Fiber Scrambling at Lick and Keck Observatory

Julien Spronck
Christian Schwab
Debra Fischer

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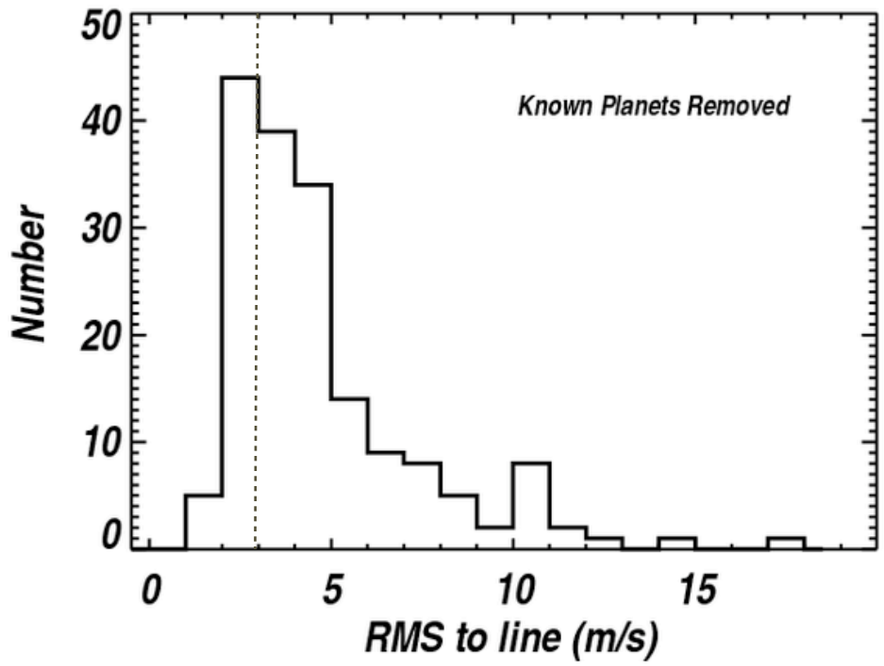
RV Precision / Noise

Keck/HIRES



Eta-Earth Survey stars
GKM
Chromospherically quiet
~10-100 observations each

HARPS

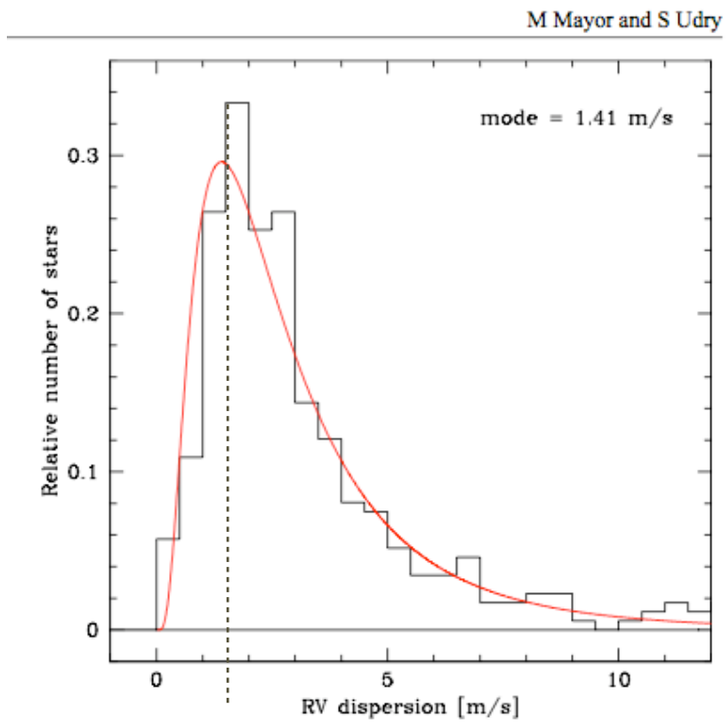
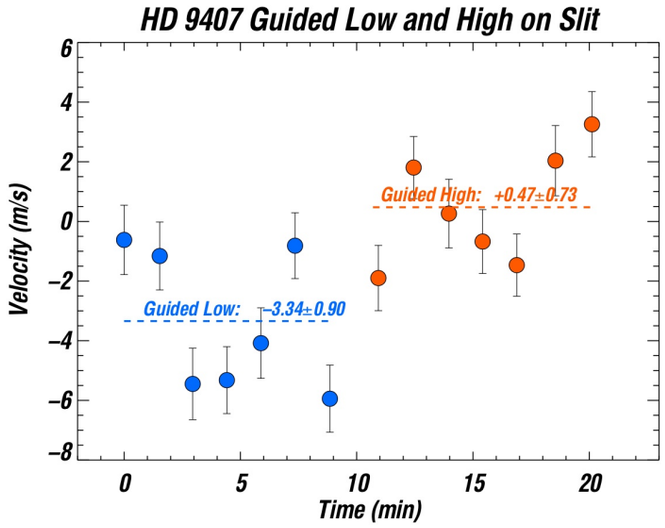


Figure 2. Histogram of radial-velocity rms for the stars in the high-precision HARPS subprogramme aiming at detecting very low-mass planets. Part of the 'large' rms observed in the tail of the distribution results from stellar activity or from still undetected planetary systems.

Mayor and Udry, 2008,
Phys. Scr. T130, 014010

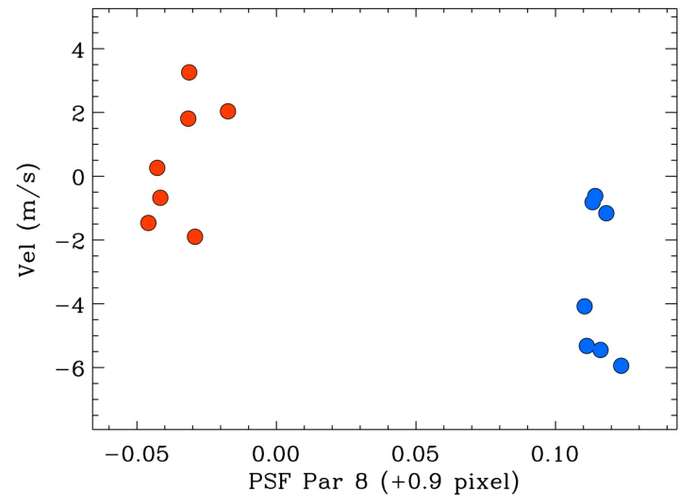
Courtesy A. Howard

What can cause PSF variations on time scales of minutes?



Courtesy G. Marcy

Derived Doppler velocities of HD 9407 for the seven images guided low (left) and guided high (right). The velocities systematically changed by 3.8 meters/sec, caused by guiding 0.3 arcsec low and high, and putting the telescope out of focus by -0.15 mm

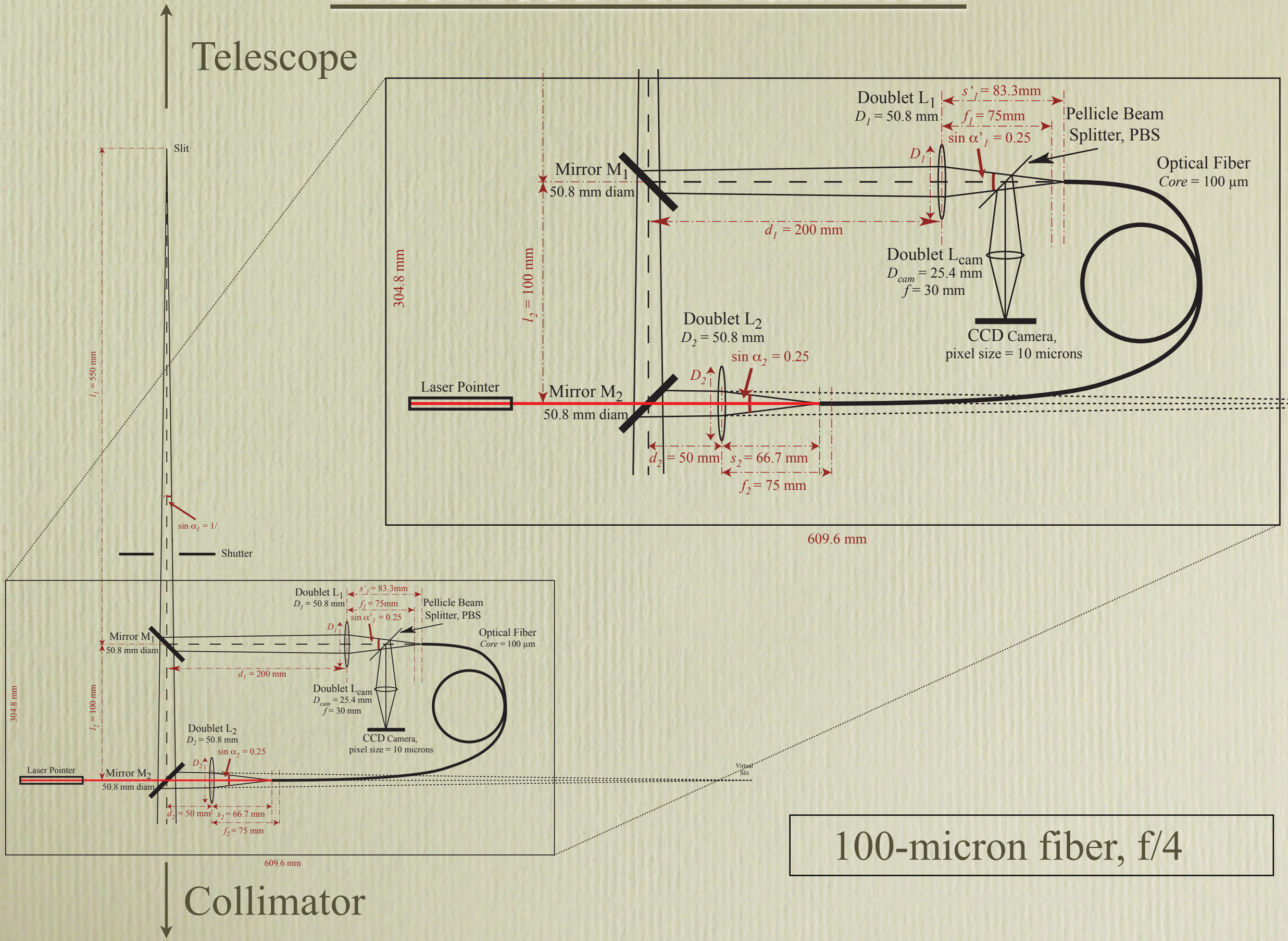


Courtesy G. Marcy

Measured velocity vs PSF Parameter #8. The PSF clearly varied with guiding location of the star. The velocities are systematically high when PSF#8 is low, and the velocities are low when PSF#8 is high. The dots colored red and blue were taken with the telescope guided high and low, respectively. Both sets were taken with the telescope out of focus by -0.15 mm.

Fiber feed for Hamilton

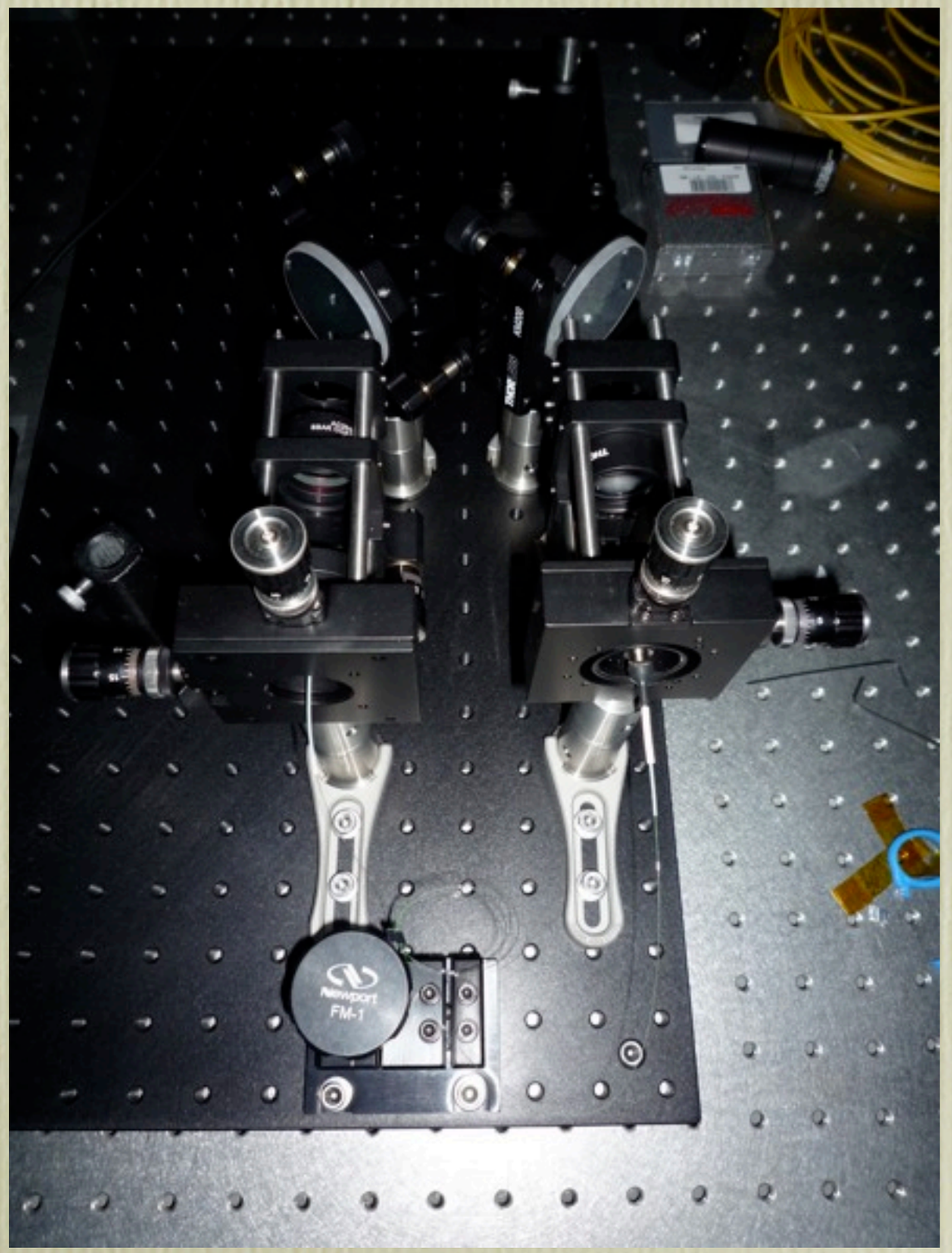
Telescope

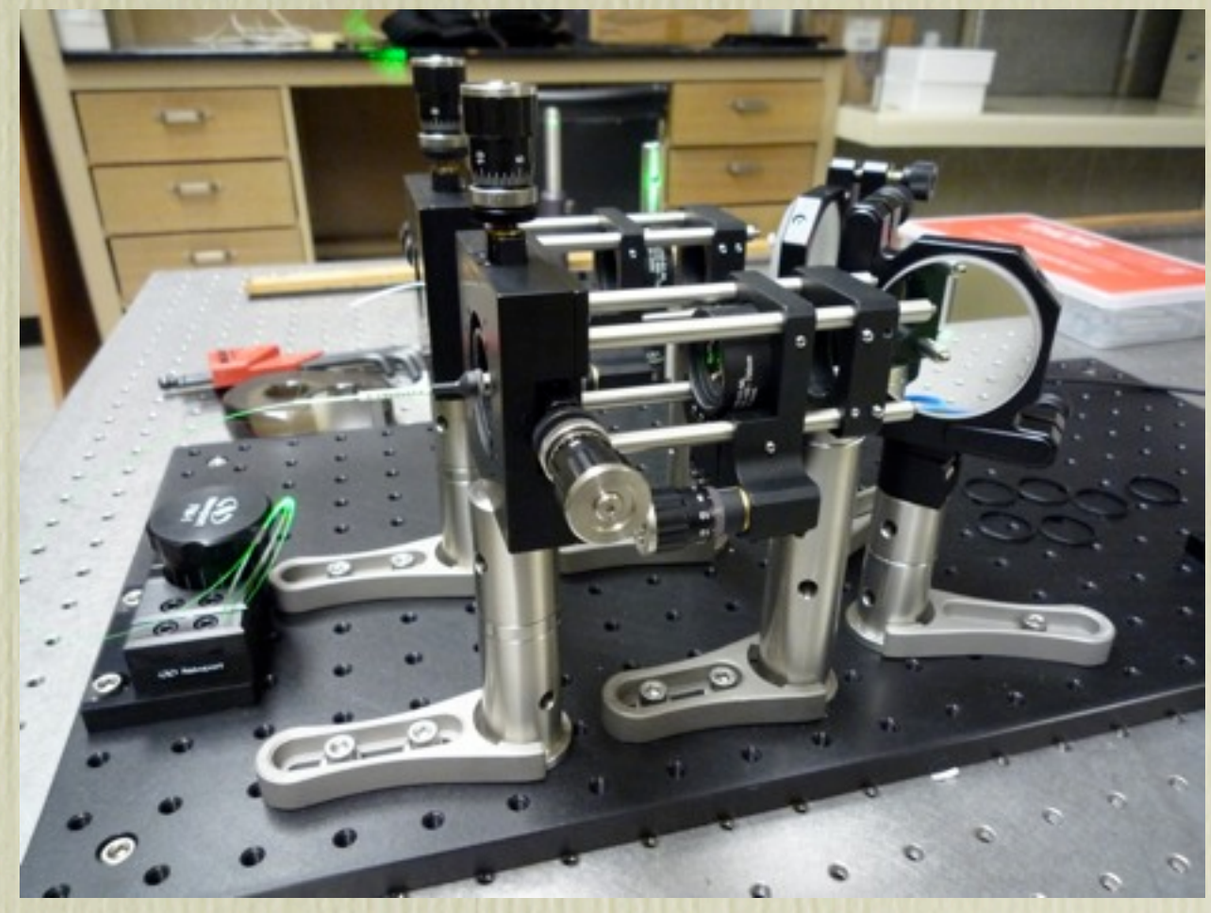


100-micron fiber, f/4

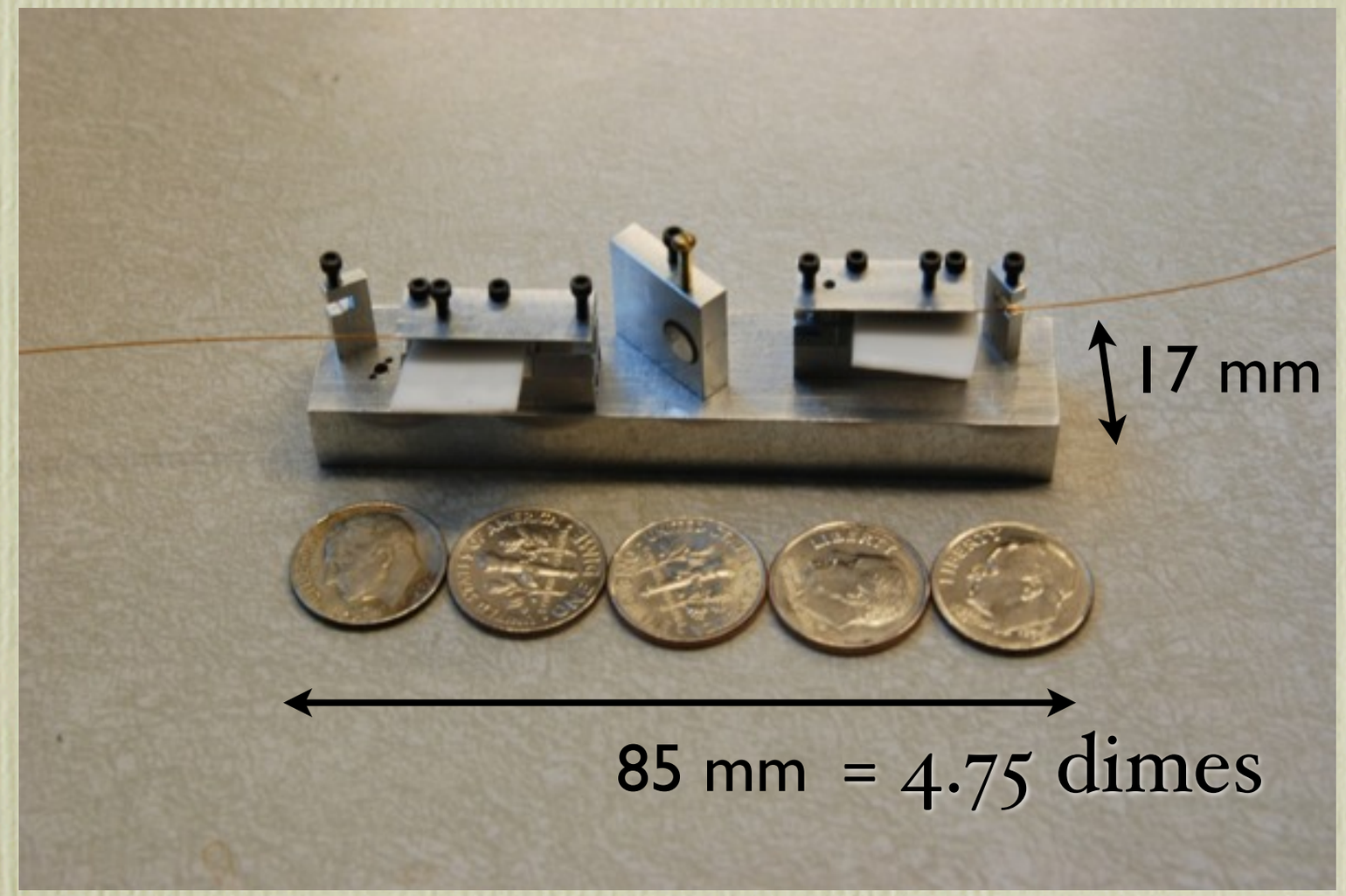
Collimator

Fiber feed for Hamilton





Fiber feed for HIRES (will be tested soon)



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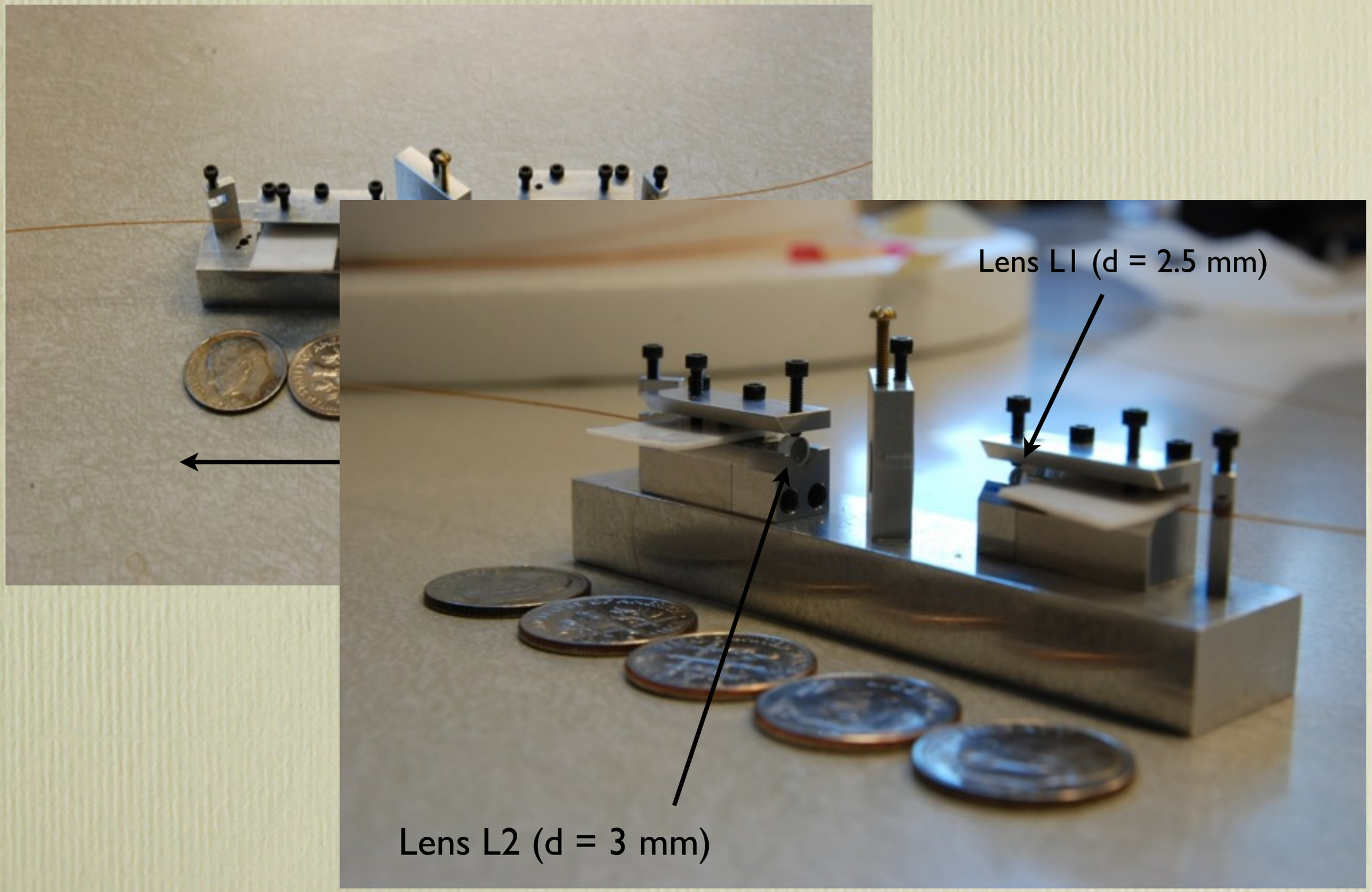
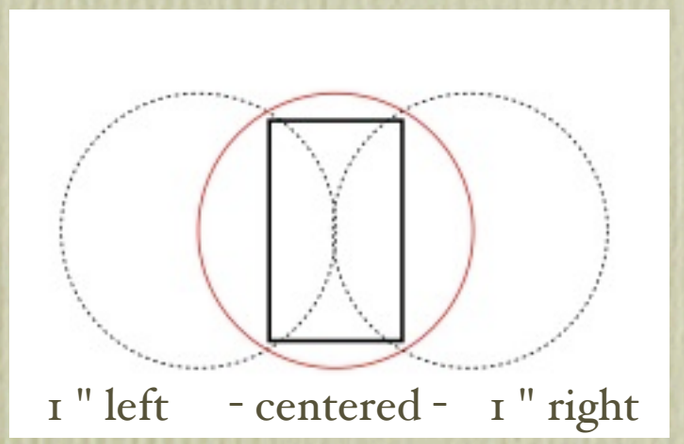
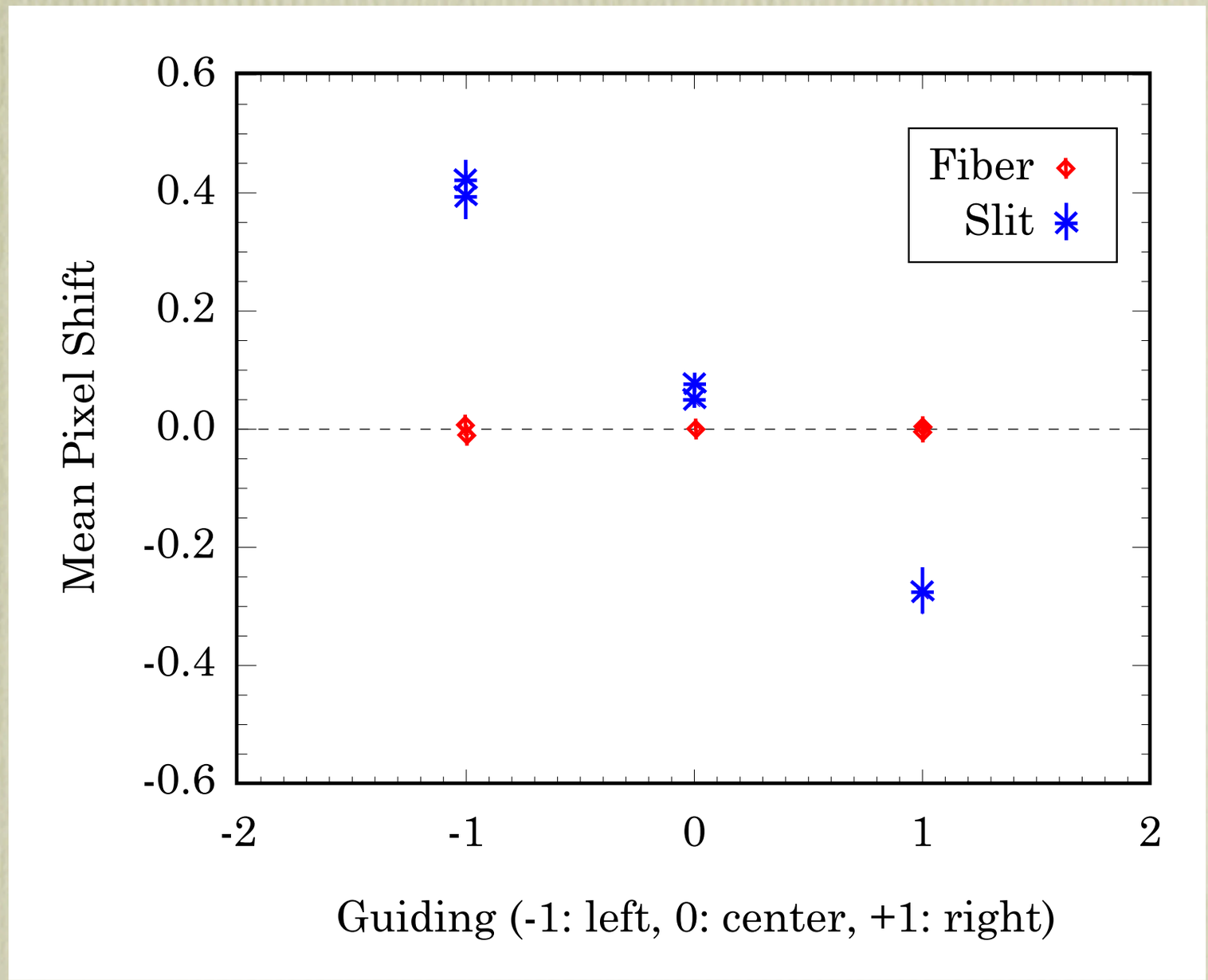


First Lights: Guiding test at Lick

65% throughput, FWHM = 2.3 pixels (expected at 1.5 arcsec)

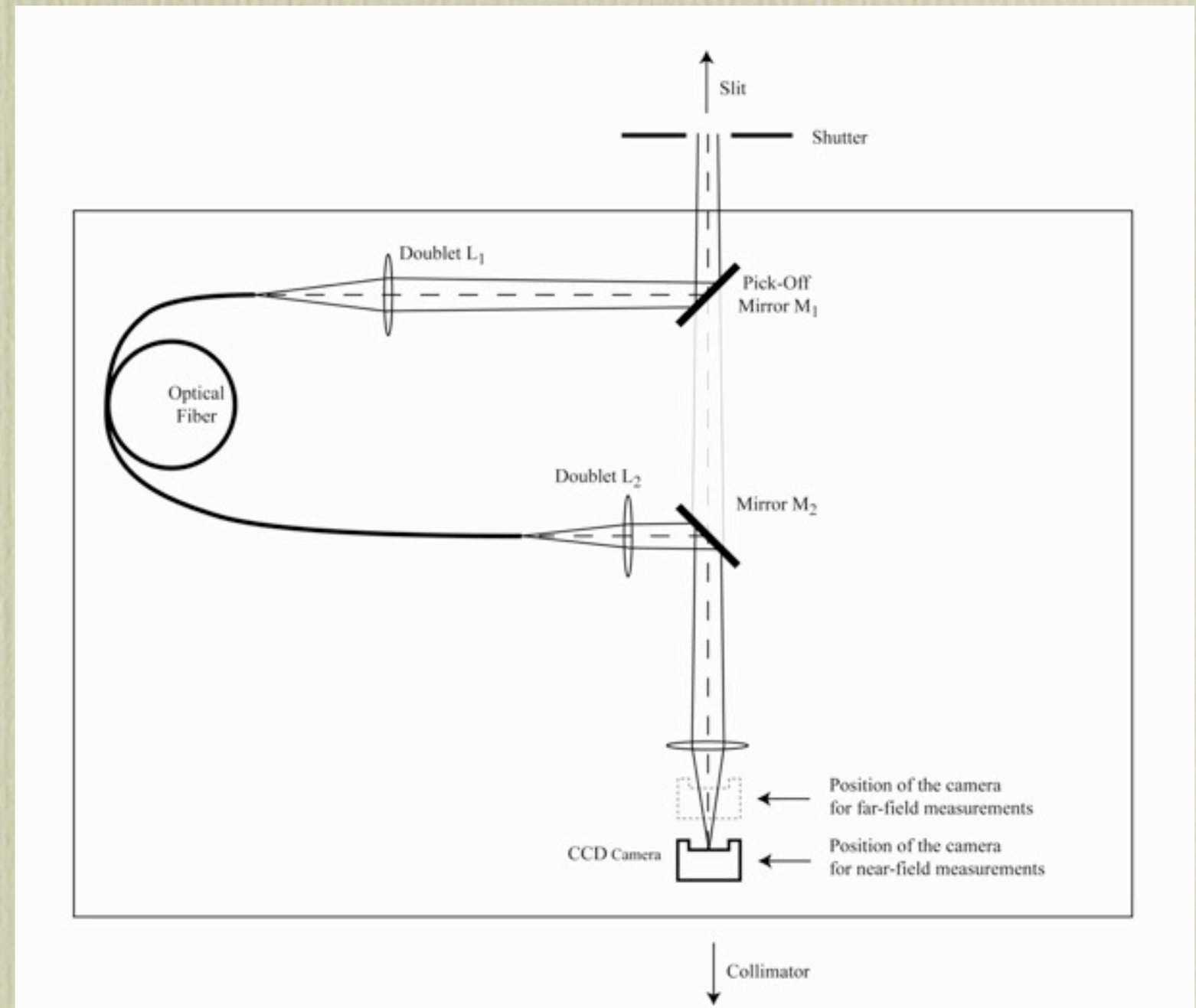




Far field measurements

Far-field: Intensity distribution of the beam diverging from the fiber.

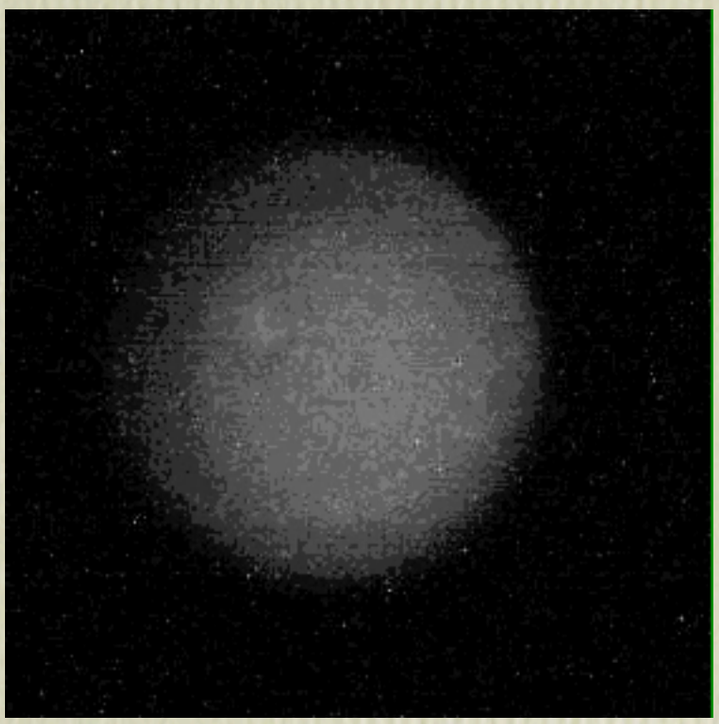
Variations of the far field will be projected onto the collimator.



Pupil illumination

Guiding on alpha Cygni with the Coudé Auxiliary Telescope

Slit (time span: 60 s)



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Pupil illumination

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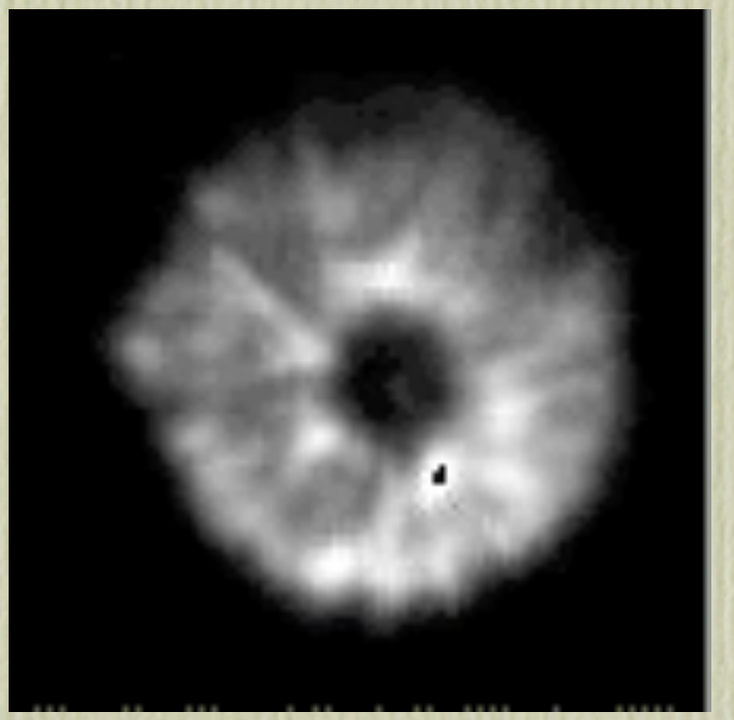
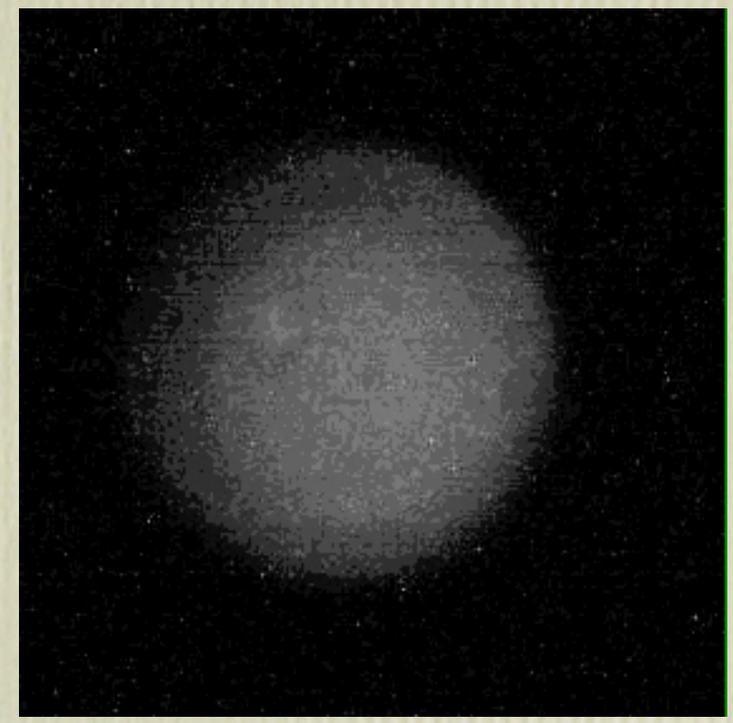


Slit (time span: 60 s)



Fiber (time span: 60 s)

Pupil illumination

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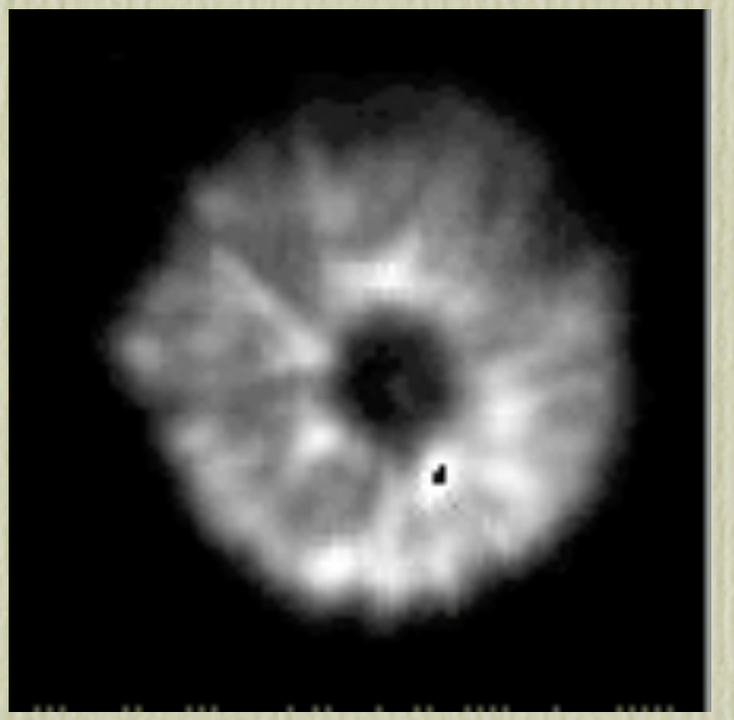
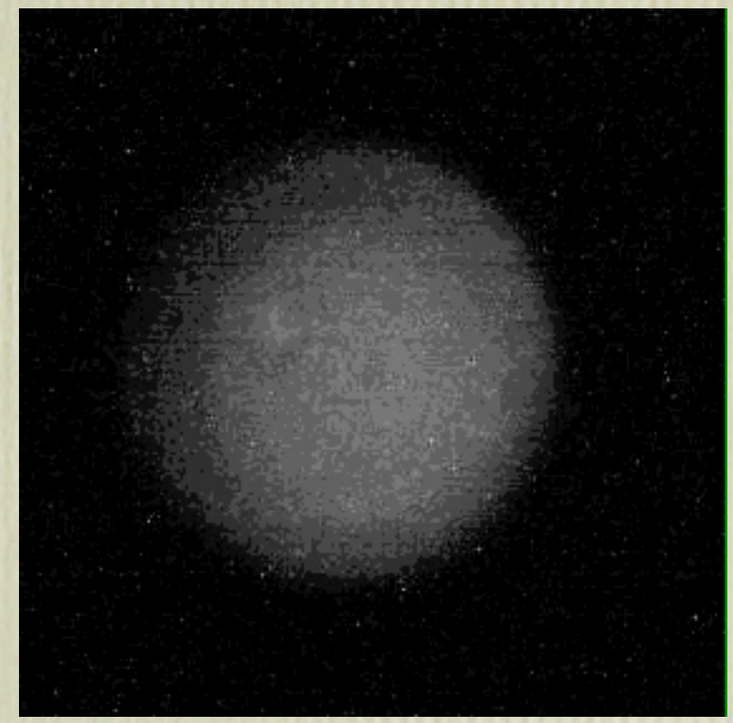


Slit (time span: 60 s)

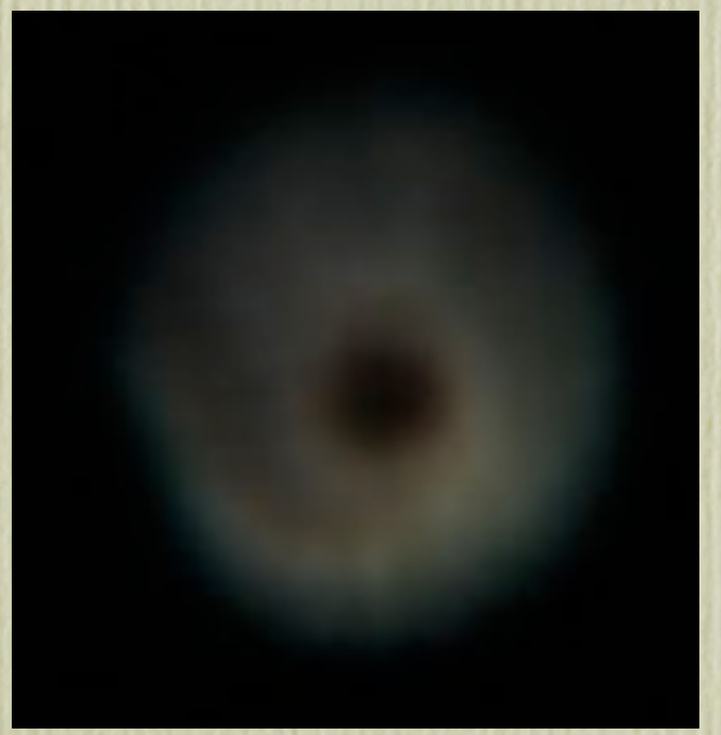


Fiber (time span: 60 s)

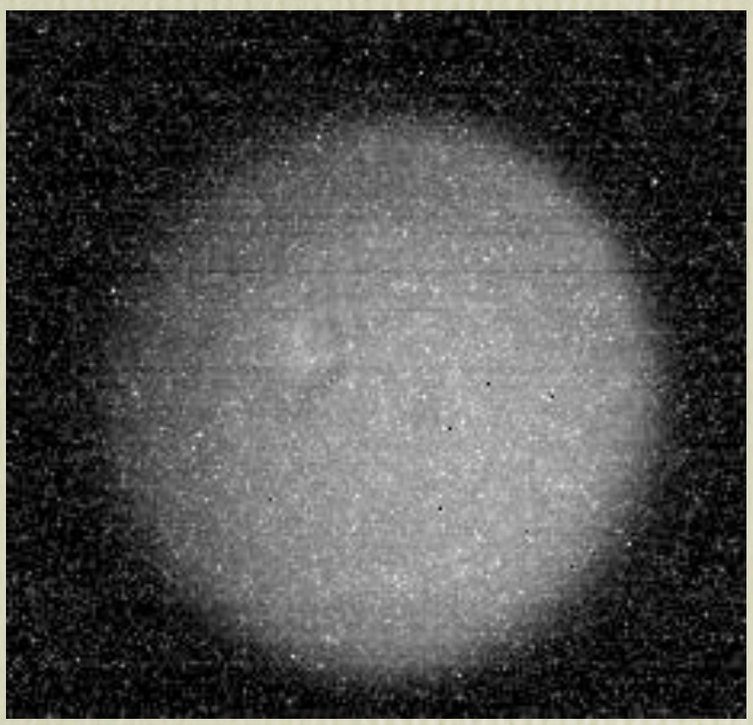
Very good azimuthal and non-perfect radial scrambling

Pupil illumination

Guiding on alpha Cygni with the Coudé Auxiliary Telescope



Slit (time span: 60 s)

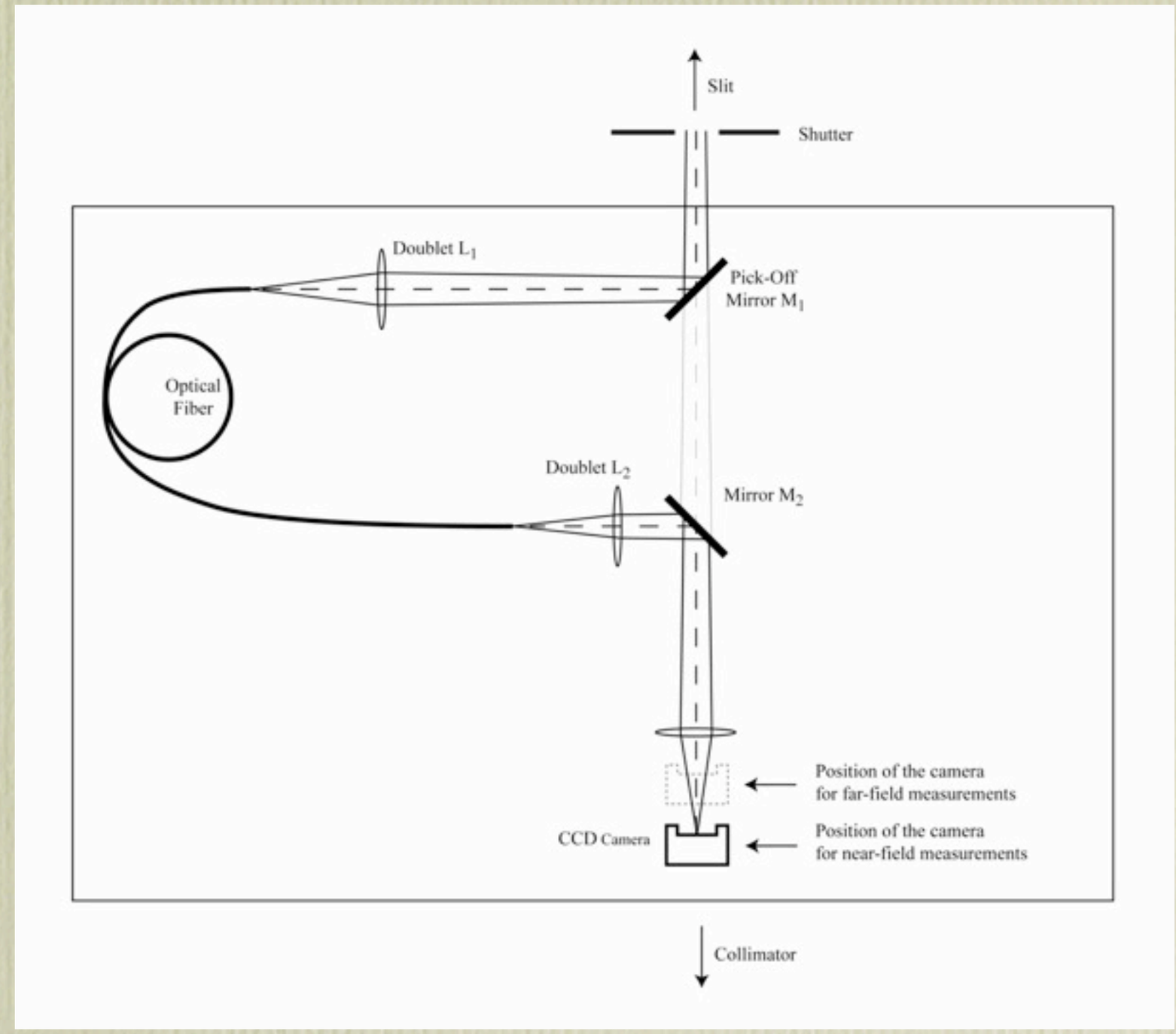


Fiber (time span: 60 s)

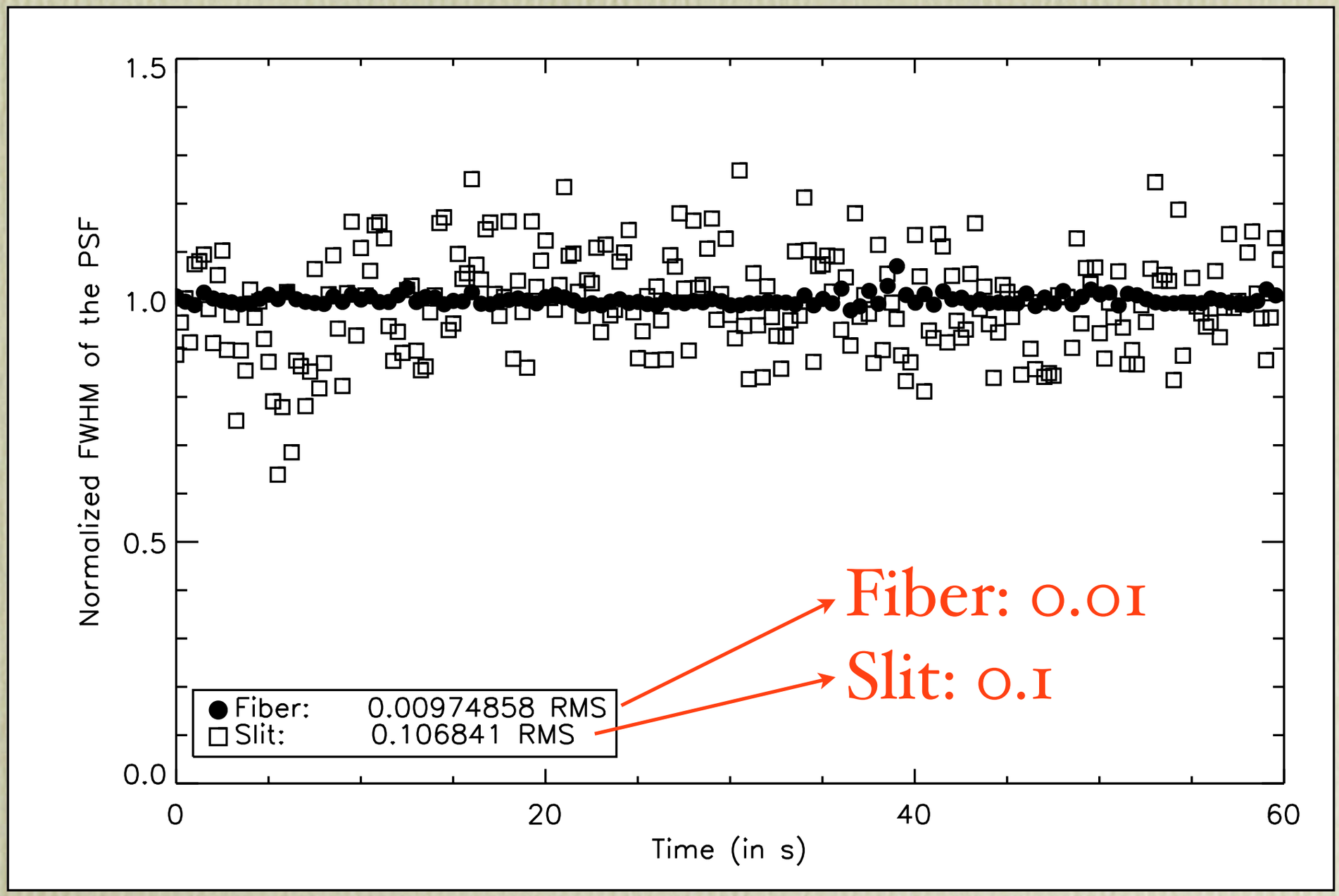
Near field measurements

Near-field: Intensity distribution across the output face of the fiber.

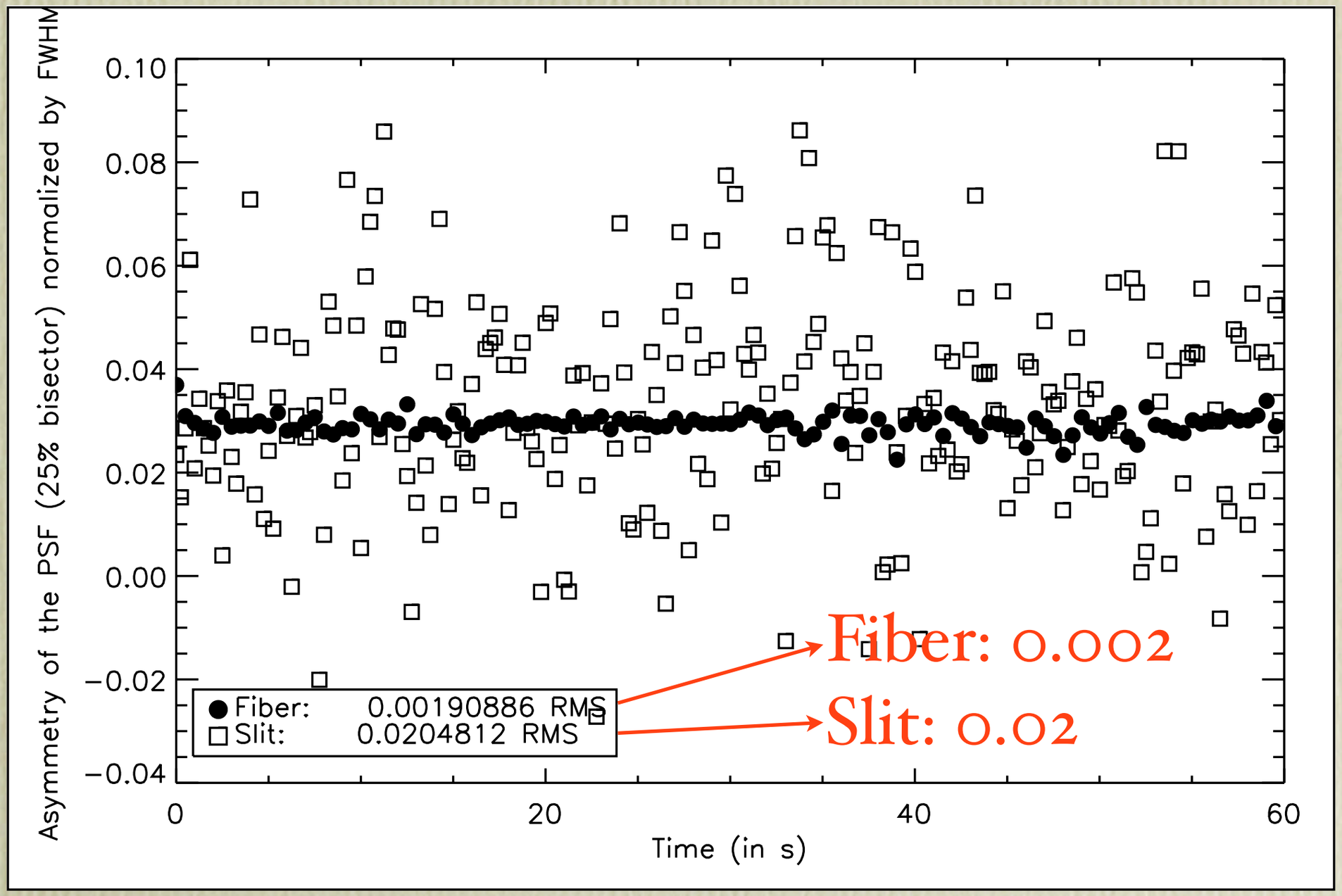
Directly affects the PSF since the spectral “lines” are the image of the fiber onto the detector.



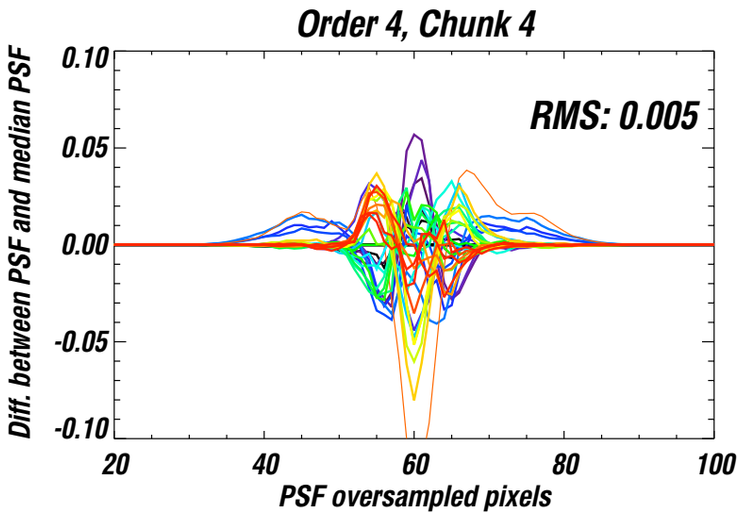
PSF Stability (FWHM of a gaussian fit to the near-field pattern)

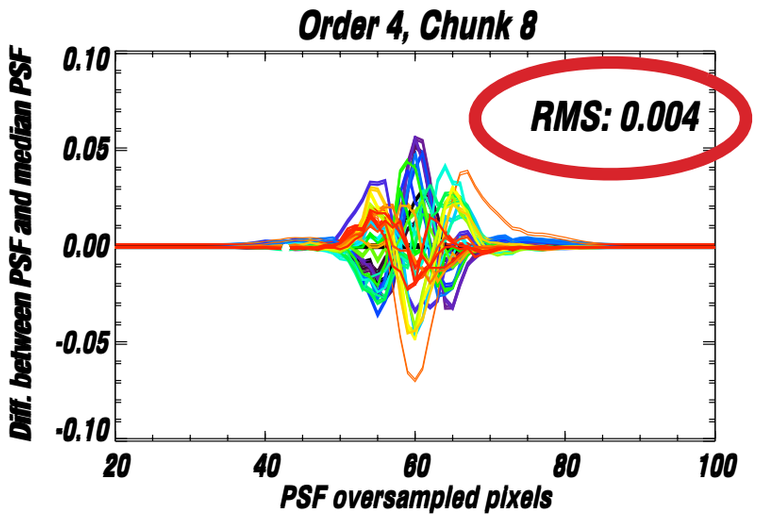


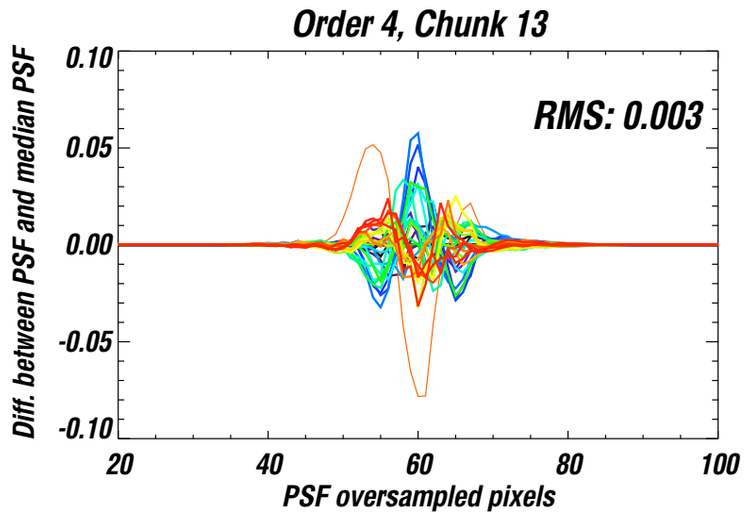
PSF Stability (Asymmetry)

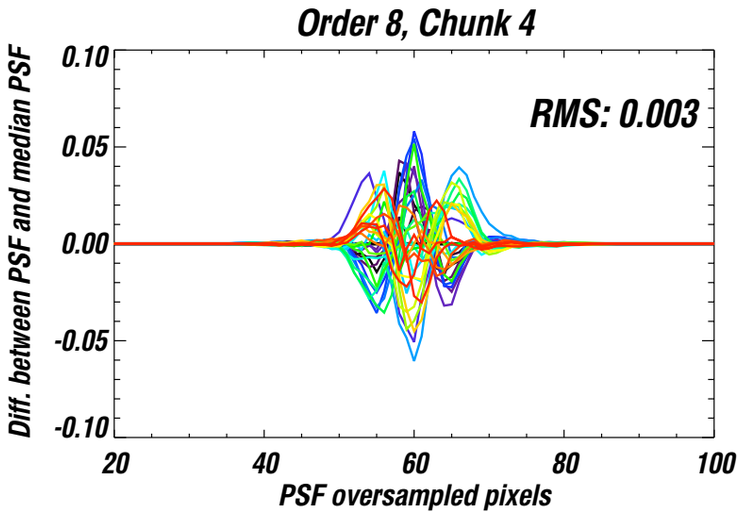


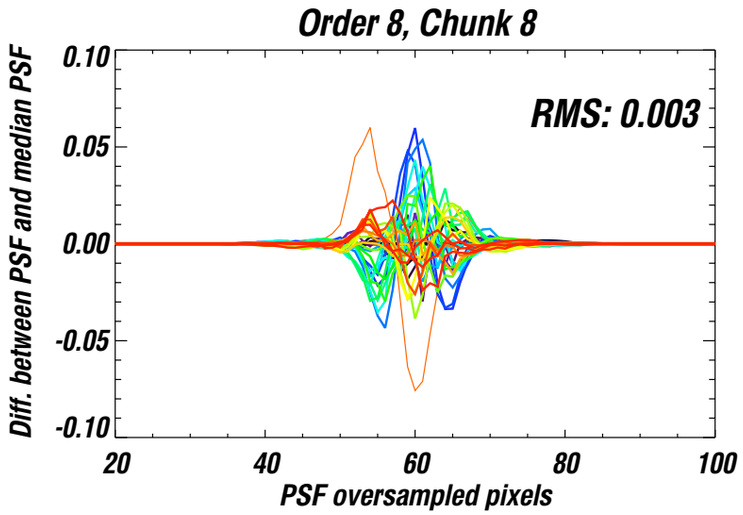
PSF variation across the CCD over the night: Slit

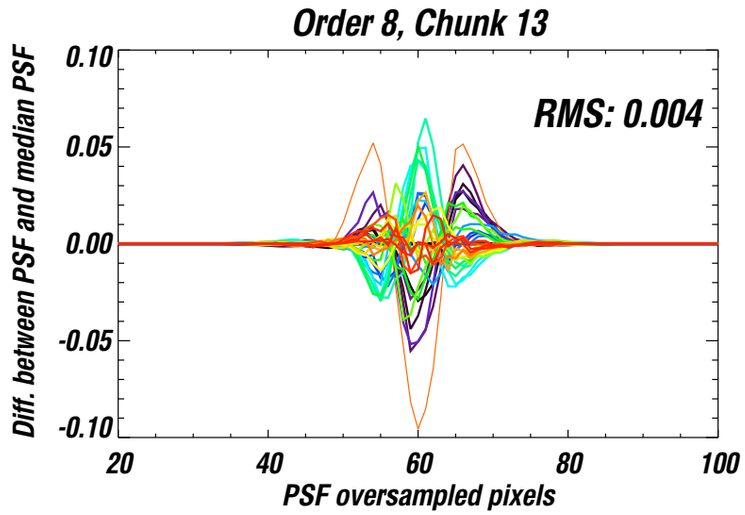


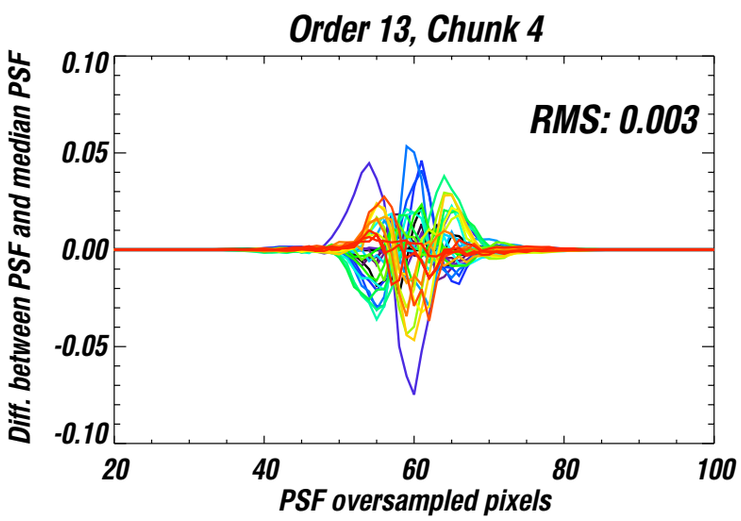


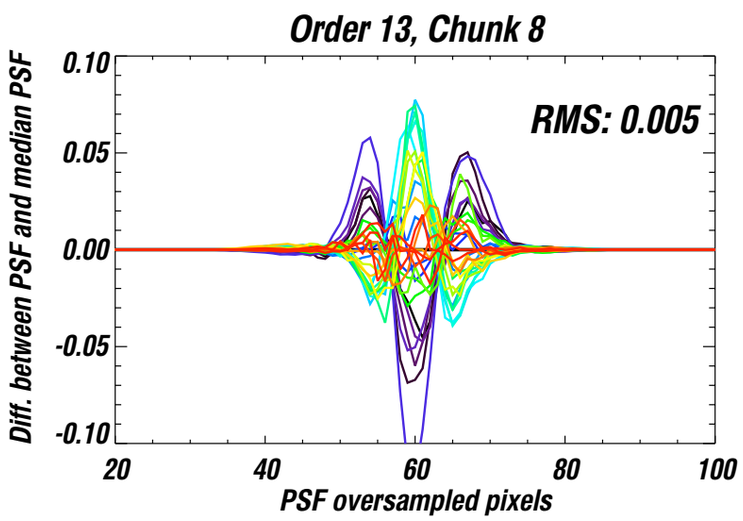


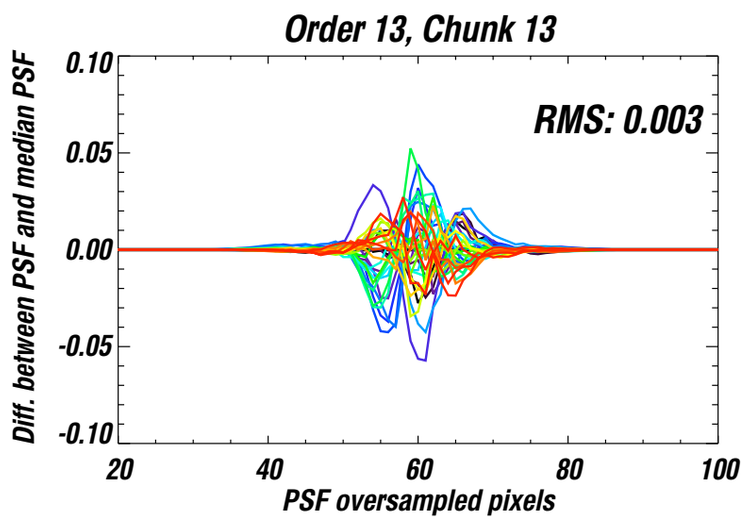




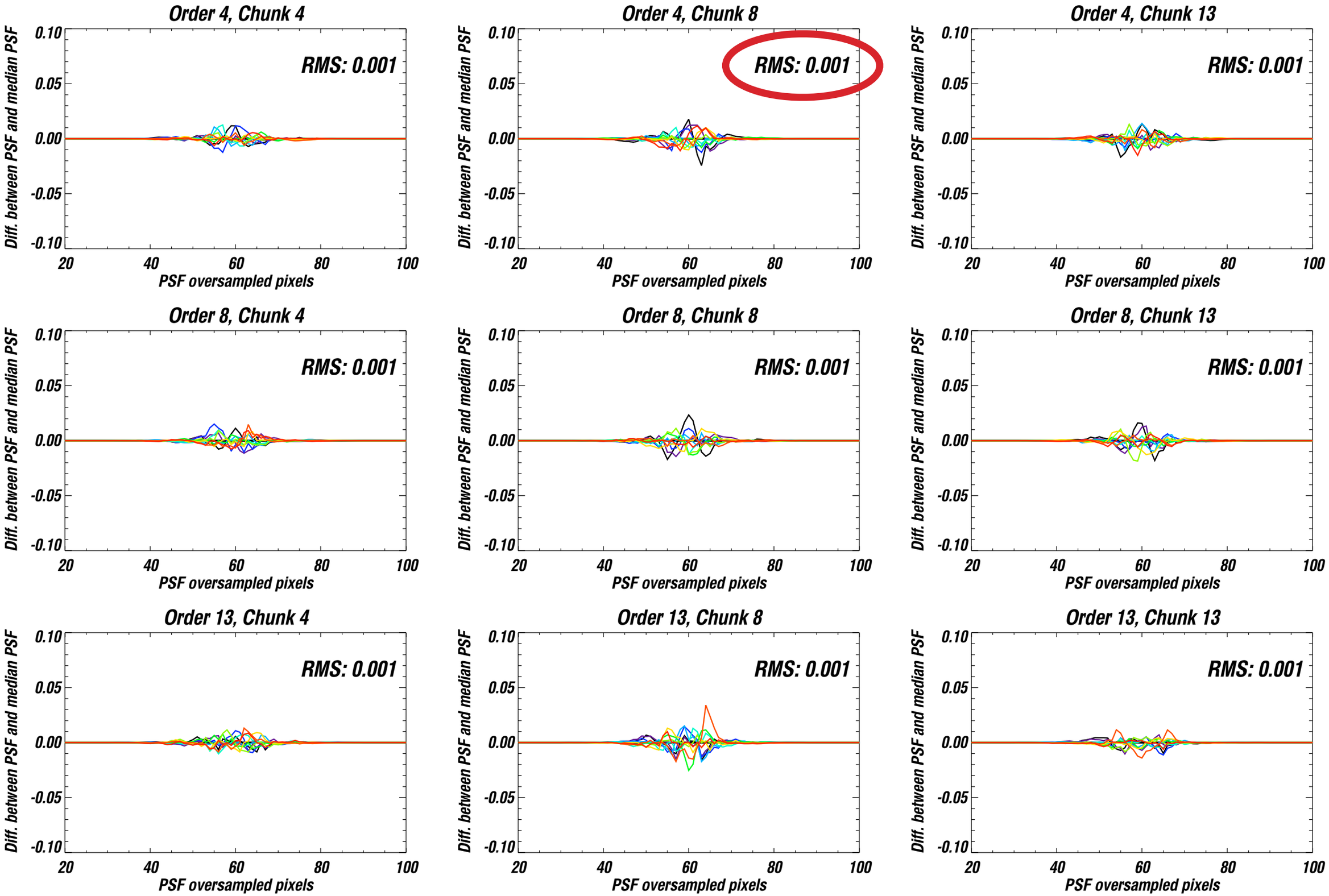






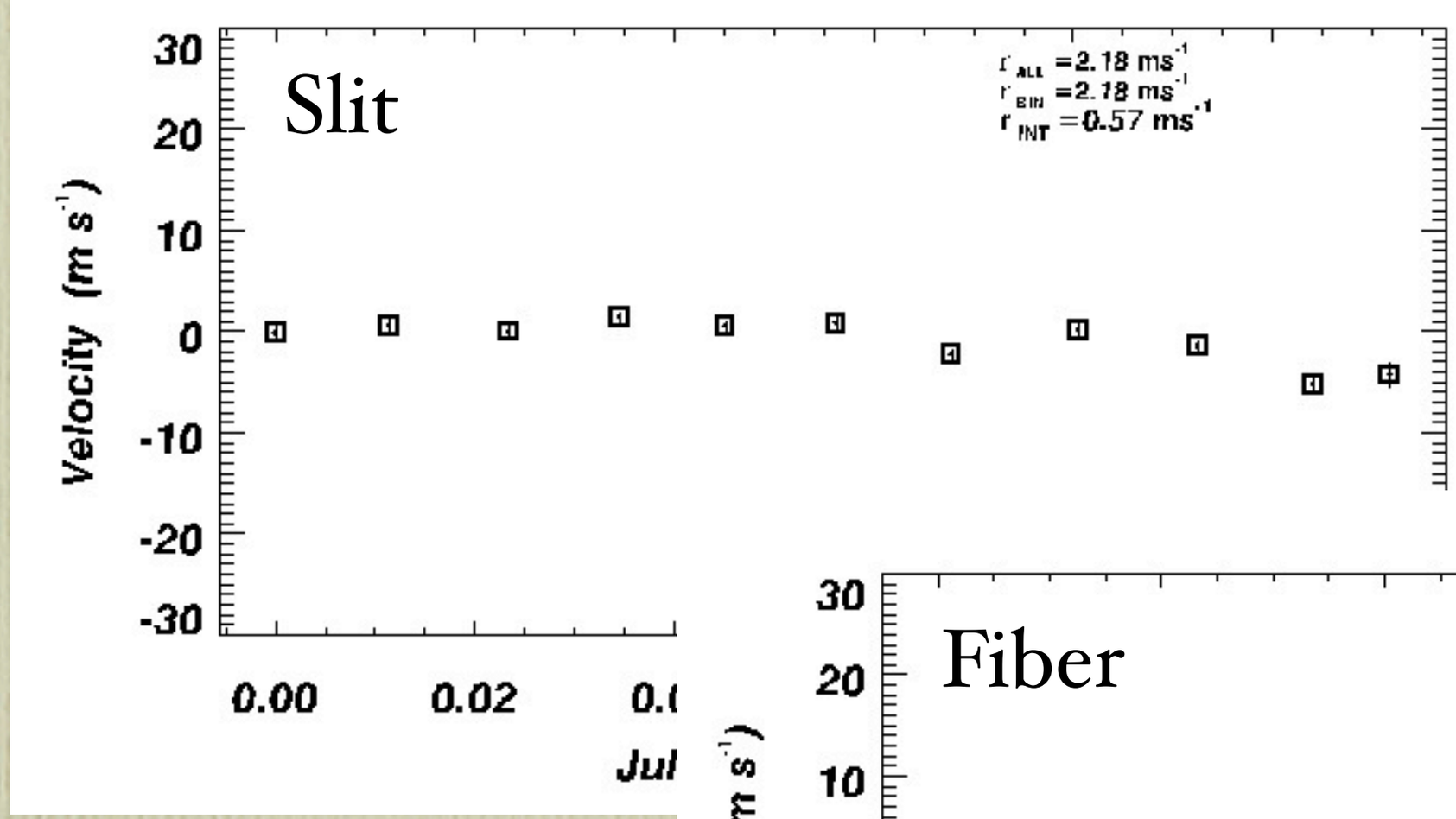


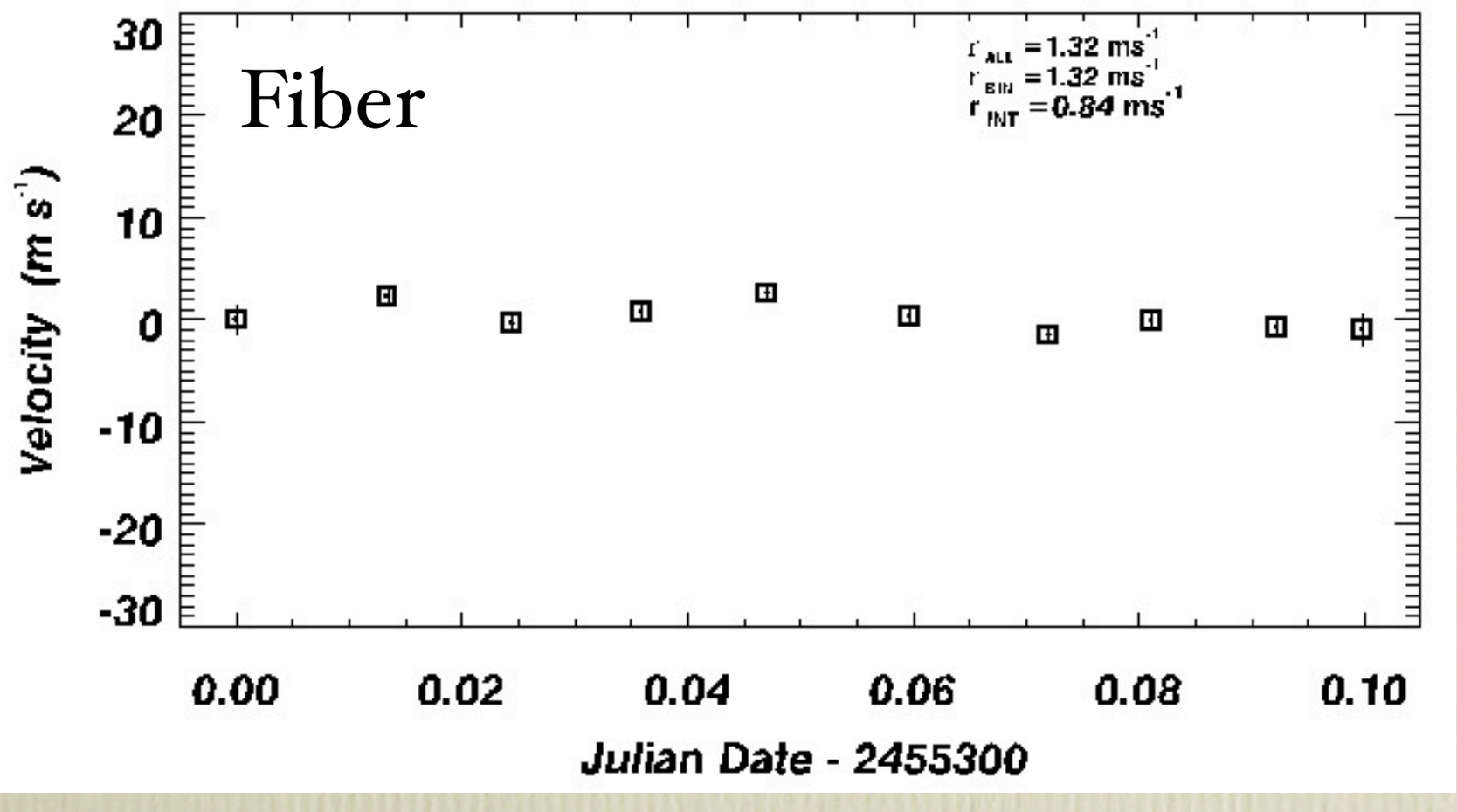
PSF variation across the CCD over the night: fiber



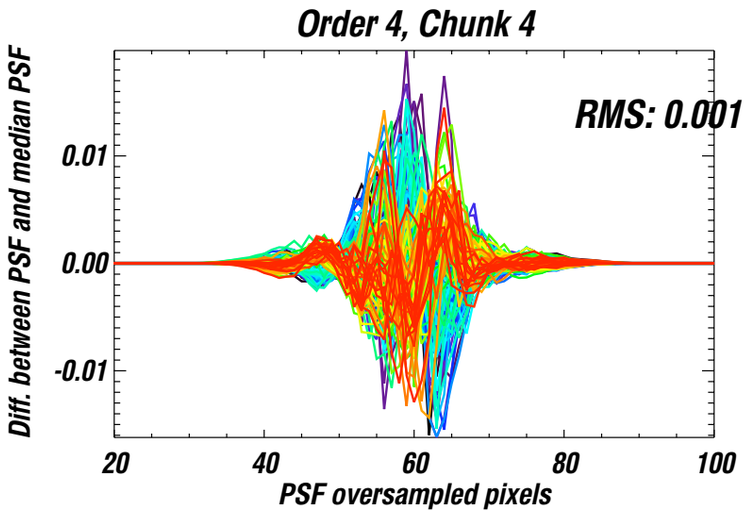
Radial velocities (HD161797)

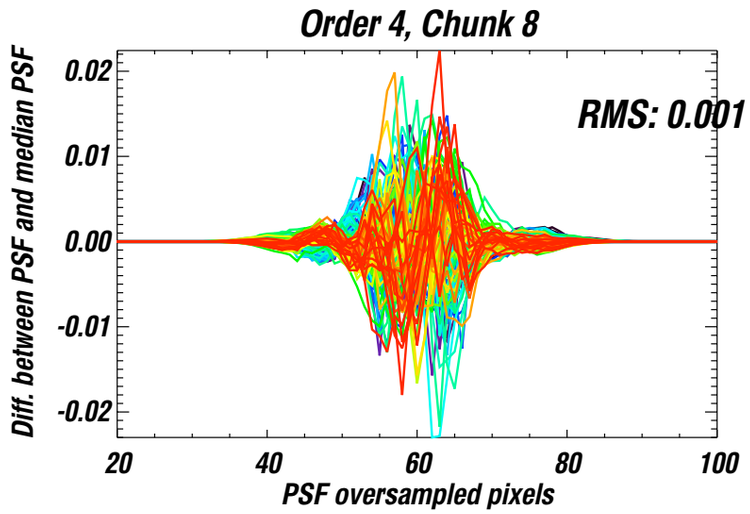
15 min bins

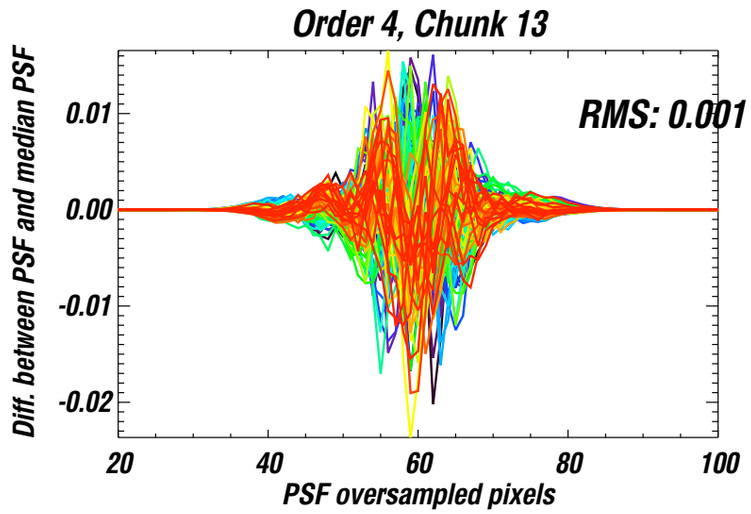


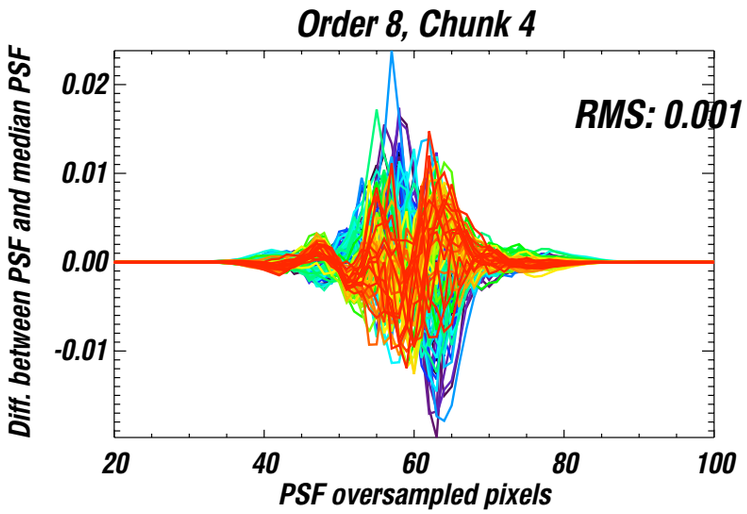


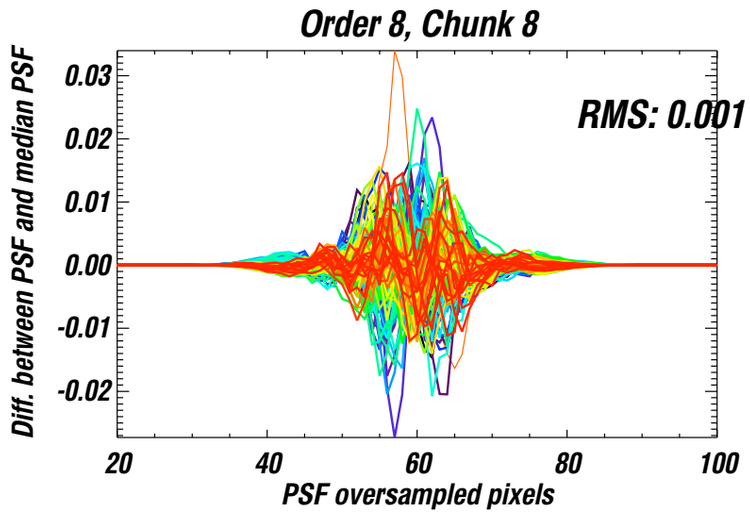
PSF Variation: fiber

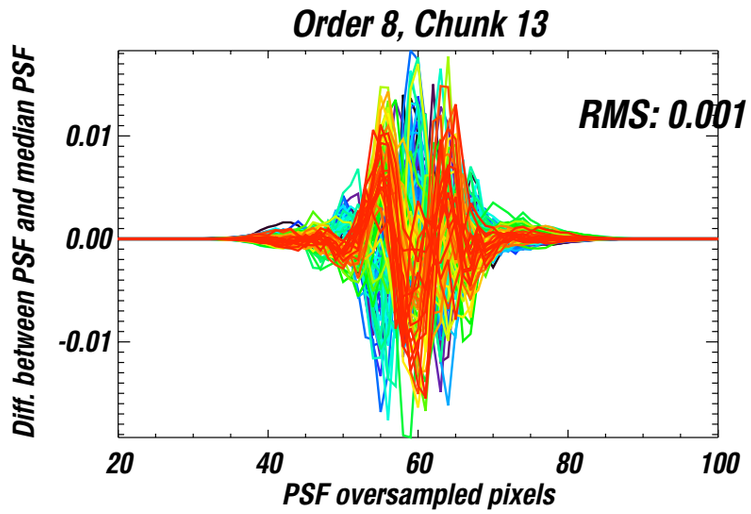


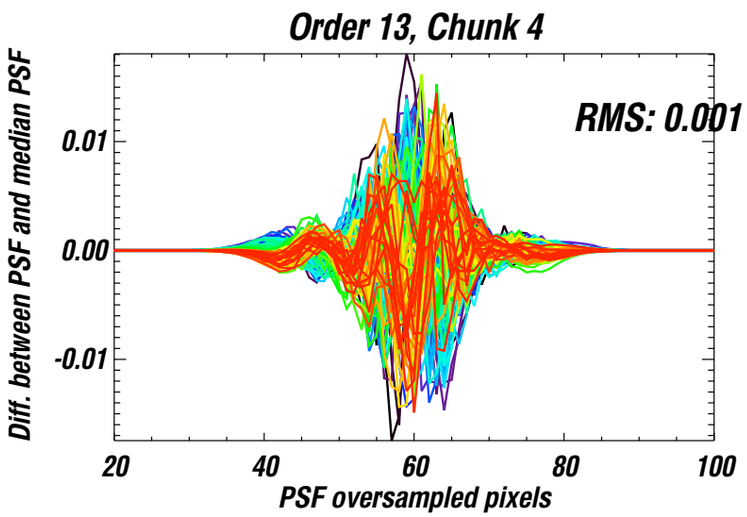


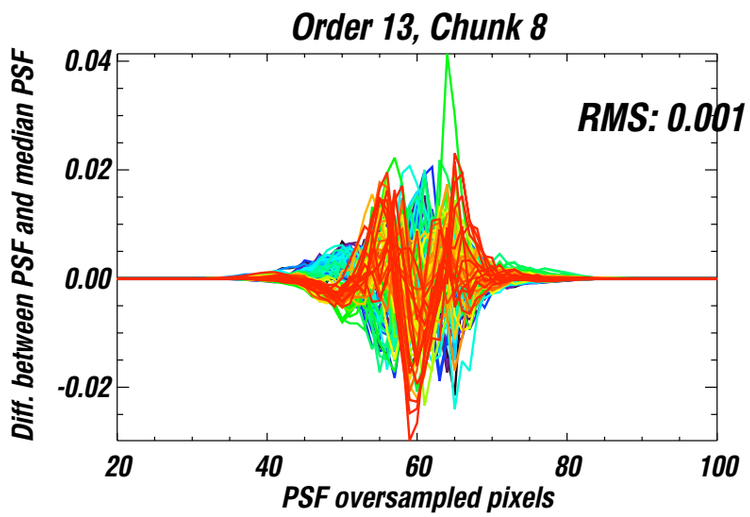


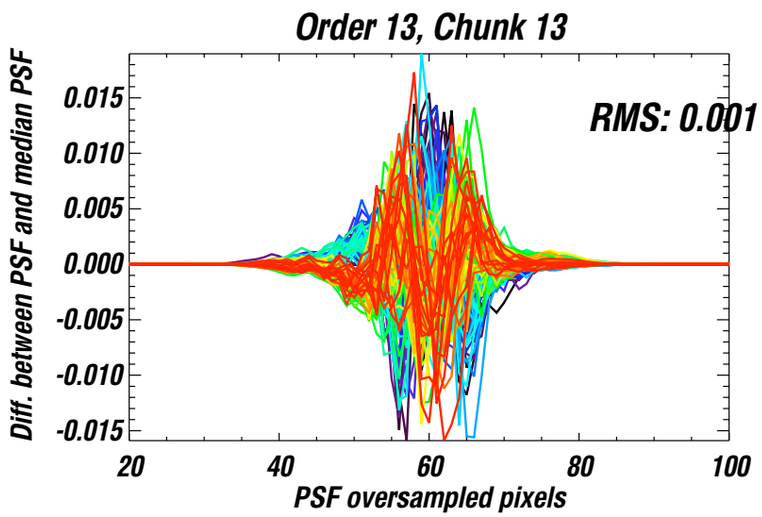






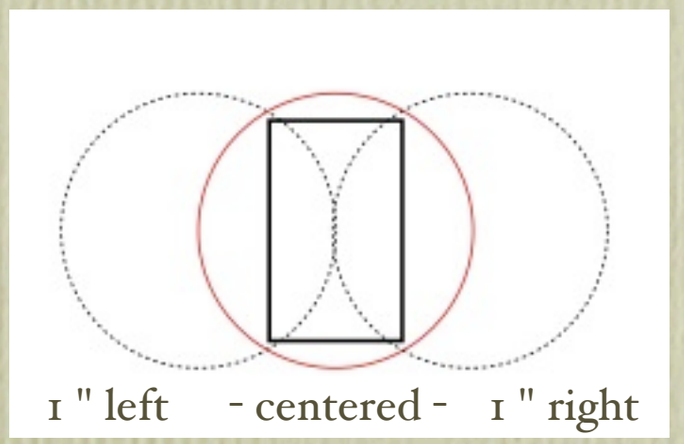


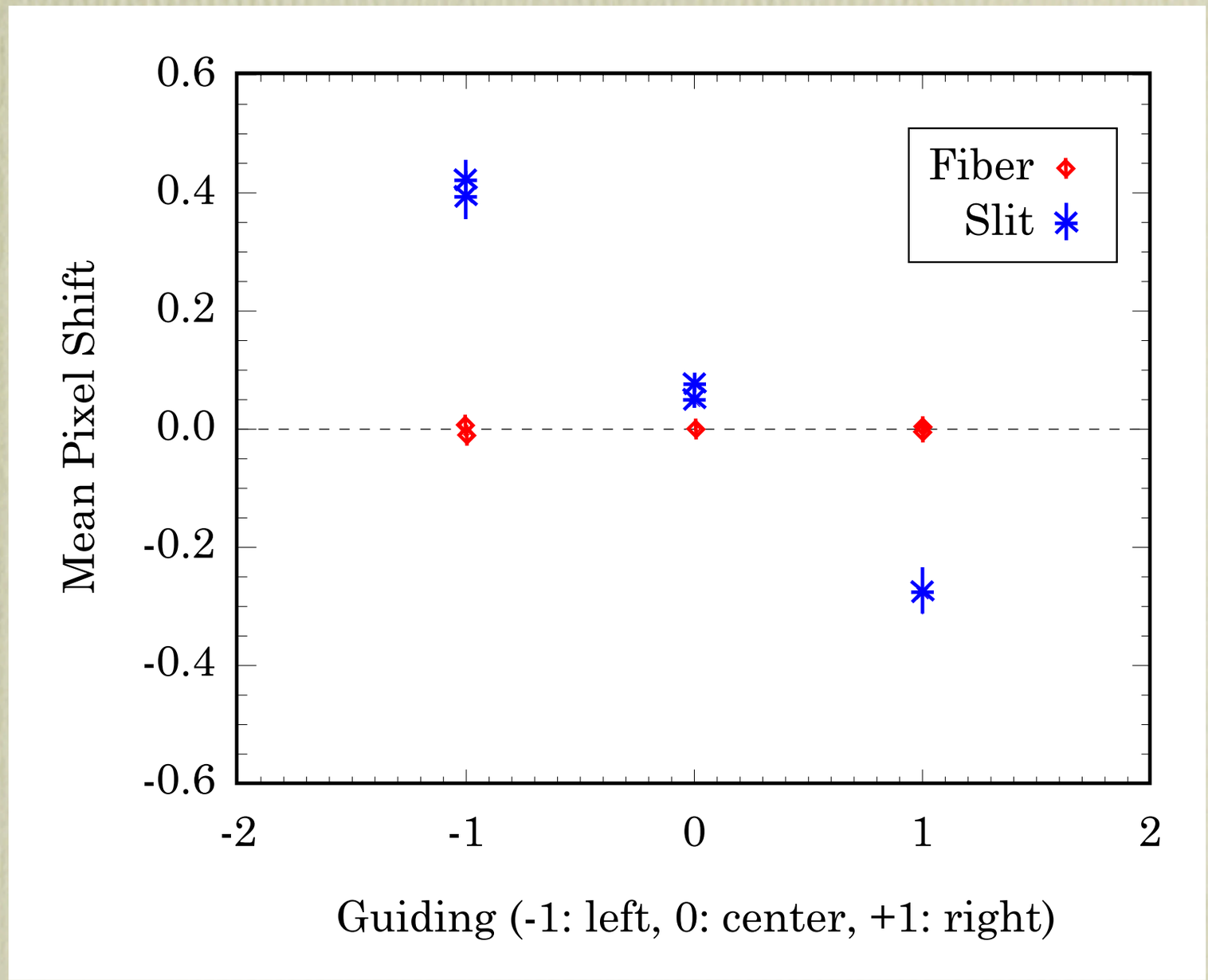




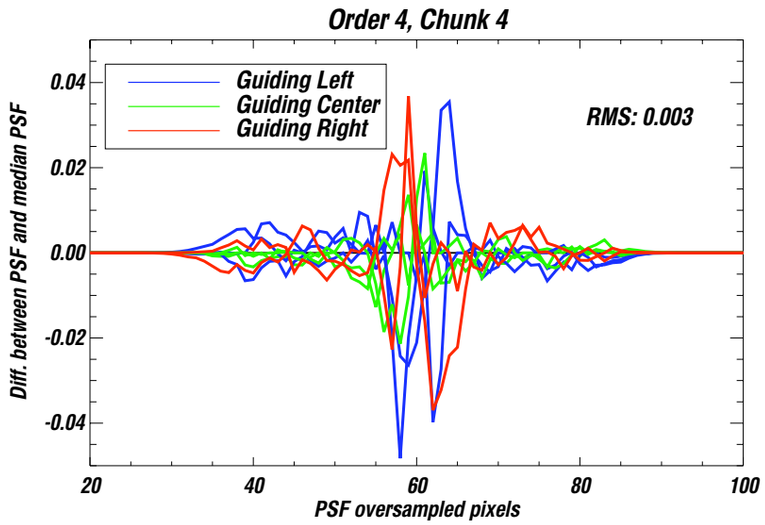
First Lights: Guiding test

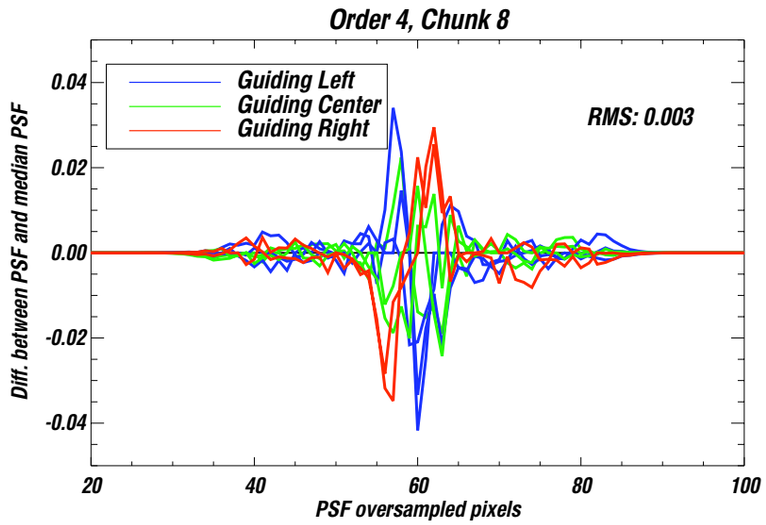
65% throughput, FWHM = 2.3 pixels (expected at 1.5 arcsec)

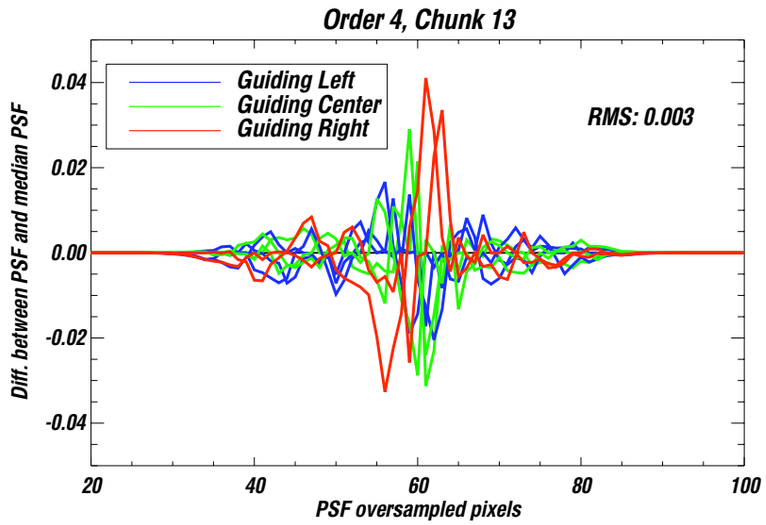


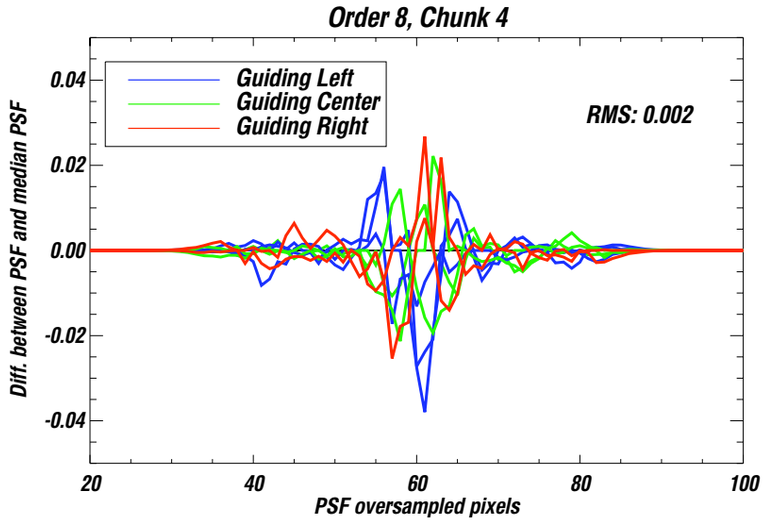


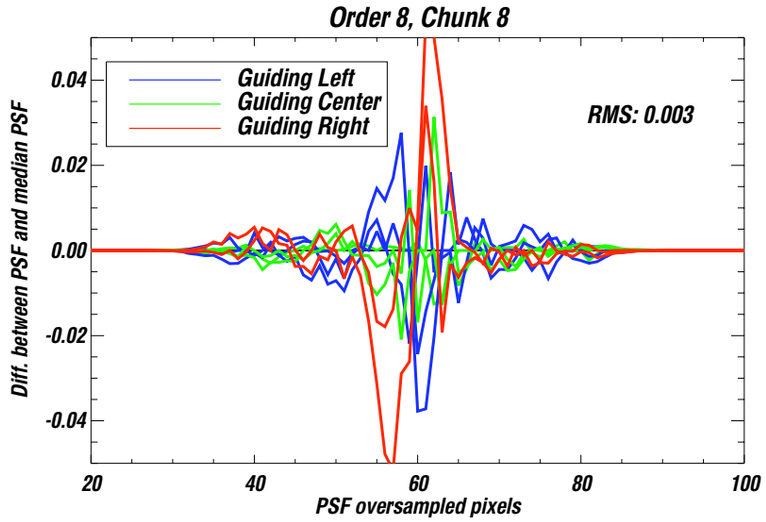
Guiding test: PSF variation with fiber

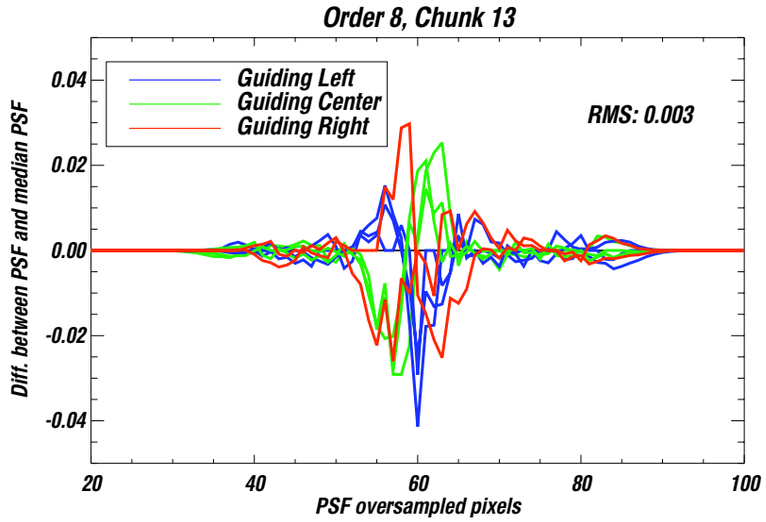


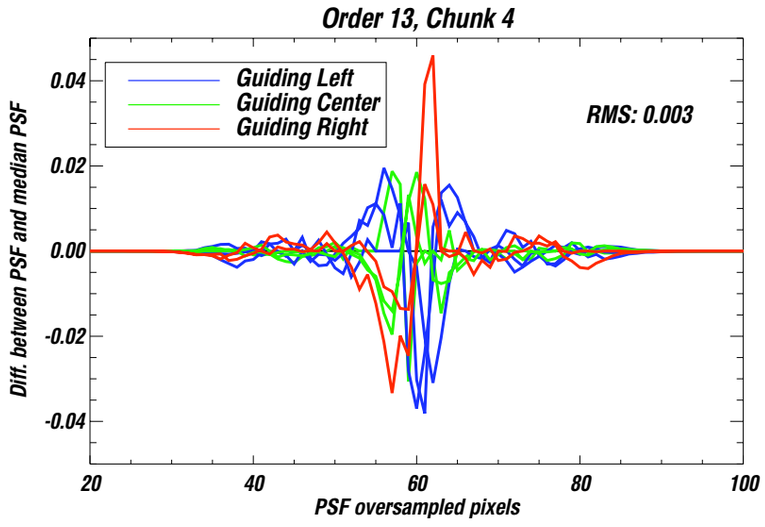


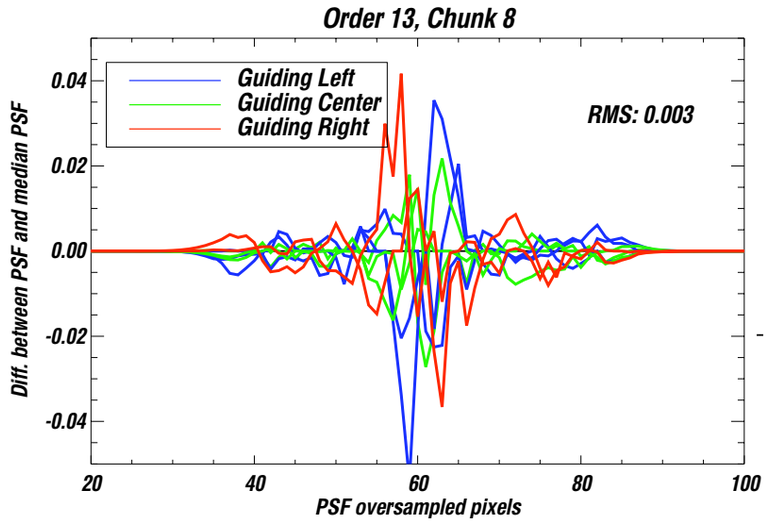


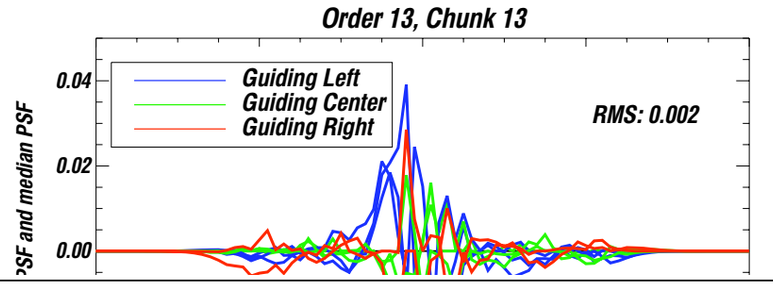










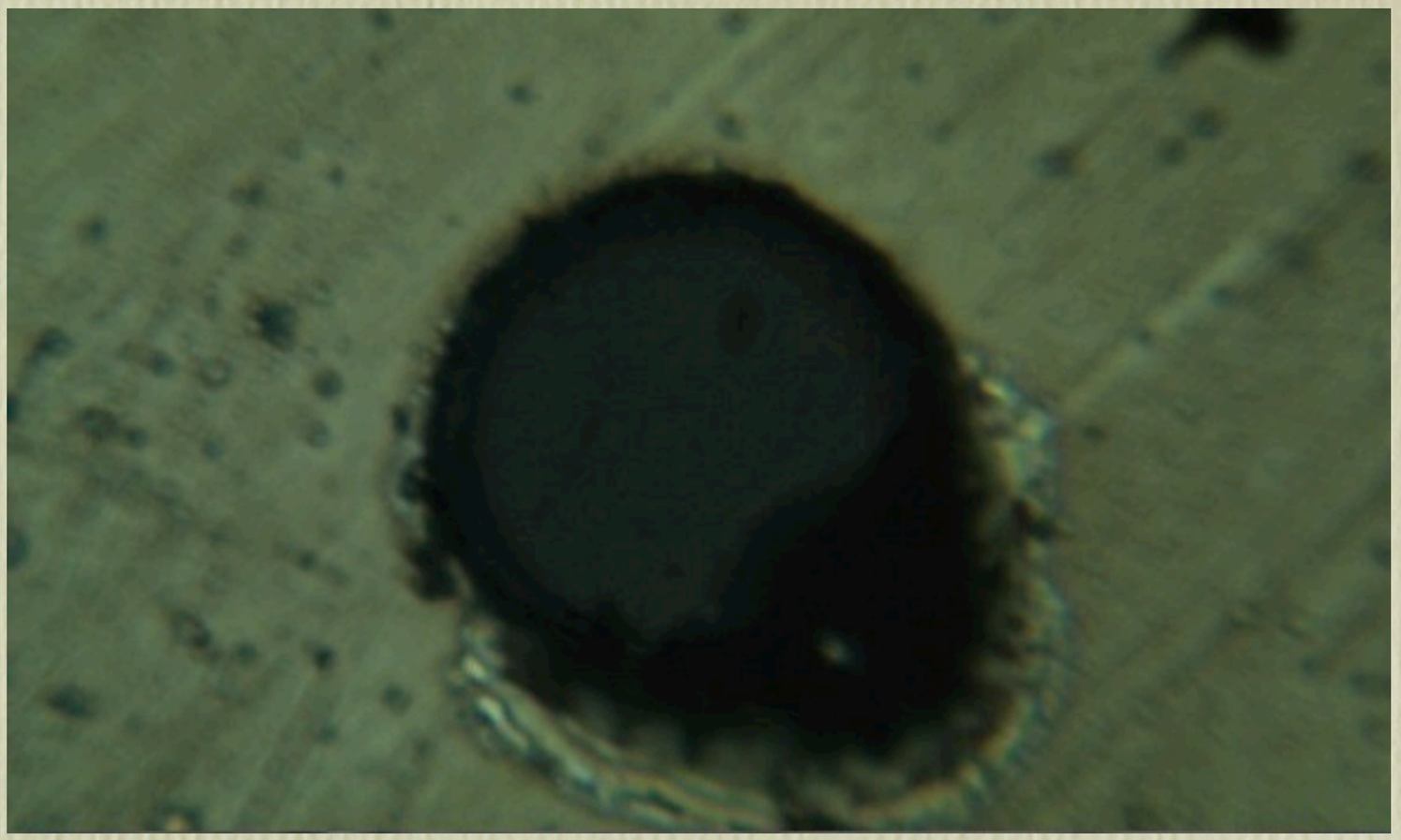


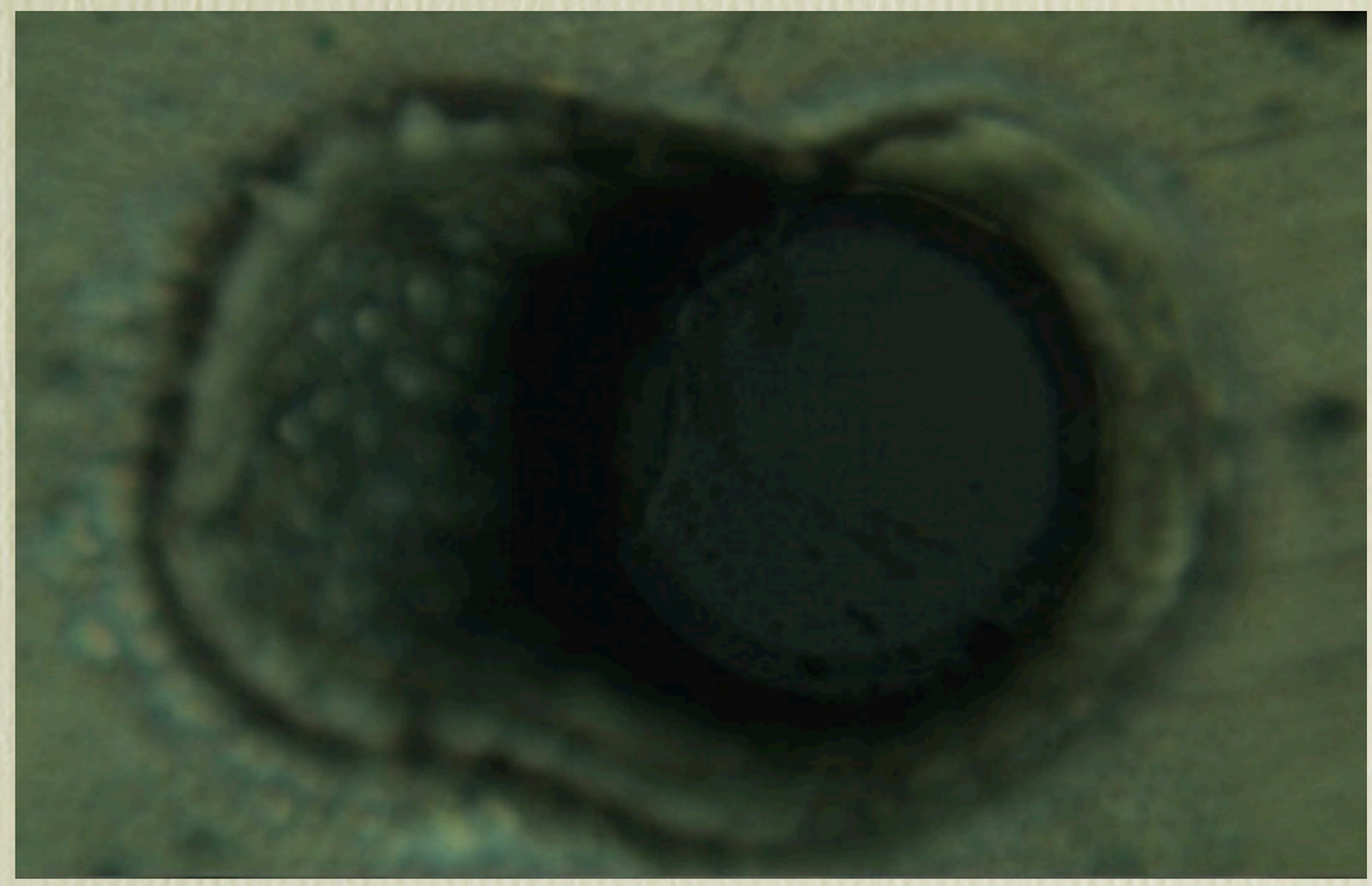
Guiding Left
Guiding Center
Guiding Right

Conclusions and discussion

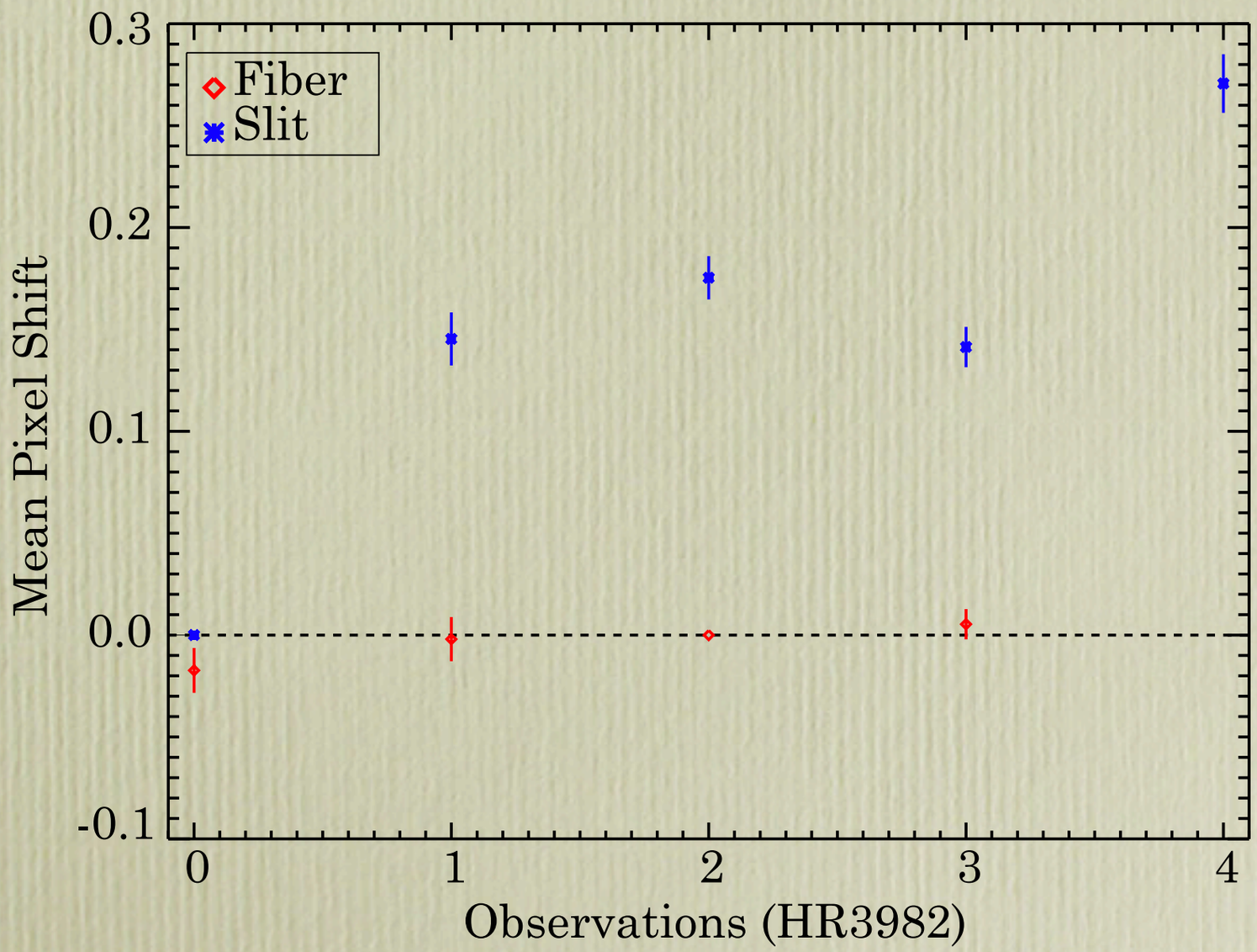
- We have built a fiber feed for Hamilton and for HIRES
- Fiber stabilizes position of spectral lines
- Fiber gives a well-behaved pupil illumination and more stable PSF (by a factor 10)
- Fiber improves the Doppler precision

  BUT ...





First Lights:
B star cross correlations



The fiber drastically reduces movements of the spectral lines on the CCD by a

Near-field measurements

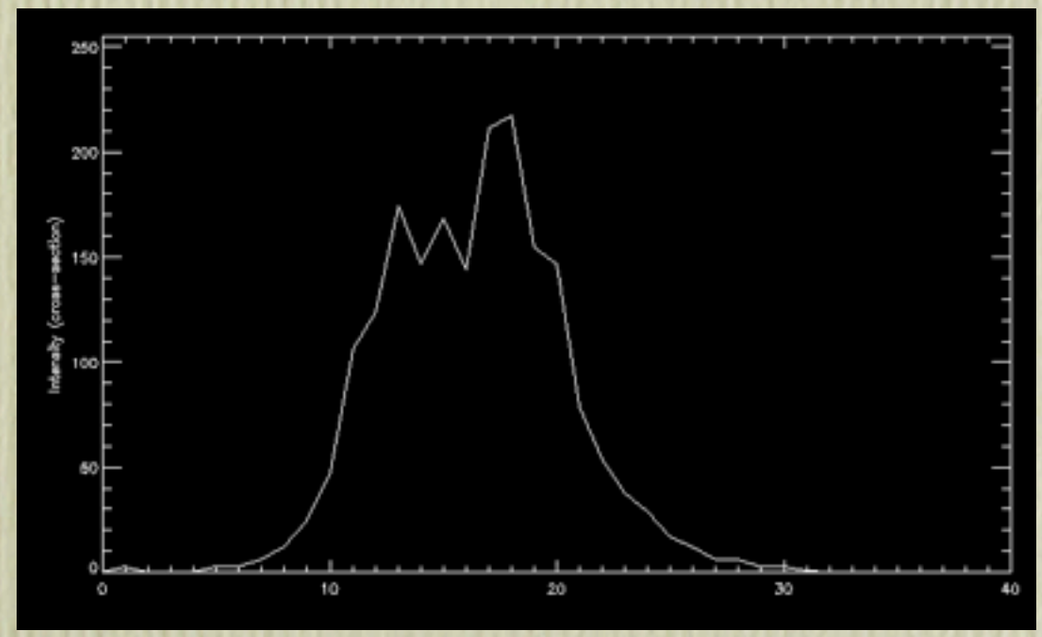
Guiding on alpha Cygni with the Coudé Auxiliary Telescope

Slit (time span: 60 s)

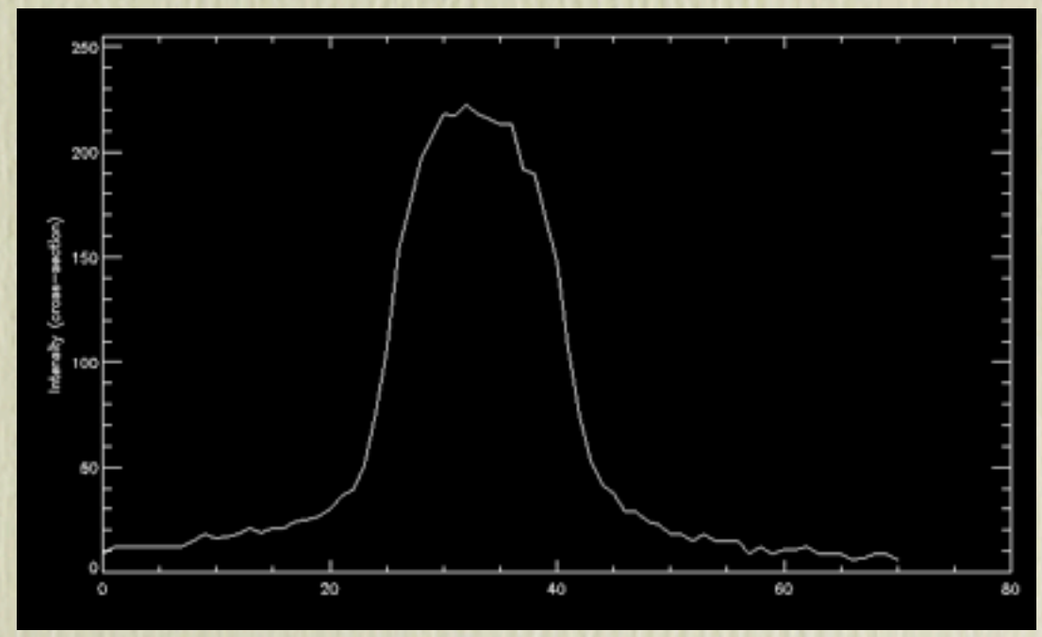
Fiber (time span: 60 s)

Near-field measurements

Guiding on alpha Cygni with the Coudé Auxiliary Telescope



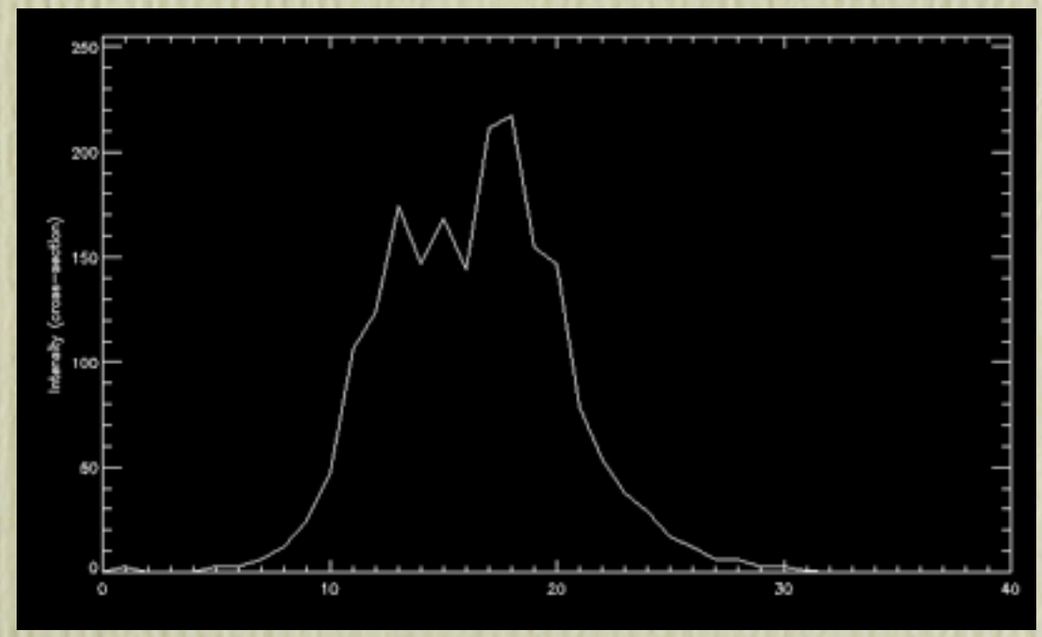
Slit (time span: 60 s)



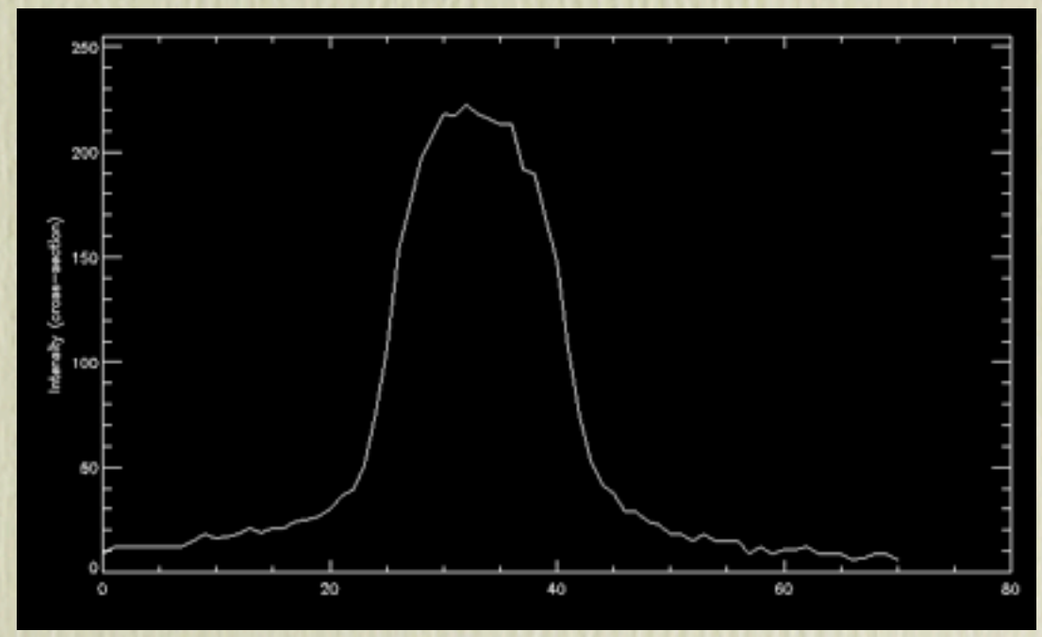
Fiber (time span: 60 s)

Near-field measurements

Guiding on alpha Cygni with the Coudé Auxiliary Telescope



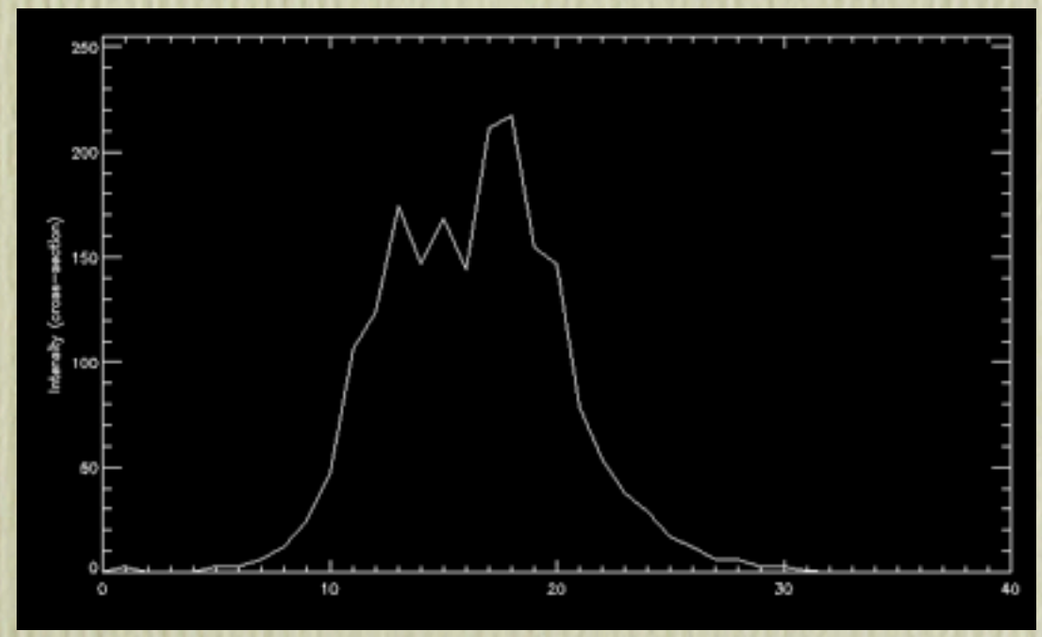
Slit (time span: 60 s)



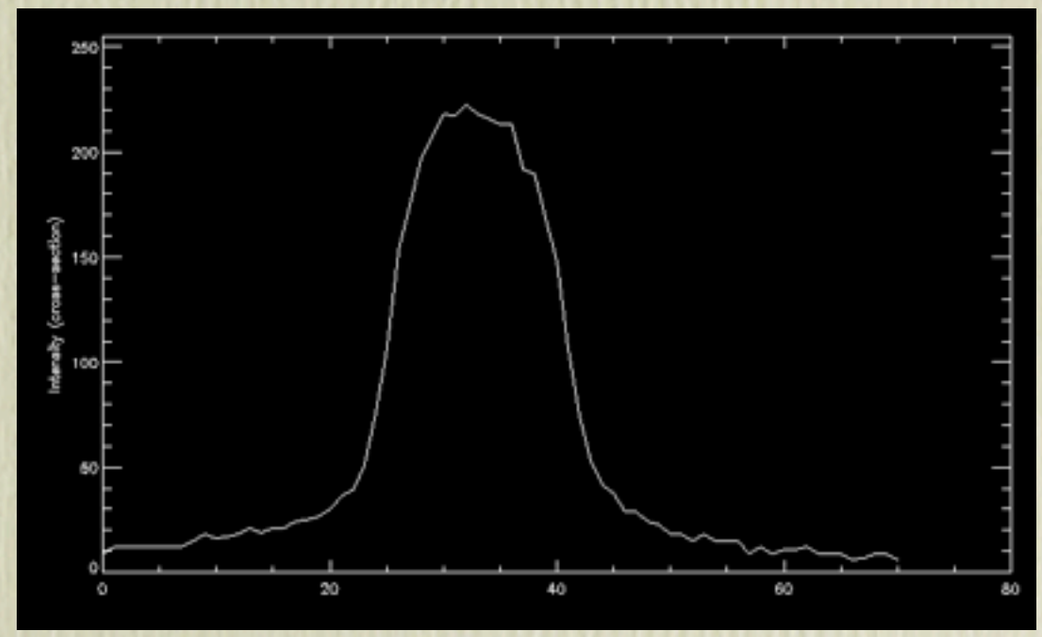
Fiber (time span: 60 s)

Near-field measurements

Guiding on alpha Cygni with the Coudé Auxiliary Telescope



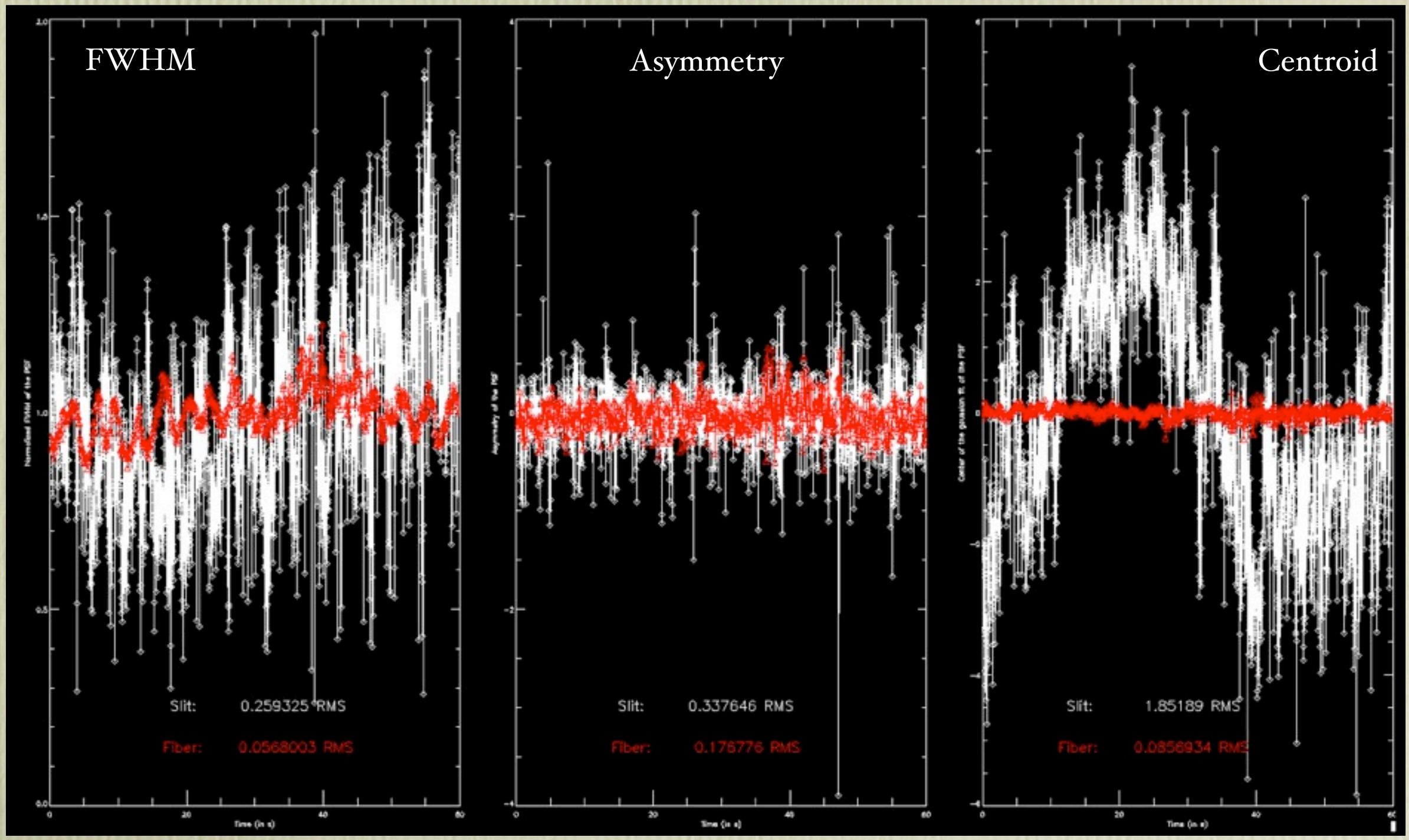
Slit (time span: 60 s)



Fiber (time span: 60 s)

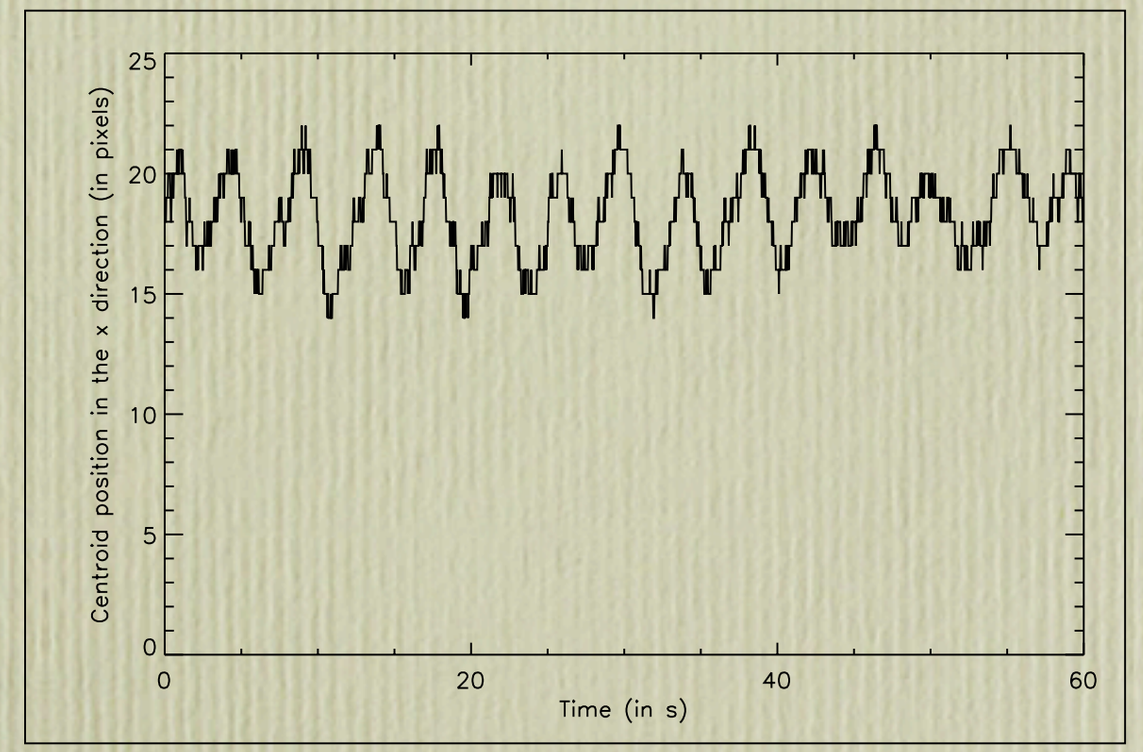
PSF with fiber is much more stable

Near-field measurements

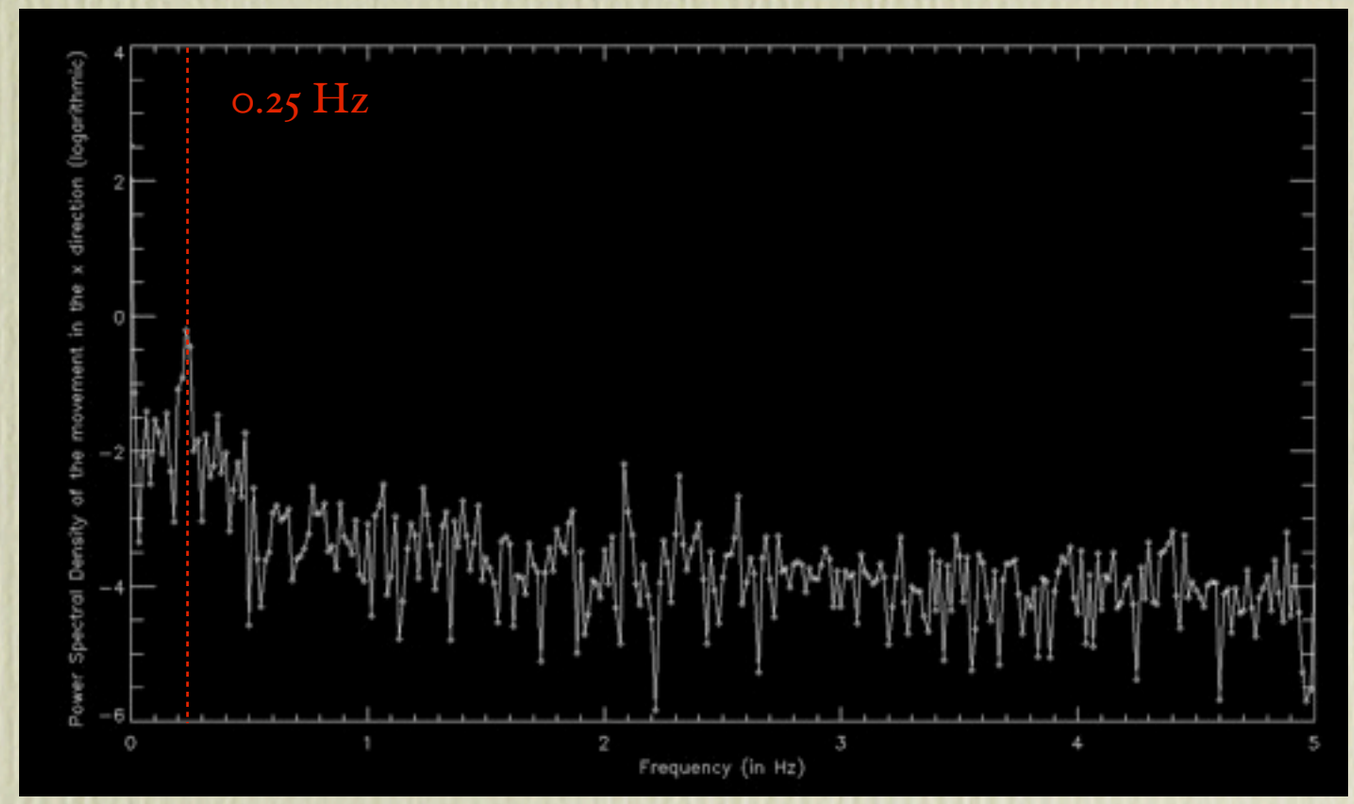


=> Clear improvement of the PSF stability BUT ...

Movement of the intensity pattern due to guiding, tracking, ...



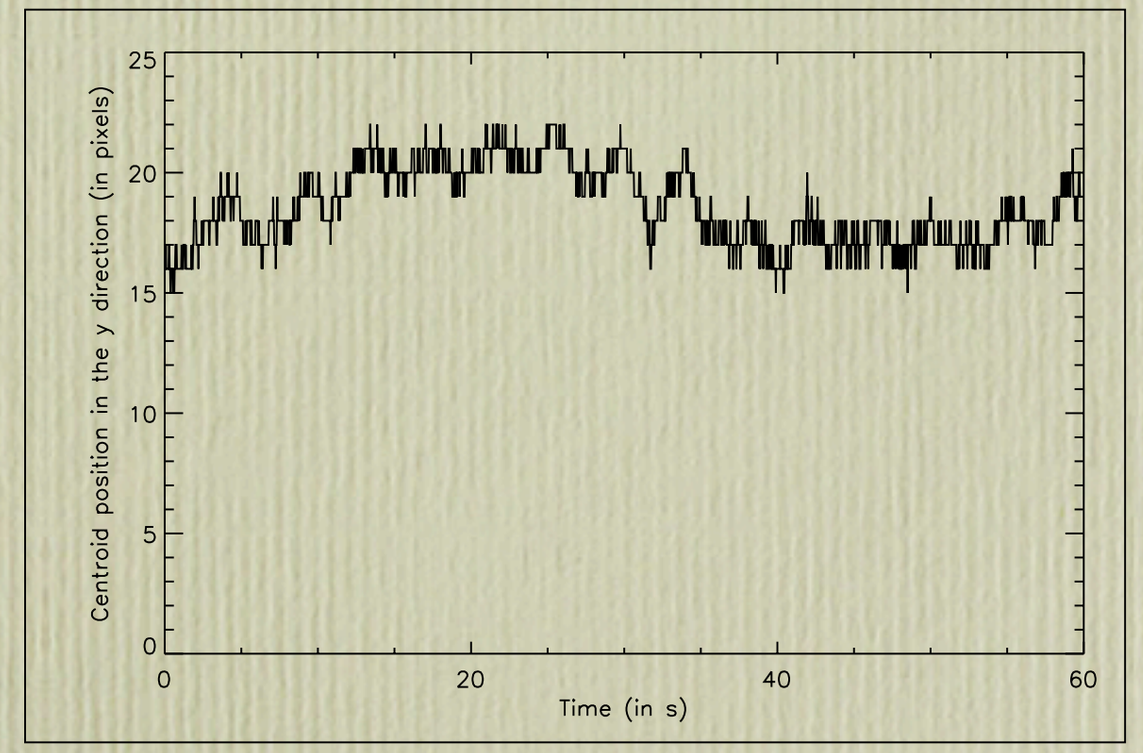
Movement of the centroid of the intensity pattern due to guiding, tracking, ... in the dispersion direction



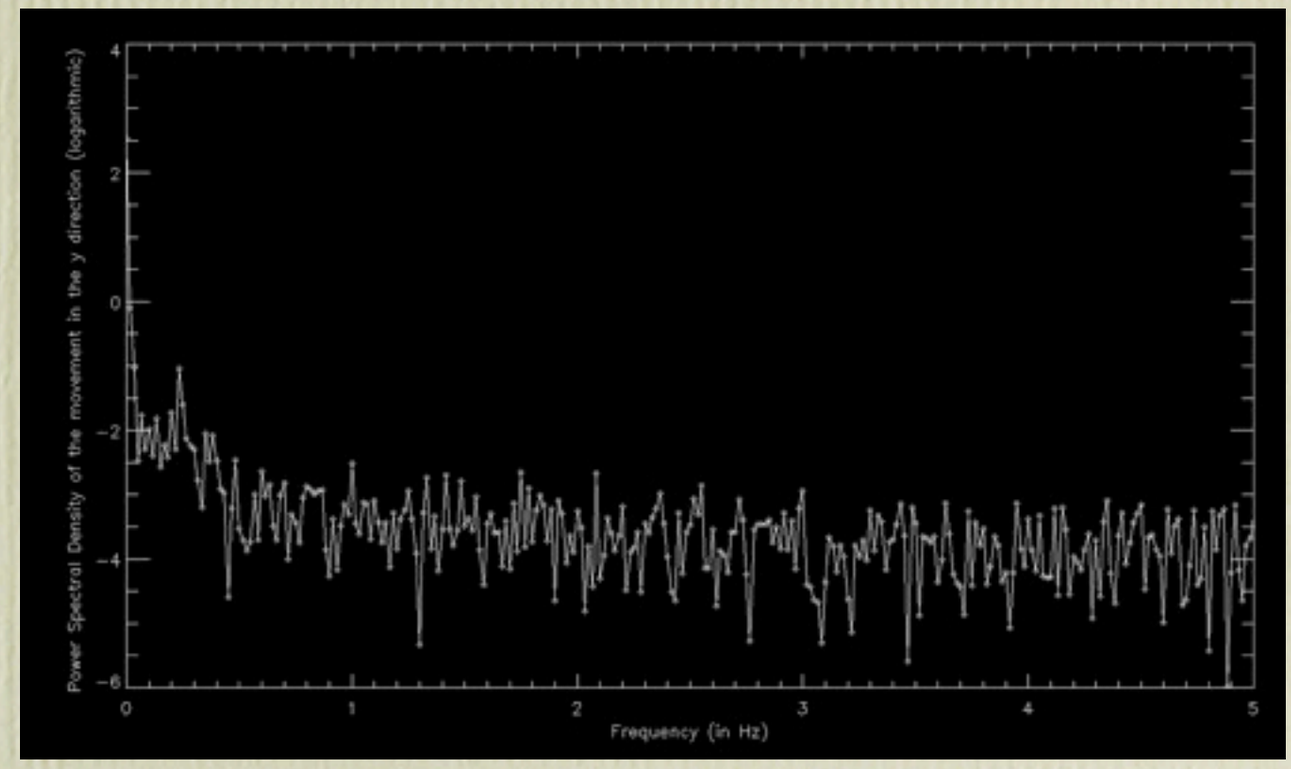
Power Spectral Density of the movement

=> Correlation between guiding, seeing and FWHM of the PSF with fiber

Movement of the intensity pattern due to guiding, tracking, ... (slit direction)



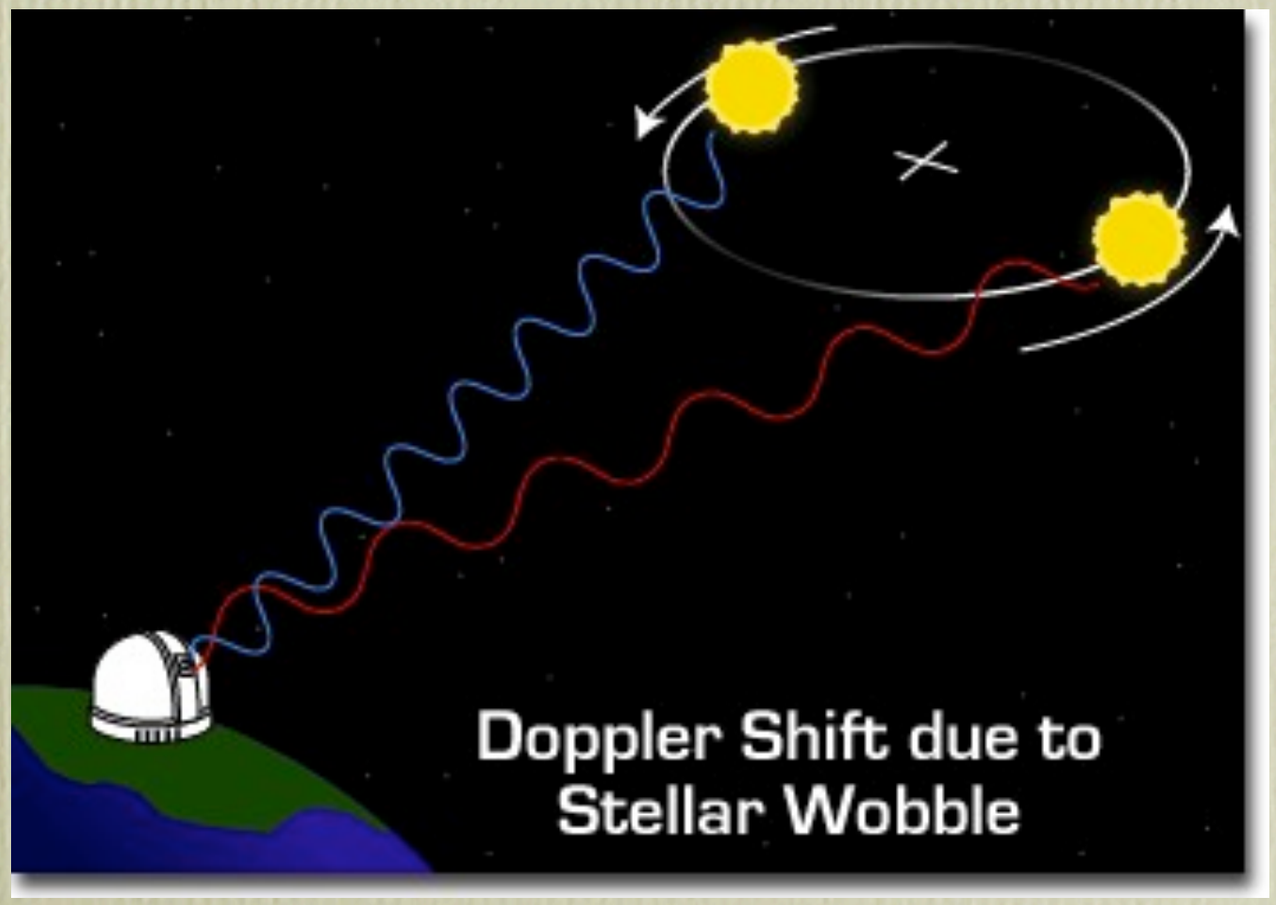
Movement of the centroid of the intensity pattern due to guiding, tracking, ... in the slit direction

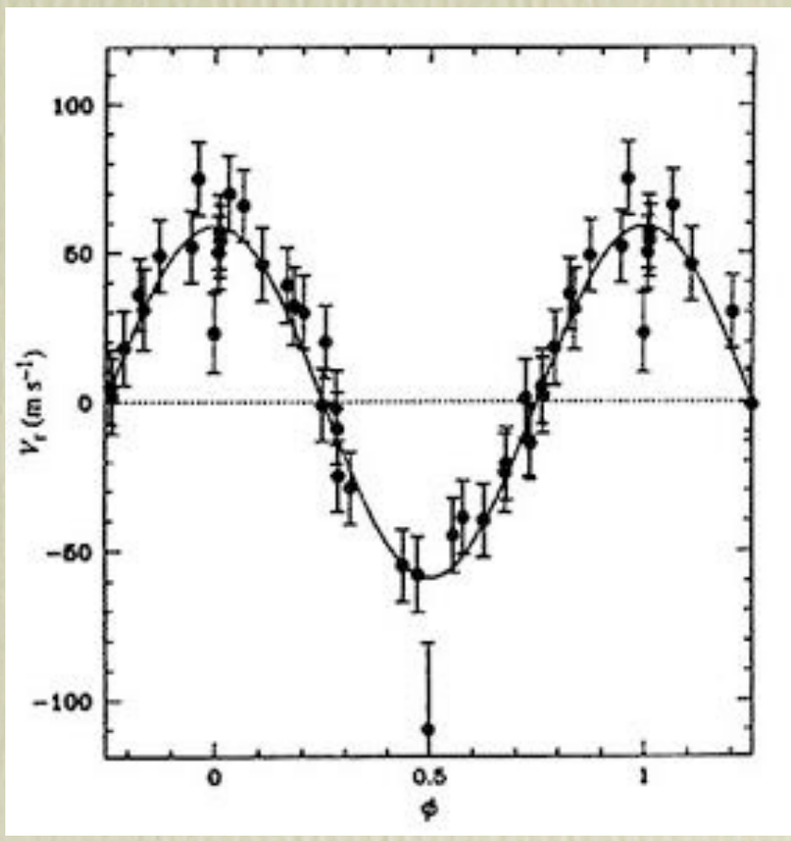


Power Spectral Density of the movement

=> Correlation between guiding, seeing and FWHM of the PSF with fiber

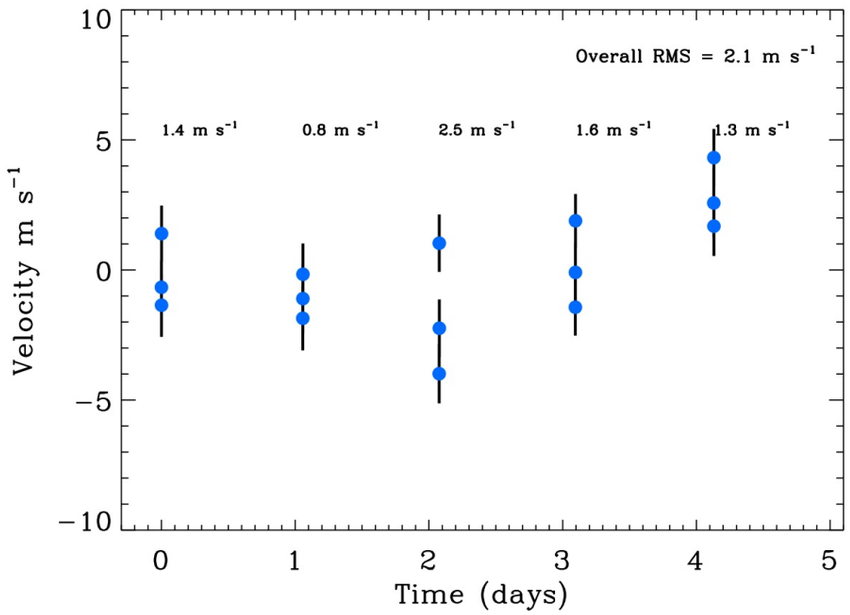
Search for exoplanets by radial velocity method



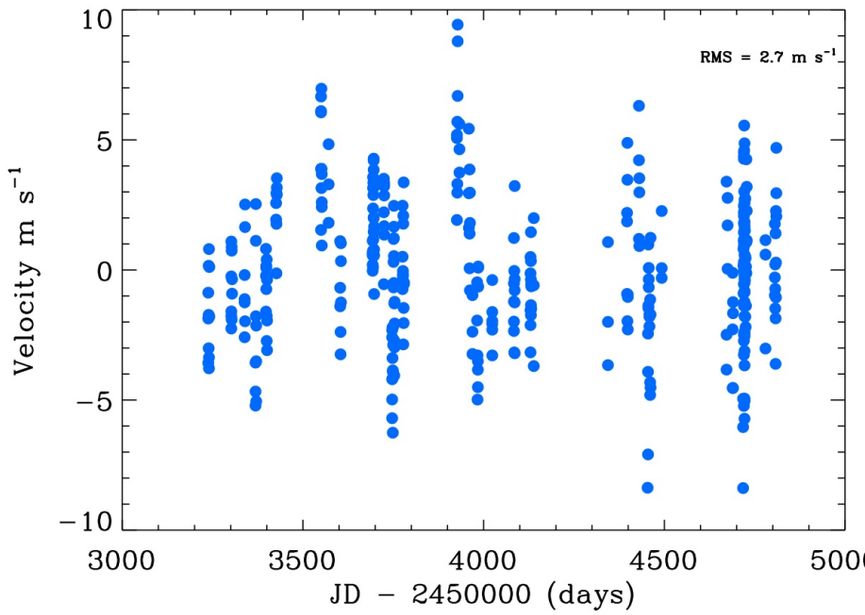


Example: 51-Peg at OHP

Systematic errors



Courtesy G. Marcy

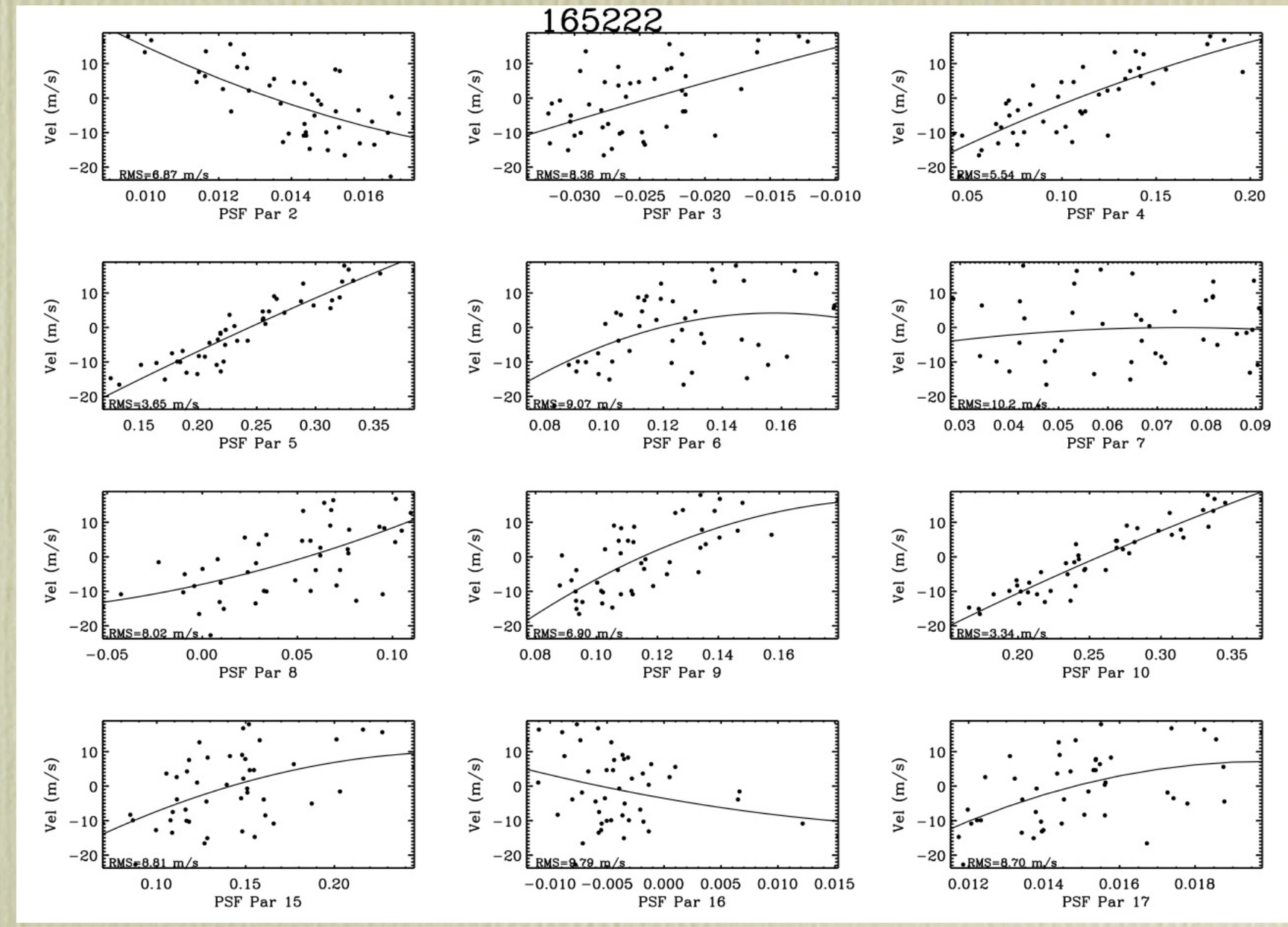


Courtesy G. Marcy

Measured velocities of Tau Ceti during five nights (left) and during five years (right). The RMS scatter of 2.1 and 2.7 m/s, respectively, are both well above the photon-limited errors of ~0.5 m/s.

Dominant systematic errors must have time scales of minutes and hours.

Correlation between velocities and PSF (HIRES)

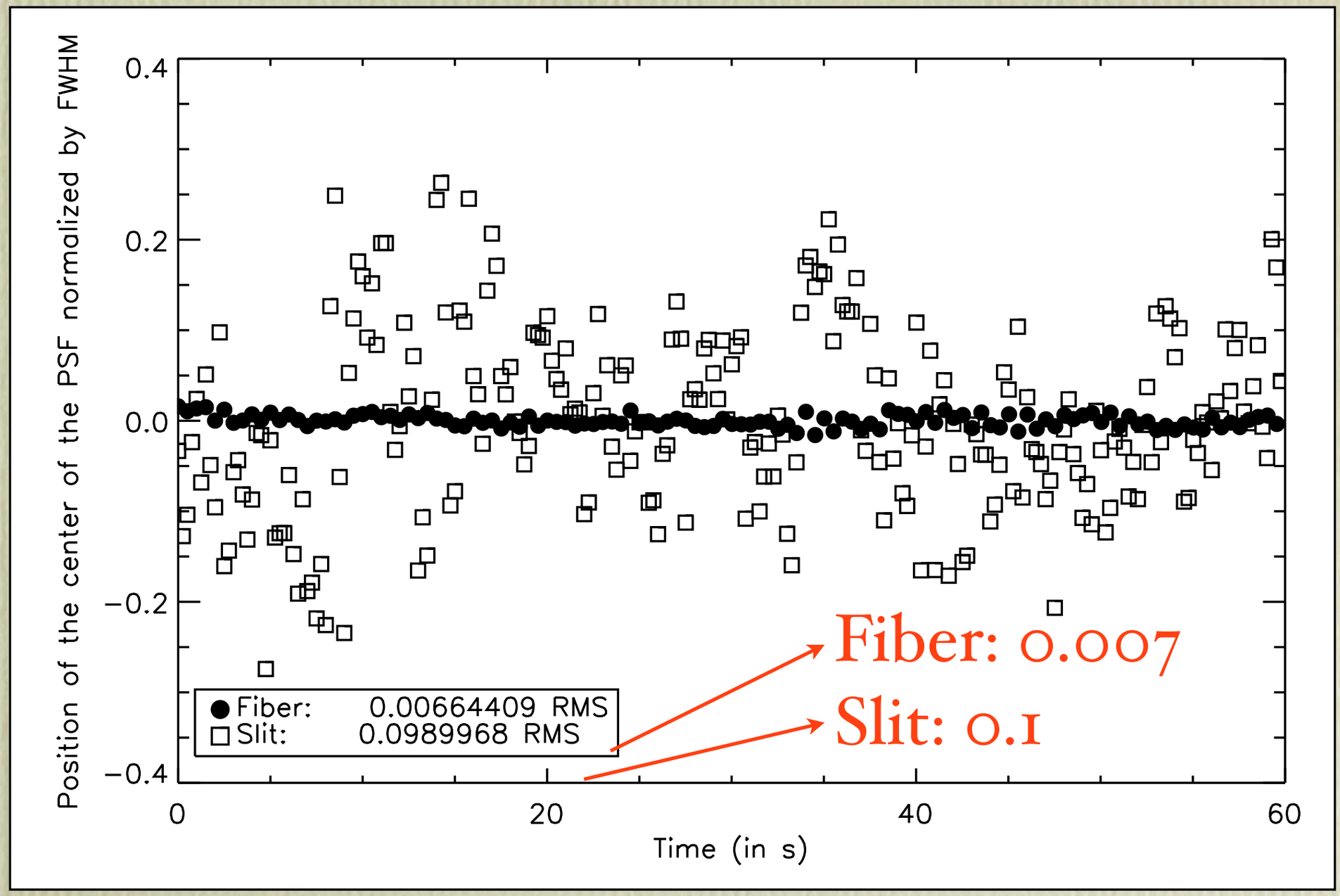


Courtesy G. Marcy

Velocity vs the median value of the PSF parameters

Strong correlation between PSF and velocity, suggesting that systematic errors in velocity are related to errors in the PSF

PSF Stability (Centroid)



=> Improvement in PSF stability by a factor 10 or more