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First results from the AMBER/VLTI near-infrared spectro-interferometer

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AMBER, a high-precision, high-sensitivity instrument for near-infrared spectroscopy at the Very Large Telescope, is returning its first astrophysical results.

Progress in astronomy requires instrument developments in several important directions. For instance, we need larger collecting areas to observe fainter, more distant—and therefore more ancient—sources closer to the birth of the universe, and larger spectral coverage to probe different physical processes. Also, finer observations would allow us to investigate the physics in peculiar and extreme situations (such as the vicinity of putative black holes) or to find hidden details (such as extrasolar planets overwhelmed in the dazzle of their sun). Long baseline interferometry—difficult and uniquely valuable—would provide orders-of-magnitude improvements in spatial resolution.

To achieve these goals down to the milliarcsecond (mas) scale, the European Southern Observatory (ESO) has equipped its Very Large Telescope (VLT) with an interferometric mode (VLTI) combining giant telescopes spread over 100 meters at an exceptional site (Cerro Paranal in Chile; see Figure 1). At the focus of the VLTI sits a beam recombiner—the near-infrared Astronomical Multiple BEam Recombiner, or AMBER[1]—installed by a consortium consisting of France's Université de Nice-Sophia Antipolis, Laboratoire d'Astrophysique de Grenoble, and Observatoire de la Côte d'Azur, Germany's Max-Planck-Institut für Radioastronomie, and Italy's Osservatorio Astrofisico di Arcetri.

AMBER coherently merges the light of three telescopes and analyzes the resulting interference fringes in many spectral channels simultaneously, with low (35) and, for the first time ever, medium (1500) and high (12,000) spectral resolution. By merging three giant apertures into a single telescope (see Figure 2), AMBER makes the VLTI the largest existing optical telescope, both in collecting power and in angular resolution.

Figure 1. *The Very Large Telescope observatory features four large and several medium-sized telescopes with a complete infrastructure for performing optical interferometry.*

We installed AMBER in March 2004. Although we are still in the test and commissioning phase, we have obtained a wealth of original results about the close environment of a variety of stars. For example, by using amplitude and phase wavelength dependencies, we have constrained estimates of the size and geometry of these sources, as well as the relative morphology between the continuum and line emissions. In the following, we detail results obtained for star formation, a hot massive star, and an interacting binary.

The young stellar object MWC 297 is an embedded B1.5Ve star exhibiting strong hydrogen emission lines. A strong near-infrared continuum excess was observed with the AMBER instrument during its first commissioning run.[2] MWC 297 has been spatially resolved in the continuum with a visibility of ∼0.50, as well as in the Brγ emission line where the visibility decreases to ∼0.33. From these observations, a picture emerges in which MWC 297 is surrounded by an equatorial flat disk that is possi-

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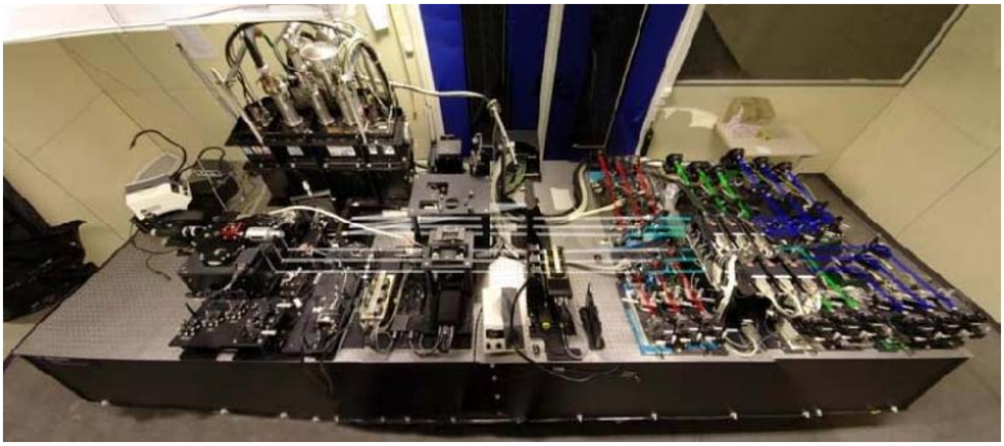

Figure 2. The AMBER instrument combines the light collected by three of the apertures of the VLTI in the near-infrared domain. The incoming beams have been superimposed on the photograph. The beams travel from the bottom left to the right and then from the upper right to the left towards the cryogenized spectrograph.

bly still accreting, and by an outflowing wind. AMBER's unique ability to measure spectral visibilities has allowed, for the first time ever, the comparison of a young stellar system's disk structure with the apparent geometry of a wind.

Our second example has a bearing on hot, massive star characteristics. The brightest, most massive, unstable luminous blue variable, η Carinae—which is undergoing an extremely high mass loss—has been observed with AMBER in both medium and high spectral resolution.[3] In the K-band continuum, we measured a $\sim$4mas optically thick wind region elongated along a position angle of 128°, whereas the Brγ and HeI emission line regions are larger. Our observations support theoretical models of anisotropic winds from fast-rotating, luminous hot stars with enhanced high-velocity mass loss near the polar regions.

Our final early result example provides an estimae of the structure and distance of the Wolf-Rayet (WR) and O star binary system γ^2 Velorum.[3] Using WR- and O-star synthetic spectra, we show that the features observed by AMBER result primarily from the contribution of the individual components of the WR+O binary system, although there may be a secondary continuum component. This secondary component may originate from the free-free emissions *(bremsstrahlung)* associated with the wind-wind collision zone, and contributes no more than about 5% to the observed K-band flux. Using theoretical estimates for the spatial extent of both continuum and line emissions from each component, we demonstrate that the binary system lies at a distance of 368pc, in agreement with recent estimates but larger than the Hipparcos value.

AMBER has been successfully implemented and is now available to the general user for all resolutions in the K band. The first scientific results are breakthroughs in the understanding of circumstellar environments and stellar wind mechanisms. New bands should be progressively offered during the next 18 months. At the end of the current VLTI consolidation period, we will reach the specified performances in terms of limiting magnitude. This will allow observations of the environment of putative black holes in the centers of active galaxies, and the first spectroscopic studies of extrasolar planets.

These observations would not have been possible without the support of many colleagues and funding agencies. We would like to thank the entire AMBER consortium and the staff of the ESO who provided their help in the design and commissioning of the AMBER instrument.

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