**Diffraction-limited high dynamic range imaging from the visible to the infrared**

Takayuki Kotani¹, Guy Perrin¹, Sylvester Lacour², Julien Woillez³, Éric Thiébaut⁴

¹ Observatoire de Paris, ² University of Sydney, ³ W.M. Keck Observatory, ⁴ Observatoire de Lyon

**abstract**

We propose a novel technique to achieve high angular resolution imaging at high dynamic range that will be well adapted to some astrophysical cases such as imaging of planets very close to their central star and of structures in disks. The fundamental idea is to apply techniques developed for long baseline interferometry to the case of a single-aperture telescope. The pupil of the telescope is broken down into coherent sub-apertures each feeding a single-mode fiber. A remapping of the exit pupil allows interfering all sub-apertures non-redundantly. A diffraction-limited image with very high dynamic range is reconstructed from the fringe pattern analysis with aperture synthesis techniques, free of speckle noise. Raw dynamic ranges of a million can be obtained in only a few tens of seconds of integration time for bright objects and can be improved with off-line processing techniques. The technique can be applied to either visible or infrared wavelengths, the number of fibers matches the number of coherent patches over the pupil. The technique can also be applied to space coronography. First simulations show that contrasts of $10^{-5}$ can be achieved within a distance of a fraction of $\lambda/D$ on regular brightness candidates for planet search (for more detail about the application to space coronagraph, please visit the poster by Lacour et al).

**Concept**

The telescope pupil is divided into sub-apertures each feeding a single-mode fiber in order to filter out atmospheric turbulence. Output sub-apertures will be rearranged non-redundantly. The advantages of this technique are following: First, the use of single-mode fibers filter out atmospheric turbulence effects, as already demonstrated by a single-mode fiber long-baseline interferometry. Second, non-redundant pupil configuration eliminates redundant noise which affects wavefront measurement accuracy. Third, the full incident pupil of the telescope can be used thanks to the pupil remapping by fibers. The removal of atmospheric turbulence and redundant noise allows the calibration of degraded wavefront almost perfectly. Therefore this technique can take a full advantage of intrinsic high angular resolution of large ground-based telescopes and its large photon collecting capability.

**Performance**

The right panels show the simulations of reconstructed images with 36-element pupil remapping technique. They consist of 10000 snapshots of 4 ms each on an 8 meter telescope in the case of $r_0 = 20$ cm at the visible wavelengths. The field of view of each image is $30/\lambda/D$. The object is a central star with a circumstellar disk and two companions, of relative flux a $10^{-6}$ and $10^{-8}$. From left to right, the difference in the reconstructed images are due to the brightness of the object (magnitudes 10, 5 and 0). The reconstructions show dynamic range around or over $10^{-6}$. Further enhancement of a dynamic range may be possible: by increasing the number of exposures, increasing the number of sub-apertures, direct theoretical visibility fitting to observed visibilities to avoid image reconstruction noise.

**6-element lab demonstrator**

We have constructed the 6-element laboratory tested in order to demonstrate our concept. The input telescope pupil is divided into the 6-redundant sub-pupils (Fig. 3 Left) and the laser light is injected into the single-mode fibers. The output light from the fibers are collimated and remapped non-redundantly (Fig. 3 Right). The light is combined on the image plane to measure the interferometric fringes.

**References**