Dr. Jeffrey. When I say information-extraction, what it is doing is designing an experiment. It is saying that two-point statistics as an experiment are less good. Can you design some other summary of the data? In terms of questions like 'Can you invalidate. . . ?', I think it comes back to this question of goodness-of-fit, and obviously as a scientist that is what we would like, which is additionally 'Can our model not in every way describe our data?' I suppose that is almost always true and then you get rid of all sources of systematic error and hopefully find that it still doesn't match. I think that is like goodness-of-fit but I don't think that design is necessarily the way to go, partly because we are not limited by our data anymore. Cosmology is not a data-limited exercise, it is a methodology, a theoretical statistics-limited problem. At the moment all the dark-energy results combine galaxy observations, CMB, and SN. With *Euclid* weak lensing alone will be able to beat down the error bar on some things. Rather than trying to think what the next step is we will have our work cut out just trying to use that dataset alone.

The President. Thank you very much. [Applause.] I'm not sure what I have learned. [Laughter.] I'm actually wondering if I should give a talk on what differential calculus can do for us. A big thank you to our speakers this evening, it has been absolutely wonderful. The next Highlights meeting will be on Friday, November 14th. We are unable to offer drinks at Burlington House today due to a mixture of licensing laws and fire-regulation problems. We are looking at it and will find an alternative solution. Thanks for coming and thank you again to our speakers and we'll see you in a month.

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2025 November 14 at $16^{h}\,00^{m}$
in the Geological Society Lecture Theatre, Burlington House

MIKE LOCKWOOD, *President*
in the Chair

The President. A couple of speakers were unable to make it today so we have two talks on-line and one in person. The first speaker is Nigel Meredith. Nigel started at UCL in 1984 and moved to the downland outstation at Mullard Space Science Laboratory in 1996. Since 2004 he has worked at the British Antarctic Survey in Cambridge and his work on the radiation belts won him the RAS Chapman Medal this year. He will be talking about 'Extreme relativistic electron fluxes in the Earth's outer radiation belt'.

Dr. Nigel Meredith. Relativistic electrons ($E > 0{\cdot}5$ MeV) are a major source of radiation damage to satellites. These, so-called 'killer electrons', can penetrate satellite surfaces and embed themselves in insulating materials and ungrounded conductors. Here, the charge accumulates over time, resulting in the build-up of high electric fields which may eventually exceed breakdown levels. The subsequent discharge may lead to phantom commands, logic errors, loss of functionality and, in rare cases, serious harm to a satellite.

Relativistic electrons in near-Earth space normally occupy two distinct zones. The inner radiation belt, which typically occurs in the region $1{\cdot}2 < L < 2{\cdot}0$, is relatively stable. Here L is the distance from the centre of the Earth to the magnetic equatorial crossing of a given geomagnetic field line measured in Earth radii. Further out, the outer radiation belt typically lies in region $3 < L < 8$ and is highly dynamic.

Our critical infrastructure extends to 6·6 Earth radii. As of 2023 there were over 7500 operational satellites in Earth orbit, including 6800 in low Earth orbit, 143 in medium Earth orbit, and 590 in geostationary orbit. Most are exposed to relativistic electrons in the Earth's radiation belts at some or all points in their orbits.

To determine the highest fluxes that may potentially be encountered in any given orbit we use a branch of statistics known as extreme-value analysis. For consistency with an earlier study of relativistic electrons at geostationary orbit, we use the excess-over-high-threshold method. For this approach the appropriate distribution function is the Generalized Pareto Distribution.

In 2014, we conducted an extreme-value analysis of the daily averaged $E > 2$ MeV electron fluxes from the *GOES* satellites in geostationary orbit during the 19·5 year period from 1995 January 1 to 2014 June 30. We found the 1-in-10, 1-in-50, and 1-in-100-years daily averaged $E > 2$ MeV electron fluxes at *GOES West* to be $1{\cdot}8 \times 10^5$, $5{\cdot}0 \times 10^5$, and $7{\cdot}7 \times 10^5$ cm^{-2} s^{-1} sr^{-1}, respectively. The largest event seen during this period was a particularly extreme event, which the extreme-value analysis suggests was a 1-in-50-years event.

More recently, we conducted an extreme-value analysis of the daily averaged electron fluxes in GPS orbit as a function of energy and L using data from the US *GPS NS41* satellite during the 19·5 year period from 2000 December 10 to 2020 July 25. We found that the 1-in-10-years flux at $L = 4{\cdot}5$, in the heart of the outer radiation belt, decreases with increasing energy ranging from $8{\cdot}2 \times 10^6$ cm^{-2} s^{-1} sr^{-1} MeV^{-1} at $E = 0{\cdot}6$ MeV to 33 cm^{-2} s^{-1} sr^{-1} MeV^{-1} at $E = 8{\cdot}0$ MeV. In this region, the 1-in-100-years event is a factor of 1·1–1·7 times larger than the corresponding 1-in-10-years event. Further out, the 1-in-10-years flux at $L = 6{\cdot}5$, on field lines which map to the vicinity of geostationary orbit, decreases with increasing energy ranging from $6{\cdot}2^5$ cm^{-2} s^{-1} sr^{-1} MeV^{-1} at $E = 0{\cdot}6$ MeV to 0·48 cm^{-2} s^{-1} sr^{-1} MeV^{-1} at $E = 8{\cdot}0$ MeV. Here, the 1-in-100-years event is a factor of 1·1–13 times larger than the corresponding 1-in-10-years event, with the value of the factor increasing with increasing energy.

The determination of the 1-in-10 and 1-in-100-years extreme fluxes of $E > 2$ MeV electrons in geostationary orbit had immediate impact. They have been used by the Met Office to update the UK Cabinet Office National Security Risk Assessment and included the US 'Space Weather Phase 1 Benchmarks' report. They have also been used by SES Global, a major satellite operator, to improve the definition of spacecraft requirements and in the evaluation of satellite proposals, and by Atrium Space Insurance Consortium, a consortium of ten Lloyd's of London insurance syndicates, in dialogues with clients.

Having discussed some of my recent research, I will now spend the remainder of my talk discussing my outreach activities with the 'sounds of space'. Space is a near-perfect vacuum and utterly silent. However, space is full of a rich variety of electromagnetic and gravitational waves. Converting these waves to sound reveals series of weird and wonderful noises, known as the 'sounds of space'.

In 2017 we set up a multi-disciplinary art–science collaboration, the Sounds of Space Project, comprising musician/composer Kim Cunio, multimedia artist Diana Scarborough, and myself, to exploit these amazing natural 'sounds' and make them more accessible to wider audiences. We have since used the space 'sounds' in talks, performances (including animations, soundscapes, and contemporary dance), short films, and music.

In 2018 we started work on an album, combining 'sounds' from the VLF receiver at the Halley Research Station in the Antarctic with original music. The resulting album, *Aurora Musicalis*, was released in 2020 May. It is partly a soundscape drawn from our most mysterious continent and partly a response to the natural radio 'sounds' of our planet. It invites us to relax and enjoy the 'sounds of space' set to ambient music on the grand piano.

Our second album, *Celestial Incantations*, released in 2021 June, builds on the first album by introducing a whole new spectrum of space 'sounds' and a huge musical palette — including orchestral instruments, traditional instruments, and electronics. This album invites us to consider the vastness of space, and embark on a spectacular journey of 'sound' from Earth to beyond the Galaxy.

We have since released additional albums, exploring different themes. *Sunconscious*, released in 2022, features music inspired by and including 'sounds' of the Sun. These eclectic 'sounds' are accompanied by the hurdy-gurdy, the theremin, an electronic keyboard, and harmonic chanting into a well. More recently, *Moontopia*, released in 2025, features music inspired by and including space 'sounds' recorded by spacecraft in the vicinity of moons of Jupiter and Saturn. These 'sounds' are accompanied by a variety of instruments including the piano, percussion, keyboards, the daegum, and a didjeridoo.

In a separate venture the 'sounds of space' from Halley were incorporated into an update of the space simulation video game *Elite Dangerous* in 2018 December. In this collaboration I worked with Frontier Developments, the creators of *Elite Dangerous*, to incorporate the eerie sounds into the new gameplay.

The President. Thank you very much. Do we have any questions?

Mr. Horace Regnart. It is worth remembering that about 20% of the world's economy depends on near-Earth space activity.

Dr. Meredith. That's right.

The President. Could I ask you a question? You mentioned insurance issues. I notice that my home insurance is invalidated if I don't lock the front door when I go out. Is the same sort of thing happening in space if people, for example, power down and then leave the spacecraft. Is the insurance invalidated or is that not yet on the cards?

Dr. Meredith. I don't have access to any precise details on how our findings have been used by the insurance industry. However, I do know that they have been used by spacecraft insurers to help them make sure that satellite manufacturers and operators are doing all they can to ensure that satellites have sufficient design margins.

The President. The reason I ask it is because it raises the level of trust in the forecast.

Dr. Meredith. Space weather, like weather on Earth, can be highly variable and difficult to forecast accurately all of the time. We provide our best forecasts to our stakeholders and they use them as part of their analysis of on-going risks. As our forecasts develop and their use increases our stakeholders will be able to get a better assessment of the utility of the forecasts.

Dr. Pamela Rowden. John Fairweather comments "Those of us who remember *Journey into Space* these sounds will remind us of that programme".

Mr. Jerry Stone. I have another comment. When you played the first sounds it immediately reminded me of the *Cassini–Huygens* mission that there was a transmission showing sounds when *Cassini* passed through the plane of Saturn's rings. There was a quite remarkable sound difference when that happened.

Dr. Meredith. I've not heard those sounds. I expect they are amazing.

Mr. Stone. I have been on to YouTube to see clips of *Aurora Musicalis* and other things and I am looking to get some copies.

Dr. Meredith. The albums, together with extensive liner notes, are available on bandcamp (`https://soundsofspaceproject.bandcamp.com`). A selection of our albums are also available on the usual streaming platforms (Amazon music, Spotify, YouTube music *etc*.).

The President. I have to admit that I found some of them quite relaxing but I was worried that, as Chairman, I would fall asleep.

Dr. Meredith. I think *Aurora Musicalis* is especially relaxing. It covers 24 hours of activity at Halley Base so you can sit down and listen, and imagine that you are at Halley listening to the sounds. The 'sounds' changes as the day goes by, adding an extra dimension to the album

Dr. Paul Daniels. I am on the RAS Megaconstellation committee. Over the next decade to 15 years or so there are estimated to be 100 000 to 250 000 satellites launched into low Earth orbit which will very likely mean very serious consequences for ground-based astronomy across all wavelengths. I have heard that Space-X are planning to expand their three LEO [low-earth-orbit] satellites to include data centres distributed around the Earth in low Earth orbit. I'm concerned that there could be a serious effect on satellites raising the risk of collision by so many of them becoming non-responsive. On the other hand if we start to place too much of our computing infrastructure into orbit then it becomes vulnerable to natural events, not counting malicious actors, we may find ourselves running into problems in the future. Would you agree that that is a reasonable summary?

Dr. Meredith. I think that is a very reasonable summary. During space-weather events we get beautiful and stunning displays of the aurora which contain huge electrical currents that heat the atmosphere and cause it to expand upwards. The expansion slows down satellites and space junk and increases the risk of collision. At BAS we use radars to measure and model the effects of space weather on satellites and space junk. Putting more satellites up increases the risk of collisions as well.

The President. Thank you very much, Nigel. [Applause.] We should say that space is a very hostile place and some people would do well to remember that. Our next speaker is also on-line, Steven Cunnington, from the University of Manchester. Steven started at Jodrell Bank and then for a while he was the Stephen Hawking Fellow at the Institute of Cosmology and Gravitation at the University of Portsmouth. He is now back at Jodrell Bank, particularly because of *SKAO*. He specializes in optical- and radio-survey synergies, particularly looking for large-scale structure. The title of his talk is 'A new way to map the Universe with radio intensity maps of neutral hydrogen'.

Dr. Steven Cunnington. I am going to a new approach to studying the large-scale structure of the Universe using intensity of neutral hydrogen (H I). This method, currently being developed with the *MeerKAT* radio array in South Africa, measures the combined 21-cm emission from extragalactic H I without resolving individual galaxies, allowing cosmologists to chart the cosmic web more efficiently across much greater volumes.

I will begin by setting the cosmological context. While the CDM model successfully accounts for much of what is observed, it leaves open major questions concerning the nature of dark matter and dark energy, the origin of cosmic inflation, and the validity of general relativity on the largest scales. Persistent tensions between independent measurements, most notably of the Hubble constant, also continue to attract scepticism over the completeness of CDM.

Traditional optical surveys map structure by cataloguing millions of galaxies individually, but this approach is both observationally expensive and increasingly limited at high redshift. Intensity mapping offers an alternative: by measuring the total, unresolved 21-cm emission from neutral hydrogen across the sky and frequency, one obtains a three-dimensional map that traces the matter-density fluctuations. The technique can reach higher redshifts than optical surveys, and the radio telescopes provide an independent probe of cosmology with different systematics. Furthermore, the capability to cover vast volumes spanning billions of light-years unlocks unexplored fluctuations across ultra-large scales, where evidence for new physics may be revealed. These scales are sensitive to the physics of inflation and provide unique tests of Einstein's theory of gravity.

Whilst offering great promise, the 21-cm signal from the cosmic web is, however, extremely faint compared with bright foregrounds from Galactic synchrotron emission, extragalactic radio sources, and radio-frequency interference (RFI). These challenges can be mitigated through careful calibration and statistical cross-correlation with optical galaxy surveys, which help isolate the cosmological component.

The *MeerKAT* telescope, comprising 64 dishes in the Karoo Desert, serves as a world-class observatory and a precursor to the forthcoming *SKA-Mid* array of the *Square Kilometre Array* Observatory (*SKAO*). Its key cosmological programme, *MeerKAT*'s Large Area Synoptic Survey (MeerKLASS), will map roughly 10 000 square degrees over the redshift range

$0{\cdot}4 < z < 1{\cdot}45$. Several pilot surveys in both the L-band and UHF-band have already been completed.

The unique observational strategy is crucial for accessing the largest scales. The field of view from conventional interferometric imaging, where signals from pairs of dishes are correlated, is limited by the array's minimum baseline and therefore loses sensitivity to very broad angular modes. MeerKLASS instead operates the *MeerKAT* array in single-dish mode, using each antenna independently to measure total power, with the results combined statistically. This enables sensitivity to large cosmological scales.

Recent work has demonstrated the success of this approach. From a MeerKLASS pilot survey, Cunnington *et al*. achieved a $7{\cdot}7$-σ detection of clustering through cross-correlation of *MeerKAT* intensity maps with overlapping optical galaxy surveys, the first detection of cosmological large-scale structure using a multi-dish radio telescope [see Fig. 1]. This marked an important milestone for 21-cm cosmology and confirms that the single-dish technique can recover the desired signal.

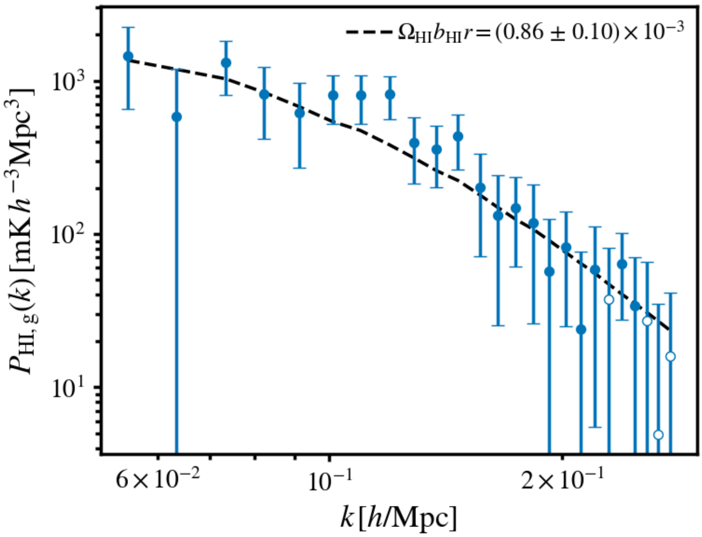

Fig. 1

$7{\cdot}7$-σ spatial-power-spectrum-detection between the *MeerKAT* pilot 21-cm intensity map and WiggleZ galaxies at $z \approx 0{\cdot}43$ (https://arxiv.org/abs/2206.01579 [*MNRAS*, **518**, 6262, 2023]), demonstrating a shared clustering signature between the two tracer fields (21-cm and galaxies). This validates the 21-cm intensity-mapping method on which MeerKLASS is building. Hollow markers indicate negative power. The dashed line is a theoretical model.

Deeper follow-up observations, with around four times more observing hours, further improved sensitivity and control of systematics. Consistent detections of a cosmological power spectrum with MeerKLASS are now being made, plus direct detections of an H I profile by stacking the maps onto positions of overlapping galaxies has also been demonstrated.

Owing to these successful detections, MeerKLASS is now receiving increased support and has grown to become the largest project conducted within *MeerKAT* in terms of observational resources. New observations are now underway, with a planned 2500 hours of observing time over several years. The survey has now reached nearly 3000 square degrees, already making MeerKLASS the largest-volume spectroscopic survey in the southern hemisphere, and will ultimately extend to 10 000 square degrees in the pre-*SKAO* era. Early analyses indicate that even as the survey approaches the bright Galactic plane, foreground contamination remains well controlled, reinforcing the potential for ultra-wide radio surveys with both MeerKLASS and the future *SKAO*.

In conclusion, it is clear that radio intensity mapping of neutral hydrogen is emerging as a powerful new tool for large-scale cosmology. The continuing MeerKLASS observations will refine methods and demonstrate the feasibility of precision cosmology in the radio domain, paving the way for the transformative surveys to be carried out with the *SKAO*.

The President. Thank you very much. When you mentioned using more telescopes to get more done presumably if you were using different combinations of interferometers to improve the resolution you can still get things done when you have the full array — is that true?

Dr. Cunnington. We always use the full array, but crucially do not primarily use it as an interferometer. We instead use it in single-dish mode, *i.e.*, we take the autocorrelations from each dish as it rapidly scans to give low-resolution maps but over vast sky areas very quickly. However, we are now demonstrating an 'On The Fly' technique whereby images can be constructed from the cross-correlations between antennas, despite the constantly moving dishes. This effectively provides a high-angular-resolution interferometric survey at no additional cost.

Professor Richard Ellis. Very exciting. In the frequency range that *MeerKat* can cover is there any possibility of intensity mapping in other spectrum lines or not?

Dr. Cunnington. Not in the region that *MeerKat* is sensitive to. *MeerKat* is pretty well centred on 21 cm. This can be seen as an advantage. Given the highly isolated 21-cm emission feature, the probability of line confusion or interlopers is very low, which is a problem for other line experiments.

The President. Thank you very much indeed. [Applause.] Now we come to the George Darwin Lecture from Dr. Dimitri Veras of the University of Warwick. Dimitri started off with his PhD at the University of Colorado, Boulder. He has worked in Florida and Cambridge, and for the past 12 years he has been at Warwick. He is going to tell us about what is a gloriously multi-science activity: looking at white-dwarf planetary systems. His talk is entitled 'The growing, interdisciplinary field of post-main-sequence planetary-system science'.

Dr. Dimitri Veras. I would like to thank the RAS for the George Darwin Lecture. I am honoured to win it and I hope that my talk reflects that today.

The fate of planetary systems represents a growing field of study which draws from different disciplines, including stellar science, planetary science, and geophysics. Related observational campaigns and theoretical pursuits vary significantly, accommodating a wide range of expertise, and different communities are invited to contribute to this research area.

The future evolutionary path of our Sun qualitatively mirrors that of the vast majority of stars in the Milky Way, passing through giant-branch phases before becoming a white dwarf. During the giant-branch phases, the star's resulting radius expansion, mass loss, and luminosity changes significantly alter the architecture of the orbiting planets, asteroids, comets, and dust. The radius expansion will envelope all material within a few astronomical units, the mass loss stretches out the orbits of the survivors while altering their stability boundaries, and the luminosity increase is sufficient to spin up asteroids to rotational fission on a system-wide scale.

Observations indicate that the resulting planetary system is far from quiescent. As the star becomes a white dwarf and cools down for its remaining lifetime, a combination of the gravitational interactions between planets and asteroids, the influences of stellar fly-bys and Galactic tides on exo-Oort-cloud comets, and the drag from dimming stellar radiation draw in material into the immediate vicinity of the star. This planetary material breaks up close to the white dwarf, yielding debris discs. These debris discs then accrete onto the white dwarf, whose crushingly high density breaks apart the compounds and molecules in the debris into constituent elements.

The debris, the discs, and the photospheric metals are all observable, and have represented the primary drivers for study of the field of white-dwarf planetary systems for decades. The relative abundances of the observed metals are used to reconstruct the compositions and extent of differentiation of the broken-up asteroids and comets, providing a direct glimpse into the bulk chemical composition of exo-planetesimals. The discs are eccentric, wispy, and largely transient, unlike many other astrophysical discs, and in particular unlike protoplanetary discs. Some minor planets are observed in the process of breaking up into debris, as evidenced by their dusty effluences and how the corresponding photometric light curves vary on time-scales of weeks or even days.

Much harder to observe are the major planets themselves, despite the likely pivotal role they play in shaping these systems. The small number of planets found so far have been discovered through a wide variety of techniques, and the community is actively pursuing additional discoveries through current and future facilities.

Theoretical efforts to understand the formation, evolution, and destruction of these systems as well as the individual objects within them have varied from purely analytical to purely numerical investigations. These studies have tackled a wide range of relevant questions, including: How can gravitational instability be triggered late in the life of a white dwarf? How do the orbits of minor planets circularize when reaching the close vicinity of the white dwarf? How do the white-dwarf discs evolve and what is their lifetime? Do the chemical constituents of exo-asteroids differ fundamentally from our knowledge and thinking of Solar System objects?

These questions represent one of several reasons why the research field of planetary-system fates has garnered interest in the astrophysics and geophysics communities. Another reason is that the observations are enticing and usually surprising in some manner, keeping the field fresh and well suited for both exploratory and follow-up investigations.

Professor Ellis. Truly amazing, all that data is absolutely fantastic. White dwarfs are spanning the whole age of the Milky Way. If you go to the very bottom of the cooling curve you are seeing objects that formed when the Milky Way was in its infancy and the protostellar gas clouds would presumably be chemically pristine. I would imagine that you don't have planets at that stage. Do you have material that is chemically pristine?

Dr. Veras. The older the white dwarf is, the cooler it is, the more difficult it is to observe, but we have actually found metal enrichment around white dwarfs that have cooling ages of ten billion years. That is the extreme case, the paper was published only in 2022, but there is one white dwarf with a cooling age of about nine billion years and one with ten billion years and we have seen metal enrichment there. Unfortunately with a sample size of two it is hard to obtain too many correlations but they do show some unusual traits, so we hope to find more especially with all this unpublished data.

Mr. Stewart Coulter. You said that the first exoplanet to be discovered was around a pulsar?

Dr. Veras. It was the first discovered and confirmed exoplanet.

Mr. Coulter. That is a very rare sort of planet. Was it observational bias that revealed that?

Dr. Veras. I think that Aleksander Wolszczan and Dale Frail found those planets. Alex told me that he found them using Arecibo which was undergoing maintenance so he asked the Director if he could use the telescope and he was able to get a lot of data. There was a bit of good fortune there and also we do know that they are generally quite rare: there have been dedicated studies to look for millisecond pulsars and there have been only a handful of detections since then. Those planets are also second-generation planets — any existing planets did not survive the supernova so we think that those planets re-formed from the fallback from the supernova. The first known planetary system was detected around a white dwarf in 1917 by Adriaan van Maanen. He actually saw calcium lines in the photosphere of the white dwarf. He did not understand what he was seeing and neither did we until 100 years later and in terms of firsts that is actually the first planetary system found. For completeness, before 1992, there were hints of radial-velocity exoplanets by Bruce Campbell in 1988 but he could not confirm at the time because the curves did not look very robust. That was γ Cep B and it turns out there is a planet there but it was not confirmed until much later. [The planet is γ Cep Ab, orbiting the primary. — Ed.]

The President. You are going to have everyone scurrying back to look at old journals!

Dr. Veras. I actually asked Aleksander Wolszczan about the first newspaper article reporting that so I had to do some digging myself to find that.

Miss Maria Kuznetsova. I wanted to ask you what kind of metal core do the white dwarfs have? Is it diamagnetic metals or magnetic metals such as nickel or iron? That would be an important point.

Dr. Veras. Most white dwarfs have a core of oxygen and carbon but the more massive ones can have a neon/oxygen core and in terms of the origin of the magnetic fields it could be relics but some of the white dwarfs are spinning fast enough that they generate magnetic fields.

Miss Sabiya Tamadar. When you mentioned the detection of calcium I was interested in how it was differentiated. Do you have any insights about that?

Dr. Veras. When the white dwarf is so dense it will crush any minor planet at the Roche radius. The minor planets are composed of many different metals. Calcium as a spectral line shows up very brightly in the photospheres so that is why we are able to see so much calcium there. We might be missing those other metals that are harder to see.

The President. Thank you very much Dimitri. [Applause.] We can welcome you back to Burlington House for tea. See you next month.

REDISCUSSION OF ECLIPSING BINARIES. PAPER 29: THE F-TYPE TWIN SYSTEM BS DRACONIS

By John Southworth

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We present an analysis of BS Dra, a detached eclipsing binary containing two almost-identical F3 V stars in a 3·36-d circular orbit, based on 40 sectors of observations from the *Transiting Exoplanet Survey Satellite* (*TESS*) and published spectroscopic results. We measure masses of $1{\cdot}305 \pm 0{\cdot}015\,M_\odot$ and $1{\cdot}284 \pm 0{\cdot}017\,M_\odot$, and radii of $1{\cdot}409 \pm 0{\cdot}006\,R_\odot$ and $1{\cdot}400 \pm 0{\cdot}006\,R_\odot$, for the two components. The high quality of the *TESS* data allow — for the first time — a definitive identification of the primary eclipse, which is 0·007 mag deeper than the secondary. The primary star is the hotter, larger, and more massive of the two: the ratios of the radii and surface brightnesses are both slightly but significantly below unity. We find a distance concordant with the *Gaia* DR3 parallax and, by comparison to theoretical models, an age of 1600 ± 300 Myr and a slightly sub-solar chemical composition. Our mean times of primary eclipse, each representing all eclipses in one sector, have a