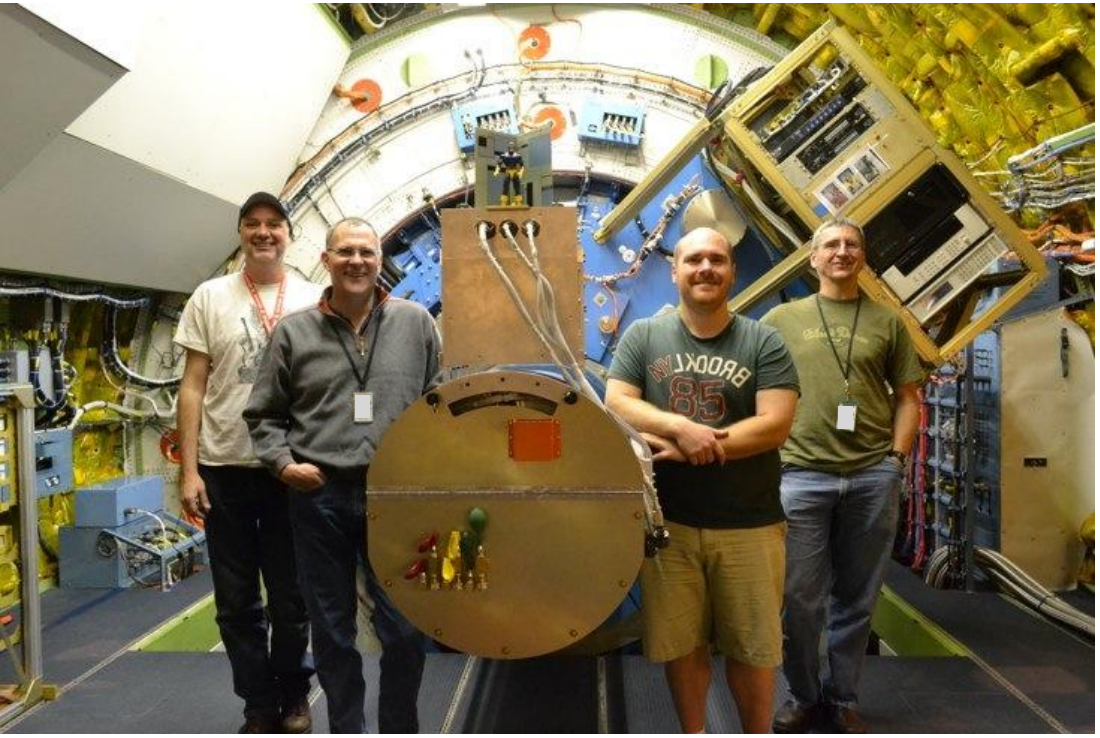
EXES on SOFIA



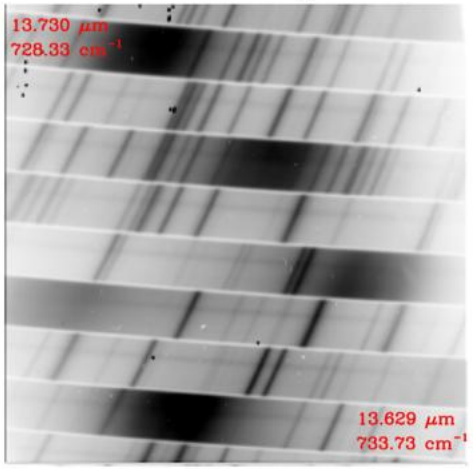
Matthew J Richter
UC Davis

with Mark McKelvey, Mike Case, and Curtis DeWitt

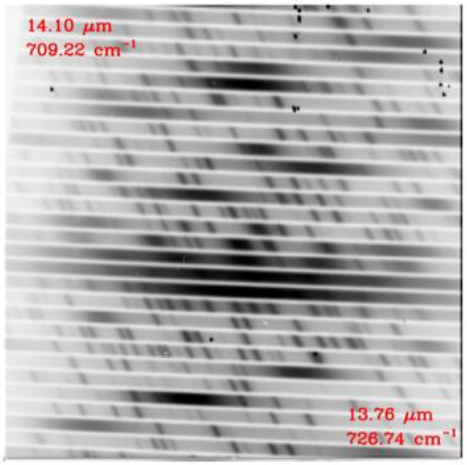
About EXES

- EXES is a PI instrument optimized for high spectral resolution in mid-IR
- High resolution mode:
  - cross-dispersed with R = 50,000 to 110,000 depending on slit width
  - single setting coverage of ~0.8% with 4-40” long slit or ~4% with >1” long slit
- Other modes
  - Medium single order: R ~ 5,000 to 20,000
  - Low single order: R ~ 1500 to 4000
  - limited focal plane and pupil imaging
- Wavelength range ~4.5 μm to ~28.3 μm
  - includes H_2 J=2-0, although detector response fading at that wavelength
- Detector is a 1024 X 1024 pixel Si:As optimized for low background

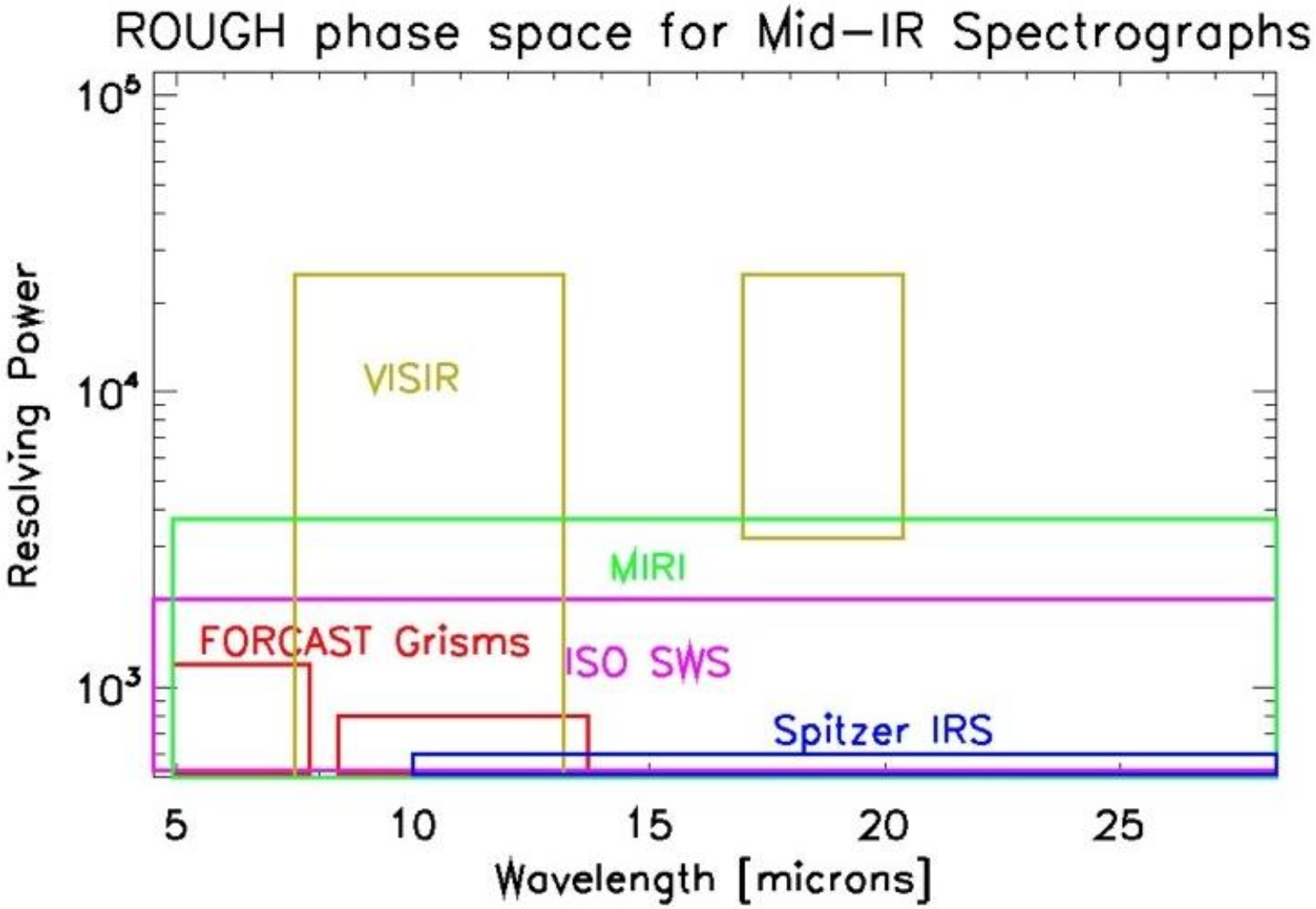
HIGH_MED Configuration



HIGH_LOW Configuration



Other Mid-IR Spectrographs



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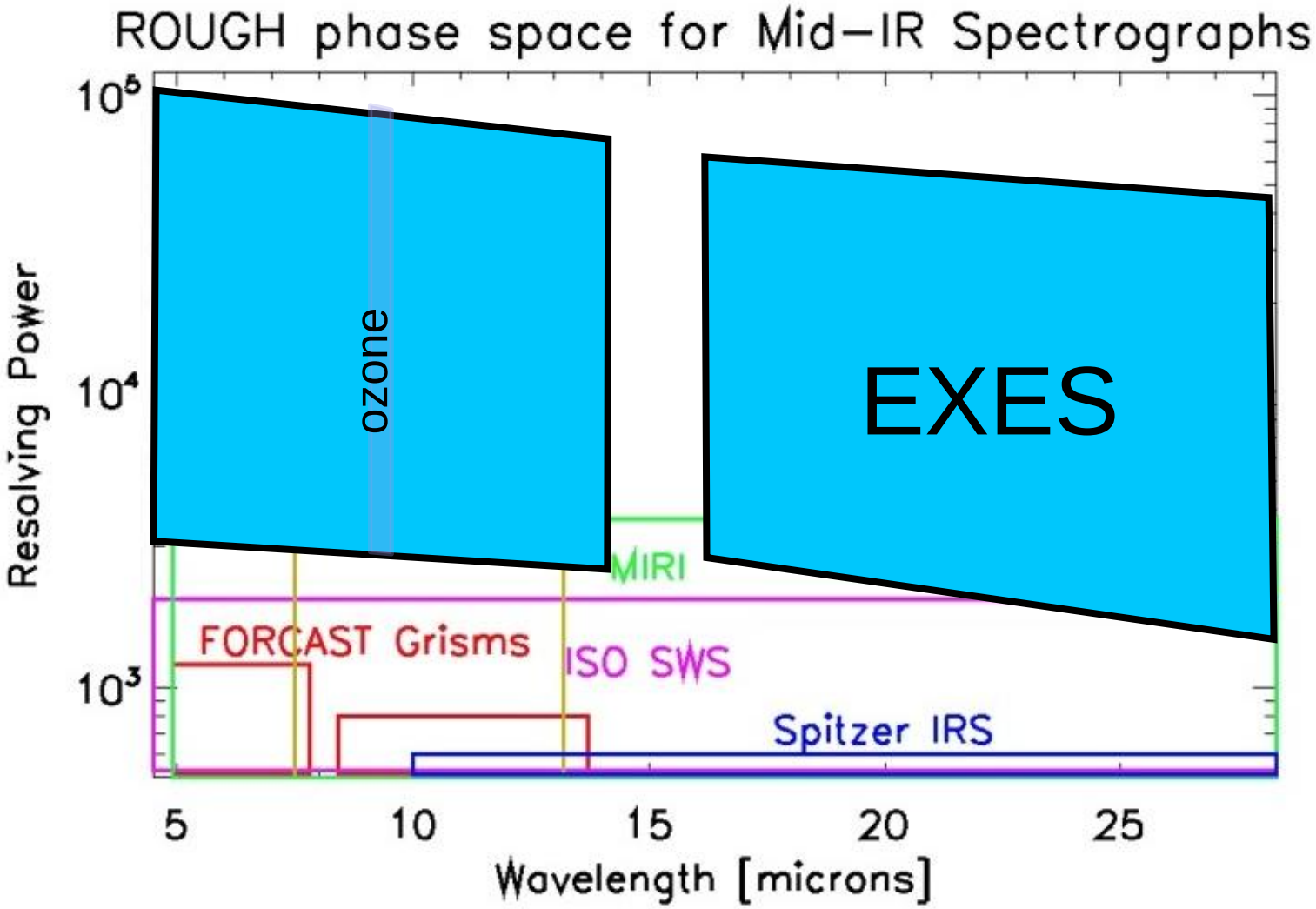
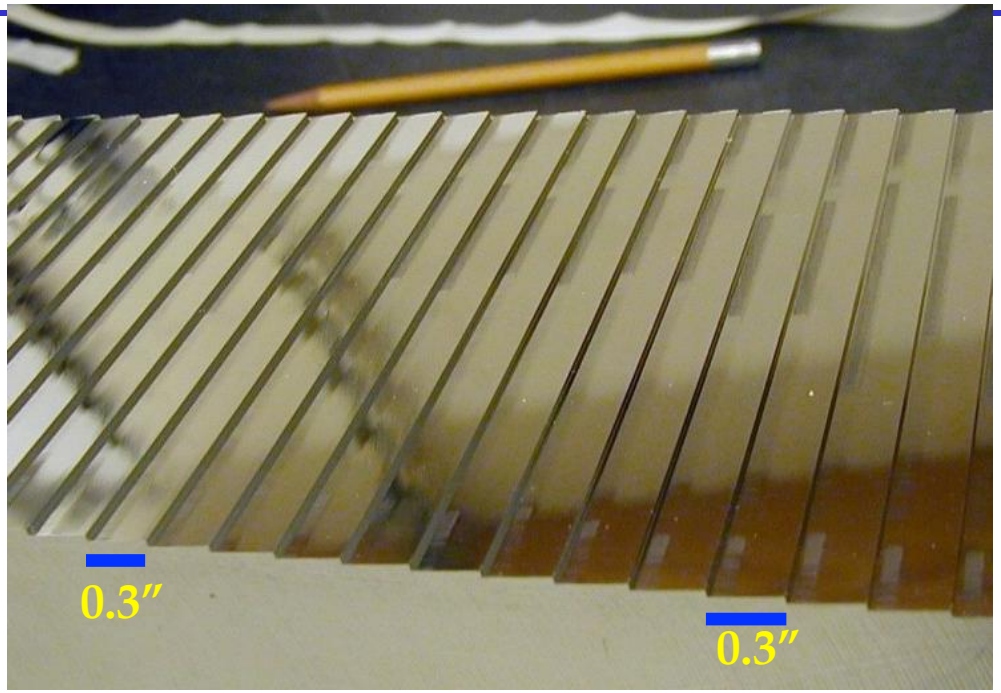


Echelon grating

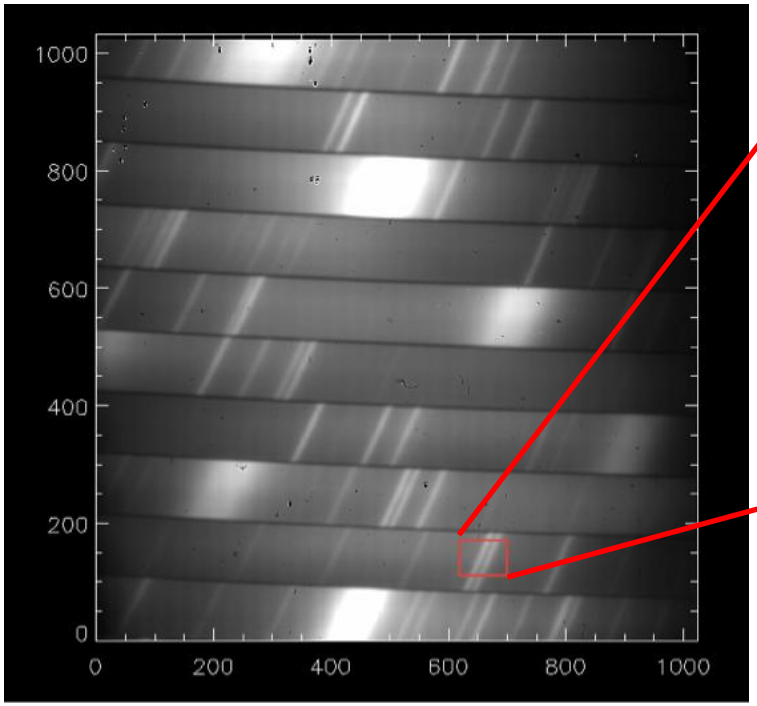
- 40” long
- 0.300” groove spacing
  - 0.131 grooves/mm
- 84.2 degree incidence angle
  - 0.03” groove height
- Diamond machined Al 6061
  - Hyperfine Inc

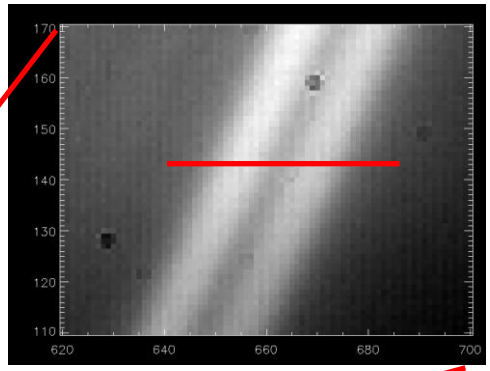


EXES flights

- 7 flights so far
  - 2 Flights in Apr 2014
  - 5 flights in Feb/Mar 2015
- Nod and map observations
- Most observations in 6-8 micron range in high resolution mode
  - What can be done from the ground should be done from the ground
  - 50% Mauna Kea transmission for point sources - TEXES on Gemini

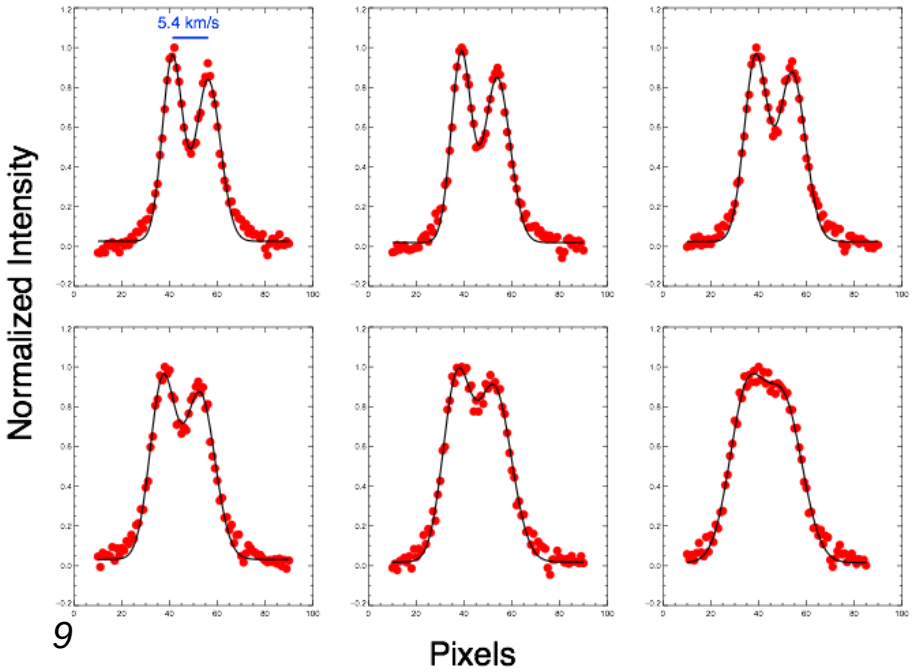
Spectral Resolution



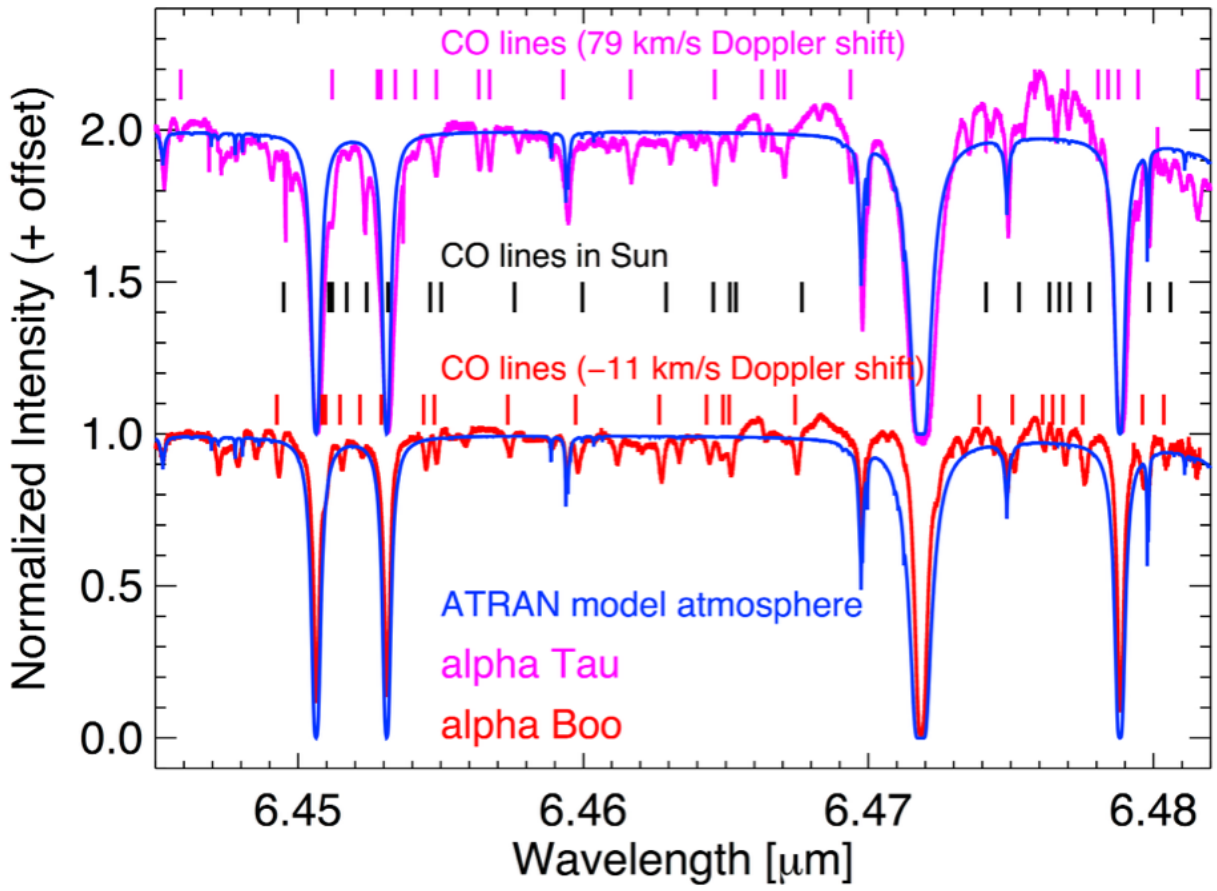


- Use sky lines with 6 different slits
- FWHM of Gaussian fits
  - 3 km/s to 5.4 km/s
- Titan spectra for further investigation

5.4 km/s



Standard Stars

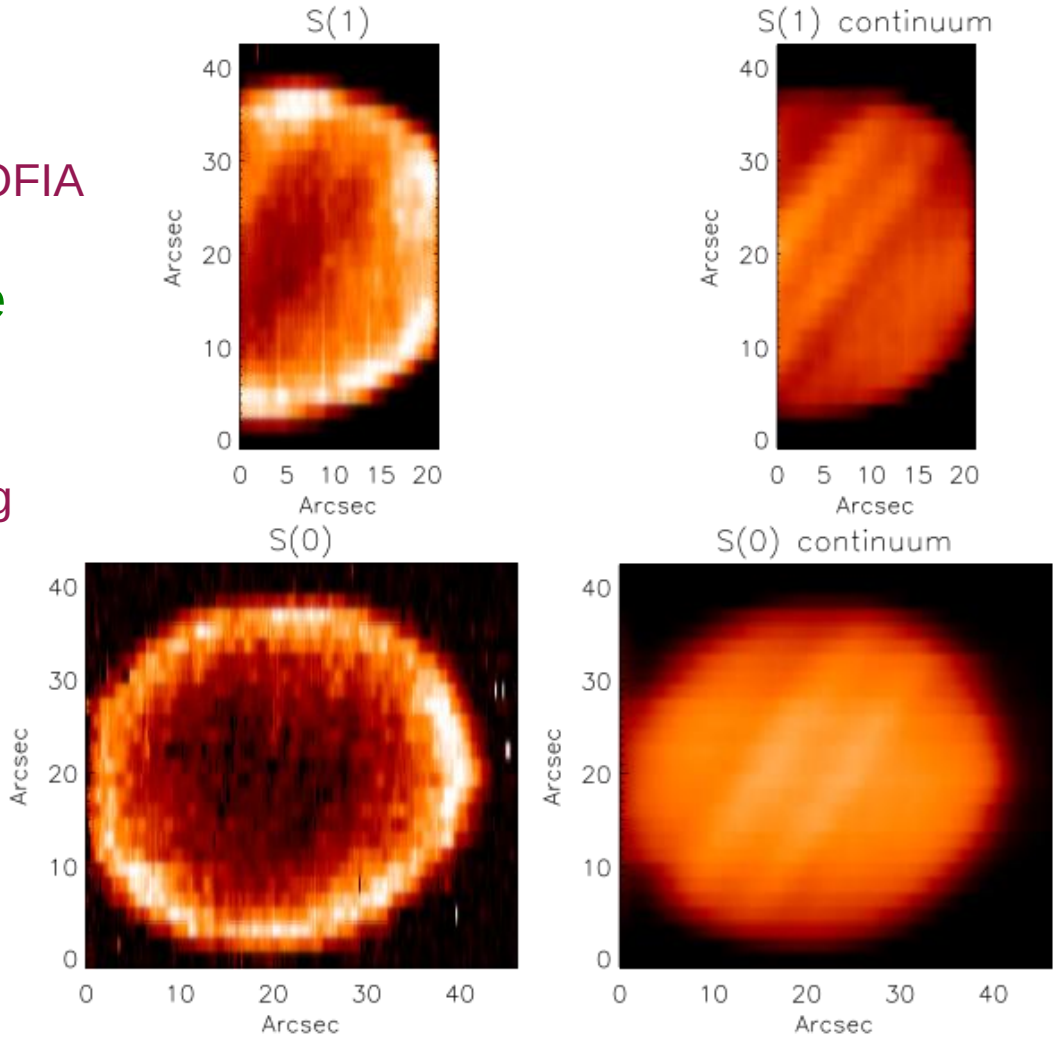


- H_2O lines in stars are weaker than expected based on 12 um observations with TEXES
- First stars other than Sun explored at this wavelength range with this resolution

Ryde et al (in prep)

Jupiter H_2

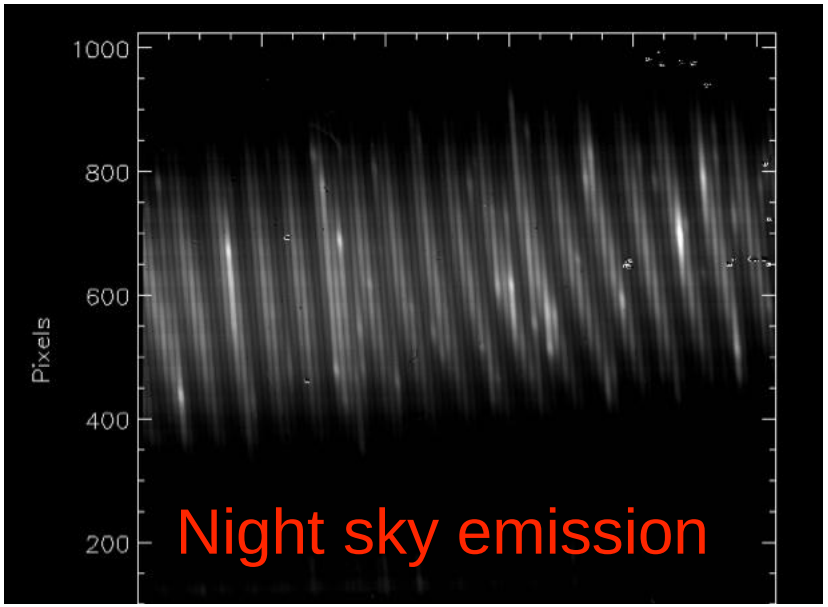
- Use H_2 ortho-para ratio to study dynamics
  - Only possible with EXES/SOFIA
- EXES/SOFIA can produce data cubes
  - slit stepped across Jupiter
  - both maps done in single leg



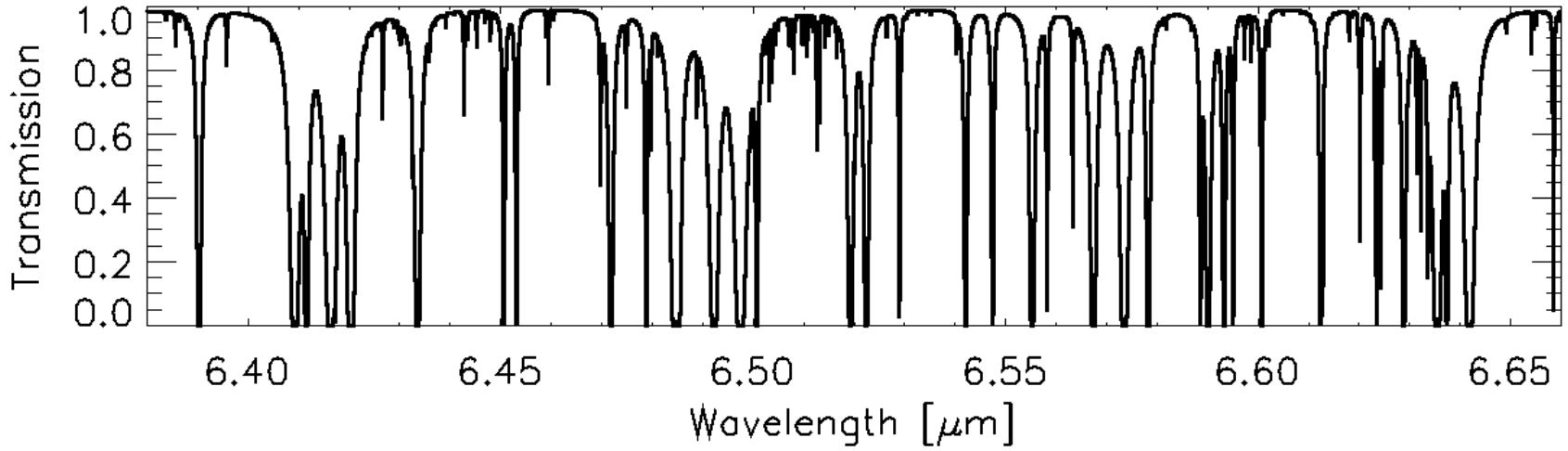
H_2 maps of Jupiter and continuum at 17.03 microns (top) and 28.22 microns (bottom)

Greathouse et al, in prep

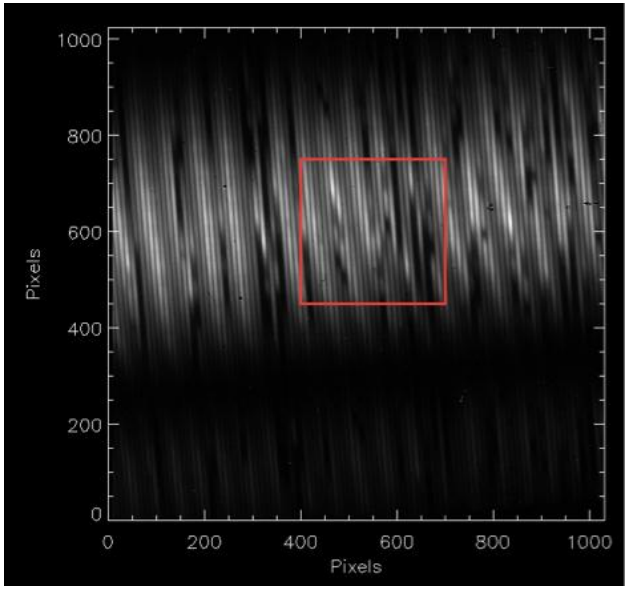
Spectral Surveys



- Use low dispersion for cross-dispersion - High_Low **mode**
- large wavelength coverage at cost of short slit
- powerful tool for bright objects

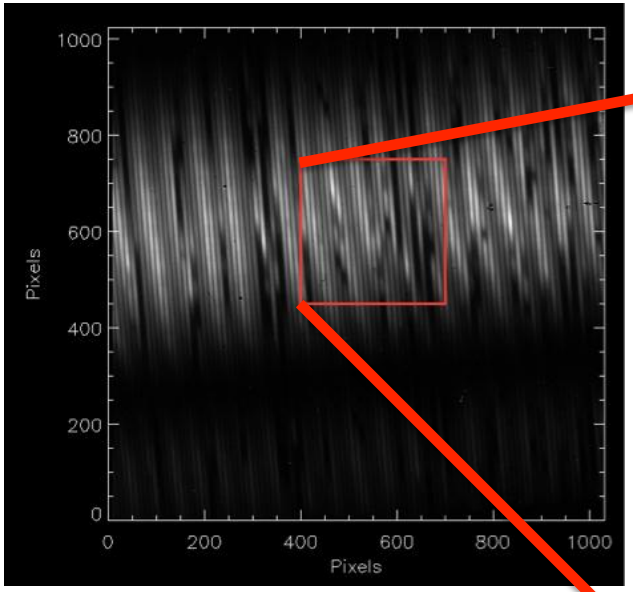


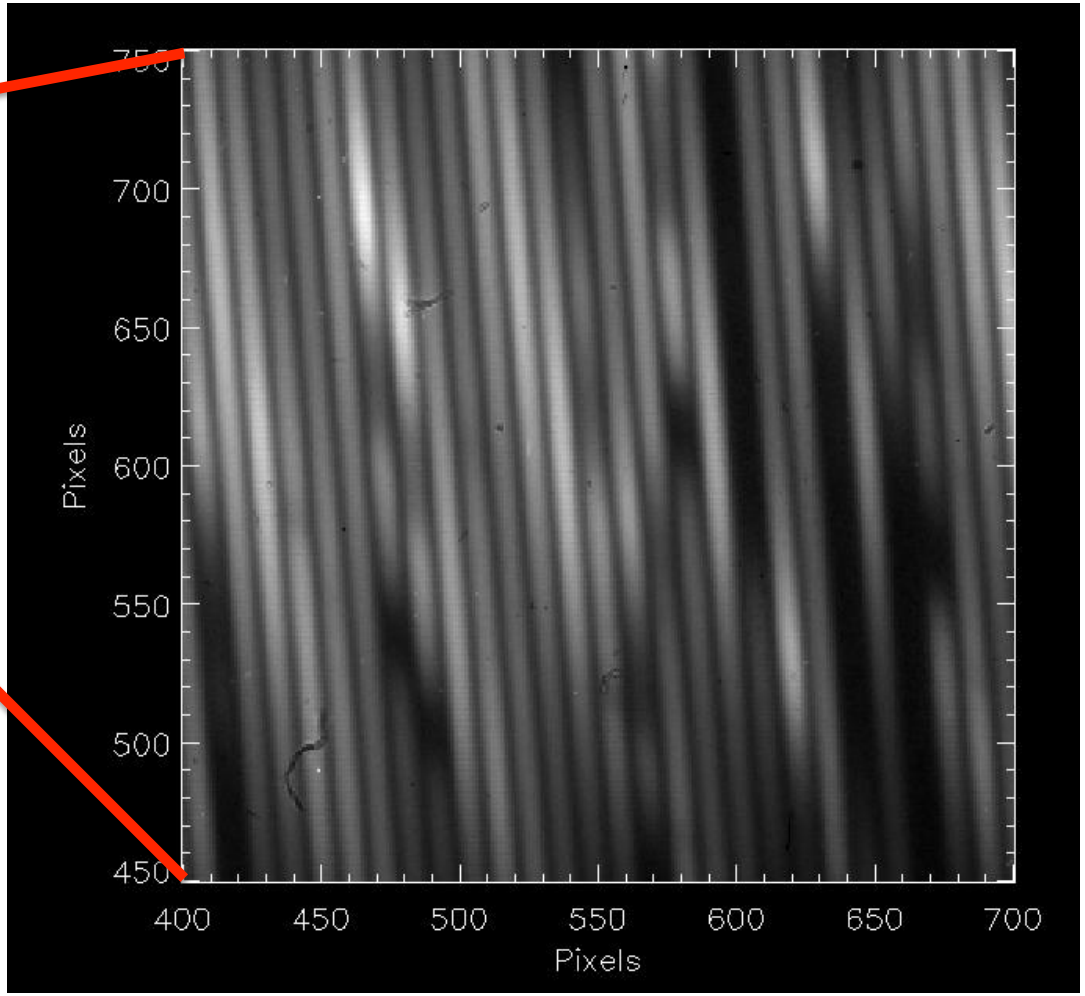
VY CMa Survey



- Nod difference
  - atmosphere absorbs

VY CMa Survey





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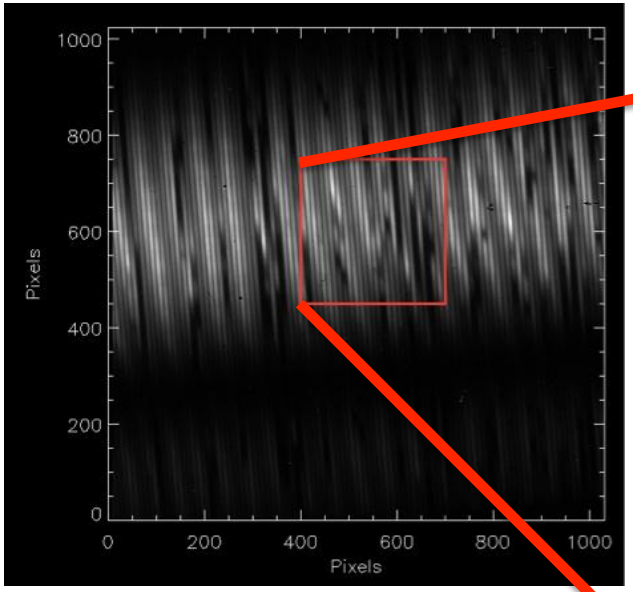

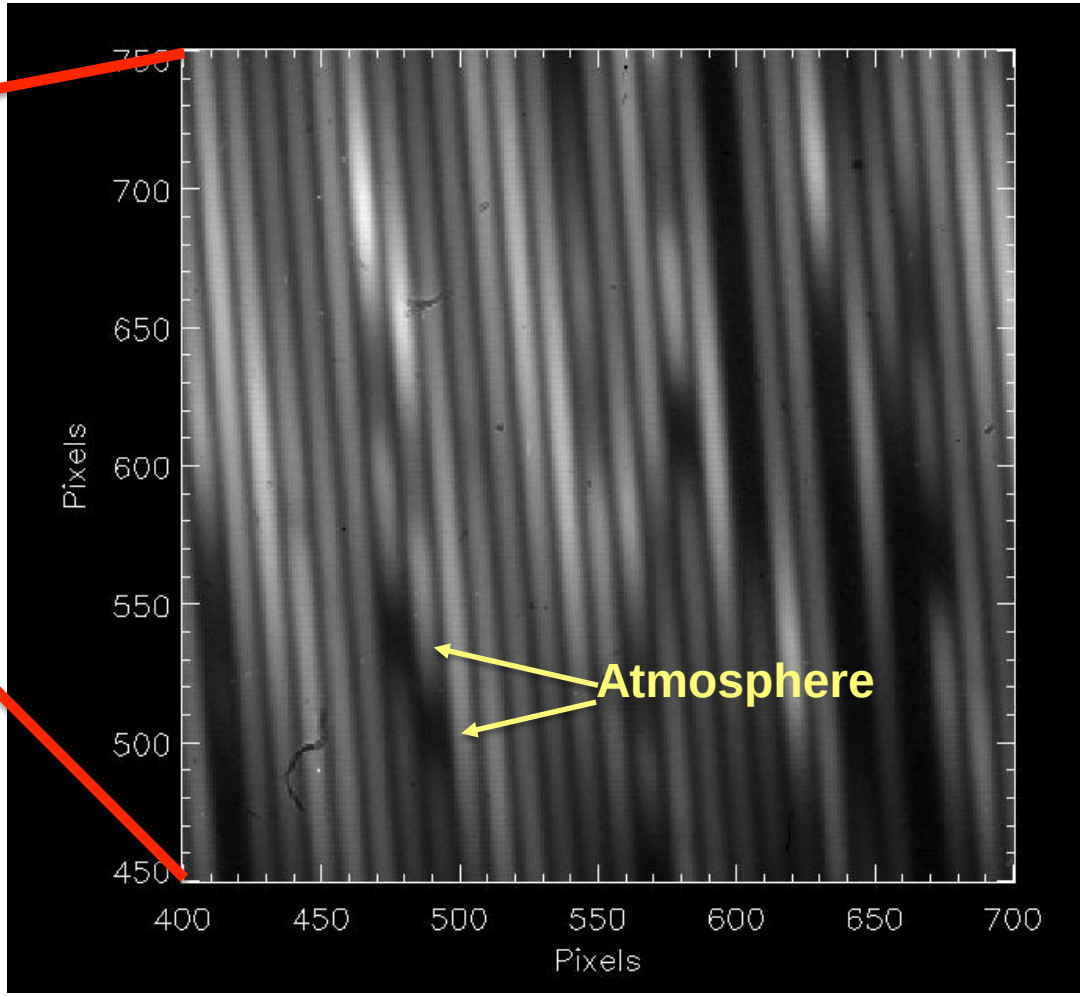

- Nod difference
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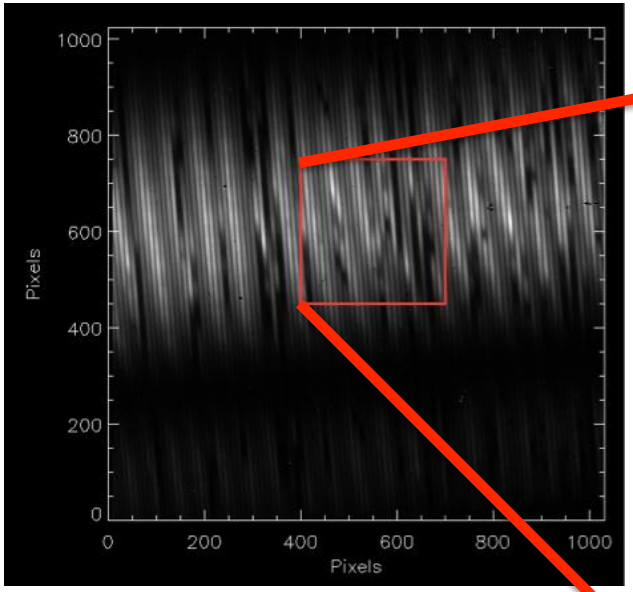
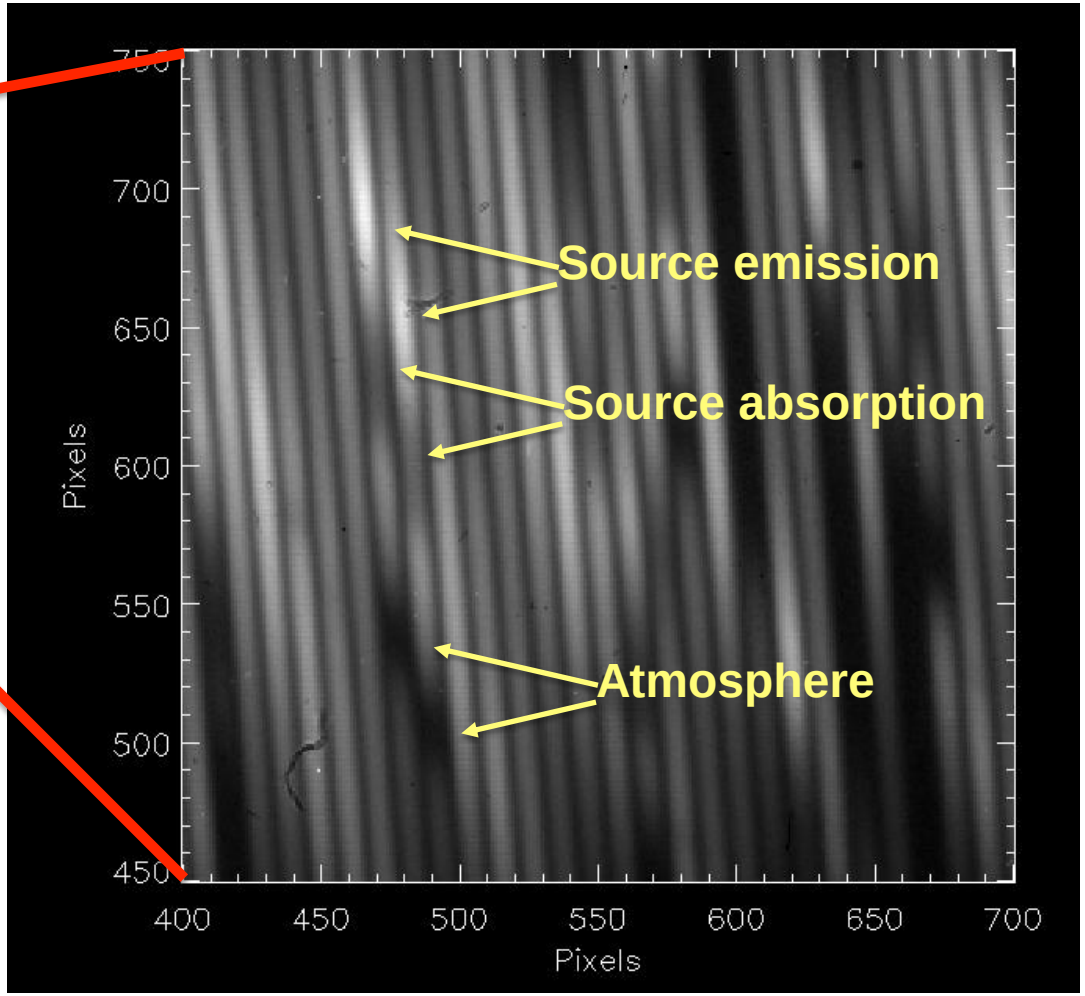
VY CMa Survey

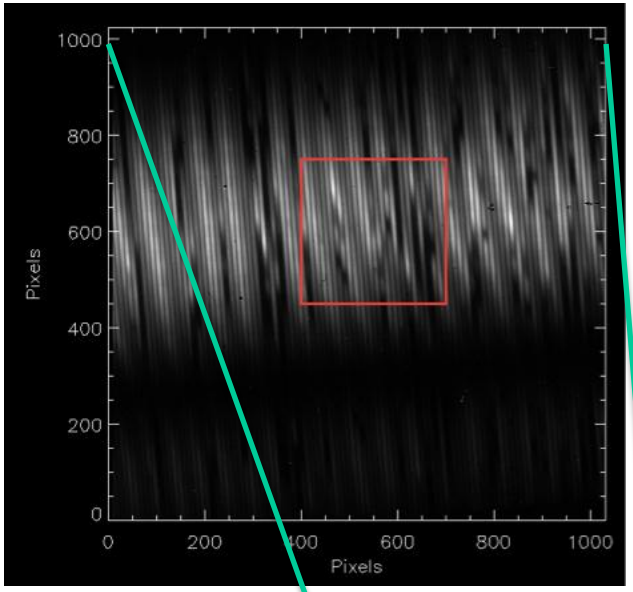


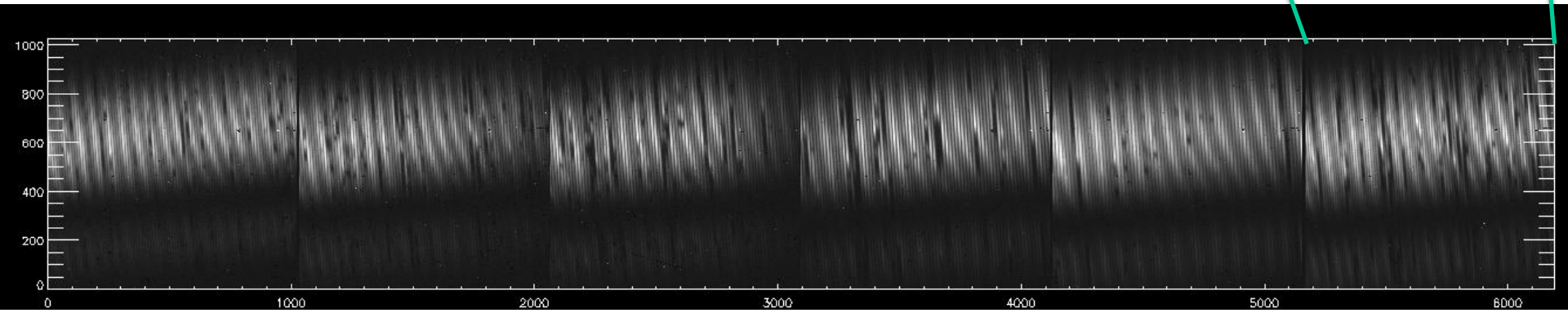


- Nod difference
  - atmosphere absorbs
  - P Cygni profiles

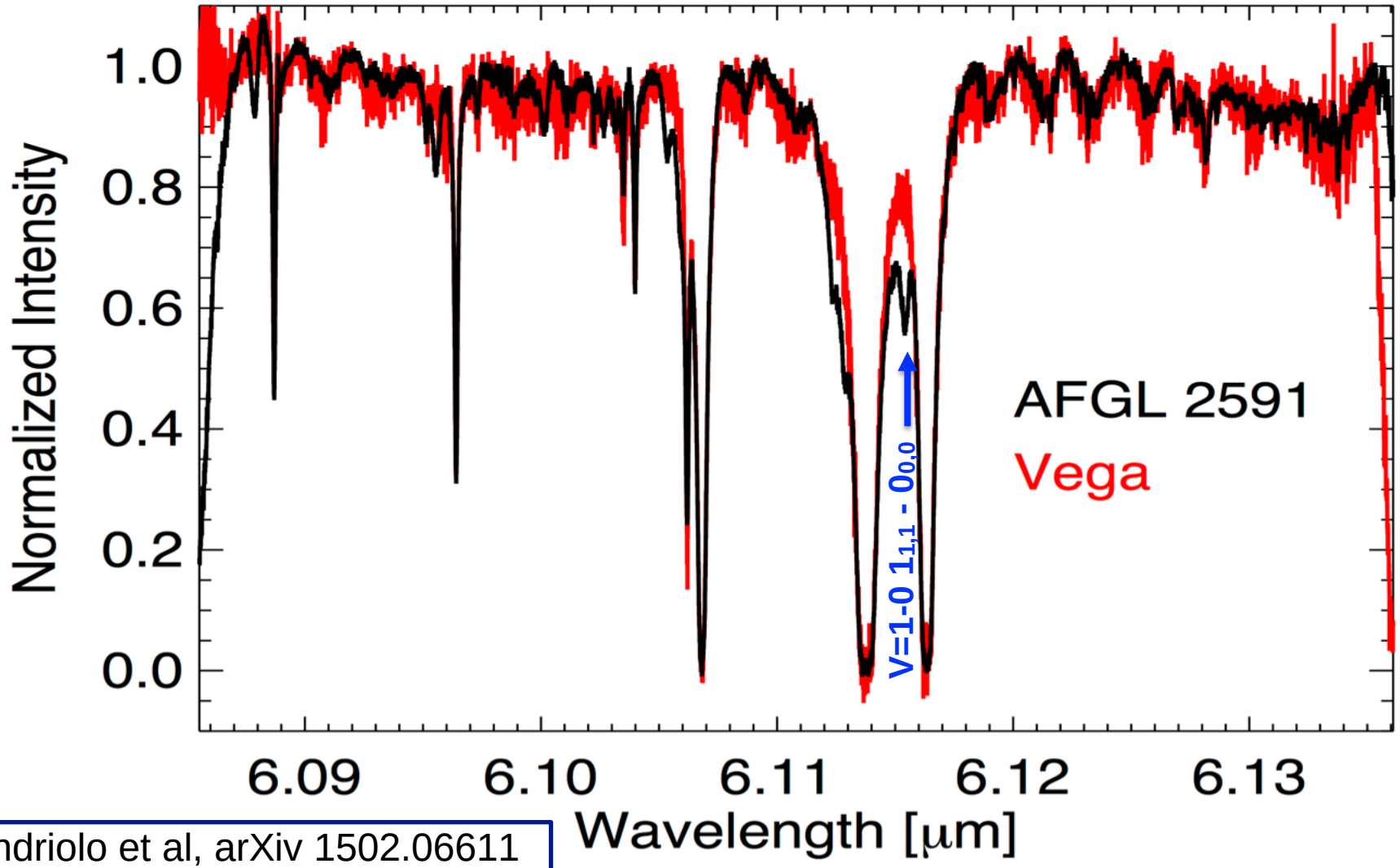
VY CMa Survey

- 80 minute leg
- completed 6 settings
  - 5.6 to 6.7 microns





H_2O toward massive YSO

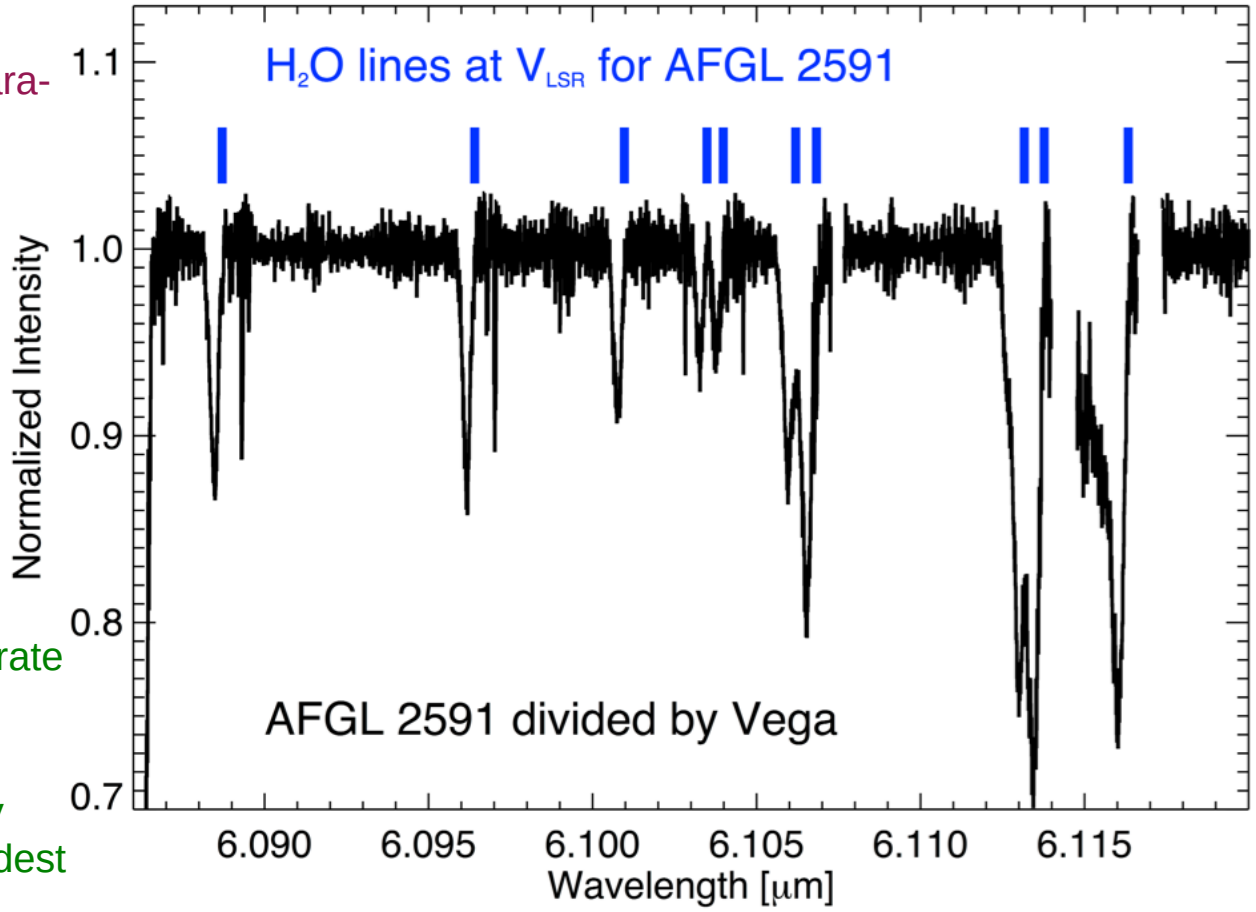


Indriolo et al, arXiv 1502.06611
Accepted to ApJ Letters

H_2O toward massive YSO

- 10 lines detected
  - ground state of para-H_2O
  - 1 $H_2{}^{18}O$
  - 2 2-1 lines
- Line profiles
  - FWHM ~14 km/s
  - blue-shifted
- T = 700 K
- N = 10^{19} cm^{-2}

- EXES/SOFIA can separate target lines from strong atmospheric lines
- EXES/SOFIA can study absorption from the coldest H_2O gas



Summary

- EXES on SOFIA producing new science data
  - unseen combination of sensitivity and spectral resolution at wavelengths blocked from the ground
- Able to separate astrophysical lines from Earth's atmospheric lines with moderate Doppler shift
- Basic observing modes work
  - Still lots of work to be done….