Status of the first Antarctic Survey Telescopes for Dome A

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ABSTRACT

The preliminary site testing carried out since the beginning of 2008 shows the Antarctic Dome A is very likely to be the best astronomical site on earth even better than Dome C and suitable for observations ranging from optical wavelength to infrared and sub-millimeter. After the Chinese Small Telescope Array (CSTAR) which is composed of four small fixed telescopes with diameter of 145mm and mounted on Dome A in 2008 for site testing and variable star monitor, three Antarctic Survey Telescopes (AST3) were proposed for observations of supernovas and extrasolar planets searching. AST3 is composed of 3 large field of view catadioptric telescopes with 500mm entrance diameter and G, R, I filter for each. The telescopes can point and track autonomously along with a light and foldable dome to keep the snow and icing build up. A precise auto-focusing mechanism is designed to make the telescope work at the right focus under large temperature difference. The control and tracking components and assembly were successfully tested at from normal temperature down to -80 Celsius degree. Testing observations of the first AST3 showed it can deliver good and uniform images over the field of 8 square degrees. The first telescope was successfully mounted on Dome A in Jan. 2012 and the automatic observations were started from Mar. 2012.

Keywords: Astronomical site, Dome A, Antarctica Survey Telescope, Automatic observations

1. INTRODUCTION

The site testing works organized by Chinese Center for Antarctic Astronomy (CCAA) since the beginning of 2008 show that the Antarctic Dome A is very likely to be the best astronomical site on earth even better than Dome C[1,2] and suitable for observations ranging from optical wavelength to infrared and sub-millimeter. The first-generation Chinese Antarctic optical telescope CSTAR was mounted on Dome A in January 2008 and automatically observed for four consecutive winters. CSTAR[3] was composed of four fixing telescopes with diameter 145mm, a 20 square degree FOV and different filters (G, R, I and open band). The main science of CSTAR was for variable sources detection and optical site testing[4].

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The AST3 composed of three catadioptric telescopes are the second-generation Chinese Antarctic telescopes[5]. Each of AST3 with entrance pupil diameter 500mm, primary mirror diameter 680mm, f-ratio 3.73, and field of view 4.14°(2.92°×2.92°), is matched respectively with different filter and 10K×10K CCD which is currently the largest single-chip CCD in the world. The image quality of AST3 is 80% energy encircled in 1 arcsecond and distortion in the whole field less than 1 pixel. The telescopes can automatically point and track the objects in the observing sky area with zenith distance $z \leq 70°$. The main science is for observations of supernovas and extrasolar planets searching.

In order to keep the telescope properly work under temperature range from 30°C to -80°C, low thermal expansion materials were used to minimize the thermal effect. Zerodur and fused silica were selected for most of AST3's optical components except for the lens-prism of the corrector. INVAR36 was selected as the material for the main structure. A motorized focusing mechanism with a stepping accuracy of 1 micron was designed to adjust the focal plane to the best position in order to compensate for the thermal effect. This mechanism was successfully tested in the winterization chamber from normal temperature down to -80 °C. Considering of the snow and frost problem in Dome A, a light foldable dome which can move along with the telescope was adopted to keep the snow off the dome and the outer optical surface, ITO(Indium-Tin-Oxide) coating was used to heat the outer surface of the aspheric plate to make the surface always warmer than the open air and the dynamic dry nitrogen filling system was used along with the sealed optical tube to keep the tube dry all the time.

The first Antarctic Survey Telescope (AST3-1) was successfully mounted on Kunlun Station on Jan. 24, 2012, where is 7km far away from Dome A which is the highest point of the Antarctic continent[6]. Four astronomers of 28th Chinese Antarctic Inland Scientific Research expedition (Fujia Du, Zhengyang Li, Yi Zhang and Yi Hu) spent 19 days on finishing this amazing job including assembly and alignment of AST3-1, installation and testing the power supply and communication system PLATO-A, maintenance of the previous astronomical instruments. Since there is no person during the winter time at Kunlun Station nowadays, AST3-1 can be remotely controlled to point and track in the domestic lab via the Iridium satellite and Open port, the main computer in the instrument module of PLATO-A collects images and makes some process and calculations, then sends back the statistic data and partial regions of the images if necessary. AST3-1 was tested after the team left the Kunlun Station, and it started to observe since the early Mar. 2012.

2. WINTERIZATION AND TESTING OBSERVATION

Dome A is possibly the coldest point in Antarctica, the lowest temperature recorded is about -83℃. Average temperature at Kunlun Station is -56℃. The ultra environment makes Dome A the best astronomical site on the earth, however it results in many tough technical problems. The mechanical and tracking components such as bearing, gear, motor, reducer and resolver must be specially developed and tested from normal temperature to -80℃. With special low temperature grease, the tracking assembly was successfully tested at down to -80℃[7]. In order to test the performance of the whole system in low temperature, we put the whole telescope in a large low temperature chamber for the winterization test (figure 1). The telescope can work properly with fast driving mode, slow mode at different low temperatures and the power consumption is all within the designed total 500w with fast moving(figure 2), the detailed power distribution is shown in figure 3. There's a separate 24V DC outlet for CCD which consume about 120w working in cooling mode.

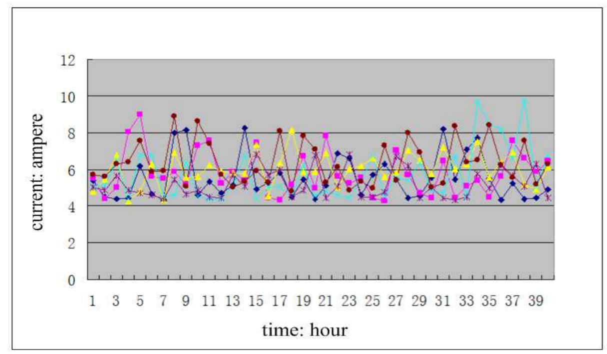

Figure 1. Winterization test of the whole telescope.

Figure 2. Power consumption of AST3-1 with different moving mode and different low temperature.

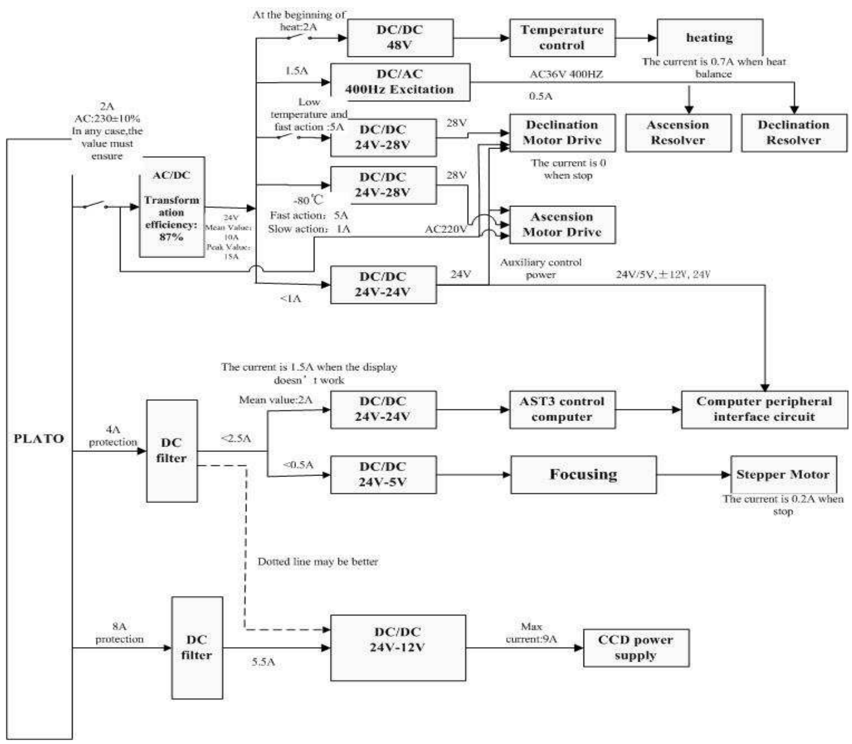

Figure 3. Power distribution of AST3-1.

From Aug.29 to Oct. 16 2011, we did testing observations with AST3-1 at Xuyi observation station with latitude N32°44'. On the one hand, we need to confirm the transportation plan was safe enough for the long journey transportation to Dome A. .On the other hand, we want to check the AST3-1's performance at the temperate site. Due to the latitude difference between Xuyi site and Dome A, AST3-1 was tested as alt-azimuth telescope. The testing results show the telescope can deliver a uniform flat field with image FWHM about 2.2 arcsecond with exposure time 1 second which corresponds to the local seeing value. The astrometry accuracy is about 0.2 arcsecond comparing to PPMX catalog.

Figure 4. Alignment of AST3-1 at Xuyi station.

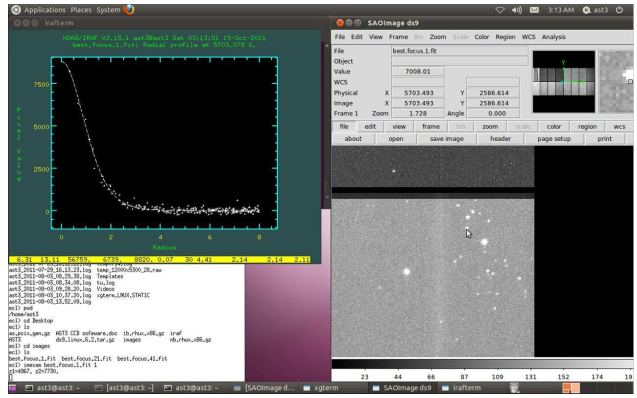

Figure 5. Double Cluster (expose time 1s, about 2.2 arcsecond image quality over the full flat field of view include seeing)

3. MOUNTING AND ALIGNMENT ON DOME A

The Antarctic inland expedition team composing of 26 members including 4 astronomers left for Antarctica from Shanghai on 29th Oct. 2011, and arrived at Kunlun Station on 4th Jan. 2012. Though Dome A is a perfect site for astronomical observation depending on its cold and dry atmosphere[8], it is torturous for us to install and operate the telescope there in such a short time.

The optical system of AST3-1 was assembled on the spot since the optical components were transported by a separate multi-anti-vibration container, not along with the mounting system which was transported as a whole by another anti-vibration container. We need to align the optical axis and adjust the polar axis. Normally we used reticules to mark the position of axis and made use of micro-alignment telescope (MAT) to build the optical axis accurately, then to adjust the axis position to make declination axis perpendicular with right ascension axis and optical axis. Polar axis inside the north-south plane has inclination angle 9°34′57″ from the zenith which correspond to the site latitude. For an equatorial telescope, adjustment of polar axis is crucial otherwise it would result in inaccurate pointing and tracking. We used theodolite for the angle adjustment. After the alignment of the optical system, the tube was covered and dry nitrogen was filled in for several times to keep the tube dry enough and then the tube was sealed with silicon gel. At last, the light foldable tent dome was mounted to keep the snow away from the telescope[9].

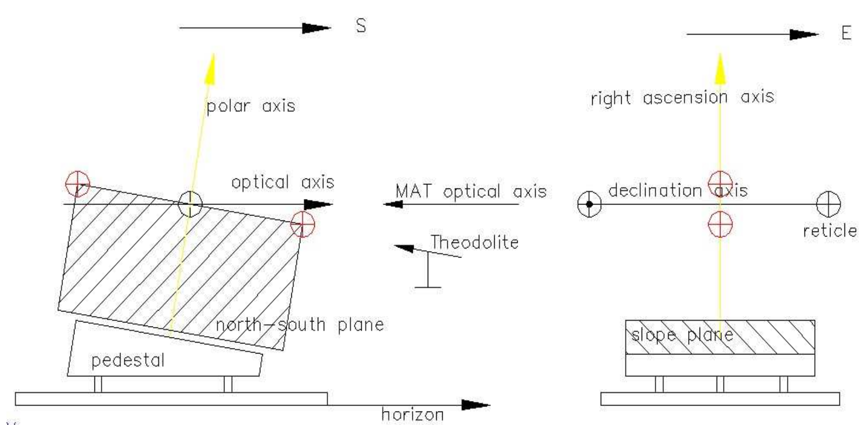

Figure 6. Axial schematic diagram

Also observing stars drifting on the image plane can accurately correct the misalignment of the polar axis. Though AST3-1's CCD cannot acquire useful image at daytime due to the sky brightness, we successfully tracked the Canopus (-0.72^m) by using Celestron C14 telescope which was fixed on the tube of AST3-1. Adjusting the two optical axis parallel could help us do the precise polar alignment. Unfortunately due to the limited work time and lack of proper tools, we failed to finish this precise correction, for the optical axis of the two telescopes were not exactly parallel. By the way, the daytime star monitor carried out by the C14 telescope with two subaperture mask did give us four days' seeing data of Dome A with median seeing about 0.85 arcsecond measured at 3m height from the ground similar like the daytime seeing measured on Dome C with DIMM at 3m elevation [10,11].

Figure 7. AST3-1 alignment at Kunlun station.

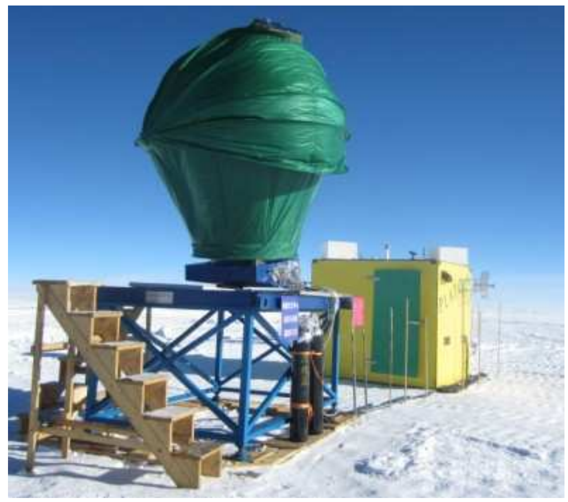

Figure 8. AST3-1 with dome on Dome A.

4. OBSERVATION ON SITE

The unattended telescope can only be operated via remote communication with the Open port device since the expedition team left Kunlun Station on 24th Jan. 2012. As long as you can log on the internet, you can check the real-time status of AST3-1 recorded in the log file. In middle March with twilight the telescope was controlled by astronomers in the National Observatory in Beijing. With the arrival of the polar night, AST3-1 can continuously survey the sky for observations of supernovas and extrasolar planets searching. It is too expensive to send back one full frame image, occasionally a small region of the image was sent back for image quality check and focus adjustment.

Figure 9 is an image of 1600×1600 pixel with exposure time 20 seconds. The black line represents the gaps between the slices of CCD camera. Comparing the different regions of the 10K×10K image by sampling a few small 300×300 pixel images shows that the AST3-1's focal plane is flat and the image spot difference between central and the edge in one image is about 0.2 arcsecond due to the CCD alignment error. Figure 10 is an image of 300×300 pixel with exposure time 60 seconds which shows the limited magnitude of 19.5^m with FWHM about 1.8 arcsecond. Though the optics can give a better performance, the ground seeing, mirror heating and the sealed tube with the CCD in-between the optical light may degrade the quality of the image.

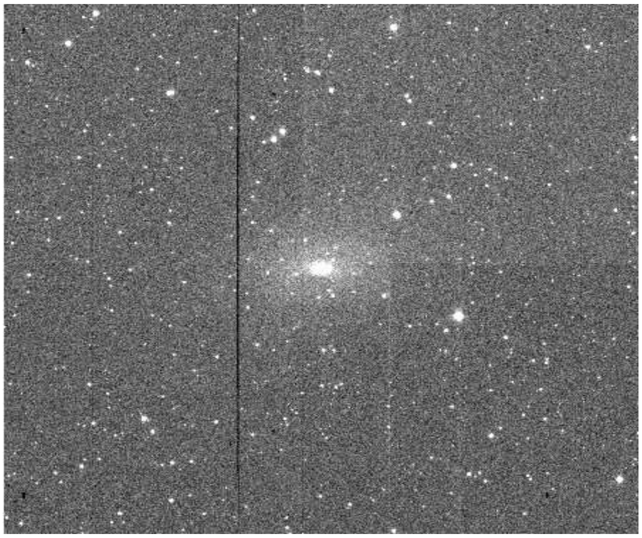

Figure 9.Image of NGC6744 1600×1600 pixel with exposure time 20 seconds.

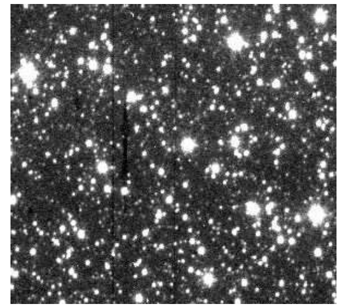

Figure 10 Image of 300×300 pixel with exposure time 60 seconds.

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