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Nanjing Institute of Astronomical Optics & Technology
National Astronomical Observatories,CAS

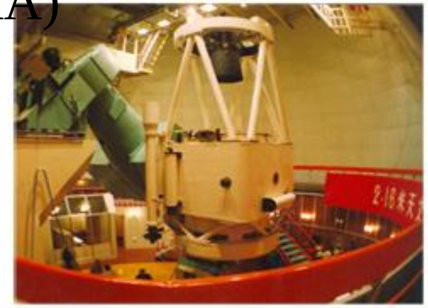
# Development of AST3 and AST3-NIR


Xiangyan Yuan

On behalf of AST3 telescope group

Nanjing Institute of Astronomical Optics & Technology(NIAOT);

Chinese Center for Antarctic Astronomy(CCAA)

9–12 March. , 2015, HKU

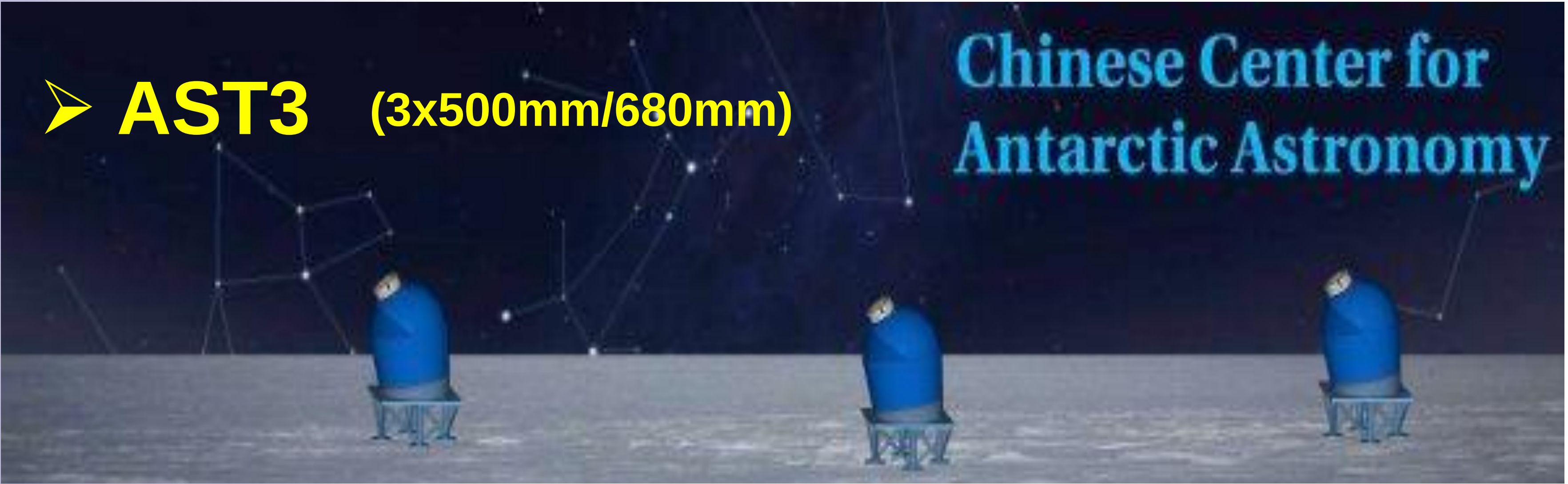
- NIAOT (Xiangyan Yuan, Xiangqun Cui, Bozhong Gu, Xinnan Li, Shihai Yang, Xiaoyan Li, Fujia Du, Daxing Wang, Zhengyang Li, Haiping Lu, Haikun Wen, Xuefei Gong, Lingzhe Xu, Cong Pei, Kaiyuan Zhang, Yi Zhang, Ru Zhang,et al)

- NAOC (Zhaohui Shang, Yi Hu, Bin Ma, Qiang Liu, Peng Wei)
- PMO (**Lifan Wang**, et. al.)
- UNSW( Michael Ashley, Jon Story, et. al)
- Tsinghua University
- Nanjing University
- Beijing Normal University
- PRIC
- AAO (AST3-NIR Detector, Jon Lawrence, Jessica et.al)
- ……..

# 2015 International Collaboration Meeting on Antarctic Survey Telescopes (AST3)

- Introduction
- Development of AST3-1 and AST3-2
- Design of AST3-3(-NIR)

## ➢ AST3 (3x500mm/680mm)




✓ clear sky and continous obser.

✓ stable atmosphere and precise photometry

- **Supernova**
  - Very early discovery
  - Uniform, multi-color light-curve
- **Exoplanets**
  - Transients
  - Micro-lensing
- **Variable stars**
- **Asteroseismology**
- … …

# ➤ Telescope Optical System

X. Yuan & D. Su, "The Optical System of Antarctic Survey Telescopes AST3", MNRAS., 201

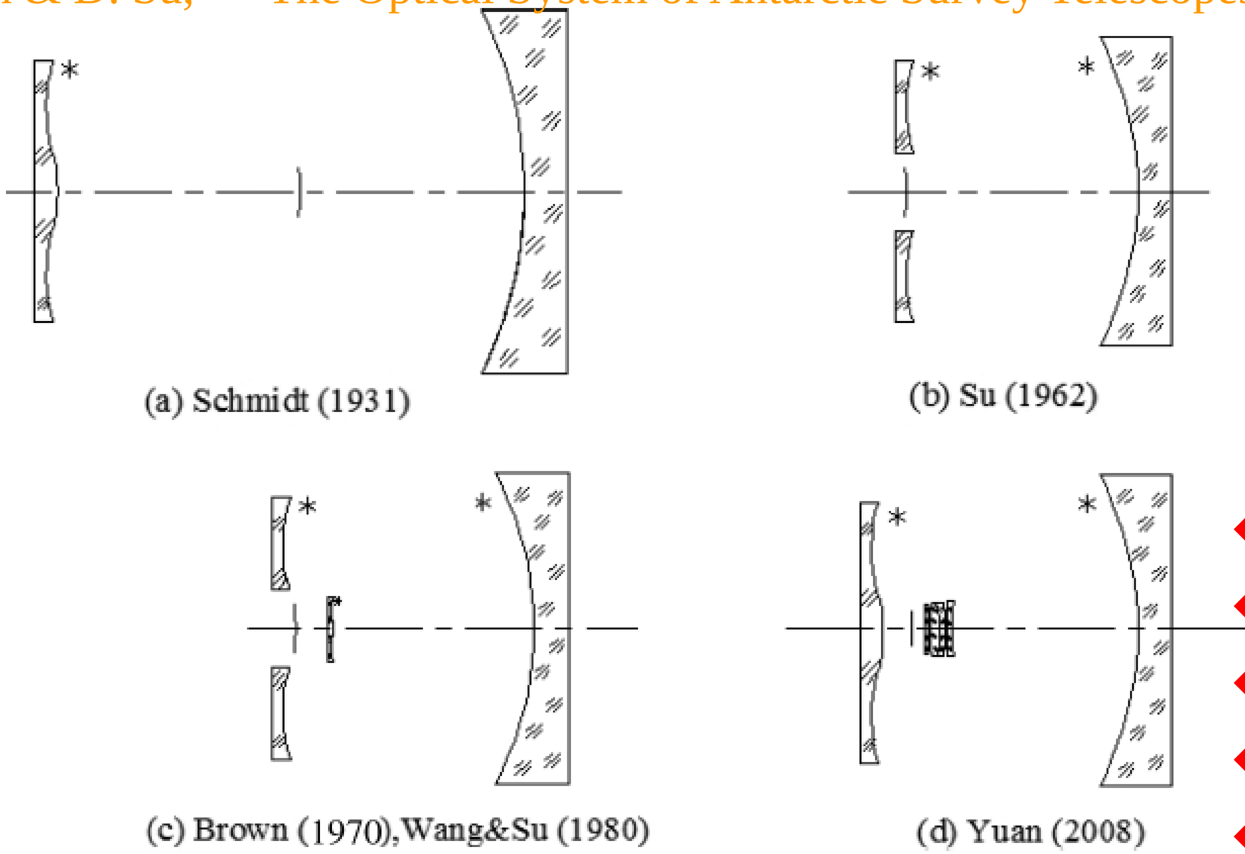



**Figure 2.** The evolution of the optical system from Schmidt to AST3 (* means aspherical surface).

- ◆ Smaller primary
- ◆ Shorter tube;
- ◆ distortion free;
- ◆ ADC;
- ◆ spherical lens correctors

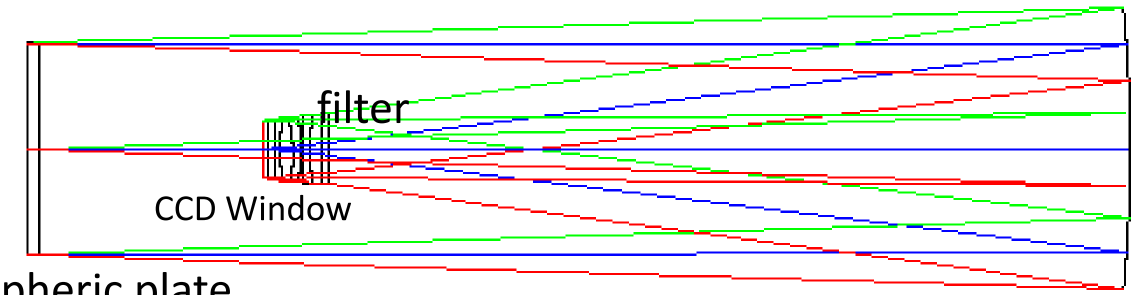
free from spherical abberation, coma, astigmatism, distortion

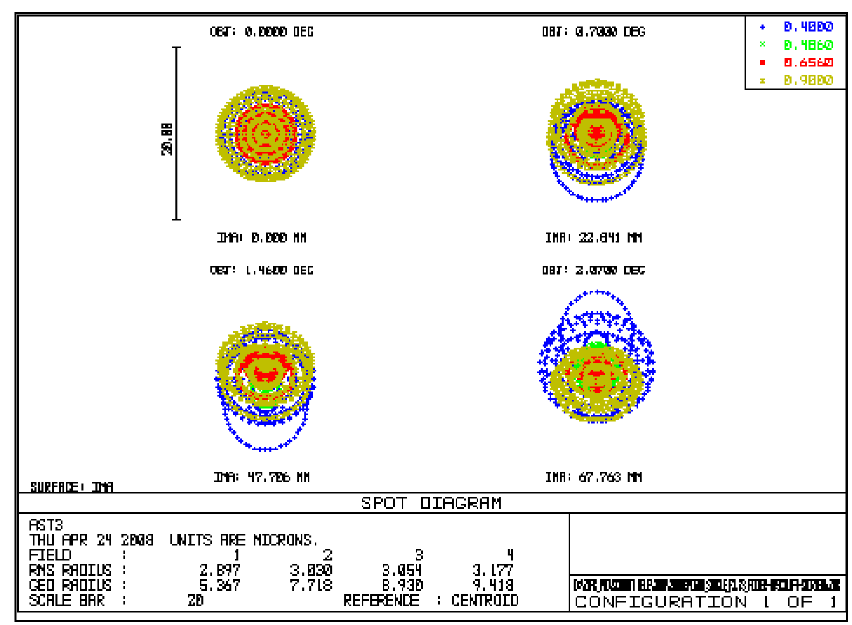
# Main specifications:

- Focal length: 1867mm
- Field of view: 4.1°
- Working wavelength:

  400nm-900nm, g, r, i filters
- designed Image quality:

  80% light energy encircled in 1″
- Very low distortion in the whole field
- Total optical length: 2.4m
- 10K X 10K CCD from STA




spot diagram of AST3 with open filter (without considering atmospheric dispersion)

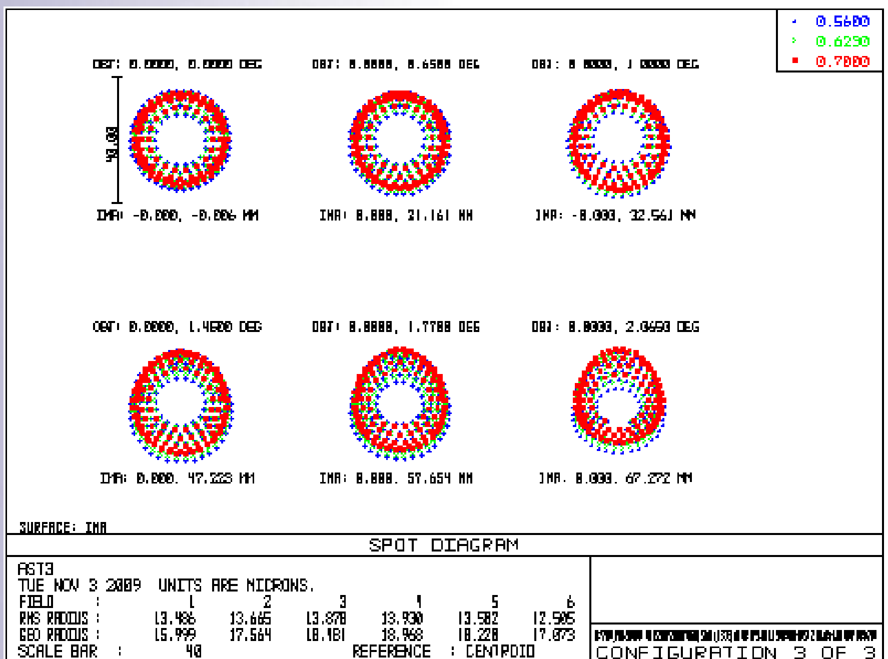
# Atmospheric dispersion calculation

Table1. image quality before and after ADC (80% energy diameter, unit： μm）

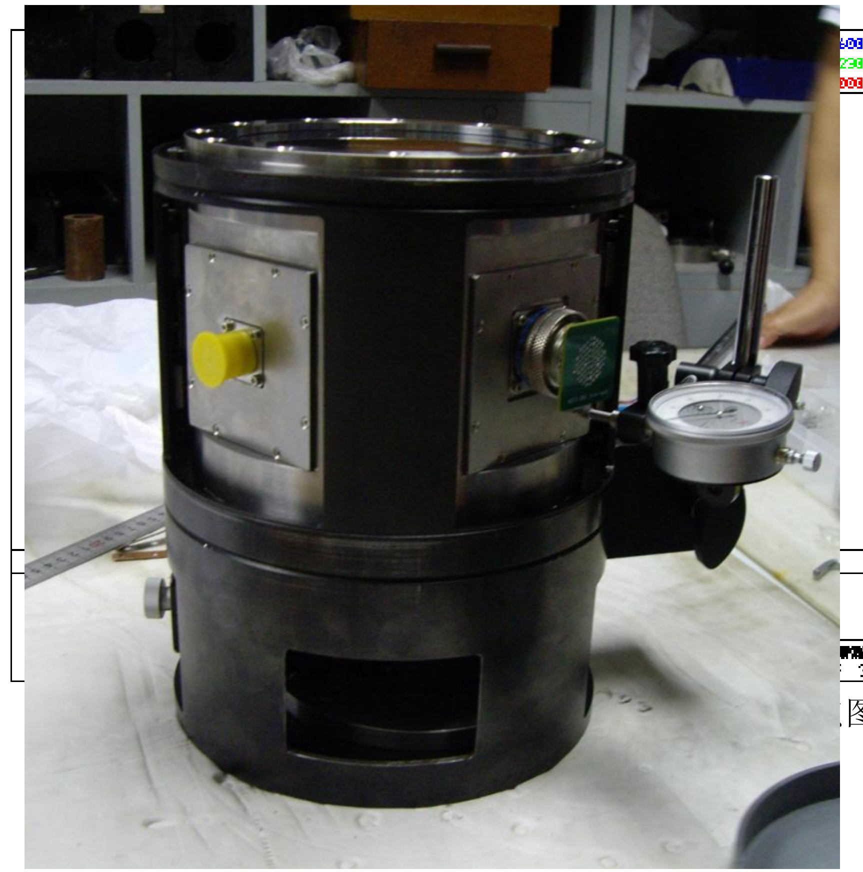
| | | filter G (0.4~0.55μm) | filter R (0.56~0.7μm) | filter I (0.685~0.84μm) |
|---|---|---|---|---|
| Z=50° | tilted 0° | 11.2 | 5.2 | 7.4 |
| | tilted 2.1° | 7.7 | 4.2 | 7.3 |
| Z=56° （lensm 1.17") | tilted 0° | 13.2 | 6.8 | 7.4 |
| | tilted 2.1° | 7.6 | 4.5 | 7.3 |
| Z=70° | tilted 0° | 22.4 | 9.2 | 8.6 |
| | tilted 2.1° | 12.6 | 6.3 | 7.6 |

the dispersion was clearly improved for 64% sky area above 20° from horizon。

Thermal analysis：from normal temp. to Dome A winter, 20° ~ -80 ° ， 1atm~0.57atm， clearly defocused without the focusing mechanism though the usage of low thermal expansion materials。

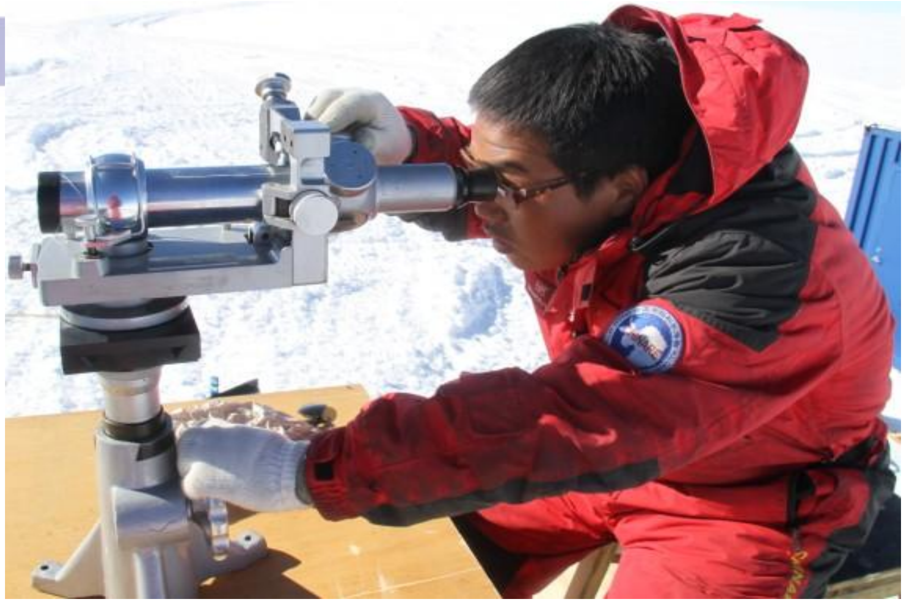


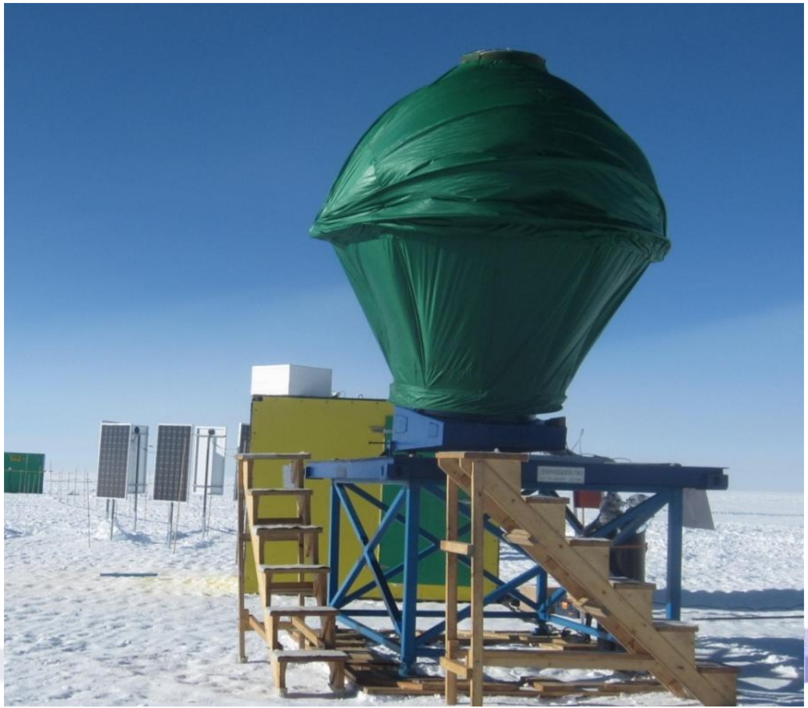

图(a) r 波段望远镜在-80 ° 和 0.57 atm相对夏季焦面位置不调焦时的像斑点图



**motorized stage：range：±4mm，accuracy:1μm**

# AST3-1 alignment on Dome A , Jan. 2012





## Status of AST3-1

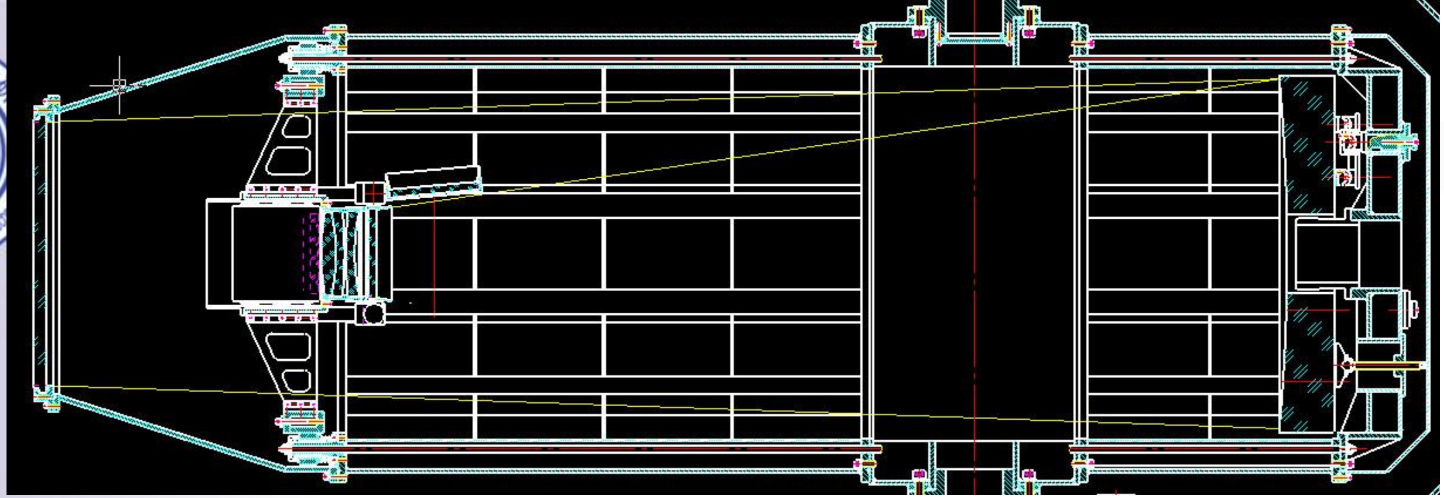
- Total observing time was 746 hours, only 3 nights lost due to reasons possibly related to bad weather.
- About 3.3TB images were collected. The photometry in I band is 19.5magnitude (3 sigma) in 1 minute exposure time with bright end precision~2mmag.
- Jan. 2012~2014, some problems also happened: single failure from Power supply system, CCD controller and the telescope DEC axis problems. In Jan 2015, the foldable dome was dismounted, based on the onsite performance (telescope still work!) and the too limited time to package it back, the telescope was kept there with replaced CCD and expected to work.

## Development of AST3-2

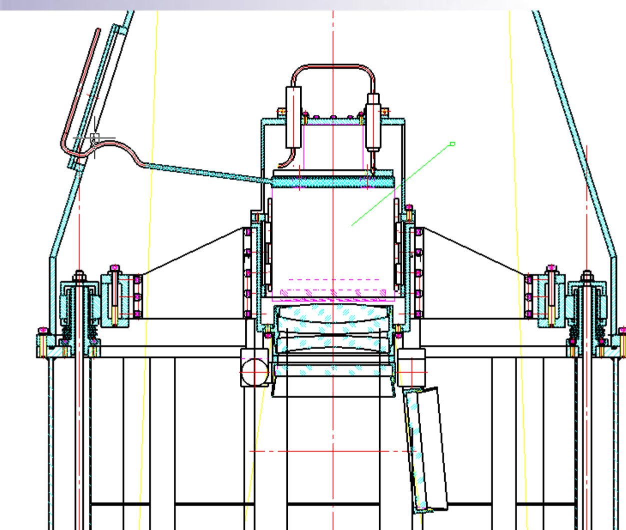
- 2011.11 review for the AST3-2
- 2012. 2~2013.2 contracts, manufacture and Assembly
- 2013.2~2013.4 Xinglong testing observation
- 2013. 5 winterization test
- 2013.11~2014.4 Mohe test
- Jan. 2015 deployed on Dome A

# improvements for AST3-2 (2011.11~2013)

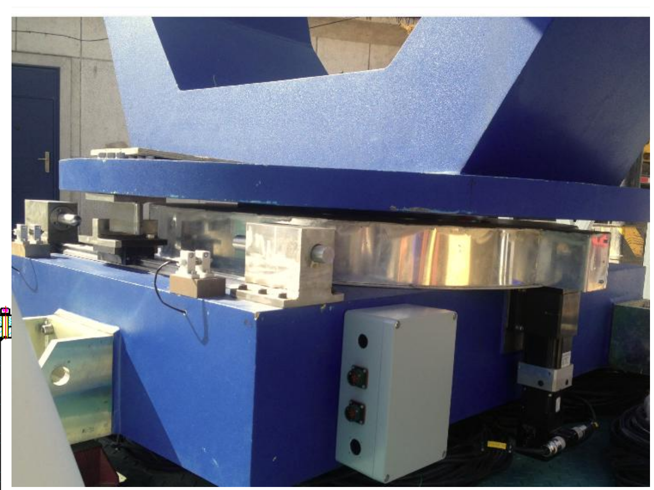
- two filters at the focal plane(r and g or white)；
- high resolution encoder for better tracking acurracy ；
- UMAC for the telescope control ( TCC backup; better realtime control)
- thermal dissipation of the in-between CCD (better tube seeing)
- better anti-vibration design for safe transportation
- some modifications for easier onsite assembly



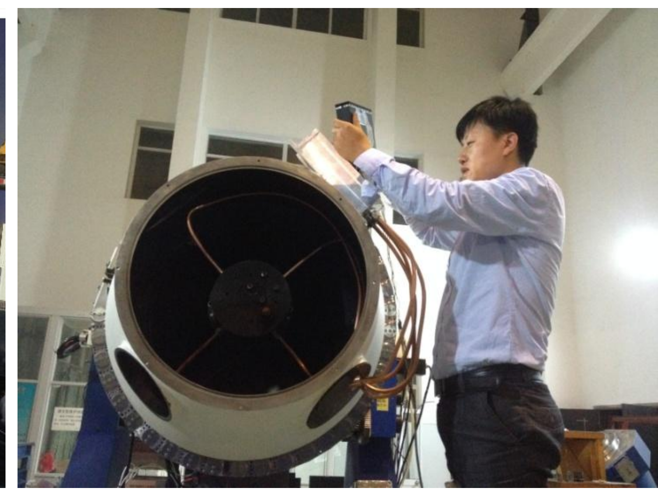
titanium alloy tube with INVAR rod to keep the distance between primary and focal plane (better for the tube sealing)



Switch mech. for two filter



proximity switch and mech.
(RA : -190° ~190° )



CCD heat pipe

# ➢Testing observations & winterization

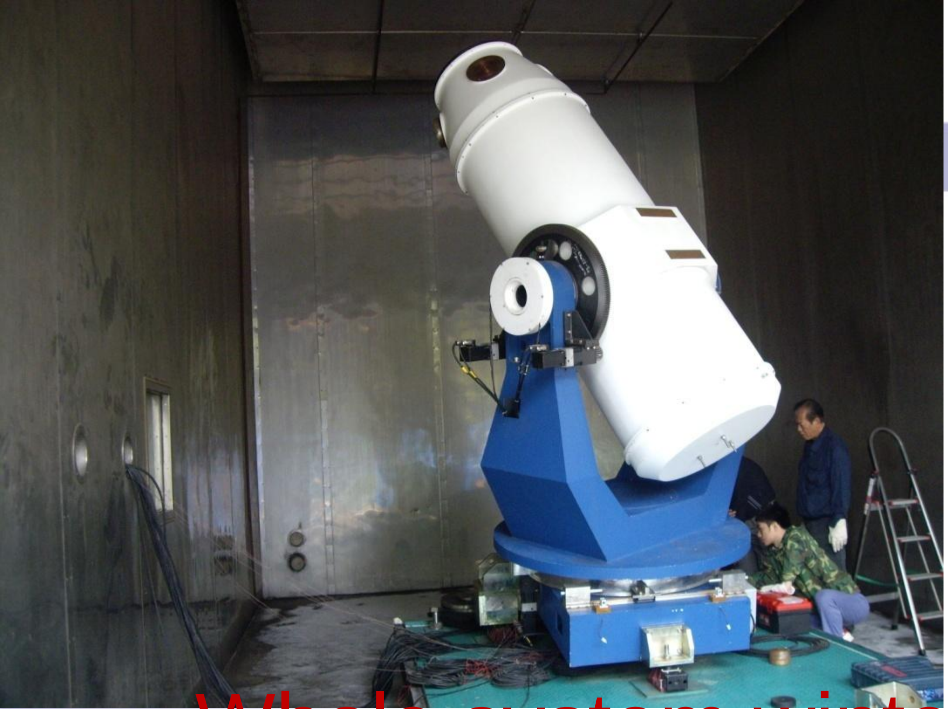
2013.2.28 ~ 4.14 Xinglong testing observation

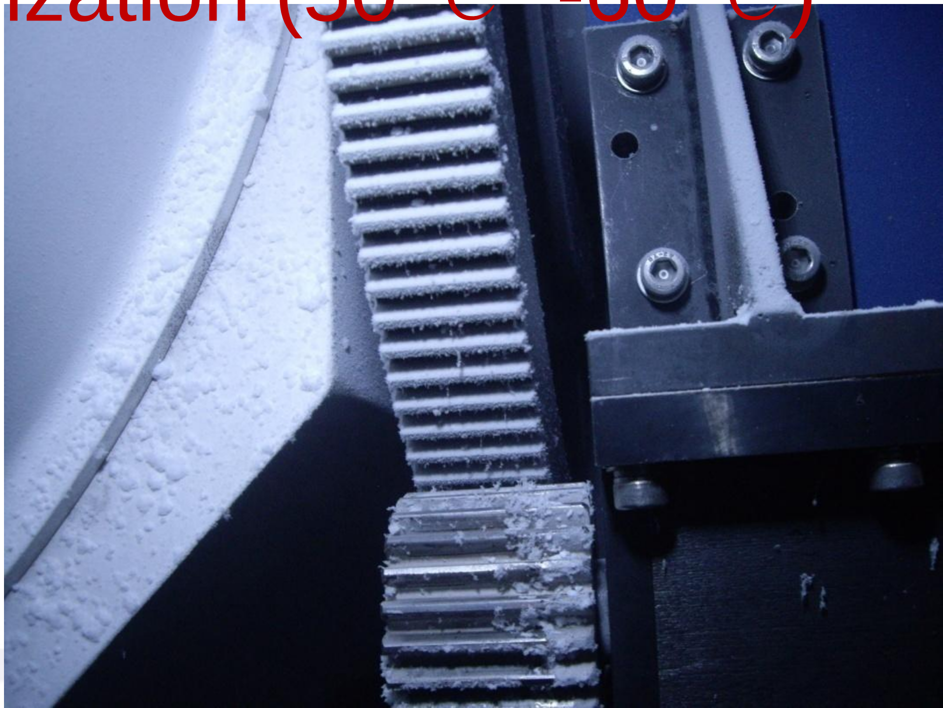
- ✓ Image quality: 2” ~4 ” (seeing)
- ✓ Pointing : < 30 ”
- ✓ Tracking: DEC rms ~0.8 ”;
  RA rms ~0.5 ”;
- ✓ Pointing to tracking time: ~15s

X occasionally oscillation on DEC axis.;

X CCD’s cooling work unproperly

# Whole system winterization (50 ℃~-60 ℃)





# Whole system winterization (50 ℃~-60 ℃)

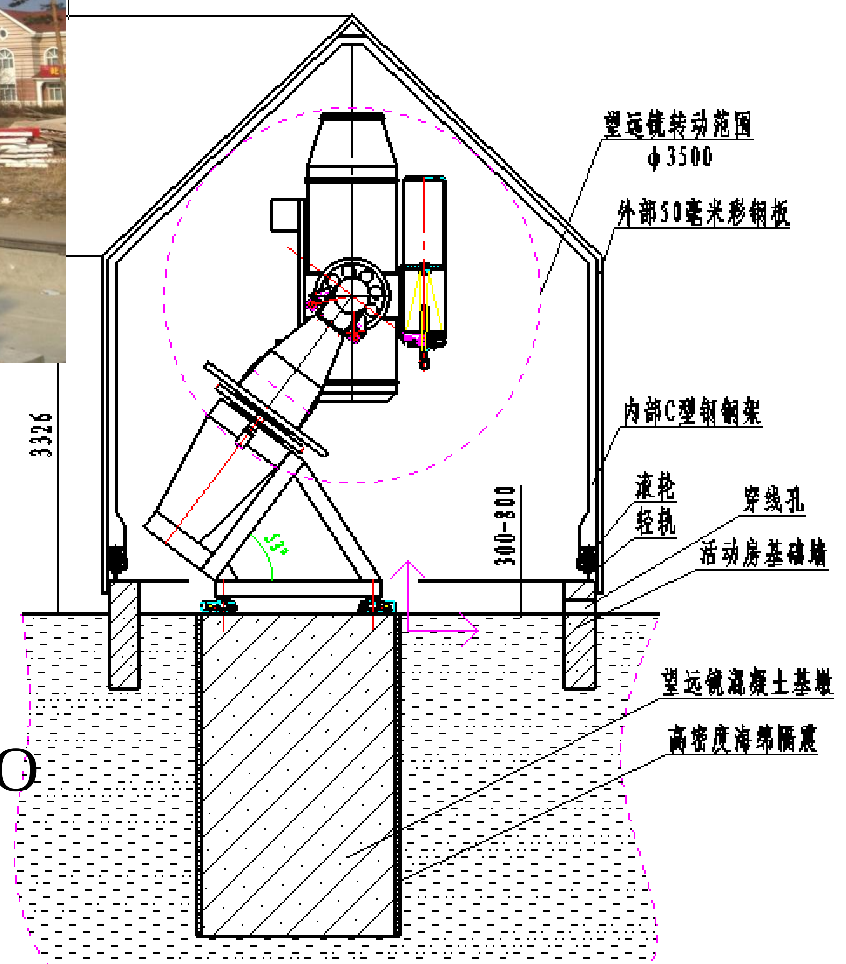
- Testing duration:  total 124hours for both Alt-Az. Mounting & equatorial mount as in Dome A;
- Tracking accuracy is near that  at normal temperature;
- pointing & tracking can work properly with frost;
- Energy consumption increase but within the budgedt.

Control room

（simulate the instrument module in Dome A，0° ~-15℃）

movable telescope house

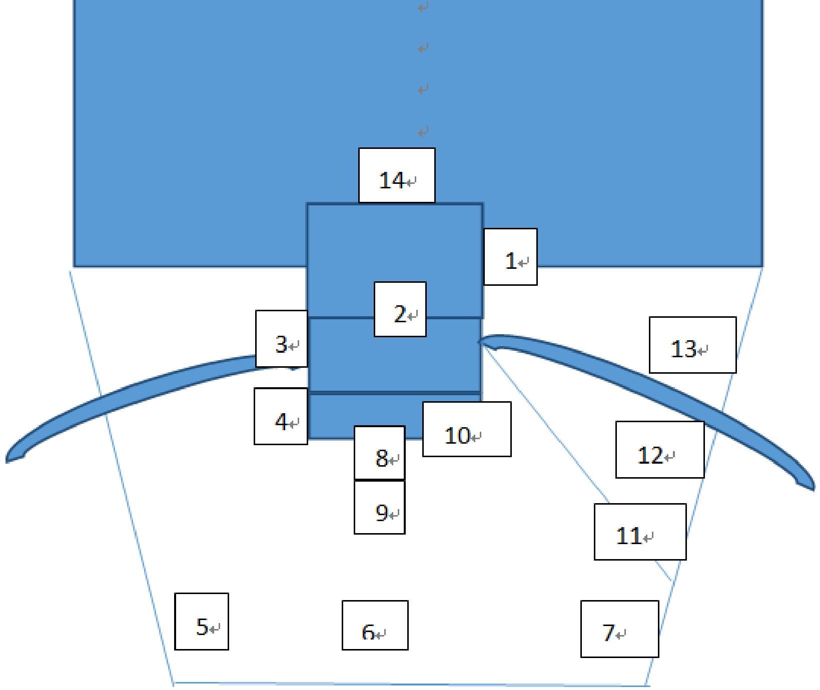
（simulate the ambient enviorenment in Dome A，~ -45° ）




# —Mohe winterization observation (in Arctic village)

（2013.11~2014.4）

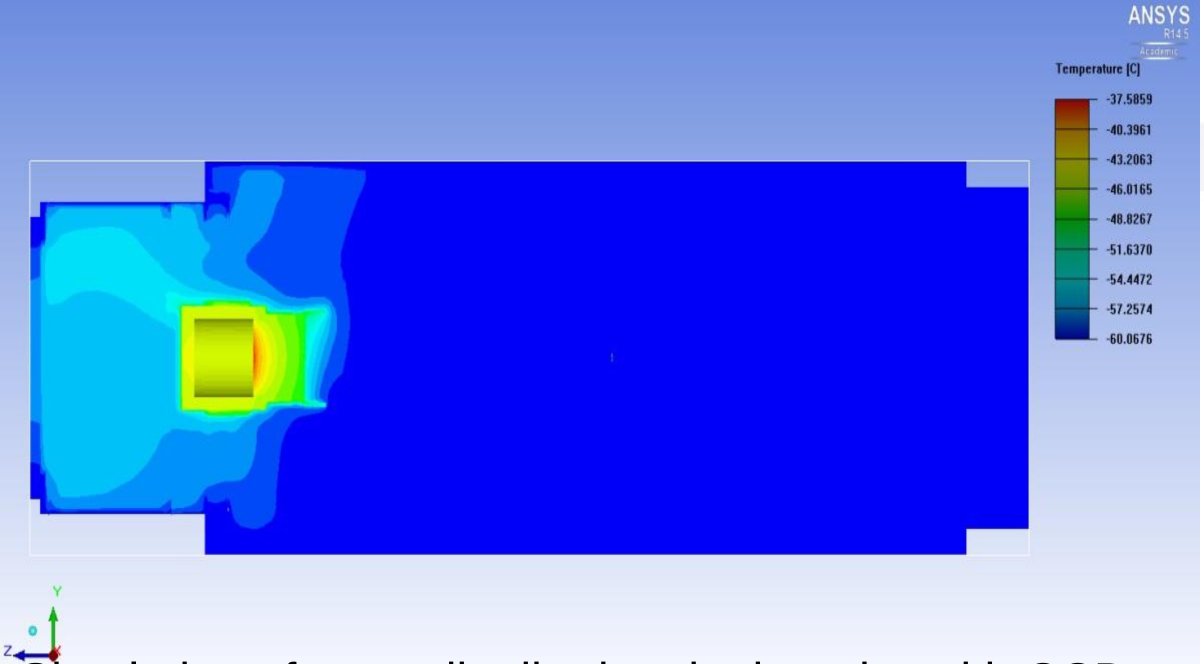
Jiont work by： NIAOT；NAOC；PMO




Maybe underestimeated!

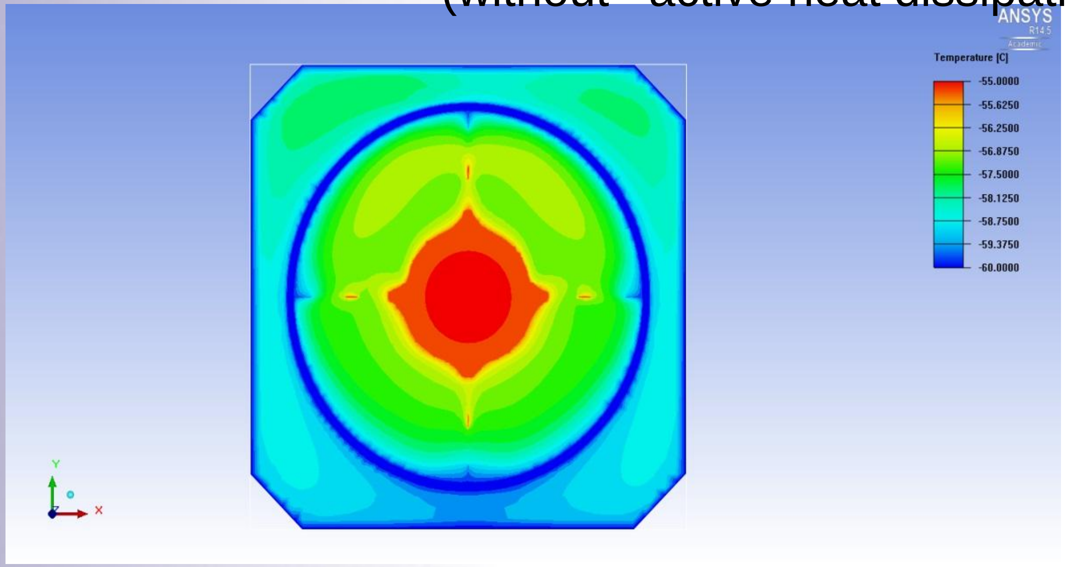
Need to be checked by simulation.

| | CCD | CCD TEC | OUTSIDE TEC | Air Extractor | CCD side temp. (℃) | Heat transfer plate (℃) | Ambient temp. (℃) | Image Spot Deteriorate RMS diameter (μm) |
|---|---|---|---|---|---|---|---|---|
| Case 1 | on | on | off | off | -12.5 | 1.2 | -21.2 | 22 |
| Case 2 | on | on | on | on | -21.8 | -16.2 | -25.8 | 7.2 |
| Case 3 | on | on | off | on | -20.3 | -13.6 | -24.1 | 10.5 |
| case4 | on | on | on | on | -27.4 | -21.3 | -28.5 | 6 |
| case5 | on | on | on | off | -17.3 | 7.3 | -24.8 | 18.5 |

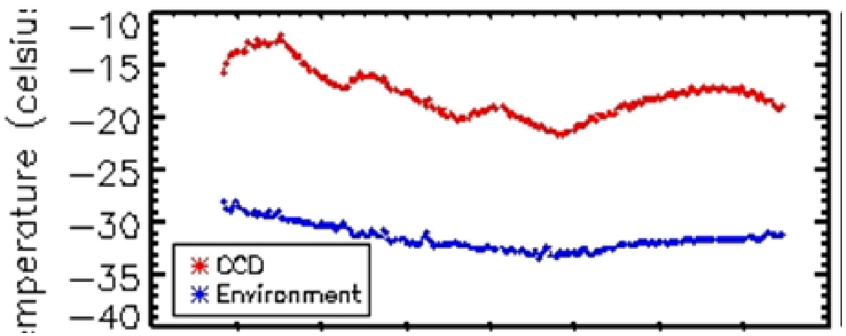



• 30W CCD can make the max. temp. of the CCD box increase ~20°C (consistent with tested values)

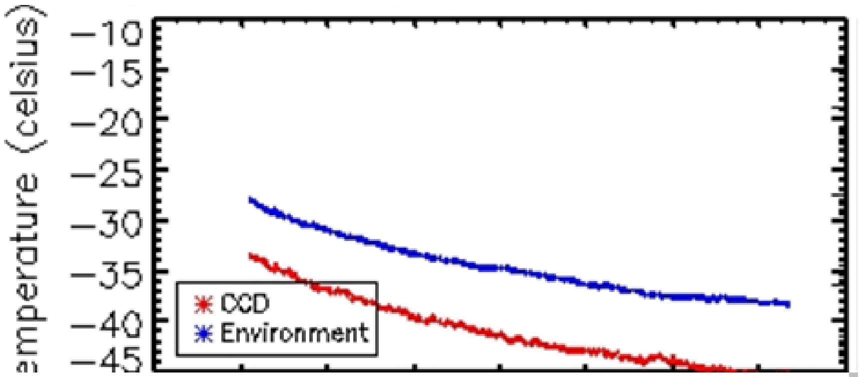
Simulation of temp.distribution in the tube with CCD and TEC on (without active heat dissipation)




• In the cross-section, the temp. diffirence is ~4 °C




被动导热效果



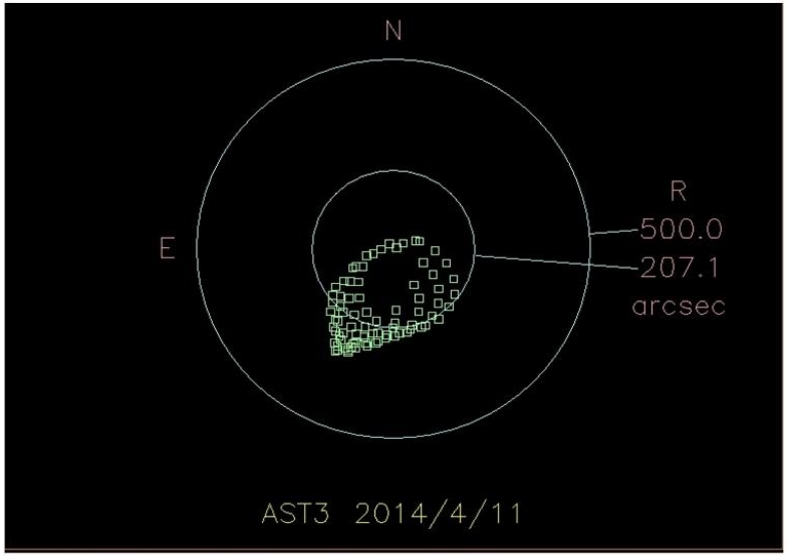

主动导热效果

CCD active heat removal： better tube seeing and better CCD dark current;

**But with increased light block and complicated FP!**

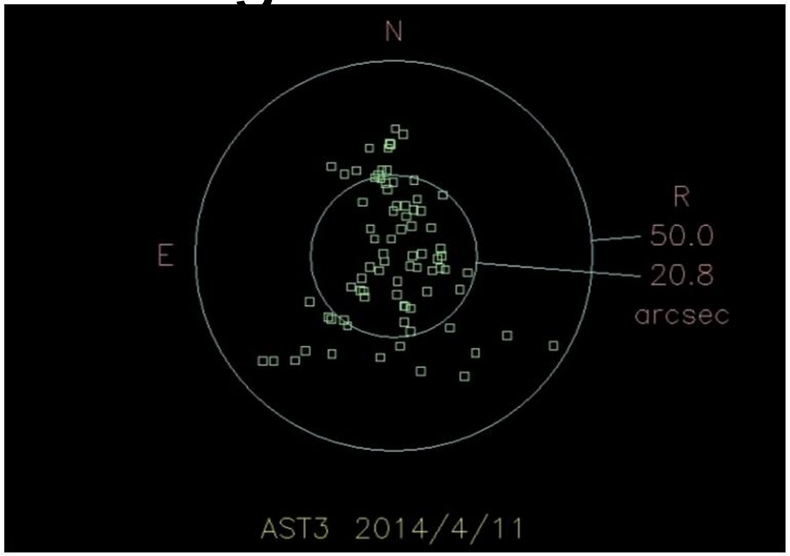
# ——pointing error of AST3-2

指向模型校正结果




$\Delta HA_{PV} = 1417.4''$ $\Delta HA_{rms} = 300.6''$

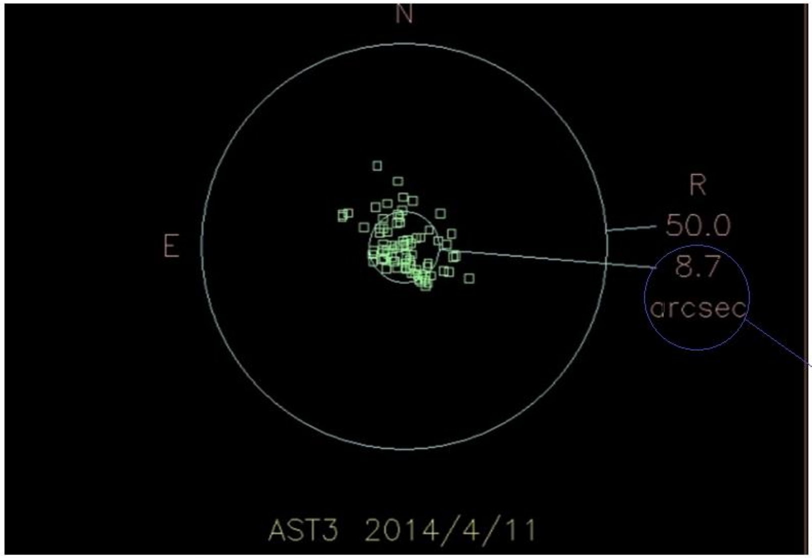
$\Delta DEC_{PV} = 293.9''$ $\Delta DEC_{rms} = 84.9''$




$\Delta HA_{PV} = 135''$ $\Delta HA_{rms} = 34.3''$

$\Delta DEC_{PV} = 103.7''$ $\Delta DEC_{rms} = 23.4''$

更高指向精度校正




镜筒弯沉误差项，无实测

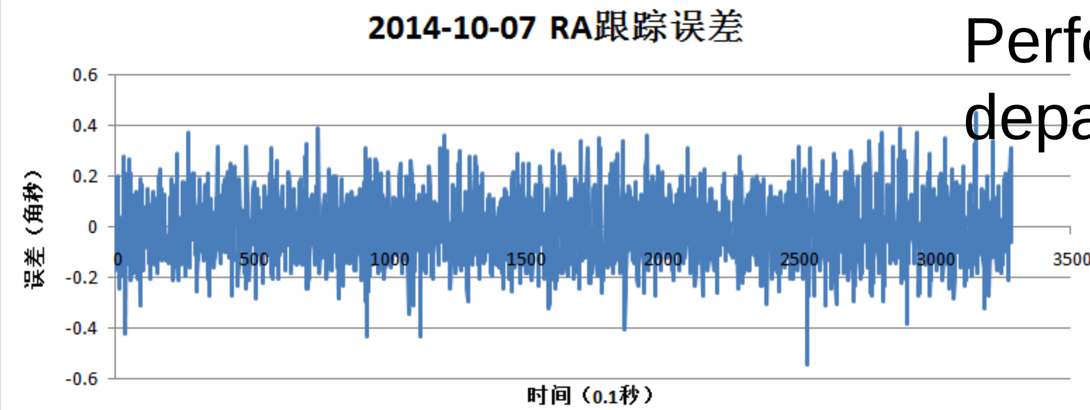
$$\begin{cases} Ha\_error_{TX} = TX\dfrac{\cos(\varphi)\sin(ha)}{\cos(D)[\sin(D)\sin(\varphi)+\cos(D)\cos(ha)\cos(\varphi)]} \\ Dec\_error_{TX} = TX\dfrac{[\cos(\varphi)\cos(ha)\sin(D)-\sin(\varphi)\cos(D)]}{\sin(D)\sin(\varphi)+\cos(D)\cos(ha)\cos(\varphi)} \end{cases}$$

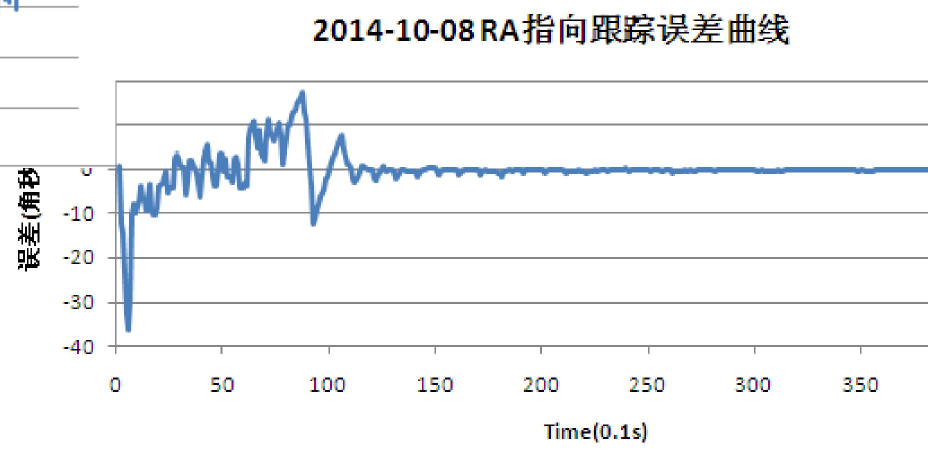
| 误差项 | IH | ID | CH | MA | ME | TX |
|---|---|---|---|---|---|---|
| 系数 | 218.82 | 88.07 | -74.69 | -24.72 | 156.15 | -46.6 |

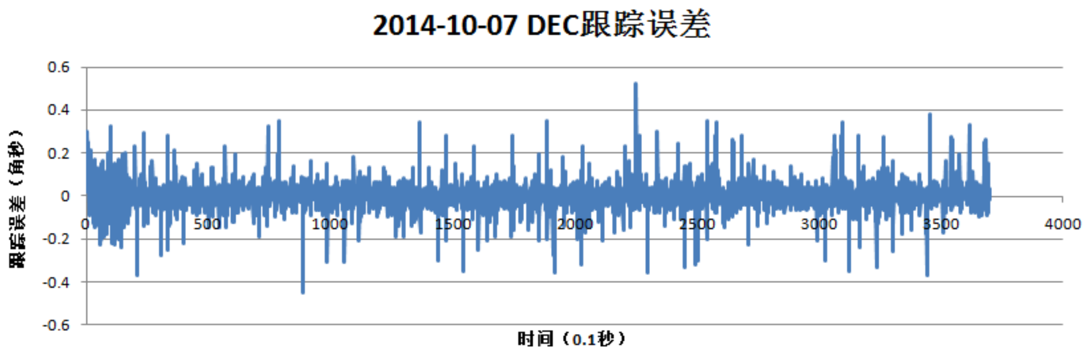
指向精度均方根小于9"

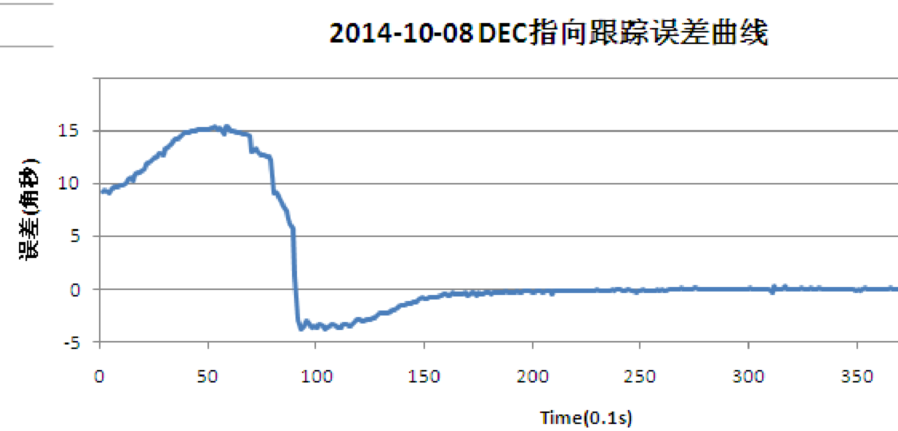
全天区密度更高采样，建立时角赤纬等自变量的函数可以实现指向精度小于2"

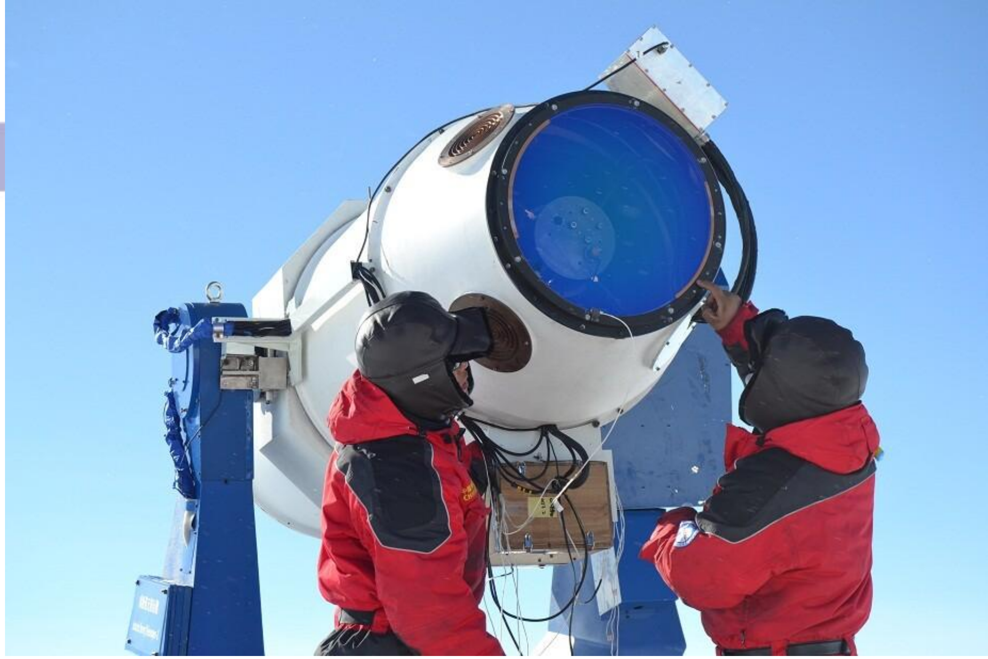
# Performance of AST3-2 before departure to DOME A



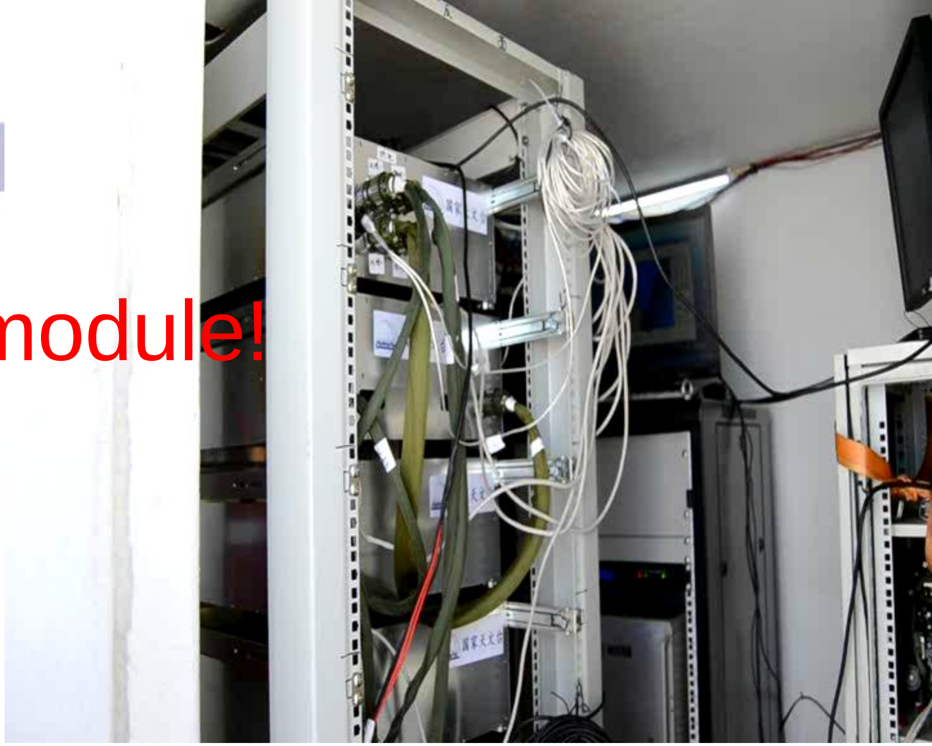



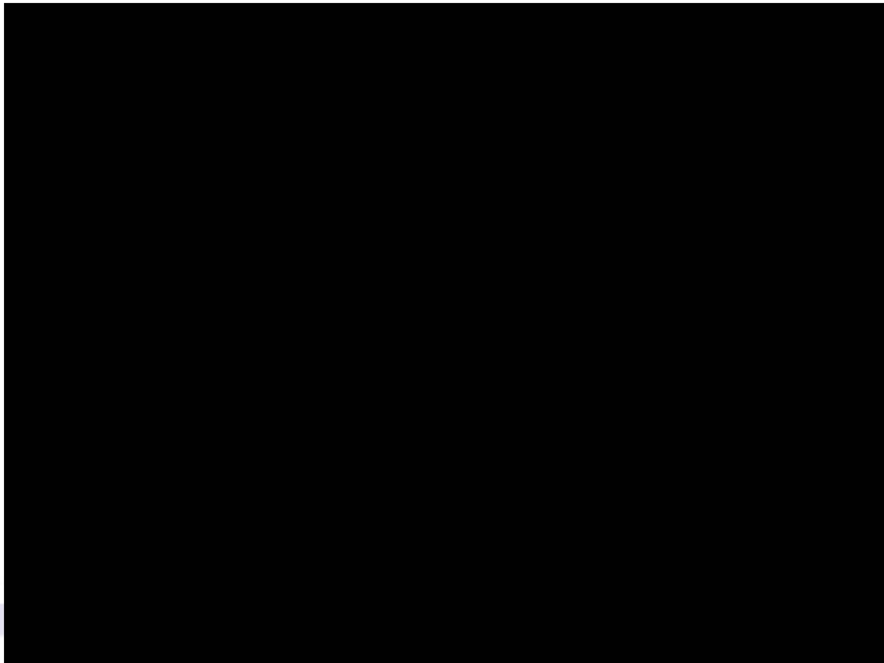
AST3-2  mounted on Dome A in Jan. 2015

Fujia Du & Zhengyang Li

Very crowed instrument module!



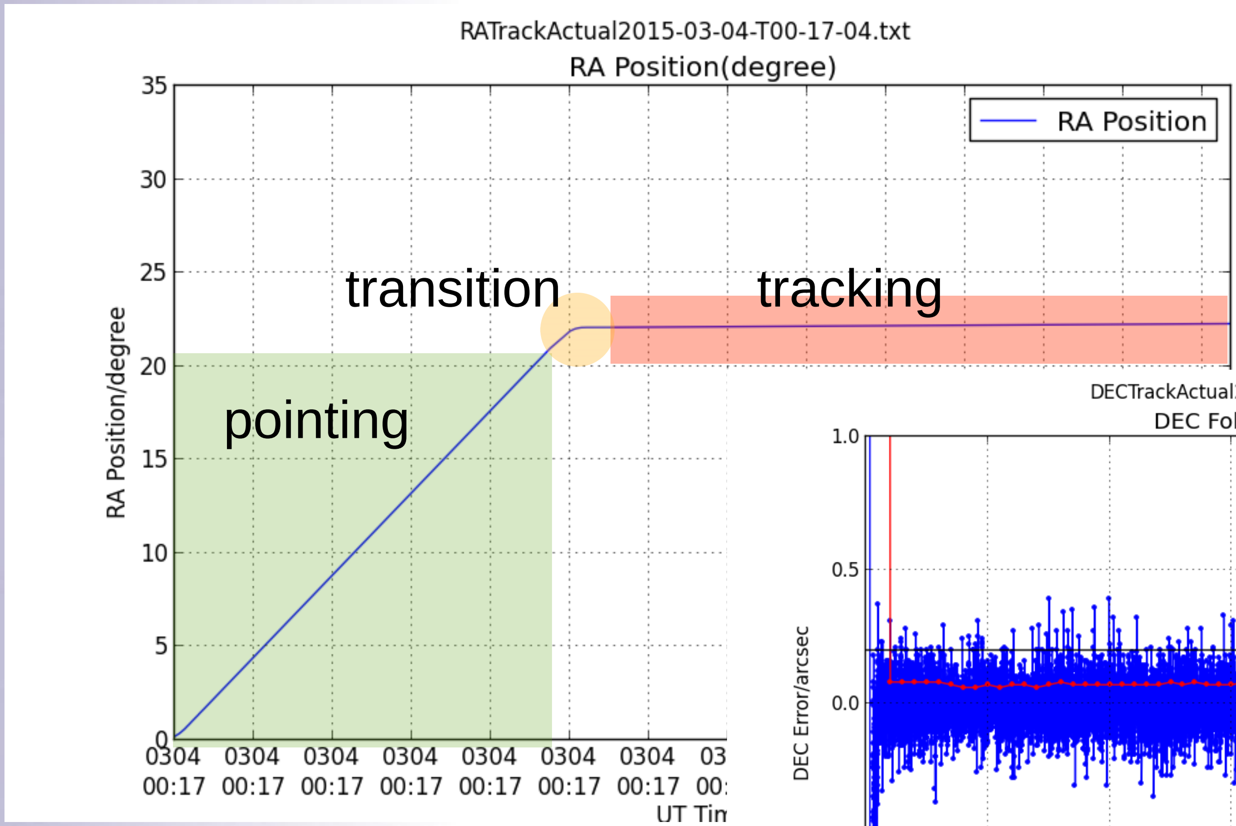
Very busy two guys!

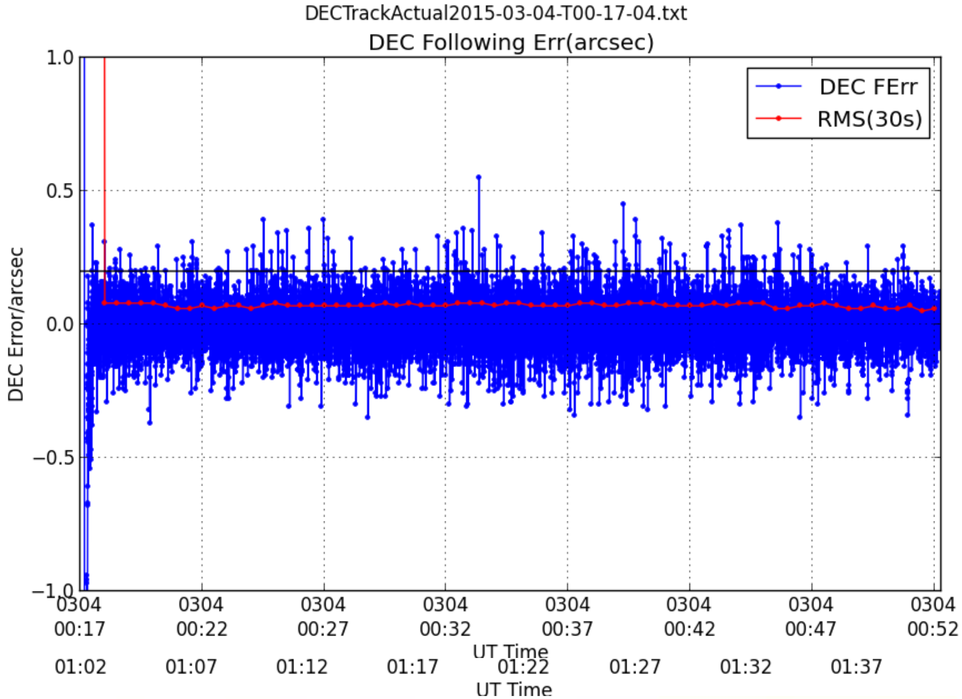


# status of ast3-2

## Pointing and Tracking

From Jan.23 2015 to today
(-35℃ ~ −60 ℃)




PV: 1 arcsec
RMS: < 0.2 arcsec

# Some lessons learned for AST3-1 & AST3-2

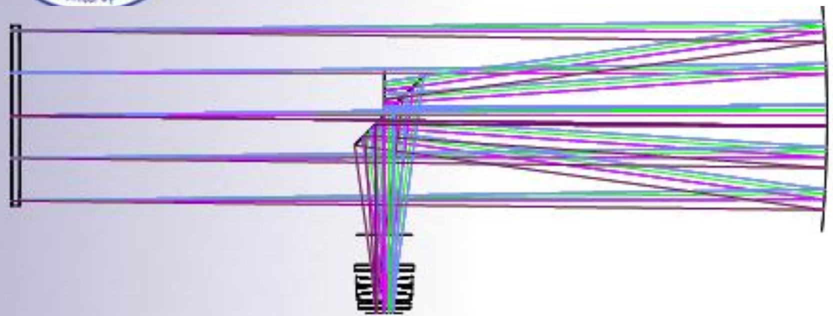
- Anti-vibration/safe transportation is very important
- Redundancy design is very important
- Back-up TCC is always needed
- Shorten the  drive chain is better for the telescope control
- Foldable moving enclosure is a potential risk for  tele control
- Auto-monitoring (all kinds of records: ) is very important

# ➢ Design of AST3-3 (NIR) 2016/2017

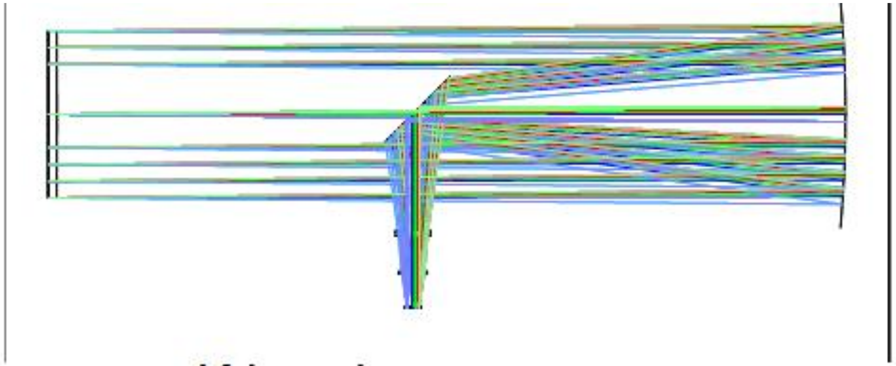
The Antarctic plateau is the best site on Earth for infrared and submillimetre astronomical observations.

Ashley, Michael C. B., Burton, Michael G.et al, PASP 108, 721–723(1996)b

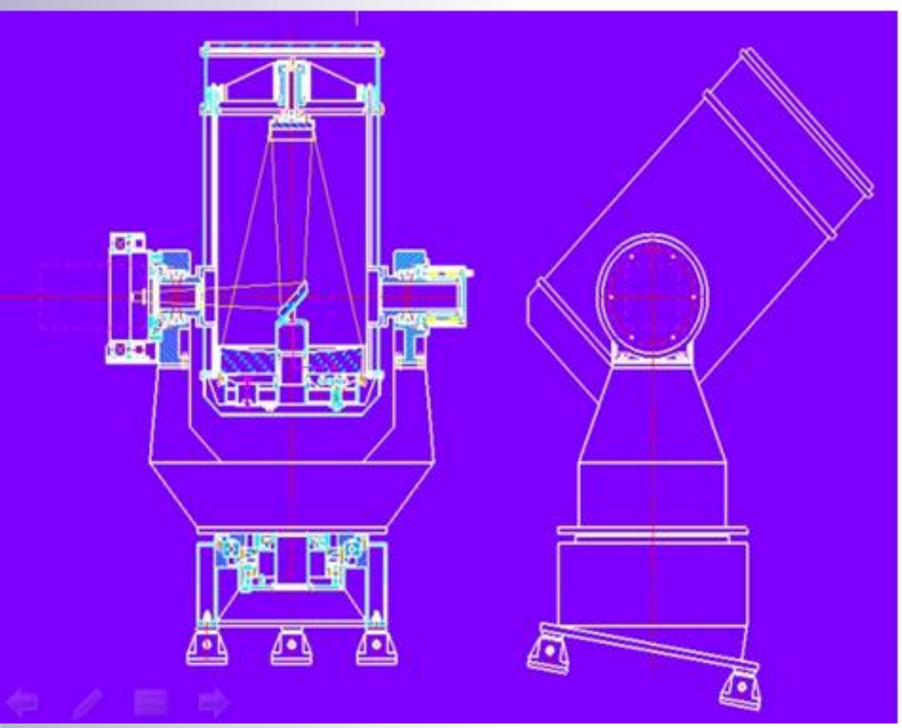
- The AST3-3 will have the same performance with AST3-1 and 2 in optical band. But can also be a test bench for the Dome A NIR observation.
- By new correctors and adding a fold mirror to move the focus out the tube based on the original AST3.
- Or design a new simple R-C system with compact size. There's a trade study about the optical system according to the time , budget and science.



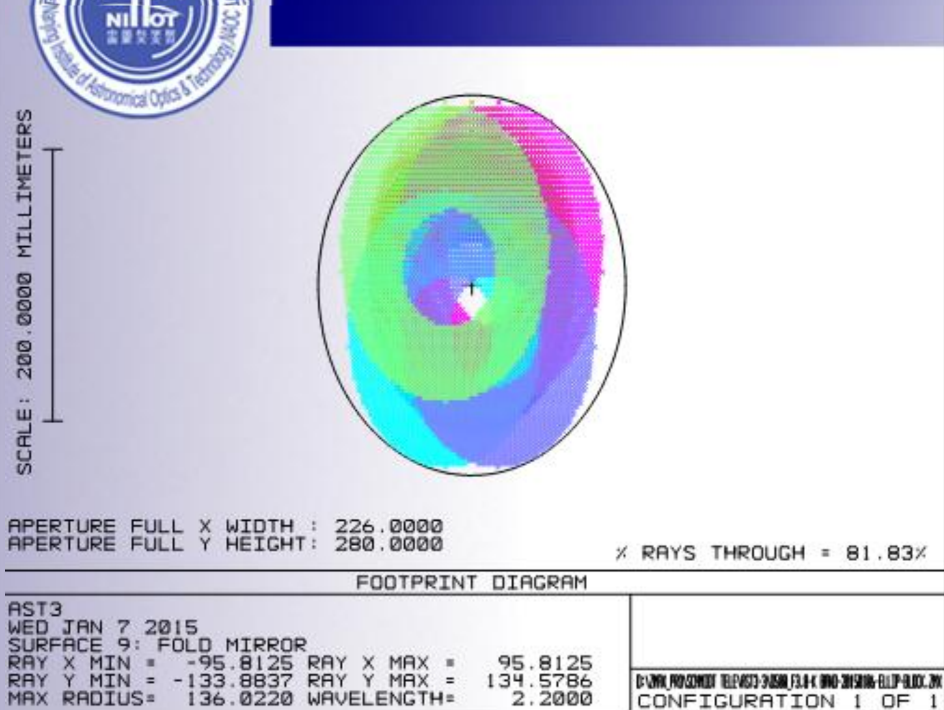
- optical band



- K band
- Focal length=1911mm
- f/3.82
- 1.94“/18μm，2k x 2k
- lens in dewar

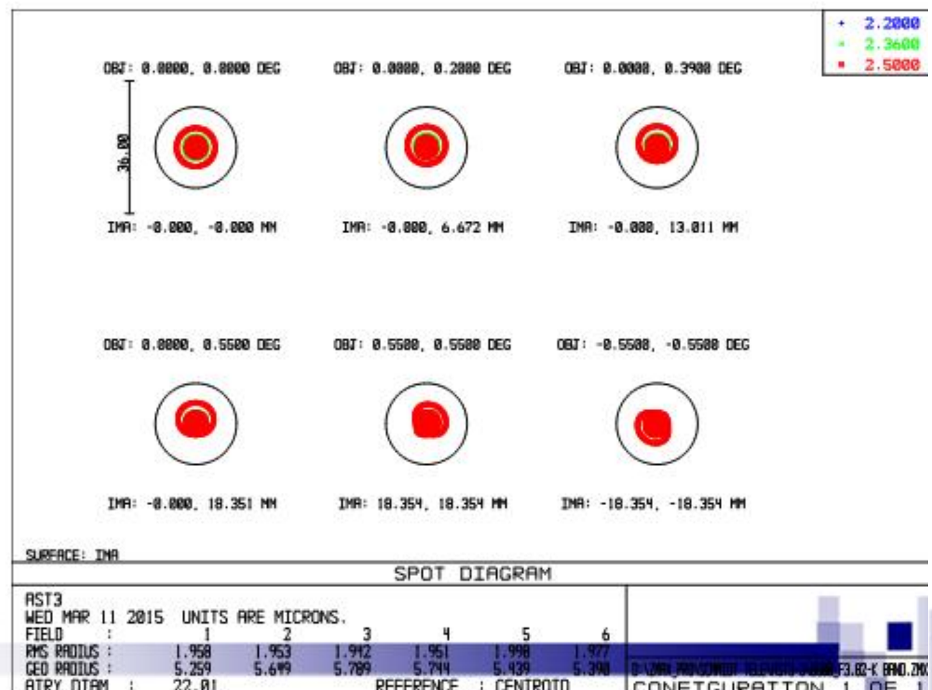


- ALT-AZ mount at temperate site and Equatorial mounte at Dome A.

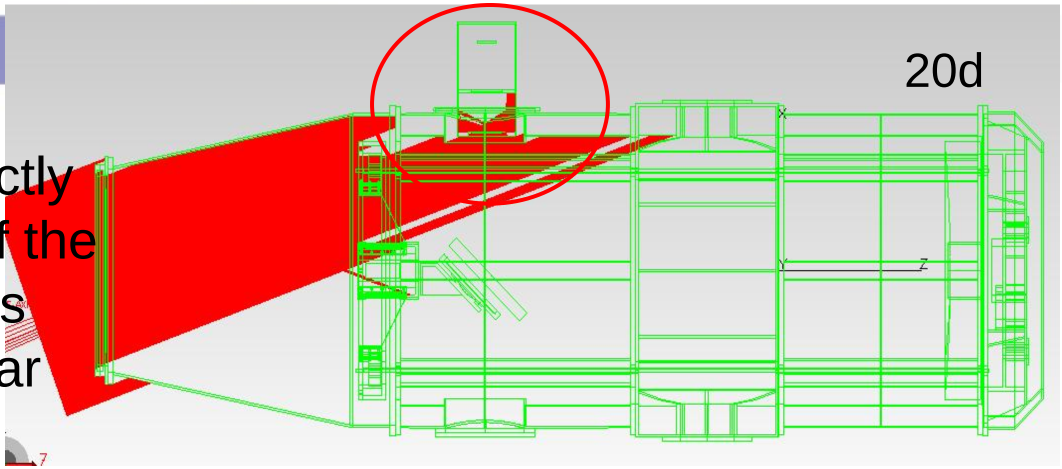



Footprint on FM

Image spots in K Band



- The out-FOV source can directly illuminate the inside surface of the rear tube or dewar, new baffles needed (according to the dewar design and the observation strategy)

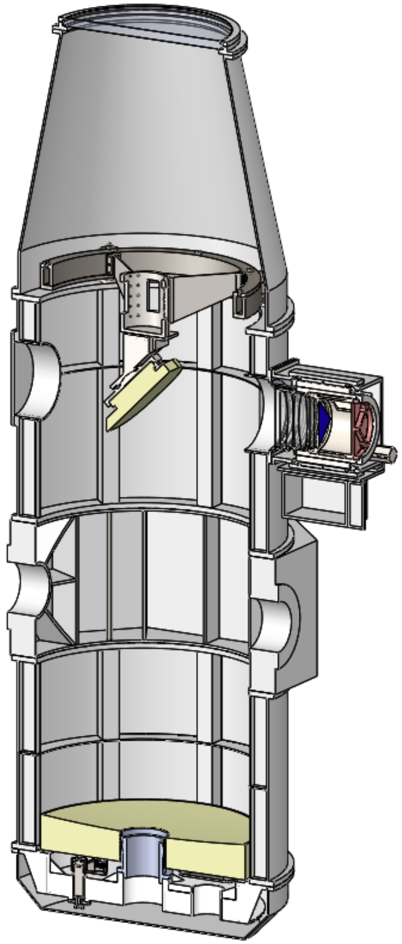


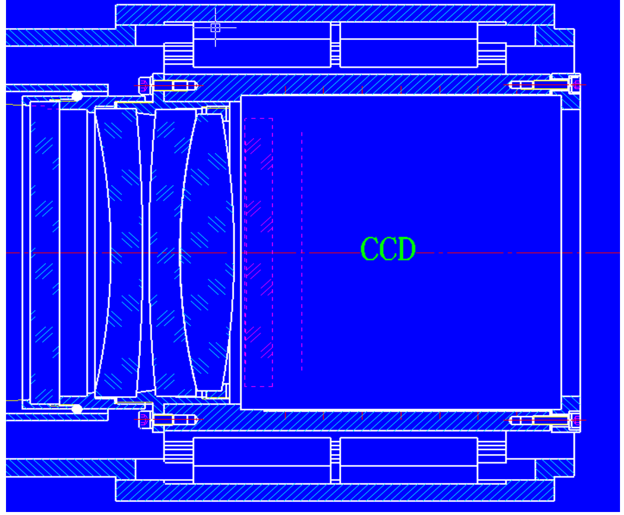

- thermal emission of the telescope on the imaging plane simulated as about 1.2e-8w/m^2。 it is about the backgroud in K band . (with dewar -100℃ and window -57 ℃, tube -60 ℃)

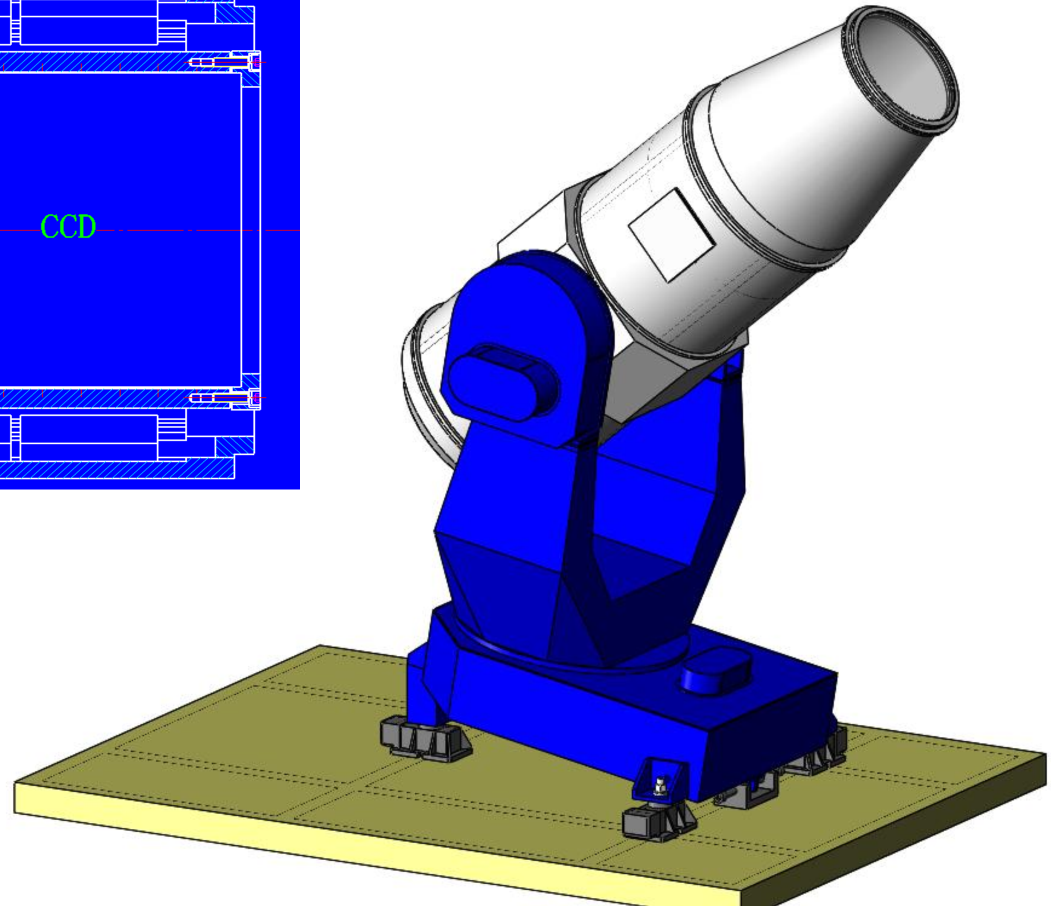
| Surfaces | Emissivity |
|---|---|
| window | 0.138 |
| Anti Reflect | 0.02 |
| mirrors | 0.03 |
| Nextel | 0.95 |

- lower temperature will be need for better performance and thermal emission suppression design

More details see the next Haiping Lu's talk!





## Compared with AST3-1 and AST3-2

- Better designed gear box, without enclosure;
- Easier CCD assembly and maintainace;
- Easier CCD heat removal ;
- Reliable focusing mechnism.

# Thank you !