# Phase Retrieval of Elongated Laser Guide Star by Sphere Packing Coded Apertures

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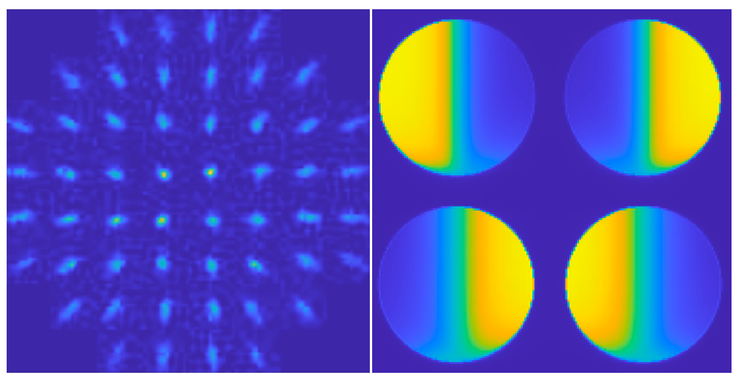
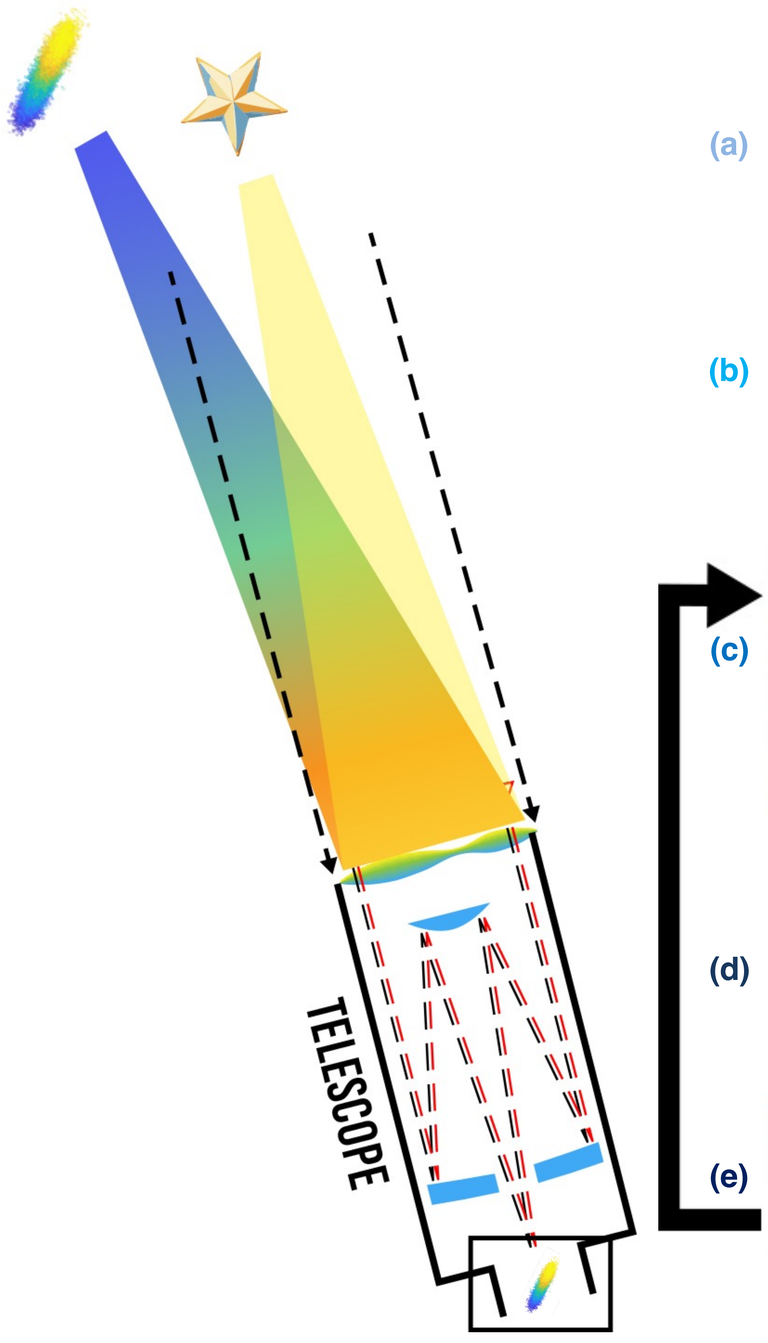
## INTRODUCTION

The Shack-Hartmann wavefront sensor (SHWFS) or pyramidal wavefront sensor (PyWFS), which measures the phase with difficulty using an elongated laser guide star as reference.



SHWFS spot pattern for a laser guide star[1] and Intensities in the detector of the PyWFS for a flat wavefront[2].

**An elongated laser guide star is the result of perspective and sodium layer distortion. This effect just increases with the new generation of large telescopes.**



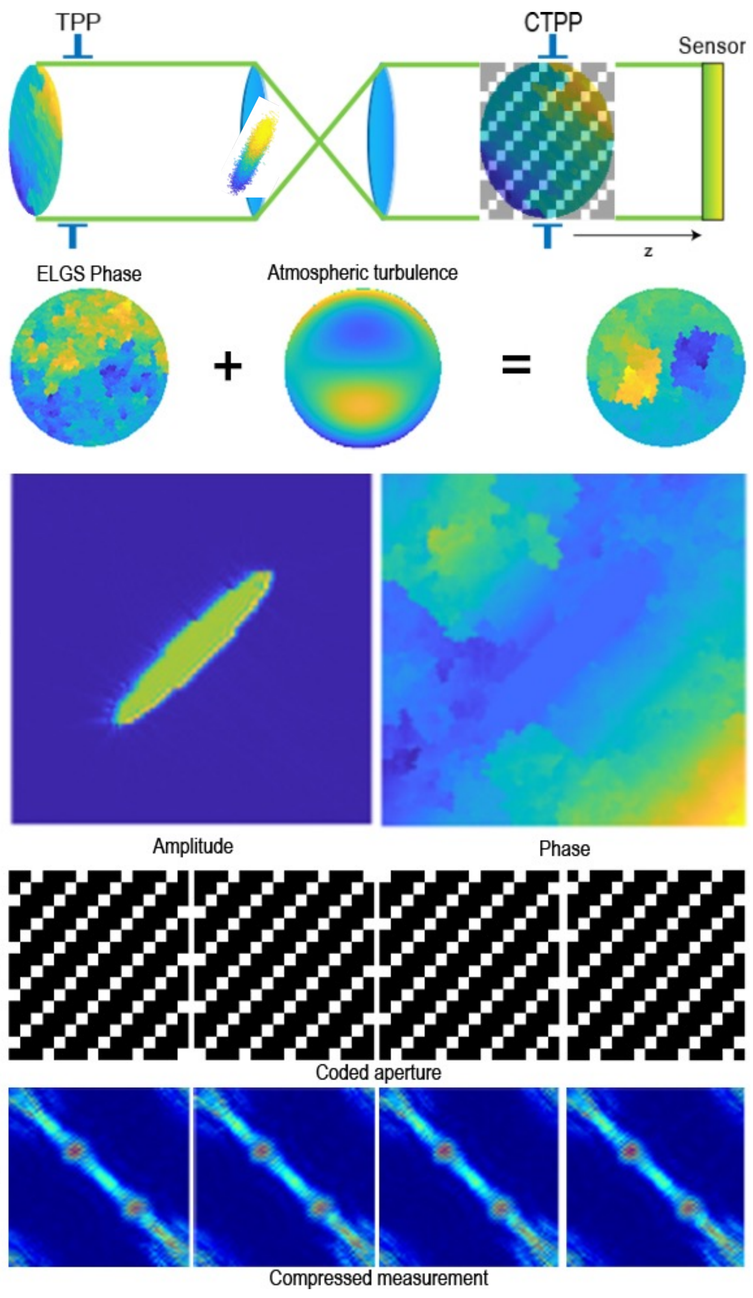

## METHODS

The scheme of the Complex Field Wavefront Sensor (CFWFS that measures an elongated reference star **(a)**. The phase information of the telescope pupil plane (TPP), represented in **(b)**, is propagated through a $4f$-system with a specific magnification, where the amplitude and phase **(c)** is imaging at the focal plane between the two lenses that comprise it. The goal of this $4f$-system is to generate a conjugate telescope pupil plane (CTPP), place where it is superimposed with the information of Sphere Packing Coded Aperture (SPCA)[3] **(d)**. Finally, the encoded light in CTPP is propagated a distance z up to the sensor, generating the compressed measurement to obtain the phase of the ELGS with PR algorithm[4] , as is shown in **(e)**. When the reconstructed phase is computed, this phase is backwards propagated to the pupil plane to correct the turbulent phase. Finally, the phase in the pupil plane is decomposed into Zernike modes by the least absolute shrinkage and selection operator (LASSO)[5].

$$\boldsymbol{I_\ell = |P(z)\{A_\ell \odot O\}|^2}$$

$I_\ell \rightarrow Compressed\ measurement$ $P(z) \rightarrow$ Propagator

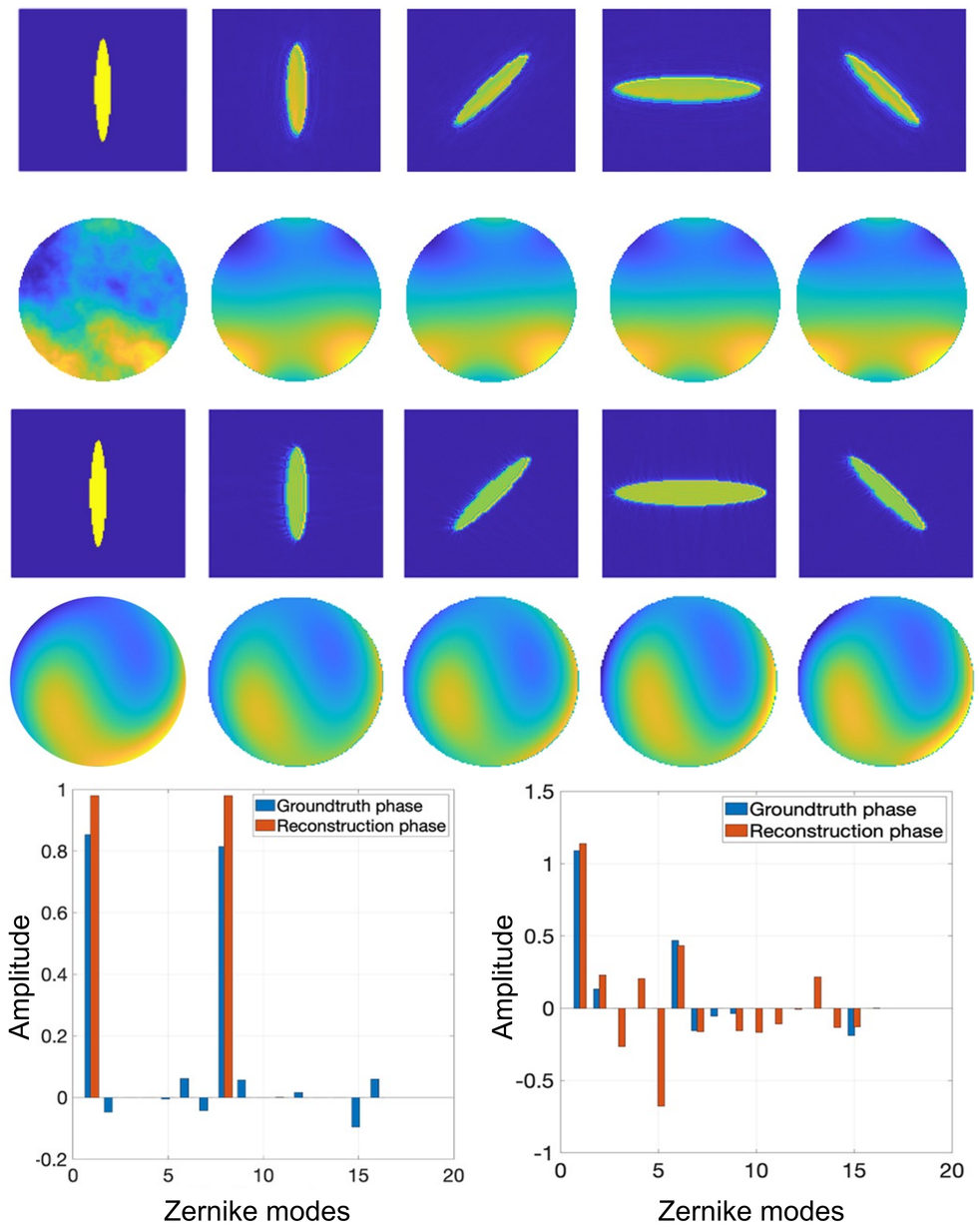
$O \rightarrow Complex\ object$ $A_\ell \rightarrow Coded\ aperture$




**Scheme of adaptive optics with designed coded aperture.**

## RESULTS

We use an ellipse under different rotations to simulate an ELGS. The phase is the linear combination of tilt and vertical coma Zernikes and simulated atmospheric turbulence. The Zernike reconstrucction is do with low-order reconstruction with the main components of the Zernike modes.




## CONCLUSIONS

We introduce a novel wavefront sensor to recover the underlying phase and amplitude of the elongated reference star, and hence the turbulent phase at the pupil plane, using phase retrieval and tensor completion. We perform extensive simulations using our SPCA. Furthermore, the complex field wavefront sensor simulation demonstrates that our approach exploits the sparsity of the recovered phase at the pupil plane to filter out components that may belong to the extended object.

## ACKNOWLEDGE

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