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Towards Poisson-Limited Photometric Precision from Ground-Based Telescopes

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Ground-Based Telescopes supported by lidar and calibrated spectrophotometry can attain levels of precision for all-sky photometry previously only attainable from space-based instruments, with uncertainties dominated by fundamental photon counting statistics and detector noise. Earth's atmosphere is a wavelength-, directionally- and time-dependent turbid refractive element for every ground-based telescope, and is the primary factor limiting photometric measurement precision. To correct accurately for the transmission of the atmosphere requires direct measurements of the wavelength-dependent transmission in the direction and at the time that the supported photometric telescope is acquiring its data. While considerable resources have been devoted to correcting the effects of the atmosphere on resolution, the effects on precision photometry have largely been ignored. We describe the facility-class lidar that observes the stable stratosphere, and a spectrophotometer that creates and maintains NIST absolutely calibrated standard stars, the combination of which enables fundamentally statistically limited photometric precision. This inexpensive and replicable instrument suite provides the lidar-determined monochromatic transmission of Earth's atmosphere at visible and near-infrared wavelengths to 0.25% per airmass and the wavelength-dependent transparency to less than 1% uncertainty per minute. The atmospheric data are merged to create a metadata stream that allows throughput corrections from data acquired at the time of the scientific observations to be applied to broadband and spectrophotometric scientific data. This new technique replaces the classical use of nightly mean atmospheric extinction coefficients, which invoke a stationary and plane-parallel atmosphere and ultimately limit ground-based all-sky photometry to 1% - 2% precision. We demonstrate application of this instrument suite to stellar photometry, and discuss the enhanced value of routinely provably precise photometry obtained with existing and future ground-based telescopes.

Primary author: ZIMMER, Peter (University of New Mexico)

Presenter: ZIMMER, Peter (University of New Mexico)

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