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Recent activities of solar astronomers in Korea

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Abstract. At present, about twenty PhDs are carrying out education, research, and observation in the field of solar astronomy in Korea. The history and recent activities of the Korean solar community are briefly reviewed in this paper. We expect that the current efforts of Korean solar astronomers contribute to the promotion of cooperative solar research in the Asian-Pacific countries.

Keywords : Sun: general – history and philosophy of astronomy

1. Introduction

Modern solar physics in Korea was initiated by Prof. Hong Sik Yun as he joined the Department of Astronomy at Seoul National University in 1976. He carried out solar research on umbral chromospheric models until the early 1980s and supervised several Korean solar astronomers who are leading the Korean solar physics society in these days. In 2003, upon retirement, he wrote a review paper on the growth of solar physics in Korea and expected that the future of solar astronomy in Korea is bright and promising (Yun 2003). His expectation has come from the outstanding achievement of research paper publications of the Korean solar physicists in major journals. In this paper, we mainly describe recent activities of solar physics in Korea after the first growth phase that was reviewed by him.

At present, two universities, Seoul National University (SNU) and Kyung Hee University (KHU) offer graduate programs for solar physics. Korea Astronomy and Space Science Institute (KASI) is the only national institute for solar astronomy. Over

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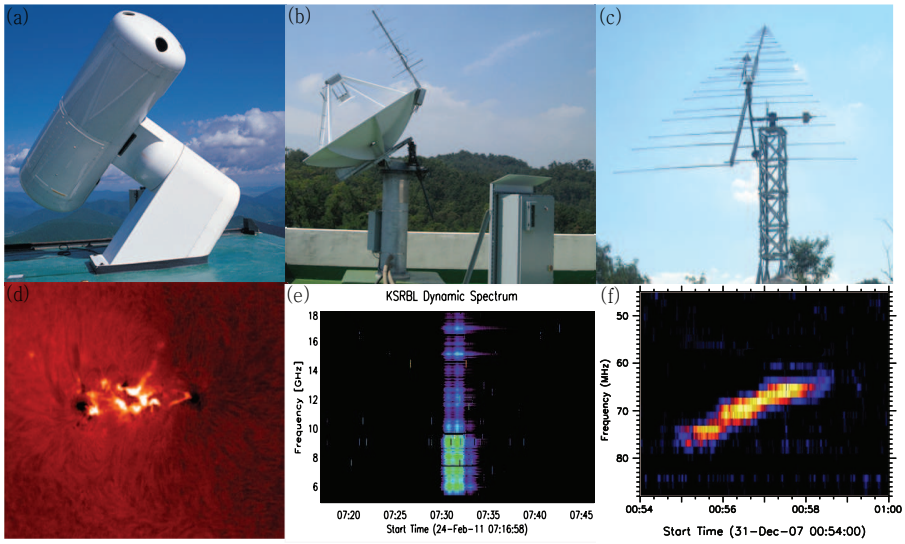

Figure 1. Representative solar observational systems and data in Korea. (a) Solar Flare Telescope (SOFT), (b) Korean Solar Radio Burst Locator (KSRBL), (c) e-CALLISTO, (d) Hα flare observed by SOFT on 15 Feb. 2011, (e) Solar radio burst observed on 24 Feb. 2011 by KSRBL, and (f) type II radio burst observed on 31 Dec. 2007 by e-CALLISTO.

thirty graduate students are pursuing their domestic PhD studies and around twenty PhDs are studying in diverse fields of solar astronomy.

2. Instruments

Most of solar observation systems in Korea have been operated by KASI. Fig. 1 shows the representative ground observation systems in Korea such as Solar Flare Telescope (SOFT, Park et al. 1997), Korean Solar Radio Burst Locator (KSRBL, Dou et al. 2007), and e-CALLISTO (Bong et al. 2009). SOFT is the first research-oriented solar observing facility in Korea that was installed at the top of the Bohyun Mountain in 1995. The SOFT was originally designed for the observations of solar active regions as a 4-channel instrument including white light and Hα observing systems, a vector magnetogram (VMG) and a longitudinal magnetogram (LMG). In 2006, an Hα full-disk monitoring system for the observations of the chromosphere was added to the SOFT. KASI has two solar radio observation systems. One is the Korean Solar Radio Burst Locator (KSRBL), a single dish radio spectrograph with broadband frequency range (0.5 $\sim$ 18GHz). The KSRBL was developed in collaboration with New Jersey Institute of Technology (NJIT) and was installed at KASI in August, 2009. It has a unique capability to locate the position of a burst within 2 arcmin and record the spectra of solar microwave bursts with high time (1 sec) and frequency resolution (1MHz). In lower frequency range, there is the e-CALLISTO (Earth-wide, Compact

Astronomical Low-frequency, Low-cost Instrument for Spectroscopy in Transportable Observatories), which is a global network of frequency-agile radio spectrometers that was constructed in a collaboration between ETHZ of Switzerland and KASI as a part of IHY 2007 (International Heliophysical Year) activity. The e-CALLISTO is monitoring the solar radio bursts in frequency range between 45MHz and 870MHz and is usually used for studying type II solar radio bursts. The e-CALLISTO and KSRBL will be used for studying solar eruptions and monitoring solar radio bursts which can disturb many kinds of high-tech radio instruments such as cellular phone, GPS, and radar.

The SNU group has made efforts in solar instrumentation as well. The first experience was to operate a fast CCD camera on the old telescopes at Big Bear Solar Observatory to observe filaments. The next one is the development of Fast Imaging Solar Spectrograph (FISS, Ahn et al. 2008). It is an Echelle spectrograph that can do fast imaging based on the slit scan, and that can record two spectral bands simultaneously. The basic idea and optical design originated from J. Chae, and the development was carried out by the collaboration between the SNU solar group and the KASI solar group. The instrument is installed in the Coude room of the 1.6 meter off-axis New Solar Telescope (NST) at Big Bear Solar Observatory, and is currently the major observing facility of the SNU solar group.

Solar observing facilities of KHU are partly located on the housetop of the College of Applied Science Building and partly in Kyung Hee Astronomical Observatory. These comprise a 6″ refractor with diverse filters and cameras, a spectrograph developed internally for the sole purpose of solar observation, and a space weather monitoring and demonstration facility.

3. Research activities

3.1 Korea Astronomy and Space Science Institute

3.1.1 *History*

KASI has done sunspot observations since 1987 using the Sunspot Telescope (Sim et al. 1990). However, there was no solar astronomer at that time. Dr. YoungDeuk Park joined the KASI in 1990 and led the solar group. His first achievement was the construction of the SOFT on Bohyun mountain. SOFT was the first research-oriented solar instrument. After installing the SOFT, Dr. Young-Jae Moon (now at KHU) was employed as a research scientist and worked from 1995 to 2007. In 2002, Dr. Kyung-Suk Cho joined the KASI after the group was chosen as Solar Activity Research Laboratory by the Ministry of Science and Technology (MOST). After that the KASI initiated a project in 2004 which comprises the development of Korean Solar Radio Burst Locator (KSRBL) and participation in the construction of 1.6 m New

Solar Telescope (NST) with NJIT. For this project, Drs. Yeon-Han Kim and Su-Chan Bong were added as faculty members. The group started a new project in the year 2007 to establish a Korean Space Weather Prediction Center (KSWPC). Scope of the project includes extension of ground observation system, construction of space weather database and networking, development of prediction models, and space weather studies. Currently, Drs. Sung-Hong Park, Soyoung Park, and Pankaj Kumar are working with the staff as post-doctoral researchers, and there are seven PhD candidates working for solar physics in KASI.

3.1.2 *Current Research and Prospect*

Their research includes studies of CME and type II radio burst shock kinematics (Cho et al., 2008), magnetic reconnection of flare-associated CMEs (Bong et al., 2006), small-scale X-ray/EUV jets (Kim et al., 2005), vector magnetic fields in the photosphere, and Hα spectral properties of quiescent filaments. To improve capability of space weather forecast, they have studied geo-effective CMEs since the CME is one of the most important events that can trigger a geomagnetic storm. Their main goal is to forecast geomagnetic storms (Dst < -50nT) based on initially observed CME parameters at the Sun. This forecast is very meaningful because it allows us to make an earlier warning, two or three days in advance. For this, they examined geoeffectiveness of CMEs and developed an empirical geomagnetic storm prediction model based on solar information (Kim et al., 2008). Recently Dr. Kyung-Suk Cho, one faculty member of the group, investigated an empirical relationship between CME initial speed and solar wind dynamic pressure and proposed an empirical model based on CME initial speed for prediction of solar wind dynamic pressure change triggered by high speed CMEs (Cho et al. 2010). These activities of KASI may help a satellite operator to make preparations for an upcoming space weather disturbance caused by solar eruption, such as attitude and angular momentum control.

In 2010, KASI turned its main scientific focus to space observations. As a part of the activity, KASI made an agreement with NASA and started initial setup of the data system to store, use, and disseminate the Solar Dynamics Observatory (SDO) data. The SDO data center has four subsystems. The first is data transfer system (DTS) to transfer SDO data from Stanford University to KASI. It will be connected through 10 Gbps GLORIAD network. The second is data archiving system (DAS) to archive and manage SDO/AIA (650 TB/year) and SDO/HMI data files (180 TB/year), which was designed in consideration of a compatibility and scalability of the system so that we can extend its capacity and performance at any time by adding more storage and clustered gateway, respectively. The third is cluster system (CS) to compute data for researches and applications. The last one is data service system (DSS) to provide SDO data to users. The users can access SDO data through DSS system via FTP, HTTP, and etc. In 2011, we are going to construct DTS and initial small part of DAS and then we

will gradually extend its archiving capacity by 2015. It is hoped to provide free and unfettered access for scientists from 2012 after developing of various applications for data query and analysis.

3.2 Kyung Hee University

3.2.1 *History*

Solar physics studies at Kyung Hee University (hereafter KHU) earnestly began in 1988 when Prof. Kap-Sung Kim assumed professorship at the Department of Astronomy and Space Science (hereafter DASS), which was established in 1985. Prof. K.-S. Kim had earned his PhD degree from Kyoto University, Japan, with a thesis on sodium lines in solar prominences. At KHU, he continued to work on non-LTE radiative transfer calculations in the solar atmosphere, and later also worked on solar wind models. As a lonely solar astronomer in the Department for some ten years, he strived hard to establish solar observing facilities in KHU and bring up students to be major solar astronomers in the future Korean solar physics community. Among his students were Dr. Kyung-Suk Cho and Dr. Yeon-Han Kim, who are now at KASI.

In 2002, Prof. Minhwan Jang, whose research field had been extragalactic astronomy till then, entered the solar physics community, when his proposal of the Lyman alpha Solar Telescope (LIST) onboard the Korea Science and Technology Satellite-2 was granted by the Korean government. In 2006, the Department added another faculty member Prof. Gwangson Choe, who had worked on theories and numerical computations of solar activities at the Princeton Plasma Physics Laboratory. One year after, Prof. Yong-Jae Moon, who had acquired reputation in solar observations and space weather at KASI, joined the DASS faculty.

In 2008, the already grown solar physics group and the space physics group of the Department joined forces to land a big grant of the Korean government, the World Class University Program (WCU). Within this program, the School of Space Research (hereafter SSR) was established in KHU in 2009 and two world-renowned solar physicists were invited to join its new faculty. They were Prof. Sami K. Solanki of Max Planck Institute for Solar System Research, Germany and Prof. Robert P. Lin of the Space Science Laboratory in University of California Berkeley. In the same year, Prof. Tetsuya Magara, who is famous for solar numerical simulations, also joined the DASS-SSR faculty. Now the solar physics-related groups of the DASS and SSR have seven tenured and tenure-track professors, three research scientists (Dr. Junho Shin, Dr. V. Pandey and Dr. Jin-Yi Lee), and about 15 graduate students. At present, the Department of Astronomy and Space Science is responsible for undergraduate programs and administrative relations while the School of Space Research is in charge of graduate programs and research.

3.2.2 *Facilities and Current Research*

Prof. Kap-Sung Kim, who is the president of the Korean Astronomical Society and Dean of College of Applied Science in KHU, is engaged in non-LTE line transfer calculations in collaboration with Prof. Ichimoto of Kyoto University, working part time on multi-fluid solar wind models.

Prof. Gwangson Choe, the current Department chairman of DASS/KHU, is working on energetics of multiple flux systems in relation to coronal mass ejections, incremental growth of magnetic flux systems, ballooning instability in the solar atmosphere, and interaction of emerging flux ropes and overlying fields (Choe 2009).

Prof. Minhwan Jang, the former director of Kyung Hee Observatory, is investigating coronal magnetic field measurement by observed plasmoid dynamics (Jang et al. 2009), morphological evolution of coronal holes in relation to solar wind dynamics, geometry of observed features in coronal mass ejections, characteristics of EIT and Moreton waves.

Prof. Yong-Jae Moon and his students are studying solar activity and space weather prediction with the following scientific subjects : (1) solar eruptions (Kim et al. 2007, 2008) and solar EUV spectroscopy (Lee et al. 2011), (2) solar proton events (Park et al. 2010), (3) automatic solar data analysis and flare prediction, (4) flux rope and cone models for CMEs, and (5) the prediction of geomagnetic storms (Ji et al. 2010) and geoeffective CME parameters (Choi et al. 2009, Moon et al. 2009).

Prof. Tetsuya Magara is leading the solar dynamics laboratory. An important goal of this research group is to understand the nature of the Sun by clarifying the dynamic behaviour of solar magnetic field, which provides the origin of activity affecting the solar-terrestrial environment. Toward this end, they use the theoretical modeling based on numerical simulations and data analysis of space and ground-based observations (Magara & Tsuneta 2008; Magara 2009; Magara 2010; Magara 2011a, b). They also collaborate closely with a space weather group at NiCT (National Institute of Information and Communications Technology) in Japan to develop a realistic space weather model.

3.3 Seoul National University

3.3.1 *History*

In 2003, Prof. Jongchul Chae succeeded Prof. Hong Sik Yun by taking up a professor position in the Astronomy Program, Department of Physics and Astronomy in this university. He is currently the only day-time astronomer among twelve professors in the Astronomy Program, five of whom are in the field of cosmology and extragalactic

astronomy, three in our Galaxy (stars and interstellar medium), two in astrophysical theory, and one in the solar system. From 2008 to 2011, under the supervision of J. Chae, five (Hyewon Jeong, Kwangsu Ahn, Eun Kyung Lim, Ryun-Young Kwon, Soyoung Park) got their doctorates in Seoul National University, and one (Hyung-Min Park) in Chungnam National University. H. Jeong and R.-Y. Kwon are working as post-doctoral researchers at Goddard Space Flight Center of NASA, USA, and K. Ahn and E. K. Lim are post-doctoral researchers at Big Bear Solar Observatory. S. Park and H.-M. Park are post-doctoral researchers at KASI and SNU, respectively. The solar astronomy group in SNU now consists of one professor (J. Chae), one post-doctoral researcher (H. Park), two PhD candidates (Donguk Song and Heesu Yang), and two MS candidates (Gyuhyun Cho and Miryo Han).

3.3.2 *Current research*

The SNU solar astronomy group has kept several international connections/ collaborations. The first is with Japanese colleagues in the solar physics division of NAOJ. As mentioned by Yun (2003), the development of solar physics in Korea was greatly aided by Japanese colleagues. J. Chae also got much help from Professors Takashi Sakurai, Kiyoshi Ichimoto, and Yoshinori Suematsu when he was a graduate student. After Chae began to lead the SNU solar astronomy group, the group has kept close collaborations with Japanese colleagues as represented by T. Sakurai focusing on the analysis of data that came out of the Hinode mission. Recently, the group is also collaborating with the group led by Professor Saku Tsuneta in the development of the sounding rocket experiment called Chromospheric Lyman-Alpha SpectroPolarimeter (CLASP). The next connection is with Big Bear Solar Observatory. This connection is a consequence of J. Chae's experience as a post-doctoral researcher in the observatory under the supervision of Professors Philip Goode and Haimin Wang. After Chae came back to Korea, Big Bear Solar Observatory has become the main provider of ground-based observations for his group. The observatory also provided a natural link to Chinese colleagues who visited there, including Hongqi Zhang, Jingxiu Wang, Mingde Ding and Haiseng Ji. Connection to other Chinese colleagues such as Chen Fang came from their early connections to and collaborations with Professor Yun. Finally, the SNU solar group has worked with Yuri Litvinenko at University of Waikato, New Zealand. Since they have many common research interests like prominences/filaments and cancelling magnetic features, and Litvinenko is good at MHD theory while the SNU group is good at observations and data analysis, the collaboration has been mutually beneficial and quite productive.

The SNU solar group has focussed on understanding the nature of magnetohydrodynamic phenomena in the solar atmosphere. The major topics include 1) the structure, formation and eruption of prominences/filaments (Chae et al. 2005, 2008; Lim & Chae 2009), 2) small-scale events of magnetic reconnection in the photosphere and chromosphere as represented by canceling magnetic features (Park et al. 2009; Chae

et al. 2010), 3) helical structures and measurements of magnetic helicity (Chae 2001; Jeong & Chae 2007; Lim et al. 2007), and 4) coronal loops (Chae & Moon 2005; Kwon & Chae 2008). The basic approach is to carry out ground-based observations, and analyze the data in combination with the space-borne observations. A number of papers on these topics were published by the group in major journals, some of which are cited above.

4. Concluding remarks

KASI has been developing and operating solar instruments, and universities are carrying out education and bringing up human resources in Korea solar astronomy society. They are pursuing international collaborates for cutting-edge science in solar physics and extending their research scope to the world. In this situation, the collaboration among solar astronomers in the Asian and Pacific regions started by the APSPM 2011 could give impetus to extend current activities of Korean solar astronomers. In this respect, we expect that Korean experience through the construction of SDO Asian data center, development of FISS, and education in the WCU program will contribute to Asia-Pacific solar physics community.

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