The recent progress of *CHAIN* Project and the method for utilizing its data for Space Weather Prediction

Shibata, K.[1], Ichimoto, K.[1], Ueno, S.[1], **Seki, D.**[1,2],
Otsuji, K.[1], Cabezas, D. P.[1], Isobe, H.[2], et al.

1 Kwasan and Hida Observatories, Kyoto University
2 Graduate School of Advanced Integrated Studies in Human Survivability, Kyoto University

Outline

I. What is *CHAIN* Project?

II. 2 characteristics of CHAIN

   1. Scientific aspect

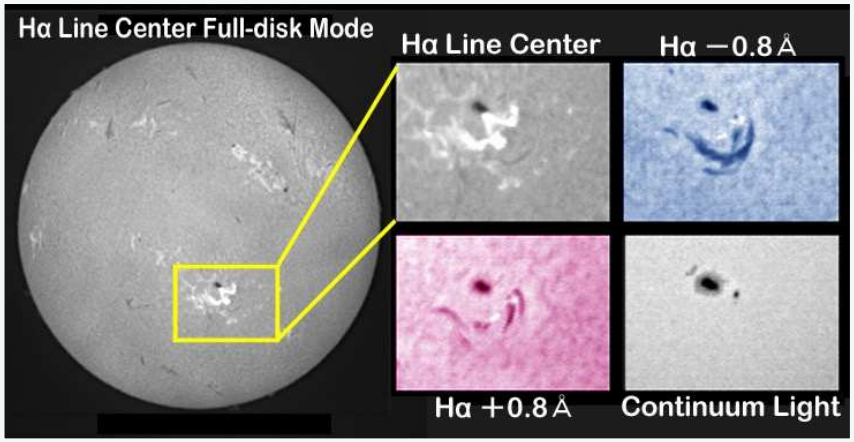
   2. Educational aspect

III. Application for Space Weather Prediction

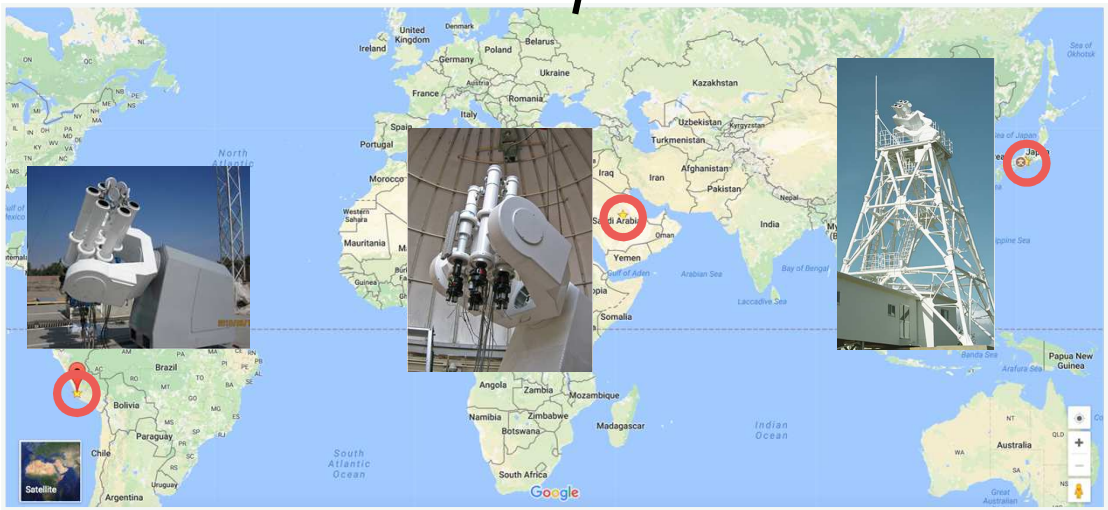
I. What is *CHAIN* Project?

Continuous H-Alpha Imaging Network

24 hours every day

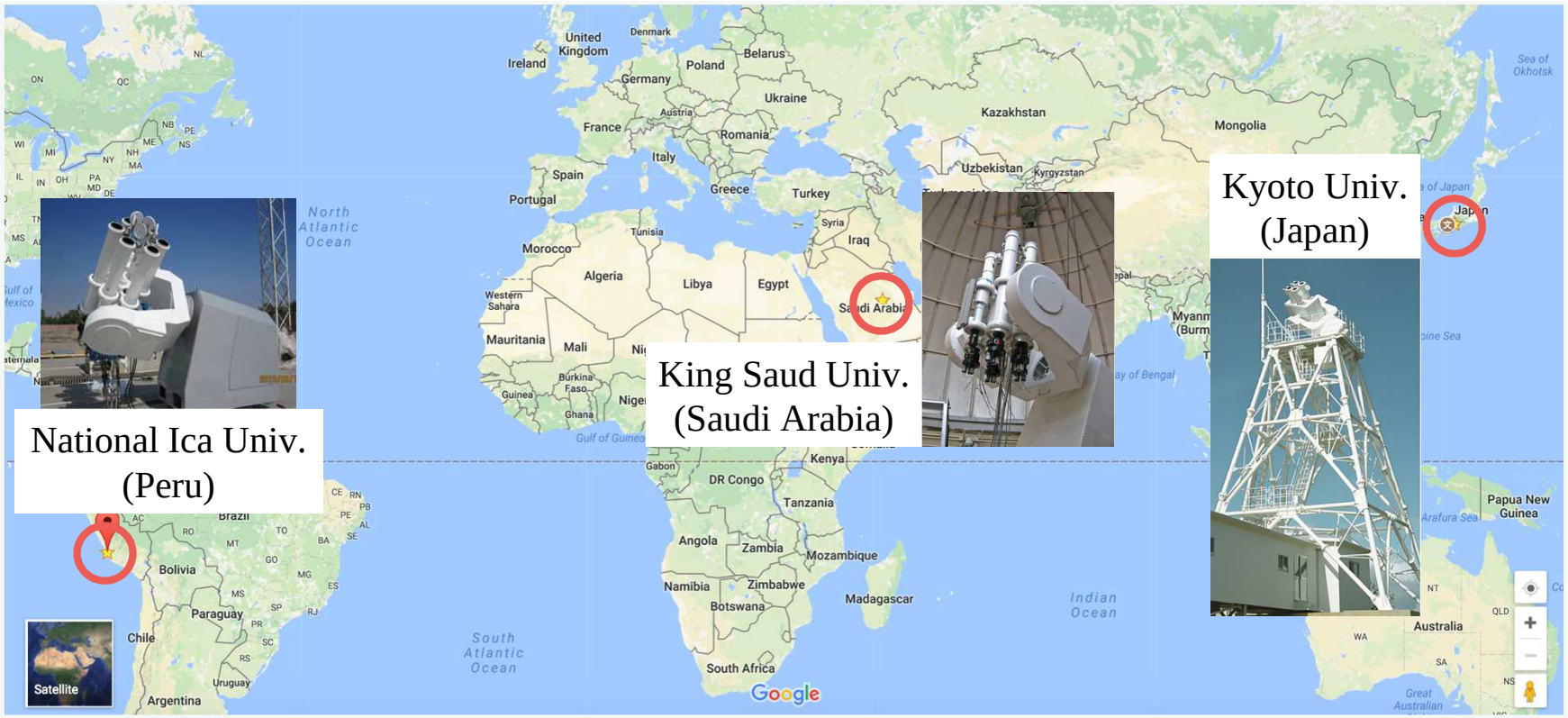


Multi-wavelength imaging around Hα line (6563 Å)



A World-wide Network for coordinated ground-based solar observation

I. What is *CHAIN* Project?



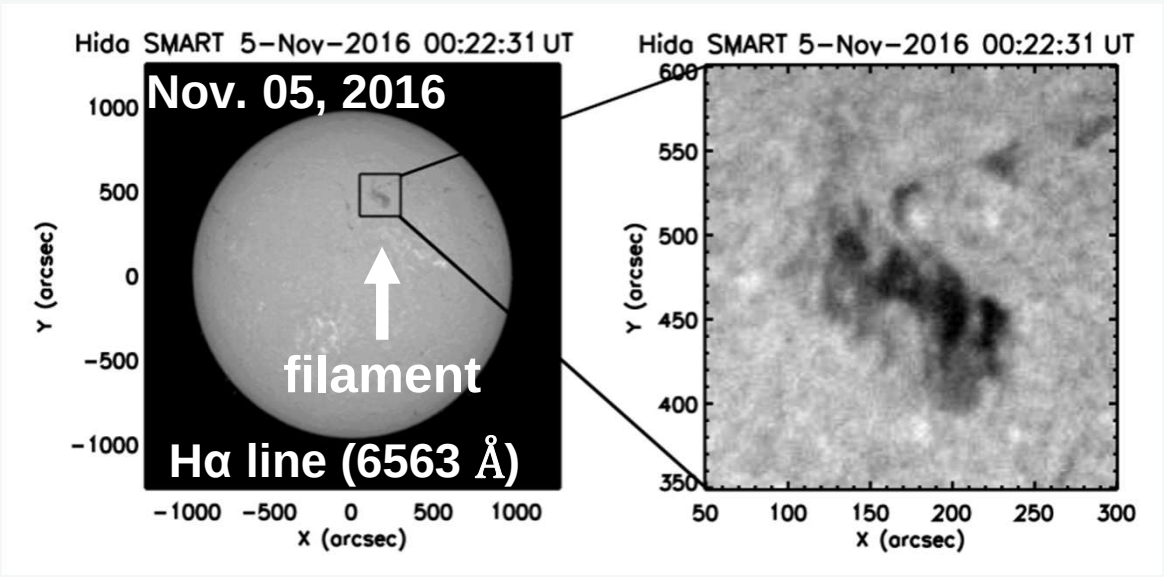
- 3 countries are involved; Peru, Saudi Arabia, and Japan
- In theory, now we can conduct 24-hour solar observation.

II. 2 characteristics of CHAIN

1. Scientific aspect
    - Multi-wavelength imaging around Hα line
2. Educational aspect
    - Capacity building

II. 2 characteristics of CHAIN

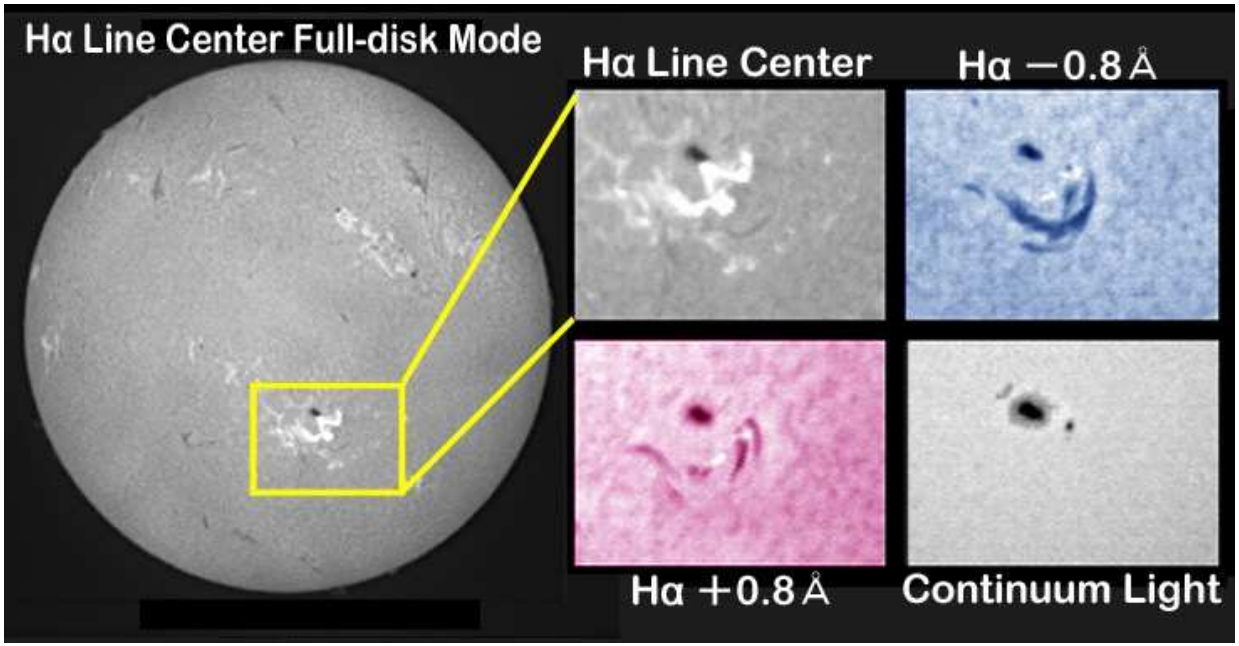
1. Scientific aspect

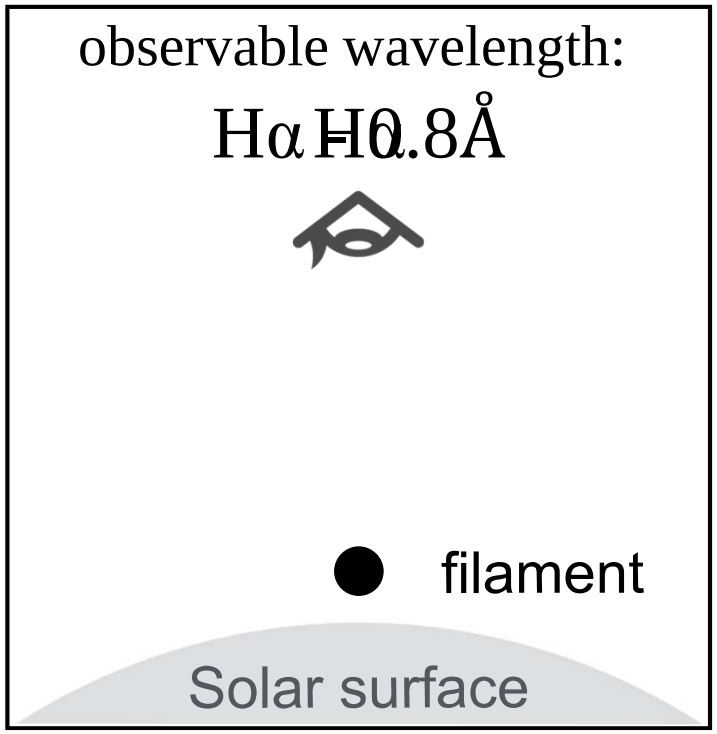


- Filament is a dense cooler plasma floating in the solar corona supported by magnetic field.
- Filaments can be observed in Hα line as the dark feature in the solar disk.
- Associated with solar eruptive phenomena like flares and CMEs, **filaments often erupt.**

II. 2 characteristics of CHAIN

1. Scientific aspect

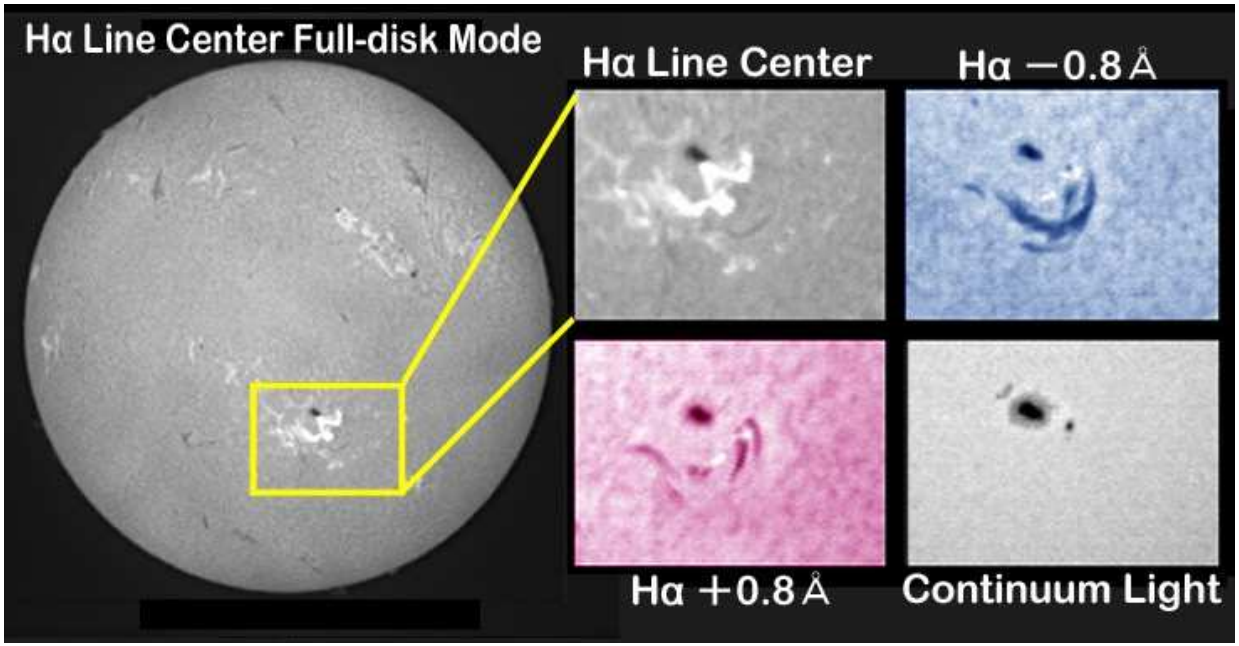


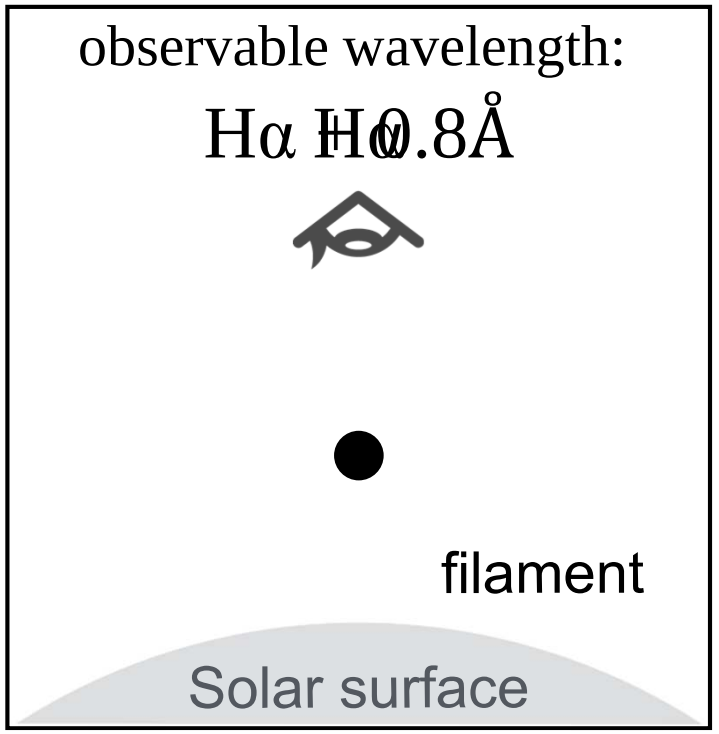


- Because of **Doppler effect**, the observable wavelength of moving filament along the line-of-sight changes.
- In other words, **multi-wavelength imaging around Hα** enables us to determine the **line-of-sight velocity of a filament.**

II. 2 characteristics of CHAIN

1. Scientific aspect





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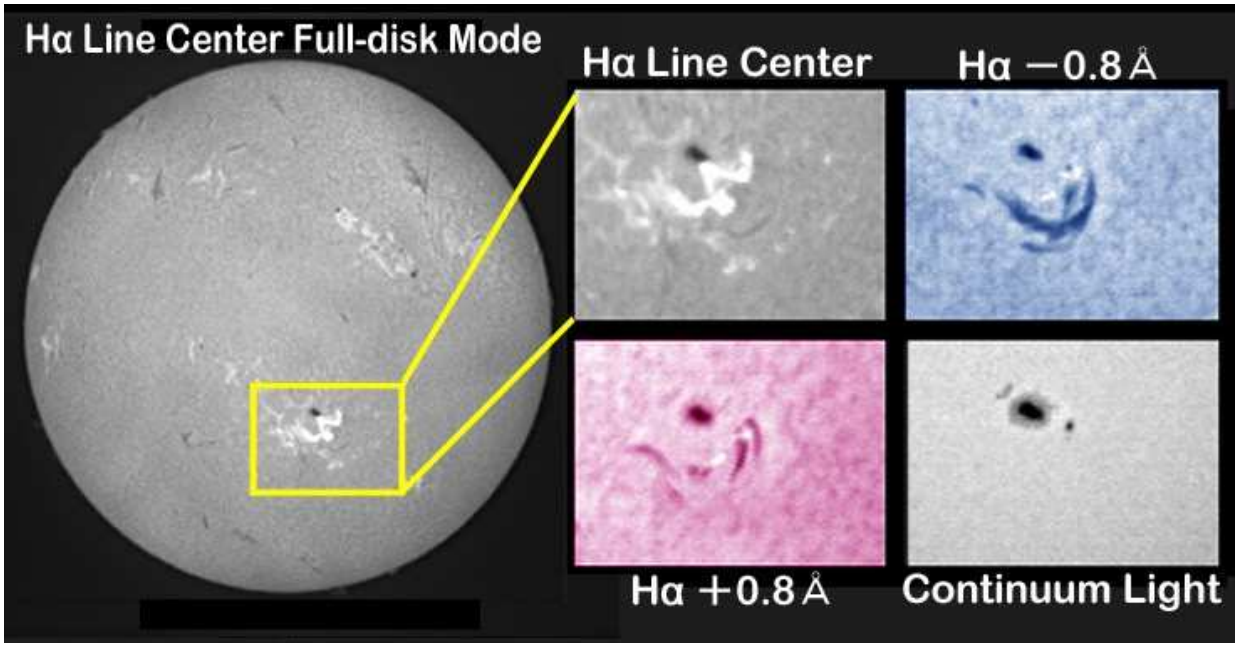

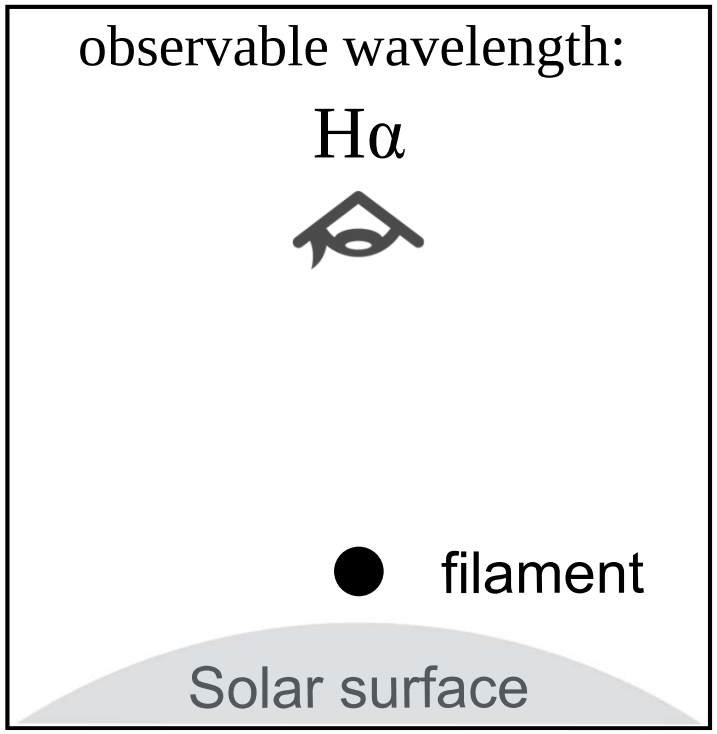

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II. 2 characteristics of CHAIN

1. Scientific aspect

RECENT PROGRESS:

- **15** peer-review papers related to CHAIN has been published since 2007.
  - ✓ **6** papers: About CHAIN project
  - ✓ **9** papers: Scientific results based on the data of CHAIN
  - ✓ **3** papers: Related to CHAIN in Peru
  - ✓ **1** paper : Related to CHAIN in Algeria

II. 2 characteristics of CHAIN

2. Educational aspect

7 lectures

- Jan. 2007 @ Ica Univ. in Peru
- Jan. 2007 @ IGP in Peru
- May 2008 @ CRAAG in Algeria
- June 2008 @ Ica in Peru
- Mar. 2010 @ Ica in Peru
- May 2011 @ Riyadh in Saudi Arabia
- Aug. 2015 @ Riyadh in Saudi Arabia

4 scientific educations

- June 2010 @ Ica Univ. in Peru
- Oct. 2010 @ Ica Univ. in Peru
- Nov. 2010 @ Ica Univ. in Peru
- Oct. 2015 @ King Saud Univ. in Saudi Arabia

2 technical trainings

- Jan. 2007 @ Ica Univ. in Peru
- July 2009 @ Hida in Japan

5 scientific data-analysis workshops

- Nov. 2010 @ Ica in Peru
- July 2011 @ Hida in Japan
- Mar. 2013 @ Hida in Japan
- Mar. 2015 @ Kyoto in Japan
- Feb. 2017 @ Kyoto in Japan

Jan. 2007 @ Ica Univ. in Peru

(Red: Newly held since the previous ISWI symposium)

II. 2 characteristics of CHAIN

2. Educational aspect

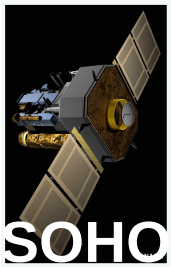
RECENT PROGRESS:

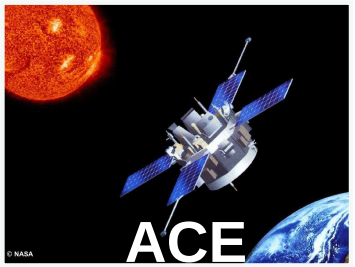
- **Educating young researcher in Peru**
  - ✓ Young Peruvian researcher (Mr. Cabezas, D. P.) got Japanese Government Scholarship for 2016 to Kyoto University from Apr. 2016 to Mar. 2017.
  - ✓ From Apr. 2017, he has been a graduate student in Ph.D. course and will be a doctor in 3 years (Mar. 2020).
- **Global co-working with CHAIN group.**
  - ✓ Mr. Cabezas, D. P. published his academic paper in the Astrophysical Journal on Feb. 2017.

III. Application for SWx Prediction

Motivation:

- The present SWx prediction methods are mainly based on **satellite-based** telescopes' data

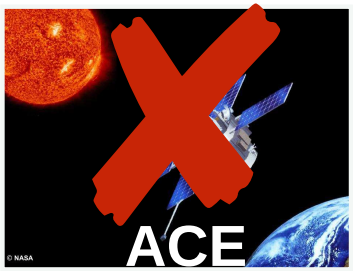




III. Application for SWx Prediction

Motivation:

- The present SWx prediction methods are mainly based on **satellite-based** telescopes' data
  - ❖ However, satellites are vulnerable to the SWx effects.
  - ❖ If a huge flare happened and almost all the satellites were broken, how could we prepare for the next flare or CMEs…?

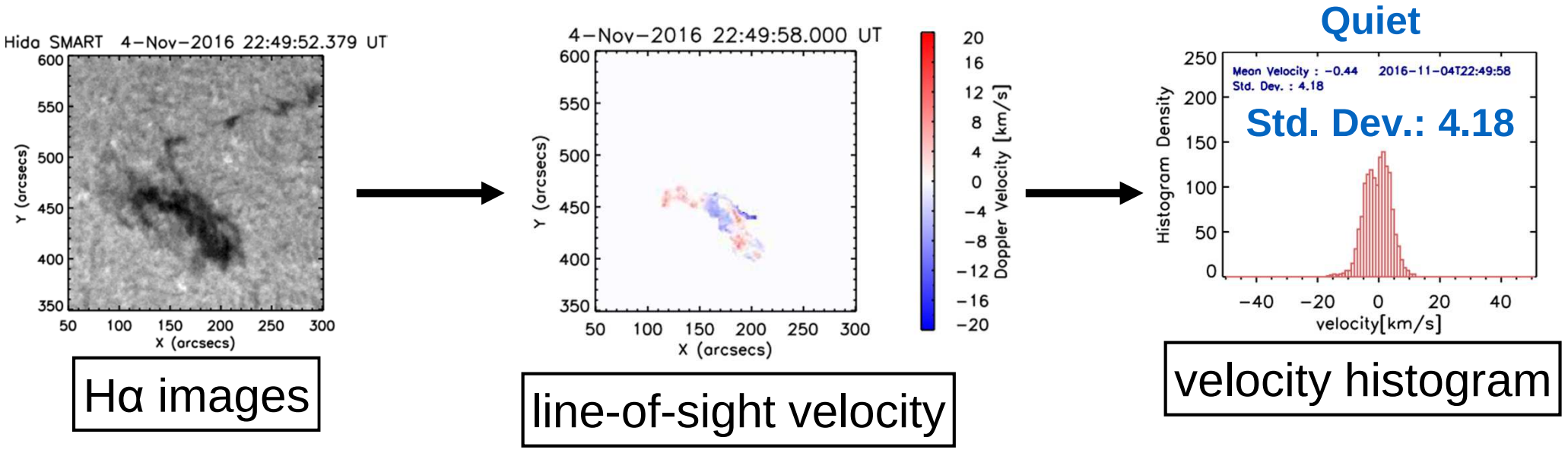


★ We think it also important to predict SWx
only by using the Ground-based telescopes' data.

III. Application for SWx Prediction

An example of our approaches:

- **Prediction of a filament eruption** is a key (because it is associated with a flare or a CME).
- Recently we found that increase in the amplitude of the small-scale motion in a filament could be used as the **precursor of a filament eruption** (Seki et al. 2017).



Hα images

line-of-sight velocity

velocity histogram

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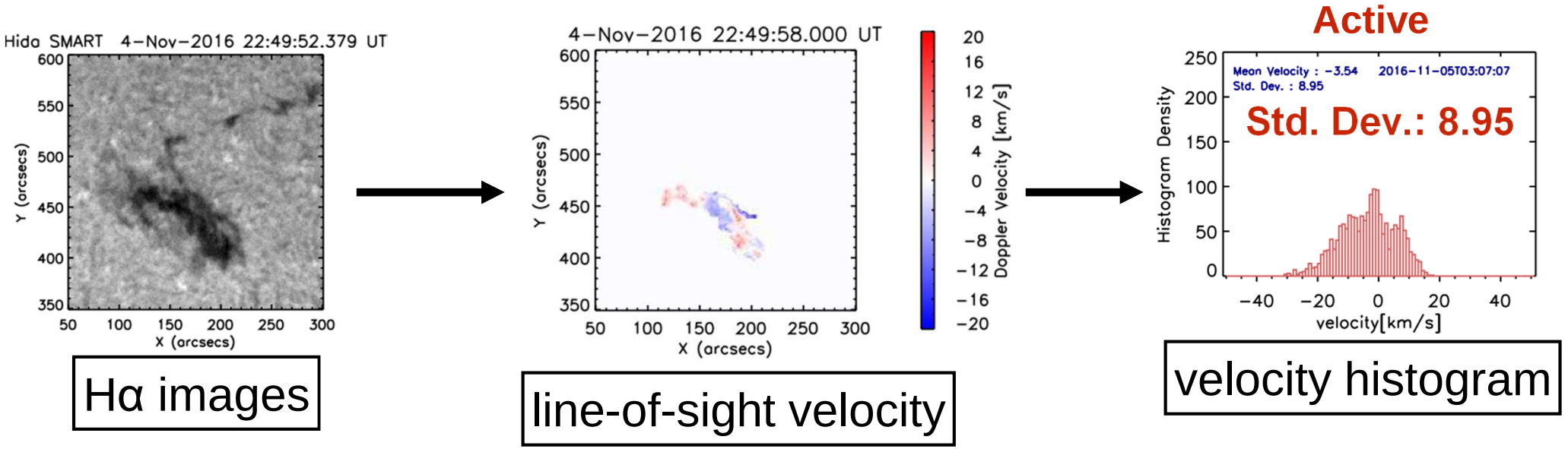

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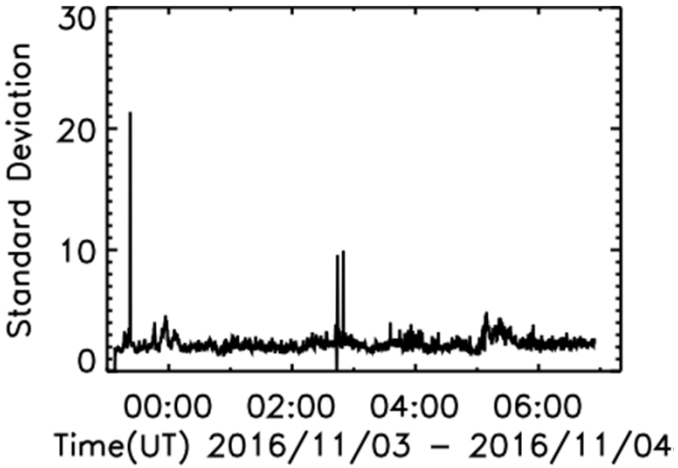
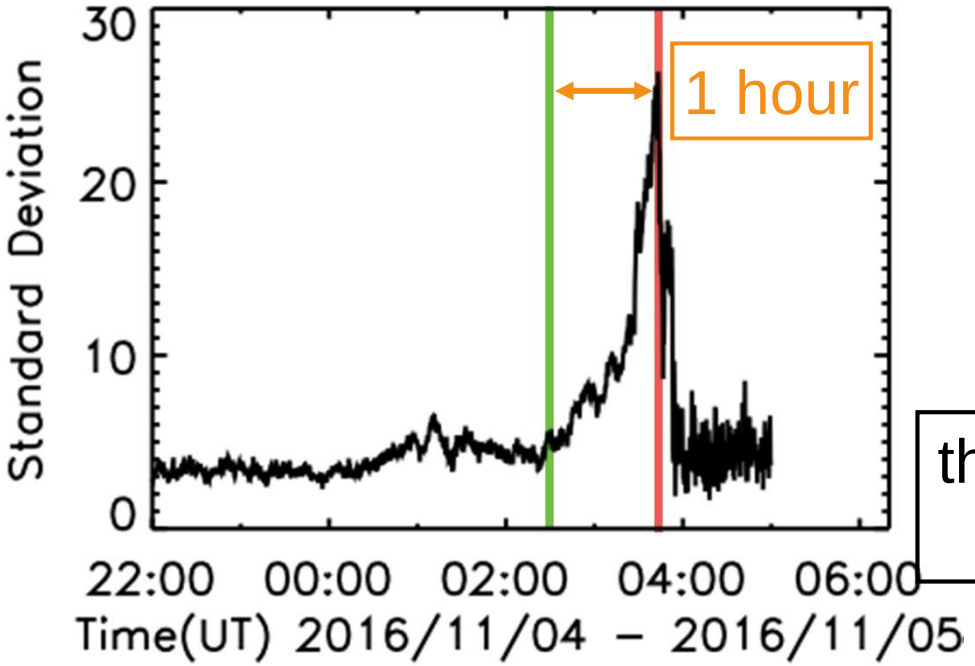


Previous day



the eruption day

Summary

I. CHAIN is a world-wide ground-based telescopes' network for observing the sun around Hα lines for 24 hours.

II. 2 characteristics of CHAIN

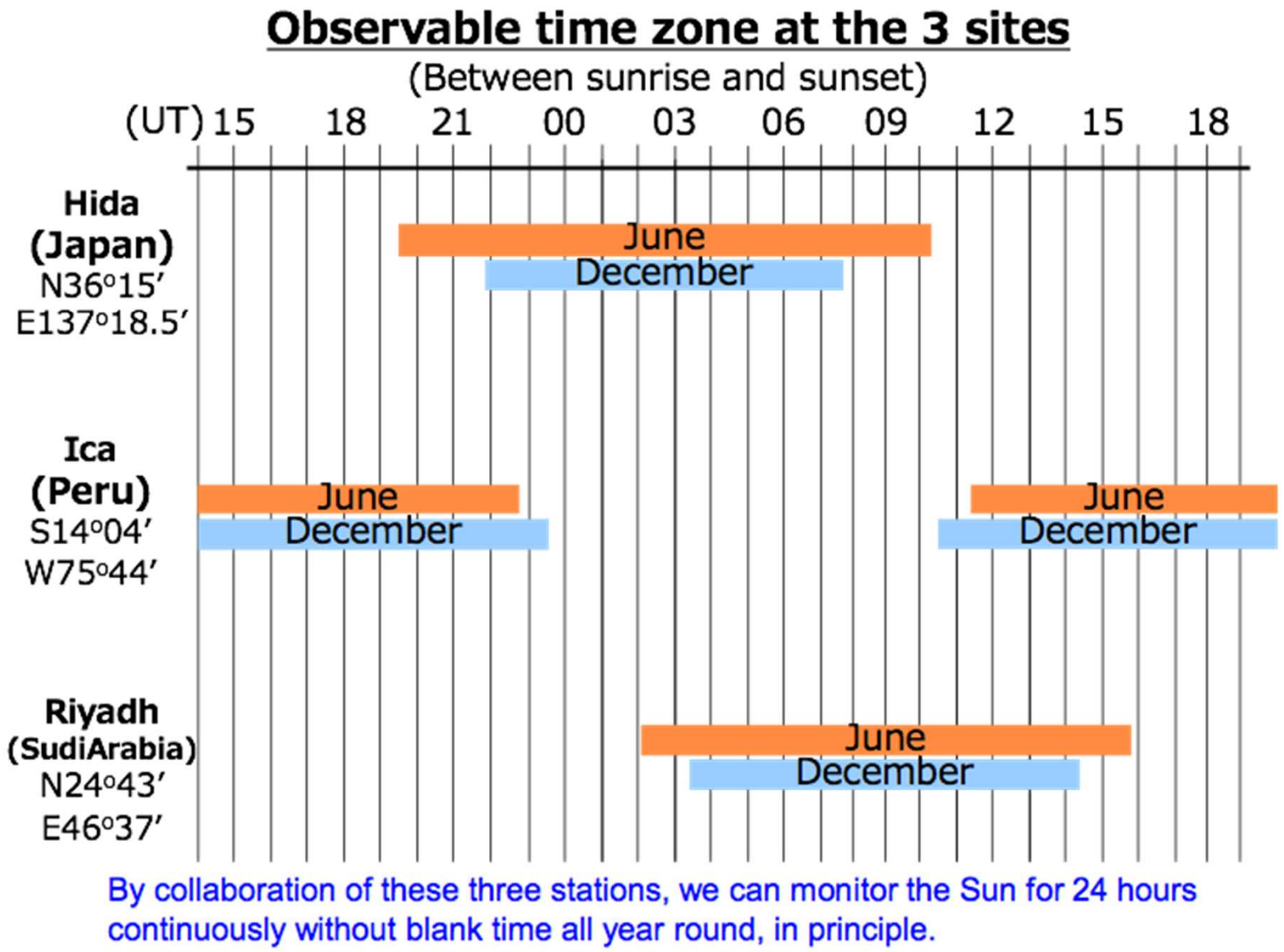
1. Scientific aspect
   - CHAIN telescopes observe the sun in **multiple wavelengths around Hα** enabling us to **determine line-of-sight velocity of a filament**.

2. Educational aspect
   - So far we have held **18** lectures, trainings, and workshops.
   - **Young Peruvian researcher** has been working hard and will **get Ph.D.** in 3 years.

III. Application for Space Weather Prediction
   - Our recent work showed a possibility to **predict a filament eruption** about 1 hour before and may create a new SWx prediction method.

More information:
Dr. Shibata: shibata@kwasan.kyoto-u.ac.jp, Dr. Ueno: ueno@kwasan.kyoto-u.ac.jp,
Mr. Seki: seki@kwasan.kyoto-u.ac.jp, Mr. Cabezas: denis@kwasan.kyoto-u.ac.jp

Appendix


Observable time zone at the 3 sites
(Between sunrise and sunset)
(UT) 15 18 21 00 03 06 09 12 15 18
Hida
(Japan)
N36°15′
E137°18.5′
June
December
Ica
(Peru)
S14°04′
W75°44′
June
December
June
December
Riyadh
(SudiArabia)
N24°43′
E46°37′
June
December
By collaboration of these three stations, we can monitor the Sun for 24 hours
continuously without blank time all year round, in principle.

Appendix

SDDI paper + smart paper + chain paper

year	title	author	journal	type	country
2007	Chain-Project and Installation of the Flare Monitoring Telescopes in Developing Countries	Ueno et al.	Bull. Astr. Soc. India	about CHAIN	Japan
2007	Triggering Mechanism for the Filament Eruption on 2005 September 13 in NOAA Active Region 10808	Nagashima et al.	ApJ	academic	Japan
2007	A solar observing station for education and research in Peru	Ishitsuka et al	Bull. Astr. Soc. India	about CHAIN	Peru
2008	Three Successive and Interacting Shock Waves Generated by a Solar Flare	Narukage et al.	ApJL	academic	Japan
2009	The CHAIN-Project and Installation of Flare Monitoring Telescopes in Developing Countries	Ueno et al.	Data Science Journal	about CHAIN	Japan
2009	Evolution of Anemone AR NOAA 10798 and the Related Geo-Effective Flares and CMEs	Asai et al.	ApJL	academic	Japan
2010	Un Observatoire dans la Region de Aures"	N.Seghouani	African Skies	about CHAIN	Algeria
2010	Continuous H-alpha Imaging Network Project (CHAIN) with Ground-based Solar Telescopes for Space Weather Research	Ueno et al.	African Skies	about CHAIN	Japan
2012	"First Simultaneous Observation of an Hα Moreton Wave, EUV Wave, and Filament/ Prominence Oscillations	Asai et al.	ApJL	academic	Japan
2013	High-Speed Imaging System for Solar-Flare Research at Hida Observatory	Ishii et al	PASJ	academic	Japan
2014	International Collaboration and Academic Exchange of the CHAIN Project in this Three Years (ISWI Period)	Ueno et al.	Sun and Geosphere	about CHAIN	Japan
2014	Within the International Collaboration CHAIN: a Summary of Events Observed with Flare Monitoring Telescope (FMT) in Peru	Ishitsuka et al.	Sun and Geosphere	academic	Peru
2017	A New Solar Imaging System for Observing High-Speed Eruptions: *Solar Dynamics Doppler Imager* (SDDI)	Ichimoto et al.	Solar Physics	academic	Japan
2017	Increase in the Amplitude of Line-of-sight Velocities of the Small-scale Motions in a Solar Filament before Eruption	Seki et al.	ApJL	academic	Japan
2017	"Dandelion" Filament Eruption and Coronal Waves Associated with a Solar Flare on 2011 February 16	Cabezas et al.	ApJ	academic	Peru

2

Appendix

Cost of a Standard New Telescope without Infrastructure

Items	USD
Telescope itself (1)	250,804
Optical Filters (5)	54,107
CCD Cameras (5)	29,375
Computers for Cameras (5)	10,179
Computer for Analysis (1)	6,161
Transfer & Installation	80,357
Total	**430,983**

It is not so expensive **compared with** other professional solar telescopes, but it is never cheap.

Appendix

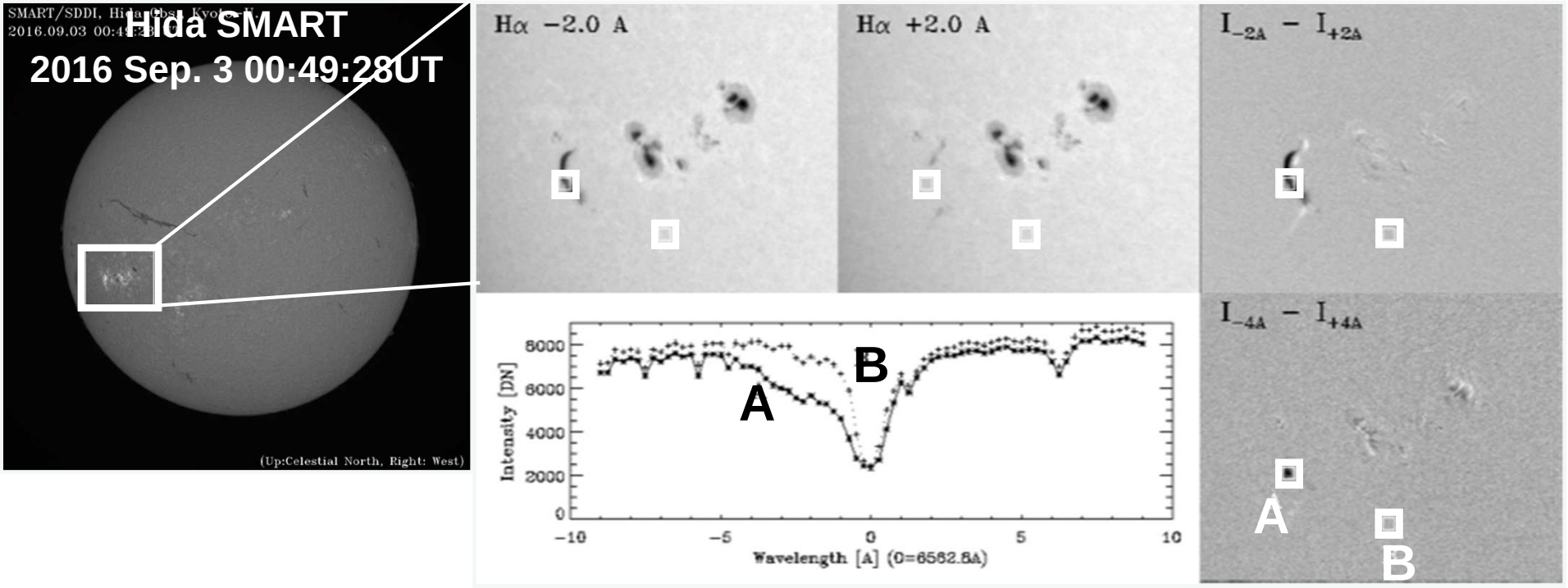
Problems

- **Peru**
  - ❖ Short of funds for maintenance
    - Personnel expenses
    - Fixing air conditioner in the computer room
    - Fixing the damaged building by heavy rains
  - ❖ Fixing and improving the telescope
  - ❖ Low speed of internet
    - ➡ It takes more time than observing time to send the observational data for a day.
- **Saudi Arabia**
  - ❖ High temperature on summer days
    - ➡ Affects the observational wavelength.

etc…

Appendix

Beckers' cloud model (Beckers 1964)

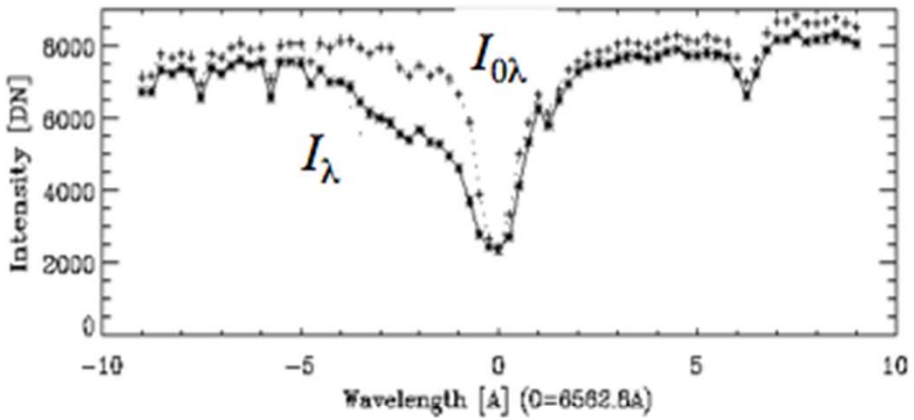


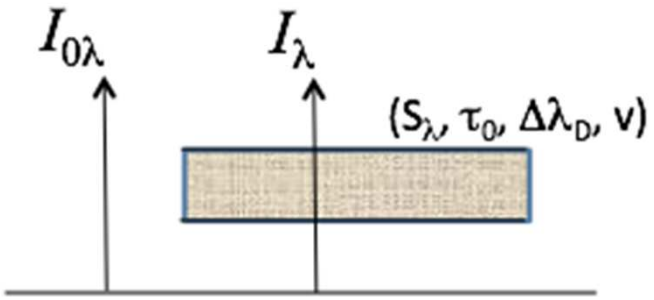
※ Actually **B** is the average of the 10x10 pixels at the disk center.

From Otsuji-san' slide

Appendix

I_λ : intensity of A in the previous slide $I_{o\lambda}$: intensity of B in the previous slide





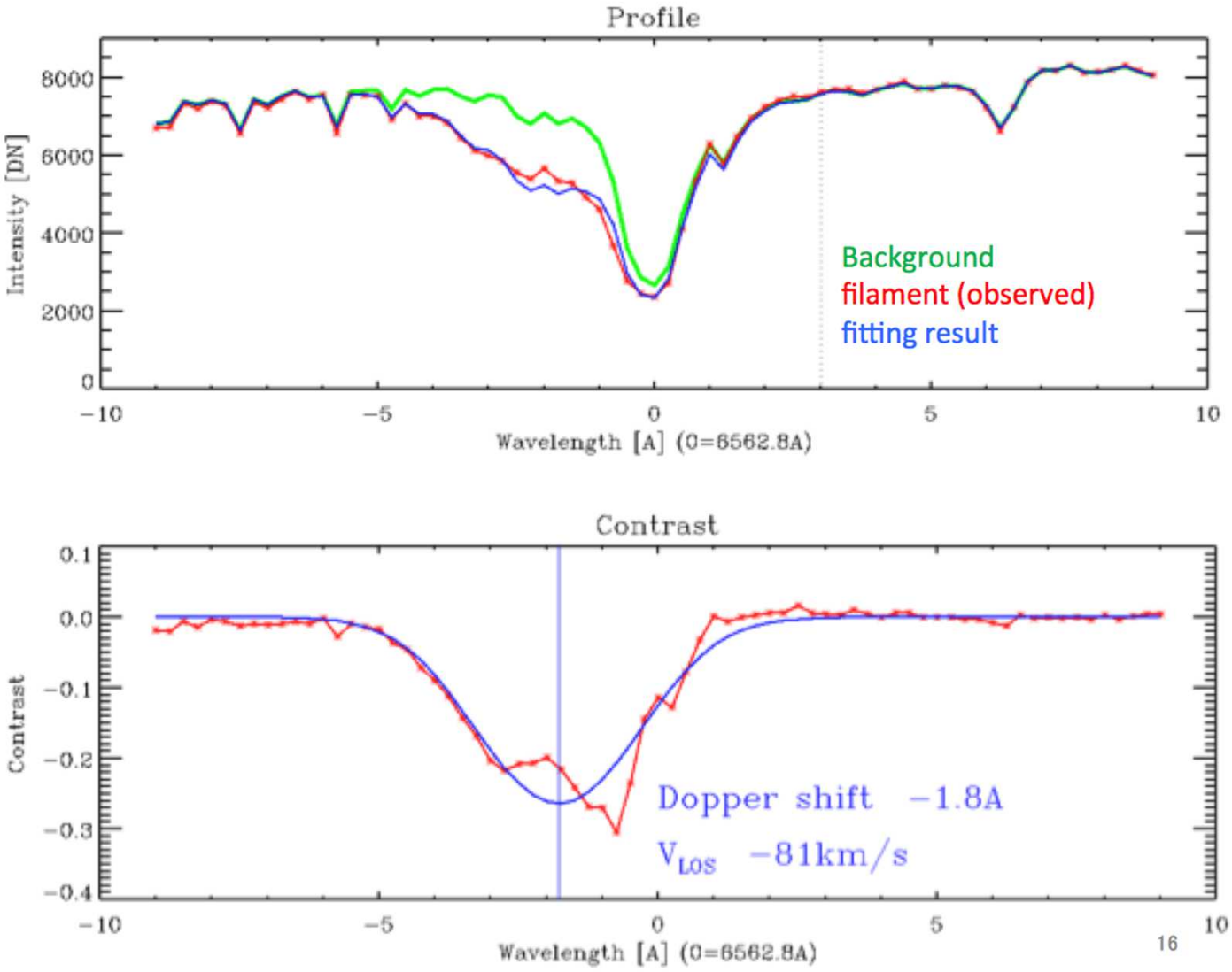
Beckers' cloud model

$$C_\lambda = \frac{I_\lambda - I_{0\lambda}}{I_{0\lambda}} = \left(\frac{S_\lambda}{I_{0\lambda}} - 1\right)\left(1 - e^{-\tau_\lambda}\right)$$: Contrast function

$$\tau_\lambda = \tau_0 \exp\left[-\left(\frac{(1 - v/c)\lambda - \lambda_0}{\Delta\lambda_D}\right)^2\right]$$: fitting parameters

From Otsuji-san' slide

Appendix



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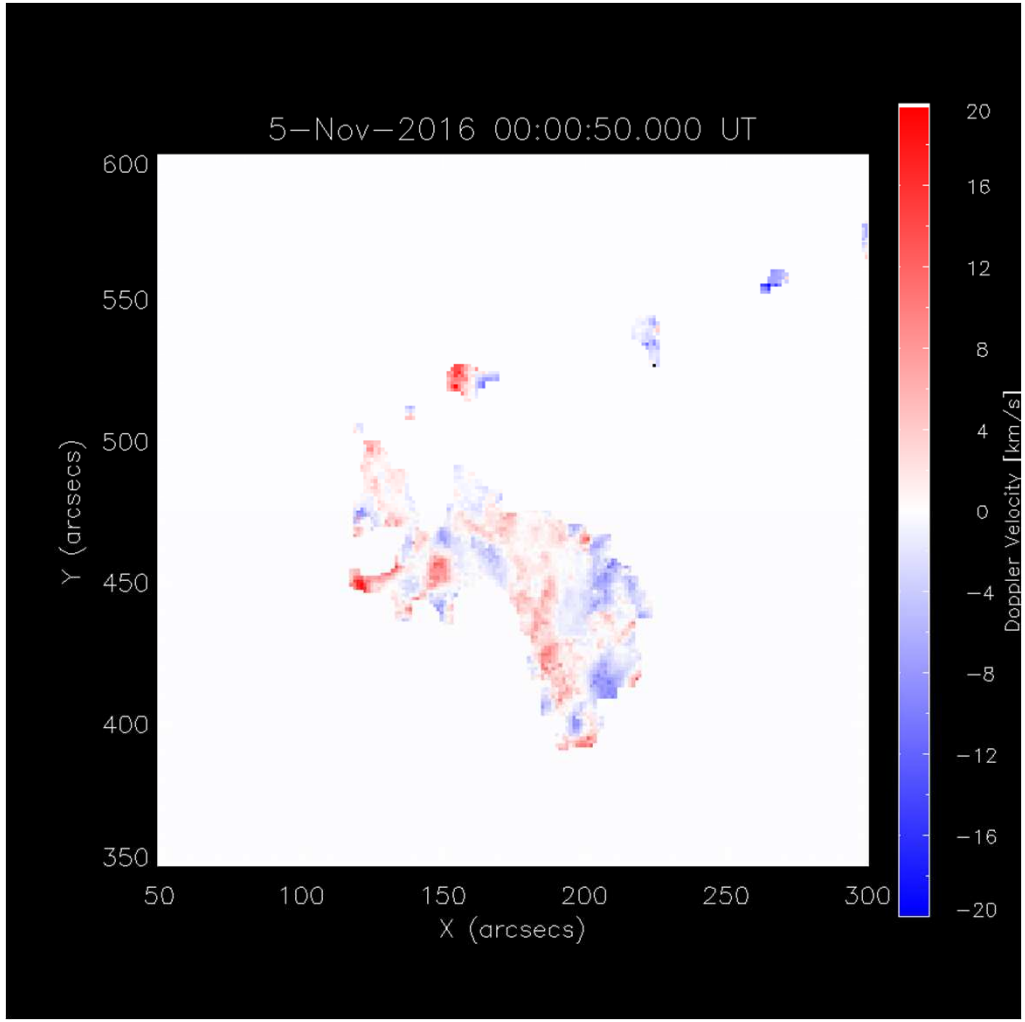
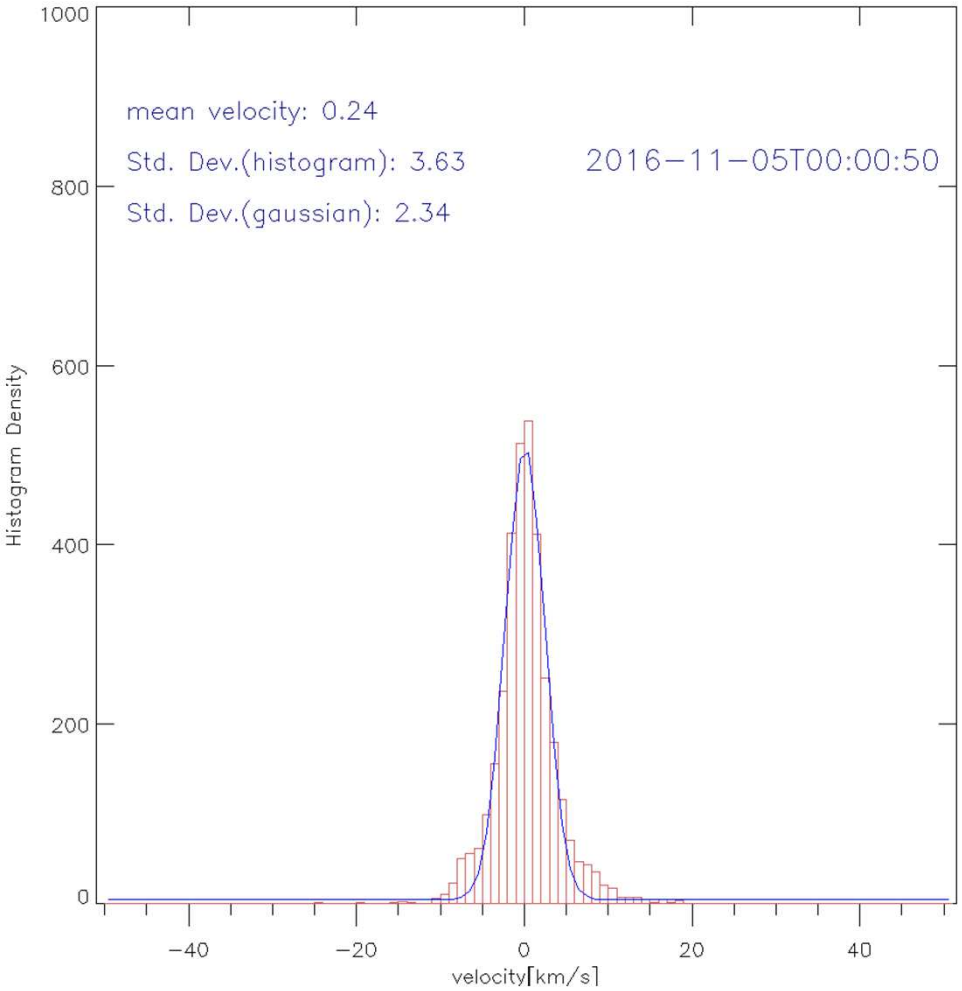

5-Nov-2016 00:00:50.000 UT
Y (arcsecs)
X (arcsecs)
Doppler Velocity [km/s]
600
550
500
450
400
350
50
100
150
200
250
300
20
16
12
8
4
0
-4
-8
-12
-16
-20


mean velocity: 0.24
Std. Dev.(histogram): 3.63
Std. Dev.(gaussian): 2.34
2016-11-05T00:00:50
Histogram Density
velocity[km/s]
1000
800
600
400
200
0
-40
-20
0
20
40