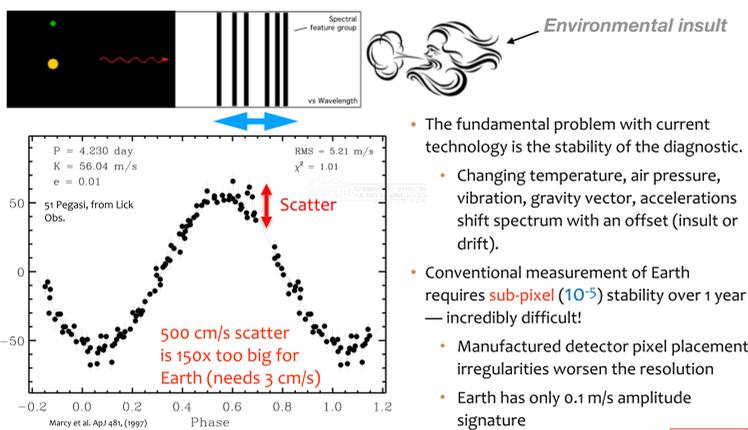


Enabling 1000x more sensitive spectrographs for exoplanet search

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with Erik Davies (LLNL), Ed Wishnow, Martin Sirk (UC Berkeley Space Sciences Lab) and Richard Ozer

Exo-Planets are discovered by Doppler velocity shifts of starlight

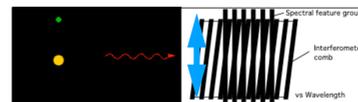


Externally Dispersed Interferometry* (EDI), advantage for Doppler planet search:

Horizontal Moire are perfectly robust to wavelength distortions

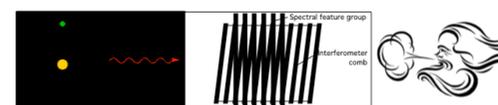
Under a Doppler shift:

(Feature moves relative to comb, producing phase change)



Under an environmental wavelength shift:

(Feature and comb move together since they are embedded in same beam, producing NO phase change)

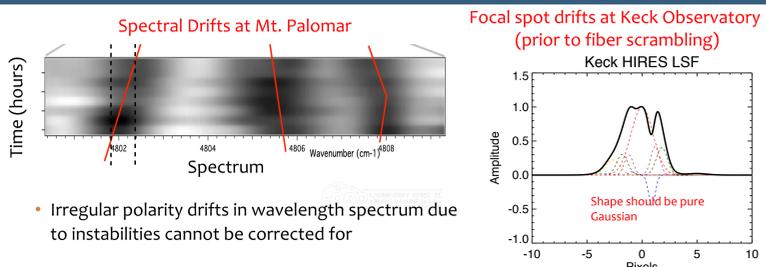


Horizontal Moire occurs when feature frequency matches interferometer comb

Problem: realist spectra have a variety of frequencies—will generate Moire with variety of tilts

4

Spectrograph Drift and focal irregularities define the system resolution



Irregular polarity drifts in wavelength spectrum due to instabilities cannot be corrected for

Conventional mitigations: large vacuum tanks, bulky thermal blankets, massive sturdy mounts

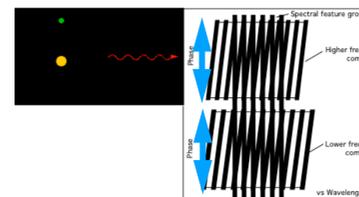
Still, the required 10^{-5} pixel stability needed is not achieved

A fundamentally different approach is needed to advance the sensitivity of Doppler spectroscopy

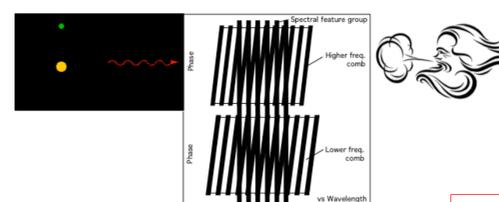
New Idea: use two slightly different interferometers simultaneously

For each frequency, select weights and combine data to effectively cancel slope of moire

Under Doppler the pair produces phase shift as usual



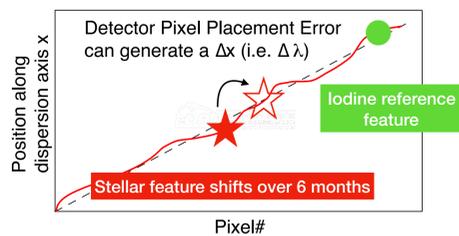
Under wavelength offset, the two moire behave like a horizontal moire and have zero net phase reaction to offset



5

Another problem: Manufactured Pixel Placement is Irregular on Detector

This error (~milli-pixel) is a "baked in" drift— not reduced by conventional mitigations (vacuum tank, thermal control, fiber scrambling).



6 month Earth orbital velocity change causes different pixels to be used, which can cause different Δx error

These could be much larger than the 10^{-5} pixel tolerance needed to detect Earth-like planets

3

Demo of software using multiple pairs of intrfr. delays

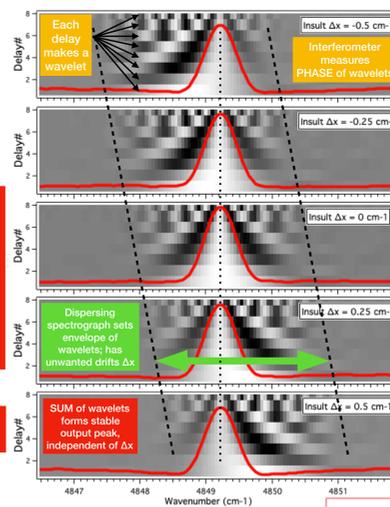
Using EDI measured data of ThAr lamp at Mt. Palomar project

but simulated insult Δx

The wavelet location is deliberately shifted sideways to simulate Δx .

The EDI output is the sum of wavelets which is the red peak, which is nearly stationary.

1000x reduction in drift!



6

We recommend using BOTH conventional mitigations and EDI

Conventional mitigations: reduces environmental insult Δx

EDI: reduces TRC to $\sim 0.001 - 0.1$

$$\text{Output spectrum shift } \Delta \lambda_{out} = \Delta x * TRC$$

TRC is Translational Reaction Coefficient

(Conventional: TRC = 1)

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