Spectrograph Stabilization Method using a Single-Delay Interferometer on the Hale Telescope

David J. Erskine[a], J. Edelstein[b], M. Sirk[b], E. Wishnow[b]

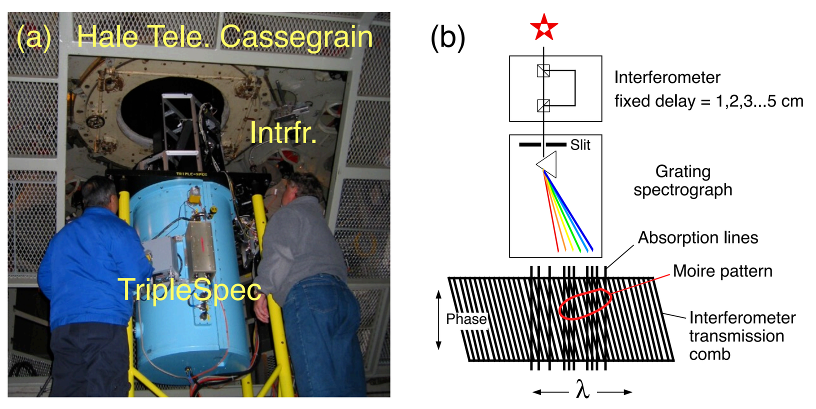
(a) derskine@spectralfringe.org, (b) ***UC Berkeley Space Sciences Lab***

Method called "*Crossfading*"

SPIE. Paper 14149-402

SPIE Astron. Tele. Instrm.
July 5-10, 2026, Copenhagen

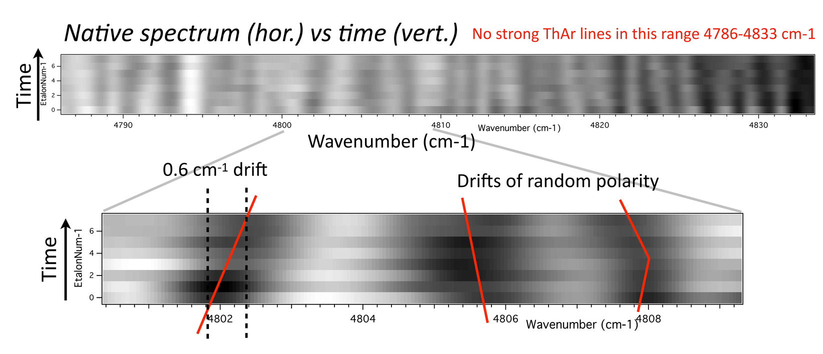
-- Apparatus: EDI * TripleSpec



1

Externally Dispersed Interferometer[1-11] (EDI) on TripleSpec NIR spectrograph dewar (blue) at Hale 5m Telescope.

-- Problem: Irregular disperser drift Δx

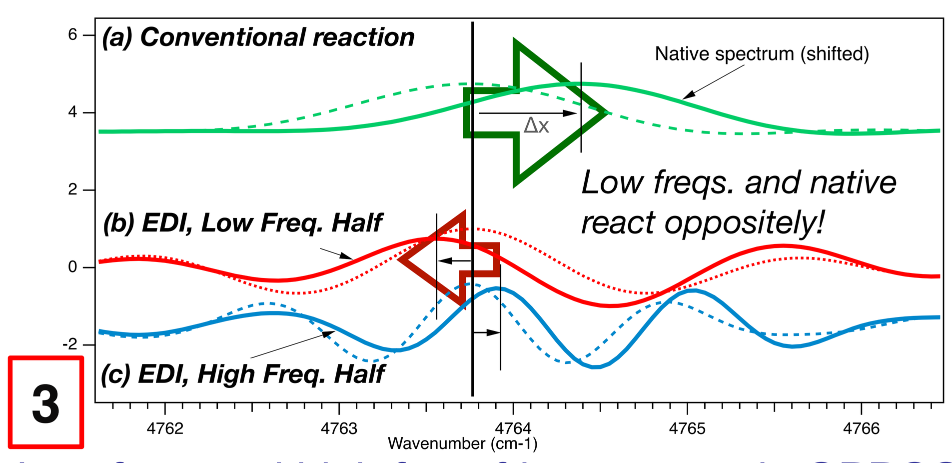


2

And no nearby spectral reference lines !

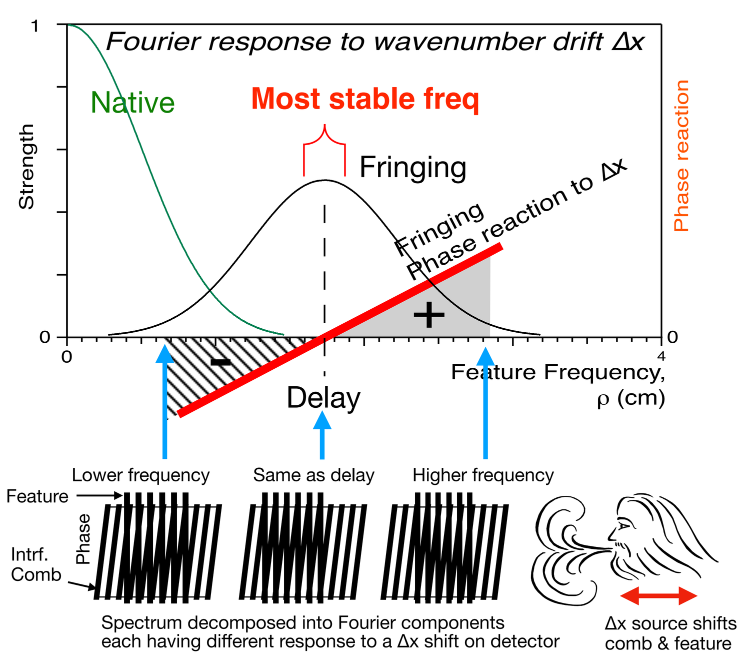
-- Aha! moment

Low freq. fringes move in **OPPOSITE** direction as Δx drift!



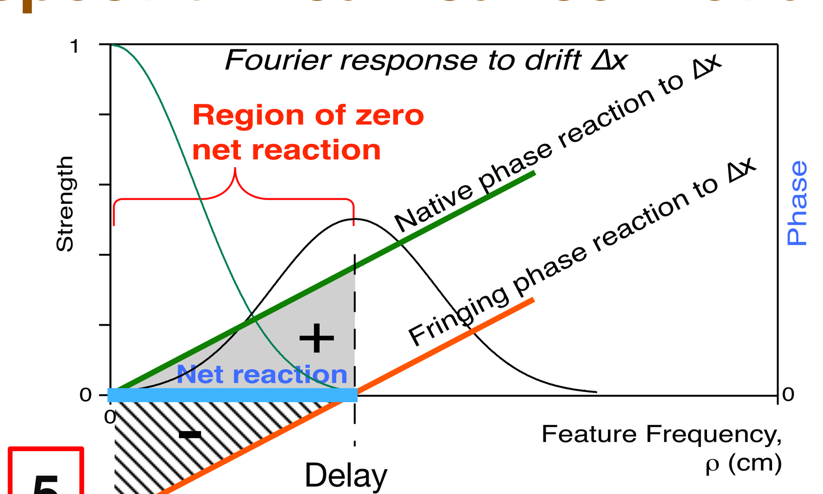
3

Low freq. and high freq. fringes move in **OPPOSITE** directions to a Δx



4

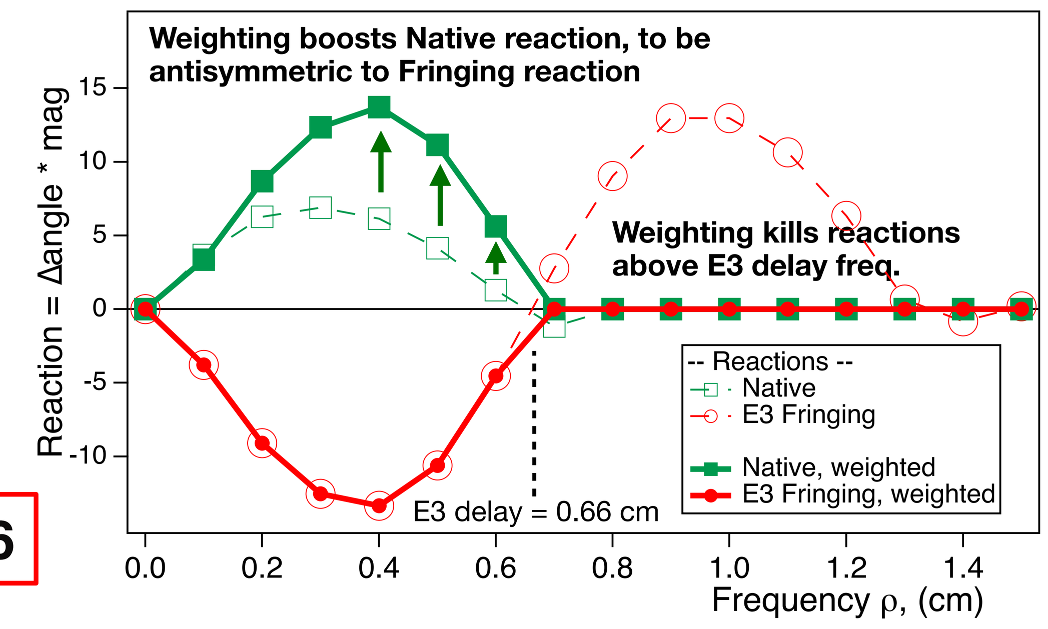
-- Solution: low freq fringes & native spectrum can cancel net drift



5

Provided freq. dependent weights chosen strategically (e.g. Native must be weighted to zero at Delay, Fringes must be weighted to zero at zero freq.)

-- Process: ThAr data in Fourier space



6

Fourier transform of a measured ThAr line displaced by Δx wavenumbers to compute reaction in phase direction of complex Fourier components.
(Red) S-shaped result for Fringing reaction, zero crossing at delay 0.66cm.
(Green) Mountain-shaped result for Native reaction.

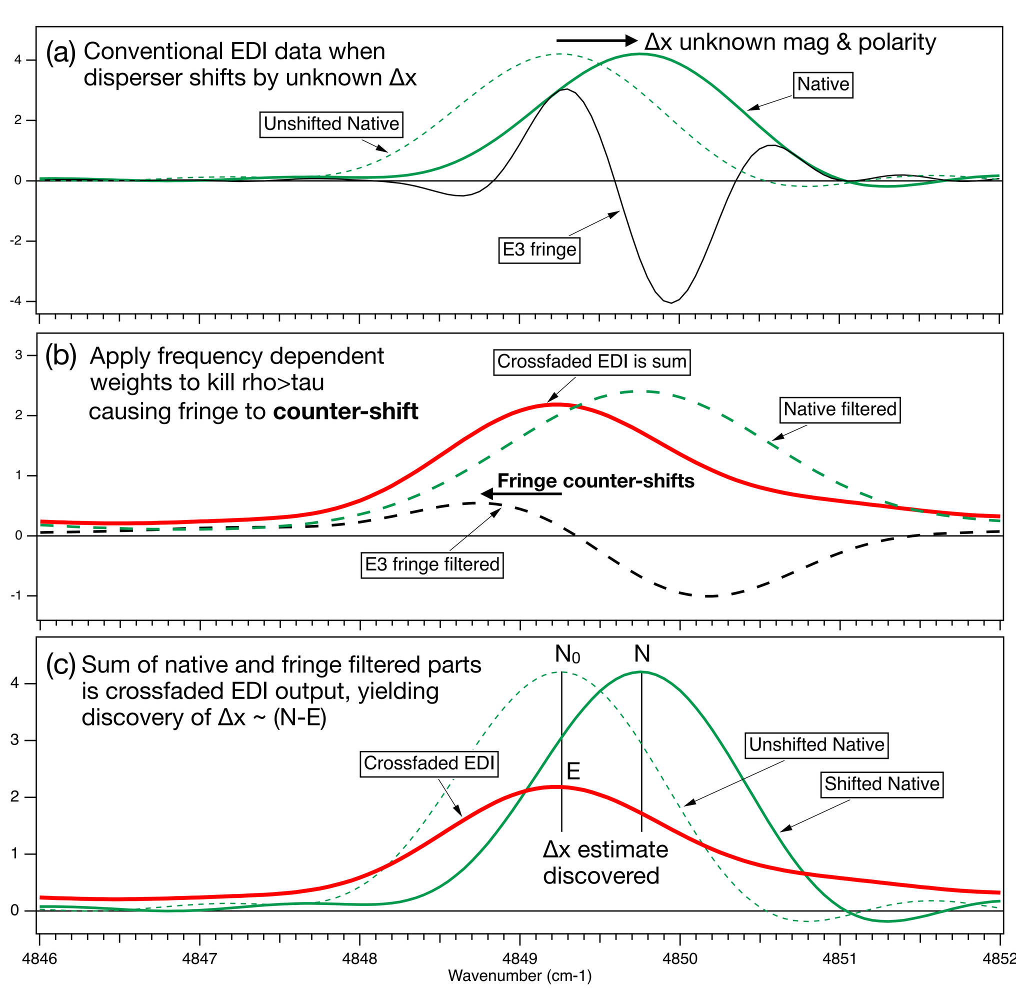
Freqs. above Delay of 0.66 cm are suppressed so S-shape becomes an anti-Mountain.

Without weights, Native (mountain) & Fringing (anti-mountain) do not perfectly cancel.

Weights chosen so that Native cancels Fringing for each frequency bin in Fourier space.

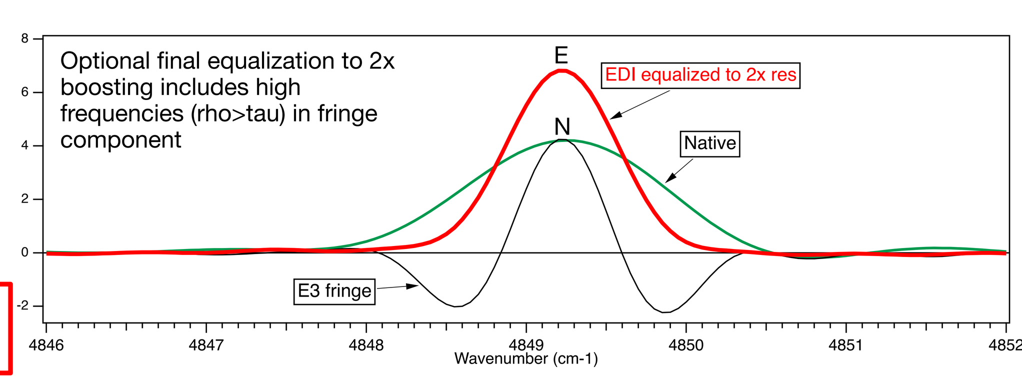
-- Process: ThAr data in wavenumbers

Using weighted (filtered) data. Drift Δx is initially unknown. It is discovered after the first pass.



7

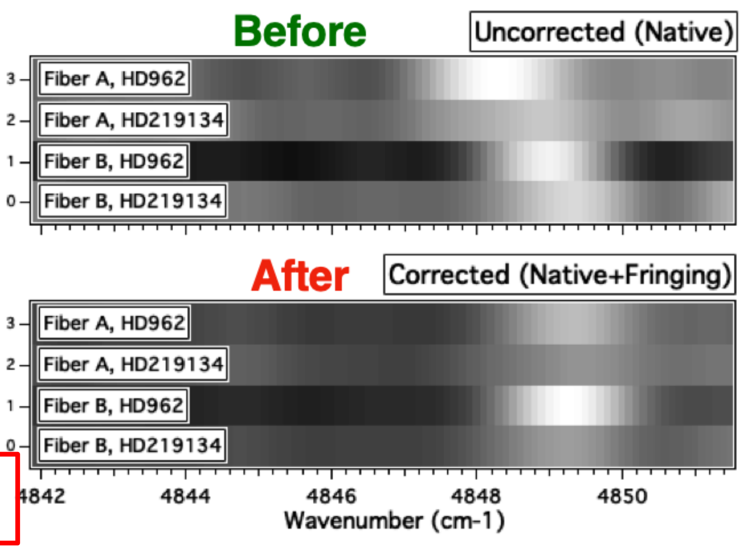
Tau is Delay. rho is freq variable.



8

After Δx is discovered, all the Fringing frequencies can be used, high and low, in an optional recalculation that combines Native and Fringing but with an equalization that produces 2x resolution of the Native alone. (Note red peak is now narrower than green native peak.)

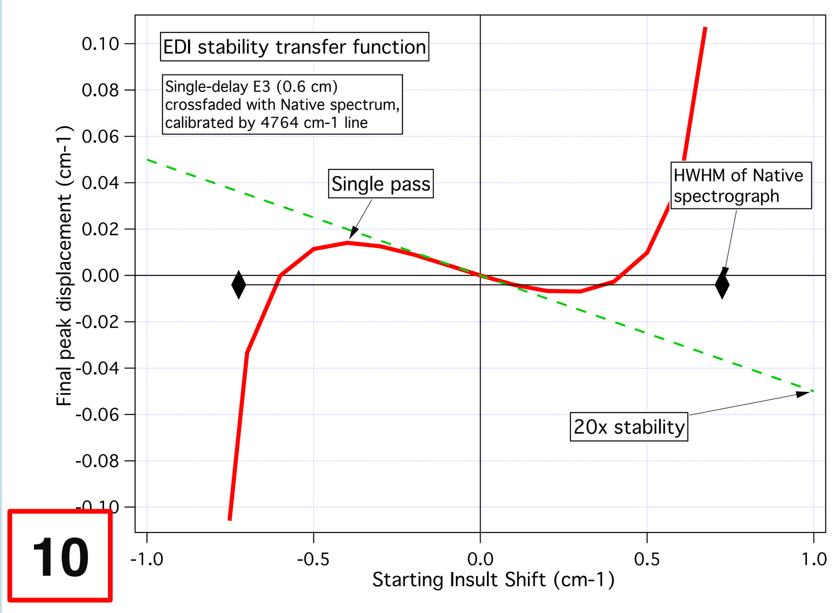
-- Results (single-pass)



9

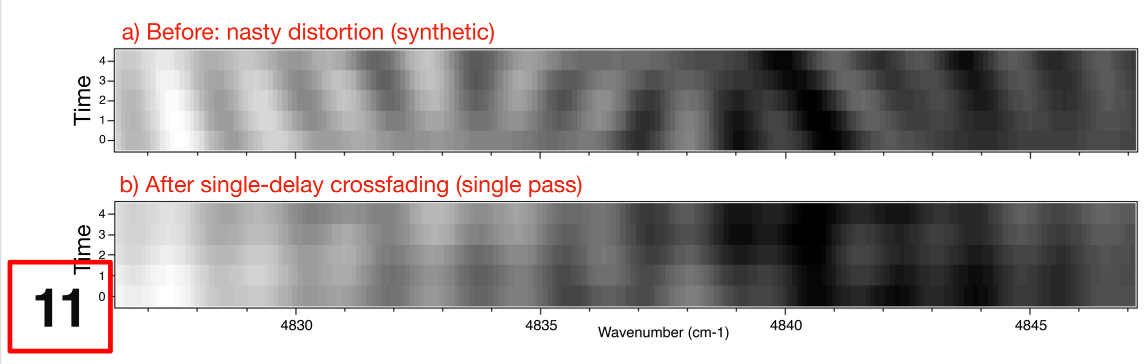
Four data sets having independent drifts Δx, due to combination of Fiber A to B offset, plus drift over time when target star changed.

Vertical alignment of bottom panel shows success. **Drift has been defeated.**



10

A single pass produces a 20x reduction of effect of drift. Here is an out vs in graph.



11

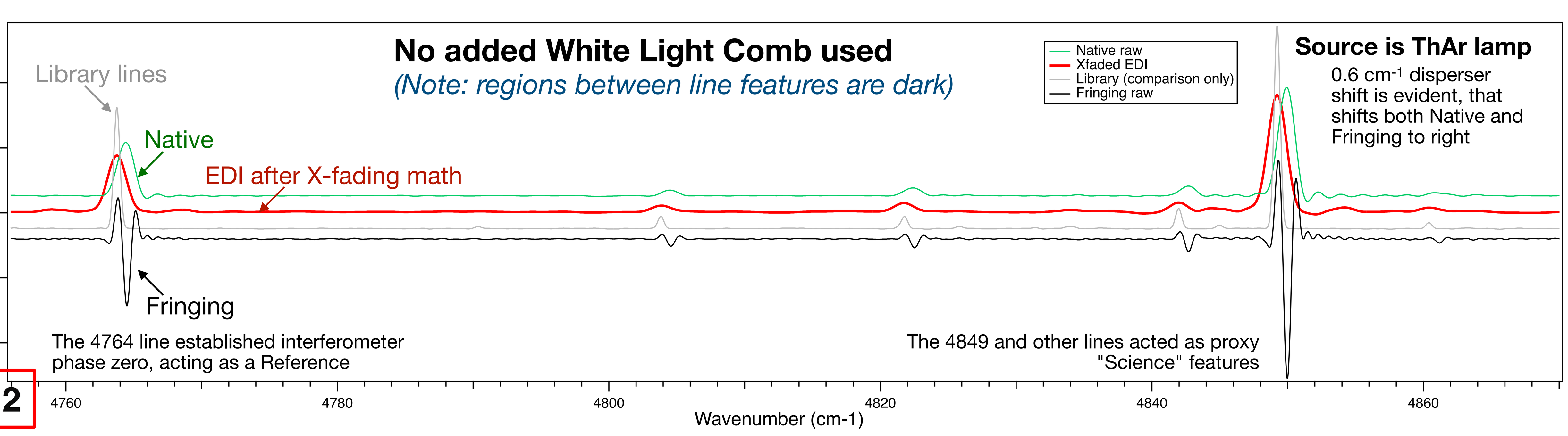
Here is a simulation that models the bipolar irregular drift seen in Fig. 2, and its correction in a single-pass

Vertical alignment of bottom panel shows success. **Drift has been defeated.**

-- Results (iteratively)

Using **7 iterations**, we reduce in simulation an initial drift of 0.5 cm-1 [31 km/s] **10^6 times**, down to 4x10^-7 cm-1 [**2.5 cm/s**]. This result has not yet been experimentally confirmed at the cm/s level.

Darkness between lines is proof of **Multiplicative sine comb,** which allows resolution boosting, and opposition between low and high fringing frequency phase shifts which is basis for crossfading stabilization. Additive sine comb not used.



12

-- References

1. D.J. Erskine and J. Ge, in Imaging the Universe in Three Dimensions, W. van Breugel and J. Bland-Hawthorn, Eds., ASP Conf. Series 195, 501 (2000); http://digital.library.unt.edu/ark:/67531/metadc780974/

2. D.J. Erskine, "Combined dispersive/interference spectroscopy for producing a vector spectrum," US Patent 6,351,307 (2002).

3. D. J. Erskine, "Techniques in broadband interferometry," Tech. Rep. UCRL-TR-201695, Lawrence Livermore Nat. Lab. (2004); (chapter 6 on EDI patent); https://doi.org/10.2172/15009760

4. D.J. Erskine, PASP 115, 255 (2003); doi:/10.1086/345995

5. D.J. Erskine, J. Edelstein, et al., ApJ 592, L103 (2003); doi:/10.1086/377703

6. D.J. Erskine and J. Edelstein, SPIE 5492, 190 (2004); doi:/10.1117/12.549947

7. P.S. Muirhead, J. Edelstein, D.J. Erskine, ... J.P. Lloyd, PASP 123, 709 (2011); doi:/10.1086/660802

8. D.J. Erskine, J. Edelstein, E. Wishnow, M. Sirk, P. Muirhead, M. Muterspaugh, J.P. Lloyd, et al., JATIS 2(2):025004 (2016); doi:/10.1117/1.JATIS.2.2.025004

9. D.J. Erskine, "Method for boosting dispersive spectrograph stability 1000x using interferometry with crossfaded pairs of delays," JATIS 7(2):025006 (2021); doi:/10.1117/1.JATIS.7.2.025006

10. D.J. Erskine, "Spectrograph Stabilization using a Single-delay Interferometer," US Patent 12,480,815 (2025).

11. D.J. Erskine, J. Edelstein, E. Wishnow, et al., "Spectrograph Stabilization of using a Single-delay Interferometer on the Hale Telescope." Accepted by JATIS (2026 June).

12. Wan, X. and Ge, J., "Monolithic Michelson Interferometer as ultra stable wavelength reference," Danchi, W. C., Delplancke, F., and Rajagopal, J. K., eds., SPIE 7734, 77343N (2010).

13. Xiaoke Wan and Jian Ge, "Stable monolithic interferometer for wavelength calibration," US Patent 8,570,524 (2013).

Technology described in detail in this JATIS journal article[11] pre-print and US Patent 12,480,815 held by LLNL[10]

Proceedings for this poster

v9x

Some work prepared by LLNL under Contract DE-AC52-07NA27344, and supported by Laboratory Directed Research and Development project 22-LW-020