Rosseland
Centre
for Solar
Physics

Annual report
2019

UiO : University of Oslo

Norwegian
Centre of
Excellence
The Research Council of Norway

Contents
Annual report 2019

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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.

M. D'Angelo, ITA

From the opening of the new facilities, November 1 2019.
From left: Viggo Hansteen (PI), Sven Wedemeyer (PI), Tiago Pereira (PI), Luc Rouppe van der Voort (PI), Benedikte Karlsen (RoCS coordinator), Boris Gudiksen (PI) and Mats Carlsson (director).

From the Director

This is the second 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 in temporary premises at Ullevål stadium (the national soccer stadium of Norway), while our home building, Svein Rosseland's house at Blindern, underwent renovation. At Ullevål we were sitting in an open landscape (except for myself and the centre coordinator, who had our own offices). The whole Institute of Theoretical Astrophysics had such open seating together, on one floor. This went surprisingly well – the open landscape facilitated new collaborations and the presence of many small and large meeting rooms meant that such collaborations could take place with minimal disturbances for the others. We also got a group feeling just from the fact that we started from scratch, away from the usual offices.

During this period, we had the second retreat of RoCS. Since we actually didn't go anywhere (stayed at Ullevål) and "retreat" sounds defensive, it was jokingly named "advance". The theme of the gathering was new collaborations and a number of flash-talks with suggestions for new projects were followed by group discussions on a selected number of them.

After ten months at Ullevål, we could finally move back, on November 1st 2019, exactly two years after the start of RoCS. Moving in took a week with a lot of hard work put in by our administrative and technical staff, while the rest of us were working from home or from rooms booked at the university in various places. The renovation resulted in new paint, completely new wiring of the network with CAT-7 cabling, mechanical ventilation of the larger rooms enabling more people in an open landscape, sound-absorbing material on the walls with astronomical pictures printed on them and a RoCS kitchen and meeting rooms in the old library storage rooms.

"The Sun, with all those planets revolving around it and dependent on it, can still ripen a bunch of grapes as if it had nothing else to do."

Galileo Galilei

The new facilities were celebrated with a two-day RoCS gathering, November 28-29, and an official opening ceremony with speeches by the dean of the Faculty of Mathematics and Natural Sciences, Morten Dælen, the Research Council of Norway through Liv Furuberg, the head of the Institute of Theoretical Astrophysics, Per Lilje, and the RoCS director. The two-day gathering featured short talks by all scientific personnel at RoCS with focus on on-going work. Although the program was packed with 24 talks, the feedback was very positive. We also had a workshop on harassment issues which raised our awareness in a very important area.

In 2019 the ramp-up of activities continued. Two postdoctoral researchers and four PhD students started. The possibility through a centre to attract leading scientists to come for shorter or longer visits has often been highlighted as one of the most important aspects by other centres of excellence. We completed a contract with the University of Copenhagen, enabling professor Åke Nordlund to work 20% for RoCS. Adjunct positions (20%) were also filled with Dr. Juan Martínez Sykora from Lockheed Martin Solar and Astrophysics Laboratory and professor Ineke De Moortel from University of St.Andrews. These hirings expand our scientific profile in very exciting ways. Another important activity here is our International Rosseland Visitor Programme, which is described in more detail in Section 5.

During 2019 we have also worked to strengthen internal collaboration within the centre. Apart from the "advance" and the November gathering mentioned above, we continued our active part in a pilot project on career development for temporary researchers. This is in collaboration with other centres of excellence in Oslo, after the initiative from the Hylleraas Centre for Molecular Quantum Chemistry. A group has been formed at RoCS to implement the ideas we got through this project. One of the results is the formation of a "parliament" formed by the postdoctoral researchers and PhD students, with monthly representation at the PI meetings. We have also strengthened the on-boarding programme for new employees, both with improved written material and through the appointment of a mentor from the group of temporary researchers for each newcomer.

The European Research Council (ERC) synergy grant WHOLE SUN had its kick-off meeting in May 2019. In this project we work with groups in Paris, Göttingen, St. Andrews and Tenerife. One of the goals is to develop a new code that can treat the whole Sun as one system. We are well underway in our development of Bifrost in the DISPATCH framework as a possible solution, see Section 4.4.

For the first annual report (2018) we had a presentation of the vision and scientific programme of the centre. This year we have selected to give some glimpses from the life at RoCS in Section 3.

A number of exciting results have been obtained in 2019. A selection of these are reported on in this annual report in Section 4 with a full list of papers published in refereed journals in Appendix 2. We published 53 papers in refereed journals in 2019, up from 38 in 2018.

As the most important part of a centre is people, we have short presentations of all the members in Section 6.

Adding to our substantial involvement in the Hinode/EIS and IRIS space borne observatories, RoCS takes part in the Solar Orbiter mission of ESA/NASA with co-investigator status on the instrument PHI and co-Principal investigator status on SPICE. The PRITS (Project Related IT Services) group of the institute is responsible for the pipeline translating telemetry into scientific images for SPICE and a functioning pipeline was completed in 2019. At the time of writing, Solar Orbiter has been successfully launched (February 5, 2020) and the instruments have been switched on, one by one. We are heading for very exciting times in the years to come.

March 2020

Mats Carlsson,
Director of RoCS

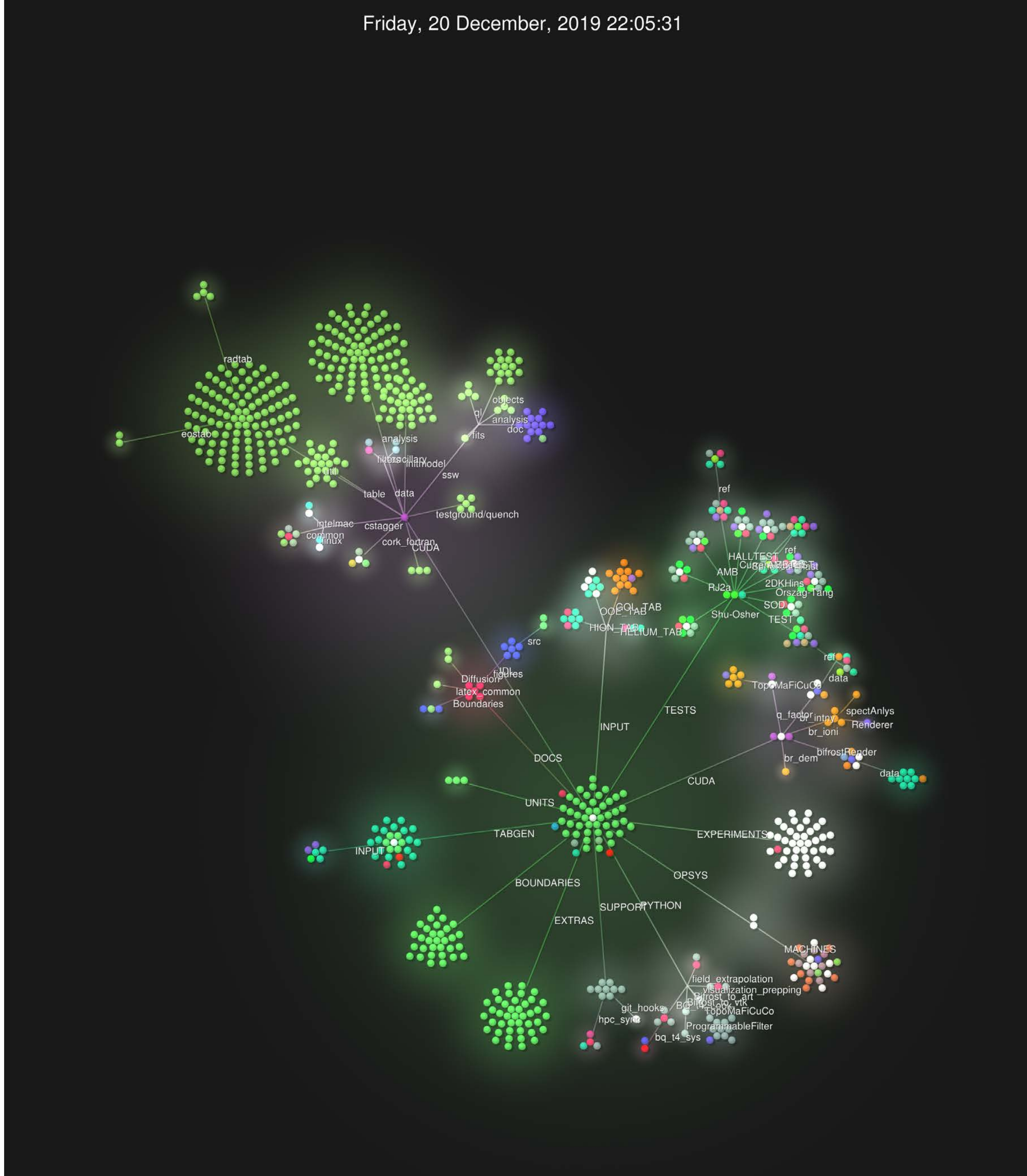
Towards understanding: RoCS goals

New hardware and novel techniques, both computational and observational, promise to revolutionise our understanding of the workings of the entire coupled solar atmosphere. The solar physics group of the Institute of Theoretical Astrophysics (ITA) at the University of Oslo has played a central role in these developments and has also exploited them to make significant contributions at the forefront of solar physics.

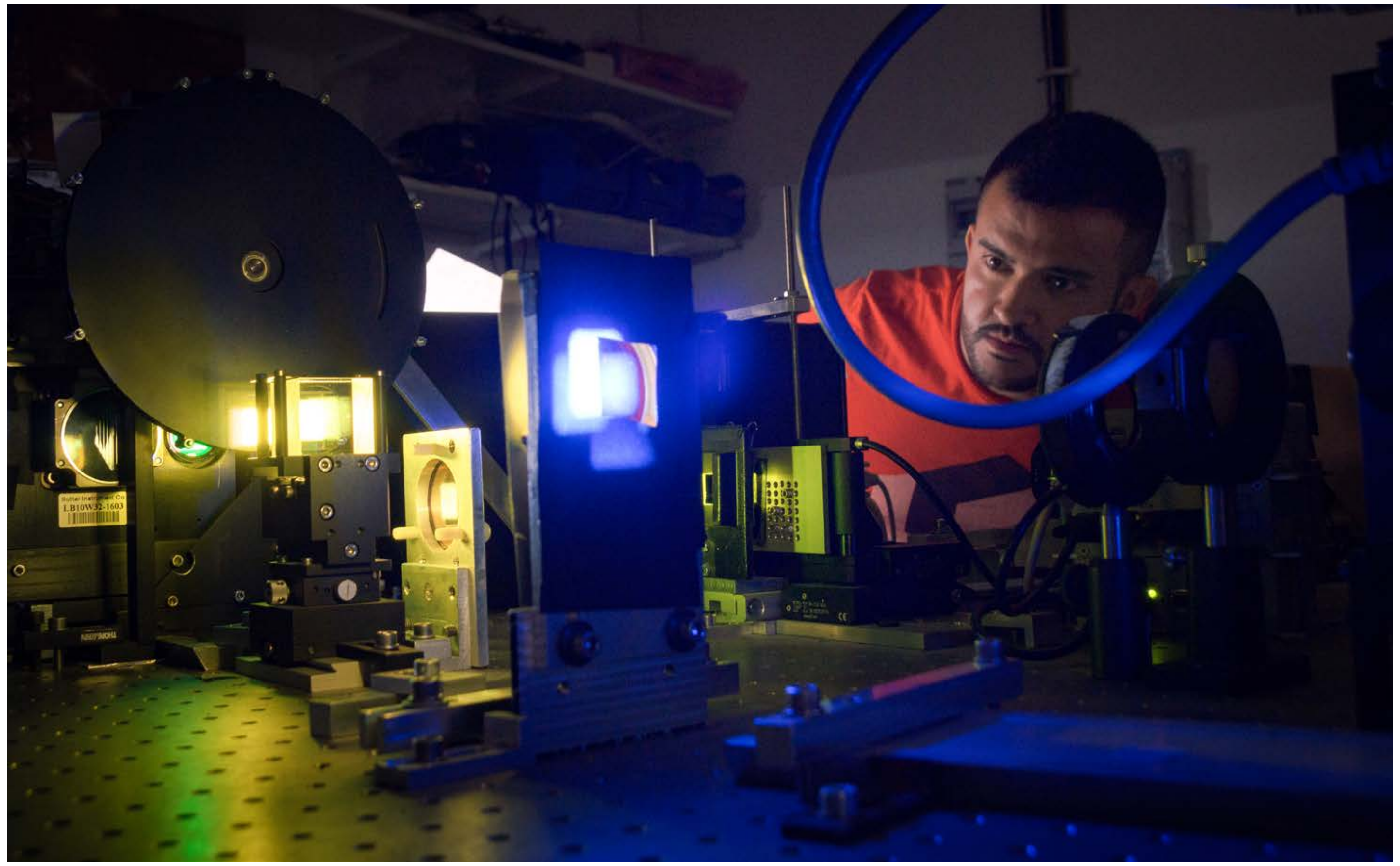
The Rosseland Centre for Solar Physics (RoCS), named after the founder of ITA who initiated solar physics research in Norway, dramatically expands these efforts to build a comprehensive understanding of chromospheric and coronal heating and violent solar activity.

Several recent developments have made the complex physics of the outer solar atmosphere tractable to quantitative analysis. In particular, the development of high performance computers has allowed us to build 3D radiative MHD codes designed to treat the physics of the chromosphere and corona as well as software capable of converting simulation output into synthetic observables. Similarly, the last few years have seen major progress in extremely high resolution imaging spectroscopy, enabled by adaptive optics and image reconstruction techniques, as well as novel diagnostics from space based observatories. RoCS is in a unique position to capitalise on these exciting developments and drive major breakthroughs in understanding the interplay between the magnetic field and the plasma in the outer solar atmosphere, and the deeply rooted connections between convective motions in the Sun's interior and the structuring and activity of the corona. The investigations are two-pronged: advanced 3D numerical simulations, which can be directly compared to high-resolution observations from the ground and from space. Synthetic diagnostics are computed from the models and compared with high-resolution observations. The similarities and discrepancies are used to investigate the role of various physical mechanisms that have been proposed as drivers of the energetics and dynamics of the active solar atmosphere, such as shocks, magneto-acoustic waves, magnetic reconnection and various plasma instabilities.

> Our primary objective is understanding the workings of the energetic Sun.



Bifrost repository structure
(M. Szydlarski, RoCS)



D. Nóbrega Siverio, RoCS

A day in the life at RoCS

Occupying the second floor of Svein Rosseland's Hus, the Rosseland Centre for Solar Physics (RoCS) is sandwiched between the Extragalactic and Cosmology groups at the Institute of Theoretical Astrophysics. Days here begin as they do in all productive institutions: with coffee and good conversations.

Passing through the hallways at ITA, the passerby might not notice the unassuming way by which RoCS scientists go about our work; peeking into any given RoCS office, one would generally find a collection of faces leaning into screens and, more often than not, several pairs of furrowed brows. But it is through those screens that we maintain and nourish our international collaborations, collect and process our data, and develop algorithms by which we can analyze and learn about the Sun. RoCS plays host to observational astronomers, code developers, specialized theoreticians, simulation builders, educators, and lifelong learners.

Throughout the day, it is important that we take time to confer with our internal collaborators, attend institute seminars, and check in with one another on a regular basis. Later, we break again for coffee to process, debrief, and discuss next steps for our work as well as our play. Evenings wrap up quietly as, one by one, we each find our respective stopping points for the day. Although we are different people from different places, each of us know that our common belief in scientific progress and our passion for the work will bring us together tomorrow for another day of Sun.

Rebecca Robinson

A day in the Sun

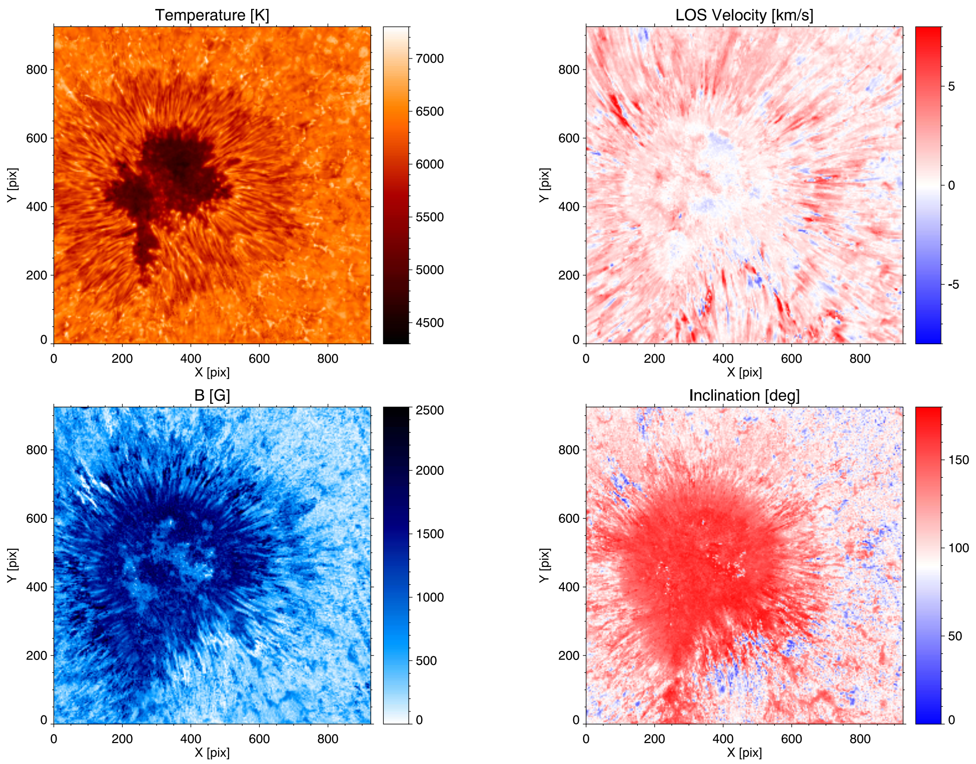
Doing observations at the Swedish 1-m Solar Telescope (SST) is synonymous with getting up before sunrise and greeting the nighttime observers, as they make their way back from their shifts. As solar observers, we have the privilege of watching sunrise every morning as we open the telescope. Each and every morning the Sun will greet us, while its beauty only grows larger for every passing day. After opening the telescope, breakfast will be indulged in the company of each other, while the Sun can rise to full position. We make our way down to the basement afterwards, where calibrations will be first on our task list. If the seeing is promising we will spend most of the day in the basement, with some breaks in between for food, phone calls and walks in the mountain.

When the optimal conditions arise, energies are flowing and everyone gets excited to hit the record button. Since clear, lasting data is not an everyday occurance, it definitely is the highlight of the day, the days we get it. During a passing of clouds, we may close the telescope, and work on our individual research to make time pass, until we are able to observe again. As sunset gets near, we make our way up to the roof and lower the telescope and shut it down. We drive down to the residencia under the dim, purple sky, reflecting over the sights of the day. Dinner is served and an early night needed, to prepare for yet another sunrise at SST.

Ingrid Marie Kjelseth

"Working in academia, I find it refreshing and fun to bring our work to pupils; it's a good opportunity to practice communicating our science in accessible and captivating ways. Young minds are inquisitive and demanding: being able to meet them with knowledge and insight is important not only for their growth, but for mine as a budding scientist and educator."

Rebecca Robinson



Spatial distribution of selected atmospheric parameters inferred from NLTE inversions of Ca II 8542 A. The observations of a sunspot were taken by the CRISP instrument at the SST. These results are from a preliminary analysis done with the DeSIRe code.
(C. Quintero Noda, RoCS).

Inversion

Inversion codes fit spectro-polarimetric observations solving the radiative transfer equation in an iterative process. During this process, the code infers the information about the atmospheric physical parameters allowing us to understand the physics of different solar features. In the 1990s and early 2000s, those codes worked mainly under the so-called Local Thermodynamic Equilibrium (LTE) approximation. This approximation is reasonably accurate in the photosphere and for certain spectral lines, but it breaks down when we use spectral lines that are sensitive to chromospheric phenomena. Fortunately, we have had in recent years an advent of new inversion codes that work under non-LTE (e.g. Socas Navarro et al. 2015, Milic & van Noort 2018, de la Cruz Rodriguez et al. 2019) that allow overcoming the mentioned limitations. We are also developing at RoCS, together with various international partners, a non-LTE inversion code called Departure coefficients Stokes Inversion based on Response functions. All of the mentioned inversion codes, although different in concept and how they tackle the inversion problem, will be used on future data from state-of-the-art observatories like DKIST and EST 4-m class telescopes. They will allow the solar community to improve their knowledge on the physics, in particular the magnetic field configuration, of solar features from the bottom of the atmosphere to upper layers in the chromosphere.

Moreover, we also helped to organise a workshop called "Stokes inversions under non-LTE conditions" celebrated at the Stockholm University in December 2019. This workshop aimed to bring together the community developing inversion codes. We discussed common aspects of the codes, and we cooperatively learnt from each other. We also expect to have this kind of workshops regularly, around once per year, in the future.

Carlos Quintero Noda

DKIST

The Daniel K. Inouye Solar Telescope (DKIST), which saw first light in late 2019, is the largest solar telescope in the World with an aperture of 4 meter. It is an American enterprise located in Hawaii that will allow science not presently feasible at any other facility. The initial instrumental setups and observations are being guided by the key "Critical Science Plan" set of documents. This plan is composed, at its core, by "science use cases" contributed by solar physicists, including individuals beyond those of the American community. Each science use case comprises of a set of scientific goals and complete scientific motivation, necessary observations to achieve such goals, and a detailed parameterised setup for each of the instruments that are in commission for the telescope. RoCS researchers have contributed 7 of 81 such science use cases of which 5 received the highest grade in an April 2019 assessment (out of a total of 23 cases with such grade) and are involved as collaborators in a multitude of other use cases. With this involvement and the experience of RoCS researchers with the highest resolution spectro-polarimetric diagnostics in existence today via the Swedish 1-meter solar Telescope, RoCS is in a unique position to benefit from the DKIST open data policy (6 months from observations to release for non-USA scientists) and in a great position to establish new and expand existing collaborations targeting continued leadership in high-resolution Solar Physics.

Vasco Henriques

NSO/AURA/NSF

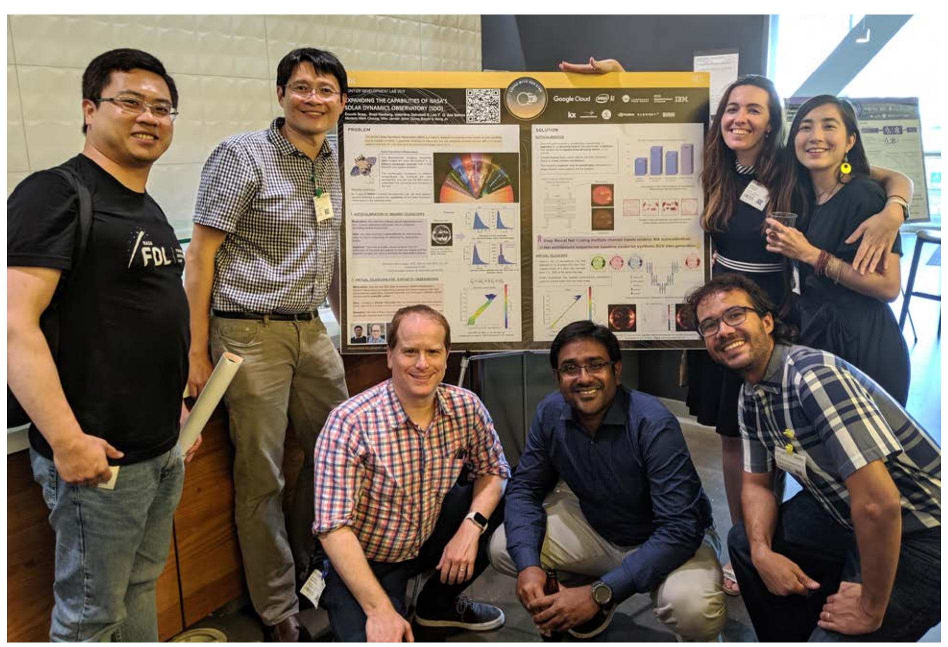
The Frontier Development Lab (FDL)

The Frontier Development Lab (FDL) is an initiative to apply artificial intelligence (AI) technologies to space science to push the frontiers of research and develop new tools to help solve some of the biggest challenges that humanity faces. These range from the effects of climate change to predicting space weather, from improving disaster response to identifying meteorites that could hold the key to the history of our universe. FDL is a public-private partnership with NASA in the USA and ESA in Europe. They work with commercial partners such as NVIDIA, Intel, and Google Cloud, IBM, Lockheed Martin, SpaceResources Luxembourg, KBRWyle, XPrize, Kx, and Miso Technologies who provide expertise and the computing resources necessary for rapid experimentation and iteration in data-intensive areas, as well as partners such as the SETI Institute, Satellite Applications Catapult, USC MASCLE, and the University of Oxford.

I was selected to be a part of NASA's **Living with our star** team working on "expanding the capabilities of NASA's Solar Dynamics Observatory (SDO)". During the summer, I participated in an intensive 8-week program in the Silicon Valley area in California together with 3 fellow PhD students and 3 mentors from science and industry. Our challenge was to apply advanced state-of-the-art machine learning techniques to enhance the value of SDO. We focussed on auto-calibration using deep learning and the creation of virtual observations of the solar corona.

During the intensive 8 weeks,we had multiple presentations in the form of reviews with members of the FDL fraternity, with technical partners like Google, IBM and Intel, and with senior members of the NASA Ames Research center. Towards the end of the program, we submitted a technical memorandum to NASA, followed by a final technical presentation to the committee members in-charge. Finally, the team delivered a TED-style talk at Google headquarters in Mountain View. Results were also published in December at the prestigious conference on Neural Information Processing Systems (NeurIPS) held in Vancouver, Canada.

Souvik Bose



Souvik Bose with his fellow FDL "Living with our star" team members during the presentation of the final results at Google Headquarters.

S.Jafarzadeh, RoCS.

WaLSA

WaLSA is an international science team studying waves in the lower solar atmosphere (https://WaLSA.team). RoCS has supported WaLSA through a generous grant for hosting the kickoff and follow-up team meetings (in January and August 2019) as well as for data storage facilities. These have brought together world-leading experts (from 8 countries) in observations, instrument design, wave theory, numerical simulations, spectro-polarimetric inversions, and radiative transfer processes, to concentrate research efforts to yield reliable estimates of the energy transported by MHD waves into the upper solar atmosphere, and provide new insights into the wave dissipation mechanisms and their contribution to heating the upper solar atmosphere.

The WaLSA team aims to obtain a comprehensive picture of wave propagation in the lower solar atmosphere, from wave generation in the sub-photospheric layers to their channelling and eventual dissipation in the magnetised outer atmosphere. These studies will be performed using high-resolution observations that will be interpreted, in tandem, with theoretical models and simulations.

Shahin Jafarzadeh

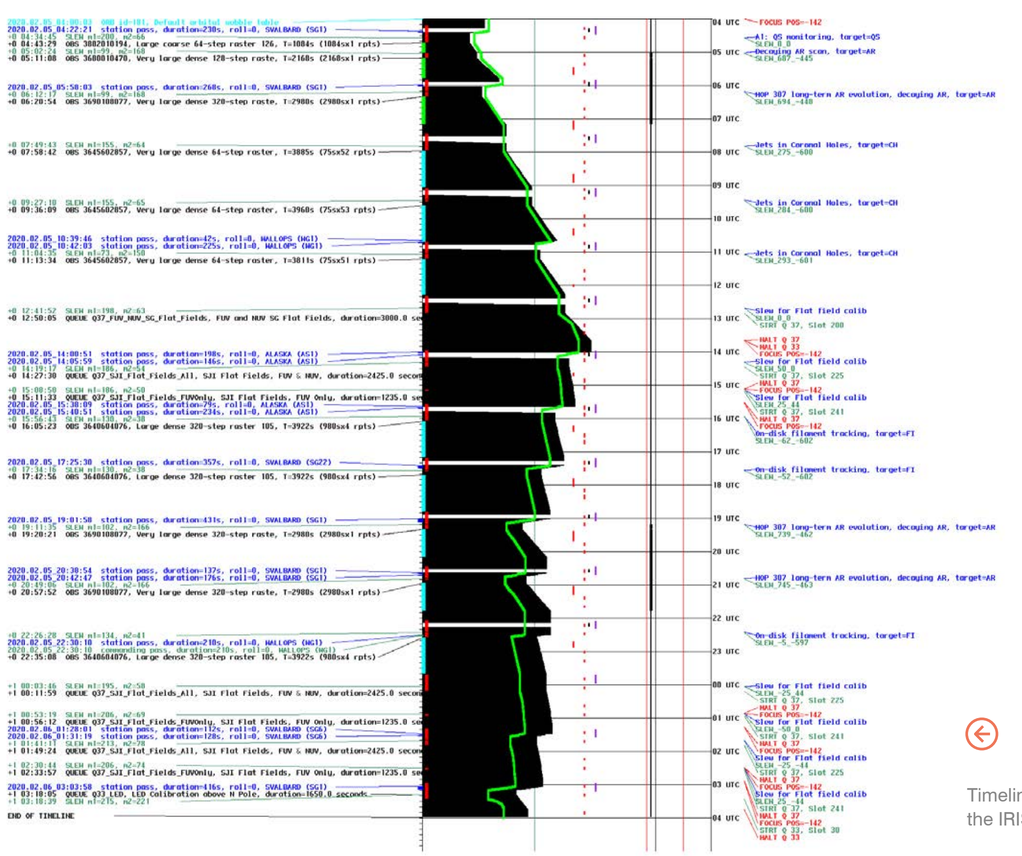
Steering the gaze of IRIS

IRIS provides detailed, "zoomed-in" views of the Sun, unlike instruments such as AIA, which provide a medium-resolution view of the whole Sun. This means that a *planner* must decide where and how IRIS observes. Unlike the SST, controlling IRIS is not possible in real-time; all commands for a whole day (or more) must be uploaded many hours in advance.

RoCS was the first institution outside the US to participate in IRIS planning. In 2019 we had two IRIS planners: Souvik Bose and myself. Planning for IRIS is both a privilege and a great responsibility: the fate of the mission is literally at the mercy of our mouse clicks! Planning can be both stressful and rewarding. A planner has to juggle the science requirements with the possibilities of the instrument, the amount of on-board memory and the satellite's downlink speed, while trying to guess what the Sun will be doing the next day!

At the busiest times, we need to coordinate with multiple teams scattered around the world. We have had to work with multiple telescopes: from the Canary Islands to Japan, rocket launches in New Mexico, Korean balloon launches, and other space missions such as Hinode or even the blazing Parker Solar Probe! And all on tight deadlines, so that we can send the plan to NASA mission control, who then upload it to the satellite. It is very rewarding when you can precisely point and time IRIS to catch that powerful flare in great detail!

Tiago M.D. Pereira



Timeline for IRIS observations – the end product of the IRIS planning. (T.M.D. Pereira, RoCS)

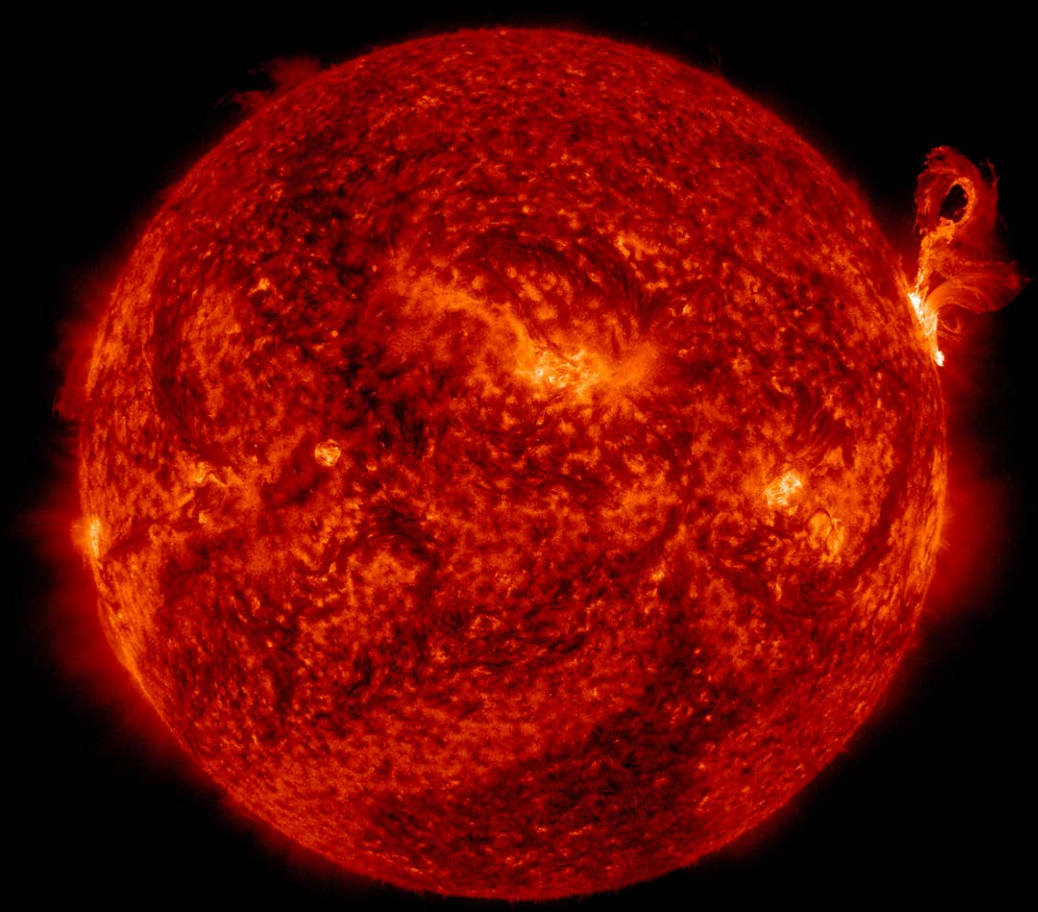
Gabriel Pérez (IAC)

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 (lowermost facility) and the William Herschel Telescope (to the top left).

EST

The **European Solar Telescope (EST)** is the next generation 4-m solar telescope in Europe. EST is the top-ranked mid-size project in the ASTRONET roadmap for infrastructures in Astronomy 2010-2030 and was included in the European Strategic Forum on Research Infrastructures (ESFRI) Roadmap 2016. 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. After some setbacks in 2019, the project has taken the consequences of the criticism that decisions for the funding of construction should be based on a more mature design. The preparatory phase has now been consolidated, including full contributions from Norway and Sweden, and the design is progressing with tenders having been issued for the EST three main systems: the primary mirror assembly (M1), the telescope structure, pier and enclosure (TS) and the adaptive secondary mirror (M2). The Scientific Advisory Group (with three members from RoCS) has finished the update of the Science Requirements Document, feeding into the updated technical requirements. First light for EST is expected in 2028.

2019 Activities by theme



NASA

Simulations

The Bifrost code is designed to model the outer layers of the solar (or stellar) atmosphere and aims to include all the relevant physics needed to interpret and understand the observations.

Modelling the energetic Sun

Understanding active regions, the key players in the energetic Sun, regions of the Sun where strong magnetic fields have pierced the surface, the *photosphere*. These fields rise up into the outer atmosphere where their interactions, both self-interactions and interactions with pre-existing ambient fields, are the source of most, if not all, activity. In order to build numerical models of the life of active regions one needs to understand the physical laws of how magnetic fields and the hot gases of the solar atmosphere relate to each other and a numerical scheme to put these laws into play. One can choose one of several levels of approximation depending on the specific mechanism(s) that is being studied.

In the simplest case the gases of the solar atmosphere are treated as a single fluid, and the interactions of this fluid with the magnetic field are done assuming that the particles comprising the fluid are charged. This approach leads to the so-called magnetohydrodynamic (MHD) equations, incorporated in the Bifrost code, including the extensions to the MHD approximation necessary to model the outer solar atmosphere with some fidelity: Optically thick radiative transfer to model the primary radiative energy loss process from the photosphere (Sunlight!), thermal conduction, which is the most important term in the energy equation in the tenuous corona, optically thin radiative losses from the chromosphere, transition region, and corona.

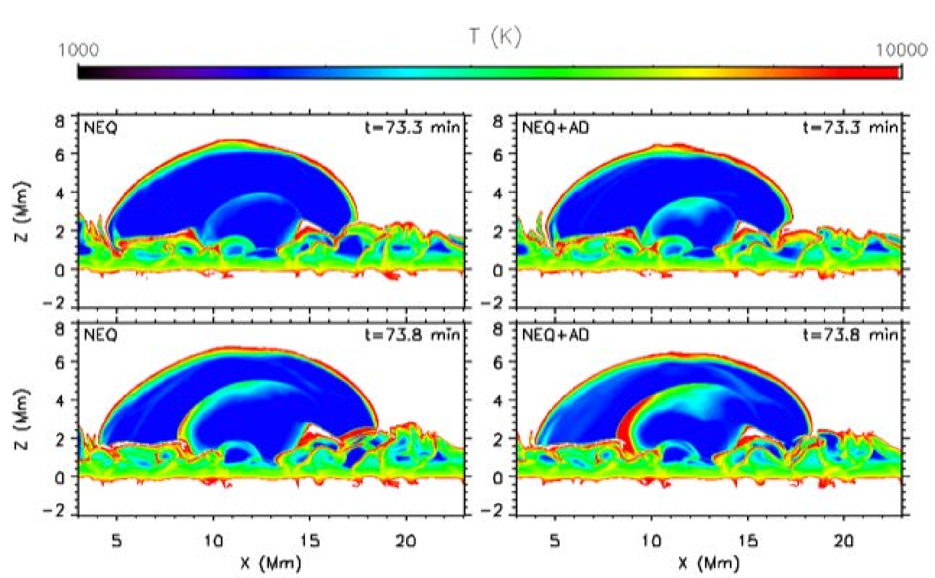
MHD solver in hand, it is necessary to set the boundary conditions: How much magnetic field should we include in our models, what shape should it have? These choices are partly constrained by observations of the Sun, partly by the type of region or phenomena that is to be studied.

Early stages of flux emergence

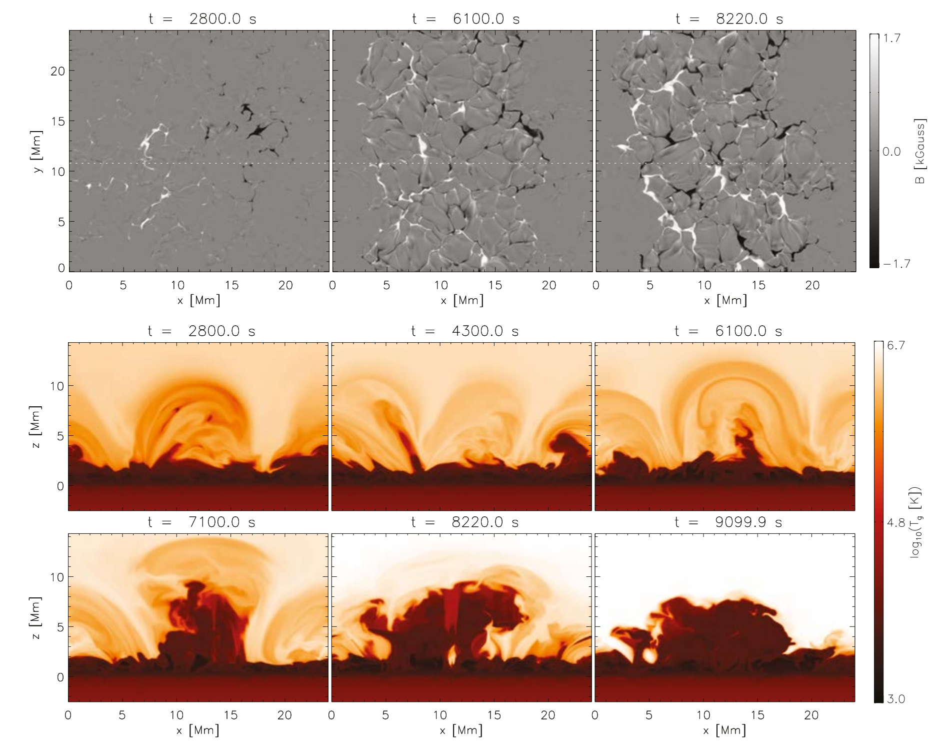
In 1917 Ferdinand Ellerman discovered strong brightenings in the wings of the Hα spectral line that seemed to occur in the vicinity of newly formed active regions. These brightenings eventually became known as Ellerman bombs. In 2014 a similar phenomena, named UV-bursts, was seen in the Si IV and Mg II spectral lines observed with IRIS, in principle both formed far from the site of formation of Hα's wings. These brightenings were clearly related. And more importantly were giving clues as to how active regions are formed from the emerging magnetic field. But how? Bifrost simulations of flux emergence into an atmosphere containing a pre-existing ambient field were able to reproduce both Ellerman Bombs and UV-bursts and show them to be a result of the reconnection of newly emerging fields at different heights in the bloated chromosphere formed by emerging fields.

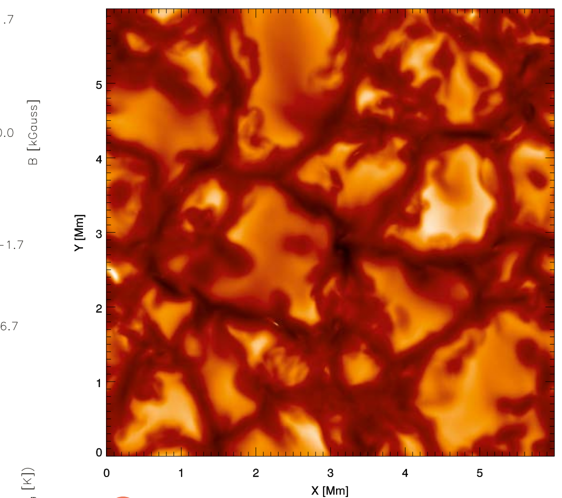
Big models, small models

The Sun operates on many scales from the microscopic to the gigantic, and it is important to be able to assess what the consequences of studying the Sun at a given scale are. For example, models of coronal heating require an understanding of how magnetic fields are churned by convective motions in the photosphere which can lead to waves or the tangling of magnetic fields in the chromosphere and corona or



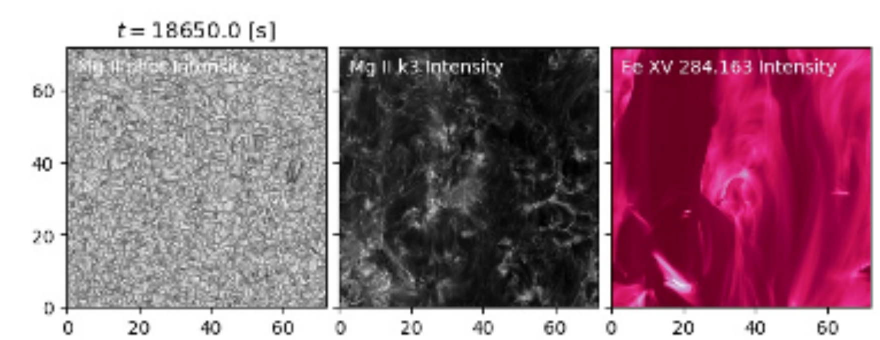
Temperature maps showing the thermal differences in the shock evolution within an emerged region in a non-equilibrium ionization experiment (left column) and in the same experiment including ambipolar diffusion (right column). (D. Nóbrega Siverio, RoCS)





Intensity from a “small, high-resolution” simulation of solar convection with 3 km spatial resolution. (M. Carlsson, RoCS)

Vertical magnetic field in the photosphere during a flux emergence event and the atmospheric temperature response as the field expands through the photosphere and into the chromosphere and corona carrying cool chromospheric material to great heights.(V. Hansteen, RoCS)



Photospheric, chromospheric, and coronal intensities as modeled in a “large, low-resolution” simulation with a grid size of 100 km, designed to study the importance of large scale structure in forming the outer solar atmosphere. (V. Hansteen, RoCS)

both. At what scale do we need to study the photosphere in order to pick up these motions? What is the importance or role of large scale, several tens of megameters, magnetic structures, in the heating of the corona? Bifrost models spanning spatial resolutions of 2 km to 100 km and horizontal sizes from 6x6 Mm to 72x72 Mm are being run to investigate these questions.

(Further) Beyond MHD

As stated above, the solar atmosphere is characterized by an interplay of complex physical processes such as magnetic reconnection, radiation, thermal conduction, amongst others. In particular, in the chromosphere, it is of special interest the ion-neutral interactions and the nonequilibrium ionization. The ion-neutral interactions are important because the chromosphere is partially ionized, meaning that ions and neutrals can drift with respect to each other breaking the total coupling between the constituent microscopic species usually assumed for the plasma. With respect to the nonequilibrium ionization, it is relevant because in the chromosphere the density drops orders of magnitude in comparison with the photosphere. This decrease hugely impacts on the transition rates, which will be substantially slower, leading to large departures in the number densities of the computed ions and neutrals when compared with a statistical equilibrium approximation. Even though both, ion-neutral interactions and nonequilibrium ionization, are key processes in the Sun, understanding their effects is challenging due to basic uncertainties concerning relevant microphysical aspects and the strong constraints it imposes on the numerical modeling. In fact, most theoretical studies about these processes are focused on either one or the other process, but not together.

In 2019, the RoCS group accepted the challenge, and has been actively involved in unraveling the joint role of those two processes on the dynamics and thermodynamics of the chromosphere and transition region, and more specifically, in magnetic flux emergence processes, shocks, and spicules. To that end, new code has been developed to combine in an efficient way the interaction between ionized and neutrals species together with with departures of the ionization state from the LTE. Exciting new results have been found that will lead to a new perspective of the chromosphere in 2020.

Observations with SST and IRIS

The RoCS group 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 2019 these campaigns were in May, June, September and October. These campaigns are very much a team effort and this year 11 RoCS members participated in the observations. For 6 of them, it was their first time at the SST. We stimulate members of the centre to join observation campaigns. Not only because we need all the help we can get, but also because the practical experience of observing at the telescope is very valuable in a young scientist's career.

All observations were in coordination with the IRIS satellite which involves daily interaction with the IRIS planners to decide what target to observe and which observing program to run. Despite the fact that the Sun is currently still in the quiet phase of its 11-year magnetic activity cycle, we managed to acquire some good observations of active regions. On September 4th, we managed to acquire a 3.5 hour time series of a small active region. During this period, a small filament eruption happened and this event was well covered with the CRISP and CHROMIS instruments, as well as with IRIS. An H-alpha line core image and associated map of the magnetic field are shown in the bottom pair of images on the right.

For most of the observing days during our campaigns, there were no active regions present on the Sun and we focused on quiet Sun regions. One particular program was chromospheric observations in the H-beta line with CHROMIS. These observations were augmented with CRISP H-alpha imaging and Fe I 6173 spectropolarimetry. The chromosphere has a striking different morphology in these two spectral lines, see the top figure on the right. The combined CRISP and CHROMIS observations will be used for a study on small-scale magnetic reconnection events in the lower solar atmosphere. These are among the smallest scale activity processes that can be observed and the SST has unique capabilities to characterize these fundamental physical processes in detail.

Data reduction

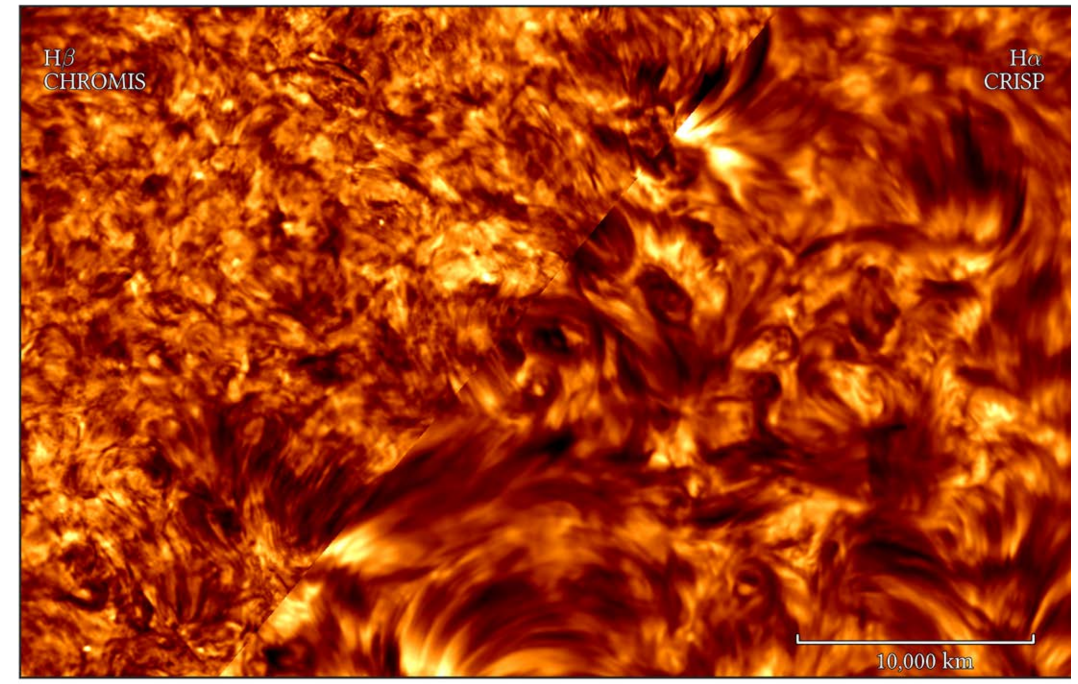
Besides planning and acquisition of new observations, the reduction and data processing of current and earlier observations is one of the other main activities of the observations group. We employ image restoration techniques to mitigate the effect of atmospheric turbulence (so-called "seeing") on the data quality. Like all modern telescopes, the SST employs an adaptive optics system to correct for seeing in real time during the observations. Adaptive optics provides a significant improvement of the data quality but post-facto image restoration is mandatory to attenuate residual seeing deformations. With image restoration, high data quality can be achieved over larger field of view and over longer periods of time. Besides considerable computing power and data storage capacity, data reduction requires a fair amount of manpower and is handled as a team effort. We collaborate with the SST staff in Stockholm and La Palma to improve, optimize and further develop the data processing pipelines for the CRISP and CHROMIS instruments.

Magnetic reconnection

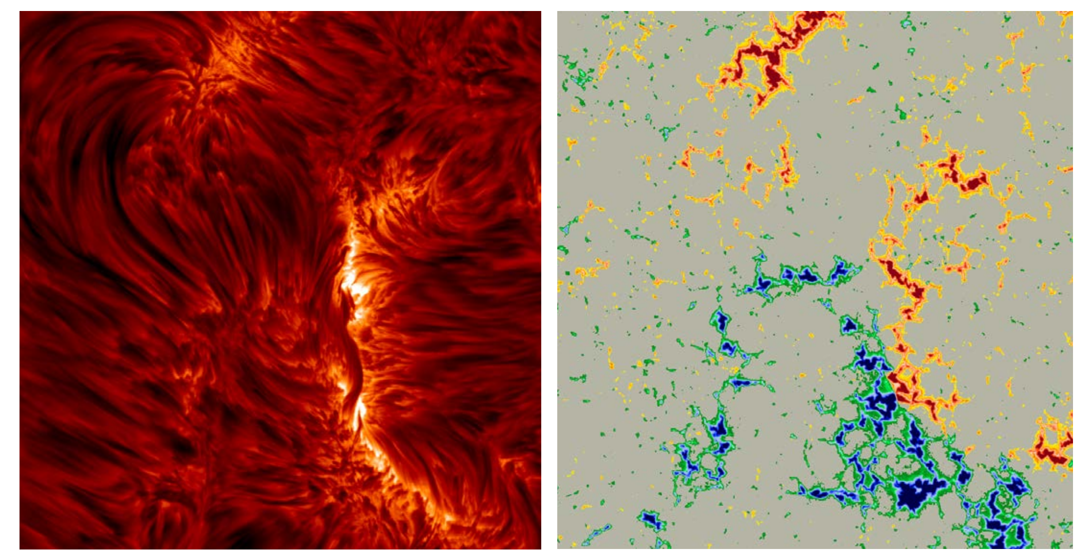
Magnetic reconnection is a fundamental physical process that is responsible for a wide variety of dynamical phenomena on the Sun and is one of the main topics of research at RoCS. For example, magnetic reconnection has been argued to drive a particular type of jet in the chromosphere of sunspot penumbrae. We published a detailed study of the dynamical evolution of these so-called penumbral micro-jets based on ultra-high cadence (1 second) observations in the Ca II H line. We further participated in a publication on the magnetic and thermo-dynamical properties of penumbral micro-jets lead by Dr. Esteban Pozuelo from Stockholm University. For this study, spectro-polarimetric observations from both CRISP and CHROMIS were subjected to advanced inversion techniques.

Magnetic reconnection is further manifested in so-called Ellerman Bombs in the lower solar atmosphere and UV bursts in the upper chromosphere and transition region. This year, we completed a comprehensive study of Ellerman Bombs and UV bursts in multiple coordinated SST and IRIS datasets, augmented with observations from NASA's Solar Dynamics Observatory. We further collaborated on a publication by Dr. Vissers from Stockholm University who conducted extensive multi-line inversions of UV bursts combining the Ca II K, Ca II 854.2 nm and Fe I 630 nm spectral lines from SST and the Mg II h, k, and triplet lines and Si IV lines from IRIS.

Another highlight in 2019 was the publication of an ApJ Letter with RoCS PhD Souvik Bose as the lead author. This work presented the first full characterizations of spicules on the disk in the Ca II K line. The statistical k-means clustering technique was used to characterize millions of Ca II K, H-alpha and Mg II h & k spectral lines.



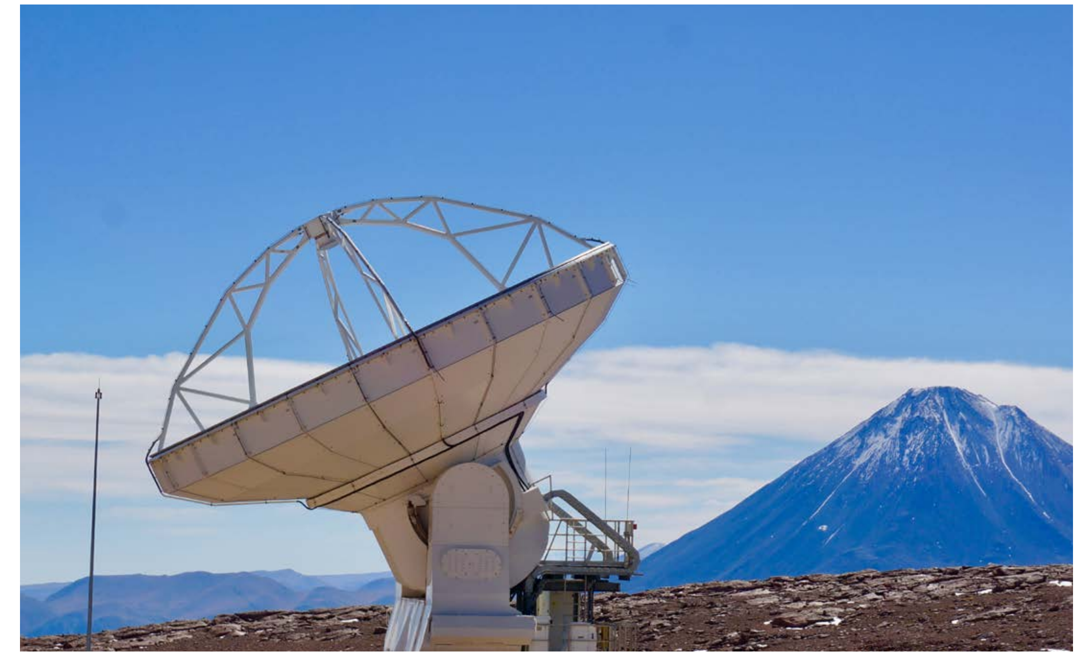
Split image showing a Quiet Sun region in H-beta (top left) and H-alpha (bottom right). This is a nice illustration that the fibrils and spicules are thicker and longer in H-alpha. (J. Joshi, RoCS)



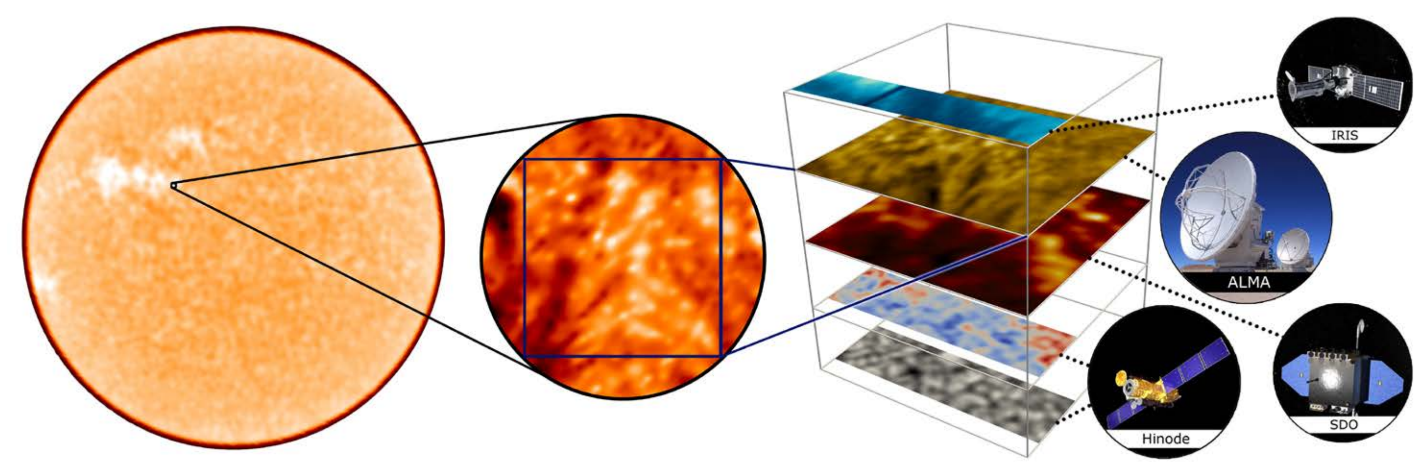
Active region AR12748 observed with the CRISP instrument at the SST on 4 September 2019. At left is an image in H-alpha and at right a map of the magnetic field derived from spectropolarimetric observations in the Fe I 617.3 nm line. Yellow/red colors indicate negative polarity and blue/green positive polarity. At the interface where the two opposite polarities meet, we observed a small filament eruption (which can be seen at left). This event was also successfully observed with IRIS. (L. Rouppe van der Voort, RoCS)

Solar Science with ALMA

The year 2019 has been a year of expansion for ALMA-related science at RoCS in terms of addressed topics and involved staff.



A 12m antenna of the Atacama Large Millimeter/sub-millimeter Array (ALMA) at an altitude of 5100m on the Chajnantor plateau in the Chilean Andes with the stratovulcano Licancabur in the background. (S. Wedemeyer, RoCS)



Simultaneous observations of the Sun with ALMA and space-borne telescopes. Left: Single-dish ALMA scan of the whole Sun (Band 6). Middle: Interferometric ALMA observations (Band 6) of a region on the Sun. Right: Images from different heights in the solar atmosphere as obtained with ALMA, IRIS, Hinode, and SDO. (S. Jafarzadeh, RoCS)

Continued development of the ALMA group

The newly started EMISSA project now complements the ongoing efforts of the Solar ALMA project. EMISSA, short for "Exploring Millimeter Indicators of Solar-Stellar Activity" is funded in the FRINATEK program by the Research Council of Norway, and aims at a re-evaluation of stellar activity as observed with ALMA. The new project complements our key scientific goal of exploiting ALMA's diagnostic potential for studies of the Sun's small-scale dynamics with the aim to constrain heating processes in the solar atmosphere. The group grew to one permanent staff, two researchers, and three PhD research fellows, of which one (Pandit) was newly hired on the EMISSA project.

New scientific tools

The further development of imaging and data processing routines for solar ALMA data remained a core activity. The Solar ALMA Pipeline (SoAP) has been optimized and used for processing in a more routine and stable way (Szydlarski). Work on the ESO-funded ALMA development study in co-operation with the Nordic ALMA Regional Center node at the Onsala Space Observatory and Stockholm University, Sweden, continued. For this purpose, a time series of 3D numerical models of the solar atmosphere was produced with Bifrost and then used as input for the Advanced Radiative Transfer code (ART). The resulting time series covering frequencies in the ALMA receiver bands 3, 6, and 7 will be an important test case for the optimisation of SoAP and the development of a high-cadence solar observing mode for ALMA. First experiments with the Solar ALMA Simulator (SASim) that transforms the ART output into artificial observational measurement sets have been carried out (Szydlarski & Eklund).

First scientific results published

The first publication by Jafarzadeh et al. (2019) uses SoAP-processed ALMA Band 6 mosaic observations of a sunspot in comparison with ultraviolet observations from IRIS, while the first paper using a time series of a Quiet Sun observations in Band 3 was submitted end of 2019 (Wedemeyer et al.) The analysed observations were among the first regular observations of the Sun with ALMA in 2016. In addition, a "First Spectral Analysis of a Solar Plasma Eruption Using ALMA" was published (Rodgers et al.).

Observational studies of the dynamic chromosphere

The analysis of early data from ALMA Band 3 and Band 6 was continued in 2019 as part of PhD projects (Eklund and Guevara Gomez) with focus on the small-scale structure and dynamics of the solar chromosphere. ALMA's spatial and temporal resolution make it possible to search the data for signatures related to diverse phenomena such as propagating shock waves or magnetic reconnection events. The signatures of shock waves can be seen in the data as dynamic bright or dark features. The challenges with the identification and tracking of these features led to the development of automated codes specially designed to deal with the peculiarities of ALMA data. The statistical analysis of the detected features has begun and will, in comparison to observations at other wavelengths, give insight into the origin and physics of the phenomena behind these signatures.

Oscillations at millimetre wavelengths

Waves and oscillations are among the prime candidates for the transport of energy and momentum to the upper solar atmosphere. Direct observations of temperature fluctuations in the solar chromosphere in active and quiet regions with ALMA receiver bands 6 and 3, were complemented by co-observations of the same targets in far and near-ultraviolet with the IRIS and SDO space telescopes. In the quiet region, a large temperature fluctuation above a small network patch was found with ALMA, while no corresponding temperature excess is observed in the layers above (i.e. as sampled by SDO), suggesting the possibility of energy release in the upper chromosphere. In the active region, the temperature fluctuations with transverse and line-of-sight velocity oscillations in chromospheric fibrils were compared. Furthermore, power spectra of the observed wave phenomena from ALMA were opposed to those from synthetic spectra computed from Bifrost simulations, providing new insights into the nature of various wave phenomena and thus their potential role in heating the upper solar atmosphere (Jafarzadeh, WaLSA).

Applications for observations in 2019

The group was involved as Co-Is in the successful ALMA observing proposal "3D Structure of the Quiet Solar Chromosphere". The observation, which was to be carried out in ALMA's observing Cycle 7, included receiver bands 3, 6, and the newly offered Band 7.

Presentations, public outreach and networking

The SolarALMA project was presented at a number of international meetings, including the IAU Symposium 354 in Chile. The latter was combined with a visit to ALMA and APEX in the Atacama Desert (Wedemeyer). The project was also the topic of a public talk at an Astronomy on Tap event in June 2019. As in the years before, a Norwegian ALMA Day was organized in spring in co-operation with the Nordic ALMA Regional Center node.

*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).

Roque de los Muchachos, La Palma.
(D. Nóbrega Siverio, RoCS)

New code developments

One of the main goals for RoCS is to simulate the active sun. That requires a code that is able to incorporate many different kinds of physics to model the varied environment of the Sun, from the deep convection zone to the corona.

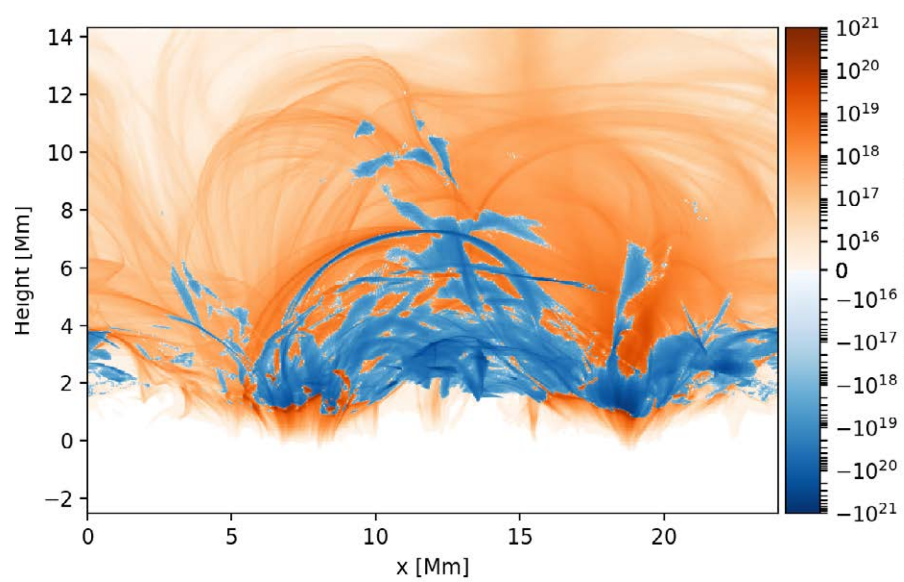
To be able to describe an active region environment, the numerical code must be able to handle amongst others, ionization imbalance, radiative transfer, dissipation of magneto-hydrodynamic waves and the chaotic, super-heated environment at the center of solar flares. Bifrost is the workhorse code at RoCS and is able to handle many of these physical problems, but struggles with large ranges in both time and space. Requiring high resolution as well as spanning a large volume of space is not possible with the current version so the code development group at RoCS are working on transposing most of Bifrost into the DISPATCH framework. Throughout 2019, work has advanced on many aspects of our simulation tool set, reaching from advancing our work process to become more up to date, integration and investigating details of the interplay between Bifrost and DISPATCH and developing new physics modules.

Foundations

In 2019 the code development at RoCS has primarily been focused on strengthening the foundation for a more efficient and robust development cycle and continuous integration of improvements to the numerical codes. To strengthen this work, a scientific software developer was hired and the process of hiring another started during 2019. The present and foreseen increase in number of developers requires that we can trust the code to produce correct results, and that it is possible to continue the long running simulations without problems. Any development to our codes now has to pass a number of tests before being allowed into the working version of the codes. The number of tests is continuously increased and now allows us to be more confident in the working copy of our codes, making the growth in the developer base of smaller concern.

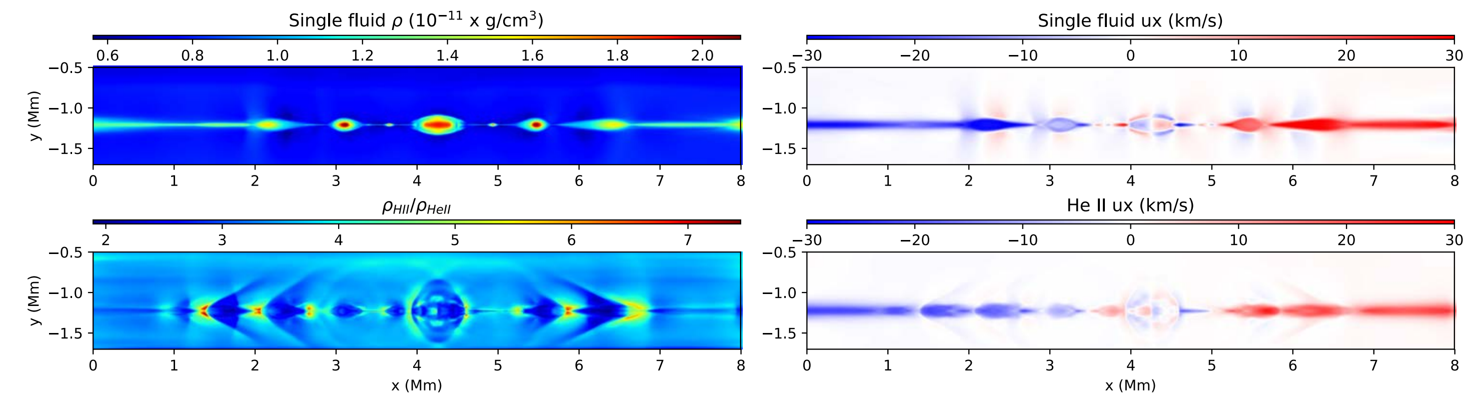
New physics implemented in Bifrost

An integral part of modelling solar active regions is the violent reorganization of the magnetic field which release large amounts of energy in a solar flare. This energy is released in the form of thermal energy, energy in different types of waves and highly accelerated non-thermal particles. The particles transport a significant amount of energy away from the solar flare region but so far it is not known which acceleration mechanism produces these particles. Including the accelerated particles in our simulations represents two main problems: The acceleration process itself and transport and thermalization of the particles.



The acceleration location (blue) and the path(orange) of simulated non-thermal particles in a Bifrost simulation. (L. Frogner, RoCS)

A current sheet test for the Ebysus code showing the difference between a single fluid description and a multifluid description. The fractionization of species is obvious. (J. Martínez Sykora, RoCS)



The acceleration process requires a fully developed PIC simulation and is not yet possible, but meanwhile work has been focused on the transport of the particles and their impact on the lower atmosphere. This new physics module is now implemented in Bifrost and is ready to be transferred into the DISPATCH framework.

Software libraries based on Bifrost

The testing of Bifrost on large number of nodes has also been advanced with a collaboration with USIT, funded in part by the Partnership for advanced computing in Europe (PRACE). The goal of the project is to develop and test a software library for halo-exchange that should be more efficient than the standard MPI-library.

Development of multi-fluid code

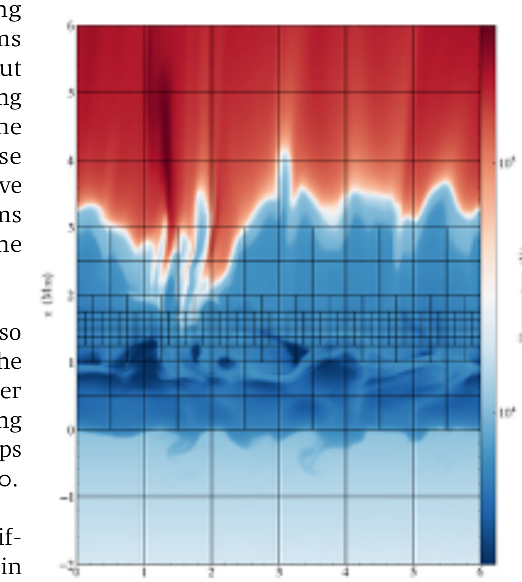
The development of a multi-fluid code has also advanced in 2019. The Ebysus code is based on Bifrost, using most of the internals and architecture of Bifrost. In Ebysus it is now possible to treat electrons, ions and even ion-species and their excitation levels as separate fluids. The final tests were conducted in 2019 and Ebysus should be ready for production in 2020.

Bifrost-DISPATCH integration

The integration of Bifrost and DISPATCH is continuing. 2019 made it clear that the transfer of Bifrost into the DISPATCH framework was a good opportunity to investigate details of the Bifrost implementation, and we realized that certain methods are not suited for direct transfer to DISPATCH. The first basic tests of radiative transfer and the multi-physics modules in Bifrost have been undertaken and works, even though efficiency has not yet been fully optimized. Working on optimizing Bifrost for the DISPATCH framework, made us investigate a number of different options for diffusion which, in the standard Bifrost implementation, was not well suited for DISPATCH. Radiative transfer, thermal conduction and the handling of noise in the magnetic field are all "global" problems meaning that a simple solution to these problems is computationally heavy for Bifrost, but becomes extremely inefficient when scaling to hundreds of thousands of CPUs as the DISPATCH framework would otherwise allow us to do. New methods therefore have been investigated to solve these problems in a "local" way that will not impede the scaling of the DISPATCH-Bifrost runs.

Adaptive Mesh Refinement (AMR) has also been investigated. AMR is the ability of the code to zoom in on locations where higher resolution is needed. This effort is ongoing and has been shown to work for easy setups and it will be further worked on in 2020.

DISPATCHs ability to switch between different solution methods is one of the main arguments for transposing Bifrost into DISPATCH. The ability of DISPATCH to handle using a Particle In Cell method in one sub volume and using a fluid solver in another sub volume is critical for the ability to handle the simulation of solar flares. The translation of variables across the interface between the two sub volumes has been shown to be not straight forward with the version of the PIC code that we have available. Other implementation methods of PIC have therefore been researched, and evaluations of their potential of handling this problem assessed.



A snapshot from a Bifrost simulation of the solar atmosphere run as a test case in DISPATCH including AMR. The black lines show the level of refinement of the simulation grid. (A. Popovas, RoCS)

Outreach

RoCS organises and develops different activities and events to promote general awareness of science and, in particular, to spread our understanding of the Sun out among the general public.

EST outreach

The Institute of Theoretical Astrophysics, through RoCS, together with 26 institutions from 18 countries, is a member of the European Association for Solar Telescopes (EAST). EAST is in charge of the future European Solar Telescope (EST): a next-generation solar telescope, to be located in the Canary Islands. As part of this ambitious project, the EST consortium is carrying out a number of outreach activities where RoCS participates. The aim is to explain why we need better knowledge of the Sun and how EST will be essential.

An example of these outreach activities is the project #TheScienceOfEST, run by a team of four EST scientists including RoCS researcher Ada Ortiz. #TheScienceOfEST is a series of short posts written by solar scientists that explain, in an accessible way, interesting solar problems that EST can address. We have periodically published these posts since May 2018 in social media, and they were very well received by the public. Following the lead from our own Ada Ortiz and Luc Rouppe van der Voort in 2018, more RoCS scientists contributed new posts in 2019. Daniel Nóbrega-Siverio explains how EST will contribute to understanding surges: *"we will be able to capture the elusive details of the physical processes that lead to surges"*; Souvik Bose describes the relevance of studying horizontal plasma velocities on the Sun at high resolution and how the 4-m aperture of EST *"will help us understand the twisting motions responsible for the generation of vortex flows and waves in the solar atmosphere"*; finally, Clara Froment discusses coronal rain, arguing that with EST *"we will see how small the rain blobs can get and better understand their formation"*.

The EST scientific communications officer for Norway, Ada Ortiz, has been promoting EST at different levels: together with high-level representatives, NASA astronauts, and amateur astronomers at the IAU's 100th anniversary in Brussels, with international researchers at the Flux Emergence Workshop held in Tokyo, to families and children at *Forskningstorget* (Oslo's science fair). In addition, in 2019 the EST Communications Office *"A Tour of the Sun: The EST Solar Gallery"*, a book made of stunning images of the sun that will be a powerful educational tool. Many of the images appearing in this book have been taken by RoCS researchers. It is a showcase of the high quality observations that our scientists work with.

Astronomy Olympiad

The Norwegian Astronomy Olympiad is a national competition for students at upper secondary schools. The top 5 students, selected through three rounds of exams/workshop, will represent Norway at the International Olympiad on Astronomy and Astrophysics. Our Institute and RoCS jointly organise the Astronomy Olympiad in Norway. The PI of the project, Shahin Jafarzadeh, received a grant from the Research Council of Norway to support organisation of the Olympiad in the 2019-2020 school year.

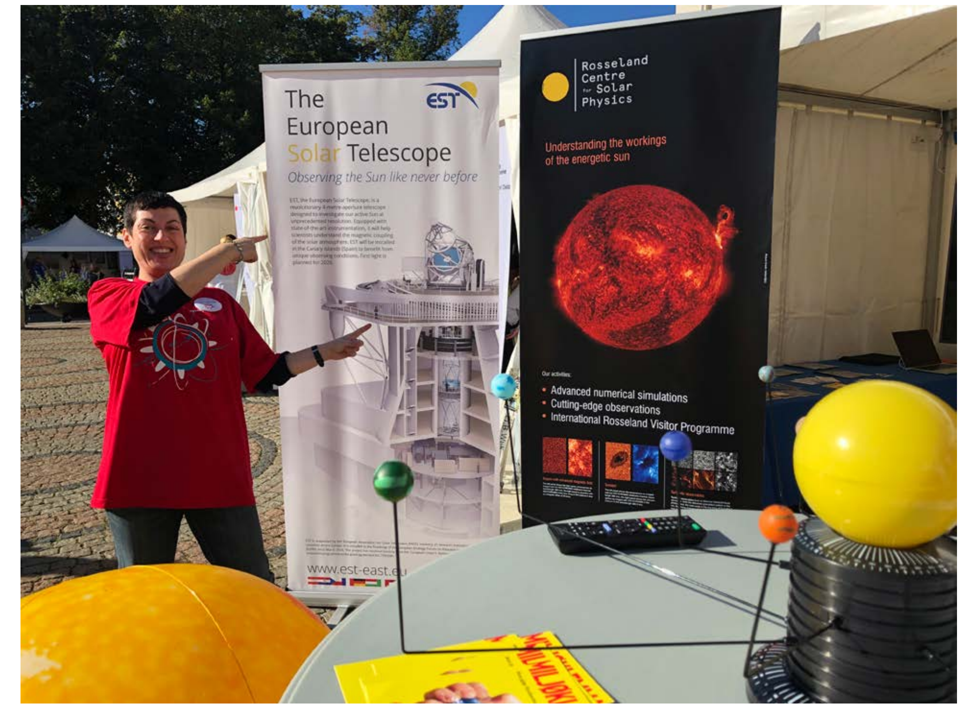
Through the Astronomy Olympiad, we let promising high school students deepen their passion for astronomy and encourage them to study astronomy at university. We not only promote a growing interest in astronomy and astrophysics by educating the young public, but also build an international contact network for the promotion of astronomy and astrophysics in schools

Astronomy on Tap

Astronomy on Tap is a global organisation with a chapter in Oslo, managed by members of our Institute. Astronomy on Tap events are targeted to the general public. In Oslo they include popular talks by scientists, and astronomy quizzes with prizes.

In 2019, three of the bi-monthly Astronomy on Tap gatherings were hosted by RoCS researchers. Sven Wedemeyer presented his ALMA research with *"High Tech and Llamas: Sungazing with the World's Largest Telescope."* During a special *"Women in Astronomy"* episode of Astronomy on Tap, Ada Ortiz taught us about female astronomers throughout history with *"Hidden Figures: Amazing women astronomers and their legacy."* In the autumn, Rebecca Robinson combined her work in glaciology with her love for astronomy with *"Not Just a Cold Dead Rock: exploring exocryospheres."*

Looking forward, RoCS will continue to contribute to Astronomy on Tap events, not only by giving talks but also by helping to organise (Petra Kohutova and Andrius Popovas) and advertise them (Shahin Jafarzadeh, Juan C.G. Gomez, Frederik Clemmensen, and Rebecca Robinson.) We are looking forward to watching Astronomy on Tap grow in Oslo!



Ada Ortiz explaining the European Solar Telescope. (A. Ortiz, RoCS).

Ingrid Marie Kjelseth explaining solar wonders for high school students.(S. Jafarzadeh, RoCS).

School Visits

During 2019, RoCS researchers visited elementary schools on two occasions; Clara Froment visited *Den Franske Skolen i Oslo*, and Sneha Pandit and Rebecca Robinson visited *Northern Lights International School.* During these visits we taught pupils about gravity, planetary and lunar orbits, the structure of the Sun, spectroscopy, exoplanets, black holes, and anything else about which they were curious. We have a wealth of teaching materials including inflatable planets, spectroscopes, and telescopes that the students always enjoy.

Women in Astrophysics

Several RoCS researchers are involved with the in-house *Women in Astrophysics blog.* This project exists to encourage talented young women and girls to consider careers in astrophysics, and it's also a platform for us to write about what we do, why we do it, the challenges we've overcome, and our goals for the future. In 2019, two RoCS researchers contributed posts to the blog.

Ada Ortiz gave a summary of her work with observational astrophysics, and discussed her background and why she became interested in astronomy. Ada also wrote about her involvement with the European Space Telescope as a member of its scientific advisory group.

Clara Froment wrote about her trip to *Den Franske Skolen i Oslo* as a visiting educator. She described her experience with the pupils as well as her enjoyment of communicating with young students in French, her native language

International Rosseland Visitor Programme

Visits from internationally leading scientists are very important for the success of RoCS. The International Rosseland Visitor Programme is our programme for international exchange, including funds for visits by researchers at professor, post-doctoral and PhD level for shorter or longer visits to RoCS.

"Looking in the rear mirror and questioning myself what made the biggest change with the creation and the operation of CIR, I am tempted to say the Visiting Professor programme."

Ludvig M. Sollid, director of Centre for Immune Regulation (CIR).
From CIR final report 2007-2017.

WaLSA-team. A team working on waves in the lower solar atmosphere was hosted during a week in January and a second week in August (see Section 3). A total of 15 members (*Andres Asensio Ramos, Ben Snow, Bernhard Fleck, David Jess, Elena Khomenko, Gary Verth, Hanna Schunker, Marco Stangalini, Nazaret Bello González, Oskcar Steiner, Peter Keys, Richard Morton, Samuel Grant, Samuel Skirvin, Tony Arber*) hosted by Shahin Jafarzadeh visited either one or both weeks.

Atul Mohan. Visited Sven Wedemeyer in September and worked on ALMA data in preparation for a postdoctoral position he started in 2020.

Basilio Ruíz Cobo and Maria Esperanza Paez Maña visited Carlos Quintero Noda in July to work on the inversion code "Departure coefficients Stokes Inversion based on Response functions"

Hugh Hudson, professor from University of Glasgow, worked with Mikolaj Szydlarski and Mats Carlsson in April on cosmic ray interactions in the solar atmosphere.

João Fernandes, professor from University of Coimbra. He spent part of his sabbatical in March-June, working on the usage of Ca II spectroheliograms from Coimbra and co-observing with SST. He also worked on the membership of Portugal in EAST and Portuguese contributions to EST.

Jorrit Leenaarts, professor at the Institute for Solar Physics, Stockholm University, visited in March to work on multidimensional radiative transfer and the usage of the Multi3D code in Oslo.

Malcolm Druett, postdoc at the Institute for Solar Physics, Stockholm University, visited in February to work on cork modules for the Bifrost code.

Maryam Saberi took part in the RoCS gathering in November in preparation for a postdoctoral position with Sven Wedemeyer on the ALMA project, starting in 2020.

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

Robert Rutten, emeritus adjunct professor of RoCS, visited Luc Rouppe van der Voort in April to work on solar H-α features with hot onsets.

Valentin Martinez Pillet, director of NSO, visited in October-November to work with Carlos Quntero Noda and also to inform us all on the status of DKIST.

Yusuke Kawabata, postdoc at NAOJ, visited in December to work on inversion codes with Carlos Quintero Noda.

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 2019 we had four master students, eleven doctoral research fellows, ten postdocs and researchers, one research software engineer (one more transited from postdoc to RSE in March 2020), two associate professors, four professors and one centre coordinator. In addition we had five adjunct professors, as well as six associated members in the administrative and technical staff. Our Scientific Advisory Committee consisted of 4 members. Two emiriti contributed to publications in refereed journals. 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. All our members are putting their best efforts into strengthening our scientific achievements, set forward new goals and reach 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.

Frederik Clemmensen

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

Ainar Drews

Ainar Drews 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.

Henrik Eklund

Henrik Eklund is a doctoral research fellow at RoCS. His research is focused on determining optimal ways to handle interferometric data from ALMA observations of the Sun. He also makes use of ALMA data in combination with space-borne observations to study physical phenomena, primarily waves motions in the chromosphere. A strong combination of numerical simulations and observations is used in his work. Henrik is also active in contributing to public outreach.

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 data from both ground and space-based solar telescopes for his research. In addition, he makes use of numerical radiative transfer codes for reproduction of synthetic data to compare with the observations. He is also interested in applying machine learning techniques in solar physics.

Lars Frogner

Lars Frogner is a doctoral research fellow at RoCS. Lars' 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 magnetic flux emergences in the active regions of the solar atmosphere, hoping to generate some UV bursts and surges at the dome-shaped magnetic structures that emerges.

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.

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' is to use solar observations to estimate properties or features of other stars and in the process understanding the Sun and stars in general a little better. She wants to learn more about the solar-stellar observations and different techniques of data analysis and simulations. She enjoys contributing towards outreach activities.

Rebecca Robinson

Rebecca Robinson is a new 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

Clara Froment

Clara is mainly investigating the processes that heat the outer layer of the Solar atmosphere, the Corona. She is using both observations (SDO, IRIS, SST) and numerical simulations to study the thermodynamics of active regions. Her main research topic focuses on the characterisation of evaporation and condensations cycles in coronal loops, which are the signature of a steady heating mainly concentrated in the lower atmosphere of the Sun. While at RoCS, she lead an International Team at ISSI, Bern, Switzerland, working on this topic. After 3 years in Oslo, Clara moved to Orléans, France in late 2019 to start a CNES postdoctoral position. She is now working on Solar wind observations from the Parker Solar Probe.

Vasco Henriques

Vasco Henriques is a researcher at RoCS. Vasco investigates poorly understood dynamic processes at small scales in our star, especially in active regions. For this, he primarily observes using the Swedish 1-meter Solar Telescope and then uses supercomputers to find models that reproduce those observations. He is also working on the connection across multiple layers in the Sun's atmosphere via jet-like features, which are ever-present but difficult to observe, especially in satellite data. Vasco has had a passion for astronomy since a teenager, when he would bring his small telescope to astronomy festivals in the Portuguese countryside, and has a passion for new technologies for and beyond science.

Shahin Jafarzadeh

Shahin Jafarzadeh is a researcher in 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.

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.

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.

Nancy Narang

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

Daniel Nóbrega Siverio

Daniel Nóbrega-Siverio 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.

Ada Ortiz

Ada Ortiz is a researcher at RoCS. She studies the process of magnetic flux emergence from the interior of the Sun into the outer solar atmosphere. She also studies the process known as reconnection. She is an observer with a big data analysis component, and uses a combination of ground-based and space-borne observations. She is involved in the European Solar Telescope project, participating in the Science Advisory Group and being the EST Norwegian Communications officer.Ada has now started a job working with big data for Expert Analytics in Oslo but is still involved in the EST outreach activities.

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.

Research Software Engineers

Andrius Popovas

Andrius Popovas is a postdoctoral researcher at RoCS: numerical simulations of the Solar atmosphere are his working horse. He is working on 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. From March 2020, Andrius has transferred to a Research Software Engineer position at RoCS.

Mikolaj Szydlarski

Mikolaj Szydlarski used to be researcher at RoCS but from January, he is working as research software engineer. Physicist and Mathematician by education, but Computer Scientist by heart. Mikolaj is interested in the application of high-performance computing (HPC) to challenging problems in solar astrophysics. His fields of expertise include MHD simulations and Solar ALMA data reduction.

Adjunct professors

Ineke De Moortel

Ineke De Moortel is an Adjunct Professor at RoCS. Her research focusses on coronal heating, in particularly 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 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. 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. She was a member of RoCS' Scientific Advisory Committee until the 30th of November 2018.

Juan Martínez-Sykora

Juan Martínez-Sykora is an Adjunct Associated Professor at RoCS and based at LMSAL and BAERI. His major contributions are on numerical modeling of the solar atmosphere. His main interests focus on chromospheric heating and dynamics and multi-fluids using and developing state of the art 3D radiative MHD codes and compare the models with ground based and space observations.

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. He is the science lead of the IRIS mission.

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 visualisation, 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. After years of main focus on the lower parts of the solar atmosphere, he is extending his interest up into the transition region and corona through coordinated observations with the IRIS satellite.

Sven Wedemeyer

Sven Wedemeyer is an associate professor and PI at RoCS. Sven leads the research activities related to solar observations with ALMA and supporting simulations, which involves the ERC-funded Solar-ALMA project, the EMISSA project (RCN), an ESO-funded 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 is filling Benedikte's position as centre coordinator while Benedikte is away on maternity leave until December 2020.

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. He carries out numerical simulations of the solar and stellar atmospheres, presently focussing on vortical motions and their connection with magnetic fields. He is also interested in polarimetry and numerical methods of radiative transfer and is member of RoCS' WaLSA international science team.

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.

Technical and administrative associated staff

Martina D'Angelo

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

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. We are currently operating one server room and will start operating a second in the spring of 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, doing research in helioseismology in his spare time.

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.

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.

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.

Master students

Bruce Arnold Chappell

Bruce is a first-year masters student in the Computational Science department 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.

Ida Risnes Hansen

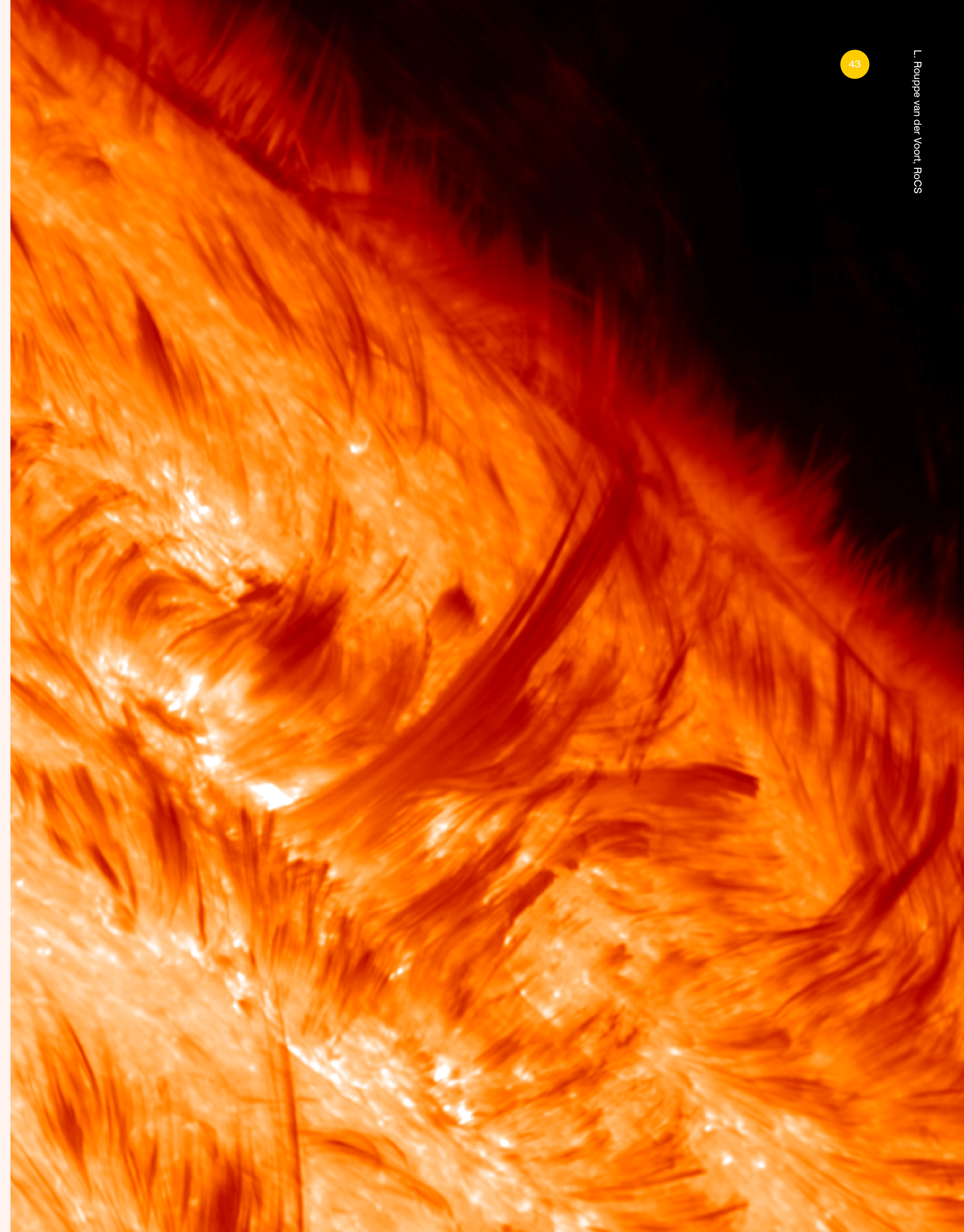
Ida Risnes Hansen is a Master's student at RoCS. She joined Tiago M.D. Pereira's project on Monte Carlo radiative transfer methods in stellar atmospheres. Ida is interested in the history of discoveries in astronomy, and the lives of the scientists behind them.

Ingrid Marie Kjelseth

Ingrid Marie Kjelseth is a master's student at RoCS. Ingrid's research involves mainly the solar radiation, looking at both its magnetic field dependency and how it affects the Earth climate. She has taken part in observations and use data from both SST, ALMA and IRIS for studying different spectral lines and improving today's solar irradiance models.

Mats Ola Sand

Mats Ola Sand is a master's student at RoCS. Mats Ola's research is focusing on detecting the full extent of spicules in the Ca II spectral images from the new CHROMIS instrument at the Swedish 1-m Solar Telescope (SST). He will start his thesis under supervision by Tiago M. D. Pereira in the autumn of 2020. He is also a representative for the students at the institute board.



L. Rouppe van der Voort, RoCS

Talks and presentations 2019

Bose, Souvik. Expanding the Capabilities of NASA's Solar Dynamics Observatory. NASA Frontier Development Lab Event Finale; 2019-08-16 - 2019-08-17

Bose, Souvik. How might we expand the capabilities of NASA's Solar Dynamics Observatory using Machine Learning?. NASA Frontier Development Lab Event Finale; 2019-08-16 - 2019-08-17

Bose, Souvik; Henriques, Vasco; Joshi, Jayant; Rouppe van der Voort, L. H. M.. Characterization and formation of Ca II K and Mg II k spectra of spicules. IRIS 10; 2019-11-04 - 2019-11-08

Carlsson, Mats. Bifrost. WholeSun kickoff meeting; 2019-05-27 - 2019-05-29

Carlsson, Mats. Bruk av IT i solforskning. IT-konferansen 2019; 2019-06-03 - 2019-06-03

Carlsson, Mats. Innovation in Solar Physics Research. Birkelandforelesningen 2019; 2019-09-24 - 2019-09-24

Carlsson, Mats. New Bifrost models. WALSA workshop; 2019-08-12 - 2019-08-16

Carlsson, Mats. New 3D models of the chromosphere and TR. CLASP2 Science Meeting; 2019-11-12 - 2019-11-13

Carlsson, Mats. Numerical simulations of the chromosphere. ISSI team 399 workshop "Studying Magnetic-Field-Regulated Heating in the Solar Chromosphere"; 2019-11-18 - 2019-11-21

Carlsson, Mats. RoCS. Birkeland Centre for Space Science retreat; 2019-03-05 - 2019-03-05

Carlsson, Mats. Solar storms: Wildest weather in the solar system. Njord Christmas Seminar; 2019-12-02 - 2019-12-02

Carlsson, Mats. The F-CHROMA grid of 1D RADYN flare models. RoCS gathering; 2019-11-28 - 2019-11-29

Carlsson, Mats. WP4 Heating and thermo-dynamical coupling of the solar atmosphere, Energy budget. WholeSun kickoff meeting; 2019-05-27 - 2019-11-29

de Jorge Henriques, Vasco Manuel; Rouppe van der Voort, Luc. Unifying umbral chromospheric dynamics at small scales. IRIS-10; 2019-11-04 - 2019-11-08

Eklund, Henrik; Szydlarski, Mikolaj Marcin; Wedemeyer, Sven. Shock wave propagation with high cadence solar ALMA time series. Hinode-13/IPELS 2019; 2019-09-02 - 2019-09-06

Fletcher, Lyndsay. Energy Transport and Dissipation in Solar Flares. Seminar; 2019-03-12 - 2019-03-12

Fletcher, Lyndsay. Multi-wavelength Observations of Solar Flares. 2nd China-Europe Solar Physics Meeting (CESPM 2019); 2019-05-06 - 2019-05-10

Fletcher, Lyndsay. Solar Flares - observational gaps and priorities. Preparing for the next generation of ground-based solar physics observations; 2019-07-23 - 2019-07-25

Fletcher, Lyndsay. Solar Flares and Eruptions. The 27th IUGG General Assembly; 2019-06-08 - 2019-08-18

Fletcher, Lyndsay. Will we all fry in the next solar storm?. Glasgow Skeptics; 2019-06-24

Fredvik, Terje. Oslo SPICE Status. SPICE Consortium Meeting 4; 2019-05-14 - 2019-05-15

Fredvik, Terje. Oslo SPICE Status. SPICE Consortium Meeting 5; 2019-11-19 - 2019-11-20

Fredvik, Terje. Quicklook and Analysis Tools. SPICE Consortium Meeting 4; 2019-05-14 - 2019-05-15

Froment, Clara. Le système solaire. Presentation at the French School in Oslo - for elementary school students; 2019-03-07 - 2019-03-07

Froment, Clara; Antolin, Patrick; Henriques, Vasco; Kohutova, Petra; van der Voort, Luc H.M. Rouppe. Multi-scale observations of thermal nonequilibrium cycles in coronal loops. Coronal Loops Workshop 9; 2019-06-10 - 2019-06-13

Froment, Clara; Antolin, Patrick; Henriques, Vasco; Kohutova, Petra; van der Voort, Luc Rouppe. Multi-scale observations of thermal nonequilibrium cycles in coronal loops (presenting author: Patrick Antolin). National Astronomy Meeting (NAM); 2019-06-30 - 2019-07-04

Guevara Gomez, Juan Camilo; Martinez Oliveros, Juan Carlos; Krucker, S; Hudson, Hugh; Buitrago Casas, Juan Camilo. On the observation of a classical loop-prominence system during the 2017 September 10 flare. HINODE 13 / IPELS 2019; 2019-09-02 - 2019-09- 06

Guevara Gomez, Juan Camilo; Wedemeyer, Sven; Jafarzadeh, Shahin; Szydlarski, Mikolaj Marcin. Dynamics of solar isolated features observed by the Atacama Large Millimeter/submillimeter Array (ALMA). HINODE 13 / IPELS 2019; 2019-09- 02 - 2019-09-06

Guevara Gomez, Juan Camilo; Wedemeyer, Sven; Jafarzadeh, Shahin; Szydlarski, Mikolaj Marcin. Structure and dynamics of isolated features in the solar chromosphere observed with ALMA. 2nd China-Europe Solar Physics Meeting (CESPM 2019); 2019-05-06 - 2019-05-10

Hansteen, Viggo. EBs and UV-bursts: reconnection at different heights in the solar atmosphere. AGU; 2019-12-09 - 2019-12-12

Hansteen, Viggo. Ellerman Bombs and UV bursts - observations. IRIS 10; 2019-11-04 - 2019-11-08

Hansteen, Viggo. Ellerman bombs and UV bursts in the solar chromosphere. Nordita Conference on Helicity in the Solar Atmosphere; 2019-03-04 - 2019-03-08

Hansteen, Viggo. Ellerman Bombs and UV bursts, numerical simulations and IRIS observations. Hinode 13; 2019-09-02 - 2019-09-06

Hansteen, Viggo. Ellerman Bombs and UV bursts, reconnection at different heights in the chromosphere?. IAUS 354; 2019-07-01 - 2019-07-05

Hansteen, Viggo. Ellerman Bombs and UV-bursts, a result of flux emergence. Flux Emergence Workshop series; 2019-03-18 - 2019-03-22

Hansteen, Viggo. Ellerman Bombs and UV-bursts, a result of flux emergence. Flux Emergence Workshop series; 2019-03-18 - 2019-03-22

Hansteen, Viggo. The FIP effect in the Chromosphere, Transition Region, Corona, and Solar Wind. ISSI meeting Bern; 2019-02-11 - 2019-02-14

Jafarzadeh, Shahin. Learning physics with our living star, the Sun. Faglig-pedagogisk dag; 2019-10-31 - 2019-10-31

Jafarzadeh, Shahin; van der Voort, Luc H.M. Rouppe; Wedemeyer, Sven; Noda, Carlos Quintero. Magnetic-field topology of fibrillar structures throughout the solar chromosphere. Solar Polarization Workshop 9; 2019-08-26 - 2019-08-30

Jafarzadeh, Shahin; Wedemeyer, Sven. Observing Waves in the Lower Solar Atmosphere with ALMA. Preparing for the next generation of ground-based solar physics observations; 2019-07-23 - 2019-07-26

Jafarzadeh, Shahin; Wedemeyer, Sven; Noda, Carlos Quintero; Wiegelmann, Thomas; Rouppe van der Voort, Luc. Magnetic-field topology throughout the solar chromosphere. NLTE inversion Workshop; 2019-12-15 - 2019-12-18

Jafarzadeh, Shahin; Wedemeyer, Sven; Szydlarski, Mikolaj Marcin. Temperature Fluctuations in the Solar Chromosphere with ALMA. AOGS 2019; 2019-07-28 - 2019-08-02

Jafarzadeh, Shahin; Wedemeyer, Sven; Szydlarski, Mikolaj Marcin; Fleck, Bernhard. Wave heating of the lower solar atmosphere. Hinode-13/IPELS 2019; 2019-09-02 - 2019-09-06

Jafarzadeh, Shahin; Wedemeyer, Sven; Szydlarski, Mikolaj Marcin; Fleck, Bernhard; Stangalini, Marco. Wave heating of the solar chromosphere from observations with ALMA. ALMA-2019: Science Results and Cross-Facility Synergies; 2019-10-14 - 2019-10-18

Joshi, Jayant. Properties of Chromospheric Magnetic Field of Sunpots. Invited seminar; 2019-01-10 - 2019-01-10

Joshi, Jayant. Spectro-polarimetry of two B-class flares in the Ca II 8542 A line. IRIS 10; 2019-11-04 - 2019-11-08

Kohutova, Petra. Probing the nature of coronal heating through thermal instability and coronal rain. Institute colloquium; 2019-11-07 - 2019-11-07

Kohutova, Petra. Waves in the solar atmosphere and MHD seismology. Institute colloquium; 2019-03-29 - 2019-03-29

Kohutova, Petra; Antolin, Patrick; Popovas, Andrius; Szydlarski, Mikolaj Marcin; Hansteen, Viggo. 3D radiative MHD simulations of coronal rain formation and evolution. Hinode 13; 2019-09-02 - 2019-09-06

Kohutova, Petra; Verwichte, Erwin; Froment, Clara. Propagating torsional oscillation of a chromospheric surge. 9th Coronal Loops Workshop; 2019-06-11 - 2019-06-14

Martinez-Sykora, Juan. Beyond single fluid or two fluids: Multi-component (multi-species) and multi fluid effects in the solar atmosphere. ISSI meeting: Studying Magnetic-Field-Regulated Heating in the Solar Chromosphere; 2019-11-18 - 2019-11-21

Martinez-Sykora, Juan. Ebysus: a multi-fluid and multi-species numerical code: on coupling between ionized species. AGU Fall meeting; 2019-12-09 - 2019-12-13

Martinez-Sykora, Juan. Ebysus: Multi-fluid & multi-species numerical code. Partially Ionised Plasmas in Astrophysics – PIPA2019; 2019-06-03 - 2019-06-07

Nóbrega Siverio, Daniel Elias. An updated vision of solar surges. 2nd China-Europe Solar Physics Meeting (CESPM 2019); 2019-05-06 - 2019-05-10

Nóbrega Siverio, Daniel Elias. Modeling UV bursts. IRIS 10; 2019-11-04 - 2019-11-08

Nóbrega Siverio, Daniel Elias. Nonequilibrium ionization and ambipolar diffusion in magnetic flux emergence processes. Partially Ionised Plasmas in Astrophysics (PIPA2019); 2019-06-03 - 2019-06-07

Nóbrega Siverio, Daniel Elias. Nonequilibrium ionization effects in magnetic flux emergence processes. Flux Emergence Workshop (FEW 2019); 2019-03-18 - 2019-03-22

Nóbrega Siverio, Daniel Elias. Surges: a missing piece in the solar atmosphere puzzle. Whole Sun kick-off meeting; 2019-05-27 - 2019-05-29

Nóbrega Siverio, Daniel Elias. Unraveling the heating in the chromosphere: nonequilibrium and partial ionization effects. Whole Sun kick-off meeting; 2019-05-27 - 2019-05-29

Ortiz, Ada. A tour to the Sun: so close, so mysterious. Apen Dag 2019; 2019-03-07 - 2019-03-07

Ortiz, Ada. Hidden figures: amazing women astronomers and their legacy. Astronomy on Tap; 2019-02-25 - 2019-02-25

Rouppe van der Voort, Luc. Penumbral micro-jets at high spatial and temporal resolution. IRIS-10 meeting; 2019-11-04 - 2019-11-08

Rouppe van der Voort, Luc. Penumbral micro-jets at high spatial and temporal resolution. ISSI team 399 workshop "Studying Magnetic-Field-Regulated Heating in the Solar Chromosphere"; 2019-11-18 - 2019-11-21

Wedemeyer, Sven. High-cadence imaging of the Sun. ALMA Development Workshop; 2019-06-03 - 2019-06-05

Wedemeyer, Sven. High-tech and llamas. Astromomy on Tap; 2019-06-24 - 2019-06-24

Wedemeyer, Sven. Magnetic Field Measurements with the Atacama Millimeter/submillimeter Array. IAU Symposium 354 - Solar and Stellar Magnetic Fields: Origins and Manifestations; 2019-07-01 - 2019-07-05

Wedemeyer, Sven.
Magnetic Tornadoes on the Sun. ISSI International Team 449 - The nature and physics of vortex flows in solar plasmas; 2019-02-04 - 2019-02-04

Wedemeyer, Sven.
Our Dynamic Sun. Seminar ved IFT UiB; 2019-10-15 - 2019-10-15

Wedemeyer, Sven.
Solar Astronomy with ALMA. ALMA2019: Science Results and Cross-Facility Synergies; 2019-10-14 - 2019-10-18

Wedemeyer, Sven.
Solar science with ALMA in Norway. Norwegian ALMA Day 2019; 2019-04-04 - 2019-04-04

Papers in refereed journals 2019

Al-Janabi, K., Antolin, P., Baker, D., Bellot Rubio, L. R., Bradley, L., Brooks, D. H., Centeno, R., Culhane, J. L., Del Zanna, G., Doschek, G. A., **Fletcher, L.**, et al.:2019, Publications of the Astronomical Society of Japan 71, R1, Achievements of Hinode in the first eleven years

Armstrong, J. A., & **Fletcher, L.**:2019, Solar Physics 294, 80, Fast Solar Image Classification Using Deep Learning and Its Importance for Automation in Solar Physics

Bai, X., Socas-Navarro, H., **Nóbrega-Siverio, D.**, Su, J., Deng, Y., Li, D., Cao, W., & Ji, K.:2019, The Astrophysical Journal 870, 90, Signatures of Magnetic Reconnection at the Footpoints of Fan-shaped Jets on a Light Bridge Driven by Photospheric Convective Motions

Bergemann, M., Gallagher, A. J., Eitner, P., Bautista, M., Collet, R., Yakovleva, S. A., Mayriedl, A., Plez, B., **Carlsson, M.**, Leenaarts, J., Belyaev, A. K., & Hansen, C.:2019, Astronomy and Astrophysics 631, A80, Observational constraints on the origin of the elements. I. 3D NLTE formation of Mn lines in late-type stars

Bose, S., Henriques, V. M. J., Rouppe van der Voort, L., & Pereira, T. M. D.:2019, Astronomy and Astrophysics 627, A46, Semi-empirical model atmospheres for the chromosphere of the sunspot penumbra and umbral flashes

Bose, S., Henriques, V. M. J., Joshi, J., & Rouppe van der Voort, L.:2019, Astronomy and Astrophysics 631, L5, Characterization and formation of on-disk spicules in the Ca II K and Mg II k spectral lines

Carlsson, M., De Pontieu, B., & Hansteen, V. H.:2019, Annual Review of Astronomy and Astrophysics 57, 189, New View of the Solar Chromosphere

Cheung, M. C. M., Rempel, M., Chintzoglou, G., Chen, F., Testa, P., **Martínez-Sykora, J.**, Sainz Dalda, A., DeRosa, M. L., Malanushenko, A., **Hansteen, V., De Pontieu, B., Carlsson, M., Gudiksen, B.**, & McIntosh, S. W.:2019, Nature Astronomy 3, 160, A comprehensive three-dimensional radiative magnetohydrodynamic simulation of a solar flare

Cheung, M. C. M., **De Pontieu, B., Martínez-Sykora, J.**, Testa, P., Winebarger, A. R., Daw, A., **Hansteen, V.**, Antolin, P., Tarbell, T. D., Wuelser, J.-P., Young, P., & MUSE Team:2019, The Astrophysical Journal 882, 13, Multi-component Decomposition of Astronomical Spectra by Compressed Sensing

Chitta, L. P., Sukarmadji, A. R. C., **Rouppe van der Voort, L.**, & Peter, H.:2019, Astronomy and Astrophysics 623, A176, Energetics of magnetic transients in a solar active region plage

De Pontieu, B., Martínez-Sykora, J., Testa, P., Winebarger, A. R., Daw, A., **Hansteen, V.**, Cheung, M. C. M., & Antolin, P.:2019, The Astrophysical Journal 888, 3, The Multi-slit Approach to Coronal Spectroscopy with the Multi-slit Solar Explorer (MUSE)

Engvold, O:2019, Proceedings of the International Astronomical Union 13, 75, IAU's Interaction with Young As- tronomers

Esteban Pozuelo, S., de la Cruz Rodríguez, J., Drews, A., **Rouppe van der Voort, L.**, Scharmer, G. B., & **Carlsson, M.**:2019, The Astrophysical Journal 870, 88, Observationally Based Models of Penumbral Microjets

Freudenthal, J.; von Essen, C.; Ofir, A.; Dreizler, S.; Agol, E.; **Wedemeyer, S.**, et al.:2019, Astronomy and Astrophysics 628, A108, Kepler Object of Interest Network. III. Kepler-82f: a new non-transiting 21 M planet from photodynamical modelling

Froment, C., Antolin, P., **Henriques, V. M. J., Kohutova, P., & Rouppe van der Voort, L. H. M.**:2019, Astronomy and Astrophysics 633, A11, Multi-scale observations of thermal non-equilibrium cycles in coronal loops

Graham, D. R., **De Pontieu, B.**, & Testa, P.:2019, The Astrophysical Journal 880, L12, Automated Detection of Rapid Variability of Moss Using SDO/AIA and Its Connection to the Solar Corona

Hansteen, V., Ortiz, A., Archontis, V., **Carlsson, M., Pereira, T. M. D.**, & Bjørgen, J. P.:2019, Astronomy and Astrophysics 626, A33, Ellerman bombs and UV bursts: transient events in chromospheric current sheets

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"Even after all this time
The Sun never says to the Earth,

'You owe me.'

Look what happens with a love like that,
It lights the whole sky."

Hafez

D. Nobrega Siverio, RoCS

Design: Anagram design, print: Konsis

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