Continued Operation of Nobeyama Radioheliograph and height distribution of accelerated electrons in a solar flare

Satoshi Masuda (ISEE, Nagoya University)
and the International Consortium for the Continued Operation of Nobeyama Radioheliograph (ICCON)

Nobeyama Radioheliograph (NoRH)

The NoRH operation by the International Consortium started in April, 2015.
The representatives are Gopalswamy (NASA), Yan (NAOC), Cho (KASI), Ishii (NICT), Shibasaki, and Masuda (Nagoya U.).

http://hinode.stelab.nagoya-u.ac.jp/ICCON/

Nobeyama Radioheliograph (NoRH)

FoV: full Sun
Antenna diameter: 80 cm
Number of antennas: 84
Baseline: NS 250 m, EW 500 m
Frequencies: 17, 34 GHz
Spatial res.: 10 arcsec@17GHz, 5 arcsec@34 GHz
Polarization: circular pol. @17 GHz
Time res.: normal 1 sec, event 0.1 sec
Operation start: July 1992 (17GHz),
November 1995 (34GHz)
Observational time: 22:45 – 6:30 UT

Time history

June 2014:

agreement between NAOJ and STEL, Nagoya U.

December 2014:

MOU between STEL and each ICCON member

February 2015:

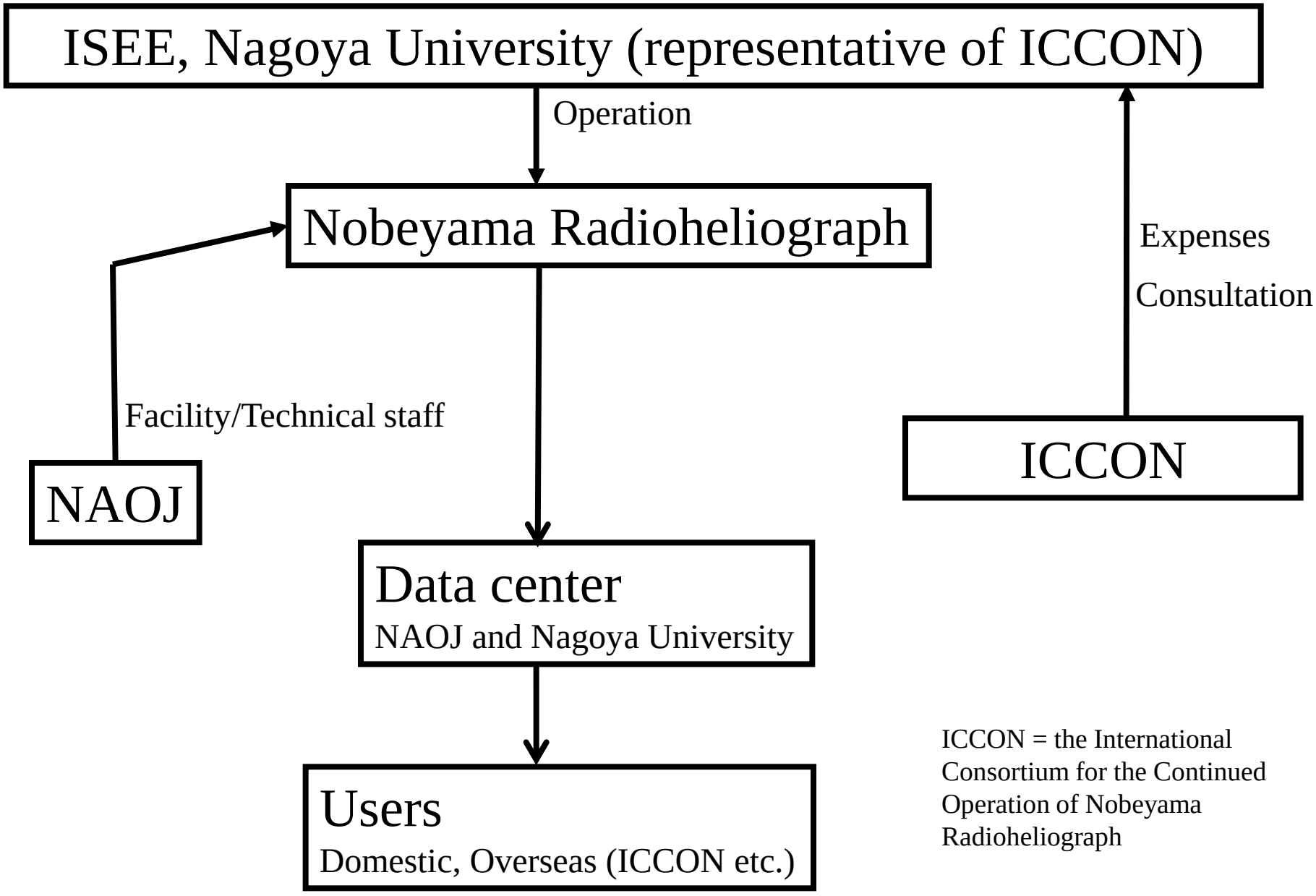
Preparation for operation by ICCON

March, 2015: kick-off meeting of ICCON @Fukuoka

April, 2015:

ICCON began the continued operation of NoRH

Organization



ICCON = the International Consortium for the Continued Operation of Nobeyama Radioheliograph

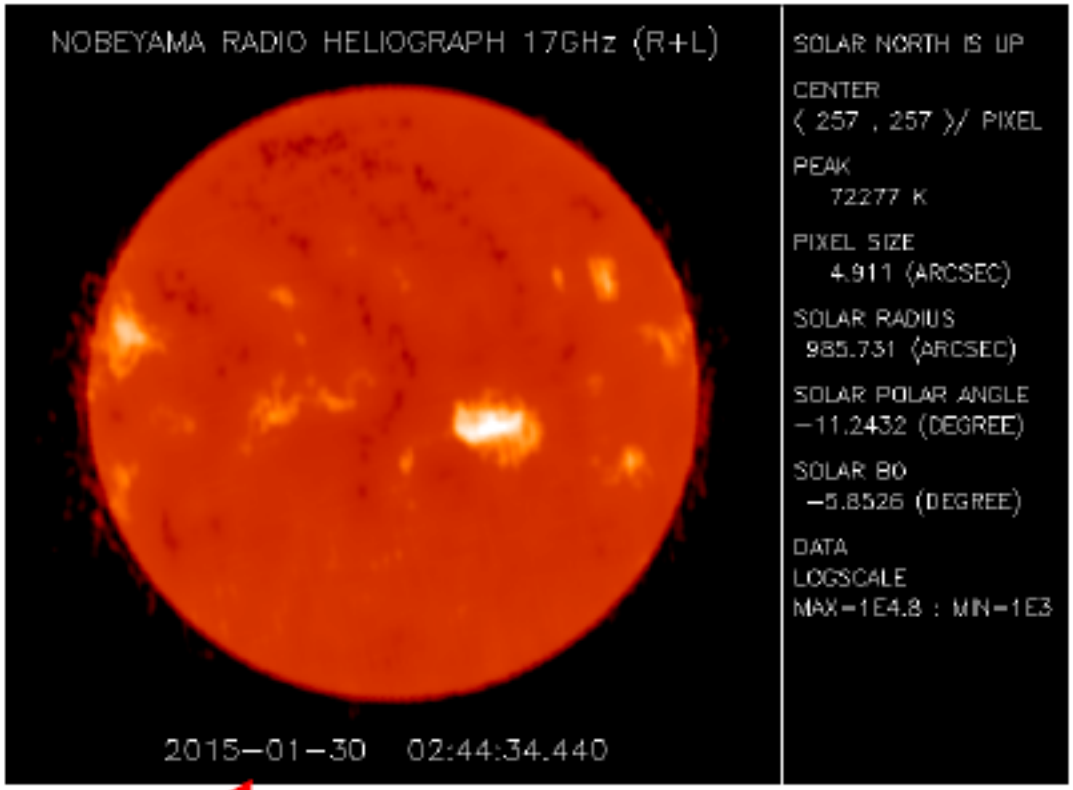
NoRH Chief Observer (CO)

Tasks
(1) Health check of the instruments/computers
(2) Data verification

How to do it.
After 0 UT (starting daily observation), just visit the following URL.
http://solar.nro.nao.ac.jp/kansi/NoRH_CODV/

Then look at each status and send the summary mail to
‘norh_co@st4a.stelab.nagoya-u.ac.jp’.
If there is an error or something wrong,
Shinohara/Shibasaki/Masuda correspond to it.

DV3: Daily Image

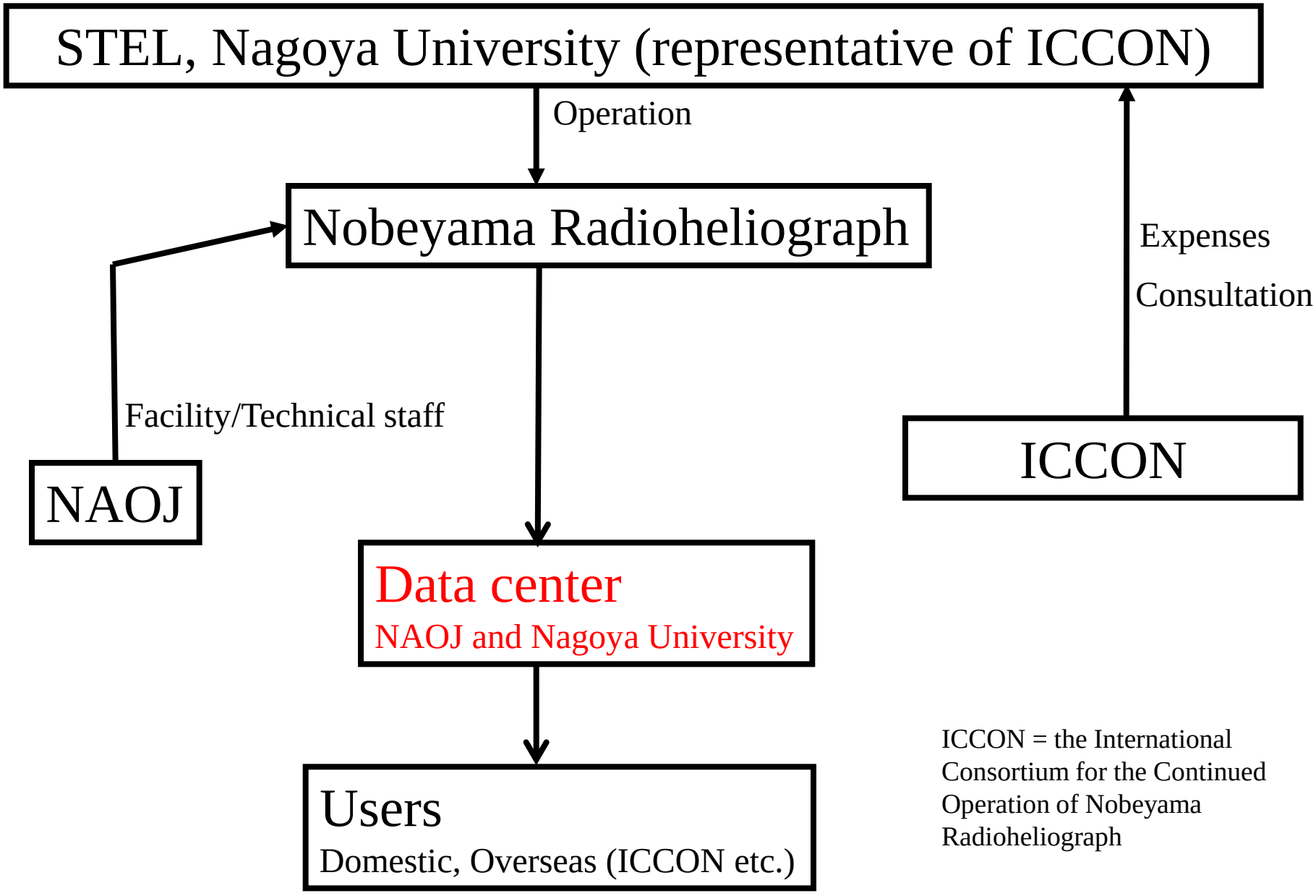


- Check the date on the image.
- Choose “NG” if no image was made for the target date.
- Choose “NG” if the image quality of the target date is low.
  - The daily-image movie will help you to determine the image quality by comparing to other dates.

Norh_CO schedule as of June 30, 2015.

Peirod	Name	Organization	Country	Remarks
2015/04/01-04/03	S. Yashiro	Catholic U.	USA	
2015/04/06-04/10	S. Yashiro	Catholic U.	USA	
2015/04/13-04/17	S. Masuda	Nagoya U.	Japan	
2015/04/20-04/24	K. Shibasaki	Nagoya U.	Japan	
2015/04/27-05/01	N. Shinohara	NAOJ	Japan	
2015/05/04-05/08	S. White	AFRL	USA	holiday week in Japan
2015/05/11-05/15	J. Huang	NAOC	China	
2015/05/18-05/22	Y. Zhang	NAOC	China	
2015/05/25-05/29	T. Kawate	Queen's U. Belfast	UK	JPGU (Japan)
2015/06/01-06/05	A. Asai	Kyoto U.	Japan	
2015/06/08-06/12	N. Shinohara	NAOJ	Japan	power outage on June 11
2015/06/15-06/19	S. Masuda	Nagoya U.	Japan	
2015/06/22-06/26	S. Kim	KASI	Korea	
2015/06/29-07/03	G. Nistico	U. of Warwick	UK	
2015/07/06-07/10	L. Chen	NAOC	China	
2015/07/13-07/17	D. Kolotkov	U. of Warwick	UK	
2015/07/20-07/24	F. Liu	NAOC	China	
2015/07/27-07/31	W. Wang	NAOC	China	
2015/08/03-08/07	K. Shibasaki	Nagoya U.	Japan	IAU, AOGS
2015/08/10-08/14	S. White	AFRL	USA	IAU, Summer holidays (Japan)
2015/08/17-08/21	Y. Zhang	NAOC	China	
2015/08/24-08/28	J. Huang	NAOC	China	
2015/08/31-09/04	S. Miyawaki	Ibaraki U.	Japan	
2015/09/07-09/11	V. Melnikov	CAO at Pulkovo	Russia	ASJ meeting (Japan)
2015/09/14-09/18	V. Abramov-Maximov	CAO at Pulkovo	Russia	Hinode-9
2015/09/21-09/25	S. Kuznetsov	CAO at Pulkovo	Russia	
2015/09/28-10/02	N. Meshalkina	Institute of STP of SB	Russia	
2015/10/05-10/09	I. Bakunina	National Research University	Russia	
2015/10/12-10/16	A. Morgachev	CAO at Pulkovo	Russia	
2015/10/19-10/23	E. Kupriyanova	CAO at Pulkovo	Russia	
2015/10/26-10/30	V. Smirnova	CAO at Pulkovo	Russia	
2015/11/02-11/06	A. Kochanov	Institute of STP of SB	Russia	APSPM2015
2015/11/09-11/13				

Organization



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Data Flow

7:45 – 15:30 JST: NoRH observations
every 10 minutes: one image (fits and gif) is transferred to SDAS.

Night: All data are transferred from Nobeyama to SDAS (Mitaka).

Night on the next day: All data are mirrored to Nagoya.

Database

All data (1992 – present) are stored in SDAS and Nagoya.
Anyone can analyze data there.

Software

All of NoRH software are included in Solarsoft (IDL-based software library).

Useful data/information on the Web

Today's Sun Image at Japan noon, Latest Image (Small), (Large)
Daily Images & Movies
Event Images & Movies (strong), (weak),
Limb Event (Prominence Activities) List
    Prompt List
    Complete List(July 1992 - March 2013)
17GHz 3mins-cadence database with image quality verification
    (1992/07/01 - 2014/12/31)
10min Images & Movies (full size) (half size)
Monthly Images
Synoptic Chart (1992 - 1998)
Number of Flares Observed by NoRH

http://hinode.stelab.nagoya-u.ac.jp/ICCON/

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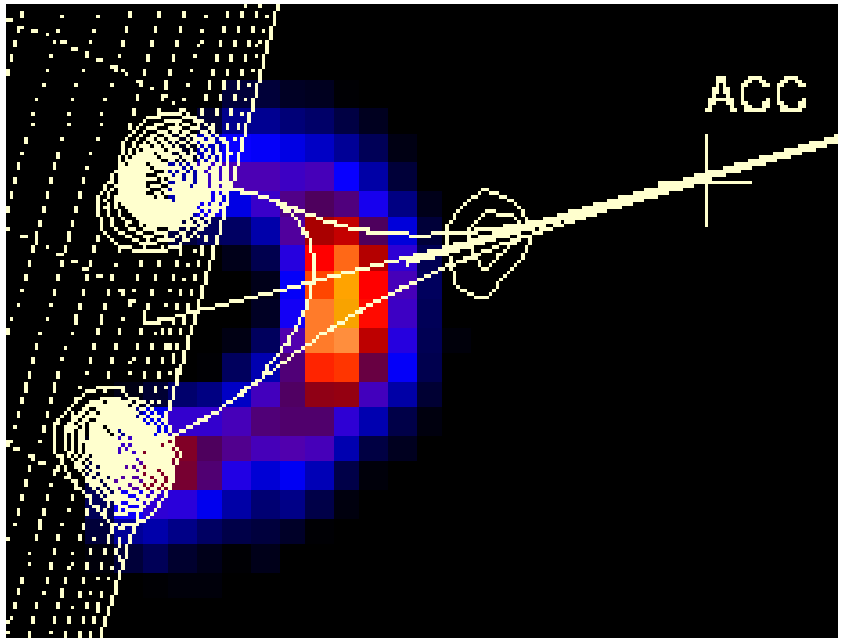
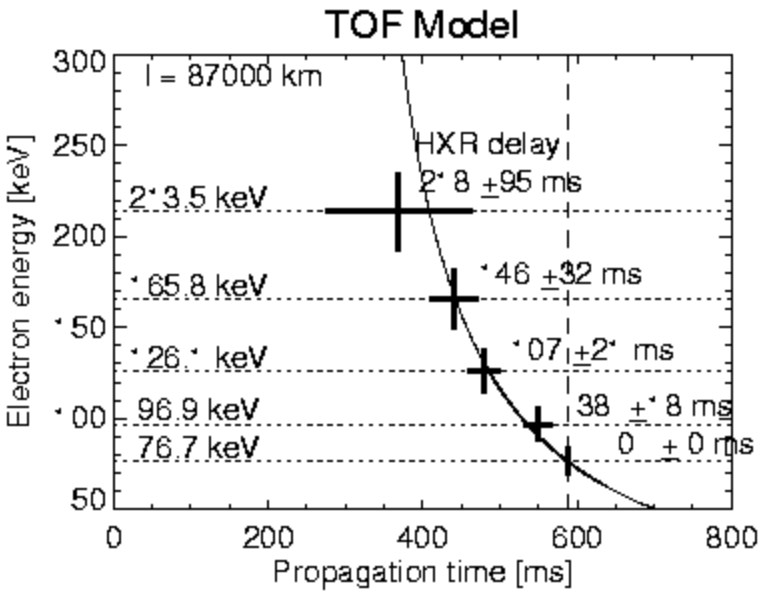
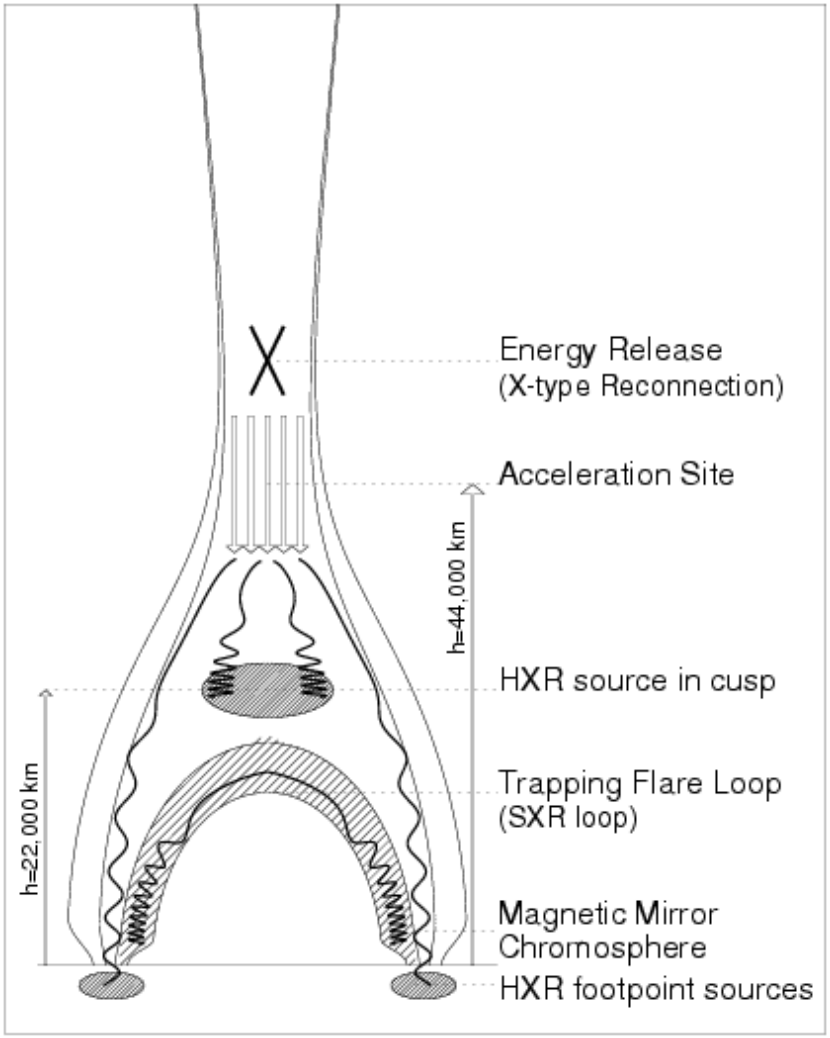
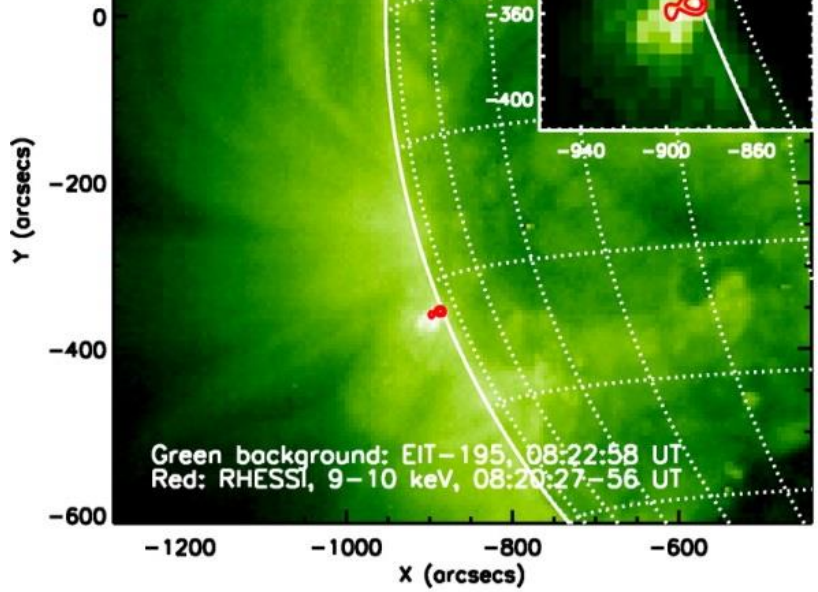


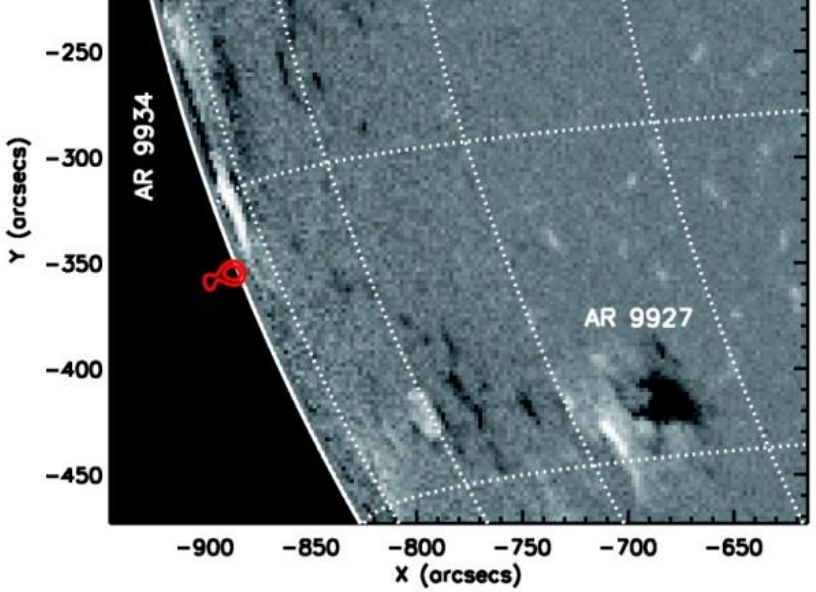


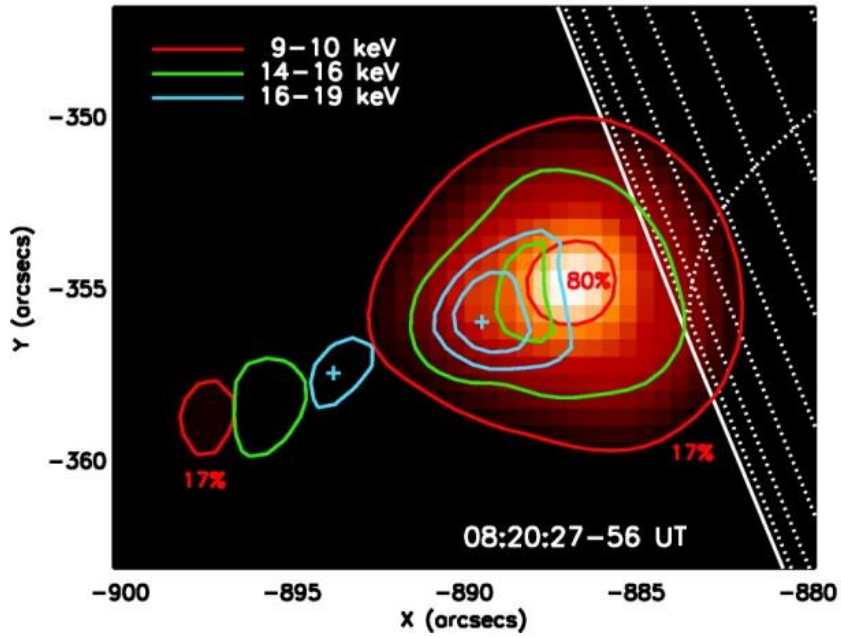


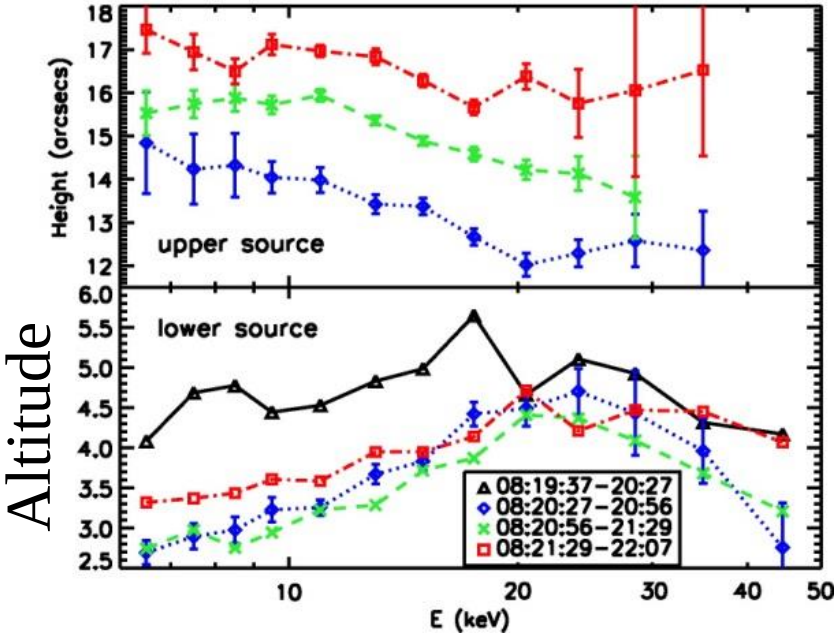
Reconstruction of height of electron acceleration region: L/s ~ 1.5-2.0

(Aschwanden et al. 1996)





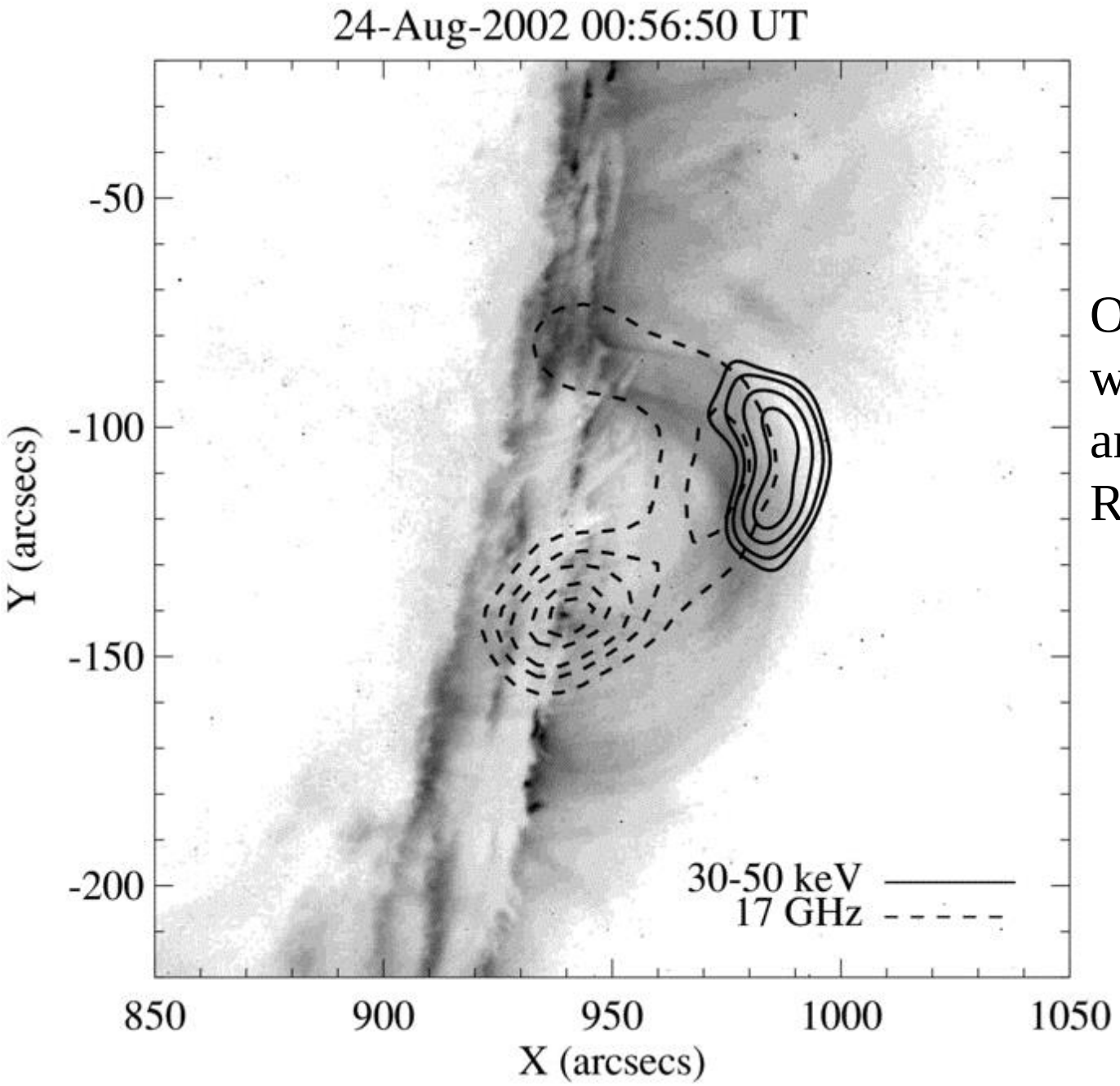




Altitude

Photon energy

Liu et al., ApJ (2008)



Observations with RHESSI and Nobeyama Radioheliograph

17GHz microwave

← ~MeV electrons

Minoshima et al., ApJ (2011)

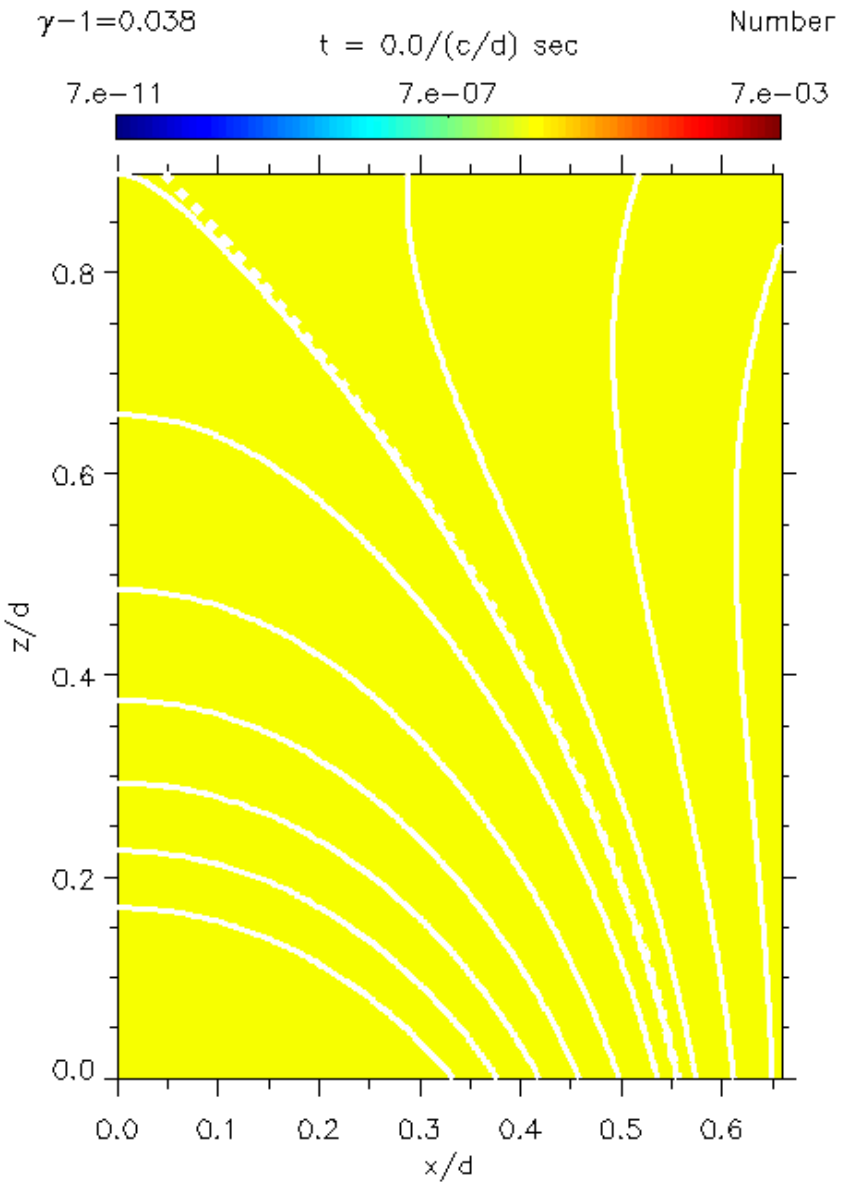
Summary of observations

radiation	electron energy	altitude
Low-energy HXRs	~ 50 keV	Low
high-energy HXRs	~100keV	High
microwave(17GHz)	~1 MeV	Low

What kind of physical process produces this result?

→ Modeling / Simulation

Modeling of particle acceleration



Minoshima, Masuda, Miyoshi, ApJ, 2010

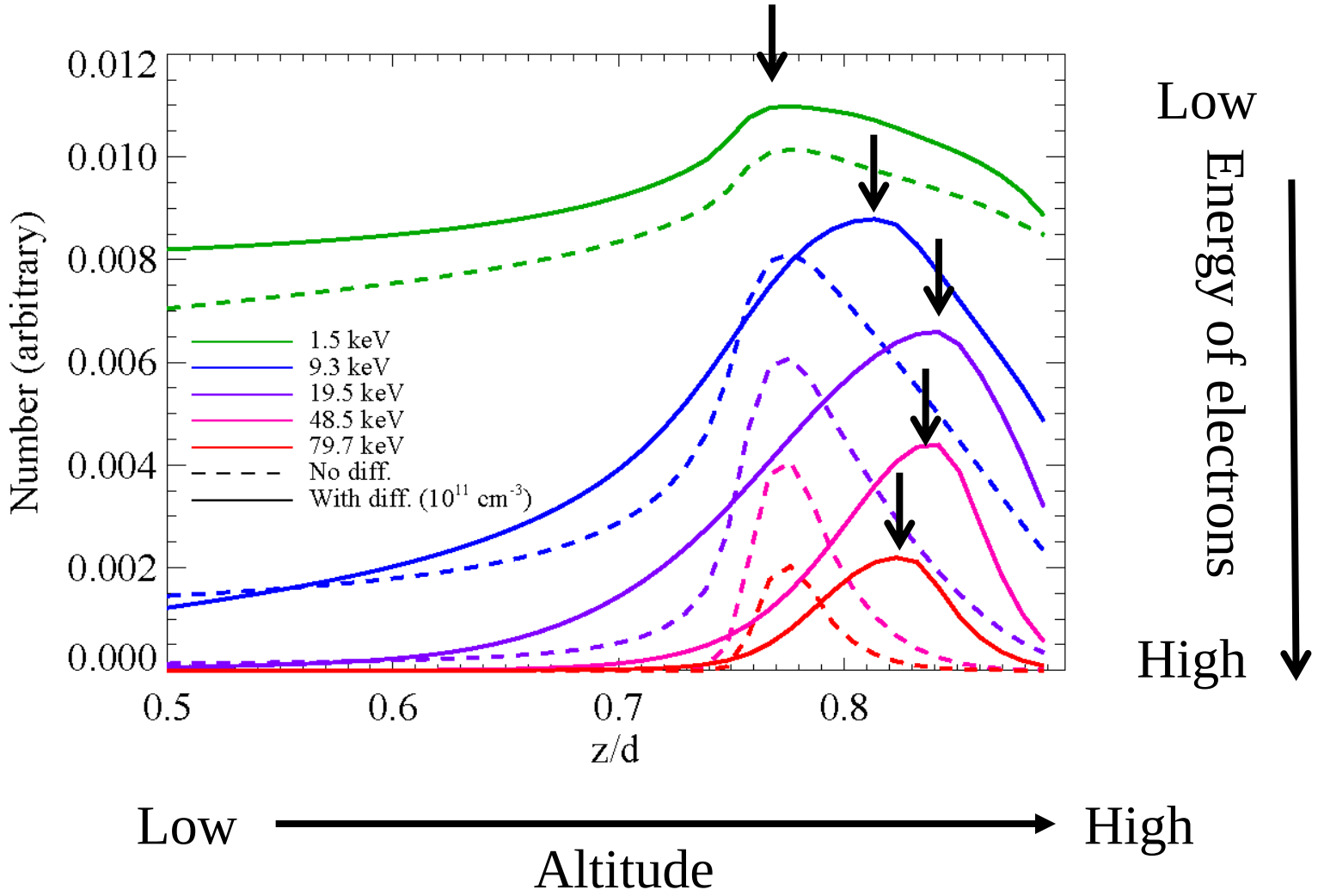
- **Modeling based on drift-kinetic theory**
- **Particle acceleration and time evolution of distribution function of electrons due to inductive electric field ($-\boldsymbol{v}$x$\boldsymbol{B}$)**
- **Direct comparison with observations**
  - spatial size : 1x1.3 Mm^2
  - time : 10 seconds

Number density of 20 keV electrons
Solid line : magnetic field
Dashed line : separatrix

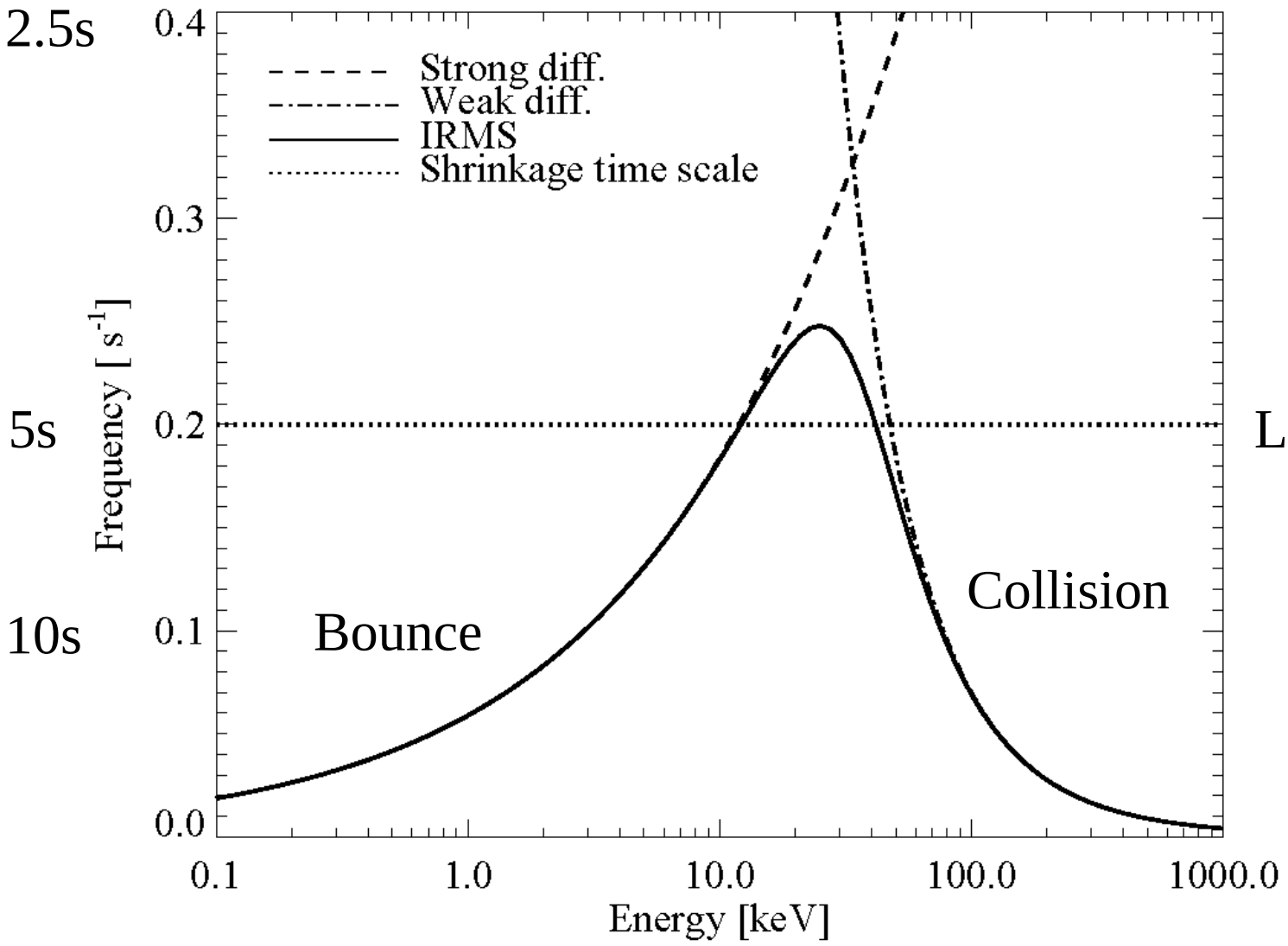
Modeling of particle acceleration based on drift-kinetic theory with collisional process

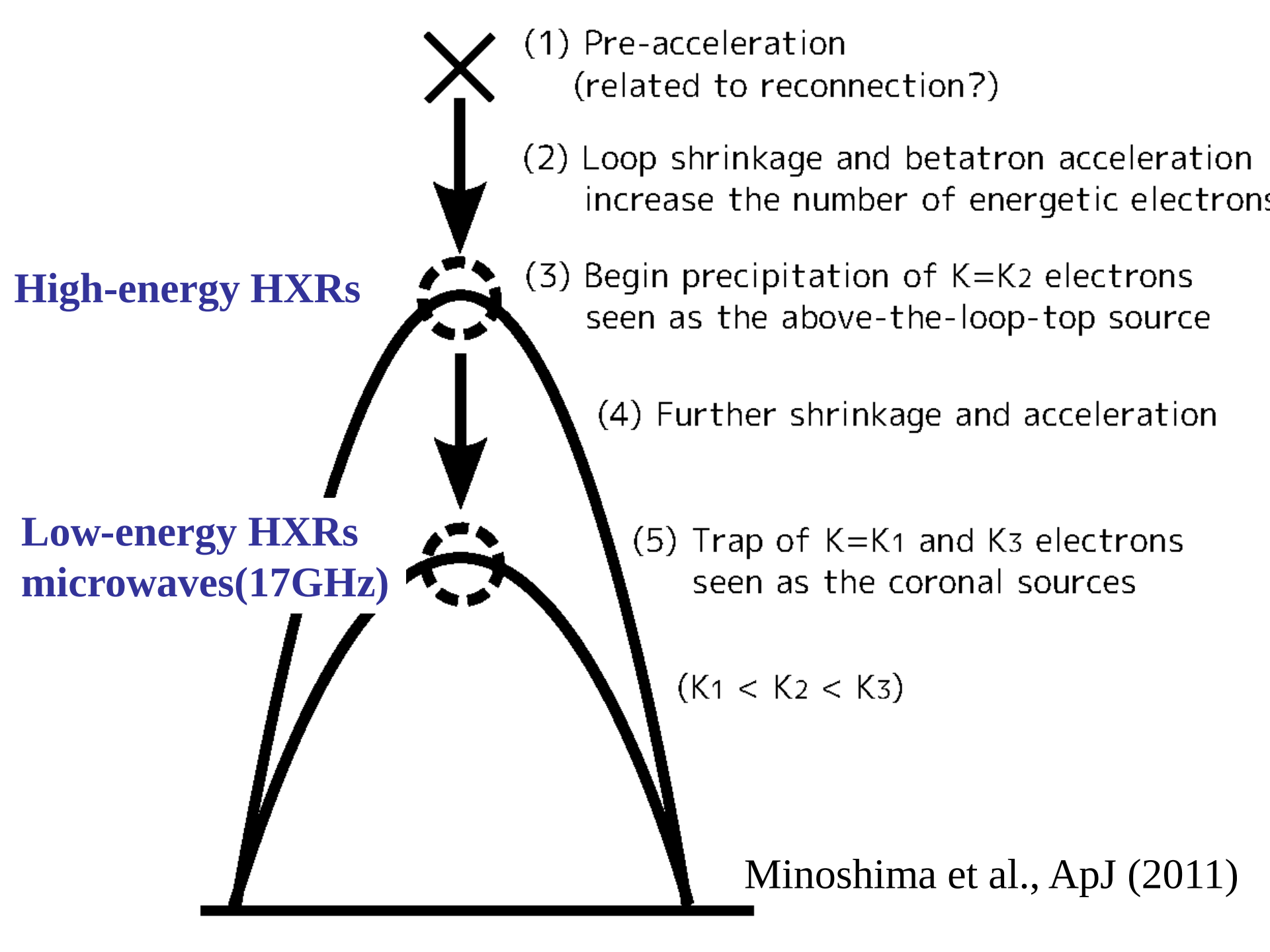
(Minoshima, Masuda, Miyoshi, and Kusano, ApJ submitted)

Height distribution of electrons with different energies



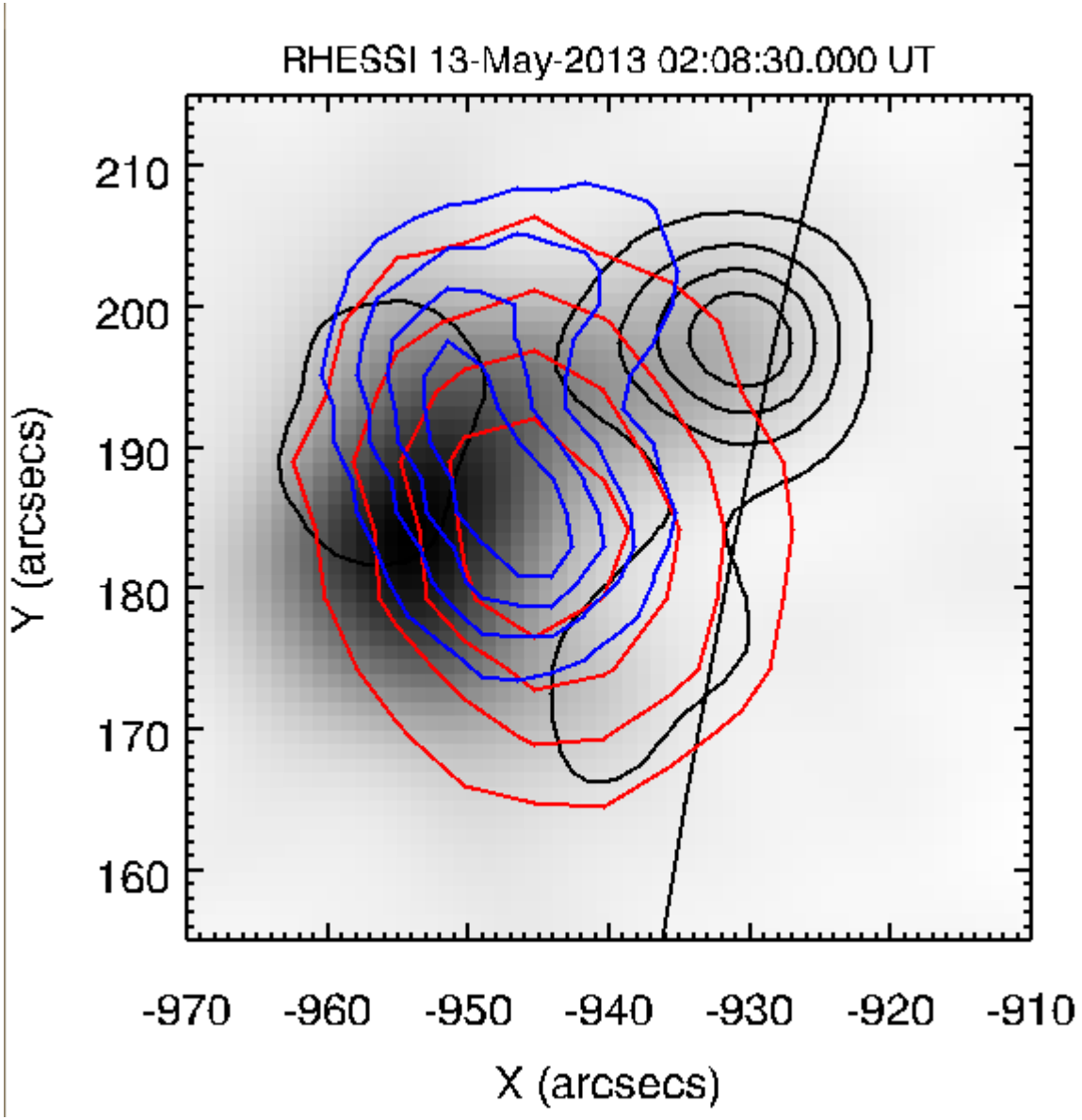
Collisional time-scale vs Bounce time-scale + shrinkage time-scale





Minoshima et al., ApJ (2011)

X1.7-class flare on 13 May 2013

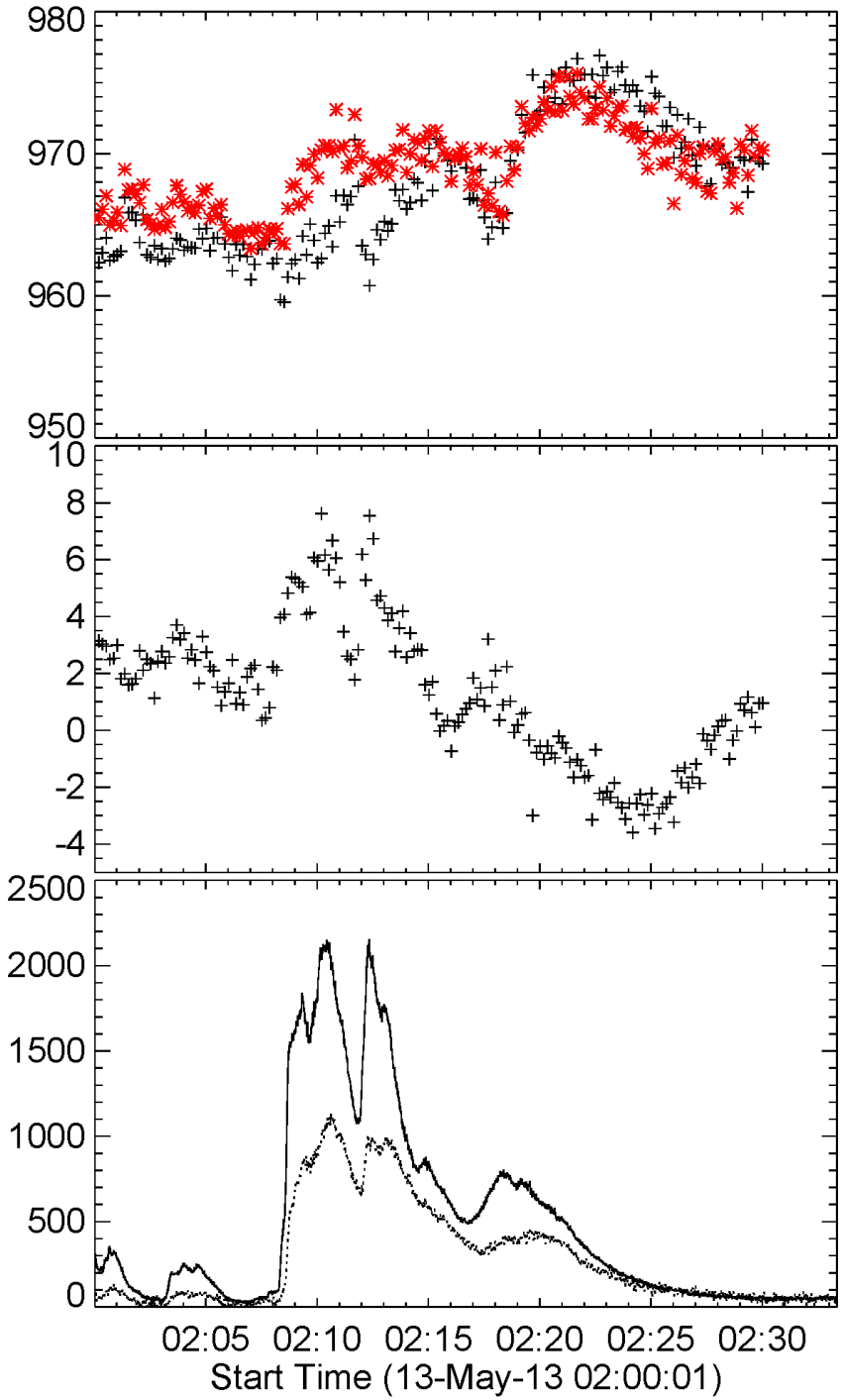


From low-energy
to high-energy electrons

Gray-scale:
① RHESSI 20-30 keV
Black:
② RHESSI 40-50 keV
Red:
③ NoRH 17 GHz
Blue:
④ NoRH 34 GHz

Height

High Low
② >> ① > ④ > ③



Altitude of radio sources (NoRH)

black: 17 GHz

red: 34 GHz

Height difference

34 GHz – 17 GHz

Light curves (NoRP)

solid line: 17GHz

dotted line: 35 GHz

Observational results

(1) In HXRs, higher-energy source is located at a higher altitude than that of a lower-energy source.

(2) The hard X-ray source is located at a higher altitude than that of the microwave sources.

(3) During the impulsive phase, the 34GHz source is located at a higher altitude than that of 17GHz source. The largest difference is detected around the peak time.

The result (3) cannot be explained by the model proposed by Minoshima et al. (2011).

Discussions (Interpretations)

(A) The effect of magnetic field intensity?

→ Usually the magnetic field is more intense at a lower altitude. So the 34 GHz should be at lower. △

(B) Contamination from footpoint sources?

→ possible, but not due to the simple effect of the difference of the spatial resolution. △

(C) Additional loss process for the higher energy electrons emitting 34GHz during the shrinkage of the loop?.

→ We must check the decay time-scale between the observations and the Coulomb collision. ○

(D) Additional acceleration process at a higher altitude?

→ After the loop-shrinkage stops, maybe possible. △

(E) Razin effect → spectral change depending on density △

Summary

Heights of coronal sources in HXRs and microwaves are investigated in a solar flare using the data of Nobeyama Radioheliograph and RHESSI.

The sources are located from lower to higher altitudes as below.
17GHz < 34GHz < 20-30 keV < 40-50 keV

There are a few possibilities to explain this order.
We must reveal how this order is created.

Anyway, still the (above the) looptop region is important to understand the particle acceleration in a solar flare.

International Meeting

Solar Physics with Radio Observations
- Continued Operation of Nobeyama Radioheliograph –

Date: September 9 – 10, 2016 (just after Hinode-10)
Venue: Nagoya University, Nagoya, Japan

Excursion: round-trip to Nobeyama on September 11
(almost final chance to see NoRH)

Registration & Abstract Submission
Deadline: July 31 (Sun), 2016

NOT too late!!