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AO Telemetry as a Remedy for the Metapupil Partial Illumination Issue

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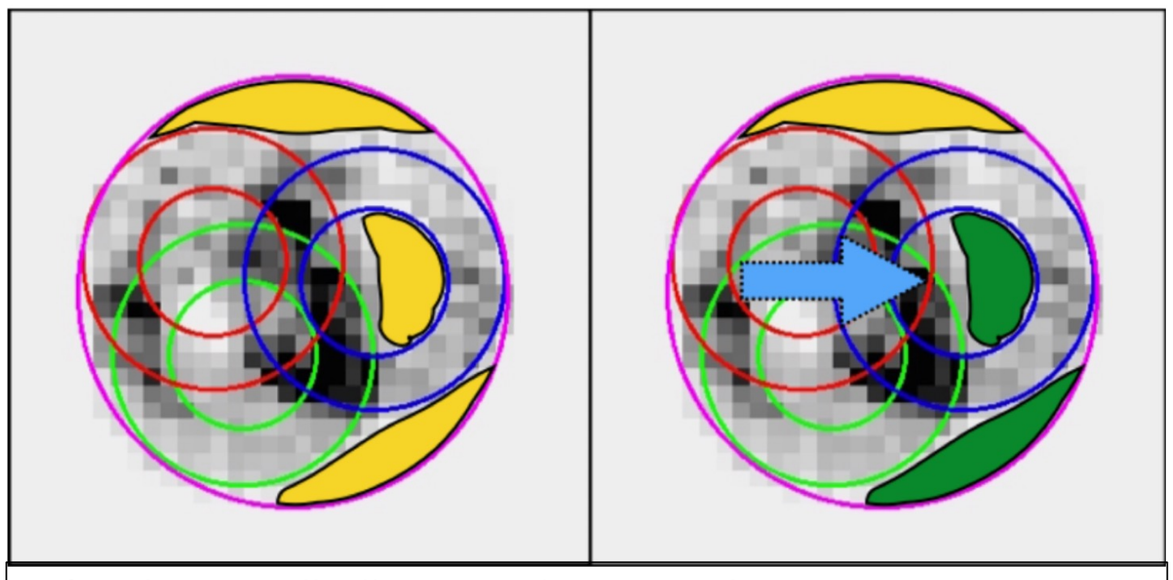
Goal of the Project

Multi-Conjugate Adaptive Optics (MCAO) systems provide uniform turbulence correction over a wide field of view, thereby attenuating the effect of isoplanatism. For the ground layer, the footprints of the stars overlap completely, fully illuminating the entire pupil-plane. However, for the higher altitude layer, the star footprints do not completely overlap, and depending on the asterism of reference stars, the 'metapupil' may only be partially illuminated. AO performance and stability are affected by partial illumination. Star-oriented MCAO systems tackle the partial illumination issue within the tomographic reconstruction, whereas, for layer-oriented MCAO systems, the reconstructor needs to be modified according to the illumination pattern.

LINC-NIRVANA (LN), a near-infrared high-resolution imager at the Large Binocular Telescope, utilizes layer-oriented MCAO and therefore faces this issue. We aim to use AO telemetry to extract the wind vector of the layer and alleviate this problem by using appropriate weighing criteria and algorithms to virtually illuminate the non-illuminated sub-apertures, thereby stabilizing and improving the AO performance.



Left - The partially illuminated metapupil.
Right - A favorable wind direction virtually fills-in some of the non-illuminated sub-apertures.

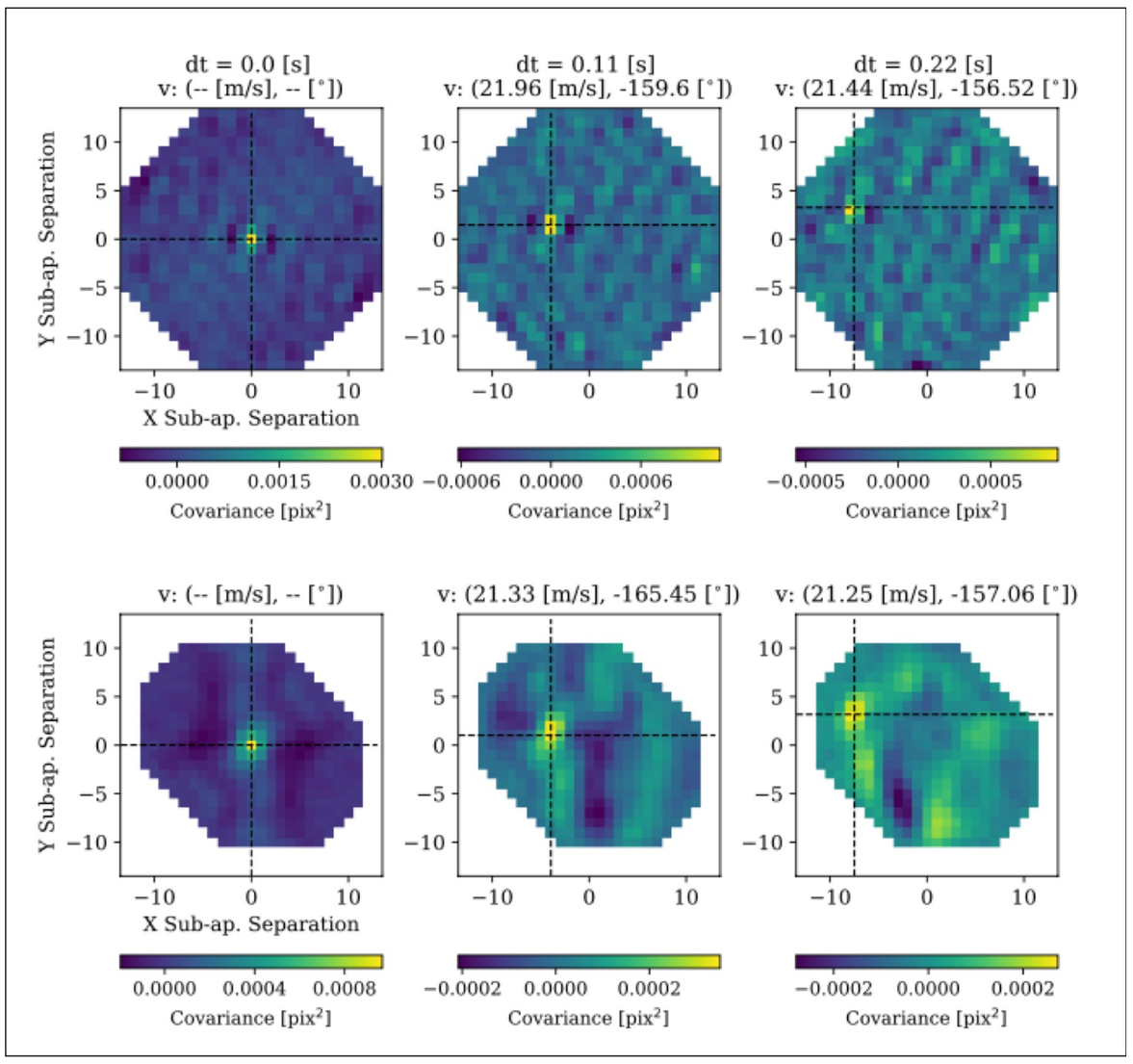
Project Status

We have developed a python code to extract the wind vector from the LINC NIRVANA AO telemetry. This stand-alone algorithm is verified by laboratory testing (using LINC-NIRVANA instrument and calibration sources onboard the instrument). Due to the non-availability of LN in the last semester, further laboratory testing and implementation of the algorithm on to the LN AO software is pending. In the mean time, we are also looking into the prospects of using machine learning to improve the metapupil partial illumination issue. Below are are some of the laboratory test results with data taken from the LN system.

Laboratory tests (on LN instrument)

Turbulence was introduced at the Xinetics DM on board LN with the parameters tabulated below.

Parameter	Value
Fried's Parameter	0.92 m
Num. layers	1
Altitude	7 km
Wind speed	20 m/s
Wind direction	0 °



Covariance maps of closed-loop fully illuminated (top row) and partially illuminated (bottom row) metapupil of binning 2 for increasing temporal offsets.

For an input wind speed of 20 m/s, the estimated average output wind speed for open loop and pseudo-open loop (from closed loop data) are 22 m/s and 21 m/s respectively.

The input simulated wind direction is 0deg. The output is close to -159deg. This is because, there are flips and rotations of the plane between the DM and the WFS CCD for a given k-mirror angle. This results in the value we estimate here.

Summary and Future Prospects

The Minigrant work is progressing despite delays due to instrument down and telescope schedule. Potential use of machine learning is being explored at this moment to improve the system. With an extension of six months, we hope to complete the project.

References

1. Santhakumari K. K. R. et al., "Operation of a layer-oriented multiconjugate adaptive optics system in the partial illumination regime," JATIS 5, 049002 (Oct. 2019).
2. Santhakumari K.K.R., Perera S. et al., "Wind estimates from layer-oriented MCAO telemetry: working towards wavefront prediction," SPIE 2020 conference proceeding.

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