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FIRST-YEAR REPORT

OPTICAL OBSERVATIONS OF THE AMPTE ARTIFICIAL COMET AND MAGNETOTAIL BARIUM RELEASES

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ABSTRACT

The first AMPTE artificial comet (12/27/84) was observed with a low-light-level television camera operated aboard the NASA CV990 flying out of Moffett Field, California. The comet head, neutral cloud, and comet tail were all observed for four minutes with an unfiltered camera. Brief observations at T + 4 minutes through a 4554Å Ba^+ filter confirmed the identification of the structures. The comet disappeared during an interruption of the data acquisition between T + 260 and T + 344s. The ion cloud expanded along with the neutral cloud at a rate of 2.3 km/sec (diameter) until it reached a final diameter of ~ 170 km at ~ T + 90 s. It also drifted with the neutral cloud until ~ 165 s. By T + 190 s it had reached a steady-state velocity of 5.4 km/sec southward. The tail extended rapidly in a generally anti-sunward direction while drifting southward. Additionally, there were impulsive events during which barium appears to have drifted at ~ 700 km/sec along a direction ~ 25°south of anti-sunward.

A barium release in the magnetotail (3/21/1985) was observed from the CV990 in California and also from ground stations at Eagle, Alaska and at the Poker Flat Rocket Range near Fairbanks, Alaska. Over a twenty-five minute period, the center of the barium streak drifted southward (~ 500 m/sec), upward (24 km/sec) and eastward (~ 1 km/sec) in a non-rotating reference frame. An all-sky TV at Eagle showed a single auroral arc in the far North during this period.

INTRODUCTION

The University of Alaska participated in the AMPTE program by using sensitive TV cameras to observe the chemical releases. The first artificial comet (12/27/84) was observed from the NASA CV990 flying out of Moffett Field, CA. A similar system was operated at Poker Flat, Alaska. But owing to the low elevation angle and the contamination from a bright auroral display, it was not possible to detect the barium from Alaska. The aircraft data have been analyzed extensively and are discussed below.

The magnetotail release on 3/21/85 was observed by the University of Alaska from three locations: the CV990 in California; Eagle, Alaska, and Poker Flat near Fairbanks, Alaska. Auroral observations were also made from Eagle and from Poker Flat. The drift (latitude, longitude, altitude) of the barium streak has been determined by triangulation from the three locations. Other aspects of the data are still under investigation.

The April release-window could not be covered from Alaskan ground stations because of excessive sunlight. The University of Alaska did operate its low-light-level television system aboard the CV990. However, there were no releases while the CV990 was airborne.

In July, the system was again operated aboard the CV990 (flying out of McGuire AFB in New Jersey) to observe the optical effects of water produced by the Spacelab II orbital injection burn. This effort was thwarted by an aborted launch when the main engine of Challenger unexpectedly shut off. Because of a conflict with the schedule for the second artificial comet, the CV990 was unable to support the rescheduled launch of Spacelab II.

(The additional expenses associated with the effort to observe the water injection were covered separately through Boston University).

The second artificial comet experiment occurred on 7/17/85. We had chosen to observe this from the CV990 flying off the coast of Baja California, Mexico. It was determined that this could be achieved by means of a long local flight out of March AFB near Riverside, California.

On the morning of July 17, we flew from Moffett Field to March AFB and we prepared for a late afternoon takeoff for the data run. Unfortunately, a serious accident occurred on rollout. After the pilot brought the aircraft to a stop, we evacuated and then watched helplessly as the aircraft completely burned.

THE 12/27/1984 ARTIFICIAL COMET

The first artificial comet was generated by the release of 1.25 kg of barium in the dawn magnetosheath at 12:32:00 UT on 27 December, 1984. Extensive cloud cover restricted the optical observations. But the release was observed from White Sands, N.M.; Boulder, Colorado, the NASA CV990 flying out of California; and the Argentine Boeing 707 flying out of Tahiti. Preliminary reports have been issued covering the White Sands observations by Los Alamos Scientific Laboratory (Bernhardt, personal communication, 1985) and the Fabry-Perot imaging aboard the CV990 (Rees, personal communication, 1985). This report covers the video imaging system operated aboard the CV990 by the University of Alaska.

Description of Equipment - The basic sensor was an image orthicon tube with a 40 mm diameter S-25 photocathode and a magnesium-oxide target. The video camera was equipped with a 300 mm focal length f2.5 lens and a removable 30Å filter for the Ba^+ line at 4934Å. The field-of-view was

4° x 5°. The system was aimed by means of a gyro-stabilized mirror (heliostat) controlled by a joy-stick. Since the heliostat is a two-axis system, it stabilizes the image at the center and aircraft pitch and roll are converted into a rotation of the image about this central point. The imager was operated with reversed sweep to rectify the reflected image. The latitude and longitude of the aircraft (derived from the inertial navigation system) were displayed in the TV image along with time.

Description of Observations - For the first 3 minutes and 58 seconds, the imager was operated unfiltered (total light) and at the NTSC standard rate of 60 fields per second. At 12:35:58 (T + 238 s) the 4934 filter was inserted and at 12:36:12 (T + 252 s) the camera was switched to a one-second integration mode. During the following eight seconds the camera controls were not yet optimized for the one-second integrations, but images of the barium ion emissions were obtained. The two brightest stars in the field-of-view were visible in the filtered images, thereby enabling accurate registration with the unfiltered images.

At T + 260 s the heliostat control was accidentally engaged and the imager was no longer pointed at the comet. The filter was removed to allow recognition of star fields for repointing. By T + 344 s the imager was again aimed at the release location, but the comet was no longer detectable in either the filtered or unfiltered mode. The preliminary report of Rees and a verbal report from Mendillo both indicated that the comet faded very rapidly between T + 240 s and T + 300 s.

The release cloud or comet head was readily visible throughout the four-minute period of observation. The extended tail is not noticeable in the TV images when played at the standard TV rates. But the information is recoverable by means of time-averaging or by summing sequential TV frames.

Figure 1 illustrates the major features of the comet. The head is still bright at this time (4 minutes after release). The tail is extended roughly parallel to the anti-sunward direction (indicated by a series of white crosses at 1000 km intervals starting at the release point). The tail is also considerably spread out perpendicular to this direction and it appears to be somewhat curved.

Near the original release point (indicated by the first cross) there is another cloud that has a larger diameter then the comet head and is also less intense. This cloud does not appear in the filtered images and therefore is not ionized barium. The cloud may be BaO left over from the injection reaction or may be strontium contamination. In any case, it is presumably a neutral species and thus provides a useful reference. This cloud is hereinafter referred to as the neutral cloud.

Analysis of Data - The video data were first integrated to produce a series of two-second sums. These were digitized and stored on disk. At ten-second intervals the aircraft coordinates were entered into the computer and the angular calibration of each image was determined by matching the stars brighter than magnitude eight to the SAO catalog. The measured release coordinates were RA = 200.882, $\delta = -13.792$. The aircraft at the time of release was at latitude 38.137° and longitude -120.268°.

Using an assumed altitude of 103,346 km from the nominal trajectory of the IRM, the latitude and longitude of various features were measured. The results are shown in Figures 2 and 3. Both the comet head and the neutral cloud drifted steadily westward in the earth's reference frame. The straight line on the graph is the 0.25°/minute drift due to the rotation of the earth.

The plot of latitude shows a steady drift southward for the neutral cloud (0.7 km/sec). The motion of the ionized comet head can be approximated by two straight-line segments. The initial drift is similar to that of the neutral cloud. Later, the head drifts southward at a constant rate of 5.4 km/sec. The two slopes intersect near 165 seconds and the head reaches steady velocity near 190 seconds.

The diameter of the neutral cloud was measured in several images after it had separated sufficiently from the comet head to allow independent measurement. The diameters are given in Table I. The expansion velocity, assumed to be constant, was calculated for each measured diameter. The average of the velocity determinations was 2.3 km/second. The corresponding radial expansion is then 1.1 km/sec.

The diameter of the comet head at +4 min was ~ 170 km. The neutral cloud reached this diameter near T + 75 s (based on the expansion velocity of 2.3 km/sec.). A review of the images shows that the diameter of the neutral cloud is visibly greater than that of the comet head after T + 95 s.

Evolution of Comet Tail - The comet tail is first noticeable in the 2-second summed images at 12:33:34 (T + 94 s). At this time it appears to be already longer than the 4000 km limit imposed by the edge of the field-of-view of the TV camera. One would expect that the first few thousand kilometers of tail were probably increasing in brightness during the first minute as the total number of ions in the head increased according to the time constant for solar ionization of ~ 20 s. Also, as the peak intensity of the comet head decreased due to expansion, it was possible to increase the sensitivity of the TV camera. Accordingly, it seems likely that the tail had formed and extended beyond ~ 4000 km well before T + 94 s (Rees reported a visible tail at T + 30 s).

Unfortunately, unless we can achieve further enhancement of the early-time images, the data do not allow determination of an average velocity for the extension of the tail. We note, however, that the development of the tail is highly turbulent. While the tail is generally aligned anti-sunward, there are at least three examples of impulsive events in which barium is pulled out of the head along a direction inclined by ~ 25°south of the antisunward direction.

In one example, at T + 170 s, there is a vague hint of some barium that has been pulled out along this line. Two seconds later (T + 172) there is a distinct jet terminating at RA 13:21.1, δ -13.98. The constant altitude projection of the jet has a length of 1014 km. At T + 174, the jet terminates at RA 13:18.6, δ -13.84 and the length of the projection is 2324 km. The velocity of the tip in this projection is ~ 500-600 km/sec. The corresponding velocity projected onto the antisunward direction is ~ 700 km/sec. At T + 176 s the jet has diffused.

The apparent curvature of the tail in many of the images seems to result from the combination of a series of impulsive events such as that described above and a more or less steady diffusion antisunward. In addition to these two types of motion, the entire tail appears to be drifting slowly southward along with the comet head.

Summary and Discussion of Comet Observations - The neutral cloud drifts steadily southward at a velocity (0.7 km/sec), somewhat less than the radial expension velocity (1.1 km/sec). This drift presumably results from an asymmetric injection of the barium.

The ion cloud expands with the neutral cloud until ~ T + 80 s and drifts with the neutral cloud until ~ T + 165 s. Since the ionization of the cloud is probably not complete until sometime after T + 60 s, most of the apparent expansion results from continuing ionization of the expanding cloud of neutral barium rather than from radial motion of barium ions.

The continued drift of the ion cloud with the neutral cloud after T + 80 s suggests that the magnetic field is still excluded from the core of the cloud. By T + 165 s the ion cloud is moving away from the neutral cloud and by T + 190 s it has reached it's steady-state velocity (5.4 km/sec). One interpretation of these measurements is that the diamagnetic cavity has collapsed partially or completely by T + 190 s. However, in this case it is not clear why the ions in the head are not picked up immediately by the solar wind. The southward drift is clearly an intriguing observation and more work is required to provide a fully satisfactory explanation.

The tail, on the average, is extending anti-sunward and also drifting southward along with the comet head. In addition, there are impulsive events lasting a few seconds that appear to pull barium out of the comet head at a velocity of ~ 700 km/sec at an angle of 25° south of the anti-sunward direction.

The 3/21/1985 MAGNETOTAIL RELEASE

This release was observed from the CV990 in California and from ground stations at Poker Flat, Alaska and at Eagle, Alaska. In addition, there were extensive auroral observations at Poker Flat, including an all-sky television camera and a meridian-scanning photometer. An all-sky television system was also operated at Eagle.

These data have not yet been analyzed as extensively as the data from the artificial comet. However, we have been able to triangulate between the three stations to determine the three-dimensional drift rate over a 25-minute period. Basically, the center of the barium streak drifted southward (~ 500 m/sec), upward (~ 4 km/sec) and eastward (~ 1 km/sec) in a non-rotating coordinate system.

Projected along the magnetic field to the ionosphere, these drifts are negligible. The streak was, on the whole, remarkably stationary. There are short episodes of striations peeling off from the main cloud, which have not yet been analyzed. The surprisingly quiescent behavior of the barium is consistent with the auroral observations. The only aurora seen from Poker and Eagle during this period is a single quiet arc along the arctic coast of Alaska.

PLANS FOR CONTINUED ANALYSIS OF THE DATA

Additional analysis of the artificial comet data will emphasize the following:

1) The images will be reprocessed using techniques that have been developed for this purpose since the early analysis was completed.

2) We will seek a better understanding of the southward drift of the barium ions relative to the neutral cloud.

3) The instances in which tail rays appear to evolve rapidly will be examined in more detail.

4) In collaboration with other groups, we will try to define the relative location and shape of the bright core seen with our low-light-level television, the cold-plasma region seen by D. Rees with his Doppler imager, and the diamagnetic cavity detected by the IRM satellite.

The line-of-sight component of the drift velocity for the 3/21/85 magnetotail release will be compared with the values obtained from Doppler imagers by D. Rees and by S. Mende and G. Swenson. This will be a useful comparison of techniques of measurement. The auroral data from Poker Flat will be examined more closely to provide a better description of the magnetospheric environment for this release. If the data permit, the individual rays that appear to peel away from the main cloud will be tracked.

TABLE I

Artificial Comet 12/27/85

Time after release seconds	Diameter of neutral cloud Km	Expansion rate Km/sec
180	460	2.6
190	493	2.6
208	469	2.2
220	403	1.8
Average		2.3

TABLE II

Artificial Comet 12/27/85

Time after Release Seconds	Remarks
0-240	Neutral cloud expands at ~ 2.3 km/sec (diameter)
0-240	Neutral cloud drifts steadily southward at 0.7 km/sec
0-75	Ion cloud expands with neutral cloud
95	Neutral cloud visibly larger than ion cloud
0-140	Ion cloud drifts with neutral cloud
165	Nominal transition of ion drift from initial to final rate.
140-190	Ion cloud accelerates southward
190-260	Ion cloud drifts steadily southward at 5.4 km/sec
172	Impulsive jet expands at ~ 700 km/sec, ~ 25° south of ecliptic.
260-344	No data
344-	Comet no longer visible

FIGURE CAPTIONS

Figure 1. This 10 s integration of the total-light video signal shows the comet head, comet tail, and neutral cloud at 330-338 s after release. (4° x 5.5° FOV). White crosses mark 1000 km increments along the anti-solar direction.

Figure 2. Longitude of comet head (dots) and neutral cloud (crosses) vs. time. Constant altitude is assumed.

Figure 3. Latitude of comet head (dots) and neutral cloud (crosses) vs. time. Constant altitude is assumed.

Figure 4. Two second integration, total light, (T + 170 - 172 s) shows thin jet of barium to the right (south) of the ecliptic. Crosses mark the anti-solar direction at 1000 km intervals.

Figure 5. Two-second integration (T + 172 - 174 s) shows the jet seen in Figure 4, except that it is more extended.

Fig 1

GI84-25a

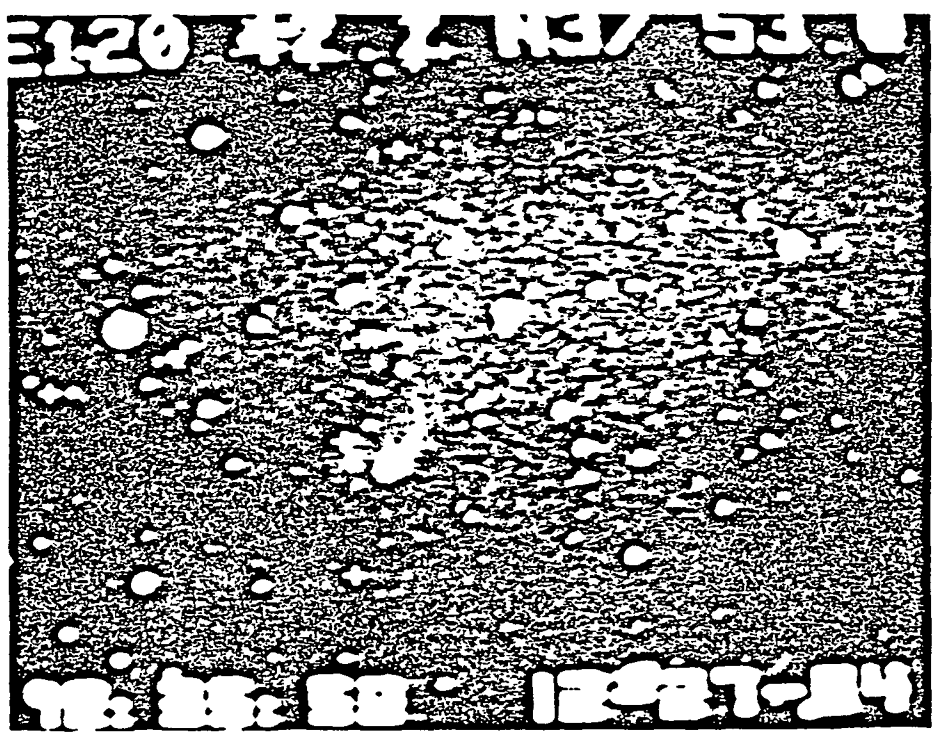
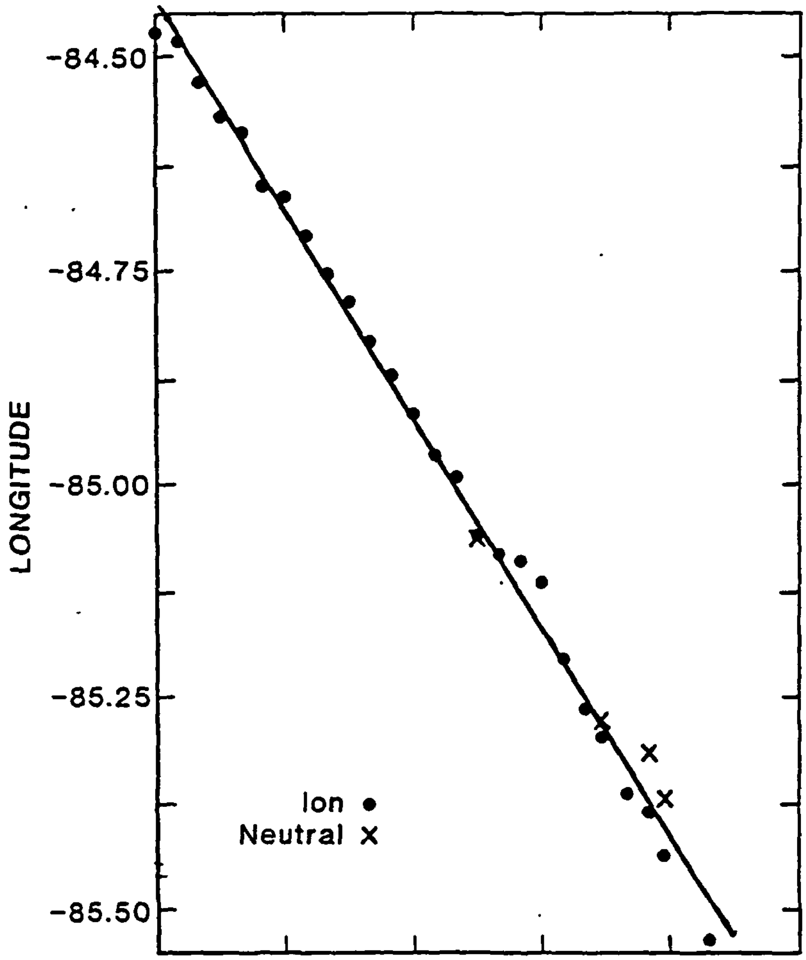


Fig 2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-85.25
-85.50
Ion
Neutral

Fig 3

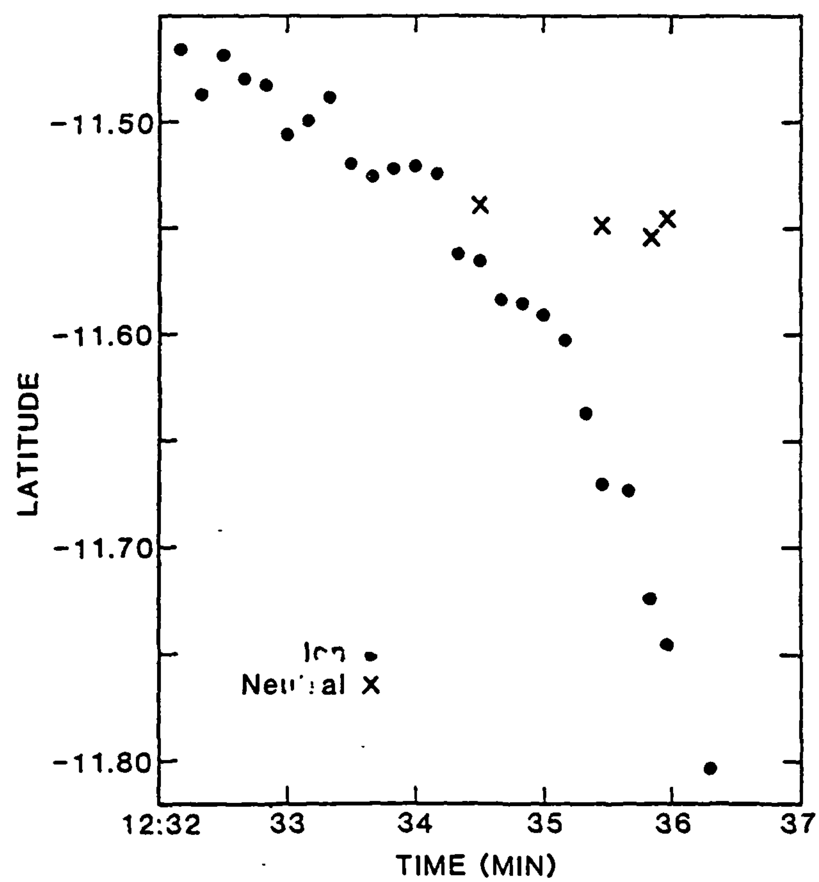
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Fig 4

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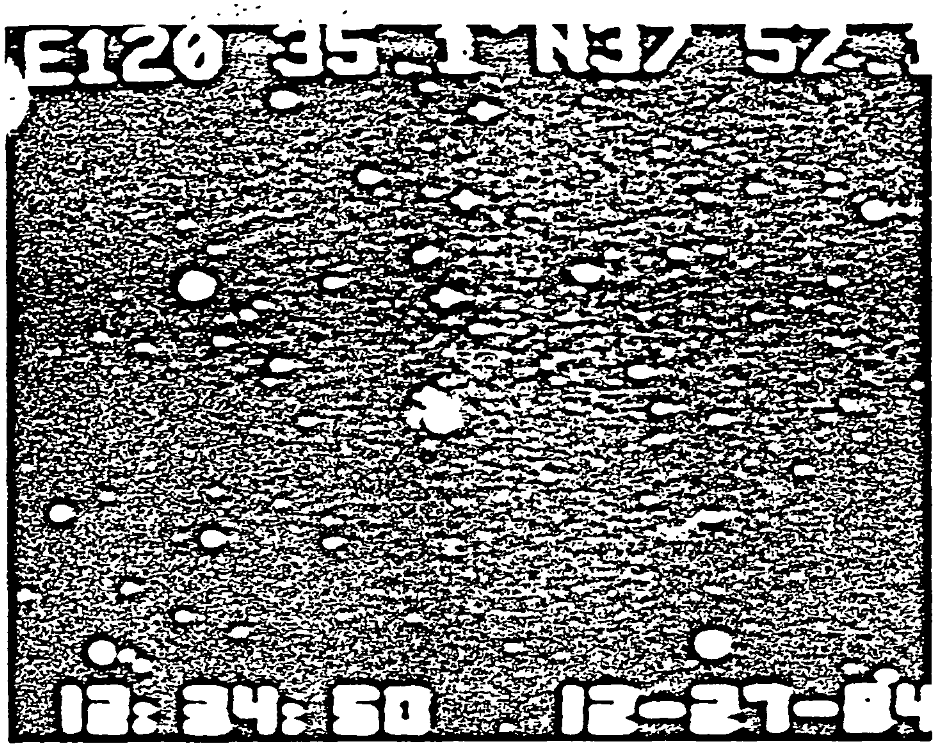

Fig 5