



# Contributions of the Nobeyama Radioheliograph to space-weather science

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.).

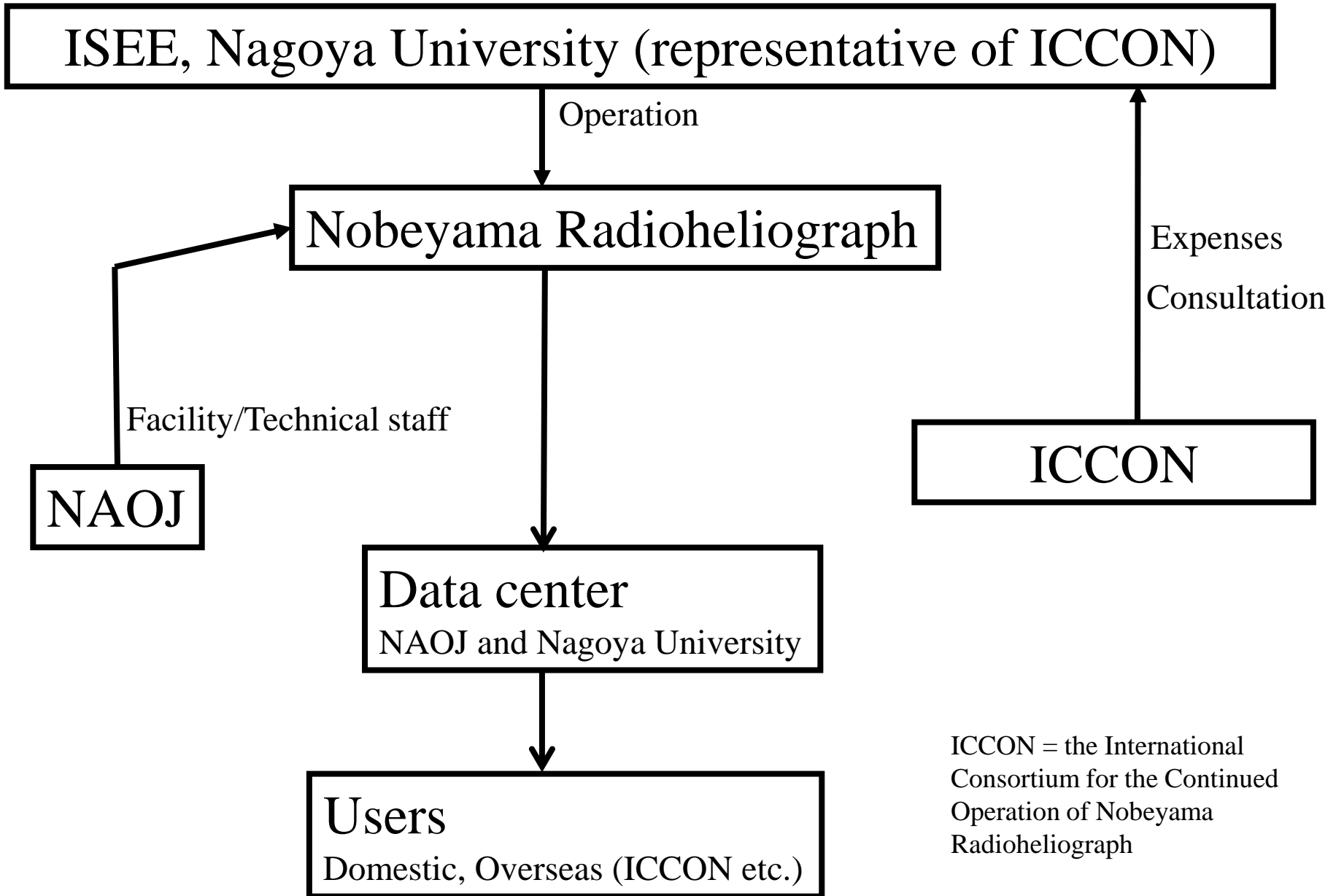
<http://hinode.stelab.nagoya-u.ac.jp/ICCON/>



# kick-off meeting of ICCON @Fukuoka in March 2015



# Organization



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				

# 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

# 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/>**

Why do we need to extend the operation of NoRH?

## Science

### long-term solar activity

polar brightening in microwave

uniform and high-quality dataset for longer than 2 solar cycles

### space weather

prominence eruption

solar flare

particle acceleration

**Simultaneous observations with MUSER**



# Space Weather Research using NoRH

NoRH is a powerful tool for space weather research.

## Solar flares

17 and 34 GHz

→ High-energy electrons ( $\sim$ MeV)

0.1 sec time resolution

→ transport of high-energy electrons

## Prominence eruptions

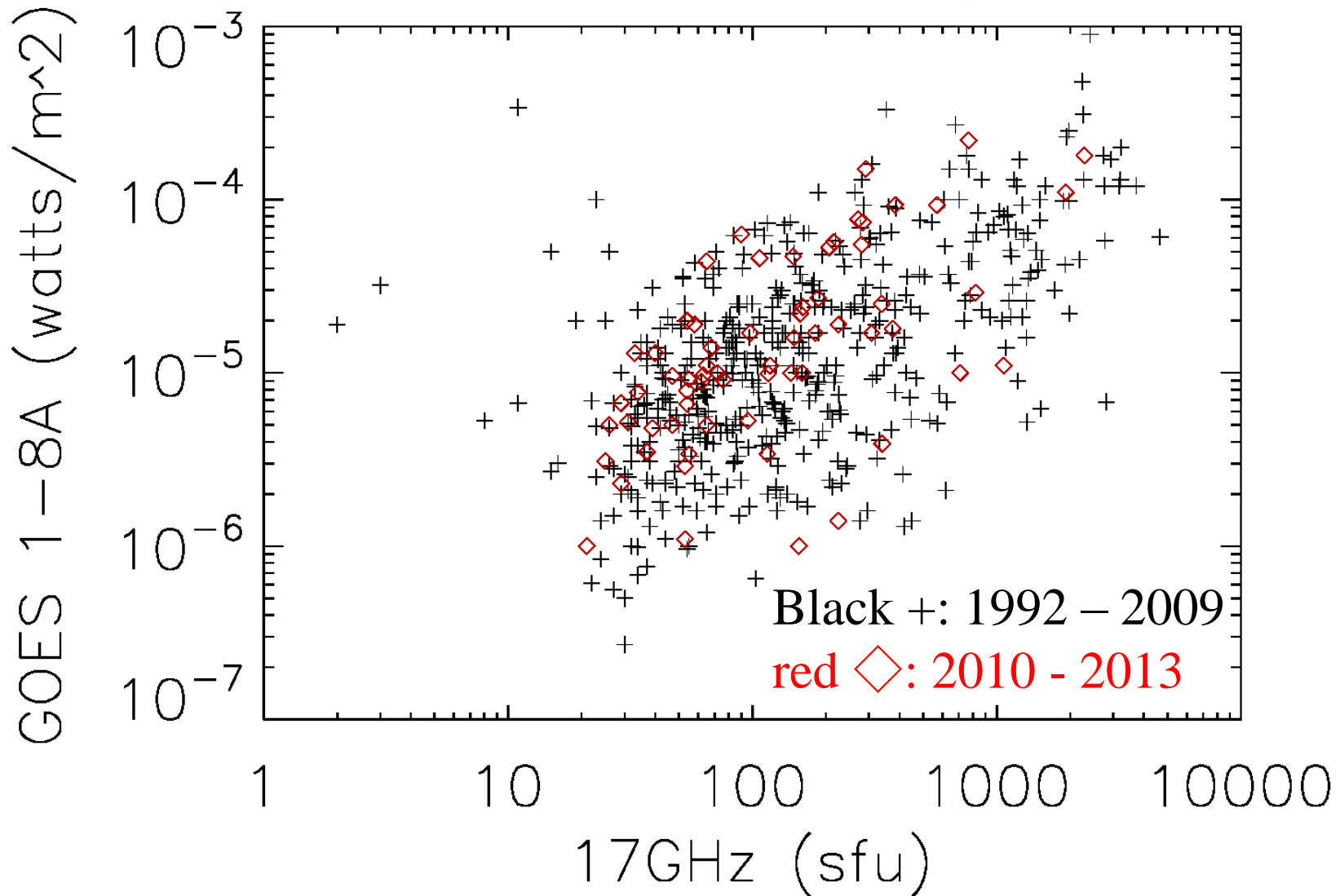
no weather (rain, cloud) effect

→ good for monitoring

no Doppler shift

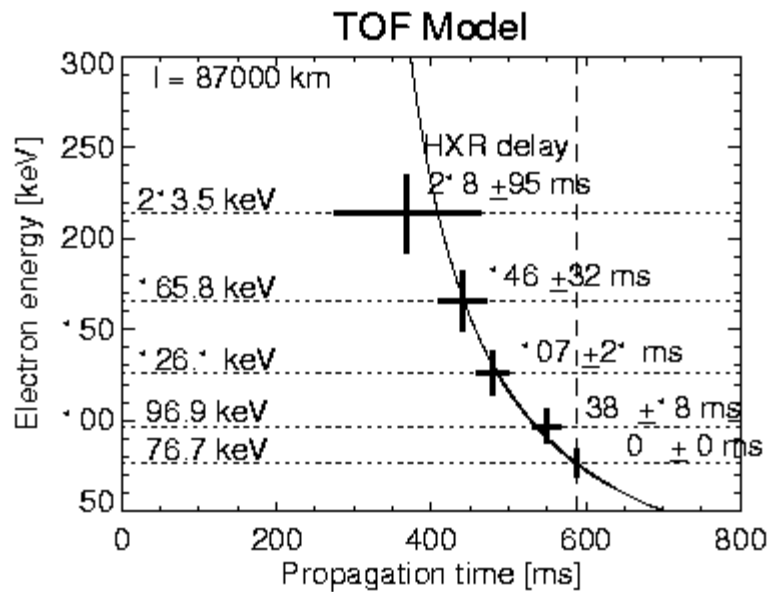
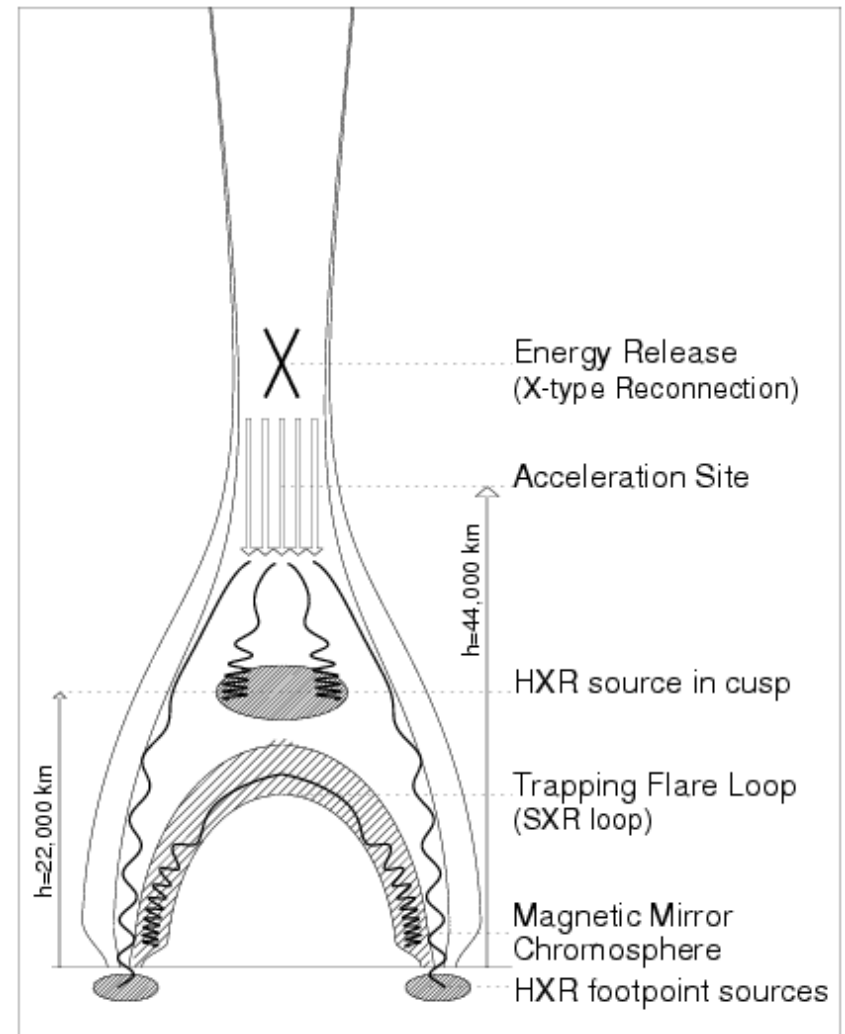
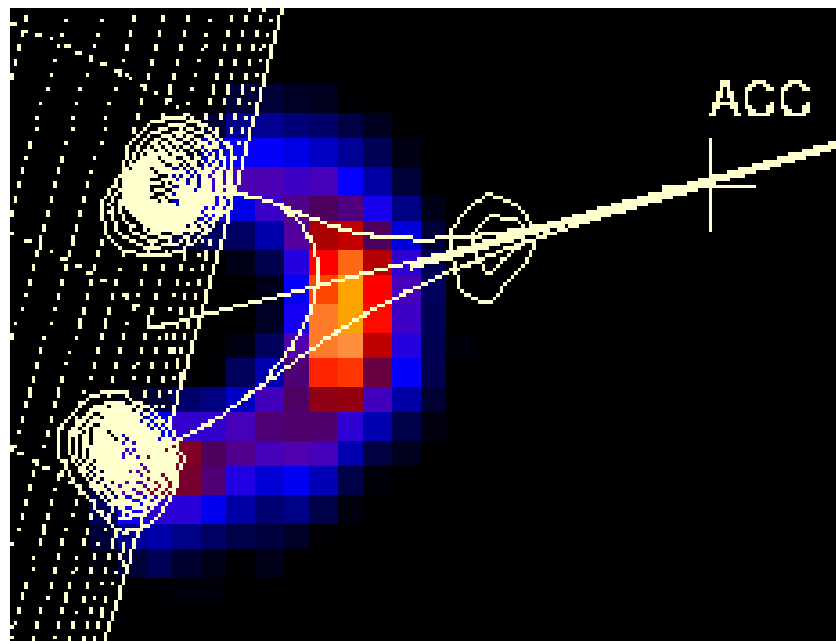
→ possible to follow it even at the higher altitude ( $\sim 2 R_s$ )

# 17 GHz flux vs GOES soft X-ray flux



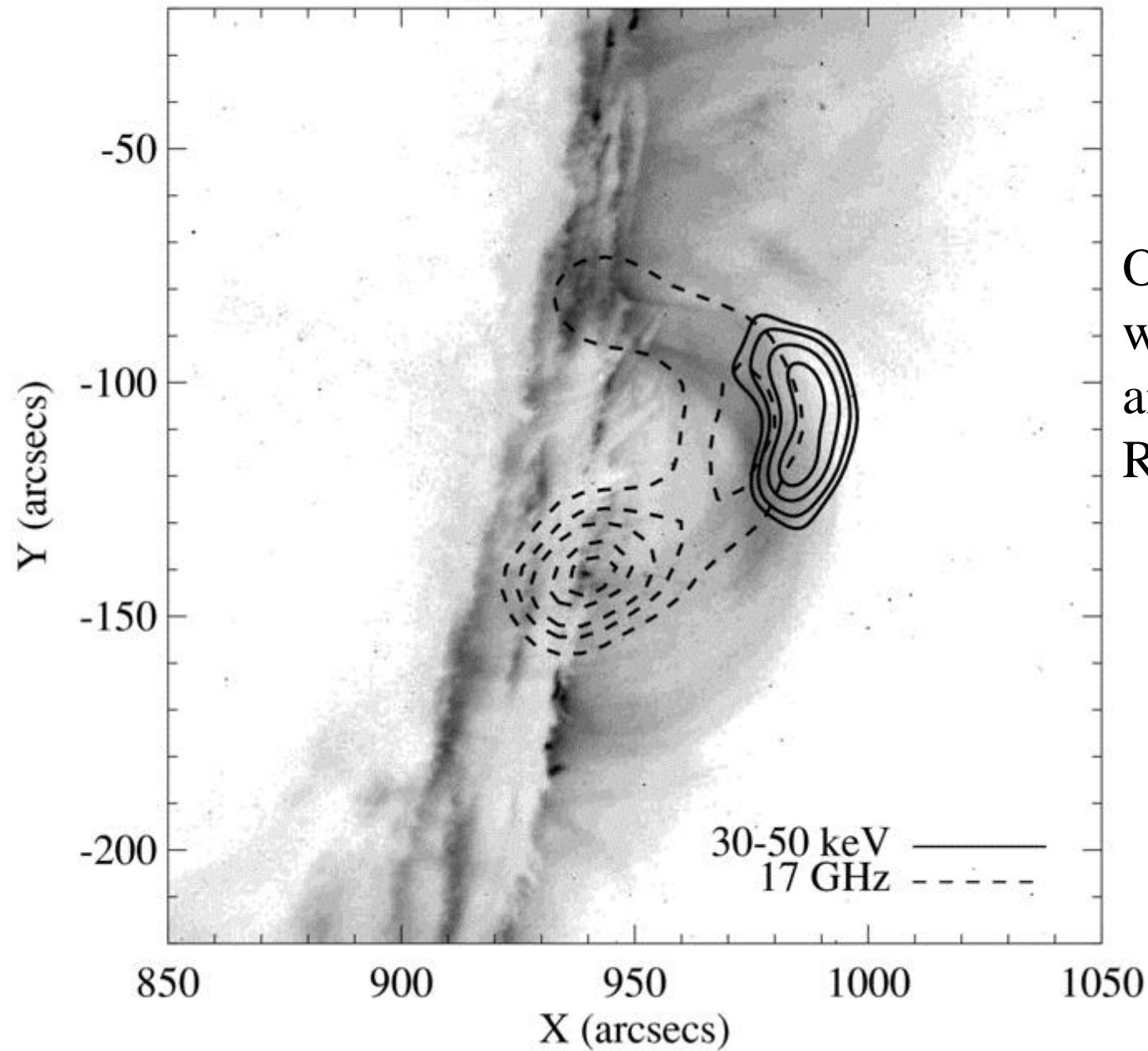
17GHz: gyro-synchrotron emission

→ strongly depends on magnetic field



Reconstruction of height  
of electron acceleration region:  
 $L/s \sim 1.5-2.0$   
(Aschwanden et al. 1996)

24-Aug-2002 00:56:50 UT



Observations  
with RHESSI  
and Nobeyama  
Radioheliograph

17GHz microwave

← ~MeV electrons

Minoshima et al., ApJ (2011)

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## Solar flares

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→ High-energy electrons ( $\sim$ MeV)

0.1 sec time resolution

→ transport of high-energy electrons

## Prominence eruptions

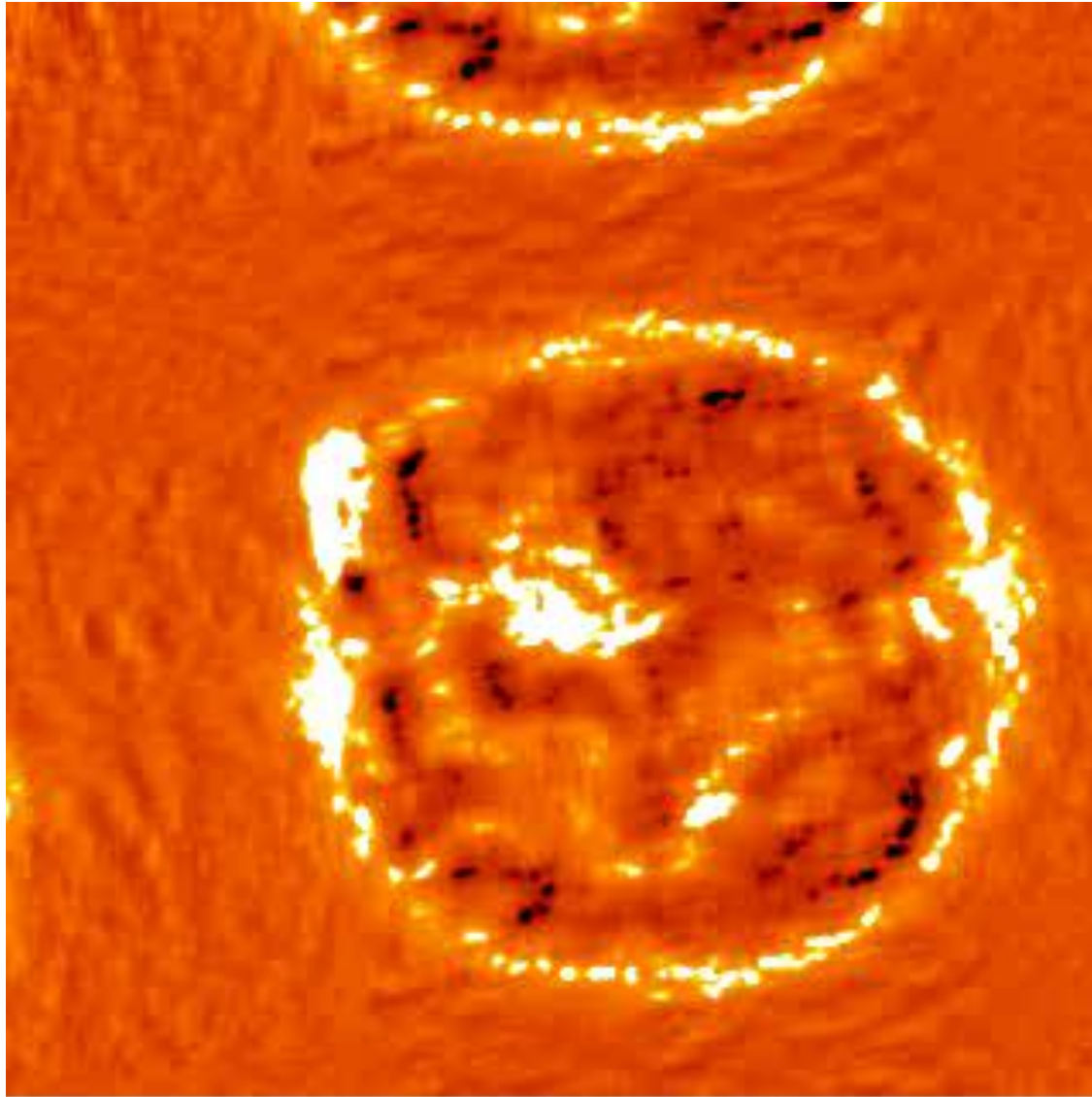
no weather (rain, cloud) effect

→ good for monitoring

no Doppler shift

→ possible to follow it even at the higher altitude ( $\sim 2 R_s$ )

# Prominence eruption observed with NoRH



1992 July 31 00:15UT  
Y. Hanaoka

# Nobeyama Radioheliograph Limb Events

2014

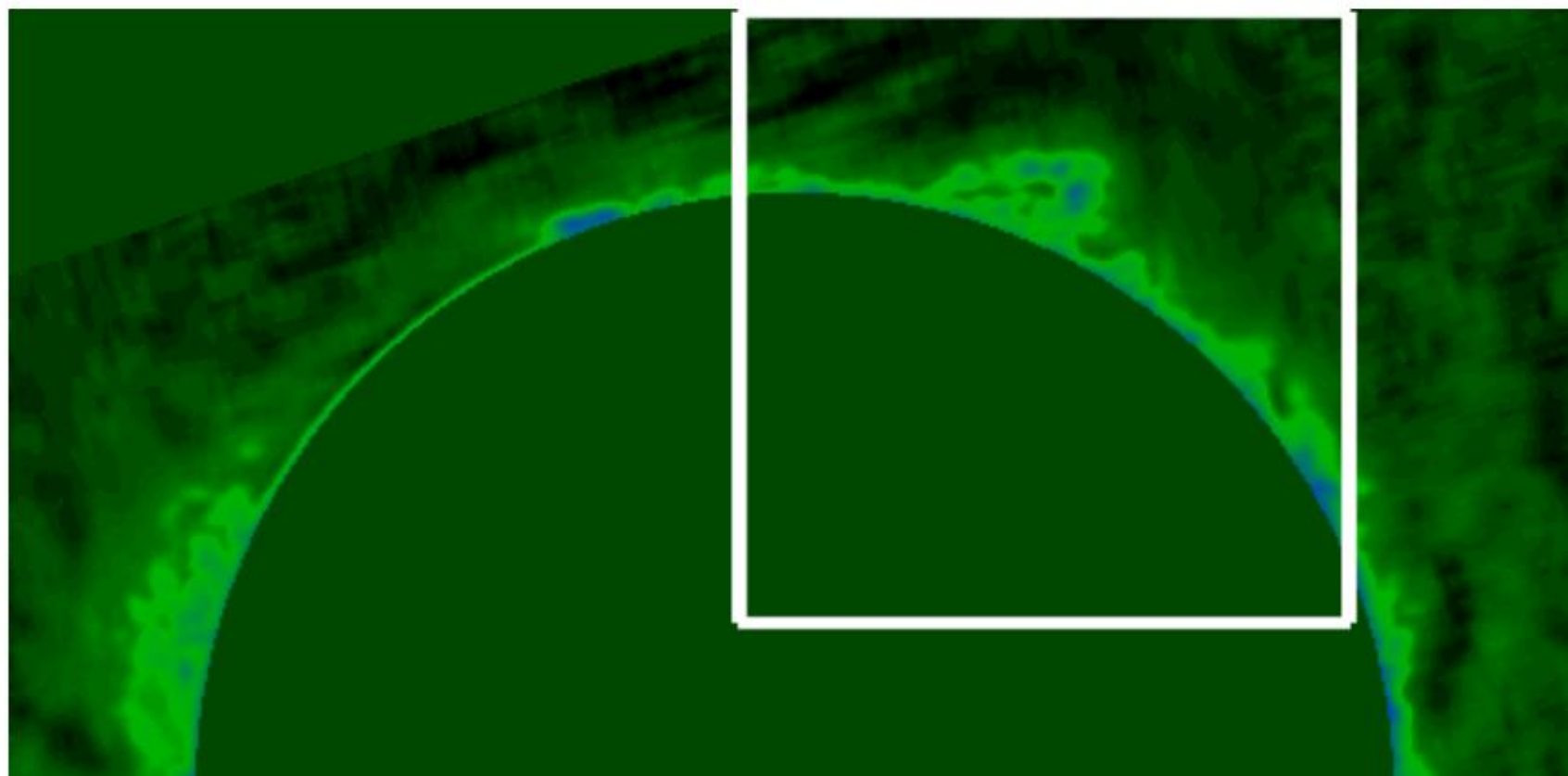
Event ID	Date	Start (UT)	Peak (UT)	End (UT)	X (arcsec)	Y (arcsec)	Index (Pixel)
<a href="#">PE20140726_2320</a>	26-Jul-14	23:20:02	23:20:02	00:20:02	406	1022	440
<a href="#">PE20140722_2340</a>	22-Jul-14	22:50:02	23:40:02	00:00:02	671	826	407
<a href="#">PE20140710_0620</a>	10-Jul-14	05:50:02	06:20:02	06:20:02	1073	-227	716
<a href="#">PE20140704_0200</a>	04-Jul-14	02:00:03	02:00:03	02:40:03	-822	720	411
<a href="#">PE20140702_0120</a>	02-Jul-14	01:10:00	01:20:00	01:30:00	-983	64	497
<a href="#">PE20140609_0010</a>	09-Jun-14	00:00:01	00:10:01	00:40:01	-1145	-266	2553
<a href="#">PE20140531_0310</a>	31-May-14	02:50:01	03:10:01	03:20:01	802	-676	541
<a href="#">PE20140523_0620</a>	23-May-14	06:00:00	06:20:00	06:20:00	-795	-689	537
<a href="#">PE20140517_0540</a>	17-May-14	05:40:01	05:40:01	06:10:01	-1030	359	403
<a href="#">PE20140511_0020</a>	11-May-14	00:00:01	00:20:01	00:30:01	-564	-852	847
<a href="#">PE20140509_0250</a>	09-May-14	02:30:00	02:50:00	03:10:00	1108	-338	2339
<a href="#">PE20140428_0130</a>	28-Apr-14	01:30:03	01:30:03	02:10:03	1198	-320	1224
<a href="#">PE20140421_0340</a>	21-Apr-14	03:30:02	03:40:02	04:10:02	1017	424	1199
<a href="#">PE20140421_0100</a>	21-Apr-14	00:40:02	01:00:02	01:20:02	947	-649	867
<a href="#">PE20140410_0040</a>	10-Apr-14	00:40:00	00:40:00	01:00:00	-678	-785	571
<a href="#">PE20140406_0200</a>	06-Apr-14	01:40:02	02:00:02	02:20:02	-941	-544	977
<a href="#">PE20140405_0000</a>	04-Apr-14	23:40:02	00:00:02	00:00:02	-933	-594	2967
<a href="#">PE20140326_0520</a>	26-Mar-14	05:10:03	05:20:03	05:40:03	-641	-818	682
<a href="#">PE20140224_2330</a>	24-Feb-14	23:20:01	23:30:01	23:40:01	737	-759	628
<a href="#">PE20140219_0600</a>	19-Feb-14	06:00:01	06:00:01	06:20:01	75	-1015	498
<a href="#">PE20140217_0530</a>	17-Feb-14	04:40:02	05:30:02	05:40:02	1120	-203	2094
<a href="#">PE20140216_0110</a>	16-Feb-14	01:10:03	01:10:03	01:30:03	1029	1012	1808
<a href="#">PE20140212_0620</a>	12-Feb-14	06:00:03	06:20:03	06:20:03	769	-660	676
<a href="#">PE20140117_2300</a>	17-Jan-14	22:50:01	23:00:01	23:10:01	-432	-914	452
<a href="#">PE20140116_2250</a>	16-Jan-14	22:50:02	22:50:02	23:10:02	-527	-861	664
<a href="#">PE20140106_0610</a>	06-Jan-14	06:00:03	06:10:03	06:20:03	-975	592	1695
<a href="#">PE20140103_0340</a>	03-Jan-14	03:30:00	03:40:00	04:00:00	-1142	364	1098

# The Results of Automatic Detection of Limb Events using Radio Heliograms (17 GHz)

EVENT\_ID : PE20140726\_2320

Event_ID	Date	Start (UT)	Peak (UT)	END (UT)	X (arcsec)	Y (arcsec)	Index
PE20140726_2320	26-Jul-14	23:20:02	23:20:02	00:20:02	406	1022	440

Radio-Coronagraph





# Conclusion

NoRH is a unique instrument even in the world which provides fundamental and high-quality microwave images in this frequency range. There is no doubt that **NoRH is one of the powerful tools for Space Weather** and Space Climate research.

From April 2015, an international consortium, ICCON, began the operation of NoRH instead of NAOJ.

We need more contribution for the stable operation of NoRH and for producing more scientific outputs.

ICCON:

International Consortium for the Continued Operation of Nobeyama Radioheliograph

N. Gopalswamy (**NASA**), Y. Yan (**NAOC**), K. S. Cho (**KASI**), M. Ishii (**NICT**),  
K. Shibasaki, and S. Masuda (**ISEE, Nagoya U.**)