

# Data Release of the AST3-2 Automatic Survey from Dome A, Antarctica

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2023.04.20

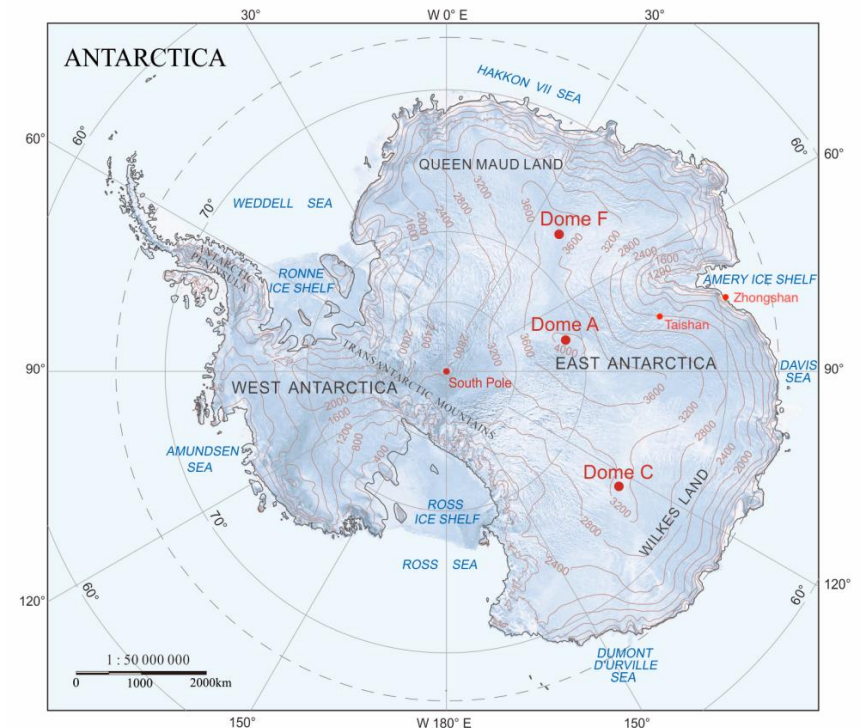
# Outline

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1. Introduction
2. Instrument
3. Observation
4. Data Process
5. Stellar Variability
6. Conclusion

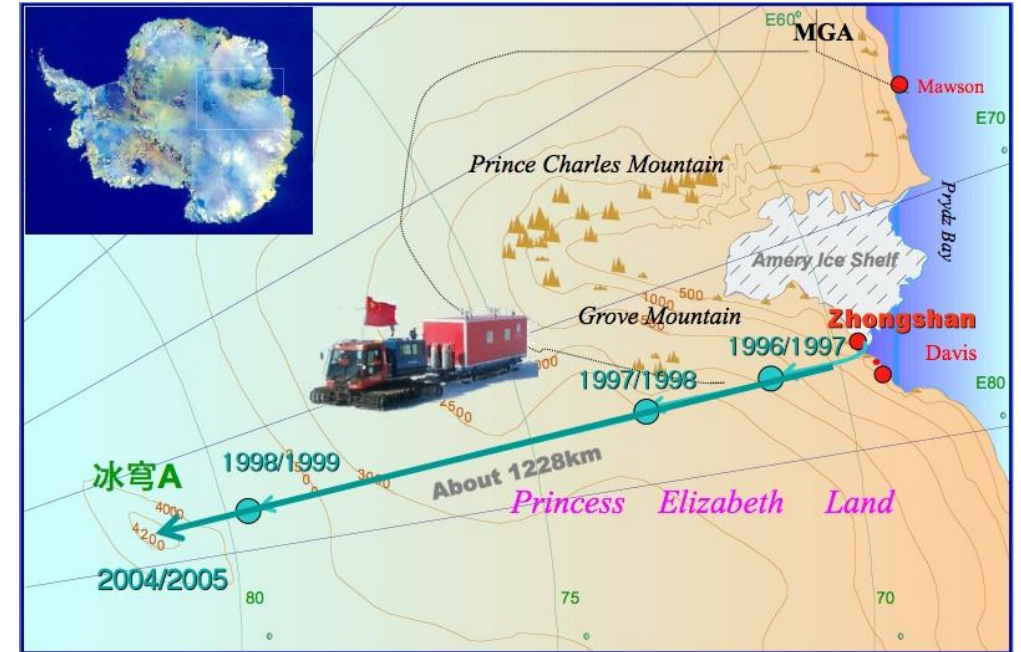
# Introduction

- Astronomy in Antarctica
  - An exceptional place for ground-based astronomical observations
  - Domes on Antarctic Plateau
- Advantages of doing Astronomy
  - Clean air – low scattering
  - Stable atmosphere – good seeing
  - Away from artificial light – dark
  - Long polar night – 24h observation
  - Extremely cold – low IR background
  - Extremely dry – THz window



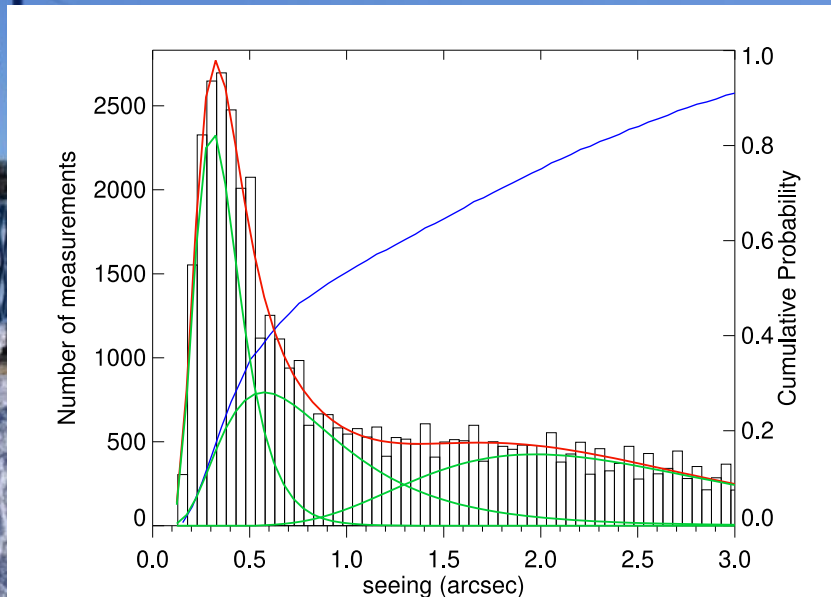
# Introduction

- Dome A, Antarctica
  - The highest dome in Antarctic plateau
    - Altitude: 4093m
    - Latitude:  $>80^\circ$
    - 1200 km from Zhongshan station
  - First arrival by CHINARE in 2005
    - First visit by astronomer in 2008
    - KunLun Station was constructed in 2009

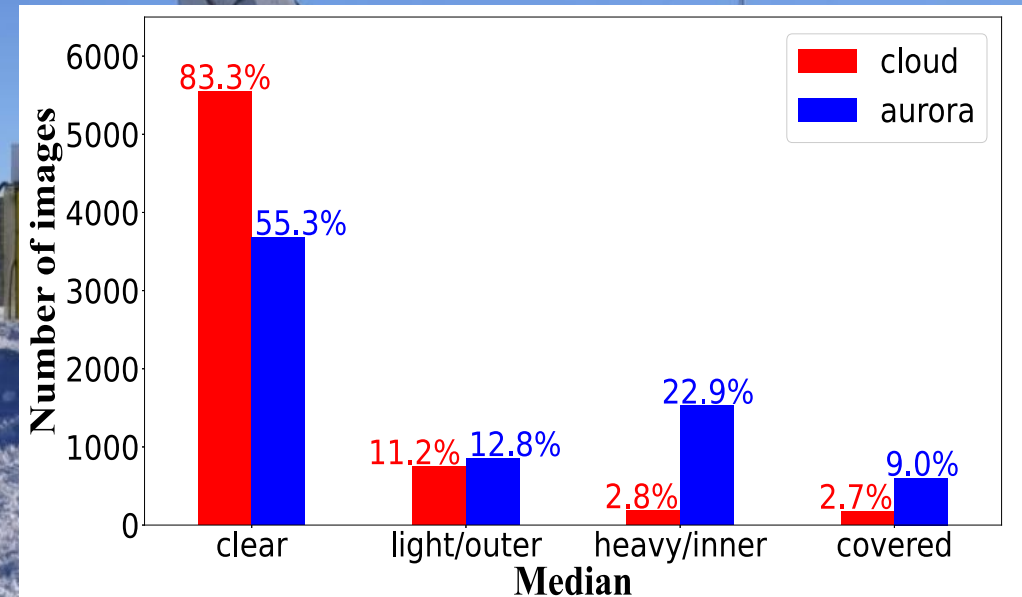


# Introduction

- Dome A, Antarctica
- The best optical observing condition on the ground (Shang 2020):
- Median free-atmosphere (FA) seeing: **0.31"** (Ma et al. 2020);
- Night-time clear rate **83%** (Yang et al. 2021)



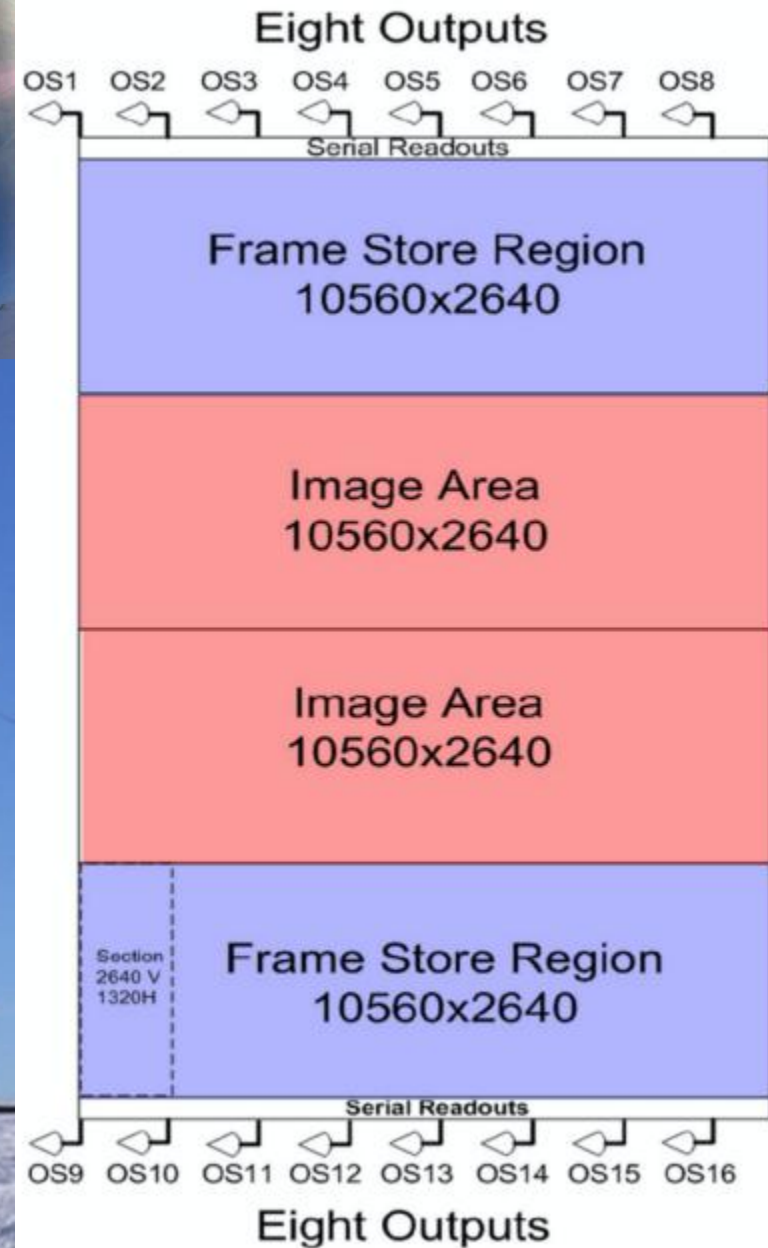
Ma et al. 2020



Yang et al. 2021

# Instrument

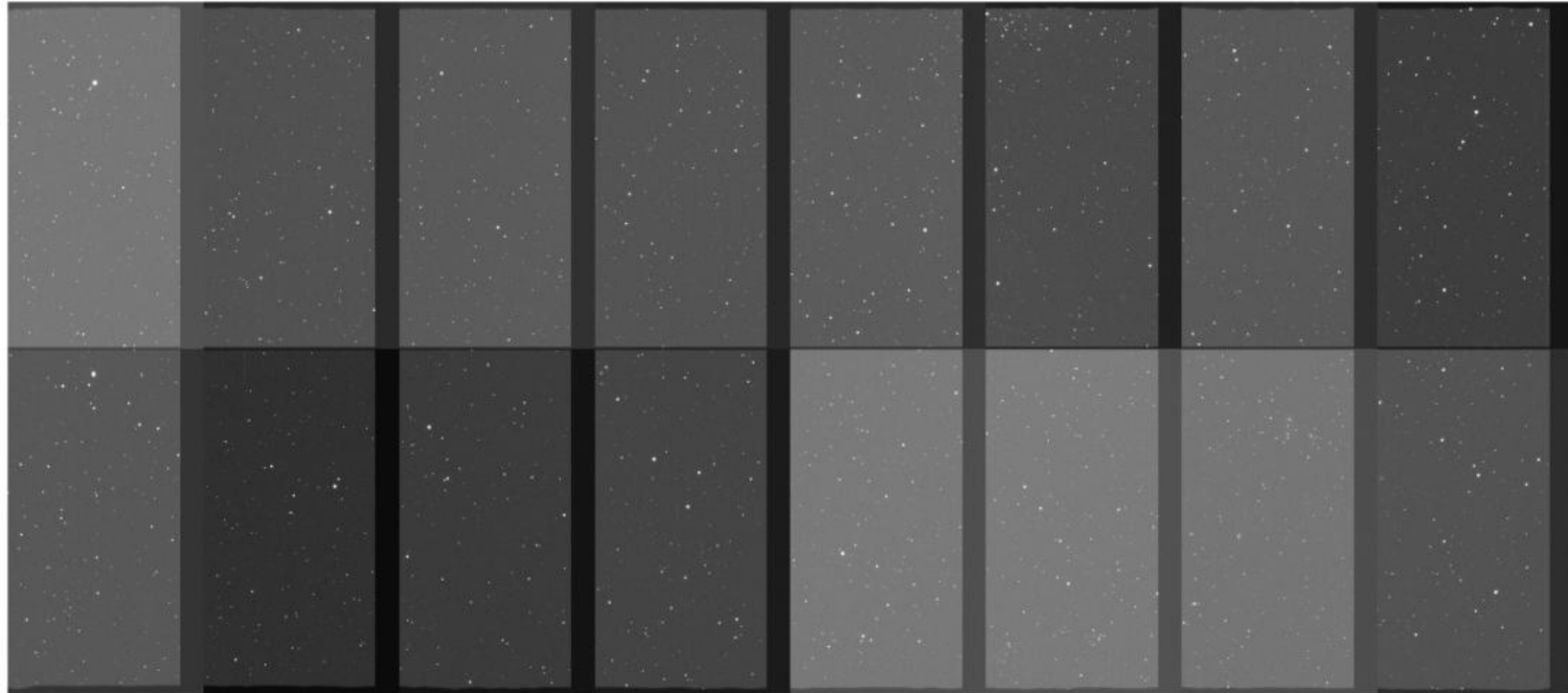
- AST3-2
  - Installed by 31<sup>st</sup> CHINARE
  - 50/68 cm
  - f/3.73
  - Sloan *i*-filter
- CCD:
  - 10k × 10k STA CCD,
  - Frame-transfer mode
  - 4.3 square degrees FOV
  - 1"/pixel



# Instrument

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- CCD:
  - 16 readout channel



# Instrument

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- Troubles in Dome A
  - Harsh environment – frosting and icing
  - Limited power and network – PLATO-A
  - Real unattended – CODS system
- Control, Operation, and Data (CODS) system
  - Hardware and software
  - Unattended, fully automated survey
  - Real-time data processing



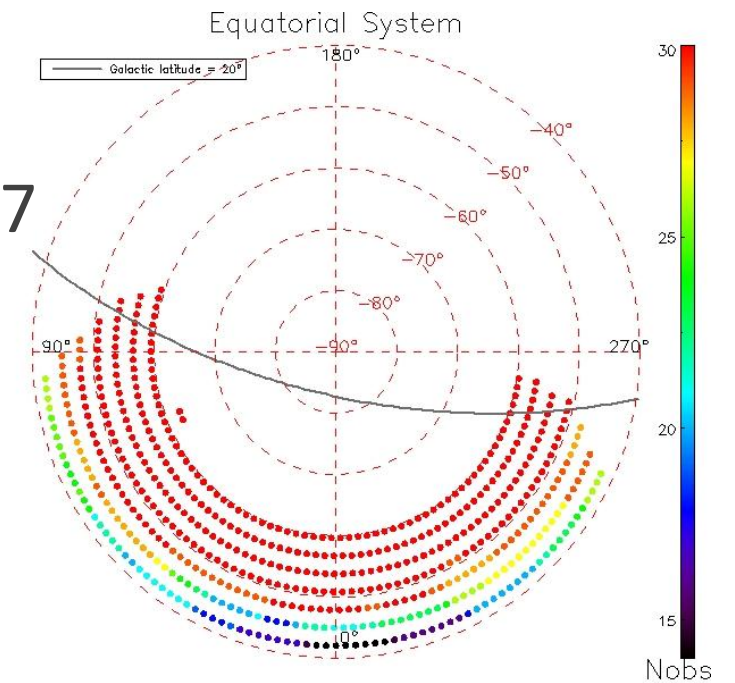
# Observation

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- Observation mode:
  - SN survey:
    - Real-time pipeline
    - SN 2016ccp, SN 2017fbq
    - SN 2014J, SN 2014M (Mohe)
  - Exoplanet observation
    - Zhang et al. (2019a,b), Liang et al. (2020), ...
  - Follow-up:
    - GW170817

# Observation

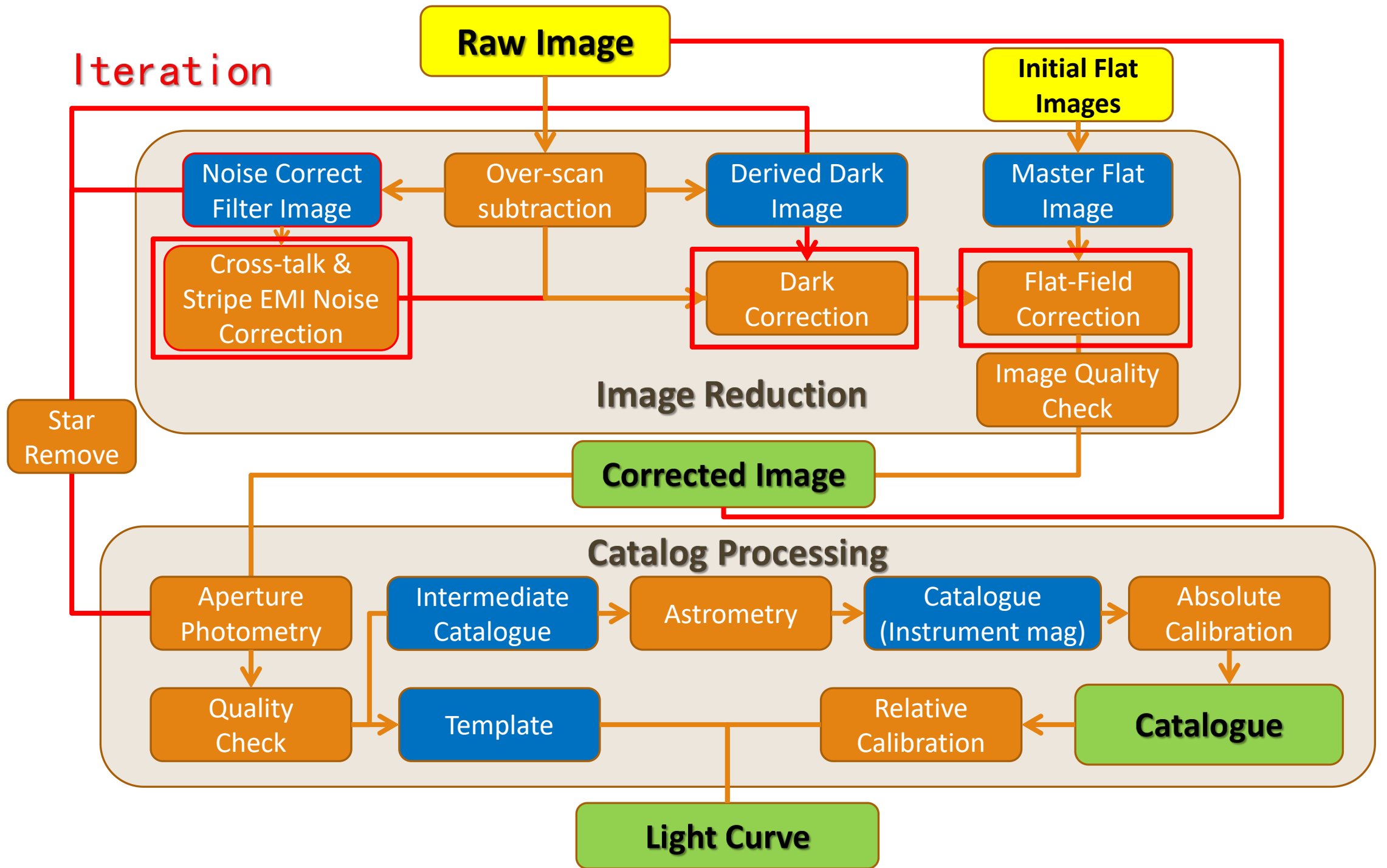
- SN Survey mode
  - Started after twilight (Mar. 23 2016)
  - Switched to exoplanet observation after May 17
  - 2200 square degree
  - 539 fields x 30 obs. (less for low Dec fields)
  - 2.6 TB, 22576 images
- The 2016 data was retrieved by the 33<sup>rd</sup> CHINARE



# Data Process

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- Data Process Pipeline
  - Preprocess
    - Derive dark image from science images
    - Flat-field gradient correction
    - Cross-talk effect
    - Special electromagnetic interference noise
  - Photometry
  - Astrometry
  - Flux Calibration



# Data Process - Preprocessing

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- Special Dark Correction

- CCD Heat dissipation problem
- Could work at temperature as high as -50°C to -40°C
- Dark current cannot ignore

- Dark current:

- At -50°C: dark ~ 2 ADU/sec/pix
- Changing pattern – different from Lab
- Derived dark from science image
- Select 2 images at different background but same temperature
- Get dark image at temperature T

$$I(x, y) = S + D(T) + \Delta d(T, x, y)$$

$$\begin{aligned} I_1(x, y) &= I_{0,1} + \Delta d(T, x, y) \\ I_2(x, y) &= I_{0,2} + \Delta d(T, x, y) \end{aligned} \quad k \equiv I_{0,2}/I_{0,1}$$

$$I'_1(x, y) = kI_1(x, y) = I_{0,2} + k\Delta d(T, x, y)$$

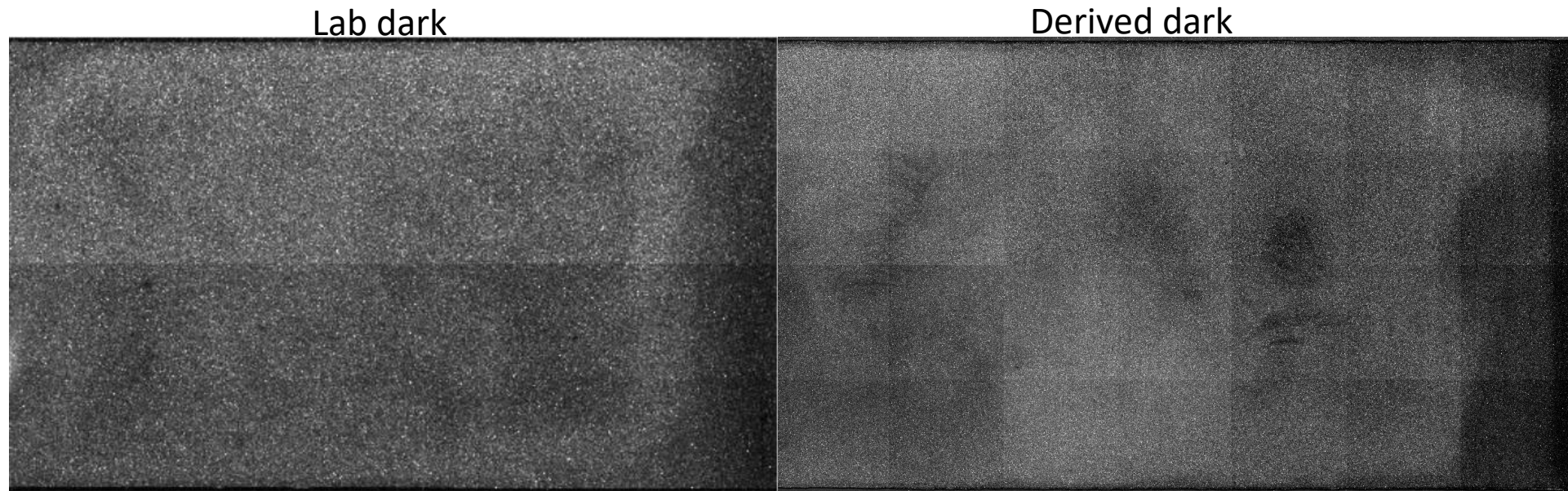
$$\Delta d(T, x, y) = \frac{I'_1(x, y) - I_2(x, y)}{k - 1} = \frac{kI_1(x, y) - I_2(x, y)}{k - 1}$$

(Ma et al. 2014)

# Data Process - Preprocessing

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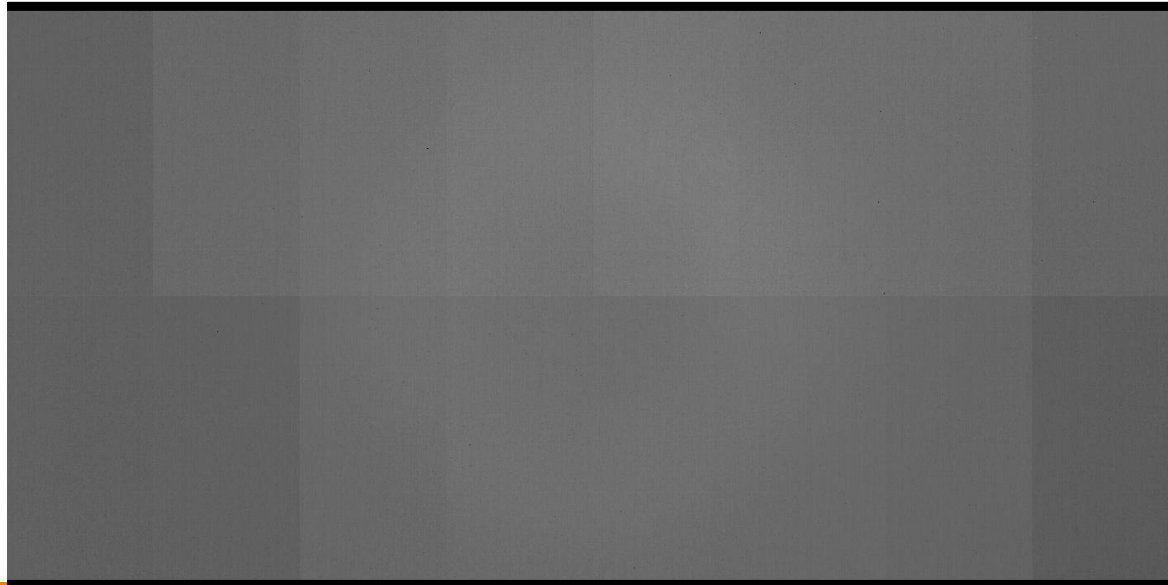
- Special Dark Correction
  - Obtain master-dark at a certain temperature  $T$
  - Scale master dark image to different temperature/exposure time



# Data Process - Preprocessing

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- Flat-field gradient correction
  - Master flat-field from twilight sky image
  - Non-uniform large-scale gradient correction
  - Corrections: RMS of master flat < 1%



$$Flux_{sky} = 10^{0.415alt_{sun}+5.926}$$

$$G_i = 10^{-0.00486\theta_i+1.939}$$

$$Z = a+bX+cY \quad G_i = \sqrt{b^2 + c^2}$$

$$MasterFlat = comb \left( \frac{F_i}{fitting \left( \frac{F_i}{comb(F_i)} \right)} \right)$$

(Wei et al. 2014)

# Data Process - Preprocessing

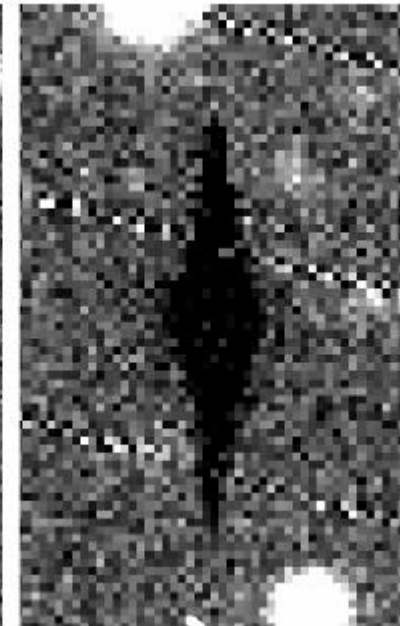
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- Cross-talk effect

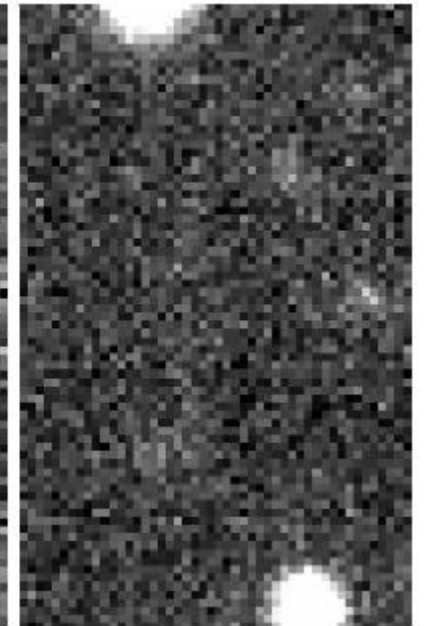
- Cross-talk:
  - saturated pixel in 1 channel
  - ghost image in other 15 channel ( same position )
- Problem:
  - pixels around saturated pixel also have a lower cross-talk effect
  - hard to locate



Saturated star



Cross-talk



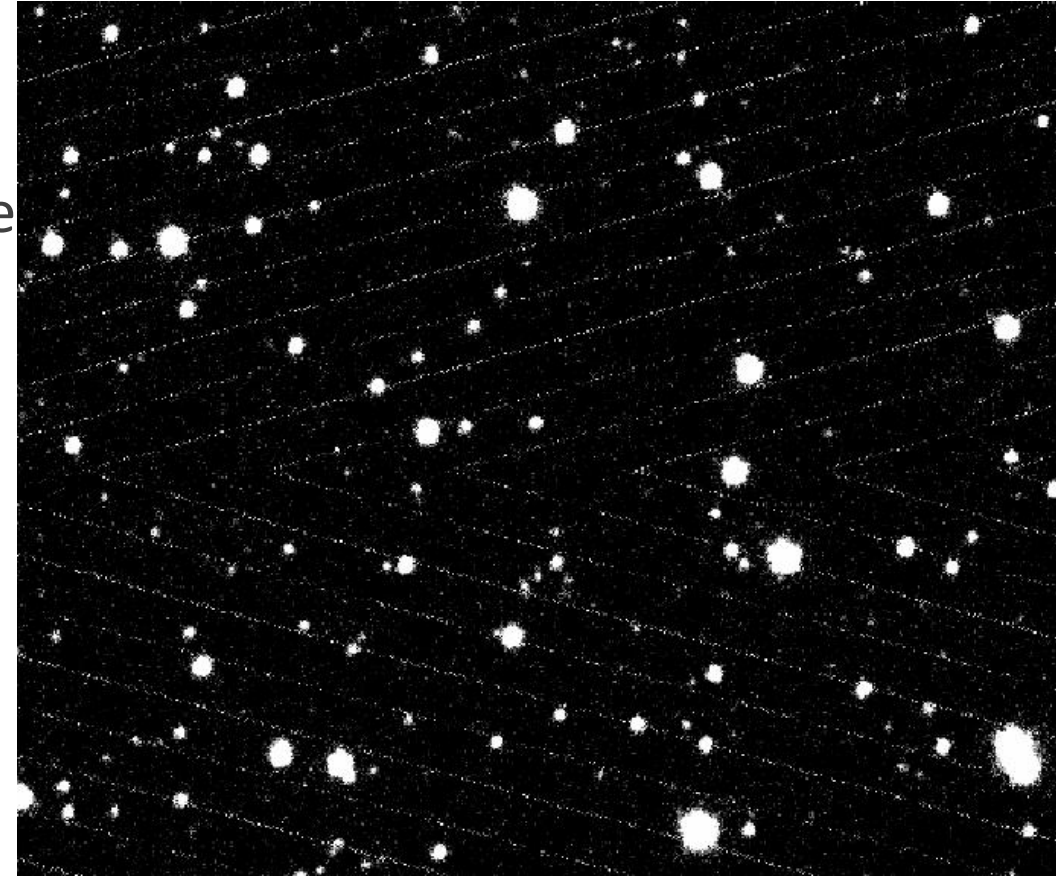
Corrected



# Data Process - Preprocessing

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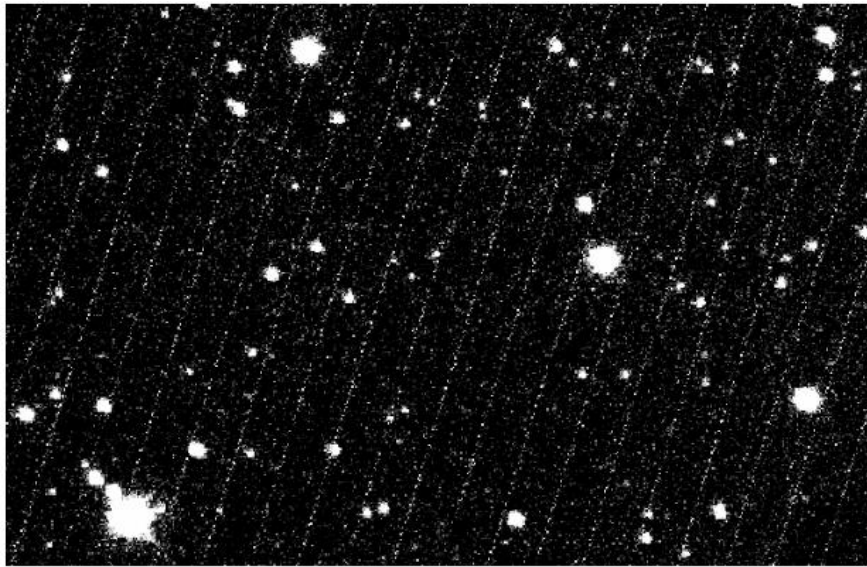
- Electromagnetic Interference
  - Diagonal stripe noise
  - 16kHz, same as the telescope DC motor drive
  - Caused by broken cable shield
  - Position: different between images  
same between channels
  - Cable shield fixed in 2019



# Data Process - Preprocessing

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- Filter Image
  - Construct filter image for each channel from other 15 channels
  - Median combine the star removed channels



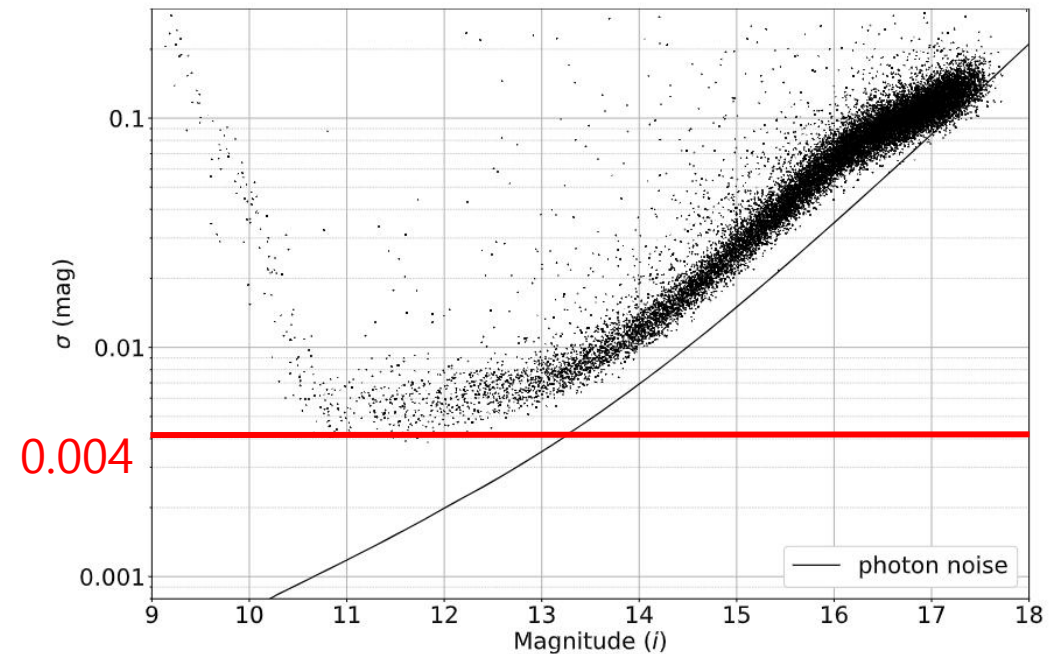
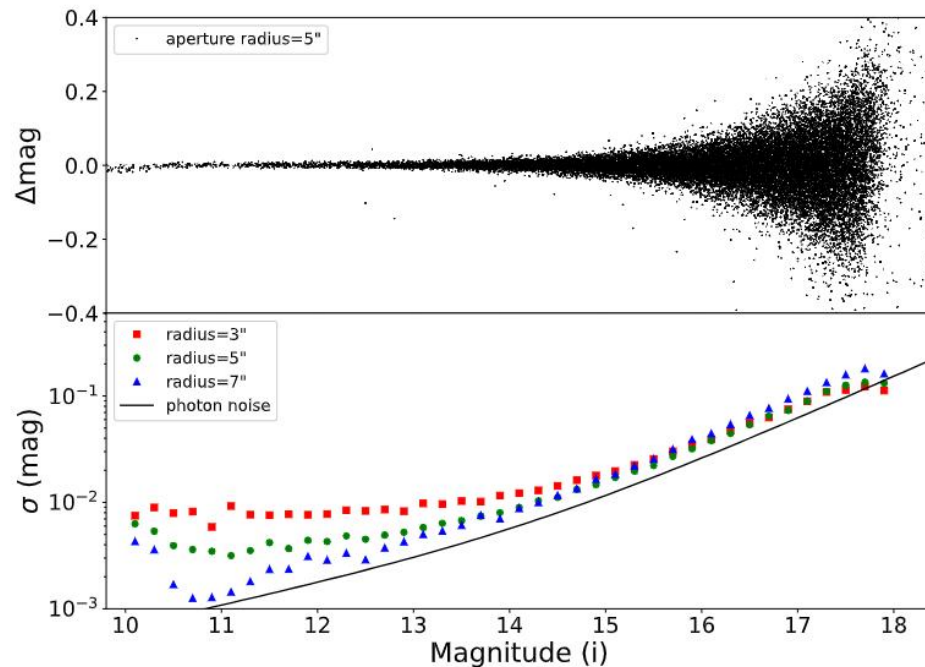
Stripey noise



corrected

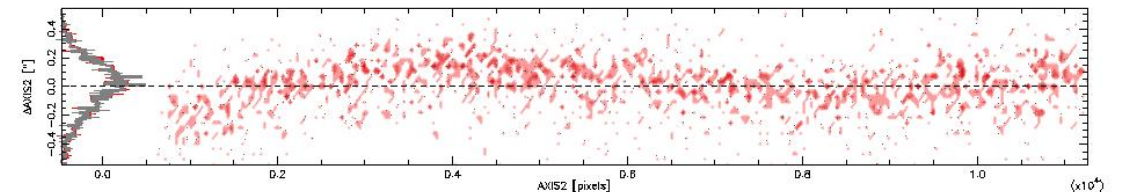
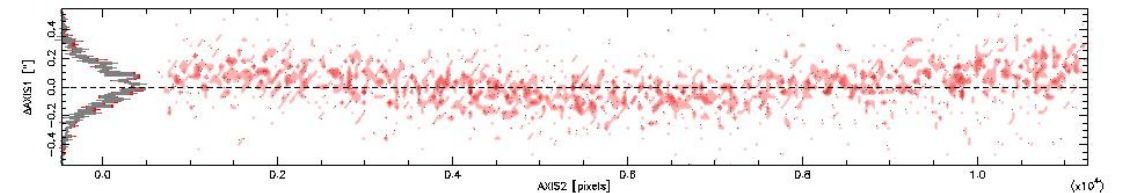
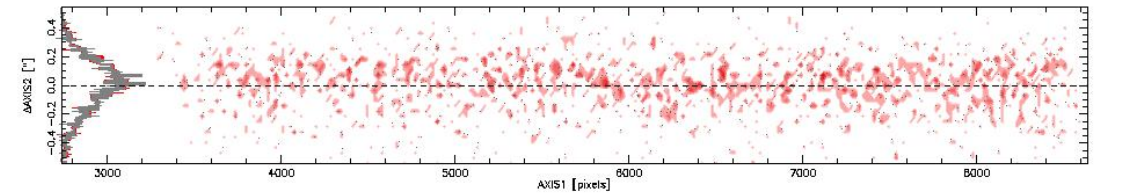
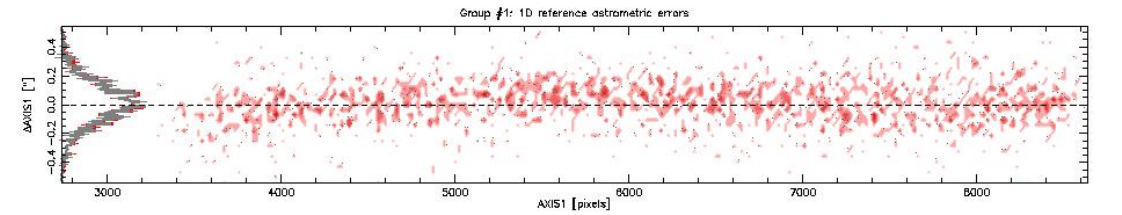
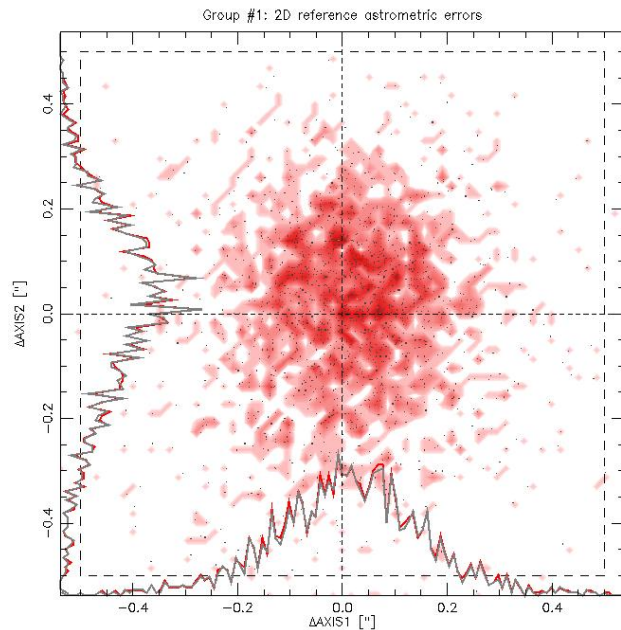
# Data Process - Photometry

- Photometry
  - SExtractor + 3, 5, 7" aperture photometry
  - Kron like elliptical aperture (MAG\_AUTO)



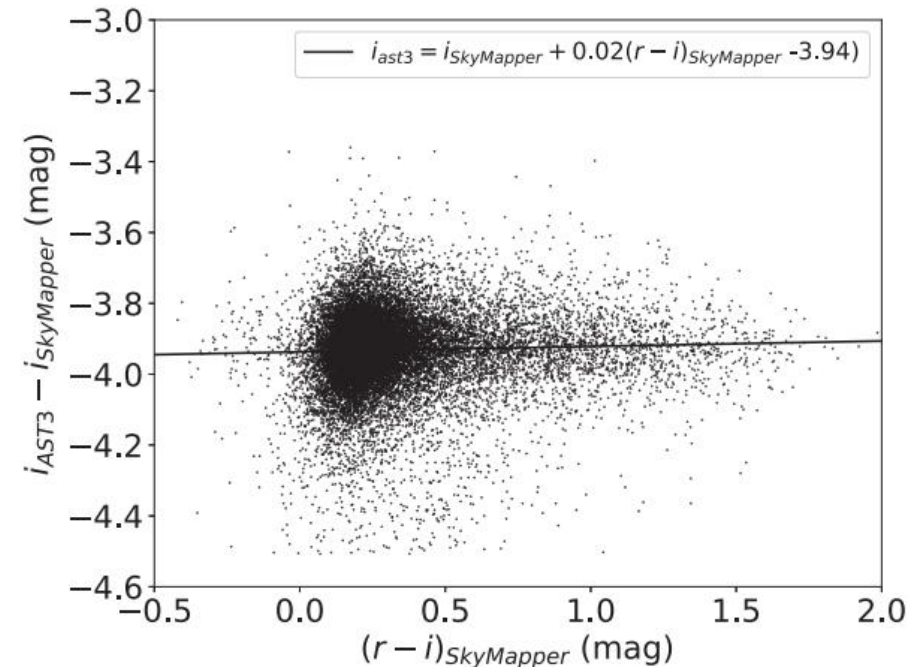
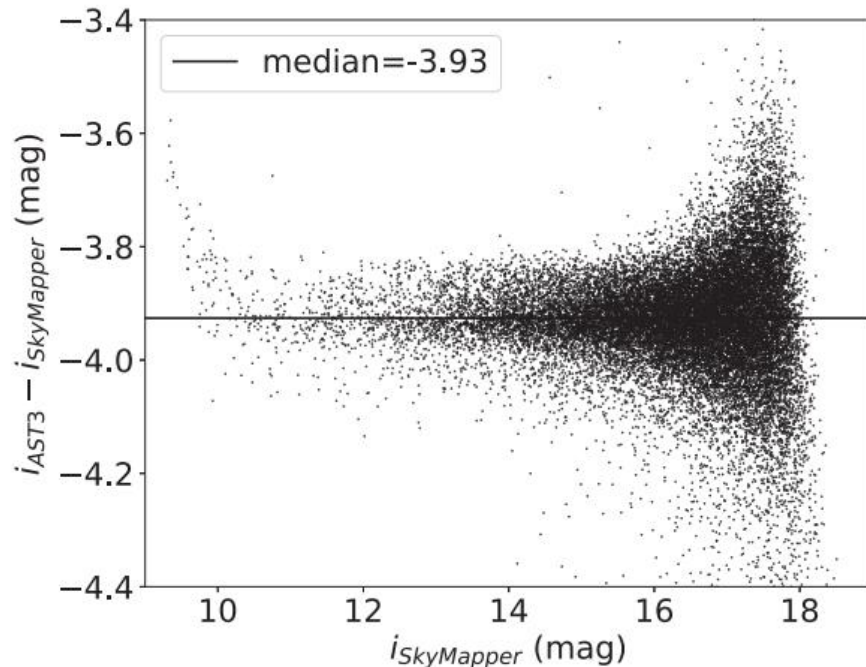
# Data Process - Astrometry

- Astrometry
  - SCAMP + PPMX Catalog
  - Precision 0.1''

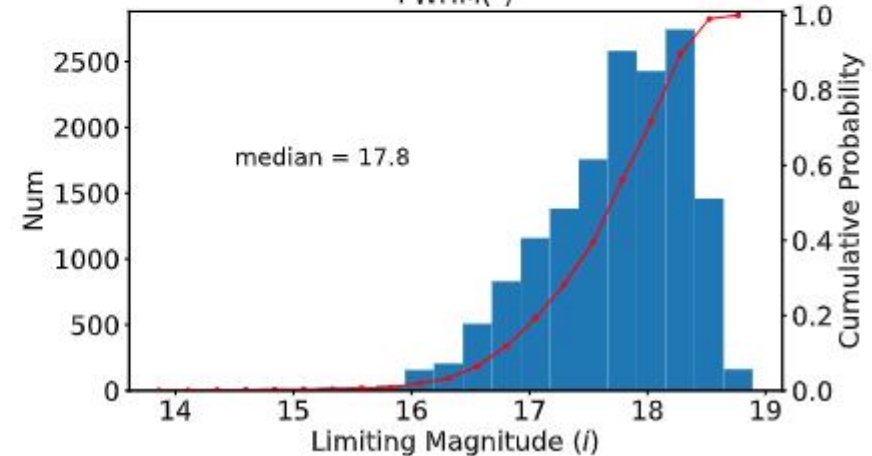
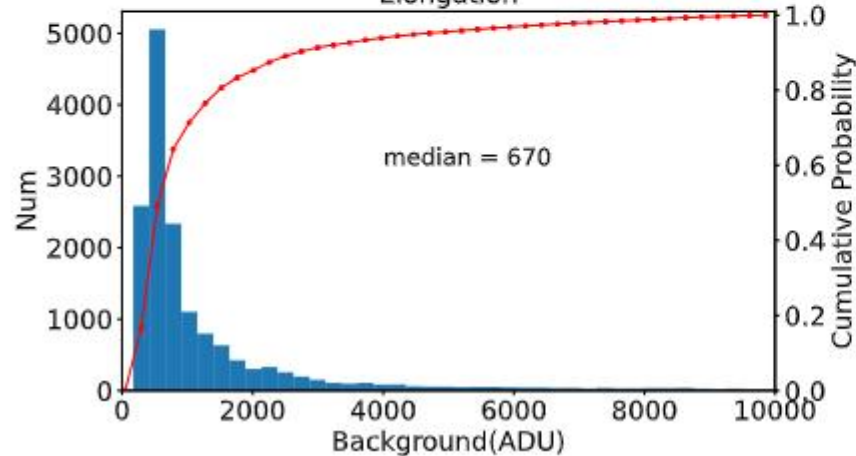
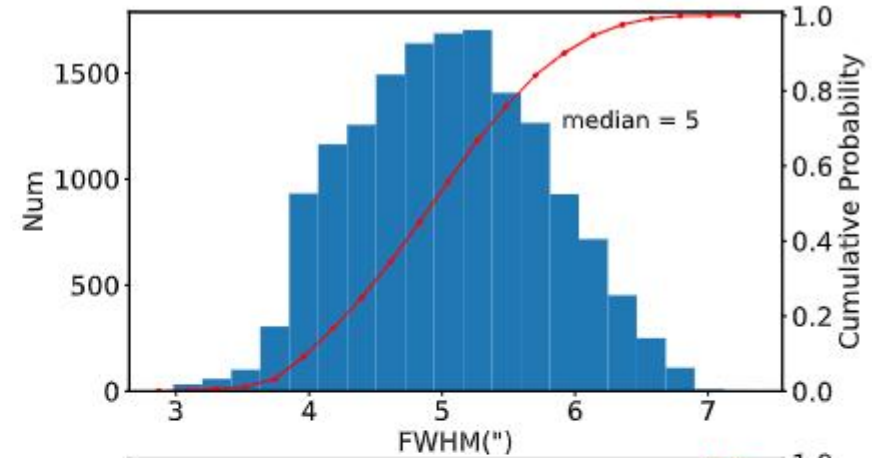
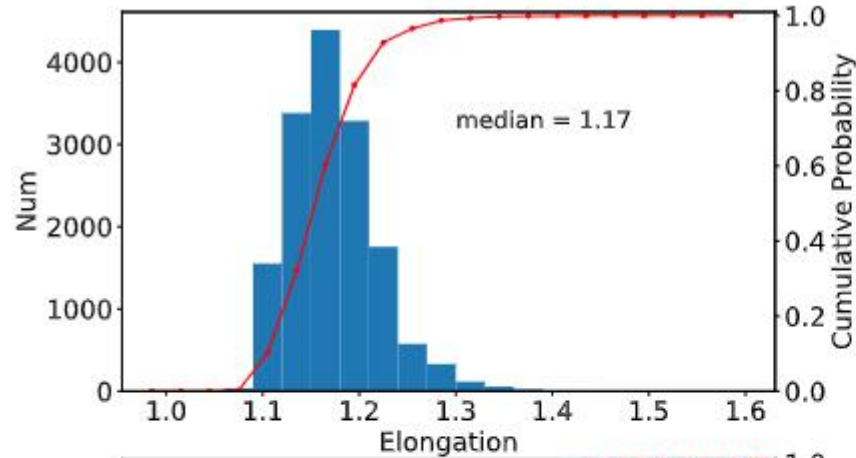


# Data Process - Flux Calibration

- Flux Calibration
  - Reference catalogue: SkyMapper
  - Colour term:  $0.02 (r - i)$ , close to SkyMapper



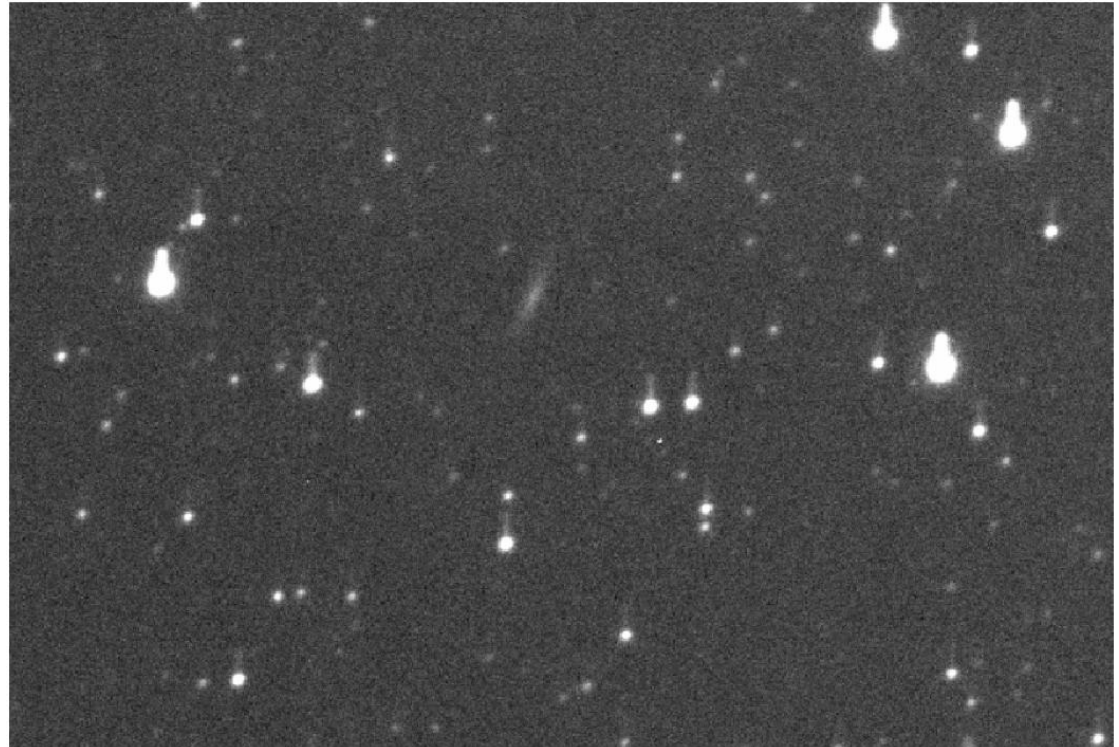
# Data Process - Data Quality



# Data Process - Data Quality

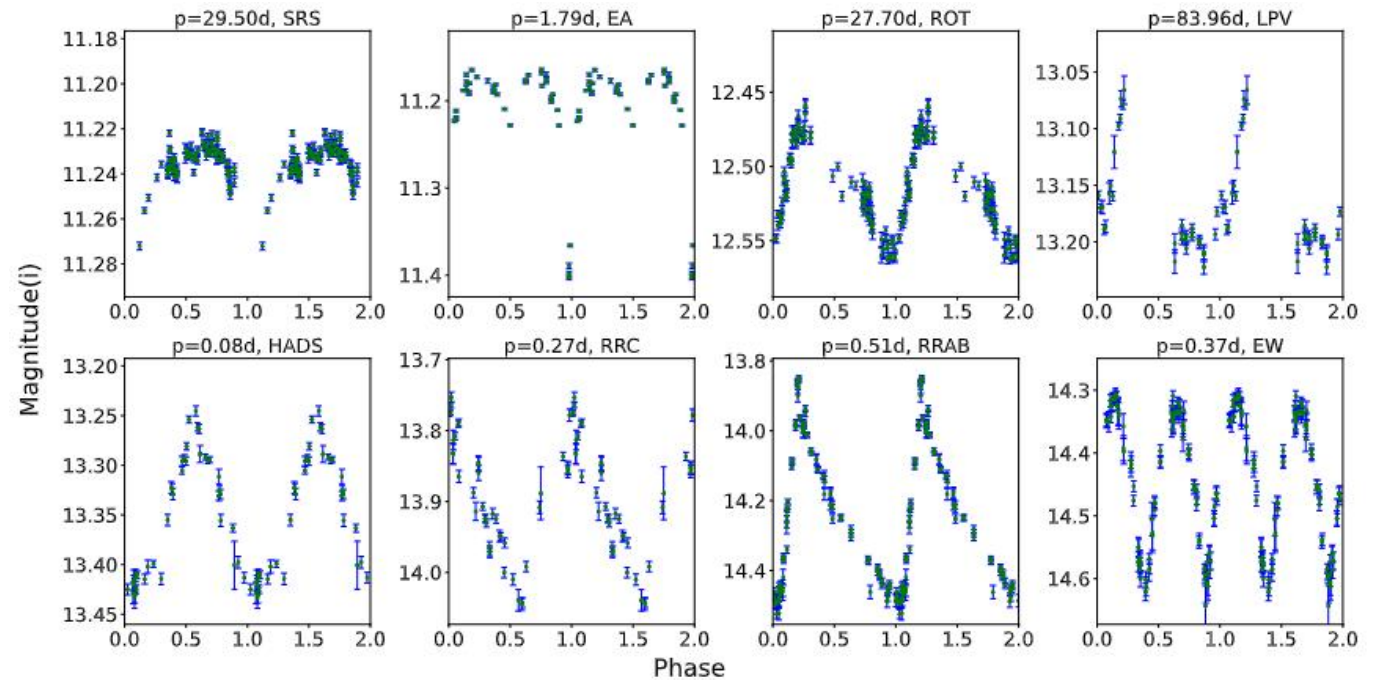
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- Data quality
  - Frosting on the mirror
    - large extinction
    - blower – bad tube seeing
  - Jam and stuck caused by icing
  - Exposure when mounting
    - trailing



# Stellar Variability

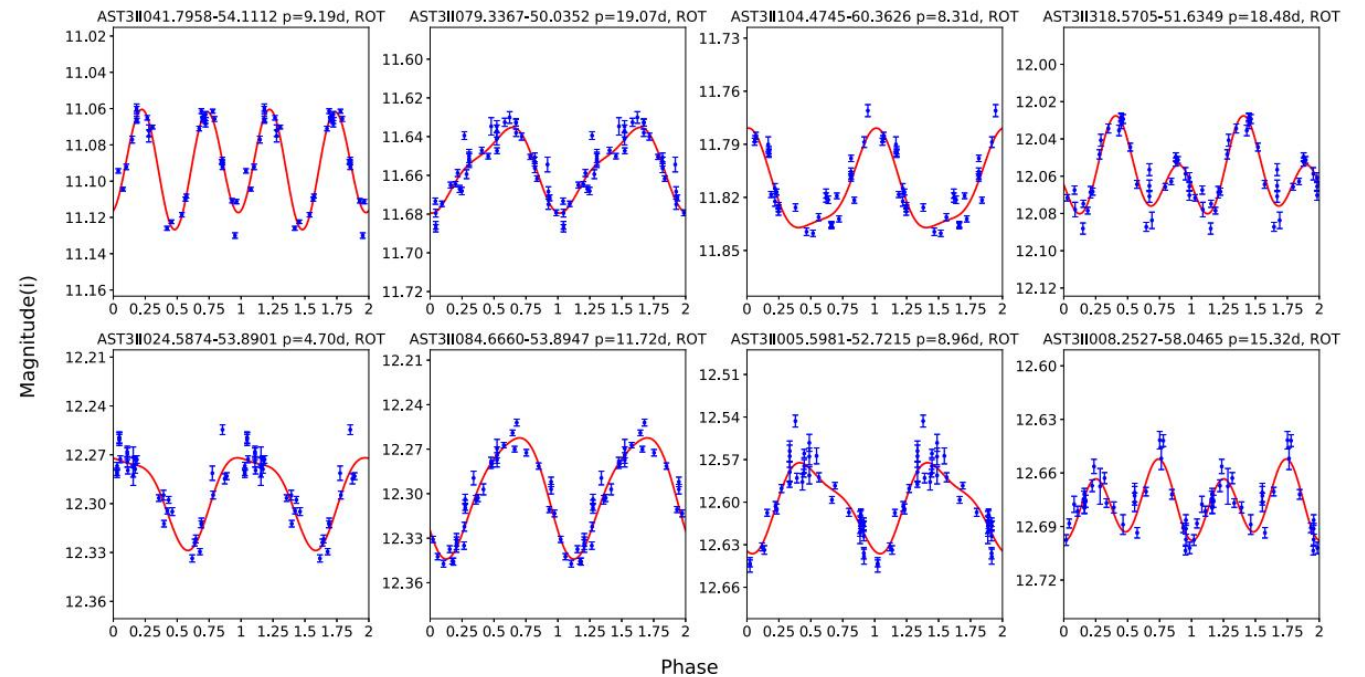
- Light curve statistics
  - 7 million light curves
- Period search ( $\geq 30$  obs.)
  - L-S method
  - ref: VSX catalog
  - $\sim 3500$  known variables
  - $\sim 70$  new variable candidates





# Stellar Variability

- Light curve statistics
  - 7 million light curves
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  - $\sim 70$  new variable candidates



# Stellar Variability

- Data Publish through CADC

<https://cstr.cn/11379.11.100669>

Name <sup>a</sup>	Mag <sup>b</sup>	P	Amp.	Type	B-V	B-V ref.	Teff <sup>c</sup>	logg	[Fe/H]
	(mag)	(days)	(mag)		(mag)		(K)	([cm/s <sup>2</sup> ])	
AST3II070.9519-50.9647	14.3	0.13	0.25	pROT	1.02	UCAC4	5433	4.41	0.12
AST3II009.0299-53.6067	14.8	0.14	0.60	pROT	0.75	NOMAD	5482	4.40	0.12
AST3II031.0155-53.2111	16.5	0.12	0.89	pROT	1.71	NOMAD	4145	4.62	0.40
AST3II290.4978-60.8112	13.5	0.41	0.08	EC	0.60	UCAC4	6397	3.97	-0.29
AST3II288.4890-60.4526	13.5	0.78	0.06	EC	0.43	UCAC4	6349	2.68	-1.38
AST3II288.6902-59.7634	13.7	0.37	0.07	EC	0.85	UCAC4	5801	4.13	0.00
AST3II339.6513-56.7764	14.1	0.40	0.33	EC	0.28	UCAC4	6630	4.08	-0.49
AST3II287.9363-60.0357	10.6	23.72	0.04	LPV	1.07	UCAC4	4480	1.14	-1.40
AST3II314.4222-46.9618	10.7	200	0.04	LPV	0.30	UCAC4	8526	4.25	-0.15
AST3II347.0135-60.9865	10.6	55.93	0.05	LPV	0.89	UCAC4	5023	3.55	-0.11
AST3II344.2833-48.7002	10.8	34.12	0.07	LPV	1.54	UCAC4	3728	0.79	-0.21

# Conclusion

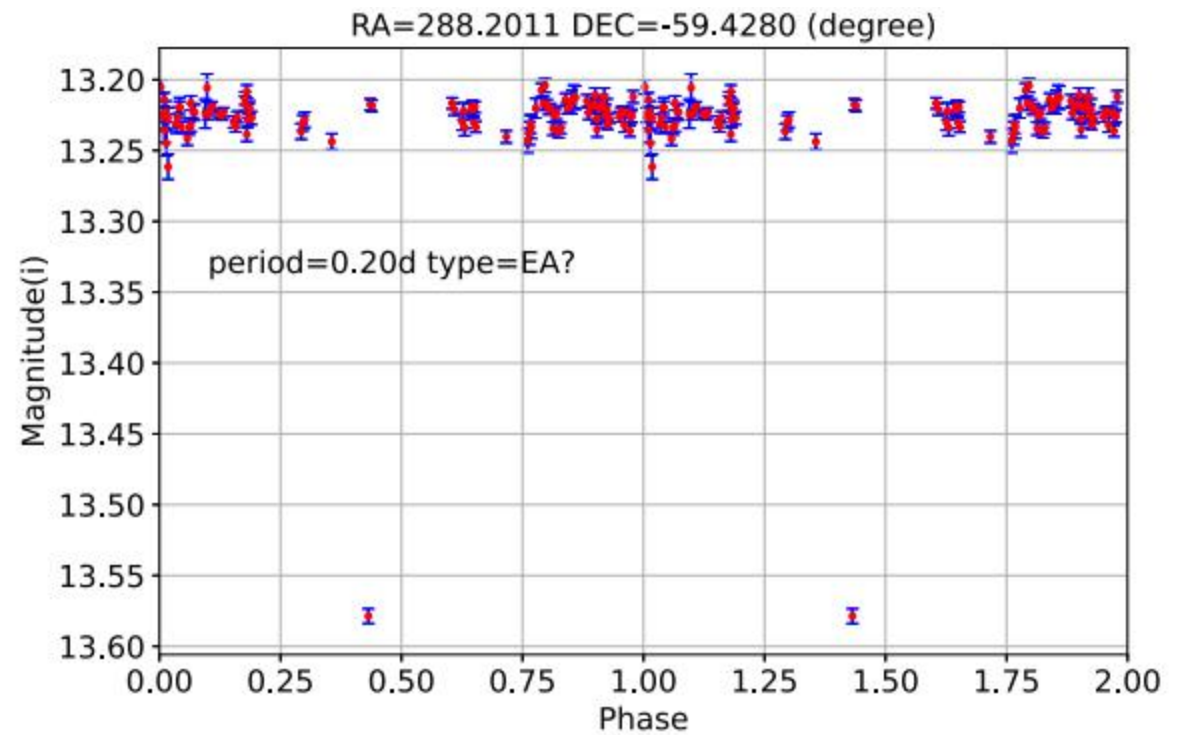
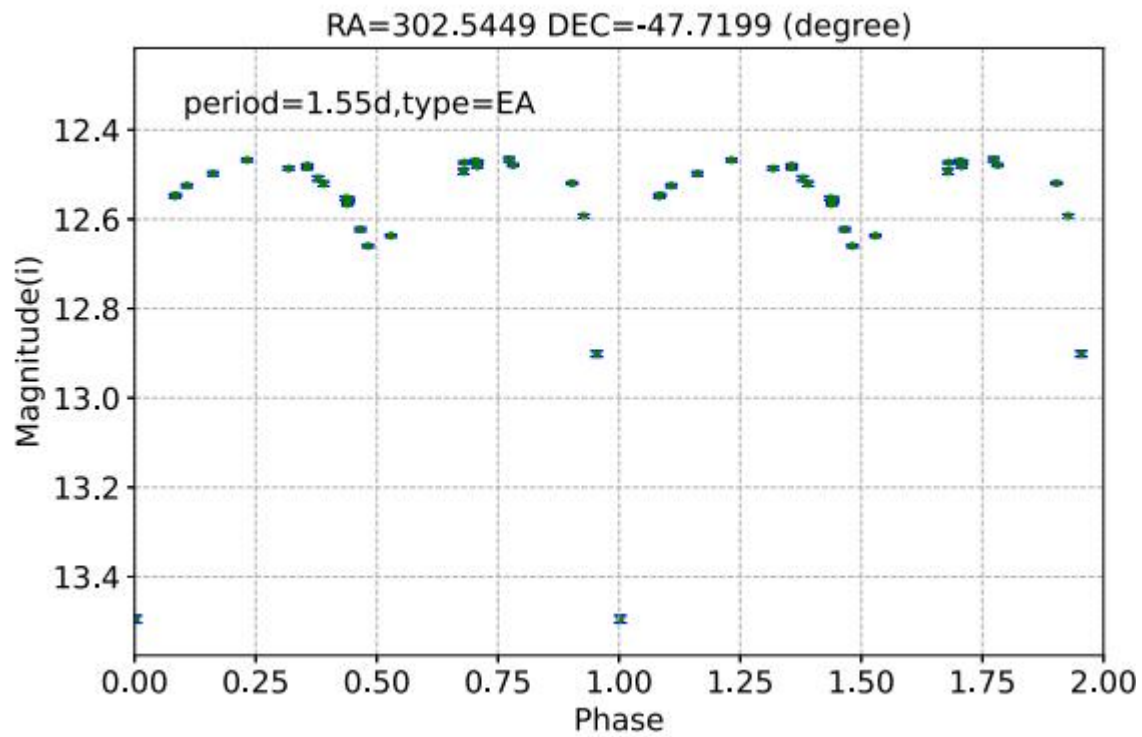
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- Data release of the 2016 AST3-2 data
  - Special Preprocessing
  - Astrometry precision 0.1''
  - Median  $5\sigma$  limiting magnitude  $\sim 17.8$  *imag*
  - 7 million light curves
  - 3500 known variables, 70 new variable candidates
  - Data published through CADC  
<https://cstr.cn/11379.11.100669>

# Thanks!!

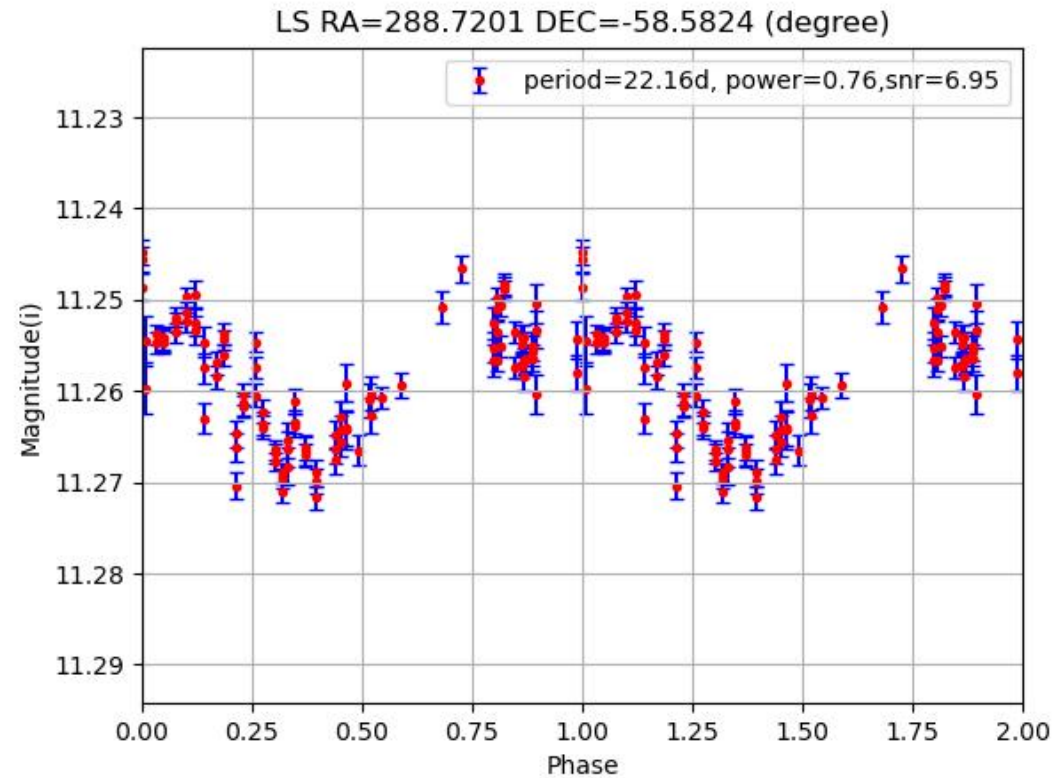


# EA type variable: Real vs. Fake

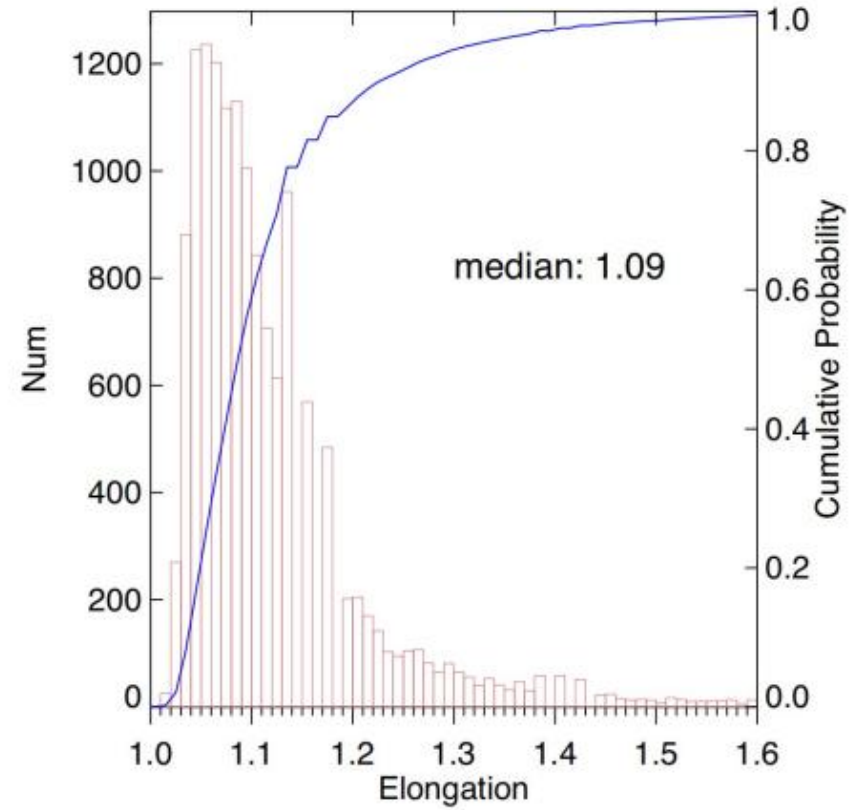
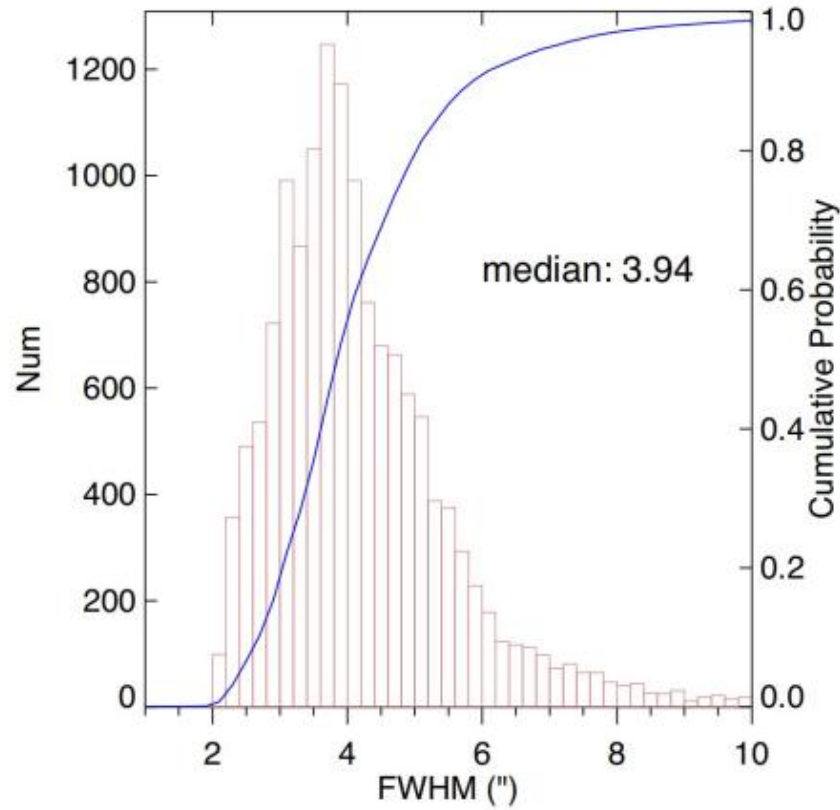


# Small Amplitude Variables

- Period  $> 10\text{d}$
- Amplitude  $< 0.02\text{ mag}$
- Rotational variables?



# Image Quality – AST3-1



# Data Process - Preprocessing

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- Dark Correction method
  - Select 2 images at different background but same temperature
  - Remove stars and scale to same background level
  - Consider the sky is flat enough
  - Subtract one from another
  - Divide scale factor  $k-1$
  - Get dark image at temperature T
  - Repeat to different pairs of images

$$I(x, y) = S + D(T) + \Delta d(T, x, y)$$

$$I_1(x, y) = I_{0,1} + \Delta d(T, x, y) \quad k \equiv I_{0,2}/I_{0,1}$$

$$I_2(x, y) = I_{0,2} + \Delta d(T, x, y)$$

$$I'_1(x, y) = kI_1(x, y) = I_{0,2} + k\Delta d(T, x, y)$$

$$\Delta d(T, x, y) = \frac{I'_1(x, y) - I_2(x, y)}{k - 1} = \frac{kI_1(x, y) - I_2(x, y)}{k - 1}$$

(Ma et al. 2014)