Next Generation High Resolution and High Doppler Precision Optical and Near IR Spectrographs

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Team Members

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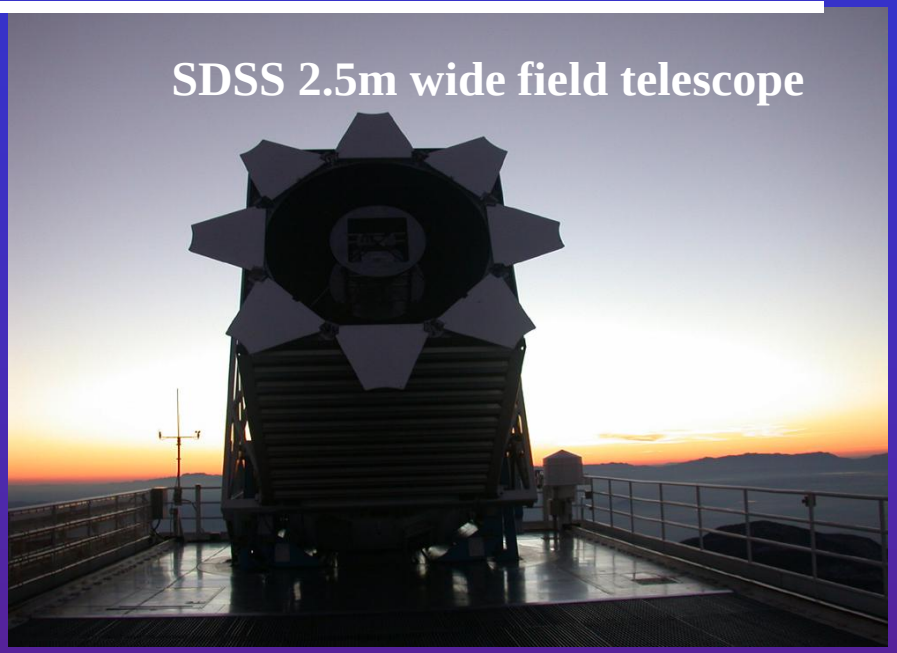
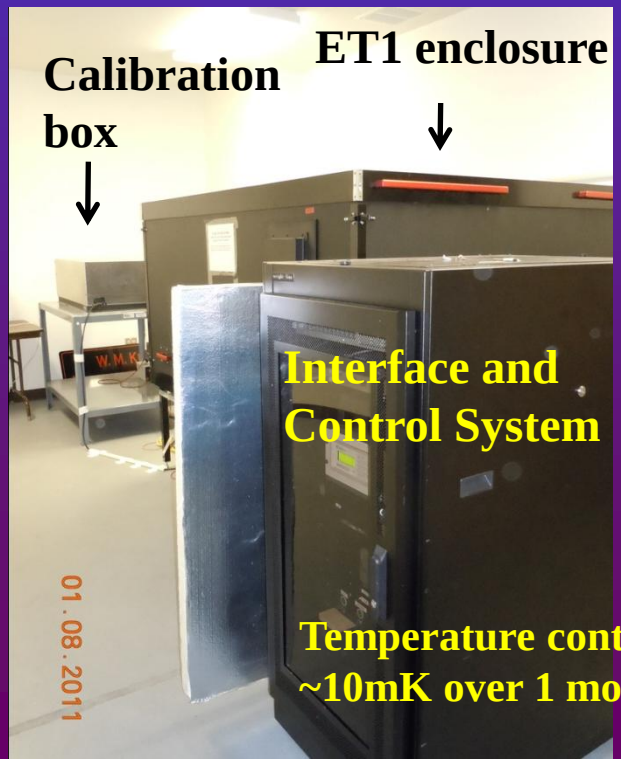
Maui Double Star meeting, 2/10/2013

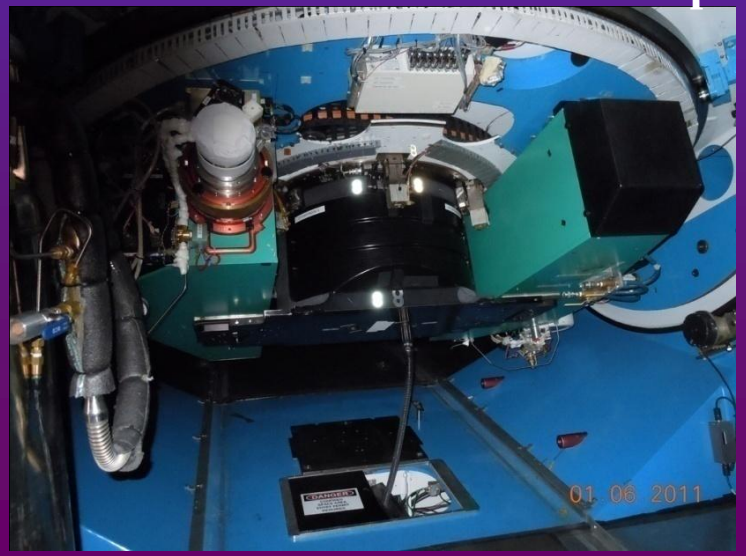
First Generation RV Instrument: Multi-object MARVELS at SDSS telescope with 60 Object RV Capability



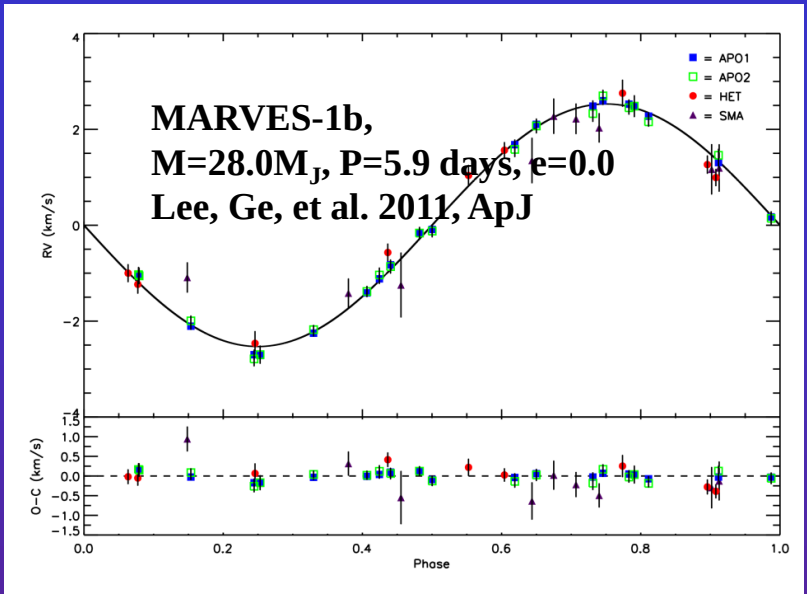


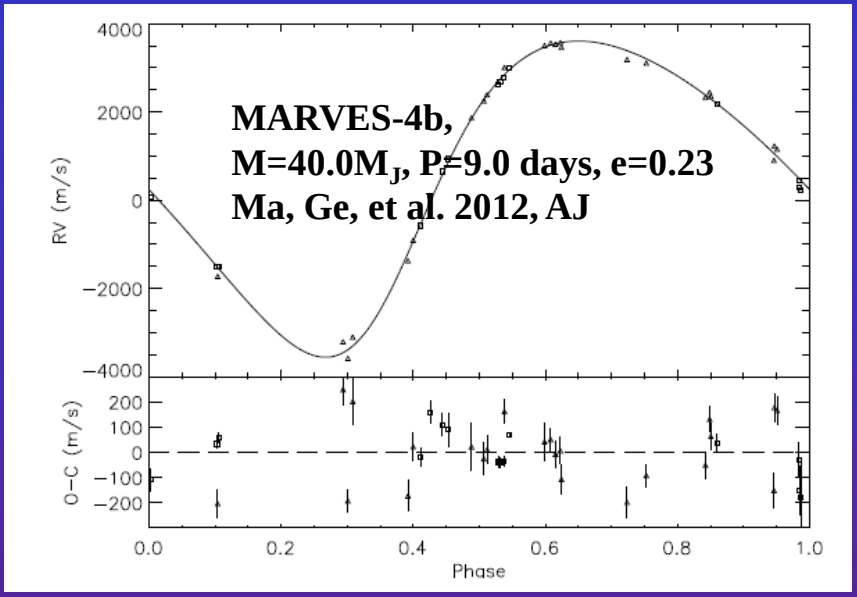
MARVELS has observed ~3300 FGK stars with V=7.6-12 in 2008-2012, with each observed ~27 times over 2 years

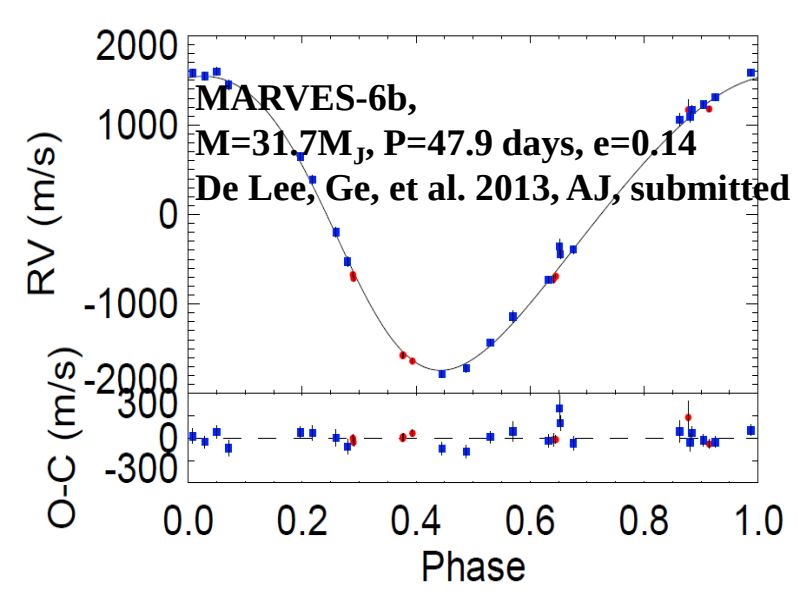
New Fiber Bundles at the Telescope

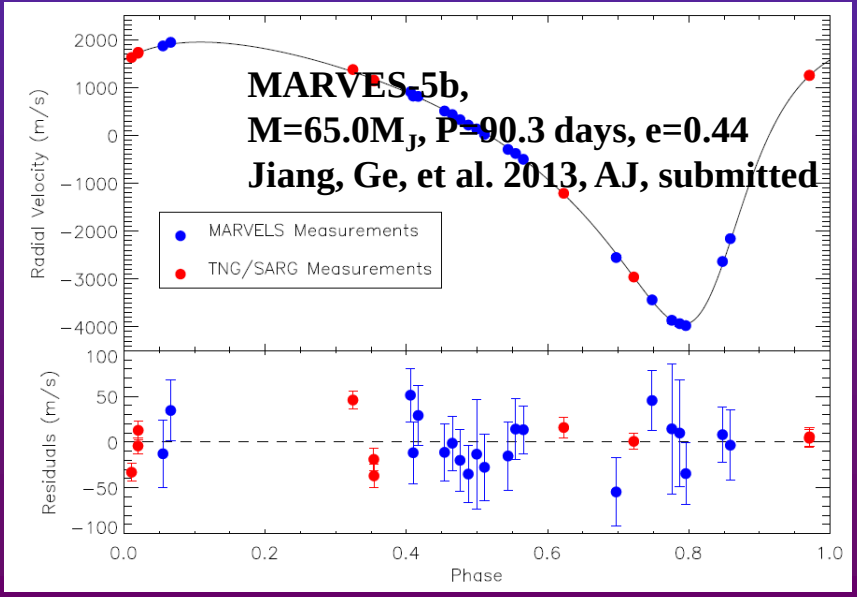


Some of the Published Substellar Companions in MARVELS

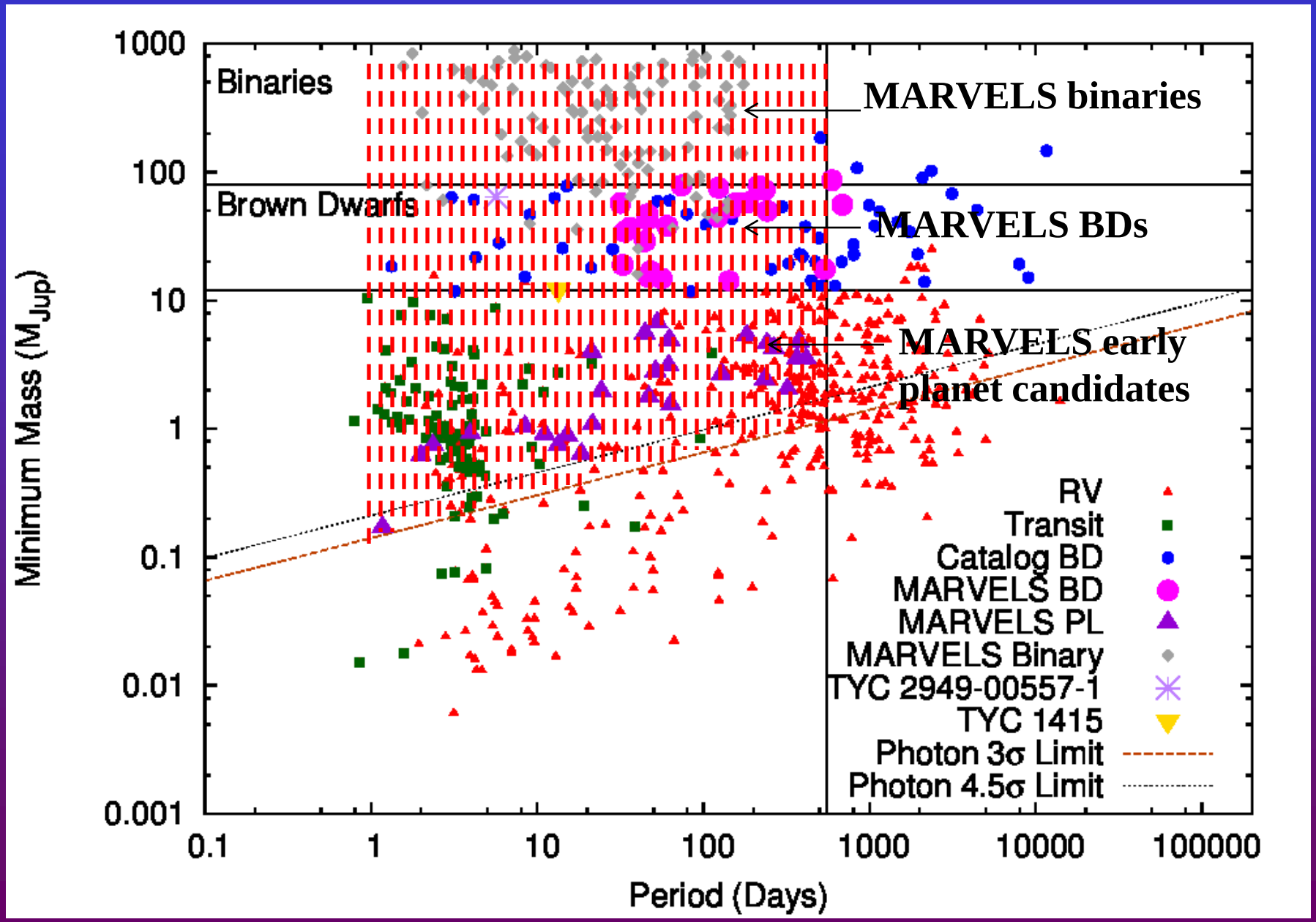




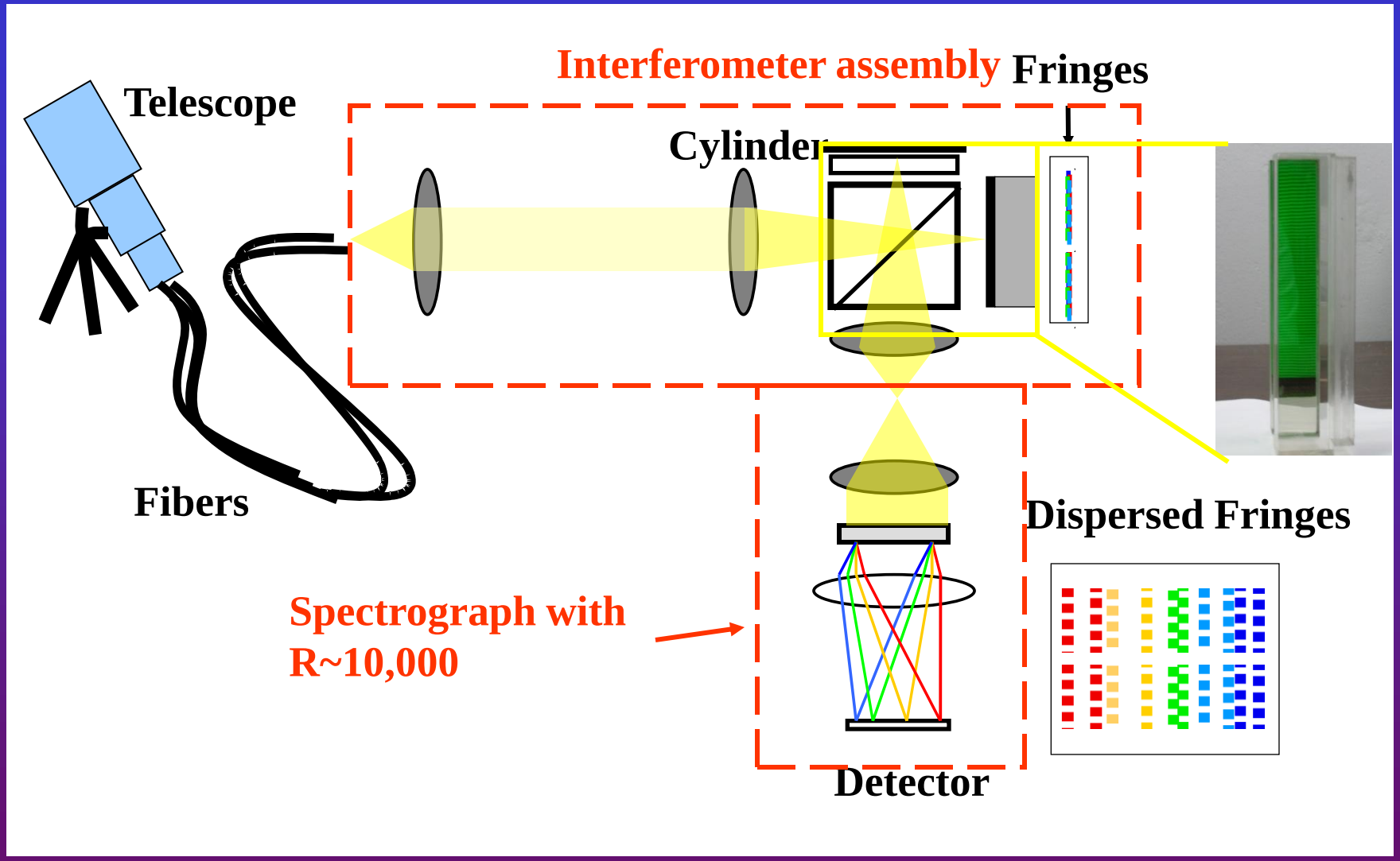




MARVELS Starts to Fill its Designed Landscape



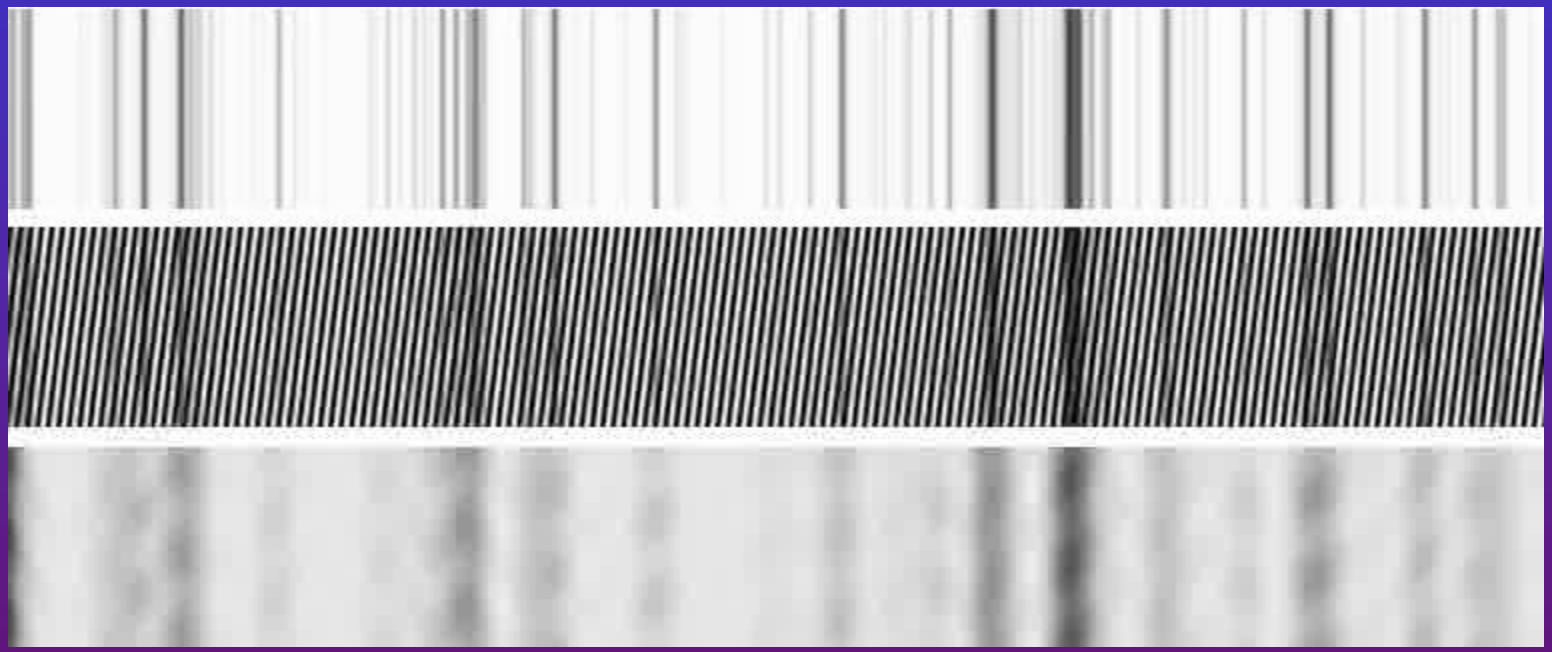
MARVELS Doppler Instrument principle: Dispersed Fixed-delay Interferometry (DFDI)



Erskine & Ge (2000), Ge et al. (2002), Ge (2002)

Doppler shift: $\Delta V \propto \Delta \Phi$ (phase shift)

DFDI principle



Credits: Julian van Eyken

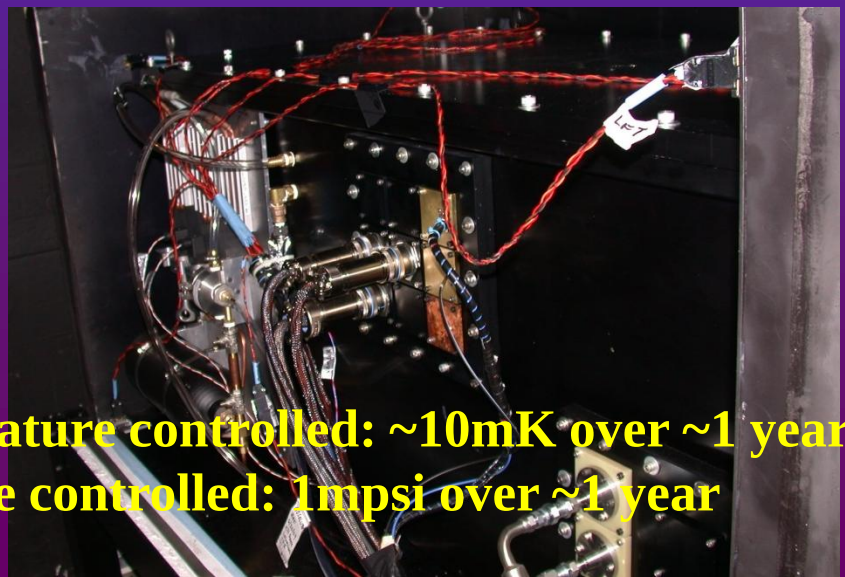
Second Generation RV instrument: EXPERT at Kitt Peak 2.1m telescope in 2009, motivated by MARVELS follow-ups


Exterior of the 2.1-Meter Telescope


EXPERT team

EXPERT control chassis

EXPERT inside a 2.1m Coude room



Temperature controlled: ~10mK over ~1 year
Pressure controlled: 1mpsi over ~1 year

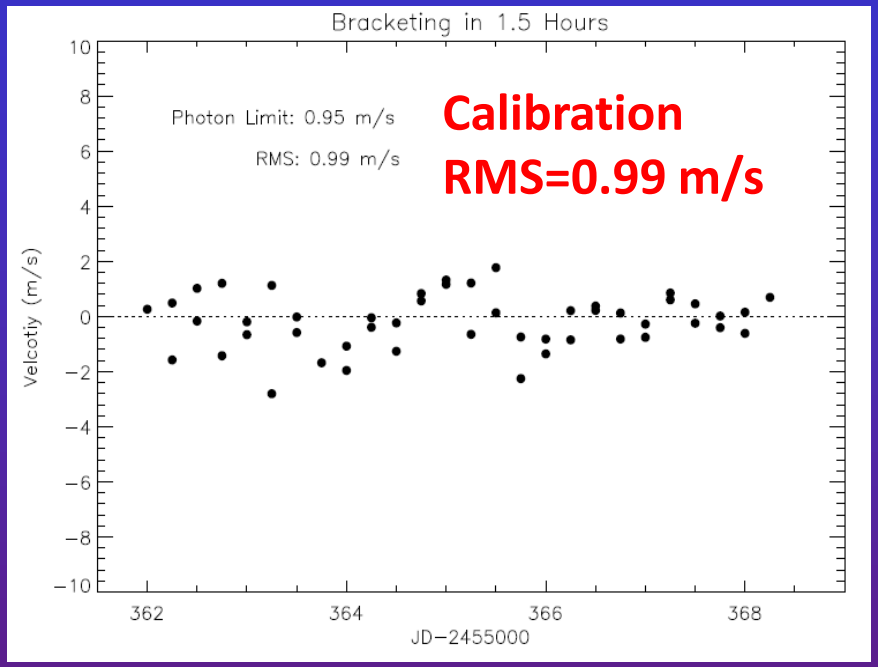
LiJET Commissioning at the LiJiang 2.4m in Feb. 2011

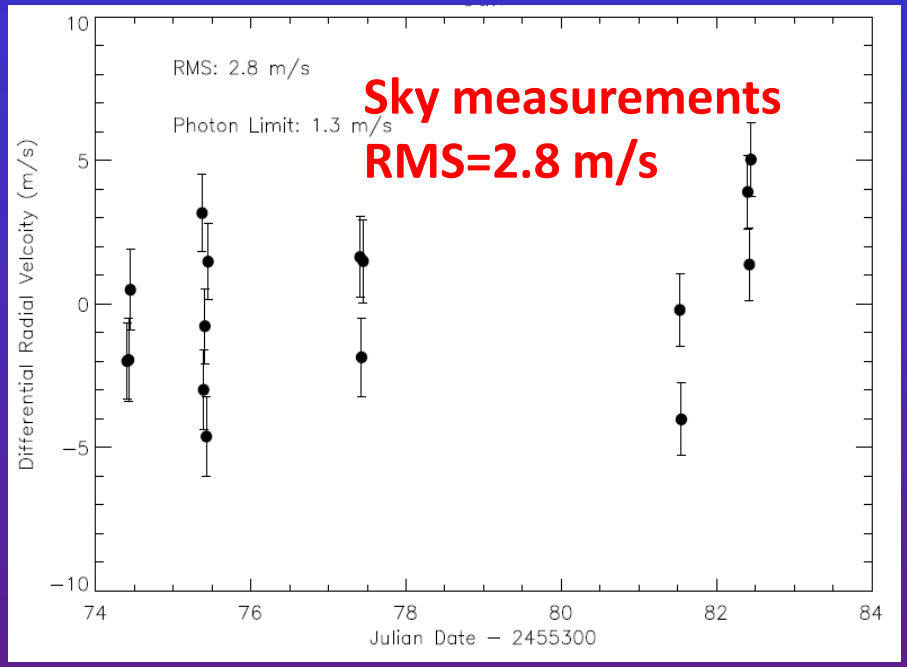
LiJET chamber

Control System

LiJET telescope interface

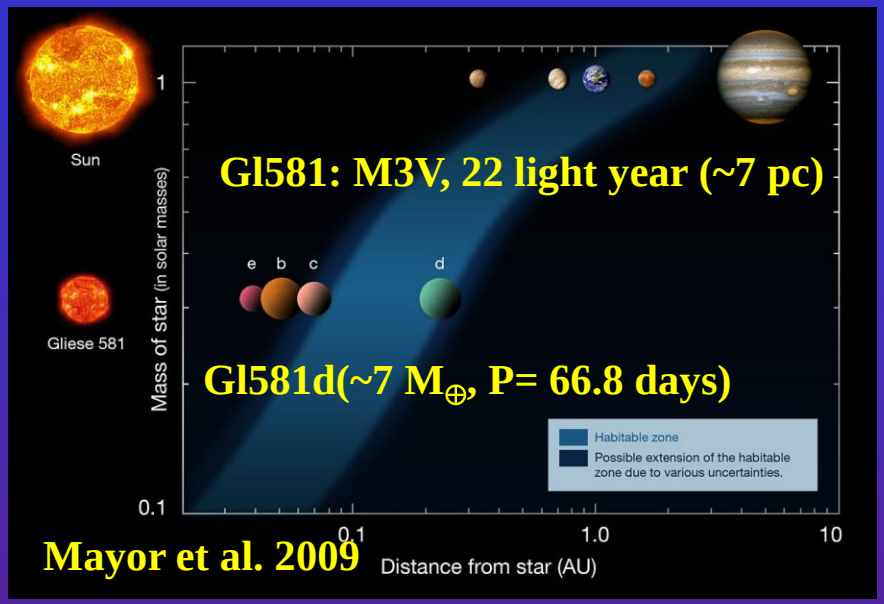
Current Instrument Performance and Network Status





- **EXPERT has its science operation since June 2010**
- **LiJET (EXPERT clone) was commissioned at the LiJiang 2.4m telescope in Feb. 2011 and completed telescope trial observations by January 2012.**
- **Working on data pipeline to reach a long term RV precision of 1-2 m/s**
- **Working on low mass planet survey simulation to come up with a survey plan, strategy, and cadence**

New Era of Habitable Planet Searches

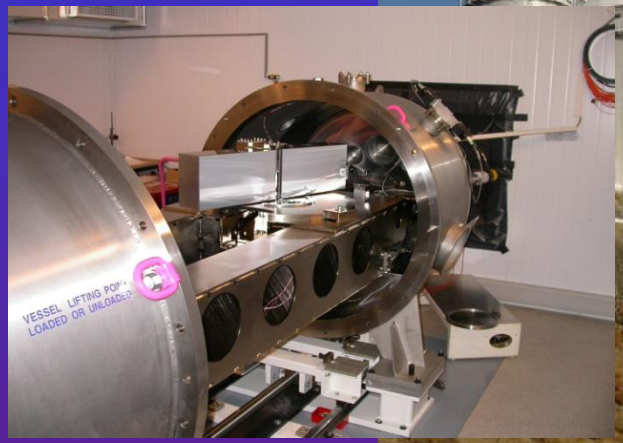


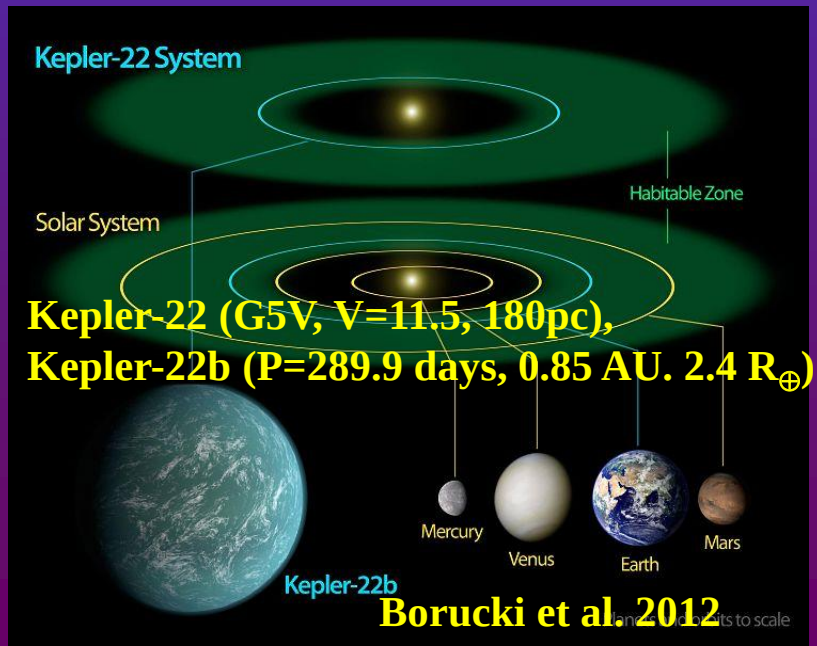
Gl581: M3V, 22 light year (~7 pc)

Gl581d(~7 $M_{\oplus}$, P= 66.8 days)

Mayor et al. 2009

ESO 3.6m at La Silla and HARPS

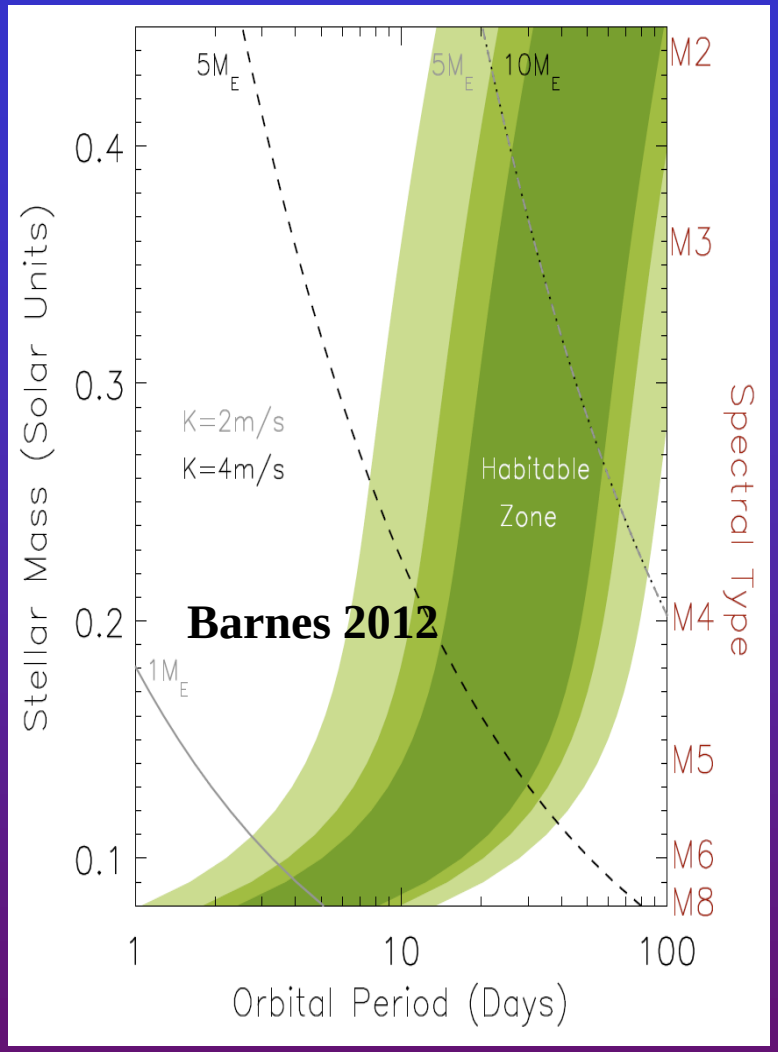


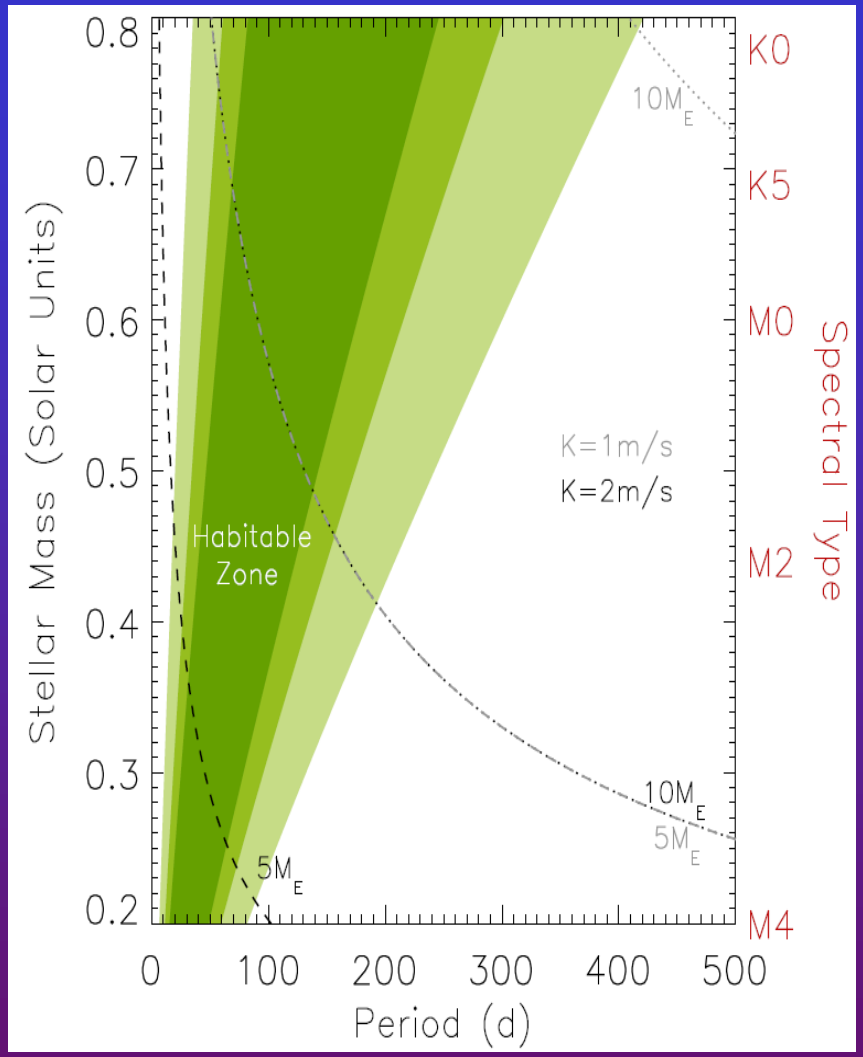


Kepler-22 (G5V, V=11.5, 180pc),
Kepler-22b (P=289.9 days, 0.85 AU. 2.4 $R_{\oplus}$)

Borucki et al. 2012

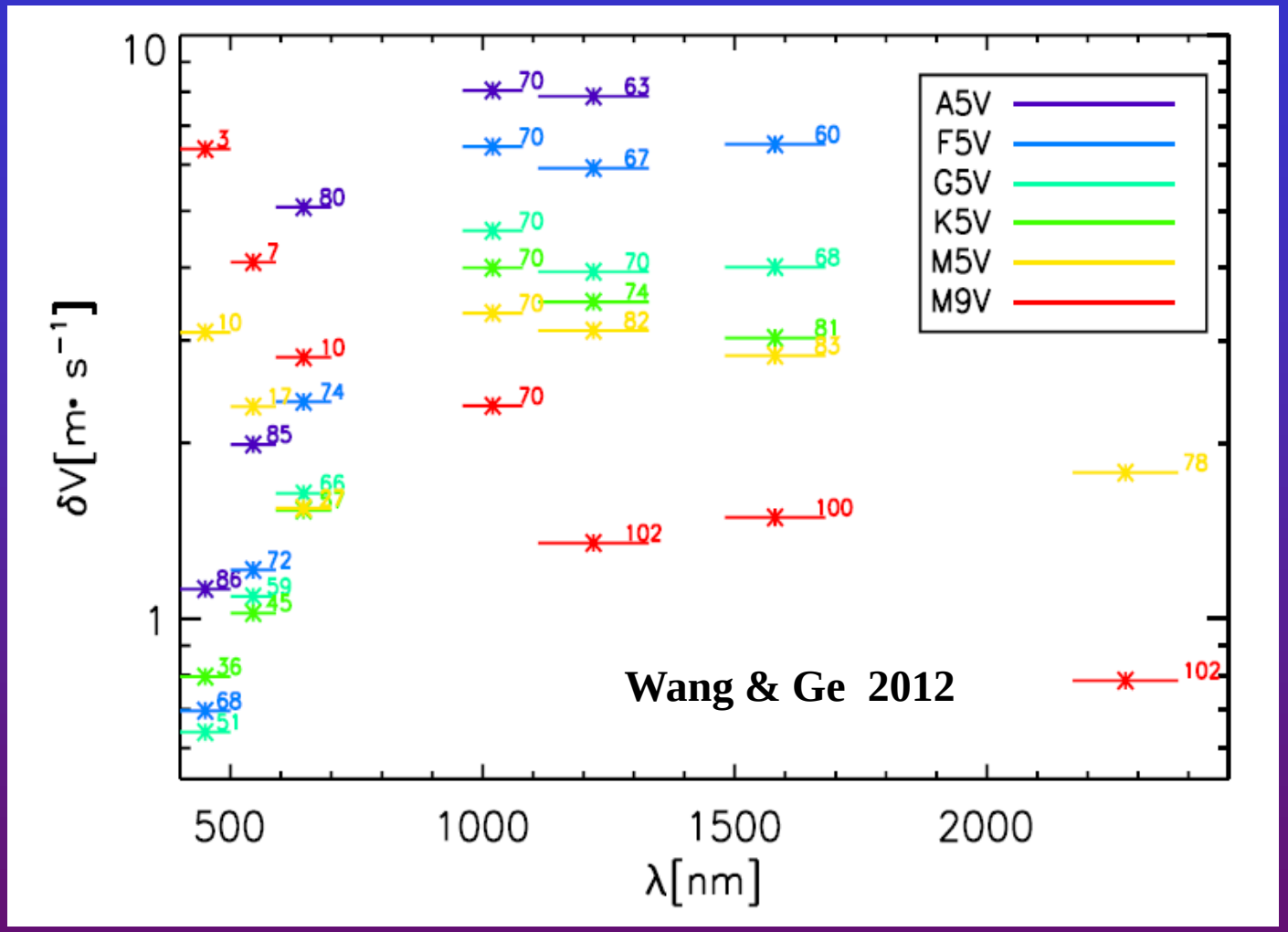
Habitable Zones among M & K Dwarfs and Doppler Sensitivities





- **RV precision ≤ ~3 m/s required to detect habitable super-Earths around M4V-M9V dwarfs**
- **RV precision ≤ ~1 m/s required to probe habitable super-Earths around K0V-M4V dwarfs**

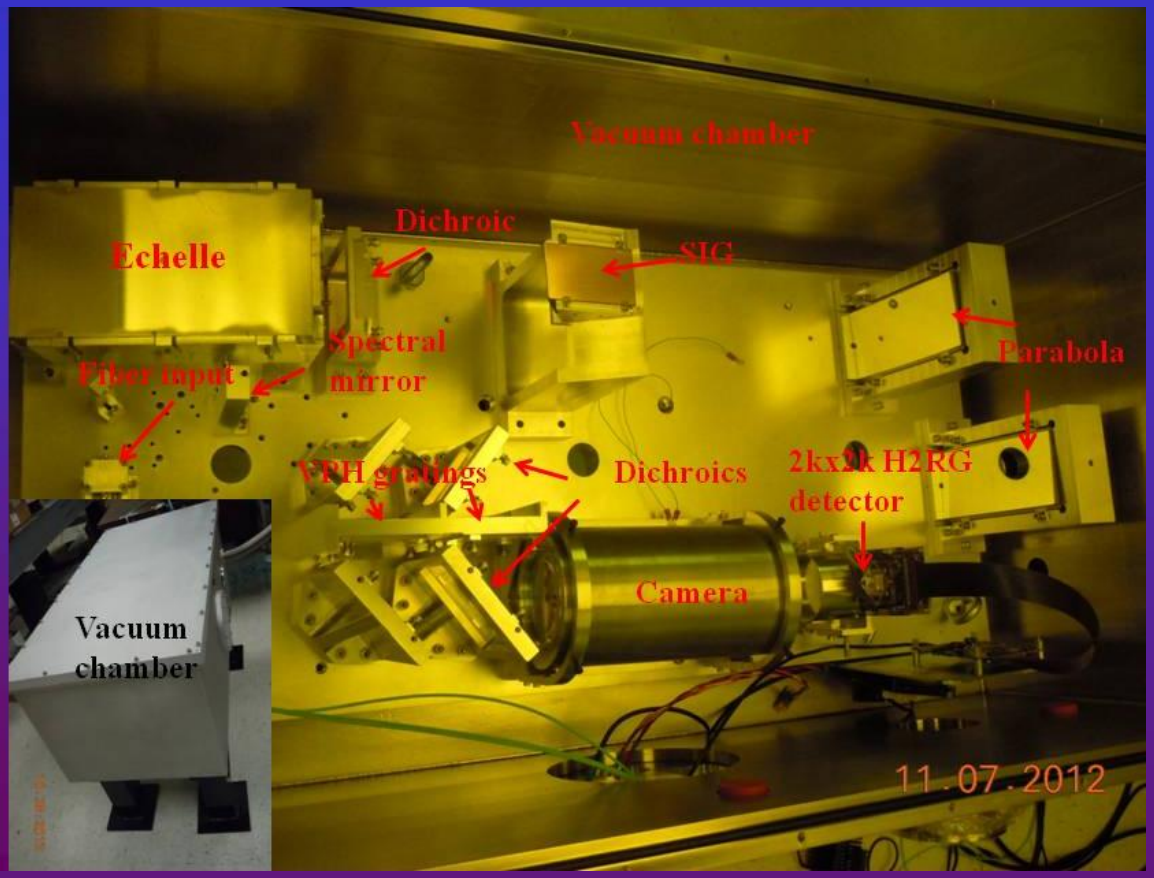
RV Uncertainties Limited by Photons with R=120K at Different Bands



- **High precision and high resolution optical spectrographs are needed for habitable planet surveys around K0-M4V dwarfs**
- **High precision and high resolution near IR spectrographs are needed for habitable planet surveys around M4V-M9V dwarfs**

FIRST IR Doppler Instrument Development

FIRST Chamber and Optical Bench



AST 2m Robotic Telescope at Fairborn Observatory

- R=68K at 1.4-1.8 μm and R=56K at 0.8-1.35 μm, overall detection efficiency ~7%
- Operated in a vacuum chamber (<0.01 torr for 1 month) at 193K for the bench and 77K for a H2RG array and temperature controlled to within ~4 mK over a month
- A silicon immersion grating (1.4-1.8 μm) and a R4 echelle (0.8-1.35 μm) with a mirror image slicer
- Compact design (0.5x1.0x0.4m dimension) to keep the total cost within $1.5M

FIRST Spectral Format and Engineering Data in November 2012

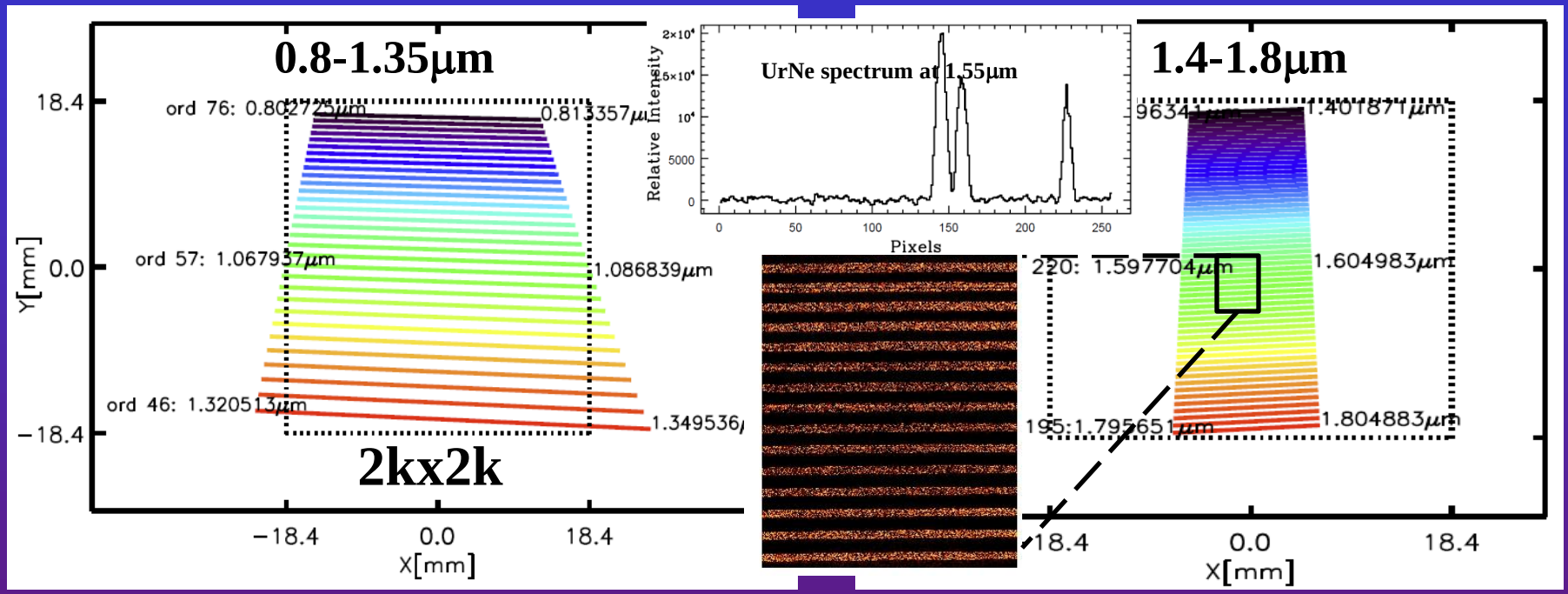


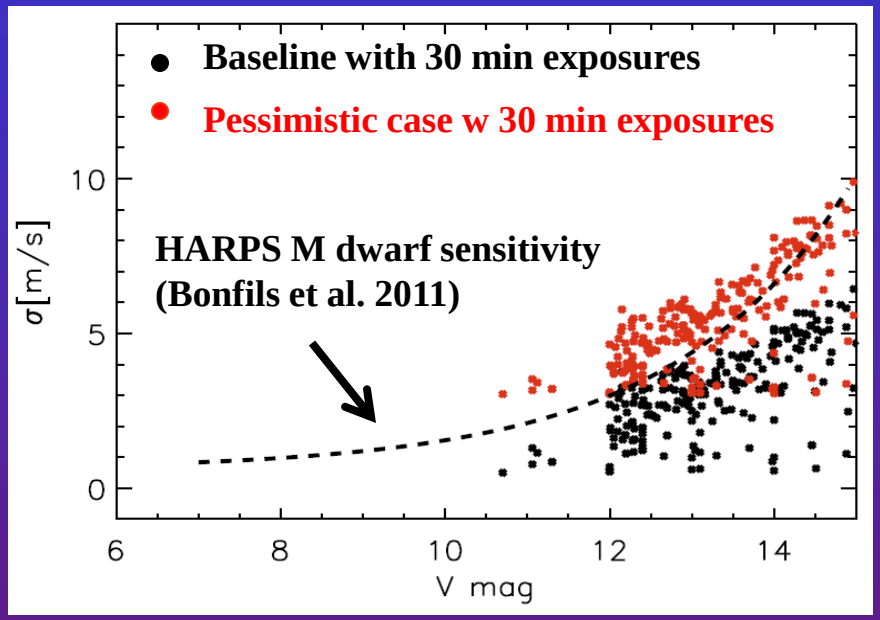
Image quality and throughput meet requirements

Remaining major tasks before commissioning late this spring:

- **Install the image slicer**
- **Integrate the H2RG with the instrument**
- **Cryogenic cooling and vacuum testing**
- **Acceptance test**

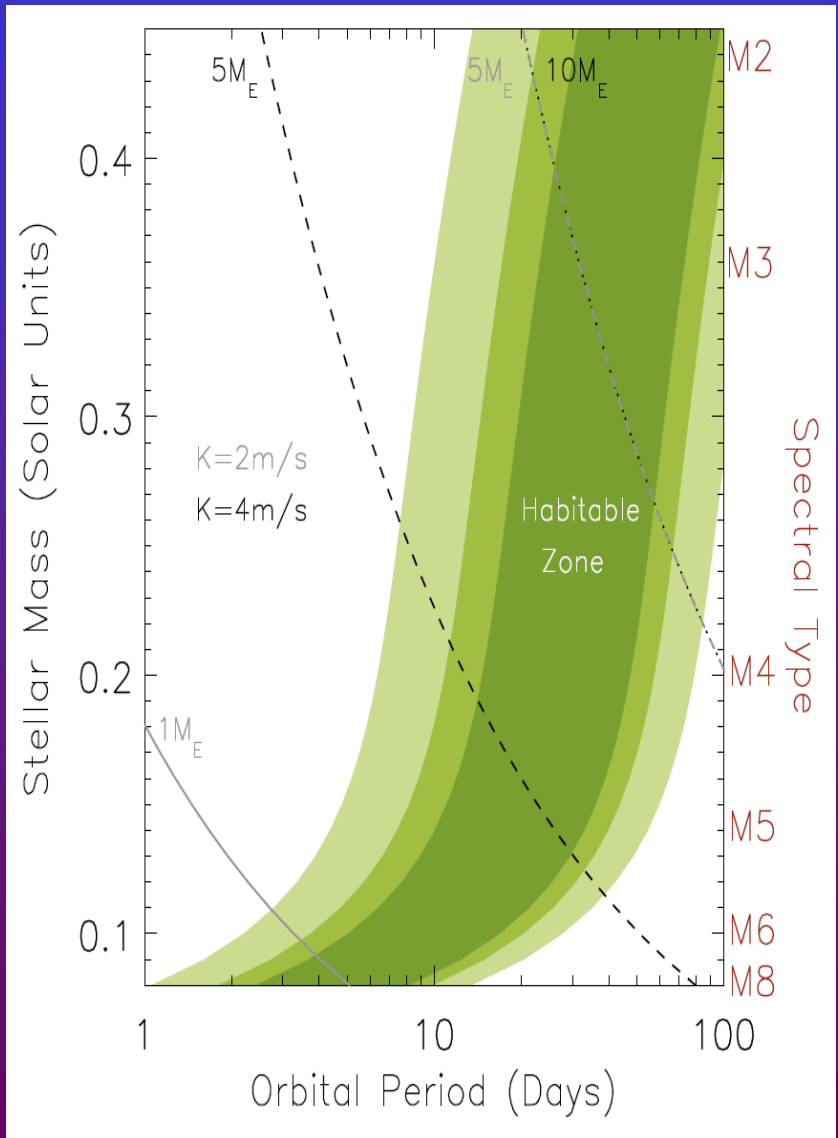
FIRST at Fairborn Observatory to Hunt for Habitable super-Earths around 200 J<10 Late M Dwarfs in 2013-2017

Simulated Doppler Precision



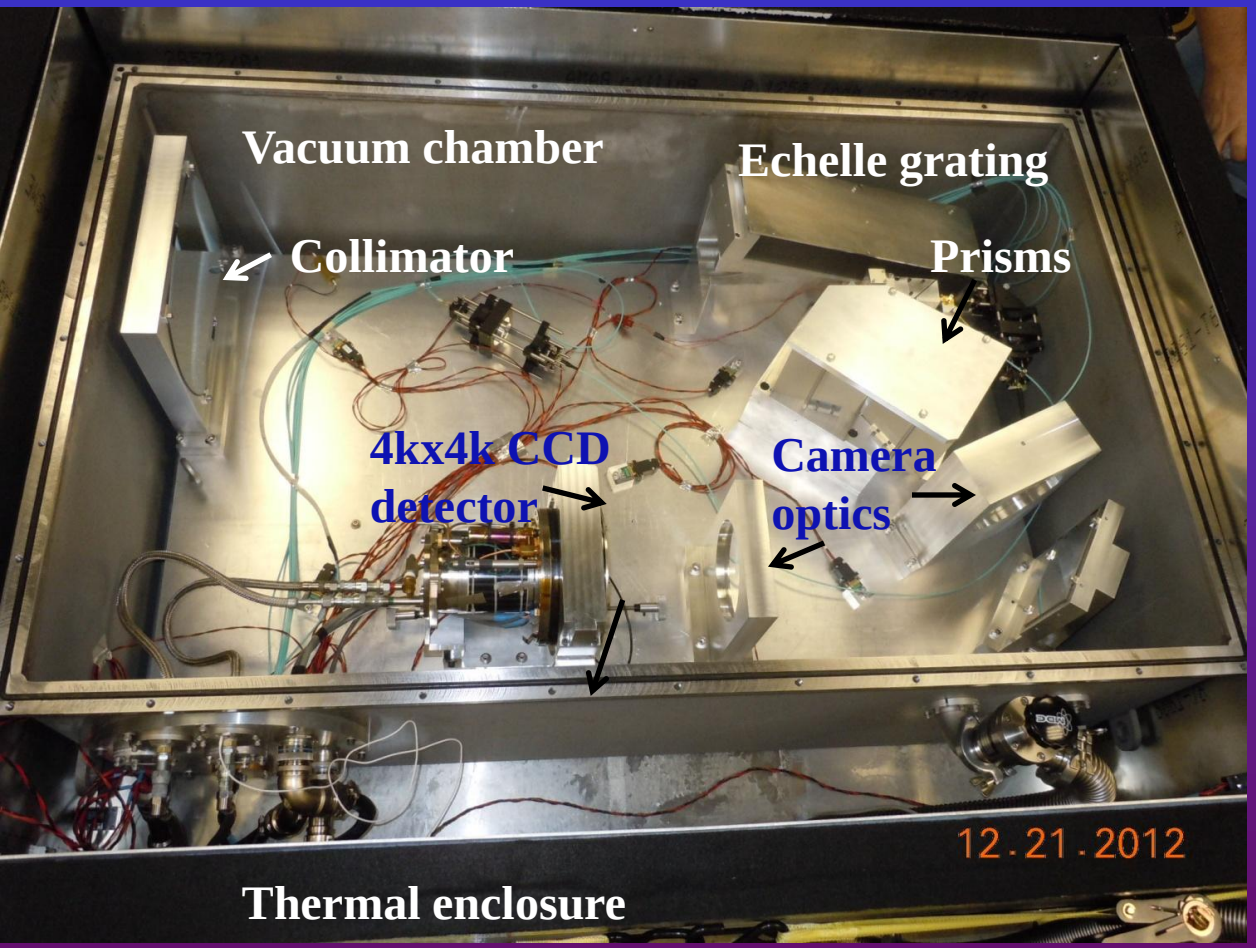
- High cadence and queue schedule with the AST 2m robotic telescope offers the great flexibility for hunting for super-Earths
- Expect to detect ~30 exoplanets, including 10 super-Earths, within 100 day periods

FIRST Exploration Space



EXPERT-III for Extremely High Precision RV Measurements at the KPNO 2.1m Telescope

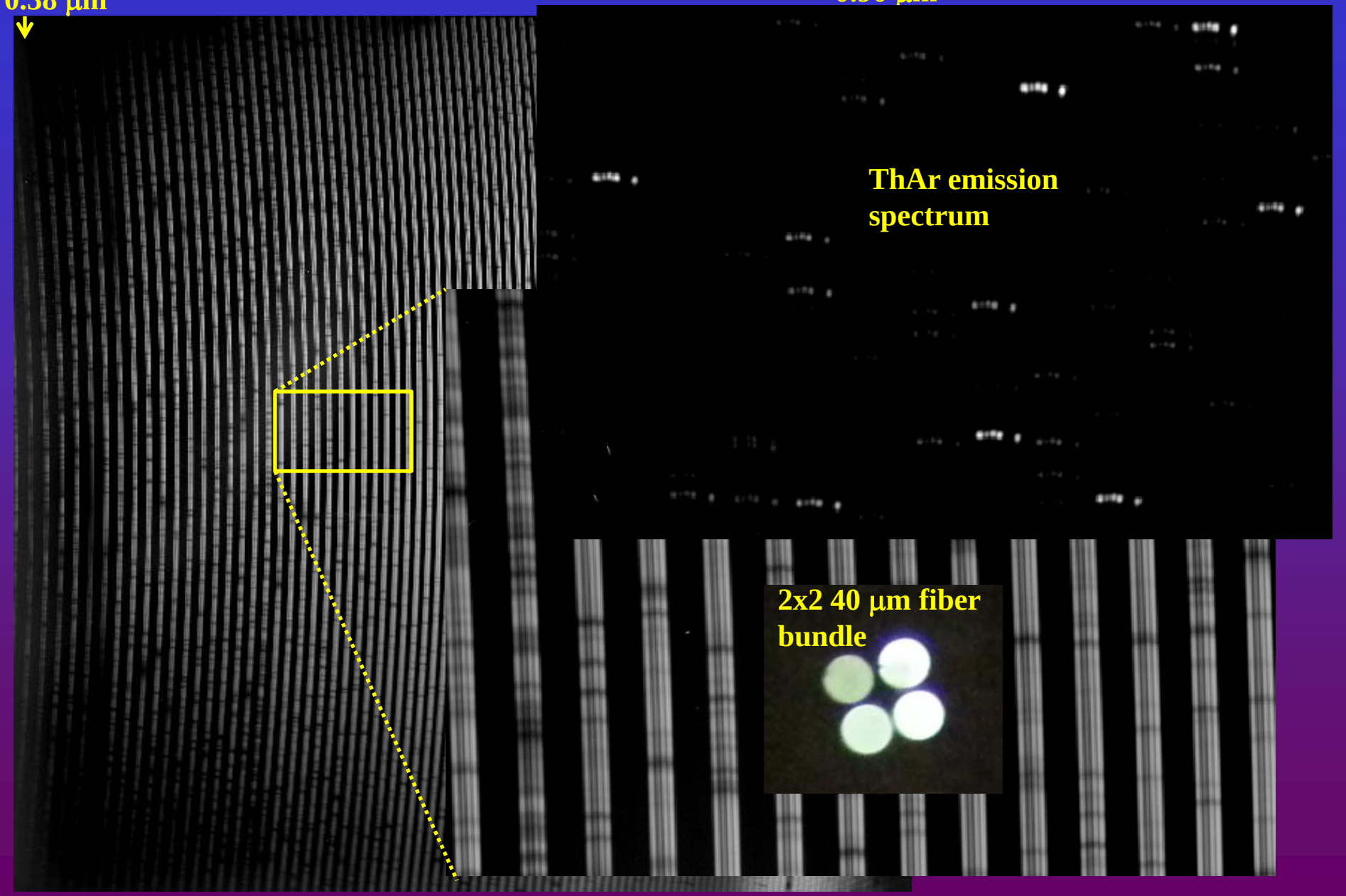
Thermal enclosure, vacuum chamber and optical bench



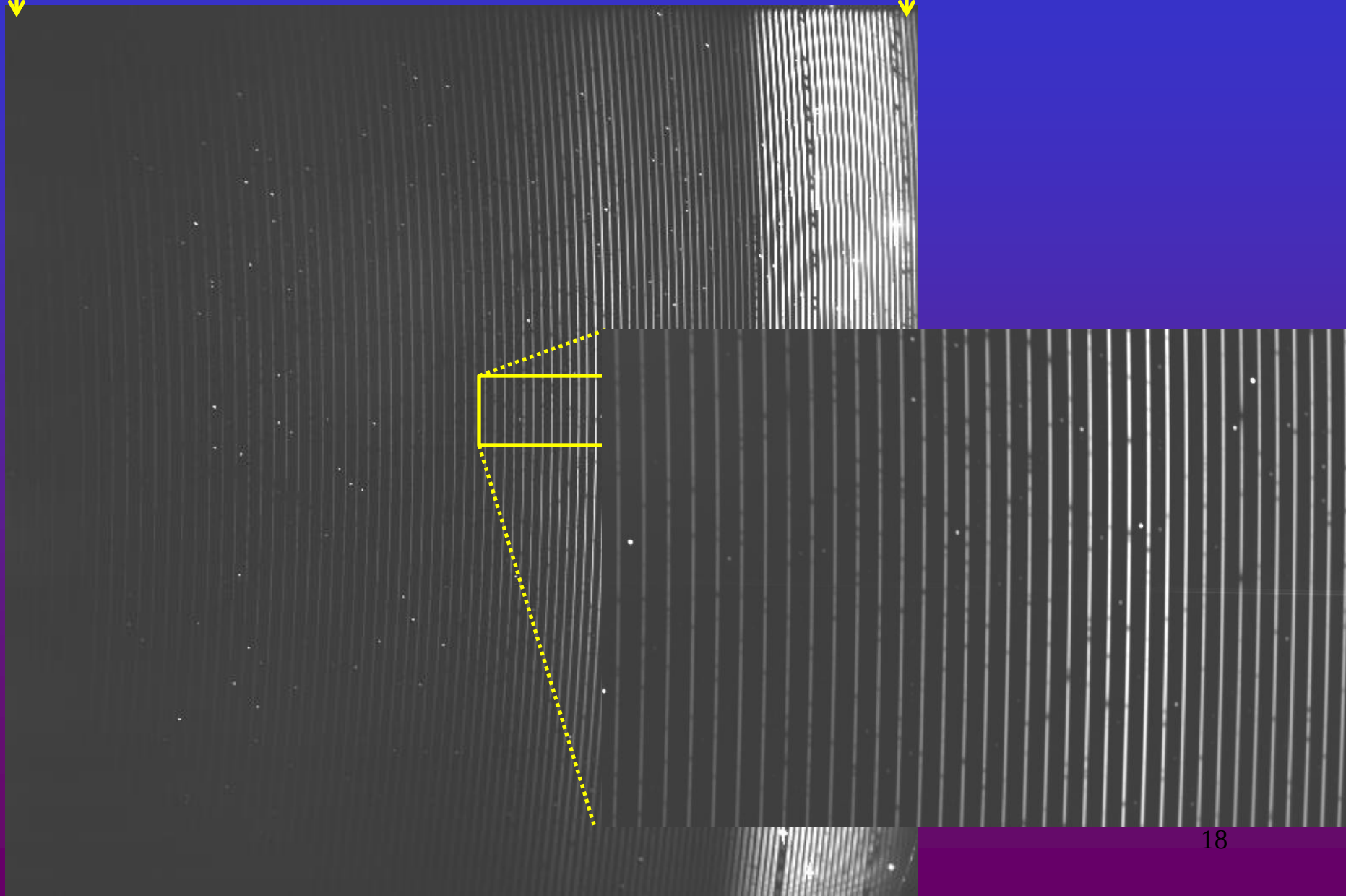
- R≈100,000 & 50,000 at 3800-9000Å
- an R4 echelle with 1-4 fiber image slicer to reach R=100K
- ~8% total detection efficiency
- Vacuum operation (0.01 torr over 1 month and high precision temperature control (~2 mK over one month)
- ~0.4 m/s photon limiting precision in 15 min for a V=8 solar type star
- Total construction cost within $1M

Major remaining tasks: Vacuum system refining, System optimization & Acceptance test

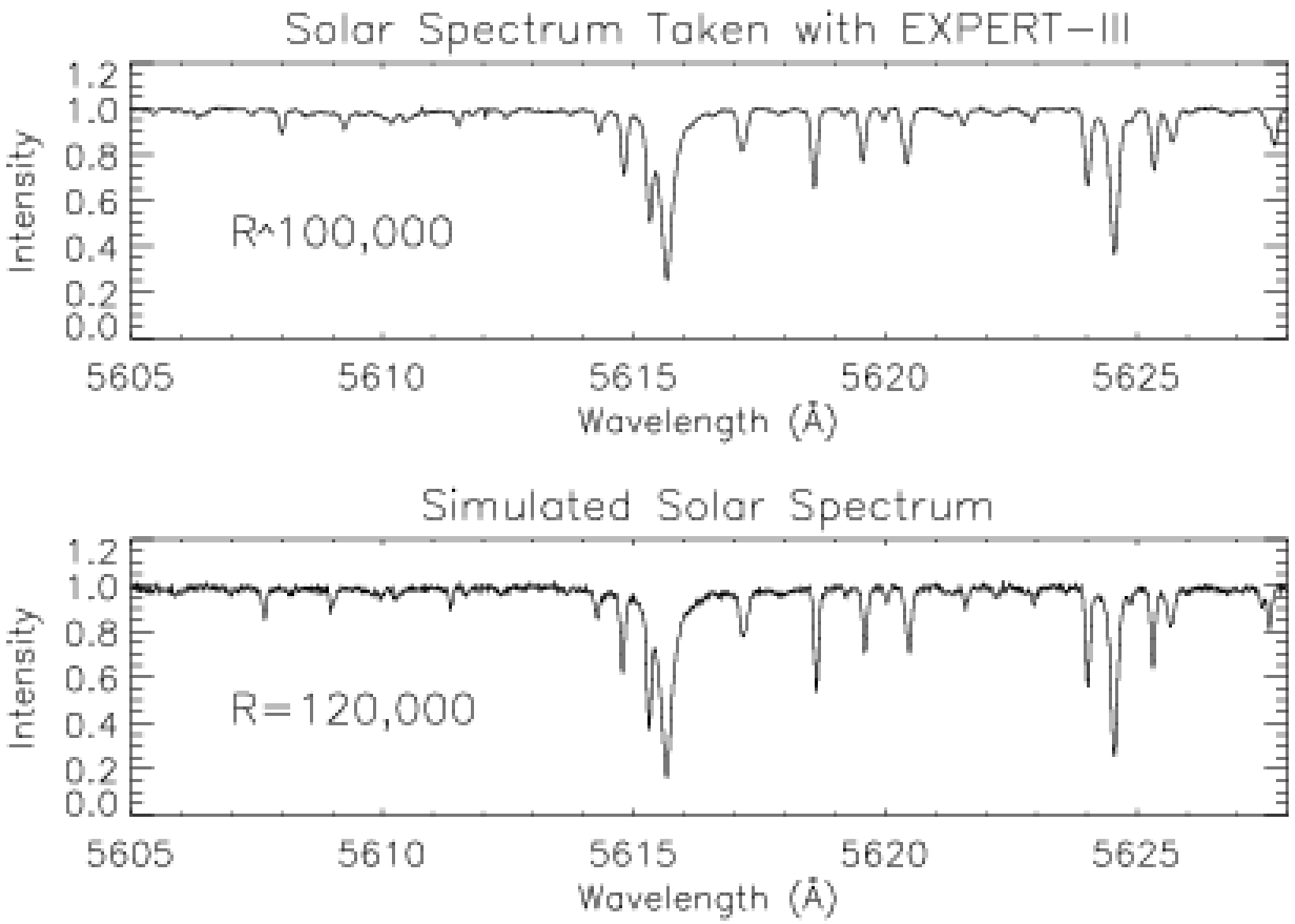
Lab First light R=100K Sky Spectrum Taken with EXPERT-III



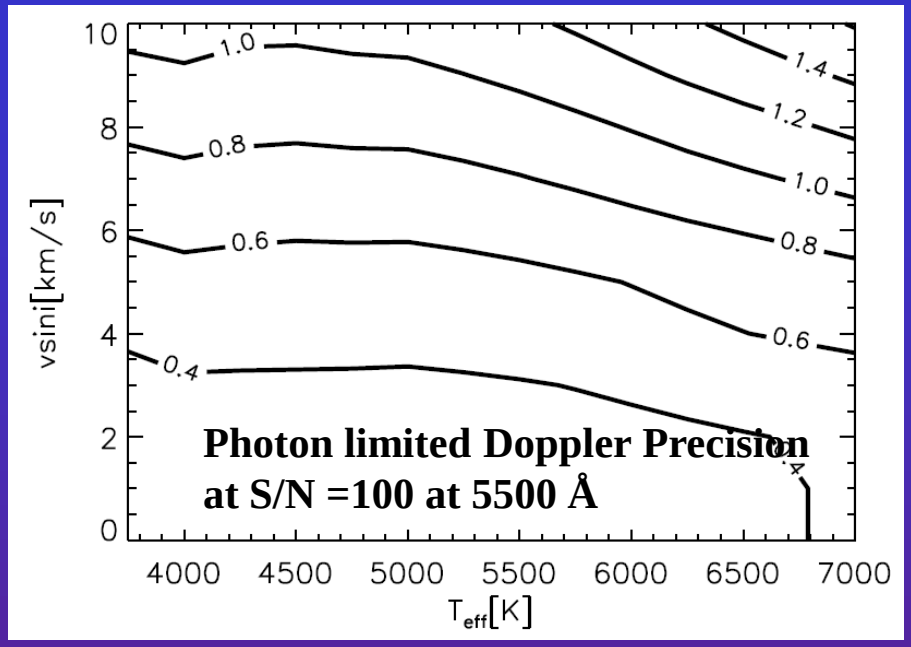
Lab First Light R=50K Sky Spectrum

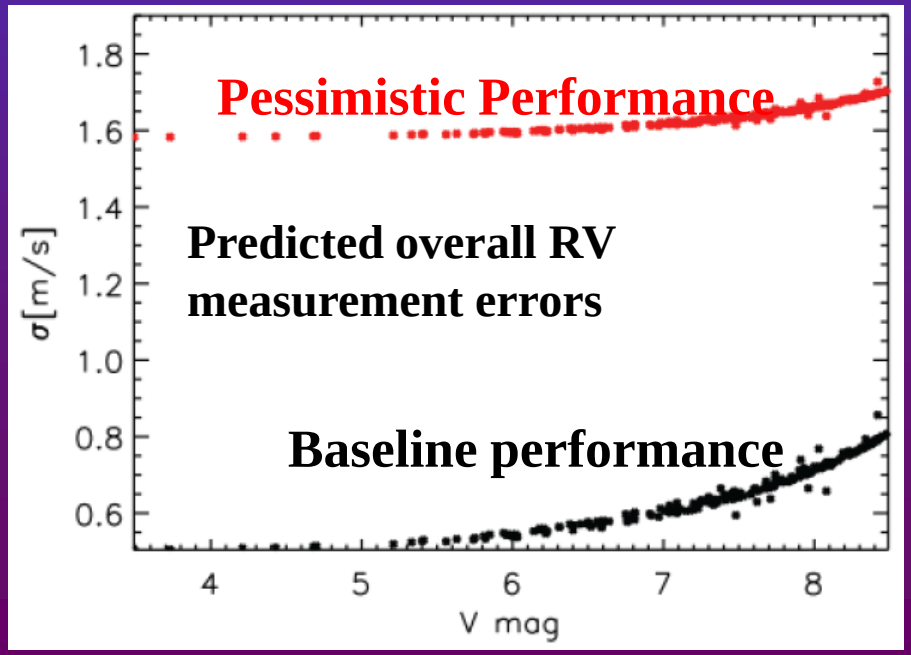


Reduced R=100K Solar Spectrum with EXPERT-III

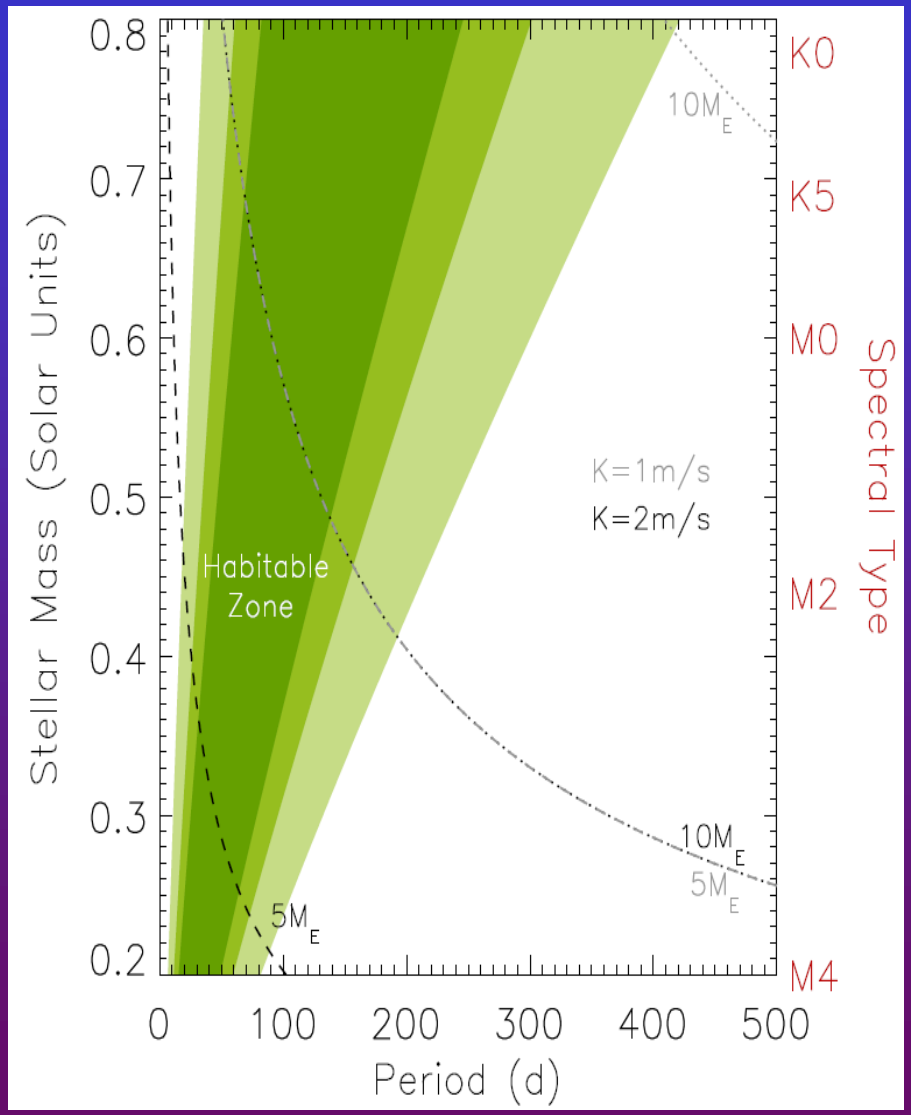


EXPERT-III Doppler and Survey Sensitivity

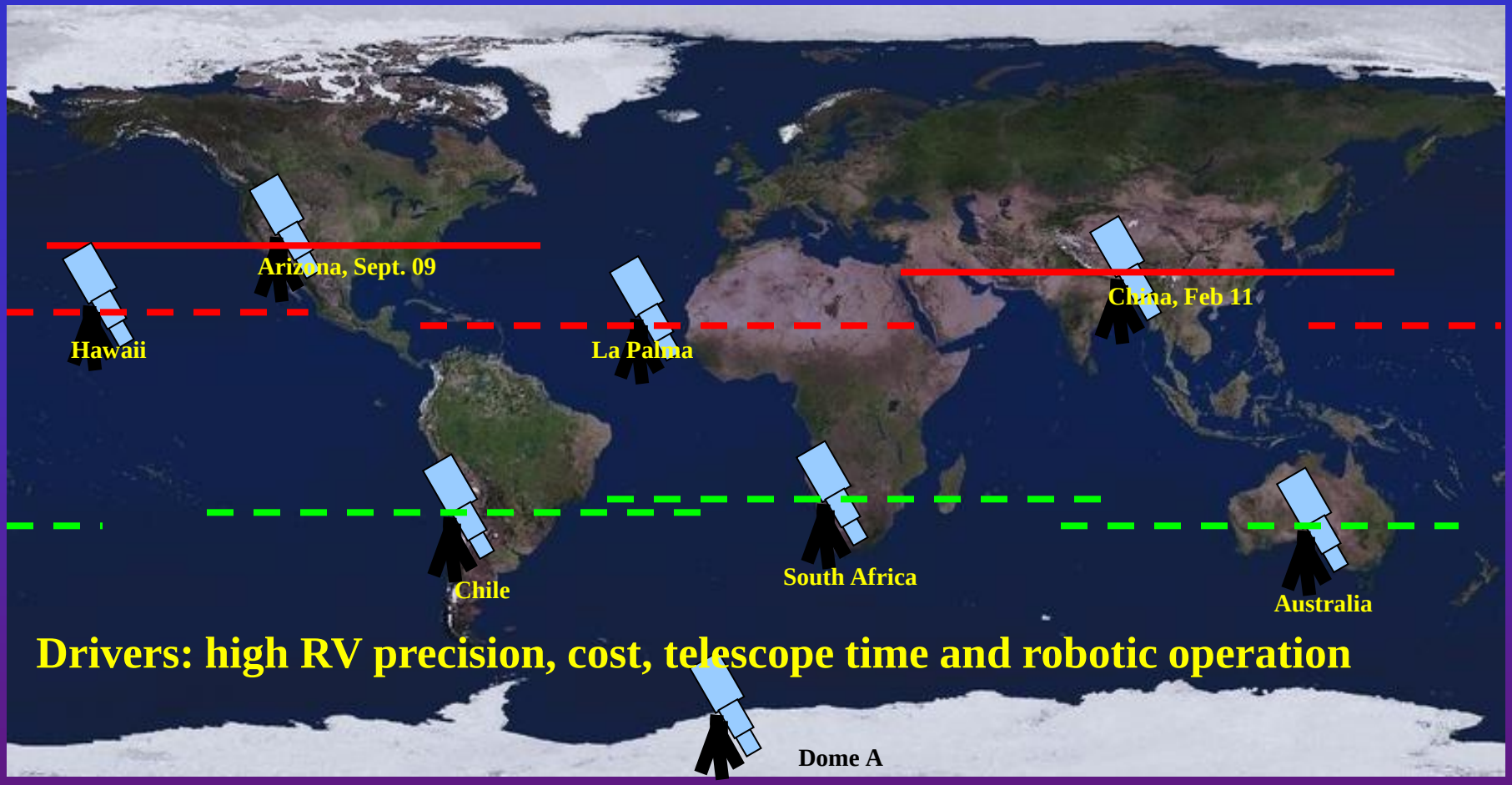




Survey Sensitivity for low mass habitable planets



Future Perspective: Global Exoplanet Tracker (ET) Network



Main Science Objectives:

- **Search >200 FGK dwarfs with V<8 for low mass planets, including habitable rocky planets with a few Earth masses**
- **Follow up MARVELS and *Kepler* planet candidates**

Summary

- Three generation high precision RV instrument and technologies have been developed at UF
  - ❑ Dispersed fixed-delay interferometry (DFDI) with R~5-20K has multiplicity advantage : ~9 times speed gain over high resolution echelle spectrometer to obtain multi-object moderate high precision RV measurements for a fixed detector size
  - ❑ High resolution echelle spectrograph has ~2 times precision advantage over the DFDI instrument for a fixed wavelength coverage
- The UF 3rd generation high resolution IR and optical spectrographs are being tested and will be commissioned late this spring:
  - ❑FIRST silicon immersion grating spectrometer in vacuum and with temperature control will be used for a survey of ~200 nearby M dwarfs for habitable super-Earths in 2013-2017
  - ❑EXPERT-III high resolution optical spectrograph in vacuum and with temperature control will be used for habitable super-Earth searches around ~200 early M and K dwarfs, SDSS-III MARVELS and Kepler candidate follow-ups
- Future global network high precision RV instruments require compact, low cost, robust and robotic operation: the DFDI instrument is an attractive option

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