The first 'OHANA fringes with the Keck telescopes  Towards kilometric arrays of telescopes in the near-infrared

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An international team of astronomers has demonstrated the first coherent coupling of large telescopes with single-mode fibers in the near infrared. The test, performed with the two 10 m Keck telescopes of the Mauna Kea Observatory in Hawaii, is the first step of the 'OHANA project whose aim is to turn the observatory seven largest telescopes into a gigantic imager of 800 m diameter. This first experiment is a milestone on the way to future very large arrays of telescopes connected with single-mode fibers to produce astronomical images with sub-milliarcsecond angular resolution. Very high angular resolution and sensitivity are required to study very compact sources such as the environment of black holes in other galaxies or the inner regions of exoplanetary systems where life may have developed. The results are published in the January 13 2006 issue of the Science magazine.

The ability of a telescope to resolve small-scale structures of astronomical sources is ultimately limited by its size. The larger the telescope, the higher its angular resolution. The current largest telescopes have diameters of 8 to 10 m. The size of the next generation telescopes will increase to a few tens of meters with 100 m appearing as a technological limit for single-aperture systems. This limit can be overcome if the light of distinct collectors is coherently recombined. The distance between telescopes then gives the resulting angular resolution. This technique known as astronomical interferometry was first suggested by Hyppolite Fizeau in the XIXth century and demonstrated by Albert A. Michelson with a single telescope as a beam combiner. A new era started in 1974 when Antoine Labeyrie first demonstrated interferometric fringes between separate apertures. Since then, about twenty interferometric optical observatories have been in operation and have allowed resolving stellar surfaces and environments otherwise point-like to telescopes. With the advent of very large telescopes equipped with adaptive optics, the Keck Interferometer and the Very Large Telescope Interferometer have inaugurated the era of very sensitive high angular resolution with the very first studies of the environment of the core of active galactic nuclei. Higher angular resolutions are needed to resolve the core which hosts a super-massive black hole.

Figure 1: The Mauna Kea observatory and the 7 telescopes of the project 'OHANA: Optical Hawaiian Array for Nanoradian Astronomy. OHANA means also "family" in hawaiian language. © Richard Wainscoat Click on the image to enlarge it

Current interferometers have baselines at most a few hundred meters long. Propagating beams over large distances requires a large number of mirrors, which together with the effects of diffraction induce a low throughput. Single-mode fibers can transmit light over even larger distances with potentially lower losses. They may therefore play a key role to build very large arrays of telescopes of kilometric or larger size. The effectiveness of single-mode fibers for this purpose has been studied by Observatoire de Paris and Institut de Recherche en Communications Optique et Micro-ondes in the framework of the 'OHANA (Optical Hawaiian Array for Nanoradian Astronomy and which also means family in the Hawaiian language) project. 300 m long single-mode fiber cables have been shown to convey the coherence of light in 300 nm large bandwidths in the near infrared with transmissions from 50% to 95%. 'OHANA aims at connecting the seven largest telescopes of the Mauna Kea Observatory in Hawaii (Figure 1). The resulting array will have a diameter of 800 m and will provide unprecedented angular resolution in the near infrared.

Figure 2: Experiment set-up (1). Routing of single-mode fibers from the Keck Nasmyth foci down to the basement beam combination laboratory. Fibers are attached to the telescope structure like regular cables and go through the cable wrap system to prevent any damage when the telescopes rotate in azimuth. The remaining fiber lengths (approximately 200 m for each arm) are wrapped on spools in the basement (see Figure 3). © W.M. Keck Observatory et Observatoire de Paris Click on the image to enlarge it
The first interferometric test has been performed between the two 85 m apart Keck telescopes in the astronomical K-band (2-2.3 µm) with fluoride glass single-mode fibers manufactured by the France based company Le Verre Fluoré. Two 300 m long fibers were used in the experiment thus simulating a 500 m long baseline with respect to beam propagation. The fiber inputs were directly set at the adaptive optics corrected Nasmyth focus of each telescope and were routed down to the interferometric laboratory in the basement of the telescopes building (Figure 2). Prior to mixing, the beams output from the fibers were delayed with classical optical delay lines to match the optical paths of the two beams in order to detect the narrow fringe pattern (Figure 3). No long stroke fibered delay line is yet available and this remains a field of research to further develop for future large arrays. Despite cloudy conditions, first fringes were detected on the 4.6 K band magnitude star 107 Herculis (Figure 4).

Figure 3: Experiment set-up (2). Sketch of the interfacing of the output of the 'OHANA fibers with the Keck interferometer delay lines and beam combiner. Only one beam/fiber is shown for the sake of clarity. The two beams follow equivalent paths. The fiber is placed at the focus of an off-axis parabola (OAP) to produce a collimated beam. The beam is reflected with a flat mirror (M10) towards the Long Delay Line. It is then launched into the Fast Delay Line. The beam size is reduced in a Beam Compressor and feeds the Beam Combiner. Click on the image to enlarge it.

This first successful 'OHANA test is the beginning of the effort to characterize each 'OHANA baseline before completing the entire array. The next baseline will link the Canada-France-Hawaii and Gemini North telescopes. This success also opens the way to the design of dedicated large interferometric facilities in the optical domain comprising a large number of individual telescopes separated by kilometric distances and which will bring a far more accurate vision of our universe than current facilities. Figure 4: Fringes on the star 107 Herculis. The interference fringe signal is the high frequency 200 Åµm large pattern. The low frequency intensity fluctuations are due to vibrations in the top panel. The signals have been high-pass filtered in the bottom panel to remove the low frequency vibrations. Click on the image to enlarge it.

Reference Perrin G., et al., 2005 “The first 'OHANA fringes with the Keck telescopes” Science, 2006, 13 January issue

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