each element should be produced by each event. What is the mass ratio between the compact objects? The relative contribution between neutron-star mergers will be different with the new improvements from binary-star studies.

The President. In my undergraduate lectures I have always known that when it came to element abundances I would simplify and I have just learned by how much! [Laughter]. I used to make fun of Joni Mitchell — she sings in her song *Woodstock* "we are stardust" and then "we are golden". One of my students pointed out that gold is a very important component of our brains because of its electrical properties, so although we are not exactly golden it's an important part of us so it is interesting that it is still a mystery. One more round of applause for a wonderful lecture. [Applause.]

Finally, drinks will be back in our new house and the next monthly A and G Highlights meeting will be on Friday, December 13th. What can go wrong?

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2024 December 13 at 16^{h} 00^{m}
in the Geological Society Lecture Theatre, Burlington House

MIKE LOCKWOOD, *President*
in the Chair

The President. Welcome to the meeting. This is a hybrid meeting. Questions can be put in the Q and A and they will be read out by Dr. Pam Rowell. As you will know we are losing Phil Diamond in about six months. He will be an extremely hard act to follow but we are in the process of finding a successor.

Our first talk is from Deborah Kent from the University of St. Andrews. She is a reader in history and mathematics at the School of Mathematics and Statistics and is an affiliate at the Institute of History at the University of St. Andrews. Her research focusses on mathematical sciences in the 19th and 20th Centuries with a recent emphasis on 19th-Century eclipse expeditions including personal experience from two 21st-Century total eclipses. She is a librarian of the London Mathematical Society, a Council Member of the British Society for the History of Mathematics, and a member of the RAS. Her talk is entitled 'To Burlington House and the Kerguelen Islands: The 150th anniversary of RAS movements near and far'.

Dr. Deborah Kent. I'm delighted to be here to speak about the 150th anniversary of RAS activity in two very different places in 1873: the well-known Burlington House and the less-familiar and less-hospitable Kerguelen Islands.

Beginning in 1820, the Society first met in various locations, including the rooms of the Geological Society, then in Covent Garden and later in rented rooms in Lincoln's Inn Fields. On receiving the original Royal Charter on 1831 March 7, the (then) Astronomical Society of London became the Royal Astronomical Society. In 1834, the government provided RAS accommodation in Somerset House, which housed other learned societies. Space soon became a concern. To address this, the British government bought Burlington House in 1854 for £140,000 (in 2023 this equates to £293·4 million) to put public offices on the site. By 1857, the Royal Society, the Linnean Society, and the Chemical Society had moved from Somerset House to Burlington House. The Royal Academy of Arts moved in 1867.

The RAS relocated in 1874. Across the courtyard that year, the RA began with a memorial exhibition of Sir Edwin Landseer who had died in 1873 October. The exhibit featured 532 of his works, including the iconic *Monarch of the Glen*. An RA sensation that year was *The Roll Call*, an oil painting by Elizabeth Southerden Thompson Butler that portrayed ordinary soldiers after battle. It made the artist a national celebrity and drew crowds that required police intervention. According to *The Times*, "this one of the pictures of the year least likely to be forgotten".

Elsewhere in Burlington House in 1874, the Linnean Society was busy enumerating lichens, algae, plants, and fungi from the *Challenger* expedition. The President of the Chemical Society was William Olding, noted for his involvement with the development of the Periodic Table. The Geological Society was discussing the skull of an extinct sea cow *Halitherium*. As for the RAS, they had two main concerns in 1874: the transit of Venus and their own relocation to Burlington House.

There were then (as now) both objections to spending public money in support of the learned societies and counterarguments reinforcing the national advantages of doing so. In the end, support prevailed. The Geological Society of London, the Society of Antiquaries, and the RAS would move. The RAS Council were then occupied with renovations: sorting out seating, meeting with architects, sourcing brass rods to hang pictures, and complaining about the costs of heating. (Current members of Council may relate!) The first meeting in Burlington House was held on 1874 November 13 at "8 o'clock precisely".

The Society has held regular meetings there for 150 years and, following a recent landmark 999-year lease agreement between the Government, the RAS, and its fellow learned societies, this will continue.

The year 1874 also brought a long-anticipated transit of Venus. Starting in 1857, Astronomer Royal George Biddell Airy had written articles in *MNRAS* to facilitate expedition planning. Already in 1716, Edmond Halley suggested that simultaneous observations of a transit of Venus from widely separated locations had the potential for improving the measurement of the mean Earth distance (now known as the Astronomical Unit). Airy hoped more accurately to determine this distance, and provided an overview of the upcoming 25 years of prospects.

By 1869, Airy was lobbying the Secretary of the Admiralty for support and funding. He sent estimated expenses, copies of related discussions, and a paper by Mr. De La Rue (celebrated for the first photo of the corona showing prominences) on the application of photography. The Admiralty granted support, and according to the initial parliamentary report on 1869 July 6, £5,000 (equivalent to about £10·5 million today) to cover actual expenditures, but not the costs of operating the naval ships used to transport the expeditions.

Preparations included assembling instruments and training observers. At Greenwich, they practised on a special machine designed to simulate the anticipated black-drop effect. Both the RAS council and individual members lent instruments for the expeditions.

Official British expeditions were sent to Hawaii, which was then a British possession known as the Sandwich Islands (observing stations were at Honolulu, Kailua, and Waimea), Egypt (Cairo and Suez), Rodriguez Island (Point Coton, Point Venus, and Hermitage Islet), Kerguelen Island (Observatory Bay, Supply

Bay, and Thumb Peak), and New Zealand (Burnham, near Christchurch). There were also German, Dutch, Australian, US, French, Russian, Austrian, and Italian expeditions to observe the transit of Venus. Agnes Clerke enumerated 62 parties observing the 1874 transit from nearly 80 separate locations. It may have been the largest ever international effort to observe a single astronomical event.

British observers made elaborate efforts to determine correct longitudes for each of the main observing sights. The party at Kerguelen stayed for several months, persevering through bad weather to take 100 double observations of lunar altitudes and 30 transits of the Moon across the meridian. They also made extensive geomagnetic measurements and laid a tidal gauge. In all locations, British observations of the black drop did not occur as expected from the model. Many observers missed the initial contact and some were entirely clouded out. Overall, it was not brilliant.

In early 1877, Parliament pressed for a report of results from all the effort and expenditure. Airy and Tupman rushed out a partial report, published in 1877 July. The world over, reduction of the observations proved a lengthy chore. For one example, the observations made in 1874 in New South Wales were not published until 1892. The final volume of Airy's expeditions appeared in 1881.

One notable outcome of the 1874 transit of Venus came from a private expedition mounted by Lord Lindsay. Together with David Gill, they sailed to Mauritius on Lindsay's yacht *Venus*. Their plans included using a state-of-the-art heliometer to test the method of diurnal rotation for determining parallax of minor planets. An article in the current issue of *A&G* details their work.

I would be remiss not to mention a beautiful pamphlet on the transit written by Chintamanny Ragoonatha Chary, who worked with Norman Pogson at Madras Observatory. The RAS archives have a beautiful copy of this document — originally written in Tamil, then translated into Sanskrit, Canarese, Malayalum, and that relates the transit of Venus phenomenon to traditional Hindu astronomy. There's more on this story in the 2022 February issue of *A&G*.

I would like to express my special thanks to Dr. Siân Prosser for assistance with RAS archives and her predecessor the late Peter Hingley for work on the transit of Venus expeditions.

The President. Thank you so much. I might be asking you for some references to Airy's creative accounting [laughter]. Were the guys with bowler hats theoretical cosmologists? [Laughter.] Given that the 1870s is the height of Empire, do you know why they chose to go to an island in the middle of the Indian Ocean, rather than India, Hong Kong, or Singapore which had telegraph facilities and commercial shipping?

Dr. Kent. Part of it was connected to where they needed to be in terms of latitude. That is part of the consideration. Kergulen was a French territory at the time and the French had also gone. The transit of Venus is a very interesting episode in scientific competition — they may have been discussing methods with each other; additionally there is a deep national competition going on. Perhaps it is still a matter of establishing British dominance.

Dr. Robert Massey. A couple of points. Firstly, there is the risk to contemporary projects if they don't work. Imagine what would we would be doing if *JWST* had failed to make it into space. The transit of Venus was recorded a century earlier by Lomonsov — you can see it by eye when the planet is on the edge of the Sun. I wondered how they would sell the event. It wasn't, strictly speaking, a discovery.

Dr. Kent. At this point in the 1870s, the state of photography and astronomy is a point of great debate particularly when it starts being used for solar eclipses and partly for other kinds of astronomical observation. A lot of total solar eclipses leading up to 1874 were viewed as practice for the transit of Venus. The fact of having an image is viewed as incontrovertible by some and by others is viewed as "well, you might have some dust on your slide". In brief, the debate is between the status of a photograph and a visual observation. The statement of the results is that that is due to capturing it on a photograph.

Dr. Simon Mitton. I caught your comment about them making a lot of magnetic observations and that is very significant since in the 1860s Victoria had launched a huge magnetic campaign which went throughout the Empire and that also may explain why they went to Kerguelen, because they would not have detailed material from that part of the world

Dr. Kent. There is something about there truly being nothing there and that would have been part of the appeal of taking measures from there.

The President. Thank you very much, that was really interesting.

Our next speaker is Professor Sugata Kaviraj from the University of Hertfordshire. He is a Professor of Astrophysics at Hertfordshire, and a Senior Research Fellow at Worcester College, Oxford. Before going to Hertfordshire he spent his postdoctoral period at Oxford where he was funded by a Leverhulme Early-Career Fellowship, then at UCL funded by a Research Fellowship from the 1851 Royal Commission, and at Imperial College London funded by an Imperial College Research Fellowship. He is a past recipient of the RAS Winton Capital Award and his talk is called 'Dwarf galaxies in deep-wide surveys: a new frontier in the study of galaxy evolution'.

Professor Sugata Kaviraj. Dwarf ($M < 10^{9·5}\ M_{\odot}$) galaxies dominate the galaxy number density, making them critical to a complete understanding of galaxy evolution. However, typical dwarfs are not bright enough to be detectable, outside the very local Universe, in past large surveys like the SDSS, because they are too shallow. The dwarfs that do exist in such surveys have extreme star-formation rates which boost the luminosities of the dwarfs above the detection limits of shallow surveys like the SDSS. However, this also makes them anomalously blue and unrepresentative of dwarfs in general.

New deep-wide surveys from the *Hyper Suprime-Cam* (*HSC*), *LSST*, and *Euclid* are poised to revolutionize our understanding of galaxy evolution, by offering unbiassed statistical samples of dwarfs for the first time, *e.g.*, down to $M \sim 10^8\ M_{\odot}$ out to at least $z \sim 0·4$. These surveys will enable us to study key aspects of galaxy evolution in the dwarf regime which we were historically restricted to studying only in massive galaxies. While *LSST* and *Euclid* will offer footprints of several thousand degrees, the *HSC* surveys, albeit much smaller, offer a preview of the game-changing science that is rapidly becoming possible.

For example, the fraction of red/quenched dwarfs in the *HSC* ultra-deep survey is around 40%, a factor of eight higher than what is concluded using shallow surveys like the SDSS. Red dwarfs reside in higher-density environments and closer to nodes, large-scale filaments, and massive galaxies. However, the probability of dwarfs being red is most strongly correlated with the distance to the nearest massive galaxy, rather than the density of its local environment. Interestingly, many red dwarfs reside in regions of very low ambient density. Around 15% of the red-dwarf population resides both outside the virial radii of massive galaxies and in regions which represent the lower 50% in density percentile. A large fraction of red dwarfs must, therefore, be quenched by mechanisms unrelated to local environment, such as stellar and AGN feedback.

Dwarfs show three principal morphological types: early-type, late-type, and a featureless class which lacks both the central concentrations found in early-types or the spiral structure that typified late-types. The featureless class is particularly interesting because it lacks an obvious counterpart in the massive regime. Dwarf early-types, unlike their massive counterparts, do not show an abundance of tidal features (even in ultra-deep images which are capable of revealing them). Thus, dwarf early-types are more likely to be shaped by secular processes, not interactions.

Finally, spectral-energy-distribution fitting on deep-ultraviolet to mid-infrared broadband photometry suggests that around a third of dwarfs show signs of AGN activity, indicating that AGN could be important in this regime, as they are in massive galaxies. This is supported by new broadband variability studies which suggest that the incidence of AGN in dwarf galaxies may be similar to that in their massive counterparts.

In summary, dwarf galaxies represent a vast discovery space for new and future deep-wide surveys like *Euclid* and *LSST* which promise revolutionary new insights into how galaxies form and evolve over cosmic time.

The President. Thank you very much, Sugata. One thing I didn't understand — your completion lines, how are they calculated?

Professor Kaviraj. I asked the question "If I had a purely old stellar population at a given stellar mass, at what redshift would that stellar population fall below the detection limit of my survey?" I'm assuming that a purely old stellar population, *i.e.*, something that doesn't have any star formation whatsoever is like a faintest limiting case. If you believe that is a good approximation of the faintest limiting case, at what redshift does that faintest limiting case drop below the detection limit of the survey? I would say that completeness thresholds calculated in this manner are pretty pessimistic, because if you look at real populations, no galaxy in the local Universe has a truly old population.

The President. My question was really based on how model dependent they were because that could have implications further down the line.

Professor Kaviraj. In terms of population synthesis it is not model dependent at all; whatever model you use, you will get the same answer.

Professor Richard Ellis. Very interesting. How reliable do you think your identification of AGN is in this new deep survey, just in photometry? You are proposing a very high fraction and in the spectroscopic fraction in massive galaxies is only a few per cent so why should there be so many AGN in the faint population?

Professor Kaviraj. There are two parts to this answer. Firstly, if you try and work out the AGN fraction of dwarfs using BPT [a Baldwin, Phillips & Terlevich diagram] but if you do it in a spatially resolved manner (there is work by Mezcua *et al.* that came out this year) what you find is that the AGN fractions are very high in dwarf galaxies. They are higher than what you find in massive galaxies — up to 50% or so. In fact the BPT technique becomes less sensitive as you go into the dwarf regime because the accretion discs are becoming hotter and therefore the AGN fractions may actually be lower limits. I don't think it is an issue that the dwarf AGN fraction is larger than the massive AGN fraction. I think that is the trend that we see. Secondly, you are right that when I do SED fitting it is inherently uncertain at some level; what has been done so far has used data from the ultraviolet to the infrared, but it doesn't go beyond 15 microns. It is possible that the models are not quite right and I would agree that there is potentially a large error bar. For variability results that I mentioned, the *VST*-COSMOS survey has a one-square-degree footprint, but all the other characteristics are basically identical to the *LSST* survey. In that kind of survey it is very clear about what is variable. I would say that the variability results are pretty clear. If you look at the variability results the AGN fractions are high whether you do it by SED fitting or variability. I don't think it is surprising any more that the AGN fraction of the dwarfs may actually be higher. For example, you can trigger gas infall using a small perturbation in dwarf galaxies and perhaps trigger AGN formation in that way.

Mr. Suryansh Saxena. Due to their small size how long can they sustain star formation? What kind of of stars are actively formed in the blue dwarfs?

Professor Kaviraj. Star formation is the same in all galaxies. You have a young stellar population of hot, massive, main-sequence stars and the reason why a young stellar population is brighter is because these stars are brighter and they also die off quite quickly. Whilst these stars are alive the population is bright and blue and then it essentially fades away. How long they can sustain star formation depends on how long they can be supplied with gas. To answer your question I would have to repeat these experiments at different epochs so you can work out how long the star formation time-scales are. Clearly dwarfs are not all quenched so it is possible for dwarfs to have star formation. To work out what the time-scales are you would need a larger redshift baseline.

The President. Thank you so much.

The last talk is from Dr. Ryan Ogliore. He is an Associate Professor in Physics at Washington University in St Louis. He received his bachelor's degree in Physics and Mathematics from Claremont McKenna College and his PhD in Physics from California Institute of Technology. His graduate research was in cosmic-ray astrophysics and he uses various microanalytical techniques to study extraterrestrial samples from all over the Solar System. He has worked on several past, current, and future NASA planetary missions in physics and astrophysics and today he is going to tell us about 'Sample return missions: past, present and future'.

Dr. Ryan Ogliore. The study of Earth rocks by high-precision laboratory techniques has been critical to our understanding of the geological processes that have shaped our planet. To put Earth in its appropriate cosmo-geological context, we need to understand the formation and evolution of the Solar System with the same precision. Therefore, it is necessary to have actual samples of the moons, asteroids, comets, and planets of our Solar System in the lab.

Rocks from space that fall to Earth naturally are called meteorites. More than a hundred years of studying nearly 80 000 known meteorites have answered some fundamental questions about our origins: Exactly how old is the Solar System? (4567 million years). What heat source caused planets to differentiate into a crust, mantle, and core? (The radioactive decay of aluminium-26). Studies of the *Apollo* samples returned from the Moon told us about one of the most significant events in Earth's history: the Moon-forming impact between the Earth and a Mars-sized body named Theia.

The meteorite record is, perhaps, the most spectacular record of nature known to science, but it is highly biassed. This natural record of extraterrestrial samples is biassed towards small objects on Earth-crossing orbits. Large bodies are not represented in the meteorite record except for the HED meteorites (thought to be derived from asteroid 4 Vesta), the SNC meteorites (originating from ancient Mars), and meteorites from our own Moon. The giant-planet region, from the asteroid belt to Neptune, is unsampled and therefore a geochemical unknown. A small body that likely originated in the outer Solar System, beyond Neptune, was sampled by a daring NASA space mission called *Stardust*.

Comet Wild 2 was in an outer Solar System orbit until 1974, when a close encounter with Jupiter sent it closer to the orbit of Mars. The *Stardust* mission collected many thousands of tiny dust grains, totalling only a milligram, in a novel low-density silica-glass foam called aerogel. The *Stardust* samples returned to Earth in 2006 and were distributed to scientists all over the world for analysis. After 18 years of study by scientists using the best laboratory instruments on Earth, a remarkable story emerged. The mission was called 'Stardust' because it was expected to return stardust leftover from the origin of the Solar System, 4567 million years ago. However, the rocky component of Comet Wild 2 contained very little stardust. Instead, most of the dust was igneous in nature, formed in unknown high-temperature events in the young Solar System.

Meteorites derived from asteroids contain igneous rocks with similar mineralogy, but detailed analyses of the Comet Wild 2 samples showed another surprise. Asteroids accrete 'local' materials with similar characteristics, all formed in a relatively confined area of space (and then altered on the asteroid). Comet Wild 2 accreted an enormous variety of materials from all over the Solar System which remained unaltered on the comet. The lack of excess magnesium-26, a decay product of aluminium-26, showed that the comet accreted material that formed relatively late (more than 3 Myr after the Solar System's birth). At this time, the Solar System can be thought of as a 'debris disc', containing very little gas but lots of leftover dust from impacts and other energetic events. This material migrated to the outer Solar System where it was slowly accreted into Comet Wild 2, along with abundant ices that formed beyond the orbit of Neptune.

The Sun contains the overwhelming majority of the mass in the Solar System and is obviously bright enough to be studied from Earth with spectroscopy. But to understand the formation of the Sun and planets from the primordial solar nebula, it was necessary to collect and return an actual sample of the Sun in the form of the solar wind. The *Genesis* mission, despite crash-landing on its return home, allowed scientists to compare the precise isotopic composition of the Sun with the rest of the sampled Solar System. The results were shocking. Oxygen, very common in both rocks and gases, was highly enriched in the light isotope compared to the planets (as sampled by the Earth, Mars, and asteroids). By studying tiny objects inside primitive meteorites, scientists now think that this Sun–planets dichotomy was established by irradiation of the forming Solar System by nearby massive O- and B-type stars in the Sun's birth cluster.

In addition to the large Sun–planets dichotomy revealed by *Genesis*, there is a smaller but well-resolved dichotomy within the sampled planetary bodies. Very precise analyses of meteorites show that these bodies can be divided into two groups that seem to reflect differences in the abundance of nuclei that formed by the rapid- and slow-neutron-capture processes. A forming Jupiter, which opened a gap in the Sun's protoplanetary disc, may have kept these two reservoirs separate. The Earth, Moon, and Mars are grouped with those bodies enriched in slow-neutron-capture nuclei, and thought to have formed in the inner Solar System.

However, many mysteries remain because the Earth and Moon lie at an extreme end of the inner Solar System bodies that have been measured so far for isotopes. Therefore the Earth could not have been built from known meteorites. There was a component, enriched in nuclei formed by the slow-neutron-capture process and lost from the meteorite record, that was incorporated into the forming Earth, and likely also Venus and Mercury. Returned samples from Mercury and Venus could help us understand the Earth's building blocks.

The gravitational tug-of-war between the giant planets and some of their moons creates heat, transforming some satellites into ocean worlds that may support life, and in one case, a volcanic wonderland. Jupiter's innermost Galilean moon, Io, has enormous lava lakes, 300-km active lava flows, and volcanoes thousands of times more powerful than our own. Plumes erupt a hundred miles off Io's surface into the hard vacuum of space, entraining volcanic ash. A daring space mission flying through one of those plumes (Fig. 1) can collect hundreds of milligrams of ash that contains a record of Io's formation and evolution and can test the hypothesis that Jupiter kept the chemical reservoirs of the inner and outer Solar System separate.

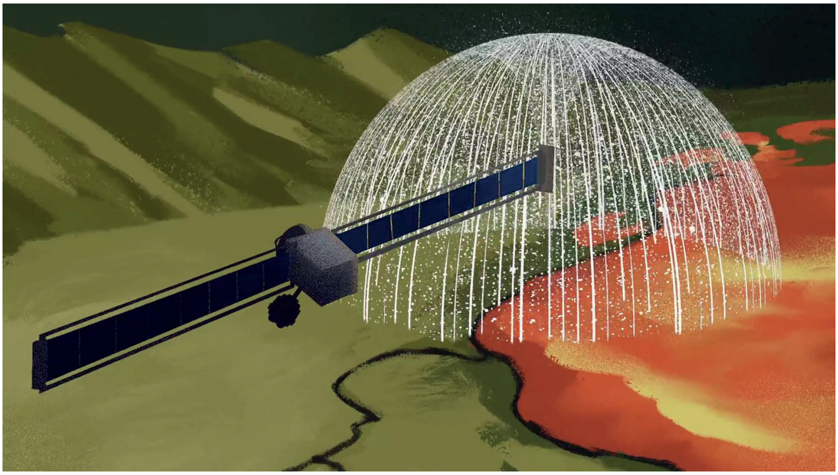

FIG. 1

Artist's rendition of a spacecraft approaching a plume on Io, ready for sample collection. (Image credit: Sofia Shen, NASA–JPL.)

Emerging nuclear-rocket technologies may radically change what is possible for future planetary-science space missions. It may be possible (within reasonable cost and time constraints) to sample the surfaces of Mercury, the moons of the gas giants, Uranus and Neptune, Pluto, and Kuiper-Belt objects. The science return from such missions would revolutionize our understanding of the processes that create the strange and habitable worlds we see in our own Solar System and operate in other planetary systems across the Universe.

The President. Thank you very much, Ryan. How do you know the difference between extrasolar material and Solar System material because you said that *Stardust* did not return?

Dr. Ogliore. We have grains that formed around other stars that pre-dated the Sun's birth and they all have very large isotopic anomalies. For rocks that formed in the Solar System, the differences are usually no more than a part per thousand. For grains that formed around other stars, the differences could be a factor of 2! It could not be more obvious. Some interstellar grains may have been sputtered and then re-condensed in the local interstellar medium. Then they would have the same isotopic composition as the Solar System and it is a trickier problem to identify those grains.

The President. Is that about processing and transport of the material?

Dr. Ogliore. Yes. It's processing somewhere, so if you sputter and re-condense a heterogeneous reservoir it eventually samples the bulk average and so that is the kind of thing that may have happened with interstellar grains that are harder to identify.

Mr. Horace Regnart. I hope I haven't read too much H. G. Wells and Ray Bradbury but am I right in my understanding that it will establish that what I would call called diploids from the Moon and Mars have arrived here? Is that an adequate guarantee that sample returns won't bring back something nasty?

Dr. Ogliore. Indeed this is worth thinking about. I was part of a group that was thinking about Mars sample return, including how to sterilize those samples before they are sent out to various labs. A huge amount of radiation would do it! However, Martian material can be found on the Earth right now. Martian meteorites are something that you can buy on eBay. Those meteorites have spent a long time in space and have been sufficiently sterilized. We don't have to worry about planetary protection for Io because it is a very inhospitable place for life as we know it. There are rules in place for planetary protection (both protecting a planet from Earth contamination, and *vice versa*). A sample directly from an asteroid or the Moon is of no concern. I think the probability is very, very, small that there is anything alive in the samples cached by the *Perserverance* rover. Nonetheless we have to do due diligence and sterilize the samples before we analyse them.

Ms. Frances Chapman. Would it help you if we all went out at night and took selfies? Do you have instruments in place?

Dr. Ogliore. Totally. There have been many meteorites detected on doorbell cameras, so we have a lot of footage and we can tell where that strewn field is. People also look at Doppler-radar detections of falling meteorites. We find more meteorites now because we have more video recordings and weather-radar data. You can report fireballs on-line at fireball.amsmeteors.org.

The President. I was struck by how many were spotted on car dashcams — in Russia in particular.

Professor Sara Russell. I was interested in what you were saying about cryogenic curation. Is that mission-critical for the Io sample return? We had a return mission from a comet that was not cryogenically stored, and also how difficult is it to keep it cryogenically stored in transit from the body back to Earth?

Dr. Ogliore. It's not critical at all for Io because we will be bringing back volcanic glass. If we were bringing back water or ice samples from Europa that would be necessary, but then there would be planetary-protection concerns. In the future we will want to return rock and ice from a comet — for example, a thin section where we can see CO_2 ice next to some igneous rock. We want that geological context with ice too, all the way through analysis. Johnson Space Center in Houston, Texas, is looking at a low level for cryogenic sample return for *Artemis* samples from the Moon. I think we are a long way from cryogenic return from these outer Solar System bodies because we need to keep these things undisturbed all the way from collection throughout analysis, which is really hard.

Dr. Paul Daniels. In the UK there is *UKMON* which is the UK monitoring network for meteors. It is a fairly dense camera network and quite often the cameras will capture more than one image of a meteor which will give a 3-D track of the meteor. For the brighter ones quite often you can get a fairly good idea of where you might find the debris in the case of meteorites.

Dr. Ogliore. This is fantastic! We have 70 000 meteorites but many fewer 'fresh' meteorites from witnessed falls. The more we collect the higher the chance we're going to get something that is really amazing, like something on a hyperbolic orbit or from the Kuiper Belt.

The President. I often wonder about doing spectroscopic analysis on those. It won't tell you about isotopes but it will give you chemistry. I think we should thank all three speakers [applause]. You are all invited, as usual, for drinks across the road in our new premises and the next meeting will be Friday, January 10th.

REDISCUSSION OF ECLIPSING BINARIES. PAPER 24: THE δ SCUTI PULSATOR V596 PUP (FORMERLY KNOWN AS VV PYX)

By John Southworth

Astrophysics Group, Keele University

V596 Pup is a detached eclipsing binary containing two A1 V stars in a 4·596-d-period orbit with a small eccentricity and apsidal motion, previously designated as VV Pyxidis. We use new light-curves from the *Transiting Exoplanet Survey Satellite* (*TESS*) and published radial velocities to determine the physical properties of the component stars. We find masses of $2{\cdot}098 \pm 0{\cdot}021\ M_{\odot}$ and $2{\cdot}091 \pm 0{\cdot}018\ M_{\odot}$, and radii of $2{\cdot}179 \pm 0{\cdot}008\ R_{\odot}$ and $2{\cdot}139 \pm 0{\cdot}007\ R_{\odot}$. The measured distance to the system is affected by the light from a nearby companion star; we obtain $178{\cdot}4 \pm 2{\cdot}5$ pc. The properties of the system are best matched by theoretical predictions for a subsolar metallicity of $Z = 0{\cdot}010$ and an age of 570 Myr. We measure seven significant pulsation frequencies from the light-curve, six of which are consistent with δ Scuti pulsations and one of which is likely of slowly-pulsating B-star type.

Introduction

Eclipsing binary systems contain the only stars for which a direct measurement of their mass and radius is possible. Detached eclipsing binaries (dEBs) are an important class of these objects because their components have evolved as single stars. Their measured properties can be compared to the predictions of theoretical models of stellar evolution to check the reliability of the predictions and help calibrate the physical ingredients of the models[1–3].

Another approach to improving the theoretical descriptions of stars is that of asteroseismology[4]. The measured stellar oscillation frequencies can be compared to theoretical predictions to infer their densities, ages, rotational profiles, and the strength of chemical mixing[5–8].