Solar Physics with the Nobeyama Radioheliograph – Nobeyama Symposium 2004 –

Kiyoto Shibasaki
Nobeyama Solar Radio Observatory, Minamisaku, Nagano, 384-1305, Japan
shibasaki@nro.nao.ac.jp

Abstract

The Nobeyama Radioheliograph (NoRH) has been in operation since 1992 and well covered one solar cycle. Many user groups of NoRH have been formed in the world and we have organized three symposiums related to NoRH in the past.

1. "Symposium on Nobeyama Radioheliograph" November 26-28, 1990 at Nobeyama
2. "New Look at the Sun with Emphasis on Advanced Observations of Coronal Dynamics and Flares" September 6-10, 1993 at Kofu (jointly with *Yohkoh*)
3. "Solar Physics with Radio Observations" October 27-30, 1998 at Kiyosato

We are glad to know that more and more data from NoRH are used and scientific outputs are still increasing. In this symposium, we would like to summarize recent development of solar physics using NoRH and discuss future direction of NoRH.
Key words: Nobeyama Radioheliograph — Plasma — Sun: flares — Sun: corona — Sun: radio

1. Short History of Nobeyama Radioheliograph

The idea of construction of a large radioheliograph was proposed early 1980s by late Professor Haruo Tanaka and solar radio groups in Japan: one at Toyokawa (Research Institute of Atmospherics, Nagoya University) and the other at Nobeyama (Tokyo Astronomical Observatory, University of Tokyo). To realize such a large project, merger of two major solar radio groups was suggested. On the occasion of establishment of National Astronomical Observatory (NAOJ) in 1988, Toyokawa group and Nobeyama group merged together and pushed to construct the Large Radioheliograph at Nobeyama. Finally in 1990, it was financed and the construction work started.

The original plan of the construction period was three years. Due to the delay of financing, solar activity was in the declining phase and the possibility of cooperation with *Yohkoh* satellite during the active period of the Sun was decreased. So, we decided to shorten the construction period to two years. We successfully completed the hardware construction before the end of March 1992 and started test observation in April (Nakajima et al. (1994), Nishio et al. (1994)). Soon after the start of the test observation, we could manage to get the first 17 GHz image of the Sun. Routine observation started late June 1992. The observing frequency of NoRH in the beginning was 17 GHz only. We added 34 GHz receivers and replaced sub-reflectors by frequency selective ones to realize dual-frequency observations in 1995 (Takano et al. 1997). Circular polarization observing capability is limited to 17 GHz.

In 2004, NAOJ joined newly established National Institute of Natural Sciences (NINS, 5 national research institutes including NAOJ). NINS is fully supported by the government but has more freedom compared to the former national institutes which had been directly attached to the Ministry of Science and Education. Nobeyama Solar Radio Observatory benefited from this change. We can invite many scientists from abroad and can attend international meetings more frequently. We hope this change further enhances cooperation between foreign users and Nobeyama Solar Radio Observatory and more data are used to enhance solar physics.

2. Scientific Objectives of NoRH

Main scientific objective of NoRH construction was to understand particle acceleration mechanisms in solar flares. After more than one solar cycle of observations, we still do not understand how high-energy electrons, which emit strong microwave through gyro-synchrotron mechanism, are produced in solar flares.

Geometrical configuration of magnetic loops which favors particle acceleration was found by combining microwave images with hard X-ray and soft X-ray images taken by HXT and SXT telescopes onboard *Yohkoh* respectively (Nishio et al. (1997), Hanaoka (1996)). Interaction regions of small loops and large loops seem to be the location of particle acceleration. NoRH found a clear evidence of high-energy electron injection into a large loop and propagation along the loop (Yokoyama et al. 2002). This is one of the targets of NoRH design. The spatial and temporal resolutions were determined to be able to detect these phenomena. Many oscillatory phenomena were found which may reflect particle acceleration mechanism itself or magnetic loop modulation (e.g. Asai et al. (2001), Nakariakov et al. (2003)). Highly anisotropic pitch angle distribution of accelerated electrons is suggested to explain localized emission around loop top instead of loop foot points where magnetic field is stronger (Melnikov et al. 2002).

Although the main scientific objective of NoRH construction was to understand particle acceleration mechanisms in solar flares, NoRH showed its capability for many other subjects. One is for the study of eruptions. NoRH is a very good detector of prominence eruptions above the solar limb due to very steady operation and to weather insensitive observing wavelength compared to optical observations. It is also important that microwave observation is continuum observation, not line observation. Large Doppler shift due to large line-of-sight velocity does not affect the detectability of eruptive prominences. Statistical studies of prominence eruptions covering several years or one solar cycle were done (Gopalswamy et al. (2003), Shimojo et al. (2006)).

Studies of sunspot oscillations (Gelfreikh et al. (1999), Shibasaki (2001a)), magnetic field in active regions and in the corona and polar brightening studies (Shibasaki 1998) are also very interesting subjects. Studies of solar cycle dependence of these phenomena will contribute to understand global activities of the Sun.

3. A New Solar Flare Model

The current standard model of solar flares is based on magnetic reconnection. Normal solar corona is in low beta state: plasma pressure is negligibly small compared to magnetic pressure. In the low-beta corona, it is believed that free energy is stored in the form of electric current. Sudden dissipation of the current or release of stored energy is a solar flare.

Recent microwave, soft X-ray and EUV imaging observations of solar flares with high-cadence and high spatial resolution show that dense plasma is involved in solar flares from the beginning. Based on these observations, I have been proposing a high-beta model of solar flares, which is very similar to high-beta disruptions in magnetically confined nuclear fusion experiments. (Shibasaki (2001b), Shibasaki (2002)).

When plasma beta value increases in a curved magnetic loop, a localized interchange mode of instability, called ballooning instability is triggered. Energy source of the instability is free thermal energy of plasma due to confinement. Ballooning instability develops where beta value is larger than the critical value and curvature radius is the smallest. Top of coronal loops filled with high-density plasma is the favorable location for ballooning instability. Plasma flows along curved magnetic loops are also good candidate for ballooning instability. The critical value of the plasma beta is order of several percent depending on magnetic field geometry. From the analogy of high-beta disruption in magnetically confined nuclear fusion experiments, we can expect finger-like plasma structure perpendicular to the magnetic field, plasma turbulence, particle acceleration and so on. They are very similar to various solar flare phenomena.

To prove this model, it is necessary to measure plasma beta values in the solar corona. With the use of NoRH circular polarization measurements above the limb, we can measure line-of-sight values of magnetic field strength in the hot and dense plasma in the solar corona. I hope, the high-beta model will explain many puzzling features of solar flares including particle accelerations and more generally activities in the solar atmosphere.

4. Data Use and Future

We adopt open data policy for NoRH data. Immediately after observations, raw data and some processed data are freely available for research, educational and public outreach purposes. Solar flares and prominence eruption events are automatically detected and listed with images and movies on our home page (`http://solar.nro.nao.ac.jp/`). Due to development of the INTERNET and increased capability of image synthesis computers and storage disk space, open data policy resulted in forming large number of international user groups. To further enhance data usage of NoRH, we invited many users to Nobeyama for data analysis and organized international meetings. We hope, this trend of increasing data usage will continue and finally to find clear answer to particle acceleration mechanisms and other solar phenomena in near future.

This symposium is supported by Japan Society for the Promotion of Science as one of International Meeting Series.

References

Asai, A., Shimojo, M., Isobe, H., Morimoto, T., Yokoyama, T., Shibasaki, K., & Nakajima, H. 2001, ApJL, 562, L103

Gelfreikh, G. B., Grechnev, V., Kosugi, T., & Shibasaki, K., 1999, Sol. Phys., 185, 177

Gopalswamy, N., Shimojo, M., Lu, W., Yashiro, S., Shibasaki, K., & Howard, R. A. 2003, ApJ, 386, 562

Hanaoka, Y. 1996, Sol. Phys., 165, 275

Melnikov, V. F., Shibasaki, K., & Reznikova, V. E. 2002, ApJL, 580, L185

Nakajima, H. et al., 1994, Proc. IEEE, 82, 705

Nakariakov, V. M., Melnikov, V. F., & Reznikova, V. E. 2003, A&A, 412, L7

Nishio, M. et al., 1994, Proc. Kofu Symposium, NRO report 360, 19

Nishio, M., Yaji, K., Kosugi, T., Nakajima, H., & Sakurai, T. 1997, ApJ, 489, 976

Shibasaki, K. 1998, ASP Conf. Ser, 140, 387

Shibasaki, K. 2001a, ApJ, 550, 1113

Shibasaki, K. 2001b, ApJ, 557, 326

Shibasaki, K. 2002, ESA SP-506, Proc. 10 th. European Solar Physics Meeting, 749

Shimojo, M., Yokoyama, T., Asai, A., Nakajima, H., & Shibasaki, K. 2006, PASJ, 58, 85

Takano, T. et al., 1997, Coronal Physics from Radio and Space Observations, Proc. CESRA Workshop, Lecture Notes in Physics, Springer, 183

Yokoyama, T., Nakajima, H., Shibasaki, K., Melnikov, V. F., & Stepanov, A. V. 2002, ApJL, 576, L87