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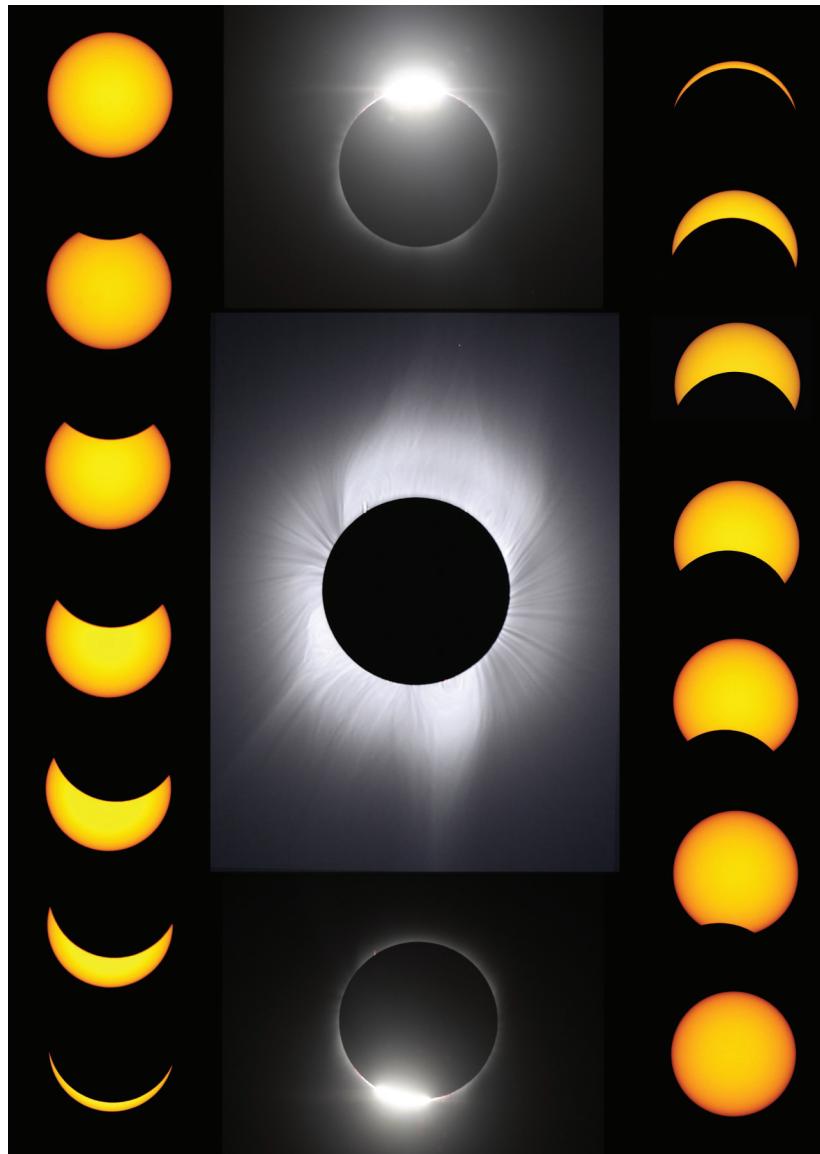


PLATE 1. Total solar eclipse over Novosibirsk, Siberia, Russia (2008 Aug 1): A time-series presentation of the various partial phases before and after totality spaced 15 minutes apart, the two diamond rings announcing the onset and completion of totality, and the totally eclipsed Sun with extended corona in all its glory. Images taken from the rooftop of the Institute of Nuclear Physics in Novosibirsk by Anthony Aiyionamatis.

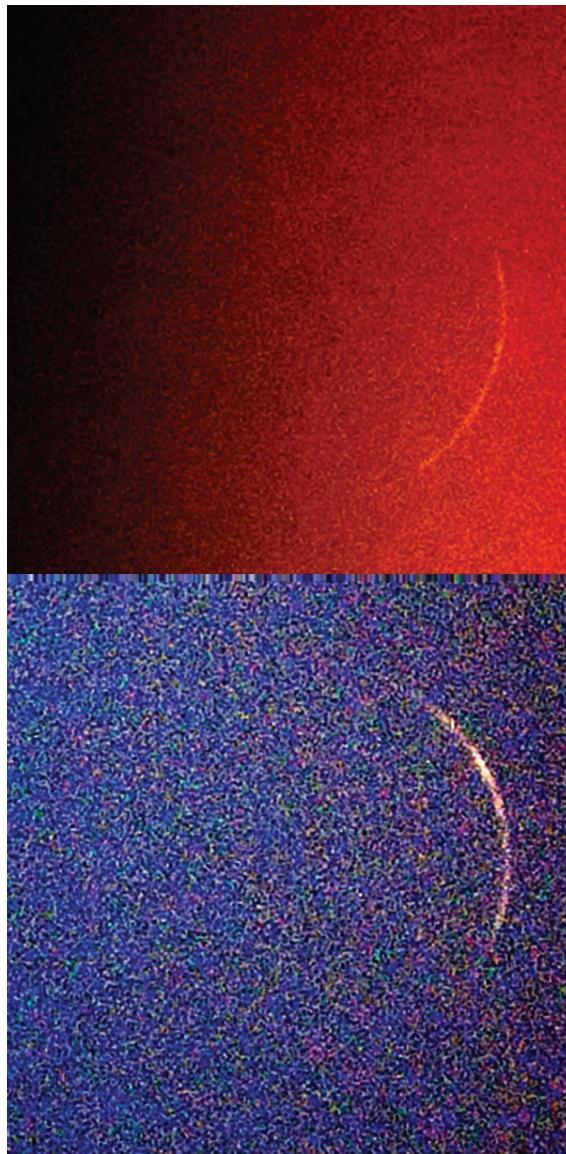


PLATE 2. Back-to-back crescents as seen from Ma'ale Adumim, Israel: on the right the waning crescent on Tuesday 2008 June 03 05:04 (UTC+3) and on the left the waxing crescent Moon on Wednesday 2008 June 04 20:12. These photographs are contrast enhanced for clarity. Images supplied by Roy Hoffman to accompany his paper which commences this issue.

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BACK-TO-BACK CRESCENT MOONS

By Roy E. Hoffman

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The waning and waxing crescent Moon on consecutive days, a back-to-back sighting, has been photographed for the first time in the world and observed for the first time in the Middle East. This possibility is a very rare occurrence whose observation is reported in detail and its archaeo-astronomical significance is discussed.

Introduction

The appearance of the young crescent Moon has been used throughout recorded history to determine calendars and is still the basis of many around the world including the Jewish, Chinese, and Hindu calendars. Some calendars still use actual Moon sightings today, the most prominent of them being the Moslem one. As a result, the appearance of the crescent Moon has been studied for millennia, although modern scientific studies only date back 150 years^{1,2}.

The possibility of sighting the thinnest crescent Moon is difficult to calculate³ and is an observational challenge that has been taken up by amateur and professional astronomers. Many observers around the world look for these crescents each month. While some are applying or researching lunar calendars, others are doing it only for the challenge.

It is very rare for there to be only one moonless night between the last waning crescent and the appearance of the new crescent, a so called back-to-back sighting. At tropical and subtropical latitudes there are usually two or three and occasionally four moonless nights. Opportunities for such double observations arise on average about once in 15 years at any one location and even then require very clear conditions on both occasions.

Apart from the observational interest, these observations are of archaeo-astronomical significance as their occurrence is discussed in ancient and historical religious writings as described below.

Results

Naked-eye back-to-back sightings have been reported on two occasions. The first, from the South African Astronomical Observatory, was on 1985 December 11/12 by Laing⁴. The second was from Mauna Kea, Hawaii, on 1994 December 31/1995 January 1 by O'Meara⁵. There are also three reported back-to-back crescent observations using optical aid (Table I).

The Israeli New Moon Society was set up in 1999 to research the appearance of the crescent Moon with respect to the Hebrew calendar⁶. The Society has trained observers, gathered a large database of sightings⁷, and fine-tuned lunar-visibility criteria⁸.

A concerted effort was made by tens of members of the Israeli New Moon Society to observe these back-to-back crescents. This is the first, well-documented case of a back-to-back naked-eye sighting from one location in Israel, the Middle East, or at less than 1750 metres above sea-level from anywhere in the world, and the first time that such a pair of sightings has been photographed (Plate 2)⁹.

Usually, at the latitude of Israel, the Moon disappears for two, three, or occasionally four nights. Theoretical calculations using the 'DALT-width' (difference in altitude of the Moon and Sun – width of lunar crescent) criterion as described in a previous paper⁸ indicate that once in about 15 years in Israel, the Moon has a reasonable chance of disappearing for only one night. There was a relatively good case on 2008 June 3/4 where the probability of a single observer observing both crescents was calculated⁸ at 24%. These occurrences are very rare with only one better opportunity this century, on 2073 October 30/31 with a probability of 28%. Other examples in this century with a probability above 10% occur on 2014 January 30/31, 2026 May 16/17, 2027 June 4/5, 2062 July 6/7, and 2080 June 17/18. In theory the new Moon should have been easier to see than the old Moon, but hazier skies on 2008 June 4 meant that both observations were extremely difficult.

As a result of a concerted effort by the Israeli New Moon Society, six observers in five locations reported attempting to observe the very difficult waning crescent on the morning of 2008 June 3. The author (Hoffman) observed the Moon in a clear sky from 04:53 till 05:10 (UTC+3) from Ma'ale Adummim ($31^{\circ} 47' N$, $35^{\circ} 18' E$) with binoculars but could not see it with the naked eye. Two observers at Efrat ($31^{\circ} 38' N$, $35^{\circ} 9' E$) both saw the Moon with binoculars from 04:50 till 05:10 but only one (J. Rosenfeld) saw it with the naked eye from 04:50 till 04:52. This is the closest naked-eye sighting to a conjunction ($16^h 32^m$)

TABLE I

Back-to-back crescent observations previously reported and reported in this work

Date	Name	Location	Latitude	Longitude	Height	How seen
1985 March 09/10	J. D. Laing	SAAO	$32^{\circ} 23' S$	$20^{\circ} 49' E$	1763	Naked eye
1990 April 24/5	J. Bortle	NY, USA	$41^{\circ} 36' N$	$70^{\circ} 42' W$	30	Binoculars
1994 December 31/	S. J. O'Meara	Mauna Kea, HI, USA	$19^{\circ} 48' N$	$155^{\circ} 30' W$	4160	Naked eye
1995 January 1						
1998 January 27/28 ^{13,14}	D. Pearce	Houston, TX, USA	$29^{\circ} 46' N$	$95^{\circ} 22' W$	10	Binoculars
2004 October 13/14 ¹⁵	J. Stamm	Tucson, AZ, USA	$32^{\circ} 18' N$	$111^{\circ} 02' W$	760	Telescopic
2008 June 3/4	J. Rosenfeld	Efrat, Israel	$31^{\circ} 38' N$	$35^{\circ} 09' E$	900	Naked eye
2008 June 3/4	R. Hoffman & N. Guberman	Ma'ale Adummim, Israel	$31^{\circ} 47' N$	$35^{\circ} 18' E$	420	Binocs/Naked eye

TABLE II

Observations of the waning crescent Moon from Israel on 2008 June 3

Name	Location	Latitude	Longitude	Height m	How seen	Time
Roy Hoffman	Ma'ale Adumim	31° 47'N	35° 18'E	430	Binoculars	04:53–05:10
Chaim Mackler	Beer Sheva	31° 15'N	34° 47'E	330	Not seen	Clouds
Yosef Musa	Ofakim	31° 19'N	34° 37'E	140	Not seen	Haze
Joshua Rosenfeld	Efrat	31° 38'N	35° 09'E	900	Naked Eye	04:50–04:52
Tom Rosenfeld	Efrat	31° 38'N	35° 09'E	900	Binoculars	04:50–05:10
Magdi Shmuel	Ashdod	31° 48'N	34° 39'E	0	Not seen	Clouds

and the thinnest crescent (17'') ever reported in Israel. The other observers did not see the Moon, possibly due to clouds or haze (Table II).

Because only one observer saw the waning crescent, it is important to provide extra evidence to support this claim. J. Rosenfeld is an experienced observer who has received observational training. Two examples of his previous observations are on 2007 July 15 when he was second out of 11 observers distributed around Israel to see the Moon and on 2008 May 6 when he was the first of 16 observers. His description of the 2008 June 3 sighting matched the calculations for height, direction, orientation, and crescent thickness. His observation was confirmed with binoculars. All of the above lends support to the reliability of his observation.

At least 28 observers gathered around Israel to observe the Moon on Wednesday 2008 June 4. A group of about 15 observers at Kerem Byavne Yeshivah observed the Moon with binoculars between 20:07 and 20:20. Four of them saw the Moon with the naked eye starting at 20:10. The author photographed the Moon from Ma'ale Adumim but could not see the crescent. However, another observer (N. Guberman) there did manage to see the Moon with the naked eye. Three people observed the Moon with the naked eye from Efrat completing the back-to-back naked-eye observation from a single location. The results for the evening of 2008 June 4 are listed in Table III.

Archaeo-astronomical significance of back-to-back Moons in ancient and historical religious texts

The fact that these observations were made from the Middle East and Israel in particular is of significance because of the wealth of ancient and religious texts written in the region that deal with the appearance of the Moon.

Up until about 1600 years ago the months of the Jewish calendar were determined by a religious court according to eyewitness accounts of the Moon's appearance. The *Mishna* is a compendium of Jewish law that was compiled in the 1st and 2nd Centuries and in the following case refers to an event that took place around the year 84. The *Mishna* (*Rosh Hashanah*, Ch.3, para. 9) relates a story of two observers who claimed to have seen the waning crescent Moon in the morning and the waxing crescent the same evening. The *Mishna* states that if the crescent Moon is seen in the evening, it cannot have been seen the same morning, and then goes on to discuss whether the evening report is acceptable while discounting the morning report. Most importantly, the *Mishna* does not state that if the Moon is seen in the morning the Moon cannot be seen the next day in the evening, indicating that this possibility was known. Having said that, there is a lone 17th-

TABLE III

Observations of the waxing crescent Moon from Israel on 2008 June 4

Name	Location	Latitude N	Longitude E	Height m	How seen	Time
Reuven Chadad & one other	Kerem Byavneh	31° 49'	34° 43'	30	Naked Eye	20:10-20:15
Devorah Gordon	Pisgat Zeev, Jerusalem	31° 50'	35° 14'	774	Not seen	Clear
Nehemia Gordon	Pisgat Zeev, Jerusalem	31° 50'	35° 14'	774	Naked Eye	20:10-20:11
Natanel Guberman	Ma'ale Adummim	31° 47'	35° 18'	430	Naked Eye	20:16-20:17
Roy Hoffman	Ma'ale Adummim	31° 47'	35° 18'	430	Photograph	20:12
Danny Levy, Rephael Levanon, Shai Walter, & 9 others	Kerem Byavneh	31° 49'	34° 43'	30	Binoculars	
Chaim Mackler	Beer Sheva	31° 15'	34° 47'	330	Not seen	Clouds
Uri Mizrachi	Acre	32° 55'	35° 05'	11	Not seen	Clouds
Yosef Musa	Ofakim	31° 19'	34° 37'	140	Not seen	Clouds
Becky Rosenfeld	Efrat	31° 38'	35° 09'	900	Naked Eye	20:07-20:20
Sue Rosenfeld	Efrat	31° 38'	35° 09'	900	Naked Eye	20:07-20:20
Tom Rosenfeld	Efrat	31° 38'	35° 09'	900	Naked Eye	20:15
Johan Schutte	Pisgat Zeev, Jerusalem	31° 50'	35° 14'	774	Naked Eye	20:10-20:20
Isaac Sergani	Arad	31° 14'	35° 13'	600	Not seen	Clouds
Eli Shmuel	Ashdod	31° 48'	34° 39'	0	Naked Eye	20:15-20:20
Magdi Shmuel	Ashdod	31° 48'	34° 39'	0	Naked Eye	20:09-20:25
Ehud Urielli	Kerem Byavneh	31° 49'	34° 43'	30	Naked Eye	20:10-20:20

Century commentary that suggests that the *Mishna* is discounting the Moon disappearing for only one night. This view is dismissed by all other commentaries.

Lunar visibility criteria in the Jewish literature, such as 18 hours from conjunction or the more sophisticated criterion of Maimonides¹⁰, also allow for back-to-back sightings.

Karaism, broke away from mainstream Judaism around the 4th Century. Although Karaism is rejected by the overwhelming majority of Jews, Karaites claim to be observing the true Jewish calendar. The Karaite calendar resembles the ancient observational Jewish calendar since the Karaites never accepted the use of the calculated rabbinic Jewish calendar. Instead, most Karaite authorities fix their calendar according to the possibility of seeing the crescent Moon in a clear sky. This criterion has been the subject of much study, debate, and disagreement by Karaite scholars through the centuries. Yehudah Haddassi in his book *Eshkol ha-Kofer* (1148) discounts the possibility of back-to-back Moons, stating that if the Moon is visible on the morning of the 28th of the month then it is not visible the following night¹¹. On the other hand, Elijah Bashyachi, in his 15th Century book *Aderet Eliyahu*, states that the Moon is visible 18 hours or at least 17 hours from conjunction, leaving open the possibility of back-to-back Moons¹². Other Karaite authorities prefer criteria based on astronomical angles.

The Moslem calendar today is based on lunar observation and, as such, the understanding of the Moon's appearance is of great importance to Islam. In the Moslem literature, there is a concept of 28 separate phases of the Moon, one for each day of the month, according to the 16th-Century commentary of *Tafsir Al-Jalalayn* on the *Koran*. A similar statement appears in two places: *sura 10, aya 5* and *sura 36, aya 39*. The translation by Feraz Hamsa¹² is "twenty eight phases in twenty eight nights of every month; it becomes concealed for two nights when

the month has thirty days, and for one night when it has twenty nine days." This indicates a view that the Moon can be seen for 28 days during the month. Since the month is 29 or 30 days long, the Moon is not visible for the remaining one or two days. This indicates that the Moslem scholars are aware of the possibility of there only being one moonless night.

Conclusions

This is the first well-documented, naked-eye observation of back-to-back Moons in the Middle East and the first ever to be photographed. A concerted and well-prepared effort by the Israeli New Moon Society made this possible. The possibility of back-to-back observations is of archaeo-astronomical significance because it is discussed and considered as a realistic possibility although no such actual observation appears to have been reported in historical and ancient texts.

Acknowledgements

I wish to thank the members of the Israeli New Moon Society for carefully making and reporting their observations, Usama Hasan for useful discussions about Moslem literature, and Nehemia Gordon for useful discussions about Karaite literature.

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SPECTROSCOPIC BINARY ORBITS
FROM PHOTOELECTRIC RADIAL VELOCITIES

PAPER 204: HR 738, HR 831, HR 5692, AND HR 7252

*By R. F. Griffin
Cambridge Observatories*

The four bright stars are all giants, with absolute magnitudes of about zero (HR 7252) or +1 (the others); their spectral types, in order of HR number, are about K0, F6, G8, and K3, respectively. Their orbital periods are all within the range 500–800 days, being 637, 799, 506, and 675 days, but their eccentricities are much more diverse, ranging from the tiny (but significantly non-zero) 0.02 of HR 7252 to the extraordinary 0.89 of HR 831; the others are 0.16 (HR 738) and 0.33 (HR 5692).

Introduction

The stars discussed here were all brought to the author's attention by discordances noticed in their radial velocities by de Medeiros & Mayor¹, although the spectroscopic-binary nature of HR 831 had actually been demonstrated by Harper² before the present writer was born.

HR 738 (HD 15755)

HR 738 appears as a 6^m star in Triangulum, four or five degrees following β and γ Tri (the stars forming the short base of the triangle). Its magnitude and colour index have been given by Häggkvist & Oja³ as $V = 5^m.83$, $(B-V) = 1^m.075$; it seems that no ultraviolet measurement has ever been made. The *HD* type is G5; the type widely quoted in the literature is K0 III, probably taken from the *Bright Star Catalogue*⁴, but where that *Catalogue* got it from is a mystery to the writer: the only authentic first-hand classification that he can discover is the K1 IV given by Harlan⁵ on the basis of a slit spectrogram taken at a reciprocal dispersion of 75 Å mm⁻¹ at H γ with a prism spectrograph on the Lick 36-inch refractor. *Hipparcos*⁶ gives a parallax that translates to a distance modulus of $4^m.51 \pm 0^m.21$ and thus to $M_V = +1^m.32$ with the same uncertainty. That is quite faint for a giant, according to post-*Hipparcos* assessment: in the diagram shown by Keenan & Barnbaum⁷ it would come at the faint (lower) edge of the 'clump', falling in the region of overlap between luminosity classes IIIb and IIIb–IV, largely vindicating Harlan's classification⁶. The parallax was computed by *Hipparcos* only after taking account of orbital motion, whose period was found to be 604 ± 38 days, of the photocentre of what was implicitly a binary system. The astrometry was not sufficiently precise in relation to the amplitude of the photocentric motion to provide all of the orbital elements, so the *Hipparcos* authors took the pragmatic step of assuming the orbit to be circular, putting $e = 0$ and also $\omega = 0$ (the latter simply being a way of saying that the value given for the epoch, T , is what we would call T_0 , the epoch of zero mean longitude or of maximum velocity of recession). An observation⁸ of HR 738 by speckle interferometry at the McDonald 82-inch

telescope did not reveal any secondary star. A recent paper⁹ by Mishenina *et al.* on the elemental abundances in the atmospheres of clump giants has concluded that the abundances in HR 738 are very close to solar; there is no detectable lithium.

Radial velocities and orbits for HR 738

The radial velocity of HR 738 was first measured by Shajn & Albitzky¹⁰ with a prism spectrograph (36 \AA mm^{-1} at $H\gamma$) on the 40-inch Grubb reflector at the Simeis out-station of the Pulkovo Observatory. They obtained three plates, which yielded a mean velocity of -2.7 km s^{-1} with a ‘probable error’ of the mean of 0.7 km s^{-1} . The three measures were subsequently listed individually in the *Pulkovo Publications*¹¹, which shows that they were all made within an interval of one month. Four velocities were subsequently obtained at Mount Wilson and published by Wilson & Joy¹²; they gave the type as GKI and a mean velocity of -1 km s^{-1} with a ‘probable error’ — large, for the mean of four plates — of 3.1 km s^{-1} . We are indebted to Abt¹³ for publishing the observations separately; we see that they were obtained at 36 \AA mm^{-1} at $H\gamma$ with the 60-inch telescope and show a range of more than 20 km s^{-1} . When, however, they are compared with the orbit derived below, after the application of an empirical zero-point correction, their r.m.s. residual is reduced to 1.9 km s^{-1} . That would translate to the much more acceptable value of 0.74 km s^{-1} if expressed as a ‘probable error of the mean’. Although the scatter of the raw velocities was so large, Wilson & Joy¹² themselves did not mark the star as being variable in velocity, although they *did* so mark others that had only slightly greater spreads. The same (R. E.) Wilson shortly afterwards published the *Radial Velocity Catalogue*¹⁴ and gave the mean of the seven (Simeis and Mount Wilson) velocities as -2.2 km s^{-1} , with quality *b* which was intended to indicate a ‘mean probable error’ of 1.2 km s^{-1} . The compiler of the *Bright Star Catalogue*⁴, however, took an initiative in the matter and listed the velocity as “ $-2V$ ”, the *V* indicating ‘variable’. She could, perhaps, therefore, be credited with ‘discovering’ HR 738 to be a spectroscopic binary. The Pulkovo and Mount Wilson velocities have been transcribed here to the head of Table I.

In much more recent times de Medeiros & Mayor¹⁵, whose observations were made with the Haute-Provence (hereinafter OHP) *Coravel*, included HR 738 in a 1995 paper concerned with the connection between stellar rotational velocity and coronal activity; their observations gave the projected rotational velocity, $v \sin i$, as 1.3 km s^{-1} , and the star is flagged as a spectroscopic binary. Later the same authors¹ published a much larger listing of radial and rotational velocities, in which they noted that they had just two measurements of HR 738, which gave a mean velocity of $+2.70 \text{ km s}^{-1}$ with a standard error of 9.31 km s^{-1} — a way of saying that the individual values were $+2.70 \pm 9.31$. The mean rotational velocity was given as 1.0 km s^{-1} , which is the lowest fixed value given for any star (but is assigned to many) in their listing, although certain objects are given as “ < 1.0 ”. Those authors subsequently lodged with the Centre de Données Stellaires (CDS) the dates and velocities for all the measurements individually, and from there the entries for HR 738 have been drawn for inclusion in Table I. There, as is usual with OHP observations used in these papers and will apply equally to those in other tables in this paper, they have been adjusted by $+0.8 \text{ km s}^{-1}$; the same adjustment has been made to the Pulkovo¹¹ velocities, while an empirical addition of 3.0 km s^{-1} has been made to the Mount Wilson^{12,13} ones. The mean of the CDS velocities (before adjustment) already differed by half a km s^{-1} from the tabulated¹ mean, possibly because all the values were

TABLE I

Radial-velocity observations of HR 738

Observed with Cambridge Coravel (weight 1) except as noted

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O-C) km s ⁻¹
1930 Oct. 17·93*	26266·93	-0·2	41·510	+0·2
Nov. 2·91*	282·91	-3·0	.535	-1·6
16·88*	296·88	-2·4	.557	-0·2
1944 Jan. 12·12 [†]	31101·12	+15·4	33·093	+1·0
1946 Oct. 11·44 [†]	32104·44	-3·1	32·667	+2·1
Dec. 15·25 [†]	169·25	-5·0	.769	+0·4
1949 Nov. 5·32 [†]	33225·32	+0·6	30·425	-2·8
1987 Nov. 18·96*	47117·96	+13·3	8·217	+0·1
1988 Aug. 30·08 [‡]	47403·08	-5·3	8·664	-0·2
2002 Sept. 2·14	52519·14	-5·5	0·689	0·0
28·07	545·07	-5·7	.730	0·0
Oct. 28·08	575·08	-5·0	.777	+0·2
2003 Jan. 11·90	52650·90	+0·3	0·896	-0·1
15·93	654·93	+0·8	.902	-0·1
Feb. 19·81	689·81	+5·5	.957	0·0
Mar. 15·84	713·84	+8·8	.995	0·0
Aug. 30·13	881·13	+11·5	1·257	-0·1
Sept. 23·06	905·06	+9·8	.295	0·0
Oct. 27·05	939·05	+7·1	.348	-0·1
Nov. 16·94	959·94	+5·6	.381	0·0
Dec. 11·99	984·99	+3·6	.420	0·0
2004 Jan. 2·16 [§]	53006·16	+2·4	1·453	+0·3
24·90	028·90	+0·7	.489	+0·2
Mar. 1·85	065·85	-2·2	.547	-0·4
Sept. 5·10	253·10	-3·1	.841	0·0
21·14	269·14	-1·7	.866	0·0
24·23 [§]	272·23	-0·9	.871	+0·5
Oct. 22·11	300·11	+1·8	.914	0·0
Nov. 2·12 [§]	311·12	+3·5	.932	+0·2
5·03	314·03	+3·6	.936	-0·1
Dec. 20·92	359·92	+9·7	2·008	-0·2
2005 Jan. 4·90	53374·90	+11·6	2·032	0·0
16·84	386·84	+12·9	.051	+0·2
Feb. 1·99 [§]	402·99	+14·3	.076	+0·4
Sept. 28·11	641·11	+2·5	.449	+0·2
Nov. 9·99	683·99	-0·6	.517	+0·1
Dec. 26·92	730·92	-3·2	.590	+0·1
2006 Jan. 25·84	53760·84	-4·7	2·637	-0·1
Feb. 9·12 [§]	775·12	-5·9	.660	-0·8
Aug. 30·16	977·16	+7·4	.977	+0·2
Nov. 24·04	54063·04	+14·8	3·111	0·0
30·22 [§]	069·22	+15·1	.121	+0·3
Dec. 8·99	077·99	+14·8	.135	-0·1
2007 Jan. 20·84	54120·84	+13·8	3·202	+0·1
29·17 [§]	129·17	+13·0	.215	-0·3

TABLE I (concluded)

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O-C) km s ⁻¹
2007 Feb. 6·82 28·10 [§] Mar. 30·09 [§]	54137·82	+12·7	3·229	-0·1
	159·10	+11·1	·262	-0·3
	189·09	+8·8	·309	-0·4
2008 Feb. 11·83 Aug. 4·10 28·11	54507·83	-4·3	3·809	+0·1
	682·10	+14·0	4·082	-0·1
	737·11	+14·7	·169	+0·1

^{*} Pulkovo observation¹¹, weight 0.[†] Mt. Wilson observation^{12,13}, weight 0.[‡] OHP observation¹, weight 1/2.[§] Massarotti *et al.* observation¹⁷, weight 0.

re-computed on a different basis¹⁶. Analogous (but not identical) discrepancies occur for practically all stars between the velocities held by the CDS and those given by de Medeiros & Mayor¹ in their actual paper, but we shall not refer to the matter any more in regard to the other stars discussed below.

Most recently of all, Massarotti *et al.*¹⁷ have given another listing of radial and rotational velocities. They obtained for HR 738 a $v \sin i$ of 0·0 km s⁻¹, and they had just enough velocities (nine, over an interval of some three years) to derive an orbit for the star. Their velocities, which are contemporaneous with the writer's, are inserted in Table I in their proper chronological places; they are discussed below in connection with the orbit. Their entries in Table I have been subjected to an empirical adjustment of +1·2 km s⁻¹ to bring their mean residual to zero; that has been done only for cosmetic reasons, since those data are not incorporated in the solution of the orbit.

The star was placed on the observing programme of the Cambridge *Coravel* in the autumn of 2002; 33 observations have been made with that instrument and are listed in Table I. They readily yield an orbit, whose period is $637\cdot6 \pm 0\cdot4$ days. Inclusion of the two Haute-Provence measures retrieved from the CDS, with half weight, greatly increases the overall time base and appreciably refines the period, to $637\cdot51 \pm 0\cdot25$ days. The orbit is illustrated in Fig. 1; Table II gives the orbital elements, first the published ones from Massarotti *et al.*¹⁷ and then those newly computed from the data obtained with the Cambridge and OHP *Coravels*.

TABLE II

Orbital elements for HR 738

Element	Massarotti <i>et al.</i> ¹⁷	This paper
P (days)	$629\cdot2 \pm 2\cdot7$	$637\cdot51 \pm 0\cdot25$
T (MJD)	53978·5 ± 10	53992·1 ± 1·9
γ (km s ⁻¹)	$+2\cdot729 \pm 0\cdot096$	$+3\cdot865 \pm 0\cdot024$
K (km s ⁻¹)	$10\cdot67 \pm 0\cdot13$	$10\cdot30 \pm 0\cdot03$
e	$0\cdot135 \pm 0\cdot015$	$0\cdot164 \pm 0\cdot003$
ω (degrees)	$294\cdot6 \pm 6\cdot5$	$296\cdot5 \pm 1\cdot1$
$a_1 \sin i$ (Gm)	$91\cdot45 \pm 0\cdot50$	$89\cdot04 \pm 0\cdot30$
$f(m)$ (M_\odot)	$0\cdot0770 \pm 0\cdot0013$	$0\cdot0694 \pm 0\cdot0007$
R.m.s. residual (wt. 1) (km s ⁻¹)	0·23	0·12

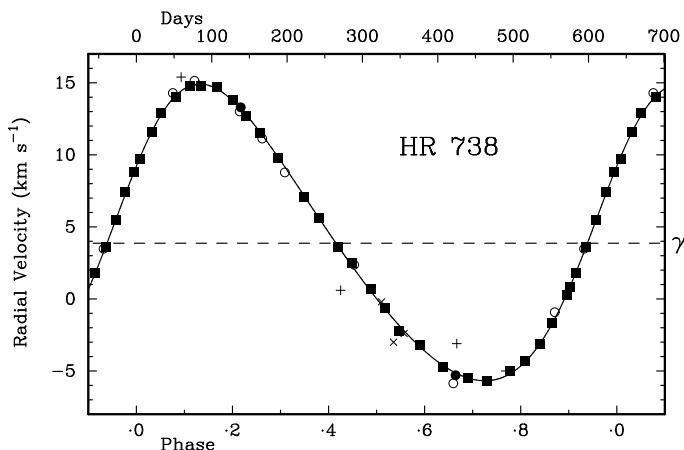


FIG. 1

The observed radial velocities of HR 738 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. The orbit, like the others in this paper, depends very largely on the author's observations made with the Cambridge *Coravel*, plotted as filled squares, but two early measurements obtained at OHP by de Medeiros & Mayor¹ and made available through the CDS were included, with half-weight, in the solution of the orbit. They are plotted as filled circles. Zero-weighted were measurements by Shah & Albitzky^{10,11} (crosses), Wilson & Joy^{12,13} (pluses), and Massarotti *et al.*¹⁷ (open circles).

The r.m.s. residuals of the Cambridge orbit are agreeably small, the best found for any orbit yet published in this series, although a particular set of measurements of 56 Peg¹⁸ was noted as having an r.m.s. deviation of only 0.09 km s^{-1} from a pre-determined orbit.

In any comparison of the Massarotti *et al.* orbit with the new one, one has to bear in mind that the former is based on only nine measurements, so after the fitting of six orbital elements there remain only three degrees of freedom. It should be mentioned that the figure of 0.23 km s^{-1} given for the residuals of the published orbit takes account of the loss of the six degrees of freedom, *i.e.*, it is actually the figure for the computed r.m.s. *error* of an observation; the equivalent figure for the Cambridge measurements would be 0.13 . The discrepancy of $1.13 \pm 0.10 \text{ km s}^{-1}$ in the γ -velocities of the two orbits must be seen merely as a difference in zero-points of the velocity scales. It does not differ very much from the discrepancy between the implicitly admitted offsets of the Massarotti and Cambridge zero-points from better-considered ones, of -0.14 and $+0.8 \text{ km s}^{-1}$, respectively. When we look at the other elements, for which the only apparent reasons for differences are observational and possibly computational errors, it seems a bit distressing to find that the values of P and K differ by about three times their joint standard errors, and the comparisons between the 'derived' quantities $a_1 \sin i$ and $f(m)$ are worse, 4.1 and 5.2 standard errors, respectively. The trouble with P and K most probably lies in the standard errors of the solution having only three degrees of freedom being optimistic; the theory of standard errors is based on the assumption that the errors form a normal distribution, which in practice they never do, but in a sufficiently large data pool they do often tend towards it and

then the errors arising from the assumption decrease. In the cases of the 'derived' quantities such an effect is compounded by the quoted standard errors being wrongly calculated. In the case of $a_1 \sin i$, that can be demonstrated at sight, because one of the multiplicative terms in the expression for that quantity is K . Since the uncertainty in K alone is more than 1%, it is impossible that that of $a_1 \sin i$ could be less. A re-calculation of the Massarotti *et al.* orbit by the writer produces an exact correspondence, to the number of significant figures given, in the orbital elements and their standard errors, but the standard errors of $a_1 \sin i$ and $f(m)$ come out at 1.2 Gm and $0.0029 M_{\odot}$, respectively; the former, at least, passes the reality check based upon the fractional uncertainty of K . After Massarotti *et al.* had been gently alerted to the disagreement, Dr. G. Torres kindly informed the writer that he had discovered an error in the program that computed the quantities concerned, and has now corrected it.

It seems an obvious final step to pool the two data sets to obtain an improved solution of the orbit, but that turns out not to be a significantly profitable exercise. When the Massarotti *et al.* measurements are included in the solution, with their zero-point offset and weighting empirically optimized to bring their mean residual to zero and their weighted variance to the same as that of the Cambridge observations ($+1.2 \text{ km s}^{-1}$ and 0.1 , respectively), the resulting orbital elements and their standard errors are so very nearly the same as are given by the Cambridge plus OHP data alone that there would seem to be no purpose in tabulating them. That is actually not surprising in view of the smallness of the relative total weight of the added data. The r.m.s. error of the Massarotti *et al.* observations, as determined from the combined solution, is 0.40 km s^{-1} , nearly double the value found internally. The residuals are dominated by one that is as much as 0.8 km s^{-1} ; it illustrates how, when there are very few degrees of freedom, a computed orbit has the propensity to accommodate to some extent a non-statistically large residual, but as the number of degrees of freedom increases the residuals necessarily become more realistic. It may be noted parenthetically how standards of precision, even in this series of papers let alone in the work of others whose interests are in planets, have changed: a residual of 0.8 km s^{-1} here sticks out like a sore thumb, whereas it was a characteristic r.m.s. value in many of the earlier papers.

A comparison of the spectroscopic orbit with the astrometric one found by *Hipparcos* shows that the satellite did indeed see the orbit that is documented here. The period of 637 days is within the admitted uncertainty of the *Hipparcos* value of 604 ± 39 days. Since *Hipparcos* adopted a circular approximation to the orbit we cannot compare e and ω but, if the astrometric value of T can be supposed to correspond to the maximum velocity of recession in the spectroscopic orbit, that value (MJD 47778 ± 51) can be compared with the MJD of 47702 extrapolated back nine cycles of the spectroscopic orbit, so it appears to be about $1^{1/2}$ standard errors adrift. Perhaps more interesting is the inclination found for the astrometric orbit, 85 ± 10 degrees, which shows that the values of $\sin i$ and even $\sin^3 i$ can be taken as unity to a fair approximation. The mass function of $0.07 M_{\odot}$ can then be interpreted as indicating that, if the primary is assumed to have a mass of $2 M_{\odot}$, the secondary must be about $0.8 M_{\odot}$, so unless it is a white dwarf it must be near type K0, about four magnitudes fainter than the primary. Then the mass ratio of 2.5 would indicate that the $a_1 \sin i$ value of about 0.6 AU needs to be multiplied by 3.5 to give the linear separation, about 2 AU , of the components; at the 80-pc distance of the system that would mean a maximum angular separation of $0''.025$, which with $\Delta m \sim 4^m$ is perhaps not too encouraging for direct optical resolution in the near future.

HR 831 (HD 17484)

HR 831 is a $6\frac{1}{2}$ ^m star in Perseus, to be found about 1° south of the fourth-magnitude 16 Per and 5° south-preceding Algol. Photometry has been published by Imagawa¹⁹: $V = 6^m\cdot47$, $(B-V) = 0^m\cdot42$, $(U-B) = 0^m\cdot12$. The spectral type of F6 III–IV given by Morgan²⁰ has been widely adopted and has indeed been used as a standard on occasion²¹. The *Hipparcos* parallax points to a distance modulus of $5^m\cdot33 \pm 0^m\cdot23$, and so to an absolute magnitude of about $+1^m\cdot1$. It is not necessarily to be believed, however, because in order to try to make sense of the astrometry the *Hipparcos* authors adopted an ‘acceleration solution’, whereby they attributed to the star — or at least to the photocentre of the system, which seems likely to approximate to the same thing — a continuous acceleration whose amount is actually slightly larger than they deduced for the parallax itself. Acceleration solutions are supposed to be appropriate to cases where the stars concerned are in orbits with periods long in comparison with the ~ 3 -year duration of the *Hipparcos* mission; in the case of HR 831 we now know from the 800-day period that more than one whole circuit of the orbit took place during the time that *Hipparcos* was watching, so the model of the position in terms of a continuous acceleration must be at best a very rough one. Mason *et al.*⁸, in their survey of ‘problem *Hipparcos* binaries’ by speckle interferometry on the McDonald 82-inch telescope, were not able to resolve the system.

The absolute magnitude of HR 831 was determined at Victoria as long ago as 1924, quite soon after the potentialities of spectroscopy for assessing luminosities were first realised. Young & Harper²², though publishing jointly, made independent estimates of the absolute magnitude by comparison of the strengths of various pairs of lines that had different luminosity sensitivities; they obtained $M_V = +1^m\cdot8$ and $+1^m\cdot9$, respectively. Much later, the star’s luminosity was estimated from Strömgren photometry by Middlekoop²³, who obtained $M_V = +1^m\cdot8$, and by Perry *et al.*²⁴, who made it $+1^m\cdot48$ from seemingly the same or analogous data. Gray *et al.*²⁵ found that the metallicity of HR 831 is very close to solar; the star also appears in the large table of F and G dwarfs by Nordström *et al.*²⁶, wherein it is assigned a metallicity [Fe/H] of $+0\cdot12$.

Radial and rotational velocities and orbit of HR 831

The Dominion Astrophysical Observatory (DAO), Victoria, as well as publishing luminosity estimates for HR 831 more than fifty years in advance of others, was also the place where by far the earliest measures of the radial velocity of HR 831 were obtained. Harper² published five velocities from plates taken in 1923–26 with a prism spectrograph giving 29 \AA mm^{-1} at H γ on the 72-inch reflector. Four of them were within quite a small range ($+4\cdot4$ to $+9\cdot5 \text{ km s}^{-1}$), but one was wildly outlying at $+30\cdot6 \text{ km s}^{-1}$, and Harper not unnaturally concluded that it “indicated” that the star is a spectroscopic binary. A mean of the five velocities (with a small zero-point correction) was given in the *Radial Velocity Catalogue*¹⁴ as if it truly represented the mean velocity, and was assigned quality *c*, which was supposed to have a ‘mean probable error’ of $2\cdot5 \text{ km s}^{-1}$. Perhaps more by luck than judgement, the figure of $+12 \text{ km s}^{-1}$ given in the *Catalogue* does in fact prove now to be correct to that sort of precision.

Danziger & Faber²⁷ determined a projected rotational velocity of 13 km s^{-1} for HR 831; Wolff & Simon²⁸ subsequently ‘quoted’ that value as 6 km s^{-1} after ‘converting’ it according to a recipe of their own, which does seem to have been

a bit drastic and had the effect of putting the result further from what we now believe to be the true one than it was in the un‘corrected’ state. In their paper on rotational and radial velocities of a lot of late-type stars, de Medeiros & Mayor¹ reported the existence of just two observations made with the OHP *Coravel*, which gave a mean radial velocity of $+7.02 \text{ km s}^{-1}$ with a standard error of 2.04 (implying that the two individual values were $+7.02 \pm 2.04$), and a rotational velocity of 11 km s^{-1} . Later, in another paper on the same subject but concerned with a much smaller sample of stars, restricted to binaries, de Medeiros, da Silva & Maia²⁹ gave what are evidently the results of the same two observations again, and later still Famaey *et al.*²⁶ listed them, though with slightly changed numbers for the radial velocities, for a third time.

As a result of a belated reappraisal of the de Medeiros *et al.* papers^{1,29}, HR 831 was placed on the Cambridge observing programme and was first observed in late 2004. The observer was not then aware of the old DAO observations that showed a dramatic change of velocity on a relatively short time-scale, but only of the two OHP measures which differed only by about 3 km s^{-1} , so no urgency was felt and the object was not observed again until the following season, when it was initially scheduled for observation once a month. The third observation showed it to have been changing unexpectedly rapidly, so the frequency of observation was increased, and at the next measurement the observer recognized with fortunate promptitude that what was happening was that the velocity was accelerating *away* from the γ -velocity in a fashion that betokened a very high eccentricity, so the object instantly became one of the highest priority, to be observed on every possible night until the dramatic excursion of its velocity appeared to be over; a good record of the event was obtained. A monthly frequency of measurements was then resumed until such time as there might be another periastron passage, which turned out to be some two years later. The total number of Cambridge observations is now 47; they are set out in Table III together with the measures from the DAO² and OHP¹. A correction of -0.6 km s^{-1} has been applied to the ‘as initially reduced’ Cambridge velocities, on the basis of experience with other stars of comparable colour index. The DAO observations have been increased in Table III by 3 km s^{-1} to bring near to zero the mean residual of the four that are away from the velocity maximum.

The solution of the orbit has been performed with the Cambridge observations alone. There are only two OHP measures, and they are at phases where they have little value to the solution and moreover one of them has an extraordinary residual whose significance so far as the orbit is concerned seems very doubtful. That point is attributed an exceptionally large internally estimated standard error in the listing of OHP velocities. The orbit is shown in Fig. 2, and has the following elements:

$$\begin{aligned}
 P &= 799.39 \pm 0.12 \text{ days}^* & (T)_1 &= \text{MJD } 53692.26 \pm 0.09 \\
 \gamma &= +9.26 \pm 0.06 \text{ km s}^{-1} & a_1 \sin i &= 69.4 \pm 0.5 \text{ Gm} \\
 K &= 13.72 \pm 0.08 \text{ km s}^{-1} & f(m) &= 0.0209 \pm 0.0005 M_{\odot} \\
 e &= 0.8878 \pm 0.0012 & & \\
 \omega &= 7.1 \pm 0.5 \text{ degrees} & \text{R.m.s. residual} &= 0.30 \text{ km s}^{-1}
 \end{aligned}$$

*but see discussion below

The exciting feature of the orbit is obviously the extreme eccentricity, which with an ω close to zero is manifested as a very sudden and narrow maximum in the velocity curve.

TABLE III

Radial-velocity observations of HR 831

Observed with Cambridge Coravel except as noted

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O-C) km s ⁻¹
1923 Oct. 13·44*	23705·44	+7·8	37·488	+0·1
27·35*	719·35	7·4	·505	-0·3
1924 Nov. 25·31*	24114·31	33·6	37·999	-1·5
Dec. 24·33*	143·33	12·5	36·036	+1·0
1926 Oct. 31·43*	24819·43	8·1	36·881	-1·7
1986 Nov. 17·92†	46751·92	5·3	8·318	-2·3
1987 Sept. 16·13†	47054·13	8·7	8·696	+0·5
2004 Dec. 20·92	53359·92	8·0	0·584	+0·1
2005 Aug. 22·09	53604·09	10·0	0·890	0·0
Sept. 7·18	620·18	10·9	·910	+0·4
Oct. 27·05	670·05	15·6	·972	0·0
Nov. 5·08	679·08	19·4	·984	0·0
10·07	684·07	23·6	·990	-0·2
13·10	687·10	28·5	·994	+0·2
14·09	688·09	30·2	·995	+0·1
17·05	691·05	34·6	·998	-0·2
18·04	692·04	35·0	1·000	-0·1
19·04	693·04	34·1	·001	-0·2
21·09	695·09	30·5	·004	+0·3
25·03	699·03	22·3	·008	-0·1
29·96	703·96	17·2	·015	+0·1
Dec. 8·91	712·91	13·1	·026	0·0
2006 Jan. 4·87	53739·87	9·5	1·060	-0·2
Feb. 8·87	774·87	8·3	·103	-0·3
Mar. 3·83	797·83	8·1	·132	-0·1
Apr. 1·81	826·81	7·7	·168	-0·3
July 25·13	941·13	8·6	·311	+1·0
Aug. 30·16	977·16	7·9	·356	+0·3
Sept. 30·14	54008·14	8·0	·395	+0·4
Oct. 25·05	033·05	7·8	·426	+0·1
Nov. 24·05	063·05	8·1	·464	+0·4
Dec. 16·98	085·98	7·5	·493	-0·2
2007 Jan. 11·85	54111·85	7·3	1·525	-0·5
Feb. 14·83	145·83	7·8	·567	-0·1
Mar. 25·84	184·84	7·9	·616	-0·1
July 27·12	308·12	8·8	·770	+0·2
Aug. 31·12	343·12	8·1	·814	-0·8
Sept. 26·14	369·14	9·6	·847	+0·3
Oct. 31·98	404·98	9·6	·892	-0·5
Nov. 24·00	428·00	10·9	·920	0·0
Dec. 7·96	441·96	11·4	·938	-0·3
2008 Jan. 5·93	54470·93	16·1	1·974	+0·1
24·82	489·82	34·1	·998	0·0
27·96	492·96	33·7	2·002	+0·2
30·89	495·89	26·7	·005	-0·4
31·81	496·81	+25·1	·006	-0·1

TABLE III (concluded)

<i>Date (UT)</i>	<i>MJD</i>	<i>Velocity</i> <i>km s⁻¹</i>	<i>Phase</i>	<i>(O-C)</i> <i>km s⁻¹</i>
2008 Feb. 1.99	54497.99	+23.1	2.008	0.0
4.75	500.75	19.9	.011	+0.5
6.92	502.92	17.5	.014	+0.1
8.76	504.76	16.2	.016	0.0
10.94	506.94	14.7	.019	-0.3
26.81	522.81	10.8	.039	-0.3
Mar. 30.82	555.82	8.9	.080	-0.1
Aug. 30.17	708.17	+8.0	.271	+0.3

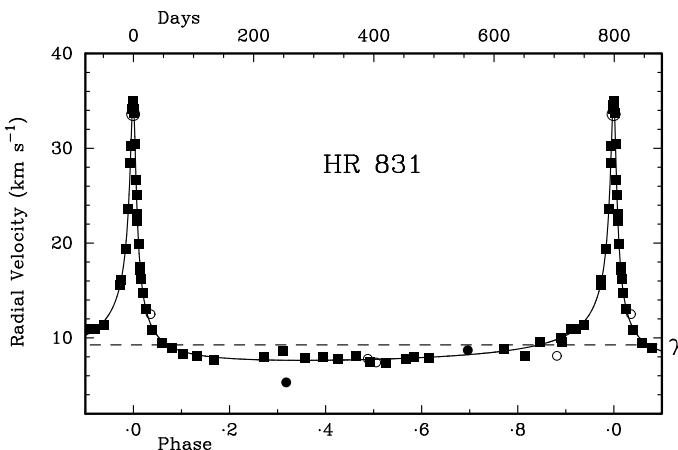
* DAO observation², weight 0.† OHP observation¹, weight 0.

FIG. 2

As Fig. 1, but for HR 831. The orbit depends on the Cambridge observations alone in this case, because one of the OHP measurements (filled circles, as in Fig. 1) has an excessive residual. The open circles refer here to the observations, zero-weighted in the solution, made at the DAO by Harper²; one that falls right at the sharp maximum of the velocity curve of this very eccentric orbit ($e \sim 0.89$) is plotted over-size for clarity.

By a most fortunate chance, one of the old DAO observations was made very close to an epoch of maximum velocity. Since it was made 38 cycles ago its phase is extremely sensitive to the adopted period. It would have been even more fortunate if it had been displaced just a few days in either direction, because as it stands it falls with great exactness (within five hours!) on the maximum of the curve defined by the orbital elements just given; at that phasing it has a residual of -1.5 km s^{-1} , which is not enough in relation to its accuracy that we can discount the possibility that it should be exactly *there*, so we cannot make a decision as to which side of the maximum it ought to lie. The writer knows from experience with velocities from the paper² concerned that they are normally reliable to 2 km s^{-1} , and that their standard error could be estimated at appreciably less than that. The four velocities of HR 831 that fall away from the maximum show a mean-square residual from the computed orbit of just over $1 \text{ (km s}^{-1})^2$; in view of the fact that they have been arbitrarily corrected to bring their mean residual nearly to zero we have lost one out of the four degrees of freedom, so

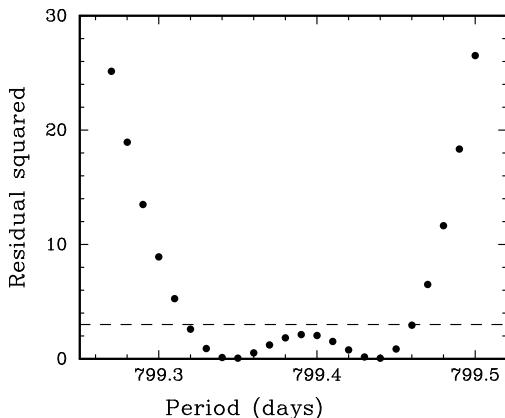


FIG. 3

The computed variance (the square of the residual; units are $(\text{km s}^{-1})^2$) of the critical DAO observation² that lies on the peak of the velocity curve in Fig. 2, as a function of the period attributed to the orbit. The dotted line shows the level $(3 \text{ km s}^{-1})^2$ below which the variance is considered to be immediately acceptable. Outside the range of acceptable periods, the variance is seen to rise so quickly that the exact level adopted as the criterion of acceptability is not at all critical.

their mean-square *error* (as distinct from *residual*) is four-thirds as great, and corresponds to a standard error of nearly 1.2 km s^{-1} . It is in that light that we can usefully examine the relationship of the critical DAO observation to the phasing implied by small changes of period. That relationship can best be appreciated by reference to Fig. 3, where the apparent variance of the point on the orbit graph represented by the DAO observation is plotted as a function of the adopted period. Beyond certain limits the variance rapidly becomes enormous, but in the more sensible range of periods there are two places where it goes to zero, at periods of 799.3456 and 799.4365 days. There, it falls exactly on the ascending and descending branches, respectively, of the velocity curve; between the zeroes it does not rise high enough for us to reject any period within that range. Outside the zeroes it reaches $3 (\text{km s}^{-1})^2$, which we might consider to be the borderline of acceptability, at about 799.32 and 799.46 days, which by coincidence are exactly symmetrically placed at ± 0.07 days from the period found from the Cambridge observations. On the evidence of the single 84-year-old DAO datum, therefore, we could reasonably propose the adoption of a 'standard deviation' of 0.07 days for the period in place of the 0.12 days of the computed solution, although the 0.07 figure obviously lacks the formal mathematical justification of the 0.12 .

The mass function is small and does not offer any real clue as to the nature of the secondary object in the HR 831 system. Famaey *et al.*'s table²⁶ lists a mass of $2.06 M_{\odot}$ for the observed component; on that basis the secondary must have a mass of at least $0.5 M_{\odot}$. The Cambridge radial-velocity traces give extremely reproducible estimates for the rotational velocity, which repeats with an r.m.s. spread of only 0.7 km s^{-1} per individual observation; the mean is $10.20 \pm 0.10 \text{ km s}^{-1}$, although of course the formal standard error is not to be taken as a true indication of the real uncertainty of the mean value. Owing to the simplicity of the model and the ignoring of differences in other sources of line broadening, the true uncertainties of mean values obtained from radial-velocity traces are not claimed to be better than $\pm 1 \text{ km s}^{-1}$.

HR 5692 (HD 136138)

HR 5692 is a star rather brighter than the sixth magnitude, to be found in a patch of sky barren of bright stars, roughly halfway between Pulcherrima (ε Boo) and what one used to think of, before the local light pollution got so bad, as the *conspicuous* triangle of stars at the northern end of Serpens Caput. Its magnitude and colour index have been listed by Häggkvist & Oja³ as $V = 5^m\cdot70$, $(B - V) = 0^m\cdot966$. Its spectral type (which is G5 in the *HD*) and an absolute magnitude estimated spectroscopically were given in 1935 by Adams *et al.*³⁰ as G5 and $+0^m\cdot5$. Harlan & Taylor³¹ classified it in 1970 as G5 IV, but in 1979 Cowley & Bidelman³² called it G6 III, and the following year it continued its advance towards later types and higher luminosities when Keenan & Pitts³³ found it also to show slight ‘barium’ characteristics and gave its type as G8 IIIa Ba $0\cdot3$, which was reaffirmed by Keenan³⁴ in 1983. Subsequently, however, Keenan & McNeil³⁵ omitted the barium index, listing the type as plain G8 IIIa. Analogous changes occurred to quite a number of other classifications that had been promulgated by Keenan and his collaborators, and caused a good deal of confusion, and derision by Eggen³⁶; they were explained by Keenan in a paper³⁷ 99 numbers back in the series of which this paper is a member. An absolute magnitude of $+1^m\cdot3$ was derived for HR 5692 by Brown *et al.*³⁸ from photometry³⁹. It could be expected that *Hipparcos* has had pretty much the last word on the true luminosity of the star: the parallax equates to a distance of 89 ± 7 pc (a modulus of $4^m\cdot75 \pm 0^m\cdot17$) and shows that the absolute magnitude is very close to $+1^m\cdot3$. That could be seen, from the post-*Hipparcos* diagram in Keenan’s last paper⁷, to be a rather low luminosity for a giant star and to merit a luminosity class of IIIb, so the luminosity class IV proposed by Harlan & Taylor³¹ in the first MK classification of the star appears scarcely further from the mark than the class IIIa favoured by Keenan and his collaborators.

*Hipparcos*⁶ lists HR 5692 as being photometrically constant, and gives the r.m.s. spread of the magnitudes measured at the 150 individual transits as $0^m\cdot007$. That corresponds to a spread in brightness of $0\cdot7\%$, and to put it in perspective it could be remarked as the fifth-smallest number among the 100 stars on that page (vol. 8, p. 1505) of the *Hipparcos Catalogue*⁶. Koen & Eyer⁴⁰, however, in a comprehensive search of the *Hipparcos* photometry for additional variable stars, considered that they could see a sine-wave variation with a frequency of $0\cdot00300$ day⁻¹ (a period of 333 days) and an amplitude of $0^m\cdot0044$. Such an amplitude appears to be in the lowest percentile of the amplitudes of the 2376 stars that they listed as newly recognized ‘candidate variable stars’. Koen & Eyer give, with each entry, a ‘standardized test statistic’ that they call R_* ; in the relevant case it is listed as 4.302, which is not far above the lower limit (3.543) to what they regard as significant. (Initially they refer to a signal/noise ratio R , the ratio between the amplitude of the apparent variation to the standard deviation of the photometric residuals; R_* is related to it, but in a way which tends to conceal its immediate significance from a layman.)

Plotted directly against time, the *Hipparcos* photometry looks far from promising for showing any periodic variation, but an effort to fit to it a sine wave with a fixed period of 333 days did indeed produce a plot (Fig. 4) with an appearance of some significance. The remaining three elements (mean brightness, phasing, and amplitude) were left free. The mean magnitude was $5^m\cdot8484 \pm 0^m\cdot0006$; it must be close to, but is not expected to be identical with, the straightforward mean magnitude, since the irregularities of phasing place more of the data points above (*i.e.*, brighter than) the mean magnitude than below it. The straight mean calculated here was $5^m\cdot8476 \pm 0^m\cdot0006$ and so does not check exactly with *Hipparcos*^{*}

^{*}Mishenina *et al.*⁹, however, starting from the same data, list its absolute magnitude as $+0^m\cdot638$.

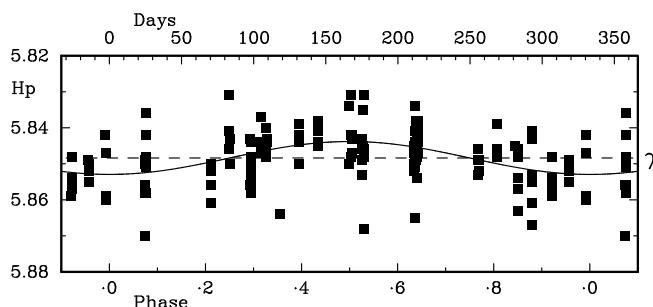


FIG. 4

The *Hipparcos* photometry of HR 5692, folded upon the period of 333 days proposed by Koen & Eyer⁴⁰. The line is the best sine wave that can be fitted to the points by optimizing its amplitude, zero-point, and phase. The text explains how this periodicity, taken by itself, seems highly significant statistically, but its actual significance is greatly impaired by its being the most promising period found among more than 60 000 trials.

own value of $5^m\cdot8469 \pm 0^m\cdot0006$, but we notice that the number given by *Hipparcos* is actually a *median* and not a mean, although the idea of giving a standard deviation applying to anything other than a mean seems a strange one.

An epoch of numerically largest magnitude was MJD 48498 \pm 9. The amplitude came out at $0^m\cdot0046 \pm 0^m\cdot0008$, near enough to Koen & Eyer's $0^m\cdot0044$. (Koen & Eyer rejected a few of the outlying points, so their data set, of 142 points, was not quite identical with the one analysed here, which has 147 points. Here, the only rejected observations among the 150 *Hipparcos* transits are two with huge 'quality flag' numbers, 64 and 66, and one hopelessly 'low' point at MJD 48790.85 (1992 June 17), which is not near a time of conjunction and therefore cannot represent an eclipse. *Hipparcos* itself records that its photometric statistics for HR 5692 depend on 150 transits, but it simply *could not* have included the three that we have rejected without grossly inflating the standard error.)

We could try to assess the significance of the fitted sine curve in Fig. 4 by appeal to the second Bassett⁴¹ test. When only a mean is formed from the magnitudes, the number of degrees of freedom is 146 and the sum of squares of the deviations is $0\cdot00759$ magnitudes-squared; when the 333-day variation is fitted, the number of degrees of freedom is reduced to 143 and the sum of squares falls to $0\cdot00616$. In round numbers, therefore, one-fiftieth of the number of degrees of freedom cost about one-fifth of the total variance, showing that $F_{3,143} \sim 10$ — overwhelming significance, very much less than one chance in a thousand of arising by chance, since the $0\cdot1\%$ point of $F_{3,143}$ is only $5\cdot7$. We have to temper that demonstration, however, with the *caveat* that we did not test that period just at random. While we find unambiguous significance when we test that particular periodicity, we have to remember that that was the *best one* found by Koen & Eyer out of what Koen⁴² has told us were between 60 and 70 thousand trial periods. It would therefore need to have a chance occurrence of less than one in a million before any real significance could be attached to it. Tables of F ratios do not plumb such depths, and might not be very meaningful in practice even if they did. The writer unashamedly clings to his characterization of the photometry as "far from promising" for demonstrating a periodicity, although he recognizes that such a

subjective assessment lacks the numerical quantification that is desired by people brought up on computers and is of course needful for dealing wholesale with large-scale photometric programmes. Without wishing to be seen as throwing down any gauntlet, he invites photometrists who may relish an opportunity to demonstrate their superiority to make a more accurate series of measurements of HR 5692 and adjudicate between Koen & Eyer and the writer.

Leroy^{43,44} included HR 5692 in two papers concerned with polarization of the light of stars within 50 pc of the Sun, and listed for it a distance of only 23 pc. That figure was apparently drawn from *Sky Catalogue 2000.0*⁴⁵ and is only partly excused by its calculation from a spectroscopic parallax stemming from an absolute magnitude based on the Harlan & Taylor³¹ classification. At first it seemed that the error must be exacerbated by an arithmetical mistake as well, since the apparent and absolute magnitudes are both tabulated and should lead to a distance of 32 and not 23 pc. A reading of the *Introduction* to the *Sky Catalogue*, however, brought to light the fact that its spectroscopically estimated distances are 'corrected' for interstellar absorption whose amount is derived from 'colour excess'. Working backwards from the distance listed for HR 5692, we find that the apparent magnitude must have been 'corrected' by $0^m.7$ — on the basis that its measured $(B-V)$ is much too red to correspond to the listed spectral type!

Random checks on other entries in the *Catalogue* suggest that a mean colour index is attributed to each spectral type, and then — in a splendid demonstration of a mindless application of computers — all deviations on the red side of the mean are deemed to arise from interstellar absorption. The absorption is deemed to be a multiple of the colour deviation, regardless of the ludicrously excessive absorption attributed in some cases (such as the one of present interest) to stars that are thereby found to be very close, even where (as is again the case here) they are at high Galactic latitude. It would be almost equally sensible (but it seems that the *Catalogue* refrains from doing it) to interpret blueward colour deviations as negative interstellar absorption! This paper must not be allowed to degenerate into a review of *Sky Catalogue 2000.0*, but one might remark also that the listing of distances seems very haphazard, since many stars for which all the seemingly needed data (apparent and absolute magnitude and spectral type) are present nevertheless lack an entry in the 'distance' column.

HR 5692 features in a paper⁹, already mentioned above in connection with HR 738, by Mishenina *et al.* (notwithstanding that they asserted that known spectroscopic binaries were excluded) on the elemental abundances in the atmospheres of clump giants. They listed such abundances for 177 stars, finding for HR 5692 that $[\text{Fe}/\text{H}] = -0.19$ and $\varepsilon(\text{Li}) = 1.3$ on the usual scale with $\varepsilon(\text{H}) = 12$. They noted that they had identified 21 clump giants and about 54 clump candidates among their sample of stars, but as far as the present writer can see they did not flag them in any way, so it is difficult for the reader to know what they considered to be the 'clumpiness status' of HR 5692 (or HR 738 or any other star). Long before the Mishenina *et al.* paper, Brown *et al.*³⁸ had found almost the same metallicity ($[\text{Fe}/\text{H}] = -0.24$) and the identical lithium abundance ($\varepsilon(\text{Li}) = 1.3$), and those values had received an *imprimatur* from Taylor's 'critical appraisal'⁴⁶.

Radial and rotational velocities and orbit of HR 5692

The radial velocity of HR 5692 was first determined at Mount Wilson; a mean of three measurements was published by Adams *et al.*³⁰. They were listed

individually much later by Abt⁴⁷, from whose compilation we see that they were made in 1924/5 at the 60-inch reflector. There was then an interval of more than 60 years when HR 5692 was not observed, until de Medeiros & Mayor¹ identified the spectroscopic-binary nature of the star from four observations, which they published only as a mean value, with the OHP *Coravel*. When they later made the individual dates and velocities available through the CDS, the star was selected for addition to the Cambridge observing programme, so since 2002 it has been observed systematically with the Cambridge *Coravel*, and 47 measurements have been made of it. All the radial velocities are listed in Table IV. The OHP ones have received the usual adjustment of $+0.8 \text{ km s}^{-1}$; the Mount Wilson ones have in addition been adjusted by $+0.5 \text{ km s}^{-1}$, as recommended by Table 3 of the *Radial Velocity Catalogue*⁴⁸. The Cambridge velocities have been adjusted by -0.2 km s^{-1} , in the light of experience such as that of Paper 190⁴⁹ with stars of similar colour indices.

Very recently there has appeared the paper, also referred to above in the section on HR 738, by Massarotti *et al.*¹⁷, which includes orbital elements for HR 5692. In the case of HR 5692, unlike that of HR 738, there is a fully satisfactory number of observations (38). The observations are accessible through the web site of the journal (*Af*) in which the elements are published. After experimenting with including them in the data set and comparing the elements given by the separate and the joint data sets, the writer has decided *not* to include them in Table IV but to present in Table V the elements independently derived by Massarotti *et al.* and from those in Table IV. In computing the second set, the Mount Wilson measurements have been given no weight, and the OHP ones have been half-weighted. The orbit is illustrated in Fig. 5, where both sets of observations are plotted although the velocity curve was computed on the basis of the Cambridge and OHP velocities alone.

A comparison of the two sets of elements does not suggest any non-statistical discrepancies except in the case of the γ -velocity. (The difference of 512 days in T , of course, arises almost entirely through the difference of one cycle in the choice as to which epoch is defined, in turn reflecting the difference in the mean dates of the respective observing campaigns.) The discrepancy of 0.95 km s^{-1} in the γ -velocity reflects with almost embarrassing accuracy the difference of 0.94 km s^{-1} in the admitted departures, mentioned in the section on HR 738 above, of the two sets of observations from a fiducial zero-point.

The reason for not amalgamating the data sets, apart from providing orbital elements that are completely independent of those by Massarotti *et al.*, is that the combined solution is so very similar to that of the writer's observations alone. When a joint solution is made, the Massarotti *et al.* data being increased by 0.9 km s^{-1} and weighted $1/4$ to bring their zero-point and variance into line with those of the Cambridge observations, the solution is almost unchanged. In no case is the difference as much as half a standard error from the elements given in the last column of Table V, and the standard errors of the combined solution are very nearly the same (generally just slightly reduced, as could be expected from the comparatively small total additional weight.)

The mass function of little more than $0.01 M_{\odot}$ is uninformative, requiring a minimum of $0.4 M_{\odot}$ for the mass of the secondary if the primary is taken as $2 M_{\odot}$. The secondary could well be a main-sequence star; it could be anywhere from mid-F (above which its presence might have been detected) to the mass-function limit in the early M types. A cool white dwarf is also a possibility, which is encouraged by the 'mild barium' classification that was for a time favoured by

TABLE IV

Radial-velocity observations of HR 5692

Observed with Cambridge Coravel (weight 1) except as noted

Date (UT)	MJD	Vélocity km s ⁻¹	Phase	(O-C) km s ⁻¹
1924 May 26·31*	23931·31	-4·7	56·123	+3·0
1925 Mar. 4·52*	24213·52	-9·7	56·680	-2·6
4·54*	213·54	-4·6	·680	+2·5
1986 Aug. 15·84†	46657·84	+0·3	11·003	+0·3
1987 May 10·05†	46925·05	-9·7	11·531	+0·2
1989 May 7·09†	47653·09	+1·0	10·968	-0·2
8·08†	654·08	+0·7	·970	-0·5
2002 May 29·94	52423·94	-10·9	0·390	+0·3
July 14·94	469·94	-10·4	·481	+0·1
Aug. 14·89	500·89	-9·7	·542	0·0
Sept. 10·85	527·85	-8·8	·595	0·0
2003 Feb. 15·27	52685·27	+0·2	0·906	-0·3
Mar. 19·09	717·09	+1·3	·969	+0·1
Apr. 15·08	744·08	-1·1	1·022	0·0
May 13·07	772·07	-5·0	·077	0·0
24·06	783·06	-6·3	·099	+0·1
June 11·04	801·04	-8·2	·135	0·0
13·01	803·01	-8·1	·138	+0·3
July 4·96	824·96	-9·9	·182	0·0
27·93	847·93	-10·6	·227	+0·2
Aug. 16·88	867·88	-11·1	·267	+0·1
Sept. 14·80	896·80	-11·6	·324	-0·2
Oct. 16·75	928·75	-11·8	·387	-0·5
2004 Mar. 1·20	53065·20	-7·2	1·656	+0·4
31·13	095·13	-6·0	·715	+0·1
Apr. 22·13	117·13	-5·0	·759	-0·1
May 17·05	142·05	-3·1	·808	+0·1
June 12·98	168·98	-1·0	·861	+0·1
July 5·97	191·97	+0·5	·907	0·0
26·91	212·91	+1·4	·948	+0·1
Aug. 29·83	246·83	-0·6	2·015	+0·1
Sept. 13·81	261·81	-2·9	·045	-0·2
Oct. 7·76	285·76	-6·6	·092	-0·6
2005 Jan. 22·26	53392·26	-11·6	2·302	-0·2
Mar. 23·18	452·18	-11·1	·420	-0·1
May 5·04	495·04	-9·8	·505	+0·4
July 9·92	560·92	-8·4	·635	-0·3
Aug. 6·87	588·87	-6·7	·690	+0·1
Sept. 25·78	638·78	-4·0	·789	-0·1
2006 Jan. 29·28	53764·28	-2·1	3·037	0·0
Apr. 4·11	829·11	-9·3	·165	+0·1
26·05	851·05	-10·2	·208	+0·3
July 11·96	927·96	-11·4	·360	0·0
Aug. 28·85	975·85	-10·8	·455	0·0
Sept. 20·80	998·80	-10·6	·500	-0·3

TABLE IV (concluded)

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O-C) km s ⁻¹
2007 Feb. 3.28	54134.28	-4.8	3.767	-0.2
	192.12	-0.3	.882	0.0
	221.07	+1.2	.939	0.0
	30.04	+0.6	.996	+0.3
	July 6.98	-4.5	4.071	+0.1
	29.88	-7.3	.116	+0.1
	Oct. 4.77	-11.1	.248	-0.1
2008 July 21.91	54668.91	-2.4	4.823	+0.2
	Aug. 1.89	-1.8	.845	0.0

* Mt. Wilson observation^{30,47}, weight 0.† OHP observation¹, weight $1/2$.

TABLE V

Orbital elements for HR 5692

Element	Massarotti <i>et al.</i> ¹⁷	This paper
P (days)	508.7 ± 1.6	506.38 ± 0.20
T (MJD)	53751.8 ± 4.0	53239.3 ± 1.5
γ (km s ⁻¹)	-7.743 ± 0.074	-6.788 ± 0.034
K_1 (km s ⁻¹)	6.19 ± 0.12	6.36 ± 0.05
e	0.327 ± 0.016	0.333 ± 0.006
ω (degrees)	39.0 ± 3.4	35.0 ± 1.4
$a_1 \sin i$ (Gm)	40.9 ± 0.9*	41.76 ± 0.34
$f(m)$ (M_\odot)	0.0106 ± 0.0007*	0.01135 ± 0.00028
R.m.s. residual (wt. 1) (km s ⁻¹)	0.40	0.21

* Re-computed; see discussion following Table II above.

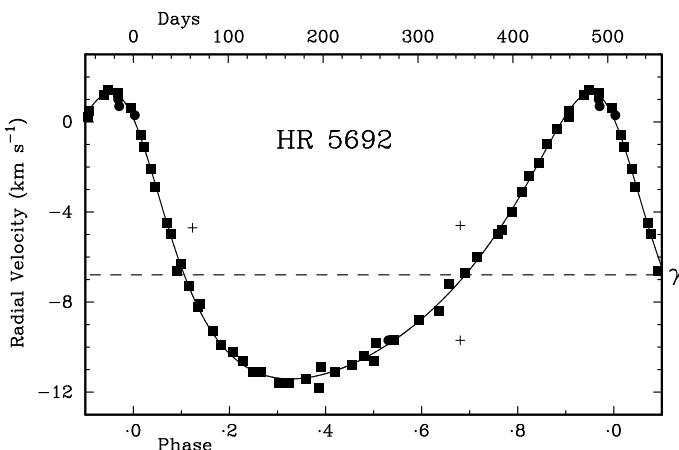


FIG. 5

As Fig. 1, but for HR 5692. The plusses refer to Mt. Wilson observations (zero-weighted) by Adams *et al.*^{30,47}.

Keenan^{33,34}, although if the system has really undergone the complete evolution of one of its members it is a little surprising that the orbital eccentricity has not been left lower than it actually is.

HR 7252 (HD 178298)

HR 7252 is a 6^m star to be found in the extreme south of Draco, about three-quarters of the way from Vega towards κ Cygni, the westernmost bright star in Cygnus. As befits its magnitude, it is shown in the relevant map in *Norton*⁵⁰, where its symbol has a line through it to indicate visual duplicity. It features in Aitken's great double-star catalogue⁵¹ as ADS 12034, but it is not really a worthwhile double star: in 1911 Espin⁵² measured the relative position of a 12^m companion 12" distant, but he did not dignify it with a 'discovery number', as he did for 75 other stars which he listed in the same paper but for which he measured separations less than 8". The *Aladin* picture that can be called up through *Vizier* of the immediate area round HR 7252 plots a position for a star of about the right brightness only about 4" away from the principal star, and nothing else anywhere like as close. If the *Aladin* star were to be identified with the Espin one, it would need to have a substantial proper motion, because the motion of the bright star (less than 0".01 per annum) is too small by an enormous factor to account for such a change in relative position. It is not clear, anyway, how the 4" companion could have been measured (it is attributed to the *USNO-A2.0* catalogue, compiled from the early *POSS* plates), because the *Aladin* picture shows the image of HR 7252 on such a plate as burnt-up out to a radius of 12" or so. More reassuring is a measurement in the *2MASS* infrared catalogue⁵³ of a star answering very closely to the brightness and position of the Espin companion but apparently undetected in the *USNO* compilation notwithstanding that it is about the same brightness and three times as far from the principal star as the companion listed there.

As late as 1986 HR 7252 was one of the objects in a (rather short) list⁵⁴ of stars in the *Bright Star Catalogue* that were still lacking any sort of photometry; that omission was rectified in 1991 by Oja⁵⁵, who gave the broad-band magnitude and colours as $V = 6^m\cdot43$, $(B-V) = 1^m\cdot37$, $(U-B) = 1^m\cdot60$. *Hipparcos* lists a magnitude of 6^m.45 derived from its own measurement of the H_p magnitude, and a $(B-V)$ of 1^m.348 derived from the *Tycho* V_T and B_T measurements.

The *HD* spectral type of HR 7252 is K5; that is also the type that Young & Harper²² listed in their paper on spectroscopically estimated luminosities, in which each of the authors independently derived for it an absolute magnitude of $-0^m\cdot2$. The first MK classification appears to have been made by Abt⁵⁶, as K4 III-IV. HR 7252 subsequently appeared in successive revisions by Keenan and his collaborators of the list of MK standards^{34,35}, as K3 III. The parallax measured by *Hipparcos*⁶ corresponds to a distance modulus of $6^m\cdot26 \pm 0^m\cdot19$ and thus to an absolute magnitude of $+0^m\cdot19 \pm 0^m\cdot19$. That is at the lower-luminosity margin of MK luminosity class III, according to the plot of *Hipparcos* absolute magnitudes by Keenan & Barnbaum⁷. The only other astrophysical information about HR 7252, apart from radial velocities, seems to be that it is a radio star⁵⁷ (which most visible stars are not), and that has led to an astrometric interest in it to assist in tying together optical and radio reference frames.

Radial and rotational velocities and orbit of HR 7252

The radial velocity of HR 7252 was first measured at the DAO, whence it was published in the 1934 paper² by Harper. The observations were, however, not actually made by Harper, and they do not appear in the main body of the paper but in a small *Addendum* entitled 'Velocities of Ten Additional Stars'. The text of the *Addendum* reads, in full, "The following measures, made some time ago by P, came to light as this publication was going through the press, and it seemed fitting to include them in this list." In the main paper, by far the majority of the reported radial velocities stemmed from plates taken and measured personally by Harper, with a sizeable minority by Young, who 'bequeathed' them to Harper in 1924 when he (Young) left the DAO for Toronto, where he subsequently became the first Director of the David Dunlap Observatory. Relatively trivial numbers of plates were contributed by six other observers. In the lists of results the observers and measurers responsible for each individual velocity were identified by initials. 'P', to whom are credited just four plates, stood for J. S. Plaskett. He was the Director of the DAO at the time that Harper's paper was published, and indeed had founded the place, which had become operational in 1917, and been its Director ever since. In the 1920s he had published papers⁵⁸ of his own giving many radial velocities of stars analogous to the ten presented in Harper's *Addendum*. The velocities given for those ten stars were, without exception, obtained in 1918, and could perfectly well have been included in Plaskett's own papers but had evidently been overlooked; one can imagine with wry amusement the manner in which Harper must have been obliged by *force majeure* to include them at the last moment in *his* paper when 'P' belatedly came across them! One of the ten stars is HR 7252, of which Plaskett obtained six observations over a span of four months. They are transcribed to the head of Table VI here. In the case of the second one there is a conflict in the original publication² between the civil and Julian dates, both of which are listed in Harper's paper; it is assumed here that it is the Julian date that is in error, because it is out of chronological order, which the civil date is not. The velocities span a range of 6.3 km s^{-1} ; there is circumstantial evidence that Plaskett thought that that was excessive, because the plates that gave the velocities at the extremes of the range are both flagged as having been measured a second time. The range was not enough, however, to have warranted a suggestion of real variability.

Sixty years elapsed before HR 7252 was observed again for radial velocity. Then, Beavers & Eitter⁵⁹ obtained three measures with the Fick Observatory photoelectric instrument⁶⁰; two were obtained close together in time and the third nearly two years — very nearly one orbital cycle — later, so the discovery of the binary nature of the object was left for the next observers. They were de Medeiros & Mayor¹, using the OHP *Coravel*; they made only two measurements, whose mean was given as $+2.62 \pm 7.29 \text{ km s}^{-1}$, from which it can be deduced that the actual velocities are given individually by exactly that same expression. The projected rotational velocity was given as $1.4 \pm 1.0 \text{ km s}^{-1}$. Later, de Medeiros, da Silva & Maia²⁹ gave the same information again (even to the extent of repeating a misprinted $(B-V)$ colour index), and finally Famaey *et al.*⁶¹ refrained from publishing it a third time because in listing the characteristics of a lot of late-type stars they omitted some known data for stars that were rejected from their analysis through being binary systems with undetermined γ -velocities.

Like the other stars discussed here, HR 7252 was selected from the de Medeiros & Mayor¹ list after the individual data were lodged with the CDS and available

TABLE VI

Radial-velocity observations of HR 7252

Observed with Cambridge Coravel (weight 1) except as noted

Date (UT)	MJD	Vélocity km s ⁻¹	Phase	(O-C) km s ⁻¹
1918 Aug. 20·28*	21825·28	+2·3	45·122	-0·1
23·21*	828·21	+7·5	127	+4·9
Oct. 9·13*	875·13	+5·1	196	-0·9
20·10*	886·10	+6·5	213	-0·3
25·13*	891·13	+8·6	220	+1·4
Dec. 22·08*	949·08	+7·9	306	-2·5
1978 July 23·24†	43712·24	+10·0	13·560	+1·0
Aug. 12·18†	732·18	+9·3	589	+1·5
1980 May 8·42†	44367·42	+8·7	12·531	-1·3
1987 Aug. 13·93‡	47020·93	+11·2	8·463	-0·4
1988 July 16·99‡	47358·99	-3·3	8·964	0·0
2002 May 29·96	52423·96	+11·5	0·471	+0·1
31·06	425·06	+11·2	472	-0·2
July 15·00	470·00	+9·9	539	+0·2
Aug. 14·95	500·95	+8·2	585	+0·2
Sept. 11·01	528·01	+6·1	625	-0·2
Oct. 4·88	551·88	+4·5	660	-0·1
Nov. 14·78	592·78	+1·8	721	+0·1
Dec. 9·75	617·75	+0·1	758	0·0
2003 Feb. 18·24	52688·24	-2·9	0·862	+0·3
Mar. 19·16	717·16	-3·8	905	-0·2
Apr. 19·10	748·10	-3·4	951	+0·1
May 15·11	774·11	-2·9	990	-0·1
June 15·05	805·05	-1·3	1·035	+0·1
July 13·98	833·98	+0·3	078	0·0
Aug. 4·02	855·02	+1·8	110	+0·1
Sept. 10·93	892·93	+4·4	166	-0·1
Oct. 17·86	929·86	+6·9	220	-0·3
Nov. 27·73	970·73	+9·9	281	+0·3
Dec. 28·74	53001·74	+10·7	327	-0·3
2004 Apr. 15·14	53110·14	+11·4	1·488	+0·3
June 8·07	164·07	+8·8	568	+0·1
July 6·05	192·05	+6·9	609	-0·1
Sept. 5·96	253·96	+2·7	701	0·0
Oct. 5·88	283·88	+0·4	745	-0·2
Nov. 13·82	322·82	-1·4	803	+0·2
Dec. 5·75	344·75	-2·7	835	-0·1
2005 May 5·08	53495·08	-0·6	2·058	0·0
June 27·03	548·03	+3·1	137	0·0
July 28·97	579·97	+5·4	184	0·0
Aug. 6·93	588·93	+6·1	197	0·0
Sept. 2·89	615·89	+8·0	237	+0·1
20·89	633·89	+9·2	264	+0·2
Oct. 25·84	668·84	+10·8	316	+0·1
Nov. 18·80	692·80	+11·6	351	+0·1

TABLE VI (concluded)

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O-C) km s ⁻¹
2006 Mar. 23.21	53817.21	+9.8	2.536	0.0
	915.01	+3.6	.680	0.0
	955.05	+0.9	.740	0.0
	985.99	-1.0	.786	0.0
2007 Oct. 19.86	54392.86	+11.7	3.389	-0.2
	418.82	+11.8	.427	-0.1
2008 Aug. 10.97	54688.97	-2.4	3.828	0.0
	727.89	-3.6	.885	-0.1

* DAO observation², weight 0.

† Fick observation⁵⁹, weight 0.

‡ OHP observation¹, weight 1/2.

for scrutiny. It soon proved to change velocity at such a rate that a monthly frequency of observation was appropriate; the star being favourably placed in the sky, in 2003 it was in fact observed in every calendar month except January. The total number of Cambridge radial velocities stands at 42; they are listed, with all the published ones, in Table VI. The two OHP measurements¹ have been included in the solution of the orbit, with half-weight; the DAO and Ames ones have not been used, although they are plotted in the diagram of the orbit, Fig. 6. The orbital elements are:

$$\begin{aligned}
 P &= 674.7 \pm 0.5 \text{ days} & (T)_2 &= \text{MJD } 53456 \pm 22 \\
 \gamma &= +4.29 \pm 0.03 \text{ km s}^{-1} & a_1 \sin i &= 72.4 \pm 0.4 \text{ Gm} \\
 K &= 7.81 \pm 0.04 \text{ km s}^{-1} & f(m) &= 0.0333 \pm 0.0005 M_{\odot} \\
 e &= 0.022 \pm 0.004 & \text{R.m.s. residual (wt. 1)} &= 0.15 \text{ km s}^{-1}
 \end{aligned}$$

It will be noticed that the eccentricity is very small, but is nevertheless five times its standard error. In an experimental solution upon which zero eccentricity was forced, the sum of squares of the residuals from the orbit was raised to 1.58 (km s⁻¹)² from the 0.96 of the solution given above. Thus the two degrees of freedom represented by e and ω cost 0.62 (km s⁻¹)² whereas the 38 degrees remaining in the original solution cost 0.96. Those figures yield a variance ratio, $F_{2,38}$, of about 12 — well beyond the 0.1% point which is⁶² 8.33, so there is no reasonable doubt that the orbit is non-circular. The smallness of the eccentricity causes the standard error of T to be very large, so it is useful to give also a value of T_0 , a time of maximum velocity, which is MJD 53735.1 ± 0.7; it is seen to be defined some 30 times more precisely than T .

The mass function requires the secondary star to have a mass of at least 0.6 M_{\odot} if the primary is supposed to be 2 M_{\odot} , so if it is a main-sequence star it could be no later than late K. As usual, a cool white dwarf would also be possible; in this case the low eccentricity of the orbit is a point in favour of that possibility although it is by no means decisive, especially in view of the absence of evidence of excess abundances of s-process elements in the atmosphere of the primary.

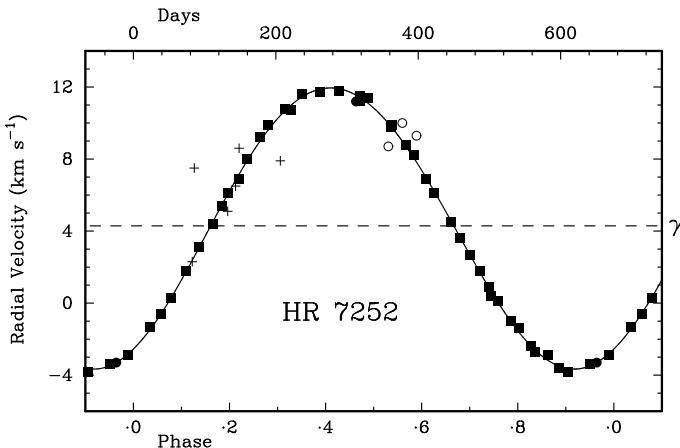


FIG. 6

As Fig. 1, but for HR 7252. The plusses identify DAO observations made by Plaskett in 1918 and appended to a paper by Harper², while the open circles plot the Fick Observatory measurements of Beavers & Eitter⁵⁹; neither source was utilized in the determination of the orbit.

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SPECTROSCOPIC BINARY ORBITS
FOR THE HENRY DRAPER CATALOGUE STARS

PAPER I: HD 1

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HD 1, a star strangely neglected in the literature, is shown to be a K giant in a binary system whose orbit has an accurately determined period of some six years and an eccentricity of 0.5.

HD 1 is a seventh-magnitude star in a corner of Cepheus, very nearly half-way between β Cassiopeiae and γ Cephei. Its high declination (about 68°) could have been anticipated on statistical grounds. Star positions in the *Henry Draper Catalogue*¹ are listed in successive zones each spanning a tenth of a minute of time; there are therefore 14 400 such divisions in the whole sky, so since the *Catalogue* contains 225 300 stars there must on average be about 16 stars in each $0^m.1$ zone. Within each zone they are listed in descending order of declination. Statistically, therefore, one could expect to find HD 1 in the first $1/16$ of the area of the first zone (the one between right ascensions $0^m.0$ and $0^m.1$ at the epoch (1900) of the *Catalogue*). That part of the zone reaches from the North Pole to a declination of $\arcsin(1 - 1/8)$; its centre, by area, comes at $\delta \sim \arcsin(1 - 1/16)$ — about 69° , very satisfactory!

The star seems never to have been observed photometrically, and no classification of its spectrum has been made apart from the K_α given in the *HD*. The *Hipparcos Catalogue*², however, gives its V magnitude, determined by *Hipparcos* itself, as $7^m.41$, and its $(B - V)$ colour index, from *Tycho*, as $1^m.29$. The parallax of only $0''.00253 \pm 0''.00069$ corresponds to a distance modulus close to eight magnitudes, suggesting that HD 1 has an absolute magnitude close to — most probably a little brighter than — zero, exactly as befits a late-type giant. The colour index is decidedly redder than corresponds to the *HD* type, and suggests a type of K_3 III — but that is obviously not a proper spectroscopic classification and must not be entered into catalogues of spectral types.

The only astrophysical datum to be found in the literature about HD 1 is a measurement of its radial velocity by Delgado *et al.*³, who in an investigation of a Galactic star cluster used the star as a standard of spectral type and radial velocity (notwithstanding that they did not know either!) and measured its radial velocity. They gave a velocity having a standard error of 8.9 km s^{-1} at a time given to six decimal places of a day; evidently their clock was more sophisticated than their spectrograph. The only useful radial velocities, therefore, appear to be our own.

The star was placed on RDM's radial-velocity programme at the Dominion Astrophysical Observatory (DAO) in 1980, and proved in the following year to be variable in velocity. It was observed quite assiduously for some years with the radial-velocity spectrometer⁴ at the coudé focus of the 48-inch reflector, and then less frequently after the general nature of its orbit had become apparent, until 1994. In 2002 RFG, recalling from conversations with RDM that the latter had discovered the binary nature of HD 1, thought it would be nice to conclude an investigation of that star, and added it to the programme of the Cambridge *Coravel*. Altogether, there are now 64 velocity measurements, 34 from the DAO and 30 from Cambridge; they are listed in Table I. To bring the two sources into systematic agreement, the DAO velocities have been increased by 1.2 km s^{-1} , and in the solution of the orbit they have been weighted 0.4 , the Cambridge measures being given unit weight. On that basis the orbit illustrated in Fig. 1 is obtained; its elements are:

$P = 2315.9 \pm 2.7$ days	$(T)_4 = \text{MJD } 52213 \pm 9$
$\gamma = -29.33 \pm 0.05 \text{ km s}^{-1}$	$a_1 \sin i = 120.9 \pm 2.4 \text{ Gm}$
$K = 4.35 \pm 0.08 \text{ km s}^{-1}$	$f(m) = 0.0132 \pm 0.0008 M_\odot$
$e = 0.488 \pm 0.013$	
$\omega = 224.0 \pm 2.2 \text{ degrees}$	R.m.s. residual (wt. 1) = 0.31 km s^{-1}

TABLE I

Radial-velocity observations of HD 1

Observed at DAO 1980–1994, Cambridge 2002–2008

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O—C) km s ⁻¹
1980 Sept. 3·35	44485·35	−29·1	0·663	+0·2
1981 July 14·42	44799·42	−30·3	0·799	+1·1
Aug. 1·48	817·48	−32·2	·807	−0·7
Sept. 23·31	870·31	−31·5	·829	+0·5
29·32	876·32	−32·1	·832	0·0
Oct. 2·34	879·34	−32·3	·833	−0·2
3·27	880·27	−32·4	·834	−0·3
30·22	907·22	−32·3	·845	+0·1
Nov. 27·29	935·29	−32·8	·858	−0·1
1982 Apr. 9·51	45068·51	−34·0	0·915	+0·3
June 8·46	128·47	−34·9	·941	+0·1
July 21·50	171·50	−36·1	·960	−0·9
Aug. 19·49	200·49	−35·7	·972	−0·6
24·53	205·53	−34·4	·974	+0·7
Oct. 19·57	261·57	−33·7	·998	+0·4
1983 Apr. 17·52	45441·52	−29·2	1·076	−0·4
May 12·50	466·50	−28·1	·087	+0·2
July 19·49	534·49	−28·0	·116	−0·5
Sept. 8·46	585·47	−26·9	·138	+0·1
Oct. 1·51	608·51	−28·2	·148	−1·3
Dec. 1·30	669·30	−26·4	·174	+0·3
1984 May 29·48	45849·48	−25·1	1·252	+1·4
Aug. 3·49	915·49	−27·5	·281	−0·9
Sept. 29·55	972·55	−26·5	·305	+0·2
1985 Sept. 26·25	46334·25	−27·4	1·462	0·0
1986 Aug. 15·48	46657·48	−28·3	1·601	+0·3
Oct. 11·40	714·40	−28·5	·626	+0·4
1987 June 24·45	46970·45	−30·1	1·736	+0·2
Sept. 19·38	47057·38	−31·4	·774	−0·5
1988 Aug. 4·37	47377·37	−34·5	1·912	−0·2
1989 Aug. 25·37	47763·37	−28·6	2·079	+0·1
Sept. 20·33	789·33	−27·7	·090	+0·6
1993 Oct. 1·44	49261·44	−29·8	2·726	+0·3
1994 Oct. 22·20	49647·20	−33·9	2·892	−0·2
2002 Sept. 28·03	52545·03	−27·0	4·143	0·0
Oct. 4·08	551·08	−26·7	·146	+0·2
2003 Jan. 4·77	52643·77	−26·4	4·186	+0·2
Feb. 22·81	692·81	−26·4	·207	+0·1
Sept. 11·02	893·02	−26·9	·294	−0·3
2004 July 10·09	53196·09	−27·6	4·424	−0·4
Sept. 14·06	262·06	−27·4	·453	0·0

TABLE I (concluded)

Date (UT)	MJD	Velocity km s ⁻¹	Phase	(O-C) km s ⁻¹
2005 Jan. 18.80	53388.80	-27.7	4.508	+0.1
May 12.13	502.13	-28.4	.557	-0.2
June 23.06	544.06	-27.9	.575	+0.4
July 20.10	571.10	-28.6	.586	-0.1
Aug. 15.13	597.13	-28.3	.598	+0.3
Oct. 25.99	668.99	-29.1	.629	-0.2
2006 Jan. 4.73	53739.73	-29.4	4.659	-0.2
Mar. 2.80	796.80	-29.5	.684	0.0
May 30.08	885.08	-30.8	.722	-0.8
July 17.11	933.11	-29.9	.743	+0.4
Sept. 8.10	986.10	-30.6	.766	+0.1
Nov. 1.98	54040.98	-31.3	.789	-0.1
2007 Jan. 10.82	54110.82	-31.5	4.819	+0.3
May 30.09	250.09	-33.5	.880	-0.2
July 27.08	308.08	-33.8	.905	+0.2
Sept. 26.09	369.09	-34.8	.931	0.0
Nov. 23.96	427.96	-35.2	.956	0.0
2008 Jan. 5.85	54470.85	-35.1	4.975	0.0
Feb. 8.79	504.79	-34.3	.990	+0.3
Mar. 7.78	532.78	-33.9	5.002	0.0
May 19.10	605.10	-31.8	.033	-0.3
June 26.08	643.08	-30.3	.049	0.0
July 24.11	671.11	-29.4	.061	+0.1

The mass function is too small to be informative; it requires a minimum mass of not much more than $0.4 M_{\odot}$ for the secondary if the primary is arbitrarily supposed to have a mass of $2 M_{\odot}$.

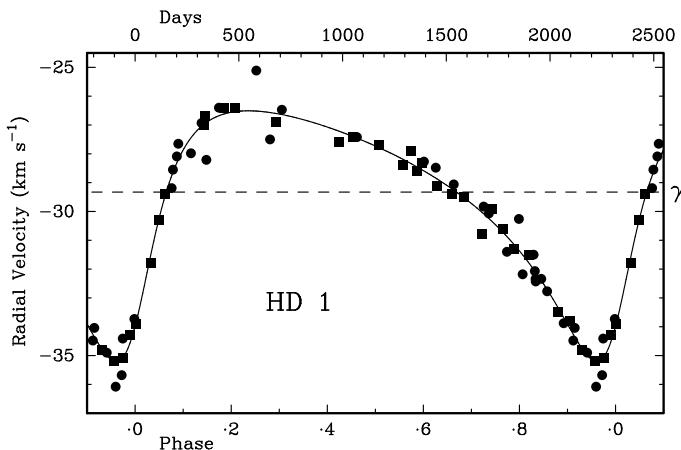


FIG. 1

The observed radial velocities of HD 1 plotted as a function of phase, with the velocity curve corresponding to the adopted orbital elements drawn through them. Circles and squares plot measurements made at the DAO and Cambridge, respectively.

The equivalent width of the dip seen in radial-velocity traces is not quite as large as could be expected from a star of the putative spectral type of HD 1. Possible reasons for that might be significant metal deficiency, or else the dilution of the light of the primary star (in the violet, where the radial-velocity instruments operate) by a hotter companion star, perhaps of late-A or early-F type. Coming as they do from a K giant, the traces show the unusual feature of substantial excess width, corresponding to a projected rotational velocity of 9.0 km s^{-1} . The width reproduces extremely well from one trace to another, the r.m.s. spread of the individual values obtained at Cambridge being only 0.5 km s^{-1} and the standard error of the mean only 0.09 km s^{-1} . Of course that is only a formal precision; the true external accuracy of the result might be put at 1 km s^{-1} .

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REVIEWS

Against the Tide, edited by M. López Corredoira & C. Castro Perelman (Universal Publishers, Boca Raton, Florida), 2008. Pp. 265, $21.5 \times 14 \text{ cm}$. Price \$25.95 (about £17) (paperback; ISBN 1 599 42993 4).

The concept of this book was to present some candid opinions on what is not right with prevailing practices regarding the management of research, primarily in astronomy and physics, and whether such management is on balance detrimental to the overall health and future of the disciplines. In principle it sounds an intriguing read, especially if you wonder whether your own unease over the way some matters appear to be handled are isolated instances or more widespread signs of dysfunction. However, what we are offered is a collection of 14 contributions from 11 authors (three are permitted two bites at the same cherry) who are sufficiently bold or desperate, or who believe they have nothing to lose. Consequently their views are for the most part at the more extreme end of the spectrum, and smack very seriously of output from people with a huge chip on the shoulder.

It starts out quite promisingly, with definitions of ‘dissenter’, ‘challenger’, and degrees thereof that one may live with or which drive one along (or away). Three or four of the articles are relatively gentle accounts of experiences with which not a few of us can identify and certainly sympathize; peer pressure, peer review, and funding allocations all come in for some heavy and not undeserved criticism. Then cynicism takes over, and we are plunged into tirades against every aspect of ‘Establishment’ and its paid servants. Unfortunately, those more zealous contributions tip the balance heavily by what can only be described as ranting about their career experiences and opinions (which, for some reason, are mostly

connected with theoretical cosmology). And seemingly unsatisfied with just stating the problem, they go on long enough to become rather boring.

A scientific analysis would have been more persuasive: a statement of the altruistic objectives (whether awarding telescope time, grant funding or faculty positions, selecting topics for research or publishing results), followed by a careful appraisal of how far those ideals are met in a variety of sub-disciplines, and countered by 'observation': a succinct, balanced account of personal experiences from both sides to illustrate where actual practice falls short of the ideal. By identifying with what is right as well as with what is wrong, the reader would be more likely to sympathise, empathise, and draw upon the book as a cogent source for reference when endeavouring to modify on-going practices in the home government, institution, or sub-department.

Instead, most of the articles yell so persistently and unrestrainedly that their actual messages, though nucleated on grains of truth, are obliterated by torrents of words that effectively tell us merely that the author senses a grievance and is unhappy. The hyperbole employed, and the repeated use of words like 'threat', 'lie', and 'false priests', fail to convince. One author introduces the rather sensible idea of a *Charter for Scientific Human Rights*, but even there, instead of stating simply what those 'Rights' should be, each is prefaced with a string of examples in which violations need to be curbed.

The editors have allowed bad spelling and bad grammar. Some of the authors struggle to express themselves adequately in English, thus adding to the pervading sense of frustration. Even the fundamentals of editing have been overlooked: one article refers frequently to section numbers, but the book has no section numbering, and we are left wondering if the article was some journal's reject.

What worries me most about this book is its sub-title: *A Critical Review by Scientists of How Physics and Astronomy Get Done*. The picture it paints of our heavily-funded research disciplines is so biased, so prejudiced, and on balance so incorrect, that it could cause considerable damage were it to be read by those with executive power or even by the general public (whose money ultimately supports it all). Many contributors describe their bad experiences as though they are general and widespread, and while there is occasional parenthetical mention that maybe it's not all that bad for everyone, this is not the message that emerges and nor is it intended to be. Even the basic understanding of astronomical research is faulty. Astronomy is an observational science, and the great majority of telescope time is used in order to amass data, to measure, and eventually to deduce. Only relatively rarely is one in a position to request time to make a definitive observation to clinch or disprove a major hypothesis, whereas what we are persuaded to believe (actually by one of the editors) is that observational astronomy is *only* about competing for telescope time in order to prove this or that.

In principle there is no harm in pointing out that there are corruptions in the present systems, if the claims can be substantiated by balanced and truthful evidence of what is awry. But to scream at length that *all* cupboards are bursting with skeletons bares itself to the danger of getting dismissed as the mere venting of frustration. We all know that there *are* cases of mishandling, bias, and maybe worse, but what we have here is surely not the way to tackle it. This book may do a great deal of harm, and should never have been published. —

ELIZABETH GRIFFIN.

Sirius Matters, by Noah Brosch (Springer, Heidelberg), 2008. Pp. 216, 23·5 x 15·5 cm. Price £79/\$159/€99·95 (hardbound; ISBN 978 1 4020 8318 1).

About half of this slender volume is devoted to a number of fascinating historical topics, despite which the author does not answer the burning question, “Who was the first to make the Sirius/serious pun?”. Both Sirius A and B appear, and the author begins with the Ancient Egyptians and continues down to modern observations and calculations of structure and evolution of single and binary stars. Do I agree with every word? No, of course not (despite being thanked for comments and input at some point). But that is what the blank inside cover pages are meant for — to record the page numbers to which one might want to attach comments like “eh?”, “ugh”, “nuts”, and “out of date”. The “out of date” comment belongs primarily to topics where the author has traced out the full history of how we came to understand things without visibly tagging the line between ‘history’ and ‘current events’ for topics like the relationship between main-sequence mass and final white-dwarf mass.

Half way through the main text takes you to Huggins looking at the Fraunhofer lines in the spectrum of Sirius A, and if you are so pressed for time that you cannot finish the whole book, this might be about the right place to stop. Two of the most controversial topics explored at length are: (i) was Sirius red somewhere around year zero, and if so why? and (ii) did the Dogon people of what is now Mali know about Sirius B back in the 1930s, and, if so, did they learn about it from extraterrestrial visitors? The author would, I think, like to be able to say firmly “yes” to the first, and to explain it as rapid drift of a small, reddening cloud of interstellar dust (and gas) between us and Sirius. My reservation here is that it will take a *very* dense cloud to get 1·0–1·5 magnitudes of *B*–*V* reddening into a volume small enough to drift by in a few hundred years. As for the Dogon, Brosch hints at an explanation (roughly analogous to implanted memory) that I had not heard suggested before, and would rather like to be true. Although the author’s and review copies of the book are in glorious black and white, the copy you or your library buys will have several images of Dogon ritual dances, some spectra and images, and historical pictures in colour. The only case where I wished ‘siriously’ for colour was the photograph of the *Atlas Farnese*, which is said to retain traces of the original pigments on the marble, and which one might want to examine for red around Sirius.

Brosch also, of course, touches on many things that I had not properly thought of before (nor perhaps have you), for instance, the gradual change in the date of the heliacal rising of Sirius (traditional harbinger of Nile flooding) due to precession of the equinoxes. It now comes too late to be of much use (but then Aswan no longer lets the Nile flood anyhow). The author also cites one of my all-time favourite books, C. W. Ceram’s (real name W. K. Marek) *Gods, Graves, and Scholars*, though in a late 1967 edition, undoubtedly inferior to the one I loved in 1954. — VIRGINIA TRIMBLE.

Border Heritage, edited by M. E. Bailey (The Stationery Office, Norwich), 2008. Pp. 285, 21 x 15 cm. Available free from TSO Bookstore (www.tsoshop.co.uk) (post & packing to be paid) and on application to Professor Bailey at Armagh Observatory (paperback; ISBN 978 0 337 09011 0).

One might be forgiven for thinking that, of all the sciences, astronomy has a distinct cultural dimension, such that a country might be proud of its achievements in that field and thus wish to preserve its astronomical heritage,

both by maintaining the institutions that have nurtured the subject and by encouraging it to flourish in the present day and into the future. Unfortunately that seems not to be the case in England where the national observatory (the RGO) has been closed, or in Scotland where the ROE has been downgraded to a workshop with an uncertain future; and so far as I am aware, Wales never had a national observatory.

Fortunately, the situation is much rosier in Northern Ireland where Armagh Observatory is not only flourishing but is clearly held in high regard by the local community as part of *their* heritage. This comes to light in one chapter of this nicely produced and very well-illustrated book collecting together presentations from the 2006 and 2007 Armagh Heritage Days. Owing much to the direction of Richard Robinson, Archbishop of Armagh from 1765 to 1794 (and whose date of birth, 1708, is unambiguously determined in this book for the first time), a number of locations in Armagh (libraries, churches, museums, etc.) now form the basis for significant civic pride in that city, and each is given space in the book to show what they offer to the public. It is a venture that can readily be extended to a wider area — and it already embraces nearby County Monaghan in Ireland — and which is a wonderful development in the aftermath of 'the Troubles'. From the astronomical perspective, a very central element is the Observatory, which not only participates in front-rank research but also has a major outreach programme, including an associated planetarium and the recently opened 'Human Orrery' (see these pages 126, 236, 2006). The book also contains an interesting piece of research on the third Director of Armagh Observatory, Thomas Romney Robinson (no relation of the Archbishop), whose date of birth is often given in the literature — and on his gravestone! — as 1792, but which turns out to be 1793 April 23.

For the future, it is clear that a wider public involvement is essential to make the politicians sit up and take notice, and for Armagh Observatory the benefits are already clear. Long may they prosper. — DAVID STICKLAND.

Astronome des lumières — Jérôme Lalande, by Simone Dumont with a foreword by Jean-Claude Pecker (Ed. Vuibert/Observatoire de Paris, Paris), 2007. Pp. 360, 15·5 × 24·0 cm. Price €35 (about £28) (paperback, ISBN (Vuibert) 978 2 7117 4028 4 & (Obs. de Paris) 978 2 901057 54 3).

Before I read this volume, Jérôme Lalande (1732–1807) was for me just a name in astronomy books and manuals, occasionally associated with an ephemeral constellation sounding like a joke, *Lalande's Cat*, proposed by himself and drawn by Johann Elert Bode in his 1801 atlas. Now Lalande (or Lefrançois de Lalande, later Delalande or de la Lande, and finally Lalande) appears to me not only as a man of flesh and blood, but also as a formidable hard worker who influenced his times. Dumont's style is fluid. Her discourse is very pleasant to follow as it leads and retains the reader through the various stages of Lalande's life, along which the book is structured. The wealth of information provided is impressive, resulting in a remarkably well-documented volume.

Dumont extensively uses excerpts and quotations, which efficiently help set the context in the wording of the times. This gives also a sense of Lalande's own character, said to be bad tempered by some. But I would simply rate him as strong willed — quite likely the moving force behind the enormous amount of his achievements, also outside astronomy with his deep involvement in freemasonry, for instance. Lalande's yearly reviews (in the *Journal des Savants*, *La Connaissance des*

Temps, and other outlets) are still used today by historians of astronomy. The prize (Gold Medal or the equivalent in cash) he founded in 1802 was bestowed until 1970 (when it was merged with other prizes) by the French Academy of Sciences to the person who made the most intriguing observation or the one that had been most useful to the progress of astronomy, in France or elsewhere. The first recipient was Giuseppe Piazzi in 1803 for his discovery of Ceres on 1801 January 1.

In 1763, Lalande travelled to England at his own expense. He met James Short, the constructor of optical instruments, and Nevil Maskelyne, who was to become Astronomer Royal two years later. He attended meetings of the Society of Arts and of the Royal Society of London (of which he had been a correspondent and would be elected a Fellow). In 1776, Lalande considered returning to England, an interest possibly triggered by Ramsden's instruments and Dollond's glasses. But a decade later, the construction by Herschel of a large telescope became the decisive motivation. That second trip took place in 1778. Lalande met numerous personalities and visited many places. Herschel's observatory was qualified as a "centre of astronomy in the universe". His instrument was definitely "constructed by a musician".

All illustrations of Dumont's book have been printed in black and white, something quite understandable for historical reproductions even if some colour here and there (given its relative cheapness nowadays with the right printing equipment) might have made a more appealing volume. Some readers would probably make good use of an exhaustive index, including also subjects in addition to just people's names — a suggestion for a possible second edition. But those reservations do not remove anything substantial from this wonderful contribution to the gallery of astronomers' biographies. It ought to be translated quickly into English too. — A. HECK.

The Universe in a Mirror: The Saga of the Hubble Telescope and the Visionaries Who Built It, by Robert Zimmerman (Princeton University Press, Woodstock), 2008. Pp. 287, 24 × 16.5 cm. Price £17.95/\$29.95 (hard-bound; ISBN 0 691 13297 6).

Putting to one side the science-fiction musings of Hermann Oberth in 1923, and the lunar telescopes dreamt of by Henry Norris Russell in 1933 and Richard Richardson in 1940, the first realistic, concrete, and technologically-based vision of an actual, optical, general observatory telescope being placed into low Earth orbit was advanced by the visionary American astrophysicist Lyman Spitzer, Jr. in his 1946 paper *Astronomical Advantages of an Extra-Terrestrial Observatory*.

The rest, as they say, is history. Serious instrument design started in 1970; launch of NASA's *Hubble Space Telescope* occurred on 1990 April 24, and the telescope remains up there, working superbly.

The award-winning American science writer Robert Zimmerman is a first-class story-teller. His book is incisive, engaging, well researched, well referenced, and riveting. We are skilfully led through all the twists and turns of this saga of modern scientific and technological endeavour. We read of the initial indifference of many astronomers who realized that one space telescope costs more than at least ten Earth-bound giant instruments. Then there is the mission de-scoping where the *Large Space Telescope* was replaced by a modified spy satellite with an 'off-the-shelf' 2.4-m mirror blank, followed by the delicate art of the 'buy in', where you only reveal the full cost-to-completion when so much money has been spent that those responsible dare not cancel.

Next comes the drama of the 'first-light' image of the star τ Carinae, where the tell-tale halo revealed the presence of spherical aberration, a mis-polished primary mirror, and the possibility that the whole instrument was a 'techno-turkey'. Jittering solar panels and failing gyros add to the problems. We learn that intense lobbying eventually led to the defeat of the funding crisis and we are taken step by step through the technological breakthrough that resulted in corrective optics and a rescue mission.

'Second light', 1993 December, revealed that the nightmare of '*Hubble Trouble*' was over. The radiation from one star now hit one pixel. The cloudy, hazy, fuzzy, foggy, wavelength-restrictive, Earth atmosphere had been well and truly conquered. Things were now really seen in the cosmos that had never been seen before. The *Hubble* was revealed in all its glory as a magnificent achievement. And the way in which it could be serviced and upgraded by regular Shuttle visits underlined the importance of the partnership between robotic and human spaceflight.

The *Hubble Space Telescope* is a magnificent stepping-stone on the unending journey to astronomical enlightenment. Anyone interested in the future of our subject and the trials and tribulations of planning, manufacturing, and operating space instrumentation will benefit hugely from reading this marvellous book. —

CAROLE STOTT

Classical Novae, 2nd Edition, edited by M. F. Bode & A. Evans (Cambridge University Press), 2008. Pp. 375, 25·5 \times 18 cm. Price £75/\$145 (hardbound; ISBN 978 0 521 84330 0).

A nova is the result of the explosive burning of partly degenerate gas at the base of an accreted layer on a white dwarf (WD), the optical brightening of 6–16 magnitudes being due to the expanding optically thick ejecta. Novae show a number of behavioural regularities, for example, allowing them to be used as distance indicators, but also many individual peculiarities which new techniques may resolve into recognizable patterns. With perhaps only 5–10% of Galactic novae being discovered, at least the coming era of high-cadence, all-sky optical monitoring promises to result in a much larger sample, while the scheduling flexibility of the *Swift* X-ray and optical/UV telescopes is already providing much better coverage of these novae after outburst.

The first edition of *Classical Novae*, edited by Bode & Evans and published in 1989, was a collection of thirteen articles by experts in the field. The new edition is similarly authoritative, providing updates from the *IUE* and *Einstein* era and considerable advances in modelling. It spans the radio to gamma-rays and extends the discussion from an historical overview to novae in external galaxies. We now have articles on subjects not previously covered: evolution, atmospheres and winds, abundances, nova remnants, and dust production, as well as an overview and four waveband-specific articles.

Duerbeck provides a brief outline of the evolution of the nova concept from the first use of the word by Pliny in AD 75. After a concise overview of the optical properties of novae and their classification by Warner, we are taken in some detail by Iben & Fujimoto through the evolution of the binaries which become the semi-detached white-dwarf-containing systems undergoing thermonuclear nova explosions, and a description of the nova-ejecta abundances for various WD conditions. Starrfield, Iliadis & Hix discuss how new opacities and nuclear-reaction rates are changing the interpretation of observed nova explosions; they

also highlight how continuous surface hydrogen and helium burning on hot WDs provides a natural progenitor for the type-Ia supernovae. The article by Hauschildt emphasizes the massive radial extension, low density, and flat density profile of the optically thick nova wind compared to normal stellar atmospheres, and illustrates their unusual nature with new NLTE model atmospheres showing how the short-wavelength (optical–UV) spectrum is utterly dominated by line blanketing. The review by José & Shore stresses the complex structure of real nova ejecta and the importance, but relatively low reliability, of observational abundance measurements. As most reaction rates have been measured experimentally for the rather limited set of nuclear reactions that occur in novae, there is hope of real progress if the spatial photo-ionization and possible elemental variations can be modelled correctly. Radio emission has been seen from only 19 novae and has been well studied in very few; Seaquist & Bode show that the predominantly thermal emission (which rises over tens of days and declines over hundreds of days) points to a wide velocity dispersion in the wind, and that distance, ejected mass, and kinetic-energy estimates are possible. Gehrz explains that the low-mass CO novae are dust-forming at 30–80 days whereas the high-mass ONe novae make little dust; this leads to very different IR signatures with a strong ~ 1000 -K blackbody for the former, and a $12.8\text{-}\mu\text{m}$ [Ne II] emission line lasting years in the latter case. The article by Shore summarizes the spectroscopic evolution shown by all novae, and emphasizes the importance of the UV flux from the WD in understanding the constant (usually Eddington-limited) luminosity phase of novae. The flux variation of UV lines such as He II 1640 Å can be used to determine the time at which nuclear burning ends, while optical line profiles reveal the complex velocity and ionization structure present. Krautter reviews the much younger study of novae in the X-ray band. Surprising forms of short-term X-ray-flux variation have been seen, most of which remain to be understood. One clear result is that high-mass WDs are implied by the short duration of the nuclear-burning phase, which is seen directly as super-soft X-ray emission. Nuclear gamma-rays have not yet been confidently detected from any nova, although this remains in prospect if satellite concepts currently under study are realized. Hernanz reviews the importance of gamma-ray observations, showing how emission-line spectra can distinguish CO from ONe WDs. The impressive increase in the number of resolved nova remnants, especially at non-optical wavelengths, is discussed by O'Brien & Bode. The clumpiness, occasional ring structure, and overall shape are fascinating and highly diagnostic of the nova explosion and its environment. Dust formation causes a very deep minimum in the optical light curves of some novae; Evans & Rawlings provide the chemistry for the formation of the precursor molecules, and show that in spite of the intense UV radiation field from the WD, carbon- and silicon-rich dust will form quickly if sufficient density contrast exists in ejected gas below 1700 K. Shafter describes how M 31 novae have clearly been shown to be associated with the bulge rather than the disc, and it seems likely that they were born in the dense stellar environments of the globular clusters. Novae are potentially useful extragalactic distance estimators, although limited by the possible existence of a class of super-bright novae.

Classical Novae is a comprehensive description of the state of current knowledge of novae. It serves as an excellent introduction to the subject, and is well referenced. Its articles are written by people who have made substantial contributions to the subject, and it will be a first port of call for anyone who needs to know about these fascinating stellar explosions. — JULIAN OSBORNE.

Pathways Through an Eclectic Universe (ASP Conference Series, Vol. 390), edited by J. H. Knapen, T. J. Mahoney & A. Vazdekis (Astronomical Society of the Pacific, San Francisco), 2008. Pp. 588, 23·5 × 15·5 cm. Price \$77 (about £50) (hardbound; ISBN 978 1 58381 650 9).

If 'Origins' was a popular theme in astronomy in recent years (at least so far as NASA was concerned), then 'Formation' is clearly the key-word for this conference held on Tenerife in 2007 April, for it covers the formation of stars and galaxies — and their interdependence — through a wide-ranging set of reviews and reports of work in progress. That broad topic was chosen to celebrate John Beckman's 40 years in astrophysics, and it is notable for a number of contributions from John and his colleagues. It is also poignantly significant as Bernard Pagel's last major astronomical appearance before his untimely death in July of that year. So this volume has both joyous and sad overtones. But it is also a fine tribute to both men in respect of the large number of excellent papers from Spanish astronomers it contains — demonstrating just how far that country has come in our science over the last 30 years or so — by recalling that British involvement has played its part in that progress, in this particular instance through John's work at the Instituto de Astrofísica de Canarias and Bernard's work with young Spanish astronomers at the RGO.

These proceedings have appeared in good time and have benefitted from the inclusion of the discussions scattered through the meeting and two more-formal Panel Discussions. Mike Edmunds summarizes the conference well, but not before Dave Lambert has shown that "all that glisters is not gold". The proceedings are themselves eclectic in respect of a couple of distinctly non-astronomical contributions at the end, but are well rounded out with good indices. Definitely one for the library. — DAVID STICKLAND.

Star-Disk Interactions in Young Stars (IAU Symposium No. 243), edited by J. Bouvier & I. Appenzeller (Cambridge University Press), 2007. Pp. 375, 25·5 × 18 cm. Price £65/\$130 (hardbound; ISBN 978 0 521 87465 6).

The conference, held in Grenoble in 2007, largely considered the interaction between young stars and their surrounding discs. It is now universally accepted that young stellar objects are surrounded by relatively thin circumstellar discs and that it is these discs that provide the conduit for the outward transport of angular momentum, allowing mass to accrete onto the central star. What is still uncertain is how this accretion actually takes place. The general consensus is that mass is transported inwards through the disc and then accretes onto the star along stellar magnetic-field lines, and the first two papers, written by Claude Bertout and Gibor Basri, introduce very nicely the accretion disc and magnetospheric-accretion paradigms. The next two sections of the book then consider, in quite some detail, our current understanding of stellar magnetic fields and how these magnetic fields interact with the inner parts of the disc.

Although the process of mass accretion in young stars is interesting in its own right, what I thought the book did relatively well was discuss the implications of star-disk interactions. An entire section was devoted to winds and jets, and although much work is being done in these areas, there still seems to be quite a lot of uncertainty about the launching mechanisms. There was also discussion on how stellar magnetic fields may truncate the inner disc, influencing the rotational evolution of the central star, which could have implications for the evolution of

close-in planets. It is also still not entirely clear how discs finally disperse, one possibility being that discs are photoevaporated by EUV and X-ray emission from the central star. A number of papers discuss X-ray emission from young stars and how this may be attenuated by the accretion columns, interestingly suggesting that the flux from the central star may be insufficient for photoevaporation to be significant and potentially creating problems for models of disc dispersal.

Although many of the papers discuss star-disc interactions in young solar-like stars, there was some discussion of other systems. There were a couple of very interesting papers on brown-dwarf stars illustrating, to a certain extent, that their early evolution is very similar to stars that will ultimately evolve onto the low-mass end of the main sequence. There was only one paper on one of the classical star-disc systems — cataclysmic variables — a nice reminder that much of our understanding of accretion discs and star-disc interactions came from studying cataclysmic variables and dwarf novae, and is now being used to try and understand the formation and evolution of young stars. All in all, this was a pretty good collection of papers discussing our current understanding of star-disc interactions, but also illustrating that there is still a lot that we don't know and a lot still to do. — KEN RICE.

Massive Stars as Cosmic Engines (IAU Symposium 250), edited by F. Bresolin, P. A. Crowther & J. Puls (Cambridge University Press), 2008. Pp. 590, 25 × 17 cm. Price £65/\$130 (hardbound: ISBN 978 0 521 87472 4).

More than most, this symposium looked to the future, for the introductory speaker began by writing, “Fifty years ago, Peter Conti *et al.* (1967) found that ...”. As far as recent developments, there are mentions of clumping in stellar winds, the increasing importance of infrared data, quantitative spectroscopy beyond the Milky Way, and theoretical evolution models including rotation and magnetic fields, among other topics.

The editors have, I think, made good use of their page allotment. Most of the 24 invited talks got 12–14 pages, the contributed ones 6–8, and about 130 poster contributions are represented by abstracts printed, on average, three to the page. Are such brief summaries of use? In the near term, at least, yes, because for each poster there is a presenter with an affiliation and email address. I did a spot check of 25 (the first alphabetically under each letter whom I don't know) and only one bounced back, so if you want more information about some topic, you can ask, at least for a while. Otherwise empty pages and half pages contain the now-standard photographs, often of the person who has just spoken. A subset of discussion remarks are preserved but (like the photographs) not indexed.

The meeting was the 9th in a series on massive stars that began with IAU Sympsius 49 in Argentina in 1971. Most have taken place in beach settings, this one on the oldest of the major Hawaiian islands, Kauai, at 5 Myr not so different from the lifetime of a very massive star. The conference dinner was a *luau* at which (a subset of) the participants joined with the hula dancers. Three people had also been at the first meeting in the series, Peter Conti, Lindsey Smith (though the L. Smith who spoke was Linda), and Nolan Walborn. Indeed Conti has been at all nine, though the senior registrant was probably G. R. Burbidge (and the youngest participant a tie between two toddlers-in-arms).

The symposium summary by Claus Leitherer is, I think, superb. As well as pointing out some exciting new results and lessons to be learned from them (e.g., “spectroscopists do it better”), he carried out a brief statistical study of the

frequency of occurrence in ADS of keywords associated with both stellar and extragalactic topics, in quinquennia from 1975–80 to 2000–05. You will not be surprised to hear that extragalactic is winning. Perhaps less obvious are the gradual overtaking of UV data by IR and of Hertzsprung–Russell diagrams (meaning spectra of individual stars) by colour–magnitude diagrams (generally broad-band colours from surveys). A few concepts, like re-ionization, really didn't exist 30 years ago, and in a couple of other cases the wrong word was selected. "AGN" should probably have been "quasars" and "AGBs", "red supergiants", but the ensemble of numbers repays a good deal of study and thought. — VIRGINIA TRIMBLE.

Astrophysics is Easy!, by M. Inglis (Springer, Heidelberg), 2007. Pp. 224, 23.5×15.5 cm. Price £24.50/\$39.95/€32.95 (paperback; ISBN 978 0 85233 890 9).

Many of us are persuaded that astrophysics is not easy and, indeed, many of us would be without a job if astrophysics were easy. The author's aim is to show that the reverse is true. There are four chapters: 'Tools of the trade', 'The interstellar medium', 'Stars', and 'Galaxies'. The mathematical material, which occurs mostly in the first chapter, is separated off into boxes. Each chapter is supplemented by explanatory notes so that the flow is not needlessly broken. There are three pages of colour diagrams, with all the others in halftone, including duplicates of those already presented in colour. The figures vary in clarity; the worst has lettering 1.3 mm high (4 pt. in printers' parlance).

Each section of the book is accompanied by a list of objects that illustrate that section, together with their accessibility to amateur telescopes. The reader is advised to supplement these lists from the author's companion book *Field Guide to the Deep Sky Objects*, which was harshly reviewed in these pages (122, 56, 2002). The lists in the present book are usually roughly in order of right ascension, starting somewhere near 6^h. The strange starting point appears to have been taken from the companion, which lists objects by each month, starting in January. No equinox is given for the positions but it is evidently 2000. The declinations of Procyon and ϵ Eri are wrong by 51° and $50'$, and ϵ Lyrae and 61 Cygni have declinations negative instead of positive. Magnitudes are treated as units rather than pure numbers so that the apparent and absolute magnitudes of Sirius are given as $-1.44m$ and $1.45M$, and so on for other stars. It is not clear how these lists make astrophysics easy. Comparison of the present book with its companion reveals that they have mistakes in common (e.g., misspelling Lacaille as Lacleille) and that the criticisms levelled in the earlier review, e.g., failure to check facts, inattention to detail, and poor presentation, are equally valid here.

'Tools of the trade' begins with a discussion of the methods for determining stellar distances, and a list of the nearest stars. Barnard's Star is said to be HD 21185 although it is not even in the *Henry Draper Catalogue*. There is another red dwarf of large proper motion, Lalande 21185, listed adjacent to Barnard's Star in the companion, which may have been confused with it. Barnard's Star is given a proper motion of $0''.4$ a year, rather than $10''.4$. Luyten's Star is conventionally identified with BD +5° 1668, not with UV Ceti as given here. There are definitions and descriptions of stellar luminosity, colour, radius, and spectral type, with lists of stars illustrating each aspect. The theoretical explanation is simplified by ascribing to each star a single surface temperature and not exploring how the temperature of a stellar atmosphere can be defined in different ways. The Hertzsprung–Russell diagram forms a case study to bring all the material together.

‘The interstellar medium’ contains illustrative lists of the “Brightest Emission Nebulae”, “Famous Dark Nebulae”, and the “Brightest Reflection Nebulae”. The southern Coal Sack is surprisingly omitted. This leads naturally into protostars and a separate box to explain Jeans’ criterion for gravitational collapse. There is no mention of the common effects of the interstellar medium, *i.e.*, interstellar reddening, polarization, and absorption lines. The author asserts that the blue sky on Earth is caused by scattering by water-vapour molecules, rather than the widely accepted N_2 and O_2 .

The chapter on ‘Stars’ is the longest in the book. The material begins with star formation and the most easily observed stellar nursery is the Orion Nebula, which is defined twice in the same sentence. Stars are predominantly formed in clusters and the Pleiades are discussed at length, followed by an illustrative list of bright open clusters. It omits the fine open cluster, NGC 4755 — Herschel’s ‘Jewel Box’, associated with κ Crucis. Stellar structure and energy generation are treated by using the Sun as an example. Double stars are the best way of measuring stellar masses and there is an illustrative list, which surprisingly omits the striking double α Centauri. Following a theoretical account of stellar evolution on and away from the main sequence, there is a list of “Bright Globular Clusters”, which omits the bright southern clusters ω Centauri and 47 Tucanae. There are also lists of variable stars of different types. RR Lyrae gives the author particular trouble as the spectral type varies from A8 to F7 in one place and A2 to F1 in another. He advises the reader to “Take your pick”. This may make astrophysics easy, but there is a solid scientific explanation: RR Lyrae variables are metal-poor, so the spectral type estimated from the K -line is earlier than that from the hydrogen lines, and the difference in spectral types is an index of the star’s metallicity. The chapter ends with a discussion of the end points of stellar evolution: white dwarfs, neutron stars, or black holes.

The last chapter is about galaxies, their different types, structure, and content, leading on to Hubble’s tuning-fork diagram. There are lists of the more prominent members of each type. However, there is no list of dwarf galaxies, which might have contained the Magellanic Clouds at least. Although dwarf galaxies are much more common in space, highly luminous objects like quasars and active galaxies can be observed to much greater distances and offer more targets within the range of amateur telescopes. The chapter ends with a brief overview of Hubble’s Law, separated into its own box.

The author shows that astrophysics is easy, but only if the difficult parts are left out. The large number of errors, and the indiscriminate scattering of exclamation marks, make it impossible to recommend this book. — DEREK JONES.

From Here to Infinity, by J. & M. Gribbin (National Maritime Museum, London), 2008. Pp. 248, 23 × 16 cm. Price £14.99 (paperback; ISBN 978 0 948065 78 1).

As one of the major visitor attractions in Britain, the Royal Observatory at Greenwich is an excellent place to advertise our science to the public, both domestic and from overseas. And what better way to reinforce the message, after an instructive tour around that wonderful historic site, than with an inexpensively priced, superbly illustrated, and well-produced souvenir, such as *From Here to Infinity*, published by the NMM, which runs the Observatory. This guide to the Universe by science writers John & Mary Gribbin takes us on a comprehensive journey from Earth, across the Solar System, out to the stars, and on to the deeper

cosmos, with a final chapter on 'Life and the Universe'. A basic glossary acts as an *aide memoire* to the many new terms the reader will encounter, while a list of further reading will enable those enthused by the subject to progress further; a good index completes the book. The target level appears to be that of the educated layman, although I feel it is always difficult for someone 'in the trade' to assess that quality since much of the language of the subject is second nature. However, the Gribbins' experience in the 'outreach' business ensures that the text should reach most of those on the Clapham omnibus.

A few points come to mind if a second edition is contemplated. The book, especially the Solar System parts, is heavy with statistics (made even heavier by always following the metric units with imperial units in parentheses) and I wonder if a table or two might lighten the load. And then there are a few gaffes that need to be fixed. On page 56 we read that a lunar eclipse "happens in the middle of the night", shortly followed by the assertion on page 57 that a solar eclipse happens "around midday". On page 83 we discover that "All of the planets orbit around the Sun ... all in the same plane, known as the ecliptic", whereas what is meant is surely the invariable plane of the Solar System. A nice schematic H-R diagram is shown on page 139, but its ordinates ought to be luminosity rather than mass. Page 148 discusses planetary nebulae and refers to Fig. 90 whereas Fig. 92 is meant. And on page 160 we learn that the Milky Way "contains several hundred million stars", although later on the reader is given the truth that it's more like a thousand times more.

Nonetheless, this is a fine addition to the library of any astronomically inclined visitor to the Royal Observatory, and, indeed, to the bookshelves of anyone with an interest in more than the everyday turmoil of planet Earth. — DAVID STICKLAND.

Annual Review of Earth and Planetary Sciences, Vol 36, 2008, edited by

R. Jeanloz, K. C. Burke & K. H. Freeman (Annual Reviews, Palo Alto), 2008.

Pp. 668, 24 × 19.5 cm. Price \$225 (institutions, about £146), \$89 (individual, about £58) (hardbound; ISBN 978 0 8243 2036 2).

As usual, this year's volume of *Annual Review of Earth and Planetary Sciences* is a fascinating collection of commentaries on today's hottest topics. It offers something to interest even the most focussed specialist, and is ablaze with beautiful colour figures. The broad range of themes represented includes the Solar System, the atmosphere, the hydrosphere, and the solid Earth, on scales ranging from single grains to the largest terrestrial objects known to exist.

The book kicks off with a charming chapter by Margaret Galland Kivelson on her life and career as a space physicist. Including, as she does, how her personal and professional lives wove together surely presents a heartening example for those modern scientists who wonder if they can afford themselves the luxury of both.

Recent spacecraft observations suggest that future visitors to Mars may find dust one of the most important climate aspects there (Smith). Back at the ranch down on Earth, wind erosion in deserts is illustrated by beautiful *Landsat* images (Goudie). Several chapters focus on climate. Freshening of the seawater in the north Atlantic could dramatically affect ocean circulation by changing the density stratification (Barreiro *et al.*) and rising sea levels could deliver the double whammy of not only inundating the land but also causing the very geography of the coasts to change in response (FitzGerald *et al.*).

The solid Earth is well represented. Karato *et al.* summarize recent advances in anisotropy and explain why it matters. The anisotropic signature of mantle plumes

is discussed, though some might say that first we should try to find out whether or not they exist. The latest results on subducting slabs (Billen) and mantle wedges (Wiens *et al.*) are summarized. Both are associated with the kind of lateral variations in temperature commonly attributed to mantle plumes. The depth of penetration of subducting slabs is nicely covered. This is a key factor regarding the depth from which counterflow rises. This chapter is complemented by a highly palatable one on Earth rheology (Bürgmann & Dresen) — check out Figure 1!

This year's volume maintains the high standard and readability of the whole recent series. I strongly recommend it to everyone who is interested in keeping up with the latest developments in Earth science and still has time to read books.

— GILLIAN FOULGER.

Here and There

THE FIRST SHALL BE LAST?

Hoyle was the first named author of the famous 108-page B²FH paper. — *JBA*A, 115, 195, 2005.

IT STILL IS

The Dominion Astrophysical Observatory was established in 1918. Its 1085 metre telescope was the largest in the world at the time. — *Victoria Times-Colonist*, 2008 March 30, p. 8.

ONE HECK-OF-AN-ACRE

... will be an area ten kilometres square, or one hectare. — *Astronomy Now*, 2008 April, p. 62.

STRETCHING THE TRUTH

But this outburst [of GRB 080319B] took place 7.5 billion light years away, some seven times further away than the Andromeda galaxy, ... — *A&G*, 49, 3·6, 2008.

COULD GET TO BE BORING

1 August 2008. Total eclipse of the Sun. Maximum duration of totality 22m 27s — *RAS Diary for 2008*, Eclipse section.



PLATE 3. Photographed by Professor David Hanes, these clocks were found in the Visitor Centre at Herstmonceux Castle, once home of the Greenwich Time Service!



PLATE 4. Deep partial lunar eclipse (2008 Aug 16): The fourth and final eclipse for 2008 reached a depth of 81%, allowing a major portion of the lunar disc to be eclipsed by Earth's umbral shadow. All exposures were kindly supplied by Anthony Ayiomamatis and, with the exception of the first, are spaced 30 minutes apart, with the camera held fixed in relation to the ecliptic during the complete eclipse.

ADVICE TO CONTRIBUTORS

The Observatory magazine is an independent journal, owned and managed by its Editors (although the views expressed in published contributions are not necessarily shared by them). The Editors are therefore free to accept, at their discretion, original material of general interest to astronomers which might be difficult to accommodate within the more restricted remit of most other journals. Published contributions usually take one of the following forms: summaries of meetings; papers and short contributions (often printed as *Notes from Observatories*); correspondence; reviews; or thesis abstracts.

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

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