Space weather related studies with the Chinese solar radio instruments

Rositsa Miteva

Space Research and Technology Institute
Bulgarian Academy of Sciences
rmiteva@space.bas.bg

Chengming Tan
Yin Zhang
Jing Huang
Yuhua Yan
and Baolin Tan

Solar Radio Research Group, Key Laboratory of Solar Activity
National Astronomical Observatories (NAOC)
Chinese Academy of Sciences

7th Workshop "Solar Influences on the Magnetosphere, Ionosphere and Atmosphere"
Sunny Beach, Bulgaria, 1–6 June 2015

Key Laboratory of Solar Activity (KLSA)

established: 28–Dec–2008; 58 staff members (incl. 13 professors)

Research groups

(1) Solar Magnetism & Activity Group

(2) Solar Radio Research Group

(3) Solar Activity Prediction Center

Observational stations

(1) Huairou Solar Observing Station (HSOS) in Beijing

(2) MingAnTu Observing Station in Inner Mongolia

Instruments

(1) Solar Multi-Channel Telescope (SMCT) at HSOS

(2) Solar Broadband Radio Spectrometer (SBRS) at HSOS

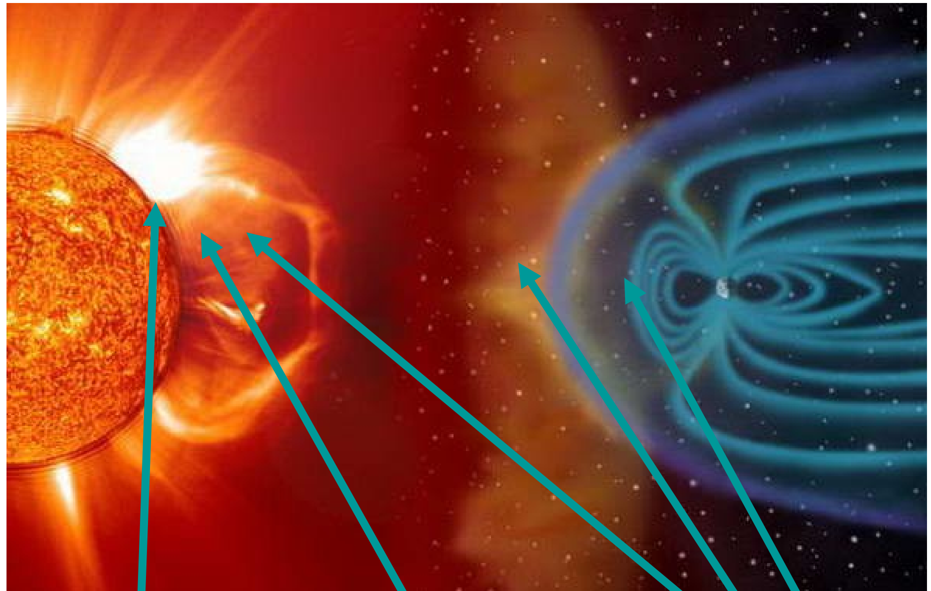
(3) Chinese Spectral Radioheliograph (CSRH) at MingAnTu

Director: Prof. Yihua Yan

Deputy Director: Prof. Yuanyong Deng, Jun Zhang, Jie Jiang

Senior Professor: Prof. Guoxiang Ai, Jingxiu Wang, etc.

Organization of KLSA



Core
Solar Activity

Methods

optical | infrared | radio

Observing stations

Huairou Solar Observing Station

MingAnTu Sation

Technical support

Space detection

Directions

Origin of solar activity

Formation of solar cycle

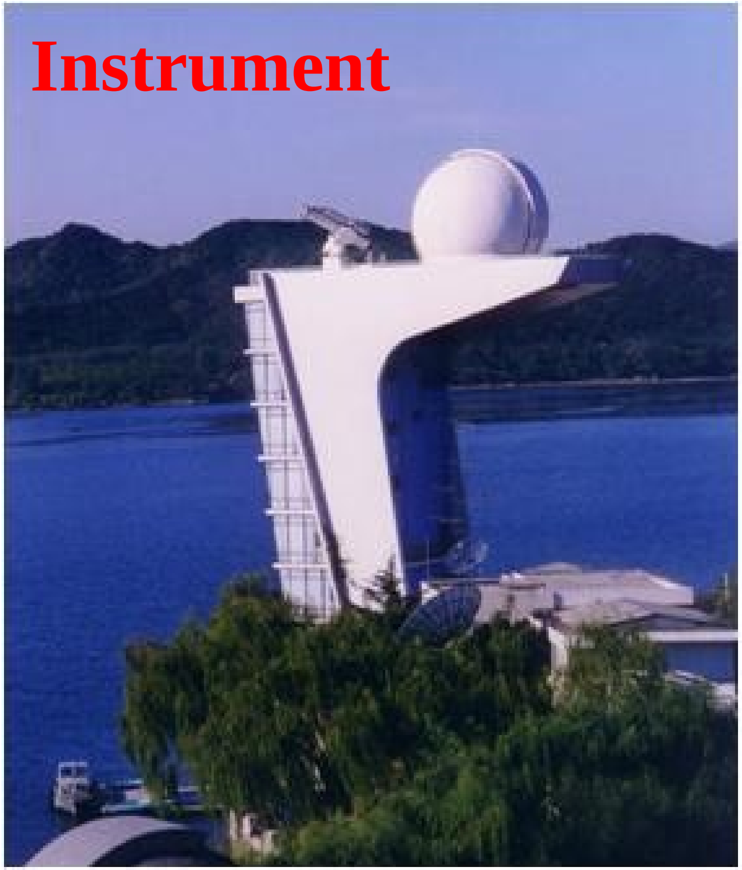
Energetic particles and solar wind

Impact to solar terrestrial space

Prediction of solar activity

Observational station

Huairou near Beijing



- **35-cm Solar Magnetic Field Telescope**

photospheric, chromospheric vector magnetic fields and line-of-sight velocity fields at Fe I 5324.19 Å and Hβ 4861 Å

- **60-cm Solar three-channel Telescope**

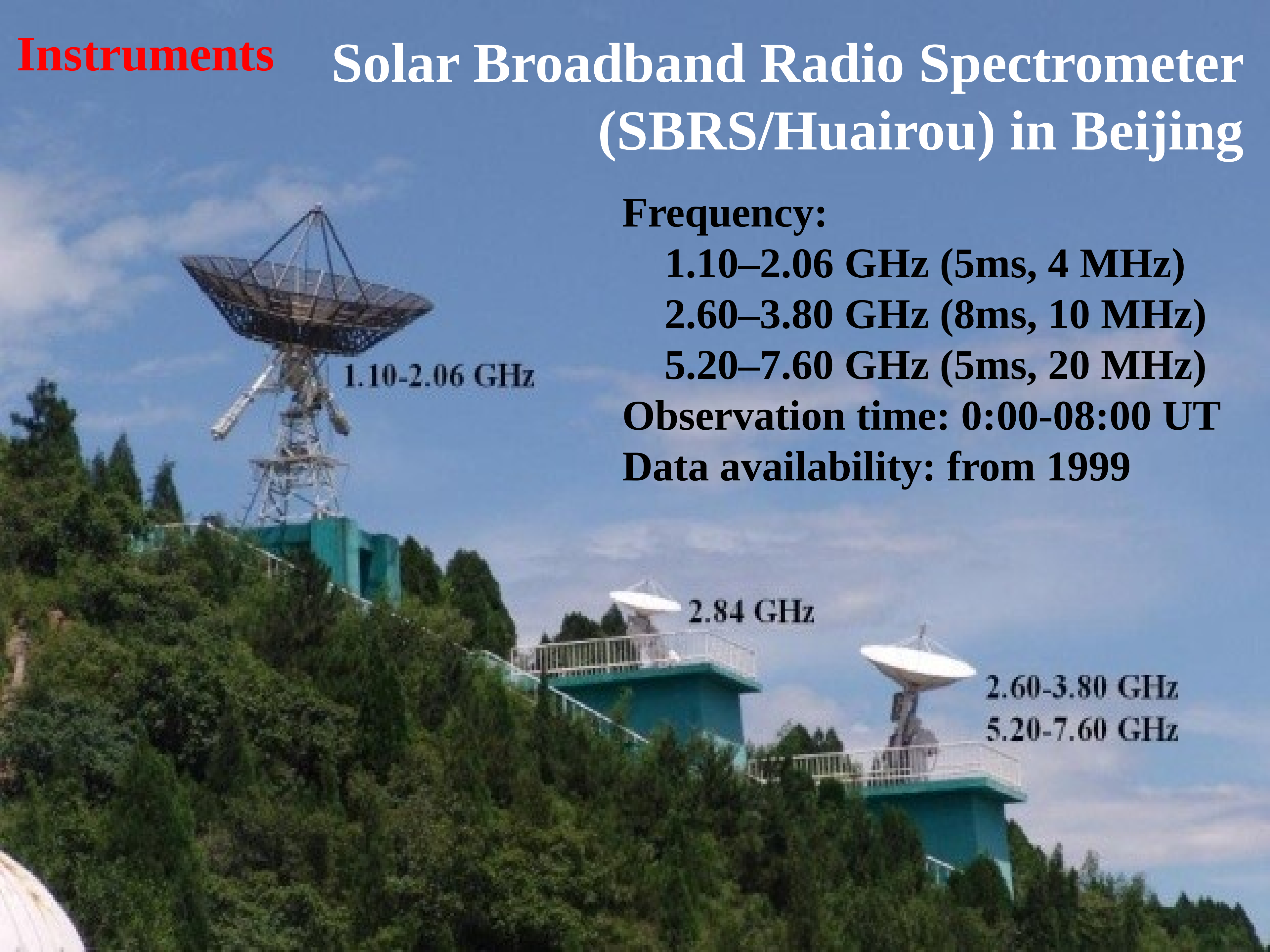
monochromatic images and the vector magnetic fields simultaneously at three spectral lines (Mg I 5173 Å, Fe I 5247 Å, Fe I 5250 Å)

Monitoring System of Solar Activity

10 cm vector magnetograph (full-disk vector magnetic field at Fe I 5324.19 Å) and 20-cm Hα telescope (full-disk Hα monochromatic images)

Instruments

Solar Broadband Radio Spectrometer (SBRS/Huairou) in Beijing



Frequency:

- 1.10–2.06 GHz (5ms, 4 MHz)
- 2.60–3.80 GHz (8ms, 10 MHz)
- 5.20–7.60 GHz (5ms, 20 MHz)

Observation time: 0:00-08:00 UT

Data availability: from 1999

Summary of radio spectrometer data

Station/ Location	*Frequency range*	*Time resolution*	*Frequency resolution*	*Polarization*
SBRS/ Kunming	**0.7–15 GHz**	**80 ms**	**4 MHz**	**R, L**
SBRS/ Nanjing	**4.5–7.5 GHz**	**10 ms**	**10 MHz**	**total**
SBRS/ Huairou	**5.2–7.6 GHz**	**5 ms**	**20 MHz**	**R, L**
	2.6–3.9 GHz	**8 ms**	**10 MHz**	**R, L**
	1.1–2.1 GHz	**5 ms**	**4 MHz**	**R, L**
SBRS/ Kunming	**70–700 MHz**	**80 ms**	**1.2 MHz**	**R, L**

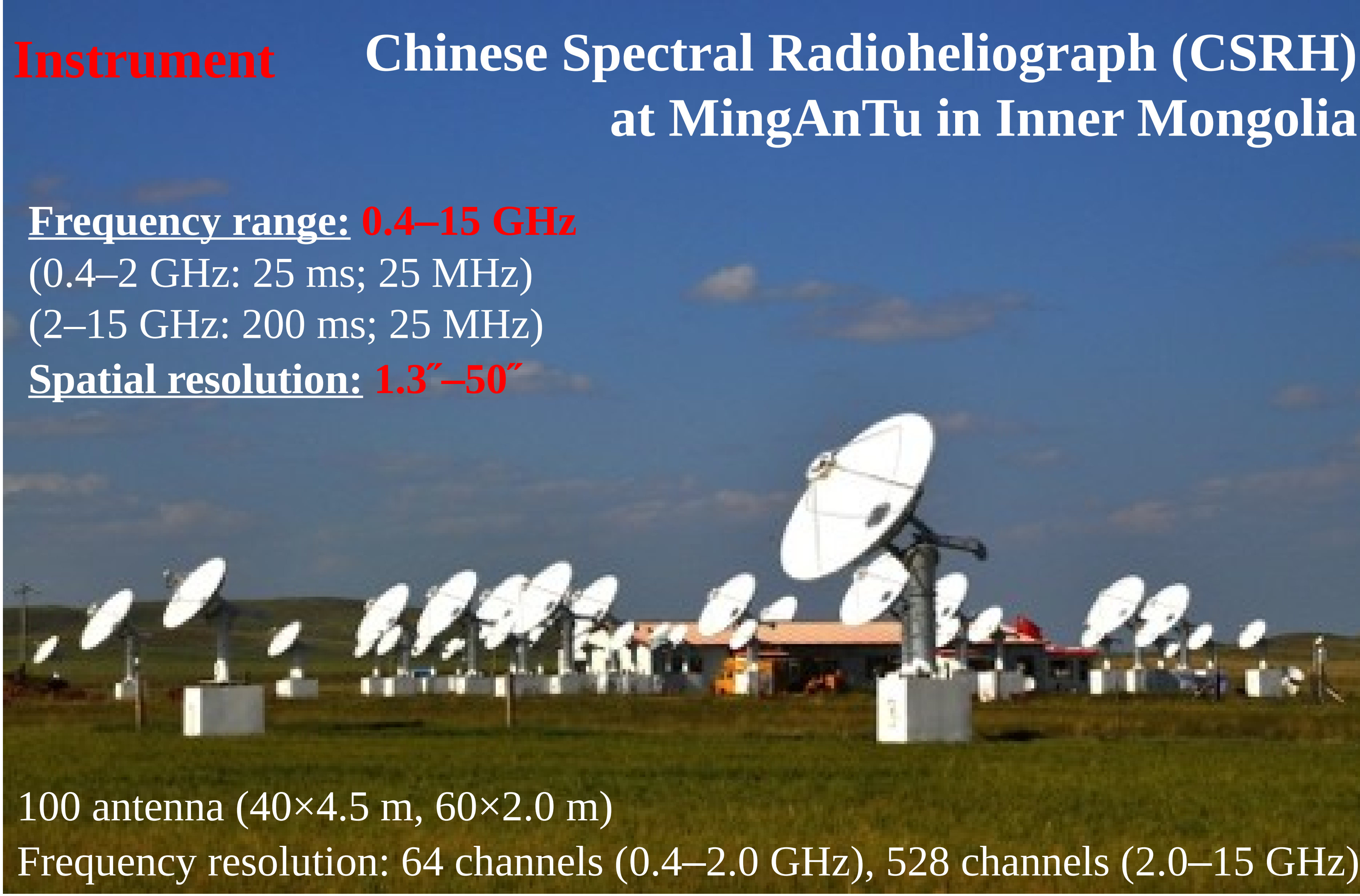
Contact person: Dr. Chengming Tan tanch@nao.cas.cn

Observational station

MingAnTu in Inner Mongolia

Instrument

Chinese Spectral Radioheliograph (CSRH) at MingAnTu in Inner Mongolia



Frequency range: 0.4–15 GHz
(0.4–2 GHz: 25 ms; 25 MHz)
(2–15 GHz: 200 ms; 25 MHz)

Spatial resolution: 1.3″–50″

100 antenna (40×4.5 m, 60×2.0 m)

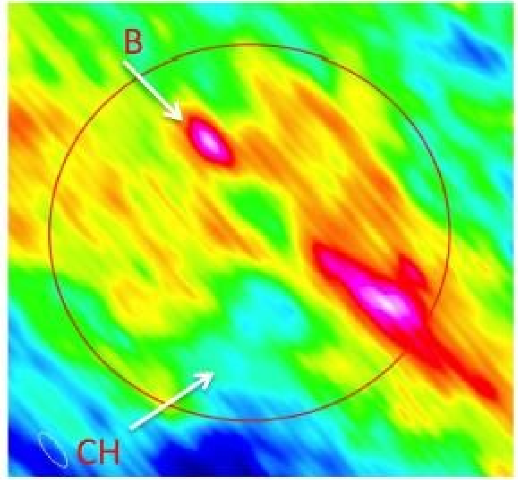
Frequency resolution: 64 channels (0.4–2.0 GHz), 528 channels (2.0–15 GHz)

Max. baseline: 3.0 km

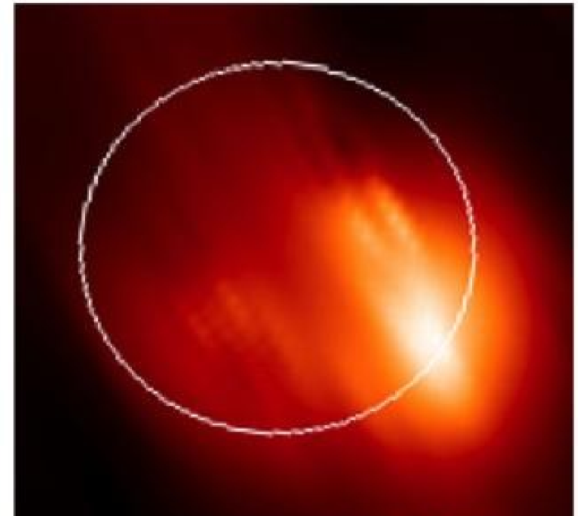
Status: finished construction in 2014, presently test observations, calibrations

Contact person: Dr. Wei Wang **wwang@nao.cas.cn**

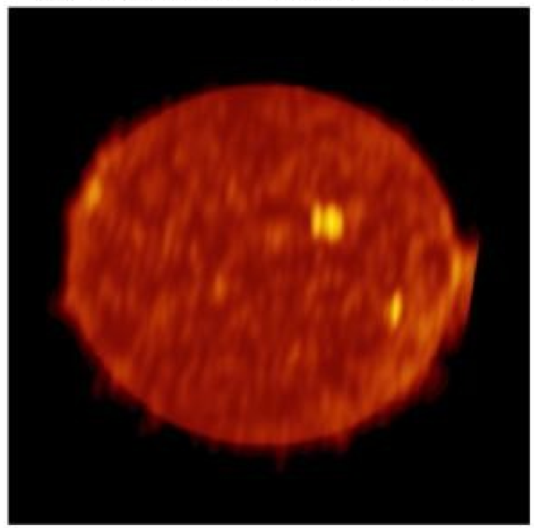
First test results from CSRH (MUSTER)



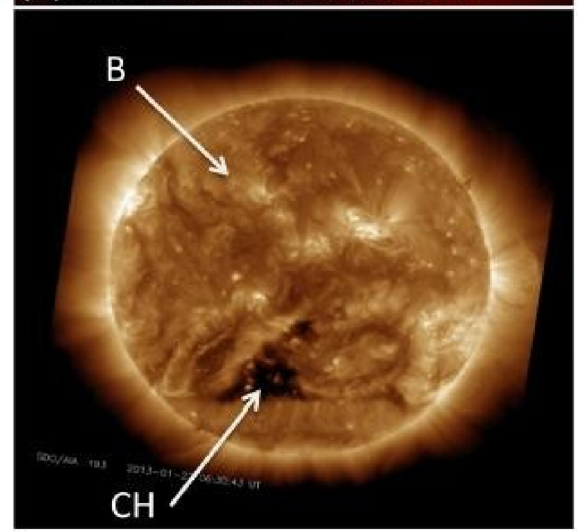
(a) CSRH-I 1.7 GHz 06:30UT



(b) NRH 432 MHz 15:13:53UT



(c) SSRT 5.7 GHz 05:50 UT



(d) AIA/SDO 193Å 06:30:43UT

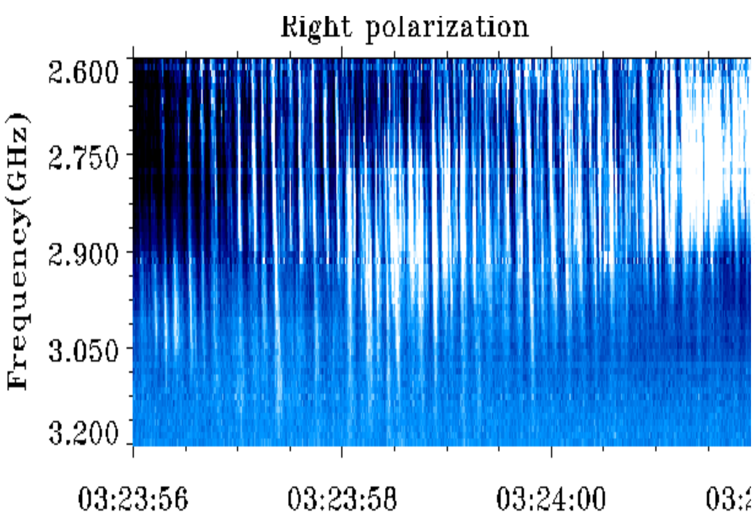
image from
http://srg.bao.ac.cn/csrh.htm

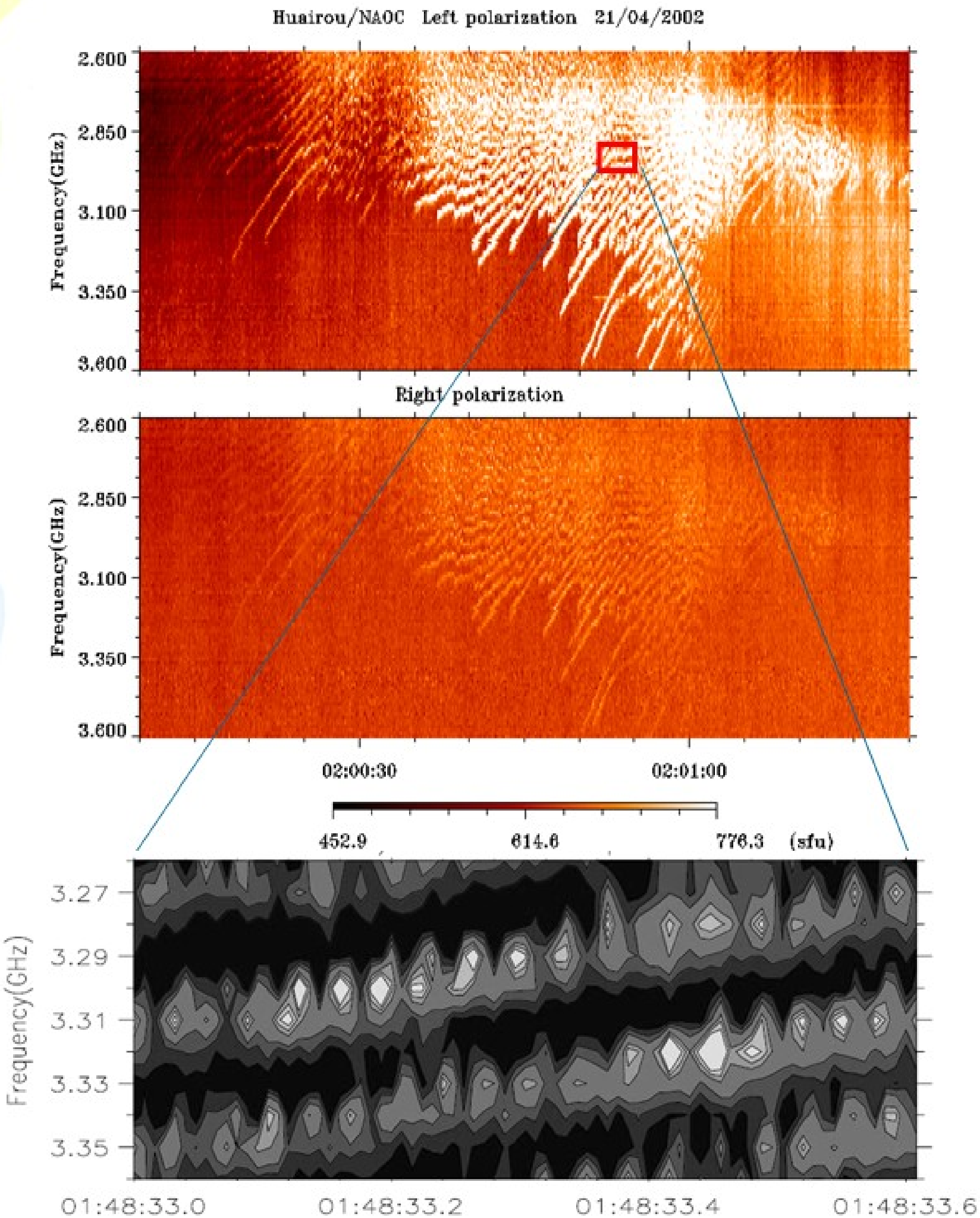
图 2：2013 年 1 月 22 日 6:30 UT 由 CSRH 低频阵观测经 CASA 软件处理获得的 30ms 积分时间的宁静太阳射电图像（a），同日法国南茜天文台（b）和俄罗斯十字阵（c）在不同频率上的射电图像，以及 SDO 卫星 193 埃波长的极紫外图像（d）。可以看出 CSRH 低频阵 1.7 GHz 图像中的亮源 B 在 432 MHz 和 5.7 GHz 图像中均无显著辐射，但是在极紫外图像上明显对应着亮冕环结构，射电辐射弱的区域对应着冕洞（CH）。

Space Weather related studies

High frequency precursors of solar eruptive events

images from SBRS

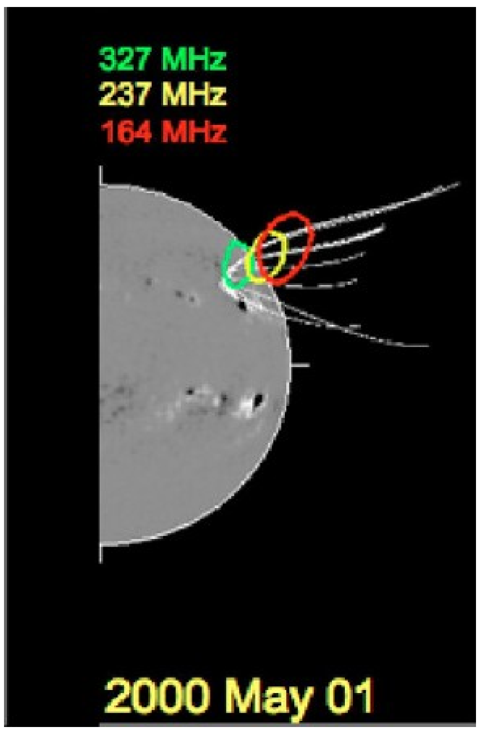




Space Weather related studies

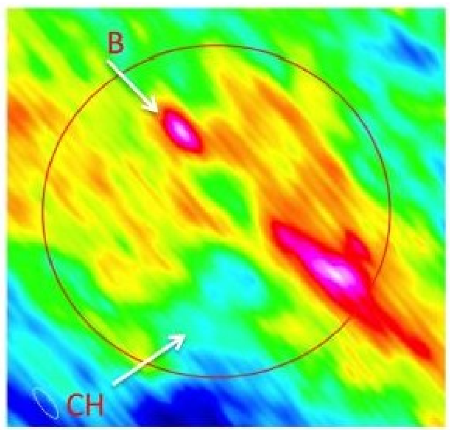
Positioning of SEP related radio emission from low to high corona

150–450 MHz
Nancay RH
(8–15 UT)
data available



Klein et al. (2008)

0.4–15 GHz
Chinese Solar RH
(0–8 UT)
data in calibration



(a) CSRH-I 1.7 GHz 06:30UT

image from
http://srg.bao.ac.cn/csrh.htm

17, 34 GHz
Nobeyama RH
(22–7 UT)
data: 1992–May 2015

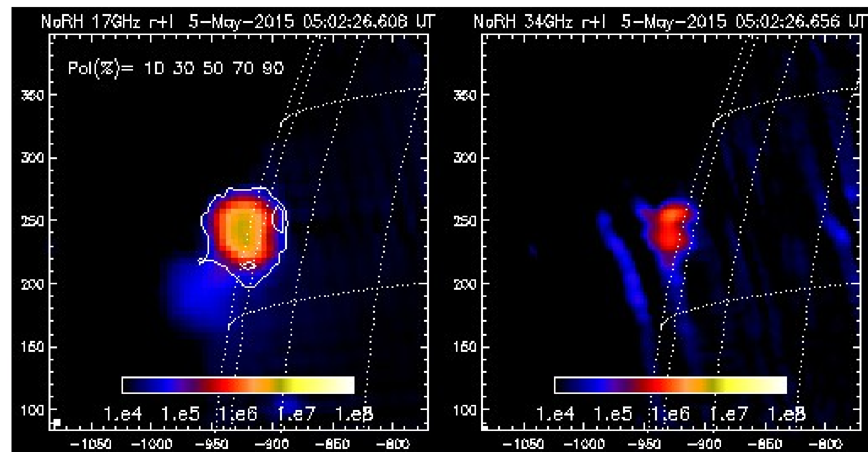


image from
http://solar.nro.nao.ac.jp

Space Weather related studies

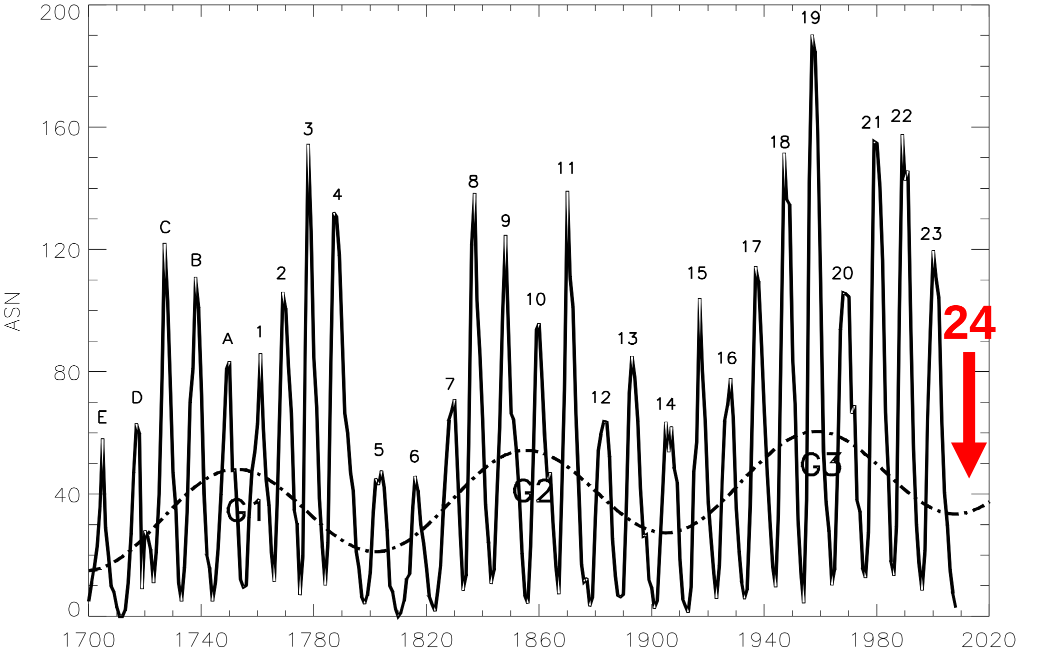
Multi-timescales of solar cycles

In addition to the famous 11-year solar cycle, there are 51-year and 103-year cycles in solar long-term activities.

The solar cycle 24 is just located in the minimum between two 103-year cycles.

The Strong flares tend to occur in the late phase of solar cycles.

Tan ApSS 2011



The analysis of solar sunspot number and microwave emission data show that there multi-timescale periodicities (with periods from 89 days to 11 years) which are related to the planetary motions.

Tan & Cheng ApSS 2013

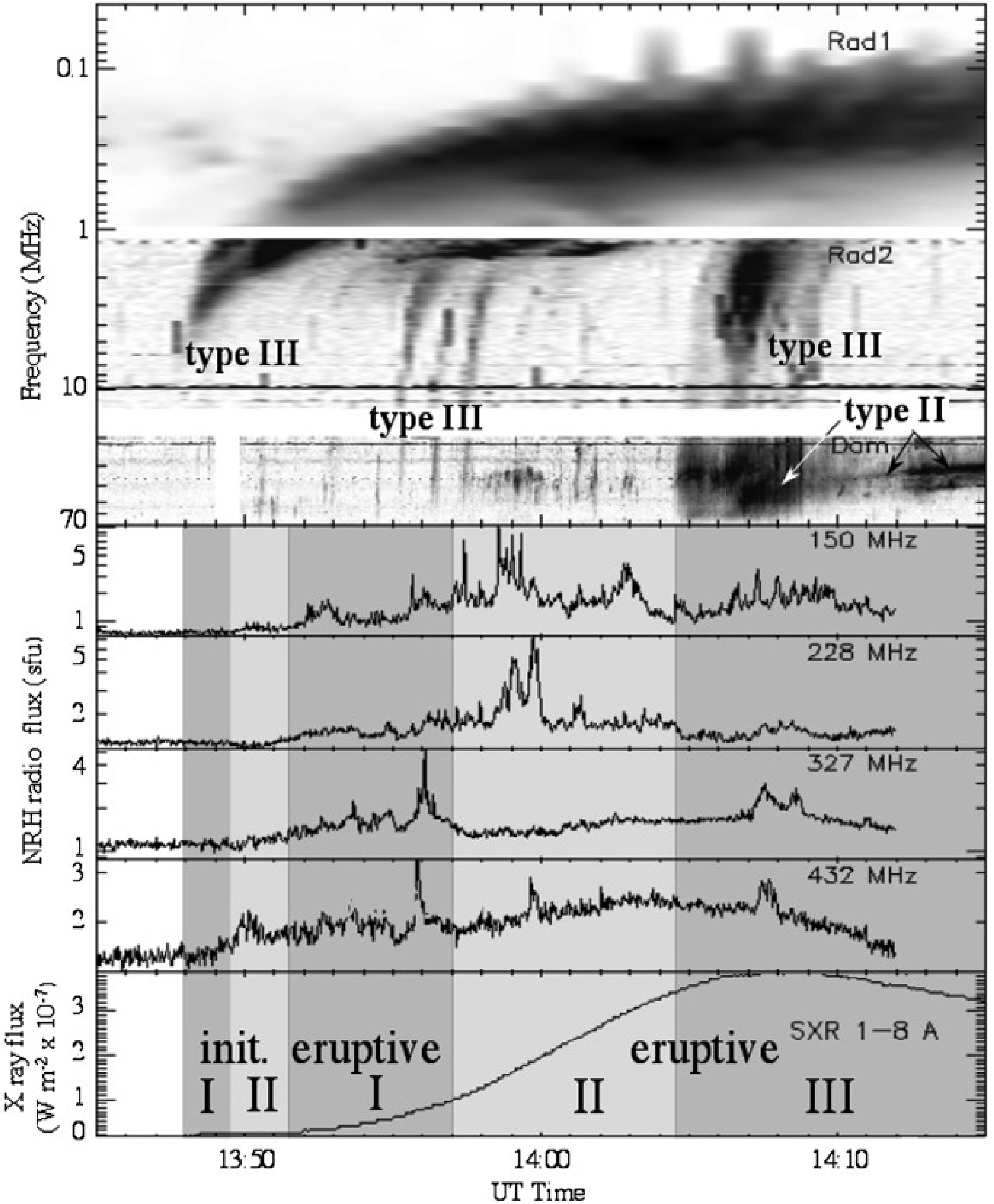
Space Weather related studies

Radio characteristics of CME evolution

5-stage evolution of coronal mass ejection (CME)

- radio bursts with different spectral fine structures at different phases
- may help us to understand the nature of CMEs

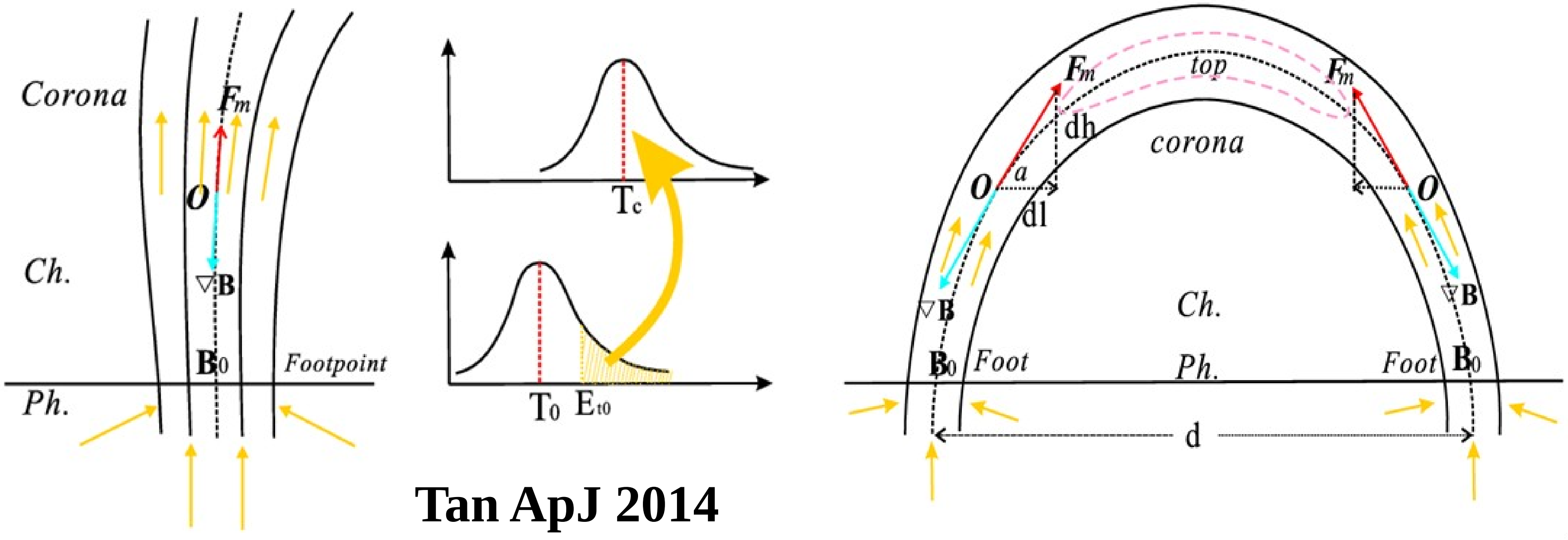
Huang et al. ApJ 2011



Space Weather related studies

New coronal heating model: Magnetic gradient pumping (MGP) mechanism

In magnetic flux tubes, the magnetic gradient drives the energetic particles upwards from the underlying solar atmosphere thus forming hot upflows. These upflow energetic particles are deposited in the corona where they are heated. Rough estimations indicate that the solar corona can be heated to above 10^6 K, and the velocity of the upflows is about 130 km/s in the corona. MGP mechanism can naturally explain the mystery of the coronal heating.

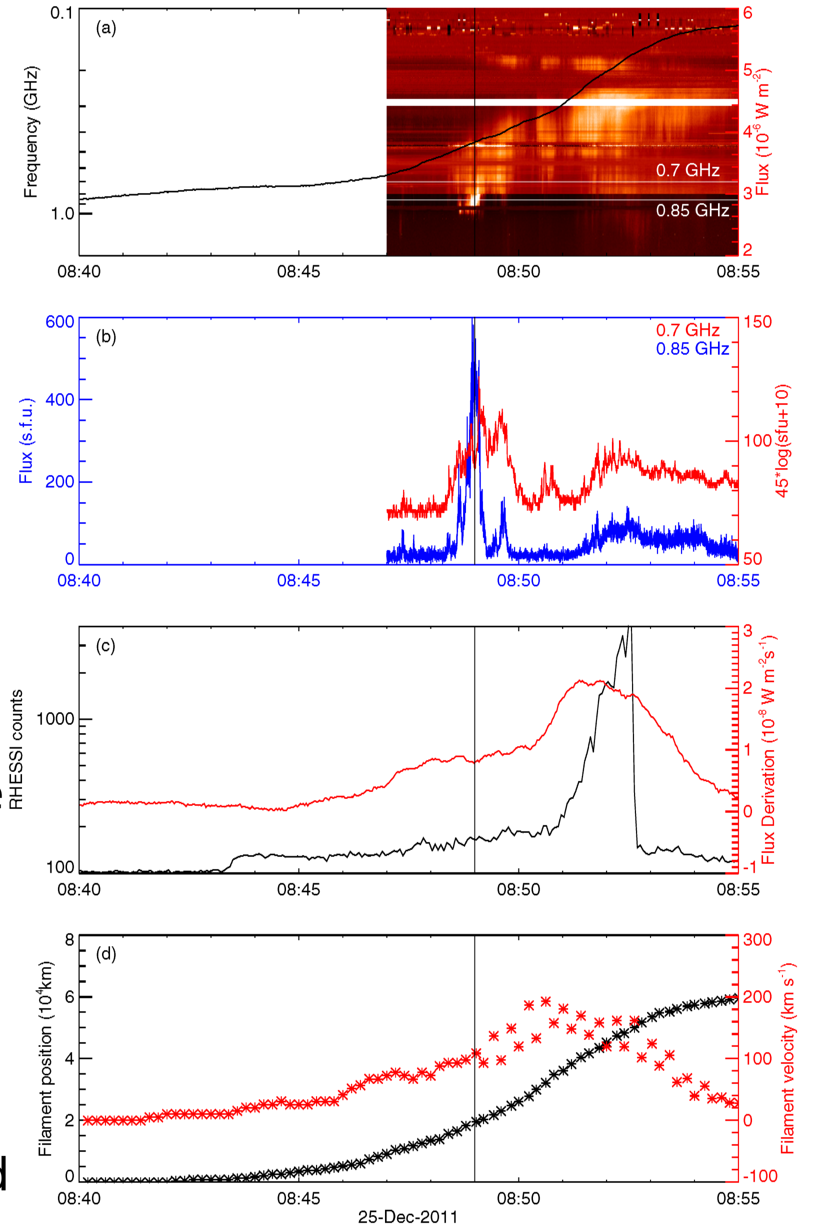


Tan ApJ 2014

Space Weather related studies

Radio bursts with spectral fine structures in pre-flares

Microwave spectral fine structures as pre-flare activities are observed by the Ondrejov radio spectrograph in frequency range of 0.8–2.0 GHz. Is is found that these microwave bursts which occurred 1–4 minutes before the onset of flares have spectral fine structures with relatively weak intensities and very short timescales. They include microwave quasi-periodic pulsations with periods of 0.1–0.3 s and dot bursts with ms timescales and narrow frequency bandwidths. Accompanying these microwave bursts are filament motions, plasma ejection or EUV loop brightening, and non-thermal hard X-ray emission enhancements. These facts reveal that a certain independent non-thermal energy releasing processes and particle acceleration occur before the onset of solar flares. These may help to understand the nature of solar flares and to predict their occurrence.



Zhang et al. ApJ 2015