PHOTOGRAPHIC OBSERVATIONS OF COMETS AT LOWELL OBSERVATORY

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INTRODUCTION

I have reported on the extensive collection of direct photographs of comets available at Lowell Observatory previously at a similar meeting here six years ago (NASA SP-393). This time I would like to review briefly the 1910 observations of Halley's comet and illustrate just one morning's observations as an example of utilizing every possible observational resource available at the Observatory at that time. It also exemplifies the comprehension that the opportunity to observe objects of this nature from a ground base is limited and, therefore, had to be maximized at the opportune time. I will then describe a few observational improvements we have developed since and some suggestions for the coming return of Halley's comet.

Observations of Halley's comet at Lowell Observatory cover a period from November 10, 1909 to May 17, 1911: 334 direct photographs were taken, 118 objective prism spectra, and 32 slit spectrograms of the nucleus, many of them including 5 arcminutes of the surrounding coma. These latter were taken with the Brashear spectrograph on the 24-inch refractor by V. M. Slipher with the same spectrograph he used for observations of the radial velocity of spiral nebulae.

Direct photographs of Halley's comet were taken with the 40-inch reflector by C. O. Lampland from November 1909 until March 5, 1910. On April 5, 1910, an intensive observing program by three resident staff members at that time was initiated, lasting through the end of June. Six assorted lenses were mounted near the objective end of the 24-inch refractor for direct photography, as well as two objective-prism spectrographs, all guided by an image of the comet's nucleus on the slit of a one-prism spectrograph attached to the 24-inch lens. Table 1 lists the cameras employed. Except for the Brashear 12.7-cm doublet and the 15.2-cm Clark finder, most of the cameras were fashioned from portrait and enlarging lenses used in the darkrooms. Most of these lenses are still in existence around the Observatory and could easily be reactivated for exact scale comparison use in 1986.

Examples of the photographs obtained on the morning of May 13, 1910, are depicted in Figures 1-7. They may appear to be redundant, but each direct photograph shown was obtained with a different camera with a range of f-ratios from 3.5 to 15. All exposures on this date were made between 3:27 and 4:31 a.m. M.S.T., just as the comet rose in the early morning above the eastern horizon.

Each camera is identified by its focal length, and the dark line lying betweeen Venus and the city street lights is the eastern horizon. The aspect of the comet is almost in the east-west direction, as seen from the direction indicator in Figure 7. The tail extends some 3 hours of right ascension. Gamma and alpha Pegasus (that form the bottom of the square) are identified; the tail extends to alpha Aquarius. A scale has been added to some of the photographs.

The objective prisms were mounted so that the refractive edge of the prism stands roughly parallel to the comet's tail; thus guiding for the slit spectrogram sufficed for all cameras. All emissions on this date were very faint; those of the tail were invisible. The continuous spectrum is strong, that of the tail being present in the blue and violet as well as the yellow, where it can be seen to extend into the tail some 13 or 14 degrees (to Venus). The OT 27 (Figure 8), same emulsion as OV 26 (Figure 9), shows faint emission and strong continuous spectrum of head and tail. The wavelengths of lines and bands were measured on these objective prism spectrograms by V. M. Slipher, and a discussion of their development and changes of intensity is given in Lowell Observatory Bulletin No. 52, 1911.

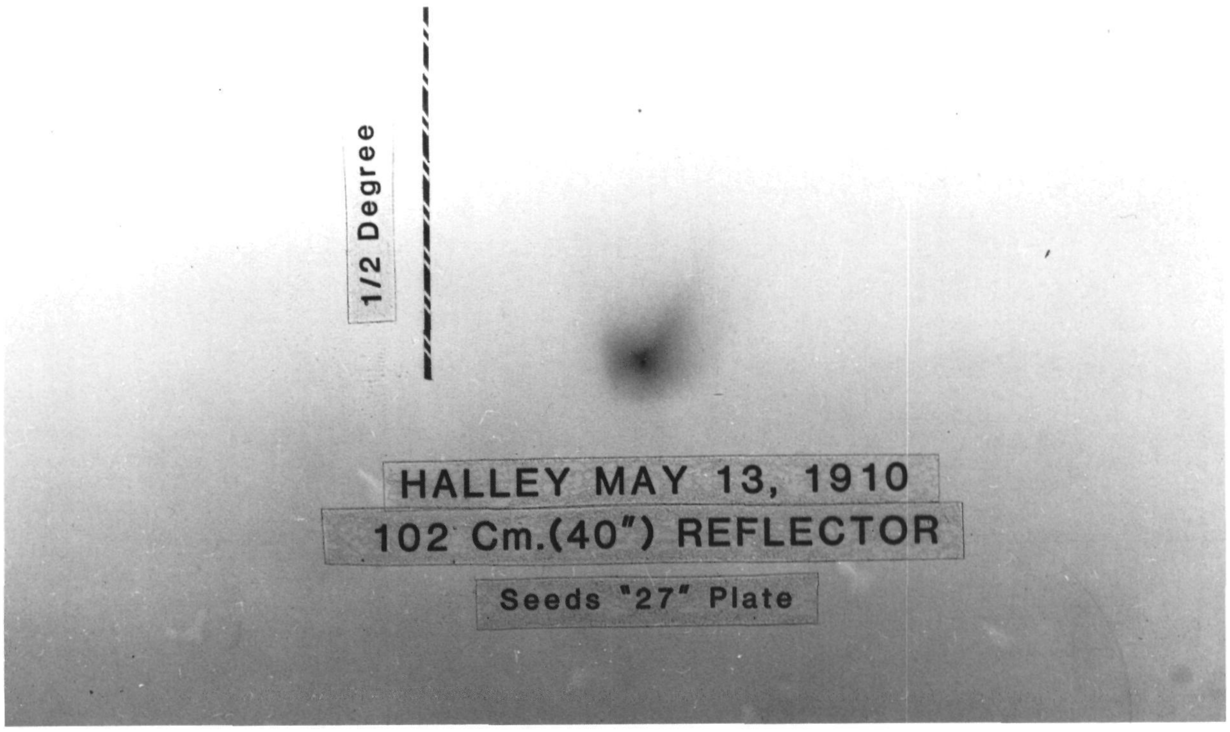

Figure 1. Direct photograph of the head region of Comet Halley 1910II on May 13, 1910.

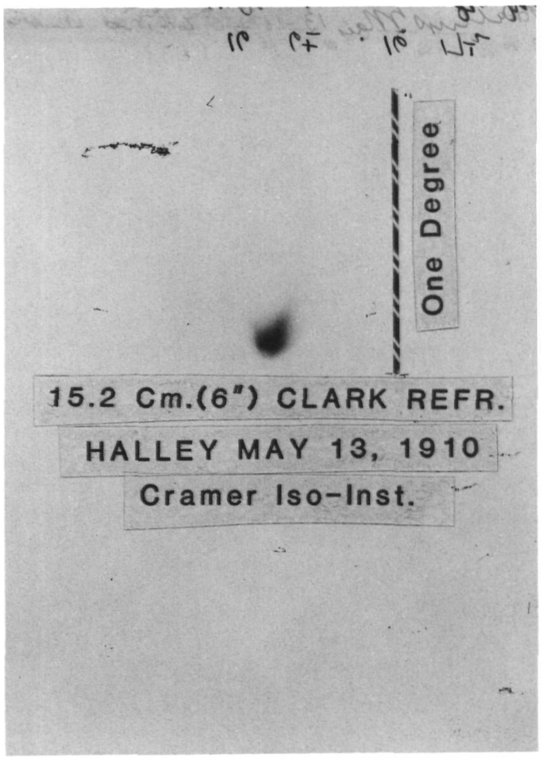

Figure 2. Photograph of Comet Halley obtained on May 13, 1910.

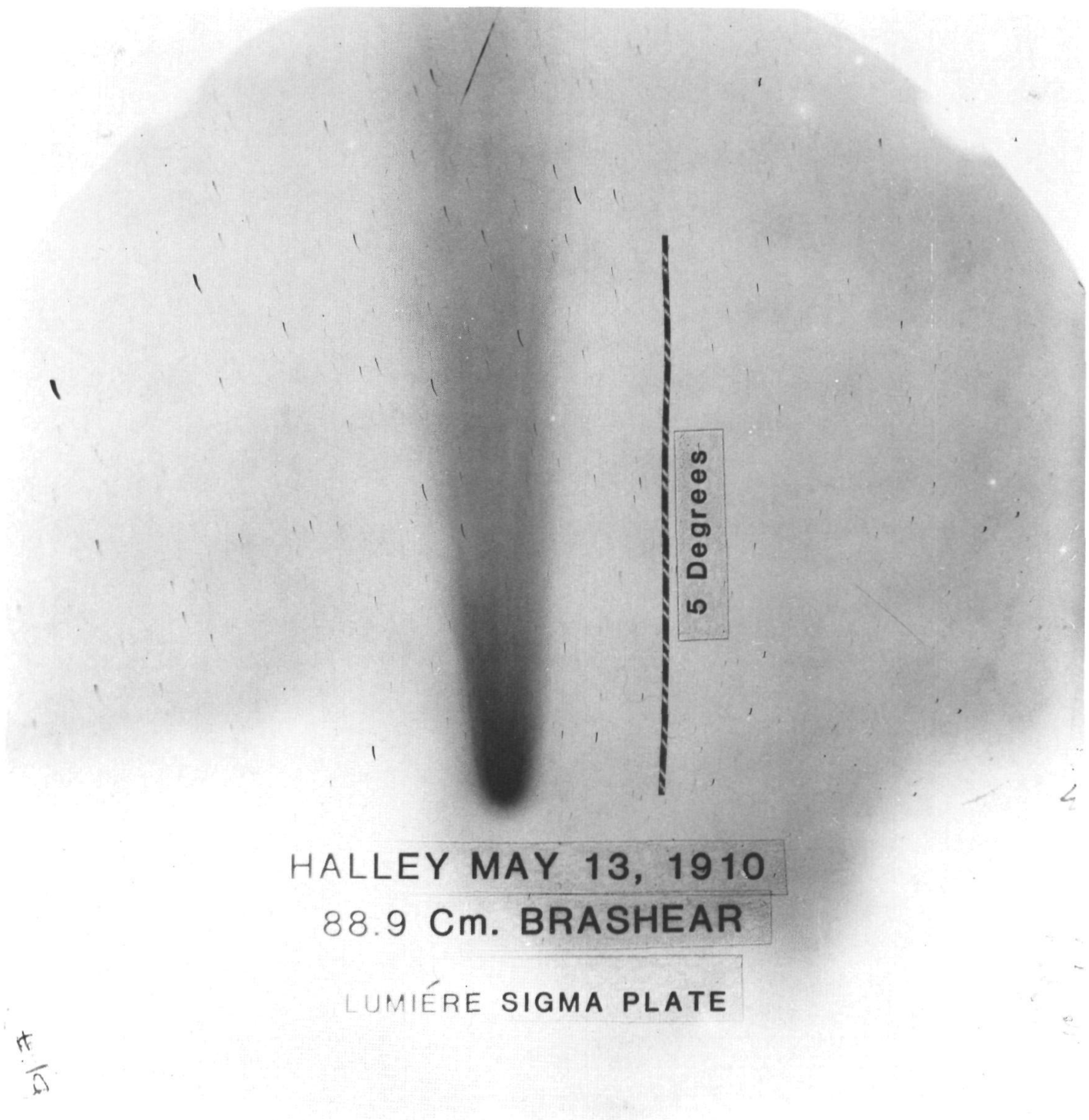

Figure 3. Photograph of Comet Halley obtained on May 13, 1910.

Figure 4. Photograph of Comet Halley obtained on May 13, 1910.

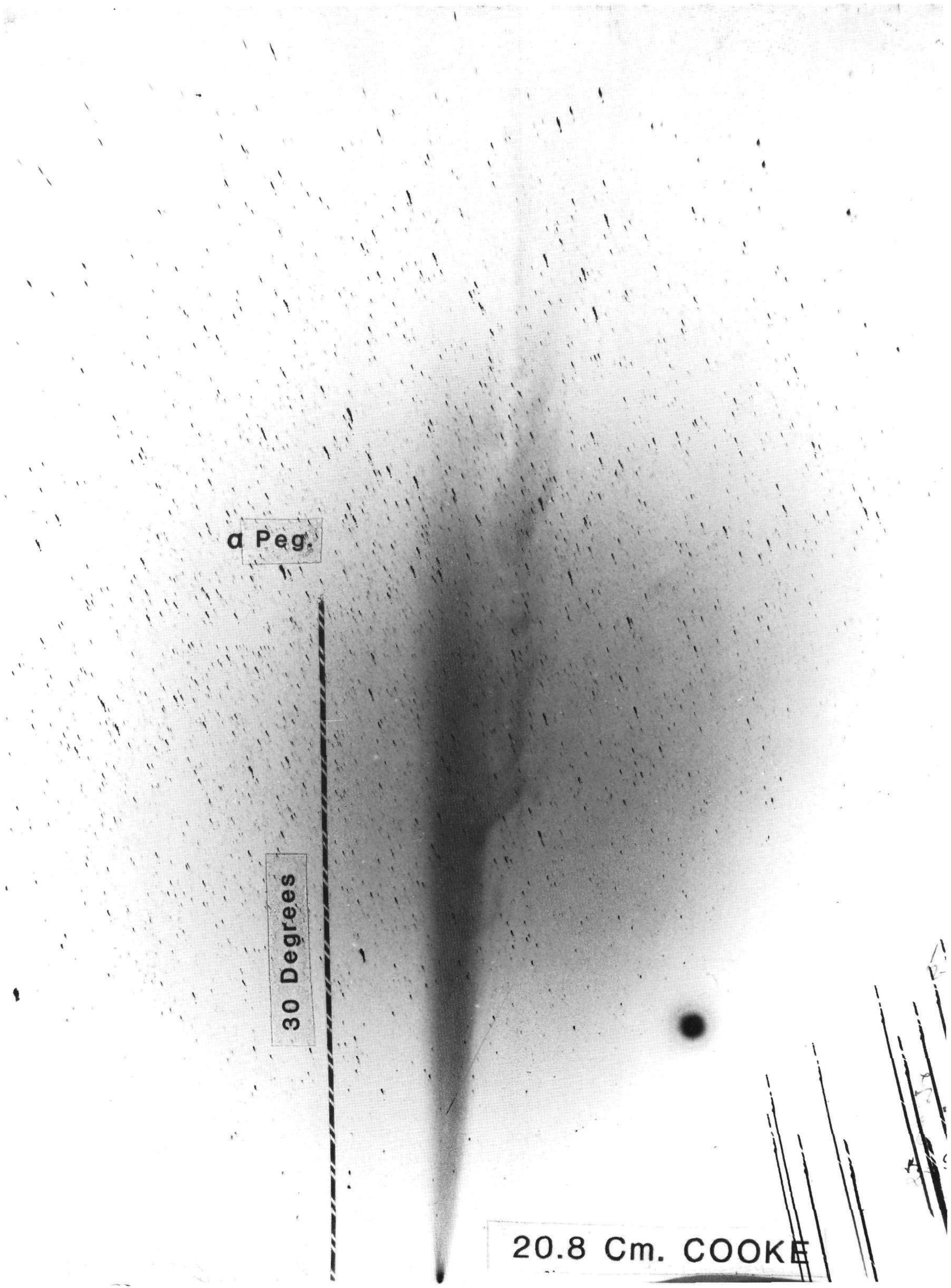

Figure 5. Photograph of Comet Halley obtained on May 13, 1910.

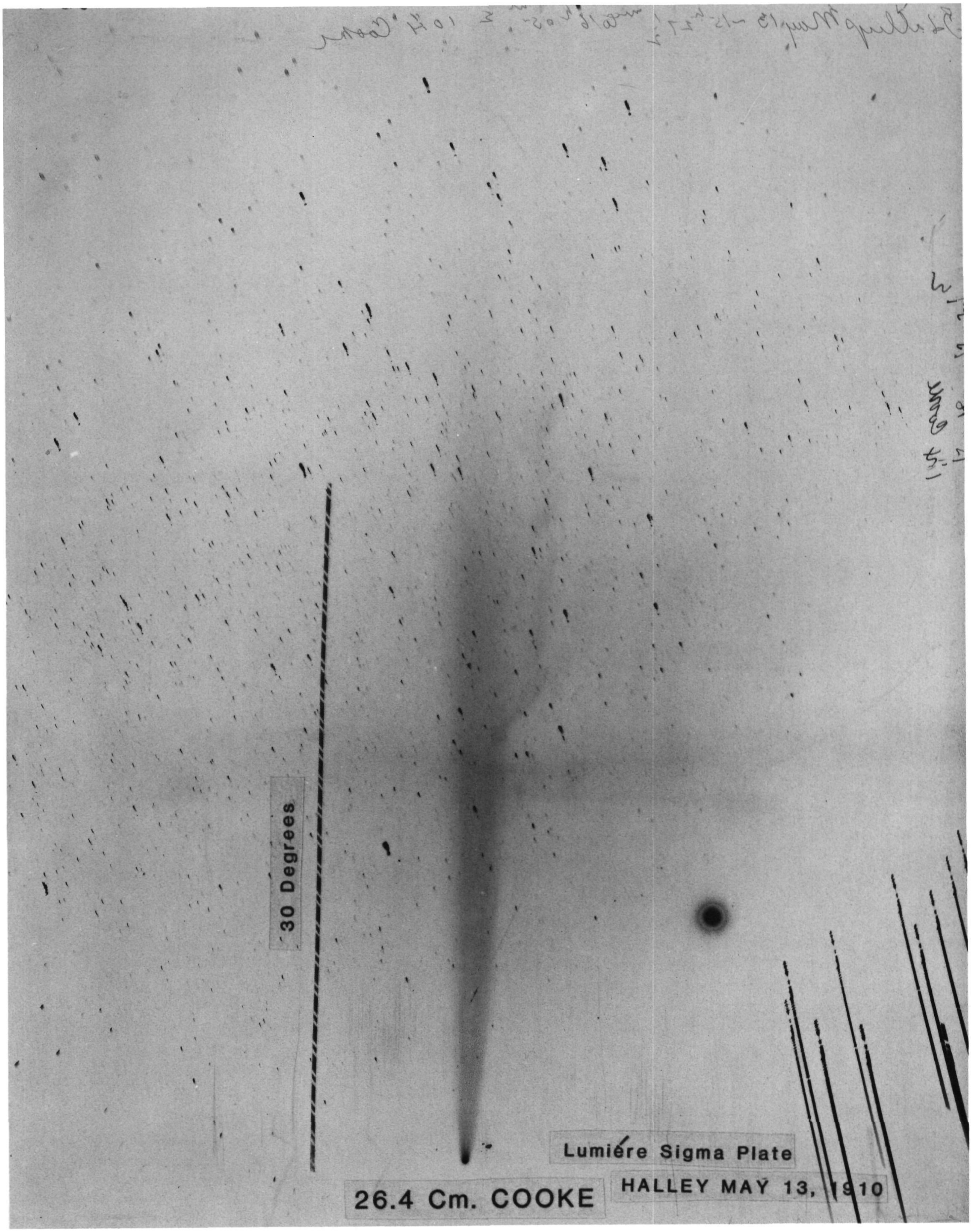

Figure 6. Photograph of Comet Halley obtained on May 13, 1910.

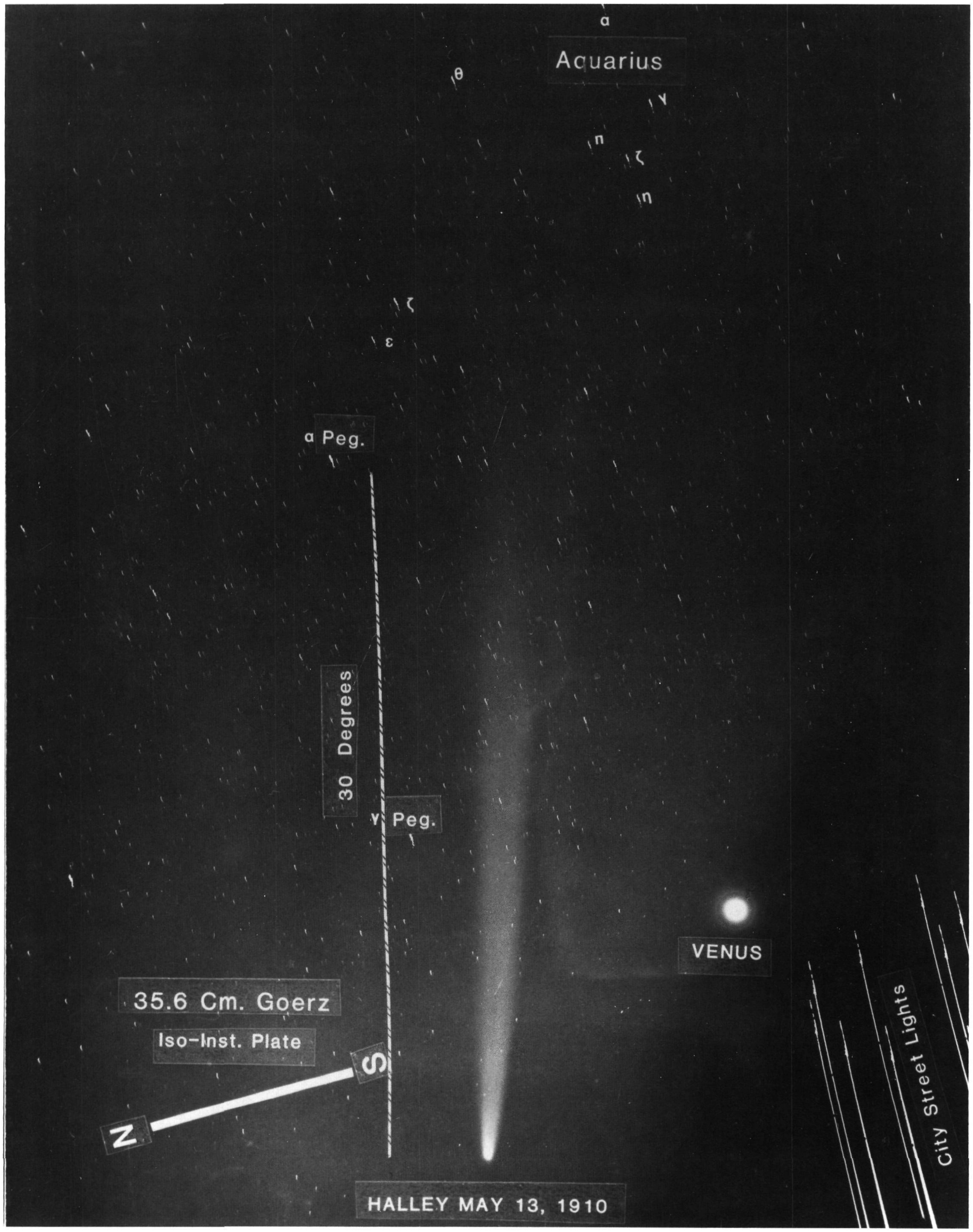

Figure 7. Photograph of Comet Halley obtained on May 13, 1910, with the 35.6-cm Goerz lens. Due to the longer f ratio, it does not show the comet's tail extending beyond Alpha Aquarius like the photographs obtained with the 17.8-cm Goerz and the 26.4-cm Cooke lenses.

Table 1

Cameras used to Observe Halley's Comet in 1910
Lowell Observatory, Flagstaff, AZ

Lens	Diameter (mm)	Focal Length (mm)	f:Ratio	Scale "/mm	1° = mm	Notes
Goerz	37	178	4.8	1160	3.1	
Voigtlander	36	197	5.4	1047	3.4	
Cooke	46	208	4.5	990	3.6	
Tessar	60	210	3.5	982	3.7	
Cooke	59	264	4.5	781	4.6	
Goerz	65	356	5.5	580	6.2	
Brashear	127	889	7	232	15.5	
Clark Refractor	152	2280	15	90	40	6" finder on 24"
40" Reflector	1020	5580	5.5	37	98	
			Objective Prism Cameras			
Voigtlander	37	200	5.4	1031	3.5	62° Prism Jena 03863 107Å/mm
Tessar	60	210	3.5	982	3.7	64° Prism Jena 0192 69Å/mm
			Brashear Spectrograph			
24" Refractor	610	9770	15	21		64° Prism Jena 0192 f:11 Camera

The slit spectrogram of May 13, covering 3800 to 7000Å, is shown in Figure 10. The slit of the spectrograph was set parallel to the daily motion of the comet and hence crossed the comet's nucleus at a rather small angle to the axis of the tail. The exposures were made with the nucleus centrally on the slit. The slit was left open lengthwise in order to also include the spectrum as far from the nucleus as possible (5 arcmin). Also, in this way the skylight could be recognized if it happened that the exposure was continued too long into dawn. The observing plan called for several higher- dispersion spectrograms on each observing date, placing the slit on different diameters across the comet's head for determining differential velocity, but the plates were too insensitive and the fast ratio spectrograph camera later employed for the nebular velocities had not yet been developed. Since the older refractors were most efficient in the visual, much of the blue portion of the image is out of focus and missing when in focus for the yellow. For this reason, the sensitivity of the photographic plates employed was augmented in the visual with dyes (pinacyanol, pinaverdol) and hypersensitized in ammonia. The CN band at 3883 is the most prominent seen in the shorter wavelengths. The curvature of the slit is noticeable; yet in spite of this, I would like to point out the high quality of these slit spectrograms and the wealth of

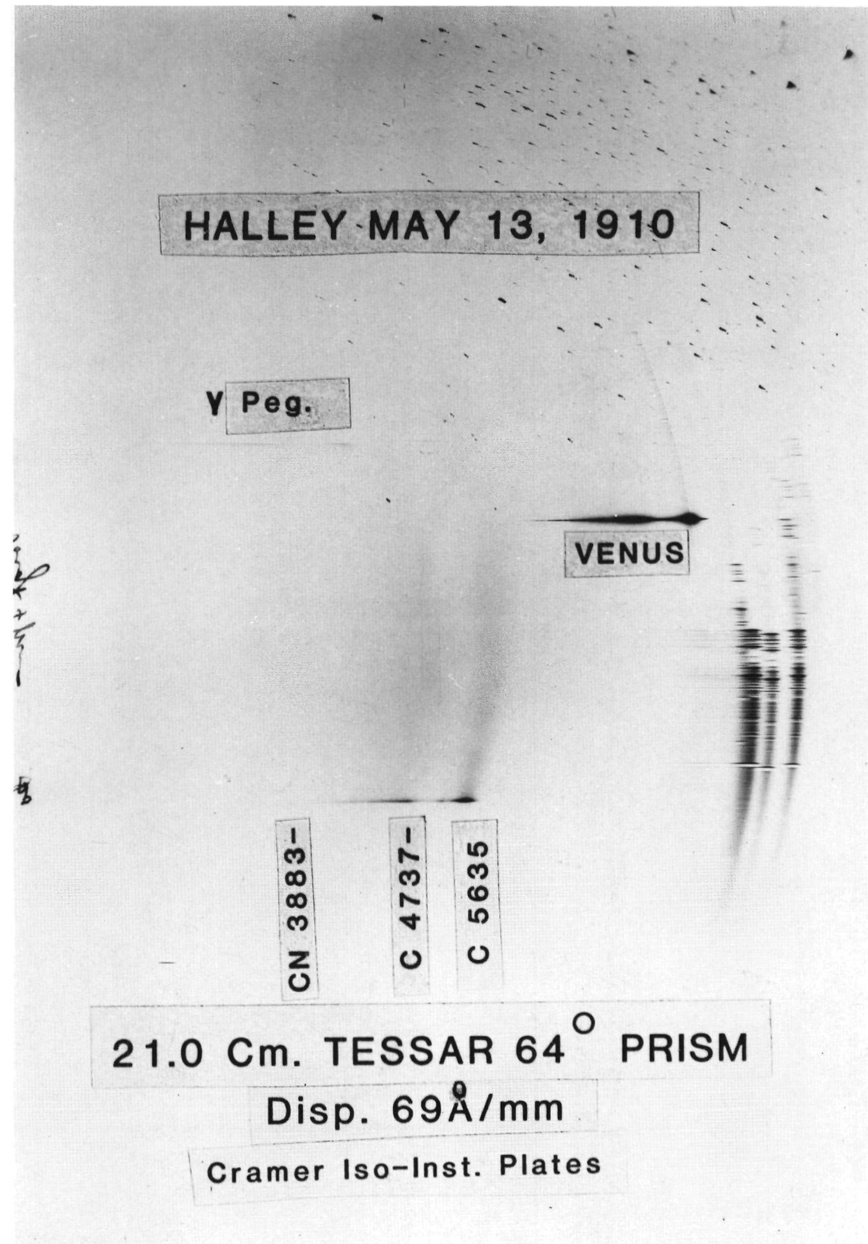

Figure 8. Objective prism spectrogram of Comet Halley obtained on May 13, 1910.

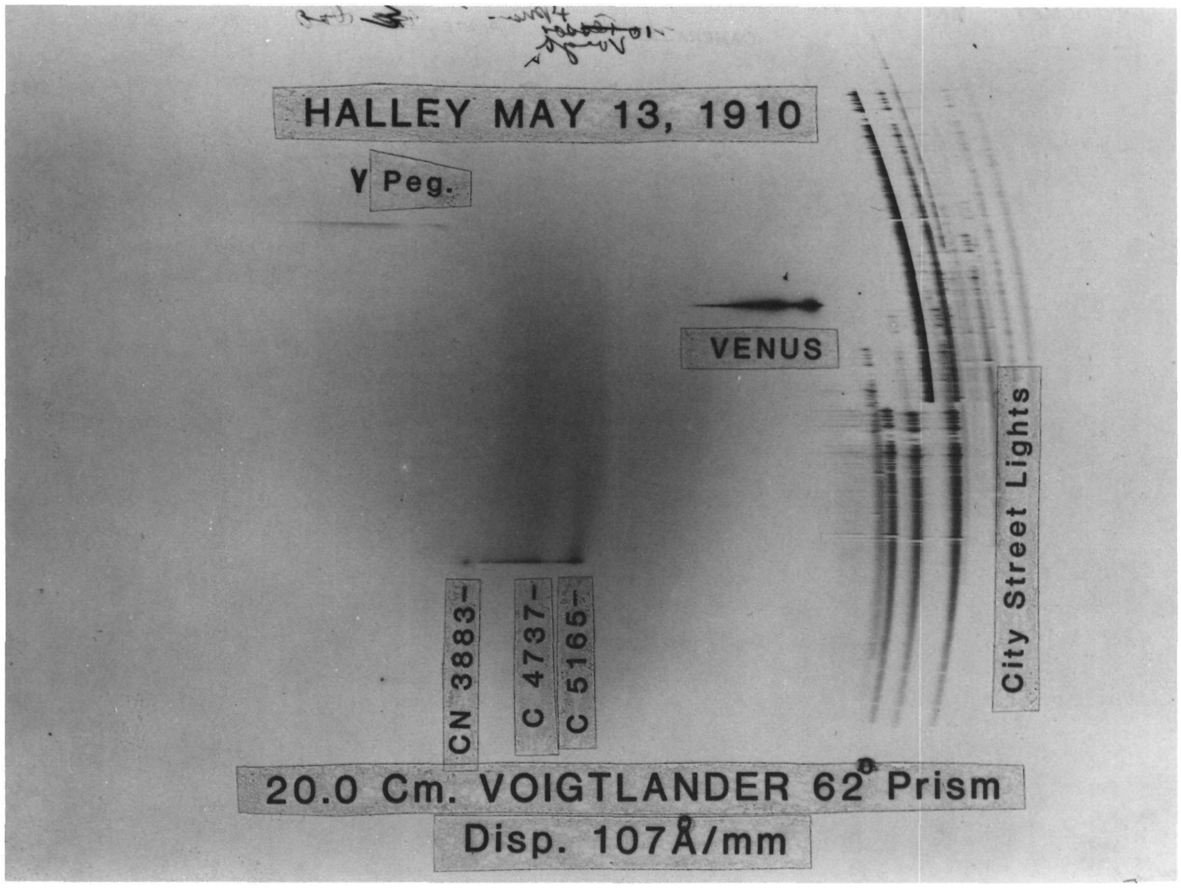

Figure 9. Objective prism spectrogram of Comet Halley obtained on May 13, 1910.

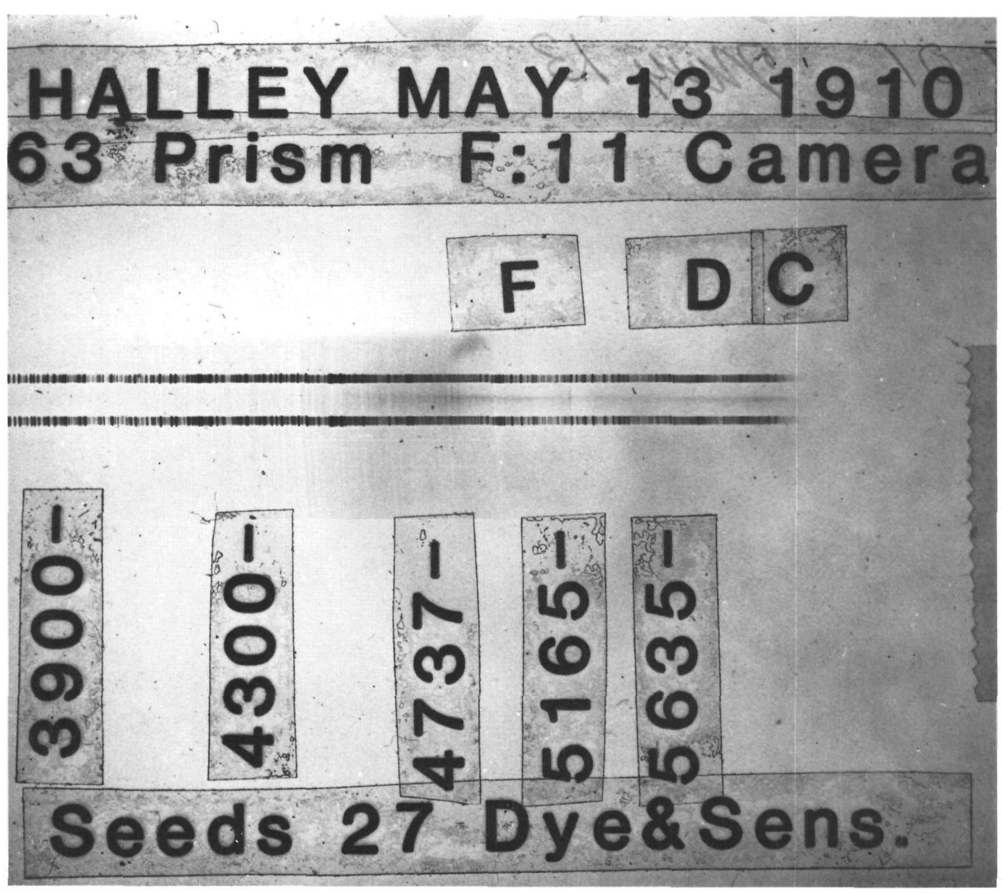

Figure 10. Slit spectrogram of Comet Halley obtained on May 13, 1910.

data they still contain, and that they have never been quantitatively measured with modern microdensitometer techniques. The bright lines and bands on these spectrograms were measured and discussed in the same Bulletin (No. 52, 1911) by Slipher; but I could not find where the radial velocity had been measured on this date.

Looking forward now to the coming reappearance, we have been briefed by Dr. Yeomans' IHW Group on what to expect and some of the contemplated observing programs, together with an admonition not to build up another Kohoutek image with the public.

At Lowell Observatory, in addition to the original 1910 instrumentation just described, several wide-field cameras for direct photography with special tracking capabilities have been added. First is the 33-cm astrograph (the Pluto Telescope) that takes a 12x15-degree area of the sky on a 35x43-cm (14x17-inch) plate at a scale of 29 mm/degree. Also mounted on the same mounting is the 12.7-cm Cooke triplet of 57-cm focal length that covers a slightly larger area than the astrograph on a 20x25-cm (8x10-inch) plate. Also mounted with these two is the wide-field 6-cm Xenar lens of 36-cm focal length used in 1931 to take some of the check fields for the Ross-Calvert Atlas of the Northern Milky Way (University of Chicago Press, 1934).

The simplest adaptation of these lenses, all on the same polar axis, for comet photography is an adjustable supplementary offset-guide telescope. For a bright comet with an extensive tail, the head can be set near the edge of a large plate and the guiding done manually on the comet's nucleus. An example is the March 8, 1976, observation of Comet West, 1975n, on a large 14x17-inch plate with the 33-cm astrograph.

Another adaptation for comet observation is devices to drive the plate in position angle and distance in the focal plane (Metcalf method). Two of these are available; one covers 50 square degrees (20-cm-square plate) of the astrograph field (total field 180° sq.). (It has been inadvisable to disturb in any way the full field of the astrograph, as it could affect its use for proper motion determinations where the first epoch plates made 50 years ago must match exactly contemporary plates.)

The other is a 14x17-inch plate drive adaptable to either the 183-cm Perkins reflector or the 106-cm Ritchey-Chretien reflector. These are driven by the Slo-Syn variable-speed stepping motors that can follow an object moving up to 3 degrees a day in any direction.

Another adaptation that is available is to drive the telescope at variable rates in both right ascension and declination. This has proved to be the least satisfactory because monitoring and maintaining the exact frequency in each coordinate is difficult to attain.

Not mounted on any telescope at this time are three f-1:2.5 Aero Ektar cameras of about 30-cm focal length. The advantage of these, besides their speed, is that reasonably sized filters may be obtained for narrow-band emission-line photography. If these could be strategically placed and manned geographically in latitude and longitude, data on the development of the appearance of compounds in a comet as a function of distance from the Sun could be studied.

This brings us to the consideration of incorporating the Planetary Patrol observing sites into the large-scale and near-nucleus observing network. These stations were operated by Lowell Observatory under a NASA grant beginning in 1969 and are still in partial operation (Planet. Sp. Sci. 21, 1511, 1973). In 1971 there were seven stations in operation. These stations were equipped with 24-inch, f/75 ULE Cassegrain reflectors and also an f13.5 Cassegrain (Icarus 12, 435, 1970). At the present time, in addition to Lowell at Flagstaff, these telescopes are available at Perth (Australia), Cerro-Tololo (Chile), and Mauna Kea (Hawaii); but funds for observers would have to be provided. In addition to operating the narrow-bandpass and direct photographic cameras, the existing planetary cameras would be ideal (field size about 8 arcminutes at f13.5) for systematically photographing the near-nucleus activity and for studies of rotation.