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A REVIEW OF ASTRONOMY

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MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2008 October 10th at $16^h\ 00^m$
in the Geological Society Lecture Theatre, Burlington House

A. C. Fabian, *President*
in the Chair

The President. Can I welcome everyone to the new session of meetings. A few things I must say to start with. The first is congratulations to the former RAS President, Professor Donald Lynden-Bell, who with Martin Schmidt has shared the Astrophysics Kavli Prize. The Kavli Prize is a partnership between the Norwegian Academy of Science and Letters, the Kavli Foundation, and the Norwegian Ministry of Education and Research, whose purpose is to complement the Nobel Prizes. Donald is best known for theories on galaxies containing black holes as the principal source of energy in quasars, and many other things. He wrote a wonderful paper in 1969 that we all would love to have written. He was also the first director of the Institute of Astronomy at Cambridge, and is the holder of our Eddington and Gold Medals. So congratulations to Donald. [Applause.]

Such awards are important when speaking to politicians and trying to impress on them how we're good at doing astrophysics, and, of course, other things. The Royal Society's Faraday Prize for Science Communication has been awarded to John Barrow, who is Professor of Mathematical Sciences at Cambridge. A former member of the Council of the RAS, he was the first Gerald Whitrow Lecturer, and has also given the George Darwin Lecture. Many of you will also know that Professor Penny Sackett FRAS has been appointed Chief Scientist by the Australian Federal Government; an astronomer in government as Chief Scientist is wonderful. Professor Sackett is a former director of ANU's research school of astronomy and astrophysics at Mount Stromlo.

Now I want to move to announcing the winners of the 2007 Michael Penston Astronomy Prize. The winner of first prize is Dr. Joern Geisbuesch from Cambridge, from the astrophysics group in the Cavendish Laboratory, for his thesis entitled 'Cosmology with Sunyaev–Zel'dovich cluster surveys'. The runner up, receiving a fifty-pound book token, is Dr. Joseph Zuntz of Imperial College, now at Oxford, and his thesis is entitled 'Cosmic-microwave-background power-spectrum estimation and prediction with curious methods and theories'. The Runcorn Prize and one thousand pounds goes to Dr. Leigh Fletcher of Oxford, currently based at JPL, for her thesis entitled 'Saturn's atmosphere, structure and composition from *Cassini*', and the runner-up prize of a fifty-pound book token goes to Dr. Dirk-Jan van Maanen of the Grant Institute for Earth Sciences, Edinburgh, now at WesternGeco London Technocentre, for his thesis entitled 'Time-reversal and interferometry with applications to forward modelling of wave propagation and a chapter on receiving functions' — just trips off the tongue! [Laughter.] We hope that the prize-winners are going to give talks about their theses at future monthly meetings of this Society.

So now we move on to our programme, and our first talk is by Professor Lars Stixrude from University College London and is on 'Fluid helium: conditions of giant-planetary interiors'.

Professor L. Stixrude. As the second most abundant chemical element in the Universe, helium makes up a large fraction of giant gaseous planets, including Jupiter, Saturn, and most extrasolar planets discovered to date. Using first-principles molecular-dynamics simulations, we find that fluid helium undergoes temperature-induced metallization at high pressures. The change in electronic structure of He at elevated pressures and temperatures has important implications for the miscibility of helium in hydrogen, and for understanding the thermal histories and the origin of magnetic fields of giant planets.

Despite its abundance, little is known about the physics of helium at the conditions of giant-planetary interiors. Helium is known to be an electrical insulator at low pressure, with a wide energy gap between occupied and unoccupied electron orbits; it exhibits almost no chemical bonding. Under compression, however, helium is predicted to metallize *via* closure of the energy gap at ≈ 100 Mbar (10 TPa), a pressure greater than that at Jupiter's centre. Thus, one might expect helium to be insulating at giant-planetary conditions, for its solubility in metallic hydrogen to be limited, and for addition of helium to limit the electrical conductivity of the gaseous envelope.

However, recent high-pressure results have revealed the rôle of temperature in metallization, particularly in the fluid state. Fluid hydrogen becomes metallic at 1·4 Mbar at high temperature ($>$ 1000 K) whereas at low temperature ($\geqslant$ 300 K) crystalline hydrogen is expected to metallize only above 4 Mbar. In a sense, hydrogen at elevated pressures resembles other materials that undergo insulator-to-metal transitions on melting, such as silicon and carbon, in which the liquid has a more densely-packed structure than the solid phase. Yet the metallization of fluid hydrogen may also be related to changes in the fluid, from dominantly molecular (H_2) at lower pressures to dominantly atomic (H) at higher pressures. That ionization and dissociation of the molecule take place across overlapping régimes of density and pressure is a complication that has confounded a full understanding of the metallization of hydrogen. The case of helium is thus revealing in that it effectively isolates the influences of temperature and density on the development of metallic bonding, because both liquid and solid are monatomic and close-packed at high pressure.

Using first-principles molecular-dynamics simulations based on density-functional theory, we find that fluid helium undergoes temperature-induced metallization at high pressures. The electronic energy gap (band gap) closes at 20 000 K at a density half that of zero-temperature metallization, resulting in electrical conductivities greater than the minimum metallic value. Gap closure is achieved by a broadening of the valence band *via* increased structural disorder and *s–p* hydridization with increasing temperature, and this influences the equation of state: the Grüneisen parameter, which determines the adiabatic temperature–depth gradient inside a planet, changes only modestly, decreasing with compression up to the high-temperature metallization and then increasing upon further compression. The change in electronic structure of He at elevated pressures and temperatures has important implications for the miscibility of helium in hydrogen, and for understanding the thermal histories of giant planets.

The large influence of temperature on the electronic structure of helium implies that helium rain is unlikely in present-day Jupiter or Saturn. It has been suggested that exsolution and gravitational segregation of helium from hydrogen, on cooling of the planet, may be responsible for the excess luminosity of Saturn. This argument comes from estimates of the hydrogen–helium miscibility gap that, so far, have been based on calculations performed at temperatures too low to induce the metallization that we find. For models of Saturnian evolution, He rainout, if it occurs, would take place at pressures and temperatures in the range of 1–10 Mbar and 5000–10 000 K, which encompasses the régime ($V \approx 2$ Å^3) in which we find that temperature increases the valence band width, and decreases the pseudogap by a factor of two as compared with 0 K. For Jupiter, and for extra-solar planets larger and older than Jupiter, still higher pressures and temperatures become relevant, and the He energy gap may be completely closed according to our calculations.

Miscibility of He in hydrogen is thus likely to be enhanced in comparison with the predictions of previous low-temperature calculations, as temperature transforms dense fluid helium from an insulator to a semi-conductor and ultimately a metal. Enhanced solubility would reduce the critical temperature for miscibility, below which hydrogen and helium are immiscible, to values below those indicated by thermal-evolution models for Saturn. Other mechanisms must therefore be found to explain the excess luminosity of Saturn, and the helium deficiency of the Jovian and Saturnian atmospheres.

The electronic structure of helium may also have an important influence on magnetic-field generation. Temperature-induced band-gap closure in helium tends to enhance the electrical conductivity over the values typically assumed. Larger electrical conductivity in turn means a longer free-decay time for the field, and may influence our understanding of the power of the field and its form, whether it be dipolar or multipolar.

Our predictions of the equation of state and electronic properties can be tested with emerging experimental technology. Shock waves, including multiple shocks and 'ramp' waves, generated by powerful lasers in samples pre-compressed in a diamond-anvil cell, provide a means of experimentally accessing the entire range of pressure–temperature conditions of giant planets. For example, we predict that the energy gap closes at a density of 2·3 g cm^{-3} along the Hugoniot for 4-fold pre-compression: one fifth the density required for gap closure under static conditions. The influence of temperature on the electronic structure is also illustrated by the carrier concentration, which increases with increasing pressure and increasing temperature, primarily due to closing of the energy gap. We predict that experimental measurements along the 15-fold pre-compressed Hugoniot will be particularly revealing: requiring an initial (pre-compressed) pressure of 1 Mbar at ambient temperature, this Hugoniot includes pressure–temperature conditions at which our results differ significantly from those of the plasma model, and the non-metal to metal transition should be experimentally detectable *via* optical absorption and reflectance measurements.

The President. Thank you very much. Some questions?

Mr. M. F. Osmaston. Certainly this is very interesting to me, but I tend to regard the central Earth-mass, or 'core', of Jupiter as being actually silicate, not liquid hydrogen or helium or whatever. So my question really is, if you are restricted to being outside such a core, will you still reach conditions in Jupiter at which helium might be ...

Professor Stixrude. The answer is yes, but there are several uncertainties. Conventional wisdom is that the base of the envelope is at about 40 megabars, and that is well beyond the condition of metallization in fluid helium as we predicted.

Rev. G. Barber. That of course leads to the question of what does cause the helium deficiency in the outer envelope? Perhaps it's primordial: that's the important topic about the solar nebula.

Professor Stixrude. It's a really interesting question. The other surprising thing that the *Galileo Atmospheric Entry Probe* found was that Jupiter is enriched in heavy elements compared to the Sun by far more than people had thought before, and it's possible then that those heavy elements might be raining out, or helium in some combination with one of those heavy elements might be raining out; but that's another possibility which is really in the realm of speculation at this point because as little as we know about hydrogen and helium, we know far less about something like neon, which is one of these candidates for another rain composition that's been proposed. So that's an area of future study.

Mr. J. Stone. The late Sir Arthur Clarke in some of his writings made reference to suggestions that the core of Jupiter may be a rather dense form of carbon. Do you have any comments on that?

Professor Stixrude. I think it may be more likely that the core of Jupiter would be somehow representative of solar composition, and that it probably would contain some carbon, but that it would also contain oxygen, silicon, magnesium, iron — the things that terrestrial planets are made of. That is certainly how giant-planetary models are generally built: the core is generally assumed to be composed of rock and iron. Whether you can make it out of pure carbon or not — I think that would require some special formation mechanism. But the other point about these calculations is that they will give us a better feeling for how density varies with depth inside these planets, and it's based on information like that that we infer the presence of a core in Jupiter in the first place. So better knowledge of the equation of state of helium is going to give us better constraints on just how big that core is, how massive it is, and how dense it might be.

Professor D. W. Hughes. Experimentally, in my lifetime for example, is there any way you're going to be able to check or work out what it's going to be like in the centre of Jupiter? It's always been a mystery to me, throughout all my life, and it doesn't seem to be getting any better.

Professor Stixrude. It's getting a lot better. That is the answer. These experiments are actually planned and they will reach pressures like those at the centre of Jupiter. A pre-compressed, laser-driven shock is ideally suited to exploring these conditions. The biggest experimental challenge is actually keeping the temperature down. That's why you have to pre-compress so much, or you have to shape the laser pulse in such a way that you can keep the temperature down to planetary temperatures as you're compressing it by ten, twenty, thirty fold.

The President. That's the opposite problem of doing fusion, I suppose?

Professor Stixrude. Right.

Professor A. Fitzsimmons. Will the planned *Juno* mission with its gravity-field measurements of Jupiter give you any insight into the central conditions?

Professor Stixrude. Yes. The gravity measurements are very important. Measurements of the mass and moment of inertia I think we know pretty well but the higher moments of the gravity field can put very important constraints on the interior structure. It will be very interesting to see how greater precision in these higher-order moments of the gravity field are confronted with this evidence of helium deficiency — whether there is some incompatibility there or whether we'll need some fundamental rethinking about how we model them.

The President. A last question from the audience.

Mr. M. Hepburn. Surely if the temperature at the centre of Jupiter is of the order of several electron volts, you're not going to have silicates there. All those bonds will be shifting or not there at all.

Professor Stixrude. They certainly won't have crystals. It'll be in some supercritical fluid state. The point is that just on the basis of universal abundances of elements one expects some oxygen and iron and so on, but it certainly won't be in a crystalline state.

The President. Could I ask my question? I don't know much about what you've been saying but I do know that in white dwarfs helium undergoes sedimentation. Why doesn't it happen in Jupiter?

Professor Stixrude. That's interesting. Well ... I don't know anything about white dwarfs! [Laughter.]

The President. They have a much stronger gravitational field, but I'm just thinking in principle, with a strong gravitational field, if you put hydrogen and helium in a box, wouldn't the helium sink to the bottom?

Professor Stixrude. I think the limitation on whether you get helium rain out or not is primarily the solubility, which depends on the pressure and temperature. What we're finding in Jupiter and Saturn is just that they're too warm to create this helium rain.

The President. Thank you very much. [Applause.] The next talk is from Charles Barclay who is from several places [laughter] — the Blackett Observatory of Marlborough College, and Astrophysics, Oxford. He is talking about 'Kielder Observatory — a new platform for dark-sky outreach.'

Mr. C. E. Barclay. My talk is more down to Earth than the last; rather soggy earth and certainly at lower temperatures, but it still relates to significant pressures, at least in terms of project deadlines. I am very pleased to have the opportunity to speak here again only two years after presenting the outreach work that I oversee in Marlborough and Oxford. I am a teacher but an astrophysicist by training and closely involved in secondary-level qualifications in astronomy; but my main interest is in outreach, particularly to 10- and 11-year olds. Though now well publicized in architectural circles, tonight I want to tell the story of Kielder Observatory, the newest, largest, and most unusual dedicated outreach observatory in the UK.

I spoke previously about the remarkable coincidence of finding myself restoring a telescope at the Blackett Observatory in Wiltshire, which not only bore my name but which had been originally commissioned by my great-grandfather's first cousin (Joseph Gurney Barclay, a Fellow of this Society), though the telescope's 'stay' in Oxford is well documented.

As an astronomer, the chance to put one's mark on an observatory is exciting, as the restoration of the ex-Radcliffe 10-inch Cooke has been, and I feel very privileged to have been in the right place at the right time to do this. But through my connection with Oxford Astrophysics as a PEST (Public Engagement with Science and Technology) visitor, I was also involved with the new dome design and move of the 16-inch *Wetton* telescope to the top of the Astrophysics building and the structuring of an outreach programme for local schools and teachers. I would thus not have expected to be involved in yet a third observatory.

In early 2005, an international open competition was launched by the Royal Institute of British Architects, driven by the Kielder Partnership in Northumberland, which desired another art project. Kielder already boasts art projects by James Turrell (the skyscape), Softroom's Belvedere, Combe & Kitchen's Minotaur Maze, and Kisa Kawakami's Mirage sculpture. Kielder Water itself was opened by the Queen in 1982, at 200 billion litres the largest man-made reservoir in England, built to ensure a water supply to the then-important heavy industry in Tyne and Wear, and Tees. The Kielder area is also home to the Calvert Trust whose aim is to allow joint holidays for families with disabled children. Informal star camps have also been held very successfully from this location. But specifically there was a proposal for an observatory on Black Fell (at just under 500-m altitude), which would make use of the remoteness and especially dark skies of the Kielder Forest: 400 km^2 of largely Sitka spruce (managed since 1920) and the last, non-mountainous, magnitude-6 dark site in England and already the location of successful star camps attended by amateur astronomers from all over the UK and indeed some from Europe.

At Marlborough College, our artist in-residence at the time heard of the competition and approached me to join him as astronomy adviser; however, we lacked an engineer or architect. When nothing progressed, I was pleased to be contacted a couple of weeks later by Charles Barclay, distant cousin and direct descendant of Joseph Barclay, with whom I'd been in touch only since the story of the Marlborough restoration had been published in *Astronomy Now*. I am very pleased that Charles has been able to join us today. I am also grateful for his willingness to answer architectural questions at the end of this lecture.

Charles' business (founded in 1996 and based in Brixton since 2000) is design led and had the flexibility to enter such a competition, and for fun he decided that we should team up. A meeting at my observatory in 2005 July with Charles and designer Francesco Pierazzi seemed fitting and, undaunted by a thunderstorm outside, we pored over initial ideas. With perhaps rather too teacherly a hand I corrected ideas that wouldn't work and suggested areas of importance in running an observatory, not only for outreach but also to cover a wide range of potential users; and we talked through the running of the Blackett Observatory. More iterations and ideas followed. Entries were sent in over the summer and nothing was heard, till a surprise e-mail (given the 230 entries) from Charles saying we were in the final six. Shortly afterwards, following short-list presentations, we were announced as winners.

The initial post-competition budget proposed was some £125K. It was clear from the start that artistically and in terms of a contemporary non-invasive structure Charles' design would 'touch down very gently on the wild landscape' but would necessarily involve some innovative mixing of contemporary and old technologies, most importantly being ecofriendly.

Envisioned from the outset as a 'pier', it is a platform from which to launch a voyage of discovery of the night sky. Charles put together the team of contractor Stephen Mersh, structural engineers Michael Hadi Associates, and builders, *etc.*, all the while liaising with Kielder Partnership and the end-user astronomers.

The building was started in 2007 July, having passed through all the local planning processes. The winter weather was not kind but the building continued undaunted. I visited one cold day in January. At a final cost of ~£415K it has no CO_2 emissions: its 2·5 kW of power is supplied by wind turbine and voltaic cells on the roof and stored in batteries; the toilet is of the composting variety. Only the wood is not local, as the Sitka of the forest is not mechanically strong enough and Douglas fir, Redwood, and Siberian larch was used instead, all from Forest Stewardship Council certified sources.

Kielder Observatory Astronomical Society (KOAS) was formed with Gary Fildes at its helm; he became the key individual to whom the intricacies of the design had to be unveiled. KOAS now has an active website and the talks, tours, and star camps are already underway. There are five active astronomical societies in the North-East and he will liaise with them to arrange access. KOAS was able to purchase the two main telescopes from the local council within the project budget: a 20-inch Pulsar Dobsonian equatorial *f*/4 of 2-m focal length, manually operated and ideal for eye-to-eyepiece viewing, and a Meade LX200 14-inch *f*/10 and 3·6-m focal length which can be used to do imaging work. KOAS have now added a dedicated Coronado Hα solar telescope of 60-mm aperture, 40-cm focal length, to expand outreach importantly into the daytime.

The dome-rotation system was modelled on 19th-Century hard engineering, and hand cranked as at the Blackett Observatory. The weight of the dome, however, being some three times as great requires considerable effort — a useful task for an over-energetic young visitor perhaps.

The artist Alec Finlay was brought in to develop a 'Star Diary' book for the next century in conjunction with Professor Ray Sharples at Durham and designer Denis Moskowitz. Alec has already produced imaginative logos for some of the main events in our long-range diaries.

First light occurred on 2008 April 25 and the opening ceremony was presided over by Sir Arnold Wolfendale, 14th Astronomer Royal. Kielder Observatory is unique in the UK as a large, open-access (non-professional), purpose-built facility, sited in a truly dark-sky location. It houses the largest telescope dedicated to amateur and public use in the UK and though the facility cannot be open '24/7', the site is always accessible for walkers, and by day provides a superb destination and vantage point over the surrounding Fell and Kielder Water.

Whether seen as a 'battleship' or 'insect', the construction has a life of its own. The dark sky is to be treasured and sensitive red lighting enables dark vision to be maintained whilst making the environment safe for the young at night. Access and publicity for the Observatory has been a balance between facilitation for observers and visitors and dissuasion for potential vandals who have already struck at Kielder's other art projects.

If you are close by you might like to note the 2008 December 20 lecture at the observatory by Sir Arnold Wolfendale 'Cosmic space — a place for the sacred?' accompanied by suitable festive refreshments and followed by observing if clear.

The design is already being recognized on the worldwide architectural scene and is in the running for several prestigious awards. I wish Charles and his firm the best of luck in these endeavours.

The President. That looks like a splendid venture — we certainly must visit it.

Mr. C. J. North. With all that wood, how do you deal with the problem of insects and fungal attacks?

Mr. C. E. Barclay. I expect it's treated. Charles, I knew there would be questions here that I wouldn't immediately have the answer to! [Laughter.]

Mr. C. R. Barclay. It is all treated.

Mr. North. Organic or inorganic?

Mr. C. R. Barclay. I think it's inorganic actually. We had to have fire protection for the timber as well for various reasons, and the protection system we've got provides fire protection and protection against fungal attack and so on.

Mr. North. Do you use something like borax or boric acid?

Mr. C. R. Barclay. I couldn't tell you the actual chemical composition but I can refer you to the manufacturer and they'll tell you.

Dr. R. C. Smith. I happened to pass by there in the summer not even knowing it existed. The car park is a long way from the observatory! How do you cope with that?

Mr. C. E. Barclay. I think that is going to change.

Mr. C. R. Barclay. When they're having observation evenings they open the gates and you can actually drive up to the observatory. But they wanted to keep it gated off to avoid the risk of vandalism. In fact Skyspace, which is nearby, had its photovoltaic panel stolen last year. So that's another reason why they don't want you climbing onto the observatory. The weekends when the observing is happening are advertised, so you know you'll be able to drive up. There is a car park quite close to the observatory itself, but not right by it, and then it's an easy walk. Other times walkers come up from the village and go past the gate: it's a popular walking destination.

Mr. R. Steppe. Can it be used for astrophotography as well as visually?

Mr. C. E. Barclay. Yes. The idea is that it should be as versatile as possible. There are already ideas to use it for exoplanet-type observations.

Dr. A. Longstaff. How many clear nights do you get there per year on average? You've got great dark skies but the weather's not so hot!

Mr. C. E. Barclay. Absolutely. I think it's great to have the facility there. I think that's why its terribly important to have solar capabilities as well because we see more clear day skies than we do night skies. I don't know what the average has been; I would suspect not great over the last couple of years — we've had some pretty bad winters. In terms of outreach it's therefore important also to have other things going on and specifically lectures. It's absolutely key to have backup activities as you would at any observatory. It's no miracle spot for weather.

Mr. C. R. Barclay. It's meant to be one night in three, but I think that's rather optimistic.

Mr. C. E. Barclay. That's what I tell people!

Mr. H. Regnart. As a Northumbrian I'm somewhat aware of the history of astronomy in Northumbria, most notably, perhaps, that of Sir Charles Parsons who was a member of the same family as Lord Rosse, and owner of the Grubb–Parsons telescope-manufacturing facility. In fact, although that company is now deceased, the business was partly taken over and continues on a smaller scale. Newcastle University has a couple of telescopes out at Close House, a few miles to the west of Newcastle, and I've looked through them. You get a lovely warm glow when you do so. Unfortunately, this is sodium and not stars! So it may well be that universities — not just Durham which you mentioned but other universities, such as Northumbria and Sunderland, for instance — may be interested in getting involved.

Dr. D. McNally. The observatory is opening at quite an opportune time given that 2009 is the International Year for Astronomy. Are the people at the Kielder Observatory coordinating with the RAS's activities to organize a lot of outreach during this year?

Mr. C. E. Barclay. I have to say, given that I'm now beginning to get more involved with the International Year of Astronomy in my observatory and also through Oxford, it's next on my list to make sure that Gary Fildes is also keying this event into the hundred hours of observing. But I can't answer immediately because the operations side is all going to be done locally and I won't have any part of it. However, I very much hope that will be the case if it isn't already. Things are at an early stage in getting up and running, but yes, next year should provide a very good focus.

Dr. McNally. And are they interested in trying to get the Kielder area declared an international-quality dark-sky reserve?

Mr. C. R. Barclay. I haven't heard that but it should be. There is certainly a large awareness of light pollution and the planning authorities, for example, don't allow floodlighting on buildings. So there is an awareness but whether it's actually going to be declared a reserve or not I don't know.

The President. Thanks very much to both Charles Barclay the speaker and Charles Barclay the architect. I am now pleased to introduce Professor Alan Watson, from the School of Physics and Astronomy at Leeds, to give the George Darwin Lecture. The title of his talk is 'The birth of cosmic-ray astronomy on the Argentinian pampas'.

Professor A. A. Watson. [It is expected that a summary of this talk will appear in a future issue of *Astronomy & Geophysics.*]

The President. Thank you very much, Alan; that was a splendid lecture. Some questions?

Mr. Osmaston. I've seen a report, I can't remember where, that nuclear species at low energies are distributed with a first-ionization-potential-type distribution.

Professor Watson. Yes, it's certainly true they are distributed that way. This is at very low energies, a GeV and below. There's actually an alternative explanation that is more favoured now, which is due to Drury, Ellison & Meyer. The elements are actually trapped in dust grains, and the dust grains are accelerated and the elements are released into space.

Mr. Osmaston. But this is only up to 1 GeV?

Professor Watson. Oh yes, entirely. But there are some fantastically good mass measurements. We know the mass and isotopic composition of cosmic rays with extraordinary accuracy down at low energies. But up at the energies I'm talking about we really are struggling to distinguish between protons and iron nuclei.

The President. Do you agree that if you associate more than a handful of events with relatively nearby objects, then from a simple Olbers' paradox argument, there must be a cutoff?

Professor Watson. Oh yes, I certainly do. Sorry, perhaps I didn't stress that, as it seems so obvious! I think that the work you've done, and even the work with the Veron–Cetty catalogue, make me believe that we have seen the effect. Please don't call it a cutoff because it will revive! And if we live long enough we will see particles of 10^{21} eV. Once you get away from the resonance, and the peaky blackbody spectrum, the spectrum recovers. It's just that the flux then comes down to a few per tens of millennia!

Rev. Barber. You've tried to correlate the observations with AGN; are there any other objects that might correlate, such as gamma-ray bursts?

Professor Watson. Gamma-ray bursts are actually not very promising for two reasons. First, I believe there's been only one gamma-ray burst seen within 100 megaparsecs since they started measuring distances. Secondly, although we can preserve the direction of the particle through intergalactic fields, we lose correlation because of the dispersion in time. They make tiny scatters of the order of every megaparsec or so. That's thought to be the coherence length. And this builds up to time delays of the order of tens to hundreds of years. So that does not look very promising. Equally it means we won't be able to tell the gravitational-wave people that there was a magnetar in such and such a place, or a high-energy cosmic ray in such and such a place, and we won't see anything that is contemporaneous. So that is a difficulty — although the direction is preserved, we lose a lot to time dispersion.

Professor M. Rycroft. Are there any sources of interference to your optical detectors? I'm thinking about lightning.

Professor Watson. Yes, lightning is a problem. At certain times of year we get quite a lot of lightning, but we do shut down if there's too much. You see very spectacular storms, but so far we have not yet had one of the water Čerenkov detectors hit by lightning. That could happen, but of course the area of each tank is quite small, although they do have an antenna sticking up! We can see a flash of lightning and of course the time pattern is totally different, so it's not a background in the sense that we have to fight against it. It's just an operational problem.

The President. Perfect timing. There is a drinks party in the Society's apartments now, and the next A & G meeting will be held on Friday November 14.

SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 205: HD 9519, d AURIGAE, HR 4427, AND HR 7795

By R. F. Griffin
Cambridge Observatories

Orbits are presented in this paper for four late-type giants. One of them, d Aurigae ($3^{m}\cdot 72$), is noteworthy as being the second-brightest object among the more than 300 that feature in this series, yet its binary nature was not discovered until more than 100 years after its radial velocity was first measured.

HD 9519 has an orbit of modest eccentricity (0·27), small amplitude (2·8 km s^{-1}), and a period of almost 23 years; nearly two cycles have elapsed since the writer's observations of it began. The orbit of d Aur is of very similar eccentricity and even smaller amplitude (2·3 km s^{-1}), and has a 3½-year period that facilitates good phase coverage in only two cycles. HR 7795 is another long-period object, with an eccentricity of 0·33 and a period of just over 20 years; it is a composite-spectrum system whose A-type secondary is detectable but is rendered inconspicuous at visual wavelengths by the high luminosity ($M_V \sim -2^{m}$) of the primary star. HR 4427 is a neglected object whose 2½-year orbit is indistinguishable from a circle.

The paper presents, in addition to the orbits of the binaries, radial velocities of two stars (BD +41° 306 and HR 7800) that happen to be near the sky positions of HD 9519 and HR 7795, respectively, and prove to have constant velocities.

Introduction

The stars treated in this paper came to attention in different ways. HD 9519 was observed in a very early Cambridge programme that was soon abandoned; its binary nature was discovered in a subsequent re-observation of the few stars that had already been measured in that programme. The variability of the velocity of d Aur was discovered by observers who used the Haute-Provence (OHP) *Coravel*, from whose listing it was selected for observation by the writer. HR 4427 is another object whose binary character was first detected by the OHP observers. HR 7795 has been observed since a comprehensive programme on such composite-spectrum objects was initiated in 1982.

HD 9519

HD 9519 is an eighth-magnitude star 30 minutes of time (about 5½°) preceding the beautiful multiple system γ Andromedae. The *Henry Draper Catalogue* shows its spectral type as K2, but otherwise it has been completely neglected by astronomers: no photoelectric magnitude, MK type, or radial velocity has ever been determined for it, and the sole paper in which *Simbad* records finding it is Paper 174[1] of this series. There, the star is noted as one of three long-period spectroscopic binaries whose orbits still remained to be published, out of nine discovered among the 40 stars observed on the 'thick-night' programme, a 'fall-back' programme to be pursued on nights of particularly poor transparency in the earliest days of photoelectric measurement of velocities with the original radial-velocity spectrometer[2] in Cambridge. Selected to be of ideal types and well placed for observation with that instrument, and not too faint, they were defined as being of type K2 and brighter than 8^m in the *Henry Draper Catalogue*, and in the declination zone 40° – 50° north.

We are indebted to *Tycho*[3] for photometry of HD 9519; transformed from V_T and B_T, it gives $V = 7^m\cdot90$, $(B-V) = 1^m\cdot33$. *Tycho* also found a very small parallax with an uncertainty much larger than the value itself, but the great depth of the dips in radial-velocity traces means that we do not need a parallax (or to know that the proper motion is small, as it is) to assure us that the star is a giant and not a dwarf. Its colour index then suggests a type of K3 III, but obviously that must not be regarded as any sort of actual spectral classification.

The first two radial-velocity observations were made in 1967 and 1968 and were mutually concordant. After that, the programme concerned was more or less in abeyance, but after several years (during which time the potentiality of stars to change their velocities on a long time-scale had become apparent to the observer) those objects that had already been observed were measured again. A discrepancy that might have been just within observational error was ignored in 1975, but a very slight increase in the discrepancy in 1979 triggered the transfer of HD 9519 to the spectroscopic-binary programme, and has resulted in its being observed in every one of the last thirty years. There is now a total of 72 observations, of which 24 were made with the original spectrometer, 24 with the OHP *Coravel*, 20 with the Cambridge *Coravel*, and four at the DAO. The OHP velocities have been adjusted by the usual offset of $+0\cdot8$ km s^{-1} before being entered, with the others, in Table I. All the data have been given unit weight in the solution of the orbit, apart from those obtained with the original spectrometer, which have been given half-weight; one specially bad one has been rejected. Fig. 1 plots the orbit, whose elements are given in the informal table on p. 58.

Table I

Radial-velocity observations of HD 9519

Except as noted, the sources of the observations are as follows:
1967–1990 — original Cambridge spectrometer (weighted 1/2 in orbital solution);
1991–1998 — OHP Coravel; 1999–2008 — Cambridge Coravel

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O−C)* *km s⁻¹*
1967 Nov. 21·92	39815·92	−22·7	0·217	+0·9
1968 Dec. 21·83	40211·83	−22·3	0·265	+0·7
1975 Sept. 4·11	42659·11	−19·8	0·560	0·0
1979 Jan. 13·83	43886·83	−19·6	0·708	−0·6
Sept. 23·05	44139·05	−19·4	·739	−0·4
1980 Jan. 2·78	44240·78	−18·2	0·751	+0·8
1981 Sept. 19·02	44866·02	−19·3	0·826	0·0
1982 Jan. 18·76	44987·76	−19·3	0·841	+0·1
Sept. 14·08	45226·08	−19·1	·870	+0·7
1983 Sept. 20·07	45597·07	−20·9	0·914	−0·2
Oct. 24·38[*]	631·38	−20·7	·919	+0·1
Dec. 10·88	678·88	−21·1	·924	−0·1
1984 Feb. 8·76	45738·76	−21·5	0·932	−0·3
Dec. 11·85	46045·85	−22·6	·969	−0·3
1985 Oct. 20·01	46358·01	−22·6	1·006	+0·8
1986 Jan. 5·82	46435·82	−23·8	1·016	−0·2
Aug. 29·10[†]	671·10	−24·3	·044	−0·1
Sept. 26·02	699·02	−24·6	·047	−0·4
Oct. 16·99[R]	719·99	−26·5	·050	−2·2
1987 Feb. 28·77[†]	46854·77	−23·7	1·066	+0·7
Oct. 14·00[†]	47082·00	−23·8	·094	+0·8
1988 Jan. 26·19[*]	47186·19	−25·3	1·106	−0·7
Mar. 15·78[†]	235·78	−24·6	·112	0·0
Nov. 4·02[†]	469·02	−24·5	·140	−0·1
1989 Jan. 17·76	47543·76	−24·4	1·149	−0·1
Mar. 22·87	607·87	−24·5	·157	−0·2
Sept. 7·09	776·09	−24·2	·177	−0·1
Oct. 14·99	813·99	−25·3	·182	−1·3
29·95[†]	828·95	−23·9	·184	+0·1
Nov. 25·89	855·89	−23·5	·187	+0·5
1990 Jan. 30·88[†]	47921·88	−23·9	1·195	0·0
Oct. 8·03	48172·03	−24·6	·225	−1·1
Dec. 24·80	249·80	−23·4	·234	0·0
1991 Jan. 28·87	48284·87	−23·3	1·239	0·0
Oct. 29·98	558·98	−22·7	·272	+0·2
Dec. 17·85	607·85	−22·5	·278	+0·3

TABLE I (*concluded*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1992 Jan. 17·79	48638·79	–22·8	1·281	0·0
Aug. 14·06	848·06	–22·8	·307	–0·4
Dec. 21·84	977·84	–22·4	·322	–0·2
1993 Feb. 14·78	49032·78	–22·2	1·329	0·0
July 9·12	177·12	–21·9	·346	+0·1
Dec. 24·81	345·81	–21·3	·367	+0·4
1994 Aug. 3·09	49567·09	–21·3	1·393	+0·1
Dec. 12·84	698·84	–21·2	·409	0·0
1995 Jan. 2·83	49719·83	–21·1	1·412	+0·1
Dec. 26·90	50077·90	–21·3	·455	–0·5
1996 Nov. 15·94‡	50402·94	–20·5	1·494	–0·1
1997 Mar. 6·79‡	50513·79	–19·9	1·507	+0·4
July 23·10	652·10	–20·1	·524	0·0
Sept. 10·02	701·02	–20·3	·530	–0·2
Dec. 20·88	802·88	–20·0	·542	0·0
1998 July 12·10	51006·10	–19·8	1·567	0·0
1999 July 13·46*	51372·46	–19·6	1·611	–0·1
Nov. 3·28*	485·28	–19·2	·625	+0·2
Dec. 28·87	540·87	–19·3	·631	0·0
2000 Feb. 28·78	51602·78	–18·5	1·639	+0·8
Aug. 9·14	765·14	–19·9	·658	–0·7
Oct. 9·06	826·06	–19·1	·666	+0·1
2001 Dec. 14·96	52257·96	–19·1	1·718	–0·1
2002 Feb. 5·80	52310·80	–19·0	1·724	0·0
2003 Jan. 11·90	52650·90	–18·8	1·765	+0·2
Sept. 13·09	895·09	–19·1	·795	0·0
2004 Feb. 23·85	53058·85	–19·6	1·814	–0·4
Dec. 31·92	370·92	–19·4	·852	+0·2
2005 Feb. 15·80	53416·80	–19·5	1·858	+0·1
Sept. 8·11	621·11	–20·1	·882	–0·1
2006 Mar. 1·77	53795·77	–20·3	1·903	+0·2
Sept. 9·11	987·11	–20·8	·926	+0·2
2007 Jan. 31·80	54131·80	–21·8	1·944	–0·3
Sept. 12·11	355·11	–22·2	·971	+0·1
2008 Feb. 19·84	54515·84	–23·3	1·990	–0·4
Aug. 15·16	693·16	–23·6	2·011	–0·1

* Observed with DAO 48-inch telescope.
† Observed with Haute-Provence *Coravel*.
‡ Observed with Cambridge *Coravel*.
R Rejected observation.

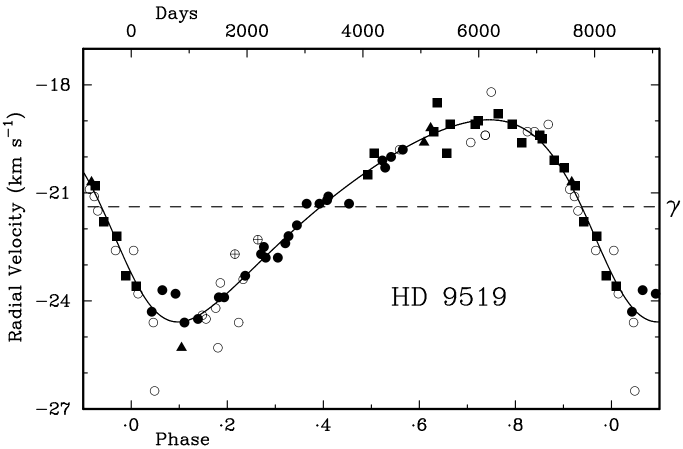

FIG. 1

The observed radial velocities of HD 9519 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. Open circles are used to plot the measurements made with the original Cambridge radial-velocity spectrometer[2]; they were given half-weight in the solution of the orbit, apart from the lowest point of all, which was rejected. The two earliest points, obtained in the 1960s, are distinguished by crosses within the circles. Measurements made with the OHP *Coravel* are plotted as filled circles, those with the DAO spectrometer as filled triangles, and those with the Cambridge *Coravel* as squares; all were given unit weight in the calculation of the orbit.

P	=	8292 ± 61 days	$(T)_1$	=	MJD 46306 ± 113
γ	=	−21·38 ± 0·05 km s^{-1}	$a_1 \sin i$	=	309 ± 8 Gm
K	=	2·81 ± 0·07 km s^{-1}	$f(m)$	=	0·0171 ± 0·0013 $M_\odot$
e	=	0·270 ± 0·022			
ω	=	121 ± 5 degrees	R.m.s. residual (wt. 1)	=	0·34 km s^{-1}

The small mass function allows the mass of the secondary to be less than 0·5 $M_\odot$ if the primary mass is taken as 2 $M_\odot$; it could be a white dwarf but seems more likely to be a lower-main-sequence star, probably several magnitudes fainter than the primary. The separation of the stars is probably a few times larger than the 2 AU which is the projected semi-major axis of the orbit of the primary about the common centre of gravity ($a_1 \sin i$ in the little table above), and at the putative distance of HD 9519, corresponding to a modulus of eight or nine magnitudes, it would subtend less than 0″·02. It is probably beyond resolution by speckle interferometry, except perhaps with the largest telescopes, and even with them (or by interferometry with separated apertures) the probability of a large disparity in magnitudes between the components makes it an unattractive prospect.

The optical companion to HD 9519

Without wishing to claim that he has discovered a visual double star, the author sees fit to draw attention to the fainter star that is about 2½ minutes of arc directly following HD 9519 (145″ in p.a. 88° according to informal measurement on a picture brought up by *Aladin* from *Vizier*). It is of course only a field star, whose proper motion is not at all the same as that of HD 9519 itself. If anyone could be said to have 'discovered' it, the distinction could probably be awarded to Argelander, who logged it in the *BD*[4] as +41° 306 (HD 9519 being +41° 304). *Tycho* has provided for it the magnitudes $V = 9^{m}\cdot18$, $(B-V) = 0^{m}\cdot97$. Seeing it there whenever he turned the telescope to HD 9519, the writer eventually succumbed to the temptation to measure it, and — a disheartening analogy with life in general! — once he did so it became almost routine to do it again, with the result in this instance that there are 12 measurements of the star. They are set out in Table II, and show no evidence of variability; with the initial observation weighted ½, the mean velocity is $-35\cdot69 \pm 0\cdot13$ km s^{-1}, and the r.m.s. scatter of the individual values is 0·47 km s^{-1}. The dips in radial-velocity traces, together with the colour index, suggest that the star is a late-G giant; a mid-K dwarf might also be possible, but the star's very small proper motion argues against that although it cannot be claimed as conclusive. There is a type of G0 given[5] in the *AGK3*, in which the star is listed as +42° 151. The types in the AGK3 are said, in the brutally brief introduction, to be "mostly from the HD or Vyssotsky". Since the star is not in the *HD*, one might hope to find it in Vyssotsky's publications, but it is not in the obvious one[6] that has a gigantic list of classifications made on purpose for the *AGK3*; it seems likely nevertheless to be a Vyssotsky classification that was passed privately to the editors of the *AGK3*.

TABLE II

Radial-velocity observations of +41° 306 ('HD 9519 B')

Date (UT)	*Velocity km s⁻¹*	*Date (UT)*	*Velocity km s⁻¹*
1984 Feb. 8·76*	−36·7	2000 Aug. 9·14‡	−35·6
1991 Dec. 17·85†	−35·3	2002 Feb. 5·80‡	−35·5
1992 Jan. 17·79†	−35·5	2004 Dec. 31·92‡	−35·8
Aug. 14·06†	−36·3	2005 Sept. 8·11‡	−35·8
1993 Dec. 24·81†	−35·1	2006 Sept. 9·11‡	−35·2
1997 July 23·11†	−36·5	2008 Aug. 15·16‡	−35·6

* Observed with original spectrometer.
† Observed with with OHP *Coravel.*
‡ Observed with Cambridge *Coravel.*

d *Aurigae* (*HR 2077, HD 40035*)

Delta, the northernmost bright star in the constellation Auriga, escaped being recognized as a spectroscopic binary until 1999, more than 100 years after its radial velocity was first measured, although at a V magnitude of 3·7 it is the second-brightest star to feature in this series. (The sole brighter one, ζ Cygni, was treated[7] in Paper 105, by coincidence exactly 100 numbers back.) The broad-band magnitudes of d Aur have been measured so many times (from one author alone they appear in seven papers all within an interval of five years!) that it seems scarcely warranted to give references to all the papers; suffice it to say that they are in tolerable mutual agreement, with representative values of $V = 3^{m}\cdot72$, $(B-V) = 1^{m}\cdot00$, $(U-B) = 0^{m}\cdot85$.

By virtue of being such a bright star, d Aur was first classified for spectral type in the 1890 *Draper Catalogue*[8], where it is given as "K?". Miss Maury[9] placed it in her Group XVa, which corresponds to K0. She included a note about it: "This star resembles α Boötis in the absorption shown in the region having wavelength shorter than 4307, and in the apparent brightness between the lines 4227·0 and

4215·7." — and she then refers the reader to a passage in her careful description of the type, wherein she contrasts the spectra of α Boo and α Cas, stars in which she had accurately recognized differences that we now ascribe to CN strengths and absolute luminosities. The impression of the brightness between the strong line of Ca I at λ 4227 Å and the CN band head (reinforced by a strong Sr II line) at λ 4215 Å is largely controlled by the strength of the CN band, which creates a step change in the intensity of the spectrum at the latter wavelength, the red limit of the molecular band. The recognition of the relative weakness of the CN band in d Aur, analogous to that in α Boo, at a time when no *reason* could be given for any differences between stars and even the presence of CN in stellar spectra lay undiscovered, demonstrates once more the remarkable acuity of Miss Maury's observations of spectra; allusions to it have been made previously in this series (most notably in Paper 180[10], wherein a special section was devoted to it). In the objective measurements made of CN strengths by the writer[11] as a graduate student 50 years ago, α Boo ranks 44th out 53 K2 III stars (thus 83% of the way down the list) in terms of CN intensity. It gave a numerical 'CN ratio' of 2·19, in a listing that runs from a maximum of 2·43 to a minimum of 2·11, with a mean of 2·278. (The actual strength could be taken as proportional to the departure of the ratio from 2·00.) d Aur, with a CN ratio of 2·16, ranks 68th out of 79, 86% of the way down the CN-ordered list of K0 III stars, whose ratios run from 2·41 to 2·10 with a mean of 2·243. (The details quoted here, though implicit in the results given in the published paper[11], are to be found explicitly only in ref. 12.)

d Aur is classified K0 in the *Henry Draper Catalogue*. Shortly before that catalogue was published, the star had been given by Adams *et al.*[13], in their first foray into spectroscopic estimation of luminosities, as having an absolute magnitude of $+0^{m}\cdot7$. They also gave a type of G7, 'estimated' in what has subsequently been regarded as the normal way (visual matching against standards), and G8 'measured' (quantitative comparison of certain Balmer lines with specified nearby metallic lines). The same luminosity and types were repeated in a subsequent paper[14] which they described as a "revision and modification" of the first, but were slightly modified to G6, $+0^{m}\cdot8$ in a third[15]. Meanwhile, at the Norman Lockyer Observatory Rimmer[16] had found the luminosity to be $+0^{m}\cdot8$, and at the DAO Young & Harper[17] had made independent estimates of $+1^{m}\cdot5$ and $+2^{m}\cdot0$, respectively, and put the type at G6.

Even before the MK system of spectral classification had been published, Keenan[18] had given the type of d Aur as G7 III; when the *MKK Atlas*[19] actually appeared, however, the star was listed as a standard of type K0 III. The same type was reaffirmed by Morgan[20,21]. In a series of revisions of the MK classifications in the 1980s, however, Keenan[22–26] repeatedly called it K0 – III, before placing it in his final paper[27] at K0 IIIb and showing that its parallax put it definitely in the 'clump' of slightly under-luminous giants, with $M_V = +0^{m}\cdot55$; the uncertainty of the parallax[3] corresponds to $\pm0^{m}\cdot09$ in the absolute magnitude. It is far from clear how O'Neal[28] could have re-interpreted the parallax of $0''\cdot02322$ as implying a distance of 50·0 pc and thereby $M_V = +0^{m}\cdot25$. In fact a recent official re-interpretation of the parallax information has gone decidedly in the opposite direction: the new *Hipparcos* reductions[29] show the parallax and its standard error increased from 23·22 ± 0·91 to 27·99 ± 1·61 arc-milliseconds, bringing the star's distance down from 43 to 36 pc and lowering its luminosity from $M_V = 0^{m}\cdot55$ to $0^{m}\cdot95$. It is disconcerting to find that such a large change (more than five times the originally quoted standard deviation) could be made merely by re-reducing the same data. The original reduction did demonstrate that something fishy had been noticed in the astrometry of d Aur, in the form of an 'acceleration solution'; the new reduction instead wraps the uncertainties up into the increased standard error of a 'stochastic solution'. What is clearly warranted now is a third bite at the same cherry, this time taking explicit account of the orbit determined here.

Miss Roman[30], while recording d Aur as an MK standard of type K0 III and assigning it an absolute magnitude of 0·7 and a spectroscopic parallax of 0″·023 that is in exact agreement with the (original) *Hipparcos* value, placed it in her 'wk-l' [weak-line] sub-division; the name is admitted not to be descriptive, and actually implies that the *G* band and the Ca I line are *stronger* than average for the type.

Wilson & Bappu, in their 1957 paper[31] demonstrating the utility of measured *K*-line widths in assessing stellar luminosity, derived $M_V = +1^m\cdot2$ for d Aur; the same value, but with an associated uncertainty of $0^m\cdot2$, was given by Wilson in his more comprehensive 1976 list[32]. Williams[33] derived from Cambridge narrow-band measurements a logarithmic metal abundance with respect to the Sun, [Fe/H], of +0·02. Hansen & Kjærgaard[34], starting from narrow-band filter photometry by Dickow *et al.*[35], obtained [Fe/H] = −0·26 with respect to the Hyades. Gustafsson, Kjærgaard & Andersen[36] found a value of +0·07 or +0·02, with respect to the Sun, depending upon what value they adopted for the microturbulence parameter. Brown *et al.*[37], whose main concern was with abundances of lithium, of which they could see none in d Aur, found [Fe/H] to be +0·01 and asserted that an average value from the previous literature was −0·04. They also quoted the absolute magnitude derived from the *K*-line width as being $+0^m\cdot9$, and said that the same was to be found from *DDO* photometry. By actual spectroscopy, McWilliam[38] obtained [Fe/H] = −0·15 ± 0·07. In his "critical appraisal" of published values for [Fe/H], Taylor[39] gave the result as −0·05 ± 0·112, listing it as having 17 degrees of freedom (it appears that the number refers to the number of chemical elements for which abundances were given, not to the number of independent data sources) but only one source paper — that of Brown *et al.*[37].

In comparatively recent years there have been two analyses[40] of CCD spectra of d Aur obtained at the Crimean 2·6-m telescope by a consortium led by Boyarchuk. As far as can be judged from the papers, the same syndicate is discussing the same observations in both, but they have used different model atmospheres in the two analyses. In the earlier paper, 14 elements from Na to Zr were found to have very similar abundances averaging a logarithmic enhancement of +0·14 with respect to the Sun, and six heavier elements ranging from Ba to Eu appeared to be more enhanced, averaging +0·27. In the second paper, five years later, 12 elements up to Y (Mn and Zr, which were present in the first paper, were missing) were shown as being up by 0·09 and the six heavy elements by 0·25. In summary, one could lament that despite the brightness of the star and the several efforts that have been made to determine its abundances, there is not even qualitative agreement as to whether it is metal-deficient[38] or metal-rich[40] in comparison with the Sun. A cynical overview of the whole literature flags up the repeated G-type classifications from the early days as indicating that the general line-strength in d Aur is less than that in the average K0 III giant (as is certainly the case for CN[9,11,12]), encouraging the idea that the star may be metal-*poor*.

In one[41] of Eggen's papers in which he was prone to list basic data for numerous stars, d Aur is to be found in a table of "old-disk-population giants". Later, however, it appears in a paper[42] devoted to the *young* disc population, and in a table (Table 9), whose caption says that it is based on Geneva photometry but in a column whose heading implies that it was from *DDO* photometry, there is given a value of M_V of $+0^m\cdot61$.

Before the *Hipparcos* results were available, there was some dissent over the absolute magnitudes of giant stars. The tabulation in *AQ*[43] illustrates the then-received luminosity calibration for class-III stars, with luminosities rising towards cooler temperatures from M_V $+0^m \cdot 7$ at G5 to $-0^m \cdot 4$ at M0. Writing in 1982, Egret, Keenan & Heck[44] derived from trigonometrical and statistical parallaxes — a somewhat unpromising basis, it must be said, in view of the smallness of the number of giant stars close enough to have reliable parallaxes in pre-*Hipparcos* days — a new calibration that was about half a magnitude brighter, rising from $+0^m \cdot 31$ at G8 to $-1^m \cdot 08$ at M2. They found that class IIIb — stars that later became more fully recognized as the core-helium-burning 'clump' — had a mean absolute magnitude of $+0^m \cdot 68$, without appreciable dependence upon spectral type.

Robin[45] took issue with them, and was supported by Flynn & Mermilliod[46], who relied mainly on absolute magnitudes derived from *DDO* photometry calibrated by Janes[47] on star clusters, and by Gould & Flynn[48] who looked again at trigonometrical parallaxes. All those authors found class-III luminosities to be on average a whole magnitude fainter than those of Egret *et al.*, and they put the 'clump' at $+1^m \cdot 0$. Specifically, Robin[45] assessed the luminosities of class-III stars as rising rapidly from $+1^m \cdot 6$ at G8 to $0^m \cdot 0$ at K5. The star of immediate interest here well illustrates the dichotomy: d Aur was given as $M_V = +0^m \cdot 01$ by Egret *et al.*[44] but as $+1^m \cdot 05$ by Flynn & Mermilliod[46] and Gould & Flynn[48]. In its particular case, the truth, as initially adjudicated by *Hipparcos* and as already noted above, falls exactly between the competing values, at $+0^m \cdot 55$. But since the new reduction[29] of the *Hipparcos* data changed the absolute magnitude to $+0^m \cdot 95$ it favours the Flynn & Mermilliod[46] conclusion. That does not contribute, however, to a more general solution of the problem of the luminosities of class-III stars, since d Aur is now probably to be regarded as of class IIIb.

More generally, now that we have supposedly reliable parallaxes available for a good number of stars (it may be hoped that the changes in the new reductions are less dire for the non-binary majority of them), we can see how they are distributed in the type–luminosity diagram plotted for us by Keenan & Barnbaum[27]. The class-III 'ridge' is shown by those authors to rise gently in luminosity from $-0^m \cdot 4$ at G8 to $-0^m \cdot 8$ at M0. Thus the warmer (G8–K0) giants are more luminous even than Egret *et al.*[44] said and are as much as *two magnitudes* brighter than Robin[45] proposed, but the increase of luminosity towards the later types is very muted, such that the K5/early-M giants are slightly less bright than Egret *et al.* wanted and are only slightly brighter than in the *AQ* tabulation[43]. The 'clump' lies between $+0^m \cdot 5$ and $+1^m \cdot 0$, without any dependence upon spectral type. The question of giant luminosities appears now to be quite well cleared up: it would be as difficult to refute as it would be foolish to ignore Keenan & Barnbaum's[27] Fig. 1. As far as the present writer is aware, however, no explanation has been forthcoming for what are clearly substantial errors in the purported refutations[45,46,48] of the proposals of Egret *et al.*[44], which are now seen to have been a substantial step in the right direction.

Borde *et al.*[49] included d Aur in a catalogue of objects vetted as suitable for use as 'calibrator stars' for long-baseline stellar interferometry. Among the criteria for qualification were the requirements for radial-velocity stability and lack of evidence of multiplicity. In view of the fact that, several years previously, *Hipparcos*[3] had noted astrometric idiosyncrasy in d Aur in the form of an 'acceleration solution', and de Medeiros & Mayor[50] had explicitly characterized the star as a spectroscopic binary, it is hard to see how it could have passed Borde *et al.*'s checks. The star was actually *utilized* as a calibration star by Kraus *et al.*[51] in an investigation of Capella. Famaey *et al.*[52] later noted a significant discrepancy between the *Hipparcos* and *Tycho 2* proper motions; since the former were determined over a relatively short time of about three years and the latter over about a century, a discrepancy tends to point to orbital motion having an intermediate period, as is indeed the case with d Aur.

Radial velocities and orbits for d *Aurigae*

The first radial-velocity measurements of d Aur were made in 1897, early in the great Lick survey[53], with the *Original Mills Spectrograph*[54] on the 36-inch refractor. The total number of measurements listed in the survey is seven; they have an extreme range of 2·3 km s^{-1}, and an r.m.s. residual of only 0·8 km s^{-1} from their own mean of +7·7 km s^{-1}, so there was no suggestion of any real variation of velocity. In retrospect we can see that they were unfortunately distributed in phase.

Three velocities were obtained by Küstner with the 12-inch *Repsold* refractor at Bonn, and were actually the first to be published[55] of d Aur, before the Lick measures. They were all made in the same month of 1907 March, and were in mutual accord but differed significantly from the Lick results — something that Küstner was not in a position to know and upon which the Lick authors forbore to comment when they published their own work[53]. One velocity from the DAO, obtained in 1922, and being between the Lick and Bonn means was consonant with either of them, was published by Harper[56].

There ensued a gap, as happened in all too many cases among the bright stars, of more than half a century before the velocity of d Aur was measured again. Barnes, Moffett & Slovak[57] obtained three measures of it as a 'standard star' with the McDonald 82-inch reflector and a radial-velocity spectrometer whose performance was unfortunately not as good even as that of the original instrument[2] with which the technique was developed at the Cambridge 36-inch. They gave an undated mean velocity whose standard error they put at 0·6 km s^{-1}. A single velocity, with a quoted uncertainty of 0·9 km s^{-1}, was published by Strassmeier & Schordan[58]. Not until 1999 did de Medeiros & Mayor[50], on the minimal basis of just two measurements made with the Haute-Provence *Coravel* and in significant mutual disagreement, identify d Aur as a spectroscopic binary. In their published paper they noted a mean velocity of +5·98 km s^{-1} with a standard error of 1·39 km s^{-1}, implying that the two velocities were in fact +5·98 ± 1·39, or +7·37 and +4·59 km s^{-1}. Subsequently they lodged with the Centre de Données Stellaires the individual values, which were there given as +7·82 and +5·04 km s^{-1}, with dates.

It has been explained previously[59] in this series of papers how certain stars were adopted, from the listing deposited by de Medeiros & Mayor at the Centre de Données Stellaires, for observation with the Cambridge *Coravel*; d Aur was one of them. Measurements began in 2002 and have been continued till the time of writing; they number 43 and are listed in Table III, after the various published measures. The latter have all been increased by 0·8 km s^{-1} before being entered in the table, to take account of the difference that has usually been found between the zero-point adopted in this series of papers, on the one hand, and the IAU and recently reduced OHP measures on the other. The early Bonn and DAO measures have additionally been adjusted by the systematic offsets proposed for them, of −1·6 and +0·5 km s^{-1}, respectively, in Table 3 on p. vi of the *Radial Velocity Catalogue*[60]. The Cambridge measures have been adjusted by −0·2 km s^{-1}, as has been previously found[61] appropriate to stars of the colour of d Aur.

TABLE III

Radial-velocity observations of d *Aurigae*

Observed with Cambridge Coravel (weight 1) except as noted

Date (UT)	*MJD*	*Velocity* *km s*$^{-1}$	*Phase*	*(O−C)* *km s*$^{-1}$
1897 Oct. 20·48*	14217·48	+9·0	$\overline{30}$·797	+1·2
Nov. 11·41*	239·41	8·4	·814	+0·8
1898 Oct. 25·52*	14587·52	7·7	$\overline{29}$·085	+0·3
27·53*	589·53	8·3	·086	+0·9
1903 Jan. 15·42*	16129·42	9·7	$\overline{28}$·286	−0·4
1906 Jan. 30·15*	17240·15	8·9	$\overline{27}$·152	+0·3
1907 Mar. 3·82†	17637·82	10·4	$\overline{27}$·462	−0·1
6·81†	640·81	10·7	·464	+0·2
20·79†	654·79	9·3	·475	−1·1
1922 Jan. 11·27‡	23065·27	9·5	$\overline{23}$·691	+0·4
1926 Nov. 4·88*	24823·38	7·4	$\overline{21}$·061	+0·5
1989 Jan. 8·93§	47534·93	8·6	$\overline{4}$·757	+0·2
Oct. 24·04§	823·04	5·8	·982	−0·2
1994 Mar. 5·10¶	49416·10	8·4	$\overline{2}$·223	−1·2
2002 Aug. 31·21	52517·21	9·1	0·639	−0·5
Dec. 11·18	619·18	9·0	·719	+0·2
2003 Feb. 19·76	52689·76	8·1	0·774	−0·1
Apr. 7·86	736·86	7·5	·810	−0·1
May 13·87	772·87	7·2	·838	0·0
Sept. 24·21	906·21	5·9	·942	−0·1
Nov. 17·11	960·11	6·1	·984	+0·1
28·07	971·07	6·0	·993	0·0
2004 Jan. 30·06	53034·06	6·1	1·042	−0·5
Feb. 25·86	060·86	7·2	·063	+0·2
Apr. 21·86	116·86	8·2	·107	+0·4
Sept. 14·19	262·19	9·6	·220	0·0
Oct. 27·16	305·16	9·8	·253	−0·1
Dec. 18·11	357·11	10·3	·294	+0·1
2005 Jan. 22·08	53392·08	10·3	1·321	0·0
Feb. 12·93	413·93	10·3	·338	−0·1
Mar. 17·91	446·91	10·6	·364	+0·1
Apr. 18·86	478·86	10·7	·389	+0·2
May 10·86	500·86	10·6	·406	+0·1
Aug. 22·12	604·12	10·4	·486	0·0
Sept. 17·21	630·21	10·3	·507	−0·1
Oct. 10·20	653·20	10·4	·524	+0·1
Nov. 4·17	678·17	10·3	·544	+0·1
Dec. 17·15	721·15	10·0	·577	0·0
2006 Jan. 28·98	53763·98	9·6	1·611	−0·2
Mar. 3·92	797·92	9·5	·637	−0·1
Apr. 3·90	828·90	9·5	·661	+0·1
May 3·87	858·87	+9·5	·685	+0·3

TABLE III (*concluded*)

Date (UT)	*MJD*	*Velocity km s⁻¹*	*Phase*	*(O–C) km s⁻¹*
2006 Sept. 21·20	53999·20	+7·8	1·794	−0·1
Oct. 27·15	54035·15	7·4	·822	−0·1
Nov. 26·15	065·15	7·1	·845	0·0
2007 Jan. 2·11	54102·11	6·6	1·874	−0·1
Feb. 2·89	133·89	6·5	·899	+0·1
Mar. 3·94	162·94	6·2	·922	0·0
Apr. 4·88	194·88	6·1	·946	+0·1
May 12·86	232·86	6·2	·976	+0·2
Oct. 5·22	378·22	7·6	2·089	+0·1
Nov. 3·22	407·22	7·6	·112	−0·3
Dec. 8·13	442·13	8·4	·139	0·0
2008 Jan. 6·06	54471·06	8·7	2·162	−0·1
Feb. 19·91	515·91	9·2	·197	−0·1
Mar. 17·93	542·93	9·4	·218	−0·1
Dec. 27·11	827·11	+10·5	·439	0·0

* Lick photographic velocity[53]; weight 0·1.
† Bonn photographic velocity[55]; weight 0.
‡ DAO photographic velocity[56]; weight 0.
§ Observed with OHP *Coravel*; weight 1.
¶ Kitt Peak CCD velocity[58]; weight 0.

An orbit with a period of 1292 ± 7 days is readily given by the Cambridge observations alone. In that orbit, the Lick and Bonn measures from about 100 years (nearly 30 cycles) ago appear to mimic the velocity curve but to be displaced in phase by about +0·2 cycles, indicating the need for a reduction of the period by about eight days. Just in case the next-nearest choice, in which the displacement of the early measures would be interpreted as −0·8 cycles, a trial was made of a considerably increased period, but it was totally unsatisfactory — not only were the Cambridge observations made to look much more ragged, but the Lick and Bonn measures themselves no longer fitted plausibly to the 'solution'. A return to the Cambridge value as a preliminary period, and with the two OHP measures included in the solution with weight equal to the Cambridge data and the seven Lick ones with weight 0·1, produced a fully satisfactory result, which is shown in Fig. 2 and has elements as follows:

$$
\begin{array}{lll lll}
P & = & 1283{\cdot}4 \pm 0{\cdot}7 \text{ days} & (T)_1 & = & \text{MJD } 52980 \pm 16 \\
\gamma & = & +8{\cdot}73 \pm 0{\cdot}03 \text{ km s}^{-1} & a_1 \sin i & = & 39{\cdot}1 \pm 0{\cdot}8 \text{ Gm} \\
K & = & 2{\cdot}28 \pm 0{\cdot}04 \text{ km s}^{-1} & f(m) & = & 0{\cdot}00145 \pm 0{\cdot}00008\, M_{\odot} \\
e & = & 0{\cdot}231 \pm 0{\cdot}017 & & & \\
\omega & = & 200 \pm 5 \text{ degrees} & \text{R.m.s. residual (wt. 1)} & = & 0{\cdot}18 \text{ km s}^{-1}
\end{array}
$$

It is noticeable that in the above solution six of the seven Lick observations have positive residuals, the mean residual for all seven being $+0{\cdot}49 \pm 0{\cdot}20$ km s^{-1}. The idea of applying an empirically assessed optimum offset to them, instead of the one actually applied, has its attractions; it is rejected on the grounds that it is better to stick with a value that has been found representative in many previous comparisons than to change it on this particular occasion just to make an infinitesimal (and largely cosmetic, and moreover probably illusory) apparent

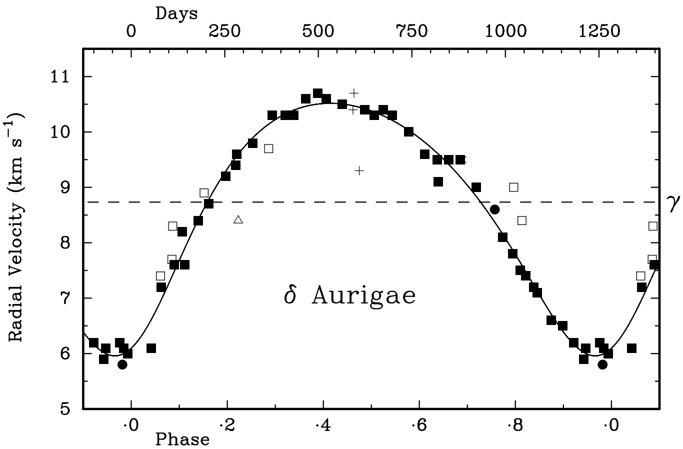

FIG. 2

The observed radial velocities of d Aurigae plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. The orbit is largely dependent upon the 43 measurements made with the Cambridge *Coravel*, which are plotted as filled squares, but the solution also includes two measurements[50] made with the OHP *Coravel* (full weight, filled circles) and the seven[53] made long ago photographically at Lick (weight 0·1, open squares). Plotted but not incorporated in the solution are three early velocities from Bonn[55], one from the DAO[56], and one from Kitt Peak[58]; they are shown as plusses, a cross (almost hidden), and an open triangle, respectively.

improvement to this solution. The two sources which each had only one observation were not used in the calculation. The Bonn observations fit the solution as well as the Lick ones do, but have not been used in it because they are in effect at only a single epoch and their zero-point is none too certain — the recommendations in the *Radial Velocity Catalogue* show a considerable difference between G and K stars, and d Aur is on the borderline. It may be mentioned that the Lick and Bonn observations, taken together just as published without any questioning of their zero-points, produce an orbit having a period of 1288 ± 16 days; but anyone who obtained such an orbit before the Cambridge measurements were available would have been uneasy as to whether the period was anywhere near the true one, since the distribution in time of the restricted Lick/Bonn data set is not satisfactory for a unique period determination.

The orbit has quite a small amplitude and gives a correspondingly small mass function; unless the K giant has a mass considerably above 2 $M_{\odot}$ the companion need be no more than half a solar mass and could well be a K or early-M main-sequence star. If it were a white dwarf one might well expect to see some evidence of its completed evolution in the enhancement of the abundances of specific heavy elements, notably barium, in the surface of the star we now observe.

HR 4427 (HD 99913)

HR 4427 is a sixth-magnitude late-type giant in Ursa Major, to be found about 1° south of the midpoint of an imaginary line drawn between β and γ UMa (the stars that delineate the bottom of the bowl of the 'Dipper' asterism). Despite its brightness it has been surprisingly neglected — there is very little to be found about it in the literature. Its V magnitude and $(B-V)$ and $(U-B)$ colours have been given by Guetter & Hewitt[62] as $6^m\cdot52$, $0^m\cdot94$, and $0^m\cdot68$, and by Oja[63] as $6^m\cdot49$, $0^m\cdot95$, and $0^m\cdot68$, respectively. The discrepancies between those authors are not great, but the one in V could be said to be very significant, because it makes all the difference as to whether HR 4427 ought genuinely to qualify for inclusion in the *Bright Star Catalogue* (cut-off $6^m\cdot5$), or not! The spectral type has been put at K0 III by Cowley & Bidelman[64], and at G9 III by Sato & Kuji[65]. The *Hipparcos* parallax of $0''\cdot00508 \pm 0''\cdot00082$ puts the distance of the star close to 200 pc, distance modulus $6^m\cdot5$, and absolute magnitude therefore very close to $0^m\cdot0$, with a standard error of about $0^m\cdot35$.

Until comparatively recently the only radial velocities to be found for HR 4427 were two, obtained in 1932 March and May, by Harper[56]. He has a deprecating note against each of them: the March one is noted as "made with IS", signifying that it was obtained with the short-focus 'IS' camera, which gave a reciprocal dispersion of about 50 Å mm^{-1} at Hγ, against the 30 Å mm^{-1} of the 'IM' camera with which the great majority of Harper's work was done. The May observation is noted as "Weak plate", which speaks for itself. The two observations are listed at the head of Table IV, having first been adjusted by the routine $+0\cdot8$ km s^{-1} plus the correction of $+1\cdot0$ km s^{-1} advised in the *Radial Velocity Catalogue* for stars of the G type that Harper considered HR 4427 to be. They have, however, not been used in the orbital solution, from which they give residuals of about 4 km s^{-1} in opposite senses — larger than the errors usually found in Harper's work. It could be mentioned that there is a phasing uncertainty of about $0\cdot03$ orbital periods when the solution given below for the orbit is extrapolated back to the Harper epoch, but that is not enough to make a significant difference to the residuals.

Coming to relatively modern times, one finds that the star features in de Medeiros & Mayor's large catalogue of rotational and radial velocities for evolved stars[50], wherein the results of just two observations made with the OHP *Coravel* are summarized as giving a rotational velocity of "$<2\cdot4$" km s^{-1}, and a mean radial velocity of $-20\cdot61 \pm 2\cdot21$ km s^{-1}, from which it may be deduced that the individual values must be given by that same expression, which when evaluated gives $-18\cdot40$ and $-22\cdot82$ km s^{-1}. Later the separate values and the corresponding times of observations were lodged with the Centre de Données Stellaires, where they had changed to $-17\cdot73$ and $-22\cdot16$ km s^{-1}. Those, too, have been included in Table IV, with the usual $+0\cdot8$ km s^{-1} adjustment, and have been given equal weight with the author's in the calculation of the orbit. A later paper by de Medeiros, da Silva & Maia[66] repeated some of the same information as was given by de Medeiros & Mayor[48], but the actual radial velocity was nowhere given and the rotational velocity had become $2\cdot4$ km s^{-1} in place of the "$<2\cdot4$" given previously. HR 4427 also features in principle in the further paper by the *Coravel* syndicate (Famaey *et al.*[52]) on kinematics of late-type giants, but since they did not know the systemic velocity of the star they were unable to include it in their analysis and they actually substituted zeroes in their table for all the relevant quantities.

It was the modest discordance between the two de Medeiros & Mayor velocities that prompted the writer to put HR 4427 onto the observing programme of the Cambridge *Coravel*, with which he has made 35 measurements tolerably well distributed around the orbit — not a difficult thing to do, since the period is very close to 2½ years, so the observations made in one cycle interleave nicely with those made in the next. (The same is true of d Aur with its period of 3½ years.) Moreover, at $+54°$ (again the same as for d Aur) the declination of

TABLE IV

Radial-velocity observations of HR 4427

Observed with Cambridge Coravel (weight 1) except as noted

Date (UT)			*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1932	Mar.	8·37*	26774·37	–26·0	$\overline{28}$·682	–3·8
	May	10·21*	837·21	–15·9	·750	+4·6
1988	June	5·90†	47317·90	–16·9	$\overline{6}$·931	–0·3
1989	Apr.	22·05†	47638·05	–21·4	$\overline{5}$·278	–0·2
2002	May	30·90	52424·90	–24·3	0·462	+0·3
	Dec.	9·20	617·20	–22·2	·671	+0·3
2003	Jan.	7·20	52646·20	–21·8	0·702	–0·1
	Feb.	18·07	688·07	–20·7	·747	–0·2
	Mar.	16·03	714·03	–19·7	·775	+0·1
	Apr.	16·93	745·93	–19·1	·810	–0·2
	May	14·91	773·91	–18·0	·840	+0·2
	June	11·90	801·90	–17·5	·871	+0·1
	Nov.	3·17	946·17	–16·6	1·027	–0·3
	Dec.	8·26	981·26	–16·6	·065	0·0
2004	Jan.	9·17	53013·17	–17·1	1·099	–0·1
	Feb.	9·13	044·13	–17·7	·133	–0·1
	Mar.	17·10	081·10	–18·1	·173	+0·4
	Apr.	14·98	109·98	–19·1	·204	+0·2
	May	6·97	131·97	–19·7	·228	+0·2
	June	7·90	163·90	–20·6	·263	+0·2
	July	6·90	192·90	–21·4	·294	+0·2
	Dec.	26·22	365·22	–24·7	·481	0·0
2005	Jan.	22·14	53392·14	–24·7	1·510	0·0
	Mar.	19·00	448·00	–24·2	·570	+0·1
	Apr.	18·99	478·99	–23·7	·604	+0·1
	May	21·92	511·92	–22·8	·640	+0·4
	Nov.	5·25	679·25	–18·7	·821	0·0
2006	Jan.	27·25	53762·25	–16·7	1·911	+0·2
	Feb.	21·05	787·05	–16·7	·938	–0·1
	Apr.	25·95	850·95	–16·0	2·007	+0·2
2007	Feb.	7·07	54138·07	–22·6	2·318	–0·4
	Mar.	22·03	181·03	–23·5	·364	–0·2
	Apr.	14·96	204·96	–24·1	·390	–0·4
	May	5·94	225·94	–24·1	·413	0·0
		29·97	249·97	–24·6	·439	–0·2
	Nov.	24·26	428·26	–23·1	·632	+0·2
2008	Jan.	6·24	54471·24	–22·8	2·679	–0·5
	Feb.	9·08	505·08	–21·5	·715	–0·1
	Mar.	31·03	556·03	–20·0	·770	–0·1

* DAO photographic velocity[56]; weight 0.
† OHP *Coravel* velocity[50]; weight 1.

HR 4427 brings it within about 2° of the Cambridge zenith, so one cannot complain that it is difficult of access! Surprisingly, the 2½-year orbit proves to be circular as nearly as can be distinguished: when the eccentricity is allowed as a free parameter it takes the value 0·023 ± 0·013, but application of Bassett's[67] second statistical test yields for $F_{2,31}$ a value of only about 1·7 whereas even the 10%-significance point is about 2·5. Fig. 3 shows the velocity curve according to the adopted orbital solution, whose elements are

P	=	923·3 ± 1·1 days	$(T)_1$	=	MJD 52921·4 ± 1·8
γ	=	−20·47 ± 0·04 km s^{-1}	$a_1 \sin i$	=	53·7 ± 0·7 Gm
K	=	4·23 ± 0·06 km s^{-1}	$f(m)$	=	0·00727 ± 0·00030 $M_\odot$
e	≡	0 (fixed)			
ω is undefined in a circular orbit			R.m.s. residual (wt. 1)	=	0·22 km s^{-1}

Once again the mass function is small, requiring the secondary to have a minimum mass of only about 0·35 $M_\odot$, corresponding to that of an M2 or M3 main-sequence star, if the primary is taken as 2 $M_\odot$. If the orbital inclination is high, as is statistically probable, then the disparity in the masses would imply that the separation of the components of the binary system would be several times the $a_1 \sin i$ value given above, so it could be about 2 AU; it would subtend an angle of just 0″·01 at the 200-pc distance of HR 4427. That small separation, coupled with a Δm that could be up to ten magnitudes, makes the system an unattractive object for optical interferometry.

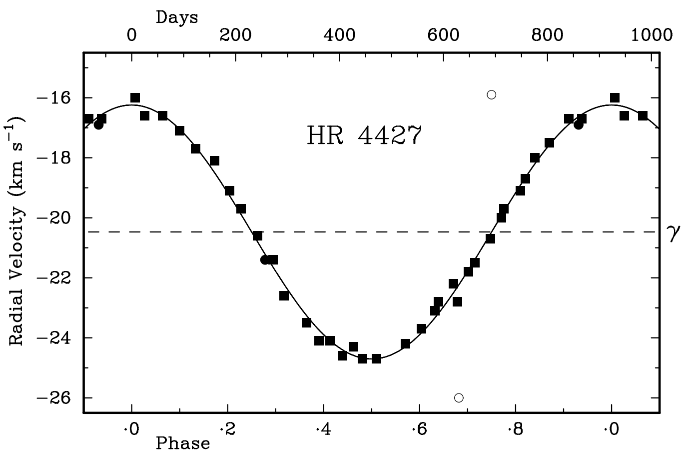

FIG. 3

As Fig. 2, but for HR 4427. The orbit depends on 35 Cambridge and two OHP[50] velocities; two DAO[56] ones are plotted (as open circles) but not used in the solution. The symbols are the same as in Fig. 2.

HR 7795 (HD 194069)

Norton's Star Atlas[68] shows the sixth-magnitude object HR 7795 as one of two stars closely (1°) north of γ Cygni, the central star in the 'cross'. On the map it is the right-hand one of the two stars; the other one (about 10′ south-following) is HR 7800, which will be mentioned again below. The corresponding chart can be viewed in *Tirion*[69] without even opening the book, as it is right in the centre of the map on the dust-jacket, both on the front of the atlas and on the back! Between those two stars and γ Cyg itself lies the open cluster NGC 6910. That area of sky is a particularly rich Milky Way field, as is witnessed by the fact that *Uranometria 2000·0*[70] devotes one of its few enlarged-scale charts to it. According to a naïve low-power, wide-field telescopic view, the area of NGC 6910 might be a chance aggregation that is not so much richer than elsewhere as to represent a real cluster with any certainty, but a deeper view dispels that misgiving, and photometry of stars in that area already showed[71] nearly fifty years ago (it could be argued that it had already been done earlier than that) that it is a physical entity that includes a number of young B-type stars at a distance of more than a kiloparsec and has a radial velocity near -25 km s^{-1}.

The broad-band magnitudes of HR 7795 have been measured by Argue[72] and Appenzeller[73] (whose paper is attributed by *Simbad* to de Vegt, the author of the immediately preceding one), with very similar results that are averaged here as $V = 6^{m}\cdot39$, $(B-V) = 1^{m}\cdot07$, $(U-B) = 0^{m}\cdot82$. The *HD* type is G5. Young & Harper, in their early work[17] on spectroscopic parallaxes, gave its type as G7 and made independent assessments of its absolute magnitude as $+0^{m}\cdot3$ and $-0^{m}\cdot6$ respectively. In a preliminary search for high-luminosity stars on the objective-prism plates of the 'Case survey' of the northern Milky Way, undertaken with a 4° prism giving 280 Å mm^{-1} on the *Burrell* Schmidt[74] of the Warner & Swasey Observatory, HR 7795 was classified by Nassau & Morgan[75] on different plates as G2 I: and as G0 I–II. In a follow-up investigation, Bidelman[76], who obtained what were described simply as low-dispersion slit spectra at the Yerkes and Lick observatories (but we know that both of them had prism spectrographs giving reciprocal dispersions of about 75 Å mm^{-1} at Hγ on their respective large refractors), found the type to be G2 II. (Anne) Cowley[77], however, from plates of similar dispersion obtained with a 2-prism spectrograph on the 37-inch Ann Arbor reflector[78], discovered the composite nature of the spectrum, giving the type as G5 III + A:.

Bidelman's overlooking of the hot companion may be excused on the grounds that the poor transmission of the refractors in the critical short-wavelength region would have resulted in his plates being inadequately exposed there. Certainly the contribution of the early-type component must be small even in the violet, because the present writer's early work[11] on the intensity of the λ 4200-Å CN band yielded an intensity in the case of HR 7795 that was very strong in relation to the G2 II type[76] that was the best available classification at that time, and indeed is on a par with the mean for G8-type stars among those of luminosity class II. On the other hand Wilson[32], who took at the Mount Wilson and Palomar coudé spectrographs plates that would ordinarily be considered heavily over-exposed, in order to obtain a good sight of the emission reversals at the cores of the *H* and *K* lines, reported for HR 7795: "Emission very low contrast. Not measurable. All absorption lines weak." That suggests that the contribution of the companion must be considerable in the region, well below the wavelength of the *K* line, where Wilson's plates would have been suitably exposed for normal purposes, and enough to dilute seriously the residual light of the primary star at the bottom of the *K* line itself. The *Bright Star Catalogue*[79] lists the Ann Arbor type of G5 III + A for HR 7795. So far as can be discovered, there has not been any subsequent spectroscopic effort at classification. Straižys *et al.*[80] derived a type of G5: III as an interpretation of Vilnius photometry[81], which evidently did not alert them to the compositeness of the spectrum, but of course that was not a real spectroscopic classification. The *Hipparcos* parallax, though very small and therefore not giving a very precise distance, yields an absolute magnitude of −2 with an uncertainty of the order of half a magnitude and therefore fully supports the Case observers' recognition of the star's high luminosity and in particular Bidelman's classification of it as a bright giant (luminosity class II).

An exercise by Parsons & Ake[82] in synthesizing the flux distributions of composite spectra over a wide wavelength range from the *IUE* ultraviolet to the infrared led them to give types of bG8 + A4+, where the 'b' signifies a bright-giant luminosity, interpolated between their calibrating standards of luminosity classes I and III in the absence of actual class-II standards. The '+' after A4 is not explicitly explained in the paper but presumably means 'somewhat later than'. They considered that the components have a ΔV of $3^{m}\cdot 0$. In fitting the fluxes, Parsons & Ake adopted a colour excess, $E(B-V)$, of $0^{m}\cdot 08$, although they quoted an estimate of $0^{m}\cdot 177$ by Bersier[83] (and did not quote the listing by Mathewson *et al.*[84] of an interstellar absorption of as much as $0^{m}\cdot 9$ in a table of polarizations). Eritsian[85] seized on the combination in that table of substantial interstellar absorption with low linear polarization to suggest that the light of HR 7795 (and of 215 other stars) must be significantly circularly polarized, but made no observations to try to verify that proposal. Geisler[86] listed a colour excess of $0^{m}\cdot 30$, which might seem to agree with the Mathewson *et al.* value for the absorption. His colour excesses, however, come simply from a comparison of the observed colour indices with the spectral types of the objects concerned. The $0^{m}\cdot 30$ is therefore wholly dependent on the spectral type of G2 II that he lists. The observed colour index cannot be expected to represent the colour of the primary star, which is in any case now regarded as being later than G2, so the true excess must be expected to be a good deal less than $0^{m}\cdot 3$.

Brown *et al.*[37] observed HR 7795 in the course of a large spectroscopic programme principally intended to identify lithium-rich giant stars; they did not find any detectable lithium in it but they did find it to be otherwise metal-rich, with an [Fe/H] of +0·25. That result appears to be quoted, perhaps with some proposed correction, as +0·19 ± 0·149 by Taylor[39] in his "critical appraisal of published values". In a subsequent review by the same author[87], but billed that time as "a statistical search for metallicity", the same original result seems to be quoted as +0·21 ± 0·09.

Radial velocities and orbits for HR 7795

The radial velocity of HR 7795 was first observed at the DAO in 1923; three measurements were published from there by Harper[56]. They are the sole source of the entries (of −4 km s^{-1}) for the velocity in both the *Radial Velocity Catalogue*[60] and the *Bright Star Catalogue*[79]. The mean given by Harper is −4·5 km s^{-1} but is represented in the *Radial Velocity Catalogue* as −4·0 after receiving a small systematic correction whose amount, however, does not accord with what it ought to have been according to the tabulation (Table 3) in the *Catalogue* itself. The three velocities were not in very good mutual accord, and Harper flagged

TABLE V

Radial-velocity observations of HR 7795

Except as noted, the sources of the observations are as follows:
1982–1990 — original Cambridge spectrometer (weighted 1/8 in orbital solution);
1991–1995 — OHP Coravel (weight 1/2); 1996–2008 — Cambridge Coravel (weight 1)

Date (UT)			MJD	Velocity km s^{-1}	Phase	(O−C) km s^{-1}
1923	Aug.	3·35*	23634·35	−7·5	$\bar{2}$·024	+4·7
1930	Oct.	21·23*	26270·23	−0·3	$\bar{2}$·376	+1·3
1931	Aug.	9·29*	26562·29	−1·9	$\bar{2}$·415	+0·1
1965	Aug.	29·92†	39001·92	−14·0	0·076	−6·2
1968	July	25·99†	40062·99	−19·0	0·217	−17·3
		27·99†	064·99	−18·0	·218	−16·3
	Aug.	27·03†	095·03	−15·0	·222	−13·3
1982	May	24·08	45113·08	−16·2	0·892	−1·2
	July	10·02	160·02	−15·2	·898	0·0
	Aug.	31·90	212·90	−14·5	·905	+0·9
	Sept.	18·87	230·87	−16·3	·907	−0·8
1983	June	13·06	45498·06	−16·0	0·943	−0·1
	Aug.	3·97	549·97	−16·5	·950	−0·6
	Oct.	2·90	609·90	−14·0	·958	+1·8
1985	Oct.	24·80	46362·80	−9·6	1·058	−0·4
1986	June	5·07‡	46586·07	−6·5	1·088	+0·3
	Aug.	8·03‡	650·03	−6·8	·097	−0·6
		28·98¶	670·98	−6·0	·100	+0·1
	Sept.	28·92	701·92	−6·2	·104	−0·4
	Nov.	6·81	740·81	−5·1	·109	+0·4
		15·77‡	749·77	−5·1	·110	+0·3
		24·13§	758·13	−6·1	·111	−0·8
1987	Mar.	5·23¶	46859·23	−3·5	1·125	+1·1
	May	9·11	924·11	−5·1	·133	−0·9
	July	5·00	981·00	−3·5	·141	+0·3
	Aug.	9·09	47016·09	−3·5	·146	+0·1
	Oct.	13·80¶	081·80	−3·3	·154	0·0
1988	Jan.	31·61‖	47191·61	−3·4	1·169	−0·6
	Mar.	13·22¶	233·22	−2·5	·175	+0·1
	June	3·10	315·10	−1·2	·186	+1·1
	July	18·99	360·99	−1·7	·192	+0·5
	Sept.	11·94	415·94	−1·5	·199	+0·5
	Oct.	27·78	461·78	−2·3	·205	−0·4
	Nov.	3·87¶	468·87	−2·1	·206	−0·2
1989	Mar.	26·19¶	47611·19	−2·5	1·225	−0·9
	Apr.	29·16¶	645·16	−1·1	·230	+0·5
	May	31·08	677·08	−0·3	·234	+1·2
	June	26·03	703·03	−2·9	·237	−1·4
	July	19·07‡	726·07	−1·6	·240	−0·1
	Aug.	27·99	765·99	−2·0	·246	−0·6
	Nov.	25·74	855·74	−2·0	·258	−0·7

TABLE V (*continued*)

Date (UT)	*MJD*	*Velocity km s⁻¹*	*Phase*	*(O – C) km s⁻¹*
1990 Jan. 30·74¶	47921·74	−0·9	1·266	+0·4
July 6·09	48078·09	−2·1	·287	−0·9
Oct. 6·92	170·92	−1·8	·300	−0·6
1991 Oct. 28·87	48557·87	−1·0	1·351	+0·4
Dec. 16·75	606·75	−1·7	·358	−0·2
1992 Jan. 15·73	48636·73	−1·2	1·362	+0·3
Apr. 28·16	740·16	−1·3	·376	+0·3
June 26·06	799·06	−1·6	·384	+0·1
Aug. 13·97	847·97	−2·0	·390	−0·3
Dec. 21·73	977·73	−2·6	·407	−0·7
1993 Feb. 14·24	49032·24	−2·2	1·415	−0·2
Mar. 23·18	069·18	−1·6	·420	+0·4
July 9·04	177·04	−1·9	·434	+0·3
Sept. 11·99	241·99	−1·9	·443	+0·4
Dec. 26·78	347·78	−2·4	·457	+0·1
1994 May 3·15	49475·15	−2·8	1·474	0·0
Aug. 2·98	566·98	−2·8	·486	+0·1
Dec. 10·74	696·74	−4·2	·503	−1·0
1995 Jan. 1·75	49718·75	−3·0	1·506	+0·3
June 6·09	874·09	−3·3	·527	+0·3
Dec. 23·72	50074·72	−4·5	·554	−0·3
1996 Mar. 31·18¶	50173·18	−5·1	1·567	−0·7
Nov. 15·73	402·73	−4·9	·598	+0·2
Dec. 17·77¶	434·77	−5·2	·602	0·0
1997 Mar. 29·21	50536·21	−4·8	1·616	+0·7
May 3·11	571·11	−5·5	·620	+0·1
July 20·01¶	649·01	−5·9	·631	0·0
Sept. 8·97¶	699·97	−6·6	·637	−0·5
Dec. 23·71¶	805·71	−6·3	·651	+0·1
1998 May 3·16¶	50936·16	−7·0	1·669	−0·1
July 8·07¶	51002·07	−7·6	·678	−0·4
1999 Apr. 17·39‖	51285·39	−8·8	1·716	−0·5
July 8·35‖	367·35	−8·7	·726	0·0
Nov. 3·23‖	485·23	−9·8	·742	−0·6
Dec. 19·74	531·74	−9·1	·748	+0·3
2000 Jan. 8·73	51551·73	−9·3	1·751	+0·2
Apr. 10·17	644·17	−10·3	·763	−0·3
June 18·02	713·02	−10·5	·773	−0·2
Aug. 28·96	784·96	−10·7	·782	0·0
Oct. 13·87	830·87	−10·6	·788	+0·3
Dec. 9·69	887·69	−10·9	·796	+0·3
2001 May 13·14	52042·14	−12·3	1·817	−0·3
July 26·07	116·07	−12·0	·826	+0·4
Sept. 25·89	177·89	−12·5	·835	+0·3
Nov. 1·80	214·80	−12·7	·840	+0·3
2002 Jan. 1·77	52275·77	−13·3	1·848	0·0
Mar. 27·19	360·19	−14·3	·859	−0·5

TABLE V (*concluded*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
2002 May 16·12	52410·12	−14·3	1·866	−0·3
July 14·05	469·05	−14·6	·874	−0·3
Sept. 9·01	526·01	−14·6	·881	0·0
Nov. 7·85	585·85	−14·7	·889	+0·2
2003 Jan. 11·72	52650·72	−15·2	1·898	0·0
May 24·11	783·11	−15·8	·915	−0·2
July 14·04	834·04	−16·0	·922	−0·2
Sept. 22·94	904·94	−15·7	·932	+0·2
Nov. 27·76	970·76	−15·6	·941	+0·3
2004 June 19·09	53175·09	−15·5	1·968	+0·1
Aug. 13·03	230·03	−15·4	·975	−0·1
Oct. 18·92	296·92	−14·9	·984	0·0
Dec. 16·73	355·73	−14·4	·992	+0·1
2005 May 8·14	53498·14	−13·1	2·011	+0·1
July 29·02	580·02	−12·5	·022	−0·2
Sept. 14·92	627·92	−12·3	·028	−0·5
Nov. 9·84	683·84	−11·1	·036	+0·1
2006 Apr. 9·16	53834·16	−9·5	2·056	−0·1
June 23·09	909·09	−8·4	·066	+0·2
Sept. 8·02	986·02	−7·7	·076	0·0
Nov. 18·83	54057·83	−7·1	·086	−0·1
2007 Jan. 10·74	54110·74	−6·3	2·093	+0·2
May 2·14	222·14	−5·6	·108	−0·1
July 25·05	306·05	−4·6	·119	+0·3
Sept. 29·94	372·94	−4·1	·128	+0·3
Dec. 5·84	439·84	−4·1	·137	−0·1
2008 Jan. 7·77	54472·77	−4·2	2·141	−0·4
July 4·11	651·11	−2·9	·165	0·0
Sept. 18·94	727·94	−2·5	·175	+0·1

* DAO photographic velocity[56]; weight 0.
† OHP objective-prism velocity[88]; weight 0.
‡ OHP *Coravel* velocity[50]; weight ½.
§ Observed with 200-inch telescope; wt. ½.
¶ Observed with OHP *Coravel*; weight ½.
‖ Observed with DAO 48-inch telescope; wt. ½.

the discrepant one to indicate that he had measured the plate a second time to make sure that there had been no avoidable mistake. Four measurements were made by Fehrenbach *et al.*[88] by their objective-prism method; they were published in 1997 in a paper whose title asserts that the observations were intended to complement the *Hipparcos* astrometric data, but since they were actually made in the 1960s their authors must have been either clairvoyant or romancing! Five velocities obtained in the 1980s with the OHP *Coravel* were published as a mean by de Medeiros & Mayor[50] and subsequently made available individually through the Centre de Données Stellaires. Those authors were the first to publish the fact that HR 7795 is a spectroscopic binary, although that fact had been known in Cambridge many years before. All the mentioned velocities have been included in Table V, after adjustment by $+0·8$ km s^{-1}, plus, in the case of the DAO ones, an additional 0·5 km s^{-1}, representing the correction that was actually applied in the entry in the *Radial Velocity Catalogue* rather than the +1·0 proposed in its Table 3. For the objective-prism observations, the adjustment was rounded up to +1 km s^{-1} to avoid the impression that those velocities were worth quoting to decimals of a kilometre.

The star was placed on the radial-velocity programme of the original Cambridge spectrometer in 1982, in connection with a systematic campaign on composite-spectrum binaries. It seemed not to show any change in velocity over the first two seasons, and was then not observed again for a couple of years; a further year elapsed, owing to delay in the reduction of the Cambridge observations, before a measurement with the spectrometer[89] on the 200-inch telescope brought to attention the fact that the velocity had moved quite a long way from where it had been standing. In retrospect it was soon seen that through that inattention there had been missed a very significant part of the orbit, an omission which it has taken more than 20 years to redeem. It could be remarked that many composite-spectrum binaries show little or no change of velocity, but one cannot be sure that they will not do so unless they have been resolved on the sky and their angular separations are known to be too great for significant velocity changes to occur on a human time-scale. If, for example, the components of HR 7795 were known to be even a tenth of a second of arc apart, at its distance of the order of 500 pc that would represent 50 AU; if the sum of the masses were taken to be, say, 6 $M_\odot$, then the period — for a circular orbit and even on the assumption that we had fortuitously seen the maximum possible angular separation — would be about 140 years, the amplitude of the relative radial-velocity changes would be just over 10 km s^{-1}, of which the primary's share would be at most 5 km s^{-1}, and it would be safe to leave intervals of a few years between successive observations.

Since 1986 the star has been followed quite systematically, and 105 measurements, all set out in Table V, have been made of it. They consist of 22 made with the original spectrometer, 33 with the OHP *Coravel*, 45 with the Cambridge *Coravel*, four at the DAO and one at Palomar. The orbital solution is based on those 105 velocities together with the five additional OHP ones provided through the CDS by de Medeiros & Mayor. The usual +0·8-km s^{-1} adjustment has been made to the OHP ones; they, and the DAO and Palomar ones, have all been attributed half-weight, while the 'original Cambridge' ones have been weighted 1/8. On that basis the orbit illustrated in Fig. 4 is obtained; its elements are as follows:

P	=	7491 ± 20 days	$(T)_2$	=	MJD 53416 ± 22
γ	=	−6·78 ± 0·04 km s^{-1}	$a_1 \sin i$	=	715 ± 6 Gm
K	=	7·36 ± 0·05 km s^{-1}	$f(m)$	=	0·260 ± 0·006 $M_\odot$
e	=	0·333 ± 0·006			
ω	=	222·7 ± 1·4 degrees	R.m.s. residual (wt. 1)	=	0·29 km s^{-1}

Apart from the accurately determined 20·5-year period, and perhaps the very large value of $a_1 \sin i$ — surpassed among stars tolerably well documented in this series of papers only by HD 176695[90] and by the values found for four of the objects of exceptionally long period treated in Paper 200[91] — the most interesting quantity among the elements is the mass function. If, by analogy with the eclipsing system HR 6902[92,93], which includes a G9 II primary that has a well-determined mass of 3·9 $M_\odot$, we consider that the primary star in HR 7795 has such a mass, then the minimum mass of the secondary is 2·1 $M_\odot$. That is just about the mass that the secondary star, for which a type near A4V has been

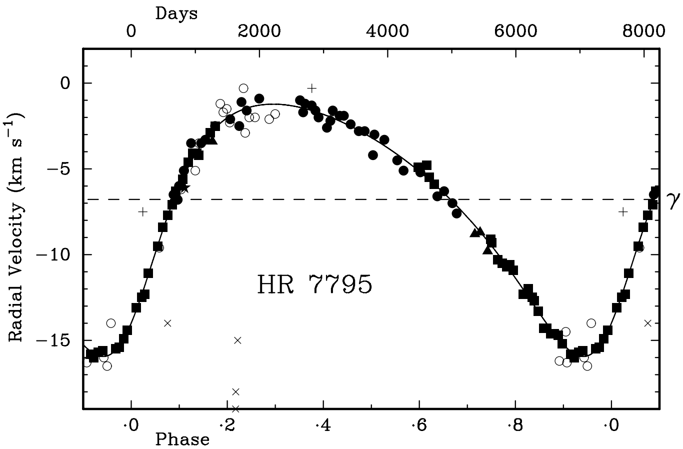

FIG. 4

As the previous figures, but for HR 7795. The orbit depends on 105 velocities measured by the author mostly at Cambridge and OHP (symbols as noted for Fig. 1) but including four obtained at the DAO (filled triangles) and one at Palomar (filled star); five measurements made by others[50] at OHP were also included in the solution. Only the Cambridge *Coravel* velocities were given full weight; the others were half-weighted, except for those made with the original Cambridge spectrometer, which received weight 1/8. Also plotted, but not utilized in the solution, are three early photographic velocities[56] from the DAO, plotted as plus signs, and four objective-prism measures[88], shown by crosses.

suggested[82], could be expected[43] to possess. We might deduce, therefore, that the primary star cannot be significantly more massive than its counterpart in HR 6902, and also (on the supposition that it has about that same mass) that the inclination of the HR 7795 orbit is high.

An eclipse would be almost too much to hope for: since the sum of the radii of the stars could be estimated at about 30 Gm, and the separation at the time of eclipse (not far from periastron) must be about 1500 Gm, one can see that the inclination would need to be within about 1/50 of a radian, not much more than 1°, for eclipses to occur. In a model in which the components have masses of 3·9 and 2·1 $M_{\odot}$ and the orbital inclination is 90°, the relative transverse velocity of the stars at the time of eclipse is about 26 km s^{-1}. The time taken to travel the sum of the diameters of the stars, 60 Gm according to the above estimate, would be 2·3 Ms or about 27 days, which therefore represents the duration to be expected for a central eclipse. Purely by chance, the radial-velocity observation of 2006 June 23 was made within half a day of a computed time of conjunction, and demonstrates definitely that no eclipse was in progress then. The date of conjunction is uncertain by several days, so it is not possible to state categorically that there is no eclipse, but certainly the prospects of one are not bright.

At the distance of HR 7795, only very approximately known to be about 500 pc, the mean separation of the stars, $(1+q)(a_1 \sin i)$ or about 2 Tm or 13 AU, would subtend an angle approaching 0″·04. The orbital eccentricity and orientation imply that that would indeed be about the maximum angular separation to be expected, and would occur a few years before apastron, due in 2015. It looks as if resolution could be possible with telescopes of apertures that have been much used for speckle interferometry, and would be easily done by optical interferometry with separated apertures; the ΔV of something like 3^m between the components, however, could represent a difficulty.

Radial velocities for HR 7800 (HD 194193)

When setting up a measurement with the OHP *Coravel*, the observer had first to use the excellent 17-cm finder and centre the required star on crosswires to bring it into the small field of the *Coravel* eyepiece. An arresting feature of the finder field of HR 7795 was HR 7800, half a magnitude brighter than the actual programme star and most impressively red, and for reasons admitted in the third section of this paper the observer could not always forbear from looking at it. It was measured 12 times at OHP; since the programme was transferred back to Cambridge, where objects are set directly into the field of the main telescope, HR 7800 has not normally been seen and the temptation to observe it has been removed, although two observations have deliberately been obtained just to check that no significant change in velocity has occurred. The measurements are set out here in Table VI.

TABLE VI

Radial-velocity observations of HR 7800

Date (UT)	*Velocity km s⁻¹*	*Date (UT)*	*Velocity km s⁻¹*
1986 Aug. 28·98	+2·7	1992 Apr. 28·16	+3·6
1987 Mar. 5·23	+2·9	June 26·06	+2·7
Oct. 13·79	+4·1	Aug. 13·97	+3·0
1988 Mar 13·22	+3·4	1993 July 9·04	+3·0
1989 Oct. 29·79	+2·9	Dec. 26·78	+2·9
1991 Jan. 27·73	+3·1	1997 Mar. 29·20*	+2·9
Dec. 16·75	+2·8	2008 Aug. 14·98*	+2·6

* Observed with Cambridge *Coravel*; all others with OHP *Coravel*

The obvious conclusion is that the velocity is 'constant', with the rider that it probably shows a certain amount of jitter, since the spread of values is appreciably greater than would normally be expected to arise from instrumental uncertainties. The mean value is $+3 \cdot 04 \pm 0 \cdot 11$ km s^{-1}, the r.m.s. scatter of the individual values being $0 \cdot 4$ km s^{-1}.

The only previous measurements of the radial velocity of HR 7800 appear to be those published in 1923 by Adams & Joy[94], who (listing the star by its alias of Boss[95] 5231, of spectral type K6) gave a mean of $+1 \cdot 1$ km s^{-1} with a 'probable error' of $2 \cdot 0$ km s^{-1} from three plates. The dates (in 1917 and 1918) and the three velocities were long afterwards published individually[96]. The same authors, in collaboration with Humason, gave[97] the spectroscopically estimated luminosity of the star as $M_V = -0^m \cdot 5$, with a corresponding π_{sp} of $0'' \cdot 005$, not far from the *Hipparcos* value of $0'' \cdot 00381$; in the interim they had made a specific effort on the classification of very red stars, and their type for HR 7800 had advanced to M0. Photoelectric photometry of HR 7800 has been published by Eggen[98], as $V = 5^m \cdot 92$, $(B-V) = 1^m \cdot 63$, $(U-B) = 1^m \cdot 98$; corresponding quantities measured by Shevchenko, Ibragimov & Chernysheva[99], however, are not at all in agreeement, being $6^m \cdot 09$, $1^m \cdot 58$, and $1^m \cdot 87$. The *BV* magnitudes transformed from *Hipparcos* and *Tycho* are close to Eggen's results, and so are ones that are referred to in the Mermilliods' compendium[100] as having been supplied privately by Oja and that are listed separately by *Simbad*; the *Hipparcos* 'epoch photometry' shows a slight lack of constancy in brightness but no changes on the scale of the discrepancies between the Russian work and the rest. Shevchenko *et al.* gave what is believed to be the first MK type for the star, K5 III, which they say (without explanation or reference) was "obtained by the Q method". HR 7800 subsequently became an MK standard[23–26] for type K7 III.

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THE NATURE OF HD 212827

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HD 212827, a star with a spectral type close to A1 II, appears to have a constant radial velocity near -65 km s^{-1} and is not a short-period spectroscopic binary as previously reported. Radial velocities of A-type stars can normally be measured with a *Coravel*-type instrument, in which the stellar spectrum is cross-correlated with a K-giant spectrum, only if they have enhanced metallic lines and/or their spectral lines are narrow. HD 212827 fulfils the latter condition, and produces a weak but measurable cross-correlation dip; according to our high-dispersion spectroscopy, it is not a metallic-lined star. The Ca II *H* and *K* lines exhibit unchanging profiles with three components, of which the shortward one is in the position expected for the stellar line. We demonstrate explicitly that the stronger of the other two features is interstellar, but can only postulate a similar origin for the weaker, more red-shifted component.

Introduction

In a recent instalment[1] (Paper 196) of the series on spectroscopic orbits, it was mentioned that casual observations had been made of HD 212827, merely because of its proximity in the sky to one of the stars discussed in that paper. Since a brief summary of the salient literature on the star was given so recently it is not repeated here, except for saying that HD 212827 is to be found in a rich Milky Way field near to β Lac, has a V magnitude of $8^{\mathrm{m}}\cdot3$, and has a published spectral type of A0 II. An orbit with a period of 5·7 days and an eccentricity of 0·35 was given for it in 1970 by Abt *et al.*[2] on the basis of 11 radial-velocity measurements, of which three had been published previously[3] and eight were being presented for the first time.

The improbability of an eccentric orbit at such a short period as 5·7 days (especially for a high-luminosity star), and the scarcity and poor temporal distribution of the observations, prompted the writer of Paper 196 to express distrust of the published orbit, even though he had no observations of his own to support an objective assessment of it. The misgivings largely stemmed from a fact which had been pointed out previously[4], namely, that if one searches a sparse data string for sufficiently short periods it is possible to find a period that arranges the velocity data in almost *any* order in terms of phase, and thereby to make even random data seem to mimic an orbit. The data set[3,2] for HD 212827 has a mean interval between observations of more than 30 times the published orbital period; only in one case were two observations made in adjacent cycles. It may also be remarked that, after six orbital elements have been fitted to 11 observations, there remain only 5 degrees of freedom.

Observability of HD 212827 with a radial-velocity spectrometer

Out of three early efforts to measure the velocity of HD 212827 with the Cambridge *Coravel*, only one appeared to have been even marginally successful. That was not surprising, because the *Coravel* cross-correlates, in real time, the spectrum of the observed object with a mask that represents the spectrum of Arcturus, which is of type K2 III. A-type stars whose metallic lines are narrow, and/or enhanced as in the Am types, do give cross-correlation 'dips' measurable with the *Coravel*, but many A stars do not, probably because rapid rotation smears out beyond detection what is in any case a very shallow dip. At A0 II[5], the spectral type of HD 212827 seems quite inappropriate for measurement with the Cambridge instrument, but when making the casual observations of the star the observer was not aware of its spectral type.

More deliberate efforts have since been made with the *Coravel* to observe HD 212827 for radial velocity. It has been found that the star *is* measurable, although (as expected) it gives only a very shallow dip in the cross-correlation traces, an example of which is illustrated in Fig. 1. The dip is, however, quite narrow, indicating that the same is true of the spectral lines. When a number of measurements had been accumulated and they were found to exhibit no mutual discrepancies larger than the observational uncertainties, they were discussed with Dr. Abt. He was inclined to think that they were illusory and/or of another component of the system and not of the A-type star, and he pointed out that the r.m.s. deviation from a constant mean of his 1970 consortium's eight velocities[2] was more than five times the 'probable error' of their observations. He suggested that, as a test, efforts be made to observe other early-A stars with the *Coravel*. That was done; it was found that HR 204 (A2 III[6]; the first early-A giant encountered in a trawl of the *Bright Star Catalogue*) gave a rather deeper dip than HD 212827, but Vega (A0 V) gave none. Clearly the case of an A0 II star such as HD 212827 would be expected to be marginal, and the exact spectral type is of considerable interest.

By a most fortunate coincidence, a communication at that juncture from Mr. B. Skiff (Lowell Observatory) offered carefully-considered classifications for the stars referred to in Paper 196[1], including HD 212827 as an optical companion to HD 212790. For HD 212827, he recommended A1 II, which is close to the original Morgan, Code & Whitford type[5] of A0 II; he suggested that the *K*-line strength might be enhanced by interstellar absorption (though the region of the Milky Way in which it is situated is fairly clear), in which case A0 might be a better

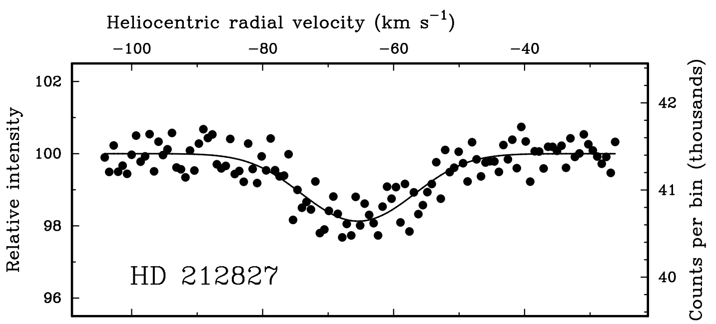

FIG. 1

Radial-velocity trace of HD 212827, obtained with the Cambridge *Coravel* on 2007 September 12.

temperature type. He concluded that it was not as late as A2, that it was not of particularly high luminosity (Deneb, at A2 Ia, was a poor match), nor was it a strong Am star since the enhancement of metals exhibited by such objects was not apparent.

Spectroscopic observations

The two crucial questions (does the star have narrow lines, and is it an Am star?) were best answered through high-dispersion spectroscopy. The first such spectrum was kindly obtained at the coudé spectrograph of the 1·2-m telescope of the Dominion Astrophysical Observatory (DAO) by Dr. C. D. Scarfe in 2007 October. It spans the region $\lambda\lambda$ 4355–4499 Å, and demonstrates that HD 212827 does indeed have narrow lines. The first of the questions was thus answered. In order to investigate this object more closely, one of us (REMG) then obtained a spectrum of it in the Ca II *H* & *K* region with the same telescope and coudé spectrograph. That spectrum (illustrated in Fig. 2) reveals not only a narrow *K* line characteristic of an early-A giant, but also a multiple redward structure whose source could be either interstellar absorption or one or more companion stars. The existence of a similar structure on the redward side of the Ca II *H* line suggests that the multiple structure represents velocity-shifted components of the Ca II lines rather than some quite different chemical element; moreover, no other features in the observed region of the spectrum show any hint of multiplicity. Two additional high-dispersion spectra of the *K*-line region were obtained the following season. No changes in line strengths were apparent, nor were there any radial-velocity shifts in any of the features. HD 212827 was observed in the Hδ region as well, since the profile of the Balmer line is a reliable guide to a star's temperature. Examination of the patterns of line strengths observed also revealed no evidence that the star could be metallic-lined.

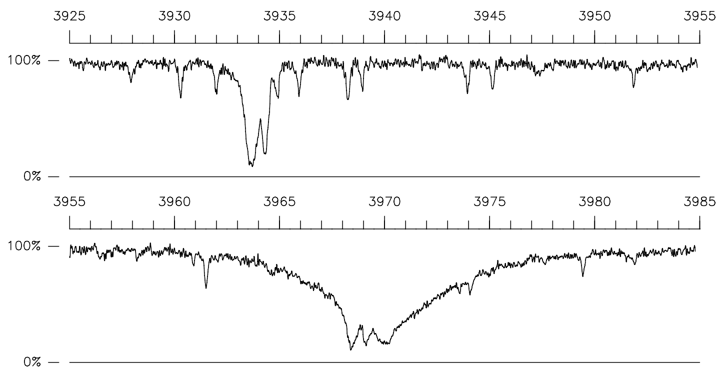

FIG. 2

The spectrum of HD 212827, observed at the DAO, in the vicinity of the Ca II *K* line (upper panel) and of the *H*-line/Hε blend (lower panel). A noteworthy characteristic of the spectrum is the narrowness of the metallic lines, some of which have counterparts in the spectrum of the K-type giant Arcturus and thereby enable the radial velocity of HD 212827 to be measured by cross-correlation with the Arcturus-based mask in the *Coravel*. The wavelength scale (Å) is in the rest-frame of the star, in which the *K* line is at λ 3933·7 Å. The two lines immediately to the right of the stellar *K* line are considered to be of interstellar origin; their counterparts can be seen in the *H* line (rest wavelength 3968·5 Å) in the lower panel, although the weak (redmost) line is rather obscured by the broad profile of the Balmer line Hε.

A log of the spectroscopic observations is given in Table I. Because of the faintness of the star, each of the four exposures made by REMG consisted of two sequential one-hour integrations which were co-added in order to improve the S/N ratio. Each of the DAO spectra was recorded on a SITe-4 CCD, and reduced with an IRAF-based pipeline.

TABLE I

Log of spectroscopic observations of HD 212827

'Phases' refer to the published orbit[2]; they are needed for Fig. 1
The last three columns give the radial velocities measured from the spectrum, first for the stellar lines and then for the two interstellar features

Observation ID	*Date UT*	*MJD*	*Phase*	*Central λ Å*	*Velocities (km s⁻¹) Stellar*	*IS*	*IS*
*17267	2007 Oct. 24	54397·25	2949·786	4427	−65·7		
19537/8	2007 Nov. 23	54427·09	2955·018	3933	−66·7	−13·0	+31·2
11875/6	2008 July 24	54670·43	2997·687	3933	−65·9	−13·0	+32·0
13152/3	2008 Aug. 14	54692·43	3001·545	4101	−65·7		
13875/6	2008 Sept. 1	54710·42	3004·699	3933	−66·6	−13·7	+30·5

*Observed by Dr. C. D. Scarfe

The radial velocity of each spectrum was measured directly from its displacement relative to a standard (iron arc) observation. As an additional check on the performance of the *Coravel* on such an early-A spectrum, the *K*-line region of HD 212827 was cross-correlated with a spectrum of β Gem observed with the same equipment. The cross-correlation function showed a distinct and unique peak. Two measurements were made — one making use of all the features in the spectrum (including Ca II *H* & *K* and the Balmer lines), and one in which those strong features were carefully excluded. The two results were almost the same, being −65·1 km s^{-1} for the first case and −65·8 km s^{-1} for the restricted one. Our spectroscopic measurements thus not only confirm the *Coravel* results but also demonstrate their objectivity.

The K line

The multiple structure of the Ca II *K* line demanded special attention. To investigate the explanation of interstellar absorption, we searched for another star of similar spectral type, distance, and direction, and selected HD 213050, classified[7] as A0 II, as the closest match to those requirements. Its spectrum was observed in the *H* & *K* region by REMG on 2008 June 27·45 with the same DAO spectrograph. It proved to be a remarkably good choice inasmuch as it too has sharp lines, and line strengths and profiles that are very similar to those of HD 212827 (see Fig. 3), but it shows only a single feature at the position of the *K* line. A partial explanation is to be found in the radial-velocity difference between the two A-type stars; HD 213050 has only a modest velocity, and when the two spectra are superimposed in the heliocentric rest-frame, the stronger of the redward-displaced features in HD 212827 falls right at the position of the stellar *K* line in HD 213050, so the line seen in that star is almost certainly an irresolvable blend of stellar and interstellar components. There is, however, no feature in HD 213050 corresponding to the additional smaller component displaced even further to the red in HD 212827, near λ 3934·95 Å in the rest-frame of that star (see Fig. 3).

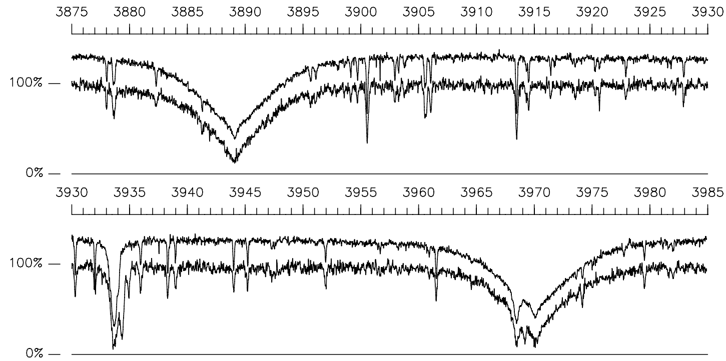

FIG. 3

The spectrum of HD 212827 compared with the remarkably similar one of the A0 II star HD 213050, whose profile is drawn to the same vertical scale but displaced upwards by 30% relatively to that of HD 212827. The wavelength scales for both stars are in the stellar rest-frames. The upper panel includes the Balmer line Hε and a plethora of metallic lines; the lower panel includes both *H* and *K*. HD 213050, like HD 212827, has very narrow lines, but because of its different heliocentric velocity the stronger interstellar *K* line is almost completely blended with the stellar line; the weaker one, seen at nearly λ 3935 Å in HD 212827, has no counterpart in HD 213050, presumably because the interstellar cloud that causes it does not extend into our sightline to that star.

The distances of HD 212827 and HD 213050 are not known; both are clearly of the order of a kiloparsec or more, since *Hipparcos*[8] reported negative parallaxes for both of them. The two stars are close to the Galactic equator and are sufficiently near to one another in the sky (the separation is about 1° in Galactic longitude and 2° in latitude) that we might hope our lines of sight to them traverse somewhat similar samples of the interstellar medium, particularly in the regions nearest to us. HD 212827 is, however, almost a magnitude fainter than HD 213050; it may well be more distant, and in any case the sightlines to the two stars are increasingly divergent at greater distances, so it could (and we suppose *must*) lie beyond an additional interstellar cloud.

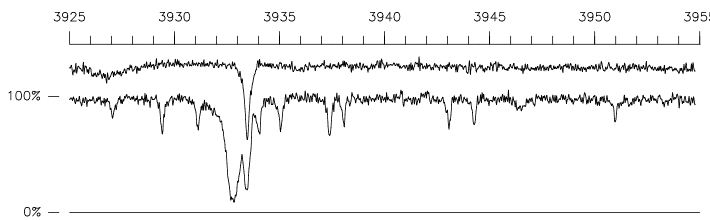

FIG. 4

The spectrum of HD 212827 compared with that of the B2 IV star HD 213322 (upper trace) in the vicinity of the *K* line. In this figure, unlike Figs. 2 and 3, the scale of abscissae is heliocentric wavelengths. The B star is too hot to have any *K* line of its own, so the strong narrow line there is necessarily identified as interstellar in origin. It is seen to coincide with an exactly analogous feature in HD 212827, demonstrating that that feature shares the same origin, probably in the same interstellar cloud, the two stars being within 1° of one another in the sky.

In a further effort to elucidate the matter, a spectrum was obtained (with the same instrumentation as before) of the B2 IV[9] star HD 213322, which is less than 1° in longitude from HD 212827 and in almost the same latitude, and whose parallax[8] is less than its own standard error. The star's spectral lines are broad, and owing to its early type it has no *K* line of its own at all. There is a strong interstellar line, at just the same heliocentric velocity as the strong feature immediately to the red of the stellar *K* line in HD 212827, but of the second feature there is no sign (see Fig. 4). All the same, the conclusion here has to be that the redmost component of the *K* line in HD 212827 arises from absorption in an additional interstellar cloud, even though we have not yet found corroborative evidence of the same cloud in other spectra in that part of the sky.

Radial velocities

Our accumulation of photoelectric radial-velocity measurements made of HD 212827 with the Cambridge *Coravel* now numbers 46 (including the original 'marginal' one). They are all listed in Table II, and are plotted, phased to the published orbit, in Fig. 5, where they are supplemented by the radial velocities measured from the five DAO spectra. They clearly do not confirm the published orbital elements, and as they show no mutual discrepancies larger than the appreciable observational uncertainties, and no systematic variation with time, they may be considered to demonstrate a constant velocity, at least on a time-scale of up to a year or so. The actual mean value of that velocity, $-65 \cdot 6$ km s^{-1}, is identical with the γ-velocity ($-65 \cdot 6 \pm 1 \cdot 0$ km s^{-1}) of the published orbit. The r.m.s. deviation per *Coravel* observation is $1 \cdot 0$ km s^{-1} and the standard deviation of the mean velocity is only $0 \cdot 15$ km s^{-1}. (It should be mentioned that the 'marginal' velocity has been omitted from the statistical analysis.) A negative correction of $0 \cdot 8$ km s^{-1} is suggested by experience for *Coravel* velocities of unusually blue stars such as HD 212827, and should be applicable to the initially-reduced values of the *Coravel* data in order to place them on the zero-point that is usually adopted in Cambridge and is traceable to an investigation[10] made some 40 years ago. That zero-point is itself about $0 \cdot 8$ km s^{-1} more positive than has been suggested by other assessments[11,12], so a total adjustment of $-1 \cdot 6$ km s^{-1} has been made to the *Coravel* velocities, the aim being to avoid as far as possible any systematic discrepancy from the Abt *et al.*[2] zero-point. No correction has been applied to the DAO measurements; their mean is $-66 \cdot 1$ km s^{-1}, with an r.m.s. scatter per observation of $0 \cdot 5$ km s^{-1} and a standard deviation of the mean of little more than $0 \cdot 2$ km s^{-1}. That is at least as close to the *Coravel* mean as could be expected in view of the zero-point uncertainty here, which is no doubt larger than the statistical uncertainty of the mean velocity.

If it can validly be assumed that the width of the zero-rotation dip profile given by the *Coravel* is the same for A-type stars as for late-type ones, as is believed to be near to the truth, then the projected rotational velocity ($v \sin i$) of HD 212827 is found to be $10 \cdot 0$ km s^{-1} with an (unrealistically small) formal standard deviation of $0 \cdot 7$ km s^{-1}.

The obvious conclusion from the new observations is that they do not support the published orbit. Since the measurements upon which that orbit was based showed a range of more than 30 km s^{-1} and most of them were reported[2] as having 'probable errors' near 2 km s^{-1}, it was thought[1] that they must demonstrate *some* variation of velocity even though the proposed orbit was viewed with reservation. It is evident, however, that the orbital ephemeris fails to represent the new observations, whose complete lack of any variation or temporal trend in excess of the

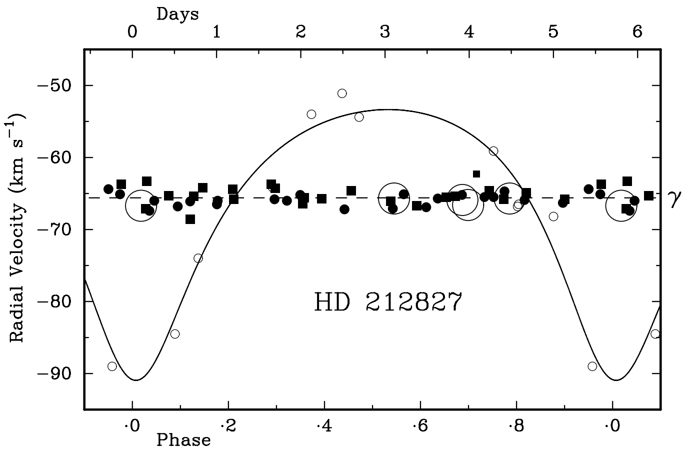

FIG. 5

The radial-velocity curve of HD 212827, plotted according to the published orbital elements[2], with the underlying measurements plotted as open circles and the new Cambridge velocities represented by filled symbols. In order to demonstrate the absence of any perceptible drift in the velocities in the longer term, the new set of measures has been split into temporal halves which are plotted with different symbols: the first 23 are shown as squares (the initial 'marginal' one has a smaller symbol), while the later 23 appear as circles. The velocities measured from high-dispersion DAO spectra are plotted as large open circles.

TABLE II

Radial-velocity observations of HD 212827

The first section of the table lists the published observations[3,2], from which were derived the orbit which is plotted in Fig. 5 and was used in the calculation of the phases and residuals listed here. The second section presents the recent measurements made with the Cambridge Coravel, with the phases that would correspond to the same orbit.

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O−C)* *km s⁻¹*
1961 Oct. 5·43	37577·43	−54·4	0·472	−0·7
1962 May 17·44	37801·44	−59·1	39·752	+0·3
Sept. 15·38	922·38	−89·0	60·958	−2·2
1964 May 22·42	38537·42	−66·5	168·804	−2·9
Aug. 6·46	613·46	−74·0	182·137	+0·6
24·45	631·45	−64·2	185·292	−4·6
Sept. 28·13	666·13	−54·0	191·373	+1·9
1965 June 20·34	38931·34	−68·2	237·877	+4·7
21·55	932·55	−84·5	238·089	−2·3
Sept. 13·46	39016·46	−66·8	252·802	−3·4
1966 Aug. 2·44	39339·45	−51·1	309·437	+3·1

TABLE II (*concluded*)

Date (UT)			*MJD*	*Velocity km s⁻¹*	*Phase*
2000	Jan.	13·78	51556·78	−61·5:	2451·716
2007	July	8·09	54289·09	−64·1	2930·820
		19·06	300·06	−63·8	2932·744
		27·06	308·06	−63·4	2934·146
	Aug.	1·10	313·10	−62·5	2935·030
		6·06	318·06	−65·0	·900
		7·06	319·06	−64·5	2936·075
		10·01	322·01	−65·9	·593
		11·04	323·04	−65·0	·773
		13·06	325·06	−64·6	2937·127
		30·13	342·13	−67·8	2940·121
		31·09	343·09	−62·9	·289
	Sept.	7·98	350·98	−64·6	2941·672
		11·04	354·04	−63·6	2942·209
		11·89	354·89	−64·8	·358
		12·10	355·10	−64·9	·395
		12·92	355·92	−65·3	·539
	Oct.	19·93	392·93	−66·3	2949·028
		20·97	393·97	−65·0	·211
2008	July	25·08	54672·08	−62·9	2997·976
	Aug.	15·05	693·05	−64·7	3001·654
		19·05	697·05	−65·6	3002·355
		30·13	708·13	−63·5	3004·298
		31·03	709·03	−63·8	·456
	Sept.	13·95	722·95	−65·5	3006·896
		18·96	727·96	−63·9	3007·775
		19·96	728·96	−63·6	·950
		20·93	729·93	−65·3	3008·120
		26·95	735·95	−65·7	3009·176
		27·94	736·94	−64·4	·350
	Oct.	1·91	740·91	−65·2	3010·046
		5·94	744·94	−64·7	·752
		9·04	748·04	−65·0	3011·296
		10·98	749·98	−64·9	·636
		12·01	751·01	−65·1	·817
		12·91	751·91	−64·3	·974
		16·97	755·97	−64·4	3012·686
		18·96	757·96	−66·6	3013·035
		21·98	760·98	−64·3	·565
		22·94	761·94	−64·7	·733
		25·00	764·00	−66·0	3014·094
		26·98	765·98	−66·4	·442
		27·95	766·95	−66·1	·612
	Nov.	1·00	771·00	−65·2	3015·322
		7·96	777·96	−66·3	3016·542
		22·99	792·99	−65·2	3019·178

measuring errors actually suggests that there is no variation of velocity at all; in that respect the reader may find Fig. 5 reminiscent of Fig. 1 in ref. 4.

Acknowledgements

It is a pleasure to thank Mr. B. Skiff for volunteering new and carefully considered spectral types for HD 212827 and other stars, and Dr. C. D. Scarfe for obtaining the first DAO spectrum of the star. We are grateful too to Dr. H. A. Abt for his comments upon a draft of this paper. REMG thanks the Herzberg Institute for Astrophysics for Visiting Worker privileges, including observing runs on the DAO 1·2-m telescope. This research has made use of the *Simbad* database at the CDS, Strasbourg, France.

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NOTES FROM OBSERVATORIES

A CONSTANT PERIOD FOR THE W UMA STAR BH CAS

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The variability of BH Cas (V = 12·58) was discovered by Beljawsky[1] and confirmed by Metcalfe[2], who classified BH Cas as a W UMa eclipsing binary with a period of about 0·39 days[3]. Later observations by the same author[4] provided the first ephemeris of the system:

$$\text{Min. I} = \text{HJD } 2449998{\cdot}6187(3) + 0^{\text{d}}{\cdot}40589004(13)\, E,$$

from 12 minima obtained using B and V observations. Those observations, combined with spectroscopic data, allowed the first determination of the physical parameters of the system[5], which showed that BH Cas is a W-type W UMa system with a more-massive and cooler primary component and a less-massive and hotter secondary component. In a study of the link between the period changes and mass ratios in W-type contact binaries, Qian[6] obtained a quadratic ephemeris:

$$\text{Min. I} = \text{HJD } 2449998{\cdot}61832(3) + 0^{\text{d}}{\cdot}40589026(6)\, E + 6^{\text{d}}{\cdot}57(27) \times 10^{-10} E^2.$$

New linear and parabolic ephemerides were presented by Zola *et al.*[7] using minima from the literature and new minima obtained from *V*, *R*, and *I* observations. The linear ephemeris:

$$\text{Min. I} = \text{HJD } 2449998{\cdot}6183(3) + 0^{\text{d}}{\cdot}40589160(5)\, E,$$

is similar to that obtained by Metcalfe[4], although with a longer period. On the other hand, the parabolic ephemeris:

$$\text{Min. I} = \text{HJD } 2449998{\cdot}6187(3) + 0^{\text{d}}{\cdot}4058907(2)\, E + 0^{\text{d}}{\cdot}52(15) \times 10^{-10} E^2,$$

shows a period change (as derived from the coefficient of the parabolic term) smaller than that obtained previously by Qian, and in better agreement with the values provided for other contact systems. In this regard, the quality of the fit of Zola *et al.* was better for the parabolic model than for the linear model, with the *O–C* residuals distributed more symmetrically around zero in the former case.

Note that the time interval spanned by the observations included in the work of Qian is short ($\approx 4{\cdot}2$ years, or 3800 cycles) while the *O–C* data of Zola *et al.* add only two years more (about 1850 cycles). This casts doubt upon the reliability of the period change determined by those authors (suggested by the great difference between the coefficient of E^2 in the parabolic ephemeris). For this reason, in order to determine the real behaviour of the period for BH Cas, we have analyzed all the data available in the literature until now, including minima obtained by us very recently.

Our differential photometric observations were carried out using a $0{\cdot}35$-m telescope ($f = 1760$ mm) equipped with a Starlight MX7 CCD camera and a Johnson *V* filter, between 2008 August 20 and September 13. The comparison star was GSC 3665 – 0146 ($V = 12{\cdot}12$). Table I shows the new minima obtained from our data using the Kwee & van Woerden[8] procedure. These new minima, together with the minima collected in the literature[3,4,7,9–19] (67 in total, spanning $13{\cdot}9$ years, or about 12 500 cycles), have been used to determine a new ephemeris for BH Cas. Fig. 1 displays the *O–C* diagram obtained from those minima.

Although the *O–C* data in Fig. 1 show a noticeable dispersion, a linear trend is clearly visible, with the *O–C* values distributed homogeneously around the best fit line at $O–C = 0$. In fact, the best fit to the data was obtained with the linear ephemeris

$$\text{Min. I} = \text{HJD } 2449998{\cdot}6182(3) + 0^{\text{d}}{\cdot}40589171(5)\, E.$$

This result shows clearly that BH Cas exhibits no continuous period variation in the $13{\cdot}9$-year interval analyzed here, although a very small parabolic behaviour on a long time scale is not excluded. Note particularly that the reliability of an *O–C* parabolic model depends on the accurate determination of the quadratic term. In our case, assuming a parabolic trend, the coefficient of E^2 is $0^{\text{d}}{\cdot}32(16) \times 10^{-10}$, slightly lower than the value obtained by Zola *et al.*, but with a considerable uncertainty. According to Eggleton[20], the time required to measure $t_P = P/\dot{P}$ with an accuracy of X% is $\Delta t = 10\sqrt{[(t_P \mathrm{d}t)/X]}$, where $\mathrm{d}t$ is the accuracy of the individual eclipse timings. Assuming conservative values of $X = 10$ and $\mathrm{d}t = 0{\cdot}003$ days (an approximate value obtained from the scatter of the data in the *O–C* diagram), $\Delta t \cong 24$ years, using our coefficient of the quadratic term. (Shorter times are obtained for the coefficients of equations of Zola *et al.* and Qian, $18{\cdot}9$ and $5{\cdot}3$ years, respectively; clearly, the limited range of the

TABLE I

New minima timings obtained for this work

HJD	*Error*	*Type*
2454699·4549	0·0002	II
2454702·4966	0·0001	I
2454706·3546	0·0001	II
2454707·3667	0·0002	I
2454708·3834	0·0002	II
2454709·3969	0·0002	I
2454710·4137	0·0003	II
2454712·4433	0·0001	II
2454721·3728	0·0002	II
2454722·3851	0·0001	I
2454723·4025	0·0002	II

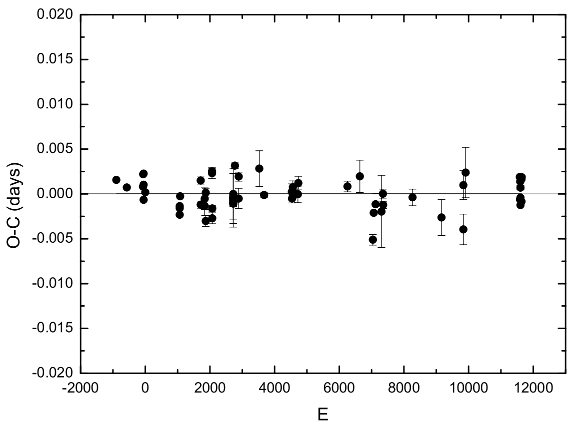

FIG. 1

O–C plot of the minima data of BH Cas. The *O–C* diagram has been constructed using our linear ephemeris and the best-fit line lies at $O–C = 0$.

time spanned by the observations analyzed by Qian led to an overestimation of the coefficient of E^2. Note that these values of Δt are longer than the time span of their data.) This result shows that a long time interval of timing measurements is necessary to verify whether a possible small parabolic dependence of the *O–C* is real.

Moreover, in order to exclude other possible sources of period changes (such as the presence of a third body), a linear–sinusoidal model in the form

$$O–C = a + b\,E + c \sin(d\,E + f)$$

was also fitted to the data, but no significant results were obtained.

Fig. 2 displays our observations using the phases computed according to the linear model obtained in this work. Note that the *V* curve obtained by us shows a noticeable dispersion around the secondary minimum and a significant difference (of about $0^m\cdot05$) between the maximum at phase 0·25 on the nights of

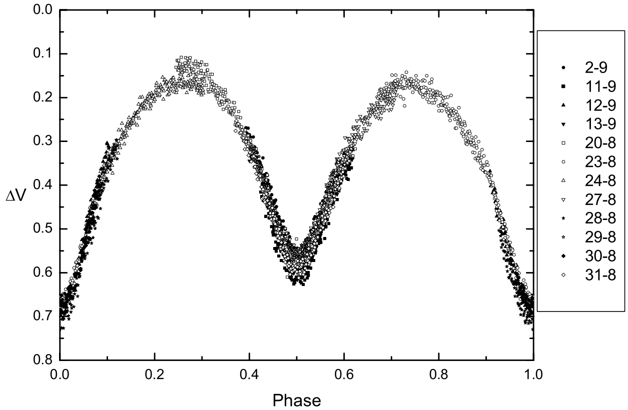

FIG. 2

V light-curve of the system BH Cas derived from CCD data obtained in this work. The data of different nights are represented by different symbols.

August 20 and 24. The previous study of Zola *et al.* showed no significant distortion of the light curve of BH Cas in the *U*, *V*, *R*, and *I* filters, in contrast to the usual case of the W-type W UMa systems. Although we must be cautious (only *V* data have been obtained in this work), the visual inspection of the light-curve suggests the possible presence of changing surface features, such as spots, on the system components. For this reason, future photometric observations in several bands are required to confirm or refute this hypothesis.

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In this work use has been made of the Astrophysics Data System (ADS). Thanks are due to the anonymous referee for his helpful comments that improved the presentation of this paper.

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REVIEWS

Ruth Belville: The Greenwich Time Lady, by D. Rooney (National Maritime Museum, Greenwich), 2008. Pp. 192, 20·5 × 13·5 cm. Price £12·99/$25 (hardbound; ISBN 978 0 948065 97 2).

As readers of these pages over the years will have realized, I have long been enthusiastic about the Royal Observatory (RO) at Greenwich (and its successor at Herstmonceux) and the rôle that it played in both the astronomical and civil lives of the nation — the latter aspect including the provision of an accurate time service — before the destruction of that great institution as a working observatory by one of the bureaucratic 'quangos' created by an ignorant government just a few years ago. I thought I knew something of the history of the RO but this splendid book by David Rooney, Curator of Timekeeping at the RO (now, of course, a very successful museum, part of the National Maritime Museum), was a complete surprise.

Although time keeping had long been a function of the RO, arising from its importance to marine navigation and especially the determination of longitude, the dissemination of time to the wider community didn't really take off until the 6th Astronomer Royal, John Pond, installed a time ball above the Octagon Room in 1833. So, at precisely one o'clock every day, the ball dropped down the mast and everyone who had a view of the RO, perched as it is on a hill, could set their timepieces. But what of those who could not see that signal? The answer was to have an accurate chronometer, set to Greenwich time, carried out into the community for those with a need for precise time to set their own clocks. And the man to provide that service was the superintendent of the Chronometer Department of the RO, John Henry Belville, using a superb chronometer called 'Arnold', after its maker John Arnold.

When George Airy took over as 7th Astronomer Royal in 1835, one might have expected this rather quaint service to disappear given Airy's enthusiasm for the electric dissemination of Greenwich time signals. But amazingly it didn't, and when Belville died in 1856, his third wife, Maria, picked up 'Arnold' and continued to provide the service to a number of clients in London, despite the fact that she had no formal connexion with the RO. Perhaps Airy felt sorry for her, even though he was a well-known stickler for the regulations, because she certainly didn't get much support from the authorities on the death of her husband.

Quite astoundingly, by the 1890s and with the RO now under the direction of William Christie (8th Astronomer Royal — and founder of this *Magazine*) the Belvilles' time service was *still* operating, with Maria having been joined by her daughter Ruth; and it is — by now — not surprising to learn that when Maria died in 1899, Ruth continued to provide that personal service so clearly appreciated by a few dozen clients in the city. What is quite remarkable is that, in spite of living for a while as far away as Maidenhead (in Berkshire) and Ewell (in Surrey) — which necessitated a prodigious amount of travel on public transport and on foot, Ruth kept up the tradition (under the watchful eyes of two further Astronomers Royal — Frank Dyson and Harold Spencer Jones) until 1940! It was a combination of the war, the introduction of the talking clock (TIM) by the Post Office (who operated the telephones in those far off days!), and her incredible age of 86 that finally brought a halt to a quite outstanding service.

This is a wonderful story, well told and complemented throughout with fascinating nuggets of history, especially those relating to the growth of time dissemination in Britain, resulting in a full-colour picture of a bygone age. Highly recommended. — David Stickland.

Secrets of the Hoary Deep: A Personal History of Modern Astronomy, by Riccardo Giacconi (Johns Hopkins University Press, Baltimore), 2008. Pp. 416, 23·5 × 18·5 cm. Price £30/$45 (hardbound; ISBN 0 8018 8809 0).

Very few astronomers have bothered to sit down and write an autobiography, and this is a great shame. Imagine how revealing it would be if we could read the autobiographies of, say, Galileo Galilei, Isaac Newton, Edmund Halley, and Robert Hooke. And then balance those presumably insightful tomes against the groaning shelves of worthy views of what scientific historians think these chaps were aiming for, how they were motivated, and how they interacted with their colleagues.

Fortunately, as the years pass, the number of astronomical autobiographies slowly increases. Maybe our great modern astronomers have more time on their hands when they semi-retire, or they have a greater desire to 'put the record straight', or today's publishers are hunting more assiduously for juicy revelations to fill their flagging book lists.

Professor Riccardo Giacconi, 2002 Nobel Prize winner in physics, Gold Medallist of the RAS, father of X-ray astronomy, pioneer director (1981–1992) of the Space Telescope Science Institute, Baltimore, director general (1993–1999) of the European Southern Observatory, president (1999–2004) of Associated Universities Inc. (AUI, the organization in charge of the USA's National Radio Astronomy Observatory, and thus the USA's contribution to the millimetre and submillimetre array, *ALMA*) has, aged 77, written his autobiography. It is a real page-turner. We are presented with a detailed overview of the birth and evolution of X-ray astronomy and its ever-growing influence on the other branches of our subject. The birth-pains of the *Hubble Space Telescope* are discussed in detail, as is the construction of the array of four identical 8-m telescopes in Paranal, Chile (the *VLT*).

Giacconi is not just an originator of great scientific ideas, a designer of spacecraft that actually work, a manager of space missions that get things built on time and within budget, a grant raiser who understands the machinations of monolithic organizations like NASA, and a polymath who appreciates the contributions of all electromagnetic wavelengths to the advancement of astronomy. He is all of these. Fortunately, he is also a great writer. There are no dull pages in this book. It is inspirational. Not only will it enthuse those embarking on a career in observational astrophysics, it will also encourage other astronomers toward the twilight of their astronomical endeavours to start typing their life histories into the word processor. — David W. Hughes.

Epic Rivalry: The Inside Story of the Soviet and American Space Race, by V. Hardesty & G. Eisman (National Geographic, Washington), 2008. Pp. 275, 23·5 × 17·5 cm. Price £9·99/$28 (hardbound; ISBN 978 1 4262 0119 6).

This two-horse race started at the end of World War II with the Americans and Soviets rushing towards the Mittelwerk factory in Nordhausen, and the Dorten mine nearby (both in the intended Soviet-controlled Harz Mountain region of the defeated Germany), in an endeavour to bag as much V2 rocket hardware and documentation as possible. The USA won and, more important, they also convinced SS Major Wernher von Braun and most of his team to move to the US Army's White Sands Proving Ground near Fort Bliss, New Mexico, and continue development.

The second part of the race concerned rockets. After WW II there were only two competing superpowers. Militarily the US was in the lead, ringing the USSR with airbases and equipping them with strategic bombers capable of turning any USSR city into a cross between Hiroshima and Dresden. The only answer for the Soviets was the Inter-Continental Ballistic Missile. And here they made a very useful mistake. The military boffins were convinced that the nuclear warhead would weigh about 6·5 tons, so the rocket engineers had to develop a very powerful new rocket. This R7 rocket then gave them a huge lead when it came to placing cosmonauts into low Earth orbit.

The third part of the race occurred at the time of the International Geophysical Year, 1957–1958. The 84-kg *Sputnik 1* and the 508-kg *Sputnik 2* (containing Laika, a dog) were 'Red Triumphs' and revealed an embarrassingly huge Cold War missile gap. This so concerned the American people and politicians that 1961 May 25 saw John F. Kennedy throwing down the gauntlet to a joint session of Congress "to win the battle that is now going on around the world between freedom and tyranny … (and) achieving the goal, before this decade is out, of landing a man on the Moon and returning him, safely, to the Earth."

Eventually the USA won. Their Saturn V rocket worked. The Soviet's N-1 did not. By 1972 December 14 six men had walked on the Moon. The Soviets pulled out of the race. The remaining 13 Apollo lunar missions were speedily cancelled. The Space Race was over.

Von Hardesty is a curator and Gene Eisman a researcher at the Smithsonian National Air and Space Museum in Washington, DC. Their book starts by detailing the history of the German V2 Vengeance Weapon, stressing the funding benefits that rocket research received during Hitler's massive rearmament programme after 1933. They then discuss the Space Race proper and compare and contrast the Soviet's approach, cloaked in a shroud of secrecy, with concealed goals and unmentioned backroom personnel, with the USA's approach, completely open and apparent to all, and critically dependent on public support. The importance of the Cold War views of Nikita Khrushchev, Leonid Brezhnev, John F. Kennedy, and Lyndon B. Johnson are also discussed. Hardesty and Eisman then highlight all the successes and pitfalls in the real race, the finishing post being the lunar surface.

Their book is an absolute joy, an illuminating, balanced, well-researched, and insightful read from beginning to end. You quickly realize that, without the ideological and military rivalry between those two superpowers, rocketry would still be close to the November-the-5th stage, and the great astronomical space observatories would still be a dream of the future. Interestingly, as soon as the race was over, Hardesty and Eisman put their pens down. I am still looking forward to the permanently inhabited lunar base, and the human exploration of the surface of Mars. I wonder how long I will have to wait? — DAVID W. HUGHES.

Facts and Speculations in Cosmology, by J. V. Narlikar & G. Burbidge (Cambridge University Press), 2008. Pp. 287, 25·5 × 18 cm. Price £30/$60 (hardbound; ISBN 978 0 521 86504 3).

The jibe "What about epicycles?" is always worth trying when the opposition looks to be in a bit of a tight spot and in need of introducing an extra assumption or effect to bring about that hopefully final tweak that will make their peace with the cosmos. There is of course something very appealing about the flash of inspiration that took us from epicycles to ellipses and it would certainly be nice to be around if a similarly momentous change took place in modern cosmology. Such seems to be the hope of the authors in their spirited support and defence of the progeny of the original Steady State Theory (SST).

The vast majority of this book is a comprehensive romp through the basics of cosmology from ancient cosmologies *via* stellar evolution, nuclear synthesis, and the observed expanding Universe to details of the standard Big Bang Theory (BBT). Unfortunately, once again CUP appears to have gone for the 'economy package' in terms of editing standards as at times the text has a distinct 'cut and pasted from previous texts' feel to it. The authors admit that, throughout, their approach maintains, and indeed is prefaced upon, a healthy scepticism for the BBT ideas. While never missing a chance to point out that theory's shortcomings they also never seem to miss an opportunity to take a swipe at the moral fibre or intellectual honesty of any BBT proponents whom they perceive as having been particularly anti-SST. While such diversions from a classical textbook style may add spice and interest to the narrative (and indeed perform an important service in terms of recording some hints at the sociology of the science) it is always unsatisfactory that the presentation is perforce one-sided in that respect.

Towards the end of the book details of the quasi-steady-state-cosmology alternative to BBT are presented. Its characteristics, assumptions, and predictions are all clearly defined and the authors do an apparently decent job in trying to compare it point for point with BBT. The non-expert should always be sceptical of course as to whether what is presented is not only the 'truth', but equally importantly is the truth in equal measure on both sides. Overall it seems to boil down to the conclusion that, for these authors, the quasi-steady-state model simply has fewer inherent 'epicycles' than the BBT. Will quantum theories of gravity one day produce a reconciliation?

Given the history (and sociology) of 20th-Century cosmology research, the authors obviously felt obliged to make passing reference to some cosmological misfits — observations, that is, although some of the personnel involved would no doubt wear that badge with pride! Anomalous redshifts and aligned or grouped quasars are highlighted as warnings that all may not be well with the basic assumptions of current cosmologies. History does indeed suggest that discrepant data are occasionally vital indicators of the need for fundamental rethinking and are ignored at our peril. Such may be the case with these observations and they may yet prove to be the components of the cosmological puzzle which eventually bring down the whole pack of cards. In the context of this book, however, one has the sneaking suspicion that they are included as a little insurance policy — not so much "remember you heard it here first" but more "remember we were the ones who wouldn't let the blinkered establishment forget". — Dave Pike.

The Cosmic Microwave Background, by R. Durrer (Cambridge University Press), 2008. Pp. 401, 25·5 × 18 cm. Price £40/$80 (hardbound; ISBN 978 0 521 84704 9).

In the last decade the cosmic microwave background (CMB) has become the primary tool for the researching cosmologist. Although only first detected in 1964, the isotropic 3K heat-bath from the creation of the Universe is very useful for two reasons. Firstly, the spectrum is a perfect black body (or as near as we can detect), so is easy to distinguish from other astrophysical sources. Secondly, the physical processes that govern its creation are very linear, so it is very easy to model theoretically. Since the first detection of the CMB anisotropies by *COBE* in the 1980s, the CMB has blazed a trail for other cosmological probes to follow. The release of this timely volume is perfectly positioned between two major CMB satellite experiments: after the data release of the NASA/Princeton *Wilkinson Microwave Anisotropy Probe* (*WMAP*), but prior to the launch of the ESA *Planck Surveyor*.

The first three chapters deal with Friedmann–Lemaître–Robertson–Walker cosmology and the basic theory behind the generation of perturbations in the early Universe, a subject that has been dealt with by many authors before. It is really with Chapter 3 that we get into the more unique material. It covers the generation and evolution of different types of perturbations during inflation and the early Universe, while Chapter 4 goes on to explain how these are transformed into CMB anisotropies on the surface of last scattering. Chapter 5 covers polarization of the CMB, an important and timely subject given the detection of polarization by *WMAP*, and the expected gain in accurate measurements by *Planck*. Chapter 6 covers cosmological-parameter estimation, a subject completely neglected by almost every other textbook, but of vital importance to the researching cosmologist. After that, the book starts to become more forward-looking, examining the topics of gravitational lensing (Chapter 7) and spectral distortions (Chapter 8), subjects that are not so important now, but may well prove to be in the future. The end of the book has a number of useful appendices outlining the mathematical principles behind some of the results in the book.

There really is no other book on the market like this at the moment. Other cosmology books have covered the CMB before, in varying amounts of detail depending on when they were written. By deciding to write a book that focusses purely on the CMB (and doesn't spend so much time on explaining other aspects of cosmology, such as inflation or General Relativity), Durrer has written a reference text that is both less general and so more useful to the researching graduate student or post-doc, and it is these I judge to be its target readership. I do have some minor quibbles with the book, such as the notation (*e.g.*, tau refers to physical time and *t* to conformal time (*i.e.*, scaled with the expansion)), which I find a little irritating. Aside from that, I believe this to be a very interesting and useful textbook, which I recommend highly. — DAVID PARKINSON.

The Formation of the Solar System: Theories Old and New, by M. Woolfson (Imperial College Press, London), 2007. Pp. 318, 23 × 15 cm. Price £49/$65 (hardbound; ISBN 978 1 86094 824 4).

Michael Woolfson is a professor at the University of York, emeritus, one might guess, given that he was 15 at the time of the death of his great-grandmother, who was born in 1845. Several aspects of his book are very likeable. He provides pictures of some folks, like T. C. Chamberlin, R. A. Lyttleton, and W. H. McCrea, whom one doesn't often see. There is a careful discussion of the work of some non-Anglophone astronomers, including Otto Schmidt and Victor Safronov, who are often neglected in English-language studies of planet formation. And among his chapter-head epigrams is the correct shoulders-of-giants remark by Bernard of Chartres (*c.* 1113), though we are not told whether the author found it on his own or encountered it in the writings of R. K. Merton.

Roughly the first half of the volume covers familiar territory. Begin, of course, with the Greeks; romp past Tycho, Kepler, Newton, and all to dock next to Chamberlin and Moulton after passing Kant and Laplace. Woolfson then rejects modern versions of planet-system formation in solar nebulae and puts forward his own capture hypothesis, in which our planets (plus moons, asteroids, and all) come from material captured by the young Sun from a close-passing, less-developed protostar. Initially the material fragmented into six large units. Four are now the major planets; the other two began with (for instance) 618 and 116 times the current mass of Earth and highly eccentric orbits. A collision between them triggered some deuterium fusion and expulsion of gas, with their solid cores giving rise to Venus and Earth. The author presents a number of details within this scenario. Mars and Mercury were originally satellites, our Moon remains so, and so forth.

Curiously, the item that left me least in sympathy with the author was not his original scenario for the origin of planetary systems, about which he has clearly thought a great deal, but the Epilogue, in which a Solar System astronomer is settled next to a fireplace remembering the dinner his wife has cooked and waiting for her to finish putting the children to bed and bring him his coffee. Oh, and his recipe for omelettes neglects to mention (*a*) that you must break the eggs (this is perhaps profound) and (*b*) that you must put the egg–salt mixture into the buttered pan before turning the heat back up (p. 159). — VIRGINIA TRIMBLE.

The Cosmic Connection: How Astronomical Events Impact Life on Earth, by J. Kanipe (Prometheus Books, Amherst, NY), 2008. Pp. 287, 22·5 × 15 cm. Price $27·95 (about £20) (hardcover; ISBN 978 1 59102 667 9).

In recent years much 'serious' scientific broadcasting, such as the *Horizon* series of programmes, has tended to be somewhat sensationalist, dealing with the gloom and doom of imminent catastrophe. I vividly remember having to explain carefully to my young son after one such programme why there was no (well almost zero) chance that we would be fried to death by a gamma-ray burst the following day, or soon after. As an astronomer, I have the background knowledge to be able to answer my children's questions, but that is a rather lucky position to be in. I had visions of parents across the country unable to calm down upset and disturbed offspring, or even themselves. How could they be helped? Well, this excellent book provides the solution.

Jeff Kanipe has written a thoughtful and interesting volume that examines the range of possible 'cosmic' connections between what goes on in the wider Solar System, Galaxy, and Universe and how these processes can and do interact with the Earth and humanity. The writing style is engaging and keeps the reader's interest without having to resort to a sensationalist approach. Indeed, the author displays a certain amount of amusement in the contrast between some of the more grandiose doom mongering and the scientific reality he presents.

I have always had an interest in this area and have examined much of the scientific background in the process. I would like to have written a book about it myself. Sadly, I have been beaten to it by Kanipe, who has pulled off a *tour de force*. He covers the broadest range of topics from potential asteroid and cometary impacts, through supernovae and gamma-ray bursts to interactions with the interstellar medium and the effect of cosmic rays on the Earth's climate. In all cases, the quality of the science is excellent and the result is a definitive examination of the impact of the cosmos on us that is easily accessible to the non-expert. It also holds much of interest to those of us who like to think we know something about the subject.

I found this book a thoroughly enjoyable read. It should be required reading for all prospective science-documentary producers … but then maybe their programmes would not make it onto our screens. — MARTIN BARSTOW.

Annual Review of Astronomy and Astrophysics, Volume 46, 2008, edited by R. Blandford, J. Kormendy & E. van Dishoeck (Annual Reviews, Palo Alto), 2008. Pp. 585, 24 × 19·5 cm. Price $205 (institutions; about £150), $84 (individuals; about £60) (hardbound; ISBN 978 0 8243 0946 6).

Just as the annual pageant of the skies is marked for observational astronomers by the coming and going of the familiar constellations, so the passing of the years is marked for me by the autumnal apparition of the *Annual Review of Astronomy and Astrophysics*, and the 2008 offering is well up to standard. And I should say at the outset that, although I complained about the new format introduced in 2006 (see **127**, 134, 2007), I think that the series has settled into a model of printing excellence, with first-rate use of colour in many contexts; see by way of example the superb image of the Crab Nebula on page 129. And I'm delighted to see that the large margin about which I railed has been reduced in width!

Now to the contents. As is customary the first chapter is given over to one of the grandees of astronomy, and this time it's Alexander Dalgarno's turn. He gets off to a promising start with a couple of pages of family background and early life in London, where we might have found him on a career in football with Tottenham Hotspur! But thereafter it becomes something of a catalogue of atomic-and-molecular-physics problems solved and collaborators with whom he worked. Impressive enough, and doubtless of interest to those involved in that aspect of science, but not too exciting for the average astronomer on the Clapham Omnibus.

Then follow thirteen reviews, each of which, with their extensive reference lists, serve as benchmark studies for the research community, especially those new to the particular topics covered. The highlight for me was an authoritative and up-to-date appraisal of the origin of elements produced by neutron capture, by Sneeden *et al.*, coming almost exactly half a century after the ground-breaking work known to all as B^2FH (*Rev. Mod. Phys.*, **29**, 547, 1957). The supernovae that give rise to some of these (*r*-process) elements also feature in other reviews in this volume: on the Crab Nebula (Hesser), supernova remnants (Reynolds), and a fascinating look at the information that spectropolarimetry can provide on supernova explosions (Wang & Wheeler) — this should have pedagogic value in advanced undergraduate courses.

The results of stellar evolution feature in several other reviews. The stellar remnants are considered in a study of pulsating white dwarfs through high-precision asteroseismology (Winget & Kepler), while a comprehensive account of the double pulsar PSR J0737–3039 (Kramer & Stairs) leads to important results for fundamental physics. The more-diffuse products of stellar evolution are to be found in the interstellar medium where a complex array of molecules is seen, including polycyclic aromatic hydrocarbons, discussed by Tielens, and the water which turns up in the Solar System (Encrenaz). This leads into discussion of the debris discs now found around many stars (Wyatt), some of the material from which goes to form the protoplanets considered by Blum & Wurm.

Five years into the *Spitzer* mission, Soifer *et al.* examine some of the splendid harvest of extragalactic results gathered in thus far, together with pointers for future research both before and after the end of the cryogenic phase of operations. And now that black holes at the centres of galaxies have become taken for granted, Ho treats us to a survey of nuclear activity in nearby systems. Finally, Frieman *et al.* examine the (apparently) accelerating universe and the rôle of 'dark energy' (although not universally accepted — not least by sceptics like me!). I shall be interested to see how that topic fares in future volumes of this important series! — DAVID STICKLAND.

Alien Volcanoes, by R. M. C. Lopes & M. W. Carroll (Johns Hopkins University Press, Baltimore), 2008. Pp. 152, 28·5 × 22 cm. Price £20/$29·95 (hardbound; ISBN 0 8018 8673 2).

A major result of the last 35 years of Solar System exploration has been the realization that volcanism as a process is very widespread. All of the planets have a store of internal heat, partly left over from the violent accretion processes whereby they formed and partly the result of the decay of naturally occurring radioactive isotopes. The rocks and ices of which the non-gaseous planets and their satellites are constructed are poor thermal conductors. As a result, these bodies get rid of heat most efficiently when the internal temperature rises to the point that some fraction of the body melts. Heat is then advected to the surface by the molten material released in volcanic eruptions. What is beautifully illustrated in this book is the enormous variety of the results of this one basic process.

Silicate volcanism as we experience it on Earth was common in the past on Mars, Venus, and our Moon. We strongly suspect that Mercury was as active as the Moon in the past, with confirmation eagerly awaited from the current *MESSENGER* mission. Activity may still be occurring intermittently on Venus and Mars, though we have not actually seen any eruptions yet. However, violent volcanic eruptions are currently common on Jupiter's rocky satellite Io.

The earlier *Voyager* and *Galileo* missions to the Jovian satellites hinted at a second kind of volcanic activity: cryovolcanism. Jupiter's satellites Ganymede and Callisto contain a high proportion of water. Some surface features of these bodies suggested that water ice was replacing silicate rock as the material that melts and carries heat to the surface. While still being debated for these Jovian satellites, this idea has been confirmed in spectacular fashion by the current *Cassini–Huygens* mission to the Saturnian system. Structures revealed in radar images of the largest satellite, Titan, are almost certainly the equivalents of volcanic mountains and lava flows, but made of frozen water instead of frozen rock. And violent explosive eruptions occur on the small satellite Enceladus, with water vapour and freezing water droplets replacing the volcanic gases and cooling molten rock droplets that would be encountered on Earth.

All of these features are documented in this entertaining and informative book, at least half of which is taken up by high-quality illustrations. Most are spacecraft images, but a significant number are reproductions of works of art, some classical, some by modern 'space artists'. An equal mix of education and entertainment for all, much to be recommended. — Lionel Wilson.

Numerical Modeling of Space Plasma Flows: ASTRONUM–2007 (ASP Conference Series, Vol. 385), edited by N. V. Pogorelov, E. Audit & G. P. Zank (Astronomical Society of the Pacific, San Francisco), 2008. Pp. 334, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 333 1).

This book represents a welcome development in the simulation of fluid environments across astrophysics, namely the growth of dialogue between scientists pursuing different approaches including hydrodynamics, magnetohydrodynamics, and kinetic particle transport. It is the proceedings of the second conference in the ASTRONUM series, which took place in Paris in 2007 June. The meeting, and the book, bring together expertise from many parts of the simulation community and from many countries (though a small turnout from the UK).

The book is neatly structured. The first part of the book focusses on the simulation of specific physical phenomena. This opens with a series of papers on turbulence in astrophysical fluids which touches on both the general issue of turbulence (a good place to start as turbulence is a universal process that we don't yet understand) and on the specific rôle of turbulence as a key factor controlling the transport of cosmic rays throughout the Universe. This is followed by a section with papers on astrophysical flows — ranging across topics from proto-planetary discs to cosmological shock waves. The focus then moves closer to home with a series of papers on space-plasma flows — looking in particular at flows in the heliosphere and the local interstellar medium.

The second part of the book focusses on simulation techniques. The first section in this part is a series of papers on kinetic and hybrid simulations, *i.e.*, simulations where we recognize astrophysical fluids are composed of particles. This is followed by a section with papers looking at common technical aspects of simulations including methods and algorithms for solving the appropriate equations and for establishing and controlling the grids and meshes used in many simulations. The final section presents papers on data handling and visualization. This reflects the critical importance of understanding simulation outputs — modern simulations can produce huge amounts of data so scientists need tools to handle those data and to present them in an understandable form.

This is a nicely balanced book. It brings together different approaches to astrophysical simulations and in a way that will promote dialogue and scientific advance. I was particularly pleased to see a strong emphasis on coupling between different fluid components, *e.g.*, plasma and neutrals, and across spatial scales. There was also a clear recognition that some constituents must be modelled using kinetic-transport equations, *i.e.*, the equations of Boltzmann and Vlasov rather than those of Euler. I was also pleased to see recognition of the rôle of plasma physics in astrophysical fluid dynamics. As someone who understands something of space-plasma physics, I've long been bemused by the way that plasma effects are ignored in parts of modern astrophysics. This book is a step towards the broader understanding that is needed.

In summary, this is a good book to dip into to sample the state of the art in respect of simulations of astrophysical fluids across the Universe and as an example of the need for dialogue between scientists working on different approaches to those simulations. There is nothing new in that need — but it is good to see it working in practice. — MIKE HAPGOOD.

Superstructures in Space: From Satellites to Space Stations — a Guide to What's Out There, by M. H. Gorn (Merrell, London), 2008. Pp. 192, 32·5 × 27 cm. Price £24·95/$39·95 (hardbound; ISBN 1 8589 4417 1).

This is the big picture-book of space research. By which I mean it is a large book full of pictures of the machines that are used for space research. Why the title mentions superstructures was not clear to me; the subtitle is self explanatory. Also not clear is the purpose of the book or the intended readership — more of which later. The author, Michael Gorn, as a NASA historian and author of *The Complete Illustrated History of NASA*, is experienced at distilling readable text from technical documents — in the case of this book, by mining documents from the internet.

The space missions covered are all within the civil space programme and although dominated by NASA achievements, contributions from Europe, Japan, and Russia are well represented. Fifty-seven space missions have been selected to illustrate space research under four themes: 'Human spaceflight', 'Earth observation', 'Exploring the Solar System', and 'Exploring the Universe'. Each mission is given roughly a double-page spread, often formatted as one large photograph and a few smaller ones with about a page of descriptive text. The descriptions are at the level you might expect from a very short executive summary; in fact "Space — an Executive Summary" might have been a better title. The book answers those questions about what has been going on in space research in recent times — roughly from the mid 1990s onwards. However, if your question is "why has this research been carried out?" or "was this research valuable or necessary?" — then you need a different book. Gorn is a committed insider who does not address the reasoning behind space missions but takes the mission purpose (as defined on the mission web page) pretty much at face value. Although readable at a technical level, the text is so full of acronyms and space jargon that space outsiders might need a glossary, and even space old-timers will need to use the handy acronym table at the end of the book.

The missions themselves are beautifully illustrated and reasonably accurately but rather superficially described, presumably because of the format restrictions. The illustrations, generally of space hardware in the blackness of space are, however, not for enlightenment but for artistic qualities and a sort of 'nerdy gee whizzery'. The text is likewise spare to a pointless degree. I could see no purpose in simply listing the names of the instruments on board a particular spacecraft without saying what they do and how that information helps to understand the object being investigated. One might as well simply say "here is a beautiful photograph of a complicated space machine, and it also carries a lot of really fancy technical stuff".

Nevertheless, putting such criticism aside I found the book a valuable reminder of how much has been achieved in space research, and how much we currently take for granted. So much so that, especially in the 'Earth observation' section, I started thinking "how can there be any questions or debate about cause and effect on the Earth's climate? Surely all the required information must now be available from the vast amount of satellite data." Although this highlights my ignorance of the issues it also illustrates the problem of lack of depth with this book. Equally worth the reminder was the complex and lengthy build-up of the *International Space Station* (*ISS*), which for a time required almost complete dependence on Russian launchers. (There is a beautiful double-page spread of the seemingly chaotic interior of one of the Russian modules (*Zveda*) for the *ISS*.)

So for whom is this book? The text is not for the novice: while intermittent explanation is sometimes given, it is generally superficial and worthless without some level of technical familiarity. There is no science content that might be useful in understanding the workings of stars, planets, or the Universe, and no engineering content that might help explain why doing stuff in space is just so damned difficult, so it is not for the scientist or engineer. A possible reading strategy is to simply take these spacecraft names and technical terms as a sort of background wash of technical authenticity and just look at the pictures. And I suppose that is the book's intended use. As a picture book it is fine, and although a picture book, it is not for children, and although littered with technical language it is not detailed enough to be technically or scientifically interesting. One possible use, through the direct appeal of stunning photographs, is as a primer for a non-technical layperson who would like a quick overview of the subject. For example, it might help politicians to understand the amazing achievements of civilian space research

— but not UK politicians! Uniquely among the larger contributors to ESA and in spite of the significant UK contributions to many of the missions covered, on the evidence of this book's index, the UK as a coherent, competent, space-research nation does not exist (although the university groups at Imperial College, MSSL, and Sheffield get one mention each in the body of the text).

Ultimately this is a coffee-table book with some stunning photographs and a small amount of technical description, which you could probably find on the web, but for £25 Michael Gorn has searched the web for you and selected and summarized what he found there. The photographs are beautiful and the themes are an intelligent approach to summarize the wide diversity of space research. As such I would be happy to find this book available to browse at my local coffee shop or institute coffee lounge. — BARRY KENT.

Lights in the Sky, by M. Maunder (Springer, Heidelberg), 2007. Pp. 227, 23·5 × 15·5 cm. Price £19/$29·95/€24·95 (paperback; ISBN 978 1 84628 562 2).

As the title suggests, this is a handbook for identifying and setting out to observe the enormous variety of atmospheric and astronomical phenomena that can be seen with the naked eye. As much of what the book describes takes place in the atmosphere, the preliminary chapters are given over to the structure of the atmosphere, its various layers and temperature régimes, and some of the relevant optical processes that go on there, like refraction and scattering. The effect of atmospheric and light pollution, and the weather, on what can be seen is also described.

The bulk of the book describes the myriad glows, bows, halos, and glories that grace the daytime and night sky. For convenience these are divided up into the dawn glows, daytime glows, dusk glows, and night lights. Although the only real difference between the dawn and dusk phenomena is the green flash, there is a difference in perception as the eye is dark adapted at dawn and there are subtle differences due to the cooler dawn temperatures. The section on each phenomenon follows a general pattern: after a detailed description, the mechanism that produces it is described, and then tips are given on what to look for and how best to observe it. There are frequent comments on how best to photograph the particular phenomenon. The chapter on night lights covers atmospheric phenomena like noctilucent clouds and aurorae, and astronomical phenomena as diverse as the *gegenschein* on the one hand and the Milky Way and M31 on the other. Of course, it must be remembered that, with increasing light pollution, seeing the Milky Way from some locations these days is a significant achievement. There is a separate chapter on halos, with a good description of the different light paths through the ice crystals responsible for the different types of arcs and halos. There is also a chapter on UFOs and the rôle of perception on what is seen, but this does seem rather off-topic.

This book provides a useful and practical guide to observing a wide range of atmospheric and astronomical phenomena — and understanding what produces them. — CHRIS LLOYD.

Philip's Stargazing 2009, by H. Couper & N. Henbest (Philip's, London), 2008. Pp. 64, 23 × 16 cm. Price £6·99 (paperback; 978 0 540 09314 4).

This publication is one of a number available each year which introduces the beginner to the northern night-sky on a month-by-month basis. After a brief introduction, each month is covered in four pages. Therein are charts of the southern and northern aspects of the sky which include the Moon and the planets together with some of the more prominent celestial objects. The text gives a necessarily brief survey of the constellations and an adequate review of planetary phenomena. A summary of special events together with the month's 'object', 'picture', and 'topic' complete each section.

A four-page description of the Solar System, including eclipses, meteor showers, and comets is followed by a list of deep-sky objects suitable for viewing through small telescopes. Finally, there is a useful review of 'GO TO' telescopes. This publication is attractively presented with clear diagrams and photographs and performs its function very well. At its price it can be considered a bargain and may be recommended for any beginner wishing to know what the night sky has to offer. — R. H. CHAMBERS.

Stargazing Basics: Getting Started in Recreational Astronomy, by Paul E. Kinzer (Cambridge University Press), 2008. Pp. 147, 24·5 × 17·5 cm. Price £11·99/$19·99 (paperback; ISBN 978 0 521 72859 1).

There you are, in your armchair, reading about the stars and the planets, when it suddenly dawns on you that looking at the real thing might be much more satisfying than just browsing through second-hand pictures in books. But you need help. What instrument should you start looking through? How much should you spend? What should you look at first? Should you just go into the back garden or must you wander further afield? How do you interpret all those 'what is in the night sky' pieces in the astronomy magazines?

Well, Paul Kinzer, a planetarium lecturer with many years of amateur-astronomy experience, has come to your rescue. Look no further. His book starts by telling you what the night sky is doing from hour to hour and month to month. He then moves from naked-eye astronomy to the choice of some suitable binoculars and finally, for someone with between about £150 and £400 to spend on their new hobby, to the agonizing decision between the array of refracting and reflecting telescopes that are available. On the way, he guides you through the choice of eyepieces and filters and relates the fun you can have attaching your camera to the scope. Finally, Kinzer provides a very sensible overview of what you can expect to see, and gives practical tips on viewing the planets, nearby stars, clusters, and galaxies. The extensive glossary is a real jargon buster and will be a great help for the absolute beginner.

I enjoyed this book hugely and recommend it very strongly. Kinzer is a true enthusiast. If he does not get you out there and looking up, no one will. — CAROLE STOTT.

Stephen James O'Meara's Observing the Night Sky with Binoculars, by S. J. O'Meara (Cambridge University Press), 2008. Pp. 149, 29·5 × 21 cm. Price £19·99/$34·99 (paperback; ISBN 978 0 521 72170 7).

The author is a well-known commentator on observing the night sky, having written a number of well-received books and contributing regularly to popular magazines. This publication fulfils its purpose of giving an authoritative view of the night sky as seen with the aid of low-power, hand-held binoculars.

The introductory chapter deals with the basic techniques of finding and observing objects in the night sky. This is followed by the naming of stars and the significance of colour in a star's lifetime, wherein the spectral sequence and the H–R diagram are briefly described. A short account of non-stellar objects concludes the introduction.

The following chapters are a month-by-month description of the more important constellations as seen from mid-northern latitudes divided into the four seasons, starting in the spring. The book is replete with clear diagrams and photographs, many taken by the author, all in black and white. These give a more realistic view of the sky, in refreshing contrast to so many popular books where highly coloured images taken through large telescopes or in space give a completely wrong impression of what is to be seen through modest equipment.

O'Meara is not only an expert sky watcher, he is also keen on the cultural background, as exemplified in the literature and mythology. Thus, most descriptions of the constellations are prefaced by the associated fables derived from a variety of ancient sources. In truth, the author sometimes does go on a bit, but it can be argued that an appreciation of the lore associated with the heavens is an important part of the educational process. There are two appendices: a list of constellations and a description of the art of nova searching. There is an excellent index.

Throughout the text the author's enthusiasm is almost overwhelming, being particularly keen on the colours of the stars. This reviewer has to confess that his old eyes can no longer detect the subtleties so described — if he ever could!

The book does have some drawbacks. Coordinate systems are not mentioned; the process of finding an object is based solely on star hopping. There are also some errors of fact. The light from M44 does not take 400 million years to reach us, that being the age of the cluster. The Sun at the distance of the Coma Berenices cluster (100 parsecs) would not shine as a first magnitude star, and β UMi was never as near to the celestial pole as Polaris is now. It is dust not hydrogen gas that causes obscuration, and it was Schiller in 1627 and not a "collective of theologians" 1000 years ago who depicted the constellations as biblical figures.

These criticisms apart, this is a fine book that should encourage any possessor of simple optical aids to go out and seek for themselves what the night sky has to offer. — RICHARD H. CHAMBERS.

Frontiers of Astrophysics: A Celebration of NRAO's 50th Anniversary (ASP Conference Series, Vol. 395), edited by A. H. Bridle, J. J. Condon & G. C. Hunt (Astronomical Society of the Pacific, San Francisco), 2008. Pp. 390, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 660 8).

The NRAO has much to celebrate. This penetrating survey of astrophysics at the 50th anniversary shows radio astronomy at the centre of rapid advances in all areas, and especially cosmology. From the start the NRAO has been open to astronomers from all institutions in all countries, attracting the best observers with the best programmes to use the best set of radio telescopes. Furthermore, the technical advances at NRAO, especially in receiver techniques and most notably in low-noise amplifiers, have been made available to all radio observatories; for example, practically all receivers in both ground-based and space-based radio telescopes measuring the cosmic microwave background use amplifiers developed at NRAO.

There is a useful and entertaining companion volume to this symposium report: *But It Was Fun: the First Forty Years of Radio Astronomy at Green Bank* (see review in these pages **128**, 60, 2008) describes how the dream became reality. NRAO now extends well beyond Green Bank itself, to the large-scale interferometers *EVLA* and *VLBA*, and to the international millimetre-wave project *ALMA*. Its outstanding success is properly commemorated in this symposium volume. — FRANCIS GRAHAM-SMITH.

Formation and Evolution of Galaxy Bulges (IAU Symposium 245), edited by M. Bureau, E. Athanassoula & B. Barbuy (Cambridge University Press), 2008. Pp. 480, 25·5 × 18 cm. Price £65/$130 (hardbound; ISBN 978 0 521 87467 0).

Galaxy bulges remain surprisingly poorly understood. They contain most of the stars in the Universe, yet do not even appear in Baade's classic stellar-population concept. Our own Galactic Bulge remains almost entirely ignored, in spite of the predominance of large telescopes in the south. Indeed, justification for locating those telescopes was more based on two rather dull satellite galaxies — the Magellanic Clouds — than the availability of the Bulge. Bulges contains super-massive black holes, tiny in spatial scale, yet in some mysterious way intimately linked in their properties to the large-scale bulge stellar mass and kinematics. Bulges superficially resemble small elliptical galaxies, but are also different. Their properties somehow correlate with their embedded discs, in spite of profound distinctions in the fundamental parameter of specific angular momentum. They are old, perhaps older than anticipated by naïve model predictions. Given their long existence, secular evolutionary processes may well have modified significantly whatever their original states were. All in all, there is clearly much to learn in modelling and in observing galactic bulges.

This volume reports on a symposium held in Oxford (UK) in mid 2007, providing an overview of this important subject. There are many talks, most well presented, and having them all in one place is the ideal way to identify inconsistencies, unjustified claims, and unexplained observations — the very point of a meeting, of course. One comes away from this informed, confused, persuaded that there is a vast amount of understanding still to be provided by future analysis, and reassured that bulges are indeed still a topical research field. That, I suspect, is a definition of a successful meeting, and a book worth browsing. — GERRY GILMORE.

New Horizons in Astronomy: Frank N. Bash Symposium 2007 (ASP Conference Series, Vol. 393), edited by A. Frebel, J. R. Maund, J. Shen & M. H. Siegel (Astronomical Society of the Pacific, San Francisco), 2008. Pp. 304, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 656 1).

My political advice for today is that you cite, soon, some item from this volume, and 30 years from now you may find yourself with a powerful friend in court, for the 11 authors of the review papers and first authors of the 28 poster presentations are all postdoctoral fellows, nearly all from the US and many from the University of Texas and McDonald Observatory, where the conference was held. This should actually be fairly easy, since the topics range from Solar System and exoplanets through stars and star clusters to galaxy formation and evolution. Four poster contributions report results from the *Hobby–Eberly Telescope*, in case you wonder what it has been doing lately. The reviewers are actively engaged in their topics, in the sense that all but one cites one or more of his/her own first-author papers. There are two 'herses', seven 'hises', and two about whom I would want more information before deciding. The reviews seem to be at least as well thought out and carefully written as would be a more standard set from better-known authors, though perhaps somewhat narrower in focus. More-senior astronomers and some graduate students appear among the '*et al.*s' of the poster presentations. The conference photo shows lots of women and significant numbers of Asian-Americans but apparently no African-Americans. And I shall immediately take my own advice by citing in an upcoming public talk the informative review by Avi M. Mandell of how to look for, recognize, and validate habitable planets. — VIRGINIA TRIMBLE.

Other Books Received

Modern Quantum Field Theory: A Concise Introduction, by T. Banks (Cambridge University Press), 2008. Pp. 271, 25·5 × 19 cm. Price £35/$65 (hardbound; ISBN 978 0 521 85082 7).

This very approachable textbook, for graduate students in high-energy physics and related subjects, is billed by the author, a professor at UC Santa Cruz and at Rutgers University, as a "quick and dirty introduction to the techniques of quantum field theory". It comes complete with end-of-chapter problems (which develop many of the points raised in the chapters), numerous appendices, an extensive bibliography, and author and subject indices.

THESIS ABSTRACTS

The Dynamics of Planets in Multistellar Systems

By Patricia Verrier

Exoplanets have now been discovered in both binary- and triple-star systems, several of them with stars close enough to affect significantly the dynamics of the planetary system. An initial study of γ Cephei, with a giant planet in an eccentric orbit around a relatively close binary, reveals that the stability of small bodies in the system is extremely complex and provides possible locations for additional planets and planetesimals. A zone of stability is also seen around the secondary star, the habitability and observational properties of which are considered. Subsequently, a mixed-variable symplectic integration scheme is developed specifically for planetary orbits in hierarchical triple stellar systems.

After thorough testing of the implementation of this scheme in a new computer program, the dynamics of particles in these more complicated stellar environments are investigated. A general study of the circumbinary region shows that, although often well modelled by the overlay of the effects of two decoupled binary systems, there is a régime, when the stars are relatively close and eccentric, where the stability is far more complex, as the combined effect of all three stars acts to destabilize test particles.

A more specific study of planetesimals in the circumbinary debris disc of the quadruple-star system HD 98800 further illustrates the complex dynamics of these stellar–planetary systems. It is found that coplanar and retrograde warped discs could exist, as well as a high-inclination halo of material. Significant gaps are seen in the discs, as well as unexpected regions of stability due to the retrograde nature of the stellar orbits, and the dynamical structure goes some way to explaining observational features of the system, limiting the possible range of stellar eccentricities. The stable, high-inclination particles are further investigated, resulting in the derivation of a general empirical formula for polar stability in hierarchical triple-star systems.

Finally, in contrast to the numerical simulations, some interesting mathematical aspects of the generalized Kepler problem are discussed before possibilities for future work are given. — *University of Cambridge; accepted 2008 October.*

Huygens' Measurements of the Speed of Sound on Titan

By Philip D. Rosenberg

On 2005 January 14 the *Huygens* probe descended to Titan's surface, measuring, amongst other properties, the speed of sound in the moon's dense, haze-filled atmosphere. These measurements were made by the *Acoustic Properties Instrument – Velocimeter* (*API–V*). In addition, the *Huygens Gas Chromatograph Mass Spectrometer* (*GCMS*) indicated that the only bulk components of Titan's atmosphere were methane and nitrogen. For a binary mixture of gases, with known components, the temperature, pressure, and mixing ratio define the speed of sound. Hence, an attempt has been made to use the sound speed measured by *API–V* as a fast-response indicator of the methane abundance in Titan's atmosphere. To achieve this, flight-spare replicas of *API–V* have been used for calibration purposes and a non-ideal equation of state, supplied by the Groupe Européen de Recherches Gazières (GERG), has been employed to model the sound speed in the cold, dense mixtures of nitrogen and methane found on Titan.

The sound speed on Titan was found to increase from 183·2 m s^{-1} at 11 km altitude to 194·0 m s^{-1} at the surface. Use of the GERG equation of state with *Huygens* temperature and pressure data indicated that the mole fraction of methane at the surface is 0·026, remaining approximately constant up to 7 km altitude, then decreasing slightly to 0·012 at 11 km altitude. The estimated uncertainty in these values is ± 0·018. There is also a possibility of enhanced methane abundance at the surface and reduced methane abundance at an altitude of approximately 3 km. The low-altitude value presented here is lower than the estimate by *GCMS* of 0·049 ± 0·0025.

After impact the sound speed was found to increase by approximately 2 m s^{-1}. As *API–V* was in a separate thermal environment to all temperature sensors, it is not known whether this was due to an increase in temperature of approximately 2 K, an increase in the methane mole fraction of approximately 0·08 caused by evaporation from the potentially wet ground, or a combination of both these possibilities. — *The Open University; accepted 2008 February.*

OBITUARY

Peter Berners Fellgett (1922–2008)

Peter Fellgett was perhaps the archetypal 'boffin', defined for me some years ago as a "brainy old fellow full of ingenious notions", although he was far from 'old' when he showed that he had all the other attributes. This certainly comes across when one looks over the range of topics covered in his numerous contributions to these pages, which span well over half a century, from his first in 1950 (**70**, 189) on 'On setting up a Gerrish drive' (a telescope-driving mechanism) to his last in October 2008 (**128**, 409) on 'Sherlock Holmes' knowledge of astronomy not even elementary'. In between he'd written on galaxy counts, iris photometers, site testing, Olbers' paradox, comets, and much more. And these were just at the tip of an iceberg of subjects that interested him and about which he wrote in numerous journals, especially those concerned with instrumentation, and more-popular media.

But to start at the beginning, Peter Fellgett was born in Ipswich on 1922 April 11 and educated at The Leys School in Cambridge. From there he progressed to the university in that city, finally producing a PhD there in 1949 on the subject of infrared spectroscopy, during which he developed the ideas of multiplex interferometry, now known as the "Fellgett Advantage", a technique with wide application elsewhere. Between 1949 and 1959 he continued to be based at Cambridge whilst he worked on a range of research projects, including investigations into sharpening photographic images, and development of multiplex spectrometry. He spent 1951–52 working at the Lick Observatory of the University of California on observations of stellar magnitudes in six colours and the development of photoelectric photometers for very low light levels. He was then recruited to the Royal Observatory at Edinburgh by the Astronomer Royal for Scotland, Herman Brück, where he laid the foundations for the development of advanced plate-measuring machines such as *GALAXY* and *COSMOS*. Along the way, he came up with the idea that was to lead to the cross-correlation radial-velocity spectrometer, so successfully employed by Roger Griffin to determine the highly accurate spectroscopic-binary orbits reported in these pages and elsewhere, and more recently exploited by searchers for planetary systems around other stars.

In 1964, he was appointed the United Kingdom's first Professor of Cybernetics at Reading University, developing instruments and control systems — and ideas — for a wide range of applications, especially in optics and acoustics. His friendship at this time with James Lovelock (of Gaia-hypothesis fame) only broadened Fellgett's interests further. He retired from university life in 1987 to Cornwall but, as the Editors of this *Magazine* can attest, he certainly did not retire from science, keeping up a flow of correspondence, although interestingly, not through the medium of e-mail.

Peter Fellgett, or πϕ, as he liked to sign his letters, was a Fellow of the Royal Astronomical Society since 1951 and a Fellow of the Royal Society since 1986. He had the good fortune to die peacefully in his sleep on 2008 November 15. We shall miss his lively intellect. — DAVID STICKLAND.

Here and There

ANTHROPIC PRINCIPLES IN THE MILKY WAY

The Cosmic Dairy aims to put a human face on astronomy. — *IAU Information Bulletin 101*, p. 55.

THE LAST LAUGH

Comic impacts teach lessons about science. — *Nature*, **453**, contents page, 'Editorials'.

THE TRANSIENT NATURE OF CHARM AND BEAUTY

A simulated Higgs bosom production and decay event. — *University of Cambridge 800 Years: 1209–2009* (Cambridge University Press), 2008, p. 15.

CAREER ADVICE

… anyone who takes a university position will get no research support or time on telescopes, … — *Ann. Rev. A&A*, **45**, 41, 2007.

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(1) G. H. Darwin, *The Observatory*, **1**, 13, 1877.
(2) D. Mihalas, *Stellar Atmospheres (2nd Edn.)* (Freeman, San Francisco), 1978.
(3) R. Kudritzki *et al.*, in C. Leitherer *et al.* (eds.), *Massive Stars in Starbursts* (Cambridge University Press), 1991, p. 59.

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