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Introduction to the Chinese Giant Solar Telescope

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Abstract. Chinese solar community has proposed a next generation ground-based solar telescope – Chinese Giant Solar Telescope (CGST). CGST will be an Infrared and Optical solar telescope. Its spatial resolution is equivalent to an 8 m-diameter telescope, and the light-gathering power equivalent to a 5 m-diameter telescope. The major scientific goal is to get precise measurement of solar vector magnetic field with high spatial resolution. A brief introduction to this project is given here.

Keywords : Sun: general – telescopes

1. Introduction

The elemental magnetic structures play a key role in the process of all kinds of solar magnetic interactions. However, after one-hundred-year developments since Hale's pioneer detection, the nature of the solar magnetic field is still one of the most important mysteries in solar physics. The detection of the fundamental structure of magnetic field always requires (spatial, temporal, and spectral) resolution and sensitivity as high as possible. Although solar physics has got big progress with ground-based and space-borne observations in the past decades, it seems that we do need more efforts to approach the whole right answers to the problem of the basic magnetic structures.

Up to now, almost all precise measurements of magnetic field are based on the Zeeman effect. As the quantity of Zeeman-split is much smaller than the line width, one cannot measure it directly and has to do this by the so called Stokes parameter measurement. In this case, the sensitivity of traverse component of magnetic field is quite poor, i.e., one order lower than the sensitivity of longitudinal component (Evans 1966). To avoid this, one should give up the traditional method by Stokes parameter

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measurement. A possible solution is to measure the Zeeman split directly. This requires the split quantity to be large enough compared with the line width. Because the Zeeman split is proportion to the square of wavelength, and line width (by Doppler broadening) proportion to wavelength, one may get direct measurement with far infrared spectral line.

As the solar radiation in infrared region is very weak, gathering more photons with larger telescope is necessary. Thus, larger solar telescope is not only the requirement of the high resolution but also of the high magnetic sensitivity.

In 2009, Chinese solar community reached a consensus to develop a very large infrared and optical solar telescope—Chinese Giant Solar Telescope, CGST. This project was first proposed by National Astronomical Observatoreies, Yunnan Observatory, Purple Mountain Observatory, Nanjing University, Nanjing Institute of Astronomical Optical Technology, and Beijing Normal University. These six partners cover almost all of the Chinese solar community.

2. Scientific objectives of CGST

2.1 Scientific Objectives

The scientific objectives consist of three parts. The first one is to observe the solar vector magnetic field, velocity, and thermodynamics structure with 20 km spatial scale and 1s temporal scale and to get systematic and quantitative result about the solar MHD process.

The second one is to basically determine the origin of small-scale magnetic field – local dynamo process, to quantitatively understand the process of 1ower atmospheric magnetic reconnection and to reliably diagnose the coupling process between solar flare, CME, solar wind and the small-scale magnetic field, mass flow, etc.

The third one is to reveal the transportation process of solar energy and mass flow from the lower photosphere to coronal. Furthermore, we hope to understand the causes of solar eruptive activity, and provide new physical method and tool for the forecast of the solar activities and the space weather.

2.2 Telescope and instrument requirements

In order to resolve the solar structure in the scale of 20 km, an optical telescope with diameter not less than 4m (same as the ATST and EST) is necessary. As in the longer wavelength, it is easier to realize AO than in shorter wavelength, we prefer the diame-

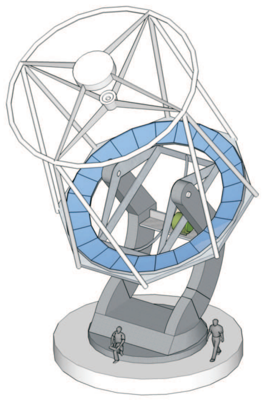

Figure 1. The sketch of the CGST which is designed as the 'ring solar telescope'.

ter larger and thus get diffraction-limit resolution in near infrared instead of in visible region.

In order to diagnose the coupling process among deferment scales, different layers, and different objects, multi-wavelength observations are necessary. For ground-based optical telescope, from visible to far infrared is the best solution. In addition, different instruments are necessary to satisfy different scientific purposes.

In order to get reliable and quantitative diagnostic of solar magnetic field, high magnetic sensitivity is necessary. Measuring the direct split of Zeeman effect should be the most effective way to get accurate observational result of transverse magnetic component. This kind of observation can only be achieved in mid or even far infrared region. For this purpose, the light-gathering capability should be, at least, same as or better than ATST.

In order to get extremely high magnetic sensitivity, non-polarization design of telescope is necessary. Symmetrical telescope could be the better selection.

3. Overview of CGST

3.1 Telescope

In the concept design, CGST employs structure of 'ring solar telescope' (Liu et al., 2008). The sketch of this construction is shown in Fig.1, and the basic parameters are listed in Table 1. From Fig.1 and Table 1, one can see that the spatial resolution of CGST is equivalent to an 8 m-diameter telescope, and the light-gathering power is about 22 m^2, equivalent to a 5 m-diameter telescope.

Table 1. Performances of the CGST.

Type	Ring Solar Telescope
Diameter	8 m
Width of ring	1 m
FOV	$\sim 3'$
Spectral coverage	$0.4 \sim 15\ \mu$m
Spatial resolution	$0.03''$ (wavelength below 1 μm)
	diffraction limit resolution (wavelength above 1 μm)
Polarization accuracy	2×10^{-4}
Magnetic sensitivity	1 G (longitudinal); $\leq$10 G (transverse)

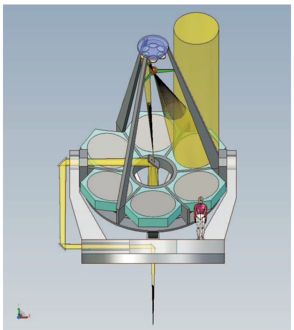

Figure 2. The sketch of an alternative CGST design which is based on the multi-mirror consideration.

The ring solar telescope has superiority in the thermal design of big aperture solar telescope for measurement of magnetic field. "How to reduce the effect of heat" is always a key problem in the design of a big solar telescope. The best solution is to use the System. By using field stop in this kind of system, one can block the "no-use" field and energy from first focal plane (*F1*). However, this will bring some other problems. The most serious one is the large temperature gradient nearby *F1*. This introduces dramatic inside turbulence and will largely destroy the spatial resolution and image quality. There are two solutions to this problem. One is to use the vacuum system, and the other is to use off-axis Gregorian system. The vacuum system is ideal but one can hardly make its window larger than 1 m. Off-axis system is successful for larger solar telescope, but it introduces instrument polarization, i.e., cross-talk for magnetic measurement. There are some special designs to reduce the instrument polarization, but it may not be overcome thoroughly. Thus it decreases the accuracy of magnetic measurement. By the design of the ring solar telescope, *F1* is not in the light path, and the whole system is symmetrical. This could be an ideal design for very large solar telescope. Thus, the CGST prefers to apply this design.

The details of ring solar telescope of CGST, including the design and feasibility need further study. In fact, some colleagues also proposed some other kinds of designs, for example, multi-mirror consideration as shown in Fig.2. The final design is an important advance research of CGST in the near future.

3.2 Instrument

The CGST will equip series of scientific instruments, such as two-dimensional real-time spectrograph, fiber arrayed solar optical system, F-P etalon, etc.

The two-dimensional real-time spectrograph is a birefringent filter-type magnetograph. However, as it utilizes the method of multi-channel birefrigent filter, it can get the rough Stokes profile simultaneously. That means it can carry out imaging spectral observations in real-time. This is very useful for ground-based observations to avoid the effect of the earth's atmosphere.

The fiber arrayed solar optical system (Qu 2010) aims at obtaining fast spectral imaging of vector magnetic fields and line-of-sight velocities over multiple solar layers of photosphere and chromosphere with temporal resolution better than 10 s.

3.3 Site

At present, the best site in China for solar observations was found in Fuxian Lake, Yunnan Observatory (Liu 2011). However, as CGST will mainly work in infrared, this site may not be a suitable candidate. In the western part of China, (Tibet and its nearby provinces), geological and weather conditions may provide us more candidates for the site of CGST. Chinese solar community already started a project called as "Site survey for solar observation in western part of China". The main purpose of this project is to find the best site for CGST and other forth-coming solar projects.

3.4 Others

By the present conditions, the budget of CGST is about 600M RMB, or 90M USD and the construction period is expected to be 10 to 15 years.

4. Status of CGST

4.1 Organization

In October 2010, Chinese solar community established some organizations to promote the CGST, including Advisory Committee, Scientific Committee, and Promotion

Committee. Under the Promotion Committee, there are several working groups, such as Scientific Objectives, Scientific Instruments, Detector, Telescope Design, AO, Site Survey, etc.

4.2 Promotion Status

1. In January 2010, CGST was selected and recommended by Chinese Academy of Sciences (CAS) to National Development and Reform Commission (NDRC) as "National major basic scientific project for 2016-2030";
2. In February 2010, CGST was selected by National Science Foundation of China (NSFC) as 13-5th (2016-2020) planning project for astronomy;
3. In August 2010, as the advance project of CGST, the projects of "Site survey in western part of China" and "Fiber Arrayed Solar Optical Telescope" were supported by NSFC. The budgets are 1.86M and 1.84M RMB, respectively;
4. In October 2010, "Advanced research of CGST key science and technology" was supported by CAS with 2.6M RMB;
5. In November 2010, CGST was selected by NDRC as a National 14-5th (2021-2025) planning project for astronomy;
6. In March 2011, proposals of "Key method and technology for mid-infrared solar polarization measurement" and "Key telescope technology of CGST" were submitted to the NSFC.

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