Automated Error Signal Blending

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Introduction

- Lock acquisition needs (multiple) handoffs between different signals for same DoF in different states and regimes

- In general, we often have multiple signals for single physical quantity
  - Common arm length
  - DRMI lengths (1F/3F)
  - Optic angular position

- Why not blend these in some way to reduce uncertainty?

Lock Acquisition Strategies

- "Guided Lock": Estimate mirror velocity from observed fringe, apply an impulse to counteract that momentum
- "LIGO1" multi-step: update sensing matrix at intermediate unstable states, based on calculations and simulations of the interferometer response
- Virgo "Variable Finesse": acquire in decoupled state, slowly transition to final sensing and operating point

Lock Acquisition Strategies

- aLIGO: Decoupled green light control + CARM offset reduction. Handoffs triggered at certain CARM offsets.
- Izumi et al “Self Locking”: “Automatic” blending behavior of ALS and PDH due to cavity build up.

A New Approach

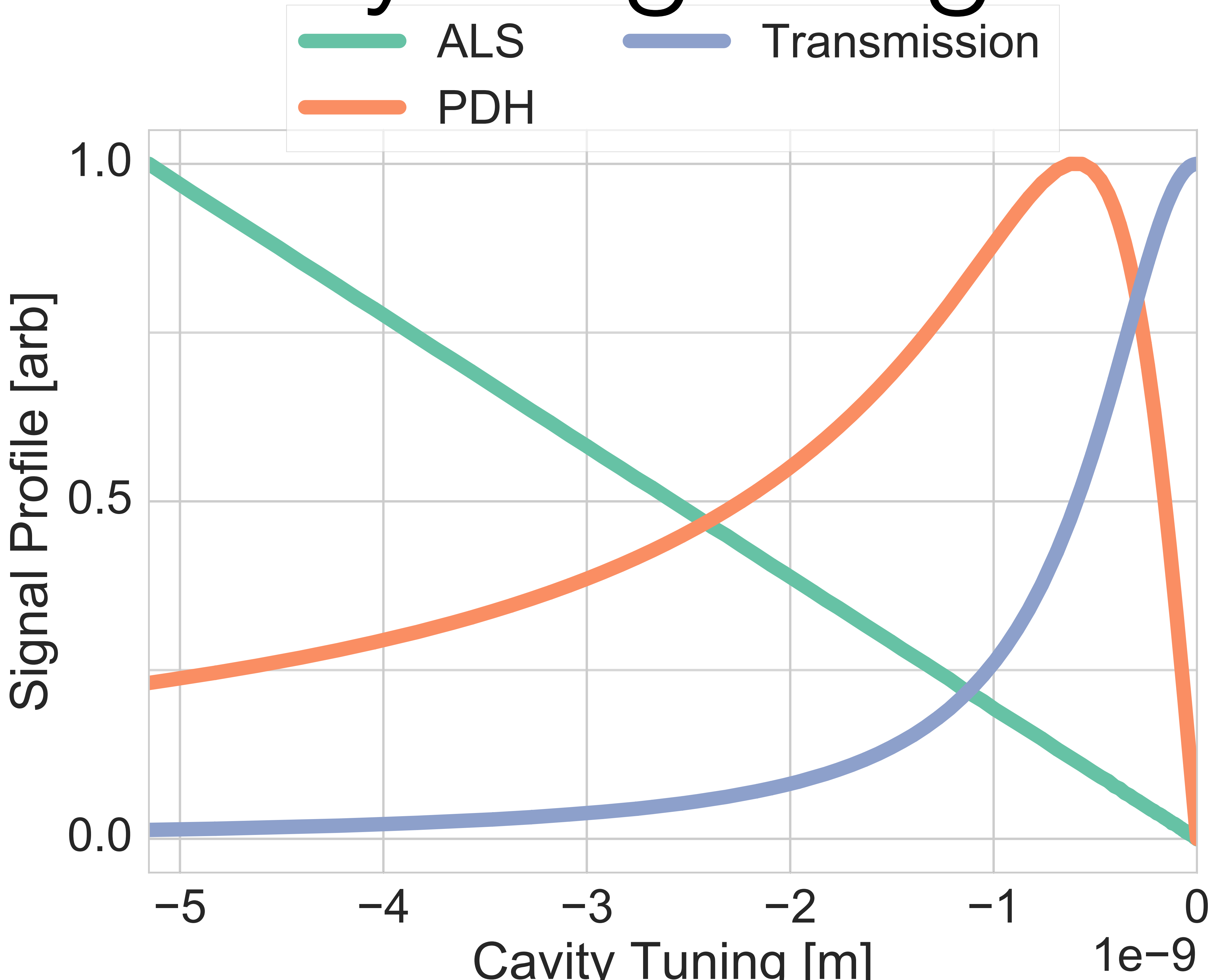
Try to minimize a-priori characterization:

- Continuously demodulate each available signal to determine slopes and monitor noise levels
- Weigh each signal by relative incoherent noise
- Take small offset steps towards desired operating point, recalculate input matrix coefficients
- “**C**ombined **E**rror **S**ignal by **A**utomatic **R**egression”

A New Approach

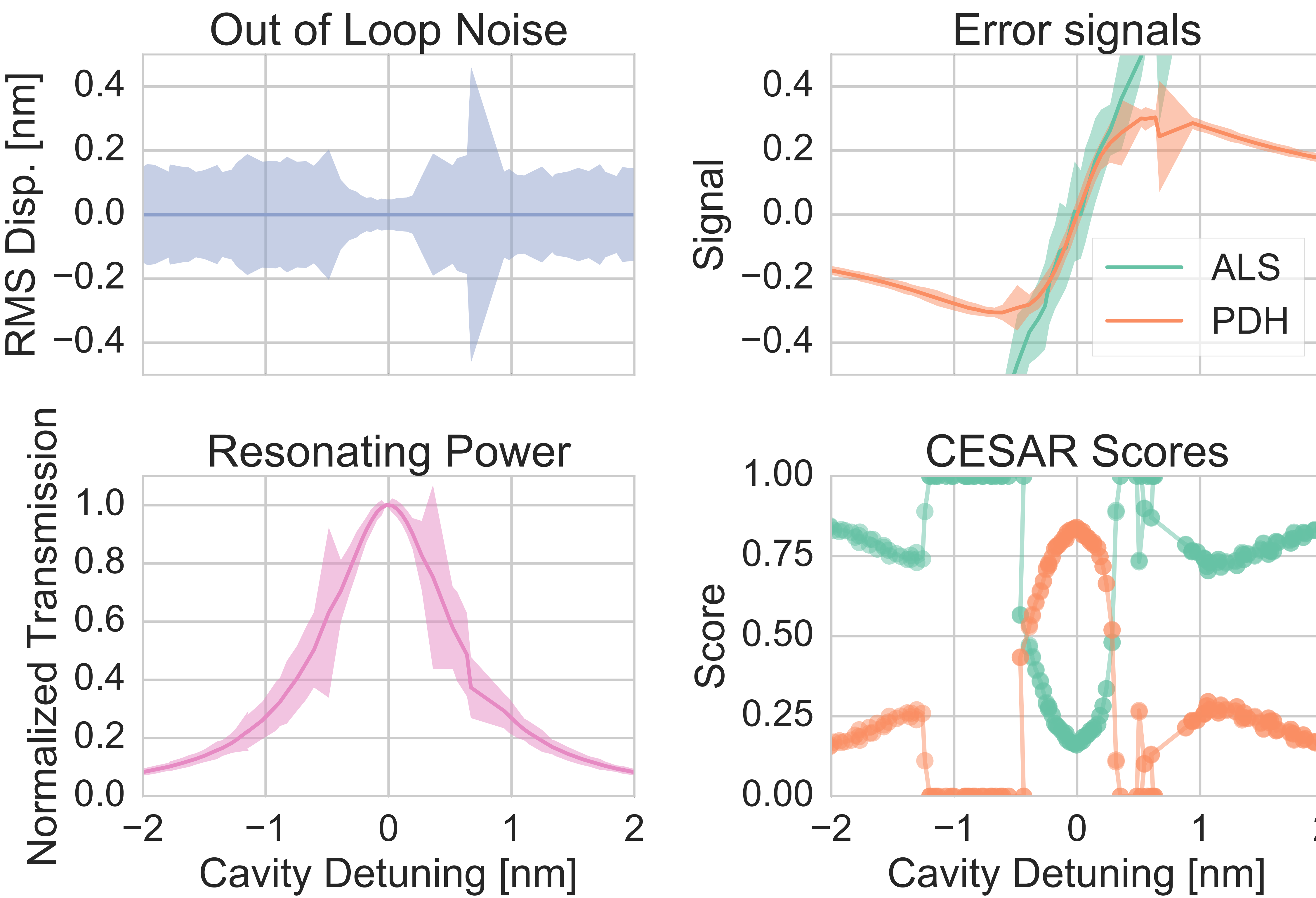
- Single 40m arm cavity as testbed, can iterate quickly, three signals usable for testing (ALS, PDH, DC Transmission)
- First tested on “realistic” E2E time domain simulation to see if the approach has any merit
- Test on actual hardware with same weighting code

3 cavity length signals

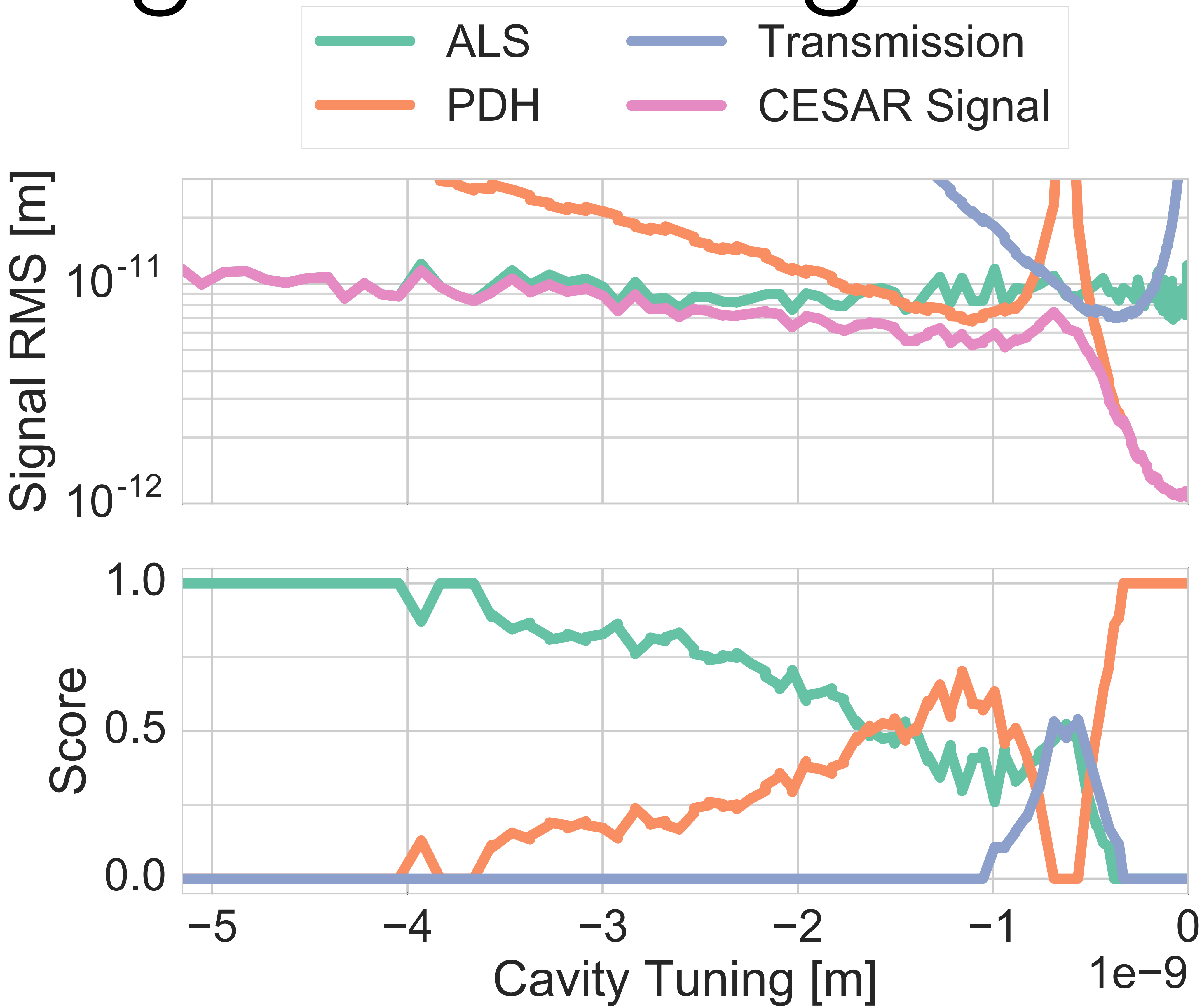


Two signal Simulation

Shaded Areas = RMS fluctuations



3 signal blending at 40m



Lessons Learned

Benefits:

- Less a priori knowledge needed than previous strategies
- Blending, rather then discrete handoffs, reduces noise

Issues:

- Slow, no memory
- No frequency dependent blending
- Can become unstable around sensing singularities

aLIGO Prospects

- This can provide a “push-button” approach to transitioning between two signals at a given operating point.
- DRMI signals don’t have frequency dependent mismatch, so this approach could automate the 1F/3F handoffs even when the signal chains change
- If the ETM replacement improves the ALS performance enough, there could be a straightforward ramp to PDH CARM control

Prospects

This may be a problem suitable for machine learning techniques

- Attempted to train a very simplified system via “deep Q learning”
- “Reinforcement learning”: reward choices of input matrices with lower error signal RMS
- So far, appears to have trouble with presence of noise, which leads to a nondeterministic reward function.