Solar magnetic field: The key to understanding the Sun

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The Sun is our star, which gives us light, heat and life. The Sun is also the nearest star, detailed observations of which provide us a unique chance to test our understandings of fundamental physics. So far we have understood why the Sun gives out that much heat, how old it is, what its internal structure is, and so on. With these understandings we have already been able to study other stars, galaxies and even the universe with certain successes.

However, there are still three long-standing unsolved questions in solar physics. They are: What process heats the corona to a million degrees? What makes the Sun have an 11-year cycle? What causes solar flares and coronal mass ejections?

Although these problems have not been fully solved, a consensus has been reached that the magnetic field is the controlling factor that drives these phenomena. Understanding the production, evolution and transportation of magnetic fields has been the central task of current solar physics study. Chinese scientists have contributed much to this dynamic field.

As an example, Professor Jingxiu Wang of the National Astronomical Observatory of the Chinese Academy of Sciences has won the Chinese National Natural Science Award (Second Class) in 2009 for his pioneering work on “The Study of Structure and Evolution of Solar Magnetic Fields”. Over the past 20 years, his work has not only covered vector magnetic field measurements of solar active regions [1,2] but also the ubiquitous small-scale magnetic field in quiet-Sun regions [3]. This work has inspired many of his Chinese colleagues to contribute in these areas [4,5].

Professor Wang has proposed a series of methods and concepts to analyze the observed vector magnetic fields, with particular interest in quantifying the way free magnetic energies are built up in active regions [6–9]. He was the first to estimate the amount of magnetic helicity from observations [8]. This set the stage for later studies such as the importance of magnetic helicity in driving solar coronal mass

ejections [10]. He is also a pioneer in calculating various non-potentiality quantities such as magnetic shear and current helicity from vector magnetograms, with his results and methods being confirmed and extended by various follow-up studies [11,12].

Professor Wang has also studied the observational evidences of magnetic reconnection in the low solar atmosphere and has proposed a two-stage-reconnection model of solar flares [9,13,14]. Magnetic reconnection is crucial in the energy release process of solar flares and coronal mass ejections [15]. Detailed observations [16–19] have shown that it has many consequences to the magnetic field as well as the field topology. For example, even on the photosphere, magnetic fields have been found to become more horizontal after major flares [16].

In addition to the above studies that focus on strong magnetic fields in active regions and magnetic networks, Professor Wang has shed light on the properties of magnetic intra-networks. He pointed out that even though these fields are relatively weak, they contribute more than 20% to the total magnetic flux on the Sun at any time [20]. In recent years these weak, but possibly important, components of the magnetic field have attracted increasing attention [21–23], with increasingly powerful space telescopes providing higher-spatial-resolution data with better sensitivity. In particular, heating from these elements may contribute significantly to the coronal heating [24].

It is worth mentioning that these achievements have benefited much from the success of the Solar Magnetic Field Telescope (SMFT) located in the Huairou Solar Observing Station of the National Astronomical Observatory of China. SMFT is a telescope fully designed and built by Chinese scientists [25] and has been working continuously on a daily basis since 1984 [26]. It is fair to say that this telescope and research based on data obtained through it have led the Chinese solar physics community to the fore in the world scientific community. In this connection, developing new telescopes [27–31] is obviously important to keep the Chinese solar physics community to the fore.

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