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MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2010 May 14 at $16^h\ 00^m$
in the Geological Society Lecture Theatre, Burlington House

R. L. DAVIES, *President*
in the Chair

The President. It's my sad duty to announce the deaths of the following: Sir Ian Axford died on March 30 this year — he was awarded the Chapman Medal in 1994, and was Director of the Max Planck Institute for Solar System Research in Germany for 16 years; Professor Sidney 'Ben' Gascoigne, professor of astronomy at the Australian National University in Canberra from 1964 to 1980, died on March 24 — he was made an Honorary Fellow of the Society in 1982; Professor Chushiro Hayashi of Kyoto University, deviser of the 'Hayashi tracks', died on February 28 — he was awarded the Society's Eddington Medal in 1970 and was elected an Honorary Fellow of the Society in 1981; and Professor Henry Rishbeth of the University of Southampton died on March 23 — he was a former Vice-President of the Society, and was awarded the Society's Gold Medal in 2001. I ask you to stand for a moment to remember those colleagues.

On to this afternoon's programme: I shall introduce the first talk, but not attempt to pronounce the title, except to say that Peter Sammonds of UCL's Institute for Risk and Disaster Reduction will speak on volcanic eruptions in Iceland [laughter].

Professor P. Sammonds. Thank you for the invitation — a month ago people didn't even know where Eyjafjallajökull was, let alone how to pronounce it! [Laughter.]

The explosive eruption on 2010 April 14 of the Eyjafjallajökull volcano, Iceland, caused an unprecedented closure of UK, European, and North Atlantic air space, which must be understood if similar situations are to be managed better in the future. I have been examining the Eyjafjallajökull eruption, its impact on aviation, and implications for the future, in the expectation of further activity in Iceland; and attempting to provide an integrated analysis covering volcanology, geophysics, rock and ice physics, meteorology, statistics, mechanical engineering, systems engineering, transport engineering, hazard and risk communication, law, and ethics, drawing on opinion from colleagues in the UCL Institute for Risk and Disaster Reduction.

The current volcanic activity in Iceland is not unusual. Explosive eruptions, comparable to the 2010 Eyjafjallajökull event, occur in Iceland every 20 to 40 years on average. The 1821–23 Eyjafjallajökull eruption lasted 14 months. Volcanic activity at Eyjafjallajökull only becomes a major problem over Europe if this activity is coincident with north to north-westerly air flow between Iceland and North West Europe, which prevails for only 6% of the time. The implication, however, is that the most recent disruption of air transport in mid-May may not be the last, despite the current cessation of ash production.

The impact of the eruption on regional air space could have been predicted and better prepared for as the growing problem of aircraft–ash-cloud encounters has been recognized for decades. Similarly, the potential for ash clouds, specifically from Icelandic volcanoes, to interfere with air traffic in UK, European, and North Atlantic air-space was appreciated by the aviation industry well before the start of the Eyjafjallajökull eruption. The response to the ash cloud's arrival in UK and adjacent air space was entirely reactive and therefore less effective than it should have been. This was primarily a function of the failure to recognize in advance the potential threat presented by volcanic ash clouds from Iceland. The situation was made worse by the inflexible nature of existing aviation protocols and by the absence of any pre-existing agreement on safe ash levels.

Volcanic ash in the atmosphere can be highly damaging to the airframes, avionics, and engines of civil jet aircraft: ingestion by engines of 2 $g m^{-3}$ of ash has in the past caused loss of power and near-crashes. The newly defined safe limits of ash are *ad hoc* and arbitrary and cannot be scientifically justified. Determining a range of robust best-estimate safe levels of ash for a wide range of situations, aircraft, engine types, and pilot responses will cost time and money and will require the commitment of the aviation industry.

Since the start of the Eyjafjallajökull eruption there has been much speculation about an eruption of the larger neighbouring Katla volcano. With the high frequency of eruptions of Katla, an eruption in the short term is a strong possibility. It is likely to be preceded by new earthquake activity, but presently there is no unusual seismic activity under Katla.

There is no doubt that future explosive eruptions in Iceland and elsewhere, coupled with appropriate meteorological conditions, have the potential to cause further disruption to air transport. It is not possible, however, to predict either when this will occur, or at what scale. The Eyjafjallajökull eruption has demonstrated the limits of a precautionary approach. This then raises ethical issues, over who is to articulate the values to be taken into account when managing risk.

The President. I am sure there are lots of questions.

Mr. M. F. Osmaston. Geo-mechanically, is it suspected that there is a ridge jump happening from the Reykjanes Ridge to here?

Professor Sammonds. I'm afraid I don't know. All I have been looking at was a very localized expansion of the dome of Katla and Eyjafjallajökull.

Mr. M. Hepburn. Most of my friends seem to have terrible hacking coughs at the moment; is that likely to be due to the ash?

Professor Sammonds. The public health agency did put out a warning to people not to go out. I have been trying to get some health experts at UCL involved in this but they have only commented that there seems to be no health risk from the very dilute levels of ash that we have.

Mr. H. Regnart. According to *The Observer*, there was a meeting arranged to discuss the issue of when it was safe to fly and what criteria should be used, about one or two years ago, and apparently airline representatives were invited but did not attend.

Professor Sammonds. This has been going on for ten years, to try and get a recognized limit; in fact there was a meeting, I think, that finished just a few days before the eruption of Eyjafjallajökull, where there was no agreement reached. There is clearly an inhibition on the part of aircraft manufacturers to say what is safe and what is not. In a sense, they have taken a precautionary approach, which has proven to be a false one.

Dr. P. Wheat. It seemed to be quite some time before research aircraft took off; were there any tethered or un-tethered weather balloons put up to sample the ash clouds?

Professor Sammonds. I think a weather balloon went up at Stranraer on the Saturday, but this was also quite late — I heard a story of someone trying to get onto a military flight to Scotland, but they were not allowed on because they were a civilian, and had to travel up with a police escort! There have obviously been insufficient measurements, but there have been ground-based measurements. As to the aircraft themselves, I understand the Met. Office aircraft was out of action and they had to use the NERC aircraft, and that took up to a day or so to get flight-worthy; and when it did fly, it could not go higher than some 15 000 feet. I know these are real issues, and we weren't very well set up for sampling the ash cloud.

Dr. Wheat. You could pre-position them now and be ready for the next one.

Professor Sammonds. I think that is right. If there is a new phase of volcanism and there really is a chance that Mount Katla is going to erupt, these sampling régimes need to be in place. There is also another question as to how much sampling one needs to do, and statisticians are beginning to look at that, but it is not an easy question, since it has to be tied in with the design of engines, *etc*.

Professor Monica Grady. The Met. Office modelling received a lot of criticism at the time. Are there other European met. offices refining their models all together to improve them? You've shown the work of the Barcelona supercomputer.

Professor Sammonds. Well, the Met. Office, in their defence, uses an internationally recognized model for this. Yes, more sophisticated models are needed and obviously these do exist, but I do not know whether they have the input data to process that in sufficient time.

The President. Thank you very much. [Applause.] The next speaker is Foteini Lykou from Jodrell Bank, and she is going to speak about 'Discs around evolved stars and high angular resolution'.

Ms. Foteini Lykou. Evolved stars are giant dust factories. The dust is created in the outskirts of stellar envelopes and is driven outward by stellar winds, which can expel up to $10^{-4}\ M_{\odot}\ \mathrm{yr}^{-1}$ from a star. Eventually, a star may lose 20–80% of its mass, forming a nebula that is sequentially ionized by the remaining hot stellar core. Thousands of years later, the gaseous and dusty products/ejecta are dispelled into the surrounding interstellar medium (ISM), thus enriching the Galaxy with new materials.

The stellar ejecta, interestingly, form round, bipolar/multipolar, or irregular nebulae. The transition from a round, symmetric structure, like a star, into an asymmetric one is not fully understood. The suggested shaping mechanisms are magnetic fields and binary interactions, such as tidal forces and common-envelope evolution for the latter. It is important to note that most angular momentum is held in binary orbits (*e.g.*, Solar System planetary orbits), and not in stellar rotation, which of course diminishes during stellar mass loss.

Apart from nebulae, the ejecta include dusty (and gaseous) structures that surround the stellar remnants along the equatorial/orbital planes in the form of discs, tori, or spirals. Their rôle in shaping and collimating bipolar outflows can be important, as was suggested by theoreticians in the 1980s. Yet the size of such structures is rather small, approximately a thousand times smaller than the size of a nebula, and they cannot be resolved by single-mirrored infrared telescopes. Infrared interferometry presented us with a solution to that problem by reaching resolutions as high as a few milli-arcseconds. For example, an interferometer similar to the *Very Large Telescope Interferometer* (*VLTI*, in Chile), situated 1 kpc away from us, would be able to resolve our Solar System. An interferometer is basically a 'telescope' comprising an array of individual single-dish telescopes, whose maximum separation, or baseline, gives us the interferometer's diameter. Its product is called the visibility, which is the Fourier transform of the brightness function of the observed target.

In order to observe dusty structures around evolved stars, we have used the mid-infrared-recombiner (*MIDI*) instrument of the *VLTI*. Flat-like structures can be inferred from the spectrally dispersed visibilities and they are resolved in many cases. In more detail, a visibility lies within a range of zero to one, the former showing a dense/large structure, the latter a thin/small structure. Covering as many position angles on the sky as possible with the projected baselines, we see how the dusty structure in the nebular cores becomes larger as we progress from the polar direction to the equator. Images and geometric properties of those dusty structures can be recovered with radiative-transfer codes.

Menzel 3 is an elongated, bipolar planetary nebula with a complex gaseous structure and a pinched waist with high infrared excess. With the use of *MIDI* we have detected a predicted disc composed of amorphous silicates that has survived gas expansion in the system. It extends from 9 to 500 AU from the central heating source and its mass is 3 $M_\oplus$.

M2–9 is another elongated, bipolar nebula and a spectrophotometric twin of Menzel 3. A binary system (a red giant and a white dwarf) resides in its core, as is inferred by the orbiting-lighthouse-beam effect in its lobes (period approximately 100 years). *MIDI* gave us the first detection of an amorphous and crystalline silicate disc in the core of M2–9. The disc (15–900 AU and 5·5 $M_\oplus$) is still evolving due to the binary interactions.

Sakurai's Object was a star that underwent a very-late-thermal-pulse (VLTP) eruption; that is, a helium flash (thermal pulse) occurred in the degenerate, pre-white dwarf at the centre of a 10 000-year-old, round planetary nebula, returning the star back to the red-giant phase. The event was observed in 1996 by an amateur astronomer (Yukio Sakurai) and has been monitored ever since. The star has been hidden behind a dusty cocoon since 2002. This cocoon has altered in shape and is expanding radially, but the dust is not replenished. A dusty structure was detected with *MIDI* in 2007. Its size is 65–500 AU (larger than our Solar System) and 20 $M_\oplus$ of amorphous carbon is stored within. We have also found an alignment between the position angle of the disc and a density enhancement in the old planetary nebula, suggesting that the same mechanism has shaped both structures. Whether that happened due to a binary system, a fast-rotating stellar core, or accretion from a pre-existing debris disc is not fully understood, since the star is still hidden within the thick, dusty structure.

MIDI has given us three disc detections for three objects at different evolutionary stages. Another project is currently under development: observing a large sample of evolved stars from the red-giant phase to very-late-thermal-pulse phase with 'single-telescope interferometry'. Instead of using an array of telescopes, we have used masks to convert a single, 8·2-m telescope into an interferometer. A 2-cm-diameter flat disc is placed at the pupil plane and its predefined holes act as apertures with baselines ranging between 0·5 and 8 metres. This technique, called aperture masking, is fast, gives good sky coverage, and diffraction-limited images. Recovered data are still being processed.

Infrared interferometry has allowed us to detect and thus confirm the existence of discs around stars at different evolutionary stages from the AGB (V Hya) to VLTP (Sakurai's Object). There seems to be a strong connection between mass loss, shaping mechanisms, and disc creation. It can be suggested that such discs are by-products of the long-lived shaping mechanisms. These structures can survive and evolve (M2–9) near hostile, UV-irradiated environments, and eventually they replenish the Galaxy with their dust.

The President. It is tremendous to see that the *VLTI* is doing such exciting science. Any questions?

Dr. I. A. Crawford. You made a final comment about asteroids — is it not possible to have a remnant of a planetary system as the origin of these discs?

Ms. Lykou. Maybe, if they actually survived for billions of years, which is the evolutionary time on the main sequence — say 10 billion years.

Dr. Crawford. So when the star leaves the main sequence, what happens to the planetary system? Some of it may get turned into dust.

Ms. Lykou. Well, let's say that in the case of our own Solar System, some of the inner planets will be absorbed by the Sun as it becomes larger; the outer planets will probably still be there. There is a possibility of their being driven away, or there is another scenario where Jupiter will come closer to the Sun itself. But those discs are usually very compact dusty structures and our Solar System is not so dense in terms of what I showed you for evolved stars.

Professor Grady. Do you see silicon carbide in any of these dusts, or other compounds that we find in meteorites and may come from evolved stars?

Ms. Lykou. Silicon carbide has been observed in stars, but in these particular discs, the answer is no, we haven't seen it.

Professor Grady. Can you compare the dust that you are seeing to the dust round newly forming stars? Do you see much difference in composition?

Ms. Lykou. No, not so much; but there are different kind of discs since discs around new stars are smaller in size and eventually most of the material is driven away and you are left with a planetary system.

Professor M. Barstow. There is quite a lot of evidence growing about discs around white dwarfs, particularly from observations with *Spitzer*, and also the fact that white dwarfs might be accumulating material from debris surrounding them. Are these the same discs, do you think?

Ms. Lykou. Yes, Sakurai's Object could be an example of this. There have been some recent models giving the idea that one has a debris disc around a white dwarf, that material can fall onto the star, and you have the eruption; this can become a red giant later on. So yes, it is possible, but we do need to prove it.

The President. Thank you very much. [Applause.] Our next speaker is John Armstrong from Weber State University, on 'Sixty minutes to near space: high-altitude ballooning with applications in geology, astrobiology, and astronomy'.

Dr. J. Armstrong. Weber State's *High Altitude Reconnaissance Balloon for Outreach and Research* (*HARBOR*) is a near-space platform for delivering student-built science and engineering projects to altitudes above 100 000 ft. Our basic flight system, based on the successful BOREALIS programme at Montana

State University, consists of one or more payload boxes attached to a parachute which is, in turn, connected to a high-altitude weather balloon. A redundant system of GPS receivers and ham-radio transmitters sends telemetry to a chase team on the ground. The complete system includes a small digital camera, and pressure and temperature sensors that characterize the environmental conditions of the flight.

These environmental conditions, at times similar to those on Mars, provide students with an opportunity to engineer robust instruments that can survive extreme conditions. Flight instruments must withstand extreme changes in temperature (+30° C to –30° C during flight) and pressures as low as 0·01 atmospheres. The instruments must also be automated or controlled remotely. A mass limit of 12 lbs, set by United States FAA regulations, as well as the limited power that such restrictions imply, impose additional design constraints. The system also requires pre-flight testing, documentation, and flight checklists.

The result is a real-life experience in science and engineering that emulates the type of mission-driven design processes found in the space-flight industry.

Space flight is one of the most exciting applications of science and engineering. It's also expensive, challenging, and often dangerous. How can we leverage the excitement of space flight in a learning environment where people are expected to make mistakes? In this context, there are several virtues to high-altitude ballooning.

Firstly, it's cheap: a basic payload-delivery system, including off-the-shelf radio, GPS, and camera components, can be developed for only a few thousand dollars. Additional flight costs are determined by expendables (batteries, helium, and the flight balloon) as well as transportation costs, which taken together are typically below $500 per flight.

For example, the *HARBOR* flight system contains a *Command and Telemetry System* (*CATS*) built with a Garmin GPS 15LW chip receiver and antenna coupled to a Microtrak 8000 2-metre FM transmitter. *CATS* also controls a modified Nikon CoolPix digital camera. These are assembled with some custom-built timing circuitry and project boxes for approximately $500. A redundant system (the *Balloon Auxiliary Telemetry System*, or *BATS*) is assembled minus the camera for $350.

The addition of the parachute, ham antennas, payload boxes, custom box bags, line, and custom-built cut-down system brings the total to $1500. This leaves room in the budget for instruments to characterize the payload environment, including a Pace scientific XR440 Pocket Logger with multiple pressure and temperature sensors. The entire base flight system, including instruments, boxes, and parachute, weighs less than 8 lbs.

Given the modest cost, it is a useful exercise (and usually necessary) to build under a tight budget. This provides a realistic experience for students involved in the design process. They must determine which systems must be redundant, where they can 'splurge' on off-the-shelf components, and when to save money by making their own custom components.

Of course, if money is no object, the sky's the limit. Improvements can include a custom panoramic camera, an infrared camera, several additional sensors to determine the orientation of the stack during flight, and video capabilities. This is a primary advantage of high-altitude ballooning: since the payload is recoverable, additional improvements are relatively inexpensive and rarely require a major re-design of the flight system. The *HARBOR* team has several extensions to our basic design under development, in the testing phase, or ready for the next flight season.

It's also quick: the total flight duration is from one to four hours, governed by the ascent rate and burst height of the balloon. Even including time for setup and recovery, flight operations can be completed in a day. Provided the recovery was successful and more expendables are on hand, the flight turnaround is nearly immediate. This combination of short flight duration and rapid turnaround provides for an accelerated design cycle, encouraging students to design, fly, modify, and fly again.

This rapid turn-around also makes the high-altitude balloon platform perfect for 'guest payloads'. These can be parts or instruments that need to be tested in a real-world, extreme environment, or payloads provided by school or community groups interested in sending items to near-space.

Finally, it's accessible: since the flight-line duties include basic operations (such as holding the balloon or stabilizing the stack), new team members with developing skills can participate in the excitement of a launch with limited knowledge. As such, the flight team can involve new university students, younger students through school-outreach programmes, and local participants in the launch. And, since flight tracks are captured on-line, the progress of the flight can be monitored remotely.

Community outreach is an automatic outcome of the flight experience. In our case, one call to Duchesne Mayor Clint Park resulted in several dozen participants and spectators from the community. The extensive flight preparations of laying out the flight stack, readying the equipment, and filling the balloon always sparks interest. In fact, the *HARBOR* team periodically holds test-fills and tethered launches with the express purpose of attracting a crowd.

Perhaps most importantly, the activity is specifically allowed by the FAA, governed by section 101 of the Federal Aviation Regulations. As such, ballooning under these guidelines requires no additional permission. Guidelines for filing a Notice to Airmen (NOTAM) and communicating with the FAA are readily available.

The *HARBOR* programme provides students with more than a flight experience. To ensure success, flight systems must be well designed, rigorously tested, and well documented. Students in the programme come out with an exceptional skill set. Our students learn to work collaboratively, relying on other teams to complete essential tasks critical to the success of their own work. Students hone skills in design and time management. They learn how to anticipate problems before they occur, solving unforeseen problems on the fly.

We know the importance of science and technology in our society, and hear about the dearth of highly skilled scientists and engineers. By participating in hands-on, real-world design projects, students gain technical skills and collaborative abilities that make them indispensable in the workplace. High-altitude ballooning is another avenue for students interested in science and engineering to gain this experience, while developing critical mission-planning skills, and having a good time doing it.

A Fellow. Most of your flights have got to just under 100 000 feet. Is that about the limit to how high you can go?

Dr. Armstrong. No, in fact the record is 128 000 feet, currently held by Cornell. I was so happy with the video footage we had recorded, pointing up at the balloon: what the students found was brilliant, and you can see this — we fly in sunny weather and the Sun is focussed through one half of the balloon to a very sharp image on the other half. I think what is going on is that the latex is surviving until it is heated to the point that the balloon bursts, because of this image from the Sun. The balloon rotates around so it takes a little time, but this

100 000 ft seems to be a hard limit for the season we are flying in. We are trying to fly some earlier flights, in April and May, to see if we can get higher. We've got some early-morning flights planned to see if we can get up there before the Sun is too high, so we'll see what happens.

Dr. G. Q. G. Stanley. I've always been intrigued by this kind of effort, but the one thing which stops one here is the problem of landing on a motorway or something. It is not so much the damage to the package, but the paperwork thereafter: we don't like paperwork! How have you handled the possibility of something untoward happening?

Dr. Armstrong. Our students analyse the flight range for a number of difficulties. One thing they look at is to make sure we are outside any major flight paths, because it is one thing to wreck someone's BMW, it is another thing to bring down someone's jet-liner. We fly in an area with very few aircraft. The second thing is that we fly in an area with very few roads, and it becomes a sort of statistical exercise: if you think about landing in a region where you have 30 square kilometres to land in and there is one road going through, the chances of hitting that road are very slim. Additionally, the area in which we fly has very little traffic. I do know some people who fly outside Chicago, who are on the east coast, and I don't understand how they do it; I wouldn't do it. I think you need to land in a place that is relatively unpopulated, which is why we chose the area that we fly in.

Dr. A. Chapman. Just as a point of information: the earliest very-high-altitude flight that was actually manned was, of course, James Glaisher in 1862, which reached 37 000 feet above Wolverhampton in an open balloon with 17 meteorological instruments, and he and the pilot survived. He mentioned the sky darkening.

Dr. Armstrong. My students have suggested we try something similar. They really want to go up; I told them "No! I'm not going to do that!" [Laughter.]

Dr. S. Mitton. I'm interested in the astrobiology applications, because there have been organisms recovered from heights of, I think, a little over 40 km. Those flights were done by astrobiologists who wanted to show that organisms are coming in from space, and so they were not widely accepted. I think in your work, what would be interesting would be to investigate what is the profile of biological material and how is it getting to those altitudes?

Dr. Armstrong. Yes, that is exactly what one student is working on with this dust sampling. Micro-organisms are entrained on dust, there are micro-organisms in the dust column, and I think that we need to know what these are — you may find organisms up to a certain altitude and then you don't find any, and suddenly you get more at 40 km, and somebody might say they think they are coming from space. I don't think that is the case; I know the report you are talking about, and I suspect they were blown off the top of Mount Everest or something similar. But we have a plan to sample dust and we will try it. Now the question is, can we sample quickly enough to get enough to culture anything? I don't know. Those were long-duration flights — they were up there for weeks at a time.

Dr. Mitton. Yes, and if you are spending $1000, you are going to have problems of really protecting against contaminants.

Dr. Armstrong. And I should point out that while we *can* fly for $1000, we would like to get a lot more money to do this. Our dust-monitoring grant for this year is $25 000. You can get up there for $1000; to do something significant, you need a research budget. But you know, that's how you get funded: you get up there and make a start.

Professor Kathy A. Whaler. Could you tell us a little about the geomorphological studies?

Dr. Armstrong. In one of our projects in southern Utah, we have a geoscience professor who looks at the formation of hoodoos — those strange-looking rock-column structures that occur in southern Utah. The problem is that the regions where they occur are not very accessible, and you have to hike in for days, you cannot really drive there; so, they usually fly over with aircraft. What we are attempting to do this summer is to tether a balloon at a certain altitude, and we have to get waivers from the FAA to do this. And then we want to see if we can control the balloon enough actually to take repeated imagery at the same resolution as a low-flying aircraft. It would be significantly less expensive if we could manage to do this.

Professor Whaler. What kind of altitude would you tether up to?

Dr. Armstrong. Not much more than 1000 feet. It's very rural, so it should not be a big deal, but the FAA has pretty strict rules; we can do anything we want, providing they clear it, and we are working with them on that. It would be a low-altitude tether; in fact some people are even suggesting we use a blimp rather than a helium balloon.

The President. Thank you again. [Applause.] Our final speaker this afternoon is Everett Gibson, from the Astromaterial Research Office at Johnson Space Center, and he is going to be speaking on 'Life on Mars hypothesis: the status of research on ALH84001'.

Dr. E. K. Gibson. In 1996 our research team published in *Science* the manuscript 'Search for past life on Mars: possible relic biogenic activity in Martian meteorite ALH84001', which presented a suite of characteristics related in space and time, all of which could be explained by the hypothesis that the features were formed by microbes early in Martian history. These observations included the presence of chemically-zoned carbonates precipitated from water in cracks opening into the meteorite, morphological forms similar to known terrestrial biomorphs (*i.e.*, microfossils), reduced organic compounds in the form of polycyclic aromatic hydrocarbons (PAHs) associated with the carbonates, and, embedded within the carbonates, nanophase magnetites which closely resembled those produced from magnetotactic bacteria on Earth. Because of the spatial relationship of the four characteristics, our team offered a single hypothesis that all of these features were formed or assisted by the activity of early Martian microbes. This suite of features taken together provided the possible evidence for the biogenic hypothesis. Note that no single feature was either definitive for biology, or conversely, that showing that no single feature was definitely produced by non-biogenic processes would invalidate the hypothesis, although it would clearly weaken it.

The Martian meteorite ALH84001 preserves evidence of interaction with aqueous fluids while on Mars in the form of microscopic carbonate discs. These carbonate discs were precipitated 3·9 Ga ago at beginning of the Noachian epoch on Mars during which both the oldest extant Martian surfaces were formed, and perhaps the earliest global oceans. Intimately associated within and throughout these carbonate discs are nanocrystal magnetites (Fe_3O_4) with unusual chemical and physical properties, whose origins have become the source of considerable debate.

A number of early objections to our hypothesis were made at meetings and in publications. Among those objections were: the carbonate globules formed at high temperature by volcanic or impact processes on Mars; the meteorite was contaminated in Antarctica; carbonates were formed in Antarctica; PAHs were deposited from Antarctic melt water; magnetites were from terrestrial sources such as wind-blown dust; magnetotactic bacteria would not develop on Mars because Mars had no magnetic field; the 'microfossils' were coating artifacts added during preparation for SEM studies; or the microfossils were too small to be the remnants of biogenic activity.

Our team addressed virtually all of these objections in published rebuttals and papers. In addition, some of the earliest criticisms were essentially retracted by more careful analysis of the available data. For example, one of the earliest criticisms was that the carbonates were formed at high temperatures (600–900° C). If true, this would rule out microbial involvement and seriously weaken our hypothesis. Those papers were given wide play in the media and in some scientific meetings. The consensus began to develop that we had been discredited. The same authors later published papers supporting a low-temperature aqueous precipitation hypothesis for the carbonates and did a complete reversal from their earlier interpretation of the carbonates. Although this complete turnaround received no press publicity, the majority of scientific papers published in the past ten years now accept that carbonates formed on Mars at low-temperature by precipitation from water, consistent with our original hypothesis.

Terrestrial contamination was another issue. However, detailed oxygen-isotope studies proved that the carbonates formed on Mars, not in Antarctica. Careful searches for PAHs in Antarctic melt waters near the collection site failed to find detectable PAHs, casting doubt on the hypothesis that they resulted from terrestrial contamination. Laboratory results showed that PAHs are relatively insoluble in water and would not be concentrated in carbonates by melt water. It is now generally accepted that the PAHs in ALH84001 are of Martian origin.

Similarly, if the carbonates are Martian, the completely embedded magnetites must also be Martian. No mechanism has been proposed to embed terrestrial magnetite in the Martian carbonates. Since the magnetites have not been oxidized to maghaemite or haematite by exposure to oxygen in the Earth's atmosphere, these reduced iron oxides were formed on Mars and incorporated into the carbonates at around 3·9 Ga ago. One objection to the hypothesis that the magnetites were produced by Martian magnetotactic bacteria is that Mars did not have a global magnetic field, thought to be a requirement for bacteria to develop magnetic inclusions within their cells. However, after the original paper was published, mapping of the Martian surface by orbiting spacecraft revealed that early crustal rocks did have strong remnant magnetism which could only be explained if Mars had an early strong magnetic field, now gone.

While some researchers have supported our biogenic hypothesis for the origin of many of the magnetites, a number of researchers have proposed an alternative hypothesis: that the magnetite was formed totally non-biologically by thermal decomposition of the iron-rich carbonate during or following an impact shock or heating event. This alternative non-biological hypothesis has been used for the past decade as the primary argument against our hypothesis. In a recent paper, we have now addressed this alternative hypothesis in detail and have shown that it cannot explain the pure chemistry of most of the magnetites and their lack of other cations such as Mn and Mg considering that the surrounding carbonate is mostly a mixed carbonate containing Mg, Mn, and Ca as well as Fe. Virtually all laboratory studies have shown that thermal decomposition of a mixed carbonate produces a mixed-composition spinel (magnetite), not the pure Fe magnetite common in the ALH84001 carbonates.

Two heating scenarios presented by investigators have been proposed for the formation of the magnetites from decomposition of iron-bearing carbonates. The geological context for the decomposition models developed independently by Brearley and Treiman have been critically evaluated by our team and found not to be applicable for the formation of the unique magnetites within ALH84001's carbonate globules. These models are contradictory; that is, they cannot both have occurred since application of one model negates the applicability of the other. The first is based on carbonate decomposition occurring under "extreme disequilibrium conditions" in which "kinetics are the dominant controlling factor" determining the chemical and physical nature of the magnetites that are formed. Although never explicitly addressed, this model is most consistent with the impact event that ejected ALH84001 from Mars. In the Treiman model, carbonate decomposition occurs "at some depth beneath the Martian surface where the pressure was greater than the atmospheric pressure and the temperature declined slowly." However, on the basis of kinetic and thermodynamic arguments, both models proposed for the high-temperature, inorganic formation of ALH84001 magnetite would not have produced the results observed in ALH84001 carbonate discs.

Our recent paper shows that pure Fe magnetite is completely embedded in all existing carbonate compositions within ALH84001 including the pure Mg carbonate, magnesite. We conclude that the nanophase pure Fe magnetites in this meteorite could not have been made by thermal or shock decomposition of the carbonate and therefore these magnetites had a separate origin not directly related to the carbonates. Our original hypothesis, that they were produced by Martian magnetotactic bacteria and introduced and trapped in the precipitating carbonate pancakes, remains a viable explanation. The unique properties of these magnetites (elongated along the c-axis, single-domain grain size, extremely pure Fe oxide, tightly sorted grain-size distribution) remains a suite of properties absolutely unique to magnetotactic magnetites on Earth. This suite of properties has been used for decades as certain biosignatures when found in terrestrial sediments or water. Application of this biosignature concept to the Martian magnetites remains a viable and credible approach.

ALH84001 carbonate assemblages can be best explained as the result of low-temperature, disequilibrium precipitation from a single fluid with variable composition or from multiple fluids. Nanophase magnetite and Fe-sulphides were suspended in the fluids that formed the disc cores and rims. After deposition, ALH84001 carbonate discs were exposed to multiple fluids containing amorphous silica, additional nanophase magnetite, and S- and Fe-rich phases, some of which were deposited in veins. While the majority of ALH84001 magnetites were deposited in silica-enriched rims and veins, some are also distributed throughout the cores and within the magnesite bands. Most magnetites are chemically pure, although a few contain minor Al/Cr. Their presence is inconsistent with formation by thermal decomposition of their host carbonate. We suggest that the majority of ALH84001 magnetites have an allochthonous origin and were added to the carbonate system from an outside source. This origin does not exclude the possibility that a fraction is consistent with formation by biogenic processes, as proposed in our previous studies.

In 2001, Gibson *et al.* reviewed the requirements for proof of life on the Earth and found eight criteria are required. For a geological sample to be accepted as a possible representative of early life on the Earth a majority of the following criteria must be known. The geological context of the sample must be understood. Do we know the age and history of the sample? Are there any cellular morphologies present within the sample? Do associated biofilms and microbial colonies exist within the sample? Does the sample contain representative biominerals or evidence of chemical disequilibria? Are the isotopic signatures of the biogenic elements compatible with biogenic activity, and are there significant organic biomarkers or components present in the sample? And finally, are the features indigenous to the sample?

For ALH84001, we know the sample is from Mars because the oxygen isotopic composition of the silicates is identical to that of other meteorites known to be from Mars along with them containing trace levels of Martian atmospheric gases. The crystallization age of the ALH84001 silicates is 4·09 Ga and the carbonates were formed at 3·9 Ga. At that period of Martian history, the early magnetic field on the planet was still present. Within the ALH84001 carbonates, biomorphs with segmented structures are present.

When we compare the number of features required for life to be recognized within a geological sample with those observed in the ALH84001 and other Martian meteorites, it is obvious that a majority of the criteria required for acceptance of life in a geological sample have been met. Because the samples are from another planet (*i.e.*, Mars), we must take the extra step and be extremely cautious in positively identifying the signatures of life from another body in our Solar System. However, the lack of absolute smoking-gun evidence must not negate the weight of many kinds of supporting positive evidence.

Dr. Stanley. I am pleased to say that I was at the RAS meeting where you spoke 13 years ago. Over those 13 years, what was the thing which really convinced you there was evidence for life on Mars, and took away any doubt; or were you always convinced?

Dr. Gibson. I was convinced in late 1995, early 1996, when things started coming together. What is the evidence? I think our work on the magnetite is beginning to convert a lot of critics. Some samples we have are still waiting for the right analytical techniques. I'll give you one example: when we dissolved this rock in 1993–94, we had an organic thin-film residue in the bottom of the little vial we had used to dissolve the carbonate; the post-doc we had working with us came out of the microbial-mediated carbonate field, and he said "Everett, if I didn't know better, I would think there was biology operating, because I see the organic residues as if from organisms here." Things like that began to come together — perhaps that was contamination, we had to rule that out, we still have to keep an open mind on that; but the evidence of the magnetite is what really drove us.

Mr. Regnart. I understand how knowledge of the relatively recent and current Martian atmosphere and results of probes identifying materials on the surface could enable you to identify some meteorites as having come from Mars, but what about those meteorites that you reckon were ejected from Mars very long ago? How are you able to say uniquely that those have to come from Mars?

Dr. Gibson. There is the evidence of the noble gases not changing in composition over geological time, but most importantly, the oxygen reservoir that is seen on Mars is unique — the oxygen-isotope composition which goes all the way back to the time of the formation of Mars.

The President. If there are no more questions, it is time to bring this to a conclusion, so let's thank our speaker again. [Applause.]

We've had four very memorable talks this afternoon; I just need to remind you that there is a drinks party following this meeting in the RAS library across the courtyard. I'll bring this meeting to a close and inform you that our next ordinary meeting is on Friday, October 8. I hope you all have a great summer.

SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 215: HD 105074, HD 105182, HD 108613, AND HD 115445

By R. F. Griffin
Cambridge Observatories

Orbits are given for four more of the binaries discovered in the Yoss/Griffin radial-velocity survey of all the late-type *HD* stars north of Galactic latitude $b = 75°$. The orbits all have quite long periods by the standards of spectroscopic binaries — they are about 7, 10, 24, and 12 years, respectively — and they are all of moderate eccentricities.

Introduction

The stars treated in this paper are all unobtrusive objects near the North Galactic Pole (NGP). Rather little is known about them, and still less is retrievable from the *Simbad* bibliographies, which systematically omit the paper[1] by Yoss and the writer in which the basic data, reproduced here in Table I for the objects of immediate interest, are given for nearly a thousand stars. It should be mentioned that the spectral types given in the survey are not classified from actual spectra but are inferred from narrow-band photometry, as are the luminosities.

TABLE I

NGP Survey[1] results for the four stars

Star	*V* *m*	*(B–V)* *m*	*Type*	M_V *m*	*z* *pc*
HD 105074	9·69	0·93	K3V	+6·5	43
HD 105182	8·26	1·34	K4 III	+1·4	232
HD 108613	9·71	1·54	K5 III–IV	+1·0	535
HD 115445	9·57	0·92	G8 III	+1·6	381

HD 105074 and 105182 are in the north-preceding corner of Coma, the latter star particularly being very close to the boundary with Ursa Major; they are on the outskirts of the Coma Cluster, although they are not actual members of it. HD 108613 and HD 115445 are near the southern boundary of Coma; the former is projected against the background of the Coma (actually Coma/Virgo) cluster of galaxies, near M88, while the latter is further to the east, about 3° south-following α Comae.

HD 105074

UBV photometry of HD 105074 has been given by Sturch & Helfer[2], as $V = 9^{m}\cdot65$, $(B-V) = 0^{m}\cdot935$, $(U-B) = 0^{m}\cdot693$. Those authors also measured the *R* and *I* bands, and reckoned that they could obtain luminosities and metallicities just from their broad-band photometry; for HD 105074 they gave $M_V = +1^{m}\cdot4$ and [Fe/H] = +0·05. It remains for the future to resolve the discrepancy in luminosity, by a factor of more than 100, between the ideas of

Yoss & Griffin[1] on the one hand and of Sturch & Helfer[2] on the other! Upgren[3] found a spectral type of G9 IV, classified from objective-prism spectra; in his listing there is a large dot after some of the types, including that of HD 105074, but its significance does not seem to be explained. There is an implication in the text of his paper that both the type and the luminosity class given for HD 105074 are averages of multiple classifications, because it appears that the grid of classified types included G8 and K0 but not G9, and luminosity classes III and V only. Woolley *et al.*[4] reported a classification of K1 IV for HD 105074 from spectra obtained with a prism instrument giving 66 Å mm^{-1} at Hγ on the Kottamia 74-inch telescope. Thus both Upgren and Woolley *et al.* sit on the fence as far as giant/dwarf luminosity adjudication is concerned. Hansen & Radford[5] obtained Copenhagen-style narrow-band photometry[6] of the star; the photometry identified it as a dwarf, but then lacked calibrations to determine any further characteristics except to provide an estimate of the *V* magnitude as $9^{m}\cdot71$.

There are two photographic measurements of the radial velocity of HD 105074 in the literature; they were obtained a few days apart at Kottamia by Woolley *et al.*[4]. The star's velocity was determined photoelectrically by Radford with the original Cambridge spectrometer in 1973 and 1974, but it was not until it was re-observed in 1989 that a significant discrepancy brought to light the fact that the star is a spectroscopic binary. A total of 75 radial-velocity observations has by now been made of it; the contributions of the various spectrometers with which they were made are shown in Table II, which also gives the corresponding information for the other stars treated in this paper.

TABLE II

Sources of radial-velocity measurements of the four stars

Source	*Ref.*	*HD 105074*	*HD 105182*	*HD 108613*	*HD 115445*	*Totals*
Cambridge (old)	7	4	1	10	1	16
Palomar	8	—	1	—	—	1
DAO	9	2	2	2	2	8
OHP	10	21	17	25	25	88
ESO	—	1	—	1	1	3
Cambridge (new)	—	47	49	33	28	157
Totals		75	70	71	57	273

The measurements are set out in Table III. As usual, the OHP and ESO velocities have been increased by 0·8 km s^{-1} from the 'as reduced' values; the same offset has been applied to all the velocities from those sources for the other stars in this paper too. The Cambridge *Coravel* velocities of HD 105074 have been corrected by –0·4 km s^{-1} from the initial reductions. In the solution of the orbit, the observations made with the Cambridge *Coravel* have been given full weight and all the other sources have been weighted ¼, apart from the Kottamia velocities, which were not utilized at all. The orbital elements are listed in Table VIII (below, after the other stars have been described), and the solution is illustrated in Fig. 1.

HD 105182

Häggkvist & Oja[11] have given photometry of HD 105182, $V = 8^{m}\cdot27$, $(B-V) = 1^{m}\cdot34$, in good accord with the survey[1] values. The spectral type, K2 in the *Henry Draper Catalogue*, features also in the *Bergedorfer Spektral-*

TABLE III

Radial-velocity observations of HD 105074

Except as noted, the sources of the observations are as follows:
1989–1998 — OHP Coravel (weight ¼); 1999–2010 — Cambridge Coravel (weight 1)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1967 Mar. 27·82★	39576·82	+14·3	0·047	+4·0
Apr. 7·82★	587·82	9·5	·052	−1·1
1973 Feb. 27·02‡	41740·02	12·4	0·927	+1·5
1974 Mar. 3·12‡	42109·12	12·2	1·077	+0·1
1989 Apr. 30·01	47646·01	17·0	3·329	+0·9
May 1·87	647·87	16·4	·330	+0·3
1990 Jan. 27·11	47918·11	16·3	3·440	0·0
Feb. 12·28§	934·28	15·7	·447	−0·6
Mar. 28·93†	978·93	16·1	·465	−0·2
Apr. 29·93†	48010·93	16·6	·478	+0·3
1991 Jan. 28·10	48284·10	15·7	3·589	−0·4
Feb. 6·10	293·10	16·1	·593	0·0
1992 Apr. 29·88	48741·88	14·9	3·775	0·0
1993 Feb. 15·08	49033·08	11·8	3·894	−0·6
1994 Jan. 5·22	49357·22	9·7	4·025	+0·8
Feb. 19·13	402·13	11·1	·044	+1·0
Apr. 30·93	472·93	11·9	·073	+0·1
Aug. 2·85	566·85	13·7	·111	+0·3
Dec. 12·19	698·19	15·2	·164	+0·5
28·19	714·19	15·3	·171	+0·5
1995 Jan. 3·12	49720·12	13·7	4·173	−1·2
June 2·92	870·92	16·0	·234	c0·4
Dec. 27·14	50078·14	14·5	·319	−1·6
1996 Mar. 29·02	50171·02	15·7	4·356	−0·5
1997 Feb. 8·11¶	50487·11	16·2	4·485	−0·1
Apr. 15·00¶	553·00	16·1	·512	−0·2
July 19·86	648·86	16·6	·551	+0·4
Dec. 24·21	806·21	15·2	·615	−0·8
1998 May 1·90	50934·90	15·8	4·667	0·0
July 25·85	51019·85	14·4	·702	−1·2
1999 Apr. 9·38‖	51277·38	15·4	4·806	+0·9
July 9·25‖	368·25	12·5	·843	−1·3
Dec. 20·21	532·21	11·7	·910	0·0
2000 Jan. 9·13	51552·13	11·6	4·918	+0·2
Feb. 14·04	588·04	10·6	·933	0·0
Mar. 22·02	625·02	9·6	·948	−0·2
May 7·94	671·94	8·4	·967	−0·3
June 6·91	701·91	7·8	·979	−0·4
Nov. 17·24	865·24	10·0	5·046	−0·2
Dec. 14·20	892·20	+10·9	·057	0·0

TABLE III (*concluded*)

Date (UT)		*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
2001	Jan. 6·21	51915·21	+11·5	5·066	0·0
	Feb. 17·11	957·11	12·4	·083	+0·1
	Apr. 28·96	52027·96	13·4	·112	−0·1
	May 29·94	058·94	13·4	·124	−0·4
	Dec. 15·23	258·23	15·1	·205	−0·2
2002	Jan. 18·16	52292·16	15·2	5·219	−0·3
	Mar. 1·08	334·08	14·9	·236	−0·7
	May 1·98	395·98	16·2	·261	+0·4
2003	Jan. 16·18	52655·18	16·2	5·367	0·0
	Mar. 3·02	701·02	16·2	·386	−0·1
	May 7·96	766·96	16·5	·412	+0·2
	Dec. 27·26	53000·26	16·7	·507	+0·4
2004	Feb. 26·11	53061·11	16·1	5·532	−0·2
	Apr. 16·98	111·98	16·3	·553	+0·1
	June 14·93	170·93	16·3	·577	+0·1
	Dec. 27·21	366·21	16·0	·656	+0·2
2005	Mar. 12·11	53441·11	15·6	5·687	−0·1
	May 7·92	497·92	15·4	·710	−0·1
	Dec. 18·22	722·22	14·2	·801	−0·3
2006	Jan. 29·17	53764·17	14·3	5·818	0·0
	Mar. 1·06	795·06	14·7	·831	+0·7
	Apr. 4·04	829·04	13·5	·844	−0·3
	May 10·98	865·98	13·2	·859	−0·2
	June 5·93	891·93	13·3	·870	+0·2
2007	Jan. 14·21	54114·21	9·0	5·960	−0·1
	Feb. 15·12	146·12	9·0	·973	+0·6
	Mar. 22·05	181·05	8·3	·987	+0·3
	Apr. 15·96	205·96	7·9	·998	0·0
	May 22·97	242·97	8·0	6·013	−0·3
	June 21·93	272·93	8·8	·025	−0·1
2008	Apr. 7·99	54563·99	14·7	6·143	+0·4
2009	Mar. 5·07	54895·07	16·5	6·278	+0·6
	Apr. 19·98	940·98	16·0	·297	0·0
	May 28·91	979·91	16·2	·312	+0·1
2010	Mar. 5·08	55260·08	16·8	6·426	+0·5
	Apr. 12·94	298·94	16·1	·442	−0·2
	June 3·91	350·91	+16·5	·463	+0·2

* Photographic data by Woolley *et al.*[4]; wt. 0.
† Observed with original spectrometer; wt. ¼.
‡ Ditto, by G. A. Radford.
§ Observed with ESO *Coravel*; weight ¼.
¶ Observed with Cambridge *Coravel*; weight 1.
‖ Observed with DAO 48-inch telescope; wt. ¼.

Durchmusterung[12] owing to the circumstance that HD 105182 is within Selected Area[13] 56; it is there given as "d::K2" with a note, "Sp var?G8-K5?". Wilson & Joy, in the context of a paper[14] giving the radial velocity as −16·2 ± 1·7 ('probable error') km s^{-1} as the mean from four low-dispersion Mount Wilson plates, put

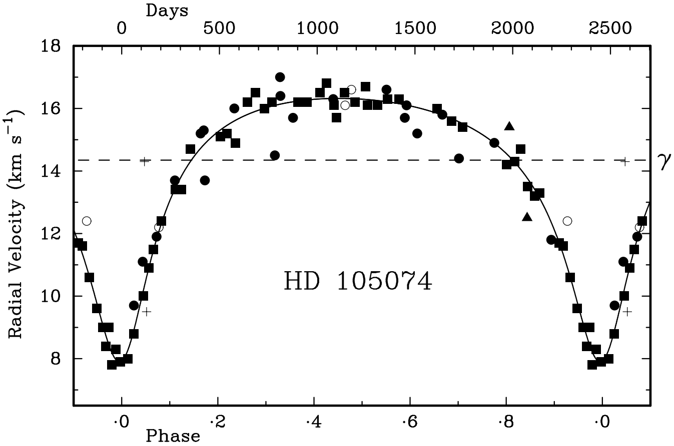

FIG. 1

The observed radial velocities of HD 105074 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. The principal sources of the data are the Cambridge *Coravel* (plotted as filled squares) and the OHP *Coravel* (filled circles; one ESO observation is similarly plotted). There are also four observations made with the original radial-velocity spectrometer at Cambridge (open circles), and two made with the DAO spectrometer (filled triangles). Two Kottamia photographic velocities[4] are plotted as plusses but were not used in the solution of the orbit.

the type of HD 105182 at gK4; the four measurements were later published individually by Abt[15]. Upgren[3] gave the type as K3 III. Like HD 105074, HD 105182 was observed by Hansen & Radford[5], who found it to be a giant with $V = 8^{m}{\cdot}28$, $M_V = 0^{m}{\cdot}0$, and [Fe/H] = +0·07. Analogous data obtained by the same observers at Palomar in 1976 and communicated privately to the present writer gave results of $M_V = +0^{m}{\cdot}2$ and [Fe/H] = –0·01:.

Alone among the stars discussed in this paper (of which it is much the brightest), HD 105182 was observed by *Hipparcos*; the parallax was found to be only 0″·00016, formally indicating a distance modulus of 14 magnitudes. The standard error was given as 0″·00105, yielding a 1-σ lower limit of $9^{m}{\cdot}6$ for the modulus, which would then still suggest an absolute magnitude as bright as $-1^{m}{\cdot}3$. The Hansen & Radford photometric–spectroscopic modulus of about $8^{m}{\cdot}2$ would indicate a parallax of 0″·00229, quite 2σ away from the *Hipparcos* value. Much worse still is the agreement with the survey[1] distance of 232 pc (actually intended to be the *z*-distance but very close to being the actual distance found for the star), which corresponds to a parallax of just over 0″·004. It is to be noticed that the re-reduction of the *Hipparcos* data by van Leeuwen[16] yielded a parallax of 0″·00149 ± 0″·00070, reducing somewhat the discrepancy from π_{sp}. Famaey *et al.*[17], starting from the original *Hipparcos* parallax of 0″·00016, managed to interpret it as implying a distance of 447·8 pc and an $M_V(Hp)$ of $+0^{m}{\cdot}11$ — an achievement that smacks of magic to the present writer despite his efforts to understand the text of the paper[17] concerned. The four-digit precision of the distance, stemming as it does from a parallax that is more than ten times too small to correspond with it and whose standard error is more than six times its own value, is particularly noteworthy.

TABLE IV

Radial-velocity observations of HD 105182

Except as noted, the sources of the observations are as follows:
1989–1998 — OHP Coravel (weight 1); 1999–2010 — Cambridge Coravel (weight 1)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1938 May 14·22[*]	29032·22	−16·8	$\bar{4}$·739	0·0
1939 Apr. 5·36[*]	29358·36	−10·3	$\bar{4}$·831	+6·6
1940 Apr. 19·34[*]	29738·34	−21·7	$\bar{4}$·939	−2·5
May 23·18[*]	772·18	−12·8	·948	+6·9
1971 Feb. 4·09[†]	40986·09	−22·7	0·124	−0·3
1972 Jan. 28·56[‡]	41344·56	−20·4	0·225	+0·1
1989 May 1·00	47647·00	−22·9	2·010	+0·1
1991 Feb. 5·08	48292·08	−21·4	2·193	−0·3
1992 Apr. 29·88	48741·88	−19·1	2·320	+0·2
1993 Feb. 15·08	49033·08	−18·4	2·403	+0·2
Mar. 25·08	071·08	−18·5	·413	0·0
July 8·87	176·87	−18·3	·443	−0·1
Dec. 26·09	347·09	−17·8	·492	+0·1
1994 Feb. 19·15	49402·15	−18·0	2·507	−0·2
Apr. 30·93	472·93	−18·2	·527	−0·5
Dec. 13·17	699·17	−17·8	·591	−0·5
1995 Jan. 3·11	49720·11	−17·1	2·597	+0·2
June 2·92[R]	870·92	−18·0	·640	−0·9
Dec. 27·14[R]	50078·14	−18·0	·699	−1·2
1997 Mar. 28·97[§]	50535·97	−16·5	2·828	+0·4
May 2·91[§]	570·91	−17·3	·838	−0·3
July 19·87	648·87	−17·0	·860	+0·2
Dec. 25·15	807·15	−18·3	·905	−0·3
1998 May 1·90	50934·90	−19·5	2·941	−0·2
July 25·86	51019·86	−20·8	·965	−0·2
1999 Apr. 13·26[¶]	51281·26	−24·2	3·039	−0·6
July 9·25[¶]	368·25	−23·6	·064	−0·1
Dec. 20·20	532·20	−22·6	·110	+0·1
2000 Feb. 14·05	51588·05	−22·7	3·126	−0·4
Apr. 5·94	639·94	−22·1	·141	−0·1
June 6·90	701·90	−21·8	·158	−0·1
Dec. 22·15	900·15	−21·0	·215	−0·3
2001 Jan. 7·18	51916·18	−20·7	3·219	−0·1
Mar. 2·13	970·13	−20·3	·234	+0·1
May 7·97	52036·97	−20·0	·253	+0·1
Dec. 15·23	258·23	−20·0	·316	−0·6
2002 Feb. 4·17	52309·17	−19·1	3·330	+0·1
Apr. 4·01	368·01	−18·7	·347	+0·4
June 1·94	426·94	−18·7	·364	+0·2

TABLE IV (*concluded*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
2003 Jan. 16·19	52655·19	–18·3	3·428	0·0
Mar. 3·03	701·03	–18·2	·441	0·0
May 7·97	766·97	–18·3	·460	–0·2
2004 Jan. 9·19	53013·19	–17·6	3·530	0·0
Mar. 2·12	066·12	–17·8	·545	–0·2
May 18·95	143·95	–17·1	·567	+0·3
July 6·91	192·91	–17·2	·581	+0·2
Dec. 27·21	366·21	–17·0	·630	+0·1
2005 Mar. 12·11	53441·11	–16·9	3·651	+0·1
May 4·97	494·97	–16·5	·666	+0·5
June 6·90	527·90	–17·1	·675	–0·2
Nov. 5·23	679·23	–17·0	·718	–0·2
Dec. 17·25	721·25	–16·4	·730	+0·4
2006 Jan. 29·17	53764·17	–16·8	3·742	0·0
Mar. 1·06	795·06	–17·2	·751	–0·5
Apr. 5·99	830·99	–16·4	·761	+0·3
May 10·98	865·98	–16·8	·771	–0·1
June 5·94	891·94	–16·8	·779	–0·1
2007 Mar. 2·09	54161·09	–17·6	3·855	–0·5
Apr. 10·00	200·00	–16·6	·866	+0·6
May 18·95	238·95	–17·2	·877	+0·2
June 21·93	272·93	–17·7	·886	–0·1
2008 Feb. 2·16	54498·16	–19·8	3·950	–0·1
Mar. 5·12	530·12	–20·1	·959	+0·1
28·06	553·06	–20·5	·966	+0·1
Apr. 7·99	563·99	–20·8	·969	0·0
May 2·92	588·92	–20·8	·976	+0·4
June 30·93	647·93	–22·3	·993	–0·1
Dec. 27·26	827·26	–23·6	4·043	+0·1
2009 Feb. 4·19	54866·19	–23·5	4·054	+0·1
Mar. 29·04	919·04	–23·2	·069	+0·3
May 3·97	954·97	–23·2	·080	+0·1
June 18·92	55000·92	–22·8	·093	+0·3
2010 Mar. 23·02	55278·02	–21·2	4·171	+0·2
June 3·91	350·91	–20·8	·192	+0·3

*Photographic data by Wilson & Joy[14]; wt. 0.
† Observed with original spectrometer; wt. ¼.
‡ Observed with Palomar 200-inch telescope; wt. 1.
§ Observed with Cambridge *Coravel*; weight 1.
¶ Observed with DAO 48-inch telescope; wt. 1.
R Rejected.

As noted above, the radial velocity of HD 105182 was first observed at Mount Wilson. The first Cambridge observation was made in 1971, but it was not until the fifth measurement was made, in 1992, that a distinct discordance — which even then was a small one — was recognized. Since then the star has been observed systematically, and 65 further measurements have been made of it. All the velocities are listed in Table IV, which has the four Mount Wilson ones at its head. In the solution of the orbit, the Mount Wilson data were not used,

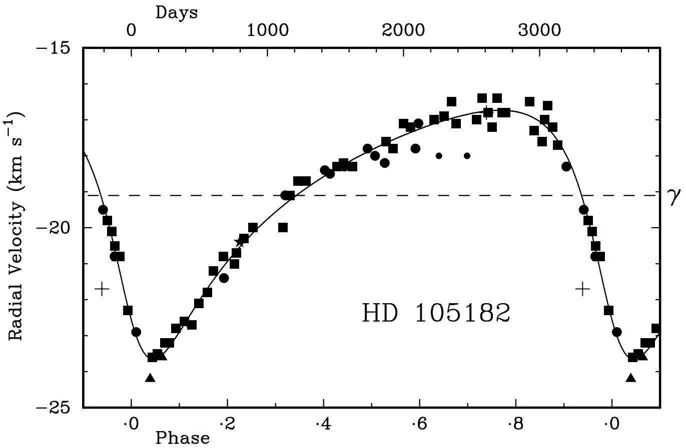

FIG. 2

As Fig. 1, but for HD 105182. The coding of the various sources by the plotting symbols is the same, except that here there is in addition one Palomar observation, plotted as a filled star, and the plusses represent Mount Wilson photographic velocities[14]; there are actually four of them, but two are off the top of the box. Two rejected OHP measures are plotted as smaller-than-normal symbols.

and the single observation made with the original spectrometer at Cambridge was arbitrarily weighted ¼ although its residual is not bad. Two of the OHP velocities gave unusually large residuals and were rejected. The rest of the data were weighted equally, and gave the orbit whose elements appear below in Table VIII and which is plotted here in Fig. 2.

'HD 105182 B'

There is a 12^{m} star, noted at the eyepiece to be 1½ minutes of arc north of HD 105182 (a measurement on a picture of the field brought up on *Vizier* made it 1′·32 in position angle 346°), which the observer felt impelled to observe occasionally, with the results noted in Table V. There is no obvious variation of velocity; the mean is –8·3 ± 0·5 km s^{-1}.

TABLE V

OHP radial velocities of 'HD 105182 B'

Date (UT)	*RV (km s^{-1})*
1991 Feb 5·08	–8·7
1995 June 2·92	–7·8
1997 Dec. 25·15	–9·3
1998 May 1·90	–7·3

The star is in the *Bergedorfer Spektral-Durchmusterung*[12] as Area 56 no. 785, with type G3, HD 105182 being no. 786; it is also in Upgren's listing as 30° 30, with type G6, HD 105182 being 30° 31. It was too faint to be found by *Tycho* in the first reduction, but *Tycho 2* detected it and obtained photometry that transforms to $V = 11^{m}\cdot96$, $(B-V) = 0^{m}\cdot39$. The formal uncertainties are about $0^{m}\cdot17$, but the colour index (at least) must be further adrift than that, because the star gives a 'dip' of quite satisfactorily measurable depth in radial-velocity traces, whereas at $(B-V) = 0^{m}\cdot 39$ it would scarcely be expected to be measurable at all. Although it is not an *HD* object, the faint star was included in the NGP survey[1], in which it is noted as having $V = 11^{m}\cdot 90$, $(B-V) = 0^{m}\cdot 74$; the type inferred from the narrow-band measurements was G6 V, and its luminosity was put at $M_V = 5^{m}\cdot 2$, yielding a z distance of 216 pc — actually slightly less than that of HD 105182 itself. There is no suggestion that the two stars are actually related to one another — their radial velocities and their proper motions (in declination, at least) differ conspicuously.

HD 108613

The only information recorded by *Simbad* concerning HD 108613 concerns its broad-band magnitudes. Häggkvist & Oja[11] observed it on one night and obtained $V = 9^{m}\cdot 70$, $(B-V) = 1^{m}\cdot 53$, $(U-B) = 1^{m}\cdot 85$. Andruk *et al.*[18] found corresponding values of $9^{m}\cdot 770 \pm 0^{m}\cdot 022$, $1^{m}\cdot 584 \pm 0^{m}\cdot 050$, $2^{m}\cdot 028 \pm 0^{m}\cdot 049$ from observations on five nights. They listed the mean values of the standard errors in the three bands, for many stars of about the magnitude of HD 108613, that were much smaller than those they obtained on that star, by factors of three, seven, and five, in the respective bands. The internal discordances and the discrepancies in external comparisons[1,11] strongly suggest that there are real photometric variations in HD 108613.

The first two radial-velocity measurements of the star were made by Radford with the Cambridge spectrometer in 1973 and 1976 and were in major disagreement with one another. The star was then observed quasi-annually on the general principle that it is premature to conclude that an object is a spectroscopic binary until one has seen *three* mutually discordant results; firm corroboration of the variability was not obtained for 15 years, and it was only then that the object was transferred to the binary programme and watched more attentively. With hindsight, the annual observations are seen to have been documenting, rather roughly, the long apastron side of a leisurely orbit whose period is now recognized as $24\cdot 6 \pm 0\cdot 4$ years. There are 71 measurements altogether, listed in Table VI and distributed between the various instruments as indicated in Table II; they have all been attributed the same weight in the solution of the orbit apart from those made with the original spectrometer, which have needed to be given a weight of only 1⁄10, and the single ESO observation, which gives a residual below -1 km s^{-1} and has been rejected on statistical grounds. Although they are supposed to be reduced in the same manner and are kept in the same data base as OHP data, ESO measurements in practice often seem somewhat discordant, and the writer has no means of investigating the problem. The orbit is illustrated by Fig. 3 and its elements are included in Table VIII.

Trouble with the electro-mechanical right-ascension readout of the Cambridge telescope led on two occasions to the inadvertent observation of HD 108676, a star of the same spectral type as HD 108613 and almost identical declination but about half a minute of time later in RA. It gave velocities of $+22\cdot 2$ and $+22\cdot 4$ km s^{-1} on 2000 March 4·06 and 2002 April 5·99, respectively. A third measurement was made deliberately, in the course of resolving the problem, on 2002 April 19·98; the velocity that was found then was $+21\cdot 8$. The mistakes of identification could be seen as a form of poetic justice, because HD 108676 *ought* to have been on the NGP survey programme[1], but wasn't; the programme was intended to include all late-type *HD* stars at Galactic latitude $b > 75°$, but it was compiled (in 1967) by 'hand' from the *Henry Draper Catalogue* according to a boundary drawn on a piece of graph paper, and its margin is seen in retrospect to have been a bit fuzzy.

TABLE VI

Radial-velocity observations of HD 108613

Except as noted, the sources of the observations are as follows:
1986–1998 — OHP Coravel (weight 1); 1999–2010 — Cambridge Coravel (weight 1)

Date (UT)	*MJD*	*Velocity km s⁻¹*	*Phase*	*(O–C) km s⁻¹*
1973 Mar. 31·01†	41772·01	+23·8	0·054	+0·8
1976 Dec. 1·24†	43113·24	15·7:	0·204	−1·8
1977 Apr. 2·03*	43235·03	18·4	0·217	+1·1
1979 May 14·97*	44007·97	16·1	0·304	−0·3
1980 Jan. 2·14*	44240·14	15·9	0·329	−0·5
1981 May 4·97*	44728·97	18·6	0·384	+2·3
1982 Mar. 16·86*	45044·86	18·1	0·419	+1·7
1984 Apr. 27·94*	45817·94	18·5	0·505	+1·6
1986 Apr. 10·92	46530·92	18·2	0·585	+0·5
1987 Mar. 4·00	46858·00	17·9	0·621	−0·3
1988 Mar. 13·04	47233·04	18·8	0·663	0·0
1989 Mar. 28·15	47613·15	19·2	0·705	−0·4
1990 Feb. 15·36‡	47937·36	19·3	0·741	−1·1
1991 Feb. 4·20	48291·20	22·0	0·781	+0·7
May 9·91*	385·91	21·3	·791	−0·3
June 10·92*	417·92	20·4	·795	−1·3
Dec. 19·19	609·19	22·3	·816	0·0
1992 Jan. 16·10	48637·10	22·4	0·819	0·0
Apr. 23·03	735·03	22·7	·830	−0·1
June 25·87	798·87	22·9	·837	−0·1
Dec. 20·20	976·20	23·4	·857	−0·2
1993 Feb. 15·09	49033·09	24·2	0·864	+0·4
Mar. 23·06	069·06	23·7	·868	−0·2
July 7·91	175·91	24·0	·879	−0·3
Dec. 27·16	348·16	25·3	·899	+0·4
1994 Feb. 21·08	49404·08	25·9	0·905	+0·8
May 2·91	474·91	25·6	·913	+0·3
Aug. 1·85	565·85	24·8	·923	−0·7
Dec. 12·19	698·19	25·9	·938	+0·1
1995 Jan. 4·26	49721·26	25·0	0·940	−0·9
June 4·92	872·92	26·3	·957	+0·3
Dec. 27·16	50078·16	26·3	·980	+0·4
1996 Mar. 30·97	50172·97	25·6	0·991	−0·1
1997 Mar. 29·05§	50536·05	23·8	1·031	−0·4
May 2·92§	570·92	24·2	·035	+0·2
July 21·87	650·87	+23·7	·044	+0·1

TABLE VI (*concluded*)

Date (UT)		*MJD*	*Velocity* *km s*$^{-1}$	*Phase*	*(O – C)* *km s*$^{-1}$
1998 May	1·97	50934·97	+21·8	1·076	−0·1
July	27·86	51021·86	21·4	·085	0·0
1999 Apr.	2·37¶	51270·37	20·4	1·113	+0·2
July	13·22¶	372·22	19·9	·124	+0·2
Dec.	20·24	532·24	18·3	·142	−0·8
2000 Jan.	9·16	51552·16	18·8	1·144	−0·2
Feb.	11·17	585·17	18·9	·148	0·0
Apr.	5·96	639·96	19·3	·154	+0·6
May	25·93	689·93	18·4	·160	−0·1
Nov.	20·26	868·26	18·1	·180	+0·1
2001 Jan.	7·21	51916·21	18·4	1·185	+0·5
Mar.	2·15	970·15	17·8	·191	0·0
May	5·01	52034·01	17·5	·198	−0·1
Dec.	22·24	265·24	16·9	·224	−0·3
2002 Feb.	7·09	52312·09	16·6	1·229	−0·5
Apr.	19·98	383·98	18·1	·237	+1·1
June	4·93	429·93	16·8	·242	−0·1
2003 Jan.	28·14	52667·14	16·2	1·269	−0·5
Mar.	16·06	714·06	16·3	·274	−0·3
May	9·97	768·97	16·1	·280	−0·5
2004 Jan.	17·21	53021·21	16·6	1·308	+0·2
Mar.	30·05	094·05	16·1	·316	−0·3
May	22·93	147·93	16·4	·322	0·0
Dec.	27·24	366·24	16·2	·347	−0·1
2005 May	8·97	53498·97	16·7	1·361	+0·4
June	10·95	531·95	16·2	·365	−0·1
2006 Apr.	11·01	53836·01	16·5	1·399	+0·1
June	10·96	896·96	16·2	·406	−0·2
2007 Apr.	30·94	54220·94	16·9	1·442	+0·4
June	10·96	261·96	17·0	·446	+0·4
2008 Apr.	8·03	54564·03	17·0	1·480	+0·2
2009 Mar.	28·01	54918·01	16·8	1·519	−0·3
May	30·93	981·93	16·7	·527	−0·4
2010 Apr.	18·00	55304·00	17·4	1·562	−0·1
June	22·93	369·93	+17·3	·570	−0·3

* Observed with original spectrometer; wt. 1/10.
† Ditto, by G. A. Radford.
‡ Observed with ESO *Coravel*; weight 0.
§ Observed with Cambridge *Coravel*; weight 1.
¶ Observed with DAO 48-inch telescope; wt. 1.

HD 115445

The only paper retrieved by *Simbad* on HD 115445 is a recent one by Soubiran *et al.*[19], who obtained low-*S/N* spectra of a considerable number of NGP stars and offered interpretation in terms of luminosities, distances, metallicities, *etc.*;

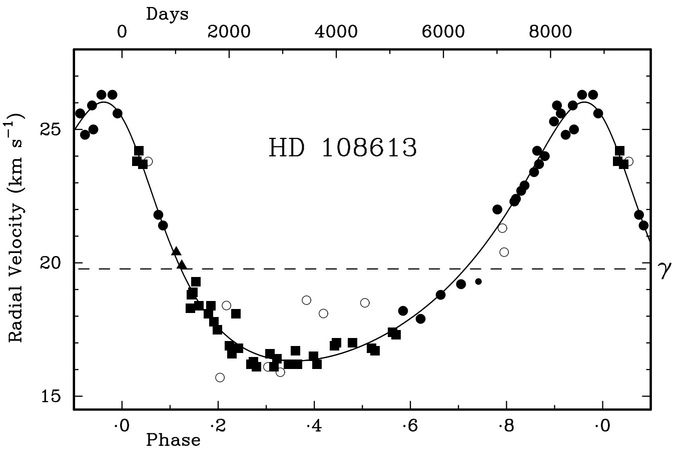

FIG. 3

As Fig. 1, but for HD 108613. The small symbol denotes a zero-weighted ESO observation.

the most interesting thing about HD 115445 is the [Fe/H], which is listed as –0·68. The NGP survey[1] also offers metallicities, although they have not been entered into Table I above; those of the first three stars are indistinguishable from zero, but the value for HD 115445 is –0·77, nicely corroborated by the metal deficiency tabulated by Soubiran *et al.*

HD 115445 was not observed on the writer's NGP programme until 1984; the variability of its velocity was not regarded as fully convincing for several years, and it is only since 1993 that the star has been measured reasonably systematically. There are now 57 velocities, as shown in Table VII, distributed between sources as noted in Table II. They have all been given the same weight

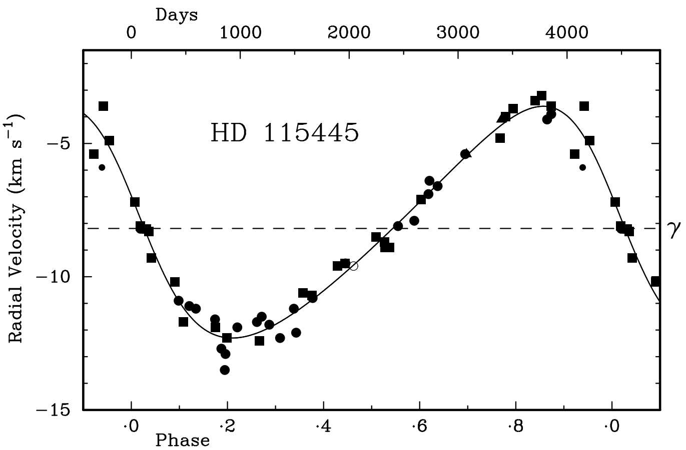

FIG. 4

As Fig. 1, but for HD 115445. The small symbol denotes a zero-weighted ESO observation.

Table VII

Radial-velocity observations of HD 115445

Except as noted, the sources of the observations are as follows:
1986–1998 — OHP Coravel (weight 1); 2000–2010 — Cambridge Coravel (weight 1)

Date (UT)	MJD	Velocity km s⁻¹	Phase	(O–C) km s⁻¹
1984 May 13·97*	45833·97	−9·6	0·462	0·0
1986 Apr. 11·02	46531·02	−6·4	0·620	+0·4
1987 Mar. 5·12	46859·12	−5·4	0·695	+0·1
1988 Feb. 1·51†	47192·51	−4·1	0·770	+0·2
1989 Mar. 26·14	47611·14	−4·1	0·865	−0·5
May 3·04	649·04	−3·9	·874	−0·3
1990 Feb. 15·40‡	47937·40	−5·9	0·939	−1·2
1991 Feb. 4·23	48291·23	−8·2	1·019	−0·4
1992 Jan. 20·19	48641·19	−10·9	1·098	0·0
Apr. 27·12	739·12	−11·1	·121	+0·4
June 26·98	799·98	−11·2	·134	+0·5
Dec. 19·25	975·25	−11·6	·174	+0·6
1993 Feb. 15·20	49033·20	−12·7	1·187	−0·4
Mar. 19·12	065·12	−13·5	·195	−1·2
25·07	071·07	−12·9	·196	−0·6
July 11·93	179·93	−11·9	·221	+0·4
1994 Jan. 8·18	49360·18	−11·7	1·261	+0·4
Feb. 21·14	404·14	−11·5	·271	+0·5
May 1·07	473·07	−11·8	·287	+0·1
Aug. 7·84	571·84	−12·3	·309	−0·6
Dec. 13·21	699·21	−11·2	·338	+0·2
1995 Jan. 3·23	49720·23	−12·1	1·343	−0·8
June 2·99	870·99	−10·8	·377	+0·1
1996 Mar. 31·07	50173·07	−9·5	1·446	+0·3
1997 Mar. 31·09§	50538·09	−8·9	1·528	−0·4
May 10·03§	578·03	−8·9	·537	−0·6
July 25·86	654·86	−8·1	·555	−0·1
Dec. 22·21	804·21	−7·9	·589	−0·5
1998 May 2·04	50935·04	−6·9	1·618	0·0
July 24·88	51018·88	−6·6	·637	−0·1
1999 Apr. 15·42†	51283·42	−5·4	1·697	+0·1
2000 Feb. 20·24	51594·24	−4·8	1·768	−0·5
Apr. 7·10	641·10	−4·0	·778	+0·2
June 17·95	712·95	−3·7	·795	+0·3
2001 Jan. 7·26	51916·26	−3·4	1·841	+0·2
Mar. 3·15	971·15	−3·2	·853	+0·4
May 31·95	52060·95	−3·6	·873	0·0

TABLE VII (*concluded*)

Date (UT)	*MJD*	*Velocity km s⁻¹*	*Phase*	*(O – C) km s⁻¹*
2002 Jan. 1·24	52275·24	−5·4	1·922	−1·2
Mar. 30·14	363·14	−3·6	·942	+1·1
May 22·96	416·96	−4·9	·954	+0·2
2003 Jan. 11·27	52650·27	−7·2	2·007	+0·1
Mar. 3·14	701·14	−8·1	·019	−0·3
Apr. 29·07	758·07	−8·2	·031	+0·2
May 20·02	779·02	−8·3	·036	+0·3
June 14·94	804·94	−9·3	·042	−0·5
2004 Jan. 17·25	53021·25	−10·2	2·091	+0·5
Apr. 3·11	098·11	−11·7	·108	−0·5
2005 Jan. 23·24	53393·24	−11·9	2·175	+0·3
May 9·03	499·03	−12·3	·199	0·0
2006 Mar. 1·14	53795·14	−12·4	2·266	−0·3
2007 Apr. 5·08	54195·08	−10·6	2·357	+0·5
June 26·94	277·94	−10·7	·376	+0·2
2008 Feb. 16·18	54512·18	−9·6	2·429	+0·5
Apr. 24·03	580·03	−9·5	·444	+0·4
2009 Feb. 4·25	54866·25	−8·5	2·509	+0·3
Apr. 22·03	943·03	−8·7	·527	−0·2
2010 Mar. 23·10	55278·10	−7·1	2·602	+0·1

* Observed with original spectrometer; wt. ¼.
† Observed with DAO 48-inch telescope; wt. 1.
‡ Observed with ESO *Coravel*; weight 0.
§ Observed with Cambridge *Coravel*; weight 1.

in the orbit, apart from the single 'original Cambridge' observation, which has been weighted ¼, and the single ESO observation, which has been rejected. The Cambridge *Coravel* velocities have received an adjustment of –0·4 km s^{-1} from the 'as reduced' values. The resulting orbital elements, together with those of the three stars described above, are shown in Table VIII, and the orbit is plotted in Fig. 4.

TABLE VIII

Orbital elements for the four stars

Element	*HD 105074*	*HD 105182*	*HD 108613*	*HD 115445*
P (days)	2459 ± 4	3531 ± 9	8973 ± 157	4413 ± 30
T (MJD)	51753 ± 8	51143 ± 14	50257 ± 60	52619 ± 55
γ (km s^{-1})	+14·35 ± 0·05	−19·10 ± 0·04	+19·77 ± 0·06	−8·19 ± 0·06
K (km s^{-1})	4·21 ± 0·08	3·46 ± 0·06	4·85 ± 0·08	4·35 ± 0·09
e	0·534 ± 0·012	0·462 ± 0·014	0·328 ± 0·018	0·239 ± 0·022
ω (degrees)	186·3 ± 2·0	133·1 ± 2·0	28·1 ± 3·0	77 ± 5
$a_1 \sin i$ (Gm)	120·3 ± 2·5	149·0 ± 2·8	565 ± 14	256 ± 6
$f(m)$ ($M_\odot$)	0·0115 ± 0·0007	0·0106 ± 0·0006	0·090 ± 0·005	0·0345 ± 0·0023
R.m.s. residual (wt. 1) (km s^{-1})	0·32	0·26	0·38	0·45

Discussion

There has been no sign of a secondary dip in the radial-velocity traces of any of the four stars discussed here. The velocity amplitudes of the primaries are all small, however, so any secondary would be seriously blended with the primary, even at the nodes of the orbit, unless it were of much smaller mass, in which case its luminosity would be so much smaller than the primary's that the second dip would be too weak to see. Much the largest mass function among the four stars is that of HD 108613; if the mass of the giant is taken arbitrarily as 2 $M_{\odot}$ then the secondary must be at least 0·9 $M_{\odot}$, so if it is a main-sequence star it must be no later than about G8. It could not be much earlier than that, or the colour indices of the system could not be as extremely red as they are; and if it has nearly the minimum mass it will be something like four magnitudes fainter than the primary, as well as having a dip that is intrinsically weaker, so it is not at all surprising that it has not been detected.

Comparison of the $a_1 \sin i$ values in Table VIII with the z distances in Table I suggests that the orbits have characteristic angular radii of the order of 19, 4, 7, and 4 arc-milliseconds, respectively. Inasmuch as the secondary orbits will be larger, the angular separations of the systems at favourable times may be three or four times those angles. Except in the case of HD 105074, however, they are still too small for there to be much hope of resolution with telescopes of the apertures that have usually been used for speckle interferometry; and while small secondary masses increase the potential angular separations, still more do they exacerbate the magnitude differences with which the observer has to contend. None of the stars discussed here, therefore, can be seen as a good prospect for resolution on the sky.

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THE VERY-LOW-FILL-OUT, W-TYPE BINARY V1799 ORIONIS

By R. G. Samec, R. A. Melton, E. R. Figg, C. M. Labadorf and H. A. Chamberlain
Bob Jones University

and D. R. Faulkner
University of South Carolina, Lancaster

We present the first precise observations, taken at Lowell Observatory, of the recently discovered, high-amplitude W UMa system, V1799 Ori. A complete photometric analysis of *BVRI* light-curves is presented, including a photometric spectral-type determination, an accurate period analysis, and a simultaneous *BVRI* light-curve analysis including a mass-ratio search. V1799 Ori is an active, early-K-type binary with unequal components ($q = m_2/m_1 \sim 1{\cdot}4$). The binary is found to be spotted and the computation surprisingly iterated to a very-shallow-contact solution with a fill-out of $3 \pm 1\,\%$. Hence our model depicts V1799 Ori as a near-critical-contact late-type binary that has already, and quite unexpectedly, achieved a W-type configuration.

Introduction

V1799 Ori was observed as a part of our student/professional collaborative studies of interacting binaries from data taken in conjunction with the National Undergraduate Observatory. Its variability was first suspected by Hanley & Shapley[1] (NSV 1719), and confirmed by ROTSE1 as an EW eclipsing binary[2]. They reported the following ephemeris:

$$\text{HJD } T_{\text{min I}} = 241424{\cdot}829 + 0{\cdot}29031\,E \qquad (1)$$

Its maximum magnitude is $V = 13{\cdot}6$ and its amplitude was reported as $0^{\text{m}}{\cdot}85$. NSVS[3] has 149 observations included in its database along with a median ROTSE magnitude ($\sim V$) of 13·091. Its standard variable-star name was designated in the *79th Name-List*[4]. Our preliminary report on this variable was presented at the IAU General Assembly in 2009[5].

Observations

Our light-curves were taken on the nights of 2008 December 20, 21, 23, and 26 at Lowell Observatory with the 0·81-m reflector on Anderson Mesa, near Flagstaff, Arizona, with a thermoelectrically-cooled (–100° C), 2048 × 2048 pixel, Lowell-built, *NASAcam*, using standard $UBVR_cI_c$ filters. (Our observations were taken by DRF, RGS, CML, HAC, and ERF, and the reductions and analyses were carried out by RGS and RAM.) Two similar, nearby field stars were used as comparison (C, GSC 0096 0887) and check (K, GSC 0096 0826). The finding-chart showing the relative position of these stars is given as Fig. 1 for the convenience of future observers. Our observations can be found at http://data.boulder.swri.edu/samec/v1799ori/.

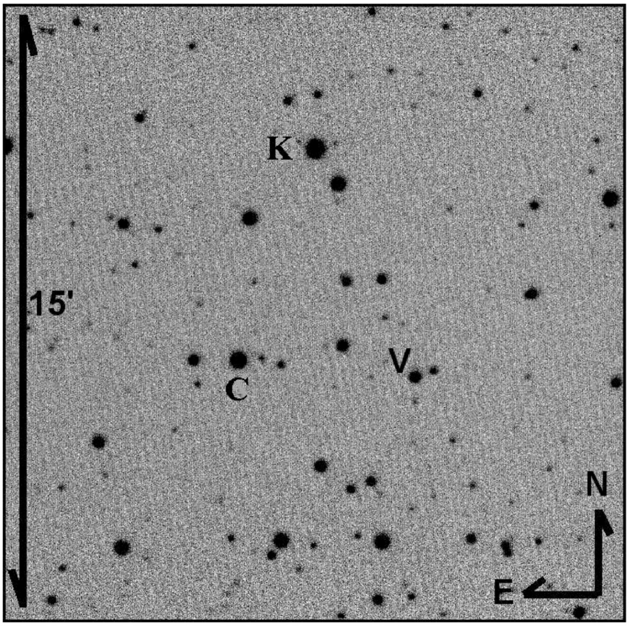

FIG. 1
Finder chart for V1799 Ori (V), comparison (C), and check (K).

Period determination

We were able to use nine times of low light taken from the ROTSE1 magnitudes[3] in our period determination; they are given as the first nine epochs in Table I. Eight high-precision mean times of minimum light were calculated from our observations using parabolic fits. These include four primary and four secondary eclipses, also given in Table I with their errors, in days. The following linear ephemeris was calculated from all these data:

$$\text{HJD } T_{\min\,\mathrm{I}} = 2458425{\cdot}7115 \pm 0{\cdot}0008 + 0{\cdot}29030944 \pm 0{\cdot}00000012\,E \qquad (2)$$

The O–C plot of the data from Table I and the linear ephemeris overlaying the data is shown in Fig. 2. Equation 2 represents the first precise linear ephemeris for V1799 Ori, but future observations of this binary are needed for the determination of its long-term periodic behaviour.

Light-curves and standard magnitudes

The phased light-curves of V1799 Ori arising from Equation 2 are shown later in Figs. 4a and 4b, with the main light-curve characteristics given in Table II. The light-curve is that of a high-amplitude, but partially eclipsing, EW system: the amplitude exceeds $1^{\mathrm{m}}{\cdot}0$ in *V*, yet no total eclipse is visible in the light-curves. There is also an appreciable difference in the maxima, which tells us that spot activity is prevalent. Further, the curves show night-to-night changes in the maxima and minima, emphasizing the presence of dynamic magnetic activity.

TABLE I

O–C residuals of times of low light

	Epochs HJD 2400000+	Error (days)	Cycles (orbits)	O–C (days)	Min.	Source
1	51454·360		−24013·5	−0·0058		1
2	51463·360		−23982·5	−0·0050		1
3	51466·412		−23972·0	−0·0016		1
4	51490·225		−23890·0	0·0058		1
5	51517·219		−23797·0	0·0014		1
6	51536·235		−23731·5	0·0025		1
7	51540·301		−23717·5	0·0040		1
8	51554·225		−23669·5	−0·0071		1
9	51597·204		−23521·5	0·0059		1
10	58422·6634	0·0001	−10·5	0·0002	II	2
11	58422·8085	0·0001	−10·0	0·0001	I	2
12	58423·6797	0·0005	−7·0	0·0005	I	2
13	58423·8241	0·0003	−6·5	−0·0004	II	2
14	58425·7114	0·0003	0·0	−0·0001	I	2
15	58425·8563	0·0003	0·5	−0·0003	II	2
16	58428·7591	0·0021	10·5	−0·0006	II	2
17	58428·9056	0·0005	11·0	0·0007	I	2

Sources: 1. http://skydot.lanl.gov/nsvs/nsvs.php
2. Present observations

A slight angularity in the out-of-eclipse portions shows that the fill-out factor is low. We hypothesize, therefore, from the light-curves, that V1799 Ori has near-equal masses, is near critical contact, and has 'solar-type' activity.

Standard magnitudes were determined from observations of Landolt standard stars on December 26–27; we used standard procedures in their determination[6]. Extinction and transformation coefficients were calculated and standard magnitudes were derived for the variable, comparison, and check star. The results of our calculations are given in Table III. The colours suggest[7] that the variable is an early-K-type dwarf, the comparison star is a late-K-type dwarf,

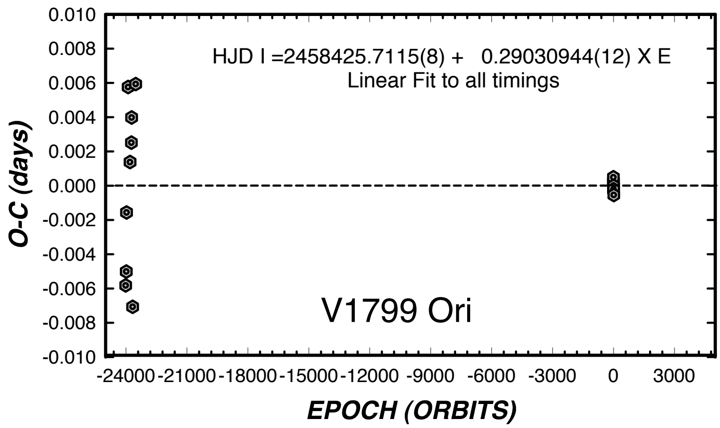

FIG. 2

O–C residuals for V1799 Ori, calculated from Equation 2.

TABLE II

V1799 Ori's light-curve characteristics (amplitudes in magnitudes)

Phases	*ΔB*	*ΔV*	*ΔR*	*ΔI*
0·00 – 0·25	1·121	1·039	0·961	0·916
0·50 – 0·25	0·813	0·771	0·760	0·743
ΔMaxima				
0·25 – 0·75	0·038	0·031	0·015	0·061

and the check star is a mid-A-type dwarf. Both transformation and standard-star errors are included in the table.

Synthetic-light-curve modelling

We first hand-fit each light-curve individually with BINARY MAKER 3·08, using standard convective parameters and limb-darkening coefficients from reasonable values dictated by the 'spectral type'. In these models we used dark spots to fit the asymmetries in the curves. With our starting values and the temperature and temperature-related values dictated by the standardized photometry, we proceeded to compute a simultaneous four-colour light-curve solution with the 2004 Wilson Code[9–12], which includes Kurucz stellar atmospheres, two-dimensional limb-darkening coefficients, and a detailed reflection treatment. Our fixed inputs included standard convective parameters, gravity darkening, $g = 0{\cdot}32$, and albedo values of 0·5. Adjustable parameters include those accompanied by errors (see Table III), the inclination, i, the temperature of the secondary component, T_2, the potential, Ω, the mass ratio, q, and the normalized flux (at 4π) in each wavelength, L, the phasing ephemeris, JD_0 and the period, and the four spot parameters. We then conducted a mass-ratio search (Fig. 3), at the conclusion of which the mass ratio minimized at 1·4. Our complete $q = 1{\cdot}4$ solution is given in Table IV and the curves are shown in Figures 4a and 4b where our solution overlays the normalized-flux light-curves. The Roche-lobe surfaces arising from the calculation are displayed in Fig. 5.

Discussion

Our solution depicts V1799 Ori as a W-type, extremely shallow-contact, W UMa-type eclipsing binary. This means that the less-massive, yet hotter, component is eclipsed at phase zero. Our modelled fill-out (3%) is exceptionally low for W UMa binaries, but this low value (3–4%) was maintained throughout all our solutions so we believe this is a firm finding. It is true that W-types (where

TABLE III

V, R, and I standard magnitudes and photometric 'spectral types' for V1799 Ori and comparison and check stars

Star	*Phase*	*V (mag.)*	*R – I*	*'Sp. Type'*
Var.	0·25	13·00 ± 0·53	0·42 ± 0·06	K2 ± 2
Var.	0·50	13·36 ± 0·53	0·42 ± 0·06	K2 ± 2
Var.	0·75	13·13 ± 0·54	0·43 ± 0·06	K2 ± 2
Comp.		12·14 ± 0·56	0·88 ± 0·05	K9 ± 1
Check		9·98 ± 0·56	0·26 ± 0·05	A7 ± 1

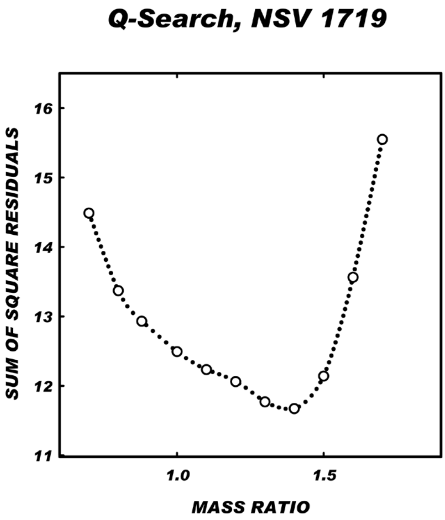

FIG. 3
Mass ratio (q) search: mass ratio *vs*. goodness-of-fit parameter.

the hotter component is the lower-mass star) usually have shallow contact (~10–20%), but 3% is exceptional. This makes V1799 Ori rather unique, and we suggest that the star has just recently reached contact. Before contact, we would expect the more massive component of a detached system to have been the hotter one, but V1799 Ori has already attained the W-type configuration. Perhaps in very-short-period late-type-dwarf binaries, the more massive component has a larger convective zone and therefore it has more magnetic cool-spot activity *even before contact*[13]. So the binary comes into contact having already attained a W-type configuration. If this is first contact, then the stars were in a V1010 Oph configuration[14] before (the more massive star of a semi-detached binary is filling its critical Roche lobe). The driving mechanism for this supposed process is the torque supplied by out-flowing winds along 'stiff' field lines originating from the late-type dwarf stars. In later stages, gravity waves will contribute significantly to the coalescence phase. Alternatively, V1799 Ori may be a proto-type of a binary caught in oscillations about a critical-contact configuration resembling thermal relaxation. Future observations will tell! The solution shows two small spot regions, which may represent bright areas on surfaces saturated with dark star-spot activity or they may be zones of faculae. Whatever the case, the system is presumably magnetically active.

We stress that radial-velocity curves are needed to confirm the mass ratio and to result in absolute mass values. In addition, this system should be monitored for the next ten years to investigate the period behaviour of the system.

Acknowledgements

An Arizona Space Grant supported this observing run. We wish to thank NURO for their allocation of observing time. This research has made use of the NASA/IPAC Infrared Science Archive, which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

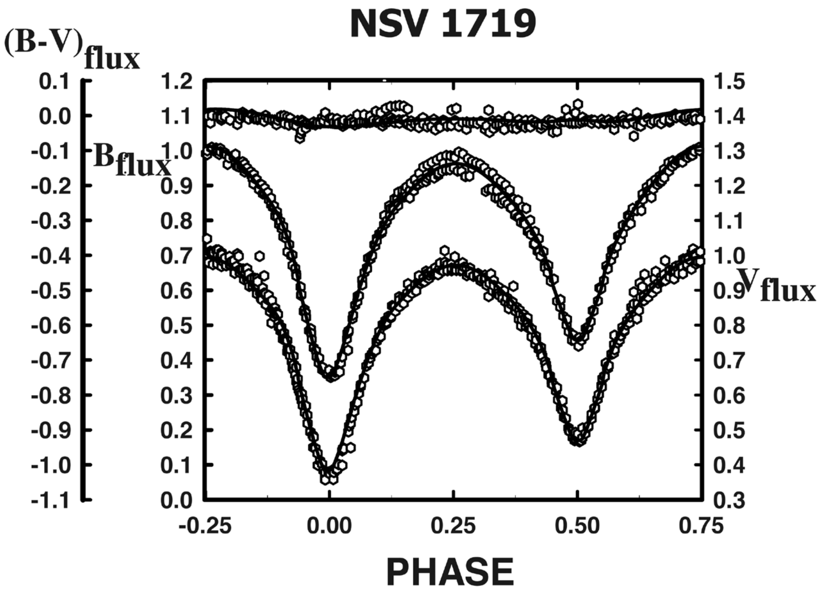

FIG. 4a
B and *V* normalized flux curves overlain by our solution.

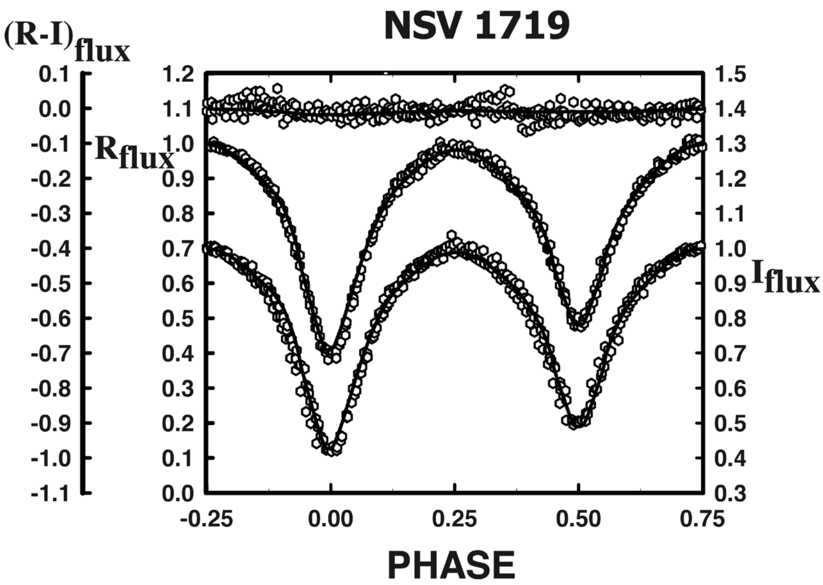

FIG. 4b
R and *I* normalized flux curves overlain by our solution.

TABLE IV

Synthetic-light-curve model parameters for V1779 Ori

	Solution (Mode 3 — Contact)
λ_B, λ_V, λ_R, λ_I (nm)	440, 550, 640, 790
$x_{bol_{1,2}}$, $y_{bol_{1,2}}$	0·643, 0·603, 0·160, 0·160
$x_{1I,2I}$, $y_{1I,2I}$	0·607, 0·607, 0·251, 0·251
$x_{1R,2R}$, $y_{1R,2R}$	0·691, 0·691, 0·232, 0·232
$x_{1V,2V}$, $y_{1V,2V}$	0·762, 0·762, 0·232, 0·232
$x_{1B,2B}$, $y_{1B,2B}$	0·852, 0·852, -0·018, -0·018
g_1, g_2	0·32
A_1, A_2	0·50
Inclination (°)	89·7 ± 0·6
T_1, T_2 (K)	5000 ± 200, 4728 ± 1
$\Omega_1 = \Omega_2$	4·3527 ± 0·0025
q (m_2/m_1)	1·397 ± 0·002
Fill-outs: $F_1 = F_2$	3 ± 1%
$L_1/(L_1+L_2)_I$	0·4793 ± 0·0005
$L_1/(L_1+L_2)_R$	0·4889 ± 0·0007
$L_1/(L_1+L_2)_V$	0·5055 ± 0·0005
$L_1/(L_1+L_2)_B$	0·5263 ± 0·0006
JD_o *(days)*	2458425·71125 ± 0·00004
Period (days)	0·290278 ± 0·0000005
r_1, r_2 (pole)	0·3304 ± 0·0007, 0·3861 ± 0·0005
r_1, r_2 (side)	0·3461 ± 0·0009, 0·4077 ± 0·0008
r_1, r_2 (back)	0·3790 ± 0·0015, 0·4382 ± 0·0012
	Starspot parameters
Location	*Primary*
Colatitude (°)	62·8 ± 0·5
Longitude (°)	81·6 ± 0·6
Spot Radius (°)	9·4 ± 1
Temp. Factor	1·35 ± 0·01
Location	*Secondary*
Colatitude (°)	105 ± 1
Longitude (°)	70 ± 2
Spot Radius (°)	10·0 ± 0·3
Temp. Factor	1·11 ± 0·01

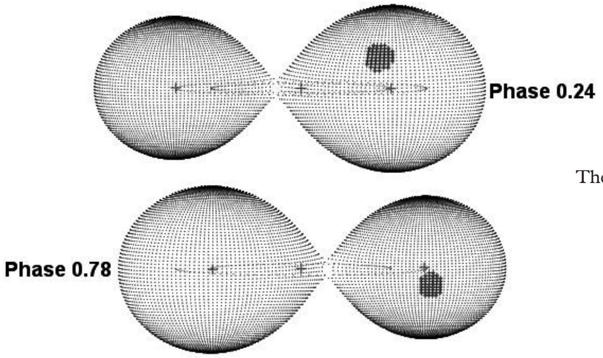

FIG. 5
The Roche-lobe surface of V1799 Ori.

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CORRESPONDENCE

To the Editors of 'The Observatory'

The Hanwell Community Observatory

Following the note in February's issue[1], readers of *The Observatory* may be interested to hear that, after 'first light' some months previously, the new 30-inch reflector at the Hanwell Observatory delivered a magnificent view of M42 Orion on one glittering night of early March, when stars to below 16th magnitude were obvious in the telescope and Sirius so brilliant it could be *projected* a yard or more from the eyepiece as a bright spot of light. HCO hopes to begin public astronomy with the new instrument shortly.

We are also now looking ahead to the setting-up of a permanently-mounted solar facility on the Hanwell site, whose motivation is two-fold: firstly, to provide visitors the possibility of a first-hand observational experience during daylight hours, something which may be of particular interest to local schools and colleges; and secondly to use solar astronomy to focus more closely than our nocturnal public events will do, in general, on overtly educational ends in relation to the teaching of the physical sciences — an aim to which the Sun, of all celestial bodies, is pre-eminently suited. The plan is to make as many different ways of viewing the Sun available to visitors as we can, so giving the experience variety and interest in both visual and scientific terms. To achieve this, the intention is to mount a coelostat-fed suite of instruments fixed in the meridian, generating images of the whole disc by white-light projection, by direct view in Hα, at higher resolution by neutral-filtered direct view, as well as images of the solar spectrum both by projection at low resolution and in greater detail by direct view to display the Fraunhofer lines in all their glory. By identifying the principal lines in the latter by chemical element — or even projecting actual comparison spectra alongside it — we can, of course, link the observatory experience directly to GCSE and A-level physics and chemistry, for instance, to provide some of their content with a 'real-world' illustration of unique vividness.

If any reader is interested in becoming involved in any way in this next phase of HCO public astronomy we really would like to hear from you, as also from anyone who may be able to help with the acquisition of a suitable 2-mirror-type coelostat delivering a beam between 4 and 12 inches clear aperture: it doesn't matter how old and well-worn, as long as the optical surfaces are undamaged and the mechanical parts serviceable. In either event, please telephone 01295 730762 and leave a message.

Yours faithfully,
CHRISTOPHER TAYLOR

Hanwell Community Observatory,
Hanwell,
Oxon
OX17 1HN

2010 August 23

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Celestial Shelf-Marks

The traditional signs of the zodiac, and to a lesser extent planetary and other astronomical signs, are familiar symbols which can occur in many contexts in wider culture. Nonetheless it was a surprise when I discovered that they had been used as part of library shelf-marks on at least one occasion, and I thought that the details might be of interest.

The Faculty of Advocates (lawyers) in Edinburgh dates from 1532. In 1680 it decided to maintain its own library, and one was subsequently inaugurated in 1689[1]. Originally the Library included books on a wide range of subjects, not just law, and it became the largest institutional library in Scotland before the non-law stock was transferred to become the base for the National Library of Scotland in 1925.

Before 1800 Scottish institutional libraries stored their books in 'presses' (bookcases) rather than stacks, and the location of each volume was specified by *ad-hoc* schemes typically involving identifying each press and the shelf within it. In the Advocates' Library the presses were identified by letters. The Library's holdings grew rapidly during the decades following its founding and additional presses were soon required to house the growing collection. Eventually the alphabet was exhausted and 'signs of the zodiac, constellation signs, and the letters of the Greek alphabet were, therefore, gradually introduced to denote the press of shelves.' This snippet is reproduced in a recent paper by Murray Simpson[2], quoting an article by Peter Wellburn[3]. The latter's source appears to be a shelf list compiled in 1703 by Thomas Ruddiman who was then Assistant Keeper at the Library.

Yours faithfully,
CLIVE DAVENHALL

National e-Science Centre,
15, South College Street,
Edinburgh
EH8 9AA

[acd@staffmail.ed.ac.uk]

2010 July 13

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(1) See URL: http://www.advocates.org.uk/library
(2) M. Simpson, *J. Edinburgh Biblio. Soc.*, **4**,11, 2009 (the quotation is on p. 24).
(3) P. Wellburn, 'The Living Library', Chapter 9 of P. Cadell and A. Matheson (eds), *For the Encouragement of Learning: Scotland's National Library, 1689–1989* (HMSO, Edinburgh), 1989, p. 186 (the quotation is on p. 191).

REVIEWS

Scientific Europe: Policies and Politics of the European Research Area, by C. Madsen (Multi-Science Publishing, Brentwood), 2010. Pp. 234, 23 × 16 cm. Price £37·50/€45 (paperback; ISBN 978 1 907132 15 5).

This is a quite remarkable book. The vision of a European Research Area (ERA) emerged — slowly, almost reluctantly — as a conceivable force to balance the massive magnetism of the United States (the post-war 'brain drain'). But Europe was not united, politically, linguistically, or culturally. The design and creation of the ERA implied dismantling as well as re-creating; most research organizations were well established and functioning long before any concept of Europe as a cooperating scientific entity. Indeed, the more senior of us were raised in an atmosphere of intense nationalism and the fallout of war, when a vision of Europeanization had no credence whatsoever. Yet somehow the impossible has been addressed, and a scientific Europe is becoming a force to be reckoned with, and respected. Its history is complex, often confusing, barely unified, and riddled with acronyms, and it is not easy for anyone (particularly politicians and scientists) living among all the developments to see the whole story, to understand the inter-relationships of the various stages, to chart the successes, and to identify the weaknesses. But Madsen manages to, and does it well.

The new dimensions of a European science policy are challenging, but a pan-European integration of effort, resources, and ideals is finally emerging, and the focus of this book is how it all came about. But Madsen does more than document events; he tells a story. He charts a careful course through the developments, past individual organizations with E-names like ESA and ESO (the latter is acclaimed as an exemplary success story), through policy measures like the Framework Programmes, emphasizing the added value of 'science in society', but not hesitating to show how unfavourably the statistics compare with other major world players like the USA and Japan. Whether you are a Europhile or a Euro-sceptic, the convolved history of creating a scientific force (a 'knowledge-based economy') out of a hodge-podge of proud, protective, independent, individualistic, sovereign 'Babeldoms' linked only by their accidental geography is fact, and here you will find it properly explained.

By working through the stages and setting each in its scientific and political perspective, Madsen paints a picture which shows the challenges in a comprehensive light. Even the major pan-European structures are contingent upon the attitudes and goodwill of the individual, and must recognize that "it is not European policies for national ends, it is national policies for European objectives". Madsen also highlights the value of teaching science as basic training for the mind, whether or not specific knowledge is also acquired. The preface describes him as not only an insider but a *believer*, and he is clearly a very enthusiastic one. His perceptions and constructive criticisms lightly peppered with humour advance the whole into a wisdom with which every European scientist, whether practising, administering, or planning at the political level, should — no, must — have familiarity. Even though this formative period may become dwarfed as the years pass, the fundamental principles will remain, etched in the essentials of Progress.

Danish by upbringing, Madsen has excellent (though not quite perfect) command of the English language, its idioms, and its manifold oddities — except the use of commas, and their frequent non-pairing or misplacement can give rise to ambiguities which just might irritate the perfectionist. But if s/he can rise above the sovereignty of grammar and embrace the internationalism of scientific thought, design, and operation, then here is the perfect cook-book. It should be within reach of every European who is involved in pursuing, managing, or enabling science. — ELIZABETH GRIFFIN.

Science: A Four Thousand Year History, by Patricia Fara (Oxford University Press), 2009. Pp. 482, 19·5 × 13 cm. Price £20/$34·95 (hardbound; ISBN 978 0 19 922689 4), £9·99/$18·95 (paperback; ISBN 978 0 19 958027 9).

To endeavour to understand where science might be going it is useful to know where it came from. And I can think of no better way to start this intellectual journey than by reading Fara's excellent book on the last 4000 years' history of the subject. Words like style, insight, and common sense continually came to mind when reading it. The book is pacey, thought-provoking, riveting, and an absolute joy.

Fara stresses the facts that the science that dominates the world today has its roots firmly placed in previous European activities, and that science, unlike many other creative pursuits, depends not only on personal endeavour but also on the social and political environment of the scientist. Astronomy, our subject, is a modern 'big science', and like other big sciences, depends, and has depended, on the 'five Ms' — money, manpower, machines, the military, and the media. The present-day UK's astronomical effort is built around some 300 tenured university astronomers. A new big telescope costs about 150 million pounds, and a space mission about ten times that figure. Space astronomy, telescopic instrumentation, and astrophysical computers have a strong military heritage and the media encourages the tax-payer to foot the bill.

Fara reviews the historical development of all the sciences. And what is fascinating is not only the way that science in general advances but how the emphasis continually changes. Each scientific age has a different mood. Specific subjects progress and others languish. The delicate balance between usefulness and truthfulness sways back and forth. Science has played a dramatic rôle in both the advancement of the inhabitants of planet Earth and the way in which those inhabitants exploit Earth's potential. And it is such a one-way street: once a discovery has been made it cannot be forgotten.

Patricia Fara is a Cambridge don in the Department of the History and Philosophy of Science. Her book underlines the present-day significance of that discipline. I have benefitted hugely by reading it. All other scientists will do likewise. — DAVID W. HUGHES.

The Heavens on Earth: Observatories and Astronomy in Nineteenth-Century Science and Culture, edited by D. Aubin, C. Bigg & H. O. Sibum (Duke University Press, Durham, NC), 2010. Pp. 400, 23·5 × 15·5 cm. Price £69/$94·95 (hardbound; ISBN 978 0 8223 4628 9), £16·99/$25·95 (paperback; ISBN 978 0 8223 4640 1).

It is hard to do justice to this excellent book in a short review, but let me say at the outset that it constitutes a pioneering historical study of the rôle played by the observatory in European and American scientific culture in the 19th Century. It is not a study of the detailed technical astronomical (not to mention geomagnetic and meteorological) procedures that developed over the 19th Century, though these are discussed. Rather, it assesses the impact of the observatory as a scientific and intellectual institution within the broader culture of the age: an institution very much in the tradition of Alexander von Humboldt's place where scientific data of various kinds were collected, analysed, and disseminated.

David Aubin and his co-editors present twelve essays written by themselves and ten other scholars working in the history of science and astronomy. Each essay is a self-contained piece, with the whole fitting together to form an elegantly-crafted volume.

Broadly speaking, the essays divide into two classes: those dealing with specific institutional case studies or research projects, and those discussing the observatory's rôle in the wider public understanding of science. The volume opens with a study of that influential Tsarist showcase observatory of the age, Pulkowa, near St. Petersburg, and its influence in Europe and America after 1839. Other essays examine the rise of physical astronomy at the Jesuit-directed Papal Observatory in Rome; Australia's first observatory, Paramatta (a private observatory founded by Governor Sir Thomas Brisbane in 1821); the researches of the great American observatories, both publicly- and privately-endowed; and the observatory-related science of geodesy, navigation, eclipse expeditions, and military survey work.

What I find particularly fascinating is the growing perception of the observatory as a place for the popularization of science. And in this respect, one must bow to François Arago, Director of the Paris Observatory between 1813 and 1848, who gave open-house public lectures on astronomy at the Observatory once a week, and drew capacity crowds; for Arago saw popular physical and astronomical education as an extension of his egalitarian political views. Then in 1889 was opened the 'Urania' Observatory and scientific theatre in Berlin, which catered for a growing popular thirst for astronomical and scientific knowledge across Europe and America.

The essays as a whole constitute an extremely valuable resource for astronomical historians. And of particular importance is the insight they give into the European continental scene, with its great astronomical vigour — especially in France and Germany — a scene that is not especially well covered elsewhere by English-language historians.

The Heavens on Earth is a meticulously-documented scholarly work, and contains a 20-page bibliography as well as 62 black-and-white illustrations. All the essays are well and clearly written, and the book would be a valuable addition to the library of anyone interested in 19th-Century astronomy. — ALLAN CHAPMAN.

Ultimate Explanations of the Universe, by M. Heller (Springer, Heidelberg), 2009. Pp. 216, 24 × 16 cm. Price £39·99/$69·95/€50 (hardbound; ISBN 978 3 642 02102 2).

Even when cosmology is carried out as a purely technical exercise, it inevitably involves philosophical assumptions. They come to the foreground if one attempts to provide some kind of ultimate reason for the existence of the Universe — as many cosmology papers are increasingly attempting. This book will be a valuable resource for writers wishing to approach these issues with an adequate depth of historical and philosophical knowledge, also relating them to the science of the subject — such issues as creation of the Universe out of fluctuations of a vacuum, the wave function of the Universe, path integrals, and so on. One will also find the kinds of issues one might expect, such as a discussion of the anthropic principle and the search for unity in physics. Heller is very clear on the nature of creation, distinguishing between creation as an event at the start of the Universe, and creation as an on-going process of acting as a ground of being — a distinction already made by Augustine, but forgotten by various cosmologists and at least one Pope. He shows how philosophical agendas have often driven cosmological programmes, such as the Steady-State-Universe proposal and current multiverse ideas (the latter concept having been proposed by Origen in 200 AD). Various proposals as to how the Universe might have started are critically reviewed, a recurring one being that the Universe might never have had a beginning. He explains how that does not, in fact, solve the ultimate problem of cosmology: it does not explain why the Universe is the way it is.

Heller is both a Jesuit priest and an astronomer–physicist, so he also considers theological issues — which is inevitable if one is to deal with questions concerning ultimate origins. However, one can omit those sections and still learn much of use in understanding the philosophical issues at the foundations of cosmology, which to a considerable degree shape our attitudes towards the subject. He closes with Leibniz' question: "Why is there something rather than nothing? After all, nothing is simpler and easier than something". He considers various attempts to nullify this question, and shows how they fail because they are based on strong and essentially arbitrary assumptions. The underlying philosophical issues will remain, however the science progresses: and one can suggest the science will be done in a wiser way if they are carefully considered and taken into account. — GEORGE ELLIS.

The Dark Matter Problem: A Historical Perspective, by R. H. Sanders (Cambridge University Press), 2010. Pp. 205, 25 × 18 cm. Price £35/$60 (hardbound; ISBN 978 0 521 11301 4).

Robert Sanders is no fan of dark matter, especially the non-baryonic sort. Instead, he has preferred, for about a third of a century, some deviation from Newtonian or Einsteinian gravity as the best explanation for a very wide range of galactic and sub-galactic data, while pointing out in the present volume that the best-known alternative still requires some dark matter in clusters and superclusters. Initially, he advocated a theory of his own, but abandoned it in favour of MOND and TeVeS in the face of contradictory data. This sort of individual paradigm shift is very rare in modern cosmology and definitely praise-worthy; Dennis Sciama's abandoning the Steady State in the 1960s may be the only previous example.

MOND is MOdified Newtonian Dynamics, strongly associated with the name of Moti Milgrom; and TeVeS is a tensor-vector-scalar relativistic version largely due to Jacob Bekenstein. It is not surprising, and not objectionable, that Sanders has heavily weighted his pages with the galaxy-scale phenomena to which MOND (*etc.*) are a good fit, at the expense of superclusters and the CMB, *etc.*, Universe, where they are not. TeVeS is also a good fit to the *Pioneer* anomaly (if as advertized) and predicts a small ether-drift effect on the orbit of the Moon which might be observable with extended lunar laser ranging. Again it is perfectly appropriate for the author to point out these things and also, indirectly through citations, to make clear that MOND/TeVeS has attracted the interest and at least partial support of a good many astronomers in addition to the original proposers. This is a sharp contrast to another contemporary alternative to conventional ΛCDM, the quasi-steady-state theory, which is now rapidly vanishing with the last of its original propounders.

What I do object to with some violence, in what is said to be "a historical perspective" that has "included reference to most of the major contributors in this field", is the very large number of serious omissions and misrepresentations. There is room here for only three (though my list averages about one per page of the text). Oort is said to have been the first to use the words "dark matter" in his 1932 paper about motions of stars perpendicular to the Galactic disc. No. He indeed preceded Zwicky's "*dunkle materie*", but in 1922 Kapteyn wrote, concerning his analysis of the motions of stars perpendicular to the disc, "we therefore have the means of estimating the mass of dark matter in the universe", and "as matters stand at present it appears that this mass cannot be excessive". Jeans the same year did the same sort of thing, but spoke of dark stars outnumbering luminous ones by about three to one. Their 'universe' was, of course, our 'Galaxy', but neither makes the cut for Sanders' book.

Second, the author looks in considerable detail at a 1974 paper by Ostriker, Peebles & Yahil that collected together data from many sources, indicating that the effective mass per galaxy (or M/L ratio) rises monotonically with the length scale on which it is measured. All well and good, in that they did and it does. But there was a slightly earlier 1974 paper by Einasto, Kaasik & Saar (whose preprint is cited by Ostriker *et al.*) that does just the same thing, and makes more of a point that this seems to be a genuinely new phenomenon, although not a word of it or them is mentioned by Sanders. You are perhaps thinking, "Estonian names? Probably published in Tartu, like Öpik's work on *M*/*L* for Andromeda — also ignored. Why should it be mentioned?" No, Einasto *et al.*, on the advice of Zel'dovich, published in that obscure journal *Nature*.

That Zwicky gets credit for the Coma cluster (1933) but not for pointing out repeatedly (1937 onward) that gravitational lensing was the right way to resolve the difference in mass-per-galaxy between his cluster numbers and Hubble's single-galaxy numbers, counts as 2½.

Third is the prevailing viewpoint in 1961, when the IAU met for the first time in the US. Sanders has convolved two meetings (Santa Barbara & Berkeley) into one (forgivable!) but says "the general feeling was that the discrepancy would disappear with improving observations or theoretical understanding". My count says that seven of the presenters thought the Virial-theorem results were approximately right and large clusters of galaxies bound; six (if you count the Burbidges separately) favoured expanding, unstable clusters; and one each blamed observational errors of many sorts, favoured transient groupings, and considered (but rejected) non-gravitational forces.

But, instead of going on to complain that the author has given Gamow credit for work done by Alpher and Hermann, completely ignored the rôle of radio-source counts in falsifying the Steady State, and neglected to ask Finzi (who said G(*r*) back in 1963) what he thinks now, I would like to give the last word to Fred Hoyle, speaking at a 1988 meeting in Bologna on the history of cosmology: "There were many international meetings in the late 1950s and 1960s at which the possibility of dark matter was mentioned" (remember the Steady State must have the critical density). "The possibility was quite strongly opposed by the establishment of the day, largely because of the difficulties of observing it — a difficulty which still persists of course. The difference between then and now is that people today are far more ready to admit that unobserved particles may have an important influence in cosmology." — VIRGINIA TRIMBLE.

Gravitation: Foundations and Frontiers, by T. Padmanabhan (Cambridge University Press), 2010. Pp. 700, 25 × 18 cm. Price £50/$85 (hardbound; ISBN 978 0 521 88223 1).

Setting out to write a high-level physics textbook requires a certain degree of ambition and self-confidence. It's clearly going to take a lot of time and effort, and probably there are already good competing books around; one can easily become discouraged at the thought of failing to reach the standard needed for a worthwhile advance. But no such self-doubt for Thanu Padmanabhan, the widely-respected Indian cosmologist and gravitational theorist. His preface describes two monuments of the gravitation-textbook literature (Landau & Lifshitz and Misner, Thorne & Wheeler) as "... out of date in their emphasis", and that his new book "... is expected to fill this niche and I hope it becomes a standard reference in this field". That's fighting talk, but it demands to be treated with respect, since Padmanabhan is a noted author, with an astonishing output. He has previously published seven high-level textbooks, totalling 3635 pages, plus two books on popular science, as relaxation. Those texts have been well received and have gained the author a reputation for a mathematically rigorous and wide-ranging style. This is just the background needed for the challenge that Padmanabhan sets himself on gravitation.

The first decision to be faced when writing on gravity is mathematical language. Misner, Thorne & Wheeler set out self-consciously in the early 1970s to be iconoclasts, who were determined that their readers would cast aside traditional tensor calculus in favour of a more modern formalism using differential geometry. But revolutions mature, and these gains can now be taken for granted. Thus Padmanabhan is able to set out on his journey using language and tools that will be more familiar to typical physics undergraduates, so that the book has a relatively traditional feel on a first flick through. But the first two chapters, treating Special Relativity and electrodynamics largely in the language of action principles, already make it clear that the book will demand a good level of sophistication from its readers. There follow four chapters in which General Relativity is developed, with substantial discussion of alternatives and why they fail. We then have four chapters on standard applications (black holes, gravitational waves, and cosmology), followed by six chapters on diverse advanced topics. The ordering of these seems slightly haphazard, with two formal chapters on differential geometry (of which a fair bit is already introduced *in-situ* in earlier chapters) and the Hamiltonian approach. There then follows cosmological perturbations, although there seems no reason why this material did not follow homogeneous cosmology; quantum fields in curved spacetime come next, and the book is completed by two chapters of frontier material that reflect Padmanabhan's personal research interest — especially the extent to which relativistic gravity can be understood as an approximation to a deeper theory. Here, the text focusses on elements such as holography (information about a space-time region resides on a boundary to that region) and gravitational thermodynamics.

The approach to all this material is much as might be expected by readers of Padmanabhan's previous books. There is immense erudition, and mastery of both formal tools and calculational details; it really is impressive that one individual can understand so much, so deeply. Personally, I do not find it the easiest book to read, however. Padmanabhan favours getting stuck into details at quite an early stage, without devoting huge amounts of space to intuitive motivation, or indeed signposting. Rather than being able to skip over less-critical items in a first reading, just to get an overview of a topic, I found myself having to stick with most of the details of the discussion. This makes it a difficult book to dip into, and perhaps one better suited to intensive and committed study of selected broad areas. More diagrams would have helped, but these are pretty thin on the ground: most chapters have only two or three plots, and even these do not always have much of a pedagogical function. Visual enhancement of the text was certainly a strength of Misner, Thorne & Wheeler, or, *e.g.*, Hartle's excellent 2003 textbook.

A further contrast with both Landau & Lifshitz and Misner, Thorne & Wheeler is in the treatment of exercises. Padmanabhan's book is replete with these (over 200 of them), but they are presented simply as challenges, rather than worked examples. Views differ on this: one can argue that real learning only happens in the course of solving problems, and that solutions destroy this possibility. But I would say that a student learns nothing from a problem they can't see how to tackle, and that textbooks really should give outline solutions or extensive hints to make sure that the exercises aren't wasted. Given that one of Padmanabhan's best books is entirely devoted to solved problems in cosmology and astrophysics, it is a pity that a different approach was taken here. On the other hand, one can entirely forgive the lack of solutions to the 'projects': each chapter comes with two or three suggestions for rather openended investigations, which are stimulating ideas suitable for readers who want to direct their personal research towards those subjects. That is one of the nicest features of the book.

So does Padmanabhan succeed in replacing Landau & Lifshitz and Misner, Thorne & Wheeler? In terms of including more modern topics, undoubtedly. In terms of digging deeper into some of the details, yes, on occasion. This success would have been more complete if the book had supplemented its strength in detail with a greater visual and intuitive element, but this is undoubtedly a personal reaction, and other readers may prefer things just as they are. But if the scarcity of diagrams is a matter of taste, the index is not: a mere six pages for a book of this length and complexity is really too little, and it would be nice if this could be remedied in future printings. The short index reinforces the impression of a text for the reader who is prepared to work systematically through connected portions; those who make this effort stand to be richly rewarded. — JOHN PEACOCK.

Galaxy Formation and Evolution, by H. Mo, F. van den Bosch & S. White (Cambridge University Press), 2010. Pp. 820, 25 × 18 cm. Price £50/$85 (hardbound; ISBN 978 0 521 85793 2).

The subject of galaxy formation bridges the physics and time-scales from the formation and evolution of individual stars to those of the evolution of the cosmos as a whole. As such, it spans a vast array of physics from atomic processes in the interstellar medium, through the stellar dynamics of galactic structure, to the relativistic metric perturbations of cosmic structure formation.

Driven by the technological advances of the past few decades, both observational information and our ability to simulate the processes of galaxy formation have grown exponentially. The 2dF and Sloan Digital Sky Survey have together produced a 3-dimensional catalogue of over one million galaxies with luminosities, colours, and spectra, providing a comprehensive inventory of the properties of the present-day galaxy population. They are supplemented by several specialized deeper surveys that probe galaxy evolution at higher redshift. Tying these observations together and linking them to the observed spectrum of primordial density fluctuations probed in the cosmic microwave background by the *WMAP* and *Planck* satellites has become the primary goal of theoretical studies of galaxy formation.

There are several excellent textbooks on the physics of cosmology and structure formation and others on the properties and dynamics of galaxies, but this text breaks new ground in being the first comprehensive review of our present understanding of galaxy formation. Mo, van den Bosch & White have themselves played a very significant rôle in the substantial theoretical advances that have been made in understanding and modelling galaxy formation. Their book presents and explains rigorous mathematical models of everything from the evolution of stellar populations and chemical enrichment to the hierarchical growth of structure from cosmological perturbations. For example, the chapter on the formation and structure of dark-matter halos contains detailed modelling of halo density profiles, halo merger rates, and the origin of halo angular momentum. Every topic is extremely well referenced and current (citing approximately 1500 research papers and books with a median publication date in the mid 1990s). This book is likely to be an essential reference for any galaxy-formation-research student or professor. In the coming years I can see myself dipping into this treasure trove on a very regular basis. — SHAUN COLE.

The Magnetic Universe: The Elusive Traces of an Invisible Force, by J. B. Zirker (Johns Hopkins University Press, Baltimore), 2009. Pp. 298, 23 × 15 cm. Price £18 (paperback; ISBN 978 0 8018 9302 5).

Magnetic fields are ubiquitous in the cosmos: they are observed and measured in planets, in the Sun and other stars, in galaxies, and in galactic clusters as well as in the voids between them. Field strengths vary greatly, from 10^{15} gauss (10^{11} teslas) in magnetars down to microgauss in intergalactic regions. Here on Earth we are now able to generate 8-tesla fields in the *Large Hadron Collider* (and, hopefully, 13 teslas to confine plasmas in the *ITER* experiment). Nevertheless, our understanding of how cosmic magnetic fields originated when the Universe was formed, or how the fields within galaxies and stars are now maintained, remains woefully incomplete.

This book is an informal survey of this huge subject, written by an experienced solar physicist and aimed at a broad readership. The presentation tends to follow historical developments (with an inevitable emphasis on US astronomers), and this anecdotal approach helps to make it all extremely readable. I certainly liked it, and appreciated being reminded of results that I had forgotten as well as of others that I ought to have known about but didn't. Many observational details are included but there are no equations to deter the amateur, who is helped out by words and figures. The author's enthusiasm is apparent through every chapter, as he moves outward from the Earth to the Sun, then to the heliosphere and planets, and on to other stars (including pulsars) and galaxies with active nuclei and black holes, yet further to galactic clusters and, finally, to cosmological origins of magnetic fields.

The coverage naturally reflects Zirker's own experience and commitments. More than half the book is devoted to the Solar System and, to be sure, we know much more about magnetic fields that are relatively local. A brief account of geomagnetism is followed by several chapters on solar magnetic activity, starting with sunspots and their recurrent cycles, then moving out into the Sun's tenuous atmosphere, with its flares and coronal mass ejections, and further into the heliosphere until the circle is closed by the impact of the solar wind on the Earth's magnetosphere, and geomagnetic storms. Other planets are dealt with fairly briskly. Throughout these chapters, hydromagnetic dynamos are invoked in order to explain the generation of magnetic fields, whether in the Sun's outer convection zone, or in the Earth's electrically conducting core or in layers of metallic liquid hydrogen within Jupiter and Saturn. Computers are now sufficiently powerful for theoreticians to produce realistic numerical models of the geodynamo, but the solar dynamo is proving a harder nut to crack.

It is easy to jump from the Sun to other stars. Surprisingly, there is no mention of the H–R diagram, nor is there much emphasis on the rôle of rotation: among stars with deep convection zones there are slow rotators that exhibit cycles like the Sun's, but rapidly rotating stars are much more active and exhibit prominent polar spots. The best known magnetic stars are the peculiar A-type stars, which are discussed in some detail: as well as possessing anomalous abundances, a typical Ap star has a strong non-axisymmetric magnetic field that is carried round as the star rotates; the most famous example is Babcock's Star, with a 34-kilogauss field.

Moving beyond individual stars, the book covers molecular clouds and star formation within them. Here the competition between rotation and magnetic fields is all-important. Although there is a discussion of discs surrounding protostars, the magneto-rotational instability, somewhat surprisingly, receives no mention, here or later. At the other end of a Sun-like star's life is its ultimate contraction to form a white dwarf, with a field that may reach hundreds of megagauss in strength. More-massive stars explode dramatically as supernovae and then collapse to become neutron stars, spinning rapidly and radiating as pulsars. Typically, they have magnetic fields of around 10^{12} gauss but some neutron stars possess fields a thousand times stronger, associated with bursts of soft X-ray emission: they are the magnetars. Yet-more-massive stars may collapse to form black holes.

Zirker next turns to galaxies. The black holes at their centres are most spectacular in active galactic nuclei, which are again associated with accretion discs, and with jets that must be collimated by magnetic fields. Within galaxies like the Milky Way, the fields measured by radio astronomers follow the pattern of the spiral arms, themselves produced by density waves. Over the years there has been a dispute between advocates of a dynamo and supporters of other amplification processes but (as of now) the former seem to be in the ascendant. Finally, we come to the biggest puzzle of all: how did all these magnetic fields appear in the beginning? Were they created somehow in the Big Bang, or did they appear later through some more straightforward process (the so-called Biermann battery)? Either way, they have to be amplified enormously to reach the strengths that we see around us now.

It is easy to pinpoint omissions in a broad-brush survey such as this. For instance, the vital rôle of spectroscopy is scarcely mentioned. More serious is the lack of any explicit references. Although the authors and dates of many key papers are identified (and any reader familiar with ADS could gain access to the original texts), there is no clear guide to further reading, either of books or of significant reviews. That, however, is beside the point. What we have is a wide-ranging and stimulating account of the rôle of magnetism in astrophysics, aimed primarily at non-specialists. The discussion does inevitably grow more specialized and more complicated as it proceeds; so the naïve reader who is introduced to lines of force in Chapter 1 may later be bemused by details of the solar wind. I hope, however, that such readers will persevere, and I recommend the book to them. — NIGEL WEISS.

Physics and Astrophysics of Neutron Stars and Black Holes, 2nd Edition, edited by R. Giacconi & R. Ruffini (Cambridge Scientific Publishers), 2009. Pp. 1017, 25 × 18 cm. Price £55 (hardbound; ISBN 978 1 904868 71 2).

Perhaps one of the triumphs of astrophysics in the 20th Century was the discovery and explanation of neutron stars and black holes as stages in the evolution of stars, and a key conference in the elucidation of those matters was held at Villa Monastero on the shores of Lake Como in Italy in 1975. In fact, so central to the development of the field was this *Scuola Internazionale di Fisica Enrico Fermi* that the original proceedings, published by the Società Italiana di Fisica, has been reproduced in its entirety by Cambridge Scientific Publishers as a valuable archival record. But it's not just a souvenir volume since it contains numerous fundamental reviews, by heavyweight experts of the day, of which modern researchers should be aware.

To add value to this weighty tome, the editors — both 'founding fathers' of the subject — have added five further essential papers: three Nobel Lectures (by Chandrasekhar, Giacconi, and J. H. Taylor) together with Giacconi's biographical review from *ARA&A* (**43**, 1, 2005), and a theoretical review on black holes by Ruffini.

If your library claims to hold the most important works in astrophysics but does not have a copy of the original conference proceedings, then the present volume is a not-too-expensive way of filling the gap. — DAVID STICKLAND.

Bioastronomy 2007: Molecules, Microbes, and Extraterrestrial Life (ASP Conference Series, Vol. 420), edited by K. J. Meech, J. V. Keane, M. J. Mumma, J. L. Siefert & D. J. Werthimer (Astronomical Society of the Pacific, San Francisco), 2010. Pp. 531, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 720 9).

Astrobiology, the field involved in understanding the conditions necessary for the emergence and maintenance of life and its distribution beyond the Earth, is currently striding from strength to strength. Several dedicated journals regularly publish astrobiology papers, and many larger conferences now host an astrobiology session. This book contains the set of papers presented at the 'Bioastronomy 2007' conference held in Puerto Rico, the home of the Arecibo radio observatory.

The scope of this publication is understandably broad, and ranges from the earliest origins of chemical complexity in the Universe to the possibilities of there existing intelligent alien life. Each of 14 parts of the book is themed on a session at the conference, and covers all the different disciplines coming together under astrobiology: astrophysics, cosmochemistry, planetary science, prebiotic chemistry, extremophile organisms, extrasolar planets, and detecting signs of life ('biosignatures'). Highlights for me include Seth Shostak's piece on new strategies for SETI, David Schwartzman on the climate of the early Earth, and Ruiz-Bermejo's argument that the dye Prussian Blue (ferrocyanide) may have played a rôle in the origin of life on Earth.

A particularly handy resource is provided in the book's Glossary. In preparation for this 'Bioastronomy 2007' conference, delegates were invited to submit their suggestions and definitions of key astrobiological terms, from accretion to zwitterion. This represented the core vocabulary list likely to be needed for understanding the papers presented at the meeting, and was a prescient idea considering the great diversity of disciplines collaborating within astrobiology, each with their own set of esoteric terminology. — LEWIS DARTNELL.

The Second Hinode Science Meeting: Beyond Discovery — Toward Understanding (ASP Conference Series, Vol. 415), edited by B. Lites, M. Cheung, T. Magara, J. Mariska & K. Reeves (Astronomical Society of the Pacific, San Francisco), 2010. Pp. 465, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 710 0).

This report of a meeting in 2008 September/October on results from the Japanese solar spacecraft *Hinode* comes hard on the heels of a first meeting in Dublin held less than a year after launch. The contents, numbers of papers (around 90), and the numbers of participants (60 per cent more than the first meeting), all reflect the much more detailed analyses and results contained in the proceedings. Even so, more than half the participants did not submit material for these proceedings, preferring instead to publish their work in journals. I found it particularly hard just to summarize for this review the main results, there have been so many and in so many different fields, so I can do no more than pick out from a personal perspective some interesting papers that I think enhance the value of the book and make it worth buying.

There are a few common threads: the quiet Sun, coronal loops, magnetic activity, active regions, and sunspots, and even flares, though solar activity has remained at a low level throughout *Hinode*'s operational period.

The papers are ordered into nine sections of which the most substantial are those on coronal/chromospheric heating, magnetic activity, coronal loops, sunspots, and flare physics. The items that caught my attention and should be generally useful included an informed review by Judge on the interface between the chromosphere and corona and its importance in coronal heating, and some ideas advanced by Klimchuk, mirrored in some of the contributed papers, that the greatly improved spatial resolution of coronal loops is only leading to the suspicion that what have commonly been called "fine" loops by those analyzing data from *TRACE* may be bundles of extremely small strands that are impulsively heated by nanoflares or MHD waves. *Hinode* observations have either led to the discovery, or at least a much better understanding, of several important solar phenomena: the two categories of spicules (article by McIntosh & DePontieu), the 'reverse granulation' seen in the Ca II quiet Sun intra-network (De Wijn *et al.*), sunspot structure and dynamics (Tritschler), and the quiet-Sun near-surface dynamo are examples. Some sophisticated modelling work is described in papers composing the second section, with interesting comparisons with *Hinode* data.

Observations by *Hinode* were seriously compromised early in 2007, just a few months after launch, when the X-band transmitter on the spacecraft started to fail. The spacecraft now downloads *via* its S-band transmitter, resulting in a much slower download, but through data compression and an increased ground-station network the effects of the restrictions have been minimized. This augurs well for future operations when solar activity starts to pick up. Meanwhile, these proceedings will provide a very useful starting point for our current understanding of fields such as coronal loops, fine structure of sunspots and prominences, and coronal and chromospheric heating. The all-important quality of illustrations, particularly *Hinode* solar images, is generally high, and the reviews and contributed papers have mostly been written with some care. At a reasonable price, this book is worth buying and reading. — KEN PHILLIPS.

Cosmic Dust — Near and Far (ASP Conference Series, Vol. 414), edited by T. Henning, E Grün & J. Steinacker (Astronomical Society of the Pacific, San Francisco), 2010. Pp. 543, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 708 7).

The days are long gone when extinction caused by dust was merely an irritation to be allowed for in making measurements of astronomical bodies. Dust is now recognized as an essential component that pervades the Universe. It is not only a useful tracer of gas in regions where the two are mixed, but an active component whose presence can modify and control the evolution of interstellar gas. The story of dust, from its formation around evolved stars and supernovae to its eventual destruction by fast shocks, touches many of the processes which are at the heart of modern astronomy. These include star and planet formation, astrochemistry, and astrobiology. It is therefore not surprising that many recent missions, such as *Spitzer*, *Stardust*, and — most recently — *Planck*, have been devoted at least in part to dust and to the emissions from dust.

This volume reports the proceedings of a conference held at Heidelberg in 2008 September attended by nearly 300 participants. About 40 substantial papers cover a very wide range of topics, the most exciting of which for this reviewer are those on the results of the *Stardust* comet-dust-return mission, and the discussions of dust in the early Universe. A thoughtful summary by Adolf Witt notes that some longstanding unsolved problems remain (unidentified interstellar bands; 217·5-nm bump; extended red emission, *etc*.). Evidently, there are still fundamental problems in our present understanding of the nature of cosmic dust. Witt also lists the newer issues (such as the origin of early-Universe dust, or the processing of dust in protostellar discs). It's clear that a full understanding of cosmic dust still eludes us; however, this excellent summary of the modern position on dust research will be the standard reference for years to come. Thomas Henning, Eberhard Grün and Jürgen Steinacker deserve our thanks for assembling such a vast amount of high-quality research on dust in such a convenient and well-produced form. — DAVID WILLIAMS.

IAU Transactions XXVIIB: Proceedings of the Twenty Seventh General Assembly Rio de Janeiro 2009, edited by I. F. Corbett (Cambridge University Press), 2010. Pp. 519, 25 × 18 cm. Price £70/$125 (hardbound; ISBN 978 0 521 76831 3).

If you want to find out what science was discussed at the IAU GA in Rio de Janeiro, you will need to find the proceedings of the six symposia, or the *Highlights of Astronomy* volume that records the Joint Discussions and other special and scientific sessions. In this volume you will find primarily the reports of the formal proceedings of the General Assembly — the Inaugural Ceremony, the Business Sessions, and the Closing Ceremony, together with the formal Resolutions that were passed. The volume also contains the triennial report of the Executive Committee, the reports of the Division, Commission, and Working Group meetings, a list of the statutes (in English and French, the French version being authoritative), bye-laws and rules of the IAU, lists of the composition of the Divisions, of the nations that are members (four new ones: Costa Rica, Honduras, Panama, and Vietnam), and finally of individual members, both by nationality and by commission.

This sounds very dry, and much of it is. However, there are bits of science scattered throughout the book, including the texts of two presentations at the opening ceremony. Although the reports of Divisions, *etc*., were largely to do with formal business, some science was included in some reports. For example, Commission 42 was concerned about "the mechanical application of light curve synthesis codes" to close-binary stars without spectroscopic checks on the mass ratio; Division IV discussed (without resolving the issue) the discrepancy that has arisen in solar-abundance determinations as a result of the new 3-D time-dependent hydrodynamical models of the solar atmosphere; Commission 19 heard a report from Pat Wallace (RAL) on a set of 160 software routines maintained at RAL under IAU auspices (http://www.iau-sofa.rl.ac.uk). Although none of the Resolutions was as controversial as the proposal to demote Pluto at Prague in 2006, it is interesting (and disappointing) that the resolution supporting women in astronomy had the largest number of abstentions (7).

I noted one oddity, and some interesting information. The oddity is in the lists of individual members, which are printed in three columns — but each column runs on from page to page, so that (for example) on p. 401 column 1 has names starting with A, column 2 those starting with H, and column 3 those starting with P; this system is fine on the IAU website, but makes finding someone a little disconcerting in a printed list. The IAU suffered a serious internal fraud over a 10-year (and possibly 20-year) period, revealed only by the sudden death in 2008 January of the Executive Assistant, who had been systematically inflating the apparent costs of the administration and pocketing the difference. However, the finances of the IAU remain in a healthy state. Finally, there were 2434 registered attendees in Rio — how many will there be in Beijing in 2012 and Hawai'i in 2015? — ROBERT CONNON SMITH.

Stargazers' Almanac 2011 (Floris Books, Edinburgh), 2010. Pp. 32, 29·5 × 42 cm. Price £14·99/$25 (ISBN 978 086315 757 8).

Now a regular player on the night-sky-watching scene, the *Stargazers' Almanac* for 2011 has appeared in good time to be selected as a Christmas gift for anyone with the slightest interest in what is going on 'up there'. Bob Mizon's text is predictably authoritative, giving accurately all you need to know of the annual celestial pageant together with information on the more-interesting phenomena with different cycle times, principally those of Solar System objects. The monthly charts are attractive and yet clear, being set out with views to the North and South, whilst the information panels above the charts provide realistic targets for stargazers of even limited experience, together with useful facts such as lunar phases, mid-month sunrise and sunset times, and when to abandon GMT in favour of BST (and *vice versa*!).

The special feature this year is on sunspots, with an historical overview and an introduction to the related solar activity. And, as in previous years, the *Almanac* campaigns for dark skies by highlighting the problems of light pollution and advocating action to minimize it; all in all, a very worthwhile publication. — DAVID STICKLAND.

Exploring the Solar System with Binoculars: A Beginner's Guide to the Sun, Moon, and Planets, by S. J. O'Meara (Cambridge University Press), 2010. Pp. 156, 30 × 21 cm. Price £19·99/$29·99 (paperback; ISBN 978 0 521 74128 6).

The naked-eye or binocular observer could hardly hope for a better guide to exploring the Solar System than Stephen J. O'Meara. A skilled visual observer of vast experience and international repute, he is also an engaging and imaginative writer capable of firing the enthusiasm of observers at all levels of ability. Although quite up-front about the inescapable fact that binocular views of the Sun, Moon, and planets are likely to prove disappointing to those familiar with the spectacular images taken by spacecraft, O'Meara advances the view that "binocular observing is half reality, half imagination". Binoculars provide the reality of a Solar System half-glimpsed, while O'Meara's prose, along with the fine illustrations that accompany it, feed the mind and heart and permit the imaginative leap required to reconcile the wonders disclosed by close-up imagery with the more subdued views provided by the eye and binocular. This is no mean achievement, and O'Meara accomplishes it by taking every opportunity to embed the practicalities of observation within a rich context of historical, cultural, and scientific discussion.

Separate chapters deal with the various Solar System bodies and related phenomena. The first, devoted to the Sun, offers an exhaustive account of what can be seen on the solar disc, as well as a guide to safe observing that includes suggestions for practical data collection that will permit the amateur observer to keep a systematic record of the Sun's changing face. The chapter on the Moon provides a remarkably detailed description of the features that are revealed to the binocular observer as the Moon goes through its monthly cycle of phases. A further chapter compellingly describes the often spectacular effects produced by both solar and lunar eclipses, as well as the best methods to observe these. The final two chapters deal thoroughly with the science and lore of comets and meteors, as well as offering useful tips for observation.

The chapter on the planets is perhaps the least successful, not for want of any effort on the part of O'Meara, but because of all the Solar System bodies the planets are the most reluctant to yield their glories to the binocular or naked-eye observer. Nevertheless, this chapter still provides an excellent introduction to the Sun's family of planets.

There are some weaknesses in this volume: a bibliography or guide to further reading would have been helpful, and there are a few small errors and typos which can occasionally be misleading. Nevertheless, this book packs an enormous amount of information into its 150 pages, and it is thoroughly recommended to those wishing to maximize the potential of naked-eye and binocular observation. — BILL LEATHERBARROW.

THESIS ABSTRACT

THE FORMATION OF MOLECULAR HYDROGEN IN THE INTERSTELLAR MEDIUM

By Farahjabeen Islam

H_2 is the most abundant molecule in the interstellar medium and forms on the surface of interstellar dust grains. Laboratory studies have been conducted of HD formation on a dust-grain analogue, a highly-orientated pyrolytic graphite surface held at 15 K, under ultra-high vacuum. The molecules desorb from the surface in a distribution of ro-vibrational states, which are probed using resonance-enhanced multi-photon ionization spectroscopy. HD in a particular ro-vibrational state is ionized using laser photons detected by a time-of-flight mass spectrometer. The HD^+ ion yields are then data processed to obtain the relative rotational populations of HD formed within one vibrational level, and an average rotational temperature can be found. In this thesis, HD formed in vibrational states $\upsilon = 3$ to 7 have been studied. This carries on from previous studies of HD and H_2 in the $\upsilon = 1$ and 2 states. Within each vibrational level, the most populated rotational state was found to be $J = 1$ or 2. The most populated vibrational state was found to be $\upsilon = 4$.

The HD experimental results were extrapolated to give the relative ro-vibrational population distribution of nascent H_2, which provides a new model for the formation pumping of H_2. This new formation-pumping model has been implemented into a radiative-transfer code, written by Casu and Cecchi-Pestellini, which takes into account formation, radiative, and collisional-pumping mechanisms to calculate the total population distribution of H_2 in an interstellar cloud and to generate H_2 spectra. The sensitivity of the H_2 spectra to the physical conditions of interstellar dark clouds, such as cloud density and temperature, has been investigated. H_2 spectra generated using the new experimentally-derived formation-pumping model has also been compared to H_2 spectra generated using other established, theoretically-derived formation-pumping models. — *University College London; accepted 2010 March*.

Here and There

COLOUR BLIND

… a red dwarf … is so densely packed with matter that a cubic inch of it would weigh more than 10 tons! — *Daily Telegraph*, February Night Sky.

HARDLY SURPRISING

Spica, if seen from close-up, would be one of the super-bright stars. — *Daily Telegraph*, March Night Sky.

THIRSTY WORK, ASTRONOMY

Following Sir Arnold's talk there was a welcome break for coffee. — *SHA Bulletin*, 2009 June, p. 24.