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# Comparing the Shack-Hartmann and Pyramid wavefront sensors with laser guide stars for 40 m telescopes

Francisco Oyarzun<sup>\*1</sup>, Cedric Taissir Heritier , Vincent Chambouleyron<sup>2</sup>, Paul Rouquette<sup>3</sup>, Thierry Fusco<sup>4,5</sup>, and Benoit Neichel<sup>6</sup>

<sup>1</sup>Aix Marseille Université, CNRS, CNES, LAM – Aix Marseille Université, Centre National de la Recherche Scientifique – France

<sup>2</sup>Department of Astronomy and Astrophysics [Univ California Santa Cruz] – University of California, Santa Cruz, CA 95064, USA, United States

<sup>3</sup>Laboratoire d’Astrophysique de Marseille – Aix Marseille Université, Centre National d’Études Spatiales [Toulouse], Centre National de la Recherche Scientifique – Pôle de l’Étoile Site de Château-Gombert 38, rue Frédéric Joliot-Curie 13388 Marseille cedex 13, France

<sup>4</sup>Département d’Optique Théorique et Appliquée (DOTA) – ONERA – BP 52 29 avenue de la Division Leclerc 92320 Châtillon Cedex, France

<sup>5</sup>Aix Marseille Université, CNRS, LAM – CNRS : UMR7326 – France

<sup>6</sup>Aix Marseille Université, CNRS, CNES, LAM – Aix Marseille Univ, CNRS, LAM, Laboratoire d’Astrophysique de Marseille, Marseille, France – Laboratoire d’Astrophysique de Marseille Pôle de l’Étoile Site de Château-Gombert 38, rue Frédéric Joliot-Curie 13388 Marseille cedex 13 FRANCE, France

## Abstract

The new generation of extremely large telescopes will rely on adaptive optics (AO) to operate at their fundamental resolution limits. To extend the sky coverage of these AO systems, laser guide stars (LGS) will be used. Given the finite distance of the LGS, and the geometry of the laser launch telescope and sodium layers, the LGS is a 3D object that resembles a cylinder located at around 90 km above sea level. The cylinder has a height of around 10-20 km and a width determined by the laser launch telescope and the seeing conditions, making it around 1-2 arcseconds wide. This 3D nature affects the measurements of the wavefront produced by both the Shack-Hartmann (SH) and Pyramid (PWFS) wavefront sensors. In this work, we compare the noise performance of both of these wavefront sensors operating with an LGS. To do this, we extended a noise propagation formalism originally developed for the PWFS (and other Fourier filtering wavefront sensors) to work with the SH, which allowed us to use the same metrics for both the SH and PWFS and have a fair comparison between the two. We found that when using a single LGS and WFS the PWFS has a higher limiting magnitude than the SH, but when using multiple LGSs and WFSs, the advantage of the SH of selecting only the highest signal-to-noise ratio measurements (by using only the non-elongated measurements) makes it a better alternative than the PWFS.

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\*Speaker

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