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## RESEARCH ARTICLES

## Appulses of faint stars by fragments of Comet Shoemaker–Levy 9

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**Geocentric circumstances of stellar occultations by coma around the fragments of the split comet Shoemaker–Levy 9 are presented. Estimation of the extinction of starlight during its passage in the vicinity of the fragment (an appulse) will help in studying the density of dust in this region. A method to revise the predictions using corrections to the cometary coordinates is suggested.**

COMBES *et al.* first pointed out that observations of stellar occultations by comets can lead to measurement of density of dust in comae without any assumption of their albedo<sup>1</sup>. Larson and A'Hearn<sup>2</sup> and Lechacheux *et*

*al.*<sup>3</sup> have reported results of cometary occultations and indicated that this technique could be exploited as a powerful tool in cometary research. Much interest now centres in studying the nature of the fragments of comet Shoemaker–Levy 9 (S–L 9) and its dusty environment: This object was discovered by Shoemaker *et al.*<sup>4</sup> as a dense linear bar. Subsequent observations by other groups revealed several fragments<sup>4,5</sup>. Jewitt *et al.* identified and numbered 21 fragments<sup>6</sup>. Recent computations by Marsden<sup>7</sup> indicate that the original comet was disrupted into these fragments during its last close encounter with Jupiter on July 7.8, 1992. Observations by the Hubble Space Telescope (HST) of S–L 9 during July 1993 indicated that each nucleus is surrounded by a roughly spherical

coma<sup>8</sup>. The spatial brightness distribution of the coma in the HST images was found to be flatter than those of comets at heliocentric distances of one astronomical unit. Weaver *et al.*<sup>8</sup> therefore inferred that the coma is not due to the steady-state production of dust flowing outward from the nucleus. The dusty surroundings created at the time of tidal disruption make this comet a more favourable candidate for studying its stellar occultations. Absence of emissions<sup>9</sup> in this comet immediately implies possibility of accurate estimation of extinction by the dust grains, even while using broad band filters to improve the signal-to-noise ratio. Slow motion (<0.45 arcsec per min) of the cometary fragments would enable one to follow the events by obtaining a series of CCD images at intervals of about one minute. Thus the extinction measurements can be made differentially with respect to the field stars. Therefore a search for candidates in the Guide Star Catalogue<sup>10</sup> (GST) was carried out to predict the appulses by the cometary fragments.

### The predictions

The impact parameters and times of close approach of the fragments 1, 5, 6, 7, 11, 12, 14, 16, 17 to the stars were predicted using their most recent positions computed by Yeomans and Chodas<sup>11</sup>. The geocentric circumstances of the events are given in Tables 1–9. The first column gives the star identification<sup>12</sup>. The UT dates and close approach times are given in columns 2 and 3. Columns 4 and 5 give the right ascension and declination of the star referred to the equator and equinox of 2000.0. For stars with multiple entries in the catalogue the position with the least co-ordinate error was chosen. The impact parameter IP is given in the 6th column. A positive impact parameter indicates that the star is to the north of the fragment. The sky plane velocity  $V$  of the comet is given in the 7th column. The velocity is positive when the comet is moving eastwards with respect to the star. The last column contains the magnitude of the star as given in the Guide Star Catalogue.

Table 1. Appulses by fragment 1

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	$V$ km/s	Mag
06153 00353	1994/01/27	04:07:06	14 34 37.246	-15 59 18.528	-9.320	15.6	15.53
06153 00537	1994/01/27	03:21:02	14 34 37.104	-15 58 47.460	19.777	15.6	11.56
06153 00107	1994/01/28	20:48:09	14 35 15.718	-16 01 45.696	12.315	14.8	14.84
06153 00468	1994/01/29	01:19:42	14 35 20.054	-16 01 53.580	22.993	14.7	13.86
06153 00357	1994/01/29	07:58:47	14 35 25.764	-16 02 34.476	7.826	14.6	15.49
06153 00565	1994/01/29	12:24:25	14 35 29.837	-16 02 47.400	12.532	14.5	15.07
06153 00832	1994/02/02	18:06:15	14 36 55.493	-16 08 47.688	22.423	12.5	15.14
06153 01004	1994/02/08	03:51:14	14 38 27.485	-16 15 09.936	24.503	9.9	13.47
06154 00315	1994/02/16	18:10:11	14 40 11.837	-16 22 06.132	9.890	5.7	15.39
06154 00347	1994/02/20	08:48:52	14 40 39.924	-16 23 44.052	2.166	4.0	15.02
06154 00909	1994/02/21	15:59:14	14 40 47.815	-16 24 01.008	6.322	3.4	13.84
06153 00915	1994/03/30	20:03:23	14 36 05.774	-15 50 48.840	22.988	-11.5	14.90
06153 00889	1994/03/31	07:37:49	14 35 56.050	-15 50 01.896	12.608	-11.6	15.33
06153 01177	1994/04/03	23:37:09	14 34 40.606	-15 42 25.020	18.307	-12.6	15.30
06153 00487	1994/04/06	18:05:30	14 33 38.782	-15 36 39.276	-3.568	-13.3	14.89
06153 00187	1994/04/09	23:18:13	14 32 23.964	-15 29 01.248	5.649	-13.9	12.51
06152 00416	1994/04/17	01:10:09	14 29 27.358	-15 10 55.128	23.945	-15.0	15.09
06152 00639	1994/04/18	18:56:13	14 28 42.010	-15 06 14.976	27.326	-15.2	15.17
05574 00591	1994/04/29	09:30:41	14 23 56.818	-14 37 13.440	-1.628	-15.7	14.46
05574 00649	1994/05/05	17:39:00	14 21 07.243	-14 19 10.668	-7.558	-15.4	13.06
05574 00809	1994/05/07	04:34:35	14 20 29.938	-14 14 34.872	21.411	-15.3	15.45
05574 00803	1994/05/12	01:04:22	14 18 25.438	-14 01 15.492	-5.184	-14.7	12.92
05561 01516	1994/05/14	09:19:43	14 17 28.188	-13 54 40.392	-1.171	-14.3	12.97
05561 00784	1994/05/16	14:58:30	14 16 35.244	-13 48 33.084	.991	-13.9	15.63
05561 00629	1994/05/22	19:53:57	14 14 18.607	-13 32 19.968	-2.681	-12.6	11.74
05561 01040	1994/05/24	08:32:50	14 13 47.621	-13 28 32.628	-4.987	-12.2	14.00
05561 00798	1994/05/25	07:13:21	14 13 29.818	-13 25 51.888	18.887	-12.0	13.91
05561 00218	1994/05/28	19:18:17	14 12 25.181	-13 17 28.896	22.471	-11.0	13.69
05561 00367	1994/05/29	23:29:57	14 12 04.111	-13 15 10.476	-3.362	-10.6	15.15
05561 00226	1994/05/31	15:19:04	14 11 37.308	-13 11 17.520	9.592	-10.1	13.75
05561 00253	1994/06/05	16:46:44	14 10 24.326	-13 00 48.456	8.160	-8.5	13.69
05561 01208	1994/06/15	11:53:38	14 08 50.774	-12 44 02.796	11.681	-5.0	14.42
05558 01029	1994/07/09	00:24:56	14 09 50.107	-12 24 11.556	25.677	7.2	10.13
05558 01005	1994/07/12	18:18:23	14 10 40.310	-12 23 52.764	-4.599	9.4	14.34
05558 01276	1994/07/17	06:37:12	14 11 58.020	-12 22 42.636	23.124	12.2	15.27
05558 00973	1994/07/22	00:25:54	14 13 42.341	-12 19 09.696	18.718	10.4	13.98

Table 2. Appulses by fragment 5

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00107	1994/01/28	19:49:18	14 35 15.718	-16 01 45.696	-1.205	14.8	14.84
06153 00357	1994/01/29	06:58:51	14 35 25.764	-16 02 34.476	-5.747	14.6	15.49
06153 00468	1994/01/29	00:20:26	14 35 20.054	-16 01 53.580	9.450	14.7	13.86
06153 00565	1994/01/29	11:24:05	14 35 29.837	-16 02 47.400	-1.061	14.5	15.07
06153 00832	1994/02/02	16:55:01	14 36 55.493	-16 08 47.688	8.408	12.5	15.14
06153 01004	1994/02/08	02:20:06	14 38 27.485	-16 15 09.936	10.128	9.9	13.47
06154 00315	1994/02/16	15:24:26	14 40 11.837	-16 22 06.132	-5.048	5.8	15.39
06154 00909	1994/02/21	11:00:09	14 40 47.815	-16 24 01.008	-8.088	3.5	13.84
06154 01043	1994/02/23	05:05:02	14 40 57.048	-16 23 49.020	24.068	2.7	15.28
06154 00695	1994/03/09	05:14:19	14 40 48.355	-16 19 46.380	24.597	-3.7	15.44
06153 01084	1994/03/15	22:17:19	14 39 53.196	-16 13 47.856	9.437	-6.4	15.56
06153 00634	1994/03/29	21:00:15	14 36 25.867	-15 52 28.668	18.020	-11.2	14.67
06153 00915	1994/03/30	21:28:30	14 36 05.774	-15 50 48.840	-1.025	-11.5	14.90
06153 00923	1994/03/31	15:54:47	14 35 50.962	-15 49 07.356	10.776	-11.7	15.34
06153 00011	1994/04/01	02:56:39	14 35 42.065	-15 48 02.160	21.799	-11.8	15.40
06153 01177	1994/04/04	00:56:26	14 34 40.606	-15 42 25.020	-6.455	-12.6	15.30
06153 00349	1994/04/06	04:29:21	14 33 54.221	-15 37 13.260	25.153	-13.1	15.15
06153 00175	1994/04/08	16:41:15	14 32 56.414	-15 31 35.436	17.325	-13.7	15.43
06152 00416	1994/04/17	02:22:42	14 29 27.358	-15 10 55.128	-3.274	-15.0	15.09
06152 00747	1994/04/17	06:59:04	14 29 22.766	-15 10 11.424	11.229	-15.1	15.45
06152 00100	1994/04/17	11:28:49	14 29 18.017	-15 09 37.728	15.604	-15.1	13.38
06152 00172	1994/04/18	19:33:53	14 28 42.703	-15 06 17.064	1.744	-15.2	15.28
06152 00639	1994/04/18	20:08:59	14 28 42.010	-15 06 14.976	-242	-15.2	15.17
05561 00987	1994/05/17	03:26:29	14 16 25.697	-13 46 50.484	-1.140	-13.8	14.80
05561 00860	1994/05/18	17:19:57	14 15 49.956	-13 42 31.428	5.108	-13.5	10.62
05561 00445	1994/05/20	15:27:29	14 15 08.126	-13 37 13.944	21.277	-13.1	12.38
05561 01429	1994/05/21	01:22:36	14 14 58.440	-13 36 33.084	-4.904	-13.0	15.46
05561 00334	1994/05/23	01:28:45	14 14 16.550	-13 31 22.296	-1.129	-12.5	14.37
05561 00634	1994/05/23	11:30:00	14 14 08.753	-13 29 58.812	21.801	-12.4	15.02
05561 00843	1994/05/28	18:16:34	14 12 28.500	-13 17 19.356	15.237	-11.0	15.17
05561 00042	1994/06/01	11:54:51	14 11 26.698	-13 09 03.708	9.011	-9.9	13.27
05561 00072	1994/06/06	18:34:27	14 10 13.898	-12 58 20.820	7.954	-8.1	11.11
05558 01029	1994/07/08	14:26:22	14 09 50.107	-12 24 11.556	-4.405	7.1	10.13
05558 01024	1994/07/14	17:38:41	14 11 17.345	-12 22 16.140	26.154	10.8	14.95
05558 01281	1994/07/18	01:47:25	14 12 20.830	-12 21 34.272	23.811	13.6	15.48

Table 3. Appulses by fragment 6

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00107	1994/01/28	18:51:36	14 35 15.718	-16 01 45.696	-9.201	14.9	14.84
06153 00468	1994/01/28	23:22:22	14 35 20.054	-16 01 53.580	1.454	14.8	13.86
06153 00565	1994/01/29	10:25:01	14 35 29.837	-16 02 47.400	-9.062	14.6	15.07
06153 00358	1994/01/30	07:10:09	14 35 48.878	-16 03 38.484	21.533	14.1	15.50
06153 00832	1994/02/02	15:43:42	14 36 55.493	-16 08 47.688	.189	12.5	15.14
06153 01004	1994/02/08	00:44:57	14 38 27.485	-16 15 09.936	1.709	9.9	13.47
06154 01043	1994/02/22	22:13:38	14 40 57.048	-16 23 49.020	17.271	2.8	15.28
06154 00695	1994/03/09	09:34:13	14 40 48.355	-16 19 46.380	10.480	-3.8	15.44
06153 01084	1994/03/16	01:01:49	14 39 53.196	-16 13 47.856	-4.275	-6.5	15.56
06153 00634	1994/03/29	22:43:03	14 36 25.867	-15 52 28.668	3.574	-11.2	14.67
06153 00923	1994/03/31	17:34:11	14 35 50.962	-15 49 07.356	-3.853	-11.7	15.34
06153 00011	1994/04/01	04:35:24	14 35 42.065	-15 48 02.160	7.132	-11.9	15.40
06153 00435	1994/04/04	06:10:26	14 34 38.230	-15 41 33.180	13.344	-12.7	15.57
06153 00090	1994/04/04	12:31:02	14 34 32.633	-15 40 54.408	18.204	-12.7	14.83
06153 00349	1994/04/06	06:00:15	14 33 54.221	-15 37 13.260	9.995	-13.1	15.15
06153 00111	1994/04/08	12:31:05	14 33 02.323	-15 31 54.084	17.459	-13.6	15.04
06153 00175	1994/04/08	18:08:57	14 32 56.414	-15 31 35.436	1.927	-13.7	15.43
06152 00796	1994/04/11	09:42:11	14 31 53.441	-15 24 59.436	17.946	-14.2	13.91
06152 00670	1994/04/15	09:19:31	14 30 13.949	-15 14 54.384	21.250	-14.8	7.09
06152 00747	1994/04/17	08:21:06	14 29 22.766	-15 10 11.424	-5.004	-15.1	15.45
06152 00100	1994/04/17	12:50:47	14 29 18.017	-15 09 37.728	-.659	-15.1	13.38
06152 00777	1994/04/20	01:12:39	14 28 12.502	-15 02 37.032	17.338	-15.3	14.60
06152 00342	1994/04/20	08:37:43	14 28 04.435	-15 01 42.528	21.866	-15.4	10.45
05561 00661	1994/05/16	09:37:57	14 16 45.742	-13 48 21.636	23.001	-14.0	15.16
05561 00445	1994/05/20	17:07:22	14 15 08.126	-13 37 13.944	.410	-13.1	12.38
05561 00410	1994/05/21	06:08:13	14 14 56.849	-13 35 39.408	11.836	-13.0	14.61
05561 00611	1994/05/22	21:27:48	14 14 22.714	-13 31 22.944	17.558	-12.6	11.83
05561 00634	1994/05/23	13:15:50	14 14 08.753	-13 29 58.812	.329	-12.4	15.02
05561 00457	1994/05/24	13:00:09	14 13 49.322	-13 27 20.880	11.630	-12.2	13.87
05561 00843	1994/05/28	20:15:09	14 12 28.500	-13 17 19.356	-7.424	-11.0	15.17
05561 00231	1994/06/03	04:22:02	14 11 03.854	-13 05 19.680	10.158	-9.3	13.10
05561 01325	1994/06/10	15:19:38	14 09 34.370	-12 51 09.900	9.873	-6.7	13.41
05561 01335	1994/06/21	13:25:25	14 08 32.328	-12 35 42.108	7.557	-3.0	12.98
05558 00974	1994/07/14	04:55:13	14 11 11.674	-12 22 01.128	25.915	10.5	11.84
05558 01024	1994/07/14	12:50:58	14 11 17.345	-12 22 16.140	6.473	10.7	14.95
05558 01281	1994/07/17	21:22:18	14 12 20.830	-12 21 34.272	.991	13.5	15.48



Table 4. Appulses by fragment 7

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00468	1994/01/28	22:57:37	14 35 20.054	-16 01 53.580	-6.860	14.8	13.86
06153 00358	1994/01/30	06:44:15	14 35 48.878	-16 03 38.484	13.119	14.2	15.50
06153 00832	1994/02/02	15:14:45	14 36 55.493	-16 08 47.688	-8.453	12.6	15.14
06153 01004	1994/02/08	00:08:57	14 38 27.485	-16 15 09.936	-7.181	10.0	13.47
06154 00091	1994/02/18	06:59:35	14 40 28.373	-16 22 12.756	24.726	5.0	15.07
06154 01043	1994/02/22	19:42:31	14 40 57.048	-16 23 49.020	8.024	2.9	15.28
06154 00695	1994/03/09	10:32:45	14 40 48.355	-16 19 46.380	-2.148	-3.8	15.44
06154 00006	1994/03/11	08:11:32	14 40 36.605	-16 17 53.340	22.991	-4.6	14.48
06153 00927	1994/03/17	04:07:54	14 39 42.139	-16 12 00.612	15.799	-6.9	13.60
06153 00933	1994/03/25	21:51:25	14 37 39.252	-15 59 15.936	21.550	-10.0	15.14
06153 00684	1994/03/28	11:04:11	14 36 54.660	-15 54 49.356	19.011	-10.8	13.03
06153 00011	1994/04/01	05:05:24	14 35 42.065	-15 48 02.160	-7.751	-11.9	15.40
06153 01166	1994/04/01	09:29:07	14 35 39.175	-15 47 12.048	22.523	-11.9	14.88
06153 00461	1994/04/03	05:41:31	14 35 01.003	-15 43 26.940	19.122	-12.4	14.78
06153 00435	1994/04/04	06:39:42	14 34 38.230	-15 41 33.180	-1.852	-12.7	15.57
06153 00090	1994/04/04	13:00:15	14 34 32.633	-15 40 54.408	2.987	-12.7	14.83
06153 00349	1994/04/06	06:29:24	14 33 54.221	-15 37 13.260	-5.441	-13.2	15.15
06153 00111	1994/04/08	13:00:26	14 33 02.323	-15 31 54.084	1.675	-13.6	15.04
06152 00796	1994/04/11	10:11:22	14 31 53.441	-15 24 59.436	1.773	-14.2	13.91
06152 00223	1994/04/13	23:19:59	14 30 50.654	-15 18 25.524	15.189	-14.6	15.02
06152 00670	1994/04/15	09:49:08	14 30 13.949	-15 14 54.384	4.510	-14.8	7.09
06152 00777	1994/04/20	01:42:51	14 28 12.502	-15 02 37.032	.053	-15.3	14.60
06152 00342	1994/04/20	09:08:04	14 28 04.435	-15 01 42.528	4.543	-15.4	10.45
05574 00586	1994/04/29	01:48:24	14 24 11.556	-14 37 07.032	23.735	-15.7	15.60
05574 00404	1994/05/03	04:51:33	14 22 20.503	-14 25 28.704	12.396	-15.6	11.43
05574 00164	1994/05/06	23:29:39	14 20 40.747	-14 14 43.872	7.563	-15.3	15.62
05561 00390	1994/05/14	05:00:21	14 17 38.753	-13 54 20.880	8.392	-14.4	14.35
05561 01469	1994/05/14	12:39:46	14 17 31.078	-13 53 27.816	8.627	-14.3	14.48
05561 01039	1994/05/16	07:13:10	14 16 49.320	-13 48 28.800	17.256	-14.0	14.09
05561 00661	1994/05/16	10:24:26	14 16 45.742	-13 48 21.636	1.192	-14.0	15.16
05561 00611	1994/05/22	22:22:46	14 14 22.714	-13 31 22.944	-5.631	-12.5	11.83
05561 00510	1994/06/08	18:31:49	14 09 54.749	-12 54 19.008	- .747	-7.4	14.70
05561 01564	1994/06/11	18:56:07	14 09 26.100	-12 48 49.896	18.290	-6.3	15.44
05561 01565	1994/06/14	16:41:25	14 09 03.226	-12 44 24.072	6.562	-5.2	15.06
05561 01548	1994/06/15	06:18:00	14 08 59.654	-12 43 31.980	8.711	-5.0	15.37
05558 01070	1994/07/04	16:50:40	14 09 16.738	-12 24 42.552	15.885	5.2	14.80
05558 00974	1994/07/13	23:18:36	14 11 11.674	-12 22 01.128	-4.424	10.5	11.84
05558 00976	1994/07/14	16:17:11	14 11 23.758	-12 21 44.136	1.703	11.0	13.40

Table 5. Appulses by fragment 11

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00354	1994/01/28	19:31:19	14 35 19.162	-16 00 58.356	24.743	14.8	15.08
06153 00358	1994/01/30	05:17:23	14 35 48.878	-16 03 38.484	-4.484	14.2	15.50
06153 00693	1994/02/08	09:45:55	14 38 35.700	-16 15 01.872	13.963	9.8	14.22
06153 00690	1994/02/13	08:31:22	14 39 41.659	-16 19 16.860	16.484	7.4	14.93
06154 00309	1994/02/17	16:15:58	14 40 24.972	-16 21 55.584	11.640	5.3	15.08
06154 00091	1994/02/18	02:19:13	14 40 28.373	-16 22 12.756	5.688	5.1	15.07
06154 01043	1994/02/22	11:04:20	14 40 57.048	-16 23 49.020	-9.823	3.1	15.28
06154 00479	1994/03/10	08:01:06	14 40 45.684	-16 18 28.980	20.831	-4.1	13.96
06154 00006	1994/03/11	12:31:25	14 40 36.605	-16 17 53.340	-5.323	-4.7	14.48
06153 00933	1994/03/26	00:12:54	14 37 39.252	-15 59 15.936	-8.746	-10.0	15.14
06153 00932	1994/03/26	04:06:09	14 37 37.145	-15 58 38.280	14.170	-10.1	14.23
06153 00129	1994/04/01	05:09:39	14 35 44.698	-15 47 38.904	-3.307	-11.9	13.22
06153 01166	1994/04/01	11:32:43	14 35 39.175	-15 47 12.048	-9.152	-11.9	14.88
06153 00075	1994/04/01	12:18:27	14 35 39.403	-15 46 37.992	23.553	-11.9	11.39
06153 00298	1994/04/04	05:13:48	14 34 42.612	-15 41 05.784	15.449	-12.7	15.49
06153 00613	1994/04/04	16:27:07	14 34 32.575	-15 40 01.776	18.902	-12.8	14.88
06153 01113	1994/04/05	12:35:49	14 34 14.352	-15 38 04.488	26.139	-13.0	15.04
06153 00293	1994/04/09	06:45:22	14 32 47.690	-15 29 49.056	2.467	-13.8	15.34
06152 00587	1994/04/18	21:55:07	14 28 45.907	-15 05 24.828	-1.578	-15.2	15.18
06152 00178	1994/04/20	18:34:29	14 27 57.139	-15 00 11.520	10.446	-15.4	13.80
05574 00674	1994/04/27	02:31:18	14 25 07.517	-14 42 30.600	13.061	-15.7	9.83
05574 00821	1994/05/04	22:18:03	14 21 38.155	-14 20 02.148	19.290	-15.5	14.98
05574 00335	1994/05/05	05:37:10	14 21 29.918	-14 19 16.068	12.286	-15.4	12.02
05561 01512	1994/05/14	07:13:10	14 17 40.286	-13 53 32.820	17.607	-14.3	14.94
05561 01026	1994/05/23	15:57:40	14 14 11.894	-13 28 55.596	6.298	-12.4	15.13
05558 01070	1994/07/03	23:03:22	14 09 16.738	-12 24 42.552	-5.043	5.0	14.80
05558 01048	1994/07/04	19:34:46	14 09 23.275	-12 23 44.124	27.975	5.4	10.26
05558 00988	1994/07/14	21:06:55	14 11 35.230	-12 20 12.264	24.349	11.5	14.40
05558 00995	1994/07/17	01:58:15	14 12 19.402	-12 19 14.664	23.745	19.9	9.99
05558 01413	1994/07/20	06:46:33	14 13 16.716	-12 16 43.464	-1.134	4.2	15.33

Table 6. Appulses by fragment 12

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag.
06153 00354	1994/01/28	18:42:12	14 35 19.162	-16 00 58.356	14.384	14.9	15.08
06153 00876	1994/01/31	17:59:08	14 36 21.905	-16 05 22.812	21.714	13.5	13.47
06153 00693	1994/02/08	08:26:53	14 38 35.700	-16 15 01.872	2.870	9.8	14.22
06153 00820	1994/02/10	02:17:20	14 39 01.375	-16 16 20.820	25.489	8.9	11.45
06153 00690	1994/02/13	06:42:59	14 39 41.659	-16 19 16.860	5.243	7.4	14.93
06154 00091	1994/02/17	23:34:58	14 40 28.373	-16 22 12.756	-5.556	5.2	15.07
06154 00309	1994/02/17	13:38:46	14 40 24.972	-16 21 55.584	.372	5.3	15.08
06154 00479	1994/03/10	10:50:26	14 40 45.684	-16 18 28.980	4.028	-4.2	13.96
06154 01018	1994/03/14	19:25:11	14 40 10.822	-16 14 05.892	25.362	-6.0	14.23
06153 00932	1994/03/26	05:31:15	14 37 37.145	-15 58 38.280	-3.749	-10.1	14.23
06153 00075	1994/04/01	13:33:35	14 35 39.403	-15 46 37.992	4.896	-11.9	11.39
06153 00298	1994/04/04	06:25:38	14 34 42.612	-15 41 05.784	-3.579	-12.7	15.49
06153 00613	1994/04/04	17:38:29	14 34 32.575	-15 40 01.776	-.166	-12.8	14.88
06153 01113	1994/04/05	13:46:27	14 34 14.352	-15 38 04.488	6.978	-13.0	15.04
06153 00183	1994/04/07	02:49:35	14 33 40.181	-15 34 18.228	26.076	-13.3	14.95
06152 00275	1994/04/11	23:05:50	14 31 45.058	-15 22 57.612	13.304	-14.3	15.48
06152 00113	1994/04/15	19:08:25	14 30 09.221	-15 13 00.624	27.115	-14.8	15.18
06152 00018	1994/04/16	13:09:08	14 29 49.836	-15 11 06.756	23.054	-15.0	11.77
05574 00487	1994/05/01	12:08:56	14 23 11.021	-14 29 43.800	13.330	-15.6	13.35
05574 00821	1994/05/04	23:28:34	14 21 38.155	-14 20 02.148	-4.675	-15.4	14.98
05574 00184	1994/05/11	22:32:34	14 18 40.210	-13 59 49.812	21.522	-14.7	12.13
05561 01512	1994/05/14	08:33:20	14 17 40.286	-13 53 32.820	-8.365	-14.3	14.94
05561 00857	1994/05/15	14:46:03	14 17 10.795	-13 49 50.088	8.178	-14.1	12.70
05561 01493	1994/05/17	08:34:30	14 16 30.744	-13 44 52.116	23.699	-13.8	15.27
05561 00450	1994/05/22	05:17:10	14 14 43.906	-13 32 14.820	12.437	-12.7	13.67
05561 00325	1994/05/24	04:39:41	14 14 03.482	-13 27 23.184	3.938	-12.2	12.77
05561 00124	1994/06/04	08:56:24	14 10 54.996	-13 02 01.032	-.486	-8.9	14.30
05561 00317	1994/06/08	16:45:29	14 10 03.019	-12 53 23.892	19.296	-7.4	14.94
05558 01048	1994/07/04	09:16:14	14 09 23.275	-12 23 44.124	15.248	5.2	10.26
05558 00988	1994/07/14	14:22:26	14 11 35.230	-12 20 12.264	-9.669	11.5	14.40
05558 00778	1994/07/17	16:05:26	14 12 45.826	-12 17 30.804	8.453	19.2	13.18

Table 7. Appulses by fragment 14

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00354	1994/01/28	17:53:01	14 35 19.162	-16 00 58.356	2.391	14.9	15.08
06153 00876	1994/01/31	17:04:23	14 36 21.905	-16 05 22.812	9.533	13.5	13.47
06153 01014	1994/02/04	08:39:59	14 37 31.541	-16 10 00.948	25.938	11.7	14.66
06153 00820	1994/02/10	00:50:58	14 39 01.375	-16 16 20.820	12.635	9.0	11.45
06153 00690	1994/02/13	04:55:13	14 39 41.659	-16 19 16.860	-7.874	7.5	14.93
06154 00014	1994/02/20	22:41:28	14 40 51.230	-16 22 41.232	19.817	3.7	15.37
06154 01018	1994/03/14	21:26:59	14 40 10.822	-16 14 05.892	6.098	-6.0	14.23
06153 01085	1994/03/20	18:36:24	14 39 02.431	-16 06 38.556	16.078	-8.2	14.46
06153 00169	1994/04/02	13:29:54	14 35 20.647	-15 44 17.448	8.780	-12.2	14.82
06153 00317	1994/04/06	00:23:36	14 34 06.151	-15 36 52.596	5.526	-13.1	13.14
06153 00138	1994/04/06	08:21:25	14 33 58.867	-15 36 02.664	11.127	-13.1	14.19
06153 00183	1994/04/07	03:58:00	14 33 40.181	-15 34 18.228	3.615	-13.3	14.95
06153 01162	1994/04/07	08:26:46	14 33 36.002	-15 33 49.752	6.656	-13.4	14.80
06153 00427	1994/04/10	11:27:55	14 32 22.925	-15 26 18.096	16.536	-14.0	15.09
06152 00125	1994/04/14	22:26:06	14 30 32.722	-15 15 08.892	17.018	-14.7	14.54
06152 00113	1994/04/15	20:13:59	14 30 09.221	-15 13 00.624	3.148	-14.8	15.18
06152 00018	1994/04/16	14:14:34	14 29 49.836	-15 11 06.756	-1.066	-15.0	11.77
06152 00702	1994/04/16	15:51:37	14 29 48.763	-15 10 33.384	23.631	-15.0	15.28
06152 00792	1994/04/18	05:10:48	14 29 08.150	-15 06 36.396	12.653	-15.1	12.51
06152 00079	1994/04/19	11:39:13	14 28 35.064	-15 03 05.760	19.212	-15.2	12.41
05574 00224	1994/05/01	18:52:01	14 23 05.309	-14 28 48.360	3.361	-15.6	13.32
05574 00738	1994/05/05	08:00:14	14 21 31.162	-14 18 36.288	4.064	-15.4	12.40
05574 00287	1994/05/06	20:34:44	14 20 51.223	-14 14 15.792	2.191	-15.3	13.72
05574 00233	1994/05/11	11:53:23	14 18 53.138	-14 00 57.816	9.981	-14.8	10.51
05574 00184	1994/05/11	23:53:00	14 18 40.210	-13 59 49.812	-7.939	-14.7	12.13
05561 01493	1994/05/17	10:02:49	14 16 30.744	-13 44 52.116	-7.236	-13.7	15.27
05561 00458	1994/06/10	15:45:27	14 09 44.998	-12 49 56.208	-7.910	-6.7	14.24
05561 01379	1994/06/20	07:13:54	14 08 47.856	-12 35 33.216	8.062	-3.3	15.06
05558 01048	1994/07/03	20:52:32	14 09 23.275	-12 23 44.124	.558	5.0	10.26
05558 01286	1994/07/09	23:10:38	14 10 27.931	-12 20 56.616	2.249	8.3	15.02
05558 00729	1994/07/17	02:35:57	14 12 34.783	-12 17 15.828	-3.244	25.8	12.67
05558 01438	1994/07/18	21:54:18	14 13 16.334	-12 13 13.656	-1.036	6.0	15.27

Table 8. Appulses by fragment 15

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00354	1994/01/28	17:08:57	14 35 19.162	-16 00 58.356	-7.506	14.9	15.08
06153 00710	1994/01/31	12:00:17	14 36 18.838	-16 04 42.312	25.584	13.6	13.64
06153 00876	1994/01/31	16:15:19	14 36 21.905	-16 05 22.812	-.616	13.5	13.47
06153 01101	1994/02/01	02:00:24	14 36 30.482	-16 05 37.140	20.868	13.3	13.65
06153 01014	1994/02/04	07:43:04	14 37 31.541	-16 10 00.948	15.536	11.8	14.66
06153 00941	1994/02/08	23:43:28	14 38 47.494	-16 15 06.372	20.605	9.5	11.85
06153 00820	1994/02/09	23:33:50	14 39 01.375	-16 16 20.820	1.859	9.0	11.45
06154 00014	1994/02/20	19:15:15	14 40 51.230	-16 22 41.232	9.141	3.8	15.37
06154 00839	1994/03/13	14:26:18	14 40 24.245	-16 15 07.848	15.208	-5.5	15.55
06153 00647	1994/03/17	21:55:34	14 39 40.030	-16 10 13.512	19.693	-7.2	13.90
06153 01085	1994/03/20	20:01:57	14 39 02.431	-16 06 38.556	-.619	-8.3	14.46
06153 00814	1994/03/21	14:28:22	14 38 52.210	-16 05 17.808	15.118	-8.5	14.78
06153 00717	1994/03/22	17:24:02	14 38 35.983	-16 03 38.052	14.452	-8.9	15.58
06153 00747	1994/03/28	15:13:40	14 36 58.394	-15 53 37.680	18.495	-10.8	15.26
06153 01150	1994/04/01	23:05:58	14 35 34.730	-15 45 09.360	21.095	-12.0	15.28
06153 00138	1994/04/06	09:21:21	14 33 58.867	-15 36 02.664	-7.564	-13.2	14.19
06153 00427	1994/04/10	12:26:09	14 32 22.925	-15 26 18.096	-2.690	-14.0	15.09
06152 00125	1994/04/14	23:23:03	14 30 32.722	-15 15 08.892	-2.847	-14.7	14.54
06152 00702	1994/04/16	16:48:14	14 29 48.763	-15 10 33.384	3.459	-15.0	15.28
06152 00792	1994/04/18	06:07:17	14 29 08.150	-15 06 36.396	-7.761	-15.1	12.51
06152 00079	1994/04/19	12:36:00	14 28 35.064	-15 03 05.760	-1.391	-15.3	12.41
05574 00494	1994/04/27	05:17:07	14 25 09.912	-14 41 30.444	11.617	-15.6	14.61
05574 00790	1994/05/03	10:33:55	14 22 23.621	-14 23 28.536	26.394	-15.5	14.46
05574 00795	1994/05/10	01:28:45	14 19 31.066	-14 04 44.796	12.016	-15.0	14.23
05574 00645	1994/05/10	08:56:45	14 19 23.549	-14 03 41.004	23.985	-14.9	15.07
05574 00267	1994/05/12	09:01:47	14 18 33.293	-13 58 11.856	13.453	-14.6	13.75
05561 00342	1994/05/14	23:54:39	14 17 29.813	-13 50 55.608	12.707	-14.2	15.02
05561 00759	1994/05/25	17:15:55	14 13 38.198	-13 23 06.684	-.283	-11.8	15.62
05561 00274	1994/05/31	07:11:10	14 12 00.139	-13 10 05.556	-1.298	-10.2	14.02
05561 00071	1994/06/05	19:01:38	14 10 41.952	-12 58 19.092	15.899	-8.4	12.24
05561 01299	1994/06/11	07:26:05	14 09 42.214	-12 48 15.372	11.958	-6.5	14.19
05561 01157	1994/06/22	09:48:37	14 08 46.325	-12 32 49.704	-1.676	-2.7	14.28
05558 01492	1994/07/10	03:32:06	14 10 34.231	-12 20 09.024	13.774	8.5	15.02
05558 00514	1994/07/17	06:21:31	14 12 42.420	-12 15 37.008	15.577	14.5	13.51

Table 9. Appulses by fragment 17

GST No.	Date	UT	$\alpha$ (2000.0)	$\delta$ (2000.0)	IP arcsec	V km/s	Mag
06153 00830	1994/01/30	11:44:25	14 35 58.908	-16 03 11.376	15.441	14.1	13.82
06153 00710	1994/01/31	11:01:01	14 36 18.838	-16 04 42.312	10.499	13.6	13.64
06153 01101	1994/02/01	00:59:43	14 36 30.482	-16 05 37.140	5.739	13.3	13.65
06153 01014	1994/02/04	06:33:53	14 37 31.541	-16 10 00.948	.118	11.8	14.66
06153 00941	1994/02/08	22:15:48	14 38 47.494	-16 15 06.372	4.669	9.5	11.85
06153 00824	1994/02/11	05:05:28	14 39 19.644	-16 16 52.824	23.592	8.4	15.27
06154 00014	1994/02/20	15:08:10	14 40 51.230	-16 22 41.232	-7.056	3.9	15.37
06154 00839	1994/03/13	16:41:37	14 40 24.245	-16 15 07.848	-8.146	-5.6	15.55
06154 00906	1994/03/15	16:53:09	14 40 05.568	-16 12 44.640	8.859	-6.3	12.65
06153 00647	1994/03/17	23:46:13	14 39 40.030	-16 10 13.512	-4.189	-7.2	13.90
06153 00679	1994/03/28	12:21:57	14 37 02.239	-15 53 35.448	16.453	-10.8	15.58
06153 00747	1994/03/28	16:36:26	14 36 58.394	-15 53 37.680	-7.124	-10.8	15.26
06153 01150	1994/04/02	00:22:59	14 35 34.730	-15 45 09.360	-5.346	-12.1	15.28
06153 01131	1994/04/03	02:03:04	14 35 13.308	-15 42 30.168	22.238	-12.3	15.05
06153 00114	1994/04/08	00:04:21	14 33 24.228	-15 31 55.308	.293	-13.5	15.16
06153 00402	1994/04/08	15:02:25	14 33 10.154	-15 30 13.464	15.759	-13.6	15.45
06153 00167	1994/04/09	02:17:03	14 32 58.860	-15 29 18.204	3.709	-13.7	13.89
06152 00938	1994/04/18	01:45:03	14 29 15.170	-15 06 39.600	-.746	-15.1	13.33
05574 00247	1994/04/26	19:43:28	14 25 23.119	-14 42 09.900	20.093	-15.6	15.13
05574 00350	1994/04/30	15:00:30	14 23 40.241	-14 31 41.088	-4.625	-15.6	15.50
05574 00408	1994/05/01	09:23:37	14 23 20.544	-14 29 02.616	24.385	-15.6	15.46
05574 00790	1994/05/03	11:52:24	14 22 23.621	-14 23 28.536	-7.180	-15.5	14.46
05574 00264	1994/05/05	04:20:28	14 21 39.888	-14 18 11.232	21.726	-15.4	13.99
05574 00720	1994/05/06	06:36:34	14 21 10.826	-14 15 15.120	8.019	-15.3	15.50
05574 00337	1994/05/11	11:36:56	14 18 58.344	-14 00 08.028	26.798	-14.7	15.31
05561 00866	1994/05/14	15:54:33	14 17 39.763	-13 51 47.304	-8.432	-14.3	14.46
05561 00377	1994/05/18	20:56:32	14 16 02.626	-13 40 19.452	-6.331	-13.4	12.79
05561 00609	1994/05/24	03:26:08	14 14 12.216	-13 26 22.884	14.986	-12.2	15.64
05561 00986	1994/05/27	04:03:12	14 13 14.842	-13 18 50.148	24.642	-11.4	15.62
05561 00121	1994/05/27	17:54:23	14 13 04.438	-13 17 26.376	26.200	-11.3	11.76
05561 00258	1994/06/04	17:57:18	14 10 57.799	-13 00 18.504	-8.026	-8.8	12.86
05561 00059	1994/06/09	18:06:12	14 10 00.698	-12 50 21.696	22.467	-7.0	11.21
05561 01422	1994/06/12	19:40:58	14 09 33.151	-12 45 14.472	16.185	-5.9	15.45
05558 01046	1994/07/04	04:04:03	14 09 33.648	-12 22 18.516	11.277	5.3	14.89



Although the predicted times in Tables 1–9 are given to the nearest second, their accuracy depends on the precision of the stellar and cometary positions. Cometary positions are constantly updated based on new observed positions and it is never possible to predict their positions much ahead in advance. The stellar positions<sup>12</sup> have an uncertainty of about 0.45 arcsec. If the cometary positions are accurate to only about 0.1 arcmin, the predictions for the fast events with sky plane velocities of 16 km/s may be in error by 38 min. The slower events with sky plane velocities as low as 2.5 km/s may be off by 3.8 hours. The impact parameters may similarly be in error by about 6 arcseconds. Therefore to provide scope for revision of the present prediction when more precise positions of the fragments are available, the search was extended to 10 arcsec to the south and to a larger limit of 30 arcsec to the north along the direction of the tail. The predictions extend until the time of impact with Jupiter in July<sup>13</sup> for completeness, however the late June and July events would be difficult to observe due to scattered light from Jupiter. The appulse of the relatively bright star GSC 06152 00670 of magnitude 7.09 to fragment 7 would be of special interest as this can be monitored by obtaining a series of low resolution CCD spectra to investigate the wavelength dependence of the extinction.

### Updating the predictions

The correction  $\Delta T$  to be applied to the tabulated timings when the current position  $(\alpha_0, \delta_0)$  of the fragment at the event time is updated to  $(\alpha', \delta')$  can be calculated using the relation,

$$\Delta T = \frac{\pi \cdot s \cdot \cos(P - E) \cdot d}{180 \cdot |V|}, \quad (1)$$

where  $d$  is the geocentric distance of the comet. The angular distance  $s$  (degrees) and position angle  $E$  (with respect to the direction of the celestial north) of the new position with respect to the old position are given by

$$s = [225 (\alpha' - \alpha_0)^2 \cos^2 \delta_0 + (\delta' - \delta_0)^2]^{1/2} \quad (2)$$

$$E = \arctan \left( \frac{15(\alpha' - \alpha_0) \cos \delta_0}{(\delta' - \delta_0)} \right) \quad (3)$$

The position angle  $P$  of the sky plane velocity vector of the fragment measured from the celestial north is given by

$$P = \arctan \left( \frac{15(\alpha_1 - \alpha_0) \cos \delta_0}{(\delta_1 - \delta_0)} \right), \quad (4)$$

where  $(\alpha_1, \delta_1)$  are the coordinates of the comet after an arbitrary length of time (approximately one hour for slow events and about 20 min for fast events).

The correction  $\Delta IP$  (arcsec) to the impact parameter can be obtained from

$$\Delta IP = \pm s \cdot \sin(P - E) 3600, \quad (5)$$

where the negative sign applies to eastward motion of the comet, and positive sign to its motion westwards.

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