10-2011

The real orbital period of the double-lined spectroscopic binary HD 31738

Francis C. Fekel
Tennessee State University

Roger F. Griffin
University of Cambridge

Recommended Citation

Fekel, F.C.; Griffin, R.F. "The real orbital period of the double-lined spectroscopic binary HD 31738" The Observatory, Vol. 131, No. 5, p. 283-293 (2011)

understand how this can happen, because basically when a parameter like the fine-structure constant changes, the radiative correction to the vacuum energy also changes. And that change would be huge, for the proposed variation of alpha. So I find it hard to understand, but who knows, maybe something subtle is going on.

The President. This has been a fantastically mind-expanding lecture; let's thank Professor Vilenkin once more. [Applause.]

THE REAL ORBITAL PERIOD OF THE DOUBLE-LINED SPECTROSCOPIC BINARY HD 31738

By F. C. Fekel
Tennessee State University
and
R. F. Griffin
Cambridge Observatories

The extraordinarily short orbital period given for HD 31738 in this *Magazine* in 2009 was mistaken. The true value, a 1-day^{-1} alias of the published one, is even shorter, 0·3102061 days.

Introduction

In Paper 209[1] of the long-running series of spectroscopic-orbit papers in this *Magazine*, one of the present authors (RFG) put forward an orbit of extraordinarily short period (0·45 days) for HD 31738. That object had previously been observed by FCF, who had recognized it as double-lined but had not identified a period for it. Alerted privately to the period proposed by RFG, FCF not only found that his measurements accorded with it, but (through having observed it in previous seasons) he was able to offer a more accurate value for it, enabling it to be refined further by the use of published[2] (though single-lined) radial velocities obtained 30 years before.

A curious discrepancy between the FCF and RFG data came to light, inasmuch as there seemed to be an inexplicable difference in the *phasing* although the two sets of observations gave identical periods. Hindsight is of course always very clear, and it obviously indicates that something was seriously wrong with the orbit, but all that was done at the time was that the observers merely agreed that they would both make further measurements of the object and together would sort the matter out in the ensuing season — as they hereby do. With uncharacteristic impetuosity, however, RFG went ahead and published[1] his orbit, duly acknowledging FCF's assistance in refining the period.

Disclaimer and apology

RFG is obliged now to eat humble pie and admit that the period that he gave proves to be an alias of the true one, which is even shorter than the 0·45 days given in Paper 209. At 0·31 days, it represents an orbital frequency greater by exactly one cycle per day than the published one. RFG has been quite aware of the problem of aliasing, having identified it in the work of others in such cases as HD 16884[1], HD 23642[3], the Hyades stars van Bueren 34 and 38[4], 1 Gem B[5], HD 51565[6], HD 89959 and HD 143705[7], and HD 152028[8] (some of the cited publications are collaborative). Now, however, he apologizes to the astronomical public for having fallen into the error himself. He hopes partly to redeem his name by participating in the correction described below.

New observations and revised orbit

Both authors of this paper have made fresh observations of HD 31738. FCF observed with the remotely operated Tennessee State University 2-m *Automatic Spectroscopic Telescope*[9], situated in south-eastern Arizona at Fairborn Observatory, which enabled him to make a dense series of measurements without even moving from his desk. Although those observations were begun in early 2009, it was not until late 2010 that the observing frequency was greatly enhanced in accord with our agreement for a more intense contemporaneous campaign. RFG, more prosaically, undertook observations in person with the *Coravel*-type spectrometer[10] at the coudé focus of the Cambridge 36-inch reflector.

From the Fairborn Observatory échelle spectra velocities were obtained from approximately 170 regions between λλ4920 and 7100 Å, centred on the rest wavelengths of relatively strong, mostly Fe I lines that are not excessively blended with other nearby strong features. The always-blended line profiles were initially fitted with Gaussian functions, but the rotational broadening of the components is such that the overlapping Gaussians produced velocities that exhibited systematic residuals. The reductions were therefore repeated with an empirical profile that was rotationally broadened by shifting and adding together a set of similar profiles after weighting them according to the limb darkening adopted for the Sun. Fekel *et al.*[11] have provided additional information about the general velocity analysis.

From 2010 December onward, 149 Fairborn measurements have been made, which together with 45 earlier ones that were already in hand make a total of 194. They are all listed in Table I, to which have been added the 21 Cambridge velocities that formed the basis of the original orbit[1]. Also included are six Cambridge measurements made in the 2009/10 season after the orbit paper[1] had gone to press, plus 16 from the recent (2010/11) season. Two of the original 21 measurements were of irresolvable blends and are not useable in the solution of the orbit. Among the more recent observations, two of the velocities of the primary, made at almost identical phases and listed within brackets in Table I, have been rejected on statistical grounds. There is, therefore, a total of 233 measurements of the primary and 235 of the secondary available to serve as the basis for the new orbit. To homogenize the data from the two sources, the Cambridge velocities have been subject to an empirical adjustment of $-1{\cdot}8$ km s^{-1} and have been given half-weight in comparison with the Fairborn Observatory ones. Furthermore, all the velocities of the secondary star have been half-weighted with respect to the corresponding ones of the primary.

A few earlier observations have been utilized to refine the orbital period. In a number of seasons, FCF obtained spectra of HD 31738 at Kitt Peak

TABLE I

Radial-velocity observations of HD 31738

The observations flagged with an asterisk were made at Cambridge; all others with the Tennessee automated telescope in Arizona

Date (UT)			MJD	Velocity Prim. km s⁻¹	Velocity Sec. km s⁻¹	Phase	(O–C) Prim. km s⁻¹	(O–C) Sec. km s⁻¹
2008	Nov.	8·115*	54778·115	+14·3	−19·5	0·970	+0·3	−1·0
		19·082*	789·082	+5·2	+20·6	36·324	−0·6	0·0
		23·082*	793·082	+9·1	+3·9	49·218	−0·4	+1·0
	Dec.	3·012*	803·012	+7·4		81·229	—	—
		7·091*	807·091	+5·4	+28·0	94·378	+1·2	−0·2
		10·035*	810·035	+11·9	−9·8	103·869	−0·4	+0·5
		27·008*	827·008	+3·8	+31·2	158·584	+0·4	−0·9
2009	Jan.	2·977*	54833·977	+13·6	−18·7	181·050	−0·2	−1·0
		6·917*	837·917	+8·2		193·751	—	—
		13·957*	844·957	+3·3	+35·8	216·446	+0·3	+1·6
		18·889*	849·889	+6·3	+24·5	232·345	+1·1	+0·7
		19·931*	850·931	+6·4	+17·3	235·704	−0·3	+1·1
		20·944*	851·944	+13·6	−19·7	238·969	−0·4	−1·2
		23·928*	854·928	+4·5	+32·9	248·589	+1·0	+1·3
		29·763*	860·763	+4·6	+32·8	267·399	+0·8	+2·3
		29·952*	860·952	+13·9	−19·8	268·008	−0·2	−0·8
		30·924*	861·924	+11·2	−9·8	271·142	−0·8	−0·9
	Feb.	10·878*	872·878	+3·9	+36·1	306·454	+1·0	+1·5
		10·896*	872·896	+2·1	+36·4	·512	−0·6	+0·7
		11·161	873·162	+5·2	+27·1	307·367	+0·7	+0·3
		11·866*	873·866	+6·5	+27·3	309·639	+1·8	+1·2
		19·111	881·111	+15·5	−19·8	332·993	+1·4	−0·8
		21·261	883·261	+13·8	−17·1	339·924	+0·3	−1·2
		21·822*	883·822	+7·9	+10·9	341·733	+0·1	−0·4
		26·131	888·131	+4·2	+27·1	355·625	−0·1	−0·6
	Mar.	15·158	905·159	+3·3	+36·5	410·515	+0·6	+0·8
		21·183	911·183	+13·5	−19·2	429·936	−0·2	−2·3
	Apr.	7·139	928·139	+4·8	+31·1	484·596	+1·1	+0·2
	Aug.	8·434	55051·435	+14·3	−16·6	882·060	+0·6	+0·5
		23·419	066·419	+4·9	+26·1	930·364	+0·3	−0·3
		27·496	070·496	+2·4	+36·3	943·506	−0·3	+0·5
	Sept.	18·414	092·414	+11·9	−5·2	1014·165	+0·6	+0·4
		23·310	097·310	+15·4	−17·4	1029·946	+1·6	+0·1
		25·353	099·353	+2·2	+34·9	1036·533	−0·6	−0·3
		30·308	104·308	+2·1	+35·3	1052·506	−0·6	−0·5
	Oct.	17·256	121·256	+12·7	−8·6	1107·142	+0·7	+0·3
		25·156*	129·156	+4·5	+32·1	1132·607	+0·6	+2·3
	Nov.	1·388	136·388	+14·0	−16·4	1155·921	+0·6	−0·7
		1·413	136·413	+14·8	−18·8	1156·002	+0·7	+0·2
		1·438	136·438	+14·4	−15·9	·082	+1·0	−0·5
		3·388	138·388	+4·8	+26·8	1162·369	+0·3	−0·2
		3·413	138·413	+3·1	+35·2	·450	+0·2	+0·8
		3·438	138·438	+2·9	+36·1	·530	+0·1	+0·8
		4·196	139·196	+14·3	−18·5	1164·972	+0·3	+0·1
		6·365	141·365	+14·5	−18·9	1171·966	+0·5	−0·5
		19·368	154·368	+13·0	−11·2	1213·882	+0·4	+0·6
		24·066*	159·066	+15·0	−20·2	1229·027	+1·0	−1·6
		24·366	159·366	+14·9	−20·1	·995	+0·8	−1·1
	Dec.	23·058*	188·058	+2·7	+36·0	1322·488	0·0	+0·3
2010	Jan.	29·931*	55225·931	+2·9	+34·2	1444·577	−0·4	+1·6
		30·879*	226·879	+3·6	+28·2	1447·633	−1·0	+1·5
		31·907*	227·907	+12·8	−17·7	1450·947	−1·0	−0·1
	Feb.	12·135	239·135	+12·1	−9·2	1487·143	+0·1	−0·5

TABLE I (*continued*)

Date (UT)	*MJD*	*Velocity* *Prim.* *km s⁻¹*	*Sec.* *km s⁻¹*	*Phase*	*(O–C)* *Prim.* *km s⁻¹*	*Sec.* *km s⁻¹*
2010 Feb. 27·106	55254·106	+4·1	+29·9	1535·403	+0·4	−1·0
Mar. 14·168	269·168	+14·7	−17·8	1583·960	+0·8	+0·4
20·139	275·139	+10·1	+2·2	1603·208	+0·2	+0·9
26·140	281·140	+2·3	+35·0	1622·552	−0·7	+0·6
Apr. 4·136	290·136	+3·1	+34·8	1651·552	+0·1	+0·5
11·117	297·117	+14·4	−17·3	1674·056	+0·6	+0·1
Sept. 19·461	458·461	+10·7	−4·7	2194·176	−0·2	−0·8
25·515	464·515	+6·6	+18·6	2213·693	+0·2	+0·6
Oct. 1·511	470·511	+13·9	−18·6	2233·020	−0·2	+0·2
8·488	477·488	+3·1	+35·2	2255·513	+0·4	−0·5
11·401	480·401	+13·2	−13·7	2264·904	+0·1	+0·5
16·464	485·464	+8·9	+4·8	2281·223	−0·4	+1·0
17·353	486·353	+13·1	−14·7	2284·090	−0·1	0·0
20·174*	489·174	(+7·9)	−1·7	2293·184	−2·8	+1·0
25·442	494·442	+10·3	−4·6	2310·168	−0·9	+0·5
30·501	499·501	+3·0	+35·3	2326·474	+0·3	−0·1
Nov. 4·476	504·476	+3·6	+35·4	2342·512	+0·9	−0·3
10·476	510·476	+11·8	−8·7	2361·855	−0·1	−0·2
15·072*	515·072	+6·8	+20·3	2376·670	+1·2	−1·2
16·388	516·388	+13·6	−14·5	2380·914	+0·3	+0·6
23·994*	523·994	+4·3	+34·1	2405·432	+1·1	+0·8
25·377	525·377	+13·6	−12·3	2409·890	+0·8	+0·4
26·090*	526·090	(+7·6)	−0·3	2412·189	−2·9	+1·6
27·101*	527·101	+3·2	+35·7	2415·448	+0·2	+1·3
27·988*	527·988	+5·8	+18·8	2418·307	−0·6	+0·8
Dec. 1·182	531·182	+4·4	+29·5	2428·604	+0·6	−0·6
1·232	531·232	+8·6	+7·4	·766	−0·3	+1·7
1·282	531·282	+13·6	−15·8	·927	+0·1	+0·4
1·332	531·332	+12·9	−15·9	2429·088	−0·4	−0·9
1·382	531·382	+8·5	+7·4	·249	+0·1	−0·8
1·432	531·432	+3·2	+30·5	·410	−0·3	−1·1
1·447	531·447	+2·8	+34·4	·457	−0·1	−0·4
2·132	532·132	+6·4	+21·1	2431·667	+0·9	−1·0
2·182	532·182	+11·1	−5·3	·828	0·0	−0·8
2·232	532·232	+14·1	−19·4	·989	0·0	−0·4
2·282	532·282	+10·9	−8·2	2432·150	−0·8	−0·5
2·332	532·332	+7·4	+17·9	·312	+1·2	−0·8
2·382	532·382	+2·5	+34·5	·473	−0·2	−0·9
2·432	532·432	+4·6	+26·1	·634	0·0	−0·6
2·447	532·447	+6·0	+18·9	·680	+0·1	−1·2
2·482	532·482	+9·9	+1·6	·795	−0·1	+0·9
3·132	533·132	+12·1	−13·6	2434·890	−0·7	−0·8
3·182	533·182	+13·9	−17·9	2435·052	+0·1	−0·3
3·232	533·232	+8·9	+2·6	·213	−0·8	+0·6
3·282	533·282	+4·0	+26·4	·374	−0·4	−1·3
3·332	533·332	+3·0	+34·4	·535	+0·2	−0·7
3·382	533·382	+6·8	+16·6	·696	+0·3	−0·8
4·232	534·232	+3·6	+33·5	2438·437	+0·5	−0·2
4·282	534·282	+4·3	+30·8	·598	+0·6	0·0
4·332	534·332	+9·0	+7·5	·759	+0·3	+0·6
4·382	534·382	+13·4	−15·7	·920	0·0	0·0
6·093*	536·093	+2·6	+32·2	2444·435	−0·5	−1·4
6·132	536·132	+3·3	+34·0	·561	+0·2	+0·2
6·182	536·182	+8·3	+13·0	·723	+0·9	−0·1
6·232	536·232	+13·3	−12·2	·884	+0·6	−0·1
6·282	536·282	+13·6	−18·4	2445·045	−0·3	−0·5
6·332	536·332	+9·4	+1·8	·206	−0·5	+0·9
6·382	536·382	+4·2	+26·6	·367	−0·3	−0·2
6·432	536·432	+3·1	+34·8	·529	+0·4	−0·6

TABLE I (*continued*)

Date (UT)		*MJD*	*Velocity* Prim. km s^{-1}	Sec. km s^{-1}	*Phase*	*(O–C)* Prim. km s^{-1}	Sec. km s^{-1}
2010 Dec.	6·447	55536·447	+3·8	+32·0	2445·575	+0·5	−0·8
	6·482	536·482	+6·6	+18·3	·690	+0·3	−0·2
	7·453	537·453	+10·8	−3·5	2448·820	0·0	−0·2
	8·182	538·182	+10·7	−3·8	2451·170	−0·4	+1·0
	8·232	538·232	+5·7	+21·9	·331	+0·1	+0·1
	8·282	538·282	+2·4	+35·0	·492	−0·3	−0·8
	8·332	538·332	+5·2	+23·2	·654	+0·1	−0·8
	8·382	538·382	+11·0	−2·8	·815	+0·3	−0·3
	8·432	538·432	+14·3	−18·9	·976	+0·2	−0·2
	8·446	538·447	+14·1	−18·8	2452·022	0·0	0·0
	8·482	538·482	+11·5	−9·8	·137	−0·6	−0·3
	9·032*	539·032	+12·9	−15·3	2453·909	−0·3	−0·6
	9·132	539·132	+8·8	+4·9	2454·232	−0·2	−0·5
	9·182	539·182	+3·7	+29·2	·394	−0·2	−0·7
	9·232	539·232	+3·2	+33·7	·555	+0·2	−0·5
	9·282	539·282	+7·8	+13·6	·716	+0·6	−0·6
	9·332	539·332	+13·1	−11·2	·877	+0·6	+0·1
	9·382	539·382	+13·9	−18·2	2455·038	−0·1	0·0
	9·432	539·432	+9·6	+0·6	·199	−0·6	+0·8
	10·102	540·102	+4·9	+25·3	2457·357	+0·1	−0·2
	10·116	540·116	+3·4	+31·4	·404	−0·3	+0·4
	10·130	540·130	+2·7	+33·9	·450	−0·2	−0·6
	10·145	540·145	+2·6	+35·3	·497	−0·1	−0·5
	10·159	540·159	+3·2	+35·2	·543	+0·3	+0·4
	10·174	540·174	+3·8	+31·1	·590	+0·3	−0·5
	10·188	540·188	+4·7	+25·7	·636	+0·1	−0·7
	10·202	540·202	+6·9	+19·3	·682	+0·9	−0·4
	10·217	540·217	+7·9	+12·7	·729	+0·3	+0·7
	10·231	540·231	+9·0	+5·7	·776	−0·3	+1·8
	10·246	540·246	+10·1	−4·0	·822	−0·8	−0·4
	10·260	540·260	+12·3	−10·7	·869	0·0	−0·4
	10·275	540·275	+13·6	−15·4	·916	+0·3	−0·1
	10·289	540·289	+14·2	−18·4	·962	+0·2	−0·1
	10·304	540·304	+14·1	−19·5	2458·009	0·0	−0·5
	10·318	540·318	+13·5	−18·0	·056	−0·3	−0·6
	10·333	540·333	+12·2	−13·7	·102	−0·8	−0·2
	10·347	540·347	+11·1	−7·8	·149	−0·7	0·0
	10·362	540·362	+9·5	0·0	·196	−0·8	+0·7
	10·376	540·376	+8·9	+5·7	·243	+0·3	−1·5
	10·391	540·391	+7·3	+14·0	·290	+0·3	−1·2
	10·405	540·405	+5·7	+22·5	·337	+0·3	−0·1
	10·420	540·420	+3·6	+28·1	·384	−0·5	−0·7
	10·434	540·434	+2·8	+32·2	·430	−0·4	−1·0
	10·449	540·449	+2·7	+34·9	·477	0·0	−0·6
	10·463	540·463	+2·8	+35·4	·524	+0·1	−0·1
	11·332	541·332	+6·4	+21·5	2461·324	+0·6	+0·7
	11·382	541·382	+3·0	+35·5	·486	+0·3	−0·2
	11·432	541·432	+4·6	+24·4	·647	−0·3	−0·5
	12·020*	542·020	+3·6	+36·1	2463·542	+0·8	+1·2
	12·132	542·132	+13·7	−13·8	·903	+0·6	+0·3
	12·182	542·182	+13·4	−17·2	2464·065	−0·2	−0·4
	12·232	542·232	+9·2	+3·8	·226	−0·1	−0·4
	12·451	542·451	+13·8	−17·0	·932	+0·2	−0·4
	13·132	543·132	+12·0	−10·6	2467·127	−0·4	+0·1
	13·182	543·182	+7·4	+14·0	·288	+0·4	−0·9
	13·232	543·232	+2·5	+33·5	·449	−0·4	−0·9
	13·282	543·282	+4·3	+29·0	·611	+0·3	−0·4
	13·311	543·311	+7·5	+15·4	·704	+0·8	−0·8
	13·332	543·332	+9·3	+5·4	·772	+0·1	+0·8

TABLE I (*continued*)

Date (UT)		*MJD*	*Velocity Prim. km s⁻¹*	*Velocity Sec. km s⁻¹*	*Phase*	*(O–C) Prim. km s⁻¹*	*(O–C) Sec. km s⁻¹*
2010 Dec.	13·382	55543·382	+13·8	−18·1	2467·933	+0·2	−1·5
	13·432	543·432	+12·9	−14·8	2468·094	−0·2	−0·4
	14·132	544·132	+4·7	+24·7	2470·350	−0·3	+0·1
	14·182	544·182	+3·4	+35·6	·512	+0·7	−0·1
	14·232	544·232	+5·7	+21·0	·673	0·0	−0·2
	14·282	544·282	+11·5	−4·9	·834	+0·2	+0·5
	14·312	544·312	+13·7	−16·8	·929	+0·1	−0·4
	14·332	544·332	+14·2	−19·4	·995	+0·1	−0·4
	14·382	544·382	+11·9	−6·4	2471·156	+0·3	+0·4
	14·432	544·432	+5·9	+20·8	·318	−0·1	+1·1
	15·132	545·132	+3·1	+33·6	2473·574	−0·2	+0·7
	15·182	545·182	+8·2	+11·4	·735	+0·3	+0·5
	15·232	545·232	+13·6	−13·1	·896	+0·7	+0·3
	15·282	545·282	+13·5	−18·0	2474·058	−0·2	−0·7
	15·297	545·296	+12·1	−14·1	·104	−0·8	−0·7
	15·332	545·332	+9·0	+3·8	·219	−0·5	+0·7
	15·382	545·382	+3·2	+26·9	·380	−1·0	−1·5
	15·432	545·432	+3·3	+34·9	·541	+0·5	0·0
	16·132	546·132	+9·6	+1·9	2476·798	−0·5	+1·6
	16·182	546·182	+14·2	−18·0	·959	+0·3	+0·1
	16·232	546·232	+11·9	−12·3	2477·120	−0·7	−0·7
	16·282	546·282	+7·6	+12·5	·281	+0·3	−1·2
	16·296	546·296	+5·7	+20·4	·328	0·0	−0·9
	16·332	546·332	+2·4	+32·5	·443	−0·6	−1·5
	16·382	546·382	+4·3	+29·7	·604	+0·5	−0·5
	17·056*	547·056	+8·3	+5·3	2479·776	−1·0	+1·4
	18·132	548·132	+8·2	+6·8	2483·245	−0·4	−0·7
	18·182	548·182	+3·0	+29·7	·406	−0·6	−1·5
	18·232	548·232	+3·0	+33·2	·567	−0·2	−0·2
	18·995*	548·995	+12·5	−20·1	2486·027	−1·5	−1·4
	19·132	549·132	+2·3	+35·2	·468	−0·5	−0·1
	19·182	549·182	+4·3	+26·7	·630	−0·2	−0·5
	19·232	549·232	+9·8	+2·7	·791	0·0	+1·3
	19·282	549·282	+13·8	−18·7	·952	−0·1	−0·9
	19·296	549·296	+14·4	−19·4	·998	+0·3	−0·4
	19·332	549·332	+12·5	−12·8	2487·113	−0·2	−0·4
	19·382	549·382	+7·8	+11·1	·274	+0·3	−1·5
	19·432	549·432	+2·5	+32·3	·436	−0·6	−1·3
	20·232	550·232	+13·9	−19·6	2490·014	−0·2	−0·7
	20·282	550·282	+11·0	−3·2	·176	0·0	+0·8
	20·296	550·296	+9·0	+3·4	·222	−0·4	−0·2
	20·332	550·332	+5·6	+23·3	·337	+0·2	+0·7
	21·432	551·432	+13·5	−12·8	2493·883	+0·9	−0·9
	27·321	557·321	+12·0	−10·3	2512·867	−0·2	−0·2
2011 Jan.	3·276	55564·276	+7·7	+13·4	2535·288	+0·7	−1·5
	9·291	570·291	+6·8	+19·4	2554·677	+0·9	−1·0
	9·995*	570·995	+13·3	−18·3	2556·948	−0·5	−0·7
	13·274	574·274	+2·6	+35·5	2567·518	−0·1	−0·1
	14·167	575·167	+3·0	+29·4	2570·396	−0·8	−0·7
	14·946*	575·946	+11·3	−15·2	2572·908	−1·9	−0·6
	16·161	577·161	+11·0	−4·2	2576·825	0·0	−0·1
	17·215	578·215	+8·8	+4·0	2580·224	−0·5	+0·2
	18·215	579·215	+2·8	+34·1	2583·447	−0·2	−0·2
	18·929*	579·929	+8·8	+8·0	2585·748	+0·5	−0·8
	20·215	581·215	+13·3	−13·8	2589·894	+0·4	−0·7
	21·215	582·215	+12·6	−11·7	2593·117	0·0	+0·2
	22·215	583·215	+5·7	+22·5	2596·341	+0·4	−0·7
	23·338	584·338	+14·3	−18·1	2599·962	+0·3	+0·2

TABLE I (*concluded*)

Date (UT)		*MJD*	*Velocity*		*Phase*	*(O – C)*	
			Prim. *km s⁻¹*	*Sec.* *km s⁻¹*		*Prim.* *km s⁻¹*	*Sec.* *km s⁻¹*
2011 Jan.	24·886*	55585·886	+13·5	−18·1	2604·951	−0·3	−0·4
	29·314	590·314	+8·7	+5·2	2619·225	−0·6	+1·0
	31·886*	592·886	+1·9	+35·4	2627·517	−0·8	−0·3
Feb.	7·228	599·228	+14·4	−18·4	2647·961	+0·5	−0·2
	13·173	605·173	+13·2	−10·9	2667·126	+0·8	0·0
	17·147	609·147	+14·4	−16·6	2679·936	+0·7	+0·2
	23·176	615·176	+4·3	+27·6	2699·372	−0·1	+0·2
Mar.	7·150	627·150	+14·8	−18·5	2737·974	+0·8	+0·2

National Observatory (KPNO) with the coudé-feed telescope. Tomkin & Fekel[12] have discussed in general the reduction and velocity measurement of such spectra. Fifteen observations of HD 31738, obtained between 1991 and 2003, have been adjudged useful here. However, the reductions of those earlier unpublished velocities were performed by approximating the line profiles with Gaussian functions, which we have found to produce systematic residuals. We have therefore used the KPNO velocities, which increase the time base nearly tenfold, only in a preliminary step simply to improve the orbital period, and have imposed the resulting value on our final solution, which is based on the Fairborn and Cambridge observations alone.

The new period, a close approximation to which was first divined by FCF on the basis of the intensive measurements with the automated telescope, is 0·31020614 days. Owing to the much increased time base of our own measurements, there is no longer any occasion to try to refine it by appeal to the old single-lined measurements published by Balona[2], although they do qualitatively exhibit the expected relationship to the orbit, following the velocity changes of the *secondary* component though with greatly muted amplitude.

With the originally proposed period[1] of 0·4502588 days, reasonably good fits appear to be obtained with each source of measurements *separately*, but when the two sets are concatenated the solution with that period goes haywire because the two sets are out of phase with one another by an amount related to the time-equivalent of the difference in longitudes between the observatories. Significantly, however, the new period is a much better fit to the original batch of secondary observations (*cf.* ref. 1, Fig. 7), whose phases were considerably falsified by the use of the wrong period in cases where the observations were made at appreciable hour angles. Indeed, in the original solution[1] the secondary velocities needed to be weighted only 1/10 in comparison with those of the primary, and the only reason that they were not worse still was because observations were restricted to relatively small hour angles by the low declination (~0°) of HD 31738 and physical obstructions to the movement of the Cambridge telescope. Of course the same phasing errors applied equally to the observations of the primary star, but the very much (fivefold) smaller velocity amplitude of that component tended to bury them in the noise and render them comparatively innocuous.

The old and new periods, inverted to frequencies, differ by 1·0027 day^{-1}. The reason that the difference is not the exact inverse day is that all intervals between observations are necessarily near to multiples of the time between successive culminations of the star, *i.e.*, of a *sidereal* day. Expressed in inverse sidereal days, the difference between the old and new frequencies (2·214881 and 3·214861 d^{-1} respectively) is seen to be almost exactly unity, differing by only two units in the fifth decimal place. The only time that a photometric period has been proposed for the star (by Strassmeier *et al.*[13], from observations in 1984–86) it was 4·55 days, which, expressed as a frequency in inverse sidereal days, is 0·219 d^{-1} and so is very probably another alias of the orbital period. That likelihood was noted in the paper[1] that gave the erroneous orbital period, but the reference there to the *sum* of the orbital and photometric frequencies being close to 2 inverse days should have been to the *difference*, as can be seen from the numbers here. There are other undoubted (but usually slow and irregular, as is evident from the *Hipparcos* 'epoch photometry') variations in the magnitude of HD 31738, which has the variable-star designation V1198 Ori.

The new orbit is illustrated in Fig. 1 and its parameters are as follows:

P = 0·31020614 ± 0·00000011 days*	$(T_0)_{2156}$ = MJD 55446·61866 ± 0·00013
γ = +8·38 ± 0·03 km s^{-1}	$a_1 \sin i$ = 0·02445 ± 0·00020 Gm
K_1 = 5·73 ± 0·05 km s^{-1}	$a_2 \sin i$ = 0·1170 ± 0·0003 Gm
K_2 = 27·42 ± 0·08 km s^{-1}	$f(m_1)$ = 0·00000607 ± 0·00000015 $M_\odot$
q = 4·78 ± 0·04 (= m_1/m_2)	$f(m_2)$ = 0·000664 ± 0·000006 $M_\odot$
e ≡ 0	$m_1 \sin^3 i$ = 0·000971 ± 0·000008 $M_\odot$
ω is undefined in a circular orbit	$m_2 \sin^3 i$ = 0·0002030 ± 0·0000029 $M_\odot$

R.m.s. residual for an observation of unit weight = 0·51 km s^{-1}

*Period determined with the inclusion of 15 earlier KPNO velocities not used in final solution. The 'true' period (in the rest-frame of the system) is 0·31019746 ± 0·00000011 days. It differs from the observed period by 76 standard deviations.

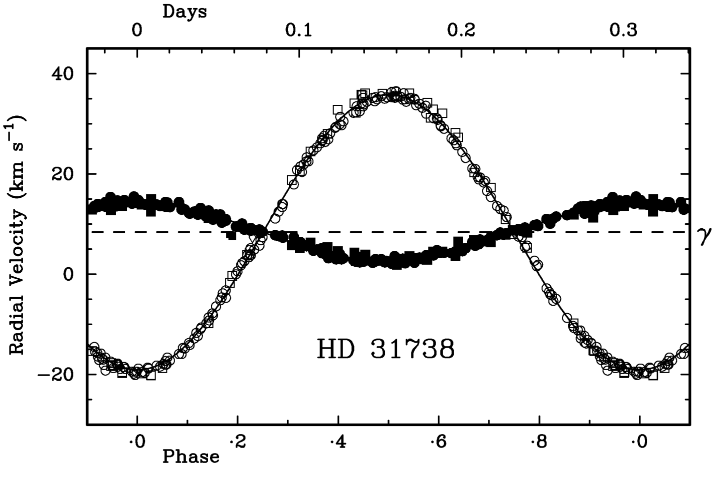

FIG. 1

The observed radial velocities of HD 31738 plotted as a function of phase, with the velocity curves corresponding to the adopted orbital elements drawn through them. Radial velocities of the primary are plotted with filled symbols, circles for Fairborn and squares for Cambridge, while those of the secondary are indicated by corresponding open symbols. Two rejected measurements of the primary are shown as *small* filled squares near phase ·2.

The smallness of the formal standard errors of the amplitudes is misleading. There are differences, very significant statistically, between the amplitudes found from the Fairborn and Cambridge data sets separately. The overwhelming number of the Fairborn ones would cause them to dominate the solution, even if they were not weighted more heavily than the Cambridge ones, which are thereby made to appear worse than they really are because discrepancies that are actually systematic are treated as random. In the case of the secondary, the tendency of the Cambridge observations (squares) to be 'more extreme' near the nodes is obvious from Fig. 1. A sufficiently jaundiced eye might also notice a tendency for the velocities in general to be drawn towards the γ-velocity when they are within about 15 km s^{-1} of it; that could possibly occur as a result of non-sphericity (not considered in the radial-velocity reduction procedure) of the stars.

We give here a comparison of the amplitudes, their ratio q, and the mean-square residuals for each data set separately when computed from (*a*) Fairborn only, (*b*) Cambridge only, and (*c*) both, with Cambridge half-weighted (the same solution as in the informal table above). In the separate solutions (*a* and *b*), the mean-square residuals are given 'as computed' (the Cambridge ones have not been halved), but in all cases the secondary's 'raw' mean squares have been halved, since it is clear from all solutions that the observations of the secondary are less accurate than those of the primary.

Quantity		*Fairborn solution*	*Cambridge solution*	*Joint solution*
K_1		5·78 ± 0·05	5·29 ± 0·14	5·73 ± 0·05
K_2		27·33 ± 0·08	28·24 ± 0·25	27·42 ± 0·08
q		4·73 ± 0·04	5·34 ± 0·15	4·78 ± 0·04
Mean-square deviations (km s^{-1}):				
Fairborn	A	0·24	0·37	0·24
	B	0·24	0·49	0·25
Cambridge	A	0·71	0·55	0·34
	B	0·69	0·43	0·32

It is seen that the differences between the amplitudes computed from the two data sources individually are more than three times their formal standard errors, and the difference in q is about four standard errors. We have not identified any obvious reason for the discrepancies, nor are we in a position to recommend one solution in preference to another. We can only advise that the true uncertainties are considerably greater than the formal ones, and might prudently be taken to be comparable with the discrepancies seen in the little table immediately above. The perceptive reader will also find some interest in the tabulated mean-square deviations. The fact that the numbers for Fairborn data from their own Fairborn solution are about half those of the Cambridge data from the Cambridge solution validates our attribution of half-weight to the Cambridge velocities in the merged data set. The similarity of the numbers for A and B in every case validates our adoption of half-weight for the observations of B. The fact that, in the case of star A, for which the numerical value of the discrepancy in amplitudes is less than for B, the Fairborn velocities have smaller residuals than the Cambridge ones *even from the solution computed from the Cambridge measurements alone* further emphasizes (if only qualitatively) the superiority of the Fairborn observations in terms of random errors.

In comparison with the orbital elements given in 2009 on the basis of the erroneous period, most of the elements are in principle unchanged in the new solution, although the increase in the data base has appreciably improved their precision. The γ-velocity (when account is taken of the empirical correction made to the Cambridge observations here), the velocity amplitudes, and the zero eccentricity remain much as before; it is only the timing information and the repercussions that it has on the 'derived' elements (the separations and masses) that have changed. In particular, we note that the sum of the projected rotational velocities, previously determined independently by each of us[1,14] as being close to 23 and 9 km s^{-1} for the primary and secondary, respectively*, remains the same as the sum of the projected orbital velocity amplitudes to well within observational uncertainty, demonstrating that the stars are touching one another.

The original paper[1] neglected to remark how that conclusion is reinforced by the fact that the ratio of the rotational velocities (and thus of the stellar radii) is very close to the square root of the mass ratio of the components, confirming that the gravitational forces of the two stars balance (as they obviously ought to do) at the point of contact between them.

We turn now to the revisions needed to the original discussion[1] of the HD 31738 system. The shorter period requires the projected radii of the two stars (simply computed from the period and rotational velocities) to be reduced, to about 0·135 and 0·055 $R_\odot$ for the primary and secondary, respectively. The discussion[1] gave reasons (which are still valid), starting from the known parallax, for suggesting that the primary must be a little cooler and a little larger than the Sun, with a true radius close to 1·2 $R_\odot$; thus it now appears to be about nine times the projected radius, making $\sin i \sim 1/9$ or $i \sim 6°$. The reduction in period has the same effect in reducing the projected linear separation of the stars ($a_1 \sin i + a_2 \sin i$ in the informal table above), leaving the implied actual separation at about 0·0086 AU. Inserting that quantity, and the orbital period of 0·00085 years, into the Keplerian equation $m = a^3/P^2$, where all the quantities are in Solar System units, we obtain m, the sum of the masses, to be about 0·88 $M_\odot$. That is still remarkably small for a star whose size and colour put it not far from solar type, plus its companion, which is only about one magnitude fainter. There has clearly been opportunity for mass transfer in this contact binary, and we must suppose that some mass has been lost to the system.

Following the procedure of Strassmeier & Fekel[15] we have compared a KPNO spectrum of HD 31738, which has the components at a phase near maximum velocity separation, with the spectra of various G-dwarf stars with well-determined spectral types. For HD 31738 we conclude that the spectral type of the more-massive star is G8 V and that of the less-massive star is G2 V. Were this system to be seen at a significantly higher inclination, it would have the light-curve of a W UMa variable, and because the more-massive star is larger but cooler than its companion it would be assigned to the W-type subclass, *e.g.*, ref. 16.

For normal main-sequence stars the spectral types would suggest a total mass of nearly 2 $M_\odot$, which is clearly at odds with our estimate that the sum of the masses for HD 31738 is just 0·88 $M_\odot$. However, such a discrepancy is not particularly unusual for a contact system. For example, the work of Pribulla *et al.*[17] indicates that HD 31738 has properties somewhat similar to those of V345 Gem. That W-type contact binary has a shorter period of 0·275 days, a

*Re-determination of the rotational velocities by FCF from the abundant new Fairborn Observatory spectra yields values of 22 and 11 km s^{-1}.

higher mass ratio of 7·0, and an earlier spectral type of F7 V, but like HD 31738, its total mass, being in that case not much greater than 1·05 $M_{\odot}$, is clearly deficient relative to normal main-sequence stars.

More generally, Gazeas & Stępień[18] have tabulated masses derived from light-curve modelling of 112 contact binaries. From those data they determined period–mass relationships for the primary and secondary components. Those relationships show a great deal of scatter, but the resulting power-law fits would indicate a mass sum of 1·44 $M_{\odot}$ for HD 31738. Although that value is much larger than our estimate of 0·88 $M_{\odot}$, it is still significantly smaller than the expected main-sequence mass total.

While a comparison of the properties of HD 31738 with those of field W UMa stars, such as those listed in the catalogue of Pribulla *et al.*[16] and in an extensive series of papers by Rucinski, Pribulla, and their colleagues, *e.g.*, refs. 19 & 20, suggests that, although the magnitude difference and mass ratio of the HD 31738 components are larger than most, other general properties of the HD 31738 system are in accord with predictions for contact binaries. For example, the period–colour relationship[21] of W UMa stars produces $(B-V) = 0^{m}{\cdot}73$, to be compared with an observed value of $0^{m}{\cdot}71$. Likewise, if we adopt the apparent magnitude and $(B-V)$ colour from the *Hipparcos* catalogue, the absolute-magnitude calibration of Rucinski & Duerbeck[22] for stars of the W UMa type results in a parallax of 0″·029, a value that is spot-on the newly reduced[23] *Hipparcos* value of 0″·0290.

W UMa-type variables are often part of multiple systems. From their northern-sky sample, Pribulla & Rucinski[24] estimated a lower limit of 59% for the frequency of contact binaries that are part of triple systems. Although the solutions of our respective data sets produce slightly different γ-velocities, the velocities to date provide no strong evidence for a third component.

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