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HARVARD & SMITHSONIAN



# TARdYS

an Upcoming Exoplanet Hunter  
in Southern Hemisphere

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Prof. Leonardo Vanzi



PIs

Prof. Kentaro Motohara

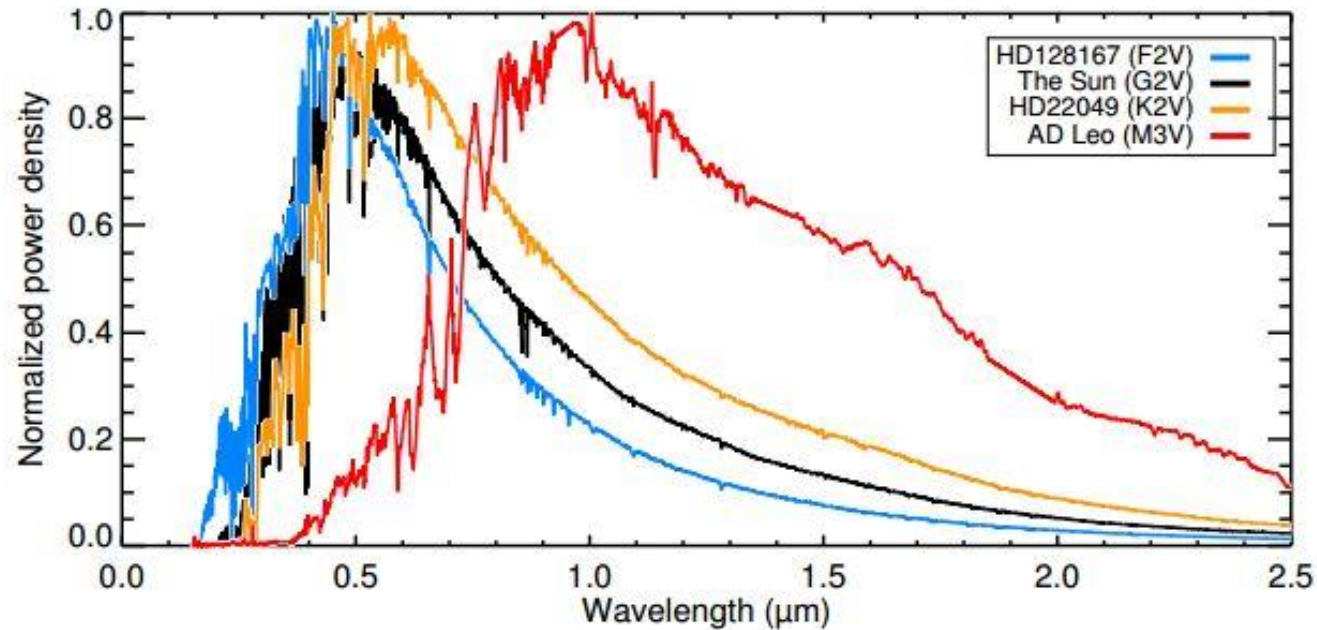
# OVERVIEW

- Project Motivation
- TAO: The University of Tokyo Atacama Observatory
- TARdYS: Tao Aiuc high Resolution d Y band Spectrograph
  - Design and Prototype
  - Current Status
- What's next?



Team AIUC

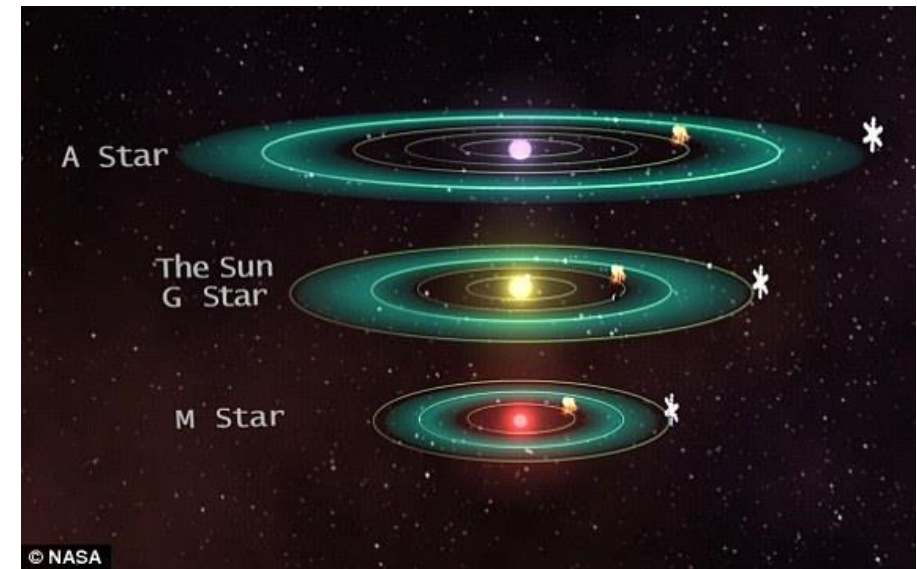
To detect M-stars in Y band, we need resolution of **60,000** (Reiners et al. 2010)



Shields et al. (2013).

Resolution	S/N				RV precision ( $\text{m s}^{-1}$ )			
	V	Y	J	H	V	Y	J	H
Spectral-type M3								
60000	50	100	101	95	3.6	5.7	22.9	10.0
80000	43	86	87	82	2.9	4.4	18.1	8.4
100000	39	77	78	74	2.5	3.8	15.5	7.6
Spectral-type M6								
60000	20	100	114	107	4.7	3.8	11.2	9.7
80000	18	86	99	93	3.7	3.0	8.8	7.8
100000	16	77	88	83	3.2	2.6	7.5	6.9
Spectral-type M9								
60000	12	100	134	128	8.0	2.2	4.6	4.0
80000	10	86	116	111	6.2	1.7	3.5	3.5
100000	9	77	104	99	5.3	1.5	2.9	3.3

Reiners et al. 2010



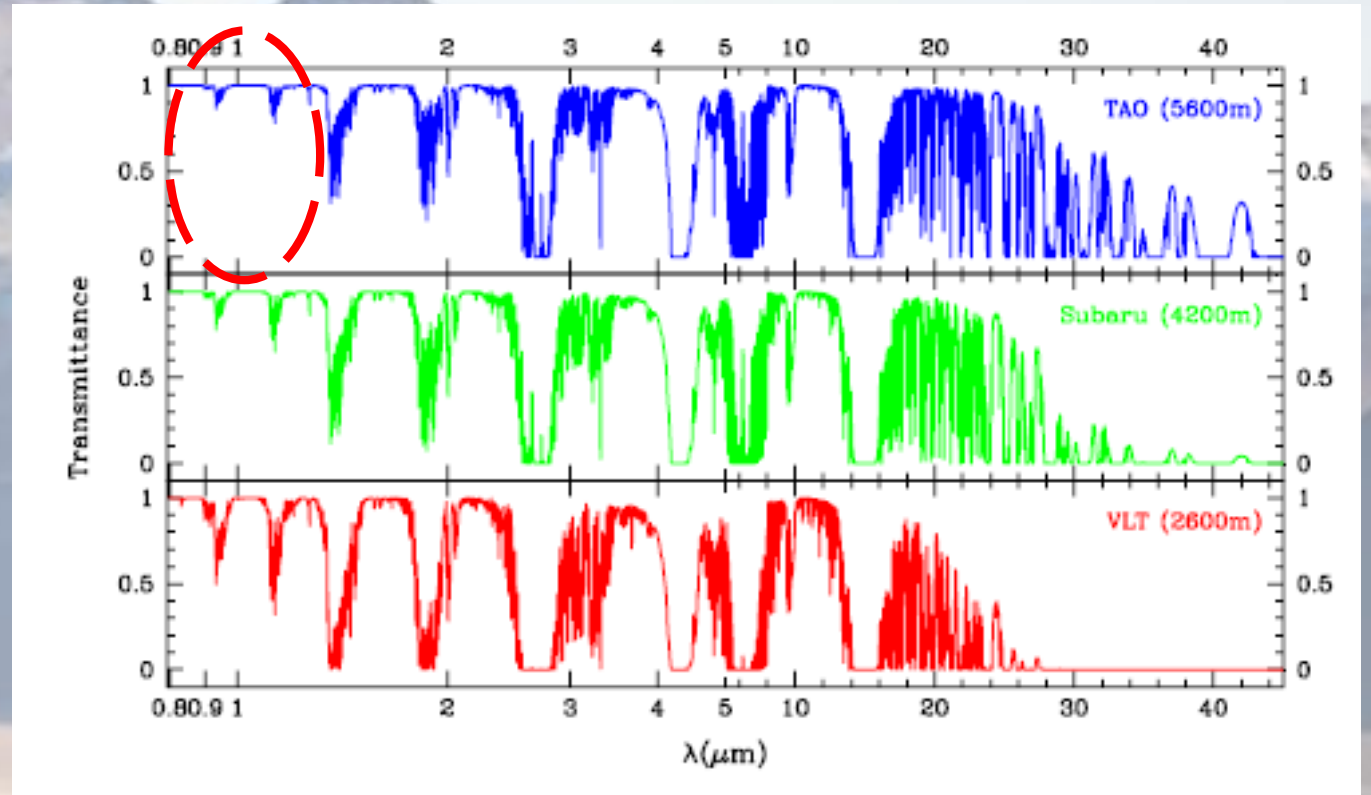
Instrument	Coverage	Resolution	Telescope
UPF	1-1.75 $\mu\text{m}$	R=70,000	UKIRT 4m
NIRSPEC	1-5.5 $\mu\text{m}$	R=25,000	Keck 10m
GIANO	0.9-2.5 $\mu\text{m}$	R=46,000	TNG 4m
FIRST	1.3-1.8 $\mu\text{m}$	R=50,000	ARC 3.5m
WINERED	0.9-1.35 $\mu\text{m}$	R~100,000	??
<b>CARMENES</b>	0.9-1.75 $\mu\text{m}$	R~80,000	Calar Alto4m
<b>SPIRou</b>	0.98-2.35 $\mu\text{m}$	R~70,000	CFHT 3.6m
<b>IRD</b>	0.97-1.75 $\mu\text{m}$	R~70,000	Subaru 8m
<b>HPF</b>	0.85-1.7 $\mu\text{m}$	R~60,000	HET 10m

Instrument	Coverage	Resolution	Telescope
PHOENIX	1-5 $\mu\text{m}$	R=70,000	Gemini 8m
IGRINS	1.5-2.5 $\mu\text{m}$	R~45,000	Gemini 8m
<b>CRIRES+</b>	1-5 $\mu\text{m}$	R=100,000	VLT 8m
<b>NIRPS</b> (upcoming)	0.97 – 1.8 $\mu\text{m}$	R=80,000	ESO 3.6 m
<b>TARdYS</b> (upcoming)	<b>0.84-1.12 <math>\mu\text{m}</math></b>	<b>R~66,000</b>	<b>TAO 6.5m</b>

(Pepe et al. Nature, 2014), (Moorwood et al., 2003), (Gennari et al., 2006), (Artigau É. et al. 2014), (Yuk et al., 2010), (Quirrenbach et al., 2014), (Mahadevan et al., 2010), (Tamura M. et al. 2012)

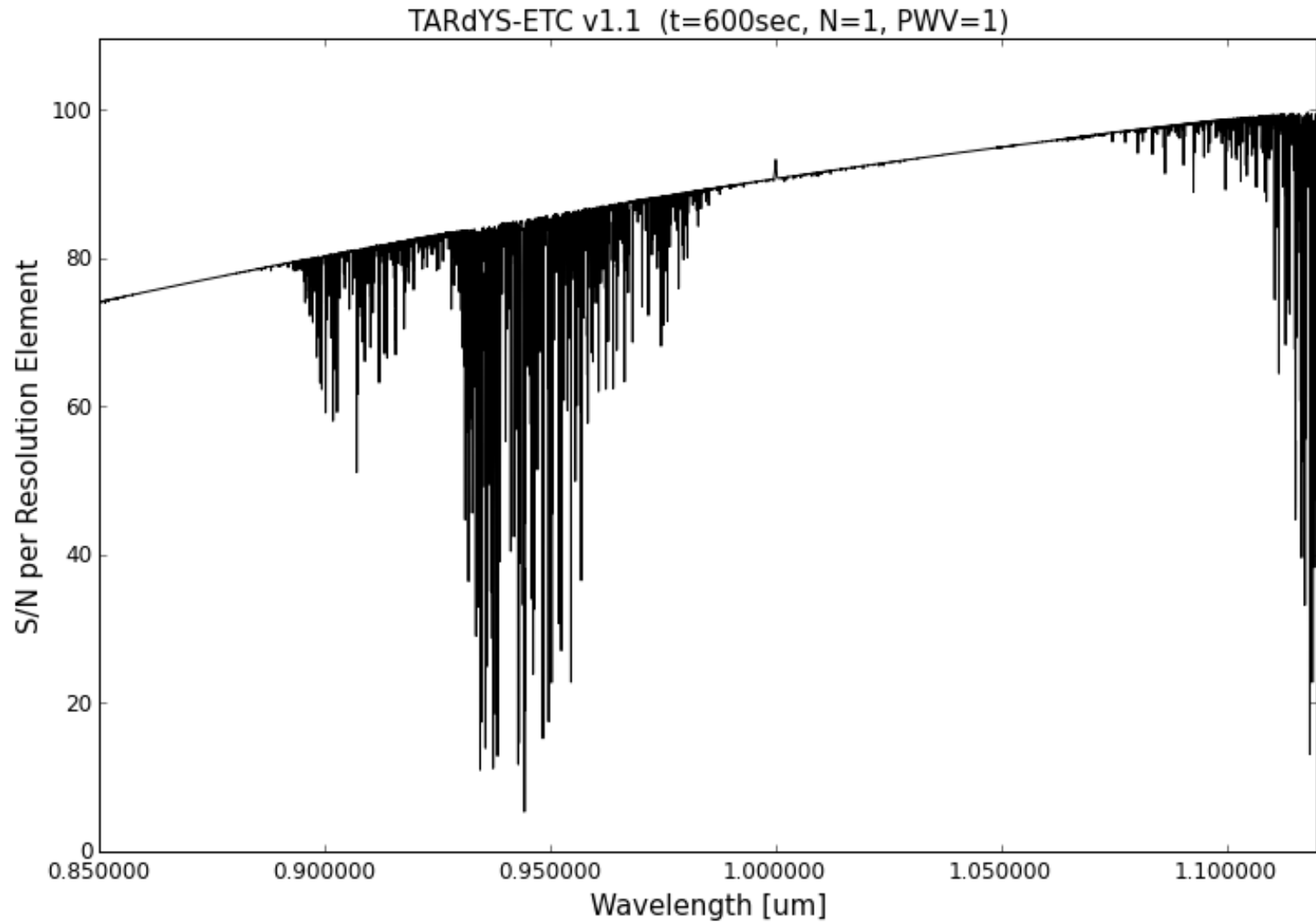
# Technological Motivation

- IR-Optimized 6.5 m telescope
- Cerro Chajnantor (5,640 m)
- Excellent site conditions
  - High clear fraction
    - 82% photometric
  - Good seeing
    - median 0.69" @ V-band
  - Low water vapor
    - PWV: 0.85 mm median



Y. Yoshii, 2010  
Credit: ESO

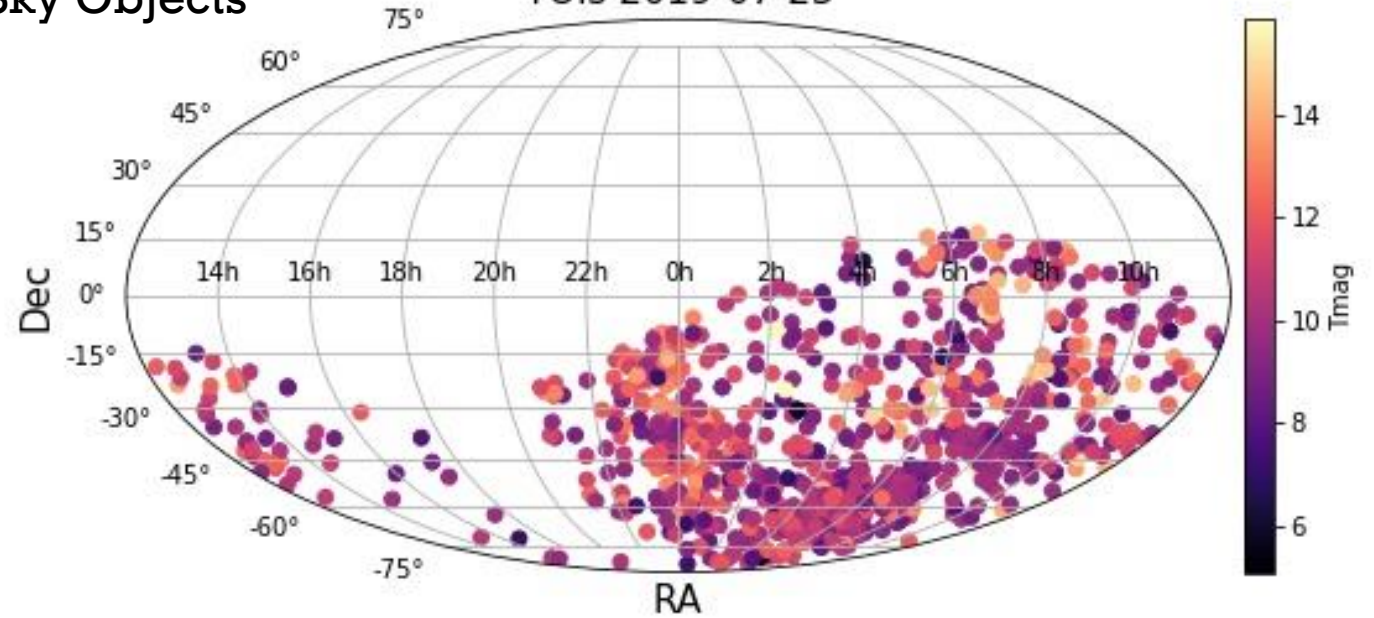
# Sensitivity Simulation



- Source: Blackbody
- Atmospheric Transmission
- OH Emission Lines
- Background Emission
- System Throughput + Noise

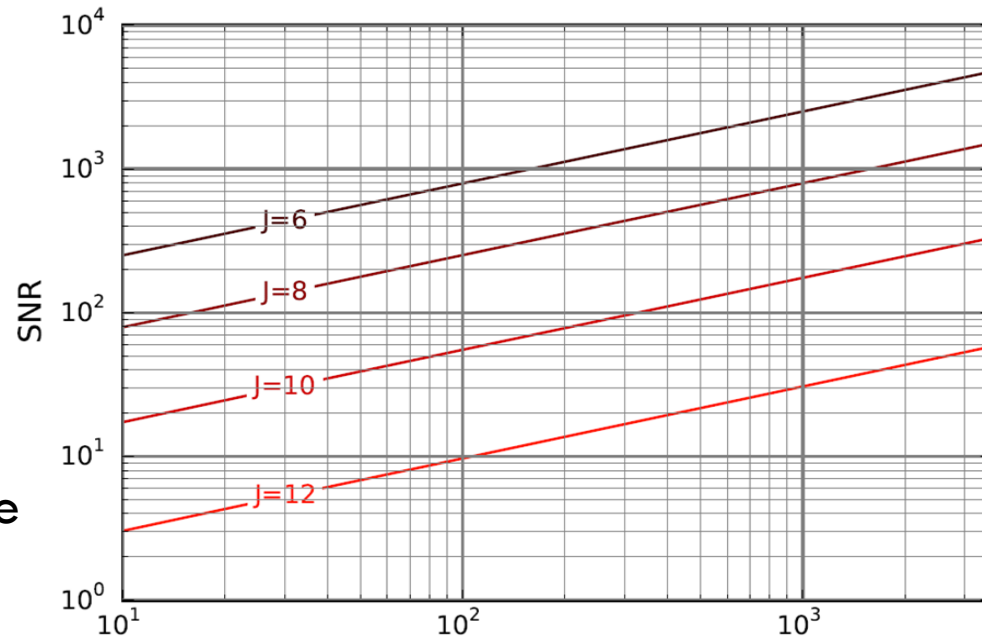
# TESS Southern Sky Objects

TOIs 2019-07-23



Follow up  
Opportunity

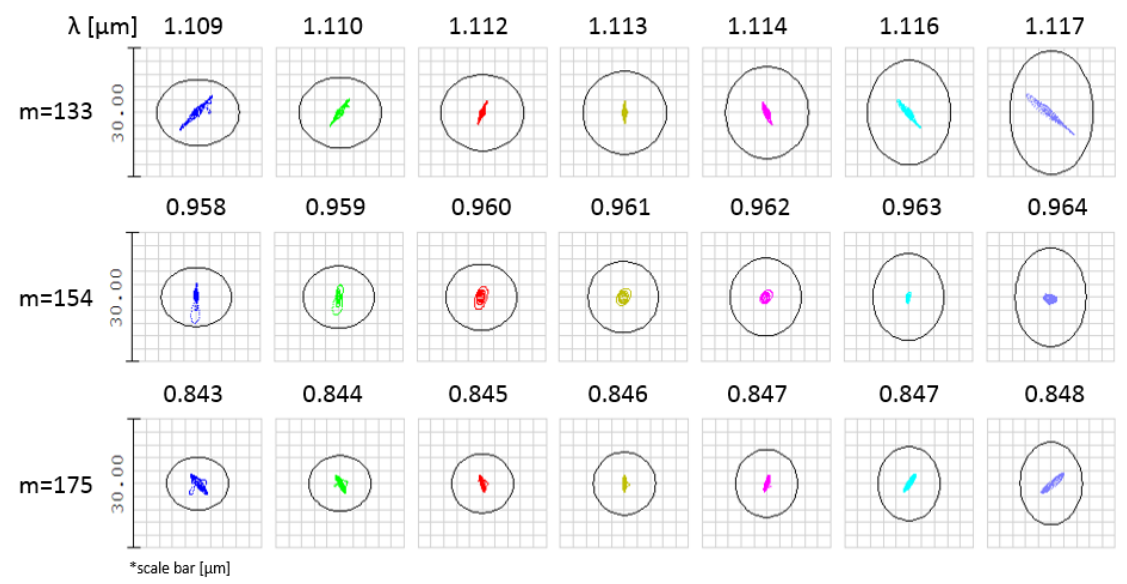
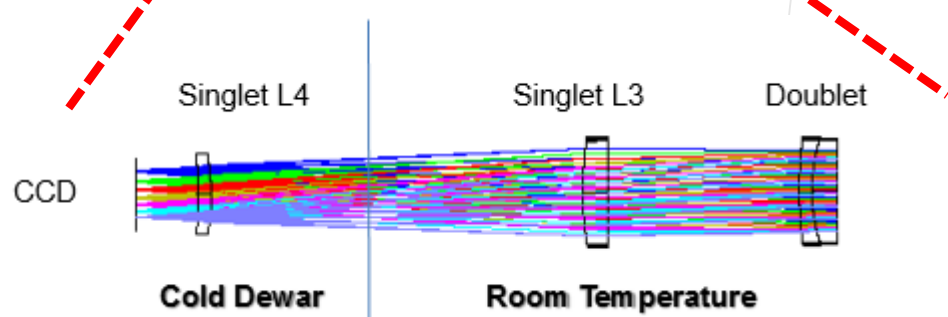
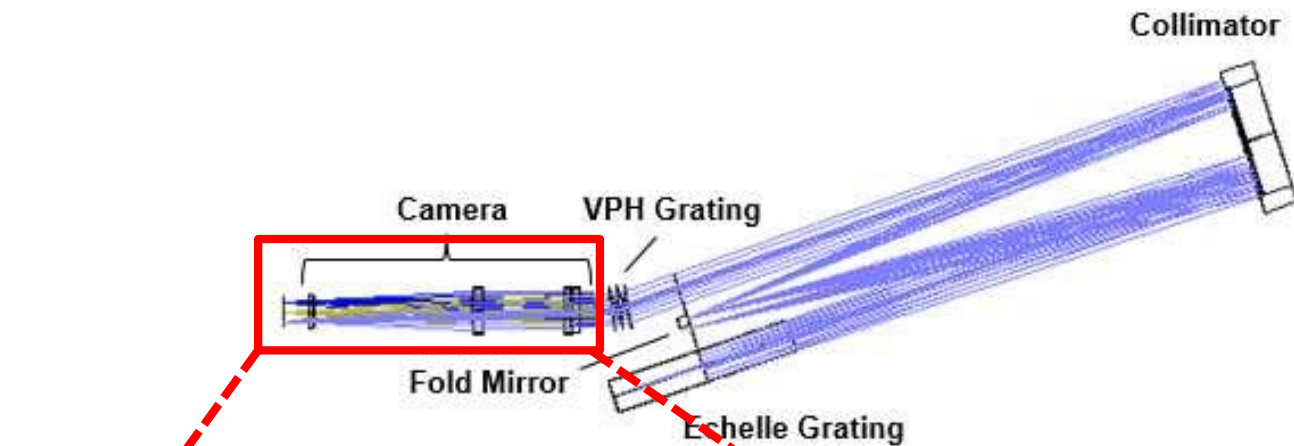
TARdYS  
Limiting Magnitude



The image features a white background with several overlapping circles of varying radii. Some circles are solid light gray, while others are dashed light gray. A large, solid blue oval is positioned in the center-right, containing the word "Spectrograph" in white, sans-serif font. A thick, black, curved shape is located on the left side, partially overlapping the blue oval.

Spectrograph



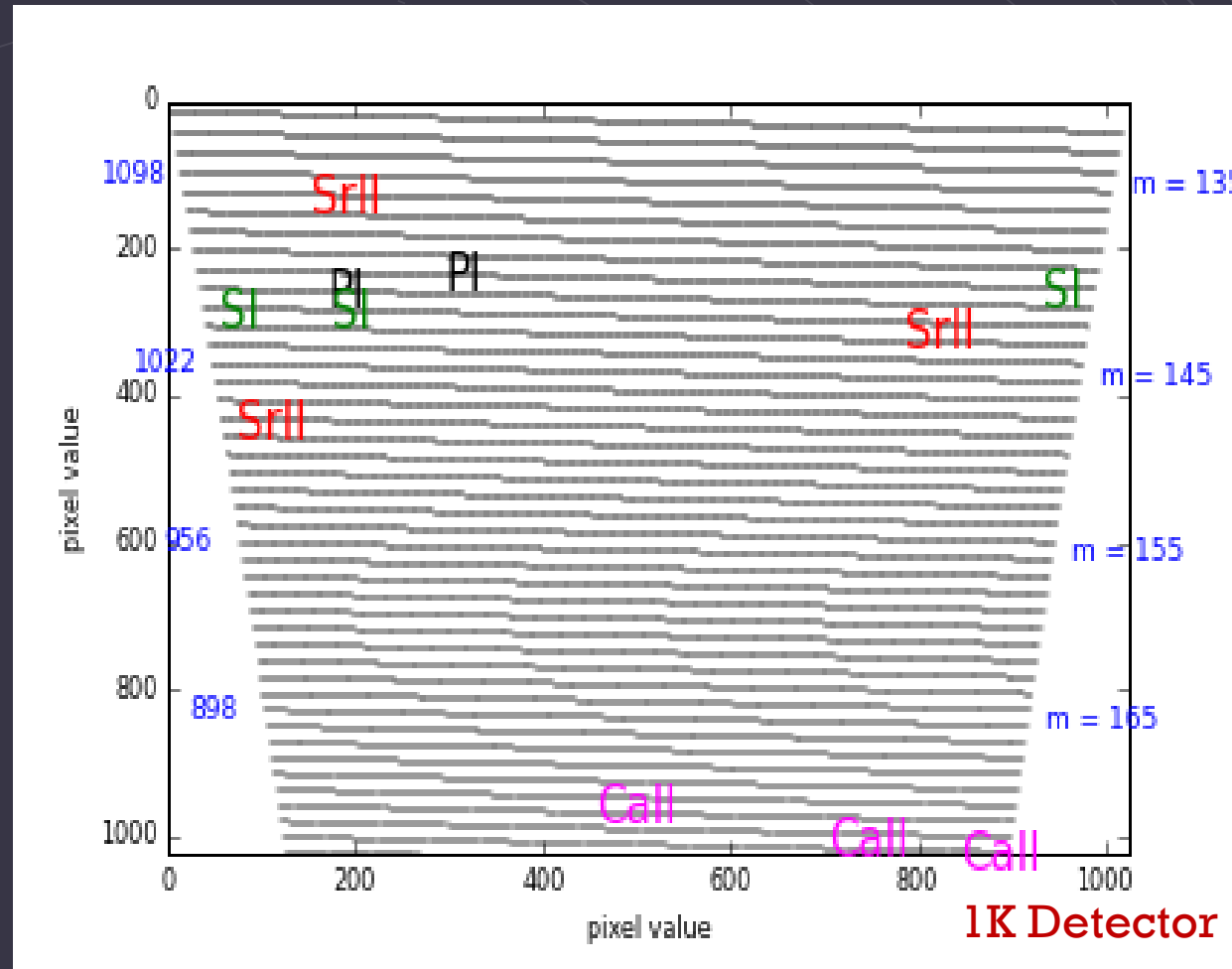


# Design

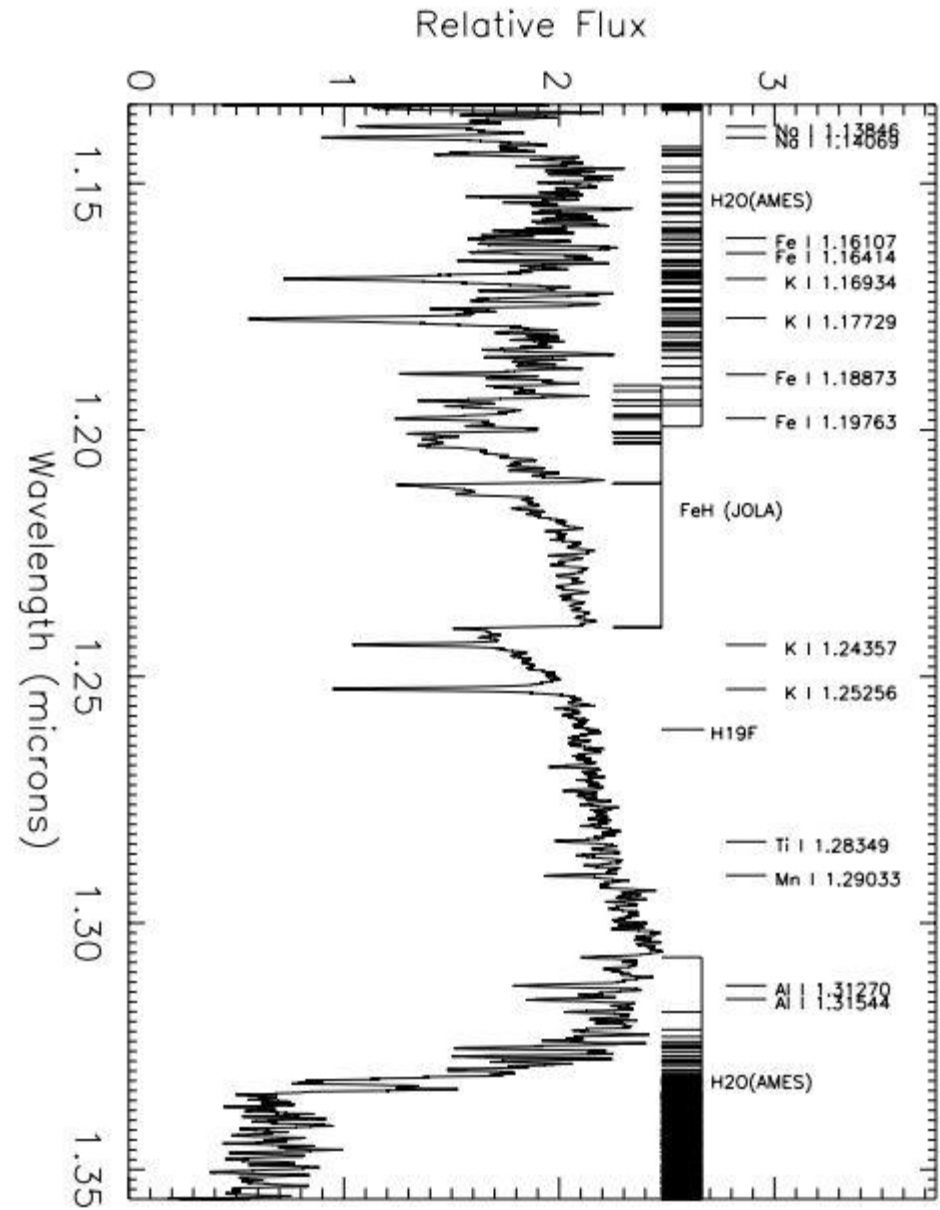
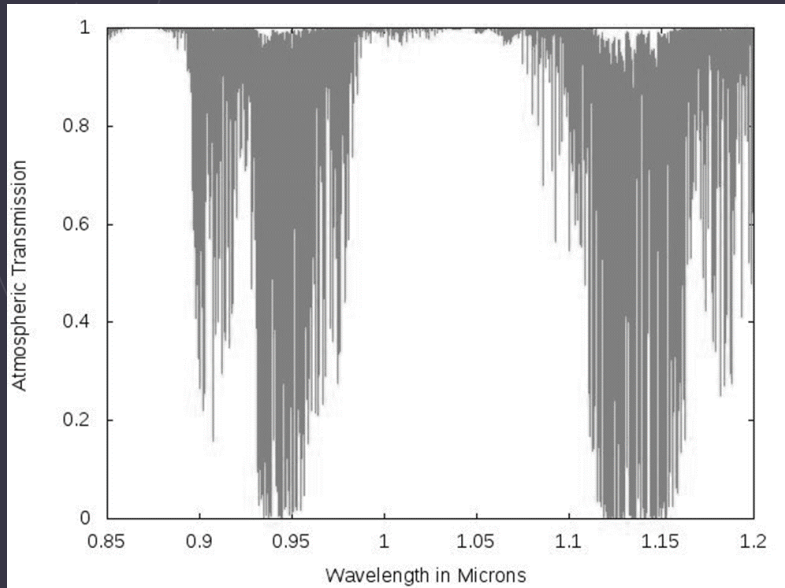
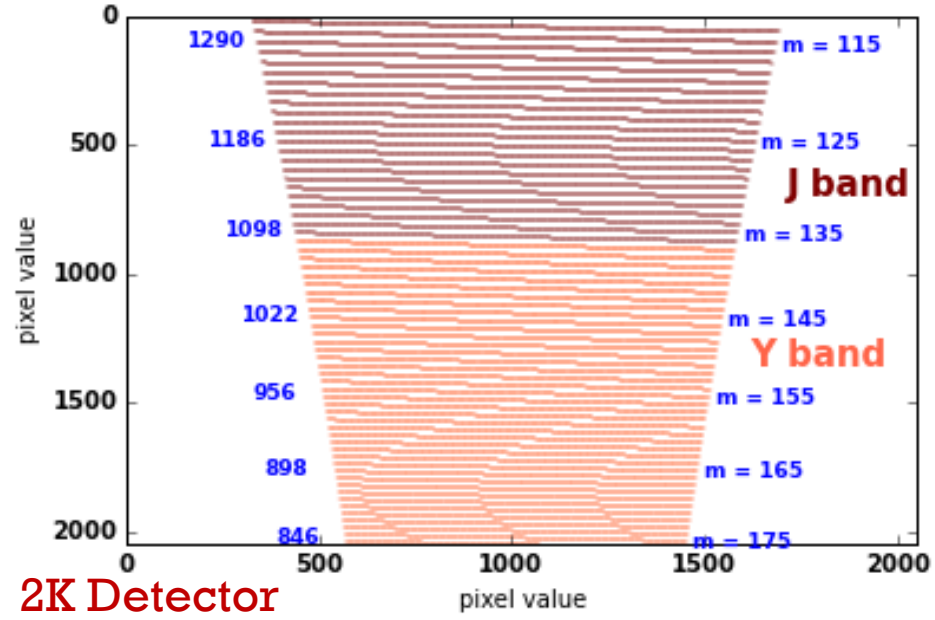
- Fiber + image slicer; 0.4" on-sky
- R = 66,000 over 0.843-1.117  $\mu\text{m}$
- Grating: Echelle R6 and VPH
- Detector 1kx1k
- Calibration
  - Simultaneous
  - Lamp/Fabry Perot (plan)

Rukdee et al. 2019 (under review)

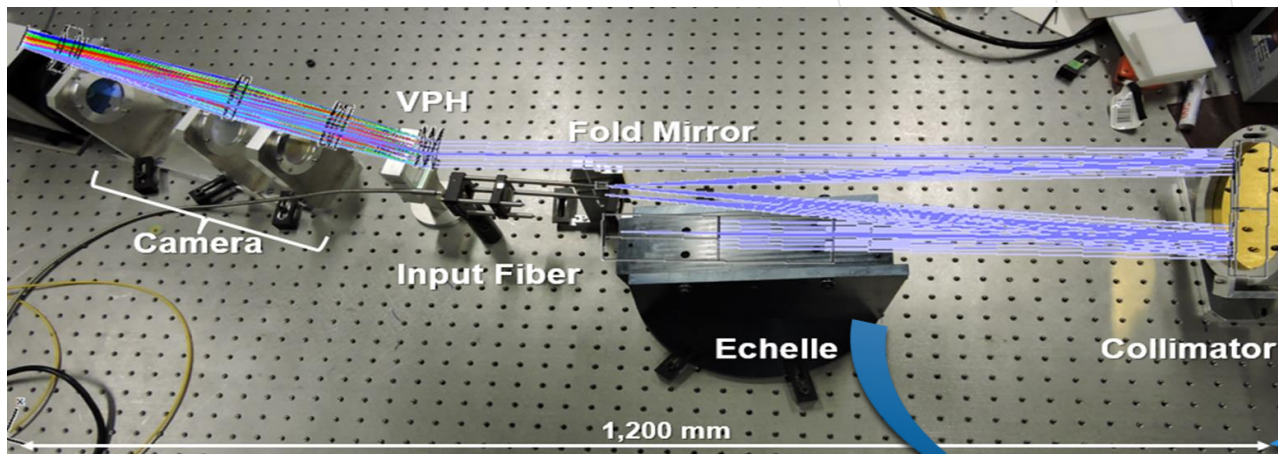
# Detector Simulation



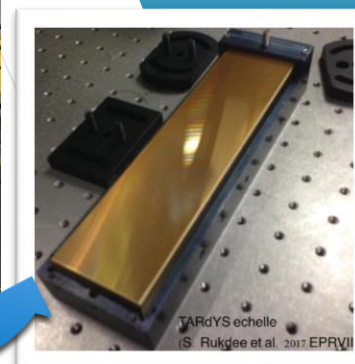
# Detector Simulation



# Prototype



Rukdee et al. 2019 (under review)



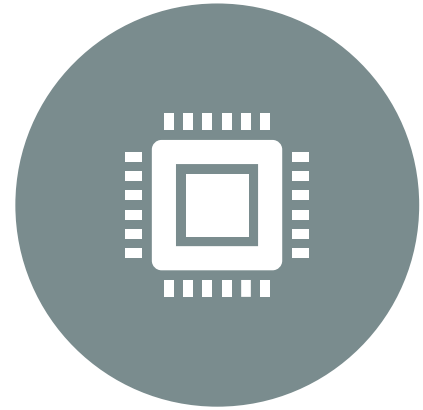
# Current Challenges



**ADAPTIVE OPTICS  
SOLUTION**



**MECHANICAL INTERFACE  
AND ENCLOSURE**



**ACQUIRE A DETECTOR**



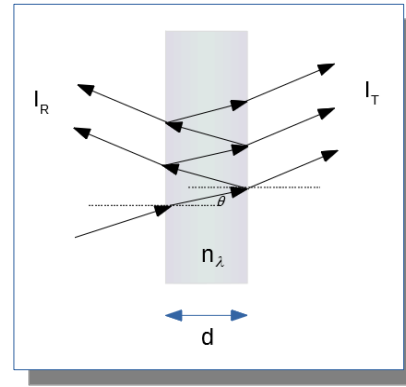
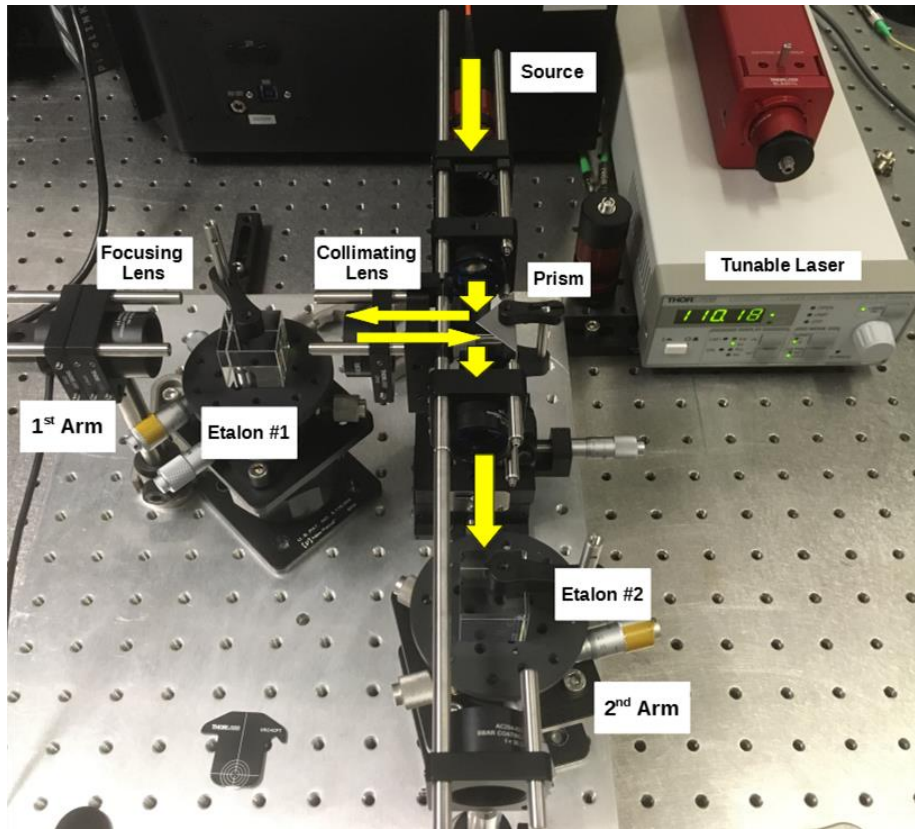
# FIOS

## Fabry perot Interferometer for Oxygen Searches

 JOHN  
TEMPLETON  
FOUNDATION

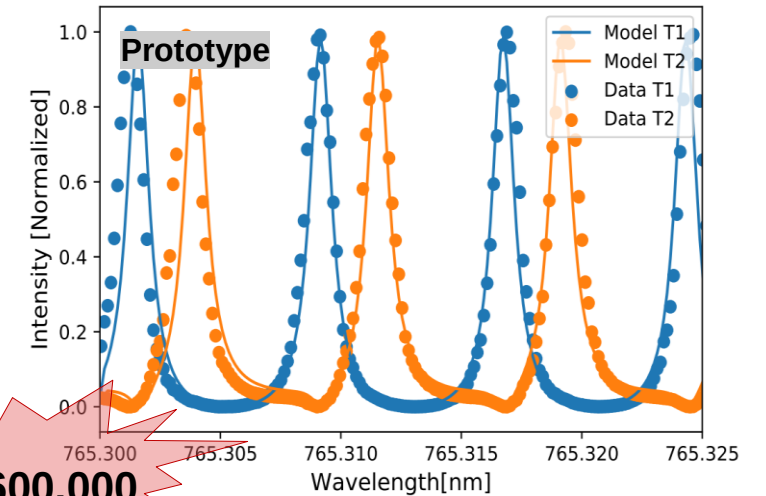
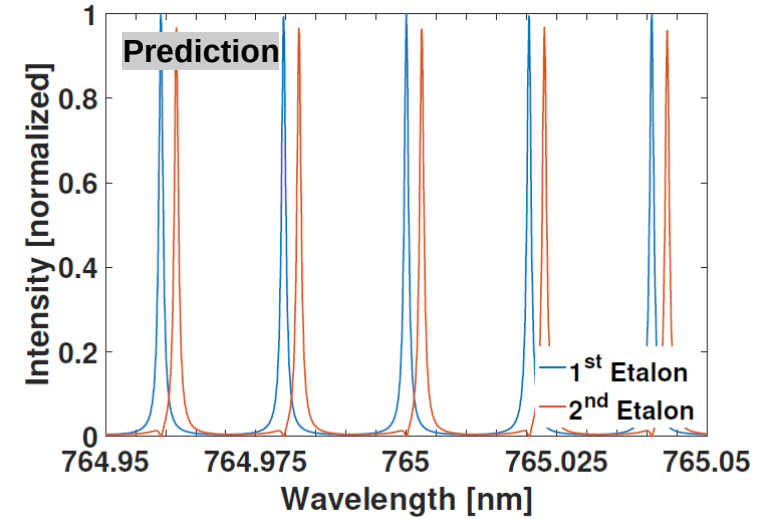
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S. Rukdee, S. Ben-Ami, M. López-Morales,  
J. Garcia-Mejia, D. Charbonneau, A. Szentgyorgyi



- Needs large telescope aperture.
- Needs high resolution spectrograph to cross-disperse.

Ben-Ami et al. 2018



**R ~ 600,000**

Rukdee et al. (in prep.)

# FIOS: Prototype

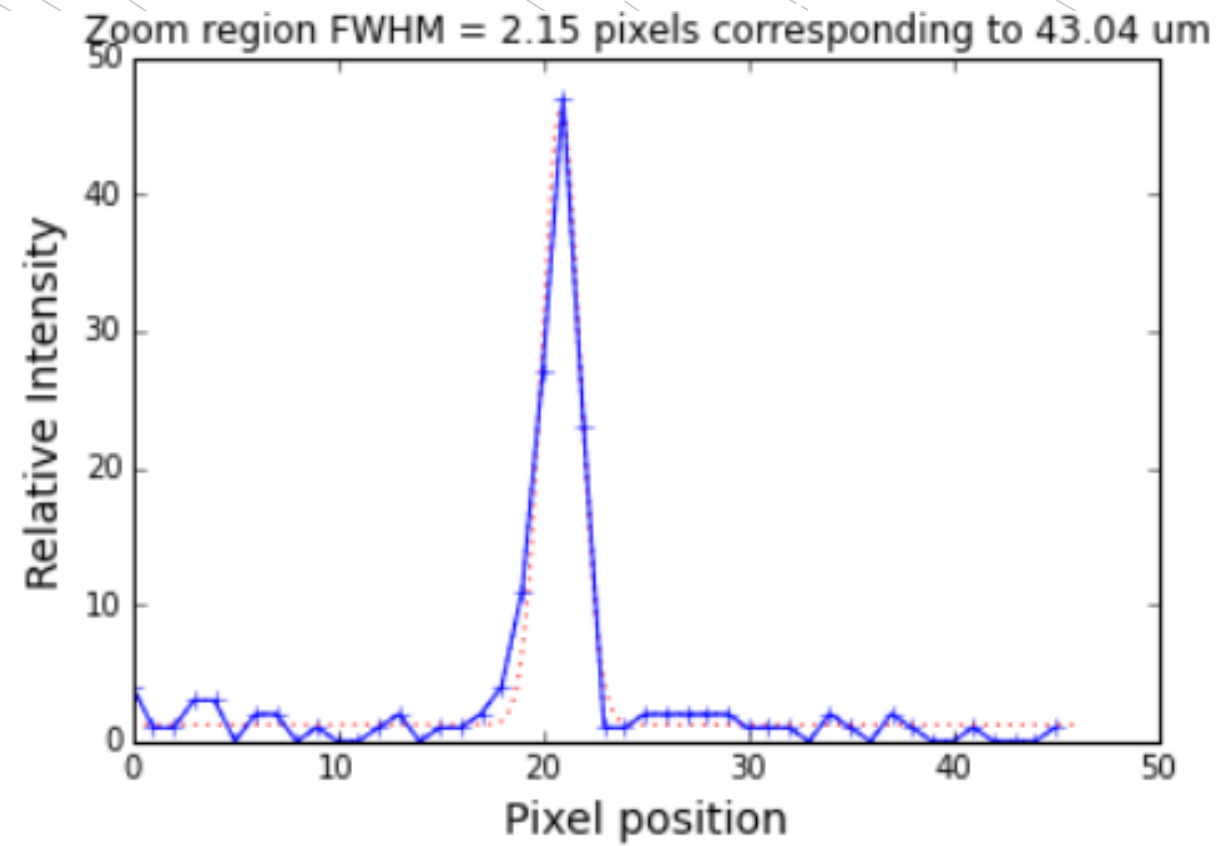
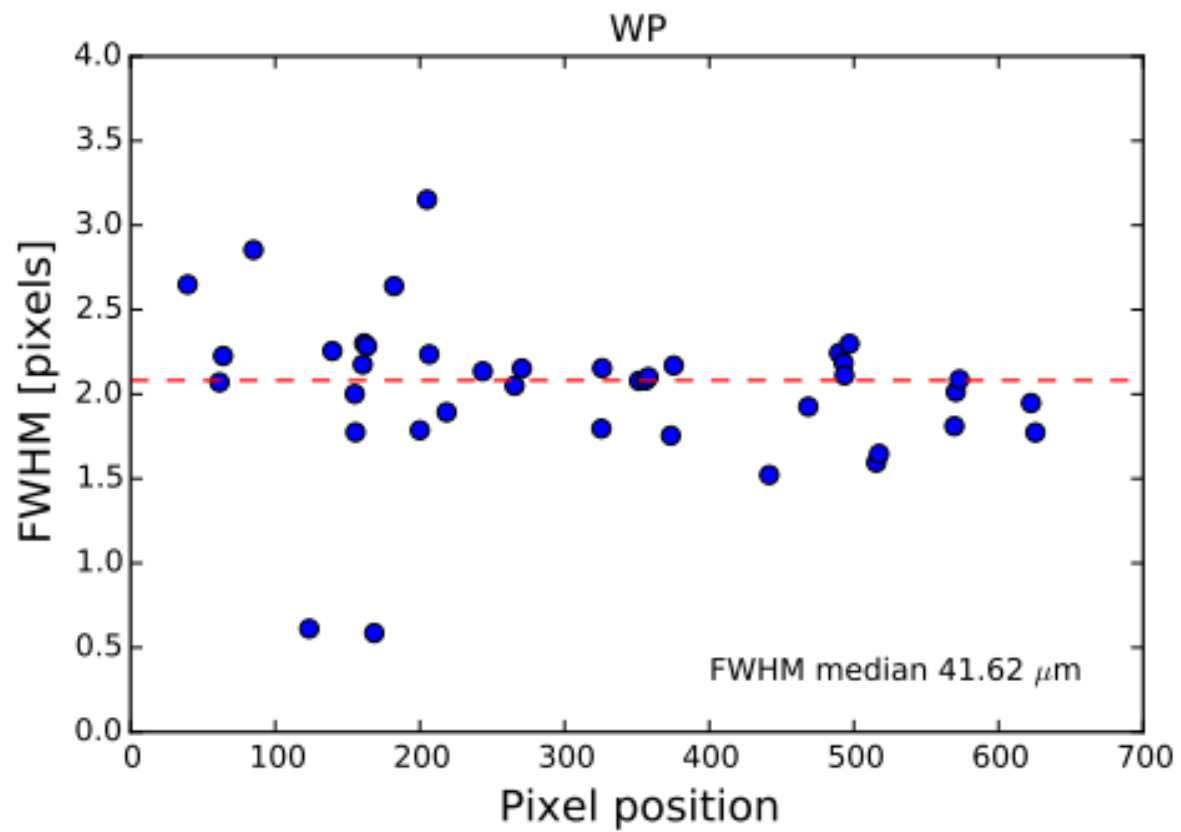
## Conclusion

- TARdYS is a fiber-fed infrared echelle spectrograph planned to be installed at the TAO 6.5-meter telescope in Chile.
- The concept design of TARdYS based on the white pupil configuration using an Echelle R6 and a VPH and will achieve the spectral resolution of  $R=66,000$  with fiber + image-slicer. (Rukdee et al. 2019)
- The telescope and spectrograph are currently under construction.
- TARdYS will open up opportunities for high-resolution Y-band infrared spectroscopy including studies of M-dwarfs and searches for their planets.
- A TARdYS-like spectrograph can be used to cross-disperse an ultra-high resolution Fabry Perot Interferometer based instrument to study exoplanet atmospheres.

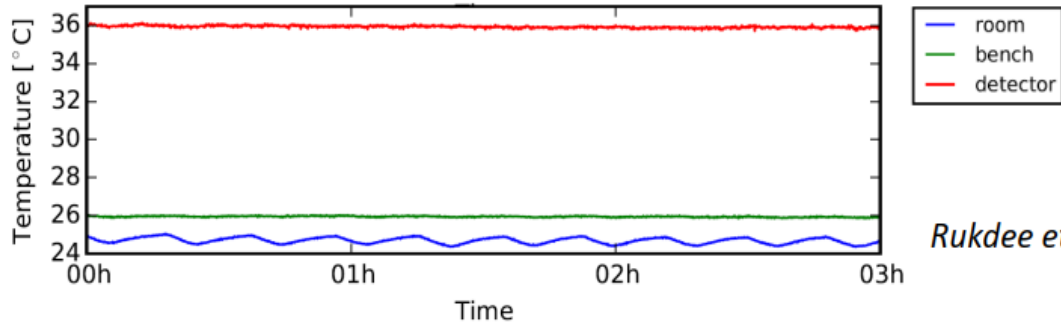
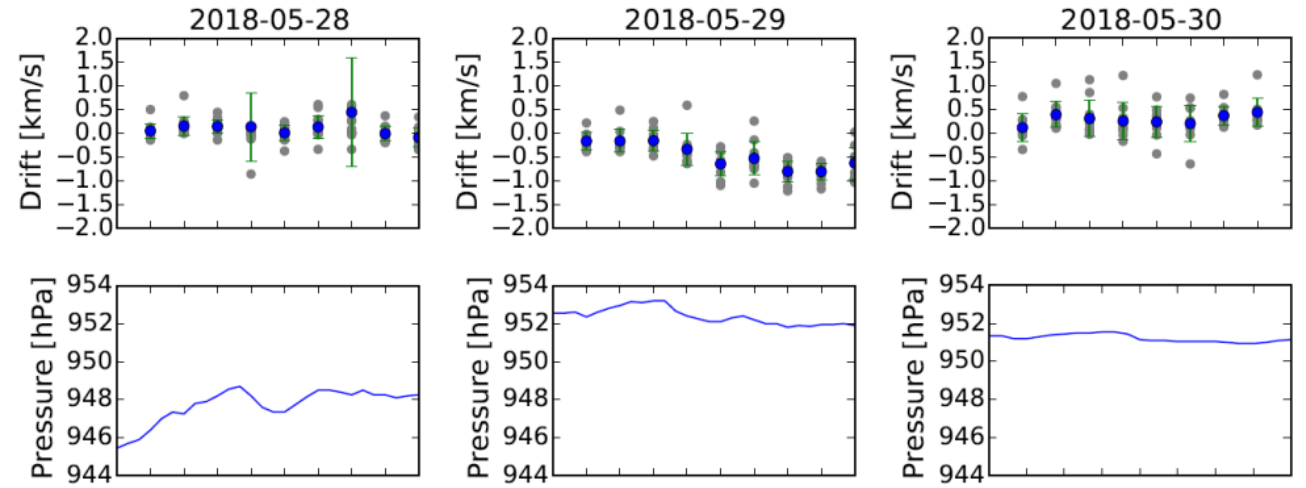
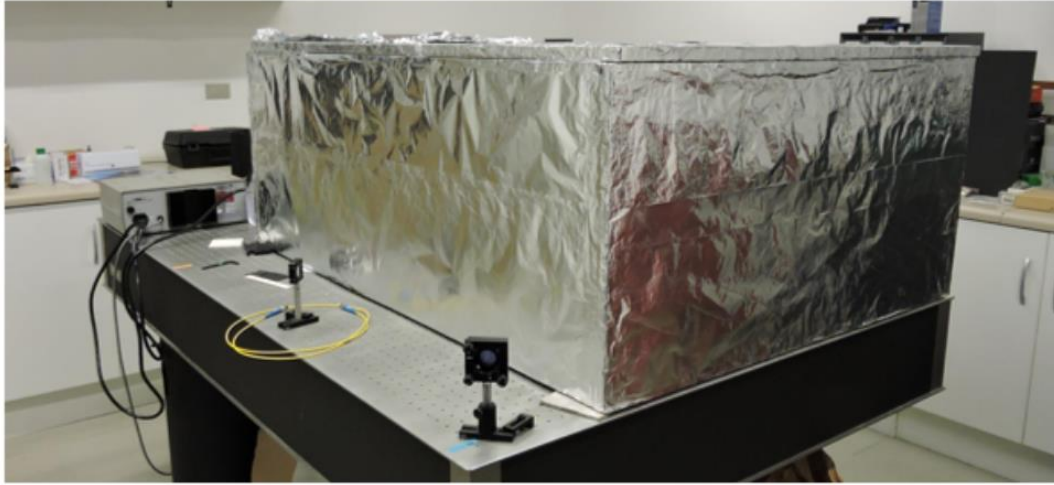




Back Up



## Image Quality

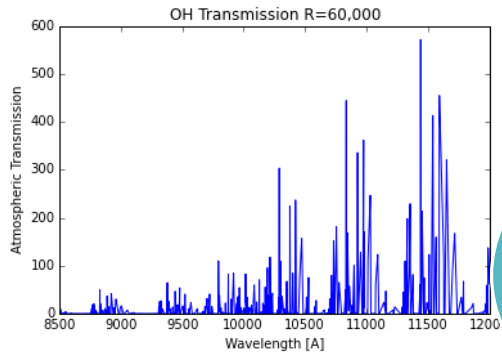


*Rukdee et al.*

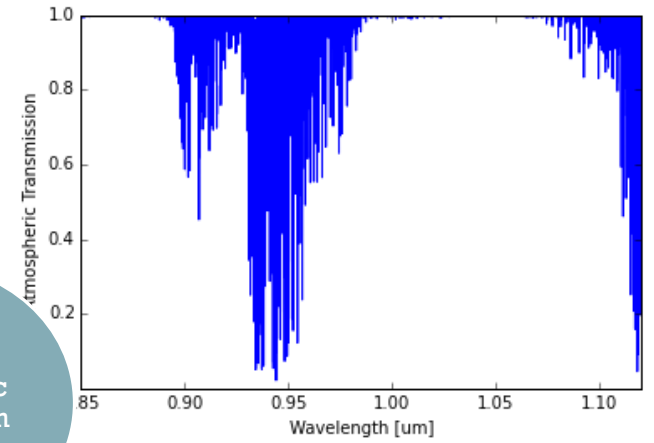
Rukdee et al. 2019 (under review)

# Current Stability : Temperature Control

# Sensitivity Simulation

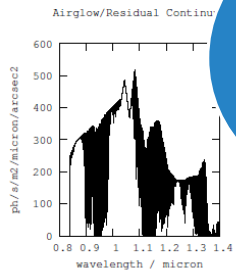
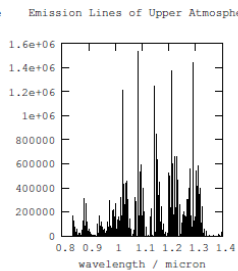
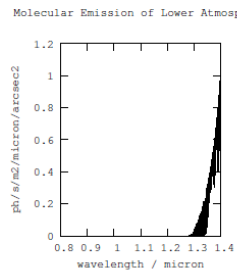
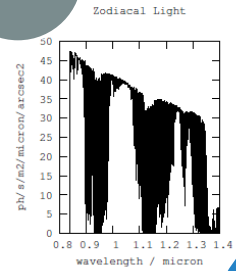
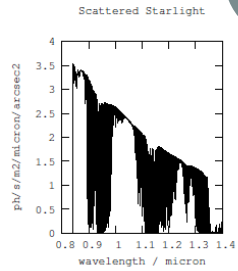
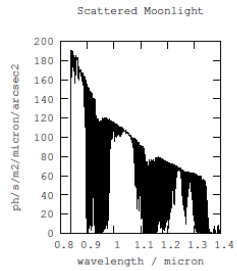


OH Transmission



Atmospheric Transmission

Blackbody Object



Background emission

