

## International Collaboration and Academic Exchange of the CHAIN Project in this Three Years (ISWI Period)

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**Abstract** We will introduce contents of international collaboration and academic exchange of the CHAIN project in recent three years (ISWI period). After April of 2010, we have not obtained any enough budget for new instruments. Therefore, we have not been able to install new Flare Monitoring Telescopes (FMT) in new countries, such as Algeria. On the other hand, however, we have continued international academic exchange through scientific and educational collaboration with mainly Peru, such as data-analysis training, holding scientific workshops etc. Additionally, in this year, King Saudi University of Saudi Arabia and CRAAG of Algeria have planned to build a new FMT in their university by their own budget. Therefore, we have started some collaboration in the field of technical advices of instruments and scientific themes etc. Moreover, Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) also offered us participation in the CHAIN-project. We would like to continue to consider the possibility of academic collaboration with such new positive developing nations, too.

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**Keywords:** CHAIN project, Flare Monitoring Telescope, multi-wavelength H-alpha imaging, solar flare, filament eruption, Moreton wave, UV radiation, international collaboration, capacity building, ISWI

### 1. Introduction

The purposes of CHAIN Project (Continuous H-alpha Imaging Network Project) are (1) reinforcement of observations of the solar activity by formation of an international network of ground-based solar observations, (2) observation and study of filament eruptions, shock waves (Moreton waves) with solar flares and variation of UV radiation on the full-disk of the Sun in order to understand and predict the change of space-weather environment from the Sun to the Earth, and (3) international spread, academic exchange and promotion of the space-weather research including developing countries. (UeNo et al. 2007, 2009, 2010)

As for the formation of the international ground-based solar observation network, currently, main stations of the CHAIN project as of May 2012 are as follows:

1. Hida Observatory in Japan
2. National Ica University, Peru

In Hida Observatory, we are using the Solar Magnetic Activity Research Telescope (SMART) that was installed at Hida Observatory in 2003 (figure 1) for this purpose. (UeNo et al. 2004) This telescope daily observes H-alpha multi-wavelength full-disk chromospheric images. On the other hand, in National Ica University, the FMT (Flare Monitoring Telescope) that also simultaneously observes full-disk solar chromosphere at multi-wavelength around H-alpha (Kurokawa et al. 1995) is working since March 2010 (figure 2).

So, we can observe solar explosive phenomena on the full-disk Sun continuously for about 20 – 22 hours per one day, and we can measure physical parameters,

such as 3D velocity field, density and temperature, of erupted plasma by analyzing the data obtained with these telescopes.

In order to cover all 24 hours for continuous monitor of the Sun all year around, we need one more station around Africa or Middle East at least (figure 3). Therefore, we have progressed cooperation with Algeria and Saudi Arabia for this purpose.

### 2. FMT at National Ica University in Peru

The 1st oversea FMT of CHAIN project was installed at National Ica University in Peru in March 2010 with cooperation of Geophysical Institute of Peru (IGP) and Ica University. The latitude of this station is  $-14^{\circ} 11'$ , the altitude is  $\sim 400$  m, the annual precipitation is about 0 mm, the temperature is  $10 - 27$  degree C, and averaged humidity is about 20 %.

After the installation of the FMT in Peru, Peruvian young researchers and students have performed routine observations with the FMT (figure 4) and we have done capacity building activities, such as lectures, technical and scientific training, holding scientific data analysis workshops, as we describe in section 5 of this paper.

### 3. Cooperation with Algeria and Saudi Arabia

CHAIN Project originally aims to install FMT like telescopes around the world, but it is not easy having funds for that. Though the FMT is not so expensive compared with other professional solar telescopes, it is never cheap. The total cost is about 600 thousand USD including optical filters, CCD cameras and fee of transfer and installation etc. We have continued to make efforts for obtaining funds mainly in Japan for

installation of new FMT in Algeria as 2<sup>nd</sup> oversea main station during ISWI period. However, it did not succeed.

However, in 2012, two institutes in Algeria and Saudi Arabia began to consider the possibility of installing FMT by their own funds.

**3.1. Contribution of CRAAG in Algeria**

Centre de Recherche en Astronomie, Astrophysique et Geophysique (CRAAG) in Algeria has three scientific departments as shown in figure 5.

The department of astronomy and astrophysics aims at the construction of a new educational astronomical observatory in Aures area (the northern part of Algeria) because of deterioration and the light pollution of the current Alger Observatory. The solar monitoring observation with the FMT telescope is also considered as one important ability of this new observatory.



Figure 1 Solar Magnetic Activity Research Telescope (SMART) at Hida Observatory, Japan

On the other hand, Tamanrasset Observatory of the department of geophysics and seismology also has hope to install some solar-observation instruments in the observatory for the purpose of improving the scientific activity.

Kyoto University of Japan could not obtain appropriate fund for building the FMT for Algeria during ISWI period. Therefore, in 2012, CRAAG began to consider the possibility of installing FMT by their own

funds. In near future, they will hold a future-planning symposium in which the installation-site of the FMT will also be decided finally. Kyoto University will also perform scientific and technical advice to CRAAG in this symposium.



Figure 2 Flare Monitoring Telescope (FMT) at National Ica University, Peru

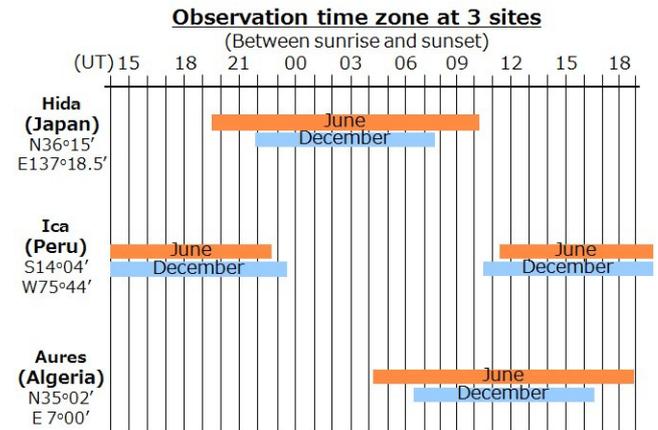


Figure 3 Time zone that each site can observe the Sun. If we have only two stations of Japan and Peru, there is a few hours blank around 10 UT. The 3<sup>rd</sup> station is needed for continuous monitor of solar activities.

**3.2. Contribution of King Saud University in Saudi Arabia**

King Saud University (KSU) in Saudi Arabia has a 6.6m astronomical dome on the roof floor of a building in the university. In this dome, they have an old 15cm refractor telescope (made by Carl Zeiss). However, it is not installed any filters and it does not perform multi-wavelength observation of the Sun. Therefore, they decided to replace this refractor telescope with the FMT by their own fund.

In December of 2012, the open tender will be done. After about 10 months from the decision of the agency, the new FMT will be installed at KSU. In this process, Kyoto University has also performed scientific and technical advice to them.

This site will also be one of stations that can cover the blank between Japan and Peru.

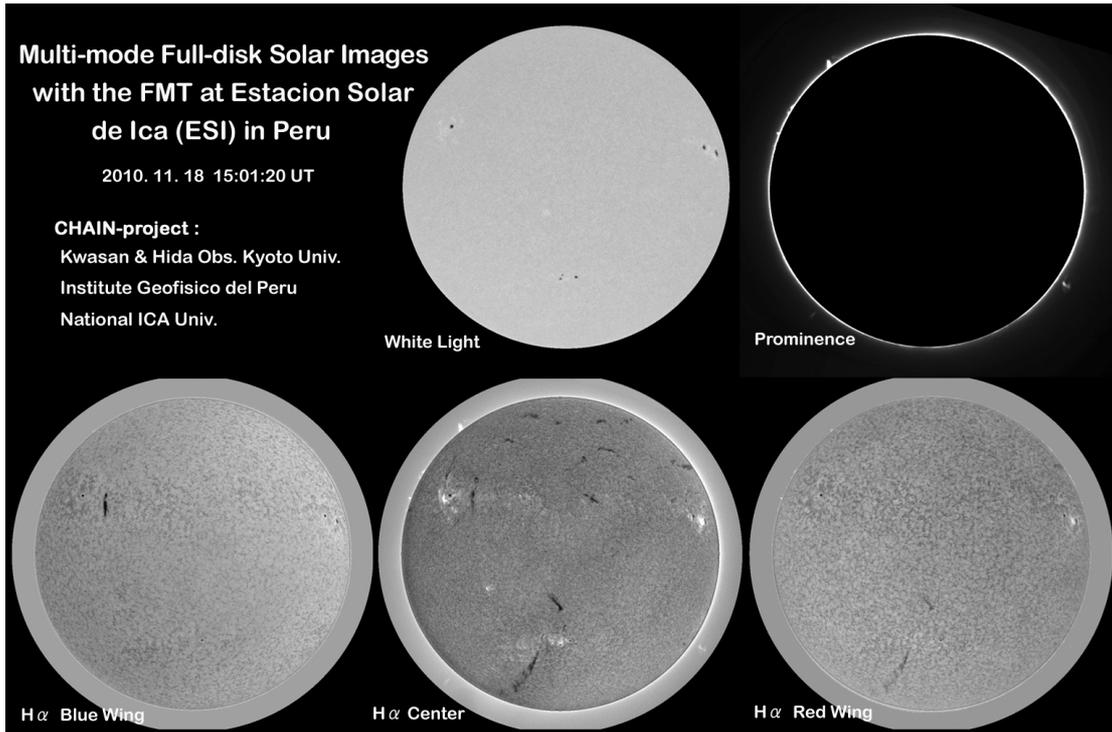


Figure 4 Example of multi-mode full-disk solar images with the Flare Monitoring Telescope (FMT) at National Ica University, Peru

### The Situation of Algeria/CRAAG (Centre de Recherche Astronomie Astrophysique et Géophysique)

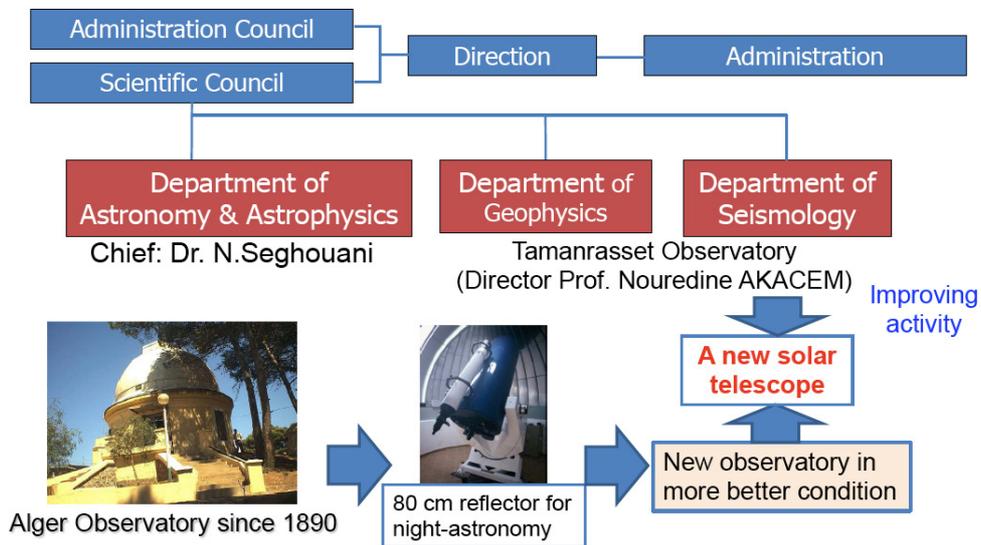


Figure 5 Organization and situation of CRAAG in Algeria

#### 4. Other Candidate Countries for Future Collaboration

Since IHY and during ISWI, the CHAIN project has been receiving proposals from some countries and institutes that are interested in participation in our project. We show such 12 candidate institutes for future collaboration with classifying in the following three groups.

1. Candidate sites that has multi-wavelength solar telescope or some other kinds of instruments:

- Helwan Observatory, Cairo, Egypt (Spectrograph)
- Huairou Solar Observatory, China (Solar imaging telescope, sometimes multi-wavelength)

2. Candidate sites that has some solar telescope but at only one wavelength:

- National Space Agency of Malaysia
- Tanjung-sari Solar Observatory, Indonesia
- Bosscha Observatory in Indonesia
- Bangalore Association for Science Education, India
- Research Center of Astronomy and Geophysics, Mongolia
- King Abdul-Aziz University, Saudi-Arabia

3. Candidate sites that does not have any solar telescope:

- Jawaharlal Nehru University, India
- Universidad Nacional Autonoma de Mexico, Mexico
- Southern Space Observatory (SSO) in Brazil
- Space and Upper Atmosphere Research Commission (SUPARCO) Space Sciences Division in Pakistan

As for the 2<sup>nd</sup> group, their instruments are desired to be improved so that they can observe the Sun at multi-wavelength in order to fill our scientific requirement. For the 3<sup>rd</sup> group, FMTs are required to be newly installed, if they hope to participate in this project in the field of solar observation. However, as we described in the section 3, it is currently difficult for us to provide such instruments to these institutes because of lack of fund.

On the other hand, viewed from the aspect of academic exchange, we consider that we can promote the following cooperation and collaboration after this:

- Training of solar observation and its instrument by sending or inviting researchers or students.
- Training of data analysis and cooperative scientific researches by using existing data.
- Participation in international workshop, summer school etc. together.

#### 5. Capacity Building

During ISWI and also during IHY, we have emphasized on capacity building activities in order to spread researches of solar physics and space weather and to increase collaborators for scientific themes of the CHAIN project.

The first item is lectures. We have performed several lectures about solar physics and space weather in Peru, Algeria and Saudi Arabia as follows:

- Jan. 2007 at Ica University and IGP in Peru
- May 2008 at CRAAG in Algeria
- Jun. 2008 at Ica in Peru
- Mar. 2010 at Ica in Peru
- May 2011 at Riyadh in Saudi Arabia

The second item is technical trainings. For example, we invited Peruvian young researchers to Hida Observatory in Japan in Jul. 2009 and performed technical instruction about solar observation method, maintenance method of solar telescopes, camera controlling software, data archiving and analysis software. On the other hand, when we installed the FMT to Peru in Mar. 2010, we also performed such instruction again to more Peruvian young researchers and students (figure 6).



Figure 6: Technical instruction and training at Ica University in Peru in Mar. 2010.

The third item is scientific training. In June and October, November of 2010, we sent an assistant teaching staff to Peru from Japan and performed scientific training of Peruvian students and young researchers. The subjects of this program were

- Acquisition method of calibration data and calibration method
- Calculation of physical parameters from multi-wavelength solar images and scientific analysis
- Lectures of solar physics and space weather.

The last item of our capacity building is holding scientific data-analysis workshops. We held the following three workshops in the ISWI period.

- The 1st FMT Science Workshop on 22 – 26 Nov. 2010 at Ica University in Peru (<http://esi.igp.gob.pe/FMTworkshop/>)
- The 2nd Japan and Peru Data Analysis Workshop on 20 – 31 Jul. 2011 at Hida Observatory and National Astronomical Observatory (NAOJ) in Japan (figure 7) (<http://www.kwasan.kyoto-u.ac.jp/CHAIN/WS/2011Jul/>)
- The 3rd Japan and Peru Data Analysis Workshop on 10 – 15 Mar. 2013 at Hida Observatory in Japan (<http://www.kwasan.kyoto-u.ac.jp/CHAIN/WS/2013Mar/>)

The purposes of these workshops were as follows.

- - To bring together the prospective user community of the FMT.
- - To explore current and future science targets of solar observations.
- - To progress actual data analysis of filament eruptions and shock waves associated with solar flares obtained with the FMT.
- - To get all analyzed results in shape of scientific papers.

A remarkable point is that young researchers in host country (Peru) began to attend plural international meetings and give scientific talks by themselves in the ISWI period as the results of such workshops.

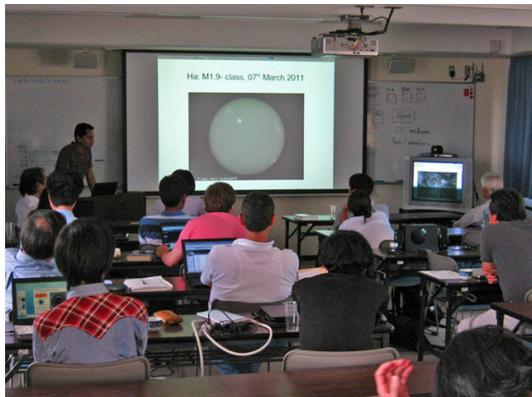


Figure 7: The 2<sup>nd</sup> Japan and Peru data analysis workshop in 2011.

## 6. Scientific Collaboration

Finally we briefly introduce current three scientific themes of the CHAIN project.

### **The 1<sup>st</sup> theme is “3D velocity field measurement of eruptive phenomena”.**

We can calculate physical parameters of floating and moving features on the chromosphere by applying “cloud model fitting” to multi-wavelength solar chromospheric images observed with SMART and FMT.

We especially focus on the 3D velocity field (figure 8) among the physical parameters to understand the process of growth and propagation of coronal mass ejection (CME).

We investigate relationship between filament eruptions and other typical turbulent phenomena in the space. The goal of this theme is the prediction of geo-effectiveness of CMEs from information of observed characteristics of filament eruptions on the Sun.

This theme was the most important subject of the three scientific workshops mentioned in section 5.

### **The 2<sup>nd</sup> theme is “shock wave detection (Moreton waves)”.**

Shock waves are also very important phenomena that determine intensity and timing of large disturbances of space weather and that accelerate SEP.

The FMT and SMART is quite effective to detect intersections of shock waves on the solar chromosphere that are called as Moreton waves (Moreton 1960, Uchida 1968, Narukage et al. 2002).

However, for the flares that have almost the same intensity, sometimes they are accompanied by Moreton waves, sometimes they are not accompanied by them. Therefore, the current our subject is what is the difference between such two kinds of flares, for example, the difference of impulsiveness of flares, speed of erupted filaments, direction of erupted filaments etc. At present, we have progressed statistical investigation of inclination angle and absolute speed of erupted filaments for the flares with and without Moreton waves (figure 9).

This theme was also treated as an important subject in the above-mentioned three scientific workshops.

### **The 3<sup>rd</sup> theme is “estimation of solar UV radiation”.**

Solar radiation is also one of very important element for understanding the change of space weather. Especially solar UV around from 50 to 140 nm has strong influence for the ionosphere of the earth.

One of good index of the change of ionosphere is the “geomagnetic Solar daily Quiet variation (Sq)”. It basically changes obeying the solar activity due to the variation of solar UV radiation.

Because actual UV observations from satellites started just after around 1995, geophysicists often use solar radio flux (F10.7), instead of UV radiation, for investigating long-term variation of Sq. However it makes some errors when they distinguish solar origin

component and terrestrial component of the Sq variation.

Therefore, we are trying to reproduce long-term solar UV radiation by using long-term solar chromospheric full-disk images obtained with CHAIN's solar telescopes and older photographic observations (figure 10).

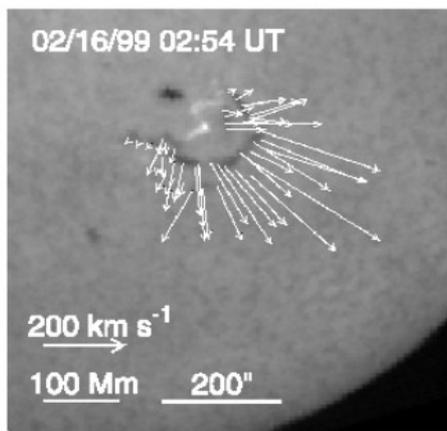
Our current two main subjects are

1. Contribution of solar radiation to long-term variation of Sq
2. Reason of unusual fall of Sq at solar minimum phase around 2008.

We consider that this theme will become an influential candidate as a new subject of the future international cooperative studies especially with researchers in the field of geophysics. For example, in 2012, the SUPARCO of Pakistan made proposal to CHAIN-project to cooperatively study on the following themes:

- Study of Maximum Electron Density NmF2 at Karachi and Islamabad during Solar Minimum (1996) and Solar Maximum (2000)
- Variations in F2-layer parameters and comparison with IRI over Pakistan for deep solar minimum
- Ionospheric variability of low and mid latitude for solar cycle 22 and 23
- Solar cycle effect on coupling of neutral and ionized species at F2 altitude

### Transversal Velocity Field



### Time Evolution of the Doppler Velocity at the top of the filament

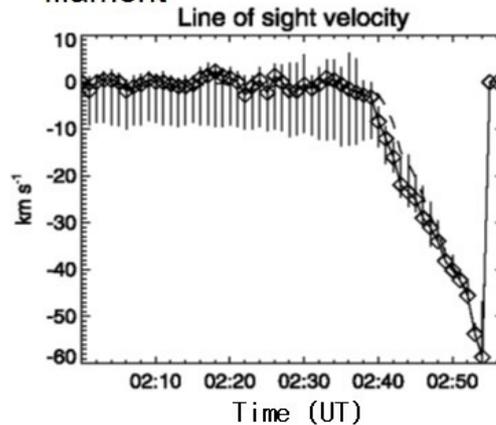


Figure 8: Example of calculation of 3D velocity field and its time-evolution for an erupting filament (Morimoto and Kurokawa, 2003)

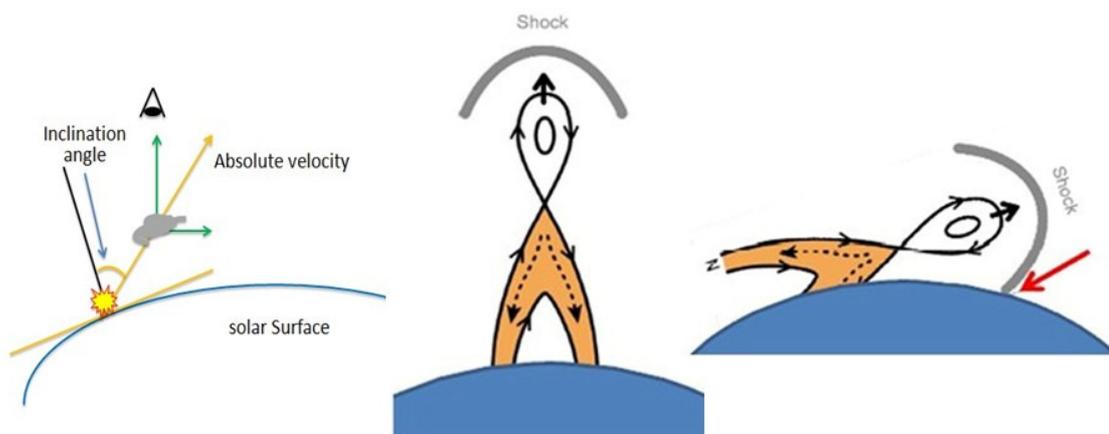


Figure 9: we have progressed statistical investigation of inclination angle and absolute speed of erupted filaments for the flares with and without Moreton waves.

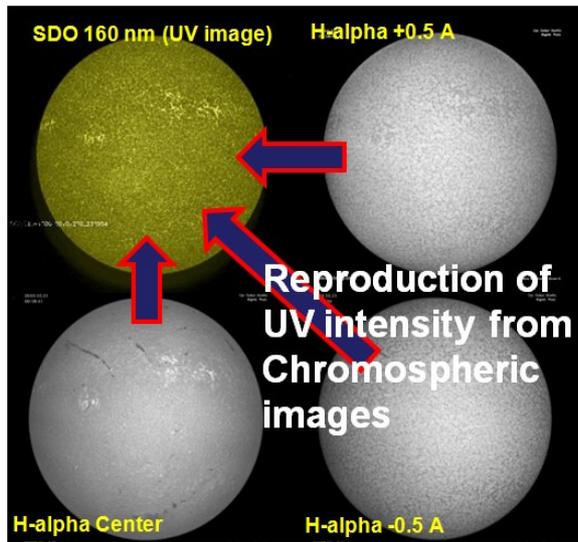


Figure 10: We are trying to reproduce solar UV radiation by using solar chromospheric full-disk images obtained with CHAIN's solar telescopes.

## Conclusions

From IHY and now, during ISWI, we are having significant advances on CHAIN project objectives; instrument deployment, capacity building and scientific collaboration.

Concerning instrument array, we installed the 1st oversea FMT to Peru/Ica on March 2010. On the other hand, installation of the 2nd oversea FMT to Algeria is not achieved yet because of lack of fund. However, CRAAG of Algeria plans to build the FMT by their own funds. Moreover, KSU of Saudi Arabia also started a plan to build a FMT in their university by their own funds.

On the other hand, we have performed many kinds of capacity building activities, such as lectures, technical training, scientific education, holding scientific data-analysis workshops, presentations at international symposiums.

Moreover, we have promoted international cooperative researches, focusing on three themes: (1) 3D velocity field measurement of eruptive phenomena, (2) shock wave detection, (3) estimation of solar UV radiation.

Regarding future activities of this project, in the field of instruments, we have currently no fund for some new instruments for more new stations, though we will continue to make efforts. However, we intend to provide technical training and advising on instruments, operation, data calibration of the FMT or of their own instruments for cooperative institutes, for example, by sending Japanese researchers and engineers, or by inviting staffs and students of each country.

On the other hand, in the field of academic exchange, we hope to continue above-mentioned capacity building activities for main stations and expand the activities to other cooperative countries including developing nations that are important existence for spreading this CHAIN project.

## 8. Acknowledgements

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