Model-based reinforcement learning and inverse problems in extreme adaptive optics control

Jalo Nousiainen(a), Tapio Helin(a), Markus Kasper(b)

(a): Lappeenranta–Lahti University of Technology
(b): European Southern Observatory

Abstract

The field of exoplanet research is one of the most rapidly expanding research fields in modern astrophysics. In recent decades, astronomers have found most exoplanets via indirect techniques such as the transit and radial velocity method. The direct imaging technique called high contrast imaging (HCI) enables new ways to expand our knowledge of these exoplanets and exoplanetary systems. However, direct imaging of exoplanets is challenging due to the high contrast ratio and small angular separation from the host star. Thus, HCI detections, so far, are mostly limited to a few tens of young and luminous giant exoplanets.

The new generation of HCI instruments, under development, will push direct imaging to increasingly challenging areas, discovering and characterizing exoplanets dimmer and closer to their host start. The ultimate goal is direct imaging and characterization of potentially habitable exoplanets. On ground-based telescopes, HCI instruments are equipped with eXtreme Adaptive Optics (XAO) that correct the phase fluctuations caused by the atmosphere. With an optimized instrument design, the residuals left by XAO correction set the limitation of sensitivity; thus, minimizing the XAO residuals is a crucial objective for ground-based HCI. Further, most habitable exoplanets are located at small angular separations from their host stars, where current XAO control algorithms leave strong residuals of stellar light that could be suppressed with more advanced algorithms.

We explore novel data-driven control methods for XAO control that cope with crucial limitations of traditional control laws, such as temporal delay and calibration errors. Improvement in these potentially reduce the residual flux of stellar light in the coronagraphic point spread function and thus enables fainter observations closer to the host star.