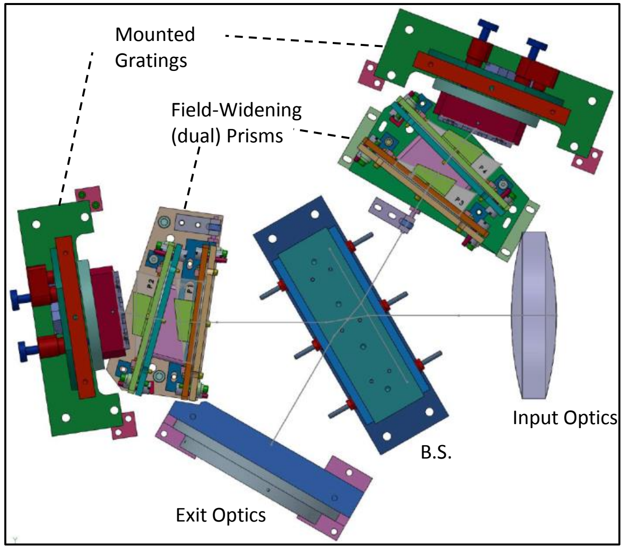
First Hα Airglow Temperature Observations using Field-Widened

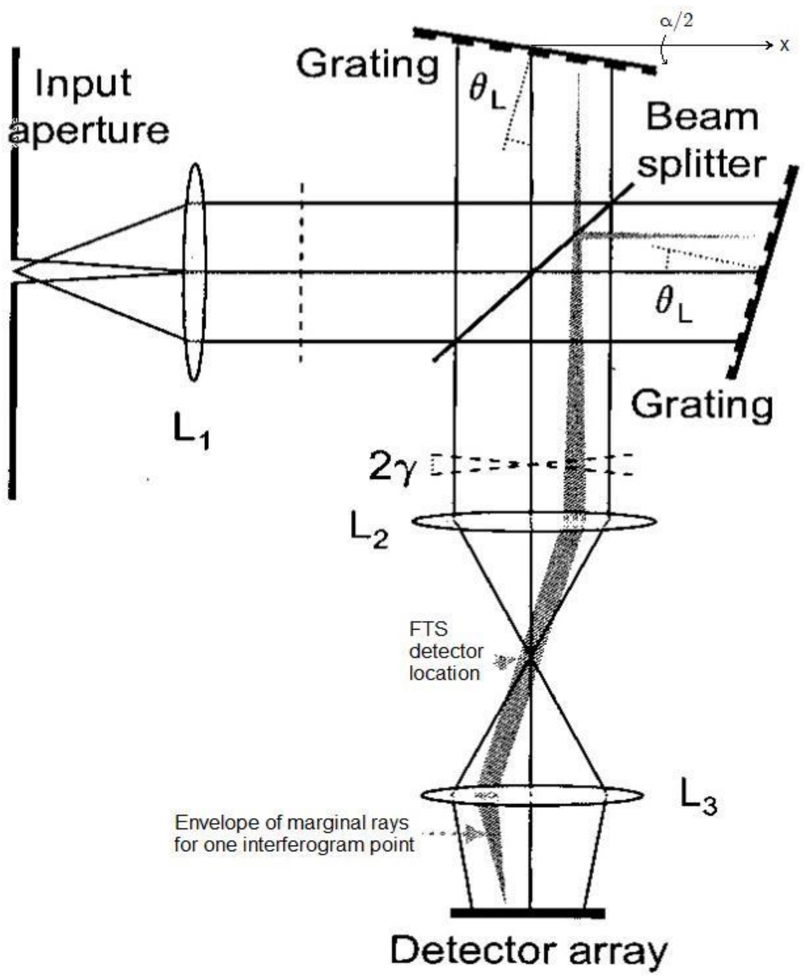
Spatial Heterodyne Spectroscopy



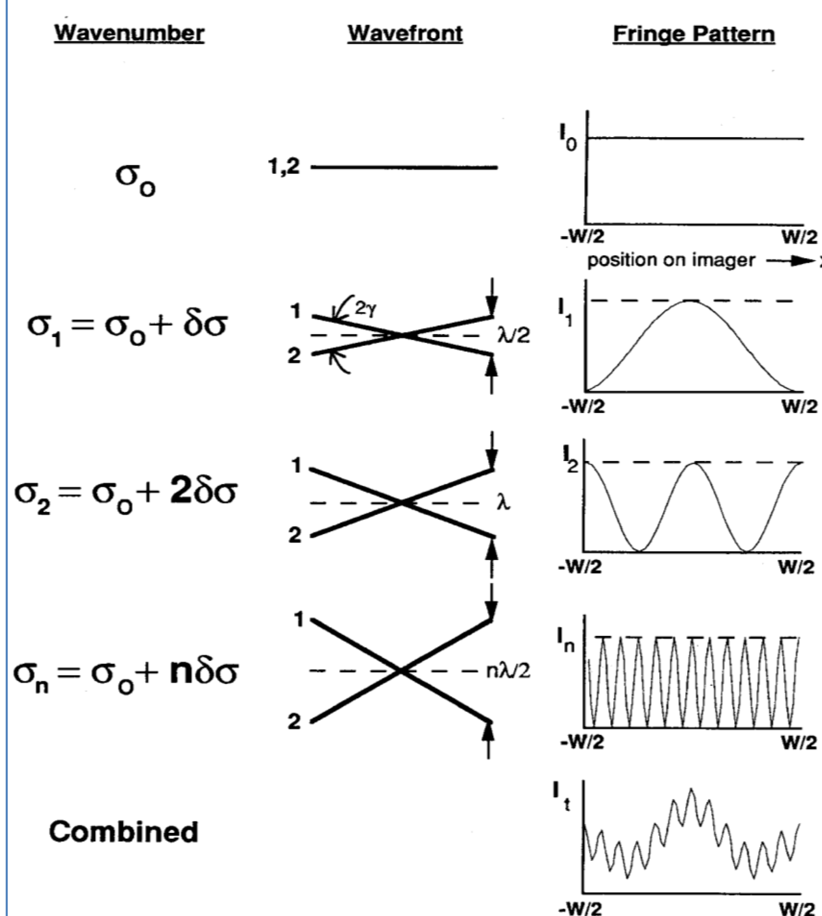
D. D. Gardner[1], E. J. Mierkiewicz[1], F. L. Roesler[1], J. M. Harlander[2], K. P. Jaehnig[1], L. M. Haffner[1], S. M. Nossal[1], J. W. Percival[1]

[1]University of Wisconsin-Madison, [2]St.Cloud State University

SHS Crash Course



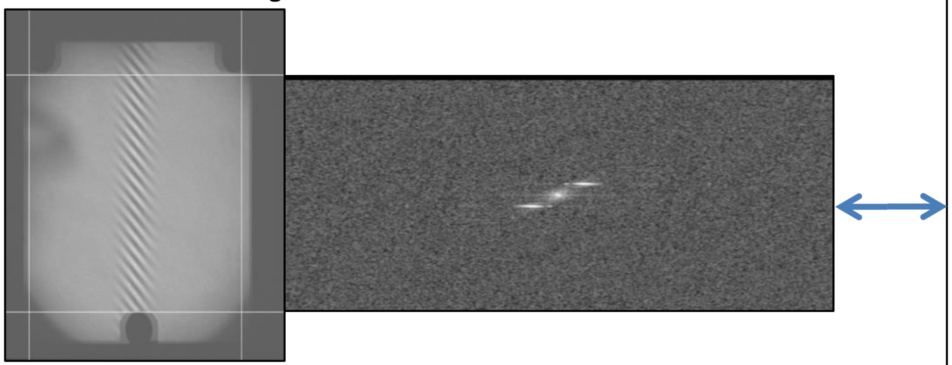
Basic non-field-widened SHS configuration



Relationship between wavenumber, wavefront, and fringe intensity

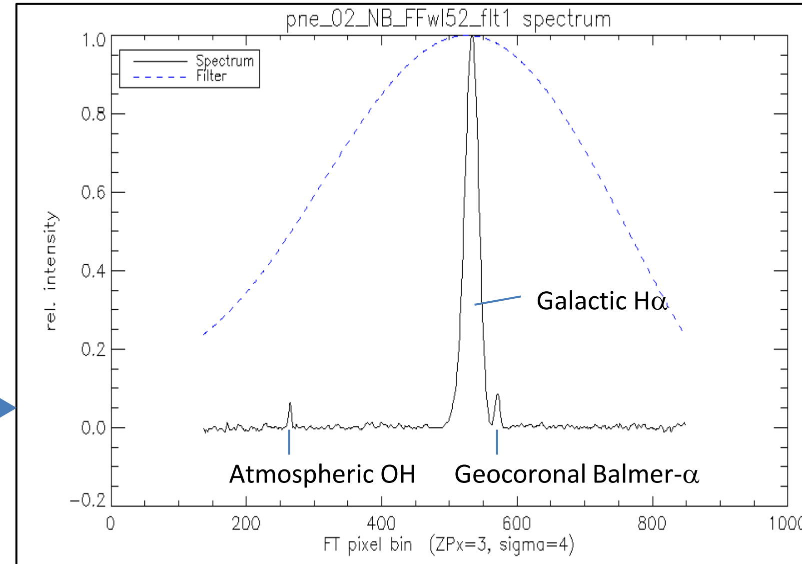
SHS Data Reduction

Hα FW-SHS Interferogram and Fourier Transform



(left) 512x512 pixel (24µm) Fizeau-fringe interferogram exposure (5 min) of well-resolved Hα emission from NGC1499, showing selected region fourier transformed (on right), after median bias subtraction, flat-field correction, custom Hanning + Norton-Beer apodization windowing and 3x zero-padding. FT symmetry is broken by a small grating cross tilt (α/2, see Fig. 6) so the NGC1499 spectrum (Fig. 8) can be obtained in lower half plane cut through the transform.

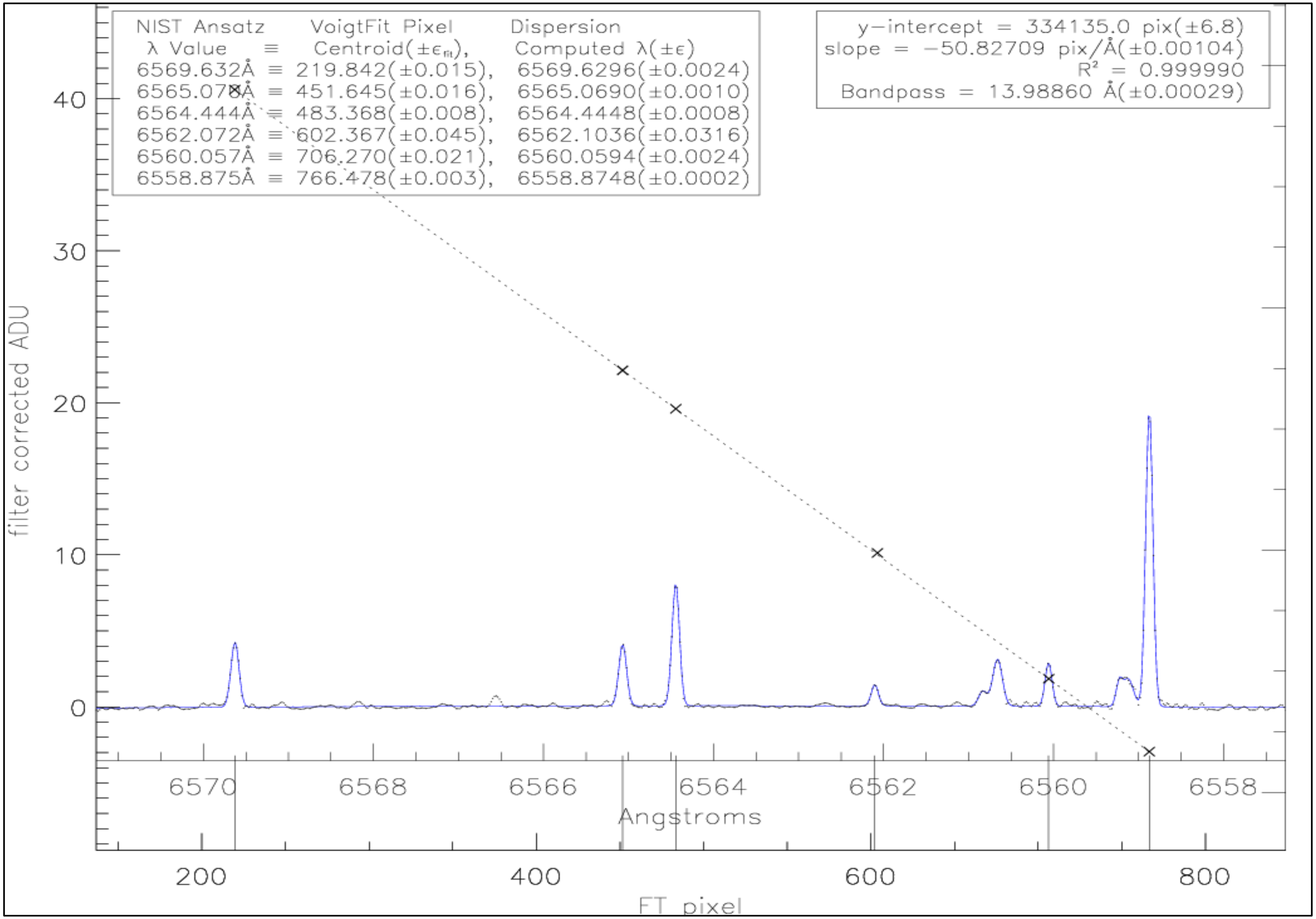
California Nebula (NGC1499) Hα Spectrum



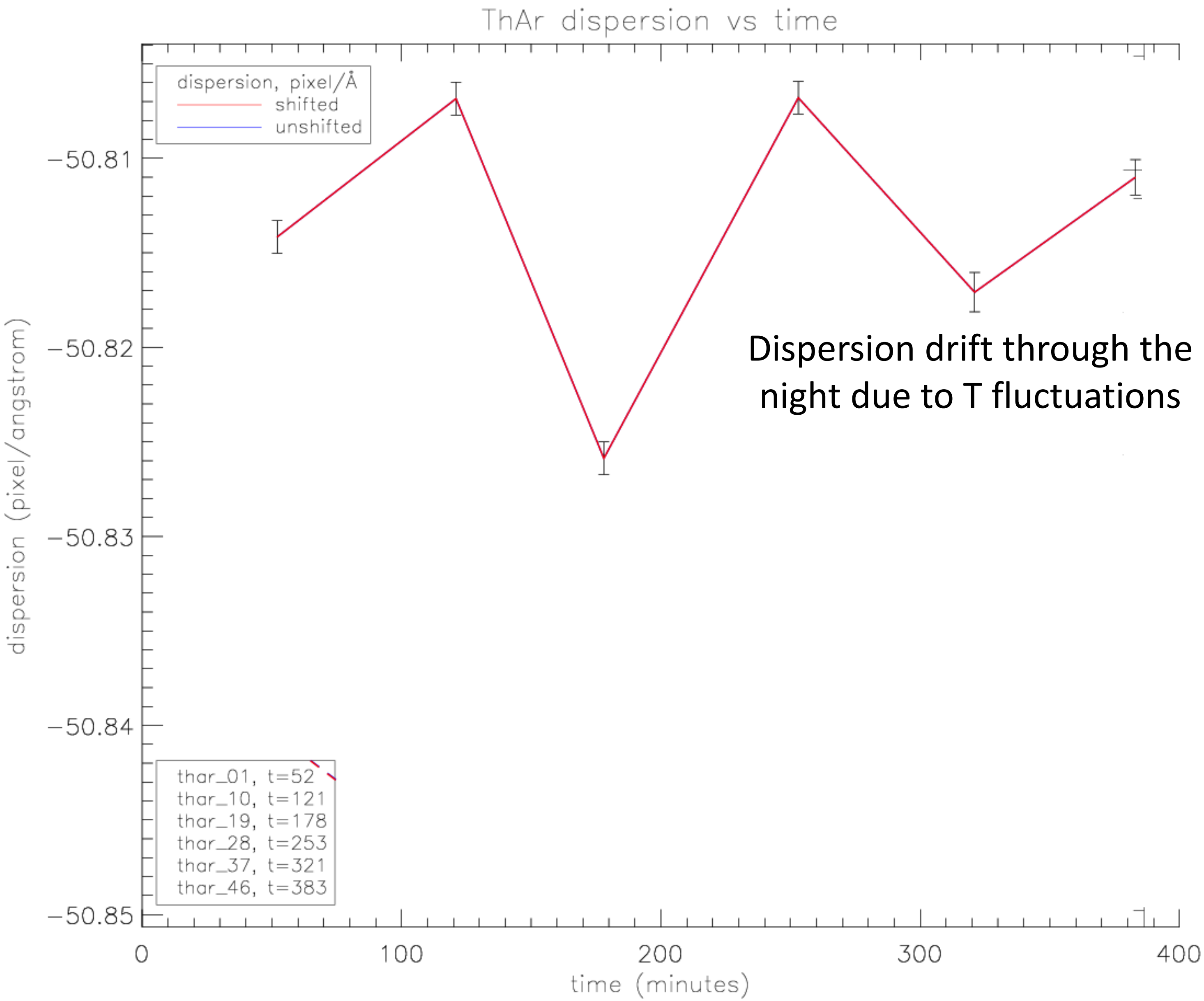
(02/22/14) 5 minute Hα FW-SHS exposure, at 1.8° FOV, towards NGC1499. The filter response to broad spectrum white light source is over-plotted & divided into each raw spectrum, giving an effective bandpass ~8.5A. Galactic Hα intensity is ~160 Rayleighs, illustrating need for well planned observations at sufficient VLSR to spectrally isolate geocoronal Balmer-α from Galactic Hα emission for intensity calibration.

	SHS initial (Hanning apodization)	SHS initial (Norton-Beer apodization)	SHS theoretical (boxcar apodization)	Fabry Perot
Resolving power	~51,000	~80,000	115,000	80,000
Effective Bandpass (A)	8.5	8.5	~14	1.6
Resolution (A)	0.13	0.08	0.058	0.08
Field of View (degrees)		1.8		1.4
Sensitivity (cm^2 sr)		4.2×10^{-2}		4.0×10^{-4}

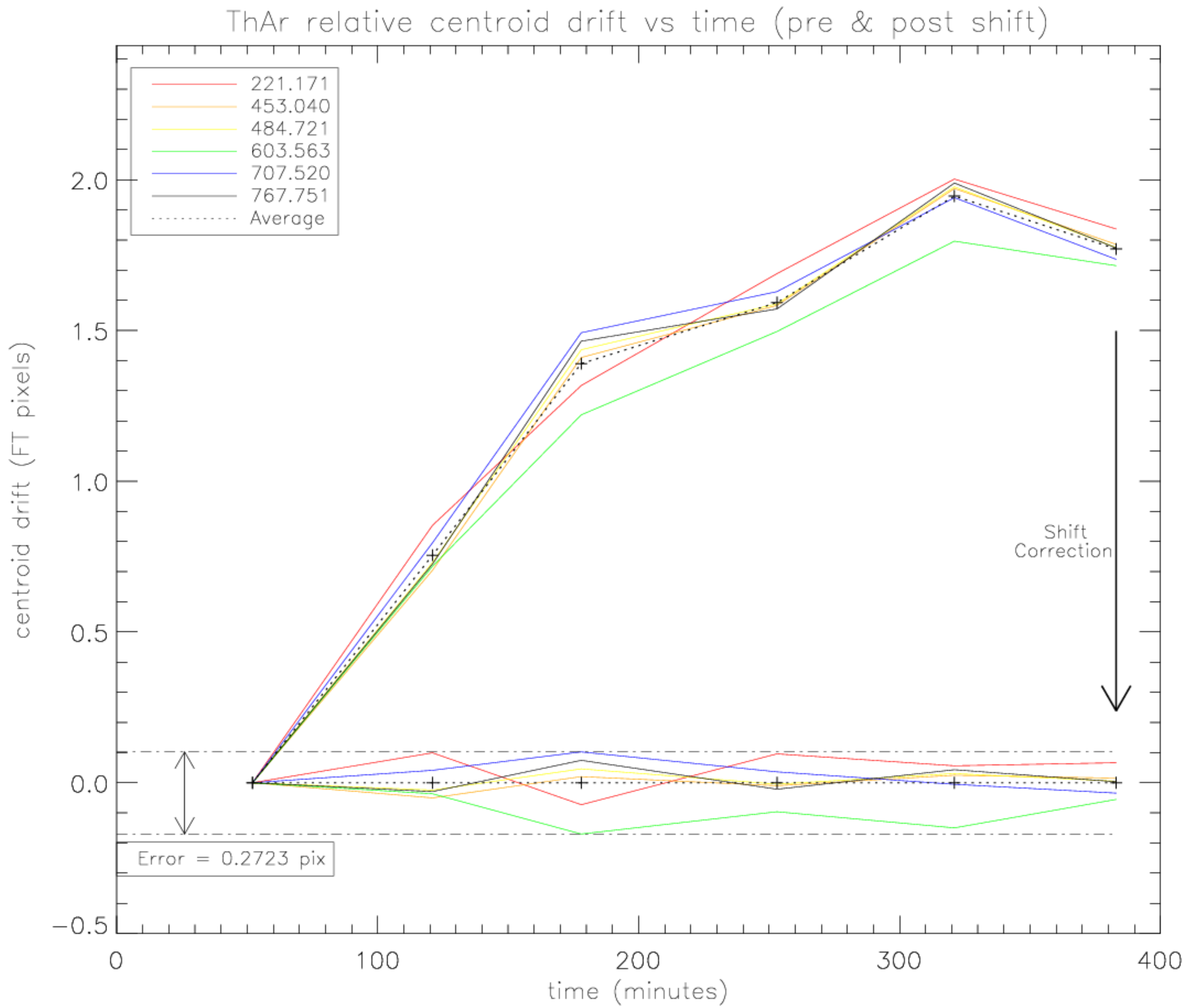
Thorium-Argon Hollow Cathode Lamp (ThAr HCL) Calibration Spectrum



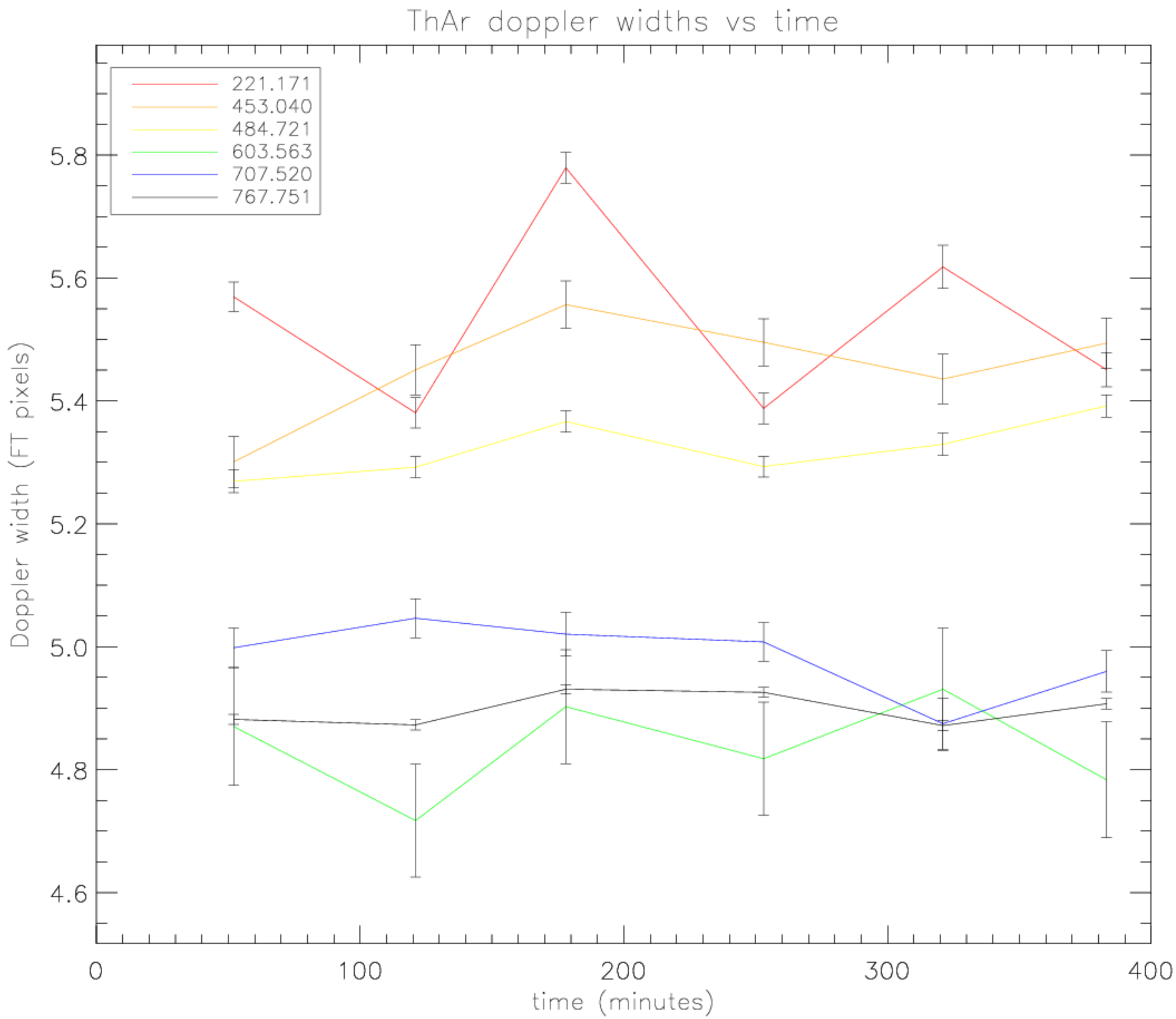
ThAr HCL readings are interspersed at hourly intervals during observing nights to correct for sub-angstrom (~<2km/s) dispersion drift due to room temperature fluctuations. Spectral calibration of each Hα observation is then obtained to precisely determine how Balmer-α airglow spectral peaks may be shifting, and if theoretically predicted trends in line fits with deepening shadow altitude exist (in order to constrain dynamical exospheric signatures).



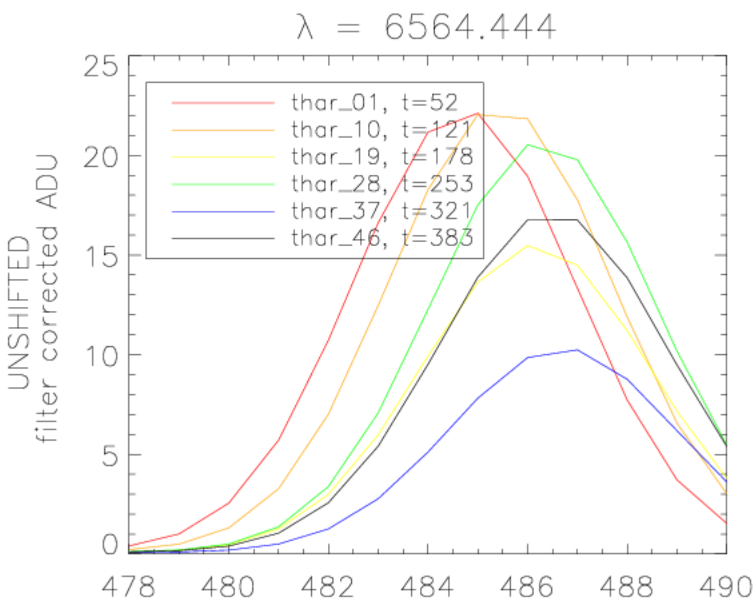
Dispersion drift through the night due to T fluctuations



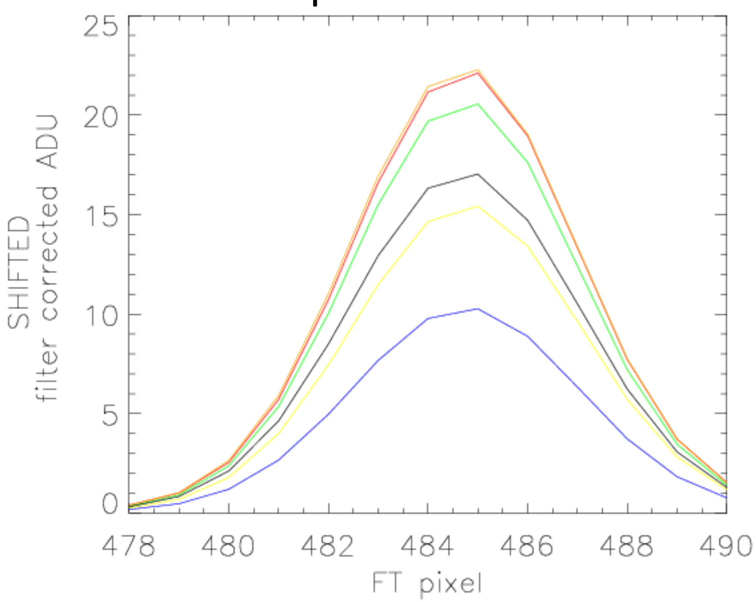
ThAr relative centroid drift vs time (pre & post shift)
221.171
453.040
484.721
603.563
707.520
767.751
Average
Shift
Correction
Error = 0.2723 pix
2.0
1.5
1.0
0.5
0.0
−0.5
0
100
200
300
400
centroid drift (FT pixels)
time (minutes)

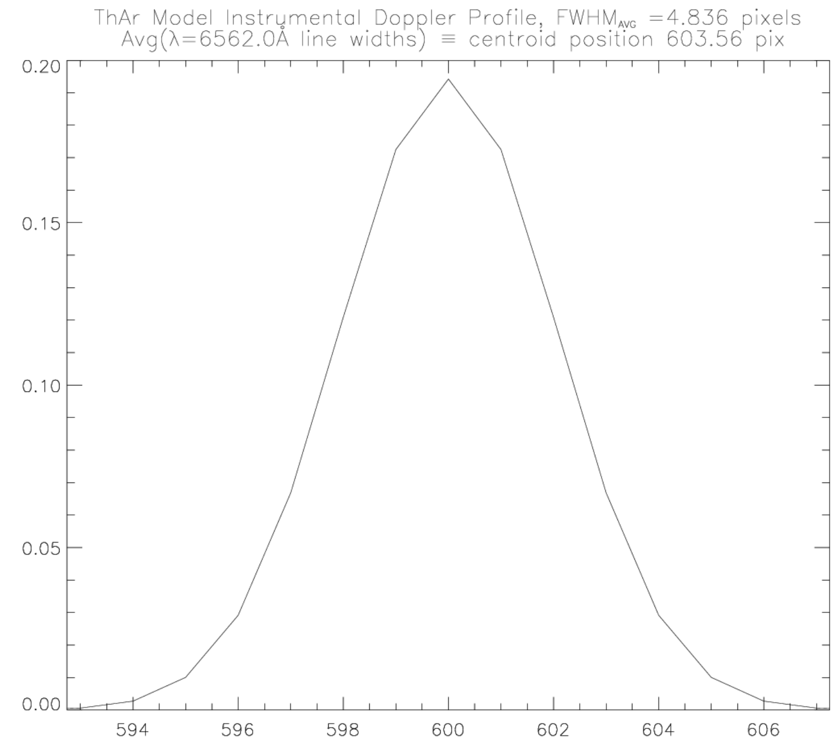


ThAr doppler widths vs time
221.171
453.040
484.721
603.563
707.520
767.751
5.8
5.6
5.4
5.2
5.0
4.8
4.6
Doppler width (FT pixels)
0
100
200
300
400
time (minutes)

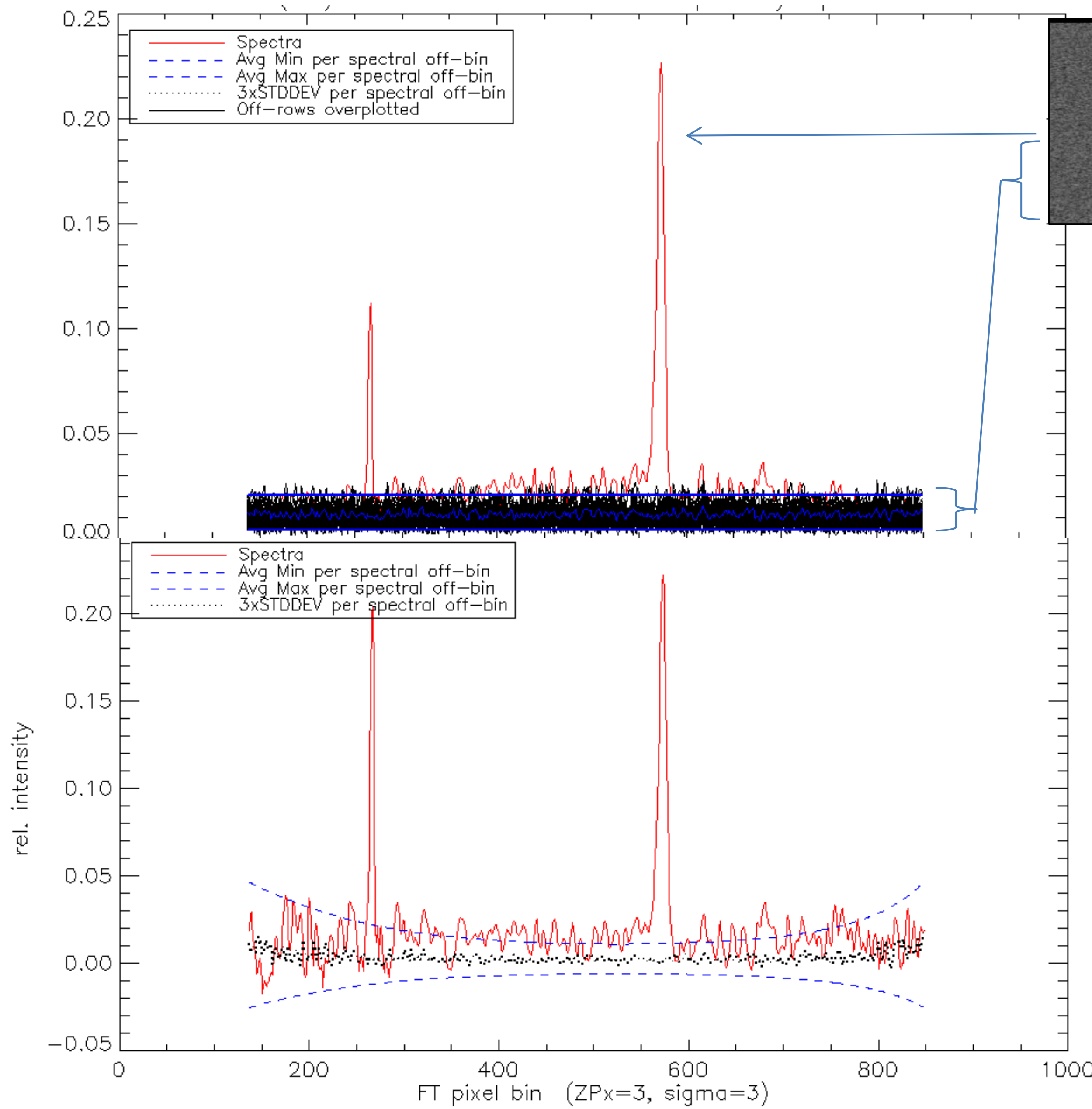


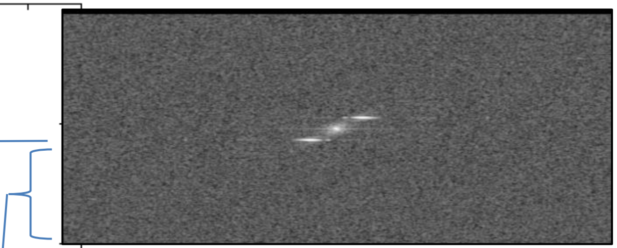
Example Shift Correction





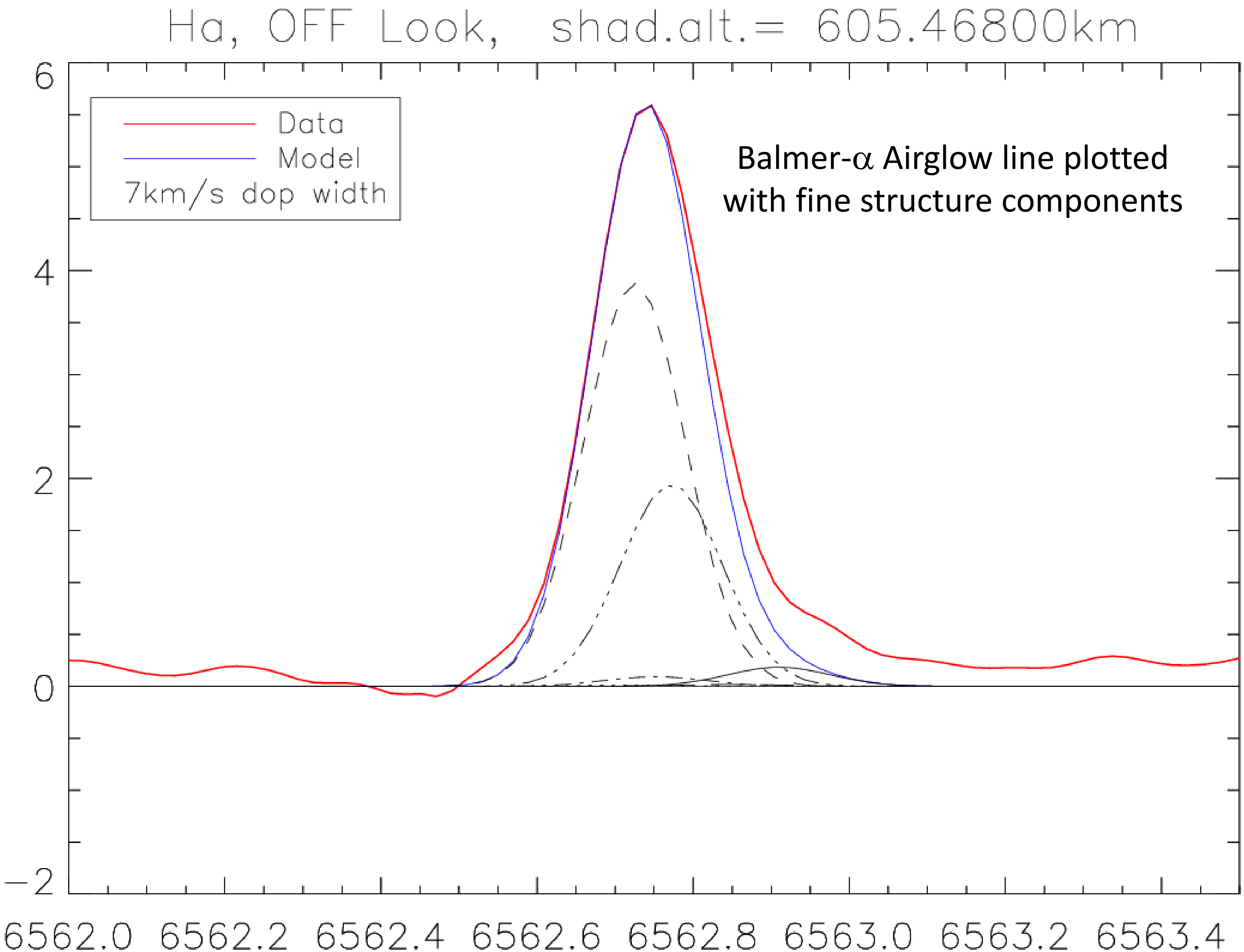
Instrumental profile retrieved from average FWHM of ThAr HCL



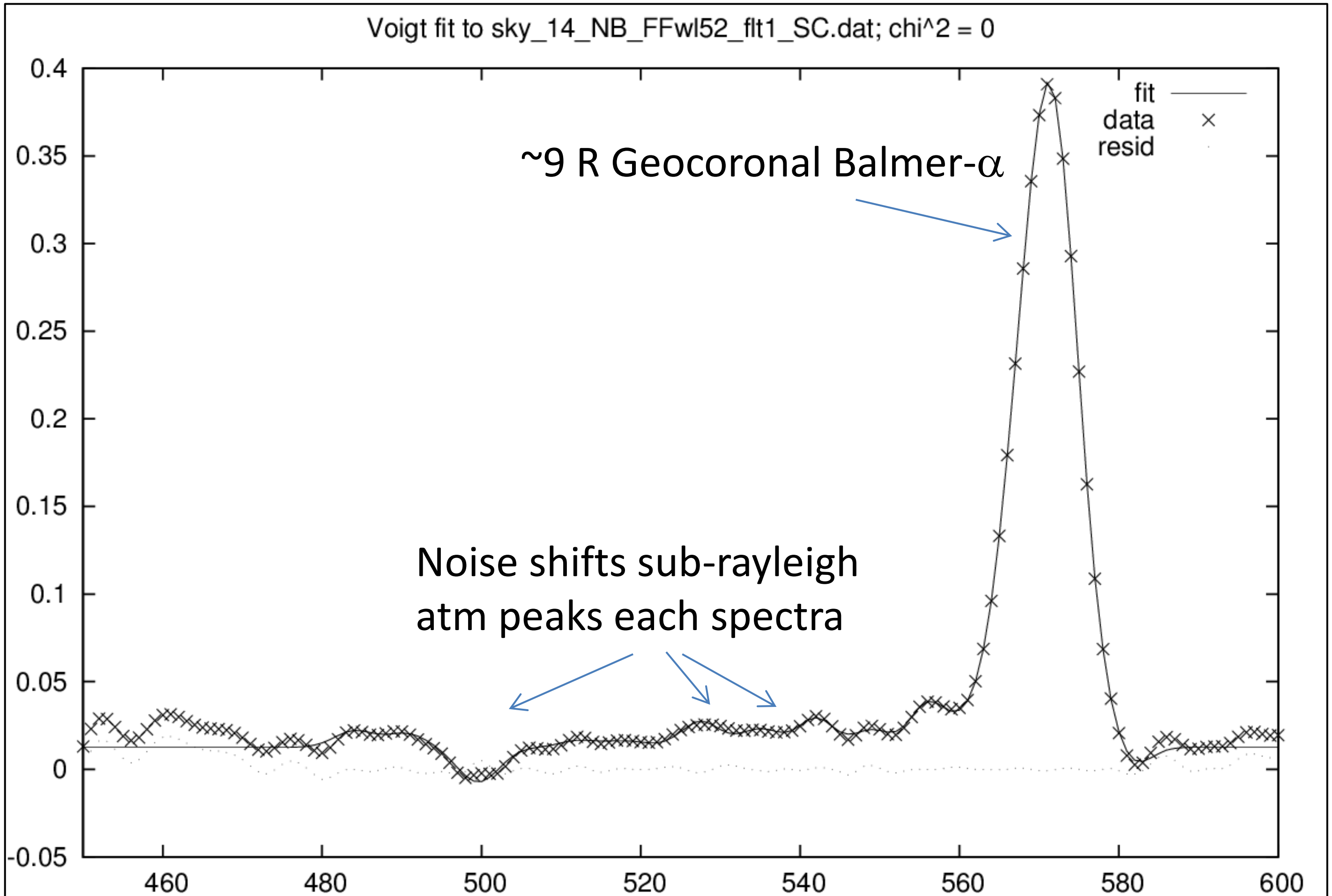


Example raw night sky airglow spectrum showing OH line near 6567A, a ~9 Rayleigh Balmer-α airglow line at 6562.7A and the effective Fourier Transform noise band across an ~8.47A bandpass. (*Abscissa units are FT pixel bins and ordinate units are relative ADU, pre-filter correction*.)

Same spectrum, ***after filter correction*** illustrating noise amplification


Ha, OFF Look, shad.alt.= 605.46800km
Data
Model
7km/s dop width
Balmer-α Airglow line plotted
with fine structure components
6
4
2
0
−2
6562.0
6562.2
6562.4
6562.6
6562.8
6563.0
6563.2
6563.4

Hα Night Sky Spectrum (Balmer-α redwing zoomed-in)



Balmer-α doppler width is ~6km/s, obtained from a seven (Fine Structure linked)-component Gaussian fit to the 6562.7 A spectral line near pixel 572. The spectral redwing portion is magnified to illustrate the complexity of the modeling process involved in each spectrum in order to isolate redwing cascade component contributions and remove Galactic signal. 15 separate Gaussian line fits were needed to model atmospheric + noise background from pixels 480 to 590.

Hα FW-SHS Conclusions:

Pros = High resolution, long spectral baseline
Detecting peak shifts
Galactic background subtraction

Cons = Multiplex disadvantage
Constraining FS-cascade, charge exchange and exospheric escape population contributions to Balmer-a redwing fine structure components is ...