Bull. Astr. Soc. India (2007) **35**, 697–704

CHAIN-project and installation of the flare monitoring telescopes in developing countries

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Abstract. The Flare Monitoring Telescope (FMT) was constructed in 1992 at the Hida Observatory in Japan to investigate the long-term variation of solar activity and explosive events, as a project of the international coordinated observations programme (STEP). The FMT consists of five solar imaging telescopes and one guide telescope. The five telescopes simultaneously observe the full-disk Sun at different wavelengths around H-alpha absorption line or in different modes. Therefore, the FMT can measure the three-dimensional velocity field of moving structures on the full solar disk without the atmospheric seeing effect. The science target of the FMT is to monitor solar flares and erupting filaments continuously all over the solar disk and as many events as possible and to investigate the relationship between such phenomena and space weather. Now we are planning to start a new worldwide project called as "Continuous H-alpha Imaging Network (CHAIN)-project". As part of this project, we are examining the possibility of installing telescopes similar to the FMT in developing countries with cooperative help by the United Nations. We have selected Peru as the candidate country where the first oversea FMT will be installed, and are beginning to study the natural environment, the seeing conditions, the proper design of the telescope for Peru and the training and education programme of operating staff, etc.

Keywords : Sun : flares, shockwaves, filaments, prominences, coronal mass ejections, solar-terestrial relations

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1. Introduction

The Hida Observatory has three solar telescopes, i.e., the Domeless Solar Telescope (DST), the Solar Magnetic Activity Research Telescope (SMART), the Flare Monitoring Telescope (FMT) and the two nighttime telescopes, i.e., the 60 cm reflector and the 65 cm refractor. Our main fields of research and education are solar physics, solar astro-plasma physics, solar-system physics and solar-stellar physics. In recent years, studies of the environmental variation of the solar-terrestrial system has become quite important in the field of solar physics, because solar active phenomena have been recognized as the main sources of space disturbances, and studies of solar active phenomena are indispensable basis of space weather prediction. In our observatory, such studies have been done in two complementary ways. One way is to perform detailed studies of solar events with high spatial-resolution imaging, spectrum measurement with high wavelength- resolution and multi-wavelength spectra measurement at the DST. However, its field of view (FOV) is limited to 6 arcmin, it is not enough for spatially large-scale events. The other way of our studies is the solar full-disk observations with the FMT and the SMART. With the FMT we do simultaneous observations of the full-disk Sun at different wavelengths around H-alpha absorption line or in different modes (Fig.1), and we do simultaneous observation of the full solar-disk vector magnetic field on the photosphere and full-disk chromosphere with the SMART (UeNo et al. 2004). Therefore, the FMT and SMART particularly suitable for studying large-scale active phenomena on the whole solar-disk which are directly connected with the space weather. In other words, observational studies with these two telescopes can contribute well and to our understanding of space weather environment.

As space weather research can be advanced more efficiently with 24-hour continuous observations of solar events, it is planned to create a world-wide observational network with FMT-type telescopes distributed all over the earth called as "Continuous H-alpha Imaging Network (CHAIN)-project". As part of the CHAIN-project, we are examining the possibility of installing FMT-type telescopes in developing countries with cooperative help by the United Nations. More precisely, we are considering Peru as the country where the first oversea FMT will be installed.

In the following, we introduce characteristics of the FMT, some scientific results and our plans of installing the FMT in Peru.

2. Characteristics of the FMT

The Flare Monitoring Telescope (FMT) was constructed in 1992 at the Hida Observatory in Japan to investigate the long-term variation of solar activity and explosive events (Kurokawa et al. 1995). It has been one of the fruitful projects of the international coordinated observations program (STEP) that started from 1991. The FMT consists of five solar imaging telescopes and one guide telescope that have a simple and compact design. We show the optical system and specifications of the telescopes in Fig. 2. Optical

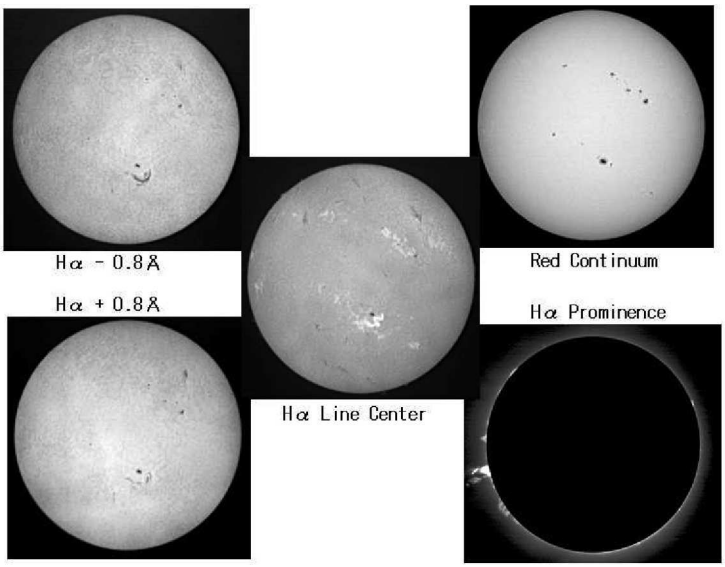
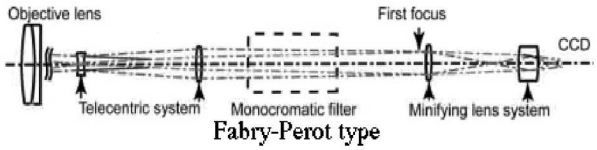


Figure 1. Sample images obtained with five kinds of telescopes of the present FMT at Hida observatory.

layout is almost common to the five telescopes. The images were obtained every two seconds and recorded with time-lapsed video from 1992 to May 2006. From September 1996, we installed a digital data recording system of 1 min cadence. Moreover, in May 2006, we introduced a new digital CCD camera system (Takenaka System Co.LTD/ digital full frame shutter camera FC1500CL), so that pixel resolutions and digital bit depths were improved (2.1 arcsec/pix, 10 bit) and the exposure-time was reduced (4 ms). Normally, the time cadence for obtaining a series of digital images with this new system is 20 seconds. Simultaneous exposures among five cameras is within 64 ns in principle. Therefore, the five telescopes can almost simultaneously observe the full-disk Sun at different wavelengths around H-alpha absorption line or in different modes (H-alpha line center, H-alpha -0.8 Å, H-alpha + 0.8 Å, continuum light, prominence mode with an occulting disk). In other words, the FMT can measure the three-dimensional velocity field of moving structures on the full solar disk without seeing errors.

The data that have been obtained with the FMT during 15 years are now publicly opened on the web (http://www.kwasan.kyoto-u.ac.jp/general/facilities/fmt/database_en.html). At present, this data archive consists of the following four contents:

1. Event lists Monthly compiled lists: Physical characteristic and classification are given for every event. GIF-images are shown by clicking the record.
2. MPEG-movies of outstanding events: Classified into categories of flares, filament eruptions, surges and prominence eruptions.



Optics	
Diameter	64 mm
F-ratio	30
Focal length	1920 mm
Spatial resolution	1.8 arcsec

Filters	
Telescope name	Central / Passband
Ha center	6562.8 / 0.42 A
Ha +0.8 A	6563.6 / 0.5 A
Ha -0.8 A	6562.0 / 0.5 A
Continuum	6100 / 60 A
Prominence	6562.8 / 3 A

Figure 2. Optical system and specifications of the FMT.

3. Real-time images: Four kinds of the latest images (except continuum images).
4. All the digital raw images for download

3. Representative scientific results with the FMT

In this section, we introduce two kinds of typical examples of the studies done with FMT data. The first theme is "investigation of the three- dimensional velocity field of large-scale filament eruptions and their relationship with coronal mass ejections (CMEs)". Making the best use of the feature of the FMT, Morimoto & Kurokawa (2003a, 2003b) measured 3-D velocity fields of disappearing solar filaments. Then, they distinguished whether each active filament really erupted or not by analyzing time-variations of their radial upward velocities (Fig. 3) and investigated the relationship with coronal structures or CMEs. They clearly showed that erupting filaments, which escaped from the sun, almost perfectly corresponded to appearances of coronal arcade structures and CMEs. The future subject in this theme will be the investigation of the correlation between "the velocity strength and direction of the eruption" and "the strength of effects of the corresponding CMEs on the earth".

The second theme of the typical study is "Moreton waves that accompany flares". Eto et al. (2002) and Narukage et al. (2002) detected many Moreton waves in the chromosphere that accompanied solar flares by investigating time-evolutions of the Doppler velocity fields around flares obtained with the FMT. The Moreton wave has theoretically been considered as the cross section in the chromosphere of a shockwave generated by a strong solar flare. Narukage et al. actually investigated the relationship between the Moreton wave and coronal wave observed in X-ray with Yohkoh-satellite (Fig. 4a). They found the consistency among speeds, timings and directions (Fig. 4a,b). Moreover, they confirmed that their speeds indeed correspond to one of the expected MHD shockwaves. By the way, more than half the number of Moreton waves that were found in the past

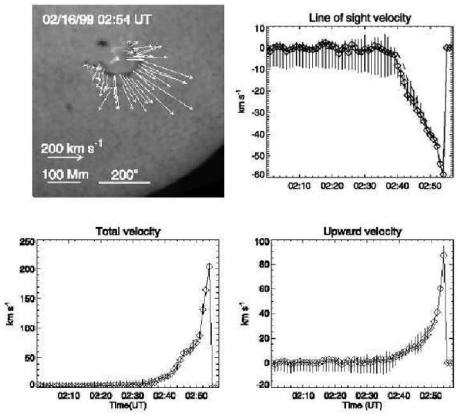


Figure 3. Transversal velocity field distribution and time-variation of the Doppler velocity, total velocity and upward velocity of the disappearing filament observed with the FMT (from Figs 7 & 9 in Morimoto & Kurokawa 2003a).

have been discovered with the FMT. Therefore, we can say that the FMT is a very useful instrument for inferring the characteristics of the shockwaves that are generated by solar flares and propagate to space.

4. CHAIN-project and the plan of the FMT in Peru

Though the FMT is a simple and small-diameter telescope, it is a powerful instrument for studying the large scale solar active phenomena that can affect the space environment as discussed above. Therefore, we want to monitor more solar flares and erupting filaments continuously as many as possible by such characteristic telescopes. We are now planning to execute "Continuous H-alpha Imaging Network (CHAIN)-project" as part of the CAWSES (Climate And Weather of the Sun-Earth System) project by distributing several similar telescopes all over the world. Two groups of the telescopes are candidates for network members. The first group is made up of the existing H-alpha solar full-disk telescopes. Staff of our observatory have begun to contact ground-based observatories in China, France etc. The second group is formed by newly installed H- alpha multi-wavelength telescopes. As for this group, we are examining the possibility of installing the telescopes in developing countries with aids from the United Nations. This is not only to increase the number of flare-monitoring locations, but also to encourage the education and study of the solar- terrestrial physics in the developing countries. This project is also being pushed by a new space weather project in Japan entitled "Basic Study of Space Weather Predictions" under the CAWSES programme (Shibata and Kamide, 2007 (in preparation)).

We have already selected Peru as the first candidate where the oversea FMT will be

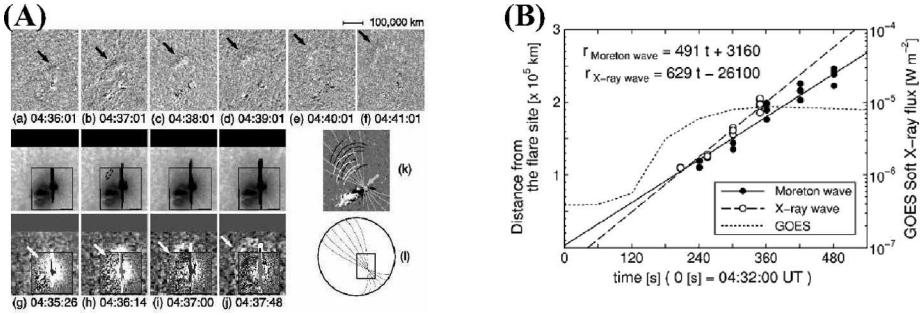


Figure 4. Relationship between the Moreton wave observed with the FMT and the coronal wave detected with Yohkoh Soft X-ray telescope. (a) Time-evolution and direction of each wave. (b) Timing and propagating speed of each wave. (From Figs 1 & 2 in Narukage et al. 2002).

installed, because the time difference between Japan and Peru is 14 hours and a telescope in Peru can almost cover Japanese nighttime. Moreover, Peru has kept deep connections with Japan and especially with our university for 50 years. The relationship between Japan and Peru is concretely shown in the paper of Dr. Ishitsuka in this book.

Currently, there are three candidate locations where a new FMT will be installed in Peru. Each position on the map of Peru is shown in Fig. 5. In general, there are quite a lot of fine days in Ica city compared with that of Huancayo city. Moreover, the educational and studying environment of the campus of Ica University is comparatively excellent. For example, a coelostat for measuring the solar spectra will also be installed in this campus in 2007 with the support by National Astronomical Observatory of Japan, and the campus ground will be developed and provided as the "Solar Station" by Ica University (cf. Dr. Ishitsuka's paper). Therefore, we are currently considering that the campus of Ica University will be the first candidate location. We will actually visit all of these sites in January 2007. After our actual inspection, we will finally decide the location for the FMT in Peru.

On the other hand, we still have a lot of items in various aspects that should be investigated in advance, such as the seeing condition and the height of the turbulence due to the heat haze at the candidate site, the best structure of the housing of the telescope, the efficient method of remodeling the telescope matching with the latitude of Peru, the best combination of the observing wavelengths, the appropriate software for data processing under the computer environment at Ica University, training and skill-up of the local staffs, etc. The biggest issue is a large amount of monetary budget. This problem will also affect future plans to install other FMTs in other developing countries. We must select minimum necessary functions for oversea's FMTs and study the way of cutting down the expenses.

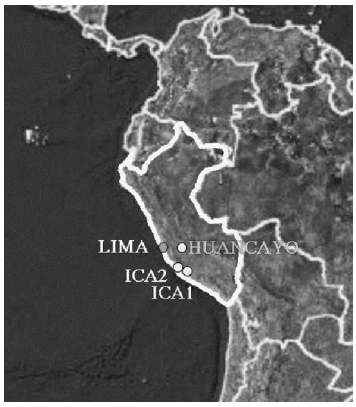


Figure 5. The positions of candidate sites for installing the FMT in Peru besides Lima, the capital city of Peru. ICA1: Ica University, ICA2: new educational astronomical observatory, HUANCAYO: Huancayo Observatory. (Background map: from Google Earth).

5. Conclusion and future subjects

In recent years, we recognize the scientific and social importance of the studies of the environmental variations of the solar-terrestrial system (space weather studies) in the field of solar physics. Though the FMT at Hida observatory is simple and a small telescope, it can measure the three-dimensional velocity field of the full disk Sun without seeing influence. Therefore, it is a powerful instrument for studying physical properties of large-scale active phenomena on the whole solar-disk that are directly connected with the space weather. In order to obtain more data of the solar flare and erupting filaments continuously, we are planning to install the first oversea's FMT in Peru as part of CHAIN-project with cooperative help from the United Nations. The present first candidate site in Peru is the campus of Ica University. Currently, we are investigating various items, aiming to start the operation of the FMT in Peru by the end of 2009, as follows:

- The seeing conditions and the height of the turbulence due to the heat haze at the candidate site
- The best structure to house the telescope (protecting it from sand storms)
- The efficient method of remodeling the telescope matching with the latitude of Peru
- The way of cutting down required expenses and finding the funds
- The best combination of the observing wavelengths (improvement of the accuracy of the velocity estimation)
- The appropriate software for data processing under the computer environment at Ica Univ.

- The training and skill of the local staff (for daily operation, maintenance and management of the software)

We hope to install the FMT in Peru successfully and also to extend the CHAIN network by promoting FMT's in other countries in future.

Finally, we greatly appreciate the very kind support given for this project and for our talk in this meeting by staff of IHY, United Nations and Dr. J.K. Ishitsuka, Dr. M. Ishitsuka from Instituto Geofisico del Peru (IGP).

This work was supported by a Grant-in-Aid for the 21st Century COE "Center for Diversity and Universality in Physics" from the Ministry of Education Culture, Sports, Science and Technology (MEXT), and by a Grant-in-Aid for Creative Scientific Research of the MEXT "Basic Study of Space Weather Prediction" (17GS0208 PI: K. Shibata).

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