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COMMUNICATIONS FROM THE OBSERVATORY AT LEIDEN

PHOTOVISUAL LIGHT-CURVE OF THE MINIMA OF CASTOR C=YY GEMINORUM,

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Photovisual observations of the minima were made with the 33-cm Leiden refractor. The period derived by VAN GENT was confirmed, but has now a much greater accuracy. An indication of orbital eccentricity was found in both the photovisual and photographic material, amounting to $e \cos \omega = \cdot 0024 \pm \cdot 0010$ (m.e.). For the depths of the photovisual minima $^{m}\cdot 59$ and $^{m}\cdot 49$ were found, for those of the photographic minima $^{m}\cdot 56$ and $^{m}\cdot 52$ respectively.

The star Castor C = YY Geminorum was observed photovisually with the Leiden 33-cm refractor during the years 1929—1942 by Dr P. TH. OOSTERHOFF (plates 1649 and 1655), Dr A. J. WESSELINK (plates 2622 and 2627), Dr A. BLAAUW (plates 3882 to 4328 inclusive) and the author (plates 4328 to 6014 inclusive). In the middle of their series of exposures plates 2622 to 5490 inclusive were reversed 180° in their own plane to eliminate errors resulting from unequal sensitivity over the plate. However, this did not show any advantage in the reduction. Eastman Spectroscopic plates, 9 cm × 12 cm, were used with a yellow filter. The effective wavelength was $\mu \cdot 550$, the exposure times ranged from 5 to $2\frac{1}{2}$ minutes.

The plates were measured in the Schilt photometer by Mr C. J. KOOREMAN (plates 1649 and 1655), Dr A. BLAAUW (plates 3882 to 3919 inclusive) and the author (all others). In Table 1 data concerning the variable and the five comparison stars are given. The magnitude scale has been derived from plates with grating exposures. The grating constant was adopted as $^{m}\cdot 97$ in agreement with recent results for this grating.

TABLE 1

Star	BD		α (1855)	δ (1855)	m_{pg}
	°		h m s	° ′	
YY	+ 32	1582	7 25 22·1	+ 32 10·5	—
a	31	1624	26 41·4	31 46·5	$-^{m}\cdot 66$
b	31	1627	27 8·9	31 58·7	− ·43
c	31	1611	24 15·7	31 59·9	− ·08
d	32	1575	23 44·1	32 5·5	+ ·43
e	32	1580	25 8·6	32 9·5	+ ·74

All galvanometer readings have been converted into magnitudes with the aid of WESSELINK's table[1]). For each exposure the difference between the provisional magnitude of the variable and the mean provisional magnitude of the comparison stars was formed. These provisional magnitude differences were divided by the gradation to obtain magnitudes in the ordinary scale of magnitude. In this way the magnitude of the variable was found by least squares for every exposure in the scale and zeropoint system of the comparison stars.

On some nights the magnitudes of a minimum needed a systematic correction to make the maximum brightness agree with the average value, viz. $- ^{m}\cdot 33$. The star Castor C is so near the brighter components on the Leiden plates, that variable fog depending on the haziness of the atmosphere may easily cause such an effect. A correction of $+ ^{m}\cdot 33$ was added to all magnitudes to reduce the maximum brightness to zero-magnitude.

The Julian Day Heliocentric Mean Astronomical Time Greenwich was computed for every exposure. The reduction to the sun was read off from a graph giving the light-time as a function of the calendar date, constructed after the formula:

$$\text{Reduction} = + {}^{d}\cdot 00188\, X - {}^{d}\cdot 00584\, Y.$$

The Julian date of each minimum was found according to the method of HERTZSPRUNG [1]).

In his publication on the photographic minima VAN GENT[2]) gave the half period and a combined minimum, adopting therefore a circular orbit and equal depths and shapes of both minima. However, his material as well as the present, shows that the minima were not exactly half a period apart. This effect can be already noted in VAN GENT's Table 1, which

[1]) *B.A.N.* **8**, 331, 1939.

[1]) *B.A.N.* **4**, 179, 1928; **5**, 39, 1929.
[2]) *B.A.N.* **6**, 99, 1931.

shows a systematic difference between the mean $O-C$ for the odd and even minima, amounting to respectively $-{}^{d}\cdot 0007$ and $+{}^{d}\cdot 0006$. We will see later on that there is also a difference in the depths and shapes of his minima, indicating which is the primary minimum.

At first the period was determined separately for each minimum; using, however, both the photographic and photovisual material. The result for the primary minimum is:

$$\text{Min. I} = 2426228^{d}\cdot 45368 + {}^{d}\cdot 81428230\,(E_{I} - 2005)$$
$$\pm\ 28 \pm\ 14 \quad \text{m.e.}$$

and for the secondary minimum

$$\text{Min. II} = 2426228^{d}\cdot 04778 + {}^{d}\cdot 81428216\,(E_{II} - 2005).$$
$$\pm\ 42 \pm\ 19 \quad \text{m.e.}$$

If we assume that the period is the same for both minima a combined solution gives the following result:

$$\text{Min.} = 2426228^{d}\cdot 04778 + {}^{d}\cdot 40591\ q + {}^{d}\cdot 81448222\,(E - 2005),$$
$$\pm\ 26 \pm\ 53 \pm\ 12$$

where $q = 0$ for the secondary and $q = 1$ for the primary minimum. The difference between the epochs is ${}^{d}\cdot 40591 \pm \cdot 00053$ m.e., giving an indication of an eccentricity effect amounting to: $e \cos \omega = \cdot 0024 \pm \cdot 0010$ m.e. The time interval is five times as large as in the case of VAN GENT. Almost the same period is found, but with a much smaller error. Table 2 gives the observed minima, the number of periods elapsed E_{I}, E_{II}, E as given by the formulae, and the corresponding values of $(O-C)$. The phases were computed from the formula:

$$\text{Phase} = 1^{d^{-1}}\cdot 2280755\,(\text{J.D.} - 2420000).$$

TABLE 2

J.D. min. I	E_{I}, E	$O-C_{I}$	$O-C$	J.D. min. II	E_{II}, E	$O-C_{II}$	$O-C$
d		d	d	d		d	d
2424916·6466	394	+ ·0017	+ ·0016	2424595·4105	0	− ·0015	− ·0014
4921·5306	400	0	− 1	4791·6548	241	+ 7	+ 9
4922·3441	401	− 8	− 9	4848·6537	311	− 1	0
4961·4304	449	0	− 2	4875·5268	344	+ 17	+ 18
5242·3568	794	− 10	− 11	4920·3112	399	+ 6	+ 7
5698·3561	1354	+ 2	+ 1	5230·5519	780	− 2	− 2
7158·3641	3147	0	+ 1	5234·6211	785	− 24	− 24
8596·3861	4913	− 5	− 3	5687·3656	1341	+ 12	+ 12
9639·4827	6194	+ 5	+ 8	7160·4011	3150	+ 2	+ 2
				8545·4929	4851	− 19	− 21
				8571·5540	4883	+ 22	+ 20
				2430466·3861	7210	− 3	− 6

Table 3 gives the plate number, the heliocentric Julian Day, the phase and the magnitude, the zeropoint being the maximum brightness.

The phases of the primary and secondary minima

TABLE 3

Plate	J.D. 242	phase	m_{pg}	Plate	J.D. 242	phase	m_{pg}	Plate	J.D. 242	phase	m_{pg}	Plate	J.D. 242	phase	m_{pg}
	d	P	m		d	P	m		d	P	m		d	P	m
1649	5687·3140	·4510	− ·03	1655	5698·3365	·9874	+ ·24	2622	7158·3617	·0086	+ ·63	2627	7160·4205	·5370	+ ·32
	·3182	·4561	− ·03		·3403	·9921	+ ·35		·3693	·0180	+ ·58		·4243	·5417	+ ·18
	·3223	·4612	− ·05		·3441	·9968	+ ·39		·3731	·0226	+ ·52		·4281	·5463	+ ·14
	·3265	·4663	+ ·02		·3479	·0014	+ ·46		·3769	·0273	+ ·39		·4319	·5510	+ ·01
	·3306	·4714	+ ·02		·3517	·0061	+ ·56		·3808	·0321	+ ·34		·4357	·5557	+ ·01
	·3348	·4765	+ ·10		·3555	·0108	+ ·62		·3846	·0367	+ ·11	3882	8544·6222	·4412	− ·04
	·3389	·4816	+ ·10		·3593	·0154	+ ·57		·3884	·0414	+ ·11		·6253	·4450	− ·07
	·3431	·4867	+ ·15		·3631	·0201	+ ·50		·3922	·0461	+ ·07		·6295	·4501	+ ·02
	·3473	·4919	+ ·27		·3669	·0248	+ ·39		·3960	·0507	+ ·12		·6329	·4543	+ ·08
	·3514	·4969	+ ·36		·3746	·0342	+ ·18		·3998	·0554	+ ·07	3883	·6527	·4786	+ ·13
	·3556	·5021	+ ·36		·3784	·0389	+ ·15	2627	7160·3633	·4667	− ·07		·6558	·4824	+ ·19
	·3597	·5071	+ ·46		·3822	·0436	+ ·12		·3671	·4714	− ·04		·6596	·4871	+ ·18
	·3639	·5123	+ ·49		·3860	·0482	+ ·11		·3709	·4761	+ ·02		·6627	·4909	+ ·30
	·3680	·5173	+ ·47		·3898	·0529	+ ·01		·3748	·4809	+ ·16	3885	·6942	·5296	+ ·39
	·3722	·5225	+ ·51		·3936	·0576	+ ·07		·3786	·4855	+ ·23		·6973	·5334	+ ·29
	·3763	·5275	+ ·34		·3974	·0622	+ ·11		·3824	·4902	+ ·29		·7012	·5382	+ ·12
	·3805	·5327	+ ·34	2622	7158·3274	·9665	+ ·04		·3862	·4949	+ ·38		·7043	·5420	+ ·10
	·3847	·5378	+ ·21		·3312	·9712	+ ·03		·3900	·4995	+ ·32	3891	8545·4404	·4460	− ·04
	·3888	·5428	+ ·02		·3350	·9758	− ·01		·3938	·5042	+ ·32		·4440	·4504	− ·04
	·3930	·5480	+ ·10		·3389	·9806	+ ·08		·3976	·5089	+ ·41		·4470	·4541	− ·02
	·3971	·5530	+ ·07		·3427	·9853	+ ·09		·4014	·5135	+ ·48	3892	·4567	·4660	+ ·01
1655	5698·3174	·9640	+ ·06		·3465	·9900	+ ·26		·4052	·5182	+ ·36		·4598	·4698	− ·02
	·3212	·9687	+ ·03		·3503	·9946	+ ·44		·4090	·5229	+ ·31		·4634	·4742	− ·07
	·3289	·9781	+ ·16		·3541	·9993	+ ·48		·4128	·5275	+ ·29		·4664	·4779	+ ·04
	·3327	·9828	+ ·20		·3579	·0040	+ ·56		·4167	·5323	+ ·35	3893	·4740	·4873	+ ·20

TABLE 3 (*continued*)

Plate	J.D. 242	phase	m_{pg}	Plate	J.D. 242	phase	m_{pg}	Plate	J.D. 242	phase	m_{pg}	Plate	J.D. 243	phase	m_{pg}
	d	P	m		d	P	m		d	P	m		d	P	m
3893	8545·4771	·4911	+·23	4258	8949·4250	·5696	+·02	4801	9363·4521	·0261	+·42	5628	0093·4398	·5061	+·50
	·4810	·4959	+·28		·4261	·5709	+·01		·4563	·0313	+·25		·4419	·5087	+·39
	·4841	·4997	+·43		·4273	·5724	−·01		·4584	·0339	+·24		·4440	·5113	+·57
3894	·4928	·5103	+·59	4328	8969·3517	·0411	+·22		·4604	·0363	+·24		·4461	·5139	+·49
	·4959	·5142	+·54		·3528	·0424	+·17	5225	9639·4444	·9655	−·02		·4481	·5163	+·43
	·4995	·5186	+·43		·3540	·0439	+·20		·4464	·9680	−·06		·4502	·5189	+·46
	·5025	·5223	+·36		·3551	·0452	+·11		·4485	·9705	−·05		·4523	·5215	+·40
3895	·5115	·5333	+·22		·3563	·0467	+·15		·4506	·9731	−·01		·4544	·5241	+·38
	·5146	·5371	+·14		·3579	·0487	+·16		·4527	·9757	·00		·4565	·5266	+·32
	·5182	·5415	+·14		·3590	·0500	+·15		·4548	·9783	+·09	5629	·4606	·5317	+·23
	·5214	·5455	+·14		·3602	·0515	+·09		·4589	·9833	+·12		·4627	·5343	+·22
3901	8551·5567	·9573	+·02		·3614	·0530	+·11		·4610	·9859	+·21		·4648	·5368	+·23
	·5596	·9608	−·03		·3625	·0543	+·18		·4631	·9885	+·19		·4669	·5394	+·14
	·5633	·9654	·00	4329	·3870	·0844	−·04		·4651	·9909	+·33		·4689	·5419	+·08
	·5662	·9689	+·08		·3881	·0858	−·03		·4672	·9935	+·37		·4710	·5444	+·11
3902	·5740	·9785	+·07		·3893	·0872	+·03		·4693	·9961	+·38	5847	0356·4481	·5002	+·41
	·5769	·9821	+·12		·3904	·0886	+·03	5226	·4755	·0037	+·50		·4502	·5027	+·42
3903	·5900	·9982	+·48		·3916	·0901	−·01		·4776	·0063	+·48		·4523	·5053	+·39
	·5929	·0017	+·56	4749	9314·5226	·9370	+·02		·4797	·0089	+·60		·4543	·5078	+·47
	·5965	·0061	+·48		·5246	·9395	−·02		·4818	·0114	+·57		·4564	·5104	+·45
	·5995	·0098	+·54		·5267	·9420	−·02		·4838	·0139	+·62		·4585	·5129	+·48
3915	8571·5026	·4523	−·03		·5295	·9455	·00		·4859	·0165	+·59		·4606	·5155	+·51
	·5052	·4555	−·03		·5316	·9481	+·04		·4901	·0216	+·50		·4626	·5180	+·44
3916	·5141	·4665	−·04	4754	9326·3397	·4493	+·04		·4922	·0242	+·44		·4647	·5206	+·41
	·5167	·4697	−·02		·3418	·4519	+·06		·4942	·0267	+·44		·4668	·5231	+·38
	·5200	·4737	+·10		·3439	·4544	+·02		·4963	·0292	+·43		·4700	·5271	+·45
	·5226	·4769	+·14		·3470	·4583	−·08		·4984	·0318	+·35		·4730	·5307	+·37
3917	·5307	·4869	+·13		·3491	·4608	+·02		·5005	·0344	+·23		·4751	·5333	+·40
	·5323	·4900	+·24		·3512	·4634	−·04	5227	·5088	·0446	+·10	5848	·4852	·5457	+·12
	·5366	·4941	+·29	4755	·3574	·4710	+·01		·5109	·0472	+·07		·4872	·5482	+·04
	·5392	·4973	+·40		·3595	·4736	+·06		·5129	·0496	+·10		·4893	·5508	+·06
3918	·5487	·5089	+·57		·3616	·4762	+·09		·5150	·0522	+·01		·4914	·5534	+·06
	·5513	·5121	+·45		·3647	·4800	+·09		·5171	·0548	·00		·4935	·5559	+·01
	·5546	·5162	+·40		·3668	·4826	+·17		·5192	·0574	+·05		·4955	·5584	·00
	·5572	·5194	+·35		·3688	·4850	+·12		·5295	·0700	+·04		·4976	·5610	−·03
3919	·5667	·5311	+·34	4756	·3806	·4995	+·37		·5316	·0726	−·02		·4997	·5635	+·04
	·5694	·5343	+·18		·3827	·5021	+·38		·5337	·0752	−·01		·5018	·5661	+·07
3938	8596·3506	·9676	+·05		·3848	·5047	+·38		·5358	·0777	+·01		·5038	·5686	+·04
	·3537	·9714	+·04		·3875	·5080	+·45		·5379	·0803	+·02		·5059	·5711	+·05
	·3579	·9765	+·08		·3893	·5102	+·46		·5399	·0828	+·05		·5080	·5737	+·08
	·3610	·9803	+·14	4758	·4197	·5475	+·01	5489	9985·4843	·9286	−·01		·5101	·5763	+·06
3939	·3721	·9940	+·33		·4218	·5501	+·08		·4863	·9311	−·04	6013	0466·3491	·4669	+·06
	·3750	·9975	+·41		·4239	·5527	+·08		·4884	·9337	−·03		·3511	·4694	−·02
	·3790	·0024	+·55		·4270	·5565	+·10		·4905	·9362	+·01		·3532	·4719	+·04
	·3821	·0062	+·56		·4291	·5591	+·06		·4926	·9388	+·05		·3552	·4744	+·05
3940	·3928	·0194	+·51		·4312	·5617	−·02		·4946	·9413	+·04		·3574	·4771	+·10
	·3958	·0231	+·42	4759	·4384	·5705	−·02		·4967	·9439	−·01		·3594	·4796	+·13
	·3996	·0277	+·34		·4405	·5731	−·04		·4988	·9464	+·01		·3615	·4821	+·16
	·4025	·0313	+·27		·4426	·5757	−·03		·5113	·9618	+·02		·3636	·4847	+·14
3941	·4122	·0432	+·18	4797	9363·3746	·9309	·00		·5134	·9644	−·02		·3657	·4873	+·13
	·4152	·0469	+·11		·3766	·9334	·00		·5155	·9670	+·02		·3678	·4899	+·23
	·4191	·0517	+·06		·3787	·9360	·00		·5175	·9694	−·02		·3698	·4923	+·30
	·4221	·0554	+·03		·3822	·9403	−·05		·5196	·9720	+·02		·3719	·4949	+·25
3942	·4323	·0679	−·03		·3843	·9429	−·01		·5217	·9746	+·03		·3761	·5001	+·44
	·4352	·0714	+·01		·3863	·9453	−·03		·5237	·9770	+·09		·3781	·5025	+·43
	·4391	·0762	+·01	4798	·3919	·9522	−·01		·5258	·9796	+·10		·3802	·5051	+·46
	·4420	·0798	+·04		·3940	·9548	−·04		·5279	·9822	+·14		·3866	·5130	+·46
4257	8949·3995	·5383	+·21		·3960	·9572	−·01	5490	·5508	·0103	+·64		·3885	·5153	+·55
	·4006	·5396	+·19		·3988	·9607	−·02		·5528	·0127	+·54		·3906	·5179	+·38
	·4018	·5411	+·16		·4030	·9658	−·02		·5549	·0153	+·59		·3927	·5204	+·34
	·4029	·5424	+·22	4799	·4092	·9734	−·02		·5570	·0179	+·57		·3948	·5230	+·39
	·4040	·5438	+·23		·4113	·9760	·00		·5591	·0204	+·49		·3968	·5255	+·39
	·4060	·5462	+·15		·4133	·9785	+·05		·5611	·0229	+·47		·3989	·5280	+·37
	·4072	·5477	+·06		·4182	·9845	+·20		·5632	·0255	+·40	6014	·4114	·5434	+·08
	·4083	·5491	+·02		·4203	·9871	+·24		·5653	·0281	+·39		·4135	·5460	+·06
	·4095	·5505	+·05		·4224	·9896	+·28		·5736	·0383	+·15		·4156	·5486	+·05
	·4107	·5520	+·04	4800	·4286	·9973	+·44		·5757	·0409	+·12		·4176	·5510	+·04
4258	·4161	·5587	+·01		·4307	·9998	+·52		·5778	·0434	+·10		·4197	·5536	−·03
	·4172	·5600	−·08		·4327	·0023	+·55		·5798	·0459	+·11		·4218	·5561	−·02
	·4184	·5615	+·02		·4362	·0066	+·59		·5819	·0485	+·02		·4239	·5587	−·04
	·4195	·5628	−·02		·4383	·0092	+·58		·5840	·0511	−·02		·4259	·5612	−·04
	·4207	·5643	+·06		·4404	·0118	+·58		·5861	·0536	·00		·4280	·5638	−·02
	·4227	·5668	−·01	4801	·4480	·0211	+·54		·5881	·0561	−·03		·4301	·5664	−·01
	·4238	·5681	+·01		·4501	·0237	+·40	5628	0093·4378	·5037	+·49				

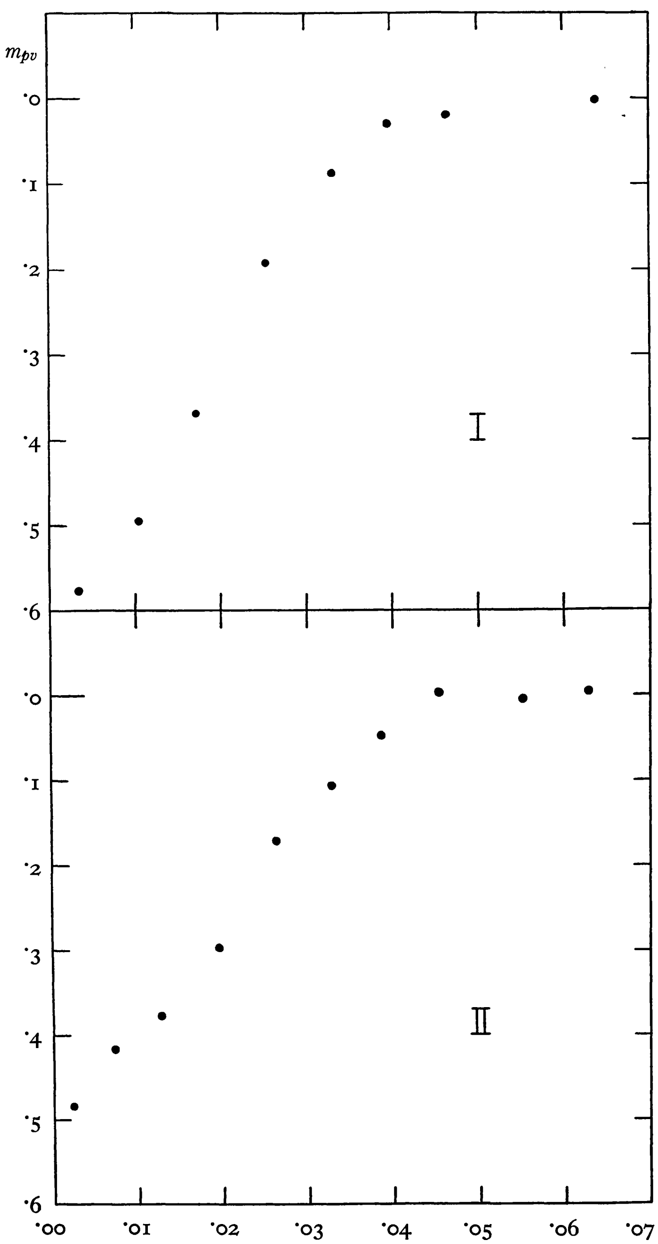
TABLE 4

Phase	I m_{pv}	n	Phase	II m_{pv}	n
P	m		P	m	
·0033	+ ·575	20	·0023	+ ·482	20
·0104	+ ·493	20	·0073	+ ·416	20
·0172	+ ·368	20	·0128	+ ·376	20
·0255	+ ·190	20	·0198	+ ·296	20
·0333	+ ·087	20	·0262	+ ·170	20
·0396	+ ·030	20	·0328	+ ·105	20
·0465	+ ·017	20	·0386	+ ·046	20
·0637	+ ·002	20	·0454	− ·004	20
			·0551	+ ·004	17
			·0626	− ·003	16

are respectively ^{P}·0114 and ^{P}·5129. Table 4 and Figure 1 give the reflected light-curve of these minima, n being the number of observations in one normal point. The depth of the primary is ^{m}·59, that of the secondary is ^{m}·49. The mean error of a normal point consisting of 20 exposures is found to be ± ^{m}·007, derived from magnitude differences of observations with successive phases.

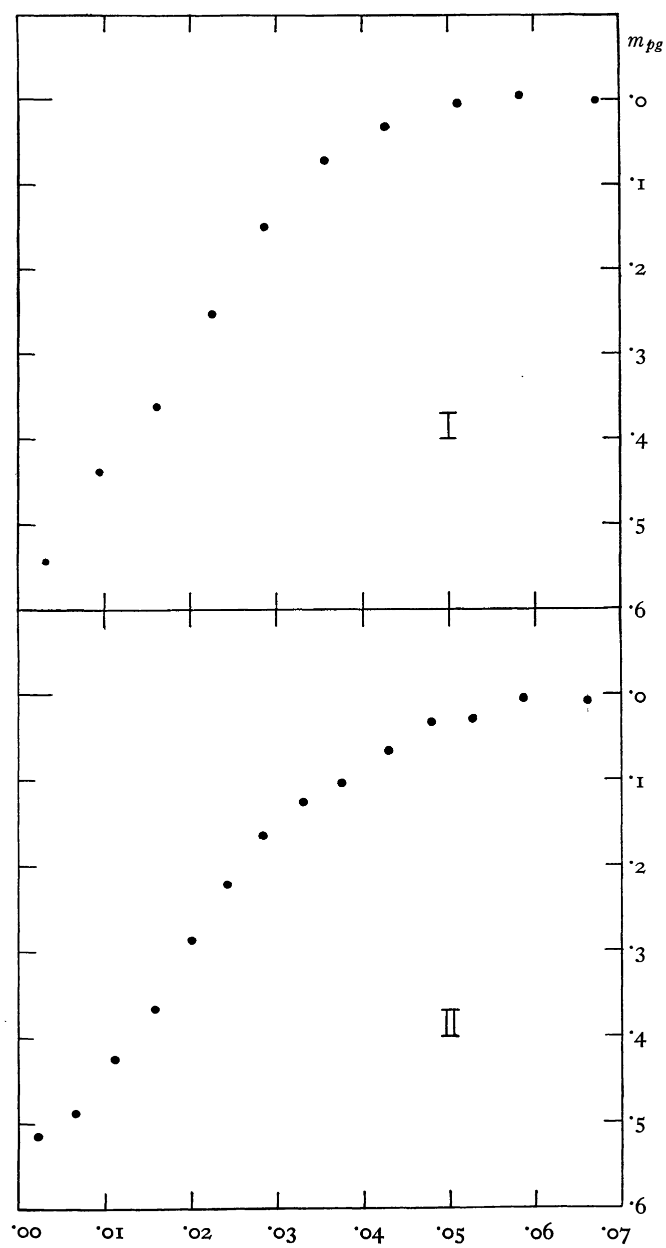
Table 5 and Figure 2 give the reflected light-curves of both minima for the photographic material of VAN GENT, treated in the same way. His magnitudes were multiplied with a factor 1·05 to bring his grating constant into agreement with the now adopted constant ^{m}·97. The depth of the photographic primary is now

FIGURE 1



Reflected photovisual light-curves of the minima.

FIGURE 2



Reflected photographic light-curves of the minima (VAN GENT).