

The 1.4 μm water-vapor-absorption band imaging from Dome A

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On behalf of AIRBT team from SYSU, NAOC and UNSW



Outline

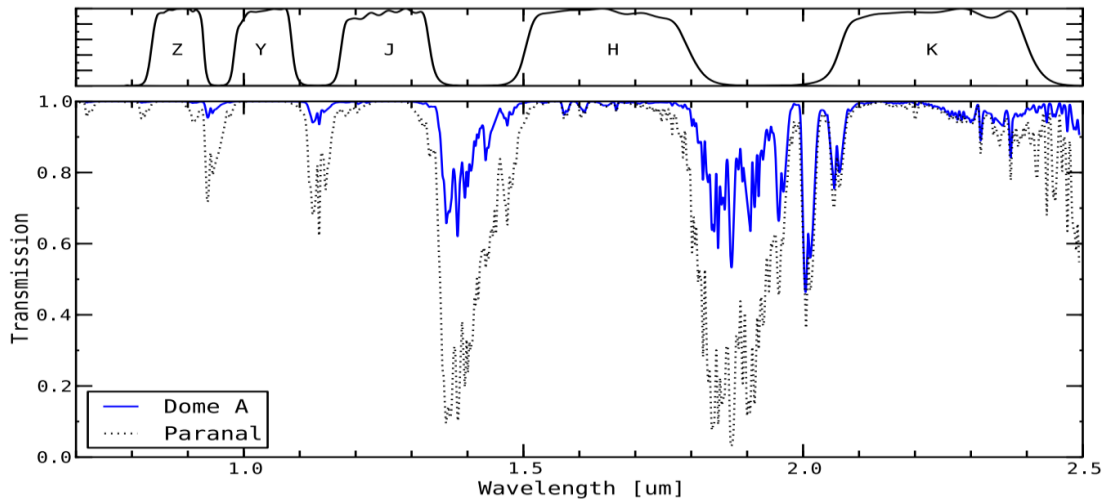
- 1. Introduction
- 2. Observations at Dome A
- 3. Data Reduction
- 4. Results
- 5. Summary



Antarctic IR Binocular Telescope (AIRBT)

1. Introduction

- Water-vapor absorbs light of certain IR wavelengths
 - Gaps between normal IR filters
- Extremely dry atmosphere at Dome A opens new windows (IR to THz) for ground-based telescope

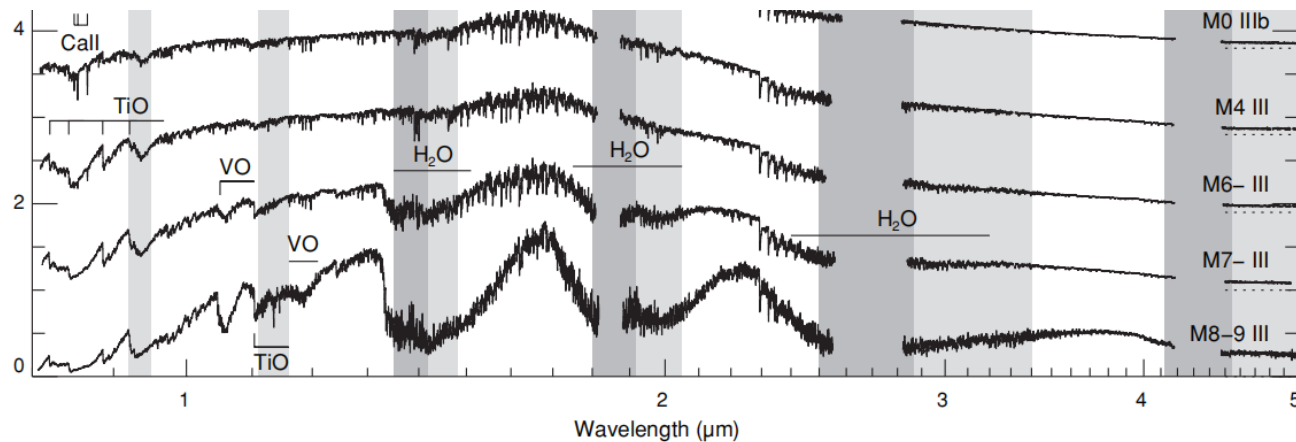


PWV COMPARISON AT DOME A, CHAJNANTOR, AND PARANAL

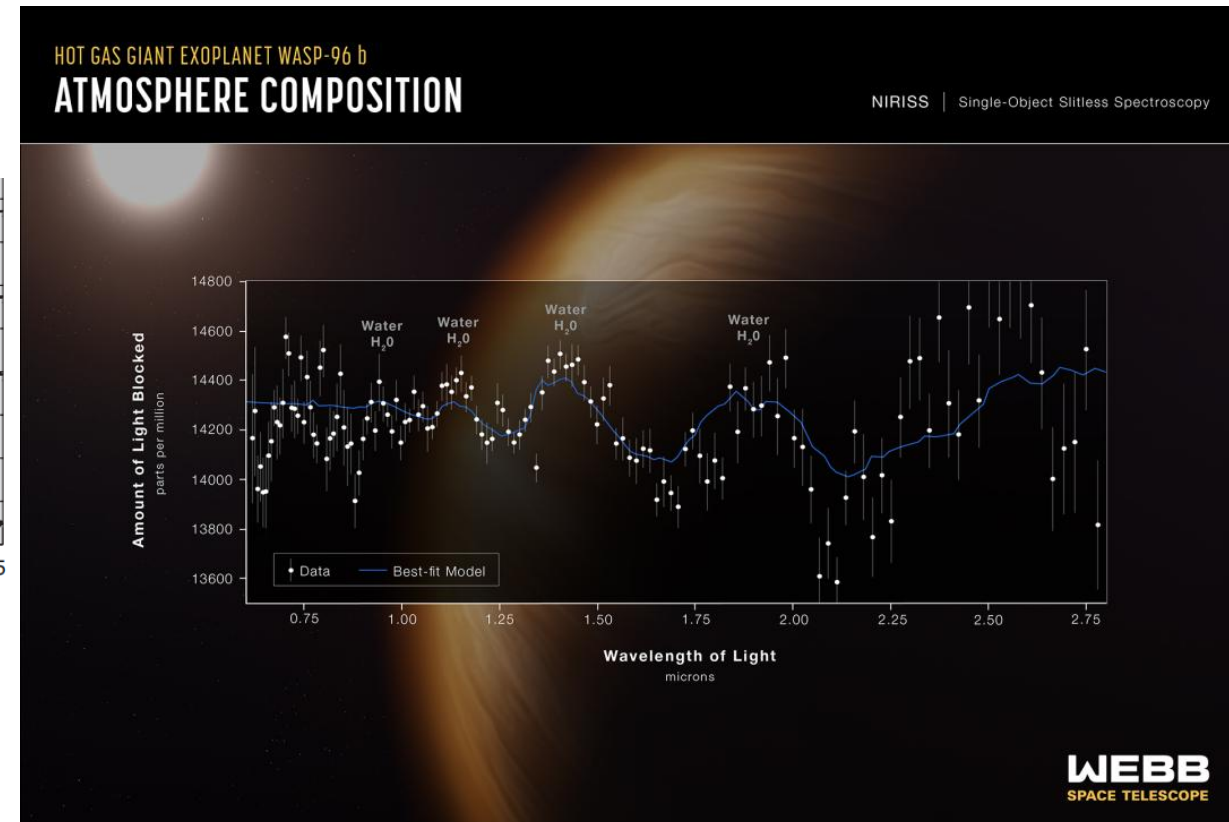
Site	Altitude (m)	Median (mm)	Best 25% (mm)	Best 10% (mm)
Dome A, Antarctica ^a	4083	0.13	0.09	0.06
Chajnantor, Chile ^b	5640	1.13	0.50	0.42
Paranal, Chile ^c	2635	2.30	1.60	1.07

Sims et al. 2012

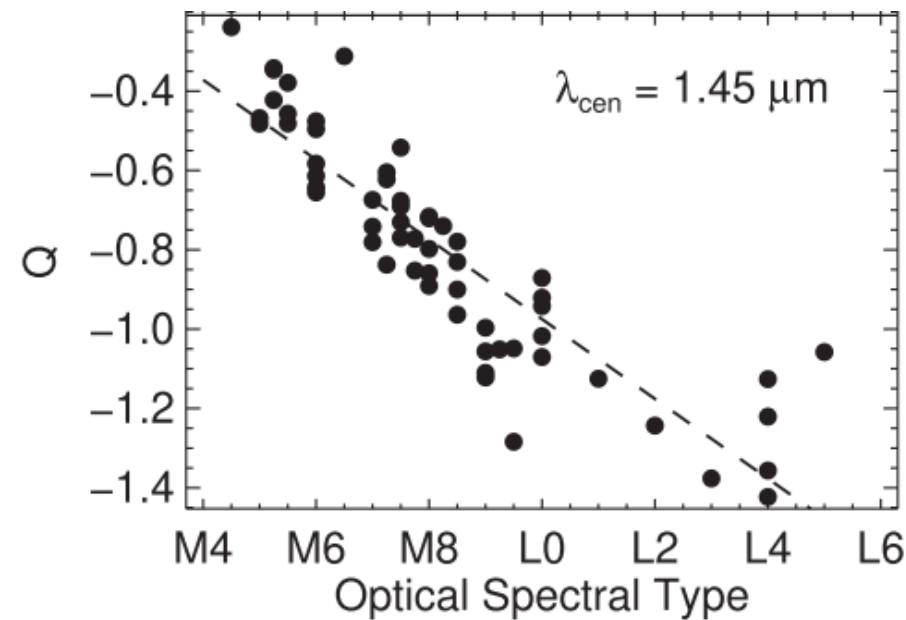
- **New filters: water-vapor-absorption bands**
- **To observe targets with water-vapor features, eg. ultra cool stars, brown dwarfs, exoplanet atmosphere**



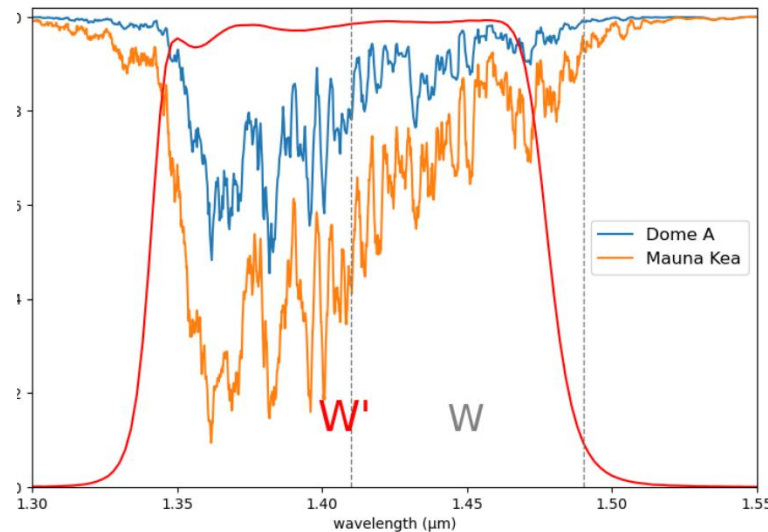
Rayner et al. 2009



- **W band (1.45 μm) for Mauna Kea by Allers & Liu (2020)**
- **W' band (1.4 μm) for Dome A by Zhang & Ma (2024) SPIE**
- **Tested at Daocheng, China before used in Antarctica**



Allers & Liu (2020)



Filter (module- average)	Pivot [*] λ (μm)	BW [†] $\Delta\lambda$ (μm)	Effective [‡] response	Blue [§] λ_- (μm)	Red [§] λ_+ (μm)	Use
F070W	0.705	0.128	0.234	0.624	0.781	General purpose
F090W	0.902	0.194	0.305	0.795	1.005	General purpose
F115W	1.154	0.225	0.326	1.013	1.282	General purpose
F140M	1.405	0.142	0.420	1.331	1.479	Cool stars, H ₂ O, CH ₄

JWST filters

2. Observations at Dome A

Antarctic IR Binocular Telescope (AIRBT)

Telescope

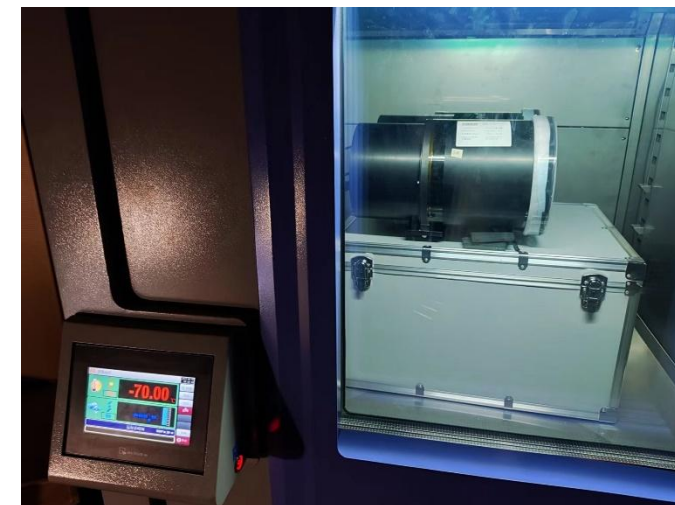
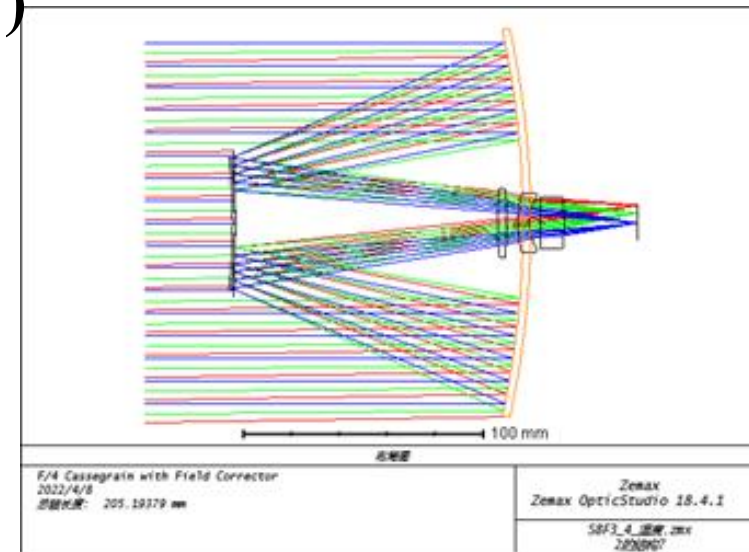
- $D=15\text{ cm}$, $f/3$
- JH filters
- FoV $1.2 \times 1\text{ deg}^2$
- $6.9''/\text{pix}$

InGaAs cameras

- $640 \times 512\text{ pix}$
- Dark current 500 e/s/pix
- Full well 41, 100, 1000 ke
- Readout noise $\sim 100\text{ e}$

Goals

- Pathfinder for IR at Dome A
- Measurement of IR sky brightness
- Variable stars



- **2022 Sept. – Oct.**
- **Tests at SYSU Zhuhai Campus**



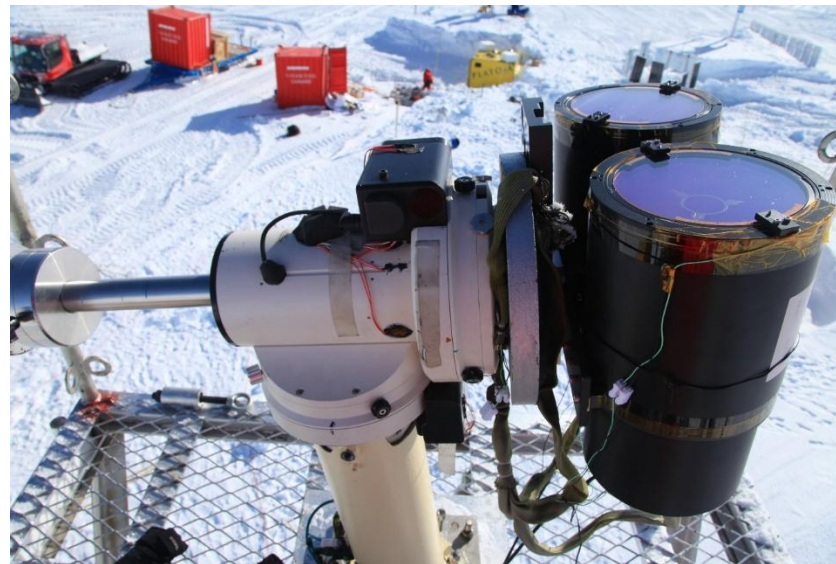
NGC 6871

Collaboration

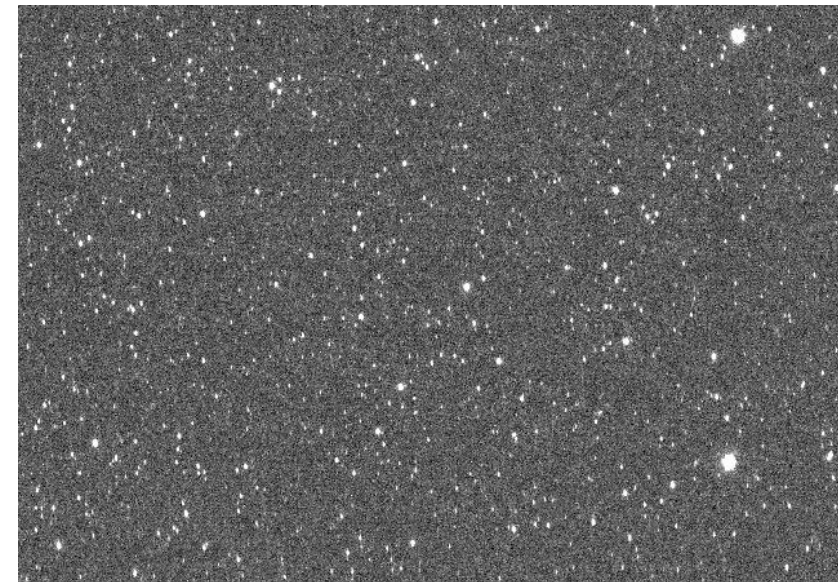
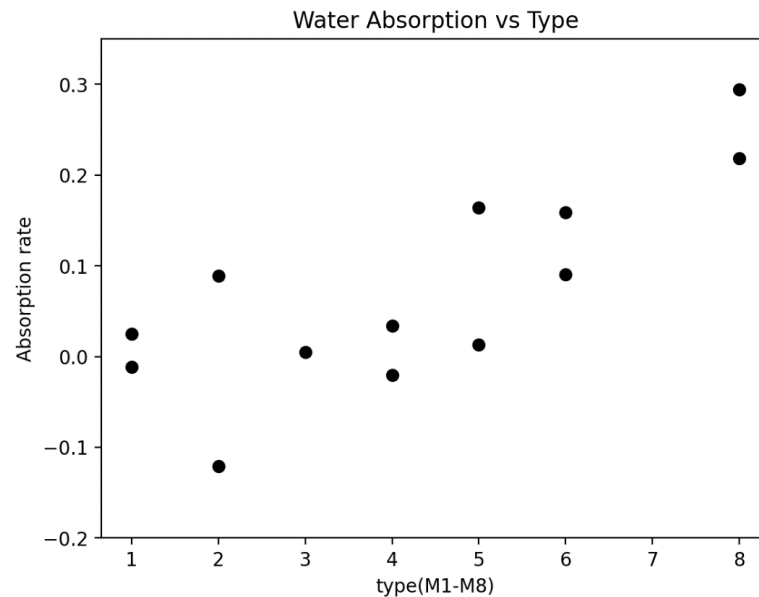
- **SYSU: telescope & cameras**
- **NAOC: mount, control & data system**
- **UNSW: power & internet by PLATO-A**

2023.1 installed at Dome A, J/H filters

2024.1 maintained

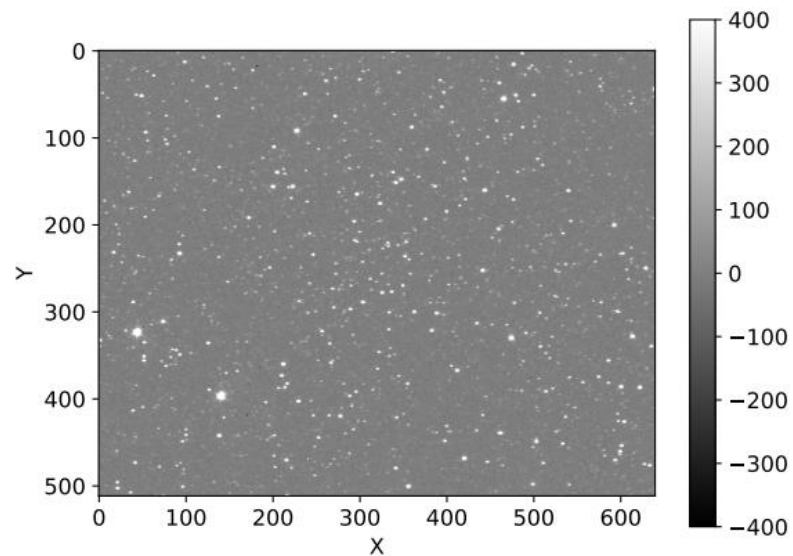
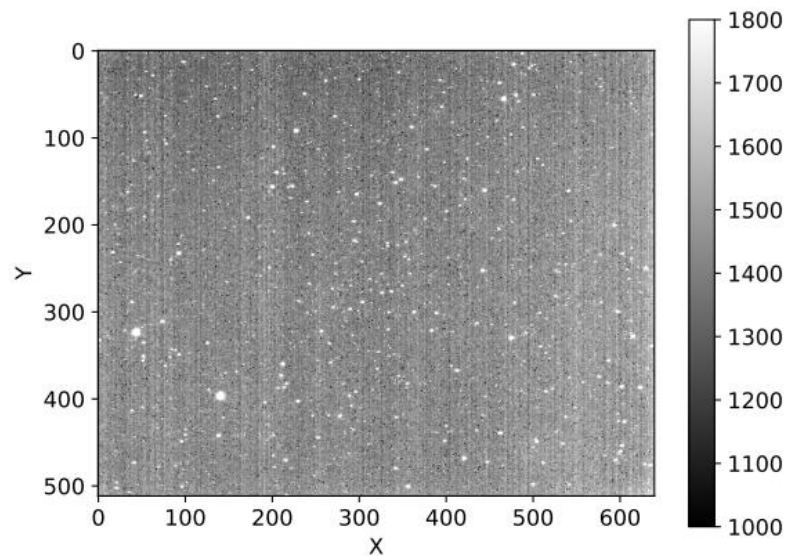


- 2025.1 replaced H with **1.4 μm filter (W) \rightarrow J + W**
- **Daytime: bright stars**
- **Nighttime: survey Dec = -61° , Galactic plane**
- **Fixed pointing, 2 s exposures, FWHM \sim 2 pix**
- **Automatic observation until 23 April**

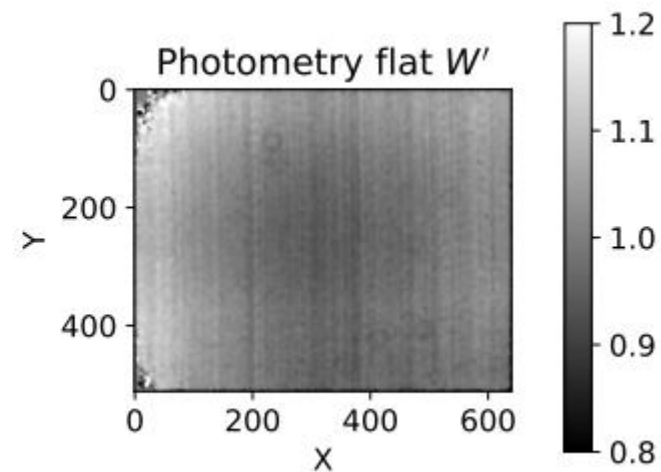
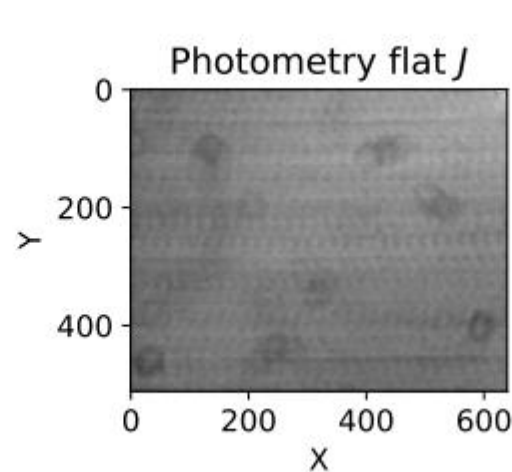
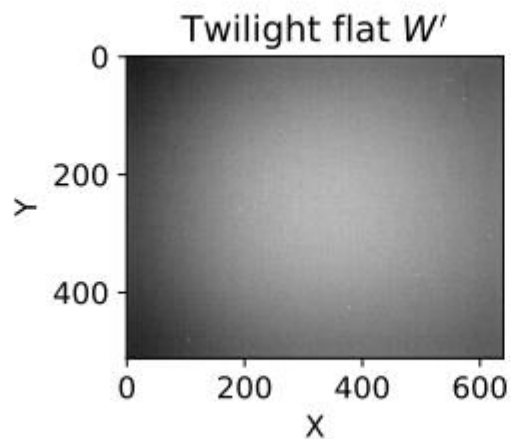
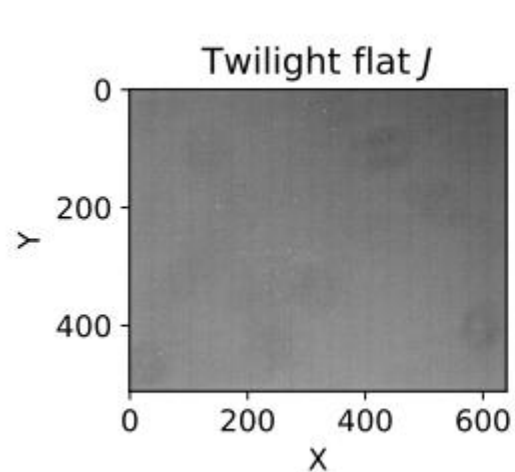


3. Data Reduction

Early Data Release: 16 March, 3 April and 20 April 2025

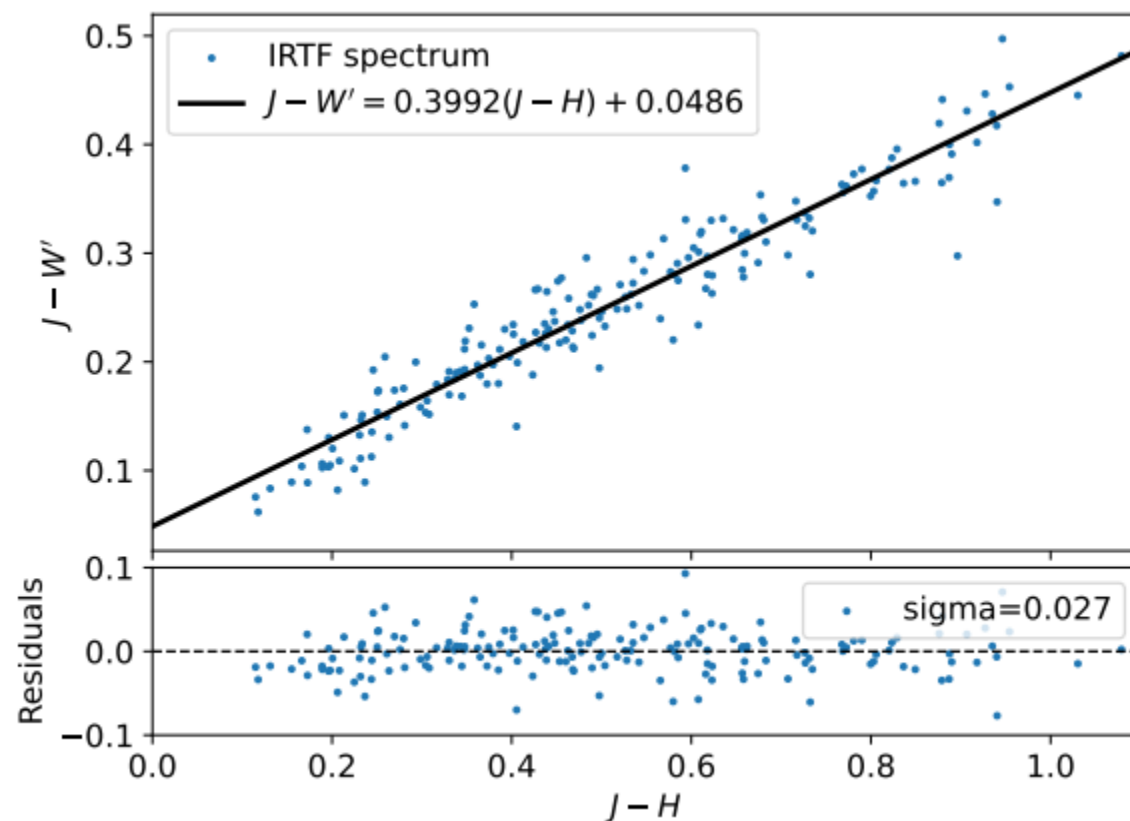
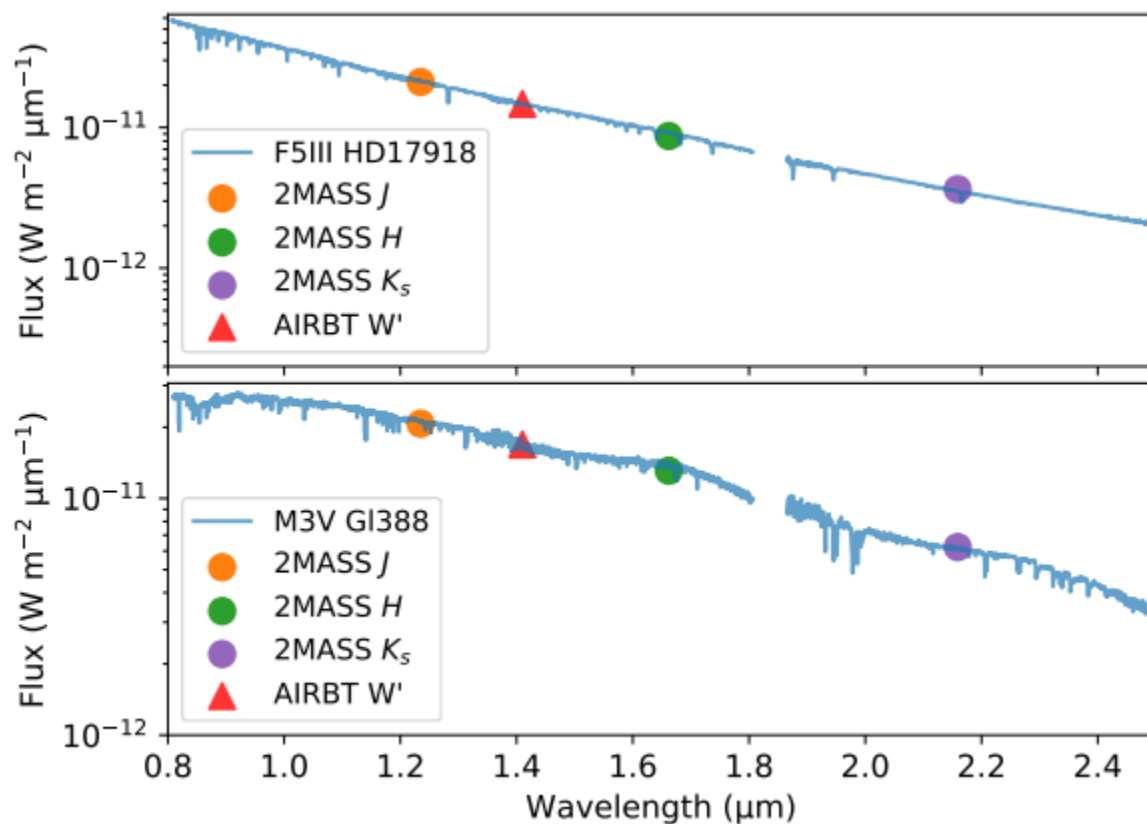


Background subtraction

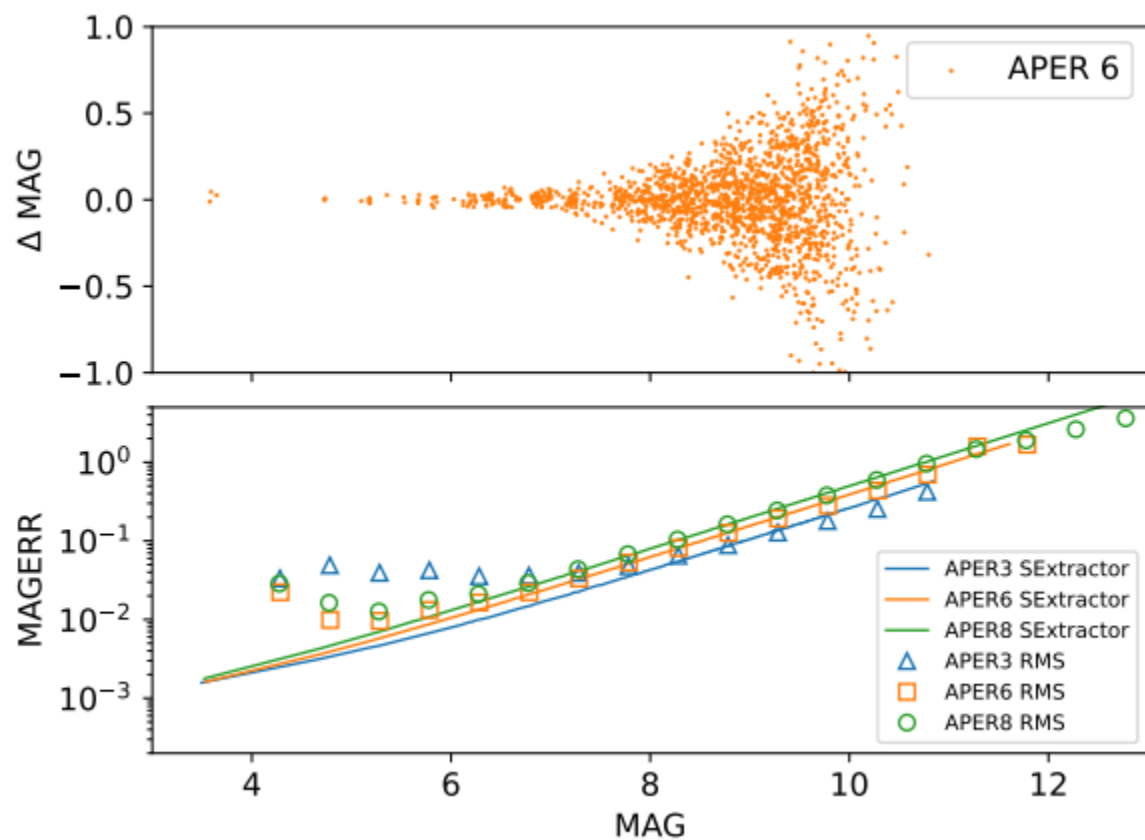
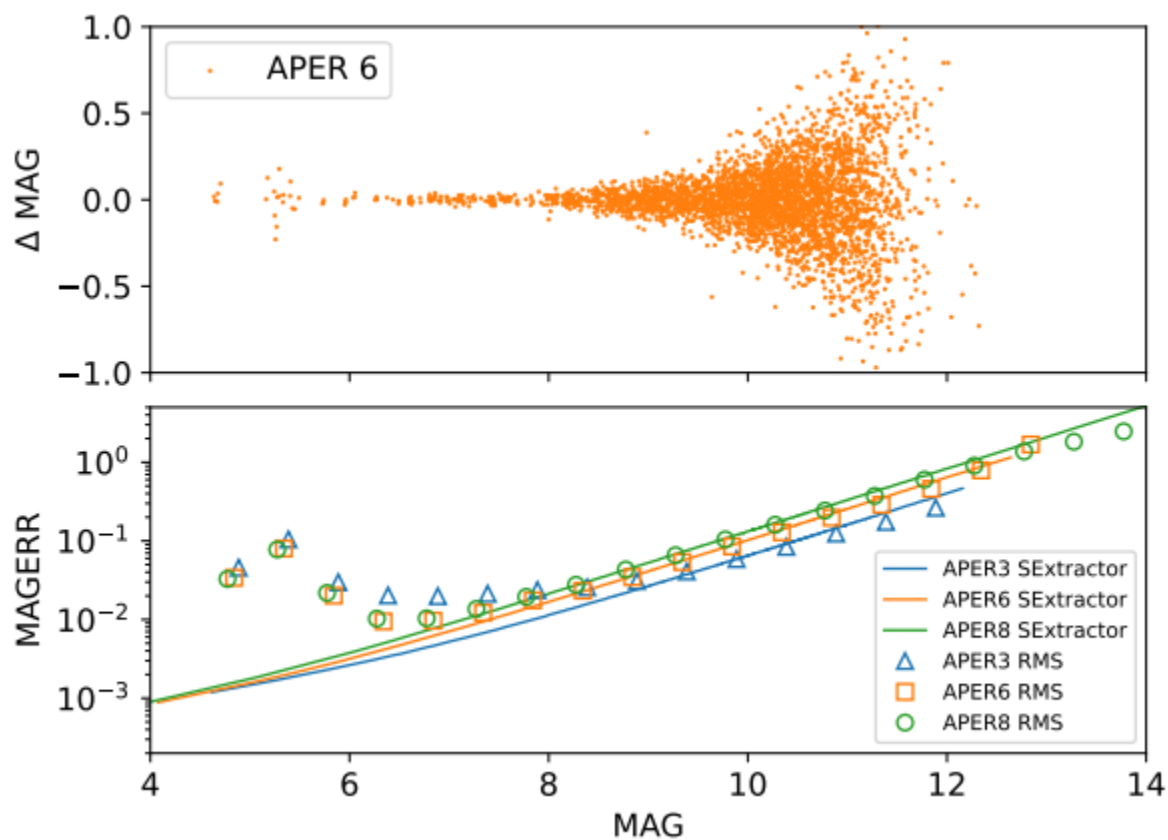


Magnitude calibration

- 197 early-type spectra from The IRTF Spectral Library
- J, W, H mag are almost linear
- Estimate W mag from J and H

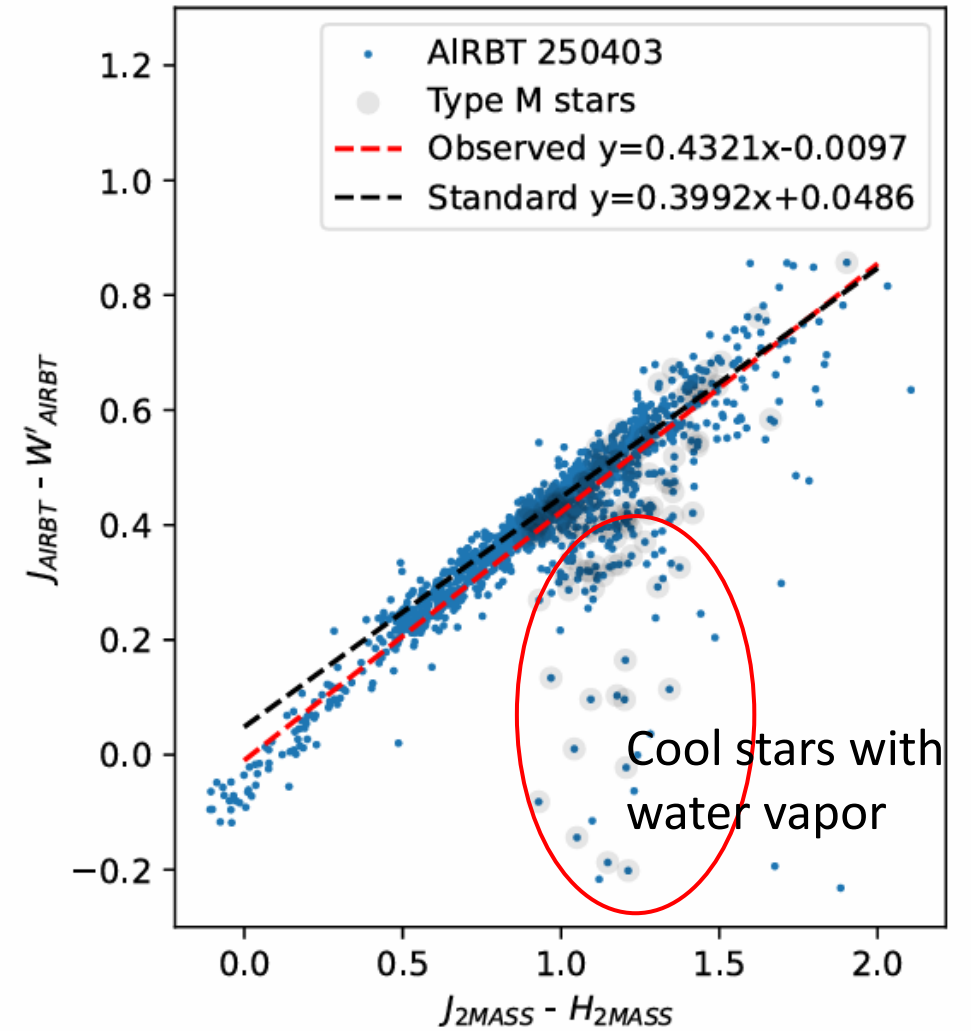
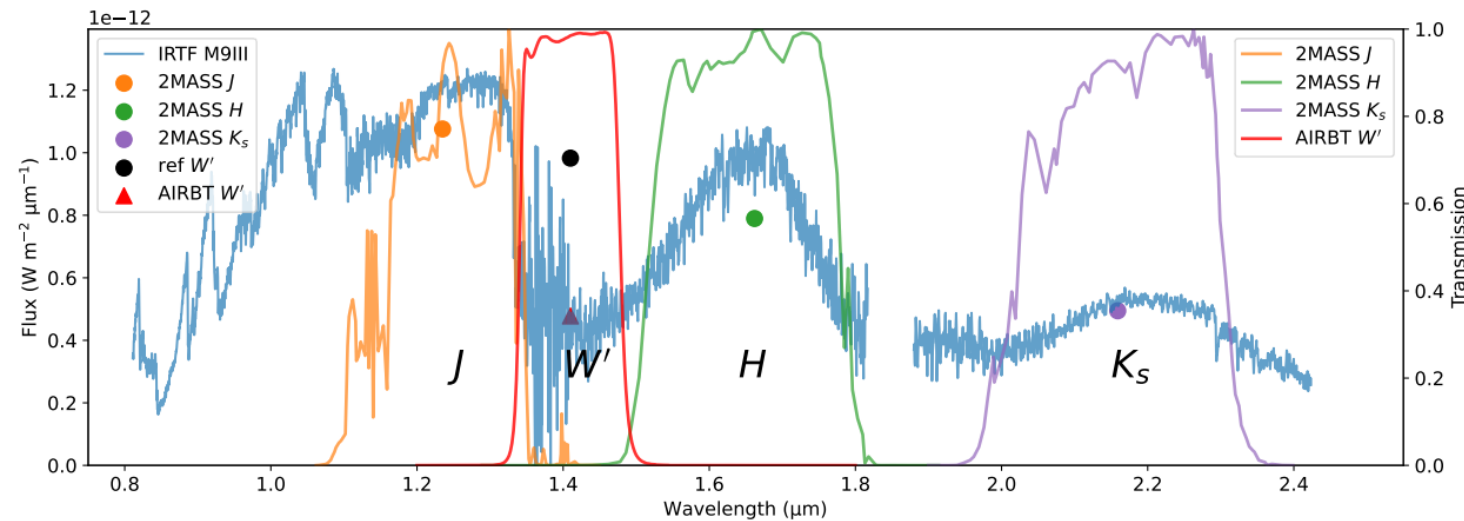


- Limiting mag: J \sim 11.5, W \sim 10 @ 2 s
- 1% precision for bright stars

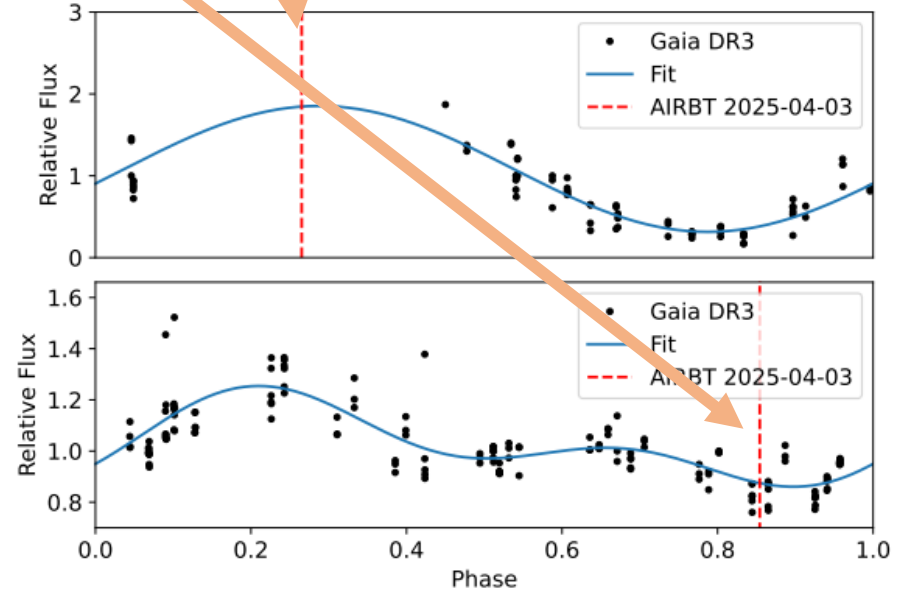
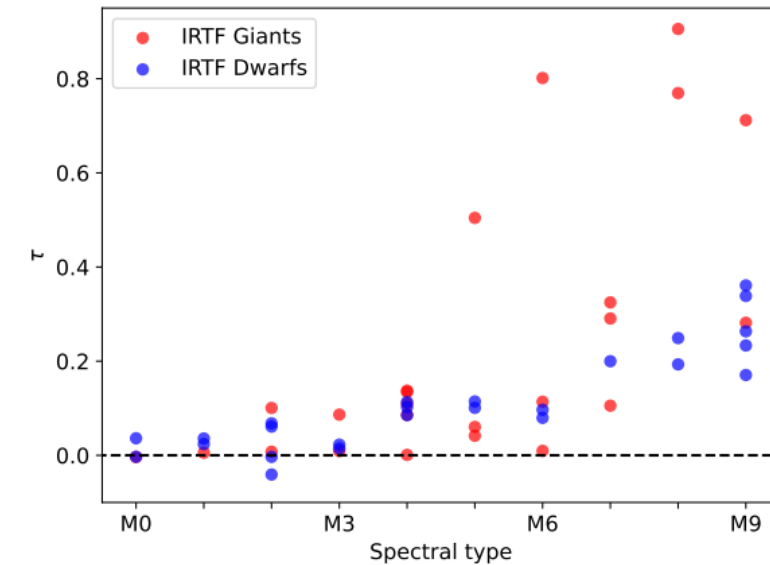
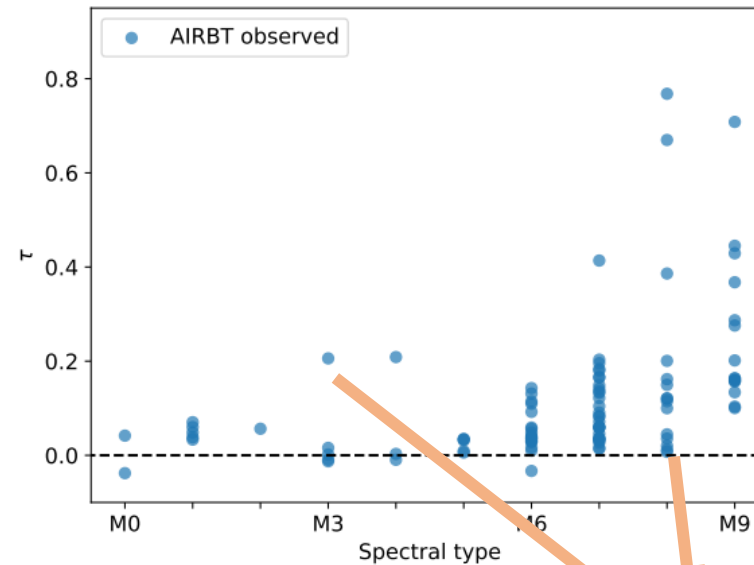


4. Results

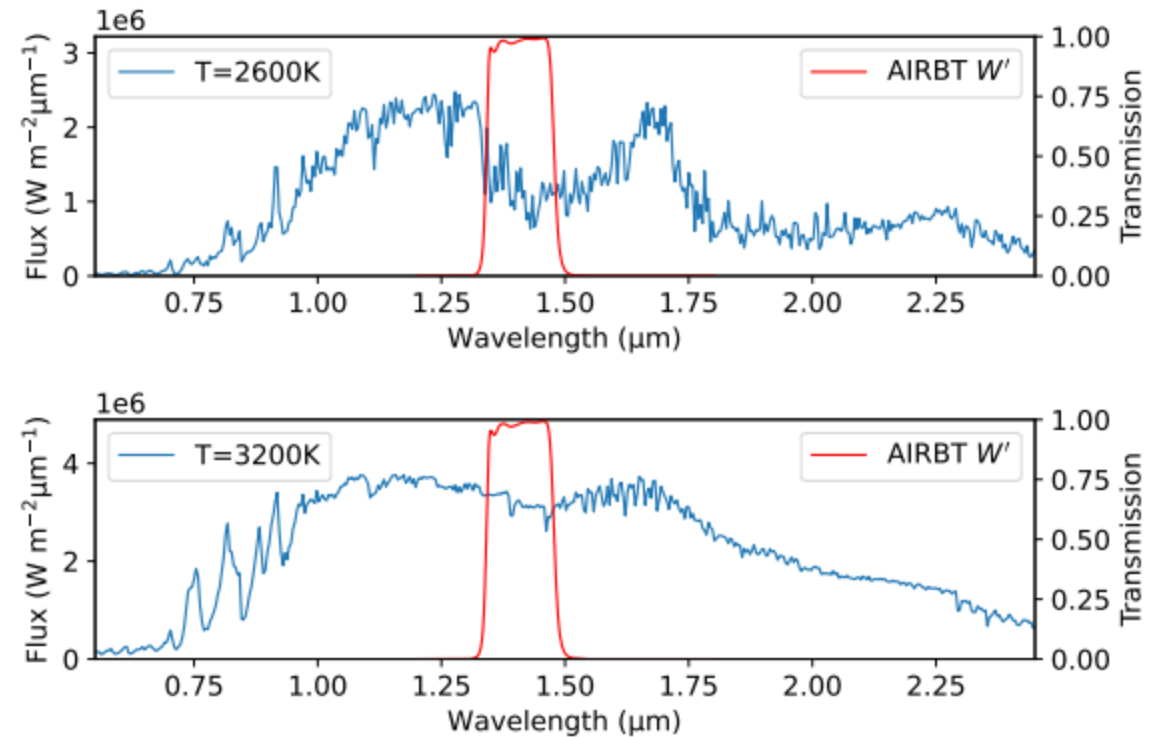
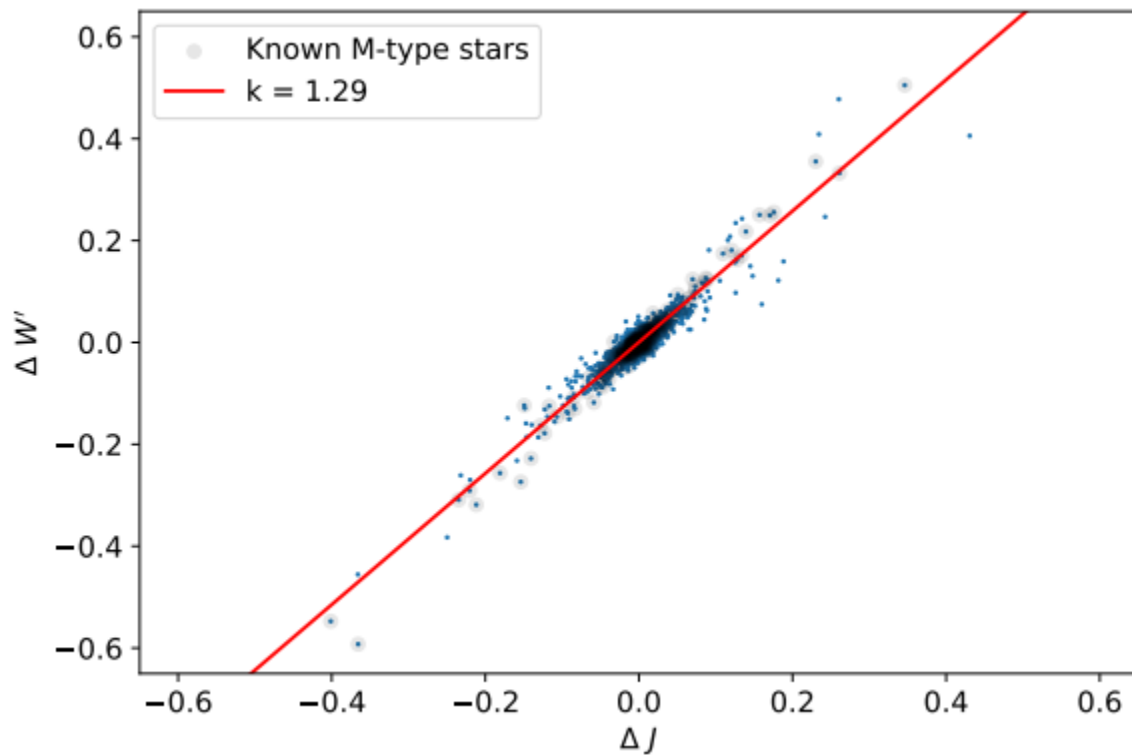
- Identify cool stars by water-vapor absorption feature from color-color diagram



- Later type, stronger absorption
- Large scatter: variability of flux, temperature, and spectral type

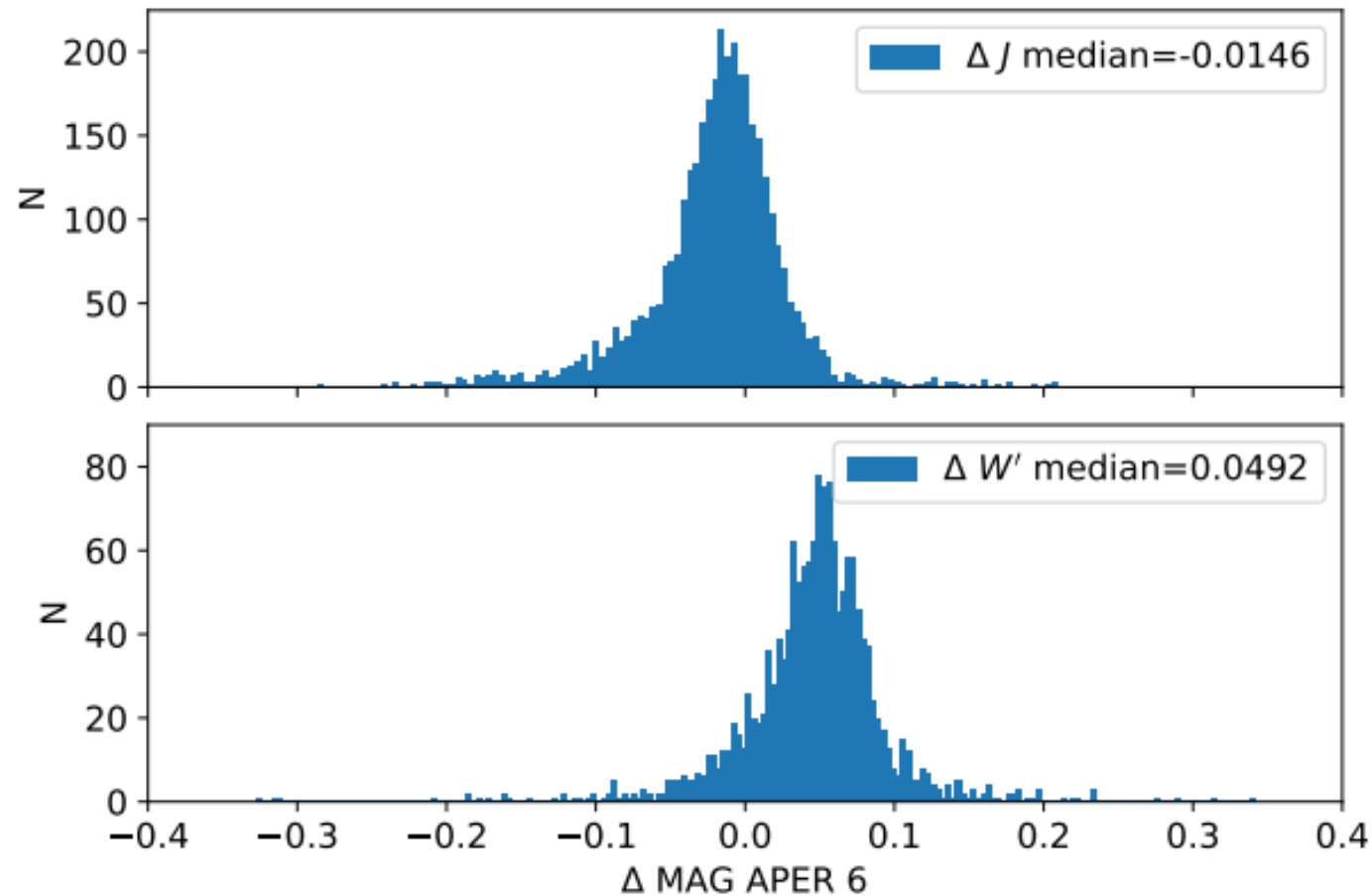


- Variability between J and W: $\Delta W \sim 1.3 \Delta J$
- Usually the longer the wavelength, the smaller variability
- Extra variability of W due to absorption variability



PHOENIX model

- **Stability of atmosphere transmission**
- **~ 5% between 16 March and 3 April**



5. Summary

- Extremely dry atmosphere at Dome A opens new windows (IR to THz) for ground-based telescope
- We designed a $1.4\ \mu\text{m}$ filter and installed it on AIRBT
- We surveyed $\text{Dec} = -61^\circ$ every day from 15 March to 23 April
- $J \sim 11.5$, $W \sim 10$ @ 2s
- Water-vapor absorption were detected
- Early Data Release is coming soon
- 40 cm telescope in 2027?
- **Collaborations on sciences are welcome**

