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The Advanced System for Observations of Large-Scale Solar Magnetic Fields on the STOP Telescope at the Sayan Observatory: Present Status, Recent Results and Future Plans

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Abstract. Although the basic concepts of magnetographic measurements of solar magnetic fields have remained unchanged for several decades, a practical implementation of personal computer-assisted automated systems made it possible to bring such observations to a qualitatively new level. This also applies in full measure to the STOP (Solar Telescope of Operative Predictions) telescope of the Sayan observatory, which is designed largely for measuring large-scale magnetic fields. The personal–computer–aided control system has been in operation at this telescope since 1992. This paper gives a description of the latest, most perfected, version of the system which permits measurements at STOP to be improved significantly. Basic data on the design and electronic solutions of this system and on its software are presented. The presentation of material is illustrated by examples of actual observations of the mean and background fields of the Sun (magnetograms for individual days, synoptic maps for several Carrington rotations). Main research objectives are formulated for the forthcoming years of the 23rd cycle of solar activity: Carrying out observations of the magnetic field of the Sun-as-a-star and obtaining magnetograms with different spatial resolutions and in different spectral lines on a regular basis. Conducting experiments on measuring transverse large-scale magnetic fields and, in some periods, on observing global solar oscillations.

1. Introduction

STOP (acronym for "Solar Telescope for Operative Predictions") is a special-purpose telescope of the Sayan Solar observatory (SSO) designed (as is reflected in its name) for purposes of predicting parameters of the interplanetary medium based on observations of large-scale magnetic fields of the Sun. That is, as far as the observational objectives are concerned, it is analogous to the telescope of J. Wilcox Solar observatory (WSO) (Scherrer et al. 1977; Duvall 1977). The STOP design capabilities make it possible to carry out magnetic field (and velocity) observations with different spatial (angular) resolutions, and yet two kinds of observations are of our principal interest: 1) measurements of the solar

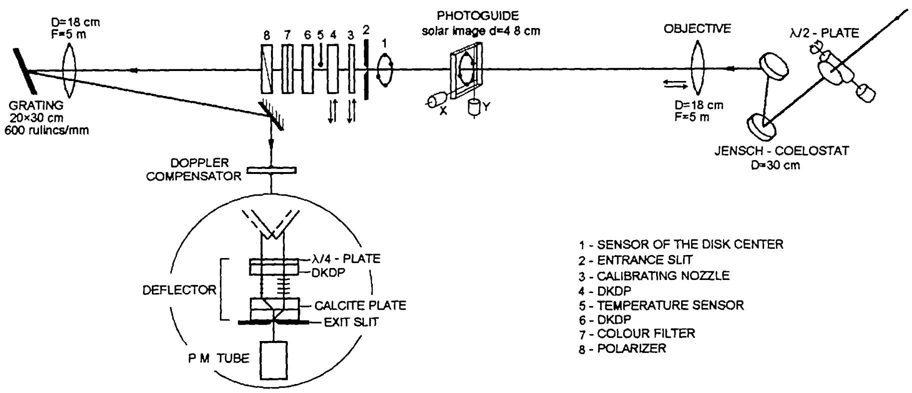

Figure 1. Optical layout of the STOP telescope at the Sayan observatory (not to scale).

mean magnetic field (SMMF); and 2) measurements of large-scale (background) magnetic fields (LSMF) with 120" angular resolution and with 100" scanning rate in both coordinates, X and Y. Basic facts about the STOP design features and procedures of SMMF and LSMF observations are reported in (Grigoryev et al. 1981, 1983; Grigoryev & Demidov, 1987; Demidov 1987, 1991, 1996; Demidov et al. 1995).

During the STOP operation since 1982, it incorporated several versions of measuring and recording equipment, but only when personal computers were available to us was it possible to create a truly state-of-the-art system meeting the objectives embodied in the STOP (operativeness). The personal computer (PC)-based automated system has been in operation at STOP since 1992, undergoing step-by-step improvements. This paper gives a groundwork of the latest, most advanced, system's version being currently in operation at the STOP. The chief merit (and the distinguishing feature) of the new system is that intensity values in each of the wings of the Zeeman components can be recorded directly by the PC, at each operating step of the electrooptic polarization analyzer (EOPA). This made it possible to reduce the number of electronic modules and, as a consequence, to get rid of many problems (especially in LSMF observations) inherent at the STOP before. Furthermore, the extensive potentialities of the new system make possible different modes of measurements, a monitoring of their quality directly at the time of observations, and on-line data treatment. Some of the results obtained with the new system are also presented for the first time in this paper.

2. Optical System, Electronics and Manager System of the STOP

The schematic diagram of the existing STOP optical system is shown in Fig. 1. At this point we wish to point out the new elements only, passing over the main characteristics which may be found in, for example (Grigoryev & Demidov 1987). The disk center sensor is located immediately ahead of the spectrograph entrance slit; prior to the observation the sensor captures and holds the solar image

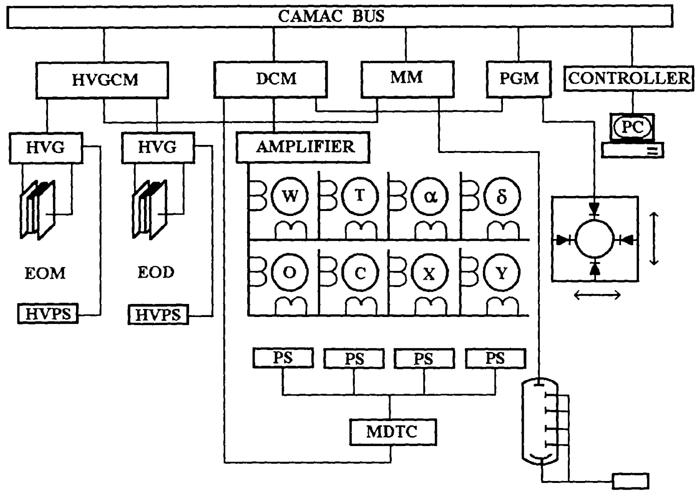

Figure 2. Functional block diagram of the STOP electronic system. Abbreviations: HVG - high-voltage generator; HVPS - high-voltage power system; HVGCM - HVG control module; DCM - drivers control module; MM - measurement module; PGM - photo-guider module; MDTC - module of detection and transformation of coordinates; PS - position sensors. Drivers: W - calibration nozzle; T, α, δ - clock, α and δ drivers of the coelostat; O -$\lambda/2$ phase plate; C - compensator of doppler velocities; X and Y - coordinatometer's drivers.

symmetric about the slit and makes the carriage with the guider photodetectors move to the same position. Another new element is the temperature sensor placed immediately near the EOPA and used to control the EOPA modulator voltage (Demidov et al. 1995, 1997). An identical sensor designed for the same purposes is located near the deflector within the photometer. The photometer slit parameters were modified, and currently they are: the width 5.6 pm, and the distance between the nearest edges 3.2 pm. It should also be noted that we have manufactured a new spectrograph entrance slit unit to accomodate two, rather than one, electrooptic modulators (EOM), which is necessary to the planned STOP-experiments on measurement of transverse magnetic fields.

Unlike the STOP optical/mechanical design that has remained basically the same, the electronics underwent cardinal changes. The functional block diagram of the electronic system is given in Fig. 2. All the STOP electronics may be arbitrarily divided into three levels: 1 - the lower level comprises the actuators, sensors, end switches, etc.; 2 - the middle level includes modules (mostly the CAMAC modules) which, on the one hand, are directly linked with the lower level and, on the other, receive control commands from the upper level systems; 3 - the upper level consists of the PC and the device to communicate with the middle level (the adapter and the CAMAC-crate controller). The special-purpose modules were developed and built at our institute.

The control module for high-voltage transistor generator (HVTGCM) is intended to control high-voltage generators (HVG), which, in turn, control the electrooptical modulator (EOM) and deflector (EOD). The module generates control pulses at a certain frequency, so that the HVTG sequently receives one of the two states corresponding to phase shifts $+\lambda/4$, or $-\lambda/4$.

The most important is the measurement module (MM). The module is designed for converting the photomultiplier current to a 10-bit binary code, transferring this code to the PC, converting the code to the voltage for visual display on the oscillograph, and for converting the control code to the doppler compensator's current. The operation of the current-code converter is locked with the HVTG operation by 1 kHz clock frequency in such a way that output current of the hotomultiplier is excluded at the time of the transition process during 10 ms. The accumulation time (the number of modulation cycles) is set by the operator before the observation, depending on the type of observations. Thus the MM does not carry out any mathematical signal processing because all processing is done by the PC.

The Telescope Manager System (TMS) is designed for automatic control of magnetographic measurements and a pretreatment of data obtained. The system performs the following functions: it controls the coordinatometer in real time; collects, records and processes observational data; displays the accumulated information on the video screen and stores it in the hard drive files. The system is implemented by IBM PC AT using the Borland C++ program development integrated environment. To control the telescope, the system uses three programmed modules (see Fig. 2): HVTGCM, MM, DCM.

Subsequently to TMS startup, the system's working window is displayed on the screen, which consists of the main menu and several functional windows. Each of the functional windows is designed for displaying a particular type of information about the system operation.

3. Some Results

With the advent of the new system, observations at STOP in full scope (both SMMF and LSMF) got under way in February 1997 (while SMMF measurements were initiated at an earlier date). Fig. 3 gives an idea of the earliest experimental data obtained through SMMF measurements by illustrating an example of a typical observation made on the April 15, 1993. All the information presented in this figure (plus much additional data) is displayed in about the same form on the PC screen immediately at the time of recording and subsequently in the summary protocol of observational data processing.

Since a relatively short time (a minimum of 25-30 min) is taken by the whole procedure of a single SMMF measurement (if the weather allows, measurements are made several times a day), it was possible to achieve a reasonably good regularity in SMMF observations at STOP. This makes it possible to somewhat override data gaps occurring (especially in the winter months) in the WSO observations. This is illustrated by Fig. 4, showing the filling functions for the period from October 1996 to March 1997 of the Sayan, Stanford and joint data sets, respectively. While the filling factor of the first and second data sets is 0.57 and 0.77, respectively, the filling factor of the joint data set is as high as 0.92. Some of the recent results based on using SMMF observations from SSO are discussed in the poster papers (Demidov & Grigoryev; Demidov) to this conference.

To record a single magnetogram at STOP requires a considerably longer time

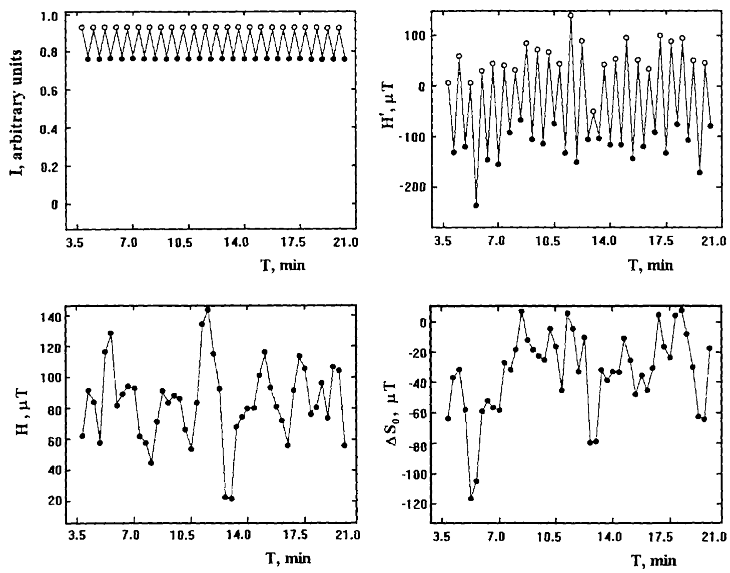

Figure 3. Example of original observations of the SMMF made at STOP on April 15, 1993. Panel 1: brightness in per-unit notation; panel H': initial signal of magnetic field strength; H: final field, corrected for zero-level displacement ΔS_0 (bottom right panel).

(a minimum of 1.5 hour); therefore, the number of days with LSMF measurements is significantly smaller. Nevertheless, even during the first few months we obtained several tens of reasonably good quality magnetograms. This made it possible to accumulate observational data for constructing synoptic maps. Some days it was possible to obtain two or even three magnetograms, and in addition to observations in the traditionally used line λ 525.0 nm FeI, records were also taken in the line λ 524.7 nm FeI. Fig. 5 gives an indication of the magnetograms obtained at the STOP. The figure shows the magnetograms observed on March 8, 1997, and March 10, 1997. Our choice of the dates for the magnetograms presented is dictated by their proximity to the date of the total solar eclipse of March 9, 1997. A reasonably good agreement of the magnetograms (with due

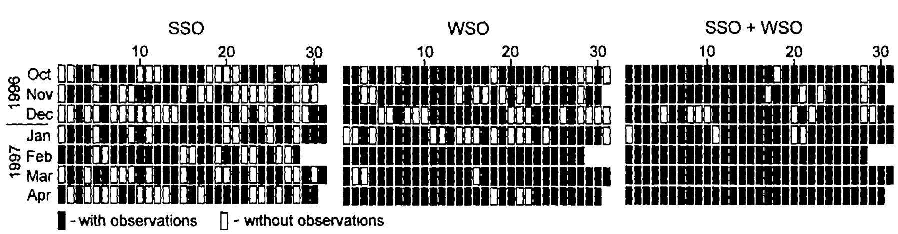

Figure 4. Filling function for the period from October 1996 to March 1997 in SMMF observations in the SSO, WSO and joint SSO+WSO data sets.

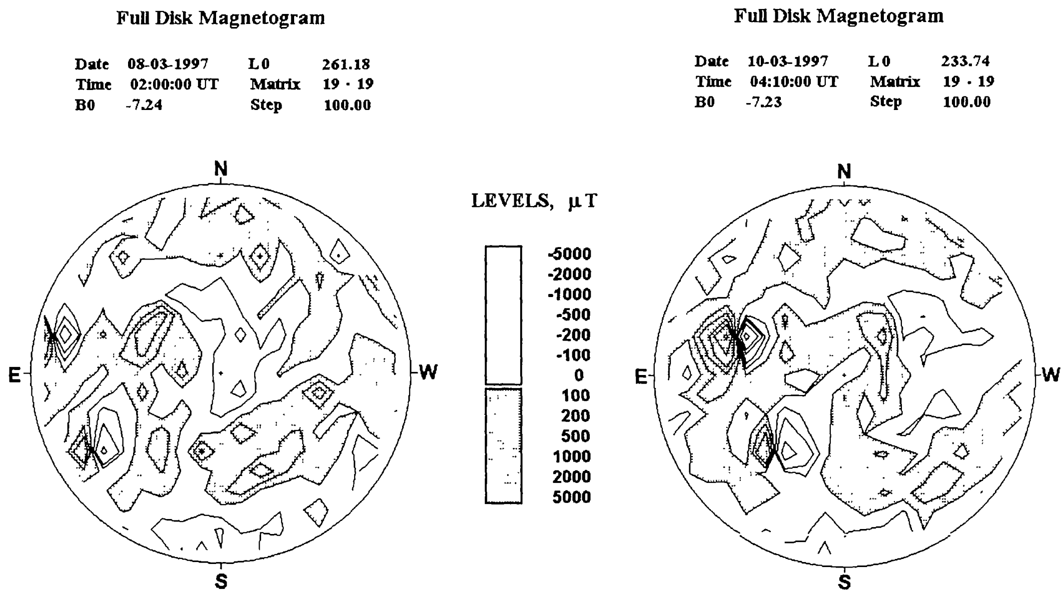

Figure 5. Example of magnetograms obtained at the STOP telescope of the Sayan observatory on March 8 and March 10, 1997.

regard for solar rotation) is testimony to their reliability. The estimates of the accuracy of LSMF measurements at the STOP made regularly prior to taking the magnetograms from the observation of the signal at the center of the solar disk ($\sim$ 2 min), give the value of the standard deviation $\approx 15\ \mu$T.

Fig. 6 shows synoptic maps for Carrington rotation 1920 as constructed from the SSO (top panel) and WSO (middle panel) data. The comparison of two maps, constructed from independent data and by different methods, bears witness to a very good agreement between them: all main structures of LSMF manifest themselves clearly on both maps. But the Sayan maps are characterized by greater details and the presence of additional contours, which stems from higher resolution in the STOP observations (120" compared to 180" at WSO). And finally, the bottom panel of the Fig. 6 shows synoptic map for subsequent Carrington rotation 1921 as constructed on the basis of SSO data.

4. Conclusion

The above information is intended to give an insight into the present status of the STOP and the recent results obtained with it. However, we cannot content ourselves with the results achieved, and we plan to improve, where it's possible, the equipment and extend the gamut of research. Of course, the key objectives of the STOP are to continue regular observations of SMMF and LSMF also in the years to come. And in addition to the line λ 525.02 nm FeI traditionally used in such observations, measurements will also be made in other Fraunhofer lines with different atomic parameters and different sensitivities to the magnetic field.

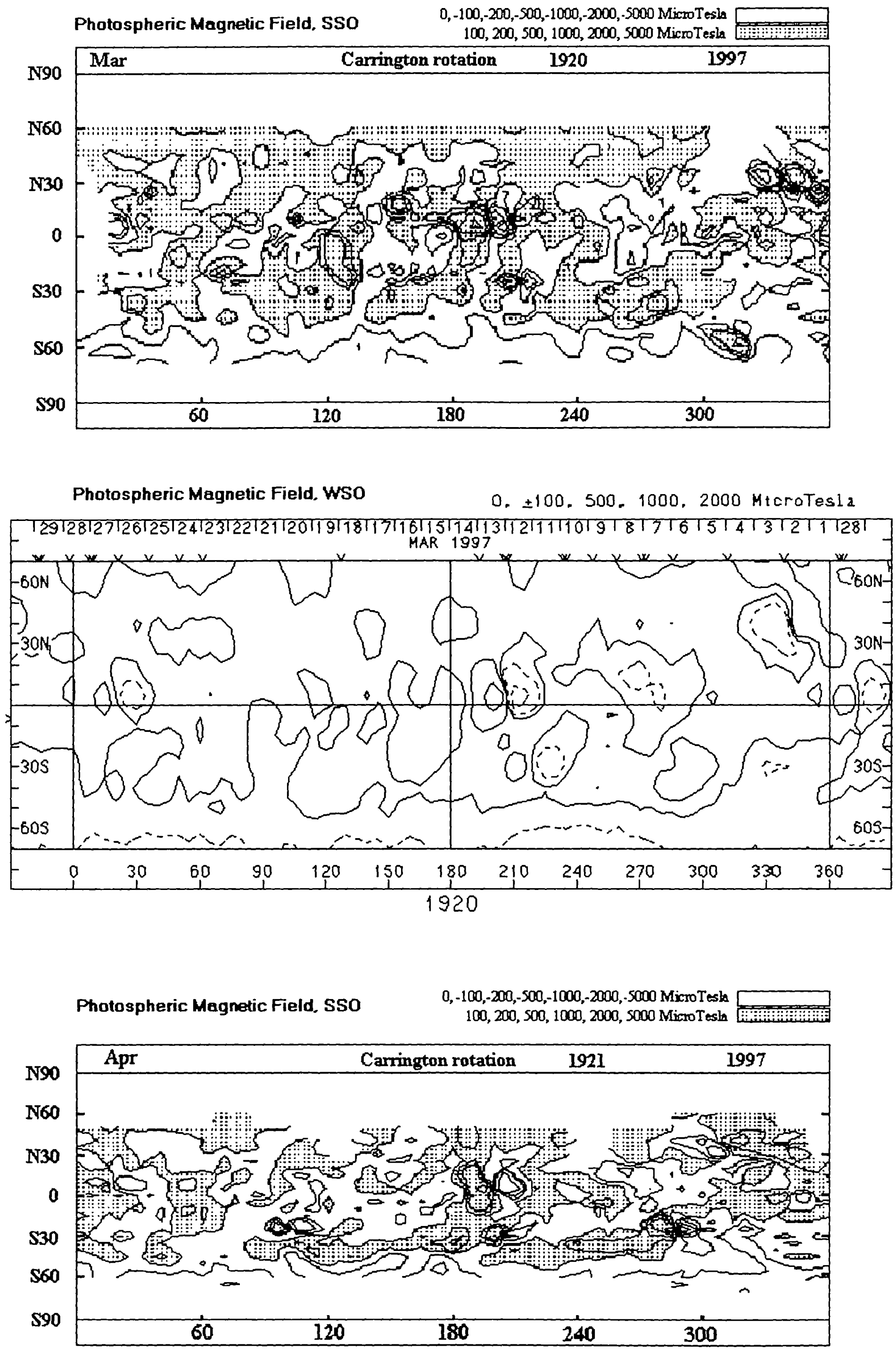

Figure 6. Synoptic maps of the large-scale solar magnetic fields (LSMF) for Carrington rotation CR 1920, constructed: top - from SSO data; middle - from WSO data. The bottom panel - synoptic map for CR 1921, constructed from SSO data.

Furthermore, with the purpose of continuing to investigate the problem of fast temporal changes in SMMF and LSMF, it is planned to obtain long-lasting (continuous during several hours) series of observations. Analysis of such variations of magnetic fields, in addition to being of independent interest, appears to be of important significance for some problems in helioseismology.

We have also scheduled (and preparatory steps are being taken) experiments on measuring the Stokes V parameter distribution in SMMF and LSMF observations, as well as experiments on recording transverse magnetic fields.

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