

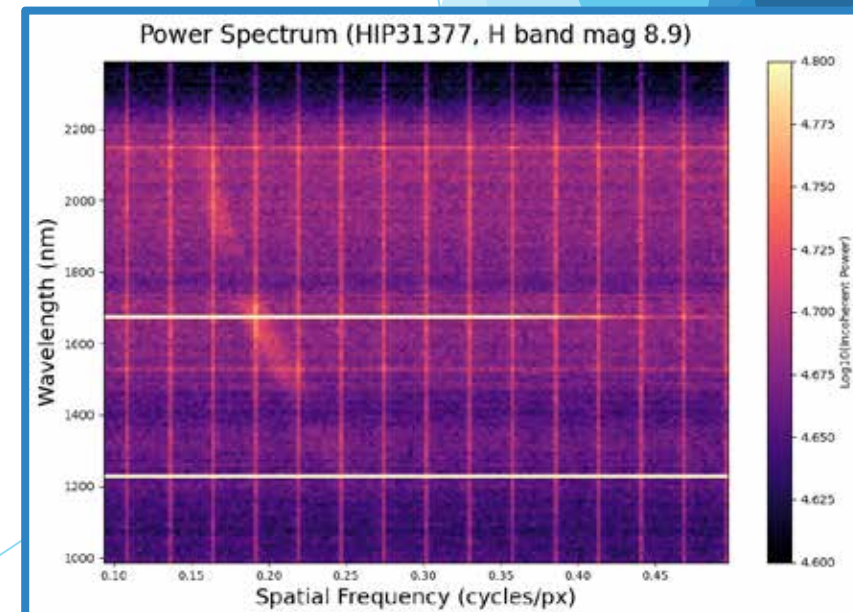
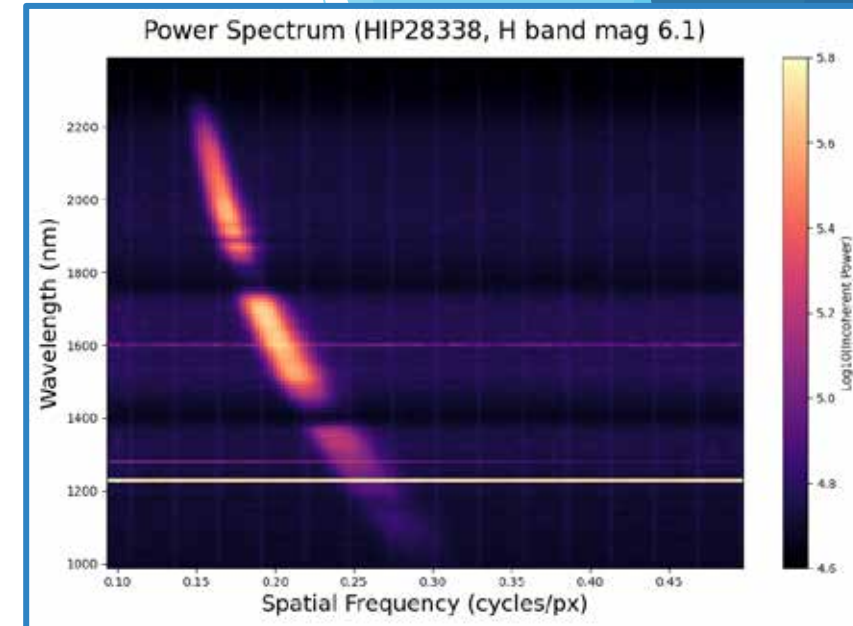
Chasing the magnitude limit:

MROI's plan for high-sensitivity observations

Emma Floyd on behalf of the team

Summary

- u The predicted limiting magnitude for our current science instrument is 13 in the H band
- u We do not have all of our systems fully operational yet, and we have recorded fringes on magnitude 8.9
- u Factors are currently limiting us
- u We have plans to reduce and remove these factors
- u This presentation is about how we plan to move from our current magnitude limit to the theoretical one



Factors that enable MROI to look at dim things

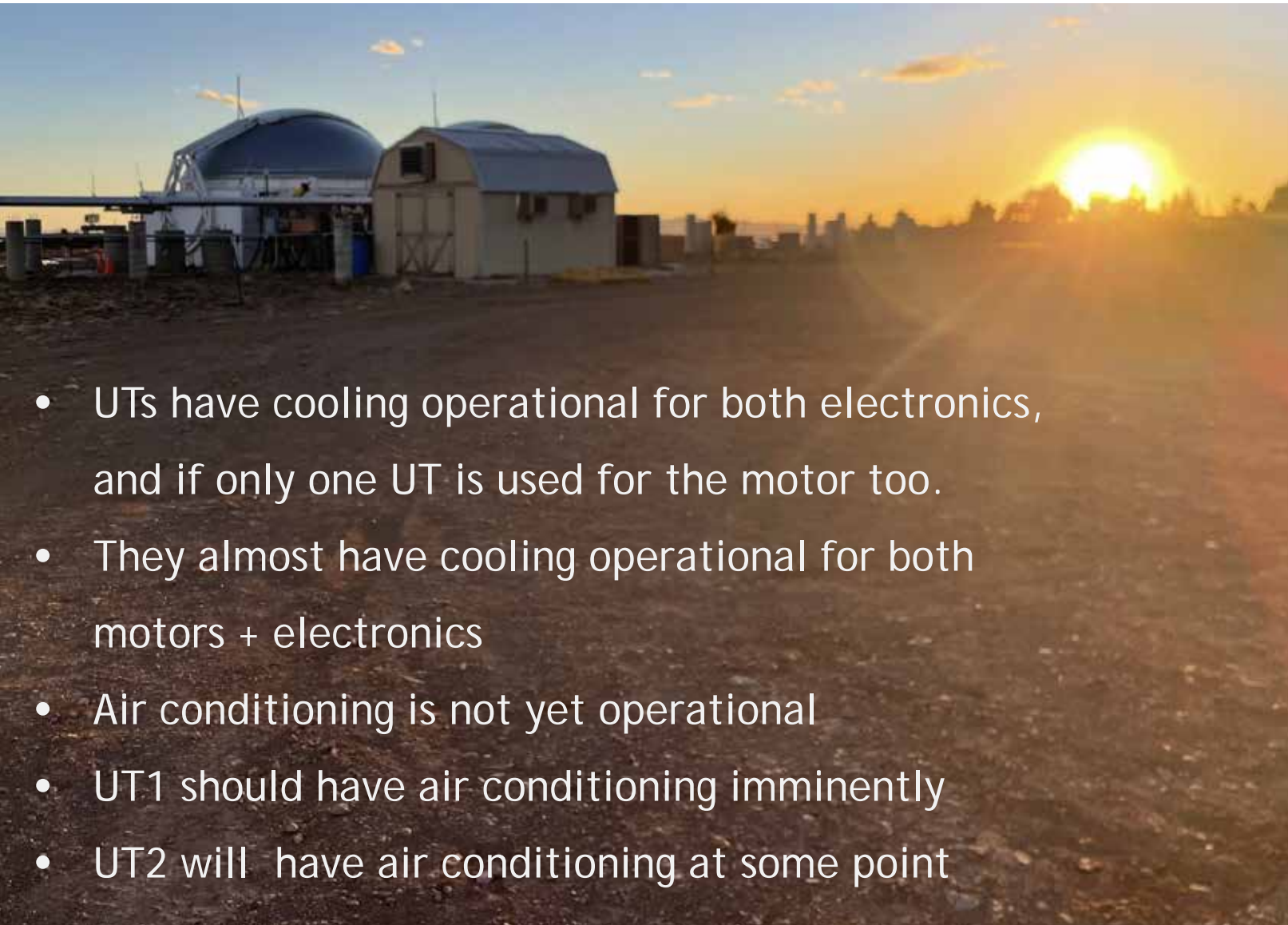
Done

- u WFE characterization and choice of best beam train optics
- u Fast tip-tilt system to correct for atmospheric seeing
- u Sealing of radiation shield and baffle placed to minimize thermal background
- u Many of other things

In progress

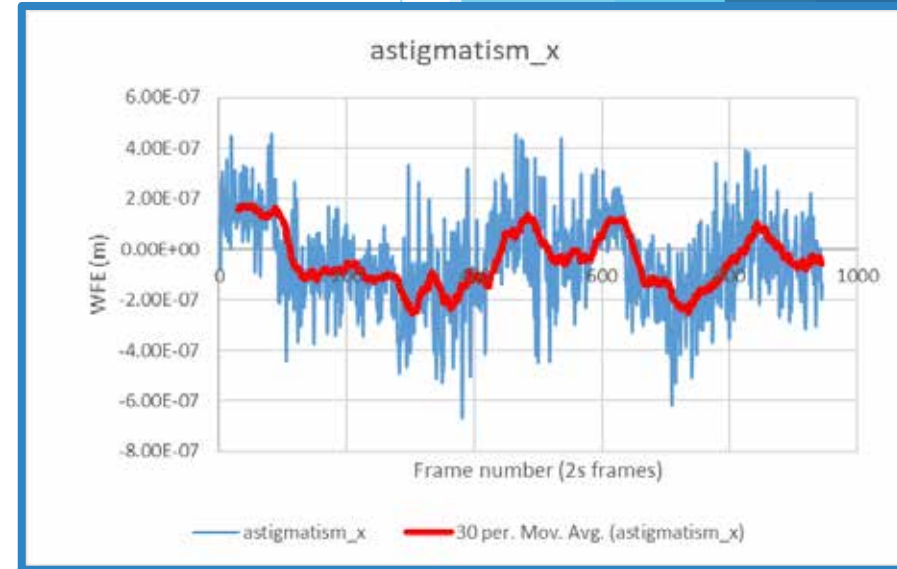
- Minimization of internal and dome seeing
- Reduction of mechanically induced WFE with telescope pointing
- Refinement of baseline solution
- Automatic alignment stabilization of beamline with temperature
- Cold blocking filter inside FOURIER

Control thermal sources of seeing



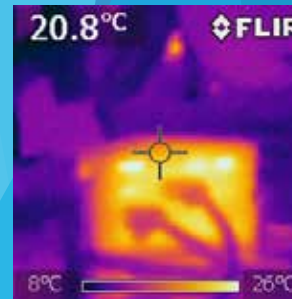
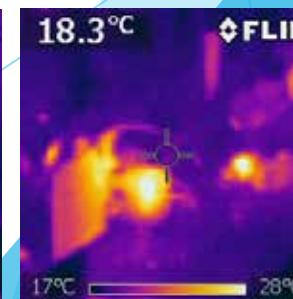
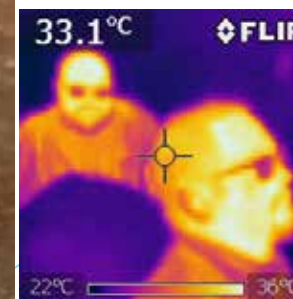
- UTs have cooling operational for both electronics, and if only one UT is used for the motor too.
- They almost have cooling operational for both motors + electronics
- Air conditioning is not yet operational
- UT1 should have air conditioning imminently
- UT2 will have air conditioning at some point

UT2 looking at Polaris, 1 min moving average



Inner BCA quadcell and flipper

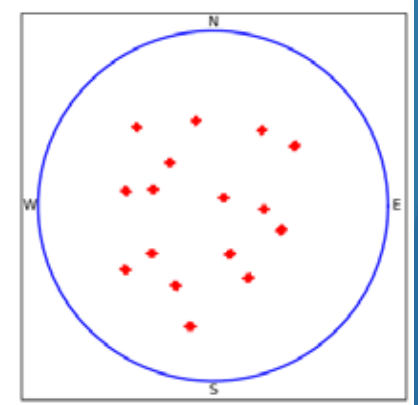
UT1 alignment mirror controller



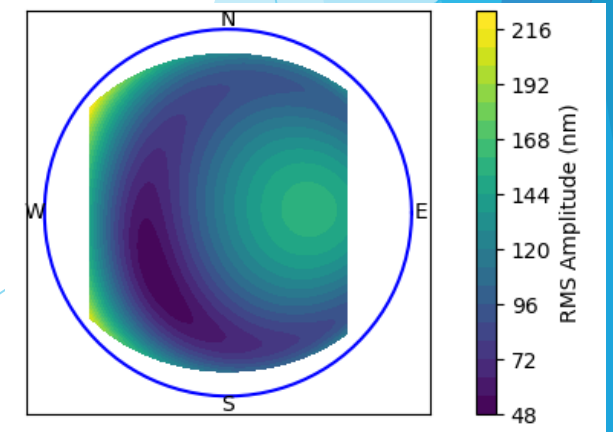
M2 open loop model WFE budget for M1-M2 alignment = 40 nm



Wave front error data from stars over the field of regard



Permutation from existing hexapod model



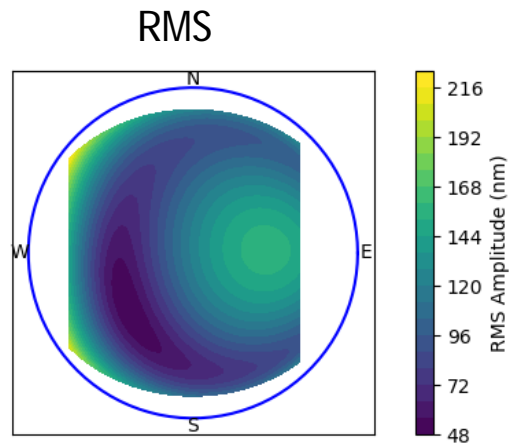
$$dF = \text{Focus}(\delta, \varphi) = A_F \sin \delta \cos \varphi + B_F \sin \varphi + C_F(1 - \cos \delta \cos \varphi) + D_F(T_t - T_0) + E$$

$$dCx = \text{Coma}_X(\delta, \varphi) = A_{C_X} \sin \delta \cos \varphi + B_{C_X} \sin \varphi + C_{C_X}(1 - \cos \delta \cos \varphi) + D_{C_X}(T_t - T_0) + E$$

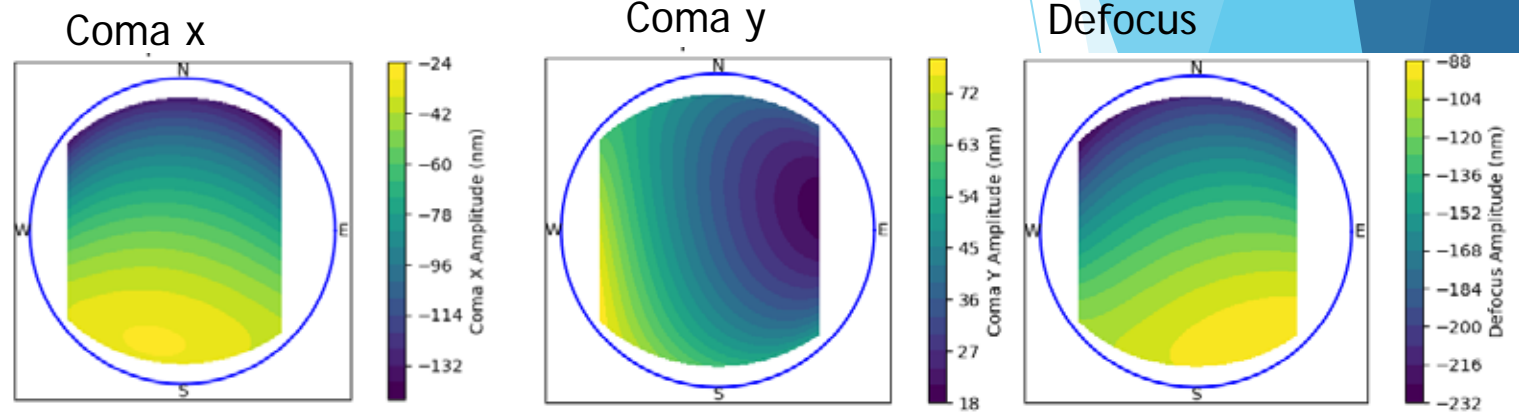
$$dCy = \text{Coma}_Y(\delta, \varphi) = A_{C_Y} \sin \delta \cos \varphi + B_{C_Y} \sin \varphi + C_{C_Y}(1 - \cos \delta \cos \varphi) + D_{C_Y}(T_t - T_0) + E$$

M2 open loop model

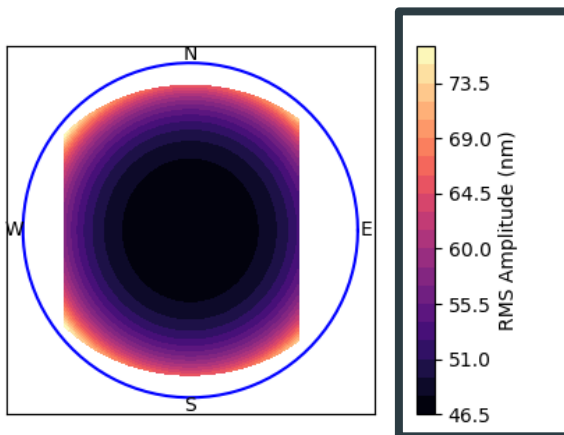
Without telescope motor cooling



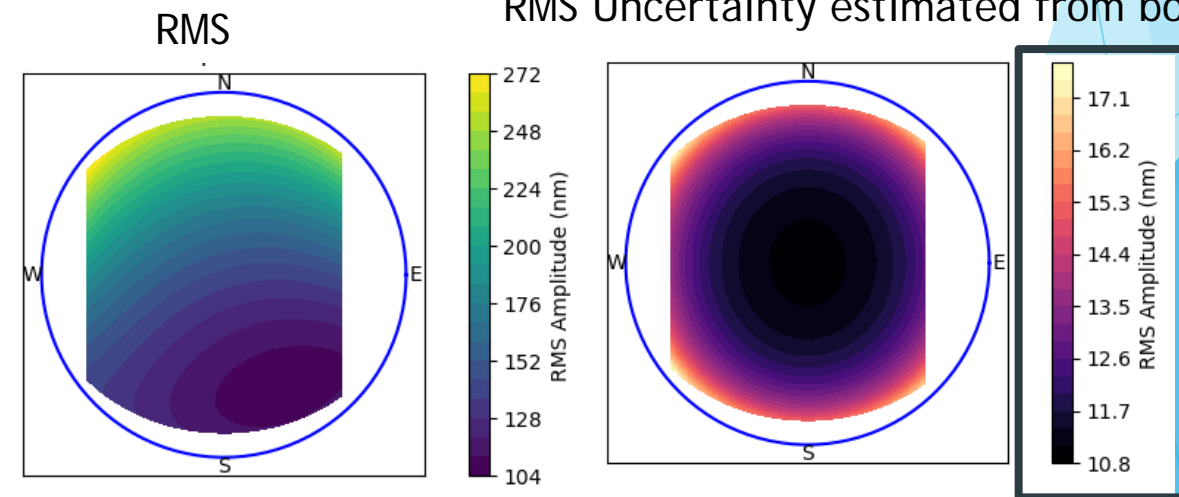
With telescope motor cooling



RMS uncertainty estimated from bootstrapping

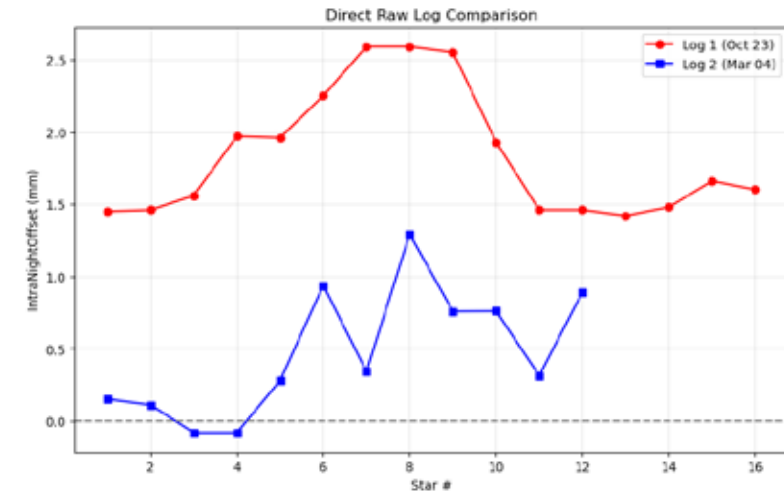


RMS Uncertainty estimated from bootstrapping

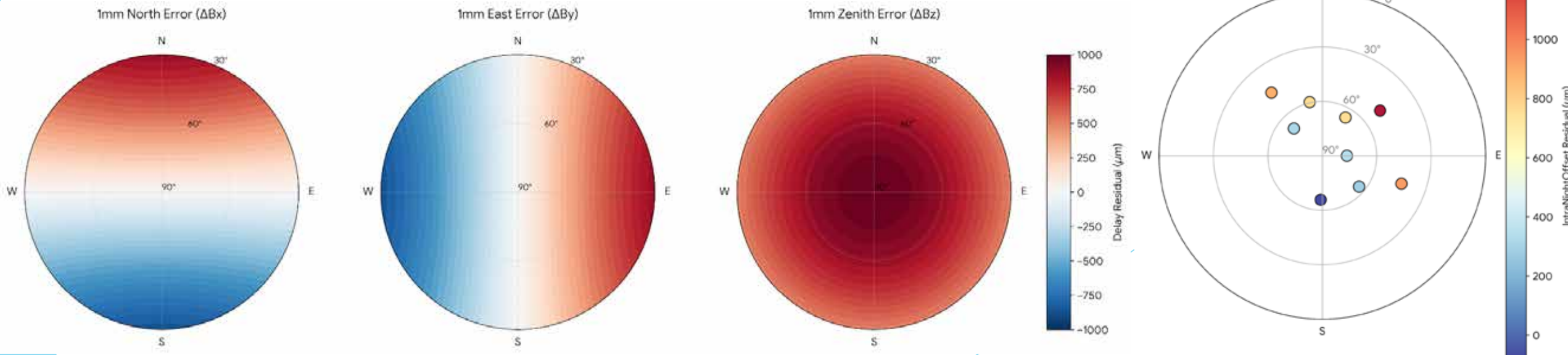


Baseline refinement

- Without fringe tracking we can find and keep fringes roughly centered on the detector with a good baseline solution.
- We refine the baseline by recording the offset from expected position based on the current baseline for multiple stars
- Keeping our baseline error within 500 μm will enable an integration time of 10 minutes



Residual Map: New Dataset (DLW1)
Comparison of Measured Phase Offsets



Fringe tracking

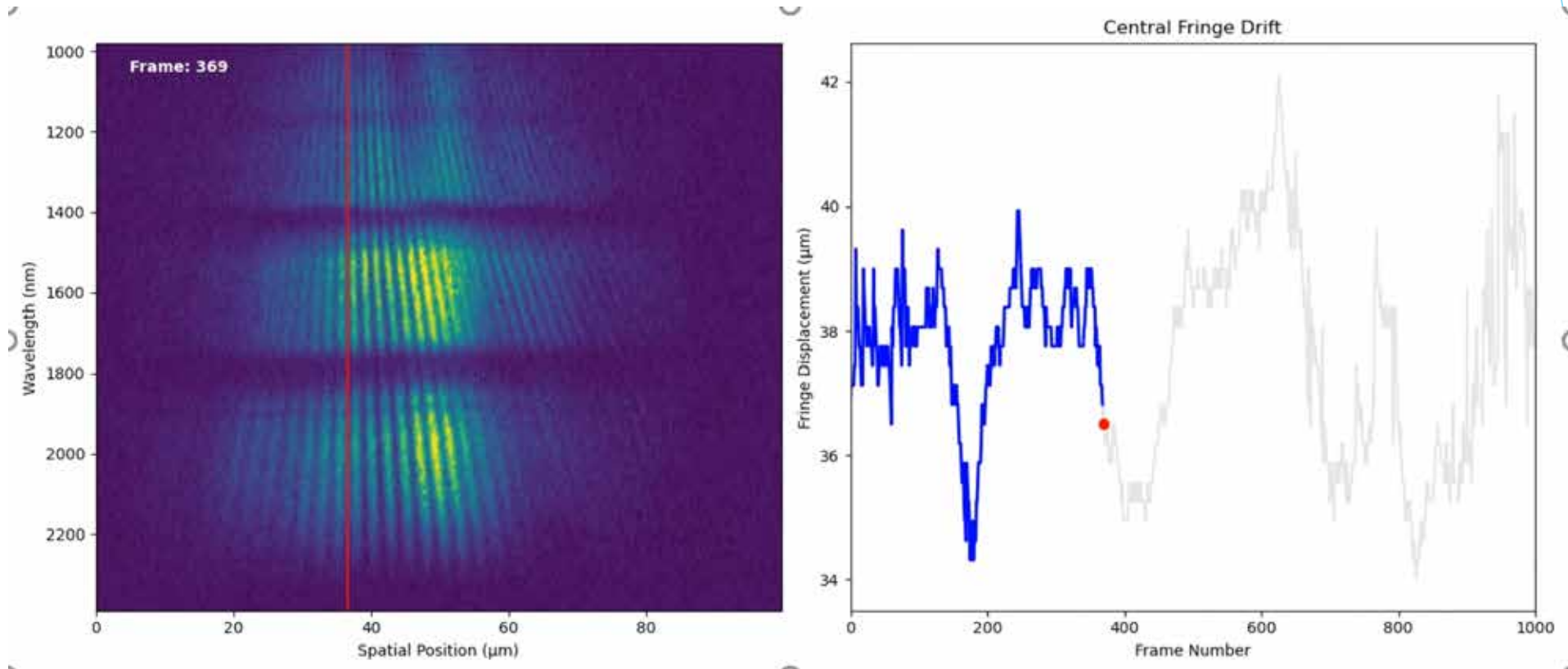
Fringes on HIP15549, October 23 2025



Without co-phasing fringe tracking we integrate incoherently - SNR proportional to the fourth root of N frames.

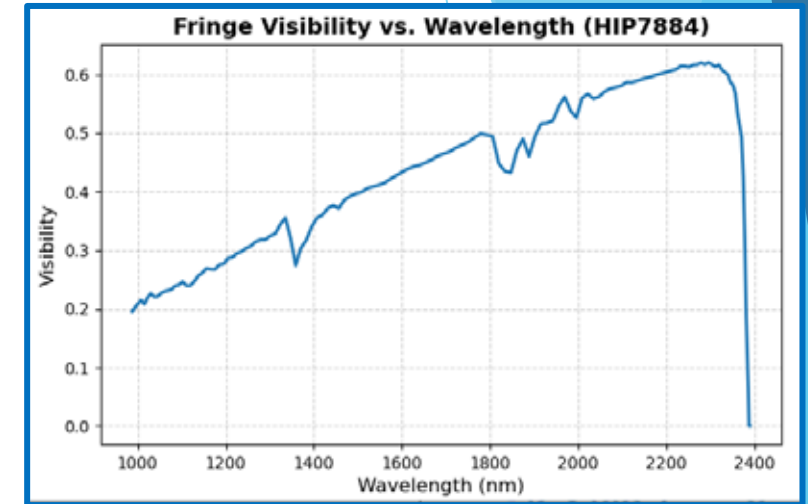
Fringe tracking

Fringes on HIP15549, October 23 2025

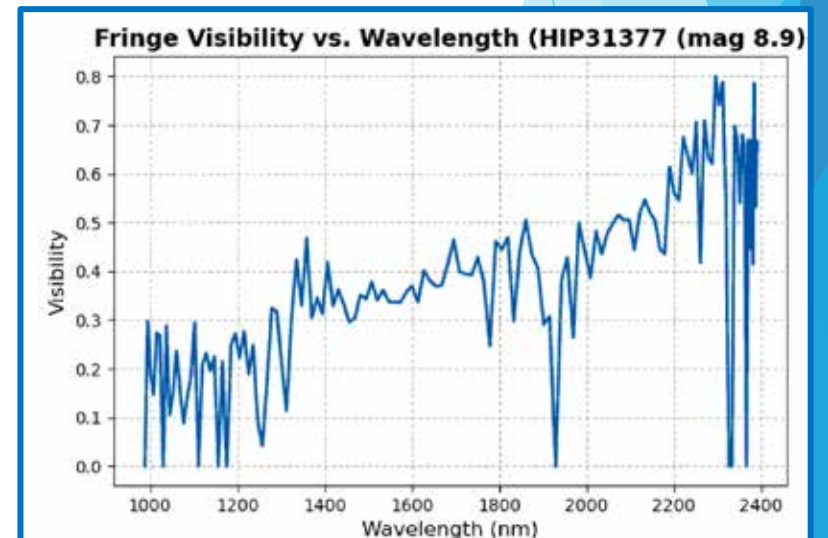


Without fringe tracking we integrate incoherently

Background, vignetting and alignment



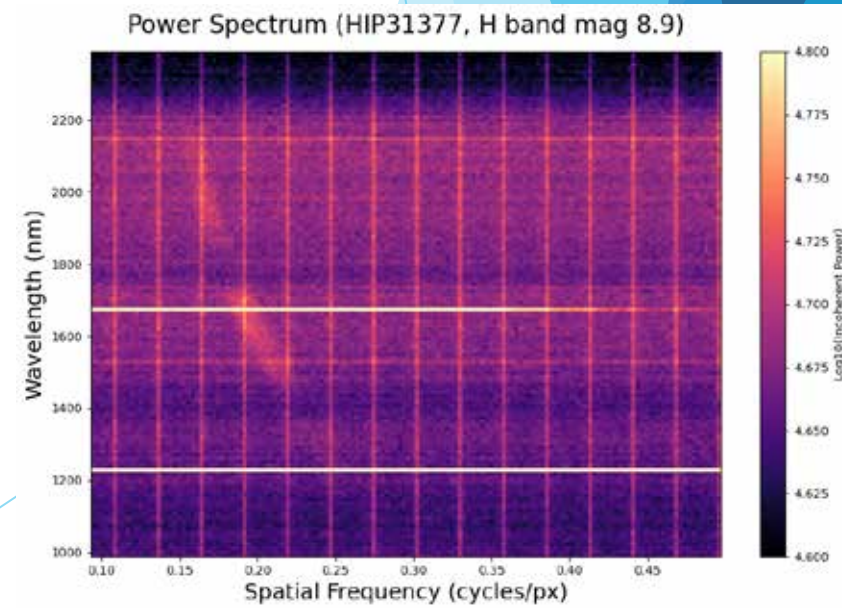
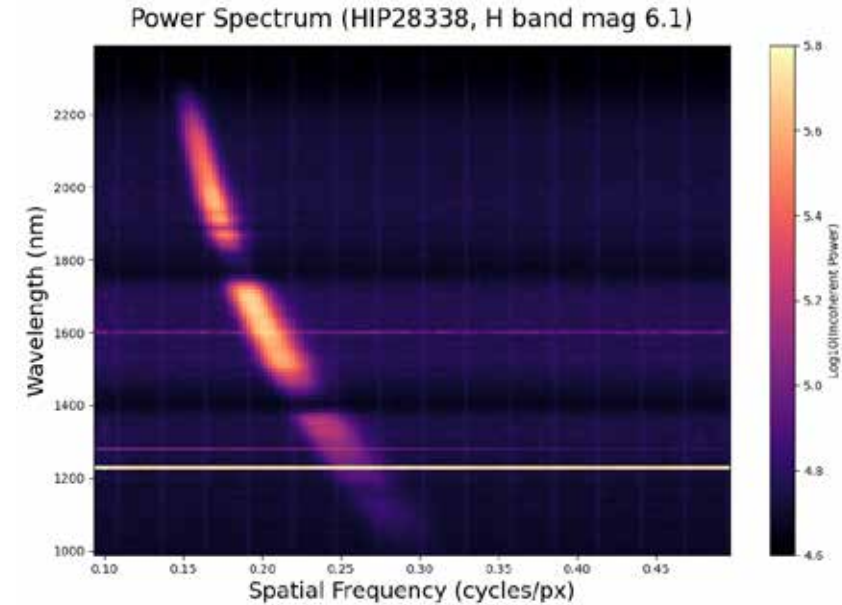
Uncalibrated



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- u We have plans to reduce and remove these factors
- u This presentation was about how we plan to move from our current magnitude limit to the theoretical one

4 minutes (4800 x 50ms frames)



Thank you for your attention!

Our team:

- u At NMT/MROI: J. Altamirano, W. Cook, M. J. Creech-Eakman, C. Eakman, A. Farris, E. Floyd, D. Frothingham, J. Giron, M. Giron, C. Greiner, A. Haque, J. Hernandez, A. Jorgensen, J. Luis, J. C. Mason, R. Norris, A. Olivares, S. Orizaga, G. Owens, S. Rochelle, V. D. Romero, C. Salcido, R. Santoro, I. Schofield
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