-structured details in the solar atmosphere. These gravity assist manoeuvres with Venus will also change the angle of the orbital plane of Solar Orbiter. Objects in the solar system move in more or less the same plane, but the Venus flybys will gradually tilt the angle of the space probe's orbital plane up to 33°. This will enable the instruments to image the Solar poles for the very first time.

Ten instruments, one goal

Solar Orbiter has an impressive collection of 10 very different and highly specialised instruments. The instruments can be divided into two main groups: 6 remote sensing instruments and 4 in-situ instruments. The remote sensing instruments provide images of flares, shockwaves, coronal mass ejections, emergence and development of photospheric magnetic

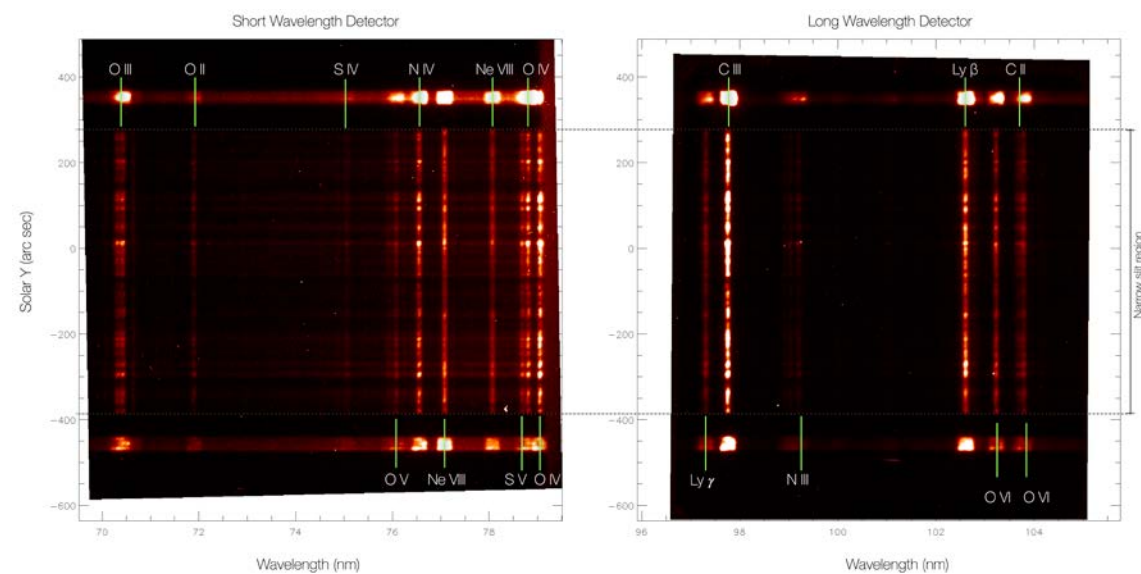
fields, and the variability of the solar wind source regions. A few minutes later the in-situ instruments reveal how these phenomena have affected the velocity, temperature, density, magnetic field and composition of the solar wind as it passes the space probe. In-situ measurements of the solar wind have been done before, but mostly with instruments placed close to the Earth. This far from the Sun, the solar wind has travelled millions of kilometres through space. Observing the solar wind from a vantage point much closer to the Sun makes it easier to unravel the initial properties of the wind.

Separately, each of the 10 instruments will provide new knowledge of the Sun. However, we will learn even more when the 10 instruments are working together, simultaneously observing the same target. The scientific output can be maximised by combining observations from Solar Orbiter with simultaneous observations obtained from Earth or other space-borne observatories.

We have a mission

Since launch, Solar Orbiter has travelled an accumulated distance of 14 AU through space. SPICE and the other instruments have obtained huge amounts of test observations, and the nominal mission phase has now begun. The very first SPICE results have already been published in Astronomy & Astrophysics, with RoCS members as co-authors. In the coming years we plan to dive deeper into SPICE observations, and we will try to make coordinated observations with SPICE, SST and IRIS.





SPICE has three narrow slits and one wide slit. When using one of the slits, solar radiation is spread out on two separate detectors. The figure shows calibrated narrow-slit spectra on the two detectors. A square region sits above and below the narrow-slits, creating the two horizontal bands of spectroheliograms. By rotating the telescope mirror the instrument can build up spatial images with spectral information for many emission lines simultaneously. (T. Fredvik, RoCS)



From telemetry to science

RoCS scientists and engineers play key roles on SPICE (*Spectral Imaging of the Coronal Environment*), one of the remote sensing instruments on Solar Orbiter. SPICE is inspired by previous imaging spectrographs, like SOHO/CDS, Hinode/EIS and IRIS. However, if SPICE had been placed at a similar distance from the Sun as these telescopes, quite close to the Earth, it would have been a surprisingly unimpressive instrument. It wouldn't have been able to distinguish details on the Solar surface smaller than 4 000 km. As a comparison, the ageing Hinode/EIS instrument has a spatial resolution of 2 000 km. Still, SPICE will be able to image even smaller structures than EIS can. SPICE has the advantage of a highly elliptical orbit that brings it close to the Sun. When observing from its closest

distance from the Sun the spatial resolution is twice as good as that of EIS. Other imaging instruments on Solar Orbiter have even higher spatial resolution, but only SPICE can detect radiation emitted from cool gas at 10 000°C all the way up to extreme coronal temperatures of close to 10 000 000°C. Being a spectrograph, the instrument also provides valuable information on the line-of-sight velocity, density and other properties of the plasma in this wide temperature range.

SPICE doesn't downlink science ready images. Instead, we receive a stream of bits and bytes that has to be parsed, sorted, decompressed and structured in a sensible way, as well as stored in a format that can easily be read and analysed by scientists. At RoCS, we have developed a software package that performs this essential task.

Our automated data pipeline runs continuously on the RoCS servers in Oslo to ensure that the latest SPICE observations are immediately available to the international SPICE team. Later, the files are transferred to ESA's Solar Orbiter archive to be enjoyed by the broader scientific community. We also provide quicklook and analysis tools that can be used to study the SPICE observations.

International collaborations

The pipeline development is an international effort and a highly dynamic process. SPICE was extensively tested on the ground by the UK designers at Rutherford Appleton Laboratory (RAL) before launch, but many of the instrument's characteristics and operation modes could not be fully explored until actual observations were performed from space. The RoCS pipeline team and the RAL SPICE team have therefore been cooperating closely both before and after launch.

The observation planning software is developed by the Institut d'Astrophysique Spatiale (IAS) in France, and by RAL. The Oslo pipeline extracts information

on the individual SPICE observations from the planning tool and also fetches SPICE telemetry from IAS. The RoCS-IAS collaboration is therefore essential to the pipeline development.

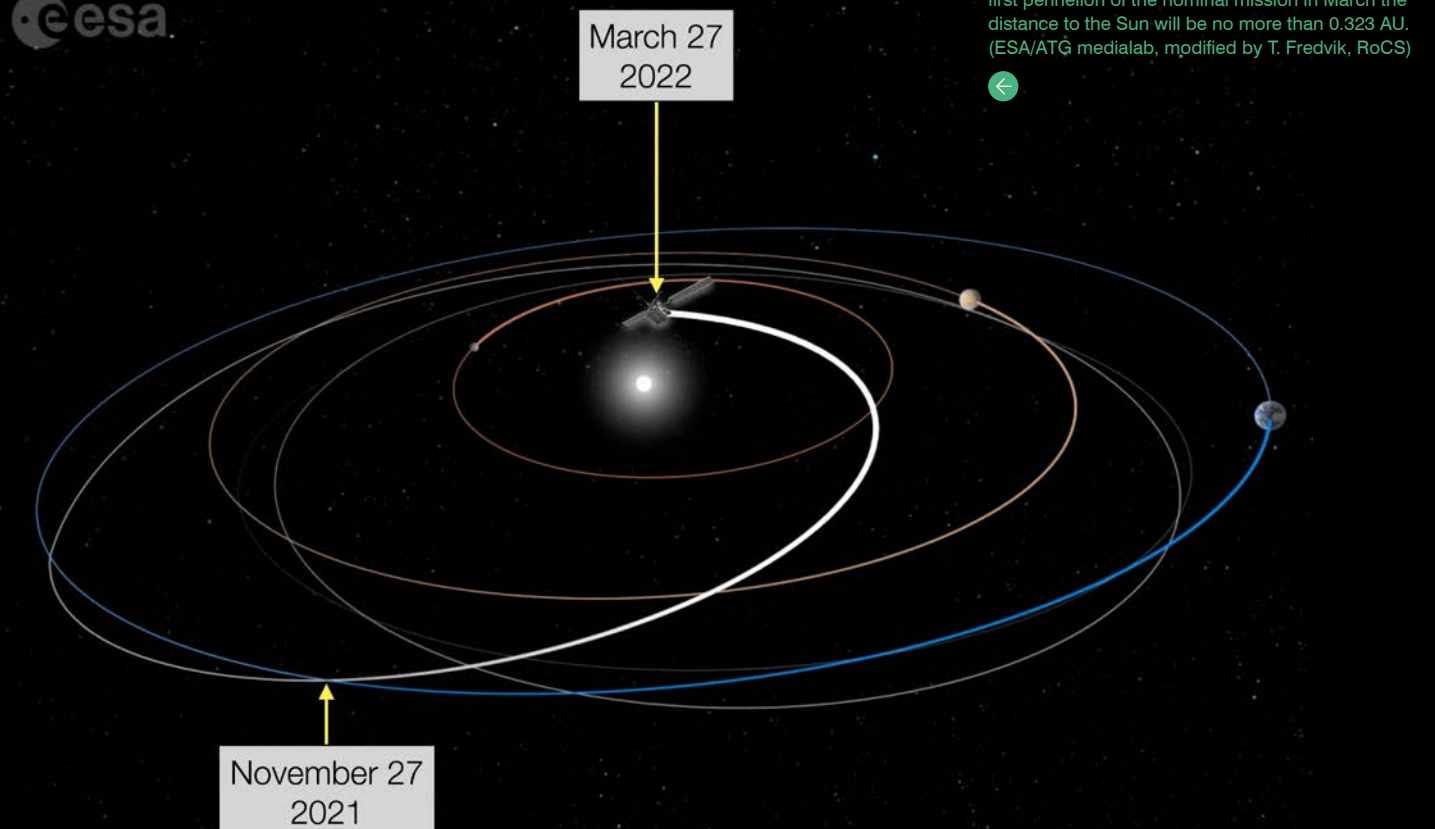
Finally, the Max Planck Institute for Solar System Research (MPS) in Germany is responsible for developing the data calibration code. Frequent discussions are needed in order to continuously integrate the calibration code into the pipeline.

Observation dissemination

Traditionally, solar observations have been distributed as FITS (Flexible Image Transport System) files. SPICE observations are no exception, but extra care has

been given to make the SPICE FITS files as comprehensible and self-contained as possible. At the same time the goal has been to take advantage of the FITS format's inherent flexibility and possibilities. The RoCS SPICE pipeline development team has therefore been working very closely with the ITA FITS Working Group in order to create files that adhere to the FITS standard, the Solar Orbiter metadata standard, and SOLARNET metadata recommendations. This collaboration has been very successful, maybe because the members of both groups are the same people.

Terje Fredvik



The gravity assist manoeuvre with Earth in late 2021 sent Solar Orbiter hurling towards the Sun. In February 2022, it crossed the orbit of Mercury. At the first perihelion of the nominal mission in March the distance to the Sun will be no more than 0.323 AU. (ESA/ATG medialab, modified by T. Fredvik, RoCS)



ORCS: Oscillations in the Realistic Corona of the Sun

The ORCS project is funded by the Research Council of Norway during 2021-2025 and is led by Petra Kohutova. It focuses on the oscillations, or waves, in the outermost layer of the solar atmosphere.

Waves in the corona

The solar atmosphere is filled with magnetohydrodynamic (MHD) waves. As the MHD waves carry magnetic energy, they have an important role in transporting energy across different layers of the solar atmosphere and in dissipating said energy. MHD waves are commonly observed in coronal structures such as coronal loops, coronal rain and prominences which act as waveguides. Waves also act as a tracer of energetic events occurring in the corona as a result of magnetic reconnection. The diagnostic properties of such waves can be exploited using a technique known as coronal seismology.

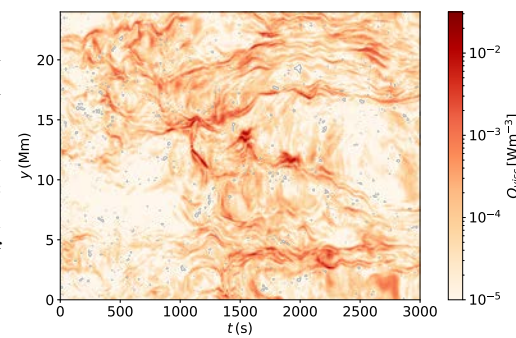
Project objectives

The primary goal of the ORCS project is 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. With the Bifrost code we can model a portion of the solar atmosphere spanning from the convection zone all the way into the corona. The evolution of the coronal magnetic field in such simulations is self-consistently driven by the dynamics of the lower solar atmosphere. This means that Bifrost simulations are capable of capturing realistic coronal dynamics, and can therefore be used as a laboratory for studying oscillations in the corona.

Coronal oscillations in Bifrost models

We have recently shown that coronal oscillations are common in Bifrost simulations (Kohutova & Popovas 2021). We used the forward-modelled EUV emission and three-dimensional tracing of the magnetic field to analyse oscillatory behaviour of individual magnetic loops. This work has shown that the oscillation characteristics and oscillation modes present in Bifrost simulations are similar to those observed in the Sun.



Oscillations in a Bifrost simulation and the associated volumetric heating rate due to viscous dissipation (P. Kohutova, RoCS)

Bifrost models also provide insights into mechanisms for damping and dissipation of coronal oscillations. These are apparent in the characteristics of the heating due to the dissipation of coronal oscillations, which is periodic, as opposed to impulsive and sporadic heating driven by the magnetic braiding and reconnection. ORCS aims to investigate how well analytical models for damping and dissipation of oscillations translate into realistic magnetic field geometries.

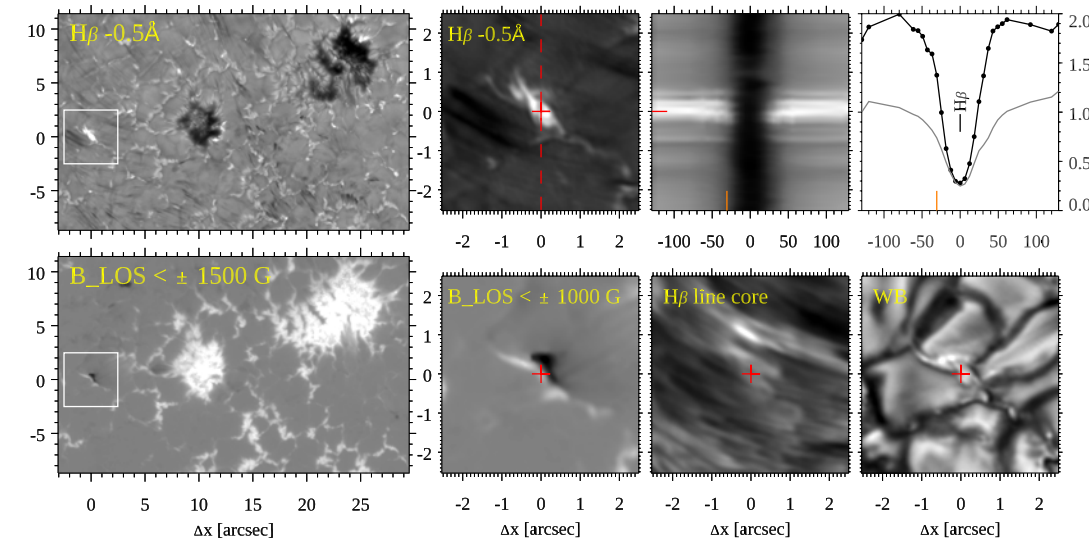
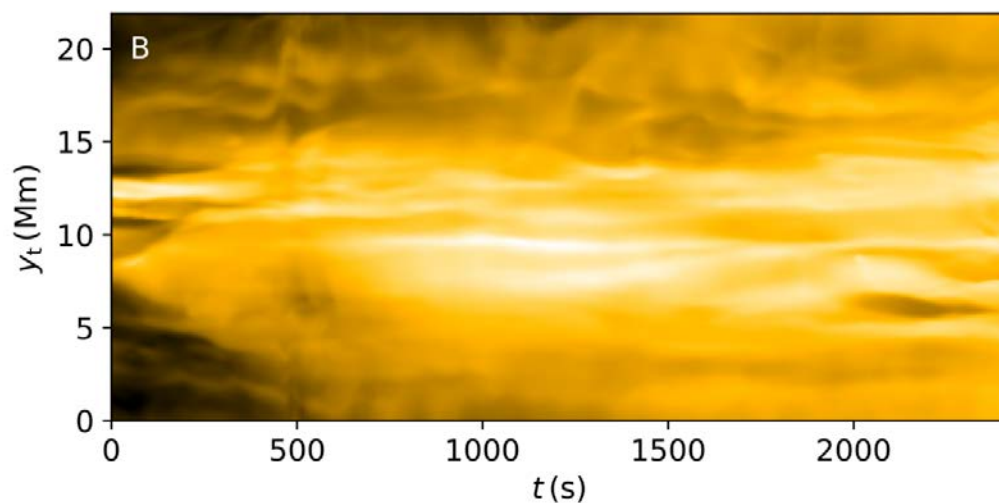
Link to solar observations

The signatures of the oscillation excitation and dissipation mechanisms inferred from the simulations will be compared to high-resolution observations of coronal oscillations using both well-established and new instruments. This will involve submitting a proposal for observing time by the Daniel K. Inouye Solar Telescope, which has started science observations in late 2021. A postdoctoral researcher will join ORCS in 2022 to focus on the observational aspects of the project.

Petra Kohutova



Oscillations in a Bifrost simulation seen in coronal emission (P. Kohutova, RoCS)



Observation of magnetic reconnection in the low solar atmosphere. The two large panels on the left show an active region with a map of the magnetic field at the bottom. The white boxes outline the region shown in close detail in the right panels. The magnetic map shows that patches with opposite magnetic fields collide (black and white) and in this region we see strong emission in the H-beta wing: a so-called Ellerman Bomb.



ISSRESS: Impact of small-scale reconnection events on the solar atmosphere

The project is funded by the Research Council of Norway for a period of 4 years and started in October 2021. This project aims 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.

Magnetic reconnection is a fundamental physical process in which the magnetic topology is rearranged and magnetic energy is converted into other forms of energy such as heat and particle acceleration. For many dynamic and transient events in the solar atmosphere, magnetic reconnection is the fundamental driving

mechanism. In the lower solar atmosphere, sites with magnetic reconnection can be observed as so-called Ellerman bombs at spatial scales of a few hundreds of kilometers. The figure above shows a clear example of an Ellerman bomb in an active region. Our recent high-resolution observations with the SST have shown that these Ellerman bombs occur on the solar surface in much higher numbers than thought before.

The central objective of the ISSRESS project is to understand the origin and formation of Ellerman bombs in the quiet Sun (areas on the Sun that are magnetically inactive) and explore their impact on the solar atmosphere. We plan to achieve

this goal by combining high quality observations from space and from the ground, and by comparing observational data with 3D numerical models of the solar atmosphere. The observations will be acquired through coordinated campaigns with NASA's IRIS satellite and the SST on La Palma.

The project will fund one postdoctoral fellow for 3 years and RoCS contributes with one PhD student. The project further provides support for hardware needed for data processing and storage.

Luc Rouppe van der Voort

EST

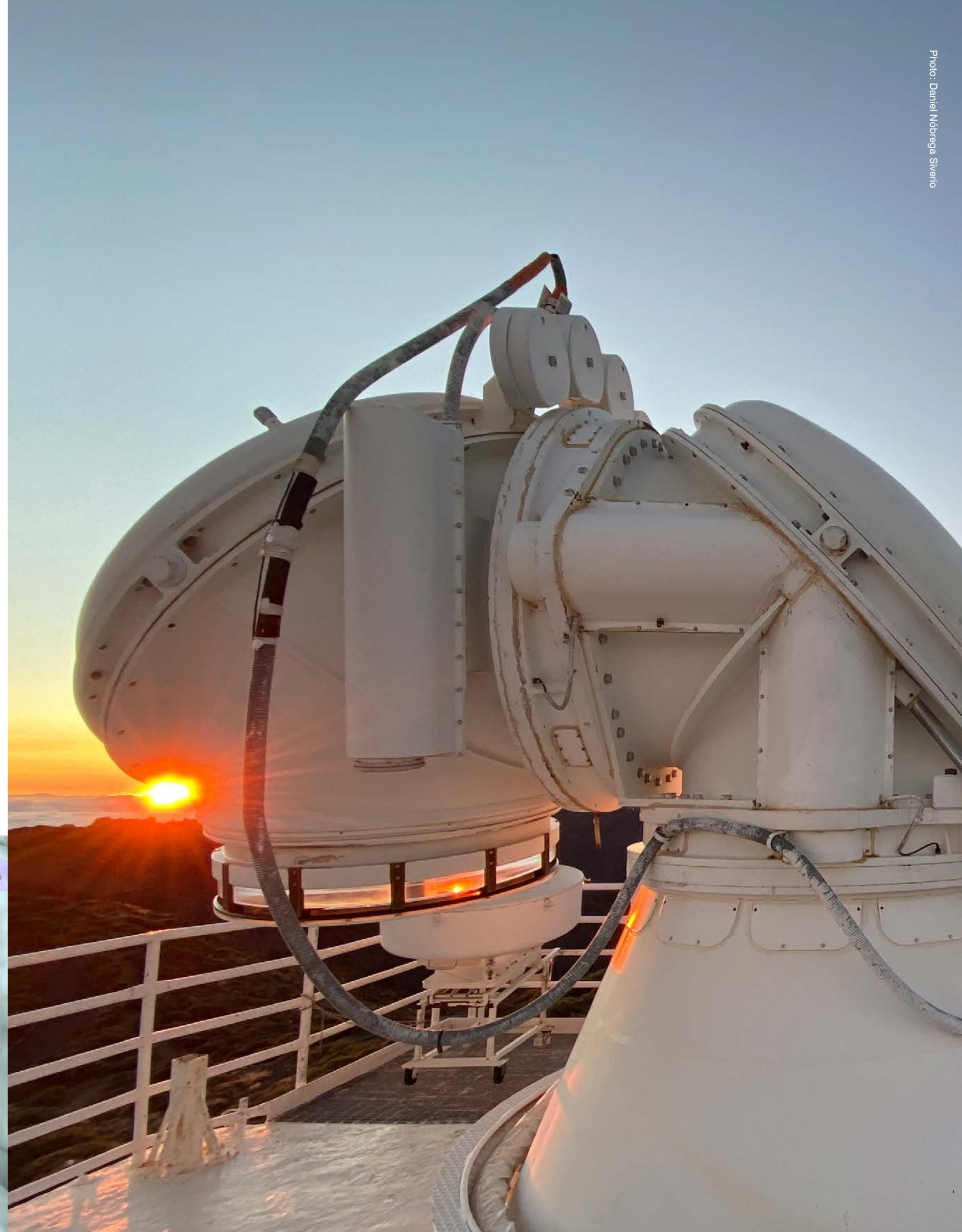
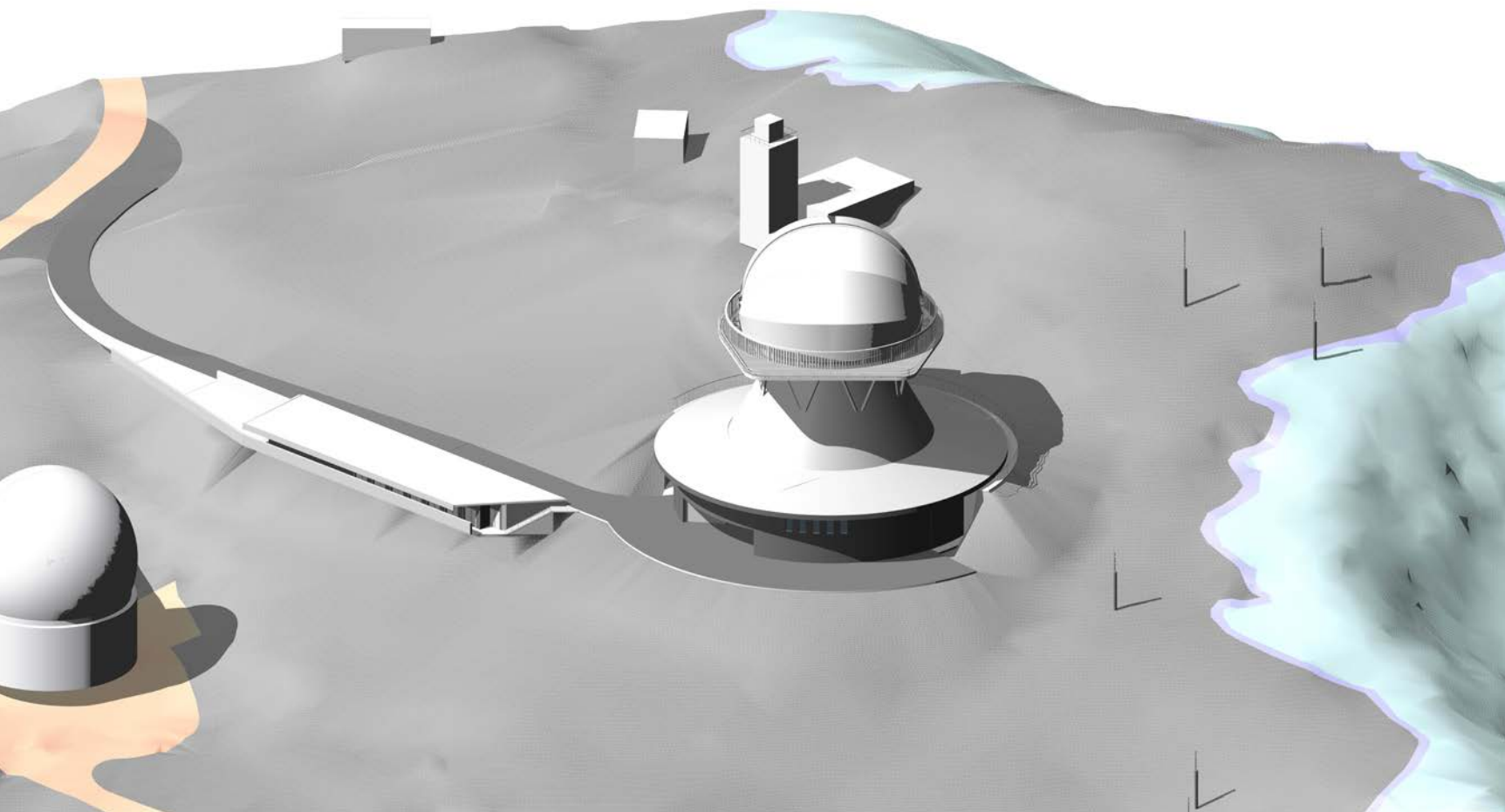
The European Solar Telescope (EST) is the next generation 4.2-m solar telescope in Europe. The European Solar Telescope has a symmetric design with a minimum of instrumental polarisation making it complementary to the off-axis DKIST telescope and ideal for measuring chromospheric magnetic fields. The large secondary mirror is to be an adaptive mirror, the largest of its kind in solar physics. This minimizes the number of reflections and increases the throughput by a factor of three in the blue, compared with the original, traditional design. This corresponds to the light-gathering power of a 7.5m diameter telescope. The project is in the preparatory phase and has seen

significant progress during 2021. A milestone for the project was the approval by the International Scientific Committee of the Canarian Observatories of the site where the telescope will be built. A site at the Roque de los Muchachos Observatory on La Palma, very close to the Swedish 1-m Solar Telescope (SST). Another major step forward was the update of the EST light distribution system and instrument suite. International consortia have been formed to undertake the design of the instruments. The crucial step is to secure the funding for the construction phase.

Mats Carlsson



Illustration of the approved EST site at Observatorio del Roque de los Muchachos, with the EST telescope in the center, the service building left of it, the Swedish 1-m Solar Telescope (tower behind EST) and the William Herschel Telescope (left corner). (Credit: Gabriel Henriquez Perez S.L.P.)



Centre for the analysis of astrophysical data

The analysis of astrophysical data often involves large data volumes and the need for significant computational resources. The Institute of Theoretical Astrophysics has as top priority to provide an infrastructure that can cope with these needs.

The institute has grown steadily for many years, and we were running out of capacity in the server room in Svein Rosseland's house. With RoCS, the capacity problem became serious. In the spring of 2021, the Institute of Theoretical Astrophysics opened our new server room in the cellar of our neighbour building, Helga Eng's house.

The construction of the new server room has been a long process. We started ten years ago when we first informed the faculty and the estate department at the

university about the need for increased server room capacity. Construction started in May 2019, after a long planning process.

After one year of construction work, the room was ready for use in May 2020. It was a technically challenging project. The cooling and power systems in the building had to be rebuilt to accommodate 250 kW of power consumption, redundant UPS battery backups and a diesel generator with capacity to run the system for 24 hours.

The cooling system is a state-of-the-art rear-door cooling system that dynamically adapts to the cooling requirements in each rack. The system is cold-water based, with under-pressure in the distribution system so that leaks will not lead to water spilling onto the racks. An advanced monitoring system sends reports on all technical problems with power and cooling to the University Security Operation Centre.

The next year was used to establish the necessary infrastructure in the room: fibre infrastructure between the two server rooms, fibre infrastructure within the server rooms, power distribution systems and networking equipment for computers, storage and system administration. A new 4 PB data storage system for RoCS was also installed.

We moved all our servers and computer nodes to the new server room in March 2021 and now the room is fully operational. The first year of operations has been very smooth without any major problems. We now have a state-of-the-art server room with capacity to house the necessary compute and storage infrastructure for RoCS and all other projects at the institute with capacity to increase further in the future.

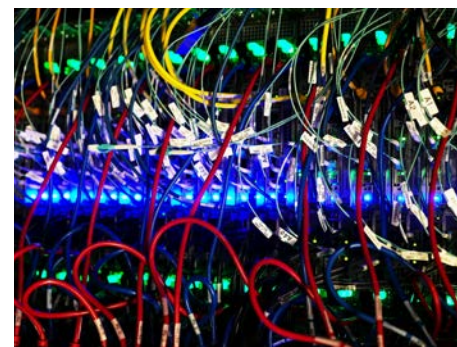
Torben Leifsen



A state-of-the-art server room.



Senior Engineer Torben Leifsen shows us what's inside the racks.



The intricate wiring that lies behind all the data transfer. (Credit: Ola Gamst Sæther)



The captivating structure surrounding the supercomputer. (Credit: Michael Haahr)



Michael and Lupe inside the structure, in front of a portion of the LUMI supercomputer. (Credit: Michael Haahr)

Photo: Private



Getting to know LUMI the supercomputer

LUMI means snow in Finnish and gives the name to one of the largest supercomputers in the world.

The final version is projected to achieve pre-exascale computing and is being assembled in Kajaani, Finland. On a sustainability note, this supercomputer runs on hydropower and the surrounding town will benefit from its excess heat. The PRACE (Partnership for Advanced Computing in Europe) autumn school accepted us, Michael and Lupe, to attend a week-long event in mid-October. We flew from Oslo to Helsinki and then in a small plane to Kajaani, where a bus drove us to the Vuokatti Sport Resort,

which is near the LUMI facility. During the week, experts in high-performance computing gave talks and the participants engaged in a selected track. We chose the hackathon track and were given access to AMD GPUs, close to what LUMI will have, in order to run two of the codes under continuous development at RoCS. For his master's thesis, Michael worked on preparing DISPATCH for the next generation of supercomputers by porting computations to GPU, with LUMI in mind. For his Ph.D., he plans to develop a new PIC solver in DISPATCH capable of running on GPUs, and hopes to get computing time on LUMI for that. Lupe has worked on updating a GPU version

of Bifrost and looks forward to doing studies of various technologies on different hardware, contributing to best practices guides, and accelerating some of the legacy setups. One of our shared highlights of the autumn school was a tour to the center hosting LUMI, where we got to appreciate the machine and grasp all the work it takes to have science done on supercomputers. The school finished with presentations on our progress, and we returned home with an enriching experience behind us and new connections within the supercomputing community.

Maria Guadalupe Barrios Sazo (Lupe) and Michael Haahr

Organising a major ESPM summit on Zoom



Photo credit: ESPD

Eight thirty in Oslo. Cup of tea ready, laptop lid open, meeting started. So far, only me. More minutes pass, a few solitary souls have joined in silence. I turn to our internal chat room, where my companions share similar feelings. Has anyone seen the second speaker for my session? No, but let me know if you see the chair of session 3.4! The minutes itch closer to nine. Most speakers are on, but one is still missing. Nine o'clock. A rush of eager attendees join, and I pass the baton to the chair. Large numbers now join, the talks start and I breathe a sigh of relief. This is going to work!

Years earlier, oblivious to the pandemic train wreck that was coming, at the ESPD board we were happily planning the next European Solar Physics Meeting (ESPM), organised every three years.

“The 16th ESPM was planned for 2020 in Turin, and our colleagues at INAF did a great job preparing for it. Sadly, it did not come to pass.”

We pushed it to 2021, but with little chance of having it in person, something else had to be done. After endless Zoom calls, a bold plan was hatched. It would go online. Worse, the ESPD would run it. One of the biggest solar physics meetings, usually with hundreds of participants, was going to be organised by the skeletal crew of the ESPD board, where reaching consensus is best described as a gathering of Ents. Some mea culpa here. I pushed for it so we could save money and have an inclusive meeting that would be free for all. In what seemed like madness at the time, we ditched the dull virtual poster options and decided to give everyone a short 7-min talk. In retrospect, this was arguably the single most successful aspect of the meeting.

With the floodgates open to participation,

“what we got was possibly the largest solar physics meeting ever, and RoCS played a major part in it.”

With 639 registered participants, and a mind-boggling 417 scheduled talks, RoCS's contribution was no less than organising the whole virtual infrastructure, from hosting large plenary meetings to 60 smaller Zoom meetings for parallel sessions.

The RoCS team, comprising Kilian Krikova, Mats Ola Sand, Nancy Narang, Souvik Bose, Thore Espedal Moe, and myself, was doing the exhausting trenchwork. I was also given the blessing/curse of organising the meeting website, including the constantly-changing timetable.

It was hard work. If you think you've seen it all in Zoom meetings, we have seen more.

But it was a sacrifice ultimately worth it. ESPM-16 was a resounding success. It served its place in European solar physics research, and helped hundreds disseminate their ideas. Critically, a large part of it rested on the six RoCS members who made it work without a hitch.

Tiago Pereira



Credit: Private

Young Prize winner at RoCS

Dr. Daniel Nóbrega-Siverio's solar physics work was acknowledged with the European Solar Physics Division (ESPD) Early Career Researcher Prize in 2021.

The prize was awarded for his important contributions to the understanding of solar chromospheric phenomena and related processes, combining theory, observations and numerical experimentation.

Daniel Nóbrega-Siverio developed his early career at RoCS as a postdoctoral researcher from August 2018 to February 2021 where he focused on the role of nonequilibrium and partial ionization effects in the chromosphere in magnetic flux emergence processes and related phenomena like surges. In addition, he also studied other key phenomena such

as UV bursts, coronal hot jets and coronal bright points that are key to understanding the solar atmosphere.

He now works at the Instituto de Astrofísica de Canarias (IAC) in Tenerife and he is still connected to RoCS as a guest researcher.

- What does this prize mean to you?

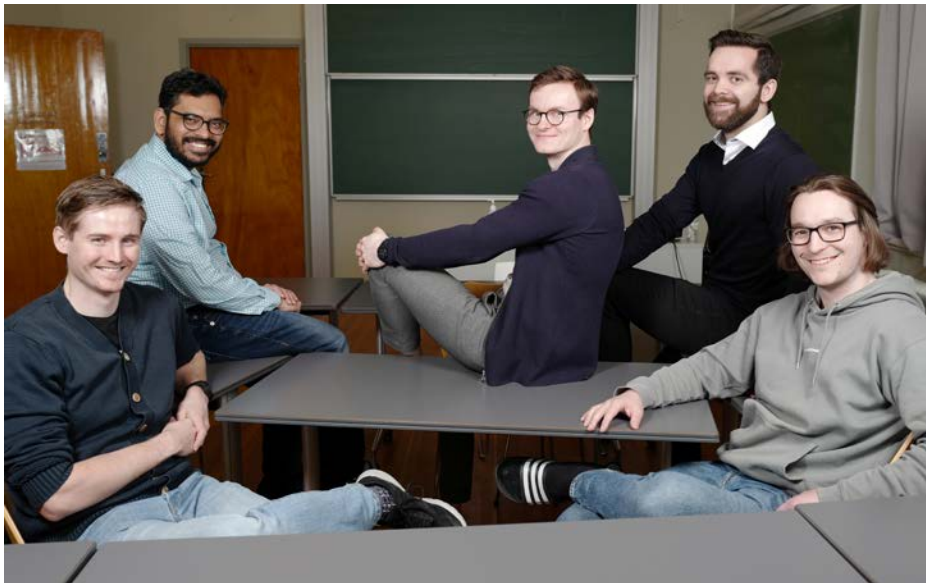
- First of all, I gratefully acknowledge this recognition from the European Solar Physics Division, taking the high-quality science also carried out by other early-career colleagues into account. Just being nominated is a big honor already, so getting the prize is a great motivation to continue working hard and contributing to the understanding of the physics of our star.

- What role has RoCS played in your work?

- RoCS has played an important role in my work, offering an ideal environment to develop my research. I have learnt a lot from RoCS colleagues and I could not be happier to have worked there during my first postdoctoral position. I also hope to keep a strong and close relationship now that I am a guest researcher in the group.

Eyrún Thune

Newcomers from near and far



From left to right: Michael Haahr, Avijeet Prasad, Eilif Sommer Øyre, Sondre Vik Furuseth and Mats Ola Sand are parts of the fast-growing scientific community at RoCS. (Credit: Ola Gamst Sæther)



Combining disciplines

Michael Haahr from Denmark started working at RoCS as a Doctoral Research Fellow in autumn 2021.

- I chose RoCS as it gives me a unique opportunity to develop myself both within physics and high-performance computing.

He expects to be part of the community at the forefront of numerical modeling of the solar atmosphere, and he hopes that his time at RoCS will prepare him for a career in astrophysics.

The work **Eilif Sommer Øyre**, a Norwegian, did with his thesis at NTNU in computational physics motivated him to look to RoCS for a PhD position. -Solar physics is a combination of many exciting disciplines in physics, and RoCS is known for its commitment and expertise in modelling the highly dynamic and intriguing solar atmosphere, says Øyre. The position gives him the opportunity to study more physics and high performance computing, and learn how to combine these fields to make scientific contributions as part of an active scientific community.

Eyrun Thune

Five young men chose in 2021 RoCS as their stepping stone to a career. Coming from various backgrounds they explain what led them to the Norwegian Centre of Excellence.

Avijeet Prasad from India first heard of RoCS in 2018 when he was looking for postdoc positions. - I applied but was not shortlisted for interviews. Another opportunity came again in 2020, when a postdoc position under the Whole Sun project was announced. RoCS was leading the work package related to coronal simulations. Prasad could offer experience from working on similar topics in previous postdoc positions.

- Given RoCS well-known reputation for numerical simulations, I was really excited to be a part of this project, and thankfully this time it worked out, says Prasad.

Easy choice

For the Norwegian **Mats Ola Sand** the choice was easy. He had lived in Oslo for most of his life: - I did both my bachelor's and master's degree at the Institute of Theoretical Astrophysics (ITA) and RoCS, and as I enjoyed everything from the people here to the work of my thesis, it was a natural choice to apply for a position as Doctoral Research Fellow at RoCS.

Sondre Vik Furuseth, another Norwegian, came to RoCS from CERN in Switzerland. He was in touch with RoCS when it was established in 2017. He had just finished his master's at NTNU in Trondheim. The positive communication with the professors at RoCS stayed with him and with a PhD from CERN in his back pocket he applied for his first Postdoc position at RoCS. - It was the combination of a large and professional scientific environment, the possibility to teach at the University of Oslo (UiO), an interesting and exciting research topic, and a focus on large numerical simulations that made me choose RoCS, Vik Furuseth explains.

Life after RoCS

Jayant Joshi applied to one of the first positions as a postdoctoral fellow at RoCS in 2017. In 2021, he moved on to the next step on the career ladder. He started working as an assistant professor at the Indian Institute of Astrophysics (IIA) in Bengaluru, India.

- I was originally planning to go to Maui, Hawaii, explains Joshi. He had received a job offer from the National Solar Observatory based there and planned for his relocation to the United States. He was going to leave winter wonderland for a tropical destination. Joshi looked forward to working with the world's largest solar telescope, the 4-meter Daniel K. Inouye Solar Telescope (DKIST), but the pandemic put a stop to it.

He was 38 years old at the time and his background was a PhD and two postdoctoral positions. When he was unable to take the job at Maui due to travel restrictions he returned to India.

- I had planned to return to India for quite some time, so in the end everything worked out well for me. He enjoys being closer to his family and in a country with more hours of sunlight than Norway.

- Bengaluru is the capital of the southern state of Karnataka. I was born in a village called Damri in Rajasthan, and that is where my parents live, and it is around 1600 km from Bengaluru, explains Joshi.

RoCS as a springboard

Joshi had his second postdoctoral fellowship at RoCS and it played an important role in his career development.

- It provided adequate support and a work environment to grow as a researcher. Teaching and supervising experiences are vital for an early career researcher, says Joshi.

- I had the opportunity to interact and work with students ranging from undergraduates to PhD candidates during my postdoc at RoCS. Overall, my time with RoCS is a highlight of my curriculum vitae.

Research focus

Joshi will continue to work with RoCS on projects: - When I was at RoCS, along with colleagues, we found ubiquitous small-scale magnetic reconnection events in the lower solar atmosphere. This phenomenon has been discovered recently, and its origin and effect on the solar atmosphere are not well understood. I will continue my research on small-scale reconnection events, and I will collaborate on this topic with Professor Luc Rouppe van der Voort and others at RoCS, says Joshi.

National projects in India

The Indian Institute of Astrophysics (IIA) is one of India's major astrophysics research institutes. IIA is leading two big national projects, space coronagraph for Aditya-L1 mission and a ground-based 2-meter National Large Solar Telescope (NLST), to advance solar astronomy in India. Joshi is excited about the prospect of contributing to two such large projects. The future looks bright!

Eyrun Thune



Jayant Joshi in his office at The Indian Institute of Astrophysics. (Credit: Private)



The building of IIA is situated in Bengaluru, India. (Credit: Private)



Members of the centre

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 2021 we had twelve master students, seventeen doctoral research fellows, eleven post-docs and researchers, three research software engineers, two associate professors, four professors, one centre coordinator and one communication adviser. In addition, we had seven adjunct professors, as well as eight associated members in the administrative and technical staff and five emiriti. 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 21 nationalities from four 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 is a doctoral research fellow at RoCS. Helle is at the interface between observations and numerical models, where she focuses on the effect of accelerated particles on the solar atmosphere. In particular, her research involves comparing synthetic observables to actual observations of low-energy events in the solar atmosphere.



Aditi Bhatnagar

Aditi Bhatnagar is a doctoral research fellow at RoCS. She is going to study the origin and impact of small-scale energetic phenomena in the solar atmosphere, mainly Ellerman Bombs in the quiet Sun (QSEBs). By combining observations from the lower atmosphere with the Interface Region Imaging Spectrograph (IRIS) observations from the higher layers, a more complete view of the impact of QSEBs on the solar atmosphere can be obtained. These results will further serve as valuable input for modelling efforts that are needed to understand their formation.



Souvik Bose

Souvik Bose finished his doctoral thesis in 2021 at RoCS. Souvik's research mainly focuses on the dynamics of the solar atmosphere, in particular the origin and the evolution of spicules in the solar chromosphere. He is mainly an observer and uses the data from both ground and space-based solar telescopes for his research. In addition, he makes use of numerical radiative transfer codes for reproduction of synthetic data to compare with the observations. He is also interested in applying machine learning techniques in solar physics.



Frederik Clemmensen

Frederik Clemmensen is a doctoral research fellow at RoCS. The primary topic of Frederik's research is the processes in the solar atmosphere that leads to highly energetic, accelerated particles. For this purpose, he uses new methods of numerical modelling which he is involved in developing. In general, Frederik is interested in programming and developments in computing.



Ainar Drews

Ainar Drews finished his doctoral thesis in 2021 at RoCS. His research focused on observations of the Sun. Some of his earlier work was dedicated to partial automation of solar observations using simple machine learning. Ainar's research revolved around the investigation of primarily chromospheric objects in the penumbrae of sunspots called Penumbra Microjets, employing both ground- and space-based instruments.



Henrik Eklund

Henrik Eklund finished his doctoral thesis in 2021 at RoCS. His research focused on determining optimal ways to handle interferometric data from ALMA observations of the Sun. He also made use of the ALMA data in combination with space-borne observations and simulations to study primarily wave motions and the evolution of small-scale structures in the chromosphere.

Phd



Elisabeth Enerhaug

Elisabeth Enerhaug is a doctoral research fellow at RoCS. She is in her first year of a joint PhD between the University of St Andrews and the University of Oslo. She will be looking at MHD waves and coronal heating using numerical simulations and analysis.



Lars Frogner

Lars Frogner is a doctoral research fellow at RoCS. His research is mainly concerned with numerical modelling 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 is a doctoral research fellow at RoCS. He is a part of the Whole Sun team, and his research is focused on numerical simulations. During his master, he simulated magnetic activity in the Quiet Sun atmosphere, and now he is experimenting with simulations of magnetic reconnection using different magnetic diffusion models to see which models can resolve the highest order of plasmoid instability.



Juan Camilo Guevara Gómez

Juan Camilo Guevara Gómez is a doctoral research fellow at RoCS. He is analyzing solar observations with ALMA seeking for signatures of heating. Mainly doing tracking of small-scale features associated either to shock waves or MHD modes. Juan is also supporting his observational analysis by comparing the results with available simulations. Finally, Juan is also enrolled in outreach activities and he is the principal Team Leader of the Norwegian team for the International Olympiad on Astronomy and Astrophysics.



Michael Haahr

Michael Haahr is a doctoral research fellow at RoCS. He 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 modelling and high performance computing.



Kilian Krikova

Kilian Krikova is a doctoral research fellow at RoCS and his PhD research is focused on studying the impact and origin of small-scale energetic phenomena in the solar atmosphere. His work is especially focused on Ellerman "bombs" (EB) which could play a significant role in transporting energy through the solar atmosphere and reconfiguration of the solar photospheric magnetic field. Therefore he will combine state-of-the-art observations, simulations, and radiative transfer tools to get a better understanding of small-scale energetic phenomena at the Sun.

Phd



Thore Espedal Moe

Thore Espedal Moe is a doctoral research fellow at RoCS. His focus is on the formation of polarized spectral lines in the chromosphere. Taking a forward-modeling approach using numerical radiative transfer codes for synthesizing polarized spectra from the output of Bifrost simulations, he aims to better understand how and where these lines are formed, and how they can be used to diagnose magnetic phenomena.



Sneha Pandit

Sneha Pandit is a doctoral research fellow at RoCS. Sneha is mainly analysing observational data taken by ALMA and comparing them with other well studied observations. She studies the Sun in order to understand the structures of stars in general by combining state-of-the-art simulations, and radiative transfer tools. The 'Sun as a star approach' uses solar observations to estimate properties or features of other stars in order to understand the Sun and stars better. She wants to learn more about the solar-stellar observations and different techniques of data analysis and simulations. She enjoys contributing towards outreach activities.



Rebecca Robinson

Rebecca Robinson is a doctoral fellow at RoCS. Rebecca is using both simulations and observations to analyze the dynamics and distribution of the quiet Sun magnetic field and hopes to contribute to our greater understanding of the coronal energy budget. She likes to travel, teach, play music, go bouldering, eat waffles, drink coffee, and explore new places and ideas. She is enjoying her position with RoCS and is looking forward to learning even more.



Mats Ola Sand

Mats Ola Sand finished his master's degree at RoCS in 2021 and is now a doctoral research fellow at RoCS. His research project will focus on the origin of jets in the solar atmosphere; these jets are commonly referred to 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 Bombs in the quiet Sun (QSEBs) and spicules, and whether the reconnection in QSEBs could be the driver of some of the spicules observed all over the Sun.



Eilif Sommer Øyre

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

Postdocs and researchers



Sondre Vik Furuseth

Sondre Vik Furuseth is a new postdoctoral researcher at RoCS. He did his PhD in accelerator physics at CERN, where he simulated the whole LHC beam. Now, he will work towards simulating the whole Sun. In particular, he is interested in simulating and understanding the physics of active regions, magnetic reconnection, and acceleration of particles.



Ana Belén Griñón Marín

Ana Griñón is a postdoctoral researcher at RoCS. Her main field of investigation is mostly focused on the long-term evolution of active regions, in particular she has studied the evolution over several days of the magnetic field topology in the solar photosphere of active regions of type alpha. Another important field of research for Ana concerns the study of light bridges by means of ground-based telescopes and space-borne missions. Her current interest aims at the characterization of light bridges through the whole solar atmosphere, from the photosphere to the corona.



Vasco Manuel de Jorge Henriques

Vasco Henriques worked as a researcher at RoCS and became a guest researcher at RoCS in 2021. Vasco enjoys modelling poorly understood dynamic processes in our star using high-resolution observations. He recently mass reduced and compiled a public database of ALMA data that opens a new window into the solar chromosphere for solar physicists. Vasco has had a passion for astronomy since he would bring his small telescope to astronomy festivals in the Portuguese countryside as a teenager, and has a passion for new technologies for and beyond science.



Shahin Jafarzadeh

Shahin Jafarzadeh is an affiliated researcher at RoCS, previously working for the Solar ALMA project. Since September 2021, he 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 is a founding member of the WaLSA international science team. He is also engaged in the science activities of the Solar Orbiter and the SUNRISE balloon-borne solar observatory. Shahin is an experienced observer, particularly with SST, and passionately engages in public outreach activities.



Chandrashekar Kalugodu

Chandrashekar Kalugodu is a postdoctoral researcher at RoCS. His research interests are understanding small-scale transient events in the solar atmosphere, observational magnetohydrodynamics, and superflares on stars and the Sun, and solar-stellar connection. His current focus is to study the coronal bright point(CBP) oscillations, chromospheric dynamics, and oscillations of the CBPs, using space-borne and ground based solar telescopes.



Petra Kohutova

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



Atul Mohan

Atul Mohan is a postdoctoral 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.



Nancy Narang

Nancy is a postdoctoral researcher at RoCS. Her research primarily includes the study of small-scale features and phenomena observed in the solar atmosphere. She employs high-resolution observations and state-of-the-art simulations to understand the dynamics of small scale events, and to have insights about their role in the mass and energy cycle of the solar atmosphere.



Daniel Nóbrega Siverio

Daniel Nóbrega Siverio used to be a postdoctoral researcher at RoCS, but from March 2021 he works at Instituto de Astrofísica de Canarias (IAC) in Tenerife. He is still connected to RoCS as guest researcher.



Avijeet Prasad

Avijeet Prasad is a Postdoctoral Research Fellow at RoCS and part of the Whole Sun project team. Avijeet's research has mainly been focused on coronal magnetic field extrapolations derived from photospheric vector magnetograms and data-constrained magnetohydrodynamics simulations of high-energetic events in the solar corona like solar-flares and coronal mass ejections.



Maryam Saberi

Maryam Saberi is a postdoctoral researcher at the ALMA RoCS group. She is mainly interested in studying solar and stellar chromospheric activity, aiming to understand the coronal heating problem. She is also interested in studying the role of strong UV photons from stellar activity on the chemical composition of evolved stars. She mainly uses observational data at mm/sub-mm wavelengths observed with the ALMA and APEX telescopes. She is also experienced in radiative transfer and chemical modelling of the outflow around evolved stars.

Postdocs and researchers

Research Software Engineers



Maria Guadalupe Barrios Sazo

Maria Guadalupe Barrios Sazo works as a research software engineer at RoCS. Her interests involve numerical methods for astrophysical simulations, high performance computing, and developing code in a sustainable manner. She looks forward to contributing to our understanding of the Sun through advanced computational techniques and state of the art supercomputers.



Andrius Popovas

Andrius Popovas works as a Research Software Engineer at RoCS. He works with developing numerical simulations of the Solar atmosphere, the next-generation simulation framework, which will use the modules from the Bifrost code and enable running experiments on an unprecedented scale and complexity. This includes static and adaptive mesh refinement, multi-solver-multi-physic, etc.



Mikolaj Szydlarski

Mikolaj Szydlarski works as a research software engineer at RoCS. 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 is a new Adjunct Professor at RoCS. He develops 3D numerical models coupled with multi-wavelength observations for solar flares, prominences, and reconnection. He is an expert in magnetic field topology, and is the original developer of the MHD code OHM. 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 Paris Science & Lettres, chair of the Sun-Earth national programme of CNRS, and policy officer for HPC at the ministry of research and innovation.



Ineke De Moortel

Ineke De Moortel is an Adjunct Professor at RoCS. Her research focuses 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), where she teaches Solar Theory to Mathematics undergraduate students as well as supervising PhD students. From September 2021, one of these PhD students, Elisabeth Enerhaug, has started a joint PhD between the Universities of St Andrews and Oslo.



Bart De Pontieu

Bart De Pontieu is an Adjunct Professor at RoCS. His research is aimed at understanding how the Sun's magnetic field energizes the coupled solar atmosphere from the photosphere into the corona and heliosphere. He focuses on combining high resolution space-based and ground-based multi-wavelength observations with advanced numerical modeling. He is the PI of NASA's IRIS satellite and manages the IRIS research team at Lockheed Martin Solar & Astrophysics Laboratory (LMSAL) in Palo Alto, California, USA. He is also the institutional PI of the JAXA/NASA EUVST project at LMSAL.

Adjunct professors



Lyndsay Fletcher

Lyndsay Fletcher is an Adjunct Professor at RoCS. Her main research interest is solar flares, specifically the transport of energy through the flare atmosphere, the energisation of the chromosphere and the interpretation of radiation signatures to help us understand this process. She works mostly on data analysis, figuring out ways to confront data with flare models. As well as research, she teaches astrophysics to students at all levels in 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 is an Adjunct Associate Professor at RoCS and based at LMSAL and BAERI. His major contributions are on numerical modeling of the solar atmosphere. His main interests focus on 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 observations.



Åke Nordlund

Åke Nordlund is an adjunct professor at RoCS. Nordlund 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.



Turn your face to the sun and the shadows fall behind you.

Maori Proverb

Principal investigators



Mats Carlsson

Mats Carlsson is a professor and the director of RoCS. 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 is a professor and PI at RoCS with focus 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 is a senior researcher at Bay Area Environmental Research Institute as well as being a part time professor and PI at RoCS. He 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.

Centre administration



Benedikte Fagerli Karlsen

Benedikte Fagerli Karlsen is the centre coordinator at RoCS. 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 employments, visitors, contracts, reporting and logistics at events.



Eyrun Thune

Eyrun Thune is a communication adviser at RoCS. She is responsible for external communication and outreach activities at RoCS.

Technical and administrative associated staff



Tiago M. D. Pereira

Tiago M. D. Pereira is an associate professor and PI at RoCS. He 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 is a professor and PI at RoCS. Luc's main area of research is 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 is an associate professor and PI at RoCS. Sven leads the research activities related to solar and stellar observations with ALMA and supporting simulations, which involves the ERC-funded SolarALMA project, the EMISSA project (RCN), an ESO-funded ALMA development study, and the SSALMONetwork. His research mostly focuses on the small-scale structure, dynamics and energy balance of the solar atmosphere with implications for other stellar types.



Martina D'Angelo

Martina D'Angelo works as a communication advisor and press contact at the Institute of Theoretical Astrophysics (ITA). Martina's main responsibilities are internal communication, outreach activities, ITA's popular-science articles and social media channels. She is the web editor of the institute's website and coordinator for the Norwegian Olympiad on Astronomy and Astrophysics.



Terje Fredvik

Terje Fredvik is an engineer in the institute's Project Related IT Services (PRITS) group. He 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 is the technical lead for the Project Related IT Services (PRITS) group. He is responsible for the Hinode Science Data Centre Europe, serving data from the Hinode and IRIS missions and soon also data from e.g. the Solar Orbiter SPICE instrument. He is a member of 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 is the Head of Office at the Institute of Theoretical Astrophysics. She is the head of our administration, and cooperates closely with both the scientific, technical and administrative staff at RoCS and the Institute.



Torben Leifsen

Torben Leifsen is the head of IT at the Institute. He 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.



Wojciech Olejarz

Wojciech Olejarz started in the Project Related IT Services group in May 2021 as a front-end developer on the new Hinode archive front end. He has a very broad background within IT, with a large skill set and a natural flair for programming.



Pratibha Shrestha

Pratibha Shrestha left RoCS in March 2021 after working as a front-end developer in the Project Related IT services (PRITS) group on a three year project assisting in the development of a new front-end for the Hinode archive.



Martin Wiesmann

Martin Wiesmann is an engineer in the institute's Project Related IT Services (PRITS) Group. He 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 is a computational plasma physicist whose interests span solar physics, space weather, laser-plasmas and QED-plasmas. He has been responsible for developing MHD codes for both solar physics and laser-driven fusion as well as kinetic codes for high-power plasma interactions. For all codes, he is interested in software development methods and uncertainty quantification.



Sarah Matthews

Sarah Matthews is a Professor of Solar Physics at UCL's Mullard Space Science Laboratory. Her research interests focus on energy storage and release in magnetised plasmas, and in particular solar eruptive events and space weather. Her work is mainly observational, bringing together multi-wavelength space and ground-based observations, but she also works in collaboration with magnetic field modellers in particular 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 is a senior researcher at the Leibniz-Institut für Sonnenphysik (KIS) in Freiburg, Germany and at the Istituto Ricerche Solari Locarno (IRSOL) in Switzerland. His research focuses 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.



Francesca Zuccarello

Francesca Zuccarello is an associate professor at the University of Catania (Italy). Francesca 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 participated in several Coordinated Observational Campaigns.

Emiriti



Oddbjørn Engvold

Oddbjørn Engvold is an emeritus professor at RoCS. One of his main areas of research is 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 in recent years edited and contributed to two books related to solar activity.



Olav Kjeldseth-Moe

Olav Kjeldseth-Moe is an emeritus professor at RoCS. His area of special interest is the transition region into the corona and over the years he has contributed to the development of instruments and observing procedures designed to map conditions in this part of the solar atmosphere. Thus, he participated in the small group of daily science planners at NASAs Skylab Observatory in 1973-74, was a co-investigator on the HRTS instrument on Spacelab 2 in 1985, and finally served for 20 years as the Norwegian co-investigator for the CDS spectrometer on SOHO.



Egil Leer

Egil Leer is an emeritus professor at RoCS. His main areas of interest include the corona, the solar wind, and the interaction of the solar wind with the local interstellar medium.



Rob Rutten

Rob Rutten is an emeritus adjunct professor at RoCS. He is a leading expert in radiative transfer and spectral diagnostics. His lecture notes are used in teaching radiative transfer worldwide. This year he published a major update.



Jan Trulsen

Jan Trulsen is an emeritus professor at RoCS. His main areas of research includes plasma physics, turbulence phenomena in ionized and neutral media, numerical simulations.

Master students



Isak Aaby

Isak is a first-year master student at RoCs. In his thesis, Isak will explore the topology of coronal magnetic fields in the Sun by combining numerical magnetic field extrapolation techniques and observations from space and ground-based telescopes. It is believed that reconnection of these magnetic fields is the origin of solar flares and coronal mass ejections. Isak will begin working on the thesis in autumn 2022 with Avijeet Prasad and Sven Wedemeyer as his supervisors.



Stian Aannerud

Stian is a first-year master student at RoCS. In his thesis he will study the effect of the Hall term on magnetic reconnection, by implementing a module in the Bifrost MHD simulation. He starts his project in spring 2022 with professor Boris Vilhelm Gudiksen as his supervisor.



Bruce Arnold Chappell

Bruce finished his master's degree in 2021 at RoCS. He has a physics bachelors background from the US and his academic interests are machine learning, data analysis, and high performance computing. In his thesis he used machine learning methods applied to 3D spectral synthesis.



Jonas Thoen Faber

Jonas is a second-year master student at RoCS. He will use coronal hole observations obtained from the IRIS instrument and implement machine learning techniques to group the data into different categories. The main goal is to look at explosive events from Si IV lines and perform analysis on other profiles such as C II and Mg II h&k. Nancy Narang and Tiago Pereira will be his supervisors and his goal at RoCS is to increase his knowledge of the behavior of the solar atmosphere.



Ida Risnes Hansen

Ida Risnes Hansen finished her master's degree in 2021 at RoCS. She worked on Tiago Pereira's project on Monte Carlo radiative transfer methods in stellar atmospheres. Ida is interested in the history of discoveries in astronomy, and the lives of the scientists behind them.



Edvarda Harnes

Edvarda is a first-year master student at RoCS. In her thesis she will apply physics-informed neural network methods to non-LTE radiative transfer, and the goal is to synthesise spectral lines from a 3D model atmosphere. She will start the work on her thesis from the autumn of 2022 under the supervision of Tiago M. D. Pereira.

Master students



Mats Kirkaune

Mats is a first-year master student at RoCS. He will start working on his thesis autumn 2022 under the supervision of Atul Mohan and Sven Wedemeyer. His thesis will be on searching for stellar emission in the sub-THz bands, where he will look for stellar emission at mm/radio wavelengths in archival observations that has not yet been reported.



Ilse Kuperus

Ilse Kuperus is a second-year master student at RoCS. Ilse's research is focused on finding the roots of microturbulence in the sun, mainly finding out if this is a real effect from unresolved motions, or is a fudge factor. This will be done by carrying out spectral synthesis of chromospheric and photospheric lines from 3D rMHD models of the solar atmosphere. Ilse started working on her thesis in the autumn of 2021 under the supervision of Tiago M. D. Pereira.



Jonas Ringdalen Thrane

Jonas is a first-year master student at RoCS. In his thesis he will perform artificial observations of different stellar types at millimetre wavelengths, using a new sequence of state-of-the-art 3D numerical simulations of stellar atmospheres. The resulting data will facilitate studying the diagnostic potential of millimetre observations of other stars. He will start his thesis in the autumn of 2022 under the supervision of Sven Wedemeyer.



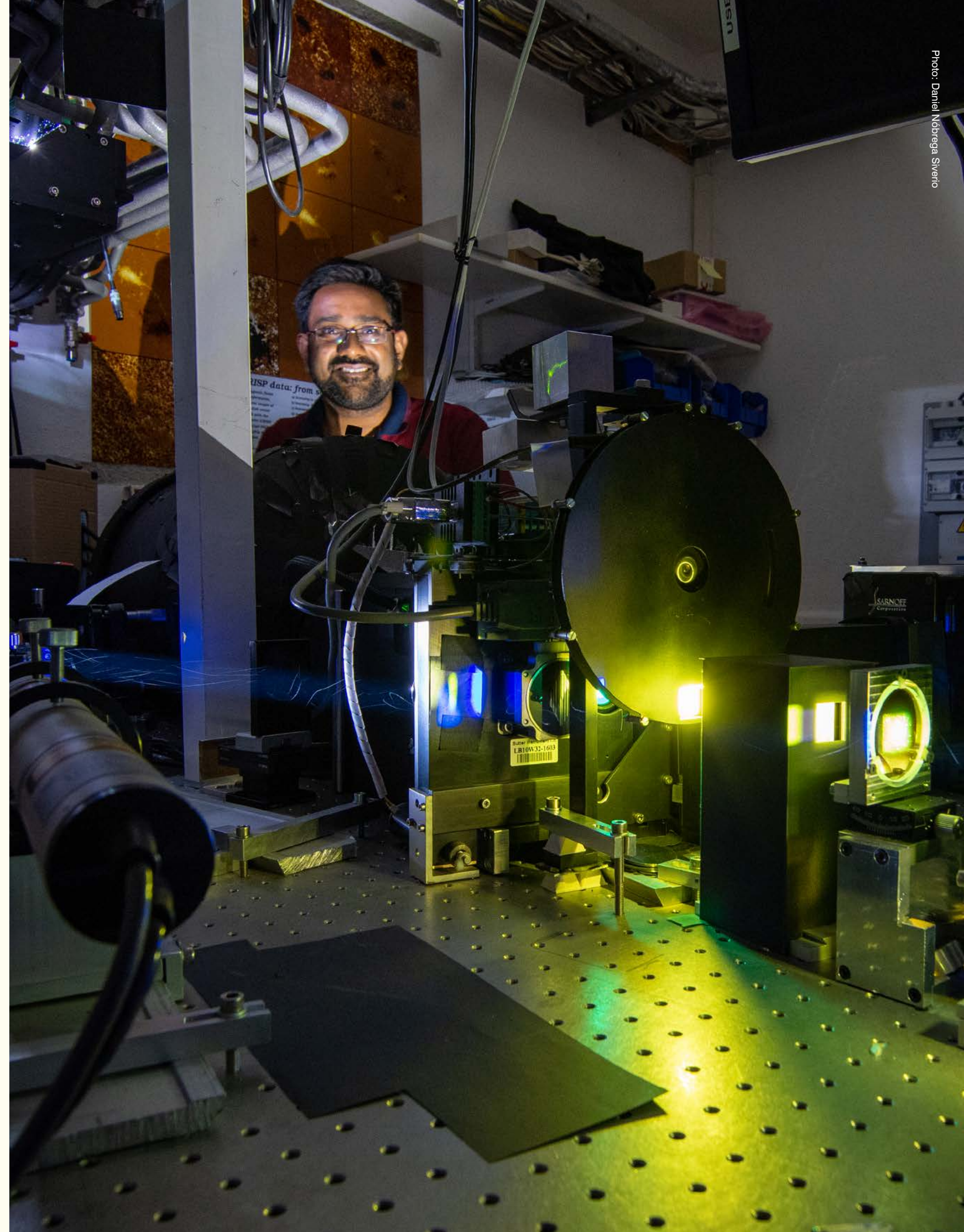
Magne Elias Roland Udnæs

Elias is a second-year master student in the Computational Science: Astrophysics programme with an interest in numerical simulations. He started his thesis work in the autumn of 2021, working with Tiago M. D. Pereira and Mats Carlsson as supervisors. Through this work, he will utilise irregular grids in 3D radiative transfer solvers to attain improvement of numerical accuracy.



Marte Cecilie Wegger

Marte is a second-year master student at RoCS. In her thesis she performs radiative transfer analysis of observed HCN lines in a circumstellar envelope (CSE) formed around an AGB star, in order to quantify the impact of UV radiation in the CSE chemistry. She started working on her thesis autumn 2021 with Maryam Saberi and Sven Wedemeyer as supervisors.



Talks and presentations 2021



Bhatnagar, Aditi. Formation of the OI and CI lines in a flare. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Bhatnagar, Aditi. Sun and the Solar system. 2021-10-15



Bhatnagar, Aditi. EST Infographics for school, Asker, Sandvika, Tromsø, Tønsberg, 4 talks 2021-10-22 – 11-24



Bhatnagar, Aditi. Formation of the IRIS OI and CI lines in a flare. University of Glasgow; 2021-12-09



Carlsson, Mats. Modelling of the Solar Chromosphere. IIA-50 conference "Advances in Observation and Modelling of Solar Magnetism and Variability"; 2021-03- 01 - 2021-03-04



Carlsson, Mats. Solen, din nærmeste stjerne. Åpen dag; 2021-03-11



Carlsson, Mats. Modelling the energy and mass coupling of the chromosphere and corona. SDO workshop; 2021-03-25



Carlsson, Mats. Modelling the energy and mass coupling of the solar chromosphere and corona. Royal Swedish Academy of Science meeting; 2021-11-12



Carlsson, Mats. Solstormer. Christmas seminar; 2021-12-07



Fletcher, Lyndsay. Living with a Star. Glasgow University Astronomy Society; 2021-03-04



Fletcher, Lyndsay. Turbulence and particle acceleration in solar flares. Seminar at the Instituto de Astrofísica de Canarias; 2021-05-04



Fletcher, Lyndsay. Solar Microscopes. SIGMA (Moray Astronomical Society); 2021-05-07



Fletcher, Lyndsay. Observations of Flare and CME onset. "Solar Flare Energy Release" NASA DRIVE Center meeting; 2021-05-24



Fletcher, Lyndsay. Solar Flares with PHI. Solar Orbiter/PHI Science Preparation Meeting; 2021-09-30



Fletcher, Lyndsay. Solar Flares and Eruptions. Solar Orbiter Eruptions Working Group; 2021-11-22



Fletcher, Lyndsay. Solar Flares: Observations and Physical Interpretation. British Astronomical Association Radio Astronomy Section; 2021-11-05



De Moortel, Ineke. Our Dynamic Sun. Edinburgh u3a Astronomy and Science Group; 2021-01-13



Griñón Marín, Ana Belén. Viaje a Través del Universo. Annual Guest Lecture at IES Pablo Serrano; 2021-01-07



Griñón Marín, Ana Belén. Científica Andorrana. Mes de la Mujer en el Colegio San Valero; 2021-03-02



Griñón Marín, Ana Belén. Científica Andorrana. Mes de la Mujer en el CRA del Mezquín; 2021-03-08



Griñón Marín, Ana Belén. Científica Andorrana. Mes de la Mujer en el CRA Ariño-Alloza; 2021-03-26



Griñón Marín, Ana Belén. Long-Term Evolution of Three Light Bridges Developed on the Same Sunspot. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Griñón Marín, Ana Belén. Long-Term Evolution of Three Light Bridges Developed on the Same Sunspot. Hinode-14 / IRIS-11; 2021-10-25 - 2021-10-29



Griñén Marín, Ana Belén. Learning about sunspot magnetism and evolution through light-bridges. Astronomy seminar in Stockholm University; 2021-11-12



Griñón Marín, Ana Belén. Solar Orbiter and new possibilities for sunspot light bridge studies. Solar Orbiter Magnetoconvection RSSWG; 2021-12-13



Griñón Marín, Ana Belén. El Sol: Breve Introducción. Solar Guest Lecture at Valencia International University; 2021-12-15



Griñón Marín, Ana Belén. Viaje a Través del Universo. Annual Guest Lecture at IES Pablo Serrano; 2021-12-22



Guevara Gomez, Juan Camilo; Wedemeyer, Sven. Dynamics of small-scale dark features observed by the Atacama Large Millimeter/submillimeter Array (ALMA). COSPAR 2021; 2021-01-28 - 2021-02-04



Guevara Gomez, Juan Camilo; Wedemeyer, Sven. Dynamics of small-scale dark features observed by the Atacama Large Millimeter/Submillimeter Array (ALMA). The 20.5th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun (CS20.5); 2021-03-02 - 2021-03-04



Guevara Gomez, Juan Camilo; Jafarzadeh, Shahin; Wedemeyer, Sven. Oscillations in small-scale bright features observed with ALMA. Solar Orbiter School at Les Houches 2021; 2021-04-06 - 2021-04-09



Guevara Gomez, Juan Camilo. ALMA co-alignment with other observations. ALMA-SOL-IMG Workshop 2; 2021-11-03 - 2021-11-05



Hansteen, Viggo. Flux emergence in the Quiet Sun and its implications for chromospheric/coronal heating. Solar Orbiter/PHI Science Preparation Meeting; 2021-09-28 – 2021-09-30



Hansteen, Viggo. Heating the outer layers of the Sun: braiding, flux emergence, and episodic events. Hinode-14/IRIS-11; 2021-10-25 - 2021-10-29



Henriques, Vasco. The corrugated umbra model. ESPOS Seminar; 2021-02-11



Henriques, Vasco. New insights from umbra modelling and new questions for cycle 25. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Henriques, Vasco. The Solar ALMA Science Archive (SALSA). IAC Solar Seminar; 2021-12-15



Jafarzadeh, Shahin; Gafeira, Ricardo; **Wedemeyer, Sven; Szydlarski, Mikolaj.** MHD waves in chromospheric fibrillar structures as observed with ALMA. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Kohutova, Petra. Formation of coronal rain and coronal heating mechanisms. Hinode-14/IRIS-11; 2021-10-25 - 2021-10-29



Moe, Thore Espedal; Pereira, Tiago; Carlsson, Mats. Effects of spatial resolution on Stokes profiles. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Mohan, Atul; McCauley, Patrick; Oberoi, Divya; Mastrano, Alpha. Quasi-periodic particle acceleration episodes during a microflare. COSPAR 2021; 2021-01-28 - 2021-02-04



Mohan, Atul. Discovery of correlated evolution in radio burst source parameters: Properties and links to local magnetic field evolution during a microflare. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Narang, Nancy. Power distribution of oscillations in plage region: Joint observations from ALMA, IRIS and AIA. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Narang, Nancy. Power distribution of oscillations in plage region: Joint observations from ALMA, IRIS and AIA. Hinode-14/IRIS-11; 2021-10-25 - 2021-10-28



Omang, Marianne Gjestvold; Hauge, Knut Ove. Spontaneous ignition of aluminum particles in a shock tube environment. International Colloquium on Shock Waves (ICSW); 2021-12-06



Pandit, Sneha. mm indicators of the solar stellar activity: full disk observations of the sun. Heliophysics summer school; 2021-06-14 - 2021-06-25



Pandit, Sneha. How do we understand habitability?. Astrophysics home delivered talk; 2021-07-06



Pandit, Sneha. Analysis of full disk solar observations from ALMA. 50th Young European Radio Astronomers Conference (YERAC); 2021-08-24 - 2021-08-27



Pandit, Sneha; Wedemeyer, Sven. The sun as a star: new insights from the full disk observations with ALMA. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Pereira, Tiago; Chappell, Bruce. A Neural Network Approach to 3D NLTE Radiative Transfer. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Prasad, Avijeet. An investigation of the magnetic topology of the inverse Evershed flow. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10



Prasad, Avijeet. MHD simulations of the solar corona initiated with non-force-free fields. Whole Sun Meeting; 2021-09-21 - 2021-09-22



Robinson, Rebecca Anne. Magnetic Field Topology and Chromospheric Heating. Whole Sun Gathering; 2021-03-10 - 2021-03-11

▶ **Robinson, Rebecca Anne.** Simulating Atmospheric Heating with Bifrost. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10

▶ **Robinson, Rebecca Anne.** Simulating Atmospheric Heating with Bifrost. Whole Sun Gathering; 2021-09-21 - 2021-09-22

▶ **Robinson, Rebecca Anne.** 1. Why Does the Sun Shine? 2. Northern Lights: Can we Really Predict Them? 3. Four Things Everybody Wonders About Space 4. Seasons at the Poles. Norway Winter Expedition Cruise from Hamburg; 2021-10-04 - 2021-11-16

▶ **Roupe van der Voort, Luc.** Signatures of ubiquitous magnetic reconnection in the deep atmosphere of sunspot penumbrae. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10

▶ **Saberi, Maryam.** UV Chemistry in the Circumstellar Envelopes of Evolved Stars. Invited talk at Sharif University of technology; 2021-05-02

▶ **Saberi, Maryam; Jafarzadeh, Shahin;** Gafeira, Ricardo; **Wedemeyer, Sven;** Szydlarski, Mikolaj. MHD waves in chromospheric fibrillar structures as observed with ALMA.16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10

▶ **Saberi, Maryam;** Khouri, Theo; Velilla-Prieto, L.; Fonfria, . P.; Vlemmings, W.; **Wedemeyer, Sven.** Tracing the role of AGB stars in the Galactic Fluorine budget. IAU Symposium 366: Virtual Meeting, "The Origin of Outflows in Evolved Stars"; 2021-10-01 - 2021-10-05

▶ **Saberi, Maryam.** The life cycle of a star from radio window. Real Fagdag - Faglig-pedagogisk dag; 2021-10-04

▶ **Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Henriques, Vasco; Eklund, Henrik; Guevara Gomez, Juan Camilo; Mohan, Atul; Pandit, Sneha; Saberi, Maryam; Barrios Sazo, Maria Guadalupe.** Observing the Sun with ALMA - First results and future opportunities. National Astronomy Meeting (NAM); 2021-07-19 - 2021-07-23

▶ **Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Henriques, Vasco; Eklund, Henrik; Guevara Gomez, Juan Camilo; Mohan, Atul; Pandit, Sneha; Saberi, Maryam; Barrios Sazo, Maria Guadalupe.** Five years observing the solar chromosphere with ALMA - First results and future opportunities. 16th European Solar Physics Meeting; 2021-09-06 - 2021-09-10

▶ **Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Henriques, Vasco; Eklund, Henrik; Guevara Gomez, Juan Camilo; Mohan, Atul; Pandit, Sneha; Saberi, Maryam; Barrios Sazo, Maria Guadalupe.** Five years observing the solar chromosphere with ALMA - First results and future opportunities. Hinode-14/IRIS-11; 2021-10-25 - 2021-10-29

▶ **Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Henriques, Vasco; Eklund, Henrik; Guevara Gomez, Juan Camilo; Mohan, Atul; Pandit, Sneha; Saberi, Maryam; Barrios Sazo, Maria Guadalupe; Wegger, Marte.** A brief introduction to solar observing with ALMA. International Workshop on Solar Imaging with ALMA - ALMA-SOL-IMG2; 2021-11-03 - 2021-11-05

▶ **Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Henriques, Vasco; Guevara Gomez, Juan Camilo; Eklund, Henrik; Mohan, Atul; Pandit, Sneha; Saberi, Maryam; Barrios Sazo, Maria Guadalupe.** Lessons learned from 5 years of solar observing with ALMA. FASR21 - Solar Physics with a Next Generation Solar Radio Facility; 2021-12-01 - 2021-12-03

Papers in refereed journals 2021

▶ Andriantsaralaza, M.; Ramstedt, S.; Vlemmings, W. H. T.; Danilovich, T.; De Beck, E.; Groenewegen, M. A. T.; Höfner, S.; Kerschbaum, F.; Khouri, T.; Lindqvist, M.; Maercker, M.; Olofsson, H.; Quintana-Lacaci, G.; **Saberi, Maryam;** Sahai, R.; Zijlstra, A.: 2021, Astronomy and Astrophysics, 653, A53, DEATHSTAR: nearby AGB stars with the Atacama Compact Array. II. CO envelope sizes and asymmetries: the S-type stars

▶ **Aulanier, Guillaume:** 2021, Nature Astronomy, 5, 1096, The return of the jet.

▶ Ayres, Thomas; **De Pontieu, Bart;** Testa, Paola: 2021, The Astrophysical Journal, 916, 36, In the Trenches of the Solar-stellar Connection. IV. Solar Full-disk Scans of C II, Si IV, and Mg II by the Interface Region Imaging Spectrograph

▶ Baker, Deborah; Stangalini, Marco; Valori, Gherardo; Brooks, David H.; To, Andy S. H.; van Driel-Gesztelyi, Lidia; Démoulin, Pascal; Stansby, David; Jess, David B.; **Jafarzadeh, Shahin:** 2021, The Astrophysical Journal, 907, 16, Alfvénic Perturbations in a Sunspot Chromosphere Linked to Fractionated Plasma in the Corona

▶ Banerjee, D.; Krishna Prasad, S.; Pant, V.; McLaughlin, J. A.; Antolin, P.; Magyar, N.; Ofman, L.; Tian, H.; Van Doorsselaere, T.; **De Moortel, Ineke;** Wang, T. J.: 2021, Space Science Reviews, 217, 76, Magnetohydrodynamic Waves in Open Coronal Structures

▶ Bergemann, Maria; Hoppe, Richard; Semenova, Ekaterina; **Carlsson, Mats;** Yakovleva, Svetlana A.; Voronov, Yaroslav V.; Bautista, Manuel; Nemer, Ahmad; Belyaev, Andrey K.; Leenaarts, Jorrit; Mashonkina, Lyudmila; Reiners, Ansgar; Ellwarth, Monika: 2021, Monthly Notices of the Royal Astronomical Society, 508, 2236, Solar oxygen abundance

▶ **Bose, Souvik; Joshi, Jayant; Henriques, Vasco M. J.; Roupe van der Voort, Luc:** 2021, Astronomy and Astrophysics, 647, A147, Spicules and downflows in the solar chromosphere

▶ **Bose, Souvik; Roupe van der Voort, Luc; Joshi, Jayant; Henriques, Vasco M. J.; Nóbrega-Siverio, Daniel; Martínez-Sykora, Juan; De Pontieu, Bart:** 2021, Astronomy and Astrophysics, 654, A51, Evidence of the multi-thermal nature of spicular downflows. Impact on solar atmospheric heating

▶ Chintzoglou, Georgios; **De Pontieu, Bart; Martínez-Sykora, Juan; Hansteen, Viggo;** de la Cruz Rodríguez, Jaime; **Szydlarski, Mikolaj; Jafarzadeh, Shahin; Wedemeyer, Sven;** Bastian, Timothy S.; Sainz Dalda, Alberto: 2021, The Astrophysical Journal, 906, 82, ALMA and IRIS Observations of the Solar Chromosphere. I. An On-disk Type II Spicule

▶ Chintzoglou, Georgios; **De Pontieu, Bart; Martínez-Sykora, Juan; Hansteen, Viggo;** de la Cruz Rodríguez, Jaime; **Szydlarski, Mikolaj; Jafarzadeh, Shahin; Wedemeyer, Sven;** Bastian, Timothy S.; Sainz Dalda, Alberto: 2021, The Astrophysical Journal, 906, 83, ALMA and IRIS Observations of the Solar Chromosphere. II. Structure and Dynamics of Chromospheric Plages

▶ **De Pontieu, Bart;** Polito, Vanessa; **Hansteen, Viggo;** Testa, Paola; Reeves, Katharine K.; Antolin, Patrick; **Nóbrega-Siverio, Daniel;** Kowalski, Adam F.; **Martínez-Sykora, Juan; Carlsson, Mats;** McIntosh, Scott W.; Liu, Wei; Daw, Adrian; Kankelborg, Charles C.: 2021, Solar Physics, 296, 84, A New View of the Solar Interface Region from the Interface Region Imaging Spectrograph (IRIS)

▶ Dos Santos, Luiz F. G.; **Bose, Souvik;** Salvatelli, Valentina; Neuberg, Brad; Cheung, Mark C. M.; Janvier, Miho; Jin, Meng; Gal, Yarin; Boerner, Paul; Baydin, Atılım Güneş: 2021, Astronomy and Astrophysics, 648, A53, Multichannel autocalibration for the Atmospheric Imaging Assembly using machine learning

▶ **Eklund, Henrik; Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin:** 2021, Astronomy and Astrophysics, 656, A68, The Sun at millimeter wavelengths. III. Impact of the spatial resolution on solar ALMA observations

Felipe, T.; **Henriques, Vasco M. J.**; de la Cruz Rodríguez, J.; Socas-Navarro, H.: 2021, Astronomy and Astrophysics, 645, L12, Downflowing umbral flashes as evidence of standing waves in sunspot umbrae

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My sun sets to
rise again.

Robert Browning

