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Image quality degraded by instrument polarization

Frequently images are delivered to users with little or no knowledge of the optical system that recorded that image. Often optical systems are designed with little or no consideration for the applications of images. The very high image quality required for exoplanet coronagraphs is used as an example.

In this paper we apply a vector representation of physical optics of the Fresnel-Kirchoff diffraction integral, sometimes called polarization aberration theory to study image formation in telescopes and instruments. We describe image formation in-terms of interferometry and use the Fresnel polarization equations to show how light, upon propagation through an optical system become partially polarized. We make the observation that orthogonally polarized light does not interfere to form an intensity image. We show how the two polarization aberrations (diattenuation & and retardance) distort the system PSF, cause it to be non-isoplanatic, decrease transmittance, and increase unwanted background above that predicted using the non-physical scalar models.

We modeled a typical 2.4-meter Cassegrain telescope system with one 90-degree fold mirror and analyzed the system for polarization aberrations. We find: 1. The image plane irradiance distribution is the linear superposition of four images: One for each of the two orthogonal polarizations and one for each of two cross-product polarization terms. 2. The PSF image is brighter by 9% for one polarization component compared to its orthogonal state. 3. The image of the PSF for orthogonal polarization components are shifted across the focal plane with respect to each other, causing the PSF image for astronomical sources (polarized or unpolarized) to become slightly elongated (elliptical) with a centroid separation of about 0.6 masec. 4. The orthogonally polarized components of unpolarized sources contain different wavefront aberrations, which are separated by approximately 32 milliwaves. This implies that a wavefront correction system cannot optimally correct the aberrations for all polarizations simultaneously. 5. The polarization aberrations couple small parts (~1E-5) of each polarization component of the light into the orthogonal polarization to create highly distorted secondary, or “ghost” PSF image. The radius of the spatial extent of the 90% encircled energy of this ghost PSF image is centered on the axis and twice as large as the Airy diffraction pattern. 6. This ~1E-5 scattered light level is to be compared to the 1E-9 scattered light level required for terrestrial exoplanet imaging coronagraph.