CHAIN project: Typical Solar Active Phenomena Obtained with CHAIN's Instruments and a New Solar Station in Saudi Arabia

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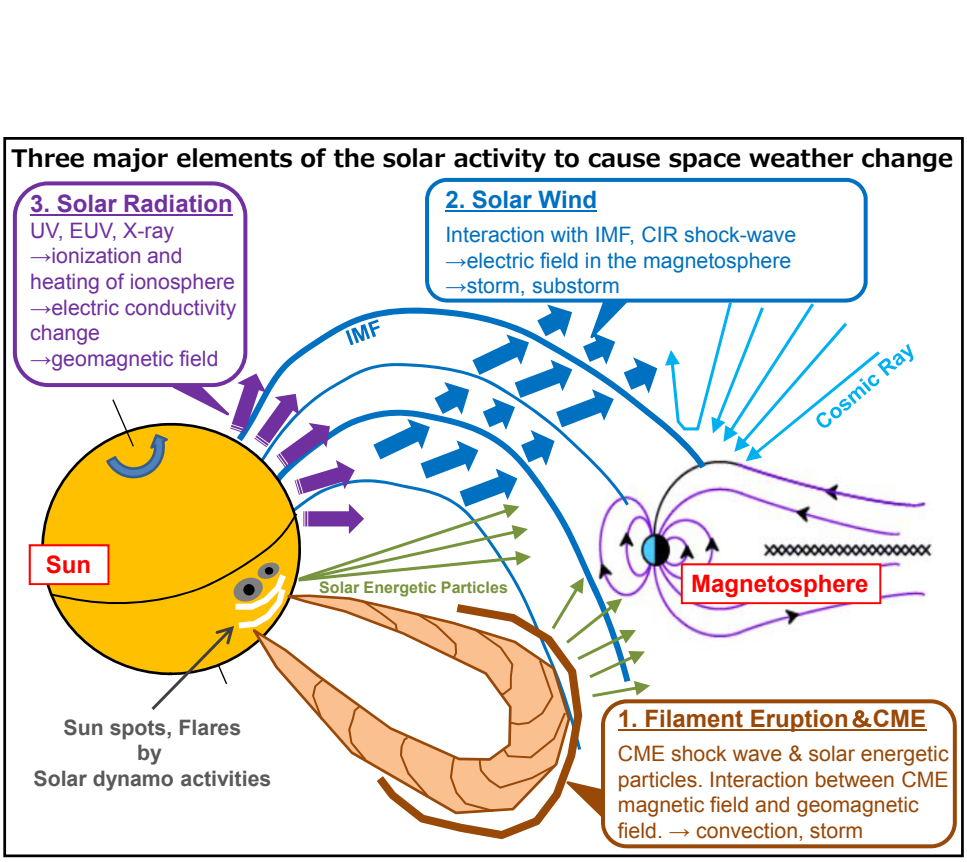
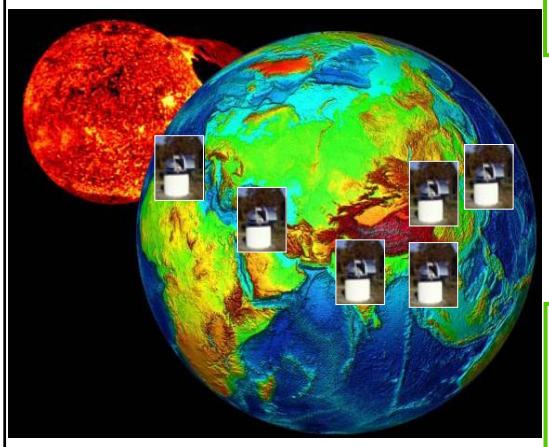


Observational & Scientific Themes of CHAIN Project

(**C**ontinuous **H**-**a**lpha **I**maging **N**etwork Project)



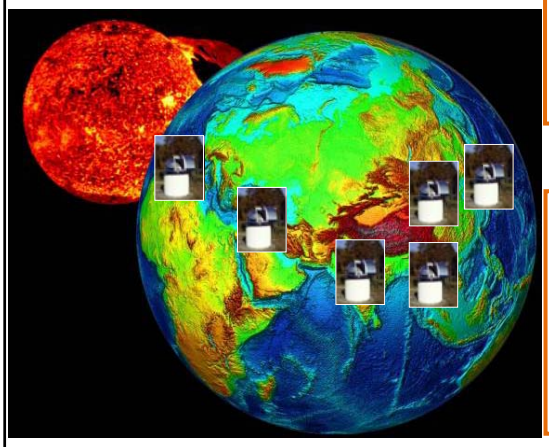
(1) 3D velocity field measurement of eruptive phenomena on the solar surface

(2) Detection of shock waves (Moreton wave) generated by solar explosive phenomena

(3) Estimation of solar UV radiation and comparison with ionospheric variation

Purposes of CHAIN Project under the ISWI program

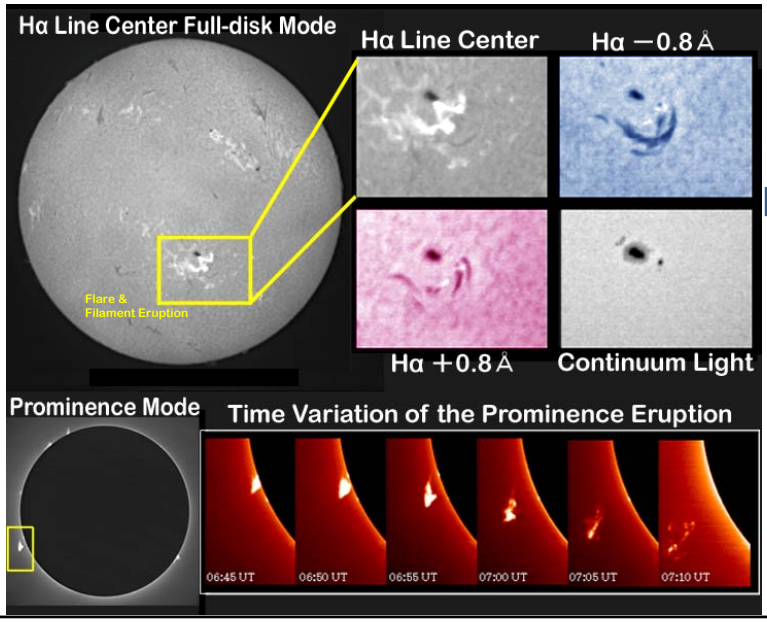
(**C**ontinuous **H**-**a**lpha **I**maging **N**etwork Project)



Reinforcement of **multi-wavelength H-alpha observations of the full-disk Sun** by formation of an international network of ground-based solar station

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

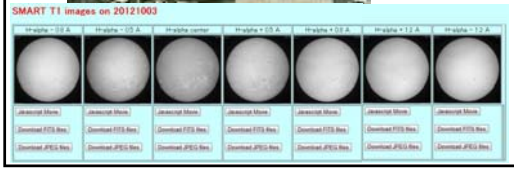
The largest observational characteristics of the CHAIN: Multi-wavelength imaging around H-alpha line



3-D Velocity Field

Main two stations during ISWI period 2010 – 2013

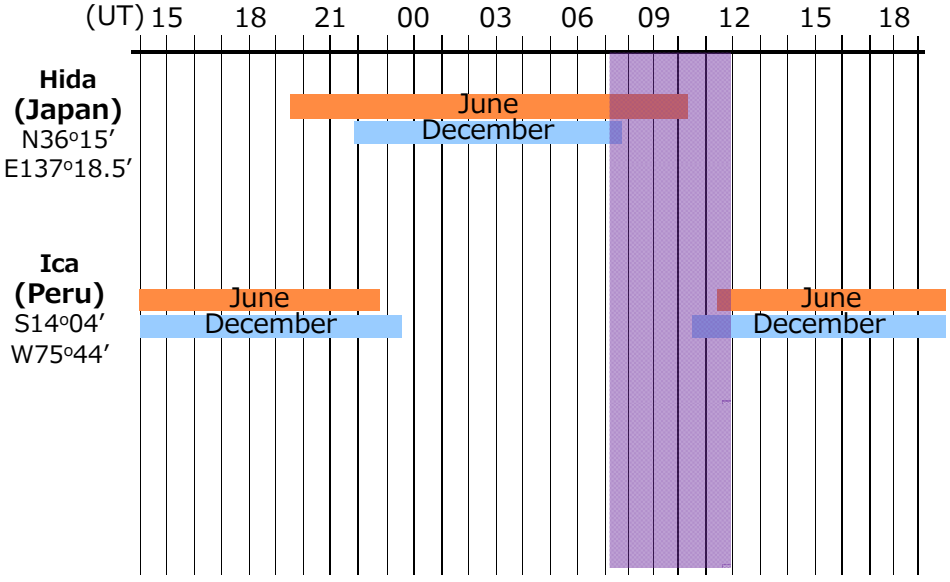
Hida Obs. Japan
SMART telescope
(2003 Oct. ~)



Ica Solar Station, Peru
FMT telescope
(2010 Mar. ~)

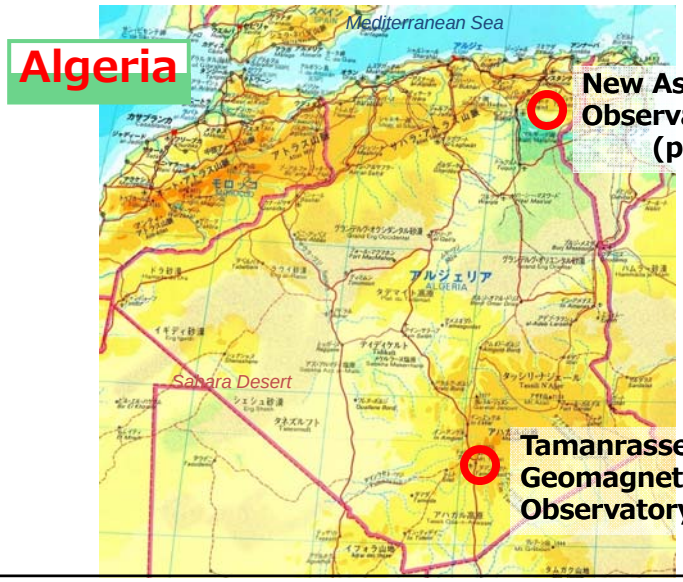
Observable time zone at main 2 sites

(Between sunrise and sunset)

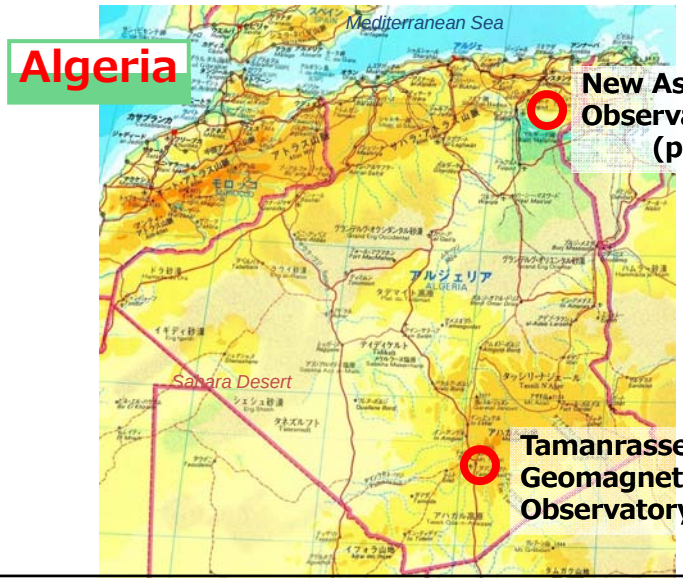


Between Japanese sunset and Peruvian sunrise, there is a blank time of a few hours around 10 UT. So, for the purpose of filling this blank time….

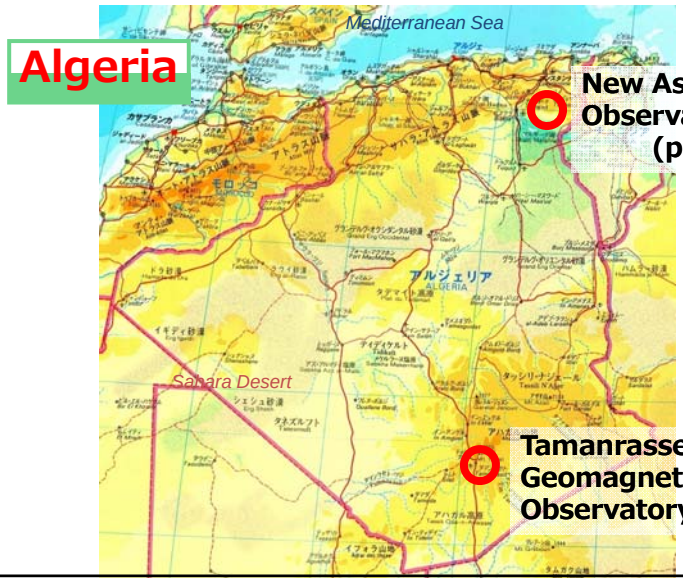
During ISWI period, we aimed at installing a Flare Monitoring Telescope in Algeria as the 3rd CHAIN station under collaboration with CRAAG (Centre de Recherche Astronomie Astrophysique et Géophysique).



We focused on two places from among several candidate sites and were investigating each merit & demerit.

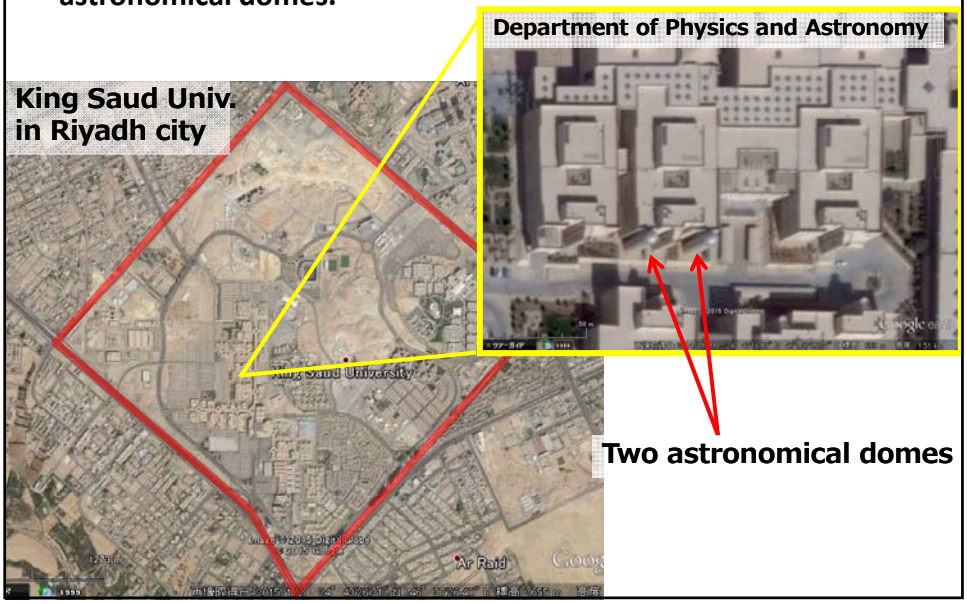


However, the installation of the telescope in Algeria is not implemented yet, because of mainly financial problems.



On the other hand, in 2011, King Saud University in Saudi Arabia also started a project to install the Flare Monitoring Telescope by their own budget and to participate in the CHAIN project.

King Saud Univ has very wide campus in the capital city Riyadh. The department of physics and astronomy has two 6.6m astronomical domes.



In the one dome, a telescope for solar observation in white-light are working.

In the another dome, a telescope for night astronomy was working.

However, nighttime observation in Riyadh city has became difficult due to the light pollution.

Therefore, they decided to replace this nighttime telescope with the Flare Monitoring Telescope and focus on the researches of solar activities and space weather.

December, 2014
Japanese telescope company and
Kyoto University installed
a new Flare Monitoring Telescope
to King Saud University
in Saudi Arabia

The building and astro-domes of the department of physics and astrophysics of KSU

Carrying materials in the astro-dome

Carrying the fork-mount of the FMT in the astro-dome

Assembling the FMT

Almost assembled FMT

The following systems were also setup and provided.

- Telescope-controlling PC and Camera-controlling PCs
- The data-analysis PC (including IDL and Solar Software)
- Data-storage system (RAID5)

Test of the function to track the Sun

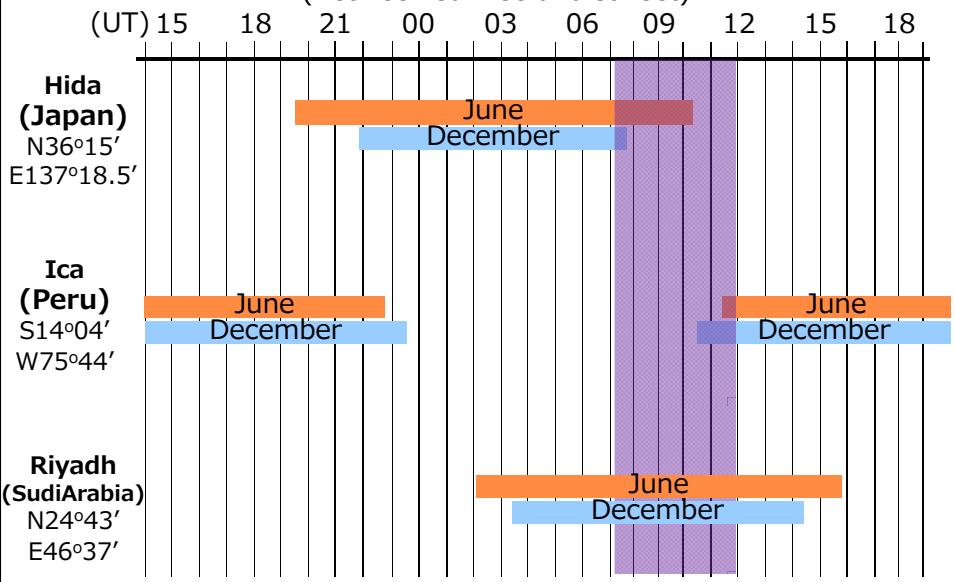
Installation of the data-analysis PC (including IDL and Solar Software) and data-strage system (RAID5)

Installation of the telescope-controlling PCs and camera-controlling PCs

At the end of March 2015, we will do more optical adjustment and training of operation & data-analysis for Saudi Arabian researchers.
After that, the daily solar observation can be started.

Observable time zone at the 3 sites

(Between sunrise and sunset)



After the observation in Saudi Arabia will be started, we can monitor the Sun for 24 hours continuously without blank time all year round, in principle.

Regarding the details,
please see the poster UN-03 by

Dr. Ahmed A. Ibrahim
(Physics and astronomy department,
King Saud Univ., Saudi Arabia)

Researches on solar activities using CHAIN's data

Ica Solar Station, Peru

The number of observed flares

Flare List 2010 at Ica					
GOES-CLASS					
2010	B	C	M	X	Total
Jan	NR	NR	NR	NR	0
Feb	NR	NR	NR	NR	0
Mar	0	0	0	0	0
Apr	0	0	0	0	0
May	0	1	0	0	1
Jun	0	0	0	0	0
Jul	1	1	0	0	2
Aug	1	0	0	0	1
Sep	0	2	0	0	2
Oct	2	3	0	0	5
Nov	13	2	1	0	16
Dec	1	0	0	0	1
TOTAL	**18**	**9**	**1**	**0**	**28**

NR: Not Registered

Flare List 2011 at Ica					
GOES-CLASS					
2011	B	C	M	X	Total
Jan	2	0	0	0	2
Feb	14	16	1	0	31
Mar	12	37	7	0	56
Apr	13	11	1	0	25
May	13	3	0	0	16
Jun	NR	NR	NR	NR	0
Jul	NR	NR	NR	NR	0
Aug	7	4	0	0	11
Sep	5	41	8	2	56
Oct	4	16	0	0	20
Nov	4	27	0	0	31
Dec	7	10	0	0	17
TOTAL	**81**	**165**	**17**	**2**	**265**

NR: Not Registered

Flare List 2012 at Ica					
GOES-CLASS					
2012	B	C	M	X	Total
Jan	1	5		0	6
Feb					
Mar	7	8	1	0	16
Apr	3	13	1	0	17
May	4	13	0	0	17
Jun	0	2	0	0	2
Jul	0	2	0	0	2
Aug	17	13	2		32
Sep	8	14	1		23
Oct	1				1
Nov	1	5			6
Dec	5	2			7
TOTAL	**47**	**77**	**5**	**0**	**129**

NR: Not Registered

International cooperative studies through capacity-buildings such as holding several data-analysis workshops including young researchers of developing countries:

(1) Relationship between filament disappearance and CME

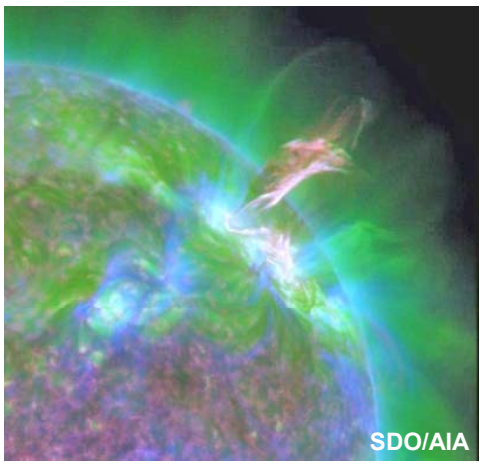
(2) Relationship between filament eruption and shockwave generated by solar flare

(3) Estimation of variations of the solar UV radiation

(1) Relationship between filament disappearance and CME

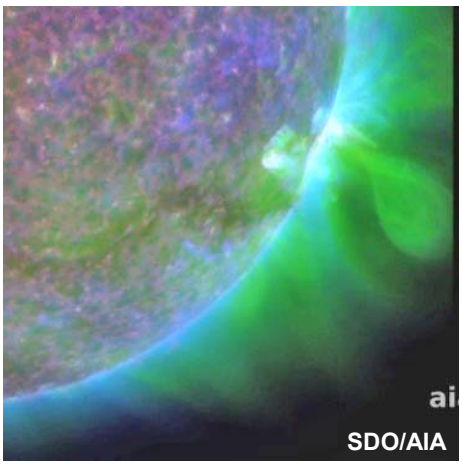
Roughly speaking, there are two types of CME.

1. CME that has an erupted filament



Generally rapid evolution

2. CME that does not have a filament

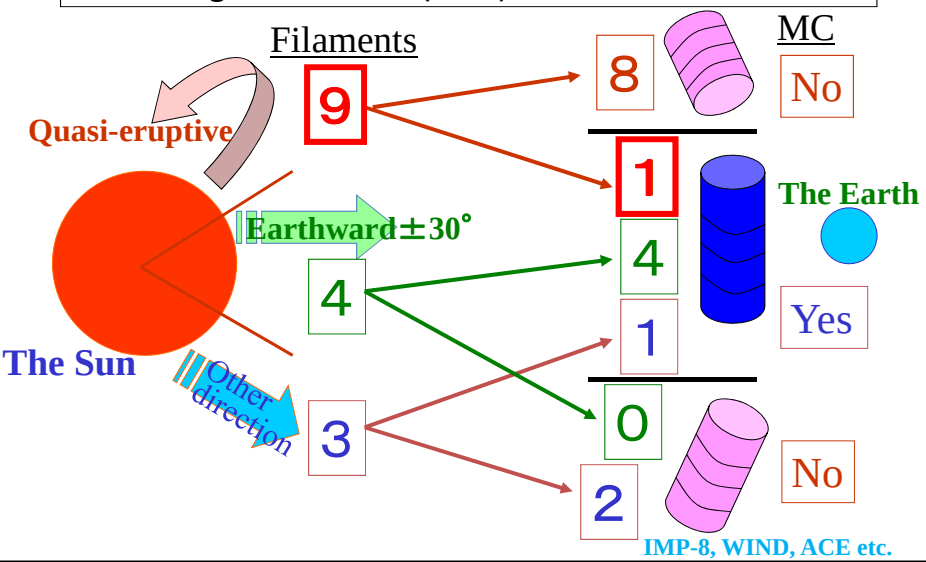


Generally slow evolution

(1) Relationship between filament disappearance and CME

Preliminary result of Morimoto & Kurokawa in 2001

Relation between disappeared filaments and Magnetic Clouds (MCs) that reach the Earth



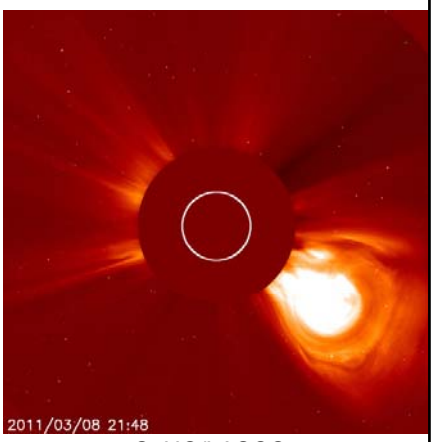
(1) Relationship between filament disappearance and CME

2011-03-08 M-class Flare
taken with the FMT in Peru

Image of full-disk solar chromosphere and AR11165 (S17-W88) obtained with the FMT. The flare started at 18:08 and reached its peak at 18:28.

CME

About 3 hours later



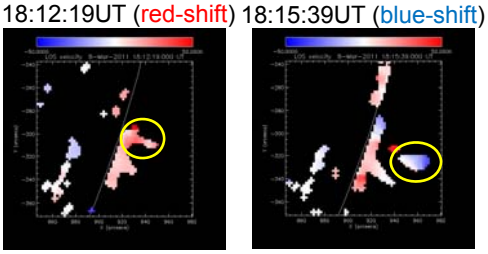
SoHO/LASCO

(1) Relationship between filament disappearance and CME

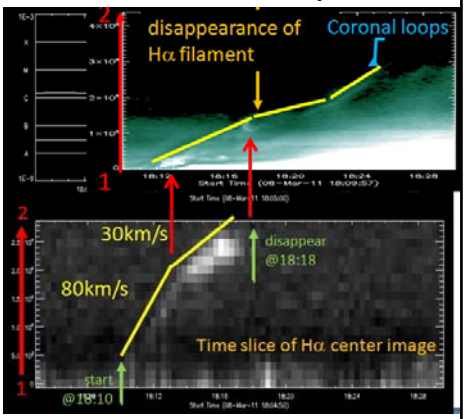
Maria V. GUTIERREZ (a Peruvian young researcher) et al. are investigating the case-study of this event and generating process of the CME.

Time evolution of the velocity field of the disappeared fiilament

18:12:19UT (red-shift) 18:15:39UT (blue-shift)

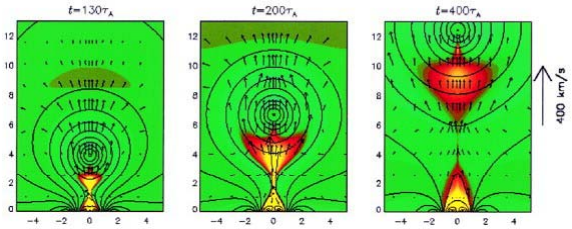


Time evolution of the height of the disappeared fiilament and coronal loops



(1) Relationship between filament disappearance and CME

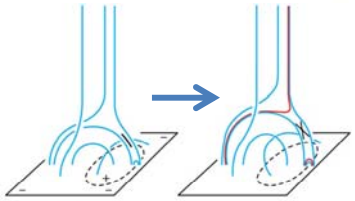
CME Models



Simple standard model

For example:
Chen & Shibata, 2000, ApJ

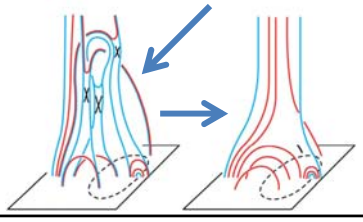
Rapid evolution
Directly related to filament eruption



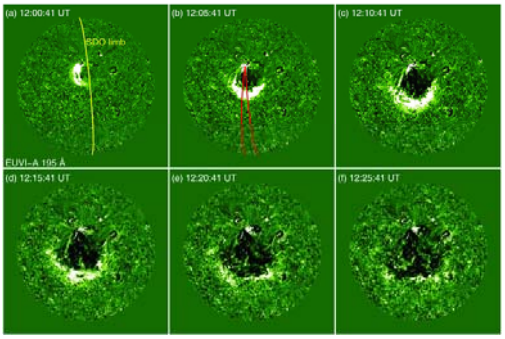
Blowout-jet model

For example:
Moore et al. 2010, ApJ

Multi-phased magnetic reconnection and **slower evolution**



(2) Relationship between filament eruption and shockwave generated by solar flare



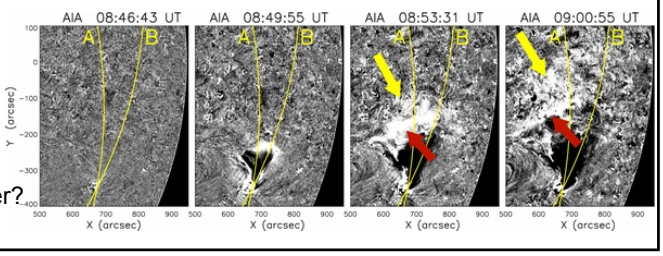
Two kinds of coronal shockwaves

← **EIT-wave:**
- Isotropic propagation
- Slow speed (a few hundred km/s)

↓ **EUV-wave:**
- Directional propagation
- High speed (several hundred km/s)

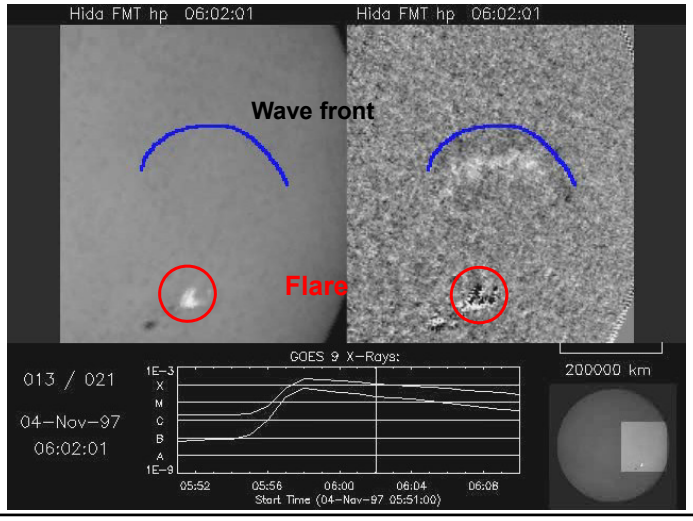
* What is the reason of the difference between these two kind of shockwaves?

* What is the difference of effects of these two kinds of waves on space weather?



(2) Relationship between filament eruption and shockwave generated by solar flare

The Flare Monitoring Telescope of CHAIN project is quite effective to detect intersections of shock waves (EUV-wave) on the solar chromosphere (Moreton waves).



Statistical study of relation between filament eruption and Moreton wave (Master thesis of Yamaguchi et al. 2014 Mar.)

Filament eruptions that are **accompanied by Moreton wave**

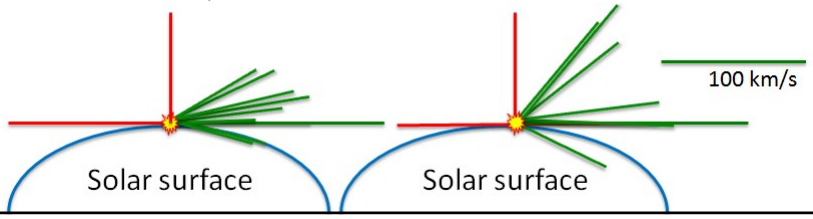
Date	Inclination Angle (°)	Absolute Velocity (km s^{-1})	moreton start time (UT)	filament start time (UT)
1997/11/4	0	150	05:57	06:04
1999/2/16	13	90	02:53	02:51
2000/3/3	9	100	02:11	02:20
2000/6/15	-15	60	23:37	23:38
2001/5/13	2	60	03:01	03:11
2001/12/19	30	60	02:30	02:36
2003/5/27	-15,25	70,80	23:01	23:01,23:09
2005/8/3	7	80	05:01	05:03

Filament eruptions that are **NOT accompanied by Moreton wave**

Date	Inclination Angle (deg)	Absolute Velocity(km/s)
1998/4/11	50	110
1999/6/1	50	90
2000/6/4	7	100
2001/11/20	-2	110
2002/2/4	-26	70
2002/4/4	0	160
2002/9/18	38	90

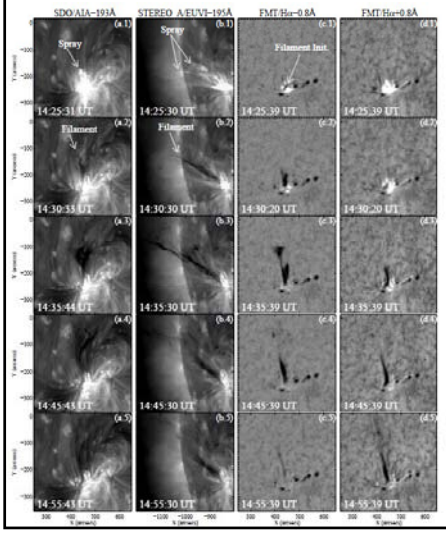
0～30° ～80 km/s

0～60° ～100 km/s



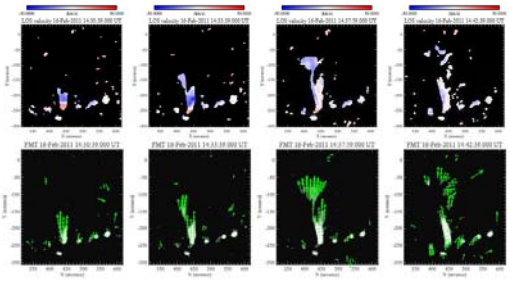
(2) Relationship between filament eruption and shockwave generated by solar flare

M1.6 class flare and filament eruption on 2011-02-16



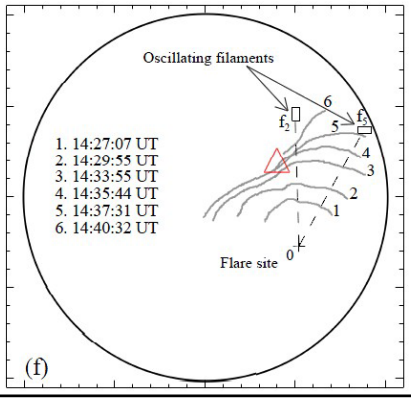
Mr. Denis Cabezas (a young Peruvian researcher) et al. are doing a case study of a flare & filament eruption (surge) without Moreton wave but with EUV-wave.

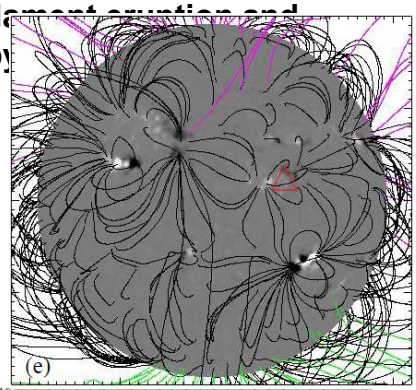
* Relationship between characteristics of the 3-D velocity field of filament eruption and shock-wave(EUV-wave)

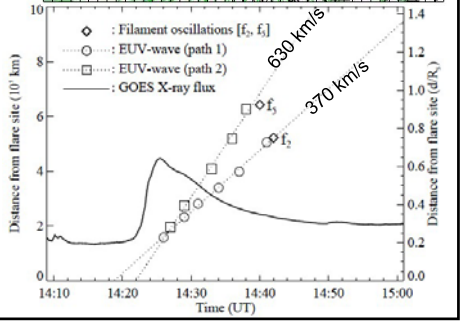


(2) Relationship between fila… shockwave generated b…

* Understanding the properties of the EUV-wave from the relationship between coronal magnetic field, propagating velocity, change of the wave's shape and far-located filament's oscillations.





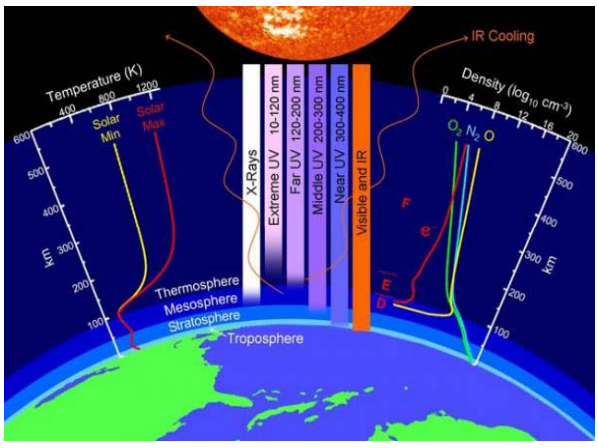


Regarding this study,
please see the poster UN-05 by

Mr. Denis P. Cabezas
(1. Centre for Radio Astronomy and Astrophysics,
Sao Paulo, Brazil
2. Institute of Geophysics in Peru)

(3) Estimation of variations of the 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.

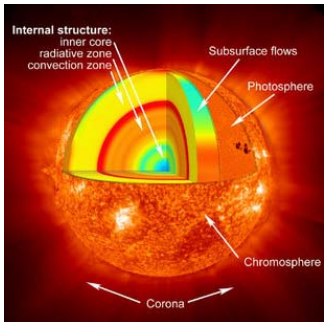


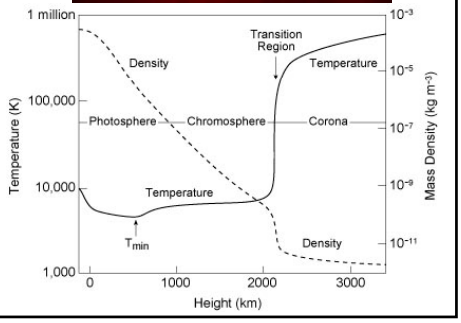
Element	Ionization	
	Vp(eV)	λ(nm)
N_2	15.58	79.6
O_2	12.08	102.6
O	13.61	91.1
N	14.54	85.3
NO	9.25	134
H	13.59	91.2
He	24.58	50.4

(3) Estimation of variations of the solar UV radiation

UV radiation from the Sun

- Photosphere ...
  ~6000K
  → visible light
- Chromosphere ...
  ~10,000 – 100,000 K
  → EUV - UV
- Corona ...
  > 1000,000 K
  → X-rays - EUV



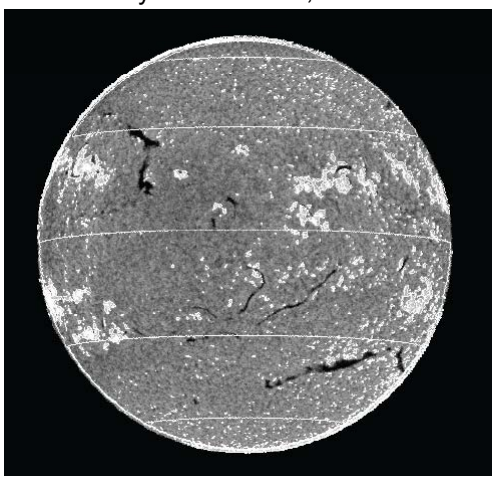


(3) Estimation of variations of the solar UV radiation

Attempt to calculate "Hα Plage Index"

By H.Watanabe, S.UeNo et al.

By using H-alpha imaging data for 21 years, we calculated "Hα Plage Index" as a candidate proxy of the solar UV radiations
It is defined as the percentage of the area covered by plages & active network in the solar disk obtained at Hα line center.

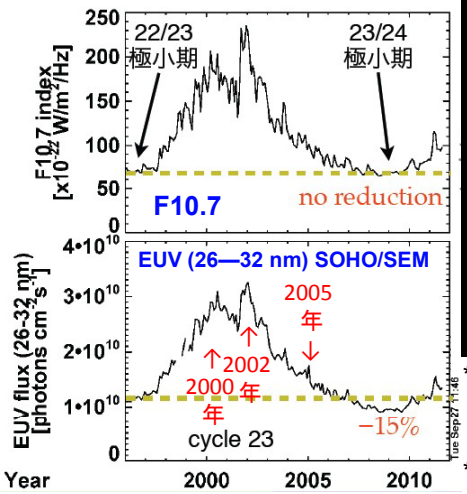


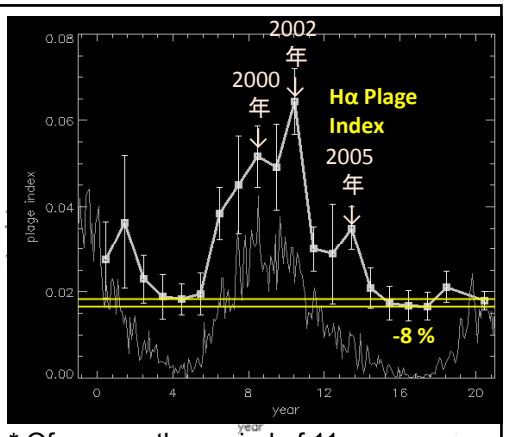
If

$I(x,y) > (\text{averaged intensity}) + 2\sigma_{(\text{standard deviation})}$

then, (x,y) is the plage or active network.

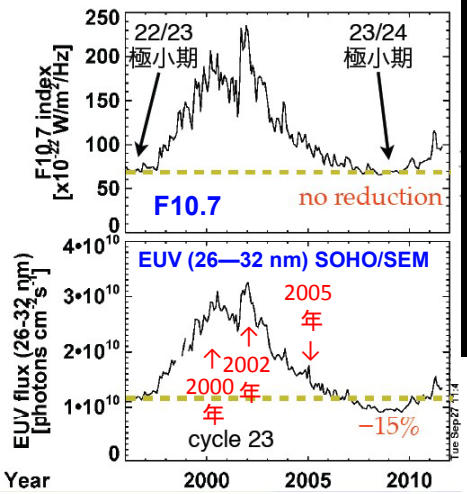
Result

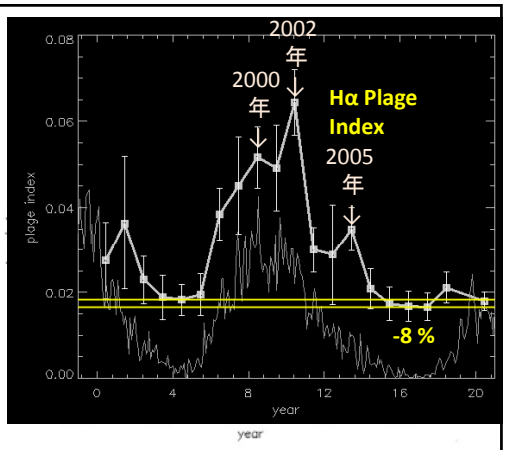




* Of course, the period of 11 year synchronizing with solar activity were clearly detected.
* During solar active phase, this index can reproduce some peaks of EVU radiation in 2000, 2002, 2005.
* The intensity of minimum phase between SC23/24 is sufficiently smaller than that of minimum phase of SC22/23.

Result





* Quantitatively, however, the reducing ratio of H-alpha index is smaller than actual variation of EUV radiation.

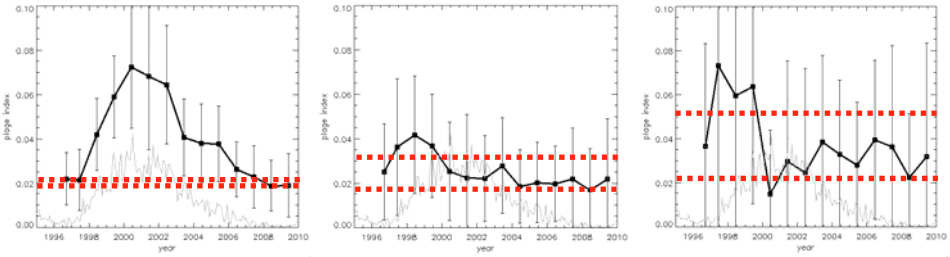
=> Quantitatively more accurate reproduction is the next subject.

Dependency on Latitude 1996 – 2009 (preliminary)

lat. 0° ~30° (Active region belt)

lat. 30° ~60°

lat. >60° (Polar)

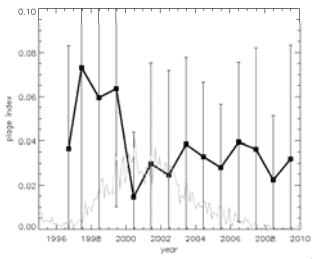


0.021 0.019 0.03 0.02 0.05 0.03

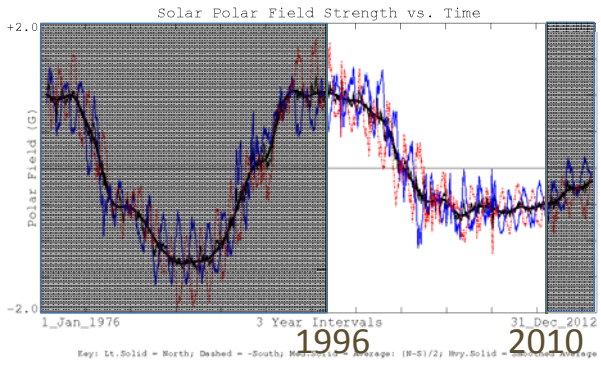
In the higher latitudinal region, reducing ratio from minimum phase 22/23 to 23/24 of this index become larger.

Compare with polar magnetic field observation

lat. >60° (Polar)



- Wilcox Solar Observatory



The reason of large reducing ratio of EUV from minimum phase 22/23 to 23/24 seems to decreasing of EUV radiation at polar region due to decreasing solar polar magnetic field.

[Summary of the CHAIN-project]

- The CHAIN's observation network is spreading slowly but surely.
- In December 2014, we installed a new Flare Monitoring Telescope at King Saud University in Saudi Arabia. The daily solar observation with it will be started from April 2015.
- By using CHAIN's data, we are promoting international cooperative studies as follows:
  * By measuring time evolution of 3-D velocity field of erupted filaments, we are investigating CME's generation process in both cases that it has erupted filament and it does not have filament.
  * By analyzing 3D velocity field of solar explosive phenomena, we are investigating generation process and characteristics of coronal shockwaves.
  * By using long-term H-alpha imaging data, we are making appropriate proxy index of solar EUV/UV radiation.

The End