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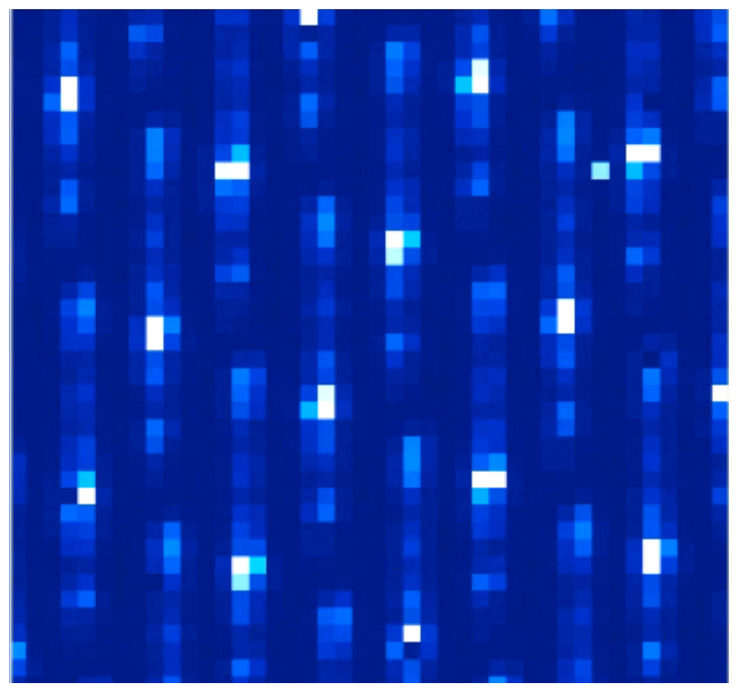
Enhanced atmospheric biosignatures from interferometer addition to low res spectrographs

D. Erskine, P. Muirhead, A. Vanderburg, A. Szentgyorgyi
LLNL, Boston U., Harvard
erskine1@llnl.gov

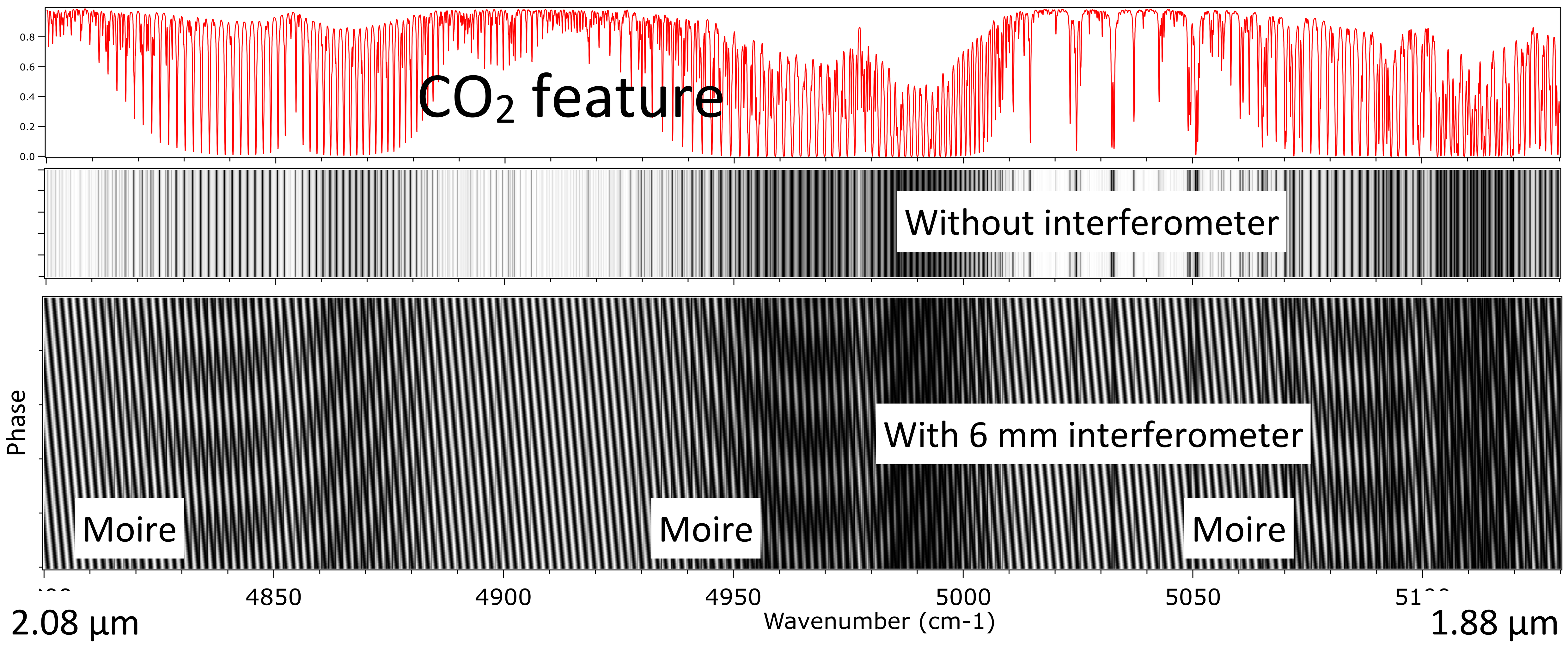
INTRODUCTION

Exoplanet atmospheric molecules (water, CO2, methane etc) vibrational spectra normally require high resolution to detect. But because the physics of vibrating molecules create a quasi-periodic set of 30-40 absorption lines as a fingerprint, they are fortuitously easier to detect. We show how a small (6mm) EDI interferometer, which has the same periodic transmission spacing as these lines, added to a low (R~70) res spectrograph can create moire patterns for this fingerprint. These are detected having a photon limited sensitivity similar to a R~4000 spectrograph.



This effective resolution boost, 70 to 4000, is especially important for Integral Field Spectrographs which are often pixel limited. We use the Gemini Planet Imager IFS resolution as an example, (even though it may lack the aperture to collect the needed photons from small exoplanets). The method can be generally applied to any spectrograph.

CO2 line spacing nearly periodic, hence strong moire patterns produced passing through interferometer comb



Moire intensity fluctuations can be measured by dithering delay by ½ wave

Using several different delays, software reverses moire patterns to deduce high res feature shape. We have demo'd this technique in the NIR at Mt. Palomar 5-meter, boosting native R~2,700 by 10x to effective R~27,000, using 7 delays up to 45 mm. Works over entire band of native spectrograph.

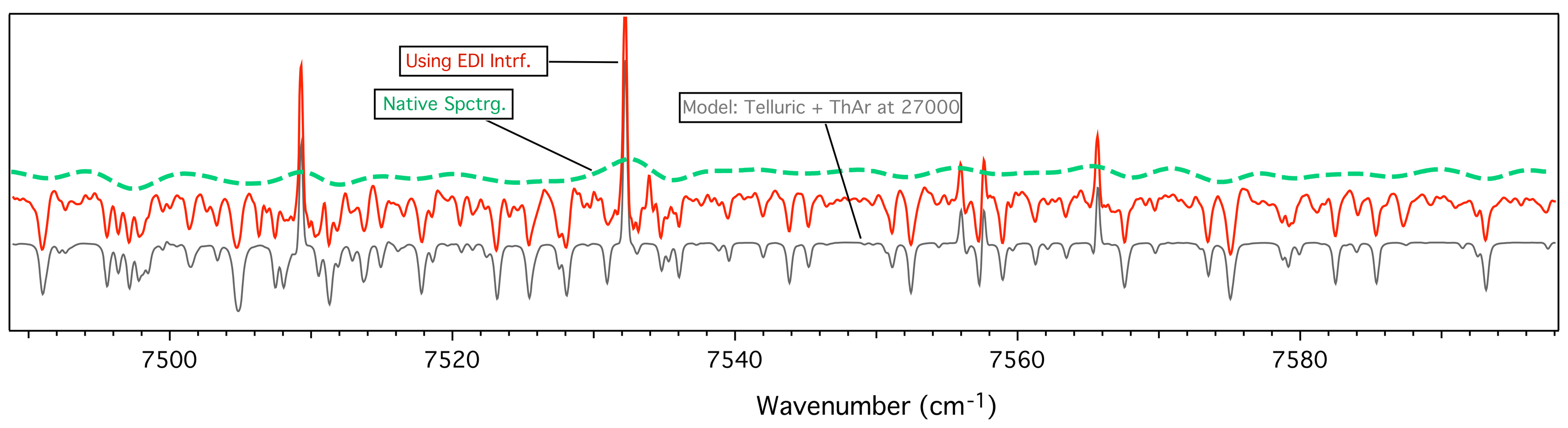
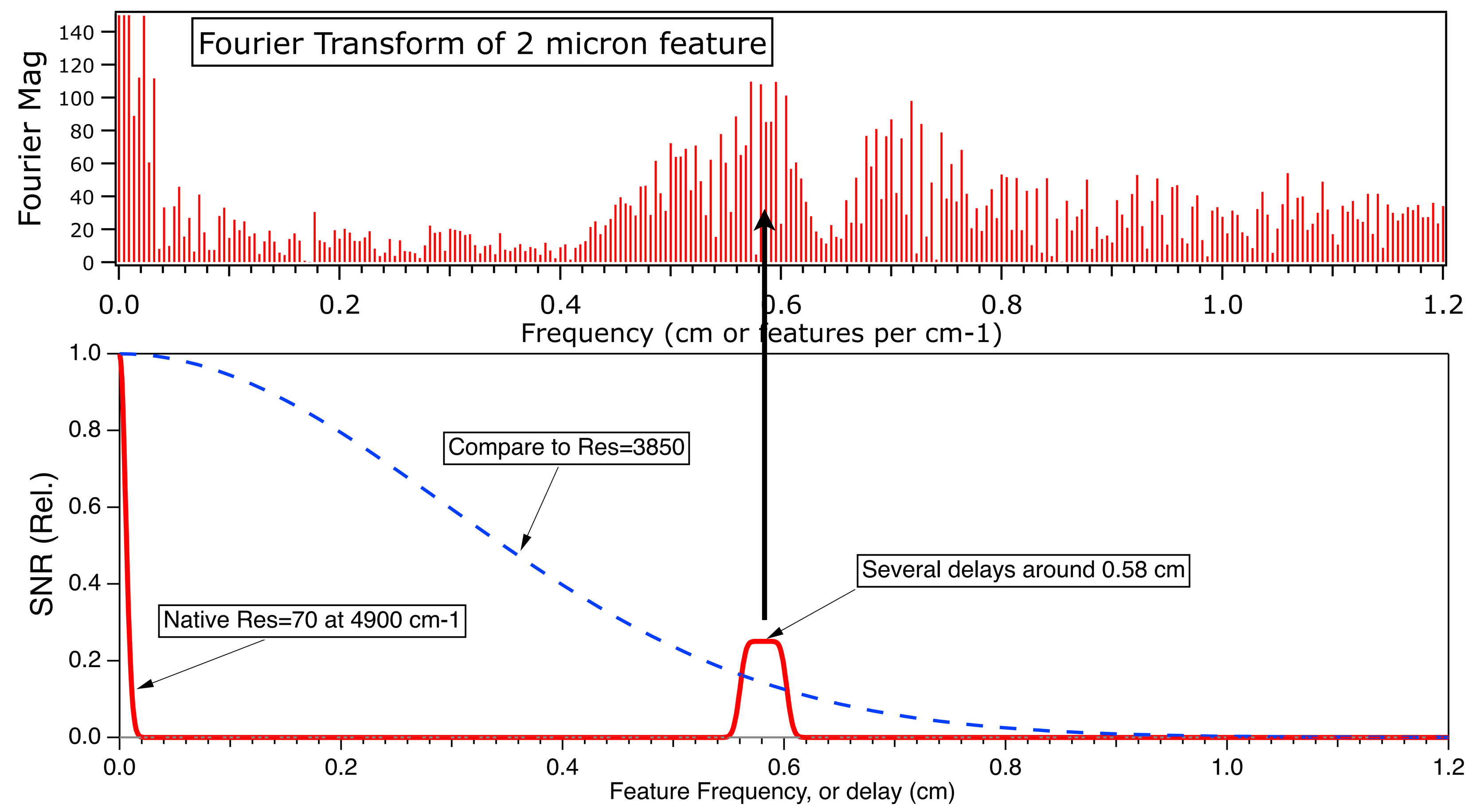


Fig. 22 Demonstration of a 10-fold resolution boost observing telluric features mixed into spectrum of star κ CrB along with ThAr calibration lamp emission lines. The green dashed (top) curve is the "ordinary" spectrum measured without the interference, having native resolution 2700. It cannot resolve any of the telluric features. The red (middle) curve is the EDI (TEDI) reconstructed spectrum measured with seven contiguous delays, up to 3 cm, and equalized to a Gaussian resolution of 27,000. The gray (bottom) curve is a model of telluric[19] and ThAr[20] features blurred to resolution of 27,000, showing excellent agreement with EDI reconstructed data. Resolution boosting occurs simultaneously across the full bandwidth (0.9 to 2.45 μm) of the native spectrograph (final resolution varies linearly with wavenumber times largest delay). *Y*-axis is intensity, vertically offset for clarity. Data from June 19, 2011.

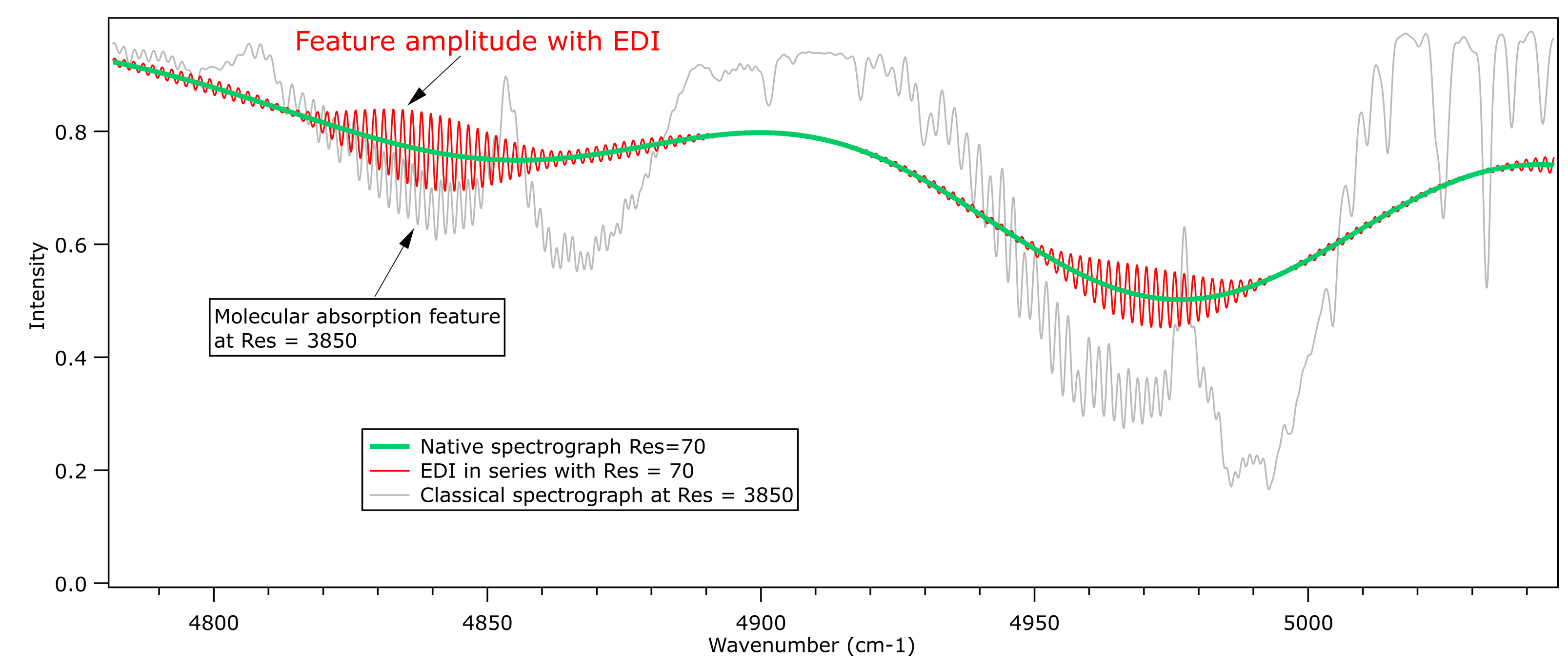
METHOD: Externally Dispersed Interferometry

Fourier transform shows concentration of CO2 feature at high frequencies. Horiz axis is in units of interferometer delay (cm). We pick the 6 mm region for the delay.

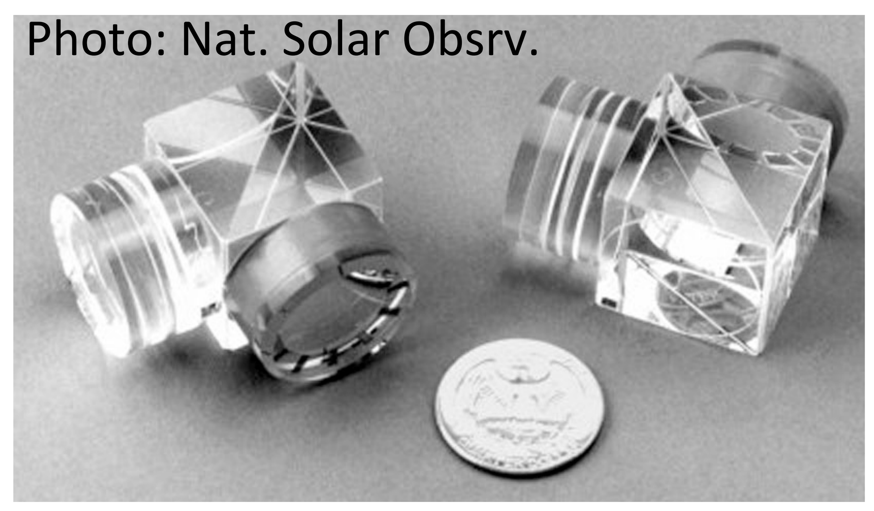


Classical R=3850 photon limited sensitivity curve (blue dashes) is similar to our red EDI peak at 5.8 mm.

EDI produced results below (red) are calculated by applying the red curve in above graph as a filtering function, and the blue dashed curve produces the gray result



Compact prism interferometers can be inserted into beam like a filter



Delay is dithered with a voltage

"**High-resolution broadband spectroscopy using externally dispersed interferometry at the Hale telescope: Part 1, data analysis and results**", D.J. Erskine, J. Edelstein, E. Wishnow, M. Sirk, P.S. Muirhead, M.W. Muterspaugh, J.P. Lloyd, Y. Ishikawa, E. McDonald, W. V. Shourt, and A. M. Vanderburg, J. Astr. Tele. Instrm. Sys. 2(2), 025004 (2016), doi: 10.1117/1.JATIS.2.2.025004.

http://spectralfringe.org/EDI/MyPubs4/TediTenxPart1gen.pdf
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