ON THE EXPERIMENTAL DETERMINATION OF THE NORTH DIRECTION OF A HELIOGRAM

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Abstract. A new method to determine the experimental north direction of a heliogram is suggested and a method of reduction for the measurements is given. The accuracy achievable by this method exceeds that generally used.

1. Introduction

To measure the global motion of different features on the Sun, it is important to determine the north direction of the Sun's image obtained by a heliograph as accurately as possible. With a $\Delta \tau$ error in the north direction of the heliogram, the errors in the heliographic longitude $L$ and in the heliographic latitude $B$ are as follows (Györi, 1989b):

$$
\Delta L = \{\sin(\alpha) - \cos(\alpha) \tan(B) \cos(L_{cm})\} \Delta \tau,
$$

$$
\Delta B = \cos(\alpha) \sin(L_{cm}) \Delta \tau,
$$

where $\alpha$ is the heliographic latitude of the center of the Sun's disc, and $L_{cm}$ is the heliographic longitude measured from the central meridian of the Sun. These relations can be obtained by using the Taylor series of the equations connecting the polar coordinates of a spot in the heliogram with its heliographic coordinates and supposing $\Delta \tau$ to be a small quantity.

The north direction of a heliogram can be described by the formula (Györi, 1989a)

$$
\Delta P_0 = \left(\frac{\pi}{2} - |\alpha|\right) \text{sign}(\alpha) + \lambda \sin(t - \rho) \sec(\sigma) \pm \\
\pm[\omega \sec(\delta) - \varepsilon \tan(\delta)],
$$

where $\Delta P_0$ is the angle between the north direction of the image plane of the heliograph and the image of a thread located in the primary image plane; $\alpha$ is the angle between the "imagined image of the declination axis" and the image of the thread; $\lambda$ is the pole distance of the hour angle axis; $\rho$ is the hour angle of the hour angle axis; $\omega$ is the angle between the declination axis and the hour angle axis of the heliograph (which is $\pi/2 + \omega$); $\varepsilon$ is the angle between the declination axis and the optical axis (which is $\pi/2 + \varepsilon$); $\delta$ is the declination of the Sun; $t$ is the hour angle of the Sun; the plus sign before the last term...
in (2) stands for the east position (E) of the heliograph and the minus sign for the west position (W).

The parameters $\lambda$ and $\rho$ can be determined with high accuracy with the method proposed by L. Győri (L. Győri, 1990). Using experimental north directions and fitting the curve described by formula (2) to them, the other parameters can be determined.

There are two different methods generally used to infer the experimental north direction of a heliogram: a) from the double exposed heliogram; b) from the trail of a sunspot while the heliograph is at rest. Generally, the first method is more accurate because the measurements can be done on a photographic plate while the second one is done on a less accurate drawing. But the sunspot trail method can be converted into a photographic one with the use of a suitable gadget described in the next chapter.

2. The Instrument

The method of having a star trail (stopping the clock mechanism, opening the slit of the shutter, and allowing the star to go through the image plane of the telescope) cannot be applied to the Sun because the result would be an overexposed image. A cover (thin steel plate) in the primary image plane of the heliograph with a slit centered on a sunspot group and moving together with this group is necessary. With successive exposures a discontinuous spot trail can be obtained.

The main features of the instrument are shown in Figure 1. The thin steel plate $P$ with the slit $A$ on it is moved automatically by an electric motor controlled by a computer to the next location of the exposure in advance to allow time for the damping of the vibration caused by the movement, and when