Planet Finder Spectrograph

Jeff Crane

Carnegie Observatories

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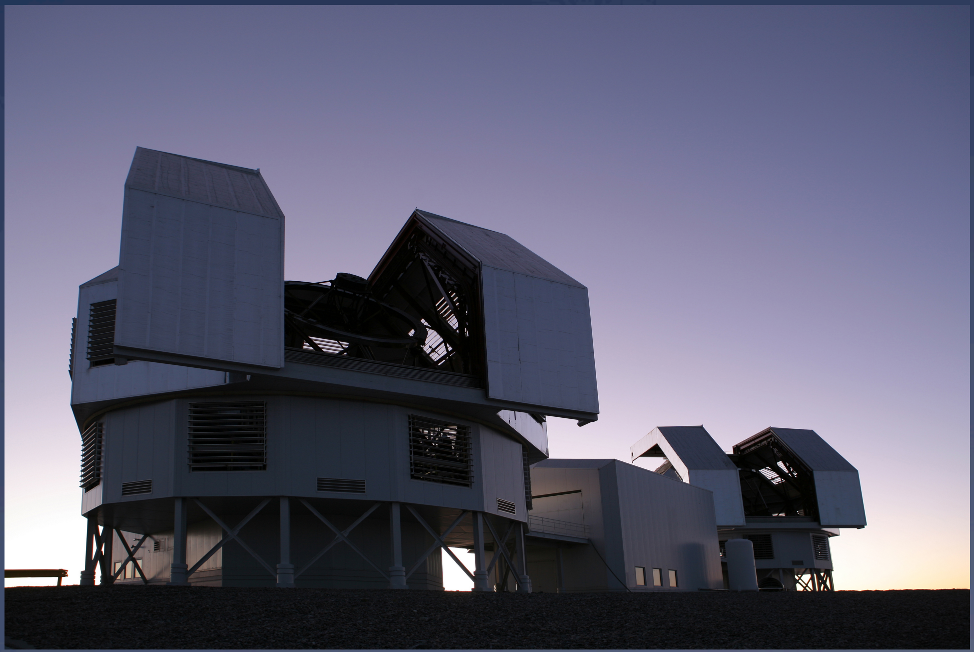
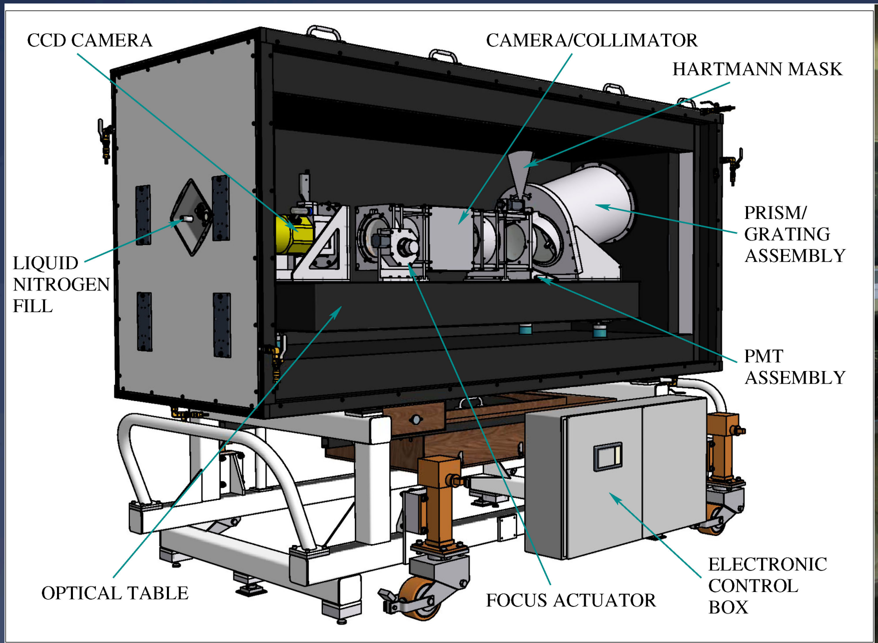
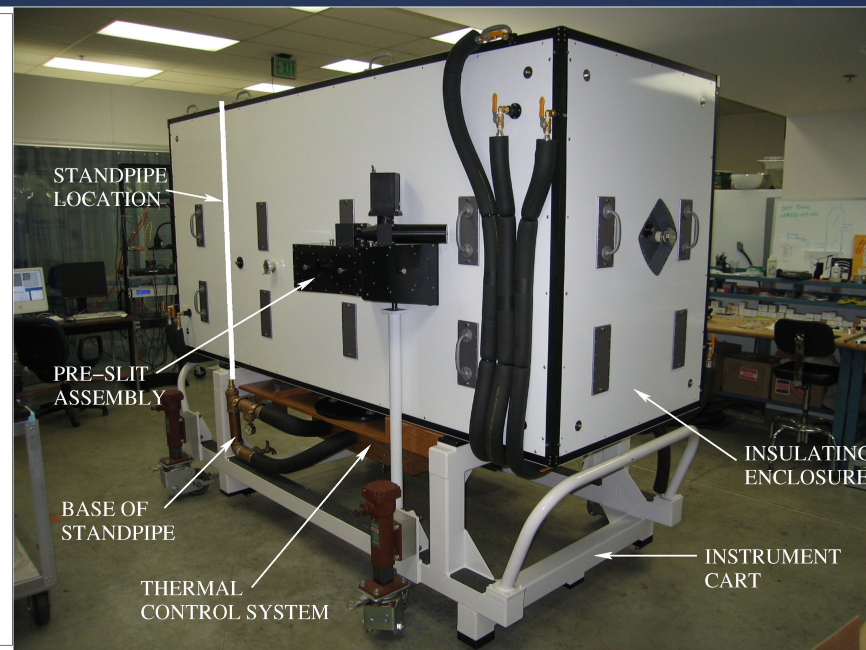
Magellan



6.5 meter Magellan Clay telescope at Las Campanas Observatory, Chile

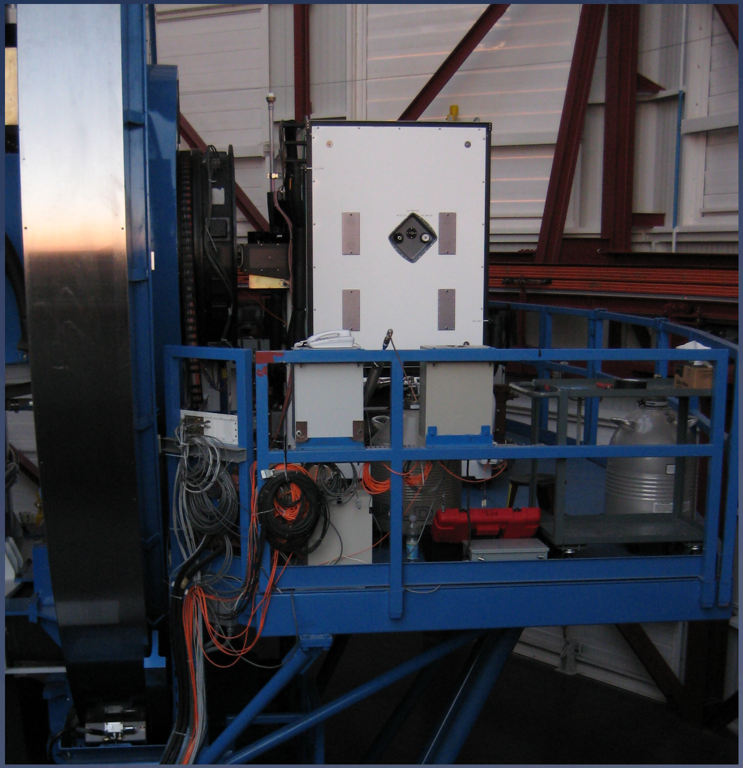
Overview

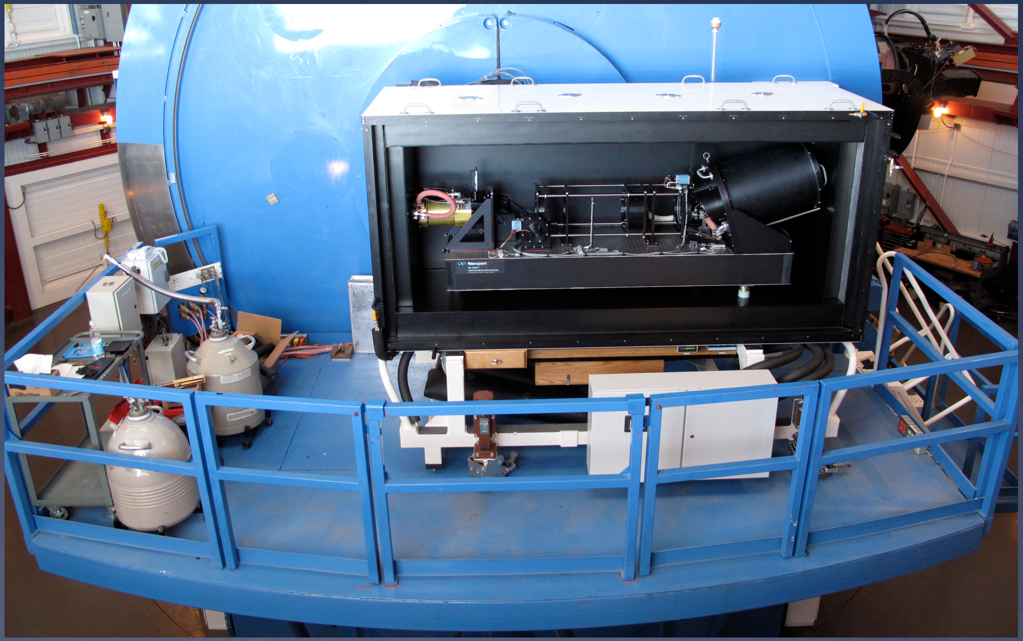




- Optical echelle with a fixed format covering $388<\lambda<668$ nm
- Iodine cell
- Total cost roughly $1M

On the Nasmyth Platform

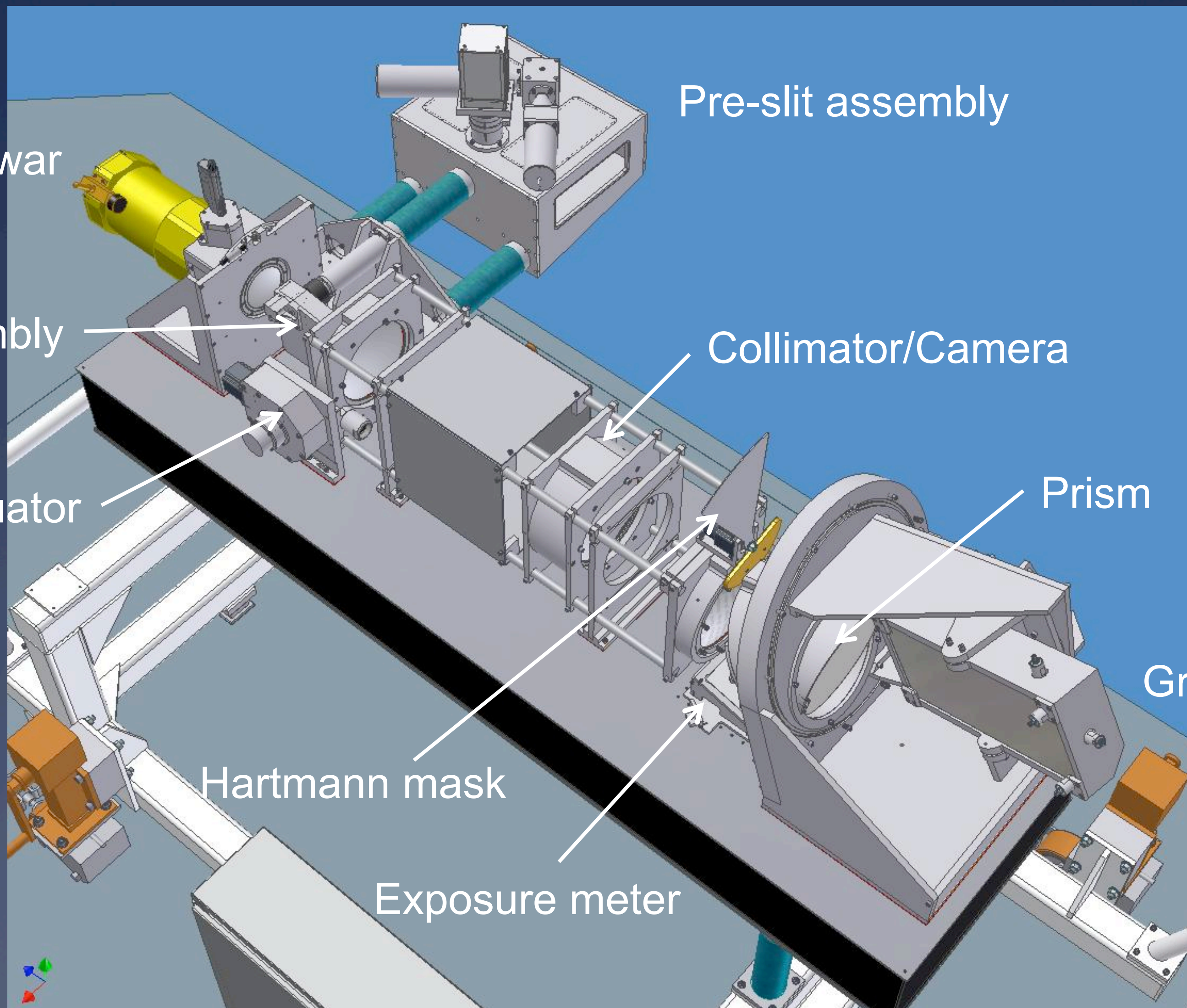




Side insulation panel is removed to show instrument interior

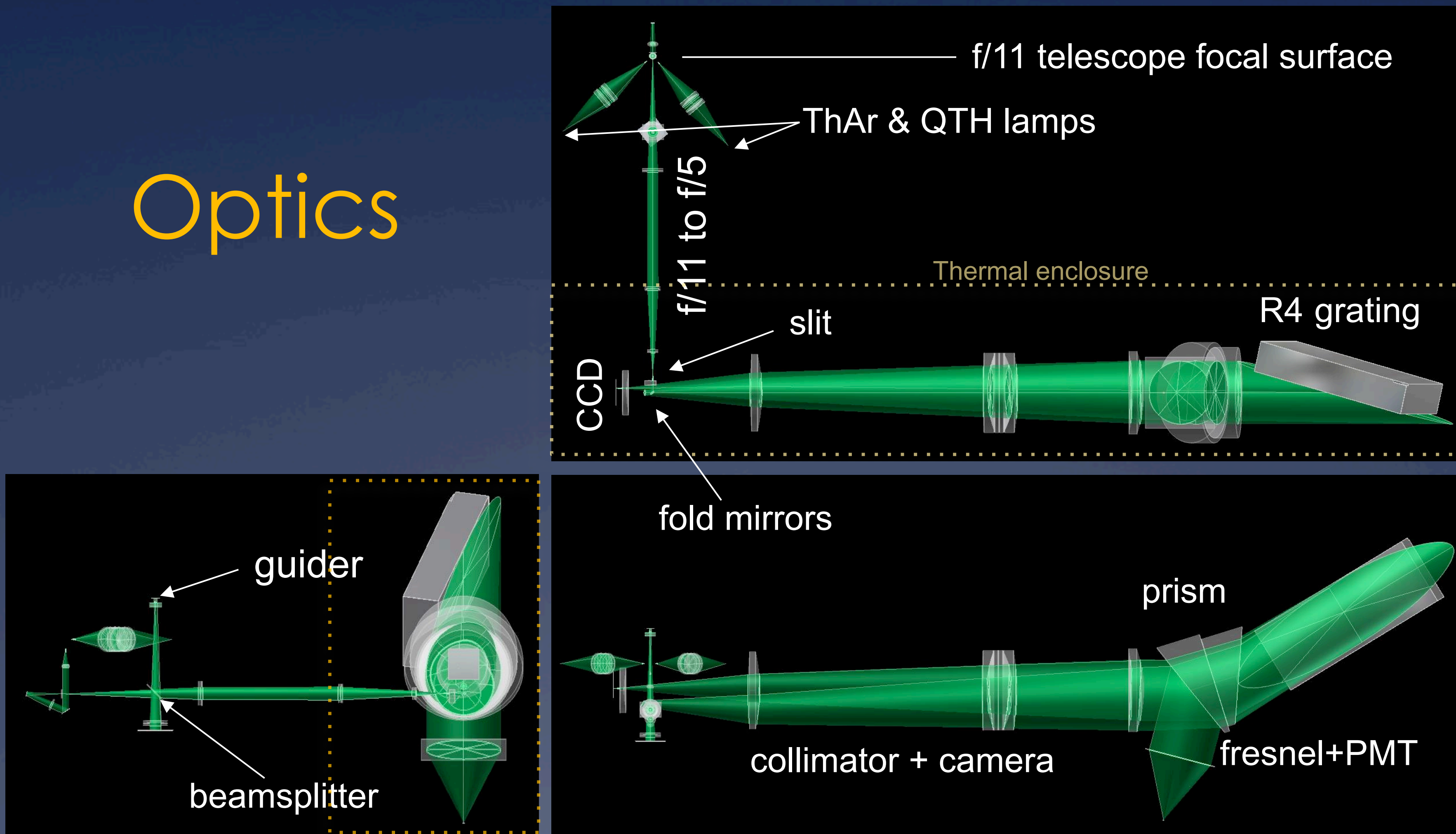
- Mobility required since the nasmyth focus is shared with other instruments

Mechanical Layout



Thermal enclosure removed

Optics



Calibration lamp system enabled in configuration shown

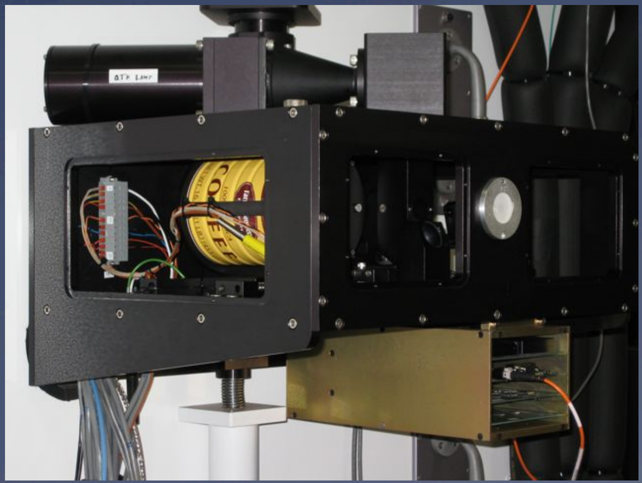
Enhancements

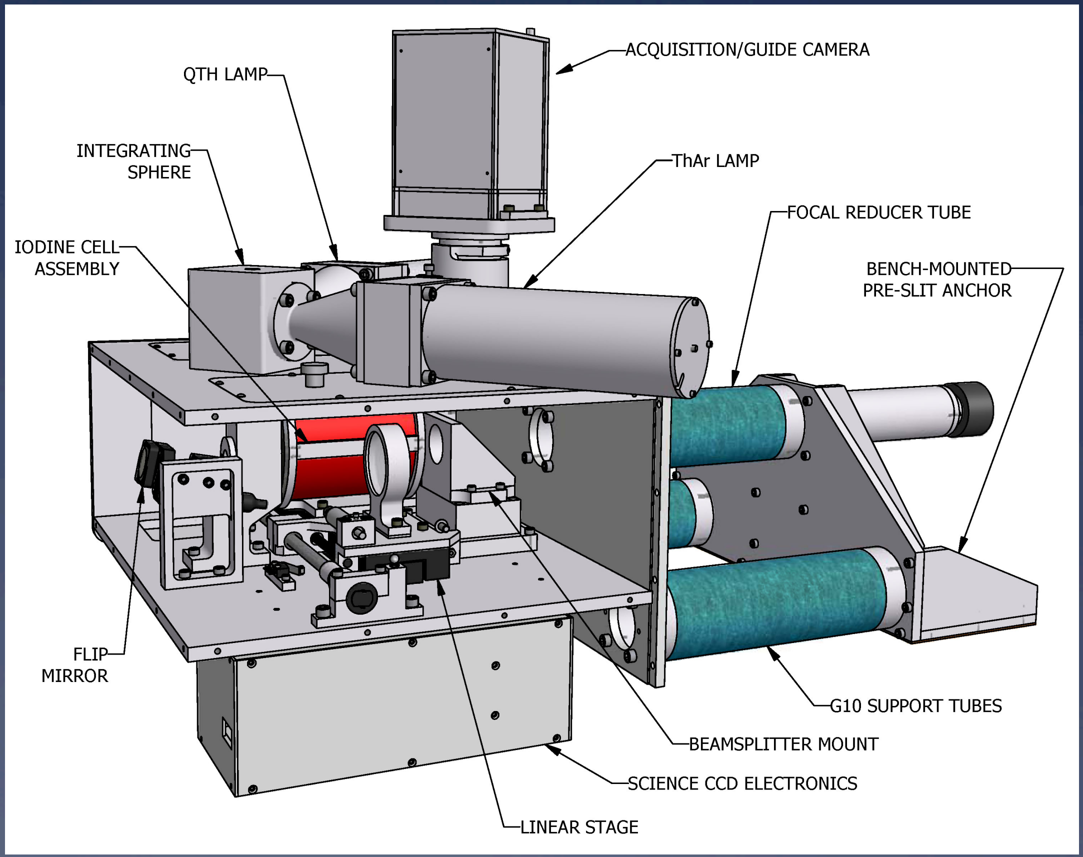
High dispersion, good optics, and the iodine cell are primarily responsible for enabling good velocity precision with PFS.

What else can we do to improve RV precision? A few ideas…

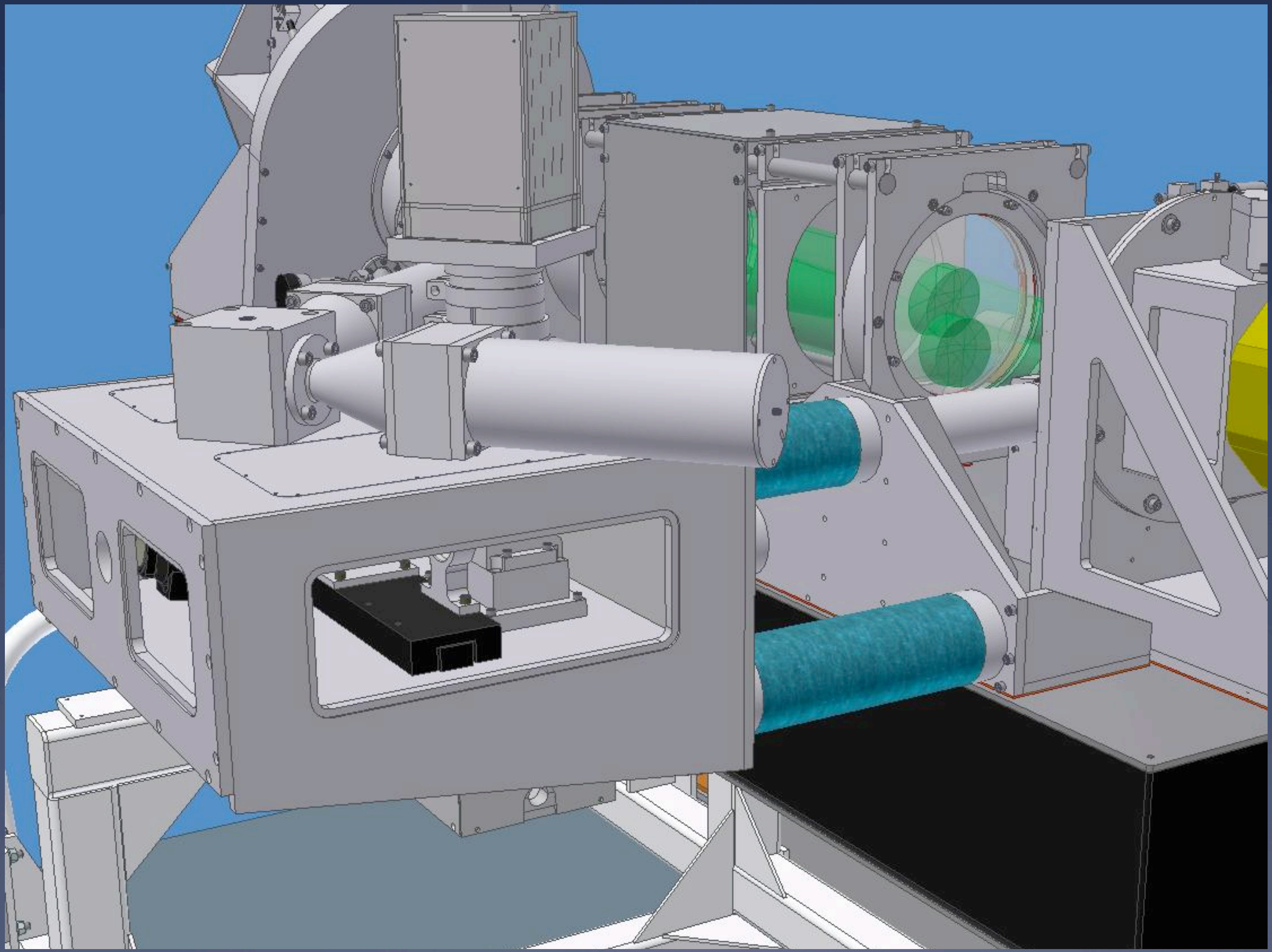
1. Maintain even pupil illumination through active, on-slit focus and guiding

Pre-Slit Assembly

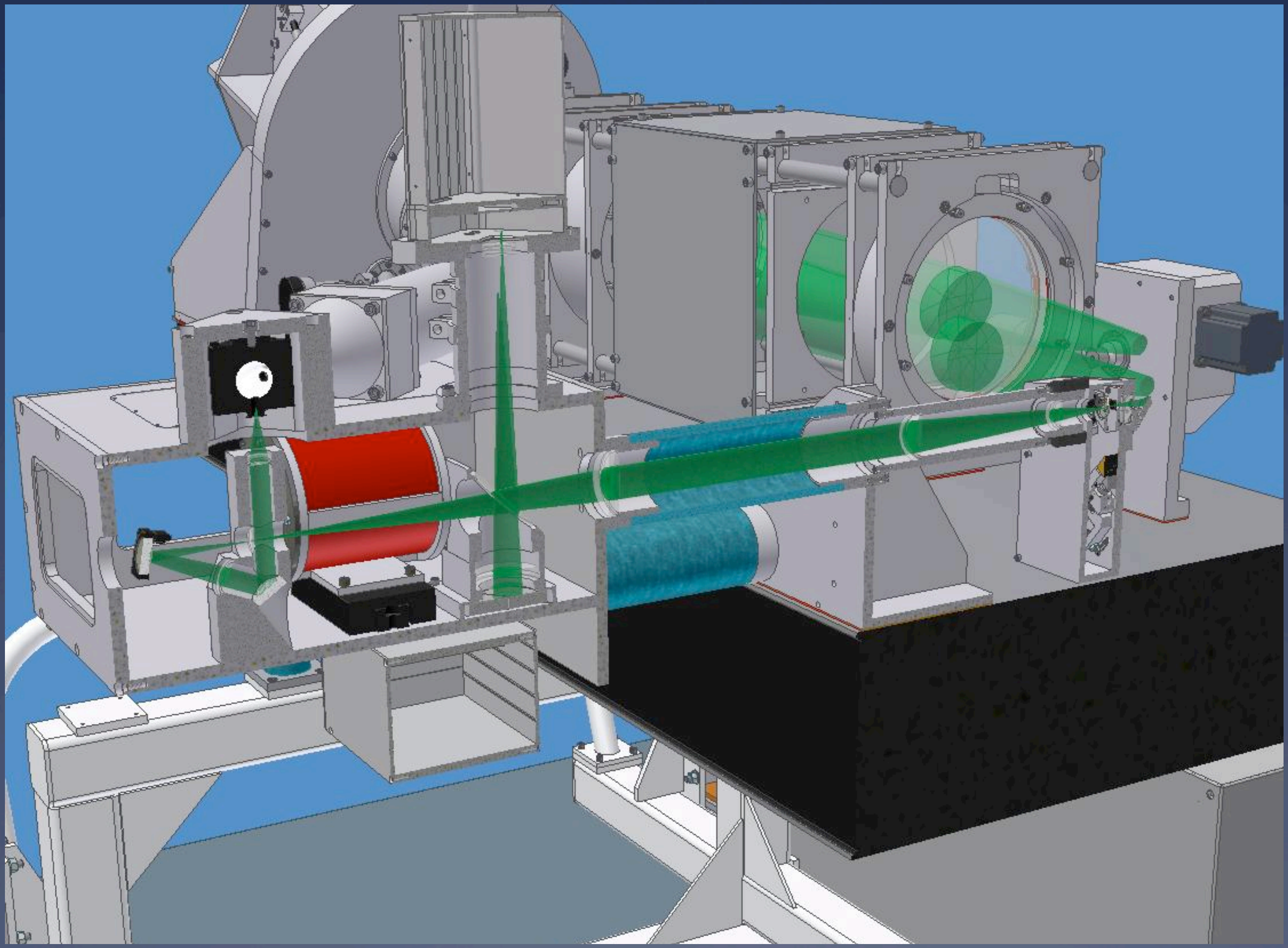




Pre-Slit Assembly

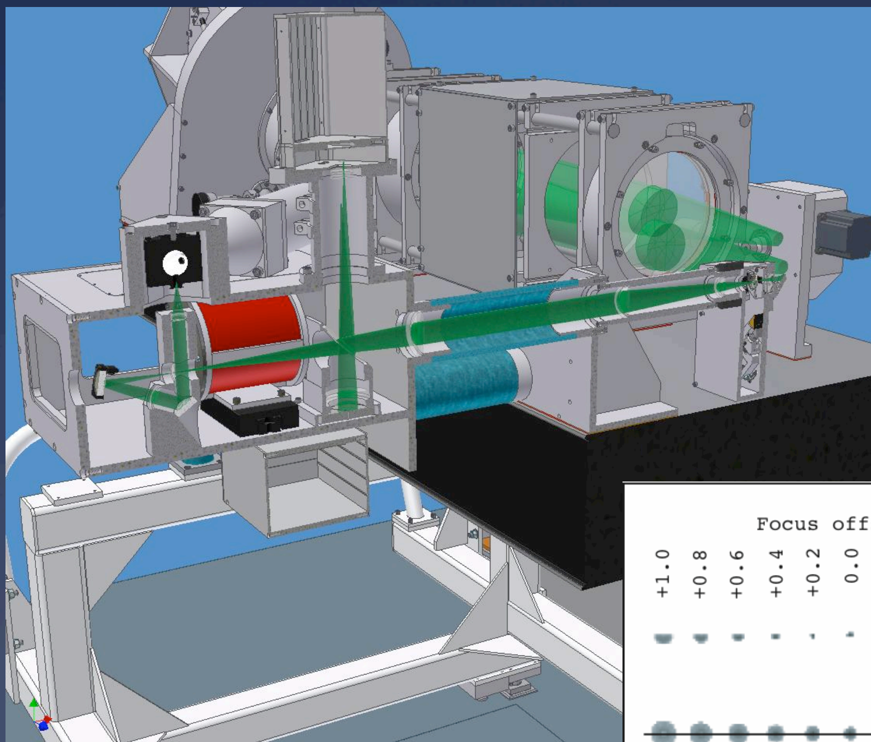


Pre-Slit Optical Path

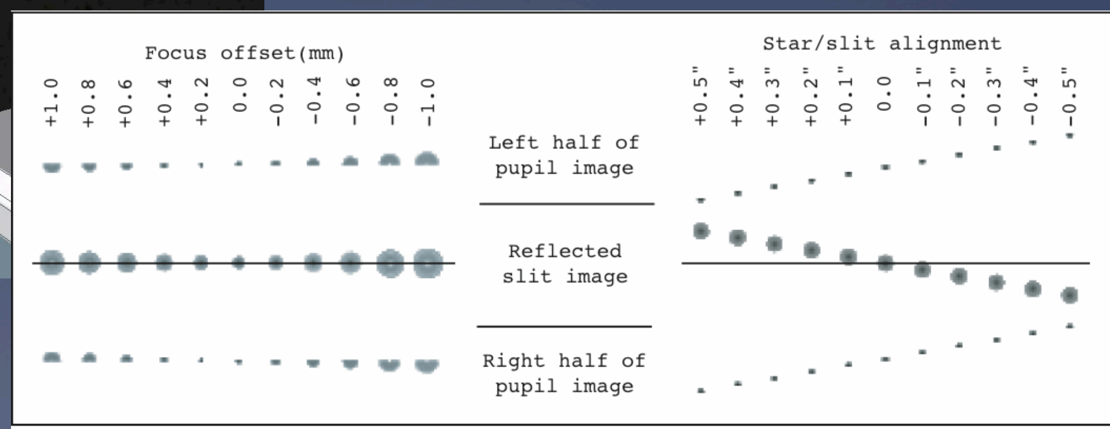


Beamsplitter enables two optical paths necessary for on-slit guiding and focus.

On-slit Guiding and Focus

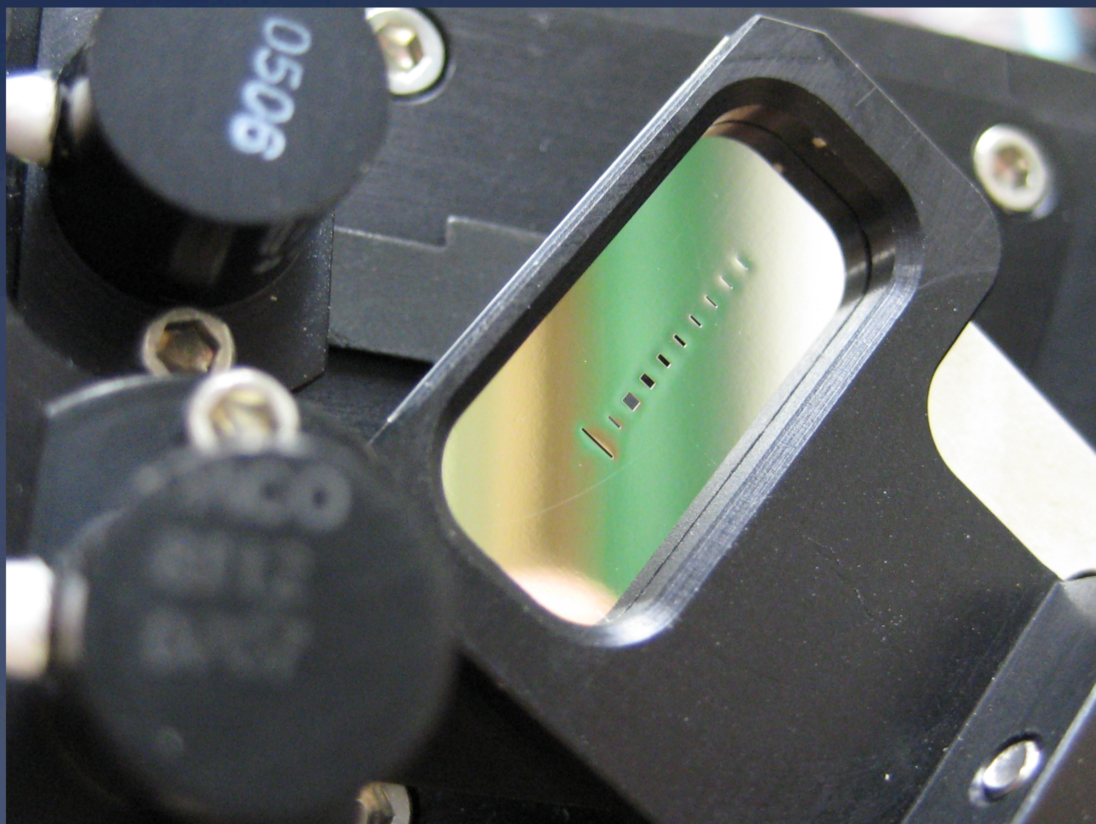


Separation and lateral motion of pupil half images diagnostic of focus and centering



* System not yet implemented

Slit mask



Aperture	R
⌀ 0.3"	N/A
0.3 x 2.5"	127,000
0.5 x 2.5"	76,000
0.7 x 2.5"	54,000
0.7 x 3.9"	N/A
0.2 x 3.7"	190,000
0.3 x 3.7"	127,000
0.5 x 3.7"	76,000
0.7 x 3.7"	54,000
1.0 x 3.7"	38,000
3.0 x 3.7"	N/A
0.7 x 10"	N/A

Enhancements

High dispersion, good optics, and the iodine cell are primarily responsible for enabling good velocity precision with PFS.

What else can we do to improve RV precision? A few ideas…

1. Maintain even pupil illumination through active, on-slit focus and guiding

2. Enclose the grating in vacuum – a compromise vs. whole-instrument vacuum

Disperser Assembly

- Cross-dispersing prism
- R4 grating in quasi-Littrow configuration
- Grating enclosed in medium vacuum (~10^{-4} mbar)

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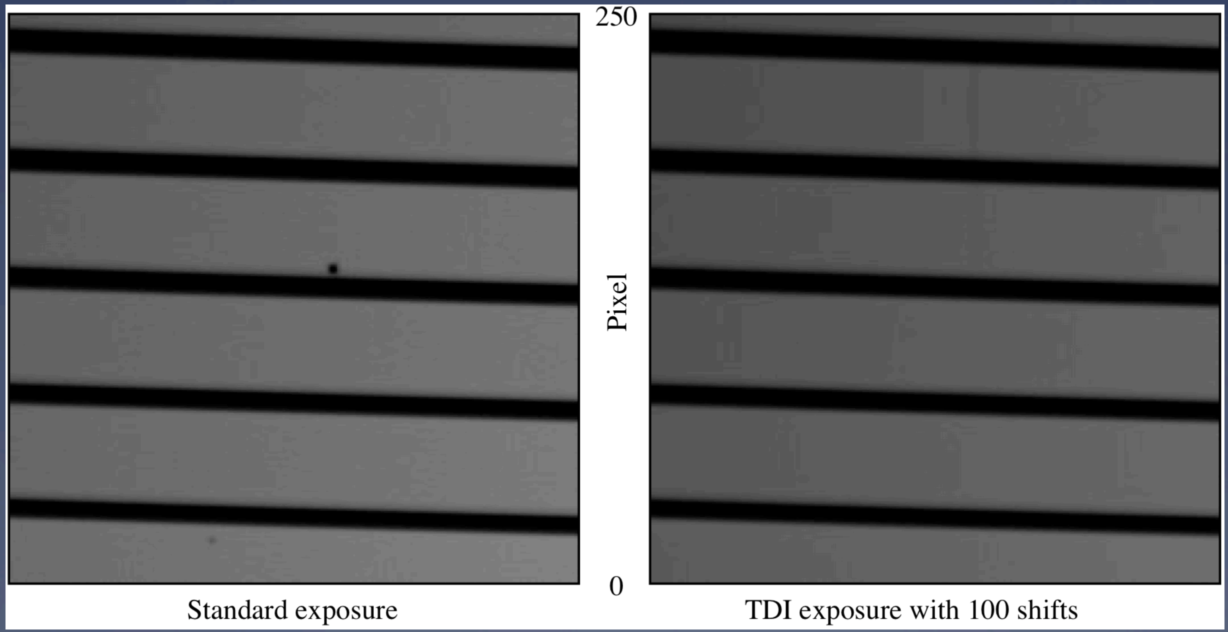
2. Enclose the grating in vacuum – a compromise vs. whole-instrument vacuum

3. Minimize sub-pixel level errors using Time Delayed Integration (TDI)

Time Delayed Integration (TDI)

- 1 m/s corresponds to about 1/1000th pixel
- Attempt to minimize errors due to sub-pixel defects by averaging them down
- During exposure, shift charge 100 times while shifting CCD in other direction
- Each image pixel is made from combination of 100 detector pixels

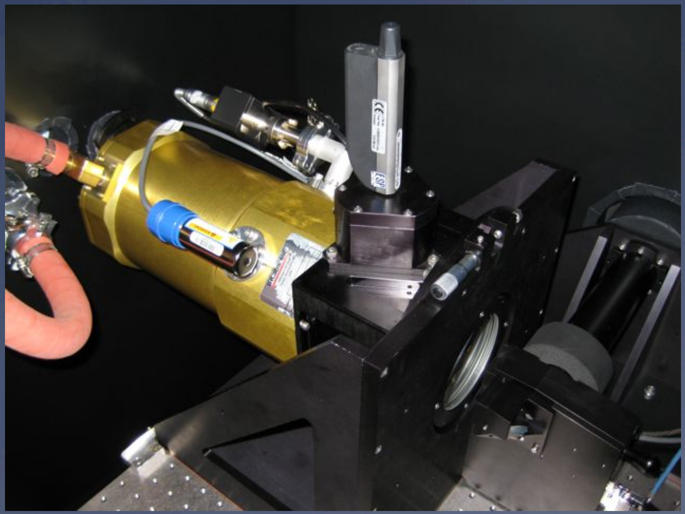


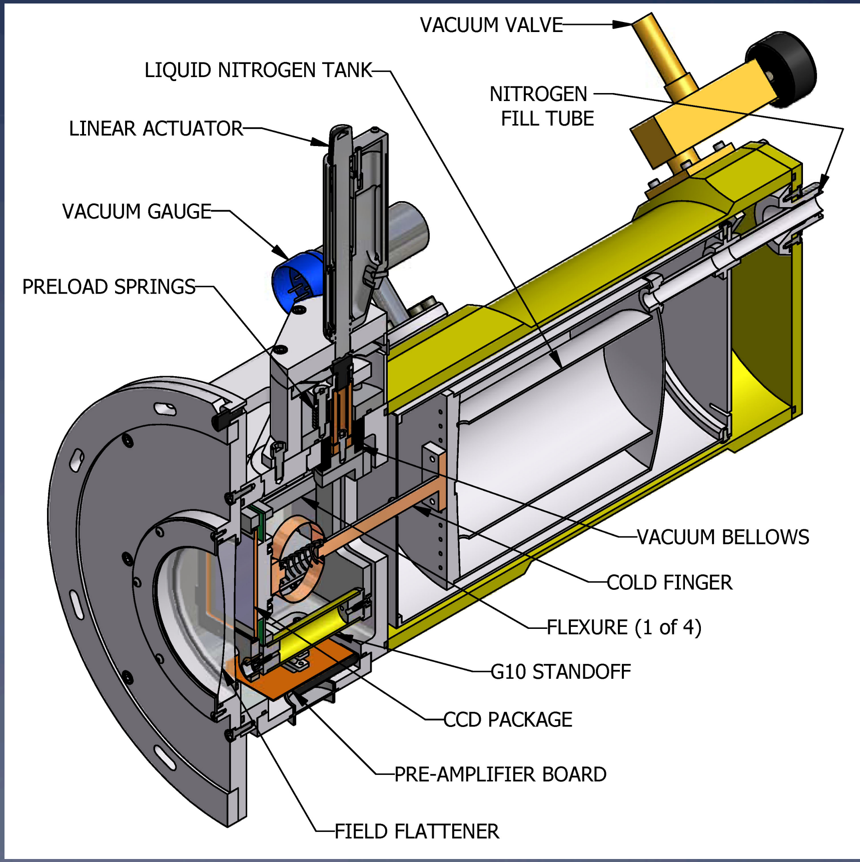
CCD Camera

4K x 4K x 15 micron pixels

0.1 arcsec/pixel

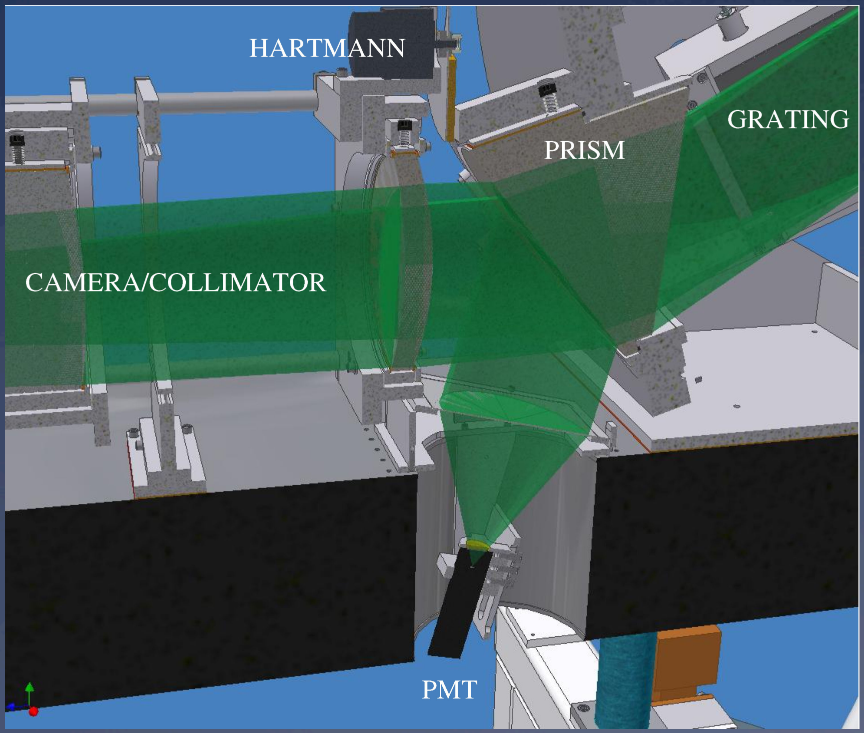
Flexure-mounted to allow TDI

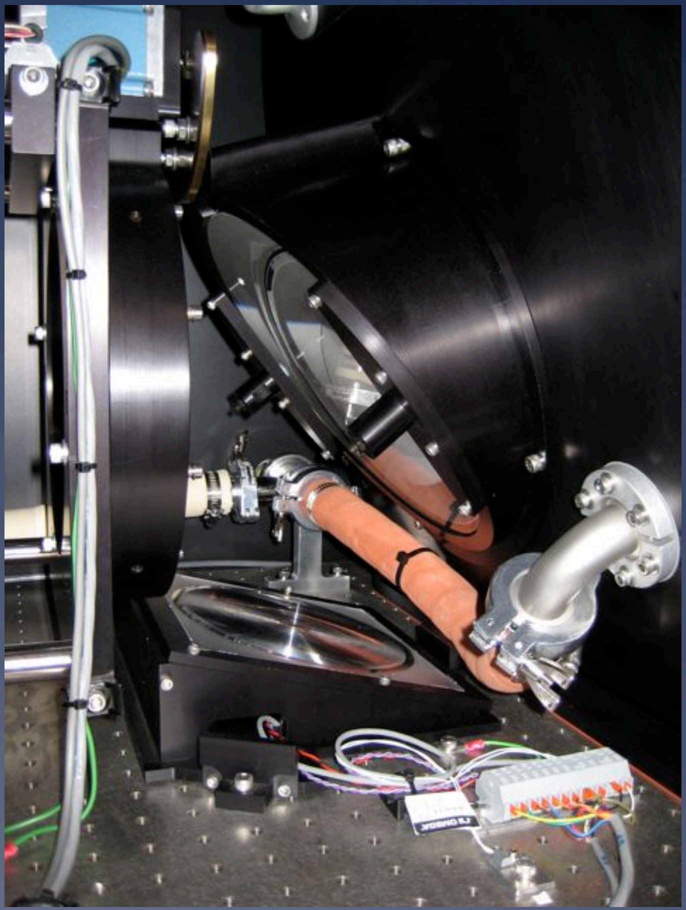




Exposure Meter

Reflection from prism feeds a photomultiplier package behind fresnel





Exposure monitor required for TDI control and calculation of weighted exposure center

Enhancements

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1. Maintain even pupil illumination through active, on-slit focus and guiding

2. Enclose the grating in vacuum – a compromise vs. whole-instrument vacuum

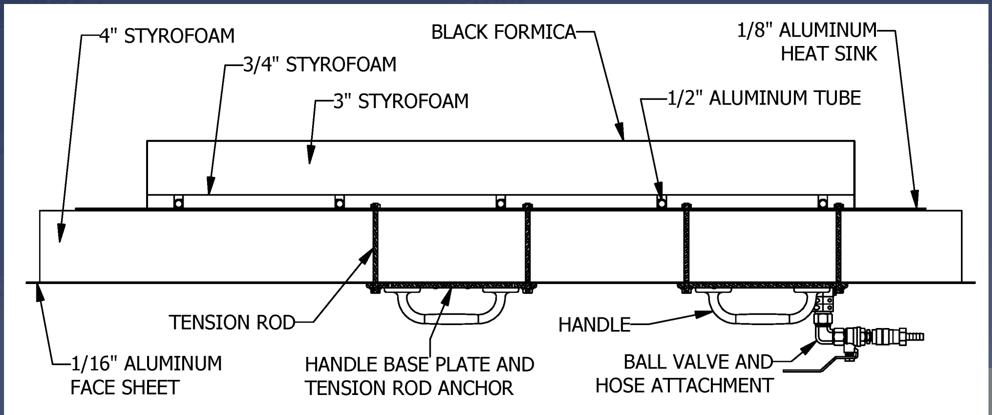
3. Minimize sub-pixel level errors using TDI

4. Stabilize temperature, or at least dampen temperature changes

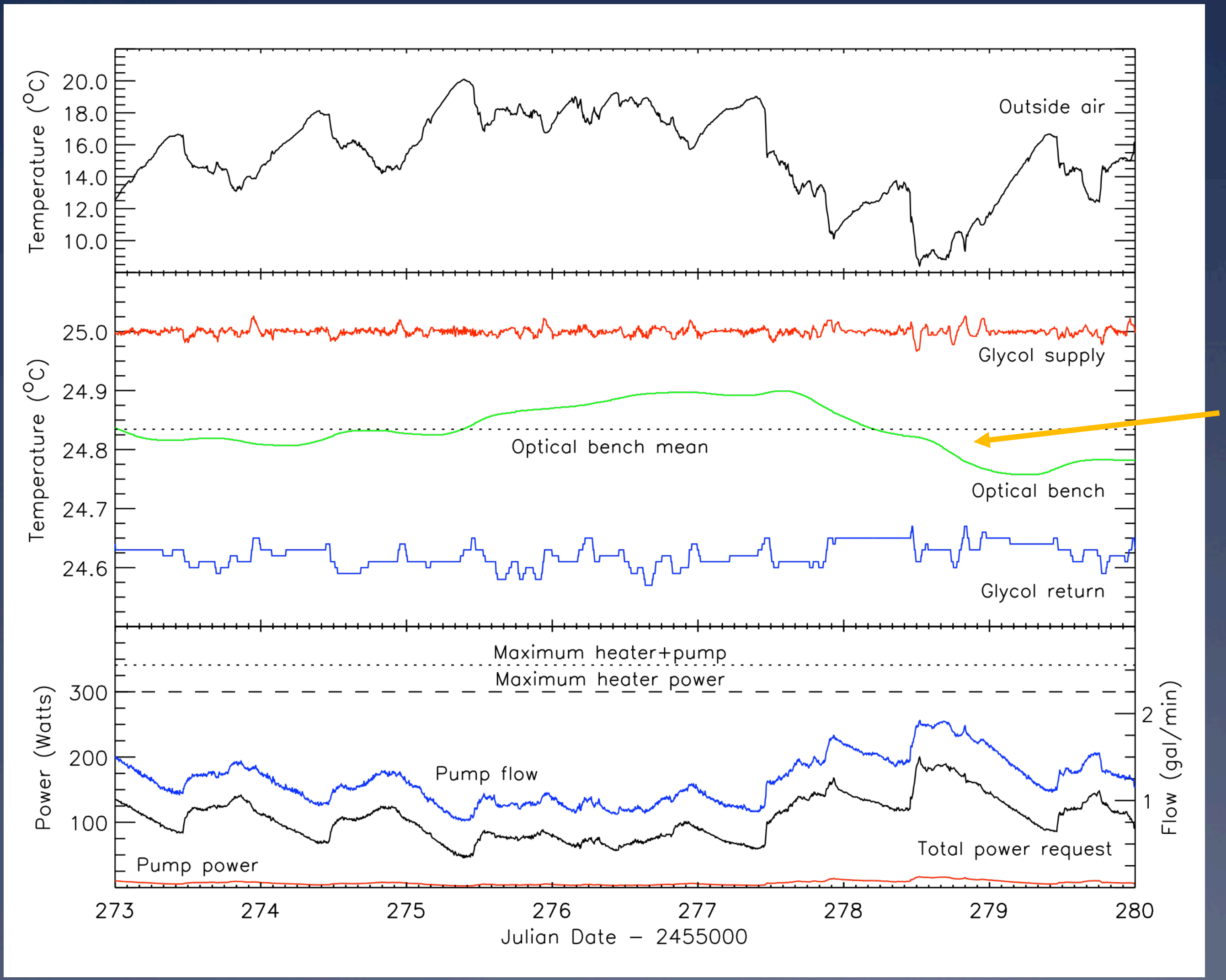
Thermal control

Instrument sees a 25°C isothermal box around it.

- Metal plates embedded in foam enclosure
- Closed-loop, re-circulating glycol solution



Thermal Control - Performance



Current stability:

0.03°C RMS

Heat required:

11-13 W/°C difference between 25°C and outside T

Enhancements

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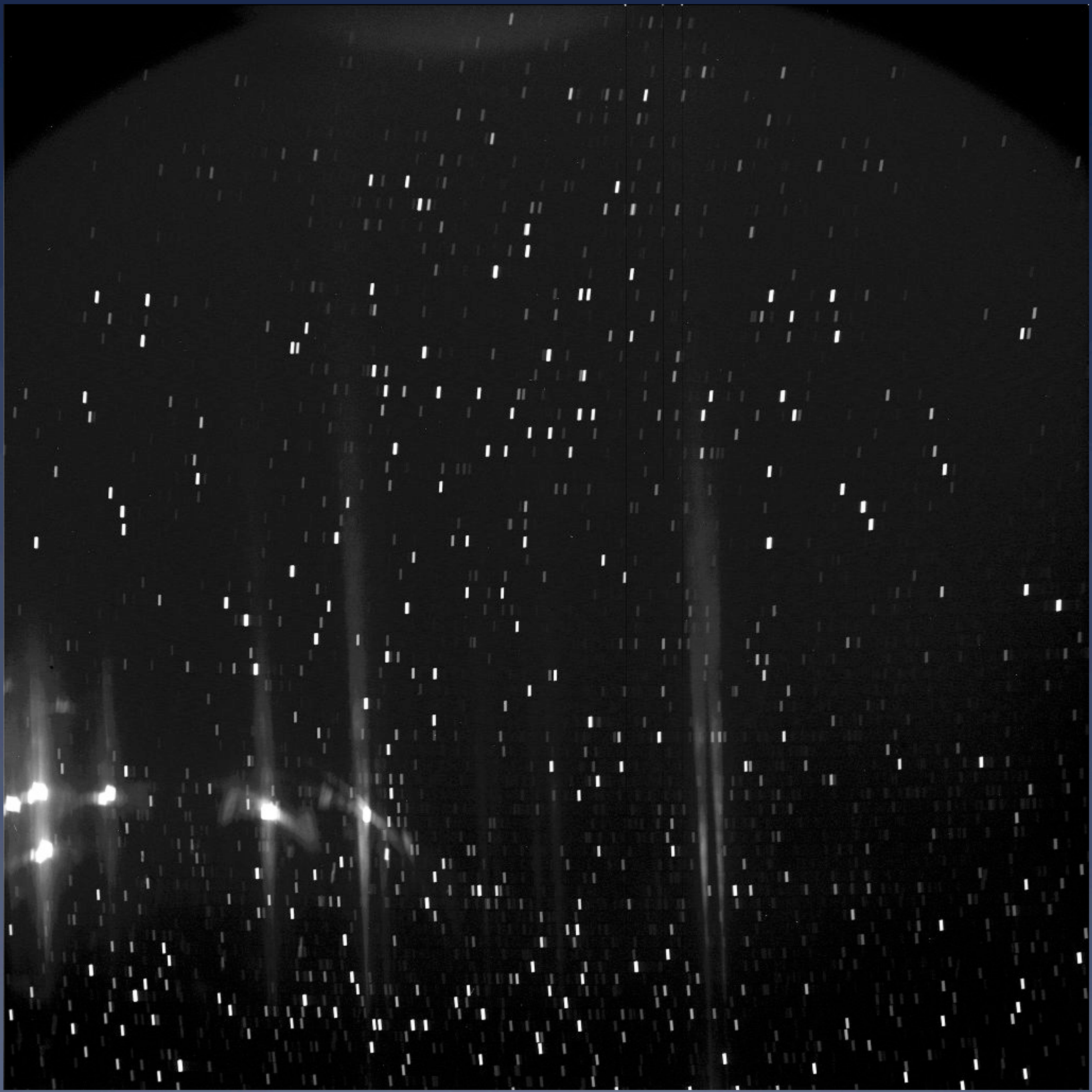
What else can we do to improve RV precision? A few ideas…

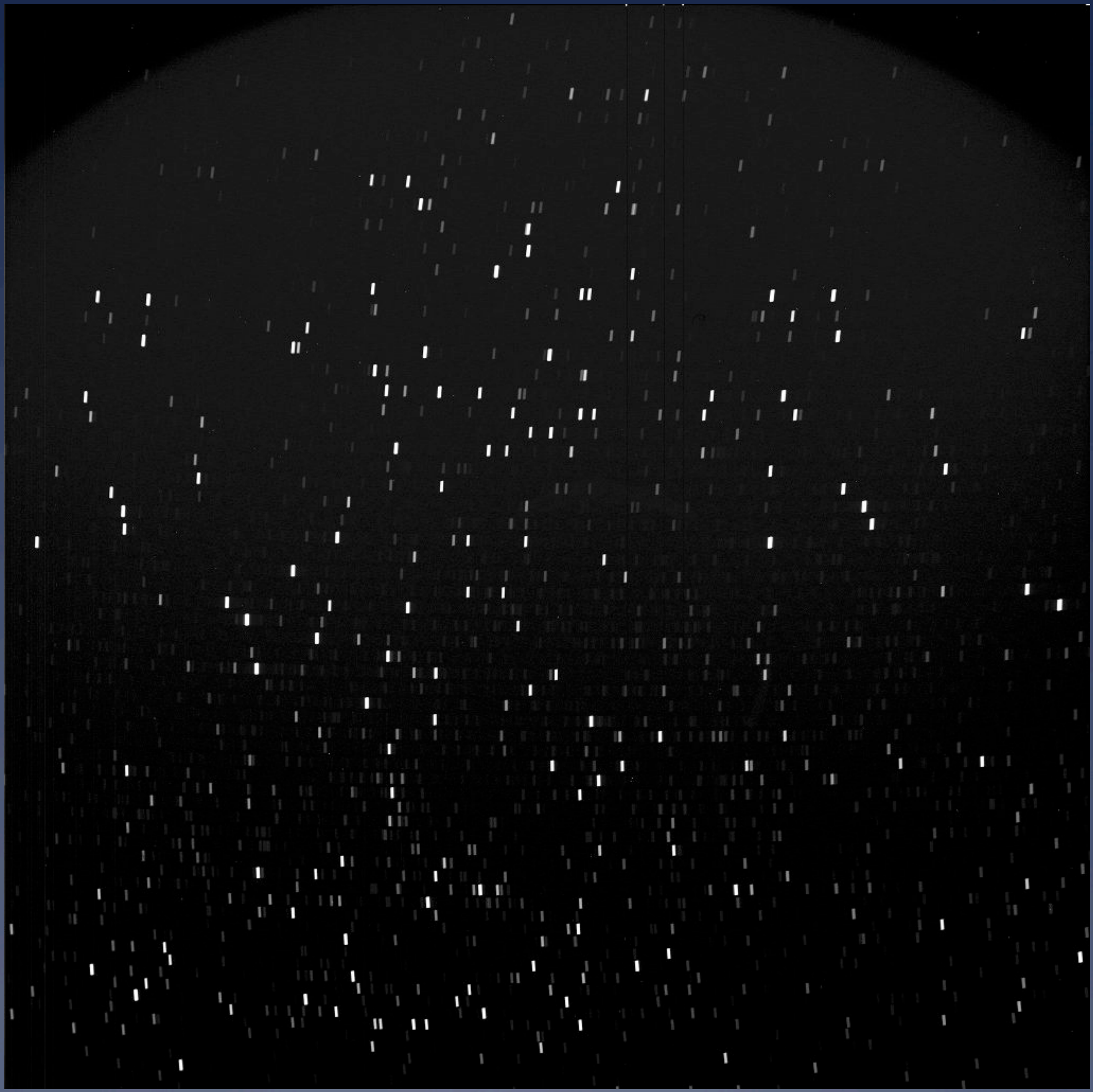
1. Maintain even pupil illumination through active, on-slit focus and guiding
2. Enclose the grating in vacuum – a compromise vs. whole-instrument vacuum
3. Minimize sub-pixel level errors using TDI
4. Stabilize temperature, or at least dampen temperature changes
5. Minimize scattered light through filtering

Early in-lab
ThAr exposure



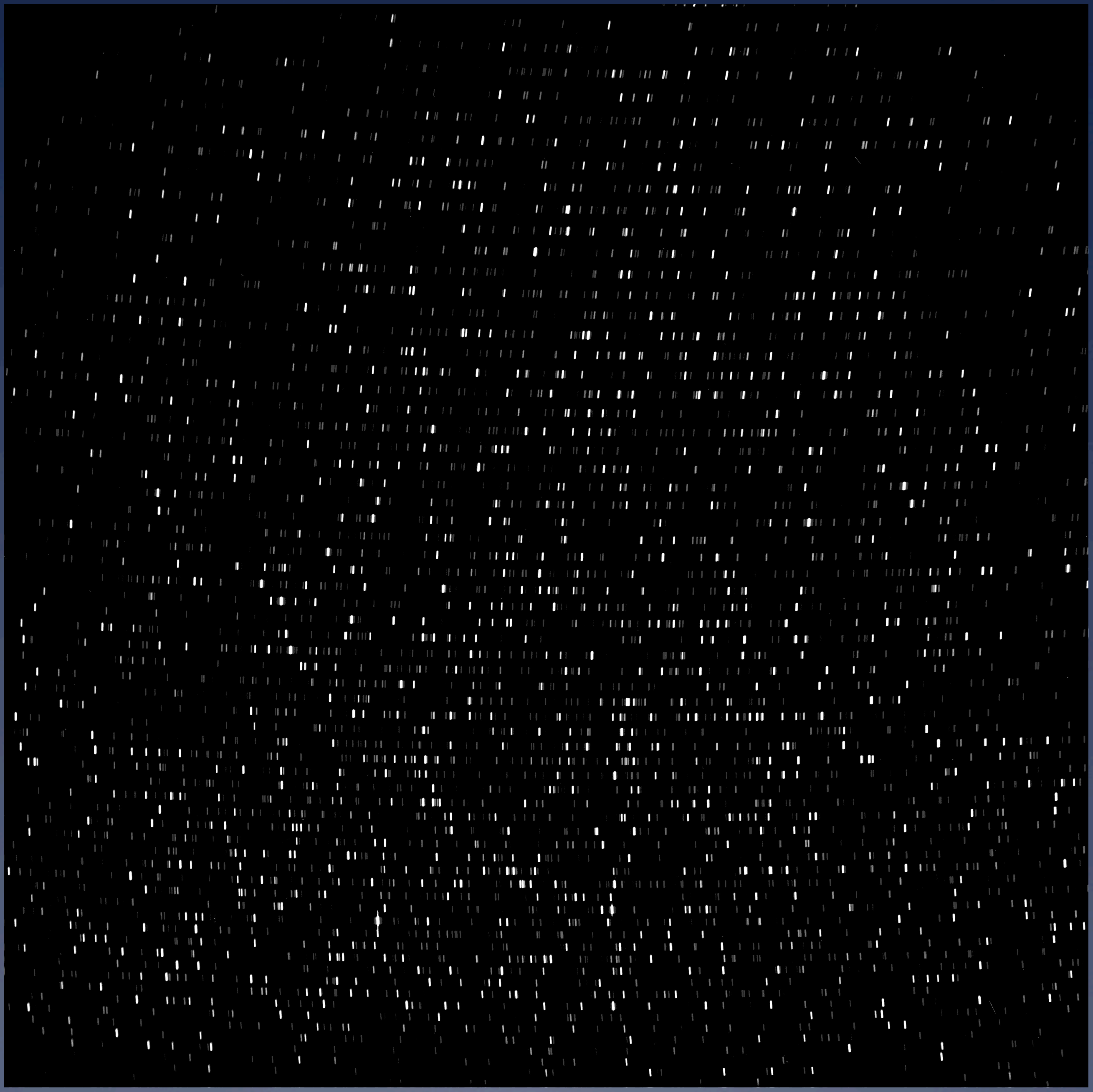
Lots of scattered light from bright red Argon emission lines

ThAr exposure
after introduction
of BG-38 filter



Scattered light
suppressed

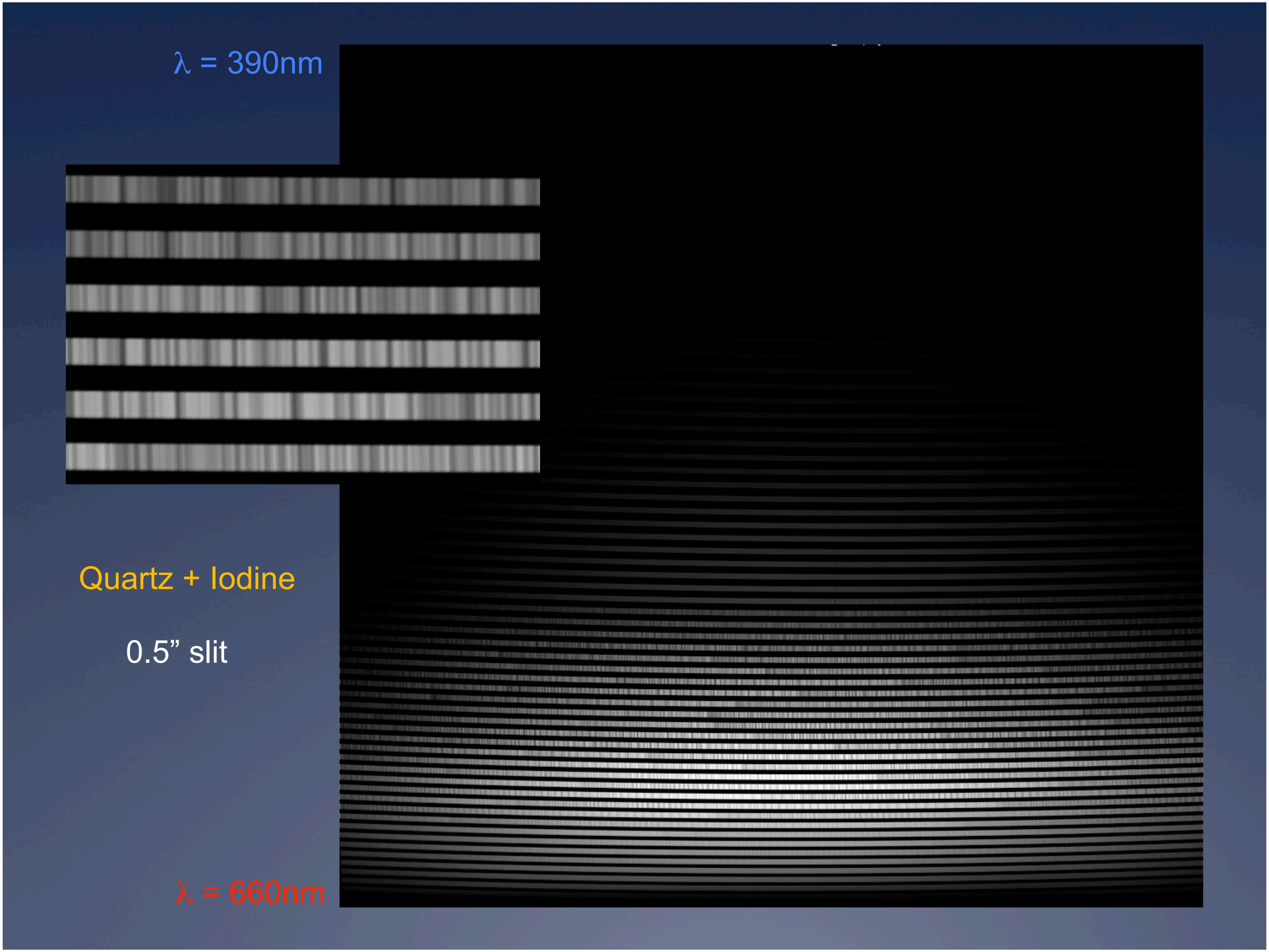
λ = 390nm



ThAr spectrum today

0.5” slit

λ = 660nm

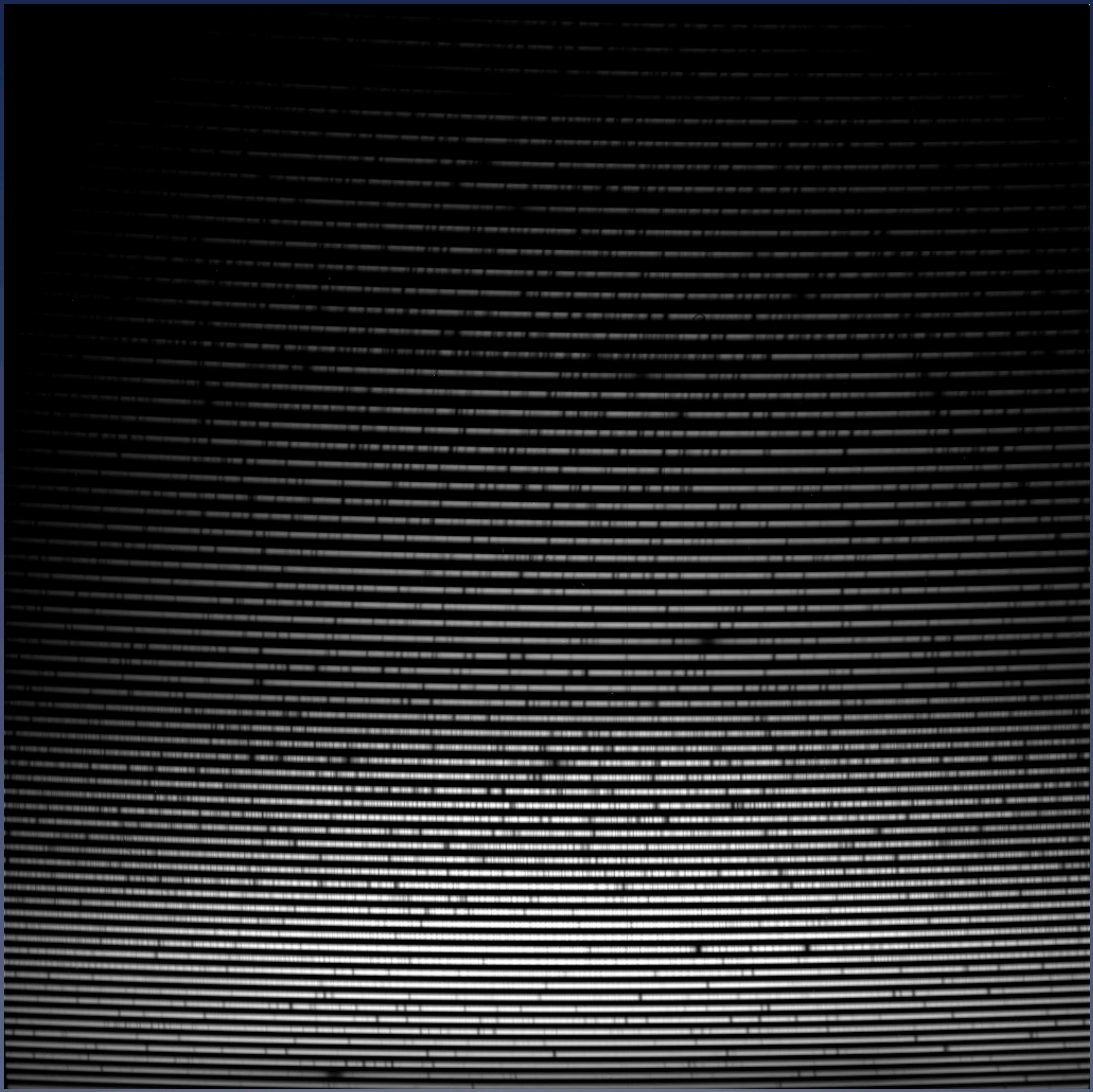


λ = 390nm
Quartz + Iodine
0.5” slit
λ = 660nm

λ = 390nm

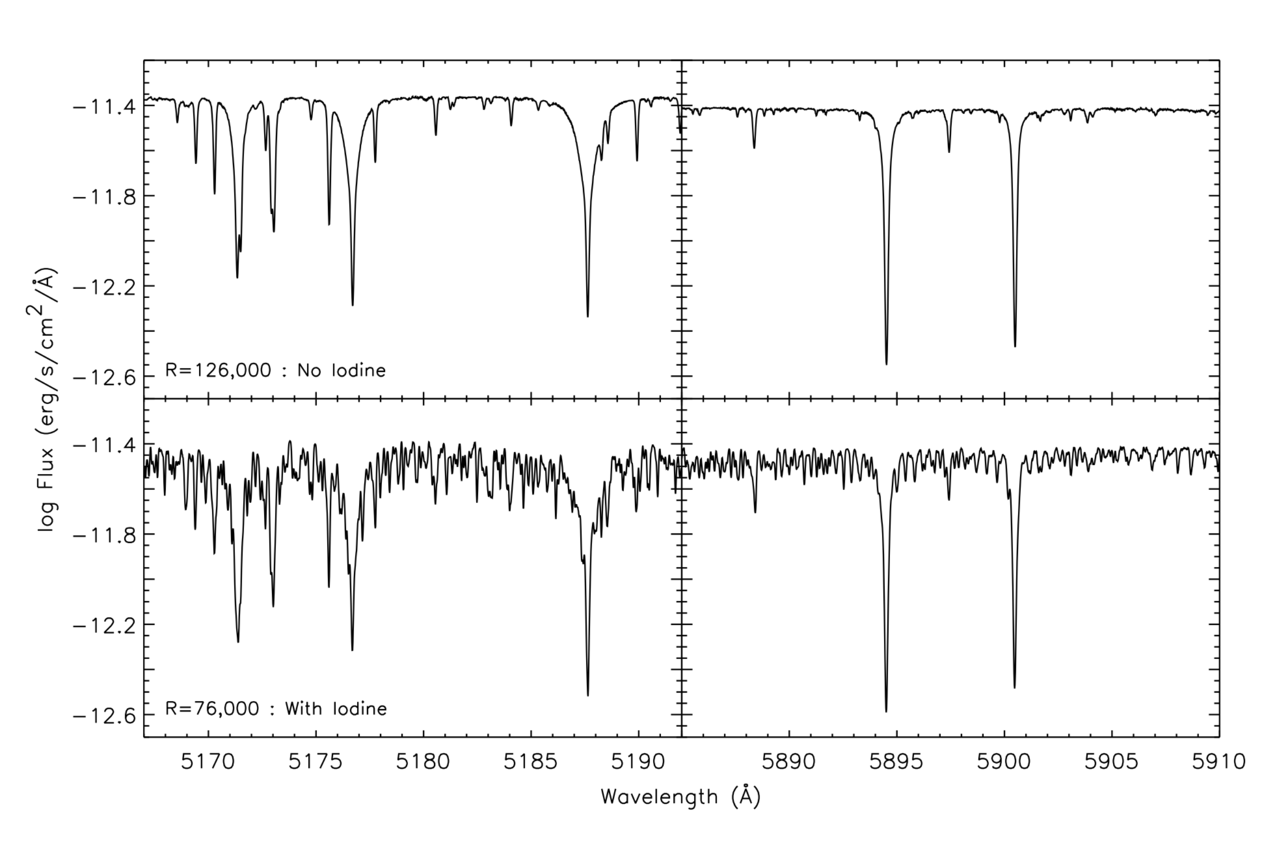
Program star

0.5” slit

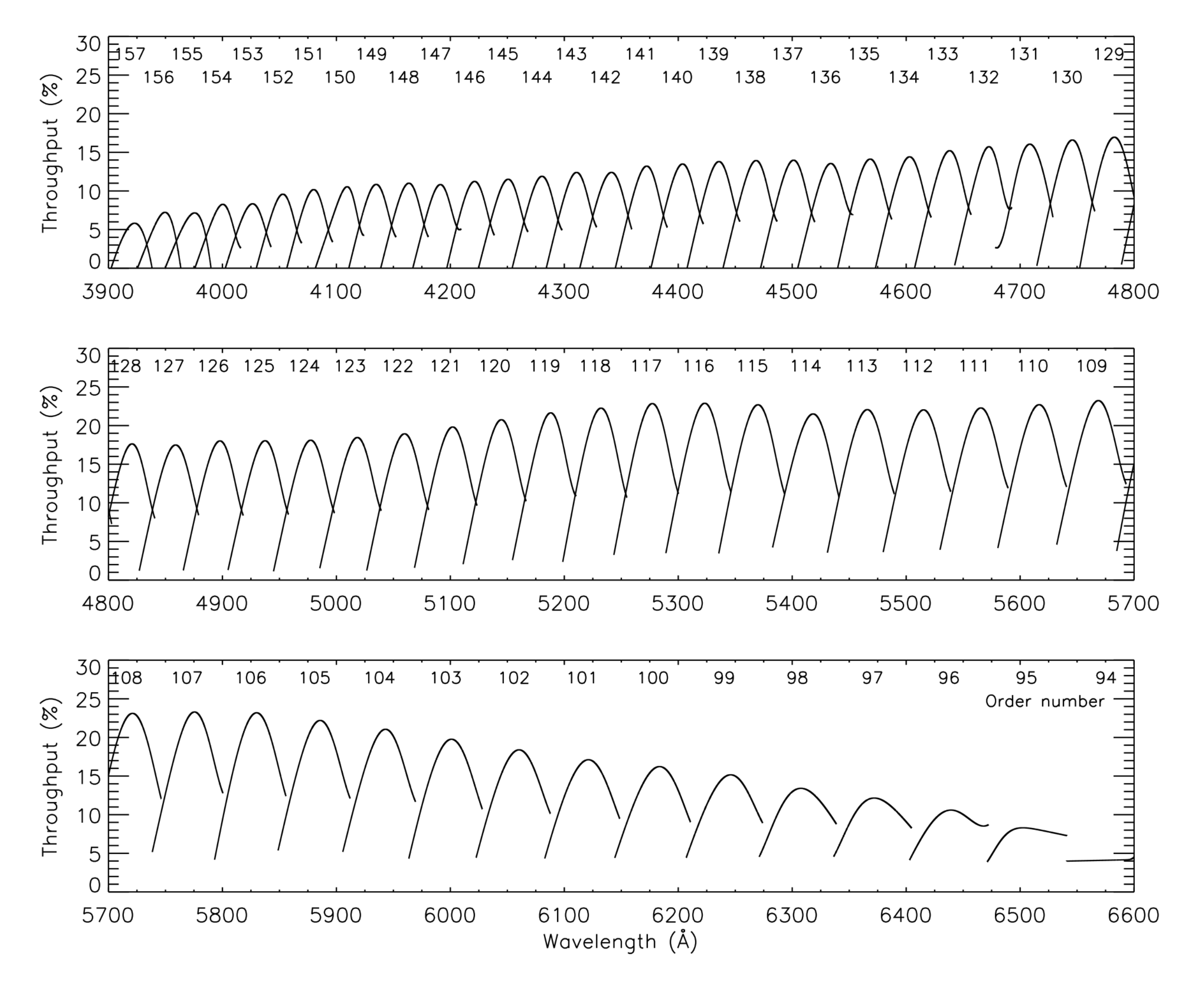


λ = 660nm

Sample Spectrum

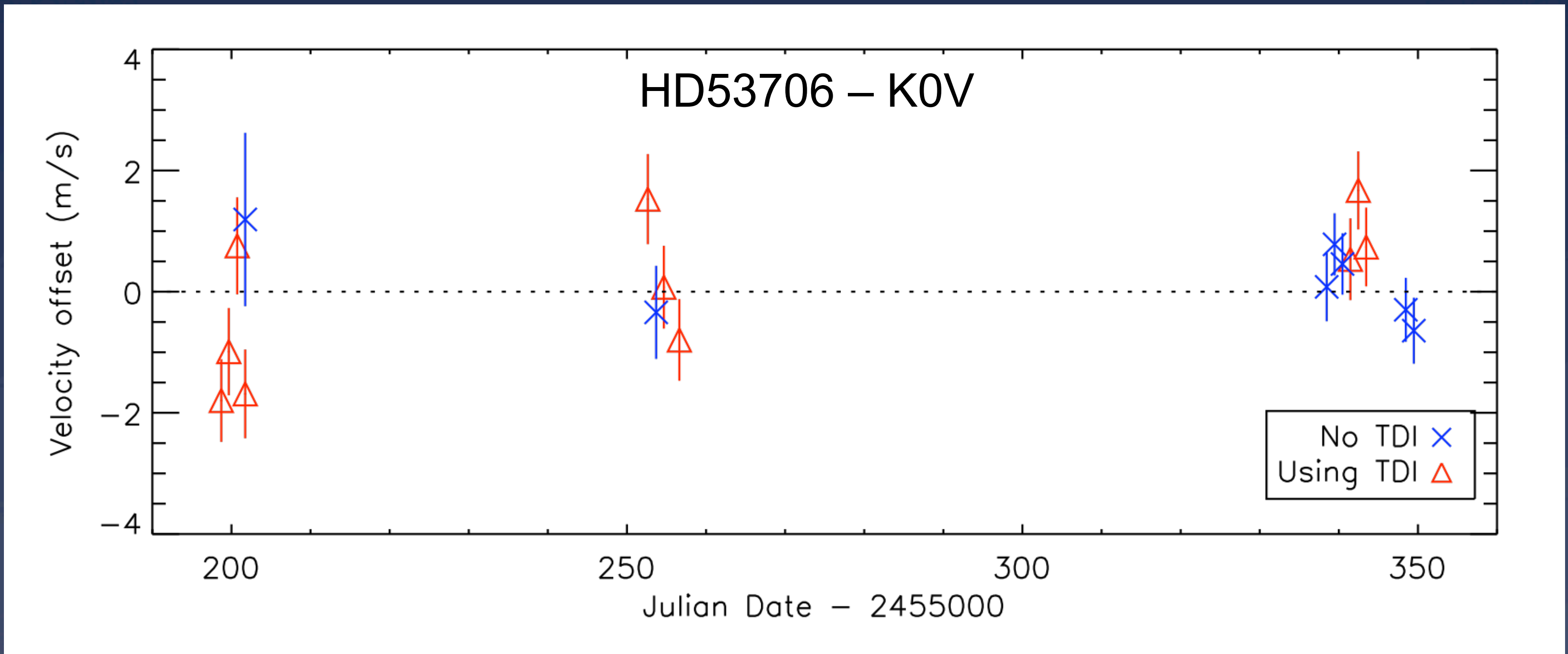


Instrumental Efficiency



Does not include telescope or atmosphere

Velocity Stability



* data points not averaged over P-modes

All measurements: Δv_{RMS} = 1.05 m/s

TDI only: Δv_{RMS} = 1.25 m/s

Non-TDI only: Δv_{RMS} = 0.66 m/s

Observing program

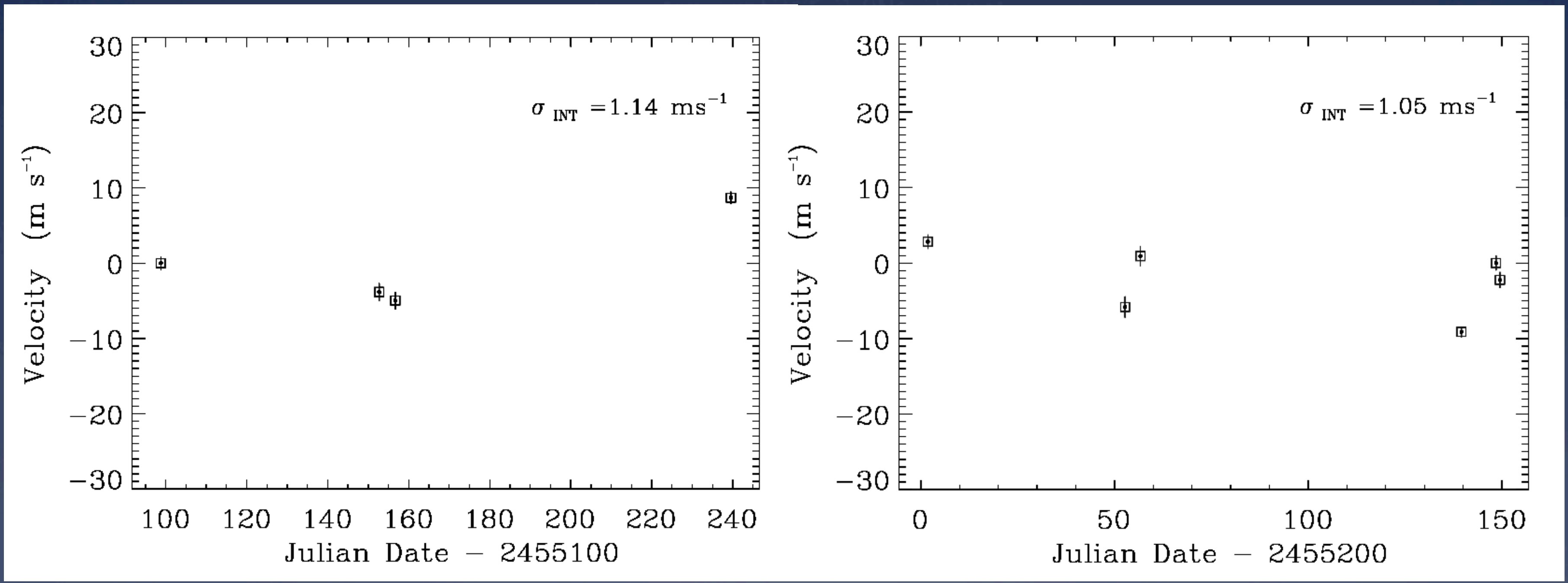
PFS scientific observing began 1 January 2010 and is ramping up to 50-60 nights/year. The program includes:

- About 400 late F, G, and K dwarfs with V<8.5
- About 100 M dwarfs with V<11

Guest Observer programs available through collaboration only. Examples:

- Rossiter-McLaughlin effect in transiting exoplanets
- Cepheid P-factor refinements through studies of changing line profiles
- Stellar population age estimates through Mg isotopic abundances

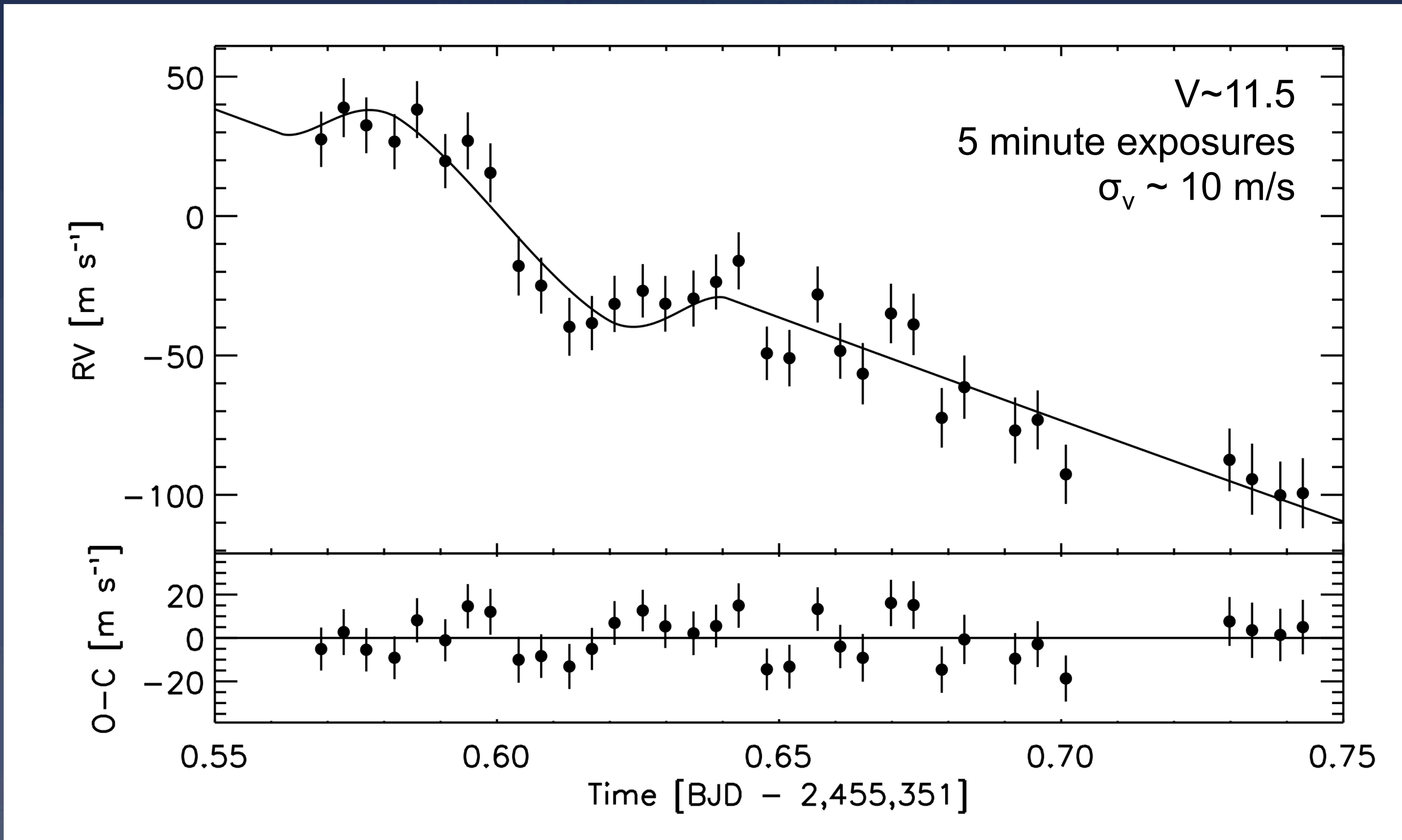
Early Signs of Variability



Example 1

Example 2

Rossiter-McLaughlin Effect



Remaining Work

- Implement on-slit telescope focus and guiding
- Improve thermal control
- Replace CCD
  - Involves building an entirely new camera; may drop TDI
- Improve velocity reduction pipeline