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## COMMUNICATIONS FROM THE ASTRONOMICAL INSTITUTE AT AMSTERDAM.

### Description of the actinometer of the Amsterdam Astronomical Institute,

by *A. Pannekoek* and *A. van Zutphen.*

**1.** The first instrument to measure photographic magnitudes on a stellar photograph by means of a thermo-electric current was constructed 1916 by H. T. Stetson and described *Astrophysical Journal* **43**. Prof. J. C. Kapteyn, being desirous to have such an instrument, invited in 1920 Dr. W. J. H. Moll, who had been constructing and improving thermo-couples and galvanometers during many years, to inform him about the possibility of applying them to the measurement of photographic stellar magnitudes. Some years afterwards experiments were made and an instrument for this purpose was constructed at the Groningen Astronomical Laboratory by Dr. J. Schilt, making use of a Zernike thermopile; it was described 1924 in his thesis and *Public. Groningen* No. **32**. Instruments of this kind, constructed after the design of Dr. Schilt, when he was at the Leiden Observatory, and described *B.A.N.* No. 60, are in regular use on several observatories under the name of Schilt photometers.

After Dr. Moll had succeeded in improving the sensitiveness of thermo-electric measurement by the construction of vacuum thermo-couples, and after these were successfully applied to various measuring apparatus, the P. J. Kipp firm wished to use them also for the measurement of stellar magnitudes on photographic plates. Thus in collaboration with Dr. Moll an actinometer was constructed for the Amsterdam Astronomical Institute, and after many trials and changes it took the form as described here after.

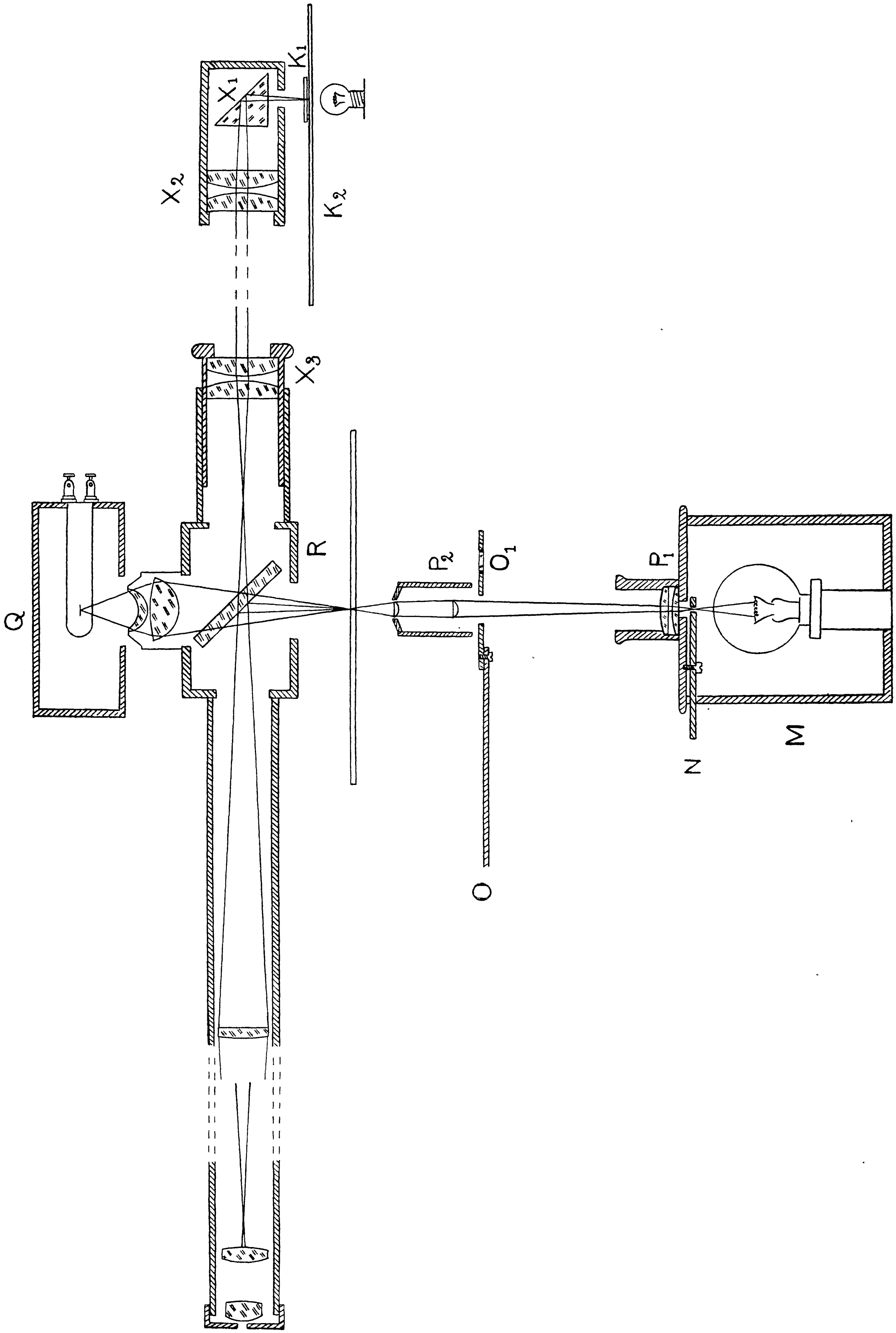
In principle the instrument measures, by means of a thermo-element the weakening of the intensity of a pencil of strong light, produced by the interposing of the photographic image of a star.

**2.** In its general plan the actinometer consists of a frame in which the vertically placed negative can be moved in its own plane; at its right hand side is the lamp with projecting apparatus, producing a horizontal pencil which perpendicularly traverses the negative; at the left hand side this pencil falls upon the thermo-element. At the left is also the telescope, which is arranged in such a way that the plate is viewed in diffuse light, and that both the galvanometer scale and the rectangular coordinates of the star may be read at the same eye piece. All readings being made by the same telescope the observer need not move from his place.

Upon a heavy cast iron baseplate is mounted a rectangular frame whose vertical members A1 and A2 are iron pillars, and whose horizontal cross-pieces B are steel cylinders upon which the outer plate frame slides horizontally by means of two rings above, one ring below. A similar pair of vertical cylinders C forming the side pieces of this frame, permits vertical motion of the inner plate frame D whose weight is counterbalanced by means of weights hanging within the cylinders C. The plateholder is attached to this inner frame by means of 4 screws at the corners, with provision for a limited rotation in position angle. Plates 20 × 20 cm can be clamped in the holder; smaller plates are accommodated by aluminum holders of different size.

The horizontal motion of the frame is operated by the observer, sitting at the front pillar A1, by means of a handwheel E at his left hand, fastened on an axis going through the pillar and carrying at the other side a small pulley F1 around which a steel string is wound. This string runs upward, is bent over two pulleys F2, then runs horizontally to the middle of the upper steel cylinder B1, where it is wound over a fixed wormwheel F3 that engages a toothed bar attached to the upper side of the frame. The tension of the string is adjusted by displacing the middle pulleys. By turning the handwheel the frame slides horizontally along the cylindrical rods.

For the vertical motion the observer turns a handwheel at his right hand G, which is attached to a horizontal rod H parallel to the frame.


K1
X1
X2
K2
X3
Q
R
P2
O1
P1
N
M
O

This rod carries two small cogwheels I attached to either vertical cylinder of the outer frame and operating upon vertical toothed bars attached to the sides of the inner frame. By turning this handwheel the inner frame with the starplate slides up and down.

In later specimens of the instrument the steel cylinders carrying sliding rings have been replaced by rectangular rods over which run small wheels carrying the frame. The transmission by cogwheel and toothed bar is replaced there by strings fastened to the frame.

Rectangular coordinates for the position of frame and plate are read upon two glass scales K, divided into half millimeters. The vertical scale K1 is attached to the rear vertical side of the inner frame; it moves up and down with this frame and is displaced in a horizontal direction with the whole outer frame. The horizontal glass scale K2 is attached to the rear vertical pillar A2. The graduated surfaces of the two scales are almost in contact and slide along one another when the movable scale is carried up and down or to and fro by the two motions of the frame. Their readings at their intersection represent the rectangular coordinates of the observed point of the star plate. At the point of intersection a small lamp with diffusing screen is placed at the right hand side and allows a simultaneous reading of both scales from the left hand side.

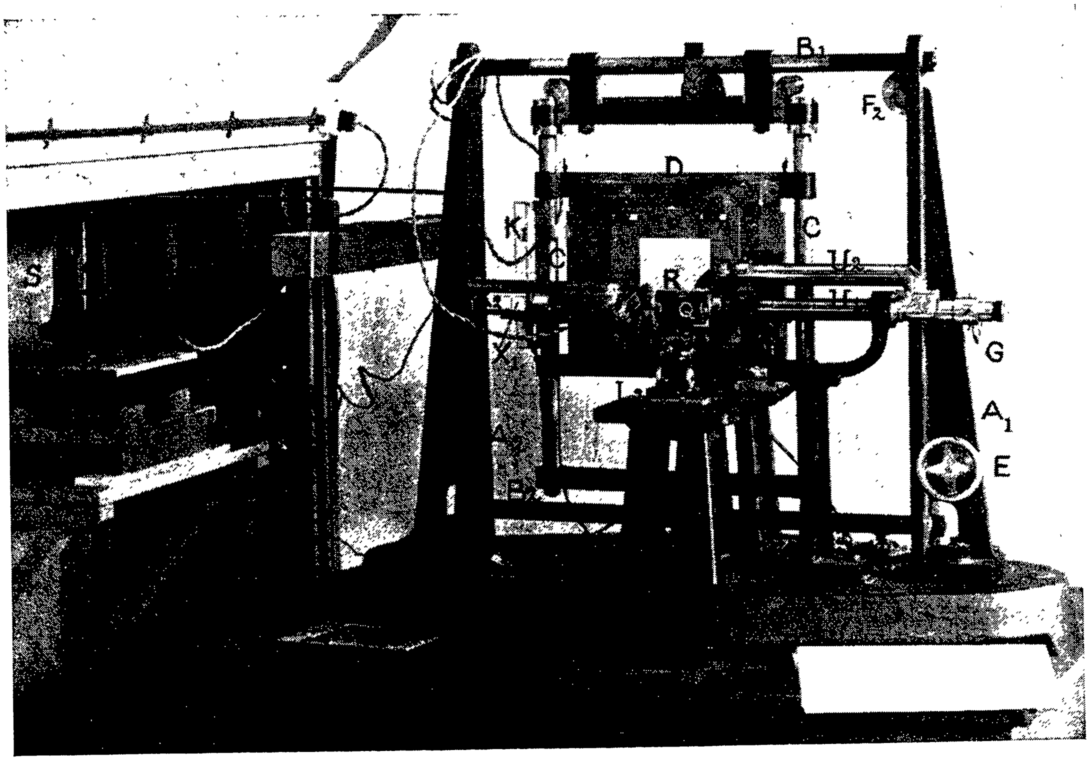
3. The measuring pencil of radiation produced by an incandescent lamp emerges from a small circular aperture. By means of an optical system a sharp image of the aperture is produced exactly in the plane of the film with the star images of the negative. Having passed the film from the right to the left hand side the pencil traverses a vertical glassplate at an angle of 45°, so that a small part of the light is reflected into the direction of the observer. The remainder falls upon a condensor, which produces a sharp image upon the thermo-element.

The part of the optical system to the right hand side is carried by a low iron table L1 tightly fastened to the base plate. The lamp is a small Philips lamp 4 V, 3-4 A, with a short straight vertical glowing spiral, fed by a 6 V storage battery; the intensity is adjustable by different resistances. The lamp is contained in a brass case M, with openings for air circulation, and can be displaced in two directions and clamped. A series of small circular apertures (0·3, 0·6 and 0·9 mm diameter) drilled in a brass plate N that can rotate about an axis at the side of the lamp case, is used for varying the diameter of the illuminated spot. A small lens P1 (f = 18 mm) near to the aperture forms a real image of the glowing spiral upon the front lens of the optical system P2. This optical system consisting of a microscope objective Zeiss 11.10.06. $f = 23{\cdot}5$, forms a sharp image of the aperture, 2/5 of the original size, on the film of the plate. This system is mounted on a sledge so that it can be focussed by a screw; moreover it can be adjusted in height and rotated about a vertical axis, and firmly clamped by screws after regulation.

The sharp image of the aperture produces an intense illumination at one circular spot of the plate, somewhat larger than the star images. If a star is found just within this spot, part of the radiation is absorbed and the transmitted pencil is weakened. This diminution of radiant energy falling upon the thermo-element is measured by the decrease of the galvanometer deflection. In order to have a diffuse illumination of a larger area for recognizing the stars in a large field, a piece of ground glass can be put into the path of the pencil just before the microscope objective. This ground glass O1 is attached to a horizontal rod O, ending in a knob at the right hand of the observer, so that by simply pushing the rod in and out he can bring the ground glass before the objective or remove it.

After passing the star plate the pencil falls upon the vertical glass plate inclined at 45°, which is contained in a brass box R carried by a low iron table L2 at the left hand side of the instrument. The box has circular openings at the four sides; one at the right hand side allows the pencil to enter, the opposite one contains a condensor (aplanat 0·6) of large aperture, which produces a sharp image on the thermo-element; the other two are used for light beams parallel to the frame.

The thermo-element Q is supported by a steel shaft which rests on the same iron table in such a way that it can be moved up and down and firmly fixed by screws. On this shaft a sledge rests by means of a collar so that it can rotate somewhat about this axis; the sledge can be moved in the direction of the light pencil. It carries another piece that can be moved horizontally perpendicular to the light pencil, and this piece carries the thermo-element. Thus besides the rotation it is movable in three perpendicular directions, so that the careful adjustment necessary for a thermo-element of such small dimensions can be made. The thermo-element is one of the Moll vacuum cells; the sensitive metal strip, blackened to increase the absorption of heat, is placed vertically. The thermocurrent is led to a Moll galvanometer S, placed upon a small table attached to the wall. At first the vibrations of the wall (in the midst of the town at second floor height) made reading of the scale difficult. After trying several other contrivances a sufficient arrangement




was obtained by placing a sheet of rubber bathing sponges of a total thickness of 12 cm under the board that carries the galvanometer. This sheet absorbs nearly all the vibrations and readings could be made now to a few tenths of a millimeter of the reflected scale. The scale is a celluloid scale of 70 cm, divided into millimeters and set in a wooden box T at a distance of 48 cm before the galvanometer mirror.

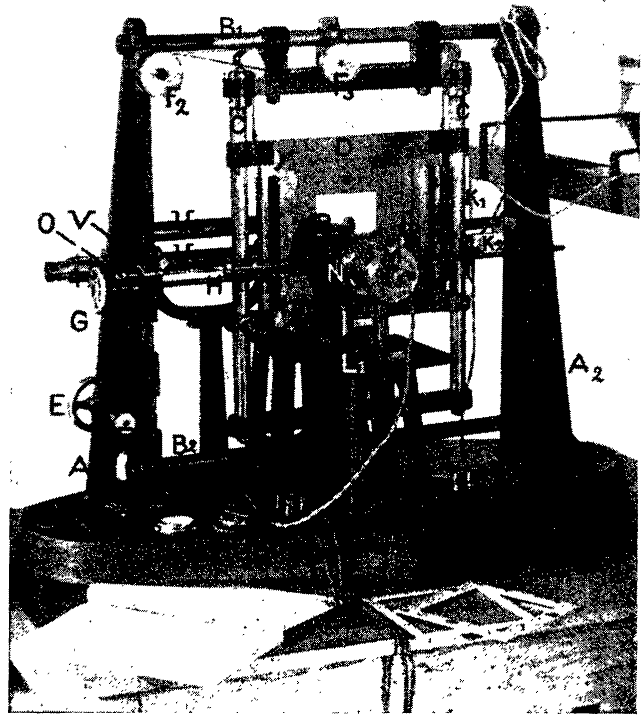
4. The reading telescope is fastened upon an iron standard at the left hand side of the frame. It has two parallel objective tubes one above the other; the lower one U1 is attached to the brass box and receives, reflected at 45° by the glass plate, the light of the pencil illuminating the starplate; the upper one U2 is pointed to the galvanometer mirror. The two objectives have one common eye piece that is in line with the lower one; the light pencil of the upper one is reflected into the eye piece by means of two mirrors inclined 45°. The lower mirror is movable; if it is pressed by a spring horizontally at the upper side the path in the lower telescope is free and the observer observes the starplate and the rectangular coordinates. If brought into the inclined position it reflects the light pencil of the upper tube, and the observer reads the galvanometer deflection. The motion of this mirror is coupled to the motion of the ground glass rod O which at the other side of the frame is pushed in and out to produce a diffuse or a sharp illumination of the star plate. In this way the star plate is observed only under diffuse illumination, and when the light source is focussed on the plate and concentrated upon the thermo-element, the observer views the scale in the galvanometer mirror. The coupling consists of a nut V caught between two pins of the rod and carried along with the rod. It is easy to uncouple the mirror when necessary by turning the rod a little bit around its own axis, so that the nut is freed and the mirror takes its horizontal top position.

Through the lower telescope one observes the star images of the plate reflected by the glass plate at 45°; these images are brought into focus with the cross wires of the eye piece. At the same time the coordinate scales are seen through this glass plate. The light coming from the intersection point of the two scales, which are illuminated from behind, is reflected by a 45° prism X1 into a direction parallel to the frame, into the lower objective. Because this intersection point moves in a horizontal direction with the whole frame and thereby its distance to the telescope objective is variable, it is necessary first to make the rays parallel by means of a lens X2. Then this parallel beam runs over a variable distance to a fixed lens X3, attached to the 4th opening of the brass box and forming a real image before the glass plate is reached, at the same distance from the objective as the virtual image of the starplate. In this way the coordinate scales are seen in focus at the same time with the starfield, for every position of the frame. The diffusely illuminated starfield occupies only a part of the field of view in the telescope, and next to it the image of the rectangular coordinates is seen, at least when it is wanted and the illuminating lamp is burning.

5. We suppose that the optical systems have been made coaxial and the thermo-element has been adjusted, so that it receives the full energy of the pencil and produces a maximal galvanometer deviation. Then to begin a series of measurements the microscope objective must be exactly focussed upon the starplate. This is made by first looking into the observing telescope and focussing the diffusely illuminated star images upon the cross-wires. Then the ground glass is removed, but at the same time the mirror in the telescope is uncoupled so that the sharp image of the small aperture becomes visible. This image is too bright to be observed directly, so a diaphragm with a dark red glass is put before the eye piece. Now the image of the aperture can be observed; by the slow motion of the microscope objective it is focussed upon the cross wires. Then it is in focus at the same time with the star images.

There are two double cross wires in the eye piece which as a whole can be moved in two perpendicular directions. In this way the small square they are forming in the centre of the field can be brought into exact coincidence with the bright image of the small aperture. If this is accomplished we are sure that afterwards, when a star image is set at the centre of the little square, it is at the same time in the centre of the measuring light pencil. Next the coupling of the inclined mirror in the telescope with the ground glass-rod is restored, so that the starplate can only be observed when in diffuse light, and the red glass before the eye piece is removed. Then the series of observations can start.

With the ground glass in, the star in the visible field is brought into the cross wire square by moving the frame with the starplate in two directions by means of the two handwheels. If necessary the rectangular coordinates are read; but sometimes their




readings have already been used for setting the right star near to the square. Then the ground glass is moved out; the observer now sees in the telescope the galvanometer scale, which he reads when it has come to rest. Then the plate is displaced a small amount and a second reading, corresponding to a point of the clear plate beside the star is taken. When the ground glass now is put in for the next observation, we may check at the same time that the square corresponds to an empty place of the plate. Then the next star is pointed. For faint stars, where only a small part of the energy is absorbed by the star image, variations of background density over the plate are better estimated by using points adjacent to the stars in question rather than by comparing with one normal free place in the centre of the plate.

We are indebted to D. Koelbloed, computer at the Institute, for many valuable suggestions.

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