THE OBSERVATORY

Vol. 132 | 2012 DECEMBER | No. 1231

MEETING OF THE ROYAL ASTRONOMICAL SOCIETY

Friday 2012 May 11 at $17^h 00^m$
in the Geological Society Lecture Theatre, Burlington House

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

The President. Welcome to this meeting of the Society. It is my great pleasure to present the 2012 Gold Medal of the Society to Professor Andy Fabian. Professor Fabian, Royal Society Professor at the Institute of Astronomy, Cambridge, and Vice-Master of Darwin College, Cambridge, has made an exceptional contribution to astrophysics over more than four decades. He is best known for his work on black holes and on gas found in the cores of clusters of galaxies, both of which are strong sources of X-rays. Beyond that, Professor Fabian examined the origin of high-energy radiation throughout the Universe, and contributed to many other areas of X-ray astronomy. He is the author of more than 850 peer-reviewed papers that have attracted more than 44 000 citations. Professor Fabian's contribution to the broader astronomical community has been exemplary, from mentoring early-career scientists to working as editor-in-chief for the journal *Monthly Notices of the RAS*. From 2008–10, a period of severe and growing financial pressure, he served with distinction and provided strong leadership as President of the RAS. The recipient of numerous international awards and prizes, Professor Fabian received the OBE in 2006 in recognition of his services to Science. For these reasons, Professor Fabian is awarded the 2012 Gold Medal of the Royal Astronomical Society. [Applause.]

I would like to announce the results of the 2011 thesis prizes. I am pleased to announce that the Michael Penston Prize has been awarded to Dr. Ryan Cooke of the University of Cambridge, for his thesis 'Finding the first metals'. The runners-up are Dr. Adrian Barker, of the University of Cambridge, and Dr. David Sobral of Edinburgh University. The Keith Runcorn Prize has been awarded to Dr. David Kipping of UCL, for his thesis entitled 'The transits of extrasolar planets with moons', and the runner-up is Dr. David Andrews of the University of Leicester. It is hoped that both prize winners will give talks at a future RAS ordinary meeting.

Now I would like to move to the Presidential Address — actually now from the former President! It's a great pleasure to introduce Professor Roger Davies of the University of Oxford to speak on 'Telescopes of the future'. [This talk has appeared in *Astronomy & Geophysics* **53**, 4·15, 2012.]

The President. Thank you very much, Roger — questions?

Dr. G. Q. G. Stanley. Excluding synthetic apertures, do you think the *E-ELT* is the biggest that telescopes will ever get? Do you think there will ever be anything bigger?

Professor R. L. Davies. I think that would be a very ambitious project, and I was actually the chairman of the group that caused the demise of the *OWL* (*Overwhelmingly Large Telescope*) — in 2005 a 100-m aperture was demonstrably not achievable. Is it achievable now? I'd say not, for very good reasons. One must never say 'never', since people are enormously creative, but I think it would be very unlikely to have anything twice as big as the *E-ELT* by, say, 2050.

Professor S. Miller. If you look at your timeline, what you notice is that this looks fantastic for the international astronomical community; but for the UK community, we are definitely slipping south. But you just hinted in your final slides about the possibility of UK astronomers becoming involved with, say, the *Thirty Meter Telescope* (*TMT*) in the northern hemisphere through instrumentation. I wondered if you could say a bit more about that?

Professor Davies. I did show a slide that had a list of instruments on it for the *TMT*, but only three of those instruments are really being developed in detail by the *TMT*, because they don't have the resources to pursue them all during the construction phase. They *need* the other instruments to fulfil their scientific goals and we in the UK have the potential to contribute to them, technically. What we need are the finances to commit to them. And you are absolutely right: if you compare the fraction of the world's 4-m telescopes to which the UK had access in 1990 with the fraction of 8-m telescopes to which we have access in 2013, you find that our access to the leading telescopes of the day has declined significantly. If we can find a way to contribute our instrumentation expertise we can perhaps increase the share of the largest telescope to which we'll have access. That will take money but crucially it requires us to have the expertise to contribute.

Professor A. M. Cruise. If you had invited somebody to give a talk about the space telescopes that will be available in the same time frame, it would be a much less rosy picture, because there are no major X-ray-astronomy missions planned, no major UV missions, *etc*.; and that's going to create some difficulties in looking at different wavelength regions and using different techniques. The *James Webb Space Telescope* aside, the kind of missions being looked at — but for which people are unable to get funding — are all of the order of a billion dollars each.

Professor Davies. I think this is a serious problem. One thing that differentiates space science from ground-based telescopes, at least in the USA, is the ability to raise funds for the capital costs privately. The Keck Foundation contributed a large fraction of the cost of two 10-m telescopes; in fact they essentially trumped an earlier potential donor, Hoffman, to fund the telescopes. This is not something that happens in the UK [laughter]. The *TMT* is predicated on a large donation from the Gordon Moore Foundation (of Moore's Law fame) and the *GMT* has received significant support from the Texan philanthropist, George Mitchell. I agree with you that the situation in space is not good — the fact that we won't have any access to the UV once *Hubble* goes, and we are still struggling to keep hold of an X-ray mission; I hope we will keep hold of an X-ray mission, but it is not looking too good at the moment.

Dr. K. T. Smith. In the first half of your talk you gave a nice potted history of telescope development over the last 50 years or so; something you didn't mention is how over the last decade there has been an increasing trend to building *small* telescopes, mostly robotic, for time-series astronomy. In terms of scientific impact per pound invested, those have been enormously more successful, of course at the completely opposite end of the scale. I just wondered if you could comment on that.

Professor Davies. Time-domain astrophysics is a very important area for the future; I think you could debate endlessly about value for money. Small telescopes have made a huge contribution, and in particular, I think the field of time-domain astrophysics is very important. In Europe, we don't have anything equivalent to the *Large Synoptic Survey Telescope* (*LSST*), and ESO's stated policy on *LSST* is that it will not pay to join.

Mr. H. Regnart. You didn't mention the ultra-thin, near-zero-thermal-inertia metal mirror figured by partial vacuum as a possibility — it has been around as a concept — but you did mention the spun-mirror concept. Is there any comment you might like to make as to what's happened to the first technology? As to the second, are there issues, if it's a liquid metal, of evaporation, loss of material, interference from incoming radiation, and recovery of evaporated material?

Professor Davies. I don't know anything about the first one; as to the second, there are a couple of operating rotating-mirror systems, and they are used for space-debris monitoring. The issues you raised are the ones they have had to address but they have done so successfully, and you can look up the images on the web.

Professor D. Lynden-Bell. I was worried that most of the telescopes you were talking about have extremely small fields of view. If one worries about trying to get the brightest object of a given class, it is very important that you survey almost the whole sky, because the brightest object of a given class you can analyse in far greater detail than some other interesting object which you happen to find. I think the only telescope you talked about that is capable of actually observing a large fraction of the sky is the *LSST*. I am sorry to say that I don't believe that all the money should go towards these enormous telescopes that will go very deep in one tiny area.

Professor Davies. I think you are raising a good point, but the answer to that is that these monster telescopes are largely spectroscopic facilities. The *LSST* at the 8-m level will provide much of the sky; and remember there are also 4-m telescopes running with very wide fields. Those wide-field mosaics that I showed are from telescopes like *VISTA*, *VST*, and the *UKIRT* wide-field survey. Of course if you wanted to detect the brightest object of a particular kind, I agree, you need a wide field, but you don't need such a big telescope.

The President. I think on that note we should draw a line under what I think has been a very good Presidential Address, so thank you Roger. [Applause.] I remind you that there is a drinks reception in the RAS library immediately following this meeting, and the next monthly A&G open meeting of the Society is on Friday, 2012 October 12.

SPECTROSCOPIC BINARY ORBITS FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 227: HD 108815, HD 112475, HD 115463, AND HD 117319

By R. F. Griffin
Cambridge Observatories

The four stars are all in the field of the North Galactic Pole. HD 108815 and HD 115463 are single-lined objects, with luminosities of giants, whereas HD 112475 and HD 117319 are double-lined main-sequence systems. HD 108815 is of very late type. It has a very eccentric orbit ($e \sim 0.7$) and an orbital period of about 12 years; there is considerable radial-velocity 'jitter' superimposed on its orbital motion. HD 112475 and HD 115463 have orbits of moderate eccentricity and periods of about two years — so closely so in the case of HD 115463 that it has not been possible to obtain uniform phase coverage. HD 117319, too, has a moderate-eccentricity orbit; its period is about 12 years and is known within ten days, as it has been seen round three times since the system was first resolved at Palomar.

This is another paper (the seventh since no. 200 in this series) devoted to stars that are in the vicinity of the North Galactic Pole. Their binary nature was discovered in the course of the comprehensive photometric and radial-velocity survey (hereinafter referred to as the 'Survey') carried out by Yoss & Griffin[1] of all the late-type *HD* stars at Galactic latitudes above 75°. Particularly in view of the fact that the Survey, which provides most of what is known about most of the stars concerned, is not retrieved in any of the *Simbad* bibliographies*, it is useful to give its data here in Table I for the stars of immediate concern. The luminosities given in the Survey[1] were obtained from *DDO*-style photometry[2]; no result could be obtained for HD 108815 owing to the extreme type of that star, which placed it beyond the range of calibration of the system. The absolute magnitude corresponding to the (revised[3]) *Hipparcos* parallax is also given for the two stars for which it is available. The parallax of HD 115463 is scarcely more than 1 millisecond of arc, and its uncertainty is almost the same, so the implied distance and luminosity are very uncertain; the 1-σ lower limits are near 500 pc and $-0^{m}\cdot 4$, respectively — but they are still considerably greater than those found in the Survey.

TABLE I

NGP Survey[1] results for the four stars

Star	*V*	*(B−V)*	*Type*	M_V	*z*	M_V *(Hp)*
	m	*m*		*m*	*pc*	*m*
HD 108815	7·42	1·60:	K9	—	—	−0·5 ± 0·5
HD 112475	9·63	0·62	G3 V	+4·8	91	
HD 115463	8·19	1·43	K4 III	+0·7	311	−1·5:
HD 117319	9·41	0·65	G5 V	+5·1	71	

**Note added in press.* That is not true any more! Bravo!

HD 108815

This is an 8^m star that is particularly red; it is to be found about 1° south-preceding 24 Comae, a 20″ visual binary consisting of a 5^m late-type giant and a somewhat fainter early-type companion that has long been known as a short-period double-lined system. The *Henry Draper Catalogue*[4] assigns to its no. 108815 a spectral type of Mb. Not surprisingly, the star has been picked up by infrared surveys; a syndicate[5] that included Bidelman identified it as the counterpart to an *IRAS*[6] source and classified it as M5. *Hipparcos* noticed some instability in its magnitude, and on that account the variable-star designation IY Com was bestowed on it in the *74th special name-list of variable stars*[7], where the type of variability was noted as 'LB' ("Slow irregular variables of late spectral types"[8]). The *Simbad* main heading for the object calls it "Carbon Star". That may have arisen from a misapprehension that the presence of the star in a paper[9] with the words 'carbon stars' in its title implied that all stars mentioned in it were of that type — which is not so; the authority for such a description is not otherwise apparent.

The radial velocity of HD 108815 was first measured with the original photoelectric spectrometer in Cambridge in 1972; the second observation was not made until 1984 and was in tolerable agreement, and it was not until 1989 that the third measure demonstrated a significant discordance that led to the transfer of the object to the spectroscopic-binary observing programme. Since then it has been observed in every year, and 103 observations have accumulated — six with the original spectrometer, three with the instrument at the DAO 48-inch, 29 with the Haute-Provence (OHP) *Coravel*, one at ESO, and 64 with the Cambridge *Coravel*. They are listed chronologically in Table II; they readily yield the orbit that is plotted in Fig. 1 and has the following elements, of which some preliminary values were provided for Famaey *et al.*'s[10] Table 8:

$P = 4445 \pm 17$ days	$(T)_2 = \text{MJD } 50091 \pm 20$
$\gamma = -5.99 \pm 0.10$ km s^{-1}	$a_1 \sin i = 180 \pm 11$ Gm
$K = 4.22 \pm 0.22$ km s^{-1}	$f(m) = 0.0117 \pm 0.0022\, M_\odot$
$e = 0.718 \pm 0.023$	
$\omega = 253 \pm 5$ degrees	R.m.s. residual (wt. 1) $= 0.89$ km s^{-1}

The OHP and ESO measures were increased by 0·8 km s^{-1} before being entered in Table II, as is usually done in this series of papers to homogenize the zero-points of the different sources; the same adjustment is made to such measures of the other stars discussed below. All the velocities have been weighted equally in the solution of the orbit, apart from the 'original Cambridge' ones, which were given half-weight. The velocity residuals from this orbit are particularly bad*, comparably so from both of the principal sources; it is confidently asserted that they arise more from actual intrinsic instability ('jitter') in the star than from any origin nearer home. It is quite usual for giants of very late type to exhibit such jitter, which was first specifically noted (and the expression used to describe it adopted) in a discussion[11] of the most luminous stars in globular clusters.

*The worst one of all — the only one at a positive velocity — came from the prototype spectrometer in Cambridge. Both the reading of the trace (drawn with a pen in 'real time' on a Brown-Recorder chart) and the arithmetic of the reduction have been checked during the writing of this paper; it is a good trace, correctly reduced, and its result must stand.

TABLE II

Radial-velocity observations of HD 108815

Except as noted, the sources of the observations are as follows:
1989–1998 — OHP Coravel; 1999–2012 — Cambridge Coravel (both weight 1)

Date (UT)	*MJD*	*Velocity* *km s^{-1}*	*Phase*	*(O – C)* *km s^{-1}*
1972 Apr. 8·98★	41415·98	−2·5	0·049	+0·2
1984 Apr. 30·90★	45820·90	+0·3	1·039	+3·2
1989 Mar. 28·15	47613·15	−4·8	1·443	+0·5
Apr. 29·98	645·98	−5·0	·450	+0·3
May 30·94★	676·94	−4·7	·457	+0·7
1990 Jan. 27·12	47918·12	−5·7	1·511	0·0
Feb. 12·30†	934·30	−6·7	·515	−1·0
Mar. 13·39‡	963·39	−5·7	·521	+0·1
May 26·92★	48037·92	−8·1	·538	−2·2
Dec. 27·18★	252·18	−5·0	·586	+1·2
1991 Jan. 29·11	48285·11	−6·0	1·594	+0·2
June 10·92★	417·92	−5·3	·624	+1·1
Dec. 19·18	609·18	−6·0	·667	+0·7
1992 Jan. 16·10	48637·10	−7·4	1·673	−0·6
Apr. 23·03	735·03	−8·5	·695	−1·6
June 25·88	798·88	−7·9	·709	−0·8
Aug. 13·82	847·82	−6·4	·720	+0·7
Dec. 20·20	976·20	−6·4	·749	+1·0
1993 Feb. 15·10	49033·10	−6·6	1·762	+0·9
Mar. 23·07	069·07	−6·2	·770	+1·4
July 7·92	175·92	−9·3	·794	−1·4
Dec. 27·17	348·17	−7·5	·833	+0·8
1994 Feb. 21·08	49404·08	−8·5	1·845	0·0
May 2·90	474·90	−9·8	·861	−1·0
Aug. 1·84	565·84	−10·0	·882	−0·9
Dec. 12·20	698·20	−10·0	·912	−0·3
1995 Jan. 3·16	49720·16	−9·1	1·917	+0·8
May 31·00	868·00	−10·5	·950	+0·2
June 5·94	873·94	−10·4	·951	+0·4
Dec. 27·17	50078·17	−8·5	·997	+0·3
1996 Mar. 29·04	50171·04	−5·3	2·018	−0·7
Aug. 29·79[C]	324·79	−5·5	·053	−2·8
Nov. 21·26§	408·26	−3·4	·071	−0·7
1997 Jan. 23·10	50471·10	−1·6	2·085	+1·2
Feb. 8·15§	487·15	−2·7	·089	+0·1
Mar. 1·12§	508·12	−1·2	·094	+1·6
Apr. 8·03§	546·03	−2·1	·102	+0·8
May 2·92§	570·92	−3·0	·108	−0·1
July 18·88	647·88	−1·8	·125	+1·3
Dec. 24·22	806·22	−4·8	·161	−1·4
1998 May 1·97	50934·97	−4·3	2·190	−0·7
July 25·84	51019·84	−4·0	·209	−0·2
1999 Apr. 2·38‡	51270·38	−4·5	2·265	−0·3
July 9·27‡	368·27	−4·0	·287	+0·3
Dec. 20·24	532·24	−5·2	·324	−0·6

TABLE II (*continued*)

Date (UT)		*MJD*	*Velocity* km s^{-1}	*Phase*	*(O–C)* km s^{-1}
2000 Jan.	9·17	51552·17	−4·5	2·329	+0·1
Mar.	4·07	607·07	−4·3	·341	+0·4
Apr.	5·97	639·97	−3·9	·348	+0·8
May	25·93	689·93	−4·6	·360	+0·2
June	13·92	708·92	−4·5	·364	+0·3
Nov.	17·25	865·25	−6·0	·399	−1·0
2001 Jan.	7·21	51916·21	−5·1	2·411	0·0
Mar.	2·15	970·15	−5·4	·423	−0·2
May	5·01	52034·01	−6·1	·437	−0·8
Dec.	15·28	258·28	−6·5	·487	−0·9
2002 Feb.	7·08	52312·08	−3·8	2·500	+1·8
Apr.	4·03	368·03	−3·8	·512	+1·9
June	4·92	429·92	−6·1	·526	−0·3
2003 Jan.	28·15	52667·15	−6·7	2·579	−0·6
Mar.	15·07	713·07	−7·2	·590	−1·0
May	9·97	768·97	−8·4	·602	−2·1
2004 Jan.	17·22	53021·22	−5·2	2·659	+1·5
Mar.	31·01	095·01	−5·3	·676	+1·5
May	22·93	147·93	−7·5	·688	−0·6
Dec.	27·24	366·24	−7·3	·737	0·0
2005 Mar.	12·13	53441·13	−7·8	2·754	−0·4
May	7·94	497·94	−7·3	·766	+0·3
June	10·96	531·96	−8·5	·774	−0·9
2006 Jan.	29·19	53764·19	−8·5	2·826	−0·3
Mar.	23·03	817·03	−8·6	·838	−0·2
July	3·91	919·91	−9·8	·861	−1·0
2007 Feb.	3·16	54134·16	−9·5	2·909	+0·2
Apr.	5·05	195·05	−9·0	·923	+1·0
June	21·94	272·94	−10·2	·941	+0·3
Dec.	11·26	445·26	−11·0	·979	−0·1
2008 Feb.	2·19	54498·19	−10·9	2·991	−1·1
Mar.	5·14	530·14	−8·3	·999	+0·1
Apr.	8·04	564·04	−7·4	3·006	−0·7
	24·02	580·02	−4·6	·010	+1·4
	29·05	585·05	−5·4	·011	+0·3
May	2·94	588·94	−4·4	·012	+1·2
	14·92	600·92	−5·8	·014	−0·7
July	1·91	648·91	−4·8	·025	−1·1
2009 Jan.	14·20	54845·20	−3·0	3·069	−0·3
Feb.	4·20	866·20	−3·0	·074	−0·3
Mar.	21·09	911·09	−2·3	·084	+0·4
Apr.	9·00	930·00	−2·7	·088	+0·1
	29·98	950·98	−2·8	·093	0·0
May	17·94	968·94	−3·7	·097	−0·9
	31·90	982·90	−2·3	·100	+0·6
June	24·92	55006·92	−4·0	·106	−1·1
2010 Feb.	1·19	55228·19	−1·9	3·156	+1·5
Mar.	23·05	278·05	−2·4	·167	+1·1
May	17·92	333·92	−3·7	·179	−0·1
June	2·92	349·92	−3·5	·183	+0·1
July	5·91	382·91	−4·5	·190	−0·9

TABLE II (*concluded*)

Date (UT)		*MJD*	*Velocity* km s⁻¹	*Phase*	*(O–C)* km s⁻¹
2011	Jan. 19·22	55580·22	−4·3	3·235	−0·3
	Mar. 14·18	634·18	−4·2	·247	−0·1
	May 9·99	690·99	−4·0	·260	+0·2
	Dec. 5·24	900·24	−4·6	·307	−0·1
2012	Jan. 13·25	55939·25	−4·9	3·316	−0·4
	Feb. 2·19	959·19	−4·1	·320	+0·5
	May 11·97	56058·97	−4·7	·342	0·0

* Observed with original spectrometer; wt. ½.
† Observed with ESO *Coravel*; weight 1.
‡ Observed with DAO 48-inch telescope; wt. 1.
C Contributed by Dr. J.-M. Carquillat.
§ Observed with Cambridge *Coravel*; weight 1.

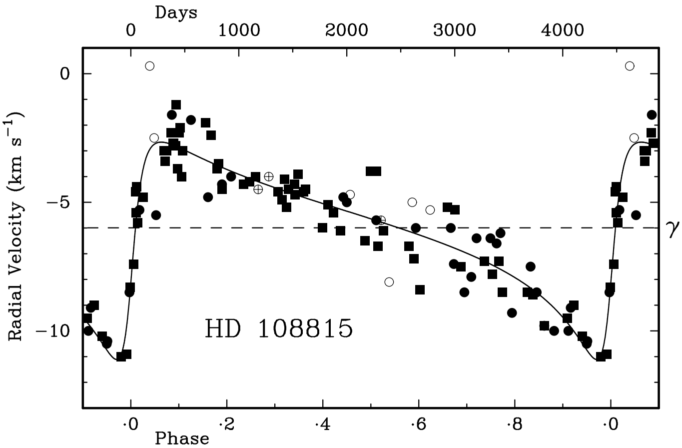

FIG. 1

The observed radial velocities of HD 108815 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. Filled symbols represent radial velocities measured with the *Coravel* spectrometers at Cambridge (squares) or at OHP (and in one case ESO) (circles). Open circles refer to measurements made with the original spectrometer in Cambridge; those with plusses in them plot DAO velocities.

A tabulation in the literature[12] gives a mean velocity for HD 108815, but it is no doubt based only on that minority of the present writer's measurements (Table II here) that the authors[12] found in the Geneva data base of measurements made with the OHP and ESO *Coravel*s. Otherwise there do not appear to be any other velocities for HD 108815 in the literature, any more than there are for any of the other stars treated here.

The mass function is small and does not demand a companion star that is more massive than 0·4 $M_\odot$, corresponding to the mass of an M2 dwarf, unless the primary has a mass exceeding 2 $M_\odot$. It is hardly likely that the companion would be a white dwarf, as its evolution would not leave the orbit so very eccentric. There could be a *Δm* of up to ten magnitudes between the components, making the system an unattractive prospect for direct resolution. Not surprisingly, an effort[13] at such resolution, prompted by a note, "Suspected non-single", against the entry for HD 108815 in the *Hipparcos* catalogue, was not successful.

HD 112475

This relatively faint star is located a little more than 1° south-preceding the 5^m object 36 Comae (HD 112769, an Mo III star that was itself on the Galactic Pole programme[1]). *Simbad* records only one paper[14] that mentions it — one by Hansen & Radford, of whom the latter was a graduate student under the writer's supervision; they obtained photometry on the Copenhagen system[15], with a view to providing the data that were ultimately supplied for the programme in a different way by Yoss. As it turned out, the only quantity that could usefully be interpreted from the Copenhagen photometric indices for HD 112475 was a *V* magnitude of $9^m{\cdot}68$.

The first radial-velocity measurement of HD 112475 was made by Radford with the original spectrometer in 1973; neither it nor the three ensuing observations were made when the velocity was well away from the γ-velocity, and it was not until the fifth observation was made, at OHP in 1991, that the double-lined nature of the object was recognized. That nature is in fact quite elusive, since the secondary dip in radial-velocity traces is only about ⅙ the depth of the primary. Moreover, the velocity amplitudes are scarcely enough ever to separate the two dips completely — Fig. 2 shows a radial-velocity trace at almost the maximum separation — so it is far from surprising that the velocities of the secondary component, which must be little brighter than the twelfth magnitude, are very ragged. There are now 16 observations made with the OHP *Coravel* and 27 with the Cambridge one, of which ten and 26, respectively, are in principle double-lined although in two cases the secondary was not actually measurable. The orbit depends on those double-lined measurements alone; to bring their variances into approximate equality, the OHP ones have been half-weighted with respect to the Cambridge ones, and (multiplicatively) the velocities of the secondary have been down-weighted by a factor of 30 with respect to the primary.

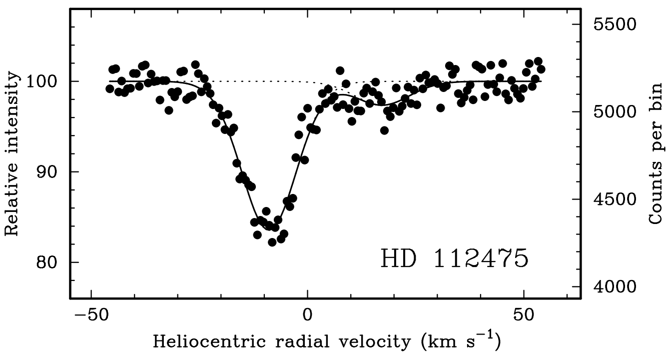

FIG. 2

Radial-velocity trace of HD 112475, obtained with the Cambridge *Coravel* on 2009 May 23, illustrating the very unequal double dips at a time when they were at almost their maximum separation.

TABLE III

Radial-velocity observations of HD 112475

Except as noted, the sources of the observations are as follows:
1988–1998 — OHP Coravel (weight ½); 2000–2012 — Cambridge Coravel (weight 1)

Date (UT)	MJD	Velocity Prim. km s⁻¹	Velocity Sec. km s⁻¹	Phase	(O – C) Prim. km s⁻¹	(O – C) Sec. km s⁻¹
1973 Feb. 24·21 *R	41737·21	−4·1		0·602	—	—
1986 May 18·99 *	46568·99	−2·2		7·593	—	—
1988 Mar. 13·06	47233·06	+0·7		8·554	—	—
1990 Feb. 15·38 †	47937·38	−0·8		9·573	—	—
1991 Feb. 4·22	48291·22	+9·2		10·085	—	—
1992 Jan. 18·17	48639·17	−1·6		10·588	—	—
Feb. 28·47 ‡	680·47	−4·8		·648	—	—
Apr. 27·06	739·06	−8·5	+15·6	·733	−0·2	−0·4
June 25·91	798·91	−10·2	+16·4	·819	−0·4	−1·5
Dec. 21·24	977·24	+10·6	−1·8	11·077	+0·7	+5·9
1993 Feb. 14·15	49032·15	+13·3	−11·1	11·157	−0·6	+1·7
Mar. 20·13	066·13	+13·9	−14·0	·206	−0·3	−0·8
July 11·90	179·90	+7·4		·370	—	—
1994 May 2·94	49474·94	−10·5	+17·6	11·797	−0·8	−0·2
Aug. 1·87	565·87	−6·3	+8·1	·929	−0·9	−4·2
Dec. 28·23	714·23	+12·9	—	12·143	−0·7	—
1995 Jan. 4·24	49721·24	+13·6	−12·0	12·154	−0·2	+0·8
June 5·01	873·01	+7·0		·373	—	—
1996 Apr. 1·03	50174·03	−10·1	+16·4	12·809	−0·3	−1·5
1997 Mar. 31·98 §	50538·98	+10·5	−10·7	13·337	+0·1	−2·4
Apr. 30·95 §	568·95	+8·0	−7·4	·380	−0·5	−1·6
1998 July 12·91	51006·91	+2·7		14·014	—	—
2000 Jan. 10·25	51553·25	−9·7	+15·9	14·804	+0·1	−2·0
Feb. 20·19	594·19	−9·4	+19·4	·863	−0·3	+2·3
Apr. 7·06	641·06	−4·7	+13·7	·931	+0·5	+1·7
2001 Jan. 11·25	51920·25	+11·0	−2·0	15·335	+0·5	+6·4
Mar. 5·17	973·17	+6·0		·412	—	—
2002 Jan. 4·27	52278·27	−9·6	+20·9	15·853	−0·2	+3·5
Feb. 24·08	329·08	−5·6	+12·5	·927	0·0	0·0
May 31·95	425·95	+8·9	−7·7	16·067	−0·1	−1·2
2003 Jan. 30·10	52669·10	+6·5	−2·1	16·418	−0·1	+1·3
June 18·94	808·94	−3·6	+10·5	·621	0·0	+0·6
2004 Feb. 9·18	53044·18	−1·9	+8·1	16·961	+0·5	−0·2
Apr. 7·10	102·10	+6·4	−4·1	17·045	−0·5	−0·3
May 21·97	146·97	+12·3	−11·7	·110	+0·1	−1·1
2005 Jan. 13·26	53383·26	+4·5	−1·4	17·452	−0·5	−0·2
May 5·01	495·01	−3·4	+9·7	·613	−0·1	+0·3
30·96	520·96	−4·7	+14·4	·651	+0·4	+2·6
June 27·95	548·95	−6·3	+13·7	·691	+0·5	−0·3

TABLE III (*concluded*)

Date (UT)		*MJD*	*Velocity* Prim. km s^{-1}	*Velocity* Sec. km s^{-1}	*Phase*	*(O–C)* Prim. km s^{-1}	*(O–C)* Sec. km s^{-1}
2008 July	3·93	54650·93	+12·9	—	19·286	+0·5	—
2009 Jan.	21·28	54852·28	−1·6	+6·6	19·577	−0·1	−0·5
May	23·99	974·99	−8·6	+17·6	·755	+0·4	+0·8
2010 Mar.	23·08	55278·08	+14·8	−13·2	20·193	+0·6	+0·1
Apr.	18·09	304·09	+13·9	−10·4	·231	0·0	+2·4
May	11·92	327·92	+13·1	−12·0	·265	0·0	−0·3
2012 Apr.	16·01	56033·01	+12·7	−10·9	21·285	+0·3	0·0
May	27·99	074·99	+9·5	−10·4	·346	−0·5	−2·6

*Observed with original spectrometer; wt. 0.
[R]Observed by G. A. Radford.
† Observed with ESO *Coravel*; weight. 0.
‡ Observed with DAO spectrometer; wt. 0.
§ Observed with Cambridge *Coravel*; wt. 1.

There are in addition two observations made with the original spectrometer, and one at the DAO and one at ESO, which were of blends and measured as single-lined. Although they are identified in Table III, where all the data are listed, they are shown in the plot of the orbit (Fig. 3), together with the six OHP blends and one Cambridge *Coravel* one, indiscriminately as open diamonds. The blends were of course omitted from the orbital solution, but in actual fact they are seen from the figure to follow closely the velocity curve of the primary (not too surprisingly, since the secondary is so weak); it looks as if they could well have been included in the solution of the orbit, but that would be contrary to proper principle. The elements are as follows:

$$
\begin{array}{llll}
P = 691{\cdot}2 \pm 0{\cdot}4 \text{ days} & & (T)_{16} = \text{MJD } 52380 \pm 5 \\
\gamma = +2{\cdot}26 \pm 0{\cdot}07 \text{ km s}^{-1} & & a_1 \sin i = 112{\cdot}2 \pm 0{\cdot}9 \text{ Gm} \\
K_1 = 12{\cdot}04 \pm 0{\cdot}09 \text{ km s}^{-1} & & a_2 \sin i = 145 \pm 5 \text{ Gm} \\
K_2 = 15{\cdot}6 \pm 0{\cdot}5 \text{ km s}^{-1} & & f(m_1) = 0{\cdot}1180 \pm 0{\cdot}0028 \, M_\odot \\
q = 1{\cdot}30 \pm 0{\cdot}04 \; (= m_1/m_2) & & f(m_2) = 0{\cdot}257 \pm 0{\cdot}025 \, M_\odot \\
e = 0{\cdot}198 \pm 0{\cdot}007 & & m_1 \sin^3 i = 0{\cdot}81 \pm 0{\cdot}06 \, M_\odot \\
\omega = 268{\cdot}7 \pm 2{\cdot}6 \text{ degrees} & & m_2 \sin^3 i = 0{\cdot}622 \pm 0{\cdot}025 \, M_\odot
\end{array}
$$

R.m.s. residual (unit weight) $=$ 0·36 km s^{-1}

The HD 112475 system is no doubt a main-sequence pair, in which the dominant primary must be just slightly bluer than the colour index of the whole system ($(B-V) = 0^{\rm m}{\cdot}62$); we could assign it a type of G0 V, whose tabular[16] colour index is $0^{\rm m}{\cdot}58$. The secondary is so much later that its spectrum must match the (K2) masks in the radial-velocity spectrometers much better than the primary, so although it gives a 'dip' that is about ⅙ as deep as that of the primary, its relative brightness (in the wavelength band, ~ B, in which the instruments operate) is likely to be only about ⅑ as great, implying $\Delta B \sim 2^{\rm m}{\cdot}4$; in the V band the difference would be close to $2^{\rm m}{\cdot}0$, suggesting that the type of the secondary must be about K2. Combination of the tabular absolute magnitudes and colours of the G0 V + K2 V combination does in fact produce a colour index of $0^{\rm m}{\cdot}62$, exactly the observed[1] value. Moreover, the tabular masses of the two stars bear a ratio close to the observed q of 1·30 ± 0·05. The integrated

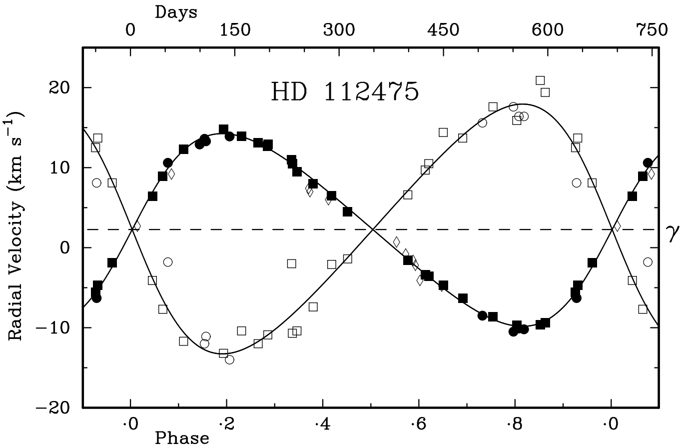

FIG. 3

The observed radial velocities of HD 112475 plotted as a function of phase, with the velocity curves corresponding to the adopted orbital elements drawn through them. The squares and circles denote measurements made with the Cambridge and OHP *Coravel*s, respectively; filled symbols are used for velocities of the primary and open ones for those of the secondary. The open diamonds plot velocities that were measured as if the traces were single-lined; the same symbol is used indiscriminately for measurements not only of the two instruments mentioned, but also of a few from the original Cambridge spectrometer, ESO, and the DAO as well.

absolute magnitude of the pair would be close to $4^{m}\cdot 2$, which in conjunction with the apparent magnitude[1] of $9^{m}\cdot 64$ leads to a distance modulus of just five magnitudes and thus to a distance of 100 pc, which we are pleased to offer, with reasonable confidence, for *Gaia*'s confirmation.

The masses found from the orbit suggest a value just under 0·8 for the factor $\sin^3 i$, so we could deduce that $\sin i \sim 0\cdot 925$, $i \sim 68°$. The mean separation of the stars $(a_1 \sin i + a_2 \sin i)/\sin i)$ is found, from the quantities in the informal table above together with the value of $\sin i$ just estimated, to be a little under 2 AU, so it would subtend an angle of nearly 0″·02 and be just within reach of speckle interferometry if pursued (as seems not actually to happen) on one of the largest telescopes.

HD 115463

The star is about 3°·7 north-following *α* Comae. It is shown in *Uranometria 2000·0*[17] as a dot with a line through it, indicating it as a visual binary, but evidence for such duplicity has escaped the present writer. Hartkopf & Yoss[18] included the object in a Galactic Pole study, carried out in part by narrow-band photometry. Quantities that they listed for HD 115463 included $V = 8^{m}\cdot 19$, $(B - V) = 1^{m}\cdot 42$, and photometrically estimated $M_V = -0^{m}\cdot 1$, type K4 II–III, and a distance of 451 kpc (the units in the column heading must be incorrect). The better agreement with the Survey[1] luminosity than with the *Hipparcos* one cannot be regarded as significant, because the Hartkopf & Yoss data no doubt contributed to the Yoss–Griffin Survey. On the other hand, the entry in Hansen & Radford's table[14], derived from a different set of narrow bands, albeit still by a photometric method, could be seen as somewhat independent. It shows $V = 8^{m}\cdot 24$ and $M_V = -0^{m}\cdot 3$, so it falls about mid-way between the Yoss–Griffin and *Hipparcos* values for the luminosity. Like HD 108815, HD 115463 features in the table by Famaey *et al.*[12], which gives a mean velocity that is probably based merely on such of the writer's observations (shown in Table IV below) as were made at OHP and therefore appear on the data base that underlies that table[12].

HD 115463 is another star whose radial velocity was first observed by Radford in 1973; the next measurement was not made until 1984, still with the original spectrometer in Cambridge. There was a decisive discordance, but it was not recognized for some years: the reduction of the observations made with the prototype spectrometer was not automatic and a large backlog had built up, such that the 1984 observation was not reduced until 1987 December. Thereupon the star was promptly transferred to the spectroscopic-binary programme and was observed systematically until 2005, by which time the orbit had been well established and the frequency of observation could be reduced. There is now a total of 66 velocities, which are set out in Table IV; they consist of eight obtained with the original spectrometer, 27, one, and 29 obtained with the *Coravel*s at OHP, ESO, and Cambridge, respectively, and one at the DAO. In solving the orbit, they have all been weighted equally apart from the 'original Cambridge' measures, which have been weighted ¼. The orbit is plotted in Fig. 4 and its elements are:

P	=	739·59 ± 0·37 days	$(T)_{12}$	=	MJD 50604 ± 6
γ	=	−25·67 ± 0·05 km s^{-1}	$a_1 \sin i$	=	63·0 ± 0·9 Gm
K	=	6·39 ± 0·09 km s^{-1}	$f(m)$	=	0·0182 ± 0·0008 $M_\odot$
e	=	0·248 ± 0·010			
ω	=	336·2 ± 2·9 degrees	R.m.s. residual (wt. 1)	=	0·35 km s^{-1}

It will be noticed that the phase distribution of the points in Fig. 4 is not as uniform as in the generality of such figures in this series of papers. That is because of the close approximation of the orbital period of HD 115463 to an integral number of years: it is 2·025 ± 0·001 years. The phase of any particular calendar date regresses slowly around the orbit by a little over 0·01, or about nine days, per cycle. The conspicuous 90-day gap in observational coverage just after the maximum of velocity would therefore take ten cycles (20 years) to close, and even then would require the cooperation of weather and instrumentation to

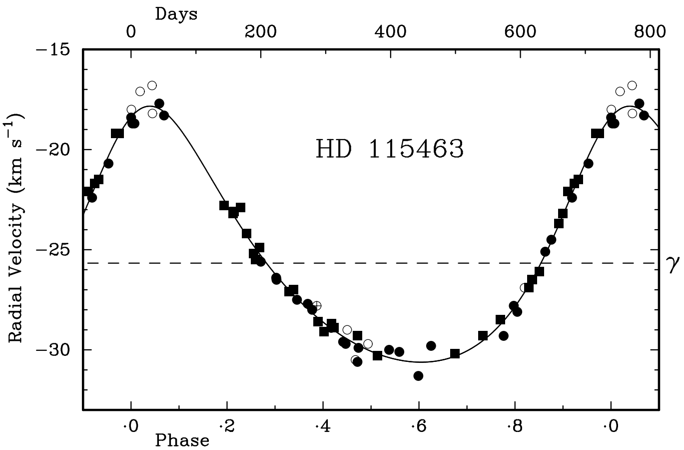

FIG. 4

As Fig. 1, but for HD 115463. The coding of symbols is as for Fig. 1.

TABLE IV

Radial-velocity observations of HD 115463

Except as noted, the sources of the observations are as follows:
1988–1998 — OHP Coravel; 1999–2012 — Cambridge Coravel (both weight 1)

Date (UT)	*MJD*	*Velocity* *km s⁻¹*	*Phase*	*(O – C)* *km s⁻¹*
1973 Mar. 2·18[*R]	41743·18	−17·1	0·019	+0·9
1984 Mar. 13·98[*]	45772·98	−30·5	5·468	−0·8
1988 Feb. 1·51[†]	47192·51	−27·8	7·387	+0·6
Mar. 13·12	233·12	−29·6	·442	−0·3
1989 Mar. 26·14	47611·14	−20·7	7·953	−0·4
Apr. 30·00	646·00	−18·4	8·000	0·0
May 1·95	647·95	−18·7	·003	−0·4
June 1·93[*]	678·93	−18·2	·045	−0·4
1990 Jan. 27·15	47918·15	−27·7	8·368	+0·3
Feb. 12·38[‡]	934·38	−28·6	·390	−0·2
Mar. 29·02[*]	979·02	−29·0	·450	+0·5
Apr. 30·04[*]	48011·04	−29·7	·494	+0·3
Dec. 27·25[*]	252·25	−26·9	·820	+0·2
1991 Jan. 28·19	48284·19	−25·1	8·863	+0·1
May 9·99[*]	385·99	−18·0	9·001	+0·4
June 10·97[*]	417·97	−16·8	·044	+1·0
Dec. 19·22	609·22	−26·4	·302	−0·1
1992 Jan. 20·21	48641·21	−27·5	9·346	−0·1
Apr. 24·05	736·05	−29·9	·474	−0·1
June 25·96	798·96	−30·1	·559	+0·4
Aug. 13·85	847·85	−29·8	·625	+0·8
Dec. 19·25	975·25	−27·8	·797	+0·1
1993 Feb. 15·21	49033·21	−24·5	9·876	+0·1
Mar. 19·12	065·12	−22·4	·919	−0·2
July 7·94	175·94	−18·3	10·069	−0·2
Dec. 28·26	349·26	−26·5	·303	−0·2
1994 Feb. 21·14	49404·14	−28·0	10·377	+0·2
May 2·04	474·04	−30·6	·472	−0·8
Aug. 3·88	567·88	−31·3	·599	−0·7
Dec. 13·21	699·21	−29·3	·776	−0·7
1995 Jan. 3·23	49720·23	−28·1	10·805	−0·4
June 2·00	870·00	−18·7	11·007	−0·5
1996 Mar. 31·08	50173·08	−28·9	11·417	0·0
1997 Mar. 31·09[§]	50538·09	−22·1	11·911	+0·6
Apr. 16·08[§]	554·08	−21·5	·932	0·0
July 18·90	647·90	−17·7	12·059	+0·3
Dec. 22·21	804·21	−25·6	·270	−0·3
1998 May 2·06	50935·06	−29·7	12·447	−0·3
July 7·92	51001·92	−30·0	·538	+0·4
1999 Dec. 20·28	51532·28	−25·2	13·255	−0·4
2000 Apr. 7·12	51641·12	−29·1	13·402	−0·4

TABLE IV (*concluded*)

Date (UT)			MJD	Velocity km s⁻¹	Phase	(O–C) km s⁻¹
2001	Feb.	17·19	51957·19	−26·9	13·829	−0·1
	May	30·98	52059·98	−19·2	·968	+0·4
2002	Jan.	1·23	52275·23	−25·5	14·259	−0·6
	Mar.	1·17	334·17	−27·0	·339	+0·3
	May	2·06	396·06	−28·9	·423	+0·1
2003	Mar.	3·15	52701·15	−26·5	14·835	0·0
	May	7·91	766·91	−21·7	·924	+0·2
	June	14·95	804·95	−19·2	·976	0·0
	Dec.	7·26	980·26	−23·2	15·213	0·0
2004	Jan.	17·25	53021·25	−24·9	15·268	+0·3
	Mar.	2·19	066·19	−27·1	·329	−0·1
	May	7·03	132·03	−28·7	·418	+0·2
	July	16·90	202·90	−30·3	·514	−0·1
	Nov.	13·26	322·26	−30·2	·675	+0·1
	Dec.	26·27	365·27	−29·3	·733	+0·2
2005	Jan.	22·24	53392·24	−28·5	15·770	+0·2
	Mar.	12·18	441·18	−26·5	·836	0·0
		23·15	452·15	−26·1	·851	−0·3
	Apr.	22·01	482·01	−23·7	·891	+0·1
	Dec.	17·29	721·29	−23·1	16·215	+0·2
2007	May	8·00	54228·00	−23·2	16·900	+0·1
	Dec.	11·26	445·26	−22·8	17·193	−0·3
2008	Jan.	6·28	54471·28	−22·9	17·229	+0·9
	July	3·91	650·91	−29·3	·471	+0·4
2012	Feb.	2·24	55959·24	−24·2	19·240	+0·1

*Observed with original spectrometer; wt. ¼.
ᴿObserved by G. A. Radford.
† Observed with DAO 48-inch telescope; wt. 1.
‡ Observed with ESO *Coravel*; weight 1.
§ Observed with Cambridge *Coravel*; weight 1.

allow observations to be made on the critical early dates (December, in odd-numbered years) at heroic easterly hour angles.

The mass function demands a secondary whose minimum mass is only 0·5 $M_\odot$ if the primary's is supposed to be 2 $M_\odot$; if the companion is a main-sequence object it need not be earlier than type M0, as much as nine or ten magnitudes down on the (rather uncertain) primary luminosity. The angular separation cannot be more than a few milliseconds of arc.

HD 117319

This star is in a region of the sky, rather barren to the naked eye even in the absence of light pollution, on the eastern fringe of Coma Berenices; it is nearly half-way between α Comae and η Boötis. *Simbad* does not record any papers at all relating to it, so it is fortunate that we have some basic information from the NGP Survey[1]. Two unsuccessful efforts were made by Radford in the spring of 1973 to measure HD 117319's radial velocity with the original spectrometer; at that epoch the faintness and rather early type of the star were compounded by the splitting of the dip into two components that were juxtaposed, jointly forming a wide and shallow feature that was difficult to recognize with the limited *S*/*N* available with the prototype instrument. Later in the same season, the writer took advantage of an observing run with the Palomar 200-inch reflector to see why the star gave no result at Cambridge, and discovered its double-lined nature. Six measurements were made at Palomar, all in different seasons; 21, two, and 31 observations have been made with the *Coravel*s at OHP, ESO, and Cambridge, respectively, as well as four with the original spectrometer and two with the DAO instrument (all reduced as single-lined, however). Fig. 5 shows a double-lined trace obtained right at the more favourable node of the orbit, when the components were as well separated as they can ever be. Seven of the OHP traces were obtained near conjunctions and were reduced as single-lined, and so were two of the Cambridge *Coravel* traces. The blending between the components in six other OHP traces, and in one of the ESO ones, was such as to require the two dips' profiles (known from traces obtained near the nodes) to be imposed upon the reductions, but they were imposed 'inverted': the dip profiles were assigned the wrong way round and the results are meaningless. Unfortunately there seems now to be no means whereby the writer can obtain fresh reductions of his own observations that are sequestered in the *Coravel* data base in Geneva. The offending data are omitted altogether from Table V here, which sets out all the other measurements.

In the solution of the orbit, the velocities obtained with the Cambridge *Coravel* have been given an empirical offset of –0·5 km s^{-1} from the 'as reduced'

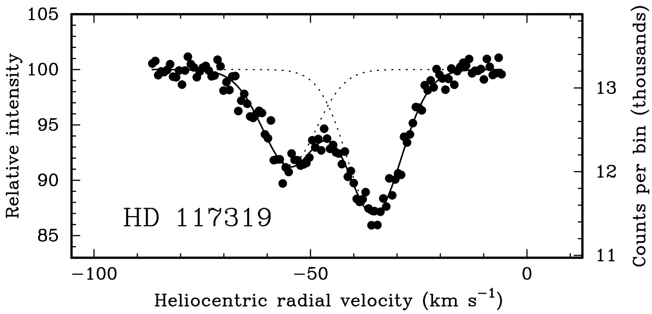

FIG. 5

Radial-velocity trace of HD 117319, obtained with the Cambridge *Coravel* on 2010 February 1, illustrating the unequal double lines right at their maximum possible separation.

observations; they have been given full weight, whereas the OHP and Palomar data have been assigned weight ¼. All velocities of the secondary component have been weighted 0·4 with respect to those of the primary. On that basis, the following orbit, which is illustrated in Fig. 6, is obtained:

P	=	4410 ± 10 days	$(T)_3$	=	MJD 55065 ± 31
γ	=	−43·84 ± 0·06 km s^{-1}	$a_1 \sin i$	=	499 ± 5 Gm
K_1	=	8·39 ± 0·08 km s^{-1}	$a_2 \sin i$	=	534 ± 8 Gm
K_2	=	8·99 ± 0·13 km s^{-1}	$f(m_1)$	=	0·255 ± 0·008 $M_\odot$
q	=	1·071 ± 0·019 (= m_1/m_2)	$f(m_2)$	=	0·313 ± 0·014 $M_\odot$
e	=	0·199 ± 0·009	$m_1 \sin^3 i$	=	1·17 ± 0·04 $M_\odot$
ω	=	338·4 ± 2·9 degrees	$m_2 \sin^3 i$	=	1·09 ± 0·03 $M_\odot$

R.m.s. residual (unit weight) = 0·36 km s^{-1}

TABLE V

Radial-velocity observations of HD 117319

Except as noted, the sources of the observations are as follows:
1986–1996 — OHP Coravel (weight ¼); 1997–2012 — Cambridge Coravel (weight 1)

Date (UT)	MJD	Velocity Prim. km s^{-1}	Velocity Sec. km s^{-1}	Phase	(O–C) Prim. km s^{-1}	(O–C) Sec. km s^{-1}
1973 June 13·25*	41846·25	−35·5	−54·6	0·002	−1·1	−0·7
1974 Mar. 3·22†R	42109·22	−41·0		0·062	—	—
1975 May 22·19*	42554·19	−36·7	−52·0	0·163	+1·2	−1·8
1978 May 23·39*	43651·39	−48·2	−41·3	0·412	+0·2	−2·3
1981 May 17·42*	44741·42	−50·3	−37·9	0·659	−0·1	−0·9
1984 Nov. 30·54*	46034·54	−37·3	−53·9	0·952	−0·7	−2·3
1986 Apr. 5·04	46525·04	−34·0	−53·5	1·063	+0·1	+0·8
11·05	531·05	−33·2	−52·2	·065	+0·9	+2·0
May 15·96†	565·96	−42·2		·073	—	—
Nov. 25·56*	759·56	−36·0	−53·5	·117	−0·3	−1·0
1987 May 7·98†	46922·98	−42·5		1·154	—	—
1988 Jan. 23·57‡	47183·57	−43·0		1·213	—	—
31·49‡	191·49	−43·7		·215	—	—
1989 June 4·94†	47681·94	−45·0		1·326	—	—
1990 Jan. 27·10	47918·10	−48·5	−39·4	1·379	−1·0	+0·6
Feb. 12·40§	934·40	−46·6	−38·6	·383	+1·0	+1·2
1991 Jan. 30·14	48286·14	−50·5	−37·8	1·463	−1·0	0·0
1992 Jan. 17·17	48638·17	−45·5		1·543	—	—
May 1·02	743·02	−50·0	−36·2	·566	+0·6	+0·3
1993 Feb. 18·17	49036·17	−50·4	−36·6	1·633	+0·1	+0·1
Mar. 19·15	065·15	−51·3	−38·2	·639	−0·9	−1·4
1994 Feb. 21·17	49404·17	−44·3		1·716	—	—
May 2·07	474·07	−44·9		·732	—	—
Aug. 4·85	568·85	−45·1		·754	—	—
1995 Jan. 8·24	49725·24	−44·0		1·789	—	—
June 5·90	873·90	−44·2		·823	—	—
1996 Apr. 1·08	50174·08	−43·2		1·891	—	—
1997 Feb. 8·18	50487·18	−35·8	−52·4	1·962	+0·3	−0·3
Mar. 29·12	536·12	−34·9	−53·6	·973	+0·6	−0·9
May 1·84	569·84	−35·0	−52·9	·981	+0·2	+0·2
July 25·88¶	654·88	−34·3	−54·1	2·000	+0·2	−0·2
2000 Apr. 10·06	51644·06	−42·7		2·224	—	—
2001 Mar. 11·14	51979·14	−43·6		2·300	—	—
2002 Apr. 27·07	52391·07	−48·5	−39·0	2·394	−0·6	+0·5

TABLE V (*concluded*)

Date (UT)	*MJD*	*Velocity* Prim. km s⁻¹	Sec. km s⁻¹	*Phase*	*(O – C)* Prim. km s⁻¹	Sec. km s⁻¹
2003 Feb. 21·15	52691·15	−49·6	−37·1	2·462	−0·1	+0·7
Mar. 17·08	715·08	−49·7	−37·0	·467	−0·1	+0·7
May 18·04	777·04	−49·6	−38·1	·481	+0·2	−0·7
2004 Apr. 3·13	53098·13	−50·1	−36·3	2·554	+0·5	+0·3
June 27·94	183·94	−50·5	−35·8	·574	+0·2	+0·7
2005 Mar. 25·13	53454·13	−50·8	−36·5	2·635	−0·3	+0·2
May 8·01	498·01	−50·1	−37·2	·645	+0·3	−0·4
June 9·00	530·00	−50·4	−37·7	·652	−0·1	−0·8
2006 Apr. 5·08	53830·08	−49·5	−38·5	2·720	−0·5	−0·2
June 21·96	907·96	−48·3	−38·6	·738	+0·2	+0·2
2007 Apr. 6·07	54196·07	−45·7	−40·7	2·803	+0·2	+1·0
2008 Mar. 31·11	54556·11	−41·5	−45·9	2·885	−0·5	+1·0
May 19·99	605·99	−40·4	−47·9	·896	−0·1	−0·2
July 23·90	670·90	−39·2	−48·8	·911	+0·1	−0·1
2009 Feb. 4·26	54866·26	−36·4	−51·5	2·955	+0·1	+0·2
May 7·01	958·01	−35·6	−52·4	·976	−0·2	+0·5
2010 Jan. 31·28	55227·28	−33·4	−53·8	3·037	+0·5	+0·7
Feb. 1·25	228·25	−33·9	−53·5	·037	0·0	+1·0
Apr. 8·12	294·12	−34·3	−54·3	·052	−0·3	+0·1
May 13·04	329·04	−34·5	−54·3	·060	−0·5	0·0
June 22·97	369·97	−34·6	−54·7	·069	−0·4	−0·5
2011 Mar. 14·20	55634·20	−36·2	−52·0	3·129	+0·1	−0·1
May 10·04	691·04	−37·3	−51·7	·142	−0·4	−0·4
2012 Apr. 16·07	56033·07	−40·4	−47·7	3·220	+0·5	−0·7
May 15·00	062·00	−41·6	−46·0	·226	−0·4	+0·7

*Observed with 200-inch telescope; wt. ¼.
† Observed with original spectrometer.
R Observed by G. A. Radford.
‡ Observed with DAO 48-inch telescope.
§ Observed with ESO *Coravel*; weight ¼.
¶ Observed with OHP *Coravel*; weight ¼.

The first things to be noticed in the above table of elements are the unexpectedly high values of the stellar masses. According to tabulations such as that in *Astrophysical Quantities*[16] (we trust more-recent ones even less because they are obviously unreliable[19]) the masses of 1·17 and 1·09 $M_\odot$ should belong to stars of types near F8 and G0 rather than the G5 that was inferred photometrically in the Survey[1]. Masses higher than the tabular ones have, however, been incontrovertibly established by orbital elements in a number of cases, of which the most extreme is the 17% excess found[20] in the case of the Hyades star vB 22. Moreover, a line that the reader might draw through the points in Andersen's[21] diagram, which plots accurately determined masses against $(B - V)$ colour index, shows the mass corresponding to the colour index of HD 117319 to be about 1·11 $M_\odot$, so it seems that we have, after all, little to worry about. Certainly the orbital inclination must be so high that $\sin^3 i \sim 1$; even so, the likelihood of eclipses in a system of two solar-type stars about 7 AU apart is very small, of the order of 1%.

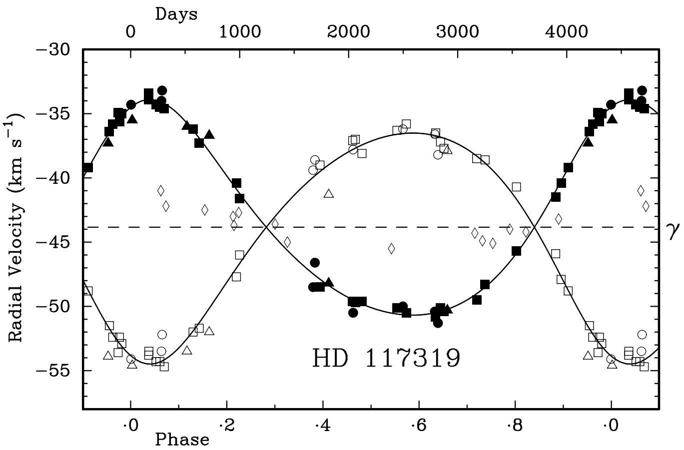

FIG. 6

As Fig. 3, but for HD 117319. In this case there are, in addition to the other sources, double-lined measurements obtained with the Palomar 200-inch telescope; they are plotted as filled and open triangles.

The ratio of dip depths (or areas, since both stars give dips of practically the minimum width, showing that $v \sin i \sim 0$), is 1 to 0·65, which corresponds arithmetically to a magnitude difference of $0^{m}{\cdot}47$; using a 'rule of thumb'[22] that the actual ΔV is 1·15 times as great, we obtain a magnitude difference of $0^{m}{\cdot}54$, which is in reasonable agreement with the difference of two spectral subtypes indicated (*via* the gradient in Andersen's graph referred to above) by the mass ratio.

The absolute magnitude proposed by the Survey[1] pre-supposed the object to be a single star; since it is two, its luminosity is approximately doubled and the distance estimate needs to be increased by $\sqrt{2}$, to 100 pc. At that distance the angular separation corresponding to the semi-major axis of the relative orbit (~7 AU) would be about $0''{\cdot}07$, seemingly making the object an easy one to resolve by speckle interferometry; it should require an aperture of no more than about 2 metres near nodal passages.

References

(1) K. M. Yoss & R. F. Griffin, *JA&A*, **18**, 161, 1997.
(2) R. D. McClure & S. van den Bergh, *AJ*, **73**, 313, 1968; R. D. McClure, *AJ*, **81**, 182, 1976.
(3) F. van Leeuwen, *Hipparcos, the New Reduction of the Raw Data* (Springer, Dordrecht), 2007.
(4) A. J. Cannon & E. C. Pickering, *HA*, **95**, 55, 1920.
(5) S. Kwok, K. Volk & W. P. Bidelman, *ApJS*, **112**, 557, 1997.
(6) G. Neugebauer *et al.*, *ApJ*, **278**, L1, 1984.
(7) E. V. Kazarovets *et al.*, *IBVS*, no. 4659, 1997.
(8) P. N. Kholopov (ed.-in-chief), *General Catalogue of Variable Stars* (4th Edn.) (Nauka, Moscow), 1985, p. 19.
(9) F. Guglielmo *et al.*, *A&AS*, **122**, 489, 1997.
(10) B. Famaey *et al.*, *A&AS*, **498**, 627, 2009.
(11) J. E. Gunn & R. F. Griffin, *AJ*, **84**, 752, 1979.
(12) [Announced by] B. Famaey *et al.*, *A&A*, **430**, 165, 2005.
(13) B. D. Mason *et al.*, *AJ*, **121**, 3224, 2001.
(14) L. Hansen & G. A. Radford, *A&AS*, **53**, 427, 1983.
(15) B. Strömgren, [*ESO*] *Messenger*, **7**, 12, 1976.
(16) C. W. Allen, *Astrophysical Quantities* (Athlone, London), 1973, pp. 206, 209.

(17) W. Tirion, B. Rappaport & W. Remaklus, *Uranometria 2000·0 Deep Sky Atlas* (2nd Edn.) (Willmann-Bell, Richmond, Virginia), 2001, p. 71.
(18) W. I. Hartkopf & K. M. Yoss, *AJ*, **87**, 1679, 1982.
(19) R. F. Griffin, *The Observatory*, **120**, 331, 2000.
(20) R. F. Griffin *et al.*, *AJ*, **90**, 609, 1985.
(21) J. Andersen, *A&A Review*, **3**, 91, 1991 (see Fig. 2).
(22) R. F. Griffin & A. A. Suchkov, *ApJS*, **147**, 103, 2003.

ASTRONOMY AND THE FIFTH DIMENSION

By Paul S. Wesson

Department of Physics and Astronomy, University of Waterloo, Canada

Astronomy is a precise and relatively simple science because objects accelerate in a gravitational field at the same rate, irrespective of their composition. Galileo knew this, and Einstein took it as the basis for General Relativity. Surprisingly, it is also a consequence of new theories that use a fifth dimension.

Imagine, if you will, a street entertainer juggling an apple, an orange, and a banana. While the juggler may not be thinking about Einstein, it is because of the latter's Equivalence Principle that the objects do not end up on the ground in a fruity mess. The juggler is probably not thinking either about the possible existence of an extra dimension in addition to the space and time of General Relativity; but recent work indicates that Einstein's Equivalence Principle follows naturally from 5D relativity.

Einstein's Equivalence Principle (EEP) says in its simplest form that objects in the Earth's gravitational field fall at the same rate, irrespective of their composition. This refers not only to chemical composition, but also to isotopic composition, including contributions to the measured mass from electromagnetic and nuclear forces. Without the EEP, it would be difficult to estimate the orbit of any object, either on the Earth or in space. It is the EEP which guarantees the juggler's art, and it is also the reason why astronomy is such an ancient and exact branch of science.

Historically, physicists have distinguished between three different types of mass. Active gravitational mass is the quantity which is responsible for the force, passive gravitational mass is the one which responds to the force, and inertial mass is the thing which resists acceleration and also measures the energy content of an object (given by Einstein's famous formula). The first two types of mass can readily be shown to be proportional to each other by reciprocity arguments, so it is the proportionality of gravitational mass m_g to inertial mass m_i which figures in the EEP.

To see why the EEP is important, consider the Kepler problem of the Earth in orbit around the Sun. Using large and small letters for the masses, the gravitational force between the Sun and the Earth is $GM_g m_g/r^2$ where G is Newton's constant and r is the separation. This attraction is countered by the centrifugal or inertial force $m_i v^2/r$ where v is the Earth's orbital velocity. As an equation we write

$$\frac{GM_g m_g}{r^2} = \frac{m_i v^2}{r}, \tag{1}$$

and we *cancel* the m_g on the left-hand side with the m_i on the right-hand side. This is allowable because the EEP says that the two masses are proportional to each other (and usually set equal). The result is a Kepler orbit for the Earth, with $v = \sqrt{GM/r}$, as every student knows.

It need not be so, however. Some modern theories of gravitation, which go beyond that of Einstein, predict extra accelerations that can be tested using astronomical observations. The bases of these theories are various, but several of them include a scalar field which (like ordinary gravity and electromagnetism) acts over large distances, and can in principle modify the dynamics of objects in the Solar System and beyond. Particular attention has been paid to the orbit of the Moon, whose effective mass depends on its binding energy; and on the trajectory of the *Pioneer* spacecraft, which appears to show an anomalous acceleration. However, when the observational uncertainties are taken into account, there is no compelling evidence for a departure from General Relativity, so as far as present data go, Einstein's Equivalence Principle holds. That it does so to reasonable accuracy has been known for centuries, and at least since the time when Galileo (supposedly) dropped balls from the Leaning Tower of Pisa.

Indeed, the EEP is often taken for granted. However, some great thinkers have sought a deeper rationale for the proportionality of gravitational and inertial mass, and some clever experimenters have verified the fact to great accuracy (of order 1 part in 10^{12}). Einstein was, of course, motivated by Equivalence to formulate the General Theory of Relativity; and indirect support for the EEP comes from the numerous tests of that theory. Recently, General Relativity was confirmed by measuring the precession rates of a set of super-cooled gyroscopes aboard a drag-free satellite in Earth orbit[1]. Another reason for carrying out the experiment was to look for possible departures from Einstein's theory. In that regard, it is widely believed that the best route to a unification of gravity with the interactions of particles is by a theory like General Relativity, but with more dimensions than the familiar four of space–time. Five-dimensional relativity is the basic extension, and there is in fact a small difference in the precession rate of a gyroscope in a gravitational field, depending on whether the world has four or five dimensions[2]. This particular effect proved too small to detect by experiment. However, more work on 5D relativity has newly revealed implications for the status of the EEP[3]. It appears, in fact, that the EEP may be a direct consequence of the existence of an extra dimension.

To see why, let us add to the four standard coordinates of space and time an extra one, say ℓ. To calculate dynamical effects, we need to write down an expression for the square of the 'distance' between two nearby points (given by the interval dS^2) and find the 'shortest' path between the two points (given by the extremum of S). This procedure is analogous to using Pythagoras' theorem to find the shortest path between two points in ordinary 3D space. We do not — to start with — know how to visualize the 'shape' of a 5D world. However, other work on 5D relativity has led to a particularly simple form which is called canonical 5D space[4]. For this, the shape in 'cross-section' resembles an ordinary circle. A circle drawn on a flat surface like this page is best described in terms of the radius r and the angle θ which sweeps around counter-clockwise from a given starting point. The square of the distance between two nearby points is then $d\sigma^2 = dr^2 + r^2 d\theta^2$. In this formula, we can replace r by ℓ, and replace the increment of angle $d\theta$ by the ratio of two lengths ds/L, where ds is the interval of Einstein's 4D General Relativity and L is a constant length whose meaning will soon be made clear. It is also instructive to rearrange the terms and swap a sign to indicate that the new ℓ is physically like a measure for space rather than a measure for time. The result is the 5D interval

$$dS^2 = (\ell/L)^2\, ds^2 - d\ell^2. \tag{2}$$

This defines 'distance' in 5D, and involves a term like that in 4D (ds^2) and a term to do with the extra dimension ($d\ell^2$), though the two parts are interdependent (and in the general case ds^2 may conceal an internal dependency on ℓ). However, while it may look strange, the equation just given is still basically that of a circle.

Paths in the 5D world described by (2) can be obtained by following a standard procedure[4]. Two remarkable things emerge. (*a*) The paths of all particles, even massive ones, can be described by (2) with $dS^2 = 0$. This means that a particle with a finite mass m follows the same kind of *null* path in 5D that a massless photon follows in 4D (where $ds^2 = 0$). A corollary of this is that all particles are in some kind of causal contact in 5D, since $dS^2 = 0$ now takes the place of causal contact defined by the exchange of light signals with $ds^2 \geq 0$ in 4D. (*b*) The paths of particles are generally affected by an extra force which is associated with movement through the extra dimension. This does not upset the law of conservation of (linear) momentum, but the mass m of a test particle will in general vary now along its path. This happens at a slow rate governed by the length L in (2), which turns out to be related to the cosmological constant by $\Lambda = 3/L^2$. Since Λ measures the energy density of apparently empty space, there is also a connection to the physics of the vacuum. The motion of a particle in the extra dimension is reversible, like the motion in ordinary 3D space in the absence of friction. However, *via* the conservation of momentum, there is now a relation between the rate at which a particle of mass m varies with proper time s and the rate of change of the extra coordinate ℓ. Technically, $(1/m)(dm/ds)$ is proportional to $(1/\ell)(d\ell/ds)$, where, however, the motion in the extra dimension is *reversible* so $d\ell/ds$ can be positive or negative. The result of this is that there are two choices for how the mass is related to the extra coordinate. These choices are given by the proportionalities

$$\ell \sim m \quad \text{or} \quad \ell \sim 1/m, \tag{3}$$

depending on the direction of motion in the fifth dimension. This is intriguing. It is in fact the analogue for massive particles in gravitational theory of the situation for electrically-charged particles in quantum theory, where following Stueckelberg and Feynman a positron may be regarded as a time-reversed electron.

The preceding is based on canonical space with interval (2), which is typical of the approach to 5D relativity known as Space–Time–Matter theory. The rationale for this theory is that mass and matter are properties of 4D space–time which owe their existence to the fifth dimension, something which follows from Campbell's embedding theorem of differential geometry. An alternative approach to 5D relativity, known as Membrane theory, typically employs a different kind of space with an interval that is warped by the extra dimension. The rationale for this theory is that the masses of particles are controlled by a singular surface or membrane, about which matter is concentrated, thereby defining space–time. In regard to the comments of the preceding paragraphs, it should be mentioned that the two things noted before — namely null paths and an extra force — also exist in the second theory[5]. Indeed, the mathematical structure of the two theories is similar[6,7], and their conceptual bases overlap somewhat[8–10]. That said, we continue the discussion using the first approach, and focus attention on the relations (3) which show how to define the mass of a test particle.

The relations (3) are in fact the geometrical representations of how mass appears in gravitational theory and quantum theory. These branches of physics are characterized by their constants: Newton's constant G and Planck's constant h, where the speed of light c is shared by both branches in their relativistic formulations. The proportionalities (3) correspond to how gravitational and inertial mass are measured by

$$\ell_g = \frac{Gm}{c^2} \quad \text{or} \quad \ell_i = \frac{h}{mc}. \tag{4}$$

These are of course the Schwarzschild radius and the Compton wavelength, as they appear in General Relativity and quantum mechanics.

The implications of the preceding account are far reaching. For example, it opens the prospect of better understanding the notorious cosmological 'constant' problem, which consists basically in the discrepancy between the sizes of that parameter as derived from astrophysics and particle physics. This problem is presently the subject of intense debate. But it is apparent that in a 5D world described by canonical space (2), a connection can be made between the $\Lambda = 3/L^2$ noted above and the product of the lengths in (4), which is Gh/c^3 or the square of the Planck length. There are also implications of the 5D theory which are more qualitative in nature but can be tested by refining cosmological data. Notably, there are solutions of the field equations of the theory which, while they are curved in 4D, are *flat* in 5D. This means that while there may be a Big Bang in 4D, the Universe is smooth and free of singularities in 5D. This sounds odd, but it can be demonstrated by having a computer draw the relevant plots, where the Big Bang appears as a point embedded in a flat background[10]. You can appreciate the same thing by taking a sheet of paper and rolling it into the shape of a cone. The sheet is intrinsically flat, but you have created the point at the apex of the cone (the 'Big Bang') by changing the shape, or in other words by *how* you describe the surface.

The implications for the Einstein Equivalence Principle are more straightforward. Gravitational mass and inertial mass are two aspects of the same thing, which presents itself in the ways given by (4). These, however, merely represent two ways of measuring motion in the fifth dimension. The motion is actually reversible, and there is no meaningful difference between going in the gravitational 'direction' and the inertial 'direction'. History also plays a part in our habit of representing mass in two different ways, because some thought shows that the constants G and h have to do with the ways in which gravitational physics and quantum physics have developed. The disposability of these constants and c is revealed by the fact that the values of all three can be consistently set to 1 by a suitable choice of units, a ploy used by researchers every day. It is clear that there is no fundamental difference between gravitational and inertial mass, so Einstein's Equivalence Principle is safe. The dedicated theorist, labouring over his arcane equations, might even suggest that the observational astronomer peering through his telescope owes something to the fifth dimension.

For those interested in further reading, ref. 7 below is a mathematical review, while refs. 8–10 are non-technical accounts.

Acknowledgements

This article is based on previous work with other members of the Space–Time–Matter group (http://www.astro.uwaterloo.ca/~wesson).

References

(1) C. W. F. Everitt *et al.*, *Phys. Rev. Lett.*, **106**, 221101, 2011; *Space Sci. Rev.*, **148**, 53, 2009.
(2) H. Liu & P. S. Wesson, *Class. Quant. Grav.*, **13**, 2311, 1996.
(3) P. S. Wesson, arXiv 1111.4698, 2011; *Gen. Rel. Grav.*, **35**, 307, 2003.
(4) B. Mashhoon, P. S. Wesson & H. Liu, *Gen. Rel. Grav.*, **30**, 555, 1998; S. S. Seahra & P. S. Wesson, *Gen. Rel. Grav.*, **33**, 1731, 2001.
(5) D. Youm, *Phys. Rev.*, **D62**, 084002, 2000; *Mod. Phys. Lett.*, **A16**, 2371, 2001.
(6) J. Ponce de Leon, *Mod. Phys. Lett.*, **A16**, 2291, 2001.
(7) P. S. Wesson, *Five-Dimensional Physics* (World Scientific, Singapore) 2006.
(8) P. Halpern, *The Great Beyond* (Wiley, Hoboken) 2004.
(9) P. S. Wesson, *Weaving the Universe* (World Scientific, Singapore) 2011.
(10) P. S. Wesson, *A&G*, **43**, 13, 2002; *New Scientist*, **178**, 30, 2003.

IMPROVING SUNSPOT RECORDS: SOLAR DRAWINGS OF THE LATE 19TH CENTURY FROM THE ROYAL ASTRONOMICAL OBSERVATORY OF LISBON

By J. M. Vaquero⋆†*, R. M. Trigo*†‡*, M. C. Gallego*⋆ *and F. Domínguez-Castro*⋆
⋆*Departamento de Física, Universidad de Extremadura, Spain*
†*IDL, Universidade de Lisboa, Lisbon, Portugal*
‡*Departamento de Eng. Civil da Universidade Lusófona, Lisbon, Portugal*

The reconstruction of solar activity in the past is very important for a number of astrophysical and geophysical studies. In this work, we recovered and analysed a collection of historical solar drawings made by the Portuguese astronomer Manuel S. Melo e Simas in 1895–6 and 1898 and preserved in the archive of the Royal Astronomical Observatory of Lisbon. We have computed the sunspot number from these observations and compared it with the standard International Sunspot Number. Moreover, we have also analysed a set of detailed drawings of a large sunspot group observed in 1898 March. That group has been associated with the great geomagnetic storm of 1898 March 15.

Introduction

The bulk of astronomical observations and theoretical research activity in Europe, since the dawn of telescopic observations, has been performed by observers and researchers from Anglo-Saxon, French, Scandinavian, and Central European countries[1]. Nevertheless, relatively peripheral countries, such as Portugal, have undertaken meritorious astronomical work during the last few centuries[2,3]. The Royal Astronomical Observatory of Lisbon (RAOL) was created in 1857. Since then, the centre has gone through various vicissitudes, gaining international recognition for its work on astrometry in the late 19th and early 20th Centuries[4,5].

Today, that institution preserves an archive served by a small staff that maintains a large amount of documentation related to the tasks of the institution and especially the observations that have been made there for more than a century and a half. The inventory of all observations undertaken during this period is available to the public through the web site of that Observatory (http://www.oal.ul.pt/).

Several branches of observationally-based astronomy can profit from the increased access to RAOL data sets, including historical solar-activity reconstructions. In recent decades, an effort has been made to reconstruct the solar activity of the last four centuries based on historical sunspot observations[6–10]. It is within this context that we intend to contribute to this effort through the recovery of the solar drawings preserved in the historical archive of the RAOL.

In the next section, we describe the collection of sunspot drawings preserved in the RAOL archive. Then we provide a brief analysis based on the computation of sunspot numbers from the drawings of the solar disc and also show an interesting series of drawings of the great sunspot group observed in 1898 March.

Solar drawings collection

In the archive of RAOL there is a handwritten book, signature A-201, entitled "Mello e Simas. Grande equatorial. Observações Sol Júpiter" [Mello e Simas. Great Equatorial. Sun Jupiter observations]. This book contains a collection of sunspot drawings that are summarized in Table I (64 drawings in total) which lists each one of the drawings including the date and hour (Local Time, if available), the corresponding page number, and the kind of drawing. It also lists the number of Groups (G) and the total number of individual spots (f) if the drawing represents the full solar disc.

We have three different kinds of drawings: (*i*) full-solar-disc drawings, (*ii*) full-solar-disc drawings incorporating detailed sketches of sunspot groups (marked with an asterisk in Table I), and (*iii*) detailed drawings of sunspot groups. A total of 64 are available (38, 12, and 14 drawings for each category described above, respectively) over a range of dates.

The drawings of the full solar disc can be divided into two sets with respect to their dates. The first set of drawings was made in 1895 January–May (31 drawings in total); the second set of drawings of the full disc corresponds to observations performed in 1896 February–March (19 drawings in total). In addition, a set of detailed drawings of sunspot groups was made in 1898 February–March (14 drawings in total).

The astronomer Manuel S. Melo e Simas (1870–1934) was the author of this handwritten book. He was an astronomer who is well known to Portuguese historians of science owing to his important rôle in the popularization and research on the relativity theory in Portugal[11]. In fact, he made a serious attempt to measure the bending of light rays bordering Jupiter's surface in order to compare with the prediction made by General Relativity theory[12].

In general, the orientation of these drawings is indicated. In the case of full-disc drawings, we found different methods to express the correct orientation of the solar disc. The simplest one is to indicate with an arrow the direction of the

TABLE I

Summary of the solar drawings included in the manuscript book: date (day, month, year) and hour (if available), page number, type of drawing and, finally, number of Groups (G) and the total number of individual spots (f) (only if the drawing represents the full solar disc). Note that full-solar-disc drawings incorporating detailed sketches of sunspot groups have an asterisk in the 'type' column.

Year	*Month*	*Day*	*Time*	*Page*	*Type*	*G*	*f*
1895	1	6	8:54	4	Full disc*	3	22
1895	1	8	9:38	5	Full disc*	3	10
1895	1	21	9:48	6	Full disc*	2	22
1895	1	24	8:33	7	Full disc*	4	6
1895	1	27	9:18	9	Full disc*	6	12
1895	1	29	8:55	12	Full disc*	11	44
1895	2	8	8:15	14	Full disc	6	13
1895	3	3	9:50	16	Full disc	6	11
1895	3	4	8:30	16	Full disc	7	13
1895	3	7	8:30	17	Full disc	6	17
1895	3	9	8:30	17	Full disc	4	20
1895	3	13	9:00	18	Full disc	8	21
1895	3	14	8:35	19	Full disc	8	21
1895	3	15	8:15	19	Full disc	9	16
1895	3	16	9:05	20	Full disc	6	16
1895	3	19	8:40	21	Full disc	4	27
1895	3	20	8:30	22	Full disc	3	35
1895	3	23	8:00	22	Full disc*	5	21
1895	3	26	8:45	23	Full disc	3	16
1895	4	3	8:35	25	Full disc	7	12
1895	4	19	8:00	25	Full disc	4	15
1895	4	25	9:10	26	Full disc	5	23
1895	4	27	9:05	27	Full disc	8	30
1895	4	28		27	Full disc	7	22
1895	4	29		28	Full disc	6	31
1895	4	30		28	Full disc	9	30
1895	5	1		29	Full disc	9	24
1895	5	6		29	Full disc	2	9
1895	5	7	8:00	30	Full disc*	2	7
1895	5	11	9:20	31	Full disc	3	5
1895	5	12	13:00	31	Full disc	5	9
1896	1	19	9:45	32	Full disc	2	2
1896	1	22		33	Full disc	2	2
1896	1	24		33	Full disc	2	2
1896	1	30		34	Full disc	6	10
1896	1	31		35	Full disc*	5	20
1896	2	4		36	Full disc	6	14
1896	2	5		36	Full disc	6	11
1896	2	9		37	Full disc	4	8
1896	2	11		37	Full disc	4	8
1896	2	12		38	Full disc	4	11
1896	2	13	10:00	39	Full disc*	4	19
1896	2	16	12:30	40	Full disc	2	8
1896	2	17	11:40	40	Full disc	2	2
1896	2	21	10:00	41	Full disc	4	16
1896	2	22	12:00	41	Full disc*	8	37
1896	2	26	10:00	43	Full disc*	9	58
1896	3	8	12:50	44	Full disc	3	4
1896	3	13	11:45	44	Full disc	1	5
1896	3	17	11:00	45	Full disc	1	5

TABLE I (*concluded*)

Year	*Month*	*Day*	*Time*	*Page*	*Type*
1898	2	26		47	Detail
1898	3	1		47–48	Detail
1898	3	2		48	Detail
1898	3	3		49	Detail
1898	3	4		50	Detail
1898	3	5		51	Detail
1898	3	7		51	Detail
1898	3	8		52	Detail
1898	3	9		53	Detail
1898	3	10		54–55	Detail
1898	3	11		56	Detail
1898	3	12		56–57	Detail
1898	3	13		58	Detail
1898	3	14		59	Detail

zenith. However, we found some drawings that show the central meridian, solar equator, and even solar parallels from 40° N to 40° S (see Fig. 1). In the case of detailed drawings of sunspot groups, it is common to find the E–W direction. Mello e Simas used two different magnifications to obtain these drawings. He used a 75× magnification to sketch the full-disc drawings, but he often opted for the 200× magnification to sketch the sunspot-group details. In some cases, faculae are shown as little circles close to the solar limb or sunspots. Note that umbra and penumbra are clearly differentiated even in the full-disc drawings.

Although the individual records do not indicate explicitly the instrument that was used, we can deduce from the book's title that the entire set of observations was made with the great equatorial telescope. That instrument was manufactured in 1864 by A. & G. Repsold in Hamburg. It has a diameter of 0·382 m and a 6·82-m focal length. The objective was made by Georg Merz (1793–1867).

In addition to this interesting collection of drawings, there is an extra drawing of sunspots in the RAOL archive made by Narciso de Lacerda, obtained on 1884 December 22 at 11:30 (Local Time). Narciso de Lacerda was one of the most important Portuguese amateur astronomers of that period, and he used a refracting telescope (D = 108 mm and 100× magnification). In this particular drawing, however, sunspots are depicted with an enormous apparent size, so it is an idealization with little scientific value.

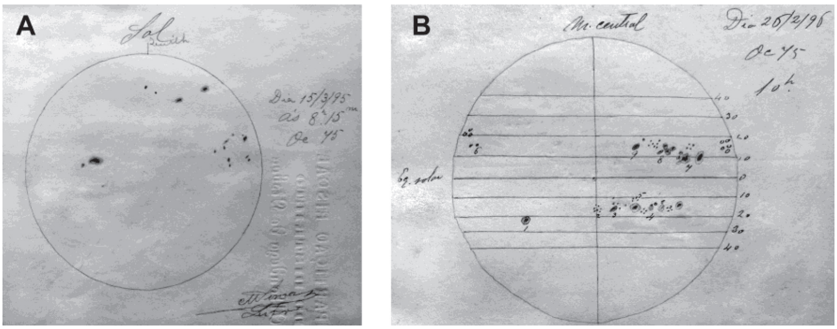

FIG. 1

Drawings of the full solar disc; (A) 1895 March 15; (B) 1896 February 26.

Sunspot number

We have analysed these drawings, maintained in the RAOL archive, mostly from the point of view of the sunspot number (SN). We have determined the total number of sunspot groups (G) and the total number of individual spots (f) for all the solar-disc drawings. These values, which are listed in Table I, allowed us to compute the 'Lisbon Sunspot Number' (LSN) for each drawing using the well-known Wolf equation, $SN = 10G + f$.

Fig. 2 shows the simultaneous daily evolution of LSN and International Sunspot Number[13] (ISN) from 1895 January to 1896 March. In spite of the typically noisy signal, we can appreciate the general agreement between the temporal evolution for both sunspot numbers. In particular, we have computed the linear relationship between LSN and ISN (Fig. 3), obtaining $LSN = (0{\cdot}951 \pm 0{\cdot}097)\, ISN + (11 \pm 6)$, and the Pearson correlation coefficient is $r = 0{\cdot}668$ (statistically significant at 1%).

After the seminal work of Hoyt & Schatten[7], who reconstructed the sunspot number using only the group count, the ratio between SN and G is of interest. Hoyt *et al.*[6] demonstrated that this ratio is close to 12 for an average modern observer. Fig. 4 shows the relationship between LSN and G using the data of Table I. The best linear fit is $LSN = (13{\cdot}4 \pm 0{\cdot}5)\, G + (0 \pm 3)$. Therefore, the ratio SN/G obtained for this Lisbon observer at the end of the 19th Century is slightly higher when compared with the average modern observer estimated by Hoyt *et al.*[6].

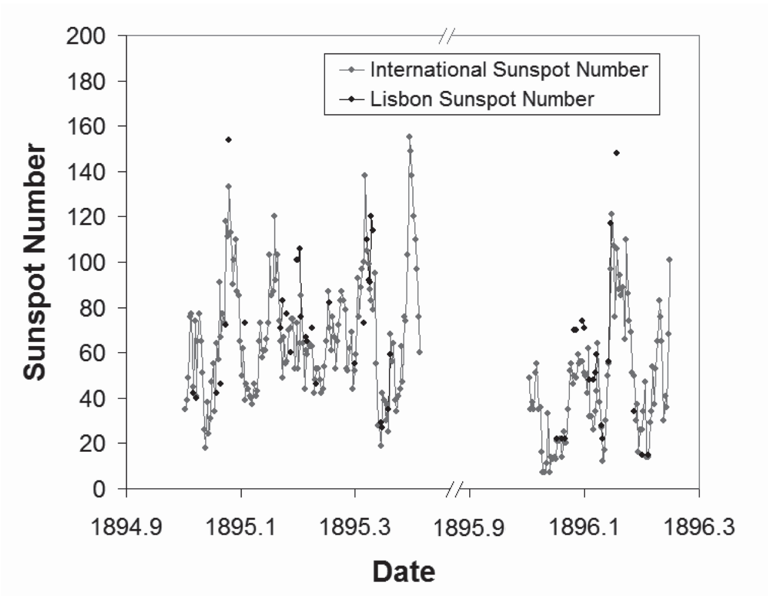

FIG. 2

Lisbon and International Sunspot Numbers from 1895 January to 1896 March.

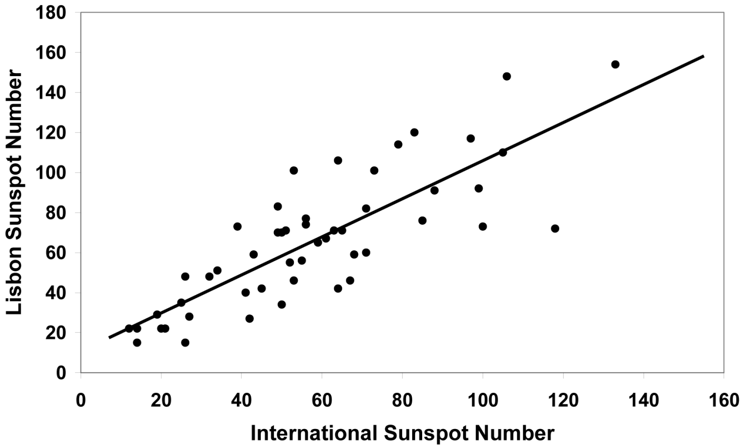

FIG. 3
Linear relationship between Lisbon and International Sunspot Numbers.

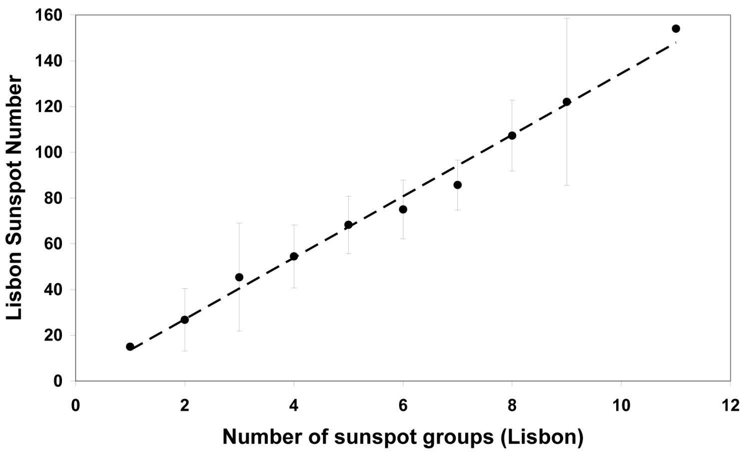

FIG. 4
Relationship between Lisbon Sunspot Number and number of sunspot groups recorded from Lisbon Observatory.

The great sunspot of 1898

Among the drawings of sunspot groups it is worth noting a series devoted to a large group observed during the interval 1898 March 8–14. We have no drawings of the full solar disc in the RAOL archive for those dates. However, other observatories have registered this large group crossing the entire solar disc, including some nice drawings made at Kalosca Observatory, Hungary[14].

Jones[15] has identified this large group as the probable solar source region of the geomagnetic storm of 1898 March 15. In the section 'Great Geomagnetic Storms recorded at Greenwich–Abinger, 1874–1954', that storm has the reference no. 35. The ranges of the storm were 83′ for the geomagnetic declination (*D*), > 345γ for the horizontal component (*H*), and > 520γ for the *Z* component. The storm was associated with sunspot group No. 4702 (see page 76 of ref. 15) and that corresponds to the large sunspot group depicted in the RAOL drawings. Unfortunately, the Sun was not monitored constantly at that time and we do not have available an observation of any solar flare[16] that could confirm the true source region of the event.

It is worthy of mention that the geomagnetic storm of 1898 March 15 is listed with the number 85 (out of 1718 events) in the ranking of storms using the geomagnetic index aa* maximum (http://www.ngdc.noaa.gov/stp/geomag/aastar.html). Therefore, this is one of the most important solar storms that took place between 1868 and 2007 (although it is far from being considered a record-breaking storm[16]).

Some additional data are available about the sunspot group No. 4702 in the *Catalogue of Sunspots >500 Millionths of the Sun's Hemisphere, 1874–1954* (see page 47 of ref. 15). According to those data, the passage for the central meridian was the day 11·6 (March), the mean area of the sunspot group was 981 millionths of a hemisphere, the maximum area was 1552, and the ratio umbral-area/whole-spot-area was 0·191. The solar coordinates in the Carrington system were 119°·3 (solar longitude) and –13°·1 (solar latitude).

Fig. 5 shows the drawings preserved in the RAOL archive of this large sunspot group from 1898 March 8 to 14. Note that the drawing corresponding to day 11 was not completed owing to the adverse meteorological conditions. These drawings are not accompanied by a graphical scale so we do not know for sure if they were all made exactly with the same scale. In any case, the group becomes increasingly more complex during days 11 and 12. We can also observe a marked tilt of about 20° thanks to Melo e Simas including the E–W direction in the drawings.

Conclusions

We have recovered 64 drawings of sunspots made by Melo e Simas in 1895–6 and 1898. The drawings are preserved in the archive of the Royal Astronomical Observatory of Lisbon. There are representations of the full solar disc and some detailed drawings of sunspots. To the best of our knowledge these observations were never analysed in the past. Here we have computed the sunspot number from the drawings of the complete solar disc. As expected, we found a statistically significant value of the correlation coefficient with the ISN. We have also obtained the ratio SN/G for these observations, showing that it is slightly higher (13·4 ± 0·5) than the average SN/G ratio obtained for modern observers (around 12). We have also analysed the detailed drawings of a large group of spots from 1898 March, having identified, with a high probability, that this large group was responsible for the flare that caused the great geomagnetic storm on 1898 March 15.

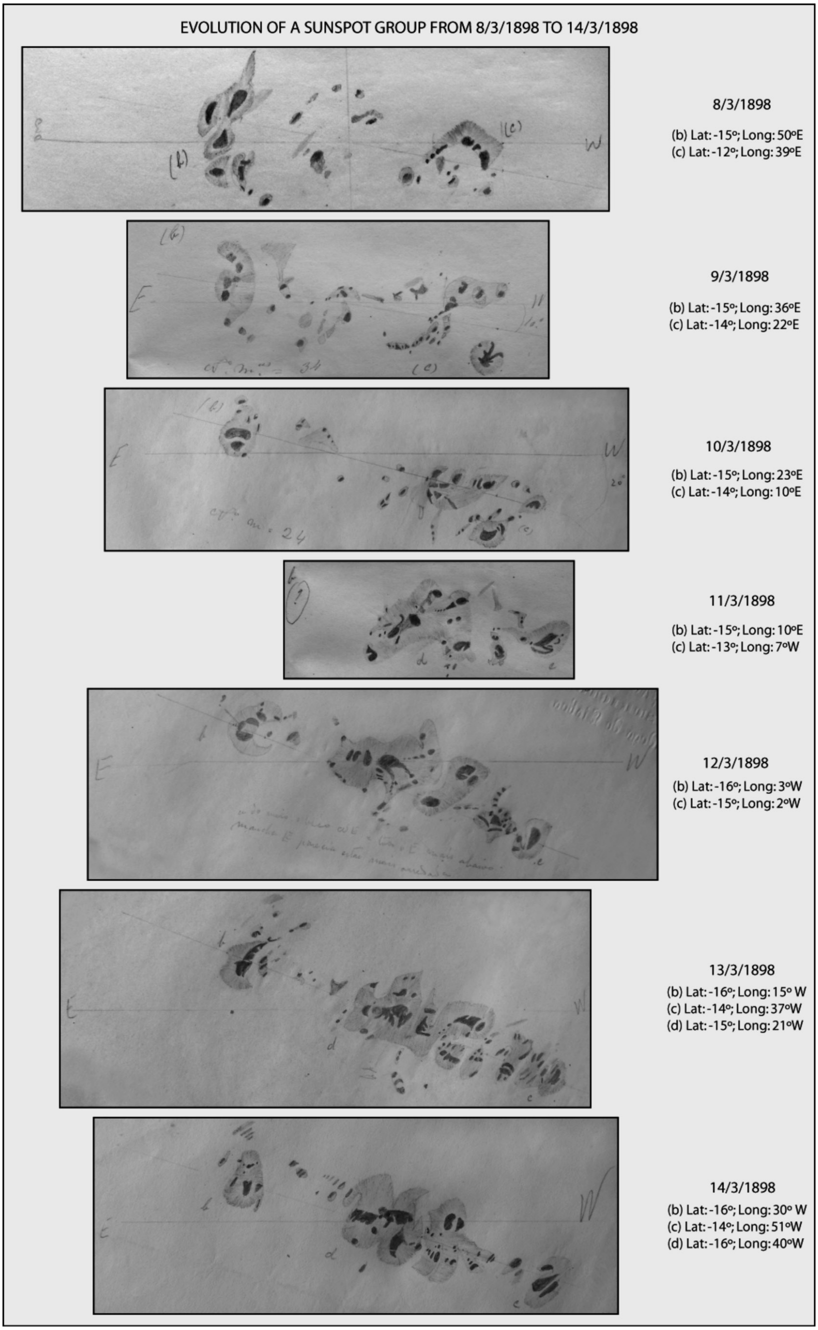

Fig. 5
Detailed drawings of sunspot group observed from 1898 March 8 to 14.

Acknowledgements

The documentary material used in the preparation of this work belongs to the Library of the Astronomical Observatory of Lisbon (Portugal). We thank Halima Naimova, librarian of AOL, for her keen interest and dedication. We also thank Henrique Leitão and David M. Willis for their useful comments. Support from the Junta de Extremadura (Research Group Grant No. GR10131) and Ministerio de Economía y Competitividad of the Spanish Government (AYA2011-25945) is gratefully acknowledged.

References

(1) M. Hoskin, ed., *The Cambridge Illustrated History of Astronomy* (Cambridge University Press), 1997.
(2) R. Carvalho, *A astronomia em Portugal no século XVIII* (Instituto de Cultura e Língua Portuguesa, Lisbon), 1985.
(3) M. Ferreira, *Para a história da Astronomia em Portugal* (CTT Correios, Lisbon), 2002.
(4) V. H. Bonifácio, *Da Astronomia á astrofísica. A perspectiva portuguesa (1850–1940)*, PhD dissertation, Universidade de Aveiro, 2009.
(5) P. Raposo, *Polity, precision and the stellar heavens: the Royal Astronomical Observatory of Lisbon (1857–1910)*, PhD dissertation, University of Oxford, 2010.
(6) D. V. Hoyt *et al.*, *Geophys. Res. Lett.*, **21**, 2067, 1994.
(7) D. V. Hoyt & K. H. Schatten, *Solar Phys.*, **181**, 491, 1998.
(8) J. M. Vaquero, *Adv. Space Res.*, **40**, 929, 2007.
(9) R. Arlt, *Solar Phys.*, **247**, 399, 2008.
(10) J. M. Vaquero *et al.*, *ApJ*, **731**, L24, 2011.
(11) E. Mota *et al.*, *British J. for the History of Science*, **42**, 245, 2009.
(12) M. S. Melo e Simas, *Jornal de Sciências Matemáticas, Físicas e Naturais da Academia de Sciências de Lisboa*, **5**, 115, 1926.
(13) F. Clette *et al.*, *Adv. Space Res.*, **40**, 919, 2007.
(14) L. Tóth *et al.*, *Journal for the History of Astronomy*, **33**, 278, 2002.
(15) H. S. Jones, *Greenwich Observatory Sunspot and Geomagnetic Storm Data* (Her Majesty's Stationery Office, London), 1955.
(16) D. F. Neidig & E. W. Cliver, *A Catalog of Solar White-Light Flares (1859–1982), Including Their Statistical Properties and Associated Emissions* (Hanscom AFB, Air Force Geophysics Laboratory, Report AFGL-TR-83-0257), 1983.
(17) E. W. Cliver & L. Svalgaard, *Solar Phys.*, **224**, 407, 2004.

CORRESPONDENCE

To the Editors of 'The Observatory'

Coleridge's "Hornèd Moon"

Smith & Smith[1] propose an interesting mechanism to explain transient lunar phenomena (TLP) and introduce their account with a reference to *The Rime of the Ancient Mariner* by Samuel Taylor Coleridge, particularly to the famous (or perhaps infamous) couplet:

> The hornèd Moon with one bright star
> Within the nether tip.

I have discussed this quotation myself recently, in the context of a partial survey of astronomical references in English literature[2], and the article by Smith & Smith prompts me to present some of the ideas there to a wider readership.

It is useful to recall that although Coleridge (1772–1834) is remembered primarily as a poet, he was keenly interested in and knowledgeable about the science of his day. He attended some of the earliest meetings of the British Association for the Advancement of Science and it was his objection, voiced at one such meeting, to the mid-19th-Century practitioners of science calling themselves "philosophers" that led William Whewell to coin the word "scientist" in the 1830s — a coinage that was not fully accepted until about a hundred years later. Coleridge, therefore, knew perfectly well that the phrase he chose, literally interpreted, described an astronomical impossibility. Thus, we are led to wonder why he wrote the line he did. Some have sought the explanation in an old sailors' superstition that a bright star close in the sky to the Moon was an ill omen, and Coleridge does indeed refer a few lines later to "the star-dogg'd Moon". If that had been his intention, however, he could equally well have written "beneath the nether tip". In fact, according to Martin Gardner[3], Coleridge did originally write "almost atween the tips", a perfectly possible configuration, which makes clear that his adoption of the final form was quite deliberate.

Martin Gardner, whose columns for many years in the *Scientific American* were often one of the highlights of the issues in which they appeared, also wrote *The Annotated Ancient Mariner*, in which he discusses this couplet at length. Like Smith & Smith, he comes to the conclusion that Coleridge had been influenced by recent reports of what we now call TLP. In particular, he cites the reports of Cotton Mather and Neville Maskelyne, also noted by Smith & Smith. Maskelyne's observation was quite recent in Coleridge's day and Mather's only about a hundred years old. Both reports were from reputable people (Mather's reputation as a Puritan preacher tends to overshadow the facts that he was a Fellow of the Royal Society and an early pioneer of a form of vaccination against smallpox). Gardner suggests that Coleridge wanted to describe a phenomenon that was real but unusual and considered the reports of these two reliable men to be sufficient evidence that the impression of "one bright star within the nether tip" could, in fact, sometimes arise.

Yours faithfully,
ALAN. H. BATTEN

2594 Sinclair Rd,
Victoria, B.C.,
Canada, V8N 1B9

2012 March 28

References

(1) G. J. Smith & A. J. Smith, *The Observatory*, **132**, 71, 2012.
(2) A. H. Batten, in E. Badolati (ed.), *Second Meeting on Cultural Astronomy* (Lofredo Editore, Napoli), 2010, pp. 21–30.
(3) M. Gardner, *The Annotated Ancient Mariner* (Antony Blond, London), 1965.

REVIEWS

Astronomy with a Budget Telescope, by P. Moore & J. Watson (Springer, Heidelberg), 2012. Pp. 173, 23·5 × 15·5 cm. Price £31·99/$34·95/€34·95 (paperback: ISBN 978 1 4614 2160 3).

While visiting the Greenwich National Maritime Museum with an old friend a few months ago, and having been singularly unimpressed with the free-to-view exhibits, we passed the time by browsing the gift shop. We came across a large display of amateur astronomical telescopes. Now the last time I checked, which was several years ago, my ambitions to own a telescope had been thwarted by thoughts of how could I possibly justify the thousands of pounds cost on merely a passing interest. The gift-shop display, which featured significantly chunky and serious-looking telescopes, revealed that with the passage of time the cost had come down dramatically to a few hundred pounds. As if pre-ordained, Sir Patrick Moore and John Watson have published this book just in time for me finally to indulge my long-term, but vague, interest in amateur astronomy and guide me through the process of buying and using one of those chunky beasts. Moore & Watson's book targets telescopes within a budget of roughly £250 that may be bought in department stores, over the internet, and, I guess, in museum gift shops, but specifically not those from respected specialist telescope shops.

I appreciate that many, maybe most, readers of *The Observatory* will be very familiar with optical telescopes and all the handy rules of thumb associated with them, but as one who has spent a career in space telescopes, usually at the X-ray or EUV end of the spectrum, these arcane rules came as something of a revelation — such as the relationship between aperture and usable magnification and the handy hint to remember to cap your finder telescope when observing the Sun. Even more of a revelation was the clarity and no-nonsense but quite chatty approach of the text, with the sound of Sir Patrick Moore's slightly impatient cadences resonating in my head. It was, however, a small source of mean-spirited delight to find a tiny error: the conversion of both half an inch and two inches to 25 mm — teacher sometimes gets it wrong. Oh yes, there is also a typo in the date the authors give for the next transit of Venus.

The initial chapter on the basics of telescopes and the huge importance of stable mounts was a delightfully accessible read. The next, on observing Solar System objects, was rather a downer simply because other than Jupiter and Saturn most Solar System objects seen in a small telescope seem to be frankly rather dull. The Moon is readily accessible with binoculars and the Sun needs either a specialist Hα telescope or a good (expensive) filter. In this observing section of the book the authors show images of cosmic targets as they would be seen visually in a typical low-budget telescope — they emphasize that these images represent the visual appearance and not what might be achieved with photography. These are a really excellent feature, and coupled with the practical tips for observing, provide a benchmark of what to expect. However, these realistic small-telescope images compared to the wonders from *HST* and other high-tech marvels, which can be seen on-line, throw the backyard astronomer's view into an unflattering light. So hope comes with the chapter on astro-photography — but again aspirations seem to be dashed by the poor manual-tracking performance of many inexpensive telescopes and the somewhat limited exposure-timing capabilities of standard digital cameras. The ever- enthusiastic Patrick and John persist and show what can be done with patience and a little work with computer processing; in their case using PAINT SHOP PRO, and some truly beautiful and detailed images result.

Finally they review low-budget telescopes, and although many were checked they publish results for just two. From unpacking the box to first light the authors declare themselves impressed. The two telescopes are the Tasco Luminova 675× Reflector (110 mm), which comes with an equatorial mount on a tripod and manual drives at about £175, and the SkyWatcher Explorer 130P SupaTrak (130 mm) which comes on a single-fork altazimuth mount and motorized drive on a tripod for around £250 — an image of this telescope decorates the front cover of the book. In these reviews the authors compare the performance of the low-budget telescope with a similar-sized but higher-quality telescope, a 90-mm Meade ETX (about £450). They view various astronomical targets and actually go some way to dispel some of the expectation management of their earlier chapters. Their obvious enthusiasm and delight as each of the telescopes achieved particular goals — image quality, drive stability, star separation, colour differentiation, lack of glare — was quite a telling insight into astronomy as a hobby. Both of the reviewed models were delivered with well-aligned optics, straight from the box, so there was no practical information on how to align them, which is a pity as it would be helpful for those whose telescopes arrive in a less-perfect condition.

This is a lovely, chatty, but also fully practical book, and if such telescopes had been around when I was 12 I am sure such a book would by now have guided me towards a serious telescope habit. The authors make the point that, although inexpensive, these telescopes are good-quality devices and not toys, and using them will inspire rather than discourage. This seems to me as good an excuse as any for generous and indulgent parents and grandparents, not already in possession of an astronomical telescope, to go out and get one and inspire the next generations of *Observatory* readers. — BARRY KENT.

Dark Nebulae, Dark Lanes, and Dust Belts, by A. Cooke (Springer, Heidelberg), 2012. Pp. 254, 23·5 × 15·5 cm. Price £35·99/$39·95/€39·95 (paperback; ISBN 978 1 4614 1185 7).

Antony Cooke is a cellist, composer, and former professor of music at North-Western University, Chicago. He is also a regular author for Springer on astronomical matters, and exudes great enthusiasm for his subject. In *Dark Nebulae, Dark Lanes, and Dust Belts*, Cooke describes a neglected area in the deep-sky observers' canon, the dark nebulae, and in addition he includes almost anything that may be perceived as dark in relation to deep-sky objects.

Cooke really should have spent less time on all these possible 'dark bits' in open and globular clusters, planetary nebulae, and galaxies, and could have usefully given us a modern view of observing true dark nebulae, a topic of increasing interest in amateur circles. The recently republished *A Photographic Atlas of Selected Regions of the Milky Way* (Barnard & Dobek, CUP, 2011; see review in **131**, 320) has inspired several amateurs to image the clouds of gas and dust from which we all ultimately are made. In fact, E. E. Barnard, the pioneer of photographing the dark clouds of the Milky Way Galaxy, gets very minimal coverage by Cooke. His catalogue is mentioned, some observing targets listed, but it is skimpy. He mentions the catalogue compiled by Brazilian astronomers Bica & Dutra in 2002, but fails to include any reference to that of Lynds, a much more familiar catalogue.

While there is lots of enthusiasm, the subject is described in a most verbose style. Trying to tease out the useful tips and descriptions is like wading through treacle. There is a great deal of up-to-date astrophysics but it is conveyed in waffly prose that can be hard going.

There is an emphasis on the use of image intensification and CCD videos. Cooke observes from dark skies and with large apertures, conditions and instruments that are not often encountered by amateurs in the UK. Such intensifiers are expensive, although clearly they can yield interesting results. Cooke does not describe other imaging techniques, but of course these can be found elsewhere.

The illustrations, all monochrome, are rather poor, particularly as so many superb amateur colour images of dark nebulae and other deep-sky objects can be seen in this era. The majority are from the *Hubble Space Telescope* and ESA, or from Cooke's own image-intensifier system. The latter look very old-fashioned, rather like pioneer CCD images of 20 years ago. It is true that Cooke is predominantly a visual observer with image intensification, but one would not be persuaded to part with much money on the basis of these examples.

There are some errors. Cooke describes the 'forbidden' spectral line attributed to 'Nebulium' as a dark absorption feature in the spectrum (p. 205) when it is of course a bright green emission line due to doubly-ionized oxygen. This reviewer has never heard of NGC 7662, a bright planetary nebula in Andromeda, being described as Barnard's nebula. It has a well-used nickname of the 'Blue Snowball'. Even the great purveyor of multiple astronomical nicknames, Steven James O'Meara, only terms it the "Light Blue Snowball". Barnard was interested in it, especially the central star, but never left his moniker with it.

The most likely beneficiaries of this book may well be the keen and more-advanced visual deep-sky observer who loves to chase features such as dark 'lanes' in globular star clusters and the dusty areas of spiral galaxies, but the volume is expensive for a poorly produced book with rather woolly text and is likely to have a small readership at present. — NICK HEWITT.

Planetary Nebulae and How to Observe Them, by M. Griffiths (Springer, Heidelberg), 2012. Pp. 302, 23·5 × 17·5 cm. Price £31·99/$34·95/€34·95 (paperback; ISBN 978 1 4614 1781 1).

One of the 'How to Observe Them' series by Springer, this is a welcome addition to the literature, as planetary nebulae, despite being some of the most popular deep-sky objects, have been seriously neglected, with few observing guides published since the relevant *Webb Society Handbook* in 1979.

Despite the book being an observing guide, the opening chapters discuss the history, discovery, and evolution of planetary nebulae. With the exception of several typographical errors, these are well written and give a comprehensive and up-to-date account of the current ideas on planetary-nebula formation. A chapter on observing discusses telescopes, eyepieces, filters, transparency and seeing, and the use of averted vision. Again these are well written and comprehensive, although the section on eyepieces is rather dated. Narrow-band filters are a vital tool for the visual observer and the use and merits of O III, UHC, and Hβ filters are discussed. Rather surprisingly, however, the Hα filter is also suggested for visual use. This is a photographic filter and is not suitable visually owing to the low sensitivity of the eye at that wavelength.

Two lists of planetaries are given for observation: a main list of 135 objects drawn largely from the *NGC* and *IC*, and a further substantial list including many faint and obscure objects. Probably the majority of these additional objects will require a telescope in the half-metre-plus class to see, but it is good to have them listed for observers wanting a challenge. Almost two-thirds of the book is taken up with descriptions and photographs of the 135 planetaries in the main list. The descriptions are largely accurate and the photographs have generally reproduced well. However, the constellation and finder charts that accompany them are extremely poor and it is difficult to see what purpose they serve. In many cases the constellation charts are reproduced to a scale that makes them impossible to read, while the finder charts appear out of focus and frequently plot several objects on top of each other so they become almost useless.

A useful and comprehensive list of further reading covering many aspects of planetary nebulae is included, although no internet resources are listed. In summary, this is a useful guide to observing these 'butterflies' of the night sky; it is just a pity that it has been spoilt by such poor-quality star charts. — STEWART MOORE.

Destination Mars: New Exploration of the Red Planet, by R. Pyle (Prometheus Books, Amherst, NY), 2012. Pp. 290, 20·5 × 13·5 cm. Price $19 (about £12) (paperback; ISBN 978 1 61614 589 7).

Firstly, the book I received for review was a pre-publication copy. The blurb on the back states: "In the next decade, NASA, by itself and in collaboration with the European Space Agency, is planning a *minimum* of four separate missions to Mars". It doesn't need me to tell anybody interested in space exploration that this is unfortunately not true. I decided to investigate inside and found a few pages about future projects — none of it about the exciting times to come prophesized on the cover. But the author appeared to believe that parts of NASA's programme which Mr. Obama changed from *Constellation* to *Cancellation* were happily proceeding.

By the time I had read several different numbers quoted for the distance from Earth to Mars (none of them very well explained) and been told that a gas chromatograph–mass spectrometer measured elements (rather than compounds) I didn't have a very good feeling about the book. It was magnified when I discovered one of the Moons of Mars was called "Diemos" [*sic*].

Nevertheless, the second paragraph of the blurb had told me to expect "an insider's look" and "stunning insights" into what had happened already so I persevered. A subject of immense interest in that respect is what happened during the behind-the-scenes debate over the results of *Viking*'s life-detection experiments. I for one would have liked to have been a fly on the wall. All I got from reading the account given by the author was that there "was much head-scratching and soul-searching". I think we all knew that already.

There are some other well-known events, such as *Mars Climate Orbiter* being lost because of a mix-up between imperial and metric units. One might have expected to read the 'what-really-happened' version. Instead we are told it was a case of "JPL trying to do too much with too little". I have many friends, including an enormous number in NASA, who will get a good laugh when they read elsewhere that to carry out the exploration of Mars and the rest of the Solar System, JPL "had to make do with leftovers". Leftovers from the Apollo programme they might have been but … .

Just before I began to write this review I was sent an actual published copy. The extravagant claims on the back had gone to be replaced by some glowing testimonials. Inside, thankfully, the spelling of Deimos had been corrected but not much else.

In summary this book is a good idea but the result doesn't quite match up with what it [said] says on the tin. It shows all the signs of having been overtaken by events and presumably the publisher has tried to recover the situation. The insertion of colour photographs doesn't make up for the inadequacy of the tiny black-and-white illustrations in the text. Important ones are unreadable; others have been shown better many times previously.

In all probability the reason I'm left unsatisfied is because I know too much. But many of *The Observatory*'s readers are likely to be informed already at a much higher level than is revealed by this treatment. I would be wrong to recommend in this *Magazine* the book's purchase for their bookshelves. — COLIN PILLINGER.

The Andromeda Galaxy and the Rise of Modern Astronomy, by D. Schultz (Springer, Heidelberg), 2012. Pp. 283, 23·5 × 15·5 cm. Price £31·99/$34·95/€34·95 (paperback; ISBN 978 1 4614 3048 3).

Author Schultz is an avid amateur astronomer with a master's degree in astronomy from the James Cook University in New Zealand, but his other six advanced degrees are in law, political science, and philosophy, and he is currently a professor in the School of Business at Hamline University in St. Paul, Minnesota. He has probably written a better book about astronomy than I could about law, political science, or business, but possibly not by much. Like the chap who was asked if he could play the trumpet, I can only say "I don't know; I haven't tried".

Schultz begins with the Greeks, trundles on to Copernicus, Curtis and Shapley*, Hubble, and bits of non-optical astronomy, and every one of the 283 pages has at least one item about which one has to say "oops", "no", "NO", "HELL NO", "eh?", or other syllables of doubt and disagreement. Here are only three favourites: (*i*) Fig. 10.13 is said to be an M 31 image from the *Hubble* telescope. It is not M 31 (unless possibly its passport picture†) and not from *HST* unless perhaps pre-repair; (*ii*) Figs. 4.7 and 4.8 are captioned "Refractor telescope" and "Reflector telescope", respectively, but the 'refractor' has a concave primary mirror, and the 'reflector' has a main lens (those and nearly all the other drawings have been pixellated to make diagonal lines and curves impossible); and (*iii*) a direct quote, "From the Population I stars Population II are created, along with the material for nebulae and rocky planets such as Earth." The Sun is, however, Population I a paragraph before. — VIRGINIA TRIMBLE.

Eta Carinae and the Supernova Impostors (Astrophysics & Space Science Library Vol. 384), edited by K. Davidson & R. M. Humphreys (Springer, Heidelberg), 2012. Pp. 339, 24·5 × 16 cm. Price £108/$169/€119·95 (hardbound; ISBN 978 1 4614 2274 7).

During its 'Great Eruption' of the 1840s, η Carinae reached apparent magnitude –1, and was the second-brightest star in the night sky. Over perhaps a decade or so during that event it ejected an astonishing 10–20 solar masses of material, creating the bipolar 'Homunculus' nebula we see today, about 10″ in size (and growing), and widely familiar from the *HST* images that have been published since the mid-1990s.

*Or Shapely as he appears on p. 152, along with a figure caption calling him Howard Shapley.

†Fans of the Richard Armour version of *The Merchant of Venice* may recall that the second suitor pulls out of the Casket of Silver an image that, if Ophelia, can only be her passport picture.

The Homunculus is a highly-structured reflection nebula, so spatially resolved spectroscopy can give us an almost 3-dimensional view of the illuminating star, revealing a latitude-dependent stellar wind. The nebula is also dusty, absorbing most of the hot central source's copious UV emission, and re-radiating it in the IR; it is the brightest object in the 10–20-μm range outside the Solar System, the luminosity of $\sim 5 \times 10^6$ $L_\odot$ implying a correspondingly high stellar mass, of perhaps 100–150 $M_\odot$. At the heart of the nebula, on sub-arcsecond scales, lie the peculiarly bright 'Wiegelt blobs', and the star itself. Attempts to characterize the temperature and radius of the central star are challenged by its optically thick wind, the current mass-loss rate of $\sim 10^{-3}$ $M_\odot$ yr^{-1} creating a false photosphere, but the hydrostatic radius (where the outflow velocity reaches the sound speed) is certainly several hundred solar radii, or ~1–2 AU, in size. Spectroscopic 'events' on timescales of ~10–100 d were eventually noticed to repeat on a 5·5-year period, and attributed to the highly eccentric orbit of a high-temperature companion; the secondary has not been directly observed, but is responsible for much of the high-ionization emission-line spectrum. It skirts perilously close to the primary at periastron, penetrating deep into the wind and generating IR, optical, and X-ray variability through mechanisms not yet understood in any detail.

With such intricate behaviour across diverse spatial, temporal, and spectral regimes, η Carinae is, as one of the editors asserts, an entire research topic, not just an object. To cover all aspects of interest in reasonable detail needs a dedicated book (and even here there are topics, such as the source's gamma-ray emission, that are, at best, skimmed over). The format is a series of review papers by recognized authorities; although by far the greater part of the text is devoted specifically to η Car, its significance as a (rather extreme) Luminous Blue Variable and its importance as the nearest 'Supernova Impostor' are examined, as is the broader context of the properties and fate of very luminous, high-mass stars.

Editorial efforts are reflected in well-considered chapter topics and consistent formatting which, together with a reasonably thorough index, complement the baker's dozen of high-quality contributions. Colour is used extensively in figures to good effect (even if some colour images aren't always shown to best advantage). Overall, this is a fine volume that provides a valuable overview of a complex object. My only reservations concern the publisher's motivation in producing a book so obviously priced outside the reach of the individual scientist; it's hard for me to think of any reason other than to exploit an opportunity to milk the hard-pressed budgets of institutional libraries that feel obliged to subscribe to the *Astrophysics & Space Science Library* series. — IAN D. HOWARTH.

Molecules in the Atmospheres of Extrasolar Planets (ASP Conference Series, Vol. 450), edited by J.-P. Beaulieu, S. Dieters & G. Tinetti (Astronomical Society of the Pacific, San Francisco), 2011. Pp. 250, 23·5 × 15·5 cm. Price $77 (about £48) (hardbound; ISBN 978 1 58381 782 7).

The science of extra-solar-planet detection and characterization is undoubtedly one of the most rapidly evolving areas of astrophysics. This volume recognizes that, and is a useful 'snapshot' of observational and theoretical achievements related to this field, taking the form of Conference Volume 450 of the Astronomical Society of the Pacific — the proceedings of a meeting held at the Observatoire de Paris in 2008 November.

The first third of the book presents a logical progression — 'setting the scene' with two major overviews of the properties of planets in our own Solar System; a collection of studies related to the characterization of exoplanet atmospheres through transit observations (*i.e.*, monitoring the light received as the exoplanet starts to pass in front of or behind the visible disc of its parent star); and an interesting theoretical study by Lewis *et al.* related to the putative atmospheric dynamics of two eccentric, transiting worlds. Important lessons to emerge here include: (*i*) the continual need to use observations of our own Solar System as a point of comparison for exoplanet studies; (*ii*) the potential importance of molecular ions such as H_3^+ in the energy balance and stability of extrasolar-giant atmospheres (*e.g.*, the Maillard & Miller paper); (*iii*) the very challenging, but important, task of accounting for instrumental systematic effects when analysing ground-based spectra of exoplanet systems; and (*iv*) the potential of using timings of transits in observed light-curves as diagnostics of not only planetary orbits, but also those of adequately massive exomoons (*e.g.*, Kipping's paper).

Part IV of the book emphasizes the importance of accurate molecular-opacity calculations for analysing exoplanet spectra, and determining the physical and chemical conditions in their atmospheres. Important new results in this field are reported accordingly. Part V draws some important comparisons between the techniques used to analyse brown-dwarf spectra and their relevance to exoplanet studies. In particular, the modelling of cloud condensates and non-equilibrium chemistry is emphasized — areas which, in the context of exoplanet studies, are still in relative infancy.

Part VI contains an interesting theoretical study (by Lammer *et al.*) of atmospheric 'erosion' from Earth-like exoplanets which have expanded beyond the confines of their putative magnetospheric boundaries. Extension of the circulation model to three dimensions, and further exploration of the ill-constrained magnetic moment of such planets, would enhance this work even further. The Bayesian analysis of exoplanet radial-velocity data by Balan & Lahav, meanwhile, indicates that the eccentricity of planetary orbits may not be as well-constrained as previous analyses have claimed.

Part VII concludes the scientific content of the book with a preview of missions being planned at the time, many of which make use of developments in coronagraph technology to provide direct imaging of exoplanets in systems with an adequate star–planet brightness contrast and planetary orbital radius.

Overall, then, this book provides a useful summary of theoretical and observational developments related to the challenges of understanding planets within and outside our own Solar System. It also serves as a useful starting point for literature searches in this subject of rapid progress, with comprehensive referencing by the various authors. — NICHOLAS ACHILLEOS.

The Formation and Early Evolution of Stars: From Dust to Stars and Planets, 2nd Edn., by Norbert S. Schulz (Springer, Heidelberg), 2012. Pp. 515, 23·5 × 15 cm. Price £81/$119/€89·95 (hardbound; ISBN 978 3 642 23925 0).

Text-like books on star formation are not quite a dime a dozen, but Schulz's 2nd edition joins two 2011 volumes, Bodenheimer's *Principles of Star Formation* (reviewed in **132**, 48) and Ward-Thompson & Whitworth's *An Introduction to Star Formation* (at 228 pp. the slimmest of the three) in competition for your book orders. A preface explains the new material since the first, 2005, edition, including binary and multiple stars, X-ray results, the implications of exoplanet systems, and more about massive stars. The 900+ references have grown to 1300+. Deletions, if any, are not mentioned. Many of the references are rather incomplete, lacking, for instance, publishers for books by folk like Eddington and Jeans.

Tables translate abbreviations (though I would disagree that an SED goes only from IR to radio wavelengths) and names of institutes, observatories, and instruments (I recommend the pair for BIMA and CARMA almost worthy of Ambrose Bierce). The index is very complete — translation: I'm in it, though for a quotation said to come from a journal called 'Sky Telegram', which has no page numbers, though the author probably means *Sky and Telescope*, which does. And I'm very sorry to report that the grammatical error ("to our point of view", where "from our point of view" is meant) is in the original, which also says "Gorden and Gurney" where "Gordon and Gurney" is meant.

Star-formation rates and a very brief discussion of other galaxies lurk in the interstellar-medium chapter, though the index takes you there immediately. People named in the text are also indexed, though the choice of reference system makes everybody else difficult to find: the 1344 are numbered in the order they occur, listed at the back, and cited in the form "The study by [493] …".

The author's personal life has also evolved: the "long-time friend A …" who provided orthographic input to the first edition having been replaced by "fiancée E …" whose contribution was very helpful proof-reading.

All around, a sane, solid volume, forcing no problems on the reader (though I still prefer Bodenheimer, who does). A good place to start a serious reading is probably the appendices on gas dynamics, magnetic fields, plasmas, radiation, and spectroscopy. — VIRGINIA TRIMBLE.

The Ninth Pacific Rim Conference on Stellar Astrophysics (ASP Conference Series, Vol. 451), edited by S. Qian, K.-C. Leung, L. Zhu & S. Kwok (Astronomical Society of the Pacific, San Francisco), 2012. Pp. 360, 23·5 × 15·5 cm. Price $77 (about £50) (hardbound; ISBN 978 1 58381 784 1).

The *Pacific Rim Conference Series* started in 1985 in Beijing, and is held in Asian Pacific Rim countries, latterly with a cadence of three years. Participation is not limited to countries on the Asian Rim; the ninth conference — the third to be held in China — included a number of international participants, though the overwhelming majority was more local. It also ran in tandem with the closing week of an IAU International School for Young Astronomers, thus exposing the latter to a professional meeting and offering a select number the opportunity to present their own original research.

There is a lot of interesting stellar science in this book. The conference series initially focussed on binary stars, but while it still strongly features binaries, variables, CVs, and star formation, it now includes galaxies, star clusters, planets, high-energy astrophysics, and black holes, presumably reflecting an actual diversification of research in the countries represented at the meeting. Many of the light-curves, SEDs, and their respective modelling look superb, and the wealth of programmes that they represent is encouragingly dominated by data supplied by local telescopes; young astronomers from that corner of the world, at least, are getting that formative 'hands-on' experience. Most contributions are short, and some dwell longer on the background than on the progress being reported (not necessarily a fault), though those that describe an idea and promise to follow it up later leave the reader somewhat unsatisfied.

By and large the reproduction of the figures is good, given the inevitable scale reductions which publications of proceedings demand, though my comments (*The Observatory*, **129**, 170, 2009) regarding the incidental human portraits with which most ASPC proceedings are lightly peppered are still germane. Some of the papers are well-written, many contain a few mistakes, but — and this is going to be difficult to express kindly — in some, particularly in the first section, the level of English is poor, plagued by typos, mis-spellings, and wrong choices of words that lead to serious ambiguities. Chinese English tends to omit the definite and indefinite article, and there is a world of difference between "few points" and "a few points". Not infrequently a wrong verb form is used, if not omitted altogether, and sometimes the intended meaning had become so distorted that I never did sort it out.

I blame the editors. I am not under-rating the difficulty of writing fluently in a foreign language, and I would be hard pressed indeed to write a paper in Chinese. But English is our science's Esperanto; help should be available to those who are thereby disadvantaged, and the editors ought to have sought advice. If they supposed that the sole task of the editors is to see that the contributions run correctly through Latex, even there they failed because several give the tell-tale '?' for a reference, and the text does not always refer to the correct figure. There are trivial inconsistencies over people's names and affiliations, reinforcing the impression that little editing or proof-reading was carried out. Some of the worst mistakes actually occur in papers in which an editor was a co-author, but the Preface takes the biscuit. To publish a book that contains so much poor English does an injustice to all the contributors, especially the young astronomers. Beware, too — the author index is in alphabetical order of *first* names.

Notwithstanding, the contents are cutting-edge, full of stellar snippets, and certainly deserving of a place on the shelf among the other ASP conference proceedings. — ELIZABETH GRIFFIN.

From Interacting Binaries to Exoplanets: Essential Modeling Tools (IAU Symposium 282), edited by Mercedes T. Richards & Ivan Hubeny (Cambridge University Press), 2012. Pp. 568, 25 × 17 cm. Price £76/$125 (hardbound; ISBN 978 1 107 01982 9).

Several organizations in Slovakia hosted IAU Symposium 282 at Tatranska Lomnica in 2011 July. These are the proceedings in standard IAU format (author index only; good introductory and concluding talks by Petr Harmanec, Pavel Koubsky, and Adam Burrows; 8-page review talks, 4–6 page invited talks, and 2-page posters). An unusual feature was a set of four panel discussions, following each of four main divisions of the meeting (observations; model atmospheres and synthetic light and velocity curves; formation and evolution of binary stars, brown dwarfs, and planets; hydrodynamics). Most of the 12 panellists have been concerned with binary stars for many years, and four (Alan Batten, Albert Linnell, Robert Wilson, and VT) had actually been at the first IAU close-binary gathering, Colloquium No. 6, 1969 September, in Elsinore, Denmark. The best picture of VT appears on the bottom of page xxvi. The Elsinore proceedings had no photographs.

Of course many of the best presentations from among the 177 participants (31 countries) came from folks who had cut their astronomical teeth on exoplanets and weren't even born in 1969. But the problem of how to extract the best values of properties of stars (*etc.*) from observations of radial velocities and light-curves is still a major concern. Important progress has, however, come from the ability to assume properties for a system and then synthesize a set of possible observations to compare with the real ones. Among other areas with significant progress are polarimetry (reviewed by Karen Bjorkman, but with interesting observations of individual systems by N. Kostogryz and others), adaptive optics (reviewed by Sasha Hinckley), large data bases (Young-Woon Kang and others), and phase-resolved spectroscopy (many). The last word, however, belongs to Bohdan Paczynski, who (at the 1969 meeting, in response to a question from Batten) said that models of interacting binaries and mass transfer were not able to predict final rotation rates. According to Orsola De Marco and her colleagues, they still don't. In a more desirable parallel universe, Paczynski, who loved the Tatra mountains, would have been at IAU Symposium 282. — VIRGINIA TRIMBLE.

Astrophysical Jets and Beams, by M. D. Smith (Cambridge University Press), 2012. Pp. 228, 25 × 18 cm. Price £65/$105 (hardbound; ISBN 978 0 521 83476 6).

"Theorists have found the field of jets to be a lucrative playground", writes Michael Smith at the start of one of the more theoretical chapters; and indeed the same is true for the observers, as is well illustrated by this comprehensive book, which is aimed at graduate students. Within my scientific lifetime, the whole subject has been transformed from one of a few curiosities (M 87, streams emanating from comets) to the key item in many branches of astrophysics. We are given here a concise, but comprehensive, chapter on all the different areas in which jets are seen to take a part. Naturally this starts with extragalactic objects — AGN, with outrageously powerful and (frequently) huge jets, then young stars (HH objects and associated jets), evolved stars ('microquasars'), and Solar System jets (cometary outflows, solar jet production). There are chapters on aspects of the astrophysics, and overview chapters trying to unite some aspects of the disparate collection. The book seems well thought out, and I would certainly recommend it; at least a copy (or two) in your departmental library, and one for any student starting work in this field. The physics is of course done largely in old-fashioned cgs units (I work in a physics, not astronomy, department), but I don't expect that to change too quickly.

I did find one or two aspects of the historical survey which might be improved. In chapter 1 the *3C Catalogue* (1959, revision in 1962) is described as containing images of many of the sources, but it did not; it was a list of positions and flux densities, with a few notes about angular sizes. Structural information in serious quantities arrived with the commissioning of the next generation of radio telescopes: the *One-mile* (1965), Westerbork (1970), the *5-km* (1972), and the *VLA* (1980). The famous paper by Fanaroff & Riley in 1974 (Chapter 4 of this volume) used data from the *One-mile* telescope on many of the 3C sources, and not only distinguished the 'edge-brightened' and 'centre-brightened' classes of extragalactic source, but also showed that they were distinguished by their radio luminosities. And of course there are some typos, of which the most amusing is the one placing W50/SS433 at a distance of 4·5 pc. — GUY POOLEY.

Relativistic Cosmology, by G. F. R. Ellis, R. Maartens & M. A. H. MacCallum (Cambridge University Press), 2012. Pp. 622, 25 × 19·5 cm. Price £80/$130 (hardbound; ISBN 978 0 521 38115 4).

Relativistic Cosmology is unusual in that its scope goes well beyond typical cosmology texts. It is an authoritative account which includes alternatives to the Friedmann–Lemaître–Robertson–Walker (FLRW) universes most students are familiar with. Prepare to drop long-held assumptions and see what happens. The result will be a little unnerving for readers whose knowledge assumes homogeneity and isotropy, which underpin the familiar FLRW metric. If these assumptions are dropped, then which of our cherished beliefs still hold? The answer is some, but not all, and the exploration of the resulting richness is very rewarding. Many of the interesting excursions here are results of original work by the authors over many decades, and some are quite surprising, such as the revelation that non-zero vorticity means that cosmic time cannot even be sensibly defined for fundamental observers, or that some solutions to the Newtonian cosmological equations are not valid solutions in General Relativity. A third example answers the question (a qualified yes) of whether observation of an isotropic microwave background sky, with the Copernican Principle, implies that the metric is FLRW. The book demands a high level of mathematics, but that is not to say that the book makes little connection with observation. Far from it — one of its strengths is a great precision in relating observable quantities carefully to the variables in the formalism. These issues are topical these days, as observational cosmology probes scales where one has to take great care of such issues in order to get precise results. Other topics of current interest, such as back-reaction effects of clustering on the global evolution of the Universe, are also presented. The material is set out logically and in detail, and would warrant careful study. Be prepared to make a big commitment though — something as simple as an Einstein–de Sitter universe does not make a real appearance until page 216, as the general framework is built up first. The book ends with musings on multiverses and alternative universes, and brief discussion of some philosophical questions such as why the Universe is as it is. It is highly recommended for readers comfortable with mathematics and cosmology at advanced undergraduate or graduate level. — ALAN HEAVENS.

Here and There

JUMPING THE GUN (AND FORGETTING 2004)

Venus passes across the face of the sun early yesterday, an event not witnessed since 1882. — *Daily Telegraph*, 2012 **June 1**. (caption to photograph of transit)

THE TIRED-LIGHT HYPOTHESIS?

… some reaching as fast as 48 million kilometres per hour (44 percent of the speed of light). — *Astronomy Now*, 2012 May, p. 9.

A WHOLE RADIUS MIGHT SAVE SOMEONE ELSE'S TOO

… pushing an NEO at least half an Earth radius one way or the other would mean it misses our precious home. — *Astronomy Now*, 2012 May, p. 22.

INFLATION MUST BE A UNIVERSAL PROPERTY!

… one of the approximately 250,000 globular clusters that surround our galaxy. — *Daily Telegraph*, May Night Sky.