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"RECONNAISSANCE AND RECOVERY OF THE BRIGHTER ASTEROIDS"

Brief Summary of Entire Project

Prof. Frank K. Edmonson
Principal Investigator

H. John Wood, Ph. D.
Research Associate

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P.I. address:

Indiana University
Department of Astronomy
Swain Hall West 319
Bloomington, Indiana 47405
(812) 335-6911

Award address:

Indiana University Foundation
P.O. Box 1847
Bloomington, Indiana 47402

NASA Technical Officer:

Dr. William W. Brunk, Code SL-4
NASA Headquarters
Washington, D.C. 20546
(202) 755-3660

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I. Goals of the Proposed Project

Knowledge of a large number of minor planet orbits provides a pool of objects for astrophysical observation and study using large telescopes and future space missions. Such astrophysical studies yield clues to the early composition and evolution of the solar nebular.

Today approximately 2100 objects have known orbits. However, many of the brighter asteroids have orbits which were calculated with perturbations by the major planets being taken into account. And modern astrographic positions are not generally available for these brighter objects as most modern observational programs are aimed at the fainter and fast-moving asteroid populations. Thus many of the brighter asteroids are in danger of becoming lost for lack of recent accurate positional data.

Thus the goal of this project was to re-start the observing program of the Indiana University Minor Planet Center using the f/6.3 25-cm astrograph at Goethe Link Observatory near Indianapolis Indiana. This telescope was used during the period 1949-1966 to accumulate the largest astrographic plate collection in the United States dedicated to minor planet study. The new Kodak IIIa-J emulsion was to be used with hypersensitization to reach a limiting magnitude of 17-17.5 way in one hour exposure.

Preliminary tests at the Goethe Link Observatory (Link) (17 mi in SSW of Indianapolis center) and the Morgan-Monroe State Forest Station of the Goethe Link Observatory (MMSF) (10 mi NW of Bloomington) had indicated that the telescope should be moved to the darker forest site to avoid objectionable sky fogging from Indianapolis lights. These tests were carried out with a 135 mm Nikon lens operating at f/5.6 and using Kodak 103a-O emulsion on a dark and clear night: the camera was transported for one-hour exposures at each site on Mt. Wilson Selected Areas so that magnitude limits could be estimated. The results clearly showed the superiority of the MMSF site both in limiting magnitude and sky fog.

II. Results of Actual Project

The grant was awarded with a start date of 15 August 1980 at a reduced funding level and with the stipulation that no NASA funds be used for construction of buildings (such as a new dome) and that it be a one-year, one-time-only grant.

Private funds for moving the telescope were sought locally and permission was sought and received from the Indiana Department of Forestry to install the 25-cm telescope at the MMSF site.

96 Kodak IIIa-J plates were ordered from Kodak and preliminary designs made for plate-baking using forming gas. It was decided to cut the participation of the Research Associate from 9 months to 5 months and the number of photographic plates by a factor of 10 for the overall project in order to come within budget. Thus the Research Associate Dr. Wood accepted an offer of guest professor at the Vienna University Observatory for the Fall-Winter semester 1980-81. He was not paid by the grant during the period of September'80 through 28 February'81. He

received a travel grant from the AAS Small Research Grants program to take a computer-compatible catalogue of the minor planet plate collection at the Vienna University Observatory. Upon his return to the U.S. in March 1981, the Kodak IIIa-J plates had arrived and he was able to dedicate full-time to instrumentation development and testing starting in early March 1981.

A very inexpensive method of baking large (8 x 10 inch) IIIa-J plates in 2% forming gas was found and tested successfully. A copy of the research paper "IIIa-J Astrometry at Goethe Link Observatory" submitted to the <u>AAS Photo-Bulletin</u> is attached describing in detail the techniques, equipment developed, and test results.

Tests in the Fall of 1981 showed that the move of the telescope to MMSF was not necessary. The large storage capability and fine grain of the IIIa-J emulsion made the sky fog negligible on plates of one-hour exposure at Link. Magnitude limits were found to be approximately $B = 18\overset{m}{.}0$ on baked IIIa-J, considerably fainter than the typical $16\overset{m}{.}5 - 17\overset{m}{.}0$ limits on the older 103a-O emulsions. One plate (H-6353, exposure 2 hours 21 minutes) on M-31 shows stars to $B = 19\overset{m}{.}2$! Money which was saved on laboratory equipment was transferred to pay Dr. Wood one additional month so that further observations could be made. A no-cost extension of the grant was sought from NASA and awarded.

Plates were taken through the end of October 1981 on various asteroids from the recent critical lists published in the _Minor Planet Circulars_ (MPC) and the Russian _Ephemeris of Minor Planets_.

In November Dr. Wood accepted the position of assistant to the Director at Cerro Tololo Inter-American Observatory and left the project.

In summary, the project provided funds to successfully re-start observations of minor planets at Indiana University. New techniques were developed for hypersensitization and use of Kodak IIIa-J emulsion at the Goethe Link Observatory. Some observations were obtained during the months of July through October 1981 on objects on the MPC critical list.

IIIa - J ASTROMETRY AT GOETHE LINK OBSERVATORY

H. John Wood
Department of Astronomy
Swain Hall West 319
Indiana University
Bloomington, IN 47405

ABSTRACT

Inexpensive methods for hypersensitization of large Kodak IIIa-J plates are described. On nights with high humidity the telescope tube is filled with dry nitrogen gas during exposure. Sky fog from a nearby large city is found to be minimal because of the large storage capacity and fine grain of IIIa-J and the f/6.3 focal ratio of the 25cm astrograph. Gains of more than a factor 8 have been obtained over untreated 103a-O using the same telescope.

INTRODUCTION

As part of a program to recover minor planets with uncertain orbital elements and in order to test the 25cm refracting astrograph for use in the International Halley Watch (IHW), techniques have been developed for the routine use of baked IIIa-J 8 x 10 inch plates. This paper reports results of sensitometric studies and actual observations at the telescope.

EQUIPMENT

Previous papers on hypersensitization (HPR) of IIIa-J have described various methods of HPR with vacuum techniques and baking using expensive laboratory-type ovens (Schoening, 1978, Smith, 1978). With a limited research grant and a view towards cooperation in the IHW, we decided to try to develop a simple and inexpensive method for routine HPR of large format IIIa-J plates. Such simple methods could be of value in the IHW where remote stations in the worldwide astrometry net might use similar telescopes and have limited funds.

A 21.5 quart tank (All American Pressure Cooker Model 921, see Figure 1.) was found to be available locally for about seventy dollars. A 30 foot coil of copper tubing pre-heats Fig.

the incoming 2% forming gas (2% hydrogen and 98% nitrogen) at the bottom of the tank. Small holes were drilled in the outer two turns of the coil to release the gas near the walls of the tank. Heat is provided by wrapping the tank with electric heating tape used for keeping water pipes from freezing. Two tapes were found necessary to provide the approximate 65°C temperature necessary for proper baking for six hours. One tape is 13 feet long and dissipates 65 watts. The second tape is 24 feet long and is rated at 120 watts. Both tapes are wound without overlap around the tank and held in place with grey duct tape. The heating tapes are not thermostatically controlled: they are "on" full time. Pre-heating of the tank for at least one hour was found essential. The used gas exits from the top of the tank.

The plates are held vertically in an aluminum frame made from aluminum sliding-door track pop-riveted together. More than 12 plates could be baked simultaneously. However, we normally bake only enough for one or two nights work.

An "integrating sphere" type spot sensitometer (Penhallow, 1978) was used for darkroom gain checks. Table 1 gives the measured relative intensities as used without filter and with a 100 watt tungsten bulb. Tab. 1

Table 1 Penhallow Sensitometer Calibration

Hole	I	Hole	I	Hole	I
1	1.000	4	0.106	7	0.012
2	0.465	5	0.058	8	0.007
3	0.195	6	0.022	9	0.003

The instrument is a large one and with appropriate diaphragms and diffusers, exposures of one and five minutes were found effective for the tests.

The telescope is a 25cm aperture f/6.3 refracting astrograph (Cooke triplet with scale 120 "/mm) which has been used since 1949 to accumulate about 6300 plates in the Indiana University Minor Planet Program described by Edmondson (1972). It is situated 17 miles SSW of Indianapolis center at the Goethe Link Observatory.

RESULTS

A. Sensitometry in the laboratory

In a regular observing program it is desirable to maintain six hours for all plate baking activities so that fresh plates can be available each clear night. Thus we limited our bake time deliberately to six hours and tested the resulting plates. Scott et al. (1977) have found the largest gains (factor 7) for IIIa-J baked in 2% forming gas are achieved in 11hr at 65°C. The fog density was 0.69. For one minute exposures without filter, baked sensitometric gains are found to be typically a factor of 5 for D = 1.0 above gross fog compared to unbaked IIIa-J directly from the same box. Here the absolute fog for the baked plates averaged D = 0.31 while the unbaked plates averaged D = 0.15 using a Welch Densichron photoelectric densitometer which measures semispecular densities. All speed gains quoted here are measured at D = 1.0 above gross fog as Hoag et al. (1978) have found at Kitt Peak that IIIa-J reaches maximum detective quantum efficiency there.

B. Magnitude Limits at Link Observatory

The goal of this test program was to see if IIIa-J could be HPR treated with the simple tank described above in order to reach the same levels of sensitivity as in the earlier 1949-1966 asteroid program. That program used 103a-O emulsion with one hour exposures and reached typically $B = 16^{m}.5$.

In addition, preliminary tests with 103a-O had indicated that the site may have become too bright for the astrograph because of the growth of Indianapolis lighting since the end of the formal observing program in 1966. For intercomparison, we have chosen Baade's field IV 96′south preceding the nucleus of M-31 where photoelectric standard magnitudes are available between B = 16^m and 22^m (Baade and Swope, 1963).

A plate (H-1331) taken in 1952 by J. P. Mutschlecner on 103a-O (exp 1^h21^m) shows star A (Baade and Swope, 1963. op. cit. Plate II and Table 1) at B = $16^m.24$ but none fainter. Our 1981 one hour exposure on baked IIIa-J/(H-6350) shows star G at B = $17^m.73$ and star H at $18^m.26$ (Figure 2). The gain is two magnitudes; with the difference in exposure times taken into account, a factor 8.4. All other instrumental factors including mean airmass are closely equal. Part of this large gain is due to the approximately 600Å of additional bandpass redward of the 103a-O cutoff. Interestingly, the absolute sky plus chemical fog on the 1981 IIIa-J plate is less (D = 0.52) than in 1952 (D = 0.55). Clearly, two to three hour exposures are still possible without objectionable sky fog with this telescope/emulsion combination. Fig

To test this hypothesis, we exposed a baked IIIa-J on M-31 for 2^h21^m. This plate (H-6353, Fig.3) reached B = $19^m.2$ in Baade's field IV. This exposure was stopped by clouds forming over the observatory with heavy dew on parked automobile windows. The absolute fog on this plate (chemical plus sky) is D = 0.61. The edges of the spiral structure seen on this plate extend to more than two degrees on the major axis of M-31.

We attribute this unexpected large gain to our efforts to keep the plate away from oxygen and water vapor after baking.

(R)

Smith (1978, op. cit.) reported serious loss of plate sensitivity due to high humidity at Rosemary Hill Observatory. To quantitatively test the effect of humidity on baked IIIa-J, we HPR baked two pairs of plates from the same box. One plate of each pair was removed from the tank and immediately exposed in the sensitometer and developed. The second plates were left uncovered in the darkroom near running water for a period of time, exposed and developed. Both pairs were tested at 68°F. The first pair was tested at 40% relative humidity and one hour uncovered. No difference in speed was measured between the "wet" and "dry" plates: they both showed the normal factor five gain over unbaked plates.

The second pair was tested at nearly 100% relative humidity and two hours uncovered. The gain at D = 1.0 above gross fog was a factor 2.7 for the speed of the dry plate with respect to the wet plate. Thus on summer nights with low relative humidity and most dry winter nights, we anticipate that exposure in a nitrogen atmosphere will not be necessary.

For exposure during high humidity conditions we have sealed the telescope tube and provided a gas inlet for dry nitrogen. The nitrogen gas enters the telescope tube about 16 inches above the declination axis (Figure 4). It exits through the dark slide slot in the plateholder which is partially covered with duct tape. After an initial flush at about 3 liters per minute, a very low rate of gas flow is found to be sufficient (about 0.5 l/m) for the most humid conditions. Dew is kept off the lens by a dew shield and heater wire. The tank regulator valve is adjusted so that the sound of escaping gas is just barely audible. Fig. 4

SUMMARY

In summary, IIIa-J, when properly baked, stored and exposed in dry nitrogen, and developed immediately in fresh D-19 can give significant gains over 103a-O used directly from the box. The long flat toe and high contrast of the characteristic curve of IIIa-J combine with the f/6.3 focal ratio of the 25cm astrograph to make long exposures possible near Indianapolis without objectionable sky fog.

The tests reported above indicate that even unbaked IIIa-J should reach $B = 16^m$ in one hour with the 25cm astrograph. Thus for the IHW in remote sites where no baking is possible, it should still be possible to participate fully in astrometric observations of P/Halley.

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Figure Captions H.J.Wood "IIIa-J Astrometry..."

Figure 1. Forming gas plate baking tank showing electrical heating tape and gas inlet and outlet valves.

Figure 2. The central portion of Baade's field IV in M-31. Left is a 103a-O plate showing star A at $B = 16\overset{m}{.}24$. Right is baked IIIa-J showing star H at $B = 18\overset{m}{.}26$. Both taken with the 25cm astrograph of Goethe Link Observatory.

Figure 3. M - 31 in Andromeda taken with the 25cm astrograph at the Goethe Link Observatory. The exposure was 2hr 21min on baked IIIa-J using nitrogen flow in the telescope tube. The limiting magnitude in Baade's field IV is $B = 19\overset{m}{.}2$.

Figure 4. The 25cm astrograph at Goethe Link Observatory showing nitrogen tank and gas inlet near declination axis on telescope tube. The baking tank is flushed with dry nitrogen after baking and used to transport the plates to the telescope. It is re-flushed after each plate is removed.

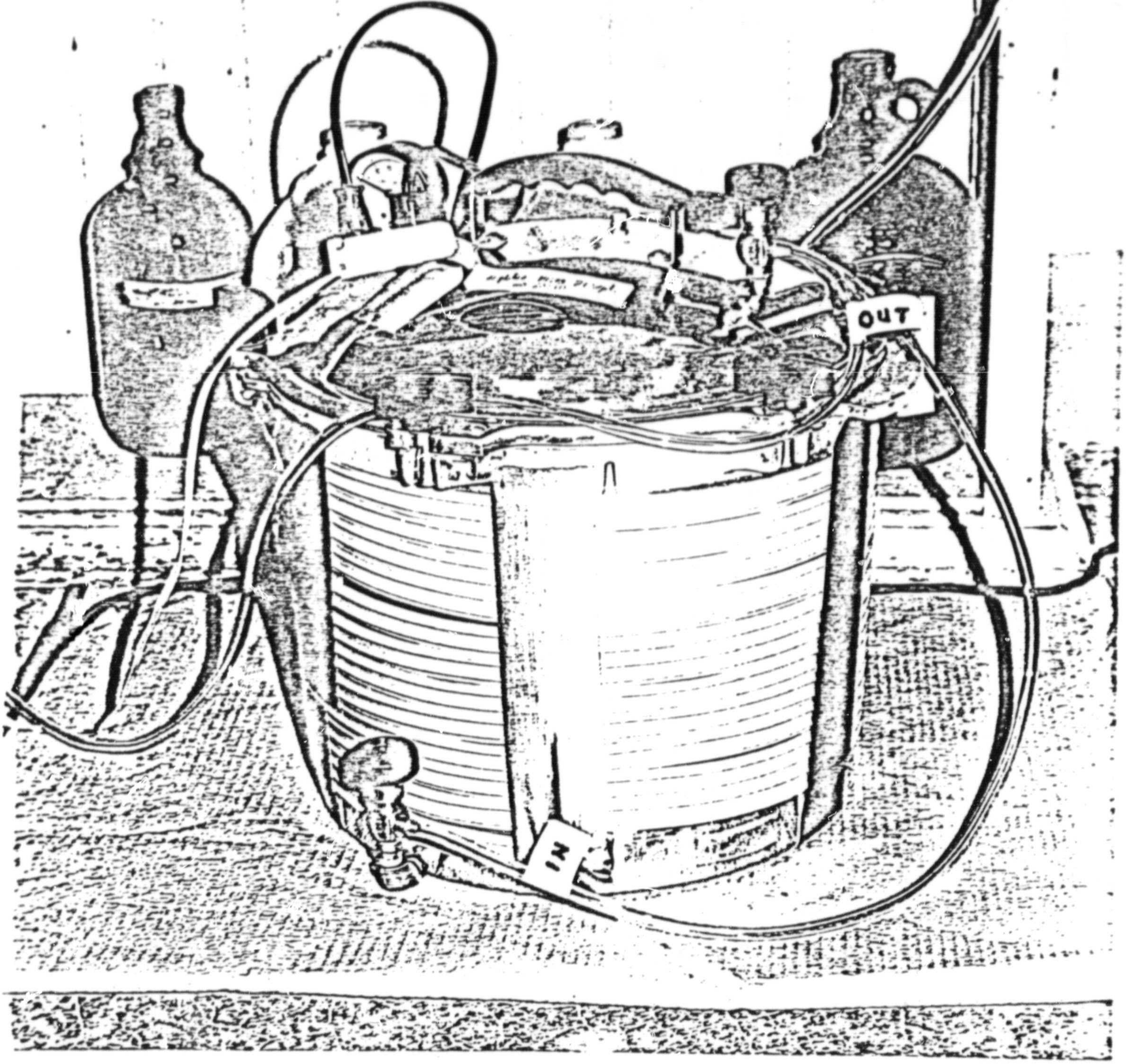

Fig. 1

Fig 2

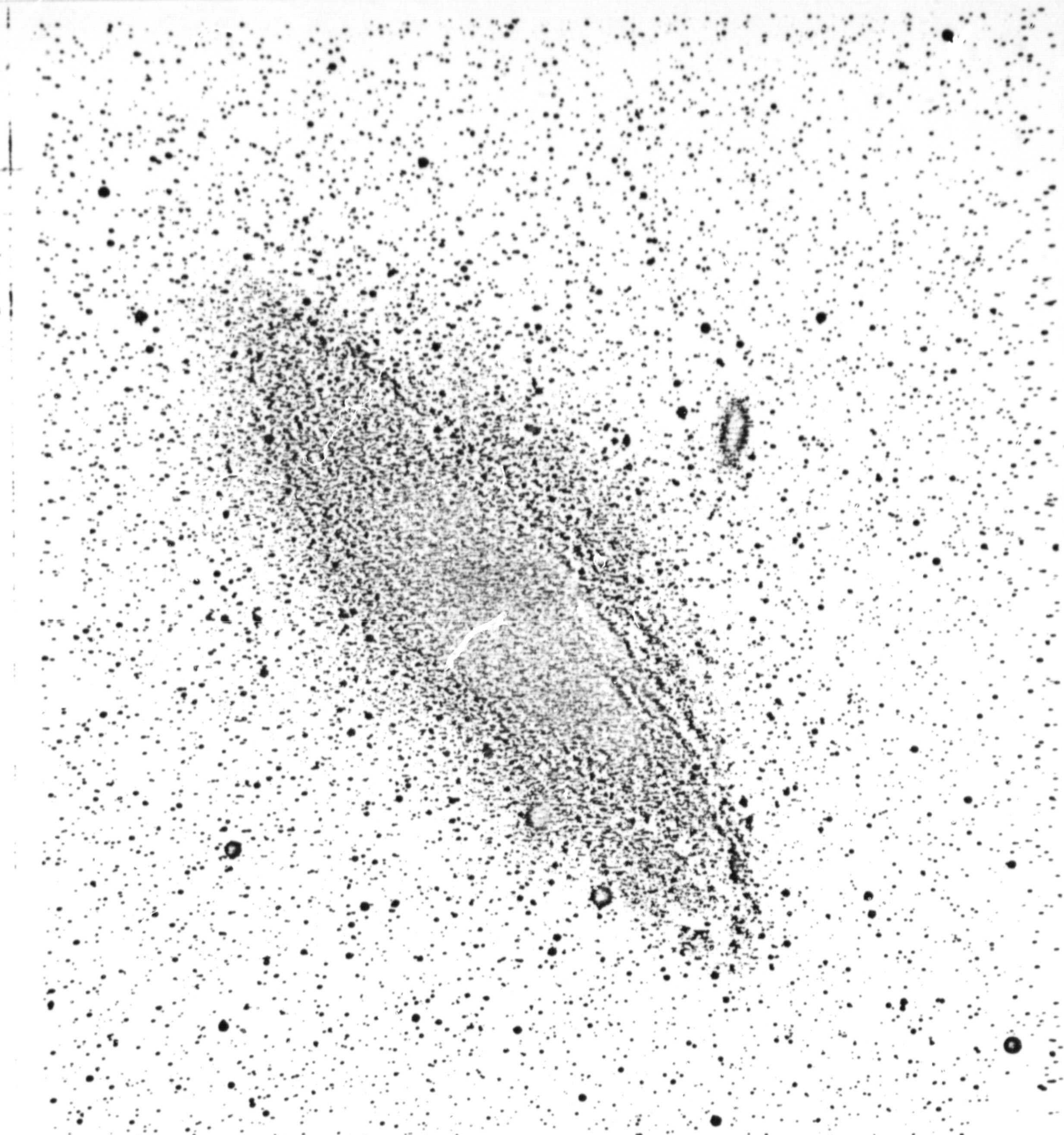

Fig. 3

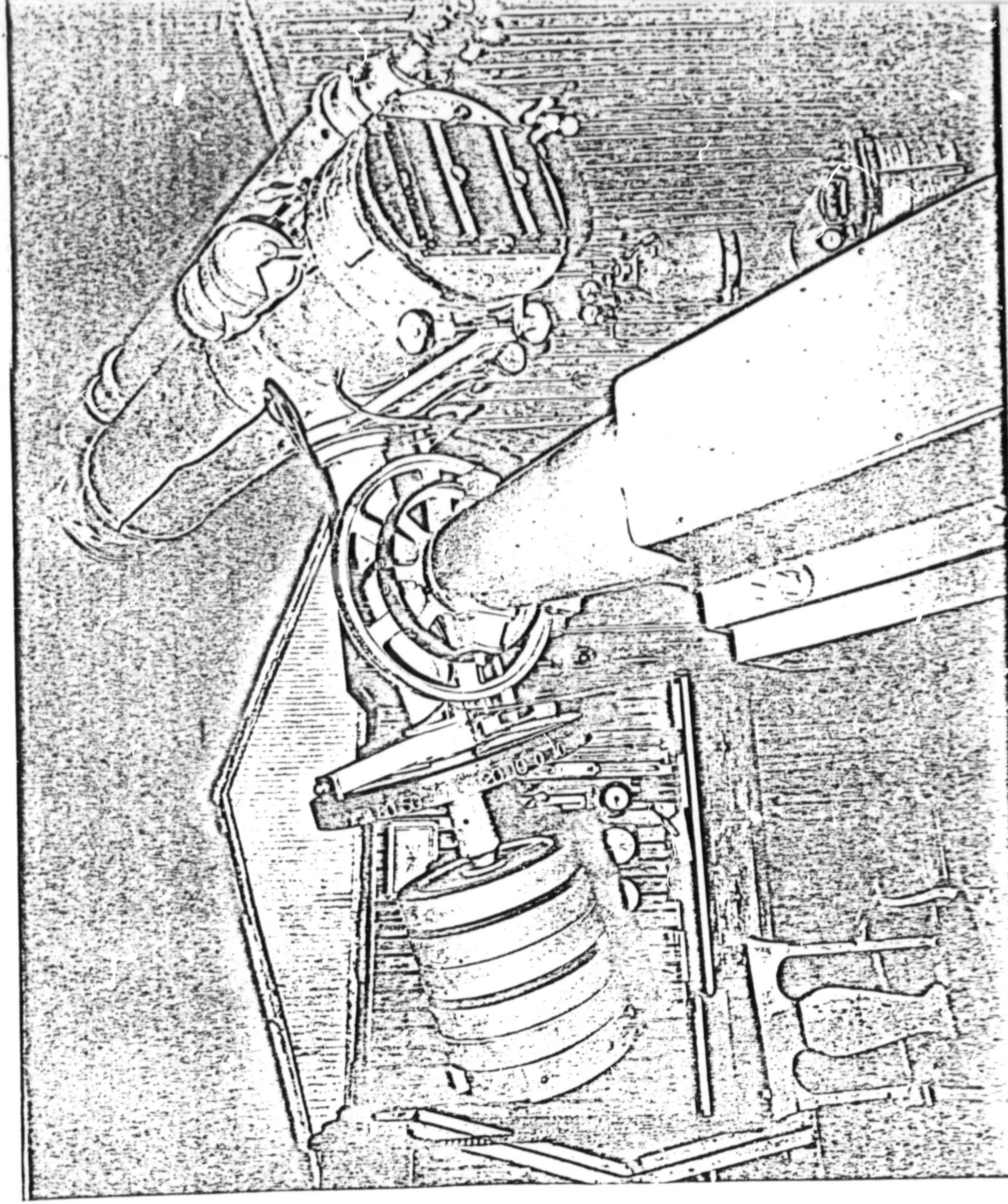

Fig. 4