September 27, 1961

A THEORY ON SLOW MOVING GREEN FIREBALLS-PART II

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MEMORANDUM
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ANOMALOUS SOUNDS AND ELECTROMAGNETIC EFFECTS ASSOCIATED WITH FIREBALL ENTRY

Mary F. Romig and Donald L. Lamar

1. Meteors
2. Atmosphere-Entry
3. Electromagnetic Waves

PREPARED FOR:
ADVANCED RESEARCH PROJECTS AGENCY

The RAND Corporation
SANTA MONICA • CALIFORNIA

METEORS

V.D. Chamberlain
Abrams Planetarium
East Lancing, Mich.

Fireball Report Form

If you saw the fireball (very bright meteor) on ______________________, please answer the following questions as accurately as possible. Please attempt to indicate whether or not you feel your estimates to be accurate. Fireballs are not only spectacular, they are important to science. Several accurate observations over a wide area may indicate the path of the meteoroid through the atmosphere and its orbit in space before collision with the earth. Such observations may also allow prediction of the most probable area in which meteorites may have reached the surface of the earth. Freshly fallen meteorites are of great value to science and thus you are encouraged to fill out the form below as quickly as possible, but carefully, and mail it at once. Your help is very greatly appreciated and may lead to discoveries of scientific value.

Your name ____

Your address ____

____

Telephone ____

Date form is filled out ____

1. Your precise location when the observation was made ______________________

____

2. Indicate whether you were in a moving vehicle, walking, or standing still when the observation was made. ____

3. Make a brief comment concerning the condition of the sky at the time of the observation. ____

____

4. The fireball was observed on the date of ______________________ at ________(hour, minute, time zone). Please indicate the accuracy of the time recorded if possible. ______________________________

____

5. Appearance of the fireball

   a. Luminosity: estimate the brightness of the fireball if possible. Perhaps you could compare it with the bright planets or the quarter moon or full moon.

   ____

   b. Duration: How many seconds did you see the fireball ______________ ± ? Repeating your actions at the time of the fireball, such as walking from one place to another while the fireball remained visible, may help estimate the above.

c. Was a lingering trail left behind the fireball? __________ If so, how long could you see it: ______________________________

d. Color: Describe the color and color variation observed along the fireball path and the color of the persistant train if one was left behind __________

e. Bursts: If bursts or flares were observed, briefly describe them.

f. Break-up: Did the fireball break up into two or more fragments? __________. If so, how many? __________

g. Did the fireball fade out before passing beyond the horizon (appearing to reach the ground)? __________

h. Form: If the fireball appeared to have a definite size, estimate its apparent size by comparison with the apparent size of the full moon, when high in the sky. Statements such as; "big as a basketball, baseball, marble, etc." are not significant. Comment on the shape, if possible.

i. Did the fireball pass directly overhead? __________

j. Was a cloud left along any part of the path of the fireball. If so, please describe it. How long was it visible? Please indicate the direction of drift of the cloud. __________

6. Sounds: Meteorite falls are usually accompanied by loud sounds heard over areas sometimes approaching 100 miles in diameter. Please describe any sounds heard together with the time interval between seeing the fireball and hearing the sounds. (Often several minutes). Any sound heard while the fireball was still visible should also be noted.

7. Do you know of any unusual effects on radio or television reception at the time of the fireball? __________. If so, describe. __________

8. Position of the fireball in the sky: The following questions are the most important of all. Please answer as thoroughly as possible. Feel free to make additional comments or diagrams if you desire. If convenient, go to the place of observation to answer these questions.

   a. What direction were you facing when the observation was made:

   ____

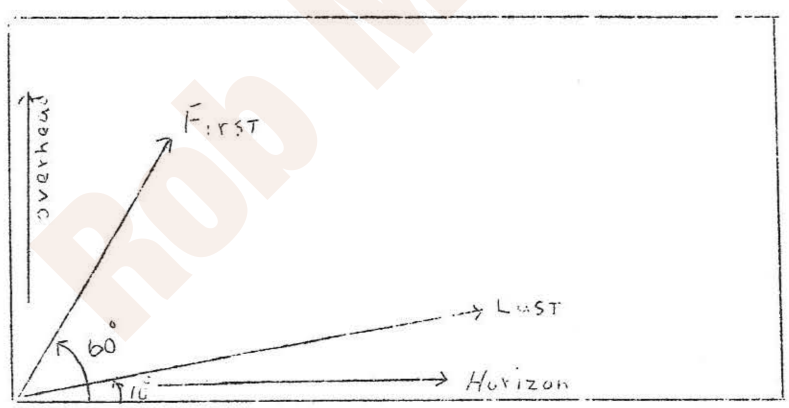
   b. If you noticed the path of the fireball against the background of stars, please describe or enclose a sketch indicating the star field and the point where you first and last saw the fireball. ____________

   ____

   ____

   c. Referring to landmarks, use the enclosed card to measure the angular distance (elevation) above the horizon of the object both at first appearance and last appearance. Do this by sighting along the bottom edge of the card toward the horizon (the level land - not treetops, etc.) and drawing a line from the corner of the card to the points of first and last appearance.

   Example: If the object had first appeared at an altitude of 60 degrees and disappeared at an altitude of 10 degrees, the completed card would be as indicated below.

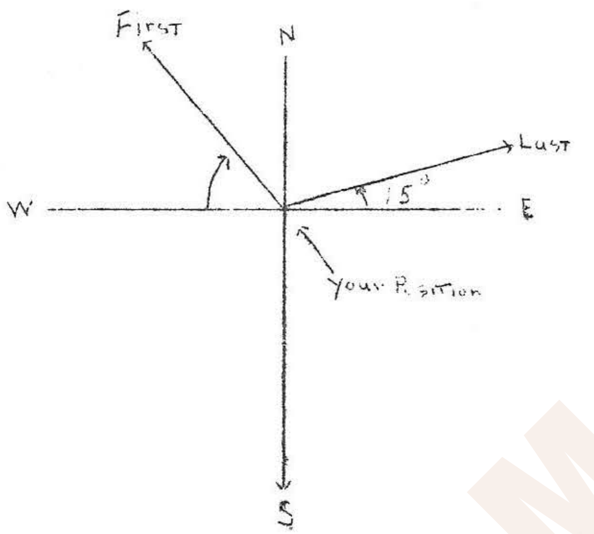


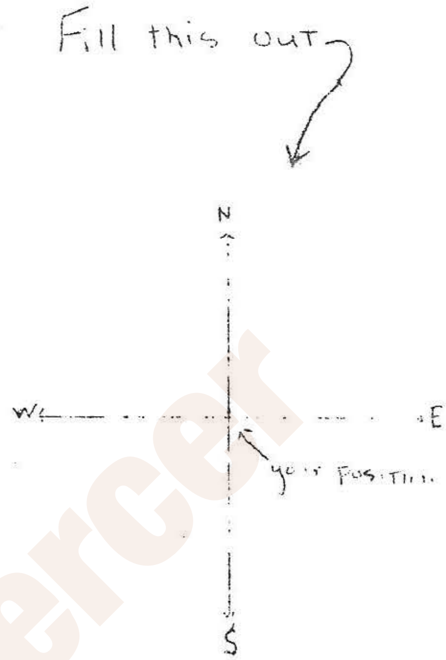
   You may wish to use both sides of the card. One side to give the elevation of the point of its first appearance and the other side for the elevation of the point of disappearance.

   If you cannot go to the place of observation please describe the elevations as you remember them and mark an "X" in the square ☐

d. Direction around the horizon: Please indicate in the figure below the direction in which you first and last saw the fireball. Not the direction in which it was traveling, but rather, the direction you would have to face to point to where you first and then last saw it. If a compass is used please state "compass used."

Example: If you first saw the object 50 degrees North of West and it traveled to the East, disappearing 15 degrees North of East, you would fill it out as follows:





e. Another way of answering the above would be to go outside on a clear night and indicate where the fireball would have been seen against the star background if the fireball occured at the time you choose to do this. If this is done, clearly indicate the date and time it is carried out.

f. What angle did the fireball path make with the horizon? That is, did it seem to come straight down toward the horizon (90 degrees) or was it traveling parallel with the horizon (0 degrees) or at an angle of 45 degrees etc? You may wish to make a sketch to explain this.

____

____

____

9. Do you know of anyone claiming to have found a meteorite either recently or some time ago? If so, please indicate name and address.

10. Please make any other comments you feel are appropriate and mail the completed form to:

Von Del Chamberlain
Staff Astronomer, Abrams Planetarium
Michigan State University
East Lansing, Michigan 48823

A NETWORK FOR (RAPID) ANALYSIS OF FIREBALL TRAJECTORIES

V. D. Chamberlain

Michigan State University, East Lansing, Michigan

1. INTRODUCTION

It has been apparent for many years that world wide, systematic collection of information on phenomena associated with meteorite fall is needed to: (1) recover meteorites as quickly as possible; (2) more thoroughly understand phenomena accompanying meteorite fall; (3) obtain data on the orbital elements of meteoroids.

The Network for (Rapid) Analysis of Fireball Trajectories (NAFT) was established to extend existing data collection attempts and to enhance rapid distribution of information about meteorite fall. It consists essentially of a well-distributed group of competent individuals who have a professional interest in astronomical and atmospheric phenomena.

To be successful, any system attempting to gather reliable information quickly from the public requires: (1) channels of communication to and from the public; (2) methods of selecting and acquiring relevant information as accurately and quickly as possible. In the investigation of meteorite fall, it follows that it is highly desirable, if not necessary, to have an alerted network of reporters who understand the phenomenon of meteorite fall, and are equipped with essential knowledge and instruments to be able to select and report observations of fireballs and accompanying events from their regions. Experience of the author and others has demonstrated that the best data are obtained from direct interviews with observers at the locations where their observations were made. Even though some information can be obtained from observers by mail, telephone, etc., its reliability is generally questionable. Interviews at the sites of fireball observations with the same observers generally yield valid and reliable results.

2. DATA REQUIRED

2.1 End-point determination

For the purposes of NAFT, the end-point of a fireball is of primary interest. Because of the spectacular nature of a fireball near the end-

The observed apparent velocity of a meteoroid must be known and then adjusted first to geocentric velocity and then to heliocentric velocity. The velocity is usually the most difficult factor to determine. Unless a system of cameras with rotating shutters exists in the region of visibility of the fireball [8], or the fireball was tracked on radar [9], or perhaps photographed with a motion picture camera [10], the velocity must be established from visual observations, relying upon estimates of the duration of the fireball. This, of course always leaves the results open to some question. Nearly all orbits which have been determined for spectacular fireball producing meteoroids are in this category.

2.4 Summary of observational data required

The preceding indicates that, except in the few cases where suitable photographic or radar data are available, observations are needed from stations spread around the trajectory. If these are reliably reported, the end-point, the trajectory and sometimes an approximate orbit can be calculated.

3. DESIRED DISTRIBUTION OF REPORTING STATIONS

3.1 Region of visibility of fireballs

A meteoroid with shallow entry path through the atmosphere may produce a fireball which can be observed over a vast region of the earth's surface, perhaps several thousand kilometers in length. Usually, however, the entrance angle into the atmosphere is steep and the region of visibility of the fireball more restricted. The great Tunguska event of June 30, 1908 was reported to have been observed over a region 1500 kilometers in diameter [11]. The Sikhote-Alin event of Feb. 12, 1947 was observed over a region 600 to 800 kilometers in diameter [12].

A point 130 kilometers above the earth's surface is at the horizon for an observer about 1300 kilometers away from the point underneath it. Since fireball visibility begins at about this height, it is apparent that the entrance of fireballs will not be visible more than this distance from the location underneath the point of entrance into the ionosphere 130 kilometers above ground.

The end-points of typical fireballs occur between 12 and 25 kilometers above the earth surface [13]. Points at these heights would be at the horizon for observers 390 and 560 kilometers away.

Considering the above, it is not surprising to find that past cases indicate that the region of observation is usually bounded by a circle about 1000 kilometers in diameter and that the best observations are restricted to a still smaller region.

3.2 Expected domain of observability

Optimum coverage of fireball events would require a system of reporting stations uniformly spread over the region of observation. In the latitude range of the United States, a region covering 9 degrees of longitude and 6 degrees of latitude is roughly 750 kilometers on a side. This unit area has been selected as the expected domain of observability of fireballs

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[12] KRINOV, E.L., Principles of Meteoritics, Pergamon Press (1960) 138.

[13] KRINOV, E.L., Principles of Meteoritics, Pergamon Press (1960) 77.

[14] Private correspondence with Robert Citron, Smithsonian Institution Center for Short-Lived Phenomena.

Figure 5. Distribution of planetariums outside the United States.

interested in cooperating. The current distribution of the network is shown in figure 3. Some of the points on the map represent more than one reporting station. Indeed, some represent as many as eight located in the indicated region.

4.4 Planned expansion of the network

Figure 3 shows deficiency of reporting stations in some parts of the country, particularly the north-central and western states. Comparison of figures 1, 2 and 3 reveal that this is due to the small number of planetariums in these regions. This situation will be improved by contacts with professional and amateur astronomy groups and individuals interested in meteoritic studies.

5. PROCEDURES OF NAFT

5.1 Spectacular fireballs

The fundamental idea of NAFT is to rapidly obtain reliable data on spectacular fireballs. A spectacular fireball is defined to be one which (1) lights the entire night sky in the region of observability, or (2) can be seen in the daylight sky, and (3) immediately attracts considerable public attention.

5.2 Functions of members

Members of NAFT are given detailed instructions for data collection and reporting. It is expected that, when a member becomes aware of a spectacular fireball in his area, he will quickly locate several appropriate observers, obtain the needed information and relay it to headquarters. It is hoped that this can be done so that reports reach headquarters within one day after the fireball.

The information desired at headquarters is indicated in figure 4 which is a copy of the data card used in interviewing observers. The coded report consists of information needed for end-point determination, condensed so that it can be sent conveniently by telegraph. When several observations have been collected, the coded portions of the reports are combined into one telegraph message. The completed data cards, together with information gathered during the next few days are later mailed to headquarters for more detailed study.

Reporting members are especially instructed to inquire about photographic radar, seismograph and other records which may be of great importance in trajectory analysis.

5.3 Field investigation

Once the end-point region has been confirmed, the information can be channeled to those who will spearhead field investigation in the region of greatest interest. Such work may be of several types: (1) more precise end-point and trajectory analysis; (2) alerting residents of the possibility of meteorite recovery; (3) actual systematic meteorite search; (4) collection of meteoritic train debris by aircraft or other procedure [14]; (5) investigation of phenomena accompanying the fireball.

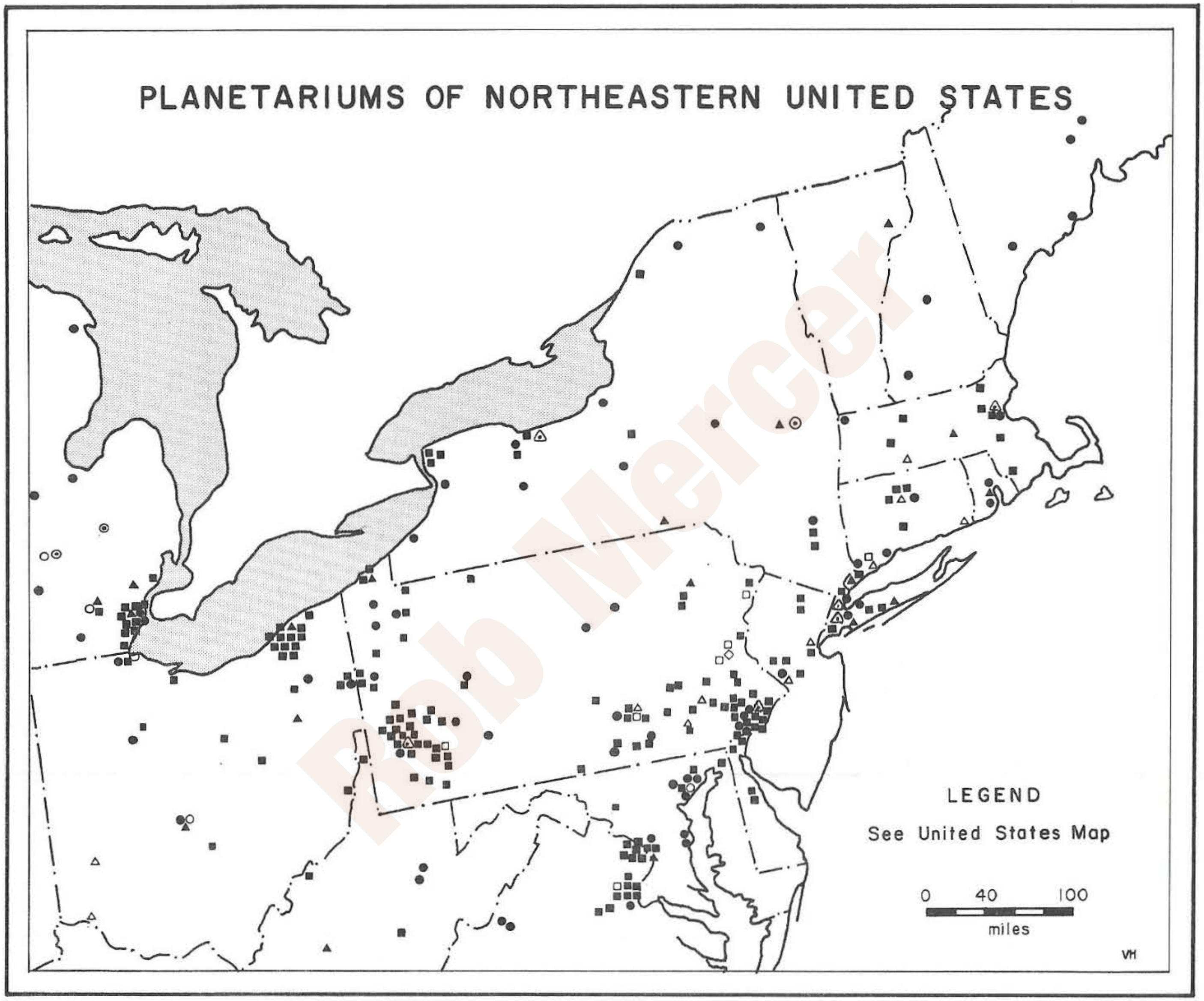


Figure 2. Distribution of planetariums in the northeastern United States.

which occur under clear sky conditions. Certainly, observations spread over a region this size would yield the required data for fireball trajectory analysis provided that the observations were of suitable quality. The unit is further divided into sub-units of 3 degrees of longitude and latitude. The idealized situation for NAFT is to have at least three reporting stations equally spread from north to south through the center of each of these sub-units. Figure 3 shows that some sub-units in the network are more than adequately represented while others are not. The reason for this will be pointed out in section 4.4.

4. THE NETWORK

4.1 Network requirements

We consider an adequate fireball reporting system to be one with the following characteristics: (1) sufficient uniform distribution of reporting stations; (2) reporting personnel capable of obtaining the required data. The second item requires interviewers with channels of communications to and from the public and basic knowledge of astronomical coordinate systems. It is necessary that capable people select observations and obtain the required data at the sites of the observations. Such observations throughout the regions of visibility should lead to quick determination of end-points and to moderately accurate trajectories. The chances of recovery of meteorites should also be increased.

How can such a reporting system be established? There are many answers to this question. We decided to approach the problem by taking advantage of the rapidly increasing distribution of planetariums in the United States.

4.2 Distribution of planetariums in the United States

Since the late 1950's the number of planetariums in the United States has been growing rapidly. At the time of this writing there are approximately 525. It is expected that the number will double within the next five years. These facilities are located in museums (about 14.5%), colleges and universities (about 39%), public and private elementary and secondary schools (about 44%), and other establishments (about 2.5%).

Each of these planetariums is staffed by at least one individual who generally meets the criteria set forth in the preceding section. He possesses a moderate, and sometimes extensive knowledge of astronomy and related science. He comes in contact almost every day with many people from his area and, since planetariums are of considerable public interest, he has a natural channel of communication regarding items of scientific interest. He is, therefore, able to receive the cooperation of the news media if he so desires. Astronomy clubs are also very often associated with planetariums.

Figures 1 and 2 show the distribution of planetariums in the United States up to the time of this writing.

4.3 Current distribution of reporting stations

Letters inviting planetarium staff to participate in NAFT were sent to about 500 planetariums. Half of these responded indicating they were point and the fact that attention of observers is established in earlier phases, it is generally the easiest point on the trajectory to determine. One good azimuth of the end-point combined with speculation as to its height above ground, drawn from past cases, will often direct the investigator to the correct end-point. This is best done by making inquiries at selected distances along the azimuth line until the region is located where sonic booms were reported. Once the region of audible phenomena has been located, the end-point may be determined more precisely by interviews of observers within that region.

One does not, however, always have a reliable bearing of the end-point to begin with. For this and other reasons, it is desirable to obtain quickly many azimuth and altitude observations of the end-point directions from throughout the region of observation. These lead more surely to approximation and subsequent confirmation of the end-point.

Quick reporting of pertinent information is necessary while it is still fresh in observers minds. It is, therefore, desirable to have end-point altitude and azimuth directions of a fireball quickly relayed from locations throughout the region of observation. This will be useful not only in determining the end-point, but in more detailed analysis of the trajectory.

2.2 The trajectory

Detailed descriptions of procedures for trajectory analysis of meteors have been published [1, 2, 3, 4]. Only a descriptive sketch will be reviewed here.

The trajectory is established when at least two points on it are determined. It is generally difficult to obtain observations which yield two reliable points. It is often easier to determine the vertical plane through the trajectory by locating observers who were in that plane and, therefore, viewed the fireball in vertical motion. Occasionally observers can be located who were not only in that plane, but also near the earth-point (extension of the trajectory to the ground) and saw the fireball remain almost motionless in the sky. If the time is known information from such observers indicates the vertical trajectory plane, the angle of penetration of the meteoroid into the atmosphere and the radiant, thus determining an approximate trajectory.

Photographs of a fireball, or of its train, which include landscape features can be most helpful in trajectory analysis. Indeed two or more photographs taken at different sites may lead to an accurate trajectory [5].

2.3 Orbit calculation

The time of atmospheric entrance, the trajectory, and the velocity of a meteoroid lead to orbit calculation by well known procedures [6, 7].

The time must be known in order to include the earth's rotational and orbital components of motion and extend the trajectory into space. The time is often determined easily to the nearest minute. Society of today includes numerous individuals who are in the habit of noting the time of unusual events. Airplane pilots, navigators, police, radio broadcasters and others generally log events which are considered to be of public importance.

a. Meteors and meteorites may be divided roughly into three classes. One class is almost wholly metallic--iron, nickel, etc. Another is largely stony; and another, members of which are frequently called aerolites, is made up of dense stony matter with many grains of nick-iron alloys. This meteorite (from Alabama) appears to be an aerolite.

b. Explosions of very large meteors are quite frequent. Most meteors are no larger than the head of a pin, and these burn up miles above the earth. On account of the heat generated, the larger meteors moving with high speeds must therefore explode. The Alabama meteorite was much larger than the smaller part recovered, for it was seen to explode. Some other fragments distributed over a very large area remain to be recovered, and much of it must have fallen as ashes.

c. The average limits of altitudes of meteor paths are known. They seldom appear at greater heights than 90 miles, for at greater heights there is insufficient air to cause one to burn; and generally they burn up before getting as low as 40 miles. Only those large enough to penetrate all the earth's atmosphere actually hit the earth; and these are called "meteorites." Velocity of a meteor plays and important part on whether or not it hits the earth.

At the time a meteor hits the earth's atmosphere--100 miles high, say--its velocity will range between 8 miles per second and 44 miles per second. Since the earth's motion around the sun gives it a

ATTACHMENT #6

velocity of 18 miles per second and the average velocity of a meteor is 26 miles per second, one therefore finds velocities between 26-18 and 26+18 miles per second.

The speed of the Alabama meteorite can be estimated only if one knows the exact direction from which it came and the time of the day it fell. The evidence seems to indicate, however, that the Alabama meteorite was a member of the Andromid shower, occurring between November 24 and December 7. These come from the north, but the exact direction depends on the time of day they are seen. Ordinarily their speeds are about 15 miles per second, but this figure may be either higher or lower. If it is a member of this shower, it is from the debris of Biela's comet which disappeared after 1852. Fragments from this comet have fallen, however, for centuries--one of the earliest perhaps being a stone weighing 260 pounds which fell in Alsace Nobember 16, 1492, between 11 and 12 AM.

The ages of some meteors have been measured. Some of them are 2,000,000,000 years old. Probably are remains of old comets which are millions of years in age.

ATTACHMENT #6

1/ INTRODUCTION

At the present time it is commonly accepted that shower meteors, and almost all sporadic meteors, are produced by either: (1) collimated stream; or (2) sporadic meteoroids (dustballs)[1]. Furthermore, meteoroids appear to be closely related to comets. They may be broken up comet skeletons, left over after the Sun vaporizes the more volatile, icy components of comet nuclei.

Whipple estimates meteoroid densities to be about 0.05 g/cm^3 and suggests that they are too frail to support their own weight on Earth[2]. We shall present evidence later to show how a meteoroid may have been brought to the ground while supported in a frozen gelatinous matrix during the great meteor shower of November 13, 1833, and again 50 years later. This dust was so fine that it vanished between the fingers when picked up.

The low meteoroid densities, and the well known absences of solid iron and stone meteorites in meteor streams, suggest that comets are formed in space under conditions of very low pressures and temperatures. During the accretion period when the nucleus of a comet is formed, metallic and siliceous dust components probably collect on the cold ices along with numerous other light atoms such as hydrogen and oxygen. There is not much chance for thick metallic layers to form. Rather we might find metallic growths in with the ice components.

In the laboratory, metals such as iron and nickel are known to form polycrystalline films when evaporated on low temperature substrates (rocksalt)[11]. The crystallites, which are randomly oriented, increase in size with increases in substrate temperature up to about 350°C.

Interatomic spacings were found to duplicate the bulk materials[12], and consequently bulk densities were achieved. However, because of the high minimum temperatures for epitaxial (oriented) growth, solid metallic fibers greater than about 1000 Å are very unlikely. Oxide pseudomorphs are even more limited in size because of the severe strains created at the boundaries.

Nickel crystallites of 50 Å in size were observed in thin films, but signs of growth strains, such as slippage and twinning, appeared in specimens a few times larger. Thus, dust particles with bulk densities are not expected to exceed about 1000 Å (0.1 micron) in size. This is also close to the maximum size expected for noctilucent cloud particles[13]. These high altitude clouds may result from meteoroid dust.

Organic binding materials may hold these dust particles together long after the volatile ices have sublimated. This is not meant to imply that adhesives are necessary for this purpose in space. The presence of organic impurities may explain other phenomena. For example, many meteors while disintegrating in the atmosphere continually throw off what looks like a miniature dust cloud. This might be attributed in part to rapid burning or explosive decomposition of organic matter. The resulting dispersal of dust may contribute to a satellite dust cloud around the Earth as surmised in another paper[3].

We also suggest that the Martian Moons may be giant meteoroids, resulting from a period when a comet exploded near Mars. The two objects may have been captured when they were composed primarily of icy hydrates. At the Martian distance from the Sun, the ices would have gradually sublimated leaving a ball of dust cemented together by organic matter, possibly polymers, derived from the ices.

List of Annually Recurring Northern Hemisphere Meteor Showers

STREAM	Date at Maximum	Extreme Limits	Radiand R.A. Declination 1950	Vel. in Atmos. km sec-1	Hourly Rate at Maximum	Transit of Radiant LOC T. M.N. = 00h
Quadrantids	Jan. 3	Jan 1-4	230 + 48	38.5	VISUAL 30	8h 28m
Aurigids	Feb. 9	5 Days(?)	75 + 42	----	5	19h 43m
Virginids	Mar 13	16 Days(?)	183 + 4	30.8	1 (?)	0h 49m
Lyrids	Apr 22	2 Days	270 + 33	48.4	5	3h 59m
Aquarids	May 4	10 Days	336 + 0	64	5	7h 36m
Arietids	June 8	May 29-June 18	44 +23	38.0	--	9h 51m
Perseids	June 9	June 1-16	62 + 23	28.9	--	10h 59m
Taurids	June 30	June 24-July 6	86 + 19	31.4	--	11h 12m
Aquarids	July 28	July 24-Aug 7	339 - 17	40.5	10	2h 14m
Perseids	Aug. 12	July 29-Aug 17	46 + 58	59.2	37	5h 43m
Orionids	Oct. 22	Oct 18-26	94 + 16	65.5	13	4h 12m
Southern Taurids	Nov. 1	Oct 27-Nov 22	51 + 14	28.1	5	0h 40m
Northern Taurids	Nov 12	Oct 17-Dec 2	52 + 21	29.5	5	0h 1m
Leonids	Nov 17	5 Days	152 + 22	70.8	6	6h 22m
Geminids	Dec 13	Dec 7-15	113 + 32	35.9	55	2h 12m
Ursids	Dec 22	Dec 22-23	217 + 76	37.4	15	8h 24m
			Periodic Stream			
Giacobinids	Oct 10 1959	1 Day	262 + 54	23.1	4200	16h 13m

The above taken from HANDBOOK OF GEOPHYSICS, Revised Edition, 1960, ARDC.

A133

BOSTON, AUG. 10 (AP)-THE PERSEID METEORS PUT ON THEIR ANNUAL SHOW TONIGHT, REACHING A CLIMAX JUST BEFORE DAWN TOMORROW.

THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY SAYS VIEWERS MAY SEE AN AVERAGE OF 15 TO 20 METEORS TONIGHT.

IN THE EARLY MORNING, THE SO-CALLED SHOOTING STARS WILL SEEM TO RADIATE FROM AN AREA HIGH ON THE EASTERN HORIZON.

THE PERSEID METEOR SHOWER IS USUALLY THE BIGGEST SUCH SHOW OF THE YEAR, BUT AN EVEN BIGGER DISPLAY WILL COME NOV. 16 AND 17 WHEN THE EARTH ENCOUNTERS THE LEONIDS, AN EVENT THAT OCCURS ABOUT EVERY 33 YEARS.

JT955AED

NETWORK FOR (RAPID) ANALYSIS OF FIREBALL TRAJECTORIES

Abrams Planetarium

Michigan State University

East Lansing, Michigan 48823

Telephone 517-355-4673

September 19, 1968

Lt. Morano, UFO group
Wright-Patterson AFB
Ohio

Dear Lt. Morano,

Robert Citron of the Smithsonian Institution has informed me that you are interested in my project. Assuming that this information is correct, I am enclosing materials sent to network members.

I would appreciate your comments if you have any to make. I would also appreciate it if you will retain the materials on file and report fireball events which come to your attention to me.

Sincerely,

Von Del Chamberlain

Von Del Chamberlain
Project Leader

Lancing Mich
517-355-4673

interest - 5 mag or brighter

FIREBALL DATA CARD

Time ____ ____ ____ ____ ____ ____ ________
year month day hour minute second time zone

Weather ________________________________

Location of observer when ________________
the fireball was seen ________________
____
____

________ ________
Latitude Longitude

POSITION IN THE SKY

First seen ________ ________
Azimuth (A) Altitude (h)

End-point ________ ________
Azimuth (A) Altitude (h)

Angle to horizontal ________

Duration (D) ________

Brightness (B) ________
____

Color ________

Form ________

Sounds ________
____
____
Interval after fireball (I)

Reliability (R) ________

Interviewer ________

Date ________

CODED REPORT

Station	Time		End-point		Flight			Sounds			
City	Mo.-Day	Hr.-Min.	A	h	RL, LR V, S	D	B	Y, N	I	R	NAFT Member

ADDITIONAL COMMENTS AND NOTES

Observer ______________________
Name

____
Street

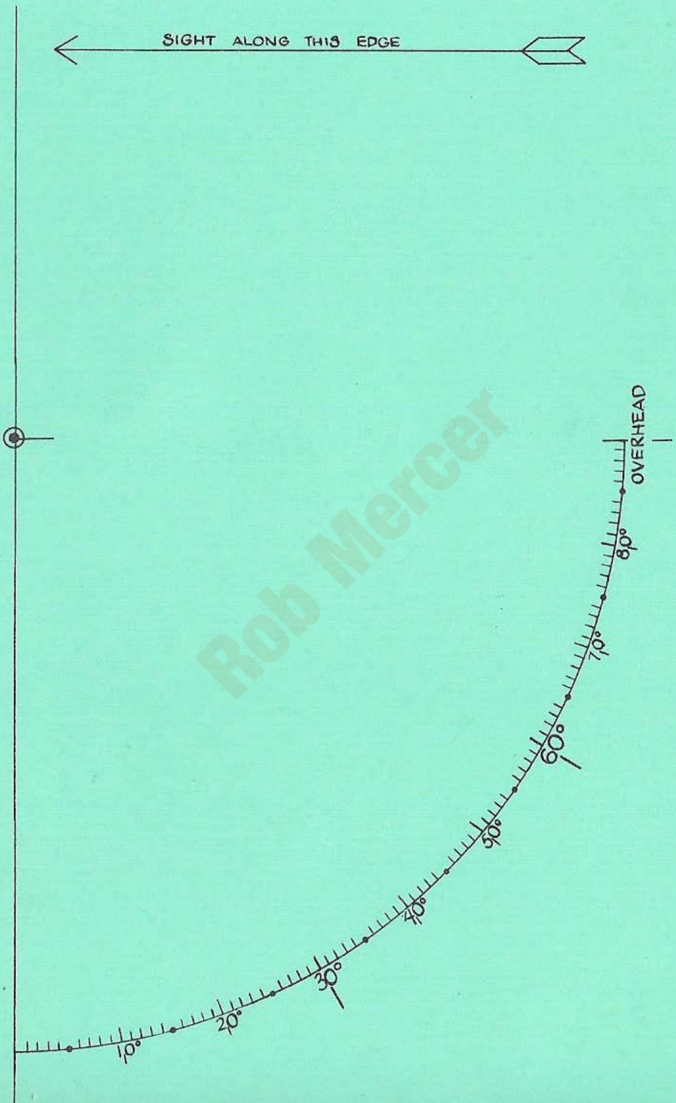
____
City State Zip Code

Telephone ______________________
Area Code Number

Directions for use: The following instructions will permit proper use of the quadrant for altitude determination.

1. Mount card, by cementing, to same sized wood slab (plywood works well). Take care to properly align edges so that the sighting edge is perpendicular to the solid base line.
2. Drill a small hole through the card and board at the center of the circle on the baseline.
3. Insert a strong thread through the hole and attach it near the middle of the back of the instrument (wood side). A thumbtack or small nail is suitable for anchoring the thread.
4. The thread should be about 8 inches long. Attach a small weight (fishing sinker) to the other end of the thread. It should now swing freely at the pivot (hole) as the instrument is turned.
5. To use the instrument, sight along the edge, as indicated, toward the point of measurement. Let the string come to rest, then press it firmly against the card, read, and record the measurement.

Note: Great care must be taken to sight along the edge of the card - NOT on a corner. A sighting tube mounted along the sighting edge will improve the instrument.


SIGHT ALONG THIS EDGE
OVERHEAD
10°
20°
30°
40°
50°
60°
70°
80°

A NETWORK FOR (RAPID) ANALYSIS OF FIREBALL TRAJECTORIES*

Von Del Chamberlain
Abrams Planetarium
Michigan State University

In the past few years intense interest has developed in meteorites, especially freshly fallen ones. Meteorite research contributes to the general problem of understanding the history of the solar system. A freshly fallen meteorite with detailed information on its fall and pre-atmospheric entry is truly a scientific treasure.

Meteorites fall when and where circumstances determine. When they fall they are seen by all kinds of people who are doing all sorts of things at the time. If meaningful information is to be gathered, it must be obtained quickly by qualified individuals. Observations are needed throughout the region of visibility of the fireball. This research requires a little time from a lot of individuals spread throughout the world. The author is seeking members for a Network for (Rapid) Analysis of Fireball Trajectories (NAFT). Planetarium Teachers are especially desired as members for the following reasons:

First, planetarium teachers possess the knowledge and interest required. They understand angular measure and appreciate the problem of determining position of objects seen in the sky. They realize that distance cannot be estimated from a single observation. They know how to determine altitude and azimuth of points in the sky and are familiar with the star background against which a brilliant fireball might be seen. In addition planetarium teachers are already interested in such natural events.

Second, planetariums possess channels of communication with the public of their regions. This is vital to the success of NAFT.

Third, planetariums are rather well spread throughout the world and the distribution promises to become even more adventageous to NAFT. Fig. 1 shows the distribution of planetariums in the United States.

The network will function in the following way. Should a very bright fireball be visible in a member's area, he would first be responsible to report it to NAFT Headquarters (Michigan State University) so that reports can be requested from other appropriate regions. On the other hand, a member might first be alerted by NAFT that a fireball may have been visible in his area. In either case, he would next request information from the public, and then be expected to select a few reports for further investigation. In these few cases he would accompany the observers to the sites

*A paper presented at the Third Annual Meeting of the Great Lakes Planetarium Association, Cleveland, Ohio, October 19-21, 1967.

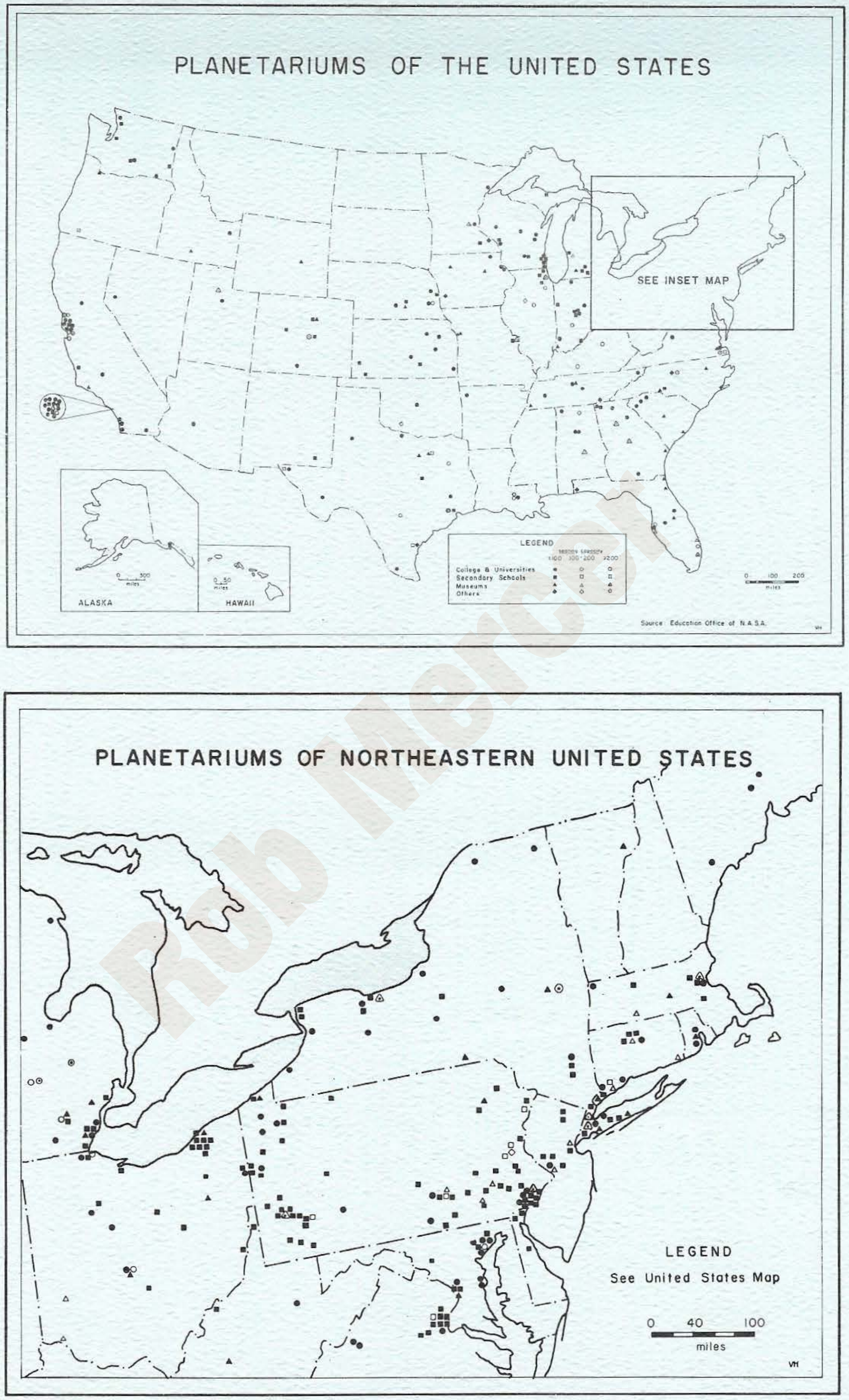


Fig. 1 Distribution of planetariums in the United States in 1966. Information supplied by the Education Office, National Aeronautics and Space Administration.

Remarkable photograph of the 17 September 1966 fireball as seen at Hamilton, Ontario, Canada (James C. Fish Photography).

of their observations and obtain the required data. This information would then be immediately sent to NAFT Headquarters to be correlated with other data. The results indicate the approximate region of possible meteorite fall. Interested meteoriticists nearest to the region would then be contacted by NAFT in order that detailed investigation could begin. Such activity would probably involve a network member once every year or so, perhaps only every few years.

Members of NAFT will find some benefits in return for their service. They will receive information which they should find interesting, thus benefiting from those who have investigated fireballs and meteorite fall in the past. They should also find satisfaction in being party to this type of research which is in keeping with other interests. The image of planetariums as a resource for public and scientific information should be strengthened. NAFT activities should yield some interesting ideas for day to day planetarium teaching. Members will also gain public recognition for this research activity.

Those interested in becoming members of NAFT may do so by corresponding with the author.

ON THE EXISTENCE OF FROZEN ORGANIC, OR GELATINOUS, MATTER IN THE METEOR SHOWER OF NOVEMBER 13, 1833

Donald H.
Design Specialist

10 October 1961

GENERAL DYNAMICS/ASTRONAUTICS

San Diego 12, California

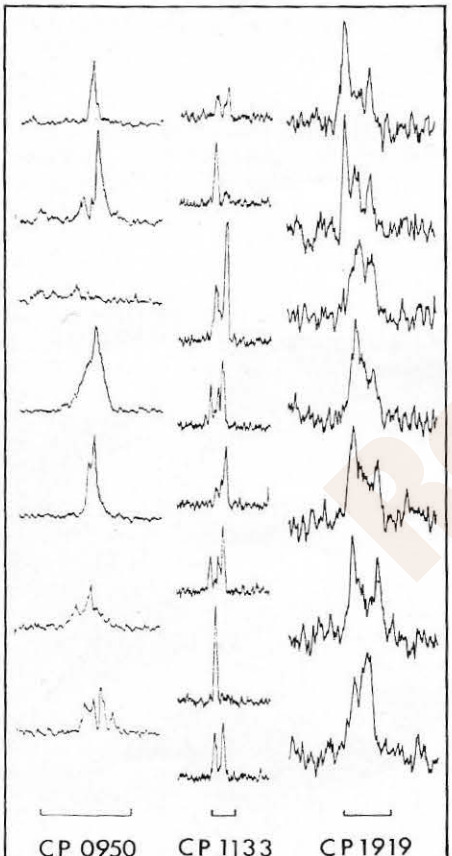
113 - 116 128 - 131 143 - 146 sec 158 - 161 sec

The Enigmatic Pulsars — Facts and Interpretation

A. G. W. CAMERON, *Yeshiva University* and *Goddard Institute for Space Studies*
and STEPHEN P. MARAN, *Kitt Peak National Observatory*

ONE of the most remarkable discoveries in the young science of radio astronomy was announced by Cambridge University astronomers early this year (see "A Rapidly Pulsating Radio Source," SKY AND TELESCOPE, April, 1968, page 207). They reported an object in Vulpecula that radiates energy at radio frequencies in pulses at precisely regular intervals of $1\frac{1}{3}$ seconds. Three other such *pulsars* are known, two with similar periods and one with pulses every $\frac{1}{4}$ second.

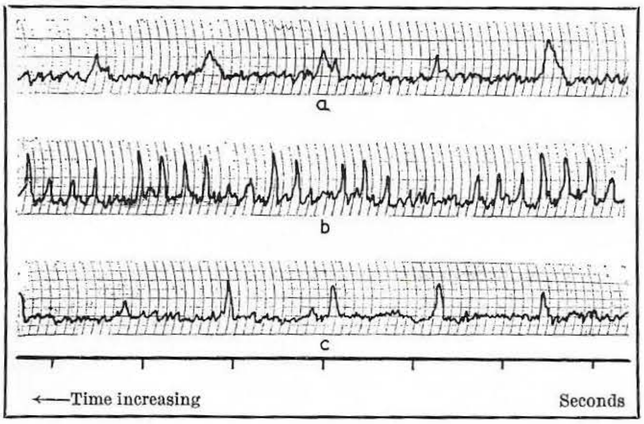
Rapidly accumulating observations indicate that these strange sources lie within our galaxy at distances on the order of several hundred light-years, and that the Vulpecula one may be associated with an 18th-magnitude star, but in other respects this hitherto unknown celestial phenomenon remains an enigma.



The great variety of individual pulse shapes for three pulsars is demonstrated by these typical sequences of consecutive pulses (arranged vertically), as recorded with the 250-foot Mark I radio telescope at Jodrell Bank. The observing frequency was 408 megahertz, the bandwidth four megahertz, and the time constant one millisecond. From A. G. Lyne and B. J. Rickett, University of Manchester, England.

English participants at the conference were (left) J. D. H. Pilkington, Cavendish Laboratory, and F. G. Smith, Nuffield Radio Astronomy Laboratories.

A large number of the scientists who are working in this new field attended a conference on pulsars in New York City on May 20-21, 1968. It was sponsored jointly by the Belfer Graduate School of Science at Yeshiva University and by the NASA Goddard Institute for Space Studies, and held at the latter's headquarters at 2880 Broadway. The senior author served as organizer and moderator of the meeting.



On March 21, 1968, at Mullard Radio Observatory, these pulse records were obtained with a time constant of 0.03 second. Note the different pulse repetition periods of (*a*) CP 0834, (*b*) CP 0950, and (*c*) CP 1133. This and some other illustrations with this article are adapted from the weekly *Nature*, published by Macmillan (Journals) Ltd., London.

Participants came from many parts of the world, in particular three from Canada, two each from England and Germany, and one each from France and Australia. The 100 or so Americans included optical and radio astronomers and many theoretical physicists, all seeking to unravel the puzzle. While the first day's program was to be devoted to reports of observations and the second to theory, exciting new data and interpretations were heard on both days.

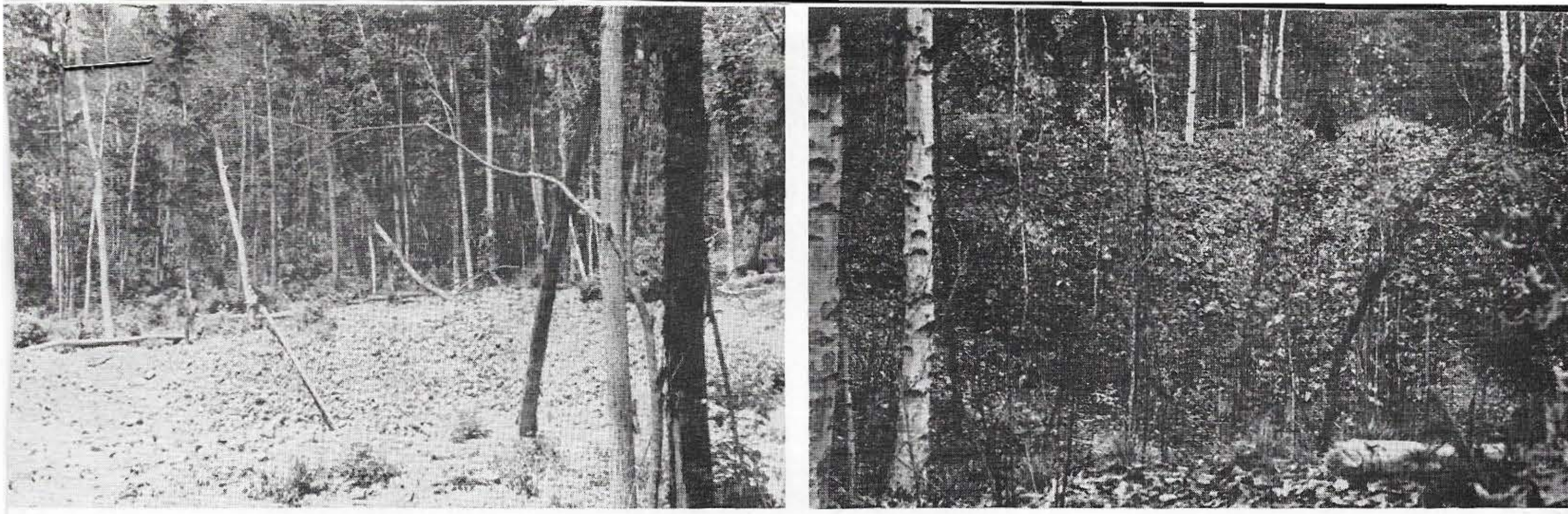
J. D. H. Pilkington brought the latest news from Cambridge, England, where the first pulsar recording was made by A. Hewish and his colleagues a year ago. There, Mullard Radio Astronomy Observatory astronomers had built a radio telescope especially for monitoring the rapid scintillations of celestial radio sources caused by the solar wind or plasma component of the interplanetary gas. This effect is similar to the optical twinkling of stars seen through our atmosphere.

Their aerial is a rectangular array of 3.7-meter-long copper wire dipoles, arranged in 16 rows of 128 dipoles each. The array is 470 meters long from east to west and 45 meters from north to south. Observations are made while the sky turns westward due to the earth's rotation. The aerial is used as a phase-switched, east-west interferometer, with half-power beamwidths of about one degree in right ascension and six degrees in declination. Phase-scanning techniques allow the observations to be made simultaneously at four declinations, spaced three degrees apart.

A weekly survey of the sky between declinations −8° and +44° was begun to study the scintillation of compact radio sources. During this program, an unusual rhythmic signal was detected on several days at the same sidereal time; it turned out to be the first pulsar, now designated CP 1919.* Restudy of the survey records disclosed three more pulsars, but no others have been found since, even though the original Cambridge program had covered each sky area about 20 times.

More of them may exist elsewhere, for the four pulsars have declinations between only +6° and +22°, and the Mullard array is most sensitive at +30°. Working at a frequency of 408 megahertz (instead of the original 81.5) with

*This notation means the Cambridge *pul*sating source at right ascension $19^h\,19^m$.



In 1948, when the second expedition investigated the great Sikhote-Alin meteorite fall, the largest crater appeared as at left. It was 26 meters wide and six meters deep. But after two decades, vegetation almost hides the crater from view (right). This picture was taken by the expedition led by E. L. Krinov during the summer and fall of 1967. Unless otherwise credited, illustrations with this article are from the author, courtesy Novosti Press Agency.

New Studies of the Sikhote-Alin Meteorite Shower

E. L. Krinov, *Committee on Meteorites, U.S.S.R. Academy of Sciences*

An extraordinary event occurred 22 years ago over eastern Siberia. In full daylight a ball of fire crossed the sky, so dazzlingly bright that it cast moving shadows. Detonating, it fell as a great rain of iron meteorites. This unique natural phenomenon was observed by many eyewitnesses, and its complex circumstances have attracted intensive scientific studies.

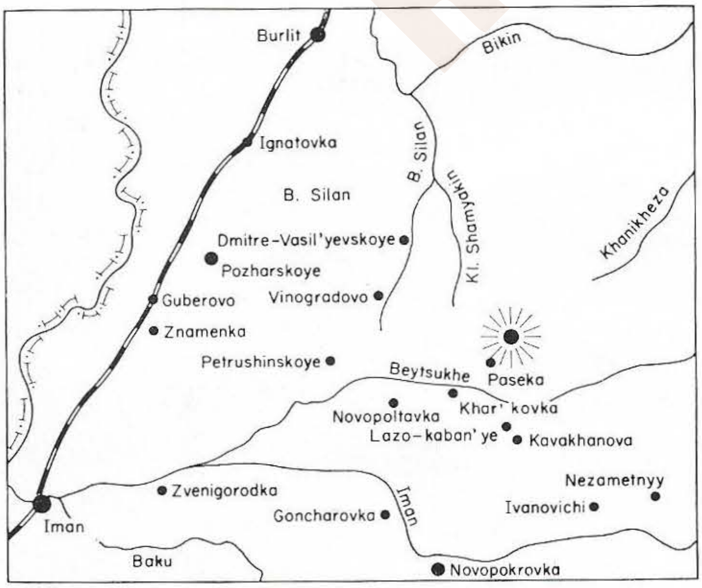
The shower fell on the snow-covered western spurs of the Sikhote-Alin mountains at 10:38 a.m. on February 12, 1947. This remote wooded site lies in Siberia's Maritime Province, 250 miles north of Vladivostok. Each year from 1947 to 1950, the Meteorite Committee of the U.S.S.R. Academy of Sciences sent an expedition to the area to study the fall and collect samples, as part of a continuing investigation.

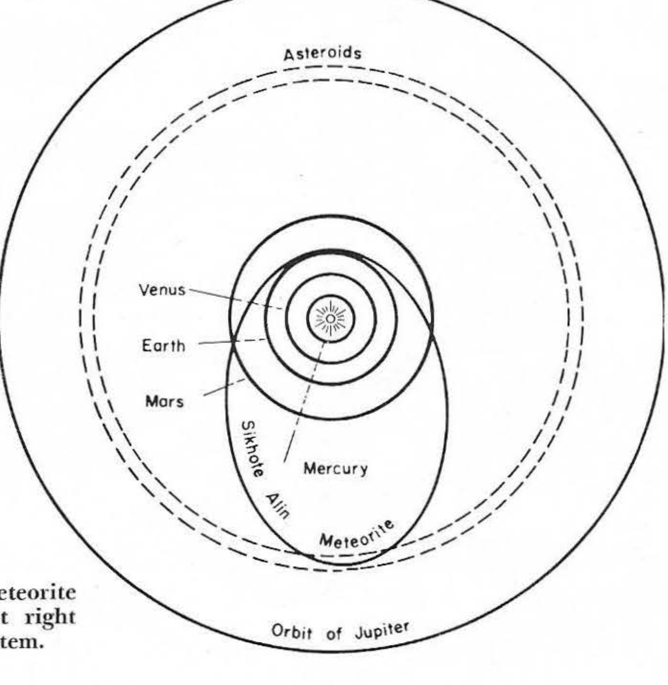
In 1950 field work was temporarily halted, but for a number of years the Meteorite Committee went on processing the scientific material, and published the results as a two-volume monograph in 1959 and 1963.

This work showed that a single large meteoritic body fragmented in the earth's atmosphere to shower debris over an area of 2.1 square kilometers. The larger fragments, weighing several tons each, crushed the mountain rock on which they fell, forming craters and large pits. On impact these fragments split into many smaller pieces. Altogether, 122 craters and pits were found with diameters ranging from 26.0 to 0.5 meters, and 78 smaller pits. Meteorites weighing from dozens to hundreds of kilograms were taken out of the smaller pits.

The iron rain was traveling southward when it struck the earth. In the rear part of the impact area, 175 undamaged small

The black dot on this map marks the approximate location of the Sikhote-Alin meteorite fall.





To right of center on this map, radial lines indicate the meteorite fall. Iman and Burlit are on the Trans-Siberian railroad. At right is V. G. Fesenkov's orbit of the parent body in the solar system.

Pulsars and Supernovae

EVIDENCE is accumulating that there may be a close connection between rapidly pulsating radio sources and supernova explosions. Two cases of such association have recently been announced, involving the pulsars PSR 0833-45 in the southern constellation Vela and NP 0532 in Taurus.

The first of these pulsars was discovered with the one-mile cross-type radio telescope at Molonglo Radio Observatory in Australia, which is operated by the Cornell-Sydney University Astronomy Center. In *Nature* for October 26, 1968, M. I. Large and his co-workers called attention to two remarkable properties of PSR 0833-45. Its period of 0.089 second was the shortest found until then for any pulsar. Also, the measured position of the object ($8^h\ 33^m\ 39^s$, $-45°\ 00'.1$ for 1950) placed it near the midpoint of the extended radio source Vela X. The latter is a shell four or five degrees in diameter, which is believed to be the result of a prehistoric supernova explosion.

During October, pulsars NP 0527 and NP 0532 in the vicinity of the Crab nebula were found by D. H. Staelin and E. C. Reifenstein, III, with the National Radio Astronomy Observatory's 300-foot transit antenna at Green Bank, West Virginia. These sources were evidently fluctuating very rapidly, though no periods were determined for them. Nothing more seems to have been reported for NP 0527, but NP 0532 has proven of exceptional interest.

R. B. E. Lovelace and his associates observed NP 0532 with the 1,000-foot dish at Arecibo, Puerto Rico. Several scans on November 15th placed the pulsar within 10 minutes of arc of the Crab nebula's center. A period of 0.033 second was found, the shortest known for this type of object.

The distance to a pulsar can be roughly determined because the high-frequency portion of each radio pulse reaches Earth ahead of the low-frequency part, which is slowed by electrons in the interstellar medium. The amount of this lag indicates how far the radio waves have traveled. The distance of NP 0532 estimated in this way agrees fairly well with that of the Crab nebula (close to 2,000 parsecs).

Therefore it is fairly probable that

(Continued on page 24)

...ill with renewal. *Subscription Manager,* Sarah E. Bulger. ...n J. Simmons, Jr. *Office Staff:* Justin K. Aldrich, Lawrence Bolton, Virginia K. Brewer, Nancy De Rocher, Robert A. ...uollo.
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...vy atoms have been built up from iron ...rapid neutron capture. These particles ...particularly liable to spallation and ...ionization losses in interstellar hy...gen, so their presence implies that ...have traveled only a short distance ...ugh interstellar space compared with ...nces traversed by nuclei having Z less ...perhaps 10. It was suggested at the conference that this may indicate two separate kinds of cosmic rays, the heavy-element kind coming from relatively nearby supernova explosions.

As more and more information about the charges and energies of the very heavy nuclei from deep space is obtained, we can expect more insight into the origin of cosmic radiation.

...ULSARS AND SUPERNOVAE

(Continued from page 3)

...pulsar is, like the Crab nebula, a ...ct of the supernova observed in A.D. ...and thus about 900 years old.

...0532 is the first pulsar to show a ...ssive change in period (as distin...d from the annual period change ...pulsar shows because we observe ...moving Earth). This discovery ...ade at Arecibo, from where D. ...ls of the Cornell-Sydney Center re...hese heliocentric periods:

...ber 20	0.03309014 second,
...ember 15	0.03309114 second,
...ember 22	0.03309140 second.

...eliocentric period seems to be ...ing at a rate of 38×10^{-9} second ... (Alternatively, it has been ... that the seeming change is due ...t of a relativistic correction in ...g from apparent to heliocentric ...

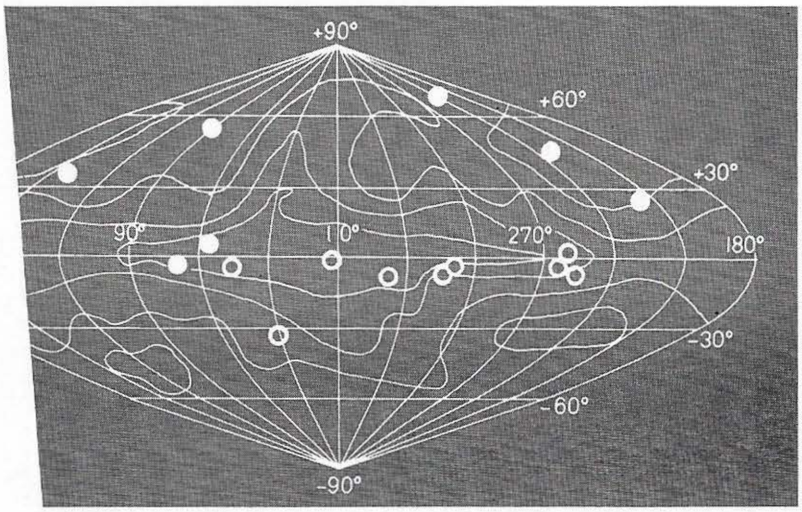
...findings add significantly to our ...ding of what a pulsar is. In ...lace, the periods of PSR 0833-45 ...532 are so short that they can ...explained by the rotation or ...of a white dwarf star. This ...possibility that the pulsars are ...eutron stars. Another alterna...l pulsation of a neutron star, ...ould not provide a period as ...1.96 seconds of PSR 2045-16. ...ons have suggested that the ...tational collapse of a massive ...has used up its nuclear-ener...eventually in an extremely ...e less than 10 miles in diameter, consisting only of neutrons. During the collapse, material is violently expelled from the star in a supernova explosion. This prediction, made several years ago, seems now to have confirmation.

Thomas Gold of Cornell University points out that the hot gas or plasma trapped in a neutron star's intense magnetic field can generate radio waves. As the star rotates, the trapped plasma cloud turns with it. And if the radio radiation were emitted by only part of the cloud, it would be observed as pulses, just as we observe pulses of light from a rotating lighthouse beacon.

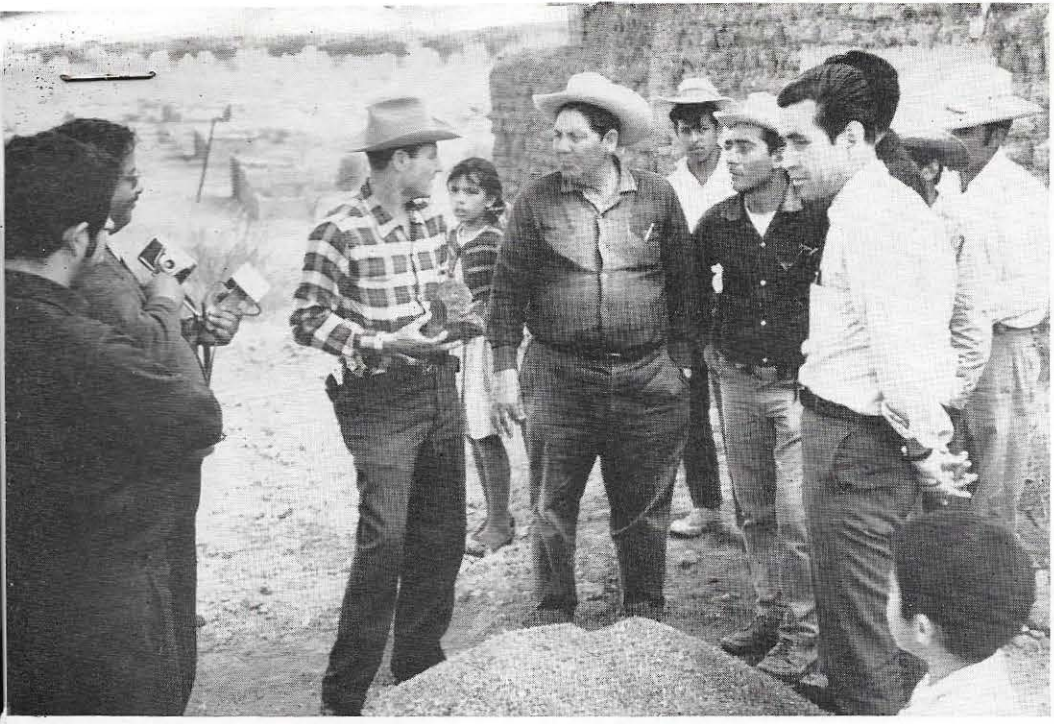
In explaining this model in *Nature* for May 25, 1968, Dr. Gold proposed that the energy emitted as pulses was derived from the rotational energy of the neutron star, thus braking the rotation. He predicted: "If this basic picture is the correct one it may be possible to find a slight, but steady, slowing down of the observed repetition frequencies."

Dr. Large and his colleagues have pointed out some of the consequences of the connection between pulsars and supernovae. If every Type II supernova results in a neutron star, there should be about 10^8 neutron stars in our galaxy. Very roughly, there would be about 10^3 neutron stars for every pulsar per unit volume of space. Thus, supposing all pulsars are neutron stars, they must represent only a temporary stage in the latter's lifetime.

This is supported by a preliminary check at Molonglo Radio Observatory of the sites of 15 possible supernova outbursts, which yielded no further pulsars.



...rs are plotted here on a grid of galactic coordinates (Milky Way ...zontal), with Molonglo Observatory discoveries as open circles. ...-wavelength background isophotes from radio observations are ...shown. Cornell-Sydney universities diagram, from *Nature*.



Arturo Rodriguez, a policeman from Hidalgo del Parral, Chihuahua State, holds a 13-pound meteorite that was recovered one kilometer north of San Juan (a small village near Pueblito de Allende). Local newspaper reporters are at left. This photograph was taken by Elbert A. King, Jr., curator of NASA's Lunar Receiving Laboratory in Houston, Texas, who collected samples only two days after the fall.

The Alandroal Meteorite

On November 14, 1968, about 6 p.m., a 25.2-kilogram iron meteorite landed in a field near Alandroal, Portugal, only 30 meters from where a farmer was standing. Alandroal is a town east of Lisbon and about six miles from the Spanish frontier. Robert Citron, director of the Center for Short-Lived Phenomena, learned on December 2nd about this fall, from Dr. J. Gomes Ferreira of the Geophysical Institute, Lisbon.

The fireball descended steeply from the southwest, with a loud noise and a brightness that changed night into day, according to the farmer. Impact of the football-sized body caused a spray of dirt and dug a crater $2\frac{1}{2}$ feet deep.

This same witness said that the object remained incandescent for some time, cooling slowly in contact with the moist ground. This statement raised some doubt about the authenticity of the fall, since meteorites are not supposed to be incandescent when they land. However, most freshly fallen meteorites are not irons but stones, and very few irons have been seen so soon after impact.

Freshly Fallen Meteorites from Portugal and Mexico

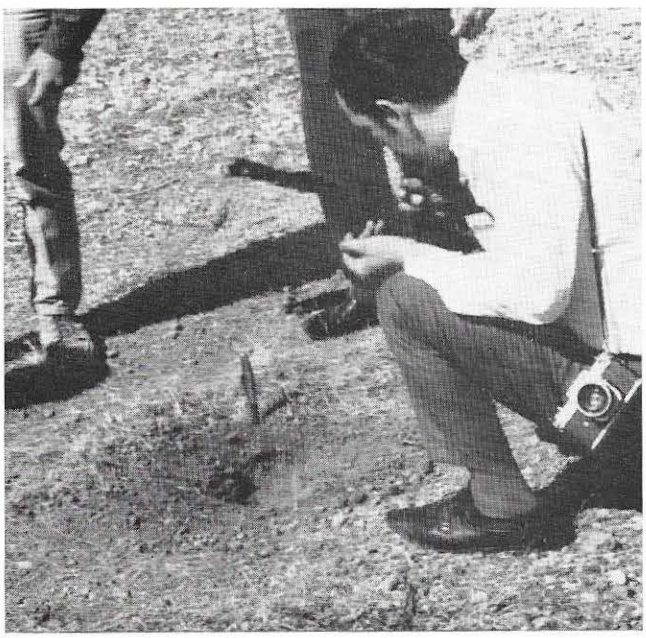
E. L. Fireman, *Smithsonian Astrophysical Observatory*

The scientific value of a meteorite is much enhanced if it can be analyzed within weeks of its fall, instead of after sitting for many years on a museum shelf. Meteoritic material that is fresh from interplanetary space contains traces of radioactivity, affording unique information about the solar system's past.

A new service of the Smithsonian Institution makes possible the speedy recovery and study of freshly fallen meteorites. Because this Center for Short-Lived Phenomena is located at the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, it can make use of the worldwide communications network set up for satellite tracking. Two important meteorite falls in recent months illustrate the value of this program.

Left: A $2\frac{1}{2}$-inch piece of the iron meteorite that fell last November near Alandroal, Portugal, has been cut in two parts. Picture from Robert Citron of the Center for Short-Lived Phenomena, which was responsible for obtaining the sample.

Right: In the main road near San Juan, Chihuahua, Mexico, is this crater formed by the 13-pound meteorite fragment seen at the top of this page. Dr. King took this picture to show the shallow crater, five inches deep and eight across, indicating a very low impact velocity.



Through cablegrams and transatlantic telephone calls, and by enlisting the aid of the United States ambassador to Portugal, Mr. Citron arranged for a 128-gram sample to be flown to the United States. Our specimen arrived on December 14th, exactly 30 days after the fall and 12 days after the Center was notified.

Chemical and isotope analyses dispelled any doubt that it was a meteorite. Metallurgical studies by M. Comerford of the observatory indicated that its structure was similar to that of the Washington County iron, which was an unusual mete-

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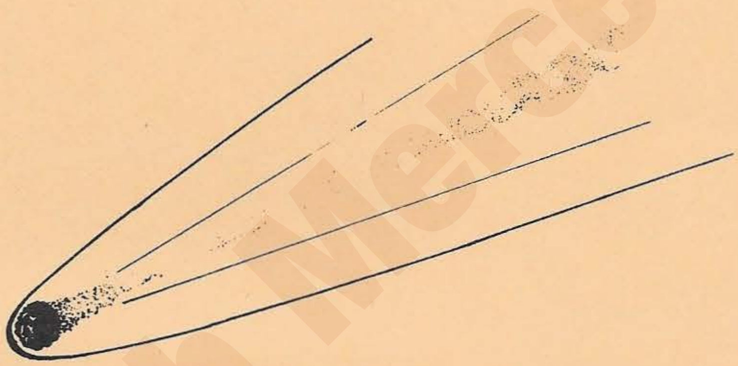

THE NETWORK FOR ANALYSIS OF FIREBALL TRAJECTORIES

Von Del Chamberlain