MEASUREMENT OF THE SOLAR ROTATION, 1978, FROM RECURRENT AND NON-RECURRENT SUNSPOTS

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Abstract. Results are presented for the solar rotation, 1978, as derived from sunspots by two different methods. Using recurrent spots only, the latitude dependence of the sidereal rotation rate was calculated to be \( \xi = (14.41 \pm 0.05) - (3.13 \pm 0.26) \sin^2 \phi \). Using recognizable spots, both recurrent and non-recurrent, average rotation rates were obtained for 5-degree intervals of latitude. The results from these two approaches were found to be in agreement with observations made between 1878 and 1951, suggesting that the solar rotation has not changed in the past 100 years.

1. Introduction

Present knowledge of the Sun's differential rotation, as determined from the motion of sunspots, is for the most part based on the work of Newton and Nunn (1951) and of Ward (1965, 1966). Both of these studies treat data taken at the Greenwich Observatory before 1951. More than 25 years have elapsed since then, and in that time the discovery has been made by Eddy et al. (1976) that the Sun's differential rotation has not always been the same. This implies that the present rate may be only a temporary feature.

In order to determine whether or not the accepted sunspot rate is still valid, 153 observations of the sun were made at Oberlin between February and July of 1978.

2. Method of Observation and Analysis

The solar telescope which was used consisted of a 12\( \frac{1}{2} \)-inch heliostat and an \( f/6 \), 12\( \frac{1}{2} \)-inch focusing mirror. An auxiliary lens was used in order to obtain an image of radius 9 cm.

In general, each observation consisted of two drawings of the Sun. The first, which was the one used for rotation measurements, was made by locating the center of each spot with a single dot. A second drawing was then made, immediately following the first, showing the detailed shape of the spots. On days when the cloud cover did not provide long enough breaks for two consecutive drawings, only the detailed drawing was made and the centers of the spots were then determined from it.

The positions of the centers of the spots were next located on the Sun's apparent disk using a system of Cartesian coordinates. The north–south diameter of the disk was chosen to be the \( y \)-axis, with north the positive \( y \)-direction and west the positive \( x \)-direction. Formulas were derived for converting a spot's Cartesian coordinates

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into heliographic latitude and longitude. The expressions involved the standard Ephemeris values $P, B_0,$ and $L_0,$ giving the orientation of the Sun at the time of observation, and also the radius of the image.

To determine the rate of a single spot, the heliographic longitude was determined for all observations made while the spot was less than 65° from the Sun's central meridian. In some cases spots between 65° and 75° were also used, for example, if more than one observation was made while the spot was in that longitude range. Observations of spots at distances greater than 75° were not used, since relatively large fluctuations were present in data obtained this close to the limb.

The change in heliographic longitude for each spot was determined by a linear least-squares fit of longitude vs time. The sidereal rotation rate was then obtained by adding the resulting value to 14.184 deg day$^{-1},$ which is the assumed value used in the Ephemeris. In addition, a graph of longitude vs time was plotted and a value of chi-squared obtained for each spot as a check against possible errors.

Factors considered in identifying a spot from one day to the next included goodness of fit, latitude, and general size and shape. Spots having sharp discontinuities in the residuals from the least-squares fit were rejected as having been mis-identified from one observation to the next. Spots having lifetimes less than 24 hr were also rejected, and this applied to perhaps half of the spots seen at any given time, on the average. Spots with lifetimes less than 48 hr were rejected unless at least three points were available for the least-squares fit.

3. Recurrent Sunspots

Between February 12 and July 31, 1978, 15 spots were seen to rotate off the west limb of the Sun and subsequently back on the east limb. The average time of observation for these recurrent spots was 29 days (see Table I), although the actual lifetime for most of them was somewhat longer since they formed or disappeared on the far side of the Sun and since observations could not be made near the limb of the Sun. They were found at latitudes between 14 and 44 deg, and mostly in the northern hemisphere. In the southern hemisphere no recurrent spots were observed within 20° of the equator. One spot was seen at the unusually high latitude of $-43.9$ deg, and one spot, located at 24.6 deg, was seen to return twice. With two exceptions, all the recurrent spots observed were leader spots of groups. They usually returned as single spots, the rest of the group having disappeared.

For identification purposes, a central-meridian passage is given in Table I for all but one of the recurrent sunspots. The spot located at latitude 36.5 deg was first observed on the Sun's western hemisphere, and it did not survive long enough to cross the central meridian on its second disk-passage. It was last observed March 24.6 UT, 36 deg east of the central meridian.

To determine the rotation rate for each recurrent sunspot, a single least-squares fit was done for all points from both (or all 3) appearances. The corresponding latitude was determined by averaging the individual observations.