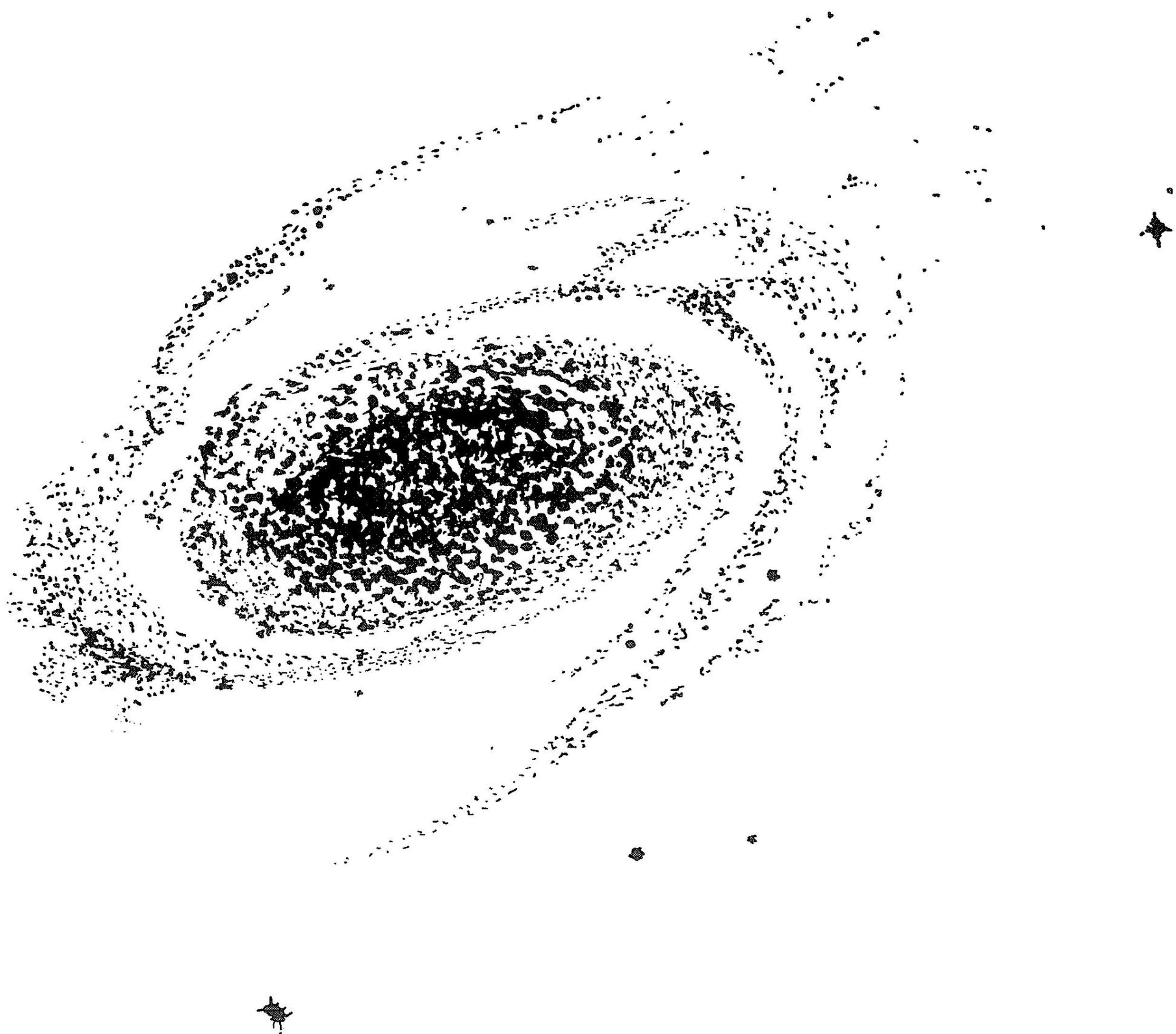
DISCRETE LEVELS OF BEGINNING HEIGHT OF METEORS IN STREAMS

A. F. COOK



Smithsonian Astrophysical Observatory
SPECIAL REPORT 324

Research in Space Science
SAO Special Report No. 324

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September 8, 1970

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006-12

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ABSTRACT

Of the 26 streams of meteors classified according to Ceplecha's discrete levels of beginning height, 13 are associated with known comets. Comet Biela produced in the Andromedids a double-peaked distribution (Classes A and C_1). Apparently no known comets produce a stream of Class B. Consideration of Whipple and Stefanik's model of an icy conglomerate nucleus with radioactive heating and redistribution of ice leads to association of Ceplecha's Class C with the residue of the ice-impregnated surface of a cometary nucleus after sublimation of the ices, and the Ceplecha's Class A with the core of a cometary nucleus. Class B meteoroids are then to be associated with less dense cores of smaller cometary nuclei that have lost their surfaces and are too small to have been observed. Furthermore, the density of Class A meteoroids (1.2 g cm^{-3}) is so close to that of Type I carbonaceous chondrites (2 g cm^{-3}) as to suggest that the latter come from old cores of very large nuclei of comets, an idea originally proposed by McCrosky and Ceplecha.

It is suggested that two inert objects that look like asteroids may yet remain from the two pieces observed at the last return of P/Comet Biela. The recovery of Comet 1930 VI, Schwassmann-Wachmann 3, at its return in 1979 is urged since it is the only available comet producing a shower (τ Herculids) of Class A. A search for an asteroidal object or a very small comet in the orbit of the Geminids is also urged as the best chance of finding an object that produces meteoroids of Class B. Further study of the distribution of radiants and velocities of meteors in June and early July in Scorpius, Sagittarius, Ophiuchus, and Serpens is required to sort out the true structure there, if indeed one exists.

RÉSUMÉ

Parmi les 26 essaims de météores classés suivant les niveaux discrets d'altitude d'apparition de Ceplecha, 13 sont associés à des comètes connues. La comète Biela produit dans les Andromédides une distribution à deux pics (Classes A et C_1). Apparemment, aucune comète connue ne produit un essaim de la Classe B. Un examen du modèle de Whipple et Stefanik d'un noyau congloméré de glace avec chauffage radioactif et redistribution de la glace conduit à associer la Classe C de Ceplecha avec le reste de la surface imprégnée de glace d'un noyau d'une comète après sublimation des glaces, et la Classe A de Ceplecha avec le centre du noyau d'une comète. Les météorites de classe B doivent donc être associées aux centres moins denses de noyaux de comètes plus petits qui ont perdu leurs surfaces et sont trop petits pour être observés. De plus, la densité des météorites de Classe A (1,2 g cm^{-3}) est si proche de celle des chondrites carbonés du Type I (2 g cm^{-3}) que cela laisse supposer qu'ils viennent des vieux centres des noyaux de comètes très larges, une idée proposée à l'origine par McCrosby et Ceplecha.

Il est suggéré que deux objets inertes qui ressemblent à des astéroides peuvent cependant être les restes des deux morceaux observés lors du dernier retour de la P/Comète Biela. La redécouverte de la Comète 1930 VI, Schwassmann-Wachmann 3, au moment de son retour en 1979 est désirée puisque c'est la seule comète disponible qui produise une pluie de la Classe A (τ Herculides). La recherche d'un petit astéroïde ou d'une comète très petite dans l'orbite des Géminides est aussi désirée, en tant qu'étant la meilleure chance de trouver un objet qui produise des météorites de la Classe B. Une étude plus poussée de la distribution des radiants et des vitesses des météores en Juin et début Juillet dans Scorpion, Sagittaire, Ophiuchus et Serpent est requise pour établir la vraie structure qui existe là, si toutefois il en existe une.

КОНСПЕКТ

Из 26 потоков метеоров классифицированных по дискретным уровням Сеплеча начальной высоты, 13 являются связанными с известными кометами. Комета Биэла произвела двух пиковое распределение (Классы А и C_1). Повидимому нет известных комет производящих поток Класса В. Рассмотрение модели Уиппла и Стефаника ледяного конгломератного ядра с радиоактивным согреванием и перераспределением льда приводит к связи группы С Сеплеча с остатками пропитанной льдом поверхности кометного ядра после сублимации льдов, и группы А Сеплеча с твердой сердцевиной кометного ядра. Метеорные тела группы В тогда должны быть связанными с менее плотными сердцевинами меньших кометных ядер потерявших ихние поверхности и являющихся черезчур малыми для наблюдения. К тому же, плотность метеорных тел Класса А (1,2 г/см$^{-3}$) является настолько близкой к плотности углеродных хондритов типа I (2 г/см$^{-3}$), что наводит на мысль, что последний происходит из старых сердцевин очень больших ядер комет, мысль начально предложенную МкКроским и Сеплечой.

Предлагается что два инертных предмета похожих на астероидов все же могут происходить от двух кусков наблюдаемых во время последнего возвращения Р/Кометы Биэлы. Очень настаивается на восстановлении кометы 1930 VI, Счвассманн-Уачманн 3, во время ея возвращения в 1979 году, так как она является единственной доступной кометой производящей поток (τ Геркулид) Класса А. Также побуждаются поиски астероидального предмета или очень малой кометы в орбите Близнецов как имеющих наилучшие шансы нахождения предмета производящего метеорные тела Класса В. Необходимо дальнейшее изучение распределения радиантов и скоростей метеоров в июне и раннем июле в Скорпионе, Стрельце, Змееносце и Змие для отбора настоящей структуры там, если таковая действительно существует.

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A. F. Cook

1. INTRODUCTION

Ceplecha (1968) plotted the photographed meteors reduced by McCrosky and Posen (1961) and not identified as members of streams, with beginning height as ordinate and velocity outside the atmosphere as abscissa. His Figure 1 exhibits the basic result. He found three ridges of maximum density of points. The lowest of these he designated as Class A, the highest as Class C, and an intermediate maximum apparent only from 27.5 to 43.7 km sec^{-1} as Class B. His Class C showed two peaks, one below 41.8 km sec^{-1} and the other above it, and he designated these regions as Classes C_1 and C_2, respectively.

Ceplecha favored the interpretation that the differences in beginning height were due solely to variations in density of the meteoroid. Subsequent studies by McCrosky and Ceplecha (1970) and by the author (in preparation) provide plots of log $(1/K_m)$ versus log V_∞, where K_m is a coefficient in the deceleration equation for meteors and V_∞ is the velocity of the meteoroid outside the atmosphere. The three classes appear in these plots too. However, the separation is not enough to explain fully the separations of Ceplecha's discrete levels. He also found that meteors of Class A had trajectories shorter than

This work was supported in part by grants NGR 09-015-033 and NGR 09-015-004 from the National Aeronautics and Space Administration.

those of Class C, which implies that they have larger values of Jacchia's (1955) fragmentation index χ. This provides the explanation for the remainder of the separation of beginning heights.

It appears, therefore, that we may be able to use Ceplecha's classes to separate streams of meteors according to the density of the meteoroids. Ceplecha (1968) has already done this for some streams. Lindblad (1970b) subsequently analyzed the meteors of McCrosky and Posen (1961) statistically to identify several new streams. Identifications of streams from more restricted groups of meteors had previously been made by Whipple (1954), Jacchia and Whipple (1961), Southworth and Hawkins (1963), and Lindblad (1970a). McCrosky and Posen (1959) identified streams from the same sample as did Lindblad (1970b). The present paper considers these additional streams as well as the better known ones classified by Ceplecha.

2. CRITERIA FOR REALITY OF STREAMS

We accept as real only those streams that show four meteors, or three meteors and an associated comet, in McCrosky and Posen's (1961) list or those that are already well known. This is almost the criterion recommended by Lindblad (1970b). Inasmuch as most of the observations used by McCrosky and Posen were obtained from 1952 to 1954, there is little assurance that all these streams recur annually. Incidentally, for the purposes of this paper, the Cyclids (Southworth and Hawkins, 1963) are regarded as the product of observational selection, caused by the earth's enhanced collisional cross section, for meteoroids in orbits nearly the same as that of the earth; they are not counted as a stream. Application of these criteria yields 39 optical streams. Of these, 1 does not appear in the observations, 12 do not show enough meteors to permit classification (this point will be discussed further below), and 11 exhibit such extreme character that some remark about their densities can be made in spite of the small number of meteors involved. We are left with 15 streams that are sufficiently abundant to be unambiguously classified.

3. CLASSIFICATION OF STREAMS

The logical method of classification is to begin with the most abundant stream and continue with decreasing numbers until it is evident that we are approaching uncertain ground.

1) The most abundant stream is the extended one of the Taurids, which are 105 in number and are usually divided into a northern and a southern component. Lindblad's search does not make this division but instead subdivides the stream into three overlapping parts according to the sun's longitude $L_\odot$. The elements q, a, i, ω remain constant as $L_\odot$ increases, while Ω and π progress steadily from part to part of the stream (here q is the distance at perihelion, a the semimajor axis, i the inclination, ω the argument of perihelion, Ω the longitude of the ascending node, and π the longitude of perihelion). There is a reversal of nodes as Lindblad switches from predominance of the northern branch to that of the southern branch. Table 1 presents the details of the Taurid streams found by Lindblad. It is apparent that the total activity extends over almost 4 months, growing steadily until the maximum at about 1 November given by McKinley (1961). Figure 1 exhibits the distribution of beginning heights of this stream.

The heights for Ceplecha's Classes C_1, B, and A are marked in Figure 1. The coincidence of the maximum with Class C_1 is evident, as are also the rather abrupt decline in numbers at greater beginning heights and the straggling tail to lower beginning heights. If the distribution were symmetrical, we might hope that as few as $3^2 = 9$ meteors would suffice to classify a stream. The process that causes skewing toward the lower heights implies, however, that 9 meteors will be insufficient. Inasmuch as Lindblad has segregated 9 of these Taurids as Piscids, we can examine their distribution as shown in Figure 2. They appear to suggest Class B, but since it is evident that three mavericks at lower beginning heights could account for this appearance, we conclude that more than 9 meteors are required to classify a stream unambiguously.

Table 1. The three Taurid streams of Lindblad (1970b).

Name	Lindblad's duration	q	a	e	i	ω	Ω	π	α_R	δ_R	V_G (km sec^{-1})	No. of meteors
N. ι Aquarids*	21 Aug. – 20 Sept.	0.33	2.00	0.83	4.°0	300°	161°	101°	354°	+ 1	31	3
Piscids	25 Sept. – 19 Oct.	0.40	2.06	0.80	3.4	291	199	130	26	+14	29	9
Taurids	19 Sept. – 21 Nov.	0.33	1.99	0.83	3.3	119	29	148	40	+13	31	91

*McCrosky and Posen (1961) identify two additional members on 27 July and 18 August, which would raise the number of meteors to five and extend the duration back to 27 July. The author concurs in these identifications.

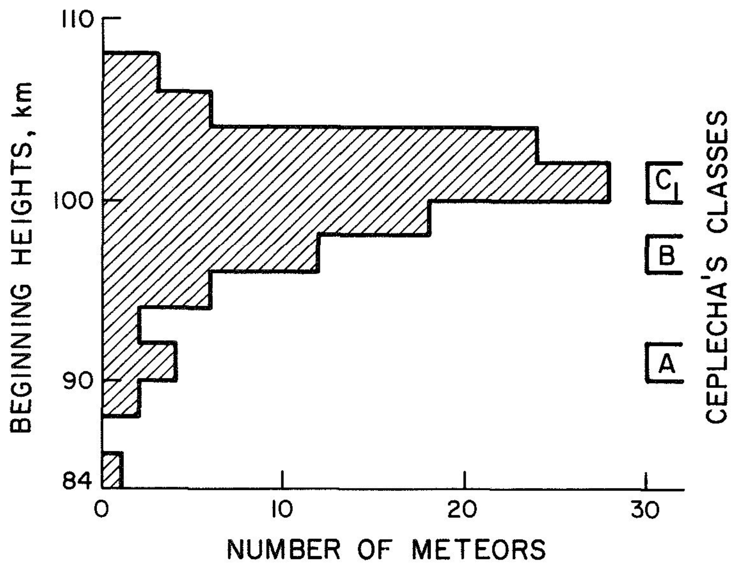


Figure 1. Distribution of beginning heights for the extended stream of the Taurids.

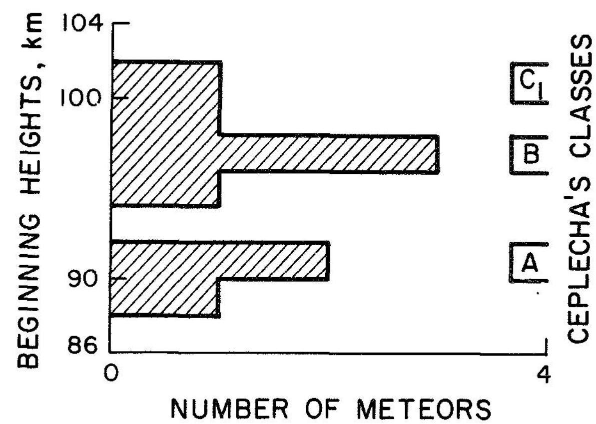


Figure 2. Distribution of beginning heights for the Piscids.

2) The Geminids are 77 in number and are displayed in Figure 3. This shower is plainly of Class B. Again we see the skew tail to lower beginning heights.

3) The Orionids, displayed in Figure 4, are 49 in number. They are plainly of Class C_2 and do not show the skew distribution.

4) The Perseids with 45 meteors are shown in Figure 5. Again these are clearly of Class C_2 and the distribution is symmetric.

5) The Andromedids (which from the current direction of the radiant have been called ε Piscids) number 33 meteors. The distribution appears in Figure 6 and is clearly bimodal with peaks at Classes C_1 and A or lower. These peaks are delineated well enough for us to conclude that 16 meteors are more than sufficient to classify a stream with one peak, whereas we have already seen that 9 meteors are apparently insufficient.

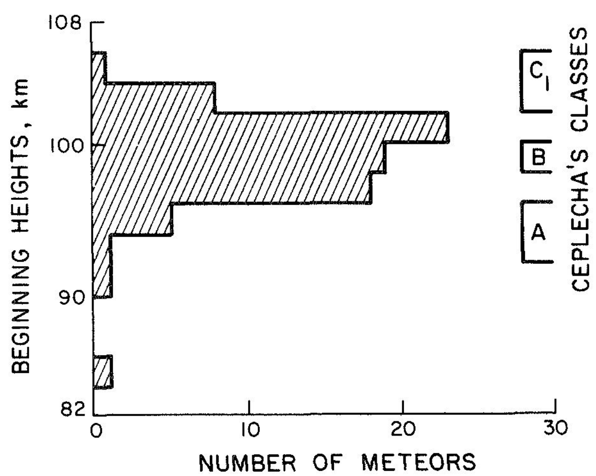


Figure 3. Distribution of beginning heights for the Geminids.

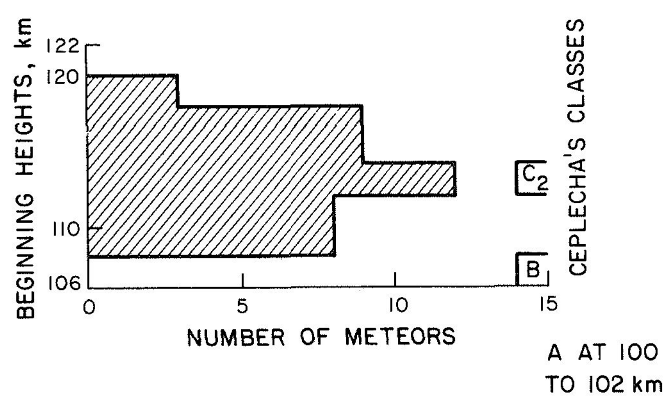


Figure 4. Distribution of beginning heights for the Orionids.

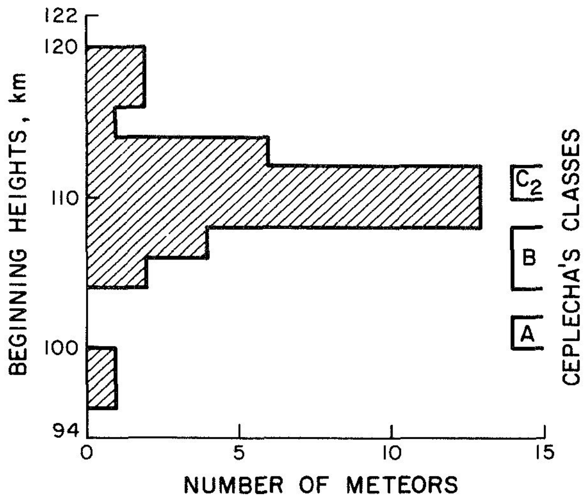


Figure 5. Distribution of beginning heights for the Perseids.

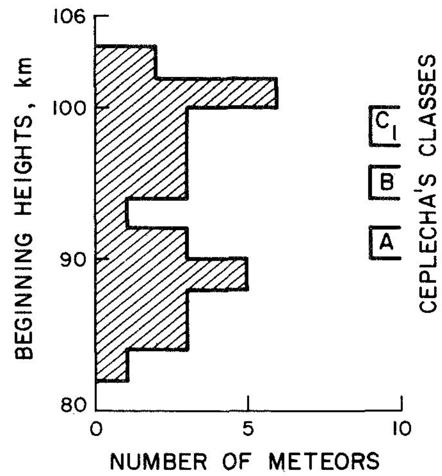


Figure 6. Distribution of beginning heights for the Andromedids.

6) The δ Leonids, newly discovered by Lindblad (1970b), contribute 24 meteors to our sample. Figure 7 exhibits a bimodal distribution with peaks at Classes C_1 and A. The peaks are well defined so that we conclude that 12 meteors are sufficient to classify a stream with one peak. Since 9 meteors appear to be insufficient, we adopt 10 meteors as a working lower limit for well-defined classification unless we see what appears to be a bimodal distribution; in such a case the working least number of meteors will be 20.

7) The δ Aquarids number 22 meteors. Figure 8 exhibits the distribution of beginning heights. Noise in the distribution is noticeable, but it seems clear that the stream is of Class B.

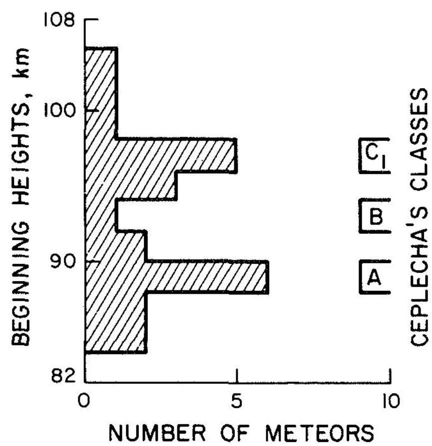


Figure 7. Distribution of beginning heights for the δ Leonids.

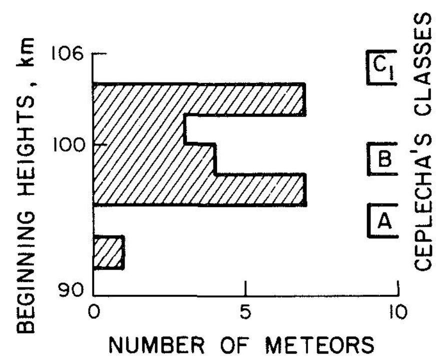


Figure 8. Distribution of beginning heights for the δ Aquarids.

8) The α Capricornids with 21 meteors are shown in Figure 9. The Class is C_1 (although B cannot be excluded), with a skew tail on the distribution to lower heights.

9) The σ Leonids with 19 meteors are exhibited in Figure 10. This stream was discovered by Southworth and Hawkins (1963). It appears to be Class B (although Class A cannot be entirely ruled out). We note two very low heights observed, which suggest skewness to lower heights in this case.

10) The Quadrantids with 17 meteors are shown in Figure 11. This stream is clearly Class B.

11) The τ Herculids number 15 meteors. Figure 12 shows their distribution; the stream is plainly of Class A or lower with a suggestion of a skewness to greater heights. The stream was discovered by Southworth and Hawkins (1963).

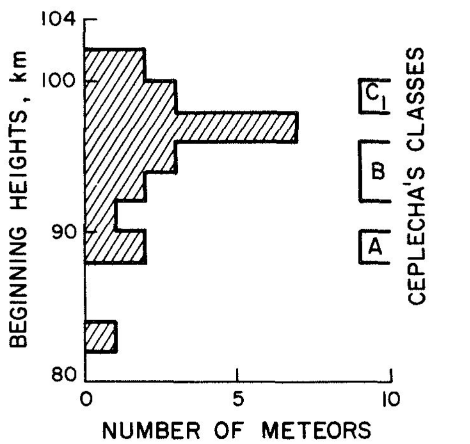


Figure 9. Distribution of beginning heights for the α Capricornids.

Figure 10. Distribution of beginning heights for the σ Leonids.

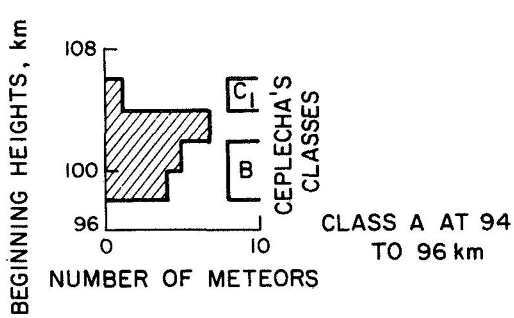


Figure 11. Distribution of beginning heights for the Quadrantids.

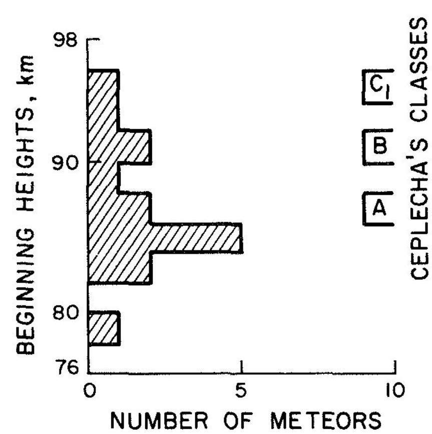


Figure 12. Distribution of beginning heights for the τ Herculids.

12) The δ Arietids with 14 meteors were discovered by McCrosky and Posen (1959). Figure 13 exhibits the distribution. The stream is of Class A (or possibly B), with considerable noise in the distribution.

13) The Southern ι Aquarids with 13 meteors are exhibited in Figure 14. They are plainly of Class A. It should be noted that the orbit of the Southern ι Aquarids is very different (a much larger semimajor axis and a somewhat smaller distance at perihelion) from the Taurid-like orbit of the Northern ι Aquarids; it also produces a geocentric velocity some 5 to 10 km sec^{-1} higher for the Southern ι Aquarids than for the Northern ι Aquarids.

14) The χ Orionids with 12 meteors are shown in Figure 15. They are of Class C_1. The two very low meteors have abrupt beginnings and thus are not really comparable to the others. The χ Orionids were first reported by Whipple (1954).

15) The χ Scorpiids with 11 meteors are newly discovered by Lindblad (1970b). Figure 16 exhibits the distribution of beginning heights. It appears to fit Class B with a broad distribution. The isolated meteor at great height may be a badly reduced interloper.

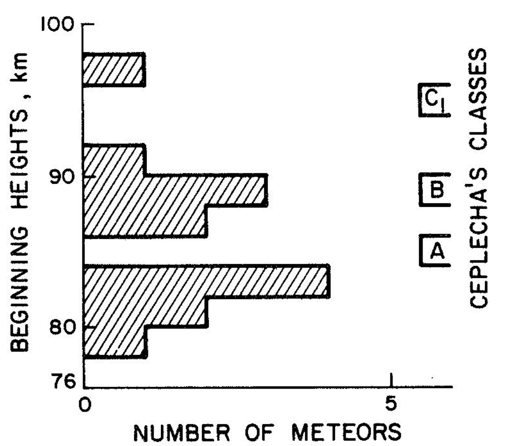


Figure 13. Distribution of beginning heights for the δ Arietids.

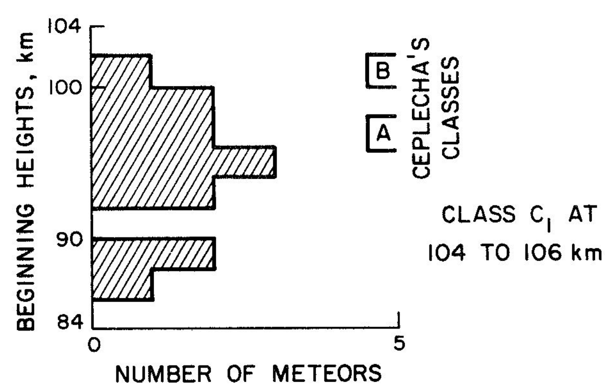
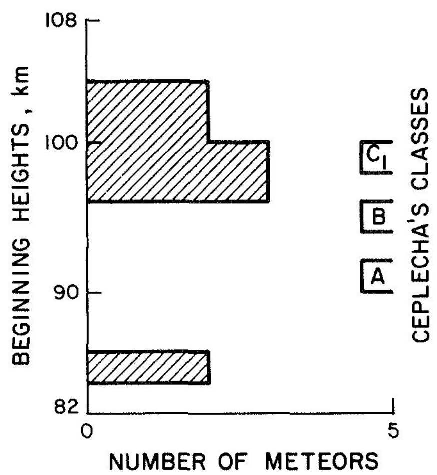


Figure 14. Distribution of beginning heights for the Southern ι Aquarids.



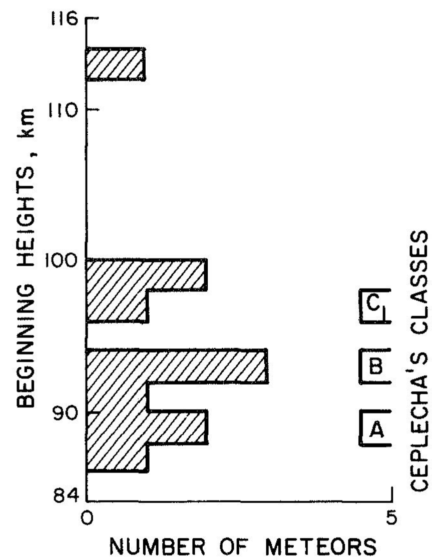


Figure 15. Distribution of beginning heights for the χ Orionids.

Figure 16. Distribution of beginning heights for the χ Scorpiids.

16) The κ Cygnids number 10 meteors and the distribution of heights is shown in Figure 17. While we might classify this stream as C_1, there is a suggestion of a double peak, i.e., C_1 and A. The meteors are too few to delineate a bimodal distribution, so that we must treat this stream as unclassifiable.

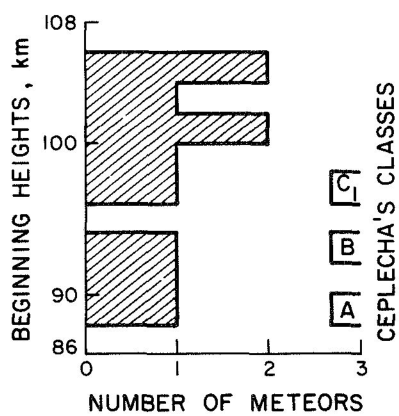


Figure 17. Distribution of beginning heights for the κ Cygnids.

One stream, the μ Sagittarids with four meteors, is so extreme in beginning heights that we can classify it as Class A or lower. This stream is newly discovered by Lindblad (1970b). Two other streams, the October Draconids with two meteors and the Monocerotids with three, are so extreme that we can classify them as higher than Class C_1. The latter stream was first reported by Whipple (1954). Finally, the Leonids with five meteors are so extreme that they can be classified as higher than C_2.

Seven streams are sufficiently extreme that Class A can be ruled out: Lyrids with five meteors, η Aquarids with seven, o Serpentids with four, κ Aquarids with five, ϵ Geminids with seven, Leo Minorids with three, and σ Hydrids with six. Of these streams, the o Serpentids are newly discovered by Lindblad (1970b), the κ Aquarids by Lindblad (1970a); the ϵ Geminids and Leo Minorids were discovered by McCrosky and Posen (1959), and the σ Hydrids by Jacchia and Whipple (1961).

The 11 streams that remain are too poorly represented in our sample to be classified: δ Cancrids (7 meteors), Coma Berenicids (7 meteors), Northern Virginids (including Northern λ Virginids) (6 meteors), κ Serpentids (4 meteors), μ Virginids (7 meteors), α Scorpiids (5 meteors), α Boötids (8 meteors), ϕ Boötids (6 meteors), θ Ophiuchids (4 meteors), α Triangulids (4 meteors), and Pegasids (5 meteors). Of these streams, the δ Cancrids, μ Virginids, α Scorpiids, and α Triangulids are newly discovered by Lindblad (1970b); the α Boötids, ϕ Boötids, and θ Ophiuchids were discovered by Southworth and Hawkins (1963), and the Coma Berenicids, κ Serpentids, and Pegasids by McCrosky and Posen (1959).

Finally, one optical stream is well known and has not been observed in the list of McCrosky and Posen (1961): the Corona Australids. It is a Southern Hemisphere shower.

Table 2 summarizes the foregoing results of classification.

Table 2. Optical meteor streams classified according to Ceplecha's (1968) system.

Name	Duration	Radiant RA	Radiant Dec.	Geocentric velocity (km sec^{-1})	Number of meteors	Ceplecha's class	Comet
Quadrantids	2-3 January	299°	+49°	42	17	B	
δ Cancrids	13-21 January	126	+20	28	7	-	
Coma Berenicids	13-23 January	187	+19	64	7	-	
N. Virginids	3 Feb.-12 March	173	+ 5	36 }	6	-	
N. λ Virginids	4-15 April	210	-10	32 }			
δ Leonids	5-19 February	159	+19	23	24	A+C_1	
Corona Australids	14-18 March	245	-48	-	0	-	
σ Leonids	21 Mar.-13 May	195	- 5	20	19	B*	
κ Serpentids	1-7 April	230	+18	45	4	-	
μ Virginids	1 Apr.-12 May	221	- 5	29	7	-	
α Scorpiids	11 Apr.-5 May	235	-21	34 }	5	-	
	9-12 May	247	-24	35 }			
α Boötids	14 Apr.-12 May	218	+19	23	8	-	
φ Boötids	16 Apr.-12 May	240	+51	16	6	-	
Lyrids	21-22 April	271	+34	47	5	Not A	1861 I, Thatcher
η Aquarids	3-12 May	340	- 2	67	7	Not A	P/Halley
τ Herculids	19 May-14 June	228	+40	18	14	A or lower	1930 VI, Schwassmann-Wachmann 3

*Class A cannot be entirely ruled out.

Table 2. Continued.

Name	Duration	Radiant RA	Radiant Dec.	Geocentric velocity (km sec^{-1})	Number of meteors	Ceplecha's class	Comet
χ Scorpiids	27 May-20 June	246°	-12°	23	11	B	
θ Ophiuchids	4-16 June	266	-28	30	4	-	
o Serpentids	9-25 June	274	-11	30	4	Not A	
μ Sagittariids	22 June-6 July	268	-15	23	4	A or lower	1770 I, Lexell
α Capricornids	15 July-10 Aug.	304	-10	25 }	21	C_1*	1954 III, Honda-Mrkos-Pajdušáková
	4-9 August	317	-17	28 }			
S. ι Aquarids	19 July-6 Aug.	320	-15	35 }	12	A	
	5-22 August	348	-10	41 }			
S. δ Aquarids	21 July-8 Aug.	340	-16	43 }	22	B	
N. δ Aquarids	5-25 August	347	+ 1	40 }			
Perseids	8-15 August	46	+57	60	45	C_2	1862, III Swift-Tuttle
κ Cygnids	10 Aug.-6 Oct.	273	+61	22	10	-	
N. ι Aquarids	27 July-20 Sept.	354	+ 1	31	5 }		
Piscids	25 Sept.-19 Oct.	26	+14	29	9 } 105	C_1	P/Encke
S. Taurids } N. Taurids }	19 Sept.-21 Nov.	40	+13	31	91 }		
Andromedids	31 Aug.-2 Nov.	10	+ 6	27	33	A+C_1	P/Biela
κ Aquarids	11-28 September	338	- 5	20	5	Not A	
October Draconids	9 October	276	+49	21	2	Above C_1	P/Giacobini-Zinner

*Class B cannot be entirely ruled out.

Table 2. Continued.

Name	Duration	Radiant RA	Radiant Dec.	Geocentric velocity (km sec^{-1})	Number of meteors	Ceplecha's class	Comet
Orionids	14 Oct. -7 Nov.	95°	+16°	67	53	C_2	P/Halley
ε Geminids	16-27 October	102	+27	70	7	Not A	
Leo Minorids	22-24 October	162	+37	62	3	Not A	1739, Zanotti
Pegasids	29 Oct. -12 Nov.	344	+19	16	5	-	1819 IV, Blanplain
α Triangulids	7-12 November	22	+30	21	4	-	
Leonids	15-20 November	152	+23	71	5	Above C_2	P/Tempel-Tuttle
N. χ Orionids	4-13 December	83	+26	28	4 } 12		
S. χ Orionids	7-14 December	85	+16	28	8	C_1	
σ Hydrids	4-15 December	128	+ 2	58	6	Not A	
Geminids	4-16 December	111	+32	37	77	B	
δ Arietids	8 Dec. -2 Jan.	54	+25	17	14*	A†	
Monocerotids	10-17 December	104	+10	42	3	Above C_1	1917 I, Mellish

*12 northern, 2 southern.

†Class B cannot be entirely ruled out.

4. ASSOCIATED COMETS

Table 2 includes in its last column the currently preferred identity of the parent comet of each stream. If we confine our attention to comets now accessible to observation, we find two streams above C_1, one above C_2, two C_1, two C_2, one not A, and one A. P/Comet Halley contributes two streams so that the classification of the η Aquarids as not A is redundant and should be preempted by the classification of the Orionids as C_2. If we consider the one comet known to have disappeared (P/Comet Biela), we find its stream exhibits Classes A and C_1 together. If we consider the one comet no longer in an orbit accessible to observation (1770 I, Lexell), we find its stream to be of Class A or lower. One comet's stream cannot be classified (1819 IV, Blanplain).

5. DISCUSSION

Four salient points command attention:

1) Meteoroids of Ceplecha's Class A have a density of about 1.2 g cm^{-3}, approaching that of Type I carbonaceous chondrite meteorites (2 g cm^{-3}) (McCrosky and Ceplecha, 1970; Cook, in preparation).

2) Whipple and Stefanik's (1966) model for the redistribution of ices within the nuclei of comets by radioactive heating might lead naturally to gravitational compaction of the less volatile material in the interior, a natural explanation of Ceplecha's Class A and of carbonaceous chondrites of Type I (although rather large nuclei would be required in the latter case). Meteoroids of Classes C_1 and C_2 would then be the low-density residual framework left after evaporation of the volatile ices from the outer shell.

3) P. M. Millman, A. F. Cook, and C. L. Hemenway (in preparation) find that faint Perseid meteors exhibit spectra ranging from the traditional atomic-line spectra of vaporized meteoroids to almost entirely atmospheric radiations or an extended continuum or both followed by an interval of radiation from atomic lines of meteoric elements lower along the trajectory. This type of behavior seems the most probable cause for the skew distribution toward lower heights because the Super-Schmidt cameras with X-ray film do not photograph the nonblue part of the atmospheric radiations or the continuum, but do respond to those in blue to ultraviolet from the meteoric vapors.

4) Whipple and Stefanik pointed out that many smaller comets that separate from large comets are short lived, as would be expected if only a piece of the ice-impregnated surface peeled off. If a comet cracks all the way through, then some core is left to hold the ice-impregnated surfaces together, which matches the behavior of P/Comet Biela. To complete the picture for that comet, we need only conjecture that the icy surface layers either peeled or were exhausted at the last observed return.

These considerations lead naturally to several ideas. Two inert pieces disguised as small asteroids may yet remain. The exposure of both core and impregnated surface layers would explain the observed bimodal A and C_1 distribution. A similar explanation would follow for the δ Leonids, although no comet has ever been observed in that orbit.

Furthermore, the presence of some ice in an old cometary core is to be expected because, of the ice sublimed by the sun, some would evaporate away but some would diffuse inward and redeposit as frost on the cold interior. In this context, we may understand the A classification of the meteors from the very faint Comet 1930 VI, Schwassmann-Wachmann 3. Recovery of this comet is desirable. B. G. Marsden (private communication) indicates that the next opportunity will come in 1979. Finally, the lower density of Class B streams compared with that of Class A may be due to comets so small that their cores were gravitationally compacted to a density of only about 0.6 g cm^{-3}. We then assume that their ice-impregnated low-density surfaces have been completely removed. Again, the cores would have accumulated some frost from ice that sublimed and diffused inward. These comets would now be very faint or would be disguised as asteroids. It is perhaps not surprising that no comets have been detected in association with streams of Class B.

In this context, it is difficult to believe that a stream as rich as the Geminids does not still have a parent body. The configuration and shortness of period of the orbit make it the only reasonable candidate for a search for such a body among the streams of Class B.

In conclusion, it is desirable to review the classifications for reliability and the individual streams for certainty of their existence. The adopted classifications appear to the author to be unassailable for 10 streams (Taurids, Geminids, Orionids, Perseids, Andromedids, δ Leonids, Quadrantids, τ Herculids, Southern ι Aquarids, and χ Orionids). These are distributed two each over the possible classifications – A (including A or lower), B, C_1, and C_2. There is room for the possibility that the A + C_1 distributions may be uniform and broad without a minimum at B. Nevertheless, all the arguments made above can be put forward on the basis of these streams alone.

It is therefore desirable to classify as many other streams as possible. Another stream (δ Aquarids) is almost as securely classified as the 10. Three more streams have somewhat uncertain classifications (α Capricornids, σ Leonids, and δ Arietids). It might be tempting but not very good practice to take note of Ceplecha's failure to find the ridge at Class B down to lower velocities among the sporadic meteors and move the σ Leonids to Class A. Similarly, the possibility of Class B would then be ruled out for the δ Arietids. One stream is of very uncertain classification (χ Scorpiids). If the Class $A + C_1$ has in fact a broad uniform distribution without a minimum at B, the χ Scorpiids would become unclassifiable.

It does not seem important to comment in this vein on the classification of the extreme cases among the less numerous streams except to draw attention to the three streams whose existence is most open to doubt: the θ Ophiuchids, o Serpentids, and μ Sagittariids. All these radiants come from a diffuse region of general activity in June and early July in Scorpius, Sagittarius, Ophiuchus, and Serpens. While more than one stream must contribute to this activity, the computer programs of Hawkins and Southworth and of Lindblad may have arbitrarily grouped these meteors to yield the three listed streams of only four meteors each.

Special suspicion attaches to a stream associated with Comet 1770 I, Lexell, because it only came close to the sun twice (in 1770 and 1776), having passed close to Jupiter in 1767 and 1779. The existence of a detectable stream almost 2 centuries later is rather dubious.

It would be convenient to be rid of these streams since the μ Sagittariids are Class A or lower and Comet Lexell was an embarrassing 5 magnitudes brighter than Comet 1930 VI (Schwassmann-Wachmann 3) and thus not a good candidate for a nearly exhausted comet. Evidently, further study of individual radiants and velocities of meteors in June and early July in Scorpius, Sagittarius, Ophiuchus, and Serpens is desirable.

6. ACKNOWLEDGMENTS

It is a pleasure to acknowledge discussions with Prof. Fred L. Whipple, Dr. Richard E. McCrosky, and Prof. Bertil-Anders Lindblad of Lund Observatory, who have read this paper. Particular thanks for a very detailed reading and extensive discussions are due Dr. Brian G. Marsden.

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BIOGRAPHICAL NOTE

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NOTICE

This series of Special Reports was instituted under the supervision of Dr. F. L. Whipple, Director of the Astrophysical Observatory of the Smithsonian Institution, shortly after the launching of the first artificial earth satellite on October 4, 1957. Contributions come from the Staff of the Observatory.

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