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MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2013 May 10 at $16^h\ 00^m$
in the Geological Society Lecture Theatre, Burlington House

A. M. Cruise, *Treasurer*
in the Chair

Professor A. M. Cruise. I'd like to announce first of all the 2012 thesis prizes. I'm pleased to announce that the Michael Penston Prize has been awarded to Dr. Adam Ingram of the University of Durham, for a thesis titled: 'A physical model for the variability properties of X-ray binaries'; and the runner up is Dr. Stephen Feeney, of University College London. The Keith Runcorn Prize has been awarded to Dr. Sudipta Sarkar of the University of Southampton, for a thesis with the quite snappy title: 'Glacial stratigraphy, gas-escape features, and ocean fine-structures from multichannel high-resolution reflection seismic data offshore West Svalbard' [laughter]. The runner up is Dr. Nicholas Johnson, of the University of Edinburgh. We hope that both prize winners will give their talks at an RAS ordinary meeting in the future, and we should perhaps give them a round of applause. [Applause.]

I now come to the main part of the programme, which is to invite the President, Professor David Southwood, to give his Presidential Address under the title of 'Saturn's mysterious magnetism'. [It is expected that a summary of this presentation will appear in *Astronomy & Geophysics*.]

Mr. M. F. Osmaston. The sign of the effective magnetic dipole is shifted to the north by 0·04 of Saturn's radius. That makes it too small to detect the actual latitude at which you get the proper balance between the frequencies north and south, I presume: I was thinking it was bigger than that.

Professor D. J. Southwood. No, I think it's actually simpler than that, and it's to do with magneto-hydrodynamics. Magneto-hydrodynamics loves to create sheets of current that create compartments. The polar-cap oscillation is confined by the fields of the polar cap; the closed-field-line region gets both, and the reason for it not crossing the boundary into the southern hemisphere, if you take the northern signal, is associated with a plasma phenomenon: simply, a shear appears in the flow, which is there quite naturally due to the different loading of the field lines in the closed-field-line region, and that means there is a well-defined boundary there, across which — and this is to do with solutions to Laplace's equation, because the bit for going across the field line requires solving Laplace's equation; you can only get Laplace's equation in a sphere to go to zero on one contour, not on two — you can get it to zero in the opposite hemisphere, but you can't get it to zero in the hemisphere where the source is. And that's a very important aspect of the morphology revealed by this work. But I think that suggests actually detecting where the dipole was from these data won't be done; you detect where the dipole is by taking out this stage when looking at the background field.

Dr. G. Q. G. Stanley. The shear between the northern and southern rotations of this magnetic field — is this discernible in the spokes that appear in the rings of Saturn, or is this something totally unrelated?

Professor Southwood. Well, we have experts on this — I saw Carl Murray here. But the point about the spokes in the rings is that they come and go. And they look like rigid rotation often, but we don't see them enough, to be perfectly frank, for anything resembling the kinds of studies you need to do — you know, the long series of data you need in order to detect the subtle differences in period that we're talking about in the magnetometer and radio data.

Dr. Stanley. Is there any phase relationship?

Professor Southwood. That I don't know, actually. Carl can correct me — he is in the imaging team — but I have not seen reports of spokes recently.

Professor C. Murray. They have been seen.

Professor Southwood. Thank you; I think it's something we should check, though. They do sort of rotate, but they rotate rigidly, which certainly suggests an electromagnetic source, so I think it's a very good point.

Mr. H. P. Regnart. A large vortex storm is apparently occurring at Saturn's northern polar region. Is that of any particular relevance to the fascinating presentation you've made, or is this just coincidental?

Professor Southwood. I don't think that's been raging since 2004, or indeed, across the previous season back to 1980, so the short answer is 'no'. But the longer answer is that I suspect it's worth investigating further. But again, it's a tropospheric phenomenon; I think you've got to have something as extreme as the Great White Spot really to pump up the energy so far through the stratosphere into regions where you can get an electromagnetic coupling. But don't regard that as absolutely secure.

Dr. A. Chapman. On a historical point, it's fascinating the idea of rotating shells in Saturn, because over 300 years ago Edmond Halley put forward a model of the Earth's own magnetic field and the drift of the pole, based on a very similar system. What he suggested was that there are up to six shells and spheres inside the Earth, with their own independent rotations, that produce the field. It's a rather fascinating parallel.

Professor Southwood. I'm going to point that out to my colleagues: I was pleased about finding a paper from 1954 [laughter], but if I can go back to Edmond Halley, I am really happy!

Professor Cruise. Good! Thank you, we should thank our speaker again. [Applause.] So I remind you, if you needed a reminder, that there is a drinks reception in the library, immediately following this meeting. And I give notice that the next open monthly meeting of the Society is on Friday, October 11.

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2013 July 3 at $16^h\ 00^m$
in the Younger Hall, University of St. Andrews

D. J. SOUTHWOOD, *President*
in the Chair

The President. There are two very short items in the Community Session. Ian Robson will start, and the subject of his talk will be ASTRONET — presumably about its future rather than its past! He will be followed by Terry O'Connor from STFC.

Professor I. Robson. This short presentation is an update on the ASTRONET Science Vision and the Infrastructure Roadmap. You'll be familiar with the US Decadal Survey; well, Europe did the same thing with ASTRONET. ASTRONET was created by a group of European funding agencies in order to establish a strategic planning mechanism for all of European astronomy. It covers the whole of the astronomy domain from the Sun and Solar System, to the limits of the observable Universe, from radio-astronomy and gamma-rays and particles from the ground as well as in space, but also theory, computing, outreach, and training and recruitment of vital human resources. There are 34 countries in the ASTRONET, eleven of which are main contributors, called "contractors", of which the UK is one. The Science Vision for European astronomy was produced by Tim de Zeeuw and Frank Molster, whilst the ASTRONET Infrastructure Roadmap was produced by Mike Bode, Frank Molster, and Maria Cruz in 2010.

A lot of work went into these but the contract requires light-touch updates to each. This task falls to STFC and it's down to me to execute this. The Science Vision Update has now been completed. It was undertaken by the chairs and co-chairs of the original Science Vision working groups along with Members at Large. The audit date was 2013 February and the final draft was agreed by the ASTRONET Board and Executive in 2013 May (see astronet-eu.org). The next task is to update the Infrastructure Roadmap which outlines facilities, instruments, and missions. There is much to report, and examples to the changes being made include the selections that ESA has made on missions M1/M2, L1, and S1 and the processes for selecting further missions from L2/L3 and M3. M1 is a solar orbiter to be launched in 2013, M2 is the *Euclid* mission to map the geometry of the dark Universe and due to launch in 2020. The L1 mission — *JUICE* — will fly in 2022 to study Jupiter and the Galilean moons in unprecedented detail. The S1 mission — *CHEOPS* — is to launch in 2017 to characterize transiting exoplanets on known bright and nearby host stars. Since publication of the documents, the economic situation in Europe means that we have flat cash budgets at best. There is also increased funding competition between existing and new facilities, in particular the difference between getting capital and the ability of actually continuing and paying for resources for on-going operations.

There are four Panels in the Infrastructure Roadmapping update: Panel A is for high-energy astrophysics and astroparticle astrophysics. It has had some success with on-going support for *XMM* and *Integral* but new missions have not been successful. Panel B deals with UV, optical, infra-red, and radio. It has been quite successful in terms of new projects (such as *E-ELT* and *SKA*). Panel C is for solar telescopes, Solar System studies, and laboratory studies. It has had some success with new programmes coming through (*e.g.*, *JUICE*); however, for the top ground-based project, the *European Solar Telescope*, full funding has not yet been obtained. Panel D is concerned with theory, computing, facilities, networking, the Virtual Observatory, and the use of computers in the future of algorthmic development for major simulations and parallelization.

I now need inputs from the community. What have we missed? Are there any gaps in the proposals especially in the technology area? Where are there identified overlaps with other surveys and strategic reviews? This is the first of a series of talks planned for this summer designed to make the European community think about these questions. I stress that community input is required — you have until October and then we need to inform the astronomical community and the RAS of the outcomes. The key people to contact are listed on the website, but you can also contact me.

The President. I'm going to take it that that was so clear we don't need any questions.

Mr. T. O'Connor. I just want to run through the plans for the new road-show that STFC is promoting — 'Seeing the Universe in all its light'. It will have the same format as the LHC road-show which has been going around for ten months and which has been extremely successful wherever it has gone. The roadshow will be set up for week-long exhibits in parliaments and at major events in all parts of the UK. It is a showcase for the UK astronomical community. The target audiences are politicians, policy makers, schools, colleges, and members of the public.

This will be a partnership with the astronomical community, relying on PhD students and postdocs to staff the stand: STFC provides transport, accommodation, and a *per diem*; students supply knowledge, passion, and time. The first show will be at Jodrell Bank this weekend (2013 July 6 and 7) and will be based around a 1:4 scale model of the *VLT*, a 1:12 scale model of an *ALMA* antenna, a 1:20 scale model of the *JWST*, and a 1:10 scale model of the *Herschel* spacecraft. It will also include interactive exhibits in topical science, including an 8-metre display wall featuring 3D and a touch screen. After that there will be another at Jodrell Bank at the end of August and then the Welsh Assembly in Cardiff in late November, followed by NAM 2014 in Portsmouth, Holyrood, Belfast, and others to be decided. Your help is needed.

The President. Thank you. We now come to the really enjoyable part where we celebrate other people's genius — the contribution to our Society and the work that we do. I will introduce the medals and awards and hand them over. The President-elect, Martin Barstow, will read the citations. We start with the highest honour, the Gold Medal. It is awarded annually for an extraordinary lifetime achievement in astronomy or geophysics. Today it is the Astronomy Gold Medal.

Professor M. A. Barstow. Roger Blandford, Luke Blossom Professor in the School of Humanities and Sciences at Stanford University, is awarded the Gold Medal on the basis of his varied and inspirational contributions to theoretical astrophysics and services to astrophysics research astronomy at an international level. Professor Blandford is widely regarded as the outstanding all-round theoretical astrophysicist of his generation — a real intellectual leader and inspiration. His early work focussed on relativistic astrophysics and high-energy processes in galactic nuclei. In the 1970s he did pioneering work on, and helped to lay the basis for, what is now the conventional model of the nature of cosmic jets. He also made key contributions to the study of relativistic effects in compact remnants of massive stars, close binary systems, and on the extraction of energy from black holes. Remaining at the forefront of research throughout his career, Professor Blandford has also become a leader in the analysis of gravitational lensing. This is an important tool for probing the nature of as yet unidentified dark matter that is found throughout the Universe. [Applause.]

The President. The next award is the Price Medal which is awarded for investigation of outstanding merit to solid-Earth physics, oceanography, or planetary sciences.

Professor Barstow. The 2013 RAS Price Medal is awarded to Professor Kathryn Whaler for her distinguished career in geomagnetism and international leadership in geophysics. Her research has treated all aspects of the geomagnetic field, from the core, and its associated flow, through the field's passage through the mantle to the Earth's surface, including the effects of induction through magnetotellurics. Professor Whaler is currently Professor of Geophysics at Edinburgh. She began her career as a theoretical geophysicist, addressing fundamental questions about the stratification of the Earth's outer core and its influence on the geodynamo. Much of her work has involved using secular variation to map fluid flow at the top of Earth's core, starting with an elegant demonstration that the top of the core could be density stratified. She moved on to the application of geophysical inverse theory to problems in geomagnetism, ranging from the analysis of the core field to electromagnetic-induction studies. She laid the foundation for regularized inversion to determine the Earth's magnetic field at the core–mantle boundary.

With near-Earth satellite data she has done more studies of lithospheric magnetization, prediction of the geomagnetic field, and the magnetic field of Mars. Her contributions to electromagnetic induction have also evolved and she has led several successful multi-disciplinary field campaigns in Africa.

She is a former President of the RAS, only the third woman (and first among solid-Earth geophysicists) to hold the post, and was the first woman to be elected to a chair in geophysics in the UK. She is currently President of the International Association of Geomagnetism and Aeronomy. [Applause.]

The President. The next award is the Herschel Medal recognizing observations of outstanding merit in observational astrophysics.

Professor Barstow. Michael Kramer is Professor of Astrophysics at the University of Manchester and Director of the Max Planck Institut für Radioastronomie in Bonn. He has rapidly developed a reputation as an international leader in the field of observational pulsar astronomy. His impressive number of achievements include the first study of pulsars at mm-wavelengths, the first detection of geodetic precession, and the first detection of ionized gas in a globular cluster. He also played a central role in the discovery of the first and only double-pulsar system in 2004. With this pulsar, Professor Kramer produced the most stringent tests yet of General Relativity in strong gravitational fields. He also played a major part in the discovery of transient radio neutron stars. Currently Professor Kramer is leading the search for long-wavelength gravitational waves *via* the *LEAP* project, which is carrying out extremely accurate timings of pulsars across the sky. Finally, Professor Kramer has pioneered the use of volunteer computing, enlisting the help of the public in the discovery of pulsars. He has had enormous influence on the blossoming of pulsar astronomy and its integration into the rest of astrophysics in the last 20 years. Awarding him the Herschel Medal honours him as an intellectual leader of the field. [Applause.]

The President. The next award is the Jackson-Gwilt Medal for the invention, improvement, or development of astronomical techniques, for achievement in observational astronomy, or for achievement or research in the history of astronomy.

Professor Barstow. Professor Vikram Dhillon's research interests lie in the area of compact objects, such as white dwarfs, neutron stars, and black holes, both isolated and in binary systems. Professor Dhillon has addressed the challenges of observations of these objects in the time domain, with his development and operation of the *ULTRACAM*, a high-speed camera that can obtain simultaneous observations in three different band-passes at extremely high cadence. It has been used as a visitor instrument on several world-leading telescopes such as the *WHT*, *VLT*, and *NTT*. The impact of *ULTRACAM* has been enormous in fields as diverse as outer Solar System objects, extra-solar planets, brown dwarfs, interacting binaries, white dwarfs, and pulsars. As well as providing support to observers, he continues to innovate and has expanded his interests to high-speed spectroscopy, conjugate-plane photometry, and robotic telescopes. For his many contributions to the development of novel astronomical instrumentation and his pioneering work on high-speed photometry, Professor Dhillon is awarded the Jackson-Gwilt Medal. [Applause.]

The President. The next award is the Chapman Medal recognizing investigations of outstanding merit in solar-terrestrial physics.

Professor Barstow. Professor Steve Milan of the University of Leicester is awarded the Chapman Medal, which recognizes investigations of outstanding merit in solar–terrestrial physics. Professor Milan has thoroughly tested predictions of Professor Dungey's open-magnetosphere model by using ground-based ionospheric radars to study the motion of newly opened magnetic flux. On the global scale, Professor Milan has analyzed satellite auroral images to measure the variation in open flux. Further analysis, taking account of solar-wind conditions and variations in open flux, has enabled him to examine quantitatively how global day-side and night-side reconnection rates vary independently.

Professor Milan was the natural choice for the role of leader of the European Space Agency's Science Study Team set up to examine the scientific value of the proposed *KuaFu-B* mission, which is designed for dual-spacecraft global auroral imaging. [Applause.]

The President. The next awards are the Fowler Prizes. I'm afraid that Mark Swinbank can't make it today so we have only the Fowler Prize for Geophysics.

Professor Barstow. Dr. Iain Hannah is an outstanding young scientist who has already made an international impact on our understanding of solar hard-X-ray emission on a variety of scales. In particular he has led pioneering studies on the energetics of solar microflares through the interpretation of observations from the *RHESSI* satellite. His work displays exceptional breadth, given that he also carried out observational studies of plasma heating and plasma-electron acceleration in solar flares, as well as computational modelling of these systems. As part of his research, Dr. Hannah developed sophisticated techniques for analysis of small-scale hard-X-ray emission, including automated analysis of 25000 microflare events, and a new ultra-sensitive mode of *RHESSI* quiet-Sun observing. [Applause.]

The President. Now we come to the Winton Capital Awards. These are for research by a postdoctoral fellow in a British institution, no more than five years after the completion of a PhD, and whose career shows the most promising development.

Professor Barstow. The Winton Capital Award for Astrophysics goes to Dr. Bao-jiu Li. Dr. Li is a world leader in the field of alternative explanations of the Nobel Prize-winning discovery of the acceleration in the expansion of our Universe. The standard ΛCDM model is highly unsatisfactory, yet sufficiently developed and promising alternatives are thin on the ground. He has authored the only software code in existence which is able to solve evolutionary structure in the Universe in modified gravity, *i.e.*, non-Einsteinian gravity. This code is being used by many of the leading groups in the field. His thesis won the RAS Michael Penston Prize in 2009; he currently holds a Royal Astronomical Society Research Fellowship, and has now been appointed to the faculty at the University of Durham. [Applause.]

The President. We now move to the Group Achievement Awards. These recognize an outstanding achievement in astronomy or geophysics when it is not appropriate to award jointly one of the other awards. The awardees will probably understand why this is so.

Professor Barstow. The Astronomy Group Achievement Award is presented to the *SAURON* team, which is a large team, and today it is represented by Professors Roland Bacon, Roger Davies, and Tim de Zeeuw. The *SAURON* instrument is an integral-field spectrograph with a 33″ × 33″ field of view, which saw first light on the 4·2-m *William Herschel Telescope* in 1999. The scientific focus of the *SAURON* team was to understand the evolution of early-type galaxies by using detailed observation and samples of nearby objects. They have shown impressive efficiency in publishing world-leading scientific results in a timely manner. The *SAURON* initiative is not only impressive because of the instrument itself, which is optimized to the scientific goals of the project, but also in using models to interpret the results, together with the effective organization of the collaboration. The *SAURON* team focussed on observations of a representative sample of 48 early-type galaxies (E, S0, Sa), and follow-up studies through the ATLAS3D project to expand on this work to encompass a much larger sample of 260 E and S0 galaxies with extensive multi-wavelength follow-up. Scientific highlights include: the finding of a clear correlation between mass-to-luminosity ratio and velocity dispersion linked to the dark-matter contents of early-type galaxies; the finding that the warm gas in a substantial fraction of early-type galaxies must have an external origin; a new kinematic classification for early-type galaxies based on a proxy for specific angular momentum; and demonstration that young stellar populations are more prevalent in the lower mass of more-rapidly-rotating early-type galaxies. [Applause.]

The President. Next is the Group Achievement Award in the area of Geophysics.

Professor Barstow. This is an equally impressive list of people in a team. The 2013 RAS Group Achievement Award for Geophysics is given to the UK MHD Consortium, represented today by Professor Alan Hood. The Consortium, which was led by Professor Hood, has nodes located at the universities of St Andrews, Warwick, and Leeds, and has successfully developed and promoted the facility and tools to carry out large-scale magnetohydrodynamic (MHD) simulations in the UK. The Consortium's strong grouping of skilled researchers has led to the development and use of common approaches to computing practice, leading to substantially greater achievements than would have resulted from individual efforts. The deployment by the Consortium of high-performance massively-parallel computing systems in the UK and the coordinated development of software and related techniques has been the key to success in this difficult field. The research, which underpins the UK's leading position in computational MHD, could not have been undertaken without the resources put in place and developed by the UK MHD Consortium. [Applause.]

The President. We now come to the Service awards to honour any individual who, through their outstanding or exceptional work, has facilitated or encouraged the science of astronomy, geophysics, or Solar System studies and developed their role in the life of the nation, often beyond the requirements of his or her paid position.

Professor Barstow. Professor Mike Hapgood is Head of the Space Environment Group at RAL Space, and Visiting Professor at Lancaster University. Professor Hapgood is an internationally recognized expert in space weather, with a deep interest in understanding how the science links to practical impacts. Over the past decade he has led several major European space-weather studies and served as chair of ESA's Space Weather Working Team (2006–2009). Professor Hapgood has good links with US experts and has played a leading role in organizing a recent series of UK–US space-weather workshops that have promoted efforts to coordinate space-weather research, infrastructure, and policy.

Since 2010 he has chaired the Space Environment Impacts Expert Group that advises government bodies on the risks that extreme space weather poses to our country. His work with Lloyds insurance led to a publication that has raised awareness of the wider impact of space weather on business activities. Over the past year, Professor Hapgood has been actively leading the preparation of a UK Space Weather Strategy and he now advises on space weather for the National Risk Register. He has also been involved with the Royal Astronomical Society, where he has been Secretary and Vice-President, 2008–2010, and he is also the current Chair of MIST, the community group that works to coordinate the activities of the UK solar–terrestrial physics community under the aegis of the RAS. [Applause.]

The President. The Patrick Moore Medal recognizes a particularly noteworthy contribution in astronomy or geophysics by secondary-school-level teachers.

Professor Barstow. Dr. Bernie Tedd, Head of Physics at King Edward High School for Girls in Birmingham, has been awarded the 2013 Royal Astronomical Society Patrick Moore Medal in recognition of his outstanding work in astronomy education. The Medal is named after the late Sir Patrick Moore who did so much to bring astronomy to the public. Dr. Tedd has worked as a physics teacher for 20 years and throughout that time has exploited astronomy as an aspect of science that inspires school pupils and the wider public alike. His colleagues describe him as unfailingly enthusiastic and tireless in his teaching.

Within his school, he introduced the subject to Year-Seven (age 11–12) pupils, firing their interest with models, videos, and a virtual trip to Mars (*via* the Challenger Centre at the National Space Centre in Leicester). He teaches the GCSE Astronomy course at lunchtimes and in after-school slots to pupils in Years Nine, Ten, and Eleven (aged 13–16), and develops the astronomy programme in greater detail. This year 12 pupils achieved six A* and six A grades between them. Another 40 pupils are working towards the 2013 examinations and the course is now being opened to an adjacent school.

This work extends well beyond his own school. Dr. Tedd runs star parties open to pupils, families, and friends, sometimes linking them with the Astronomy Society at Birmingham University. For the Transit of Venus in June last year, he set up a solar reflector and a telescope in the school car park. Despite poor-weather forecasts, he managed to gather about 150 visitors at the early time of 5:30 am. [Applause.]

The President. Now we come to our Honorary Fellow. The RAS may honour any person eminent in a field of astronomy or geophysics by election as an

Honorary Fellow of the Society. This is typically in recognition of services to astronomical and geophysical sciences such as distinguished leadership of a school, observatory, or laboratory, outstanding services to national or international scientific organizations, exceptionally important work in editing scientific publications, influential work in education and public outreach in those sciences, or especially distinguished or outstanding work in the history of those sciences.

Professor Barstow. Although hailing from Ireland, Professor George Miley has been one of the most prominent Dutch astronomers of the last three decades. On the basis of a lifetime of achievement, Professor Miley is awarded an Honorary Fellowship of the RAS. [Applause.]

The President. I'm sad to say that that concludes the proceedings, except that I will now hand over to the President-elect because he knows what comes next and I don't!

Professor Barstow. Organizing the judging for the best poster by a PhD student at the NAM Meeting is a task which falls to the President-elect, apparently by tradition! My co-judges, Lyndsay Fletcher and Mandy Bailey, have given me fantastic support, and we have made our careful choices. It has been a very difficult job because the standard of papers has been so high and I'm sure many of you will disagree with our choices! The first prizes have been sponsored by the new publishers of our journals, Oxford University Press. The first prize is for poster 3.14 by Rebecca White of the University of Warwick. [Applause.] The second-place prize is awarded to poster 31.15 by Christine Smith of the University of Manchester. [Applause.] Finally I would like to add that Springer have also agreed to give each prize-winner a book from their stand.

The President. Thank you to the prize-winners for the brilliant example you have set. Let's meet again next year at about the same time and get a set of medallists and award-winners in the same class as we did today. This is our astronomy at its best, so make sure that you get your nominations in *via* the website. It is important, once in a while, to remember your colleagues and encourage them for the work that they do.

BUILDING STARS, PLANETS, AND THE INGREDIENTS FOR LIFE BETWEEN THE STARS

By Ewine van Dishoeck
Leiden Observatory

[The Halley Lecture for 2013, delivered in Oxford on 2013 May 29]

Introduction

Where do we come from? Are we alone? It is not just astronomers who are interested in these fundamental questions about our origins — we see it throughout culture in many ways. One of my interests is the relationship between astronomy and art and I like to collect pictures and paintings which connect the two. Many different cultures across the globe have recorded the sky, from the *Starry Night* by van Gogh and German expressionist art to paintings by the Australian aboriginals and inhabitants of the Pacific North-West. The Inuit, for instance, tell the story of how the Sun was stolen by First Raven from a dark box and put on the sky, and we can see many examples of the significance of the origin and evolution of stars and planets in our culture.

Halley's comet has also been an inspiration to artists throughout history, such as the *Bayeux Tapestry* depicting the events leading up to the Norman conquest of England and including the comet in 1066 when it was particularly bright. At the same apparition the comet is shown on petroglyphs made by Native Americans. Comet Halley's apparition of 1301 is also recorded on the painting by Giotto, *The Adoration of the Magi*, which resides in a chapel in Florence.

One of the most important developments in astronomy has been the discovery of exoplanets — planets orbiting stars other than our Sun. The first was found 18 years ago and now this is a burgeoning field of astronomy — close to 1000 exoplanets have been discovered. This begs the questions: how did these planetary systems (including icy bodies like comets) form? Are they similar to our Solar System? How unique is the Solar System?

Birthplaces of stars and planets

In this talk I will be concentrating on the solar neighbourhood because that is where we have the highest spatial resolution and sensitivity. The processes I will tell you about also happen in the rest of the Milky Way and in external galaxies too, even out as far as the edge of the observable Universe. Molecules like water and carbon monoxide have been seen at distances corresponding to a time when the Universe was only a small fraction of its present age. The Sun is one of several hundred billion stars in the Milky Way galaxy and can be found about halfway out from the galactic centre to the edge.

Stars and planets are formed from the very tenuous material between the stars. Astronomers realized only a century ago that the regions between the stars are not empty but consist of a very dilute gas. A good example is the Orion nebula, and with modern telescopes and techniques we see that it contains, in fact, a stellar nursery with hundreds of stars in there just in the process of forming. William Herschel speculated in 1789 that this nebula was "the chaotic material of future suns". At that time astronomers did not yet realize that stars do not have an eternal lifetime.

Hubble Space Telescope images of clouds like those in Orion show not only colourful nebulae due to ionized gas that is emitting brightly in the optical regime, but also very dark regions. The dark areas contain very minute particles of dust such as silicates and carbonaceous compounds which both absorb and scatter the light: these are the denser and colder concentrations of the gas and this is where stars are actually born. The dark clouds can be quite large (tens of light years across) and massive (up to 10^5 solar masses) but the process of star formation is quite inefficient and we would not be able to form 100 000 stars like our Sun from such a region. Dark clouds, such as the Coal Sack in the southern Milky Way, contain about 99% by mass of gas (mostly hydrogen) and 1% of solid materials. These dust grains are typically a few tenths of a micron in size. They are responsible for making the area appear so dark, and they also shield molecules from the dissociating ultraviolet radiation emitted by nearby stars.

The temperature of the cloud material is just above absolute zero and the density is about 10 000 particles per cubic cm. The air in this lecture theatre contains about 10^{19} molecules per cc whilst a good laboratory vacuum might be

10^8 particles per cc, so what an astronomer calls a dense cloud is still a much better vacuum than can be achieved on Earth. The physical conditions in the clouds are unique and that is what interests not just astrophysicists but also chemists.

New observational facilities

To observe these clouds we need to go to longer wavelengths where the scattering and absorption of the light is much less. *Spitzer Space Telescope* observations taken between 2003 and 2009 show how, as we zoom in on one of the dark clouds and move towards longer wavelengths, the dark clouds disappear and we see the young star that is being formed in infrared images. It is trying to push away the surrounding material from which it formed by means of a bipolar jet which comes out in opposite directions.

This type of astronomy is very much driven by the large telescopes that allow us to look at the sky at a variety of wavelengths, each of which tells a different part of the story. In the last decade we have been very fortunate to have access to a number of new powerful telescopes which can probe these dark regions. I particularly want to mention the *Herschel Space Observatory* which is actually the largest astronomical telescope in space. It was launched in 2009 but ran out of its coolants a few weeks ago, so we are no longer getting data from it but we are very busy in analyzing the data that we already have. In particular I want to mention the *HIFI* instrument which was built under the leadership of the SRON institute in the Netherlands. We want to go above the Earth's atmosphere because water, oxygen, and carbon-dioxide molecules block a lot of the light which is of particular interest in this work.

The great strides in improving our imaging techniques in the far infrared are demonstrated by the beautiful images from *Herschel*. Detectors from 30 years ago consisted of one single instrumental pixel at $\sim$ 100 microns and would only show a blob. *Herschel* gives much greater resolution over much larger areas — it has revealed the filamentary structure of the clouds from which new stars are being formed, by virtue of the thermal emission from the cold dust grains. *Herschel* has also made substantial inroads into imaging the circumstellar material around young stars where planets are born. *IRAS* was the first satellite to see an excess of emission over a stellar photosphere and now it is *Herschel* which can make a beautiful image of these sources showing the star and the ring of cold 'debris' dust which is formed by the collision of larger blocks of material.

On the ground too we have been able to make significant advances. The *VLT* at ESO is the most powerful collection of optical-infrared telescopes on Earth. At longer wavelengths we also have the 15-m *James Clerk Maxwell Telescope* in Hawaii, which is a joint British, Dutch, and Canadian project and which has, in particular, opened up the submillimetre regime. A major new facility in north Chile which started operating two years ago is called the *Atacama Large Millimetre Array* (*ALMA*). It is based on the Chajnantor plateau at an altitude of 5000 metres and is the first truly worldwide collaborative project involving as it does, North America, Europe, and East Asia. Almost all of the planned 66 antennae are now on the plateau. They have been assembled at 2700 metres and then trucked up to their final location.

Chemistry between the stars

To learn more about stars and planets, and especially the ingredients that go to make them, you need to obtain spectroscopic data. The astronomers' view of the periodic table is fairly restricted. The star-forming regions are 90% hydrogen and about 10% helium (by number) and very few heavier elements such as carbon, oxygen, and nitrogen whose abundances are only about 10^{-4} that of hydrogen. The gas is very tenuous and very cold but there is an extraordinary range of molecules. Chemists once suggested that it was not worth looking for complex molecules in space because of the great spans of time they need to form under these ultra-high-vacuum conditions. Fortunately the astronomers did not take any notice of this and looked anyway. In Orion, for instance, using the *HIFI* heterodyne instrument on *Herschel*, there are thousands of lines with patterns of certain molecules, both simple and complex. We see carbon monoxide and sulphur dioxide amongst the simpler molecules and then progressively more complex ones up to methanol, ethanol, sugars, and ethers. It is also clear that there are lines due to water, with line wings indicating high velocities — perhaps up to 100 km s^{-1}. This also gives us information on the kinematics of the clouds, in the case of water, on the outflows from young stars. The relative abundances of each molecule can be obtained from the absolute line intensities. Line ratios determine the excitation of the molecule which in turn provides information both on temperature and density in the clouds.

Among the more complex molecules which we can detect are dimethyl ether, glycoaldehyde, and ethyl cyanide. Even large molecules such as PAHs are present and have a very characteristic infrared emission signature and, of course, there are the C_{60} and C_{70} fullerenes proposed by Harry Kroto which were recently found in space. Kroto got the inspiration from the long carbon chains found in interstellar clouds, but then applied his knowledge to terrestrial carbon chemistry. If we consider the molecules that are part of prebiotic material which constitute DNA and RNA and therefore the basis for life, then we need to look for amino acids such as glycine and pyrimidine. They have not yet been detected but *ALMA* should be able to find them or place stringent upper limits.

So far I have been talking about molecules as a gas but because space is so cold they can also form as an icy layer on the grains. Once atoms and molecules are on a surface, other types of reactions can occur which have large energy barriers in the gas, especially reactions involving hydrogen — the conversion of O and O_2 to H_2O, C to CH_4, N to NH_3, and actually CO hydrogenation can occur as far as methanol, which plays a very important part in interstellar chemistry.

Water in star-forming regions

Thanks to *Herschel* we can trace how and where water was formed and how it was transported to the planet-forming zones of discs. Over the last few years we have carried out the WISH (Water In Star-forming regions with *Herschel*) programme (www.strw.leidenuniv.nl/WISH). It involves 70 people from 30 different institutions with 425 hours of guaranteed time that the institutes obtained in return for building the instrument. We now have a much better view of the way in which water is formed — the hydrogen and oxygen atoms come together on the dust grains and an icy layer is formed. The chemical routes involved were proposed 30 years ago but we did not have the laboratory facilities at that time to test them. Now these reactions have been fully characterized at low temperatures in the lab, so this is a successful collaboration between laboratory astrophysics and astronomical observations. We observed pre-stellar cores with *Herschel* and this shows that water does indeed form on dust grains at an early stage before the cloud collapses. We also see water in forming solar-mass protostars, especially in inflows and outflows as the bi-polar mechanism pushes material outwards. Water emission is particularly strong at shocks where the protostars dump energy into the cloud and drive a high-temperature chemistry leading to water.

Protoplanetary discs and planet formation

Star formation is accompanied by planet formation, so I'd like to take a little time to discuss the formation of planetary systems. Based on a wealth of data obtained over the last two decades, the current model suggests that young stars are surrounded by an envelope of material as well as a rotating disc of gas and dust. This disc is about the same size as the Solar System and contains about 10 Jupiter masses of material. The envelope is dispersed by the jets and outflows, and in the case of massive stars, by the radiation from the protostar. Once the envelope has been dissipated, the disc remains and can form planets through coagulation of dust grains to pebbles, rocks, and planetesimals, although the precise mechanisms are not yet understood. The *HST* images of protoplanetary discs show that they are about the same size as our Solar System. Nearly all young stars are surrounded by discs and the masses span a range with a mean about 1% of the Sun's mass or a factor 10 times that of Jupiter. In order to study the discs in more detail we need *ALMA*.

In both protoplanetary discs and the early Solar System there is a snow-line beyond which water exists as ice. In our Solar System it is roughly at the distance of Jupiter. If you freeze out the water then you enhance the density of the solids and that makes the process of planet formation more rapid. Inside that line the water exists as a gas and is hot enough to be observed by telescopes such as *Spitzer*. Outside the snowline, the cold water is uniquely probed by *Herschel-HIFI*, so observations with it provide us with the quantity of water gas and implicitly also that of water ice. This is one of the highlights of the WISH programme — the detection of cold water in these discs. In a typical disc we find the equivalent mass of about 6000 oceans of water ice.

Although using only 16 antennae, *ALMA* is already so sensitive that it detects hot water. *ALMA* spectra show a multitude of lines which correspond to quite complex organic molecules. Even a low-mass protostar (less than half the mass of the Sun) will show signs of compounds such as glycoaldehyde, the simplest sugar, and these can now be seen within 25 AU of the source, on the scale of the orbit of Uranus! With *ALMA* we can therefore zoom in on the planet-forming zones of discs and characterize their composition.

From discs to comets and exoplanets

We have an engraving from 1798 which demonstrates that, even centuries ago, people were speculating that our Solar System was only one of many. Data from the ground and from the *Kepler* satellite are showing us that there is a great diversity in exoplanetary systems. What drives this diversity? These exoplanets are composed of the gas and dust which came from the collapsing cloud which then formed a disc and began to coagulate into larger particles. Detecting forming planets themselves is still very challenging, but we can indirectly infer their presence from the gaps in the disc where planets have already formed and are clearing out their immediate area by attracting the gas and dust as they orbit. Although we cannot see the planet itself, *ALMA* can certainly see the gaps and holes in discs and some very exciting results are starting to appear, including the first evidence for a dust trap where millimetre-sized dust grains are concentrated. In such a trap, planetesimals and cometesimals can form quickly and can lead to the analogue of a Kuiper Belt around other stars.

I'd like to go back and make a connection with comets in the Solar System. We are expecting Comets ISON and PanStarrs and, of course, we can study their composition. Comets are basically coagulated icy dust grains which are up to a few kilometres across and which spend most of their time in the outer reaches of the Solar System where it is cold and their chemical composition can be preserved. We think that they contain the most primitive material which can point to the processes which helped to form the Solar System. There is one big question to ask. Did comets bring water to earth? *HIFI* has observed three comets and detected not only water but also deuterated water (HDO) and measured their abundances. The inferred ratio of the two is within 20% of what we have in the oceans on Earth. In the early stages of Solar System formation, there would have been some very big impacts after which we would not expect water and organic molecules to survive, but perhaps the comets disintegrated and the water and organics arrived on smaller pieces with more gentle impacts.

Eventually we will use the *E-ELT* and *JWST-MIRI* to take spectra of exoplanets to look at their chemical composition. The main message of this talk is that the chemical composition of planets is already largely determined at the time of formation of the cloud and disc from which the star and planets originated.

SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 234: HD 110583, HD 111224, HD 114864, AND HD 118264

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This paper gives single-lined orbits for four stars in the field of the North Galactic Pole. Its *Introduction* recalls that the writer has now offered more than 100 orbits for stars in that field. The four single-lined objects that form the subject here are all fainter than 9^m apart from HD 118264, which is 8^m and is the only one of the four to have an *Hipparcos* parallax. Their orbital periods differ markedly in the opposite sense to the *HD* numbers, being approximately 8000, 860, 400, and 85 days, respectively; their eccentricities are not so disparate as the periods but range in the same sense (as *e*–log *P* diagrams show to be typical), at about 0·42, 0·32, 0·07, and 0·04.

Introduction

This is another of the papers that refer to binary (or in one case[1] multiple) star systems discovered in the course of the comprehensive radial-velocity and photometric survey (hereinafter called the 'Survey') by Yoss & Griffin[2] of all the late-type *Henry Draper Catalogue* stars in the field of the North Galactic Pole (NGP), defined as the area at Galactic latitude $b > 75°$. This is the eighth such paper in this series since Paper 200, which itself included one such star; all the subsequent papers, like this one, have each dealt with four systems (but in one of them there was an interloper, HD 113449, that is outside the designated NGP field), so together they treat 32 NGP systems. Before Paper 200, there were ten papers in this series that gave orbits for a total of 30 NGP stars; the first was Paper 30 (which had the distinctive reference vol. **100**, p. 1), but that was exceptional — the rest started only at Paper 167. The reason for the long gap between Papers 30 and 167 was that orbits of NGP stars were earmarked at that time for publication in the *Journal of Astrophysics & Astronomy*, in which a numbered series of 25 papers*, treating a total of 34 stars, was published with a series title (once the writer got organized, at Paper 3!) *Spectroscopic Binaries near the North Galactic Pole*. The papers in that series, and in this one, are easy to locate, and the writer refrains from giving the individual references to them all. Four additional NGP orbits were published elsewhere in collaborative papers[3–5]. An arithmetical summation of the numbers of objects treated (62 in *this* series, 34 in the *JA&A* one, and four others) would suggest a grand total of exactly 100 NGP stars. A recent *Observatory* paper[1], however, supplanted one[6] that had been published 26 years previously in *JA&A* by demonstrating that what had originally seemed like an outrageously bad residual (to which attention had honestly been drawn at the time) was in fact the first evidence of higher multiplicity which in the later paper was fully elucidated, complete with a determination of the 'outer' orbit. Thus the total number of different NGP systems so far treated is 'only' 99, although there are others still under observation. The number of *orbits*, however, is already over 100, because three triple systems[1] were each accorded two orbits, and the one quadruple system[1] needed three.

An agreeable development has occurred since the previous NGP paper in this series was written (though it took place just in time for a footnote to be introduced at a late stage in proof). *Simbad*, which for 15 years had studiously ignored in its stellar bibliographies the Survey paper[2] which in very many cases supplied most of what was known about the stars concerned, has at last taken cognizance of it. It forms the whole of the bibliography on HD 111224, and half of it in the cases of HD 110583 and 114864; only in the case of HD 118264 is it outnumbered by other papers, in that case five others, though one of them is a catalogue of published radial velocities and has no new information.

By way of a concise introduction to the four stars that are the subject of this paper, some of the Survey[2] data on them are presented here in Table I.

It may be commented that the absolute magnitudes of the three giant stars appear to be rather on the faint side for the proposed luminosity classes, particularly in the case of HD 114864, which could well be regarded as a normal giant. The Survey[2] was published just earlier than the results of the *Hipparcos* satellite, so it could not take into account the relationship, subsequently discussed by Keenan & Barnbaum[7], between luminosity classes

*The serial numbers run only to 24; a repetition (confirmation) of one of the orbits was belatedly intercalated as Paper 12A.

and trigonometrically established luminosities. The one case where we have an *Hipparcos* parallax to compare with the *z* distance in Table I is that of HD 118264, where the parallax inverts to a distance of 247 pc, with 1σ limits of 202 and 318 pc. The corresponding absolute magnitude is close to $1^{m}\cdot0 \pm 0^{m}\cdot5$.

TABLE I

NGP Survey[2] results for the four stars

Star	*V* *m*	*(B–V)* *m*	*Type*	M_V *m*	*z* *pc*
HD 110583	9·43	1·07	K1 III	+1·8	325
HD 111224	9·43	0·91	K0 IV	+3·4	155
HD 114864	9·28	1·53	K2 II	+0·1	673
HD 118264	8·03	1·03	G5 III	+1·5	198

HD 110583

This star is on the southern edge of the field defined by the criterion of +75° Galactic latitude — its declination is only +12°. It is in Virgo, about 5° north-preceding Vindemiatrix (ε Vir). There is photometry of it, additional to that in the Survey[2], by Häggkvist & Oja[8], who found $V = 9^{m}\cdot40$, $(B - V) = 1^{m}\cdot07$, $(U - B) = 0^{m}\cdot95$. A table referred to by Soubiran *et al.*[9] includes a $(B - V)$ of $1^{m}\cdot085$ and an absolute magnitude that is given to extraordinary precision as $+1^{m}\cdot327$.

The radial velocity of HD 110583 has not been observed as assiduously as would have been desirable, particularly in view of its small amplitude of not much more than 1 km s^{-1}. On the other hand, it was only through good fortune that the star was discovered to be a binary system at all: an arithmetical mistake in the reduction of the first (1971) observation created an apparent discrepancy, considerably larger than truly existed, to appear when the second measurement was made in 1987, the best part of a whole orbital cycle later. The star was therefore monitored repeatedly, which otherwise it would not have been. The large table of radial velocities in the Survey paper[2] has 15 entries for HD 110583 (including the erroneous value for the first one), but even then, after nearly another decade, no definite further change had been witnessed. If the star had been clearly recognized as binary at the time that the Survey was published, its radial velocities would not have been printed then but would have been replaced by a note simply saying 'SB', as was actually done in the cases of 125 other stars. The reason that the duplicity of HD 110583 had not become clear after nearly a decade of monitoring was merely that the amplitude was small and the decade was more or less centred on the ascending (maximum-velocity) node of the orbit where the velocity change was in any case slow. The star has continued to be observed quasi-annually and has been seen round a little more than one cycle since 1987. The observations are rather sparse in comparison with the density that is usual in this series of papers; but the writer would have to be optimistic to think he could watch another 22-year cycle (he would be a centenarian by then!) to improve the orbit, which is, however, tolerably secure as it stands. The velocities are shown in Table II, where the Haute-Provence (OHP) and ESO ones have been adjusted by the usual +0·8 km s^{-1} (as they have for the other stars treated here) in an effort to put them on the zero-point adopted in this series of papers. The Cambridge *Coravel* ones have been adjusted by –0·3 km s^{-1} from the 'as reduced' values, an offset that was indicated for stars of HD 110583's colour in a substantial comparison[10] of OHP and Cambridge

TABLE II

Radial-velocity observations of HD 110583

Except as noted, the observations were made with the Cambridge Coravel.

Date (UT)	MJD	Velocity km s^{-1}	Phase	(O–C) km s^{-1}
1971 Feb. 21·13*	41003·13	−24·5	0·298	+1·0
1987 Mar. 4·01†	46858·01	−27·2	1·016	−0·2
1988 Mar. 13·05†	47233·05	−25·9	1·062	+0·2
1989 Mar. 26·05†	47611·05	−25·3	1·108	+0·2
Apr. 29·99†	645·99	−25·4	·112	+0·1
May 30·95*	676·95	−24·9	·116	+0·6
1990 Jan. 27·14†	47918·14	−25·2	1·146	+0·1
Feb. 12·33‡	934·33	−25·6	·148	−0·3
Mar. 27·02*	977·02	−24·4	·153	+0·9
Apr. 30·92*	48011·92	−25·7	·157	−0·4
1991 Jan. 29·13†	48285·13	−25·0	1·191	+0·3
June 13·93*	420·93	−25·7	·207	−0·4
1992 Apr. 29·96†	48741·96	−25·1	1·246	+0·3
1993 Feb. 16·09†	49034·09	−25·6	1·282	−0·2
1994 Jan. 5·23†	49357·23	−26·0	1·322	−0·5
1995 Jan. 8·16†	49725·16	−25·4	1·367	+0·3
June 5·96†	873·96	−26·1	·385	−0·4
1996 Apr. 3·02†	50176·02	−25·4	1·422	+0·4
1998 May 2·95†	50935·95	−26·2	1·515	−0·1
1999 Dec. 27·23	51539·23	−26·2	1·589	+0·2
2000 Apr. 27·03	51661·03	−26·3	1·604	+0·2
2001 June 24·93	52084·93	−26·5	1·656	+0·2
2002 Apr. 4·07	52368·07	−27·1	1·691	−0·2
2003 Apr. 8·96	52737·96	−27·5	1·736	−0·4
2004 May 16·95	53141·95	−27·6	1·786	−0·2
2005 May 4·98	53494·98	−27·7	1·829	0·0
2006 Apr. 9·00	53834·00	−27·8	1·870	+0·2
2007 Apr. 30·99	54220·99	−28·1	1·918	+0·1
2009 Apr. 21·98	54942·98	−27·2	2·006	0·0
2010 Apr. 18·00	55304·00	−26·1	2·051	+0·1
May 20·00	336·00	−26·3	·055	−0·1
June 17·92	364·92	−26·0	·058	+0·1
2011 May 9·98	55690·98	−26·1	2·098	−0·5

TABLE II (*concluded*)

Date (UT)	*MJD*	*Velocity km s⁻¹*	*Phase*	*(O – C) km s⁻¹*
2012 Apr. 6·00	56023·00	–25·2	2·139	+0·2
2013 June 15·92	56458·92	–25·8	2·192	–0·5

*Observed with original spectrometer; weight ⅛.
†Observed with Haute-Provence *Coravel*; weight 1.
‡Observed with ESO *Coravel*; weight 1.

velocities as a function of colour index. In the solution of the orbit, the 30 observations made with the three *Coravel*s (OHP, ESO, and Cambridge) have been accorded unit weight, while the five made with the original spectrometer at Cambridge have been weighted ⅛ to bring their weighted variance into approximate equality. The derived orbit is plotted in Fig. 1; the elements are included, along with those of the other three stars discussed in here, in Table VI near the end of this paper.

The formal standard deviations of some of the elements are misleadingly small. Inasmuch as the two nodes of the orbit were observed with different instruments and there is some uncertainty as to the relationship of their zero-points, K is not as accurate as it is made to appear; and for the same reason this and other γ-velocities are nothing like as accurate as their standard deviations suggest — a point that has been made repeatedly in this series of papers. The discrepancy between the mean velocity of –25·2 ± 0·3 km s^{-1} reported in the Survey paper and the γ-velocity of –26·46 found here arises because the former

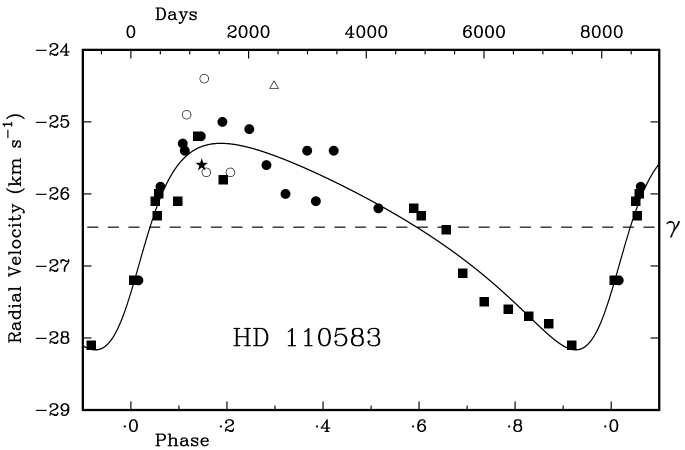

FIG. 1

The observed radial velocities of HD 110583 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. The filled circles and squares, and the single star, represent measurements made with the *Coravel* spectrometers at OHP, Cambridge, and ESO, respectively. Open circles refer to the original Cambridge spectrometer, and so does the open triangle, an observation that was made almost a full orbital cycle before any of the others; they were weighted ⅛ in the solution of the orbit.

value was not a γ-velocity but merely a mean of the then-available velocities, which so far from sampling all phases of the orbit were largely concentrated near one node.

The very small mass function demands a minimum mass of only 0·2 $M_\odot$ for the companion star if the K1 III primary is taken to have a mass of 2 $M_\odot$. The projected rotational velocity of HD 110583 is too small to measure, probably less than 1 km s^{-1}.

HD 111224

HD 111224 has many similarities to HD 110583, beginning with its situation right at the southern edge of the NGP field — it is actually a few minutes of arc *further* south than the last star, and is only about one degree following it — so about 4° from Vindemiatrix. Then it has a *V* magnitude ($9^{m}·43$) that is identical in the Survey paper; but it is modestly bluer than HD 110583 and seems to be of sub-giant luminosity. Again there is photometry by Häggkvist & Oja[8], who gave the magnitudes as $V = 9^{m}·41$, $(B - V) = 0^{m}·90$, $(U - B) = 0^{m}·59$.

The first radial-velocity observation of HD 111224 was made in 1973 by G. A. Radford, who was my student and collaborated in the early papers 3–17 in this series. The next measurement was in 1980 and not in good agreement, which was why the third one was made so *relatively* soon as 1982. Reductions of the observations, performed by hand and eye on the paper charts from the original spectrometer, were then running about a year in arrears, so recognition of the decisive discordance of the third measure was delayed, and the star was not transferred to the spectroscopic-binary programme until 1983. It is hard to find an excuse for how the work on a star with an orbital period less than 2½ years could then have taken 30 years to come to fruition, but now at last the orbit is presented. There is a total of 98 radial velocities, of which 28 were made in Cambridge with the original spectrometer and 37 with the *Coravel*, plus 26 made with the *Coravel* at OHP and two with that at ESO, and five with the spectrometer at the DAO 48-inch coudé. They are set out in Table III. The same zero-point offsets have been applied to the OHP and ESO velocities, on the one hand, and the Cambridge *Coravel* ones on the other, as for HD 110583. All the sources have been given unit weight in the solution of the orbit apart from the original Cambridge spectrometer, which is here weighted ⅕. On that basis the orbit shown in Fig. 2 has been derived; the elements will again be found in Table VI below.

The mass function sets a minimum mass for the secondary star, but only as a function of the mass of the primary. If we supposed the latter to be 1 $M_\odot$ then the minimum for the secondary would be about 0·5 $M_\odot$, but if the primary were 2 $M_\odot$ the secondary would have to be at least 0·7. Even at that, it would correspond to a type of about K5 and be about four magnitudes fainter than the primary, so it is not surprising that it has not been apparent in the radial-velocity traces. Just as in the case of HD 110583, the radial-velocity traces of HD 111224 show no significantly measurable line-broadening, and the projected rotational velocity is probably below 1 km s^{-1}.

HD 114864

HD 114864, another 9^{m} star, is to be found slightly less than 1° north-following α Com (often known instead as 42 Com: for a reason that has escaped the writer, only three stars in Coma have Greek-letter designations). 42 Com's claim to fame is as a visual binary whose orbit is seen, as nearly as can be

Table III

Radial-velocity observations of HD 111224

Except as noted, the sources of the observations are as follows:
1973–1991 — original Cambridge spectrometer (weighted ⅕ in orbital solution);
1992–1998 — OHP Coravel; 1999–2013 — Cambridge Coravel (both weight 1)

Date (UT)	MJD	Velocity km s^{-1}	Phase	(O–C) km s^{-1}
1973 Feb. 25·14[R]	41738·14	+26·2	0·291	+2·4
1980 Jan. 2·24	44240·24	22·5	3·194	−1·0
1982 Jan. 22·24	44991·24	15·5	4·066	−1·4
1983 Apr. 16·03	45440·03	17·9	4·586	−0·1
May 15·93	469·93	14·4	·621	−2·6
June 19·91	504·91	15·8	·662	+0·2
Dec. 11·24	679·24	8·8	·864	+0·9
1984 Jan. 9·18	45708·18	6·0	4·897	−1·0
Apr. 13·98	803·98	10·6	5·009	−0·6
May 12·97	832·97	14·5	·042	−0·1
1985 Jan. 24·18	46089·18	23·0	5·339	−0·3
Feb. 17·45*	113·45	22·5	·368	−0·4
May 31·94	216·94	22·4	·488	+1·8
1986 Jan. 25·17	46455·17	12·3	5·764	+0·5
Mar. 6·10	495·10	10·5	·810	+0·6
Apr. 10·93†	530·93	7·5	·852	−0·8
May 12·98	562·98	8·3	·889	+1·2
June 14·92	595·92	7·3	·927	+0·5
Dec. 12·24	776·24	20·9	6·137	−0·9
1987 Jan. 7·24	46802·24	23·2	6·167	+0·3
Feb. 1·16	827·16	24·6	·196	+1·1
Mar. 1·16†	855·16	25·4	·228	+1·6
Apr. 27·97	912·97	23·5	·295	−0·2
May 31·96	946·96	22·5	·335	−0·8
Dec. 22·25	47151·25	19·1	·572	+0·7
1988 Jan. 23·50*	47183·50	17·4	6·609	+0·1
31·45*	191·45	16·3	·618	−0·7
Mar. 11·10†	231·10	15·3	·664	−0·2
16·98†	236·98	15·6	·671	+0·3
Apr. 12·99	263·99	16·7	·703	+2·5
Nov. 6·21†	471·21	7·5	·943	+0·5
1989 Feb. 11·17	47568·17	15·0	7·056	−1·0
24·25‡	581·25	16·9	·071	−0·5
Mar. 25·10†	610·10	20·0	·104	0·0
Apr. 28·96†	644·96	23·4	·145	+1·2
May 26·94	672·94	25·0	·177	+1·9
1990 Jan. 31·12†	47922·12	21·0	7·466	0·0
Feb. 12·33‡	934·33	20·6	·480	−0·1
Mar. 27·03	977·03	19·2	·530	−0·3
Apr. 30·95	48011·95	18·1	·571	−0·3
1991 Jan. 29·14†	48285·14	7·1	7·888	−0·1
Feb. 6·15†	293·15	5·5	·897	−1·5
May 9·96	385·96	+12·9	8·005	+2·1

TABLE III (*continued*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O–C)* *km s⁻¹*
1992 Jan. 17·13	48638·13	+23·4	8·297	−0·3
Feb. 28·44*	680·44	22·9	·346	−0·3
Apr. 22·03	734·03	22·0	·408	−0·2
June 25·89	798·89	20·8	·484	+0·2
Dec. 21·22	977·22	14·5	·691	−0·1
1993 Feb. 15·11	49033·11	12·5	8·755	+0·3
Mar. 25·01	071·01	10·4	·799	0·0
July 8·91	176·91	7·7	·922	+1·0
Dec. 30·23	351·23	21·2	9·125	0·0
1994 Feb. 19·17	49402·17	23·5	9·184	+0·2
May 2·01	474·01	23·5	·267	−0·4
1995 Jan. 5·21	49722·21	18·3	9·555	−0·6
June 2·99	870·99	13·3	·728	+0·1
Dec. 27·18	50078·18	7·8	·968	−0·2
1996 Mar. 31·00	50173·00	17·4	10·078	−0·7
1997 Mar. 31·03	50538·03	19·5	10·502	−0·7
Apr. 18·06	556·06	19·1	·523	−0·6
May 13·03	581·03	18·6	·552	−0·4
July 24·85	653·85	16·8	·636	+0·3
1998 July 8·88	51002·88	15·0	11·041	+0·5
1999 Apr. 15·31*	51283·31	22·4	11·366	−0·5
Dec. 29·22	541·22	16·2	·666	+0·7
2000 Feb. 16·14	51590·14	14·3	11·722	+0·9
Apr. 10·02	644·02	10·7	·785	−0·3
May 30·93	694·93	7·5	·844	−1·1
2001 Jan. 11·23	51920·23	19·7	12·105	−0·4
Feb. 27·14	967·14	22·1	·160	−0·6
Dec. 30·22	52273·22	20·2	·515	+0·3
2002 Mar. 2·09	52335·09	18·1	12·587	+0·1
Apr. 4·07	368·07	17·7	·625	+0·9
May 5·01	399·01	16·2	·661	+0·5
2003 Jan. 27·18	52666·18	8·5	12·971	+0·3
Mar. 3·09	701·09	11·4	13·011	−0·1
Apr. 16·01	745·01	16·7	·062	+0·1
May 14·97	773·97	19·2	·096	−0·3
June 20·92	810·92	22·2	·139	+0·3
2004 Jan. 15·20	53019·20	22·7	13·381	0·0
Mar. 1·12	065·12	21·9	·434	+0·2
2005 Jan. 23·20	53393·20	9·7	13·815	0·0
Apr. 21·97	481·97	7·1	·918	+0·4
June 22·92	543·92	8·7	·989	−0·8
2006 Mar. 1·11	53795·11	23·7	14·281	−0·1
Apr. 4·07	829·07	23·4	·320	−0·1
May 11·96	866·96	23·5	·364	+0·6
June 27·92	913·92	+21·3	·419	−0·7

TABLE III (*concluded*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
2007 Mar. 27·07	54186·07	+13·0	14·735	0·0
Apr. 29·97	219·97	12·0	·774	+0·6
June 21·95	272·95	8·5	·835	−0·4
2008 May 14·93	54600·93	23·4	15·216	−0·3
2009 Jan. 6·28	54837·28	20·3	15·490	−0·2
2010 Mar. 23·07	55278·07	10·8	16·002	+0·3
Apr. 8·04	294·04	12·8	·020	+0·5
2012 Apr. 6·03	56023·03	7·8	16·866	0·0
2013 Mar. 13·08	56364·08	24·0	17·262	+0·1
Apr. 2·05	384·05	+24·2	·285	+0·4

R Observed by G. A. Radford.
* Observed with DAO 48-inch telescope; wt. 1.
† Observed with Haute-Provence *Coravel*; wt. 1.
‡ Observed with ESO *Coravel*; weight 1.

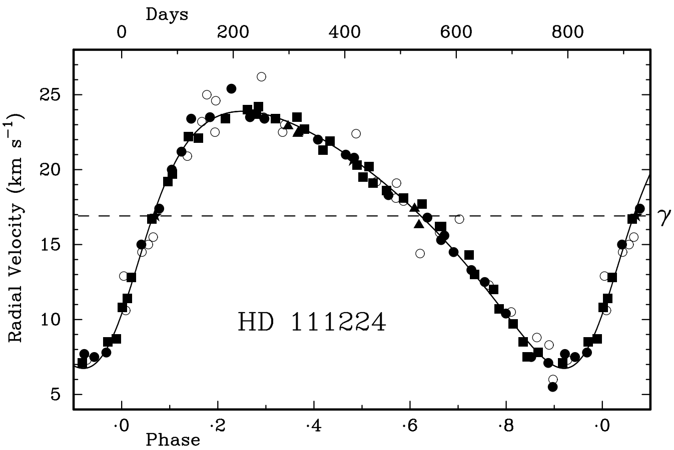

FIG. 2

As Fig. 1, but for HD 111224. In this case the measurements made with the original spectrometer have been weighted ⅕. Here there is an additional source of data: the filled triangles represent velocities obtained with the DAO spectrometer, which were given the same (unit) weight as the *Coravel*s in the solution of the orbit.

determined, edge-on, leading to speculation that it might show eclipses, which, however, have not been observed. HD 114864 is listed in Burnham's catalogue[11] as the primary component of a double star, BDS 6425 A, but it is a very wide optical one (about 87″) and was not countenanced by Aitken as worthy of inclusion in *his* catalogue[12]. The entry in the *BDS* identifies the double star as 'S 648', and the introductory material to that catalogue, page viii, gives the reference for 'S' as a long paper[13] by South in the *Philosophical Transactions* *of The Royal Society*. In it, South reports three measurements of the system (numbered there as DCXLVIII)⋆, all made in one month, 1826 May, with the "seven-feet equatorial", in plain terms a 5-inch refractor; all three observations are noted separately as "excessively difficult", and the stars are described as "extremely faint". They are first called "10th and 12th, or 13th magnitudes"; the second time they are "10th and 13th", and finally they are "10th and 14th, or 15th magnitudes" — the secondary seems to have become fainter and fainter by the week! In actual fact, the magnitude of the secondary, now identified as HD 114881, is given by *Tycho 2*[14] as $9^{m}\cdot969$, though confusingly it is reported in *Simbad*'s main entry for that star as $9^{m}\cdot93$ although the reference there is to *Tycho 2*. Interestingly, South mentions that "If this star [HD 114864 — at the time it had not got any actual name apart from the one that South was giving it] be brought into the upper part of the field, a nebula of considerable magnitude will be found in the lower part of it.". Of course South was observing with an inverting telescope; the "nebula" (actually a globular star cluster) is to the north (no joke intended) of the star. Burnham, though evidently making an effort to be helpful, made a rare mistake in commenting on the "nebula", "This appears to be *Dreyer* [*i.e.*, NGC[15]] 5053.". NGC 5053 is actually a relatively faint globular cluster nearly a whole degree south-following HD 114864; the cluster that South could see as a nebula in his five-inch telescope is M 53 (NGC 5024), centred only about 9′ away from HD 114864 and more than two magnitudes brighter in integrated light than NGC 5053.

The Survey magnitudes show HD 114864 to be an unusually red star, its $(B-V)$ being given as $1^{m}\cdot53$. Once again, Häggkvist & Oja[8] largely support that, giving the star's photometry as $V = 9^{m}\cdot25$, $(B-V) = 1^{m}\cdot50$, $(U-B) = 1^{m}\cdot62$†. For a giant, or even a supergiant, star, the $(B-V)$ index would indicate[16] a type near K5, and we cannot in good conscience postulate significant reddening at the high Galactic latitude concerned[17]. The *Henry Draper Catalogue* type is K0, and even the Survey itself proposes a type only as late as K2 II, at the same time as finding $M_V \sim +0^{m}\cdot1$ — a seeming inconsistency already mentioned in the *Introduction* above. It is in any case statistically improbable to find highly luminous stars with apparent magnitudes similar to that of HD 114864 at high Galactic latitudes, because the Galactic disc population simply is not thick enough — does not extend far enough from the plane — and the more spherical components of the Galactic population are too old to have any high-luminosity stars left.

It might be tempting to see some significance in the fact that HD 114864 shows appreciable line-broadening: expressed as a projected rotational velocity it is quantified as $6\cdot8 \pm 0\cdot6$ km s^{-1} by the OHP *Coravel* and as $7\cdot2 \pm 0\cdot4$ km s^{-1} by the Cambridge one. Values of that order are common for high-luminosity stars (particularly luminosity class Ib), and in such cases probably do not represent rotation so much as some sort of confused atmospheric motions generically (if non-commitally) designated 'turbulence'. But high-luminosity stars also normally give radial-velocity dips that have larger equivalent widths than the

⋆Comparable unwieldiness in the enumeration of the papers in the present series was fortunately averted when the writer foresaw what could transpire and quickly forsook roman numerals for arabic ones between Papers I and 2!

†*Simbad* interprets the *Tycho* V_T and B_T as yielding a somewhat less dramatically red, but poorly determined, $(B-V)$ of $1^{m}\cdot382 \pm 0^{m}\cdot076$, but there is no case for preferring that to the ground-based measurements.

relatively modest ones given by HD 114864, and the totality of evidence, albeit mostly indirect, argues against a conclusion that the star has a particularly high luminosity.

Not surprisingly, such a red star was identified as an *IRAS* source, and it is only on account of the coincidental proximity of that source to the globular cluster M 53 that the star features in the only paper[18] retrieved in the *Simbad* bibliography other than the Survey one, a paper concerned with globular clusters.

The writer's first radial-velocity observation of HD 114864 was made with the original spectrometer at Cambridge in 1975; it was not until 1987 that another measure was made — on that occasion with the OHP *Coravel*, whose result was displayed immediately and was clearly in conflict with the original one, so the star was forthwith transferred to the spectroscopic-binary programme. Although the period of about 400 days is considerably shorter even than that of HD 111224 referred to above, it is easier to explain how it could take a long time to determine the orbit satisfactorily. The closeness of the period to one year means that in any one season there is a large gap in phase coverage and one has to wait for it to migrate around the orbit. Even so, this publication has been delayed for much longer than the ten-year migration cycle. In this case it has happened for an identifiable reason. On two or three occasions there has been an appearance of a very weak second dip in the traces, and observations have been continued in the hope that the system could be reported as a double-lined, rather than a single-lined, binary. But then other traces, sometimes integrated far beyond the level at which a second dip had been suspected, have shown nothing, and the apparent weak dips themselves have not formed an acceptably coherent data set and are at last being dismissed as illusory. The smallness of the mass function, though not an infallible guide, does not encourage an expectation of an observable secondary system, and although seemingly haphazard velocities *might* arise from a single-lined short-period sub-system, it would be reprehensible to postulate such a thing on the basis of a few doubtful data.

Thus the orbit given here is a plain single-lined one. There are 63 radial velocities, set out in Table IV; they are mostly from the OHP and Cambridge *Coravel*s with 26 each, but including also eight from the original Cambridge spectrometer, two from ESO, and one from the DAO spectrometer. All have been given the same weight in the solution of the orbit apart from the eight obtained with the original spectrometer, which have been weighted ⅕. The orbit is illustrated in Fig. 3 and its elements are included in Table VI below.

The r.m.s. residual of the solution is unusually large. That could of course be interpreted in terms of unrecognized blending with a weak second dip that has a quasi-random velocity through arising in a short-period sub-system, but a more prosaic explanation would be in terms of a minor 'jitter' such as is commonly seen in the velocities of very red stars. The small mass function demands a mass of little over 0·4 $M_{\odot}$ for the secondary object if the mass of the primary is taken as 2 $M_{\odot}$; if we really believed that the primary is a massive star (it ought then to be brighter than the absolute magnitude of $+0^{m}\cdot 1$ found in the Survey), with a mass of say 4 $M_{\odot}$ then the secondary would still not be obliged to be as much as 0·7 $M_{\odot}$, corresponding to the mass of a late-K dwarf with $M_V \sim +7^{m}$ that would certainly not create an observable feature in radial-velocity traces.

The projected rotational velocity of HD 114864 has been noted above to be about 7 km s^{-1}. A late-K giant with a radius of 25 $R_{\odot}$ and having such a rotational velocity would have a rotation period of about 180 sin i days — but, in

TABLE IV

Radial-velocity observations of HD 114864

Except as noted, the sources of the observations are as follows:
1987–1998 — OHP Coravel; 2000–2013 — Cambridge Coravel (both weight 1)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1974 May 2·43*	42169·43	−1·0	0·395	−6·2
5·44*	172·44	−27·2	·402	−32·4
20·36*	187·36	−3·7	·439	−8·9
27·27*	194·27	−6·7	·457	−11·9
31·26*	198·26	−17·8	·466	−23·1
1975 June 9·92†	42572·92	+3·7	1·400	−1·5
1987 Mar. 3·20	46857·20	+15·4	12·070	−0·9
May 9·05†	924·05	+8·9	·237	+0·1
1988 Jan. 31·55‡	47191·55	+20·0	12·903	+1·2
Mar. 12·08	232·08	+18·3	13·004	−0·2
17·02	237·02	+18·5	·016	+0·3
Apr. 13·98†	264·98	+17·7	·086	+2·0
May 19·95†	300·95	+14·7	·175	+3·2
1989 Feb. 24·26§	47581·26	+18·4	13·873	+0·1
Mar. 25·12	610·12	+19·4	·945	+0·3
31·02	616·02	+18·6	·960	−0·5
Apr. 28·06	644·06	+18·2	14·030	+0·4
May 2·95	648·95	+16·7	·042	−0·7
June 4·94†	681·94	+14·3	·124	+0·4
1990 Jan. 27·09	47918·09	+12·6	14·712	+0·3
Feb. 12·37§	934·37	+13·7	·753	−0·3
Mar. 29·01†	979·01	+17·0	·864	−1·0
Apr. 30·02†	48011·02	+20·8	·944	+1·7
Dec. 27·24†	252·24	+5·4	15·545	−1·2
1991 Jan. 26·18	48282·18	+8·8	15·619	+0·1
Feb. 4·13	291·13	+10·2	·641	+0·7
1992 Jan. 20·19	48641·19	+6·0	16·513	+0·1
Apr. 27·10	739·10	+14·1	·757	−0·1
June 26·97	799·97	+18·6	·909	−0·3
1993 Feb. 15·15	49033·15	+5·5	17·490	−0·1
Mar. 25·06	071·06	+8·7	·584	+1·1
July 11·92	179·92	+17·9	·855	+0·1
1994 Jan. 3·21	49355·21	+7·2	18·292	+0·2
Feb. 21·13	404·13	+4·3	·413	−0·8
May 1·06	473·06	+7·1	·585	−0·5
Aug. 3·87	567·87	+15·6	·821	−1·1
Dec. 13·20	699·20	+12·8	19·148	+0·1
1995 Jan. 3·22	49720·22	+10·7	19·201	+0·4
June 1·98	869·98	+7·2	·574	−0·1
1996 Mar. 31·06	50173·06	+6·7	20·329	+0·6
1997 Mar. 6·18	50513·18	+12·0	21·176	+0·5
Apr. 11·10	549·10	+8·2	·265	+0·4
May 7·04	575·04	+4·9	·330	−1·2
10·01	578·01	+5·1	·337	−0·8

TABLE IV (*concluded*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1998 May 2·05	50935·05	+8·1	22·226	−1·1
July 10·94	51004·94	+3·5	·400	−1·7
2000 Apr. 6·05	51640·05	+18·2	23·982	−0·6
May 25·94	689·94	+14·3	24·107	−0·4
31·00	695·00	+14·3	·119	+0·2
2001 Feb. 17·18	51957·18	+13·8	24·772	−1·0
May 5·05	52034·05	+19·8	·964	+0·7
2002 Feb. 27·13	52332·13	+11·8	25·706	−0·2
Apr. 7·09	371·09	+16·0	·803	0·0
2003 Feb. 21·12	52691·12	+8·2	26·600	+0·1
May 10·00	769·00	+16·8	·794	+1·1
2004 Jan. 9·28	53013·28	+5·3	27·402	+0·1
Mar. 30·09	094·09	+8·4	·604	+0·2
May 22·98	147·98	+13·1	·738	−0·3
2005 May 28·99	53518·99	+9·0	28·662	−1·3
2006 Apr. 6·02	53831·02	+7·0	29·439	+1·8
9·06	834·06	+5·8	·447	+0·6
2007 Apr. 16·01	54206·01	+6·2	30·373	+0·8
2009 Jan. 21·26	54852·26	+18·0	31·983	−0·8
2010 May 23·94	55339·94	+10·8	33·197	+0·3
June 2·97	349·97	+9·5	·222	+0·1
2012 May 25·98	56072·98	+18·1	35·023	+0·1
2013 Mar. 27·09	56378·09	+15·8	35·783	+0·6
Apr. 18·08	400·08	+17·7	·838	+0·5

*Published by Hill *et al.*[19] from DAO; weight 0.
†Observed with original spectrometer; weight ⅕.
‡Observed with DAO 48-inch telescope; weight 1.
§Observed with ESO *Coravel*; weight 1.

view of the doubt about the real character of the star, that number is given only by way of perspective and not necessarily as an approximation to reality.

A remarkable fact, mention of whose existence has been deferred until here, is that HD 114864 had been asserted to be a spectroscopic binary by Hill *et al.*[19] before any radial velocities had been determined for it by the writer's cross-correlation method. Those authors included it in a small addendum to a table of measured radial velocities (their Table II) in their paper entitled '*Studies of A and F stars in the region of the North Galactic Pole—I*'. Of course HD 114864 would not qualify as an A or F star, which is no doubt the reason why it was relegated to the addendum. In fact, the text of the paper includes a paragraph stating, "Inevitably … a number of misidentifications occurred at the telescope. … When it was possible to identify these stars without ambiguity we have included their velocities at the end of Table II also." There are five velocities

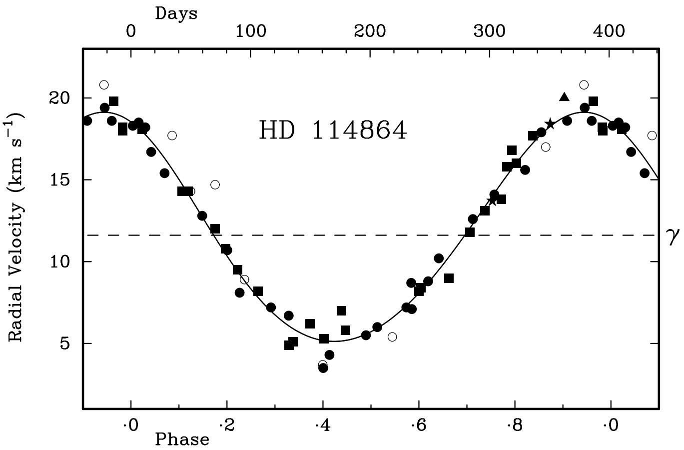

FIG. 3

As Fig. 2, but for HD 114864. The measurements made with the original spectrometer have again been weighted ⅕.

attributed to HD 114864 in the addendum; the first two of them were made at times adjacent to (~20 minutes, no doubt approximately an exposure time, away from) those reported in the main body of the same table for HD 114881, which is indeed a nearby star (being BDS 6425 B, as related in the first paragraph in this section, above) and is of F type (F5 in the *Henry Draper Catalogue*). HD 114881 was observed only on the two occasions, and each time it was *before* HD 114864, so one might deduce that it was not misidentification so much as curiosity on the part of the observer that led to the observation of the latter star in addition. Then it might further be imagined that the three additional observations were made of HD 114864, while the real programme star HD 114881 was ignored, because the first two were so discordant from one another, differing by 26 km s^{-1}. The subsequent ones fall between the first two; but the extraordinary thing is, all five are negative velocities, whereas HD 114864 always has a positive velocity, with a minimum of about +5! Fig. 4 is a version of Fig. 3 whose range of ordinates has been greatly extended on purpose to include the five DAO velocities, which are seen to be altogether out of place. It is hard to suppose that the star was misidentified every time, when the juxtaposition of the times of the first two observations with those of its neighbour HD 114881 tends to show that it was observed deliberately. Yet if the discrepancies from the velocities computed from the orbit are representative of the errors of *all* velocities in the paper[19] concerned, the implications are serious. The velocities are not only hopelessly discordant with those expected on the basis of the orbit, but are *mutually* discordant enough (an r.m.s. spread of 11 km s^{-1} although the internally estimated standard errors of the individual plates are given as ranging from 1·8 to 2·6 km s^{-1}) for Hill *et al.* to have noted "VARIABLE VEL." against their mean value of $-11{\cdot}9 \pm 4{\cdot}9$ km s^{-1}.

All the observations mentioned in the paragraph above are listed as having been obtained with a spectrograph called '2·282'. The introductory paragraph to a section entitled "OBSERVATIONS AND REDUCTIONS" in the paper[19] tells

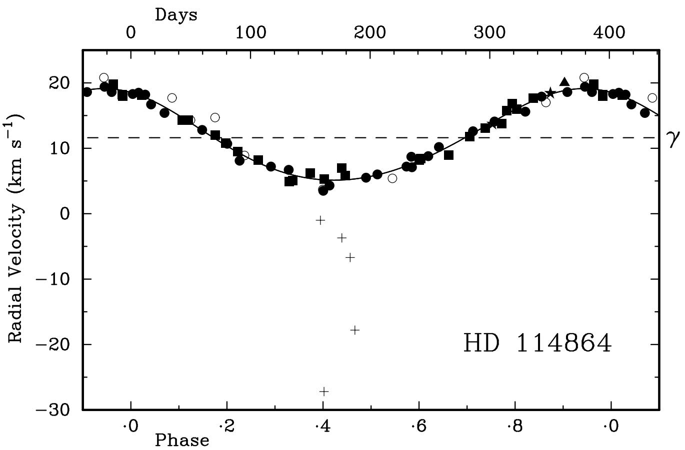

FIG. 4

The same as Fig. 3 but on a reduced vertical scale to accommodate the five observations, all made in one month and published from the DAO by Hill *et al.*[19], on the basis of which they announced HD 114864 to be a spectroscopic binary.

us that "The observations were all made with prism and grating spectrographs attached to the Victoria 72-inch reflector. Details of the spectrographs are noted in Table II." But Table II is just the list of observations, and the "details" consist only of a column that lists the *identity* of the spectrograph against each observation and does not give any idea of the character, or even the dispersion, of any of the instruments. Nor has the writer been able to locate a published description of the instrument. By direct enquiry to the DAO, however, it has been possible to discover that '2·282' is a (still extant but no longer used) spectrograph whose principal characteristics are encoded in its name. It has a focal length of 2·2 inches, uses a grating with a ruling of 8-hundred-odd (actually 830) grooves per millimetre, used in the 2nd order. If the grating were more or less face-on to the camera, that system would give a dispersion of about 110 Å mm^{-1}. The introductory section of Hill *et al.*'s paper[19] informs us about exposure times at 80 Å mm^{-1}; if there is an implication that that was the approximate dispersion of the 2·282 spectrograph, then the instrument must actually have been used in the third order and its focal length must have been only a little over 2 inches, so it seems that it would have been, in fact, despite its name, a '2·083' spectrograph!

The two DAO spectra of HD 114881, both noted as "WEAK", gave velocities of +8·0 ± 3·7 and −6·1 ± 6·5 km s^{-1}. Three observations with the OHP *Coravel* gave +0·2 ± 1·3, −3·9 ± 1·1, and −4·9 ± 1·6 km s^{-1}, so *they* are not in good mutual accord either; but the star was not on the ostensible observing programme and was observed only out of curiosity and with short integration times, and it gave only a very shallow 'dip' (10% of the continuum height), so no significance should be read into the poor inter-agreement.

HD 118264

HD 118264 is right on the eastern border of Coma Berenices, but the nearest star of (just about) naked-eye brightness is 2 Boo, about 1½° following it, in the adjacent constellation. As related in the *Introduction* above, HD 118264 is the only one among the stars treated in this paper to have an *Hipparcos* parallax[20], albeit with a standard error nearly a quarter as great as itself, so we know fairly well its distance (250^{+70}_{-50} pc) and absolute magnitude (close to $+1^{m}\cdot0 \pm 0^{m}\cdot5$). As seems to be usual, we have photometry from Häggkvist & Oja[8]: $V = 7^{m}\cdot97$, $(B-V) = 1^{m}\cdot02$, $(U-B) = 0^{m}\cdot80$. This time there is a discrepancy of $0^{m}\cdot06$ from the Survey V magnitude, although the $(B-V)$ colour indices agree to $0^{m}\cdot01$. It would be unwise to claim that there is real variation without considerably more evidence of it, especially since the *Hipparcos* 'epoch photometry' reports 95 passes that gave accordant results within an r.m.s. spread of only $0^{m}\cdot015$ — a smaller value than for the majority of the 100 stars recorded on the same page[21] in the *Hipparcos* catalogue volume. The V magnitude derived from the *Hipparcos* photometry (by transformation: the actual observations are in its private *Hp* system, which is, however, not far from V itself) is[21] $8^{m}\cdot02$, while the V obtained from V_T by *Tycho 2* is reported[22] as $8^{m}\cdot04$. Those results are seen to agree with the Survey value of $8^{m}\cdot03$ rather than with Häggkvist & Oja[8]'s $7^{m}\cdot97$.

The appearance of HD 118264 in the *New Catalogue of Suspected Variable Stars*[23] seems more reprehensible than informative: the entry is based on a photometric catalogue published[24] from Potsdam in 1907, which records a variation reaching half a magnitude, including a change of more than $0^{m}\cdot2$ in just ten days in 1898. It would tidy the literature considerably if such allegations could be regarded as refuted or withdrawn when later and more reliable observations have altogether failed to corroborate such variation, and the writer can only apologize if he seems to be perpetuating this particular *canard* by his own effort to discredit it!

The first two radial-velocity measurements of HD 118264 were made by Radford in 1973 and by me in 1986, both of them with the original Cambridge spectrometer, and they were in reasonable agreement with one another. It was Soubiran who drew attention privately to the serious discrepancy between those measurements and the one that she and her collaborators made[22]; that impelled the writer to observe the object as a spectroscopic binary, starting in 2008. Two observations in that year showed only a small range, but in 2009 a major change occurred in three weeks, whereupon the object was followed attentively (21 measurements in 2½ months) and its 85-day period was recognized. There are now 52 observations, listed in Table V; the Soubiran one (made with the OHP *Coravel*) is included, with an adjustment of $+1\cdot0$ km s^{-1} to account for the expected difference of zero-point. Apart from that and the two early Cambridge measurements, which have been weighted ⅒ in the solution of the orbit, all the data have come from the Cambridge *Coravel*. The period obtained from those *Coravel* observations alone is $85\cdot218 \pm 0\cdot012$ days. Inclusion of the three early ones increases the time base by a factor of eight and halves the formal standard error of the period, but it also changes the *Coravel*-only period by $1\cdot6$ times its standard deviation, which seems a bit unpleasant in view of the small number and lack of homogeneity of the old observations. The writer considers that the best value to adopt for the period and its standard error, though obviously not

TABLE V

Radial-velocity observations of HD 118264

Except as noted, the observations were made with the Cambridge Coravel.

Date (UT)	*MJD*	*Velocity* $km\ s^{-1}$	*Phase*	*(O – C)* $km\ s^{-1}$
1973 Mar. 15·20[*R]	41756·20	−13·1	$\overline{151}$·736	−1·1
1986 May 25·93[*]	46575·93	−14·8	$\overline{94}$·306	−0·7
2000 Apr. 26·06[†]	51660·06	−3·3	$\overline{35}$·979	−0·2
2008 May 6·96	54592·96	−16·9	0·403	+0·5
July 20·89	667·89	−13·6	1·283	−0·5
2009 Mar. 30·10	54920·10	−11·4	4·243	−0·2
Apr. 21·04	942·04	−18·5	·500	+0·1
22·06	943·06	−18·8	·512	−0·2
29·06	950·06	−17·4	·594	0·0
30·04	951·04	−16·7	·606	+0·4
May 4·03	955·03	−15·7	·653	−0·1
7·00	958·00	−13·9	·688	+0·3
8·95	959·95	−12·9	·711	+0·3
19·98	970·98	−6·7	·840	+0·3
20·96	971·96	−6·3	·851	+0·2
23·02	974·02	−5·5	·876	0·0
24·02	975·02	−5·2	·887	−0·1
27·01	978·01	−4·0	·922	0·0
29·97	980·97	−3·1	·957	+0·2
June 1·99	983·99	−3·0	·993	0·0
11·94	993·94	−5·1	5·109	0·0
17·98	999·98	−8·1	·180	+0·1
23·96	55005·96	−11·5	·251	+0·1
24·94	006·94	−11·8	·262	+0·3
30·93	012·93	−15·4	·332	−0·2
July 2·92	014·92	−16·0	·356	+0·1
6·93	018·93	−17·4	·403	0·0
2010 Jan. 31·26	55227·26	−6·4	7·848	+0·2
Mar. 23·14	278·14	−18·2	8·445	0·0
May 12·02	328·02	−3·1	9·031	+0·1
22·04	338·04	−6·7	·148	0·0
24·04	340·04	−7·8	·172	−0·1
June 2·98	349·98	−13·4	·288	0·0
11·96	358·96	−17·3	·394	−0·1
26·93	373·93	−18·1	·569	−0·2
July 18·89	395·89	−7·5	·827	+0·1
2012 Jan. 4·27	55930·27	−4·8	16·099	0·0
6·28	932·28	−5·9	·123	−0·3
13·27	939·27	−8·5	·205	+0·8
Apr. 30·02	56047·02	−18·5	17·470	0·0
May 23·00	070·00	−11·9	·739	−0·1
25·99	072·99	−10·4	·774	−0·3
27·04	074·04	−9·6	·787	−0·1
28·00	075·00	−9·1	·798	−0·2
28·96	075·96	−8·6	·809	−0·2
June 18·99	096·99	−3·7	18·056	−0·1
July 15·91	123·91	−16·7	·372	−0·1
Aug. 10·87	149·87	−14·7	·677	−0·1

TABLE V (*concluded*)

Date (UT)		*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
2013 Apr.	2·14	56384·14	−18·1	21·426	−0·2
	28·03	410·03	−12·3	·730	−0·1
June	6·98	449·98	−9·2	22·199	−0·1
	8·01	451·01	−9·8	·211	−0·1

*Observed with original spectrometer; weight 1/10.
[R]Observed by G. A. Radford.
†Observed at OHP by Soubiran *et al.*[22]; weight 1.

amenable to mathematical justification, would be the means of the *Coravel*-only and plenary values, *viz.*, 85·209 ± 0·009 days.

The orbit *looks* circular in the plot (Fig. 5), but its eccentricity is actually about seven times its own standard deviation; the illusion of circularity is greatly fostered in the figure by the fact that the longitude of periastron is very close to zero, causing the curve to be centred in the diagram just as that of a truly circular orbit would be. A solution upon which zero eccentricity is forced is a noticeably worse fit to the points and results in the sum of squares of the residuals being almost doubled, a situation that Bassett's tests[25] for circularity show to be untenable. The orbital elements are presented here, along with those of the three stars treated above, in Table VI.

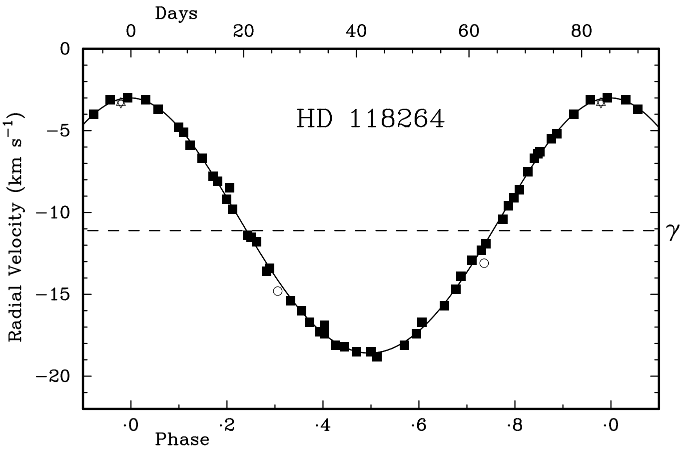

FIG. 5

The observed radial velocities of HD 118264 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. All but three of the observations were obtained with the Cambridge *Coravel*. There are two from the original spectrometer (open circles; here weighted 1/10), while the open star near phase zero represents a single observation referred to by Soubiran *et al.*[22], given unit weight in the solution of the orbit.

TABLE VI

Orbital elements for the four stars

Element	*HD 110583*	*HD 111224*	*HD 114864*	*HD 118264*
P (days)	8161 ± 94	861·8 ± 0·4	401·51 ± 0·19	85·199 ± 0·006
T (MJD)	54891 ± 126	50968 ± 4	50844 ± 16	55325·4 ± 2·1
γ (km s^{-1})	−26·46 ± 0·06	+16·91 ± 0·06	+11·61 ± 0·10	−11·11 ± 0·04
K_1 (km s^{-1})	1·43 ± 0·11	8·58 ± 0·10	7·00 ± 0·14	7·79 ± 0·05
e	0·42 ± 0·06	0·322 ± 0·010	0·080 ± 0·019	0·041 ± 0·006
ω (degrees)	244 ± 8	234·8 ± 2·1	24 ± 14	1 ± 9
$a_1 \sin i$ (Gm)	146 ± 12	96·2 ± 1·2	38·5 ± 0·8	9·12 ± 0·06
$f(m)$ ($M_\odot$)	0·0019 ± 0·0004	0·0479 ± 0·0018	0·0142 ± 0·0008	0·00418 ± 0·00009
R.m.s. residual (wt. 1) (km s^{-1})	0·25	0·53	0·69	0·23

In cases where the eccentricity is small, the periastron point is not well determined, so its longitude ω inevitably has a rather large uncertainty that does not, however, mean that the whole velocity curve has such an uncertainty in its position right-and-left along the time axis. In such cases it is useful to give, in addition to the epoch T of periastron, the time T_0 at which the radial velocity has its maximum value, which is anyway the quantity conventionally given in place of T in the case of a circular orbit. For HD 114864, where e is about 1/12, T_0 is MJD 50817·3 ± 1·2, with an uncertainty only about 1/12 as great as that of T. For HD 118264, with $e \sim 1/25$, T_0 has an uncertainty only about 1/25 of that of T, at MJD 55325·19 ± 0·08.

If HD 118264, with an absolute magnitude within the range of those of giant stars, is supposed to have a mass of about 2 $M_\odot$, the very small mass function requires the secondary to have a minimum mass of only about 0·3 $M_\odot$. That is about the mass of a star well down the M-dwarf sequence, about M4 V, which would be about ten magnitudes fainter than the primary, so the absence of an observable second dip in the radial-velocity traces is far from surprising.

Acknowledgement

I am pleased to thank Mr. David Balam of the DAO for information about the '2·282' spectrograph.

References

(1) R. F. Griffin, *The Observatory*, **131**, 351, 2011.
(2) K. M. Yoss & R. F. Griffin, *JA&A*, **18**, 161, 1997.
(3) W. I. Beavers & R. F. Griffin, *PASP*, **91**, 521, 1979.
(4) R. F. Griffin, W. I. Beavers & J. J. Eitter, *PASP*, **100**, 358, 1988.
(5) R. F. Griffin & F. C. Fekel, *JA&A*, **9**, 213, 1988.
(6) R. F. Griffin, *JA&A*, **6**, 159, 1985.
(7) P. C. Keenan & C. Barnbaum, *ApJ*, **518**, 859, 1999.
(8) L. Häggkvist & T. Oja, *A&AS*, **12**, 381, 1973.
(9) C. Soubiran *et al.*, *A&A*, **480**, 91, 2008.
(10) R. F. Griffin & A. Stroe, *JA&A*, **33**, 245, 2012.
(11) S. W. Burnham, *General Catalogue of Double Stars Within 121° of the North Pole* (Carnegie Institution of Washington, Washington, D.C.), 1906, **II**, p. 623.
(12) R. G. Aitken, *New General Catalogue of Double Stars Within 120° of the North Pole* (Carnegie Institution of Washington, Washington, D.C.), 1932.

(13) J. South, *Phil. Trans. for 1826*, 1, 1826.
(14) [Announced by] E. Høg *et al.*, *A&A*, **355**, L27, 2000.
(15) J. L. E. Dreyer, *Mem. RAS*, **49**, 1, 1888. (See pp. 140, 141).
(16) T. Schmidt-Kaler, in K. Schaifers & H. H. Voigt (eds.), *Landolt-Börnstein* (Springer-Verlag, Berlin), **2b**, p. 15, 1982.
(17) *e.g.*, K. A. Feltz, Jr., *PASP*, **84**, 497, 1972.
(18) D. K. Lynch & G. S. Rossano, *AJ*, **100**, 719, 1990.
(19) G. Hill *et al.*, *Mem. RAS*, **82**, 69, 1976.
(20) [Announced by] F. van Leeuwen, *A&A*, **474**, 653, 2007.
(21) *The Hipparcos and Tycho Catalogues* (ESA SP–1200) (ESA, Noordwijk), 1997, **7**, pp. 1333/2.
(22) [Announced by] C. Soubiran, O. Bienayme & A. Siebert, *A&A*, **398**, 141, 2003.
(23) B. V. Kukarkin *et al.*, *New Catalogue of Suspected Variable Stars* (Nauka, Moscow), 1982, p. 91.
(24) G. Müller & P. Kempf, *Publ. Astrophys. Obs. Potsdam*, **17**, no. 52, 1907 (see pp. 150, 290).
(25) E. E. Bassett, *The Observatory*, **98**, 122, 1978.

CORRESPONDENCE

To the Editors of 'The Observatory'

An Important Experiment; Reply to Phillip Helbig

When responding[1] to my reported[2] comment to Professor Liddle at the end of his Gerald Whitrow Lecture[3], 'The Universe, darkly', at the 2012 November meeting of the RAS, Mr. Helbig was at a disadvantage because, as noted[4], it contained an unfortunate but serious reporting error near the end. In the first part of my comment, correctly reported, I had said in effect that the need for dark energy had arisen from the relativistic treatment of the cosmic redshift as a velocity — a point on which Mr. Helbig elaborates and concurs.

I had then gone on to say "But if the redshift is not a velocity, it's an invalid result. But if you say of course it's a velocity, may I point out that in 1968 an experiment was done by the US Naval Research Laboratory (see Sadeh *et al.*, *Science*, **161**, 567, 1968) which showed, using caesium clocks, that the redshift is a transmission effect." in which my penultimate word was incorrectly reported as "transition". That error, of which Mr. Helbig was unaware when he wrote, made a physical nonsense of my comment, so perhaps he may be excused for his disparaging dismissal of "an experiment done by the US Navy in the 1960s" and, I infer, his consequent failure to look at the paper.

The US NRL is an institution renowned for the unbiassed rigour of its experimental work and I am pleased to report that, at the time of writing this, my contact with one of its divisional directors has led him to confirm that the possibility of a repeat of the Sadeh *et al.* experiment by NRL is now under consideration. They seem now to appreciate the potentially great significance of that earlier result.

Astrophysical observations indicating that electromagnetic waves apparently experience a progressive redshift during transmission were vigorously promoted by Finlay-Freundlich[5], but his mechanism proved unacceptable as an add-on to the existing physical theory. I have started[6] at a much deeper level and finer scale, by an (unprecedented?) implementation of Maxwell's aether, functionally and quantitatively, as a continuum of electric charge. Then, in the light of strong modern evidence that particles are not of zero size, I have followed Maxwell[7,8] and Thomson[9] in characterizing fundamental particles as 'vortex-rings' of aether motion. In this way, the aether and particles are not dynamically independent and the Michelson–Morley result is explained without throwing out the aether.

Likewise, as I recently explored[10], by 'making particles out of aether', the aether is in a corresponding state of random motion. When transmitting electromagnetic waves this motion will impose four wavelength-independent effects: redshift, frequency modulation, scattering, and attenuation, of which the first is the one at issue in the Sadeh *et al.* experiment and appears to extrapolate reasonably to the cosmic redshift. The last, being in addition to that of distance, would affect the redshift–apparent-distance relationship and offers to explain Olbers' Paradox. A fifth effect, due to the random motion and acceleration of aether electric charge, will be the low-level emission of synchrotron-type radiation at frequencies corresponding to the particle-motion temperature of the gas. It is inappropriate here to characterize these effects further. For apparent examples, for the consequently ubiquitous random electromagnetic excitation of atomic structures and for the construction of primordial hydrogen in randomly moving aether, see discussions in ref. 10.

I have found that the starting basis adopted in ref. 6 is rather well secured by the multiple expression of its expectations at the scales of the Earth[11] and the Sun[12]. This assurance carries the further expectation of a particle-tied, randomly moving aether for the transmission of electromagnetic waves. So the force of my remark to Professor Liddle lay in the potential for redshifting which then arises (ref. 10); an effect apparently observed by Sadeh *et al.* 1968.

So I would urge Mr. Helbig to consider my original comment in its corrected form. If it turns out that his dismissal of the Sadeh *et al.* experimental result was premature, there is much he could feel he needs to reconsider, and perhaps even to delight in!

Yours faithfully,
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References

(1) P. Helbig, *The Observatory*, **133**, 294, 2013.
(2) M. F. Osmaston, *The Observatory*, **133**, 136, 2013.
(3) A. Liddle, *The Observatory*, **133**, 135, 2013.
(4) *The Observatory*, **133**, 308, 2013.
(5) E. Finlay-Freundlich, *Proc.Phys.Soc.*, **67**(A), 192, 1954.
(6) M. F. Osmaston, in R. L. Amoroso, L. H. Kauffman, & P. R. Rowlands (eds.), *The Physics of Reality: Space, Time, Matter, Cosmos: Proceedings of the 8th Symposium Honoring Mathematical Physicist Jean-Pierre Vigier* (World Scientific Publishers, Singapore), 2013, p. 388.
(7) J. C. Maxwell, *Phil. Mag. 4th Ser.*, **XXV**, 161, 1861.
(8) J. C. Maxwell, *Phil. Mag. 4th Ser*, **XLIV**, 281–291 & 338, 1861.
(9) W. Thomson, *Proc. RSE*, **VI**, 94, 1867. Reprinted in *Phil. Mag.*, **XXXIV**, 15, 1867.
(10) Ref. 6, p. 411.
(11) M. F. Osmaston, *Geophys. Res. Abstr.*, **15**, EGU2013-2392, 2013.
(12) M. F. Osmaston, *EPSC Abstr.*, **8**, EPSC2013-249, 2013.

REVIEWS

Beating the Odds: The Life and Times of E. A. Milne, by Meg Weston Smith (Imperial College Press, London), 2013. Pp. 282, 23 × 15 cm. Price £18·00 (paperback, ISBN 978 1 84816 907 4).

This is not a scientific biography like Pais's of Einstein[1] or Moore's of Schrödinger[2]. In the preface, the author quotes Chandrasekhar: "Tell us about the man; don't worry about the science", and this advice is basically followed, though of course Milne's scientific work figured largely in his personal life, and the author, a daughter of Milne, provides about the right amount of information about that. The book is divided into 17 largely chronological chapters, the title of each indicating one of the main events or themes in Milne's life during the corresponding time. Edward Arthur Milne, known as Arthur, was born in 1896 to primary-school teachers in Hull. Although he had won a scholarship to Trinity College, Cambridge, his important work in ballistics during World War I provided necessary additional impetus for an academic career in Cambridge, Manchester, and Oxford. Milne's rather poor background was a constant influence in his life and it might be difficult for some today to realize how difficult an academic career was in the first half of the 20th Century for those from such backgrounds (though, sadly, if present trends continue, this might become the case again). After the war, Milne worked mainly in stellar physics, particularly stellar atmospheres, before later moving into cosmology and returning to ballistics during World War II.

The book is well written and provides not only a description of Milne's life but also of academic life in general during the first half of the 20th Century, when married dons were treated as 'honorary bachelors' and an Oxford classicist claimed that anyone with a good knowledge of the classics could master physics in a fortnight. The astronomical community was small enough that most of the major players knew each other personally. Milne, largely responsible for the revival of astronomy and astrophysics at the University of Oxford, often held unorthodox opinions, but at the same time was a pillar of the astronomical community. Many debates in which Milne was involved are recorded in the pages of this *Magazine*.

The author sometimes refers to Milne as "Milne", sometimes as "my father". This is somewhat distracting, especially since it is not the case that the former is always used when discussing Milne in general and the latter when discussing his role as the author's father. Referring to the UK, its armed forces, *etc.*, in the first person (plural) might feel a bit strange to foreign readers, especially since this is also not done consistently. Chandrasekhar, though, is almost always referred to as Chandra, which seems a bit too familiar.

Today, Milne is probably best known for his work in cosmology, though this is probably due more to the fact that cosmology is more influenced by its own history than are other branches of astrophysics. Neither his work on Newtonian cosmology (a pedagogical 'trick' to present the cosmological models of General Relativity in the language of Newtonian physics) nor on Kinematic Relativity (his own alternative cosmological theory, now widely regarded as a dead end) is described in much detail in the text. (The foreword by Roger Penrose contains a brief overview of Kinematic Relativity. Penrose was the third, and is now Emeritus, Rouse Ball Professor of Mathematics at the University of Oxford; Milne was the first, from 1929 until his death in 1950.) It is his work in ballistics which has the most, perhaps a somewhat too, detailed description.

Sometimes, the description of Milne's science is not up to the high level of the rest of the book. For example, it is implied that the carbon cycle is the main source of energy in stars (p. 123), but this is only the case for massive stars. It is also stretching things to say that the Einstein–de Sitter cosmological model "foreshadowed dark matter" (p. 132). On p. 140, the description of the currently allowed possibilities for the fate of the Universe contains both things which have been ruled out in classical cosmology (the "Big Crunch" and a cyclic universe) and speculative ideas outside the mainstream (the "Big Rip"). On p. 194, it is implied that stars should be younger than the Earth. A real howler is on p. 195: "... zero on the Kelvin temperature scale when molecular motion stops and matter ceases to exist."

Despite some inaccuracies in the description of Milne's science (to which not much space is devoted), I highly recommend the book (which contains more than enough references, to both primary and secondary sources, for those wanting to learn more about Milne's work and its influence), because it does everything else very well. The long list of acknowledgements is testimony to the extensive research on the part of the author. One gets a real feeling for what influenced Milne and what was important to him: his rise from humble origins to the pinnacle of academia, his tragic life (both wives took their own lives and he himself died at just 54), his Parkinsonism (a particularly hard blow which caused the formerly loquacious Milne to speak less and less fluently; a colleague described him as "a walking corpse"), his colleagues (both friends and enemies), and his Christian faith. Though the last was certainly important to Milne, as in the case of Lemaître (about whom the author repeats the common misconception that he was a Jesuit — he was educated by Jesuits, and was a priest, but not a Jesuit himself[3]) it doesn't seem to have influenced his scientific work in any obvious way, though as with Lemaître some people over-interpret superficial similarities.

I appreciated not having to flip back and forth to read notes: references, additional information, and basic facts about individuals (presented when they are first mentioned) are all provided as footnotes, of which there are many. These are usually years of birth and death, scientific positions held, year of Nobel Prize (if applicable), *etc.*, though in the case of Anton Pannekoek the author uncharacteristically mentions his political affiliation (communist) and fails to mention that he was the director of an institute, a fact which for others is mentioned if applicable. I am a bit puzzled about the source of quotes from the letters from Milne to McCrea, since these are described as "now lost" in the list of abbreviations used in the footnotes. The index is good and, as expected for such a book, contains mostly names of people.

Eighteen black-and-white photographs (not plates) are included in the middle of the book. There are comparatively few typographical errors, though some, such as Gröningen for Groningen, are surprising. Others ("Cephied", "Am. Rev. Astron. Astrophphys.", 1887 as Einstein's year of birth) should have been obvious to a proof reader familiar with astronomy.

Despite some weaknesses regarding science (which will not confuse most readers with a background in science), I recommend the book (which is not primarily about Milne's science) to anyone interested in astronomy, academia, or their history; it was a very enjoyable read. — PHILLIP HELBIG.

References

(1) A. Pais, *Subtle is the Lord: The Science and the Life of Albert Einstein* (Oxford University Press), 1982.
(2) W. Moore, *Schrödinger: Life and Thought* (Cambridge University Press), 1989.
(3) J. Farrell, in M. J. Way and D. Hunter (eds.), *Origins of the Expanding Universe: 1912–1932* (ASP Conference Series, Vol. 471), 2012, p. 250.

A Journey with Fred Hoyle, 2nd Edition, by N. Chandra Wickramasinghe (World Scientific, Singapore), 2013. Pp. 218, 23 × 14·5 cm. Price £28 (paperback; ISBN 978 981 4436 12 0).

Professor Sir Fred Hoyle F.R.S. was not without honour even in his own country, as is clear from his titles, though the ideas he took most seriously (some sort of steady-state universe and panspermia) were never the majority opinion anywhere. He was also, at least in relative youth, possessed of enormous charisma, so those who were converted to his views remained so for the rest of their careers. The best-known examples were Nobelist William A. Fowler, E. Margaret and Geoffrey R. Burbidge — his co-authors on 'Synthesis of the elements in stars'[1] — and Mt. Wilson–Palomar observer H. C. (Chip) Arp. All were more or less committed to a steady-state model of the Universe. Additional acolytes from the 1960s were three Cambridge postdocs: Jamal Islam (now in Bangladesh), Jayant Narlikar (now professor emeritus in India), and N. C. Wickramasinghe (Sri Lankan by birth, professor at Cardiff for many years, and now at the new University of Buckingham).

The core idea put forward by Hoyle and Wickramasinghe, and thoroughly explored and defended in this book, was frequently parodied as "plagues come from comet tails". What they meant was that life on Earth was originally seeded panspermically by bacteria and viruses from distant locales, and that the delivery of such has continued, providing new genetic material, some friendly, some not. Thus they did not accept Darwinian evolution, neither *in-situ* mutations nor the survival of the fittest. Panspermia in a steady-state universe of course allows a *very* long time for life to get started.

Hoyle was involved in many other controversies, over the founding of the Anglo–Australian Observatory, the non-award of a Nobel Prize to Jocelyn Bell, and the authenticity of fossils of the feather-bearing portions of *Archaeopteryx*. I was surprised to learn that Hoyle picked up that idea from an Israeli, Lee M. Spetner (whose visit to the Wickramasinghe home was overshadowed by the issue of kosher food; Leon Mestel, whom Chandra respected, could have helped there!).

Who is given credit for what is odd in several places — no mention that the general interstellar absorption came from Robert Trumpler, but credit to Fred M. Johnson for having thought of interstellar complex organic molecules at about the same time as Hoyle and the author. He is professor emeritus at Cal State Fullerton, and still thinks about interstellar organics. The directors of Hoyle's Institute of (Theoretical) Astronomy after he left go nameless too.

Despite panspermia, something like Darwinian evolution creeps into the author's explanation of the origin of racial prejudice (which he, and his father before him at Cambridge, surely experienced). The idea is that as people followed the retreating ice sheets northward about 11 000 years ago, they had very light skins, permitting formation of sufficient vitamin D. Interbreeding with darker-skinned folks from the south would have yielded rickets-prone offspring of low fitness. He also mentions the risk of skin cancer when the fair venture south, but the record of prejudice based on skin colour in that direction is a much spottier one, I think.

And finally, the usual conflicts of interest and such. I was at Caltech when NCW was there in the fall of 1965, and indeed not much notice was taken of him, as he says (though my thesis advisor was an infrared-dust person, Guido Munch). And in 1968 May I arrived on Fred Hoyle's doorstep uninvited and unannounced, and was told I could have a summer job for £75 a month if I would answer the phone (yes, just one in those days) at lunchtime and look after the library, which Wickramasinghe had just set up. I was initially much puzzled by a shelf called "solid state matter and interstellar medium". Now I understand! — VIRGINIA TRIMBLE.

References

(1) E. M. Burbidge, G. R. Burbidge, W. A. Fowler & F. Hoyle (B^2FH), *Reviews of Modern Physics*, **29**, 547, 1957.

Achieving the Rare: Robert F. Christy's Journey in Physics and Beyond, by I. Juliana Christy (World Scientific, Singapore), 2013. Pp. 349, 24·5 × 15·5 cm. Price £25/$42 including postage (paperback; ISBN 978 9 8144 6024 8).

Robert Frederick Christy (1916–2012) is eponymized in the Christy bomb (or gadget or device), in which the fuel of a plutonium bomb is a solid sphere rather than a hollow shell, permitting more nearly synchronized compression. The first two were dropped at Alamagordo and Nagasaki. Two decades later, Christy developed the first non-linear, non-adiabatic code for study of stellar pulsation, published in 1966. He remained a member of the American Astronomical Society and the International Astronomical Union (commissions on variable stars and stellar constitution) until the time of his death. Indeed, he began his career in contact with astrophysics, writing a thesis in 1941 on 'Cosmic-ray-burst production and the spin of the Mesotron', under J. Robert Oppenheimer, whom he followed to Los Alamos. Christy felt that his work on the bomb yielded a familiarity with shock waves that was relevant to the pulsation code. He was also among the first to recognize that the Sun must run on the proton-proton chain rather than the CN cycle, as initially proposed by Hans Bethe and Carl von Weizsäcker (separately, not together as indicated in the book).

Ilia Juliana Lilly Sackmann Christy was Bob's second wife and first biographer (though there were some earlier oral histories). And the book is like nothing else I have ever seen. It combines fairly technical material about the Manhattan project and dosimetry at Hiroshima and Nagasaki later, with lots of Caltech politics and some very personal extracts from letters and recollections of the Sackmann–Christy courtship. The photographs reproduced similarly include Oppenheimer, President Nixon, children from Christy's first and second marriages, and the family horses. The volume is not a traditional scholarly biography in that it does not include a list of publications nor, indeed, any references. Many of the people in group photographs go unidentified (though I am reasonably sure I spotted Thomas Gold and Hermann Bondi on one page). There is an index, but several dinner menus and party invitations are included, along with copies of a water-boiler plaque and the 1954 letter from Caltech president Lee A. DuBridge increasing Christy's salary to $10 000 per year. The back cover blurbs come from relativist Kip Thorne, physics Nobel laureate

David Politzer, Caltech past-president Harold Brown, and Rose Bethe (widow of Hans).

The book was about half completed when its subject died; and the author indicates that she discussed many items with him. His memory was not 100% reliable, (as whose is?), and she consulted me, among many others, specifically on the dates he had spent in Cambridge at Fred Hoyle's Institute of Theoretical Astronomy.

Conflicts of interest? Several, and perhaps a bit strange like much about this book. I purchased my copy at full price, using a flier sent by the author and after the editor said I could review it. So, at $42, including postage, I naturally wanted to find it fascinating. I adapted the Christy code, with advice from the programmer, for a study of pulsating helium stars in 1971. The author and I had a 1978 paper together on multi-shelled planetary nebulae, the acknowledgements of which end with "This work was not supported by any federal grant, and we are grateful to our husbands, Joe Weber and Robert Christy, for summer salaries". And Bob Christy and I dated briefly in 1968 May when I had just arrived in Cambridge as a very new postdoc, and he was about to return to Pasadena (*via* Canada, where Juliana first heard him speak). He said he had been watching punters on the Cam and would like to try it, but felt he needed a young lady as a passenger to do that properly, and would I be willing to be the young lady. Let it be said that he punted very skilfully, with no allowance for it being his first try, but he was very tall. Finally, Joe and I were guests in the Christys' home at a very elegant dinner for eight. The other guests included Kip Thorne (of the back-cover blurb), France Cordova (now chair of the board of the Smithsonian Institution and nominee for Director of the NSF), and Bohdan Paczyński, the first person mentioned in the acknowledgements of that 1978 paper. I said I was willing to bet that, even in that small group, two people would have the same birthday. Normally you need about 23 to make that a good bet, but I knew (and they did not) that Sackmann and Paczyński shared February 8. — VIRGINIA TRIMBLE.

370 Years of Astronomy in Utrecht (ASP Conference Series, Vol. 470), edited by G. Pugliese, A. de Koter & M. Wijburg (Astronomical Society of the Pacific, San Fransisco), 2013. Pp. 445, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 824 4).

This volume is a rather unusual one in the ASP Conference series. It does not cover the proceedings of a meeting dealing with a specialized topic in astrophysics, but marks a special conference to highlight the many and varied achievements of astronomy at Utrecht over its 370-year history. I, like so many other astronomers worldwide, have long recognized the major role that the Astronomical Institute at Utrecht has played in international astrophysics. I have had the pleasure of knowing many esteemed scientists from that institute at its sister department of space research (SRON). When I was informed by one of my Utrecht friends in 2011 that the University had decided to stop all teaching and research in astronomy at Utrecht, I was astonished. Indeed my immediate reaction was to say "is this some kind of joke" (paraphrasing a well-known comment from the BBC's *Newsnight* presenter Jeremy Paxman)! Sadly, it was no joke — astronomy at Utrecht would cease, (most) staff would transfer to other Dutch universities, students likewise, and technical and support personnel would either be made redundant or transfer to other departments. Rather than go quietly, the outgoing Utrecht staff took the bold decision to hold a conference to celebrate the achievements of the institute for which this volume is a moving testament.

The proceedings cover a wide range of topics in which the Institute of Astronomy at Utrecht and SRON have played leading international roles. These include both historical and current research in solar physics, stellar atmospheres, evolution and mass-loss phenomena, plasma astrophysics, high-energy physics, stellar clusters and galaxy evolution, instrumentation (both ground- and space-based), and astronomy education and outreach. In each area it is noticeable that many of the papers were delivered by the outgoing young researchers in the institute, highlighting the tragic loss of these people from the University of Utrecht. The first paper by the last Institute Director, Christoph Keller, spells out in graphic detail the extraordinary developments and political machinations, over a short timeframe, that led to the University's bewildering decision to close astronomy there, and the sterling efforts he and his staff made to mitigate the damage and arrange for staff transfers to other Dutch universities. It makes salutary reading! Kees de Jager's description of the history of the Utrecht Astronomical Institute, 1642 to 2012, is a *tour de force*. So are the "final comments" of de Jager where he hopes that a future Utrecht University Board might reinstate astronomy teaching and research, but he notes "they will find how difficult it is to recover something excellent that has been so brutally destroyed" — a sentiment with which I fully concur. I wholeheartedly recommend this volume for all those interested in astrophysics in the broad sense and in Utrecht astronomy in particular. — ALLAN WILLIS.

Encyclopedia of the History of Astronomy and Astrophysics, by D. Leverington (Cambridge University Press), 2013. Pp. 521, 28·5 × 22·5 cm. Price £45/$75 (hardbound; ISBN 978 0 521 89994 9).

Astronomy has a long and distinguished history and it takes a bold author to attempt the herculean task of compiling a comprehensive encyclopaedia without the obvious help of a cohort of co-authors. But this is what David Leverington has set out to do, and I'd say that he's made a good stab at it. This substantial volume is divided into ten parts, beginning with 'General Astronomy' which gives us an overview of ancient (pre-telescopic) astronomy around the globe together with the major developments of the last four centuries. I imagine that the specialist might hope for more detail than the 60 pages of this section can deliver, but for the general reader, it should suffice.

Parts 2, 3, and 4 cover, respectively, 'The Solar System', 'Stars', and 'Galaxies and Cosmology'. Again, for the lay reader, there should be enough to satisfy their curiosity and for those wanting to probe further there is a good selection of suggested reading matter; these references are, however, mainly books rather than primary sources from the vast astronomical literature, and it makes me wonder whether the author probed deeper than these books in his quest for information. That said, the works cited, such as Hearnshaw's excellent volumes on astronomical spectroscopy and photometry, do provide direct leads into the primary journals.

Parts 5–10 deal with astronomical instrumentation, observatories, and spacecraft, and it was here that I felt that Leverington had really provided a very useful reference work. Checking over those few of which I had some experience, for example, the Royal Greenwich Observatory and the *International Ultraviolet Explorer*, I found the descriptions and explanations accurate and sound. The sections dealing with spacecraft seemed remarkably comprehensive.

All in all, this is something of a *tour de force* by the author, which should be welcomed on the shelves of institutional libraries and all those interested in our science alike. — DAVID STICKLAND.

Slaying the Dragons, by Allan Chapman (Lion Hudson, Oxford), 2013. Pp. 256, 21·5 × 14 cm. Price £9·99/$16·95 (paperback; ISBN 978 0 7459 5583 4).

Any astronomer who lectures to the general public has to have a view about God. It goes with the territory. You stand there chatting about Big Bangs, the origin of life on planets, planets around other stars, the search for extraterrestrial intelligence, the fate of the Sun, and the end of the Universe, and in the following Q and A session along come the queries about the role of God and Jesus. Are you prepared? If not, read this book. And even if you are prepared, and (metaphorically) on the side of the angels, still read this book. It is an absolute joy and a 'godsend'.

Chapman's prose is engaging, erudite, humorous, and deeply insightful. He investigates the relationship between an ever-burgeoning scientific civilization and the Judeo–Christian Greco–Roman historical tradition. He rails against the modern cult of atheism, and those protagonists who happily spin myths about the science/religion relationship to serve their own ideological ends. He revels in the fact that humans are instinctive and subjective seekers after cause, purpose, and order in their surroundings. He encourages scientists to turn aside every now and again from their quest to answer the 'how' question, and to ponder the next important query, which is 'why'. Why is the Universe the way it is, and why are we humans capable of making at least some sense of it all? He punctures the myth that religion is now and always has been against science. He underlines the fact that the science/religion conflict is a myth. He is convinced that science strengthens faith and not *vice versa* and that scientific intellectual exploration can only add to mankind's awareness of the glory of God.

Chapman is a committed Christian and a first-class historian of science. This book will appeal to Christians and atheists alike. The Christians will nod sagaciously, time and again, in agreement. The atheists, new and old, will at least realize some of the huge problems they are up against. — DAVID W. HUGHES.

Spacefarers, edited by M. J. Neufeld (Smithsonian Books, Washington, DC), 2013. Pp. 256, 23·5 × 16 cm. Price $29·95 (about £19) (hardbound; ISBN 978 1 93562 319 9).

In 2011, NASA held a conference to mark the 50th anniversary of human spaceflight and the 30th anniversary of the first Shuttle mission. Entitled '1961/1981 Key Moments in Human Spaceflight', the meeting was a celebration of human spaceflight and its importance in both social and cultural history. This book was inspired by the papers presented to the conference, although many of the chapters are revised versions, completely rewritten or specially commissioned. Edited by Michael J. Neufeld, a museum curator in the Space History Division of the Smithsonian's National Air and Space Museum in Washington D.C., the book is something of a rarity because it explores themes beyond the more usual accounts of technical and programmatic evolution and geopolitical history. Instead, it comprises nine chapters devoted to the images of astronauts and cosmonauts, as presented by the media, state propaganda, and popular culture.

The chapters are grouped into three sections. The first group addresses the role of astronauts in pre-Space-Age TV dramas, the mythology of the military test-pilot/astronauts and their portrayal as heroes endowed with 'the right stuff'. The second section examines the importance of Yuri Gagarin in Russian popular culture, the press coverage of human spaceflight by *Paris Match* up to 1981, and the ways in which government propagandists used astronauts and cosmonauts to publicize national core values. The final three chapters look at the role of IMAX movies in shaping popular perceptions of Space Shuttle astronauts, the media treatment of female astronauts, and a comparison of the ways in which astronauts are portrayed in Tom Wolfe's classic of creative non-fiction, *The Right Stuff*, and a novel written three decades later.

As expected with a book which is produced as an academic resource, each chapter is well written and extensively referenced. For sociologists and students of popular culture, this investigation of spacefarers as national role models provides plenty of room for thought, discussion, and in-depth research. However, it also highlights the dramatic changes in our perceptions of astronauts and cosmonauts over the past half-century. When the Space Age began, the name of each courageous space traveller was on everyone's lips and tickertape parades were held around the globe to greet the returning heroes. Today, crewed flights to low Earth orbit are largely routine and ignored by the media, while the dedicated men and women who maintain our toehold in space remain largely anonymous. — PETER BOND.

Celestial Messengers: Cosmic Rays, by M. Bertolotti (Springer, Heidelberg), 2013. Pp. 330, 23·5 × 15·5 cm. Price £35·99/$39·95/€42·75 (paperback; ISBN 978 3 642 28370 3).

The centenary of the discovery of cosmic rays in 2012 was marked by many meetings to celebrate the remarkable work of Victor Hess, his predecessors, and the extraordinary developments that followed. I attended several such gatherings but was not at all bored by being exposed to more history in this book: a good story is worth re-telling. Professor Bertolotti is an expert in non-linear optics and it was fascinating to follow his journey into his *terra incognita*. The book is well-written and well-researched with over 1300 references.

The first two-thirds of the book covers the early research in cosmic rays, exposing its links to astrophysics and particle physics, and is enlivened through brief biographical information and anecdotes about some of the leading scientists. There is good use of photographs of people and particles and clear descriptions of the tools of the time: the Geiger counter, the Wilson Cloud Chamber, and the nuclear emulsion. The protracted efforts to understand the composition of the cosmic-ray secondaries is well-told and readers unfamiliar with what was the liveliest area of physics in the 1930s will enjoy reading of the struggles of the experimentalists to identify the muon in the face of uncertainty about the reliability of quantum electrodynamics. That now looks very odd, given that the theory has been confirmed with remarkable precision, but cosmic rays were its first testing place.

In 1953, following a famous conference at Bagnères de Bigorre, the field divided, with those most interested in particle physics moving to accelerators while others continued to study cosmic rays for their astrophysical importance and to exploit a (weak) beam of particles with energies unlikely ever to be reached on Earth. Immense progress has been made since 1953, and the author's efforts to review it in 100 pages does not quite succeed. The bibliography, though extensive, is far from complete, as he set himself the near-impossible task of trying to cover almost everything. Thus major highlights of recent years (such as the discovery of TeV gamma-rays from the Crab Nebula by the Whipple group in 1989) are overlooked and the reader is offered a catalogue of material that has not been digested with anything like the skill shown in the early part of the book.

There are a number of unfortunate errors (for example Kps for kpc, anti-particles written as v̲, and 'extensive' air showers as 'extended') and some strange attributions of nationality: H. L. F. Helmholtz was as certainly German as E. J. Williams was Welsh: neither was English. The Mediterranean neutrino detector, *ANTARES*, is not an Italian project, and, although I led the Haverah Park team from 1976, I had not started my PhD when that adventure, initiated by J. G. Wilson, began in the late 1950s. But these lacunae are small distractions from an enjoyable and informative read. — A. A. WATSON.

Night Vision: Exploring the Infrared Universe, by M. Rowan-Robinson (Cambridge University Press), 2013. Pp. 251, 23·5 × 15·5 cm. Price £30/$50 (hardbound: ISBN 978 1 107 02476 2).

Now is a good time for the publication of a review of the development of infrared astronomy over the past 50 years. The recent success of the *Herschel* space observatory sets the stage for a story which is poised between a past where a few small, innovative, research groups made the first key discoveries through this new observational window, and a future which will be dominated by a handful of gigantic observatories serving the world-wide astronomy community. That is the landscape in which Rowan-Robinson's thorough and authoritative book is set.

The early days of modern infrared astronomy in the 1960s and 70s evoke a picture of small teams of pioneering individuals bumping along dusty tracks to chilly mountain-top sites, carrying instruments which they had built from scratch themselves, combining skills in electronics, optics, and cryogenics, with personalities which reflected the frontier-like nature of the field. People got sun-burned and people drank wine, often at the same time. *Night Vision* manages to communicate a flavour of that exciting period, though the author's ambition of including all of the major players along with the scientific basis and importance of their discoveries can sometimes get in the way. His chosen habit of pausing the story to explain a new astronomical concept generally works well, but sometimes it jars, with a few too many forward and backward references and repetitions of key concepts interrupting the flow.

To be clear, the information content and quality of the scientific explanations is generally excellent; any literate reader will enjoy and benefit from the author's discussion of the high-redshift Universe and the importance of new observatories such as *ALMA* and the *JWST* to its study. The language is accurate and efficient without being excessively technical. My overall impression was that the book would have benefitted from being a bit longer, to allow more space for the story of the astronomers to be separated less abruptly from the vignettes of scientific explanation. In that regard, I particularly enjoyed the later chapters, where the text focussed on more of a review of star and planet formation, setting the scene for the next great task for infrared astronomy, the search for extra-terrestrial, life-bearing planets.

The romantic era of infrared astronomy is fading fast. I recently attended a meeting at NASA to decide whether a new space instrument was ready merely to undergo cryogenic testing (it won't be used in earnest for another five years). The meeting fully occupied fifty scientists and engineers in a stifling windowless room for two days. The effort was fully justified, given the money and time invested in the project, but it did raise the question: what has changed, and why?

Rowan-Robinson's book answers those questions quite effectively, with the key players and their contributions presented in a well-organized history. It provides an even-handed, authoritative, and thorough overview of the development of this exciting and important field of astronomy, from the initial discovery of new classes of object and new phenomena to the recent drive for large-area surveys at unprecedented sensitivities. There is even the occasional anecdote, one gem being the description of the non-discovery of Planet X by *IRAS*. However, the book is primarily informative rather than entertaining. I still remember the feeling of warmth and enthusiasm that David Allen managed to convey in his 1975 book, *Infrared: The New Astronomy*. The experience of reading *Night Vision* was somewhat cooler; the information was all there, but I did not feel drawn into the romance of the journey in quite the same way.

It is that thoroughness which I feel is the real strength of the book. It provides an approachable single source for anyone wishing to understand the major discoveries of infrared astronomy over the past few decades, and sets out the scientific rationale behind the next decade's major ground- and space-based observatories. — Alistair Glasse.

Dynamics and Evolution of Galactic Nuclei, by D. Merritt (Princeton University Press, Woodstock), 2013. Pp. 546, 23·5 × 15·5 cm. Price £85/$125 (hardbound; ISBN 978 0 691 12101 7), £52/$75 (paperback; ISBN 978 0 691 15860 0).

Galactic nuclei are the most exotic locations in the known Universe, being the residences of black holes with masses that often exceed a billion Suns. When such black holes accrete gas, they can shine more brightly than the brightest galaxies, and even when essentially dormant they prevent star formation through vast regions by keeping them filled with hot atmospheres. Over the last 20 years strenuous efforts have been devoted to detecting black holes in nearby nuclei by observing the impact of their gravitational fields on either stars or gas. Merritt has been a significant contributor to those efforts.

From a physical standpoint, galactic nuclei have two aspects: stars and plasmas. The dominant dynamics is that of the plasma and is poorly understood. This book is exclusively devoted to the reasonably well-understood stellar dynamics. This subject has again two aspects: an inner zone where the black hole's gravitational field dominates, and the far zone where stars dominate the gravitational field. The inner zone has much in common with the Solar System: stars move in a Keplerian field that is perturbed by General Relativity and the masses of the moving particles, while the outer region is a subfield of galactic dynamics.

Although the book treats both aspects, the framework is very much that of galactic dynamics rather than celestial mechanics. Much of the book is given to deriving standard results in galactic dynamics because it aims to be self-contained. However, I found its coverage of celestial mechanics and General Relativity was sketchy; the absence of a proper introduction to Hamiltonian mechanics, especially canonical coordinates and generating functions, is a real weakness given the crucial role they play in celestial mechanics.

Given that black holes did not grow up on a diet of stars, although they may very occasionally snack on one, the key questions in the area covered by the book are: (*i*) the impact that a black hole has on the observable kinematics of stars near the hole; (*ii*) the black hole's ability to destroy the barrishness of the surrounding stellar body; and (*iii*) the way stars bring together the massive black holes of merging galaxies. Item (*i*) is very briefly discussed in Chapter 2 before the apparatus required for a detailed discussion is presented. Regarding item (*ii*), fourteen pages are given to triaxial equilibria without really addressing long-lived triaxial states and discussing the timescale and manner of their disruption. Item (*iii*) is quite fully discussed in the last chapter.

My overall judgement is that this book is over-specialized: it concentrates on the collisional relaxation of stellar distributions in the presence of a stellar black hole. This is by no means the most significant aspect of the stellar dynamics of galactic nuclei, and the stellar dynamics of nuclei is itself much less interesting than their plasma dynamics. Given that few graduate schools will find it appropriate to offer a course on the stellar dynamics of nuclei, it's a pity that Merritt did not take a broader canvas and make space for that canvas by assuming a prior knowledge of graduate-level galactic dynamics. — JAMES BINNEY.

18th European White Dwarf Workshop (ASP Conference Series, Vol. 469), edited by J. Krzesínski, G. Stachowski, P. Moskalik & K. Bajan (Astronomical Society of the Pacific, San Francisco), 2013. Pp. 475, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 820 6).

The Einstein redshift in white dwarfs lives!!! Calm down, Trimble. You wrote those papers in 1967 and 1971. Forty-some years have passed, during most of which the community has agreed that the measured gravitational redshifts and implied masses were too large, hence the average white-dwarf mass of 0·55 $M_{\odot}$, coming from line profiles and/or colours fitted by model atmospheres, is the right one, rather than the 0·65 – 0·83 $M_{\odot}$ from the gravitational zs and a mass–radius relationship.

What a delightful surprise then it was to read that the disagreement indicates "an underestimated spectroscopic mass at all $T_{\rm eff}$." And R. E. Falcon and his colleagues at University of Texas, Austin, and Sandia National Laboratories are putting their plasmas where their mouths are, building laboratory experiments to measure Balmer-line profiles in hydrogen gas at $T_{\rm e} \sim 1$ eV, $n_{\rm e} \sim 10^{17}$ cm^{-3}, representative of white-dwarf atmospheres. They even cite Greenstein & Trimble from 1967 (though for a slightly different reason, and not Trimble & Greenstein from 1972).

No, this was not the focus of the white-dwarf workshop held in Krakow in 2012 August! Indeed the most closely related paper, from P. Bergeron *et al.*, in Montreal, says that even the spectroscopic surface gravities (hence masses) are too big, at least for stars cooler than 13 000 K. Instead, there were interesting answers to some other fairly old white-dwarf (WD) questions. (*i*) What is the source of the metallic pollution on many WD surfaces? Quite possibly accretion from a debris disc of disrupted planets, *etc.*, in equilibrium with gravitational settling of heavy elements out of the hydrogen (or helium) atmospheres. It is relevant that at least a few white dwarfs still have planets. (*ii*) Do Type-Ia supernovae come from white dwarfs driven over the Chandrasekhar limiting mass by merger with another white dwarf (double-degenerate scenario) or by accretion from a non-degenerate companion (single-degenerate scenario)? Yes. That is, assorted data and models of galactic evolution require some of each. (*iii*) Do the slow rotation periods measured for many/most WD surfaces imply slowing of the whole star or atmosphere/core separation with rapid rotation maintained inside? Slowing of the whole star, at least for the couple for which the spectrum of stellar non-radial pulsations permits measuring an interior rotation period. (*iv*) What is the origin of the 1–100-Megagauss-and-more magnetic fields of a few WDs? The blame has generally been placed on fossilization of the fields of magnetic A stars. But dynamo generation during a merger of two WDs also works for at least some. Notice that this is related to the double-degenerate SN-Ia scenario, representing the cases where the combined mass is less than 1·4 $M_{\odot}$. Larger numbers, perhaps 10%, have kilogauss fields. (*v*) Where are the white dwarfs missing from the Hyades if it started with a normal initial mass function? Escaped, and sometimes still to be found outside the tidal radius of the cluster. And yes, the Hyades are spectroscopically more massive than the general run of WDs, as well as showing larger gravitational redshifts. (*vi*) What else might you get from white dwarfs in binaries besides all the richness of novae and other cataclysmic variables? R Coronae Borealis variables from mergers; WDs with helium cores; planetary nebulae made out of gas expelled in common-envelope evolution; and the very funny double nebula EGB 6, where there is a large, very old, low-surface-brightness PN associated with the very hot DAOZ WD PG 0950+139, but also a compact emission nebula associated with its cool companion 0″·166 away in its *HST* image.

A bunch more questions remain incompletely answered, such as what age is implied by the very faintest WDs in globular clusters; what causes the sudden changes in the ratio of numbers of H-dominated atmospheres to He-dominated *versus* effective temperature; to what extent are the numbers, masses, and ages of WDs in some complete sample consistent with the numbers of their planetary-nebula progenitors and with the local history of star formation; are the cores made of He, C & O, O, Ne & Mg, or even Fe? And there are others.

What about the volume itself? There were 114 participants who provided 87 papers, most of four or six pages (presumably posters *versus* oral presentations), including no obvious reviews. There is an author index and one of objects (not quite complete: REJ 0317–853 also appears on p. 417), but none of subjects. Photographs of participants (all nameless) on otherwise blank even-numbered pages show them engaged in the customary dangerous conference activities: drinking, arguing with their colleagues, Polish folk dancing (only one volunteer is out of step), dining in a salt mine, shooting bows and arrows, and wearing their name tags backwards. Thanks to authors P. Chote and D. J. Sullivan of Wellington, you have a chance to learn your second phrase of Maori — Puokonui, meaning big eye. This assumes you already knew kia-ora (= good morning, or 1970s British orange juice).

The SOC came from eight countries; one member was a woman; and one has his name slightly twisted (S. O. Kepler to Kepler Oliveira). But the last, best word comes from the editor's preface: "To make organizing work easier, the scientific organizing committee was reduced to the following ten people for this year." We can perhaps look forward to a supremely efficient future workshop with zero members of the SOC, or, at most, the Lyttletonian optimum number of 0·7. — VIRGINIA TRIMBLE.

Collins 2014 Guide to the Night Sky, by S. Dunlop & W. Tirion (Collins, London), 2013. Pp. 96, 21 × 15 cm. Price £6·99 (paperback; ISBN 978 0 00 754074 7). Also **Collins Planisphere**, with instructions for use by S. Dunlop & W. Tirion. 30 × 30 cm. Price £9·99 (ISBN 978 0 00 754075 4).

Received a little too late to feature in the December issue of this *Magazine* (and thus catch the Christmas market *and* be ready in the hands of potential users for the start of 2014), this twin set of *Guide* and *Planisphere* is ideal for novices to learn their way around the sky visible to observers around latitude 50° North. Produced as a joint venture by Collins and the Royal Observatory at Greenwich, the text is provided by expert observer Storm Dunlop and leading astro-cartographer Wil Tirion, so, as one might expect, it is a polished production.

The opening pages are devoted to the basics — some definitions, the apparent movement of the sky, easily observable phenomena, and the northern circumpolar constellations which are used for orientation — before going on to the main body of the book in which each month of 2014 is accorded three double pages. The first shows the vista looking north, while the second shows the southern panorama; these pages include notes on the readily observable (by eye or binoculars) features and also show the phases of the moon. The third double page shows the location of the visible planets and gives a calendar of notable events, particularly those involving the Moon. A glossary and other useful information are given on the closing pages.

The *Planisphere*, which appeared at the same time as the *Guide*, provides an easy way of seeing what's on offer in the sky, at least as regards its stellar content; full instructions for its use are given. However, I do wonder whether, in the age of sophisticated hand-held computers, planispheres are joining the astrolabes as rather historical artefacts. — David Stickland.

THESIS ABSTRACT

Understanding X-Ray Reflection as a Probe of Accreting Black Holes

By Daniel Richard Wilkins

The reflection of the X-rays emitted from a corona of energetic particles surrounding an accreting black hole from the accretion disc is investigated in the context of probing the structure of the central regions as well as the physical processes that power some of the brightest objects seen in the Universe.

A method is devised to measure the emissivity profile of the accretion disc, that is, the reflected flux as a function of radius in the disc. This method exploits the variation in the Doppler and gravitational redshift of emission from different radii in the disc to fit the observed reflection spectrum as the sum of contributions from successive radii, and is applied to X-ray spectra of the narrow-line Seyfert-1 galaxies 1H 0707–495, IRAS 13224–3809, and MCG–6-30-15, as well as the Galactic X-ray binary Cygnus X-1. This illumination pattern of the accretion disc is a sensitive probe of the geometry of the corona that is illuminating the disc.

A formalism is developed in which systematic ray-tracing simulations can be run between X-ray-emitting coronae and the accretion disc for a range of source geometries and other physical parameters, allowing observable data products to be created that can be compared directly to data from astrophysical black holes in order to determine how those parameters affect the observed data, thus allowing them to be constrained observationally. The measured emissivity profiles are found to be in agreement with those expected theoretically, and it is also discovered that the measured emissivity profile can be used to determine the radial extent of the X-ray-emitting corona above the accretion disc.

The X-ray-emitting coronae are located and their radial extents constrained in 1H 0707–495, IRAS 13224–3809, and MCG–6-30-15, while the insight gained into accretion-disc emissivity profiles from ray-tracing simulations allows the low-flux state into which 1H 0707–495 was seen to drop in 2011 January to be explained in terms of a collapse of the X-ray-emitting corona to a confined region around the central black hole.

The rapid variability of the X-ray emission from accreting black holes is exploited in the use of reverberation time lags, where variability in the continuum is seen to lead that in its reflection from the accretion disc, to measure the distances between the X-ray-emitting corona and the reflector. Ray-tracing calculations are developed to simulate lag spectra that can be measured in X-ray observations to provide a means of constraining the extent and geometry of the corona, complementary to the use of the emissivity profiles. Combining those methods, the X-ray-emitting coronae are constrained to extend radially outward a few tens of gravitational radii over the accretion disc, while extending vertically a few gravitational radii above the plane of the disc. Furthermore, it is demonstrated how measured lag spectra can be used to understand the propagation of luminosity fluctuations through the extent of the corona, and techniques are developed for analysing energy-resolved variability that will be possible with future generations of X-ray telescopes.

Finally, those methods, along with theoretical insight gained from ray-tracing simulations, are applied to X-ray spectra extracted from 1H 0707–495 during periods of low and high flux. Evidence is found for the expansion of the corona along with a drop in the average energy density as the X-ray luminosity increases, followed by its contraction as the luminosity decreases on time-scales of hours. — *University of Cambridge; accepted 2013 July*.

A full copy of this thesis can be requested from dan.wilkins@cantab.net

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Here and There

AND WE THOUGHT THAT THE SUN WOULD DO FOR HUMANITY!

Astronomers generally believe that our galaxy will collide with the Andromeda Galaxy in about 3 million years … . — *A&G*, **54**, 4.20, 2013.

FLOWER POWER

The astral elements include cobalt and geranium, according to researchers at UCL. — *Metro* (MiniCOSM column), 2013 August 20.

THE FIRST MARTIANS?

… it is these unnamed Africans who hold the record of "closest to the sun" at 146 million miles. — *Daily Telegraph*, 2013 August 17.