NEID: the New NASA-NSF Exoplanet Observational Research (NN-EXPLORE) Precision Radial Velocity Spectrograph on WIYN

Chair: John L. Callas (JPL), NN-EXPLORE Manager

ExEP Splinter Session at the 233rd AAS, January 7, 2019, Seattle, WA

Jet Propulsion Laboratory
California Institute of Technology

NEID Splinter Agenda

2:00 - The NN-EXPLORE program (John Callas/JPL)

2:05 - NEID instrument update (Suvrath Mahadevan/PSU)

2:25 - NEID science capabilities (Jason Wright/PSU)

2:40 - NEID queue and operations (Jayadev Rajagopal/NOAO)

2:50 - NEID archive and community data (Rachel Akeson/NExScI)

3:00 - NEID proposal calls, utilization, policies (John Callas/JPL)

3:15 - Discussion

3:30 - End

NN-EXPLORE Program

2010 Decadal, "NASA and NSF should support an aggressive program of ground-based precise radial velocity surveys of nearby stars to identify potential candidates."

NN-EXPLORE is a joint NASA-NSF program for exoplanet observational research.

- **NASA** is funding the development of the NEID radial velocity (RV) spectrograph, telescope port adapter, telescope facilities modification, guaranteed-time observations (GTO) and a guest observer (GO) program.
- **NSF** contributes the NOAO partner share on the WIYN 3.5-meter telescope on Kitt Peak (40%).
- **ExEP**(JPL) provides overall project management.
- **Penn State** is building the NEID instrument and pipeline software and will conduct the GTO.
- **NOAO** is building the port adapter and performing the facility modifications, and conducts the GO selections and will operate the telescope and instrument(s).
- **NExScI** will operate the community RV data pipeline and archival database, and implements the GO awards.

NEID: An Update

Suvrath Mahadevan
The Pennsylvania State University

The NEID Team

PennState

Suvrath Mahadevan (PI)
Fred Hearty (PM)
Jason Wright (PS)
Andy Monson (SE)
Larry Ramsey (PA)
Eric Levi (ME)
Scott Blakeslee (ME)
Colin Nitroy (ME)
Tyler Anderson (EE)
Joe Ninan
Gudmundur Stefansson
Emily Lubar
Shubham Kanodia
Eric Ford
Fabienne Bastien
Thomas Beatty
Rebekah Dawson
Sree Prasumarthi

NASA · NSF

The University of Arizona

Chad Bender (IS)
Kyle Kaplan

Macquarie University

Christian Schwab (OS)

UC Irvine

Paul Robertson

Wisconsin – University of Wisconsin–Madison

Marsha Wolf
Jeff Percival
Michael Smith
Kurt Jaehnig

NExScI – NASA Exoplanet Science Institute

Rachel Akeson
BJ Fulton
Russ Laher

Penn – University of Pennsylvania

Cullen Blake (IS)

Caltech

Arpita Roy

JPL

John Callas
Phil Willems
Rich Capps

NOAO

Lori Allen
Jayadev Rajagopal
Rob Christensen
Emily Hunting
Bob Marshall
Erik Timmerman

Goddard Space Flight Center

Michael McElwain (IS)
Qian Gong
Sarah Logsdon
Ravi Kopparapu

NIST

Scott Diddams

Carleton

Ryan Terrien

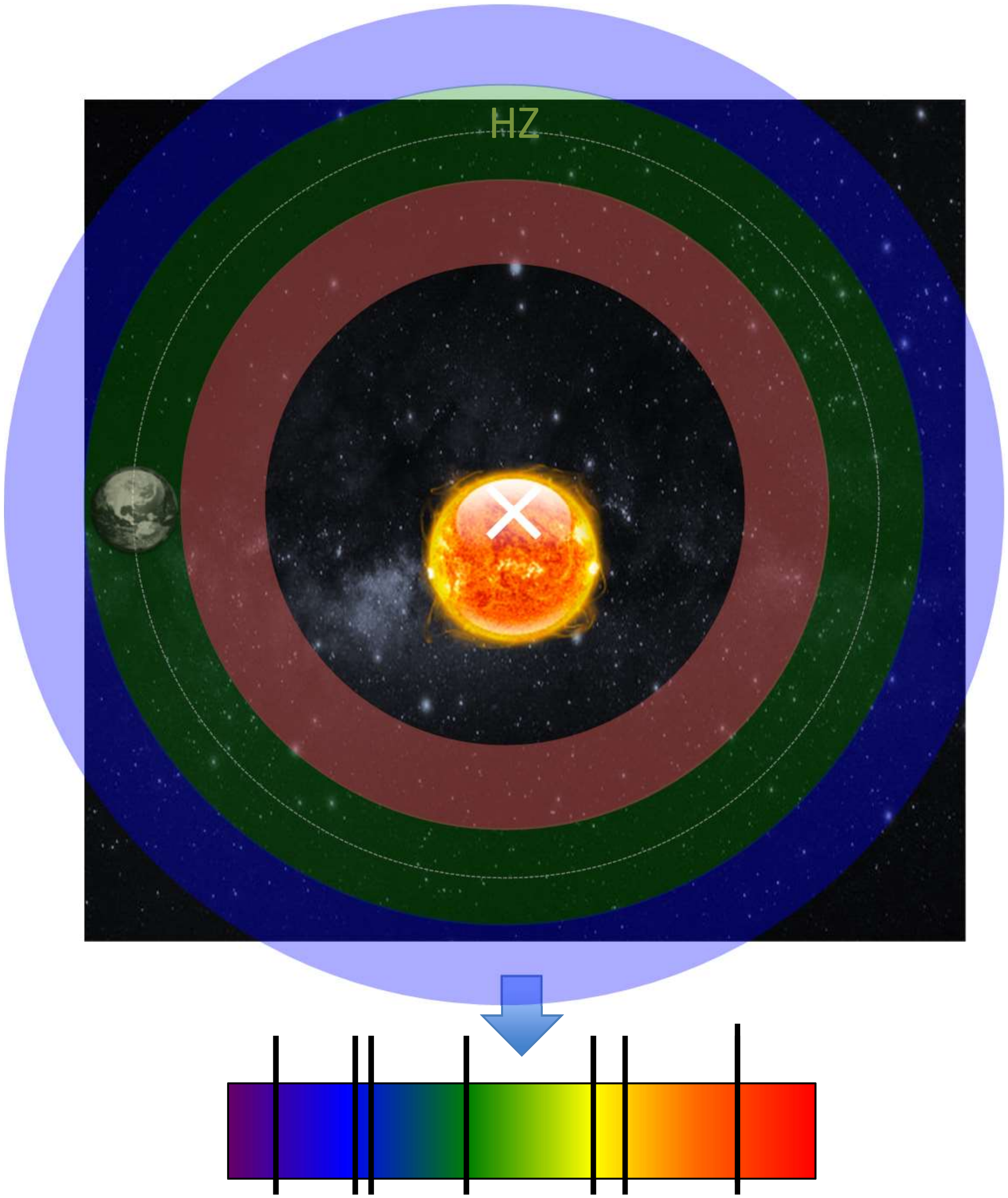
भौतिक अनुसंधान प्रयोगशाला – Physical Research Laboratory

Abhijit Chakraborty

Massachusetts Institute of Technology

Sam Halverson

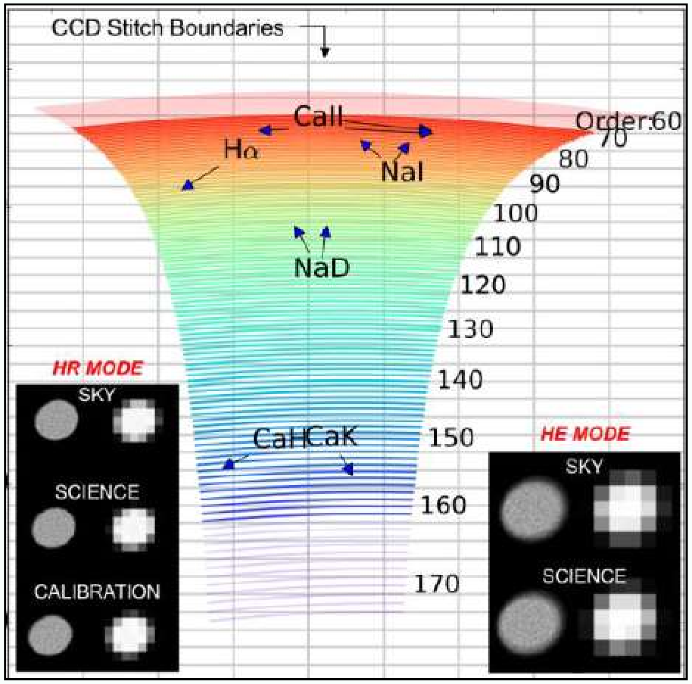
The word *neid* means discover/visualize in the language of the Tohono O'odham, on whose lands we, as a community, are privileged to be doing astronomical observations.



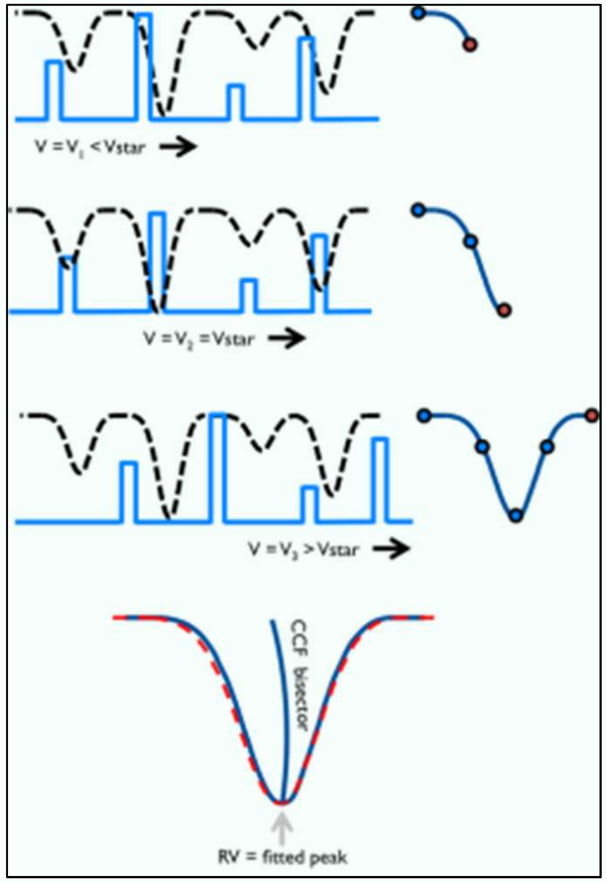
The Earth Introduces a Doppler Radial Velocity shift on the Sun of only 8.9

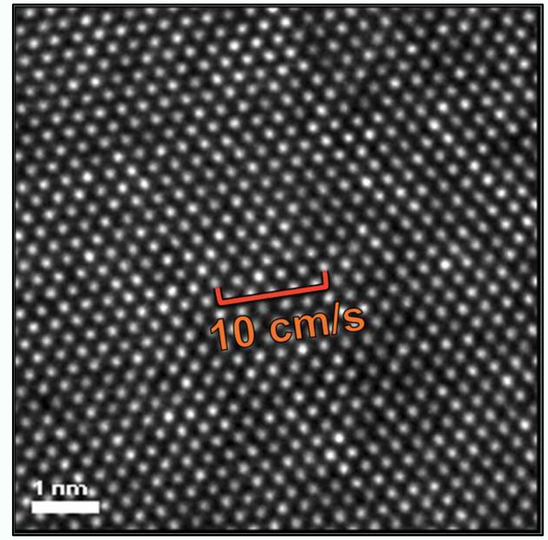
Extreme Precision Doppler Measurements are HARD!

10cm/s corresponds to 1/6,000th of a 10 micron pixel



NEID 9k x 9k CCD with **10 micron pixels**. Echelle spectral orders from 60 to 170 are shown.





Silicon Lattice: High Resolution TEM Image of **individual Si atoms**. Ki Bun Kin, SPIE 2012

Overview & Capabilities

Telescope: 3.5m WIYN Telescope @ KPNO

Waveband & Resolution: 380 – 930 nm, complete coverage, R ~90K

Expected Precision: 30 cm/s (instrumental) initial w/ path to 10 cm/s

Expected On Sky: mid-late 2019

Available to the Public!

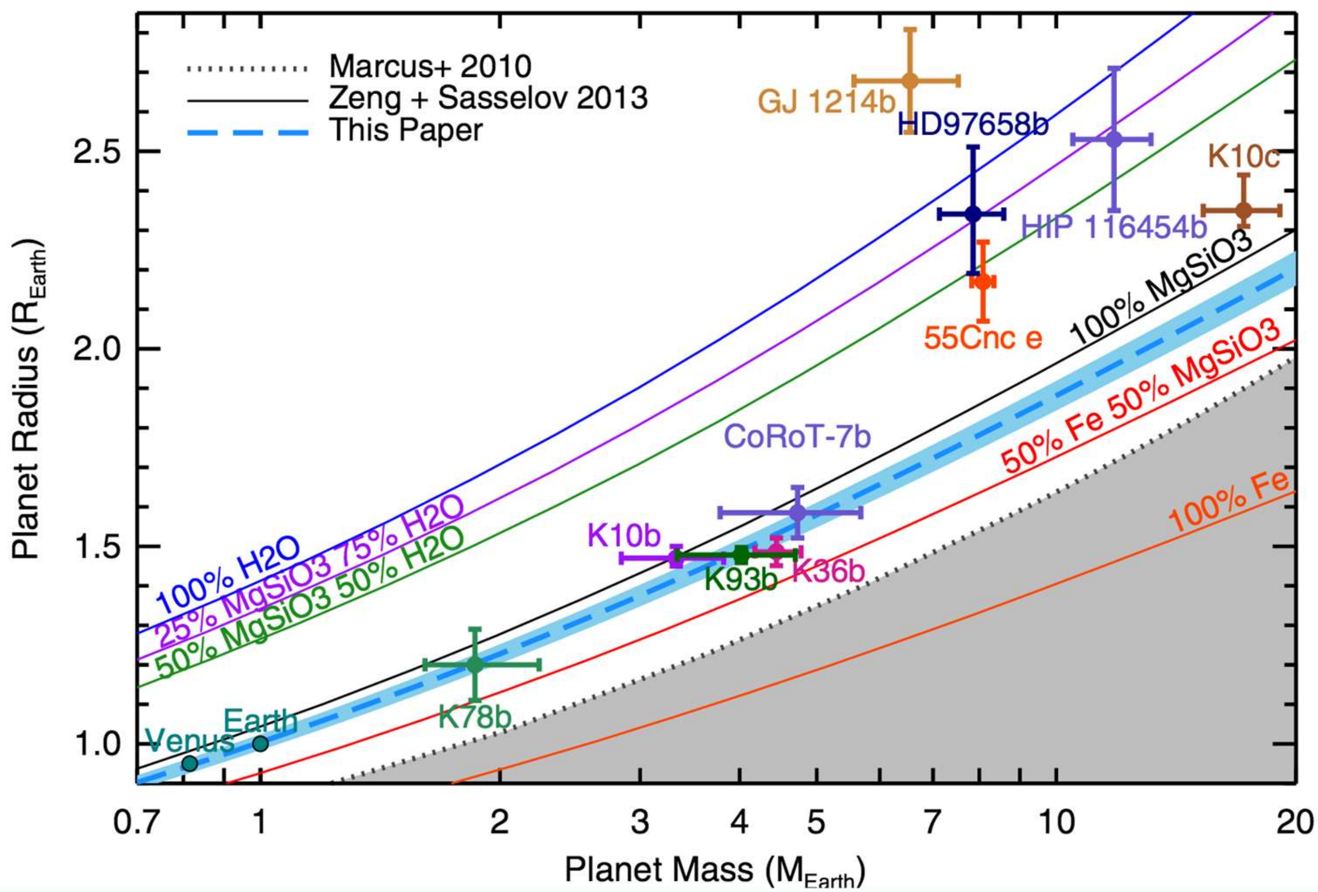
Two Observing Modes:

- HR (R~90,000)
  - Highest precision RVs on bright targets (V<12, e.g. TESS)
  - Simultaneous Cal

- HE (R~60,000) (subject to de-scope)
  - Faint targets (V<16)
  - Poor weather
  - e.g. K2

Science: The Need for sub-m/s RV

- Very precise planet masses needed to constrain composition/ formation models.
- TESS will provide transiting planets around bright stars, but EPRV resources are always tight.
- Other questions: multiplicity, obliquity, dynamics, etc. Answerable with RVs.

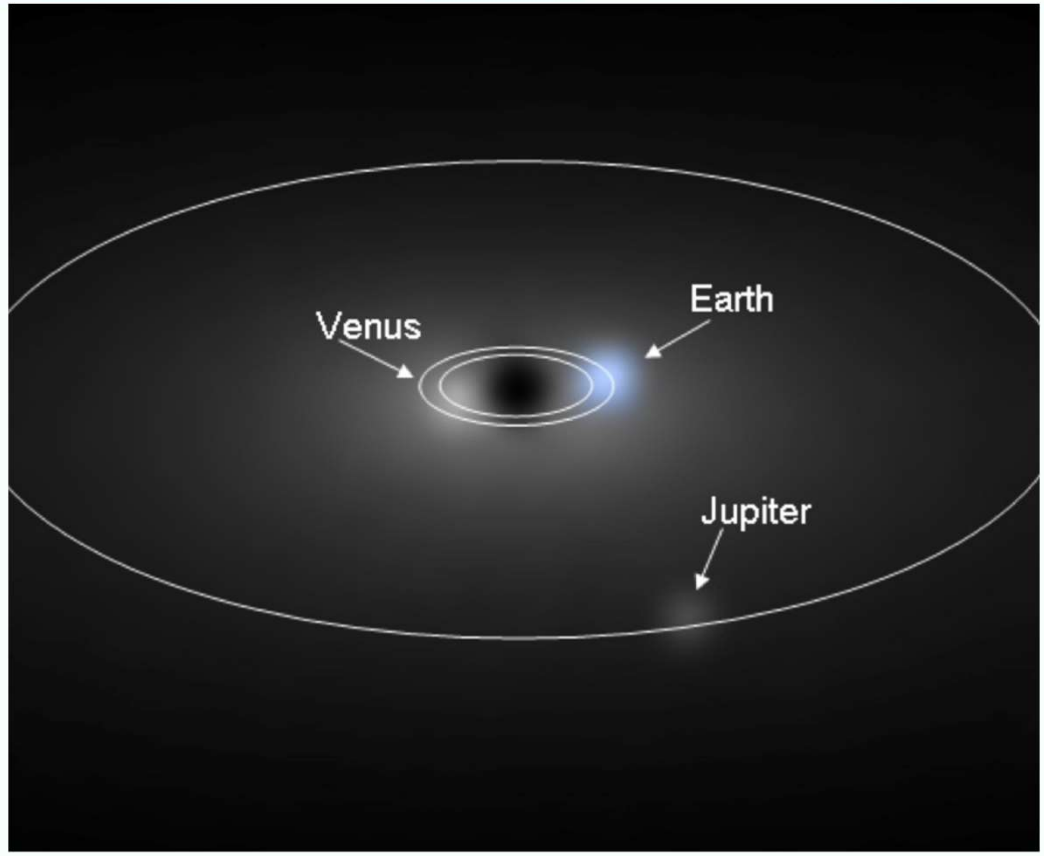


Dressing et al. 2015

Extreme precision RV follow-up is a *requirement* for the success of TESS!

Science: The Need for sub-m/s RV

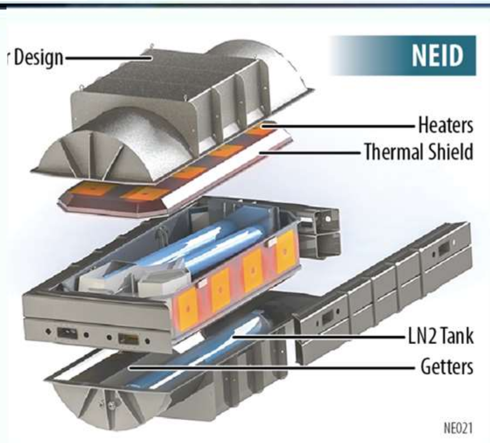
- Earth-mass planets in the HZ have 10-30 cm/s RV amplitudes, requiring observations on 10s to 100s of nights at <50 cm/s precision.
- **These planets represent the top targets for future imaging missions!**
- Knowing whether we have the ability to discover such planets could drive the choice of future flagship missions.

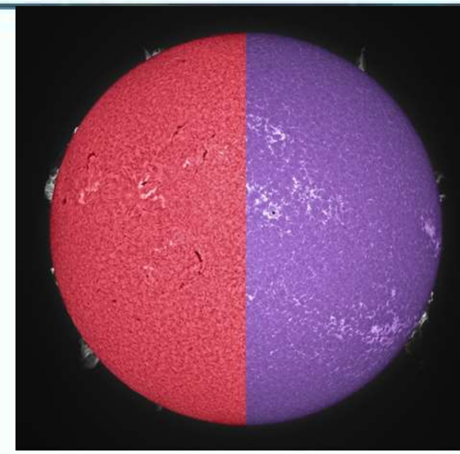


Simulated image of the solar system as viewed by a future space-based LUVOIR imager.

AAS Poster Today (Monday): 140.28 Jason Wright

So What Do We Need?





High Instrumental RV precision

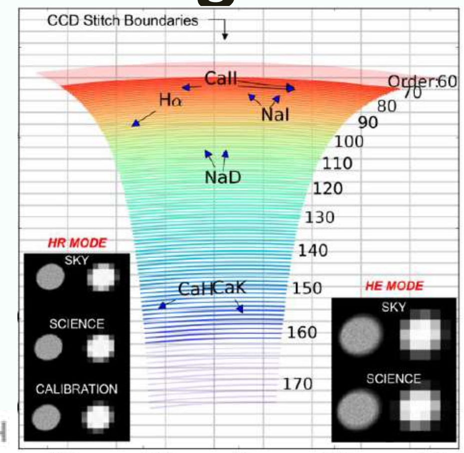
Understanding Stellar Activity

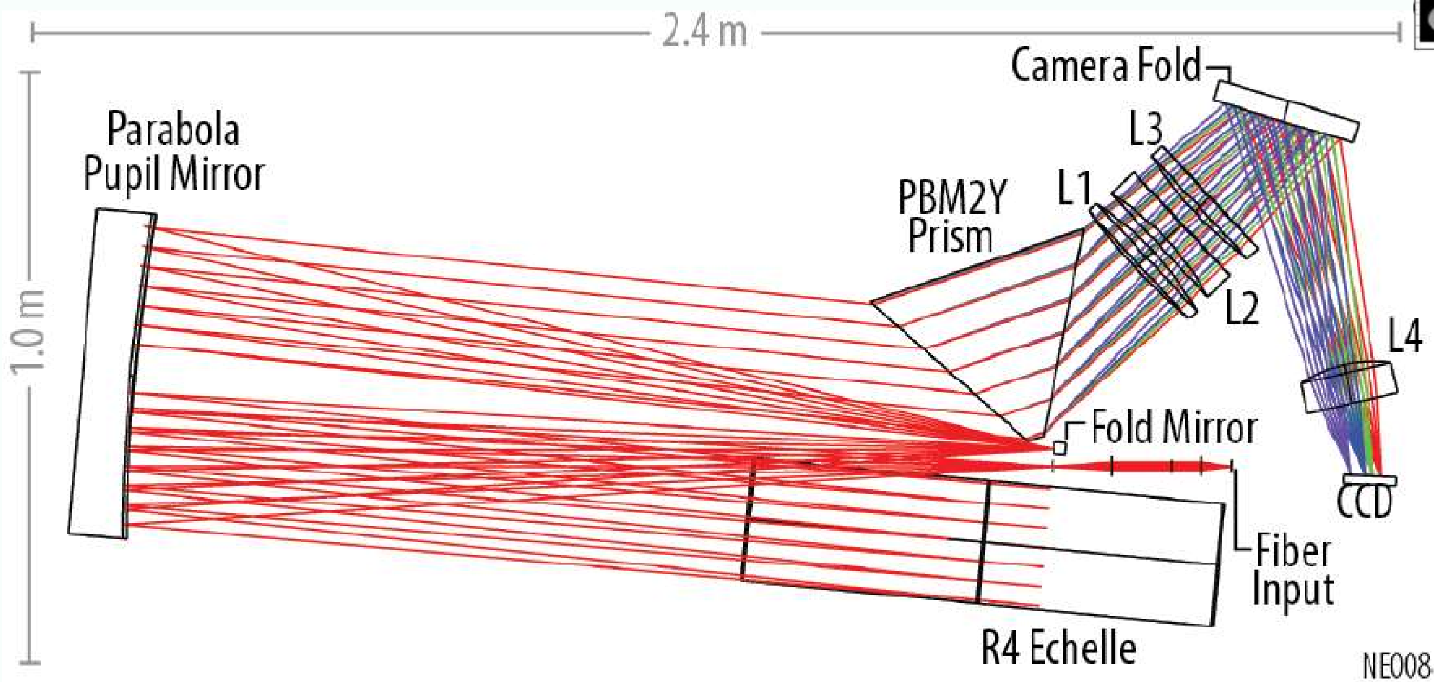
Large Amount of Observing Time

A Simple, High-Performance Optical Design

Implementation: Single arm white pupil Echelle

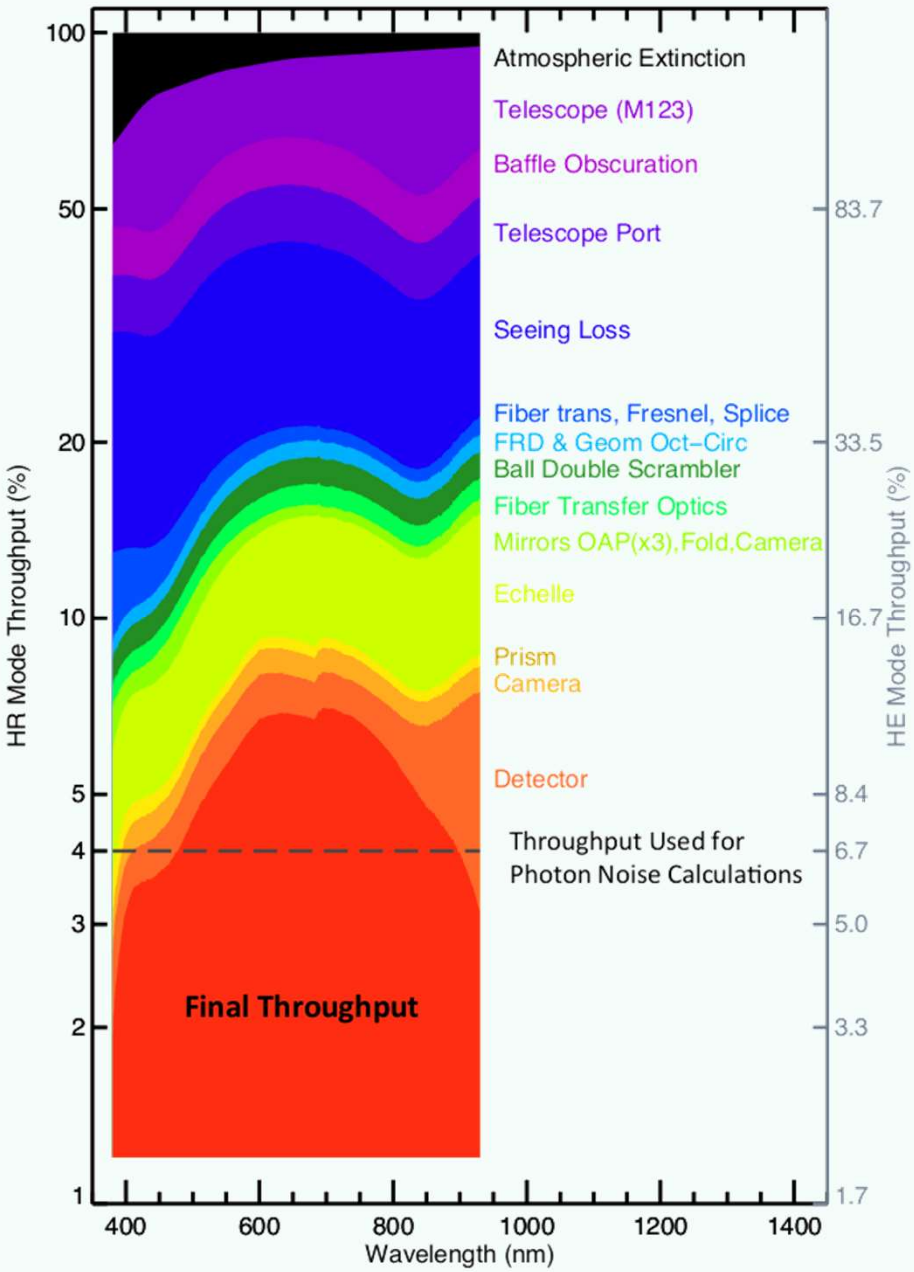
- Single mirror white pupil relay, 200mm beam
- 2x1 mosaic R4 Richardson Echelle
- Single prism cross disperser: Ohara PBM2Y
- Refractive camera, 4 elements, folded





AAS Talk
(Thursday): 408.03
Christian Schwab
10:20am, Rm#608

Throughput Flowdown

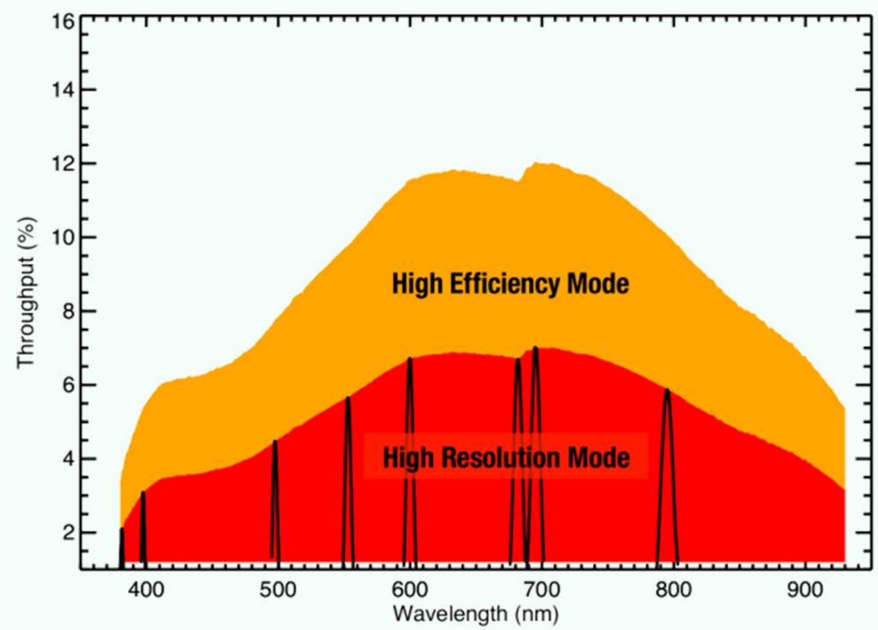


Total System throughput:

- **HR: >4% for most of bandpass**
- **HE: >8% for most of bandpass**

Spectrometer throughput ~40%

(These are theoretical expectation- which need to be vaildated with as built numbers and measurements)

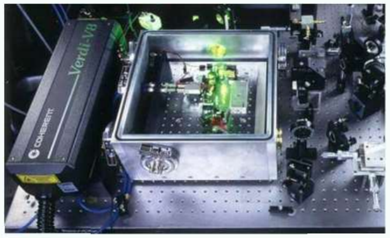


RV

Achieving high instrumental RV precision is a multifaceted problem

Fibers

Calibrators



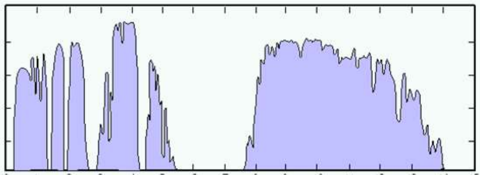
Optics

Stability

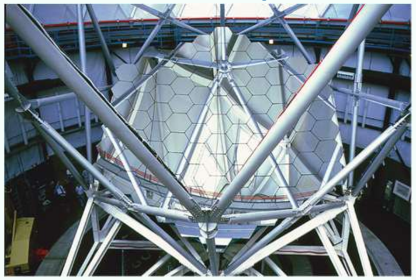
Barycentric correction

RV

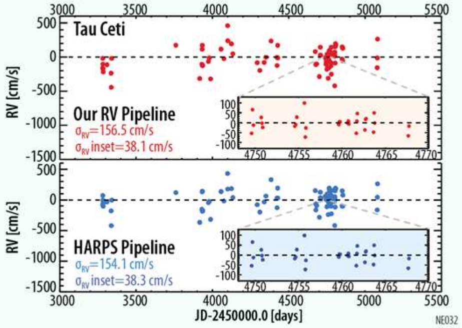
Atmosphere



Telescope



Pipeline



NEID is a precision RV System

Advanced Environmental Control System

Menlo LFC, Etalon, Lamps

White Pupil Spectrometer

e2v Detector

Telescope Port System

Unsliced high scrambling fiber feed

Data Reduction Pipeline

Operations

Radial Velocity Error Budget

CBE = Current Best Estimate
MEV = Max Expected Value (Baseline)
MPV = Max Possible Value = MEV(1+ 50% margin)

Contingency = sqrt(MEV²-CBE²)
Reserve = 1 - MPV² / Threshold² = 22%

	CBE	Cont.	MEV	MPV
INSTRUMENT TOTAL [cm/s]	16.0	24.4	29.2	44.1

% Contribution to Final MEV		CBE	Cont.	MEV	MPV
0.8%	**Instrument [cm/s] (calibratable)**	6.7	15.6	17.0	41.3
0.5%	**Thermo-mechanical**	5.3	13.0	14.0	38.7
0.4%	Room Thermal Stability [K]	0.1	0.3	0.3	0.5
	Vacuum Thermal Stability [mK]	0.6	1.7	1.8	2.7
0.2%	Thermal Stability (XD)[cm/s]	3.0	8.5	9.0	13.5
0.1%	Thermal Stability (Echelle)[cm/s]	1.8	5.1	5.4	8.1
0.0%	Thermal Stability (Bench)[cm/s]	0.6	1.7	1.8	2.7
0.1%	Opitcal Elements(Decenter)[cm/s]	2.3	6.4	6.8	34.0
0.0%	Optical Elements(Tilt)[cm/s]	0.4	1.1	1.2	1.8
0.0%	Vibrational Stability[cm/s]	1.0	2.8	3.0	4.5
0.0%	Pressure stability[cm/s]	0.1	0.3	0.3	0.5
0.0%	LN2 fill transient[cm/s]	0.1	1.0	1.0	1.5
0.1%	Zerodur phase change[cm/s]	3.0	4.0	5.0	7.5
0.2%	**Detector**	4.2	8.6	9.6	14.4
0.0%	Pixel inhomogeneities [cm/s]	0.1	1.0	1.0	1.5
0.0%	Electronics Noise [cm/s]	0.1	1.0	1.0	1.5
0.1%	Stitching error [cm/s]	2.0	5.7	6.0	9.0
0.0%	CCD thermal Expansion [cm/s]	1.0	1.7	2.0	3.0
0.1%	Readout Thermal Changes [cm/s]	2.5	4.3	5.0	7.5
0.1%	Charge Transfer Efficiency [cm/s]	2.5	4.3	5.0	7.5

% Contribution to Final MEV		CBE	Cont.	MEV	MPV
17.6%	**Telescope**	5.7	10.8	12.2	18.3
1.4%	Guiding* [RMS arcsec]	0.05	0.09	0.10	0.15
1.4%	Guiding* [cm/s]	0.9	3.39	3.5	5.3
5.7%	ADC* [Peak to Valley arcsec]	0.10	0.17	0.20	0.30
5.7%	ADC* [cm/s]	3.1	6.21	6.9	10.4
2.9%	Focus [cm/s]	2.5	4.33	5.0	7.5
7.5%	Windshake* [cm/s]	4.0	6.93	8.0	12.0
23.5%	**Atmospheric**	8.5	11.3	14.1	21.2
11.7%	Micro-Telluric Correction [cm/s]	8.0	6.0	10.0	15.0
11.7%	Sky Fiber Subtraction [cm/s]	3.0	9.5	10.0	15.0

% Contribution to Final MEV		CBE	Cont.	MEV	MPV
	fraction of instrument error propogated through:	15%			
	From Instrument [cm/s] (calibratable)	1.0	2.3	2.5	6.2
15.5%	**Calibration Source: LFC**	6.6	9.4	11.5	17.2
3.8%	**Calibration Accuracy**	4.3	3.7	5.7	8.5
1.9%	stability [cm/s]	2.8	2.9	4.0	6.0
1.9%	photon noise [cm/s]	3.2	2.4	4.0	6.0
11.7%	**Calibration Process**	5.0	8.7	10.0	15.0
11.7%	Algorithm and Software [cm/s]	5.0	8.7	10.0	15.0
42.7%	**Instrument (Un-calibratable)**	10.2	16.1	19.1	28.6
24.7%	**Fiber and Illumination**	8.2	12.0	14.5	21.8
0.7%	calibrator modal noise [cm/s]	1.0	2.3	2.5	3.8
0.7%	science modal noise [cm/s]	1.0	2.3	2.5	3.8
5.9%	calibrator fiber FRD (2-5%)[cm/s]	5.0	5.0	7.1	10.7
5.9%	science fiber FRD (2-5%)[cm/s]	5.0	5.0	7.1	10.7
2.9%	stray light [cm/s]	1.0	4.9	5.0	7.5
2.9%	Scattered light Cal to Sci [cm/s]	2.0	4.6	5.0	7.5
0.5%	Residual Fiber Polarization[cm/s]	1.0	1.7	2.0	3.0
	near-field scrambling* [GAIN]	20000	2x	10000	5000
2.9%	far-field scrambling*[cm/s]	2.0	4.6	5.0	7.5
0.0%	Fiber Input (Rotation)[cm/s]	2.2	3.7	4.3	6.5
0.4%	**Barycentric Correction**	0.7	1.6	1.7	2.6
0.1%	Algorithms [cm/s]	0.1	1.0	1.0	1.5
0.1%	Exposure midpoint time [cm/s]	0.7	0.7	1.0	1.5
0.1%	Coords and proper motion [cm/s]	0.1	1.0	1.0	1.5
5.9%	**Detector cal vs. sci fiber**	3.5	6.1	7.1	10.6
2.9%	Readout Thermal Changes [cm/s]	2.5	4.3	5.0	7.5
2.9%	Charge Transfer Efficiency [cm/s]	2.5	4.3	5.0	7.5
11.7%	**Reduction Pipeline**	5.0	8.7	10.0	15.0
11.7%	Software Algorithms [cm/s]	5.0	8.7	10.0	15.0
41.0%	**External Errors**	10.3	15.6	18.7	28.0

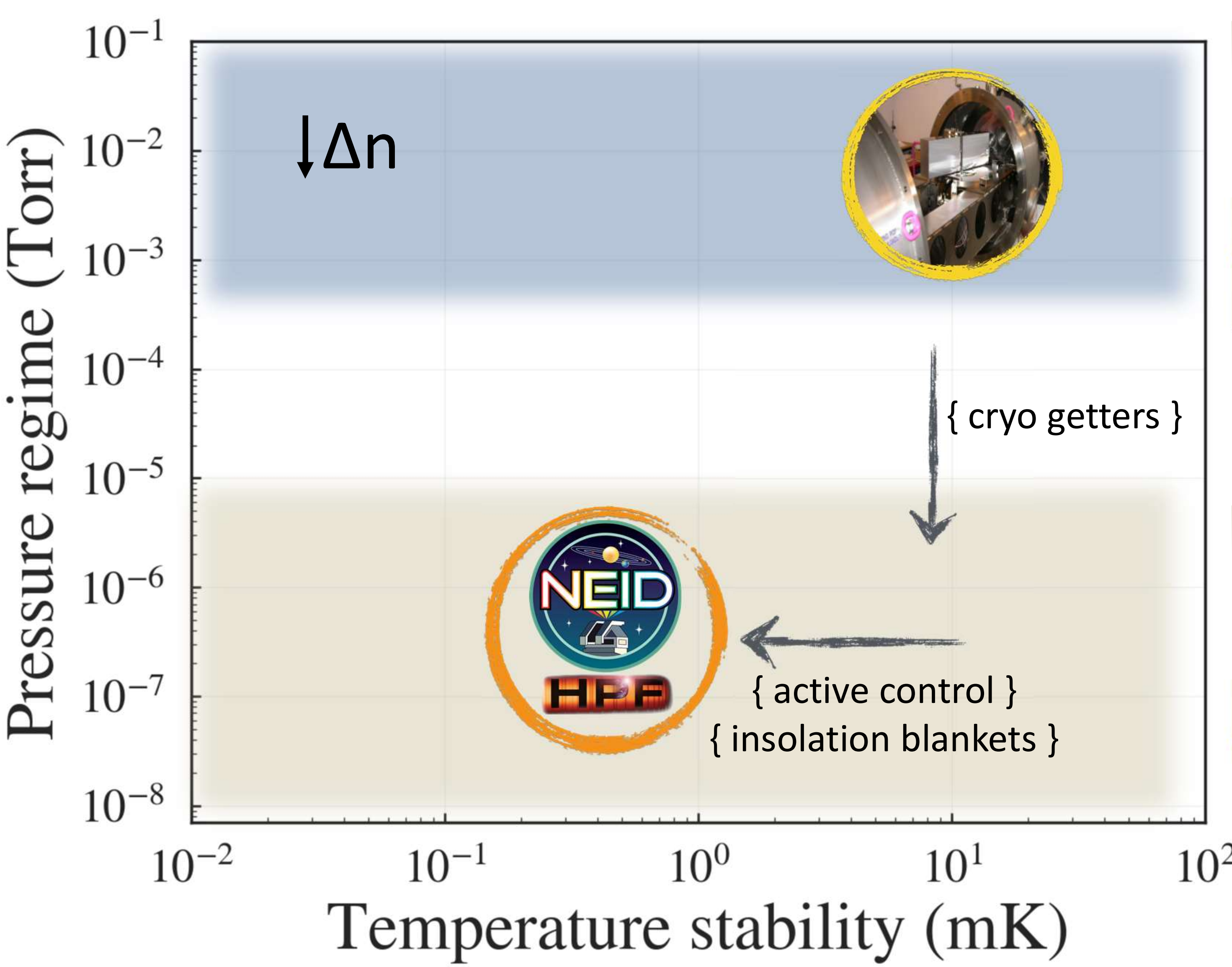
Our **Error Budget** is a compilation of sources of error, which add quadratically to inform the final performance baseline.

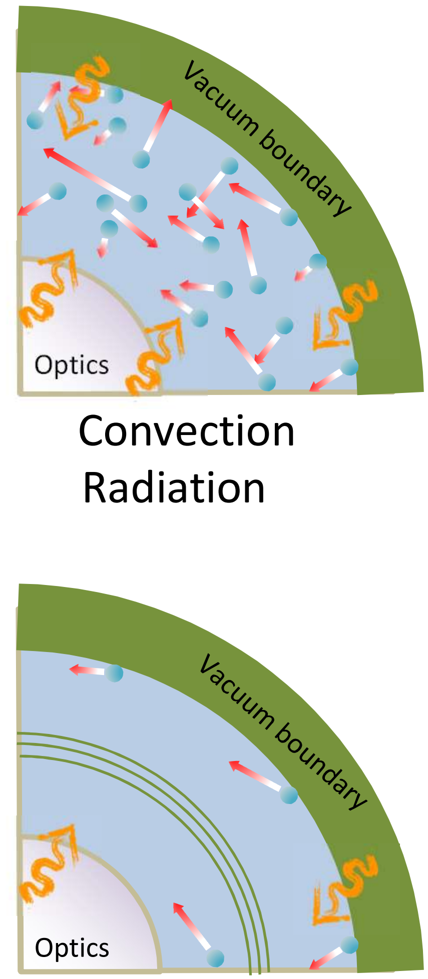
Total Instrument Error:
29 cm/s

Instrument:	43%
Atmosphere:	23%
Telescope:	18%
Calibration:	16%
Calibratable Inst:	1%

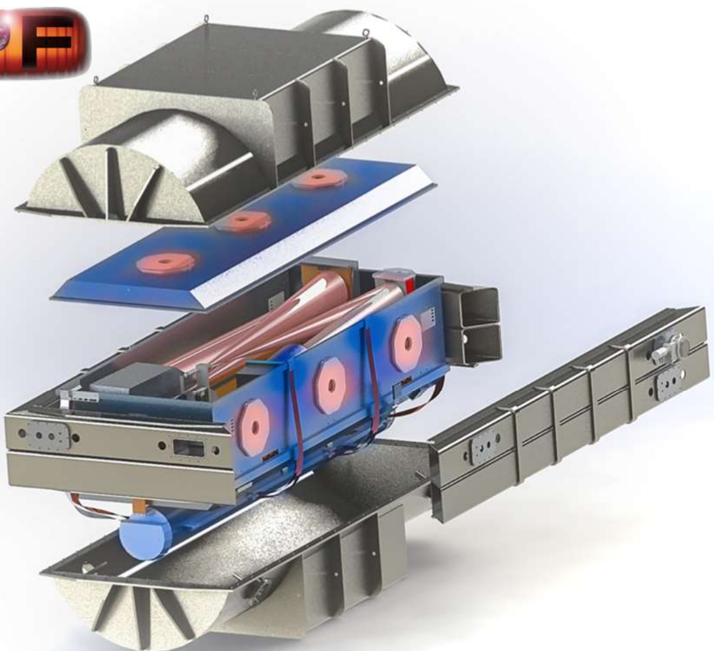
Halverson et al. 2016, SPIE, 9908.99086P

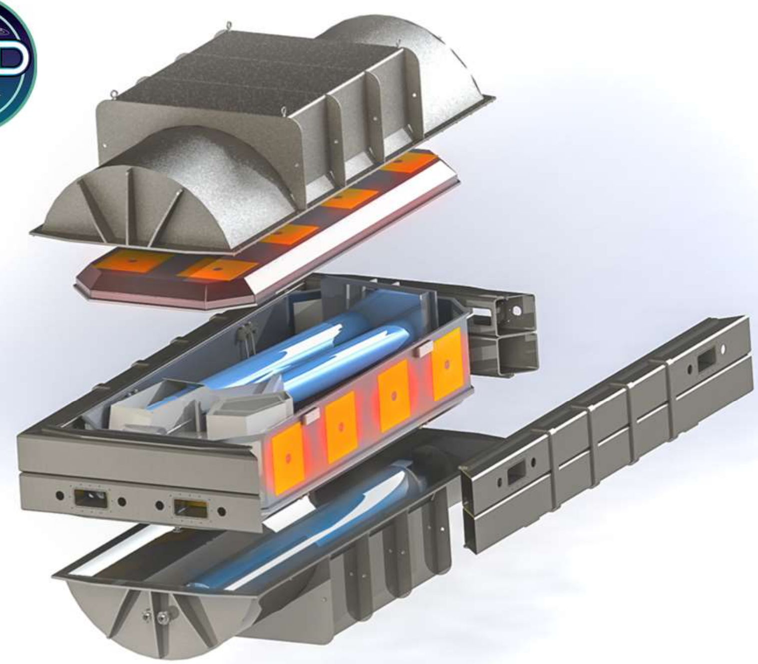
Pushing towards 10cm/s requires sub-milli-Kelvin instrument stability and high-quality vacuum chambers



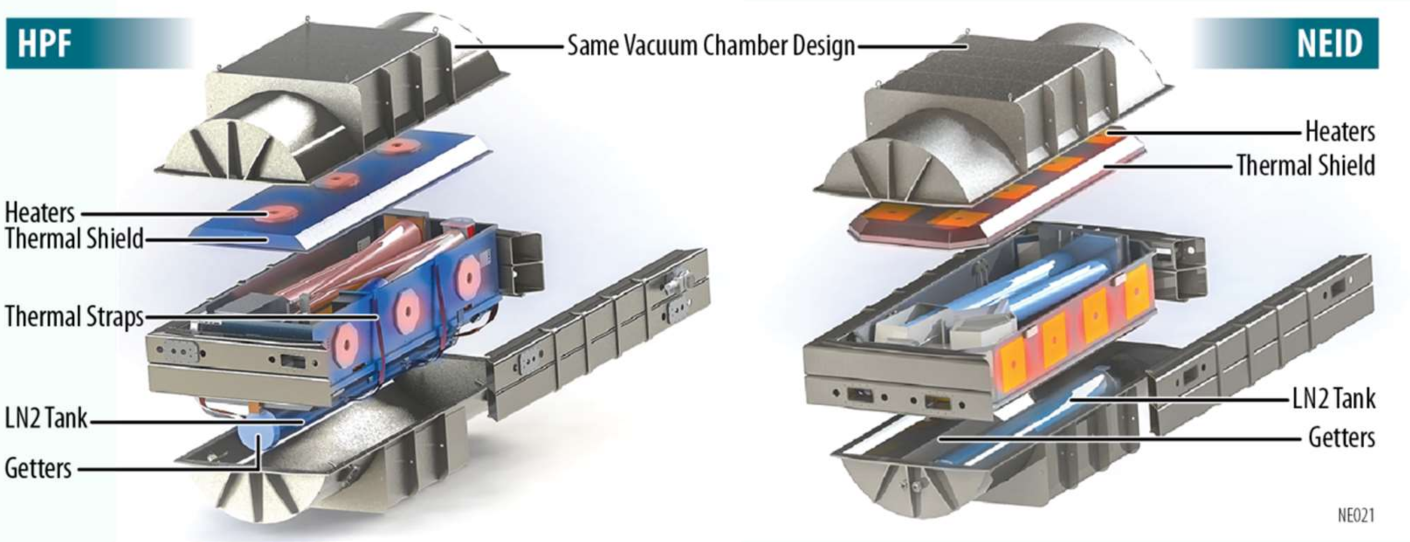


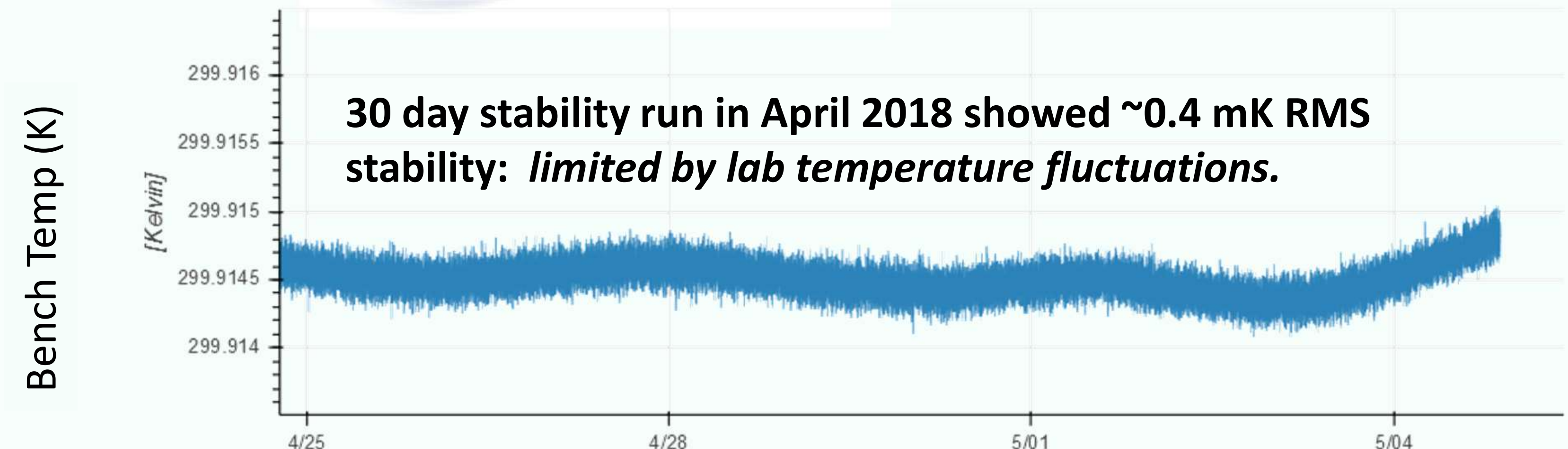
HPF and NEID: next generation fiber-fed ultra-stabilized spectrographs





State-of the art environmental control



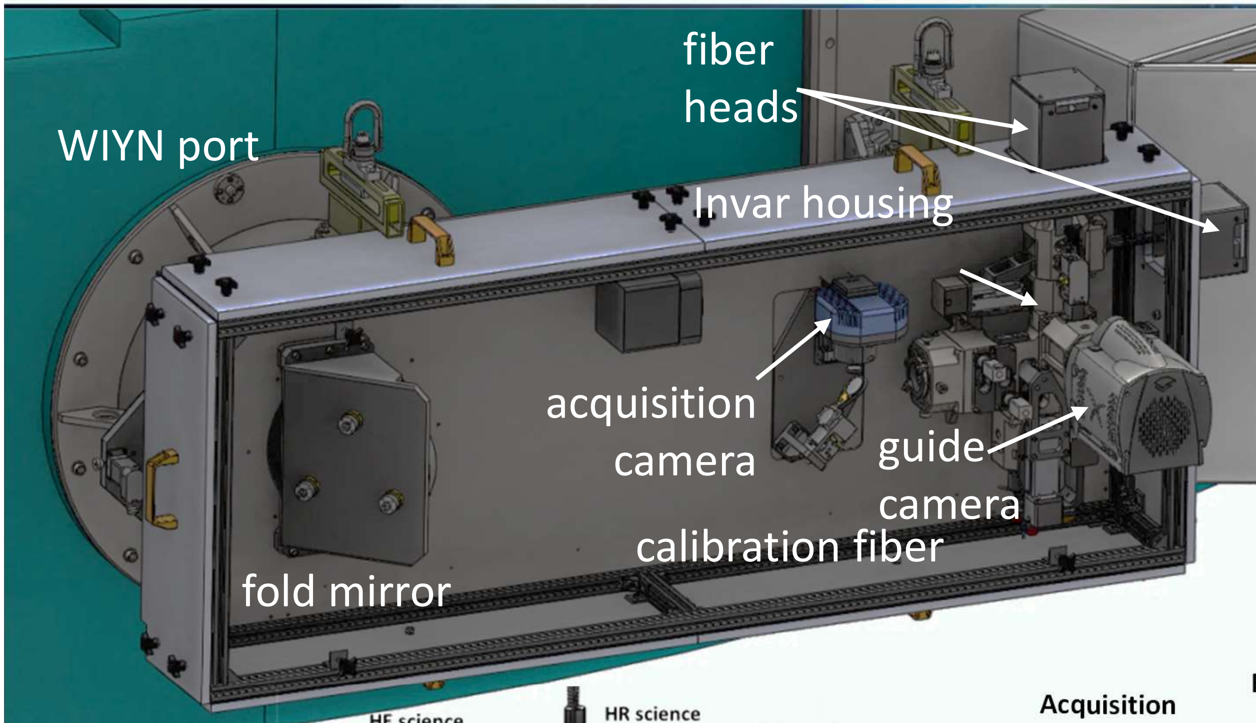


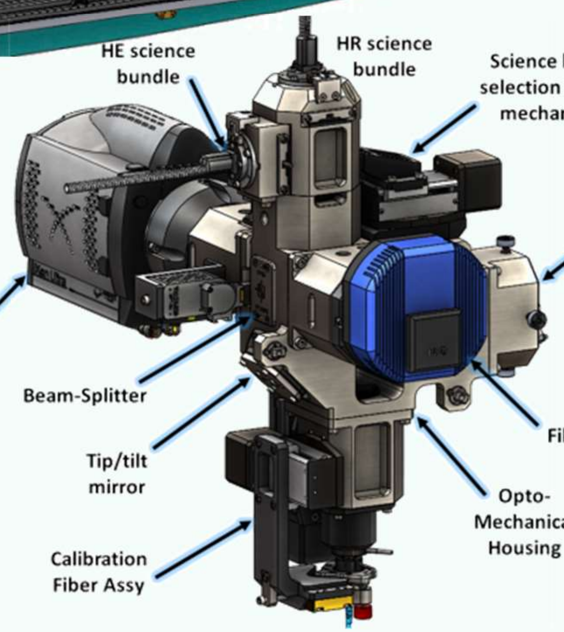
30 day stability run in April 2018 showed ~0.4 mK RMS stability: *limited by lab temperature fluctuations.*

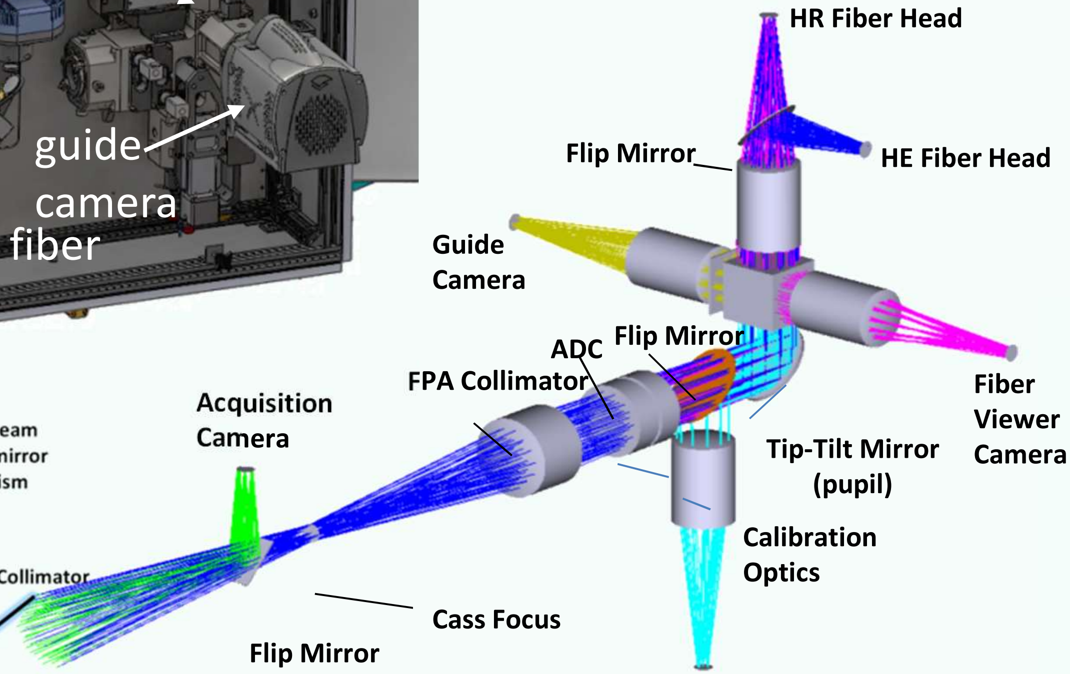
Robertson et al. 2019, in press

AAS Poster Today (Monday): 146.02 Emily Lubar, 140.27 Mark G./Cullen Blake

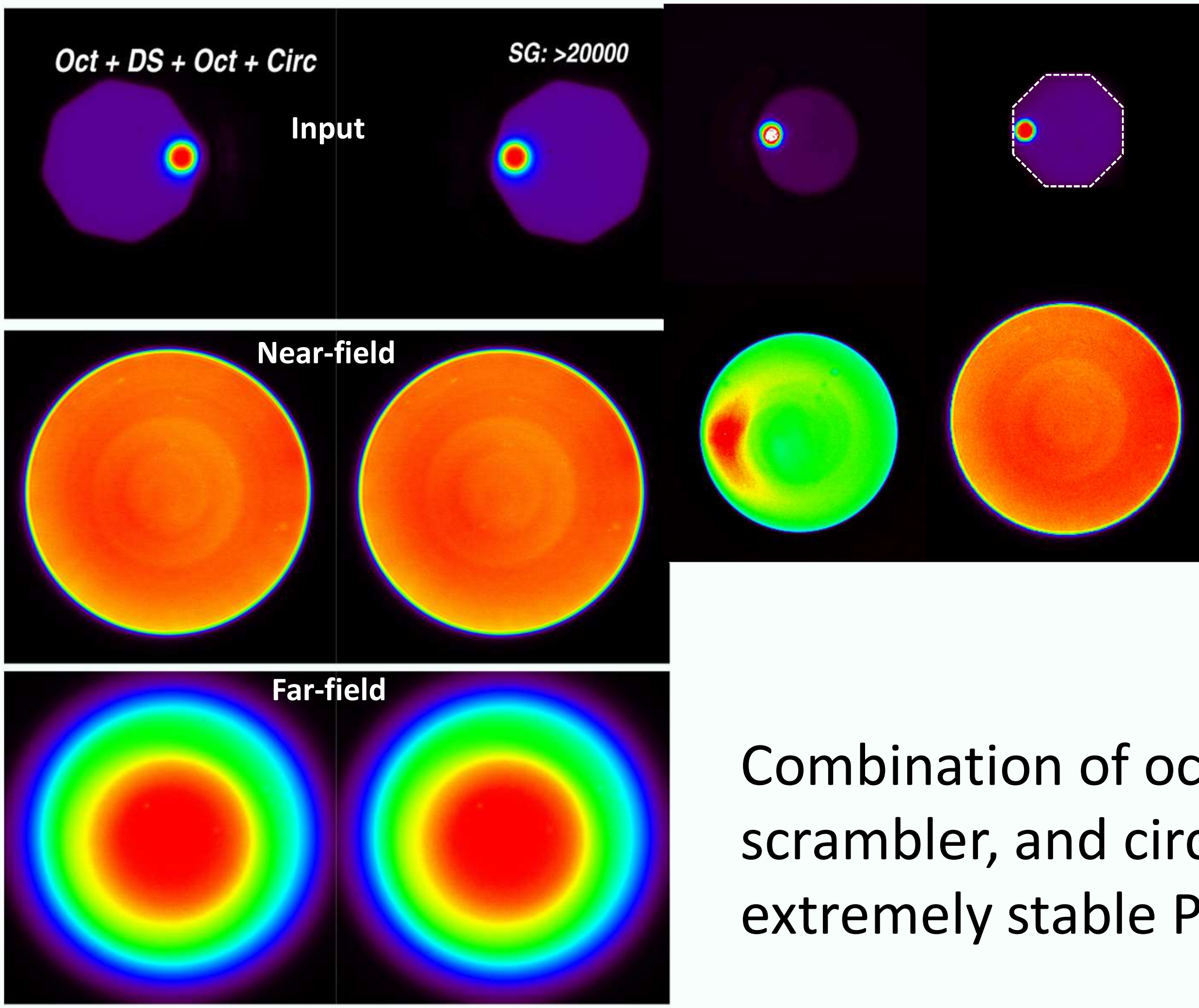
NEID Telescope Port

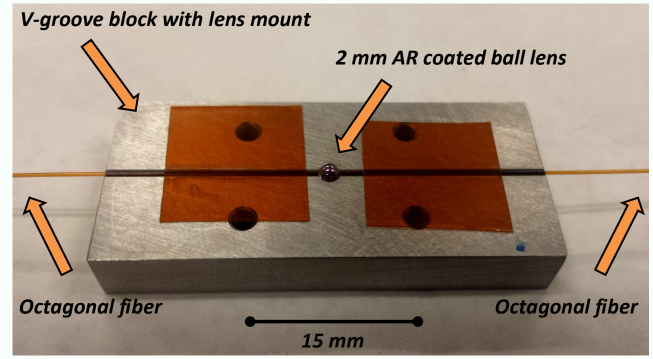






The NEID Precision RV System: Scrambling



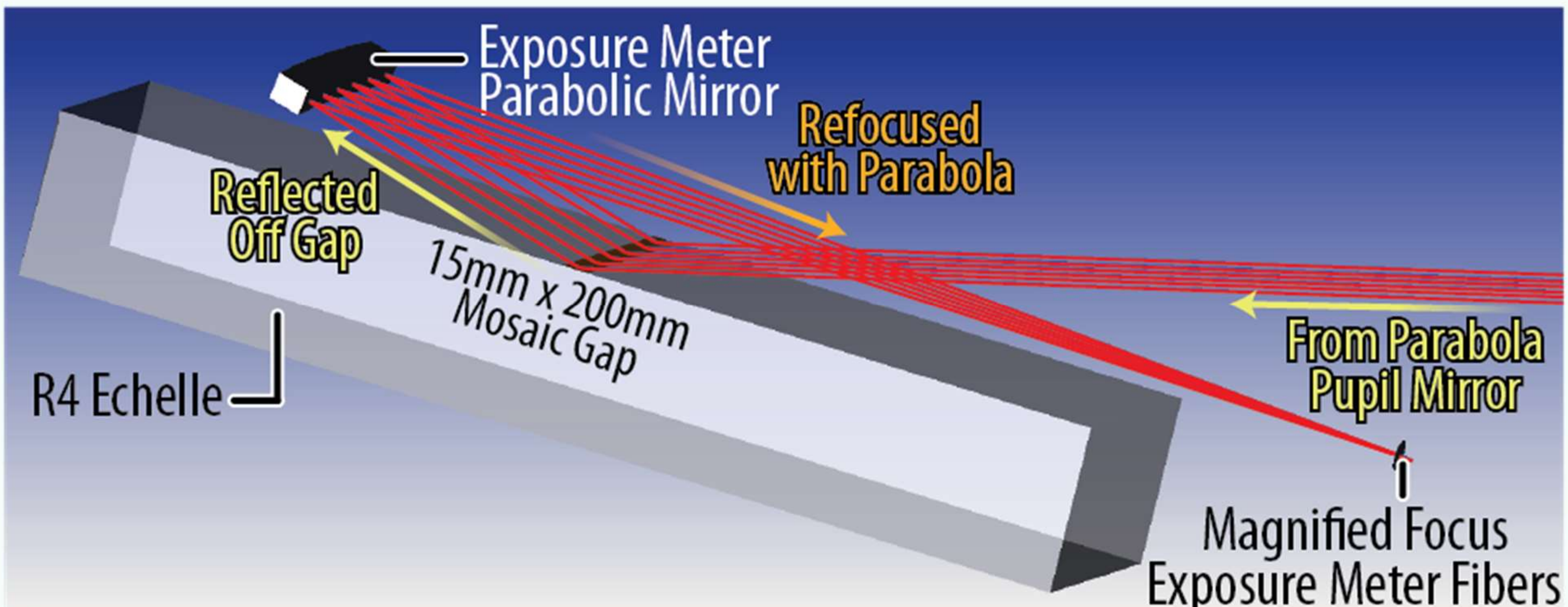


Combination of octagonal fibers, double scrambler, and circular fiber yields extremely stable PSF, spectrometer pupil

Halverson, Roy et al. 2015

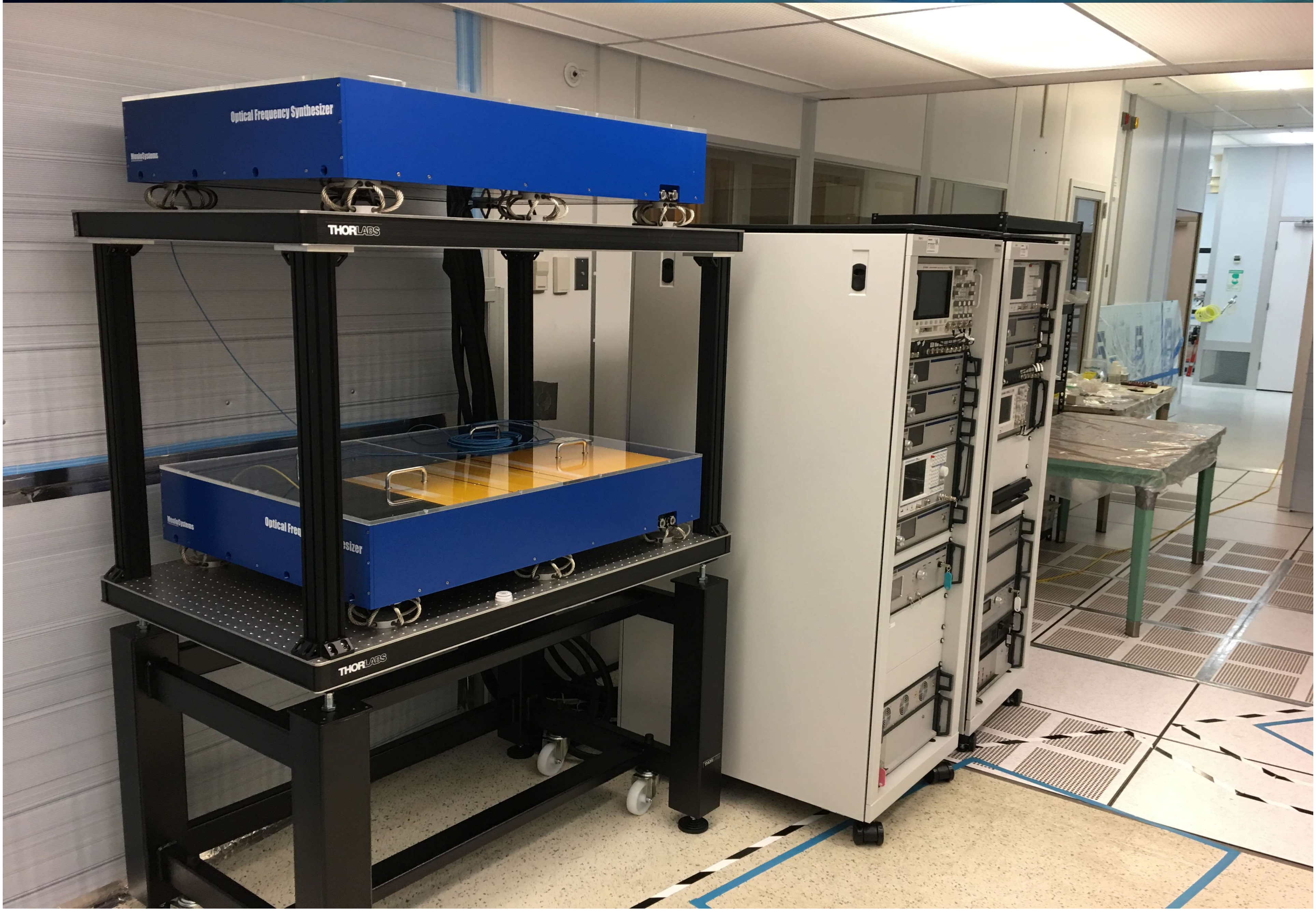
Chromatic Exposure Meter

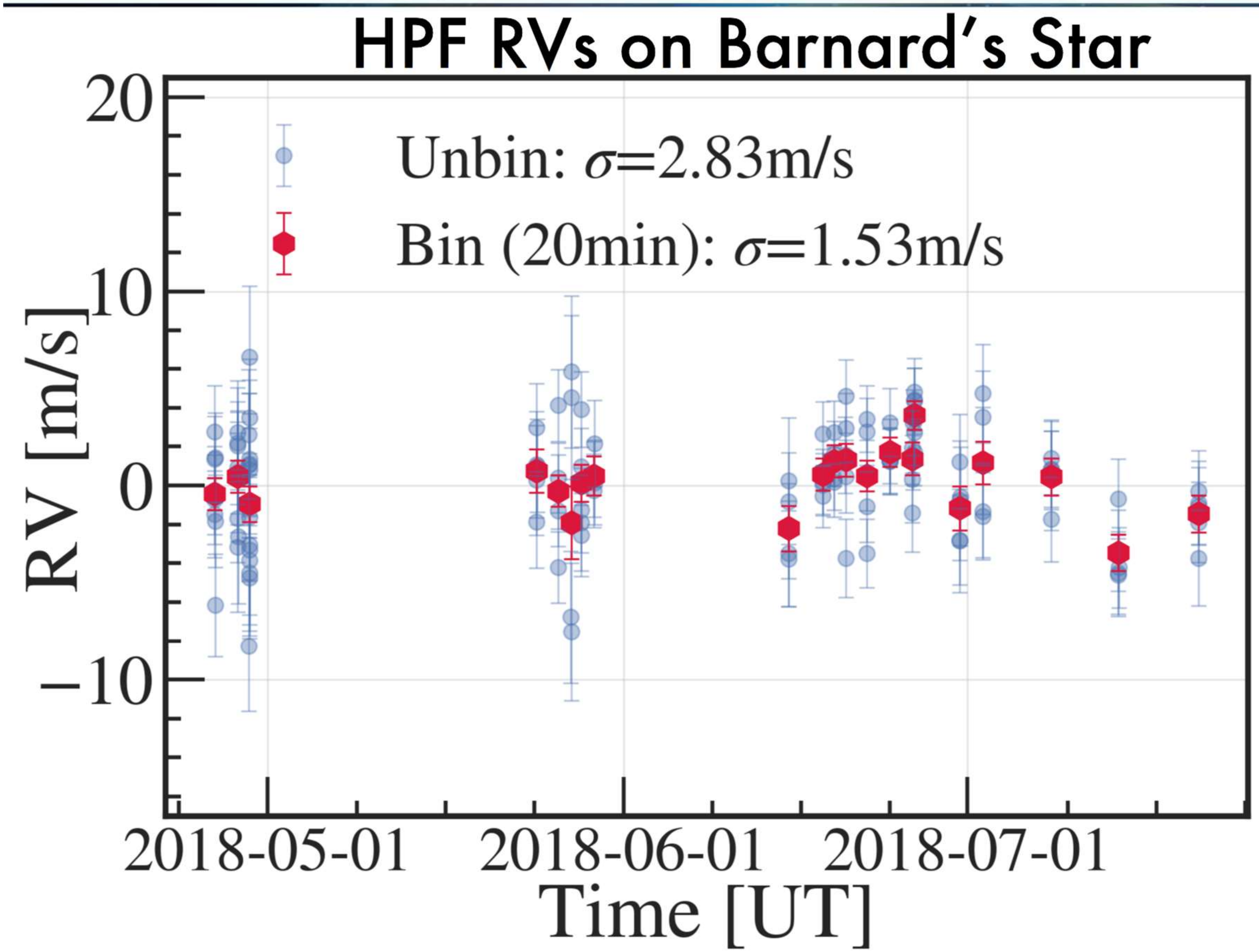
- Real-time feedback of conditions to observer
- Optimizes observing time to the science
- Low-resolution spectra
- Chromatic barycentric correction < 1 cm/s



NE030

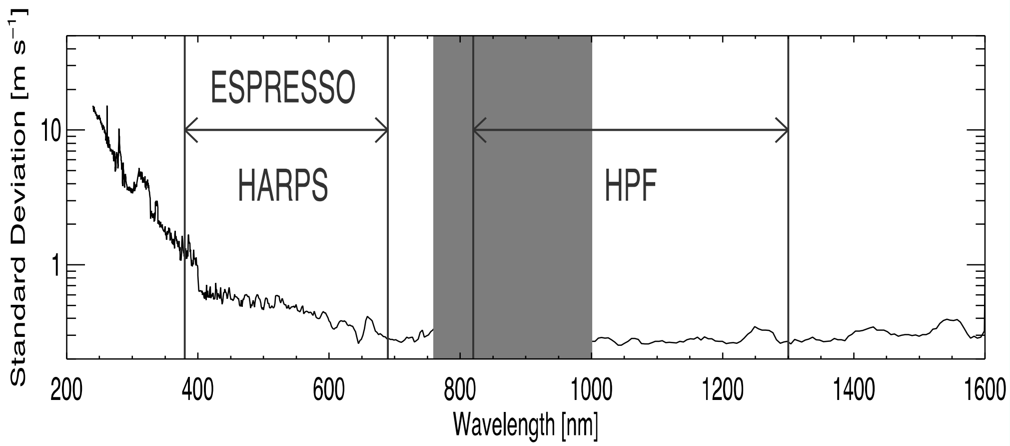
Laser Frequency Comb





Metcalf et al. 2019, Optica, in press (highest precision NIR RVs reported)

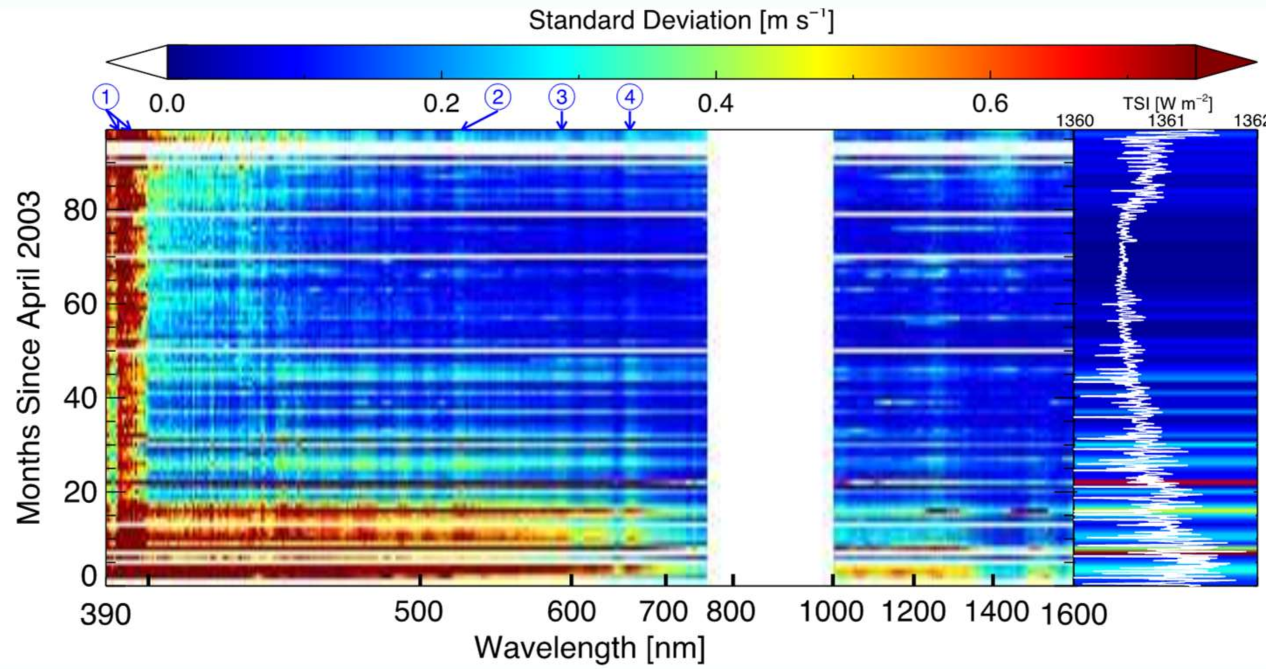
The Stellar Activity Problem



Lower NOISE in NIR

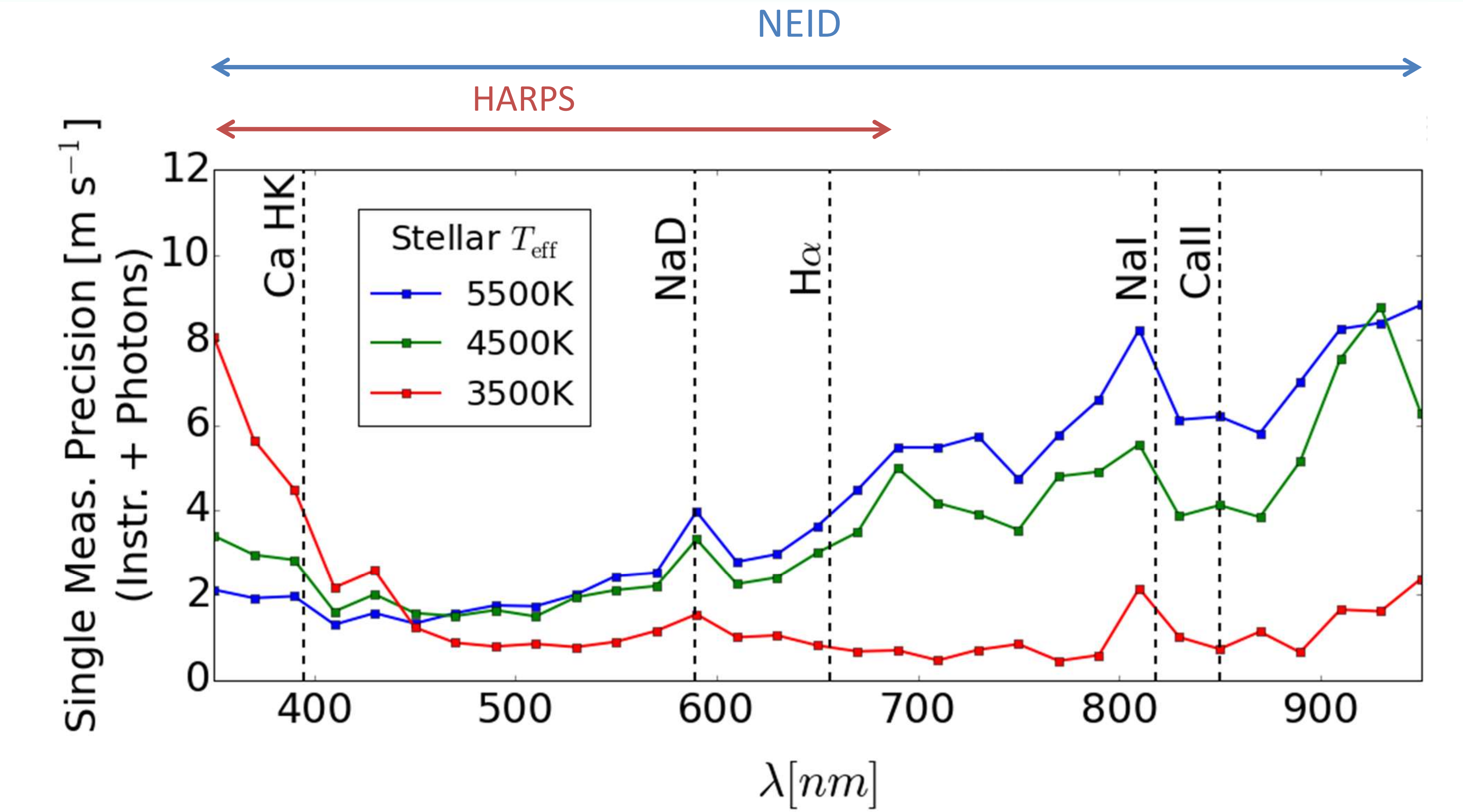
Marchwinski, et al. 2015

Using Data from SOURCE spacecraft

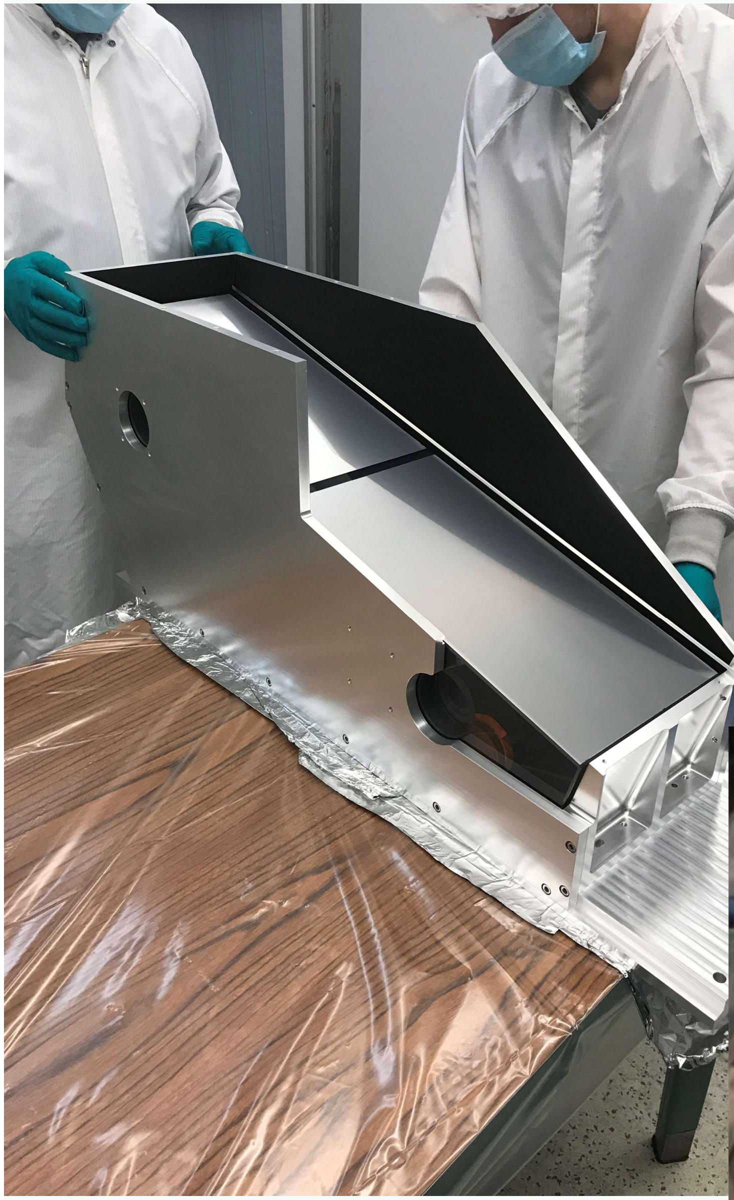


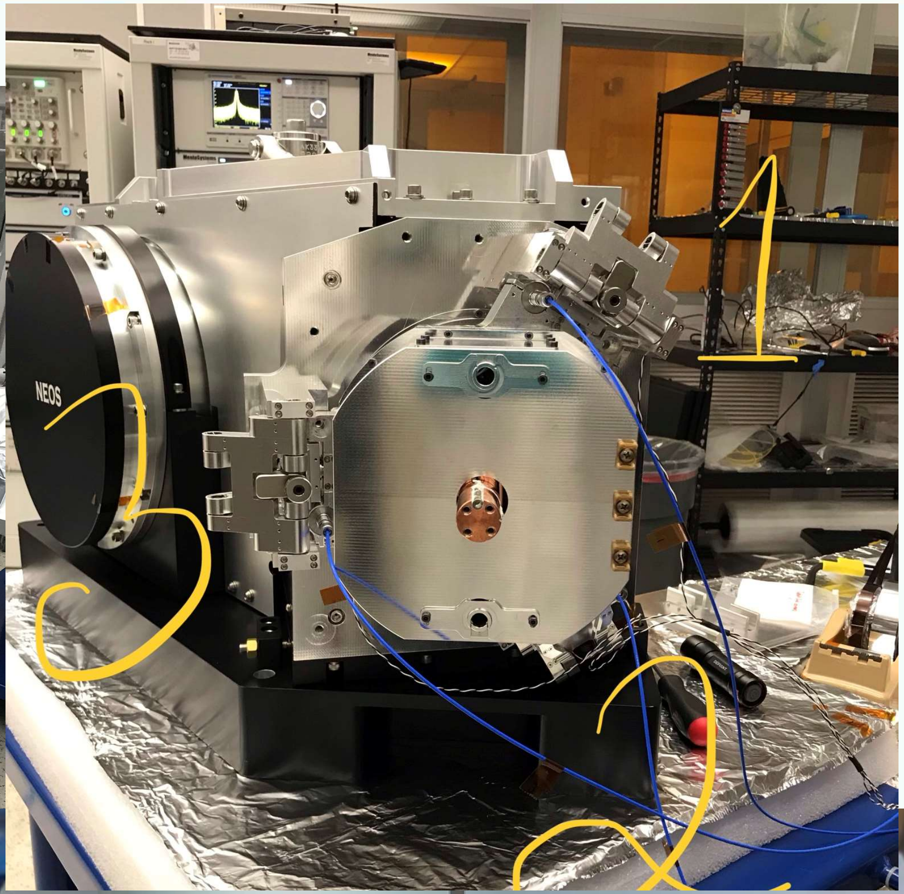
Astrophysical Noise

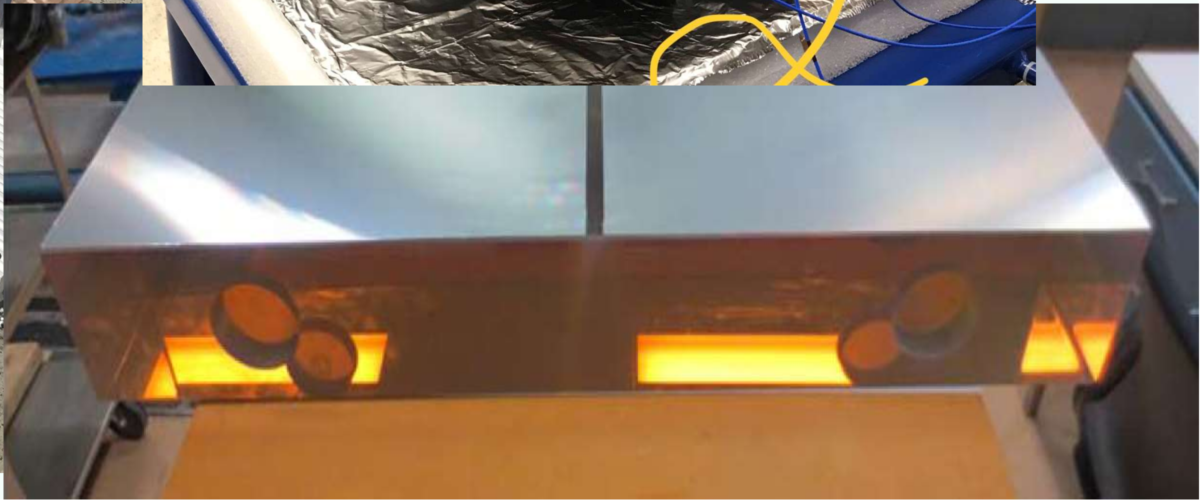
NEID captures the important activity indicators *and* most of the Doppler information for F-K dwarfs



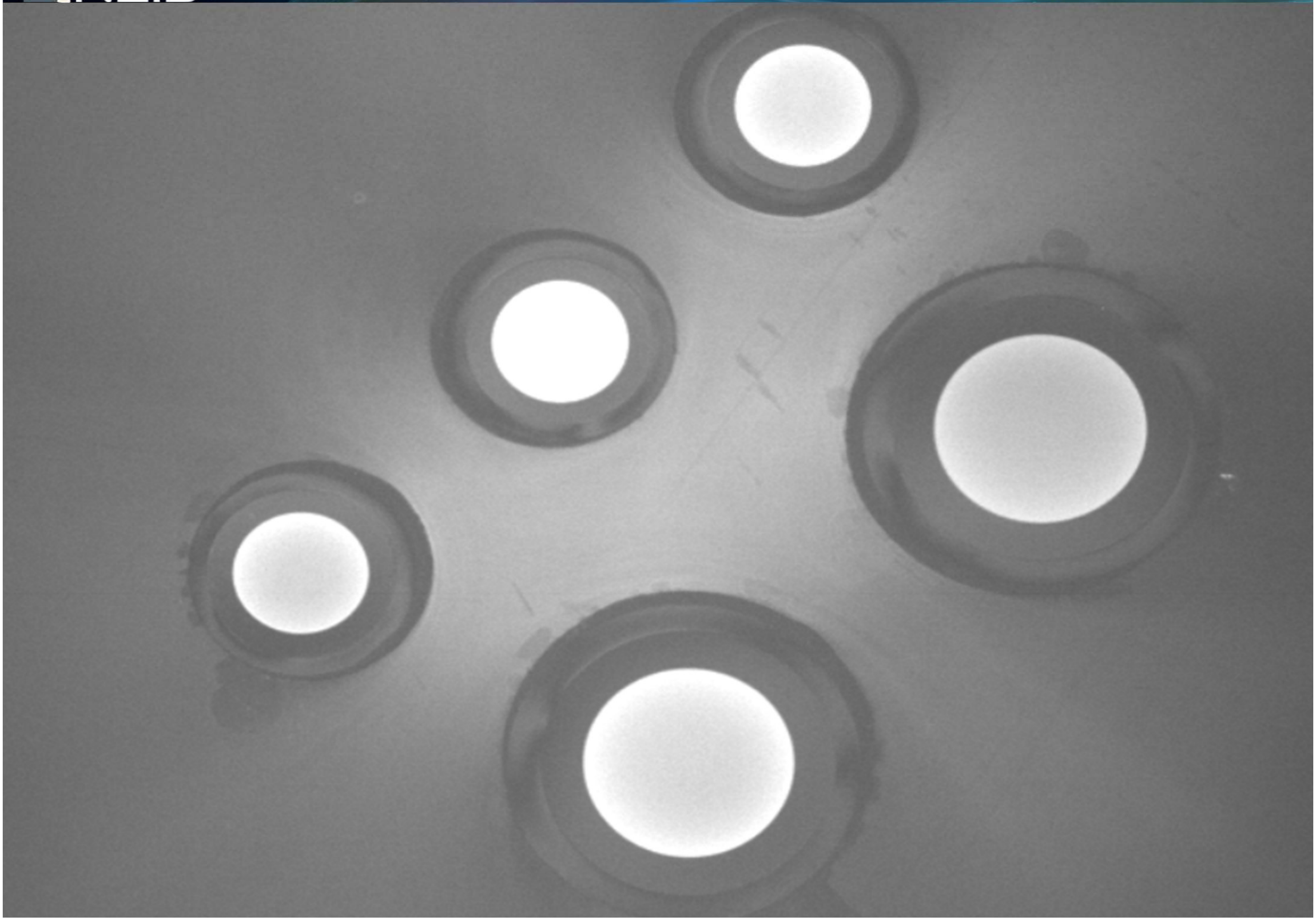
Echelle Grating & Camera



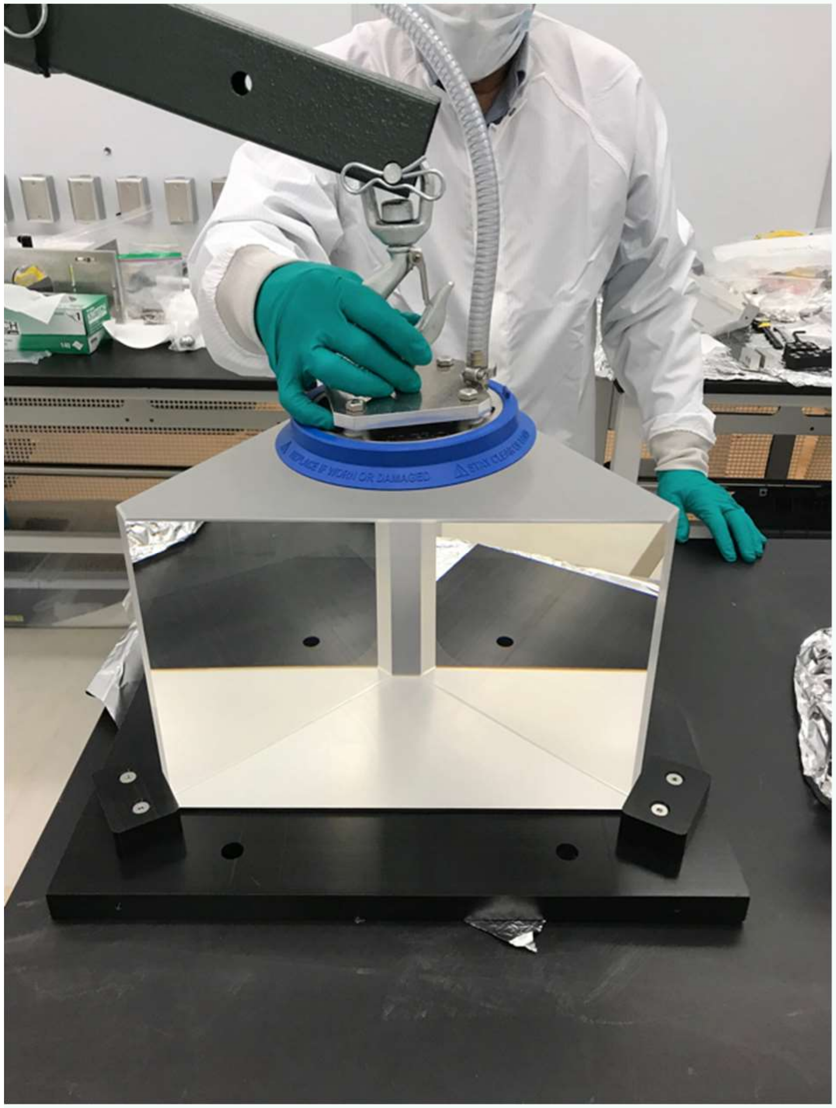


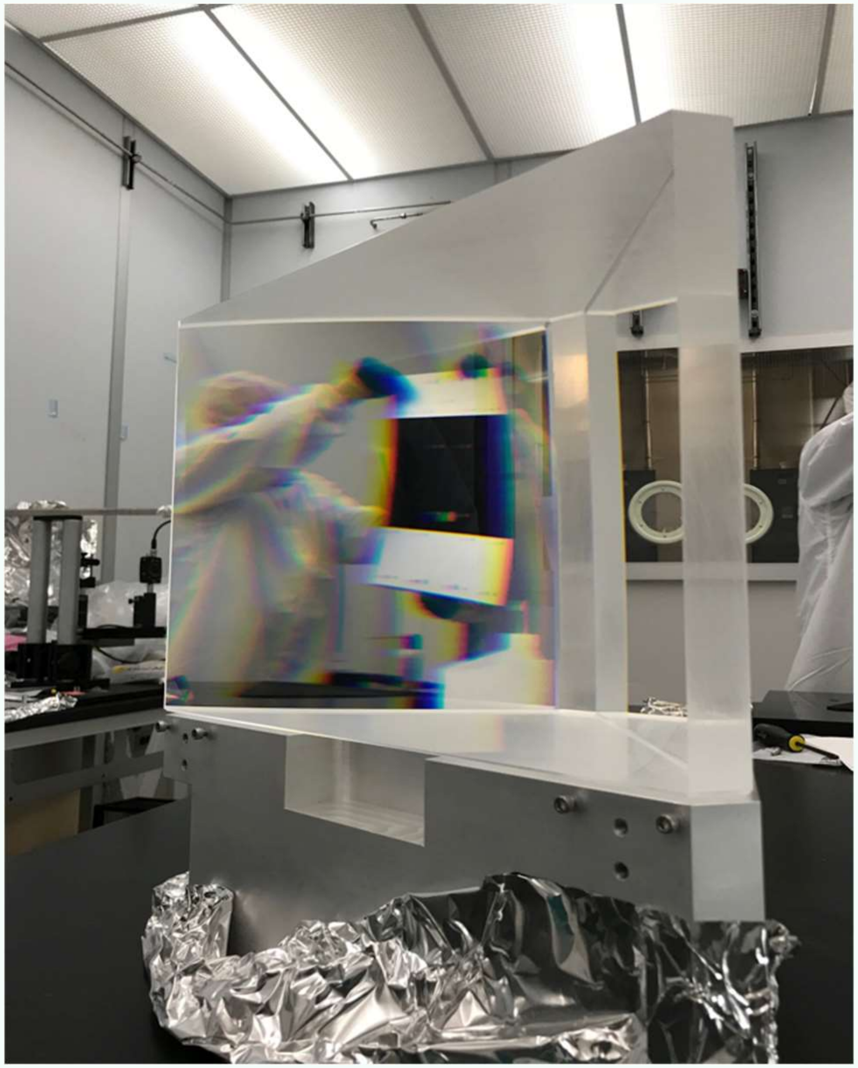


High Resolution (HR) and High Efficiency (HE) Fibers

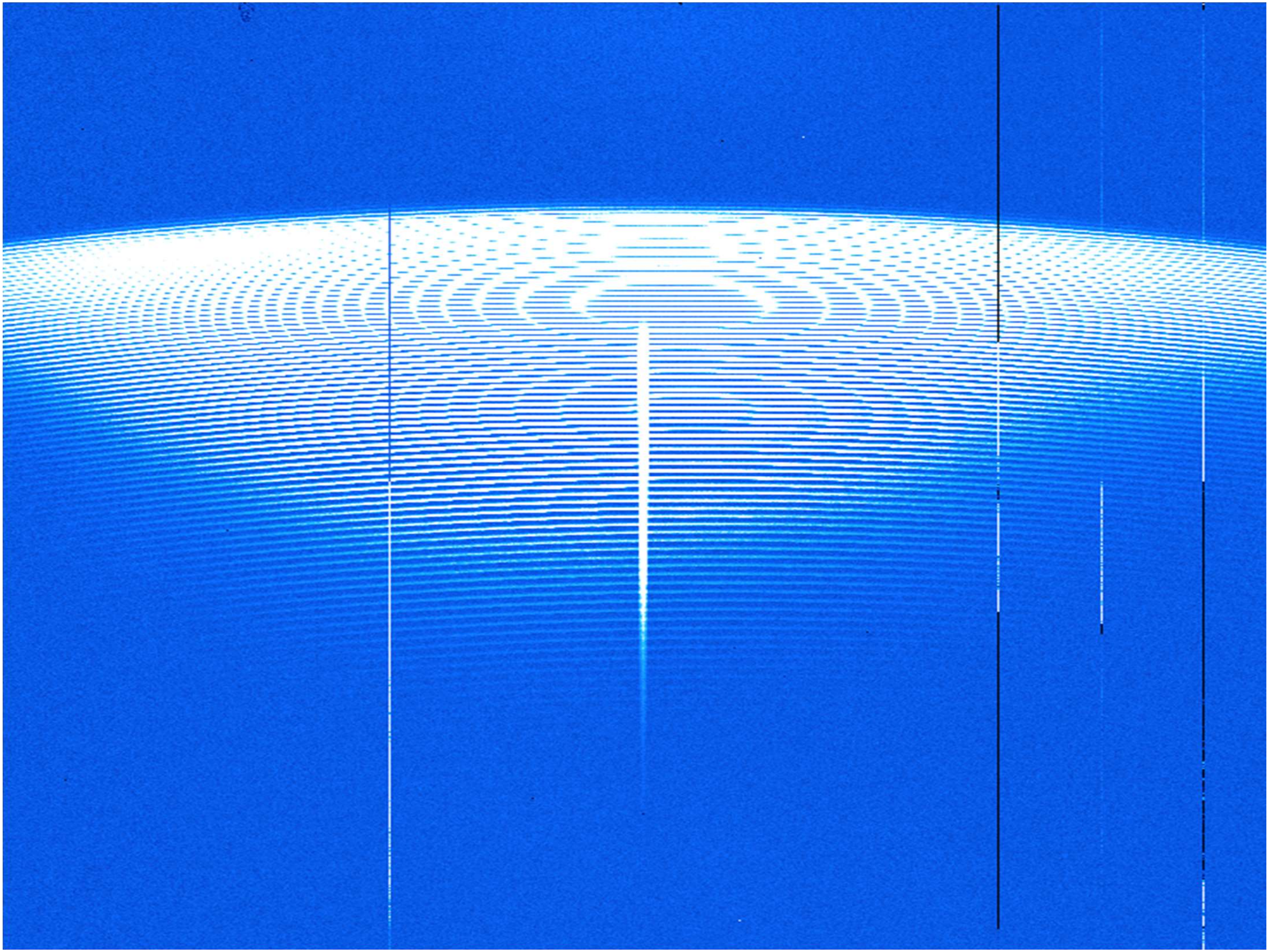


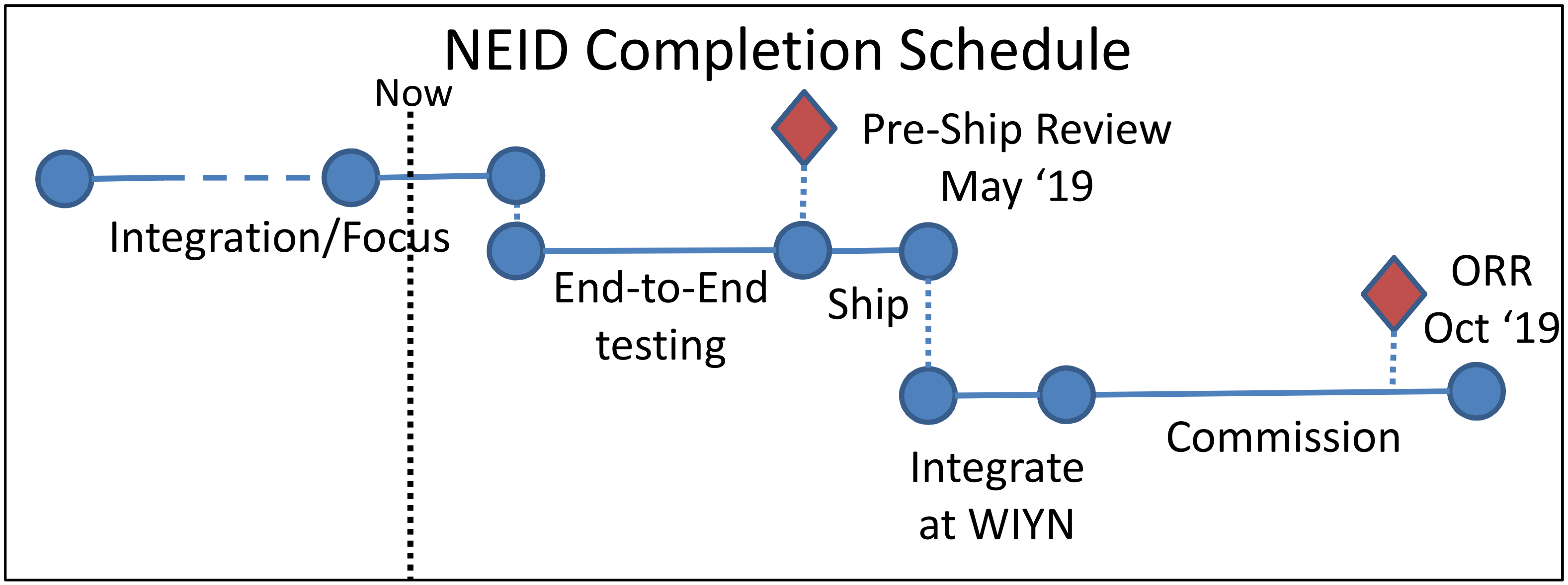
Prism Integrated into Mount





Status Update: Optics Integration




NEID Completion Schedule
Now
Pre-Ship Review
May '19
Integration/Focus
End-to-End
testing
Ship
ORR
Oct '19
Integrate
at WIYN
Commission


Status & Schedule:
1. AI&V: Now
2. Shipping: mid 2019
3. Commissioning: Q2-Q3 2019
4. Begin Science Ops: late fall 2019

NEID

Science with NEID

Jason T. Wright
Penn State

Science: The needs of the community

- Challenges
  - Present a state-of-the-art Doppler instrument
  - Improve on existing instruments
  - Address astrophysical noise
  - Enable powerful GO programs on faint *and* bright targets

Science: How NEID meets community needs

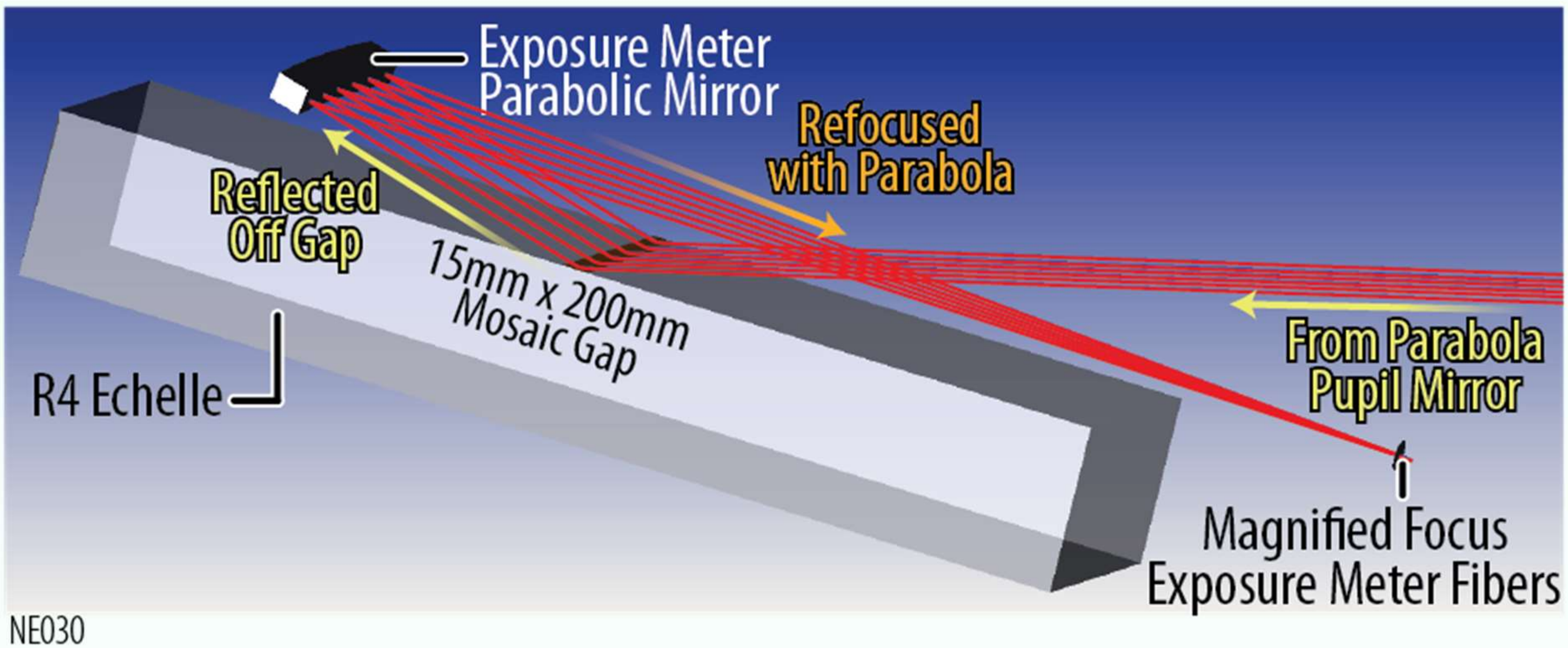
- Challenges
  - Present a state-of-the-art Doppler instrument
  - Leverage 10 years of technology development to improve on existing instruments
    - Single-measurement instrumental stability target < 30 cm/s
    - Chromatic Exposure Meter
    - Broad spectral grasp-> more RV information
  - Address astrophysical noise
    - Wavelength coverage includes multiple spectral activity tracers
    - High resolving power (R~100,000) enables line-shape diagnostics
  - Enable powerful GO programs on faint *and* bright targets
    - High-Resolution (HR) and High-Efficiency (HE) modes
    - Queue scheduling
    - Data reduction pipeline

High Resolution vs. High Efficiency Modes

High Resolution (R~100,000)	High Efficiency (R~60,000)
Line shape activity tracers (e.g. bisectors)	Survey efficiency
Superior telluric correction	Sub-optimal observing conditions (poor seeing, poor transparency)
Better stellar spectra ❾ ancillary science	Fainter stars
Matched to LFC performance	Rapid rotators

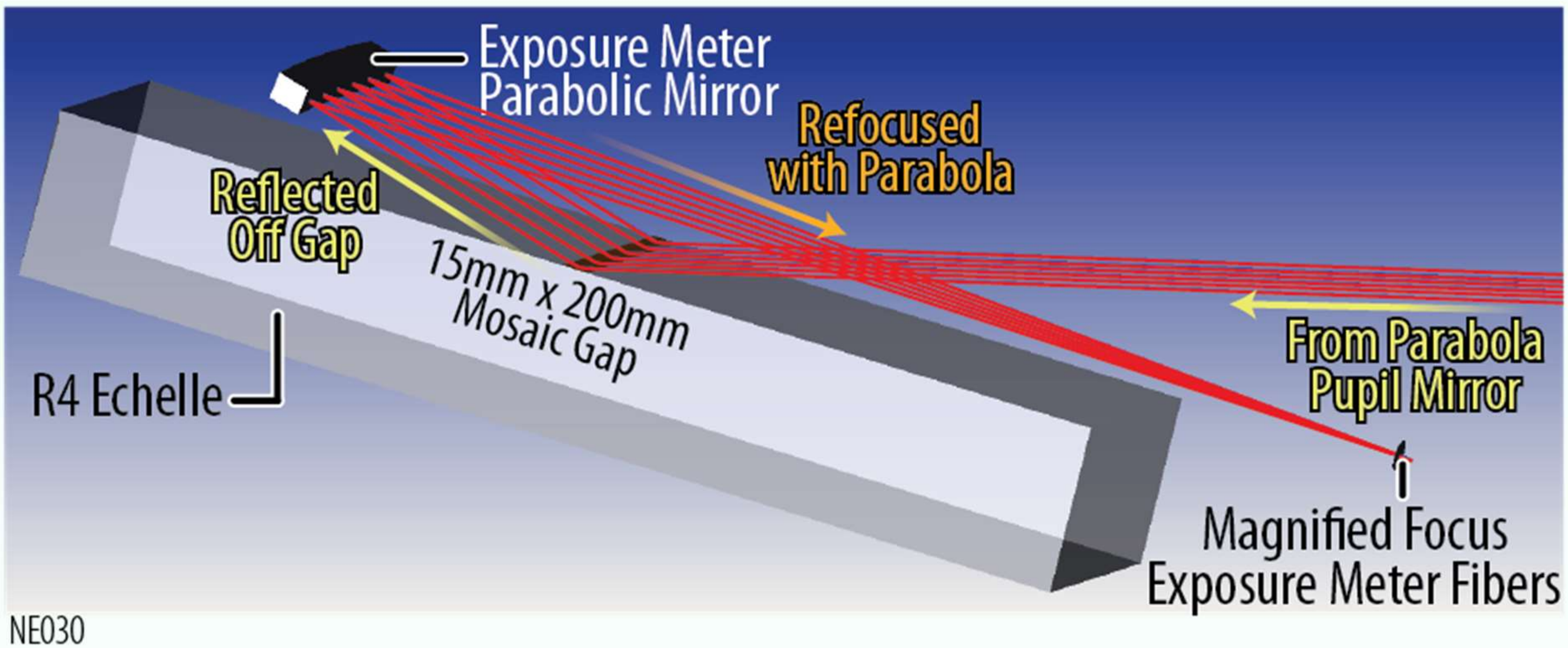
Timing challenge:

- Barycentric motion at time of observation requires timing < 1s
- Chromatic seeing makes timing a function of wavelength
- Solution: exposure meter is a low-resolution spectrograph
- Provides low-res spectrum at high cadence



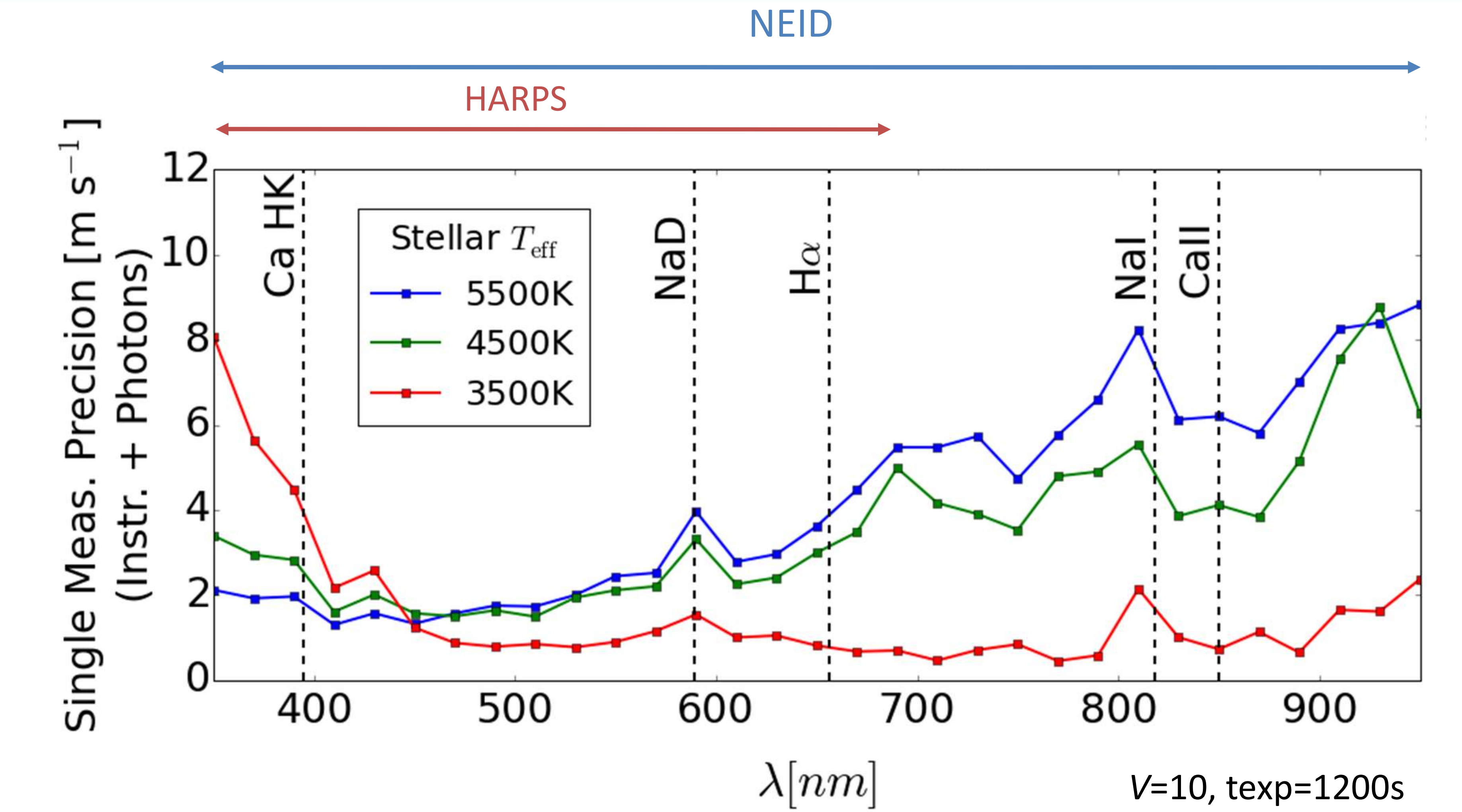
Chromatic Exposure Meter Provides:

- Real-time feedback of conditions to observer
- Optimizes observing time to the science
- Low-resolution spectra
- Precise barycentric correction as function of wavelength



Astrophysical Noise

NEID captures the important activity indicators *and* most of the Doppler information for F-K dwarfs



Science: How NEID meets community needs

- NEID science team GTO program
  - See poster 140.28 today
  - Outlines of GTO program will be described, including bright star target list
  - GTO targets are not proprietary
    - But TAC may consider science duplication at its discretion
  - Skin in the game:
    - GTO shares the queue with all observers, will work to help optimize NEID science for everyone
    - GTO science goes through same data reduction pipeline as community

Exposure time calculator

- Instrument/Science team plans to provide an exposure time calculator
  - Choose target SNR or (shot-noise-limited) RV precision
  - Will include effects of RV spectral content (Teff, vsini)
  - Also intend to include period/rough amplitude of p-modes


Status & Schedule:
1. AI&V: Now
2. Shipping: mid 2019
3. Commissioning: Q2-Q3 2019
4. Begin Science Ops: late fall 2019

NEID at WIYN: Operations

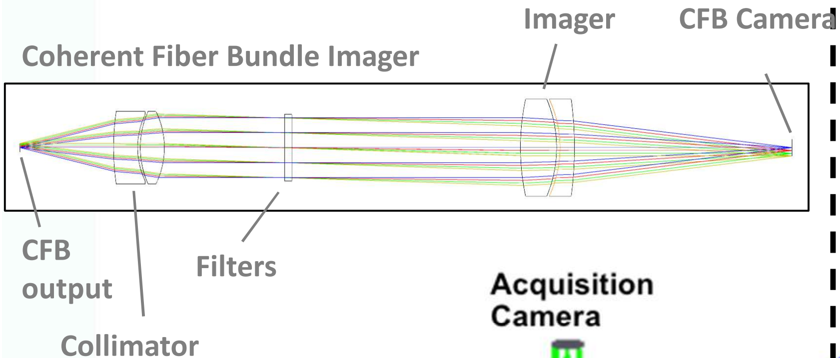
Jayadev Rajagopal
NOAO
2019 AAS, Seattle

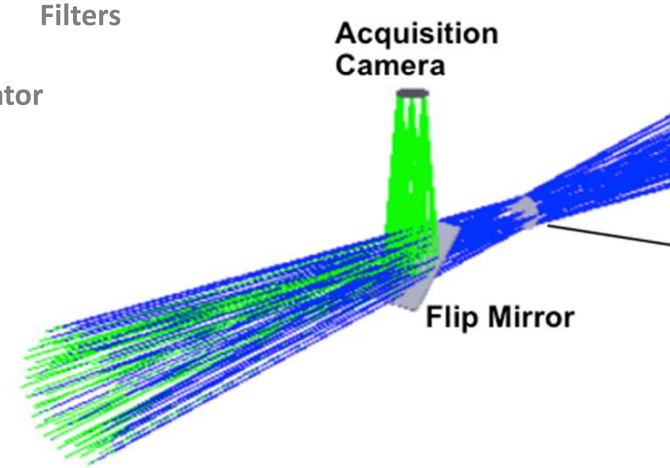
Timeline: 2019

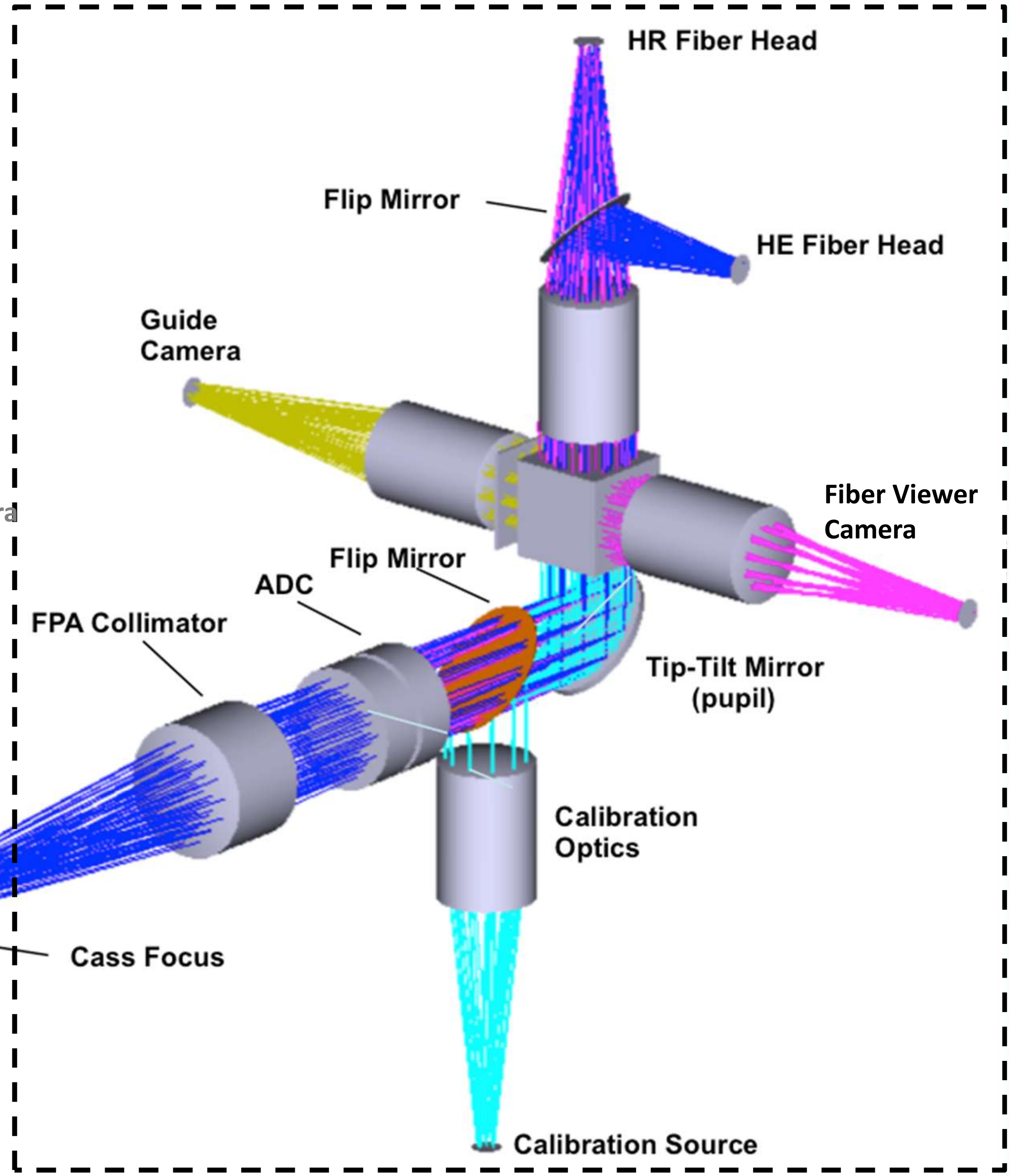
- Port Adaptor (fiber feed at WIYN Bent-Cass port) arrives from Washburn Labs (U. Wisconsin) late March-early April
- NEID arrives from PSU late May-early June
- Installation and Commissioning through to September
- Start of Operations in October-November (2019B Semester)

Port Adapter Functions

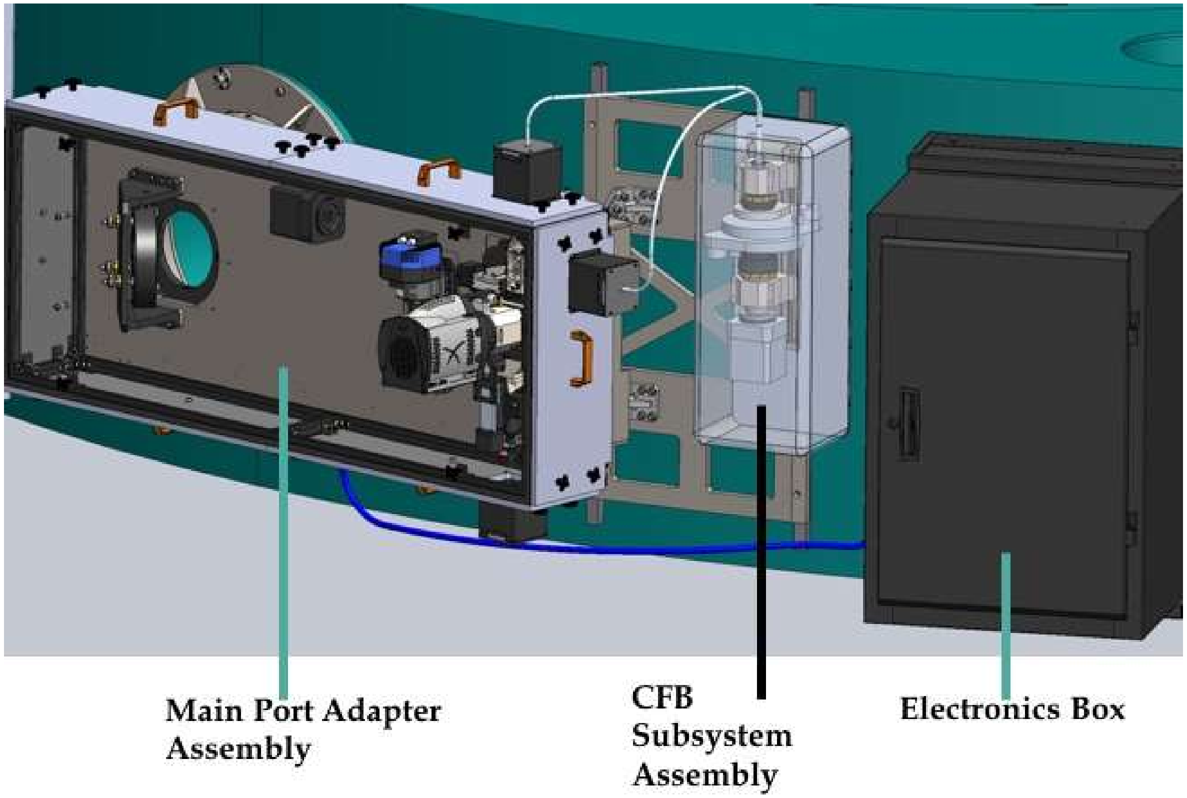
1) Acquiring the target star and placing it on the science fiber
2) Stabilizing the star position with high speed tip-tilt guiding
3) Correcting atmospheric dispersion
4) Maintaining telescope focus
5) Coupling calibration light into the science fibers
6) Monitoring the location of target star relative to the science fiber in the focal plane

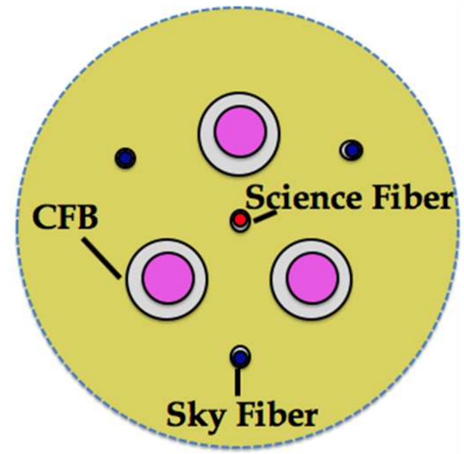






Port Adapter



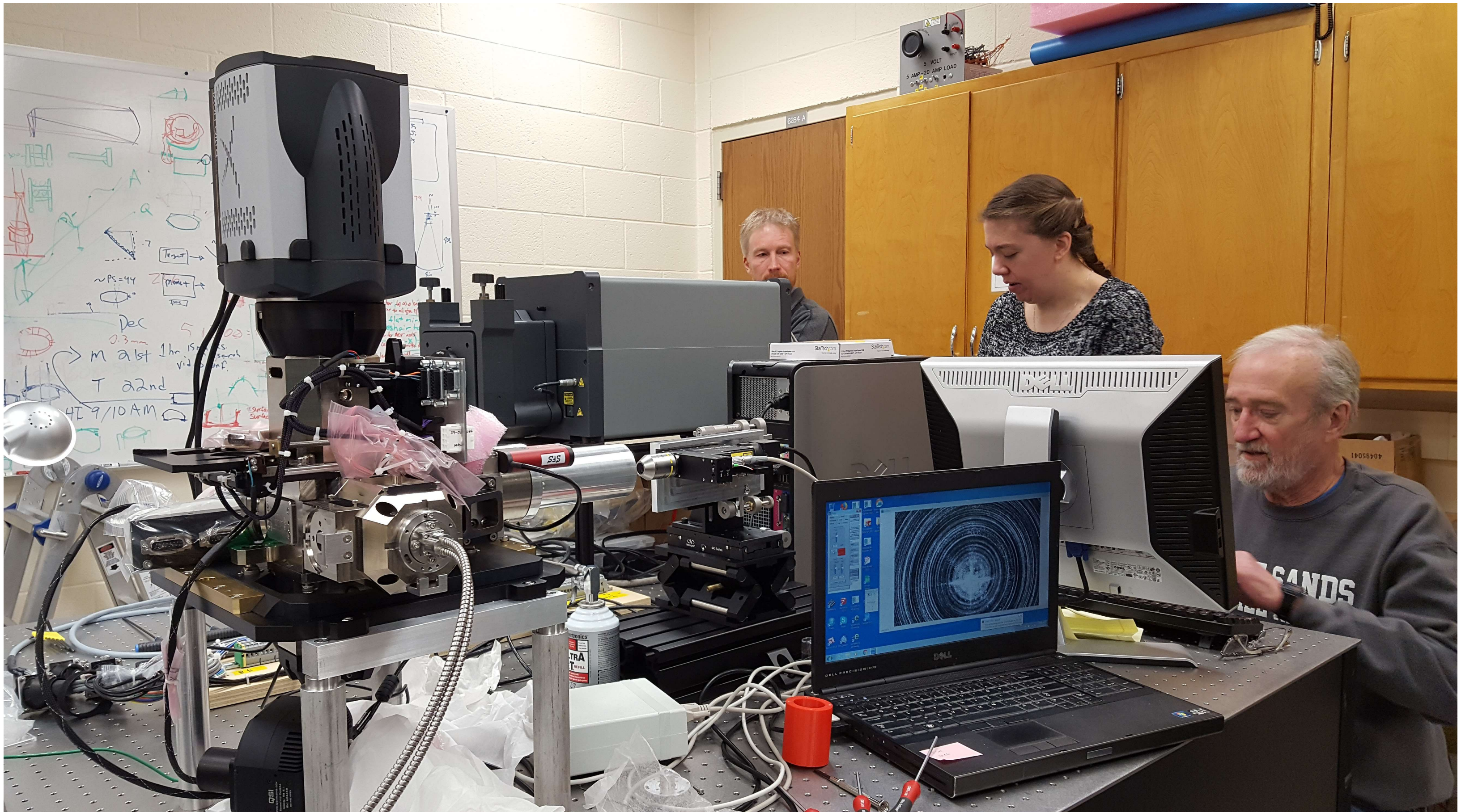


HR/HE Fiber Head

HR/HE Science (Sky) Fiber Core: 62.5 µm/102 µm

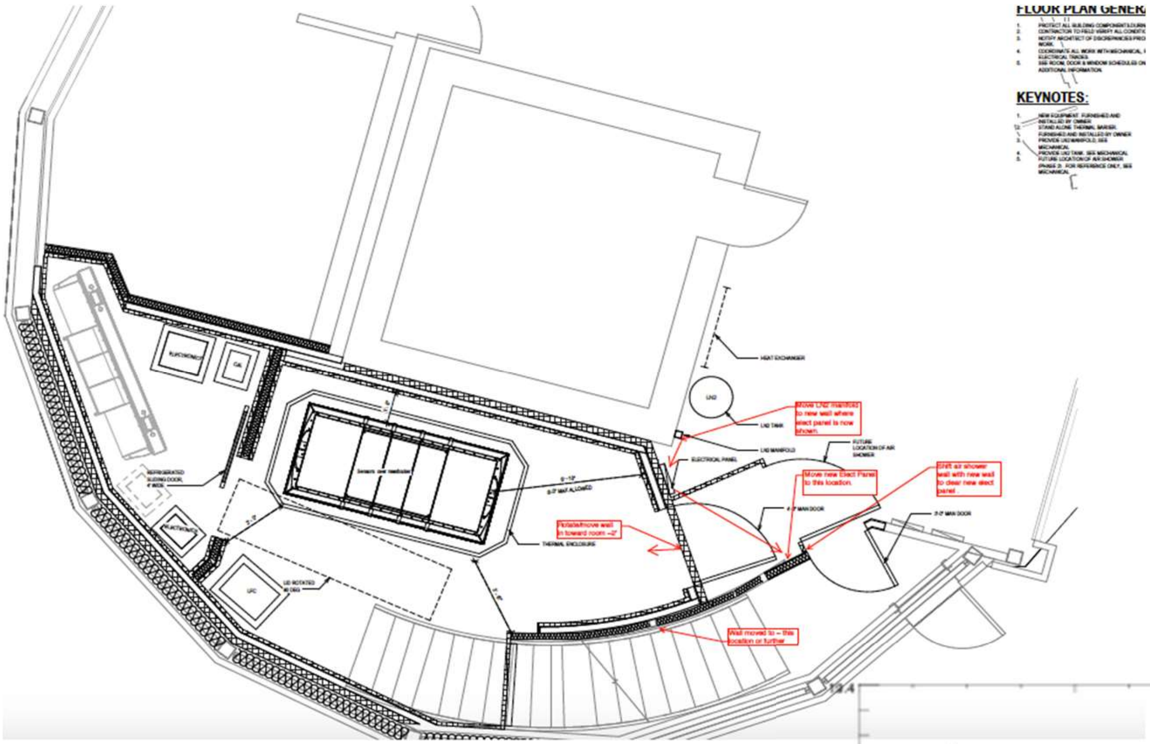
CFB Quality Image Area: 380 µm

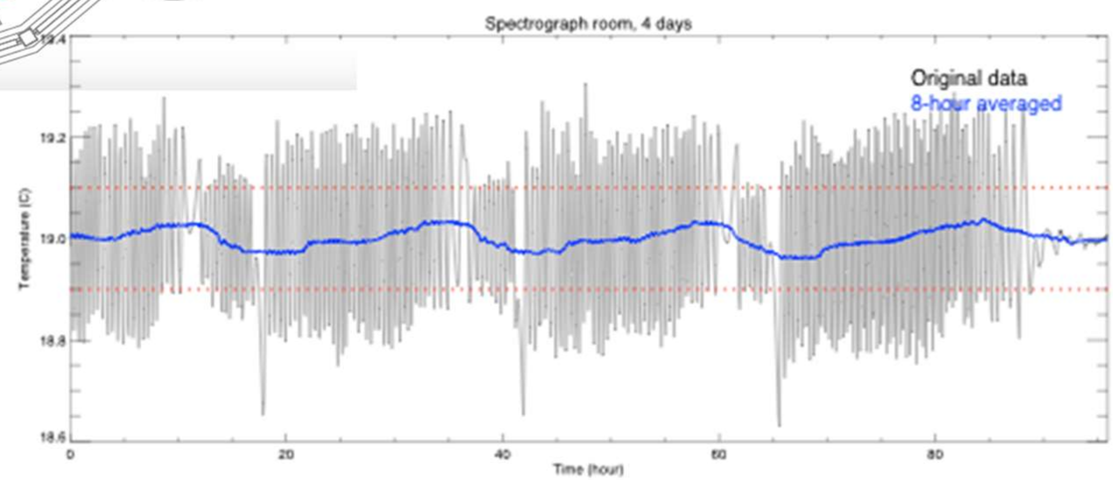
Performance Requirement:
The Port Adapter guiding system must maintain the centroid of the stellar PSF on the science fiber to within 0.05″ (3.4 µm) of the center of the fiber under median seeing and wind conditions with a V_{mag}= 12 star or brighter.



Port Adaptor: Integration at U. Wisconsin Washburn Lab

Floor plan of NEID space: Ground floor, WIYN





Enclosure designed to limit long term thermal drift to +-0.1 C over the lifetime of the mission

NEID Enclosure

NEID Ops and Queue

- **NEID will be an open access community resource**.
- Operates about 120 nights/year, in blocks. Initially full nights, phasing in half-night block capability.
- Semester-based proposal cycles
- WIYN alternates between classical time, queue NEID time and engineering time.
- Queue nights fixed at the beginning of each semester
- The queue is exclusively for NEID, optimized for RV measurements
- Programs from GO (NN-Explore time through NOAO TAC), GTO (Penn State, 30 nights a year) and university partners (IU, UW, Missouri, & Purdue)
- Nighttime staff of 2: queue observer and telescope operator
- Design based on existing HET and Gemini queues

Based on Operations Plan and Systems Integration Review April 4/5, 2018

Principles

- Uses telescope time efficiently and fairly
- Dynamic, to receive new input, requests
- PIs can monitor & adjust their programs (initially limited; phased in)
- Schedules observations within specific time windows associated with a given target
- Adopts existing software & methods
- Software developed for the queue will also be used on classical nights and for TOO observations

Lifecycle of a Queue Program

1. PIs consult documentation, WIYN staff, to plan their programs.
2. Phase 1: PIs submit proposals to NNEXPLORE TAC and a target list or example targets to the queue database.
3. TAC awards time at some priority level(s) to programs.
4. Phase 2: Successful PIs complete their target information.
5. WIYN checks Phase 2 data and approves it for scheduling.
6. Queue commences. PIs adjust ongoing programs (Phase 3) using the same interface as for Phase 2. PIs retrieve their data from a NExScI archive.

Phase 1 (initial target descriptions)

- Phase 1 targets due ~4 months before semester starts (when NN-EXPLORE proposals are due).
- Target information used to inform TACs of programs' scheduling requirements
- Phase 1 targets may be actual targets or example targets if actual targets are unknown.
- Target info is entered using a GUI or text files.
- WIYN staff (queue coordinator and instrument scientist), planning tools and documentation will be available to help proposers and the TAC. This will necessarily be limited for the first semester: will be shared-risk observing.

Role of the TACs

- After review, TACs will accept/reject proposals and award time to each accepted proposal with one or more of 4 priority levels.
- Total time a TAC shall award is proportional to the institution's share of the NEID queue.
- A TAC assigns:
  - 25% of its total time as Priority 1 (highest)
  - 25% of its total time as Priority 2
  - 25% of its total time as Priority 3
  - 50% or more (TBD) of its total time as Priority 4 (lowest)
- PIs should suggest and justify their own priority levels.
- TACs will promote queue efficiency by considering RA distribution of their proposals (with WIYN's help).

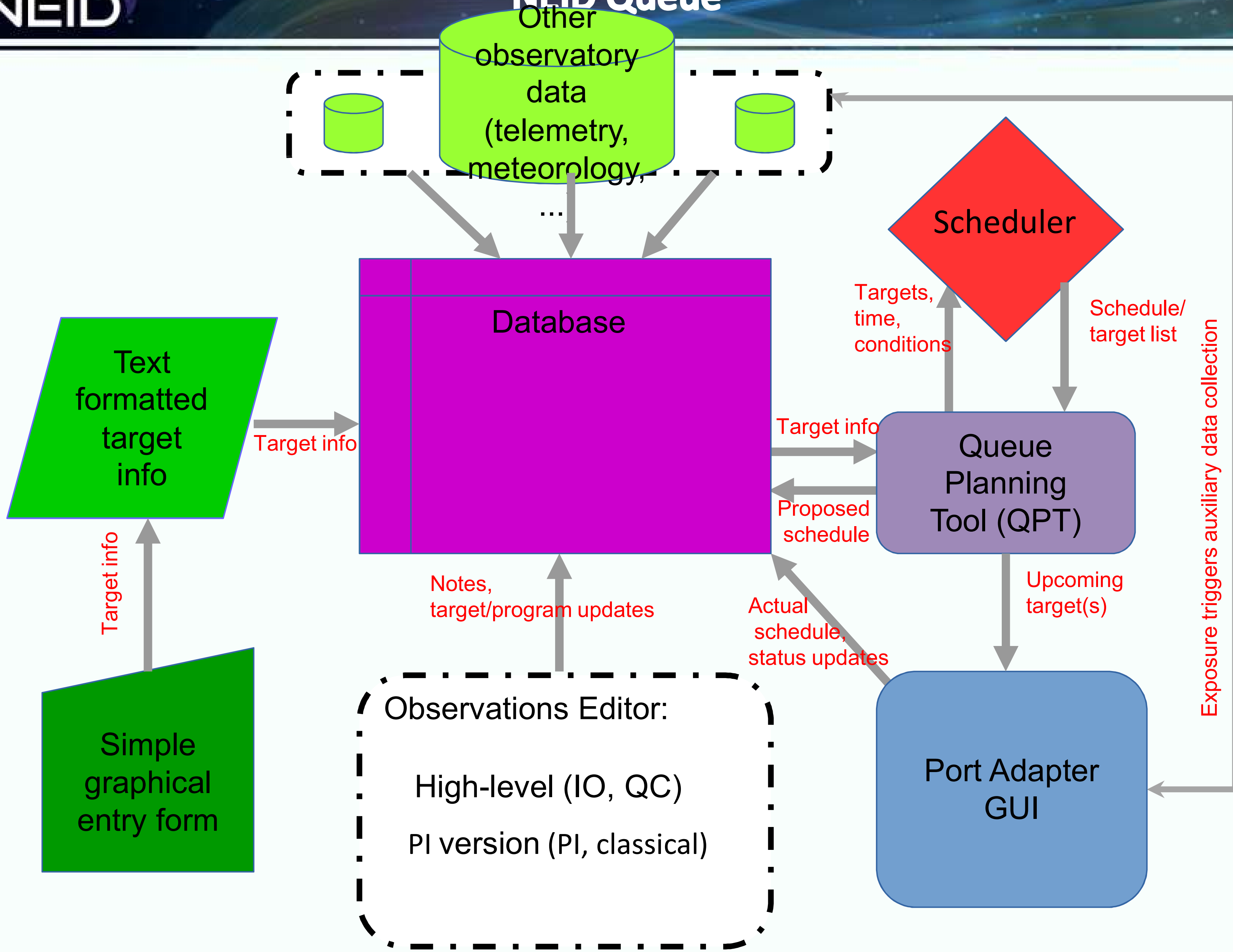
Phases 2 & 3 (post proposal target definition)

- Phase 2 begins after PIs are notified of their successful programs and lasts until shortly before a semester start.
- Phase 3 is concurrent with the semester.
- Phase 2/3 use same data entry tools as Phase 1, but complete target definition is required
- Phase 2/3 target information shall conform to archiving requirements.
- WIYN staff (the acting queue coordinator) will check new Phase 2/3 targets for completeness.

Queue Software

- Data relevant to scheduling observations, instrument configuration and event timing will be stored in the queue Database at WIYN.
- The Database is Postgres, designed using a schema from Gemini as a guide.
- Other software components run at the telescope will be written in Python with GUI components using PyQT.
- External interfaces (target entry forms) will be secured web-based applications.

NEID Queue



Other observatory data (telemetry, meteorology, …
Database
Text formatted target info
Target info
Target info
Simple graphical entry form
Scheduler
Targets, time, conditions
Schedule/ target list
Target info
Queue Planning Tool (QPT)
Proposed schedule
Upcoming target(s)
Exposure triggers auxiliary data collection
Notes, target/program updates
Actual schedule, status updates
Observations Editor:
High-level (IO, QC)
PI version (PI, classical)
Port Adapter GUI

Phased Implementation

- Step 1, March 2019:

  Call for proposals (March 2019 for 2019B semester) will feature best effort documentation and proposal planning tools.

  - Database
  - Target entry with “superuser” permissions
  - Basic, functional Scheduler for early Commissioning activity
  - Suitable for 1 program or classical observers during Commissioning
- Step 2, July 2019:
  - Target entry using better developed Observations Editor
  - Permits multiple programs, checks PI inputs. Tested during Commissioning
  - Improved public documentation in place
  - Improved planning tools in place
- Step 3, Fall 2019, in time for start of Operations.
  - Scheduler emphasizes fairness and efficiency
  - Observations Editor permits PIs to track & modify programs

NEID Job Opening:

Staff Scientist at NOAO/WIYN to support the NEID system.

Advertisement running on the AAS Job Register.

Opportunity for young researchers interested in instrumentation and RV science.

NEID Archive and Community Data

Rachel Akeson, BJ Fulton
NExScI

January 7, 2019

NEID Data Flow and Processing

Every night NEID will record:

- Science data when NEID is on sky
- Instrument calibration data

NOAO will operate quick-look pipeline during observing

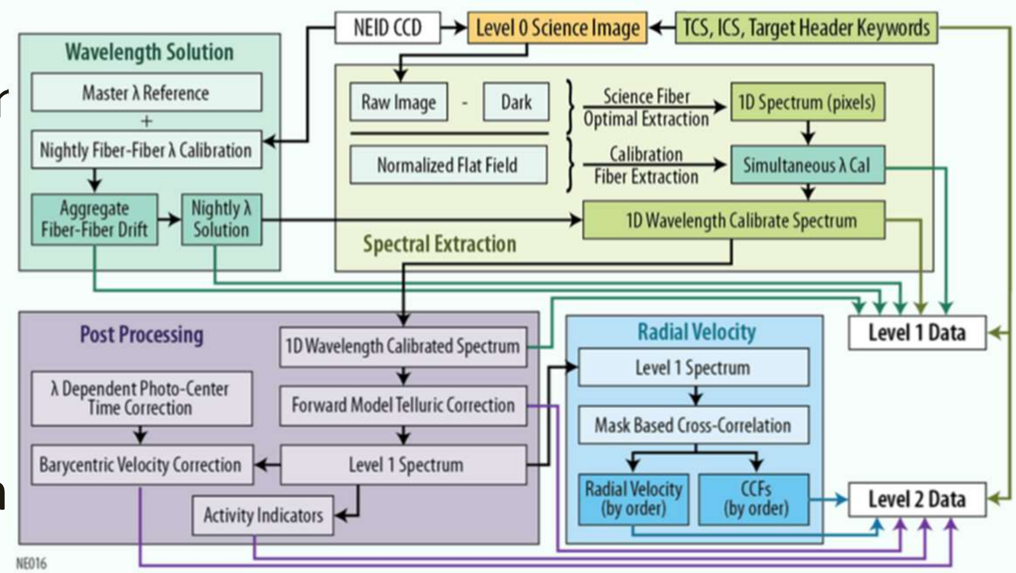
Daily transfer of data (10-100 GB)

NExScI will run all data through the NEID pipeline

- Data products generated and archived for PI and community access

NEID Pipeline

- The pipeline is provided by the NEID Instrument Team, software team lead by Chad Bender
- Pipeline steps include
  - Wavelength calibration
  - Spectral extraction
  - Spectral processing and corrections
    - Barycentric velocity
    - Wavelength-depender photon-weighted mid-exposure time
    - Telluric correction
    - Activity indicators
  - Radial Velocity calculation

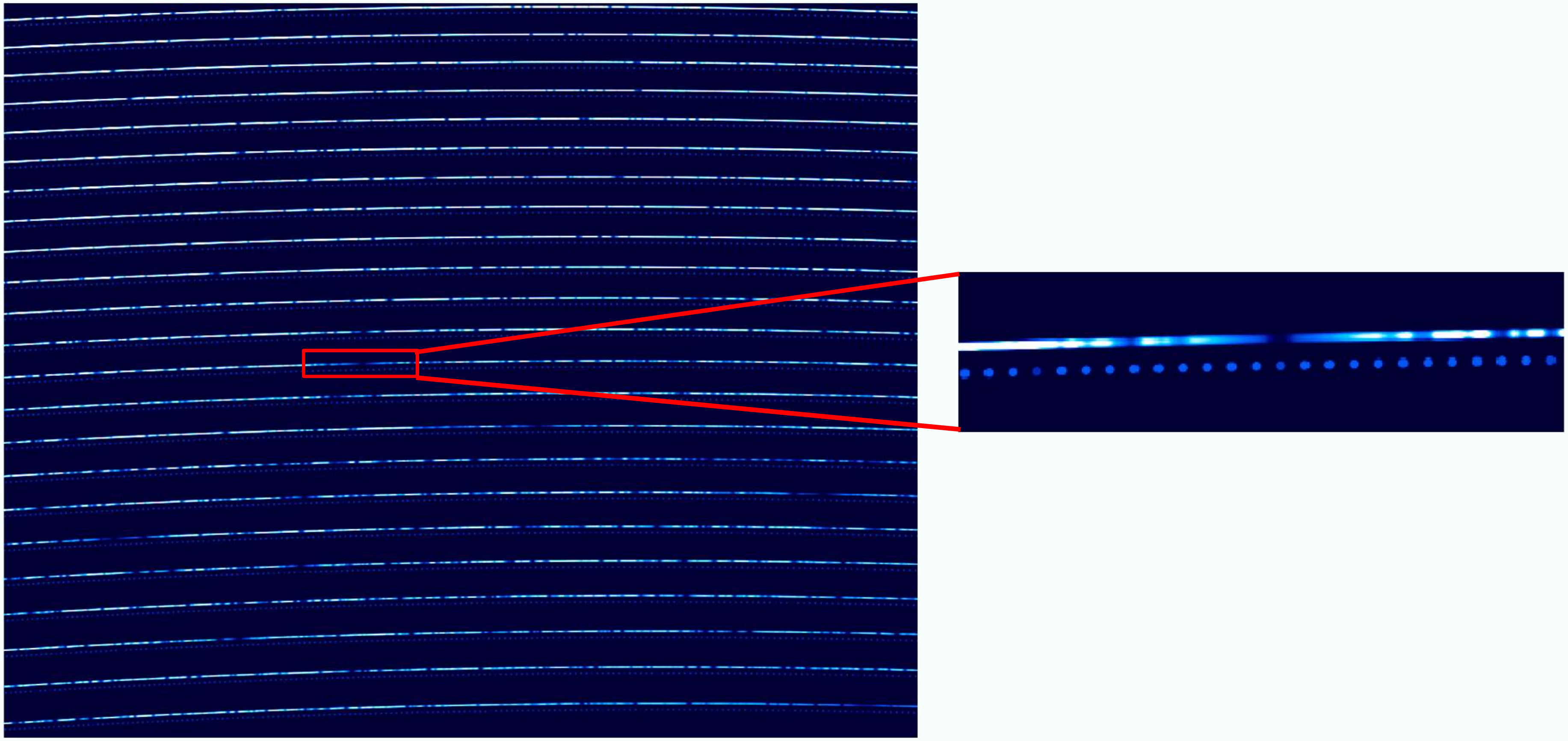


Data Types

- Science Data
  - Includes calibrations specific to that observation
    - Simultaneous wavelength calibration fiber data
    - Simultaneous sky calibration fiber data
    - Exposure meter data
- Spectrometer Calibration Data
  - Tracks and calibrates long term instrument drift and radial velocity zero point
  - No proprietary period
- Facility Calibration Data
  - Meteorological conditions at the site, telescope status, port configuration, guider camera images
  - No proprietary period etc.
- Header data added to FITS files
  - Observer program information
  - Target information
  - Exposure information
  - Telescope telemetry
  - Spectrograph configuration
  - Detector configuration, gains, and biases
  - Exposure meter information
  - Telescope port telemetry, including one or more guider images per science exposure
  - Observatory site weather telemetry

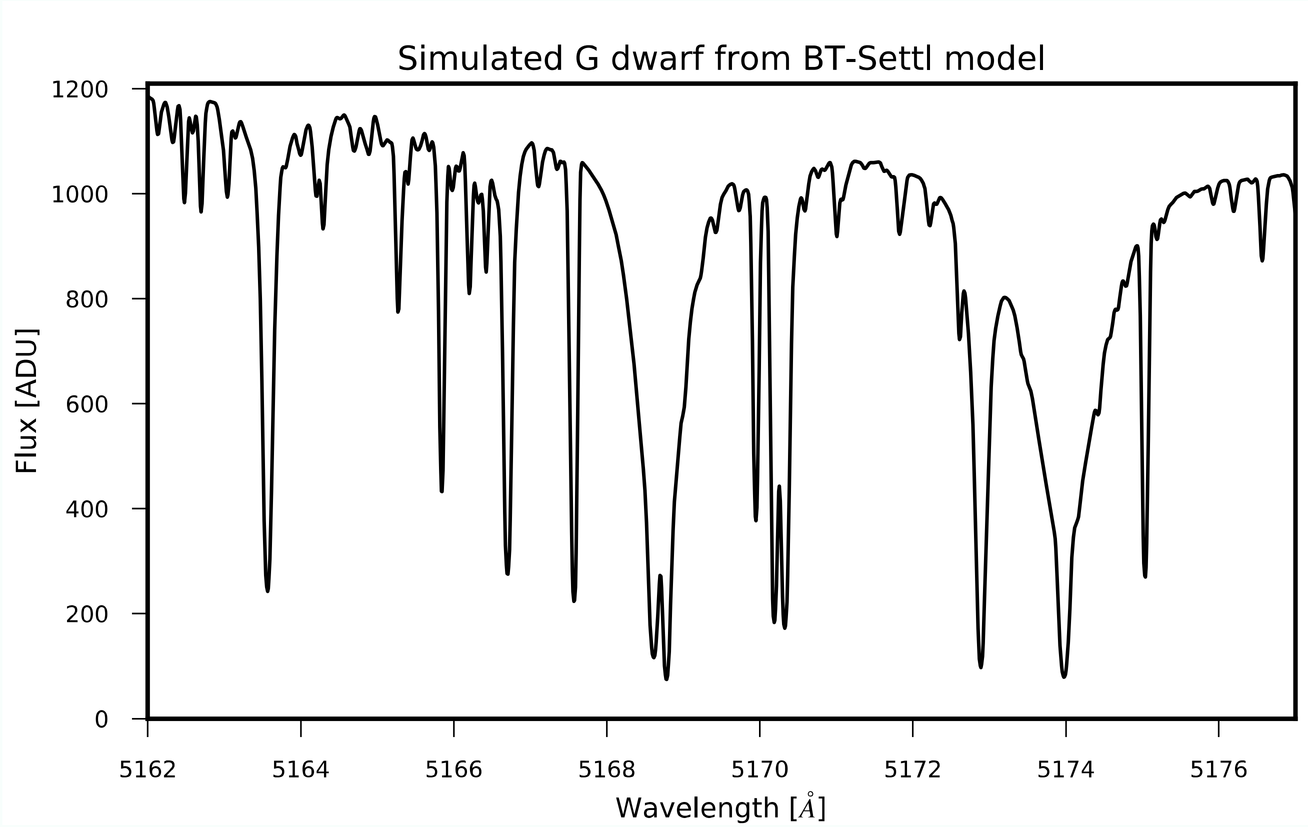
Science Data Processing Levels

- Level 0 - Raw data
  - One FITS file for each exposure
  - Each instrument readout (16 total) in an HDU
  - HDUs for exposure meter, guider image and coherent fiber



Science Data Processing Levels

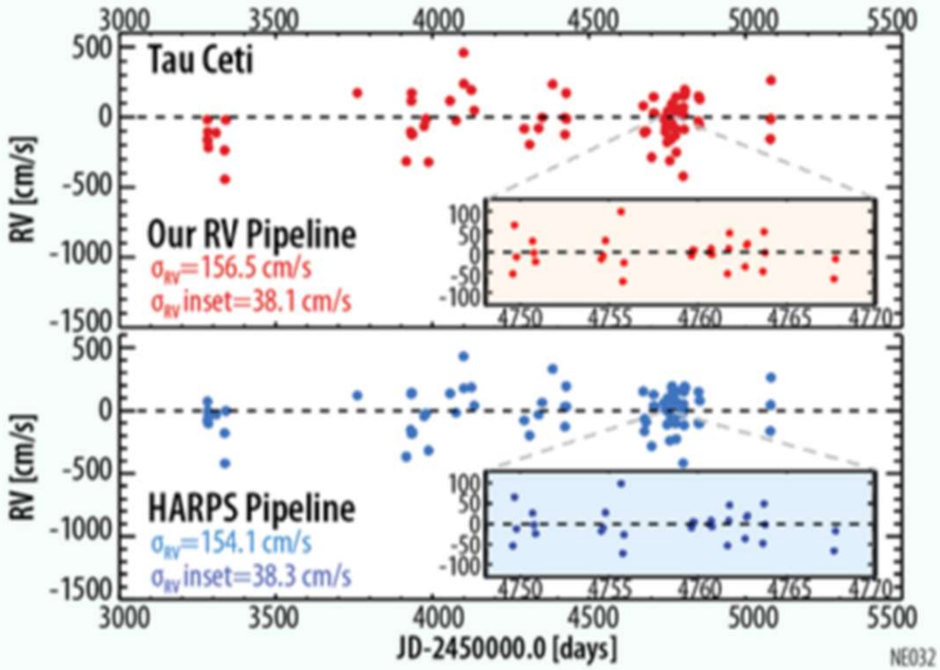
- Level 1 – Extracted Spectra
  - 2D FITS images (order x pixel column) with extensions for sky, calibration, science fibers, and wavelength solution



Science Data Processing Levels (cont)

- Level 2 – Radial Velocities
  - Cross correlation function data
  - Sky and telluric models
  - Activity indicators
  - Additional keywords include
    - Barycentric correction
    - RV per order
    - Drift terms

Comparison of NEID and HARPS pipeline on Tau Ceti data



Community Data Access

- Science data
  - Available to PI team after processing through pipeline, quality checks and ingestion into archive
  - Available to community after proprietary period
  - Level 0, 1 and 2 available to download
- Metadata available as soon as data is in archive
  - Target name
  - Integration time
  - Data release date

NEID Archive Capabilities

- NEID data will be available in an archive developed and maintained by NExScI
- Web-based interface
  - Search by source (name or position), PI/project, date
  - Download selected or all data products
    - Includes ancillary data such as weather
  - Simple, interactive plotting
    - 1D spectrum, RV timeseries
  - Additional search capabilities added in later releases
- API (programming) interface
  - Table Access Protocol (TAP) interface to DB
  - VO compliant
  - Python API (likely astroquery)
  - Search and download on same metadata as web-based interface

NEID Proposal Calls, Utilization, Policies

NN-EXPLORE Guest Observer (GO)

NN-EXPLORE provides a 2 semester/year Guest Observer (GO) program, administered by NOAO. There is limited funding support, sufficient to cover travel, modest research expenses, and publications costs, provided by NASA to observers through NExScI.

http://ast.noao.edu/observing/

- WIYN observations with NEID will begin with Semester 2019B.
- Approximately 90 nights per year awarded for GO observing.
- Semester B proposals due March 31 (awards announced mid-June)
- Semester 2019B will be a shared risk semester. NEID commissioning expected to complete in December 2019.
- NExScI will provide the automated RV pipeline and archive database.
- All NEID observations will be queue-based.
- WIYN Partners may used NEID but only through the queue and subject to NN-EXPLORE policies.
- Other WIYN instruments are available but will be evaluated for exoplanet science by the NOAO TAC.

NN-EXPLORE Policies (1/2)

- Key Science/Multi-Semester Projects
  - Key Science are large projects, evaluated separately from GO, up to 30 nights/year.
  - Allocated by the NOAO TAC
  - Not initially in Semester 2019B
- Director's Discretionary Time/Targets of Opportunity
  - TOO are top priority and submitted through the TAC.
  - DDT has no specific allocation, but push down other observations in the queue.
- Guaranteed Time Observing
  - 30 nights per year allocated to the Penn State team.
  - Same distribution of priorities as GO, perhaps with some adjustments.
  - GTO targets not exclusive and will be published with the call each semester.
- Guest Observing
  - Awarded by the TAC.
  - NEID Instrument queue-based.
- Observation Prioritization
  - Four bins of 25% each with the last bin oversubscribed.
  - PI's can request priorities for individual targets, but TAC has final authority to set the rank.
  - Priority 1 targets can carry over an addition two semesters if not completed.
  - Deadline for final object list for any proposal is set by the TAC.

NN-EXPLORE Policies (2/2)

- Duplicate Targets
  - Duplicate targets will be allowed.
  - Target lists will be published. PI's must affirm they have checked for duplicates against the published lists.
  - The NOAO TAC will make the final decision on allowing the duplicate observation.
  - Observed target metadata will be released as soon as observations are ingested into the archive.
  - For duplicate observations, each team only gets their data.
- Data Acceptance Criteria
  - As part of the proposal process, PIs will specify acceptable data quality and quantity.
  - Data acceptance based on the archival data (not quick look products).
- Data Proprietary Periods
  - 2 years for GTO.
  - 1.5 years for GO and TOO.
  - DDT is released immediately.
  - All metadata released immediately.

Note: Policies are mature, but not yet finalized. Community input welcome.

Additional Information

- Websites

  https://exoplanets.nasa.gov/exep/NNExplore/

  http://ast.noao.edu/observing/

- The NEID Splinter Session presentations will be posted on the NASA exoplanet website (above).
- Additional teleconferences on NN-EXPLORE observing will be held in the coming weeks to allow the community that missed this session to be briefed on this and to ask questions.
- Look for details in ExoPAG News and Announcements [exopagannounce].

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

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