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HARVARD COLLEGE OBSERVATORY
AND THE
NUMERICAL ANALYSIS LABORATORY
OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

TECHNICAL REPORT NUMBER TEN

A COMPARATIVE ANALYSIS OF ATMOSPHERIC
DENSITIES FROM METEOR DECELERATIONS
OBSERVED IN MASSACHUSETTS AND NEW MEXICO

BY
LUIGI G. JACCHIA

CAMBRIDGE, 1952

HARVARD COLLEGE OBSERVATORY AND THE NUMERICAL ANALYSIS LABORATORY
OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Report Number Ten

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FOREWORD

The meteor photographs which form the basic material of this report were taken at the Meteor Stations of the Harvard College Observatory under Task D of NOrd 8555 and Task I of NOrd 10449 for the U.S. Naval Bureau of Ordnance, and now under NSori-07647 for the Office of Naval Research. The measurement and reduction of the plates and the analysis of the resulting data was done at the Numerical Analysis Laboratory (formerly Center of Analysis) of the Massachusetts Institute of Technology under Tasks D and I of NOrd 8555 and of NOrd 10455 and Task A of NOrd 10455 for the U.S. Naval Bureau of Ordnance, and now under DA-19-020-ORD 1093 of the Office of Ordnance Research, U.S. Army.

The persons involved in the project were:

a) At the Harvard Stations:

Harlow Shapley, Director of the Harvard College Observatory
Fred L. Whipple, Project Director
Frances W. Wright, in charge of plate inspection and records
Richard E. McCrosky, observer-in-charge at the New Mexico Stations.

Following is a list of the observers at the New Mexico Stations; the number in parenthesis indicates the number of months served prior to January 1951 (date of the last plate included in this report):

Philip S. Carroll (29), Peter O. Cioffi (12), Keith Guard (2),
Irwin Levitan (4), Gunther Schwartz (6), Harlan J. Smith (4),
Henry J. Smith (2).
Plate inspectors in New Mexico: Catherine Carroll (29), Juanita Engle (7).

b) At the M.I.T. Numerical Analysis Laboratory:

Zdeněk Kopal, Director of the M.I.T. Numerical Analysis Laboratory and Project Director until June 1951.
Luigi G. Jacchia, Project Supervisor until June 1951; Director of the M.I.T. Numerical Analysis Laboratory and Project Director after July 1951.

Computers: Virginis K. Brenton, Robert E. Briggs, Jeannie R. B. Carmichael, Francis G. Davoren, Diana H. Mason, Laurelle B. Parrotta, Dorothy T. Pemberton, Louise Richardson, Martha B. Shapley.

Occasional Computers: Mary H. Baker, David D. Brown, Carolyn S. Littlejohn, Helen M. Pillana, Anita Porell, Sidney Shapiro, Charlotte G. Treuenfels.

Assistant Computers: Heather L. Bassett, Helen M. Carr, Belle J. Helporn.

Most of the computations involved in the present report were performed by Mr. Briggs, Miss Carmichael and Miss Pemberton.

Much of the information concerning the first fifteen Massachusetts meteors (Table II) was supplied by Dr. F. L. Whipple, who had reduced them before the inception of the present project.

ABSTRACT

Velocities, accelerations and integrated luminosities were determined on photographic plates for 46 Massachusetts meteors and 73 New Mexico meteors. Atmospheric densities, computed from the New Mexico meteors in the same general fashion as in Technical Report No. 2, are in good agreement with the slope of the density profile derived from V-2 rockets; however, in analogy with the previous results for Massachusetts meteors, the residuals from the rocket curve are strongly dependent on velocity. A change of one full power in v in the fundamental equation is needed to make the residuals independent of velocity, but then the slope of the density curve diverges considerably from the rocket profile. The introduction of an empirical scale factor R reduces the velocity-free densities back again to the rocket profile. These final densities show only a slight seasonal effect, if any.

Massachusetts observations were reduced using the same constants as for New Mexico. The final densities are in good agreement with the New Mexico densities up to 75 km, but above that height the Massachusetts densities are systematically higher. The seasonal effect is more than twice as large for the Massachusetts observations as for New Mexico. The bad distribution of the Massachusetts meteors with regard to seasons, velocities and heights should, however, suggest some caution in interpreting this last result.

1. The Observational Material:

Only double-station meteors are included in the present report. All photographs through August 11, 1948, were taken in Massachusetts, from the Cambridge and Oak Ridge (now Agassiz) stations, for which co-ordinates are given below:

Station	Oak Ridge (Agassiz)	Cambridge
λ (Greenw.)	71°33'29".82	71° 7'45".45
ϕ	+42°30'20".72	+42°22'53".70
h	190.2 m.	18.3 m.

All photographs from August 14, 1949, inclusive, were taken in New Mexico, from the twin stations near Las Cruces, whose co-ordinates are:

Station	Doña Ana	Soledad Canyon
λ (Greenw.)	106°47'58".50	106°36'42".32
ϕ	+ 32°30'21".94	+ 32°18'13".61
h	1412.3 m.	1567.4 m.

The baseline between the Massachusetts stations is 37.896 km long; the baseline in New Mexico measures 28.567 km.

The cameras with which the meteors were photographed are listed in Table I.

TABLE I

Meteor Cameras

a) Massachusetts

Oak Ridge (Agassiz)					Cambridge				
Camera	Ap.	f	r.p.m.	n	Camera	Ap.	f	r.p.m.	n
AI	1.5	6	600	2	FA	1.5	6	600	2
KB	3.0	7	1200	2	KA	3.0	7	1800	2
*AC	1.5	13	0	0	KL	1.5	6	630.5	4
*MC	16	83	0	0					

b) New Mexico

Doña Ana					Soledad Canyon				
Camera	Ap.	f	r.p.m.	n	Camera	Ap.	f	r.p.m.	n
AI	1.5	6	740	4	FA	1.5	6	630	4
KB	3.0	7	1800	2	KA	3.0	7	1200	2
KF	3.0	7	1800	2	KE	3.0	7	1200	2
KH	3.0	7	0	0	KG	3.0	7	0	0

Ap. and f are the aperture and the focal length, in inches; r.p.m. is the number of revolutions per minute of the rotating shutter associated with the camera, and n is the number of measurable features (breaks and/or dots) per shutter revolution. The cameras marked with an asterisk are not regular meteor cameras, but other astronomical instruments on which the meteor was photographed by accident.

Basic data for all meteors are given in Tables II and III. The Massachusetts material includes 63 meteors. Of these, 46 could be used to determine velocities and deceleration and yielded 86 atmospheric densities. The New Mexico material comprised 83 meteors, 73 of which yielded 168 density values.

The following is an explanation of those columns in Tables II and III which are not self-explanatory. Q is the angle of intersection on the celestial sphere of the two meteor trails, Z_R is the zenith distance of the apparent radiant, v_∞ and m_∞ are the extrapolated velocity (in km/sec) and mass (in grams) of the meteor before it entered the earth's atmosphere; t is the duration of the meteor as photographed from station A (Oak Ridge in Massachusetts, Doña Ana in New Mexico), $M_{v_{in}}$ is the magnitude, reduced to the visual scale, which the meteor attained at maximum light.

In the "shower" column all those meteors which do not belong to well-recognized showers were listed as sporadic. There are, however, two new showers in the list:

1) The Virginids, based on three meteors in 1939, 1942 and 1950, all between March 18 and March 21, with geocentric velocities of about 31 km/sec. Approximate radiant: $\alpha = 185^\circ$, $\delta = +55^\circ(1950.0)$.

2) The χ Cygnids, based on four 1950 meteors between August 19 and August 22; geocentric velocity 27 km/sec, radiant: $\alpha = 292^\circ$, $\delta = +55^\circ(1950.0)$.

The fundamental data used in the computation of atmospheric densities are given in Tables IVa and IVb for Massachusetts and Va and Vb for New Mexico meteors. In these tables $Fr.$ indicates the fraction of the tropic year, ϕ the parameter $360^\circ \times Fr.$, v the velocity in km/sec, dv/dt the acceleration in km/sec², $p.e.$ the probable error of the acceleration; the three last quantities were taken at the center of a least-squares solution involving n shutter breaks (form of the equation of condition: $D = a + bt + ct^2$; D = distance of break in space from a

fixed point, t = time, k = a pre-determined constant). H is the height above sea level, in km, and m the mass of the meteor in grams at the time for which v and dv/dt were taken. The meaning of ρ_1 , ρ_2 , ρ_3 and ρ_4 is explained in section 2; p and w are the weights computed according to equations (3) and (4), respectively. Δ_1 , Δ_2 , Δ_3 , Δ_4 are the residue of $\log \rho_1$, $\log \rho_2$, $\log \rho_3$ and $\log \rho_4$ from profile C (Table VI); Δ'_3 and Δ'_4 (for Massachusetts) are residuals of $\log \rho_3$ and $\log \rho_4$ from profile M.

Data pertaining to heights up to 90 km are to be found in Tables IVa and Va; Tables Va and Vb give the equivalent information for heights greater than 85 km. Data for heights between 85 and 90 km can thus be found in both sets of tables, listed in different fashion. Although for the computation of the mean densities the data for $H > 85$ km were handled in groups rather than individually, some of the analyses required individual atmospheric densities up to 90 km; this explains the overlap between the tables.

Meteor No. 2278 (New Mexico, 1950 Dec. 11.2) deserves a special mention. This meteor skimmed the upper atmosphere with an angle of incidence of only 12° and a velocity of 59 km/sec. Its photographic length is 53° ; its first half was caught by the AI and FA cameras, while the second half was recorded by the KE camera. On both the AI and the FA plates the trail is extremely long and extends from a point not far from the center clear to the edge of the field. The acceleration computed from both plates is small, but positive, and in our opinion this is due to the progressive change in the images of comparison stars and breaks from the center to the edge. The large number of breaks on these exceptionally long trails makes these spurious accelerations much larger than their probable errors and this, in turn, would lead to unduly high weights for the resulting (negative) atmospheric densities, with the danger of vitiating the analysis. In view of this situation, it was deemed necessary to eliminate the AI and FA densities for this meteor from the present investigation.

2. Atmospheric Densities from Meteor Data; Weights and Weighted Means:

In a first approximation the atmospheric densities ρ were computed in the same fashion as in Technical Report No. 2⁽¹⁾, using the formula

$$\rho = -K m^{\frac{1}{3}} v^{-2} \frac{dv}{dt} \quad (1)$$

The mass m was computed by equation (9) of Technical Report No. 2, which shall be repeated here for easy reference:

$$m = \frac{2}{\tau_0} \int_t^{\infty} \frac{I}{v^3} dt \quad (2)$$

τ_0 is the luminous-efficiency coefficient and I the visual intensity of the meteor⁽⁴⁾, derived from the photographic magnitude with the correction $+1.8^\circ$. For a detailed description of the photometric methods followed, see Technical Report No. 3⁽²⁾, pages 5-11. The densities thus computed, using $K = 1$, are designated as ρ_1 .

Each individually determined acceleration was used to obtain a value of ρ_1 . Accelerations determined from different plates for the same meteor were treated independently of each other. If one photographic trail yielded two or more decelerations, these were also handled separately.

The basic quantities which enter into the computation of ρ_1 are affected by observational errors in varying degrees. While the velocity v is always known to an accuracy of 1% or better, the acceleration dv/dt may have probable errors ranging from 0.01 to 10 times its actual value, and the reliability of the probable error itself will vary according to the number of shutter breaks used to compute the acceleration. The mass m , which is a function of the integrated light intensity, has an element of uncertainty in the extrapolation to zero of the intensity curve at the very end of the trajectory. This uncertainty is reflected in a

⁽¹⁾Twenty-five New Mexico meteors for which both visual and photographic magnitudes were available confirm this correction. Their mean is $+1.89$.

TABLE II

Basic Data for Massachusetts Meteors

No.	Yr.	Date	App. Rad. 1950.0 α δ	Sin θ	Cos θ	V_0 (km/sec.)	m	τ	M_{vis}	Height (km) Eng. Max L. End	Shower	Plates + n of breaks
1173	1942	Aug. 5.1839	36 26' +56° 1'	0.269	0.571	61.0	0.17	0.53	-3.1	98.0	Persid	AI 37612 (8), FA 6771 (0)
1180	1942	Oct. 4.1531	311 5 +46 19	0.198	0.850	20.7	23.9	1.45	-4.0	91.0	Sporadic	AI 37777 (23), FA 7010 (16)
1193	1942	Dec. 8.2665	144 18 +38 25	0.213	0.839	61.5	7	0.24	-5.3	91.2	Sporadic	AI 37977 (3), FA 7229 (4)
1205	1943	May. 25.2283	256 26 -14 19	0.143	0.546	33.3	183 7	1.83	-7.0	86.1	Sporadic	AI 38208 (22), FA 7586 (30)
1377	1943	Aug. 7.1964	37 29 +56 17	0.221	0.608	61.1	4.5	0.53	-6.7	100.6	Sporadic	AI 38299 (0), FA 7715 (9)
1257	1944	Jan. 22.3936	117 33 +15 35	0.138	0.386	22.6	30 :	1.64	-2.4	88.1	Sporadic	AI 38543 (16), FA 8144 (0)
1365	1944	May 13.1963	203 29 +45 37	0.577	0.944	14.47	20 7	1.177	-1.67	88.4	Sporadic	AI 38849 (11), FA 8321 (0)
1241	1944	Dec. 10.0740	84 23 +19 25	0.185	0.666	29.5	9.5	1.46	-4.8	97.3	Sporadic	AI 39253 (21), FA 8683 (13)
1265	1944	Dec. 14.2180	113 11 +32 16	0.277	0.904	36.5	9.7	1.03	-5.2	94.3	Geminid	AI 39263 (14), FA 8693 (0)
1242	1945	Feb. 6.2168	45 36 +75 43	0.790	0.632	12.2	-	5.21	-0.6	74.9	Sporadic	AI 39336 (69), FA 8806 (0)
1243	1945	Feb. 6.3046	149 2 +14 49	0.785	0.818	28.5	12.9	2.27	-3.1	95.5	Sporadic	AI 39337 (35), FA 8808 (25)
1273	1945	Aug. 11.3427	45 14 +57 50	0.908	0.898	60.5	0.11	0.58	-3.3	112.8	Persid	AI 39642 (9), FA 9074 (7)
1275	1945	Aug. 12.3185	45 31 +56 32	0.430	0.866	60.6	0.42	0.36	-5.4	102.2	Persid	AI 39646 a (6), FA 9080 a (0)
1276	1945	Aug. 12.3486	46 48 +57 22	0.463	0.904	59.3	0.15	0.41	-3.2	104.1	Persid	AI 39646 b (6), FA 9080 b (0)
1362	1946	Oct. 23.2864	95 27 +15 40	0.147	0.779	66.3	0.15	0.41	-2.7	103.4	Orionid	AI 40572 (6), FA 9976 (0)
1360	1946	Nov. 19.3397	153 53 +21 7	0.182	0.727	-	0.47	0.35	-4.0	107.4	Leonid	AI 40647 (7), FA 10053 (0)
1447	1946	Nov. 20.2869	154 32 -21 2	0.233	0.544	72.3	0.33	0.37	-4.7	104.5	Leonid	AI 40653 (5), FA 10061 (6)
1469	1947	Aug. 13.2356	47 2 +58 35	0.442	0.690	60.3	1.3	0.73	-6.2	108.2	Persid	AI 41121 (5), FB 76 (27), FA 10243 (8)
1514	1947	Oct. 12.2991	348 22 +10 45	0.382	0.399	15.5	-	3.95	-0.1	74.8	Sporadic	AI 41274 (26), MB 174 (32), FA 10331 (0)
1526	1947	Nov. 11.3569	51 37 +13 57	0.055	0.573	27.2	210	1.20	-7.4	92.8	Taurid	AI 41351 (20), FA 10448 (0)
1527	1947	Nov. 15.3717	61 10 +16 19	0.055	0.598	26.9	2.5	0.63	-2.7	72.8	Taurid	AI 41362 (8), MB 242 (18), FA 10471 (0)
1544	1947	Dec. 10.0052	74 59 +18 31	0.203	0.492	25.1	45.4	3.06	-4.6	93.3	Sporadic	AI 41394 (54), MB 283 (113), FA 10519 (27), MA 452 (0)
1542	1947	Dec. 14.1643	67 40 +64 27	0.618	0.927	23.9	16.4	1.62	-2.6	85.4	Sporadic	AC 40558 (0), MB 309 (0), FA 10556 (23), MA 488 (48)
1539	1947	Dec. 14.1979	113 12 +32 46	0.294	0.895	36.3	140	1.83	-6.5	97.6	Geminid	AI 41417 (27), FA 10557 (31)
1550	1947	Dec. 14.2920	113 53 +32 23	0.417	0.904	36.7	5.9	0.86	-4.4	97.3	Geminid	AI 41418 (10), FA 10559 (8)
1556	1947	Dec. 17.3502	201 1 +78 58	0.425	0.731	35.2	1.1	0.83	-2.0	104.4	Sporadic	AI 41427 (9), MB 323 (22), FA 10576 (9), MA 508 (19)
1587	1948	Mar. 18.3211	254 24 +12 11	0.112	0.736	68.7	1.03	0.40	-6.1	112.7	Sporadic	AI 41560 (8), FA 10675 (0)
1608	1948	Aug. 11.2875	44 18 +49 53	0.311	0.812	58.77	19.9	>0.75	-8.2	110.9	Persid	AC 40802 (0), ML 64 (31)

TABLE III

Basic Data for New Mexico Meteors

No.	Yr.	Date	App. Rad.	1950.0	Sin Q	Con Z _q	No (km/sec)	m	t	M _{mn}	Height (km) Avg. Max L. End	Shower	Plasma = 2.5 Sec
1648	1949	Aug. 16.4315	52 28	+59 34	0.428	0.785	61.5	0.13	0.52	-2.7	111.5	Perseid	AI 41670 (5), FA 10769(0)
1693	1949	July 2.2762	287 11	-41 6	0.229	0.262	28.54	11.8	3.92	-2.0	98.0	Sporadic	AI 41921 (27), FA 11107 (18)
1722	1949	July 27.3445	323 9	-12 48	0.385	0.703	41.3(?)	0.97	0.64	-3.7	99.1	Sporadic	AI 41975 (5), FA 11160 (8)
1735	1949	July 39.3779	7 46	+21 21	0.019	0.870	64.29	0.17	0.41	-2.6	98.1	Sporadic	KB 715 (0), FA 1079 (13)
1695	1949	Aug. 1.3512	314 9	-9 35	0.123	0.713	25.87	3.5	1.40	-1.6	84.1	Sporadic	AI 42011 (10), FA 11196 (12)
1728	1949	Aug. 1.3704	307 46	+5 39	0.183	0.385	23.77	1.5	0.56	-0.8	98.6	Sporadic	KB 737 (9), FA 1043 (0)
1794	1949	Aug. 6.4684	39 15	+59 16	0.101	0.859	62.2	0.1	0.25	-4.5	92.0	Perseid	KB 757 (5), FA 1051 (8)
1825	1949	Aug. 16.357	48 6	-8 47	0.126	0.309	64.5	0.61	1.26	-3.3	117.0	Sporadic	AI 42064 (5), FA 11267 (5)
1756	1949	Aug. 21.3825	359 21	-7 46	0.169	0.763	40.8	0.11	0.26	-0.5	98.7	Sporadic	KB 838 (9), FA 1146 (7)
1755	1949	Aug. 25.3757	38 33	-6 45	0.059	0.607	65.0(?)	0.17	0.47	-3.7	110.7	Sporadic	KB 863 (10), FA 1171 (12)
1736	1949	Sept. 2.5.2747	57 41	+84 48	0.279	0.570	43	-	0.39	-0.3	92.2	Sporadic	AI 42218 (4), FA 11404 (0)
1841	1949	Sept. 26.4517	86 30	+27 47	0.204	0.922	69	0.034	0.28	-1.5	107.5	Sporadic	AI 42228 (3), FA 11417 (0)
1740	1949	Oct. 19.4881	147 34	+20 59	0.022	0.685	65.44	0.48	0.86	-4.0	107.7	Sporadic	AI 42238 (3), FA 1319 (29)
1751	1949	Oct. 25.3116	97 31	+16 4	0.238	0.567	-	0.22	0.50	-3.5	115.0	Sporadic	AI 42345
1780	1949	Oct. 30.3845	49 40	+21 42	0.138	0.934	30.82	2.5	1.25	-4.4	97.1	Sporadic	AI 42345
1853	1949	Oct. 31.3315	46 19	+20 31	1.000	0.975	31.98	0.21	1.45	+1.0	98.2	Sporadic	AI 42345
1932	1949	Nov. 27.4940	90 24	+16 22	0.206	0.716	45.8	0.33	0.46	-1.8	102.2	Sporadic	AI 42345
1844	1949	Dec. 13.2894	111 6	+32 34	0.896	0.892	37.4	0.15	0.58	0.0	105.0	Sporadic	AI 42345
1850	1949	Dec. 13.1702	110 11	+32 50	0.350	0.485	37.5	0.46	0.61	-0.7	96.6	Sporadic	AI 42345
1863	1949	Dec. 14.3257	114 28	+33 5	0.113	0.951	36.1	-	>0.76	-	98.8	Sporadic	AI 42345
1851	1949	Dec. 14.3794	115 52	+31 58	0.628	1.000	36.27	39.5	1.38	-7.0	101.4	Sporadic	AI 42345
1865	1949	Dec. 15.3697	Shower	rad.	0.032	0.999	36.9	0.038	0.27	-1.3	88.9	Sporadic	AI 42345
1918	1950	Jan. 20.4352	185 44	+20 31	0.457	0.945	64.70	0.031	0.33	-0.9	101.5	Sporadic	AI 42345
1913	1950	Jan. 20.5138	229 20	+66 11	0.220	0.781	31.66	2.17	1.25	-2.2	97.8	Sporadic	AI 42345
1968	1950	Jan. 23.3164	107 6	+15 27	0.650	0.896	19.66	0.87	0.86	+0.8	82.0	Sporadic	AI 42345
1992	1950	Jan. 24.4368	133 22	+10 10	0.434	0.924	38.20	0.55	0.68	-2.1	97.5	Sporadic	AI 42345
2007	1950	Jan. 27.4674	180 34	+2 31	0.271	0.803	31.07	0.53	0.84	-0.6	94.3	Sporadic	AI 42345
1984	1950	Mar. 18.4007	189 42	+2 59	0.421	0.667	31.86	0.71	0.77	-1.3	90.1	Sporadic	AI 42345
1987	1950	Mar. 23.3476	201 6	-15 36	0.543	0.667	31.86	0.71	0.77	-1.3	90.1	Sporadic	AI 42345
1954	1950	Apr. 17.2791	262 23	+14 36	0.332	0.950	22.44	0.74	0.34	-1.3	82.8	Sporadic	AI 42345
1997	1950	Apr. 21.3235	269 14	+34 7	0.14	0.743	(50.8)	0.11	0.56	-1.0	107.5	Sporadic	AI 42345
1910	1950	Apr. 21.3508	270 1	+33 0	0.429	0.813	50.84	0.24	0.69	-1.5	111.7	Sporadic	AI 42345
1922	1950	Apr. 21.3675	270 22	+32 53	0.265	0.858	47.76	0.27	0.57	-1.5	103.4	Sporadic	AI 42345
1920	1950	Apr. 21.3955	188 37	+56 33	0.070	0.709	14.37	-	2.83	-3.8	74.5	Sporadic	AI 42345
1998	1950	Apr. 22.3688	272 45	+33 15	0.178	0.822	48.71	0.27	0.47	-1.6	102.5	Sporadic	AI 42345
2009	1950	Apr. 22.3688	272 45	+33 15	0.178	0.822	48.71	0.27	0.47	-1.6	102.5	Sporadic	AI 42345
2024	1950	June 9.1973	234 54	+27 29	0.204	0.969	20.19	2.02	0.89	-1.7	90.0	Sporadic	AI 42345
2025	1950	June 9.2327	243 24	-36 6	0.183	0.356	22.21	2.6	2.03	-0.7	95.7	Sporadic	AI 42345
2050	1950	June 18.3470	301 15	+79 11	0.685	0.680	30.58	1.06	0.77	-1.0	83.6	Sporadic	AI 42345
2061	1950	June 25.3097	331 4	+28 58	0.148	0.702	62.08(?)	0.07	0.34	-1.6	109.0	Sporadic	AI 42345
2049	1950	Aug. 10.4394	46 2	+56 24	0.104	0.824	58.12	0.062	0.46	-1.6	111.7	Perseid	AI 42345

TABLE III

Basic Data for New Mexico Meteors

No.	Yr.	Date	App. Rad.	δ	α	Sin Q	Cos Z _q	V _o (km/sec)	m ₀	t	M ₀	Height (km)	Shower	Plates + n of breaks
2002	1950	Aug. 11.2144	195 33	+42 47		0.025	0.323	17.64	(6.8)	>3.4	0.0	>85.3	Sporadic	KF 199 (127), KA 1931 (77)
2004	1950	Aug. 11.4703	42 32	+55 32		0.325	0.890	61.38	0.05	0.40	-0.7	109.2	Perseid	KF 203 (32), KA 1935(14)
2003	1950	Aug. 13.3756	46 21	+57 24		0.209	0.710	60.92	0.89	0.65	-4.4	108.9	Perseid	AI 42796 (0), FA 12162 (23)
2046	1950	Aug. 13.4375	48 31	+56 50		0.381	0.820	60.74	0.19	0.48	-3.1	109.9	Perseid	AI 42797 (0), FA 12163 (17)
2078	1950	Aug. 19.1613	289 1	+54 4		0.612	0.921	27.17	0.583	0.55	-0.8	95.7	α Cygnid	AI 42803 (16), FA 12170 (14)
2067	1950	Aug. 20.3091	290 52	+55 2		0.038	0.801	26.06	35.4	1.00	-7.2	100.0	α Cygnid	KF 222 (85), KA 1961 (30)
2071	1950	Aug. 20.4069	295 46	+58 12		0.112	0.583	28.35	0.8	0.60	-0.7	96.2	α Cygnid	KF 223 (23), KA 1962 (12)
2009	1950	Aug. 21.4764	354 46	+5 51		0.041	0.705	43.1	0.58	0.53	-2.4	99.5	Sporadic	KF 229 (15), KA 1969 (16)
2105	1950	Aug. 22.3095	295 16	+54 19		0.068	0.817	26.99	0.88	0.77	-1.4	97.2	α Cygnid	KF 232 (32), KA 1972 (19)
2236	1950	Sept. 8.4158	11 19	+1 56		0.166	0.818	39.53	13.9	1.29	-4.6	96.4	Sporadic	AI 42832 (60), FA 12205 (52)
2468	1950	Oct. 16.2044	91 21	+47 59		0.286	0.297	65.42	0.397	0.82	-3.0	117.1	Sporadic	AI 42916 (36), FA 12314 (25)
2473	1950	Oct. 16.2352	31 22	+13 59		0.096	0.844	30.74	0.81	0.47	-1.8	93.3	Taurid	AI 42917 (16), FA 12315 (15)
2679	1950	Nov. 6.1648	102 31	-26 40		0.059	0.308	52.73	0.18	0.47	-1.6	107.1	Sporadic	KF 369 (47), KE 448 (19)
2624	1950	Nov. 6.4150	34 37	+8 29		0.194	0.585	21.04	16.3	2.54	-2.6	94.4	Sporadic	KB 1754 (0), KA 2140 (90)
2610	1950	Nov. 7.2111	47 7	-36 27		0.050	0.255	24.37	3.02	4.38	-5.7	100.3	Sporadic	AI 42959 (75), FA 12361 (80)
2630	1950	Nov. 7.3417	40 18	+27 38		0.141	0.944	27.16	25.4	1.41	-4.9	98.6	Taurid(?)	AI 42960 (50), FA 12362 (55)
2176	1960	Nov. 17.3917	152 43	+21 26		0.123	0.557	70.54(?)	0.20	>0.51	-2.0	>116.7	Leonid	AI 42987 (20), FA 12386 (12)
2179	1950	Nov. 17.4732	152 11	+23 0		0.036	0.863	72.86(?)	0.081	0.26	-2.5	111.5	Leonid	AI 42989(12), FA 12388 (6)
2181	1950	Nov. 18.4796	153 40	+21 32		0.471	0.871	71.92	0.055	0.33	-3.2	114.2	Leonid	KB 1789 (0), KA 2184 (11)
2239	1950	Dec. 9.2223	97 37	+17 41		0.151	0.711	44.34	2.01	1.06	-5.2	108.2	Sporadic	AI 42998 a (33), FA 12397 a (31)
2241	1950	Dec. 9.2259	87 25	+25 25		0.341	0.851	31.20	57.0	2.13	-6.9	98.2	Sporadic	AI 42998 b (60), FA 12397 b (67)
2260	1950	Dec. 10.3116	107 20	+31 24		0.186	0.940	39.30	0.0433	0.41	+0.1	98.8	Geminid	KB 1807 (7), KA 2202 (12)
2246	1950	Dec. 10.4090	105 16	+35 31(?)		0.010	0.979	33.0(?)	0.249	0.47	-1.2	91.6	Geminid(?)	KB 1810 (22), FA 2205 (16)
2278	1950	Dec. 11.2092	125 15	+2 38		0.043	0.208	59.57	13.0	2.79*	-6.6	113.0	Sporadic	AI 43021 (48), FA 12433 (55)**
2290	1950	Dec. 12.1277	108 57	+33 7		0.202	0.299	35.93	(?)	>1.78	3.2	101.8	Geminid	AI 43031 a (58), FA 12433 a (57)
2294	1950	Dec. 12.1281	68 8	+43 55		0.272	0.775	25.41	1.56	0.83	-1.4	85.6	Sporadic	AI 43031 b (83), FA 12433 b (83)
2292	1950	Dec. 12.1368	359 58	+36 19		0.293	0.944	14.80	-	2.54	-1.2	77.3	Geminid	AI 43033 a (22), FA 12435 a (26)
2298	1950	Dec. 12.2224	109 25	+31 14		0.392	0.684	35.3	1.15	0.97	-1.8	97.4	Geminid	KB 460 (73), KE 92 (0)
2548	1950	Dec. 13.1769	110 18	+32 53		0.282	0.509	36.12	0.85	1.39	-1.4	100.6	Sporadic	AI 43043 a (25), FA 12446 a (19)
2313	1950	Dec. 13.1998	102 3	+8 55		0.120	0.553	44.42	0.24	0.74	-1.2	107.9	Geminid	AI 43044 a (10), FA 12447 a (13)
2317	1950	Dec. 13.2392	110 40	+32 32		0.297	0.746	36.8	0.57	0.61	-1.6	95.6	Sporadic	AI 43045 c (22), FA 12448 c (11)
2328	1950	Dec. 13.2888	125 31	+1 1		0.094	0.585	50.95	1.26	0.89	-4.3	112.9	Geminid	AI 43045 b (46), FA 12448 b (36)
2326	1950	Dec. 13.2928	112 12	+32 33		0.121	0.891	36.34	16.4	1.21	-5.0	92.3	Sporadic	AI 43048 (34), FA 12451 (12)
2349	1950	Dec. 13.4000	82 32	+17 13		0.068	0.809	33.85	556.0	2.20	-8.6	94.0	Sporadic	KF 472 (23), KE 114 (0)
2357	1950	Dec. 14.2557	91 31	+22 52		0.462	0.919	31.94	0.192	0.44	-0.3	89.3	Geminid	AI 43055 b (51), FA 12459 b (44)
2359	1950	Dec. 14.2851	112 52	+32 19		0.182	0.873	36.18	5.2	1.32	-3.3	92.7	Geminid	KF 473 b (37), KE 114 (0)
2591	1950	Dec. 14.2903	112 41	+32 23		0.636	0.888	36.80	0.081	0.42	+0.3	98.2	Geminid	AI 43055 a (47), FA 12459 a (47)
2357	1950	Dec. 14.3080	113 8	+32 43		0.374	0.925	35.87	3.2	1.43	-2.8	99.1	Geminid	AI 43057 a (7), FA 12461 a (23)
2377	1950	Dec. 14.3854	113 47	+32 22		0.201	1.000	36.35	1.8	0.95	-1.9	98.2	Sporadic	KF 481 (58), KA 2235 (14)
2411	1950	Dec. 15.1958	110 57	+10 24		0.255	0.461	39.73	0.64	1.15	-1.3	98.4	Quadrantid	AI 43074 (19), FA 12476 (0)
2660	1951	Jan. 3.3593	228 15	+48 18		0.368	0.314	44.07	0.203	0.54	-0.8	99.4		

* See remarks about this meteor in the text, section 1.

** Also KE 510 (56)

TABLE IV.

Data Used in the Computation and Analysis of

Atmospheric Densities in Massachusetts ($H < 90$ Km)

No.	Plate	Yr.	Fr.	ϕ	γ (km/sec)	$\frac{d\gamma}{dt}$ (km/sec ²)	p.a.	m	n	p	H (km)	$\log \rho_1$	Δ_1	$\log \rho_2$	Δ_2	$\log \rho_3$	Δ_3	Δ'_3	$\log \rho_4$	Δ_4	Δ'_4	Shower
1339	FA 10557	1947	.951	342°	30.67	-20.71	+0.76	45.5	7	2	47.1	-6.10	-27	-6.09	-26	-5.71	+12	+06	-5.69	+14	+08	Geminid
1339	AI 41417	1947	.951	342	31.63	-17.4	+1.1	54.8	8	3	48.2	-6.18	-29	-6.16	-27	-5.80	+09	+02	-5.78	+11	+14	Geminid
1339	FA 10557	1947	.951	342	32.15	-12.92	+0.24	66.8	11	5	49.9	-6.30	-33	-6.27	-30	-5.94	+02	-03	-5.92	+04	-01	Geminid
1339	AI 41417	1947	.951	342	32.85	-10.69	+0.36	75.1	12	5	51.3	-6.38	-35	-6.34	-31	-6.03	-00	-06	-6.01	+02	-04	Geminid
1243	AI 39337	1945	.099	36	24.65	-9.83	+0.13	4.17	16	5	57.1	-6.59	-31	-6.68	-40	-6.46	-18	-20	-6.31	-03	-05	Sporadic
1339	AI 41417	1947	.951	342	34.44	-6.59	+0.29	104.4	10	6	57.6	-6.58	-28	-6.52	-22	-6.26	+04	+02	-6.24	+06	+04	Geminid
1068	FA 5202	1941	.412	148	19.77	-10.07	+0.08	2.67	9	2	58.8	-6.45	-09	-6.63	-27	-6.40	-04	-05	-6.38	-02	-03	Sporadic
1339	FA 10557	1947	.951	342	34.69	-5.61	+0.15	109.6	11	6	59.0	-6.65	-29	-6.59	-23	-6.34	+02	+02	-6.32	+04	+04	Geminid
815	FA 2602	1939	.063	23	19.50	-4.25	+0.20	4.58	14	7	60.7	-6.73	-29	-6.92	-48	-6.77	-33	-32	-6.65	-21	-20	Sporadic
1205	FA 7596	1943	.995	142	31.85	-6.25	+0.20	66.9	18	6	61.3	-6.60	-13	-6.57	-10	-6.32	+15	+17	-6.28	+19	+21	Sporadic
815	AI 34470	1939	.063	23	19.71	-3.16	+0.06	4.73	13	7	61.6	-6.85	-37	-7.03	-55	-6.91	-43	-40	-6.79	-31	-28	Sporadic
1544	AI 41394	1947	.939	338	21.50	-7.10	+0.14	5.40	15	3	62.4	-6.57	-12	-6.72	-20	-6.51	+01	+04	-6.50	+02	+05	Sporadic
1068	FA 5202	1941	.412	140	21.55	-5.00	+0.15	8.13	11	5	62.8	-6.66	-12	-6.80	-26	-6.61	-07	-04	-6.56	-02	+01	Sporadic
705	AI 33580	1937	.844	304	25.36	-14.14	+0.61	1.56	9	3	63.6	-6.59	-01	-6.66	-08	-6.43	+15	+19	-6.52	+06	+10	Taurid
1542	FA 10556	1947	.951	342	22.94	-2.291	+0.048	8.44	23	7	64.6	-7.05	-42	-7.17	-54	-7.08	-45	-41	-7.06	-43	-39	Sporadic
1243	FA 8808	1945	.099	36	27.04	-4.22	+0.10	6.77	25	8	65.2	-6.93	-28	-6.98	-32	-6.84	-18	-13	-6.69	-03	+02	Sporadic
1542	KA 488	1947	.951	342	23.11	-2.034	+0.06	9.20	20	8	66.1	-7.07	-36	-7.12	-41	-7.02	-31	-26	-6.87	-16	-11	Sporadic
1527	EB 242	1947	.872	314	24.59	-1.52	+0.36	9.44	48	7	66.1	-7.10	-39	-7.21	-50	-7.14	-43	-38	-7.12	-41	-36	Sporadic
1544	AI 41394	1947	.939	338	23.43	-1.860	+0.039	13.33	19	5	67.0	-6.91	-15	-7.02	-26	-6.89	-13	-08	-6.88	-12	-07	Sporadic
1112	AI 37051	1941	.943	339	36.67	-5.96	+0.26	2.76	12	5	67.1	-7.21	-44	-7.12	-35	-7.02	-25	-21	-7.01	-24	-20	Geminid
1068	FA 5202	1941	.389	140	22.59	-2.84	+0.27	12.57	9	4	67.2	-6.89	-12	-7.01	-24	-6.88	-11	-06	-6.85	-06	-01	Sporadic
1112	FA 6032	1941	.943	339	36.59	-5.56	+0.42	2.8	10	4	67.2	-7.24	-47	-7.15	-38	-7.06	-29	-24	-7.05	-28	-23	Geminid
705	AI 33580	1937	.844	304	28.47	-7.08	+0.07	3.70	20	4	69.1	-6.87	-09	-6.89	-00	-6.73	+16	+19	-6.82	+07	+10	Taurid
712	AI 33583	1937	.858	309	23.10	-4.54	+0.76	3.60	6	1	70.2	-7.06	-09	-7.09	-08	-6.98	-02	00	-7.06	-10	-08	Taurid
1006	AI 36019	1940	.832	322	28.53	-4.56	+0.12	7.58	14	5	73.0	-6.96	+21	-6.98	+19	-6.84	+33	+30	-6.94	+23	+20	Taurid
1241	AI 38253	1944	.939	338	28.01	-8.02	+0.38	1.27	9	2	73.1	-6.96	+22	-6.99	+19	-6.86	+32	+28	-6.85	+33	+29	Sporadic
1180	AI 37777	1942	.756	272	19.98	-1.125	+0.033	31.95	21	8	73.2	-7.21	-02	-7.30	-11	-7.25	-06	-10	-7.24	-05	-09	Sporadic
1265	AI 39265	1944	.951	342	35.78	-3.59	+0.16	4.86	10	2	73.3	-6.79	+40	-6.97	+22	-6.83	+36	+32	-6.99	+20	+16	Sporadic
1339	FA 10557	1947	.951	342	35.95	-1.307	+0.052	134.4	20	9	73.3	-7.29	-09	-7.21	-01	-7.14	+06	+01	-7.12	+08	+03	Geminid
670	AI 33193	1937	.193	69	23.88	-2.07	+0.40	10.20	11	3	74.4	-7.10	+18	-7.20	+08	-7.66	+16	+09	-6.94	+34	+27	Sporadic
1205	AI 38208	1943	.995	142	33.10	-0.437	+0.046	160.0	22	7	74.5	-7.66	-37	-7.62	-33	-7.62	-30	-44	-7.62	-33	-40	Sporadic
697	FA 1422	1937	.831	299	(33.87)	-9.96	+1.69	0.465	8	1	75.0	-7.17	+15	-7.12	+20	-7.02	+30	+23	-7.13	+19	+12	Taurid

TABLE IV a

Data Used in the Computation and Analysis of

Atmospheric Densities in Massachusetts ($H < 90$ Km)

No.	Plate	Yr.	Fr.	ϕ	V (km/sec)	$d\rho/dt$ (km/sec ²)	p.a.	m	n	P	H (km)	$\log P_1$	Δ_1	$\log P_2$	Δ_2	$\log P_3$	Δ_3	Δ_3	$\log P_4$	Δ_4	Δ_4	Shower
1539	AI 41417	1947	.951	342	36.07	-0.98	± 0.80	135.8	15	7	76.0	-7.41	-0.01	-7.33	.07	-7.29	.11	.01	-7.27	.13	.03	Geminid
1550	FA 10559	1947	.951	342	35.61	-7.7	± 1.4	2.37	8	2	76.1	-7.09	.32	-7.01	.40	-6.88	.53	.42	-6.86	.55	.44	Geminid
1009	AI 36025	1940	.859	302	30.48	-4.67	± 0.64	1.81	10	3	76.4	-7.21	.22	-7.14	.29	-7.05	.38	.27	-7.15	.28	.17	Taurid
778	AI 34257	1938	.817	294	33.25	-2.62	± 0.36	18.54	12	5	77.0	-7.20	.28	-7.15	.33	-7.06	.42	.30	-7.18	.30	.18	Taurid
642	FA 369	1906	.803	269	29.79	-8.4	± 0.5	0.328	5	1	77.4	-7.19	.32	-7.19	.32	-7.11	.40	.27	-7.24	.27	.14	Taurid
1243	AI 39337	1945	.099	36	28.05	-1.19	± 0.19	11.76	19	5	78.1	-7.46	.10	-7.49	.07	-7.49	.07	.08	-7.34	.22	.07	Sporadic
710	AI 33589	1937	.852	307	29.66	-4.24	± 0.15	0.93	18	6	78.7	-7.33	.27	-7.33	.27	-7.29	.31	.15	-7.37	.23	.08	Taurid
709	AI 34319	1938	.871	314	27.62	-2.85	± 0.10	2.05	12	6	78.8	-7.32	.29	-7.32	.25	-7.33	.28	.12	-7.40	.21	.05	Taurid
1180	AI 37777	1942	.756	272	20.37	-0.939	± 0.097	14.3	22	6	79.0	-7.26	.37	-7.43	.20	-7.42	.21	.04	-7.58	.05	.12	Sporadic
705	AI 33580	1937	.844	304	30.44	-1.87	± 0.06	10.47	21	7	79.0	-7.36	.27	-7.40	.23	-7.38	.25	.08	-7.47	.16	.01	Taurid
1180	FA 7010	1942	.756	272	20.39	-0.663	± 0.074	15.5	16	5	79.2	-7.40	.24	-7.57	.07	-7.59	.05	.12	-7.75	.11	.28	Sporadic
712	AI 33593	1937	.858	309	29.20	-1.141	± 0.040	12.42	20	8	79.4	-7.51	.15	-7.52	.14	-7.53	.13	.05	-7.61	.05	.13	Taurid
1544	AI 41394	1947	.959	338	24.86	-0.508	± 0.030	33.81	21	8	79.6	-7.56	.11	-7.64	.03	-7.68	.01	.18	-7.67	.00	.17	Sporadic
1065	FA 5303	1941	.307	111	48.00	-7.57	± 0.32	1.25	10	3	80.0	-7.45	.25	-7.25	.45	-7.19	.51	.33	-7.07	.63	.45	Lyrid
1241	FA 8643	1944	.959	338	29.07	-1.72	± 0.32	7.37	13	4	80.2	-7.40	.31	-7.41	.30	-7.39	.32	.14	-7.38	.33	.15	Sporadic
1257	AI 38643	1944	.059	21	19.75	-4.86	± 0.22	14.05	16	-	80.4	[-6.57]										Sporadic
697	AI 33564	1937	.831	299	32.09	-3.82	± 0.33	1.18	15	6	80.5	-7.41	.33	-7.38	.36	-7.35	.39	.19	-7.46	.28	.08	Taurid
1550	AI 41418	1947	.951	342	36.35	-2.04	± 0.61	4.42	10	1	81.2	-7.60	.19	-7.52	.27	-7.53	.26	.05	-7.51	.28	.07	Geminid
828	AI 34591	1938	.214	77	32.50	-1.62	± 0.48	3.45	18	2	81.4	-7.64	.16	-7.60	.20	-7.53	.17	.03	-7.46	.34	.14	Virginald
736	AI 33596	1937	.951	342	36.05	-1.52	± 0.25	0.309	15	5	81.5	-8.10	.29	-8.02	.21	-8.17	.36	.57	-8.15	.34	.55	Geminid
1241	AI 39253	1944	.959	338	29.21	-0.630	± 0.053	8.15	16	7	81.7	-7.79	.04	-7.80	.03	-7.89	.06	.28	-7.88	.05	.27	Sporadic
642	AI 32906	1906	.803	269	30.65	-2.28	± 0.16	0.886	12	4	82.4	-7.63	.24	-7.62	.25	-7.66	.21	.01	-7.79	.09	.14	Taurid
1009	AI 36025	1940	.859	302	31.27	-2.54	± 0.61	2.66	11	2	83.0	-7.44	.48	-7.42	.50	-7.40	.52	.28	-7.50	.42	.18	Taurid
1526	AI 41351	1947	.861	310	26.97	-0.599	± 0.082	179.8	20	6	83.4	-7.33	.62	-7.38	.57	-7.35	.59	.35	-7.43	.51	.27	Taurid
1071	FA 5243	1941	.412	148	57.20	-2.99	± 0.24	1.61	13	6	84.2	-7.97	.04	-7.69	.32	-7.75	.26	.00	-7.73	.28	.02	Sporadic
1005	FA 4741	1940	.819	295	26.46	-2.51	± 0.58	0.462	8	1	84.7	-7.56	.48	-7.61	.43	-7.65	.39	.13	-7.77	.27	.01	Sporadic
1544	AI 41394	1947	.959	338	25.04	-0.198	± 0.049	43.67	20	4	85.5	-7.95	.15	-8.03	.07	-8.18	.08	.36	-8.17	.07	.35	Sporadic
1173	AI 37612	1942	.592	213	59.63	-6.0	± 1.2	0.074	8	2	86.1	-8.15	.01	-7.85	.29	-7.95	.19	.09	-8.10	.04	.24	Perseid
1005	AI 36060	1940	.819	295	26.77	-1.96	± 0.26	0.551	11	4	86.2	-7.65	.49	-7.70	.44	-7.76	.38	.11	-7.88	.26	.01	Sporadic
1071	AI 36443	1941	.412	148	57.62	-2.71	± 0.24	1.70	14	6	86.4	-8.01	.15	-7.73	.43	-7.80	.36	.07	-7.78	.38	.09	Sporadic
1065	AI 36491	1941	.307	111	48.47	-1.92	± 0.49	3.49	19	3	87.5	-7.91	.32	-7.70	.53	-7.76	.47	.18	-7.64	.59	.30	Lyrid
1556	FA 508	1947	.959	345	34.75	-1.31	± 0.31	0.46	19	2	88.0	-8.08	.19	-8.02	.25	-8.17	.10	.21	-8.14	.13	.18	Sporadic
705	AI 33580	1937	.844	304	30.98	-0.733	± 0.069	16.17	19	7	88.2	-7.69	.58	-7.69	.59	-7.75	.53	.23	-7.84	.44	.14	Taurid
1556	FA 10576	1947	.959	345	34.90	-6.0	± 1.9	0.48	9	1	88.3	-7.41	.88	-7.34	.95	-7.30	.99	.68	-7.27	.102	.71	Sporadic

TABLE IV b

Data Used in the Computation and Analysis of

Atmospheric Densities in Massachusetts ($H > 85 \text{ Km}$)

No.	Plate	Yr.	Fr.	ϕ	v (km/sec)	dv/dt (km/sec ²)	P.e.	m	n	w	H (km)	ρ_1 ($\times 10^9$)	ρ_2 ($\times 10^9$)	Shower
1469	FA 10243	1947	.614	221°	59.85	+ 1.8	± 1.8	0.72	8	0.1	85.1	- 4.5	- 9.0	Perseid
1544	AI 41394	1947	.939	338	25.04	- 0.198	± 0.049	43.67	20	0.5	85.5	11.2	9.3	Sporadic
1173	AI 37612	1942	.592	213	59.63	- 6.0	± 1.2	0.074	8	1.1	86.1	7.1	14.1	Perseid
1005	AI 36000	1940	.819	295	26.77	- 1.96	± 0.26	9.551	11	0.3	86.2	22.	19.6	Sporadic
1071	AI 3644C	1941	.412	148	57.62	- 2.71	± 0.24	1.70	14	4.4	86.4	.9.8	18.8	Sporadic
1065	AI 36491	1941	.307	111	48.47	- 1.92	± 0.49	3.49	19	0.4	87.5	12.3	19.9	Lyrid
1556	KA 508	1947	.959	345	34.75	- 1.31	± 0.31	0.46	19	1.0	88.0	8.3	9.6	Sporadic
705	AI 33580	1937	.844	304	30.98	- 0.732	± 0.069	16.17	19	1.2	88.2	20.	20.7	Taurid
1556	FA 10576	1947	.959	345	34.90	- 6.0	± 1.9	0.48	9	0.0	88.3	39.	45.4	Sporadic
1382	AI 40572	1946	.808	291	65.28	- 3.4	± 3.2	0.081	6	0.2	89.8	3.5	7.6	Orionid
1377	FA 7715	1943	.598	215	60.88	- 1.88	± 0.53	3.33	9	0.6	90.3	7.4	15.0	Perseid
1276	AI 39646b	1945	.612	220	58.54	- 7.1	± 1.4	0.104	6	0.5	90.3	9.8	19.1	Perseid
1089	AI 36677	1941	.609	219	59.88	- 5.7	± 1.5	1.03	7	0.1	90.9	16.	31.9	Perseid
1273	FA 9074	1945	.609	219	60.28	- 11.3	± 1.3	0.092	7	0.8	91.0	14.1	28.3	Perseid
1556	AI 41427	1947	.959	345	35.03	- 3.21	± 0.87	0.64	9	0.1	91.3	22.	25.7	Sporadic
689	AI 33416	1937	.620	223	61.19	- 10.5	± 3.3	0.46	6	0.0	91.8	21.	42.8	Perseid
1608	KL 64	1948	.609	219	58.67	- 0.785	± 0.034	18.7 :	31	45.8	92.0	6.0	11.7	Perseid
982	FA 4551	1940	.657	237	39.97	- 2.72	± 0.59	0.304	11	0.5	92.4	11.5	15.3	Sporadic
1556	KB 323	1947	.959	345	35.07	- 0.70	± 0.15	0.69	22	3.5	92.4	5.0	5.8	Sporadic
1469	KB 76	1947	.614	221	60.21	- 0.853	± 0.086	1.084	27	42.7	92.5	2.4	4.8	Perseid
982	AI 35821	1940	.658	237	39.40	+ 0.52	± 0.74	0.382	12	0.3	93.5	- 2.4	- 3.2	Sporadic
1275	AI 39646a	1945	.611	220	60.04	- 5.71	± 0.69	0.346	6	0.9	93.8	11.2	22.4	Perseid
1103	AI 36988	1941	.899	324	75.49	+ 1.1	± 1.6	0.176	8	0.9	94.7	- 1.1	- 2.8	Sporadic
1273	AI 39642	1945	.609	219	60.34	- 1.10	± 0.52	0.105	9	5.4	95.1	1.4	2.8	Perseid
1587	AI 41560	1948	.376	135	67.71	- 8.42	± 0.88	0.928	8	0.8	96.3	17.8	40.2	Sporadic
978	AI 35755	1940	.600	216	59.95	- 1.1	± 1.5	0.724	8	0.2	100.0	2.8	5.6	Perseid
792	AI 34323	1938	.874	315	71.79	- 2.2	± 1.8	0.845	6	0.2	102.8	4.0	9.6	Leonid

TABLE V a

Data Used in the Computation and Analysis of

Atmospheric Densities in New Mexico ($B < 90$ km)

No.	Photo	Yr.	Fr.	ϕ	v (km/sec)	$\frac{dv}{dt}$ (km/sec ²)	P.O.	m	n	p	H (km)	$\log \rho_1$	Δ_1	$\log \rho_2$	Δ_2	$\log \rho_3$	Δ_3	$\log \rho_4$	Δ_4	Shower
2241	AI 42998b	1950	.937	337°	18.99	-46.9	42.5	0.58	11	1	51.7	-5.94	+1.1	-6.15	-1.0	-5.78	+0.26	-5.73	+0.32	Sporadic
2241	FA 12397b	1950	.937	337	19.15	-43.45	+0.82	0.66	11	1	52.0	-5.99	+0.7	-6.19	-1.3	-5.83	+0.23	-5.78	+0.28	Sporadic
2257	FA 12459a	1950	.950	342	31.72	-24.82	+0.86	0.38	12	2	57.1	-6.75	+0.7	-6.73	-0.5	-6.52	+0.24	-6.47	+0.19	Cumid
2259	FA 12459b	1950	.950	342	31.86	-19.4	41.2	0.90	11	3	57.4	-6.73	+0.5	-6.70	-0.6	-6.49	+0.22	-6.44	+0.14	Cumid
2259	AI 43055b	1950	.950	342	32.21	-17.6	41.8	1.03	11	3	57.9	-6.77	+0.5	-6.74	-0.42	-6.54	+0.22	-6.49	+0.17	Cumid
2226	FA 12205	1950	.686	247	33.65	-39.75	41.15	2.36	10	3	58.1	-6.33	+0.0	-6.28	+0.05	-5.95	+0.38	-5.91	+0.42	Sporadic
2236	AI 43032	1950	.686	247	33.33	-26.7	42.5	3.40	8	2	59.6	-6.49	+0.10	-6.42	-0.03	-6.13	+0.36	-6.09	+0.30	Sporadic
2236	FA 12448b	1950	.948	341	33.34	-12.50	+0.58	4.45	13	4	60.4	-6.73	+0.30	-6.68	-0.25	-6.46	+0.27	-6.41	+0.02	Cumid
2241	AI 42998b	1950	.937	337	28.76	-10.50	+0.33	11.16	11	3	60.8	-6.55	+0.11	-6.57	-0.13	-6.32	+0.23	-6.27	+0.17	Sporadic
1861	FA 11666	1949	.951	342	33.72	-16.01	+0.59	18.0	22	6	61.0	-6.43	+0.02	-6.38	+0.07	-6.08	+0.37	-6.03	+0.42	Cumid
2257	AI 43055a	1950	.950	342	33.40	-13.03	+0.24	8.91	22	5	61.0	-6.95	+0.50	-6.90	-0.45	-6.74	+0.16	-6.69	+0.24	Cumid
2241	FA 12397b	1950	.937	337	28.98	-8.33	+0.79	12.8	15	4	61.9	-6.63	+0.14	-6.66	-0.17	-6.43	+0.23	-6.38	+0.11	Cumid
2236	AI 43045b	1950	.948	341	33.84	-7.77	+0.59	5.92	21	5	62.5	-6.91	+0.39	-6.86	-0.34	-6.69	+0.17	-6.64	+0.12	Cumid
2236	FA 12205	1950	.686	247	38.19	-8.06	+0.36	6.98	11	5	63.6	-6.98	+0.30	-6.87	-0.19	-6.70	+0.28	-6.66	+0.02	Sporadic
2259	AI 43055b	1950	.950	342	35.01	-5.45	+0.57	3.08	16	6	65.8	-7.19	+0.50	-7.12	-0.43	-7.02	+0.33	-6.97	+0.28	Cumid
2259	FA 12459b	1950	.950	342	35.17	-5.36	+0.57	3.11	12	4	66.0	-7.20	+0.50	-7.13	-0.43	-7.03	+0.33	-6.98	+0.28	Cumid
2236	AI 42932	1950	.686	247	38.31	-6.72	+0.28	7.24	13	6	66.0	-7.05	+0.35	-6.94	-0.24	-6.79	+0.29	-6.75	+0.05	Sporadic
1780	EB 1080	1949	.828	298	28.48	-12.03	+0.26	0.53	25	4	67.1	-6.92	+0.15	-6.94	-0.17	-6.79	+0.22	-6.72	+0.05	Thurid
2257	FA 12459a	1950	.950	342	35.11	-4.39	+0.29	1.66	14	5	67.8	-7.38	+0.57	-7.31	-0.50	-7.26	+0.45	-7.21	+0.40	Cumid
2249	AI 43048	1950	.948	341	23.23	-2.80	+0.77	105.0	21	5	68.3	-6.61	+0.23	-6.63	+0.12	-6.51	+0.33	-6.46	+0.38	Sporadic
2634	EA 2140	1950	.847	305	18.91	-5.29	+0.43	0.96	16	2	68.7	-6.84	+0.03	-6.89	-0.02	-6.73	+0.16	-6.66	+0.21	Thurid (?)
2630	FA 12362	1950	.850	306	25.93	-5.98	+0.76	4.62	12	2	68.7	-6.83	+0.04	-6.89	-0.02	-6.73	+0.16	-6.66	+0.21	Thurid (?)
2377	FA 12461a	1950	.950	342	33.89	-15.0	42.5	0.36	10	2	69.2	-7.03	+0.13	-6.98	-0.08	-6.84	+0.06	-6.79	+0.11	Cumid
2630	AI 42960	1950	.850	306	26.04	-3.42	+0.45	4.91	19	3	69.3	-7.07	+0.16	-7.13	-0.22	-7.03	+0.12	-6.97	+0.06	Thurid (?)
1861	FA 11666	1949	.951	342	35.61	-2.98	+0.39	35.2	21	6	69.7	-7.11	+0.18	-7.04	-0.11	-6.92	+0.01	-6.87	+0.06	Cumid
2682	EF 199	1950	.608	219	25.06	-3.36	+0.19	1.56	12	5	70.0	-7.21	+0.25	-7.29	-0.33	-7.24	+0.07	-7.24	+0.26	Sporadic
2682	FA 11196	1949	.581	209	14.46	-3.20	+0.14	1.07	25	4	70.1	-6.81	+0.15	-7.13	-0.17	-7.03	+0.13	-6.97	+0.06	Cumid
2682	EA 1931	1950	.608	219	14.13	-4.48	+0.35	1.07	17	3	70.1	-6.64	+0.32	-6.97	-0.01	-6.83	+0.13	-6.82	+0.14	Sporadic
1913	EA 1526	1950	.053	19	30.76	-4.45	+0.23	0.60	20	5	71.2	-7.40	+0.36	-7.39	-0.35	-7.37	+0.03	-7.35	+0.31	Sporadic
2660	FA 12038	1950	.461	166	29.43	-3.52	+0.47	0.389	21	4	71.6	-7.53	+0.46	-7.54	-0.47	-7.56	+0.49	-7.60	+0.53	Sporadic
1913	EB 1250	1950	.053	19	30.86	-3.36	+0.14	0.66	33	5	71.9	-7.44	+0.35	-7.43	-0.34	-7.42	+0.33	-7.40	+0.31	Sporadic
1695	AI 42011	1949	.981	209	24.73	-1.30	+0.18	2.03	10	5	72.1	-7.57	+0.46	-7.65	-0.54	-7.70	+0.59	-7.70	+0.59	Sporadic
2002	EF 199	1950	.608	219	15.59	-2.195	+0.22	1.70	23	4	72.1	-6.97	+0.14	-7.25	-0.14	-7.19	+0.08	-7.18	+0.07	Sporadic
2002	EA 1931	1950	.608	219	15.64	-2.28	+0.19	1.70	16	4	72.1	-6.94	+0.17	-7.23	-0.12	-7.16	+0.05	-7.15	+0.04	Sporadic
1908	FA 11740	1950	.061	22	19.08	-1.74	+0.24	0.348	37	4	73.4	-7.45	+0.25	-7.65	-0.45	-7.70	+0.50	-7.69	+0.49	Sporadic
2002	EA 1931	1950	.608	219	16.40	-1.66	+0.11	2.48	19	6	74.4	-7.08	+0.20	-7.34	-0.06	-7.30	+0.02	-7.29	+0.02	Sporadic
2002	EF 199	1950	.608	219	16.42	-1.370	+0.057	2.48	30	6	74.4	-7.16	+0.13	-7.42	-0.14	-7.40	+0.42	-7.39	+0.37	Sporadic
2024	EA 1797	1950	.436	157	18.82	-7.36	+0.86	0.45	13	2	74.6	-6.80	+0.49	-7.00	+0.29	-6.87	+0.42	-6.92	+0.37	Sporadic
1908	AI 42508	1950	.061	22	19.14	-1.18	+0.16	0.490	11	3	74.6	-7.62	+0.33	-7.82	-0.53	-7.91	+0.62	-7.90	+0.61	Sporadic
2236	FA 12448b	1950	.948	341	35.81	-2.50	+0.11	13.2	25	9	74.7	-7.34	+0.04	-7.26	+0.04	-7.20	+0.10	-7.15	+0.15	Cumid
2060	AI 42714	1950	.461	166	29.56	-3.65	+0.18	0.502	34	7	75.1	-7.48	+0.15	-7.49	-0.16	-7.49	+0.16	-7.54	+0.21	Sporadic
2069	AI 42696a	1950	.436	157	19.36	-7.97	+0.88	0.375	12	2	75.2	-6.81	+0.53	-7.00	+0.34	-6.87	+0.47	-6.92	+0.42	Sporadic
2004	EB 1440	1950	.436	157	18.57	-3.21	+0.26	0.585	23	3	75.3	-7.11	+0.24	-7.32	+0.03	-7.23	+0.07	-7.33	+0.02	Sporadic

TABLE V a

Data Used in the Computation and Analysis of

Atmospheric Densities in New Mexico ($H < 90$ Km)

No.	Place	Yr.	Fr.	ϕ	V (km/sec)	dV/dt (km/sec ²)	P.O.	α	β	$\log \rho_1$	Δ_1	$\log \rho_2$	Δ_2	$\log \rho_3$	Δ_3	$\log \rho_4$	Δ_4	Shower
2359	AI 43055b	1950	950	342	35.09	-1.11	+0.11	4.29	75.4	-7.86	-51	-7.78	-43	-7.66	-51	-7.81	-46	Geminid
1740	EA 1319	1949	798	287	63.28	-14.0	+1.7	0.114	75.4	-7.78	-43	-7.45	-10	-7.44	-09	-7.34	-03	Sporadic
2624	EA 2140	1950	847	305	30.53	-1.52	+0.11	7.17	75.5	-7.16	+20	-7.33	+08	-7.29	+07	-7.22	+14	Sporadic
1740	EB 1087	1949	798	287	63.75	-13.4	+1.1	0.129	75.6	-7.78	-41	-7.45	-08	-7.44	-07	-7.38	-01	Sporadic
2359	FA 12459b	1950	950	342	36.03	-1.173	+0.063	4.31	75.8	-7.83	-45	-7.75	-37	-7.82	-44	-7.77	-39	Geminid
1693	AI 41921	1949	699	180	25.39	-2.22	+0.22	3.25	75.8	-7.59	+09	-7.36	+02	-7.33	+05	-7.36	+02	Sporadic
1954	FA 11541	1949	828	298	30.36	-2.50	+0.16	1.64	76.3	-7.29	+13	-7.30	+12	-7.25	+17	-7.30	+12	Virgind
1954	AI 42572	1950	209	75	29.42	-10.08	+0.45	0.086	76.3	-7.29	+13	-7.48	-04	-7.48	-04	-7.43	-04	Virgind
1954	AI 42572	1950	209	75	29.42	-6.57	+0.31	0.093	76.5	-7.47	-08	-7.48	-10	-7.48	-10	-7.43	-09	Virgind
2359	FA 12453	1950	945	340	24.28	-2.20	+0.31	0.935	76.6	-7.46	-02	-7.54	-10	-7.56	-12	-7.50	-06	Sporadic
2610	AI 42959	1950	849	306	23.35	-2.33	+0.09	8.3	76.8	-7.06	+40	-7.17	+29	-7.08	+30	-7.02	+44	Sporadic
2082	EA 1981	1950	608	219	17.05	-0.64	+0.12	3.75	77.3	-7.44	+06	-7.69	-19	-7.75	-25	-7.74	-24	Sporadic
2359	FA 12361	1950	945	340	24.28	-2.20	+0.31	0.935	77.6	-7.46	-02	-7.44	+08	-7.43	+09	-7.38	+14	Geminid
2548	EP 460	1950	948	341	33.99	-8.48	+0.76	0.089	77.8	-7.40	+12	-7.34	+20	-7.30	+24	-7.29	+25	Sporadic
2082	EP 199	1950	608	219	17.08	-0.711	+0.033	3.76	77.9	-7.42	+12	-7.67	-13	-7.72	-18	-7.71	-17	Sporadic
2359	AI 43045b	1950	948	341	35.96	-2.15	+0.31	14.3	78.5	-7.40	+19	-7.32	+27	-7.28	+31	-7.23	+36	Geminid
1780	EB 1080	1949	828	298	30.48	-1.67	+0.22	1.79	78.5	-7.66	-07	-7.66	-06	-7.71	-12	-7.63	-04	Virgind
1693	FA 11107	1949	699	180	26.18	-1.60	+0.11	4.48	78.6	-7.36	+24	-7.42	+18	-7.40	+20	-7.44	+16	Sporadic
2278	EE 510	1950	942	339	56.26	-17.48	+0.80	0.15	78.8	-7.53	+08	-7.26	+35	-7.20	+41	-7.15	+46	Sporadic
1853	AI 42343	1949	830	299	31.10	-4.39	+0.25	0.091	78.9	-7.09	-07	-7.67	-05	-7.72	-10	-7.66	-04	Virgind
1954	AI 42619	1950	291	105	21.72	-4.99	+0.53	0.486	79.0	-7.08	-55	-7.22	+41	-7.15	+48	-7.21	+42	Sporadic
2357	EP 472	1950	950	342	30.86	-11.6	+1.6	0.035	79.2	-7.41	+23	-7.40	+24	-7.38	+26	-7.33	+31	Sporadic
2357	AI 43055a	1950	950	342	35.73	-0.66	+0.10	2.58	79.2	-8.15	-51	-8.07	-43	-8.23	-59	-8.18	-54	Geminid
1954	FA 11914	1950	291	105	21.79	-2.70	+0.21	0.480	79.2	-7.35	+29	-7.49	+15	-7.49	+15	-7.56	+08	Sporadic
2094	EA 1797	1950	436	157	19.39	-1.765	+0.097	2.54	79.3	-7.19	+46	-7.38	+27	-7.35	+30	-7.41	+24	Sporadic
2084	EB 1440	1950	436	157	19.09	-1.358	+0.028	2.44	79.9	-7.30	+39	-7.50	+19	-7.51	+18	-7.56	+13	Sporadic
2089	AI 42696a	1950	436	157	19.87	-1.670	+0.051	1.12	80.0	-7.41	+29	-7.59	+11	-7.62	+08	-7.67	+08	Sporadic
2359	FA 12397a	1950	937	337	43.69	-5.44	+0.76	0.90	80.2	-7.56	+15	-7.40	+31	-7.38	+33	-7.32	+39	Sporadic
1954	FA 11851	1950	209	75	30.32	-3.39	+0.10	0.234	80.4	-7.64	+09	-7.63	+10	-7.67	+06	-7.72	+01	Virgind
1693	AI 41921	1949	699	180	26.69	-1.397	+0.028	5.61	80.6	-7.69	+05	-7.68	+06	-7.74	+10	-7.78	-04	Virgind
2278	EE 510	1950	942	339	58.18	-3.28	+0.46	1.82	81.4	-7.66	+31	-7.51	+26	-7.52	+25	-7.55	+22	Sporadic
2241	AI 42953b	1950	937	337	31.16	-0.722	+0.041	54.6	81.6	-7.53	+27	-7.53	+29	-7.54	+28	-7.49	+33	Sporadic
2356	FA 12205	1950	686	247	39.48	-0.465	+0.039	12.36	81.7	-8.16	-81	-8.04	-21	-8.19	-36	-8.15	-32	Sporadic
2346	EB 1810	1950	940	338	33.55	-2.17	+0.37	0.161	82.1	-7.98	-13	-7.93	-08	-8.05	-20	-8.00	-15	Geminid ?
1957	EB 1333	1950	222	80	30.97	-6.0	+1.1	0.100	82.1	-7.54	+31	-7.53	+32	-7.54	+31	-7.59	+26	Sporadic
2358	AI 43033a	1950	945	340	35.48	-0.34	+0.53	0.62	82.2	-7.95	-09	-7.83	+03	-7.93	-07	-7.88	-02	Geminid ?
2346	EA 2205	1950	940	338	32.88	-0.39	+0.31	0.16	82.2	-7.95	-09	-7.83	+03	-7.93	-07	-7.88	-02	Sporadic
2411	EP 481	1950	953	343	39.26	-3.44	+0.49	0.127	82.3	-7.56	+32	-7.73	+15	-7.80	+08	-7.85	+03	Sporadic
2084	EA 1797	1950	436	157	19.53	-0.41	+0.25	3.03	82.4	-8.05	-17	-7.97	-09	-8.10	-22	-8.05	-17	Geminid
2089	AI 42696a	1950	436	157	20.19	-1.00	+0.15	1.38	82.4	-8.05	-17	-7.97	-09	-8.10	-22	-8.05	-17	Geminid
2357	FA 12459a	1950	950	342	35.85	-0.82	+0.18	2.76	82.4	-8.05	-17	-7.97	-09	-8.10	-22	-8.05	-17	Geminid

Data Used in the Computation and Analysis of

Atmospheric Densities in New Mexico ($T' < 90$ km)

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TABLE V b

Data Used in the Computation and Analysis of
Atmospheric Densities in New Mexico ($H > 85 \text{ km}$)

No.	Plate	Yr.	Fr.	ϕ	v (km/sec)	dv/dt (km/sec ²)	P.e.	n	n	w	H (km)	ρ_1 ($\times 10^9$)	ρ_2 ($\times 10^9$)	Shower
2630	FA 12362	1950	.850	306°	26.95	- 0.344	± 0.054	21.1	38	1.5	85.0	13.	12.	Taurid
2624	KA 2140	1950	.847	305	20.97	- 0.167	± 0.030	14.89	38	0.6	85.3	9.3	6.5	Sporadic
1693	AI 41921	1949	.699	180	27.36	- 0.861	± 0.066	8.13	17	1.2	85.6	23.	21.	Sporadic
2007	KB 1276	1950	.072	26	59.95	- 3.14	± 0.27	0.198	24	21.5	85.6	5.1	10.2	Sporadic
2473	AI 42917	1950	.789	284	29.97	- 3.13	± 1.28	0.349	16	0.0	85.8	25.	25.	Taurid
2317	FA 12447a	1950	.948	341	36.36	- 2.99	± 1.16	0.217	13	0.1	85.8	13.	16.	Geminid
2610	AI 42959	1950	.849	306	24.39	- 0.0962	± 0.0009	188.8	75	75.1	86.0	9.3	7.6	Sporadic
2473	FA 12315	1950	.789	284	30.14	- 3.42	± 1.03	0.413	15	0.1	86.4	28.	28.	Taurid
2630	AI 42360	1950	.850	306	27.10	- 0.559	± 0.061	22.0	31	1.0	86.5	21.	19.	Taurid ?
2025	KE 156	1950	.436	157	22.05	- 0.355	± 0.015	1.49	65	52.4	86.5	8.3	6.1	Sporadic
1780	KB 1080	1949	.828	298	30.74	+ 0.40	± 0.51	2.12	22	0.1	87.1	- 5.4	- 5.5	Taurid
1937	KB 1333	1950	.222	80	31.67	- 1.38	± 0.06	0.454	44	27.9	87.4	10.5	11.1	Sporadic
1937	KA 1661	1950	.222	80	31.46	- 1.09	± 0.10	0.457	28	8.2	87.5	8.5	8.9	Sporadic
1722	FA 11160	1949	.567	204	40.87	- 2.18	± 0.47	0.52	8	0.4	87.7	10.5	14.3	Sporadic
2078	FA 12170	1950	.630	227	26.35	- 4.1	± 2.5	0.29	14	0.0	87.7	39.	34.	$\times$ Cygnid
1922	KB 1264	1950	.064	23	38.16	- 0.119	± 0.026	0.442	23	39.6	87.8	.62	.79	Sporadic
2239	FA 12397a	1950	.937	337	43.97	- 1.04	± 0.06	1.62	31	33.9	87.8	6.3	9.2	Sporadic
1913	KB 1250	1950	.053	19	31.61	- 0.410	± 0.048	1.89	41	17.3	87.9	5.0	5.3	Sporadic
1913	KA 1526	1950	.053	19	31.56	- 0.187	± 0.040	1.90	31	20.1	88.0	2.3	2.4	Sporadic
1756	KB 838	1949	.636	229	39.87	+ 2.5	± 3.8	0.036	9	0.0	88.5	- 5.2	- 6.9	Sporadic
1910	KE 74	1950	.302	109	49.64	- 7.92	± 0.92	0.053	11	1.4	88.6	12.	20.	Lyrid
2610	FA 12361	1950	.849	306	24.27	- 0.0476	± 0.0077	226.7	48	10.7	88.6	4.9	4.0	Sporadic
1910	KF 53	1950	.302	109	49.67	- 6.19	± 0.47	0.053	16	7.2	88.6	9.3	15.	Lyrid
2411	KF 481	1950	.953	343	39.65	- 0.355	± 0.012	0.360	58	65.6	88.8	1.6	2.1	Sporadic
2239	AI 42998a	1950	.937	337	44.30	- 1.13	± 0.26	1.53	38	2.6	88.9	6.6	9.7	Sporadic
2278	KE 510	1950	.942	339	59.41	- 0.593	± 0.033	9.64	34	49.3	89.3	3.5	6.9	Sporadic
1740	KB 1027	1949	.798	287	65.17	- 1.08	± 0.36	0.407	28	11.4	89.6	1.9	4.1	Sporadic
1922	KB 1376	1950	.302	109	47.69	- 2.3	± 2.4	0.087	20	0.2	89.6	4.5	7.2	Lyrid
1937	KB 1333	1950	.222	80	31.79	- 0.92	± 0.16	0.580	31	3.1	89.9	7.6	8.1	Sporadic
1922	KA 1718	1950	.302	109	47.37	- 1.44	± 0.66	0.093	16	2.1	90.2	2.9	- 6	Lyrid
2591	EF 473b	1950	.950	342	36.35	- 2.66	± 0.58	0.036	37	3.0	90.5	6.6	8.0	Geminid
1998	KB 1381	1950	.940	110	48.41	- 2.62	± 0.29	0.113	25	12.7	91.0	5.4	8.7	Lyrid
2260	KA 2202	1950	.940	338	38.94	- 2.34	± 0.71	0.029	12	1.3	91.1	4.8	6.2	Geminid
2411	EF 481	1950	.953	343	39.65	- 0.212	± 0.030	0.463	43	56.0	91.1	1.04	1.38	Sporadic
1918	KA 1525	1950	.053	19	64.68	- 0.38	± 0.70	0.017	12	15.5	91.7	.23	.50	Sporadic

TABLE V b

Data Used in the Computation and Analysis of

Atmospheric Densities in New Mexico ($H > 85$ Km)

No.	Plate	Yr.	Fr.	ϕ	v (km/sec)	dv/dt (km/sec ²)	p.e.	m	n	v	H (km)	ρ_1 ($\times 10^9$)	ρ_2 ($\times 10^9$)	Shower
1998	EA 1723	1950	.305	110°	48.46	-1.52	± 0.40	0.123	17	5.3	91.8	3.2	5.2	Lyrid
2548	EF 460	1950	.948	341	36.05	-0.323	± 0.024	0.73	40	53.8	91.9	2.2	2.6	Geminid
1740	EA 1319	1949	.798	287	65.40	-1.12	± 0.29	0.430	19	15.2	92.1	2.0	4.4	Sporadic
2239	FA 12397a	1950	.937	337	44.17	-1.17	± 0.26	1.70	19	1.6	92.3	7.1	10.5	Sporadic
2033	FA 12162	1950	.614	221	60.60	-2.40	± 0.27	0.584	23	11.4	93.4	5.5	11.1	Persoid
1728	EB 777	1949	.581	209	22.14	-2.66	± 1.47	0.62	9	0.0	93.5	46.	34.	Sporadic
2328	EA 12448c	1950	.948	341	51.21	-3.1	± 1.4	0.59	11	0.1	93.7	10.	17.	Sporadic
2034	EF 203	1950	.609	219	60.60	-6.07	± 1.15	0.0128	32	9.8	94.0	3.9	7.9	Persoid
2660	AI 43074	1951	.006	2	43.71	-1.35	± 0.86	0.083	19	1.0	95.3	3.1	4.5	Sporadic
1910	EF 53	1950	.302	109	50.40	-2.34	± 0.06	0.114	35	50.1	95.4	4.5	7.6	Lyrid
1997	EA 1717	1950	.302	109	50.54	-2.19	± 0.59	0.0433	17	5.7	95.4	3.0	5.1	Lyrid
2313	FA 12446a	1950	.948	341	44.26	-0.81	± 0.79	0.11	19	1.0	95.9	2.0	3.0	Sporadic
2034	EA 1935	1950	.609	219	61.11	-3.34	± 1.40	0.0185	14	3.5	96.7	2.3	4.7	Persoid
2313	AI 43043a	1950	.948	341	44.68	+0.23	± 1.47	0.13	25	0.3	96.7	-0.6	-0.9	Sporadic
1910	FE 74	1950	.302	109	50.57	-2.33	± 0.09	0.125	30	46.0	96.8	4.6	7.8	Lyrid
2049	FA 12146	1950	.606	218	57.57	-5.5	± 3.4	0.0364	11	0.2	97.0	5.5	10.6	Persoid
1755	EB 863	1949	.647	233	63.63	+4.0	± 3.6	0.046	10	0.3	97.2	-3.5	-7.4	Sporadic
2328	AI 43045c	1950	.948	341	50.69	-1.37	± 0.24	0.91	22	5.5	97.3	5.1	8.6	Sporadic
1898	EA 1413	1949	.877	316	63.08	-0.41	± 0.65	0.054	17	9.5	97.5	0.39	0.82	Sporadic
2046	FA 12163	1950	.614	221	60.70	-0.89	± 0.69	0.107	17	4.6	97.5	1.1	2.2	Sporadic
1997	EB 1375	1950	.302	109	50.83	-2.50	± 0.35	0.0537	26	17.0	97.7	3.4	5.8	Lyrid
2061	FA 12064	1950	.480	173	60.94	-9.9	± 9.7	0.024	13	0.1	98.6	7.7	16.	Sporadic
1898	EB 1137	1949	.877	316	64.05	+1.7	± 1.4	0.086	16	1.6	99.3	-1.8	-3.8	Sporadic
1755	EA 1171	1949	.647	233	64.07	-7.0	± 1.5	0.118	12	0.9	99.4	8.4	18.	Sporadic
2049	AI 42782	1950	.606	218	57.86	-2.15	± 0.66	0.0450	14	6.6	99.8	2.3	4.4	Persoid
2061	AI 42731	1950	.480	173	61.03	-7.7	± 4.0	0.029	13	0.3	99.9	6.4	13.0	Sporadic
2278	FA 12423	1950	.942	339	59.17	+3.89	± 0.45	11.9	55	-	101.1	$[-2.5]^*$	$[-4.9]^*$	Sporadic
2679	EF 369	1950	.846	305	52.56	-0.21	± 0.33	0.074	47	25.2	102.5	0.32	0.56	Sporadic
2679	FE 448	1950	.846	305	52.59	-0.72	± 0.58	0.081	19	4.9	102.8	1.12	1.96	Sporadic
2181	EA 2184	1950	.880	317	71.54	-4.1	± 2.6	0.041	11	0.9	102.9	2.8	6.7	Leonid
2179	AI 42989	1950	.877	316	71.20	+0.68	± 1.52	0.048	12	2.5	103.3	-0.49	-1.16	Leonid
2278	AI 43021	1950	.942	339	58.93	+0.693	± 0.087	12.3	48	-	104.4	$[-4.6]^*$	$[-9.0]^*$	Sporadic
2176	AI 42987	1950	.877	316	70.21	+0.23	± 0.80	0.054	20	10.3	107.2	-0.18	-0.42	Sporadic
2468	AI 42916	1950	.789	284	65.11	-0.516	± 0.278	0.203	36	34.2	108.6	0.71	1.54	Sporadic
2468	FA 12314	1950	.789	284	65.33	-0.65	± 0.70	0.22	25	4.8	109.0	0.92	2.0	Sporadic

* See remarks about this meteor in the text, section 1.

small relative error when the point we consider is near the beginning or the center of the trail, but may become quite important when we have to compute a mass near the end of the meteor's visible path. It is, therefore, necessary to establish a weight function which will take into account all these factors.

If the scatter in the computed atmospheric densities were due only to observational errors, a weight function could be established rather simply on the basis of the probable errors of dv/dt and m . We must not forget however, that even densities computed from exact data (i.e., with probable errors equal to zero) would presumably show a scatter due to different shapes and densities of the individual meteoroids and to unaccounted day-to-day variations in the upper-atmospheric layers. While a weight function based entirely on probable errors would be justified for data with very low accuracy, there is the danger that it would lead to dangerous relative overweighting of more accurate data. As we see, an ideal weight function must follow the probable-error rule in the low-accuracy domain and reach an upper (saturation) value when the probable errors decrease beyond a certain limit. The weight functions which were finally adopted are certainly far from being ideal and would be difficult to justify on a rigid analytical basis; they do, however, satisfactorily accomplish their assigned task, so we feel they can be presented without further apologies.

Whenever values of $\log_{10} \rho$ were analyzed (i.e., for heights lower than 85 km), their weight p was assumed to be

$$p = 10 \psi \left(\frac{\dot{v}}{\epsilon} \right) \psi(n-3) \left(\frac{m}{m_0} \right)^{1/2}; \quad (3)$$

$$\psi = \frac{1}{2} [1 + \operatorname{erf}(2 \log_{10} x - 0.7)].$$

Here $\dot{v}/\epsilon$ is the ratio of the acceleration to its probable error, n is the number of shutter breaks used in the least-squares solution (which contains three unknowns) and m_0 the mass of the meteor before it entered the atmosphere. In the expression for ψ , x may be either $\dot{v}/\epsilon$ or $n-3$. The weights thus computed range from 1 to 9 and virtually all densities with $\dot{v}/\epsilon < 2$ have weight zero.

For heights above 85 km, where weighted means were taken in ρ rather than $\log_{10} \rho$, the weight function was

$$w = \left[\frac{\pi}{4} (n-3) \right]^{1/2} \operatorname{erf}(10^{-10} \epsilon_{\rho}^{-2}), \quad (4)$$

where $\epsilon_{\rho} = (\rho/\dot{v})\epsilon$. The meteor mass does not appear in this formula because at great heights all accelerations are computed from centers or early parts of trajectories.

The separation of the observational material into two sections, below and above 85 km, appeared to be necessary in view of the great disparity in the accuracy of the data. Below 85 km the observed decelerations are generally much larger than their probable errors and there are virtually no negative densities. Above 85 km it becomes increasingly difficult to get reliable decelerations and negative densities become more and more frequent.

In view of the nearly linear relation between H and $\log \rho$, it appears logical to prefer taking weighted means of these two quantities whenever possible, and this was done for $H < 85$ km. For $H > 85$ km advantage was taken of the fact that atmospheric densities in the range $0 < H < 100$ km can be represented, within a factor of 2, by the approximation $\rho = \rho_0 e^{-0.138H}$. Weighted means were therefore taken in ρ and in the quantity $e^{-0.138H}$, from which the corresponding mean value of H was computed.

3. Analysis of the New Mexico Data:

The mean atmospheric density profile over New Mexico was assumed to be sufficiently well established on the basis of the results of several high-altitude rockets launched in recent years. N.R.L. data from four rocket flights were reduced by the writer in 1948⁽¹⁾ and the mean profile derived from them (profile C, Table VI) has been used for the past 4 years at M.I.T. as

a guide in problems involving the upper atmosphere⁽⁶⁾. Our chief goal has been to establish an empirical function of the densities ρ_1 computed by equation (1) from New Mexico meteors, which would reduce the computed densities as closely as possible to those of profile C. This same function would then be applied to the densities computed from Massachusetts meteors; the two sets of data would then presumably represent true atmospheric densities and could be analyzed and compared.

A mean density profile for the upper atmosphere over New Mexico has been recently computed by the Rocket Panel* using data from 16 rocket flights⁽⁵⁾. This profile is given in Table VI under the designation of profile R. Profiles R and C are almost identical (they intersect three times in the range from 50 to 100 km) so no appreciable difference in our results could be expected if one were substituted for the other in the analysis.

As a preliminary step, the individual values of $\log \rho_1$ were compared with three different density profiles, given in Table VI. Only points lying between the heights of 65 and 85 km were used in the analysis. This limitation stems from various considerations:

TABLE VI

Atmospheric Density Profiles Used in the Analysis of New Mexico and Massachusetts Meteors (A,B,C) and Most Recent Profile from V-2 Rockets (R). $\log_{10} \rho$ in g/cm³.

H (km)	A	B	C	R	M
45	-5.744		-5.725	-5.667	
50	-6.006	-5.99	-5.971	-5.936	-5.91
55	-6.227	-6.21	-6.193	-6.199	-6.15
60	-6.421	-6.42	-6.409	-6.457	-6.41
65	-6.607	-6.63	-6.647	-6.723	-6.70
70	-6.801	-6.88	-6.955	-7.012	-6.97
75	-7.018	-7.20	-7.324	-7.334	-7.25
80	-7.287	-7.56	-7.700	-7.676	-7.52
85	-7.611	-7.92	-8.062	-8.034	-7.80
90	-7.951	-8.29	-8.400	-8.389	-8.08
95	-8.273	-8.67	-8.717	-8.734	-8.36
100	-8.569	-9.04	-9.021	-9.063	-8.66
105	-8.852		-9.314	-9.379	
110	-9.131		-9.598	-9.684	

A = Profile from Massachusetts meteors, 1949⁽³⁾.

B = Preliminary profile from New Mexico meteors, using uncorrected data and $\log K = 0.12$.

C = Profile from New Mexico rocket flights, 1948⁽¹⁾.

R = Most recent profile from V-2 rockets, 1952⁽⁵⁾.

M = Final density profile from Massachusetts meteors, from results of the present paper.

1) In the height range between 65 and 85 km there is a generous overlapping of meteor velocities and masses. At heights lower than 65 km densities are derived mostly from low-velocity, massive meteors near the end of their trajectories. At heights greater than 85 km high-velocity, low-mass meteors predominate.

*The author wishes to express his sincere gratitude to the Rocket Panel for the permission to use these data before their publication.

2) At heights greater than 85 km individual meteor decelerations become progressively less reliable.

3) The introduction of the height in the form of a linear term in the equation of condition precludes taking any wider range in heights, or the term would lose much of its significance.

Since the exact form of the drag equation (1) is still open to discussion, both the velocity v and the mass m were inserted in the equation of condition, although it was realized that they are not independent parameters; also introduced were the height H , to account for an error in the slope of the comparison curve, and the fraction of the tropic year to account for a possible seasonal effect. This last quantity was introduced through an auxiliary angle $\phi = 2\pi t/T$ where T is the duration of the tropic year and t the time elapsed since January 1.0 of the year when the meteor appeared.

The equation of condition used had the form

$$\begin{aligned} \log \rho_1 - \log \rho' &= a + b \sin \phi + c \cos \phi + d (\log_{10} v - 6) + eH + f \log_{10} m \\ &= a + M \sin (\phi + \alpha) + d (\log_{10} v - 6) + eH + f \log_{10} m. \end{aligned} \quad (5)$$

Here ρ' is the density at the height H in the comparison profile (A, B, or C).

In view of the peculiar distribution of the meteor material, none of the parameters is, strictly speaking, independent of the others: velocities are closely connected with heights, masses with velocities and there is a tendency for low-velocity meteors to abound in the winter semester and high-velocity meteors to prefer the summer season. The situation, as will be seen, is particularly bad in this respect for the Massachusetts material. For New Mexico, however, the distribution is much more uniform with respect to all parameters and some sense can be made out of the various correlations. A comparison of the solutions made using the complete equation of condition (4) with others in which the coefficients of $\log m$ or of H or both have been put equal to zero is particularly instructive.

A special effort was made by the New Mexico observers to cover the Geminids of 1950, and this resulted in an abnormally high percentage of such meteors in the analyzed material. Since a cursory inspection had shown that the atmospheric densities derived from Geminids seemed to be systematically lower than the average, separate least-squares solutions were made, with and without Geminids.

The results of the various least-squares solutions for the New Mexico data are given in Table VII. An inspection of Table VII leads to the following preliminary results:

a) No matter what comparison profile is taken, and whether or not Geminids are included, the value of d , the coefficient of $\log v$, is always -1.1 or -1.2, and exceeds its probable error by a factor of 10. The 1948 analysis of Massachusetts meteors⁽¹⁾ had given for the coefficient of $\log v$ the values of -0.91 and -0.79, according to the equation of condition used.

b) The coefficient of $\log m$, as was to be expected, is of opposite sign with respect to that of $\log v$. It is important to note that its magnitude is of the same order as that of its probable error and that, when it is put equal to zero in the equation of condition, the remaining coefficients change but very little.

c) The seasonal effect is small, with an amplitude which for most solutions amounts to less than one-half of that derived for Massachusetts in a previous analysis⁽¹⁾. The amplitude is only two to four times larger than its probable error and the phase of the fluctuation is quite different from the one found for Massachusetts. The seasonal effect is, however, strongly dependent on the comparison profile, and any more definite conclusion on its reality should be deferred until later.

A plot of $\log \rho_1$ against H (fig. 1) shows an excellent agreement with the rocket profile C. On the other hand the results listed under A) show that the residuals from this profile are strongly dependent on velocity, and that the cause of this dependence must be sought not in the comparison profile, but in the fundamental equation (1). It appears that the correct value of d is very close to -1.0, which would correspond to an error of one power in v in equation (1). As a second step, then, we tried to make the computed densities independent of velocity by

TABLE VII

Analysis of $\log \rho_1$ for New Mexico Meteors $65 < H < 85 \text{ Km}$

No.	Comparison Profile and Data Used	a	b	c	d	e	f	M	α	Min.
1	A, All Meteors	+0.197 ± 0.200	+0.077 ± 0.028	-0.006 ± 0.020	-1.19 ± 0.12	+0.0002 ± 0.0026	+0.032 ± 0.019	+0.078 ± 0.028	355° ± 15	Oct. 7 ± 16
2	A, All Meteors	+0.184 ± 0.205	+0.054 ± 0.025	-0.004 ± 0.021	-1.22 ± 0.12	+0.0004 ± 0.0027		+0.055 ± 0.025	356 ± 22	Oct. 7 ± 23
3	A, No Geminids	+0.436 ± 0.231	+0.091 ± 0.038	+0.017 ± 0.021	-1.12 ± 0.12	-0.0033 ± 0.0031	+0.049 ± 0.021	+0.093 ± 0.045	11 ± 13	Sept. 21 ± 14
4	A, No Geminids	+0.333 ± 0.229	+0.055 ± 0.024	+0.015 ± 0.021	-1.18 ± 0.11	-0.0016 ± 0.0030		+0.057 ± 0.023	16 ± 22	Sept. 16 ± 22
5	B, All Meteors	+0.490 ± 0.053	+0.088 ± 0.024	-0.032 ± 0.021	-1.09 ± 0.12			+0.094 ± 0.023	340 ± 13	Oct. 22 ± 13
6	B, All Meteors	+0.013 ± 0.018	+0.104 ± 0.029	-0.129 ± 0.022				+0.165 ± 0.025	309 ± 9	Nov. 23 ± 9
7	B, No Geminids	+0.521 ± 0.051	+0.083 ± 0.022	+0.017 ± 0.022	-1.13 ± 0.17			+0.085 ± 0.022	11 ± 15	Sept. 20 ± 15
8	B, No Geminids	+0.035 ± 0.018	+0.094 ± 0.029	-0.093 ± 0.024				+0.132 ± 0.029	315 ± 11	Nov. 16 ± 12
9	C, All Meteors	-1.133 ± 0.207	+0.076 ± 0.029	-0.009 ± 0.021	-1.22 ± 0.13	+0.0217 ± 0.0027	+0.028 ± 0.020	+0.077 ± 0.029	354 ± 16	Oct. 9 ± 16
10	C, All Meteors	-1.143 ± 0.207	+0.056 ± 0.025	-0.007 ± 0.021	-1.25 ± 0.12	+0.0221 ± 0.0027		+0.057 ± 0.025	353 ± 22	Oct. 9 ± 22
11	C, No Geminids	-0.883 ± 0.236	+0.089 ± 0.029	+0.013 ± 0.022	-1.15 ± 0.12	+0.0183 ± 0.0031	+0.041 ± 0.022	+0.089 ± 0.029	9 ± 14	Sept. 23 ± 14
12	C, No Geminids	-0.969 ± 0.233	+0.058 ± 0.024	+0.012 ± 0.022	-1.21 ± 0.12	+0.0197 ± 0.0030		+0.059 ± 0.024	11 ± 21	Sept. 20 ± 21
13	C, No Geminids	+0.505 ± 0.058	+0.116 ± 0.025	+0.020 ± 0.024	-1.05 ± 0.19			+0.118 ± 0.025	10 ± 11	Sept. 22 ± 11

This table gives the results of the various least-squares solutions computed, using the equation of condition

$$\log \rho_1 - \log \rho' = a + b \sin \phi + c \cos \phi + d(\log_{10} v - 6) + eH + f \log_{10} m$$

$$= a + M \sin(\phi + \alpha) + d(\log_{10} v - 6) + eH + f \log_{10} m.$$

Here ρ' is the density at the height H in the comparison profile specified for each solution; $\phi = \frac{2\pi}{T}t$ where T is the duration of the tropic year and t the time elapsed since January 1.0; v is the meteor velocity in cm/sec. and m the meteor mass in grams.

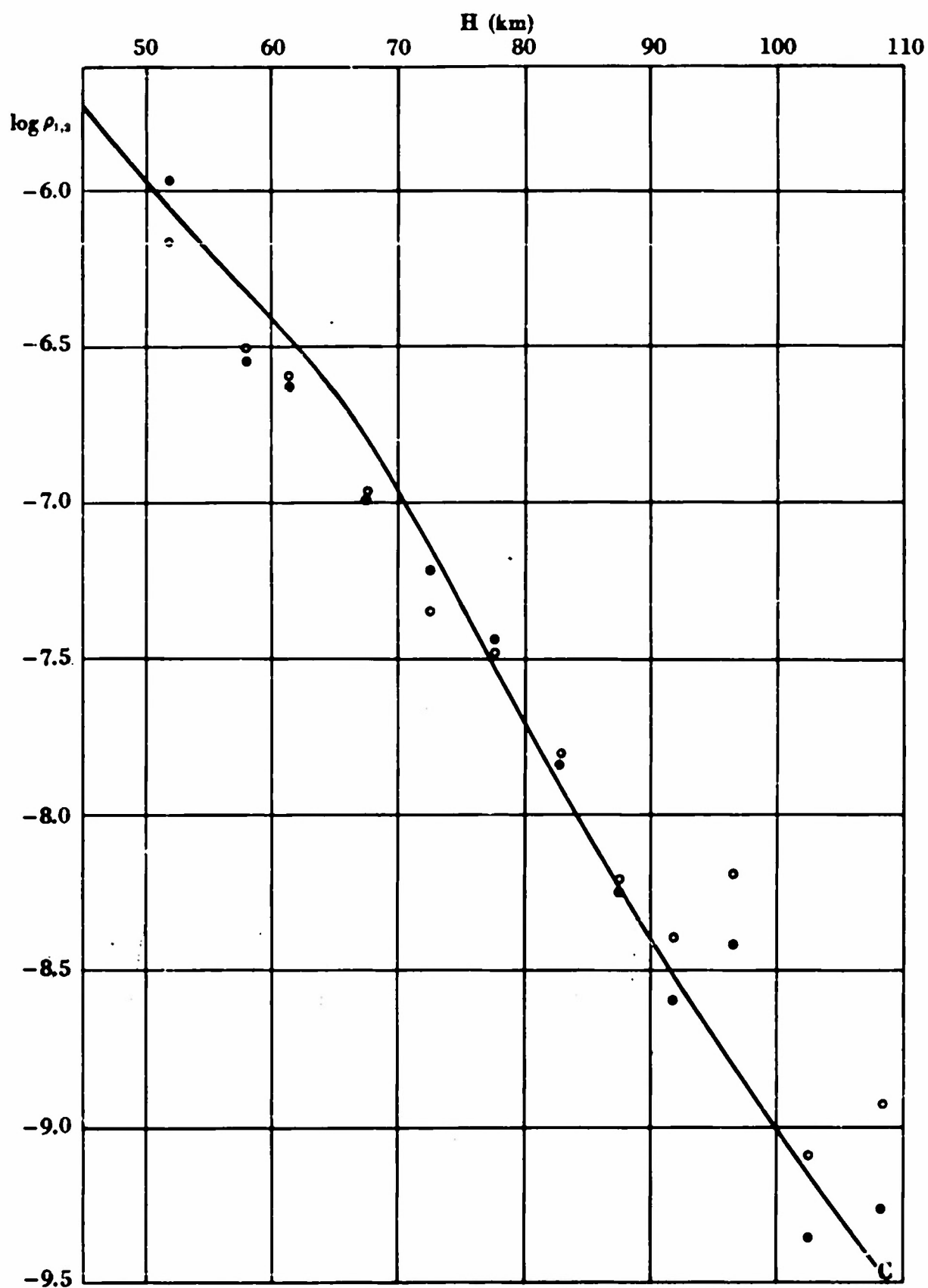


Fig. 1

Means of $\log \rho_1$ (dots) and $\log \rho_2$ (open circles) from New Mexico Meteors.
The rocket profile C is shown for comparison.

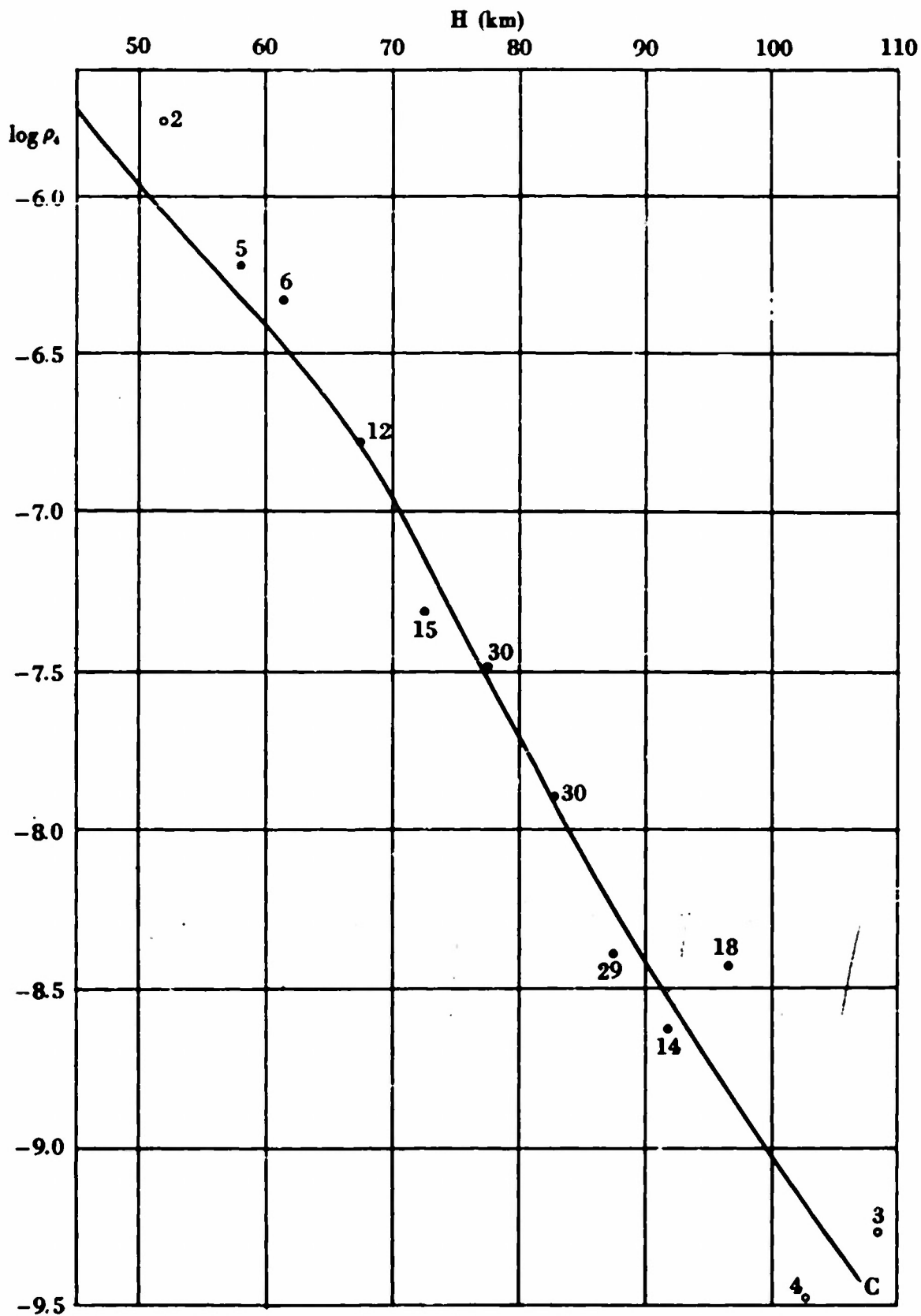


Fig. 2

Corrected Mean Atmospheric Densities ρ , from New Mexico Meteors. The figures which accompany the plotted points indicate the number of observations used to compute the mean. Means from fewer than five observations are shown as open circles. The rocket profile C is shown for comparison.

reducing them, assuming $d = -1$, to a standard velocity of 30 km/sec. These corrected densities were designated ρ_2 ; we thus have the following equation for ρ_2 :

$$\rho_2 = \frac{v}{3 \times 10^6} \rho_1. \quad (6)$$

In view of the small change in velocity during the course of a meteor trajectory, equation (2) can be written, approximately, as

$$m = \frac{2}{\tau_0 v^3} \int_t^{\infty} I dt = \frac{2}{\tau_0} L v^{-3}. \quad (7)$$

This means that, for all practical purposes, equation (1) becomes

$$\rho = -\frac{2K}{\tau_0} L^{\frac{1}{3}} v^{-4} \frac{dv}{dt}. \quad (8)$$

The change from ρ_1 to ρ_2 would imply a change from v^{-4} to v^{-3} in this equation. Were it not for the results listed under b), we could be entirely agnostic and ascribe the blame for this change indifferently to an error in the power of v in (1) or in (7). Ascribing the blame to equation (7) would mean making m independent of velocity. Then all meteors having the same brightness would have the same mass, and the thermal theory of meteor light would have to be abandoned.

There are some indications that this is not the case. The excellent agreement of theoretical light curves with observations⁽²⁾ and the behavior of low-velocity meteors⁽²⁾ would indicate a definite dependence of masses on velocity. Apart from this, the results listed under b) show that there is at best only a doubtful dependence of density residuals on the mass as computed by (2). It looks as though most of the trouble arises from the form of the drag equation.

Means of $\log \rho_2$ against H are shown in Table IX and in Fig. 1. Since greater velocities are observed at greater height, the velocity correction ($\log \rho_2 - \log \rho_1 = \log v - 6.477$) increases with height and, conforming to expectation, the slope of $\log \rho_2$ becomes smaller than that of $\log \rho_1$, which agreed with the slope of the rocket profile. We are thus left with a set of "densities" which are practically independent of velocity, as we desired, but do not agree with the known density profile. It would seem that the introduction of a scale factor R somewhat larger than unity would restore the proper slope. Densities ρ_3 computed by the equation

$$\log \rho_3 = A + R \log \rho_2 \quad (A = \text{constant}), \quad (9)$$

would leave residuals from profile C which would presumably prove independent of velocity and height, but would still be affected by a possible seasonal fluctuation. The final densities ρ_4 , corrected for seasonal effect, were computed by least-squares, using the equation of condition

$$\begin{aligned} \log \rho_c &= A + R \log \rho_2 - B \sin \phi - C \cos \phi \\ &= A + R \log \rho_2 - M \sin(\phi + \alpha) \end{aligned} \quad (10)$$

where ρ_c is the density on profile C at the height corresponding to ρ_2 . The values of ρ_4 are the values of ρ_c computed by (10), once A , B , C and R have been determined. The presence of a scale factor $R \neq 1$ must be considered as a purely empirical device to make the computed densities agree with the observed rocket profile. A theoretical explanation is not attempted at this stage.

Since a large range in heights is necessary for an accurate determination of the scale

factor R , the least-squares solution was extended to all meteors with heights lower than 90 km, Geminids excluded. The results are given below:

$$A = +2.059 \pm .288$$

$$B = +0.056 \pm .028$$

$$C = -0.034 \pm .024$$

$$R = +1.275 \pm .151$$

$$M = +0.066 \pm .027$$

$$\alpha = 329^\circ \pm 22^\circ$$

(Minimum density: Nov. 3 $\pm$ 22^d)

Within the same range of heights as that of the least-squares solution there are 25 densities determined from Geminids. When $\log \rho_4$ is computed for them, they yield residuals Δ_4 from profile C, whose weighted mean is -0.10 . We consequently assumed the value of $+0.10$ to represent the mean correction to $\log \rho_4$ as determined from Geminids. Mean values of $\log \rho_4$ in function of height are shown in Table IX and Fig. 2. For heights above 85 km, where means were taken in ρ rather in $\log \rho$, the mean of the individual seasonal corrections was applied to each mean point. For the same points the correction to $\log \rho_4$ for the presence of Geminids was taken as $+0.10$ times the ratio of the sum of the Geminid weights over the total sum of the weights within the 5 km range of heights considered.

As a final check on the non-dependence of ρ_4 from meteor velocities, the coefficient of correlation between $\log \rho_4$ and $\log v$ was computed for all meteors with $H < 90$ km (corrected Geminids included) and found to be equal to 0.002.

The amplitude of the seasonal fluctuation which results from this least-squares solution is only twice as large as its probable error. In view of the possibility that the seasonal effect might be a function of height and that the picture might become somewhat blurred if the analysis were made over too large a range in height, another solution was computed for heights between 65 and 85 km, Geminids excluded, using a slightly different method. $\log \rho_3$ was computed by equation (9), using $A = +2.059$ and $R = 1.275$, and the residuals Δ_3 from profile C were analyzed for seasonal effect. The result of the least-squares solution is given below:

$$\begin{aligned} \Delta_3 &= -0.0096 + 0.083 \sin (\phi + 359^\circ 5) \\ &\pm .0083 \pm 0.040 \end{aligned} \quad (11)$$

As we see, the results are not too dissimilar from those obtained using all meteors with $H < 90$ km. The amplitude is 25% larger, but still only twice as large as its probable error, and the minimum density falls on October 2, or one month earlier. In our judgment it would be a little premature to give a definite pronouncement concerning the reality of the effect.

4. Analysis of the Massachusetts Data:

Values of $\log \rho_1$ for most of the Massachusetts meteors have been published in Technical Report No. 2⁽¹¹⁾. For a number of meteors the data are presented here in a somewhat different form. Previously, when decelerations were determined on two plates for the same meteor, their weighted mean was used in most cases to compute atmospheric densities. To make the Massachusetts material entirely consistent with that from New Mexico, decelerations from different plates are here treated separately.

For a comparison with the New Mexico data we must compute ρ_2 and ρ_3 according to equations (6) and (9), analyze ρ_3 for seasonal variation and finally obtain a profile of ρ_4 . Before we proceed to do this, however, it will be instructive to look at the results of some preliminary analyses of ρ_1 which were undertaken, a little haphazardly, in the early stages of this investigation. Table VIII summarizes the results of least-squares solutions computed exactly in the same manner as for New Mexico meteors, with the equation of condition (5), using two different comparison profiles. This table should be compared with Table VII.

TABLE VIII

Analysis of Log ρ_1 for Massachusetts Meteors $65 < H < 85 \text{ Km}$

No.	Comparison Profile and Data Used	a	b	c	d	e	f	M	α	Min.
1	A, All Meteors	-0.734 ± 0.249	-0.104 ± 0.036	-0.041 ± 0.037	-0.762 ± 0.212	+0.0109 ± 0.0035	-0.002 ± 0.078	+0.112 ± 0.036	202 ^o ± 19	March 11 ± 19
2	A, All Meteors	-0.736 ± 0.244	-0.104 ± 0.034	-0.042 ± 0.036	-0.759 ± 0.204	+0.0109 ± 0.0034		+0.112 ± 0.035	202 ± 19	March 11 ± 19
3	A, No Geminids	-0.872 ± 0.246	-0.091 ± 0.034	+0.001 ± 0.039	-0.593 ± 0.281	+0.0122 ± 0.0037	-0.045 ± 0.031	+0.091 ± 0.034	179 ± 25	April 3 ± 25
4	A, No Geminids	-0.904 ± 0.244	-0.108 ± 0.032	+0.006 ± 0.039	-0.412 ± 0.251	+0.0109 ± 0.0036		+0.108 ± 0.032	177 ± 21	April 6 ± 21
5	A, No Geminids	-0.246 ± 0.114	-0.159 ± 0.030	-0.014 ± 0.040	-0.050 ± 0.228			+0.160 ± 0.030	185 ± 14	March 28 ± 14
6	C, All Meteors	-2.220 ± 0.255	-0.111 ± 0.036	-0.042 ± 0.038	-0.775 ± 0.217	+0.0344 ± 0.0035	+0.009 ± 0.080	+0.119 ± 0.037	201 ± 18	March 12 ± 19
7	C, All Meteors	-2.210 ± 0.250	-0.108 ± 0.035	-0.041 ± 0.037	-0.791 ± 0.209	+0.0345 ± 0.0035		+0.116 ± 0.036	201 ± 18	March 12 ± 19
8	C, All Meteors	+0.066 ± 0.143	-0.266 ± 0.045	-0.156 ± 0.051	-0.070 ± 0.281			+0.300 ± 0.047	210 ± 9	March 2 ± 9
9	C, No Geminids	-0.286 ± 0.165	-0.275 ± 0.043	-0.052 ± 0.056	+0.661 ± 0.330			+0.280 ± 0.043	191 ± 11	March 22 ± 12

For detailed explanations, see bottom of Table VII.

TABLE IX

Mean Atmospheric Densities from New Mexico Meteors

(Weighted Means within 5-Km Groups; Geminid Densities Corrected)

H (km)	$\log \rho_1$	Δ_1	$\log \rho_2$	Δ_2	$\log \rho_3$	Δ_3	$\log \rho_4$	Δ_4	n
51.9	-5.97	+0.09	-6.17	-0.11	-5.81	+0.25	-5.76	+0.30	2
58.0	-6.55	-0.23	-6.51	-0.19	-6.26	+0.06	-6.22	+0.10	5
61.3	-6.63	-0.16	-6.60	-0.13	-6.38	+0.09	-6.33	+0.14	6
67.4	-6.99	-0.20	-6.97	-0.18	-6.84	-0.05	-6.78	+0.01	12
72.6	-7.22	-0.07	-7.35	-0.20	-7.32	-0.17	-7.31	-0.16	15
77.6	-7.44	+0.08	-7.48	+0.04	-7.49	+0.03	-7.48	+0.04	30
82.7	-7.84	+0.06	-7.81	+0.09	-7.90	0.00	-7.65	+0.01	30
87.5	-8.25	-0.01	-8.21	+0.03	-8.41	-0.17	-8.39	-0.15	29
91.7	-8.60	-0.09	-8.40	+0.11	-8.66	-0.15	-8.63	-0.12	14
96.5	-8.42	+0.39	-8.19	+0.62	-8.39	+0.42	-8.43	+0.38	18
102.6	-9.36	-0.18	-9.10	+0.08	-9.55	-0.37	-9.48	-0.30	4
108.3	-9.27	+0.23	-8.93	+0.57	-9.33	+0.17	-9.27	+0.23	3

$\Delta_1, \Delta_2, \Delta_3, \Delta_4$ are residuals of the respective $\log \rho$'s from the
Rocket Profile C (Table VI)

TABLE X

Mean Atmospheric Densities from Massachusetts Meteors

(Weighted Means within 5-Km Groups; Geminid Densities Corrected)

H (km)	$\log \rho_1$	Δ_1	$\log \rho_2$	Δ_2	$\log \rho_3$	Δ_3	Δ'_3	$\log \rho_4$	Δ_4	Δ'_4	n
48.83	-6.12	-0.20	-6.10	-0.18	-5.75	+0.17	+0.10	-5.73	+0.19	+0.12	3
56.63	-6.48	-0.22	-6.47	-0.21	-6.22	+0.04	+0.01	-6.17	+0.09	+0.06	5
62.32	-6.76	-0.25	-6.88	-0.37	-6.71	-0.20	-0.16	-6.66	-0.15	-0.11	7
66.63	-7.02	-0.28	-7.07	-0.33	-6.96	-0.22	-0.17	-6.92	-0.18	-0.13	9
73.43	-7.20	0.00	-7.20	0.00	-7.13	+0.07	+0.03	-7.13	+0.07	+0.03	9
78.30	-7.36	+0.21	-7.39	+0.18	-7.36	+0.21	+0.06	-7.42	+0.15	0.00	14
81.98	-7.63	+0.22	-7.57	+0.28	-7.60	+0.25	+0.02	-7.62	+0.23	0.00	12
86.8	-7.96	+0.23	-7.78	+0.41	-7.86	+0.33	+0.04	-7.87	+0.32	+0.03	10
92.2	-8.35	+0.19	-8.07	+0.47	-8.23	+0.31	-0.03	-8.37	+0.17	-0.17	13
95.2	-8.46	+0.27	-8.12	+0.61	-8.30	+0.43	+0.07	-8.42	+0.31	-0.05	2
101.3	-8.47	+0.63	-8.12	+0.98	-8.30	+0.80	+0.41	-8.40	+0.70	+0.31	2

$\Delta_1, \Delta_2, \Delta_3, \Delta_4$ are residuals of the respective $\log \rho$'s from the Rocket Profile C.

Δ'_3 and Δ'_4 are residuals of $\log \rho_3$ and $\log \rho_4$ from the Massachusetts Profile H.

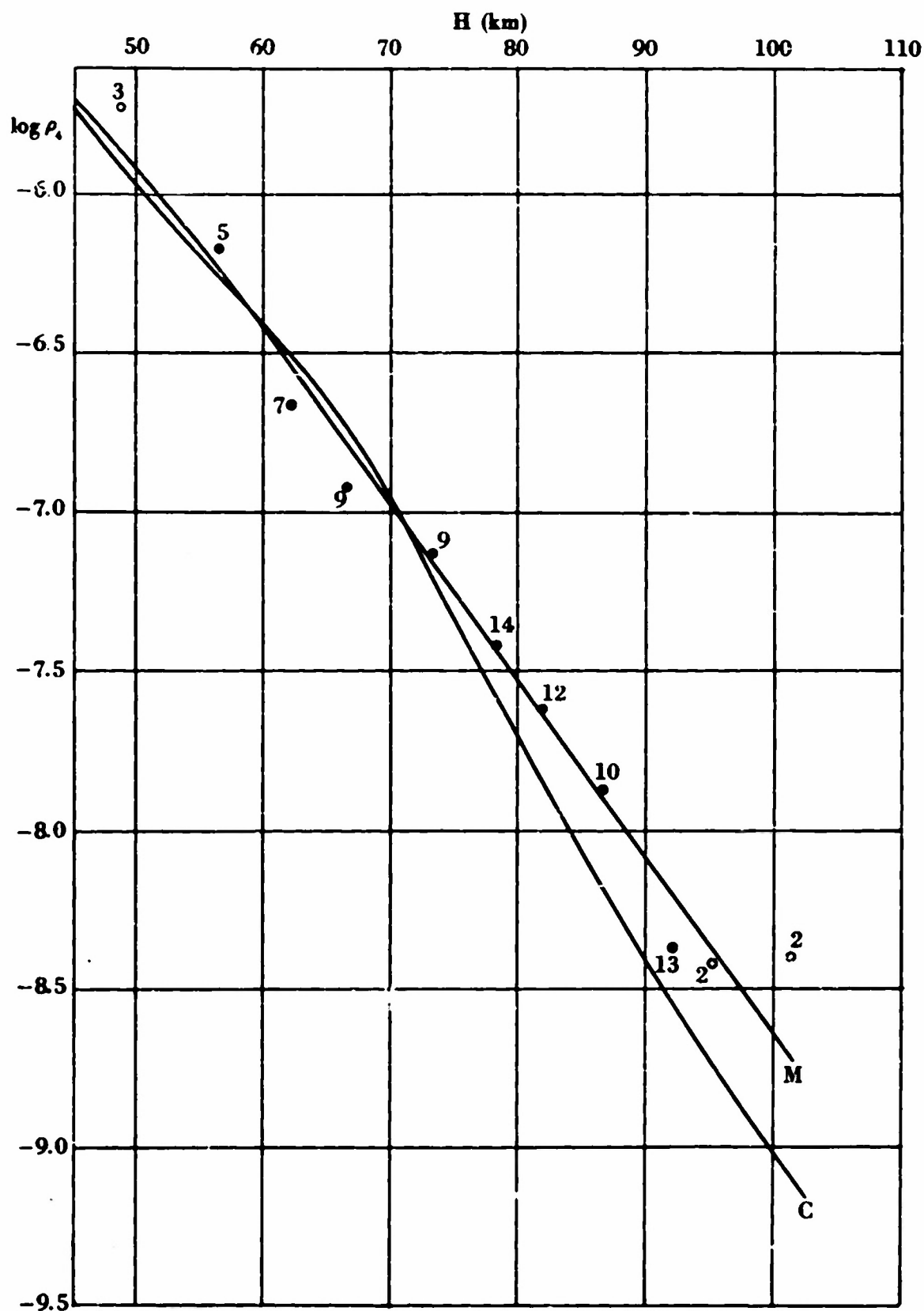


Fig. 3

Corrected Mean Atmospheric Densities ρ_0 from Massachusetts Meteors. The figures which accompany the plotted points indicate the number of observations used to compute the mean. Means from fewer than five observations are shown as open circles. The rocket profile C and the new Massachusetts profile M are shown for comparison.

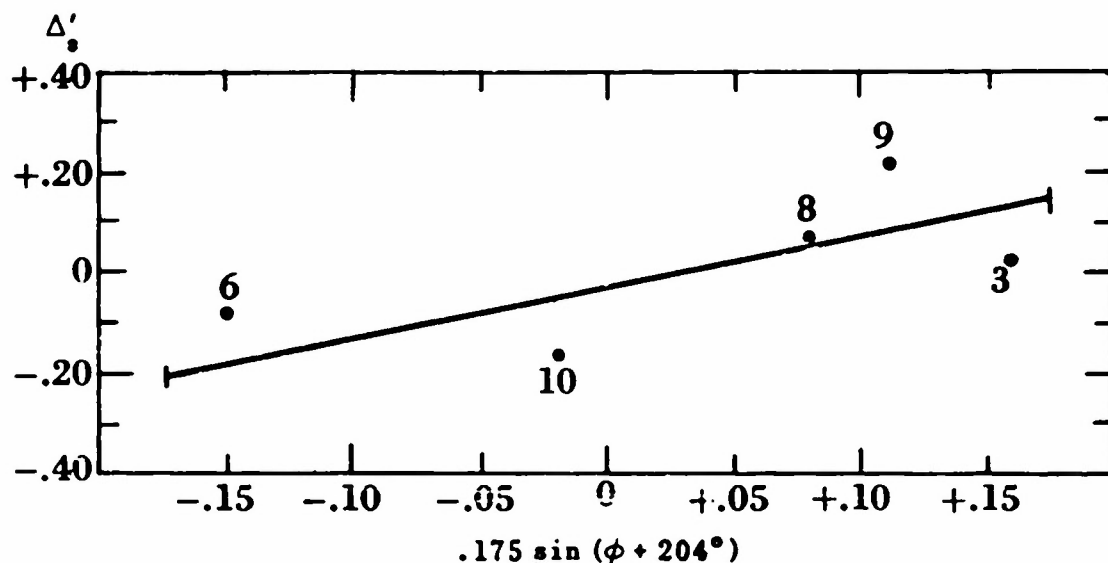


Fig. 4

Seasonal Effect in Massachusetts. Means of the residuals Δ'_3 of $\log \rho_3$ from profile M for heights between 65 and 85 km. The number of residuals which concurred to form the individual means is indicated in the diagram. The straight line represents the result of the least-squares solution.

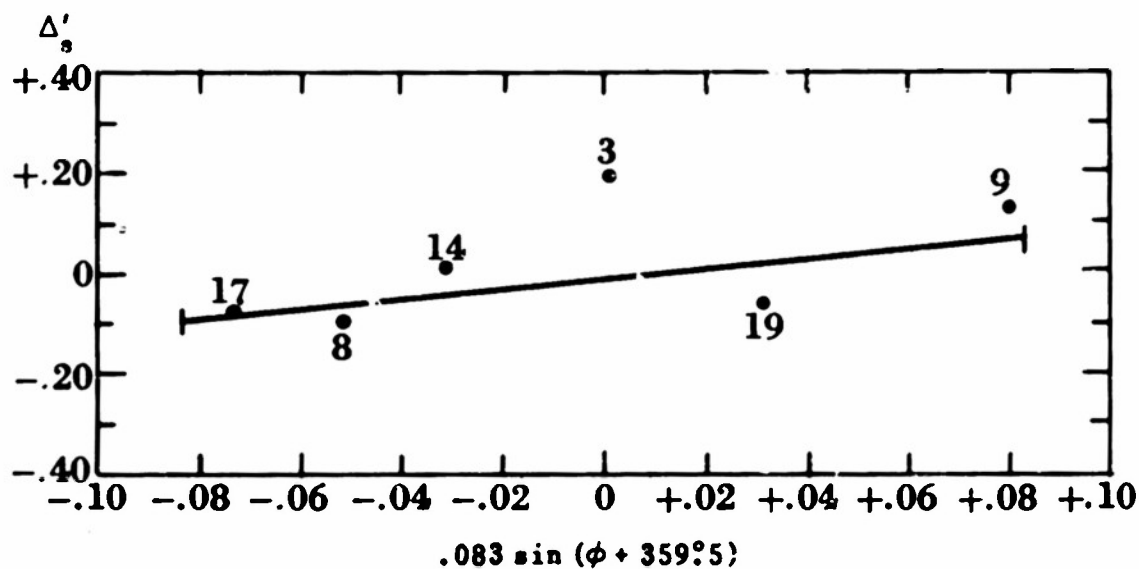


Fig. 5

Seasonal Effect in New Mexico. Means of the residuals Δ'_3 of $\log \rho_3$ from the rocket profile C for heights between 65 and 85 km. The number of residuals which concurred to form the individual means is indicated in the diagram. The straight line represents the result of the least-squares solution.

As we have previously mentioned, the distribution of Massachusetts meteors with regard to seasons, velocities and heights is quite bad. A sizable fraction of New Mexico meteors yielded more than one deceleration in the course of the visible trajectory. In Massachusetts with smaller cameras, poorer sky and slower, two-blade shutters, multiple-deceleration meteors were the exception rather than the rule. The result is that even in the region between the heights of 65 and 85 km there is little overlap in heights and velocities, and the situation is made worse by the preference - fortuitous or not - of high-velocity meteors for the summer season.

As a consequence of this situation, the parameters of the equation of condition (5) are strongly interrelated and the least-squares solutions computed on its basis lose much of their significance. This must be kept in mind when results from this analysis are compared with previous results.

The instability of the solution is made quite evident by an inspection of the d column in Table VIII. While for New Mexico the value of d was quite stable in the vicinity of -1.1 for all comparison profiles and changes of parameters, here it changes very drastically with the slope of the comparison profile. If we make $e = 0$, i.e., if we do not allow for an error in the slope of the comparison profile, the strong dependence of velocities on heights will cause d to assume practically any value, and even to change sign, according to the profile which is taken for comparison. The comparison profile has also a strong influence on the amplitude of the seasonal effect - although much less on its phase.

Of all the solutions, No. 2 is the one which can be most directly compared with the results of Technical Report No. 2, Eq. (14). The comparison profile was in one case the N.A.C.A. profile⁽¹⁾, in the other profile A, but due to the presence of the eH term in the equation of condition, the conditions are quite similar in both cases. The value of d was -0.91 in the old, -0.76 in the new solution.

After this digression, we can go back to the outlined reduction of the Massachusetts ρ_1 's. Table IVa gives $\log \rho_2$ and $\log \rho_3$ as computed from ρ_1 , with their residuals Δ_2 and Δ_3 from profile C. Mean values of $\log \rho_3$ taken in 5-km intervals were plotted against H and a smooth curve drawn through the points. The residuals from this curve, in the height range between 65 and 85 km (Geminids excluded) were analyzed for seasonal effect and the resulting seasonal correction applied to ρ_3 . A new curve (almost identical with the preceding one) was drawn through these corrected densities and was assumed to be the final Massachusetts density profile (M in Table VI). The residuals of $\log \rho_2$ from this profile are designated Δ'_3 in Tables IVa and IVb. A final analysis of Δ'_3 in the same interval as before, gives

$$\Delta'_3 = -0.033 + 0.175 \sin(\phi + 204^\circ) \quad (12)$$

$$\pm .032 \pm .040 \quad \pm 16$$

The final corrected densities ρ_4 [i.e., $\log \rho_3$ with the correction $-0.175 \sin(\phi + 204^\circ)$ applied to them, and the extra correction $+0.10$ applied to Geminids] are shown in Tables IVa and IVb. Means in 5-km height intervals are given in Table X and plotted in Fig. 3.

The seasonal effect, as given by (12) is in fair agreement with the results of Technical Report No. 2. There the fluctuation was given as a function of the mean normal temperature T in Boston, with a coefficient of $+0.015$ per $^\circ\text{C}$. This would correspond to a semi-amplitude of 0.18 with a minimum toward the end of January. Here the semi-amplitude is 0.175 with a minimum on March 9. It is perhaps significant that, while the amplitude of the seasonal fluctuation turns out to be twice as large as in New Mexico, its probable error is just about the same in both localities. Although some caution should be exercised in interpreting this result in view of the bad distribution of the meteors in Massachusetts, it might indicate a change of the seasonal fluctuation with latitude; if so, the change is definitely in the expected direction.

The final, corrected densities for Massachusetts seem to be in fair agreement with the New Mexico profile up to 75 km. For greater heights, however, the Massachusetts densities seem to be systematically higher. It would be highly suggestive to attribute this divergence to a latitude effect. We hope that future observations will throw more light on this important point.

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