Spectrograph Stabilization of 500x using a Single-delay Interferometer

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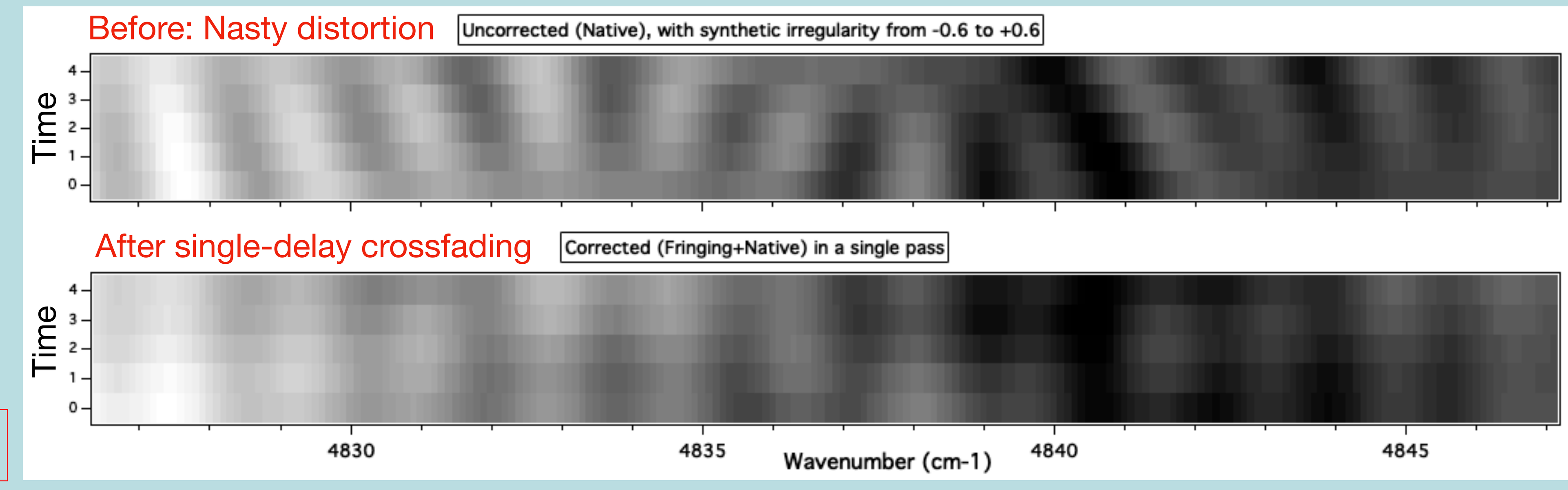
***Crossfading - combining two signal components using frequency dependent weights - can stabilize a grating spectrograph against uncontrolled wavelength drifts by using an external interferometer (EDI). This creates moiré patterns, which are processed into wavelets. The system reduces wavelength drifts by 500x - 1000x, and can sharpen the instrument profile, doubling or more the spectrograph resolution. We demonstrate stabilization on star light data and simulations.**

Demo of crossfading on the nastiest type of drift: bipolar



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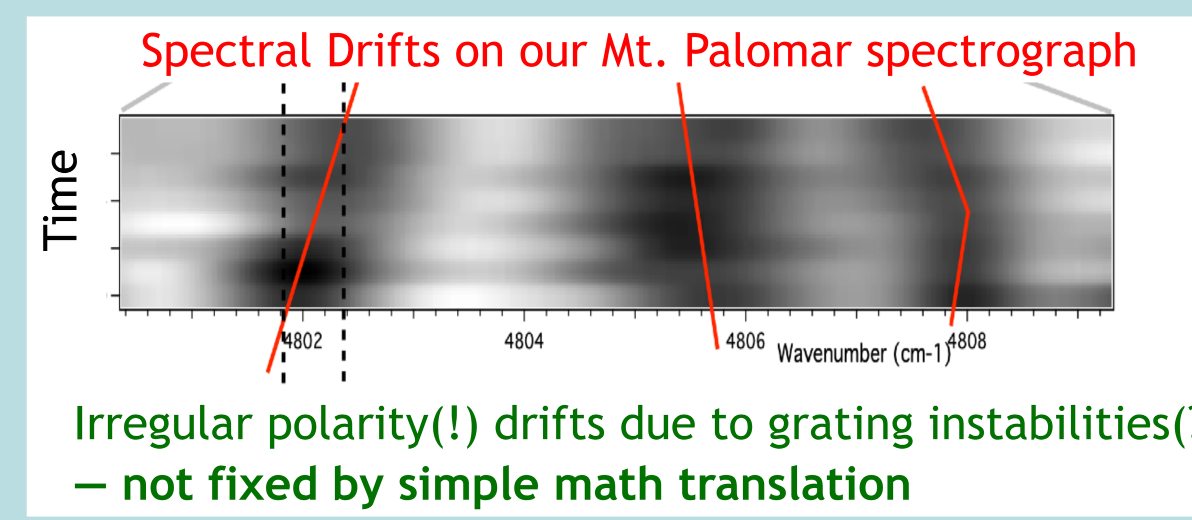
You can't repair this type of drift by a simple translation, but crossfading fixes it!

Example of nasty bipolar drift at Mt. Palomar in 2010 data



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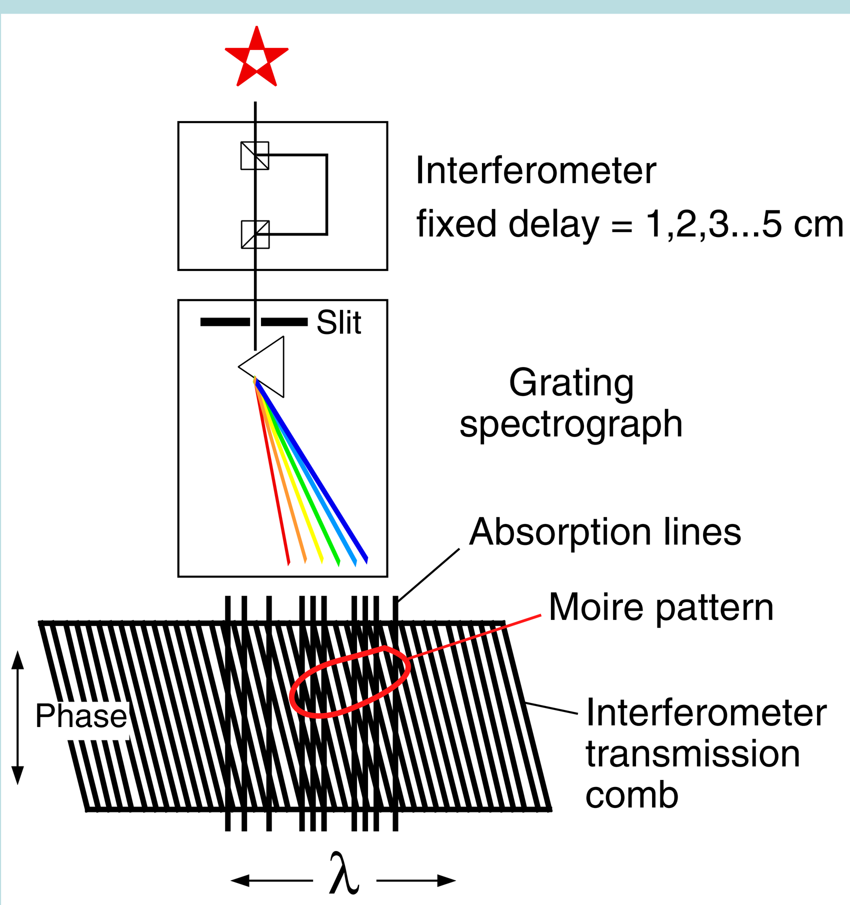

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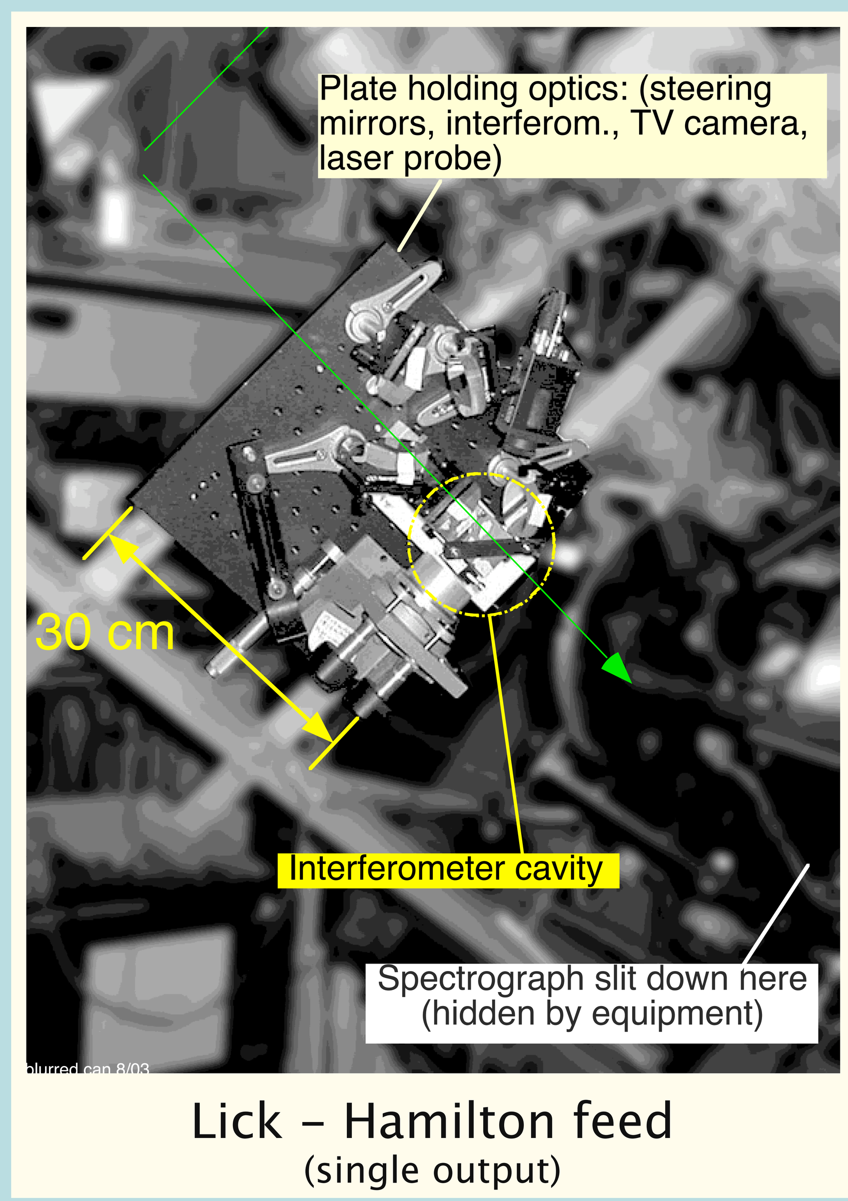

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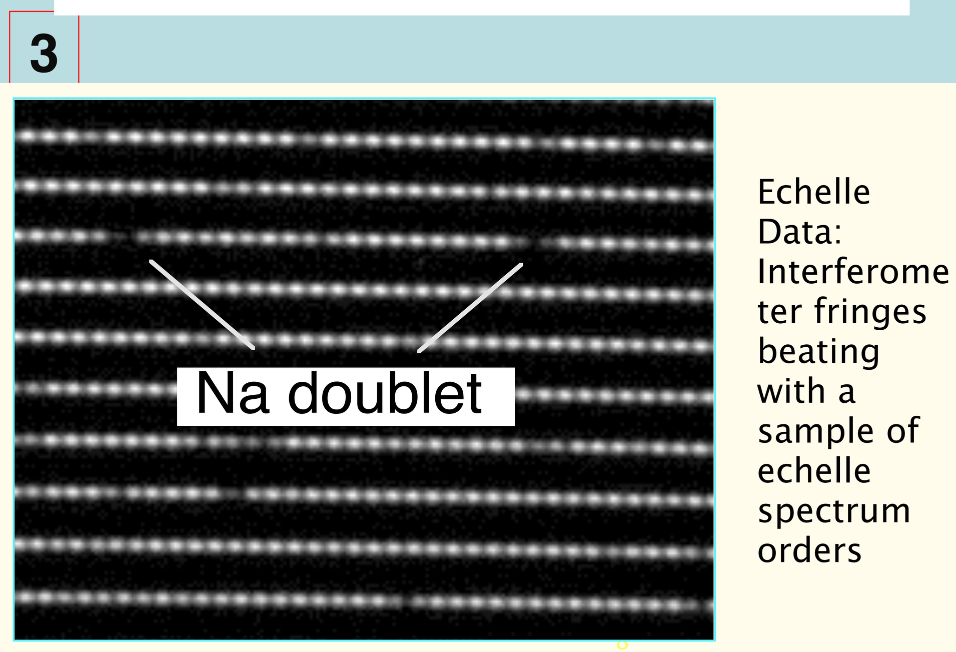

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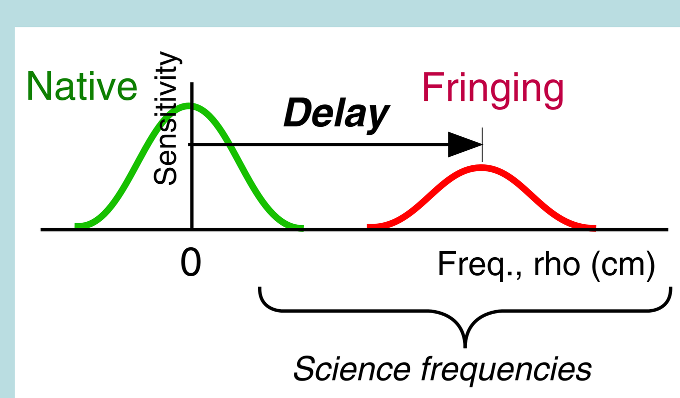

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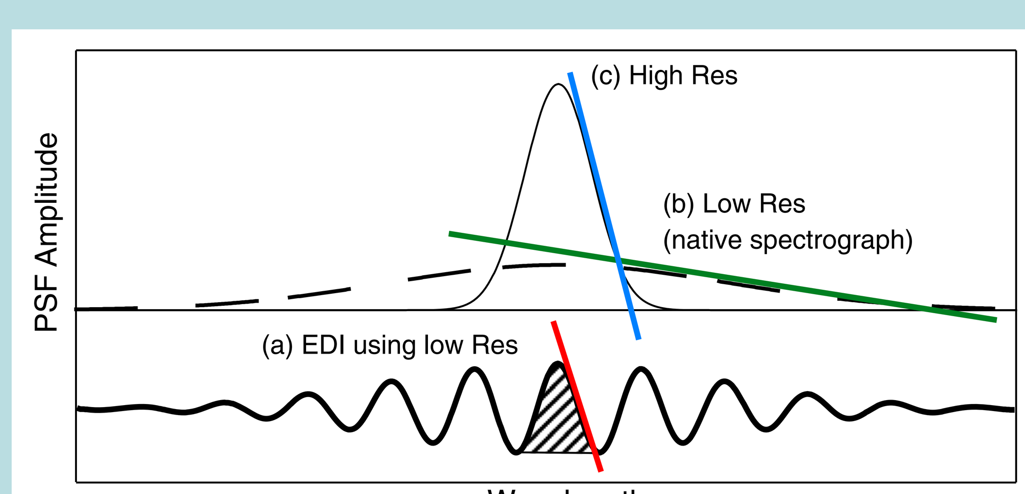
(Fig. 3) Externally Dispersed Interferometer (EDI) scheme. (Fig. 4) EDI inserted into beam prior to Hamilton echelle spectrograph at Lick Obs. In 2003. A 2x resolution boost was achieved. (Fig. 5) Snippet of echelle spectra around sodium doublet (589 nm) showing sinusoidal interferometer comb multiplying stellar spectrum. (Fig. 6) EDI instrument response in Fourier space (horiz units also of delay cm). Heterodyning effect shifts native grating response (green) up by amount equal to interferometer delay. (Fig. 7) EDI response in dispersion space (wavenumbers or wavelength) is a wavelet. The envelope of wavelet is native PSF, the internal sinusoid is set by interferometer delay. Slope of wavelet (red line) is much higher than slope (green) of native.



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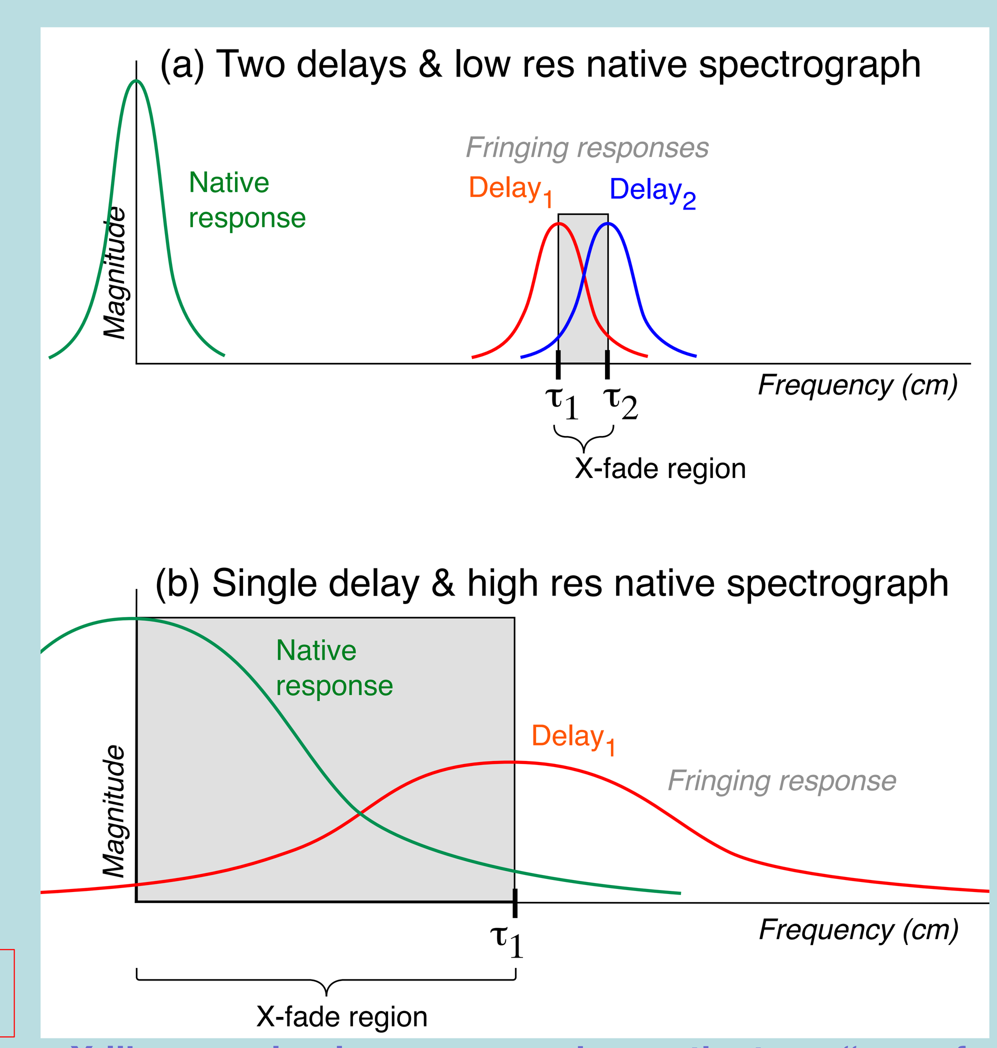
Two-delay and single-delay crossfading compared

Modulation Transfer Function (MTF) is Fourier transform of point spread function (PSF)



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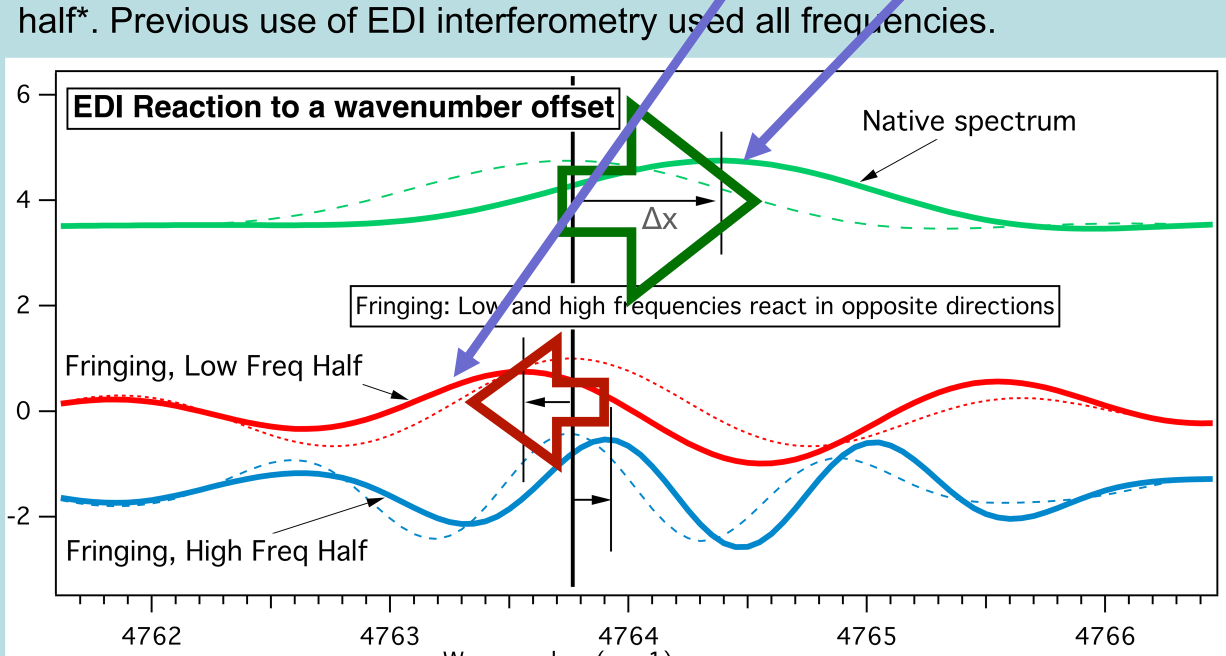
The two curves make an X-like crossing in gray areas, hence the term "crossfading"

We have discovered a signal component that moves in *opposition* to the native spectrograph drift Δx.

This allows cancellation of drift, ie a stabilized spectrograph. The opposition signal component is the fringing signal, but using *only the lower frequency half*. Previous use of EDI interferometry used all frequencies.



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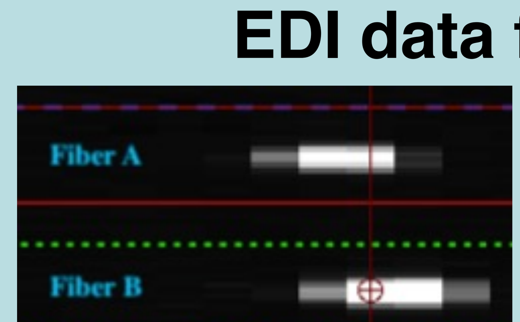
Single delay crossfading demo on starlight+ThAr using Mt. Palomar EDI data from 2010, re-analyzed



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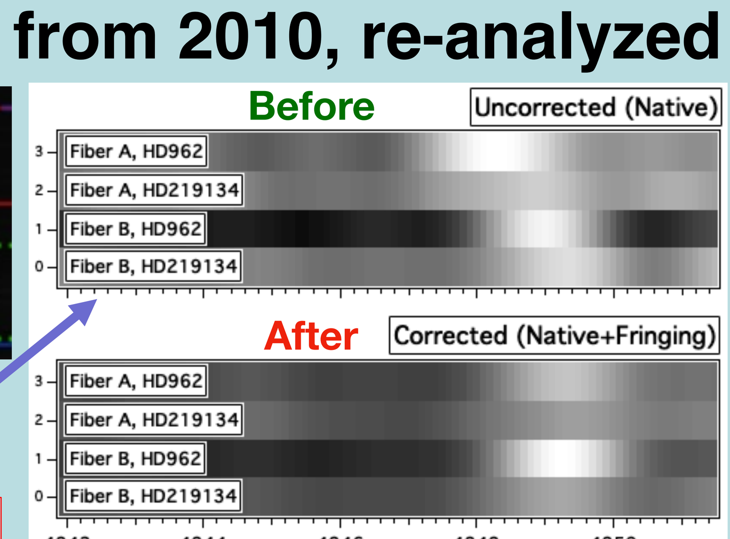

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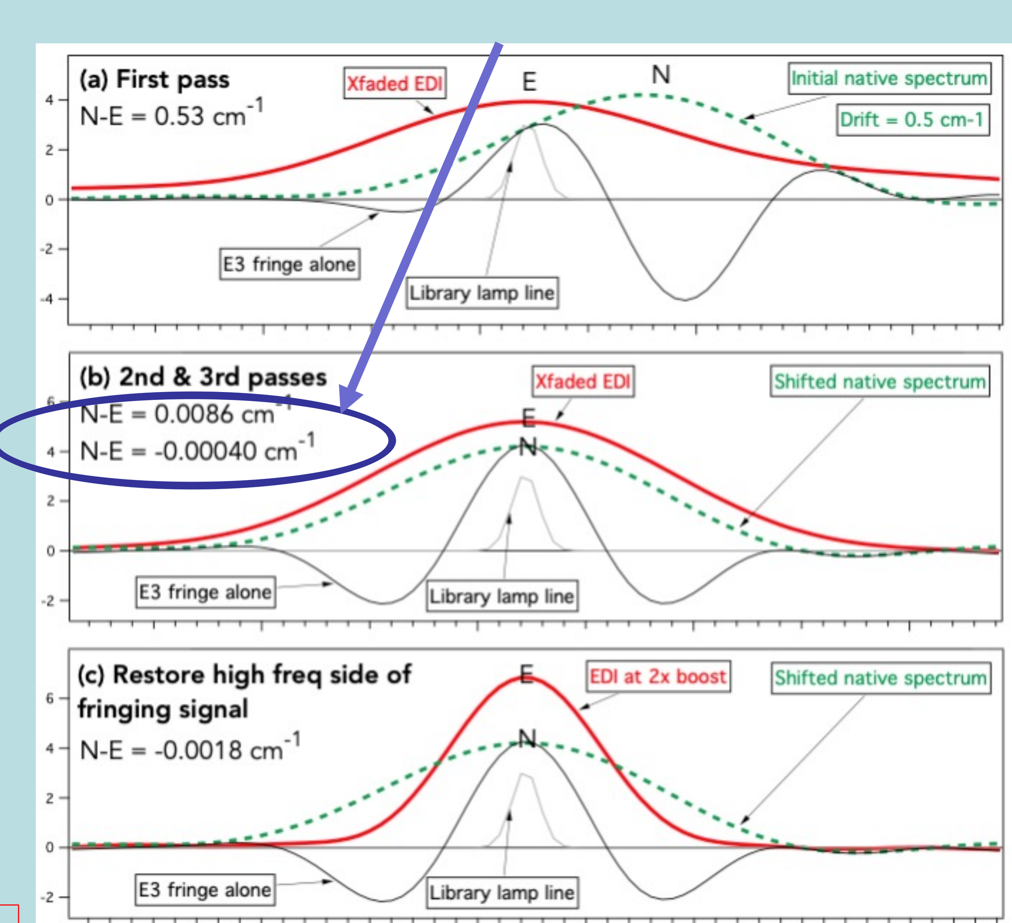
Spectrograph optics create a wavelength offset between A/B source fibers. Additional offset for different stars due to drift over time. Net offset is removed by crossfading. A 4764 cm^{-1} ThAr line (off graph) provides absolute reference for the interferometer phase.

1300x stability: 0.53 cm^{-1} initial insult reduced to 0.0004 cm^{-1} in three passes



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*See "Method for boosting dispersive spectrograph stability 1000x using interferometry with crossfaded pairs of delays", David J. Erskine, J. Astr. Tele. Instrum. Sys., 7(2):025006, June 2021
https://doi.org/10.1117/1.JATIS.7.2.025006

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