THE OBSERVATORY

Vol. 130 2010 APRIL No. 1215

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2009 October 9 at 16^{h} 00^{m}
in the Geological Society Lecture Theatre, Burlington House

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

The President. Let me welcome you all to the new session of meetings, and congratulate the following Fellows: Professor John Barrow from the University of Cambridge has been awarded the 2009 Kelvin Medal and Prize for the promotion and explanation of physics and astronomy to young people and the general public; Professor Rob Kennicutt, also of Cambridge, is to share the $500 000 Gruber Prize for cosmology for his outstanding work in constraining the value of the Hubble constant; and Professor Eric Priest of the University of St. Andrews has been awarded the 2009 Payne-Gaposchkin Medal and Prize for his numerous major contributions to many of the unsolved problems in solar physics. Going on to the 2009 Michael Penston Astronomy Prize, the first prize of £1000 goes to Kevin Schawinski of Oxford University, who is currently at Yale, for his thesis entitled 'The star formation history of early-type galaxies'. The runner-up, who gets a £50 book token, is Dr. Rita Tojeiro of the University of Edinburgh, now at the University of Portsmouth, for her thesis entitled 'Analysing observables in structure-formation theories'. The RAS Keith Runcorn Prize, worth £1000, goes to Dr. David Jess of Queens University Belfast for his thesis entitled 'High-cadence observations of the solar atmosphere', whilst the runner-up prize of a £50 book token goes to Dr. Remco de Kok of Oxford University, currently at SRON in the Netherlands, for his thesis, 'Oxygen compounds, aerosols and condensate clouds in Titan's stratosphere'. We hope that those prize-winners are going to give their talks at some future monthly meeting.

So now we move to our main programme, and the first talk is by Dr. Roger Haagmans and it's on 'ESA's Earth-observation potential'.

Dr. R. Haagmans. [The speaker started by describing how ESA's satellite programme began in the 1970s with *METEOSAT*, included the multi-platform *ERS* satellites, and was followed by *ENVISAT* in 2002. This satellite is the size of a bus and performed many functions. This led to conflicting requests in scheduling observations that, for example, required substantially different sampling intervals. The answer was to develop smaller, more-dedicated satellites which could be tailored to individual tasks.

The radar altimeter in *ENVISAT* helped to continue the coverage of sea-level height begun by the *ERS* satellites and it reveals that over the last 15 years or so the global mean sea level has increased by about 3 mm per year. This is, however, an average as there are still places on the Earth's surface where the land is rising, such as Scandinavia, or rather the level of the Baltic Sea is falling. The speaker said that because he was Dutch he was very interested in the data [laughter]. *ERS* and *ENVISAT* also measured the global sea-surface temperature, which is currently rising by +0·13 K per decade.

A document representing ESA's new science strategy for Earth observation, called *The Changing Earth*, has been prepared and is available on the website (http://esa-mm.esa.int/docs/SP-1304.pdf). It gives views on the system applications and the fundamental interactions and interfaces between different components of the Earth's system. This is the basis for the selection of new missions.

The Earth Explorer projects are research driven and consist of three core missions and three opportunity missions. There is a series of satellites called core missions (*GOCE*, *ADM-Aeolus*, and *EarthCARE*) which will look at, respectively, global ocean circulation, physics of the Earth's interior, and sea-level and ice-sheet monitoring; wind profiles and atmospheric dynamics; and improving understanding of cloud-aerosol–radiation interactions.

The three opportunity missions are *CryoSat-2*, *SMOS*, and *Swarm*. The latter aims to provide the best-ever survey of the Earth's geomagnetic field and its time variation to give new insights into the Earth's interior and the near-Earth electromagnetic environment. It is a constellation of satellites — initially two at low altitude and another higher up but all with orbital planes drifting with time.

Part of the operational service missions, more specifically the Global Monitoring for Environment and Security (GMES) space component, consists of five Sentinel missions. Three are concerned with Synthetic Aperture Radar (SAR) imaging, spectral imaging, and ocean monitoring, and will fly as independent satellites. The last two Sentinels will fly as payloads on other operational missions. Some of the satellites are expected to fly in concert as a constellation.

Perhaps the most ambitious of the Core Mission satellites is *GOCE* (*Gravity field and steady state Ocean Circulation Explorer*). This is ESA's gravity mission with objectives to measure Earth's gravity field with the intention of improving the understanding of global ocean circulation, physics of the lithosphere and mantle, and examining sea-level change and the evolution of ice shelves. After the launch in 2009 March, the satellite flies at a low altitude of 255 km. From that height very small changes of gravity will be mapped locally in 3-D. The motion of the satellite itself also acts as a sensor of the gravitational field, so it can also be utilized using GPS at the centimetre level. The accelerometers in *GOCE* will have a sensitivity equivalent to that of the acceleration due to the gravitational attraction of a supertanker to a snowflake, *i.e.*, 2×10^{-12} metres sec^{-2}, and therefore both the gradiometer instrument and the satellite need to be of very stable construction.

The speaker summarized by saying that this will be a very busy time for ESA, with about 15 satellites due to be launched in the next decade.]

The President. Thank you, Roger. Questions?

Professor M. Barstow. What's the cost for some of these missions compared to, say, an astronomy mission?

Dr. Haagmans. The big 'bus' (*ENVISAT*) mentioned at the beginning is about two and a half billion Euros. The core-missions class is about 300 million Euros, and the opportunity-mission class comes in at around 150 million Euros each.

Mr. M. F. Osmaston. I'm interested in the possible changes in gravity during the stress build-up for an earthquake and the magneto-telluric effect at the same time. So if you're going to be observing the magnetic field and gravity, you can have spatial rather than time resolution as you go around the orbit in order to be able to correlate these and possibly help in earthquake detection.

Dr. Haagmans. True, and as a US/German gravity mission *GRACE* looks at time changes, *GOCE* focusses on the static part of the gravity field. *GRACE* actually has helped understanding the Sumatra earthquake after the fact, not as a precursor. But as a post-seismic analysis, it helped to improve the model indirectly, and maybe through that you might have an improvement in prediction in the future. That's a nice desire but very difficult to achieve.

Professor Kathy Whaler. It's just an off-the-wall idea but you're talking about a wind satellite and the long-term implications for understanding ocean circulation, climate, and weather. Are there more immediate applications like locating wind farms or is the scale completely wrong?

Dr. Haagmans. In principle, if you want to have an operational system for these kind of applications, you need several satellites at the same time because they have the right space and time sampling. The Explorer programme can often only afford a demonstrator of the concept. Only if it is successful you may have a sequence like the Sentinels and try to serve these applications.

Professor D. W. Kurtz. Are you sensitive to small near-Earth asteroids in the gravity experiment?

Dr. Haagmans. Only when they hit the satellite [laughter]. No, I don't think so — it has to be a very close encounter.

Professor H. D. Greyber. Isn't there a Stanford satellite that has been up there for a few years studying gravity and could you explain to me any connection to those you've discussed?

Dr. Haagmans. Then you mean *Gravity Probe B*. I think that satellite was launched for an Einstein-related physics experiment. The missions I've talked about here and the other US/German mission I mentioned, *GRACE*, are really there to monitor the mass distribution or the mass transport in the Earth's system, so they have a completely different purpose. They are Newton-based and what you mentioned aimed, if I'm not mistaken, at a check of Einstein's equivalence principle.

The President. Thank you very much. Our next speaker is Mike Lockwood, from RAL, and he's going to tell us about what's happening with sunspots.

Professor M. Lockwood. [The speaker outlined his intention to review the recent solar minimum and place it in the context of the last century and millennium of solar activity, to see what it means for us on Earth.

He started by describing the recent descent into the present solar minimum, which is unprecedented since the beginning of monitoring the Sun and its environment from space. Since the 1960s we have collected data on the interplanetary magnetic field (IMF) and total solar irradiance (TSI) in addition to the continuous data sequences such as sunspot number and geomagnetic-activity indices. The TSI and the sunspot number peaked around 1985, and the open solar flux (OSF) about 2 years later. Cosmic rays are highly anticorrelated with the open flux and so they started to recover in 1987. Since then, the TSI and sunspot number have fallen and the global mean surface temperature (GMAST) has continued to rise. From reconstructions based on geomagnetic data, the strength of the IMF has not been as low as it is now since the 1920s. The two geomagnetic indices we use are correlated with different combinations of the strength of the IMF and also the solar wind velocity. To use the indices to extrapolate the OSF back in time we make use of a key result from the *Ulysses* spacecraft, which was the first to fly out of the ecliptic plane. This yielded an important result, namely that the measured radial field is proportional to the OSF and so, again, it is found that the OSF has fallen to record low levels since the 1920s. It has declined over the last three solar cycles as quickly as it rose over the previous five solar cycles.

Geomagnetic activity gives a very good indication of the centennial context of the present very low minimum. We can work out the IMF and solar wind speed separately and interpolate them back to 1905, the earliest epoch at which the data can be regarded as reliable. Taking running means of the OSF and the solar wind speed tells us that we have been in a grand solar maximum (as defined from a threshold value of cosmogenic isotope abundances) since 1920, and that this will come to an end in about 10 years' time. This is in good agreement with the conclusions of Abreu, Beer, Weiss, and co-workers, who studied the distribution of grand-maxima durations in cosmogenic-isotope data.

To look at the millennial context we need to consider the cosmogenic isotopes such as ^{14}C and ^{10}Be. The deposition of these two isotopes into the terrestrial reservoirs is so different that we can be sure that common features are due to the influence of the Sun on cosmic rays and not an effect of climate. The speaker said that over the last 9000 years there have been 24 cases of grand solar maxima and the period between each varies from as little as 40 years to much longer. By studying the points at which the Sun fell out of the grand solar maxima it is possible to estimate that there is an 8% chance of there being a Maunder Minimum within the next 50 years but a less than 4% chance of there not being one in the next 400 years.

The Earth is not quite in radiative equilibrium and recent data from the new *SORCE* satellite show the current TSI to be 1361 watts per metre^2, some 6 watts per metre^2 lower than the previously accepted value. The surprise is how much of that descent of the TSI over the last half solar cycle is actually due to the UV part of the spectrum. From the *CERES* satellites it has been found that the albedo of the Earth is 0·3 and we have detected no variations in this within experimental uncertainties. Of the energy incident on the Earth's surface (238 watts per metre^2), a small amount is going into the ocean (0·85 ± 0·15 watts). This may be small, but it is highly significant because it means that even if the rise in radiative forcing ceased immediately, the temperature would continue to rise for another 50 years as the ocean gives the heat back. From the GMAST change between the Maunder Minimum and the present, we know the radiative-forcing rise over the period was 5·15 watts per metre^2.

About a decade ago we noticed a nice correlation between the TSI and OSF, and if it were found to hold over more than one solar cycle it would explain why the cosmogenic isotopes were anticorrelated with the TSI. Froehlich has looked at the recent solar minimum. He finds that the minima depend on the OSF and finds a relation which explains the drop in TSI of 5·15 watts per metre^2 to the Maunder Minimum, which gives a radiative forcing change of 0·3 Wm^{-2}. To explain the observed GMAST change in terms of feedback effects would require an amplification factor of about 18. This would include cosmic rays if they do generate low-altitude clouds and alter the albedo radiative forcing by more than the change in the greenhouse forcing that they cause.

The global surface temperature rise seems to have levelled off in recent years. If this were a response to the decline in TSI and sunspots in 1985 then there is a very long and unexplained lag which is inconsistent with the small solar-cycle variation that is detected in tropospheric temperatures. Has the rise in the global mean of temperature at the Earth's surface stalled in recent years? The speaker looked at recent values of changes in GMAST and looked at trends in the data. The trend depends on the time interval which one considers adequate to define a trend. If that interval is assumed to be just 3 years, the recent trend is indeed downwards in the UEA/UKMO HadCRUT3 datasets (although the NASA/GIS data show a continued rise). However, considering that climate-active volcanoes are typically 10 years apart, 3 years is patently too short to define the trend. If one takes 10 years to define the trend then it is upward.]

The President. Thanks, Mike; the future predicted!

Professor Lockwood. I should say that I am confident I won't be here to see an awful lot of the predictions come true [laughter].

Professor E. R. Priest. On theoretical grounds, what do you expect the time scale of lag to be between solar irradiance and Earth's temperature. I saw fifteen years mentioned.

Professor Lockwood. Well, there is a researcher in America called Nicola Scafetta who is using a time-constant response of about a year, which would allow through the solar-cycle variations that you can see in tropospheric temperatures, but then a second time constant of ten to twenty years to get the long-term trends right. Now, the difficulty with that is if you allow all the inputs to have that sort of degree of freedom, actually calculating them involves you with something like twenty different fit parameters, so I'm not surprised he gets quite a good fit. And I don't think it's got much statistical significance at all for that reason. That's why I did the energetics of it. You can't get around the fact that you would have to amplify that by about a factor of 18 to explain what's going on.

Professor N. O. Weiss. Mike, you mentioned ultra-violet emission and its big changes during the solar cycle, but you didn't go on to describe the effect of that; can you say something about it?

Professor Lockwood. Well, that is interesting because there is some work that Joanna Haigh and co-workers have been carrying out. The point of ultraviolet is that it generates ozone but ozone also absorbs the UV so it's a very good source of stratospheric heating. Now, there are models and some evidence that heating of the stratosphere can interfere with oscillation models, like the El Niño oscillation, or the North Atlantic oscillation, and influence, in particular, polar temperatures, so there is a lot of interest in that; and the Harder paper (that uses data from the *SIM* instrument on *SORCE*) is actually showing much, much larger UV variation than anybody thought before. It's a factor of eight or nine bigger than, say, the *UARS* model that Judith Lean put together. The *SIM* data suggest much of the TSI variation is turning up in the UV, and actually in the other wavelength bands the variations are almost cancelling out. Out of a change of 1·3 Wm^{-2} since the last solar maximum, 1·0 Wm^{-2} was in the UV, and the other bands cancelled each other out to the extent that their nett effect was only 0·3 Wm^{-2}. And that's quite a surprise, so there is a possibility of some amplification factor which people think might be one or two, even three or four maybe, but not 18.

Professor Barstow. You've just been talking about the current minimum. Many of us who are now working on space programmes which will launch over the next three to four years are a bit exercised over the level of the next maximum. I could guess from some of the data you are presenting that perhaps it won't be as intense as the previous one. Would that be a reasonable statement?

Professor Lockwood. I think the average conditions will be lower, but that means you need to worry about cosmic rays more. It also might mean solar proton events are higher, because there is a theory from McCracken which says that, if the open solar flux is lower, the ejecta from the Sun emerges at the same velocity, so they're more super-Alvénic because the field is lower, and that gives you more acceleration of solar energetic particles, not less. It's interesting that the Carrington flare, which is by far the biggest solar energetic proton (SEP) event recorded in the nitrates found in ice cores, was actually at rather moderate solar-activity levels, so there is a possibility that although the average level is lower, the nasty events are nastier. Sorry!

Professor Barstow. It doesn't help.

Professor Lockwood. No.

The President. Do you actually understand the grand solar maximum, why it happens?

Professor Lockwood. No. I look to Nigel Weiss here, but I don't think there is a solar-dynamo model that can actually explain it. Most of the solar-value models we have are very constrained by the known behaviour of sunspots. I think that is a fair statement, isn't it, Nigel?

Professor Weiss. Well, I would say that a dynamo is a non-linear oscillator and non-linear oscillators typically do display modulation of that kind, so it's not surprising, but there isn't a predictive model that can tell you what's going to happen.

Professor Lockwood. I think that's a more erudite answer! [Laughter].

The President. Last question.

Professor Greyber. The longest allegedly-warm period was the medieval warm period when the Vikings went around. Is there any solar evidence from ice cores and so on that that might shed light on that idea?

Professor Lockwood. Globally, no. As far as I understand it, the medieval warm period was much more of a European phenomenon than a global phenomenon, but these things are difficult and we have only proxy data. The one thing that does show up all round the world that does have a really good correlation with cosmic rays and therefore solar activity is rainfall patterns. In some places it goes up, in some places it goes down, but over and over again things like speliothems (stalagmites and stalactites) are showing quite a good relationship to solar activity as inferred through cosmogenic isotopes. So it seems to me that something like the UV affecting the stratosphere, moving the jet streams apart, which is one of the predicted effects, could actually cause that kind of modulation to rainfall patterns, but it's in rainfall patterns where the correlations are most interesting.

The President. Very last question!

Professor D. Lynden-Bell. Given the fairly recent theory of lightning that says it has something to do with cosmic rays as the original triggers, do you think these rainfall patterns could be related more directly to the plasmas of thunderstorms and cosmic rays?

Professor Lockwood. I have asked that question over and over and never reached a sensible answer. It's a really interesting question because there is no doubt that the thunderstorm, the global electric circuit, functions because of cosmic rays producing ionization in the sub-ionospheric gap. Nobody seems actually to know: they just see lightning and thunderstorms as an offshoot of climate rather than a component of it. I think it is an extremely good question and the answer is I don't know, but I also know nobody else really does either.

The President. We must go on; thanks again. Our next lecture is the George Darwin Lecture and it's to be given by Neil Gehrels, the PI of *SWIFT*, who is from Goddard Space Flight Center. He is going to tell us about 'Gamma-ray bursts and the birth of black holes: discoveries by *SWIFT*'.

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

The President. Thank you very much, Neil, for a splendid talk. We've got time for some questions.

Mr. A. Land. In one of the long-burst events, you had the metallicity of the progenitor at about six percent. If you ever see a Population III object, is it just a matter of counting the metallicity down until you get to zero or are we going to see different evidence entirely at some point?

Professor Gehrels. The question is: if a very early Population III star explodes what would we see? Well, first of all you would see a very low metallicity, close to zero: it would only be hydrogen and helium at that time. Population III stars are predicted to be extremely massive, fifty to hundreds of times the mass of our Sun or even larger, and they may blow up in a different kind of way. So it will be very interesting to see how bright the gamma-ray burst is. We have had a few bursts that could be seen at a redshift of 15, but the chance of actually detecting one is small. You would probably need one of these more capable satellites to do it. But if you did detect one, and you get the metallicity, you get the density, you get the energetics; I think you could say a lot about the star itself. It's the only technique we have of spotting such an individual early star. But whether a gamma-ray burst is produced in this kind of very massive star, we don't know yet.

Professor Greyber. When you have the highest-redshift burst at 8·3, do you have a problem with the energetics and the size of the black hole and then the fluctuations which are in the millisecond region? And the second question: is there any evidence of the magnetic field occurring at the very earliest time?

Professor Gehrels. In this very-high-redshift burst the structures tend to be dilated. Also the micro-physics that takes place can be washed out in the highly relativistic outflows you have in these jets. I know you study these kind of things yourself.

Professor Greyber. It's the milli-second thing that bothers me most.

Professor Gehrels. Yes, and we didn't see milli-second time structure in this high-redshift outburst.

The President. Some people argue you couldn't do cosmology with gamma-ray bursts — do you agree with that?

Professor Gehrels. The idea is to do cosmology by using bursts — if you could use them as standard candles you could see them to much greater distances than type Ia supernovae. There is a group of people who have been trying to do this. You can use correlations in the spectrum of the burst and its duration to try to standardize them but it's been a hard business that hasn't reached the point where the technique is secure. I'm a bit sceptical — there is significant spread in each of the parameters that will be hard to narrow down well enough for that application. I wanted to mention, though, that we are doing a lot of other things with *SWIFT* and its *BAT* instrument, so we're doing one of the first all-sky, sensitive, hard-X-ray surveys, working with Andy Fabian and Richard Mushotzsky, and a lot of interesting results are coming out on AGN.

The President. It's very exciting.

Professor Lynden-Bell. I wanted to ask whether the co-moving density in redshift follows Madau plots of star-formation activity?

Professor Gehrels. That's a very good question. In general they tend roughly to follow the star-formation rate. There's a Danish group that's been looking at this carefully. The gamma-ray burst-formation rate or co-moving density tends to peak at a redshift of a few, like star formation does. There are, perhaps, some discrepancies at the low end where the gamma-ray bursts don't fall off as much as stars do. But it is a very interesting study that people are doing right now. For long bursts some kind of tie between the two is expected since long bursts are due to massive star explosions. The interesting thing is that, if we pin this down, we can use the burst to push out to higher redshifts in determining star-formation rate.

The President. Thanks again, Neil. I'm sure you're going to make great discoveries in the next ten years.

RADIAL VELOCITIES OF *CABS3* STARS OTHER THAN THOSE WHOSE ORBITS ARE GIVEN IN PAPER 209

By R. F. Griffin
Cambridge Observatories

In late 2008, the compilers of the *CABS3* catalogue invited the writer to measure the radial velocities of a number of stars that lacked orbital elements in that *Catalogue*. Thirty-seven such stars were placed on the Cambridge programme. Within a year, the orbits of twenty of them were written up for publication in Paper 209 of the long-running series of orbit papers in this *Magazine*. This note gives news of the remaining seventeen: five orbits are being published elsewhere, six objects exhibit variations of radial velocity but their orbits are not ready for publication, while six show no change whatever in velocity. Evidence provided here suggests that four of them (HD 37216, 123760, 136655, and 184591) ought never to have been entered in *CABS3* at all. For convenience, a list is given of all the *CABS3* stars for which the writer has given orbits and/or measured radial velocities, with references to published orbits or a note of the current status of the observations.

A Catalogue of Chromospherically Active Binary Stars (3rd Edition) (CABS3) was compiled by Eker *et al.*, who drew attention to its availability in a short paper[1] published in the *Monthly Notices* in 2008 October. By and large, only late-type stars have chromospheres; unusual activity is normally associated with rapid rotation (equatorial velocities $\gg 5$ km s^{-1}), which is itself often driven by axial rotation synchronized to short-period orbital motion. Of the 409 entries in *CABS3*, orbits had already been given for no fewer than 47 by the present writer; in some cases, it was the natures of the orbits that first led to the observation of the stars as potential BY Dra or RS CVn variables. The compilers of the catalogue kindly identified a number of other stars, presently lacking orbits, which might merit attention, and 37 of them have been observed from Cambridge. Orbits for twenty have recently been published in Paper 209[2] in this *Magazine*, and five more are in press elsewhere[3]. Of the remaining twelve stars, observations could not be satisfactorily concluded in a single season for two which have negative declinations, four have shown velocity changes but promise to have orbital periods much longer than a year, while six have shown no change at all. Stars which show slow or no changes of radial velocity, and have small or quasi-zero rotational velocities, present a problem. Eight of the ten long-period or constant-velocity stars just mentioned (the other two have significant rotation), plus five of those with recently published orbits, fall into that category; the origins of their respective activities will mostly warrant discussion in the future, although in one case it is elucidated below and in four instances it is suggested that the stars concerned were entered into the catalogue of active binary stars by mistake.

Table I lists all of the 84 *CABS3* stars that the author has observed, and gives either a reference* to the orbital solution (72 entries) or else a note of the present status of the observations. Table II then presents the individual radial-velocity measurements for the six stars that have shown no significant change in velocity. Those objects have now been deleted from the observing programme. They might, of course, still show long-term velocity variation, but it is already quite clear that their chromospheric activity is not linked either to membership of the measured stars in close binary systems or (except in one case) to rapid rotation. The note on HD 195434 below, however, serves to illustrate the caution with which such a conclusion should be accepted. In the cases of the remaining six stars, the hope is that in due course their orbits will be presented, probably in this *Magazine*.

Notes on the six 'constant-velocity' stars

HD 23386. This star has an abundant literature (71 papers retrieved by *Simbad*), no doubt because it has been considered a candidate for membership of the Pleiades star cluster. It is often identified in the literature by its Hertzsprung[4] Pleiades-area designation, HII 739. It appears in the sky on the outskirts of the obvious part of the cluster, nearly a degree north-preceding Alcyone. There has been no unanimity on the question as to whether it is an actual member. Its proper motion is very similar to that of the Pleiades, but not all authors consider it to be sufficiently coincident for membership; for example, the paper by Schilbach *et al.*[5] specifically addressed to, and entitled, 'Membership probabilities in the Pleiades field' attributes to it a probability of just 6%.

*Where no author is identified, the present writer was the sole author. Among papers in the *Observatory* series, collaborative papers are identified with an asterisk against the serial number of the paper, but to save space the authorship is not given.

TABLE I

CABS3 stars observed by the author

CABS no.	*Designations* *HD etc.*	*Variable*	*Reference for orbit or status of observations*	*Note*
4	HD 123	V640 Cas	Paper 144 (*The Observatory*, **119**, 27, 1999)	HR 5
6	HD 553	V741 Cas	Paper 170 (*The Observatory*, **123**, 129, 2003)	
16	HD 4449		Slow change in velocities, SB2	
30	HD 8997	EO Psc	Paper 76 (*The Observatory*, **107**, 194, 1987)	
31	HD 9313	BF Psc	Paper 2* (*The Observatory*, **95**, 98, 1975)	
34	HD 9902	BG Psc	Paper 209 (*The Observatory*, **129**, 317, 2009)	
45	HD 16884		Paper 209 (*The Observatory*, **129**, 317, 2009)	
56	HD 19942	V510 Per	Paper 103 (*The Observatory*, **112**, 41, 1992)	
64	HD 23386	V969 Tau	Constant velocity (see Table II)	
71	HDE 284163	V1136 Tau	R. F. Griffin & J. E. Gunn, *AJ*, **86**, 588, 1981	Hyades L20
72	HD 27130	V818 Tau	R. F. Griffin *et al.*, *AJ*, **90**, 609, 1985	Hyades vB 22
75	HD 27697		R. F. Griffin & J. E. Gunn, *AJ*, **82**, 176, 1977	δ Tau, HR 1373
76	HDE 284414	V988 Tau	R. F. Griffin *et al.*, *AJ*, **90**, 609, 1985	Hyades vB 43
77	HD 28291	V918 Tau	R. F. Griffin *et al.*, *AJ*, **90**, 609, 1985	Hyades vB 69
79	HDE 283716	V1110 Tau	Paper 209 (*The Observatory*, **129**, 317, 2009)	
80	HDE 283750	V833 Tau	R. F. Griffin *et al.*, *AJ*, **90**, 609, 1985	Hyades J 301
83	HDE 283882	V808 Tau	R. F. Griffin & J. E. Gunn, *AJ*, **83**, 1114, 1978	Hyades vB 117
85	HD 30738		R. F. Griffin & J. E. Gunn, *AJ*, **83**, 1114, 1978	Hyades vB 121
87	HD 31738	V1198 Ori	Paper 209 (*The Observatory*, **129**, 317, 2009)	
93	HD 33978	VV Lep	*MNRAS*, **371**, 1159, 2006	
99	HD 37216		Constant velocity (see Table II)	
103	HD 39743	V403 Aur	Paper 166 (*The Observatory*, **122**, 275, 2002)	HR 2054
109	HD 41116		Paper 10* (*The Observatory*, **96**, 188, 1976)	1 Gem
112	HD 45088	OU Gem	Paper 1* (*The Observatory*, **95**, 23, 1975)	
113	HD 45762	V723 Mon	Binary, $P \sim 60$ days	
131	HD 60803		Paper 135 (*The Observatory*, **117**, 208, 1977)	HR 2918
132	HD 61396	FG Cam	R. F. Griffin *et al.*, *New Ast.*, **11**, 431, 2006.	
134	HD 62721		*MNRAS*, **200**, 1161, 1982	81 Gem
135	HD 62668	BM Lyn	Paper 209 (*The Observatory*, **129**, 317, 2009)	
137	HD 65195		*MNRAS*, **212**, 663, 1985	
143	HD 71028		Slow change in velocity	
148	HD 73512		Paper 209 (*The Observatory*, **129**, 317, 2009)	
155	HD 80492		Paper 116 (*The Observatory*, **114**, 102, 1994)	
161	HD 82159	GS Leo	R. F. Griffin & N. Filiz Ak, *Ap&SS*, submitted	
172		EQ Leo	Paper 209 (*The Observatory*, **129**, 317, 2009)	
173	HD 88638	LX UMa	Single-lined binary, $P \sim 1600$ days	
177	HD 89959		R. F. Griffin & N. Filiz Ak, *Ap&SS*, submitted	
178	HD 90385	DW Leo	Paper 8* (*The Observatory*, **96**, 98, 1976)	
182	HD 93915		Paper 209 (*The Observatory*, **129**, 317, 2009)	
183	HDE 237944		Paper 209 (*The Observatory*, **129**, 317, 2009)	
188	HD 98230		Paper 142 (*The Observatory*, **118**, 273, 1998)	ξ UMa B
202	HD 102509	DQ Leo	R. E. M. & R. F. Griffin, *MNRAS*, **350**, 685, 2004	93 Leo
205	HD 106677	DK Dra	D. Reimers *et al.*, *A&A*, **193**, 180, 1988	4 Dra
210	HD 109011		Slow change in velocities, SB2	
214	HD 112099		Paper 209 (*The Observatory*, **129**, 317, 2009)	
216	BD +39° 2587		R. F. Griffin & N. Filiz Ak, *Ap&SS*, submitted	
217	HD 112859	BQ CVn	Paper 209 (*The Observatory*, **129**, 317, 2009)	
218		CD CVn	Paper 209 (*The Observatory*, **129**, 317, 2009)	
225	HD 115781	BL CVn	R. F. Griffin & F. C. Fekel, *JA&A*, **9**, 213, 1988	
226	HD 116093	IO Com	*JA&A*, **9**, 205, 1988	

TABLE I (*concluded*)

CABS no.	*Designations* HD etc.	*Variable*	*Reference for orbit or status of observations*	*Note*
227	HD 116204	BM CVn	R. F. Griffin & F. C. Fekel, *JA&A*, **9**, 213, 1988	
228	HD 116378		*JA&A*, **4**, 171, 1983	
231	HD 118234	IT Com	*JA&A*, **9**, 75, 1988	
233	HD 118670		*JA&A*, **11**, 533, 1990	
238	HD 122767	FR Boo	Paper 84 (*The Observatory*, **108**, 220, 1988)	
241	HD 123760		Constant velocity (see Table II)	
243	HD 127068	HK Boo	Paper 209 (*The Observatory*, **129**, 317, 2009)	
252	HD 136655		Constant velocity (see Table II)	
257	HD 138157	OX Ser	R. F. Griffin & N. Filiz Ak, *Ap&SS*, submitted	
261	HD 141690	QX Ser	Paper 110* (*The Observatory*, **113**, 128, 1993)	
265	HD 142680	V383 Ser	Paper 209 (*The Observatory*, **129**, 317, 2009)	
266	HD 143313	MS Ser	Paper 23 (*The Observatory*, **98**, 257, 1978)	
267	HD 143705		R. F. Griffin & N. Filiz Ak, *Ap&SS*, submitted	
273	HD 145230	PX Ser	Paper 209 (*The Observatory*, **129**, 317, 2009)	
276	HD 148405	V846 Her	*MNRAS*, **201**, 487, 1982	
282	HD 150202	GI Dra	Paper 209 (*The Observatory*, **129**, 317, 2009)	
291	HD 155989	V832 Her	Paper 21 (*The Observatory*, **98**, 158, 1978)	
301	HD 160952	V834 Her	Paper 7* (*The Observatory*, **96**, 56, 1976)	
304	HD 163621	V835 Her	R. F. Griffin *et al.*, *JA&A*, **15**, 304, 1994	
317	HD 171802		Paper 129 (*The Observatory*, **116**, 233, 1996)	HR 6985
339	HD 184591		Constant velocity (see Table II)	
318	2E 1848.1		Paper 209 (*The Observatory*, **129**, 317, 2009)	
347	HD 191179		Paper 209 (*The Observatory*, **129**, 317, 2009)	
348	HD 191262	V1423 Aql	R. F. Griffin & F. C. Fekel, *JA&A*, **11**, 43, 1990	
350	HD 192785		Paper 209 (*The Observatory*, **129**, 317, 2009)	
351	HD 193216		Paper 162 (*The Observatory*, **122**, 14, 2002)	
352	HD 193891	V1971 Cyg	Paper 103 (*The Observatory*, **112**, 41, 1992)	
354	HD 194765		Double-lined binary, $P \sim 160$ days	
355		BI Del	Paper 209 (*The Observatory*, **129**, 317, 2009)	
357	HD 195434	MR Del	Seemingly constant velocity (see Table II)	
361	HD 198084		Paper 148 (*The Observatory*, **119**, 272, 1999)	HR 7955
363	HD 197913		Paper 183 (*The Observatory*, **125**, 253, 2005)	
401		EZ Peg	Paper 62 (*The Observatory*, **105**, 81, 1985)	
408	HD 223971	V413 And	R. F. Griffin *et al.*, *IAPPP Comm.*, 44, 82, 1991	

*Collaborative papers

Unfortunately the star was not on the *Hipparcos* programme (although it was picked up by *Tycho*), and the available parallax[6] is actually negative. Moreover, its photometry has usually placed it some $0^{m}\cdot8$ above the Pleiades main sequence in the colour–magnitude diagram — higher than the utmost limit of $0^{m}\cdot75$ attainable by binary stars when they have equal components. On account of its position in the colour–magnitude diagram it has frequently been referred to as a 'photometric binary' (though 'photometric triple star' would be more honest), but no supporting evidence of duplicity has ever been forthcoming — it has neither been resolved as a visual (or interferometric, *etc.*) double star nor has it shown velocity variations that would qualify it as a spectroscopic binary.

Photometry of HD 23386 has not been as accordant as would be expected for a photometrically stable star. Johnson & Mitchell[7], in their paper on the colour–magnitude diagram of the Pleiades early in the *UBV* era some fifty years ago, gave the values $V = 9^{m}\cdot56$, $(B-V) = 0^{m}\cdot62$, $(U-B) = 0^{m}\cdot06$. Various subsequent observers[8–15] have attributed to it sometimes mutually discordant

TABLE II

Radial velocities of the six 'constant-velocity' stars in Table I

HD 23386

Date (UT)			RV (km s⁻¹)
2008	Nov.	8·06	+8·3
		23·06	+6·5
		26·06	+7·8
	Dec.	9·94	+5·9
2009	Jan.	2·95	+7·0
		6·85	+6·6
		18·91	+6·3
		23·85	+6·7
	Feb.	10·88	+6·8
		21·86	+7·0
	Mar	20·83	+7·5
	Oct.	12·11	+6·8
		23·19	+6·7

Mean +6·92 ± 0·18

HD 37216

Date (UT)			RV (km s⁻¹)
2009	Oct.	19·20	+12·4
		22·20	+12·4
	Nov.	8·12	+12·4
	Dec.	10·08	+12·7
2009	Jan.	3·08	+12·2
	Mar	5·93	+12·7
	May	3·86	+12·9
	Oct.	23·22	+12·4

Mean +12·54 ± 0·08

HD 123760

Date (UT)			RV (km s⁻¹)
2008	Feb.	7·25	+1·8
		12·22	+1·9
	Mar.	6·19	+2·1
	Apr.	2·08	+1·9
	May	4·04	+1·9
	June	1·99	+1·8
	July	2·94	+1·9

Mean +1·90 ± 0·04

HD 136655

Date (UT)			RV (km s⁻¹)
2009	Mar	21·17	−31·2
		27·17	−31·2
	Apr.	2·12	−30·9
	May	4·06	−31·2
	June	2·00	−30·7
	July	1·98	−30·9
		2·94	−30·9
	Aug.	11·86	−31·2
2009	Sept	10·82	−31·1

Mean +31·03 ± 0·06

HD 184591

Date (UT)			RV (km s⁻¹)
2008	Nov.	7·82	−37·0
		14·77	−36·8
	Dec.	6·74	−36·8
		9·74	−36·8
2009	July	1·06	−36·9
	Aug.	8·00	−37·0
	Oct.	8·88	−37·1

Mean +36·91 ± 0·05

HD 195434

Date (UT)			RV (km s⁻¹)
1997	July	18·00†	−51·7
		18·99†	−51·4
		20·02†	−51·0
	Sept.	10·83†	−51·4
2008	Nov.	14·78	−50·7
	Dec.	6·74	−50·3

Mean +36·91 ± 0·05

†Observed with OHP *Coravel*

V magnitudes ranging all the way from $9^{m}{\cdot}44$[14] to $9^{m}{\cdot}707$[15], without ever suggesting it to be a variable star. (The $9^{m}{\cdot}707$ given for V by Li[15] appears to be a mistake, and not to come from an original measurement by that author; it is the exact value listed by *Tycho* as the V_T (not the V) magnitude, and the corresponding value of V is actually $9^{m}{\cdot}63$.)

Magnitsky[16] was the first author specifically to regard HD 23386 as variable, and assigned to it a period of 2·70 days and an amplitude of $0^{m}{\cdot}05$; on that basis the star was gazetted in 1989 as a variable of the BY Dra type, with the designation V969 Tau, in the 69th name-list[17] of variable stars. In 1997, however, Marilli, Catalano & Frasca[18] asserted that the star had a period of $0^{h}{\cdot}906$ and an amplitude of $0^{m}{\cdot}04$; they did not refer to the discordance with the earlier finding or to the fact that the object had already been considered to be a variable star and designated as such. It is apparent from the context that the time unit in which the period was said to be 0·906 was intended to be days, notwithstanding that the superscript 'h' by which it was indicated might normally be interpreted to mean hours. Later, Messina[14] mistakenly re-asserted that "the optical band variability was discovered by Marilli *et al.* (1997) with an amplitude of $\Delta V = 0{\cdot}05$ mag and a period of $P = 0{\cdot}90^{d}$." Messina described another effort to look for a periodicity, but it yielded only 14 data points, taken in two runs of at most 8 and 3 nights separated by about a month; the result was given as 0·917 ± 0·003 days, but one could suspect that it was heavily influenced by the apparent expectation that it would be about 0·9 days, and the 'false-alarm' probability was noted by Messina as being as high as 17%. About the same time, Strassmeier *et al.*[13] weighed in with a period of 2·377 days and an amplitude of $0^{m}\cdot045$ for HD 23386. Thus we are confronted with three different periods that have all been put forward by different authors for the same star! If the writer had to make a choice, he would plump for Strassmeier's proposal, which was based on 70 data points obtained over an interval of 105 days. Despite the substantial discordances between different observers' evaluations of the magnitude of HD 23386, and the various suggestions of variability, and the fact of its having a variable-star designation, Yang & Liu[19–22] (with in one case[20] an additional collaborator) repeatedly utilized the star as one of only four ultimate photometric standards in their studies of the variable stars V396 Mon[19], UY UMa[20], V432 Per[21], and CE Leo[22], without apparently encountering any discordances (or objections from referees!) to dissuade them.

The spectroscopic literature on HD 23386 is almost as much in disarray as the photometric. Cautiously given just as type G in the *Henry Draper Catalogue*[23], the star appears to have been first classified in the MK system by Mendoza[8] as G0 V. Danziger & Conti[24] called it F8 and noted its strong red Li I line, while Kraft[25] gave its type as G1 V and listed its projected rotational velocity as ≤12 km s^{-1}. In papers specifically directed to the matter of rotational velocities of Pleiades stars, Stauffer *et al.*[26] gave its $v \sin i$ as 16 km s^{-1}, Stauffer & Hartmann[27] later as 14, Soderblom *et al.*[28] as 13, and Queloz *et al.*[29] as 14·4 ± 0·6 km s^{-1}. Boesgaard[30], however, gave $v \sin i$ as ≤12 km s^{-1}; Strassmeier *et al.*[13] listed results from two spectra individually as 14·1 and 12·5 km s^{-1}. Prosser *et al.*[31], who were concerned with rotation periods of stars in open clusters, *say* that Stauffer *et al.* — and they refer at that point to a paper "in press" which is clearly intended to be the one in ref. 32 here — give a rotation period such that log P (hours) = 1·81; put more explicitly, that means P_{rot} = 2·7 days, so it is possibly an indirect quotation of Magnitsky's[16] photometric rotation period.

Caillault & Helfand[33] identified HD 23386 with one of the five strongest X-ray sources observed in the Pleiades by *Einstein*. Stauffer *et al.*[32] included the star in a table of 'known Pleiades members' among *ROSAT* X-ray sources. Li & Hu[34] considered HD 23386 to be a 'weak-line T Tauri star' (WTTS); it is no. 97 of their list of such objects in the Taurus–Auriga region, and they (or it seems likely that it was actually their automated classification system) recognized that it was above the main sequence, assigning it a type of G5 IV. It fulfilled their criteria for WTTS candidates among *ROSAT* sources[32] by exhibiting a strong Li I line and Hα in emission. Strassmeier *et al.*[13] implicitly rejected it as a Pleiades member by listing for it a parallax of 3·00 milliseconds of arc, a corresponding absolute magnitude of $+1^{m}\cdot87$, and an MK luminosity class of III. It seems only too possible that, in the absence of an *Hipparcos* parallax, they fell back on the value in the *Parallax Catalogue*[6], which is −3 ± 12 milliseconds, that their software did not permit a minus in that column, and that they left their computer to take care of the entries that flowed from the number that it had written.

Until the writer developed[35] the cross-correlation method of determining radial velocities, there was a lot of difficulty in measuring velocities of stars as faint as HD 23386 with the sort of accuracy of interest for discussion of membership in star clusters or to estimate rotational velocities as 'small' as 10 km s^{-1}. Thus HD 23386 and stars of like magnitude were found to be too faint for the McDonald 82-inch reflector[36] and the Kitt Peak 84-inch[37], and only marginally observable[9], at low dispersion, at the DAO 72-inch; and Kraft lamented[25] that "exposure times required with the coudé spectrograph at Palomar run around 4 hours, and at Mount Wilson, 8 hours." Even though the instrumental difficulty has been overcome, the results in the case of HD 23386 remain ambiguous: the observed radial velocities have sometimes been thought to show a spread that is larger than it ought to be if the velocity were truly constant, yet they do not clearly demonstrate binary motion, and they have not been made anywhere near assiduously enough to demonstrate rotational modulation.

The first measurement of the radial velocity of HD 23386 was by Kraft[25]; he gave a result of "+4·8 var.?". The implication, surely, is that he took more than one spectrogram of the star despite the enormous cost in telescope time, but he gave no information on that point. Pearce & Hill[9], at the DAO, obtained one spectrum, which yielded a radial velocity of +5·2 km s^{-1}, albeit with a 'mean error' of 5·6 km s^{-1}. After cross-correlation and photoelectric detectors were introduced, Stauffer *et al.*[26] found for HD 23386 a radial velocity of +6·2 km s^{-1}, with an 'error' quoted as '1–2 km s^{-1}'. Later, Stauffer & Hartmann[27] obtained a result of +11. Liu, Janes & Bania[38], at the KPNO coudé feed, made two measurements that they gave individually, +5·6 and +6·9 km s^{-1}. Soderblom *et al.*[28] found the velocity to be +5·5.

Three papers have given radial-velocity results obtained for HD 23386 with the Haute-Provence *Coravel*. Mermilliod *et al.*[12] reported the results of a specific campaign to obtain radial velocities (and where possible orbits) for Pleiades binaries. HD 23386 qualified as such in their estimation through its position, which they acknowledged to be *more* than 0^{m}·75 too high, in relation to the main sequence in the colour–magnitude diagram of the cluster. They obtained 11 measurements over a total time span of 4406 days, and found a mean velocity of +5·77 km s^{-1} with what they call an "uncertainty" of 0·82 km s^{-1}. They did not explain what that was intended to mean, but it seems to be the r.m.s. spread of the individual velocities rather than the standard deviation of the mean. They gave a ratio of 1·53 between externally and internally estimated errors and derived a $P(\chi^2)$ of only 0·015, after which they commented that the duplicity of stars with $P(\chi^2)$ < 2% "probably will be proven spectroscopically at some point in time". Some years later, Raboud & Mermilliod[39], returning to the matter, gave the slightly updated data of a mean of +5·8 ± 0·2 km s^{-1}, with n = 12 and ΔT = 5561 days. They gave the mean radial velocity of the cluster as +5·67 ± 0·56 km s^{-1}, where the number after the ± surely must again mean the r.m.s spread of the velocities of the individual stars, not (as it would if taken at face value) the standard error of the mean velocity. In their study of a large number of F and G dwarf stars, Nordström *et al.*[40] overcame the problem of HD 23386's apparent over-luminosity with respect to the Pleiades main sequence by listing its distance as 85 pc, placing it well in front of the cluster and thus rejecting it as a member. Still more decisive is the age of 7·7 × 10^{9} years that they assigned to it, making it about 70 times the age of the Pleiades. One would like to enquire why such an old star — if that is what it is — would be such an intense source of X-rays (normally indicative of a very active chromosphere). Nordström *et al.*, like the other two syndicates cited in this paragraph, summarized the radial velocities that had been measured for the star at Haute-Provence. This time they reported, however, that there were only five measurements, over a total time span of 1967 days, and that the mean velocity was +8·6 ± 2·0 km s^{-1}, the standard deviation of individual observations from the mean being 4·6 km s^{-1}; the projected rotational velocity was 12 km s^{-1}. (It is difficult to understand how the number and duration of the observations could have fallen so much since the previous citations of them, since a data base is maintained in Geneva of all the measurements made with the *Coravel*.) Evidently at least one of the 'new' radial velocities must be discordant with those that were reported[12,40] previously, because the mean has changed significantly and the spread of the velocities is very much larger than before. Possibly the velocities spanned an interval when there was a considerable excursion of the radial velocity of HD 23386 towards positive velocities. The reported spread *could*, however, arise from four velocities that were all about 2 km s^{-1} lower than the mean and one that was about 8 km s^{-1} above it. One could speculate, therefore, that the measurements simply included one bad one where the object was misidentified. In that case the four others would be reasonably consonant with the others that were previously reported[12,40] but later seem to have been lost. The small discrepancy that would remain would be largely explicable in terms of the change[41] in the zero-point attributed to *Coravel* observations between the two earlier papers and the Nordström *et al.* one, a change that was particularly large for stars of the relatively early type of HD 23386.

Additional isolated radial-velocity measurements were made of the star by Strassmeier *et al.*[13], who gave two results individually as +3·6 ± 1·5 and +4·3 ± 1·0 km s^{-1}. Finally there are the writer's own observations, set out in Table II. Their author does not set much store by internally estimated uncertainties; the r.m.s. error per observation, derived from the inter-agreement of the 12 velocities, is 0·62 km s^{-1} — a little more than might be hoped, but the dip in the radial-velocity traces is rather shallow and it is considerably broadened by (presumably) axial rotation, the mean $v \sin i$ being 14·4 ± 0·3 km s^{-1}. The Cambridge observations in this paper are supposed to be on the zero-point long adopted by the writer[42,43] and can be expected to need an adjustment of –0·8 km s^{-1} for comparability with velocities that are near the IAU zero-point, and it has been found empirically that stars as blue as HD 23386 need a further negative adjustment of a few tenths of a kilometre per second. An overview of all the radial-velocity data, taking into account realistic systematic and accidental uncertainties, does not by any means force upon the present writer a conclusion that the velocity is variable, let alone that the star is a spectroscopic binary. At most there might be a few tenths of a kilometre per second jitter, such as could arise from starspots. Consider an admittedly over-simplified and extreme model of a rotating spotted star having one black equatorial spot occupying about 5% of the stellar disc, causing a periodic dimming of about $0^{m}\cdot05$ each time it comes round. When the spot is near the limb it is seen projected as only 2%, say, of the disc, so it changes the apparent radial velocity of the integrated light of the visible hemisphere of the star by 2% of its discrepancy of 14 km s^{-1}, *viz.*, 0·28 km s^{-1}, from the 'real' velocity of the star. (All right then, it is not quite at the limb, so the light that is missing would not have quite the full 14 km s^{-1} rotational offset, and would not be of full brightness owing to limb darkening, so the calculation just made of the resultant velocity discrepancy is a bit exaggerated.) At another observation the spot might be near the opposite limb, giving a reversed discrepancy. It is easy to see how a radial-velocity jitter of the order of ½ km s^{-1} could arise in such a fashion, in conjunction with photometric variations of only about $0^{m}\cdot05$. To tie down the nature and origin of the jitter would need a systematic and densely sampled set of velocities measured with one of the present generation of very precise spectrometers, preferably accompanied by an analogous and contemporaneous photometric campaign.

Meanwhile, we can usefully summarize the problems posed by HD 23386 by recalling that it has arguably the correct proper motion and radial velocity to be a member of the Pleiades cluster, but appears displaced above the photometric main sequence by an amount that is unacceptable, especially in the absence of evidence of duplicity. The writer is unable to judge the merits of (and therefore does not automatically subscribe to) the small distance or great age proposed by Nordström *et al.*[40], and is definitely inclined to reject the high luminosity and the implied large distance derived from what looks like a false premise by Strassmeier *et al.*[13]. No hypothesis could explain all of the things that have been written about HD 23386, because some of them are mutually contradictory, but the one that seems most attractive to the writer is as follows. The object is a member of the Pleiades, belatedly forming in the outskirts of the cluster, and is presently in the T Tauri phase of its collapse towards the main sequence: it is too bright for its type because it is still nearly 50% over-size, and shows the extraordinary X-ray activity, high lithium abundance, and slight photometric and radial-velocity instabilities that are part and parcel of the T Tauri evolutionary state. It is admitted that this proposal is tantamount to rejecting Nordström *et al.*'s assessment[40] of the age of the star being $7 \cdot 7 \times 10^9$ years. Credit for the suggestion that HD 23386 is a 'weak-lined T Tauri star' must go to Li & Hu[34]. It may be noted that a $1 \cdot 5$-$R_\odot$ star rotating with a $v \sin i$ of 14·4 km s^{-1} has a rotation period of about $5 \sin i$ days.

HD 37216. This is a $7^{m} \cdot 84$ G5 V star in the northern part of Auriga. It is known[44] to exhibit modest Ca II *H* and *K* emission, but there has never been any truthful suggestion that it is a binary, so it is not immediately obvious how it came to be entered into *CABS3* at all. It seems only too likely that it was because its bibliography as recorded by *Simbad* included Jancart *et al.*'s paper[45] on *Astrometric orbits of SB9 stars*, implying that the star features in the *Ninth Catalogue of Spectroscopic Binary Orbits*, a web-based listing that can be raised by typing 'SB9' into Google. Indeed, the main heading of the *Simbad* bibliography at the time that the writer first brought it up was 'HD 37216 — Spectroscopic binary'. In actual fact, HD 37216 is not a spectroscopic binary, and is not (nor ever has been) entered into *SB9*, nor does it feature in Jancart *et al.* A bit of sleuthing indicated that the whole trouble has probably arisen from the dyslexic transcription from Jancart into *Simbad* of the *Hipparcos* number 26563 (which belongs to 49 Orionis, HD 37507) as the number 26653, which is that of HD 37216. The errors in *Simbad* have now been corrected at the writer's suggestion.

The short-term constancy that is demonstrated in the radial velocity of HD 37216 by the measurements in Table II is confirmed in the long term by the entries in Strassmeier *et al.*[13] and Nordström *et al.*[40] from several years past, and is not contradicted by the relatively imprecise measures of Fehrenbach *et al.*[46] which date from about 20 years ago.

HD 123760. This is another object whose credentials as a chromospherically active binary star seem very tenuous. It is an 8^{m} star in the south-preceding corner of Boötes; its magnitude and colours have been given by Eggen[47] as $V = 8^{m} \cdot 00$, $(B - V) = 0^{m} \cdot 655$, $(U - B) = 0^{m} \cdot 15$, but Eggen later[48] listed its *V* magnitude as $7^{m} \cdot 96$, which is more in keeping with the *Hipparcos* value of $7^{m} \cdot 95$. In a survey of chromospheric activity among late-type stars, Wright *et al.*[44] found the flux at *H* and *K* to be little more than was attributable to the photospheric light alone. They gave the logarithm of the star's age in years as 9·44, *i.e.*, the age would be $2 \cdot 75 \times 10^9$ years — so HD 123760 would seem not to be a youthful object such as could be expected to exhibit much activity. Far less would be the expectation from Nordström *et al.*'s age estimate[40], discordant by several thousand million years from the one just quoted, of $8 \cdot 4^{+1 \cdot 6}_{-1 \cdot 7} \times 10^9$ years.

Then there is the question of its binary nature. HD 123760 was observed twice at Lick by Moore & Paddock[49] with the 36-inch refractor and a 1-prism spectrograph. They gave a spectral type of G5V and a mean radial velocity of +2 km s^{-1}, with a 'probable error' of 1·1 km s^{-1}, which suggests that the individual velocities differed by 3·4 km s^{-1}, an amount well within observational error. They quoted a Mount Wilson mean velocity of $-3·5 \pm 2·7$ km s^{-1}, from five plates, which they noted as an unpublished result communicated privately by R. E. Wilson — it was actually published by Wilson & Joy[50] in the immediately preceding volume of the *Astrophysical Journal*, but was no doubt still in press at the time that the Lick paper was submitted. Not the least of Joy's contributions to that paper was to classify all the 2000-odd stars in it; he gave the type of HD 123760 as dG3, thereby neatly splitting the difference between the Lick type[49] of G5 and the G1 that had been given earlier from Mount Wilson by Adams *et al.*[51], who also proposed an absolute magnitude of $4^{m}·7$, clearly indicating that the star is a dwarf. The type dG3 is the one that is listed in the *Radial Velocity Catalogue* (*RVC*). It is probably the origin of Eggen's[47] type of G3 V; he was using the *RVC* as his source catalogue, and may be supposed to have taken the slight liberty of converting the 'd' prefix into the 'V' luminosity class. The five Mount Wilson plates showed such mutual discordance that Wilson & Joy[50] listed the velocities separately in a footnote; later, Abt[52] gave their dates as well. Four of them are within a range, in comparison with the Lick mean, that experience of other velocities from the same sources (one-prism spectrographs giving dispersions of about 37 Å mm^{-1} at Hγ) indicates can be regarded as consonant with constancy; there is one outlier at -18 km s^{-1}, but it comes from a spectrogram that Abt's compilation[52] shows to have been obtained at the exceptionally low dispersion of 81 Å mm^{-1} at Hγ. The present writer does not see the *ensemble* as constituting strong evidence of real variation.

In comparatively recent times, seemingly equally weak evidence for duplicity has been put forward by *Hipparcos*, whose astrometry was described by an 'acceleration solution' — but the acceleration terms are not much larger than their own standard errors; moreover, Frankowski, Jancart & Jorissen[53] put $P(\chi^2)$ at about ¼, which does not seem very significant. Also, Nordström *et al.*[40] specifically flagged HD 123760 as a spectroscopic binary on the basis of eight radial velocities, obtained over an interval of 4102 days, which yielded a mean of $+1·0 \pm 0·2$ km s^{-1} with an r.m.s. spread per observation of 0·7 km s^{-1}. Without seeing the individual data it is hard for the reader to know what (if anything) to make of a spread that is so near to the measuring error. We notice that the mean velocity is almost identical with the one found in Table II above, when account is taken of the expected difference in the velocity scales. A curious and unusual discrepancy between the OHP[40] and Cambridge observations is that whereas the former are listed as showing HD 123760 to have a $v \sin i$ of 6 km s^{-1}, the Cambridge value (the mean of the seven observations) is only $2·1 \pm 0·6$ km s^{-1}.

The evidence points towards HD 123760 being an old and inactive star, which over the best part of the last century has shown, at most, *marginal* velocity change, and at least according to the writer's measurements has a rotational velocity too small to encourage much hope of its causing any activity.

HD 136655. This is a 9^{m} late-type dwarf star right on the southern margin of Corona Borealis, about 3° south-preceding α CrB. It seems to be another case of an object whose qualification for entry in *CABS3* is questionable. Photometry of the star has been given by Upgren & Kerridge[54] as $V = 8^{m}·92$, $(B-V) = 0^{m}·95$, $(U-B) = 0^{m}·75$. Those authors identify it only as '739 A' in the column giving the names of the objects that they observed; the text says that the column has the designation "in either the McCormick or BD catalogues". Since 739 is evidently not a *BD* designation, it must be a McCormick one; in the absence of the necessary reference, the reader is obliged to trace it for himself to a paper[55] by Vyssotsky which actually does not refer to HD 136655 at all but assigns the number 739 to a nearby star, nearly two magnitudes fainter and of type M0, about 70″ distant from HD 136655 in position angle 242°.

Hipparcos gives the V magnitudes of the pair as $8^{m}\cdot99$ and $10^{m}\cdot91$ from its own measurements, and their $(B-V)$ colours as $0^{m}\cdot95$ and $1^{m}\cdot31$. Upgren & Kerridge accord the fainter one, which they call '739 B' but which is actually the real 739, as having $V = 10^{m}\cdot88$, $(B-V) = 1^{m}\cdot32$, $(U-B) = 1^{m}\cdot27$. The two stars have large and quite similar parallaxes and proper motions, and almost certainly constitute a physical pair, at a distance of just over 40 pc (a distance modulus of just over three magnitudes). The *Hipparcos* proper motions differ by several times their joint standard deviation, but are characterized as 'quite similar' here because their difference is only a small fraction of the whole motion; they are brought closer together in *Tycho 2*[56] and are nearly within their joint uncertainty there, but it is hard to decide which (if either) star may be showing long-term proper-motion variability or whether there is merely some optimism in the quoted standard errors.

Properties asserted for HD 136655 as facts in *CABS3* are that it is a double-lined spectroscopic binary, and that the primary star has a projected rotational velocity of 10·30 km s^{-1}. Such properties would go a long way towards validating the star's presence in the catalogue. They are clearly derived from a paper by Strassmeier *et al.*[13], where a single spectroscopic observation of the star is reported as yielding two radial velocities, of $+17\cdot9 \pm 1\cdot7$ and $-29\cdot9 \pm 4\cdot1$ km s^{-1}, the former being associated with the 10·3-km s^{-1} rotational velocity. It seems clear, from the difference in the quoted uncertainties and the tabling of a rotational velocity for only one of the entries, that the two spectra that are implicitly present must be of considerably unequal intensities, with the one that is responsible for the +17·9-km s^{-1} velocity being the primary.

The present writer is quite unable to corroborate the duplicity of the spectrum. As Table II above shows, his radial-velocity measurements show a constant value of −31 km s^{-1} — near enough to Strassmeier *et al.*'s 'secondary' velocity. It is inconceivable that a double-lined binary system would remain narrowly single-lined at a constant velocity for half a year if its primary had ever been measured nearly 50 km s^{-1} away from that velocity. Moreover, so far from showing a $v \sin i$ of about 10 km s^{-1}, the *Coravel* traces do not exhibit any measurable line-broadening at all. The discrepancies between the Strassmeier *et al.* data and the writer's are so serious as to arouse suspicions that different stars must have been observed. The position listed on the writer's observing programme, and that shown on the *Coravel* screen from updating the *Henry Draper Catalogue* position, from either or both of which he set the telescope on the star on nine different nights, have been checked and found correct. Only someone conversant with the details of Strassmeier *et al.*'s observing procedures could say whether it is conceivable that a second star's spectrum could have been added to the record of HD 136655 by an inadvertent omission to read out the data between stars. In any case, sufficient doubt has surely been thrown here on the character of HD 136655 to warrant re-consideration of its qualification to be a *CABS3* object.

HD 184591. This is still another object whose eligibility to be characterized as having an active chromosphere might be questioned, although its binary nature cannot be disputed. It is a 7^{m} object, to be found in Sagitta — an unlikely domicile ($P < 1/500$) since Sagitta is the third-smallest of all the constellations, after Crux and Equuleus — nearly a degree and a half preceding α Sge. It has been known for a long time as a close visual double star, with a Δm of about one magnitude. It was discovered in 1841 or 1842 with the then-new Pulkova 15-inch refractor, and listed in a catalogue of double stars by F. G. W. Struve[57] in 1843; he estimated the magnitudes of the components as 7 and 8 and their separation as 0″·6. As is so often to be noticed, an 'estimation' by Struve is as good as a *measurement* by anyone else! The system was entered as no. 375 in his publication[57] and has been known in the double-star world as OΣ 375, thereby rather confusingly but not necessarily unjustly being attributed to his son Otto Struve, whose conventional designation is indeed OΣ, rather than to himself (Σ). (An effort was made to explain this matter rather more fully some time ago in the introductory section of Paper 42[58] of this series.)

By the time that Burnham compiled his great catalogue[59] of double stars in 1906, quite a number of measurements of the system (there designated BDS 9415) had accumulated; the components were listed as $7^{m}\cdot2$ and $8^{m}\cdot4$, and their separation was always measured at close to 0″·6. Burnham, always the arch-conservative, commented "There may be a little change in the angle, but the measures are not accordant." Certainly the measures are a bit scattered, but there is a clear upward trend in the angle; the clarity of one's perception of it may of course be sharpened a little when one is privy to the results of a further century's measurements! The system appears as no. 12623 in Aitken's double-star catalogue[60] of 1932, where the separation is shown as remaining at 0″·6 and the angle advancing from 138° in 1847 to about 156° in 1921; *Hipparcos* gives the separation as 0″·620 and the position angle as 179°. *If* the separation continues constant, it looks as though a revolution will take appreciably more than a thousand years. Aitken[60] was already able to report, however, on the basis of the area swept out by the orbital motion in unit time, dynamical parallax estimates of 0″·006 and 0″·004, which seem every bit as good as the trigonometrical parallax of 0″·00458 ± 0″·00144 determined by *Hipparcos*. The satellite was able to give a very precise measure of Δm in the Hp waveband (not far from V), of $0^{m}\cdot99 \pm 0^{m}\cdot01$.

The great majority of the literature that refers to HD 184591 reports measurements of it as a visual (or speckle, *etc.*) binary, but there are a few papers of an astrophysical nature although a set of *UBV* measures appears to be lacking. *Hipparcos/Tycho*, however, has provided values of $V = 7^{m}\cdot31$, $(B - V) = 0^{m}\cdot87$. Eggen[61] gave a V magnitude of $7^{m}\cdot34$, and in a table whose entries are, at least in this case, of enigmatic origin, lists an M_V of $-1^{m}\cdot2$, a luminosity class of II, and a spectral type of G2 I. The M_V is asserted to be "derived by the methods described above", but efforts to penetrate the labyrinthine preceding section of the paper confuse and depress (rather than enlighten) the reader. The Class II comes from a "photometric luminosity classification". The star is one of 84 in a table whose final columns list spectral types and the sources thereof; HD 184591 is one of only three stars where the 'source' column is empty, so we cannot tell how Eggen came to list the star as being of type G2 I. The *Hipparcos* parallax quoted above gives a distance modulus of $6\cdot7^{+0\cdot8}_{-0\cdot6}$ magnitudes, and thereby an integrated absolute magnitude for the system of about $+0^{m}\cdot6 \pm 0^{m}\cdot7$. Allowance for the secondary with a ΔV of one magnitude makes the primary nearly $0^{m}\cdot4$ fainter than the integrated brightness, putting it in the region shown by Keenan & Barnbaum[62] as the province of 'clump giants' or luminosity class IIIb. It would seem, therefore, that the impenetrable methods, the photometric luminosity classification, and the unreferenced spectral type, all listed by Eggen[61], were all badly mistaken.

Bidelman[63] was perceptive enough to recognize HD 184591 as having a "slightly composite spectrum: K0 III + earlier". That was long before Fabricius & Makarov[64] managed to obtain separate magnitudes and colours from the *Tycho* observations of the pair — something that the *Hipparcos* authors themselves had been unable to do or had not attempted (one could understand if they were kept quite busy with other aspects of their project!). Their figures, when transformed from V_T, B_T to the normal (Johnson[65]) V and B by means of the equations numbered [1.3.20] in the *Hipparcos* introductory volume, yield V magnitudes and $(B-V)$ colours of $7^{m}\cdot67$ and $1^{m}\cdot09$ for the primary and $8^{m}\cdot81$ and $0^{m}\cdot39$ for the secondary. The absolute magnitude and colour of the primary are very consonant with the type specified by Bidelman[63], though if we were finicky we might be inclined to write it as K0 IIIb. Bidelman was, as is to be expected, also correct in recognizing the secondary as being earlier, but it is not easy to say exactly what its type is, because at little more than one magnitude fainter than the primary it is too luminous for a main-sequence star of its colour. The central value for the parallax and the known ΔV would put the absolute magnitude of the secondary at about $2^{m}\cdot1$, corresponding to a fairly late A star whose $(B-V)$ colour index ought not to be more than $0^{m}\cdot2$; the colour of $0^{m}\cdot39$ belongs to a main-sequence star of type F3 or F4, which is at least a magnitude 'too faint'. The discrepancy could be accommodated by invoking the uncertainty of the parallax to assign fainter magnitudes to both components and by allowing for some error in the colour index, leading to a type of F0–F2 V for the secondary, or else by asserting that the secondary is beginning to evolve and is now a magnitude or so above the main sequence at type ~F3 IV. This is just another of the many cases where one could wish that people in charge of large telescopes which can use spectrographs behind adaptive optics, or indeed of the *Space Telescope*, would take an interest in visual binaries — or conversely that some of *us* could infiltrate those 'corridors of power'!

HD 184591 must have been entered into *CABS3* in response to an assertion by Strassmeier[66] (who devoted a little paragraph to each of quite a number of stars, including *this* one), which reads as follows. "Bidelman (1988) noted its composite spectrum consisting of a K0 III and an earlier star that we also see in our H and K spectrum. The very weak (blueshifted) emission from the K0 giant in the presence of a hot, early F-type companion might indicate an actually active star with moderately strong emission." He published an actual tracing of the *H* and *K* region of the spectrum, which shows only the most microscopic apologies for emission just on the shortward side of the centres of the great absorption lines — far less even than is seen in the tracing of β Gem that is fortuitously printed next to it. Allowance for the modest dilution by the fainter secondary would not make a really substantial difference to the emission intensity. Indeed, in a subsequent paper[13] in which he was joined by co-authors, Strassmeier included HD 184591 in a listing of stars that were found to be "*without H&K emission*" (*my* emphasis).

The object is, obviously, admitted to be a double-lined spectroscopic binary — double in the sense of exhibiting a composite spectrum but not of presenting two different radial velocities; but if the visual components are individually single stars and are merely in a large orbit with a period of upwards of a thousand years, that is not going to encourage significant chromospheric activity, of which indeed little or none is seen[13]. It remains to refer to the radial and rotational velocities of the giant star (we know nothing about those properties for the secondary, but early-F stars do not usually have active chromospheres anyway). The seven measurements in Table II above show an extreme range of only

0·3 km s^{-1} — less, one might think, than would be expected on the basis of the normal measuring errors! — over an interval of nearly a year. Practically the same velocity was obtained in 1998 when it was twice measured by Strassmeier *et al.*[13], and so it did in 1988–1991 when Fehrenbach *et al.*[46] obtained three plates of the spectrum. None of the observations made with the Cambridge *Coravel* shows any measurable broadening of the 'dip', so within observational uncertainty $v \sin i = 0$. It may be concluded, therefore, that HD 184591 does not deserve to be rated as a chromospherically active binary star.

HD 195434. The characterization of this object as a 'constant-velocity star' is misleading, although true up to a point. It has long been known as both a visual double star and an eclipsing binary, MR Del. In the latter capacity it seemed bound to exhibit orbital motion, and in 1997 was placed on the Cambridge observing programme (which at the time was being conducted at Haute-Provence (OHP) in the absence of a serviceable instrument at Cambridge). It proved to possess a constant velocity! A little bibliographical research led to the recognition that what was being measured was the constant velocity of *one* of the visual components, which are less than 2″ apart and would therefore both contribute to light entering the spectrometer; the *other* one must be the eclipsing object, which was known to have a period of only 0·52 days and to exhibit two, somewhat unequal, eclipses in each revolution. It could therefore be expected to give two very shallow 'dips', with $v \sin i$ values possibly approaching 100 km s^{-1} — altogether un-observable with the *Coravel*. The object was therefore dropped from the observing programme, but when it re-surfaced in the list of objects supplied privately by Eker *et al.* as needing to have their orbits determined it was re-observed a couple of times recently from Cambridge, with of course the same result as before. Its orbit has in fact been determined and published in 2009 by Pribulla *et al.*[67], a consortium based at the David Dunlap Observatory (DDO), who, with more appropriate instrumentation for that purpose and a larger telescope than those used by the present author, were able duly to see HD 195434 as triple-lined. They illustrate an observation by a 'broadening-function' trace, which looks very like what a *Coravel*-type cross-correlation trace would be expected to be, but inverted. It shows one tall and sharp peak, flanked by two low and very broad ones. The 'broadening-function' method was explained and contrasted with cross-correlation in an earlier David Dunlap paper[68]; it seems as well to mention that the relative disadvantages attributed there to cross-correlation hardly apply to *Corave*l observations — they largely arise from the shortness of the spectral region observed at the DDO. The Pribulla *et al.* paper shows very analogous triple-lined broadening functions for several other stars, certainly emphasizing the caution that is needed in accepting an apparently constant velocity at face value.

The literature is in a state of confusion over the apparent magnitude of HD 195434. *Simbad* gives $V = 11^{m}\cdot01$, $(B-V) = 0^{m}\cdot70$, evidently quoted from Muzzio[69] (who also gave $(U-B) = 0^{m}\cdot26$, and must have observed the wrong star). Sandage & Kowal[70] gave $V = 8^{m}\cdot83$, $(B-V) = 0^{m}\cdot89$, $(U-B) = 0^{m}\cdot44$. *Hipparcos* has $V = 8^{m}\cdot77$, yet *Tycho* (as reported by *Vizier*) gives the separate V magnitudes of the two visual components as $9^{m}\cdot07$ and $9^{m}\cdot32$, which lead to a total of $8^{m}\cdot44$. No doubt some (possibly all) of the measurements are compromised by the inclusion of observations obtained when the system was in eclipse.

References

(1) Z. Eker *et al.*, *MNRAS*, **389**, 1722, 2008.
(2) R. F. Griffin, *The Observatory*, **129**, 317, 2009.
(3) R. F. Griffin & N. Filiz Ak, *Ap&SS*, submitted.
(4) E. Hertzsprung, *Leiden Ann.*, **19**, 3, 1947 (see p. 34).
(5) [Announced by] E. Schilbach *et al.*, *A&A*, **299**, 696, 1995.
(6) L. F. Jenkins, *General Catalogue of Trigonometrical Stellar Parallaxes* (Yale Univ. Obs., New Haven), 1952, p. 32.
(7) H. L. Johnson & R. I. Mitchell, *ApJ*, **128**, 31, 1958.
(8) E. E. Mendoza V, *Bol. Obs. Tonantzintla & Tacubaya*, **4**, 149, 1967.
(9) J. A. Pearce & G. Hill, *PDAO*, **14**, 319, 1975.
(10) F. Rufener & P. Bartholdi, *A&AS*, **48**, 503, 1982.
(11) J. R. Stauffer, *ApJ*, **280**, 189, 1984.
(12) J.-C. Mermilliod *et al.*, *A&A*, **265**, 513, 1992.
(13) [Announced by] K. G. Strassmeier *et al.*, *A&AS*, **142**, 275, 2000.
(14) S. Messina, *A&A*, **371**, 1024, 2001.
(15) J.-Z. Li, *Chinese JA&A*, **4**, 258, 2004.
(16) A. K. Magnitsky, *Soviet Astr. Letters*, **13**, 451, 1987.
(17) P. N. Kholopov *et al.*, *IBVS*, no. 3323, 1989.
(18) E. Marilli, S. Catalano & A. Frasca, *Mem. Soc. Astr. Italy*, **68**, 895, 1997.
(19) Y. Yang & Q. Liu, *AJ*, **122**, 425, 2001.
(20) Y. Yang, Q. Liu & K.-C. Leung, *A&A*, **370**, 507, 2001.
(21) Y. Yang & Q. Liu, *A&A*, **387**, 162, 2002.
(22) Y. Yang & Q. Liu, *AJ*, **123**, 443, 2002.
(23) A. J. Cannon & E. C. Pickering, *HA*, **91**, 249, 1918.
(24) I. J. Danziger & P. S. Conti, *ApJ*, **146**, 392, 1966.
(25) R. P. Kraft, *ApJ*, **150**, 551, 1967.
(26) J. R. Stauffer *et al.*, *ApJ*, **280**, 202, 1984.
(27) J. R. Stauffer & L. W. Hartmann, *ApJ*, **318**, 337, 1987.
(28) D. R. Soderblom *et al.*, *ApJS*, **85**, 315, 1993.
(29) D. Queloz *et al.*, *A&A*, **335**, 183, 1998.
(30) A. M. Boesgaard, *ApJ*, **336**, 798, 1989.
(31) C. F. Prosser *et al.*, *PASP*, **105**, 1407, 1993.
(32) J. R. Stauffer *et al.*, *A&AS*, **91**, 625, 1994.
(33) J. P. Caillault & D. J. Helfand, *ApJ*, **289**, 279, 1985.
(34) J. Z. Li & J. Y. Hu, *A&AS*, **132**, 173, 1998.
(35) R. F. Griffin, *ApJ*, **148**, 465, 1967.
(36) B. Smith & O. Struve, *ApJ*, **100**, 360, 1944.
(37) H. A. Abt *et al.*, *ApJ*, **142**, 1604, 1965.
(38) T. Liu, K. A. Janes & T. M. Bania, *ApJ*, **377**, 141, 1991.
(39) D. Raboud & J.-C. Mermilliod, *A&A*, **329**, 101, 1998.
(40) [Announced by] B. Nordström *et al.*, *A&A*, **418**, 989, 2004.
(41) S. Udry, M. Mayor & D. Queloz, in J. B. Hearnshaw & C. D. Scarfe (eds.), *Precise Stellar Radial Velocities* (*IAU Coll.*, no. 170; *ASP Conf. Series*, **185**) (ASP, San Francisco), 1999, p. 367.
(42) R. F. Griffin, *MNRAS*, **145**, 163, 1969.
(43) R. F. Griffin & G. H. Herbig, *MNRAS*, **196**, 33, 1981.
(44) J. T. Wright *et al.*, *ApJS*, **152**, 261, 2004.
(45) S. Jancart *et al.*, *A&A*, **442**, 365, 2005.
(46) [Announced by] C. Fehrenbach *et al.*, *A&AS*, **124**, 255, 1997.
(47) O. J. Eggen, *AJ*, **69**, 570, 1974.
(48) O. J. Eggen, *AJ*, **92**, 910, 1986.
(49) J. H. Moore & G. F. Paddock, *ApJ*, **112**, 48, 1950.
(50) R. E. Wilson & A. H. Joy, *ApJ*, **111**, 221, 1950.
(51) W. S. Adams *et al.*, *ApJ*, **81**, 187, 1935.
(52) H. A. Abt, *ApJS*, **26**, 365, 1973.
(53) A. Frankowski, S. Jancart & A. Jorissen, *A&A*, **464**, 377, 2007.
(54) A. R. Upgren & S. J. Kerridge, *PASP*, **85**, 721, 1973.
(55) A. N. Vyssotsky, *AJ*, **61**, 201, 1956.
(56) [Announced by] E. Høg *et al.*, *A&A*, **355**, L27, 2000.
(57) [F. G.] W. Struve, *Catalogue de 514 Étoiles Doubles et Multiples Découvertes sur l'Hémisphère Boréal par la Grande Lunette de l'Observatoire Central de Poulkova et Catalogue de 256 Étoiles Doubles Principales où la Distance des Composantes est de 32 Secondes à 2 Minutes et qui se trouvent sur l'Hémisphère Boréal* (Académie Impériale des Sciences, St. Pétersbourg), 1843, p. 15.

(58) R. F. Griffin, *The Observatory*, **102**, 1, 1982 (Paper 42).
(59) S.W. Burnham, *General Catalogue of Double Stars Within 121° of the North Pole* (Carnegie Institution of Washington, Washington, D.C.), 1906, part I, p. 188; part II, p. 848.
(60) R. G. Aitken, *New General Catalogue of Double Stars Within 120° of the North Pole* (Carnegie Institution of Washington, Washington, D.C.), 1932, **2**, p. 1108.
(61) O. J. Eggen, *AJ*, **88**, 1187, 1983.
(62) P. C. Keenan & C. Barnbaum, *ApJ*, **518**, 859, 1999.
(63) W. P. Bidelman, *PASP*, **100**, 1084, 1988.
(64) [Announced by] C. Fabricius & V. V. Makarov, *A&A*, **356**, 141, 2000.
(65) H. L. Johnson & W. W. Morgan, *ApJ*, **117**, 313, 1953.
(66) K. G. Strassmeier, *A&AS*, **103**, 413, 1994.
(67) T. Pribulla *et al.*, *AJ*, **137**, 3655, 2009.
(68) S. M. Rucinski, *AJ*, **124**, 1746, 2002.
(69) J. C. Muzzio, *PASP*, **85**, 358, 1973.
(70) A. Sandage & C. Kowal, *AJ*, **91**, 1140, 1986.

SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 211: HD 128642, HD 144601, HD 150172, AND HD 155641

By R. F. Griffin
Cambridge Observatories

The four stars all have periods between one and six months, facilitating unusually uniform phase coverage of their orbits. HD 128642 is a seventh-magnitude late-G dwarf star only 20 pc away; its 179-day low-eccentricity orbit was first determined by *Hipparcos*. The other three stars are all near the ninth magnitude, and the little that is known about them consists mostly of the colour indices and parallaxes that *Hipparcos* provided. HD 144601 has the luminosity of a giant, or nearly so, and is in a 174-day orbit which, for a giant, is of surprisingly high eccentricity — almost 0·5. HD 150172 is an early-K dwarf at 30 pc distance, in a 90-day orbit of eccentricity 0·33, while HD 155641 appears to be an early-K subgiant in a low-eccentricity orbit with a period of only 44 days.

Introduction

The stars treated in this paper tend to exhibit the benefit (admitted to be largely just cosmetic) of a scheme that the writer adopted a few years ago whereby he could keep detailed track of the phases of all the objects on the observing programme. He could therefore schedule observations, within the inevitable constraints of weather and season, with an eye to uniformity of phase coverage. Many of the objects under observation have periods of several years, and their unobservability for part of every year when they are in the daytime sky inevitably introduces considerable gaps in phase coverage, which can easily take a very long time (several cycles of several years each — the best part of a lifetime!) to repair unless the period happens to be obligingly near to a half-integral number of years. At very short periods (a month or less), although the particular phase at which an observation is desired comes round frequently, its timing is critical at a level of hours and so it is not as easy as it might at first appear to obtain an observation at the proper time. The most favourable period is about six months, where a whole cycle is observable in any given season, and in every season there is a night that falls sufficiently close to any desired phase. With reasonable luck, within a modest number of observing seasons all gaps in phase coverage can be filled. It is hoped that the figures in this paper will be seen as illustrating that possibility.

HD 128642

HD 128642 is a seventh-magnitude star that is only about 9° from the North Celestial Pole. Its position disposed it to feature in many photometric listings (not identified here) in the late 19th and well into the 20th Century, when the primary photometric reference was the 'North Polar Sequence'. In relatively modern times, Oja[1] has determined its magnitude and colour indices to be $V = 6^{m}\cdot91$, $(B-V) = 0^{m}\cdot76$, $(U-B) = 0^{m}\cdot34$. It is of some interest that, in a 1989 paper in this *Magazine*, Wesselink[2] obtained $V = 6^{m}\cdot88$, $(B-V) = 0^{m}\cdot73$ by careful transformation from the 'photovisual' and 'photographic' magnitudes measured photographically at Leiden by A. de Sitter[3] in his Ph.D. work about 1930. De Sitter's magnitudes are of remarkable accuracy, which he achieved by deliberately spreading the star images out into small uniform patches by (*a*) exposing the plates with the focus offset by 1 mm from the plane of best focus (he was using a refractor with an aperture ratio of *f*/5), and (*b*) moving the plate-holder in a raster covering an area ¼ of a millimetre square (Schwarzschild's *schraffierkassette*[4]).

The parallax of HD 128642 is given by *Hipparcos*[5] as $0''\cdot05104 \pm 0''\cdot00058$, which inverts to a distance of 19·59 ± 0·22 pc, putting the star just within the conventional 20-pc cut-off distance for 'nearby stars'. The corresponding distance modulus is $1^{m}\cdot46 \pm 0^{m}\cdot03$, so the absolute magnitude is very close to $5^{m}\cdot45$; that would be appropriate to a star of type G7 V, but there seems never to have been an MK classification of HD 128642. *Hipparcos* also noticed significant orbital motion, and was able to deduce a full set of orbital parameters from its own observations — something that it managed to do for a total of only 45 stars. The satellite was best able to determine orbits whose periods were comparable with its own active lifetime: those with shorter periods naturally tended to have smaller orbits which were less likely to be determinable, while those with longer periods were too uncertain. Thanks to its unusual proximity to us, the HD 128642 orbit was reasonably large, having a semi-major axis a_0 of $0''\cdot01307 \pm 0''\cdot00078$, despite its relatively short period of 179·7 ± 0·8 days. That is the second-shortest of all the 45 orbits determined by *Hipparcos* (after that of HD 160346, which is only 11 pc away), and is accurately determined because it was seen round several cycles.

Other astrometric elements that are directly comparable with the spectroscopic ones are e and ω, which are, respectively, 0·15 ± 0·12 and 159 ± 70 degrees. Since the standard error of the eccentricity is almost as great as the eccentricity itself, it is only to be expected that the longitude of periastron is very poorly determined. Its uncertainty of almost a fifth of the complete 360° is reflected in the uncertainty of the epoch of periastron, which is seen to be almost a fifth of the orbital period, the epoch being given as JD 2448361·9 (= 1991 April 15) ± 35·0. Other significant quantities are a_0/π, which represents the size of the orbit's major axis expressed in AU and has the value 0·256 ± 0·016, and the inclination, 54·8 ± 5·2 degrees; together they lead to a value for $a_0 \sin i$, 0·209 ± 0·018 AU or 31·2 ± 2·7 Gm. That last value is the (semi-)amplitude of the fore-and-aft motion of the photocentre of the system in its orbit around the centre of gravity; if (and only if) the secondary star is of relatively negligible brightness, the photocentre will for practical purposes coincide with the primary star, and then its amplitude should be just what is called in this series of papers the 'derived element' $a_1 \sin i$, where the subscript 1 is retained, even in the cases of single-lined orbits, to remind us that it is the amplitude of the motion of the primary star only and not of the separation of the two components of the system — so it is not to be compared directly with, *e.g.*, separations measured as angles on the sky.

In a comprehensive catalogue of the properties of nearby stars, Fuhrmann[6] listed HD 128642 as having a mass of 0·87 $M_\odot$, radius 0·90 ± 0·04 $R_\odot$, [Fe/H] −0·06 ± 0·07, and $v \sin i$ 1·5 ± 1·0 km s^{-1}. He suggested that the unseen companion star may be a white dwarf.

Wright *et al.*[7], apparently on the basis of a single measurement of the intensity of the Ca II *H* and *K* emissions in HD 128642, and utilizing the complicated relationship put forward by Noyes *et al.*[8] between the quantity they called $<R'_{HK}>$ and $(B-V)$, deduced that it ought to have a rotation period of 35 days.

It seems that despite the interest in HD 128642 as a 'nearby' star and a known binary, the only radial-velocity information that has ever been published for it is a mean value of −50·7 ± 2·4 km s^{-1} listed in a table referred to by Nordström *et al.*[9] in 2004. The situation is retrieved here, by the 49 measurements obtained with the Cambridge *Coravel* and listed in Table I. They produce the orbit that is plotted in Fig. 1 and whose elements are:

P = 178·706 ± 0·033 days		$(T)_4$ = MJD 53156·6 ± 0·5	
γ = −37·38 ± 0·03 km s^{-1}		$a_1 \sin i$ = 32·96 ± 0·11 Gm	
K = 13·61 ± 0·05 km s^{-1}		$f(m)$ = 0·0448 ± 0·0005 $M_\odot$	
e = 0·1690 ± 0·0031			
ω = 97·5 ± 1·2 degrees		R.m.s. residual = 0·20 km s^{-1}	

Comparison with the elements found by *Hipparcos* and already noted above shows that there is agreement within their standard errors, or in the case of the period a little more; the spectroscopic values are, however, more precise by factors ranging from 24 to 70. Extrapolating dates of periastron backwards from the spectroscopically determined epoch, we find that epoch −23 would fall on MJD 48331·6 ± 1·0, or 1991 March 16, so that, too, is within the standard error of the *Hipparcos* timing. The value for $a_0 \sin i$ is also nicely confirmed; in that case the agreement can also be regarded as largely validating the assumption under which the *Hipparcos* quantity was calculated, *viz.*, that the secondary star contributes a negligible proportion of the brightness of the system. Accepting the mass of 0·87 $M_\odot$ asserted by Fuhrmann[6], which is surely reasonable for a star of the supposed type of about G7 V, and the inclination of about 55° found

TABLE I

Cambridge radial-velocity observations of HD 128642

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O–C)* *km s⁻¹*
2002 Aug. 12·87	52498·87	−46·5	0·319	+0·2
Sept. 13·80	530·80	−35·7	·498	+0·3
26·80	543·80	−32·0	·571	−0·3
Oct. 3·79	550·79	−30·0	·610	−0·4
Dec. 9·22	617·22	−37·5	·982	−0·3
2003 Feb. 15·21	52685·21	−44·4	1·362	−0·1
Mar. 1·24	699·24	−39·7	·441	−0·1
15·16	713·16	−34·5	·518	+0·3
Apr. 7·08	736·08	−28·0	·647	−0·2
May 1·08	760·08	−23·9	·781	+0·2
15·05	774·05	−25·8	·859	+0·1
24·05	783·05	−29·3	·910	+0·1
June 10·99	800·99	−40·3	2·010	+0·3
19·02	809·02	−45·9	·055	−0·3
July 4·95	824·95	−50·9	·144	0·0
12·95	832·95	−51·6	·189	−0·4
21·96	841·96	−50·4	·239	−0·2
Aug. 2·90	853·90	−47·6	·306	−0·2
16·88	867·88	−43·0	·384	0·0
29·83	880·83	−38·5	·457	+0·1
Sept. 13·80	895·80	−33·3	·540	+0·2
Oct. 16·76	928·76	−24·9	·725	0·0
2004 Feb. 9·28	53044·28	−44·0	3·371	−0·2
Apr. 7·12	102·12	−25·9	·695	−0·1
May 19·05	144·05	−31·5	·930	−0·2
June 7·92	163·92	−44·4	4·041	−0·3
12·98	168·98	−46·8	·069	+0·1
15·02	171·02	−47·8	·081	0·0
18·98	174·98	−49·1	·103	+0·2
21·99	177·99	−50·0	·120	+0·1
30·98	186·98	−50·9	·170	+0·4
July 9·90	195·90	−50·7	·220	+0·1
16·93	202·93	−49·5	·259	0·0
30·88	216·88	−45·7	·337	+0·1
Aug. 12·92	229·92	−41·3	·410	+0·2
Sept. 13·81	261·81	−30·9	·589	−0·2
2005 Mar. 25·15	53454·15	−26·7	5·665	+0·3
Apr. 22·08	482·08	−24·5	·821	0·0
May 5·05	495·05	−28·0	·894	+0·1
15·05	505·05	−33·3	·950	+0·2
23·02	513·02	−38·4	·994	+0·4
28·99	518·99	−42·6	6·028	+0·1
Sept. 12·81	625·81	−28·6	·625	+0·2
2006 May 10·00	53865·00	−35·3	7·964	−0·2
12·02	867·02	−36·5	·975	−0·1
Aug. 9·88	956·88	−37·3	8·478	0·0
2007 Mar. 26·00	54185·00	−24·1	9·755	+0·2
Apr. 4·11	194·11	−24·4	·806	−0·2
2009 June 11·94	54993·94	−48·6	14·281	0·0

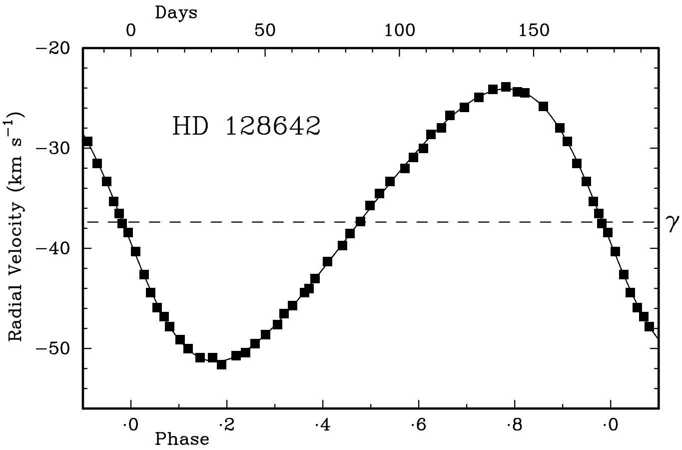

FIG. 1

The observed radial velocities of HD 128642 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. All the observations were made at Cambridge.

by *Hipparcos*, we can substitute in the expression for the mass function and determine that the mass of the secondary star must be about 0·55 $M_\odot$, not far from Fuhrmann's value of 0·51 $M_\odot$ based on the *Hipparcos* orbital elements. Knowing the mass ratio, q, of nearly 1·6, therefore, we can determine the actual separation of the components of the binary system: the semi-major axis of the relative orbit is $(1 + q)\ a_1$ — about 85 Gm or 0·57 AU. It must subtend an angle of 0″·03 at the 19-pc distance of HD 128642.

Fuhrmann reported that HD 128642 exhibited weak chromospheric activity, and he considered that that constituted support for the idea that the secondary is a white dwarf, so that "its former giant stage could be related to the nowadays observable activity". He did not spell out exactly *how* it might be related. It seems likely to the present writer that, if the companion had really passed through its giant-stage evolution so close to the star that we now observe, then that object would have been heavily contaminated with the *s*-process elements liberally ejected from the evolving star and should now show conspicuous 'barium-star' characteristics. In the absence of any such idiosyncrasy, a lower-main-sequence companion seems more probable than a white dwarf. Its mass would put it near spectral type M0, where it would be only about 3½ magnitudes fainter than the primary and would thus contribute about 4% of the total light of the system in the *V* band. That slightly compromises the assumption upon which we identified the photocentre of the binary with the primary star. So far from being worried, however, we note with some glee that the observed photocentric motion is in fact about 4% smaller than the primary star's motion that is accurately determined by the observations presented here! Upon recovering sobriety, however, we have to admit that if 4% of the light comes from a star which, in round numbers, lies at a distance from the primary star of 2½ times that of the centre of gravity of the system, it shifts the photocentre not four but *ten* per cent of the distance of the primary star towards the centre of gravity. That leaves it, however, still well within the uncertainty of the value derived for $a_0 \sin i$ from the *Hipparcos* orbital elements. The astrometric value, therefore, while not providing evidence in favour of a main-sequence companion, certainly does not argue against it. This is not the first time[10] that Fuhrmann[6,11] has been suspected of seizing a bit prematurely on the idea of an unseen companion being a white dwarf. If the companion really is a main-sequence star, spectra of sufficiently good S/N ratio ought to reveal it, particularly in the far red, where the Δm could be expected to be, at most, hardly more than three magnitudes.

HD 144601

HD 144601 is a ninth-magnitude star of *HD* type K0, on the western border of Hercules where it adjoins Serpens Caput, about 6° preceding β Herculis. It was placed on the Cambridge observing list when additional stars were sought some years ago to add to the 'Clube Selected Areas' programme[12,13] in the northern sky. Originally, the 16 Areas were all equal in — well, area — but owing to the great imbalance in the density of *HD* stars per square degree in the northern and southern hemispheres (arising simply because the observing conditions were so much better at Arequipa than at Harvard that the plates taken at the former showed clear spectra of more and fainter stars!) there were far more stars in the southern Areas[13] than in the northern[12]. The only way of adding stars of the defined character in the north was to increase the areas of sky from which they were drawn, so a lot of extra stars — still complying with the original selection criteria that, as listed in the *Henry Draper Catalogue*, they should be within half a magnitude of $9^{m}\cdot0$ visual and of spectral type K0 — was added to the programme.

Naturally, some of the extra stars turned out to be spectroscopic binaries; HD 144601 is one of those in Area 1. *Simbad* knows of only one paper in which it features, and that is a positional catalogue. The only astrophysical information about it, other than that presented below, comes from *Hipparcos*, which found its parallax to be $0''\cdot00190 \pm 0''\cdot00149$ and gave its V and $(B-V)$ magnitudes as $9^{m}\cdot04$ and $0^{m}\cdot62$. The colour index would suggest a solar-type star, but the parallax tells a different story. Its central value translates to a distance modulus of $8^{m}\cdot6$, indicating an absolute magnitude of $+0^{m}\cdot4$, but the 1-σ limits for the modulus are about $7^{m}\cdot4$ and 12^{m}, so all that can be said is that the star has at least the order of luminosity of a late-type giant and is possibly considerably brighter. At the same time, the colour shows that it is not really a *late-type* giant as that phrase is normally understood, but is more of a Hertzsprung-gap object, and is therefore of a rather rare type. At its Galactic latitude of about 45° it would not be expected to be heavily reddened, so we may suppose (although without seeing the spectrum we cannot be sure) that it has a type in the general neighbourhood of F8 III.

All of the 52 radial-velocity observations available for HD 144601 have been made with the Cambridge *Coravel*. The first was in 2003; the next was made a year later and showed immediately a substantial discordance which led to the star being transferred to the spectroscopic-binary programme and observed reasonably systematically. The measurements are given in Table II; the derived orbit is illustrated in Fig. 2 and has elements as follows:

P	=	$174\cdot744 \pm 0\cdot020$ days	$(T)_7$	=	MJD $54042\cdot88 \pm 0\cdot15$
γ	=	$-33\cdot78 \pm 0\cdot06$ km s^{-1}	$a_1 \sin i$	=	$42\cdot60 \pm 0\cdot19$ Gm
K	=	$20\cdot25 \pm 0\cdot08$ km s^{-1}	$f(m)$	=	$0\cdot1011 \pm 0\cdot0014\ M_\odot$
e	=	$0\cdot4836 \pm 0\cdot0029$			
ω	=	$273\cdot7 \pm 0\cdot6$ degrees	R.m.s. residual	=	$0\cdot36$ km s^{-1}

TABLE II

Cambridge radial-velocity observations of HD 144601

Date (UT)	*MJD*	*Velocity* *km s*$^{-1}$	*Phase*	*(O–C)* *km s*$^{-1}$
2003 Aug. 19·90	52870·90	−23·2	0·293	+0·2
2004 Sept. 18·81	53266·81	−37·2	2·559	+0·2
Oct. 7·78	285·78	−42·6	·667	+0·4
2005 Jan. 23·29	53393·29	−22·7	3·283	+0·1
Apr. 19·13	479·13	−48·1	·774	+0·6
May 8·05	498·05	−53·5	·882	−0·2
28·02	518·02	−33·2	·996	+0·1
31·99	521·99	−23·9	4·019	+0·4
June 6·99	527·99	−14·7	·053	+0·8
11·01	532·01	−13·1	·076	+0·2
23·01	544·01	−14·1	·145	+0·4
July 16·94	567·94	−22·5	·282	+0·3
28·95	579·95	−26·7	·351	0·0
Aug. 6·89	588·89	−29·9	·402	−0·5
15·89	597·89	−32·2	·453	−0·1
25·91	607·91	−34·7	·511	+0·3
Sept. 8·85	621·85	−39·2	·591	−0·2
14·82	627·82	−41·3	·625	−0·5
Oct. 2·79	645·79	−46·4	·728	−0·2
20·75	663·75	−51·8	·830	−0·2
2006 Apr. 4·13	53829·13	−49·0	5·777	−0·1
9·10	834·10	−50·0	·805	+0·4
May 3·09	858·09	−49·9	·943	+0·1
6·11	861·11	−46·1	·960	+0·2
11·04	866·04	−36·5	·988	+0·3
16·07	871·07	−25·4	6·017	−0·3
30·02	885·02	−13·3	·097	−0·4
June 2·99	888·99	−13·7	·119	−0·3
21·99	907·99	−19·8	·228	−0·3
July 8·05	924·05	−25·0	·320	0·0
Sept. 11·85	989·85	−44·6	·697	−0·1
Oct. 26·75	54034·75	−47·5	·953	+0·4
Nov. 1·74	040·74	−37·5	·988	−0·6
3·73	042·73	−32·7	·999	−0·5
2007 Apr. 2·14	54192·14	−53·1	7·854	−0·5
12·12	202·12	−52·9	·911	+0·1
16·09	206·09	−51·7	·934	−0·5
30·09	220·09	−26·3	8·014	−0·2
May 2·08	222·08	−22·7	·026	−0·6
30·05	250·05	−16·8	·186	+0·1
July 29·91	310·91	−35·3	·534	+0·9
Oct. 15·77	388·77	−39·7	·979	+0·4
19·76	392·76	−30·9	9·002	0·0
20·76	393·76	−28·5	·008	0·0
2008 Sept. 26·83	54735·83	−44·6	10·966	+0·2
27·80	736·80	−42·8	·971	+0·2
Oct. 8·77	747·77	−19·5	11·034	+0·1
31·73	770·73	−15·9	·165	−0·3
2009 June 1·04	54983·04	−29·1	12·380	−0·8
18·06	55000·06	−33·4	·478	−0·1
Aug. 29·90	072·90	−53·7	·894	−0·3
Sept. 25·79	099·79	−16·4	13·048	0·0
Oct. 22·77	126·77	−17·7	·203	+0·2

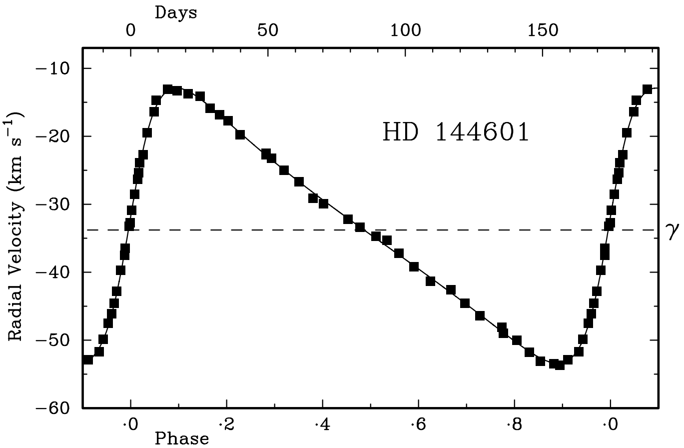

FIG. 2

As Fig. 1, but for HD 144601.

The statistical relationship between orbital eccentricity and period has been of much interest in recent years. Among systems that contain giant stars, orbits with periods up to about 120 days are normally circular, and eccentricities increase statistically towards longer and longer periods. It is unusual to find an eccentricity approaching 0·5 in the orbit of a giant with a period as short as that of HD 144601. On the rather shaky assumption of a mass of 2 $M_{\odot}$ for the observed star, the mass function demands a minimum mass of almost 1 $M_{\odot}$ for the secondary. The latter is not likely to be a white dwarf, because after one of the stars in the binary had undergone its giant-branch evolution it would be unlikely to leave the system with an orbit of such eccentricity. Thus the secondary is probably a main-sequence star, most likely of about solar type but it could be earlier to any degree. It has not been obvious in radial-velocity traces.

HD 144601 exhibits measurable (presumed rotational) line-broadening, the mean value from the Cambridge traces being 4·9 ± 0·4 km s^{-1}. We might reasonably suppose that the axial rotation of the star is pseudo-synchronized[14] to the orbital revolution, particularly since (*a*) the mass function has led us to expect that the secondary has no less than about half the mass of the primary, and (*b*) owing to the rather high eccentricity the periastron separation of the stars is scarcely more than half the mean separation. The first of those considerations indicates that the actual separation of the stars is no more than about three times the distance of the primary from the centre of gravity of the system, and the second shows that *that* distance, projected on the line of sight, is about 22 Gm (calculated as $(a_1 \sin i)(1 - e)$). At the eccentricity of the HD 144601 orbit, the pseudo-synchronous period is shorter than the orbital one by a factor of about 2·7, making it about 65 days, at which the measured $v \sin i$ represents a stellar radius of 6·3/sin i $R_{\odot}$. If sin i were as small as 0·6, the secondary would have to be as massive as the primary (still regarded here as having a mass of 2 $M_{\odot}$), so we can be reasonably sure that the radius of the primary is between 6 and 10 $R_{\odot}$, and very likely to be near the lower limit. At that limit it would have a surface area of about 40 times that of the Sun, and being of the same colour it should be brighter by that factor, *i.e.*, just 4^m expressed in terms of stellar magnitude, indicating that $M_V \sim +0^m{\cdot}8$, in general agreement with the wide limits set by the parallax.

Nearly 4′ south-preceding HD 144601 (position angle 199° as measured roughly on a picture raised by *Vizier* of the field) is a star, BD +20° 3204, a little fainter than HD 144601 itself, which is +20° 3205. Its V magnitude and $(B - V)$ colour index were found by *Tycho* to be $9^m{\cdot}40$ and $0^m{\cdot}70$. Its radial velocity has been measured three times at Cambridge, on 2008 September 26·83, 2008 November 7·72, and 2009 October 22·77, with results of –26·6, –26·3, and –26·4 km s^{-1}, respectively.

HD 150172

HD 150172 is another star in an extension of one of the northern 'Clube Selected Areas', in this case Area 2*; it is in Draco, close to the south-following vertex of an equilateral triangle, about 4° on a side, whose other vertices are η and θ Draconis

The star is well known to have a large proper motion. That was demonstrated in the *Yale Zone Catalogue*[15] for the declination zone +55°–60° in 1959, where the star has its *AG* designation[16] of (55°–65°) 8898; it was noticed also by Luyten in his '*LTT*' catalogue[17] of 1961 (*Luyten Two-Tenths* [or more, of a second of arc per annum proper motion]) and the subsequent enlarged and improved *N*[*ew*]*LTT*[18], in both of which catalogues the *BD* designation[19] of +57° 1692 is used. It featured, too, as G 225–70 and G 226–18, in the systematic Lowell proper-motion studies[20] by Giclas and his collaborators. The writer is not well enough versed in astrometric bibliography to know whether the motion was actually *discovered* at Yale. The amount of the motion was found by *Hipparcos* to be 0″·350 in p.a. 132°·2. At the *Hipparcos* distance of just over 30 pc it equates to a transverse velocity of 50 km s^{-1}, which is actually a bit less than the radial velocity. We are indebted to *Hipparcos*/*Tycho* also for photometry of the star, which is about $V = 8^m{\cdot}95$, $(B - V) = 0^m{\cdot}88$, the colour index agreeing well with the *HD* classification of K0; the accurately determined distance modulus of $2^m{\cdot}43 \pm 0^m{\cdot}05$ puts the absolute magnitude, however, at $6^m{\cdot}5$, corresponding more nearly with type K2 V. The star's position is noted by *Hipparcos* to have an acceleration of more than three times its own uncertainty in the right-ascension direction; it is hard to see how that could be caused by the motion in the orbit presented below, which would have been traversed a dozen times during the interval when *Hipparcos* was watching it.

The first radial-velocity observation was obtained at Cambridge in the summer of 2002. When the object was re-observed in the following summer, a major discordance was immediately apparent, and the star was observed to such purpose that before it had completed one 90-day cycle it had been measured on 36 nights and its orbit had been well determined. Since then, observations have been made to patch gaps in the phase coverage and their number has been increased to 67. They are set out in Table III and lead to the orbit plotted in Fig. 3 and having the following elements:

P	=	90·203 ± 0·010 days	$(T)_8$	=	MJD 53214·97 ± 0·17
γ	=	–60·42 ± 0·05 km s^{-1}	$a_1 \sin i$	=	19·41 ± 0·09 Gm
K	=	16·60 ± 0·08 km s^{-1}	$f(m)$	=	0·0359 ± 0·0005 $M_\odot$
e	=	0·108 ± 0·005			
ω	=	156·2 ± 0·8 degrees	R.m.s. residual	=	0·39 km s^{-1}

*Area 2 is centred at Galactic coordinates l +35°, b 90°, which translate approximately to RA $17^h\ 30^m$, δ +60°. The writer apologizes for the error in the declination that is given in Table 3 of ref. 12.

TABLE III

Cambridge radial-velocity observations of HD 150172

Date (UT)	*MJD*	*Velocity km s⁻¹*	*Phase*	*(O–C) km s⁻¹*
2002 Sept. 4·92	52521·92	−57·2	0·317	+0·3
2003 Aug. 9·98	52860·98	−79·6	4·076	+0·3
14·89	865·89	−73·0	·130	+1·0
15·96	866·96	−73·0	·142	−0·4
16·98	867·98	−71·2	·153	+0·2
19·96	870·96	−67·4	·186	+0·4
20·86	871·86	−66·1	·196	+0·7
24·85	875·85	−63·4	·241	−0·6
29·86	880·86	−58·8	·296	0·0
30·84	881·84	−58·2	·307	−0·1
Sept. 10·89	892·89	−51·9	·429	+0·4
13·87	895·87	−51·1	·462	+0·2
14·83	896·83	−50·6	·473	+0·4
15·95	897·95	−50·6	·486	0·0
16·93	898·93	−50·8	·496	−0·4
17·85	899·85	−50·0	·507	+0·2
19·90	901·90	−49·6	·529	+0·1
22·91	904·91	−49·5	·563	−0·3
23·93	905·93	−49·3	·574	−0·2
24·83	906·83	−49·0	·584	0·0
28·81	910·81	−48·6	·628	+0·3
28·90	910·90	−49·2	·629	−0·3
Oct. 3·83	915·83	−49·4	·684	0·0
7·92	919·92	−49·8	·729	+0·6
9·87	921·87	−50·7	·751	+0·5
11·84	923·84	−52·1	·773	+0·1
14·82	926·82	−54·5	·806	−0·2
16·79	928·79	−56·3	·827	−0·2
17·80	929·80	−57·3	·839	−0·2
18·77	930·77	−57·7	·849	+0·5
27·74	939·74	−73·7	·949	−0·3
29·82	941·82	−77·1	·972	+0·1
Nov. 1·75	944·75	−81·2	5·004	−0·2
2·78	945·78	−81·1	·016	+0·6
3·74	946·74	−81·5	·026	+0·5
4·75	947·75	−81·7	·038	+0·3
5·77	948·77	−82·4	·049	−0·7
7·79	950·79	−80·8	·071	−0·5
24·71	967·71	−62·1	·259	−0·7
27·73	970·73	−59·0	·292	0·0
Dec. 7·72	980·72	−52·7	·403	+0·6
2004 Apr. 20·10	53115·10	−63·6	6·893	+0·3
22·15	117·15	−67·7	·916	−0·1
23·11	118·11	−69·0	·926	+0·4
May 19·07	144·07	−65·3	7·214	−0·2
24·03	149·03	−60·1	·269	+0·5
31·02	156·02	−56·0	·347	−0·2
July 9·93	195·93	−52·6	·789	+0·6
16·94	202·94	−60·4	·867	−0·1
Aug. 7·98	224·98	−76·3	8·111	−0·1
12·92	229·92	−70·0	·166	0·0
30·96	247·96	−55·1	·366	−0·2
31·97	248·97	−54·4	·377	0·0
Sept. 1·90	249·90	−54·2	·387	−0·3
Oct. 25·83	303·83	−79·5	·985	−0·4
26·83	304·83	−80·5	·996	−0·2
Nov. 4·81	313·81	−78·3	9·096	−0·4

TABLE III (*concluded*)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O–C)* *km s⁻¹*
2005 Apr. 22·11	53482·11	−75·4	10·962	+0·2
2006 Apr. 9·10	53834·10	−60·5	14·864	−0·6
July 12·01	928·01	−65·8	15·905	0·0
15·04	931·04	−71·5	·938	+0·1
2007 Apr. 4·17	54194·17	−59·5	18·856	−0·6
Sept. 12·94	355·94	−49·8	20·649	−0·8
2008 July 21·92	54668·92	−75·6	24·119	−0·3
2009 May 7·10	54958·10	−57·3	27·325	−0·3
June 1·04	983·04	−49·3	·601	−0·4
Aug. 24·93	55067·93	−49·2	28·542	+0·3

If the primary is taken as having a mass near 0·8 $M_{\odot}$, as must surely be near the truth, the mass function requires the secondary to have a mass of at least 0·4 $M_{\odot}$; except in the unlikely case of its being a white dwarf it could be no further down the main sequence than M2 or fainter absolutely than $M_V \sim 10^{m}$, so it ought to be within about 3½ magnitudes of the luminosity of the primary. It has not been evident in radial-velocity traces.

The $a_1 \sin i$ value found above is about 0·13 AU; if such an orbital radius is seen directly on the sky from a distance of 30 pc it should subtend an angle of 0″·004, so it could be expected to be unravel-able from the data underlying the *Hipparcos* catalogue now that the spectroscopic orbital elements are known. The angular separation of the components on the sky would often be 2–3 times as great, but still too small for direct resolution at present.

The star having an adjacent *BD* number, +57° 1693, about a magnitude fainter than HD 150172, is a little over 3′ distant in p.a. 60°. Its radial velocity was measured on 2003 August 9·98 and 15·98, with results of −71·4 and −72·1 km s⁻¹.

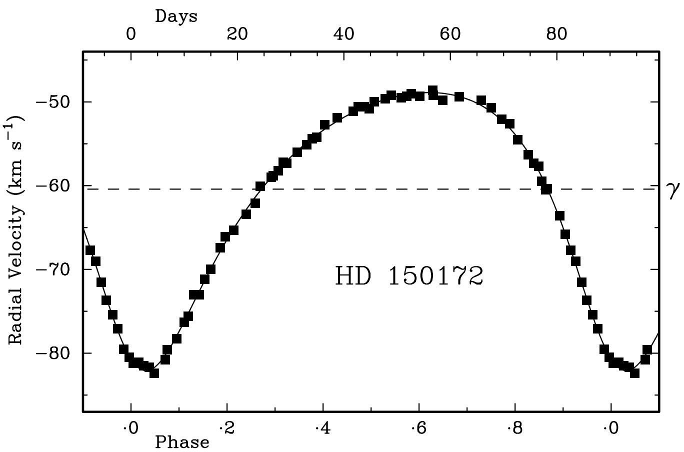

FIG. 3
As Fig. 1, but for HD 150172.

HD 155641

HD 155641, like HD 144601, is a star in Clube Area 1, but in the original and not the extended area; it is to be found in Hercules, about 2° north-preceding δ Herculis. The only paper in which *Simbad* remembers its featuring is the writer's first listing[12] of radial velocities in the Clube Selected Areas. As in the cases of the two preceding objects discussed above, however, *Hipparcos* has provided some useful information. Objects of about the ninth magnitude, such as the Clube stars are by definition, are by no means uniformly included in the *Hipparcos* catalogue, and it must be only the relative barrenness of the relevant area of sky that led to the 'Input Catalogue Consortium' resorting to the inclusion of such relatively faint stars which — except perhaps in the case of HD 150172 — had no known interesting characteristics to distinguish them.

The parallax of HD 155641 is 0″·00504 ± 0″·00113, and translates to a distance modulus of about $6^{m}\cdot5 \pm 0^{m}\cdot5$. The apparent V magnitude and $(B-V)$ colour index are $8^{m}\cdot72$ and $0^{m}\cdot91$, respectively, so the absolute magnitude is about $+2^{m}\cdot2$, with an uncertainty of about half a magnitude — an unusual luminosity, corresponding to an MK luminosity class of about III–IV or IV, while the colour is that of a star of about type K0.

Two radial-velocity measurements, made in 1970 and 1974 with the original Cambridge photoelectric spectrometer[21] with which velocities were measured by cross-correlation for the first time, were published in the initial paper[12] on the Clube Areas. Their mutual agreement was poor, but it was not quite bad enough to be regarded at the time as constituting unequivocal evidence of variability. It is to be noticed, however, that in place of their mutual discrepancy of 2·6 km s^{-1} when the star concerned was treated as having a constant velocity, they now give residuals of only 0·0 and 0·6 km s^{-1} from the adopted orbit.

When it was decided to make more and better measurements in the northern Clube Areas in an effort to bring the quantity and quality of their results up to that of the southern Areas[13], not only was a lot of fresh stars scheduled for observation but the originally selected stars were restored to the observing programme and measured anew. In the case of HD 155641 a discordance with the 'old' observations immediately arose, and the object was forthwith put on the binary programme and its orbit was quickly established. Its period is shorter than those of the other stars treated here, only 44 days. There are 47 observations, 45 of which are new (Table IV); the two early observations made with the original spectrometer have been weighted ¼ in the solution of the orbit. Their inclusion refines the orbital period significantly: the recent observations, alone, give the period as 44·073 ± 0·005 days, a value that is changed by rather more than its standard error and improved by a factor of three when the measures from 36 and 40 years ago are added. The elements are shown below, and the orbit is plotted in Fig. 4.

P	=	44·0805 ± 0·0016 days	$(T)_9$	=	MJD 53260·63 ± 0·24
γ	=	−33·04 ± 0·05 km s^{-1}	$a_1 \sin i$	=	9·17 ± 0·05 Gm
K	=	15·28 ± 0·08 km s^{-1}	$f(m)$	=	0·01583 ± 0·00024 $M_\odot$
e	=	0·144 ± 0·005			
ω	=	24·8 ± 2·0 degrees	R.m.s. residual (wt. 1)	=	0·34 km s^{-1}

TABLE IV

Cambridge radial-velocity observations of HD 155641

Date (UT)	*MJD*	*Velocity* $km\ s^{-1}$	*Phase*	*(O – C)* $km\ s^{-1}$
1970 July 31·97*	40798·97	−43·8	$\overline{274}$·297	0·0
1974 Aug. 6·89*	42265·89	−41·2	$\overline{241}$·576	+0·6
2003 Sept. 16·90	52898·90	−25·9	0·794	−1·1
Oct. 11·86	923·86	−46·2	1·360	−0·3
14·78	926·78	−46·2	·426	+0·1
16·77	928·77	−46·0	·472	−0·3
27·75	939·75	−31·4	·721	0·0
Nov. 1·74	944·74	−21·3	·834	0·0
2·75	945·75	−19·1	·857	+0·5
3·75	946·75	−17·7	·879	+0·3
4·74	947·74	−16·9	·902	−0·1
5·76	948·76	−16·2	·925	−0·1
7·77	950·77	−16·2	·971	−0·2
24·72	967·72	−46·3	2·355	−0·5
2004 Apr. 20·11	53115·11	−33·6	5·699	−0·3
22·16	117·16	−28·9	·745	+0·3
23·11	118·11	−27·8	·767	−0·5
May 31·04	156·04	−38·5	6·627	+0·2
June 8·04	164·04	−23·1	·809	+0·4
15·08	171·08	−16·1	·969	−0·1
17·04	173·04	−17·7	7·013	+0·3
19·01	175·01	−21·9	·058	−0·2
22·03	178·03	−29·2	·126	+0·1
25·05	181·05	−36·4	·195	+0·2
25·96	181·96	−38·2	·215	+0·2
27·96	183·96	−41·0	·261	+0·8
July 9·95	195·95	−43·8	·533	0·0
Aug. 12·93	229·93	−44·2	8·304	−0·1
Sept. 13·82	261·82	−19·2	9·027	−0·2
15·90	263·90	−23·8	·074	−0·3
2005 May 8·07	53498·07	−46·3	14·387	−0·1
June 9·04	530·04	−27·8	15·112	−0·1
11·01	532·01	−32·7	·156	0·0
July 17·97	568·97	−16·6	·995	+0·3
19·99	570·99	−20·0	16·041	+0·1
Aug. 15·93	597·93	−36·4	·652	+0·5
Sept. 14·87	627·87	−45·0	17·331	+0·1
25·80	638·80	−41·6	·579	0·0
2006 July 10·04	53926·04	−25·7	24·095	+0·1
12·03	928·03	−31·0	·141	−0·1
17·96	933·96	−42·6	·275	+0·1
2007 Apr. 4·15	54194·15	−35·2	30·178	−0·3
May 8·09	228·09	−15·7	·948	+0·1
30·06	250·06	−45·9	31·446	+0·2
June 1·10	252·10	−45·8	·492	−0·7
1·99	252·99	−43·9	·512	+0·6
July 19·94	300·94	−40·1	32·600	+0·3

*Observed with original spectrometer; weight ¼.

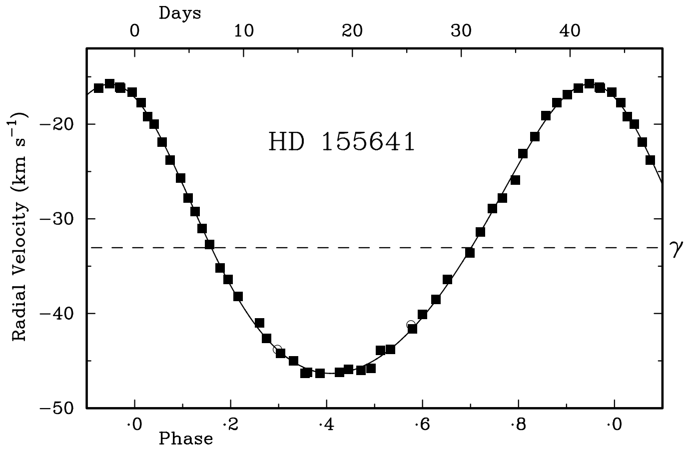

FIG. 4

As Fig. 1, but for HD 155641; in this case there are two observations, identified by being plotted as open circles, that were made many years ago with the original photoelectric radial-velocity spectrometer[21].

The mass function is so small that it is far from surprising that no evidence — other than that of the orbital motion of the primary, of course! — has been seen of the secondary star. HD 155641 has no measurable rotational velocity.

References

(1) T. Oja, *A&AS*, **57**, 357, 1984.
(2) A. J. Wesselink, *The Observatory*, **109**, 5, 1989.
(3) A. de Sitter, *Bull. Astr. Inst. Netherlands*, **6**, 65, 1930; **8**, 185, 1937.
(4) B. Meyermann & K. Schwarzschild, *AN*, **174**, 137, 1907.
(5) *The Hipparcos and Tycho Catalogues* (ESA SP–1200) (ESA, Noordwijk), 1997.
(6) K. Fuhrmann, *AN*, **325**, 3, 2004.
(7) J. T. Wright *et al.*, *ApJS*, **152**, 261, 2004.
(8) R. W. Noyes *et al.*, *ApJ*, **279**, 763, 1984.
(9) [Announced by] B. Nordström *et al.*, *A&A*, **418**, 989, 2004.
(10) R. F. Griffin, *MNRAS*, **368**, 1359, 2006.
(11) K. Fuhrmann *et al.*, *MNRAS*, **361**, 803, 2005.
(12) R. F. Griffin, *MNRAS*, **219**, 95, 1986.
(13) R. F. Griffin & A. P. Cornell, *MNRAS*, **371**, 1140, 2006.
(14) P. Hut, *A&A*, **99**, 126, 1981.
(15) *Trans. Astr. Obs. Yale Univ.*, **27**, 93, 1959.
(16) A. Krueger, *Catalog von 14680 Sternen . . .* (*Catalog der Astronomische Gesellschaft*, vol. **1** (+55°–65° (Helsingfors–Gotha) zone)) (Engelmann, Leipzig), 1890, p. 179.
(17) W. J. Luyten, *A Catalogue of 7127 Stars in the Northern Hemisphere with Proper Motions Exceeding 0″·2 Annually* (Lund, Minneapolis), 1961, page headed '14901-15000'.
(18) W. J. Luyten, *NLTT Catalogue* (Univ. of Minnesota, Minneapolis), 1979, **1**, 128.
(19) F. W. A. Argelander, *Astronomische Beobachtungen auf der Sternwarte zu Bonn* (Adolph Marcus, Bonn), **5**, 232, 1862.
(20) H. L. Giclas, *Lowell Obs. Bull.*, **7**, 31, 1967; **7**, 67, 1968.
(21) R. F. Griffin, *ApJ*, **148**, 465, 1967.

CORRESPONDENCE

To the Editors of 'The Observatory'

Saturn's Phoebe Ring and Ancient Babylonian Observations

The *Spitzer Space Telescope* recently discovered an enormous 'ghost' ring (also known as the Phoebe Ring) around Saturn[1]. With a radius of between 128 and 207 times that of Saturn, a vertical thickness 40 times Saturn's radius, and an inclination of about 27° with respect to the main ring plane, it incorporates Saturn's moon Phoebe, from which its dust is thought to derive through impacts. Some 100 times larger in diameter than the nearest rings inside it, at opposition it is estimated[2] to "span the width of two full moons' worth of sky, one on either side of Saturn". At present, the ring is only visible in the infrared, yet we wonder whether its discovery might shed some light on an unsolved problem of archaeoastronomy.

Ancient astronomers assigned specific colours to each of the traditional seven (naked-eye) planets. The earliest documented examples come from the Cuneiform texts of the Babylonians and Assyrians, dating to the 8th–7th Centuries BC. In an on-going project we have been studying the rationale behind the colours assigned to each planet and in most cases there is a straightforward naturalistic explanation. For example, the Babylonians systematically described the Sun as gold, the Moon as silver, Mars as red, and Jupiter as white, just as they appear. The 'green' colour they ascribed to Venus can be read as green or blue, as there was no distinction between those colours in the Sumerian and Akkadian languages used by the Babylonians. While Venus generally appears white, this could shift to a greenish-blue tinge to the unaided eye, as confirmed by ethnographic parallels outside Babylonia. Though less clear from the sources, our understanding is that Mercury was associated with pale red (brown, according to the medieval scholars of Harran in northwestern Mesopotamia), and the planet can appear orange-brown in colour[3].

The colour assigned to Saturn remains a distinct problem. The Babylonians regularly described it as 'black'[4], as did ancient Indian and Graeco-Roman and medieval Jewish writers[5] (working within traditions influenced by the Babylonians). Saturn is indeed a dim planet (compared to Venus, Jupiter, and Mars), but nonetheless its visibility led to its observation, a circumstance which hardly prompts an association with black! Besides, comparison with the other planets suggested that the Babylonian 'planet colours' were not based on degrees of brightness, but on actual coloration. If anything, Saturn appears yellowish in colour, yet only one of the ancient sources we have examined (Plato, *Republic*, 10·14) suggests a yellow colour.

We have experimented with astrological and cosmological explanations (in Babylonian terms) for the widespread choice of black for Saturn. For example, the Babylonians commonly distinguished between planets thought to be 'benefic' (Jupiter and Venus) and 'malefic' (Saturn and Mars, Mercury being ambiguous)[6]. As the most auspicious planets were also the two brightest, one might suspect a correlation between relative brightness and beneficence, with the 'malefic' planet Saturn being assigned the darkest colour possible. Yet this does not seem satisfactory, as it flouts the underlying logic that can be seen in the colour choice for all the other planets, where, clearly, natural appearance has dictated the choice.

The reconstruction offered of the newly-discovered Phoebe ring is thus of immense interest, not only for modern astronomers, but for those studying the thought processes of their ancient counterparts. As visualized[7], a ring of light surrounds a gigantic black space, within which the planet itself appears only as a small dot of brightness at the centre. Though the ring is presently invisible from a terrestrial standpoint, were anything like this to have been visible from the Earth in the ancient past, an explanation would readily offer itself as to why ancient observers regarded Saturn as black: perceiving the ring as the perimeter of the planet, the 'body' of the object would appear to be black. Could the amount of dust in the Phoebe ring have been considerably larger in the recent past due to an episode of cometary or asteroidal impact activity? If so, could sunlight have reflected off the particles in a process akin to the zodiacal light, producing a ring, at least partially, as seen from the Earth? The optical form of the ring might have varied between an arc and an oval if only a part of the ring was illuminated, or due to different perspectives on the ring as seen from Earth.

Not only would this successfully account for the Babylonian characterization of Saturn as 'black', it might also shed light on some other curious traditions. The Greek historian, Diodorus of Sicily (1st Century BC; *Bibliotheca*, 2·30·3) stated that the ancient Babylonian astrologers deemed Saturn *epiphanéstatos* or 'the most conspicuous' of the planets — a qualification that has remained elusive. Babylonian astrologers linked the planet to the Sun, a puzzling fact that has exercised scholars' minds for a century. Saturn was called the planet of the Sun-god Shamash by the Babylonians, followed by writers in the Greek world ('the star of Helios') and in India ('son of the Sun')[8]. The ring, greater than the Moon if visible, could have prompted the Babylonian perception of Saturn both as a nocturnal Sun and as black. Another puzzling tradition associated with Saturn comes from Hellenistic Egypt; it concerns a type of comet called the 'discus', described as round and golden, with rays around its circumference, and named after the planet Kronos (Saturn) because of its similarity in appearance[9]. Could this association have originated at a time when Saturn was still envisioned in terms of the ring?

The overriding question is whether such a ring could once have been seen by terrestrial observers? What mass of dust would be required, distributed around Phoebe's orbit, to scatter sufficient sunlight to produce a visible ring? It is beyond our ken, as historians, to guess at what kind of analysis would be involved or to do the maths. Our apologies if our naïve questions are several orders of magnitude out of bounds.

Yours faithfully,
PETER JAMES

email: Peter@centuries.co.uk

and MARINUS ANTHONY VAN DER SLUIJS

University of Pennsylvania Museum of Archaeology and Anthropology,
Philadelphia

email: mythopedia@hotmail.com

2009 November 16

References

(1) A. J. Verbiscer, M. F. Skrutskie & D. P. Hamilton, *Nature* advance online publication doi:10.1038/nature08515, 2009.
(2) A. J. Verbiscer in W. Clavin, http://www.spitzer.caltech.edu/Media/releases/ssc2009-19/release.shtml.
(3) For all references see P. James & M. A. van der Sluijs, *Journal of Cuneiform Studies*, **60**, 57, 2008.
(4) P. F. Gössmann, *Planetarium Babylonicum oder die sumerisch-babylonische Sternnamen* (Verlag des päpstlichen Bibelinstituts, Rome), 1950, p. 28; D. Brown, *Mesopotamian Planetary Astronomy-Astrology* (Styx, Groningen), 2000, p. 57; E. Reiner & D. Pingree, *Babylonian Planetary Omens; Part Three* (Styx, Groningen), 1998, p. 58 & p. 248.
(5) W. Eilers, *Sinn und Herkunft der Planetennamen* (Verlag der bayerischen Akademie der Wissenschaften, München), 1976, p. 93; Ptolemy, *Tetrabiblos* 2.9; Nigidius Figulus, apud Lucan, *Pharsalia* 1. 651; Celsus, apud Origen, *Contra Celsum*, 6. 22; Proclus, *In Platonis Timaeum Commentarius*, 14b (1.43.1); Maimonides, *Commentary on the Mišnā: 'Aboda Zara*, 3. 1.
(6) F. Rochberg-Halton, in E. Leichty, M. deJ. Ellis & P. Gerardi (eds.), *A Scientific Humanist: Studies in Memory of Abraham Sachs* (University Museum, Philadelphia), 1988, p. 323.
(7) M. Grayson, *NatureNews*, doi:10.1038/news.2009.979 (2009 October 7), at http://www.nature.com/news/2009/091007/full/news.2009.979.html.
(8) M. Jastrow, *Revue d'Assyriologie et d'Archéologie Orientale*, **7**, 163, 1910; D. Brown, *Mesopotamian Planetary Astronomy-Astrology* (Styx, Groningen), 2000, p. 57; U. Koch-Westenholz, *Mesopotamian Astrology* (Museum Tusculanum Press, Copenhagen), 1995, p. 123.
(9) Petosiris (apud Hephaestion of Thebes), in G. L. Irby-Massie & P. T. Keyser (eds), *Greek Science of the Hellenistic Era: A Sourcebook* (Routledge, London), 2002, p. 90.

To the Editors of 'The Observatory'

The History of the Royal Greenwich Observatory

During my retirement I have spent many years, on and off, preparing the text for *A Personal History of the Royal Greenwich Observatory at Herstmonceux Castle 1948–1990*. It has not been possible for me to complete and check it thoroughly, but it is now available on the website of the Cambridge University Library. Catherine Hohenkerk of H. M. Nautical Almanac Office has greatly assisted me by preparing the website. The material is in two volumes: one for the narrative and one for appendices, most of which contain detailed reference material. The chapters of the narrative and the appendices may be downloaded individually. There is no index, but the website contains a detailed list of the contents. The website address is: http://www.lib.cam.ac.uk/deptserv/manuscripts/RGO_history Alternatively the website can be found by a Google search on the two words: 'Wilkins' and 'Herstmonceux'.

Much of the narrative is concerned with the work in which I was involved in the Division of Almanacs and Time within the RGO and in various international organizations. I have also included general information about the activities in the Observatory, but I have not attempted to describe the work in other departments in any detail, as such information may be found in other publications. I would be glad to receive additional information and corrections from former members of the staff and other readers so that an errata section, and possibly new material, could be added to the website in due course.

I would also like to take this opportunity to draw attention to the complementary account by Donald Sadler of his *Personal History of HM Nautical Almanac Office 1930–1972*. This is on the website of the NAO at: http://www.hmnao.com/nao/history/dhs_gaw/index.html

This includes the period when he was Superintendent and I was on the staff of the RGO, learning about the work of the Office and being introduced by him to the international activities in which he had played important rôles.

Yours faithfully,
GEORGE A. WILKINS

Department of Mathematical Sciences
Harrison Building
University of Exeter
North Park Road
Exeter
EX4 4QF

2010 January 2

REVIEWS

Women in Early British and Irish Astronomy: Stars and Satellites, by M. Brück (Springer, Heidelberg), 2009. Pp. 277, 24 × 16 cm. Price £90/$129/€99·95 (hardbound; ISBN 978 90 481 2472 5).

This wonderful book is a fine legacy bequeathed us by Mary Brück, who so unfortunately passed away in 2008 (see **129**, 180), just months before its publication. The work of women in astronomy had occupied Mary in her latter years and I wholeheartedly praised her excellent account of Agnes Clerke (see **122**, 292) published a few years ago.

This time we are treated to portraits of a whole host of dedicated women who, on their own or as the amanuensis of a prominent male astronomer, contributed so much to our subject. Some of them we all will know at least something about: Caroline Herschel, for example, who provided such tireless support to her brother, William; and Margaret Huggins who helped Sir William to achieve fame as one of the founders of astronomical spectroscopy. Then we find the women who forged their own paths to prominence in science, principally through their published works, such as Agnes Clerke and Mary Somerville. But there were many more whose contributions were just as important but who, in several cases, were 'hidden' behind their more famous husbands. In this category we find Annarella, wife of the great observer Admiral Smyth; Jessie, wife of the man who pioneered mountain-top observing, Charles Piazzi Smyth; and Mary, wife of John Evershed, who did important solar work around the turn of the century. Even when the husband was a staunch supporter of an equal rôle for women in science, such as Walter Maunder (one of the founders of the woman-friendly BAA, and an early Editor of this *Magazine*), the name of his wife, Annie, never achieved the same 'star-billing'. This was, of course, just the way things were done in those far-off days, and the dismal failure of the RAS to elect women as Fellows was typical of that era. (Some might argue that we still haven't achieved full equality — see the report of the 2009 STFC Forum, **129**, 161!) These points are all well drawn out in Mary's book and one can only hope that women in astronomy today will derive inspiration from what their intellectual ancestors — and there are many more discussed than the handful mentioned above — contributed.

The volume itself is nicely produced with a number of monochrome images showing some of our heroines, and there are copious notes and references for the student of history who wishes to pursue the subject further. Perhaps Mary never had a chance to run over the final proofs, for there are a number of minor things to correct in a second edition. And one feature I'd like to see changed is the system used for referencing: a superscript notation is used (as it is in this *Magazine*) but for some inexplicable reason, the numerals used are lower-case Roman rather than the more compact Arabic; it all seems a bit messy to me. — DAVID STICKLAND.

Solar System Moons: Discovery and Mythology, by J. Blunck (Springer, Heidelberg), 2009. Pp. 152, 24 × 16 cm. Price £64·99/$119/€74·95 (hardbound; ISBN 978 3 540 68852 5).

The final book by historian Jürgen Blunck (1935–2008) beautifully sets essential facts about the discovery of Solar System moons and planetary rings in proper historical and mythological context. It is a worthy successor to such works as his highly accurate and comprehensive study of the history of Martian nomenclature, *Mars and Its Satellites*. By 2007 there were 63 known Jovian satellites and 62 recognized Saturnian moons, so this book constitutes a timely and accurate manual. Each moon — even the smallest — gets a dose of fact and fiction, from the satellites of Mars through the gas giants and Pluto to Eris. There is much useful information, and *Solar System Moons* is a volume that can be dipped into at random or read in its entirety.

Many satellites receive lengthy quotations: Jupiter II Europa has snippets from Apollodorus and Ovidius, whilst Uranus I Ariel receives quotes from Shakespeare, Pope, and Milton. However, satellite nomenclature is not limited to Greek or Roman mythology or to English writers: Saturn XXII Ijiraq is an Inuit character in a modern children's book, and Saturn XXIII Suttungr is a Norse giant. Nomenclature of planetary rings is nicely documented too. Blunck's book is liberally sprinkled with spacecraft images and mythological figures. It has very few typographical errors (the book being completed after the author's death by the editors at Springer). Its sole drawback will be its high price, but I do urge librarians to obtain it given its accuracy and its comprehensive nature.

We learn that some discoverers — especially Seth B. Nicholson and Charles T. Kowal — were completely opposed to names, and wanted only to use Roman numerals. The involvement of the IAU (since 1919) has resulted in logically related names for most satellites, though there is a certain overlap with names assigned to minor planets, and the various controversies about the naming processes are well covered by the author. In the end, we must admit that nomenclature is a subjective and arbitrary business, so let us conclude by quoting Simon Marius who, in suggesting the names Io, Europa, Ganymede, and Callisto in 1614, wrote: "… all of these names have been freely imagined by me, so let everyone feel free either to reject or accept them." — RICHARD MCKIM.

Annual Review of Astronomy and Astrophysics, Volume 47, 2009, edited by R. Blandford, J. Kormendy & E. van Dishoeck (Annual Reviews, Palo Alto), 2009. Pp. 630, 24 × 19·5 cm. Price $214 (print only for institutions; about £130), $84 (print and on-line for individuals; about £51) (hardbound; ISBN 978 0 8243 0947 3).

Forty years ago, I spent the first year of my D.Phil. (Sussex) at UC Santa Cruz under an exchange agreement between St. Andrews University and the University of California. Graduates at UC, most of whom had come up through physics and maths degrees, were expected to take courses in astronomy from the wonderful collection of astronomers to be found at Santa Cruz, which had recently been made the university base of Lick Observatory. I benefitted enormously from their expertise, which included a set of lectures on cataclysmic variables from one of the leaders in the field, Bob Kraft. Thus it was a great pleasure to 'catch up' on his progress in the opening chapter of this year's *Annual Review*. And it very much reminded me of the Bob Kraft I remembered: honest, modest, and with a fine underlying humour. It tells of a career in astronomy — reaching to the Presidency of the IAU — blessed with well-timed opportunities and good fortune, but from humble beginnings, and giving due credit to the public university system, which I heartily applaud.

One of the definitions of 'review' in my *Concise Oxford Dictionary* is "second view", and that is, in part, what we find in this volume, where topics that I thought were 'done and dusted' have been revisited in the light of modern techniques. Prime amongst them is a new set of solar abundances from Asplund *et al.*, which has lowered the C, N, and O values and created some difficulties for modellers of results from helioseismology. And also from 'antiquity' I recall the large-format pages of the *Bulletin of the Astronomical Institutes of the Netherlands* showing maps of the Galactic distribution of neutral hydrogen; how much more detail we have now is apparent in the chapter by Kalberla & Kerp. From the same era, I remember that rather few stars outside the Milky Way could be seen as individuals; just how different things now are is readily seen in articles on Local Group galaxies (Tolstoy *et al.*) and other nearby galaxies (Blanton & Moustakas). Of course, none of this should be a surprise given the technological progress of recent years, as evidenced, for example, in the chapter on high-contrast observations (Oppenheimer & Hinkley).

The tally of complex molecules to be found in interstellar space has also steadily risen (Herbst & van Dishoeck), with a nice selection of 'pre-biotic' species available for use on the almost-Earth-type planets now being discovered. That said, space is still a hostile environment, as demonstrated by the presence of γ rays detected by ground-based observatories (Hinton & Hofmann) and by *Swift* from γ-ray bursters (Gehrels *et al.*).

Given the value of supernova explosions to cosmological research, the examination of possible progenitors of core-collapse supernovae by Smartt is valuable, while stars that don't quite make it that far can end up as the hot subdwarfs considered by Heber. The rôle of magnetic fields in many stars is still being evaluated, but results for a wide range of non-degenerate stars are presented by Donati & Landstreet. But if you are looking to magnetism to solve your stellar problems, check out the chapter on magnetic reconnection (Zweibel & Yamada) to see what it has to offer. And to round out another excellent collection of reviews, here's one to prepare us for the future: 'Gravitational waves from compact binaries' (Hughes).

All in all, another success, but the last for Roger Blandford as editor, who retires with this volume — and with our thanks. — DAVID STICKLAND.

The Search for Life Continued: Planets Around Other Stars, by B. W. Jones (Springer, Heidelberg), 2009. Pp. 296, 24 × 17 cm. Price £19·99/$29·95/€24·95 (paperback; ISBN 978 0 387 76557 0).

This book presents a well-designed introduction to searches for extra-terrestrial existence, defining and describing life as we know it in its myriad forms and establishing the limits for such life other than on the surface of the Earth. It outlines the various astronomical techniques which should be capable of detecting signatures of distant life forms, explains the essentials of evolution, and brings us up to date with results so far. In these respects it is rather similar to a number of other hopeful books on this topic, and the fact that positive signals of actual extra-terrestrial life have not so far been proven is no fault of the author.

However, although the book is appropriately conceived in outline, its contents do not flow readily enough to make absorbing reading; the different concepts are somehow too compartmentalized, and in places the watered-down astrophysics made me wince. For good reason the author needed to simplify the descriptions of the physics, but did so by cutting the wrong corners and by inserting condescending phrases which, if they did anything, made the reader feel an intellectual inferior.

The author is an admittedly firm believer in the existence of quite abundant extra-terrestrial life in whatever form, and allows that to colour his scientific judgement; claiming that 10% of all nearby dwarf stars are "known" to harbour planets, he argues that the score is probably nearer to 25% and then quotes the *second* figure later as the "known" percentage. He confesses to being mystified as to why investigations of gravitational lensing towards the Galactic bulge plus three clusters failed to detect any planets at all when they were surely expected, but ignores the awful possibility that actually there weren't any. What *I* found mysterious was his selection of photographs to illustrate the text: why show Mayor & Queloz, during their early successes at detecting planets with the OHP spectrograph, against a backdrop of ESO, but omit Campbell, Marcy, Butler & Fischer, Wolszczan & Frail ... And why show the *WHT* instead of (say) the OHP 1·93-m or the Lick 3-m when it comes to effective support instrumentation? I was also confused by the term "Doppler spectroscopy" to describe the spectroscopic measurement of radial velocities; he is doubtless applying the more generic term to *high-precision* radial-velocity measurements, but does not say so and the reader is left puzzling why so relatively few of the fairly bright stars have "only recently" been measured by Doppler spectroscopy and what all the forefathers of astrophysics were doing with their inaccurate spectrographs whose prism (to quote) "does not spread wavelengths widely enough to be useful". The astronomer may also be surprised that there are "several ways in which observations of a star can give us its mass" precisely enough to be relevant here, and that "dwarfs have been most observed [for radial velocity] because their spectra are clean".

I was also bothered by the writing, which was often over-simplistic, got its logic confused when it launched into complex sentences, and was peppered with grammatical errors. I could not fathom why a British author, writing for a European publisher who sets type in Germany, should write in American English. That fact accounted for the persistent use of "that" in place of "which" and for the lack of hyphens (though did not excuse the sometimes humorous ambiguities which resulted), but could not be responsible for the occasional mis-selection of words or the sometimes confused descriptions of concepts for the sake of simplicity.

There is a burgeoning list of reviews in this field. After an excited start prompted by the first inferences of planets orbiting stars, the lack of finds indicative of actual life has been rather a damper. Writing more books like this one simply isn't going to make them happen. — ELIZABETH GRIFFIN.

Secrets of the Universe: How We Discovered the Cosmos, by P. Murdin (Thames & Hudson, London), 2009. Pp. 341, 28 × 22 cm. Price £24·95 (hardbound; ISBN 978 0 500 25155 3).

Weighing in at almost 2 kg, this beautifully produced book certainly does need a table (coffee or otherwise) to support it while the reader peruses the 65 short but fascinating chapters describing Paul Murdin's selection of the greatest discoveries in astronomy. Together, these chapters combine to present an up-to-date picture of astronomy and just how we got where we are today; but in doing so they also contain a wealth of history of our subject, not in the traditional chronological fashion but under each of the wide variety of topics covered.

To give a flavour of the contents, we start with the seven planets of antiquity, progress through the Solar System as we know it today, examine the physical processes at work in the cosmos, catalogue the components of the Universe 'visible' to us in all accessible wavelengths, understand how they fit into the grander schemes of galaxies and their evolution, and finally look forward hopefully to future discoveries — dark matter, dark energy, and life.

The book is delightfully illustrated with a stunning array of images ranging from a Cuneiform tablet from 1600 BC through to the Hubble Deep Field, together with a portrait gallery of the major contributors to the discoveries covered (with one or two prominent astronomers, *e.g.*, Zwicky and Hoyle, getting more than one appearance!). The text is lucid and crammed with fascinating facts and figures, and combined with the attractive layout and illustrations makes the book an inspiring gift for anyone with some familiarity with the language of science. It should be compulsory reading in the 6th Form and on the Clapham Omnibus. The book concludes with a valuable glossary, a reading list for further study, and a useful index.

I did note that the British radar expert J. S. Hey changed his name from James (correct) on page 88 to John by page 267, that the Sun switched from using the CNO cycle to the more usual proton–proton chain between pages 223 and 230, and that Technetium was claimed on page 227 (the index says 226) to be *produced* on the surfaces of red giants rather than by dredge-up. But such minor blemishes and the very occasional typo fail to detract significantly from what is a superb volume. — DAVID STICKLAND.

The Plasma Universe, by C. Suplee (Cambridge University Press), 2009. Pp. 76, 24 × 18·5 cm. Price £12·99/$20·99 (paperback; ISBN 978 0 521 51927 4).

One does not usually think of Cambridge University Press as a vanity publisher, but the back cover of *Plasma Universe* acknowledges financial support by the Division of Plasma Physics of the American Physical Society (celebrating its 50th birthday) and the University of New Hampshire (motivation less obvious). Author Suplee is a well-known science writer, who appeared regularly in the *Washington Post* during many of the years I was reading it regularly. He has produced a short volume that resembles the products of existing and planned expensive scientific projects (satellites, accelerators, national review boards, *etc*.), with nearly half the paper surface in colour images and 34 one-to-four-page sections on as many topics, including the compulsory items on spin-offs and practical applications. One of these that I had not fully appreciated is the fact that most of the night lighting that makes the USA and western Europe glow in images from space comes from plasma lights, mostly high-intensity discharge units. These are presented as a blessing, though of course we astronomers feel somewhat differently.

Four scientists rate pages and pictures of their own — Irving Langmuir, Hannes Alfvén, Eugene Parker, and Marshall Rosenbluth, all but Langmuir shown as they were long after their best-known work was done, not perhaps the image we want to project. Asked for advice, I would have suggested a fifth person, Marcia Neugebauer, who was first author on the paper that reported data from *Mariner 2*, confirming the earlier predictions of a solar wind by Parker and others.

Most of the text is very good — I especially like the description of the Debye length by analogy with journalists crowding around celebrities at a party. Among the glitches, (*i*) a picture of Comet Hale–Bopp, in which the "wake behind the comet … is caused by the solar wind", but both the plasma and dust tails are in the picture, (*ii*) a chart of examples of plasmas that puts the Crab Nebula at 10^7 K; much too hot for the thermal gas at about 10^4 K (like other ionized gases in space), and of course the non-thermal plasma is non-thermal, and (*iii*) vacuum tubes credited to Langmuir and Albert Hull, with no mention of Lee De Forest. Why should I care? Well, my father knew Lee De Forest. There is also one image (of a simulation of a tokamak plasma) provided by University of California Irvine colleague Zhibong Lin, who is in the office right next door. This is, I think, the limit of 'conflict of interest' for this book and review.

The information presented is, for the most part, compact and up to date, for instance on origins of the very-highest-energy cosmic rays, left as a mystery, as is the heating of the solar corona. *Plasma Universe* might make a good gift for a high-school senior or college freshman who needs reminding that physics is both relevant and fun. — VIRGINIA TRIMBLE.

High Energy Astrophysics, by Fulvio Melia (Princeton University Press, Woodstock), 2009. Pp. 360, 23 × 15 cm. Price £26·95/$45 (paperback; ISBN 978 0 961 14029 2).

The first conference called 'High Energy Astrophysics' took place in 1965. In the proceedings, the editors explained that the phrase meant astronomical sources and events of very large luminosity for their size (like radio galaxies and QSRSs) or very rapid variability (like supernovae). And the founders of both the IAU Commission on High Energy Astrophysics and the HEAp Division of the American Astronomical Society included many radio astronomers and theorists. The phrase has gradually evolved to mean 'large energy per photon or particle' rather than per source or per event, and Melia begins by explaining that this is what he has in mind, and that HEAp is done almost entirely from space. The intended readership is first-year graduate students, advanced undergraduates (probably very advanced), and physicists from other disciplines wanting a self-contained starting point. Enough of relativity, particle-acceleration processes, and radiation mechanisms is presented to permit interpretation of the wide range of phenomena discussed — AGNs, GRBs, XRBs, GCRs (briefly), and the rest of the familiar zoo. Most of the standard historical references are cited, with a slight North American bias. For instance, both E. E. Salpeter and Y. B. Zel'dovich are mentioned in connection with black-hole accretion as the energy source for QSRSs, but the Salpeter reference is the original 1964 paper and the Zel'dovich one is second-hand in a 1965 text.

Things I definitely like include the use of cgs units, which is how most astronomers still do their calculations, and a very informative Venn diagram for pulsars (borrowed from a radio astronomer). Less satisfactory perhaps are the colour plates, some with the colour coding not decoded (*e.g.*, the *ROSAT*, *BATSE*, and *COMPTEL* skies), and the treatment of synchrotron radiation, which makes use of electromagnetic equations in matrix form and is rather heavy going (one of the sources of my reservations about undergraduate use of the volume). Nevertheless, I had volunteered to review Melia's book with the intention of using it in a senior-level, ten-week course (but ended up with physics-major cosmology this year instead). Suggested homework problems and solutions are in a separate manual, so I cannot comment on them, The most obvious competition is a high-energy astrophysics text by M. S. Longair, which is not in the 22-page bibliography of this one and has a stronger focus on cosmic rays and particle acceleration than does Melia. The professor should have both; one is probably enough for the student. — VIRGINIA TRIMBLE.

Nuclear Reactions for Astrophysics: Principles, Calculation and Applications of Low-Energy Reactions, by I. J. Thompson & F. M. Nunes (Cambridge University Press), 2009. Pp. 466, 25·5 × 18 cm. Price £45/$85 (hardbound; ISBN 978 0 521 85635 5).

Nuclear astrophysics (NA) is a very lively and highly interdisciplinary research field that attracts inputs from astronomical observations, theoretical models of stellar evolution and nucleosynthesis, nuclear-reaction rates, and theoretical descriptions of nuclear-reaction mechanisms.

Very few textbooks are available in the field, with the existing ones mainly dealing with experimental approaches (and challenges) for studies in NA; stellar evolution and astrophysical environments; nucleosynthesis models and calculations; and, to my knowledge, only one addressing the theoretical treatment of nuclear reactions in nuclear astrophysics. Thus, the introduction of a new book specifically aimed at providing a fairly comprehensive repository of theoretical tools and techniques in the field is highly commendable.

After a very brief introduction on general features of nuclear astrophysics, the authors move swiftly into the more detailed and highly mathematical description of the various theoretical models, presenting — as the authors state — "eighty pages of solid scattering theory, which is by far the biggest hurdle a student will have to overcome". Indeed, I would add "not just the student, but also the more experienced practitioners in the field, unless theorists themselves". Unfortunately, the highly-specialized jargon, together with back-and-forward references to the same topics being treated at different depths in different parts of the book, do not make for an easy read and one could argue that understanding the various theories presented requires more than "a background in quantum physics and angular momentum theory", as claimed by the authors in the Preface to the book. As such, the book works rather better as a reference volume than as a textbook for students.

On a more positive note, a very welcome feature of the book relates to each chapter ending with some exercises, often taken from real experiments, as a way to show the practical applications of the theories presented, and to test the reader's understanding. In addition, the inclusion of whole chapters on 'Connection to the experiments', 'Spectroscopy tools', and 'Fitting data' techniques, provides a welcome link to a variety of applications as well as useful material for the student. If not exactly bedtime reading, they make for a less-dry treatment of the material presented.

Finally, the book comes with a useful Appendix on 'Getting started with FRESCO' that allows the readers to perform their own calculations with the FRESCO reaction code, using the inputs provided for many examples addressed in the book. Overall, the effort of the authors, both highly regarded experts in their respective fields, is certainly to be lauded and I am confident that the book will become essential reading for the experienced researchers in the field. — MARIALUISA ALIOTTA.

The Biggest, Baddest, Coolest Stars (ASP Conference Series, Vol. 412), edited by D. G. Luttermoser, B. J. Smith & R. E. Stencel (Astronomical Society of the Pacific, San Francisco), 2009. Pp. 263, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 704 9).

Publications reporting on symposia, conferences, and workshops appear on library shelves with a frequency too high for most astronomers with even catholic interests to peruse. This phenomenon, common to sciences in general (I suppose), no doubt provides grist to the sociologists' mill. Perhaps they even have symposia, conferences, and workshops on the topic of over-publication in the sciences. My curiosity has for some time been aroused by the simplest questions such as "What is the distinctive mark of a workshop?" An answer is that a workshop addresses one or more particular issues of contemporary interest.

This volume provides the proceedings of a workshop held in July 2007 on 'The Biggest, Baddest, Coolest Stars'. The dreadful title, as inspection of the Table of Contents reveals, refers to massive red supergiants and asymptotic-giant-branch stars. The Preface by the volume's editors lists seven "key issues" for the meeting as the formation of dust, the production of large molecules, the transition to planetary nebulae, dynamic winds, chromospheres, shock physics, and the relation of atmospheric abundances to interior evolution. The editorial triumvirate then asserts that the organizers assembled "a pool of speakers who are experts in the field to present review talks on these subjects". Sadly, my score card, as judged by the invited reviews and contributed papers that made it into the volume, shows that only one or two of the seven issues were examined at the workshop.

Although the student of astronomy — young or old — will find no enlightenment here on the formation of dust and most of the other key issues, there are papers that reward the reader. A personal sample begins with the opening talk by Phil Massey on red supergiants and matching observed and theoretical stars in the H–R diagram in which Massey's enthusiasm for astronomy could prove contagious. Ken Carpenter looks far ahead in offering a description of the *Stellar Imager*, a NASA Vision Mission, comprising 30 formation-flying spacecraft with one-metre mirrors with the purpose of resolving (some) stellar surfaces at ultraviolet and optical wavelengths (angular resolution of 50 micro-arcseconds at 1200 Å). What fun it will be to show theoreticians a picture of a stellar surface! Bruce Hrivnak offers a concise but comprehensive review of 'Proto-planetary-nebula transitional objects', a well-crafted example of an introductory paper for presentation at a workshop. — DAVID L. LAMBERT.

The Eighth Pacific Rim Conference on Stellar Astrophysics: A Tribute to Kam-Ching Leung (ASP Conference Series, Vol. 404), edited by B. Soonthornthum, S. Komonjinda, K. S. Cheng and K.-C. Leung (Astronomical Society of the Pacific, San Francisco), 2009. Pp. 374, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 685 1).

As might be readily guessed from the title, this conference and subsequent proceedings were dedicated to Professor Kam-Ching Leung, for his important contributions to stellar astrophysics in general and his particular support of the growth of astrophysics in countries surrounding the Pacific Rim. Stellar astrophysics is a very broad field and as a reviewer of this book, I was looking forward to finding out about current important topics through a few review articles and perhaps the latest results in shorter papers. Sadly, I was rather disappointed. The topics included are certainly wide-ranging with eight sections covering, for example, star formation, compact objects, binary stars, and supernovae, among others. Unfortunately, there are no significant reviews to set the scene for each of these, and the content of each section is limited to papers of only a few pages in length with no clear link between them and no particular structure beyond the main topic headings. There are some interesting new results presented but with such limited space allowed for each paper it is hard to extract anything worthwhile from these. As a record of what was probably a nice occasion in a pleasant location, the proceedings might just be interesting to those who were present. As a reference for topical thoughts and results on stellar evolution it delivers very little. I would not buy this for my own bookshelf, nor would I recommend it to my university library: a rare 'miss' from the otherwise excellent ASP Conference Series. — MARTIN BARSTOW.

Analysis of Gravitational-Wave Data, by P. Jaranowski & A. Królak (Cambridge University Press), 2009. Pp. 257, 25·5 × 18 cm. Price £70/$125 (hardbound; ISBN 978 0 521 86459 6).

The search for gravitational waves and how these signals can be used to do astrophysics are topics at the forefront of modern astronomy, and this well-produced book by Jaranowski & Królak is a welcome perspective on the problem. Aimed primarily at new researchers in the field, it covers the General Relativity behind gravitational-wave production and propagation, how these waves appear in the responses of both ground- and space-based detectors, and a selection of statistical theorems and results pertinent to their detection, measurement, and interpretation. In addition it brings together many important results in the gravitational-wave source literature, particularly post-Newtonian binary orbits and gravitational waveforms.

The chapters on astrophysical sources, wave generation, and weak plane-wave propagation are particularly useful, and I can see this material being used in PhD theses for years to come. The chapters on data-analysis methods are unashamedly mathematical throughout and set out many of the theorems and lemmas that underpin frequentist hypothesis testing and parameter estimation, covering a good deal of the material that is currently used in gravitational-wave data analysis. The coverage does not attempt to be complete though, and there is an emphasis on maximum-likelihood techniques. It should be noted that, although very important, these are just one part of the wide spectrum of methods currently used in gravitational-wave data analysis. Many current search algorithms use methods based around Bayesian principles, often exploiting Markov chain Monte Carlo algorithms (especially for *LISA* data), and hierarchical methods, often concentrating on data selection and outlier handling, none of which are covered here in any detail.

This book serves as a unique contribution to the field of gravitational-wave data analysis and presents, in a single volume, the astrophysics behind signal production, a summary of important ideas in time-series analysis and statistical testing, and the necessary detector-response relations that allow one to construct a suitable analysis pipeline for gravitational-wave data from scratch. That it comes from the developers of the *F* statistic — a quickly-computable power measure that sits at the heart of several current gravitational-wave search algorithms — adds greatly to the authority of this useful book. — GRAHAM WOAN.

Philip's Stargazing with a Telescope, by R. Scagell (Philip's, London), 2009. Pp. 192, 19·5 × 12·5 cm. Price £7·99 (paperback; ISBN 978 0 540 09023 5).

This book is aimed at the newcomer to astronomy and is one of a number of similar primers published by Philip's. They are characterized by clear explanations by authors expert in the subject, with numerous illustrations and clear diagrams — all at moderate cost. The theme of this particular volume is an introduction to the wide range of optical equipment available to the beginner, from binoculars to GO TO catadioptrics. The pros and cons of each type of equipment are covered and the techniques of achieving maximum benefit both by properly setting up the telescope and in the practice of observing are carefully explained.

A chapter on gaining a basic knowledge of the sky is followed by a summary of objects available for study. A final chapter on accessories, including filters and cameras (both conventional and digital, including web-cams), concludes a remarkably complete survey. Appendices include star maps, on a necessarily reduced scale, and a list of interesting objects is followed by a good glossary and index. One criticism is the lack of information on societies. The website addresses of the AAVSO and the Society for Popular Astronomy (of which the author is Vice President) are noted. At least a reader of this book should know about the BAA as well!

The amount of information contained in this book for the price makes it a great bargain. This reviewer would have been delighted to receive it as a teenager. — R. H. CHAMBERS.

The Sky Handbook, by J. Watson & M. Kerrigan (Saraband, Glasgow), 2009. Pp. 400, 18 × 15 cm. Price £14·99 (paperback; ISBN 978 1 88735463 9).

I have read this book twice. Was this because I found it so enthralling? Regrettably, no. I was searching (unsuccessfully) for some redeeming feature. I started to make a list of pages with some form of error or inconsistency, but soon gave up because there were so many.

The content of this "Perfect introduction to the wonders and mysteries of the heavens above us" is unusual, to say the least. There are sections on astronomical history and astronomy itself, one (more-or-less) meteorological, one on flight (natural and artificial), and a final one on the composition of the atmosphere, pollution, climate change, and even geo-engineering. The overall style is somewhat florid, breathless, and given to the use of exclamation marks and similar devices in a mistaken attempt to engender surprise and wonder. The visual design reminds me somewhat of the excellent, French, *Découvertes Gallimard* series, many of which were published in English by Thames and Hudson. Unfortunately this is only a superficial similarity, and the design and layout is, at times, seriously deficient. A photograph of the centre of the Orion Nebula, for example, is largely obscured by a 'fact box', which completely hides all the stars of the Trapezium. Illustrations of the constellations are taken from the cards of the 19th-Century *Urania's Mirror* and are accompanied by small, incomplete, modern constellation charts.

The spelling is American and non-metric units are given priority, which seems somewhat odd in a book published in Glasgow, but is presumably because the book is aimed at the US market. That may be acceptable, but the text itself is full of strained metaphors and similes; of inelegant phrasing: "... Triton ... a melon-textured icy rock ... giving it the nickname 'the cantaloupe'" (p. 224); of careless writing: "Radio telescopes 'see' the universe through radio and electromagnetic waves" (p. 71), and "in the centrifuge of gravity" (p. 77); of inaccuracies: "Binoculars will bring into view ... the moons of Mars" (p. 70); "Perseus ... the father to Andromeda, he rescued his daughter from Medusa ..."; and silly errors: "Chinese kite illustration" (p. 317) of what is obviously a Japanese print that includes Mount Fuji.

I had hoped that the meteorological and subsequent sections might be better, but this was not to be. Outstanding among the errors is one found on p. 272: "If you check the direction your water drains from your bathtub, you will see confirmation of which hemisphere you live in." And there are some fully worthy of *Here and There*: "Ulugh Beg ... built the renowned Samarkand Observatory and also built a wall-mounted 24-mile (40 km) Fakhri sextant ...".

I find this rather depressing. For years, I and authors such as Terence Dickinson, Jay Pasachoff, Ian Ridpath, Robin Scagell (and many, many others) have been attempting to write accurate works as introductions to astronomy. But still these stupid inaccuracies and downright errors are perpetuated. So, regrettably, I cannot recommend this book. That leaves me with a problem: in all fairness to possible recipients, I can't give it away; I don't want to keep it as a reference; and even though it is so poor, it really goes against the grain to burn it or send it for pulping. Ah, yes. I shall read it yet again — I must be a masochist — and do something that I normally regard as anathema. I shall mark some of the most glaring errors and use them in the light-hearted quiz I give my adult-education students: "What's wrong with these statements?" — STORM DUNLOP.

Make Time for the Stars: Fitting Astronomy into Your Busy Life, by A. Cooke (Springer, Heidelberg), 2009. Pp. 271, 23·5 × 15·5 cm. Price £22·99/$34·95/€34·95 (paperback; ISBN 978 0 387 89340 2).

I was looking forward to using this book because I have a busy life, but I found it very difficult. There was an assumption that you would read the first four chapters about the equipment before starting out. There were some clever ideas, and I was fascinated by the idea of colourizing a video frame, by doing a colour drawing at same time as taking the image. Then I got annoyed at being told I would only need 5 minutes to observe Uranus, accompanied by a picture which showed the planet plus ring from the *Keck* telescope — not what I would expect to see through even a good amateur telescope. This happened throughout the book: you would find excellent drawings (usually using an 18-inch reflector) mixed up with professional pictures from large telescopes or satellites. There was an interesting selection of websites, but only a single reference to the BAA website, despite their excellent section information, and no reference to the websites which would tell you how to find Uranus in less than 5 minutes. The author is American and he uses his 18-inch telescope in the high desert of California, so the book is American-centric. He gets very good conditions to observe the planets, and the drawings show what you can achieve in those conditions. I was very impressed by the drawings of Mars and Jupiter (the best bit of the book) but I find it hard to believe I would get results like those after 2–3 minutes of work every half hour, except after a significant amount of practice. — HELEN WALKER.

Observatories of the Southwest: A Guide for Curious Skywatchers, by D. Isbell & S. E. Strom (University of Arizona Press, Tucson), 2009. Pp. 192, 22·5 × 15 cm. Price $21·95 (about £14) (paperback; ISBN 978 0 8165 2641 3).

This splendid little book is just the ticket for the astro-tourist wanting a break from the cloudy skies of Britain and a burst of inspiration from a selection of sun-soaked observatories in the southwest of the USA. Very well written and with a nice collection of monochrome photographs, this modestly priced volume provides a valuable visitor guide, an historical background, and outreach/education contact information, together with an interview from a leading astronomer and an appropriate research highlight at each of eight major observatories, from McDonald in the east to Palomar in the west, taking in Sunspot, the NRAO at Socorro, Mount Graham, the Whipple Observatory, Kitt Peak, and Lowell Observatory on the way. Thus there is a balance of interest here too, with the inclusion of the historic site established by Percival Lowell, solar research at Sacramento Peak, radio observations with the VLA, and the world-beating *Large Binocular Telescope* on Mount Graham. If I have any regret it is that the authors didn't go on to do a similarly excellent job for Mount Wilson and Lick Observatory; maybe they are saving that for a second edition — I hope so. Highly recommended. — DAVID STICKLAND.

THESIS ABSTRACTS

ON THE FORMATION AND EVOLUTION OF PLANETARY SYSTEMS

By Matthew John Payne

The first two chapters of this thesis provide a brief review of the observations and theories upon which our current understanding of the formation of planets is based. In Chapter 1, I discuss the methods used to observe extra-solar planets and discuss their properties, highlighting the (often remarkable) differences between them and the planets of the Solar System. In Chapter 2, I then go on to outline the main basis of the sequential core-accretion model of planet formation, sketching the main physical processes which are thought to lead from the coagulation of dust to the formation of gas-giant planets.

Subsequent chapters go on to investigate in greater depth a few facets of the core-accretion model, with Chapter 3 being an application of a general, semianalytic, model of core accretion to the problem of planet formation around very-low-mass stars and brown dwarfs. It is found that the formation of gaseous planets is essentially impossible in realistic-mass brown-dwarf discs. The most massive planets in such systems are likely to be less than $5 M_{\oplus}$ and have orbits $\sim$ 1 AU.

In Chapter 4, I turn to look in some detail at the formation of terrestrial planets in the highly perturbed terrestrial-planet regions around the stars of binary systems, investigating whether successful planet formation at small semi-major axes can lead to the existence of planets at larger distances, possibly within the habitable zone. It is found that planetary embryos initially restricted to form inside $\sim 0{\cdot}5$ AU can nonetheless migrate outwards *via* planetesimal scattering, doubling their semi-major axis in $\sim 10^7$ yrs.

In Chapter 5, I again investigate the formation of planets in the terrestrial region, but this time focus on the process around single stars. I concentrate in this analysis on simulating effects related to the dissipation of the gas disc, to understand whether this phenomenon might allow different planetary architectures in extra-solar systems. Long gas-dissipation time-scales only delay, not deny, the process of high-eccentricity, chaotic evolution in the terrestrial region. The presence of gas giants external to this region can also interact with the dissipating gas disc in interesting ways, driving inward migration and ejecting significant amounts of planetary material, adding yet more layers of complication to our evolving picture of the processes that shape planet formation in the terrestrial zone.

Finally, in Chapter 6, I examine in some detail models of the formation of the HD 69830 system, trying to understand whether dynamical effects are able to explain some of the observed features of this curious system. It is found that a massive, highly eccentric, long-lived population of scattered planetesimals could easily have formed in the system. It is less clear whether such a population would be able to survive with sufficient eccentricity to be able to explain the observed infrared emission from the system. — *University of Cambridge; accepted 2009 July*.

A full copy of this thesis can be requested from matthewjohnpayne@gmail.com

Warped and Twisted Discs

By Rebecca G. Martin

Accretion discs around black holes fed with angular momentum misaligned with the spin of the black hole can become warped. The inner parts align with the black-hole spin by the Bardeen–Petterson effect. A companion star to the black hole exerts a tidal torque on the disc that aligns the outer parts with the binary orbital plane. We solve steady-state accretion-disc equations for the shape of a disc warped by both these torques. We find the torque on the misaligned black hole and the time-scale on which the warped disc causes the black hole to precess and align with the outer parts of the disc, and consider carefully the evolution of a disc that is counter-aligned with the black-hole spin.

We calculate the alignment time-scale and lifetime of steady mass transfer in the microquasar GRO J1655–40. It is not unexpected that the system is still misaligned. There is an inconsistency in the axis of the jets and the inclination of the inner disc found with the Fe Kα emission line in the microquasar V4641 Sgr. We compare the masers in the warped disc of the active galactic nucleus NGC 4258 and our steady-state disc models to find that the Bardeen–Petterson effect could warp this disc. Be stars have an outflowing excretion disc which appears to be warped. We consider whether radiation from the central star or tides raised by a companion star are the cause of the warp.

An asymmetry in a supernova explosion can give a velocity kick to a newly formed neutron star and in a binary system this can lead to a misalignment between the spins of the stars and the binary orbital axis. We consider the distribution of velocity kicks imparted to neutron stars at birth and compare to Be-star X-ray-binary eccentricities and orbital periods. We need the velocity kicks to be distributed with a peak at much smaller velocity than the standard distributions based on pulsar space velocities. It is suggested that black holes may form in the same way as neutron stars in a supernova explosion. The high space velocity of GRO J1655–40 can be accounted for by a small supernova kick at the formation of the black hole and a relatively wide pre-supernova binary.

It is in accretion discs around newly formed stars that planets form. The disc is spiralling in, so it is easy for a planet to move inwards after formation. We show how a small planet driven by a massive inner planet can actually migrate outwards through the disc to very large radii where there are several planets inferred. The disc eventually disperses and we are left with a solar system. — *University of Cambridge; accepted 2009 October*.

A full copy of this thesis can be requested from: rmartin@stsci.edu

Kinematics and Stellar Populations in Brightest Cluster Galaxies

By Susan Ilani Loubser

This thesis is devoted to the investigation of a new, large sample of brightest cluster galaxies (BCGs), their kinematic and stellar-population properties, and the relationships between these and the properties of the host clusters. Some of the questions addressed are: how the kinematic and stellar-population properties differ from those of ordinary giant elliptical galaxies; and whether these properties are more influenced by the internal parameters of the BCGs or the properties of the host clusters.

In order to do this, high-signal-to-noise, long-slit spectra of 49 BCGs (concentrating on those classified as cD galaxies) in the nearby Universe were obtained with the *Gemini* and *WHT* telescopes. The radial-velocity and velocity-dispersion profiles were measured, and the Lick/IDS system of absorption indices was used to derive Single Stellar Population (SSP)-equivalent ages, metallicities, and α-abundance ratios. A systematic comparison was made between the indices and derived parameters for this sample of BCGs and those of large samples of ordinary elliptical galaxies in the same mass range. The derived properties were tested for possible correlations with the internal properties of the galaxies (mass and luminosity) and the properties of the host clusters (density, mass, distance to X-ray peak, and the presence of cooling flows).

Clear rotation curves were found for a number of BCGs. In particular, NGC 6034 and NGC 7768 are rapidly rotating (> 100 km s^{-1} as measured from their major-axis spectra), indicating that it is unlikely that they formed through dissipationless mergers. Velocity substructure in the form of kinematically decoupled cores was detected in 15 BCGs, and five BCGs were found with velocity dispersion increasing with radius. In general, the amount of rotation and the velocity substructure detected in this sample, and the position of the BCGs as a class of objects on the anisotropy–luminosity diagram, are similar to those of ordinary giant ellipticals in high-density environments. No significant discrepancies between the index–velocity-dispersion relations of this sample and those of normal ellipticals were found, but subtle differences between the derived SSP-parameters do exist. The BCGs show, on average, higher metallicity ([Z/H]) and α-abundance ([E/Fe]) values. The SSP parameters show very little dependence on the mass or luminosity of the galaxies, or the mass or density of the host clusters. The derived ages of these massive galaxies are consistent with being old, as expected. Overall, the star-formation histories in BCGs, and the connection to the processes in the cluster centres, are very complex. — *University of Central Lancashire; accepted 2009 June.*

EXPLORING DARK MATTER LOCALLY *VIA* A HIERARCHY OF STELLAR SYSTEMS

By Damien Patrick Quinn

Most of our knowledge of the cosmos comes from the light from astronomical sources. However, in the last 40 years a consensus has emerged in the astronomical community that most of the matter in the Universe is invisible, *i.e.*, it does not absorb or emit electromagnetic radiation. The nature of this dark matter remains an unsolved mystery. In this thesis we attempt to discover what constraints can be placed on dark matter from an analysis of a variety of stellar systems in the Local Group.

The simplest composite stellar system is a stellar binary. The separation distribution function of wide binaries is sensitive to the presence of massive compact bodies such as MACHOs. Extending earlier work, we use radial-velocity measurements to validate a number of objects in the existing sample of wide-halo-binary candidates, and with the updated sample we study the constraints on MACHOs, arriving at the conclusion that the current wide-binaries sample places only very weak constraints on MACHOs, in contrast to earlier work which concluded that the separation distribution of wide halo binaries may be used to rule out MACHOs as a significant component of the dark sector. Motivated by the need to increase the sample size of wide binaries in order to derive more robust constraints, we conducted a search in the *Stripe 82* catalogue for new systems. A small number of new wide-binary systems were detected. These by themselves do not have significant implications for MACHOs, but we outline with illustrations their potential scientific importance, including for testing ideas about wide-binary formation. Stepping up the stellar hierarchy we investigate the effect of a lumpy potential on the profile of the tidal tails of a disrupting globular cluster and compare our results to the Pal 5 tidal-tail system. We find that a close encounter with a massive dark-matter sub-halo could produce features in the tails that resemble the current observations. We also show that the Pal 5 system can be used to place new, although not very tight, constraints on MACHOs. The final stellar system we consider is the galaxy-wide planetary-nebula systems in the Andromeda galaxy. Along with the galaxy's rotation curve, we use the planetary nebulae to constrain dynamical models of the galaxy, with a view to pinning down the parameters of the dark-matter halo. We find that the current data are not able to lift the disc/dark-matter degeneracy, and show that better gas-rotation-curve data rather than planetary-nebulae data may provide the best way forward to achieve this goal. — *University of Cambridge; accepted 2009 November.*

A full copy of this thesis can be requested from: damien.quinn@cantab.net

OBITUARY

Roy Henry Garstang (*1925–2009*)

Roy Garstang was born in Southport on 1925 September 18. He received his university education at Cambridge (Gonville and Caius) from 1943–1945 during the Second World War. Under War Regulations he was awarded his BA in 1946 after only two years of study. He then did his war service at the Royal Aircraft Establishment in Farnborough during 1945–1946, followed by two further years as a scientific officer with the Ministry of Works, while also teaching mathematics evening classes — mainly to ex-servicemen. He returned to Cambridge in 1948 and was awarded the Mathematical Tripos, Part III, with distinction, in 1949. An MA followed in 1950, by which time he was embarked on PhD studies under the supervision of D. R. Hartree (plus Bertha Swirles when Hartree was on sabbatical), presenting a thesis on *Atomic Transitions in Astrophysics*, duly awarded in 1954. While a PhD student he spent a year as a Research Associate at the Yerkes Observatory (under the supervision of S. Chandrasekhar). His PhD determined the principal research he was to follow for the rest of his working career.

During his PhD period he was appointed Lecturer in Astronomy in 1952 by C. W. Allen, who had just arrived at University College London and was establishing a new degree in astronomy there. In 1959 he was appointed Assistant Director of the University of London Observatory (where the UCL Department of Astronomy was located) followed by appointment as Reader in Astronomy in 1960. While Roy's principal interest was in the determination of atomic parameters of value to astrophysics, his knowledge of astronomy was encyclopaedic. He used this knowledge to good effect in his teaching on the astronomy degree, and he was particularly aware of undergraduate difficulties. Indeed, I well recall, with great affection and regard, his patience in explaining the finer points of positional astronomy to me as a new assistant lecturer and to widening my experience of astronomy.

In 1964 Roy left UCL and the UK for good — he accepted an appointment as Professor of Astrophysics in the Department of Physics and Astrophysics at the University of Colorado (after 1979 a Professor in the Department of Astrophysical, Planetary and Atmospheric Sciences) and as a Fellow at the newly established Joint Institute for Laboratory Astrophysics (JILA), holding these positions until his retirement in 1994. He served as Chairman of JILA 1966–1967 and Director of the Division of Physics and Astro-Geophysics 1979–1980. While at JILA he wrote/co-authored 53 major papers on atomic physics of relevance to astrophysics, following the 29 written in England up to 1964.

In all, his bibliography extends to 153 papers. Roy also maintained an active presence in presenting astronomy to the public. He was an enthusiastic lecturer, though sadly in his last decades illness hindered — but did not prevent — these presentations.

In 1986 a new interest began — Roy started to study light pollution and made significant contributions to its quantification. The writer of this obituary had great reason to be grateful to Roy for his last paper on the 'Brightness of the clouds over a city at night' (see **127**, 1), having had to verify the — accurate — claims for the darkness of the sky over the UK's first Dark Sky Park (Galloway Forest Park in S. W. Scotland) on a night of particularly unsuitable weather.

Roy was an enthusiastic astronomer, teacher, and a warm-hearted friend. His interests were wide and he believed in public education in astronomy. Not only did he support planetaria and write for fraternity magazines but he also wrote many articles for the wider public. He spent many happy months at one stage adjusting, and determining the errors of, the *Colorado Equatorial Sundial* (leading of course to a publication! — see **117**, 344). Above all he believed in obtaining the best possible atomic/molecular data for astrophysics. Roy was a member of 21 scientific Societies and was active in all of them. In the UK he was a Fellow of the RAS from 1945. He received many awards and honours, including the Isaac Newton Fellowship (1950–1951) and the Chalkin Memorial Lectureship (1971).

Astronomy has lost a major practitioner, an enthusiastic protagonist of the value of astronomy as a science, and this *Magazine* a distinguished Editor (1953–1960). There are few who possess his range of knowledge, which was always at the disposal of his colleagues and friends. He will be much missed. Roy died on 2009 November 1 of complications following a fall some months previously. He is survived by his wife and his two daughters. — Derek McNally.

Here and There

SUPERINFLATION

Submillimetre galaxies at redshifts ... are thought to be precursors of the giant elliptical galaxies in the present-day Universe ... — *Nature*, **458**, 673, 2009.

THE LONG VIEW

... the Solar Orbiter ... will circle the Sun every 150 years. — *The Sunday Telegraph*, 2009 April 26, p. 14.

HARDLY SURPRISING

Accelerating the craft to 38,624 kilometres per second, the six-minute TLI burn exhausted what was left of the fuel in the third stage, … — *Astronomy Now*, 2009 July, p. 25.

IF ONLY WE COULD ALL HAVE ONE

A stunning modern property … powered by a state-of-the-art solar system and is just 15 minutes from the nearest town. — *The Week*, 2009 April 11, p. 32.