High angular resolution spectroscopy in the Visible using a Photonic-Lantern on FIRST/SCExAO

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Abstract (350 words): This presentation addresses a crucial limitation of single-mode fiber based interferometers in exoplanet detection – the scarcity of received photons. This insufficiency mainly arises from difficulties in light injection into single-mode fibers, especially in the Visible, where even ExAO systems struggle to reach high Strehl ratios.

In light of this challenge, we discuss the Photonic Lantern which, coupled with a spectrograph, can provide spectral information at spatial resolutions comparable to interferometers, down to at least half of the telescope spatial resolution. We concentrate on a specific PL configuration featuring a multimode fiber input smoothly transitioning to single-mode fiber output ports (SMF). The use of a multimode input, combined with a quasi-lossless transition between the MMF and the SMF, allows for the injection of the entire telescope aperture's light into the device rather than individual sub-apertures. Analysis of relative output fluxes between the output ports enables the retrieval of the injected wavefront, containing key information about the source's position and shape. Spectral lines information contained in the output light can be used to detect spectral emission from protoplanets, while the spectral continuum information encodes wavefront errors. By addressing the aforementioned limitation of interferometer sensitivity, PL shows promising potential for enhancing exoplanet detection capabilities. Furthermore, the PL presents a potential solution to improve the use of the telescope aperture in non-redundant masking interferometers, and the coupling efficiency into Photonic Integrated Circuits-based interferometer.

We detail the integration and initial characterizations of a 19-ports photonic lantern, in the Visible, combined with a mid-resolution spectrograph on SCExAO at the Subaru Telescope. Extensive study of light coupling into the device demonstrates various performances concerning coupling efficiency, spectral information and field of view. Additionally, we investigate the relationship between coupling efficiency and the Strehl ratio, in comparison with the use of a single-mode fiber. We also report on on-sky observations made under poor seeing conditions (~1 arcsec in H-band), during which we achieved a coupling efficiency of 17.5%. We demonstrate the PL's capability to perform spectroscopy at high SNR with examples from the Ikiiki (α Leo) and ʻAua (Betelgeuse) spectra, which exhibit the expected spectral features from Earth and stellar atmospheres.