Chinese Small Telescope ARray (CSTAR) for Antarctic Dome A

Xiangyan Yuan[1,4], Xiangqun Cui[1,4], Genrong Liu[1], Fengxiang Zhai[1], Xuefei Gong[1,4], Ru Zhang[1], Lirong Xia[1], Jingyao Hu[3,4], J.S. Lawrence[5], Jun Yan[3,4], J.W.V.Storey[5], Lifan Wang [2,4], Longlong Feng[2,4] , M.C.B. Ashley[5], Xu Zhou [3,4], Zhaoji, Jiang[3,4], Zhenxi Zhu[2,4]

1 National Astronomical Observatories/Nanjing Institute of Astronomical Optics & Technology ,
Chinese Academy of Sciences

2 Purple Mountain Observatory

3 National Astronomical Observatory

4 Chinese Center for Antarctic Astronomy

5 University of New South Wales, Australia

ABSTRACT

Chinese first arrived in Antarctic Dome A in Jan. 2005 where is widely predicted to be a better astronomical site than Dome C where have a median seeing of 0.27arcsec above 30m from the ground. This paper introduces the first Chinese Antarctic telescope for Dome A (CSTAR) which is composed of four identical telescopes, with entrance pupil 145 mm, 20 square degree FOV and four different filters g, r, i and open band. CSTAR is mainly used for variable stars detection, measurement of atmosphere extinction, sky background and cloud coverage. Now CSTAR has been successfully deployed on Antarctic Dome A by the 24th Chinese expedition team in Jan. 2008. It has started automatic observation since March 20, 2008 and will continuously observe the south area for the whole winter time. The limited magnitude observed is about 16.5^{m} with 20 seconds exposure time. CSTARS's success is a treasurable experience and we can benefit a lot for our big telescope plans, including our three ongoing 500mm Antarctic Schmidt telescopes (AST3).

Keywords: Chinese small telescope array (CSTAR), Dome A, variable detection, continuous observation

1. INTRODUCTION

Astronomers need large telescopes to observe the far and faint stars, and the large telescopes need to be deployed on an excellent site to realize their high angular resolution. The high plateau of the continent of Antarctica has been proved to be the best astronomical observing sites on earth. For example, the U.S. Amundsen Scott South Pole Station(2820m) was proved to have median seeing of 0.3 arcseconds above the boundary layer which is about 200-300m high from the ground[1]. Dome C (3260m) shows a median seeing of 0.27 arcseconds above 30m from the ground, and below 0.15 arcseconds for 25% of the time[2,3]. Dome A (4093m), the highest plateau of the Antarctic inland, is widely predicted to be a better astronomical site even than Dome C according to the topographic similarity and the higher altitude. Figure.1 shows the positions of the three sites on Antarctic. Except the superb seeing conditions, the Antarctic plateau cherish the following advantages[2,3] at the same time: long periods of continuous observations (more than 4 month for Dome A in winter) which is quite suitable for the transient detection and the study of asteroseismology and so on; low windspeed; low light scatter and high atmospheric transparency; very cold and dry; low infrared background; lower scintillation; wide isoplanatic angle and long coherent time. All these advantages make the Antarctic plateau the most attractive site on earth for optical/infrared astronomy, and almost certainly the single best site for submillimetre and terahertz astronomy.

Email: xyyuan@niaot.ac.cn; Phone: 86 25 85482243; Address: No.188, Bancang Street, Nanjing, 210042, China

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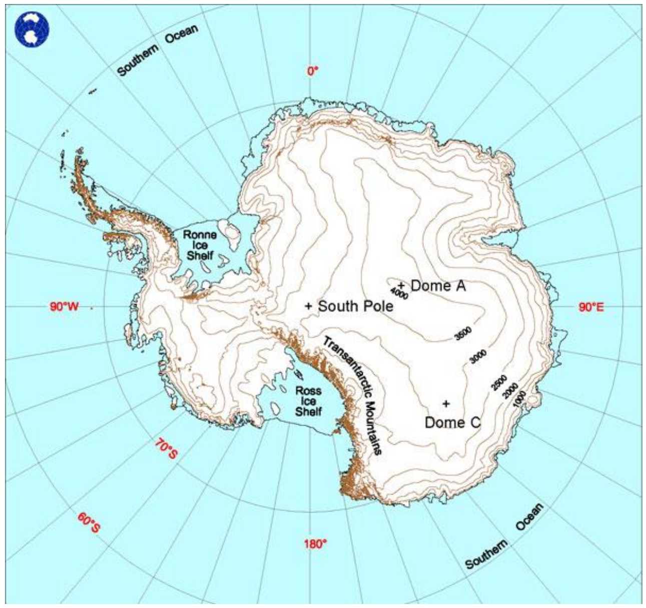

Fig. 1. The Antarctic map

Many telescope projects were put forwarded in these years, such as IRAIT[4] (International Robotic Antarctic Infrared Telescope, 80cm in diameter), PILOT [5](Pathfinder for an International Optical Telescope, 2.4 m in diameter), LAPCAT[6] (Large Antarctic Plateau Clear Aperture Telescope, 8m in diameter), KEOPS[7] (Kiloparse Explorer for Optical Planet Search, 36x1.5m, interferometry array).

In Jan., 2005, Chinese expedition team first arrived in Dome A in the world[8], thus provided the Chinese astronomers and also the foreign astronomers a good opportunity to learn and test the potential site. An international conference on Wide Field Survey Telescope at Dome A/C was hosted and co-sponsored by the National Astronomical Observatory, Chinese Academy of Sciences, and the LAMOST project. The meeting was held in Beijing, China in 3-4 June, 2005. Many famous astronomers attended the meeting and proposed many Antarctic telescope plans. In Oct. 2006, Chinese Center for Antarctic Astronomy (CCAA) put forwarded the plan of Chinese first Antarctic telescope CSTAR (Chinese Small Telescope ARray) which is composed by 4 small telescopes with different filters with 145mm in diameter . CSTAR is mainly used for the detection of variables and transient astronomy. In order to be safer for the first optical device and much time-saving, we designed the telescope to be fixed without any moving parts, this also makes the alignment on spot easier. After less one year work, CSTAR was finished in Sep., 2007 and got through it's acceptance test in Oct. Now CSTAR has been successfully deployed on Antarctic Dome A by the 24th Chinese expedition team in Jan. 2008. It has started automatic observation since March 20, 2008 and will continuously observe the south area for the whole winter time.

2. DESIGN OF CSTAR TELESCOPE

According to the CSTAR design requirement, this telescope has an equivalent aperture of 100mm with wide field of view about 4°and fast f/ratio about 1.2. Four filters from 400nm to 900nm are used for multi-color photometry. The selected detector is ANDOR DV435 1Kx1K frame transfer CCD with pixel size of 13μm. The telescope is fixed without any moving parts, including the focal plane.

2.1 Optical design

For such a compact telescope with fast f/ratio and wide field, the catadioptrive objective with spherical primary mirror is selected for our purpose which can deliver lower chromatic aberration. Image quality requires 80% light energy encircled in 2pixels. In order to keep the focus unchanged in about 100°centigrade difference from 20° to -80°centigrade, both the optics and the structure need to select low thermal expansion materials. Zerodur and fused silica are selected for CSTAR's main optical components. The main specifications of the optical system (designed by Genrong Liu) are as follows:

Entrance pupil diameter: 145mm (Effective aperture: 100mm)

Focal length: 170mm

Field of view: 4.48°x 4.48°

Working wavelength: g, r, i filter, and one open filter from 400nm to 900nm

The optical layout is shown in Fig.2, the first plano lens serves as window and filter.

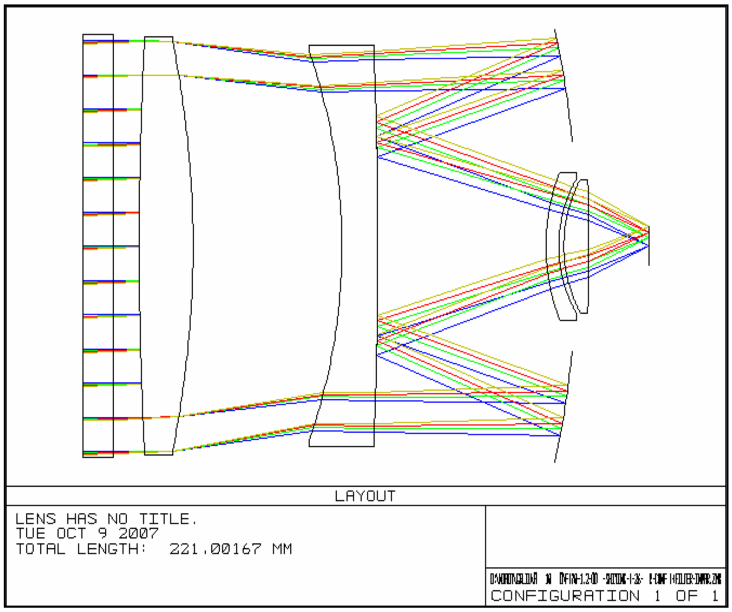

Fig.2. layout of CSTAR

The spot diagram under normal conditions, that is 20°C and 1atm pressure, is shown in Fig.3. As a result, 90% light energy encircled in 2 pixels which is better than the requirement of image quality.

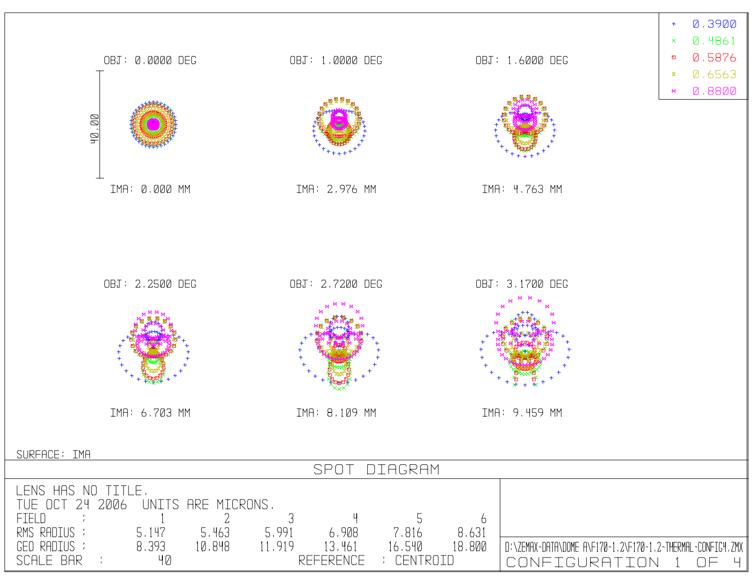

Fig.3. Spot diagram of CSTAR

In order to test the performance of CSTAR under the extremely rough conditions in Dome A, we made thermal analysis and ZEMAX simulation under circumstance of -80°C and 0.57atm pressure. We also put the telescope tube including the detector CCD in the low temperature chamber to simulate the winterization in Dome A after we finished alignment of the telescope in lab. The temperature was controlled to be lower gradually with light source and collimating system testing the image quality at the same time, shown in Fig.4. The results are quite satisfactory and the image quality is almost unchanged.

Fig.4 CSTAR winterization test

2.2 Telescope tube

To keep the focus unmoved when working in winter in Dome A, INVAR36 which has very low coefficient of thermal expansion (CTE) was selected for telescope tube. Strict thermal processing was done during the tube manufacture in order to guarantee a stable and reliable CTE. The tube was designed to be light-weighted, well sealed, easily assemble.

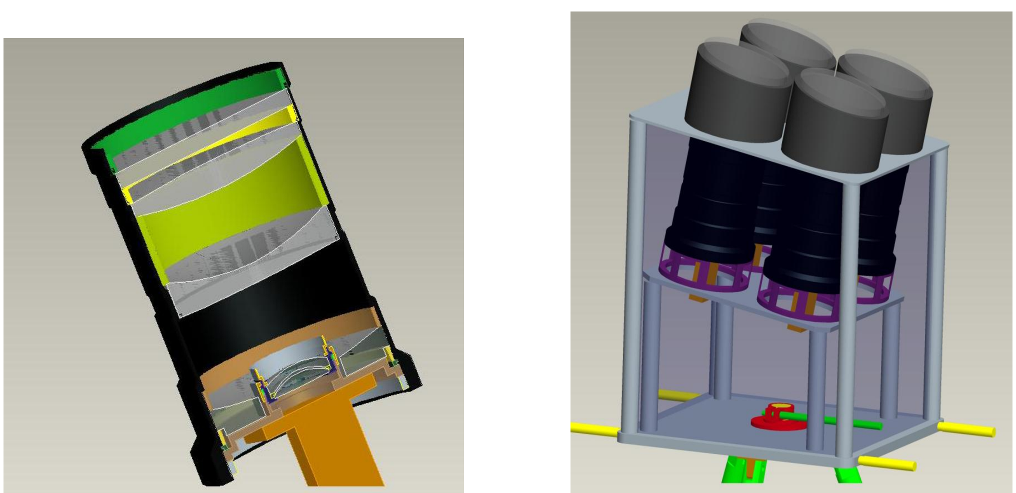

Fig.5. solid model of CSTAR tube

The last component in the tube in brown color in the left image is CCD. All the colors in the above images are used for the model not real one for the tube. The upper protruding part of the right image shows four tilted windows to slide down the dry snows. ITO (Indium-Tin-Oxide) film with 10w power for each was coated on the window to make the surface a bit warmer than the ambience, keeping the surface from icing or frosting. As for the inside tube, pure nitrogen was filled in at the last stage to make the tube dry enough avoiding icing and frosting on the inside optical surfaces. The four tubes were mounted on a tilted plated (9°38′) in the portable box pointing to zenith. The box was stuffed with foams surrounding the tubes to keep it stable during long way transportation to Dome A.

2.3 CCD and control software

The CCDs (ANDOR DV435, 1kx1k frame transfer CCD) we used were very robust, and it can work well under -80°C without warming it's electronics.

Industrial computers with wide working temperature range were selected for each telescope. Each computer has a flash disk for operating system and telescope control software and 750G hard disk for data storage. The control software can automatically collect, store or transfer images, compress the data to be sent back, and some preliminary data processing. The exposure time can be adjusted according to the observing conditions. Supposed it to be 20 seconds for one frame, for about 4month continuous observation, there will be a large amount of image datum. Due to the very limited communication band, most datum will be stored in the hard disk which will be taken back by the next expedition team and only a small subset will be sent back by the Iridium satellite network.

2.4 Special design for transportation

Considering the long way transportation on both sea and Antarctic inland, and the optical system must keep unchanged through the whole tough journey, thus a special transportation structure was designed to effectively lessen the vibration, see Fig. 6. Another paper by Xuefei Gong will introduce the transportation design in detail in this conference[9].

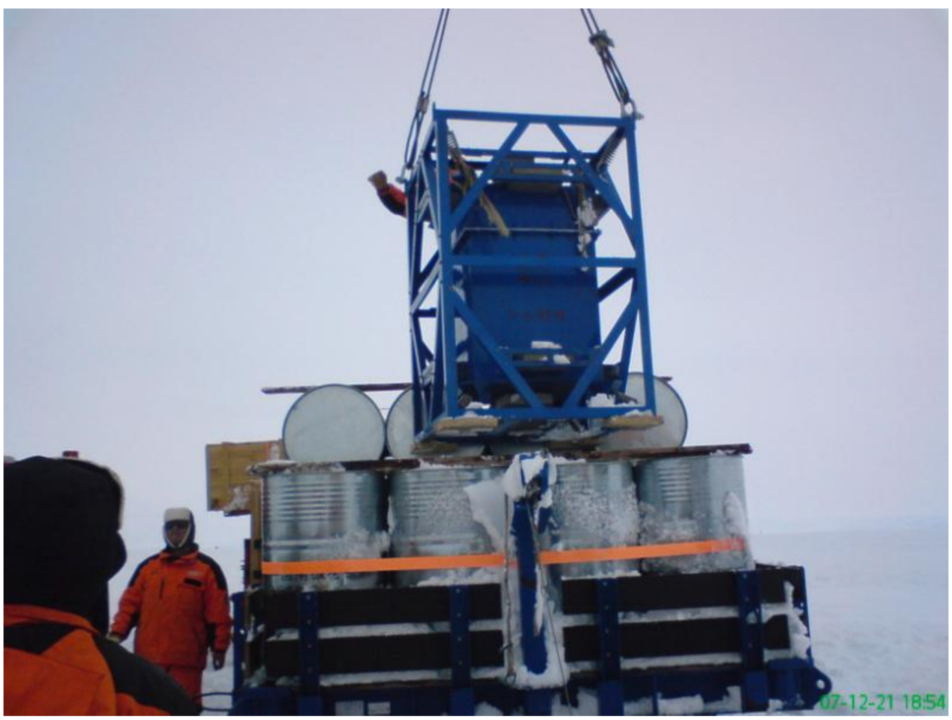

Fig.6. Transportation design for CSTAR (shown as upper blue one)

After less one year's work, CSTAR was finished successfully in Sep., 2007. Testing observation in Xinglong Station showed CSTAR worked well and the limited magnitude CSTAR can observe was about 13^m with 20seconds exposure. In

Nov.12, 2007, the 24th Chinese Science expedition team started the transverse from Shanghai. CSTAR was putted in one standard container in “Xuelong” Ice-breaker.

3. CSTAR in DOME A

In Jan., 2008, CSTAR was successfully installed on Antarctic Dome A by two astronomers Xu Zhou and Zhenxi Zhu of the 24th expedition team, as shown in Fig.7. The industrial computers for each telescope connecting with each CCD was installed inside the instrument module of PLATO (PLATeau Observatory for Dome A, mainly used for site testing, developed by UNSW, Australia) which is temperature controlled to be about zero degree Celsius. The engine module of the PLATO supply powers for all astronomical instruments and computers, included power for our CCDs and computers and the outside ITO film.

CSTAR has started automatic observation since March 20, 2008 and will continuously observe for the whole winter time. One image sent back by Iridium satellite from PLATO was shown in Fig. 8, from which we can see the ITO heating film is quite successful in deicing and de-frosting on the outside window. The limited magnitude observed is about 16.5^m with 20 second exposure time which is much deeper than CSTAR can observe at the mid-latitude observatory. This convinced us that Dome A is really a very good astronomical site.

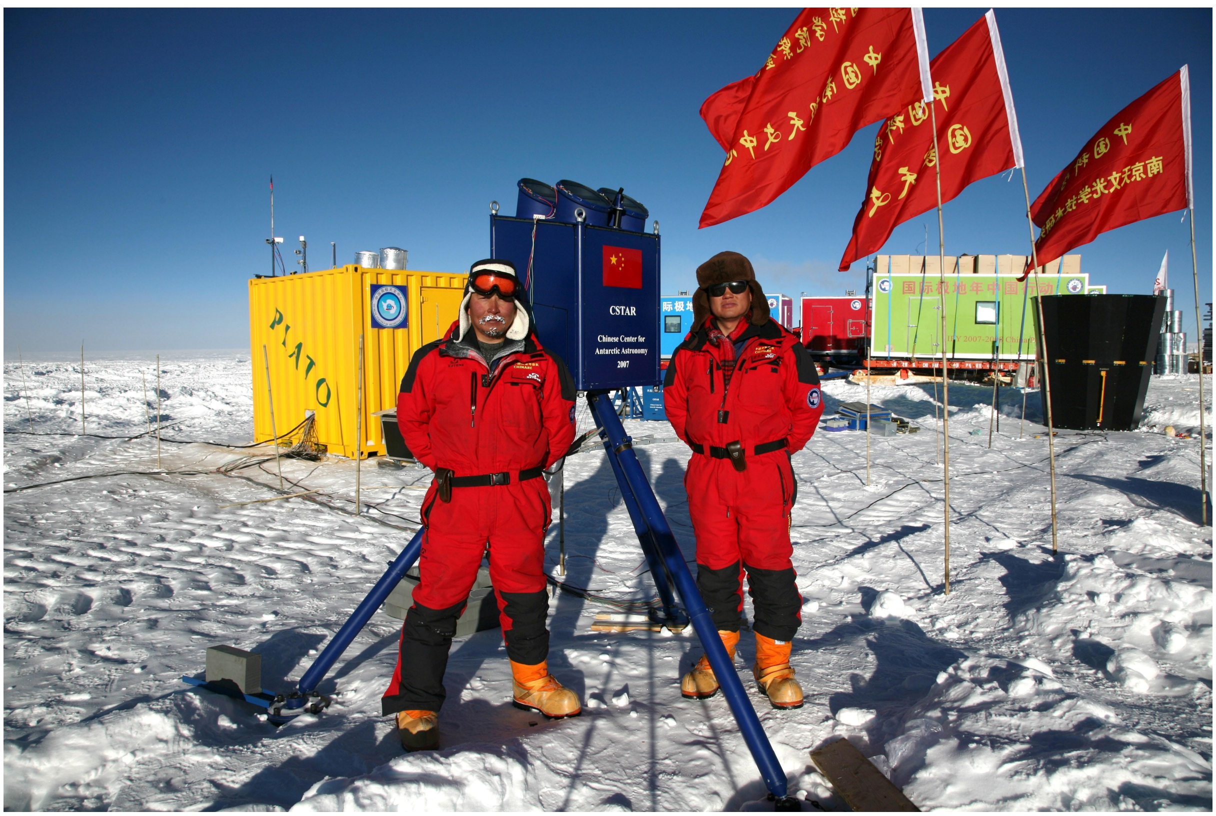

Fig.7. CSTAR in Dome A (Installed by Prof. Xu Zhou and Zhenxi Zhu)

Fig.8. Star images observed in Dome A by CSTAR

4. CONCLUSION

Antarctic Dome A is the potential best site for ground-based astronomical telescope which will be tested soon by CSTAR and PLATO. But the tough conditions of Dome A also put a big challenge for astronomical instruments, especially large telescopes. Alignment in day-time, de-icing and snow-removing, hard transportation are all unique questions needed to be settled for Antarctic telescopes, and fully automated observation is also needed since nobody can be there for running currently. From CSTAR's success we can benefit a lot for our three ongoing 500mm Antarctic Schmidt telescopes (AST3).

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