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GMTNIRS and the Promise of High Resolution Spectroscopy in the Infrared: Part 3

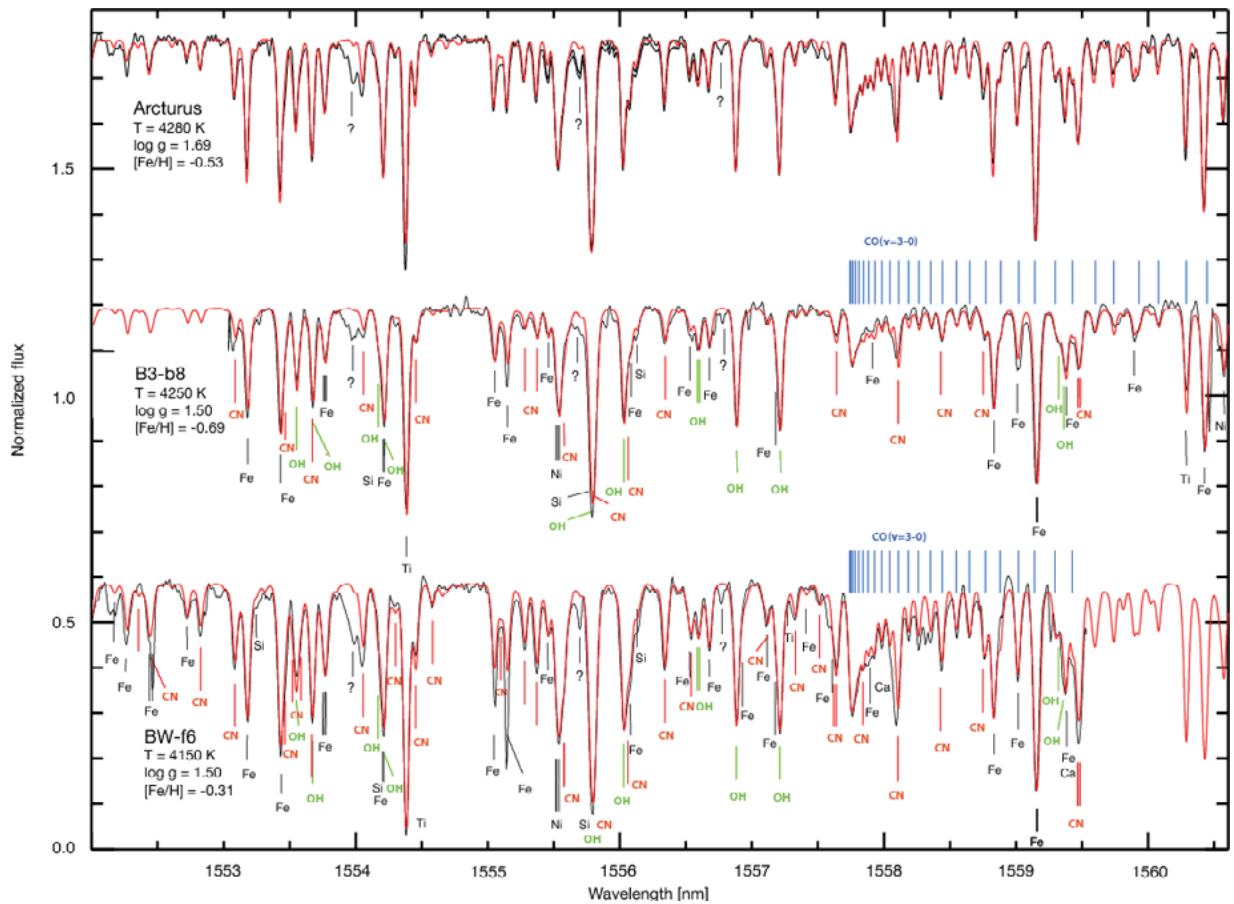
Dan Jaffe
The University of Texas at Austin

Today:

Galactic archaelogy and abundances
Globular clusters and exgal globulars

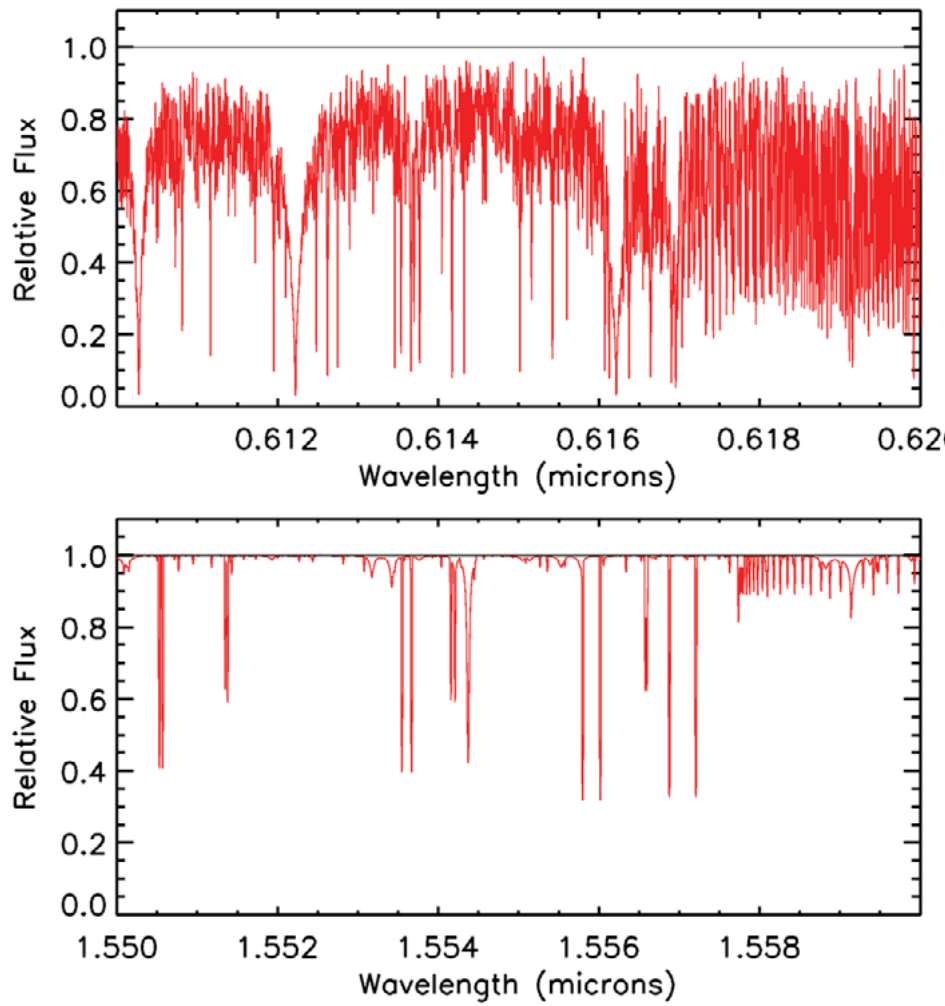
Brown dwarfs and exoplanets, captive and free-floating
BD-BD pairs
Kinematic search for exoplanets
Direct detection of exoplanets- Transits, non-transits
8799 analogs
Pushing the limits

High resolution IR spectroscopy lets us trace abundances throughout the Galaxy and look at the evolution of different kinematic components. Also study LMC, other dwarf galaxies, local group globulars. (SIMPLE science case)



Ryde et al. CRIRES results

Quantitative studies of M stars: In the IR, we can get away from the molecular bands and measure temperature and abundances.



Coelho et al. (2005)

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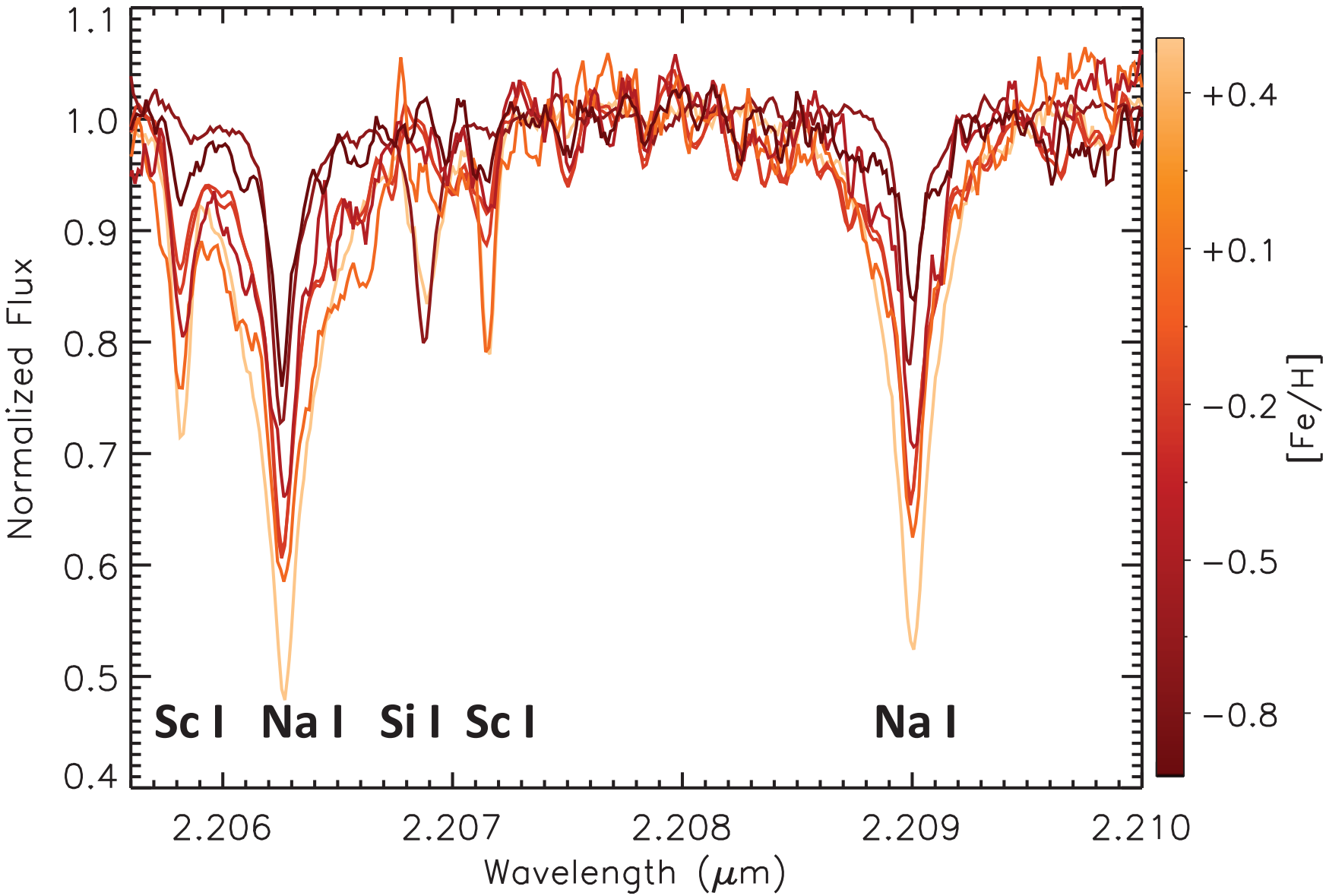
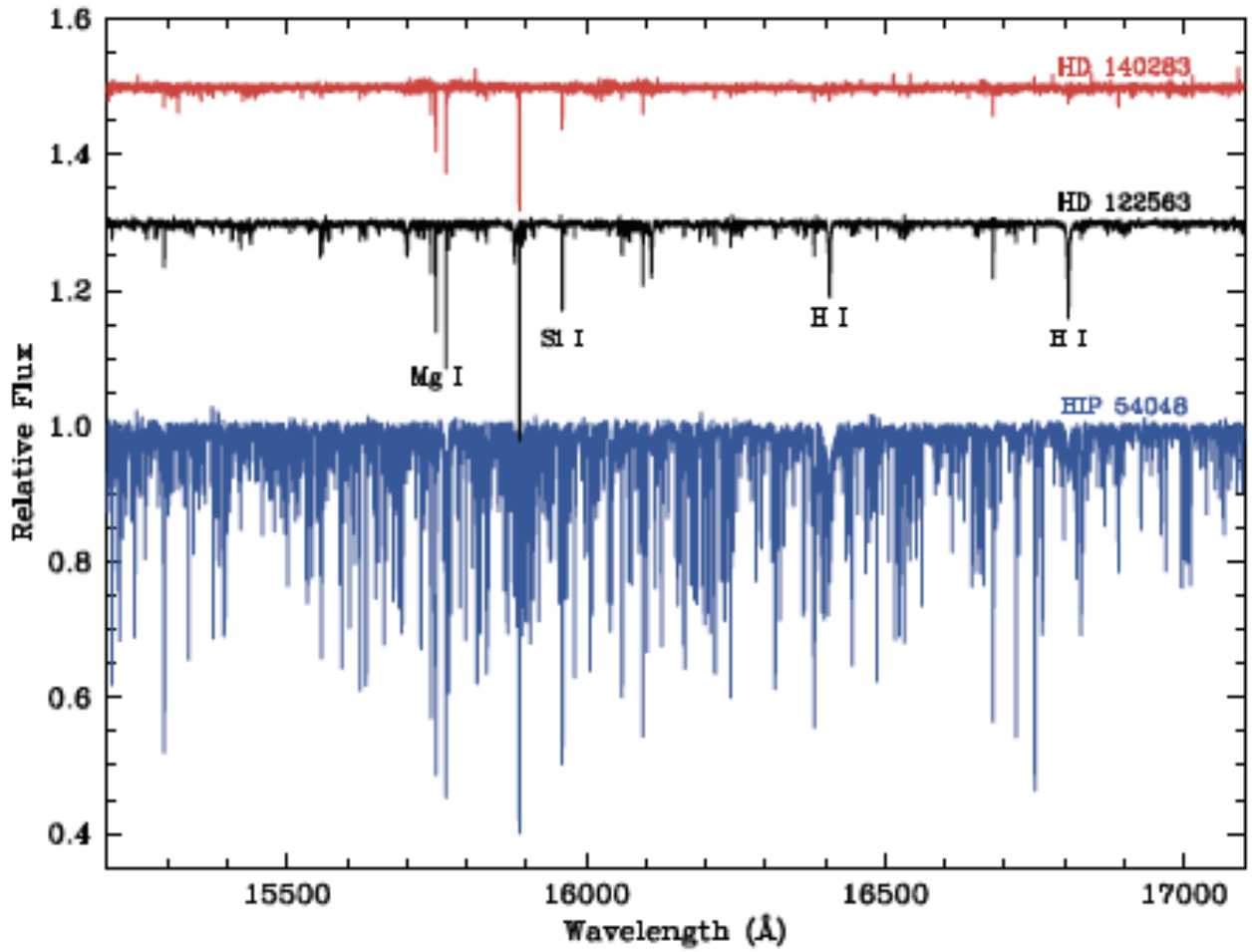
Andrew Mann et al. (CUNY) M star metallicity indicators (IGRINS)



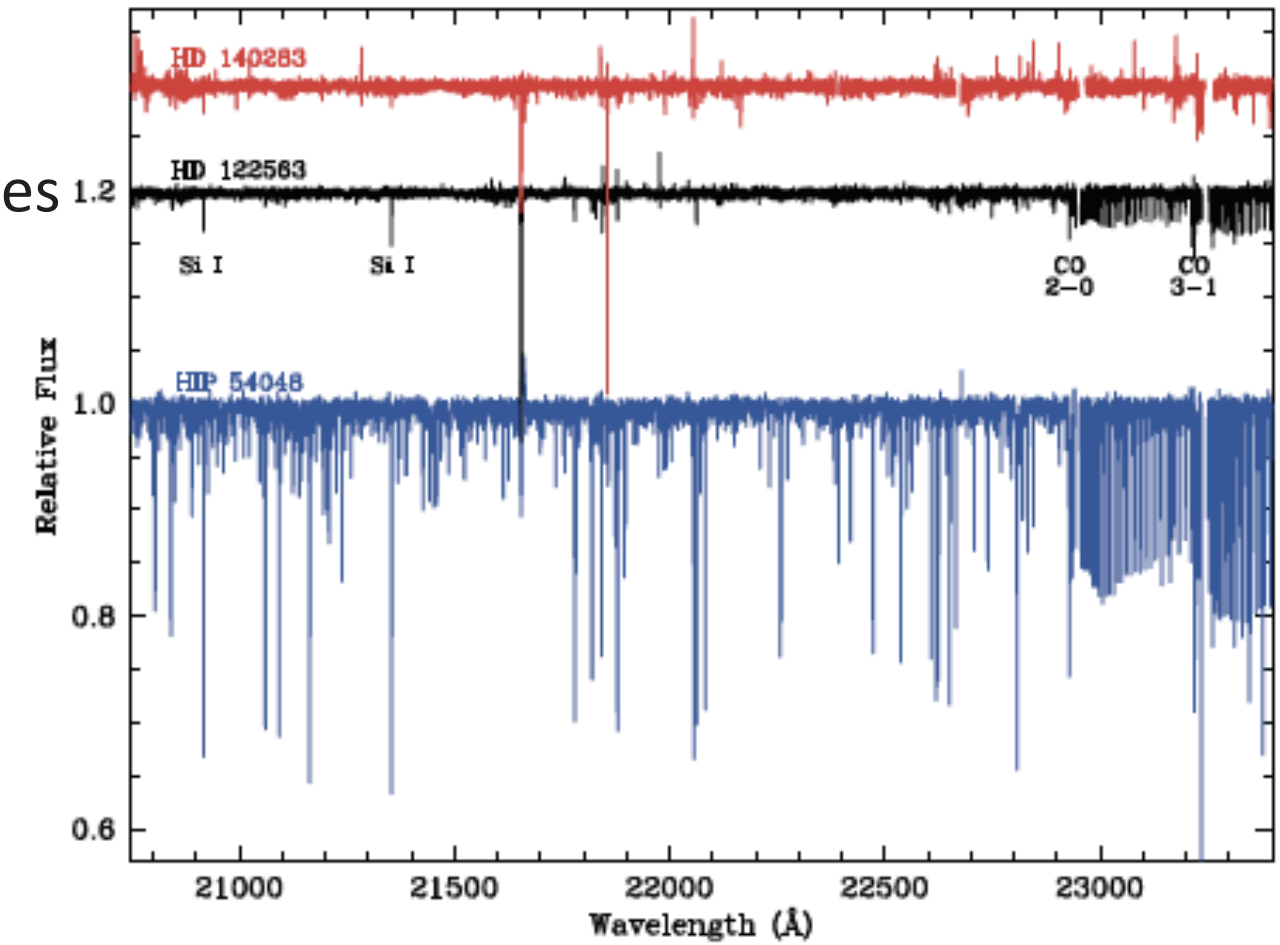
Afsar et al (2016) IGRINS

Giants with [Fe/H] ~-3



Afsar et al (2016) IGRINS

Note the strong CO lines



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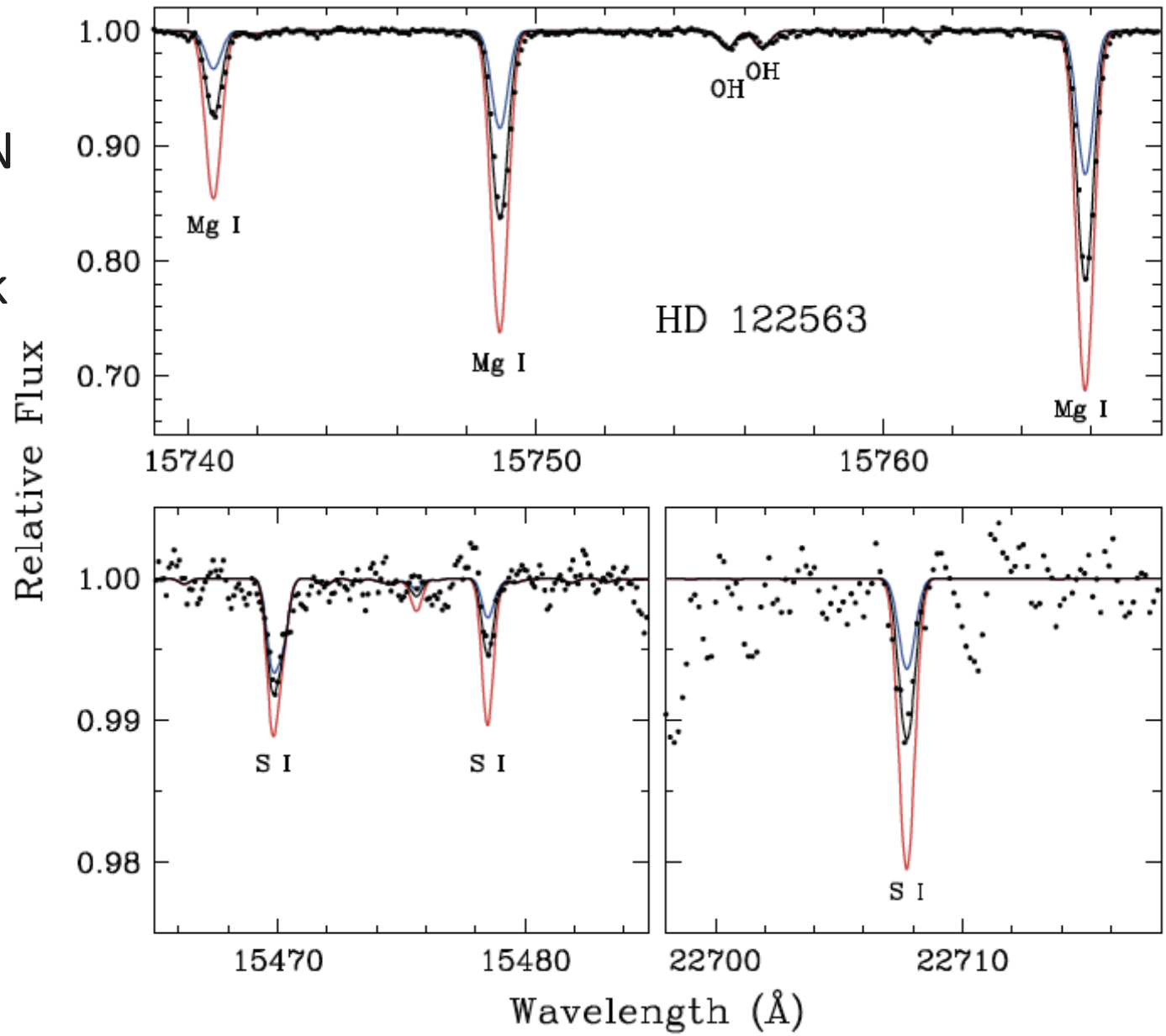
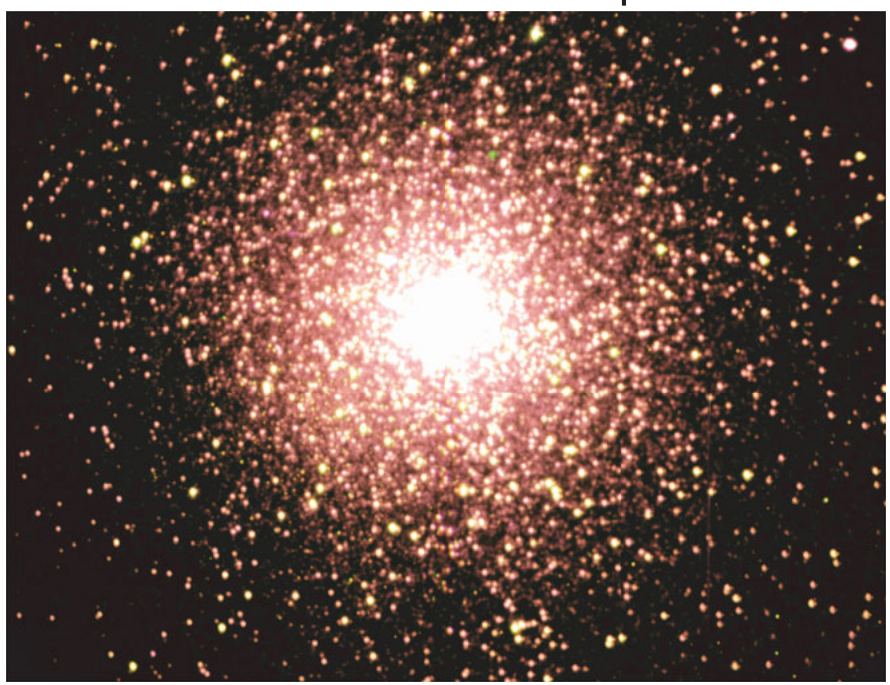
Afsar et al (2016) IGRINS

Can reach high S/N

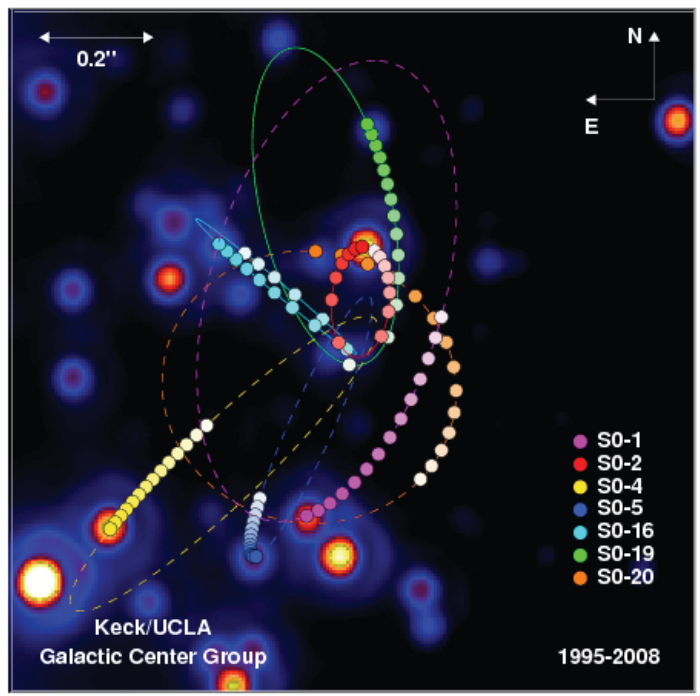
With CO, can stack lines



Basic technique of slit scanning and phase-space search can provide quantitative information in both these contexts: Low velocity dispersions and crowding call for high spatial and spectral resolution in globulars. In the Galactic Center, we can probe for a cluster of stellar black holes and find new short-period orbits.



47 Tuc



SgrA*

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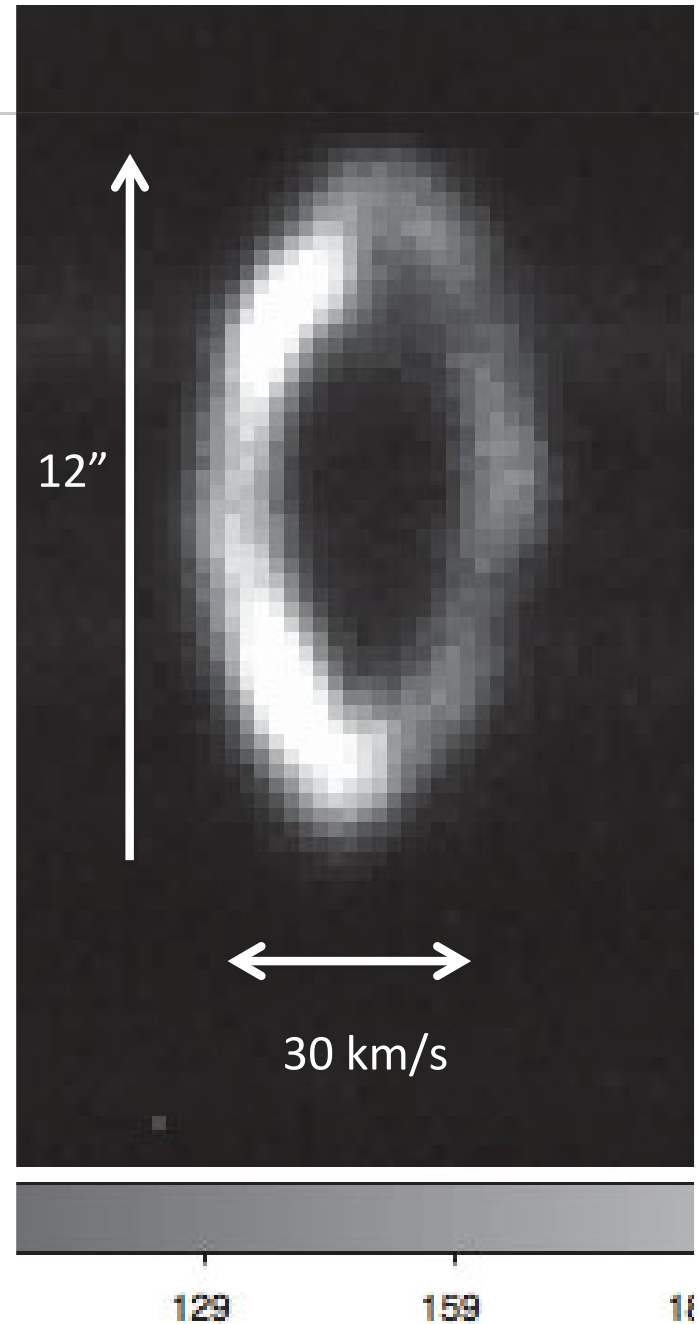
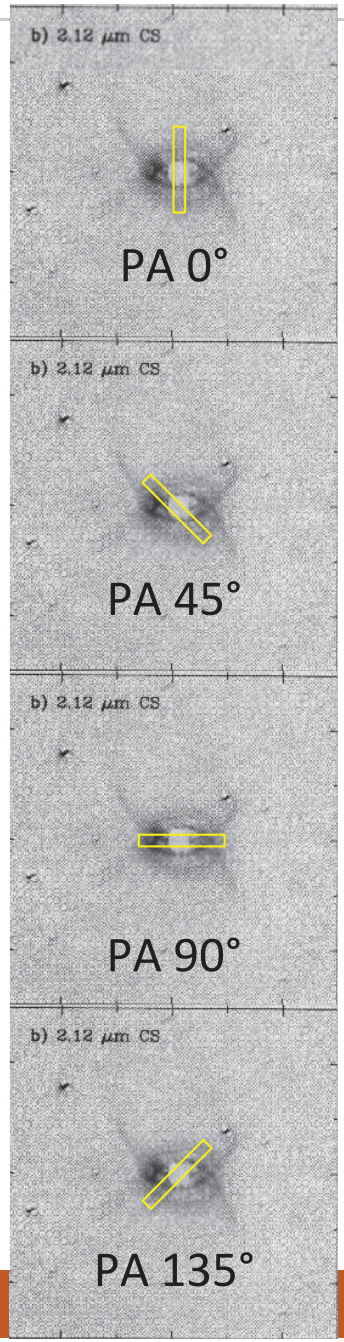
NGC 7027 Planetary Nebula
Expanding narrow-line H_2
Shell outside of dust shell

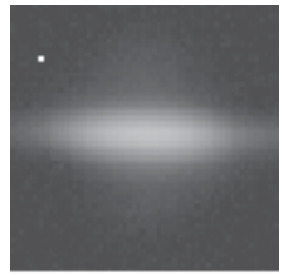


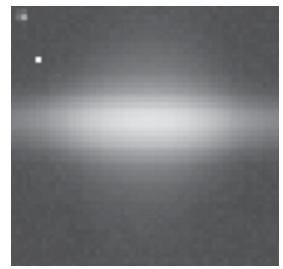
PN Hubble 12 Harriet Dinerstein, Kyle Kaplan (UT)

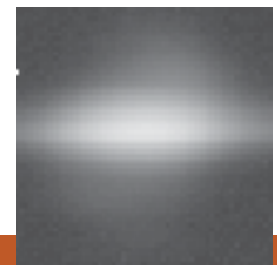
Hora & Latter (1996)

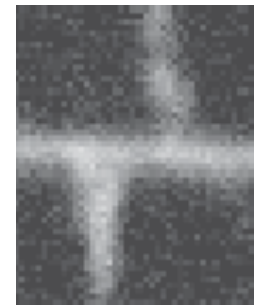
Br-gamma 2.1661 um H2 1-0 S(1) 2.1218 um [Fe II] 1.6436 um

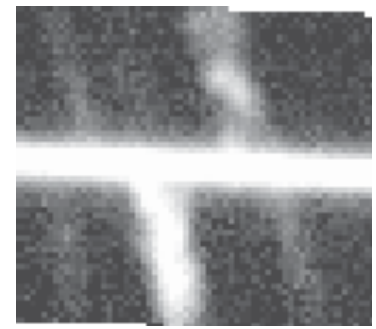


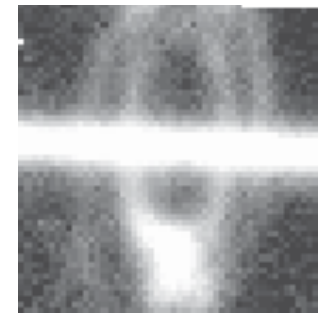


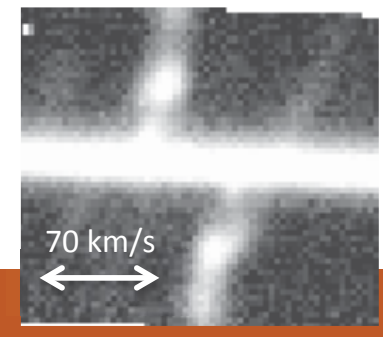


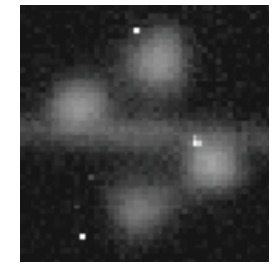


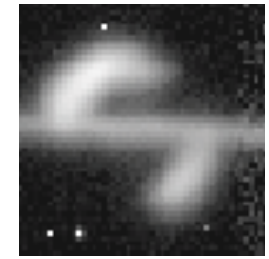


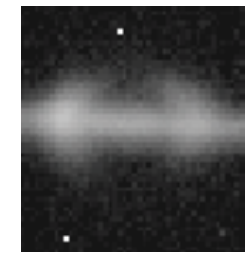


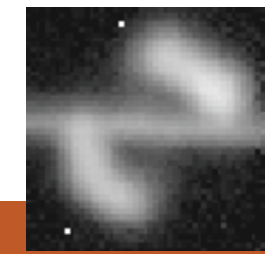












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Meet the planetary nebulae!

M 1-11

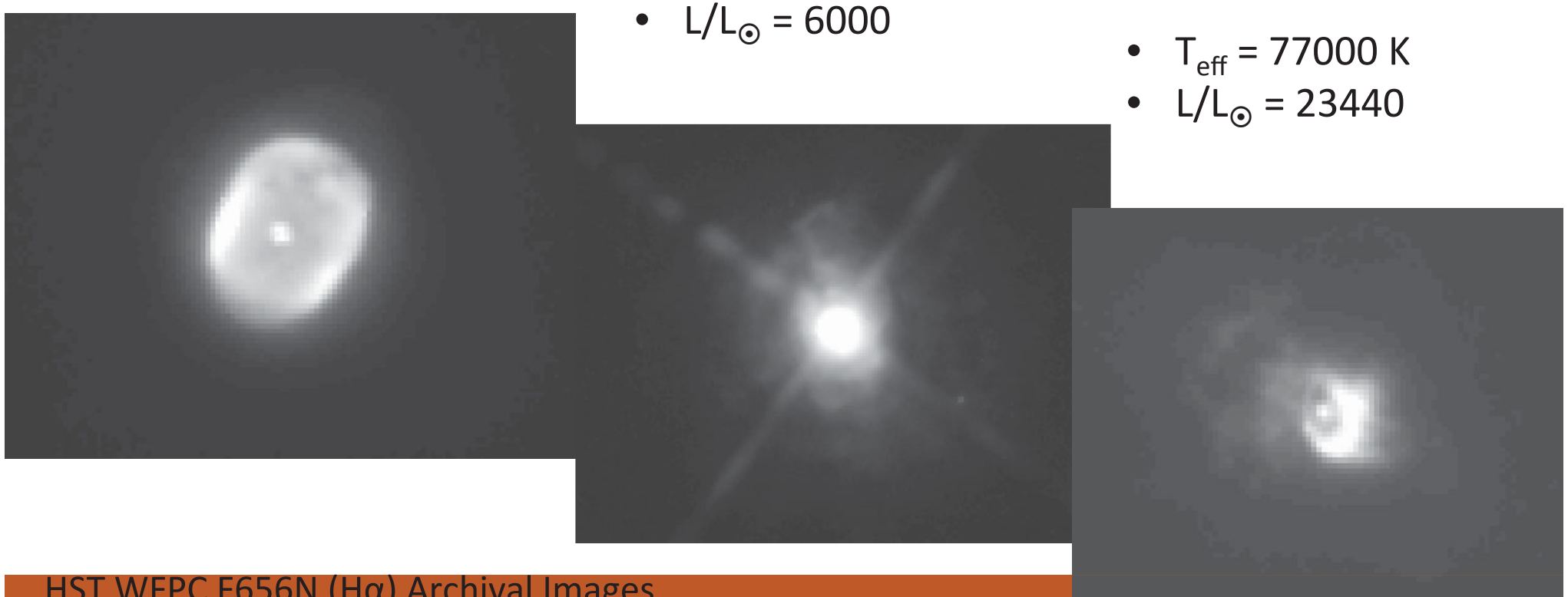
- T_{eff} = 31830 K
- $L/L_{\odot}$ = 4710

Vy 2-2

- T_{eff} = 59500 K
- $L/L_{\odot}$ = 6000

Hen 2-459

- T_{eff} = 77000 K
- $L/L_{\odot}$ = 23440



HST WFPC F656N (Hα) Archival Images

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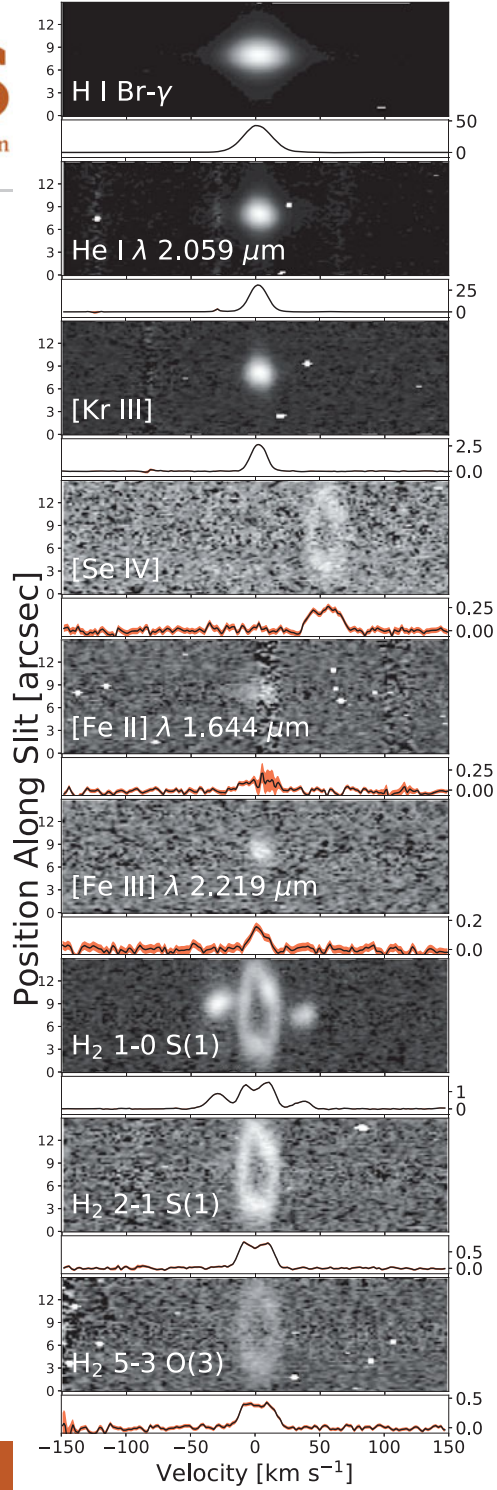
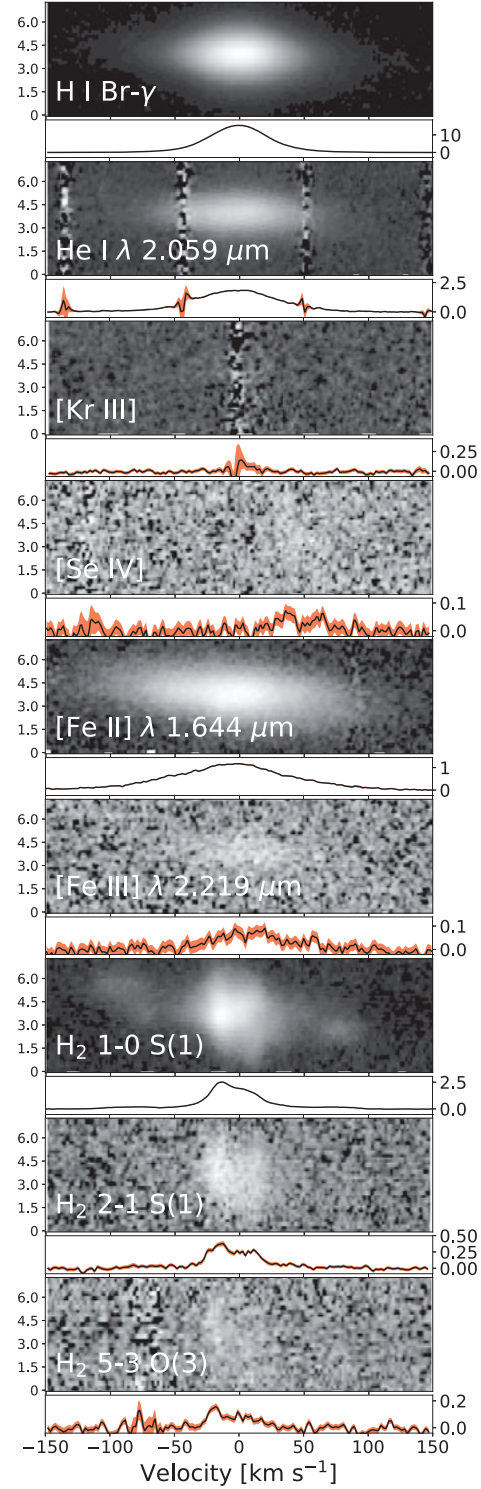
M 1-11



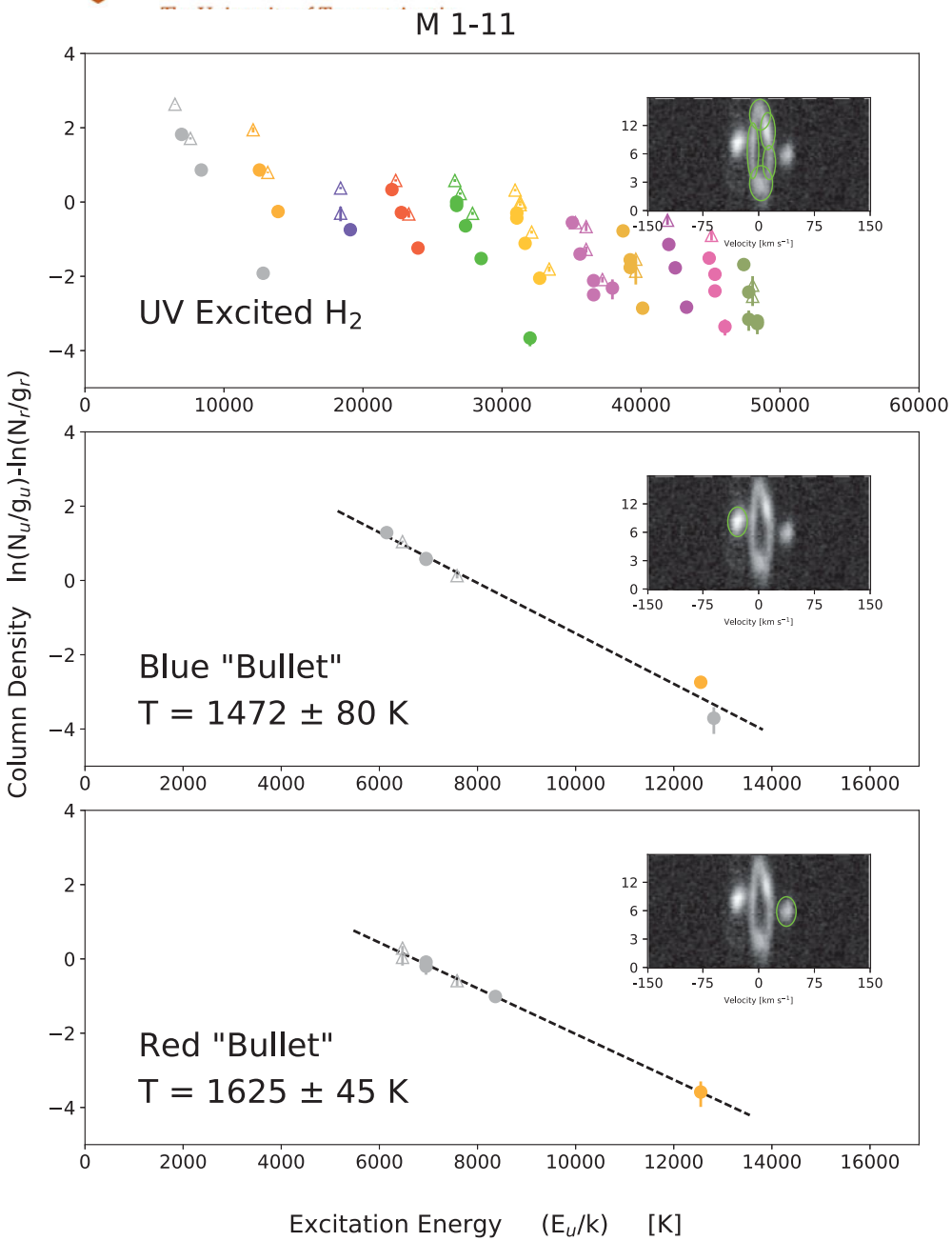
Hen 2-459

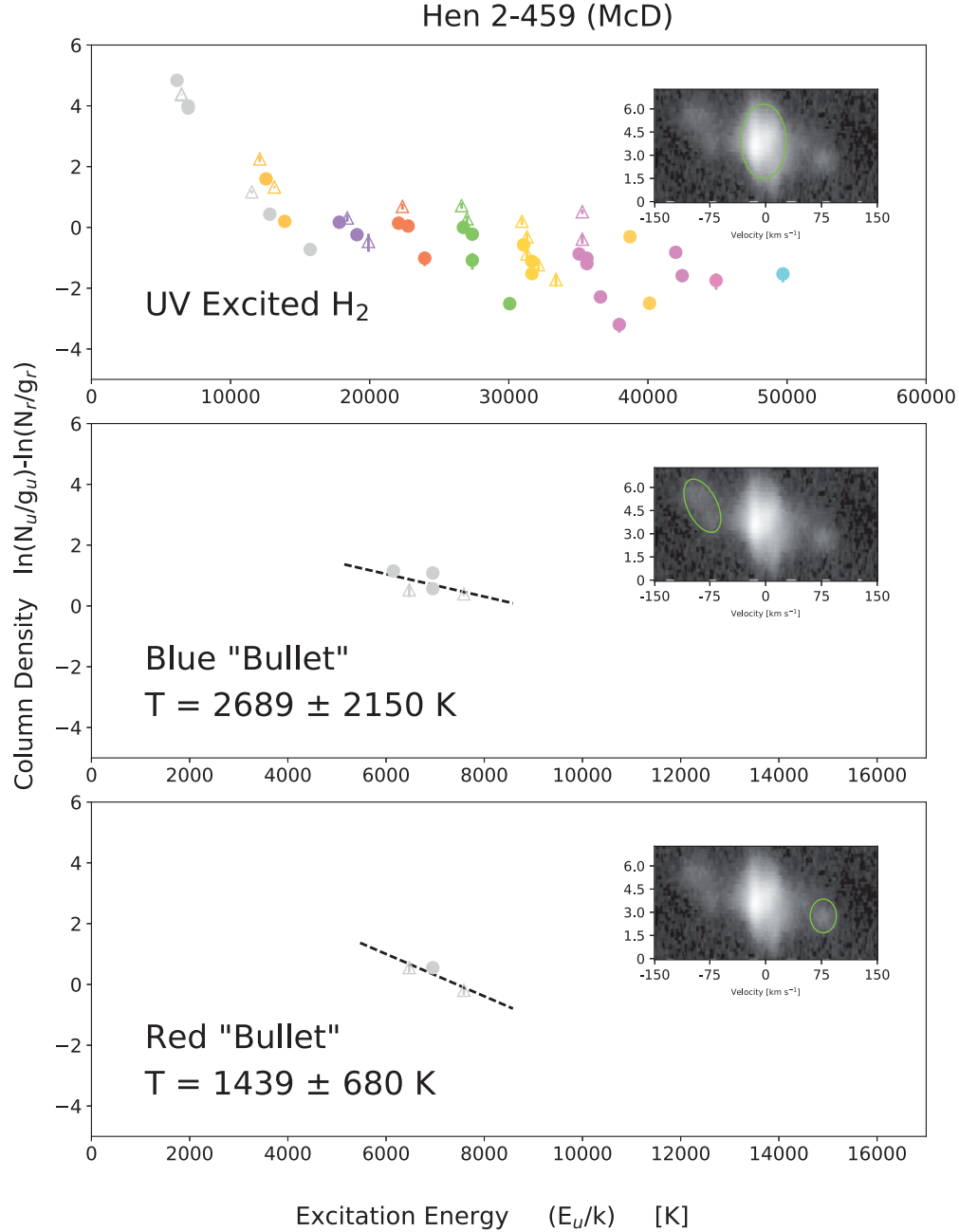


TEXAS

M 1-11

Hen 2-459





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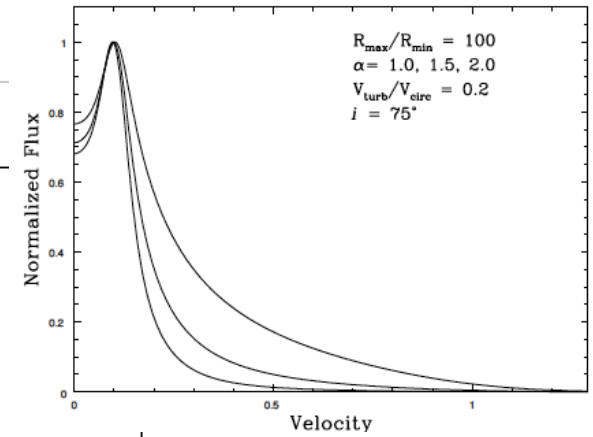
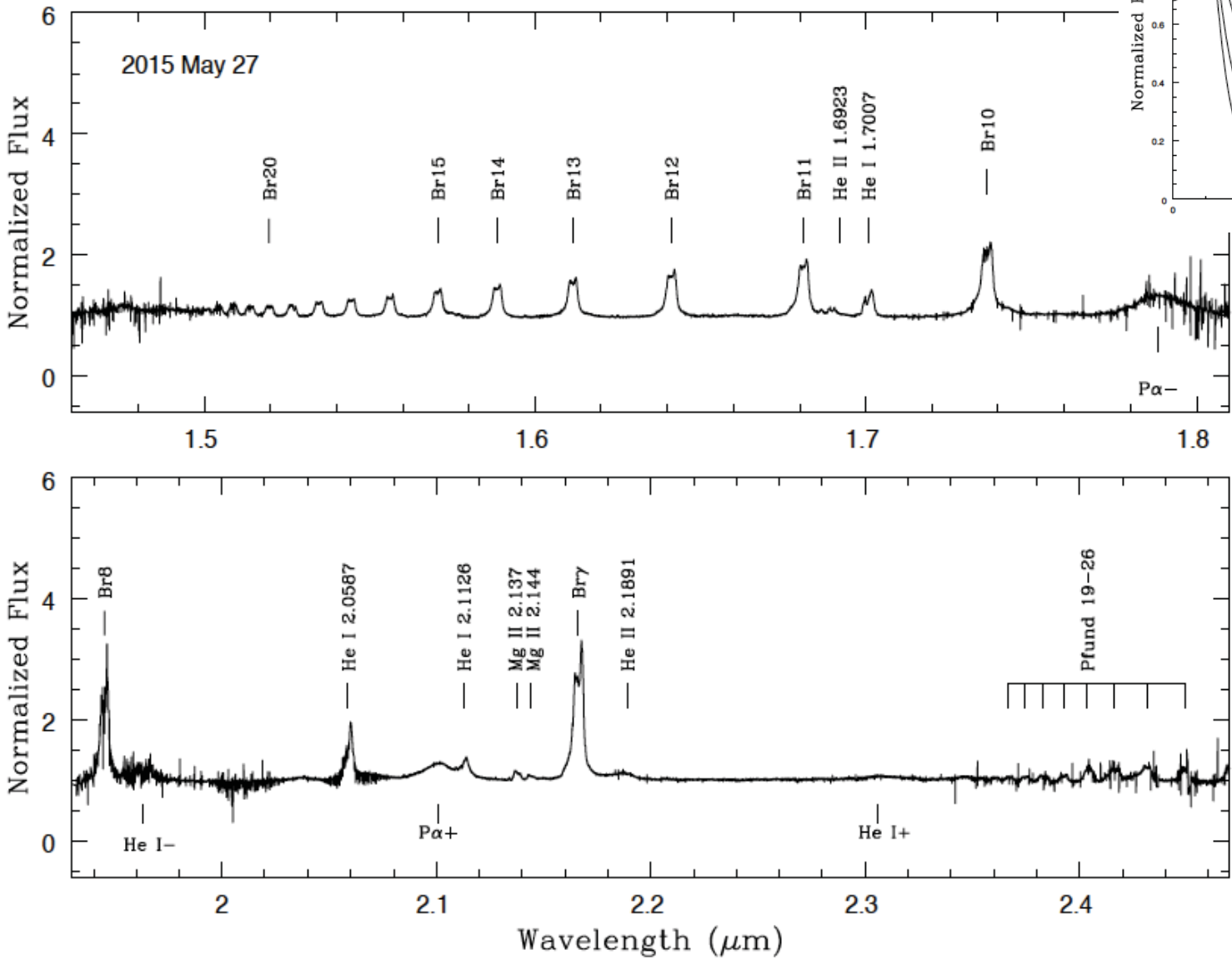
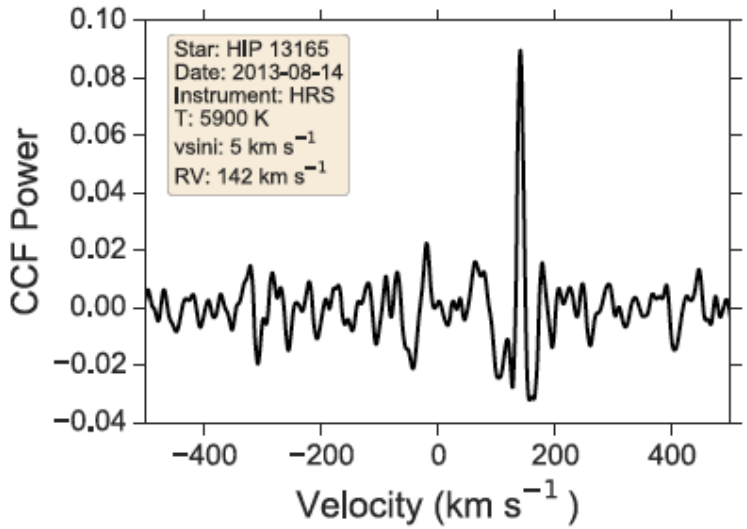
SS 433 (Robinson et al. 2017)



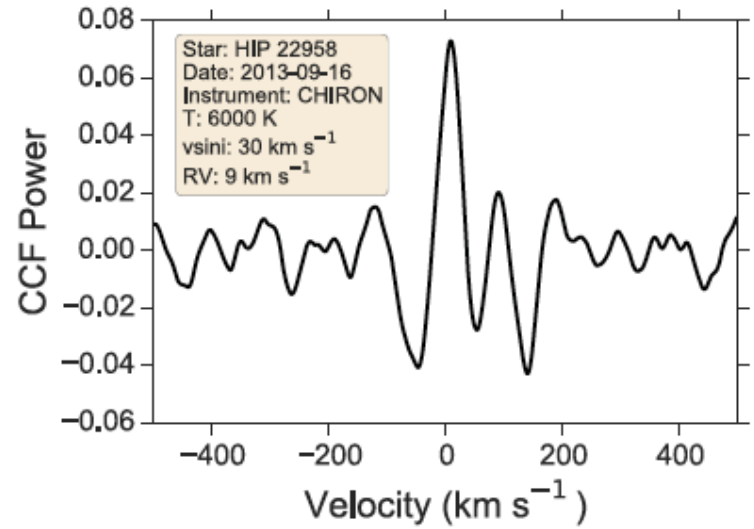


Detection of low-mass companions to high mass stars using cross-correlation techniques

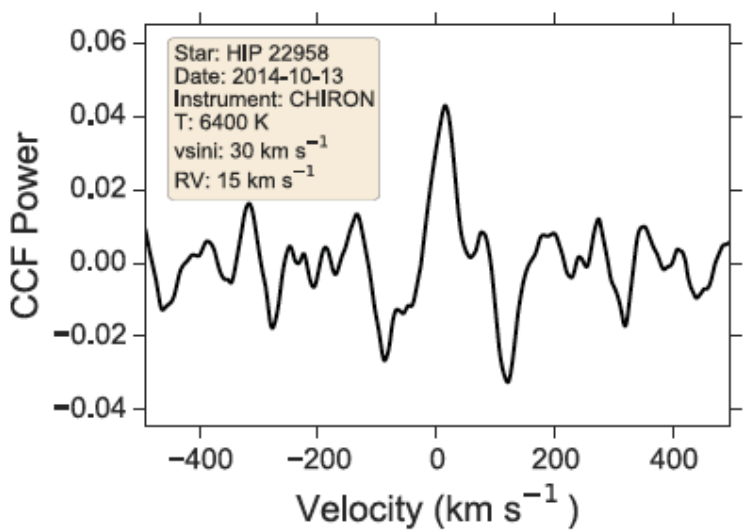
Gullikson et al. 2016



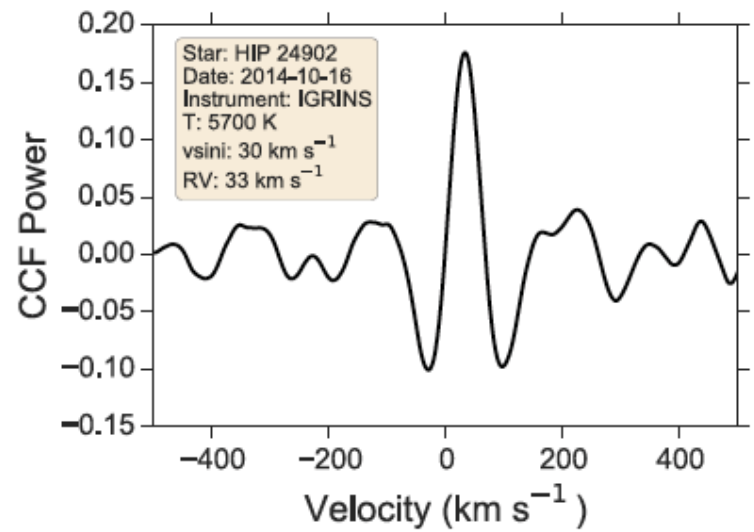
(a)



(b)



(c)



(d)

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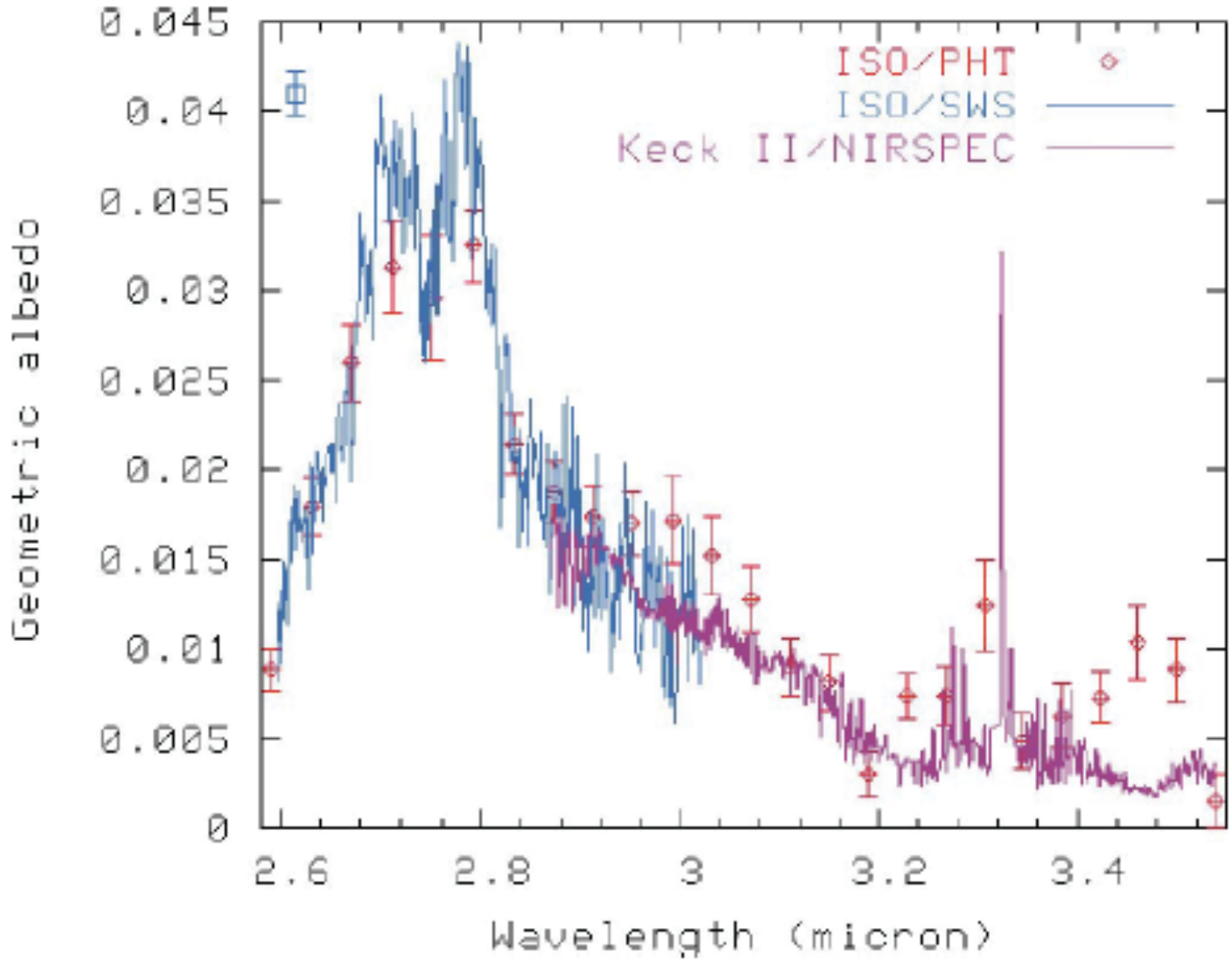
Titan - Coustenis et al. (2005)



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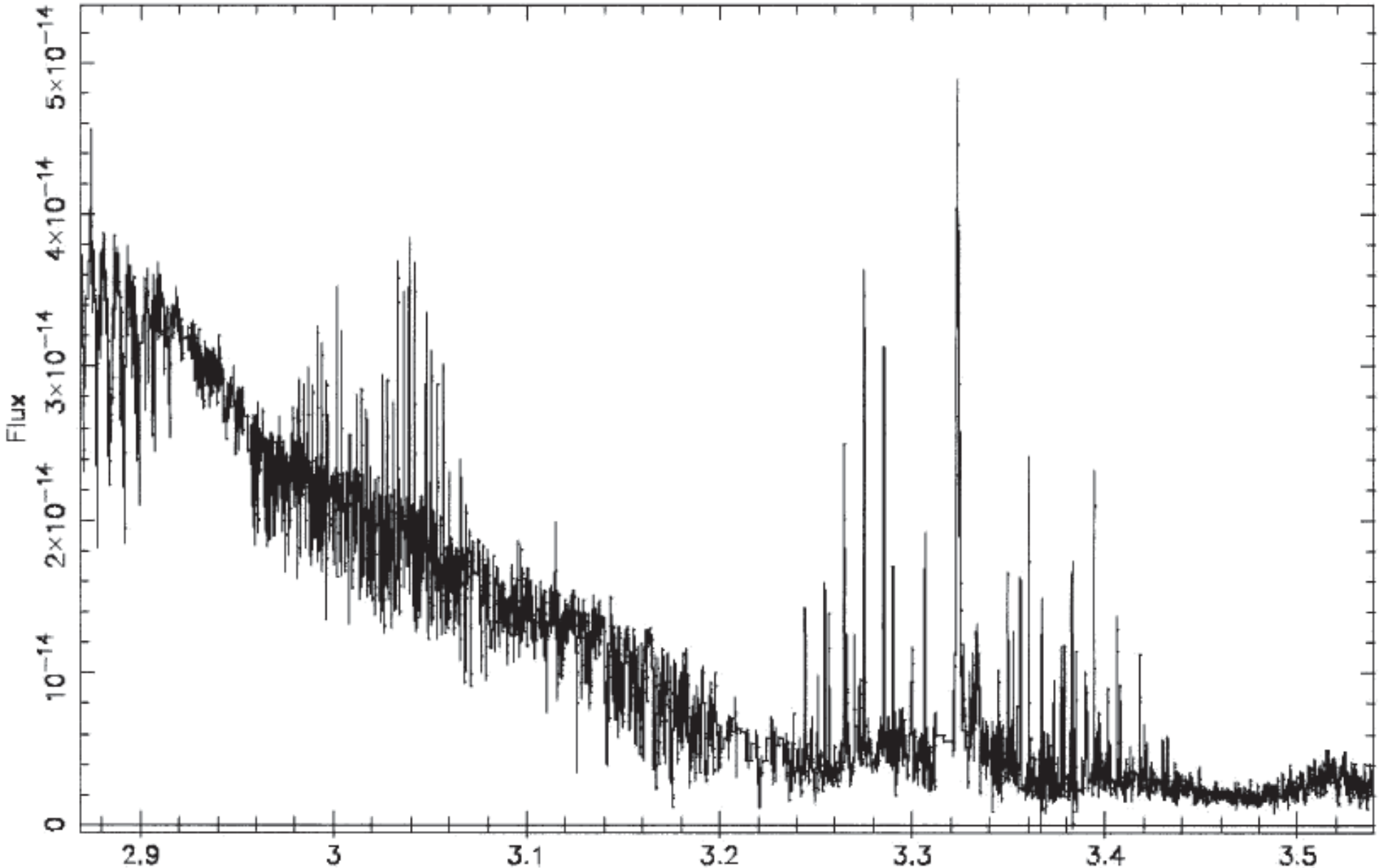
Titan at R=20,000 (Geballe et al. 2004)



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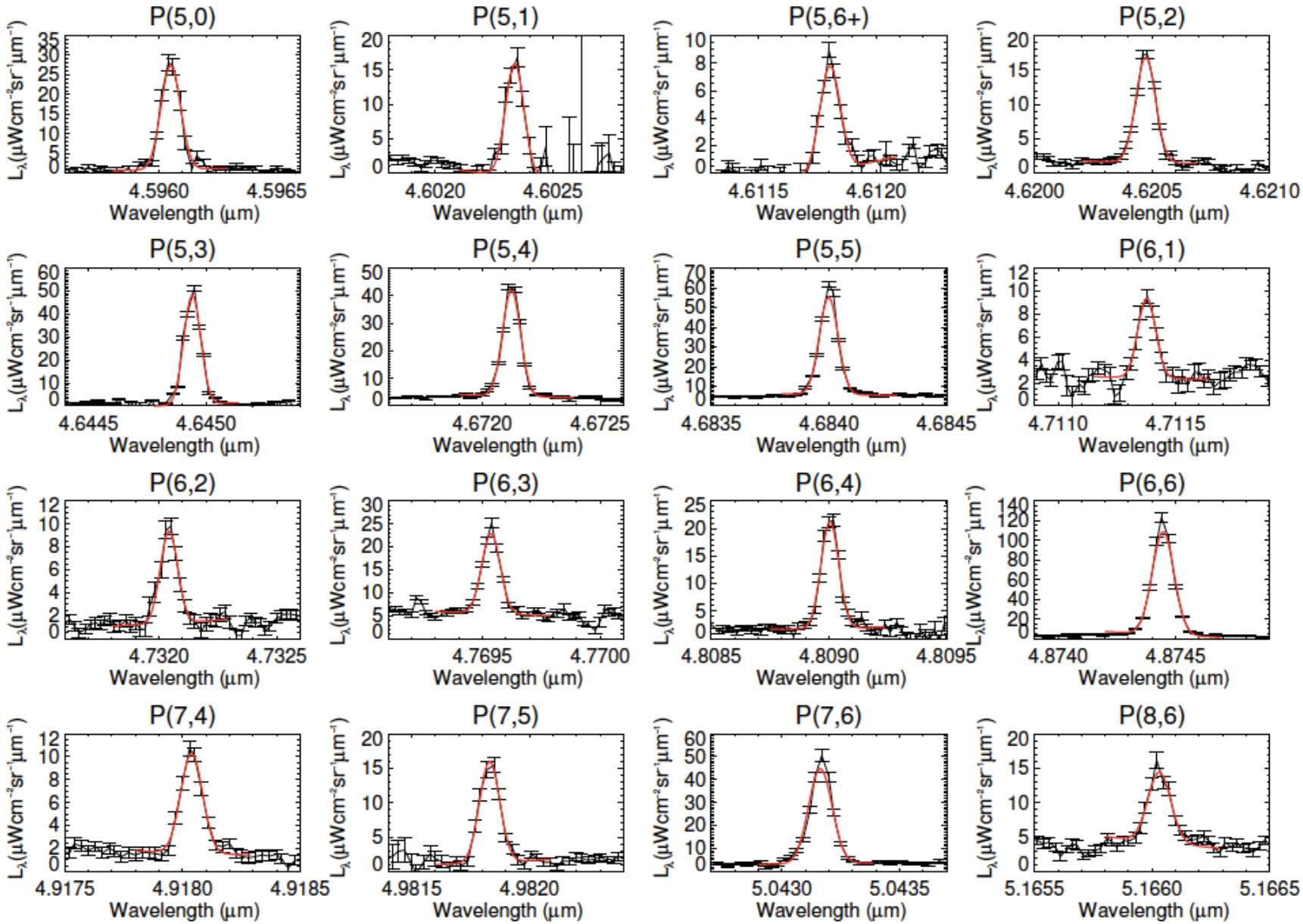
Auroral H_3^+ on Jupiter (Giles et al. 2016)



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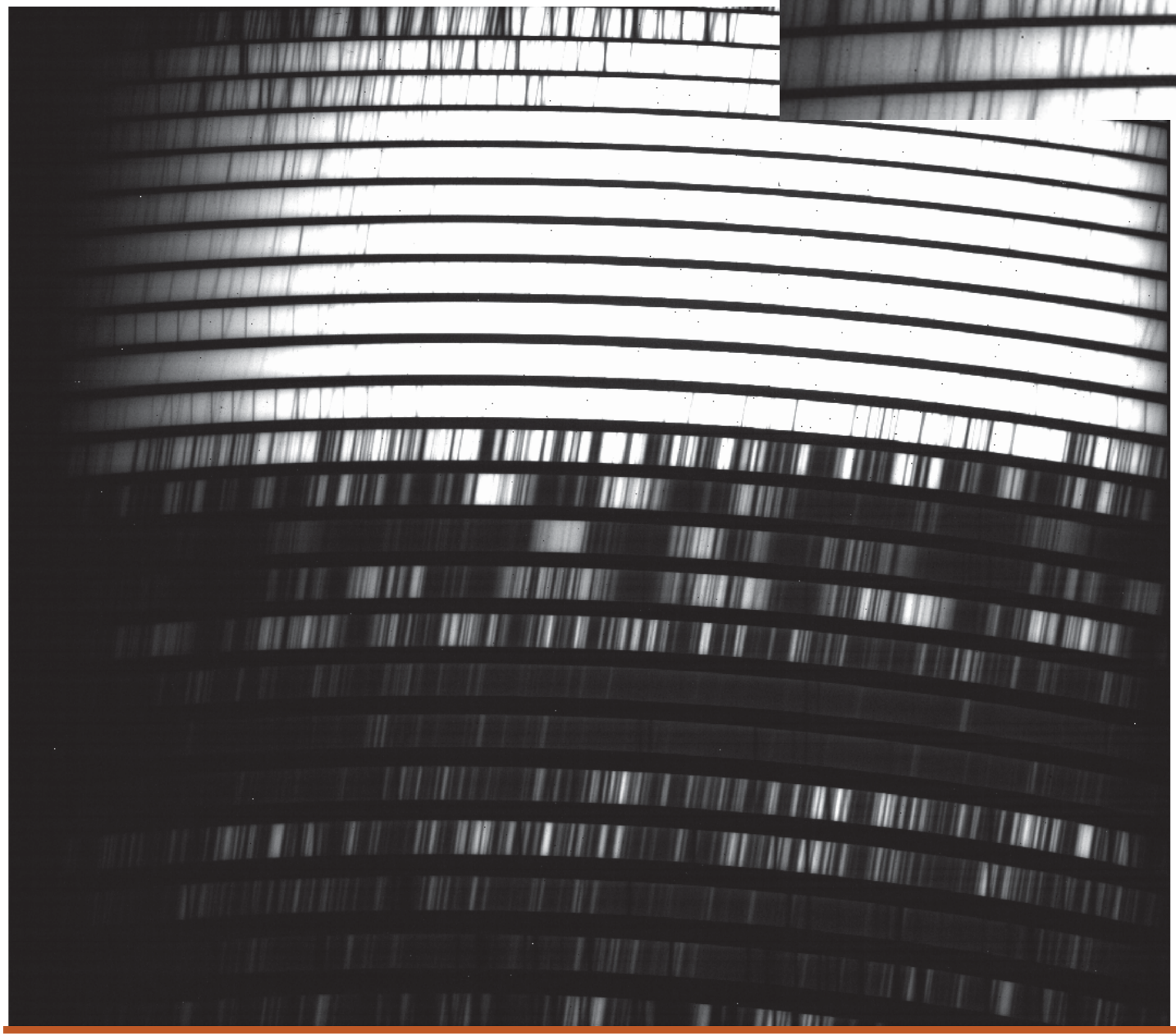
Saturn in the H band (Commissioning data)



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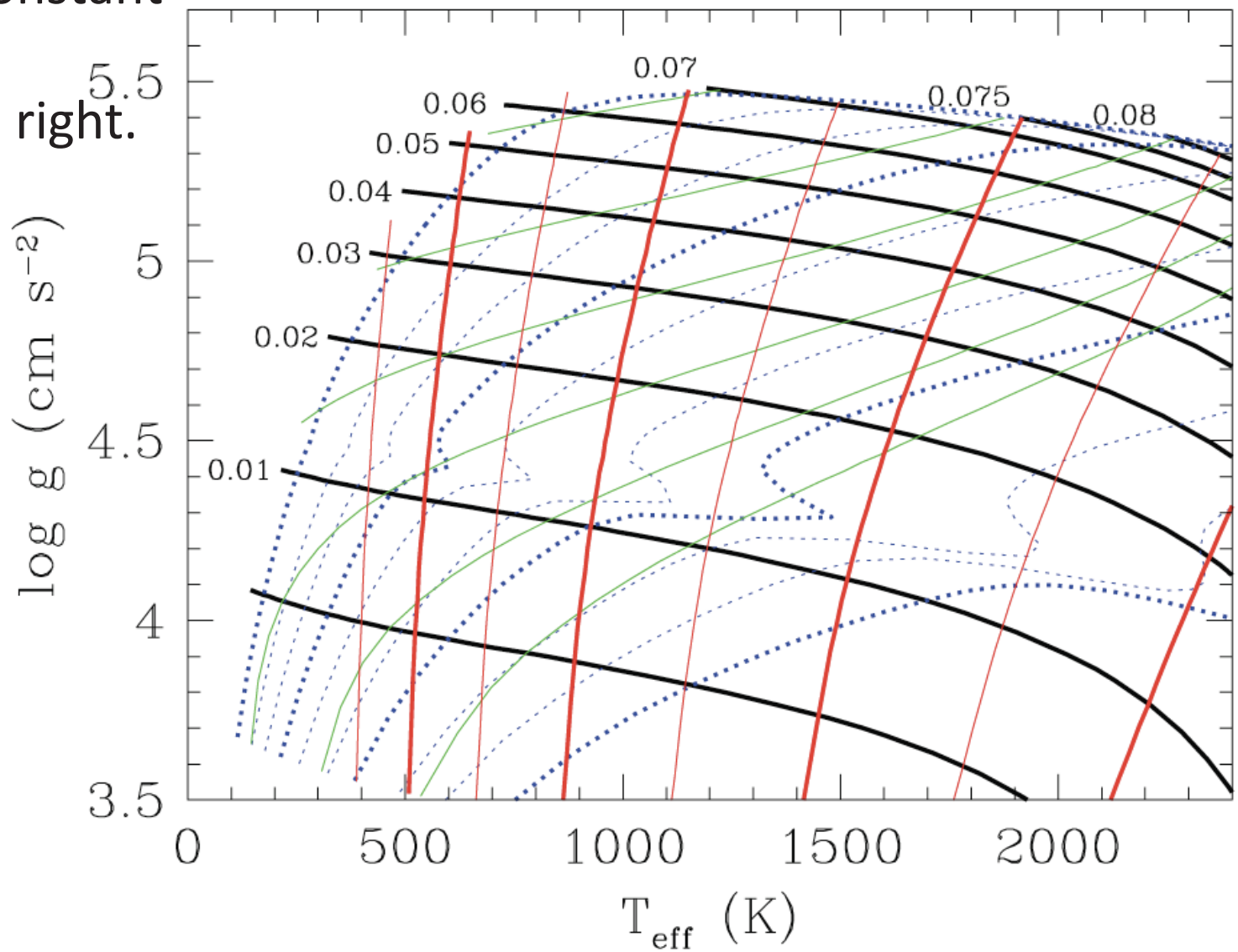
Brown Dwarfs in the HR Diagram (Saumon and Marley 2008)

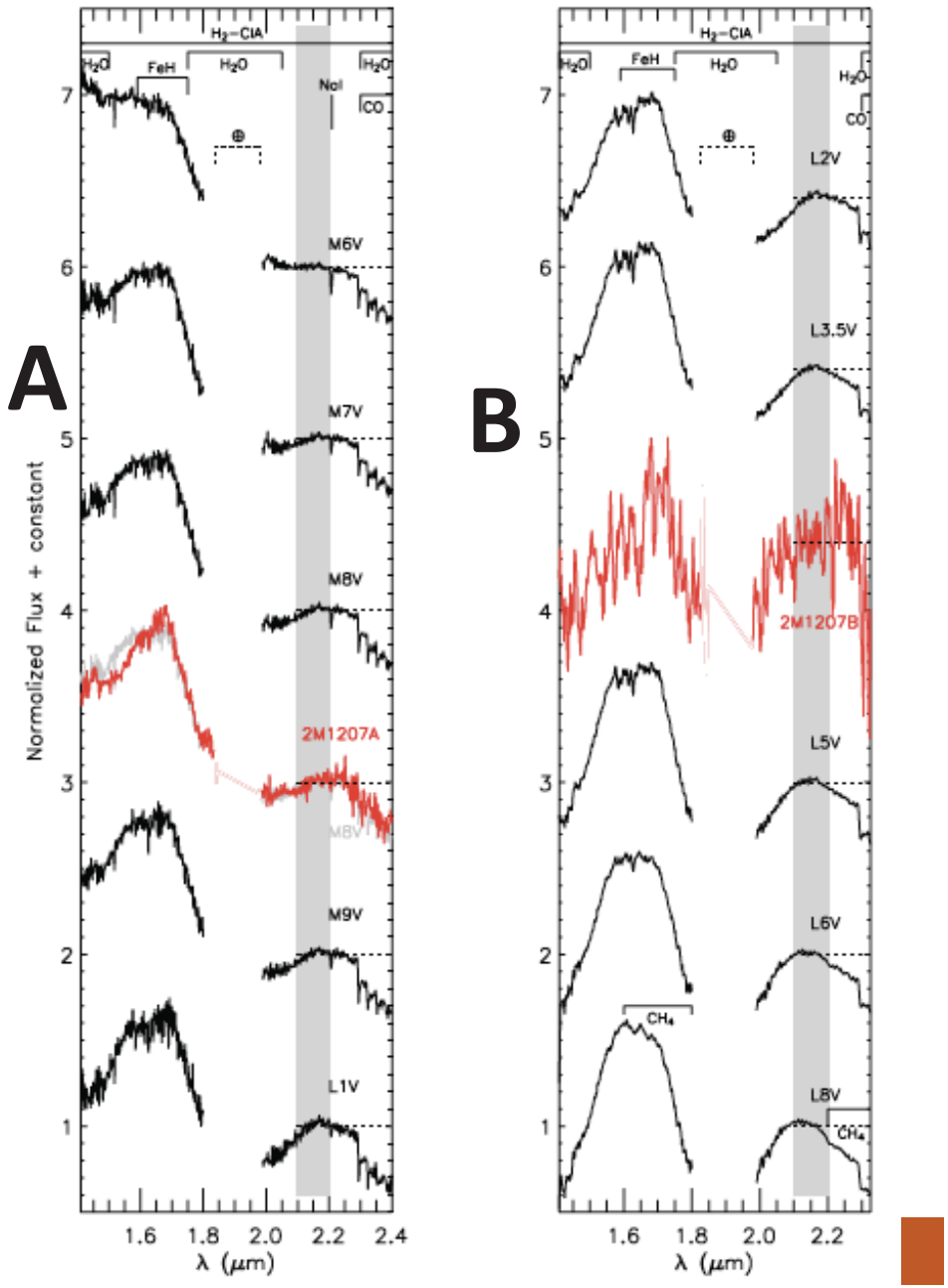
Black lines are constant mass in M_{sun}.
BDs move left to right.
Isochrones are 0.01, 0.1,1 etc Gyr (red lines)



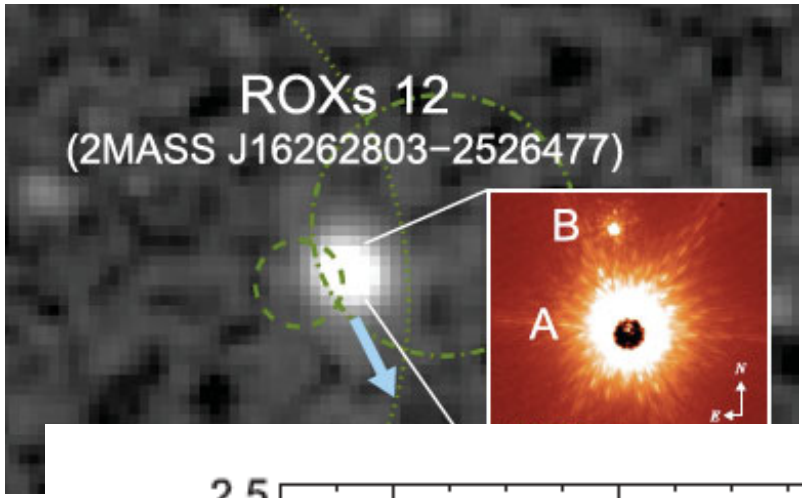
2M1207A and B (Mohanty et al. 2007)

T_A= 2550 K, M_A =24 M_J

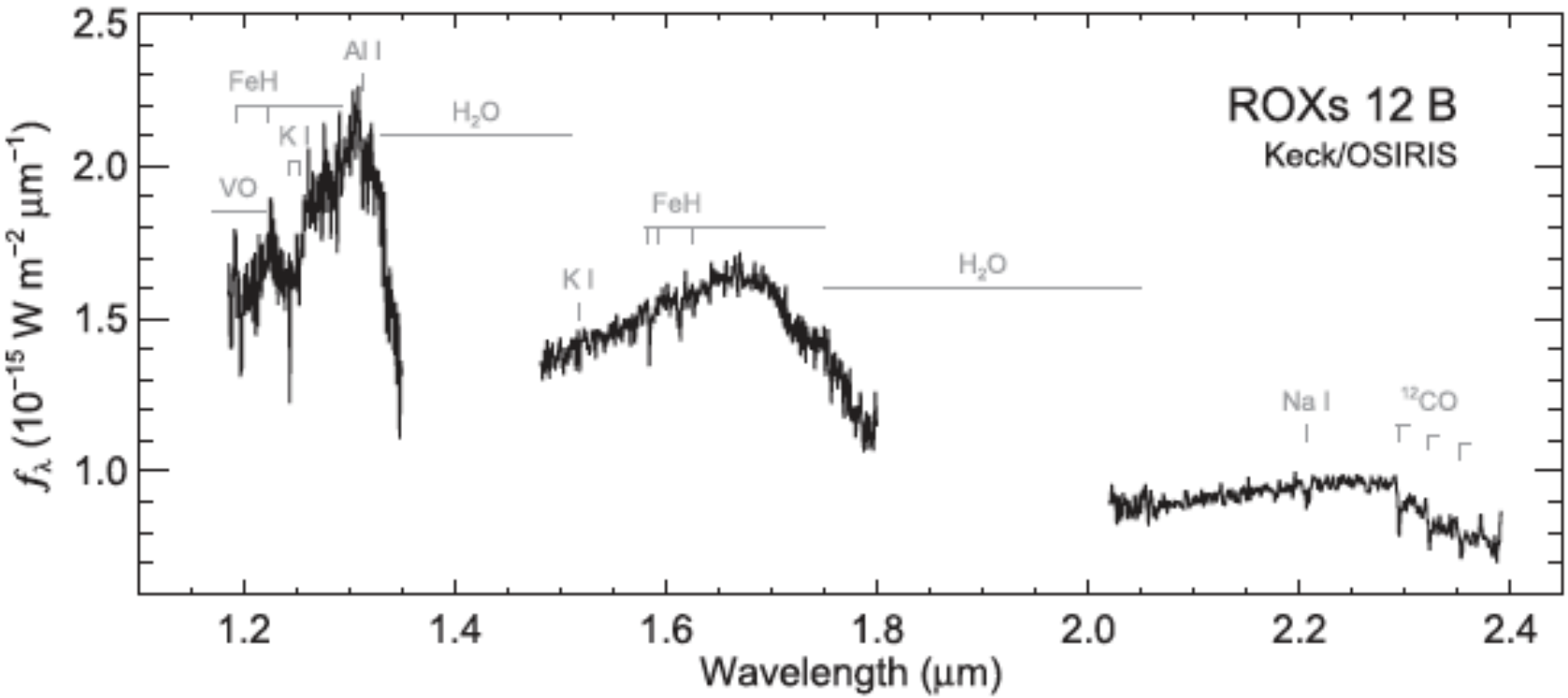
T_B= 1600 K, M_B= 8 M_J



ROXs-12B (Bowler et al. 2017)

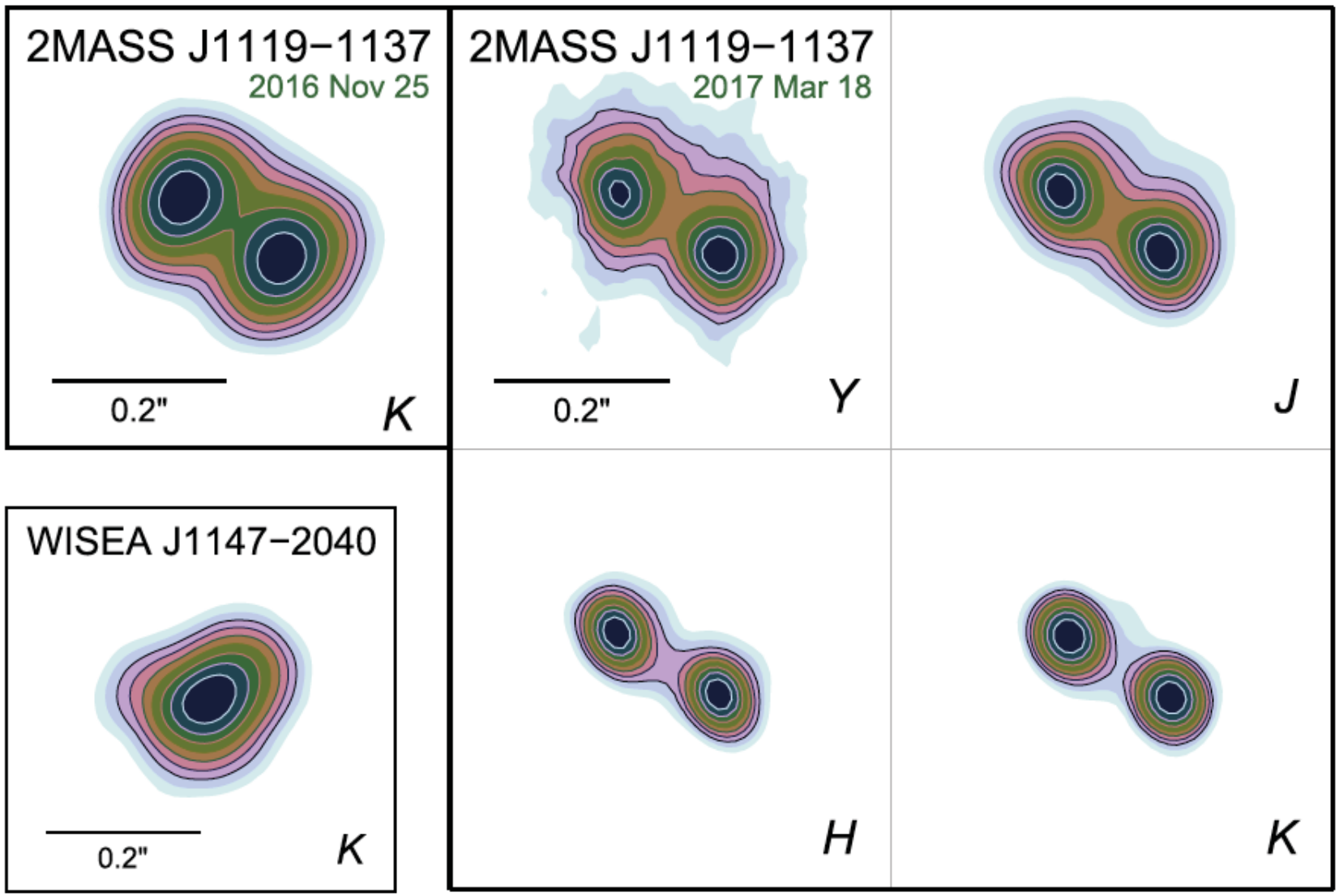


M=17 M_J
GMTNIRS could measure gravity and rotation, clouds, composition



Best et al. (2017) binary of 3.7 M_J Brown Dwarfs

Both are easily observable with GMTNIRS



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RV Searches for planets around young stars are not easy at visible wavelengths because of the effects of stellar activity

RV observations of young warm to hot Jupiters

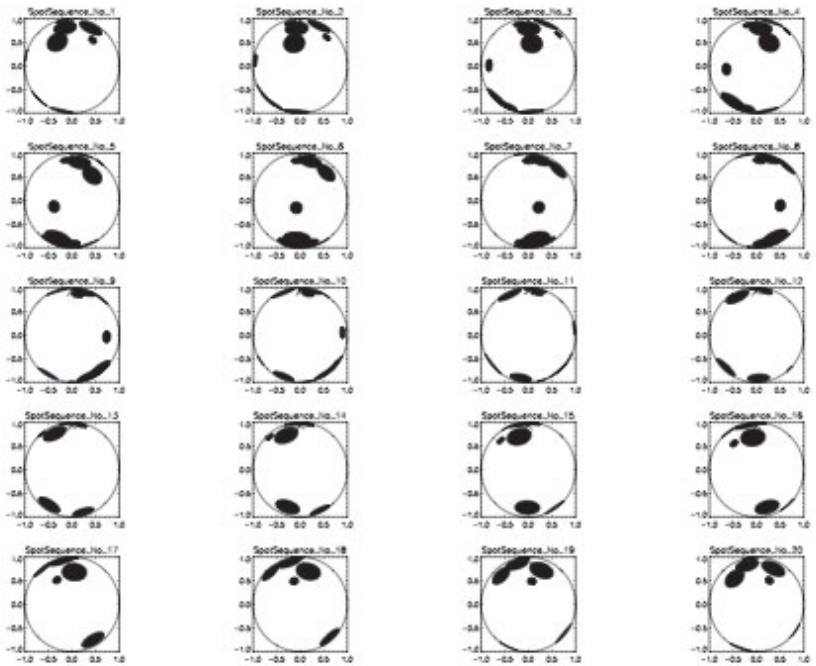


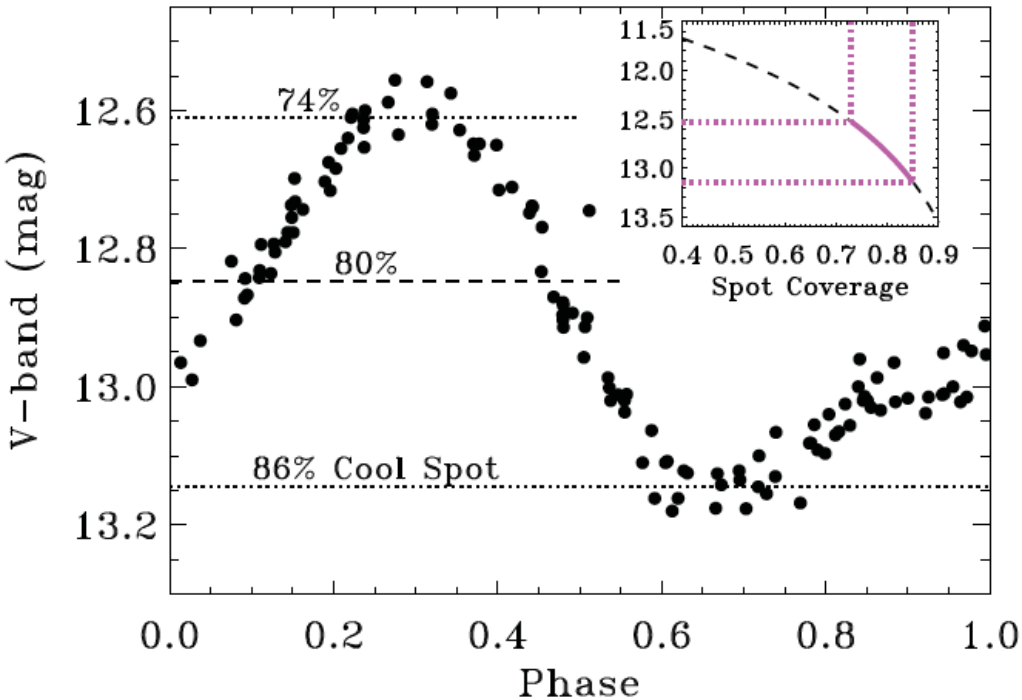
FIG. 10.—Rotation sequence of 15 random spots; $i = 86°$.

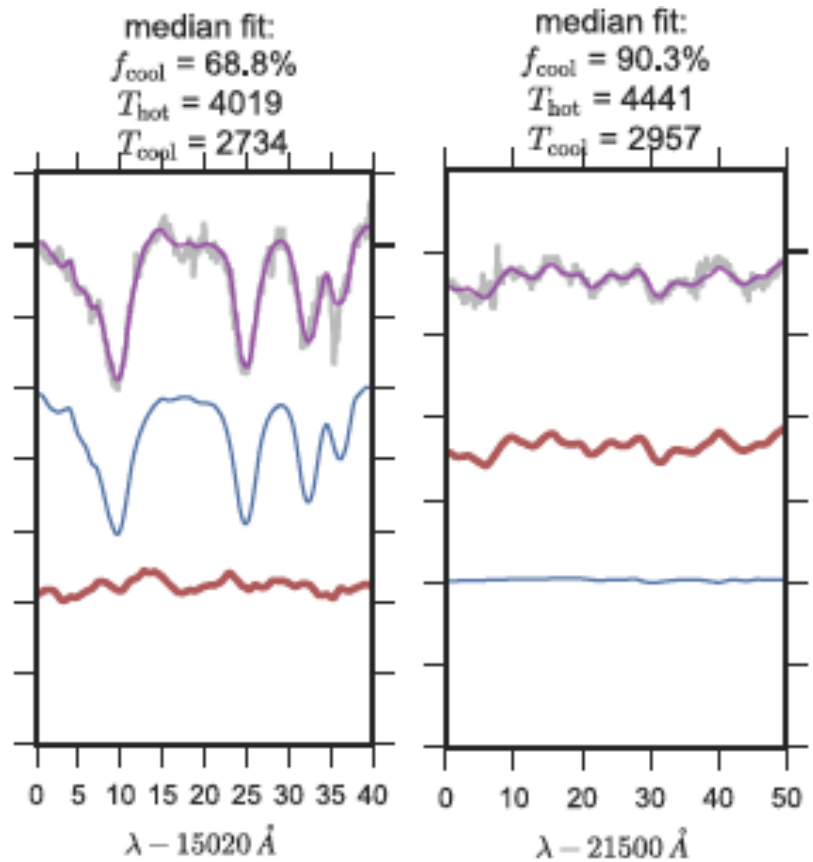
YSO RV Group led by
Lisa Prato
Our first paper:
Huerta et al. (2008)

Finding even one massive planet in a young system constrains formation timescales.

Rotating star spots cause large RV noise in young stars. Tests like the bisector span cannot always eliminate false positives.

Lk Ca 4 (Gully-Santiago et al. 2014)

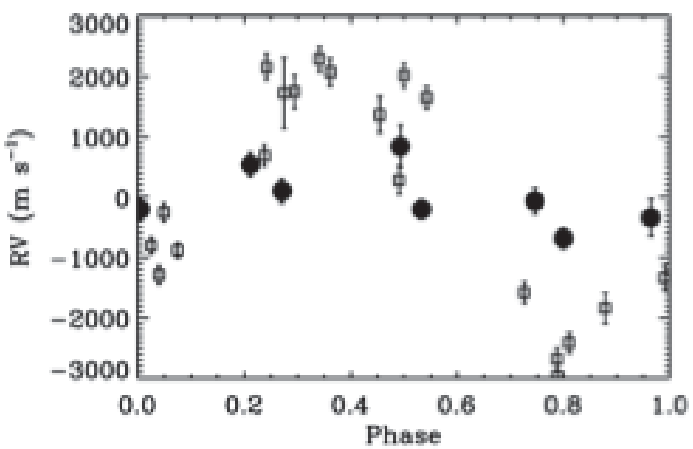




GMTNIRS is not a PRV instrument but can play a critical role through RV measurements that constrain the way in which Jupiter-mass bodies form.

Young Jupiters

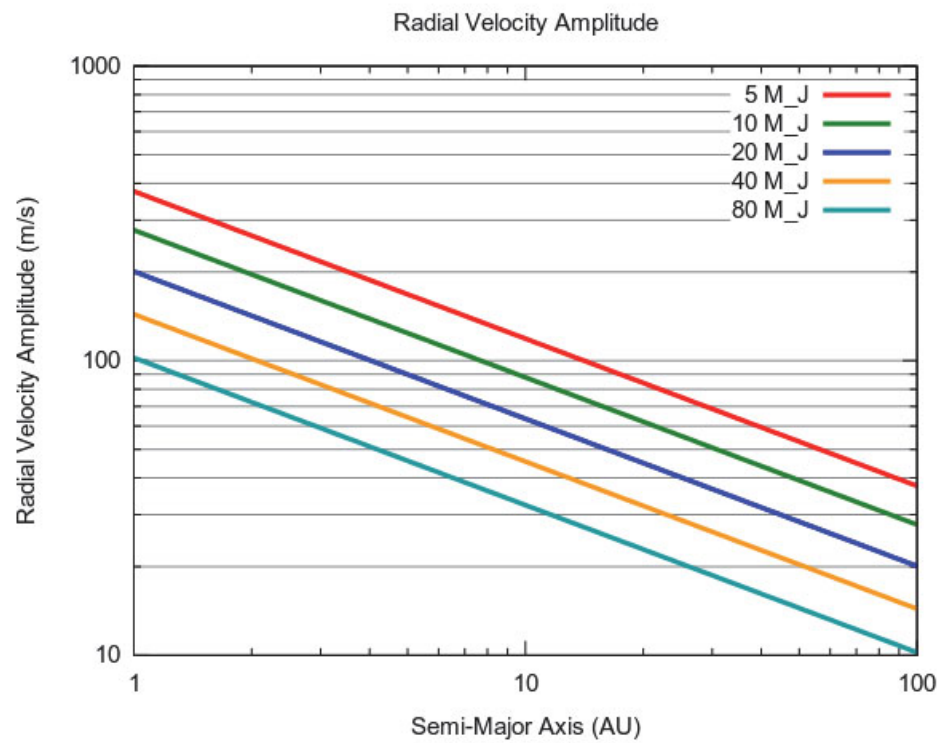
RV noise from star spots is very significantly lower at K than at visible wavelengths



Velocity curve for V827Tau (Prato et al. 2008). Open symbols are from R band measurements while closed symbols are K band.

Jupiter mass companions to brown dwarfs

Reflex motion of different mass primaries versus distance when the planet has a mass of 1 M_J



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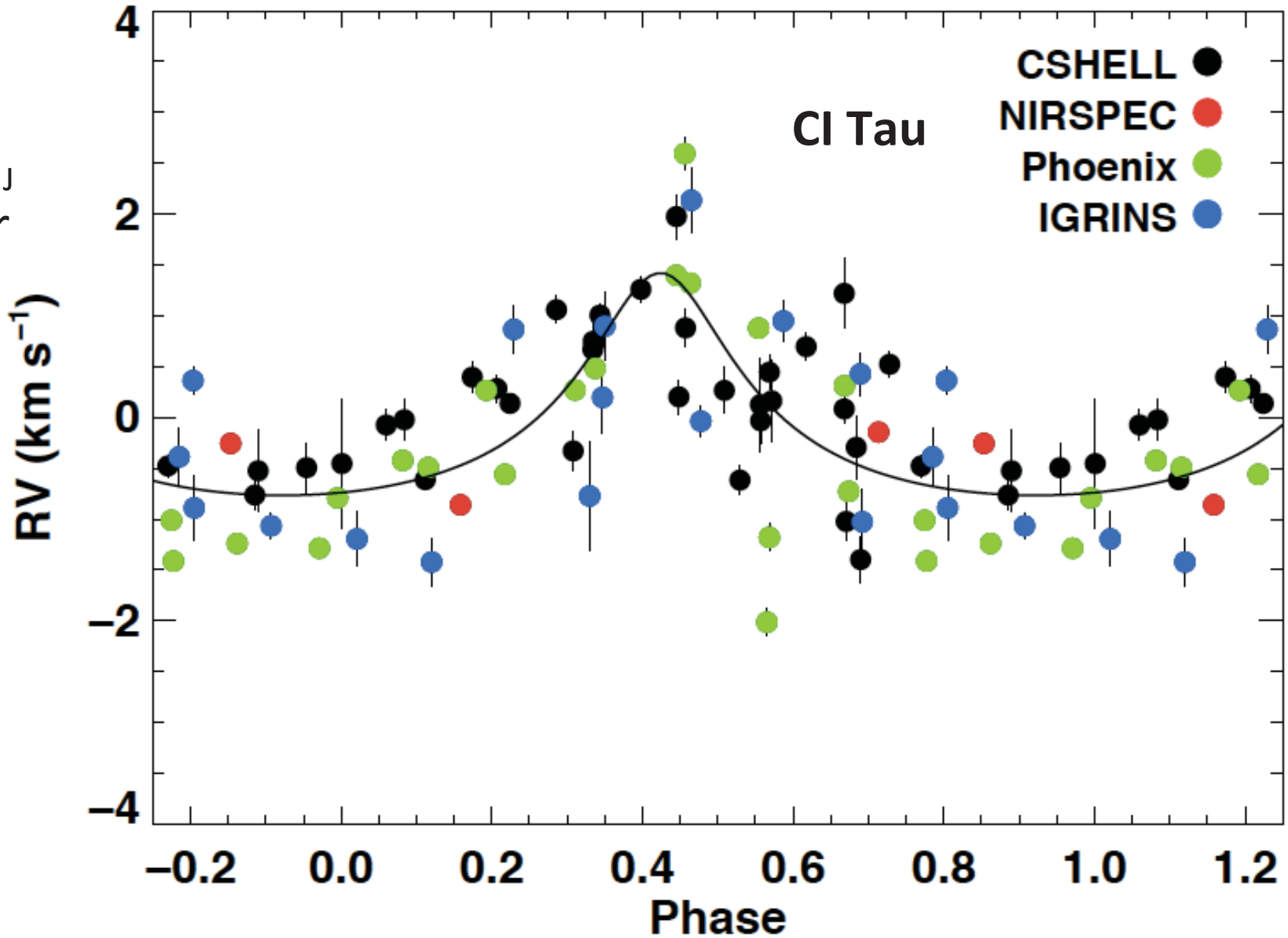
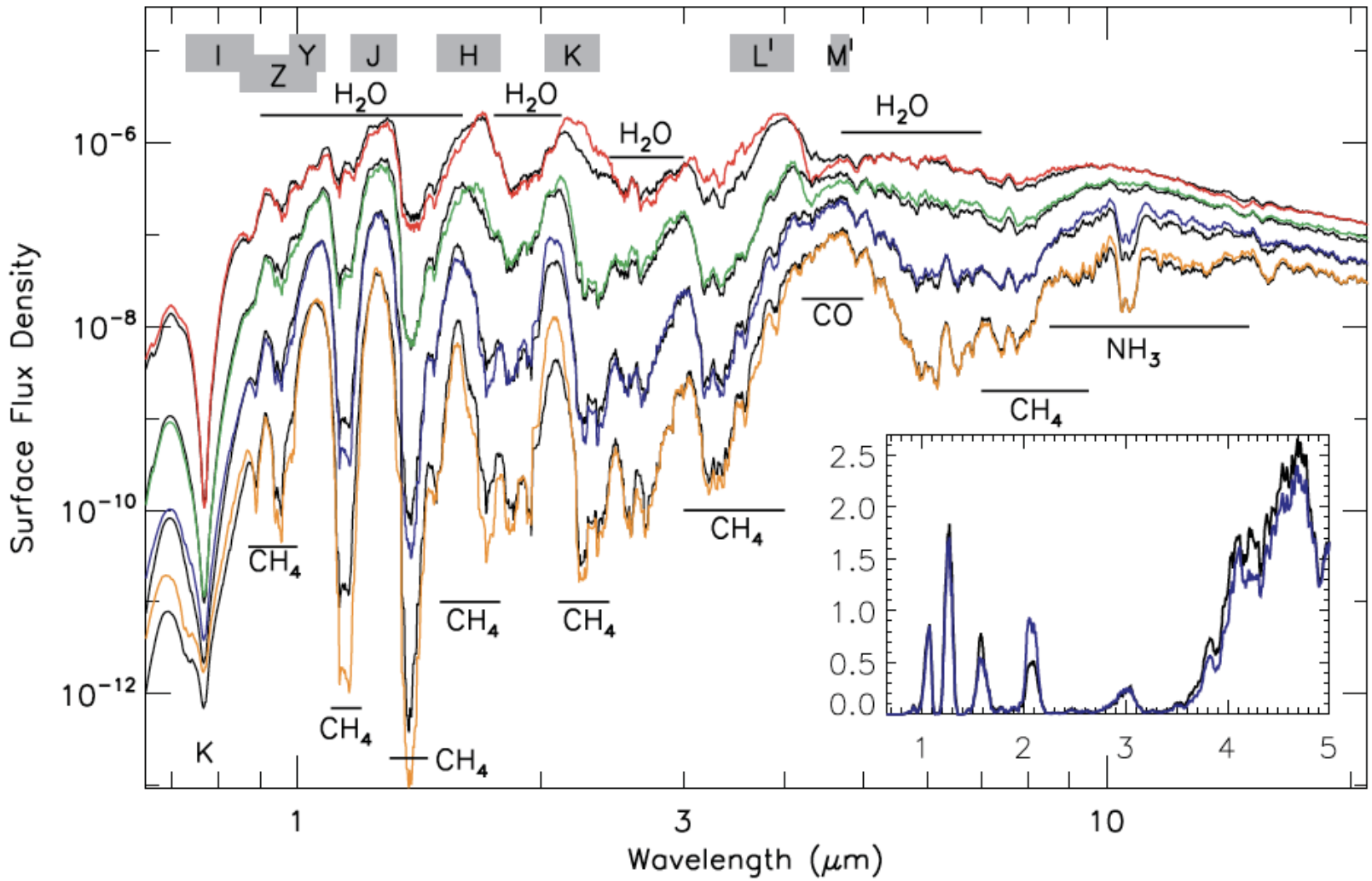
Johns-Krull et al. (2016)

P=9d
M=11 M_J
τ=2 Myr



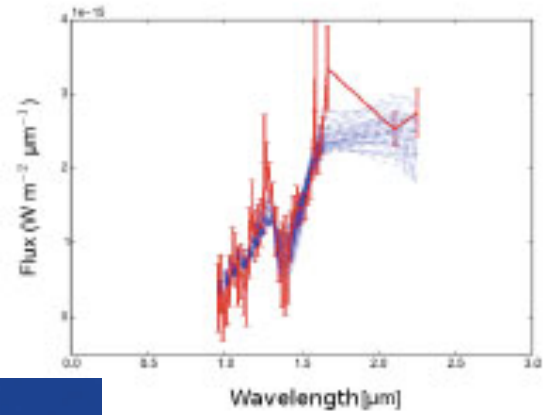
Fortney et al. 2008

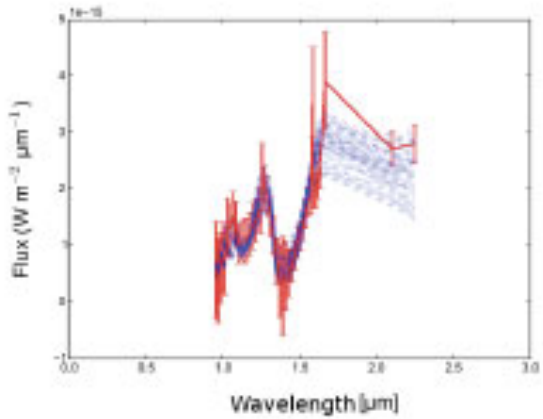
Models for 1400, 1000, 700, 500 K

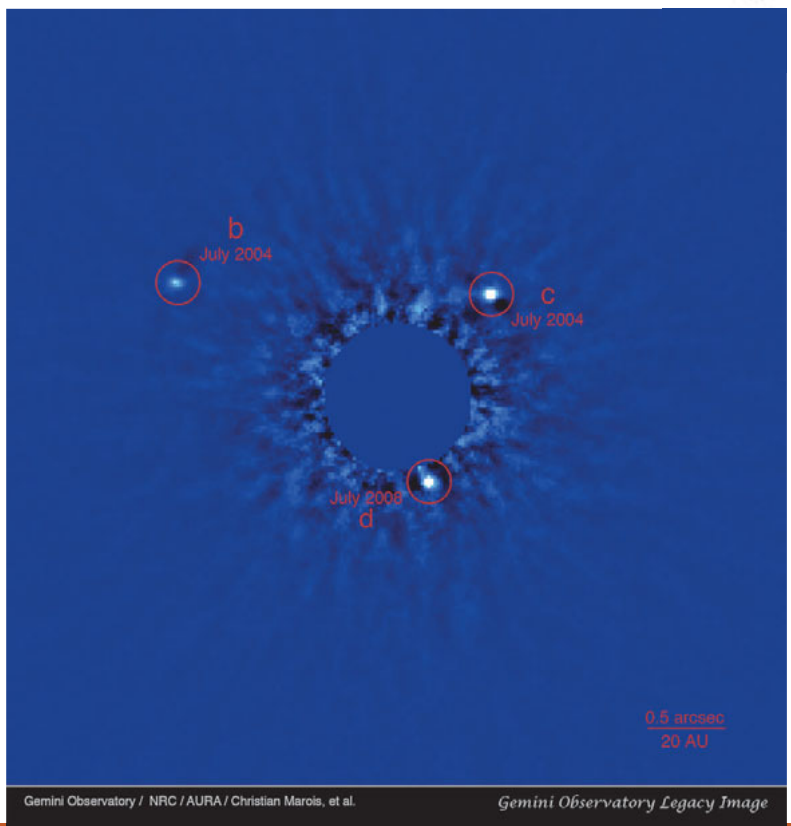


Direct spectroscopy of exoplanets

HR8799 b and c
(Baudino et al. 2017)







Gemini.edu

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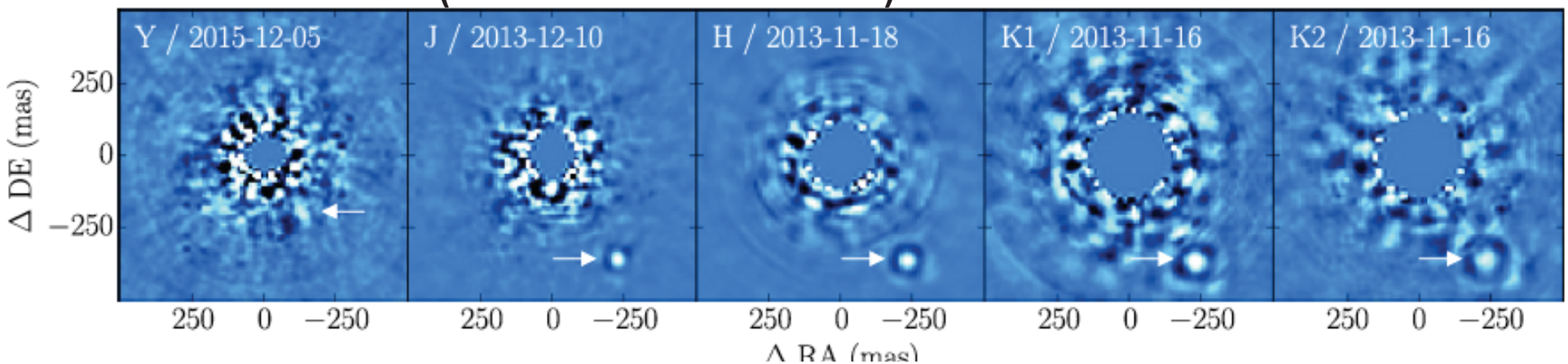
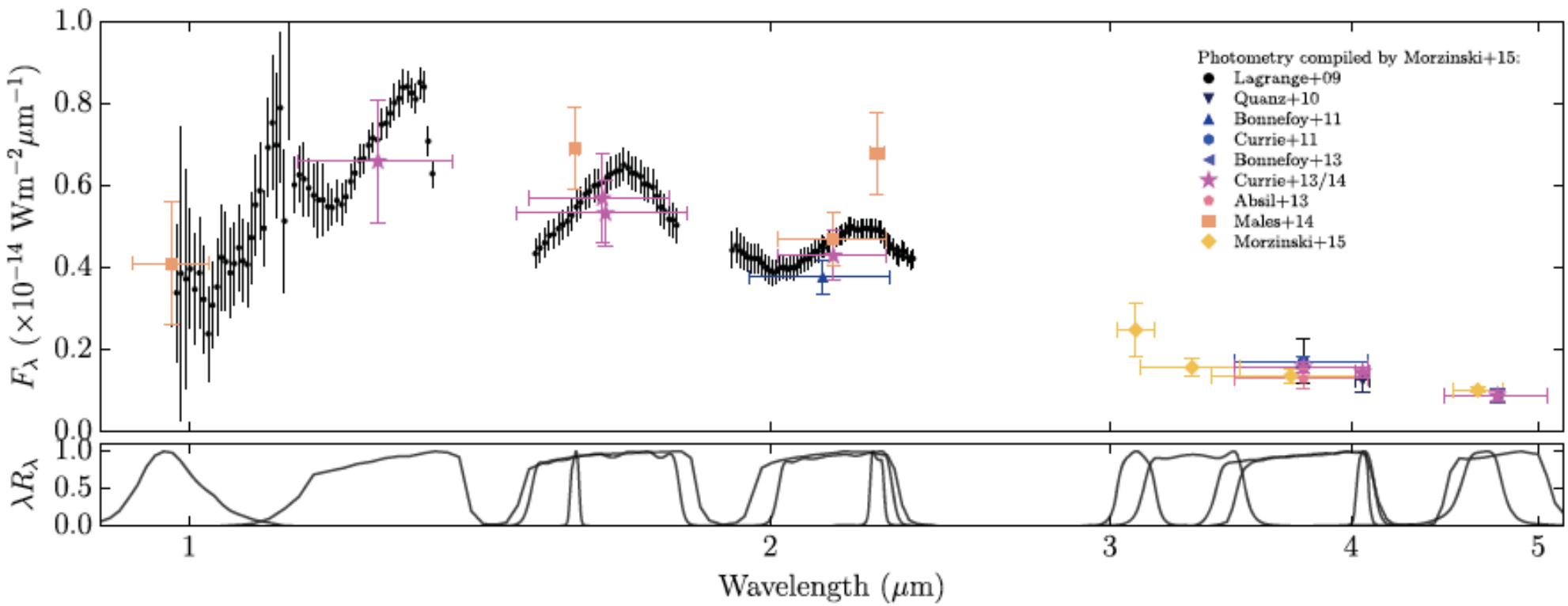
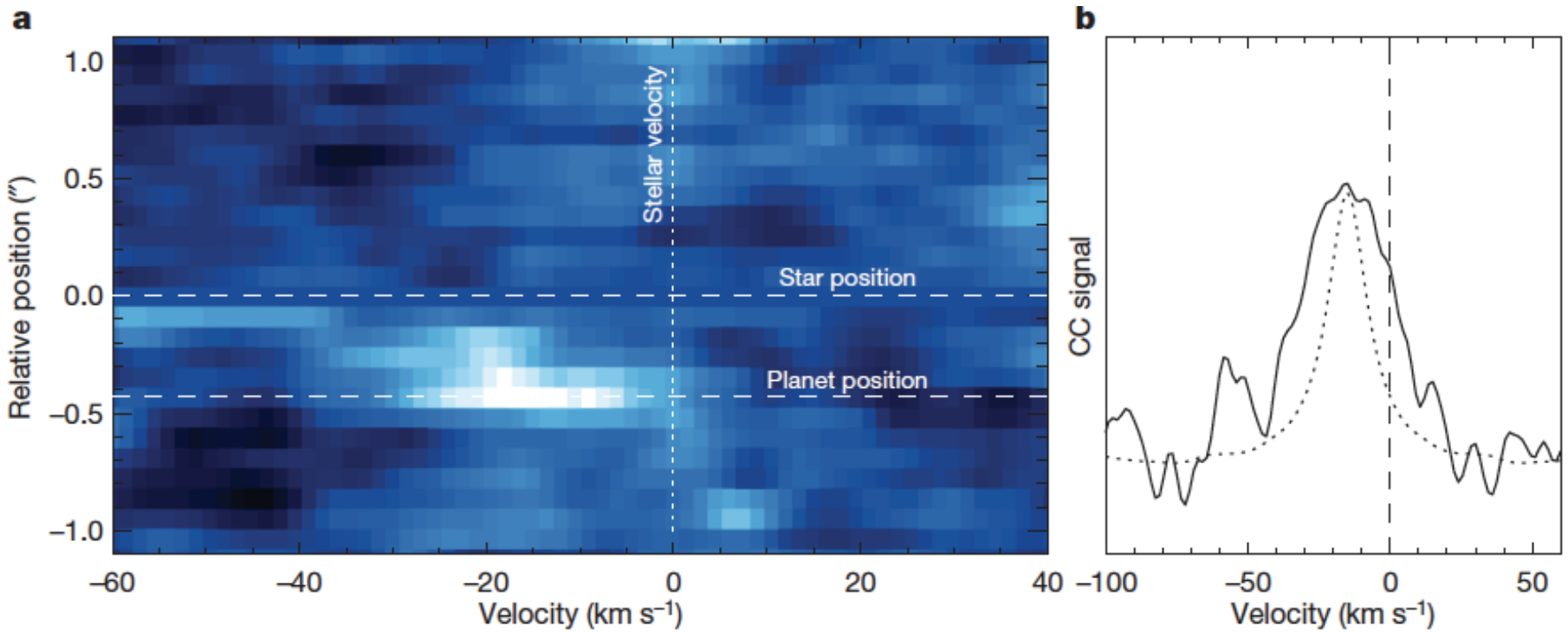
βPicb images and spectra with GPI

(Chilcote et al. 2017)





Snellen et al. (2014) Nature



Evidence for rapid rotation of βPicb

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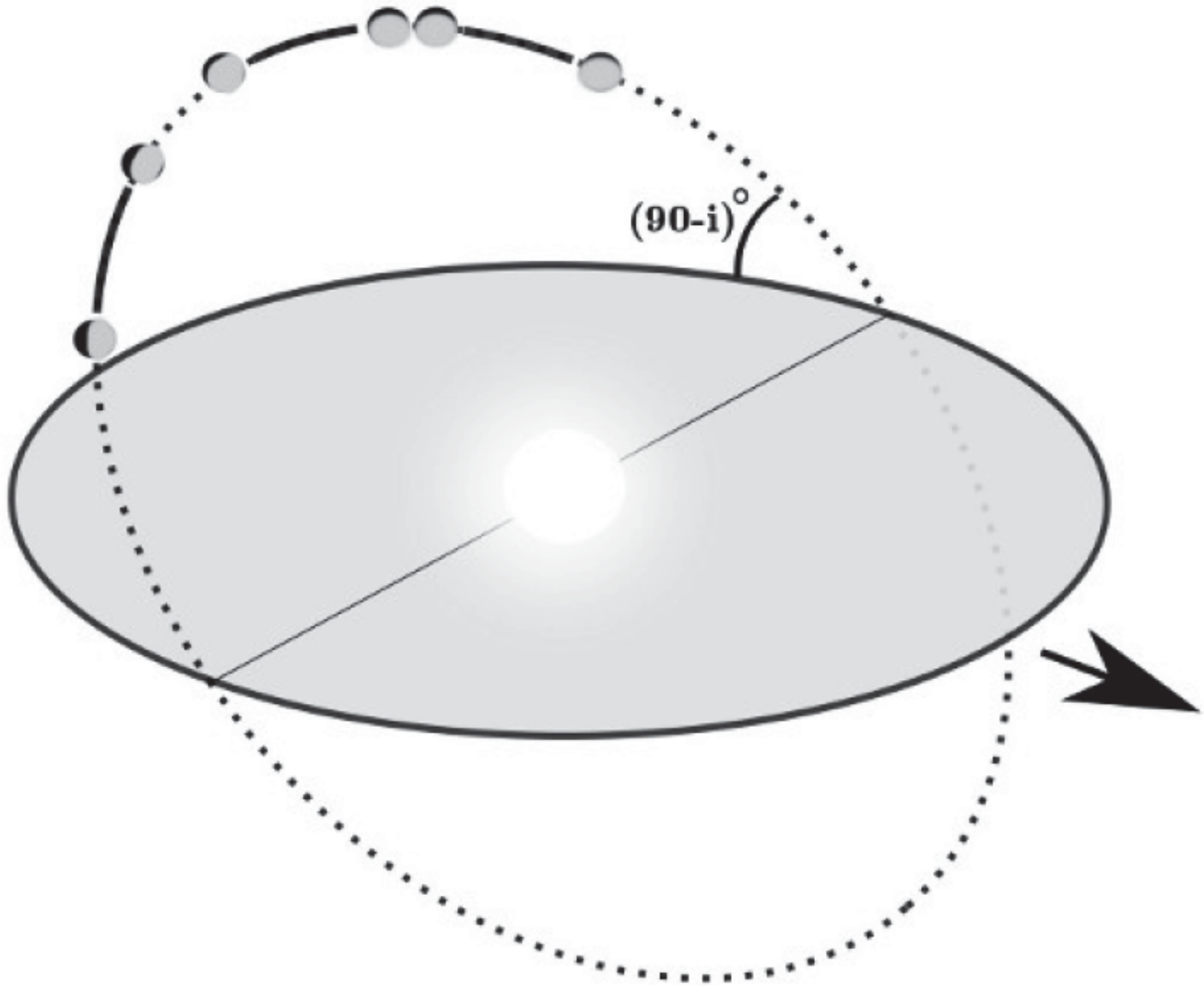
Non-transiting exoplanets (Brogi et al 2012).



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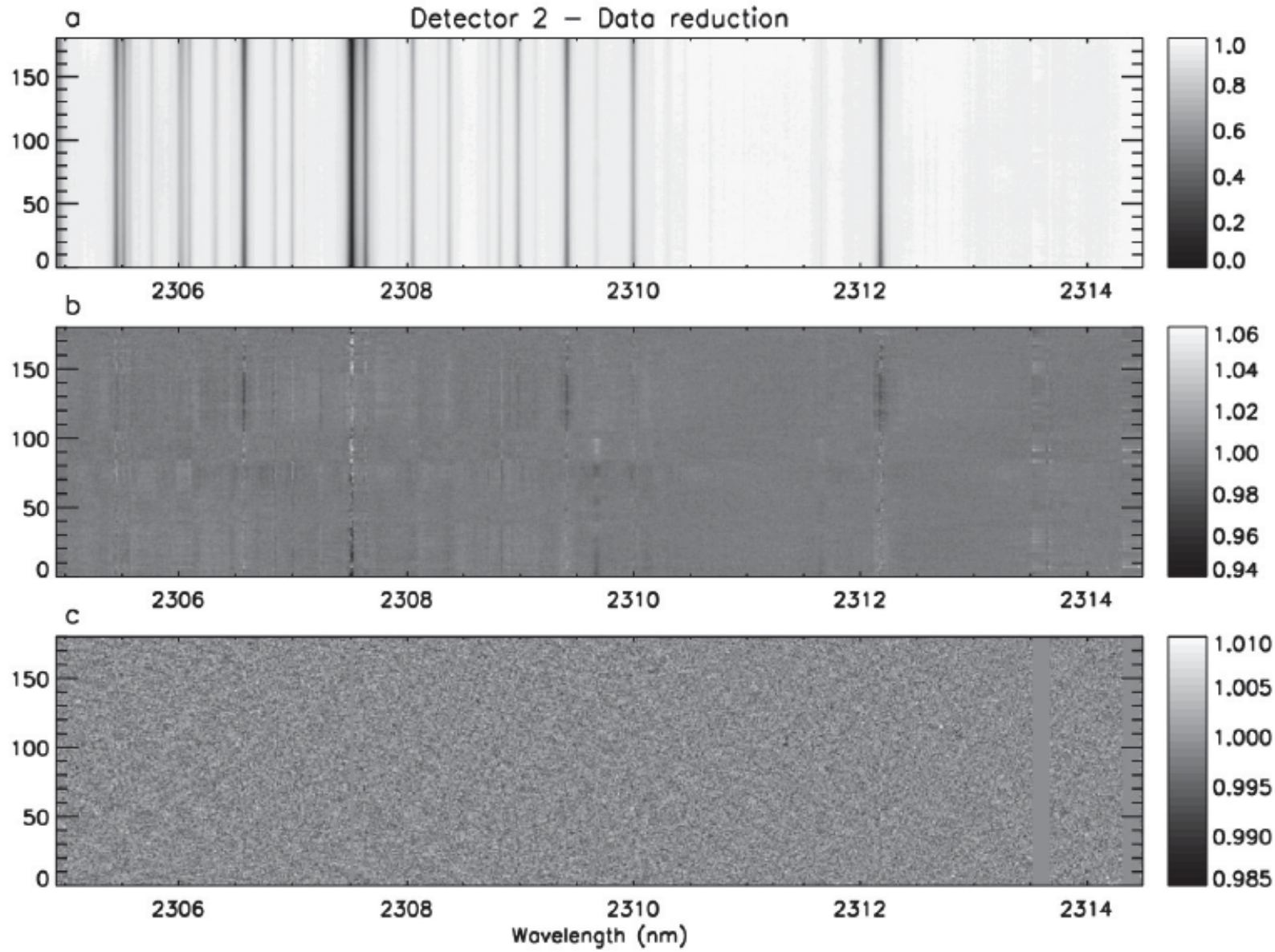
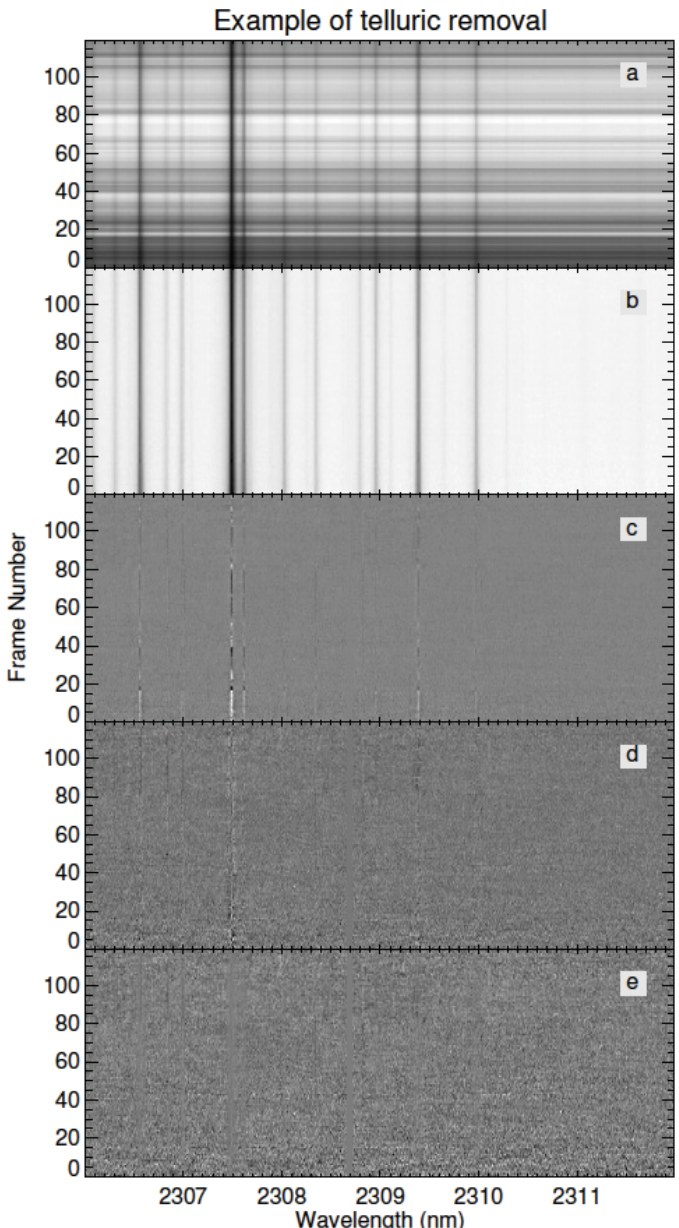
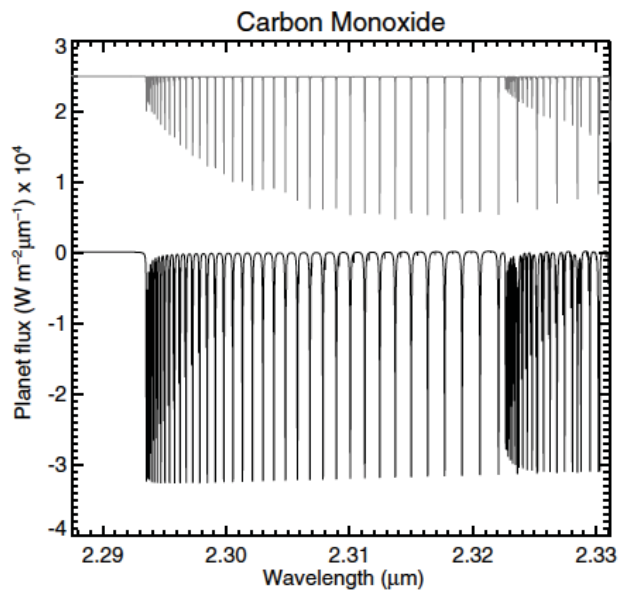
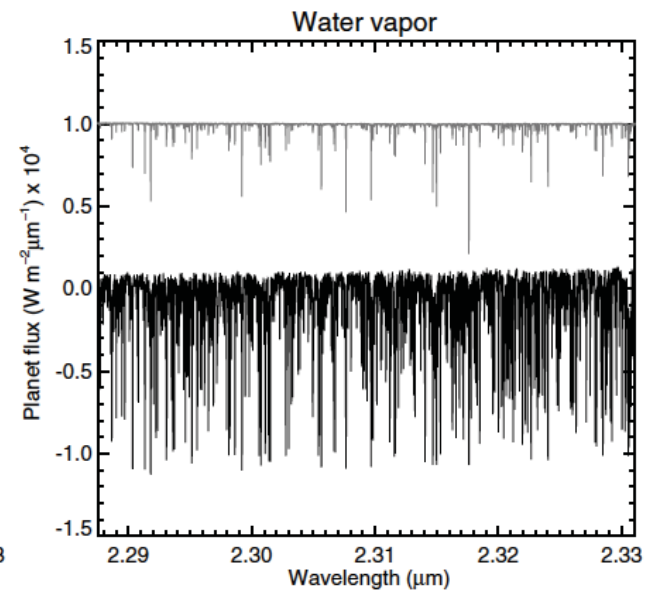
Brogi et al. (2012) Data analysis for τ Boo (note the scale of the grayscale)



HD 179949 (Brogi et al. 2014, CRIRES)







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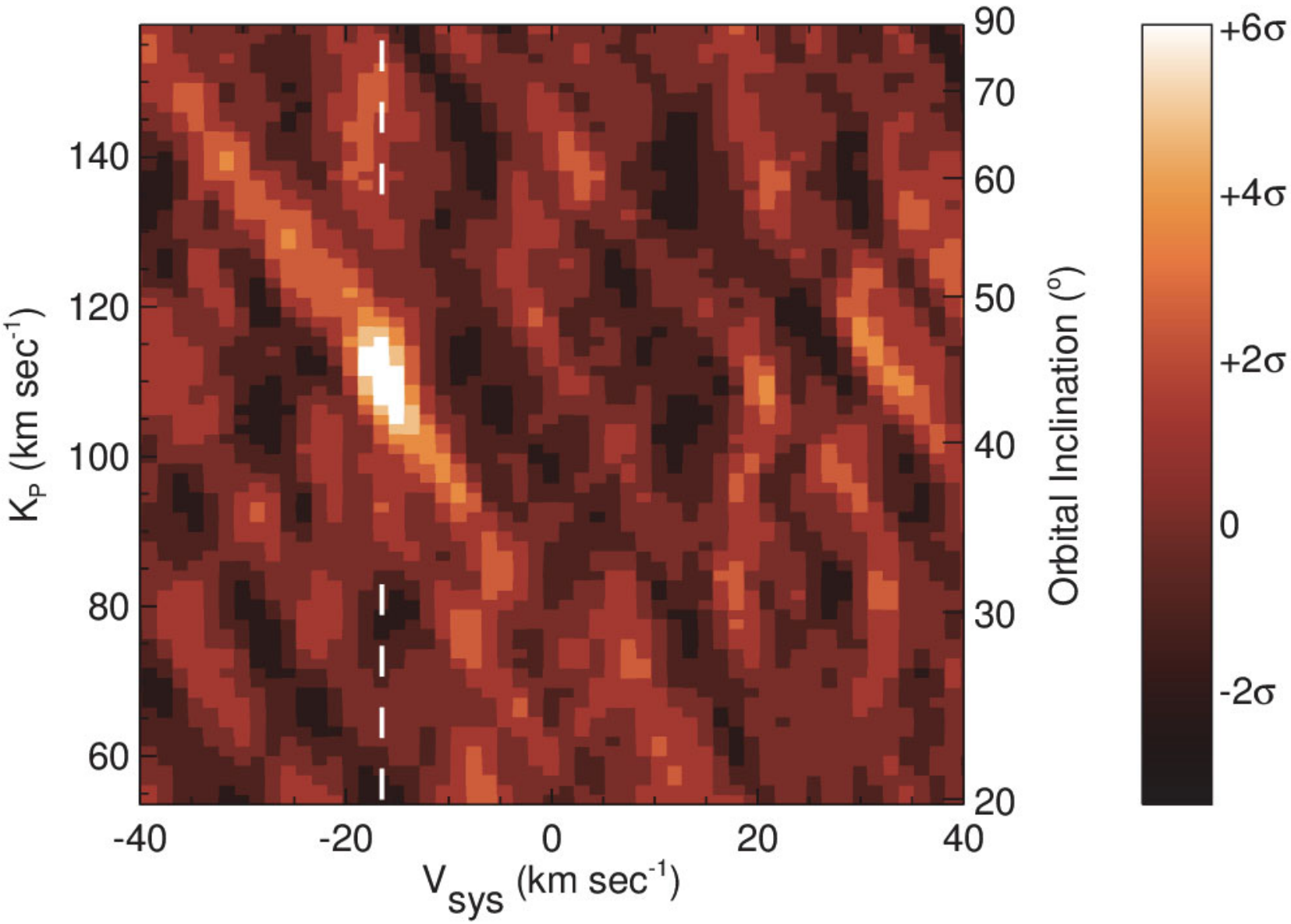
τ Boo (Brogi et al. 2012)



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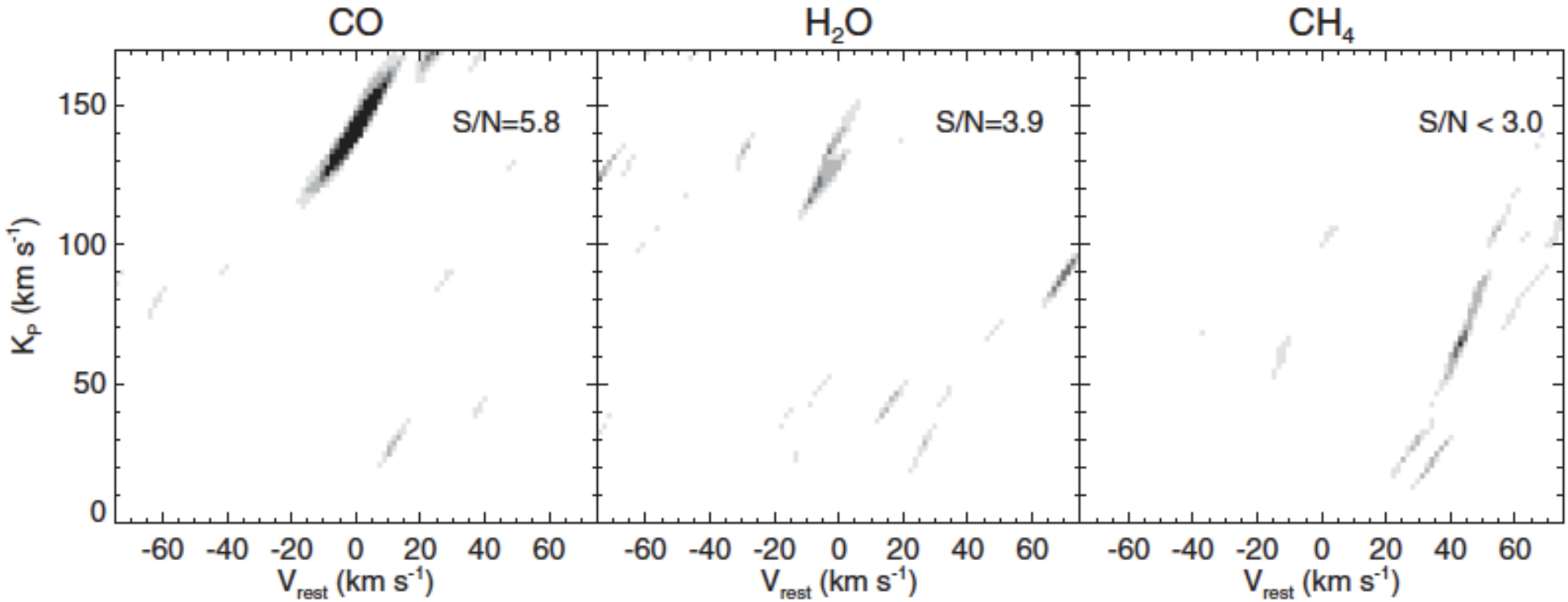
HD 179949 (Brogi et al. 2014, CRIRES)



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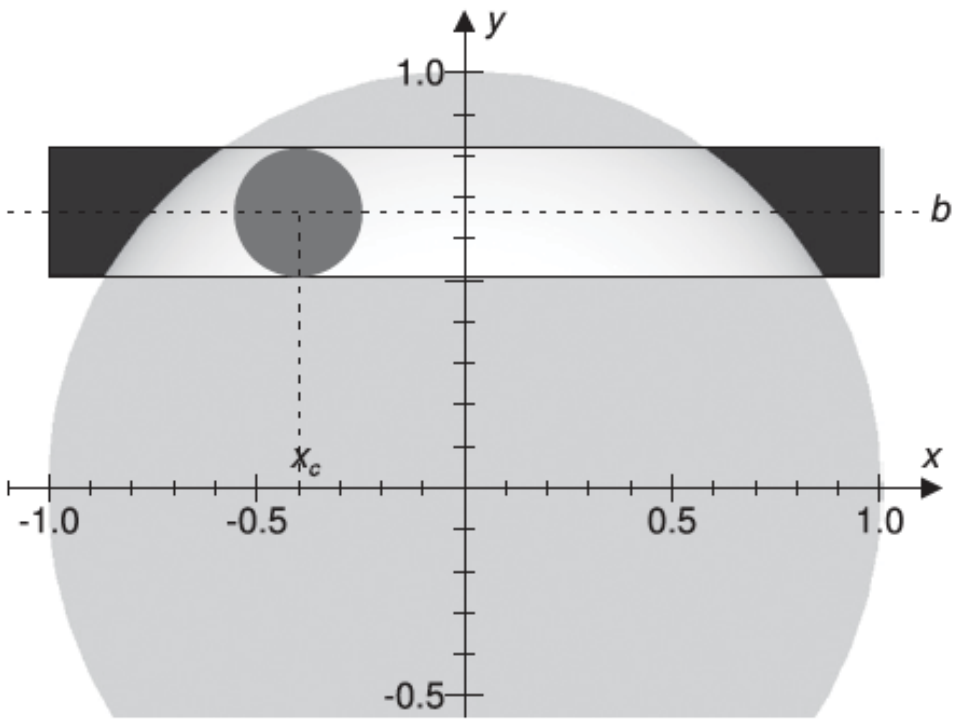
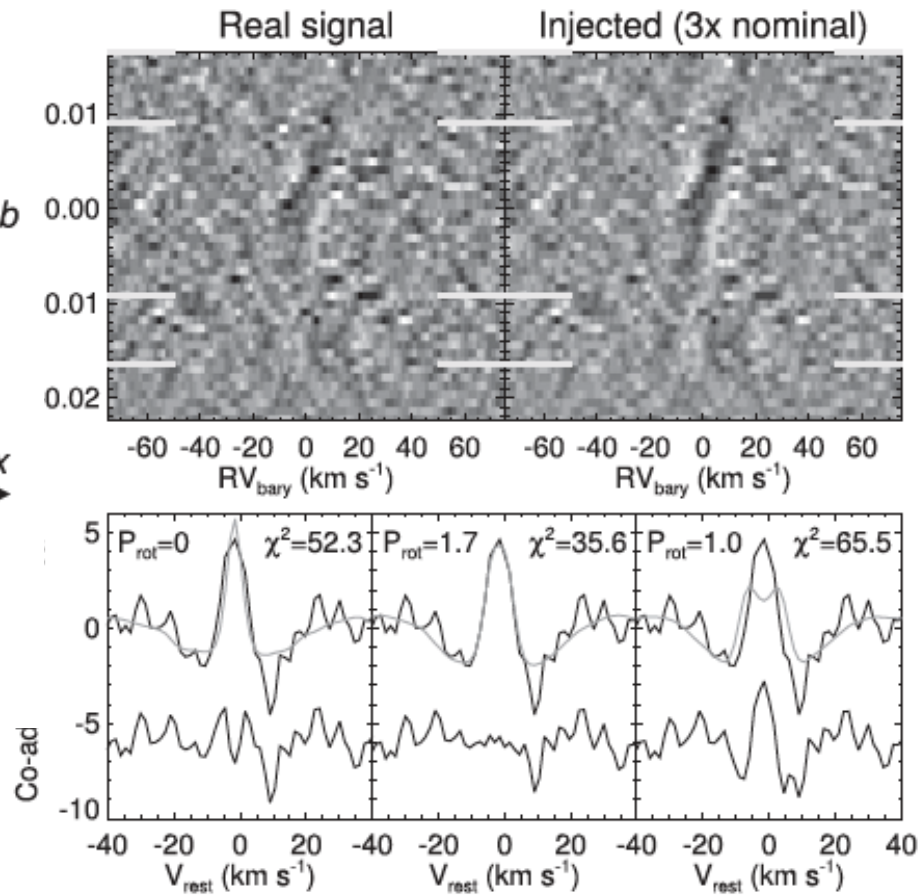
You can do more than simply detect.

ROTATION AND WINDS OF EXOPLANET HD 189733 b MEASURED WITH HIGH-DISPERSION TRANSMISSION SPECTROSCOPY





Brogi et al. 2016

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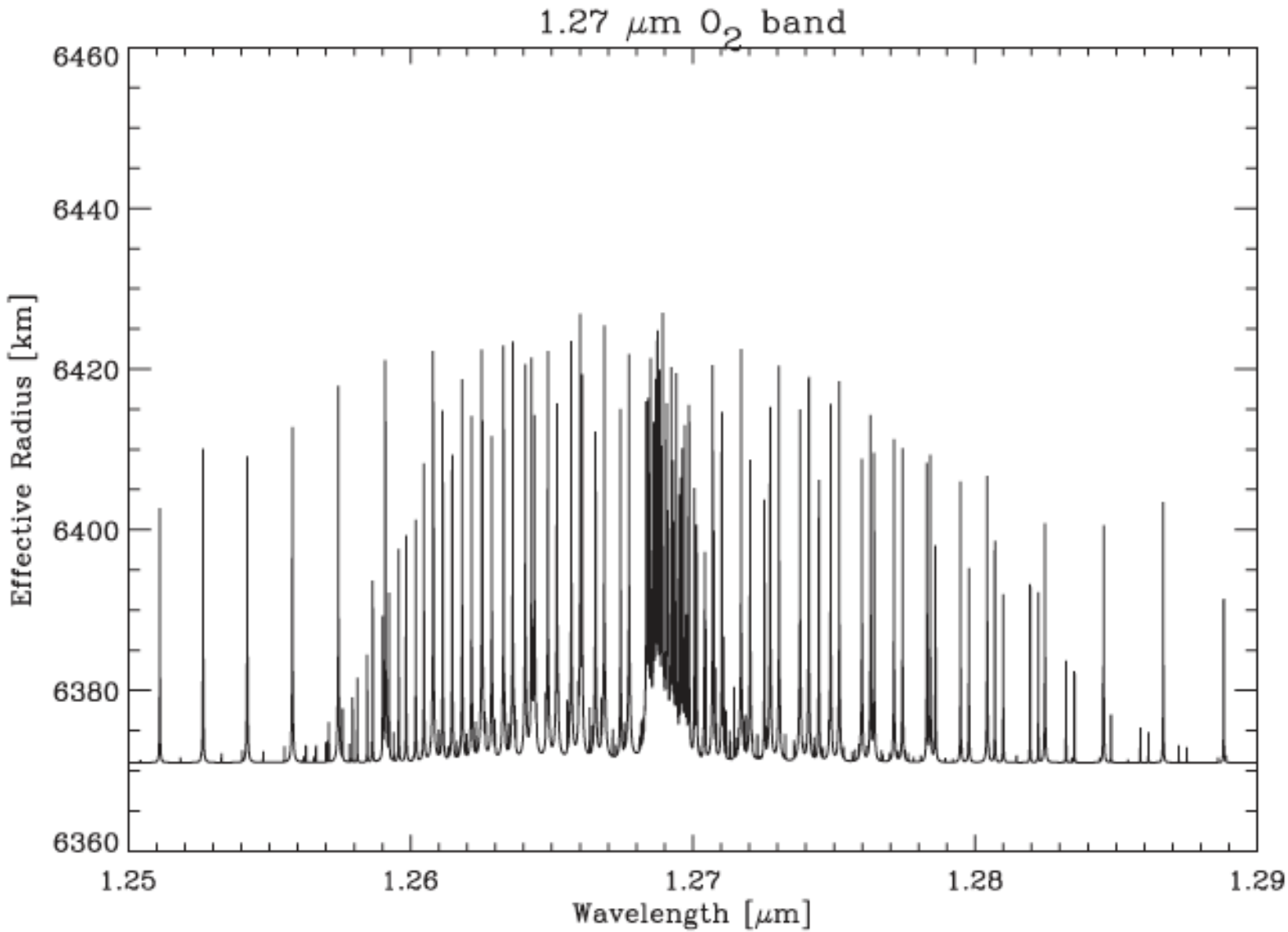
Snellen et al. (2013) IR O_2 band as biomarker



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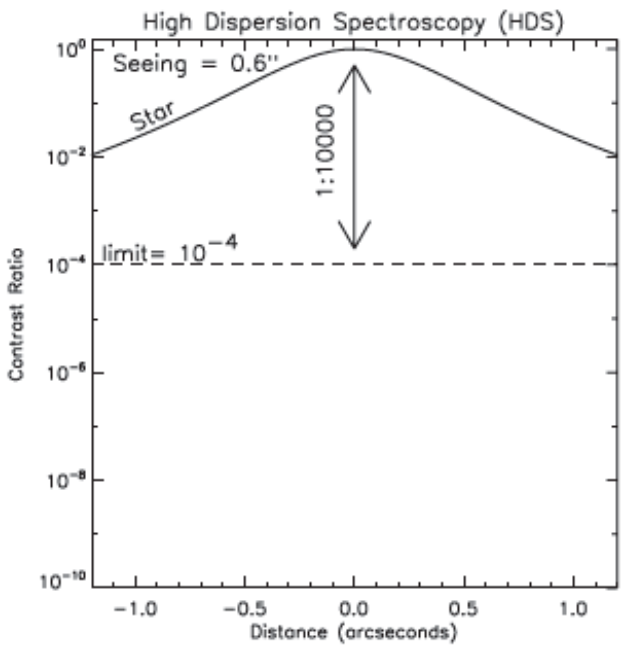
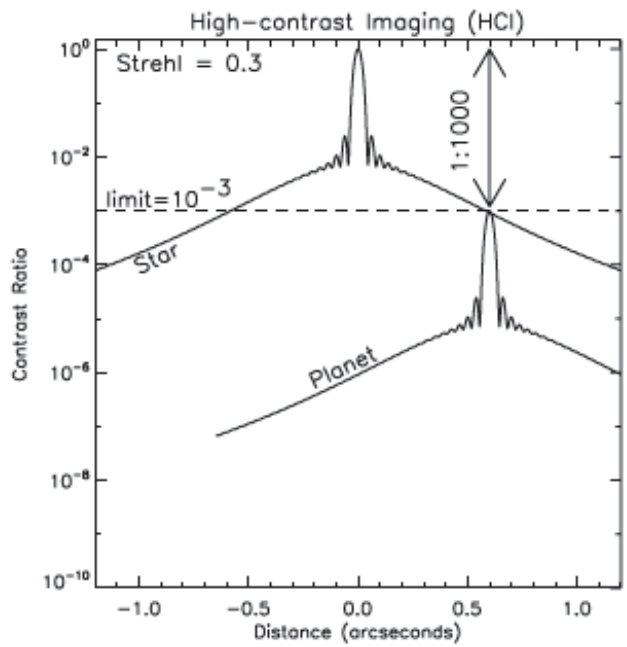
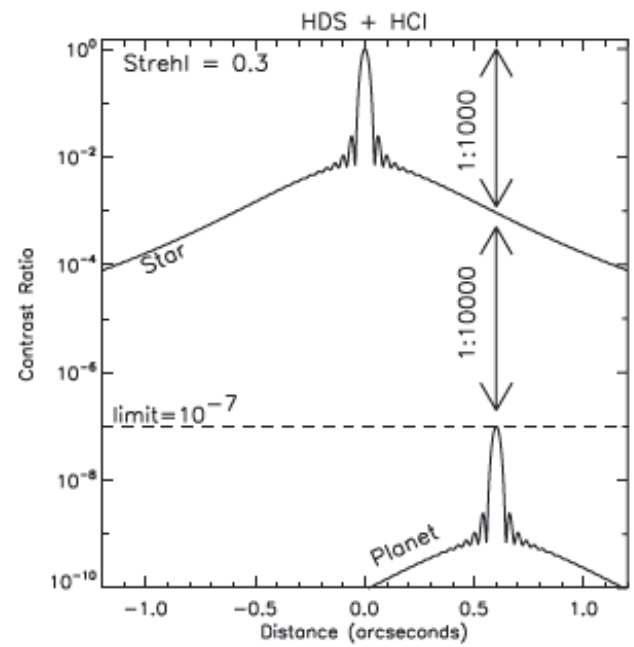
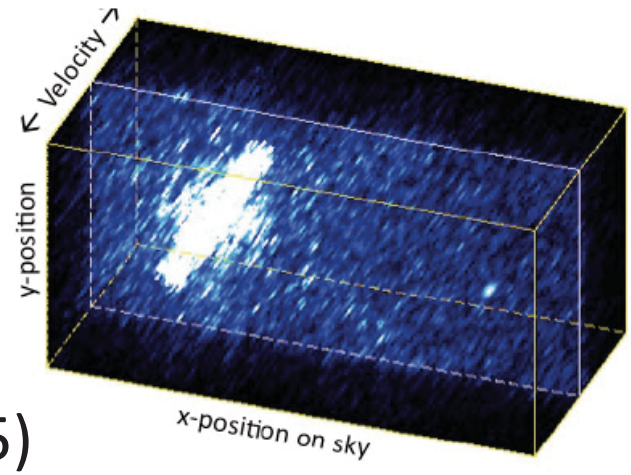
Combining high-contrast AO with high resolution spectroscopy (Snellen et al. 2015)

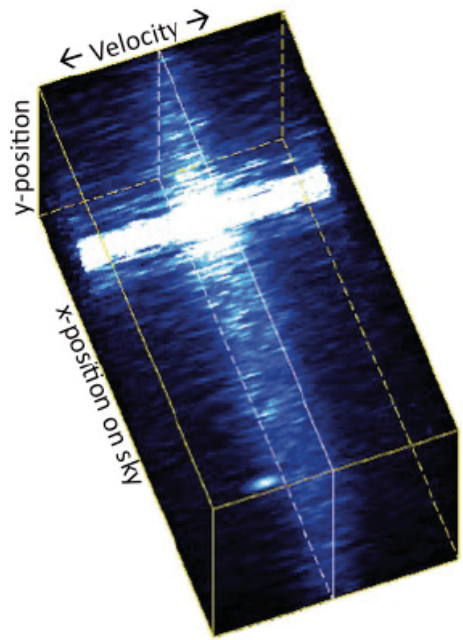






Simulation of the combination of high contrast AO and high spectral resolution from Snellen et al. (2015)





TEXAS

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