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MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2022 October 14 at $16^{h}\ 00^{m}$
in the Society of Antiquaries Lecture Theatre, Burlington House

MIKE EDMUNDS, *President*
in the Chair

The President. Welcome to our new session of meetings. And I'm sure you're all enjoying the fact that we actually are here, a lot of us, but there are quite a few of us on-line as well. We're what's known as a hybrid meeting and our experience with 'hybriding' is still developing, so I hope you'll bear with us if we have any hiccups today. We're trying to get this really slick so that people who are not present with us in the lecture theatre get a very good experience on the web. Questions can be asked at the end of the lectures, but as on-line you'll be muted. Please use the chat facility to write down your question and it will be read out later by Council member Professor Steve Miller, who is somewhere here. If you're in the audience and are here to ask a question after one of the lectures, can you please make sure that you wait until the microphone is with you? It's impossible for people on the web to hear unless you've got the microphone, so make sure you've got the microphone before you ask your question.

I'm very happy to introduce, for our first talk this afternoon, the winner of the Michael Penston thesis prize 2020, Jennifer Chan, who's going to talk to us about 'Probing the evolving Universe with confidence'. I always like to see that! 'All-sky cosmological radiative transfer and characterization for cosmic structures'. She's a joint Canadian Institute for Theoretical Astrophysics and University of Toronto Arts and Science postdoctoral fellow. She got her PhD from Mullard Space Science Laboratory and an MSc in astrophysics from University College London, before moving to Canada. She completed her bachelor's degree in physics from the University of Oxford, very impressively, with a full scholarship from the Benenden School Hong Kong Trust, so it gives me great pleasure to ask Dr. Chan to give her talk.

Dr. Jennifer C. Y. Chan. [No summary of this talk had been received at the time of going to press. Correct understanding of the Universe relies on an accurate understanding of the information encoded into the cosmic messengers we receive. In this talk, I will present a solid theoretical foundation of radiative transfer in an expanding and evolving Universe, and discuss the associated methodology underpinning two key sciences, cosmic magnetism and cosmological reionization, and of the *Square Kilometre Array* (*SKA*), the most powerful radio telescope in the next decade for studying the fundamental aspects of astrophysics and cosmology.

I will discuss some current knowledge gaps, followed by presenting a solution to each of the following research questions. (*i*) How to predict reliably the polarized radio emissions associated with magnetic fields that co-evolve with cosmic structure formation and evolution? (*ii*) How to calculate properly the 21-cm-line signals associated with cosmological reionization (as the first luminous objects ushered the Universe's major transition from a neutral phase into an ionized phase)? (*iii*) How to extract efficiently and characterize structural information encoded in data living on a sphere, *e.g.*, all-sky observational survey data?

I will conclude by summarizing the key findings from the above research, which contribute to our understanding of how the Universe that we live in came into its being today.]

The President. Thank you very much. Can I invite questions?

A Fellow. Thank you very much for a very information-packed talk. I look forward to seeing the longer version with all that data. Can I ask you, what's your mental image of the current model for magnetic fields throughout mainly intergalactic medium? Have they always existed? Where do they arise from? Do the magnetic fields come from objects — the ones you listed for example — or are they intrinsic in spacetime?

Dr. Chan. That's a great question and I think it's still an open question. There are many theories actually proposed for magnetogenesis. If you think about the Maxwell equation you'll always see a magnetic seed magnetically evolve. The question is how do we create that magnetic seed? And if you think about the situation, if you have charges and relative velocity in your charge and pressure, that can actually create a magnetic field. Right before recombination, and there is also a theory about reionization, that sort of condition can arise to create magnetic fields. The problem is that in generating a magnetic field, you'll need to explain two things: one is the amplitude, the other is the coherence length, the structure of it. You need to get both in order to nail down the right theory of magnetogenesis. The problem so far, with my understanding, is that with all these early-Universe-generated magnetic fields, the magnetic-field strength is a bit too weak. Today, in the intergalactic medium it is a nano-gauss. There is currently very little observational evidence of an intergalactic magnetic field at the present day and I think that's why we need *SKA*. I can talk more about how that nano-gauss got determined observationally, but we are not very sure whether it's actually of cosmological origin from this early-Universe generation or whether it is the later Universe that stirs up plasma and then generates magnetic fields.

Professor Richard Ellis. A very nice talk. It'll be some time before — for the topology of re-ionization — there will be the 21-centimetre data you would like to test your code; but we do have the other hydrogen line, Lyman alpha, and we're seeing already in quasars that there's patchiness there in the IGM. Can your code deal with Lyman alpha?

Dr. Chan. I've been thinking about Lyman alpha a lot, exactly as Richard said. It is very good also to look into reionization, and we already have data. In principle I can do 21 cm, I can do Lyman alpha, but Lyman alpha is much more difficult to do because you have also to consider scattering, you really have to think about more transitions between your atomic levels. I think, in general, the line-radiative-transfer formulation is covariant and generic, so this is the current thought about Lyman alpha, but we should definitely take on multi-probes to look at re-ionization. Lyman alpha is very interesting but it's hard.

The President. Then we have one more question.

Mr. Christopher Taylor. To detect cosmological magnetic fields, you're obviously going to have to use very long sight lines. I might be picking up on the earlier question, but what about dark matter? I know it doesn't interact with radiation, it can't emit or absorb. Maybe the answer to this is second-year-undergraduate physics, my memories of which are very vague. Does that mean that it actually can't cause Faraday rotation?

Dr. Chan. For the dark-matter part, I think it does invoke some exotic physics to understand it. For Faraday rotation, it does need an ionized magnetized medium. I think that really distinguishes it from actually inducing Faraday rotation.

Mr. Taylor. In the laboratory you can get Faraday rotation by putting a block of glass between poles of a magnet and, of course, that's not ionized. And microstructure is full of electric charge.

Dr. Chan. Yes, but we need to be a bit more careful. What is actually going on with that lab setting — is it truly Faraday rotation, or is it actually something else? — because it's actually interesting with new astrophysical data coming through with fast radio bursts. We also see some very interesting circular polarization, not just linear polarization, that we talk about Faraday rotation. But then it's what we observe really linking to Faraday rotation that we think the propagation effect would be happening if you have a magnetized plasma.

The President. Thank you very much [applause]. Now, it's my very great pleasure to introduce Professor Pedro Ferreira from Oxford University, who's going to give the Gerald Whitrow Lecture. Professor Ferreira is Professor of Astrophysics at the University of Oxford and director of the Beechcroft Institute for Particle Astrophysics and Cosmology. He studied and worked at Imperial College London, at the University of California in Berkeley, and at CERN in Geneva. In his time he's been recipient of a Royal Society University Research Fellowship, a Leverhulme Fellowship, and an ERC Advanced Grant. The title of his address is 'Cosmic ignorance'. It is delightful to see humility in a cosmologist.

Professor Pedro Ferreira. [It is expected that a summary of this talk will appear in *A&G*. Observations of the large-scale structure of the Universe have allowed us to validate a powerful mathematical model of the Universe. We can now measure, with remarkable precision, a number of properties such as its geometry, its matter content, and the morphology of the initial conditions.

This model is firmly rooted in physics that we know yet also reliant on speculative assumptions: inflation, dark matter, and dark energy. As our understanding of the cosmological model has developed, and with ever-improving data, we have been confronted with anomalies and inconsistencies. There is hope that, with new observations, more powerful simulations and the new developments in machine learning and data science, we will be able to resolve fully any inconsistencies. But there is a real risk that, if we don't start to think differently, we will never completely understand our mathematical model. Ultimately we may never know how our Universe really works.]

The President. Thank you very much for a very clear laying out of my last 50 years. You built us up, and then let us down. First of all, can we have questions before opinions?

Reverend Garth Barber. Let's start with an opinion and that is in an age of precise cosmology, it seems to me that what we know precisely is our ignorance about what we don't know. Specifically, are we not worried that the theory depends on inflation and we can't really get that to work properly or find real evidence for it? Dark matter — we have no idea what that is; nor dark energy. And yet science should depend on what you can actually observe and measure and build theory on that, rather than the other way around. Are you not worried?

Professor Ferreira. I'm not worried because I use the example of Brownian motion. When Einstein sat down and worked out Brownian motion he did not know how water worked at a fundamental level, but his phenomenological description was spot on, and it was enough just to say that it had certain objects of a certain size, of a certain mass, and that was revolutionary — it was a huge step. Years later, people figured out what it was and how water works and how molecules work, but that was a really important step. I look at this in exactly the same way. We have figured out that there is something out there and we can describe it really well in the same way that Einstein could describe water molecules. We can describe it in terms of a pressureless fluid for dark matter or particles with very high masses, or dark energy with negative pressure. I mean it's a very clear mathematical description. There's no ambiguity about it. The point is, we would like to do more.

Reverend Barber. Could not the same be said for epicycles?

The President. Let's not go there [laughter]. Although the Greeks, such as the Epicureans, would be delighted. It doesn't matter what it is, so long as you explain it. Right, next question, Steve?

Professor Steven Eales. Well, such a brilliant talk. I haven't got any questions at all, and I haven't got any opinions, but it just seems the only thing I can think of saying is that you drew a dichotomy between two different schools of thought. On the one hand, you have to write down the action. To some extent, this seems very reductionist. On the other hand, you say, there's just this stuff that we can't describe and that seems not right either, so neither way seems to feel totally right.

Professor Ferreira. I'm just going to correct you, although I think you're right [laughter], but I didn't say there is just this stuff that we can't describe. We can describe it really well — the question is, is that level of description enough?

Professor Eales. But it doesn't seem enough. On the other hand, maybe the other thing seems a bit too much reductionist, but yes, I thought, it was absolutely fascinating.

Professor Mike Cruise. Thank you, Pedro, for a super talk. There's another area of science where there are conflicts and that is between quantum mechanics and General Relativity. Do you have an opinion as to whether that is really going to play into these big-scale issues?

Professor Ferreira. Well, I'm going to turn your question a little bit on its head, because I've been thinking about this problem for a while, and I was talking to a fundamental-particle physicist, but because he doesn't know enough about cosmological data he hadn't understood that this could be an issue. And he said, "but that's a bit like the problem of quantum gravity in the sense that we can't measure it". How are we ever going to figure out what is the correct theory of quantum gravity? We have to use some other way of doing it, which is a bit of a concern. The opinions come in whether quantum gravity could solve this. Some of the theories of the beginning of the Universe use quantum gravity. There are these very nice ideas which talk about an early state, an initial state, which would lead to the properties that we see today. There was a paper by Neil

Turok just a week ago working out, finally, he thinks, the correct wave-function of the Universe, which is essentially quantum everything. So people do look at it under that perspective.

Professor Cruise. But you have been inviting us to try and write down an action equation to solve the big problem. But if quantum mechanics has got some flaw in it, an action equation doesn't really mean anything.

Professor Ferreira. I think the problem with that statement is we do know it means something because it works, right? When we look at the Standard Model it works in general. It works beautifully, so there's something right about it.

Professor Ellis. Turning to observations, you had a slide that said 'measure better' and you know, take dark energy. At the moment, it's Einstein's dreaded cosmological constant to 3%. And we're about to embark on these ambitious surveys that are going to take five years. I was depressed to find that many of them are going to bring the error down to, say, 2%. There was a very interesting review article recently by Ofer Lahav and Joe Silk, which was entitled 'Cosmology: When To Stop'. My question to you is exactly that. It gets harder and harder to make more precise measurements and at some point, you know we have to stop.

Professor Ferreira. No, I agree, and I think the other way of saying what they're saying is, there's a limit on how well we can measure, really, given the finite resources that we have. Even if we were able to measure down to a precision of 10^{-5} you could still fit different models of dark energy to it. I wouldn't say it is the cosmological constant; apart from all the problems that the cosmological constant has there would still be a number of theories that would fit it, and so we would still not be completely sure if it was the cosmological constant. So I agree, you're pushing to the first, which is that we know it well enough.

A Fellow. I have a question regarding a plot that you showed, a multiple total intensity in polarized light. I was wondering what is the mechanism for the polarized light; I'm not sure if this chain of thought is correct, because if the polarized light is so low compared to total intensity, then maybe in that wavelength that we use to observe the multipole, the polarized light might not be very important because you know the total intensity is two orders of magnitude greater.

Professor Ferreira. Total intensity is way higher than the polarized light. We've measured this and, because I want to keep the talk clean, I didn't show it, but the error bars on the polarized light are almost comparable to the errors on the total, and we've measured that polarization with exquisite precision. And it is in fact one of the things we use, for example, to constrain the amplitude of primordial gravitational waves. This polarized light arises from recombination and the way that quadrupoles generate polarization during a period where it's not very tightly coupled and its radiation is not very tightly coupled with free streaming. It's a very nice bit of maths.

Mr. Jayesh Modhwadia. When do you reach that point when you say okay, we know the kind of incremental progress is small enough not to justify any further research? Where is the field in the thinking right now?

Professor Ferreira. It's nowhere near that because, luckily, we've got the next ten years of surveys, which are working until we have data. We've already invested, but it's something we might want to ask ourselves in ten or 15 years' time.

Dr. Guy Morgan. Just to comment on that last comment, you're going back to the 1890s where people thought physics was complete.

Mr. Stephen King. In a similar vein, I like the message to shut up and keep measuring better, but we don't want to stop too soon. Are there other measurements that we might make that you think will qualitatively change the picture? That would change this so that it's not about measuring things, but lead us in a fundamentally new direction.

Professor Ferreira. To solve the three big problems that I put up, I have no idea. What we do know is that when we start measuring things better and observing the Universe more, we discover stuff. And I've only focussed on these three fundamental problems, but there's all this beautiful stuff going on trying to understand the evolution of galaxies, the distribution of gas in the Universe. There are all these other physical problems which I have not alluded to, which are completely valid and from which we will learn a lot. The kind of stuff that you work on. We will learn a lot from these coming observations and there are more observations that you can do. They are more, I think, related to astrophysics than to fundamental physics, which was the focus of what I'm saying and unfortunately I have no idea what we should do.

Mr. Horace Regnart. A brief practical suggestion to avoid the risk of ambiguity in the terms we use. It might help at a time when people are talking about multiverses and the possibility of structures outside the observable cosmos, if we use Cosmos or observable cosmos for what we've been talking about this afternoon and reserve the term Universe for those structures, not necessarily the whole of the Universe, which lie outside the observable cosmos.

Professor Ferreira. Thank you for your suggestion.

The President. I can think of another word for the stuff outside our Universe. I think, as you said, 'Cosmology; when to stop'. I think we should stop there. There will be a drinks reception on the second floor of Burlington House now and the next A&G Open Meeting of the Society will be held on 11th of November 2022.

THE FIRST *MONTHLY NOTICES*

By Steven Phillipps

Astrophysics Group, University of Bristol

The first self-contained *Notices* from the Astronomical Society of London (which became the Royal Astronomical Society in 1831) were printed in 1827[1], and those produced up to the end of 1830 were amalgamated as the first volume of the *Monthly Notices of the Astronomical Society of London* in 1831[2]. These were not the first publications of the Society, as *Memoirs* (containing general information and selected contributions which had been presented at the Society's meetings) had been produced since 1822[3,4], but *Monthly Notices*, in due course, took over as the main repository of information for and papers by Fellows of the RAS. Here we survey the contents of this first volume of *MN* and the astronomers who were involved.

Initially, notices of the affairs of the Society were communicated to members *via* the *Philosophical Magazine*[5], edited first by Alexander Tulloch and, from 1822, by Richard Taylor of Shoe Lane, London. They were first 'struck off'as separate copies for Astronomical Society members in 1827 February. The Council Report of 1828[6] notes that "One of the first acts of the Council in the year elapsed, was to enter into agreement with Mr Taylor, the printer to the Society [*i.e.*, of *Memoirs*], and who is also one of the editors of the *Philosophical Magazine*, for the publication of a series of monthly notices of its proceedings, and for the supply of a sufficient number of copies of them, in succession, for distribution among the members. The convenience and advantages of this plan have been sufficiently proved by the trial which has been given it, and it will, of course, be continued." In fact, due to financial considerations, the production of the monthly notices was soon transferred to publishers Priestly and Weale, High Street, Bloomsbury, and their printer J. Moyse of Leicester Square, and it was under their imprint that the earliest versions were combined to form Volume 1 of *Monthly Notices of the Astronomical Society of London* in 1831. The front cover notes that it contains "Abstracts of Papers and Reports of the Proceedings of the Society, from February 1827 to December 1830". The first seven monthly issues, totalling 43 pages, had been produced during 1827 and the whole of Volume 1 contained exactly 200 pages — though some, between the individual monthly issues, are blank — plus an index.

Volume 1 began[7] with the 'Report of the Council of the seventh Annual General Meeting February 9, 1827'. It noted that "Seven years have now elapsed since the formation of this Society: during which period, it must be evident to every intelligent observer, that a considerable progress (assisted, it is hoped, by the exertions of this Society) has been made in the science of astronomy …". It was also reported that "new tables for computing the Aberration, Precession and Nutation of 2881 fixed stars" had been prepared at the instigation of "your indefatigable president" Francis Baily and "brought to a successful termination by … Lieut. Stratford, of the Royal Navy, one of your secretaries", the pair winning that year's gold and silver medals. Col. Beaufoy also won a silver medal for his observations of eclipses of Jupiter's satellites. The only other science mentioned was the discovery of five comets during the year. Eleven new Members and three Associates had joined the Society since the last annual meeting giving a total of 212 Members and 32 Associates. Losses to the Society included the "distinguished Associates MM. Bode, Fraunhofer and Piazzi" for whom obituary notices were provided. The report ended with a list of Officers of the Society for the coming year — President: John F. W. Herschel — Vice-Presidents: Capt. F. Beaufort RN, Lieut.-Gen. Sir T. M. Brisbane, H. T. Colebrook, James South — Treasurer: Rev. W. Pearson — Secretaries: O. G. Gregory, Lieut. W. S. Stratford RN — Foreign Secretary: Charles Babbage — Council: F. Baily, Colonel M. Beaufoy, Lieut.-Col. T. Colby, Capt. G. Everest, Davies Gilbert MP, B. Gompertz, S. Groombridge, J. Horsburgh, Hon. Lord Oxmantown, E. Riddle.

Nearly all these (and various others who appear later in *MN* Volume 1) have short biographies in recent papers on the first *Memoirs*[4] and on military officers in the Astronomical Society[8] (and the references therein) which are not repeated here. Additions are Henry Thomas Colebrooke FRS, Edward Riddle, and Lord Oxmantown. Colebrooke was a founder member[9] and president in 1823–1824[10]. He had spent most of his career as an administrator with the East India Company and became a noted scholar of Sanskrit, which enabled him to study ancient Indian science. Riddle had joined the Society in 1822[11]. He was brought up in rural Northumberland but taught himself mathematics and became a schoolmaster, teaching navigation and nautical astronomy at Trinity House School in Newcastle, from where he moved to the school (then referred to as Asylum) of the Royal Naval Hospital, Greenwich. He made 14 contributions to *Memoirs* or *MN*, mostly on longitude determination. Lord Oxmantown[12] was William Parsons, the future 3rd Earl of Rosse of Birr Castle, of *Leviathan of Parsonstown* and spiral-nebula fame[13]. He only ever made two contributions to the Society's publications (in 1854 and 1864): an extract of a letter to the Astronomer Royal on mirrors, and "a series of representations of Mars taken from drawings made by [his] assistant" and "communicated by his Lordship". No details of the latter could be supplied as the unfortunate assistant was "ill with congestion on the brain".

The second *Notice*, for 1827 March, contains just two and a half pages reporting the papers presented at that month's meeting (such papers frequently also appeared in *Memoirs*): Babbage on errors in tables of logarithms; two letters from Andrew Lang to Baily concerning meridian transits of the Moon and preceding and following stars (noting the excellent conditions at his observatory in St. Croix); a method for "determining the time by observations of two stars when in the same vertical …" by Dr. T. L. Tiarks; and a letter from M. Gambart to the President presenting the elements of the orbit of a comet.

Andrew Lang had joined the Society in 1822 and continued to send communications to their journals until 1862 (when he was 83). A Scot, he was resident in St. Croix in the Danish West Indies (now part of the Virgin Islands) from about 1795, and was at first a clerk before acquiring a number of estates. (There were only 180 white people on the island in 1815 when it was returned to Denmark by Great Britain after the Napoleonic Wars.) He became a major (presumably in the local Burgher Corps), Chief Inspector of Roads, Inspector for the (Danish) King's Properties in Christiansted, and a Knight of Dannebrog[14]. According to a note in *MN* in 1849[15] (just after the St. Croix slaves' successful revolt and emancipation) he was Governor of the island, but there is no sign of this in official lists. John Louis Tiarks[10] was originally from the Duchy of Oldenburg but became Sir Joseph Banks' librarian in 1810. He was subsequently on the commission for settling the American Boundary Line and worked with the Admiralty on determining accurate longitudes for numerous places. The above, and its equivalent in *Memoirs*, was his only contribution to the Astronomical Society, though. Jean-Felix Adolphe Gambart had become director of Marseilles Observatory in 1822 when only 22 years old and discovered a total of 13 comets before his early death due to cholera in 1836[16]. He had been an Associate since 1826.

April's *Notice* was considerably more extensive. It began with descriptions of two papers read at the latest meeting on eclipses of Jupiter's satellites, another by Col. Beaufoy and one by John Goldingham FRS, who used them to determine the longitude of Madras (now Chennai). Originally an architect and civil engineer, for many years from 1802 Goldingham held the post of Astronomer at Madras Observatory (of which he had had charge of the construction in 1792), but his RAS obituary[17] notes that he had little communication with European astronomers and that no regular series of observations appeared to have been made.

"The ordinary business of the evening now being terminated", a Special General Meeting was held in which the President read a lengthy (and rather grandiloquent) address on the award of the Society's medals to Bailey, Stratford, and Beaufoy (see above). Beaufoy was unfortunately too ill to collect his medal in person and died the following month[18].

The May *Notice* contained summaries of six papers. John Herschel had talked 'On the approximate place and descriptions of 295 new double and triple stars …', the reviewer noting that "Both the stars in α Capricorni are double: and that usually designated as α^2, Mr. H. characterises as one of the most beautiful and delicate objects in the heavens". Mr Curnin, the Superintendent of the Observatory at Bombay (now Mumbai), communicated a series of observations of 'moon-culminating stars' (which appeared in full in *Memoirs*) which he had made with a tiny 2-inch telescope. It was understood, however "that a new set of instruments has lately been forwarded to the Observatory in Bombay, at the expense of the East India Company". Curnin was 'the Company's Astronomer' from 1822 to 1829[19] but was frequently in dispute with them[20]; "The committee of survey, assembled to investigate matters, asserted that Curnin had failed to improvise with his instruments as well as causing offence with his vitriolic communications". He was elected a member of the AS in 1827, after an earlier entry in 1821 was crossed out for some reason. A paper was also read on behalf of Professor Littrow, director of the Imperial Observatory at Vienna, 'On the determination of azimuths by observations of the pole star'. George Dollond sent a communication "giving an account of a singular appearance observed during the solar eclipse" which he had viewed through thin cloud, *viz*. the visibility of "a considerable part of the limb of the moon which had not yet entered on the disc of the sun". A letter from Mr. Reeves of Canton gave an account of a comet observed at sea. John Reeves FRS was a member of the AS from 1825, later giving his residence as Clapham. A tea merchant, he was another in the employ of the East India Company, though as Chief Inspector of Tea in Canton (Guangzhou), China, and was primarily a naturalist[21]. Finally, Gambart supplied improved elements of the comet of 1826 which had been predicted to pass across the Sun's disc.

In June, eight papers were reviewed. The first was Francis Baily's 'Remarks on the Astronomical Observations of Flamsteed', which he felt "to be deserving of more strict examination than they appear yet to have received" and essentially looking for volunteers to re-reduce at least some of them with the improved methods then available.

Thomas Taylor Jnr. of the Royal Observatory reported the "ephemeris of the positions of the four new planets [*i.e.*, asteroids] at their ensuing oppositions." Thomas Glanville Taylor[22] was Second Assistant to Astronomer Royal Pond at Greenwich from 1822 (his father was the Assistant). He became director of the East India Company's Madras Observatory[23] in 1830. He became an FRAS in 1841 and had two papers in *Memoirs*, but most of his observations were included in several volumes produced by 'the Company'. Next was a paper by Mr. Utting on the period of cycles of eclipses (he proposed 3803 lunations). James Utting was a resident of 'Lynn Regis' (*i.e.*, King's Lynn). As well as studying ancient eclipses, he had presented to the Society[24] his manuscript, 'Tables relating to Circles; the Squares, Cubes, Reciprocals and Roots of Numbers; Pendulums; and the Sun, the Moon and the Earth'. This was followed by a series of observations made by Major Hodgson on the transit of Mercury and timing of occultations, made at the cantonment of Futty Ghur in Bengal.

Mr. Baily read an extract of a letter from Professor Harding of Göttingen reporting his discovery of a variable star. Karl Ludwig Harding FRS[25] had briefly been director of the Observatory before Gauss was appointed in 1807 and remained a professor thereafter. He was originally trained as a theologian but became an assistant at Sternwarte Lilienthal, J. H. Schroter's private observatory, and discovered the asteroid Juno in 1804. He also carried out sky surveys and discovered the Helix Nebula. A letter was also read from Mr. George Innes of Aberdeen "giving the results of his computations relative to the solar eclipse of the 28th November last". Innes became an FRAS in 1836[26] and supplied further contributions to *MN* on later eclipses. He was recorded as a "watch and clock maker, and astronomical calculator" in the *Directory for the City of Aberdeen*.

A description of "an instrument called a Tangent Sextant" was communicated by Captain John Ross RN, and finally there was a paper by Lieutenant C. R. Drinkwater RN presenting his "method of making the necessary computations for deducing the longitude from an occultation of [a star by] the moon". "The business of the evening being concluded, Professor Amici [one of the Associates of the Society] … obligingly permitted the inspection of several instruments of his invention". Giovanni Battista (aka Jean Baptiste) Amici[27] was Professor of Mathematics at Modena and, from 1831, director of the observatory in Florence.

After the accustomed summer break, *Notice* No. 6 appeared in November. The first item was a paper by Baily 'On the right ascension of γ Cassiopeæ'. "As this paper is a short one, and of an interesting nature, we shall give it nearly in the words of the author". Next was M. Littrow's paper 'On double object glasses' in which he explored "refraction of a ray through four spherical surfaces, however situated". Finally, a letter from M. Sławiński was read, giving his observations, made at Wilna, of occultations and of eclipses of Jupiter's moons. Piotr Slawinski had been one of the founder members of the Society during a visit to London in 1820 and was later an Associate[1,28]. He was professor in Wilna in Poland (now Vilnius in Lithuania) from 1825 (the observatory continuing even after the Russian government closed the university) and produced a Polish-language handbook on theoretical and practical astronomy.

December's *Notice* was equally brief. There was a letter from Major Hodgson including lists of transit observations made from his house in Calcutta (Kolkota) and of eclipses of Jupiter's satellites supplied to him by "gentlemen in the civil service, and by officers of the Bengal Army". Littrow was back, too, with a contribution 'On the computation of the geocentric places of the planets for ephemerides'. After the meeting "an instrument contrived by Mr Henry Atkinson, of Newcastle-upon-Tyne, to illustrate some of the phenomena of rotation" (in particular, precession) was demonstrated to the members by Edward Riddle. Atkinson[29] had been a schoolteacher from a very early age and submitted numerous papers to the Literary and Philosophical Society of Newcastle, but his opportunities to progress as an academic were apparently hindered by him being a Dissenter (specifically, a leading Unitarian).

No. 8, in 1828 January, comprised entirely of John Herschel's 'Third Series of Observations' of double and multiple stars.

February's *Notice*, at the time of the AGM, gave the text of the Council's Report, where they noted that the main business of the year had been the successful instigation of *Monthly Notices*, themselves. A second item was the lamented death of Col. Mark Beaufoy and the donation of the instruments from his Bushy Heath observatory to the Society by his son Lieut. George Beaufoy. It was reported that three of the instruments had been loaned to Captain Smyth for his observatory at Bedford. The Council had also ordered iron and copper invariable pendulums "to be consigned to Captain Foster, for the purpose of investigating the possible effect of the earth's magnetism in various geographical positions". Finally, there was the report of the Finance Committee which showed a balance of £243 9s 3d. There were now 214 members — including His Royal Highness, the Lord High Admiral (the future William IV) — and 32 associates. Losses among the members and associates included Pierre-Simon de Laplace. Sir Thomas Brisbane and his assistant James Dunlop were awarded medals for their work at Brisbane's Paramatta Observatory. Then taking the chair, Sir James South announced that there was a third recipient of a gold medal, Caroline Herschel (the president's aunt, of course). As usual, the report ended with the list of officials elected for the following year. Additions compared to the previous year were Rev. Dionysius Lardner FRS, Rear Admiral Sir E. C. R. Owen, Rev. Richard Sheepshanks, Captain W. H. Smyth, and Edward Troughton. Lardner[30] was appointed the first professor of natural science and astronomy at University College London in 1828. He wrote numerous mathematical texts (though arguing erroneously with Brunel on several occasions) and was an enthusiastic popularizer of science. A matrimonial scandal ended his career in the UK. Sheepshanks was called to the bar in 1824 and took holy orders in 1825 but inherited sufficient wealth to forego either profession and concentrate on astronomy. He became an FRS in 1830 and was secretary of the RAS from 1829[31], subsequently becoming editor of *MN*. Using his background in the law, he acted as unofficial counsel for Troughton in his famous legal battle against South[1].

March's *Notice* included three papers. Baily again started proceedings, by summarizing predicted positions of Encke's Comet. Riddle talked 'On finding the rates of timekeepers' by observing the time between a given star reaching the same altitude on successive nights. Last was a communication from the Rev. Thomas John Hussey to Baily noting differences in star positions in different catalogues. Hussey was rector of Hayes where he built an observatory (later sold to the University of Durham) and from the 1830s to 1850s he was one of the individuals to whom observations made at the Royal Observatory were distributed by the RAS. He was one of the first to see Halley's Comet on its 1835[32] return and one of the first to consider perturbations of the orbit of Uranus in terms of a more distant planet[33]. He disappeared without trace in North Africa in 1866.

Notice No. 11 essentially covered a single paper, by Alexander Rogers, 'On the construction of large Achromatic Telescopes', in which he proposed inserting a composite lens between the object glass and its focus, so that a smaller lens would suffice, compared to making the large object glass itself composite. A resident of Leith, Rogers' only other appearance in the Society's annals (he is not in the lists of members) appears to be in 1837 when a "new telescope made by M. Plössl … was exhibited: it is called a dialytic telescope, and is formed on the principle announced by Mr Rogers". "There was also read a portion of a paper" by South on an occultation; the summary provided is actually just its title, though this does take up six lines.

The *Notice* of 1828 May saw a paper on the positions of southern double stars by Dunlop, now the head of the observatory at Paramatta. This was followed by an extract from a letter from Professor Harding to Dr. Tiarks concerning "an inequality of the dark space between the body of Saturn and its ring", the space on the east appearing larger than that on the west. South annexed a note stating that micrometer measurements which he and Herschel had made showed no variation, but agreed that by eye there did seem to be a difference. Another Paramatta contribution came from Charles Rumker, on the length of the seconds pendulum. Carl Ludwig Christian Rümker, to give him his original name, was a mathematics teacher and seaman before taking a post at Paramatta, where his work won him a silver medal of the Astronomical Society in 1822. He became Government Astronomer for New South Wales in 1826[34] and returned home as director of the Hamburger Sternwarte in 1830, publishing a catalogue of 12 000 stars. His son succeeded him as director.

In June's *Notice* Professor Struve added his observations of the space between Saturn and the ring, and Mr. Prinsep of Benares communicated an account of solar and lunar eclipses seen there in the past year. Rumker forwarded a variety of further observations including star positions and the great comet of 1825, while Curnin in Bombay communicated a further account of moon-culminating stars and his deduction of the longitude of his observatory. Finally, Baily described the invariable pendulums mentioned earlier. The rest of South's paper from April was also read.

(Friedrich Georg) Wilhelm von Struve was professor and director of the observatory at Dorpat (now Tartu, Estonia) from 1820 until appointed by the Tsar to oversee construction of the Pulkova Observatory. He was particularly noted for observing double stars and had won the Astronomical Society gold medal in 1826[35]. A son, two grandsons, two great grandsons, and a great great grandson were also astronomers[36]. The polymath James Prinsep FRS was assay master at mints in India and founding editor of the *Journal of the Asiatic Society of Bengal*. He was particularly noted for deciphering two ancient Indian scripts[37].

Resuming as usual in 1828 November, *Notice* No. 14 began with James Epps' "Tables for readily ascertaining the azimuthal deviation of a transit instrument from the meridian, by observed transits over the vertical it describes …". There was also Part 1 of a communication from Captain P. W. Grant of the Bengal Survey Department on "new and improved methods of finding the longitude" by means of portable instruments, proposing one requiring only a sextant and artificial horizon. A brief letter from the Astronomer Royal, Pond, to Herschel and a note from South described the first observations of the return of Encke's Comet.

"Although he had not the advantages of a regular education", Epps[38] authored a variety of papers in *Memoirs* and from 1830 to 1838 was the Assistant Secretary of the RAS (a salaried post — he was paid £100 per annum — unlike that of Secretary). After surveying in Nepal, Peter Grant spent time at the Cape Observatory. In 1825 he was posted to a survey of Ava in Burma (now Myanmar), which was then in a state of war, to carry out astronomical observations. He actually died from the effects of malaria in 1828 before his paper was read[39]. John Pond FRS was AR from 1811 to 1835 and modernized the Royal Observatory's instruments and practices (its then-remit was almost entirely the measurement of star positions), and increased the number of assistants from one to six. He won the Royal Society's Copley Medal in 1823[40].

The final *Notice* of 1828 began with 'Occultations of Aldebaran by the Moon, in the year 1829' calculated by Thomas Henderson and Thomas Maclear "at the request of the Council". The next paper was 'On the determination of the Constant of Aberration of Light' from observations at Greenwich by William Richardson. He obtained a value of 20″·502 and 20″·505 from the use of two different mural circles, remarkably close to the modern value of 20″·496. The last paper of the evening was another by Epps on determining, and correcting for, the inclination of the axis of transit instruments. Two presents were announced, a meridian circle from Dr. Lee and a 1771 telescope by Dollond, from Dr. Wollaston.

Henderson[41] was in the legal profession in Edinburgh at the time, but had access to the observatory on Calton Hill. In 1831 he was persuaded to take the position of His Majesty's Astronomer at the Cape Observatory, where he obtained the first measurement from which a stellar parallax could be determined, though he lost priority for this discovery as Bessel at Königsberg published his result first, ironically in *Monthly Notices*[42,43]. Henderson returned to the UK in 1833 becoming the first Astronomer Royal for Scotland the following year and also being appointed professor of astronomy at Edinburgh University. He became an FRS in 1840. Maclear, though originally from Ireland, was a surgeon in Biggleswade in Bedfordshire (elected an FRS in 1831) but following in Henderson's footsteps became Astronomer at the Cape in 1834[44], subsequently confirming Henderson's parallax of α Centauri. For several years he worked with John Herschel, who was living nearby. Instrumental in the creation of star catalogues among many other things, he was knighted in 1860 and remained at the observatory until 1870. He was acquainted with the explorers Livingstone and Stanley.

Richardson[45] had arrived at the Royal Observatory as an Assistant in 1822 and was subsequently responsible for reducing and publishing the catalogue of 7385 southern-hemisphere stars observed at Paramatta. Pond considered him the best of his Assistants, but Airy had him dismissed by the Admiralty in 1845 "under disgraceful circumstances which cannot even be hinted at" and which led to Richardson's trial for murder.

Dr. John Lee (originally Fiott) FRS of Hartwell House near Aylesbury had been 5th Wrangler, inherited the family estates in 1827, and served as a magistrate. Although publishing little himself[46], he was host at his stately home to a circle of notable astronomers (including Maclear), as described in detail by Allan Chapman[47]. He was RAS president 1861–1863. William Hyde Wollaston[48] had only been elected a member of the AS the previous month and died shortly afterwards. A physician until "an accession of fortune" allowed him to indulge his other wide-ranging interests — he discovered the new elements osmium, palladium, and rhodium and is remembered now (at least by physicists) mainly for his prism. He was RS president in 1820. He was one of 19 children of astronomer (and friend of William Herschel), the Rev. Francis Wollaston FRS, who held decidedly unconventional religious views. One of his brothers, another Francis and another FRS, was a Senior Wrangler and Jacksonian Professor of Natural Philosophy in Cambridge.

Notice 16 appeared in 1829 January. The president first read a letter from Professor Encke giving the positions of 'his' comet. This was followed by a paper by J. Lubbock 'On the determination of the distance of a Comet from the Earth'. There was also another contribution from Hodgson on longitudes of observatories in India, the Major noting that "Naval and military officers, who have more opportunities of multiplying useful observations than most any other class of men, seldom fail … to turn to good account the instructions of astronomers, when they are stated in plain language". Finally, there was another contribution from Rumker on determining the winter solstice and the obliquity of the ecliptic.

(Johann) Franz Encke FRS[49] was the first to recognize the periodic nature of the comet named after him — the first known short-period comet — an achievement which won him the Astronomical Society's gold medal in 1824. (He won it again in 1830.) He had studied under Gauss at Göttingen but served in the Prussian military in the Napoleonic wars before being appointed to a position in the observatory at Seeburg. He moved to Berlin in 1825.

John William Lubbock FRS (later Sir John, 3rd Bt.)[49] was a partner in the family banking business, as well as a barrister. He was a noted mathematician, exploring 'planetary theory' in a string of papers with ever more complex series expansions of the equations of motion. He was vice-president of the RS three times and the first vice-chancellor of the University of London. [Two of his sons played in FA Cup Finals, one of them in 1879 when Old Etonians defeated Clapham Rovers; remarkably two other players in this match were related to astronomers in this article, Mark Beaufoy's grandson and James Prinsep's great nephew.]

As always, February saw the Council Report to the AGM. They began by congratulating themselves for having provided "an ephemeris of Encke's comet to be circulated … amongst such persons, in distant parts of the world, as were likely to make good use of it". They also reported on the activities of the Finance Committee (the Society showing a profit over the year). Among 21 new members was the King's brother, the Duke of Sussex, while an obituary was provided for Wollaston. In the light of the donations from Wollaston and Lee, a committee was formed to formulate regulations for the acquisition and loan of instruments. There followed lengthy tributes to the careers of gold-medal winners, Rev. Pearson and Professors Friedrich Wilhelm Bessel[50] of Königsberg and Heinrich Christian Schumacher[51] of Altona. (In his RAS obituary, the latter's name is followed by a remarkable 21 lines of knighthoods (six), medals and fellowships.)

The list of officers for the coming year saw James South installed as president. Additions to the Council were Dr. Lee, John Lubbock, and the Right Hon. Lord Ashley. Anthony Ashley-Cooper, the grandson of the Duke of Marlborough, then still in his twenties and MP for New Woodstock[52], took a brief interest in astronomy around this time in addition to his usual biblical studies. Later the 7th Earl of Shaftesbury, he became a dedicated social reformer, particularly remembered for his efforts to limit child labour (not least through his memorial at Piccadilly Circus).

March's *Notice* 18 began with Captain Everest's somewhat tortuous paper 'On the errors likely to arise in the determination of the length of the [seconds] pendulum from a false position of the fixed axes'. Prinsep sent a description of a near-total solar eclipse observed at Benares, and Henderson provided his own observations of lunar transits and colleague John Adie's measurements of occultations from Calton Hill. The latter[53] was the son in Adie & Son, optical-instrument makers (Adie senior was optician to William IV and Queen Victoria) and was Henderson's brother-in-law. He shot himself while suffering "fits of despondency" in 1857. There were also contributions on Encke's Comet from Dunlop, back as Brisbane's assistant, but now at his new observatory at Makerstoun in Scotland, and 'On preserving the pivots of astronomical instruments' (*i.e.*, suggestions for their maintenance), by Lieut. Peter Lecount RN. The new regulations regarding instruments were appended.

Notice 19 begins with a note on a paper from M. Berenger Labaume of Marseilles, presenting a catalogue of double stars. M. Labaume, more correctly François-Jean-Baptiste Bérenger de la Baume[54], was a noted mathematician — "*calculateur intrépide et passionné*" — from a pre-revolution aristocratic family. His grandfather had been chancellor of the Academy of Sciences of Marseille. Lecount supplied a paper 'On observing the eclipses of Jupiter's satellites at sea' (a method of determining longitude), suggesting that the observer "limit his attention to the times when the vessel is at the extremity of her roll or pitch". Slawinski forwarded planetary observations from the Imperial Observatory in Wilna. Last came "a portion" of Sheepshanks' paper on a method of interpolation.

In May there were just two papers. Rumker supplied a variety of observations from Paramatta on the south polar distance of the Sun around the solstices and the determination of the mean obliquity of the ecliptic, while Baily provided a catalogue of stars observed by Flamsteed but not included in the *British Catalogue*, as originally noted by Caroline Herschel.

The following month, seven, mostly brief, communications were noted (including the postponement of the completion of Sheepshanks' paper). Gompertz added his contribution on the pendulum question, coming to similar conclusions to Everest in *Notice* 18, while Dunlop reported on a "small comet" which he had seen when in Paramatta. Olbers sent observations of Encke's Comet *via* Herschel, and Bessel wrote to Smyth, the 'Foreign Secretary', with a progress report on his star charts.

Colonel Ferdinando Visconti, who was elected as an Associate the following year, provided observations of occultations and solar eclipses made by Piazzi and Cacciatore at Palermo between 1794 and 1819. In the turbulent climate of the Risorgimento, the Sicilian Visconti suffered equally fluctuating circumstances, with four spells as a military officer, serving several masters, including the Emperor Napoleon, for whom he produced a map of Lombardy, and at least one as a political prisoner. Nevertheless, he collaborated with Captain Smyth in a survey of the Adriatic Sea and its shores between 1817 and 1820[55] and was later director of the army's topographical department in Naples.

In a letter to Charles Stokes, Captain King RN described an occultation of Jupiter and its satellites as observed from the inhospitable location "Port Famine, Straits of Magellan". Philip Parker King FRS[56], the son of a Governor of New South Wales, joined the navy as a 'first class volunteer' when he was 13, during the Napoleonic Wars. In 1817 he was sent to survey the coast of Australia, and then in 1825, was placed in command of a survey of the area around Tierra del Fuego (later contributing to Robert Fitzroy's *Narrative of a Ten Years' Voyage of Discovery round the World by H.M. Ships Adventure and Beagle*). Eventually a rear-admiral, he was a member of several learned societies but not the RAS.

Resuming in 1829 November, *Notice* No. 22 began with further occultation predictions for Aldebaran by Henderson and Maclear, followed by actual observations from numerous sites in England and France. [The interest in these occultations lay in a number of claims that the star could be seen briefly superimposed *inside* the limb of the Moon.] Professor Barlow appended some comments on "the capability of his liquid [filled] object-glass in exhibiting minute stars". Airy provided a 'method of determining the mass of the Moon from transit observations of Venus' when it was near inferior conjunction, by considering the offset of the Earth from the Earth–Moon centre of gravity. Lubbock gave an addendum to his paper on the orbit of a comet.

Peter Barlow FRS[57] was 'mathematical master' at the Royal Military Academy, Woolwich, and inventor of the eponymous lens but won the RS Copley Medal for his magnetic experiments. His two sons, one of whom assisted with his astronomical observations, became prominent civil engineers. George Biddell Airy FRS[58], senior wrangler in 1823, became Lucasian Professor of mathematics in Cambridge at the age of 25, but in 1828 was elected Plumian Professor of astronomy. He became Astronomer Royal in succession to Pond in 1835, remaining in post until 1881 and overseeing the introduction of both spectroscopy and photography at the Royal Observatory. He was RAS president four times and was knighted in 1872.

At the conclusion of business, the president, South, announced that he had acquired an object-glass of "11 inches and seven tenths clear aperture" from Cauchoix in Paris "and that Mr Troughton had undertaken the arduous task of forming with it an equatorial instrument … which, for delicate astronomical observations, will be superior to any which human ingenuity has hitherto contrived". This was the beginning of the saga that led to the infamous legal case[1].

First in December was an extract of another letter from Harding to Tiarks, this time concerning the clarity of sunspots near the limb, which appeared to require a change in focus compared to those in the centre of the disc. Gregory reported some errors in an ephemeris of Ceres, while Baron Zach supplied "Remarks on Capt. Thomson's methods and tables for working lunar observations at sea", finding that the tables were extremely accurate. Hungarian aristocrat Franz Xaver Freiherr von Zach FRS[59] was director of Gotha Observatory from 1791. Towards the end of the century he instigated the 'Celestial Police' (formally, *Vereinigten Astronomischen Gesellschaft*), whose aim was to search for the planet between Mars and Jupiter implied by Bode's Law. After marrying the widow of his patron, the Duke of Saxe-Gotha-Altenburg (Prince Albert's great grandfather), he directed an observatory at Genoa. He died in the Paris cholera epidemic of 1832. Finally, Lubbock lamented the use of different symbols for the same physical quantities by different authors.

The year 1830 began with *Notice* 24, containing four items. Schumacher's letter to Baily and Dolland's to Stratford continued the occultations of Aldebaran. Captain Basil Hall checked the accuracy with which standard instruments could determine the latitude of a known station and Dr. Robinson measured the longitude of Armagh Observatory using transits of the Moon. Rev. (John) Thomas Romney Robinson FRS[60] was director of the observatory from 1823 — while continuing as an active clergyman — until his death aged 89 in 1882. His major work was *Places of 5,345 stars observed from 1828 to 1854 at the Armagh Observatory*, and he also collaborated with Lord Rosse at Parsonstown. Mathematical physicist George Stokes (of Stokes' law, *etc.*) was his son-in-law.

February's *Notice*, as always, covered the AGM, the Council having "the pleasure to announce … the increasing prosperity, efficiency and consideration of the Astronomical Society". There were now 243 members and 34 associates. The whereabouts of instruments loaned out and the progress in cataloguing the library were noted, as was the offer of Captain Ross to make any "observations, for which his situation may be considered favourable" during his Arctic expedition (see below). The Council continued to encourage the observation of occultations of Aldebaran in order to try and "account for the anomalies which have hitherto been so perplexing". Henderson (for his computations) and Tiarks (for assistance in translating German papers) were presented with "handsomely bound" copies of *Memoirs*. Gold medals were awarded to William Richardson for his paper on aberration and to Encke for his *Ephemeris*, "the manual and standard of practical astronomy"; the usual somewhat verbose expositions of the merits of the medal winners by the President were appended.

There was also a discussion of a range of topics not directly associated with the AS: the output from and improvements to observatories around the world, plans for reconstituting the Board of Longitude, hydrography and naval exploration, particularly, "the British intrepidity" of Ross' recently begun voyage in the steamship *Victory*. [Though the expedition was successful in some respects, the ship had to be abandoned in the Arctic ice, the crew not making it back home until 1833.]

The list of Officers for the following year included four new names, Airy, De Morgan, Tiarks, and Wrottesley. Augustus De Morgan[61] had joined the Society in 1828 and was only 23 years old. He had been one of Airy's students at Trinity and 4th wrangler at the age of 20 but left the university rather than sign the religious 'test' declaring membership of the Church of England. He was instead appointed mathematics professor at the avowedly secular University of London in 1828, remaining there until 1866. The author of numerous mathematics textbooks he also wrote prolifically for literary and scientific journals. His father-in-law William Frend, a distinctly unorthodox thinker, was also an FRAS. An early member of the Society in 1820, Lord John (later 2nd Baron) Wrottesley[62] had his own observatory in Blackheath and created a star catalogue which won him the Society's gold medal in 1839. He later built another observatory at the family seat, Wrottesley Hall in Staffordshire. He was RAS president in 1841 and RS president in 1854. One of his sons, apparently also an astronomical observer, was killed serving with the Royal Artillery during the Crimean War.

March's *Notice* 26 had another letter from Harding to Tiarks on Aldebaran and a communication from Baily comparing Pond's recent star catalogue to earlier ones. The remainder was a further consideration of the question of determining longitude from occultations, by Riddle.

In No. 27 Littrow supplied measurements of planetary positions from the Imperial Observatory in Vienna and South submitted occultation observations made at his observatory in Kensington by himself, Ashley, and Stratford. Charles Perkins also wrote to the president concerning occultations. He was an RAS Fellow from 1822[63] but in 1840 a Special General Meeting proposed that three fellows including Mr Perkins "having treated with neglect the repeated applications made by the Council, agreeably to the 5th Section of the Bye-laws, for payment of the arrears due by them, and having suffered their names to be suspended in the Meeting Room as defaulters since the 12th May, 1837, be expelled from the Society". He was a merchant, with an office in Mark Lane, near the Corn Exchange in London.

The ever-practical Lieut. Lecount again wrote on pivots for transit instruments, following a visit to "M. Repsold in Hamburgh". [Sadly, Johann George Repsold, who had a remarkable dual career as astronomical instrument maker and fire brigade captain died in a fire in 1830.] Herschel contributed a paper on double stars, "the greater part of them not previously described".

In 1830 May, Captain Kater provided a paper 'On an appearance of divisions in the exterior ring of Saturn' (*i.e.*, what is now known as the A Ring). Henry Kater FRS[64] had worked on the Great Trigonometric Survey when an army officer stationed in India but was best known for his pendulum studies of gravity. He won the Copley Medal of the RS in 1817 and the RAS gold medal in 1831, though he did not become an FRAS until two years later. Maclear continued his observations of occultations, while South had observed a new comet whose discovery had been communicated to him by Gambart in Marseille. There was also a 'Notice of the performance of the 20-feet achromatic', as tested — apparently successfully — on the planets including 'Georgium Sidus'. (This was South's new telescope on a temporary stand[1].)

June's *Notice* No. 29, with eight contributions, began with 'Observations and remarks made on a passage from New South Wales to England' by Charles Rumker. He discussed the "dip of the needle", *i.e.*, the direction of the local magnetic field, as a means of determining positions at sea, as well as tides and the "weeds" in the Sargasso Sea. Next was a letter from "F. Hartmann, lieutenant of engineers", to Herschel, "describing an instrument [a theodolite] constructed for him by M. Hohnbaum, optician, of Hanover". Friedrich Hartmann was a German military geodesist and cartographer. Another practical contribution came from M. Kreil, 'On the rectification and use of the equatorial'. Karl Kreil[65] was assistant to Littrow at the Vienna Observatory, later moving to Milan and Prague and returning to Vienna as head of the Central Meteorological and Magnetic Bureau. This was followed by a submission from Littrow himself, 'On Barlow's new telescopes' (see above). Mr. Hubert wrote to the president concerning magnetic effects on pendulum experiments. Henry Hubert was an official of the Rock Life Assurance Company[66]. Next, Baily discussed 'Meyer's celebrated Catalogue of Zodiacal Stars' and Romney Robinson noted his observations of Venus for the purpose of determining the distance of the Moon, following Airy's suggestion (above).

Finally, there were two memoirs by "Don José Joachim de Ferrar" on observations, mainly of occultations, eclipses and planetary satellites, that he had made at "Havanna" between 1808 and 1812. José Joaquín de Ferrer y Cafranga[67] was a Basque astronomer — previously in the Spanish navy and captured by the British in 1780 — who joined perhaps the earliest solar eclipse expeditions, to Cuba in 1803 and New York State in 1806, and is credited with coining the term 'corona'. As de Ferrer had died in 1818, it is not clear how the AS came by his observations; in all, ten collections appeared in *Memoirs* over the years, the first, read in 1824, being communicated by Colebrooke[68].

The first two contributions in November were further occultation predictions by Maclear and Henderson and a comment by Gompertz on Kreil's paper (above). Robert Treat Paine provided 'Occultations observed at Boston, Massachusetts'. A prominent lawyer, Paine[69] was the grandson of the signatory of the Declaration of Independence of the same name. He supplied the astronomical sections of the *American Almanac* for many years and was an avid observer of solar eclipses. W. R. Birt contributed 'Observations of the period of β Lyrae' (found to be variable by Goodricke in 1784). William Radcliff Birt[70] was later employed by Herschel to reduce and arrange meteorological data and wrote a book about storms. He joined the RAS in 1859 and became best known for his maps of the Moon. Finally, there was a paper by the late Mr. Henry Atkinson on refraction caused by "fluctuations of the state of the atmosphere near the surface of the earth".

In 1830 December's *Notice* No. 31, there were three fairly short communications and one lengthy paper. Pond discussed 'a Method of Determining the Declination of Stars with one Mural circle'. Captain King reported the discovery of a comet near the south pole by his colleague (and brother-in-law) Lieut. Wickham of HMS *Adventure*, and further observations of the comet, by Professor Dabadie in Mauritius, were supplied to Baily *via* Sir Alexander Johnston (vice-president of the Royal Asiatic Society, of which Dabadie was a Corresponding Member). John Clements Wickham RN[71] subsequently sailed with Fitzroy and King on the *Beagle*'s circumnavigation of the world with Charles Darwin. He was later a government official in New South Wales and was given a Galapagos tortoise by Darwin which lived until 2006. Dabadie was professor of mathematics and Astronomer to the Royal College of Port Louis, but according to a later search of the records, the actual discoverer of the comet was a young Frenchman named Faraguet[72]. Brisbane contributed further occultations and the final paper of the year was 'An Account of a Private Observatory, erected at Bedford, by Capt. W. H. Smyth, R.N.', which was precisely what it said in the title, carefully describing each of his instruments.

"This Number terminates the First Volume of the Monthly Notices."

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REDISCUSSION OF ECLIPSING BINARIES. PAPER 13: THE F-TYPE TWIN SYSTEM IT CASSIOPEIAE

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IT Cas is a detached eclipsing binary system containing two F3 V stars in an orbit of period 3·90 d and eccentricity 0·089. Light-curves are available from three sectors of observations from the *Transiting Exoplanet Survey Satellite* (*TESS*), and extensive radial-velocity measurements have been published by Lacy *et al.*[1]. We model these data using the JKTEBOP code to determine the physical properties of the system. We find masses of 1·324 ± 0·009 and 1·322 ± 0·008 $M_{\odot}$, and radii of 1·555 ± 0·004 and 1·551 ± 0·005 $R_{\odot}$. The two stars are identical to within the uncertainties, and the depths of the primary and secondary eclipses are also indistinguishable. Using the effective temperature of 6740 ± 105 K from Lacy *et al.* (for both stars) gives a distance to the system of 505·5 ± 8·3 pc, in good agreement with the value of 515·0 ± 4·4 pc from the *Gaia* DR3 parallax. The properties of the stars are consistent with theoretical predictions for a solar chemical composition and an age of 2 Gyr. No pulsations are apparent in the *TESS* photometry.

Introduction

We are currently pursuing a project to determine precise and accurate masses and radii for detached eclipsing binaries (dEBs) for which high-quality spectroscopic orbits and new light-curves from the *Transiting Exoplanet Survey Satellite* (*TESS*) are available[2]. The immediate aims of the project are to use the new *TESS* data to improve the measurements of the properties of dEBs that are already in the *Detached Eclipsing Binary Catalogue* (*DEBCat**, ref. 3), and to add new dEBs to this catalogue. The longer-term aims are to use dEBs to

* https://www.astro.keele.ac.uk/jkt/debcat/

TABLE I

Basic information on IT Cas

Property	*Value*	*Reference*
Right ascension (J2000)	$23^h\ 42^m\ 01^s{\cdot}38$	27
Declination (J2000)	$+51^\circ\ 44'\ 36''{\cdot}8$	27
Tycho designation	TYC 3650-959-1	28
Gaia DR3 designation	1944868020357285504	27
Gaia EDR3 parallax	1·9419 ± 0·0165 mas	27
TESS Input Catalog designation	TIC 26801525	29
U magnitude	11·631 ± 0·020	30
B magnitude	11·640 ± 0·013	30
V magnitude	11·152 ± 0·010	30
J magnitude	10·212 ± 0·020	31
H magnitude	9·957 ± 0·021	31
K_s magnitude	9·915 ± 0·016	31
Spectral type	F3 V + F3 V	This work

improve our understanding of stellar physics and to help calibrate theoretical evolutionary models[4,5].

The availability of high-quality light-curves from space missions such as *CoRoT*[6], *Kepler*[7], and *TESS*[8] has revolutionized many areas of stellar physics[9,10]. Their effect has been keenly felt for binary stars[11–13], with light-curves of a quality unachievable from the ground now available for thousands of dEBs[14–16], of which many have an extensive observational history.

One of this number is IT Cassiopeiae (Table I), an F-type dEB which has been observed using *TESS* and for which high-quality radial-velocity (RV) measurements have been published. IT Cas was discovered by Fadeeva using photographic plates from Moscow[17,18]. Photometric analyses have been carried out by several authors since then[18–23]. The system has a small orbital eccentricity and exhibits apsidal motion[18,23–25] with a period of $U = 877 \pm 78$ yr[25].

Lacy[26] obtained high-resolution spectra which showed the system to be double-lined, with both components having narrow spectral lines indicative of low rotational velocity. Lacy *et al.*[1] (hereafter L97) subsequently presented extensive new spectroscopy and photometry from which they determined the physical properties of the system; these include the only mass and radius measurements published so far. The available light-curves had poor coverage of the first and last contact points of the eclipses. In this work we use a space-based light-curve and the radial velocities (RVs) of L97 to obtain improved measurements of the physical properties of IT Cas.

Khaliullin & Kozyreva[18] detected periodic variability in their light-curve of a secondary eclipse, and deduced that the primary component was a δ Scuti pulsator. Holmgren & Wolf[23] detected periodic variability in their light-curve of a *primary* eclipse, and deduced that the *secondary* component was a δ Scuti pulsator. Lacy *et al.*[1] did not confirm either variation and suggested that they were erroneous. Our own analysis below finds no evidence for short-period variability. Kozyreva *et al.*[24] found slow variations in the brightness of IT Cas with a time-scale of about one month. They found them to occur independent of the choice of comparison star so attributed them to the dEB.

Observational material

The *TESS* mission[8] observed IT Cas in sectors 17 (2019/10/07 to 2019/11/02), 24 (2020/04/16 to 2020/05/13), and 57 (2022/09/30 to 2022/10/29). All three sectors were observed in short-cadence mode with a 120-s sampling rate.

The simple aperture photometry (SAP) and pre-search-data-conditioning SAP (PDCSAP) data[32] are almost indistinguishable, so we used the SAP data in our analysis for consistency with previous papers in this series. The eclipses in the PDC light-curves are approximately 0·05 mag deeper than in the SAP light-curves, indicating that the PDC data have been corrected for contaminating light. We prefer to model the SAP data and fit for third light, on the grounds that it is better to adjust the model to match the data than adjust the data to match the model.

The reduced data were downloaded from the MAST archive* and converted from flux units to relative magnitude. We required a QUALITY flag of zero, which yielded 12 942 of the 18 012 data points from sector 17, 16 309 of 19 074 from sector 24, and 17 990 of 20 712 from sector 57. We further trimmed the data from sector 24 to remove parts of the light-curve associated with incompletely-observed eclipses, leaving 14 459 data points for further analysis (Fig. 1).

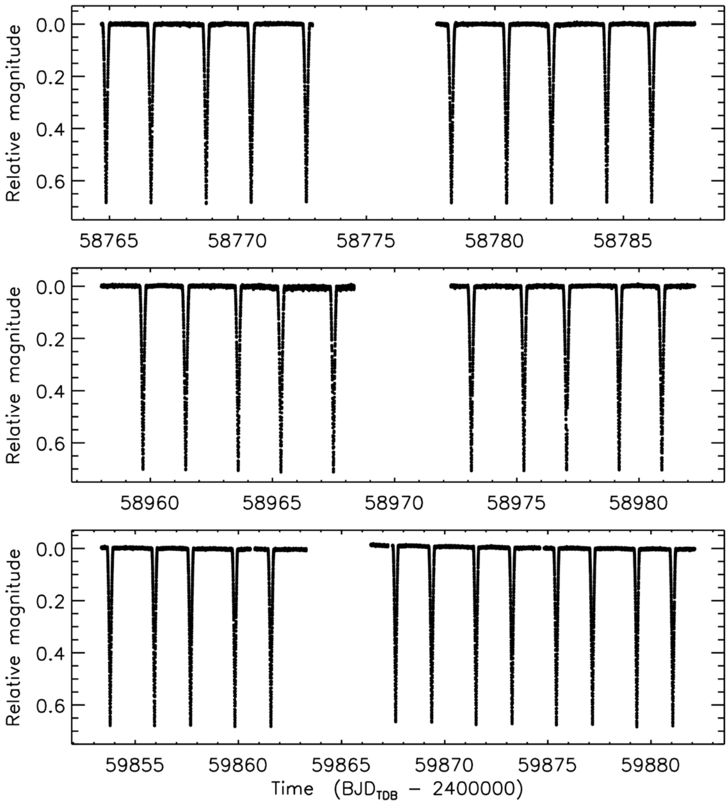

FIG. 1

TESS short-cadence SAP photometry of IT Cas from sectors 17 (top), 24 (middle), and 57 (bottom). The flux measurements have been converted to magnitude units then rectified to zero magnitude by the subtraction of quadratic functions.

*Mikulski Archive for Space Telescopes, https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html

We did not use the errors provided with the data points as they are too small. We preferred instead to determine the precision of the photometry from the scatter around the best-fitting model.

We queried the *Gaia* DR3 database* in the region of IT Cas. A total of 146 additional sources are listed within 2 arcmin — the constellation of Cassiopeia is close to the Galactic plane so has a relatively high surface density of point sources. The brightest of these is fainter than IT Cas by 4·31 mag in the G_{RP} passband (a light ratio of 1·9%). This implies that there is a small but significant amount of contaminating light in the *TESS* data which must be accounted for in the light-curve analysis.

Light-curve analysis

Inspection of the SAP light-curves showed that the eclipse depths vary between the three *TESS* sectors. The primary eclipses are approximately 0·685 mag deep in sectors 17 and 57, and 0·705 mag deep in sector 24. The secondary eclipses show exactly the same behaviour. Apsidal motion is unlikely to cause this since the apsidal period is too long and the eclipse depths do not vary in antiphase. The probable explanation is that the different spacecraft orientations in the three sectors, combined with the relatively large 21″ pixel size, means that the amount of contaminating light changes. The three light-curves should therefore be fitted separately.

The light-curves from the three sectors were each modelled using version 43 of the JKTEBOP† code[33,34]. The parameters of the fit included the fractional radii of the stars, expressed as their sum ($r_A + r_B$) and ratio ($k = r_B/r_A$), the orbital inclination (i), the central-surface-brightness ratio (J), the amount of contaminating light (L_3), and the coefficients of the reflection effect. The orbital eccentricity (e) and argument of periastron (ω) were included using the Poincaré elements ($e\cos\omega$ and $e\sin\omega$). The secondary eclipse was found to occur at orbital phase 0·552.

Following the results from Southworth[35] we included limb darkening using the power-2 law[36] and the reparameterization into h_1 and h_2 given by Maxted[37]. The two stars are almost identical so we forced them to have the same limb-darkening coefficients, and fitted for both coefficients.

IT Cas exhibits slow apsidal motion, but a full analysis is beyond the scope of the current work. We therefore determined an orbital ephemeris separately for each *TESS* sector and did not interpret them further. The primary and secondary eclipses are of practically indistinguishable depth and we cannot confidently decide which is which. This contrasts with a similar situation we found for ZZ Boo[38] where the *TESS* data definitively determined — for the first time — which of the two types of eclipses was deeper and thus by definition the primary. In the case of IT Cas the eclipse depths are even more similar and also will change over the apsidal period as ω cycles round. We therefore adopted the same convention for eclipse identifications as L97. We refer to the star eclipsed at phase 0·0 as star A and to its companion as star B.

The best fits to the eclipse light-curves are shown in Figs. 2, 3, and 4. Their parameters are given in Table II. Uncertainties in the parameters were determined using both Monte Carlo and residual-permutation simulations as implemented in JKTEBOP[39,40], the two alternatives being in close agreement for all parameters. The consistency between sectors is high, with the values for all

*https://vizier.cds.unistra.fr/viz-bin/VizieR-3?-source=I/355/gaiadr3

†http://www.astro.keele.ac.uk/jkt/codes/jktebop.html

TABLE II

Adopted parameters of IT Cas measured from the TESS light-curves using the JKTEBOP code. The uncertainties are 1σ and were determined using Monte Carlo and residual-permutation simulations.

Parameter	*Sector 17*	*Sector 24*	*Sector 57*	*Adopted*
Fitted parameters:				
Time of primary eclipse (BJD_{TDB})	58778·308750 ± 0·000013	58973·141188 ± 0·000017	59869·370277 ± 0·000015	
Orbital period (d)	3·896644 ± 0·000005	3·896638 ± 0·000008	3·896646 ± 0·000005	
Orbital inclination (°)	89·714 ± 0·015	89·679 ± 0·022	89·727 ± 0·017	89·707 ± 0·018
Sum of the fractional radii	0·21568 ± 0·00014	0·21535 ± 0·00023	0·21558 ± 0·00024	0·21554 ± 0·00020
Ratio of the radii	0·9986 ± 0·0021	0·9944 ± 0·0035	0·9942 ± 0·0050	0·9957 ± 0·0035
$e \cos \omega$	0·080838 ± 0·000007	0·080877 ± 0·000010	0·081059 ± 0·000033	0·08092 ± 0·00012
$e \sin \omega$	−0·03644 ± 0·00032	−0·03662 ± 0·00039	−0·03624 ± 0·00099	−0·03643 ± 0·00057
Central-surface-brightness ratio	0·99963 ± 0·00054	0·99995 ± 0·00083	1·00112 ± 0·00086	1·00023 ± 0·00074
Third light	0·0481 ± 0·0030	0·0222 ± 0·0044	0·0536 ± 0·0096	
LD coefficient c	0·602 ± 0·075	0·540 ± 0·038	0·595 ± 0·020	0·579 ± 0·044
LD coefficient α	0·50 (fixed)	0·50 (fixed)	0·50 (fixed)	
Derived parameters:				
Fractional radius of star A	0·10791 ± 0·00013	0·10798 ± 0·00020	0·10782 ± 0·00030	0·10790 ± 0·00021
Fractional radius of star B	0·10777 ± 0·00014	0·10737 ± 0·00024	0·10776 ± 0·00029	0·10763 ± 0·00022
Eccentricity	0·08867 ± 0·00013	0·08878 ± 0·00015	0·08879 ± 0·00040	0·08875 ± 0·00023
Argument of periastron (°)	335·74 ± 0·19	335·64 ± 0·23	335·91 ± 0·60	335·76 ± 0·34
Light ratio ℓ_B/ℓ_A	0·9969 ± 0·0038	0·9887 ± 0·0062	1·0000 ± 0·0085	0·9952 ± 0·0062

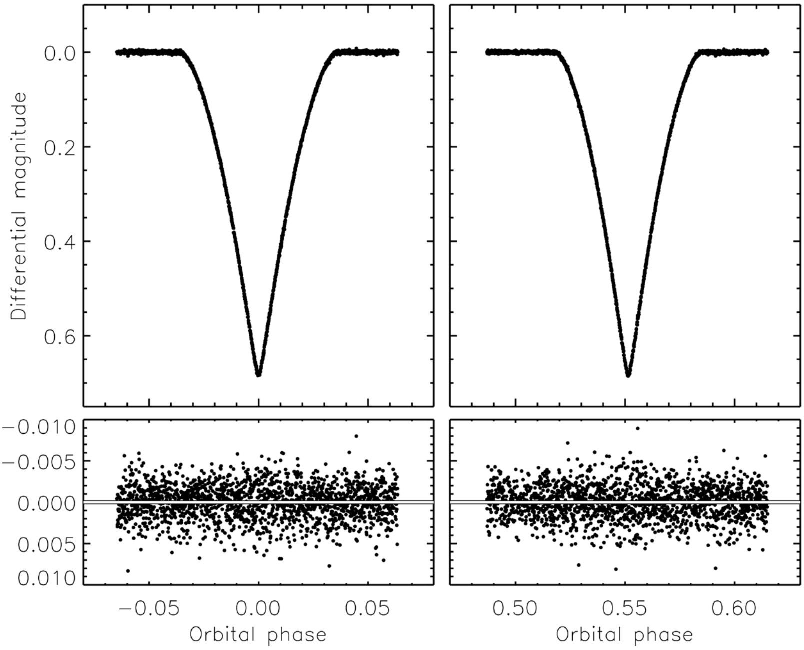

FIG. 2

Best fit to the *TESS* sector 17 light-curve of IT Cas using JKTEBOP for the primary (left) and secondary (right) eclipses. The residuals are shown on an enlarged scale in the lower panels.

but two parameters being in good agreement. Given this and the very small error bars, we adopted the straight mean of the values for each parameter. We did the same for the error bars, foregoing the division by $\sqrt{3}$ to convert to standard error. The values of L_3 are not in good agreement, as was expected given the change in eclipse depths between sectors. The disagreement in $e \cos \omega$ is stronger (reduced $\chi^2 = 49$) and remains unexplained: we have multiplied the final error bar in this quantity by a factor of seven to account for the discrepancy.

Radial velocities

We are aware of only one published spectroscopic study of IT Cas: that of L97. We copied the RVs from that work and fitted them ourselves to confirm the results. Error bars were assigned to the two different sources of RVs ('CHSL' and 'CfA') according to the standard errors given in Table 10 of L97, and were subsequently adjusted by a small amount to force $\chi^2_\nu = 1{\cdot}0$. A solution to the RVs was obtained with JKTEBOP, fitting for the velocity amplitudes (K_A and K_B) and systemic velocities ($V_{\gamma,A}$ and $V_{\gamma,B}$) of the two stars, and the reference time of mid-eclipse. The quantities $e \cos \omega$ and $e \sin \omega$ were fixed to the values given in Table II — an alternative solution with these parameters fitted returned values of K_A and K_B larger by an insignificant 0·05 km s^{-1}.

Uncertainties were determined using Monte Carlo simulations[41] and found to be slightly larger than the formal errors from the covariance matrix. Our results are: $K_A = 93{\cdot}85 \pm 0{\cdot}24$ km s^{-1}, $K_B = 94{\cdot}03 \pm 0{\cdot}31$ km s^{-1}, $V_{\gamma,A} = -38{\cdot}16 \pm 0{\cdot}18$ km s^{-1}

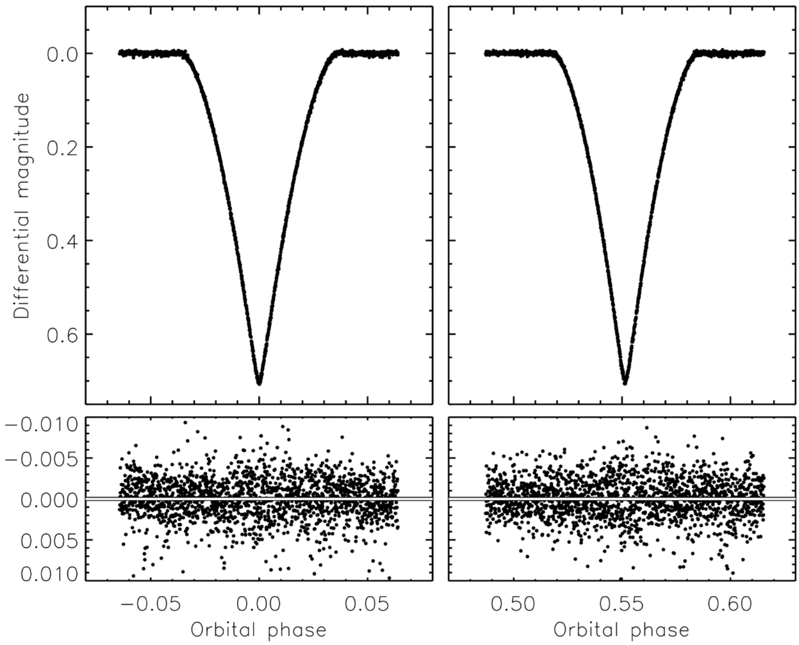

FIG. 3
Same as Fig. 2 but for the *TESS* data from sector 24.

and $V_{\gamma,B} = -37{\cdot}94 \pm 0{\cdot}24$ km s^{-1}. These agree very well with the value from L97, the main difference in the two analyses being our use of newer and more precise $e\cos\omega$ and $e\sin\omega$ values. A plot of the spectroscopic orbits is given in Fig. 5.

Search for pulsations

Previous studies of IT Cas have claimed the detection of δ Scuti pulsations in either star A[18] or star B[23], but their presence was not confirmed (L97). Pulsations in dEBs are widespread[42–44] and are important laboratories for stellar physics[45–47]. The components of IT Cas have $T_{\rm eff}$s and masses within the lower half of the δ Scuti instability strip[48,49]. We therefore searched for pulsations in the *TESS* light-curve of this system.

This was done by performing a frequency analysis on the residuals of the best fit to the full light-curves from the three *TESS* sectors individually, covering frequencies from 0 to 100 d^{-1}. The sectors were not combined as this would have led to strong aliasing effects. We find no evidence for pulsations within the frequency range considered, to a 3σ upper limit of 0·10 mmag. Although δ Scuti stars do show variations in pulsation amplitude, the likely explanation is that the features seen in the older light-curves of IT Cas are red noise rather than of astrophysical origin.

Kozyreva *et al.*[24] found slow variations in the brightness of IT Cas on a monthly time-scale. The *TESS* data are not well suited to the detection of periodicity on such long time-scales, so we did not investigate this possibility further.

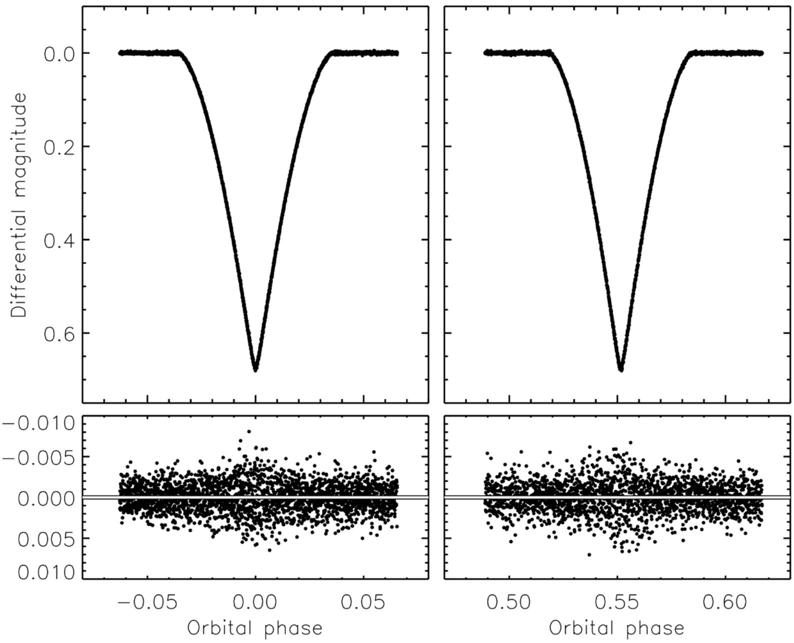

FIG. 4
Same as Fig. 2 but for the *TESS* data from sector 57.

TABLE III

Physical properties of IT Cas defined using the nominal solar units given by IAU 2015 Resolution B3 (ref. 50).

Parameter	*Star A*	*Star B*
Mass ratio M_B/M_A	0·9981 ± 0·0042	
Semi-major axis of relative orbit ($\mathcal{R}^N_\odot$)	14·414 ± 0·030	
Mass ($\mathcal{M}^N_\odot$)	1·3244 ± 0·0094	1·3218 ± 0·0080
Radius ($\mathcal{R}^N_\odot$)	1·5552 ± 0·0044	1·5513 ± 0·0045
Surface gravity (log[cgs])	4·1765 ± 0·0022	4·1778 ± 0·0021
Density ($\rho_\odot$)	0·3521 ± 0·0022	0·3540 ± 0·0023
Synchronous rotational velocity (km s^{-1})	20·19 ± 0·06	20·14 ± 0·06
Effective temperature (K)	6740 ± 105	6740 ± 105
Luminosity log($L/\mathcal{L}^N_\odot$)	0·653 ± 0·027	0·651 ± 0·027
M_{bol} (mag)	3·108 ± 0·068	3·113 ± 0·068
Distance (pc)	505·0 ± 8·3	

Physical properties of IT Cas

The physical properties of IT Cas were determined using the JKTABSDIM code[51], the measured values of r_A, r_B, i, P, and e from Table II, and the K_A and K_B from above. The results are given in Table III, where the error bars have been propagated from all input parameters using a perturbation approach. The uncertainties on the radii of the stars are 0·3%, which is slightly greater than the

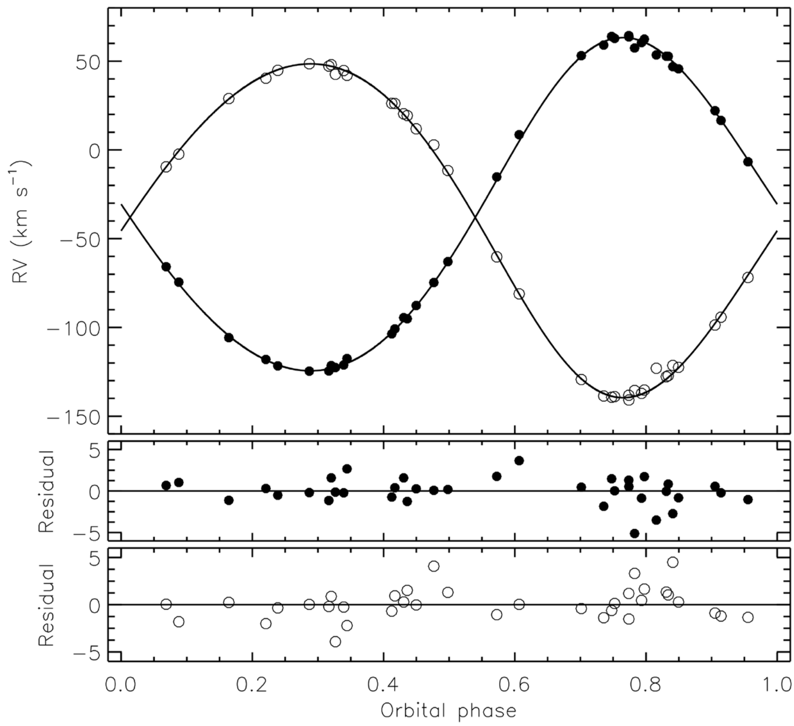

FIG. 5

RVs of IT Cas from L97 (filled circles for star A and open circles for star B) compared to the best-fitting spectroscopic orbits from our own analysis using JKTEBOP (solid curves). The residuals are given in the lower panels separately for the two components.

lower limit of 0·2% to which results are expected to be reliable[52]. The largest source of uncertainty for both the masses and radii of the stars is the uncertainty in the velocity amplitudes, thanks to the high quality of the *TESS* light-curve. The two stars are identical to within the error bars, with differences in mass of 0·3 ± 1·2% and in radius of 0·5 ± 0·6%. The agreement between our results and those of L97 is good but slightly less than expected given the error bars.

L97 gave a $T_{\rm eff}$ value for both stars of 6740 ± 105 K, somewhat larger than the values of 6579 ± 135 K in the *TESS Input Catalog* (TICv8[29]) and 6330 ± 8 K in *Gaia* DR3. To check this we determined the distance to the system using the JKTABSDIM code, the *UBV* magnitudes from Lacy[30], the JHK_s magnitudes from 2MASS[31] converted to the Johnson system using the transformations from Carpenter[53], an interstellar reddening of $E(B–V) = 0·083 ± 0·056$ mag from the STILISM* on-line tool[54,55], and the surface brightness *versus* $T_{\rm eff}$ relations

*https://stilism.obspm.fr

from Kervella *et al.*[56]. This yielded 505·5 ± 8·3 pc, which compares well with the 515·0 ± 4·4 pc from simple inversion of the parallax of the system from *Gaia* DR3. The lower $T_{\rm eff}$ from TICv8 is ruled out to 2σ, and the *Gaia* DR3 $T_{\rm eff}$ to higher confidence. Based on this, we accept the $T_{\rm eff}$ from L97 as suitable for both stars.

The adopted $T_{\rm eff}$ value corresponds to a spectral class of F3 on the scale of Pecaut & Mamajek[57]. We therefore infer a spectral type of the system of F3 V + F3 V. This is somewhat earlier than the F5 mentioned by L97 and the F6 given by *Simbad** (without reference). This spectral type was arrived at from the $T_{\rm eff}$ and evolutionary stage of the stars, and is not a true spectral classification.

Summary and conclusions

IT Cas is a dEB containing two F3 V stars on a 3·90-d orbit with a small orbital eccentricity. The two stars are identical in mass, radius, and $T_{\rm eff}$ to within the uncertainties. *TESS* observed the system during three sectors covering approximately 3 yr, giving light-curves of very high quality. We have modelled those data using the JKTEBOP code to determine the photometric properties of the system. We also analysed the RVs of IT Cas published by L97, finding results in good agreement with that work. From the measured parameters we have calculated the physical properties of the system (Table II) to precisions of 0·6% in mass and 0·3% in radius. The $T_{\rm eff}$s found by L97 yield a distance measurement in full agreement with the parallax from *Gaia* DR3. We searched for and found no evidence for pulsations in the light-curve.

As a sanity check we have compared the masses, radii, and $T_{\rm eff}$s of the stars to predictions from the PARSEC stellar-evolutionary models[58]. A fractional metal abundance by mass of $Z = 0{\cdot}014$ and an age of 2·0 ± 0·1 Gyr provide a good match to the measured properties. IT Cas is now a well-understood dEB, but would benefit from high-resolution spectroscopy for the measurement of its photospheric chemical composition and more precise $T_{\rm eff}$ values. The system shows apsidal motion, and the measured apsidal period would be a useful addition to a detailed comparison between the properties of IT Cas and theoretical predictions.

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CORRESPONDENCE

To the Editors of 'The Observatory'

Increasing Crescents

As etymology is one of my hobbies, my interest was piqued when, in a recent book review[1], Trimble pointed out that in some contexts it is necessary to specify that a crescent Moon refers to the waxing crescent. Originally, that would have been a tautology, as 'crescent' (cognate with 'increase' and the Italian 'crescendo' meaning increasingly louder music) means 'growing'. However, in modern English the term refers only to the shape. The corresponding French term, croissant, is also used to refer to the shape, be it that of the Moon or of a pastry, but also retains the meaning 'growing' or 'expanding', as cosmologists should know from the title of a famous paper[2] ('*Un Univers homogène de masse constante et de rayon croissant rendant compte de la vitesse radiale des nébuleuses extra-galactiques*') later translated into English[3] ('A homogeneous universe of constant mass and increasing radius accounting for the radial velocity of extra-galactic nebulæ'). Of course, the illuminated area of the Moon as seen from Earth increases also during the second quarter, but as far as I know 'crescent' has been used to refer only to the first and last quarters; the fact that the illuminated area is decreasing during the last quarter shows the extent to which the meaning referring to shape has completely taken over. The terms 'waxing' and 'waning' refer to increase and decrease during both corresponding quarters in each case. 'Wax' is cognate with German '*wachsen*', which is the normal word for 'grow' — though interestingly not used in reference to the phases of the Moon ('*zunehmend*' and '*abnehmend*', the normal words for 'increasing' and 'decreasing', correspond to 'waxing' and 'waning', respectively) — but in modern English is used almost only with reference to the Moon or in a figurative sense (*e.g.*, 'to wax poetic'). A crescent Moon in German is referred to as a *Sichel* due to the similarity of the shape to an agricultural tool; the English cognate 'sickle' is sometimes used to refer to the crescent Moon.

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REVIEWS

Astronomers as Diplomats: When the IAU Builds Bridges Between Nations, edited by Thierry Montmerle and Danielle Fauque (Springer), 2022. Pp. 551, 23 × 15 cm. Price £109·99 (hardbound; ISBN 978 3 030 98624 7).

If you want to catalogue the whole sky, you will need either collaborators at other latitudes or serious hiking boots. If you want to follow the time behaviour of astronomical sources, you will need collaborators at other longitudes. And if you desire to measure geocentric parallax or to time the transits of Venus, you will need collaborators at the four corners of a spherical quadrilateral. Nothing very similar seems to apply to carrying out practical work in chemistry, physics, or microbiology (though there are geosciences that require your collaborators to fly, swim, and dig, while serious anthropologists are sometimes required to eat things not on mothers' menus).

It is also true that the structure of the International Astronomical Union has developed along paths quite different from those of most of the other such Unions established in the wake of World War I. The norm is national members represented by national committees and sub-disciplinary commissions with a few dozen members. In contrast, the IAU also has individual, ordinary members, 10 000 of them at last count. Are the unique requirements of astronomy responsible for the unique structure of the IAU? I don't know, and this is not an issue addressed by the present volume.

The book is an expansion of what was originally intended as conference proceedings from a colloquium on 'Astronomers as Diplomats', held in Paris in 2019 October, following the official centenary General Assembly in Vienna in 2018, with a Centenary Symposium. The Colloquium Proceedings idea in turn grew, with the addition of chapters by other people and other chapters by some of the same people to address four main territories: 'Founding of the IAU'; 'Events after World War II including Divided Countries'; 'The IAU During and After the Cold War', and 'Interactions with the United Nations and UNESCO'.

Many fascinating things are to be found within, but I had my first "Hey! Wait a minute!" moment on page *vii* of the preface where the reader is told that "The Treaty of Versailles, signed on June 28, 1919, bearing the seeds of future conflicts because of the harsh conditions imposed on Germany and its absence at Versailles." My copy of the Traité de Paix signed at Versailles says on page 17 that it was signed for Germany by "Mr. Hermann Müller, Minister for Foreign Affairs of the Empire and Dr. Bell, Minister of the Empire Acting in the name of the German Empire and of each and every component State."* L'Allemagne (the Treaty is fully bilingual, French on left pages, English on the right) may not have been a happy camper, but they were there. Russia, having pulled out of WWI early in order to have its own revolution, was not. Other, later, treaties dealt with issues primarily concerning the Austro-Hungarian Empire, the Ottoman Empire, and so forth.

The section on founding the IAU begins with chapters on the Carte du Ciel and the (Paris) Bureau International de l'Heure, but no discussion of some other pre-IAU efforts at international astronomical collaborations like Baron von Zach's Celestial Police and expeditions to time the 19th-Century transits of Venus. Striking, if not encountered before, is the extent to which Einstein was

*Mr. Müller and Dr. Bell were not the highest-profile signers. That dubious honour belongs to US President Woodrow Wilson, UK Prime Minister David Lloyd George, and the first of the signers for Poland, Mr. Ignace J. Paderewski, President of the Council of Ministers. A few other names ring bells: Botha and Smuts for South Africa, Georges Clemenceau for the French Republic, and Eduard Benes for the Czecho-Slovak Republic.

initially perceived as a German theorist, hence no RAS Gold Medal in 1920*, while soon after he was mostly described as a Jewish theorist.

Between the wars, neutral countries were soon admitted to the International Research Council and its dependent Unions, for the IAU most profitably the Netherlands. Germany was invited (initially as individual scientists to the Leiden 1928 IAU General Assembly) but adheres only in Section II "After WWII: Divided Countries".

The three divided countries are considered in detail. First, Korea, where there had been serious astronomical observations (sunspots, comets, guest stars, eclipses) up until the Japanese invasion in 1910. By the time science was reviving, North and South were separate nations and adhered separately to the IAU (South from 1973, North from 1961). And so they remain.

Germany between the wars did not apply for IAU national membership, partly perhaps for financial reasons, and partly perhaps out of some feeling that the Astronomische Gesellschaft was all the international organization they needed (and anyhow, why should the nation that had been at the forefront of astronomy in 1914 have to beg others for acceptance). They joined in 1951 with a single adhering organization (the AG); transitioned to separate memberships, East and West in 1962, and re-assembled when the countries did in 1990, with a brief kerfuffle over whether unified Germany should pay just the dues that the West had paid before, or the sum of the previous East plus West dues. The former being accepted, the relevant chapter notes "all the other countries had then to pay (at least indirectly) for German reunification!"

The Chinese case is the most complex, appearing in five chapters, the last devoted to astronomy in Taiwan. "Story" is probably too mild a word, but the "Divorce, Separation and Reconciliation (1958–1982)" has been described in a separate volume, *China and the International Astronomical Union* by Thierry Montmerle and Yi Zhou (Springer, 2022), which I should probably not review, having committed a prologue. The solution, which has now held for about 40 years, is a single member nation, with two adhering organizations, one in Nanking, one in Taipei.

The inverse problem, when a single adhering nation divides up (USSR into 15 countries, Czechoslovakia into two, and Yugoslavia into four or five), does not appear in the present volume, but the IAU choice has been automatic admission to each and every component part if it asks and can pay reasonable dues.

Given that 2009 was duly declared the International Year of Astronomy (following an initiative headed by IAU President Franco Pacini and others) one might expect the volume to end in sweetness and light. But there was at least one more shadow, described here for the first time. Starting in 1971, a UN working group on geographical nomenclature tried to take over the naming of features on the Moon from a previously existing working group of the IAU Commission on the Moon. The IAU fought back, and in 1982 the same authority, A. M. Komkov (Vice-President of the UN Group of experts on Geographic Names) wrote again, reporting a UN Resolution (13, somehow fitting!) declaring that the naming of extraterrestrial features is done in a satisfactory manner by the Working Group for Planetary System Nomenclature of the IAU, and that the UN Working Group on Extraterrestrial Features of the United Nation Group of Experts on Geographical Names should be dissolved. We won that one, although even astronomers sometimes dispute the IAU authority, as in the case of Pluto as a dwarf planet.

*The 1926 RAS Gold went to Einstein. Of the other 1920 candidates, Henry Norris Russell was duly gilded in 1921 and Annie J. Cannon never, leaving a gender gap from Caroline Herschel in 1928 to Vera Rubin in 1996.

One more territory I could wish the editors had explored has been the role of astronomers in helping their own in difficult times. Harlow Shapley offered hospitality at Harvard to Richard Prager (1883–1945) and Luigo Jacchia (1910–1996) when they had to leave Nazified territories. And the Observatoire de Haute Provence sheltered Evry Schatzman and David Belorizky (French Jewish astronomers) and their families in the early 1940s, when much of France was under various forms of German control. Belorizky's son, who just barely remembers that period, has written his family history (of which I have a copy) and would, I think, be glad to have it published. By the time the IAU learned what was happening to Gerasimovich and Numerov in the USSR, it was apparently too late to do anything.

Is there some logical conclusion to be drawn from the history presented in this volume? My own take is that the world astronomical community has been reasonably successful at holding itself together under sometimes very difficult circumstances, using skills that can often be described as diplomatic (but also sometimes as what some of our fighting men would call "main strength and awkwardness"). How this will play out for the Ukrainian astronomical community is yet to be seen. — Virginia Trimble.

The Sky Is for Everyone: Women Astronomers in Their Own Words, edited by Virginia Trimble & David A. Weintraub (Princeton University Press), 2022. Pp. 472, 24·5 × 16·5 cm. Price £25/$29·95 (hardbound; ISBN 978 0 691 20710 0).

[The Editors felt that a second review of this important book would be of interest to the readership.]

As summarized already by Pasachoff in these pages (**142**, 303, 2022), this book is comprised of essays by forty or so women astronomers who tell their own personal stories of entry into, and achievements in, the field of professional astronomy, describing but not over-emphasizing the difficulties encountered or negative experiences that challenged them *en route*. The intended take-home message is one of positive achievement, of survival despite the odds — odds that seemed to lessen with increasing seniority. The essays are succinct, well-written, and interesting. Their message is helpful, and also necessary.

But the book has a grave weakness. Is the sky for everyone? No it's not, not in my experience or that of the unnamed silent majority whose stories do not feature here. The gap between those who made it and those who did not is, if anything, exacerbated by a collection such as this *under such a title*. Many of those who fell by the wayside were merely unlucky — in the right place but at the wrong time (or the converse), passed over because of the parallel presence of a tenured spouse, isolated through some inimical attitude of a 'queen bee', or denied access through needing to care for ailing parents or offspring. These cases are far more in number than forty, and are the realities of whom there is no record and who are now lost to memory, but their existence still sways the statistics that count how many of the promising young women from the student years did not feature later on university or institute staff. And what of the many young men whose footholds on the career ladder proved to be too shaky for survival? Fortunately — or was it created that way by hindsight? — astronomy degrees proved to constitute a valuable advantage for entry into IT jobs, both in pure science and outside of it. But through it all, the division between those who were granted tenured posts and those who were not has remained, whatever the title of this book claims, and its ramifications will linger long.

However, despite their unfortunate choice of title, the editors of this book have assembled a fine set of essays that are well worth perusing, and will make a noble addition to any scientific library. — Elizabeth Griffin.

Een passie voor precisie. Frederik Kaiser (1808–1872), Vader van de Leidse Sterrewacht, by Rob van den Berg (Prometheus), 2022. Pp. 383, 23 × 15 cm. Price €30·00 (about £26) (paperback; ISBN 978 90 446 5147 8).

While visiting Middelburg* with one of my Dutch-language courses (as a participant, not a teacher) and eager to improve my Dutch by reading something other than the typical literature studied in such courses, I made my way to the science section of a bookstore in that delightful town, looking for something written in Dutch, as opposed to a translation. One book which I bought is the one reviewed here, the title of which translates as 'A passion for precision'; the subtitle refers to Kaiser as the father of Leiden Observatory.

This is a book written by a historian of science from Leiden (while taking a pandemic-induced break from his doctoral work involving writing a biography of the chemist Jacobus Henricus van 't Hoff, the first Nobel laureate in that discipline). As such, it has extensive end notes (providing both additional information and references) and a long and detailed bibliography; probably no-one will ever need more information about Kaiser than that in the book, and certainly not more than that included in the copious references. At the same time, the text is well written and not at all in a dry, scholarly tone — the best of both worlds.

Born in 1808, Frederik Kaiser, as the name indicates of German extraction, was, like his hero Bessel, self-taught and rose to the highest ranks of 19th-Century astronomy. While German† astronomers such as Bessel and Gauß are perhaps better known, Kaiser played a similar role in the Netherlands, where he was clearly the leading astronomer of his generation. Astronomy at the time was concerned mainly with stellar surveys, astrometry, Solar System bodies, and binary stars; quantitative astronomical spectroscopy was just getting underway towards the end of Kaiser's life, as was astrophotography (of which Frederik Kaiser's son Pieter Jan Kaiser was a pioneer.)

The book covers Kaiser's science, his personal life, and the astronomy of the time. Kaiser's early interest in astronomy was supported by his uncle Johann Friedrich Kaiser (later known as the more Dutch Jan Frederik Keyser) who had essentially adopted his nephew upon the death of his brother, Frederik's father Johann Wilhelm. Jan Frederik was himself an astronomer, not a professional but

*By chance, Middelburg is the town where telescope-inventor Hans Lipperhey (1570–1619) spent the second half of his life, having moved there from Wesel in what is now Germany in 1594; in 1608 he applied for (but did not receive) a patent for his invention. While wandering around town we came across a statue of him.

†Kaiser died in 1872, about a year after the end of the 5-year process of German unification. Thus, for most of his life, there wasn't a Germany *per se*. Here, I use the term to refer to astronomers working in what was to become Germany (thus excluding Austria and Switzerland) as well as German-speaking astronomers working elsewhere (such as Friedrich Georg Wilhelm (von) Struve and his son Otto Wilhelm von Struve, who succeeded his father as director of the Pulkovo Observatory near St. Petersburg, Russia). Despite the complicated political geography, one can speak of a German astronomical community at the time. While *Monthly Notices of the Royal Astronomical Society* was the leading journal in the UK, on the Continent it was *Astronomische Nachrichten*, which was mainly in German, though articles were published in other languages as well.

more than an amateur. After a sketch of the family history, van den Berg gives us some background on pre-Kaiser astronomy in the Netherlands, concentrating on the old observatory in Leiden which can be traced back to 1632 when a quadrant was installed in the attic of the Academiegebouw, the oldest and main university building (though today used mainly for ceremonial events), by Jacob Golius, successor to Willebrord Snell(ius) (of the refraction law) as professor of mathematics in Leiden (Golius was also a professor of oriental languages). Although astronomy had been taught at the university since its founding in 1575, it was only theoretical. However, after Snell had observed a comet in 1618 with instruments paid for partly out of his own pocket, the university became interested in having its own observatory. Golius's successors, however, concentrated more on buying and maintaining instruments than actually using them. Some progress was made in the 18th Century under Johan Lulofs, but after his death in 1768 the instruments were stored in the attic and not much else happened until Kaiser arrived on the scene, who early in his career had to deal with two new reflecting telescopes which were, however, too badly made to be useful. They were formally commissioned on 1826 May 24, the same day Kaiser took up his position as observer; they were eventually auctioned off two days shy of twenty years later.

Nevertheless, Kaiser got off to a good start, managing to qualify for university studies by passing exams in Latin and Ancient Greek in 1830, enrolling in the faculty of mathematics and natural science on 1831 February 15, and getting married less than three weeks later to Aletta Rebecca Maria Barkey (1805–1872). They had a daughter in 1832 and a son in 1834, just after Kaiser had graduated *magna cum laude*.* Another son was born in 1836 and twin sons, including Pieter Jan, in 1838. Scientifically, Kaiser attained significant fame due to his calculation of the orbit of Halley's Comet, which had returned in 1835, making the necessary observations from his own house with a borrowed telescope. He then set about improving the observatory and its reputation by obtaining better instruments, corresponding with and visiting (during a 'grand tour') German astronomers, and settling down on various observational programmes: apart from the typical mid-19th-Century areas mentioned above, observations of planets and Saturn's rings (which at the time some believed to show short-term changes in structure) were important. Kaiser often had better results even though others had better instruments; his value for the period of rotation of Mars differs from the currently accepted value by only a tenth of a second, a feat which requires both precise observations and precise time-keeping. (Kaiser's younger brother Alexander was a clockmaker who also constructed pendulum clocks for the observatories in Leiden and Utrecht.)

Although he constantly complained about his lack of health (true to some extent, but also used as an excuse to avoid unwelcome tasks), Kaiser was active in learned societies and as a popular-science writer, both of which led to astronomy being more highly regarded in the Netherlands. Astronomy was of course important for navigation, and Kaiser was involved in constructing better maps of Indonesia and, within the framework of a large European project, with

*Kaiser continued to rise up through the ranks: honorary doctorate in 1835, lecturer in astronomy and director of the observatory in 1837, associate professor in 1840, full professor in 1845, and served as Rector Magnificus of the university in 1857 and 1858, thus spending his entire career in Leiden. He was still working on editing the third volume of the *Annalen der Sternwarte in Leiden* (German-language reports from the observatory) shortly before his death in 1872 July; his declining health was due in part to the death of his wife a couple of months before. His first son had died in 1836; his daughter and three other sons all lived until after the turn of the century.

measuring the precise shape of the Earth. Even more so than with respect to the bread-and-butter astronomy which Kaiser did so exactingly (while expecting similar precision from those who worked for him, which gave him a reputation for being difficult), van den Berg addresses the scientific, political, and personal aspects of Kaiser's involvement with those projects. A monument to Kaiser's effort is the then-new Leiden Observatory, finished in 1860 (the old one being in the Academiegebouw). (The astronomy department moved to a new campus in 1974, so Kaiser's is now the old observatory.) Since then, Leiden has been a world-leading site for astronomy. Kaiser was also admired as a teacher, from popular-science talks to post-graduate students, his influence extending beyond astronomy as well. Among his students were van der Waals and Lorentz (who are so famous that first names are not needed to identify them); Lorentz's wife was also Kaiser's niece.

The main text is 283 pages, so this review can only briefly touch on some of the aspects covered. Kaiser's professional and personal life and the astronomical community in the Netherlands in particular and in Europe in general are covered well, and also documented well: the endnotes comprise 63 and the bibliography 22 small-print pages. About three dozen black-and-white illustrations are scattered throughout the book, which ends with a six-page small-print index. The main text, containing occasional quotations from documents of the time, reads almost like a novel (that's a compliment) and is self-contained (but with more information available *via* the endnotes and references). I noticed just a couple of small glitches which are essentially minor oversights; I'm sure that even if my Dutch were better I wouldn't have found any more evidence of bad editing. The book represents a huge amount of work which is very well presented and should be valuable for all with an interest in mid-19-Century European astronomy (and who can read Dutch). — Phillip Helbig

Annual Review of Astronomy and Astrophysics, Volume 50, 2022, edited by E. van Dishoeck & Robert C. Kennicutt (Annual Reviews), 2022. Pp. 568, 24 × 19·5 cm. Price $496 (print only for institutions; about £400), $118 (print for individuals; about £95) (hardbound; ISBN 978 0 8243 0960 2).

This is surely the first volume of *ARAA* that has opened with a review by a Peer of the Realm! Lord Rees of Ludlow, Astronomer Royal, gives a fascinating account of his life in science, including insights on many of the policies that have affected the progress of astronomy in the UK over the last few decades. The science itself is, of course, aimed squarely at the 'big picture', to which he has made notable contributions. The remaining eleven chapters cover a wide range of topics, but all are presented in an exemplary fashion by Annual Reviews.

Starting (relatively) close to home, the matter of magnetic fields in the upper layers of the Sun is discussed by Trujillo Bueno & del Pino Alemán, with particular emphasis on the data accruing from polarimetric studies. Don Kurtz examines the state-of-the-art situation of asteroseismology for all manner of stars with the benefits of amazingly accurate space-borne photometry — such as that yielded by *TESS*, with which readers of this *Magazine* will by now be familiar! In the particular case of pulsars, the structure of their magnetospheres is treated by Philippov & Kramer.

For the most massive stars, Vink considers both the drivers and consequences of extensive mass loss, while Eldridge & Stanway examine the effects of massive-star evolution in the formation of galaxies early in the life of the Universe. That topic is also considered by Robertson, who awaits the benefits of the *JWST* to show how re-ionization of the inter-galactic medium impacts these early developments.

Although on a somewhat smaller scale, the cold ISM provides the material for star, and hence, galaxy formation, outlined by Saintonge & Catinella, but when it is subjected to X-ray heating, rather more interesting chemistry takes place according to Wolfire *et al.* And another product of the ISM is exoplanets; given its importance for life, the atmospheres of rocky exoplanets are studied by Wordsworth & Kreidberg.

Then on to the grandest scale, Sellwood & Masters puzzle over the mechanism by which spiral galaxies maintain their form. And right at the limits of detection, Newman & Gruen look to photometry to provide accurate redshifts ('photo-*z*s').

All in all, a fine collection of reviews. — David Stickland.

Astrophysics in the XXI Century with Compact Stars, edited by César Augusto Zen Vasconcellos & Fridolin Weber (World Scientific), 2023. Pp. 320, 23·5 × 15·5 cm. Price £115 (hardbound; ISBN 978 981 122 093 7).

The properties of matter at the extremely high densities that occur in supernova core collapse and in the cores of neutron stars involve physical conditions that cannot be achieved in any terrestrial laboratory. Although the interactions involved are described by quantum chromodynamics, these highly non-linear equations can be solved only in special cases. This is not adequate for considering the hypothesized phase transition from normal hadronic matter to extremely high-density quark matter. To determine whether or not such a phase transition actually exists in nature, it is thus necessary to investigate its observational consequences.

With the advent of multi-messenger astronomy — including the detection of neutrinos emitted during core-collapse supernova explosions and gravitational waves emitted by merging black holes and neutron stars — and the development of major new facilities for observations across the electromagnetic spectrum, one can expect the 21st Century to see great advances in our understanding of compact stars. Anticipating that this will enable them to be utilized increasingly to test nuclear and particle-physics theories in regimes that cannot be achieved in terrestrial laboratories, the editors of this volume have put together a series of chapters, each written by separate groups of authors, structured around this theme.

Chapter 1 utilizes the mass distribution of neutron stars to constrain the properties of matter in their deep interiors and their formation mechanisms. Chapter 2 shows that the energy released during the transition to quark matter may lead to a deflagration–detonation or quark-core-collapse supernova. Chapter 3 explores "strangeonization," the conversion of two (u, d) quarks to equal numbers of three (u, d, s) quarks during the formation of a compact star. Chapter 4 discusses electron captures and pycnonuclear reactions (*i.e.*, those induced by high densities rather than by high temperatures) in rapidly spinning, ultra-massive, and highly magnetized white dwarfs. Chapter 5 describes a covariant density-functional approach to calculating the equation of state of dense matter, emphasizing the role of hyperonization and Δ resonances. Chapter 6 discusses what can be learned from the frequency content of the continuous gravitational-wave signals that in principle are emitted by spinning neutron stars. Chapter 7 reviews the use of observations of pulsar glitches to constrain the nuclear physics of neutron-star interiors. Finally, Chapter 8 considers the potential observational signatures of a phase transition from normal hadronic matter to a deconfined quark–gluon plasma.

Although a few chapters are highly speculative, most include large numbers of references that are likely to be valuable for investigators working in these areas. Both observers and theorists may therefore find this volume to be a useful resource. — HUGH VAN HORN.

Accreting Binaries: Nature, Formation, and Evolution, by Sylvain Chaty (IoP Publishing), 2022. Pp. 232, 26 × 18·5 cm. Price £120/$190 (hardbound; ISBN 978 0 7503 3885 1).

Professor Sylvain Chaty of the Université Paris Cité presents here the fruits of 29 years of attraction to accreting binaries, though the book is dedicated to all the stars in the Universe, even the single ones. It is a volume of the future, with each of the nine chapters nearly self-contained and ending with its own lists of review articles, catalogues of objects belonging to the category discussed in the chapter, the explanation of a data base (generally a table in the chapter of all the objects of that class known at the time he was writing), and the references for that chapter.

An experienced editor at another publishing company has explained to me that the reason for the format is that many readers will want to down-load, and pay for, just one or two chapters, so that a list of references (*etc.*) for the whole book would not be useful to them.

The chosen format works well for readers who are interested only in the sub-topic of the chapter and want to find the source for a particular bit of information or, perhaps, additional information on a particular item. It does not work well for the reader who has one of the following questions: (*i*) Is any of my work mentioned? (*ii*) Has the author's presentation of historical background caught the key papers, books, or whatever? And (*iii*) when a topic is controversial, has the author given a fair representation of both or all sides? The answers are (*i*) no (but you are welcome to trawl the reference, review, and catalogue lists for your own contributions); (*ii*) not entirely — although cataclysmic variables rate their own chapter and white dwarfs are included in Chaty's inventory of compact objects, we readers are told that "the beginning of a new field of study in astrophysics: the domain of compact object astrophysics" happened in 1962 (Giacconi *et al.*'s discovery of Sco X-1). White-dwarf theory preceded this by about 30 years (think "Chandrasekhar") and white-dwarf observations by another decade-plus. Indeed Walter S. Adams' 1914 paper is cited in the next chapter, along with Chandrasekhar 1931. And the jet chapter (8) begins with Heber Doust Curtis looking at M 87 in 1918.

As for (*iii*), the related controversial topics that come to mind are the roles of accreting binaries of suitable sorts in the origins of blue stragglers and type-Ia (nuclear conflagration) supernovae, neither of which quite falls within the author's territory.

What you will find here are lots of tables, both of individual sources and of types, explanations of fundamental processes, and images, some artists' reconstructions and some at least indirectly from assorted telescopes. Many of the colour images have a sort of 'paint by numbers' appearance rather than gently-shaded *HST* tones.

These add up to expert introductions to cataclysmic variables, low-mass X-ray binaries, high-mass X-ray binaries, and other accreting binaries, beginning, of course, with intermediate-mass X-ray binaries. High and low, *etc.*, mean the masses of the donors, though the recipients also vary from fairly lightweight white dwarfs to black holes that, if solar masses were years, would be old enough to drink in California. — VIRGINIA TRIMBLE.

The Theory of Direct Dark Matter Detection. A Guide to Computations, by Eugenio Del Nobile (Springer), 2022. Pp. 250, 23·5 × 15·5 cm. Price £54·99 (paperback; ISBN 978 3 030 95227 3).

The Theory of Dark Matter Detection: A Guide to Computations is published as part of the *Lecture Notes in Physics* by Springer. It represents a modern, comprehensive, and up-to-date primer on topics necessary for any serious work in direct dark-matter searches. The material is divided into nine self-contained chapters in addition to supplementary material at the beginning and end of the book. Together, they compose a structure fairly easy to follow and consume. Each chapter starts with a short paragraph (in a foreword fashion) where Del Nobile sets the stage for the subject matter that will be presented. The meat of each chapter is represented in a pedagogical way: comprehensive, with clear explanations and (what is often, unfortunately, skipped in physics publications) detailed derivations of equations. The latter is one of the strongest points of this volume in my opinion, as the author does not seem to overlook or omit any steps, but provides the reader a full, step-by-step derivation and finally a solution of the topic that is being investigated.

The first two chapters lay the foundation of the rest of the book by giving the fundamentals of the scattering kinematics, in particular by providing the basic definitions of the scattering and detection rates. Chapter 3 delves into the dynamics of couplings between the nucleons and the dark-matter particle as a first step in calculating the scattering amplitudes. It covers all the families of couplings, from scalar to tensor, in a hierarchical way. The following chapter eases naturally into the dark-matter–nucleon interactions in the non-relativistic limit. After all the necessary physics at the elementary-particle level is covered, the reader is then equipped enough to start tackling the direct dark-matter problematics on a nuclear-physics scale in Chapter 5. The main goal in this field is to understand deeply and handle the non-trivial scattering problems (scattering cross section, scattering rate, SI and SO interactions, *etc.*), and those are presented in Chapter 6. More practical and experimentally-relevant topics (such as the annual modulation, the corrections accounting for the Earth's rotation, or the physics of dark-matter halos and cosmology) are given in the following chapter. Finally, the last 'physics' chapter (in the strict definition of the word) deals with the general phenomenology of dark-matter searches. It provides a general overview of current dark-matter models, how they relate to each other, and what their features or limitations are.

The volume concludes with a summary chapter that abridges the material covered in previous sections in a very innovative and useful way: first, as a two-page summary (a 'cheat sheet' of sorts) and subsequently in the form of Q&A. The two-page summary is an excellent concept, beyond handy, and I would imagine an advanced student or researcher having it printed on the wall of their office or study. The Q&A part of Chapter 9 is, in my opinion, the strongest feature of this book. It offers a discussion-style approach to the topic and gives both questions the reader might have while working through the book, together with succinct answers (with all the necessary in-book references).

Each chapter concludes with an extensive list of relevant-for-the-topic bibliographical references, which are essential in any further and in-depth research work (especially as the majority are research papers and not books). There is a general bibliography list at the end, as well. Chapters often include tabular data or overviews, which are always helpful, while summarizing findings or representing the information in a clear, visual way. Relevant figures and full-colour plots accompany each chapter and help in content digestion, although they could have been a bit larger as it is often hard to read the values or other pertinent information. Often, the thickness of the lines and/or curves on such a small-figure format is preventing the reader from distinguishing between each line/curve. Another point regarding the visual part is that it might have been a better choice to include more illustrative examples (such as plots), as the reader might go for dozens of pages of plain text before the next figure. That decision might result in readers getting tired of following the material quickly. On the other hand, this choice might have been made with a goal of not breaking the flow while the result is being derived. A final remark would be a general note on the notation and typesetting choices, which could have been a bit better. Even though the subject matter requires a family of font faces to be used for operators, variables, *etc.*, and those choices are, thankfully, explained and defined in the Notation section at the beginning, it is possible that a neurodivergent reader might struggle with it.

Aside from these minor comments, I personally believe this is a very useful read for students, researchers already in the field, or anyone who wants to understand the theoretical framework behind every direct dark-matter-search experiment. I think Del Nobile managed to cover all the necessary ingredients in an extensive and yet not-overwhelming way, and this volume will definitely find its spot on many bookshelves. — Nikolina Šarčević.

Neutral-Atom Astronomy. Plasma Diagnostics from the Aurora to the Interstellar Medium, by Ke Chiang Hsieh & Eberhard Möbius (World Scientific), 2022. Pp. 291, 23·5 × 15·5 cm. Price £95 (hardbound; ISBN 978 981 3279 19 3).

The purpose of this book is clearly stated in the Preface: it is to be "a primer for those who wish to learn about the diagnostics of space plasmas beyond the reach of spacecraft by detecting and analyzing energetic neutral atoms (ENAs) emanating from afar." ENAs are created in charge-exchange reactions between energetic ions orbiting magnetic-field lines and ambient low-energy neutral atoms. For example, the reaction between a fast proton and an ambient hydrogen atom may create a fast hydrogen atom (this is the ENA) and a slow hydrogen ion. The neutral atom is unaffected by local magnetic fields and can be detected by a suitable device far from the region where the charge exchange occurred. Thus, ENAs have the potential to be probes of plasmas in space.

Since the middle of the 20th Century suitable detectors have been devised and flown on many spacecraft to enable the study of regions such as the Earth's magnetosphere, the magnetospheres of other magnetic planets and satellites, and the heliosphere (the cavity formed by the Sun in the interstellar medium). ENAs are typically detected by secondary-electron emission on contact with a solid surface. Most ENAs are energetic hydrogen atoms, but ENAs of He, O, and S atoms have also been detected. Ideally, detections may be used to identify the nature, trajectories, and energies of the ENAs.

The book certainly fulfils its stated purpose. The accidental discovery of auroral ENAs and their subsequent detection and utilization in near-Earth space observations are described, followed by more general discussion of the relations between observations and the plasma where they originate. A large part of the book is devoted to instrumentation. Finally, the authors conclude the book with some interesting speculations about the future of the challenging yet highly successful subject of neutral-atom astronomy. The book also provides extensive coverage of the relevant literature. — David A. Williams.

The Whole Truth: A cosmologist's reflections on the search for objective reality, by P. J. E. Peebles (Princeton University Press), 2022. Pp. 241, 23 × 14·5 cm. Price £22/$27·95 (hardbound; ISBN 978 0 691 23135 8).

Every decade or two, starting in 1971 with *Physical Cosmology*, P. James E. Peebles has given us a book describing what he thinks about the Universe, and (therefore!), how we might want to think about it. *The Whole Truth* is the latest of these, and we trust not the last. I have just pulled down from a top shelf my copy of Peebles 1971, thinking it might be fun to compare them here. It would indeed, but this is 50+ years of the history of cosmology, not to be attempted on a few small pages. I note only one strong similarity: both are dedicated to Alison (his wife), as indeed is Peebles 1980 — *The Large Scale Structure of the Universe*. Returning to the present volume, we find that the author is now certain that there is an objective reality to be found by scientific methods, as opposed to (mere) social constructs — entities that exist because enough people have said so*. Very possibly he was always so convinced, if not in the same language. Most practising scientists probably are (including your present reviewer), and we all have been trying to explain why at least since Arthur Stanley Eddington and James Jeans wrote on the topic in the 1930s (and thereby aroused the ire of professional philosophers).

Peebles does not deny the existence of such social constructs, indeed he presents General Relativity as initially being that sort of thing, when only the orbit of Mercury and very approximate gravitational redshifts and deflections of starlight supported it. In contrast now, he presents it as a close approximation (still in need of improvement to gybe with quantum mechanics) to an objective reality. The ΛCDM model of the Universe is well on the way to achieving similar status, though dark matter (which Peebles generally calls subluminal matter here) still smells a bit of the builders' mortar. Much of the volume consists of history of cosmology, presented in a way to demonstrate the gradual transformations of social constructs to empirically-supported theories and models (Peebles regards these two words as nearly equivalent). Rather than tracking that history (much of which is also in the 2020 book, *Cosmology's Century*, another Peebles extravaganza), I would like to introduce you to three interesting people, at second hand, as it were: Charles Sanders Pierce, Hilary Putnam, and Robert K. Merton.

Pierce was a 19th-Century American scientist and philosopher who in seven cited publications (1869–1907) emphasized the "impressive predictive powers of the physical theories of the time" (meaning what we now call the classical theories of electromagnetism, mechanics, and gravity). Pierce is quoted frequently throughout the volume, and Peebles devotes an early footnote to expressing hope that the former was creative enough that he would have

*The luminiferous ether and phlogiston are well-known examples.

adopted the use of non-gendered pronouns and nouns to describe scientists if challenged to consider the evidence.

Second we meet Hilary Putnam, a more contemporary philosopher who, in a 1982 paper on 'Three kinds of scientific realism', put the case as follows: "The positive argument for realism is that it is the only philosophy that doesn't make the success of science a miracle." Peebles dubs his examples "Putnam's miracles", with numerous examples, including the constancy of the speed of light, aspects of the standard model of particle theory, and the consistency of the cosmic density of matter from multiple indicators.

The third is Robert King Merton*, from whose 1961 "Singleton and multiples in scientific discovery", Peebles takes the name "Merton Multiples" meaning near-simultaneous discoveries or inventions (of ideas) by two or more independent individuals or groups. Among the examples are five separate proposals of additional neutrinos, the recognition that the mass in a galaxy doesn't seem to be where the starlight is, and (a Merton Quadruple) the decision of four main post-war actors to choose to aim their research at the physics of gravitation and cosmology. These were Gamow, Hoyle, Dicke, and Zel'dovich (and yes I met all of them first hand). Very many more interesting people, productive ideas, and eponyms are to be found in these 211 pages!

Conflict of interest: The hard covers are unadorned grey, but there at the top of the back of the book jacket am I, the very first blurb-writer, above even Roger Penrose. "Please read the book", said I, and I still do. — Virginia Trimble.

Uranus and Neptune, by Carolyn Kennett (Reaktion), 2022. Pp. 216, 23 × 18 cm. Price £25 (hardbound; ISBN 978 1 78914 641 7).

Uranus and Neptune, the two ice giants of our Solar System, have always been difficult objects to study due to their distance from the Earth. Such studies advanced enormously following the flybys of *Voyager 2*, and more recently by observations made with the *Hubble Space Telescope*, large Earth-based telescopes, and in the case of Neptune, the *James Webb Space Telescope*.

This new book by Carolyn Kennett, entitled *Uranus and Neptune*, attempts to provide a comprehensive and up-to-date overview of both of these planets. It certainly packs a lot of information on these two planets in the 216 pages; covering their atmospheres, interiors, magnetic fields, rings, and satellites, to potential future missions. The book also briefly describes ice-giant exoplanets as these form a high percentage of the exoplanets that have so far been discovered.

As well as being an astronomer, Kennett is an historian. Probably because of this, the book has a chronological feel to it, covering the evolution of our knowledge from the discovery of each planet until the present day. The text is supported by an extensive list of references for each chapter and appendices providing data on each planet, their rings, and satellites. At various points in the text there are quotations from past and present observers and scientists who have made discoveries or observations relating to these two planets. These give a personalized aspect to the events described.

The book is very well illustrated, including a number of high-resolution images taken by *Voyager 2*, the *Hubble Space Telescope*, and large ground-based

*His birth name, in Pittsburgh was something entirely different, which is in a document long since lost. He used the surname Merlin briefly along the way, and the dedication in my own private copy of *OTSOG* is signed "with collegial and other greeting, Robert 94.03.02." Peebles, in a couple of places, comes close to having footnotes to his footnotes, and Merton did it all the time, but simpler perhaps to explain here that *OTSOG* is *On the Shoulders of Giants*.

instruments. I particularly liked the colour images showing features in the atmospheres of both planets. However, the same two images of Uranus and Neptune are reproduced both separately and as a pair on page 8.

Although this book provides a good general introduction to both planets, there are a few errors, inconsistencies, and incorrect statements here and there. For example on page 41, it is stated that *Voyager 2* discovered three rings of Uranus and lists one of these as 1986U7. This was the provisional designation of satellite Cordelia. It later states that 13 rings have been discovered but only lists 12 in Appendix III.

Although the winds in the atmospheres of each planet are briefly discussed, the book may have benefited from the inclusion of a diagram showing the variation in wind speeds with latitude, and a clearer distinction between the rotation of the interior of each planet and the rotation of their respective atmospheres. — Mike Foulkes.

Observing Our Solar System. A Beginners Guide, by Tom Kerss (Collins), 2022. Pp. 112, 21 × 14·5 cm. Price £8·99 (paperback; ISBN 978 0 00 853261 1).

I fully expected this book to describe techniques for observing objects in the Solar System. That idea was increased by the subtitle 'A Beginner's Guide'. However, the emphasis is upon the technical side of observing: one might even say 'digital methods'. Although there is extensive discussion of telescope designs, filters, *etc.*, there is a great emphasis on photography and the use of planetarium programs and on-line resources. Indeed, in the 'Resources and Glossary' section, there are no books whatsoever, merely software and websites. Even here, unfortunately, there are glaring omissions, and some of the glossary definitions are suspect. That for 'libration', for example, mentions libration in longitude, but omits libration in latitude

But what about the advice on observing? Regrettably, there is little or no discussion of some of the features of Solar System objects. Take Jupiter. There is no description of how belts are dark and zones are bright, and different regions rotate at different rates. The one annotated photograph is inadequate. With comets there is no definition of the terms 'nucleus', 'coma', or even 'disconnection event'.

In general, I am not happy with this or other 'beginners' books that include *Hubble* or similar images and discuss planetary features revealed by spacecraft imagery as if visible through any telescope. It is in order to say (for example) "clouds may be occasionally seen on Mars where we now know Olympus Mons is located", but not to speak as if Olympus Mons itself may be detected.

Quite apart from showing modern images of the planets, I am unhappy with some of the 'simulated' images of the planets. Try as I might, I simply cannot detect the Galilean Moons, Titan, or Triton on the 'simulated' images of Jupiter, Saturn, and Neptune on pages 74, 78, and 81. And do we really need images of Uranus and Neptune?

With the modern-day emphasis on taking a photograph (any photograph) of something, rather than understanding its nature, this book may serve its purpose, but as 'A Beginner's Guide', I have severe reservations. — Storm Dunlop.

Other Books Received

Electrostatic Phenomena on Planetary Surfaces, 2nd Edition, by Carlos I. Calle & Karen Aplin (IoP Publishing), 2022. Pp. 94, 26 × 18·5 cm. Price £120/$190 (hardbound; ISBN 978 0 7503 3889 9).

The principles of electrostatics as found in the Earth's atmosphere, and extended to other bodies in the Solar System, with especial focus on the Moon, Mars, and Jupiter

Large Area Networked Detectors for Particle Astrophysics, edited by Pierre Sokolsky & Gus Sinnis (World Scientific), 2022. Pp. 304, 23·5 × 15·5 cm. Price £105 (hardbound; ISBN 978 1 80061 260 0).

A collection of articles on the use of networks of large arrays for the study of cosmic rays, neutrinos, and gamma rays, particularly those of very high energy.

An Introduction to Special Relativity for Radiation and Plasma Physics, by Greg Tallents (Cambridge University Press), 2023. Pp. 318, 25 × 17·5 cm. Price £54·99/$69·99 (hardbound; ISBN 978 1 009 23606 5).

A textbook for postgraduates and researchers, with exercises, covering laser-plasma physics and detailing the radiative processes in the context of relativistic energies.

From the Library

Fundamentals of Photography, by C. E. Kenneth Mees (Eastman Kodak Company, Rochester, NY), 1935. Pp. 123, 21 × 14 cm. Price not given (purchased at auction from AAVSO) (hardback; no ISBN number).

Charles Edward Kenneth Mees was a photographic chemist who became director of Research and Development for Eastman Kodak, in which capacity he supervised the development of sensitive emulsions for astronomical use, as well as numerous defence and commercial products like Kodachrome. Wratten filters (I remember them and am sorry if you don't) carry the name of the company, Wratten & Wainwright Ltd. of Croydon, that employed him starting in 1906.

This slim volume (first edition 1920; this is the 7th edition) preceded his magisterial *The Theory of the Photographic Process* (multiple editions since the first in 1942). Its object (he wrote in the preface) was "to provide an elementary account of the theoretical foundations of photography, in language which can be followed by readers without any specialized scientific training." Mees began with J. H. Schulze discovering the darkening of 'chloride of silver' by light in 1732 and ended by advising that Kodak and Wratten filters should be kept in their cases when not in use in order to protect them (although the dyes used are quite stable to light). The preface also points out that it is perfectly possible to be a successful photographer without understanding much of the theory (clearly much more true now than in 1906 when Mees received his DSc from University College London, for work with William Ramsey already on theory of photography).

That work included an updating of what Mees here called a curve "expressing a relation between density and exposure of a photographic negative material" (Figure 43). If you have been a film-based shutterbug, you might know this as an H & D curve, for Hurter & Driffield (1890). The book explains all sorts of things you could do with lighting, processing of negatives and positives, and enlarging to obtain desired (and frequently accidental, undesired) effects. Many of the figures are great fun. His "early photographer with equipment" looks like he is prepared to climb Everest.

Light still in 1935 consists of waves in the ether, and the primary colours (Figures 9 and 10) are blue-violet, green, and red, defined by filters centred at about 450, 500, and 640 (units not given), and separated by narrow bands called blue, green, and orange–yellow. Another insight is that the sepia tones of old family portraits resulted from a different chemistry, using gold toning rather than silver compounds. Mees was, however, an honest photographer, and says nothing about airbrushing in longer hair or removing failed politicians from group images.

This particular copy of *Fundamentals of Photography* was acquired by Clinton B. Ford in October 1938 and came with two bonuses, two slips of old, yellowed paper, one containing Ford's own nine-step process for "Preparation of Silver Iodide Emulsion." The other is a note of a 2 p.m., Tues. Nov. 4 event at the Edgewater Beach Hotel "Ned Elec Conf" a paper entitled "Ultrasonic Guidance of the Blind" by F. H. Slaymaker and W. F. Meeker of Stromberg-Carleon. Both are in pencil. Of course not every year has a Tuesday November 4th, and the paper slips presumably postdate Ford's acquisition of the book. Possibilities include 1941 and 1947. Ford's dates were 1913 (Ann Arbor, Michigan) – 1992 (Wilton, Connecticut), and Mees' 1882 (Wellingborough, Northamptonshire, England) – 1960 (Honolulu, Hawaii). For Mees' dates as well as for the names of H and D and the first sentence here, I am indebted to the article by Paul Murdin in the *Biographical Encyclopaedia of Astronomers*, second edition. My copy of Mees (1942) originally belonged to my father, chemist and enthusiastic photographer, Lyne Starling Trimble (1912 Inglewood, California – 1983 North Hollywood, California). — Virginia Trimble.

THESIS ABSTRACTS

Spectroscopic Studies of Star-Forming Galaxies and the Intergalactic Medium in the Early Universe

By Joris Witstok

Current observational facilities, such as the *Very Large Telescope* (*VLT*), *Hubble Space Telescope* (*HST*), and *Atacama Large Millimeter/submillimeter Array* (*ALMA*), have enabled us to perform detailed spectroscopic analyses of distant galaxies well into the Epoch of Reionization (EoR). This crucial phase transition witnessed baryonic matter, mostly in the form of cold, neutral-hydrogen gas, being chemically enriched, ionized, and heated as a result of the formation of the first stars and galaxies. Here, I present the results of several studies aiming to shed light on the early evolutionary stages of galaxies and their contribution to cosmic reionization. Using cosmological hydrodynamical simulations, I consider the prospects of mapping the intergalactic medium (IGM) in the most prominent hydrogen emission line, Lyman-α. Turning to observations, I present and analyse multiple spectroscopic datasets of individual high-redshift galaxies with the aim of understanding the process of star formation on the scale of the interstellar medium. Firstly, I show the spectroscopic measurements of a unique, strongly gravitationally lensed galaxy at redshift 5, taken by *VLT/X-shooter* and *VLT/SINFONI*, are consistent with a young, metal-poor, star-forming system with a hard radiation field. This galaxy is likely analogous to typical EoR galaxies, revealing Lyman-α and emission lines that may indicate the leakage of ionizing photons into the IGM. Secondly, focussing on far-infrared and rest-frame UV observations of five UV-bright, star-forming galaxies at redshift 7 obtained with *ALMA* and *HST*, respectively, I show these measurements point towards similar physical properties, though there are hints of substantial metal enrichment in these systems. Constraints on the dust continuum of one source indicate the presence of a surprisingly cold and massive dust reservoir. Finally, I discuss directions for future work, in particular the synergy of existing observatories in combination with *JWST*, the much-anticipated near- and mid-infrared space-based observatory that has recently started acquiring spectroscopy of the most distant galaxies. — *University of Cambridge; accepted 2023 February*.

The Chemical Evolution of Galaxies Explored Through Multi-Object Integral Field Spectroscopy

By Connor Hayden-Pawson

Galaxies are expected to grow and evolve *via* a series of physical processes relating to gas flows into and out of the galaxy. Inflows of gas from the surrounding cosmic web provide fuel for star formation, which subsequently causes an enrichment of the interstellar medium (ISM) with the metals produced within stars, whilst supernovae-driven outflows drive gas out of the galaxy, re-distributing metals in the process. In this way, measurements of chemical abundances within galaxies can provide insight into the different physical processes that drive galaxy evolution. The interplay between these different processes has been well studied in the local Universe by large spectroscopic surveys that have established a number of scaling relations between stellar mass, star-formation rate, and gas-phase metallicity. However, the existence of such relations at earlier times in the Universe is less well studied. The aim of this thesis is to investigate the evolution of chemical abundances within galaxies across cosmic time, making use of integral field spectroscopy (IFS) obtained through the *KLEVER* (*Kmos LEnsed Velocity and Emission line Review*) survey.

In the first part of this thesis, I compare the galaxy-integrated properties of galaxies at $z \sim 2$ to those found in local galaxies, with a particular focus of the abundance of nitrogen relative to oxygen (N/O). I find that high-redshift galaxies have similar N/O values to local galaxies at a fixed metallicity, but much lower N/O values than local galaxies at a fixed stellar mass. I then demonstrate that an anti-correlation exists locally between N/O and star-formation rate, such that at a fixed stellar mass galaxies with higher star-formation rates have lower N/O values. In light of this, I parameterize a three-dimensional relationship between stellar mass, star-formation rate, and N/O abundance, before demonstrating that this relationship accurately predicts the N/O ratios of galaxies at $z \sim 2$ as well as those observed locally. As such, I name this relationship the fundamental nitrogen relation (FNR), in analogy to the fundamental metallicity relation (FMR). Furthermore, I show that the measured FNR is well described by a simple combination of the FMR and a non-evolving relationship between N/O and metallicity. These results suggest that the physical processes that govern the FMR must be sensitive not only to the metallicity, but also the N/O abundance.

In the second part of this thesis I extend my analysis to the spatially resolved scale, studying the spatial distribution of N/O in galaxies at $z \sim 2$. I present some of the first measurements of N/O gradients at $z \sim 2$, finding they are generally flatter than those found locally. This is contrary to inside-out growth models, which predict steeper gradients at earlier times: however, this difference may be reconciled by invoking star-formation-driven feedback mechanisms that effectively mix metals within the ISM. I present observations of inverted N/O gradients, which I suggest may be a consequence of the inverted metallicity gradients also observed at high redshift. I also present evidence for negative Balmer-decrement gradients within $z \sim 2$ galaxies, consistent with high levels of star formation in the galaxy centre that may be associated with early bulge formation. I note that the slope of the N/O gradients is dependent on the choice of diagnostic used to determine the N/O, suggesting this may be driven by differences in the ionization properties of sulphur relative to oxygen.

Finally, in the third part of this thesis I present preliminary work analysing the scatter in the relationship between N/O and O/H for local galaxies. I present observations of a population of galaxies with low metallicities that have enhanced N/O abundances. I show that the galaxies with the highest N/O values also have higher stellar masses and star-formation rates. I then investigate the possibility that these galaxies have undergone recent gas accretion, driving changes in their metallicities and N/O values whilst boosting their star formation. I compare to a simple gas-mixing model, finding that the deviations of galaxies from their expected metallicities and N/O values can be well modelled by the accretion of metal-rich gas with a metallicity equal to 55% of that of the galaxy. However, the models also predict that the gas fraction within the galaxy is expected to increase by between 0·64 – 1 dex during the accretion event, much larger than the changes in gas fraction inferred from the observed deviations from the star-forming main sequence for local galaxies. I demonstrate that the expected changes in gas fraction are better matched by accretion of lower metallicity gas; however, such models are unable to reproduce the observed decrease in N/O from the expected values. I conclude that improved models are needed that include prescriptions for star formation, chemical enrichment, and gas outflows in order to constrain better the impact of dilution events on the N/O values and metallicities within galaxies. — *University of Cambridge; accepted 2023 January.*

Here and There

PERFECT OPTICS, PERFECT SEEING

... counts of the stars visible in a series of fields of view, each 15 arc seconds across. ... The maximum number of stars in a field of view was 612. — *A&G*, 2022 December, **63**, p. 18.