Probing the heart of extragalactic sources

Anne Poncelet, Coralie Doucet, Guy Perrin, Hélène Sol, and Pierre-Olivier Lagage

The combination of imaging and interferometry allows astronomers to investigate the relationship between the complex structures that make up an active galactic nucleus.

Many efforts have been made to develop the capabilities of astronomical instruments and to limit the effects of atmospheric turbulence, which degrades the resolution of astronomical images. The sensitivity of recently constructed optical-infrared instruments enables us to examine the cores of very luminous extragalactic sources such as active galactic nuclei (AGNs). Observations performed by imaging or by spectroscopy with a single 8m-class telescope map the object structures with a resolution of several tens of light-years (ly) for the nearest sources. On the other hand, interferometry with two or more telescopes gives access to details of a few ly in size.

Observations with resolutions intermediate between these two cases are lacking and are currently unattainable with direct interferometry. The use of interpolations to get them is strongly model-dependent. However, this data is essential for describing the relationships between the different dust structures that make up AGNs, and for gaining a complete understanding of the accretion processes that power their central engines.

To overcome this difficulty, we applied a peculiar interferometric process to images obtained in a special observing mode. The principle is simple and based on the speckle interferometry technique first developed by Labeyrie. An image taken with an 8m-class telescope contains all spatial frequencies from 0 to the cutoff frequency of the telescope (i.e., 0–8m in terms of baselines). A Fourier transform of one image brings out frequency information (i.e., visibilities) comparable to that directly measured by interferometry. A model of the source brightness enables us to extrapolate the high spatial frequency points (obtained by direct interferometry) from those of low spatial frequency (obtained from the interferometric process applied to images). Thanks to a priori information used in this model, structures smaller than the diffraction limit of the telescope can be estimated.

NGC 1068, the brightest and nearest AGN, was observed in the mid-infrared at the European Southern Observatory (ESO) Very Large Telescope (VLT) in Paranal, Chile. 12.8µm images were acquired in January 2005 with the burst (or quasi-speckle) mode of the VLT Imager and Spectrometer for the mid-InfraRed (VISIR). The advantage of this mode is the short image-acquisition time of 16ms, which allows us to freeze the atmospheric turbulence at 10µm and to take many exposures during an observing run. The quality of data obtained through this mode is attested by Figure 1, which shows a 16ms exposure and the result of the addition of the ~13,000 individual exposures. North is up and east is on the left. The size of one pixel is ~17.6ly.

Figure 1. 12.8µm images of NGC 1068 acquired with the burst mode of VISIR. Left: A single 16ms exposure. Right: The result of adding 13,000 individual exposures. North is up and east is on the left. The size of one pixel is ~17.6ly.

Visibility points obtained this way between 0 and 8m of spatial frequencies (or baseline) are plotted in Figure 2. First data obtained with the VLT mid-infrared interferometer (MIDI)
Figure 2. Comparison between the very low spatial frequency visibilities (between 0 and 8m) measured from the interferometric treatment applied to VISIR burst mode images and the high spatial frequency visibilities from MIDI observations (at 45 and 78m). It appears that the model of Poncelet, Perrin, and Sol, first applied to MIDI data alone, cannot reproduce the strong decrease in visibility at short baselines (see the dotted line). Unif: Uniform.

corresponding to two azimuth angles of the baseline are also presented. This figure illustrates very well the need for the low spatial frequency visibility measurements, since the strong drop in visibility between 0 and 8m of baseline was not predicted by the models, in particular that of Poncelet, Perrin, and Sol, which did fit well when applied to the MIDI data set alone.

Attempts to fit both data sets simultaneously, making use of simple source brightness models, highlight two major contributors to the source flux. The first has a size of ≃5ly and is associated with the dusty core, also called the dusty torus. The second, ≃95ly in size, is associated with dust distributed inside the ionization cones of NGC 1068.

Results from the imaging process we developed met our expectations. The procedure gives access to the essential but hitherto lacking low spatial frequency information. It also enables us to probe structures much smaller than the diffraction limit of an 8m-class telescope and to address the question of how the different dusty structures inside AGNs are linked.

Author Information

Anne Poncelet, Guy Perrin, and Hélène Sol
Paris Observatory
Meudon, France

Coralie Doucet and Pierre-Olivier Lagage
Dapnia/Astrophysical Service
Atomic Energy Commission
Saclay, France

References