2° Forum della Ricerca Sperimentale e Tecnologica

Image Quality For Wide-field Telescopes

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Scope

An accurate alignment of the optical surfaces of a telescope is essential to guarantee an optimal image quality since even small displacements introduce aberrations increasing towards the edges of the field. This effect is especially detrimental in wide-field imagers. Active Optics systems are commonly employed to sense and correct the various factors affecting the wavefront, such as gravity induced aberrations and temperature gradients.

The present activity revolves around an image quality verification method to complement the traditional Active Optics approach. The method is based on the PSF ellipticity distribution map that can, in principle, provide enough information to infer the optical state of a wide-field telescope.

The method was initially conceptualized by the INAF and ESO team during the work at the VST. The present activity is continuing on this line of research to further develop the approach and produce a software tool that can be easily adapted to different wide-field telescopes.

A natural application would be towards the Vera C. Rubin Observatory, currently in its commissioning phase. Indeed, through their in-kind program, INAF has a tight collaboration with the Vera C. Rubin team, which would grant the necessary on-sky data to test the proposed method, and possibly the chance to compare it to their own Active Optics control for a final validation.

Overview

To address the challenges posed by the wide-field Active Optics control, the activity tackles the following main issues:

1. Misalignment aberration patterns modelling

The large field dependence of the wavefront error and its relationship to the optical state is captured by a general mathematical framework based on a flexible Double Zernike representation. An analysis using Zemax OpticStudio allows to produce a synthetic aberration model of the telescope. This required also tailoring the framework to the specific optical configuration of the telescope using dedicated software tools.

2. Wavefront sensing

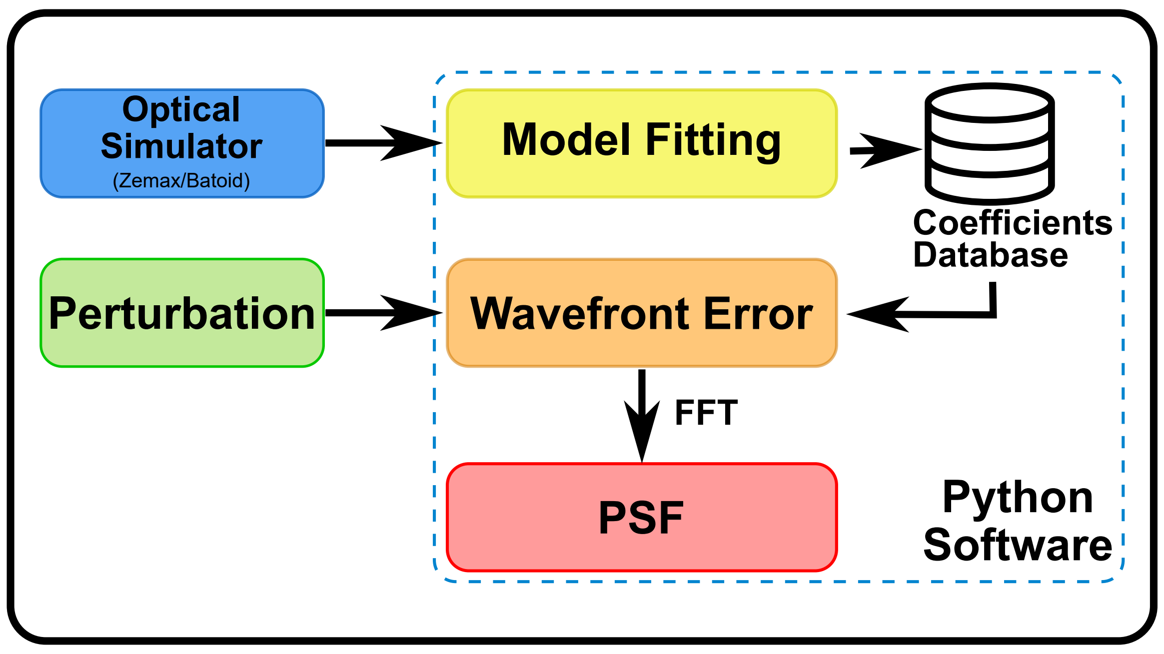
Commonly, Active Optics systems directly measure the wavefront using two or more Shack-Hartmann or Curvature sensors, generally located towards the edge of the field.

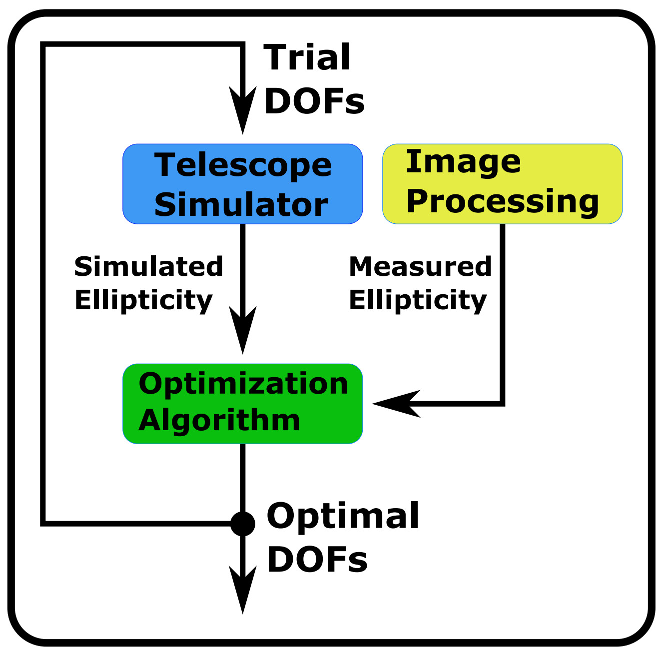
The alternative being explored leverages the information coming from the science image instead. This "sensor-less" approach extracts the PSF second order moments from the image to generate a field ellipticity map, from which the wavefront error can be inferred.

3. Active Optics algorithm

The measured wavefront error needs to be translated to the mechanical degrees of freedom of the telescope optics in order to realign them, essentially "inverting" the aberration model. How quickly and accurately this can be done has a huge impact on the correction, as this should be ideally applied in real-time. To this end, a linear inverse optimization algorithm is being considered.

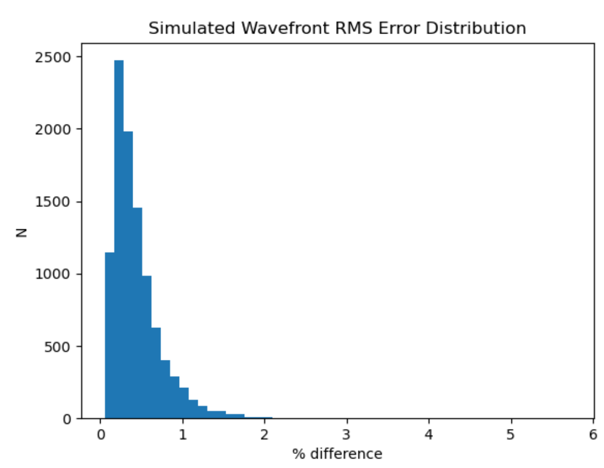
Modelling



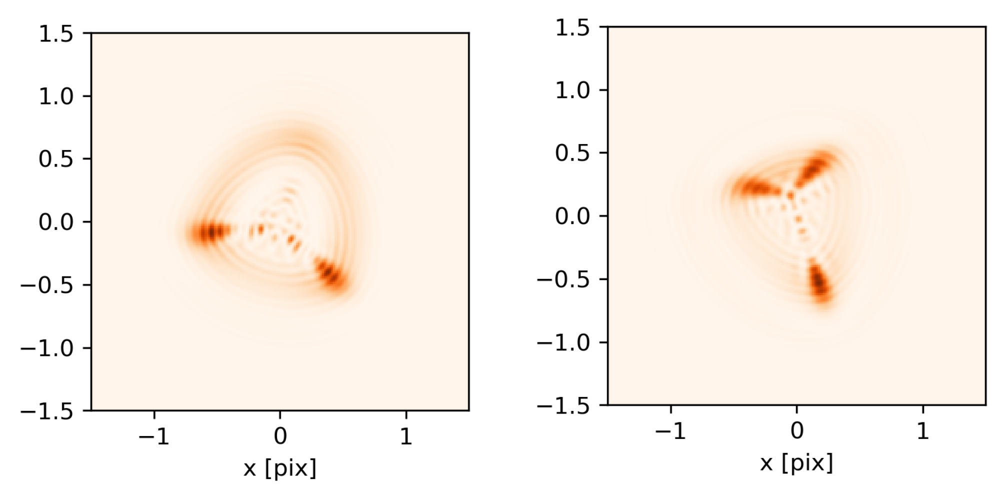


Some Results

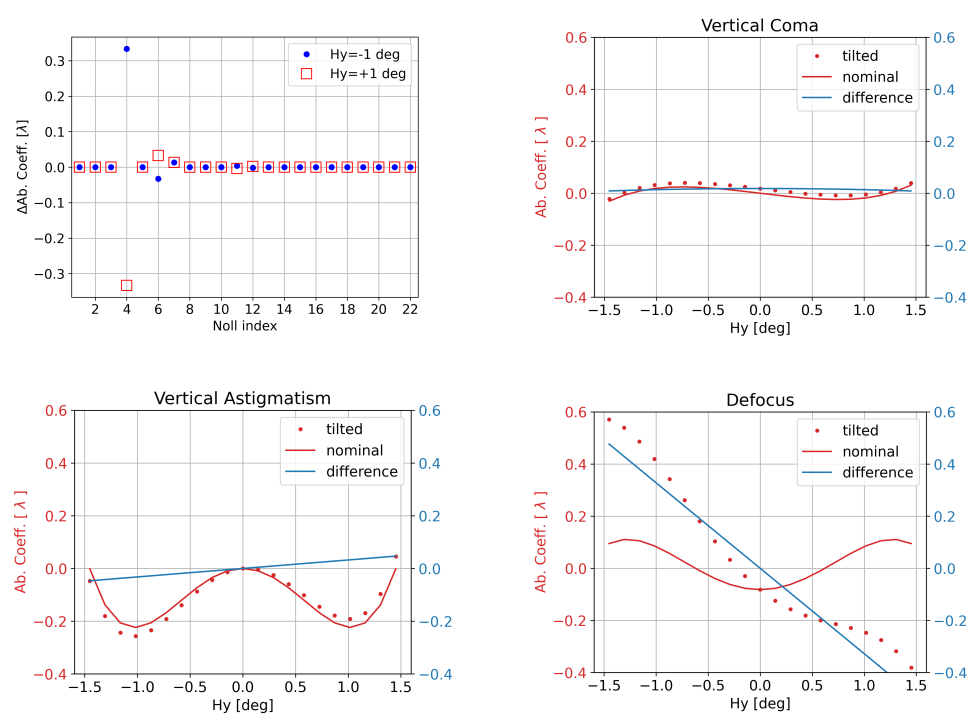
Model accuracy



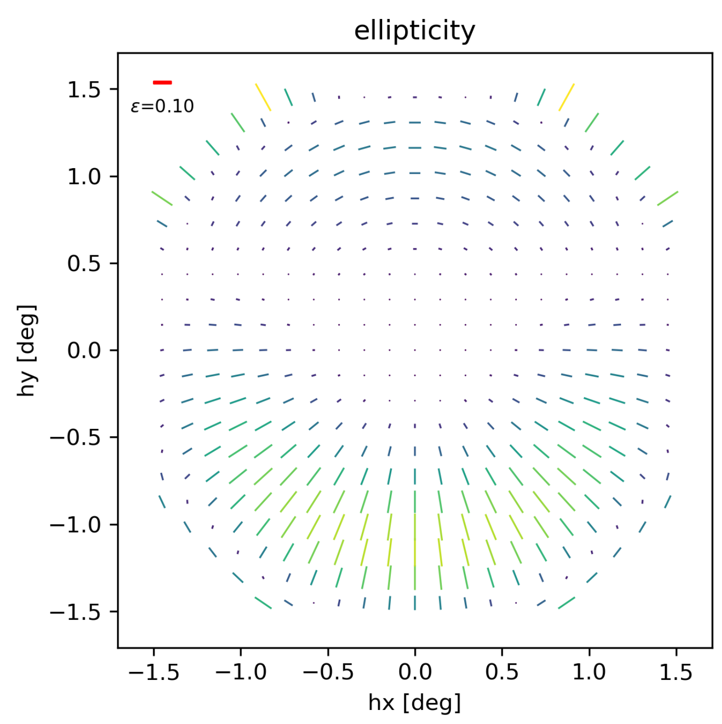
PSF Simulation



Aberrations due to a Camera tilt



Ellipticity pattern



Future Development

The activity has produced so far:

- Python software module to model and simulate the wavefront error of a wide field telescope under a generic mirror misalignment.
- Publication of preliminary results: Savarese Salvatore, et al. "*Analysis of the PSF moments of the Simonyi Survey Telescope.*" Proc. SPIE 2024.

The activity is still ongoing towards the inversion procedure that completes the reconstruction loop. The proposed method will then be tested using on-sky images from the LSSTCam when it will begin its observations. Work is still needed to outline the limitations of the method.