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POLARIMETRIC OBSERVATIONS OF COMET KOHOUTEK (1973f)

Status Report: 1 October 1973 through 30 June 1974

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Radio, optical, and visual observations were made of Comet Kohoutek (1973f) using facilities of the National Radio Astronomy Observatory (NRAO) and of the Hawaii Night Sky Observatory, State University of New York at Albany (SUNYA).

Radio Observations

Transit observations were made by J. Sulentic and N. Misconi of the SUNYA using the NRAO 300 ft radio telescope on six consecutive days beginning November 24, 1973. Observations were carried out in the continuum at 11 cm using the 4-feed system at different position angles. The data were recorded on magnetic tape and were computer reduced. Results were negative, with an rms error of 62 milli flux units (1 mfu = 10^{-29} watts/m^2 Hz), giving an upper limit of 180 mfu for the 11 cm continuum emission from the Comet. This relatively high detection limit resulted from a combination of interference and bad weather that affected these pre-perihelion observations. No observations could be scheduled near or after perihelion.

Optical Observations - Procedures and Instrumentation

A post-perihelion set of observations was planned using a 14-color photoelectric polarimeter from the Laboratory's observing facility on 10,000 ft Mt. Haleakala, Maui, Hawaii. We had hoped to measure the integrated light of the comet nucleus and to map the tail throughout the visible and near IR in a manner similar to that used with Comet Ikeya-Seki (1965 VIII) (see Appendix) but over a much wider range of wavelength* and with a larger and more efficient instrument. In addition to seeking detailed time, spatial, and wavelength coverage throughout the tail, we planned to search for changes in the zodiacal light associated with the influx of cometary material.

The polarimeter is mounted in an alt-azimuth configuration, has variable color, gain, field of view, and mode of observation (fixed position or sky scan at various rates), and measures three parameters: azimuth of vibration (or orientation of the plane of polarization), total sky radiance or brightness, and brightness of the polarized component. This 8-inch objective, refracting instrument is also used

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* The polarimeter uses narrow-band interference filters at the following wavelengths:

3700Å	5450	6435
4000	5577	6745
4355	5752	7100
4760	6080	8200
5080	6300	8700
5300	6364	

for all-sky observations of nightglow line and continuum emission and for measurements of atmospheric extinction and has analog and digital output.

If Comet Kohoutek had been as bright as Comet Ikeya-Seki (1965 VIII) we could have observed it before the end of evening astronomical twilight and probably even in the presence of moonlight - something not possible in photometry of the low light level nightglow. The proximity of Comet Kohoutek to the Sun, its faintness, and the presence of moonlight made it impossible to observe before January 9/10 even if the weather had been clear every night. Table 1 gives Haleakala ephemeris data for the period January 8/9 (the night starting January 8th) through January 22/23, 1974.

Optical and Visual Observations

Poor sky conditions associated with the worst winter storm in Hawaii in years, lasting from mid-December 1973 through mid-January 1974, limited our entire program to observations on two nights in late January (20/21, 21/22). At that time Comet Kohoutek had become so faint that it was barely distinguishable above the "background" light of the night sky.

A condensed observing log is given in Table 2. The standard calibration noted in the log refers to our regular practice of monitoring instrument sensitivity and reproducibility by use of a low light level, calibrated standard source. Polarization calibration refers to our use of an unpolarized source of brightness together with a pile of plates polarizer (Weinberg, Applied Optics, 3, 1057-1061, 1964) to determine the response of the instrument to polarized light.

Figure 1 contains annotated copies of strip chart recordings of the brightnesses of background plus Comet for Kohoutek (7100Å) and for Ikeya-Seki (5300Å) at the same elevation (8 deg). Although the wavelengths, instrument sensitivities, and atmospheric extinction are different in the two cases, it is clear that Kohoutek, shown here on January 9/10, was considerably fainter than Ikeya-Seki at a comparable time after perihelion. Although Comet Kohoutek was even fainter by January 20/21, it will be possible to compare the absolute brightnesses of Kohoutek and Ikeya-Seki at several distances from the nucleus. Since the signal levels in polarized light are very small, special methods will have to be used to derive polarization data for Kohoutek.

Other Use of the Facility

The facility was used in November and December 1973 by F. Giovane of Dudley Observatory to test equipment for Skylab experiment T025 and to determine optimum exposure times for perihelion observations of Comet Kohoutek from Skylab. The facility was also used in December 1973 and January 1974 by A. Peterson and L. Kieffaber of the University of New Mexico, Albuquerque, to observe near infrared airglow emission and to photograph Comet Kohoutek.

Table 1. Observing Ephemeris, Haleakala Observatory, January 1974 (all times HST) - approximate

Date	End of Evening Astronomical Twilight	Moonrise	Elevation of Comet at End of Evening Twilight	Time of Comet Set
Jan 1974				
8/9	1920	1836	7.7 deg	2000
9/10	1921	1942	9.6	2010
10/11	1922	2045	11.4	2020
11/12	1922	2146	13.6	2030
12/13	1923	2243	15.4	2038
13/14	1923	2339	17.5	2048
14/15	1924	0034	19.4	2056
15/16	1924	0128	21.4	2104
16/17	1925	0221	23.2	2114
17/18	1925	0314	25.5	2124
18/19	1926	0405	27.4	2132
19/20	1926	0454	28.6	2139
20/21	1927	0539	30.3	2146
21/22	1927	----*	32.1	2153
22/23	1928	----*	33.7	2201

*Moon rises after the start of morning astronomical twilight.

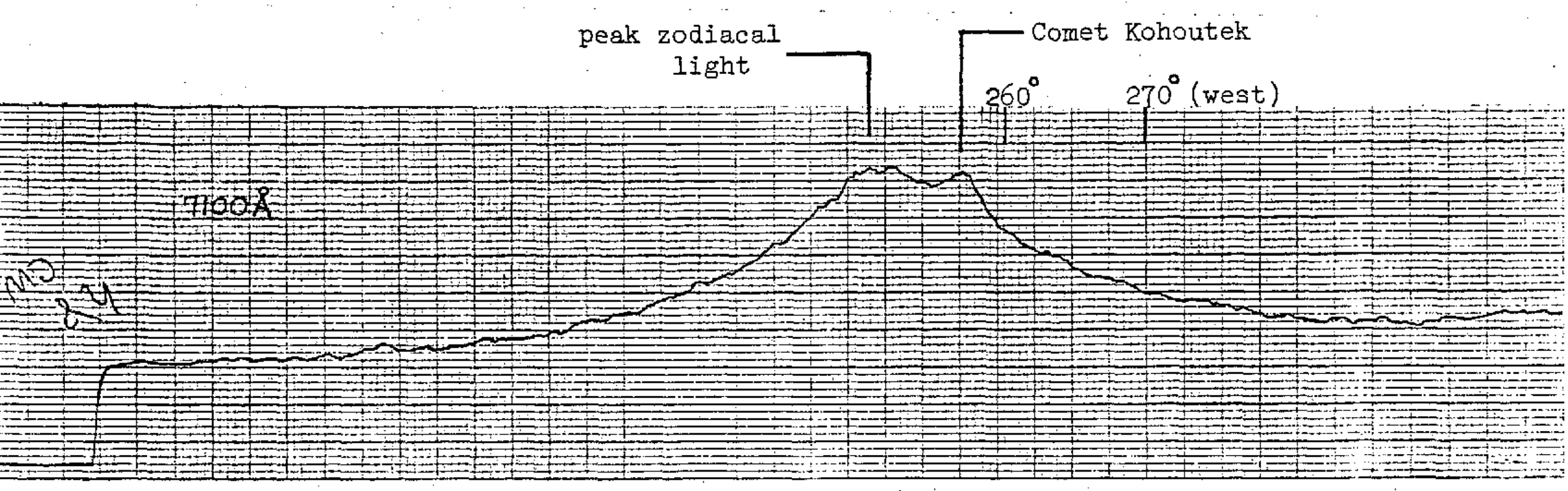
Table 2. Observing Log, Haleakala Observatory, January 1974.

Date	Weather conditions, observations
Jan 1974	
8/9	Wind, rain, fog most of night Performed standard calibration (std calib) and generated digital test tape
9/10	Widespread cirrus and brisk winds Comet Kohoutek visible to the naked eye: fainter and less extensive than Ikeya-Seki (1965 VIII); tail 10 to 15 deg long; above and to the north of Venus; estimate visual magnitude at 3 to 3.5 Sky tests performed on Comet using various gains, fields of view, scanning patterns Sky in vicinity of Comet still cloudy although some breakup started by 2000 HST Comet photographed by Peterson and Kieffaber Performed std calib
10/11	Widespread cirrus and brisk winds Comet visible in part but sky not suitable for observing Performed partial polarization calibration
11/12	Widespread cirrus; Comet not visible Heavy rain started after evening twilight Performed std calib
12/13	Widespread cirrus, brisk winds, intermittent fog Performed std calib
13/14	Heavy cirrus, wind, rain
14/15	Heavy cirrus, wind, rain
15/16	Heavy cirrus, wind, rain
16/17	Some clearing; light wind from SW; sky is milky with clouds forming from NW to SE Comet visible but not distinct Star drift crossings performed in early PM to check mounting position Mapped 30 x 60 deg region of sky containing Gegenschein-in 2 colors (5300, 7100A) Performed std calib

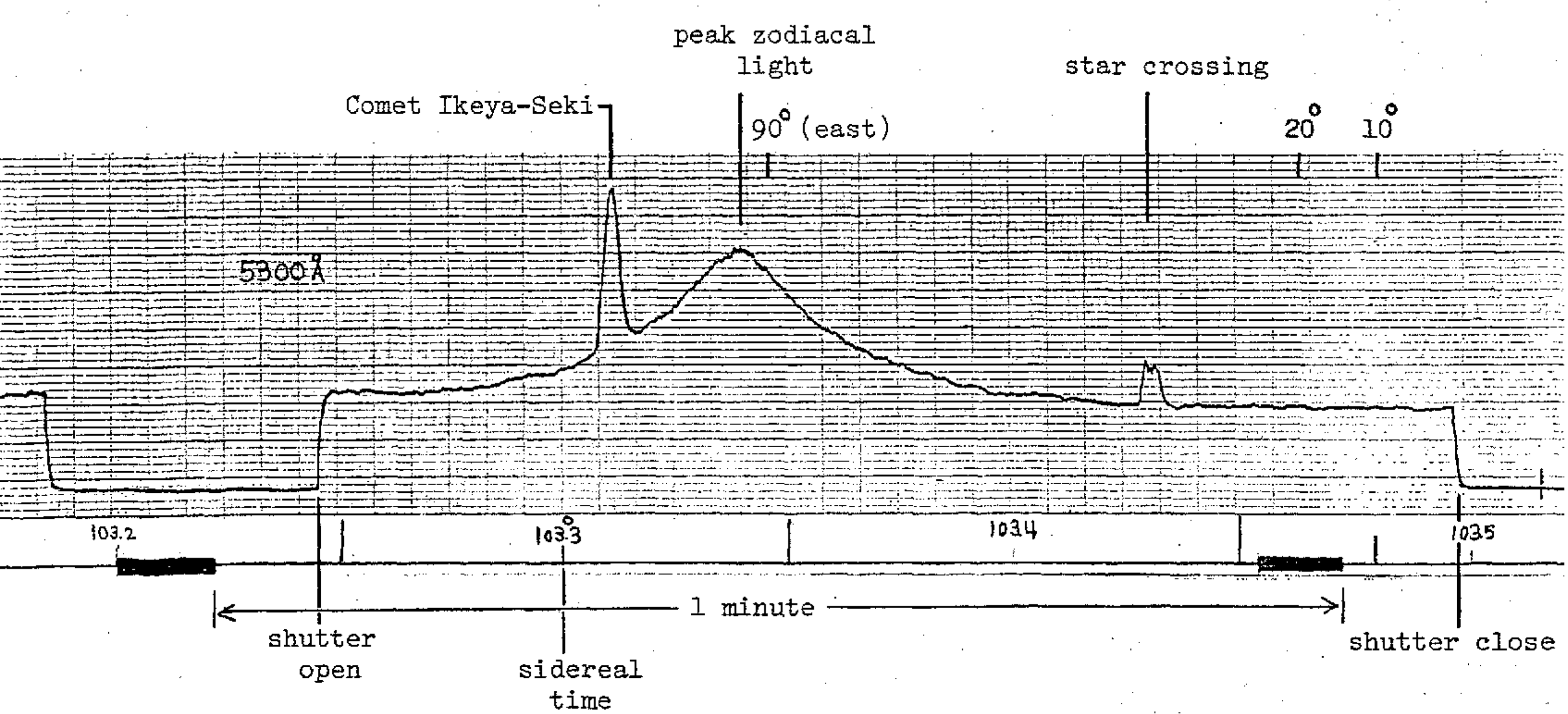
Table 2, continued

Date	Weather conditions, observations
Jan 1974	
17/18	Thin clouds to 5 deg elevation in SW to W; some wispy clouds blowing over site; continued thin clouds and poor transparency all night; not suitable for observing; fog at midnight Performed std calib
18/19	No gas available on Island - could not drive to the site (weather still bad)
19/20	Widespread cirrus and brisk Kona winds Performed std calib and polarization calibration
20/21	Clear and calm with low transparency Comet visible only by using averted vision 3-color scans made of the entire region of sky containing the Comet Performed airglow scan (search for activity in the 5577 and 6300 lines) Performed field ov view tests by scanning through part of the Milky Way using different fields of view Performed std calib and polarization calibration Fog and ice starting at approximately 2300 HST
21/22	Sky clear, trade winds back, relative humidity 35 to 45%; sky much more transparent than on 20/21 Comet as before - faint 4-color almucantar scans made at 10 deg elevation (5300, 5577, 6080, 7100) Performed std calib and polarization calibration
22/23	Intermittent fog; no observing Last night of this observing run.

Figure 1. Strip chart recordings of sky brightness including Comet Kohoutek (1973f) and Comet Ikeya-Seki (1965 VIII).



i. Sky brightness from a clockwise scan in azimuth at elevation 8 deg; January 9/10, 1974; 7100Å. The central brightness peak corresponds to the maximum zodiacal light at this elevation.



ii. Sky brightness from a counter clockwise scan in azimuth at elevation 8 deg; October 29/30, 1965; 5300Å.

APPENDIX

Multicolor Observations of Comet Ikeya-Seki (1965 VIII) from 10,000 ft. Mt. Haleakala, Hawaii in October and November 1965.

A multicolor photoelectric polarimeter was used to observe the tail of Comet Ikeya-Seki (1965 VIII) on 4 nights following perihelion on 21 October 1965[i]. Observations were made at six continuum wavelengths[ii] and with two different filters centered at the 5577Å emission of [OI].

The results of observations at 5300Å on 28/29 October 1965 are shown in Figures 1 through 5. Measurements were made by scanning at 0.5 deg/sec over a 9 x 20 deg section of the sky containing the Comet: in azimuth, from 105 to 114 deg (90 = east), and in elevation, from 0 (horizon)[iii] to 20 deg in steps of 1.0 deg. This method of scanning provides considerably more information in the direction normal to the axis of the tail of the Comet. At other times, different scanning programs were used that provided more detailed coverage along the axis.

Figure 1 shows the total brightness (radiance) of background plus Comet for elevations (altitudes) 2 to 20 deg, as seen at the base of the atmosphere. Note that the brightnesses of the Comet and of the background are comparable. The unit of brightness is S_{10}(vis): number of 10th magnitude (visual) stars per square degree[iv]. This particular set of observations began at 1432 and ended at 1441 UT on 29 October 1965. The Comet nucleus was 5.3 deg below the horizon at the start of the 2 deg elevation scan.

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i. October 27/28 and 28/29; November 1/2 and 3/4, 1965 (J. L. Weinberg, Astron. J. 71, 875, 1966).
ii. 4355, 4760, 5080, 5300, 5450, 5752Å.
iii. The Observatory at Mt. Haleakala has a depressed horizon of approximately 1.7 deg.
iv. The brightness of zodiacal light at 30 deg from the sun in the ecliptic is 2200 S_{10}(vis) or $10^{-12}B_{sun}$ (at 5300Å).

APPENDIX, continued

To illustrate the relative positions of the Comet and of our observations, we acquired a photograph of the Comet taken from Haleakala on the morning before our measurements. The position of the Comet in this photograph (Figure 2), which was made available by the SAO, was modified by a translation and a rotation. The Comet aspect is shown for 1435 UT, which corresponds to its position at the end of the 6 deg elevation scan. The Comet, horizon (solid line), and scans (even-numbered elevations from 2 through 10) are correct as shown; star positions are not. The width of the Comet tail, as recorded by the polarimeter, is a direct result of our use of a 3-deg Fabry field of view. The field of view is uniform and permits resolution of detail smaller than the field size.

Figures 3 and 4 show the brightness of the polarized component and the total degree of polarization, respectively. Of particular interest is the change in polarization between 6 and 7 deg elevation (approximately 11 deg from the nucleus). Since the background (primarily zodiacal light) and Comet radiations are independent, their Stokes parameters are additive. The polarization of zodiacal light in this area is positive; i.e., the electric vector is perpendicular to the scattering plane. Only negative polarization at distances greater than 11 degrees from the nucleus can produce the observed net decrease in total polarization in the direction of the Comet tail.

This is further illustrated by the total orientation of the plane of polarization, χ , (Figure 5). The fluctuations in χ between 7 and 15 deg elevation are a result of the combination of components polarized in nearly orthogonal directions and, between 9 and 11 deg elevation, of the nearly zero total polarization. The negative polarization continues from the neutral point (zero polarization) at 11 degrees from the nucleus throughout the remainder of the tail.

The Comet is ideally positioned with respect to the main cone of the zodiacal light, and the separation of the Comet from the smooth fall-off in total brightness is easily accomplished. The irregular variation of the background polarization makes separation of this component somewhat more difficult. One method used to derive the Comet radiation field is illustrated by the solid lines shown in Figure 1 (2 deg) and Figure 3 (3 deg).

APPENDIX , continued

Negative polarization, as in the case of zodiacal light, requires the presence of dielectric particles or of irregularly-shaped particles. The use of additional observations at several wavelengths at different times suggests that it may be possible to delineate a rather small family of allowable solutions for the size distribution and chemical composition of the particles in the tail of the Comet...if the particles are spherical or have large-volume shapes.

Numerous nightglow observations before and after perihelion made it possible to search for effects resulting from the newly-injected cometary material. We found no large-scale changes in the zodiacal light in a two-week period including perihelion.

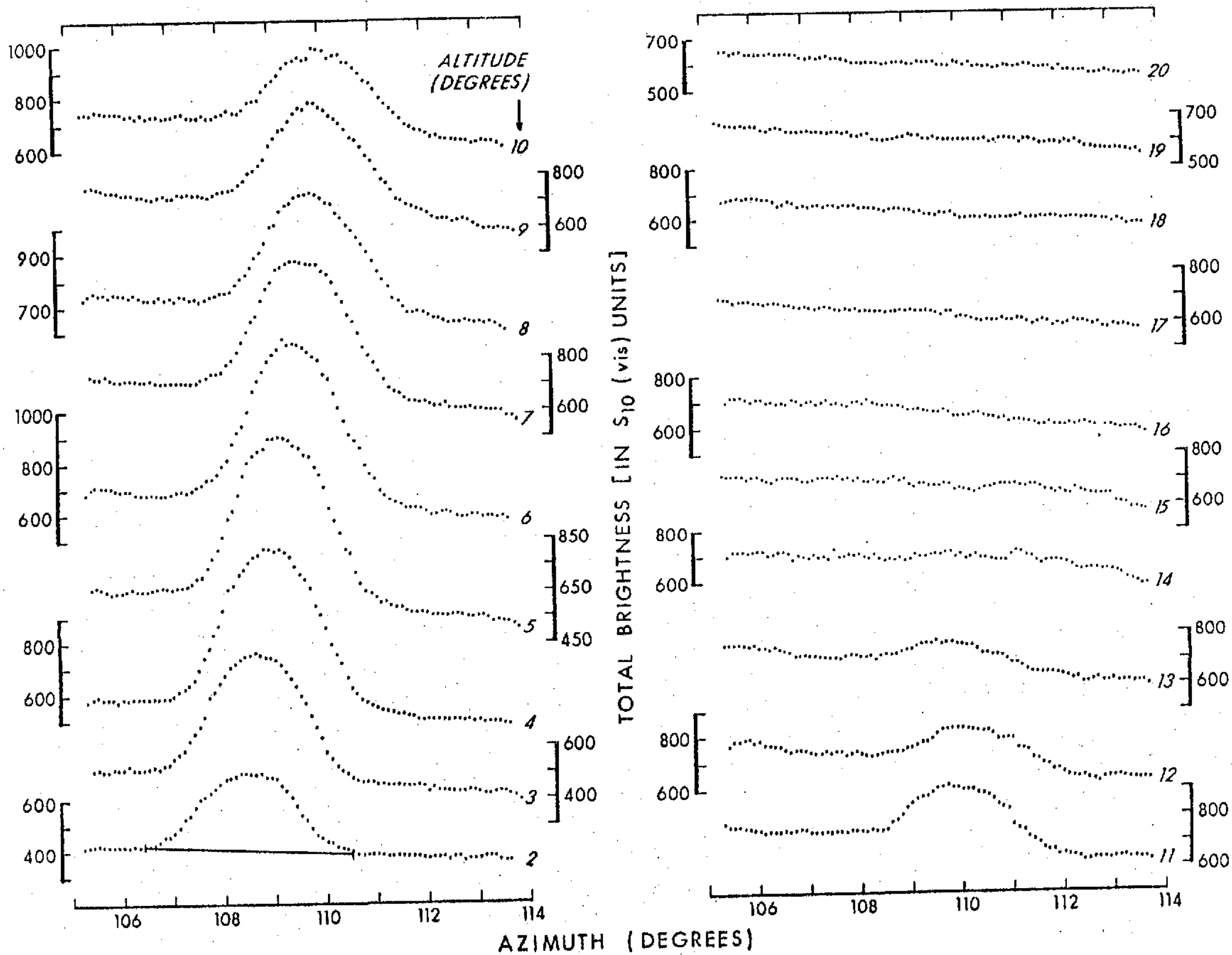
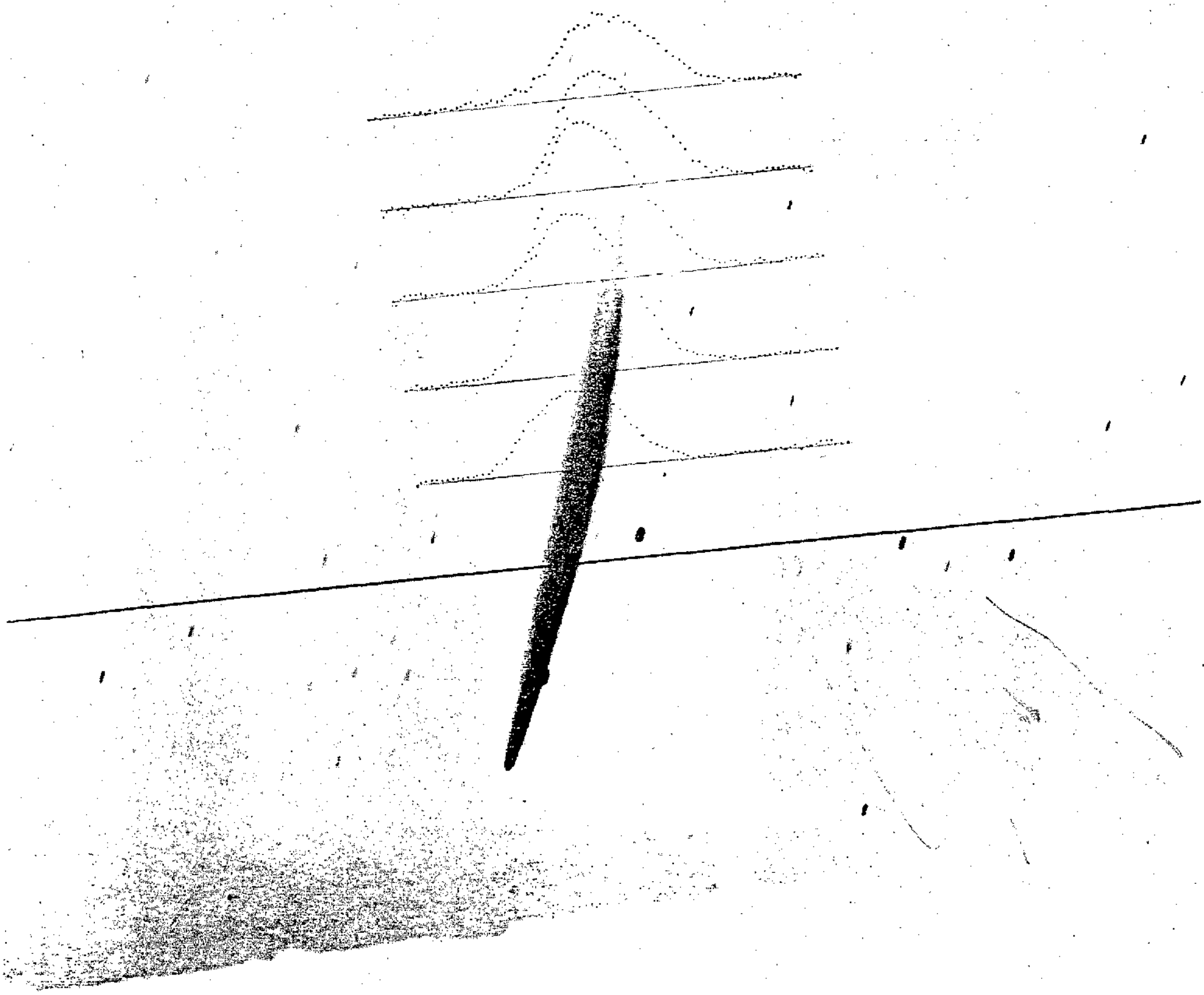
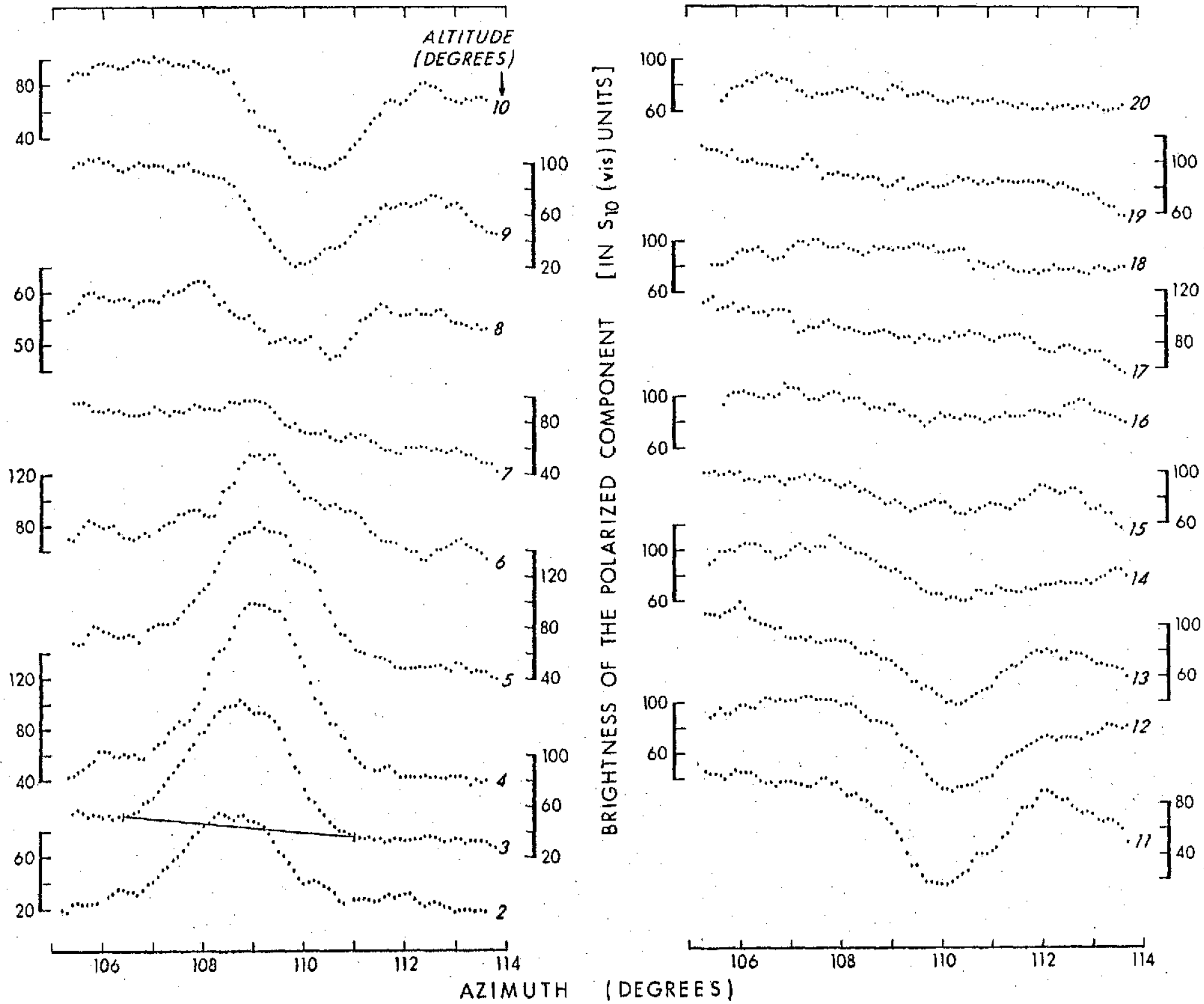

ALTITUDE (DEGREES)
TOTAL BRIGHTNESS [IN S_{10} (vis) UNITS]
AZIMUTH (DEGREES)
106
108
110
112
114
1000
800
600
900
700
850
650
450
400
500
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 1

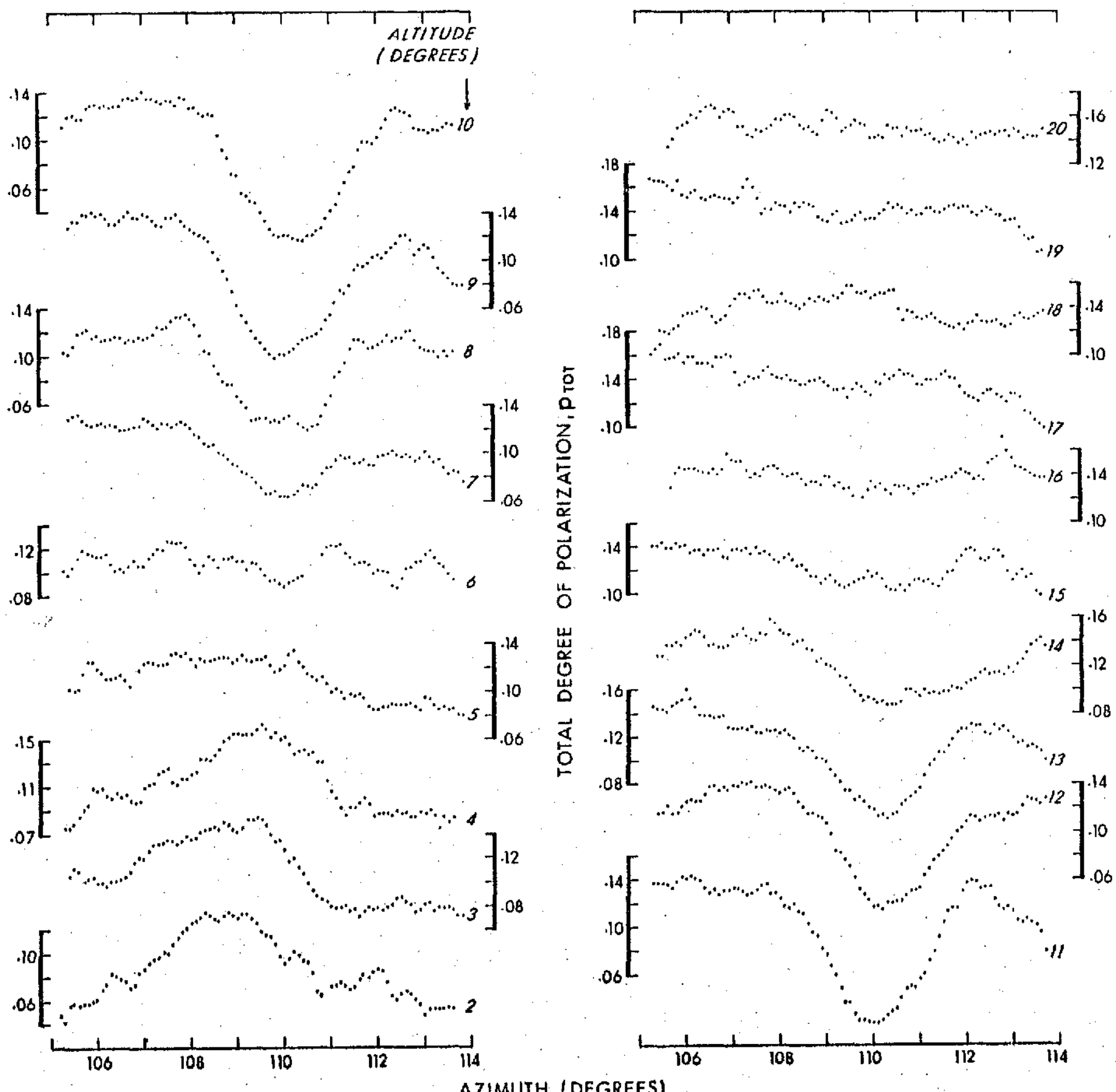
Figure 2





ALTITUDE (DEGREES)
BRIGHTNESS OF THE POLARIZED COMPONENT [IN S_{10} (vis) UNITS]
AZIMUTH (DEGREES)
106
108
110
112
114

Figure 3



ALTITUDE (DEGREES)
TOTAL DEGREE OF POLARIZATION, p_{TOT}
AZIMUTH (DEGREES)
106
108
110
112
114
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 4

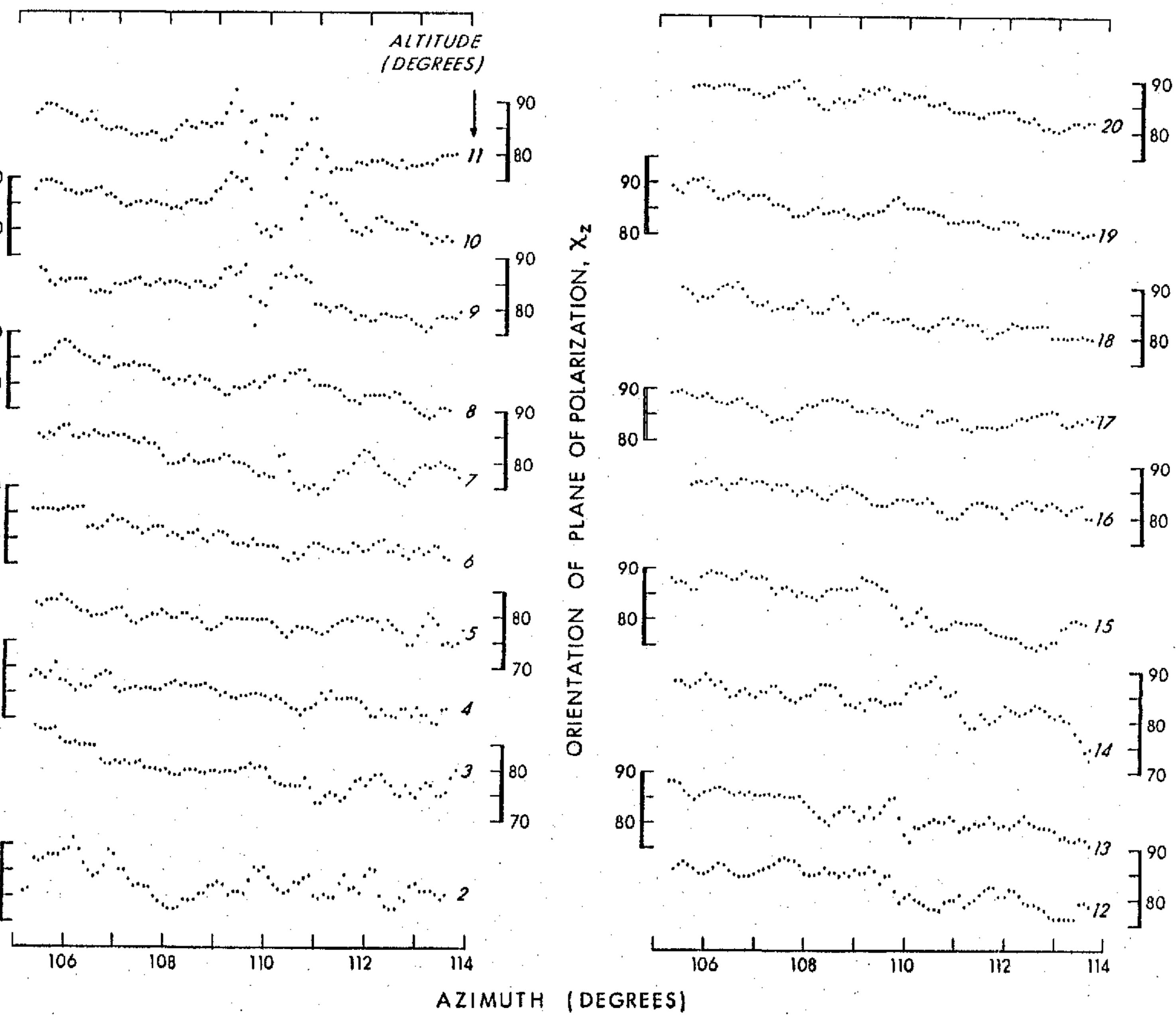

ALTITUDE (DEGREES)
ORIENTATION OF PLANE OF POLARIZATION, X_z
AZIMUTH (DEGREES)
106
108
110
112
114
90
80
70
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Figure 5