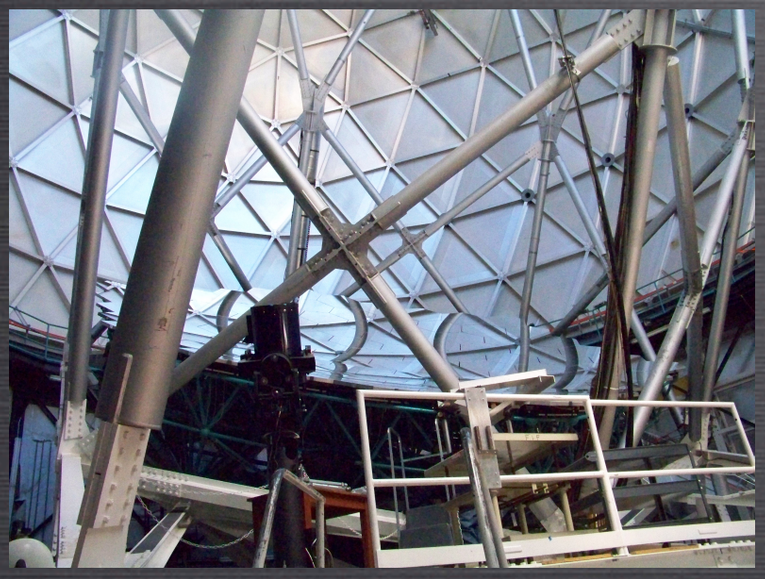
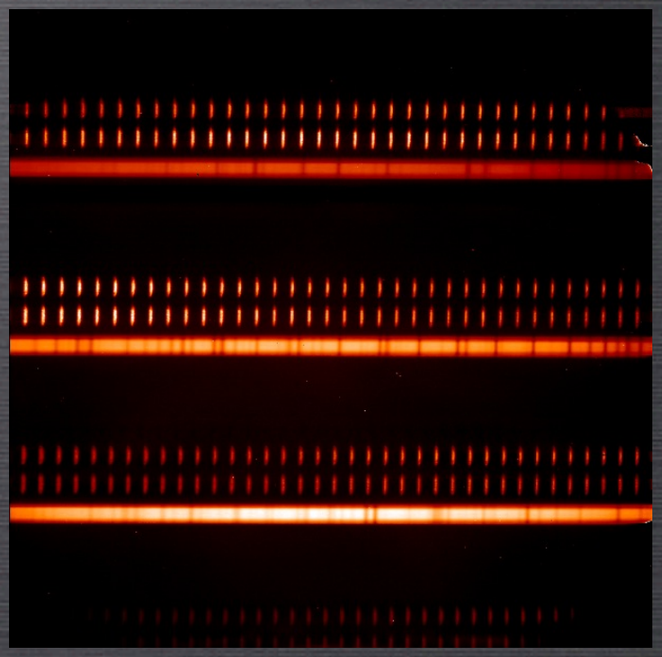
Precision RVs in the NIR

Experience from the PSU Pathfinder Testbed

Suvrath Mahadevan

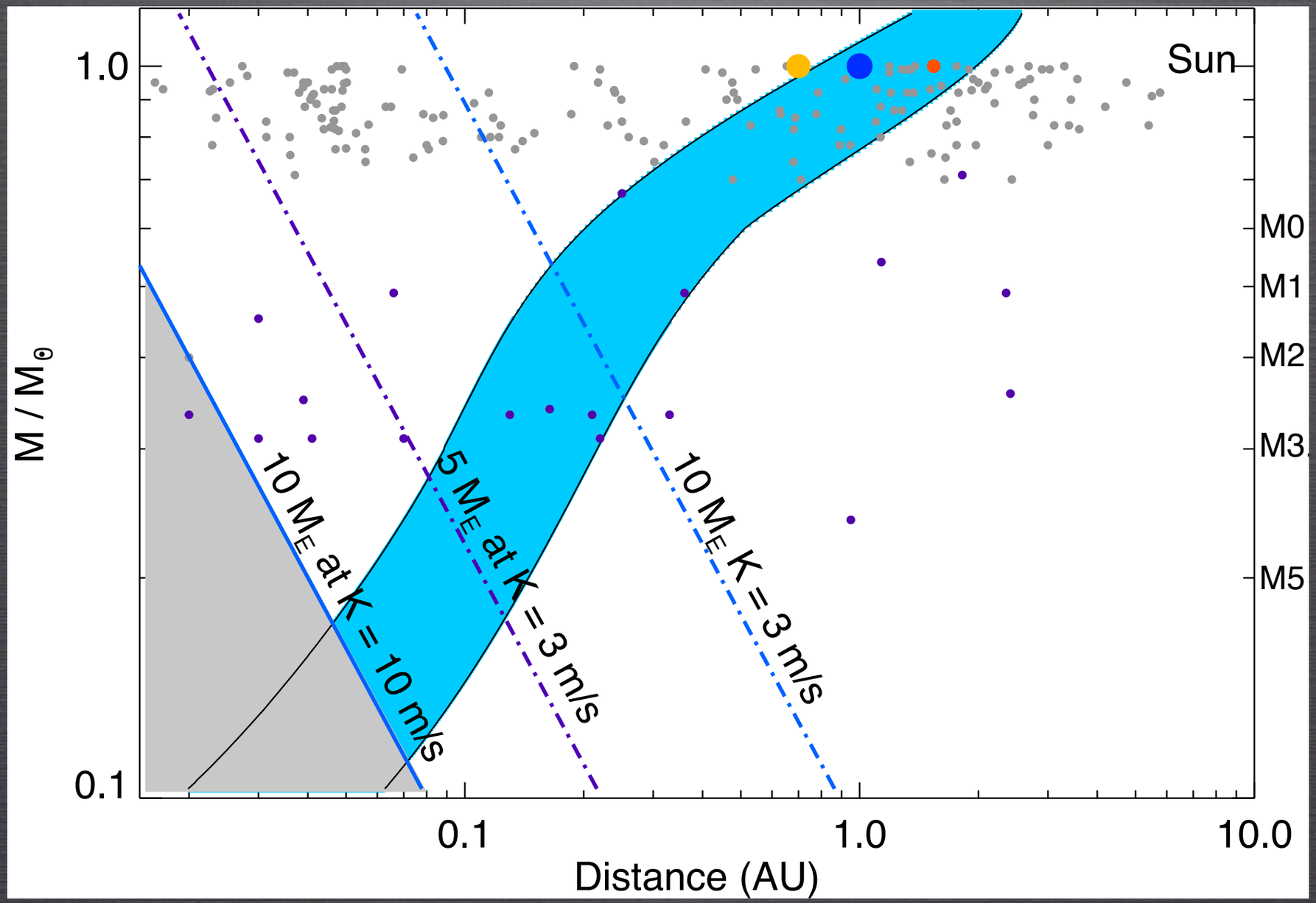
(Penn State)





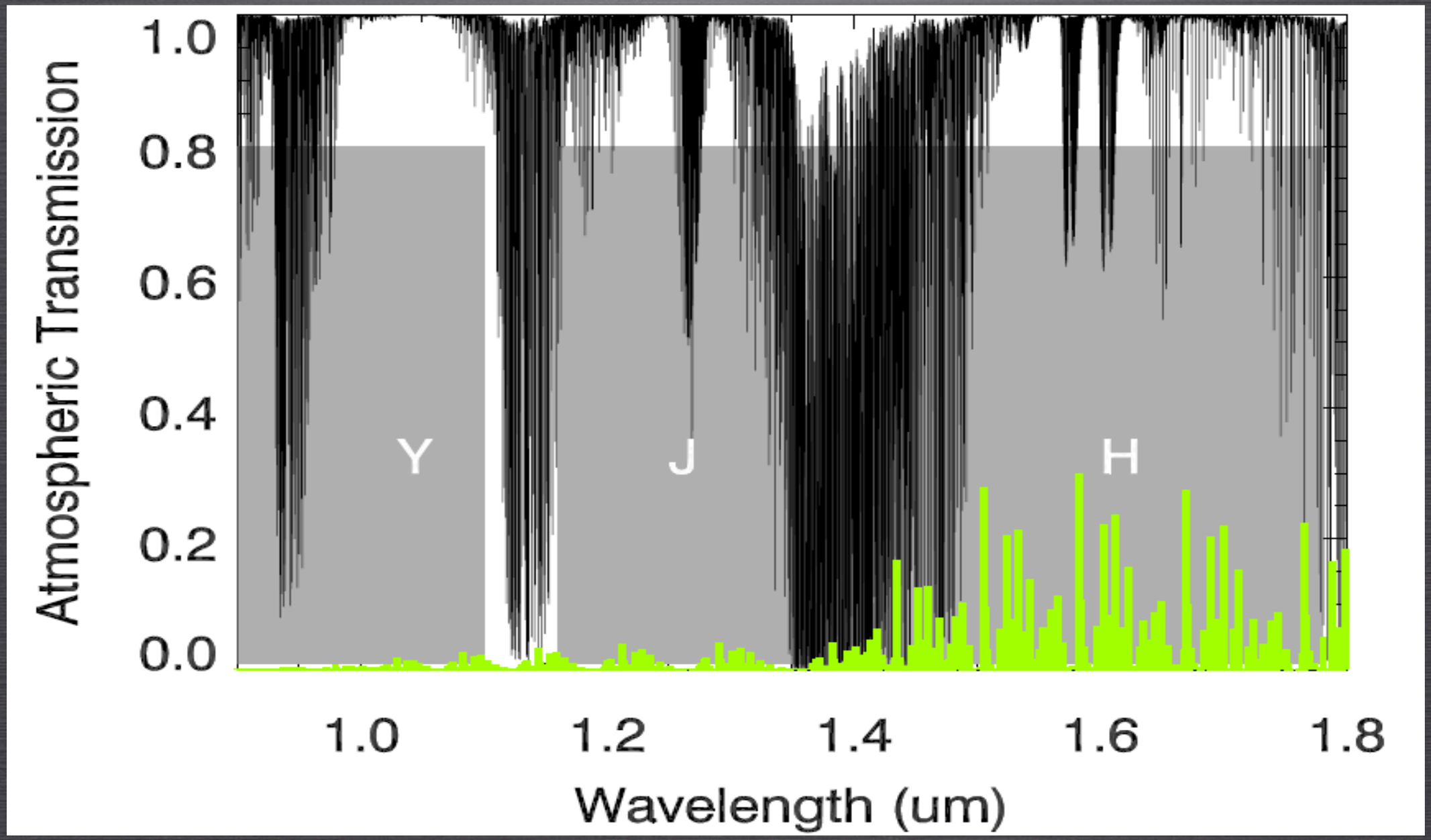
Larry Ramsey, Stephen Redman, Chad Bender, Ryan Terrien, Steve Osterman (CASA), Gabriel Ycas, Scott Diddams, Frank Quinlan (NIST), Keegan McCoy, Rohit Deshpande, Arpita Roy, Brandon Botzer, Steinn Sigurdsson, Nate Troupe(PSU)

Earths & Super Earths Around M Dwarfs



Mid/Late M stars are attractive targets since RV amplitude of terrestrial planets in HZ is so much higher than around F, G, K.

The NIR Bands



The Y band is quite clean compared to J and H, and has the most amount of RV information for mid-late M dwarfs……

Pathfinder Instrument @ PSU

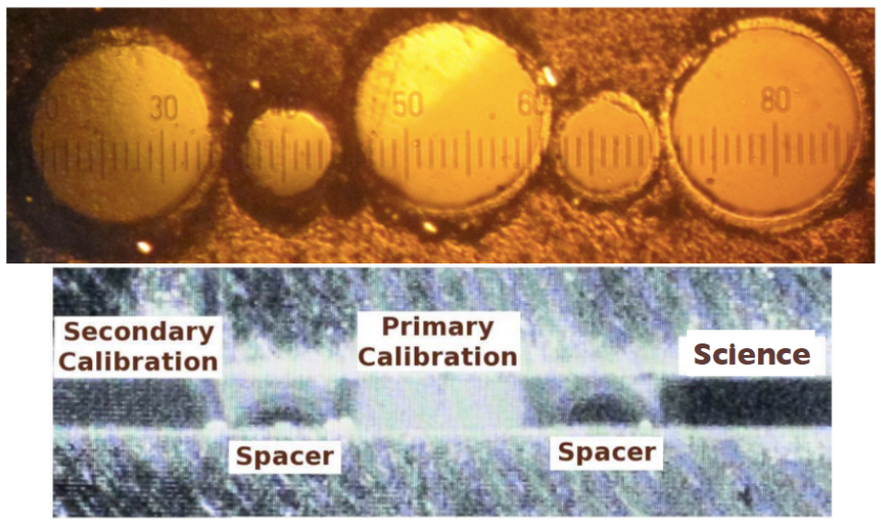
Pathfinder : One that discovers a new course or way, especially through or into unexplored regions.

- **Penn State NIR Pathfinder spectrograph is a test bed to explore challenges in precision NIR radial velocities.**

- **Pathfinder is a testbed built from existing off the shelf available parts. Uncooled, uses a H1 array that is sensitive to 2.7μm**

- **Initial motivation was to retire some of the risk in the Gemini PRVS proposal, which it succeeded in doing.**

- **Now going beyond to explore more of the fundamental issues in NIR velocity extraction to pave the way for future instruments.**

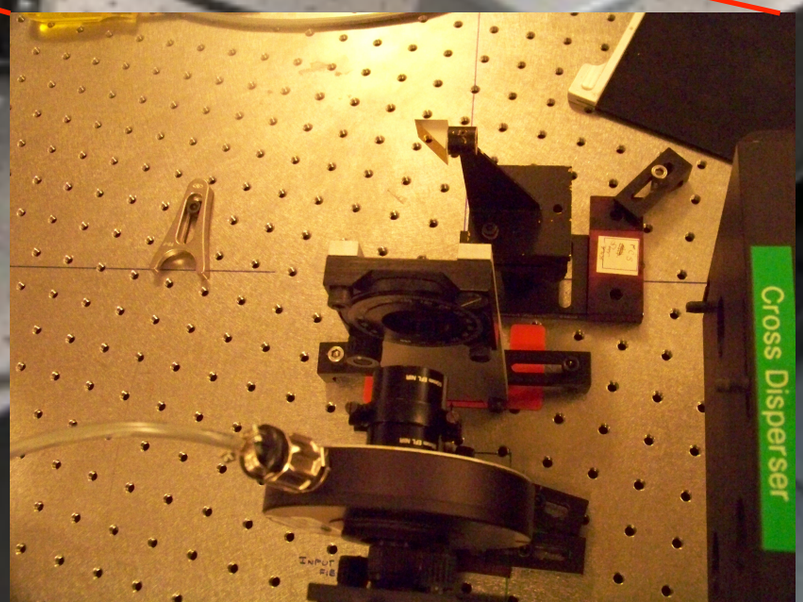


Dewar

Echelle

Fibers

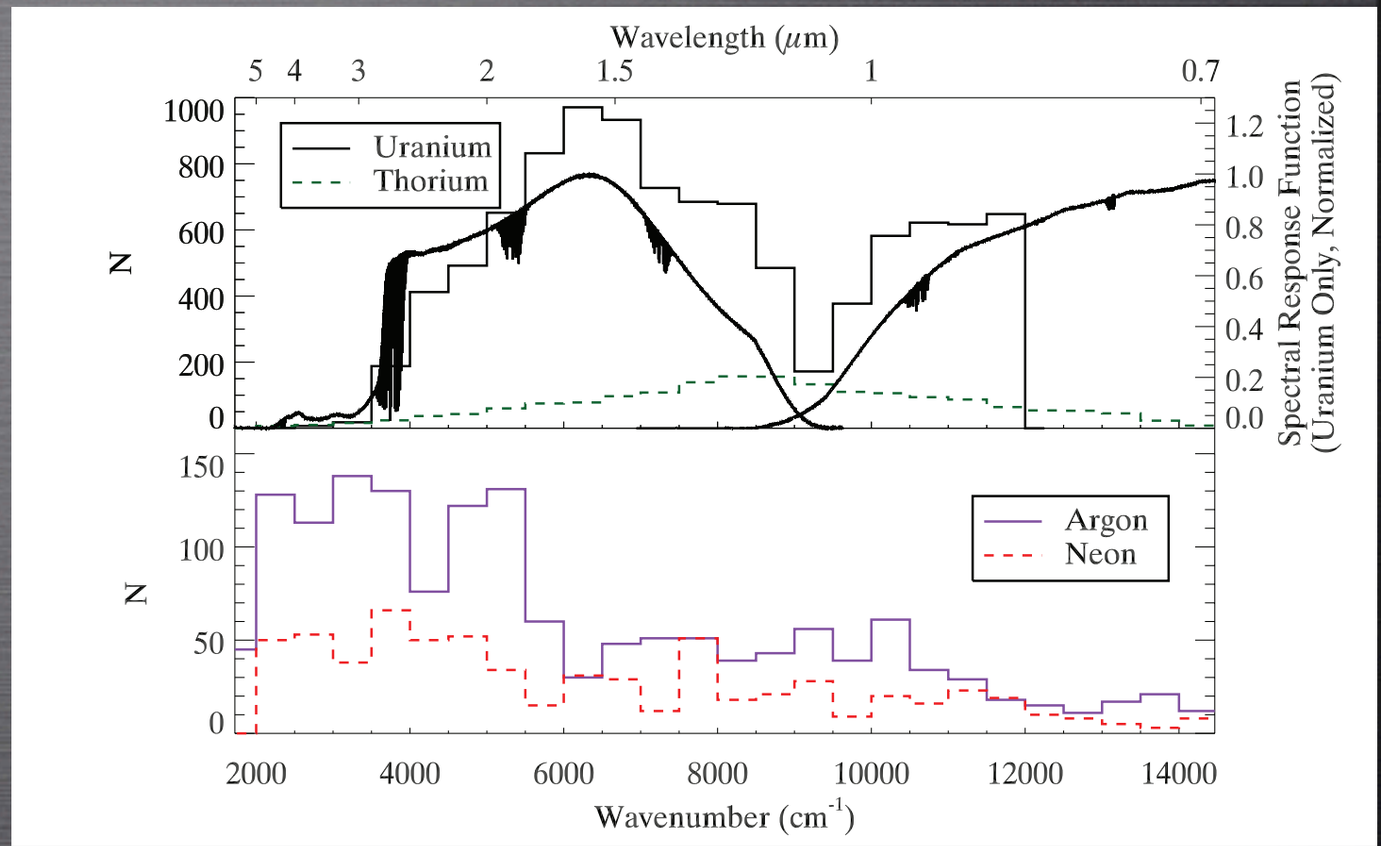
Collimator



Challenges: Calibration

- Exploring Other lamps.

	Thorium ^{232}Th	Uranium ^{238}U
Heavy Element	Yes	Yes
0 nuclear spin	Yes	Yes
Long ½ life	Yes	Yes
Many Lines	Yes	Yes
Mononucleide	Yes	NO (0.7% ^{235}U)

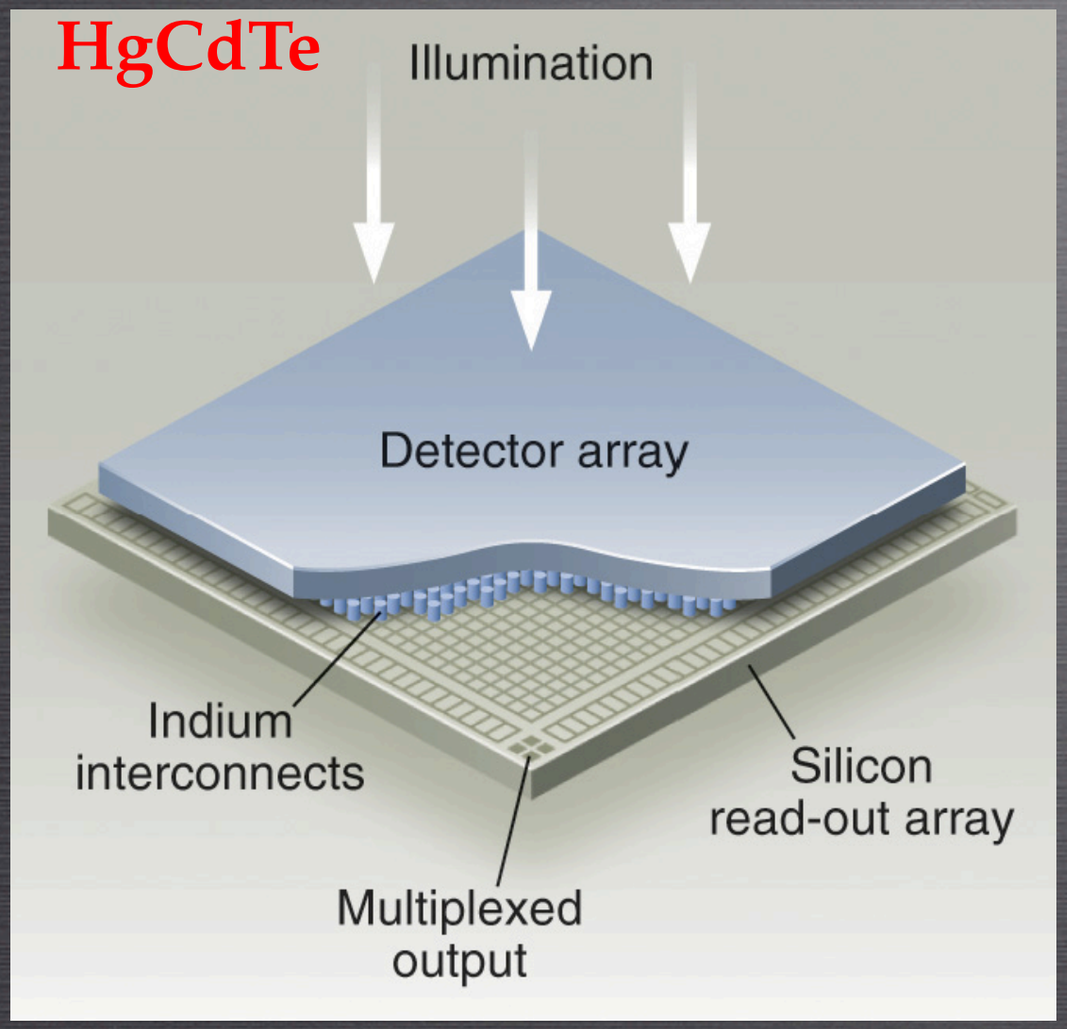


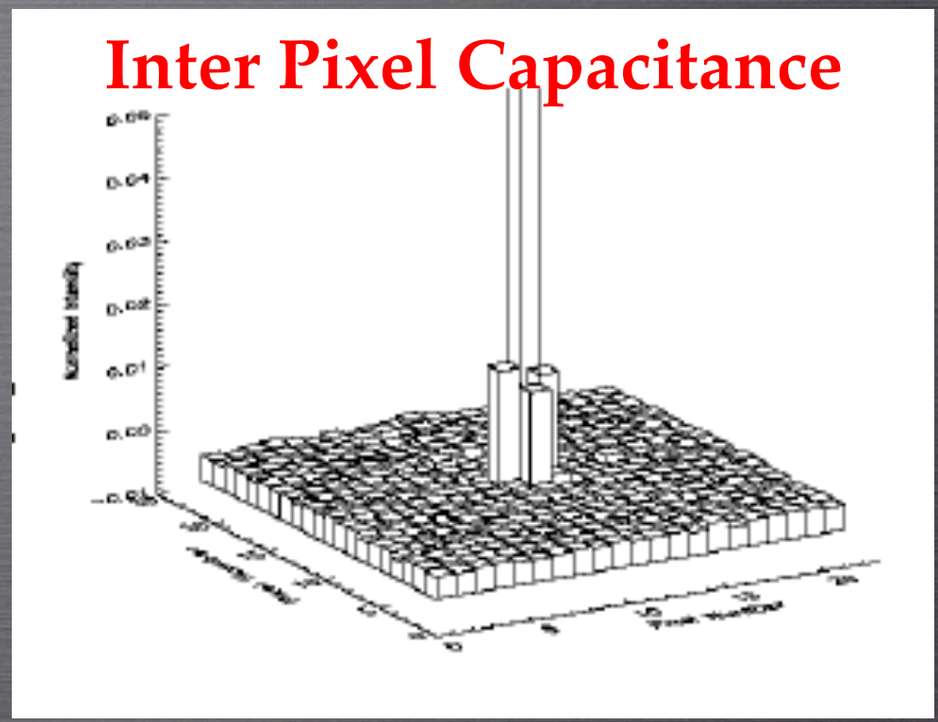
U has a lot more bright lines in the NIR than Thorium. Ar lines are extremely bright and not usable at precisions of few m/s

U-Ne lamps now in routine use in Pathfinder

An FTS NIR ATLAS OF Uranium lamps now published and available: Redman et al. 2011, APJS

Challenges:NIR Detectors





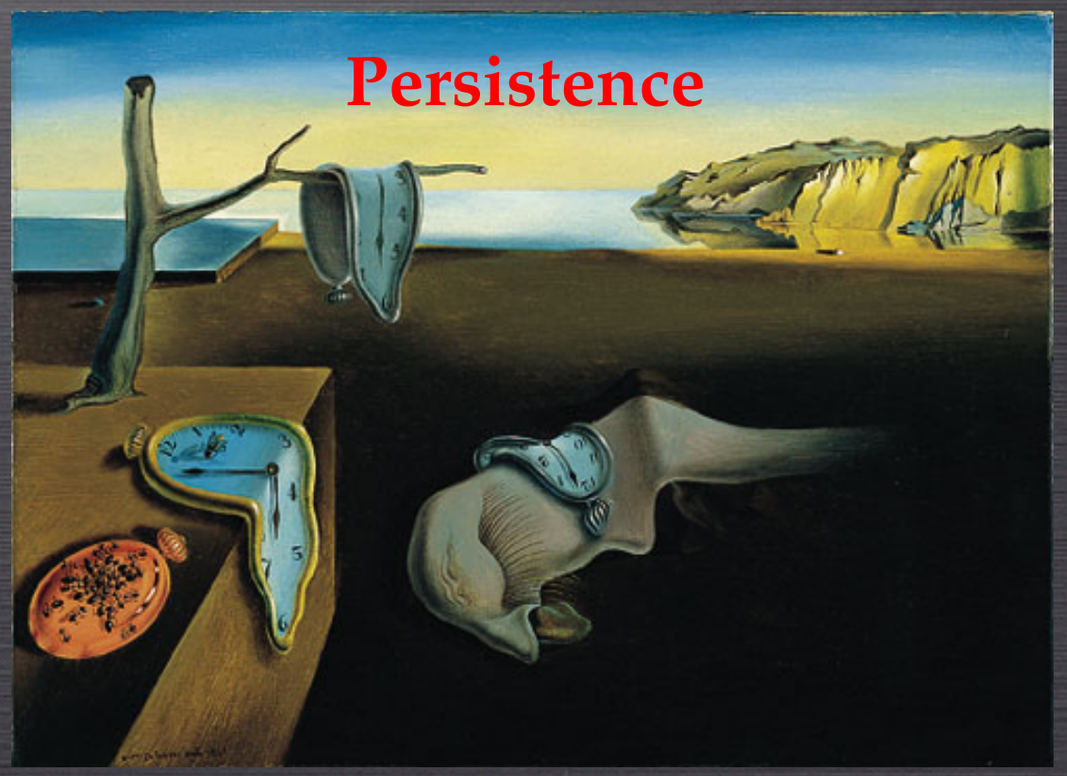
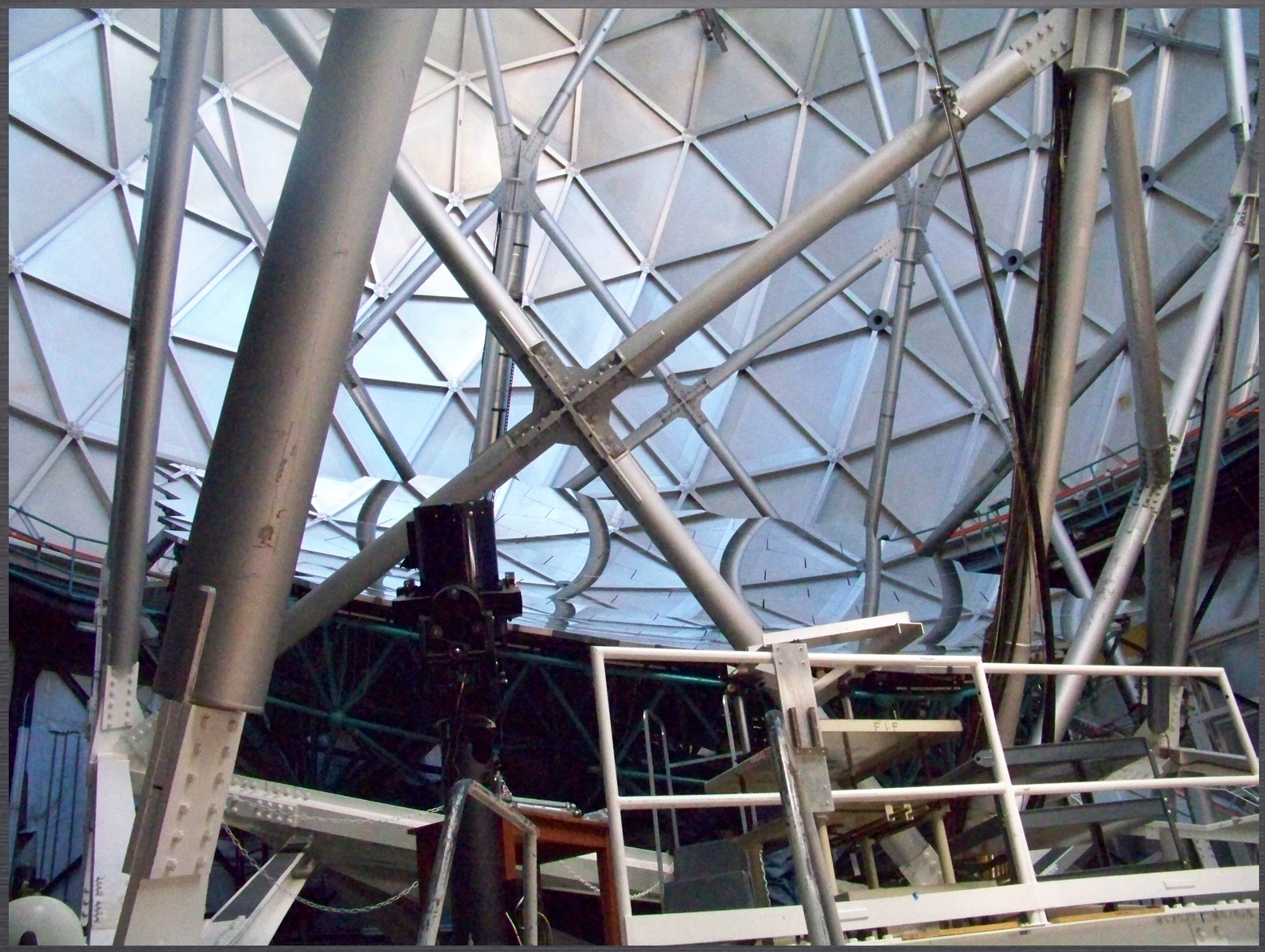


Image Credits: Ian McLean, Jim Beletic, Dali

Pathfinder @ HET

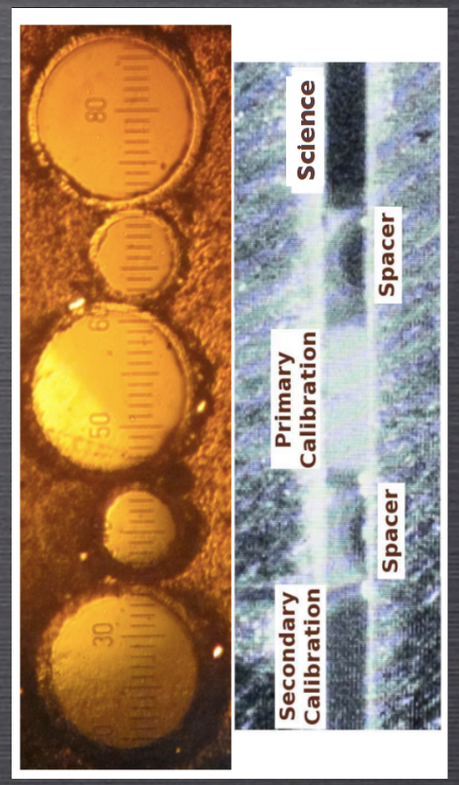


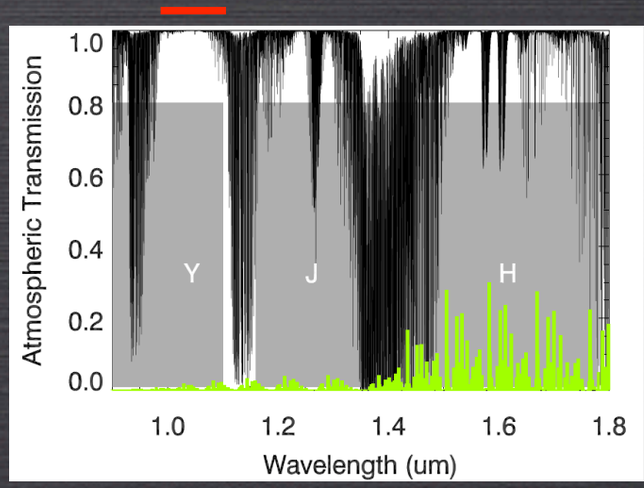
May-August 2010: Tests at the HET to obtain stellar RVs in the NIR

Pathfinder @ HET

star

U/Ne





Observations of Tau Boo with Pathfinder@ HET

10-15m/s RV precision over 6-7 days

Pathfinder @ HET

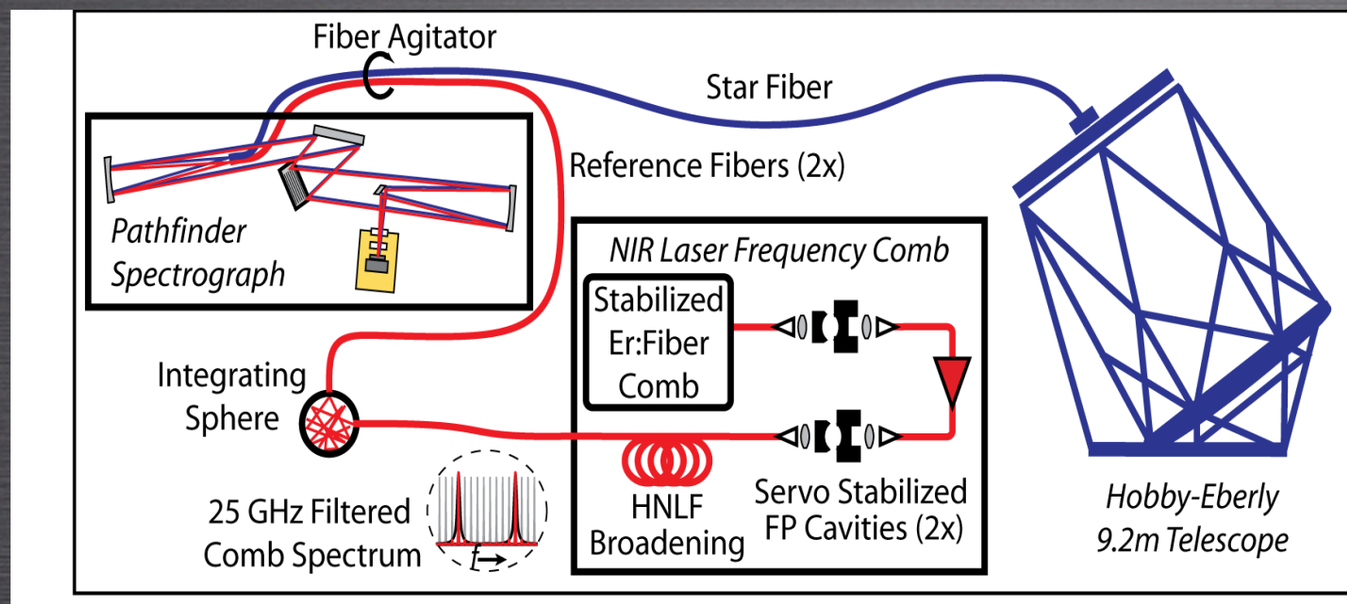
Pathfinder is currently the only high resolution fiber fed NIR astronomical spectrograph on built for RV precision

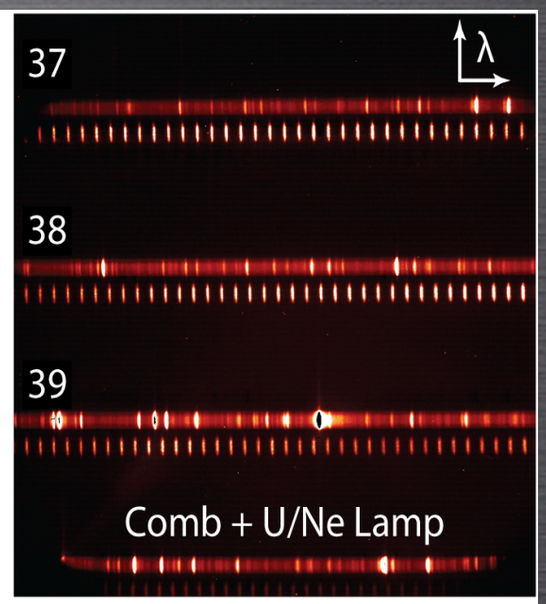
- **Valuable Test bed for Frequency Combs that really can only reach their full potential with a fiber-fed spectrograph**

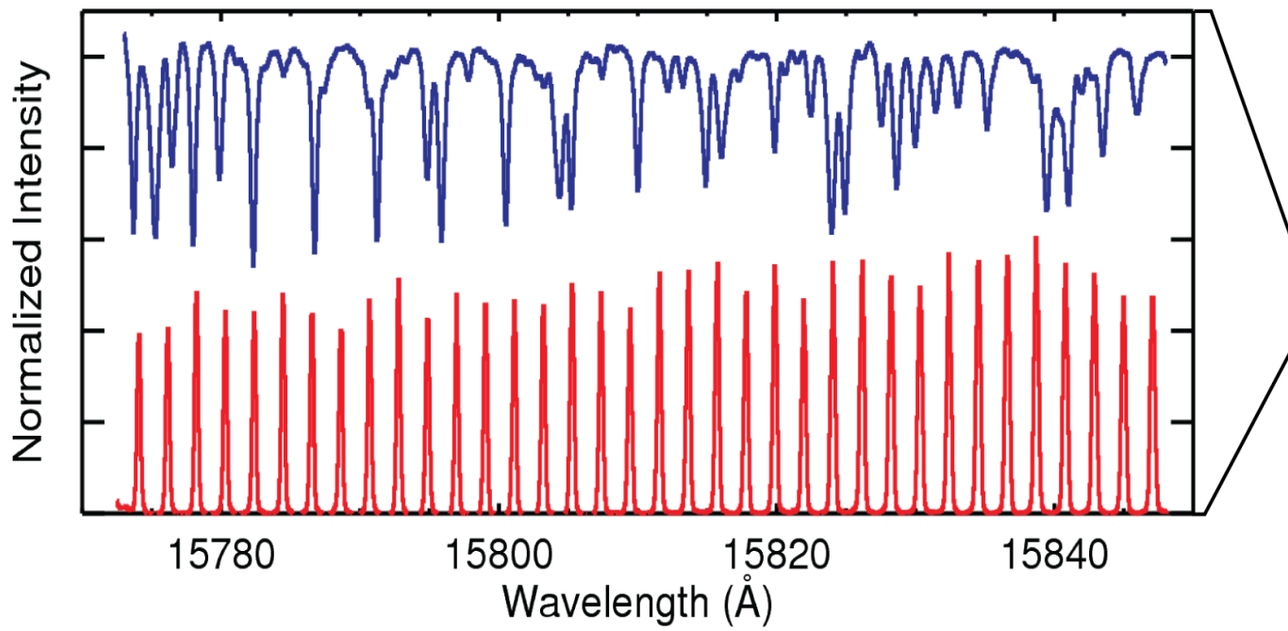
- **Pathfinder team collaboration with NIST/CASA to test their H band frequency comb.**

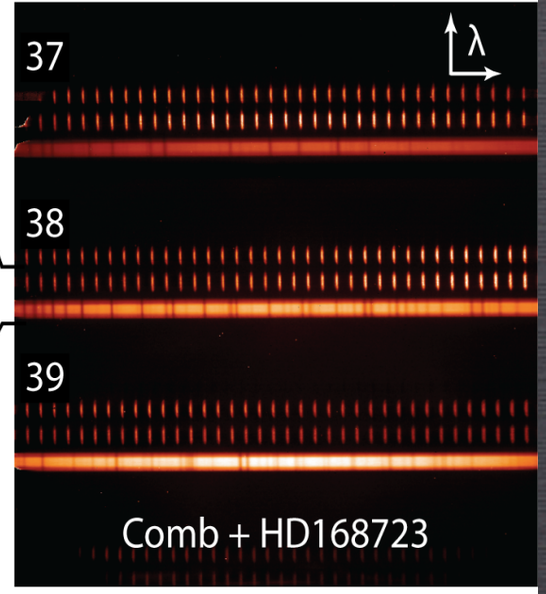
- **H band!.**

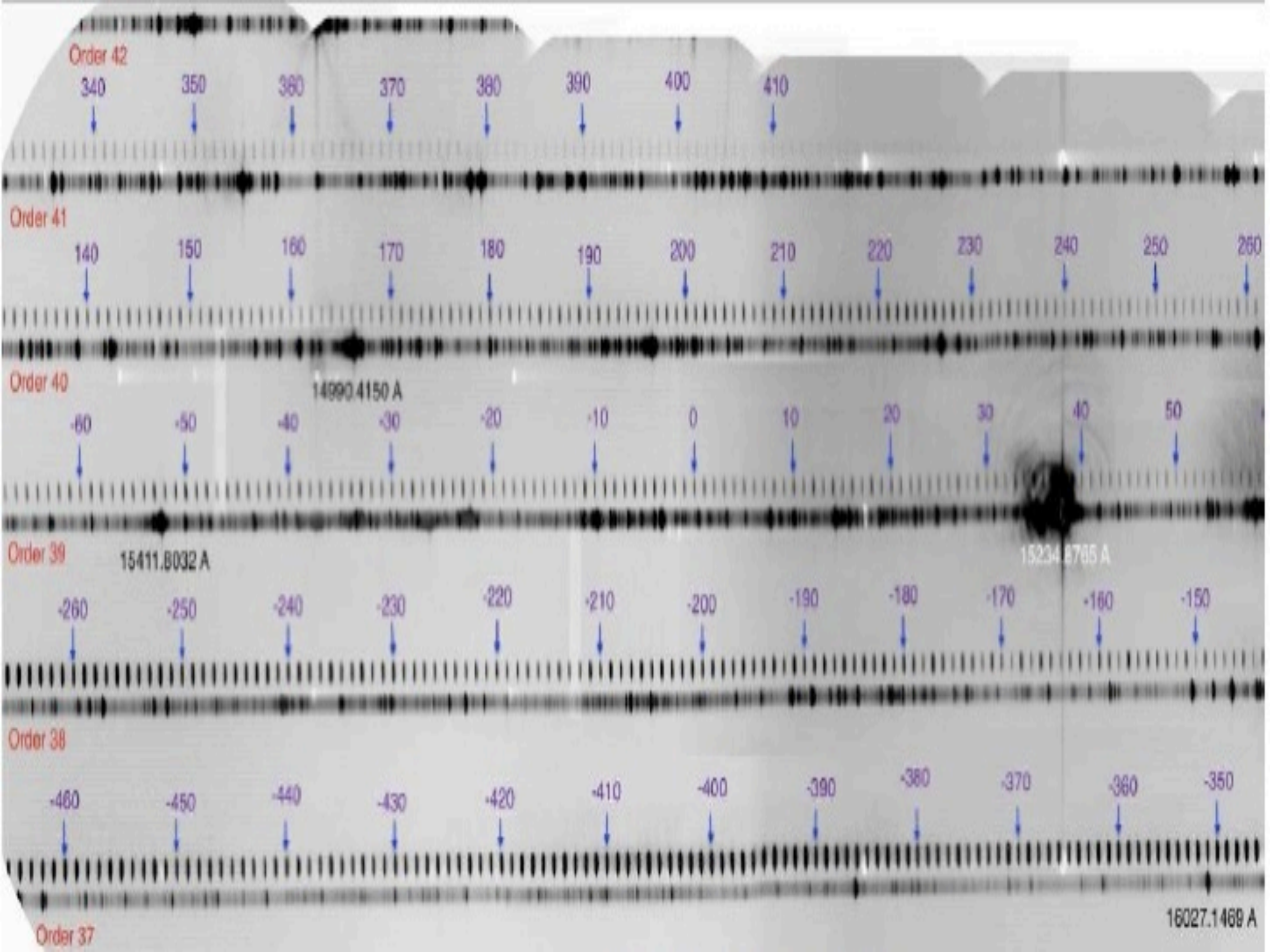
Pathfinder @ HET



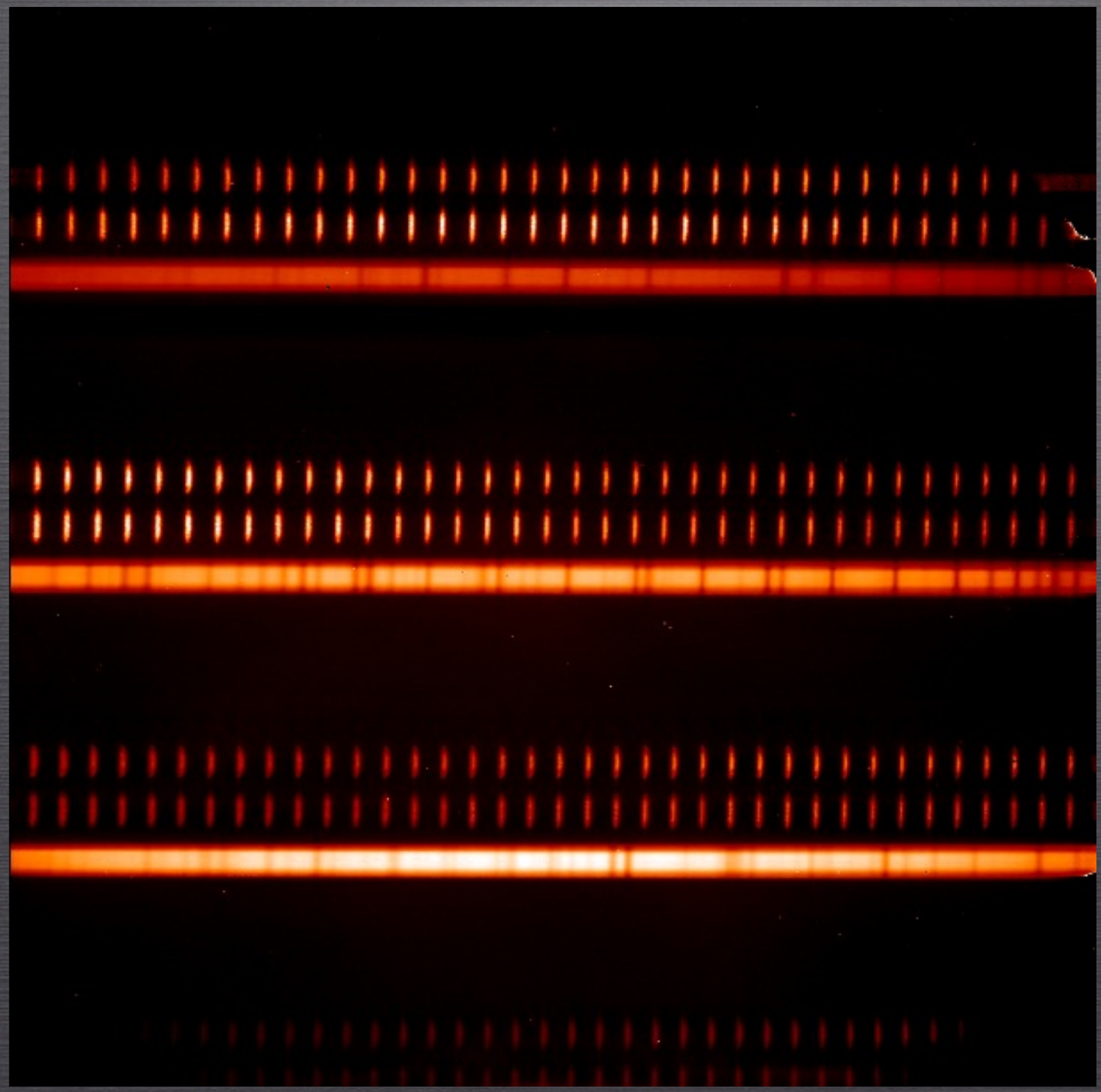






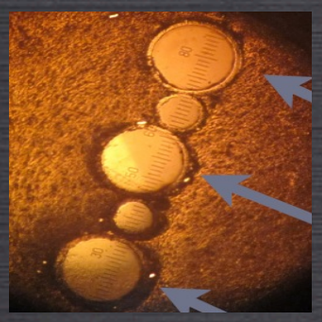

Order 42
340
350
360
370
380
390
400
410
Order 41
140
150
160
170
180
190
200
210
220
230
240
250
260
Order 40
14990.4150 A
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
Order 39
15411.8032 A
15234.8765 A
-260
-250
-240
-230
-220
-210
-200
-190
-180
-170
-160
-150
Order 38
-460
-450
-440
-430
-420
-410
-400
-390
-380
-370
-360
-350
16027.1469 A
Order 37

RVs with Simultaneous Ref.



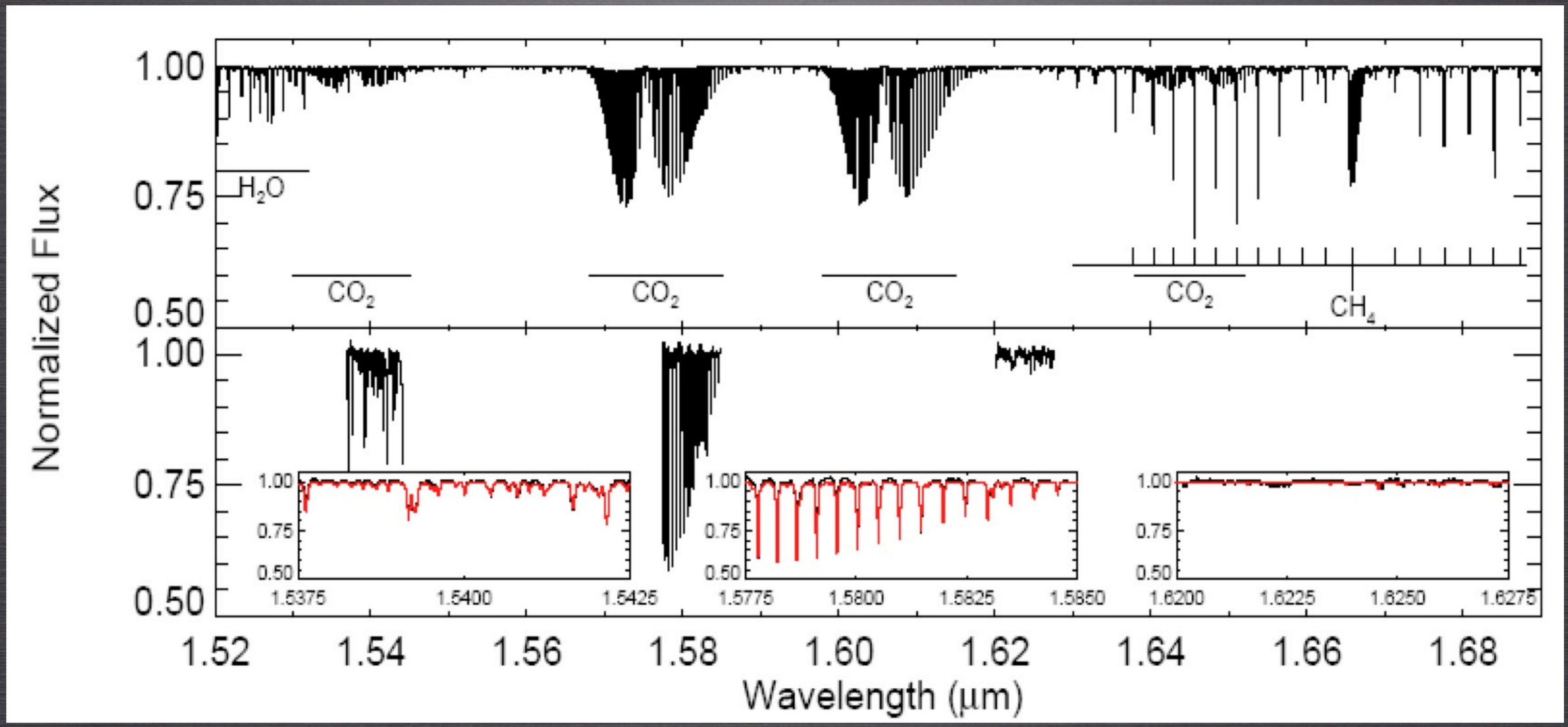
comb

star



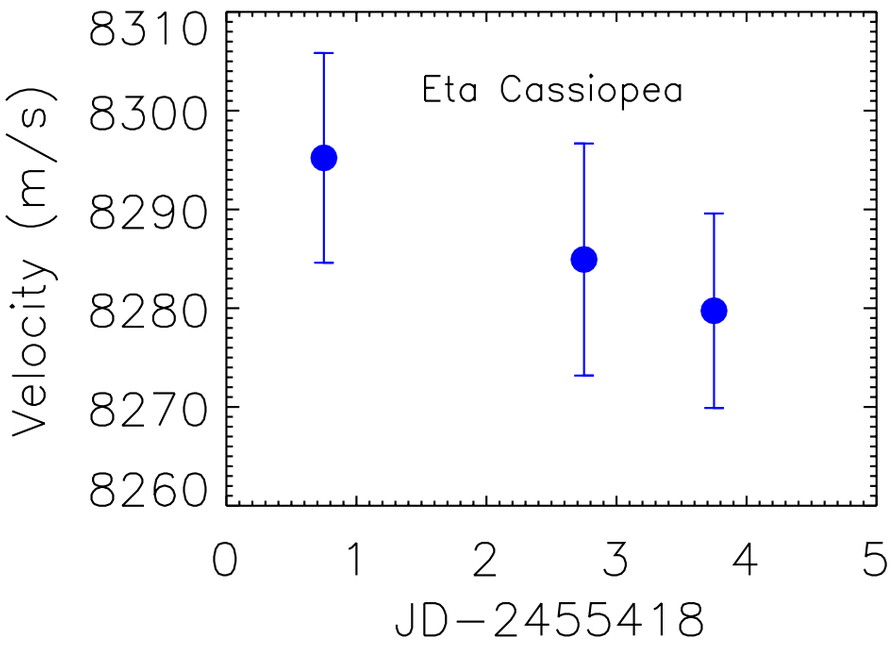
Stellar NIR RVs with Laser Frequency Comb

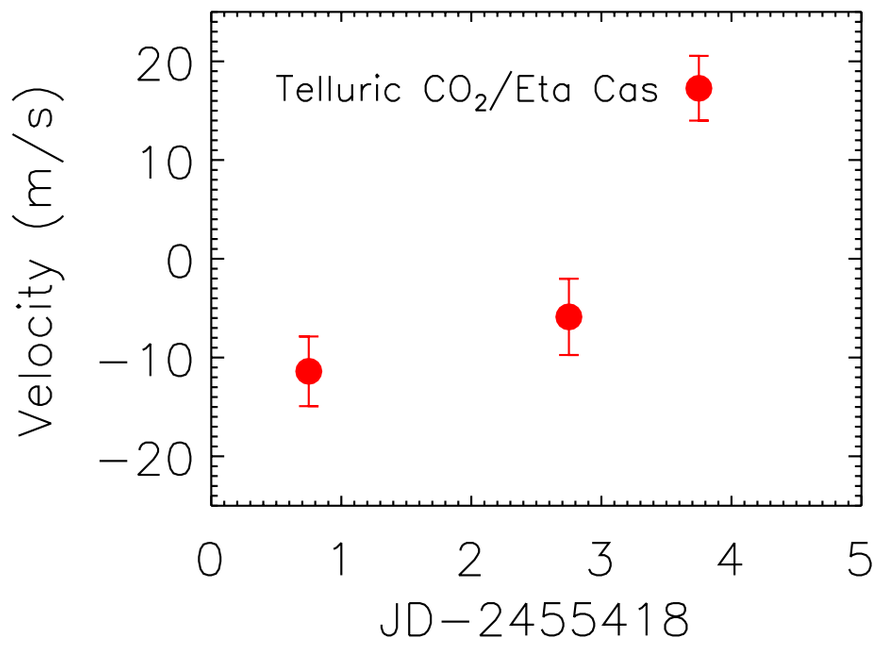
Challenges: Telluric Lines

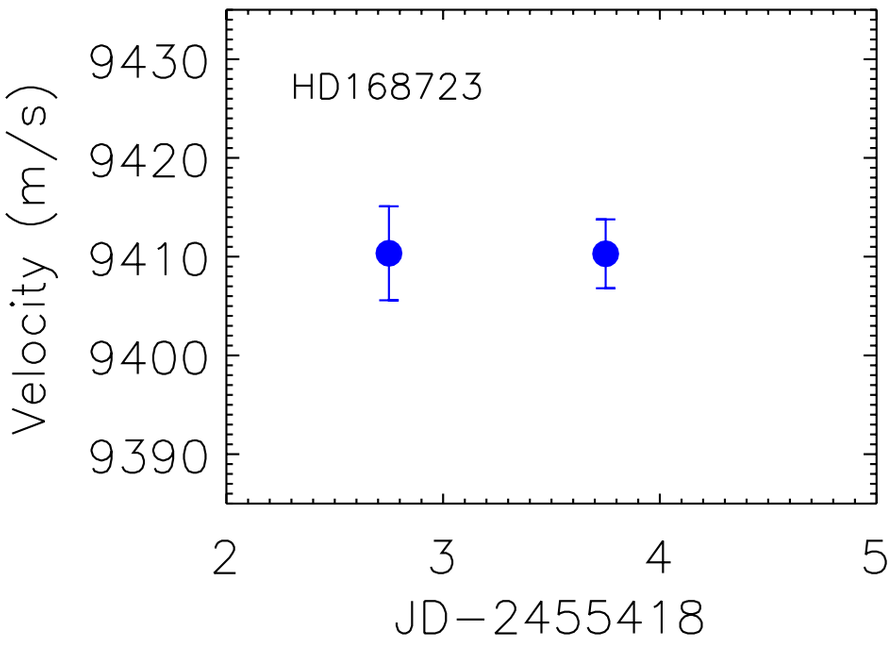


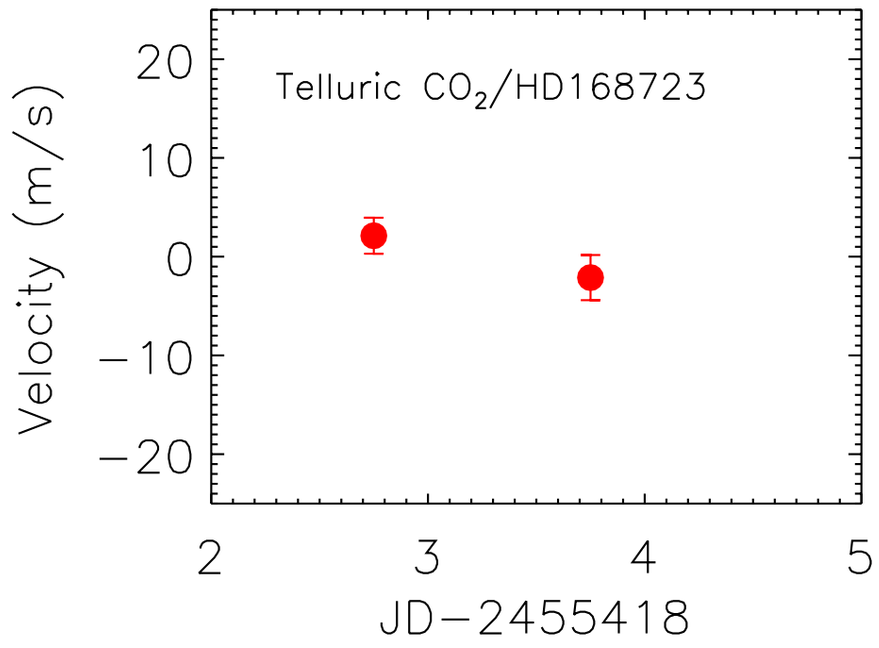
Terraspec Telluric Modeling Code (Bender et al. 2012, in prep)

First On-Star RV Results with a NIR Laser Frequency Comb!





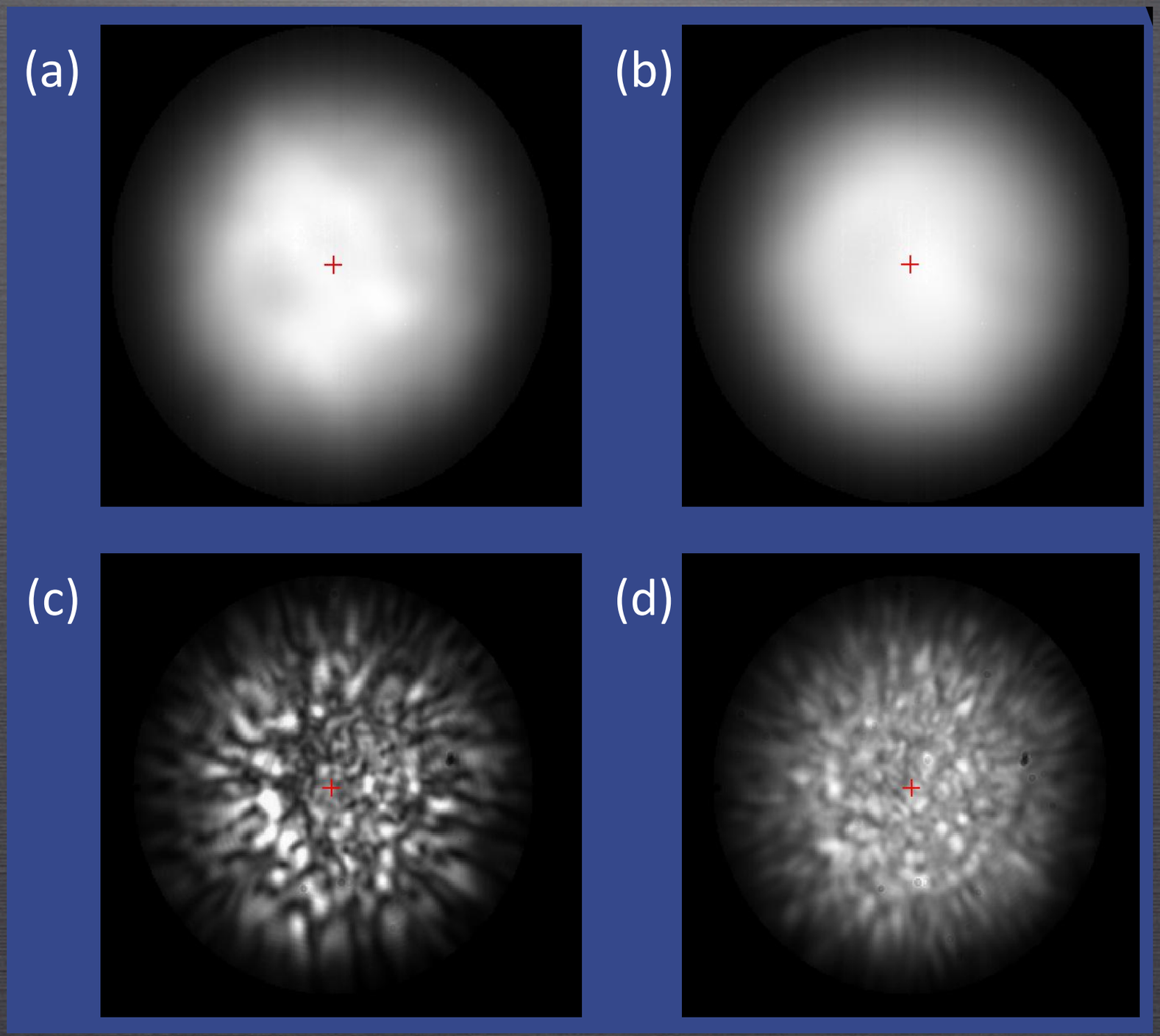




Challenges:Fiber Modal Noise

635 nm

1550 nm

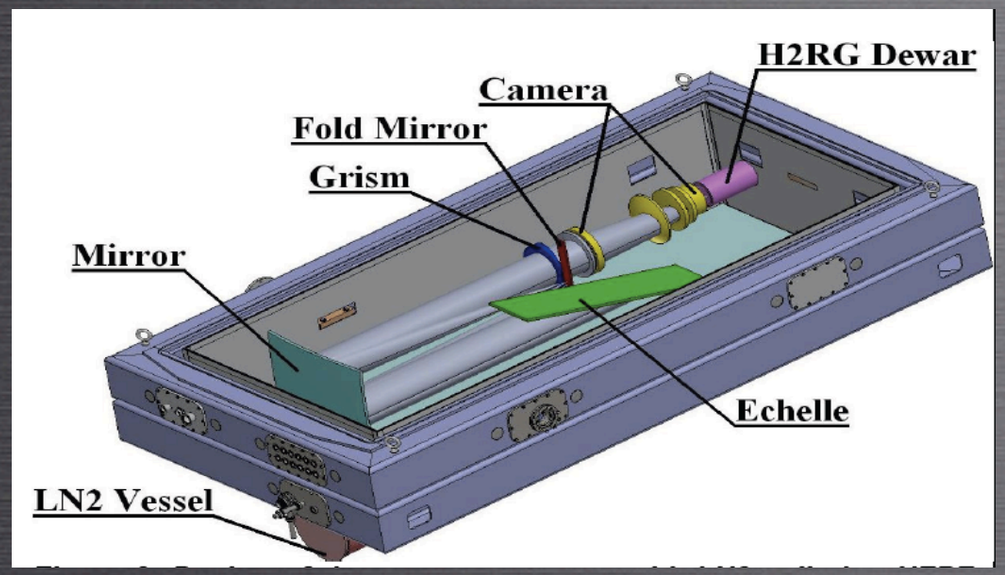


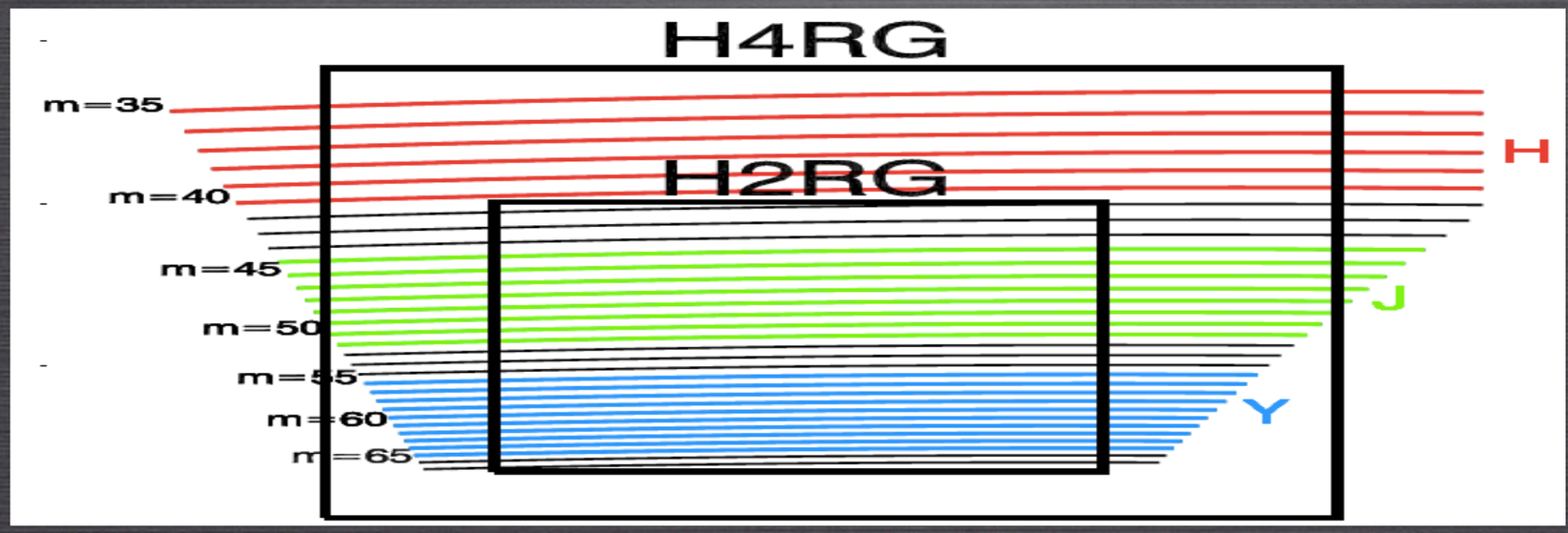
Static

Agitated

Noise due to Finite # of TE TM modes in Fiber

The HZPF on the HET

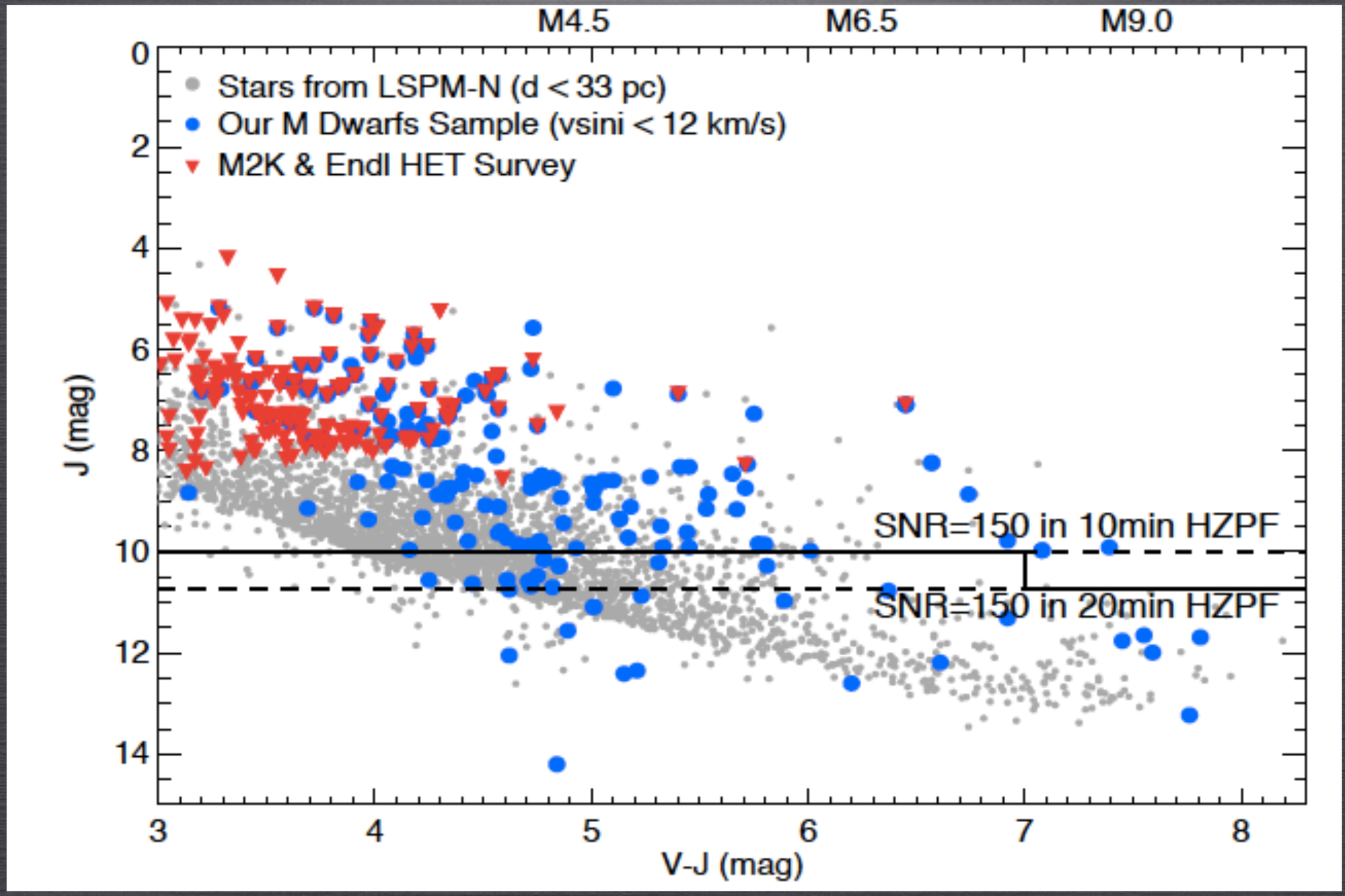




The Habitable Zone Planet Finder at the Hobby-Eberly Telescope

Timescale: ~2014

HZPF


M4.5
M6.5
M9.0
Stars from LSPM-N (d < 33 pc)
Our M Dwarfs Sample (vsini < 12 km/s)
M2K & Endl HET Survey
SNR=150 in 10min HZPF
SNR=150 in 20min HZPF
J (mag)
V-J (mag)
0
2
4
6
8
10
12
14
3
4
5
6
7
8

In Summary

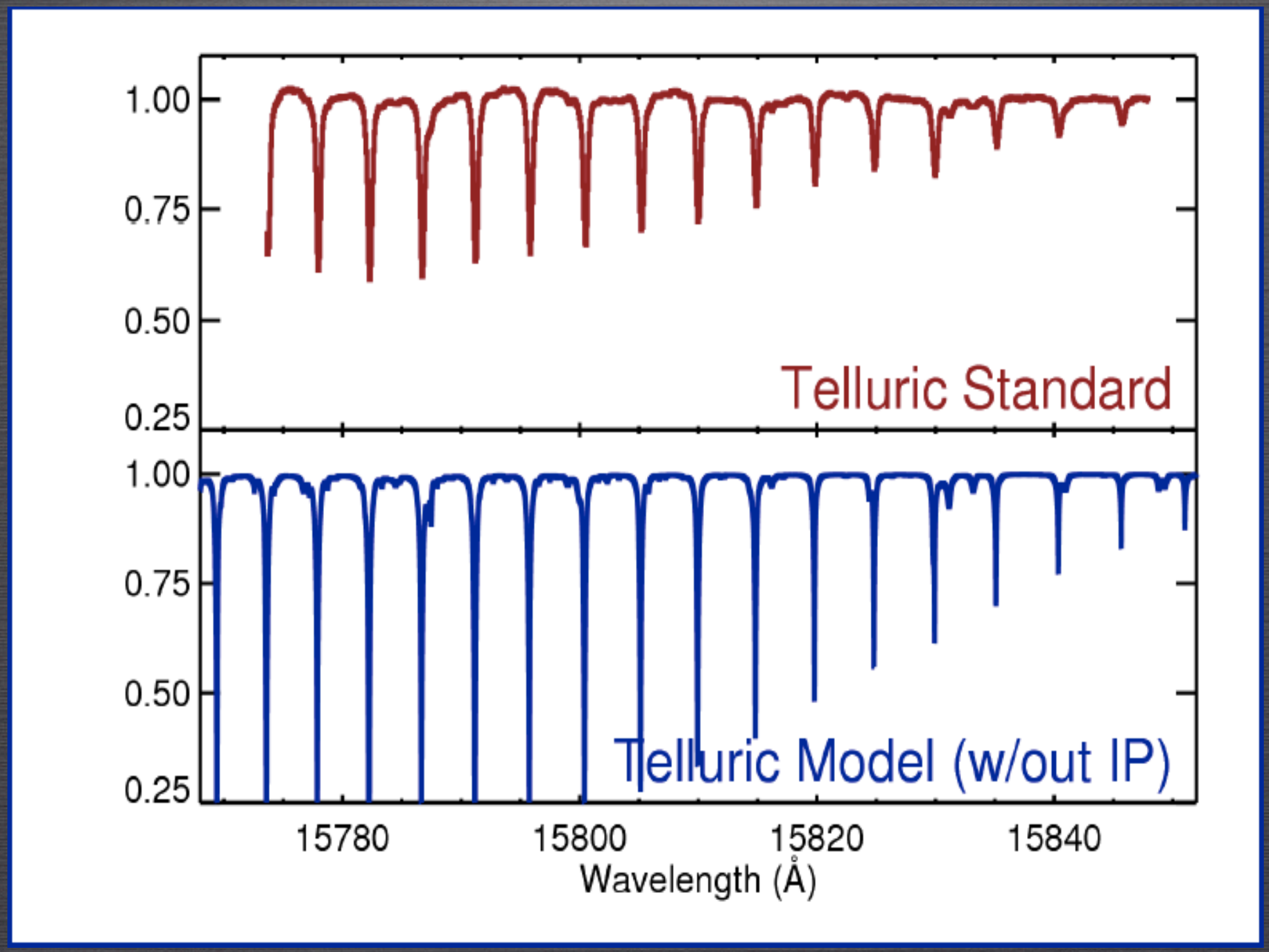
- Significant Development work is going into NIR RV Spectrographs

- Frequency combs are now in use in astrophysical settings

- Significant challenges in NIR RVs are being overcome with AMO/Laser Physics, astronomical spectrograph design, fibers, detectors, and atmospheric physics.

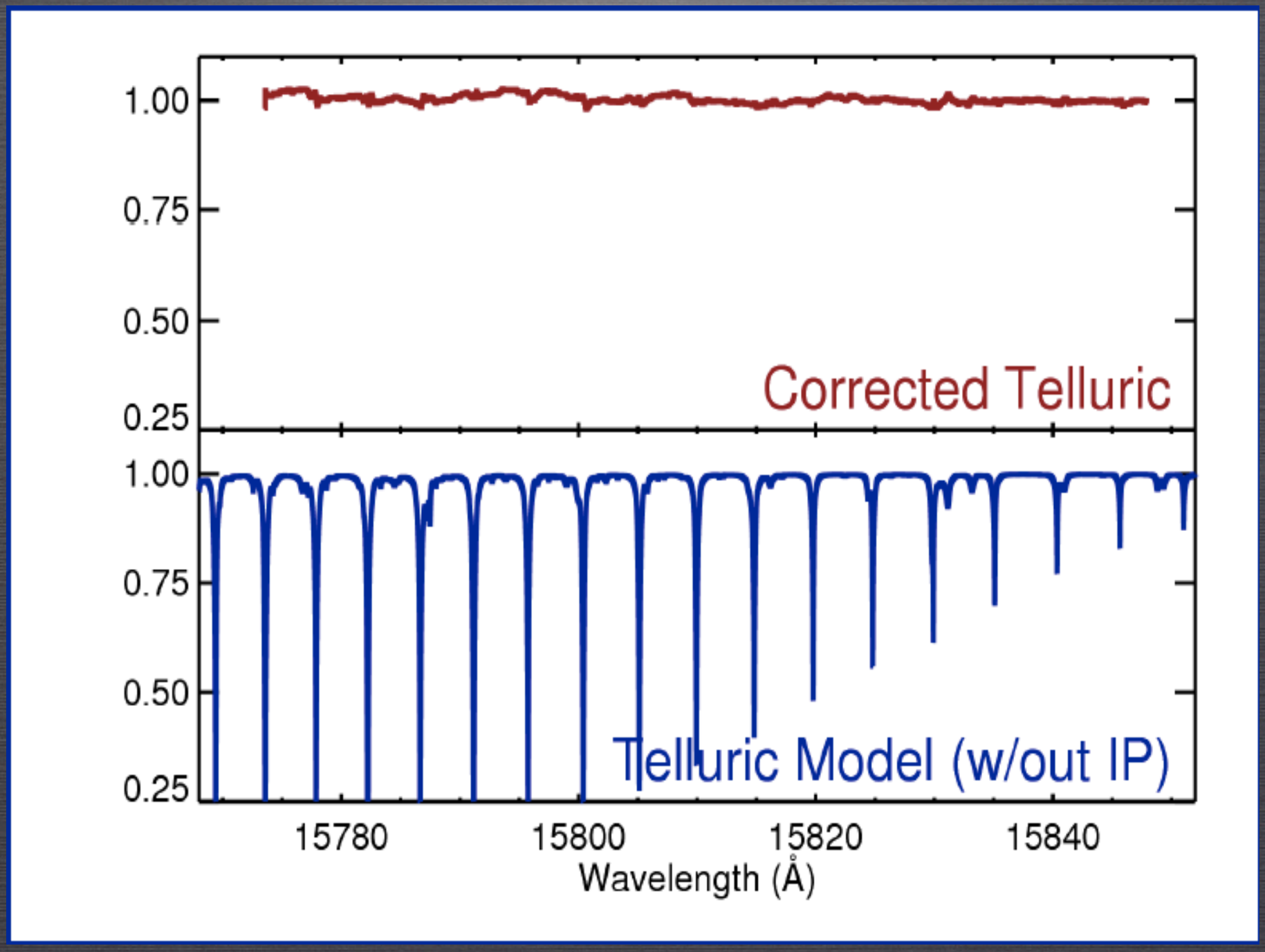
- Testbeds are REALLY useful……

Spectral Lines



Terraspec Telluric Model: Can Do Very Well with Atmospheric Physics & HITRAN

Spectral Lines



Terraspec Telluric Model: Can Do Very Well with Atmospheric Physics & HITRAN