PHOTOGRAPHIC DETERMINATION OF HELIOGRAPHIC COORDINATES OF SUNSPOTS WITHOUT TAKING DOUBLE PHOTOS

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The idea of the method is to achieve high precision in determination heliographic coordinates of sunspots, without taking double exposure photographs. For this purpose, with a level, the parallelity of one side of the photographic plate to the horizont is ensured. The moment of exposure is noted in UT.

For this moment the values of *R.A.*, declination and angular radius for the sun, α, δ, R', daily variation of *A.R.* for the sun, $\Delta\alpha/24$, the physical coordinates of the sun, P_0, B_0, L_0, the sideral time at 0^hUT, S_0, and the equation of time, η, are obtained from an Almanac. Also, geographical coordinates of the observing place, φ, λ, are necessary.

From the equations which connect horizontal coordinates z, A with local equatorial coordinates δ, t:

$$\cos z = \sin\varphi \sin\delta + \cos\varphi \cos\delta \cos t \tag{1}$$

$$\sin z \sin A = \cos\delta \sin t \tag{2}$$

$$\sin z \cos A = -\cos\varphi \sin\delta + \sin\varphi \cos\delta \cos t \tag{3}$$

by differentiating (variation of sun declination is ignored) and solving (1) for dh/dt, $h = 90° - z$, (2) and (3) for dh/dA, we can obtain dt/dA:

$$\frac{dh}{dA} = \frac{dh}{dt}\frac{dt}{dA} = tg\,\chi.$$

Here angle χ presents the inclination of the daily parallel through the centre of the solar disc to the plane which is parallel to the horizont, and passes through the centre of the sun. So we obtain

$$tg\,\chi = \frac{-\cos\varphi\, tg\, t}{\cos A + \sin\varphi \sin A\, tg\, t} \tag{4}$$

where azimut A is given by

$$tg\,A = \frac{tg\,t \cos M}{\sin(\varphi - M)}, \qquad tg\,M = \frac{tg\,\delta}{\cos t}. \tag{5}$$

The moment of observation in UT gives the hour angle t by the expression:

$$t = \mathrm{UT}\,(1 + \mu - \Delta\alpha/24) - (12^h + \lambda + \eta) \tag{6}$$
$$1 + \mu = 366{,}2422/365{,}2422.$$

(6) is obtained from:

$$s = S_0 - \alpha_0 + \mathrm{UT}\,(1 + \mu)$$
$$t = s - \alpha, \qquad \alpha = \alpha_0 + \Delta\alpha \frac{UT}{24^h}$$
$$\alpha_0 - S_0 = 12^h + \eta.$$

On the east side of the meridian $\chi > 0$, on the west is $\chi < 0$.

The system of coordinates $x0y$ is oriented so that the x-axis is parallel to the base of the photographic plate, and orientated to the west and the y-axis to the north. The distance r of a sunspot from the centre of the solar disc X_0, Y_0 is determined by:

$$r = \sqrt{(x - X_0)^2 + (y - Y_0)^2}. \tag{7}$$

If ρ and ρ' are angles, at the centre of the solar disc between directions to the Earth and to the spot, and R the radius of sun on the photograph, ther:

$$r/R = \sin(\rho + \rho'). \tag{8}$$

From (7), (8) and

$$\rho' = rR'/R \tag{9}$$

we find

$$\rho = (\rho + \rho') - \rho'. \tag{10}$$

Heliographic coordinates B, L are determined by

$$\sin B = \cos\rho \sin B_0 + \cos(p - P_0) \sin\rho \cos B_0 \tag{11}$$

$$\sin L' \cos B = -\sin\rho \sin(p - P_0) \tag{12}$$

$$\cos L' \cos B = \cos\rho \cos B_0 - \sin\rho \sin B_0 \cos(p - P_0) \tag{13}$$

$$L = L' + L_0. \tag{14}$$

Angles χ and $\varkappa$, where $\varkappa$ is obtained from:

$$tg\,\varkappa = \frac{X_0 - x}{y - Y_0}, \tag{15}$$

determine the angle p, at the centre of the solar disc, between directions to the sunspot with coordinates x, y and to the north pole of sun,

$$p = \varkappa - \chi. \tag{16}$$

Such a method gives high precission even if φ is known with $\pm 2'$. This method is applicable with small transportable instruments, which is of speciall importance for amateurs.

ЛИТЕРАТУРА

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