

THE OBSERVATORY

Vol. 146

2026 OCTOBER

No. 1314

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2026 February 13 at 16^h 00^m
in the Geological Society Lecture Theatre, Burlington House

MIKE LOCKWOOD, *President*
in the Chair

The President. This is a hybrid meeting and if you are using Zoom then you should see a little green shield in the corner meaning you are using an up-to-date version. Questions can be put in the Q&A section of the website and they will be read out by Dr. Pam Rowell after each talk.

It is my sad duty to announce the death of Mike Cruise, who passed away this week after a long battle with cancer. He was my boss for a while and he was a great leader and mentor. He has been a great servant of this Society and had served both as Treasurer and President. I will miss his calm wisdom and his sense of humour. Unfortunately, that follows on from the death of Allan Chapman. I remember his lectures here with great fondness. He would stand up and talk about a famous astronomer with no lectern, no microphone, no notes or slides, and just talk in the most beautiful prose and an hour would just fly by. He was one of the most erudite people I ever heard. It is very sad that we have lost those two, so could I ask you all please to stand and observe a short silence in their memory? Thank you.

You will have heard that there is a funding crisis. I did a quick set of calculations and this one is really bad. As a shortfall on the total budget it was 10% in 2002, 12% in 2008, and I estimate 20% this time. The Society has already mobilized a lot of people and I call upon you to write to your MP as soon as possible. I recommend that at the top of the e-mail you put your home address and a personal e-mail address if possible. It does have an impact. All Friends and Fellows have been sent a form letter.

Council has decided to triple the number of fellowships that we offer. We feel it is a powerful gesture and it says that we are fully supportive of our young scientists. We are also going to rationalize the application process. You have a week left before the grant deadline, and the summer-school bursaries are considered only in this round.

We have a new Head of Membership, Elaine Ellis, joining us from the Music Publishers Association. We reckon if she can deal with rock stars, song writers, and friends, she can deal with astronomers, geophysicists, and friends.

More good news. The Vale of Dedham in Suffolk has become a designated dark-sky community. That is now the seventh in the UK but the first in England.

The Editor-in-Chief of *Monthly Notices*, David Flowers, is retiring after 15 outstanding years of service. We will be interviewing candidates for his replacement this month. You may have also noted that *Monthly Notices* and *Monthly Notices Letters* have amalgamated, but that was not our decision. We have a new Deputy Editor-in-Chief for *Geophysical Journal International* — Dr. Stefano Lorito of INGV, Italy.

We need a venue for the NAM for the next four years beginning in 2027. If you think your university might be interested in hosting the NAM, we would like to hear from you.

Mr. Horace Regnart. Can I just mention a letter I have written to the League Against Cruel Sports of which I am a member? I've listed astronomers as a threatened species and have laid out 17 reasons why they should not be endangered. I intend to invite my local MP to have lunch with me and propagandize her!

The President. Our first speaker is Dr. Chris Osborne of the University of Glasgow. Chris Osborne is an RAS Norman Lockyer Research Fellow at the University of Glasgow developing techniques to merge modern non-equilibrium radiative transfer for magnetohydrodynamic modelling to study the formation and evolution of cool condensations in the solar corona. Chris obtained a PhD from the University of Glasgow in 2021 on radiative transfer in solar flares, and has also worked as a research software engineer.

Dr. Chris Osborne. Thanks for having me here and to the RAS for funding this work. Spectroscopic observations provide a wealth of information on remote objects where *in-situ* measurements are not feasible. Our observations are governed by the physics of light formation and propagation: radiative transfer. In particular, atomic spectral lines — electronic transitions between bound levels of atoms and ions — can provide very powerful diagnostics for the plasma where they are emitted or absorbed. In the general case, it is necessary to understand the distribution of the atomic population throughout its bound energy levels. That is determined both by collisional processes in the local environment, and also by absorption and scattering of radiation. In many regimes, the latter is negligible, and the material is often described as being in local thermodynamic equilibrium (LTE); however, the general case is termed non-LTE, and is key to the formation of many strong spectral lines between the ultraviolet and infrared. In the non-LTE case, the atomic-energy distribution is a global function of the radiation field in the region of interest, but equally that distribution affects the radiation field, leading to strong coupling between those quantities.

The techniques commonly employed in solar radiative transfer to handle those regimes need to be efficient in order to handle the large numbers of iterative solutions needed to converge to a self-consistent set of atomic-energy distributions and radiation field. To that end, the short-characteristics method has become the workhorse of the field, due to its deterministic nature and efficient scaling. That method, however, is built around the implicit requirement that in multiple dimensions, the atmospheric model must be sufficiently scattering to prevent the appearance of 'ray effects', a class of artefacts where straight rays appear with voids in between them due to the discrete nature of the angular quadrature. For the radiative modelling of complex structures, such as those produced by modern realistic magnetohydrodynamic models, structures of high opacity may be embedded within optically thin regions (such as the solar corona), and models employing short-characteristics solvers may be plagued with ray effects.

Astronomy and physics are not the only fields that require accurate and efficient solutions to radiative-transfer problems: the field of computer graphics, which provides the techniques employed in rendering modern movies and video games, must also solve those problems efficiently, and with an increasing level of physical accuracy to provide visually realistic results to audiences. In particular, we focus on the radiance-cascades technique, first introduced by A. Sannikov in 2023^{*}, and brought to astronomical radiative transfer by Osborne and Sannikov[†]. That technique builds on the so-called penumbra criterion, which allows for the derivation of a necessary set of scaling laws to represent penumbras (partially occluded regions) correctly in discretized models, and thus efficiently compute the radiation field due to nested shells around sample points. Under that scheme, contributions in more distant shells are sampled with higher angular resolution, but lower spatial resolution, whilst

^{*}<https://github.com/Raikiri/RadianceCascadesPaper>

[†]C. Osborne & A. Sannikov, *RAS*, 4, 2025, rzae062, <https://doi.org/10.1093/rasti/rzae062>

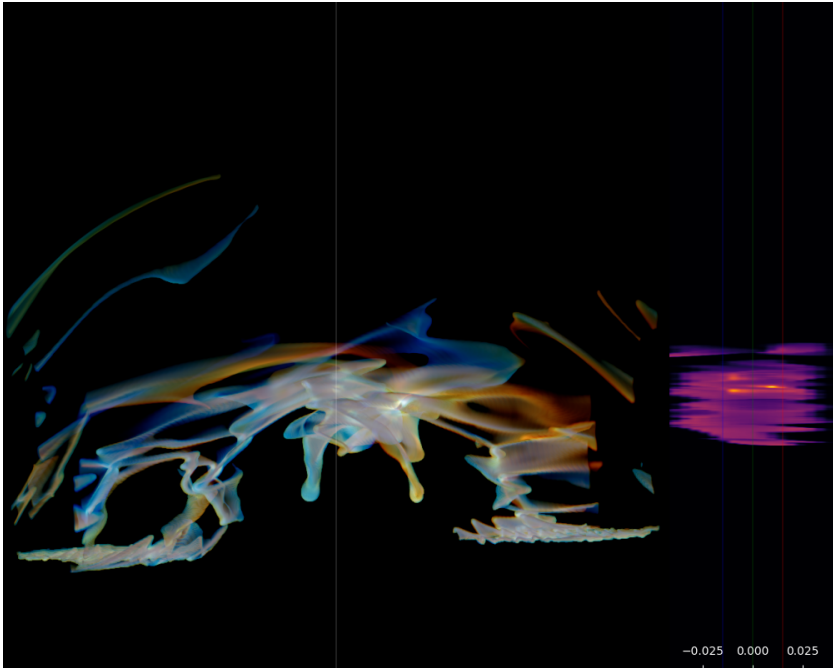


FIG. 1

Mg II *k*-line COCOPLOT. The COlour Collapsed Plot (COCOPLOT) encodes the wavelength variation across the spectral line into the colour channel. Here, blue and red represent the blue and red wings of the spectral line, whilst green represents the core. These are then merged following typical RGB synthesis to compress the 3D data visually. Both axes are spatial (essentially pixels; edge length ≈ 4 Mm) except for the inset at the right where the *x*-axis is in nanometres.

more nearby contributions are sampled with lower angular resolution, but higher spatial resolution. That is a fairly intuitive observation for discretized models, as any slight spatial movement may engender a dramatic variation in radiation due to nearby sources, but those will by definition have a large angular size. On the other hand, distant sources will be small, requiring high angular resolution, but are minimally affected by lateral movement (in essence, their parallax effect is small). The radiance-cascades technique defines a process for interpolating and merging the data stored in those cascaded shells so that many samples of the distant cascades can be efficiently reused, whilst introducing minimal artifacts. In that way, radiance cascades provide an efficient solution for multidimensional radiative-transfer modelling with intermixed optically thick and thin material where avoiding ray effects is key. That is the case, for instance, with coronal condensations, such as prominences — cool structures that form in the outer layer of the solar atmosphere.

The need for efficiency in computer graphics has also led to the development of a large number of accurate and rapid approximations. Our radiative-transfer code builds on ideas presented by the OpenVDB framework* (a two-time Academy-Award-winning software library for efficiently handling and rendering high-resolution volumetric data), along with the recursive spatial-averaging technique known as mipmapping, to provide an ef-

*<https://www.openvdb.org/>

fective adaptive-mesh-refinement technique optimized for traversal along rays integrating the radiative-transfer equation. That provides a typical order-of-magnitude speedup over the core-radiance-cascades method, at minimal additional memory cost. Combining those methods with programming techniques for graphics-processing units (GPUs) enables complex models of solar coronal condensations to be computed both more efficiently and on scales that were not previously feasible. For instance, the prominence model shown in Fig. 1 shows the Mg II *k* spectral line in a very high-resolution magnetohydrodynamic model ($1024 \times 768 \times 384$ grid cells), that would previously be a very significant undertaking with existing radiative-transfer codes, but takes less than 30 hours on a single NVIDIA H100 GPU with our new software.

The goal of this talk is less to report on the existence of our code, and present the synthesis of those models, but instead to encourage the astronomical community to look at other fields and discuss with researchers working in those fields. That can be a very difficult process, as different fields have slowly evolved both the same and novel solutions to problems, often with different terms, and it can be challenging to develop a shared vocabulary. When successful, however, it can bring about step changes in methods that are becoming increasingly hard to achieve as the body of knowledge to contribute to the cutting edge of science ever increases.

The President. That is fascinating. We spent a lot of time thinking about how we could use gaming computer graphics in science but it's mainly in outreach and things like that. Do we have any questions for Chris?

Dr. Quentin Stanley. Considering the CUDA cores you get in NVIDIA cards: the RTX 5000/4000 and I think 3000, actually use AI interpolation to increase the frame rate; are you able to use that sort of technology on this sort of problem in the same way?

Dr. Osborne. Yes, there are a few ways in which we can use that sort of technology. One is simply in terms of it acting as a smart interpolator in many ways, so for visualization work in trying to figure out 'what does this look like?', we can take sparse samples through a model, something that is efficient to compute, and fill it in with some scientifically valid science data later on. There is also a lot of work going into small neural networks that approximate expensive physical processes as part of a larger model. Those are difficult things to train but it is something that we are just starting to play around with and we are really focussing on something really small as opposed to the big networks that are common in physics, three layers of 32 neurons, but they encode just enough physics that we can't quite get otherwise.

Dr. Stanley. Could you give an idea of the computational cost?

Dr. Osborne. Yes, it ran on an NVIDIA H100 and it took a day and a bit, so feasible.

The President. Thank you very much. [Applause.]

The next speaker is Dr. Teresa Paneque-Carreño. She is a Chilean astronomer and obtained her PhD in 2014 from Leiden University and ESO. She is currently a 51 Pegasi b and Michigan Society Fellow at the University of Michigan and an Assistant Professor. She combines observations and theoretical models to understand the physical and chemical conditions of planet formation around young stars. As part of her scientific work she has a deep commitment to science communication with an on-line community of over one million people who follow her across various social-media platforms. She is an author of top-selling books and she is recognized as the first female UNICEF ambassador in Chile where she is recognized as a current female youth leader. The title of her talk is 'A recipe for planet formation, dust chemistry, and a bit of luck'.

Dr. Teresa Paneque-Carreño. A fundamental question that people who study planet formation seek to understand is what processes lead to the creation of planetary systems such as our own and how those differ from the forming conditions of the wide variety of other planets that have been detected around various stars. We know that the process starts with the collapse of a molecular cloud and the formation of a protostar. Around the nascent protostar, the accreting material settles down to form a disc structure as a natural consequence of conservation of angular momentum. That disc is labelled as a protoplanetary

or planet-forming disc and my work focusses on studying it when it has become sufficiently isolated from the surrounding cloud, at a stage where the star is labelled as a Class II Young Stellar Object. Usually Class II systems are between one and five million years old and we expect that ten million years after the molecular-cloud collapse, the disc will have been completely dissipated, leaving behind only a debris disc and a planetary system.

Protoplanetary discs are made of dust and gas, with the bulk of the material being the gaseous reservoir. They are three-dimensional structures that extend both radially and vertically for tens, and even hundreds, of astronomical units. They have radial and vertical gradients in temperature and density. The solid reservoir is distributed such that larger, mm-sized pebbles and planetesimals settle towards the midplane of the disc, while smaller micrometre-sized particles are suspended in more elevated layers, as they are well coupled with the gas. Analysing each of those dust components and the distribution of the full gaseous disc is fundamental for tracing the chemical and solid reservoir available for forming planets, as well as interpreting the on-going physical processes that lead to planetary systems.

In this context, my work focusses on understanding the dynamical motions that mix and stir molecules throughout the disc. Those random-velocity motions are called turbulence, and they are essential not only for mixing the bulk gas, but also for driving disc evolution through angular-momentum transport and triggering dust growth towards planetesimal formation. To study turbulence, it is important first to understand that the disc material is rotating following Keplerian motion around the central star. We can study distinct line profiles of rotating gas using high-resolution spectral and spatial observations taken with instruments such as the *Atacama Large Millimeter/sub-millimeter Array (ALMA)*. For each observed molecular-line emission, we are sensitive to the Doppler shift of material moving away from and towards us as it rotates in the disc. That leads to a double-peaked feature, centred at the systemic velocity, that varies depending on the observed inclination of each disc. Most importantly, line profiles have a width that is largely attributed to the velocity dispersion caused by the Doppler effect due to the thermal motion of the observed molecules. The total line-width will be a combination of thermal, opacity, and non-thermal effects. Turbulence is amongst the non-thermal-effect components, therefore lines that appear broader than expected when accounting for thermal and opacity effects may be tracing turbulent motions in the disc.

Turbulence in protoplanetary discs is expected to be an outcome of various instabilities, with distinct theoretical predictions regarding its strength and variation across the three-dimensional disc structure. Magneto-rotational or vertical-shear instabilities will create turbulent motions with higher-velocity fluctuations in the upper layers compared to the midplane, creating a vertical gradient. An inverse effect of the latter may be caused by any perturbation produced by embedded (or forming) planets, where the midplane may become more turbulent than the upper layers. On the contrary, gravitational instability, a scenario that arises when the disc is massive and cold, may create strong turbulence throughout the whole vertical extent.

It is clear, then, that to study both the strength and presence of turbulence, as well as its launching mechanism, one must use molecular-line tracers that emit from constrained and diverse vertical locations of the protoplanetary disc. To that end, CN and N_2H^+ are selected as key tracers of the upper and midplane layers, respectively. CN is a well-studied molecule that requires high-energy photons for its creation as it is a by-product of HCN photodissociation or can be created if vibrationally excited H_2^* molecules, created through FUV pumping of H_2 , are present. Therefore, CN originates in the upper disc layers, where radiation is higher. N_2H^+ , on the other hand, is an ion that is readily destroyed by gas-phase CO, therefore it can be used as a tracer of the CO snow-surface, which appears at low (<20 K) temperatures, close to the planet-forming midplane.

Using high-resolution spectral *ALMA* observations and non-parametric modelling of the line profile, I am able to measure non-thermal line broadening in CN emission from the disc around the solar-mass star IM Lup. That non-thermal broadening is related to turbulent

motions of 170–190 metres per second, in agreement with theoretical models of various instabilities. In comparison, N_2H^+ shows lower levels of non-thermal broadening for IM Lup, indicating a vertical gradient in turbulence that agrees with prior constraints from mm-sized dust observations. A larger sample of discs with modest-resolution observations of N_2H^+ is also analysed and we detect non-zero upper limits on turbulent motion, signalling that — as expected — some discs may have considerable mixing and stirring of material during the planet-formation phase. Overall, these results present a complex and chaotic view of the earliest stages of planetary systems and compel us to consider all of those simultaneous processes that likely shaped our own Solar System in its very beginning.

The President. You didn't quantify the luck.

Dr. Paneque-Carreño. I didn't quantify the luck — there are several layers of luck, one of which is finding any of those features and being able to trace all of that, and for me I think I had luck because it is my personal view of planet formation. I think a lot of things have to go right or maybe we are complicating it. It seems like a lot of things have to happen that we don't yet fully understand in order to create the number of systems that we know to exist including our own, so it's a lot of little pieces that we are trying to observe from Earth but we need luck to be able to detect them and we also need luck to be in place for them to happen.

The President. You also need luck to study the candidates in the first place.

Dr. Paneque Carreño. Also true, but we need other astronomers to trust in that luck — we can go to systems where it is less likely and see how common they are.

The President. Thank you very much. [Applause.]

The next speaker is Dr. Hannah Wakeford from the University of Bristol who is going to talk about 'The exotic nature of exoplanet clouds'. Hannah is an Associate Professor of Astrophysics at the University of Bristol where she leads a team investigating the atmospheres of exoplanets using space-based telescopes. She is an accomplished researcher and tireless communicator, having won the Philip Leverhulme Prize in Physics in 2004. She has written a nine-billion-year update to the best-selling popular science book *Bang!!* with Drs. Brian May and Chris Lintott. She was the recipient of the 2025 RAS Fowler Award.

Dr. Hannah Wakeford. Clouds are everywhere. Every world in our Solar System from planets to moons and dwarf planets with an atmosphere also has clouds. When we look to distant exoplanets, planets orbiting stars outside our Solar System, is it then surprising that clouds are there too? Well, yes, to some extent. The distant alien worlds are unlike any in our Solar System and their clouds are even more alien for us to imagine.

I am an Associate Professor in Astrophysics at the University of Bristol where I study the atmospheres of exoplanets, planets orbiting stars outside of our Solar System. To study those exoplanet atmospheres, I use the transit method, where the orbiting planet passes in front of the star from our point of view, blocking out a small portion of the star's light — proportional to the ratio of the area of the planet to that of its host star. During the transit some of the starlight is filtered through the atmosphere of the planet, imprinting scattering and absorption signatures on the transmitted light before it reaches our telescopes. Each atom and molecule has a unique spectral signature — the way it blocks the light — and by taking a spectrum of the light from the star during the transit event we can disentangle what is in the atmosphere surrounding the planet. With over a decade of data from the *Hubble Space Telescope* looking at tens of close-in giant planets known as hot Jupiters — due to their hydrogen-helium dominated atmospheres with their radii close to our gas giant Jupiter, but sitting at orbital distances 20 times closer to their star than we are, making their surfaces over 1000° C — we have measured the absorption of water, sodium, and potassium in their atmospheres. But we also saw that the amount those materials absorbed was not as strong as expected. That muting or sometimes complete obscuration of gaseous absorption is due to the presence of clouds in the planetary atmosphere, which block or scatter the light where they sit at high altitudes in their host's atmosphere. Using Mie theory we can show that small cloud particles will preferentially scatter the light at shorter wavelengths while large

particles will block light uniformly at all wavelengths. But what are the clouds made of at those temperatures? For that we need to look at the condensation conditions of different materials and at what temperature would the gas need to be when it becomes saturated and thus liquid or solid particles of that substance form. On the Earth the changing temperature of our atmosphere with altitude crosses the water-condensation line, consequently we have clouds made of water droplets. At the high temperatures of the hot Jupiters they instead cross the condensation lines of material more unusual to think of as clouds. The main cloud-forming species for a hot Jupiter should in fact be magnesium silicates, or sand as we would call it here on Earth. Those silicates condense out of the gas to form solid particles suspended in the atmosphere with their size dictated by the dynamics, chemistry, and temperature of the atmosphere they sit in. In more extreme atmospheres at over 2000°C the clouds are expected to be made of corundum, the aluminium oxide that makes up the basis of rubies and sapphires. The beauty of those materials is that they also interact and absorb light in a characteristic way. For solid minerals that absorption occurs in the mid-infrared (>5 microns) and is caused by the vibration between the main diatomic species that makes up the cloud particle — in the case of magnesium silicates the silicon–oxygen bond which absorbs around nine microns. For decades we have known that those clouds are in exoplanet atmospheres, but only since the launch of *JWST* on Christmas Day 2021 have we had the means to tell you what they are made of.

JWST has already made breakthrough measurements of exoplanet atmospheres with the first detections of carbon dioxide and methane in the gas phase for a handful of planets. Yet the obscuring quality of clouds is still very much present. Excitingly *JWST*'s *MIRI* instrument can measure exoplanet atmospheres over the expected absorption bands of the predicted silicate clouds. But surprises were still in store. My team and collaborators as part of the *JWST* Telescope Scientist Team DREAMS programme used *MIRI* to measure the atmosphere of the hot Jupiter WASP-17b as it transited its star, picking up the absorption signatures of material in its atmosphere. Those measurements revealed a tell-tale absorption spike around nine microns where we expect our sand clouds to interact with the light. But the spike was slightly narrower than expected and shifted to 8.7 microns, that meant it was not our magnesium silicate but instead silica, the more primitive form, SiO_2 , which we call quartz. That detection of silica in the mid-IR combined with scattering measured with *Hubble* in the optical helped us constrain the particle size of those clouds to just 10 nm, suspended high in the planet's atmosphere. What we saw was the first definitive detection of an exoplanet cloud species and what we learnt is that the cloud-formation sequence from corundum down to magnesium silicates and even salts (around 700°C) is more complex than we thought. Additional measurements we have made of WASP-17b have shown that those clouds are forming across the cold side of the planet and being transported by fast winds to the day side where they evaporate into their gas phase and then recondense on their next journey across the nightside. That reveals a silicate cycle very different from our own, crystals of quartz smaller than the width of a human hair raining through an atmosphere over 1000 light years away at temperatures of nearly 2000°C and with supersonic 1000-mph winds. With state-of-the-art telescopes we can bring the true nature of that and other exotic atmospheres and their clouds to light.

The President. It is just amazing the progress that has been made. You were saying that it is 30 years since the first hot Jupiter was discovered and I remember it. We know so much about it now, it's just astonishing. Are there any questions for Hannah? I just make an observation. You were pointing out that Earth-like planets are difficult because their atmosphere is so compacted but their magnetospheres are not and there are some really interesting studies using those techniques on ionized species, separating out the stellar wind from the planetary-origin stuff and they look just like Earth's magnetosphere. It's amazing.

Dr. Stanley. You mentioned the 2% change in atmosphere which is quite intriguing, because that means that you have a low-pressure/high-pressure area. Thinking of the rain

which we are currently suffering, do you end up with one side where it's always raining quartz and the other side where it is nice and sunny?

Dr. Wakeford. The question of weather is something we are interested in and you aren't wrong. We would expect that one part of the planet would be very much inundated with clouds and rain (or quartz) as it sinks down through vertical mixing. Those planets don't have a surface of any kind so it is not something you can stand on and feel as you would on a beach in Wales, say. In essence, what you are saying is actually accurate. We have a point in the atmosphere where we would expect clear skies and it's just gas-phase chemistry going on and we have got the formation of these solid particles suspended high up in the atmosphere that are travelling very fast. Imagine that they are really shards of glass flying at you at thousands of miles an hour. That is what is happening in that atmosphere and as they go around to the day side they get evaporated but that mixing is happening. Deep within the atmosphere we have other clouds that are warming being lofted up into the atmosphere and it's a big dynamical process when you have these spots of weather and we are getting down to the scale where we can tell you not just about the climate of the planet but what the weather is like in a particular location.

Dr. Stanley. So basically you are saying that I'm going to need a bigger umbrella?

Dr. Wakeford. You are going to need a much bigger umbrella and it will need to be very heatproof — 700 to 1000 degrees at that point — and you will be under millibar pressure, equivalent to about the stratosphere on Earth. You are going to need a really good spacesuit.

The President. Quentin, your thinking is close to mine. I think that it would be very good if Earth were to manage that trick, burn off the clouds every midday and reappear at night? Thank you very much, Hannah. [Applause.]

The last speaker is Lisa-Marie Zeßner from the Max Planck Institute for Solar System Research in Göttingen. She began studying astrophysics in Heidelberg in 2014, completing Bachelor's and Master's degrees there. During that time, she worked with cosmological simulations and models to study galaxy evolution and cosmic structure formation. At the end of 2020, she started a PhD at the Max Planck Institute for Solar System Research (MPS) in Göttingen and began working with the MURaM code to set up simulations of solar prominences. She finished her PhD thesis last year, and she is now staying at MPS as a postdoc to keep working on new and more advanced setups for her prominence models.

Dr. Lisa-Marie Zeßner. Solar prominences have fascinated people for hundreds of years. During solar eclipses, they can be seen as bright clouds at the edge of the obscured solar disc, meaning they could be observed long before the invention of the telescope. At that time, the nature of those features was unclear: people described them as 'burning holes', 'red flames', or even 'mountains on the Moon', as it was uncertain whether they belonged to the Sun or the Moon. Now, hundreds of years later, we know that solar prominences are plasma clouds that hover in the solar atmosphere, supported against gravity by the solar magnetic field. They can be found all over the Sun and vary in size, structure, and dynamics. Modern ground-based telescopes and satellites now allow us to study them in great detail. Nevertheless, many aspects of their physics remain unclear because the prominence plasma is highly dynamic and can exhibit complex properties. Therefore, theoretical models and numerical simulations are important tools for interpreting observations and understanding solar prominences.

During my PhD, I used the radiative-magnetohydrodynamic code MURaM to set up simulations of prominences in the solar atmosphere. MURaM simulates the solar atmosphere from the top of the convection zone up to the solar corona in a Cartesian box. In this talk, I provide an overview about the formation and properties of the simulated prominences.

We start the simulations by providing a dipped magnetic arcade as the initial condition for the magnetic field in the simulation box. We can vary the parameters of that initial condition to study different versions of the setup. During the simulation runtime, the footpoints of the magnetic arcade are fixed at the bottom boundary of the domain to stabilize the magnetic-field

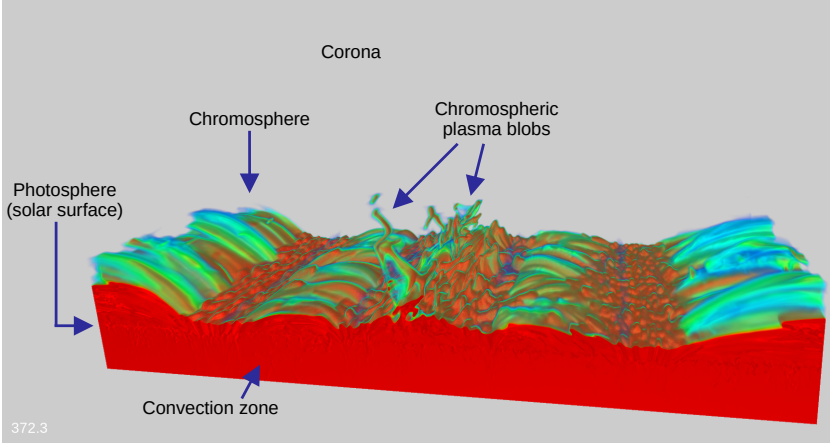


FIG. 2

3-D rendering of the plasma density for the convection zone, photosphere, and chromosphere of the simulated domain before the prominence is formed. The opacity is adjusted such that the corona ($\rho < 10^{-14} \text{ g cm}^{-3}$) is not visible. The corona spans the whole volume above the chromosphere. The visible chromospheric plasma blobs show examples of the injections that can form and feed the prominence.

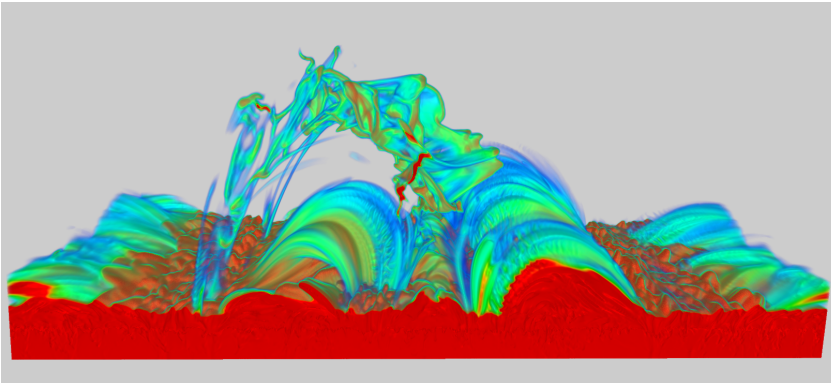


FIG. 3

3-D rendering of the prominence plasma during a draining event. The opacity is adjusted such that the corona ($\rho < 10^{-14} \text{ g cm}^{-3}$) is not visible.

structure against the dynamic convective motions. After some time, a prominence structure starts to form self-consistently by a combination of cool injections from the chromosphere and the condensation of hot coronal material. At the beginning of the prominence-formation process, cool and dense plasma blobs are ejected upwards from the dynamic chromosphere into the hot solar corona (see Fig. 2). Some of those blobs settle in the dips of the magnetic-field configuration, beginning to build up the prominence structure, while others fall back down to the solar surface. If the blobs remain in the corona for long enough, they get cooled by radiative losses, and the pressure at that location drops. That drives inflows of

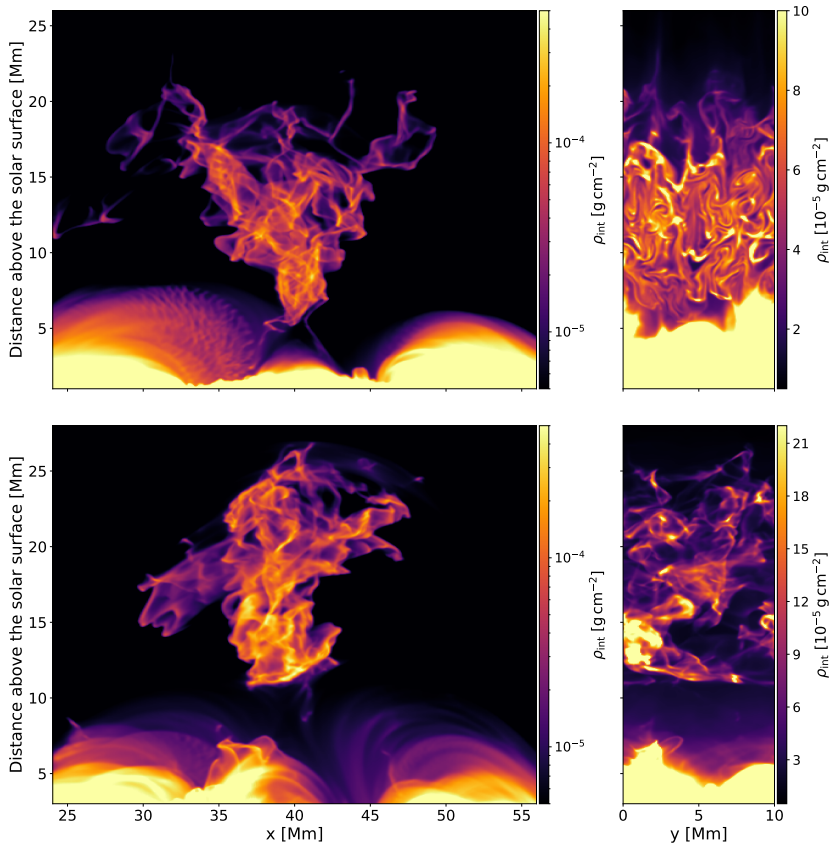


FIG. 4

Structure of two simulated prominences in integrated density. The left panels show the viewing direction from the front (line-of-sight along the y -axis) and the right panels show the viewing direction from the side (line-of-sight along the x -axis), similar to how prominences can be observed on the solar limb.

hot coronal plasma that condense onto the existing cool blobs. The condensation of that hot plasma, along with the continued injection of cool plasma from the chromosphere, feeds the prominence structure. Offsetting that mass build-up, the prominence can also lose mass through plasma draining back to the surface along magnetic-field lines (see Fig. 3). That mass loss can occur to both sides and at the bottom of the prominence.

The simulated prominences are close to the surface and have heights of $\approx 6\text{--}20$ Mm, which is similar to the size of prominences in active regions. The prominence plasma is dynamic and shows an interesting fine structure. The visible fine structures of the prominences can vary depending on the parameters chosen for the setup (see Fig. 4). Depending on the strength and orientation of the magnetic field at the location of the prominence, the structures as viewed from the side (right panels of Fig. 4) can feature horizontal, vertical, and turbulent-looking patterns that qualitatively resemble different types of observed prominences. Furthermore, we compare simulations in which the atmosphere is treated in local thermodynamic equilibrium (LTE) everywhere with simulations that take non-LTE

(NLTE) effects in the chromosphere into account, such as scattering of radiation and non-equilibrium hydrogen ionization. In the NLTE simulations, the average temperature of the prominence plasma is higher, and the temperature structure within the prominence becomes more inhomogeneous compared to the LTE case.

With the current setup, we plan to conduct more extensive parameter studies in order to gain a better understanding of the origin of the visible structures and dynamics. In the future, we intend to expand our simulation setup to include more sophisticated magnetic-field configurations, such as larger sheared arcades and magnetic-flux ropes. By calculating synthesised emission at different wavelengths, we will be able to make more detailed comparisons with observations.

The President. Questions for Lisa? I'm just amazed at the detail you are able to simulate. Some of the simulations look more like things from computer games. I was going to ask about the basis of the field model, but also the pattern of motions — are they prescribed from instrumentation or are they produced by other models?

Dr. Zeßner. The movement in general is produced by the models. You start out with a simple atmosphere and then the model gets heated so you put energy in which tries to match what energy comes out of the Sun and then you naturally get this hot-plate effect that creates granulation cells in the plasma when you heat it from below. You have to define a boundary condition because the convective zone is pretty deep — it makes up about 30% of the solar diameter. We cannot simulate all of that and also we have the problem that we don't really know exactly how the convection cells look deep-down. We simulate only the very top layer so we have to make assumptions.

The President. My question was biased because the movie didn't run. It looked as though the field was sitting within granulation cells. That is why I wondered if they were prescribed. I'm amazed at some of the things that you are able to simulate. Some of them look more like computer games.

Dr. Zeßner. That field was prescribed because it was put in by the initial magnetic-field configuration, but its shape is also affected by the turbulent convective motions.

The President. Are there any other questions? Thank you very much, that was lovely. [Applause.]

There are just two announcements before we close. The next meeting will be on Friday, March 13th and there are drinks next door in the library. Remember to write to your MP.

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2026 March 13 at 16^h 00^m
in the Geological Society Lecture Theatre, Burlington House

MIKE LOCKWOOD, *President*
in the Chair

The President. Welcome to today's meeting. This is a hybrid meeting. Questions can be put in the Q&A and they will be asked at the end of each lecture by Dr. Pam Rowell.

I have an unhappy job to do and that is to announce the death of Dame Carole Jordan. [Carole was an Editor of this *Magazine* 1968–1973. — Ed.] She was the first female President of the Society and served in that post from 1994 to 1996. I can tell you that the RAS was incredibly close to her heart. We would often talk both here at the meeting and afterwards