A KINEMATOGRAPHIC STUDY OF THE TAIL OF COMET KOHOUTEK (1973f)

K. Jockers, R. G. Roosen, D. P. Cruikshank

Introduction

By combining observations of Comet Kohoutek (1973 f) made in the Southwest US, Alaska and Hawaii, a cometary tail movie has been made. Parts of the movie were shown at the conference and some frames of the movie are reproduced in Fig. 1. In this paper we give some details of the observations and describe what we see on the movie.

Observations

Observers who contributed to the movie are listed in Table 1 with their institutions, instruments, and site locations. In all but one case, fast Schmidt cameras were used; high-speed optics are needed for this work because the interval between successive pictures should not exceed 15 minutes if plasma tail motions are to be properly visualized. The 36 cm f/2 Schmidt camera of the Joint Observatory for Cometary Research (JOCR) is clearly well-suited because of its flat field of about 8 x 10°. JOCR is located at an altitude of 3235 m at a site having frequent high transparency of the sky. In Alaska and Hawaii we used the comparatively inexpensive and easily portable Celestron 20 cm Schmidt cameras. The Celestron proved especially effective at the high altitude site in Hawaii where relatively fine grain Kodak RAR 2498 emulsion was used (Crump and Cruikshank 1974).

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Table 1

Sources for Comet Photographs

Number of Pictures	Institution	Location		Instrument	Observers
		Long.	Lat.		
47	JOCR	107.10	33.59	36 cm f/2 Schmidt	R. G. Roosen J. C. Brandt T. Armijo
4	Lunar and Planetary Lab.	110.72	32.40	46 cm f/3 Schmidt	S. Kuturoff R. B. Minton
5	Lowell Obs.	111.66	35.20	33 cm Astrograph 13 cm f/5 Cooke lens	H. L. Giclas
28	Sac Peak Obs. Observations from College, Alaska	147.50	64.50	20 cm Celestron Schmidt	K. Jockers
20	Mauna Kea Obs. University of Hawaii	155.47	19.82	20 cm Celestron Schmidt	D.P. Cruikshank P.C. Crump

Table 2

Time Intervals and Distances

Date	Time (UT) Covered in the Movie		Heliocentric Distance of Comet (a.u.)
Jan 11	1:42-2:04*	2:04-3:07	.52
Jan 12	2:42-3:21	3:50*	.55
Jan 13	1:59-2:52	3:32-4:35*	.58
Jan 14	1:40-2:47	3:45-4:08*	.60
Jan 17	1:38-2:32	3:31-5:57	.68
Jan 19	1:41-2:10	3:13-3:23	.74
Jan 20	1:19-3:01	5:24-6:44*	.76
Jan 21	2:24-2:34	5:05-6:39	.79
Jan 22	2:44-6:27		.81
Jan 23	1:35-3:25	5:25-6:35	.84

*An asterisk indicates that, because of small field, the pictures in these time intervals were used only for the sequence nearest to the cometary head.

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The resolution obtained in the photographs with the small Schmidt cameras seemed to be somewhat more sensitive to sky transparency than in those made with the larger instruments. This may be related to the dependence of resolution on the contrast of the object being photographed. The bending of the 35 mm film pieces to the strongly curved focal plane of the Celestron Schmidt cameras introduces noticeable image shifts which vary from frame to frame, therefore making precise alignment of the frames in the movie impossible.

The dates and time intervals covered in the movie are given in Table 2 together with the heliocentric distance of the comet. During the observation period the comet was always near its minimum geocentric distance of about 0.8 a.u. and the phase angle was near 90°.

Arrangement of the Movie

A typical sequence in the movie consists of about ten individual frames. To ease perception of these short sequences the pictures for each day are repeated 20 times forward and backward in time. Most of the individual frames have been printed twice on the movie. Since the original pictures were taken at intervals of about 10 min., with a projection speed of 24 frames per second 10 minutes of real time are compressed into somewhat less than 1/10 of a second in the projection. To ensure a constant time reduction in case of minor gaps in the data, some frames have been repeated on the movie up to four times. No attempt has been made to smoothe out the data gaps of about 1 hour which

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sometimes occur between the JOCR and the Alaska/Hawaii pictures. To preserve the resolution of the original data on the copy movie, the tail was divided into several parts so that the long side of the frame covers about 3° on the sky or 6 million km at the comet's distance.

The frame including the comet's head is denoted A, while frames offset to the northeast along the tail are designated B, C., etc. In order to properly display particular tail features the offsets have varying amounts of overlap. Because of the small field of the Celestron camera virtually all of the offset information comes from the JOCR observations. The alignment of the frames has been done with respect to the star background, i.e., the proper motion of the comet has not been removed.

Description of the Kinematic Behavior of the Cometary Tail

In this description we refer to the different sequences of the movie by a number denoting Greenwich date in January 1974 and a letter indicating the part of the tail concerned, i.e., 21 A means the sequence of January 21 of the first tail section, which includes the cometary head.

a. Tail Rays

Plasma comets show tail rays emerging from the coma and moving towards the main tail (Wurm 1963 p. 574f, Wurm and Mammano 1972). Long rays of this type can be seen on sequences 13A and 19A-C. The present observations show side rays originating from almost every tail condensation or kink (11B, 12C, 20B, 20C, Fig 1a, 1d). A few cases of this kind, but in rather strong condensations, have been seen in the tails of Comets Morehouse 1908 III (Bobrovnikoff, 1928) and Tago-Sato-Kosaka 1969 IX (Jockers et al. 1972). If Alfven's (1957) model of cometary tail rays is correct, this observation suggests that magnetic field lines penetrate the whole plasma tail and cause a rather complicated field structure.

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b. Wave Trains

Features looking like wave trains are frequently seen in cometary plasma tails. In the movie they appear in the center of the tail (13B) and on its edge (12B, 20B, 20C, Fig 1d). In the latter case there is a large-scale kink in the tail. Similar wave trains in a large-scale tail disturbance have been seen in Comet Bennett 1970 II (see pictures of the April 3/4 1970) event reproduced in Jockers and Lüst, 1973). The wave trains show little differential motion relative to condensations. Hence, if the wave trains represent real waves, their phase velocity must be rather low. During one hour they change shape only slightly.

c. Condensations and Kinks

Condensations can be seen in the main tail and in the tail rays. Jockers et al. (1972) report a case where higher velocities of the condensation were measured in the tail rays than in the main tail. In the present movie condensations in tail rays are seen most frequently adjacent to condensations in the main tail (11A, 11B and many other examples, Fig 1a). They move with almost the same velocity as the adjacent main tail structure. It appears that the flow in the tail ray was restricted by the main tail condensation. An interesting example of the development of a large condensation far from the cometary head is seen in sequence 21B (Fig 1e). Sequence 23A (Fig 1f) shows a condensation being ejected from the coma. Kinks can steepen during their evolution (19C, Fig 16) or be flattened out (20A, Fig 1c). Due to the short interval of time coverage the development of the large-scale kink in the cometary tail on January 20 and its possible correlation with the evolution of wavy structures cannot be studied from the available data.

In view of the limited observational material available, the above description necessarily remains subjective and has to be considered as a first attempt to describe what requires independent confirmation in observations of future comets.

Acknowledgments

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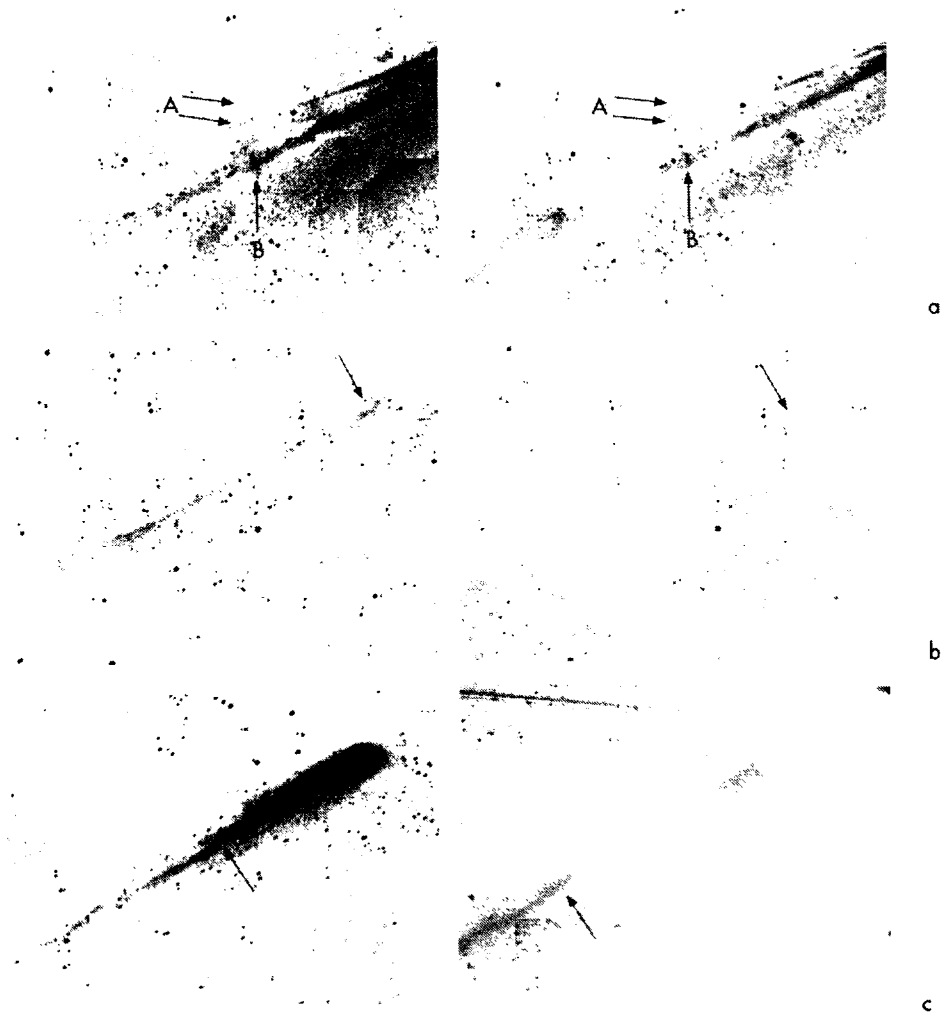

Fig. 1a-c

Fig. 1 Some frame pairs of the movie showing interesting time changes:

a) Jan 11: Time difference between frames 21 min.
Two condensations in tail rays (A) remain adjacent to a condensation in the main tail (B). On the early picture (left) two small side rays leave condensation B at both sides at almost right angles to the tail axis. These angles have diminished appreciably in the late (right) frame by motion of the side rays toward the tail axis.

b) Jan 19: Time difference between frames 66 min. A kink develops.

c) Jan 20: Time difference between frames 223 min. A kink flattens out.

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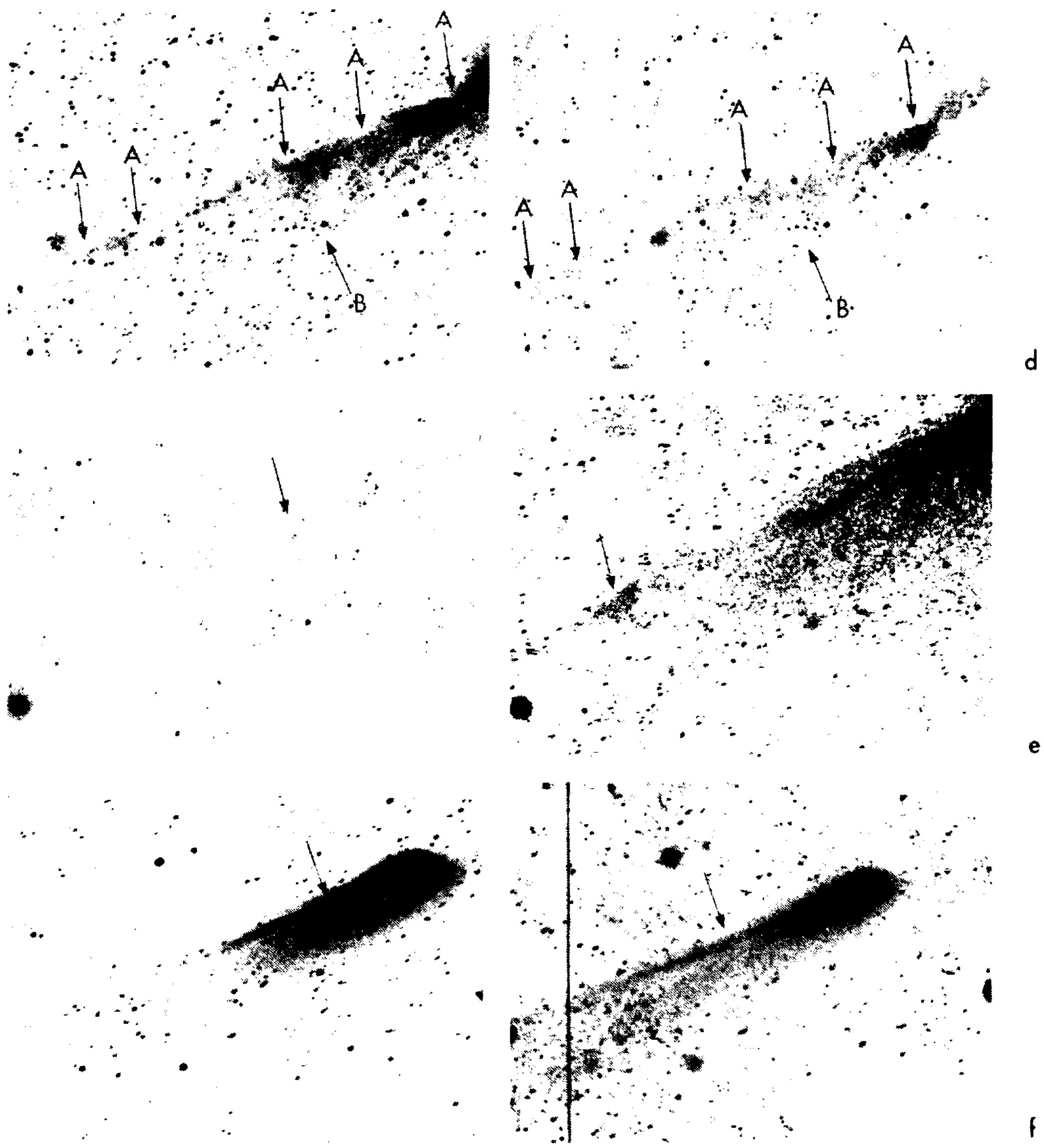

Fig. 1 (Continued)

d) Jan 20: Time difference between frames 55 min. The structure of the wave train (wave troughs marked A) remains remarkably constant. Attached side rays move towards tail axis (most prominent tail ray is marked B).

e) Jan 21: Time difference between frames 198 min. A condensation develops far from the cometary head.

f) Jan 23: Time difference between frames 208 min. A condensation leaves the dust envelope around the coma.

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