First Asia-Pacific Solar Physics Meeting
ASI Conference Series, 2011, Vol. 2, pp 343–353
Edited by Arnab Rai Choudhuri & Dipankar Banerjee

History and progress of solar research in China

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Abstract. After a brief introduction of ancient Chinese records on the Sun, we describe the beginnings of modern solar research in China in the 20th century. The main contents are focused on the progress of solar research in China after the 1950s, including the development of solar research in Purple Mountain Observatory, National Astronomical Observatories, Yunnan Astronomical Observatory, and some astronomy departments in the universities. In particular, the constructions of solar observational facilities, the increase of the numbers of solar researchers and students, as well as the main topics of solar research since 1980s are described in details. Some issues and prospects are being discussed.

Keywords : Sun: general – history and philosophy of astronomy

1. Chinese observed the Sun in ancient times

In ancient times, the Emperors of various Dynasties nominated some special officers to observe the Sun. For instance, astronomers Xi and He received commissions from Emperor Yao to observe stars and make calendar. Fig. 1 shows an ancient nomination ceremony before the Emperor.

1.1 Why did the Chinese observe the Sun in ancient times

The main purpose of the ancient Chinese astronomy was to study the correction between man and universe (Sun 2011). This made ancient Chinese astronomy the highly regarded science by the Emperors. The Sun being the closest star had certainly caught

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Figure 1. Ancient Chinese astronomers were nominated by emperors.

the attention of people. There were mainly two reasons for observing the Sun: (1) The astrological and political reasons. The eclipse observation is a good example. People used to believe that during the eclipses, the Sun is devoured by a celestial dog, an omen portending all kinds of disasters. So the Emperors and people would like to know when and how the eclipse would appear. (2) To make a good astronomical system. For instance, every dynasty needs astronomical chronology for making calendar etc.

1.2 Historical eclipse records in China

Solar eclipses have already been mentioned in oracle bone inscriptions since Shang Dynasty (1600 B.C - 1046 B.C), as seen in the left in Fig. 2. For instance, some records on oracle bones indicate that solar eclipses occurred on October 21, 1198 B.C, June 7, 1172 B.C, and October 31, 1161 B.C. Generally the recorded data include the position of the Sun at the time of eclipse, the beginning and the end of the eclipse, the magnitude of the eclipse, and the point of the first contact on the disc of the Sun etc.

The ancient records of solar eclipses have been used to study the secular change of the Earth's rotation. A decreasing rotation rate was found to be -22 - -26 seconds/century. The records can also be used for astronomical chronology. For example, the Bamboo Chronicles say: "During the first year of King Yi of the Zhou Dynasty, two daybreaks occurred." According to the eclipse that occurred in 899 B.C, people could exactly tell the day of the year. By using these records, the periodicity of eclipses have been discovered. For instance, in 100 B.C, one knew the 135 synodic months. In 762 AD, a period of 458 months was obtained, which was discovered by Newcomb 1100 years later. In 1199 AD, the Saros Cycle (223 months) was discovered.

Figure 2. Solar eclipses recorded in oracle bones (left) and sunspot recorded as a gold bird (right).

Figure 3. First Chinese astronomer delegation which visited Kitt Peak Observatory in 1976 (left). First USA astronomer delegation which visited China at PMO in 1977 (right).

1.3 Ancient sunspot records

The first well-recognized sunspot record was made back in 28 B.C, Han Dynasty, which was described as "dark air like coin on the Sun". From Han to Ming Dynasty there have been more than 100 sunspot records (Xu & Jiang 1986). Sunspots were depicted "like bird", "like coin" or "like chestnut", while the records of "disappeared in several months" and "disappeared in three days" indicate the evolution of sunspots. During Han Dynasty there was a record of sunspot as a "Gold bird" (right in Fig. 2), which was discovered in a famous tomb in Hunan province. In fact, sunspots were already recorded in the book of I Ching about 800 B.C.

2. Beginning of modern solar research in China

Chinese modern solar observations started in 1925 at Qingdao observatory, which was a former German establishment taken over and renamed by the Chinese Government. There were regular sunspot drawings based on the naked eye. In 1936, the first eclipse observation was organized. One delegation went to Hokkaido of Japan, and

Figure 4. First international meeting on solar physics in Kunming in 1983.

Figure 5. Bird's eye view of the Purple Mountain Observatory.

another one went to Khabarovsk of Soviet Union. During the period of 1939-1945, the first spectroheliograph with the naked eye was in operation. In 1956, the first Hα image was obtained at Purple Mountain Observatory (PMO). In 1958, the first spectrograph and solar radio telescope were constructed and used to observe the solar annular eclipse on Hainan island.

Just after the so-called "great cultural revolution", people realized that the international collaborations were important for development of astronomy in China. Thus the first Chinese astronomer delegation was organized and visited Kitt Peak Observatory in 1976 (left in Fig. 3). In succession, the first USA astronomer delegation visited PMO in 1977 (right in Fig. 3). Six years later, the first international workshop on solar physics was successfully organized in Kunming in 1983 (Fig. 4).

In 1928, a National Astronomical Institute was established. As the cradle of astronomy research in China, PMO was established in 1934 in Nanjing by National Astronomical Institute. Solar research at PMO started in 1930s. Fig. 5 depicts a bird's eye view of PMO.

In 1940, National Astronomical Institute established an observatory in Kunming, which became a station of PMO in 1950, later became Yunnan Astronomical Observatory. At that time, a small telescope was used to observe sunspots, a spectroheliograph for Hα observation by the naked eye and a 13 cm chromospheric telescope for Hα image survey were also in operation. Later, a 40 cm horizontal spectrograph was constructed and put in operation in 1975, and later it was developed to a solar spectroheliograph (SSHG) to observe 2D spectra (Zhong & Xuan 1989). A 18 cm chromospheric telescope was built in 1981 which can obtain full-disc solar images at Hα.

In 1958, Beijing Astronomical Observatory was established. Besides the sunspot observation with a small telescope, a 60 cm solar telescope was built in 1960s. It was used to observe solar spectra. After the total annular eclipse observation in April 1958, a 3.2 cm radio telescope was put on operation at Sharhe. A 21 cm radio telescope was built to observe the 1968 total eclipse in Xinjiang. With about 20 years's effort, a solar magnetic field telescope was finally established in 1984 at Huairou station (Ai 1986).

3. Current main organizations

Since the 1980s, solar physics research has been quickly developed in China. At present, about 50 scientists (professors or researchers), 16% of the total number of astronomers in China, are engaged in solar physics. There are more than 80 graduate students in different solar research groups. The budget on solar physics from NSFC is about 2M USD/year with an increasing rate of about 15-20% per year.

3.1 Purple Mountain Observatory (PMO)

Now the main topics of study at PMO include X-ray and γ-ray emission and particle acceleration, high temporal resolution observations of solar flares, multi-spectral study of solar flares, sunspot magnetic structures, filament eruptions and eclipse observations (e.g. 1980 February 16, 1983 June 11, 1988 March 18, 1991 July 11, 1997 March 7, 2008 August 1, and 2009 July 22).

The main facilities for solar observation at PMO include a multi-channel near-infrared spectrograph (Li et al. 1999)(upper left in Fig. 6), which is used to observe 2D solar spectra at Hα and HeI 10830Å, and a 26 cm fine structure telescope (lower left and right in Fig. 6) with FOV of $4' \times 6'$ for observing solar images at Hα and white light. Fig. 6 also shows an example of the 2D flare spectra at 10830Å (upper right in Fig. 6).

3.2 National Astronomical Observatories of China (NAOC, Beijing)

In 2001, the name of Beijing Astronomical Observatory was changed to National Astronomical Observatories of China (NAOC). The main topics of study include magnetic field observations and analysis, CME source regions and triggering, radio spectra and analysis, fine structures of solar activities and solar activity prediction etc.. The

Figure 6. The 2D spectrograph at PMO (upper left) and its 2D spectra at 10830Å(upper right). Ganyu 26cm telescope (lower left) and its dome (lower right).

solar observations are concentrated at Huairou Solar Observing Station (HSOS). The key instruments at HSOS are as follows:

(1) A Solar Multi-Channel Telescope (SMCT) (Zhang, Ai & Ming 1991) includes : a 60 cm Solar Nine-Channel Telescope, a 35 cm solar magnetic field telescope, a 14 cm full-disc and partial Hα image telescope, and a 20 cm full-disk Hα telescope. The SMCT can simultaneously measure the solar magnetic field and velocity field with different spectral lines (Ming et al. 1988). Fig. 7 gives the overview of SMCT and an example of its magnetogram.

(2) A Broadband Solar Radio Spectrograph (BSRS) (Fu et al. 2000) composed of five spectrometers at different frequencies: 0.7-1.4 GHz (at YAO), 1.0-2.0 GHz, 2.6-3.8 GHz, 4.0-5.2 GHz (at PMO) and 5.2-7.6 GHz. Fig. 8 depicts the BSRS (left) and one example of its record with some interesting fine structures (right).

(3) A full disc solar telescope gives solar Hα images regularly. It is suitable for monitoring the solar activity.

Recently a Chinese Spectral Radio Heliograph (CSRH) has been constructed at Zheng xiang bai qi, inner Mongolia. The frequency coverage is 0.4-15 GHz (75-2 cm) with resolution of 64 or 128 channels in 0.4-2 GHz, and 32 or 64 channels in 2

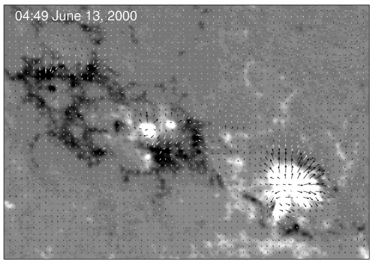

Figure 7. The solar magnetograph telescope (left) and an example of magnetogram obtained by the telescope (right).

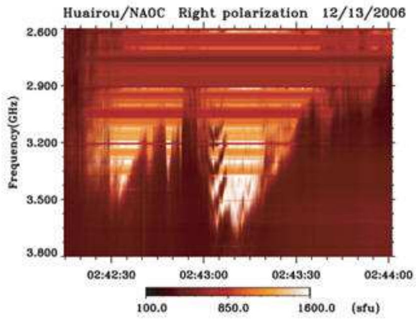

Figure 8. The Broadband Solar Radio Spectrograph (BSRS) (left) and a recorded radio fine structure as an example (right).

- 15 GHz. The spatial resolution is 1.3″-50″, depending on frequency. The temporal resolution is < 100 ms at 0.4-15 GHz and the dynamic range is 30 db (snapshot). CSRH has an array with 40×4.5 m plus 60×2 m parabolic antennas. The largest base line is 3 km and the field of view is 0.5 - 7 degree. The detailed description can be found in Yan et al. (2009).

3.3 Yunnan Astronomical Observatory (YAO, NAOC)

Since 2001, Yunnan Astronomical Observatory (YAO) has become a subordinate of NAOC. The main topics of study include spectroscopy and spectral analysis, CME current sheet and modeling, sunspot structures, filament eruptions, radio spectra and analysis, and solar activity prediction etc. A series of telescopes are in operation: a full disk Hα monitor, a 26 cm fine structure telescope (Fig. 9) (Wu et al. 1990) with FOV of 4’×6’, a 11 m radio telescope working at 70 –700 MHz since 2008, a 10 m

Figure 9. The 26 cm telescope at YAO (left) and a Hα image (right).

radio telescope working since 1999 at 625 –1500 MHz with high temporal resolution, and three antenna with a diameter of about 3-4 meters at 1.42, 2.00, 2.84, 4.00 MHz, which started to work at the end of 1980s (Xia et al. 1999).

Recently, a new 1m solar vacuum telescope has been installed near the Fuxian lake. A detail description can be found in Liu et al. (2011).

3.4 Solar research in universities

In recent years, more than 20 universities have established astronomy education and research work. Among them, five universities have solar programs. A complete series of educational programs of undergraduate, master, doctoral and post-doctoral levels have been formed.

There are astronomy departments in five key universities, including Nanjing University (NJU, established in 1952), Beijing University (BJU, 1960), Beijing Normal University (BNU, 1960), University of Science and Technology of China (USTC, 1978), and Shandong University at Weihai (2008).

The solar tower of Nanjing University was put in operation in 1980 (Fang & Huang 1983). It has a multi-channel spectrograph which can be used to obtain 2D spectra in Hα, 8542Å and 10830Å wavebands simultaneously (Huang et al. 1995). Fig. 10 depicts the full view of the solar tower (left) and an example of its 2D flare spectra at Hα band (right). The main topics to study of NJU solar group include spectroscopy and spectral diagnostics (e.g. Fang, Henoux & Guan 1993), MHD simulations (e.g. Chen et al. 1999; Jiang et al. 2010), CMEs and related phenomena (e.g. Chen & Shibata 2000; Chen, Fan & Ding 2005), multi-wavelength study of solar activities (e.g. Guo et al. 2010) etc.

Recently, a new telescope called ONSET (Optical and NIR Solar Eruption Tracer)

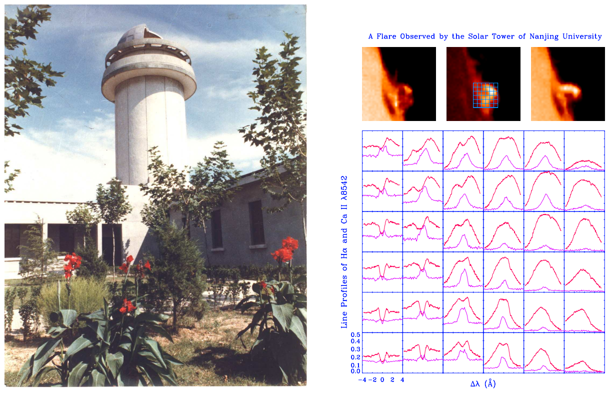

Figure 10. The solar tower of Nanjing University (left) and its 2D flare spectra at Hα band (right).

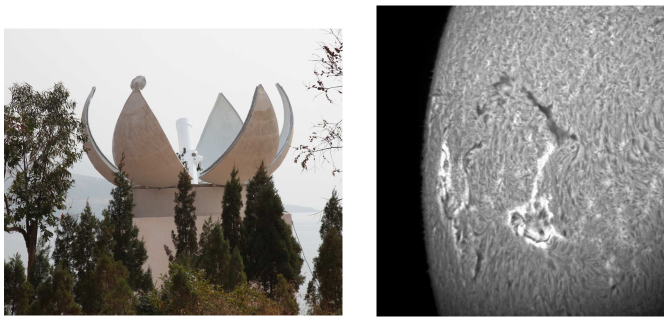

Figure 11. ONSET at Fuxian lake (left) and its Hα image(right).

has been established near the Fuxian lake at the observational base of YAO, which is 60 km away from Kunming. At present it is the best seeing place in China. ONSET can provide three images of full or partial disc (10 arcmin.) of the Sun at different wavelengths of Hα 6563Å, FWHM 0.25Å± 1.5Å, 10830 Å FWHM 0.5Å± 1.5Å, 3600Å or 4250Å. Fig. 11 shows an overview of ONSET and an example of a Hα image recorded on 18 April this year.

4. International collaboration

International collaboration has been greatly developed in recent years. We have close collaborations with scientists in United Stats, France, Germany, Japan, India, Russia, Korea and many other countries. Besides exchange of scientists, Chinese students are often sent to other countries to study and learn from foreign scientists. Some of them have obtained their Ph.D degrees abroad. Besides, we have established several bilateral meetings on solar physics during the past twenty years. Three Japan-China meetings have been organized since 1990. Three France-China meetings have been held since 1999, and the fourth one will be held in Nice this year. Two Korea-China meetings and three Indo-China meetings have been also organized since 2005. The first Asia-Pacific solar physics meeting, which was successfully held in March at Bangalore this year was well supported by all colleagues. The second one will be organized in 2013 in China. All these meetings have greatly promoted the collaborations between nearby countries.

5. Issues and prospects

Besides the universities, Chinese Academy of Sciences has also established M.S. and Ph.D programs. So we have plenty of well-educated students. One problem is the lack of solar space facilities, even though we have many ground-based telescopes. Fortunately, China has now started several space projects dedicated to solar physics. Moreover, we have started the site survey to select the best site for future solar observations. If successful, then we are hoping to construct some large solar telescopes in the future.

Acknowledgments

We are thankful to Dr. Xiaochun Sun, Dr. Hui Li, Dr. Mingchan Wu, Dr. Xiaoma Gu and Dr. Jun Lin, who provided many valuable pictures and material. This work was supported by the National Natural Science Foundation of China (NSFC) under the grant numbers 10878002, 10610099, 10933003 and 10673004, as well as the grant from the 973 project 2011CB811402 of China.

References

Ai G. X. 1986, Publ. Beijing Astr. Obs., 8, 1
Chen P. F., Fang C., Tang Y. H., et al., 1999, ApJ., 513, 516
Chen P. F., Fang C., Ding M. D., 2005, SpScR, 121, 201
Chen P. F., Shibata K., 2000, Astrophys. J., 545, 524
Fang C., Henoux J. -C., Gan W. Q., 1993, A&A, 274, 917
Fang C., Huang Y. R. 1983, Acta Astro. Sinica, 24, 190
Fu Q. J., Ji H. R., Liu Y. Y., et al. 2000, in Proc. of the first Franco-Chinese meeting on solar physics, eds C. Fang, J.-C. Henoux, & M. D. Ding, International Acad. Publ., Beijing, 282
Guo Y., Ding M. D., Schmieder B., et al. 2010, ApJ, 725, 38L
Huang Y. R., Fang C., Ding M. D., et al. 1995, Solar Phys., 158, 387
Jiang R. L., Shibata K., Isobe H, Fang C., 2011, RAA, 11, 701
Li H., Fan Z., You J. 1999, Solar Phys., 185, 69
Liu et al. 2011, in Proc. First Asia-Pacific Solar Physics Meeting, ASI Conf. Series, Vol.2, p.000

Ming C. R., Feng H., Zhang H. Q., et al. 1988, Acta Astr. Sinica, 29, 346
Sun X. 2011, IAU Symp. 260, 98
Wu M. C., Li Z. K., Li Z., et al. 1990, Publ. Yunnan Astr. Obs., 3, 1
Xia Z. G., Cao Y., Chen J. Y., et al. 1999, Publ. Yannan Astr. Obs. Suppl., p.409
Xu Z. T., Jiang Y. T. 1986, Sunspots and Human, Tianjin Science and Technic Publ.
Yan Y., Zhang J., Wang W., et al. 2009, EM&P, 104, 97
Zhang H., Ai G., Ming C. 1991, Publ. Beijing Astr. Obs., 18, 62
Zhong S. H., Xuan J. Y. 1989, Publ. Yunnan Astr. Obs., 35, 18