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

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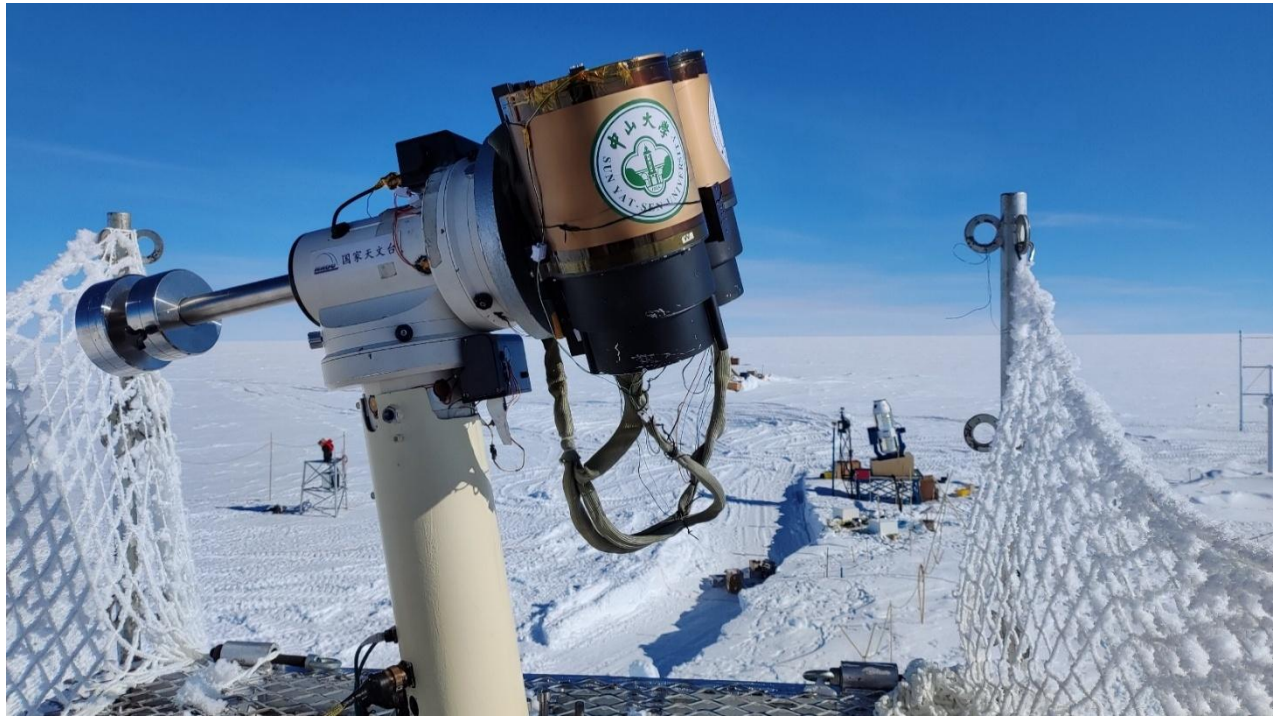
2025/10/17 @ SPHEREx thinkshop, SHAO

Outline

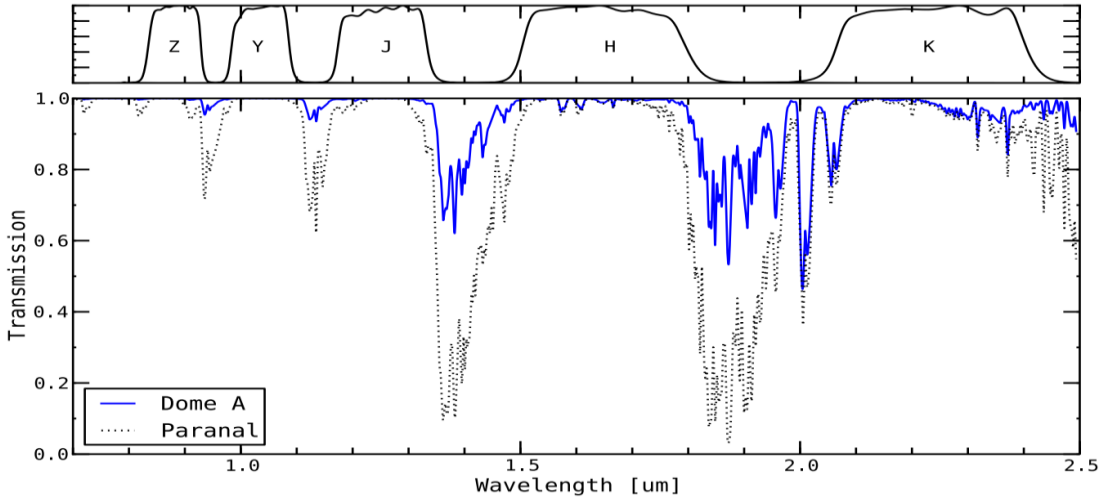
- 1. Introduction
- 2. Observations at Dome A
- 3. Data Reduction
- 4. Results
- 5. Collaboration with SPHEREx



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**

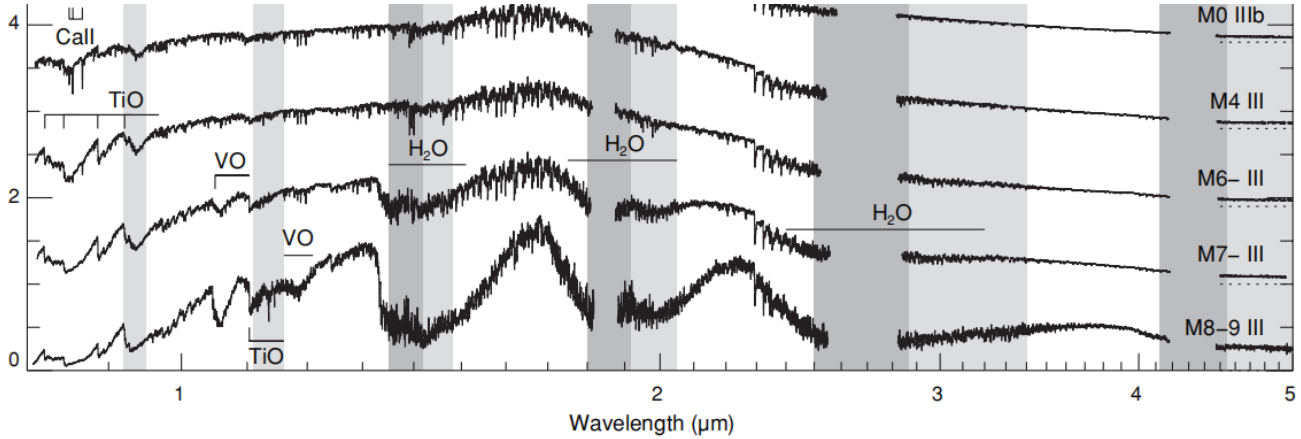


PWV Comparison at Dome A, Chajnantor, and Paranal

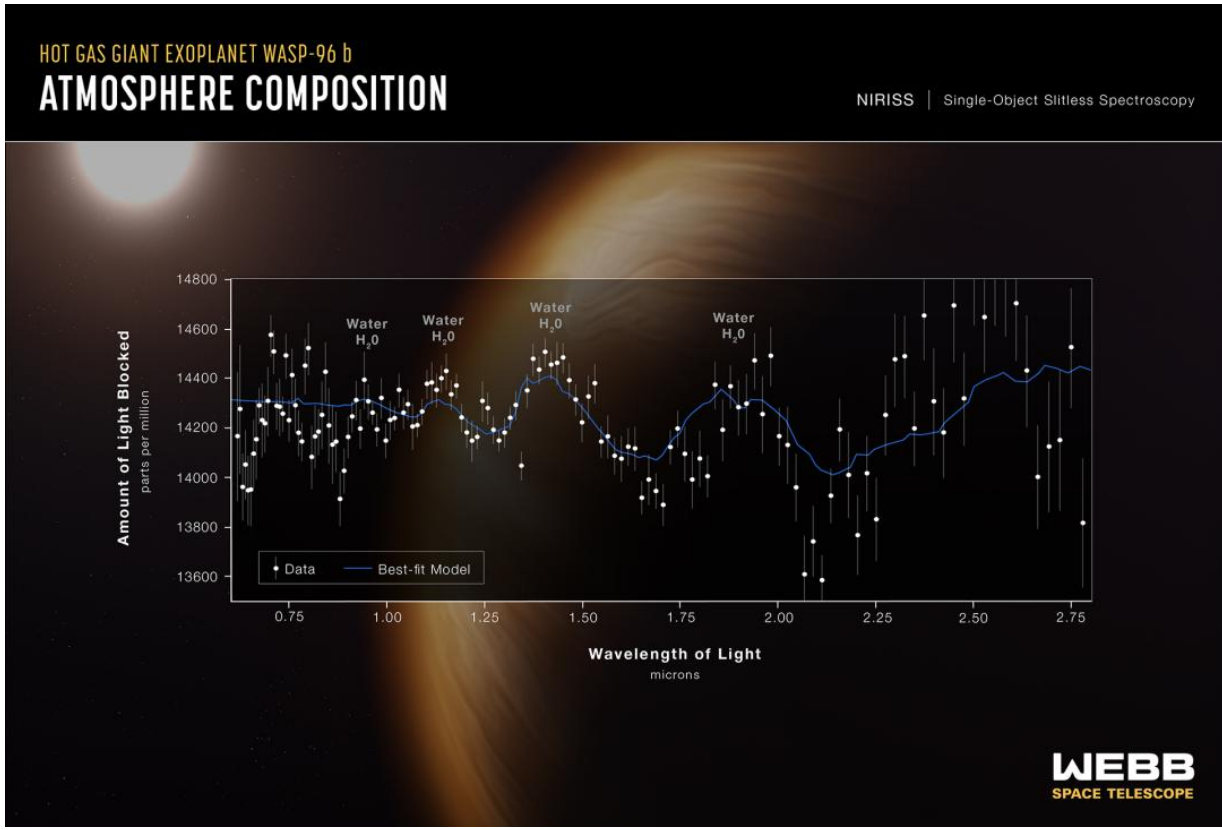
Site	Altitude (m)	Median (mm)	Best 25% (mm)	Best 10% (mm)
Dome A, Antarctica[a]	4083	0.13	0.09	0.06
Chajnantor, Chile[b]	5640	1.13	0.50	0.42
Paranal, Chile[c]	2635	2.30	1.60	1.07

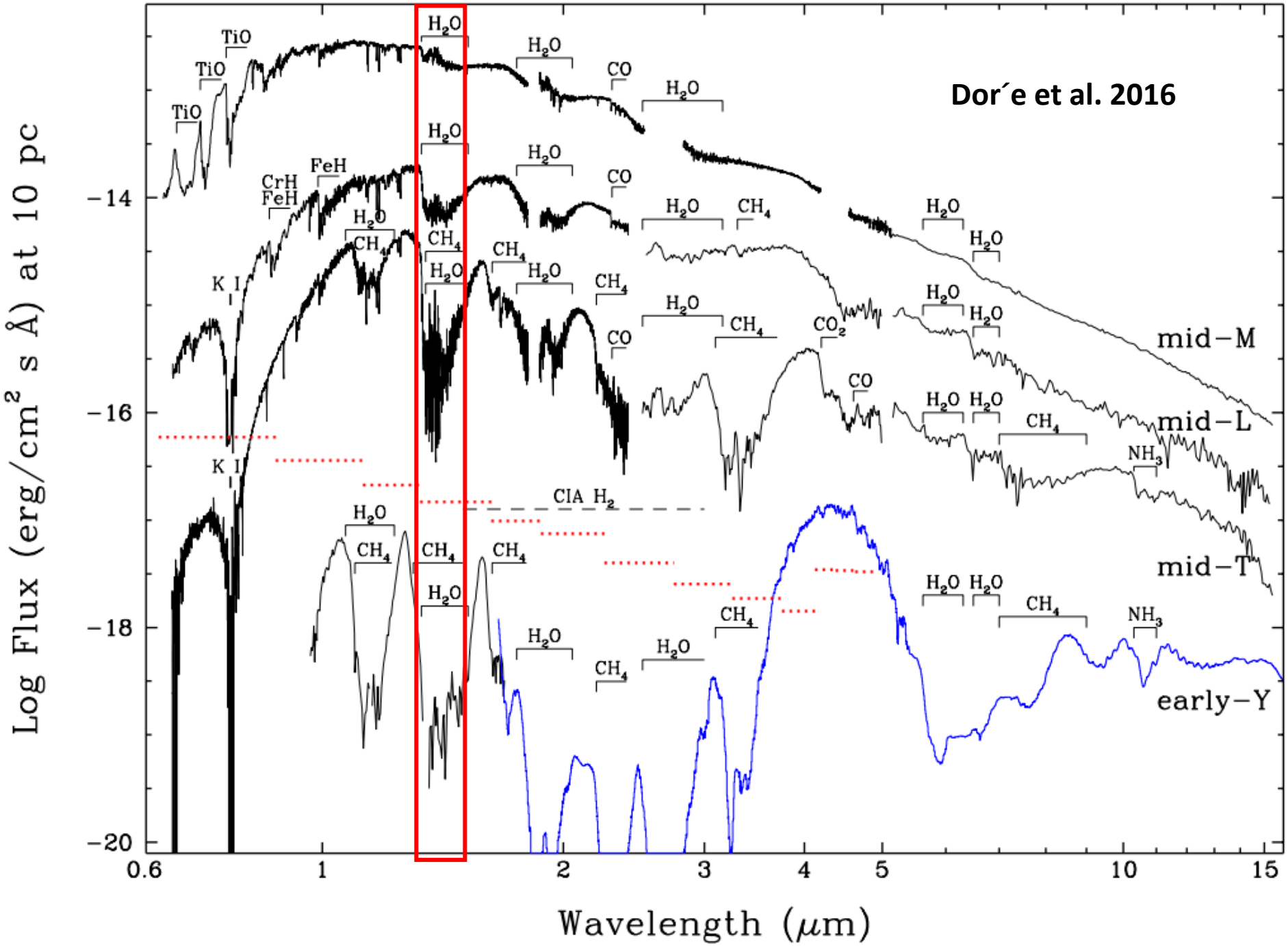
Sims et al. 2012

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

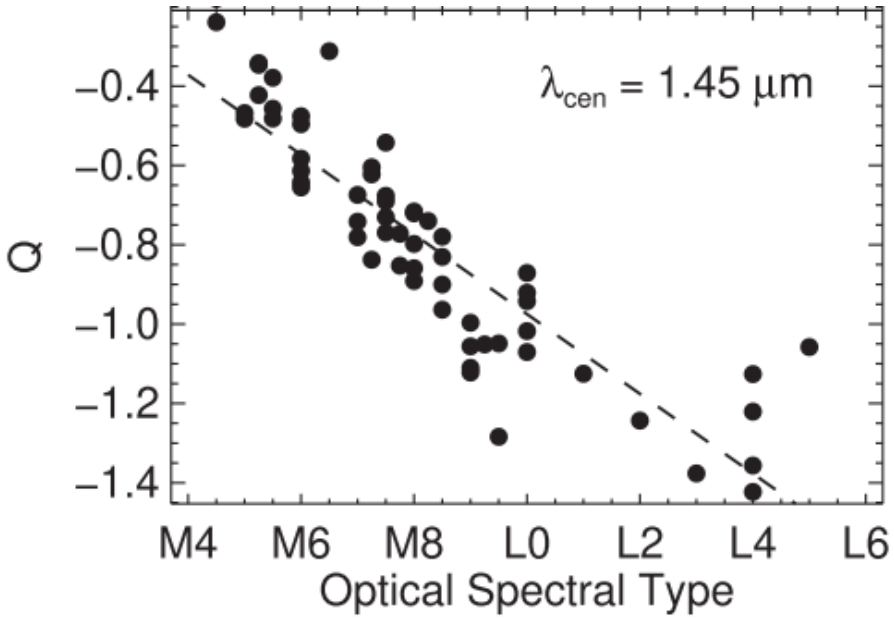


Rayner et al. 2009

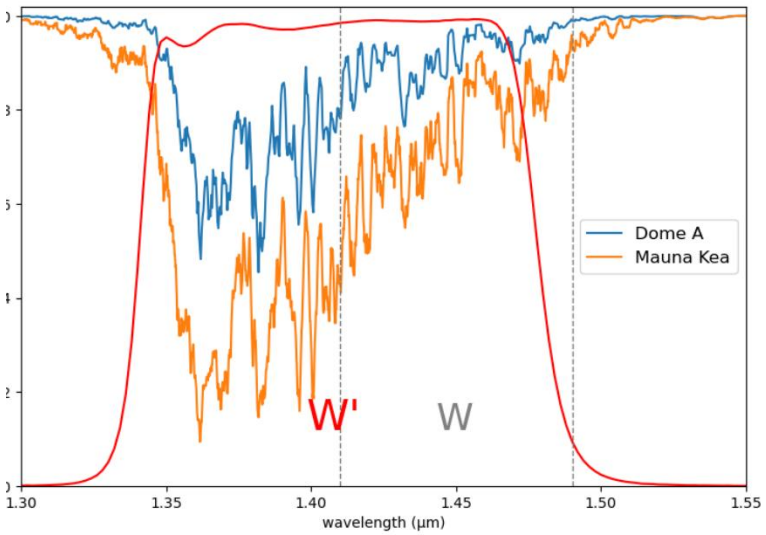



Dor´e et al. 2016
Log Flux (erg/cm^2 s Å) at 10 pc
Wavelength (μm)
mid−M
mid−L
mid−T
early−Y
TiO
CrH
FeH
K I
H$_2$O
CH$_4$
CO
CO$_2$
NH$_3$
CIA H$_2$
−14
−16
−18
−20
0.6
1
2
3
4
5
10
15

- **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† Δλ (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, H2O, CH4

JWST filters

2. Observations at Dome A

Antarctic IR Binocular Telescope (AIRBT)

(Dong et al. submitted)

Telescope

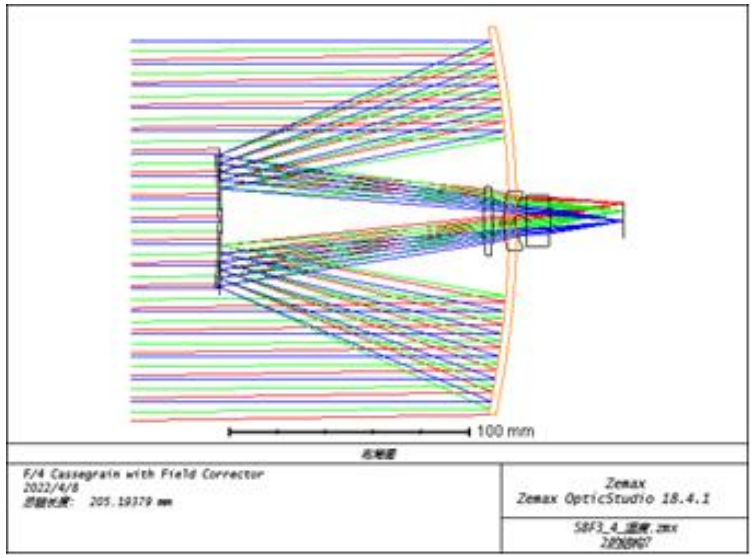
- D=15 cm， f/3
- JH filters
- FoV 1.2*1 deg^2
- 6.9”/pix

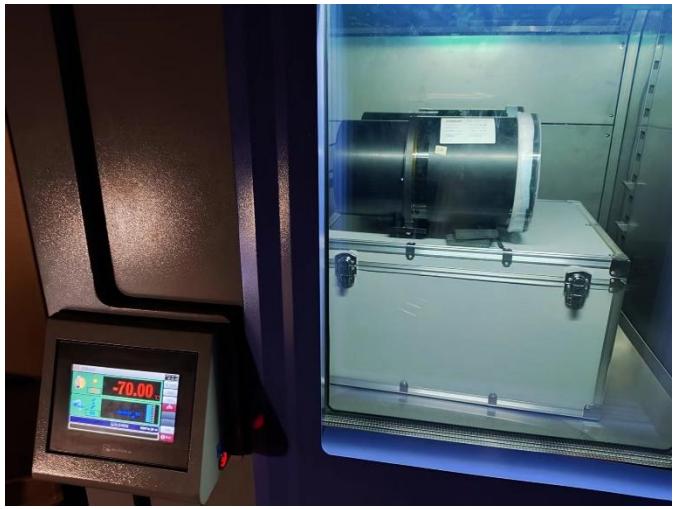
InGaAs cameras

- 640*512 pix
- Dark current 500 e/s/pix
- Full well 41, 100, 1000 ke
- Readout noise ~100 e

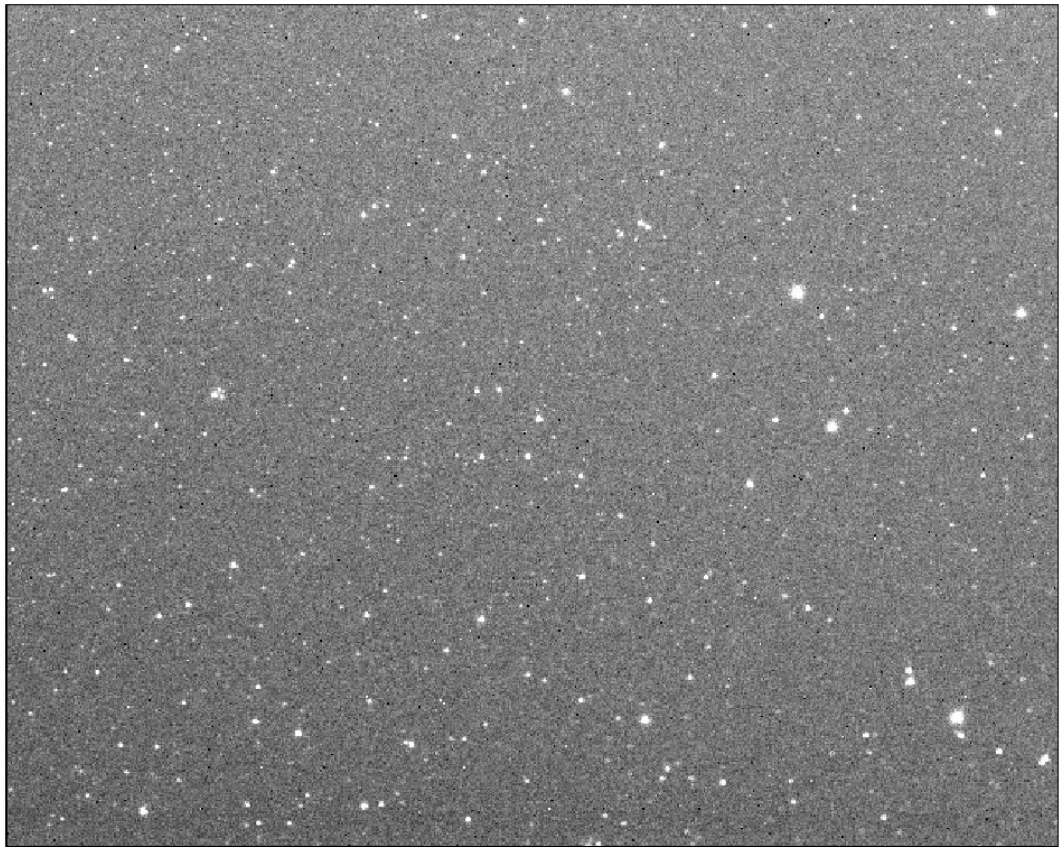
Goals

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





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



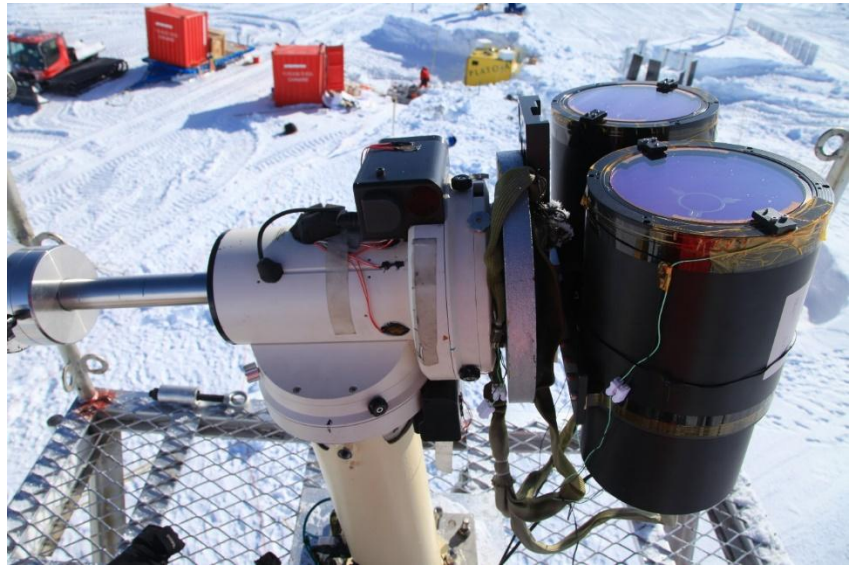
NGC 6871

Collaboration

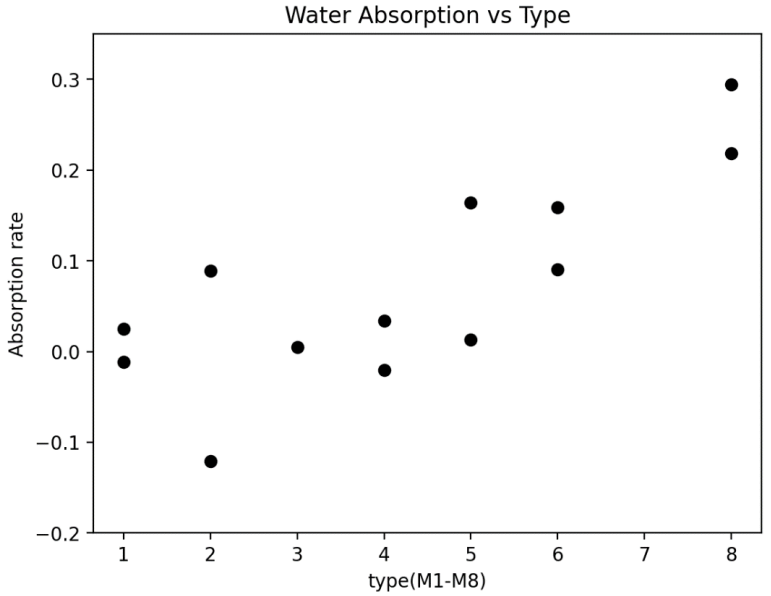
- SYSU: telescope & cameras
- NAOC: mount, control & data system
- UNSW: power & internet by PLATO-A

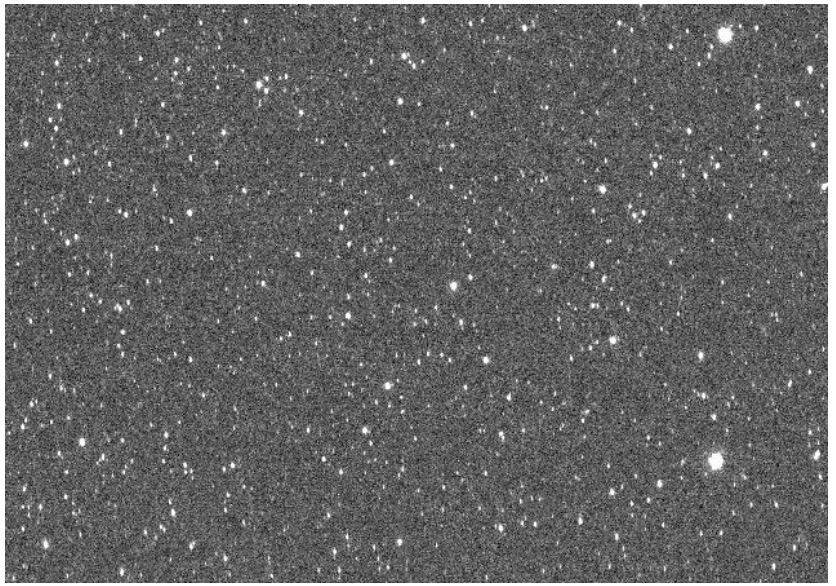
2023.1 installed at Dome A, J/H filters

2024.1 maintained



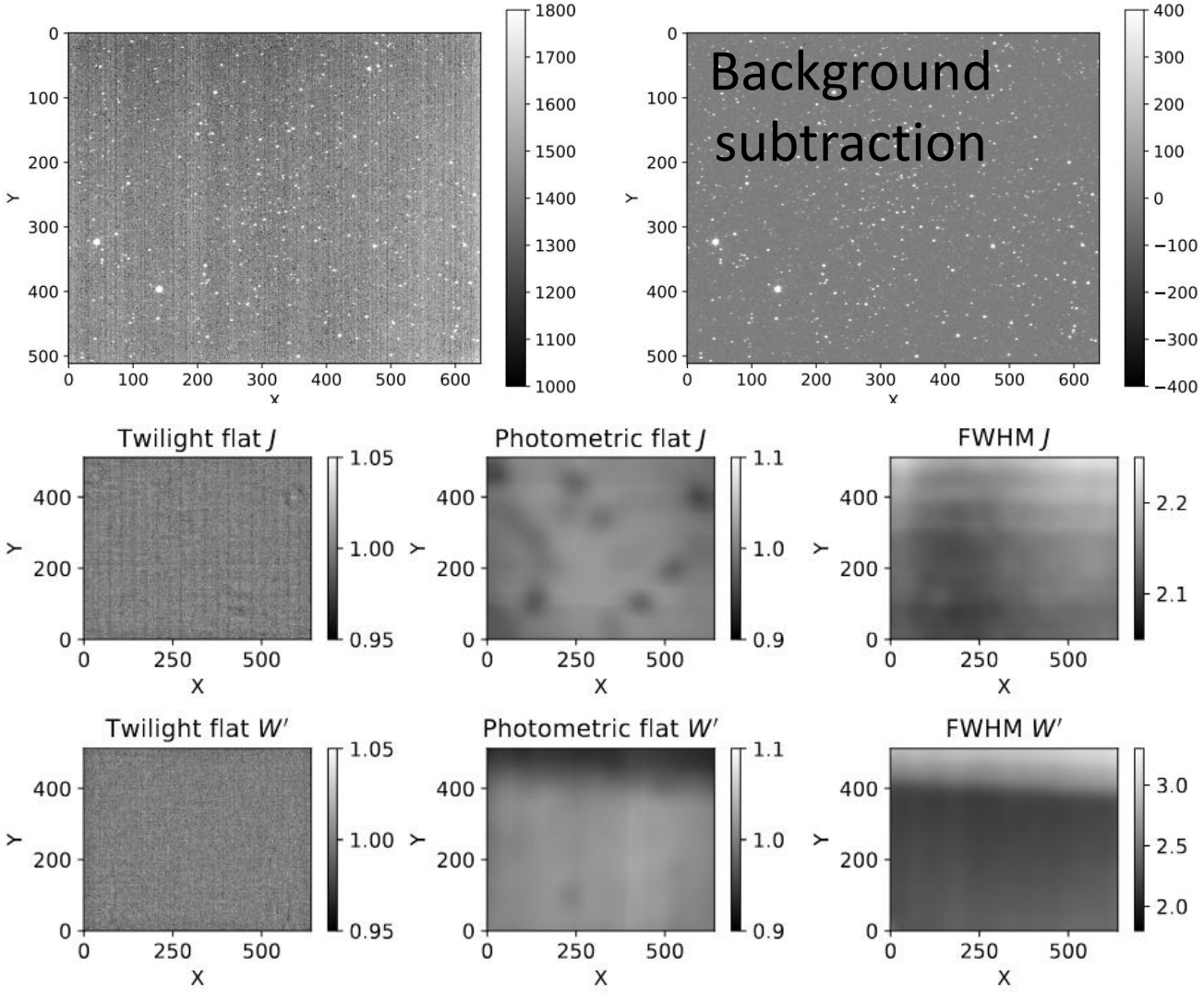
- **2025.1 replaced H with 1.4 μm filter (W) → J + W**
- **Daytime: bright stars**
- **Nighttime: survey Dec = -61°, Galactic plane**
- **Fixed pointing, 2 s exposures, FWHM ~ 2 pix**
- **Automatic observation until 23 April**

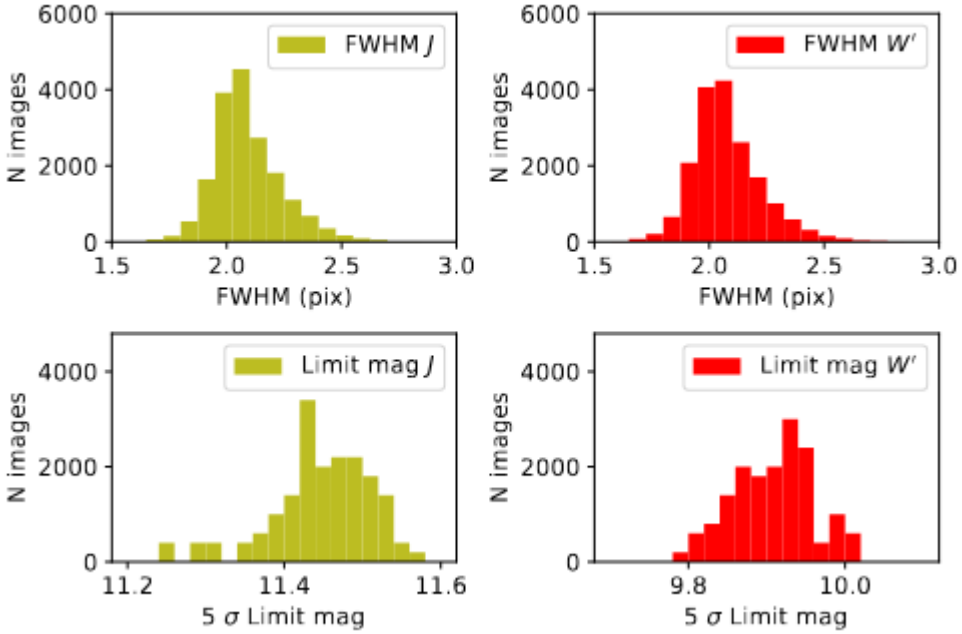




3. Data Reduction

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



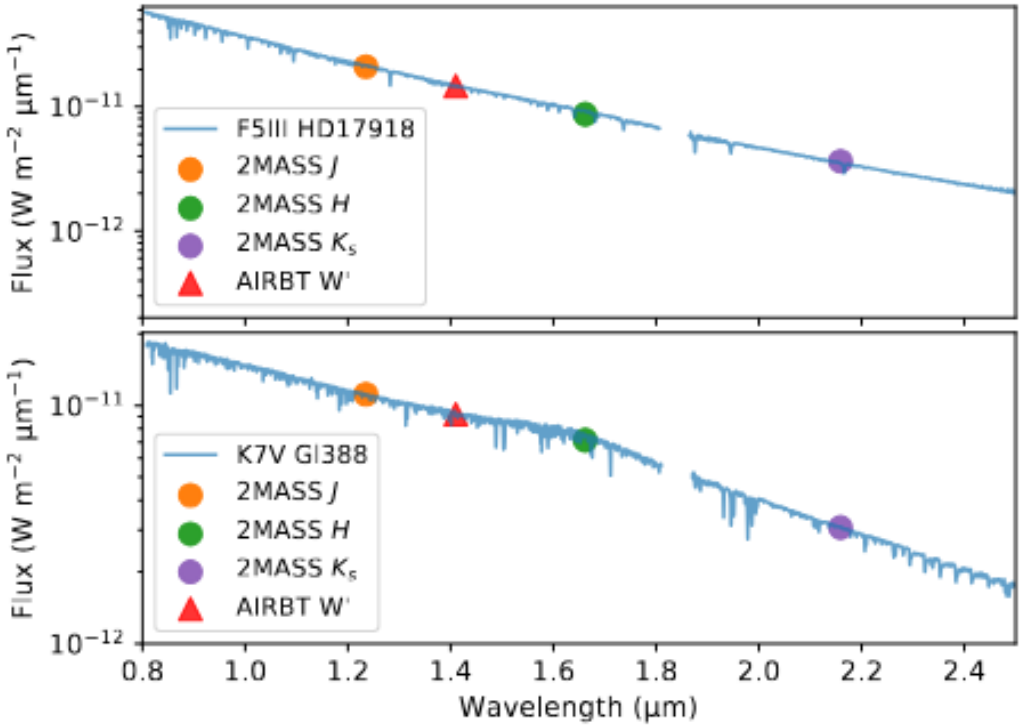


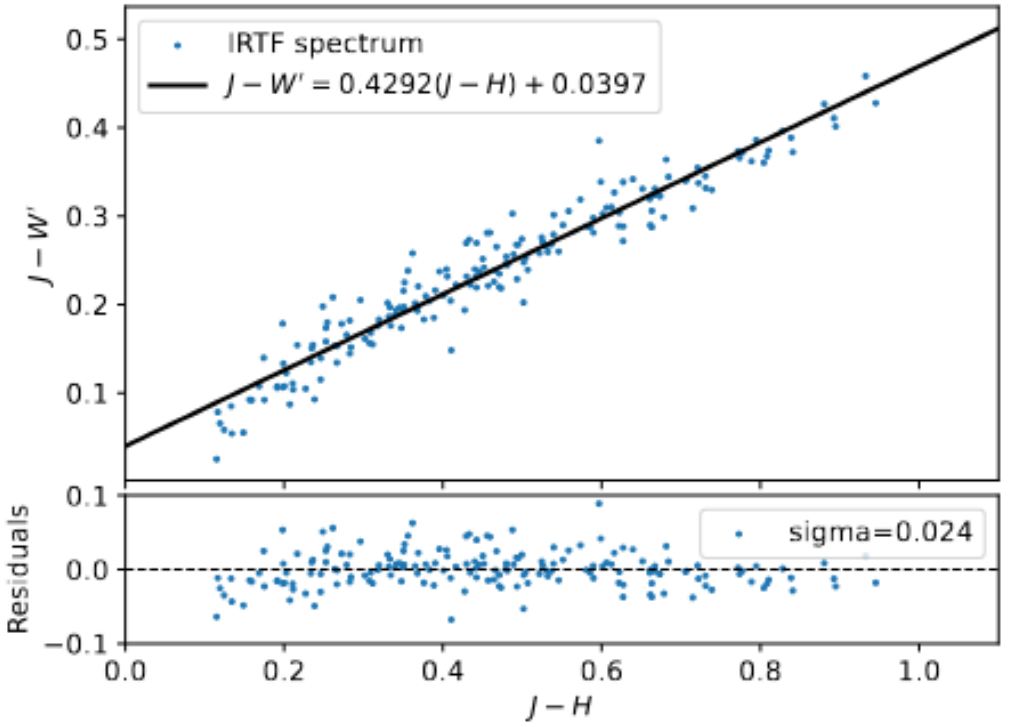
(Li et al. in prep)

Magnitude calibration

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

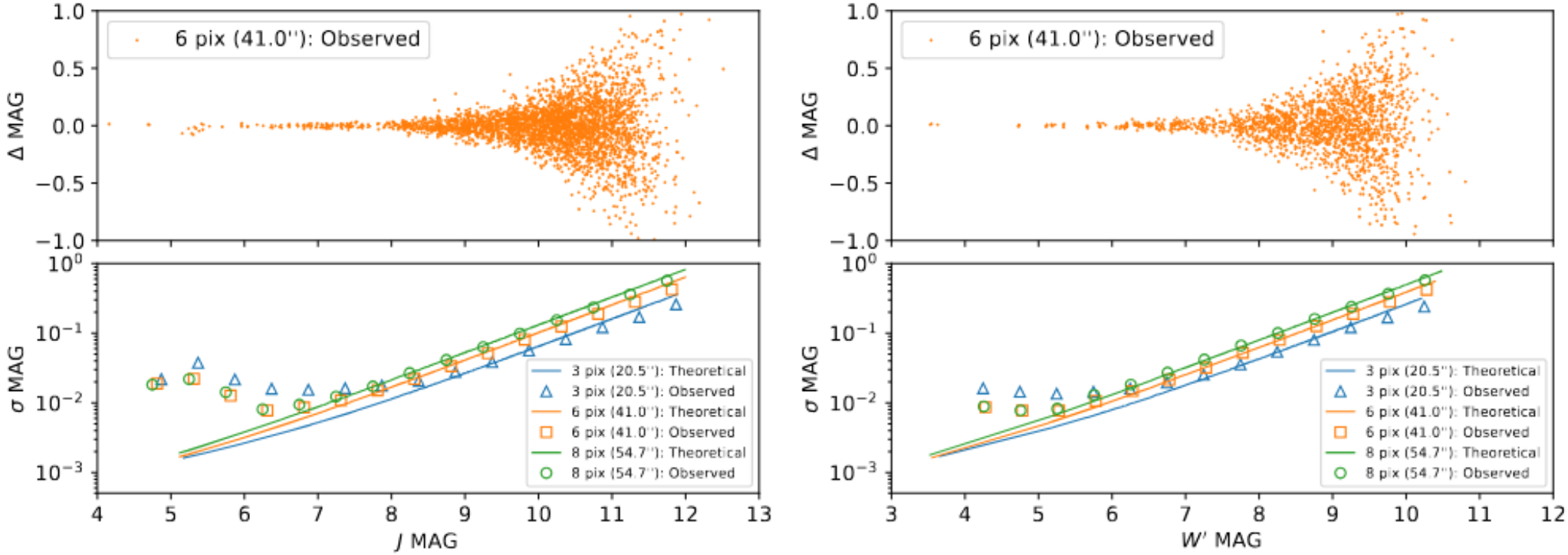
➢**Estimate W mag from J and H**





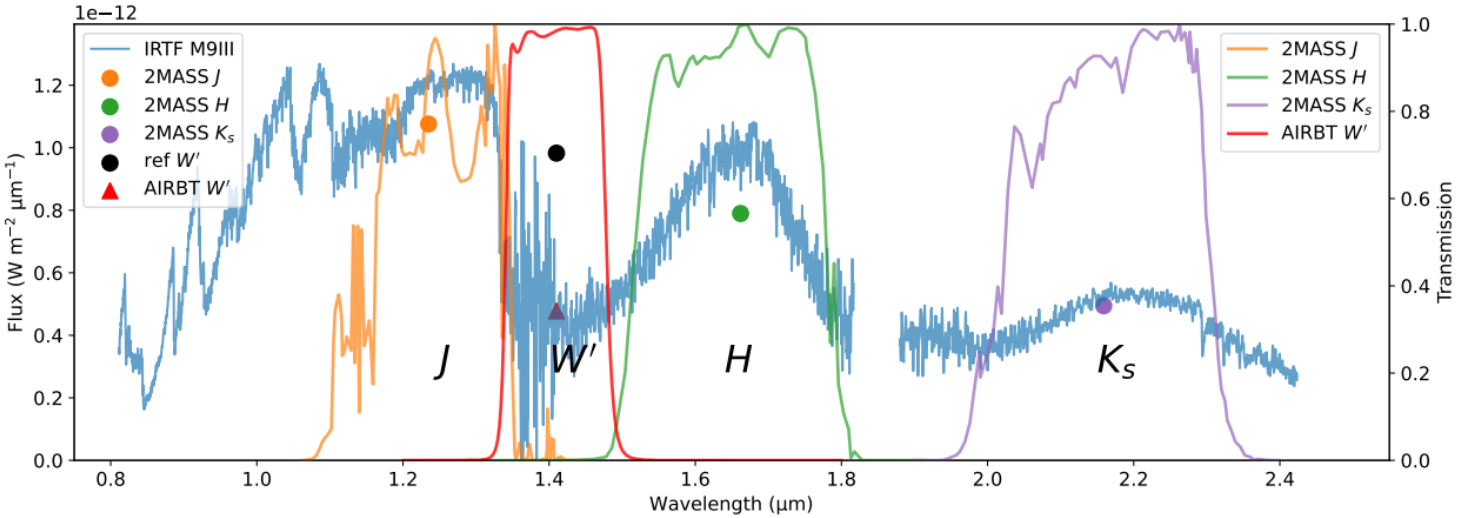
Single frame of 2 sec exposure

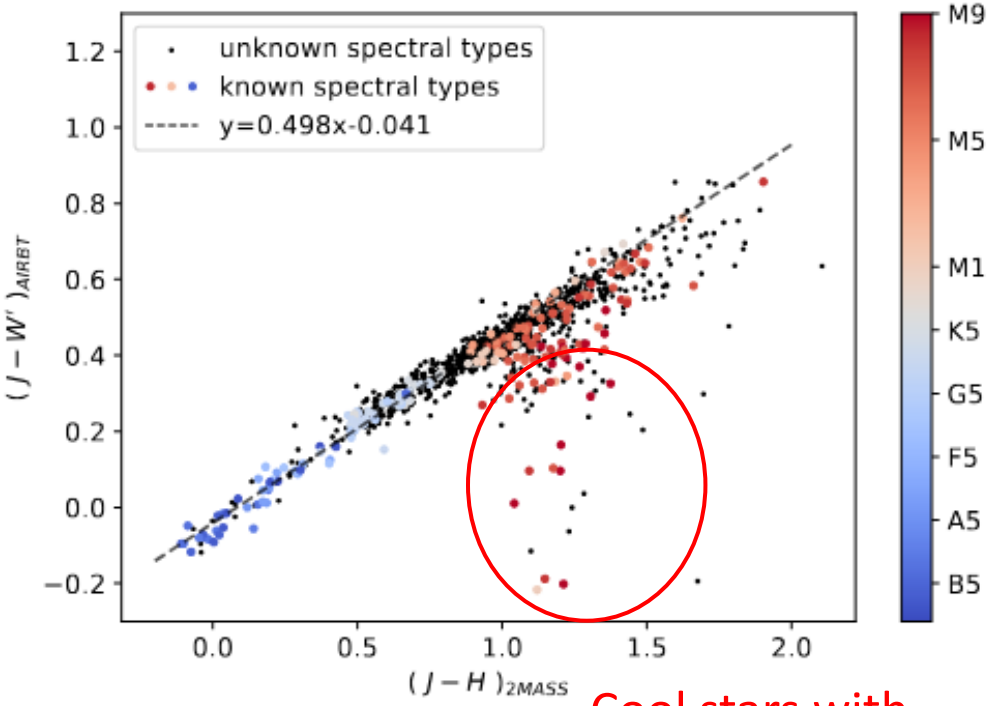
- **Limiting mag: J ~ 11.5, W ~ 10**
- **1% precision for bright stars**
- **Will be improved by image co-adding**



4. Results

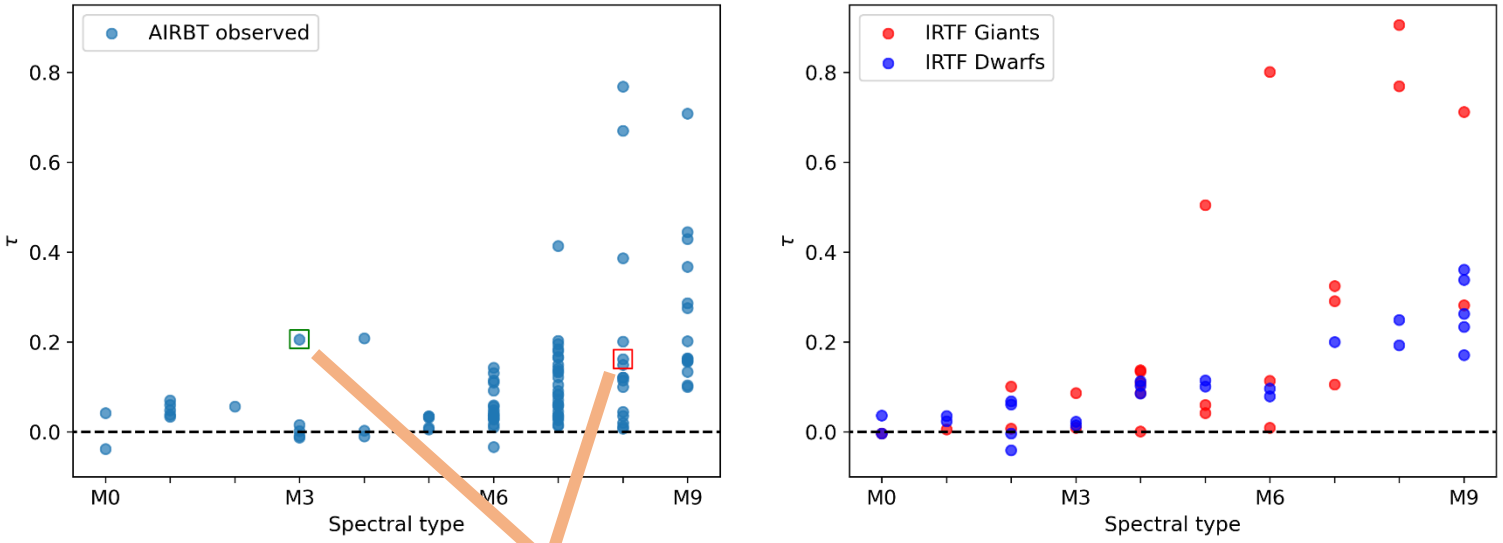
- **Identify cool stars by water-vapor absorption feature from color-color diagram**

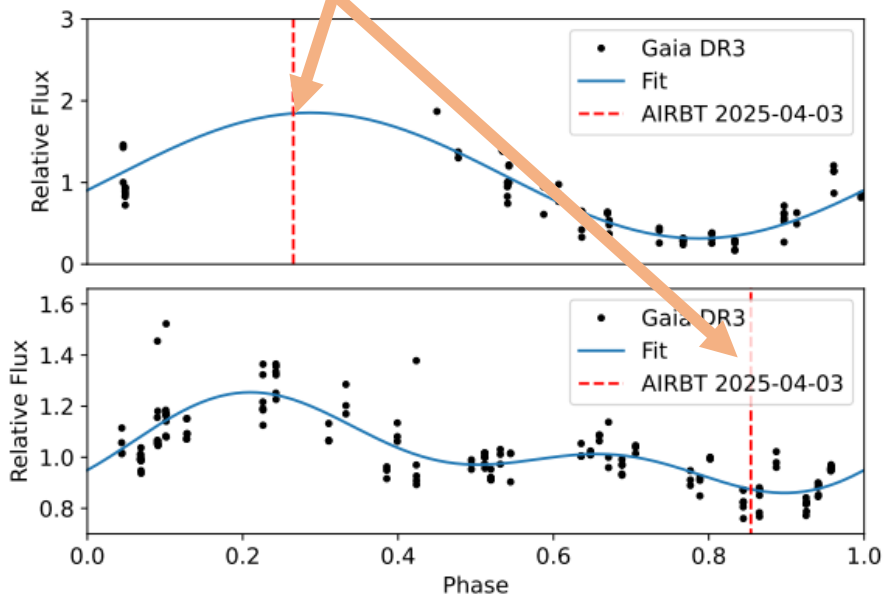




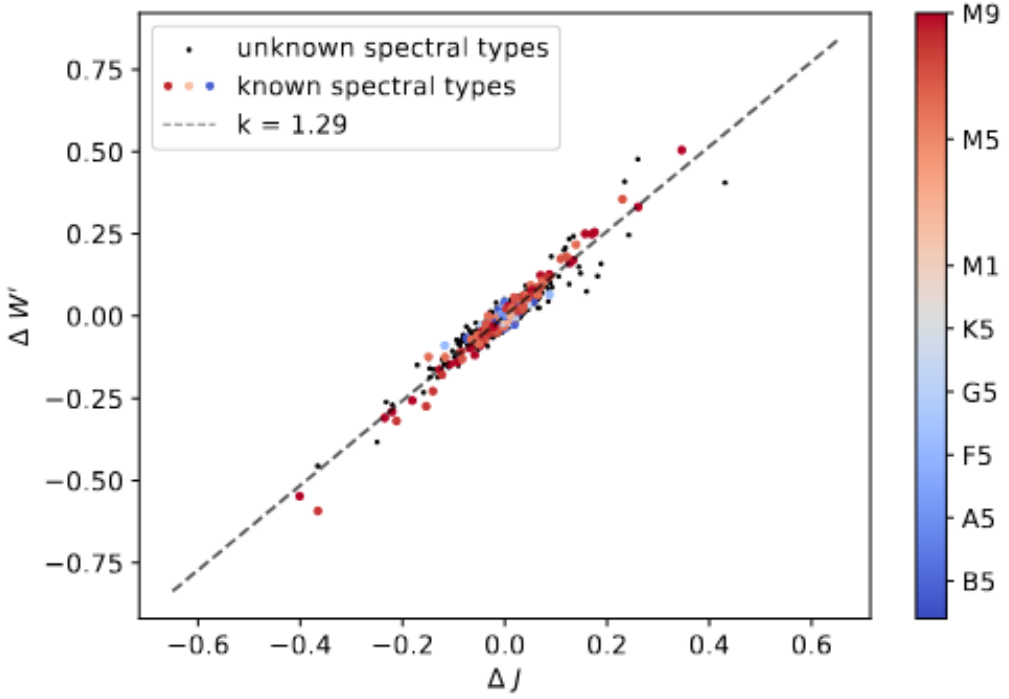
Cool stars with water vapor

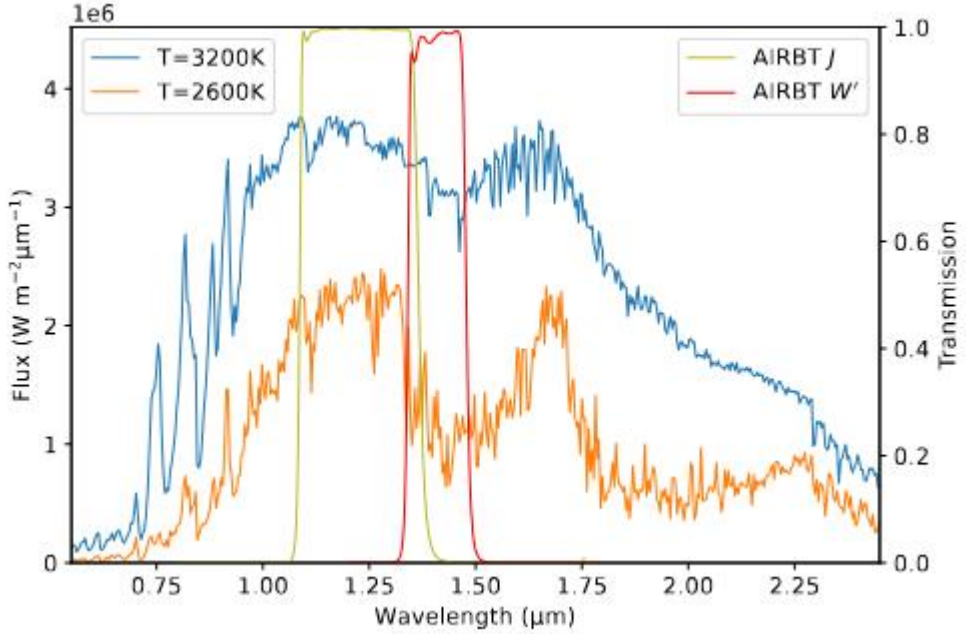
- Later spectral type, stronger absorption
- Large scatter: variability of flux, temperature, and spectral type
- To estimate spectral types via absorption





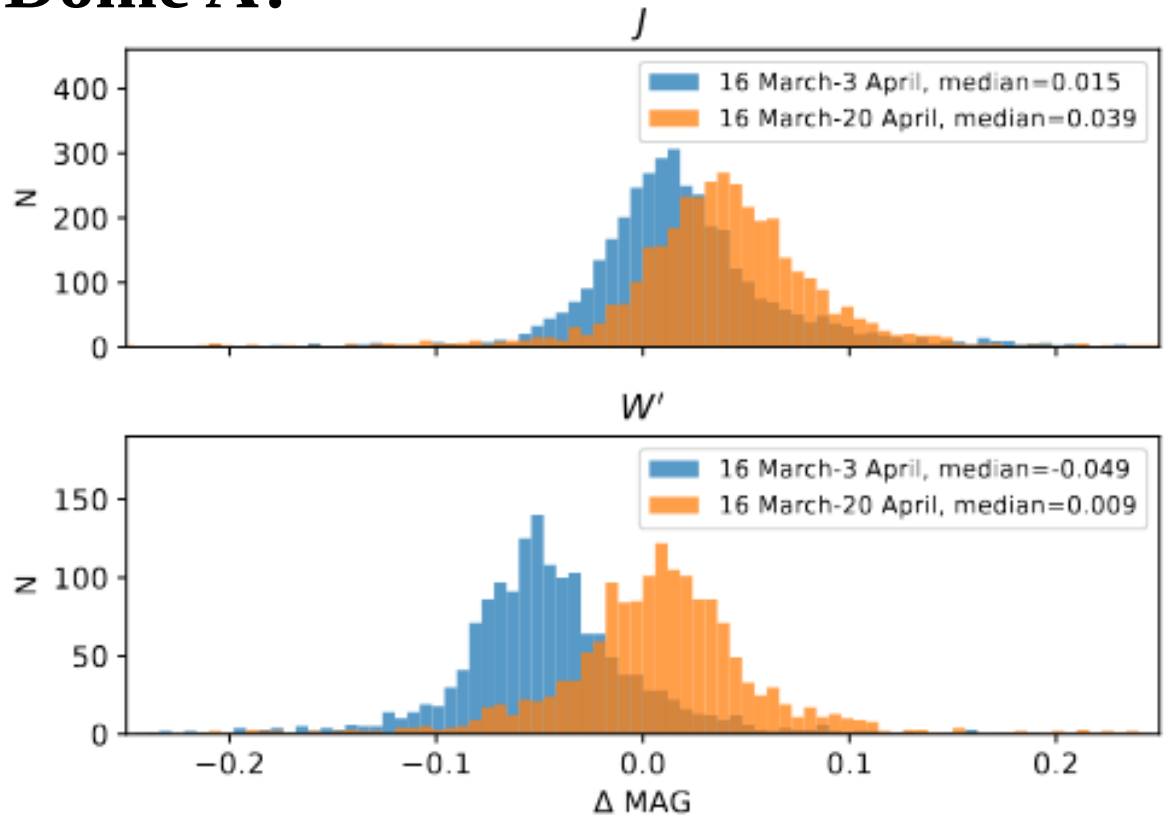
- 5% show significant variation (> 0.05 mag)
- Variability between J and W: $\Delta W \sim 1.3\,\Delta J$
- Usually the longer the wavelength, the smaller variability
- Extra variability of W due to absorption variability





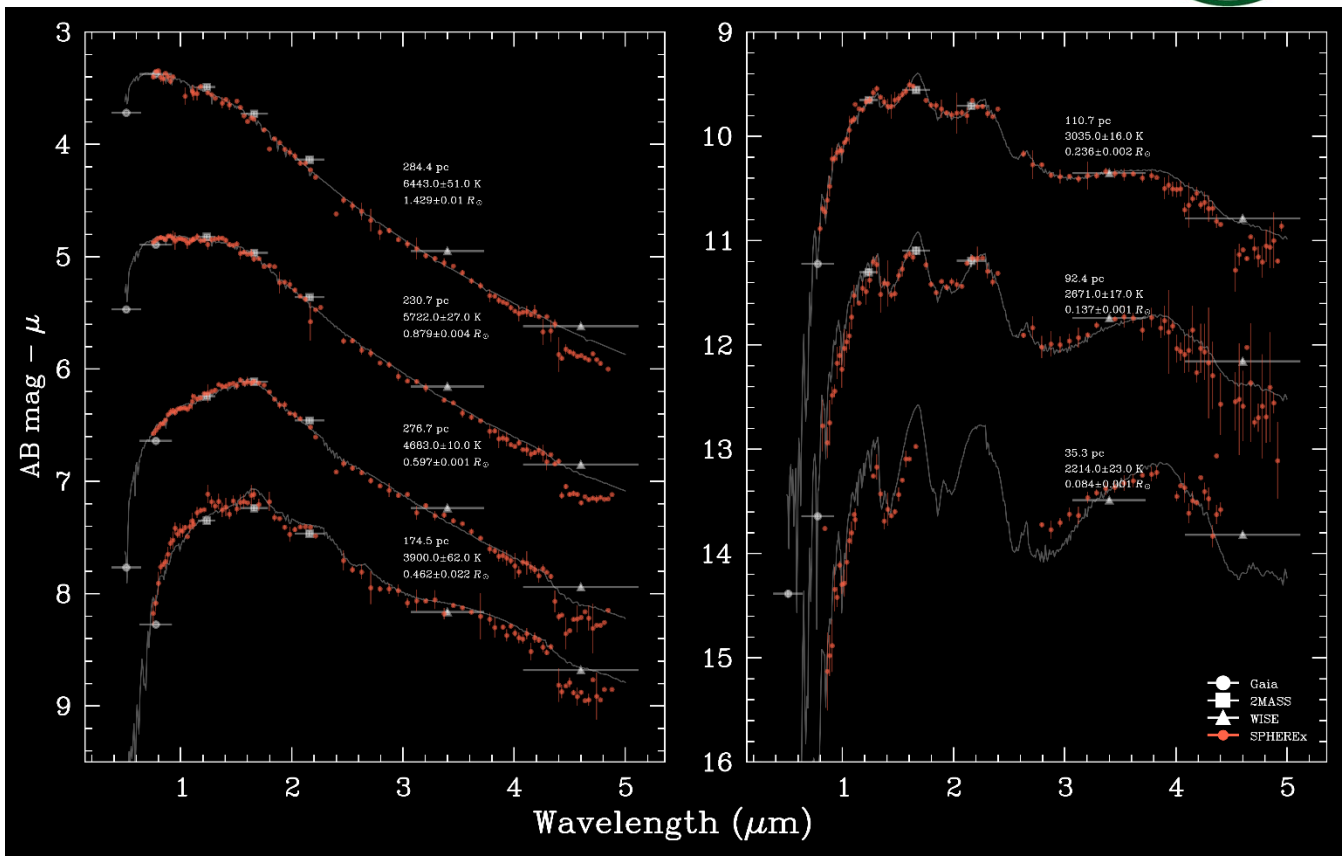
PHOENIX model

- **Stability of atmosphere transmission: < 5% daily variation**
- **Dome A is ideal for ground-based observations at 1.4 μm**
- **The possibility to detect water in the atmosphere of exoplanets with a 2-m IR telescope at Dome A?**



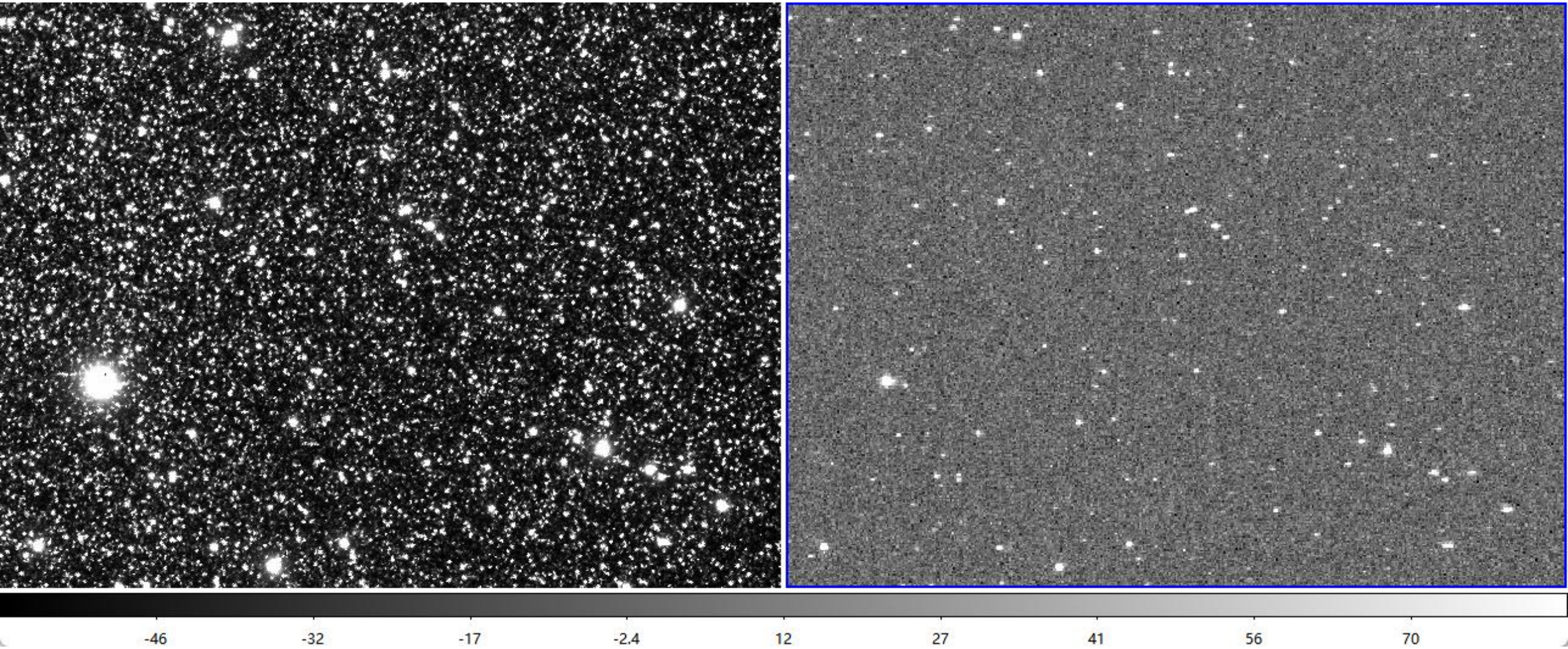
5. Collaboration with SPHEREx

- **Science: water**
- **Spectral from SPHEREx**
  - ➢ **To confirm candidates from AIRBT**
  - ➢ **To calibrate W mag of AIRBT**
- **SPHEREx will survey all sky**
- **But AIRBT could**
  - ➢ **Observe bright stars (< 10 mag)**
  - ➢ **Monitor the variability**
- **In the future at Dome A**
  - ➢ **40 cm IR telescope in 2027?**
  - ➢ **1 m IR telescope in 2030s?**
  - ➢ **Higher resolution**
- **80 cm IR telescope at Lenghu for the north sky**



From Akeson's PPT

Thank you!



SPHEREx

AIRBT