“Ground-based observation of the solar activity by Continuous H-Alpha Imaging Network (CHAIN) and outline of the analysis of solar flares and shock waves”

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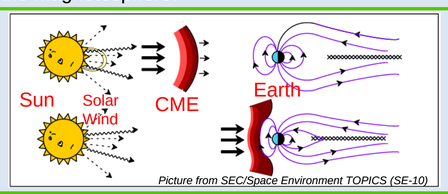
Abstract:

Kwasan and Hida Observatories has promoted “**Continuous H-Alpha Imaging Network (CHAIN)** project” whose aims are continuous monitor of all large-scale solar active phenomena, measureing those physical conditions and progress of space weather researches by internationally distributing “**Flare Monitoring Telescopes (FMT)**” that are compact solar telescopes for monitoring full-disk Sun. Under this project, we installed a FMT in the solar station of National Ica University in Peru in March 2010 and have continued to observe solar activities using also **Solar Magnetic Activity Researching Telescope (SMART)** in Hida Observatory.
On the other hand, we held two international data-analysis workshops in Peru 2010 and in Japan 2011 using the data of solar active phenomena obtained with these solar telescopes. After that, we have continued international cooperative researchs and academic exchanges. In this poster, we introduce the aims and outline of this project and some examples of scientific researches on solar flares, filament eruptions and shock waves.

1. What is the “CHAIN” ?

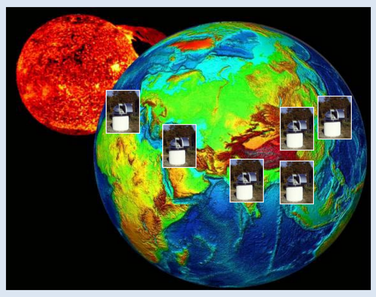
The situation of the space-weather environment around the earth greatly depends on 3-D structures and velocities of the Coronal Mass Ejection (CME), shockwave and solar-wind disturbance around the magnetosphere.



However, it is still difficult to predict whether solar active phenomena would have large geoeffectiveness or not, just when the solar phenomena occur on the solar surface.

It is a very important thing that we accurately observe filament eruptions and structures of shock waves on the Sun, in order to accurately grasp and predict the structures, velocities and evolutions of the CMEs and shock waves in the solar-terrestrial space.

Observations of filament eruptions and shock waves with the mutli-wavelength full-disk solar telescope play an important role for the space weather research.



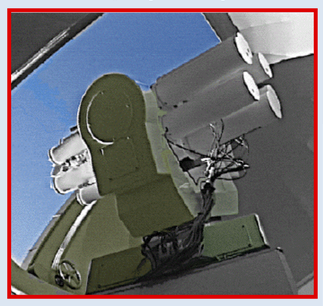
The Purposes of the CHAIN:

Reinforcement of observations of the solar activity for the purpose of understanding and predicting the change of space-weather envirionment from the Sun to the Earth.

The formation of an international network of ground-based observations of filament eruptions and shockwaves (Moreton wave) with solar flares on the full-disk Sun for the purpose of **knowing physical parameters** of all solar active phenomena.

International spread, academic exchange and promotion of the space-weather research including developing countries.

The main instrument is the Flare Monitoring Telescope(FMT)

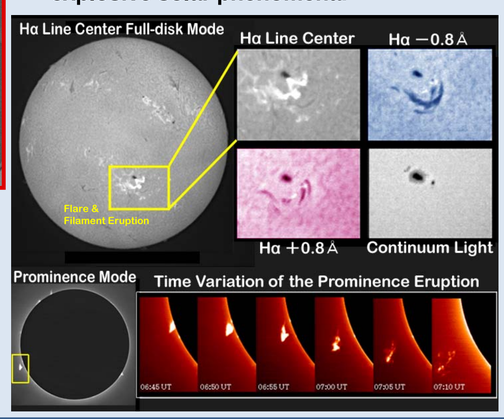


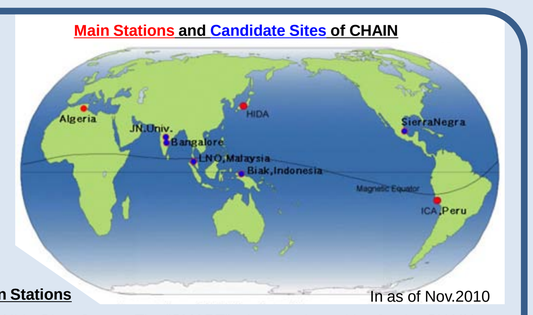
The original FMT was constructed in 1992 in Hida Observatory to investigate the long-term variation of solar activity and explosive events.

It has been a part of the Solar Terrestrial Energy Program (STEP 1990-1997) .

The FMT simultaneously observes full-disk solar chromosphere at multi-wavelength.

So, we can measure pysical parameters , such as 3D velocity field, density and temperature…, of explosive solar phenomena.





Main Stations In as of Nov.2010

* Hida Obs., Japan : The “SMART” telescope is working for the CHAIN.
* Ica Univ., Peru : The 1st oversea FMT was already installed.
* Aures, Algeria : The 2nd oversea FMT is planned to be installed.

Classification of other candidate sites

- Candidate Site who has (will have) multi-wavelength solar telescope or some other completed instruments:
  * King Saud University in Saudi-Arabia (Under planning)
  * Helwan Observatory, Cairo, Egypt (Spectrograph)
- Candidate Site who 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
- Candidate Site who does not have any solar telescope:
  * Jawaharlal Nehru University, India
  * Universidad Nacional Autonoma de Mexico, Mexico
  * Southern Space Observatory (SSO) in Brazil

2. Scientific Aims of the CHAIN Project

2.1 3D Velocity Field Measurement

The FMT performs multi-wavelength observation of solar chromosphere. So, we can calculate physical parameters of floating and moving features on the chromosphere by using “cloud model fitting”.

Especially 3D velocity field is the important parameter for understanding the process of growth and propagation of “coronal mass ejection (CME)”.

Cloud Model Fitting

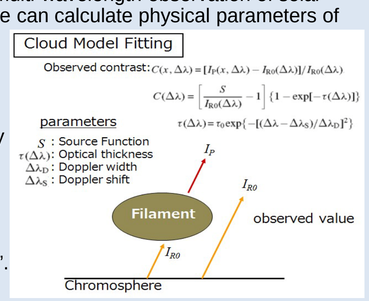
Observed contrast: $C(x,\Delta\lambda)=[I_P(x,\Delta\lambda)-I_{R0}(\Delta\lambda)]/I_{R0}(\Delta\lambda)$

$$C(\Delta\lambda)=\left[\frac{S}{I_{R0}(\Delta\lambda)}-1\right]\{1-\exp[-\tau(\Delta\lambda)]\}$$

parameters

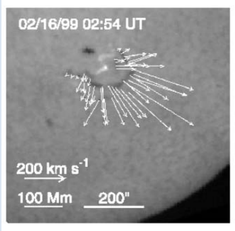
$$\tau(\Delta\lambda)=\tau_0\exp\{-[(\Delta\lambda-\Delta\lambda_S)/\Delta\lambda_D]^2\}$$

S : Source Function
$\tau(\Delta\lambda)$: Optical thickness
$\Delta\lambda_D$: Doppler width
$\Delta\lambda_S$: Doppler shift

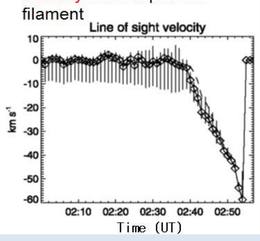


Example of calculation of 3D velocity field and its time-evolution for an erupting filament

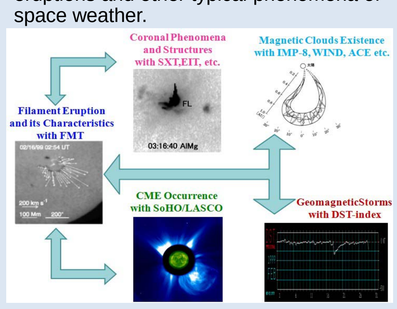
Transversal Velocity Field



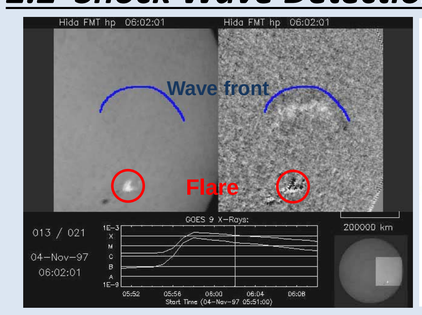
Time Evolution of the Doppler Velocity at the top of the filament

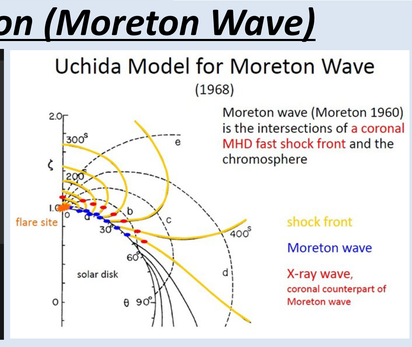


We are trying to investigate relationship between the characteristics of filament eruptions and other typical phenomena of space weather.



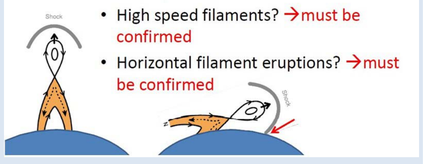
2.2 Shock Wave Detection (Moreton Wave)





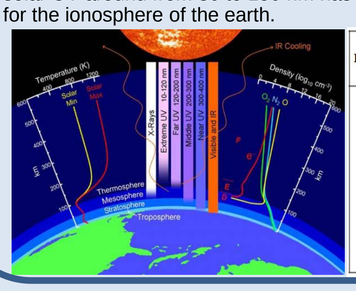
Shock waves are also very important phenomena that determine intensity and time of large disturbances of space weather.
The FMT is quite effective to detect intersections of shock waves on the solar chromosphere (Moreton waves).
For the flares that has almost the same intensity, however, sometimes they are accompanied by Moreton waves, sometimes they are not accompanied by them. So, we must investigate the following subjects:

- What is different between flares “with” and “without” Moreton waves?
- Impulsive flares (GOES X-ray light curves are impulsive)? →must be confirmed
- High speed filaments? →must be confirmed
- Horizontal filament eruptions? →must be confirmed



2.3 Estimation of Solar UV Radiation

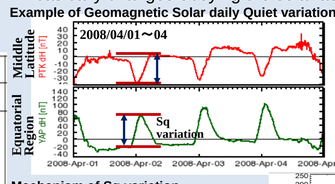
Solar radiation is also one of very important element for understanding the change of space weather. Especially solar UV around from 80 to 150 nm has strong influence for the ionosphere of the earth.



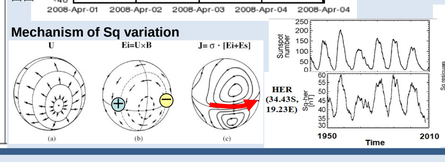
Element	Ionization Vp(eV)	λ(nm)
N_2	15.58	79.6
O_2	12.08	102.6
O	13.61	91.1
N	14.54	85.3
NO	9.25	134
H	13.59	91.2
He	24.58	50.4

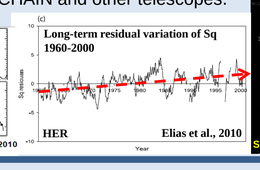
One of good index of the change of ionosphere is the “Geo-magnetic Solar daily Quiet variation (Sq)”. Though it basically changes obeying the solar activity, it is known that there are long-term small trend in the differences between Sq and solar-activity indices. In order to know this unknown true source of this trend, we have to know long-term solar UV variation. However, actually, UV observations started just after around 1995. So, we are trying to reproduce long-term UV radiation by using long-term solar chromospheric full-disk images with CHAIN and other telescopes.

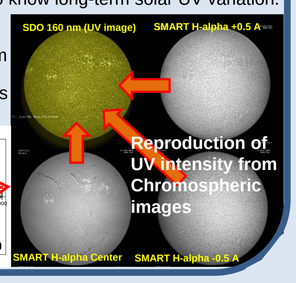
Example of Geomagnetic Solar daily Quiet variation (Sq)



Mechanism of Sq variation







3. Past Activities of the CHAIN Project

We have performed many kind of international academic and technical exchanges and “capacity building” activities to promote space-weather researches under the CHAIN project.

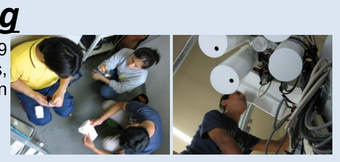
3.1 Lectures

- Jan. 2007 at Ica University in Peru,
- Jan. 2007 at IGP in Peru,
- May 2008 at CRAAG in Algeria,
- June 2008 at Ica in Peru
- Mar 2010 at Ica in Peru

3.2 Technical Training

Jan. 2007 at Lima, Peru

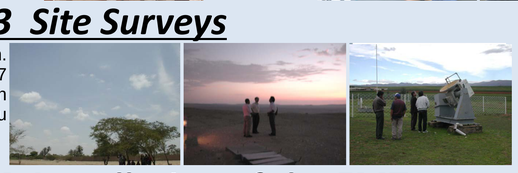
Jul. 2009 at Hida Obs, Japan



Mar. 2010 at Ica, Peru

3.3 Site Surveys

Jan. 2007 in Peru



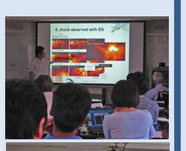
May. 2008 in Algeria

3.4 Installation of the FMT

Mar. 18th 2010 at Ica Univ. in Peru

3.5 Scientific Education at Observation-Site

A staff of Hida Obs trained Peruvian students and young researchers at Ica Univ in Peru, in **June** and **Octover – November** in 2010.



3.6 Scientific Data-analysis Workshops

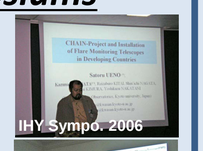
The 1st FMT Data Analysis Workshop in Ica, Peru

The 2nd FMT Data Analysis Workshop in Hida, Japan

3.7 Presentations at International Symposiums

-Dec. 2006 **IHY** Sympo. in Bangalore, India,
- Jun. 2007 **IHY** Sympo. in Mitaka, Japan,
- Oct. 2007 **CAWSES** Sympo. in Kyoto, Japan,
- Apr. 2008 Auresian Workshop in Batna, Algeria,
- May 2008 JpGU **IHY** International Session
- Jul. 2008 **AOGS** Sympo. in Busan, Korea,
- Nov. 2008 **IGY+50** Sympo. in Tsukuba, Japan,
- Jul. 2010 **CAWSES-II** Sympo. in Berlin, Germany
- Nov. 2010 **ISWI** Sympo. in Cairo, Egypt
- Oct. 2011 **ISWI** Sympo. in Abuja, Nigeria
- 2009-2011 JpGU / **CAWSES-II & ISWI** International session

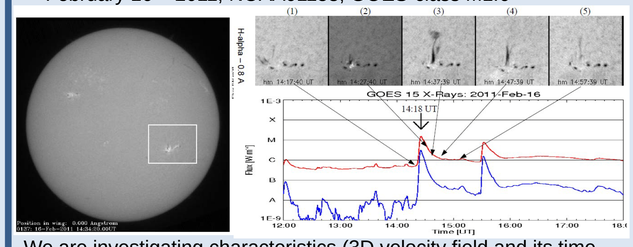
etc.



4. Examples of Scientific Researches

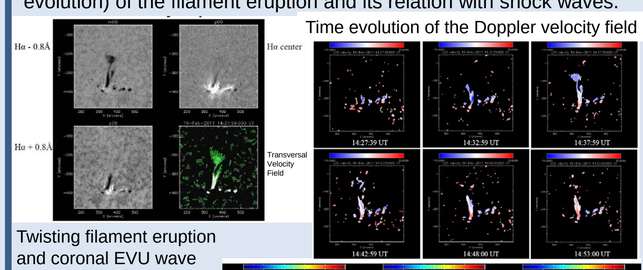
4.1 Flare on the Solar Disk

February 16th 2011, NOAA01158, GOES-class M1.6

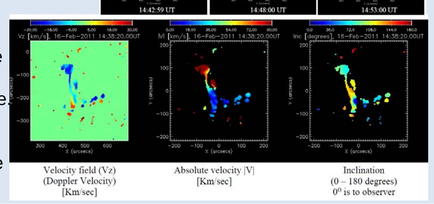


We are investigating characteristics (3D velocity field and its time evolution) of the filament eruption and its relation with shock waves.

Time evolution of the Doppler velocity field

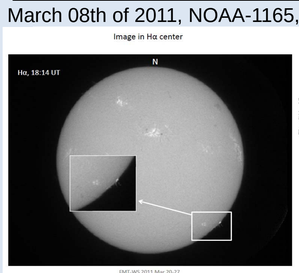


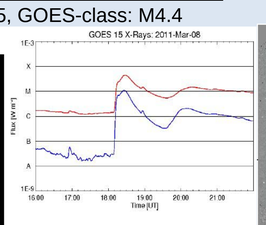
Twisting filament eruption and coronal EVU wave were detected. No clear Moreton wave, but, some filament motion was detected far from the flare. What is the relationship between the direction of the filament and structure of shockwave?



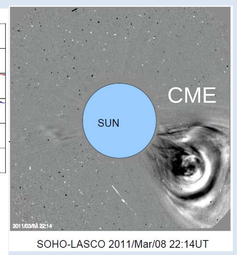
4.2 Flare on the Solar Limb

March 08th of 2011, NOAA-1165, GOES-class: M4.4



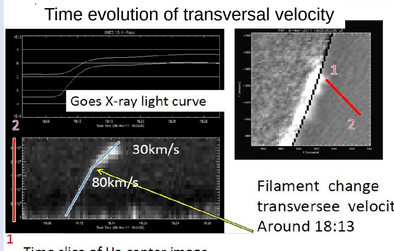


GOES Class: M4.4 - NOAA 1165
S17, W86



SOHO-LASCO 2011/Mar/08 22:14UT

Time evolution of transversal velocity



Filament change transversee velocit Around 18:13

AIA94 time slice
Peak of flare

Image of coronal loops

After collision, something propagate to higher atmosphere

18:12:19

18:15:00

18:10 Flare + filament eruption start
18:13 Filament change its direction
18:18 Filament disappear in Ha
18:28 Flare reach its peak

Filament eruption + collision with coronal loop generate loop expansion and CME that occurs several hour later (?)

4.3 Statistics of Shock Waves

The number of Moreton wave observed between 1997 and 2007 in the world → 27 events
(1: C class , 9 : M class , 17 : X class flare)
The FMT observed 20 events among them.

We have investigated absolute velocity and inclination angle of erupted filaments for the flares with Moreton waves.

Preliminary Result

Date	Flare Peak time	Position	NOAA AR	Class	Moreton wave and/or winking filament(*)	Inclination	Absolute Speed	Orientation
1997/11/03	04:38	S20 W13	8100	C8.6	MW	90	~60	NE
1997/11/04	05:58	S14 W33	8100	X2.1	MW & WF	90	130	N
1998/08/08	03:17	N17 E74	8299	M3.0	MW			
1999/02/16	03:12	S23 W14	8458	M3.2	MW & WF	70/30	130/180	NW/S
2000/03/03	02:14	S15 W60	8882	M3.8	MW			
2000/06/04	22:10	N21 E37	9026	M3.2	WF			
2000/06/15	23:43	N19 E19	9040	M2.0	MW	110	190	S
2000/07/16	06:14	S08 W25	9082	C3.8	MW	90	120	W
2001/04/10	05:26	S23 W09	9415	X2.3	WF			
2001/05/12	23:35	S17 E00	9455	M3.0	MW	70	>200	S
2001/05/13	03:04	S18 W01	9455	M3.6	MW	70	90	SW
2001/05/13	23:09	S15 W13	9455	C1.1	WF			
2001/05/21	03:20	N22 E08	9461	C9.0	WF			
2001/12/19	02:32	N09 E37	9742	C4.9	MW	90	>200	NE
2002/07/18	07:44	N19 W30	0030	X1.8	WF			
2002/08/22	01:57	S07 W62	0069	M5.4	MW			
2002/10/04	22:43	N13 E43	0139	M2.7	MW	130	120	NW
2003/05/27	23:07	S07 W17	0365	X1.3	MW	110/90	180/160	N/S
2004/11/03	03:35	N09 E45	0696	M1.6	MW			
2005/08/03	05:06	S13 E45	0794	M3.4	MW	90	>200	S

(MW: Moreton Wave, WF: Winking Filament)

- We analyzed the velocity fields about 11 filament eruptions that is observed by FMT between 1992 and 2006
- The average value of absolute velocity was 160km/s, and the direction of eruption was **almost horizontal**
- We will compare with filament eruptions not associated with Moreton wave

5. Summary & Future subjects

Uner the CHAIN project, in order to form international solar observation network, we installed the FMT to Peru in March 2010 and we plan to install the 2nd oversea FMT in Algeria. For the purpose of promoting space weather researches, we have proceeded cooperative studies with the people of related countries with cooperating with international programs, such as ISWI, CAWSES-II.

Through such international cooparations, we are especially analyzing physical characteristics of erupted filaments and shock waves that are generated by solar flares. By further proceeding these researches and study of estimation of solar UV radiation, we want to clear up relationship between solar active phenomena and changes of environment in the space and geomagnetosphere.