The Magnetic and Velocity Fields of Solar Active Regions
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MAGNETIC FIELD OBSERVATION WITH THE SOLAR FLARE TELESCOPE

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ABSTRACT The Solar Flare Telescope was constructed at Mitaka in 1989. This instrument comprises four telescopes which respectively observe (a) Hα images, (b) continuum images, (c) vector magnetic fields, and (d) velocity fields in the photosphere. The instrument aims at the study of energy build-up and energy release in solar flares, in cooperation with the Solar-A satellite. The whole system has been in regular operation since 1992 July. The methods of measuring the magnetic and velocity fields are described.

INTRODUCTION

The magnetic evolution of the active regions is considered to play an essential role for the production of solar flares. In order to understand the mechanisms of energy build-up and energy release of solar flares, a complete set of observations is actually required, i.e. photospheric magnetic/velocity fields, chromospheric structures of flares and sunspot images, together with the coronal structures by X-ray and radio observations. The Solar Flare Telescope is designed to perform simultaneous observations of continuum and Hα images, magnetic and velocity fields with an unique system (Ichimoto *et al.* 1991). Four telescopes are attached on a common mount for this purpose. Two telescopes with 20-cm diameter objective lens are assigned to the magnetic and velocity field observations. In this paper we give an outline of the method to obtain the magnetic/velocity fields and discuss possible sources of errors in the magnetic data.

INSTRUMENTS

Figure 1 shows the optics layout of the two telescopes. Each telescope observes the solar active region with the field of view of 345 × 323 arcsec.

A 1/8Å passband Lyot filter at 6303Å is used to measure the vector magnetic field. A KD*P modulator is equipped at the entrance window of the filter to switch between left- and right-hand circularly polarized lights. By rotating a turret housing two quarter wave plates and a transparent glass plate in front of the filter, linear and circular polarizations are measured alternatively in the blue wing of the FeI 6303Å line.

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A 1/5Å passband Lyot filter at 6337Å is used for the measurements of the photospheric velocity field. The filter contains two KD*Ps at the entrance and at the exit windows. The KD*P at the exit window modulates the wavelength of the transmission peak of the filter to get the Doppler signal of the FeI 6337Å line. The circular polarization can also be measured in both wings of the line by switching the KD*P at the entrance window. In this way we can take the longitudinal magnetic field. The data obtained with this system are used not only for the study of the photospheric plasma flow, but also for calibrating the vector magnetic field data obtained with the other telescope.

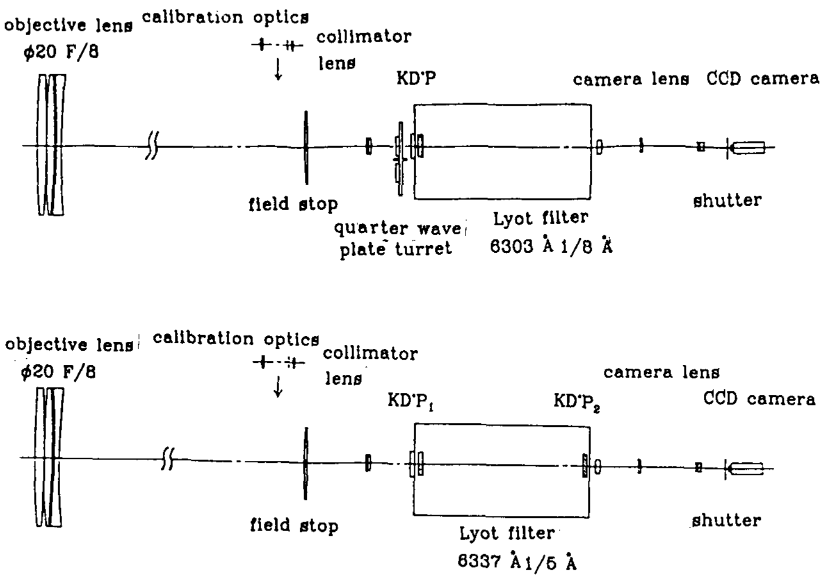

Fig. 1. Optics layout of the Flare Telescope for the measurements of magnetic (upper) and velocity (lower) fields.

In both systems, the data are obtained with a commercial CCD camera (512x480 pixels). Images are digitized with 8-bit accuracy and integrated on the image processing units for 128 times, and finally are recorded on DAT cassett tapes after real time dark and flat field corrections.

CALIBRATION

In order to know the magnetic field strength from the observed polarization degree, we made LTE transfer calculations of line profiles following the formulation by Unno(1956) and Wittmann(1974). For the calculations, we assume a uniform magnetic field in the standard atmosphere of Holweger and Muller (1974). From those calculations we obtained the following results besides the relations between the field strength and the observed quantities.

1) The most suitable wave length of the filter for measuring the vector magnetic field is −80mÅ from the center of the 6303Å line. At this wave length, the linear polarization is most sensitive to the transverse magnetic field in the weak magnetic field region of the photosphere. The circular and the linear polarization signals saturate at the magnetic field strengths of about 1800G and 1700G, respectively.

2) The accuracy of the CCD measurement after summing 128 frames is empirically found to be 0.16%. This corresponds to the detection limits of about 7 Gauss for the longitudinal and 48 Gauss for the transversal magnetic fields.

3) The polarization signal changes roughly 10% due to the wavelength shift of the filter by 10mÅ. It implies that the filter temperature should be stabilized within the accuracy of 0.03°C to keep the magnetic field error to be less than 10%. It also implies that the 5-minute oscillation will cause an error of the magnetic field strength of about 10% due to the spectral line shift.

4) If a temperature modification of 1000K is applied to the reference atmosphere, the polarization degree changes by 20% for the same magnetic field strength.

5) For 6337Å measurement, the longitudinal magnetic field and the velocity field should be derived simultaneously from the polarization degree and the Doppler signal, because the polarization and Doppler signal depend on the velocity and magnetic field strength in conbination.

The errors estimated for the vector magnetic field observation are summerized in Table 1. A calibration software for removing the systematic errors is being developed.

Table 1
Error Estimation of the Vector Magnetic Fields

			$B_{//}$	$B_{\perp}$	
< random errors >					
· accuracy of CCD measurement .	Δp=0.16 % (128 integration)	<--->	~7G	~48G	(weak area)
· guiding error ... atmospheric disturbance	Δp~3 % (max.in spot)	<--->	~130G	~ 210G (very large in cloudy sky)	(spot area)
< systematic errors >					
· wavelength shift					
+ 5-min. oscillation .... (500m/s)	Δλ=10mA	<--->	~10%	~10%	(weak area)
+ temperature drifts of the .. Lyot filter (±0.01℃)	Δλ= 3mA	<--->	~3%	~3%	(")
· atmospheric model	ΔT=1000K	<--->	~20%	~20%	(spot area)
· magneto-optical effect	U:Q~1:10	<--->		Δθ~4°	
· KDP, wave plate alignment ...	Δθ<1°	<--->		Δθ<1°	
· scattered light	Δp~15 %	<--->	~15%	~4%	(weak area)

The observation system was almost completed in July 1992, and we are now taking a set of vector magnetic field and velocity field every 3 minutes. Figure 2 shows an example of the vector magnetic field observed on August 18, 1992.

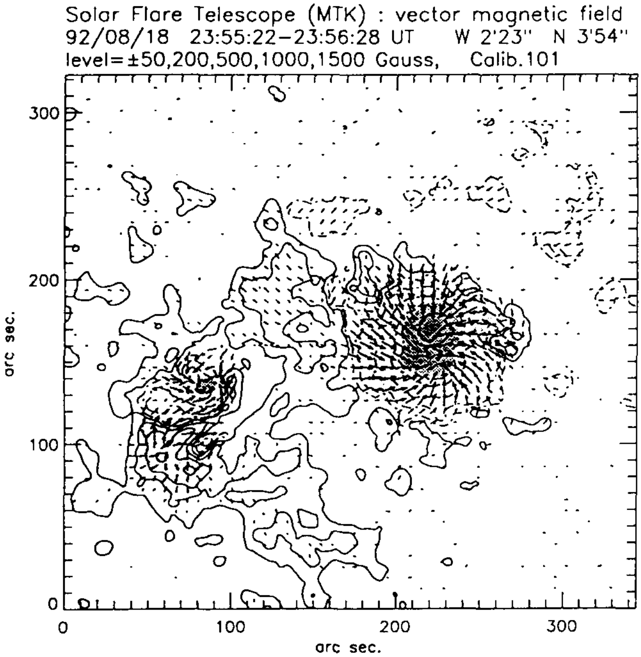

Fig. 2. Vector magnetic field obtained on August 18, 1992. The north is at the top and the east is to the left.

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