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ON THE LIGHT-VARIATION OF AI VELORUM

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The RR Lyrae-type variable AI Velorum has been observed photoelectrically with the 16″ telescope of the Leiden Station at Johannesburg during January and April—May 1951.

The light-variation shows a primary period, P_0, of $0^d.111574$, and a secondary period, P_1, of $0^d.0862075$, which by interference give a beat period of $0^d.379182$. The lightcurve may be represented as a certain distortion of the curve given by the formula:

$$m = 0^m.859 - 0^m.111 \sin 2\pi\Phi_0 - 0^m.083 \sin 2\pi\Phi_1,$$

where Φ_0 and Φ_1 are the phases corresponding to P_0 and P_1.

This distortion can be separated into a phase displacement, proportional to magnitude, or wave steepening, and a magnitude deviation which makes the maxima of the curve high and sharp.

It is assumed that the formula represents the basic underlying pulsation of the star and theoretical considerations are given about the nature of the processes which play a role in converting this into the observed lightcurve. The Riemann theory of the propagation of running waves is applied and it may account for the wave steepening.

It is suggested that shockwaves are responsible for the increase of the height of the maxima.

There are indications of the existence of two short-period oscillations, of the order of one hour, but the material does not suffice to describe these with certainty.

Introduction.

The star which is the subject of this article has been found as a variable star by HERTZSPRUNG [1]) on plates taken by VAN GENT with the Franklin-Adams camera at Johannesburg. HERTZSPRUNG considered it as a Cepheid variable and found the period as 0.111574 day. However, the observed lightcurves showed strong irregularities both in phase and shape, which was confirmed by investigations of ZAGAR [2]) and VAN HOOF [3]). Since then the star was considered as a semiregular cluster-type variable. It has been the object of two series of observations, during January 1951 and then during April and May 1951 at the Leiden Southern Station at Johannesburg. The first series was done with a straightforward photo-electric photometer, consisting of multiplier, amplifier and recorder. These observations revealed the real nature of the light-variation. They were interrupted often by unfavourable weather conditions as is usual in this time of the year. An other photoelectric photometer, of the differential type, which is much less sensitive to cloudy conditions, was put into use in March but at that time the weather was extremely bad and useful observations were started not before the middle of April. Unfortunately the star had a considerable hourangle already and although observations started immediately after twilight and ended when the star disappeared behind trees, the series obtained were rather short. New observations are planned therefore. Nevertheless from the available observations interesting conclusions could be drawn, worth while to be given in this paper.

[1]) *B.A.N.* VI, 147, 1931.
[2]) *B.A.N.* VIII, 169, 1937.
[3]) *B.A.N.* VIII, 172, 1937.

The observations.

Some data of the variable and the comparison star are given below:

TABLE I

	α_{1950}	δ_{1950}	HD	Sp.
	h m s	° ′ ″		
AI Vel	08 12 26	− 44 25 22	69213	F
comp.	08 12 47	− 45 40 53	69302	B3

For the January observations also other comparison stars have been used but as these observations have a lower degree of accuracy than the others, no use was made of them. For the same reason we describe only the observational method of the April—May period.

The photometer used in that period was attached to one component of the 16″ twin camera of the Leiden Southern Station. It was of the differential type, using the light of both variable and comparison star at the

same time. A detailed technical description of it cannot be given here. Only some principles are mentioned. A little plate containing two circular holes of 1 millimetre diameter is performing a vibrating motion in the focal plane of the objectglass in such a way that the light of one star at a time is transmitted. Both beams are concentrated on the same spot of the multiplier, type 931A. Therefore this phototube receives light containing an alternating component the amplitude of which is equal to the difference of the intensities of the star beams. By means of a wedge of neutral absorbing glass sliding in one of the beams the intensities can be made equal, as can be detected by the disappearance of the alternating component in the photocurrent. The setting of the wedge to this position is done fully automatically by a motor which is commanded by the phototube through an amplifier. Such a system is called nowadays a servomechanism. The measurement consists in reading the position of the wedge, which is related by its calibration to the magnitude difference of the stars. As the position of the wedge was transferred to a Brown recorder, the registration of the lightcurve was completely automatic, the only function of the observer being to maintain proper guiding.

The disturbing factors and sources of errors are mostly of a different nature than those of a direct photoelectric photometer. The systematic accuracy depends primarily on the perfection and rigidity of the optical parts and is nearly completely independent of the electronic performance. The accuracy and linearity of the magnitude scale for example depend on the wedge. The stability of the zeropoint of this scale depends on the other optical parts and on the guiding of the telescope. A zeropoint error may occur when by lack of correct optical adjustment the relative transmission along the optical pathways changes or when neighbouring stars contribute to the light in a varying way. On the other hand the short-period errors or the roughness of registration, which is due primarily to seeing fluctuations depends on the electronic design and on the characteristic of the motor. And its effect may be increased by wrong design. Also the weather conditions contribute to this type of error, although in a lesser degree than with a direct photometer. In short the properties of the instrument can be resumed as follows. It is inferior to the direct photoelectric photometer with respect to the zeropoint of magnitude scale unless it is of perfect optical design. It is superior with respect to the weight of the lightcurve that is obtained, because no time is lost by measuring sky background and changing the position of the telescope. It is useful only for very long series of observations of one rapidly varying star. These properties are reflected in the results. Each night the zero of the magnitude scale was controlled by switching the amplifier to D.C. performance, stopping the motion of the diaphragms and covering one of them. In this state the instrument could be used as a direct photometer. The variable and the comparison star then were observed a few times one after another. The reliable magnitude differences obtained in this way should provide a check of the zeropoint of the lightcurves from the differential arrangement. On some nights the D.C. arrangement has been used to determine the wedge characteristics; for this the comparison star was used.

The lightcurves were obtained in two colours by switching two filters to and fro in front of the diaphragms. The switching occurred every minute. However, when the tracings were rough as was the case in general when the stars were moving to the horizon and had to penetrate the smoke of the city, somewhat longer trails were made for each colour. The filters used were GG 11 (2 mm) for yellow and BG 1 (2 mm), GG 13 (2 mm) and $\frac{1}{2}''$ plateglass cemented together for the blue. The objectglass has a high transparency in the ultraviolet and for this reason the ultraviolet-cutting component GG 13 was added. The plateglass was added as a correction for the focal difference of the two colours. This is a serious difficulty interfering with all colour measurements with this telescope. The secondary spectrum is so strong that even after applying a focal correction, the remaining dispersion in focal length for the yellow region is so big that a big

TABLE 2

Date	Sid. time	Remarks
1951	h m h m	
16 April	08 44 — 12 56	
17 April	08 58 — 14 21	Photometer has been dismounted.
18 April	08 25 — 14 36	
19 April	08 25 — 14 12	Some clouds
21 April	08 20 — 09 30	Very cloudy. Observations not used.
24 April	08 30 — 14 30	
25 April	08 52 — 12 50	Clouds
26 April	08 59 — 13 59	Photometer dismounted
27 April	09 11 — 14 05	
29 April	08 40 — 14 32	Photometer dismounted
30 April	09 22 — 14 05	Thin veils
1 May	08 52 — 13 39	Thin veils
2 May	08 58 — 12 07	
3 May	09 17 — 14 29	
8 May	09 39 — 13 42	Passing clouds
17 May	10 29 — 14 36	Clouds in the beginning
18 May	09 49 — 14 28	Some small clouds
19 May	09 49 — 12 59	
20 May	10 13 — 14 00	
22 May	11 21 — 13 58	
23 May	10 15 — 14 09	
24 May	10 11 — 13 27	Much city smoke
25 May	10 21 — 13 56	Much city smoke
26 May	10 41 — 14 16	

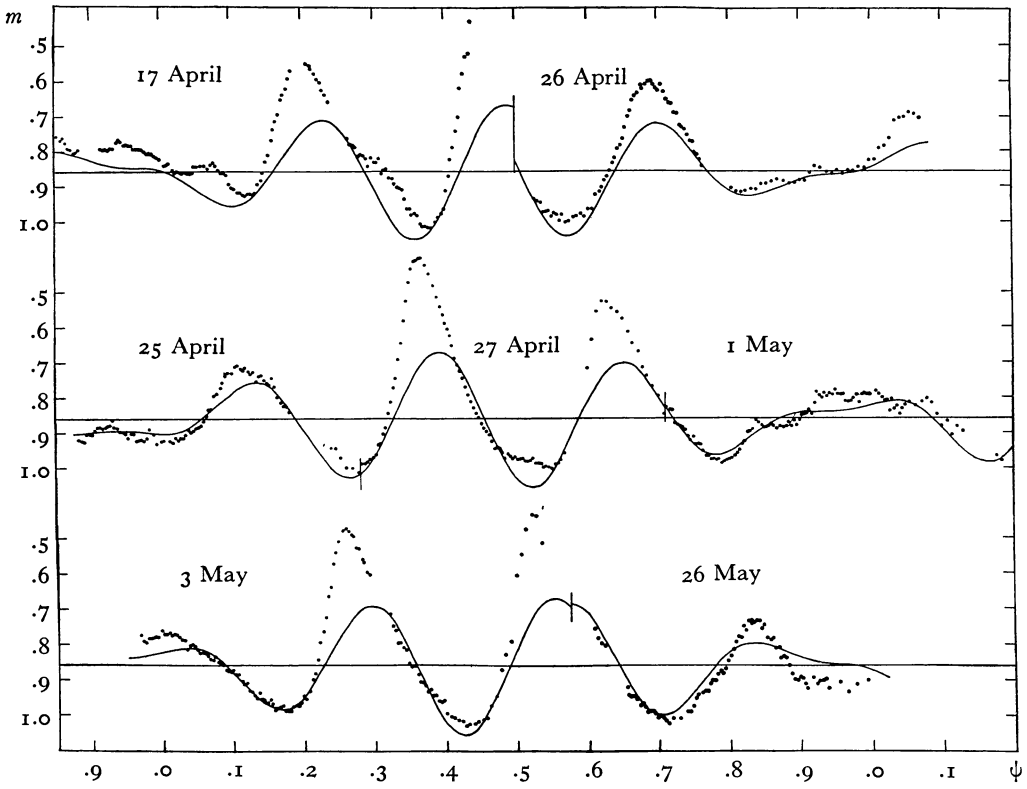
diaphragm is necessary to allow all the light to pass through. This is a consequence of the fact that the objectglass, which is a four-component type made by Zeiss, has a chromatic correction for the blue-violet part of the spectrum. Accordingly the blue lightcurves are somewhat more accurate than the yellow ones.

With regard to the complicate and rapid variations of the star the observations were extended over as long time intervals as possible and they were continued when the sky was covered with thin clouds or veils. Therefore several portions of the lightcurves are less accurate than they could be. In Table 2 the observing nights are compiled.

Reduction of the observations.

The mean reading of each minute of tracing, alternately for blue and yellow light, was taken from the Brown recorder sheets. These values were converted into magnitude differences with the comparison star by means of a linear relation. The same formulae, different only for the blue and for the yellow, were used for all observations. The reduction formulae contain the wedge constant and the zeropoint of the magnitude scale. As has been explained before, the latter was checked every night with the direct photometer arrangement. A comparison of the control measurements with the magnitudes obtained by inter-

FIGURE 1



polation from the registered lightcurves showed that the zeropoint may vary for different nights by about 0.01 magnitude. No exceptional deviations were noted and it was decided therefore to use one mean value of the zeropoint for all reductions. When the reduction of observations was more advanced and a more complete picture of the behaviour of the star was obtained, it appeared that some nights' curves were displaced some hundredths of a magnitude. This was very pronounced for the curve of 17 April where the displacement is 0.05 magnitude. The explanation is probably that weak neighbouring stars have influenced both differential and direct measurements in the same way.

The results of the reduction are given in Table 10 at the end of this paper. The first column of that table gives the heliocentric Julian day of the middle of an interval of tracing. The second column gives the magnitude difference m with the comparison star. Blue and yellow values are mixed and can be distinguished by their amount, the blue magnitude differences being always bigger than the yellow ones. The colour-index $m_b - m_y$ may be found as a blue magnitude diminished with the mean of the yellow magnitudes before and after.

Discussion of the results.

The obtained lightcurves clearly showed the real nature of the light-variation of AI Velorum.

It is an RR Lyrae star with exceptionally strong modulation of its amplitude. The modulation may, as usually, be attributed to an interference of two periods. We shall denote the two interfering periods as fundamental or primary period, p_0, and secondary period, p_1, and refer to the resulting period (which is usually called the secondary period) as the beat period p_b.

In Figure 1 some of the lightcurves are shown. They represent yellow measurements and they are chosen from the available material such as to give a nearly complete picture of the consecutive light-variations. Whereas in most RR Lyrae stars the beat period seems to be caused by a small interfering oscillation giving relatively small periodic changes in amplitude and phase of the main lightcurve, the disturbing oscillation in the case of AI Velorum has about the same amplitude as the main oscillation. The resulting amplitude therefore changes very strongly. Moreover the beat period is very short, about $3\frac{1}{2}$ times the fundamental period.

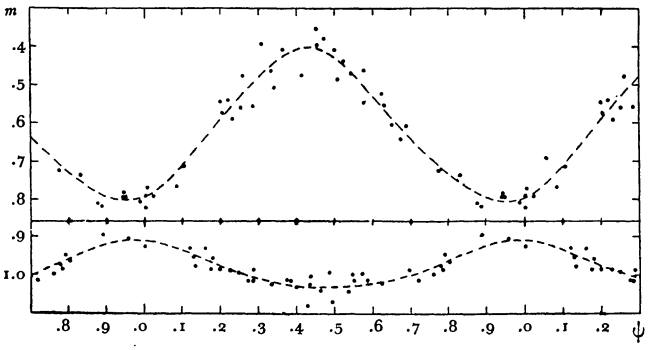
In order to find the length of the periods a procedure had to be followed which differs from the usual method. Normally the period of an RR Lyrae star is found from the moments when the ascending branch of the lightcurve reaches some defined magnitude. The secondary period can be found from the residuals between observed and computed epochs. In this case, however, this method cannot be applied because the observed lightcurves have lost almost completely their relation to the primary period. One may consider them just as well as the curves of the secondary period which are disturbed by the fundamental period. This can be illustrated as follows. Suppose the curve to be the result of two sinewaves of equal amplitude and with periods P_0 and P_1. The epochs or moments when the median brightness is reached have to be found from:

$$\sin\frac{2\pi t}{P_0}+\sin\frac{2\pi t}{P_1}=$$

$$=2\sin\left(\frac{\pi t}{P_0}+\frac{\pi t}{P_1}\right)\cos\left(\frac{\pi t}{P_0}-\frac{\pi t}{P_1}\right)=0.$$

Since in practice no epochs are observable when the cosine factor is near zero, we deal only with epochs for which the sine factor is zero. That means that from the observations we can find only $\frac{1}{P_0}+\frac{1}{P_1}$, leaving a degree of freedom for the periods themselves. Additional knowledge is required, for example the length of the beat period. This can be obtained by studying the amplitudes of the lightcurves. It may be remarked that HERTZSPRUNG derived the correct value of the primary period without knowing the secondary period, although he was doubtful about it. This shows that it is possible to derive the period by statistical methods.

FIGURE 2



From the amplitudes of the observed lightcurves, including the January observations, the beat period has been found as:

$$P_b = 0^d.379182 \pm .000010.$$

With this period phases were computed according to the formula:

$$\psi = (\text{J.D.} - 2430000)\ 2.637256. \qquad (1)$$

For some computations we used:

$$\psi = (\text{J.D.} - 2433650)\ 2.637256. \qquad (1^*)$$

Then the moments when the ascending branch of the lightcurves reached the median magnitude, in this case the magnitude just intermediate between that of the preceding minimum and of the following maximum, were determined. With HERTZSPRUNG's period the corresponding epochs were computed:

$$\text{J.D.}_{\text{med.mag.}} = \text{J.D.}_{\text{max}} - 0^d.0118 = \\ = 2426142.198 + 0^d.111574\,E. \qquad (2)$$

The correction $0^d.0118$ was derived from several high lightcurves. A plot of the differences between observed and computed epochs against the phase of the beat period ψ of the computed epochs showed that all points were lying along the same curve within the errors of observation. It was concluded therefore that HERTZSPRUNG's value of the primary period is adequate to represent our observations from January to May.

With

$$\frac{1}{P_b}=\frac{1}{P_1}-\frac{1}{P_0}, \qquad (3)$$

using the above-mentioned value of P_b and HERTZSPRUNG's value of P_0, the secondary period was found as: $P_1 = 0^d.0862075$.

Now that the periods have been found, we can proceed to the study of the amplitudes and wave-shapes of the oscillations. To facilitate this, the beat

phase of the observations was computed with (1). In Figure 2 the maxima and the minima have been plotted against their ψ, computed with (1).

The dashed lines in the figure are drawn by hand as smooth curves following centres of gravity of small groups of points. The data of the plot are given in

TABLE 3

	J.D. −2430000	ψ	m		J.D. −2430000	ψ	m
max	3753.239	.252	.562	min	3768.229	.784	.985
min	3753.306	.429	1.080	max	3768.289	.943	.793
max	3753.333	.500	.408	max	3768.312	.003	.790
max	3754.260	.945	.784	max	3769.186	.308	.393
min	3754.327	.121	.930	min	3769.256	.493	1.070
max	3754.356	.198	.546	max	3769.287	.575	.461
min	3754.423	.374	1.014				
max	3754.452	.451	.354	max	3770.209	.006	.770
				min	3770.273	.175	.986
min	3755.205	.437	1.003	max	3770.305	.259	.478
max	3755.232	.508	.485	min	3770.371	.434	1.026
min	3755.303	.695	.988	max	3770.405	.523	.436
max	3755.333	.774	.724				
min	3755.403	.959	.905	max	3775.219	.219	.541
				min	3775.287	.398	1.032
min	3756.226	.130	.954	max	3775.315	.472	.380
max	3756.254	.203	.577				
min	3756.322	.383	1.015	max	3784.275	.084	.768
max	3756.349	.454	.397	min	3784.339	.271	1.014
min	3756.414	.625	1.021	max	3784.366	.342	.508
min	3761.233	.334	1.026				
max	3761.263	.413	.475	min	3785.204	.552	1.017
min	3761.328	.585	1.014	max	3785.241	.650	.603
max	3761.361	.672	.641	min	3785.295	.792	.948
min	3762.244	.000	.927	min	3786.226	.247	.993
max	3762.284	.106	.713	max	3786.259	.334	.464
min	3762.351	.283	1.015				
				min	3787.196	.805	.966
min	3763.219	.572	.996	max	3787.251	.950	.795
max	3763.263	.688	.608	max	3787.279	.024	.792
min	3763.340	.891	.894	min	3787.331	.161	.931
max	3763.403	.057	.691				
				min	3789.241	.198	.986
min	3764.248	.286	.987	max	3789.273	.283	.559
max	3764.277	.362	.409				
min	3764.347	.547	.998	min	3790.212	.759	.999
max	3764.376	.623	.525	max	3790.257	.878	.810
min	3766.239	.536	1.043				
max	3766.275	.631	.557	min	3791.237	.462	1.041
min	3766.331	.779	.974	max	3791.268	.544	.468
max	3766.373	.890	.820				
max	3766.416	.003	.823	max	3792.195	.989	.808
				min	3792.250	.134	.977
min	3767.259	.226	.988	max	3792.287	.232	.592
min	3767.358	.487	.993				
max	3767.392	.577	.548	min	3793.230	.719	1.015
				max	3793.273	.832	.737

Table 3. Three interesting remarks can be made about the curves:

a) the upper and lower curve are not symmetrical,

b) the upper curve is slightly oblique,

c) the bottleneck is rather narrow and oblique.

These remarks rule out the hypothesis that the star is a binary composed of two Cepheids. The envelopes of the interference patterns of arithmetically combined periodic curves are symmetrical whatever the wave-shape of the components is. When given on a magnitude scale the upper envelope should be flattened as compared to the lower envelope. The observed light-variation therefore must be the result of two oscillations in the same star and the observed distortion of the envelopes should be ascribed to the physical

process by which the pulsation of the star is translated into lightcurves. Independent of the properties of this process we can conclude something about the interfering pulsations from remark *c*).

The fact that the two envelopes approach each other so closely suggests that the waveshape of the interfering pulsations is not far from sinusoidal. Only in a very restricted case the envelopes can touch each other, that is, when the interfering pulsations are sinusoidal and have the same amplitude. The more general case that the two waveshapes have the same amplitude and the same anharmonic distortion but of opposite sign can, as too improbable, be left out of consideration. Besides that, every deviation from sinewaves or unequality of the amplitudes widens the smallest distance between the envelopes.

On the other hand the shape of the high lightcurves is of the normal Cepheid type with quick rise and slow decline. In analysing these curves one might expect components which have a similar oblique shape, or at least one of them, thus contradictory to the above-said about their being sinewaves. A reasonable explanation for the discrepancy is that the two pulsations are harmonic while they are interacting and then the resulting pulsation is subject to anharmonic distortion.

The type of deformation is the same as that which changes a simple harmonic wave into the wellknown oblique lightcurve of a Cepheid. How this can happen has been studied by the theory of anharmonic pulsations.

It would be very interesting to know the exact shape and phase of the original pulsations. With these the combined curve can be found and then a comparison can be made with the observed lightcurve. The comparison may be more fruitful than in the case of a simple Cepheid because now there is a great variety of shapes and amplitudes to be studied.

For an analysis only the observed lightcurve is available at the moment, which is a distorted picture of the pulsation. However we might use the least distorted portions, as the flat lightcurves probably are, for the analysis and the result can still be compared with the high lightcurves.

Also some knowledge is needed on how the lightcurve is related to the dynamical pulsation, which can be obtained only from theoretical assumptions. For this we take the point of view that the pulsation in the outer parts of the star is a running wave, firstly because the most recent spectrophotometric investigations on Cepheids clearly point to this type of pulsation in the atmosphere of the star and because the theoretical computations of SCHWARZSCHILD [1]) explained in quite a natural way the generally observed relation between lightcurve and radial-velocity curve. On the other hand the theory of the standing-wave model is still struggling with the phase-lag problem.

Secondly, the mathematical treatment is simple in the case of the running-wave model, especially if we confine ourselves to the simplest case, that of a plane wave in a homogeneous medium. It is of no use to try a more accurate treatment of the problem because the greatly increased difficulties of mathematical treatment would grow out of proportion to the one-sided information supplied by our observations. Let u be the velocity of the particles and p the pressure and ρ the density at a point which has a distance r to the centre of the star. Then the equation of motion is:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial r}+\frac{1}{\rho}\frac{\partial p}{\partial r}=0, \tag{4}$$

and the equation of continuity:

$$\frac{\partial \rho}{\partial t}+u\frac{\partial \rho}{\partial r}+\rho\frac{\partial u}{\partial r}=0 \tag{5}$$

in the Eulerian notation.

RIEMANN has solved these equations [1]) by using the function w defined by:

$$\frac{dw}{d\rho}=\frac{1}{\rho}\left(\frac{dp}{d\rho}\right)^{\frac{1}{2}}=\frac{C}{\rho}, \tag{6}$$

where C is the velocity of sound. Then equations (4) and (5) can be written:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial r}+C\frac{\partial w}{\partial r}=0, \tag{7}$$

$$\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial r}+C\frac{\partial u}{\partial r}=0. \tag{8}$$

Adding (8) and (7) gives:

$$\frac{\partial}{\partial t}(w+u)+(C+u)\frac{\partial}{\partial r}(w+u)=0 \tag{9}$$

and subtracting:

$$\frac{\partial}{\partial t}(w-u)-(C-u)\frac{\partial}{\partial r}(w-u)=0. \tag{10}$$

The physical interpretation is that a certain initial disturbance in the medium gives rise to two waves. The function $w+u$ is travelling with velocity $C+u$ in the direction of r and the function $w-u$ is travelling in opposite direction with velocity $C-u$. After some time the two wave patterns are completely separated, which means that within the reach of the $w+u$ function the function $w-u$ is zero. So $w=u$ is the relation between particle velocity and density in the free running wave, which is the type of motion we have presumed. How w depends on density can be found from the adiabatic condition. This is:

$$\frac{p}{p_0}=\left(\frac{\rho}{\rho_0}\right)^{\gamma}, \tag{11}$$

[1]) *Harv. Coll. Obs. Circ.* Nos 429 and 431.

[1]) S. ROSSELAND, "The Pulsation Theory of Variable Stars", p. 135.

where p_o and ρ_o are the equilibrium values of p and ρ. Consequently:

$$\frac{dp}{d\rho}=\gamma\frac{p_o}{\rho_o}\left(\frac{\rho}{\rho_o}\right)^{\gamma-1}, \tag{12}$$

and therefore from (6) we get:

$$w=\int\frac{1}{\rho}\left(\frac{dp}{d\rho}\right)^{\frac{1}{2}}d\rho=\left(\gamma\frac{p_o}{\rho_o}\right)^{\frac{1}{2}}\frac{2}{\gamma-1}\left\{\left(\frac{\rho}{\rho_o}\right)^{\frac{\gamma-1}{2}}-1\right\}. \tag{13}$$

Since $w=u$, the relation between particle velocity and density is now obtained. It can be put also as:

$$\frac{\rho}{\rho_o}=\left\{1+\frac{\gamma-1}{2}\left(\frac{\rho_o}{\gamma p_o}\right)^{\frac{1}{2}}u\right\}^{\frac{2}{\gamma-1}}. \tag{14}$$

It is interesting to compare this with the formula obtained by SCHWARZSCHILD in his discussion on the lightcurves of Cepheids[1]):

$$\frac{\rho}{\rho_o}=\left\{1+S\frac{r-r_o}{r_o}+\frac{\gamma-1}{2}\left(\frac{\rho_o}{\gamma p_o}\right)^{\frac{1}{2}}\dot{r}\right\}^{\frac{2}{\gamma-1}}, \tag{15}$$

where now r is the actual distance of a particle to the centre of the star, which is r_o in the equilibrium position. SCHWARZSCHILD's relation is obtained by a far more rigorous discussion than (14), gravity and curvature of the layers being taken into account. The value of S as found by SCHWARZSCHILD in the case of δ Cephei by comparing radial velocity and lightcurve is -1.4, which is interpreted by him as indicating an increase of amplitude while the waves are running outward. Therefore the velocity term in (15) is predominant and it appears that (14) is a reasonable approximation.

Now the lightvariation can be found from $\frac{\rho}{\rho_o}$[2]). The light emitted by the star is given by:

$$L=-\frac{16\pi r^2 c a T^{m+3}\partial T}{3k\rho^{n+1}\partial r}, \tag{16}$$

where r is the distance to the centre of the star, c the velocity of light, a the light-emission constant, T the temperature and m, k and n are constants entering through the coefficient of absorption

$$\varkappa=k\rho^n T^{-m}. \tag{17}$$

Dividing (16) by its corresponding value for the equilibrium state gives:

$$\frac{L}{L_o}=\left(\frac{r}{r_o}\right)^2\left(\frac{\rho}{\rho_o}\right)^{-n-1}\left(\frac{T}{T_o}\right)^{m+3}\frac{\partial T/\partial r}{\partial T_o/\partial r_o}. \tag{18}$$

Using the adiabatic law:

$$\frac{T}{T_o}=\left(\frac{\rho}{\rho_o}\right)^{\gamma\zeta} \tag{19}$$

and the equation of continuity:

$$\frac{\rho}{\rho_o}=\left(\frac{r}{r_o}\right)^{-2}\left(\frac{dr}{dr_o}\right)^{-1}, \tag{20}$$

this becomes:

$$\frac{L}{L_o}=\left(\frac{r}{r_o}\right)^4\left(\frac{\rho}{\rho_o}\right)^{\gamma\zeta(m+4)-n}\left(1+\frac{T_o\gamma\zeta}{\partial T_o/\partial r_o}\frac{\partial\ln\rho/\rho_o}{\partial r_o}\right). \tag{21}$$

This formula is rigorous but too complicated to be useful in our discussion. Besides ρ/ρ_o, which according to (14) depends directly on the velocity $\dot{r}$, it contains the displacement of the particles through r and in the second term between brackets the derivative of velocity with respect to r_o. Therefore we decide to retain only the most essential part. There remains:

$$\frac{L}{L_o}=\left(\frac{\rho}{\rho_o}\right)^{\gamma\zeta(m+4)-n}. \tag{22}$$

Expressing in magnitudes and using (14), where u has been replaced by $\dot{r}$, we get:

$$m_o-m=\frac{5\{\gamma\zeta(m+4)-n\}}{\gamma-1}\log\left\{1+\frac{\gamma-1}{2}\left(\frac{\rho_o}{\gamma p_o}\right)^{\frac{1}{2}}\dot{r}\right\}. \tag{23}$$

The observations show that the absolute value of m_o-m does not exceed 0.4. According to SCHWARZSCHILD for δ Cephei $\gamma\zeta(m+4)-n$ is near one and therefore the term containing $\dot{r}$ does not change more than some 10% so that with sufficient accuracy:

$$m_o-m=2.5\{\gamma\zeta(m+4)-n\}\log e\left(\frac{\rho_o}{\gamma p_o}\right)^{\frac{1}{2}}\dot{r}. \tag{24}$$

This is the formula we need, for it shows that if the pulsation of the star can be considered a linear combination of the individual pulsations, then the lightcurve expressed in magnitudes is a linear combination of the lightcurves that each pulsation individually would give. For the analysis we want to perform, the lightcurve can be used as it stands. Considering that by our crude discussion only phase shift and higher-order components have been neglected and the indirect use we make of the resulting formula (24) the method seems justified. The analysis was done as follows. Portions of lightcurves were selected where the amplitude was sufficiently small. Table 4 gives the dates and the limits of the beat phase ψ of the portions used.

TABLE 4

Date	ψ	Date	ψ
17 April	.864 — .124	3 May	.002 — .230
18 April	.602 — .988	17 May	.946 — .309
19 April	.080 — .193	18 May	.743 — .993
25 April	.903 — .312	20 May	.813 — .199
26 April	.836 — .086	23 May	.701 — .110
29 April	.702 — .021	25 May	.975 — .202
1 May	.727 — .136	26 May	.681 — .000

In the following we refer to the pulsations of which we are trying to resolve the waveshapes as P_o and P_1.

[1]) M. SCHWARZSCHILD, *loc. cit.*
[2]) M. SCHWARZSCHILD, *loc. cit.*

First it was computed at what time the phase φ_1 of P_1 is 0, 0.1, 0.2 etc. using:

$$\varphi_1 = 11.599918\,(\text{J.D.} - 2433625.0092), \quad (25)$$

which is found from (1*), (2) and (3) and taking the decimal fraction only. Then within the intervals given in Table 4 the yellow lightcurves were read at these points. For each reading also the phase φ_0 of P_0 was computed with:

$$\varphi_0 = 8.962662\,(\text{J.D.} - 2433617.6560), \quad (26)$$

which corresponds to (2). Then the readings were grouped with respect to the values of φ_1 and φ_0 and the mean of each group was determined. The values found for a certain φ_1 represent a portion of the P_0-curve. Unfortunately not the whole P_0-curve, because there is a correlation between the φ_1 and φ_0 of the points used in the lightcurves. However each value of φ_1 gives a portion of the P_0-curve; in fact we have ten such portions which are partially overlapping and each of which is shifted in magnitude direction relative to the real P_0-curve with an amount equal to the P_1-value for the relevant φ_1. From the overlaps the magnitude shifts of the portions were determined. After applying an evenly distributed correction to make the closing error zero we obtained a set of ten values which were considered to represent the P_1-curve. From the ten portions shifted together we obtained the P_0-curve. The result is given in Table 5. All values are expressed in $0^m.0001$.

TABLE 5

φ_1	P_1(obs)	P_1(com)	$O-C$	φ_0	P_0(obs)	P_0(com)	$O-C$
.0	+ 436	+ 448	− 12	.05	− 701	− 721	+ 20
.1	+ 817	+ 774	+ 43	.15	− 1120	− 1082	− 38
.2	+ 791	+ 803	− 12	.25	− 1009	− 1028	+ 19
.3	+ 483	+ 526	− 43	.35	− 635	− 582	− 53
.4	+ 76	+ 48	+ 28	.45	+ 164	+ 86	+ 78
.5	− 418	− 448	+ 30	.55	+ 726	+ 721	+ 5
.6	− 841	− 774	− 67	.65	+ 1029	+ 1082	− 53
.7	− 724	− 803	+ 79	.75	+ 1007	+ 1028	− 21
.8	− 580	− 526	− 54	.85	+ 632	+ 582	+ 50
.9	− 39	− 48	+ 9	.95	− 95	− 86	− 9

The result is rather surprising as both curves are pure sinecurves showing no trace of obliquity, which certainly must be present in the combined curve. Probably its effect is smoothed out by the fact that several patterns of combination are involved in the analysis. As a check the analysis was repeated, but now the lightcurves were read along an inclined magnitude axis, the inclination of which was found in a way which shall be described later. This method should have the effect of counterbalancing the distortion of the lightcurves. The result was completely identical, within the deviations from a smooth curve, with that given in Table 5. This proves that the obliquity of the observed lightcurves has no influence on the result of the analysis. By least squares sine curves were fitted onto the values obtained by the analysis. These are given as the computed values in Table 5.

The result is that the magnitude of the star can be represented by:

$$m = 0^m.859 - 0^m.111 \sin 2\pi\Phi_0 - 0^m.083 \sin 2\pi\Phi_1, \quad (27)$$
$$\pm 0^m.0014 \quad 0^m.0033 \quad 0^m.0033$$

where the phases are given by:

$$\Phi_0 = 8.962662\,(\text{J.D.} - 2433617.6490) \quad (28)$$
$$\Phi_1 = 11.599918\,(\text{J.D.} - 2433624.9583) \quad (29)$$

and they have a mean error of about 0.006.

It may be remarked that capitals are used to denote the phase that is zero at the ascending zeropoint of the sinecurve, whereas the old phase had an arbitrary starting point.

The errors indicated for the amplitudes and phases in (27), (28) and (29) are derived from the accuracy with which the different pieces of P_0-curve could be fitted together and not from the $O - C$'s of Table 5. Due to the fact that only a selection of flat lightcurves was used in the analysis, the resolved curves are not independent and errors are correlated. Consequently when one of them is slightly varied then the other is altered also and such that:

a) amplitudes both decrease or both increase,
b) the phases change in the same direction and
c) the obliquities change in opposite direction.

That means that if unknown systematic influences affect the result of the analysis, we may expect a wrong amplitude or phase, but the conclusion that the pulsations are harmonic remains firmly established.

The next step to be taken is to compare the observed lightcurves which have not been used hitherto, i.e. the high ones, with the curves computed from (27). We start with the moments when the ascending branches reach $m = 0.859$, which is found to be the median magnitude of the star. These moments were read off the yellow lightcurves and are given in Table 6. The second column of the table contains the corresponding moments when $\Phi_0 = 0$ computed with (28). The difference of that value with the observed moment multiplied by 8.962662 is given in the third column and is therefore the phase Φ_{omm} of the observed epoch of median magnitude. The fourth column gives the beat phase Ψ of the computed epoch. This phase is found as:

$$\Psi = \Phi_1 - \Phi_0 = 2.637256\,(\text{J.D.} - 2433649.7988). \quad (30)$$

The values of the third and fourth columns are plotted in Figure 3. If the lightcurve is represented by:

$$\Delta m = a \sin 2\pi\Phi_0 + b \sin 2\pi\Phi_1, \quad (31)$$

then the moments Φ_{omm} when $\Delta m = 0$ can be found from

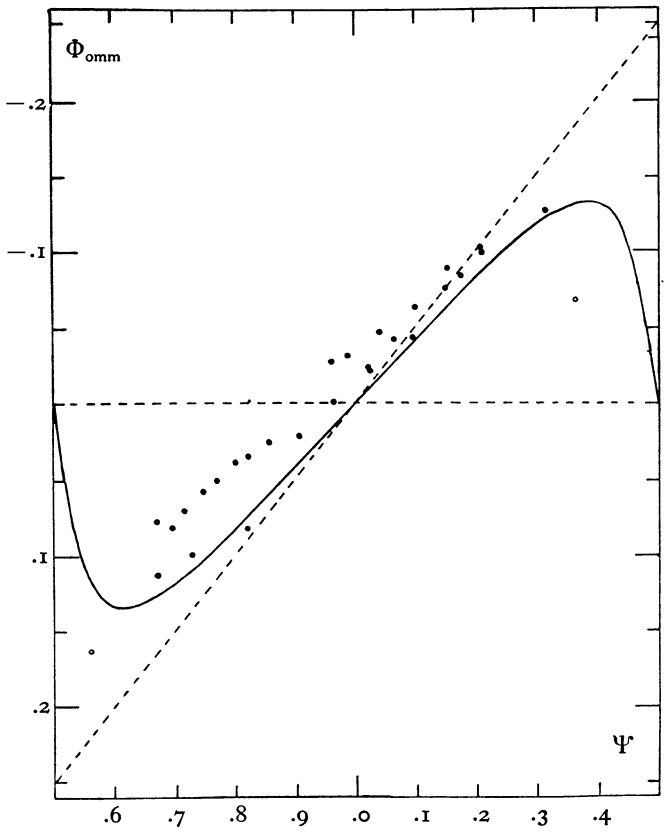
$$\tan 2\pi\Phi_{omm} = -\frac{b \sin 2\pi\Psi}{a + b\cos 2\pi\Psi} . \qquad (31a)$$

TABLE 6

J.D.(obs) − 2430000	J.D. (com) − 2430000	Φ_{omm}	Ψ
3753.2224	3753.2114	+ .099	.726
3753.3202	3753.3230	− .025	.020
3754.3358	3754.3272	+ .077	.668
3754.4355	3754.4387	− .029	.962
3755.2171	3755.2197	− .023	.022
3755.3170	3755.3313	− .128	.316
3756.2365	3756.2239	+ .113	.670
3756.3352	3756.3355	− .003	.964
3761.2471	3761.2447	+ .022	.911
3761.3448	3761.3563	− .103	.206
3762.2671	3762.2489	+ .163	.560
3763.2418	3763.2531	− .101	.208
3764.2601	3764.2572	+ .026	.856
3764.3602	3764.3688	− .077	.150
3766.2557	3766.2656	− .089	.153
3767.2740	3767.2697	+ .038	.801
3767.3764	3767.3813	− .044	.095
3769.2709	3769.2781	− .064	.098
3770.2886	3770.2822	+ .057	.746
3770.3884	3770.3938	− .048	.040
3775.2005	3775.1915	+ .081	.693
3775.2994	3775.3031	− .033	.987
3784.3498	3784.3406	+ .082	.821
3785.2236	3785.2331	− .085	.175
3786.2412	3786.2373	+ .035	.823
3789.2554	3789.2498	+ .050	.768
3791.2533	3791.2581	− .043	.064
3792.2701	3792.2623	+ .070	.713
3793.2587	3793.2665	− .070	.361

When $b \ll a$, which is normally the case in RR Lyrae stars, then Φ_{omm} is approximately represented by a sine curve. When b is nearly equal to a, then Φ_{omm} is represented by a sawtooth curve. The extreme case of equal amplitudes is given as the dashed line $\Phi_{omm} = -\frac{1}{2}\Psi$ in Figure 3. The fulldrawn line represents the Φ_{omm} computed from (31a) using the values of a and b from (27). The points of observation lie parallel to this line, thus confirming the ratio of amplitudes of P_0 and P_1 found previously. It may be emphasized that the line is based on the analysis of the flat lightcurves, whereas the points were derived from the high lightcurves and therefore depend on independent observations. As has been said previously, the errors of the analysis of P_0 and P_1 are correlated and leave not much play in the difference of the amplitudes. Since on the other hand the high lightcurves confirm the ratio of the amplitudes, the values found from the analysis cannot be far wrong. It is a pity that as a consequence of other disturbing pulsations, which shall be discussed later, it is impossible to obtain observed epochs of ascending branches near $\Psi = 0.5$. There the slope of the ascending branch is very small and the moment when it reaches the median magnitude is strongly disturbed. Two such observations are indicated by circles.

FIGURE 3

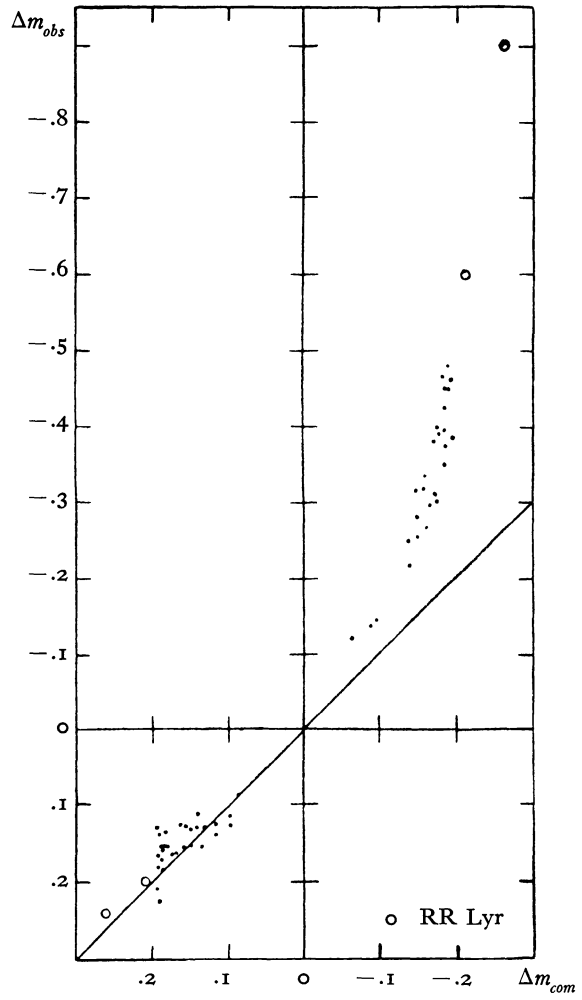


Another thing to be discussed in Figure 3 is the systematic displacement of the points with respect to the computed line. The displacement is about three times the error in the computed phase given by (28) and (29).

Therefore we are not absolutely certain that it is a real effect. So either the accuracy of the analysis was not sufficient or by some physical process the strong oscillations come slightly earlier than the weak ones.

Let us now consider the shape of the high lightcurves. These differ strongly from the curves computed by (27). This is shown in Figure 1, where the computed curves are drawn as full lines. The deviation consists of two effects: firstly the observed lightcurves are inclined and secondly they have an increased maximum. In Figure 4 are plotted the observed height of maximum Δm_{max} and depth of minimum Δm_{min} against the corresponding values of the curves computed with (27). By Δm we denote the difference of observed magnitude with the median magnitude $m = 0.859$. The numerical data can be found in Table 7. The plot shows a very marked increase of height of maximum

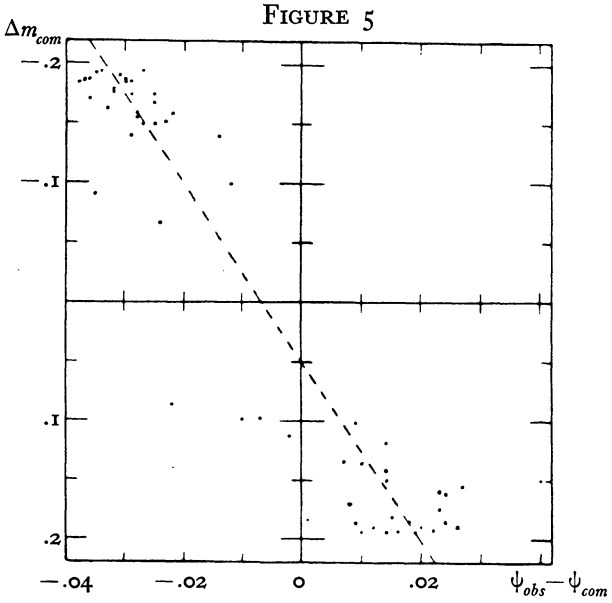
FIGURE 4



with respect to the computed value. For reference the 45° line, which shows what it should be, is drawn in the figure. It seems that the deep minima show a tendency to be filled up. This effect however might be accounted for by assuming a somewhat smaller amplitude of the combining pulsations than found from the analysis. But this would make the deviations of the maxima still more marked. It may be noted that by the small-period oscillations the low maxima are found systematically too high and the undeep minima too deep. This effect can be noted in Figure 4. It is probable that up to $0^m.1$ there is correspondence between observed and computed values and consequently the rise of the maxima seems to be a suddenly starting effect.

In order to study the steepening of the curves we have plotted in Figure 5 the difference between the observed phase and the computed phase of the maxima and the minima against their Δm_{com}. See Table 7 for the data. The strongly increased dispersion of the minima and low maxima is again due to the small-period waves, which have considerable effect. The

FIGURE 5



characteristic behaviour is that the maxima come early and the minima late. It has been shown earlier in this paper that RIEMANN's treatment of the equations of motion and of continuity gave a relation between particle velocity and density, equation (13). But moreover the velocity of propagation of a point where the particles have a certain velocity u is shown to be $V=C+u$.

With (6) and (13) this becomes:

$$V=\left(\frac{dp}{d\rho}\right)^{\frac{1}{2}}+u=\left(\gamma\frac{p_o}{\rho_o}\right)^{\frac{1}{2}}\left\{\frac{\gamma+1}{\gamma-1}\left(\frac{\rho}{\rho_o}\right)^{\frac{\gamma-1}{2}}-\frac{2}{\gamma-1}\right\}. \quad (32)$$

For points which are in the equilibrium position the corresponding velocity is $\left(\gamma\frac{p_o}{\rho_o}\right)^{\frac{1}{2}}$. The relative velocity of propagation with respect to these points is therefore:

$$V_{rel}=\left(\frac{\gamma p_o}{\rho_o}\right)^{\frac{1}{2}}\frac{\gamma+1}{\gamma-1}\left\{\left(\frac{\rho}{\rho_o}\right)^{\frac{\gamma-1}{2}}-1\right\}. \quad (33)$$

This formula shows, together with (14) and (24), that the steepening of the waveshape as predicted by our simple discussion is practically proportional to Δm. Therefore the phase differences shown in Figure 5 should be proportional to amplitude. However the straight line connecting the points in the figure is not passing through the origin. It seems hopeless to derive a reliable value for the wave-steepening coefficient from our observations. It is possible that the phase of the maxima is disturbed just as well as their height. In this case we would get a rather low value of the steepening coefficient. It is also possible that we have used the wrong phase in computing the theoretical curves. This is suggested by the fact that the displacement of the dashed line in Figure 5 with respect to the origin is practically the same as the deviation we found for

TABLE 7

Date	Δm_{com}	Δm_{obs}	$\psi_{obs}-\psi_{com}$	Date	Δm_{com}	Δm_{obs}	$\psi_{obs}-\psi_{com}$
16 April	max − .166	− .297	− .025	1 May	min + .098	+ .126	− .007
	min + .192	+ .221	+ .022				
	max − .187	− .451	− .036	2 May	max − .183	− .466	− .038
					min + .194	+ .211	+ .019
17 April	max − .148	− .313	− .027		max − .173	− .398	− .029
	min + .185	+ .155	+ .018				
				3 May	min + .119	+ .127	+ .014
18 April	max − .187	− .374	− .030		max − .170	− .381	− .036
	min + .154	+ .129	+ .027		min + .194	+ .167	+ .010
	max − .090	− .135	− .035		max − .185	− .423	− .029
19 April	max − .149	− .282	− .025	8 May	max − .156	− .318	− .028
	min + .186	+ .156	+ .024		min + .189	+ .173	+ .020
	max − .193	− .462	− .034		max − .192	− .479	− .035
	min + .170	+ .162	+ .008				
				17 May	min + .150	+ .155	+ .040
24 April	min + .174	+ .167	+ .023		max − .186	− .351	− .037
	max − .194	− .384	− .027				
	min + .181	+ .155	+ .015	18 May	min + .187	+ .158	+ .009
	max − .139	− .218	− .029		max − .151	− .256	− .023
					min + .087	+ .089	− .022
25 April	max − .098	− .146	− .012				
	min + .159	+ .156	+ .023	19 May	min + .150	+ .134	+ .014
					max − .186	− .395	− .030
26 April	min + .183	+ .137	+ .001				
	max − .139	− .251	− .014	22 May	min + .133	+ .129	+ .007
					max − .176	− .300	− .032
27 April	min + .161	+ .128	+ .024				
	max − .190	− .450	− .031	23 May	min + .113	+ .140	− .002
	min + .190	+ .139	+ .026				
	max − .159	− .334	− .028	24 May	min + .194	+ .182	+ .016
					max − .178	− .391	− .032
29 April	min + .189	+ .184	+ .012				
	max − .158	− .302	− .022	25 May	min + .102	+ .118	+ .009
	min + .099	+ .115	− .010		max − .162	− .267	− .033
30 April	min + .142	+ .129	+ .014	26 May	min + .136	+ .156	+ .010
	min + .194	+ .134	+ .014		max − .065	− .122	− .024
	max − .173	− .311	− .025				

the epochs of the ascending branches (Figure 3). In this case the wave-steepening is represented by the dashed line in Figure 5. And finally nothing prevents the coefficient of being still bigger. We assume therefore that the line in Figure 5 is right and accordingly we find a steepening of

$$\frac{dt}{dm} = 0.050 \text{ days/magn.} \qquad (34)$$

It seems of no use trying to connect this value through formula (33) with the physical properties of the star; that is too far outside the scope of a simple discussion.

In many respects the foregoing discussion was troubled by the small-period oscillations. Obviously it would be of great value if we could analyse these too and then subtract them from the observed lightcurves. Then it would be possible to find more carefully the shape of the strong pulsations P_0 and P_1, to verify the phase advance of the high lightcurves, to determine more accurately the wave-steepening coefficient. Unfortunately this turned out to be impossible. After many trials two periods prevailed. Although these could be pursued in all the observed lightcurves, they were not able to reproduce exactly all observed shapes. In many cases they gave results strikingly resemblant to observations but on other nights they represented only approximately the observed lightcurves. Many possible explanations can be put forward, but it was not tried to consider them all in detail as it seemed better to delay this until better observations, especially longer series, if possible of a complete beat period, are available. Now we confine ourselves to giving with caution the probable elements of the two small periods. They were named P_2 and P_3.

The first column of Table 8 gives one of the observed epochs when the phase Φ_2 is zero. The second column gives the corresponding value computed with:

$$\text{J.D} = 2433754.2608 + 0^d.0464600\ m. \quad (35)$$

The third column gives the number of cycles m and the fourth column gives observed minus computed epochs. The last column gives the observed amplitude.

The arrangement of Table 9 is similar. Here the computed epochs were obtained from:

$$\Phi_3 = 0 \text{ for J.D.} = 2433762.2398 + 0^d.0317584\ n. \quad (36)$$

TABLE 8

J.D. (obs) −2430000	J.D. (com) −2430000	m	$O-C$	Ampl. $0^m.001$
3754.2601	3754.2608	0	− 7	25
3755.3787	3755.3758	24	+ 29	21
3766.3818	3766.3869	261	− 51	19
3768.2948	3768.2917	302	+ 31	24
3784.2705	3784.2740	646	− 35	21
3785.2988	3785.2961	668	+ 27	14
3787.2501	3787.2474	710	+ 27	24
3790.2653	3790.2673	775	− 20	16

TABLE 9

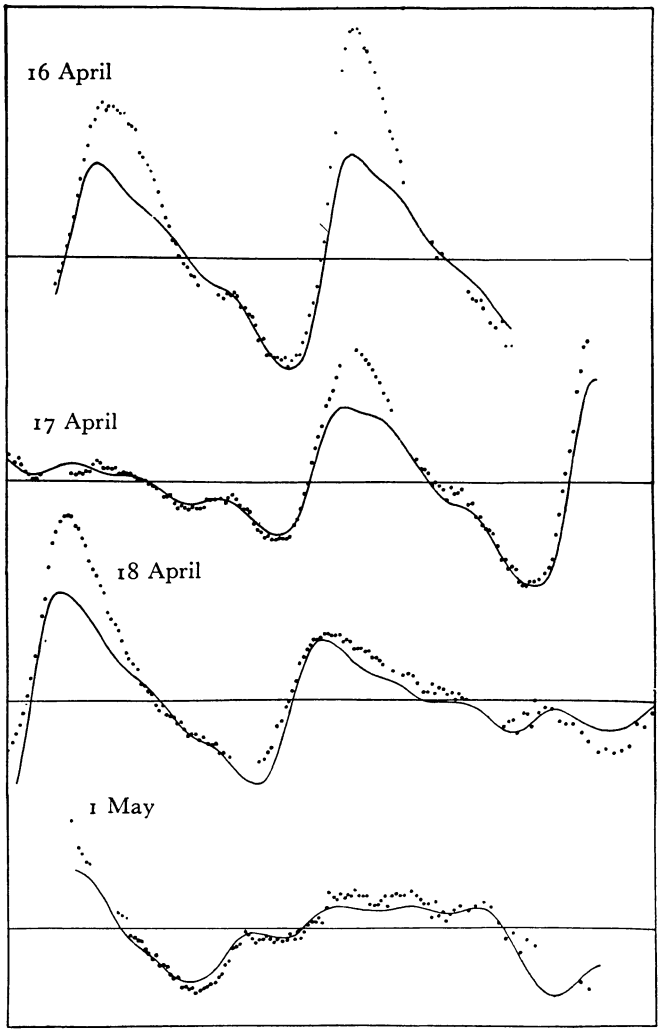
J.D. (obs) −2430000	J.D. (com) −2430000	n	$O-C$	Ampl. $0^m.001$
3754.2703	3754.2684	− 251	+ 19	9
3755.3468	3755.3482	− 217	− 14	9
3766.3681	3766.3684	+ 130	− 3	16
3768.2739	3768.2739	190	0	15
3784.2780	3784.2801	694	− 21	13
3785.3295	3785.3282	727	+ 13	13
3787.2687	3787.2654	788	+ 33	12
3790.2487	3790.2507	882	− 20	13

The $O - C$'s are in general less than one tenth of the period but are bigger than expected for a stable and regular pulsation.

Illustrating the importance of long series of observations is the fact that in both cases observations are just as well represented by periods which have with respect to the periods given in (35) and (36) a beat period of exactly a day. Only if a night of eleven hours observing gives twice the flat lightcurve, which was never the case in the present observations, we shall be able to decide which periods are the right ones. There is still another effect, which causes some of the lightcurves to lie higher than others, but I have not been able to find a periodicity in it.

We conclude this discussion of observations by giving a picture of some computed lightcurves, now involving wave steepening according to (34) and the small pulsations as given by (35) and (36) (Figure 6). It may be remarked that the observed curve of 17 April has been corrected by a magnitude shift of $0^m.05$.

FIGURE 6



Some remarks.

Some interesting points were encountered in the foregoing discussion, which may prove of general interest in the problem of Cepheids. For example the fact that it was possible to find the equilibrium magnitude from the flat lightcurves. As can be seen in Figure 1, this magnitude is crossed by the descending branches of the strong lightcurves very near the point predicted by the formula. When the same thing is true for normal Cepheids, the equilibrium magnitude in that case can be found from the condition that the time interval from ascending epoch to descending epoch is half the period. If we apply this to an RR Lyrae star, then the equilibrium magnitude will be found generally very

low, much lower than the median magnitude, which is the arithmetical mean between minimum and maximum, and which has been used regularly in most investigations.

Consequently the height of maximum is much bigger than the depth of minimum, which agrees perfectly with what has been found for AI Velorum. The similarity is also present in the case of RR Lyrae stars with secondary period where envelopes have been given of the maxima and minima, as for example for RR Lyrae itself [1]) and well pronounced for RW Cancri [2]).

There also the maximum envelope shows a bigger amplitude than that of the minima. In the case of RR Lyrae it was possible to estimate the equilibrium magnitude because the descending branch has been observed. Moreover the ratio of the amplitudes of the fundamental and interfering oscillations can be found from the phase variations.

The observed epochs are advanced or retarded with respect to the computed ones with an amplitude of about $\frac{1}{54}$ of the period. According to formula (31a) this is approximately $b/2\pi a$ and consequently $\frac{b}{a} \approx \frac{1}{9}$. Therefore the high and the low lightcurves should have an amplitude ratio of $\frac{a+b}{a-b} = \frac{10}{8}$.

Using this, the observed extreme amplitudes of RR Lyrae were tentatively plotted in Figure 4 as circles. They fit quite reasonably and it appears that the undistorted amplitude of RR Lyrae is only about $0^m.24$.

Of course not much weight should be attached to a result obtained by such a crude method, but nevertheless it shows that in the case of RR Lyrae the same things happen as in AI Velorum. On the other hand the arrangement of periods suggests a relation of AI Velorum to β Canis Majoris stars. Perhaps AI Velorum is a link between the two groups of stars.

RW Cancri provides another confirmation, although in a negative way. The phase-shift curve as given in BALAZS and DETRE's paper is not as usual a quarter period out of phase with respect to the curve of the amplitude of the lightcurves but a half period. This is in contradiction with formula (31a) and it seems difficult to explain in terms of interfering oscillations. If however the epochs are determined in the abovementioned way, that is, much lower on the ascending branch, roughly estimated $0^m.6$ lower than the magnitude adopted by the authors, the phase shift is completely changed and probably will be found in accordance with the rules that hold for AI Velorum and RR Lyrae.

[1]) *B.A.N.* XI, 17, 1949.
[2]) *Mitt. d. Konkoly Sternw.* No. 23.

Very interesting is of course the problem of what is the cause of the strong increase of maximum brightness. This effect cannot be considered as a small discrepancy between theory and observation. A separate explanation has to be found for it.

The most pronounced properties of the phenomenon are: that it depends critically on the amplitude of the original pulsation, as can be seen in Figure 4, and that it affects only the maxima of the lightcurves. These characteristics suggest the occurrence of shockwaves [1]), which in effect are able to give markedly increased light emission and moreover depend critically on the amplitude of the original waves.

Such shockwaves are the natural consequence of a continued wave steepening. The necessary steepening is bigger than that indicated by (34). It has to be considered, however, that the observed lightcurve need not represent the actual density distribution in the wave. It is very probable that the observed region of the star, responsible for the lightcurve, moves together with the wave front, which has an increased opacity. In this way a sharp perpendicular rise of density may give a gradual rise of light, with about the same slope for all the high lightcurves.

The physical process of a sharp wave front reaching the outer layers of the star must be a very complicated one. The extension of the wave front, which may be small in the adiabatic interior of the star, probably expands when it reaches the photosphere and the front may be transformed into a turbulent outward moving mass of gas — analogous to the idea of an expanding shell, such as was proposed by Professor PANNEKOEK for δ Cephei [2]).

One further observational fact might be mentioned which seems to be in accordance with the suggested process. It is that the high lightcurves all have the same sharp shape at maximum, less disturbed in phase and height than the other parts of the lightcurves by the small oscillations. This is also well pronounced in RR Lyrae. It seems that here the extra light of the shockwave, being always the same type of process, masks somewhat the original pulsations of the star. Unfortunately in this case again the small oscillations, as long as they are not known with certainty, prevent obtaining more observational evidence for or against the suggested process [3]).

This paper is concluded with the remark that a

[1]) S. ROSSELAND, *loc. cit.*
[2]) PANNEKOEK, *Physica* **12**, 761, 1946.
[3]) In a letter Dr SCHWARZSCHILD suggested to me that the non-linearity between the basic underlying oscillation and the observed light oscillation, shown in Figure 4, need not necessarily be explained by shockwaves, but might also be expected in the case of continuous waves, as long as they have appreciable amplitudes in density.

fruitful field of investigation is here, which is highly in need of better observations and more theory [1]).

I am grateful to Dr W. FINSEN of the Union Observatory for his many valuable advices and for supplying optical parts for the photometer, and to Mrs PELS-KLUYVER for taking care of the final preparation of this paper.

My wife has been extremely helpful by constructing the neutral wedge, assisting in the reductions and typing of tables.

[1]) While this paper was in proof, a new series of observations, with improved photometer, has been finished and its discussion has been started. It seems that these new lightcurves shall enable me to determine the small oscillations, which are present very clearly, and other details of the lightcurves with more certainty.

One interesting feature has been remarked already. The difference in amplitude of P_0 and P_1, the strong oscillations, has increased markedly compared to the results given in this paper.

TABLE 10

J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m
ψ : .1991 − .6374		3753.2701	0.893	3753.3297	0.437	3754.2327	0.798	3754.2964	1.310	3754.3497	0.598	3754.4176	1.451	3755.2205	0.768
		.2708	1.244	.3304	0.612	.2334	1.194	.2971	0.866	.3504	0.946	.4183	0.984	.2219	1.087
3753.2189	0.914	.2715	0.896	.3311	0.404	.2341	0.808	.2978	1.298	.3511	0.574	.4190	1.454	.2230	0.680
.2196	1.263	.2722	1.267	.3318	0.601	.2348	1.219	.2985	0.864	.3574	0.543	.4197	1.008	.2237	1.002
.2203	0.889	.2729	0.915	.3325	0.400	.2355	0.804	.2992	1.286	.3587	0.874	.4204	1.455	.2243	0.652
.2210	1.219	.2805	1.291	.3332	0.592	.2362	1.213	.2999	0.848	.3594	0.553	.4211	1.015	.2250	0.939
.2217	0.871	.2812	0.933	.3339	0.399	.2369	0.797	.3006	1.280	.3601	0.883	.4218	1.473	.2257	0.588
.2224	1.193	.2819	1.300	.3346	0.600	.2476	1.227	.3013	0.848	.3608	0.561	.4225	1.015	.2264	0.883
.2231	0.838	.2826	0.940	.3352	0.407	.2486	0.795	.3020	1.285	.3615	0.889	.4232	1.474	.2271	0.540
.2237	1.152	.2833	1.290	.3359	0.612	.2493	1.201	.3026	0.847	.3622	0.570	.4238	1.008	.2278	0.824
.2244	0.813	.2840	0.930	.3366	0.437	.2500	0.797	.3033	1.272	.3629	0.909	.4245	1.469	.2285	0.518
.2251	1.117	.2847	1.294	.3373	0.636	.2507	1.215	.3047	1.284	.3636	0.582	.4252	1.008	.2292	0.808
.2258	0.779	.2854	0.933	.3380	0.442	.2514	0.794	.3054	0.845	.3643	0.927	.4263	1.461	.2299	0.497
.2265	1.081	.2861	1.304	.3387	0.665	.2521	1.207	.3061	1.265	.3650	0.597	.4273	1.001	.2306	0.782
.2272	0.736	.2868	0.930	.3394	0.464	.2528	0.795	.3068	0.854	.3657	0.952	.4280	1.470	.2313	0.486
.2279	1.012	.2875	1.316	.3401	0.689	.2535	1.200	.3075	1.273	.3664	0.608	.4290	0.990	.2320	0.782
.2286	0.702	.2882	0.938	.3408	0.484	.2542	0.790	.3082	0.841	.3671	0.971	.4301	1.430	.2327	0.485
.2293	0.976	.2888	1.323	.3415	0.733	.2549	1.202	.3089	1.273	.3677	0.630	.4308	0.980	.2333	0.783
.2300	0.665	.2895	0.958	.3422	0.517	.2556	0.791	.3096	0.837	.3684	0.994	.4315	1.381	.2340	0.486
.2307	0.925	.2902	1.318	.3429	0.771	.2562	1.202	.3103	1.279	.3691	0.642	.4322	0.964	.2347	0.784
.2314	0.635	.2909	0.959	.3436	0.538	.2569	0.776	.3110	0.847	.3698	1.019	.4328	1.381	.2354	0.506
.2321	0.897	.2916	1.335	.3442	0.799	.2576	1.194	.3117	1.287	.3705	0.662	.4335	0.914	.2361	0.812
.2327	0.597	.2923	0.971	.3449	0.564	.2583	0.768	.3123	0.859	.3802	1.165	.4342	1.326	.2368	0.510
.2334	0.860	.2930	1.347	.3456	0.826	.2590	1.188	.3130	1.302	.3809	0.762	.4349	0.874	.2375	0.825
.2341	0.583	.2937	0.977	.3463	0.603	.2597	0.771	.3137	0.867	.3816	1.183	.4356	1.287	.2382	0.530
.2348	0.830	.2944	1.359	.3470	0.885	.2604	1.187	.3144	1.312	.3823	0.782	.4363	0.828	.2389	0.859
.2355	0.559	.2951	0.993	.3477	0.619	.2611	0.783	.3151	0.866	.3830	1.214	.4370	1.239	.2396	0.544
.2362	0.824	.2958	1.389	.3484	0.917	.2618	1.199	.3158	1.314	.3837	0.783	.4377	0.791	.2403	0.875
.2369	0.549	.2965	1.024	.3491	0.640	.2625	0.782	.3165	0.871	.3844	1.217	.4384	1.177	.2410	0.575
.2376	0.818	.2972	1.396	.3498	0.952	.2632	1.188	.3172	1.330	.3851	0.790	.4391	0.745	.2417	0.903
.2383	0.564	.2978	1.021	.3505	0.663	.2639	0.784	.3179	0.896	.3858	1.229	.4398	1.103	.2423	0.592
.2390	0.802	.2985	1.421	.3512	0.971	.2646	1.206	.3186	1.335	.3864	0.817	.4405	0.705	.2430	0.920
.2397	0.555	.2992	1.054	.3519	0.705	.2653	0.782	.3193	0.909	.3871	1.243	.4412	1.048	.2437	0.605
.2404	0.798	.2999	1.420	.3526	1.014	.2659	1.201	.3200	1.348	.3878	0.811	.4419	0.625	.2444	0.958
.2411	0.555	.3006	1.053	.3619	1.147	.2666	0.795	.3207	0.911	.3885	1.247	.4425	0.987	.2451	0.626
.2418	0.812	.3013	1.429	.3629	0.826	.2673	1.207	.3213	1.350	.3892	0.817	.4432	0.581	.2458	0.986
.2424	0.564	.3020	1.059	.3636	1.176	.2680	0.793	.3220	0.922	.3899	1.255	.4439	0.905	.2465	0.640
.2431	0.818	.3027	1.443	.3643	0.858	.2687	1.193	.3227	1.369	.3906	0.823	.4446	0.534	.2472	1.022
.2438	0.570	.3034	1.059	.3650	1.172	.2694	0.794	.3234	0.920	.3913	1.247	.4453	0.854	.2479	0.680
.2445	0.812	.3041	1.439	.3661	0.850	.2701	1.207	.3241	1.356	.3920	0.845	.4460	0.525	.2486	1.033
.2452	0.570	.3048	1.064	.3671	1.212	.2708	0.797	.3248	0.928	.3927	1.261	.4467	0.745	.2493	0.693
.2459	0.836	.3055	1.455	.3678	0.858	.2715	1.217	.3255	1.366	.3934	0.820	.4474	0.436	.2500	1.059
.2466	0.591	.3062	1.059	.3685	1.211	.2722	0.801	.3262	0.929	.3941	1.260	.4481	0.648	.2507	0.703
.2473	0.848	.3069	1.443	.3758	1.266	.2729	1.225	.3269	1.365	.3948	0.832	.4495	0.371	.2514	1.067
.2480	0.595	.3075	1.076	.3768	0.926	.2736	0.808	.3275	0.925	.3955	1.267			.2520	0.718
.2487	0.872	.3082	1.453	.3775	1.279	.2743	1.227	.3283	1.359	.3961	0.831	ψ : .4240 − .1007		.2527	1.091
.2494	0.602	.3089	1.065	.3782	0.940	.2749	0.808	.3290	0.925	.3968	1.280			.2534	0.738
.2501	0.891	.3096	1.449	.3789	1.298	.2756	1.224	.3297	1.362	.3975	0.823	3755.2001	1.412	.2541	1.116
.2508	0.650	.3103	1.054	.3796	0.944	.2763	0.809	.3304	0.927	.3982	1.271	.2008	0.992	.2548	0.761
.2514	0.909	.3110	1.441	.3803	1.285	.2770	1.236	.3310	1.348	.3989	0.867	.2015	1.430	.2555	1.139
.2521	0.658	.3117	1.053	.3810	0.942	.2777	0.815	.3317	0.921	.3996	1.279	.2022	0.993	.2562	0.773
.2528	0.939	.3124	1.405	.3816	1.322	.2784	1.238	.3324	1.346	.4003	0.856	.2029	1.425	.2569	1.152
.2535	0.673	.3131	1.029	.3827	0.958	.2791	0.820	.3331	0.897	.4010	1.267	.2036	0.999	.2576	0.784
.2542	0.980	.3138	1.384	.3841	1.323	.2798	1.249	.3338	1.314	.4017	0.852	.2043	1.427	.2583	1.180
.2549	0.687	.3145	1.009	.3851	0.986	.2805	0.823	.3345	0.887	.4024	1.304	.2050	1.004	.2590	0.795
.2556	1.018	.3152	1.359	.3861	1.352	.2812	1.261	.3352	1.308	.4031	0.879	.2056	1.427	.2597	1.197
.2563	0.713	.3159	0.974	.3875	0.998	.2826	1.267	.3359	0.864	.4038	1.316	.2063	1.000	.2604	0.822
.2570	1.033	.3165	1.334	.3886	1.346	.2833	0.841	.3366	1.289	.4045	0.880	.2070	1.419	.2610	1.219
.2577	0.729	.3172	0.949	.3896	0.982	.2840	1.283	.3373	0.832	.4051	1.316	.2077	0.991	.2617	0.826
.2584	1.067	.3179	1.290	.3906	1.369	.2846	0.841	.3380	1.244	.4058	0.896	.2084	1.413	.2624	1.217
.2591	0.757	.3186	0.918	.3911	1.035	.2853	1.289	.3387	0.814	.4065	1.323	.2091	0.981	.2631	0.839
.2598	1.092	.3193	1.236	.3920	1.387	.2860	0.838	.3394	1.223	.4072	0.905	.2098	1.395	.2638	1.250
.2605	0.780	.3200	0.863	.3934	1.033	.2867	1.281	.3400	0.770	.4079	1.348	.2105	0.959	.2645	0.844
.2611	1.116	.3207	1.164			.2874	0.855	.3407	1.165	.4086	0.907	.2112	1.364	.2652	1.261
.2618	0.797	.3214	0.825	ψ : .8535 − .4445		.2881	1.287	.3414	0.740	.4093	1.357	.2119	0.942	.2659	0.866
.2625	1.138	.3221	1.109			.2888	0.864	.3421	1.136	.4100	0.913	.2126	1.359	.2666	1.274
.2632	0.823	.3228	0.750	3754.2254	0.757	.2895	1.291	.3428	0.717	.4107	1.383	.2133	0.926	.2673	0.878
.2639	1.162	.3235	1.024	.2265	1.163	.2902	0.860	.3435	1.078	.4114	0.940	.2140	1.330	.2680	1.284
.2646	0.830	.3242	0.678	.2272	0.770	.2909	1.285	.3442	0.696	.4121	1.389	.2146	0.908	.2687	0.866
.2653	1.192	.3249	0.931	.2279	1.153	.2916	0.864	.3449	1.045	.4128	0.966	.2153	1.310	.2694	1.279
.2660	0.856	.3256	0.605	.2285	0.763	.2923	1.310	.3456	0.655	.4135	1.401	.2160	0.882	.2701	0.885
.2667	1.200	.3262	0.822	.2292	1.156	.2930	0.868	.3463	1.030	.4141	0.966	.2167	1.263	.2707	1.315
.2674	0.871	.3269	0.540	.2299	0.776	.2936	1.303	.3470	0.641	.4148	1.420	.2174	0.848	.2714	0.889
.2681	1.219	.3276	0.750	.2306	1.178	.2943	0.862	.3477	1.008	.4155	0.984	.2181	1.231	.2721	1.304
.2688	0.878	.3283	0.481	.2313	0.791	.2950	1.308	.3484	0.625	.4162	1.437	.2188	0.812	.2728	0.891
.2695	1.231	.3290	0.660	.2320	1.189	.2957	0.865	.3490	0.971	.4169	0.979	.2195	1.177	.2735	1.322

TABLE 10 (*continued*)

J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m
3755.2742	0.902	3755.3566	1.170	3756.2021	1.333	3756.2686	0.987	3756.3475	0.673	3761.1921	1.218	3761.2600	0.503	3761.3732	0.709
.2749	1.322	.3570	0.799	.2028	0.919	.2693	0.637	.3482	0.397	.1928	0.845	.2607	0.769	.3746	1.123
.2756	0.901	.3577	1.156	.2035	1.332	.2700	1.002	.3489	0.673	.1935	1.236	.2614	0.480	.3760	0.725
.2763	1.329	.3604	1.193	.2042	0.913	.2707	0.658	.3496	0.396	.1942	0.849	.2621	0.753	.3774	1.090
.2770	0.916	.3611	0.809	.2049	1.330	.2714	1.019	.3503	0.650	.1949	1.254	.2628	0.480	.3788	0.742
.2777	1.334	.3618	1.194	.2056	0.903	.2720	0.671	.3510	0.411	.1956	0.861	.2635	0.739	.3802	1.103
.2784	0.929	.3625	0.806	.2063	1.326	.2727	1.051	.3517	0.684	.1963	1.279	.2645	0.474	.3815	0.738
.2791	1.338	.3632	1.188	.2070	0.914	.2734	0.688	.3524	0.420	.1970	0.872	.2659	0.757	.3829	1.111
.2797	0.926	.3646	0.809	.2076	1.322	.2741	1.073	.3531	0.704	.1977	1.291	.2669	0.492	.3847	0.773
.2804	1.340	.3656	1.207	.2083	0.911	.2748	0.715	.3538	0.420	.1984	0.880	.2676	0.776	.3864	1.128
.2811	0.925	.3663	0.824	.2090	1.324	.2755	1.097	.3545	0.698	.1991	1.298	.2683	0.492	.3878	0.790
.2818	1.348	.3677	1.230	.2097	0.901	.2762	0.727	.3552	0.422	.1998	0.893	.2690	0.795	.3892	1.177
.2825	0.938	.3691	0.841	.2104	1.326	.2769	1.128	.3558	0.738	.2004	1.294	.2697	0.519	.3906	0.784
.2832	1.348	.3698	1.242	.2118	1.321	.2776	0.767	.3565	0.463	.2011	0.907	.2704	0.826	.3919	1.182
.2839	0.931	.3705	0.841	.2125	0.913	.2906	0.882	.3576	0.782	.2018	1.321	.2711	0.548	.3933	0.823
.2849	1.360	.3712	1.218	.2132	1.336	.2914	1.321	.3586	0.496	.2025	0.905	.2718	0.862	.4162	1.344
.2860	0.944	.3719	0.826	.2139	0.892	.2921	0.892	.3593	0.817	.2032	1.318	.2725	0.569	.4179	0.968
.2867	1.357	.3725	1.231	.2146	1.334	.2928	1.316	.3600	0.529	.2039	0.915	.2732	0.888	.4200	1.360
.2874	0.947	.3732	0.846	.2153	0.916	.2935	0.904	.3607	0.842	.2046	1.323	.2739	0.580	.4221	0.971
.2881	1.359	.3739	1.243	.2160	1.328	.2942	1.318	.3614	0.540	.2053	0.919	.2746	0.920	.4241	1.341
.2888	0.945	.3746	0.832	.2166	0.917	.2949	0.892	.3621	0.869	.2060	1.322	.2752	0.608	.4273	0.968
.2894	1.378	.3753	1.245	.2173	1.345	.2956	1.333	.3628	0.586	.2067	0.916	.2759	0.948	.4304	1.341
.2905	0.964	.3764	0.827	.2180	0.933	.2963	0.902	.3635	0.927	.2074	1.329	.2766	0.638	.4331	0.964
.2915	1.389	.3774	1.248	.2187	1.346	.2970	1.341	.3642	0.614	.2081	0.918	.2773	0.995	.4359	1.340
.2922	0.963	.3781	0.847	.2194	0.929	.2977	0.907	.3649	0.957	.2088	1.334	.2780	0.658		
.2933	1.391	.3788	1.250	.2201	1.347	.2984	1.338	.3655	0.627	.2095	0.926	.2787	1.006	ψ : .8814 − .3157	
.2943	0.971	.3795	0.841	.2208	0.940	.2991	0.886	.3662	0.984	.2101	1.332	.2794	0.674		
.3054	1.415	.3802	1.242	.2215	1.356	.2998	1.335	.3669	0.644	.2108	0.933	.2801	1.049	3762.1988	1.338
.3061	0.981	.3809	0.856	.2221	0.952	.3004	0.900	.3676	1.016	.2115	1.345	.2808	0.696	.1997	0.920
.3068	1.388	.3816	1.244	.2229	1.359	.3011	1.321	.3683	0.663	.2122	0.934	.2815	1.062	.2004	1.335
.3074	0.977	.3822	0.845	.2236	0.942	.3018	0.914	.3690	1.048	.2129	1.347	.2822	0.718	.2011	0.924
.3081	1.371	.3829	1.245	.2243	1.364	.3025	1.334	.3697	0.707	.2136	0.944	.2829	1.093	.2018	1.333
.3088	0.962	.3836	0.852	.2250	0.962	.3032	0.905	.3704	1.086	.2143	1.358	.2836	0.737	.2024	0.926
.3095	1.360	.3843	1.267	.2256	1.362	.3039	1.334	.3711	0.704	.2150	0.944	.2842	1.116	.2031	1.322
.3102	0.954	.3854	0.856	.2263	0.946	.3049	0.911	.3718	1.104	.2157	1.363	.2849	0.757	.2038	0.905
.3113	1.334	.3864	1.278	.2270	1.364	.3060	1.352	.3725	0.736	.2164	0.943	.2856	1.128	.2045	1.324
.3126	0.910	.3985	1.318	.2277	0.956	.3067	0.929	.3732	1.116	.2171	1.364	.2863	0.776	.2052	0.905
.3137	1.317	.3999	0.911	.2284	1.347	.3074	1.354	.3739	0.746	.2178	0.953	.2870	1.166	.2059	1.310
.3144	0.900	.4009	1.326	.2291	0.938	.3081	0.933	.3745	1.129	.2185	1.376	.2877	0.804	.2066	0.904
.3151	1.304	.4016	0.900	.2298	1.345	.3088	1.366	.3752	0.753	.2191	0.962	.2884	1.176	.2073	1.299
.3158	0.870	.4023	1.296	.2305	0.930	.3094	0.942	.3759	1.138	.2198	1.375	.2891	0.812	.2080	0.892
.3165	1.273	.4030	0.899	.2312	1.355	.3101	1.388	.3766	0.768	.2205	0.970	.2898	1.193	.2087	1.308
.3171	0.860	.4037	1.285	.2319	0.916	.3108	0.966	.3773	1.257	.2212	1.388	.2905	0.823	.2094	0.883
.3178	1.253	.4044	0.924	.2326	1.328	.3115	1.385	.3780	0.784	.2219	0.968	.2912	1.213	.2101	1.297
.3185	0.839	.4054	1.306	.2333	0.894	.3122	0.967	.3787	1.176	.2226	1.412	.2919	0.833	.2108	0.883
.3192	1.224	.4068	0.883	.2340	1.310	.3129	1.393	.3794	0.817	.2233	0.982	.2926	1.238	.2115	1.291
.3199	0.819	.4079	1.297	.2347	0.885	.3136	0.979	.3801	1.211	.2240	1.409	.2932	0.845	.2121	0.889
.3206	1.182	.4086	0.887	.2353	1.291	.3143	1.407	.3815	1.225	.2247	1.002	.2939	1.245	.2128	1.294
.3213	0.784	.4093	1.285	.2360	0.867	.3150	0.992	.3822	0.834	.2254	1.414	.2946	0.865	.2135	0.882
.3220	1.148	.4099	0.913	.2367	1.243	.3157	1.419	.3829	1.283	.2261	1.010	.2953	1.267	.2142	1.303
.3227	0.770	.4106	1.281	.2374	0.838	.3164	0.995	.3836	0.841	.2268	1.423	.2960	0.874	.2149	0.880
.3234	1.124	.4113	0.859	.2381	1.213	.3171	1.443	.3842	1.257	.2275	1.006	.2967	1.285	.2156	1.285
.3241	0.755	.4120	1.273	.2388	0.802	.3178	1.010	.3849	0.844	.2281	1.430	.2974	0.878	.2163	0.878
.3248	1.120	.4127	0.883	.2395	1.182	.3185	1.461	.3856	1.250	.2288	1.019	.2981	1.286	.2170	1.273
.3255	0.748	.4138	1.273	.2402	0.783	.3191	1.012	.3863	0.847	.2295	1.442	.2988	0.890	.2177	0.861
.3261	1.087	.4151	0.871	.2409	1.136	.3198	1.461	.3870	1.285	.2302	1.021	.2995	1.309	.2184	1.273
.3268	0.735	.4165	1.281	.2416	0.746	.3205	1.010	.3877	0.863	.2309	1.449	.3002	0.900	.2191	0.883
.3275	1.084	.4179	0.878	.2423	1.105	.3212	1.464	.3887	1.280	.2316	1.021	.3009	1.321	.2198	1.279
.3282	0.735	.4193	1.279	.2430	0.720	.3219	1.019	.3901	0.883	.2323	1.450	.3230	1.449	.2205	0.886
.3289	1.085	.4207	0.901	.2437	1.063	.3226	1.456	.3915	1.302	.2330	1.037	.3237	1.007	.2211	1.285
.3296	0.731	.4221	1.283	.2443	0.672	.3233	1.015	.3929	0.892	.2340	1.447	.3244	1.437	.2218	0.897
.3303	1.091	.4235	0.908	.2450	1.020	.3240	1.454	.3943	1.320	.2351	1.021	.3255	1.019	.2225	1.291
.3310	0.724	.4248	1.289	.2457	0.643	.3247	1.006	.3957	0.912	.2358	1.444	.3268	1.449	.2232	0.898
.3317	1.067	.4262	0.907	.2464	0.988	.3254	1.439	.3971	1.340	.2365	1.021	.3282	1.009	.2239	1.299
.3324	0.724	.4276	1.298	.2471	0.625	.3261	1.007	.3984	0.929	.2372	1.425	.3296	1.432	.2246	0.902
.3331	1.097	.4290	0.924	.2478	0.958	.3268	1.431	.3998	1.360	.2378	1.001	.3310	1.007	.2253	1.293
.3338	0.728	.4304	1.321	.2485	0.603	.3275	0.988	.4012	0.953	.2385	1.397	.3324	1.415	.2260	0.914
.3346	1.091	.4318	0.941	.2492	0.927	.3281	1.400	.4026	1.397	.2392	0.988	.3338	0.997	.2267	1.312
.3352	0.728	.4342	1.359	.2499	0.585	.3288	0.979	.4040	0.960	.2399	1.389	.3351	1.395	.2274	0.900
.3358	1.081	.4359	0.963	.2506	0.911	.3295	1.389	.4054	1.397	.2410	0.962	.3365	0.977	.2281	1.311
.3365	0.727	.4373	1.368	.2513	0.583	.3302	0.958	.4068	0.974	.2420	1.345	.3379	1.364	.2288	0.902
.3372	1.079	.4387	0.957	.2520	0.893	.3309	1.359	.4081	1.407	.2427	0.947	.3393	0.937	.2295	1.328
.3379	0.740	.4401	1.359	.2527	0.581	.3316	0.944	.4095	1.008	.2434	1.324	.3407	1.321	.2302	0.923
.3386	1.109	.4415	0.965	.2534	0.915	.3323	1.344	.4109	1.444	.2441	0.918	.3421	0.904	.2308	1.317
.3393	0.735	.4428	1.339	.2540	0.577	.3330	0.908	.4123	1.021	.2448	1.299	.3435	1.278	.2315	0.921
.3400	1.103	.4442	0.960	.2547	0.910	.3337	1.308	.4137	1.453	.2455	0.885	.3452	0.849	.2322	1.306
.3407	0.740	.4456	1.350	.2554	0.581	.3344	0.876	.4151	1.025	.2462	1.279	.3469	1.207	.2329	0.901
.3414	1.124	.4470	0.951	.2561	0.915	.3351	1.267	.4164	1.437	.2468	0.875	.3483	0.800	.2336	1.314
.3421	0.757	.4484	1.320	.2568	0.594	.3358	0.845	.4178	0.998	.2475	1.225	.3497	1.136	.2343	0.922
.3428	1.109	.4498	0.907	.2575	0.923	.3365	1.214	.4192	1.437	.2482	0.833	.3511	0.735	.2350	1.316
.3435	0.755	.4512	1.297	.2582	0.585	.3371	0.806	.4313	1.311	.2489	1.197	.3525	1.065	.2357	0.916
.3442	1.126	.4525	0.911	.2589	0.927	.3378	1.160	.4341	0.902	.2496	0.799	.3538	0.691	.2364	1.320
.3448	0.754	.4539	1.254	.2596	0.586	.3385	0.757	.4362	1.235	.2503	1.145	.3552	1.016	.2371	0.889
.3455	1.136	.4553	0.881	.2603	0.939	.3392	1.107	.4376	0.792	.2513	0.748	.3566	0.660	.2381	1.321
.3462	0.761	.4567	1.212	.2610	0.595	.3399	0.690			.2524	1.066	.3580	0.988	.2395	0.904
.3469	1.130			.2617	0.945	.3406	1.020	ψ : .2119 − .8694		.2531	0.698	.3594	0.647	.2405	1.328
.3476	0.759	ψ : .0539 − .6876		.2624	0.605	.3413	0.639			.2538	1.008	.3608	0.952	.2412	0.931
.3483	1.114			.2630	0.959	.3420	0.933	3761.1866	1.133	.2545	0.652	.3622	0.636	.2419	1.328
.3490	0.772	3756.1973	0.905	.2637	0.618	.3427	0.569	.1873	0.779	.2552	0.964	.3635	0.970	.2426	0.924
.3497	1.150	.1979	1.320	.2644	0.956	.3434	0.853	.1880	1.145	.2559	0.612	.3649	0.651	.2433	1.322
.3504	0.773	.1986	0.898	.2651	0.604	.3441	0.508	.1887	0.784	.2565	0.895	.3663	0.987	.2447	0.921
.3511	1.146	.1993	1.330	.2658	0.964	.3448	0.782	.1894	1.164	.2572	0.567	.3677	0.692	.2464	1.330
.3518	0.779	.2000	0.911	.2665	0.627	.3455	0.453	.1901	0.799	.2579	0.835	.3691	1.024	.2478	0.923
.3525	1.146	.2007	1.335	.2672	0.972	.3462	0.723	.1908	1.207	.2586	0.512	.3705	0.692	.2488	1.323
.3532	0.788	.2014	0.907	.2679	0.630	.3468	0.416	.1914	0.824	.2593	0.794	.3719	1.037	.2495	0.929

TABLE 10 (*continued*)

J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m
3762.2502	1.334	3762.3441	1.423	3763.2613	0.612	3763.3766	1.266	3764.2564	0.933	3764.3249	1.396	3766.2182	1.383	3766.3047	0.879
.2509	0.915	.3455	1.002	.2620	0.958	.3780	0.850	.2571	1.320	.3256	0.969	.2189	0.925	.3054	1.298
.2516	1.324	.3468	1.426	.2626	0.604	.3793	1.233	.2577	0.902	.3263	1.401	.2195	1.396	.3061	0.886
.2523	0.921	.3482	1.014	.2633	0.947	.3807	0.828	.2584	1.291	.3270	0.974	.2202	0.957	.3068	1.311
.2530	1.317	.3496	1.445	.2640	0.603	.3821	1.231	.2591	0.886	.3277	1.405	.2209	1.401	.3075	0.910
.2537	0.915	.3510	1.012	.2647	0.952	.3835	0.828	.2598	1.267	.3284	0.969	.2216	0.960	.3082	1.304
.2544	1.322	.3524	1.438	.2654	0.614	.3849	1.224	.2605	0.847	.3291	1.405	.2223	1.420	.3089	0.904
.2551	0.915	.3538	1.013	.2661	0.958	.3863	0.794	.2612	1.231	.3298	0.975	.2230	0.971	.3096	1.340
.2558	1.314	.3552	1.403	.2668	0.622	.3876	1.188	.2619	0.813	.3305	1.401	.2237	1.419	.3103	0.913
.2565	0.905	.3565	1.015	.2675	0.969	.3890	0.788	.2626	1.172	.3312	0.974	.2244	0.982	.3110	1.326
.2572	1.310	.3579	1.411	.2682	0.630	.3904	1.163	.2633	0.773	.3318	1.406	.2251	1.437	.3117	0.922
.2579	0.892	.3593	0.987	.2689	0.976	.3918	0.764	.2640	1.129	.3325	0.971	.2258	0.989	.3123	1.335
.2585	1.304	.3607	1.371	.2696	0.614	.3932	1.116	.2647	0.746	.3332	1.411	.2265	1.451	.3130	0.927
.2592	0.899	.3621	0.977	.2703	0.986	.3946	0.711	.2654	1.083	.3339	0.980	.2272	1.002	.3137	1.338
.2599	1.299	.3635	1.328	.2710	0.635	.3960	1.083	.2661	0.691	.3346	1.409	.2279	1.454	.3144	0.926
.2606	0.896			.2717	1.014	.3973	0.706	.2667	1.037	.3353	0.981	.2285	1.010	.3151	1.370
.2613	1.297	ψ : .5236 − .0714		.2723	0.654	.3987	1.085	.2674	0.644	.3360	1.403	.2292	1.469	.3158	0.914
.2620	0.887			.2730	1.002	.4001	0.702	.2681	0.957	.3367	0.979	.2299	1.012	.3165	1.359
.2627	1.296	3763.2007	1.370	.2737	0.663	.4015	1.055	.2688	0.582	.3374	1.406	.2306	1.480	.3172	0.960
.2634	0.882	.2017	0.938	.2744	1.019	.4029	0.690	.2695	0.875	.3381	0.971	.2313	1.013	.3179	1.372
.2641	1.271	.2024	1.376	.2751	0.669	.4043	1.053	.2702	0.526	.3388	1.407	.2327	1.029	.3186	0.944
.2648	0.880	.2034	0.944	.2758	1.048	.4057	0.696	.2709	0.812	.3395	0.988	.2351	1.030	.3193	1.388
.2655	1.275	.2045	1.407	.2765	0.693	.4070	1.045	.2716	0.475	.3402	1.415	.2376	1.032	.3200	0.947
.2662	0.867	.2052	0.949	.2772	1.055	.4084	0.706	.2723	0.746	.3409	0.988	.2396	1.032	.3207	1.385
.2669	1.248	.2059	1.406	.2779	0.695			.2730	0.438	.3415	1.421	.2417	1.028	.3213	0.962
.2675	0.852	.2066	0.973	.2786	1.073	ψ : .1754 − .7123		.2737	0.720	.3422	0.988	.2448	1.015	.3220	1.403
.2682	1.249	.2072	1.415	.2793	0.729			.2744	0.417	.3429	1.415	.2466	1.459	.3227	0.951
.2689	0.835	.2079	0.973	.2800	1.085	3764.2062	0.799	.2751	0.689	.3436	0.999	.2476	0.988	.3234	1.406
.2696	1.214	.2086	1.425	.2807	0.733	.2072	1.207	.2758	0.412	.3443	1.432	.2486	1.418	.3241	0.954
.2703	0.834	.2093	0.971	.2813	1.104	.2079	0.812	.2764	0.687	.3450	0.996	.2493	0.968	.3248	1.405
.2710	1.196	.2100	1.438	.2820	0.740	.2086	1.219	.2771	0.407	.3457	1.426	.2500	1.389	.3259	0.974
.2717	0.795	.2107	0.988	.2827	1.132	.2093	0.817	.2778	0.689	.3464	0.999	.2597	0.770	.3269	1.418
.2724	1.187	.2114	1.454	.2834	0.757	.2107	1.244	.2785	0.407	.3471	1.433	.2604	1.132	.3276	0.975
.2731	0.790	.2121	0.979	.2841	1.151	.2120	0.858	.2796	0.705	.3481	1.002	.2611	0.747	.3283	1.437
.2738	1.146	.2128	1.455	.2848	0.772	.2127	1.271	.2806	0.428	.3492	1.417	.2618	1.085	.3290	0.977
.2745	0.773	.2135	0.982	.2855	1.166	.2134	0.861	.2813	0.726	.3499	0.990	.2625	0.701	.3297	1.429
.2752	1.134	.2142	1.463	.2862	0.776	.2141	1.285	.2823	0.451	.3505	1.409	.2632	1.055	.3304	0.964
.2759	0.757	.2149	0.999	.2869	1.201	.2148	0.872	.2837	0.762	.3512	0.989	.2639	0.673	.3310	1.409
.2766	1.104	.2156	1.457	.2876	0.808	.2155	1.302	.2851	0.484	.3519	1.403	.2646	1.008	.3317	0.977
.2772	0.739	.2163	0.982	.2883	1.214	.2162	0.870	.2861	0.826	.3526	0.979	.2653	0.633	.3324	1.421
.2779	1.102	.2169	1.467	.2890	0.811	.2169	1.312	.2868	0.514	.3533	1.393	.2659	0.964	.3331	0.966
.2786	0.732	.2180	1.002	.2897	1.238	.2176	0.900	.2875	0.846	.3540	0.959	.2666	0.607	.3338	1.403
.2800	1.079	.2190	1.468	.2903	0.826	.2183	1.326	.2882	0.541	.3647	1.134	.2673	0.935	.3345	0.973
.2814	0.731	.2201	1.000	.2910	1.254	.2193	0.918	.2889	0.874	.3661	0.718	.2680	0.592	.3352	1.400
.2821	1.078	.2211	1.457	.2917	0.843	.2203	1.334	.2896	0.564	.3675	1.031	.2687	0.909	.3359	0.973
.2828	0.713	.2221	0.989	.3059	1.334	.2210	0.933	.2903	0.903	.3689	0.636	.2694	0.571	.3366	1.384
.2835	1.067	.2232	1.447	.3073	0.909	.2217	1.342	.2910	0.590	.3703	0.925	.2701	0.881	.3373	0.937
.2842	0.710	.2242	0.988	.3080	1.350	.2224	0.929	.2917	0.925	.3717	0.563	.2708	0.570	.3380	1.381
.2849	1.061	.2253	1.437	.3094	0.916	.2231	1.348	.2924	0.606	.3731	0.859	.2715	0.881	.3387	0.941
.2856	0.720	.2263	0.980	.3108	1.340	.2238	0.935	.2931	0.972	.3744	0.525	.2722	0.562	.3394	1.383
.2862	1.091	.2273	1.426	.3122	0.919	.2245	1.366	.2938	0.624	.3758	0.840	.2729	0.883	.3400	0.932
.2869	0.724	.2280	0.988	.3135	1.346	.2252	0.935	.2944	1.000	.3772	0.528	.2736	0.556	.3407	1.382
.2876	1.085	.2287	1.427	.3149	0.916	.2259	1.366	.2951	0.652	.3786	0.846	.2743	0.871	.3414	0.926
.2883	0.715	.2301	0.967	.3163	1.350	.2266	0.941	.2958	1.032	.3800	0.545	.2753	0.555	.3421	1.351
.2890	1.085	.2315	1.393	.3177	0.910	.2273	1.381	.2965	0.690	.3814	0.859	.2763	0.880	.3428	0.918
.2897	0.726	.2322	0.967	.3191	1.342	.2280	0.943	.2972	1.053	.3827	0.557	.2770	0.567	.3435	1.321
.2904	1.087	.2329	1.391	.3205	0.911	.2287	1.380	.2979	0.710	.3841	0.896	.2777	0.905	.3442	0.911
.2911	0.735	.2339	0.927	.3219	1.334	.2294	0.955	.2986	1.085	.3855	0.583	.2784	0.575	.3449	1.314
.2918	1.092	.2353	1.358	.3232	0.896	.2300	1.387	.2993	0.718	.3869	0.915	.2791	0.909	.3456	0.893
.2925	0.729	.2363	0.918	.3246	1.323	.2307	0.955	.3000	1.103	.3883	0.612	.2798	0.597	.3463	1.316
.2932	1.091	.2370	1.340	.3260	0.894	.2314	1.391	.3007	0.746	.3897	0.969	.2805	0.932	.3470	0.898
.2939	0.755	.2377	0.905	.3274	1.316	.2321	0.960	.3014	1.124	.3911	0.647	.2812	0.607	.3477	1.304
.2946	1.093	.2384	1.323	.3288	0.889	.2328	1.389	.3021	0.770	.3924	1.016	.2819	0.946	.3484	0.900
.2953	0.740	.2391	0.885	.3302	1.314	.2335	0.970	.3028	1.148	.3938	0.669	.2826	0.623	.3491	1.303
.2959	1.091	.2398	1.294	.3319	0.883	.2342	1.395	.3035	0.791	.3952	1.059	.2833	0.961	.3497	0.889
.2966	0.739	.2405	0.874	.3336	1.311	.2349	0.965	.3041	1.181	.3966	0.716	.2840	0.643	.3504	1.316
.2973	1.099	.2412	1.267	.3350	0.889	.2356	1.393	.3048	0.811	.3980	1.099	.2846	0.986	.3511	0.870
.2980	0.751	.2419	0.859	.3364	1.297	.2363	0.977	.3055	1.217	.3994	0.738	.2853	0.646	.3519	1.291
.2987	1.097	.2426	1.253	.3378	0.894	.2370	1.399	.3062	0.830	.4008	1.142	.2860	1.035	.3525	0.878
.2994	0.760	.2433	0.839	.3392	1.310	.2377	0.975	.3069	1.233	.4021	0.770	.2867	0.687	.3532	1.312
.3001	1.127	.2440	1.231	.3409	0.893	.2384	1.405	.3076	0.847	.4035	1.176	.2874	1.061	.3539	0.879
.3008	0.766	.2446	0.823	.3426	1.322	.2390	0.979	.3083	1.255	.4053	0.795	.2881	0.716	.3546	1.297
.3015	1.146	.2453	1.202	.3440	0.886	.2397	1.406	.3090	0.856	.4070	1.223	.2888	1.089	.3553	0.882
.3022	0.746	.2460	0.797	.3454	1.311	.2404	0.985	.3097	1.283	.4084	0.848	.2895	0.717	.3560	1.291
.3029	1.139	.2467	1.176	.3468	0.887	.2411	1.406	.3104	0.874	.4098	1.263	.2902	1.107	.3567	0.914
.3039	0.770	.2474	0.784	.3482	1.298	.2418	0.979	.3111	1.287			.2909	0.733	.3574	1.303
.3049	1.151	.2481	1.158	.3496	0.861	.2425	1.408	.3118	0.889	ψ : .3792 − .0211		.2916	1.122	.3581	0.882
.3056	0.801	.2488	0.768	.3509	1.285	.2432	0.977	.3125	1.311	3766.1794	0.729	.2923	0.753	.3591	1.263
.3063	1.190	.2495	1.104	.3523	0.846	.2439	1.396	.3131	0.897	.1808	0.497	.2930	1.140	.3605	0.878
.3070	0.817	.2502	0.737	.3541	1.281	.2449	0.985	.3138	1.329	.1815	0.812	.2936	0.772	.3619	1.260
.3077	1.196	.2509	1.074	.3558	0.850	.2460	1.401	.3145	0.905	.1821	0.530	.2943	1.141	.3632	0.850
.3084	0.826	.2516	0.702	.3572	1.279	.2467	0.988	.3152	1.334	.1828	0.865	.2950	0.784	.3646	1.236
.3091	1.214	.2523	1.054	.3586	0.860	.2474	1.407	.3159	0.924	.1835	0.570	.2957	1.194	.3660	0.823
.3098	0.828	.2530	0.689	.3599	1.284	.2480	0.988	.3166	1.360	.1842	0.903	.2964	0.795	.3674	1.211
.3105	1.221	.2536	1.029	.3613	0.867	.2487	1.401	.3173	0.947	.1849	0.606	.2971	1.217	.3688	0.822
.3112	0.841	.2543	0.657	.3627	1.285	.2494	0.986	.3180	1.360	.1856	0.946	.2978	0.808	.3702	1.196
.3309	0.933	.2550	1.012	.3641	0.858	.2501	1.393	.3187	0.942	.1863	0.622	.2985	1.214	.3716	0.815
.3323	1.341	.2557	0.647	.3655	1.271	.2508	0.975	.3194	1.369	.1870	0.972	.2992	0.836	.3826	1.255
.3337	0.942	.2564	0.987	.3669	0.868	.2515	1.379	.3201	0.944	.1877	0.636	.2999	1.245	.3840	0.853
.3351	1.348	.2571	0.637	.3683	1.273	.2522	0.970	.3208	1.374	.1884	1.030	.3006	0.856	.3854	1.253
.3365	0.944	.2578	0.974	.3696	0.859	.2529	1.376	.3215	0.959	.2140	0.909	.3013	1.266	.3868	0.831
.3378	1.375	.2585	0.615	.3710	1.271	.2536	0.964	.3222	1.391	.2147	1.351	.3020	0.869	.3882	1.263
.3392	0.971	.2592	0.966	.3724	0.859	.2543	1.364	.3228	0.971	.2154	0.931	.3026	1.285	.3896	0.869
.3406	1.394	.2599	0.624	.3738	1.262	.2550	0.933	.3235	1.394	.2164	1.387	.3033	0.861	.3909	1.283
.3423	1.002	.2606	0.970	.3752	0.849	.2557	1.340	.3242	0.960	.2175	0.937	.3040	1.286	.3923	0.880

TABLE 10 (*continued*)

J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m
3766.3937	1.311	3767.2673	0.960	3767.3642	1.421	3768.2423	1.352	3768.3102	0.792	3769.2125	0.748	3769.2907	0.477	3770.2457	0.883
.3951	0.878	.2680	1.389	.3653	0.981	.2430	0.925	.3109	1.192	.2132	1.152	.2914	0.813	.2464	1.315
.3965	1.294	.2687	0.933	.3777	1.205	.2437	1.352	.3129	0.781	.2138	0.772	.2921	0.505	.2471	0.885
.3979	0.882	.2694	1.378	.3791	0.768	.2444	0.900	.3136	1.202	.2145	1.188	.2928	0.825	.2477	1.338
.3993	1.297	.2701	0.935	.3805	1.115	.2451	1.335	.3147	0.791	.2152	0.793	.2935	0.513	.2484	0.903
.4006	0.886	.2707	1.342	.3819	0.700	.2458	0.898	.3157	1.207	.2159	1.206	.2942	0.835	.2491	1.339
.4020	1.281	.2714	0.916	.3833	1.024	.2465	1.316	.3164	0.801	.2166	0.794	.2949	0.529	.2498	0.912
.4034	0.866	.2721	1.324	.3847	0.627	.2472	0.891	.3171	1.233	.2173	1.208	.2956	0.861	.2505	1.346
.4048	1.260	.2728	0.882	.3861	0.925	.2478	1.309	.3178	0.810	.2180	0.812	.2963	0.533	.2512	0.909
.4062	0.853	.2735	1.285	.3874	0.585	.2489	0.863	.3185	1.243	.2187	1.233	.2969	0.874	.2519	1.357
.4076	1.243	.2742	0.865	.3888	0.889	.2499	1.304	.3192	0.811	.2194	0.831	.2976	0.558	.2526	0.931
.4090	0.849	.2749	1.267	.3902	0.548	.2506	0.872	.3199	1.231	.2201	1.257	.2983	0.899	.2533	1.357
.4103	1.243	.2756	0.823	.3916	0.848	.2513	1.287	.3206	0.839	.2208	0.825	.3108	0.737	.2540	0.934
.4117	0.838	.2763	1.224	.3930	0.548	.2520	0.880	.3213	1.227	.2215	1.279	.3115	1.129	.2547	1.379
.4131	1.208	.2770	0.803	.3944	0.869	.2527	1.291	.3220	0.806	.2222	0.858	.3122	0.758	.2554	0.943
.4145	0.779	.2777	1.194	.3958	0.564	.2534	0.889	.3226	1.237	.2228	1.291	.3129	1.176	.2561	1.375
.4159	1.219	.2784	0.767	.3971	0.909	.2541	1.308	.3233	0.834	.2235	0.867	.3136	0.768	.2568	0.952
.4173	0.802	.2791	1.132	.3985	0.592	.2548	0.883	.3240	1.249	.2242	1.291	.3143	1.197	.2574	1.390
.4187	1.225	.2797	0.750	.4000	0.974	.2555	1.297	.3247	0.828	.2249	0.867	ψ : .9652 − .5351		.2581	0.936
.4200	0.832	.2804	1.108	.4013	0.638	.2562	0.882	.3254	1.241	.2256	1.323			.2588	1.396
.4214	1.321	.2811	0.700	ψ : .6609 − .1841		.2569	1.304	.3261	0.847	.2263	0.872	3770.1934	1.201	.2595	0.955
.4228	0.842	.2818	1.055	3768.1821	0.595	.2575	0.878	.3268	1.242	.2270	1.332	.1944	0.775	.2602	1.412
		.2825	0.693	.1827	0.975	.2582	1.297	.3275	0.831	.2277	0.889	.1951	1.205	.2609	0.959
ψ : .0848 − .6017		.2981	0.526	.1834	0.640	.2589	0.881	.3282	1.260	.2284	1.334	.1958	0.791	.2616	1.419
3767.2053	0.798	.3009	0.570	.1841	1.001	.2596	1.299	.3289	0.823	.2291	0.904	.1965	1.194	.2623	0.964
.2063	1.202	.3023	0.932	.1848	0.663	.2603	0.889	.3296	1.249	.2298	1.350	.1972	0.795	.2630	1.419
.2070	0.794	.3033	0.595	.1855	1.037	.2610	1.290	.3313	0.815	.2305	0.918	.1979	1.211	.2637	0.955
.2077	1.211	.3040	0.951	.1862	0.695	.2617	0.883	.3334	1.243	.2312	1.368	.1986	0.784	.2644	1.408
.2088	0.789	.3047	0.626	.1869	1.053	.2627	1.291	.3348	0.823	.2318	0.915	.1993	1.207	.2651	0.968
.2098	1.207	.3054	0.981	.1876	0.706	.2638	0.885	.3361	1.225	.2325	1.379	.2000	0.783	.2658	1.424
.2105	0.792	.3061	0.634	.1883	1.080	.2645	1.297	.3375	0.812	.2332	0.944	.2007	1.197	.2664	0.986
.2112	1.202	.3068	1.010	.1890	0.722	.2652	0.883	.3389	1.243	.2339	1.391	.2013	0.782	.2671	1.425
.2122	0.790	.3075	0.663	.1897	1.085	.2659	1.297	.3403	0.805	.2346	0.957	.2020	1.190	.2678	0.982
.2133	1.201	.3081	1.044	.1904	0.727	.2665	0.870	.3417	1.231	.2353	1.413	.2027	0.779	.2685	1.431
.2140	0.794	.3088	0.685	.1914	0.727	.2672	1.285	.3431	0.817	.2360	0.966	.2034	1.190	.2692	0.979
.2146	1.212	.3095	1.055	.2005	1.231	.2679	0.881	.3445	1.255	.2367	1.425	.2041	0.781	.2699	1.431
.2153	0.803	.3102	0.702	.2014	0.828	.2686	1.287	.3458	0.849	.2374	0.966	.2048	1.182	.2706	0.971
.2160	1.219	.3109	1.085	.2021	1.253	.2693	0.867	.3472	1.280	.2381	1.432	.2055	0.762	.2713	1.439
.2167	0.801	.3116	0.713	.2028	0.832	.2700	1.291	.3486	0.880	.2388	0.966	.2062	1.160	.2720	0.988
.2174	1.213	.3123	1.098	.2035	1.278	.2707	0.880	.3500	1.231	.2395	1.431	.2069	0.771	.2727	1.443
.2181	0.814	.3130	0.723	.2042	0.836	.2714	1.286	.3514	0.869	.2402	0.988	.2076	1.176	.2734	0.988
.2188	1.215	.3137	1.112	.2049	1.275	.2721	0.867	.3528	1.317	.2409	1.449	.2083	0.771	.2741	1.443
.2195	0.810	.3144	0.751	.2056	0.872	.2728	1.285	.3542	0.908	.2415	1.003	.2090	1.168	.2748	0.988
.2202	1.218	.3151	1.150	.2063	1.298	.2735	0.852	.3555	1.316	.2422	1.473	.2097	0.768	.2755	1.437
.2212	0.812	.3158	0.775	.2070	0.878	.2742	1.274	.3569	0.882	.2429	1.000	.2104	1.152	.2761	0.977
.2223	1.219	.3165	1.156	.2077	1.299	.2749	0.849	.3583	1.401	.2436	1.474	.2110	0.773	.2768	1.431
.2230	0.824	.3171	0.773	.2084	0.882	.2756	1.261	.3597	0.896	.2443	1.006	.2117	1.160	.2775	0.971
.2237	1.231	.3178	1.188	.2091	1.314	.2762	0.847	.3611	1.395	.2450	1.486	.2124	0.770	.2782	1.424
.2243	0.817	.3185	0.790	.2098	0.885	.2769	1.250	.3763	1.408	.2457	1.011	.2131	1.168	.2789	0.975
.2292	1.255	.3192	1.200	.2105	1.320	.2776	0.838	.3777	0.966	.2474	1.041	.2138	0.773	.2796	1.420
.2299	0.847	.3199	0.812	.2111	0.901	.2783	1.248	.3791	1.399	.2492	1.048	.2145	1.176	.2803	0.966
.2306	1.269	.3206	1.221	.2118	1.339	.2790	0.849	.3805	0.980	.2512	1.054	.2152	0.781	.2810	1.411
.2313	0.877	.3213	0.828	.2125	0.910	.2797	1.207	ψ : .3005 − .6468		.2533	1.066	.2159	1.176	.2817	0.945
.2320	1.297	.3220	1.244	.2132	1.340	.2804	0.819			.2554	1.072	.2166	0.787	.2824	1.380
.2327	0.878	.3227	0.825	.2139	0.921	.2811	1.207	3769.1830	0.722	.2575	1.070	.2173	1.206	.2831	0.955
.2333	1.306	.3234	1.272	.2146	1.358	.2818	0.787	.1841	0.409	.2596	1.058	.2180	0.790	.2838	1.376
.2340	0.878	.3241	0.855	.2153	0.912	.2825	1.211	.1848	0.687	.2616	1.043	.2187	1.200	.2845	0.931
.2347	1.304	.3248	1.269	.2160	1.360	.2832	0.797	.1854	0.389	.2637	1.011	.2194	0.812	.2855	1.336
.2354	0.880	.3255	0.849	.2167	0.933	.2839	1.212	.1861	0.683	.2647	1.469	.2200	1.211	.2865	0.898
.2361	1.326	.3261	1.285	.2174	1.369	.2846	0.801	.1868	0.368	.2658	0.984	.2207	0.801	.2872	1.297
.2368	0.889	.3268	0.867	.2181	0.931	.2852	1.193	.1875	0.684	.2665	1.443	.2214	1.219	.2879	0.881
.2375	1.309	.3275	1.291	.2188	1.371	.2859	0.790	.1882	0.411	.2672	0.971	.2221	0.800	.2886	1.253
.2382	0.907	.3282	0.870	.2195	0.934	.2866	1.187	.1889	0.709	.2679	1.382	.2228	1.229	.2893	0.841
.2389	1.323	.3289	1.316	.2201	1.376	.2873	0.799	.1896	0.415	.2686	0.935	.2235	0.806	.2900	1.220
.2396	0.905	.3296	0.882	.2208	0.951	.2880	1.182	.1903	0.728	.2692	1.341	.2242	1.235	.2907	0.795
.2403	1.346	.3303	1.310	.2215	1.400	.2887	0.791	.1910	0.431	.2699	0.880	.2249	0.813	.2914	1.163
.2410	0.897	.3310	0.898	.2222	0.969	.2894	1.205	.1917	0.741	.2706	1.306	.2256	1.227	.2921	0.764
.2417	1.341	.3317	1.334	.2229	1.394	.2901	0.793	.1924	0.457	.2713	0.828	.2263	0.823	.2928	1.098
.2434	0.931	.3324	0.911	.2236	0.966	.2908	1.194	.1931	0.771	.2720	1.243	.2270	1.227	.2935	0.723
.2451	1.370	.3331	1.354	.2243	1.412	.2915	0.780	.1938	0.481	.2727	0.812	.2277	0.822	.2941	1.081
.2458	0.927	.3338	0.924	.2250	0.978	.2922	1.201	.1945	0.804	.2734	1.207	.2284	1.224	.2948	0.667
.2465	1.382	.3345	1.340	.2257	1.420	.2929	0.794	.1951	0.513	.2741	0.775	.2290	0.825	.2955	1.017
.2472	0.945	.3352	0.927	.2264	0.976	.2936	1.202	.1958	0.832	.2748	1.169	.2297	1.237	.2962	0.640
.2479	1.403	.3358	1.364	.2271	1.413	.2942	0.795	.1965	0.529	.2755	0.738	.2304	0.831	.2969	0.957
.2486	0.960	.3369	0.923	.2278	0.979	.2949	1.201	.1972	0.878	.2762	1.115	.2311	1.243	.2976	0.572
.2493	1.401	.3383	1.375	.2285	1.419	.2956	0.793	.1979	0.559	.2769	0.694	.2318	0.841	.2983	0.892
.2500	0.976	.3397	0.951	.2291	0.977	.2963	1.203	.1986	0.901	.2776	1.043	.2325	1.248	.2990	0.542
.2507	1.421	.3410	1.389	.2298	1.431	.2970	0.811	.1993	0.580	.2783	0.638	.2332	0.843	.2997	0.828
.2514	0.969	.3424	0.952	.2305	0.988	.2977	1.209	.2000	0.932	.2789	0.983	.2339	1.251	.3004	0.511
.2520	1.421	.3438	1.412	.2312	1.425	.2984	0.813	.2007	0.599	.2796	0.601	.2346	0.834	.3011	0.789
.2527	0.982	.3452	0.969	.2319	0.984	.2991	1.207	.2014	0.959	.2803	0.931	.2353	1.269	.3032	0.479
.2534	1.431	.3466	1.442	.2326	1.423	.2998	0.812	.2021	0.625	.2810	0.560	.2360	0.849	.3038	0.767
.2541	0.977	.3480	0.977	.2333	0.979	.3005	1.211	.2028	0.981	.2817	0.861	.2367	1.269	.3045	0.475
.2548	1.432	.3493	1.447	.2340	1.429	.3012	0.803	.2035	0.634	.2824	0.514	.2374	0.854	.3052	0.782
.2555	0.990	.3514	0.988	.2347	0.977	.3019	1.214	.2041	1.012	.2831	0.806	.2381	1.280	.3059	0.481
.2562	1.438	.3535	1.464	.2354	1.419	.3026	0.794	.2048	0.652	.2838	0.484	.2387	0.857	.3066	0.800
.2569	0.991	.3549	0.992	.2361	0.971	.3033	1.212	.2055	1.031	.2845	0.788	.2394	1.285	.3073	0.490
.2576	1.443	.3559	1.449	.2368	1.394	.3039	0.816	.2062	0.647	.2852	0.463	.2401	0.872	.3080	0.807
.2583	0.988	.3570	0.993	.2375	0.968	.3046	1.215	.2069	1.066	.2859	0.787	.2408	1.296	.3087	0.495
.2590	1.455	.3580	1.449	.2382	1.389	.3053	0.793	.2080	0.704	.2866	0.458	.2415	0.875	.3094	0.824
.2597	0.988	.3590	0.993	.2388	0.958	.3060	1.208	.2090	1.093	.2873	0.793	.2422	1.297	.3101	0.530
.2628	0.982	.3601	1.449	.2395	1.376	.3067	0.790	.2097	0.705	.2879	0.470	.2429	0.878	.3108	0.847
.2652	1.419	.3611	0.988	.2402	0.951	.3074	1.221	.2104	1.120	.2886	0.788	.2436	1.312	.3115	0.532
.2659	0.975	.3622	1.443	.2409	1.375	.3084	0.792	.2111	0.735	.2893	0.459	.2443	0.872	.3122	0.871
.2666	1.399	.3632	0.981	.2416	0.933	.3095	1.206	.2118	1.151	.2900	0.794	.2450	1.316	.3128	0.560

TABLE 10 (*continued*)

J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m
3770.3135	0.893	3775.2073	1.118	3775.3233	0.812	3784.2843	0.776	3785.2130	1.417	3785.3006	1.335	3786.2009	0.905	3786.2674	0.853
.3142	0.570	.2079	0.704	.3243	0.514	.2860	1.140	.2144	0.970	.3013	0.933	.2016	1.304	.2681	0.553
.3149	0.914	.2086	1.073	.3250	0.838	.2878	0.773	.2155	1.383	.3020	1.323	.2023	0.911	.2688	0.869
.3156	0.595	.2093	0.674	.3257	0.522	.2892	1.150	.2161	0.948	.3027	0.942	.2030	1.315	.2695	0.571
.3163	0.942	.2100	1.023	.3309	0.597	.2905	0.804	.2168	1.341	.3034	1.330	.2037	0.922	.2705	0.903
.3170	0.603	.2107	0.634	.3319	0.980	.2923	1.176	.2175	0.927	.3041	0.925	.2044	1.322	.2716	0.597
.3270	1.098	.2114	0.988	.3326	0.659	.2940	1.197	.2182	1.328	.3048	1.334	.2051	0.927	.2723	0.933
.3281	0.715	.2121	0.615	.3333	1.026	.2954	0.852	.2193	0.900	.3055	0.922	.2058	1.339	.2730	0.610
.3288	1.130	.2128	0.938	.3343	0.674	.2968	1.217	.2203	1.294	.3065	1.320	.2065	0.940	.2736	0.962
.3295	0.748	.2135	0.591	.3357	1.087	.2982	0.867	.2210	0.909	.3079	0.925	.2072	1.369	.2743	0.652
.3302	1.165	.2142	0.919	.3371	0.705	.3085	1.322	.2217	1.284	.3093	1.322	.2079	0.936	.2750	1.002
.3309	0.760	.2149	0.551	.3385	1.133	.3099	0.922	.2224	0.867	.3107	0.915	.2085	1.351	.2757	0.647
.3315	1.176	.2156	0.903	.3399	0.750	.3124	1.334	.2231	1.254	.3121	1.315	.2092	0.955	.2764	1.011
.3322	0.768	.2163	0.551	.3413	1.182	.3141	1.328	.2238	0.861	.3134	0.940	.2099	1.356	.2771	0.688
.3329	1.209	.2169	0.875	.3426	0.781	.3155	1.330	.2245	1.225	.3148	1.324	.2106	0.955	.2778	1.045
.3336	0.795	.2176	0.578	.3437	1.231	.3169	0.918	.2251	0.839	.3166	0.923	.2113	1.360	.2785	0.706
.3343	1.213	.2183	0.867	.3447	0.781	.3183	1.312	.2258	1.203	.3186	1.328	.2120	0.957	.2792	1.062
.3350	0.808	.2190	0.545	.3461	1.244	.3200	0.918	.2265	0.827	.3200	0.927	.2127	1.383	.2799	0.703
.3357	1.232	.2197	0.865	.3478	0.843	.3214	1.315	.2272	1.188	.3214	1.317	.2134	0.959	.2806	1.062
.3364	0.817	.2204	0.526	.3499	0.843	.3231	0.938	.2279	0.791	.3231	0.911	.2141	1.388	.2813	0.728
.3371	1.256	.2211	0.871	.3516	1.302	.3245	1.330	.2286	1.136	.3245	1.300	.2148	0.966	.2820	1.103
.3378	0.853	.2218	0.559	.3530	1.321	.3259	0.934	.2293	0.764	.3259	0.911	.2155	1.431	.2827	0.737
.3385	1.262	.2225	0.884	.3548	1.340	.3272	1.362	.2300	1.112	.3273	1.298	.2162	0.973	.2833	1.116
.3395	0.861	.2232	0.550	.3568	0.914	.3286	0.968	.2307	0.728	.3287	0.905	.2169	1.408	.2840	0.766
.3405	1.309	.2239	0.905	.3589	0.896	.3300	1.423	.2314	1.072	.3301	1.275	.2176	0.974	.2851	1.148
.3412	0.861	.2246	0.548	.3610	0.911	.3317	0.989	.2321	0.691	.3315	0.878	.2182	1.406	.2861	0.790
.3419	1.311	.2253	0.932	.3631	0.948	.3338	0.991	.2328	1.049	.3328	1.267	.2189	0.979	.2868	1.187
.3426	0.885	.2450	0.773	ψ : .9229 − .3739		.3359	1.449	.2335	0.679	.3342	0.844	.2196	1.430	.2875	0.823
.3433	1.342	.2460	1.194			.3376	1.015	.2342	1.019	.3356	1.249	.2203	0.993	.2882	1.205
.3440	0.905	.2467	0.795	3784.2071	0.927	.3390	1.443	.2348	0.665	.3370	0.863	.2210	1.439	.2889	0.828
.3447	1.340	.2474	1.223	.2078	1.317	.3404	1.015	.2355	0.982	.3387	1.231	.2217	0.978	.2896	1.213
.3454	0.907	.2481	0.795	.2085	0.931	.3421	1.474	.2362	0.636	.3408	0.839	.2224	1.438	.2903	0.834
.3461	1.390	.2488	1.245	.2092	1.311	.3439	0.966	.2369	0.964	.3425	1.235	.2231	0.988	.2910	1.237
.3468	0.914	.2495	0.813	.2106	0.914	.3453	1.362	.2376	0.607	.3439	0.871	.2238	1.448	.2917	0.861
.3475	1.383	.2502	1.257	.2119	1.318	.3466	0.937	.2383	0.953	.3453	1.236	.2245	0.993	.2923	1.239
.3482	0.932	.2509	0.832	.2126	0.921	.3480	1.300	.2390	0.608	.3470	0.882	.2252	1.449	.2930	0.863
.3489	1.405	.2516	1.273	.2133	1.323	.3494	0.859	.2397	0.925	.3488	1.255	.2259	1.001	.2937	1.279
.3496	0.927	.2523	0.841	.2140	0.913	.3508	1.208	.2404	0.613	.3502	0.882	.2266	1.439	.2944	0.878
.3502	1.389	.2530	1.300	.2147	1.305	.3522	0.803	.2411	0.931	.3515	1.262	.2272	0.990	.2951	1.260
.3509	0.944	.2537	0.876	.2154	0.913	.3536	1.133	.2418	0.615	.3529	0.867	.2279	1.433	.2958	0.878
.3516	1.396	.2543	1.311	.2161	1.309	.3546	0.737	.2425	0.921	.3543	1.272	.2286	0.993	.2965	1.298
.3523	0.944	.2550	0.889	.2168	0.915	.3556	1.023	.2432	0.600	.3557	0.876	.2293	1.439	.2972	0.867
.3530	1.400	.2557	1.321	.2175	1.286	.3570	0.647	.2438	0.939	.3571	1.250	.2300	0.992	.2979	1.310
.3537	0.960	.2564	0.880	.2189	0.897	.3584	0.910	.2445	0.613	.3585	0.866	.2307	1.445	.2986	0.878
.3544	1.413	.2571	1.334	.2202	1.267	.3598	0.570	.2452	0.938	.3599	1.242	.2314	0.978	.2993	1.322
.3551	0.973	.2578	0.890	.2209	0.885	.3612	0.840	.2459	0.621	.3612	0.854	.2321	1.413	.3000	0.900
.3558	1.430	.2585	1.341	.2216	1.257	.3629	0.524	.2466	0.952	.3626	1.237	.2328	0.974	.3007	1.323
.3565	0.970	.2592	0.911	.2223	0.872	.3646	0.783	.2473	0.652	.3640	0.821	.2335	1.360	.3014	0.902
.3572	1.441	.2599	1.366	.2230	1.238	.3660	0.512	.2522	1.042	.3654	1.220	.2342	0.960	.3020	1.321
.3579	0.995	.2606	0.933	.2237	0.876	.3674	0.800	.2546	0.707	.3671	0.823	.2349	1.363	.3027	0.905
.3586	1.454	.2613	1.370	.2244	1.237	.3688	0.508	.2560	1.091			.2356	0.946		
.3606	1.004	.2620	0.933	.2258	0.866	.3702	0.818	.2570	0.740	ψ : .1027 − .4495		.2363	1.342	ψ : .7764 − .1901	
.3627	1.008	.2627	1.369	.2272	1.236	.3719	0.548	.2577	1.102			.2369	0.931		
.3648	1.015	.2633	0.933	.2279	0.864	.3750	0.599	.2584	0.749	3786.1712	0.701	.2376	1.317	3787.1850	1.359
.3669	1.018	.2640	1.408	.2286	1.233	.3764	0.927	.2591	1.126	.1722	1.061	.2383	0.916	.1857	0.929
.3689	1.032	.2651	0.967	.2293	0.867	.3781	0.628	.2598	0.751	.1732	0.738	.2390	1.300	.1868	1.352
.3710	1.026	.2661	1.421	.2299	1.227	ψ : .4718 − .9821		.2605	1.141	.1739	1.102	.2397	0.889	.1878	0.956
.3731	1.023	.2675	0.966	.2306	0.865			.2612	0.786	.1746	0.746	.2404	1.243	.1885	1.351
.3752	1.019	.2692	1.443	.2313	1.231	3785.1736	0.809	.2619	1.152	.1753	1.116	.2411	0.856	.1892	0.957
.3773	1.014	.2706	0.979	.2320	0.861	.1746	1.231	.2625	0.801	.1760	0.757	.2418	1.231	.1899	1.368
.3793	1.009	.2717	1.450	.2327	1.239	.1753	0.854	.2632	1.163	.1767	1.127	.2425	0.831	.1906	0.960
.3818	0.973	.2724	1.003	.2334	0.877	.1760	1.249	.2639	0.794	.1774	0.757	.2432	1.203	.1913	1.379
.3831	1.407	.2730	1.459	.2341	1.231	.1767	0.879	.2646	1.188	.1781	1.142	.2439	0.797	.1919	0.956
.3845	0.947	.2737	0.992	.2348	0.880	.1774	1.296	.2653	0.808	.1788	0.768	.2446	1.175	.1926	1.388
.3859	1.333	.2744	1.468	.2355	1.237	.1787	0.883	.2660	1.192	.1795	1.134	.2456	0.768	.1933	0.966
.3873	0.872	.2751	1.008	.2362	0.876	.1794	1.314	.2667	0.827	.1802	0.773	.2466	1.108	.1940	1.388
.3887	1.302	.2942	0.999	.2369	1.253	.1801	0.912	.2674	1.207	.1808	1.145	.2473	0.727	.1947	0.959
.3901	0.828	.2959	1.429	.2376	0.894	.1808	1.323	.2681	0.838	.1815	0.771	.2480	1.041	.1954	1.387
.3915	1.207	.2966	0.951	.2383	1.244	.1815	0.933	.2688	1.226	.1822	1.146	.2487	0.680	.1961	0.955
.3928	0.793	.2973	1.365	.2455	1.261	.1822	1.332	.2695	0.849	.1829	0.770	.2494	0.969	.1968	1.384
.3942	1.101	.2980	0.905	.2469	0.882	.1829	0.931	.2702	1.226	.1836	1.154	.2501	0.614	.1975	0.962
.3956	0.608	.2987	1.316	.2483	1.253	.1836	1.348	.2709	0.849	.1843	0.773	.2508	0.915	.1982	1.362
.3970	0.910	.2994	0.854	.2497	0.881	.1843	0.930	.2716	1.235	.1850	1.158	.2515	0.560	.1989	0.960
.3984	0.548	.3001	1.263	.2511	1.243	.1850	1.365	.2722	0.871	.1857	0.776	.2522	0.861	.1996	1.391
.3998	0.808	.3007	0.802	.2528	1.225	.1857	0.949	.2729	1.266	.1864	1.151	.2529	0.530	.2003	0.966
.4011	0.475	.3014	1.170	.2545	0.850	.1864	1.382	.2736	0.870	.1871	0.779	.2536	0.812	.2009	1.383
.4025	0.737	.3021	0.740	.2559	1.199	.1871	0.966	.2743	1.254	.1878	1.164	.2543	0.491	.2023	1.389
.4039	0.437	.3028	1.132	.2573	0.820	.1878	1.401	.2750	0.883	.1885	0.788	.2549	0.771	.2030	0.953
.4053	0.735	.3035	0.702	.2583	1.183	.1884	0.971	.2757	1.273	.1892	1.192	.2556	0.481	.2037	1.358
.4067	0.438	.3046	1.024	.2601	0.795	.1891	1.411	.2764	0.878	.1898	0.801	.2563	0.768	.2044	0.946
.4081	0.762	.3056	0.625	.2621	1.152	.1898	0.971	.2771	1.279	.1905	1.188	.2570	0.467	.2051	1.354
.4095	0.514	.3063	0.933	.2635	0.770	.1905	1.425	.2778	0.889	.1912	0.801	.2577	0.753	.2058	0.937
ψ : .1541 − .5990		.3070	0.553	.2649	1.127	.1912	0.985	.2785	1.299	.1919	1.188	.2584	0.464	.2065	1.351
		.3077	0.842	.2663	0.766	.1919	1.444	.2792	0.904	.1926	0.813	.2591	0.757	.2072	0.930
3775.1944	0.968	.3084	0.484	.2677	1.128	.1926	0.987	.2799	1.316	.1933	1.218	.2598	0.464	.2079	1.342
.1955	1.401	.3091	0.788	.2691	0.765	.1933	1.443	.2806	0.912	.1940	0.820	.2605	0.765	.2086	0.929
.1969	0.927	.3097	0.437	.2705	1.138	.1940	0.998	.2899	1.341	.1947	1.226	.2612	0.489	.2093	1.332
.1986	1.328	.3108	0.686	.2725	0.770	.1947	1.474	.2913	0.940	.1954	0.845	.2619	0.782	.2100	0.931
.2007	0.849	.3118	0.392	.2746	1.134	.1961	1.013	.2923	1.356	.1961	1.249	.2626	0.494	.2106	1.330
.2027	1.175	.3136	0.664	.2760	0.768	.1981	1.013	.2934	0.947	.1968	0.858	.2633	0.788	.2113	0.907
.2038	0.793	.3146	0.384	.2774	1.139	.2002	1.012	.2944	1.357	.1975	1.263	.2640	0.494	.2120	1.315
.2045	1.170	.3156	0.697	.2788	0.784	.2051	1.012	.2961	1.345	.1982	0.867	.2646	0.800	.2127	0.916
.2052	0.772	.3167	0.382	.2802	1.140	.2071	1.015	.2972	0.940	.1989	1.273	.2653	0.516	.2134	1.322
.2059	1.157	.3177	0.692	.2815	0.762	.2092	1.010	.2982	1.358	.1995	0.883	.2660	0.825	.2141	0.905
.2066	0.735	.3194	0.415	.2829	1.122	.2113	0.995	.2996	0.940	.2002	1.280	.2667	0.530	.2148	1.314

TABLE 10 (*continued*)

J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m	J.D. hel. − 2430000	m
3787.2155	0.905	3787.2861	1.194	3789.2488	1.371	3789.3308	0.985	3790.2488	1.201	3790.3184	0.839	3791.2528	0.883	3792.2078	1.262
.2162	1.304	.2872	0.790	.2495	0.947	.3322	1.437	.2495	0.838	.3198	1.247	.2535	1.248	.2088	0.834
.2169	0.908	.2882	1.194	.2501	1.345	.3339	1.025	.2501	1.219	.3211	0.867	.2542	0.823	.2098	1.239
.2176	1.320	.2889	0.810	.2508	0.931	.3353	1.031	.2508	0.828	.3225	1.267	.2549	1.200	.2105	0.837
.2183	0.914	.2896	1.201	.2515	1.334			.2515	1.208	.3239	0.845	.2556	0.790	.2112	1.231
.2190	1.328	.2903	0.801	.2522	0.920	ψ : .6691 − .0964		.2522	0.808	.3253	1.285	.2563	1.140	.2119	0.842
.2196	0.913	.2989	1.188	.2529	1.291			.2529	1.203	.3267	0.878	.2570	0.751	.2126	1.223
.2203	1.317	.3003	0.786	.2536	0.879	3790.1778	1.221	.2536	0.806	.3281	1.294	.2577	1.101	.2133	0.837
.2210	0.929	.3021	1.181	.2543	1.286	.1788	0.850	.2543	1.194	.3294	0.921	.2584	0.703	.2140	1.223
.2217	1.327	.3034	0.801	.2550	0.877	.1795	1.229	.2550	0.814	.3308	1.290	.2591	1.037	.2147	0.831
.2224	0.912	.3041	1.176	.2557	1.231	.1802	0.863	.2557	1.181	.3322	0.933	.2598	0.663	.2154	1.237
.2231	1.330	.3048	0.801	.2564	0.835	.1809	1.249	.2564	0.814	.3336	1.311	.2605	0.960	.2161	0.828
.2245	0.915	.3055	1.189	.2571	1.214	.1816	0.861	.2571	1.178	.3353	0.900	.2612	0.603	.2168	1.213
.2259	1.323	.3066	0.808	.2578	0.806	.1823	1.267	.2578	0.812	.3374	0.915	.2619	0.896	.2175	0.828
.2266	0.914	.3076	1.200	.2585	1.164	.1830	0.875	.2585	1.172	.3398	0.922	.2625	0.559	.2181	1.224
.2273	1.312	.3083	0.828	.2592	0.793	.1837	1.298	.2592	0.810			.2632	0.824	.2188	0.834
.2280	0.911	.3090	1.209	.2598	1.132	.1844	0.893	.2598	1.186	ψ : .2916 − .6495		.2639	0.524	.2195	1.241
.2286	1.298	.3097	0.825	.2605	0.759	.1850	1.298	.2605	0.817			.2646	0.789	.2202	0.819
.2293	0.901	.3104	1.241	.2612	1.103	.1857	0.878	.2612	1.182	3791.1722	0.521	.2653	0.491	.2209	1.267
.2300	1.310	.3111	0.849	.2619	0.728	.1864	1.300	.2619	0.816	.1736	0.840	.2660	0.777	.2220	0.844
.2307	0.893	.3118	1.255	.2626	1.073	.1871	0.916	.2626	1.196	.1746	0.534	.2667	0.463	.2230	1.272
.2314	1.286	.3124	0.844	.2633	0.696	.1878	1.301	.2633	0.826	.1753	0.861	.2674	0.757	.2237	0.832
.2321	0.882	.3131	1.260	.2640	1.024	.1885	0.916	.2640	1.207	.1760	0.558	.2681	0.470	.2244	1.262
.2328	1.269	.3138	0.854	.2647	0.669	.1892	1.316	.2647	0.822	.1770	0.898	.2688	0.763	.2251	0.861
.2335	0.864	.3145	1.272	.2654	0.970	.1899	0.914	.2654	1.225	.1781	0.581	.2695	0.494	.2258	1.284
.2342	1.281	.3152	0.892	.2661	0.629	.1906	1.326	.2661	0.802	.1787	0.921	.2702	0.782	.2265	0.863
.2349	0.854	.3159	1.298	.2668	0.928	.1913	0.922	.2668	1.201	.1794	0.619	.2709	0.495	.2275	1.323
.2359	1.267	.3169	0.892	.2675	0.614	.1920	1.334	.2675	0.817	.1801	0.944	.2715	0.799	.2285	0.896
.2370	0.865	.3180	1.315	.2682	0.903	.1927	0.932	.2682	1.215	.1808	0.622	.2722	0.514	.2292	1.300
.2377	1.239	.3187	0.905	.2688	0.581	.1934	1.352	.2688	0.812	.1815	0.960	.2729	0.813	.2299	0.905
.2383	0.845	.3194	1.310	.2695	0.891	.1941	0.932	.2695	1.213	.1822	0.641	.2736	0.530	.2306	1.328
.2390	1.236	.3201	0.889	.2702	0.575	.1947	1.352	.2702	0.822	.1829	0.992	.2743	0.843	.2313	0.913
.2397	0.834	.3218	1.321	.2709	0.868	.1954	0.938	.2709	1.224	.1836	0.654	.2750	0.562	.2320	1.352
.2404	1.224	.3228	0.933	.2716	0.563	.1961	1.370	.2720	0.844	.1843	1.011	.2757	0.879	.2327	0.927
.2411	0.826	.3235	1.333	.2730	0.866	.1968	0.935	.2730	1.237	.1850	0.671	.2764	0.575	.2334	1.328
.2418	1.212	.3242	0.905	.2744	0.555	.1975	1.383	.2737	0.848	.1857	1.024	.2771	0.899	.2341	0.938
.2425	0.828	.3249	1.323	.2751	0.875	.1982	0.960	.2744	1.250	.1864	0.693	.2778	0.586	.2348	1.364
.2432	1.214	.3256	0.920	.2758	0.556	.1989	1.393	.2751	0.843	.1871	1.056	.2785	0.931	.2355	0.927
.2439	0.823	.3263	1.346	.2765	0.875	.1996	0.957	.2758	1.237	.1878	0.700	.2792	0.614	.2361	1.370
.2446	1.202	.3270	0.938	.2772	0.575	.2003	1.425	.2765	0.845	.1971	1.176	.2799	0.952	.2368	0.959
.2453	0.801	.3277	1.334	.2779	0.891	.2010	0.973	.2772	1.247	.1981	0.793	.2806	0.641	.2375	1.370
.2460	1.205	.3284	0.933	.2785	0.586	.2017	1.425	.2779	0.834	.1988	1.200	.2899	1.122	.2382	0.949
.2467	0.805	.3291	1.340	.2792	0.921	.2024	0.988	.2785	1.267	.1995	0.821	.2909	0.779	.2389	1.425
.2473	1.194	.3298	0.938	.2799	0.585	.2031	1.441	.2792	0.848	.2002	1.207	.2920	1.146	.2396	0.980
.2480	0.787	.3305	1.368	.2806	0.921	.2037	0.986	.2799	1.249	.2009	0.844	.2934	0.790	.2403	1.409
.2487	1.182	.3311	0.925	.2813	0.607	.2044	1.442	.2806	0.850	.2016	1.245	.2947	1.188	.2410	0.966
.2494	0.799	.3318	1.340	.2820	0.950	.2051	0.985	.2813	1.249	.2023	0.852	.2961	0.819	.2417	1.411
.2501	1.169	.3325	0.911	.2827	0.596	.2058	1.443	.2820	0.837	.2030	1.255	.2975	1.226	.2424	0.956
.2508	0.803	.3332	1.356	.2834	0.952	.2065	0.998	.2827	1.249	.2037	0.867	.2989	0.845	.2431	1.455
.2515	1.175	.3339	0.921	.2841	0.636	.2072	1.455	.2834	0.856	.2044	1.267	.3003	1.257	.2438	0.966
.2522	0.788	.3346	1.352	.2848	0.970	.2079	0.996	.2841	1.247	.2051	0.885	.3020	0.868	.2445	1.399
.2529	1.175	.3353	0.944	.2855	0.647	.2086	1.467	.2848	0.836	.2058	1.280	.3041	0.882	.2455	0.978
.2536	0.784	.3360	1.346	.2862	0.998	.2093	1.006	.2855	1.251	.2071	0.896	.3062	0.891	.2465	1.424
.2543	1.194	.3367	0.933	.2869	0.673	.2100	1.447	.2862	0.836	.2085	0.913	.3079	1.328	.2472	0.988
.2560	0.801	.3374	1.364	.2875	1.024	.2107	0.993	.2869	1.247	.2099	1.315			.2479	1.441
.2577	1.186	.3381	0.911	.2882	0.689	.2114	1.457	.2875	0.850	.2106	0.920			.2490	0.980
.2584	0.813	.3388	1.347	.2889	1.041	.2121	0.999	.2882	1.236	.2113	1.328	ψ : .9394 − .3332		.2500	1.424
.2591	1.202	.3395	0.933	.2896	0.687	.2128	1.449	.2889	0.852	.2120	0.932	3792.1762	1.189	.2510	0.973
.2598	0.828	.3402	1.346	.2903	1.051	.2134	1.000	.2896	1.241	.2127	1.340	.1780	0.817	.2521	1.449
.2605	1.202	.3408	0.945	.2910	0.716	.2141	1.460	.2903	0.854	.2134	0.937	.1804	1.219	.2528	0.958
.2612	0.800	.3419	1.370	.2917	1.079	.2148	0.999	.2910	1.256	.2141	1.346	.1821	0.812	.2538	1.412
.2619	1.200			.2924	0.735	.2155	1.455	.2917	0.841	.2148	0.936	.1828	1.225	.2548	0.955
.2626	0.806	ψ : .0200 − .4473		.2931	1.103	.2162	0.997	.2924	1.249	.2155	1.370	.1835	0.801	.2555	1.407
.2633	1.201			.2938	0.745	.2169	1.437	.2931	0.839	.2161	0.951	.1849	1.219	.2562	0.959
.2640	0.805	3789.1733	1.146	.2945	1.123	.2176	0.978	.2938	1.255	.2168	1.376	.1863	0.824	.2580	1.401
.2647	1.201	.1740	0.773	.2952	0.768	.2183	1.442	.2945	0.853	.2175	0.963	.1870	1.219	.2600	0.971
.2654	0.812	.1747	1.141	.2959	1.139	.2190	0.976	.2952	1.249	.2182	1.403	.1877	0.815	.2614	1.371
.2660	1.201	.1754	0.794	.2966	0.801	.2197	1.425	.2959	0.853	.2189	0.965	.1884	1.201	.2628	0.930
.2667	0.817	.2263	0.968	.2972	1.144	.2204	0.974	.2966	1.242	.2196	1.420	.1891	0.817	.2639	1.328
.2674	1.203	.2276	0.959	.2979	0.805	.2211	1.413	.2972	0.835	.2203	1.001	.1897	1.200	.2652	0.927
.2681	0.834	.2290	0.958	.2986	1.164	.2218	0.951	.2979	1.241	.2210	1.443	.1904	0.812	.2666	1.315
.2688	1.201	.2304	0.958	.2993	0.790	.2224	1.383	.2986	0.867	.2217	0.999	.1911	1.211	.2673	0.888
.2695	0.813	.2318	0.954	.3000	1.207	.2231	0.969	.2993	1.261	.2224	1.451	.1918	0.803	.2680	1.304
.2705	1.194	.2332	1.369	.3007	0.804	.2238	1.389	.3000	0.850	.2234	0.993	.1925	1.187	.2687	0.878
.2716	0.812	.2342	0.968	.3014	1.239	.2245	0.949	.3007	1.251	.2251	1.008	.1932	0.811	.2697	1.262
.2723	1.175	.2349	1.374	.3021	0.845	.2252	1.370	.3014	0.850	.2272	1.013	.1939	1.203	.2715	0.850
.2730	0.806	.2356	0.981	.3031	1.232	.2259	0.955	.3021	1.265	.2293	1.029	.1946	0.804	.2729	1.207
.2737	1.184	.2363	1.381	.3045	0.856	.2266	1.352	.3028	0.863	.2314	1.037	.1953	1.218	.2735	0.805
.2744	0.794	.2370	0.977	.3059	1.249	.2273	0.934	.3035	1.277	.2335	1.037	.1960	0.800	.2742	1.158
.2751	1.168	.2377	1.379	.3076	0.880	.2280	1.346	.3042	0.849	.2355	0.931	.1967	1.200	.2749	0.758
.2757	0.790	.2384	0.977	.3094	0.886	.2287	0.942	.3049	1.239	.2376	1.042	.1974	0.806	.2756	1.140
.2764	1.170	.2391	1.417	.3107	0.900	.2294	1.334	.3056	0.863	.2397	1.033	.1981	1.213	.2763	0.736
.2771	0.784	.2398	0.982	.3125	1.322	.2301	0.931	.3062	1.248	.2418	1.030	.1988	0.836	.2770	1.112
.2778	1.170	.2405	1.415	.3142	0.926	.2308	1.323	.3069	0.850	.2435	1.023	.1994	1.233	.2777	0.713
.2785	0.802	.2411	0.992	.3156	1.333	.2315	0.922	.3076	1.257	.2445	1.475	.2001	0.826	.2787	1.073
.2792	1.175	.2418	1.403	.3170	0.922	.2321	1.328	.3083	0.869	.2456	1.004	.2008	1.229	.2801	1.039
.2799	0.790	.2425	0.977	.3184	1.350	.2328	0.912	.3090	1.253	.2466	1.437	.2015	0.824	.2815	0.993
.2806	1.168	.2432	1.411	.3198	0.949	.2411	1.284	.3097	0.834	.2473	0.985	.2022	1.238	.2832	0.616
.2813	0.786	.2439	0.993	.3211	1.357	.2422	0.891	.3104	1.273	.2480	1.407	.2029	0.808	.2846	0.926
.2820	1.170	.2446	1.418	.3225	0.971	.2432	1.263	.3111	0.852	.2487	0.970	.2036	1.237	.2857	0.603
.2827	0.793	.2453	0.971	.3239	1.371	.2446	0.872	.3118	1.243	.2494	1.357	.2043	0.828	.2867	0.909
.2834	1.176	.2460	1.425	.3253	0.960	.2460	1.243	.3128	0.857	.2501	0.948	.2050	1.253	.2874	0.592
.2841	0.806	.2467	0.975	.3267	1.419	.2467	0.849	.3142	1.242	.2508	1.316	.2057	0.843	.2881	0.901
.2847	1.188	.2474	1.388	.3281	1.000	.2474	1.243	.3156	0.864	.2515	0.896	.2064	1.260	.2888	0.572
.2854	0.808	.2481	0.971	.3294	1.431	.2481	0.853	.3170	1.248	.2522	1.285	.2071	0.839	.2895	0.899

TABLE 10 (*continued*)

J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m	J.D. hel. −2430000	m
3792.2902	0.608	3792.3096	0.729	ψ : .6068 − .9994		3793.2160	1.456	3793.2437	0.943	3793.2624	0.816	3793.2811	0.783	3793.2998	0.898
.2909	0.947	.3103	1.108			.2167	0.992	.2447	1.352	.2631	1.193	.2818	1.156	.3005	1.304
.2916	0.608	.3109	0.735	3793.1876	1.138	.2174	1.443	.2458	0.938	.2638	0.795	.2825	0.790	.3012	0.914
.2922	0.938	.3116	1.109	.1883	0.757	.2181	0.991	.2465	1.350	.2645	1.151	.2832	1.164	.3019	1.298
.2933	0.627	.3123	0.779	.1890	1.147	.2188	1.451	.2472	0.933	.2652	0.781	.2839	0.784	.3026	0.926
.2943	0.958	.3130	1.153	.1897	0.784	.2195	0.991	.2479	1.330	.2659	1.152	.2846	1.176	.3036	1.293
.2950	0.621	.3137	0.784	.1904	1.170	.2202	1.472	.2486	0.933	.2666	0.781	.2853	0.812	.3053	0.896
.2957	0.974	.3144	1.199	.1911	0.798	.2209	0.997	.2492	1.323	.2673	1.121	.2860	1.176	.3067	1.275
.2964	0.647	.3151	0.819	.1921	1.201	.2215	1.473	.2499	0.912	.2679	0.750	.2866	0.810	.3074	0.911
.2971	0.992	.3158	1.213	.1935	0.802	.2222	1.009	.2506	1.309	.2686	1.104	.2873	1.212	.3081	1.308
.2978	0.649	.3165	0.834	.2042	1.338	.2229	1.476	.2513	0.903	.2693	0.762	.2880	0.839	.3088	0.904
.2985	1.007	.3172	1.219	.2049	0.922	.2236	1.004	.2520	1.308	.2700	1.105	.2887	1.231	.3095	1.299
.2992	0.663	.3179	0.836	.2056	1.348	.2250	1.010	.2527	0.902	.2707	0.737	.2894	0.836	.3102	0.903
.2999	1.005	.3186	1.250	.2063	0.945	.2263	1.015	.2534	1.298	.2714	1.097	.2901	1.237	.3109	1.274
.3006	0.670	.3193	0.837	.2070	1.352	.2278	1.025	.2541	0.887	.2721	0.735	.2908	0.839	.3119	0.900
.3012	1.056	.3199	1.267	.2077	0.948	.2305	1.010	.2548	1.303	.2728	1.108	.2915	1.255	.3133	1.315
.3019	0.671	.3206	0.845	.2084	1.358	.2340	1.010	.2555	0.878	.2735	0.740	.2922	0.861	.3154	0.927
.3026	1.048	.3213	1.279	.2091	0.948	.2364	1.461	.2562	1.286	.2742	1.102	.2929	1.279	.3175	1.328
.3033	0.676	.3220	0.861	.2098	1.382	.2378	0.992	.2569	0.882	.2749	0.735	.2936	0.887	.3195	0.909
.3040	1.035	.3227	1.279	.2108	0.956	.2389	1.433	.2576	1.272	.2756	1.104	.2943	1.273	.3216	1.315
.3047	0.709	.3234	0.874	.2118	1.427	.2396	0.992	.2583	0.870	.2763	0.735	.2950	0.900	.3237	0.936
.3054	1.057	.3241	1.332	.2125	0.973	.2402	1.421	.2589	1.260	.2769	1.079	.2960	1.289	.3258	1.314
.3061	0.703	.3248	0.911	.2132	1.431	.2409	0.977	.2596	0.847	.2776	0.757	.2970	0.904	.3285	0.915
.3068	1.055	.3255	1.311	.2139	0.968	.2416	1.400	.2603	1.247	.2783	1.098	.2977	1.291	.3313	1.310
.3078	0.723			.2146	1.435	.2423	0.954	.2610	0.835	.2790	0.746	.2984	0.894	.3337	0.903
.3089	1.083			.2153	0.979	.2430	1.358	.2617	1.221	.2801	1.120	.2991	1.304	.3365	1.316

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