THE MOUNT WILSON SOLAR MAGNETOGRAPH: SCANNING AND DATA SYSTEM

ROBERT HOWARD

Hale Observatories, Carnegie Institution of Washington, California Institute of Technology, Pasadena, Calif., U.S.A.

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Abstract. A description is given of a newly-installed computer-operated image scanning and data system for the 150-foot Tower Telescope at the Mount Wilson Observatory. This new system provides improved flexibility, accuracy, and reliability in the magnetograph observations.

1. Introduction

Since 1957 the magnetograph at the Mount Wilson 150-foot Tower Telescope has operated to provide full-disk magnetic scans of the Sun, fine scans of active and quiet regions of the Sun, and other observations. Since 1967 the daily magnetograms from Mount Wilson have appeared in the monthly bulletin Solar-Geophysical Data, published now by the Environmental Data Service of the U. S. National Oceanic and Atmospheric Administration. The magnetic synoptic charts, drawn from the same data, are published in the I.A.U. Quarterly Bulletin on Solar Activity.

Because these data are used by many investigators, it is of interest to document changes made in the equipment from time to time. I have recently published a detailed chronology of the improvements made to the Mount Wilson magnetograph through 1973 (Howard, 1974). This paper adds to the list a major change in the electronic instrumentation made during 1974.

This computer-operated telescope control and data collection system was put into operation on 4 April 1974. Because of some initial problems, it was replaced again by the old system on 19 April 1974, and the new system was installed finally on 11 July 1974.

One of the principal objectives of the solar program at Mount Wilson is to provide synoptic observations of the Sun which may be compared from one epoch to another. This cannot really be done without keeping the instrument unchanged. The temptation to take advantage of technological advances is stronger than the desire to maintain observations of consistent quality. If it were not so, we would be observing with very crude instruments indeed.

A price we pay for rapid technological advance is that often by the time a complicated new instrument is installed it is obsolete. This system is no exception. However, it is a considerable improvement over the old hard-wired logic system in flexibility and reliability, although the reliability is still not as good as we would like, and this system is likely to be the basis for the Mount Wilson magnetograph for some years to come.
2. The Computer and Interface

The heart of the new system is a Raytheon model 704 minicomputer. This computer has a 32K word (16 bit) core memory and a cycle time of 1 μs. The standard peripherals include two fixed-head disks, two 9-track tape units, a card reader, a line printer, and a digital plotter.

A generalized interface chassis was designed and constructed by the Astrotechnics Laboratory of the Hale Observatories. This interface unit allows us to control from the computer the image motion, the data collection, and a number of lights and two sounders to signal the operator. The operator can signal the computer through the same interface by means of a number of push buttons.

Low-level computer subroutines have been written which enable us to control or interrogate all of these functions from within FORTRAN programs. The type of system allows us enormous flexibility in observing.

The interface unit also drives a keyboard and associated television screen. The keyboard provides the operator with a means of communicating data to the computer during the setup procedure. The screen provides a display of telescope and data system functions for the observer. Actually, there are several identical screens in the observing room and the data room, and one such screen is located in the observing room of the 60-foot Tower Telescope. Figure 1 shows the data and control portions of the system. The computer is in another room.

3. Image Control

The solar image guider is unchanged from the previous system (Howard, 1974). In order to move the image it is necessary only to move the guiding ring near the focus. This guiding ring is moved in two dimensions by two stepping motors that turn long lead screws. Nuts attached to the screws move the guiding ring. The rate and distance of travel of the stepping motors are controlled through the interface chassis by the computer program. Each screw has attached to it a shaft encoder, which digitizes the location of the guiding ring in that dimension. One unit of this encoder corresponds to about 0.28 arc s. One step of the stepping motor corresponds to exactly half of one encoder unit.

4. Data Collection

A shaft encoder on the screw which drives the exit slit assembly (Howard, 1974) provides the line-shift signal as before. One unit of this signal corresponds to approximately 5 m/s. Thus encoders provide the X-Y position, as described above, the Doppler signal.

The intensity and magnetic signals, which come from the magnetograph amplifier as d.c. signals, are fed to voltage-to-frequency converters. The resulting pulses go to counters to give digital signals. The electronic circuit which handles this function through the computer interface chassis can receive from the
Fig. 1. A view of the instrumentation in the observing room at the focus of the 150-foot (45.7 m) Tower Telescope at Mount Wilson. The 42-cm solar image may be seen on the white table in the left portion of the photograph. The hole in the center of the table admits a small portion of the light to the magnetograph analyzing optics just below the table. The image slicer and spectrograph slit are below the analyzing optics, and the spectrum, formed by the 75-foot (22.9 m) vertical pit spectrograph, is located in the white box below the table. The magnetograph exit slits and detectors are located in this box. The magnetograph amplifier, digitizers, data system, and telescope control system, along with a digital clock and miscellaneous power supplies, are located in the electronic racks on the right of the picture. One of the television monitors and its keyboard may be seen in the center rack. The computer is in another room.
computer program an integrate time, i.e., an interval over which to integrate the intensity and magnetic signals. Once the process is started, this circuit will integrate for the desired interval, store the resulting digitized values where they are accessible to the computer program, then provide an interrupt to the program to inform it that an integrate interval has ended and the data are available to the program. The storage of these values is buffered so that very little time is lost between integrate times. The program can interrogate the encoders at any time. In practice this is done at the same time that the integrated data are extracted. Figure 2 shows a diagram of the basic components of the system.

5. Observing

The calibrations, magnetic and Doppler, are done basically in the same way they were done previously except that now the computer can be used to help in the process. In the magnetic calibrations, for example (Babcock, 1953), the magnetic signal is integrated by the computer for several seconds at each location in the line profile, and the subtraction is done by the computer. The whole setup procedure, in fact, is controlled in detail by a computer program.

At the end of the setup procedure the observer may begin the observation by pushing the “Start” button. The rest of the observation is handled by the computer program. The observation is a raster scan as before. Since the location
and size of the solar disk (in encoder units) are known by the computer program, it is easy to extend each scan line only slightly beyond the solar limb, thus making the observation quite efficient. The observation will be halted temporarily at any time when the observer pushes the "Hold" button. The appearance of clouds will have the same effect. The observation will restart if the observer pushes the "Start" button, or if the clouds go away.

The standard observing program can also control fine scan observations of selected regions and several other modes of observing.

6. Data Reduction

The data reduction is essentially unchanged from the previous system. It is hoped eventually to be able to provide some of the data reduction simultaneously with the observations, but that has not yet been possible. The plotting of magnetograms and Dopplergrams from plot commands generated previously on tape can be done simultaneously with the observation. The telescope control and data collection occupies only a small fraction of the available time of the computer.

A typical current magnetogram is shown in Figure 3.

Fig. 3. The Mount Wilson Observatory full-disk magnetogram for November 20, 1975. The aperture used was a square 12.5 s on a side. The "DELTAY" gives the separation of the scan lines in s, and the "DELTAX" gives the separation at which integrations were made along the X axis. The Y axis is parallel to the central meridian. Practically all the features seen on these magnetograms are real; the noise is well below the first gauss level (5 gauss). The polar magnetic fields of the Sun may be seen clearly.
7. Advantages of the New System

The new system allows us great flexibility in our observing program. We may move the image in almost any conceivable fashion, and collect the data in any way we wish, with a wide choice of integrate times. Both the motor speed and the integrate time can be varied in very small steps.

It is possible, therefore, to design observing programs that can perform specialized tasks. One need only write a program in FORTRAN. The daily magnetogram can use parameters that optimize its information content. Currently, the standard aperture size for the full-disk magnetogram is 12.5 s, and the integrate time is 0.190 seconds. It takes about 90 minutes to scan the full disk, accumulating about 23000 observations on the disk of the Sun.

A further advantage of the new system is the increase in accuracy that we obtain in the magnetic and Doppler calibrations and in the setting of the magnetic zero level. The magnetic calibration is generally accurate to about 10 or 15%; the Doppler calibration, which is the determination of the spectroscopic dispersion, is accurate to about 0.1%, and the zero level of the magnetic signal is accurate to a few tenths of a gauss. The noise level of the magnetic signal at an integrate time of 0.190 sec is about 2 or 3 gauss, in general.

Additional improvements to the instrumentation are planned, especially in the area of the exit slits and the detectors, which are now photomultipliers.

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