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COHERENCE-BASED SPECKLE IDENTIFICATION THROUGH DEFORMABLE MIRROR PERTURBATIONS

Abstract

Nothing has captured the human imagination more than the prospect of life outside our own Earth. To date, over 500 exoplanets have been detected. The majority of them have been found through indirect Doppler techniques that at most indicate the planet's minimum mass and orbital period. As such, these discoveries are not enough to fully characterize these planets. To detect the presence of biomarkers, we must directly study the planet's light. This obstacle is hard to overcome since the star the planet orbits is at least a million times brighter than the planet itself, and the angular separation between these objects as viewed from the Earth is exceedingly small. One of the leading instrument concepts for this challenge is an internal coronagraph on a ground or space-based telescope. A coronagraph has two purposes: it concentrates the diffracted light of the star and then blocks it so that the light from the planet can reach the detector with little attenuation and be easily identified. However, small wavefront errors in the telescope and instrument lead to leakage of starlight in the form of speckles on the detector. The intensity and the angular size of the speckles make them appear very similar to the image of a planet, making speckles one of the major limitations in direct planet detection.

Current methods of removing speckles involve techniques that cause the speckle pattern to change across multiple images in order to improve the signal to noise ratio. An often-overlooked property is that speckles are optically coherent with the star (since they originate from aberrations in the starlight within our telescope system). Our technique takes advantage of this property to distinguish speckles from the image of a planet. We add deliberate perturbations to a deformable mirror (DM) to create a reference field from the starlight on the image plane detector. Large variations in intensity on the detector are therefore caused due to the interference between the prior residual speckle field and the reference field, while the image of the planet remains unaffected. Our knowledge of the deliberate perturbations allows us to accurately estimate the reference field. We then use Bayesian techniques to analyze the series of images to identify a planet within a certain confidence level. Our generic technique works with any type of coronagraph, ground or space-based. We illustrate our results with simulations and lab data designed for a space-based shaped-pupil coronagraph.