Rosseland Centre for Solar Physics

Annual report 2020

University of Oslo

Norwegian Centre of Excellence
The Research Council of Norway

Contents
Annual report 2020

Contact
Svein Rosselands hus
Sem Sælands vei 13
NO-0371 Oslo
Norway

P.O box 1029 Blindern
NO-0315 Oslo
Norway

Rosseland Centre for Solar Physics (RoCS)

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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.

Some members of RoCS gathered at «Kongens utsikt» (the King's view) at the RoCS retreat 2020. (M. Carlsson, RoCS).

From the Director

This is the third 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 year started with two international gatherings in our newly renovated home at the Svein Rosseland's house at Blindern. The excellent meeting room facilities proved to be essential for the success of a workshop in January for the Whole Sun ERC Synergy project (see Section 3.1). The next meeting took place March 2-6 when we welcomed twenty-one participants from Europe, North America, East Asia and Chile. They gathered to review the status of processing ALMA observations of the Sun (see Section 3.2). More participants joined the presentations and discussions via videoconferencing. Little did we know that only a few days later, videoconferencing would become the only way of international collaboration.

The Covid-19 pandemic has changed our lives in 2020. In the perspective of human tragedy, economic catastrophes and unrest, our problems at the workplace of RoCS are relatively minor. The national lockdown (March 12 in Norway) forced us to cancel a large number of planned events (more international workshops in Oslo, longer guest-researcher visits as part of the International Rosseland Visitor Programme, SOLARNET exchanges, etc.) and our own planned travel to international conferences. Some were trapped abroad but managed to find travel back to Norway

> "Night is always darker before the dawn and life is the same, the hard times will pass, every thing will get better and sun will shine brighter then ever."

Ernest Hemingway

with some delay. Some had to cut short visits abroad and international hires had increased trouble with visas and arriving in Norway. However, it all worked out in the end. We have adapted to working from home office and through videoconferencing. We had worked to get a university license for the zoom video conferencing system for more than a year and when the lockdown happened, they managed to solve all GDPR issues and other problems in two weeks. So, crisis situations can also speed up solutions.

The situation improved during the summer to the extent that we actually managed to have a retreat in person October 6-7. With Covid prevention measures in place and strictly keeping distance, we travelled to Kleivstua hotel in the woods outside Oslo. The weather was not very nice and the walk to the famous viewing point "the Kings view" was wet and foggy. But the scientific programme was a great success and actually meeting one another in a social setting was very nice (and now deeply missed since the second wave came just after the retreat).

In spite of the Covid pandemic, the ramp-up of activities continued in 2020. Two new Research Software Engineers (Andrius Popovas, Maria Guadalupe Barrios Sazo), five postdocs and researchers (Ana Belén Griñón Marín, Daniel Jakobsson, Chandrashekhar Kalugodu, Atul Mohan, Maryam Saberi) and two PhD students (Aditi Bhatnagar and Kilian Krikova) started in 2020. We also got four new master students (Jonas Faber, Ilse Kuperus, Magne Elias Roland Udnæs and Marte Cecilie Wegger).

Research results are important, but it is also essential to communicate these results to both the scientific world and the society at large. We need to make our activities known to prospective applicants for available positions and we need to attract good students. To help us in these activities, we have hired a full-time communication adviser, Eyrun Thune.

The activity has been high in 2020 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 65 papers in refereed journals in 2020[1], up from 53 in 2019.

The International Rosseland Visitor Programme, amputated as it was in 2020, is covered in Section 3 and we continue the tradition from last year 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 2020 we were a total of 62 persons of 21 nationalities from four continents at RoCS.

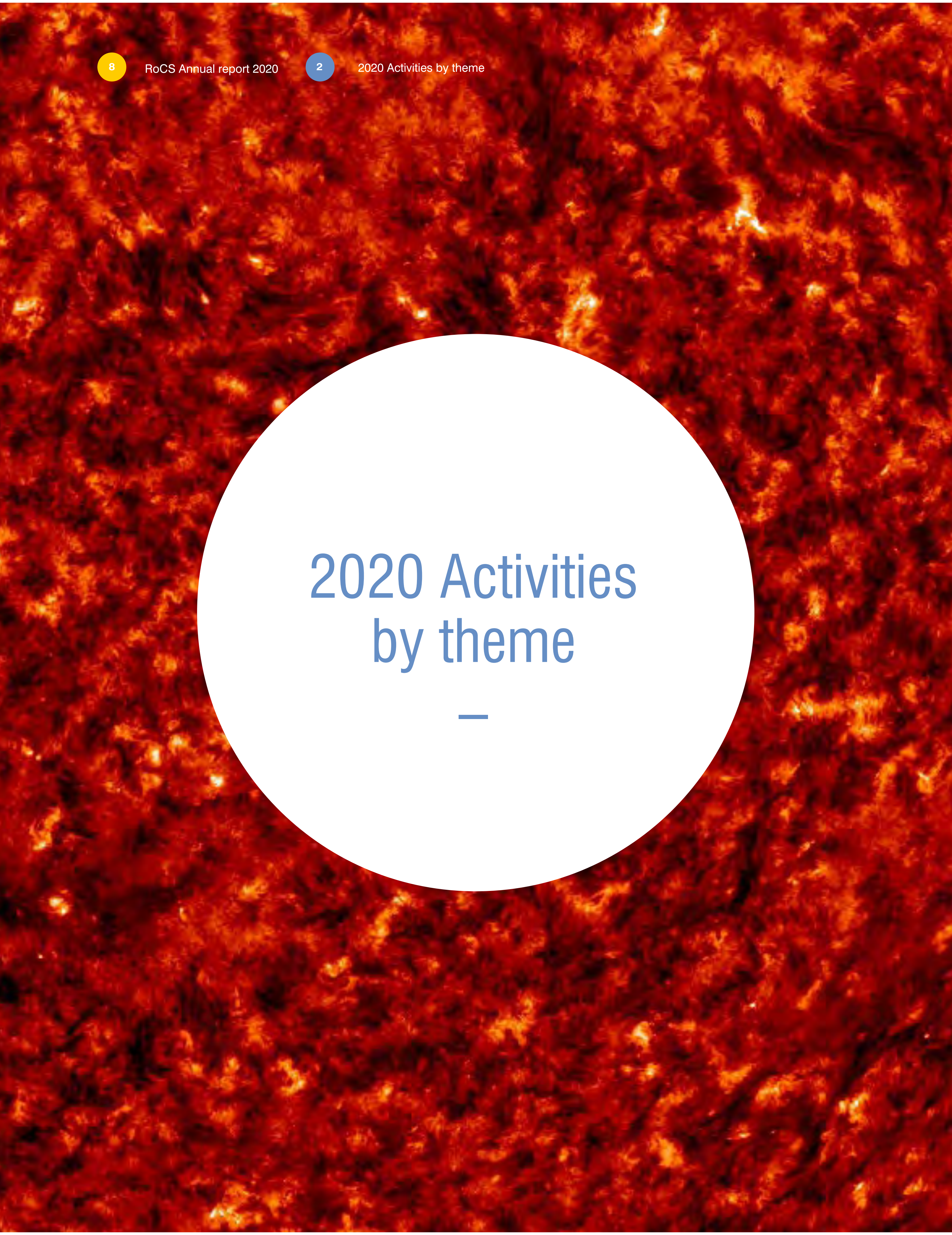
Researchers at RoCS have strong roles in the Solar Orbiter project. The PRITS (Project Related IT Services) group of the institute is responsible for the software that transforms the raw binary data from the remote-sensing instrument SPICE into a format that can be analyzed by scientists. A highlight was the launch of Solar Orbiter on February 5th 2020 and the successful testing of the instruments. The first results were shown at the meeting of AGU in December 2020.

At the time of writing, we are still working from home, infection rates are on the rise and vaccination is only slowly ramping up. We have learnt to be more efficient in remote working and right now I am participating in two international conferences organized virtually with active chat-rooms and other means of interacting. Undoubtedly, some of these new digital channels will replace (or complement) physical travel in the years to come but RLC (Real life communication) will also be welcomed with open arms. Stay safe and hope to meet you all in person soon.

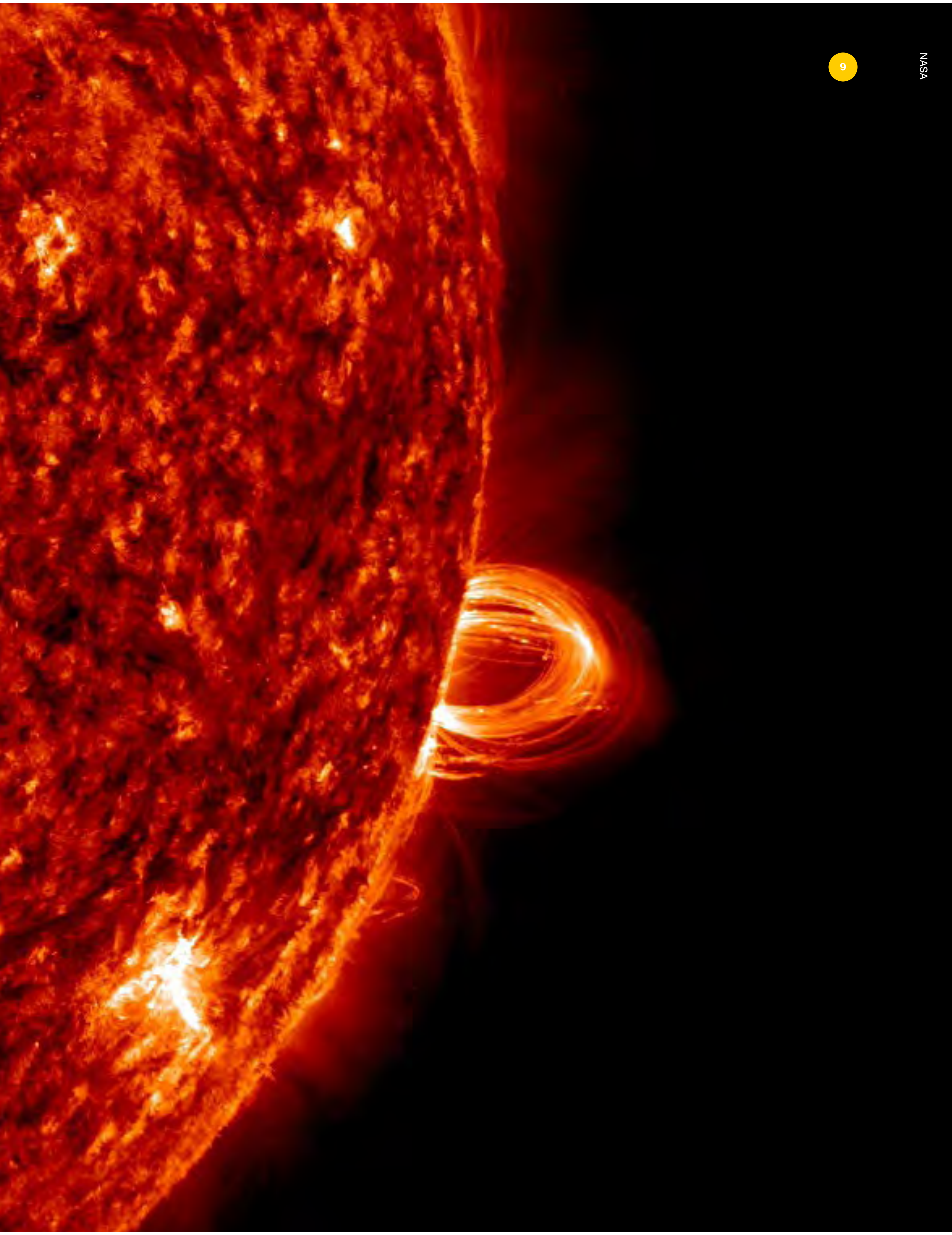
March 2021

Mats Carlsson,
Director of RoCS

1) Following the reporting practice in the Norwegian University system, we report by publication year of the paper, although in some cases the publication year of the journal issue is in 2021.



2020 Activities by theme



NASA

Simulations 2020

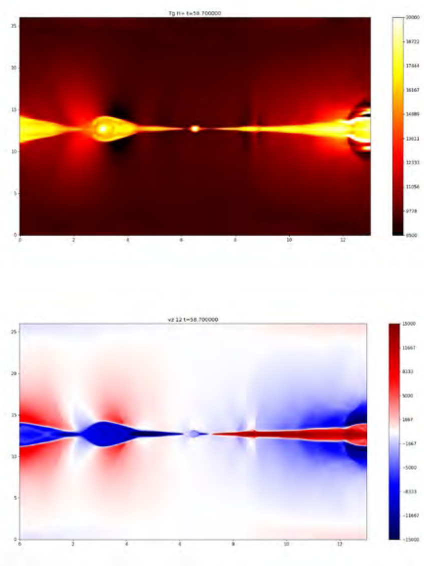
Simulating the Solar atmosphere with numerical models requires effort on disparate problems, from code development and maintenance, constructing and selecting initial models, moving vast amounts of data amongst the various compute centers in Norway and the world, writing scripts for visualizing the data, to actually displaying results and thinking about what they mean.

What's working in our Bifrost code and what isn't? Can we get of order 10-15 people to contribute to code development without stepping on each others toes? Can we apply for and get hold of computer resources? Why does it take so long to move a file from Oslo to Sunnyvale? And should we be working with IDL or with Python? And once these "administrative" tasks have been done: What physics should be included in our models? What's important? What can we ignore?

In 2020 we have progressed significantly in "cleaning up" the Bifrost code and including important physical effects, both in Bifrost, in Ebysus, and in the Dispatch code. These efforts are mainly described in the Code Development section while here we will discuss the simulations run with the current iteration of already existing "legacy" code(s), Bifrost, Ebysus and RH.

An important contributor to the work done in 2020 was the arrival of Betzy, Sigma2's new high performance computer placed in Trondheim. She allowed us to make progress on several models, both 'large' and 'small', at a rate that was markedly more rapid than earlier. But we have also utilized NASA's Pleiades (of 'The Martian' fame), and not least had good access to resources placed internally at RoCS.

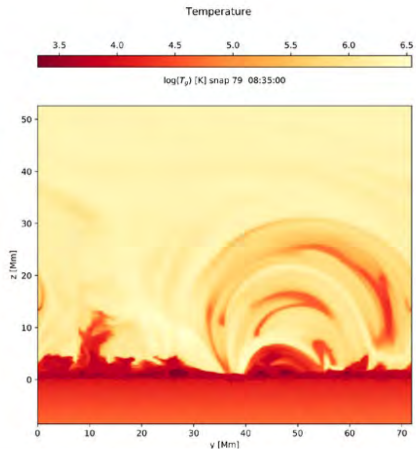
The key to using numerical simulations lies in finding out how much physical detail we need to include in order to understand the processes we are observing, and to what level we need to understand them. In practice the final judge of success is whether we can reproduce synthetic observables that mimic real solar data, and if there are differences, what are those differences telling us?



In 2020 we have modeled both the importance of describing systems relevant to the Sun in greater detail, but also generated simulated data from "coarser" numerical experiments for direct comparisons with data. In particular, both sets of models, though very different are related to the same subject, which also is a central topic for understanding the active Sun: the reconnection of magnetic field lines as they are pressed together by the motions of the controlling plasma deep in the photosphere or by the magnetics fields' own internal pressure. Such reconnection leads to heating, the acceleration of plasma to high velocity, and to the acceleration of individual particles - ions and electrons - to even higher velocities, and thus to most of the phenomena we associate with the active Sun. Numerical experiments give insight both into the details of reconnection, but also how reconnection can form the topology of the corona, how hot and cool gas are distributed and interact, and determine typical heating sites in solar-like

Reconnection is a process where magnetic fields of different directions press together forming a *current sheet* in which the magnetic energy is converted to heat and kinetic energy - ie motion - in bursty events along the sheet. This process most likely plays a critical role in the heating of the solar chromosphere and corona. In these regions of the solar atmosphere collisions between species are not always sufficient to model the plasma as a single fluid and the importance of multi-fluid effects is recently a topic of great interest to those studying the outer solar atmosphere.

The top and bottom panels show the distribution of the temperature (in Kelvin) and outflow velocity of protons (in m/s) in a test of multi-fluid, multi-species (MFMS) reconnection with a hydrogen -helium mixture using the Ebysus code. Note how plasmoids form along the reconnection sheet. (Q.Wargnier, J.Martínez-Sykora, RoCS/BAERI/LMSAL)

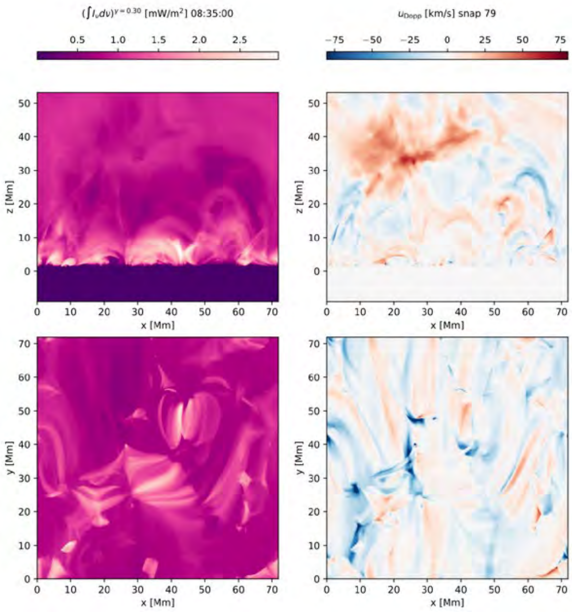


Vertical slice of the temperature in a model where new magnetic flux is rising through the photosphere (near z=0), and emerging into the chromosphere and corona. When this happens, there is magnetic reconnection between field of the pre-existing ambient field and the newly emerged field leading to cool pockets of gas lifted to great heights in the atmosphere as well as very hot regions (temperatures > 5 MK) where reconnecting fields heat the plasma in episodic bursts. (V.Hansteen, RoCS)

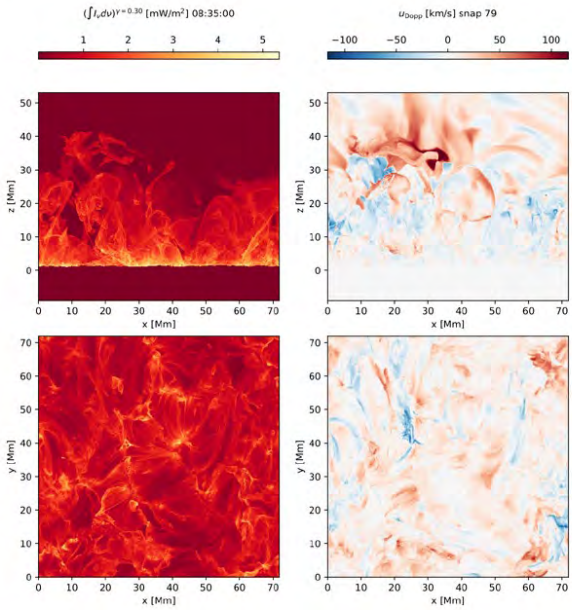
environments. As an example of reconnection induced dynamics modeled in 2020, we highlight the paper by Frogner, Gudiksen, and Bakke: “Accelerated particle beams in a 3D simulation of the quiet Sun”, described in greater detail in the section on Code Development.

We should also mention Guo et al. "Observations and Modeling of the Onset of Fast Reconnection in the Solar Transition Region” and Martínez et al. “Ion–neutral Interactions and Non-equilibrium Ionization in the Solar Chromosphere” both highly relevant for detailed studies of the reconnection process in the solar atmosphere.

While reconnection is important, it is not all that solar physicists concern themselves with: The propagation of acoustic and gravity waves in the solar interior and up to (and sometimes through) the photosphere can, when observed, give important details on the structure and workings of the atmosphere. There has been some debate about whether numerical models are able to correctly model such waves and indeed the workings of the solar convection zone at great depths. Fleck et al., in the paper "Acoustic-gravity wave propagation characteristics in three-dimensional radiation hydrodynamic simulations of the solar atmosphere” discuss such and similar issues. While Kohutova et al. in “Self-consistent 3D radiative magnetohydrodynamic simulations of coronal rain formation and evolution” look much higher in the atmosphere, in the corona, at regions where high temperatures no longer can be maintained and the coronal gas rapidly cools from 1 million K to 10 000 K, falling to the surface as a result.



Simulated emission in a spectral line of 14 times ionized iron (Fe XV 28.4 nm) formed at temperatures of 2.5 million K. This is the corona proper, and emission from the line shows how magnetic ‘loops’ organize both the structure and intensity of coronal heating. (V.Hansteen, RoCS)



Simulated emission in a spectral line of three times ionized silicon (Si IV 139.3 nm), which is formed at temperatures of some 100 000 K. This is a so-called transition region line formed ‘between’ the chromospheric plasma at some 10 000 K and the coronal gas at 1 million K. (V.Hansteen, RoCS)

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 an agreement with the Institute for Solar Physics in Stockholm which gives us observing time at the SST. The observing time is usually spread over three 2-week campaigns. In 2020 these campaigns were in May/June, August, and September/October. Unfortunately, due to travel restrictions because of the Covid19 pandemic, we could not conduct the observations ourselves like we normally do. We were lucky, however, that support astronomer Pit Suetterlin from the SST staff managed to reach La Palma just in time before the world-wide lockdowns in March. He was on the last flight from Stockholm to the Canaries, and on the last ferry from Tenerife to La Palma. Pit has done an outstanding job in conducting the observations in service mode. With extensive skill and experience, and a fine nose for the best seeing conditions, he managed to collect a number of excellent data sets. In August, Pit got help from Stockholm colleague Oleksii Andriienko. 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 do quick initial reductions shortly after acquisition so that we could fine tune our observing programs.

Ellerman bombs

One of the main focus areas of this observing season was magnetic reconnection in the low solar atmosphere, as observed in the Ellerman bomb phenomenon. Analysing high-resolution H-beta observations from the 2019 observing season, we found that Ellerman bombs in the quiet Sun are much more prevalent than what was thought before. We estimated that at any time, there are half a million Ellerman bombs occurring on the Sun, a number that is much higher than what was measured in earlier, lower resolution H-alpha observations. We published this in a letter to A&A. We expanded on the 2019 observations by exploring whether it would be possible to observe Ellerman bombs in the H-epsilon line. At a wavelength of 397 nm, this spectral line lies in the wing of the Ca II H line and is covered in one of the spectral windows of the CHROMIS instrument at SST. The H-epsilon line is expected to display similar Ellerman bomb enhanced emission as the longer wavelength H-alpha and H-beta Balmer lines. Figure 1 shows preliminary results from the August campaign where we confirm that the H-epsilon line shows enhanced Ellerman bomb emission in the CHROMIS data. The large sunspot image at left is at the wavelength of the H-epsilon line core and shows a scene that is familiar from Ca II wing images. The four zoomed images in the middle are centred on Ellerman bombs that can be found inside and around the sunspot. They have the characteristic enhanced wings in the H-beta spectral profiles at right. Furthermore, the H-epsilon line goes clearly to emission as shown in the lower right panel. We are now concentrating on determining the diagnostic potential of the H-epsilon line for assessing the impact of small-scale magnetic reconnection on the solar atmosphere.

IRIS-SST coordination

Figure 2 shows data from the September campaign when IRIS acquired a very large raster of an active region, with long exposures to get a good signal to noise level in the weakest spectral lines. The field of view covered by SST is much smaller and is targeting the leading polarity plage region. For this overlapping region, we can use the IRIS data to study the upper chromosphere and transition region, and from the SST we get measurements of the magnetic field and the temporal evolution of the atmosphere below, the lower chromosphere and photosphere.

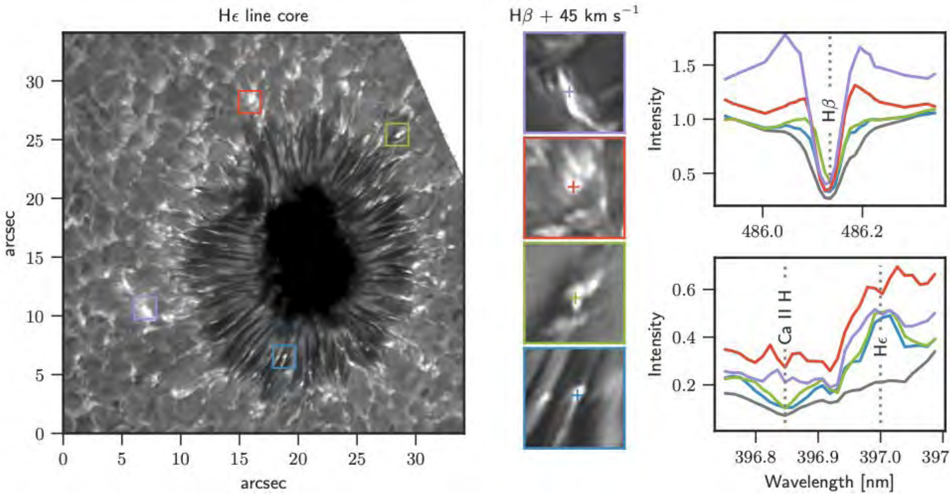
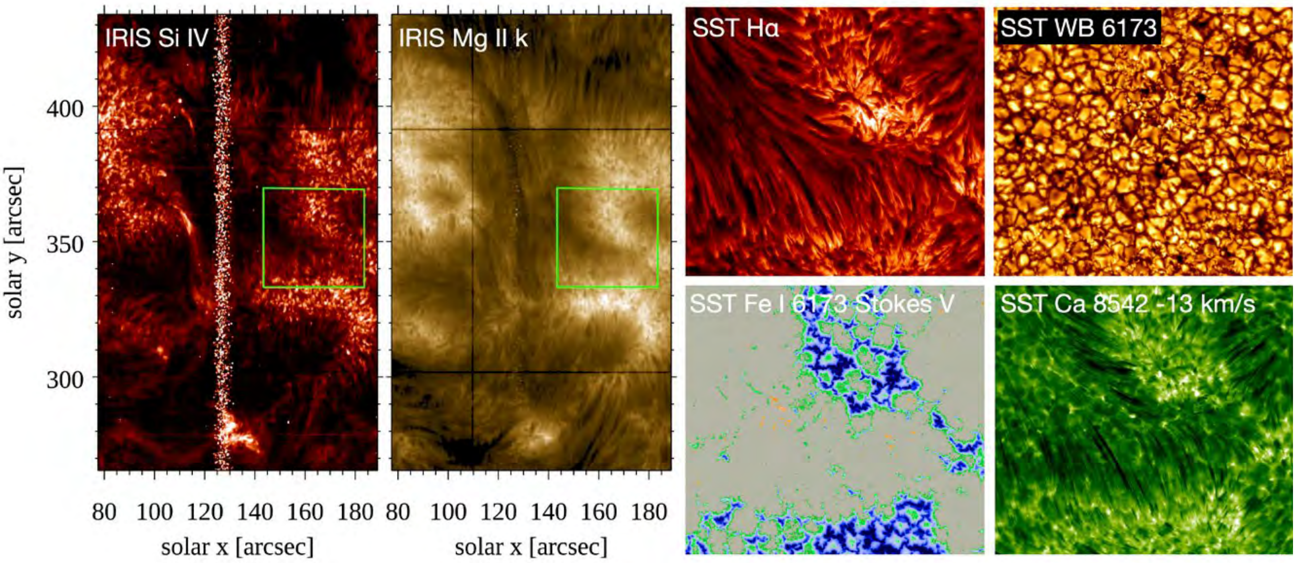


Figure 1. CHROMIS observations of Ellerman bombs in the H-beta and H-epsilon spectral lines. (J. Joshi, RoCS)



This year we also released datasets from our IRIS-SST coordinated campaigns in a public database. We have been running coordinated observing campaigns every season since the launch of IRIS in 2013 and many members of RoCS and the group at LMSAL have participated in the observations at SST. The data release was described in a publication in A&A, coauthored with 21 present and past RoCS members, as well as colleagues from the Stockholm group and LMSAL. The co-aligned IRIS-SST datasets can be found in databases hosted at LMSAL and at RoCS. We will continue to release new data sets through these databases as we continue to conduct coordinated campaigns. Among the released datasets are observations that were published by RoCS in 2020 on studies on the relation between Ellerman bombs and UV bursts, and on penumbral microjets.

Figure 2. Active region observed by IRIS and SST on 29 September 2020. On the left are two large rasters in the Si IV 1394 and Mg II k line cores, constructed from well-exposed IRIS spectrograph data taken over a time of 2 hours and 40 minutes. The green square marks the area covered by SST shown with the images on the right. (L.Rouppe van der Voort, RoCS)

Roque de Los Machachos, La Palma.
(H.Eklund, RoCS).

Science with ALMA

Improved processing of solar observations obtained with the Atacama Large Millimeter/submillimeter Array (ALMA) and supporting numerical simulations resulted in an increasing number of science-ready data sets and publications.

Impact of the pandemic

The group at RoCS that works on solar/stellar science with ALMA has continued to grow in 2020 despite the pandemic situation. Since ALMA was shut down in March 2020, the group focused on the further development of processing tools and on the scientific analysis of first data sets available on the ALMA Science Archive.

Continued growth of the ALMA group

Three post-doctoral researchers (Henriques, Saberi, Mohan) joined the SolarALMA [2] and EMISSA projects in 2020. The ESO-funded ALMA Development Study was joined by a M.Sc. student (Jakobsson) in collaboration with the University of Technology, Luleå, Sweden, resulting in the M.Sc. thesis with the title "Assessment of weather conditions for ALMA observations of the Sun". Jakobsson continued his work as a guest researcher in the RoCS Visitor programme for the rest of the year.

Transition to routine image synthesis

Next to the work done in collaboration with international colleagues, the development of the Solar ALMA Pipeline (SoAP) at RoCS has progressed substantially during 2020 (Szydlarski). SoAP turns interferometric data obtained with ALMA into time series of solar images. During 2020, SoAP has been routinely applied to an increasing number of datasets. The resulting data are further post-processed (Jafarzadeh) and collected in the precursor of the Solar ALMA Science Archive (SALSA) that will soon be hosted at RoCS (Henriques). So far, the archive contains 27 science-ready interferometric time-series and over 200 single-dish full Sun images.

Simulating solar ALMA observations

Optimising the imaging process for solar ALMA data is essential for maximising the data quality and thus the scientific output but the optimisation is complicated by the fact that the true image of the Sun at millimeter wavelengths at the time of observation is not known. A solution to this problem is the usage of simulated ALMA observations for which the original images are exactly known. This approach is at the heart of the ESO-supported ALMA Development Study carried out at RoCS in collaboration with the Nordic ARC node and Stockholm University. In 2020, the development of the Solar ALMA Simulator (SASim) has progressed notably. SASim produced artificial ALMA observation data, which were then processed with SoAP for a parameter grid and thus allowed for determining the optimal parameter sets for SoAP. A major milestone was the successful completion of the study's mid-project review in autumn 2020.

Increased scientific output

Researchers from the ALMA group were involved in an increasing number of scientific articles in 2020. A publication series was started of which the first part (Wedemeyer et al. 2020) presents a time-dependent ALMA observation of a Quiet Sun region in Band 3. The second paper in the series (Eklund et al. 2020) reports the evolution of brightening events detected in the same data set. A characterisation of the observable signatures of waves propagating through the chromosphere based on 1D and 3D numerical simulations in combination with the ALMA observations and SDO data allowed for addressing the physical mechanism behind the events, their origin and impact on the surrounding atmosphere.

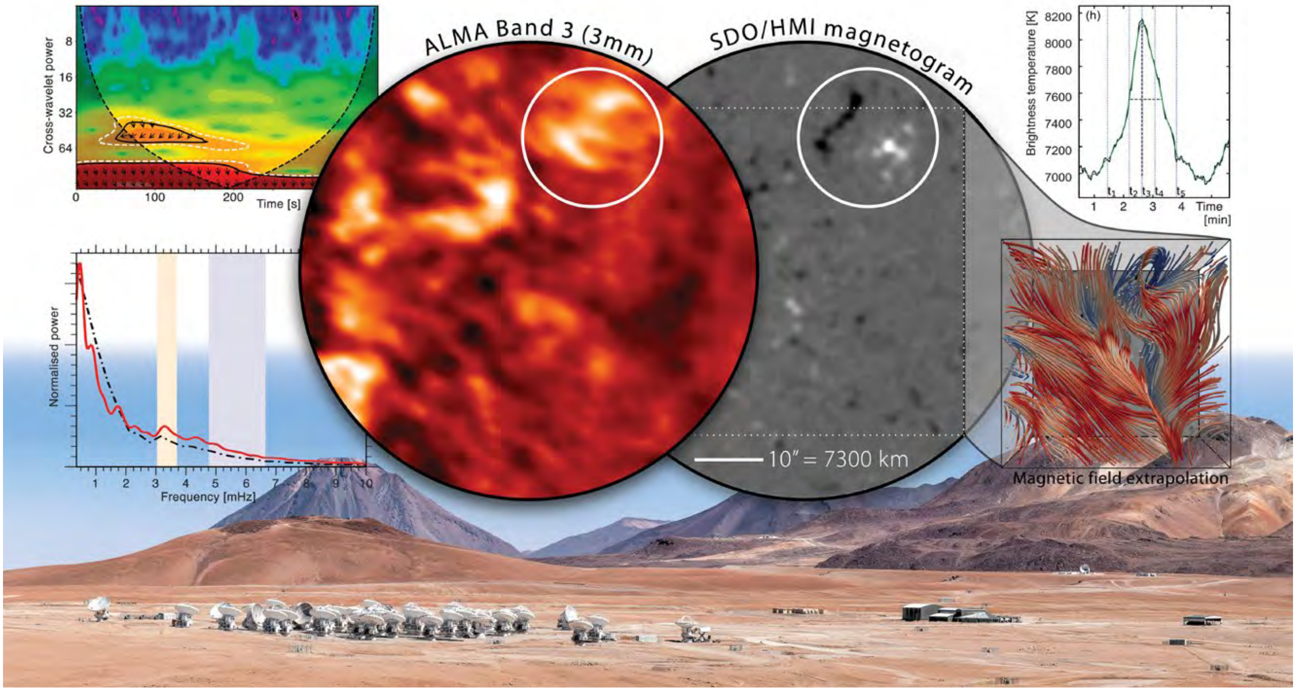
Waves and oscillations

As part of a special issue of the Philosophical Transactions A of the Royal Society on solar wave dynamics organised by the international WaLSA collaboration, three publications were co-authored by group members and a further three publications with focus on ALMA, both observed and synthetic data, were led by researchers from the RoCS ALMA group:

- Jafarzadeh et al. (2021*) provide a comparison of ten ALMA data sets for different solar regions in Band 3 and Band 6 focusing on the oscillatory behaviour of the chromosphere. It is found that the power spectrum of global p-mode oscillations varies significantly from one dataset to another with magnetically quiescent datasets showing power enhancements in the 3–5 mHz range, while it shifts to lower frequencies for regions with stronger magnetic fields.

- Guevara Gómez et al. (2021*) focus on ALMA Band 3 observations of a magnetic enhanced region and trace small structures in time and space, concluding that these structures might be associated with magnetohydrodynamic wave modes, particularly fast-sausage and kink modes.

2) 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).



ALMA observations in Band 3 combined with SDO/HMI magnetograms resulted in several publications in 2020, in particular regarding oscillations (left panels) and dynamic brightening events (top right). The background shows ALMA on the Chajnantor plateau at an altitude of 5100m (ALMA, ESO/NAOJ/NRAO, HMI-SDO/NASA, ALMA group@RoCS) ALMA data: 2016.1.00423.S

- Eklund et al. (2021*) employ synthetic mm maps calculated with the Advanced Radiative Transfer code from a 3D Bifrost simulation in order to investigate the observable signatures of propagating shock waves and ALMA's diagnostic potential for observing such waves in Band 6.

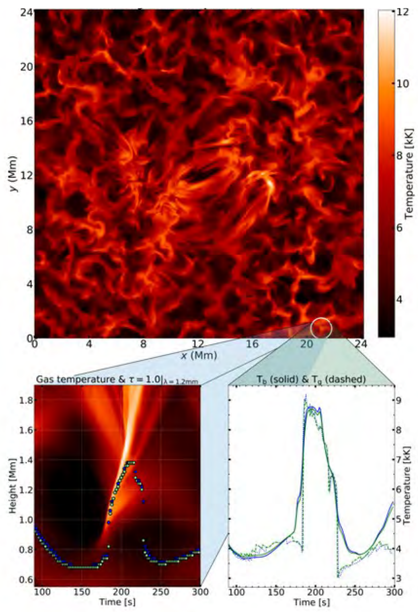
Synergies with optical observations

Amongst the group's publications, semi-empirical modelling based on optical observations have tied together the smallest observable features in sunspots with the dominating large-scale oscillatory phenomena therein (Henriques et al. 2020). In the same paper, temperature and density enhancements were reported to be interchangeable due to a fundamental aspect of line-formation in the optical so that ALMA observations are the only means of distinguishing between competing models. Simulations found two classes of models with similar temperature differences, one present under resonant conditions (Felipe et al. 2021*) furthering the ALMA case as the presence of cavities in the umbra is a major topic. Moreover, two group members participated in the publishing of the RoCS SST and IRIS database.

Towards the stars

The EMISSA project started to build up a stellar data archive based on an initial set of archival ALMA observations (Mohan). In parallel, the systematic analysis of full disk maps of the Sun has begun, aiming at developing the Sun-as-a-star reference case for the study of stellar activity (Pandit).

Giving context for the future late evolution stages of the Sun, Saberi et al. (2020) checked the validity of using CO and HCN isotopologue ratios as tracers of the atomic C isotopic ratio in the outflow of evolved stars under different physical conditions. This way, ALMA and APEX data can be used to determine elemental isotopic ratios in stellar photospheres, which give important constraints on the chemical evolution.

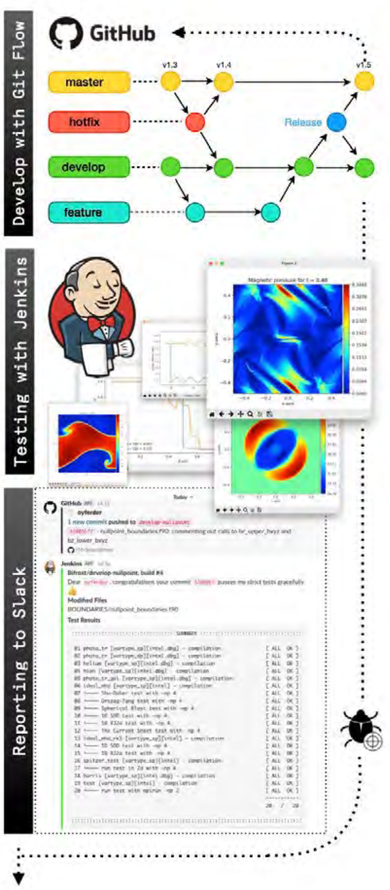


A synthetic brightness temperature map calculated with ART from a Bifrost snapshot corresponding to ALMA Band 6. High cadence time-series of such maps allow for tracking shock fronts as they propagate through the chromosphere (bottom left), resulting in the characteristic observable signature (bottom right). (H. Eklund, RoCS)

* This work was concluded in 2020 but only officially published in early 2021.

Code Development 2020

During 2020, where the pandemic has halted most of our collaborative work, great strides have been made in code development. We have hired another two software engineers who are at the end of the year up to speed and accelerating the work needed to reach the RoCS goals.



Continuous integration (M.Szydlarski, RoCS)

General improvements in continuous integration

Continuous integration of code developments is an integral part of producing stable code while including improvements all the time. In order for such a process to work, an extensive framework needs to be in place. The work on such a framework started in 2019 and progressed rapidly in 2020 and has now reached a state where we can rely on it to provide a safe and reliable code development cycle.

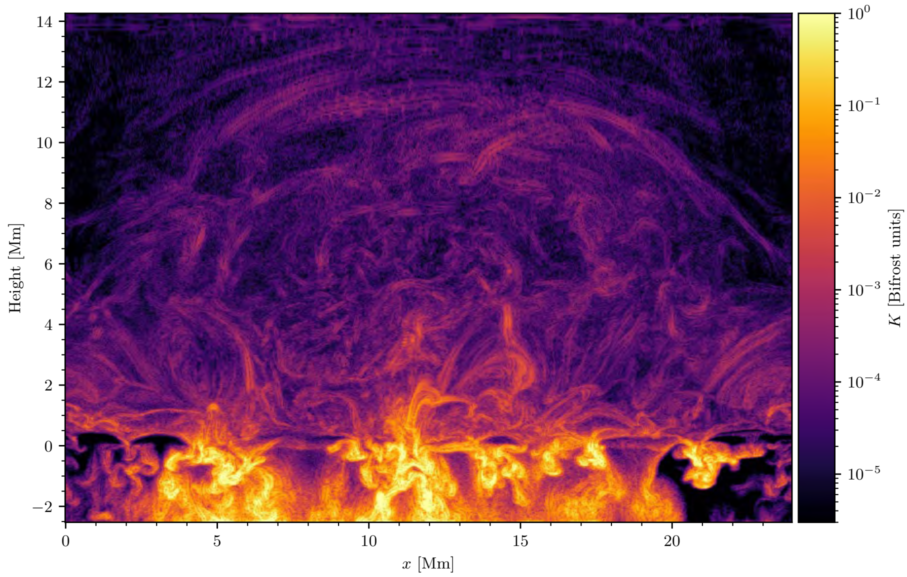
The development includes an automated validation test suite being run at each change of the code. The validation tests are grouped in a number of levels, where not all tests are run at every change of the code, but only once every 24 hours or once every week. Those tests are more comprehensive and require longer time, so running them at each change of the code is not feasible. They are implemented to catch subtle errors introduced in the code, that only change long time behaviour. The testing is now fully automated.

The expanding capabilities of Bifrost

In order for us to reach the goal of simulating the active Sun, a great deal of effort has been concentrated on simulating the violent energy bursts produced in solar active regions. The flares observed, span an energy output of more than 7 orders of magnitude. The release of energy happens in a number of ways, that are so far not well modelled. In 2020, Helle Bakke and Lars Frogner completed the first major step in modelling these flares, by including the electromagnetic acceleration of fundamental particles to high energies. Even though the acceleration mechanism itself is not well known, they are now able to model the energy transfer from the flares to the acceleration of particles using just a few free parameters that we hope to constrain further by simulating the flare process itself. The simulations of these types of reconnection processes are evolving rapidly, and relies on integrating the particle-in-cell solvers into the DISPATCH framework.

Bifrost now has most of the basics ready for simulating flares, but we have so far not conducted tests that will tell us if the rapid variations in the center of a flare can be handled by the code. Some of that work will be initiated in 2021.

More general developments of Bifrost include the capability of running with lower order spatial operators, a new time stepping procedure and the improvement of boundary conditions for the large scale simulations of the solar corona. The coronal boundary conditions are now more stable and can handle the very complex physical environment of the solar corona in a better way. The equation of state tables have



An image of the power of the reconnections happening in one of our simulations. The power depends on the magnetic field strength, so will naturally be smaller, higher up in the atmosphere. The reconnection process itself is being investigated using more detailed simulations and results are expected in 2021. (L. Frogner, RoCS)

been improved and we have solved a long standing problem with a single physics module, that made it difficult to run Bifrost with certain combinations of grid points and threads.

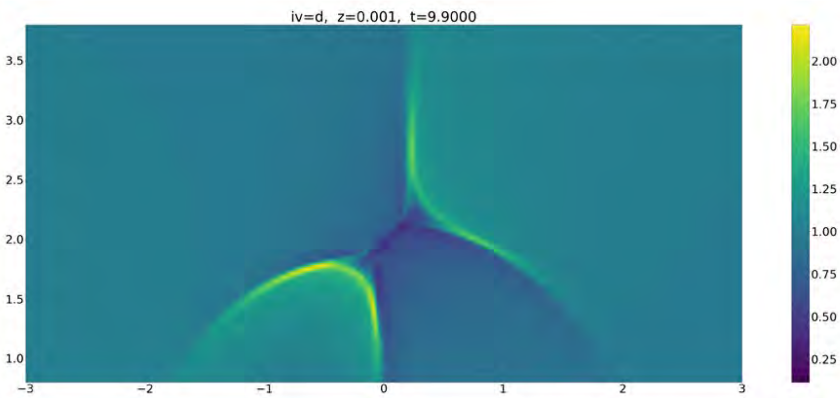
DISPATCH and the quest for the next generation simulation tool

During 2020, a major policy change has happened in our quest to integrate Bifrost into the simulation framework DISPATCH. It became more and more obvious to us, that DISPATCH is improving at such a strong pace, that our integration process was being hampered. Our goal of having a new stable code that would be able to take the place of our workhorse Bifrost in the future, was difficult due to the continuous improvements to the DISPATCH framework. DISPATCH is a framework which is being developed at a large number of locations around the world with the aim of simulating all types of objects in the universe. Therefore the developments happening are not all relevant for us. The development of Bifrost within DISPATCH is now running in parallel with the main DISPATCH development, but with fewer exchanges of developments. That allows us to spend less time on handling discrepancies in the core of DISPATCH, and allows us to focus on getting the rapid improvements to Bifrost translated to run under the DISPATCH framework. At the same time, we can translate our continuous integration policies and tests directly into DISPATCH so we can make sure that changes we make, or which are exchanged with the main DISPATCH framework are acceptable.

Based on the focused effort and the agreed policies for the development, we are now expecting rapid progress with DISPATCH in 2021.

DISPATCH and new capabilities

On top of the larger scalability provided by DISPATCH, the ability of the framework will eventually make us capable of changing the resolution of the simulation "on the fly" but also changing the solution methods. That should make it possible to zoom in on volumes in the solar atmosphere where the physical approximations we make to model the rest of the solar atmosphere break down, and instead use a more precise description which uses less approximations. The preparatory work for such possibilities are being investigated by looking at solar flares, where the central parts of the powerful explosions cannot be well modelled by the fluid equations that are sufficient in the rest of the solar atmosphere. These locations should be modelled by the more precise Particle-In-Cell models. A common setup and testing environment for these processes are almost ready for deployment and we expect results in 2021.



Solar flares are the dissipation of magnetic energy in concentrated current structures. A generalised setup for testing DISPATCHs ability to handle such structures with different types of solvers and resolution is underway. This example shows a 2D view of the evacuation of such a current structure, where the mass density is significantly lowered (dark blue) in the current structure. (F. Clemmensen, RoCS)

Training the next generation

Since its inception, RoCS attracted talented researchers from all over the world. They are the reason why our scientific productivity is so high, and why the centre is such a vibrant and diverse place to work. Internationally, RoCS is well-known as a leading institution in solar physics. And while it is often the top research that gets most accolades, it is also crucially important to invest in renewal and in the training of young researchers.

"I am interested in astronomy, but my real passion is solar physics", says Barathy Pirabahar who had a summer assignment at RoCS. (M.Ruud, UiO)

RoCS benefits from being at UiO and that several of its members lecture courses in the bachelor and master of astronomy programmes. Indeed several of our PhD students today came from UiO's master in astronomy programme, and we hope to keep attracting talented local students to continue their studies with us. Yet, more could be done to attract UiO students. From the beginning of RoCS it was identified that only a small fraction of astronomy master students elected to pursue a thesis in solar/stellar physics in previous years. This was for a variety of reasons, but a likely factor was that their study programme does not expose students to the topics and research undertaken at RoCS. At least not early enough. With this in mind, in 2020 it was decided to strengthen the summer student programme at RoCS, in particular for bachelor students.

The summer student programme of 2020 was a win-win. The students gained important insight into solar and stellar research, while RoCS researchers benefited from additional manpower for their projects. Well, strictly speaking it was as much womanpower as manpower: of our ten summer students, five were female. Their assignments were varied: some students analysed solar optical observations, others stellar radio data, a couple of students worked with our research software engineers to develop visualisation and analysis tools for 3D simulations, and finally several students helped to improve existing bachelor and master courses. Overall, the programme was a success. Furthermore, all four summer students who entered the master programme in 2020 chose to do a thesis at RoCS.

Attracting master students is a goal we are constantly working towards. Already in 2019, there were three master students who chose RoCS, a large increase from previous years. In 2020, we got a total of four master students. This is a remarkable shift and means that nearly half of all master students at the Institute are hosted at RoCS! Also important is that for the last two years, 50% of the master students in the astrophysics branch of the master in computational science programme have elected to do their theses at RoCS. This highlights a growing visibility among students of the computationally-intensive research undertaken here.

Successfully marketing RoCS among bachelor and master students comes from the hard work of many. From the postdocs and researchers who hosted summer students, to those that developed and advertised master projects, and finally to the lecturers of bachelor and master courses and their energetic teaching assistants who have been a crucial link with the students.

Tiago Pereira

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" (2019-2021), supported by ESO and RoCS, in cooperation with the Nordic ALMA Regional Center node at Onsala Space Observatory and Stockholm University, Sweden. Aim: Optimisation of solar observations with ALMA.

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

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

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 and UiO. 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 (2019-2024), 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.

ALMA antennas at sunset. Insets: The EMISSA project compares ALMA observations of the Sun (right) with ALMA observations of stars. Shown to the left is the solar-like star α Cen A together with its companion α Cen B. (ALMA data: 2018.1.01879.S, 2013.1.00170.S) (H.Calderon - ALMA (ESO/NRAO/NAOJ))

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.

Women in Astrophysics Blog

Over the past year, women in RoCS contributed to the revamp of our Women in Astrophysics blog hosted by the institute. Our aim is to showcase the achievements, stories, and work of our fem-identified folks, and to encourage girls to pursue careers in astrophysics by celebrating our own. Contributions from RoCS included:

- ***10 Biggest lies Hollywood has told you about Space:*** Have you ever wondered whether science fiction is more science or fiction? Petra Kohutova gives a rundown of common science mistakes in cinema and the films that are guilty of committing them.
- ***Adventurous Observations:*** What is it like to work on an observing campaign? Ingrid Marie Kjelseth takes us along to the Canary Islands where she visited the SST.
- ***Solving the Nonlinearity Problem:*** Managing expectations is a tough thing to do, especially in academia. In this reflection, Becca Robinson takes us through her nonlinear journey to demonstrate that it is okay to have a life that takes unexpected turns.
- ***A master student's incoherent thoughts about shoulders:*** By talking us through her memories and experiences, Ida Risnes Hansen reminds us that even though it might seem like we have no idea what we're doing, we are standing on the shoulders of giants.
- ***Work (?) From Home?:*** Navigating the realities of home office is a challenge we all had to face in 2020. Sneha Pandit brings us into her home office and illustrates her efforts to find an ideal work-life balance from home.
- ***Redd for å holde presentasjoner? Det er jeg og!:*** If you feel nervous while giving presentations, you're not alone! In this post, Helle Bakke gives us a few tips and tricks for dealing with presentation anxiety.

Astronomy Olympiad

The Norwegian Astronomy Olympiad is a national competition for students at upper secondary schools with physics and astronomy as subjects. The top five students, selected through three rounds of exams/workshop, represent Norway at the International Olympiad on Astronomy and Astrophysics (IOAA). The Institute of Theoretical Astrophysics and RoCS jointly organise the Astronomy Olympiad in Norway. The PI of the project, Shahin Jafarzadeh of RoCS, received a grant from the Research Council of Norway to support organisation of the Olympiad for the period 2020-2021.

Through the Astronomy Olympiad, it is expected that more bright high school students will deepen and feed their passion for Astronomy by studying Astronomy at the university level. Thus, this is to promote the growing interest in Astronomy and related subjects, through the general education of young people, and eventually, enhancing the development of international contacts among different countries in promoting Astronomy and Astrophysics in schools.

In 2020, the IOAA was held online due to the world pandemic. The Norwegian national team participated in the international competition and the team leaders, Rebecca Anne Robinson and Shahin Jafarzadeh of RoCS, as well as Tor Einar Aslesen of the Norwegian Astronomical Society, participated in grading the exams as part of the international committee. A total of 278 students from 39 countries attended the virtual olympiad in 2020.

Preparations for the next IOAA began in 2020, with the first round of the national exam organised from 2-15 November 2020. From which, 60 students have been advanced to the second-round exam which will be held on March 10th, 2021.

Astronomy on Tap

This was an exciting year for Astronomy on Tap, which is usually hosted physically as a series of public outreach events in bars around the globe. However, the Oslo chapter of AoT decided to adapt to the changing times and go digital for the majority of 2020. Contributions from RoCS:

- *Hosts:* Becca Robinson & Andrius Popovas
- *Speakers:* Boris Gudiksen ("Our Active Sun")
- *Social Media & Marketing:* Shahin Jafarzadeh & Becca Robinson
- *Quizzes:* Andrius Popovas, Petra Kohutova, Frederik Clemmensen, Henrik Eklund, Juan C.G. Gomez

The plan is to keep hosting digital AoT events via Zoom, but we are looking forward to hosting physical events again as soon as possible.

EST Outreach

RoCS researchers made significant contributions to The Science of EST book and social media, including:

- *Solar Coronal Jets* by Daniel Nobrega-Siverio
- *Cool solar ejections of the size of the Earth* by Daniel Nobrega-Siverio
- *Nanoflares and coronal heating* by Helle Bakke
- *The quiet Sun magnetic field* by Shahin Jafarzadeh
- *The quiet Sun magnetic field* by Becca Robinson
- *It is raining in the Sun's atmosphere, too!* by Clara Froment
- *Spicules* by Luc Rouppe van der Voort
- *The QuEST Norwegian translations* by Viggo Hansteen and Øystein Håvard Færder

Student Outreach

Even with the COVID situation, it was still possible to host some high school pupils and students physically at RoCS. RoCS researchers supervised high school and master students on these topics and projects:

- Development of exercises for AST4310: Radiative Processes in Astrophysics
- How to analyze data from Hinode SP
- Development of exercises for AST3310: Astrophysical Plasma and Stellar Interiors
- Detection of quiet-sun bright-points from CRISP/SST observations
- HCN excitation analysis of UV-active evolved stars
- Data analysis and visualization tools for new solar simulations with DISPATCH framework
- Diagnostic capabilities of the H-beta line and comparisons with the H-alpha line

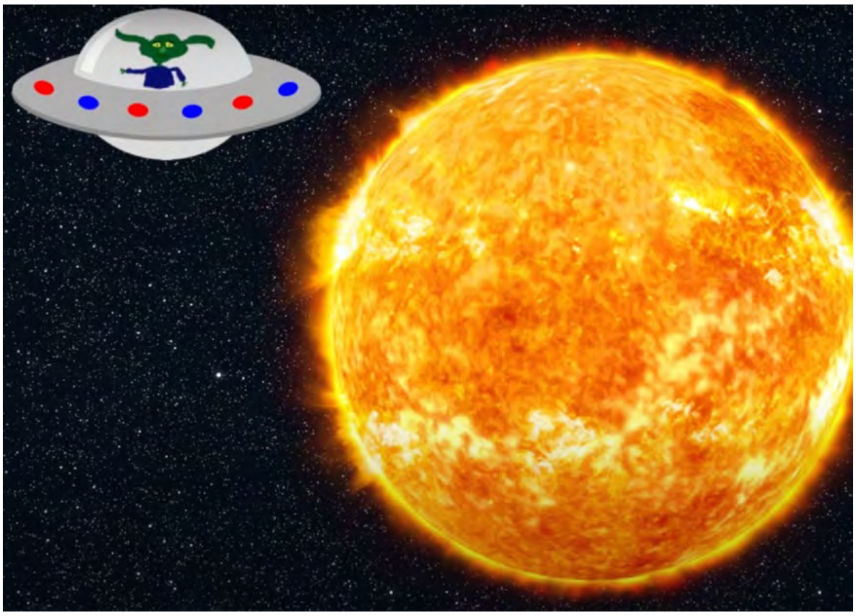
Becca gives a one-minute solar physics lesson via YouTube for Forskningsdagene.

Forskningsdagene - Science Days

RoCS participated in *Forskningsdagene* in September by creating short videos to demonstrate scientific concepts "in one minute." RoCS members Becca Robinson, Eirik Jacobsen, and Eyrun Thune released one-minute films as part of a campaign to make our research accessible to everyone.

Solar ALMA at ESERO

Over a hundred teachers from middle-school up to and including high-school level in Portugal and Brazil were given a deep introduction to state-of-the-art ground-based observations including the Atacama Large Millimeter Array (ALMA). This was done in one of the daily seminars and an enthusiastic extended question session as part of a week-long course for which teachers were credited. This online workshop was part of ESERO, an ESA program designed to improve classroom resources and teacher competence regarding STEM available to European students.



Øystein's cartoon friend Yooda flies around the Sun and explains its mysteries on the YoodaTV YouTube channel. (Ø.Færder, RoCS)

Sven Wedemeyer using a model of the moon when explaining recent discoveries on the dwarf planet Ceres. (Karla Bonilla)

Personal Outreach

In a group this size, it's no surprise that many RoCS researchers have branched out to explore our own niche corners of Outreach. Several members of RoCS have contributed to blogs, written popular science articles, and curated social media content. A few examples from 2020 include:

→ ***How can numerical simulations advance our understanding of our life-giving star?***

With the release of the DKIST media image, the Sun has been getting a lot of positive press. Souvik lets us know how solar simulations run hand-in-hand with solar observations, and how both are crucial for our comprehensive understanding of the Sun.

Souvik Bose, *Medium*

→ ***Solar musings***

Human understanding of the Sun has come quite a long way in the past centuries, but if the Sun could think, how would it perceive our lives and thoughts here on Earth?

Sneha Pandit, *My Musings*

→ ***Happy in the Long Distance Relationship!?***

The Sun-Earth relationship may seem too perfect to be true, but Sneha explains why the Sun and Earth are locked in an ideal relationship for life to exist as we know it.

Sneha Pandit, *My Musings*

→ ***No, the Sun is not in "Lockdown" (and other magnetic mysteries)***

In response to several misleading pop-sci articles claiming that the Sun was magnetically shutting down, Becca explains why this kind of extrapolation is irresponsible and premature.

Becca Robinson, *The Theory Girls Blog*

→ ***Ask Becca About Space***

A result of COVID quarantine, Ask Becca About Space is a YouTube channel that addresses questions that kids (and grown kids) have about astronomy. Topics range from galaxies and black holes to why we can't just launch all of our trash into the Sun.

Becca Robinson, *YouTube*

→ ***Yooda - Exploring the Universe***

With the help of his cartoon friend Yooda, Øystein teaches us about hot research topics like the Solar atmospheric heating problem.

Øystein Håvard Færder, *YouTube*

→ ***Mysteriet på dvergplaneten Ceres kan være løst***

Hydrohalite, a mineral associated with cold saltwater lakes, was recently found on the Dwarf planet Ceres. Sven explains that this mineral has never been seen anywhere besides Earth, and its discovery suggests that Ceres may be a saltwater world.

Sven Wedemeyer, *NRK*

→ ***Forskere får etterlengta svar på stjernemysterium etter 120 år***

Delta Scuti stars have been ill-understood for years, but now researchers have observed enough of the stars to determine luminosity patterns among them. Because of the new observations, researchers have been able to constrain the average age of these stars and learn more about our own galaxy.

Sven Wedemeyer, *NRK*

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.

Paola Testa, researcher at Smithsonian Astrophysical Observatory, visited in February to work with Luc Rouppe van der Voort, Mats Carlsson and other members of RoCS on several projects.

Daniel Jakobsson, master student at Luleå University of Technology, came to work on his master's thesis from January to May. He was supervised by Sven Wedemeyer. After finishing the master thesis, he continued at RoCS as a researcher until December.

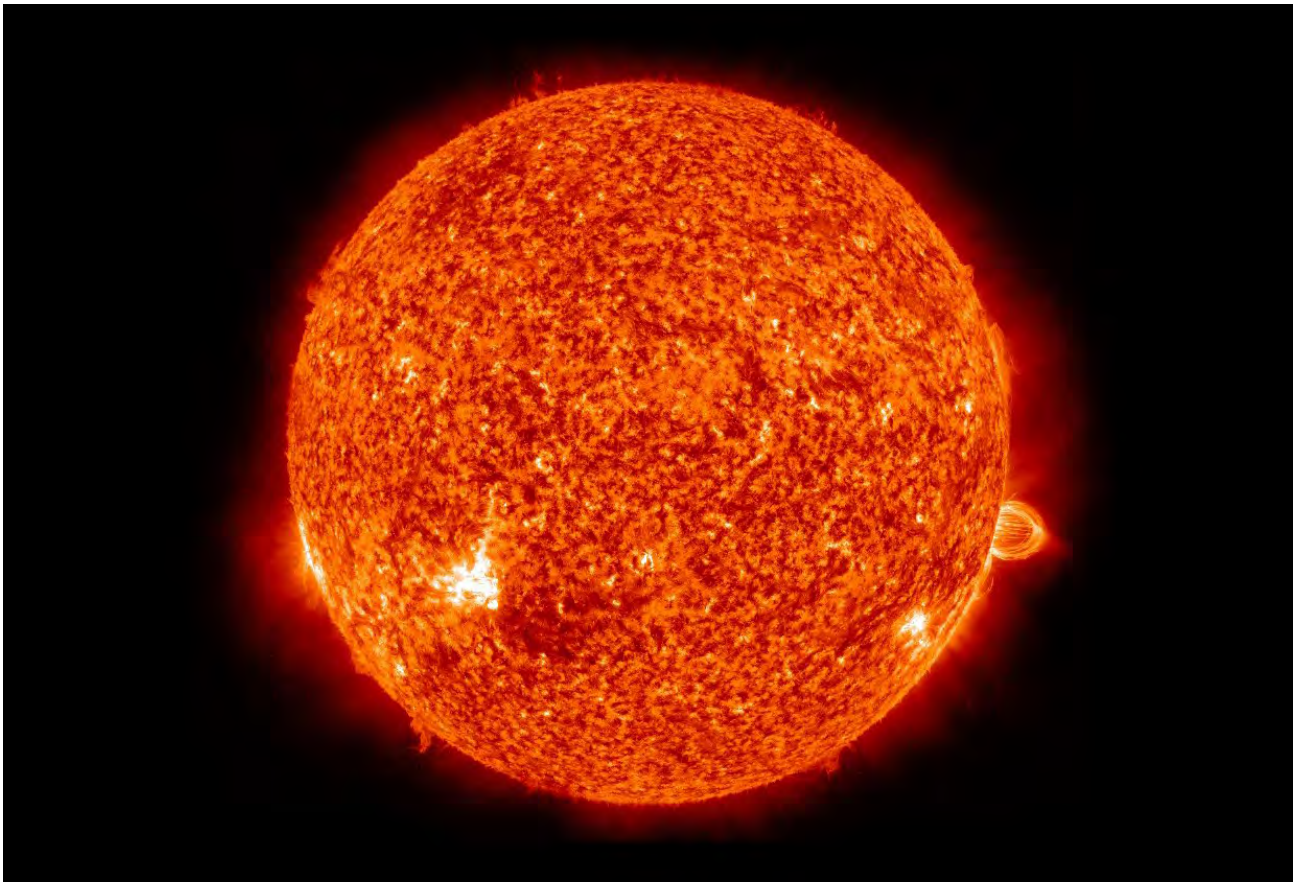
Juan Carlos Martinez Oliveros, a researcher from SPACE sciences Laboratory/University of California Berkeley, visited RoCS in February and March. He was here to collaborate with Juan Camilo Guevara Gómez.

WholeSun workshop. Members of the WholeSun ERC Synergy project came to Oslo in January for participation in a workshop. Mats Carlsson hosted 11 members (Krishnendu Mandal, Allan Sacha Brun, Maxime Delorme,Pierre Kestener, Rui Pinto, Vasileios Archontis, Fernando Moreno-Insertis, Christopher Goddard, Quentin Noraz, Petros Syntelis and Yuto Bekki) at RoCS.

Solar ALMA workshop. RoCS hosted the first international workshop on solar imaging with ALMA in March. In addition to scientists from RoCS, the following external colleagues joined: Miro Barta, Tim Bastian, Yi Chai, Antonio Hales, Juan Carlos Martinez Oliveros, Galina Motorina, Alexander Nindos, Neil Phillips, Masumi Shimojo and Ivica Skokic. Additional participants joined online because of the emerging Covid-19 situation.

Coordination during Covid-19

This has been a year full of challenges and new ways of working, being a centre with a lot of international engagement with both foreign employees and visitors. We usually have a large number of guests joining us throughout the year, with all the tasks needed to accommodate them. This year, coordination has been different, and we have learned a lot from running a centre during a pandemic. It has been more important than ever to maintain some structure and social interaction. At RoCS, we have tried keeping up moral, productivity and mental health in our team. A big part of this has been arranging Zoom meetings of different kinds, both social and scientific. Although electronic communication is not equal to proper meetings, it has given us a way to see and interact with each other. We also managed to arrange a physical retreat while infection control measures were lower. It was a great boost for everyone to be able to meet, and gave us a much needed break from the monotony of home office. We have received several new employees during the pandemic. Unfortunately, they have had issues with the bureaucracy being slower than usual. We have tried assisting them as much as possible, and tried to make the move to Norway a pleasant one. It is in no way optimal to start a new position under these conditions, but they have all been most understanding and constructive. We are looking forward to going back to normal, being very proud of the strength, stamina and positivity all members of RoCS have shown during this crisis.



NASA

Whole Sun meeting in Oslo

RoCS hosted the first workshop of the Whole Sun collaboration in Oslo in January.

Fifteen participants from all five involved institutions: CEA at Saclay outside Paris; University of St.Andrews, UK; Max Planck Institute for Solar System Research, Göttingen, Germany; Instituto de Astrofisica de Canarias, Tenerife, Spain and RoCS, University of Oslo gathered January 13-17 in Oslo. This was an intensive workshop, with talks and plenary discussions in the morning in the major meeting room at RoCS, followed by topical working sessions in the afternoons in various rooms. A number of ongoing collaborative projects were advanced forward but, more importantly, the possibility of intensive discussions followed by work on the computer systems enabled new projects to be formulated. The contrast with the digital-only world that was to follow a few months later is striking.

"WHOLE SUN" principal investigators. From top left to lower right: Laurent Gizon, Vasilis Archontis, Mats Carlsson, Sacha Brun. (S. Brun, CEA)

Working together on imaging the Sun with ALMA

RoCS hosted the first international workshop on solar imaging with the ALMA observatory, the "new eye" to the Sun.

Twenty-one participants from Europe, North America, East Asia and Chile gathered to review the status of processing ALMA observations of the Sun. Additional participants joined the presentations and discussions via videoconferencing.

Regular observations of the Sun with the Atacama Large Millimeter/sub-millimeter Array (ALMA) started in 2016. The 66 radio antennae are usually pointed towards galaxies, black holes and interstellar nebulae.

"The Sun is quite different from other astronomical targets. In particular, it varies on very short timescales. Producing reliable images was a challenging task in the beginning", explains Wedemeyer who is the Principal Investigator at RoCS for the European Research Council (ERC) project SolarALMA.

Hands-on with SoAP

A major obstacle to overcome in achieving scientific results from the ALMA solar data is the image synthesis, i.e. combining the signals from all antennae to form an image. This way, the 66 antennae act together as a much bigger telescope.

Computing image series of the Sun from the interferometric measurements comes with many technical challenges that require substantial efforts and combined international expertise.

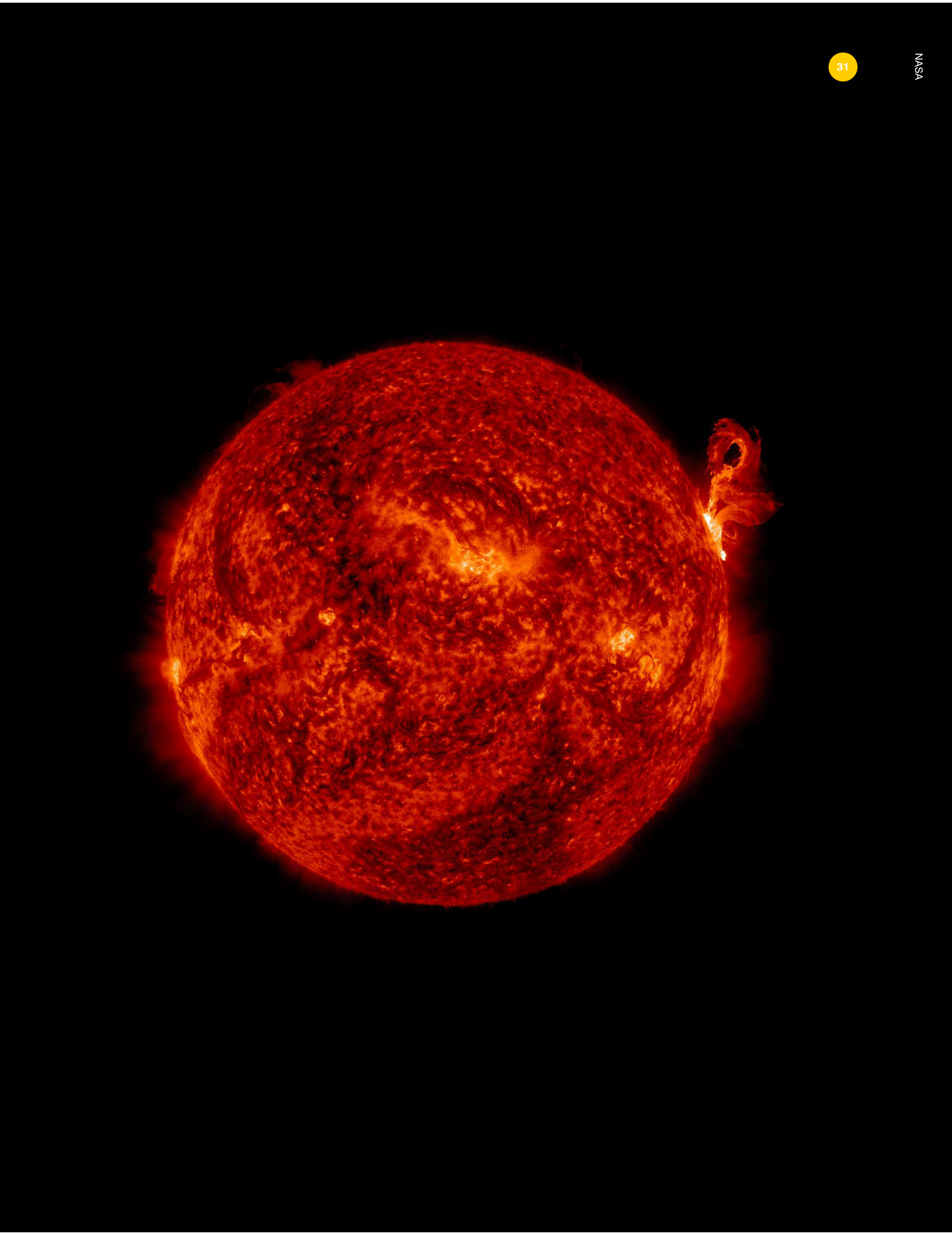
Participants to the first international ALMA-SOL-IMG1 workshop gather at the new premises of the Rosseland Centre for Solar Physics, University of Oslo. (F. Clemmensen, S. Wedemeyer, RoCS).

"Also the correct calibration, necessary for reliable brightness temperature measurements, had to be discussed", adds Wedemeyer.

At the workshop the international experts in interferometry and solar data analysis could work on selected ALMA observations using different approaches including the Solar ALMA Pipeline (SoAP) developed at RoCS for the production of images.

In 2020, ten people at RoCS worked on three ongoing projects focused on ALMA observations of the Sun (SolarALMA, EMISSA, ESO ALMA Development Study - High-cadence imaging of the Sun).

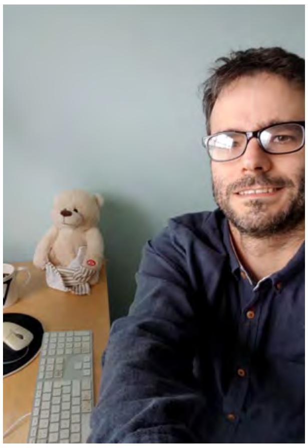
Glimpses from the life at RoCS

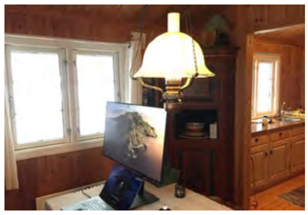


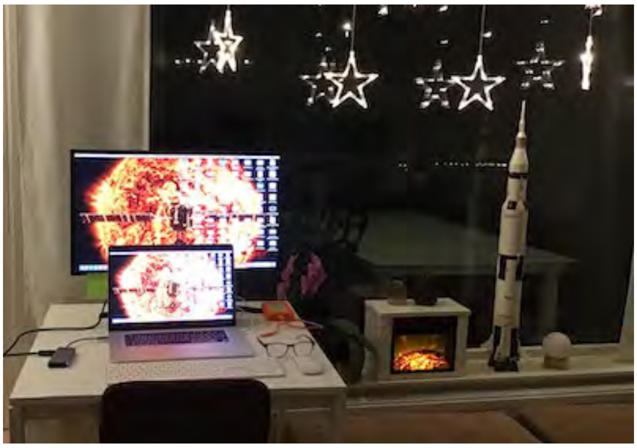
NASA

Life from home office

On and off with home office from March 12th 2020, but we managed to keep the wheels turning with a positive attitude and a lot of video meetings.





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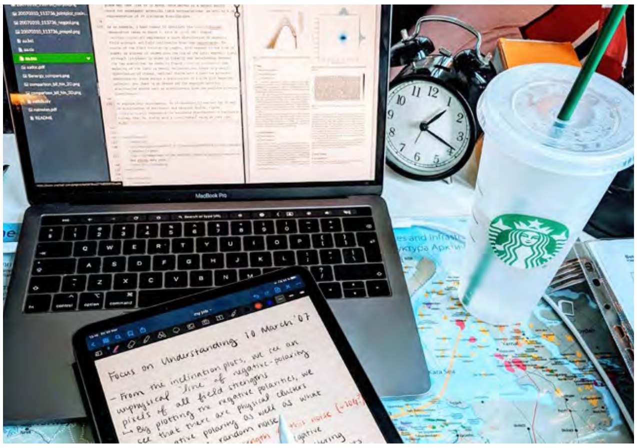
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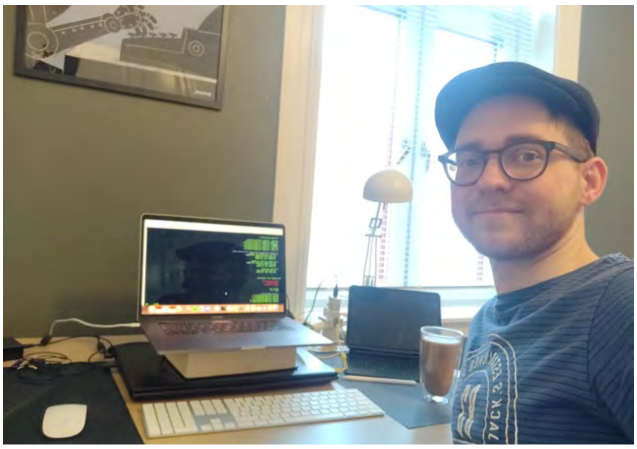


Interview with new employees: Lupe and Atul

(A.Lien, UiO)

Maria Guadalupe Barrios Sazo (Lupe) started as a research software engineer at RoCS in the autumn of 2020.

The opening of the current position at RoCS was attractive for several reasons: The science-related coding and high-performance computing, a long-term position and a good balance between future opportunities in both academia and the industry.

Once at RoCS in Oslo, she found the social environment very welcoming and liked that people regardless of positions enjoy coffee breaks and lunch together. She also likes the ergonomic office setup and modern computer screens at RoCS, which is beneficial for this type of work.

The Norwegian winter comes with its challenges, although a bit less harsh than Lupe imagined beforehand. She enjoys swimming, dancing and going for walks. When summer comes around, Lupe will most likely enjoy being in Norway and at RoCS even more than she already does.

At RoCS, ***Atul Mohan*** finds himself surrounded by motivated, focused people with a lot of excitement in what they are doing. Motivation and excitement seep into him in this nurturing environment. Working directly with an international group has been an enriching experience, and there is a lot of mutual respect and scientific exchange.

Atul has previously been working on various aspects of the solar atmosphere but mostly on the observational side, so having strong simulation support along with the observational groups under one institute is a big plus for addressing the physical conditions of the solar atmosphere.

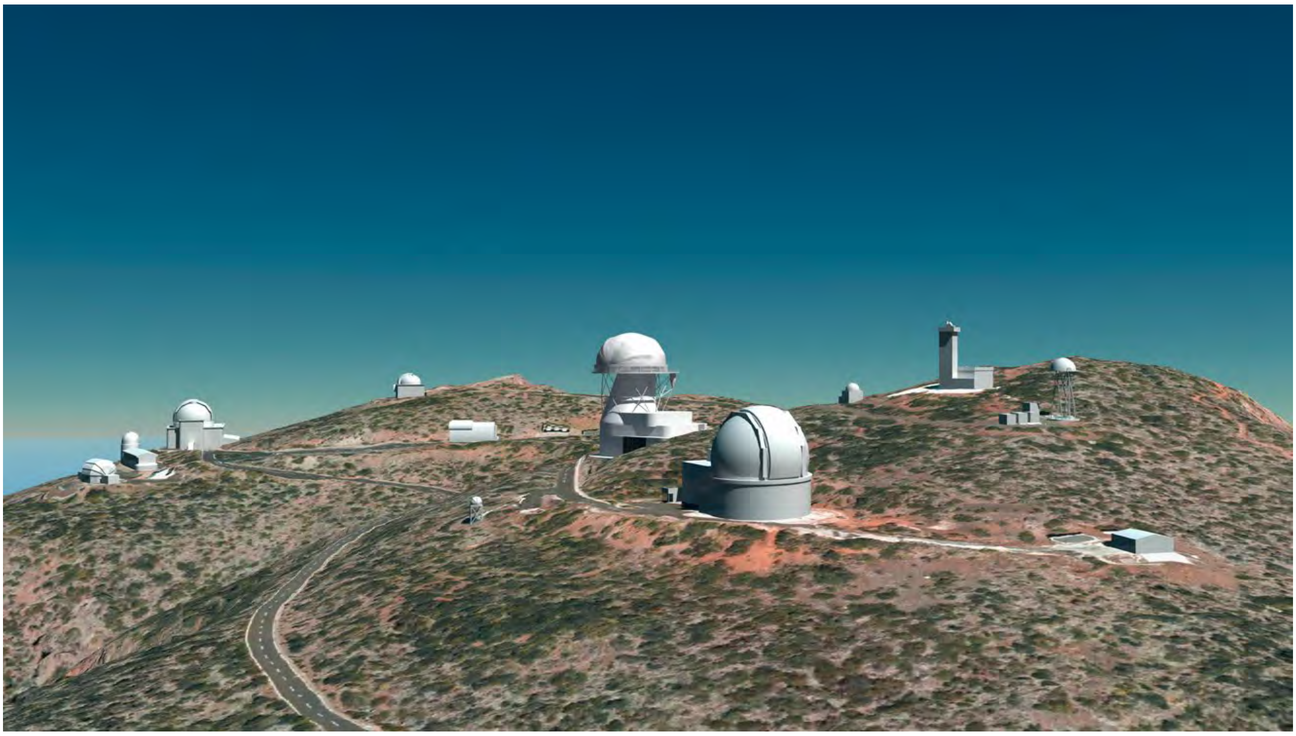
Atul Mohan is working on connecting the solar physics aspects to that of Sun-like stars, with the current question, how the atmospheres and the activity in Sun-like stars compare to the Sun.

Sneha Pandit and Henrik Eklund

“Physics is an art. The only difference between science and art is that science is art bound by physical constraints. In pure art, you can imagine anything. Science is creating a story/narrative bound by some laws.”

Atul Mohan

Illustration of the proposed EST site at Observatorio del Roque de los Muchachos, with the EST telescope and building drawn at the center, near the Swedish 1-m Solar Telescope (tower to the right) and the William Herschel Telescope (center foreground). (Gabriel Pérez, IAC).



EST

The European Solar Telescope (EST) will be 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 2020.

The project office at the Instituto de Astrofisica de Canarias has been consolidated and the first industrial contract has just been awarded for the preliminary design of the EST structure, pier and enclosure. The contract, worth 850.000 EUR, was awarded to the Spanish company IDOM (that also developed the dome for DKIST).

The final objective is to consolidate the baseline design for this sub-system, including specifications, production, and assembly, integration, and verification plan (AIV), as well as budget. First light for EST is expected in 2028.

Modelling the solar corona

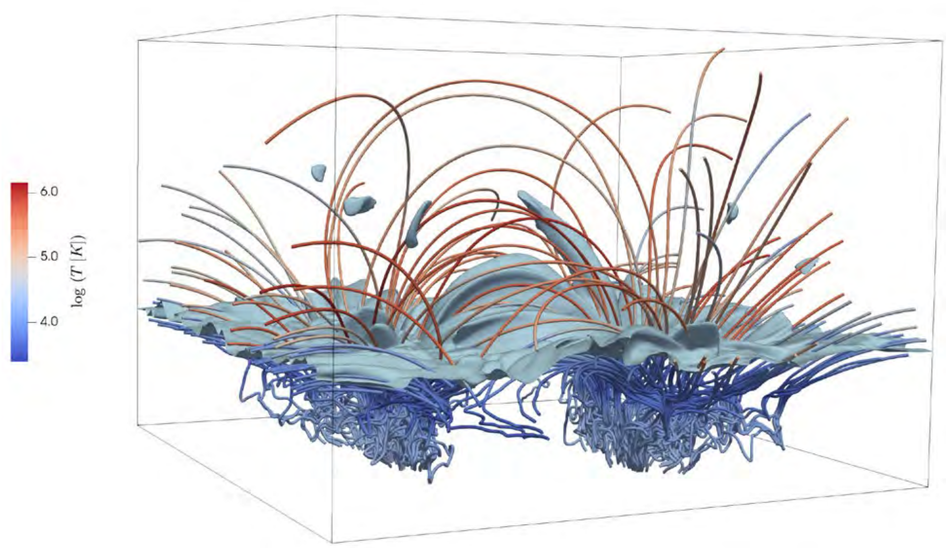
In order to understand the energetic Sun we at RoCS also look high into the solar corona.

The corona is filled with waves which are responsible for transport and dissipation of energy across the solar atmosphere. Such waves have mostly been studied using simplified models in recent years, which provided a good theoretical understanding of wave evolution in ideal flux-tube geometries. However, the real picture of the solar corona is far from simple – it is highly structured, dynamic and continuously evolving. It is not yet clear how such oscillations behave in realistic magnetic field geometries and density environments.

This is where Bifrost solar models come in handy. 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 realistically the dynamics of the solar corona. Such simulations can therefore be used as a laboratory for studying oscillations in the corona. At RoCS we have recently made first attempts at this and looked at the formation of coronal rain and coronal oscillations in Bifrost simulations (Kohutova et al. 2020, Kohutova & Popovas 2021). This opens new doors to the exploitation of Bifrost models for coronal studies.

Studying coronal phenomena in Bifrost simulations and comparing them with observations also acts as a 'sanity check' for the self-consistent solar models, where we need to ask important questions: How well does the behaviour in the simulated corona match what we see in the real solar corona, and what are the reasons for any discrepancies? Answers to these will provide important input for the development of future models.

Petra Kohutova, Postdoctoral Fellow, RoCS



Simulation showing cool (10.000 K), dense regions in the hot Corona (1 million K) falling down as "coronal rain" (the isolated grey blobs). Magnetic field-lines coloured with temperature. (P. Kohutova, RoCS)

Experiencing he Northern lights outside the city of Tromsø. (S.Pandit, RoCS).

Norway: Host to Dancing Aurorae

It's in 2020. The borders are closed. New year's weekend is coming up and I want to travel and visit someplace beautiful. Also, the sun is getting out of the quiet phase, so there would be a chance to see the northern lights. Decided! I was going to Tromsø, the second capital of Norway. For hunting the northern lights! Living in Norway has its perks.

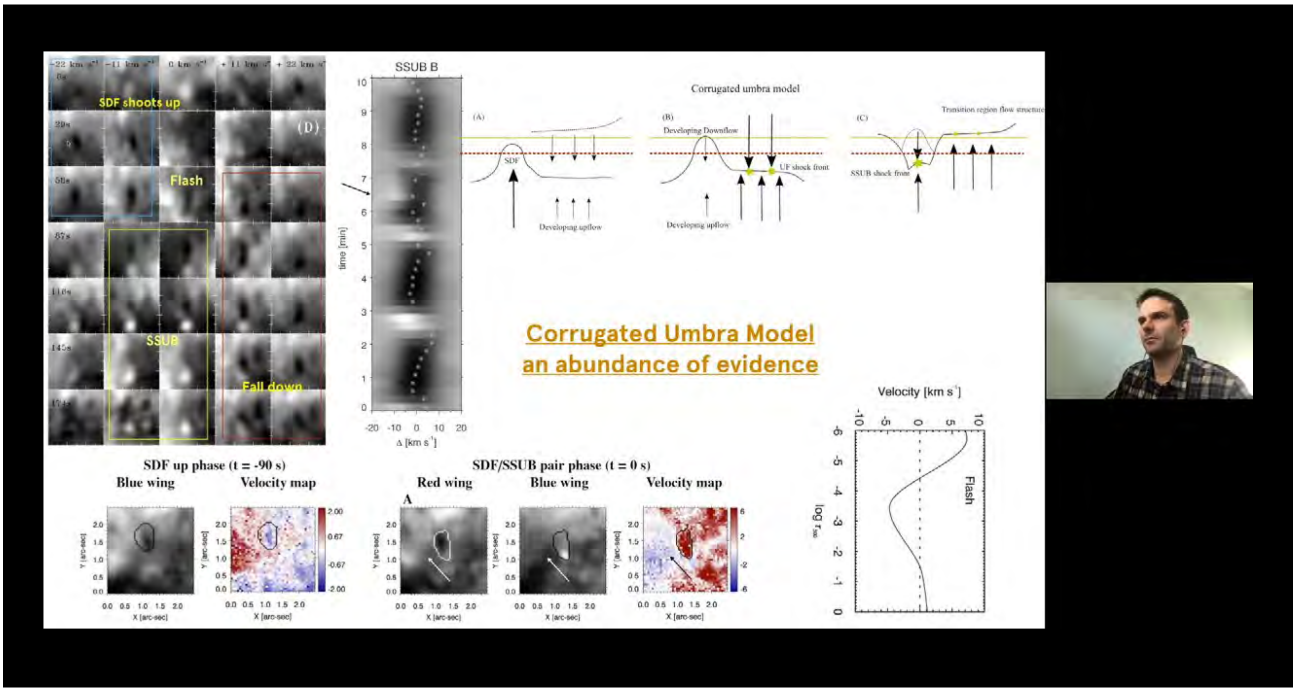
December 31st, was one of the most memorable days. We left Tromsø in the evening heading to one of the Arctic beaches. After reaching a less windy beach in the snow-clad mountains we settled down. Our trip organisers lit a cosy bonfire, took out foldable stools and we faced north awaiting for the lights to show up. It was a full moon night. I spotted some constellations, some stars and satellites. Suddenly we saw a little tinge of green in a long exposure shot. And just like that, everyone got excited.

The aurorae started as a band like a rainbow and then they started to diversify. The band became thicker and turned into a sheet. The sheet started to move eventually and voila; we were very fortunate to witness the northern lights dance. They bifurcated, rejoined, waxed and waned. We clicked many pictures and were completely awestruck to see this rare and natural phenomenon. We shouted, jumped, danced and celebrated the last day of this unique year.

The particles traveling from the sun as solar winds or coronal mass eruptions are trapped in the magnetic field of the earth and hence they travel to the magnetic poles, where due to saturation they change energy levels emitting light: closest encounter to the sun for a solar physicist!

Sneha Pandit

Supporting meetings for solar physicists



The European Solar Physics Online Seminar (ESPOS; https://espos.stream) is hosted by RoCS and held twice a month between European institutions. It is intended for a specialised audience: solar physicists, both early-career and established researchers. The goal is to create an effective and open platform for the exchange of scientific ideas among the European solar physics groups.

Meetings will have on average 100 Zoom connections and with some institutes having one connection for an auditorium, the number of participants reach well over 100 people per meeting. The talks and follow-up discussions last for an hour.

The online seminars allow researchers to share their work more widely with a specialised audience, and give some exposure to cutting-edge research for students and early-career researchers that do not regularly travel to conferences. This even became a more important event during 2020 since almost all conferences were cancelled due to the pandemic. Different institutes take turns at hosting a seminar.

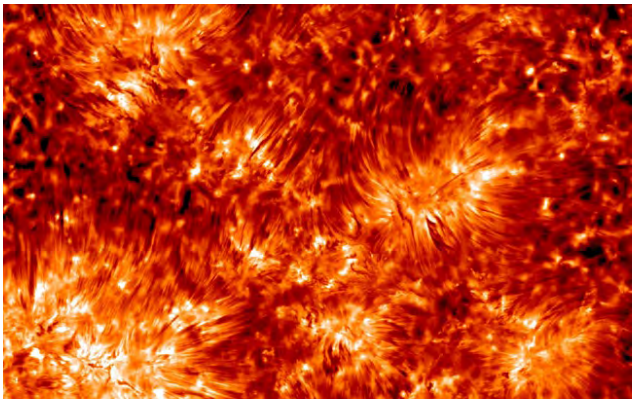
It was primarily aimed at solar physics groups in Europe, but two Indian institutes have come along to be among the host/participating institutes. It could indeed be worldwide, but the time-zone differences make it difficult. In principle, everyone is welcome to participate.

Shahin Jafarzadeh

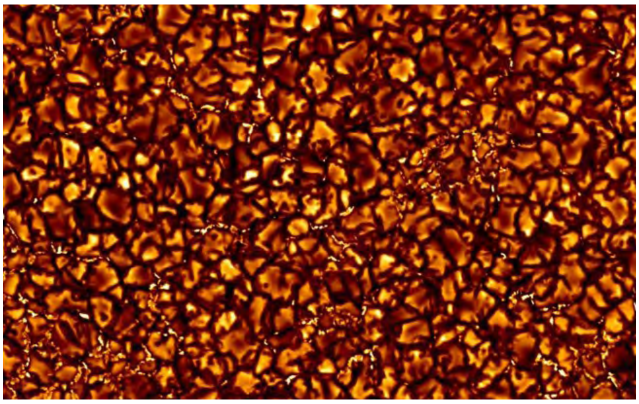
Winning solar media

In February 2020, the European Solar Physics Division (ESPD) of the European Physical Society started a "Media of the Month" contest with the aim of building a collection of high-quality images, movies, and other media of the sun or related to the study of the sun, hosted and freely available from Wikimedia Commons. The contest runs every month, and so far RoCS researchers have been prolific at providing amazing media and winning many months in 2020. Winning entries include submissions from Luc Rouppe van der Voort (March, June, and August), Daniel Nóbrega-Siverio (April), Vasco Henriques and Ainar Drews (May).

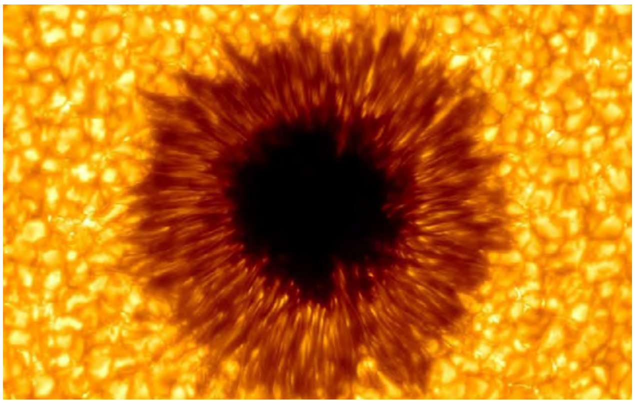
Tiago Pereira



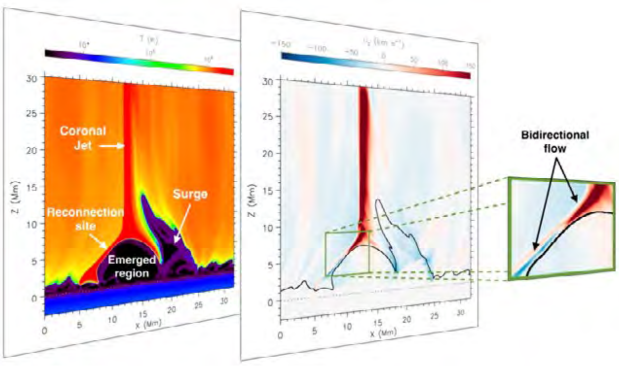
May: The Solar Chromosphere at the highest possible resolution. The chromosphere of the Sun as observed with the Swedish 1-m Solar Telescope. This is how spatially detailed we can observe the chromosphere of the Sun as of early 2020.



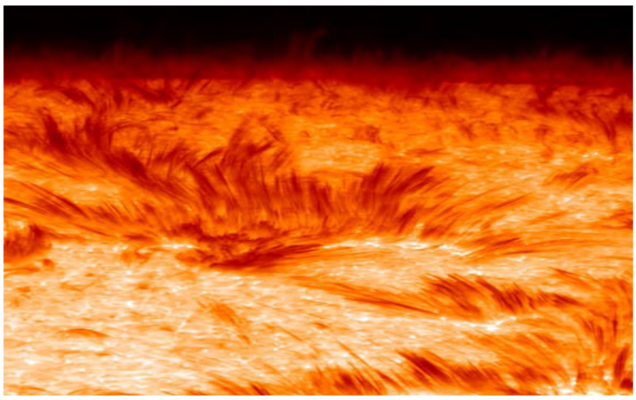
March: Granulation in quiet Sun. Surface of the Sun showing convection in the solar photosphere.



June: Sunspot in AR11084. Still from a 1 hour movie of a sunspot observed with the Swedish 1-m Solar Telescope.



April: Coronal jet and surge. Coronal jet and surge in a radiation-MHD numerical experiment by Nóbrega-Siverio et al. (2017, 2018)



August: Halpha spicules at the limb. Spicules at the solar limb observed in H-alpha with the SOUP instrument at the Swedish 1-m Solar Telescope.

Members of the centre

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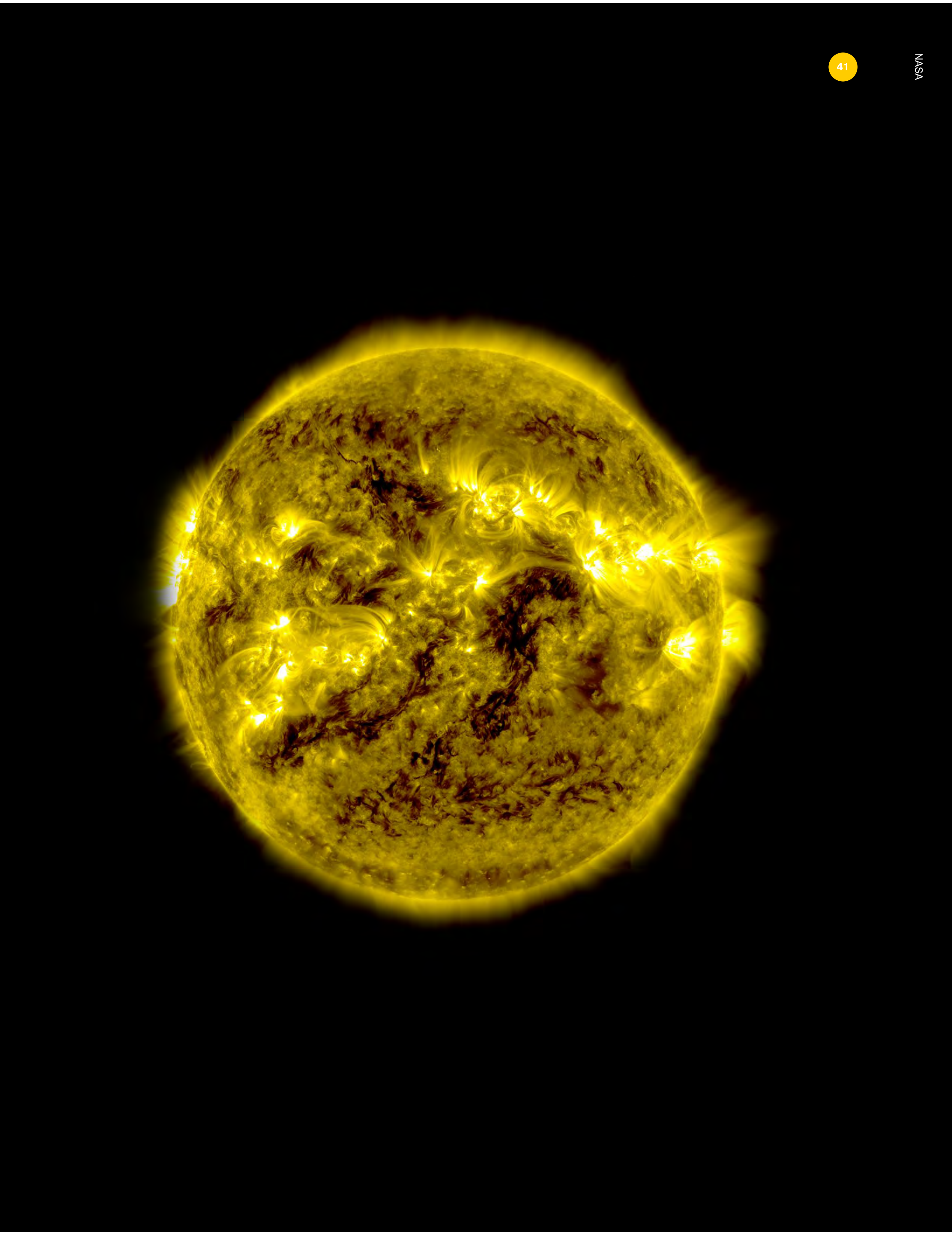


NASA

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 2020 we had seven master students, 13 doctoral research fellows, 12 postdocs and researchers, three research software engineers, two associate professors, four professors, two centre coordinators and one communication adviser. In addition we had six adjunct professors, as well as seven 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. Helle is an in-house advocate for her coworkers, and she also enjoys public education and outreach activities. One of her favorite parts of the job is being a teaching assistant.

Ainar Drews

Ainar Drews is a doctoral research fellow at RoCS and his research is focused on observations of the Sun. Some of his earlier work is dedicated to partial automation of solar observations using simple machine learning. Ainar's research revolves around the investigation of primarily chromospheric objects in the penumbrae of sunspots called Penumbral Microjets, employing both ground- and space- based instruments.

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 is a doctoral research fellow 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 generating 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.

Henrik Eklund

Henrik Eklund is a doctoral research fellow at RoCS and his research is focused on determining optimal ways to handle interferometric data from ALMA observations of the Sun. He also makes 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.

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.

Phd

Juan Camilo Guevara Gómez

As a doctoral research fellow at RoCS, Juan Camilo Guevara Gómez is analyzing solar observations by ALMA seeking for signatures of heating likely related to propagation of shock waves in the solar atmosphere or to reconnection events. Juan is also supporting his observational analysis by comparing the results with available simulations. Finally, Juan is also enrolled in outreach activities as Astronomy on Tap Oslo and lately in the organization of the Astronomy Olympiad in Norway.

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.

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 it with other well studied observations. She studies the Sun in order to understand the structures of stars in general. The 'Sun as a star approach' uses solar observations to estimate properties or features of other stars, leading to a better understanding of the Sun and others stars. 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 new position with RoCS and is looking forward to the coming years.

Postdocs and researchers

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 is a researcher at RoCS. Vasco enjoys modelling poorly understood dynamic processes in our star using observations. He presently focuses on unique ALMA data, especially interferometric, with the goal of producing an extensive archive reduced to a high quality standard that is usable by solar scientists. He believes that ALMA has the most potential of all observatories to push our empirical understanding forward, provided a few unique challenges are addressed. 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 a researcher at the Solar ALMA project. He is predominantly interested in characterisation of wave activity in the lower solar atmosphere, and is one of the coordinators of the WaLSA international science team (https://WaLSA.team). Shahin is an experienced observer and passionately engages in public outreach activities.

Daniel Jakobsson

Daniel Jakobsson is a researcher at RoCS. He was a M.Sc. student at the University of Technology, Luleå, Sweden, and joined RoCS in January to work on his M.Sc. project in connection with the ALMA Development Study. After his M.Sc. defence, he continued working with the ALMA Development Study until December. His extended stay was made possible by the International Rosseland Visitor Program. Daniel Jakobsson left RoCS at the end of the year and is now working as a technical adviser in Sweden.

Jayant Joshi

Jayant Joshi is a postdoctoral researcher at RoCS. Jayant's research is mostly focused on measuring the magnetic field in the solar lower atmosphere. His current interest is to understand small scale magnetic reconnection events, Ellerman bombs, in the lower atmosphere, as well as large scale reconnection events, flares. Jayant is mainly an observer, and he makes use of both ground-based and space-borne solar telescopes. Jayant Joshi left RoCS at the end of the year to start working at the National Solar Observatory, DKIST Science Support Center in Pukalani, Maui, USA.

Chandrashekhar 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.

Postdocs and researchers

Petra Kohutova

Petra Kohutova is a postdoctoral researcher at RoCS. Petra studies processes responsible for matter and energy transfer between different layers of the solar atmosphere by combining high resolution solar observations and numerical simulations. She focuses on using thermal instability in the solar atmosphere as a means to probe the nature of the coronal heating. She also studies waves in the solar atmosphere and their role in the energy transport.

Atul Mohan

Atul Mohan is a postdoctoral researcher at RoCS. His previous research has been on weak ubiquitous heating events in the solar atmosphere. He has experience in handling large solar datasets from typical modern radio telescopes and developing programs to extract science-relevant information. At RoCS, he works for the EMISSA project to understand the nature of atmospheric activity in different types of stars, including our Sun. This will hopefully tell us if the Sun is in any sense a special star.

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 the small scale events, and to have insights about their role in mass and energy cycle of the solar atmosphere.

Daniel Nóbrega Siverio

Daniel Nóbrega-Siverio is a postdoctoral researcher at RoCS. He studies the role of nonequilibrium and partial ionization effects in the chromosphere in magnetic flux emergence processes and related phenomena like surges. In addition, he is also interested in other eruptive/ejective phenomena like UV bursts and coronal hot jets. His main approach is theoretical, through numerical experiments carried out using the state-of-the-art Bifrost code, combined with forward modeling to compare with space and ground-based observations. In March 2021, Daniel moved to a new position at IAC, Tenerife.

Carlos Quintero Noda

Carlos Quintero Noda is a postdoctoral researcher at RoCS. He supports future missions through different theoretical studies. Carlos uses state-of-the-art 3D numerical simulations created with the Bifrost code to compare candidate spectral lines or to study the impact of different instrumental configurations on the science capabilities of those missions. He also works on numerical codes that infer the physical information of the solar atmosphere when applied to observations. In March 2020, Carlos moved to a position at IAC, Tenerife, Spain.

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.

Research Software Engineers

Maria Guadalupe Barrios Sazo

Maria Guadalupe Barrios Sazo joined RoCS as a research software engineer in September 2020. 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 used to be a postdoctoral researcher at RoCS, but from March 2020 he has transferred to a research software engineer position. He continues working 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-physics, etc.

Mikolaj Szydlarski

Mikolaj Szydlarski is 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.

“It is hard to be angry when one has seen the sun rise,' she said.
It seems to be true,' he admitted. 'I wonder why.'
Because it makes one feel so small and insignificant.
It has been rising forever and will rise forever
no matter what we do or do not do.
All our problems are as nothing to the sun.”

David Gemmell, Sword in the Storm

Adjunct professors

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.

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 to better understand the coupling between photosphere, chromosphere and corona. He is the PI of NASA's IRIS satellite and manages the IRIS research team at Lockheed Martin Solar & Astrophysics Laboratory in Palo Alto, California, USA.

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 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.

Marianne Gjestvold Omang

Marianne Gjestvold Omang is an adjunct professor in a 20% position at RoCS. She also works for the Norwegian Defence Estate Agency in the Research and Development section. Her field of interest is numerical and experimental work on shock and blast waves, looking specifically at spontaneous shock ignition of reactive particles. The numerical multi-phase in-house code RSPH (Regularized Smoothed Particle Hydrodynamics) is used for the numerical simulations. The experimental work Is performed in a Laboratory in Horten, using a high-pressure shock tube, and high speed video cameras combined with imaging techniques such as Schlieren and Shadowgraph for the visualisation.

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 research focuses on chromospheric heating and dynamics and multi-fluids using and developing state of the art 3D radiative MHD codes and compare 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 the STARPLAN center of excellence. He is a member of the Niels Bohr International Academy, the Norwegian Academy of Sciences and Letters, and the Swedish Royal Academy of Science.

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. Coronal heating and chromospheric dynamics and energetics are keywords.

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.

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.

Sara Asgari Nettum

Sara Asgari Nettum filled Benedikte's position as a centre coordinator while Benedikte was on maternity leave. Sara Asgari Nettum started a new position at UiO at the end of December 2020.

Eyrun Thune

Eyrun Thune is responsible for communication at RoCS. She started her position in July 2020 and has previous work experience from science groups at Oslo University Hospital and the University of Oslo.

Technical and administrative associated staff

Martina D'Angelo

Martina D'Angelo is communication advisor and press contact at the Institute of Theoretical Astrophysics (ITA). Martina's main responsibilities are internal communication, creating and coordinating outreach activities, writing popular science articles about the ongoing research and news at ITA. She is the main web editor of ITA's web pages and related social media channels.

Technical and administrative associated staff

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.

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.

Pratibha Shrestha

Pratibha Shrestha is a front-end developer working in the Project Related IT services (PRITS) group. She is working on a three year project assisting in the development of front-end for the Hinode archive for presenting data from solar observations in a user friendly manner. In March 2021, Pratibha moved to a new position at Bouvet as an adviser.

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 recently took on the role of Hinode EIS UK 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 structure and dynamics of solar prominences. He is a veteran user of the Swedish 1-m Solar Telescope on the island of La Palma and of solar telescopes of the US National Solar Observatory (NSO). 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 areas of interest are 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 world-leading expert in radiative transfer and spectral diagnostics. His lecture notes are used in teaching radiative transfer all over the world.

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

Bruce Arnold Chappell

Bruce is a second-year master student in the Computational Science: Astrophysics programme and writing his thesis with the solar group at ITA. He is coming from a physics bachelors background from the US and his academic interests are machine learning, data analysis, and high performance computing. The general plan for his thesis is to use machine learning methods applied to 3D spectral synthesis.

Jonas Faber

Jonas is a first-year master student at RoCS. He will compare synthesised Mg II h&k spectra from simulations with real observations by using codes such as Bifrost, RH, STiC and IRIS². Nancy Narang and Tiago M. D. 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 is a second-year master student at RoCS. She joined 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.

Ilse Kuperus

Ilse Kuperus is a first-year master student at RoCS. Ilse's research is focused on finding the roots of microturbulence in the sun, to assess how much comes from unresolved motions. This will be done by carrying out spectral synthesis of chromospheric and photospheric lines from 3D rMHD models of the solar atmosphere. Ilse will start working on her thesis in the autumn of 2021 under the supervision of Tiago M. D. Pereira.

Mats Ola Sand

Mats Ola Sand is a second-year master student at RoCS. Mats Ola's research is observational and focuses on the dynamics of the solar chromosphere in the quiet Sun. He works with data from the Swedish 1-m Solar Telescope at La Palma, and mainly analyzes the Ca II K spectral line through the extent of solar spicules.

Magne Elias Roland Udnæs

Elias is a first-year master student in the Computational Science: Astrophysics programme with an interest for numerical simulations. He will start 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 improve numerical accuracy.

Marte Cecilie Wegger

Marte is a first-year master student at RoCs. In her thesis she will perform 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 will start working on her thesis in the autumn 2021 together with Maryam Saberi and Sven Wedemeyer.

“If I had to choose a religion, the sun as the universal giver of life would be my god.”

Napoleon Bonaparte

(D.Graham)

Talks and presentations 2020

Bose, Souvik. Characterization of spicules in high resolution observations and simulations. Invited talk at the Indian Institute of Astrophysics; 2020-01-21

Bose, Souvik; Henriques, Vasco; Joshi, Jayant; Rouppe van der Voort, Luc. Rapid Downflows in the solar chromosphere. Talk at the Royal Astronomical Society of London's specialist discussion meeting; 2020-11-13

Carlsson, Mats. Radyn. ISSI team workshop; 2020-01-27 - 2020-01-31

Carlsson, Mats. Solar storms: wildest weather in the solar system. NTNU fysikkseminar; 2020-10-02

Carlsson, Mats. Solar storms: wildest weather in the solar system. Hybrid Technology Hub seminar; 2020-08-24

Carlsson, Mats. Solen, din nærmeste stjerne. Åpen dag; 2020-03-05

De Moortel, Ineke. Our Dynamic Sun, Solar Storms and Atmospheric Effects on Earth's Communities. Highlands Astronomical Society Meeting; 2020-09-01

De Moortel, Ineke. Our 21st Century Sun. Royal Society of Edinburgh Winter Lecture; 2020-02-04

De Moortel, Ineke; Howson, Tom; Pagano, Paolo; Morton, Richard; Reid, Jack. Aspects of MHD wave heating in the complex solar atmosphere. MHD Coronal Seismology 2020; 2020-12-08 - 2020-12-11

De Moortel, Ineke; Howson, Tom; Pagano, Paolo; Van Damme, Hendrik-Jan. Aspects of MHD wave heating in the complex solar atmosphere. UK Solar Physics Seminar; 2020-03-24

Eklund, Henrik; Szydlarski, Mikolaj; Wedemeyer, Sven. Image reconstruction of interferometric ALMA data. Solar imaging with ALMA; 2020-03-02 - 2020-03-06

Frogner, Lars. Accelerated particles in the solar atmosphere. Solar and magnetospheric theory group online meeting; 2020-10-28

Gudiksen, Boris. Our active Sun. Astronomy on Tap; 2020-09-28

Gudiksen, Boris; Frogner, Lars; Bakke, Helle. Accelerated particles in the solar atmosphere. ITA institute colloqium; 2020-11-27

Gudiksen, Boris; Frogner, Lars; Bakke, Helle; Clemmensen, Frederik. Accelerated particles in the solar atmosphere. Solar and magnetospheric theory group online seminars; 2020-10-28

Hansteen, Viggo. Heating of the solar chromosphere, Ellerman Bombs and UV bursts. UCLA seminar; 2020-10-02

Henriques, Vasco. Vamos conhecer melhor o Sol. 7.a Conferencia dos Professores Espaciais; 2020-11-10 - 2020-11-17

Jafarzadeh, Shahin. Magneto-acoustic Waves in the Lower Solar Atmosphere at High Resolution. Invited colloquium talk at the University of Sheffield; 2020-02-13

Jafarzadeh, Shahin. Observing Waves in the Lower Solar Atmosphere with ALMA. Theo Murphy international scientific meeting: High resolution wave dynamics in the lower solar atmosphere, Chicheley Hall, UK; 2020-02-10 - 2020-02-11

Jafarzadeh, Shahin. Waves in the Lower Solar Atmosphere. Invited review at the National Institute for Space Research of Brazil (INPE), through Zoom (online seminar); 2020-09-11

Mohan, Atul; McCauley, Patrick; Oberoi, Divya; Mondal, Surajit; Mastrano, Alpha. New insights on weak coronal events from HDR snapshot spectroscopic imaging at meter-wavebands. ITA Friday Colloquium; 2020-10-09

Narang, Nancy. What causes high-frequency oscillations in active region moss: Waves or/and Reconnection?. ITA Friday Colloquium; 2020-10-30

Nóbrega Siverio, Daniel. MHD simulations of jets and surges in the solar atmosphere. Parker Solar Probe. Science working meeting #19; 2020-10-14 - 2020-10-15

Nóbrega Siverio, Daniel. Solar surges related to UV bursts: characterization through density diagnostics, k-means, and inversions. Royal Astronomy Society (RAS) discussion meeting; 2020-11-13

Nóbrega Siverio, Daniel. Surges: a fundamental piece in the solar atmosphere puzzle. XIV.o Scientific meeting of the Spanish Society of Astronomy (SEA); 2020-07-13

Nordlund, Åke. DISPATCH: A Code Framework for Exascale Computing. NYUAD; 2020-01-21 - 2020-01-24

Nordlund, Åke. The DISPATCH Code Framework; Tutorial / HandsOn. Nordita; 2020-03-02

Saberi, Maryam. UV chemistry in the circumstellar envelopes around evolved stars. ITA Friday Colloquium; 2020-05-29

Wedemeyer, Sven. Development of tools for solar research with ALMA at RoCS. 1st International Workshop on Solar Imaging with ALMA; 2020-03-02 - 2020-03-06

Wedemeyer, Sven. Magnetic Tornadoes on the Sun. ISSI International Team 449 - The nature and physics of vortex flows in solar plasmas; 2020-02-04

Wedemeyer, Sven. Observing the Sun with ALMA – Challenges, scientific potential, and first results.

Papers in refereed journals 2020

Anderson, Mark et al. (89 authors, among them **Carlsson, Mats; Fredvik, Terje; Hansteen, Viggo; Haugan, Stein Vidar Hagfors)**: 2020, Astronomy and Astrophysics 642, id.A14, The Solar Orbiter SPICE instrument: An extreme UV imaging spectrometer.

Armstrong, John A.; **Fletcher, Lyndsay**: 2021, Monthly Notices of the Royal Astronomical Society 501, 2647-2658, A machine-learning approach to correcting atmospheric seeing in solar flare observations.

Auchère, Frédéric et al. (74 authors, among them **Carlsson, Mats**): 2020, Astronomy and Astrophysics, 642, id.A6, Coordination within the remote sensing payload on the Solar Orbiter mission.

Barnes, Will T. et al. (34 authors, among them **Pereira, Tiago M.D.**): 2020, The Astrophysical Journal, 890, id.68, The SunPy Project: Open Source Development and Status of the Version 1.0 Core Package.

Bharti, L.; Sobha, B.; **Quintero Noda, Carlos**; Joshi, C.; Pandya, U..: 2020, Monthly Notices of the Royal Astronomical Society, 493, 3036-3044, Chromospheric plasma ejection above a pore.

Bobra, Monica G; Mumford, Stuart J; Hewett, Russell J; Christe, Steven D; Reardon, Kevin P.; Savage, Sabrina L.; Ireland, Jack; **Pereira, Tiago M.D.**; Chen, Bin; Pérez-Suárez, David: 2020, Solar Physics, 295, id.57, A Survey of Computational Tools in Solar Physics.

Bose, Souvik; Henriques, Vasco; Joshi, Jayant; Rouppe van der Voort, Luc. (Corrigendum). Astronomy and Astrophysics: 2020, 637, id.C1, Characterization and formation of on-disk spicules in the Ca II K and Mg II k spectral lines.

Brooks, David H.; Winebarger, Amy R.; Savage, Sabrina L.; Warren, Harry P.; **De Pontieu, Bart**; Peter, Hardi; Cirtain, Jonathan W.; Golub, Leon; Kobayashi, Ken; McIntosh, Scott W.; McKenzie, David; Morton, Richard; Rachmeler, Laurel A.; Testa, Paola; Tiwari, Sanjiv; Walsh, Robert: 2020, The Astrophysical Journal, 894, id.144, The Drivers of Active Region Outflows into the Slow Solar Wind.

Bryans, Paul; McIntosh, Scott W.; Brooks, David H.; **De Pontieu, Bart: 2020**, Astrophysical Journal Letters, 905, id.L33, Investigating the Chromospheric Footpoints of the Solar Wind.

Criscuoli, Serena; Rempel, Matthias; Haberreiter, Margit; **Pereira, Tiago M.D.**; Uitenbroek, Han; Fabbian, Damian: 2020, Solar Physics, 295, id.50, Comparing Radiative Transfer Codes and Opacity Samplings for Solar Irradiance Reconstructions.

da Silva Santos, João Manuel; de la Cruz Rodriguez, Jaime; Leenaarts, Jorrit; Chintzoglou, Georgios; **De Pontieu, Bart ; Wedemeyer, Sven; Szydlarski, Mikolaj**: 2020, Astronomy and Astrophysics, 634, id.A56, The multi-thermal chromosphere: Inversions of ALMA and IRIS data

da Silva Santos, João Manuel; de la Cruz Rodriguez, Jaime; White, S. M.; Leenaarts, Jorrit; Vissers, Gregal Joan Maria; **Hansteen, Viggo**: 2020, Astronomy and Astrophysics, 643, id.A41, ALMA observations of transient heating in a solar active region.

De Moortel, Ineke; Falconer, Isobel; Stack, Robert: 2020, Astronomy & Geophysics, 61, 2.34-2.39, Alfvén on heating by waves.

Drews, Ainar; Rouppe van der Voort, Luc: 2020, Astronomy and Astrophysics, 638, id.A63, A multi-diagnostic spectral analysis of penumbral microjets.

Eklund, Henrik; Wedemeyer, Sven; Snow, Ben; Jess, David B.; **Jafarzadeh, Shahin**; Grant, Samuel D. T.; **Carlsson, Mats; Szydlarski, Mikolaj**: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200185, Characterization of shock wave signatures at millimetre wavelengths from Bifrost simulations.

Eklund, Henrik; Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Guevara Gomez, Juan Camilo: 2020, Astronomy and Astrophysics, 644, id.A152, The Sun at millimeter wavelengths: II. Small-scale dynamic events in ALMA Band 3.

Fleck, Bernhard; **Carlsson, Mats**; Khomenko, Elena; Rempel, M.; Steiner, Oskar; Vigeesh, G.: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200170, Acoustic-gravity wave propagation characteristics in three-dimensional radiation hydrodynamic simulations of the solar atmosphere.:

Frogner, Lars; Gudiksen, Boris; Bakke, Helle: 2020, Astronomy and Astrophysics, 643, id.A27, Accelerated particle beams in a 3D simulation of the quiet Sun.

Fyfe, L. E.; Howson, Thomas A.; **de Moortel, Ineke**: 2020, Astronomy and Astrophysics, 643, id.A86, Forward modelling of MHD waves in braided magnetic fields.

Gallagher, Andrew J.; Bergemann, Maria; Collet, Remo; Plez, Bertrand; Leenaarts, Jorrit; **Carlsson, Mats**; Yakovleva, Svetlana A.; Belyaev, Andrey K.: 2020, Astronomy and Astrophysics, 634, id.A55, Observational constraints on the origin of the elements: II. 3D non-LTE formation of Ba II lines in the solar atmosphere.

Gilchrist-Millar, Caitlin A.; Jess, David B.; Grant, Samuel D. T.; Keys, Peter H.; Beck, Christian; **Jafarzadeh, Shahin**; Riedl, Julia M.; Van Doorsselaere, Tom; Ruiz Cobo, Basilio: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200172, Magnetoacoustic wave energy dissipation in the atmosphere of solar pores.

González Manrique, Sergio Javier; **Quintero Noda, Carlos**; Kuckein, Christoph; Ruiz Cobo, Basilio; **Carlsson, Mats**: 2020, Astronomy and Astrophysics, 634, id.A19, Capabilities of bisector analysis of the SiI 10 827 Å line for estimating line-of-sight velocities in the quiet Sun.

Guevara Gomez, Juan Camilo; Jafarzadeh, Shahin; Wedemeyer, Sven; Szydlarski, Mikolaj; Stangalini, M.; Fleck, Bernhard; Keys, Peter H.: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200184, High-frequency oscillations in small chromospheric bright features observed with Atacama Large Millimetre/Submillimetre Array.

Guo, L.-J.; **De Pontieu, Bart**; Huang, Y.-M.; Peter, Hardi; Bhattacharjee, A.: 2020, The Astrophysical Journal, 901, id.148, Observations and Modeling of the Onset of Fast Reconnection in the Solar Transition Region.

Hasegawa, Takahiro; **Noda, Carlos Quintero**; Shimizu, Toshifumi; **Carlsson, Mats**: 2020, The Astrophysical Journal, 900, id.34, On the Formation of Lyman and the O I 1027 and 1028 Å Spectral Lines.

Henriques, Vasco; Nelson, Chris J.; **Rouppe van der Voort, Luc**; Mathioudakis, Mihalis: 2020, Astronomy and Astrophysics, 642, id.A215, Umbral chromospheric fine structure and umbral flashes modelled as one: The corrugated umbra.

Houston, Scott J.; Jess, David B.; Keppens, Rony; Stangalini, Marco; Keys, Peter H.; Grant, Samuel D. T.; Jafarzadeh, Shahin; McFetridge, L. M.; Murabito, Mariarita; Ermolli, I.; Giorgi, F.: 2020, The Astrophysical Journal, 892, id.49, Magnetohydrodynamic Nonlinearities in Sunspot Atmospheres: Chromospheric Detections of Intermediate Shocks.

Howson, Thomas A.; **De Moortel, Ineke**; Fyfe, L. E.: 2020, Astronomy and Astrophysics, 643, id.A85, The effects of driving time scales on heating in a coronal arcade.

Howson, Thomas A.; **De Moortel, Ineke**; Reid, J.: 2020, Astronomy and Astrophysics, 636, id.A40, Phase mixing and wave heating in a complex coronal plasma.

Hudson, Hugh S.; Simões, Paulo J. A.; **Fletcher, Lyndsay**; Hayes, Laura A.; Hannah, Iain G.: 2020, Monthly Notices of the Royal Astronomical Society, 501, 1273-1281, Hot X-ray onsets of solar flares.

Jafarzadeh, Shahin; Wedemeyer, Sven; Fleck, Bernhard; Stangalini, M.; Jess, D. B.; Morton, R. J.; **Szydlarski, Mikolaj; Henriques, Vasco**; Zhu, X.; Wiegelmann, T.; **Guevara Gomez, Juan Camilo**; Grant, Samuel D. T.; Chen, B.; Reardon, K.; White, S. M.: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200174, An overall view of temperature oscillations in the solar chromosphere with ALMA.

Jess, David B.; Keys, Peter H.; Stangalini, Marco; **Jafarzadeh, Shahin**.: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200169, High-resolution wave dynamics in the lower solar atmosphere.

Jess, David B.; Snow, Ben; Fleck, Bernhard; Stangalini, Marco; **Jafarzadeh, Shahin**: 2020, Nature Astronomy 5, 5-8, Reply to: Signatures of sunspot oscillations and the case for chromospheric resonances.

Johnston, Craig D.; Cargill, P. J.; Hood, A. W.; **De Moortel, Ineke**; Bradshaw, S. J.; Vassekar, A. C.: 2020, Astronomy and Astrophysics, 635, id.A168, Modelling the solar transition region using an adaptive conduction method.

Joshi, Jayant; Rouppe van der Voort, Luc; de la Cruz Rodriguez, Jaime: 2020, Astronomy and Astrophysics, 641, id.L5, Signatures of ubiquitous magnetic reconnection in the lower solar atmosphere.

Joshi, Reetika; Chandra, Ramesh; Schmieder, Brigitte; Moreno-Insertis, Fernando; Aulanier, Guillaume; **Nóbrega Siverio, Daniel Elias**; Devi, Pooja: 2020, Astronomy and Astrophysics, 639, id.A22, Case study of multi-temperature coronal jets for emerging flux MHD models.

Keys, Peter H.; Reid, Aaron L.; Mathioudakis, Mihalis; Shelyag, Sergey I.; **Henriques, Vasco**; Hewitt, Rebecca L.; del Moro, Dario; **Jafarzadeh, Shahin**; Jess, David B.; Stangalini, Marco: 2020, Astronomy and Astrophysics, 633, id.A60, High-resolution spectropolarimetric observations of the temporal evolution of magnetic fields in photospheric bright points.

Kohutova, Petra; Antolin, Patrick; **Popovas, Andrius; Szydlarski, Mikolaj; Hansteen, Viggo**: 2020, Astronomy and Astrophysics, 639, id.A20, Self-consistent 3D radiative magnetohydrodynamic simulations of coronal rain formation and evolution.

Kohutova, Petra; Verwichte, Erwin; **Froment, Clara**: 2020, Astronomy and Astrophysics, 633, id.L6, First direct observation of a torsional Alfvén oscillation at coronal heights.

Martinez-Sykora, Juan; De Pontieu, Bart; de la Cruz Rodriguez, Jaime; Chintzoglou, Georgios.: 2020, Astrophysical Journal Letters, 891, id.L8, The Formation Height of Millimeter-wavelength Emission in the Solar Chromosphere.

Martinez-Sykora, Juan; Leenarts, Jorrit; De Pontieu, Bart; Nóbrega Siverio, Daniel; Hansteen, Viggo; Carlsson, Mats; Szydlarski, Mikolaj.: The Astrophysical Journal, 889, id.95, Ion–neutral Interactions and Nonequilibrium Ionization in the Solar Chromosphere.

Martinez-Sykora, Juan; Szydlarski, Mikolaj; Hansteen, Viggo; De Pontieu, Bart: 2020, The Astrophysical Journal, 900, id.101, On the Velocity Drift between Ions in the Solar Atmosphere.

Mondal, Surajit; Oberoi, Divya; **Mohan, Atul**: 2020, Astrophysical Joural Letters, 895, id.L39, First Radio Evidence for Impulsive Heating Contribution to the Quiet Solar Corona.

Morton, Richard J.; Mooroogen, K; **Henriques, Vasco**: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200183, Transverse motions in sunspot super-penumbral fibrils.

Müller, Daniel et al (35 authors, among them **Carlsson, Mats**): 2020, Astronomy and Astrophysics, 642, id.A1, The Solar Orbiter mission: Science overview.

Murabito, Mariarita; Ermolli, I.; Giorgi, F.; Stangalini, M.; Guglielmino, S. L.; **Jafarzadeh, Shahin**; Socas-Navarro, H.; Romano, P.; Zuccarello, F.: 2020, Journal of Physics: Conference Series (JPCS), 1548, The penumbral solar filaments from the photosphere to the chromosphere.

Murabito, Mariarita; Ermolli, I.; Giorgi, F.; Stangalini, Marco; Guglielmino, S. L.; **Jafarzadeh, Shahin**; Socas-Navarro, Hector; Romano, Paolo; Zuccarello, Francesca: 2020, Proceedings of the International Astronomical Union, 15.(S354), 448-451, The 3D structure of the penumbra at high resolution from the bottom of the photosphere to the middle chromosphere.

Nóbrega Siverio, Daniel; Martinez-Sykora, Juan; Moreno-Insertis, Fernando; **Carlsson, Mats**: 2020, Astronomy and Astrophysics, 638, id.A79, Ambipolar diffusion in the Bifrost code.

Nóbrega Siverio, Daniel; Moreno-Insertis, Fernando; **Martinez-Sykora, Juan; Carlsson, Mats; Szydlarski, Mikolaj**: 2020, Astronomy and Astrophysics, 633, id.A66, Nonequilibrium ionization and ambipolar diffusion in solar magnetic flux emergence processes.

Ortiz, Ada; Hansteen, Viggo; Nóbrega Siverio, Daniel; Rouppe van der Voort, Luc: 2020, Astronomy and Astrophysics, 633, id.A58, Ellerman bombs and UV bursts: reconnection at different atmospheric layers.

Pagano, **P.; de Moortel, Ineke**; Morton, R. J.: 2020, Astronomy and Astrophysics, 643, id.A73, Effect of coronal loop structure on wave heating through phase mixing.

Patel, Ritesh; Pant, Vaibhav; **Kalugodu, Chandrashekhar**; Banerjee, Dipankar: 2020, Astronomy and Astrophysics, 644, id.A158, A statistical study of plasmoids associated with a post-CME current sheet.

Pelouze, Gabriel; Auchère, Frédéric; Bocchialini, Karine; **Froment, Clara**; Parenti, Susanna; Soubrié, Elie: 2020, Astronomy and Astrophysics, 634, id.A54, Spectroscopic detection of coronal plasma flows in loops undergoing thermal non-equilibrium cycles.

Polito, Vanessa; **De Pontieu, Bart**; Testa, Paola; Brooks, David H.; **Hansteen, Viggo**: 2020, The Astrophysical Journal, 903, id.68, IRIS Observations of the Low-atmosphere Counterparts of Active Region Outflows.

Reid, Aaron; Zhigulin, B.; **Carlsson, Mats**; Mathioudakis, Mihalis.: 2020, Astrophysical Journal Letters, 894, id.L21, Chromospheric Bubbles in Solar Flares.

Rouppe van der Voort, Luc; De Pontieu, Bart; Carlsson, Mats; de la Cruz Rodriguez, Jaime; **Bose, Souvik**; Chintzoglou, Georgios; **Drews, Ainar; Froment, Clara**; Goši, Milan; Graham, David R.; **Hansteen, Viggo; Henriques, Vasco; Jafarzadeh, Shahin; Joshi, Jayant**; Kleint, Lucia; **Kohutova, Petra; Leifsen, Torben; Martinez-Sykora, Juan; Nóbrega Siverio, Daniel; Ortiz, Ada; Pereira, Tiago M.D.; Popovas, Andrius; Quintero Noda, Carlos**; Sainz Dalda, Alberto; Scharmer, Göran B.; Schmit, Donald; Scullion, Eamon; **Skogsrud, Håkon; Szydlarski, Mikolaj**; Timmons, R.; Vissers, Gregal Joan Maria; Woods, M. M.; **Zacharias, Pia**: 2020, Astronomy and Astrophysics, 641, id.A146, High-resolution observations of the solar photosphere, chromosphere, and transition region: A database of coordinated IRIS and SST observations.

Saberi, Maryam; Olofsson, Hans; Vlemmings, Wouter H.T.; de Beck, Elivire; Khouri, Theo; Ramstedt, Sofia: 2020, Astronomy and Astrophysics, 638, id.A99, CO and HCN isotopologue ratios in the outflows of AGB stars.

Schmit, Donald; **De Pontieu, Bart**; Winebarger, Amy R.; Rachmeler, Laurel A.; Daw, A.: 2020, The Astrophysical Journal, 889, id.112, Understanding the Structure of Rapid Intensity Fluctuations in the Chromosphere with IRIS.

Stangalini, Marco; Baker, D.; Valori, G.; Jess, David B.; **Jafarzadeh, Shahin**; Murabito, M.; To, A. S. H.; Brooks, D. H.; Ermolli, I.; Giorgi, F.; MacBride, C. D.: 2021, Philosophical Transactions of the Royal Society A, 379 (2190), id.20200216, Spectropolarimetric fluctuations in a sunspot chromosphere

Testa, Paola; Polito, Vanessa; **De Pontieu, Bart**; 2020, The Astrophysical Journal, 889, id.124, IRIS Observations of Short-term Variability in Moss Associated with Transient Hot Coronal Loops.

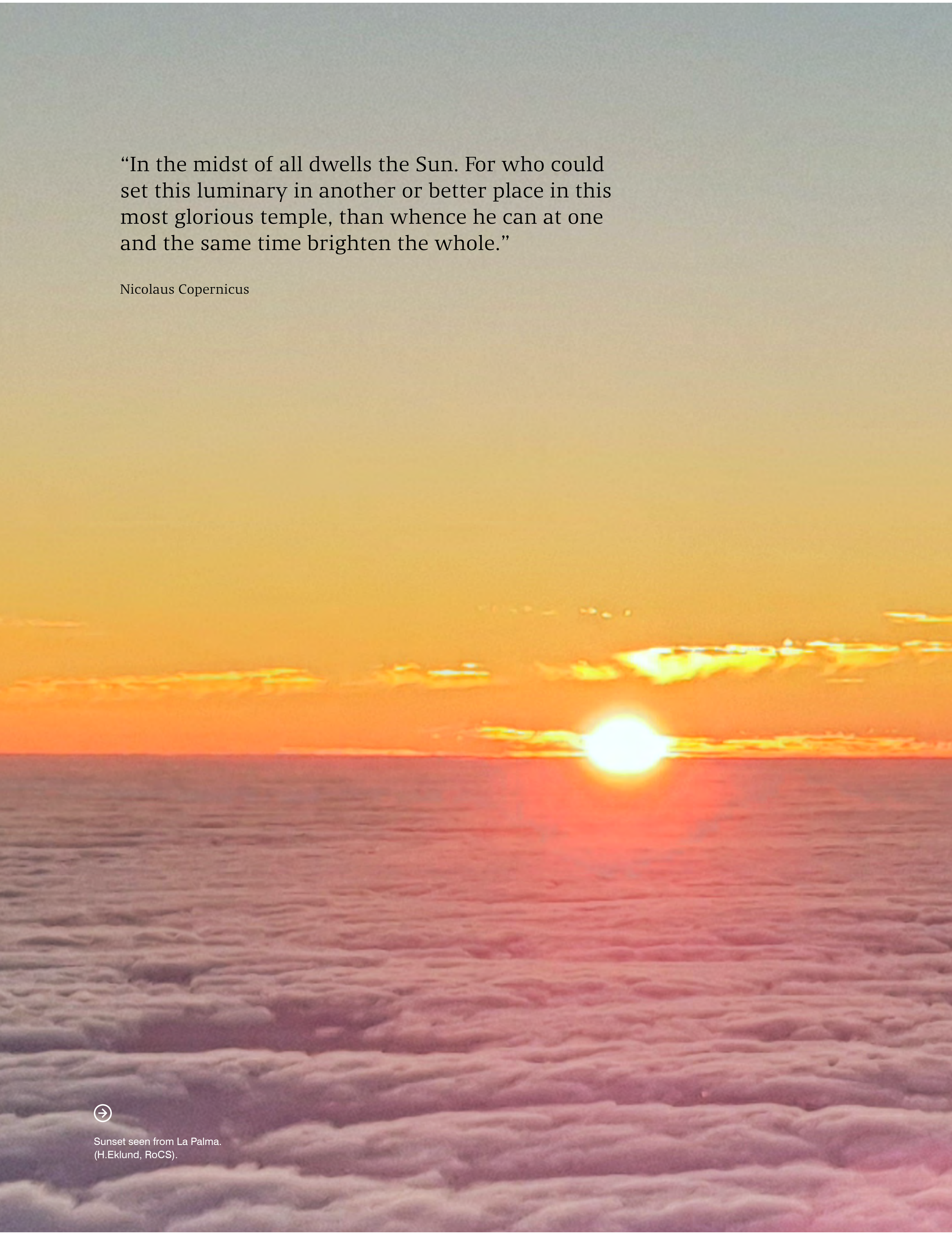
Van Damme, H. J.; **De Moortel, Ineke**; Pagano, P.; Johnston, Craig D. 2020, Astronomy and Astrophysics, 635, id.A174, Chromospheric evaporation and phase mixing of Alfvén waves in coronal loops.

Van Doorsselaere, Tom; Srivastava, Abhishek; Antolin, Patrick; Magyar, Norbert; Vasheghani Farahani, Soheil; Tian, Hui; Kolotkov, Dmitrii; Ofman, Leon; Guo, Mingzhe; Arregui, Iñigo; **De Moortel, Ineke**; Pascoe, David D. 2020, Space Science Reviews, 216, id. 140, Coronal Heating by MHD Waves.

Warren, Harry P.; Reep, Jeffrey W.; Crump, Nicholas A.; Ugarte-Urra, Ignacio; Brooks, David H.; Winebarger, Amy R.; Savage, Sabrina L.; **De Pontieu, Bart**; Peter, Hardi; Cirtain, Jonathan W.; Golub, Leon; Kobayashi, Ken; McKenzie, David; Morton, Richard; Rachmeler, Laurel A.; Testa, Paola; Tiwari, Sanjiv; Walsh, Robert: 2020, The Astrophysical Journal, 896, id.51, Observation and Modeling of High-temperature Solar Active Region Emission during the High-resolution Coronal Imager Flight of 2018 May 29.

Wedemeyer, Sven; Szydlarski, Mikolaj; de la Cruz Rodriguez, Jaime; **Jafarzadeh, Shahin**: 2020, Proceedings of the International Astronomical Union 2020 ;Volum 15.(S354) s.24-37, Observing the Sun with the Atacama Large Millimeter/submillimeter Array-from continuum to magnetic fields.

Wedemeyer, Sven; Szydlarski, Mikolaj; Jafarzadeh, Shahin; Eklund, Henrik; Guevara Gomez, Juan Camilo; Bastian, Tim; Fleck, Bernhard; de la Cruz Rodriguez, Jaime; Rodger, Andrew; **Carlsson, Mats**: 2020, Astronomy and Astrophysics, 635, id.A71, The Sun at millimeter wavelengths: I. Introduction to ALMA Band 3 observations.



“In the midst of all dwells the Sun. For who could set this luminary in another or better place in this most glorious temple, than whence he can at one and the same time brighten the whole.”

Nicolaus Copernicus

Sunset seen from La Palma.
(H.Eklund, RoCS).

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