# OPTICAL INTERFEROMETRY IN THE MULTI-SPECKLE MODE

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**Abstract.** We have studied interferometric imaging in the multi-speckle mode by computer simulations. From various simulated data sets diffraction-limited images were reconstructed by the speckle masking method and the iterative building block method. The reconstructed images show the dependence of the signal-to-noise ratio on photon noise.

## 1. Experimental Results

We have studied interferometric imaging in the multi-speckle mode by computer simulations (Reinheimer et al. 1992). In the computer experiment shown in Fig. 1 a pupil function (Fig. 1a) similar to the ESO VLT Interferometer (four 8-m telescopes), geographic latitude -24$^0$, declination -70$^0$, maximum zenith angle of 60.7$^0$, and data recording at 15 different rotation angles of the earth during 9.3 hours observing time were simulated. Fig. 1b shows the uv-coverage of the experiment. Fig. 1c is the object, a close triple star (separation between the two closest stars: 0.0042" for $\lambda$=700nm and 100m interferometer diameter). Fig. 1d shows one of the generated point source interferograms with simulated seeing corresponding to a Fried parameter $r_0$=2m. The interferograms consist of about 10 speckles with interference fringes in each speckle. Speckles with fringes were obtained since many turbulence cells in front of each telescope were simulated (multi-speckle mode). Fig. 1e is one of the 48 000 generated interferograms of the triple star after injection of photon noise corresponding to $\sim$300 photoevents/frame. From the simulated VLTI interferograms the ensemble average bispectrum was derived at those positions in the 4-dimensional bispectrum space where the bispectrum transfer function $\langle P^{(3)}(u,v)\rangle$ was greater than zero. The large gaps in the uv-plane of the VLT Interferometer cause large gaps in $\langle P^{(3)}(u,v)\rangle$. From the obtained bispectrum a diffraction-limited image of the object was reconstructed by the iterative building block method. Fig. 1f is the diffraction-limited (resolution: 0.0018", $\lambda$=700nm, 100m baseline) image reconstructed from the 48 000 interferograms (300 photoevents/interferogram) by speckle masking (Weigelt 1977; Weigelt&Wirnitzer 1983; Lohmann et al. 1983) and the iterative building block method (Hofmann&Weigelt 1990, 1992). Fig. 2b shows the diffraction-limited reconstruction of the triple star for $\sim$100 photoevents/interferogram (same parameters as for the experiment shown in Fig. 1). 100 photoevents/interferogram correspond to magnitude 14.8 for four 8-m telescopes, 20msec exposure time per interferogram, 2nm filter bandwidth and 10% quantum efficiency of detector plus optics.

Fig. 3a is the object (galaxy; diameter$\approx$0.009" for $\lambda$=700nm and 100m baseline) of a second experiment. Fig. 3b shows the diffraction-limited image reconstructed from 48 000 interferograms with photon noise corresponding to $\sim$5000 photoevents/frame (same parameter as for the experiments shown in Fig. 1 and 2).



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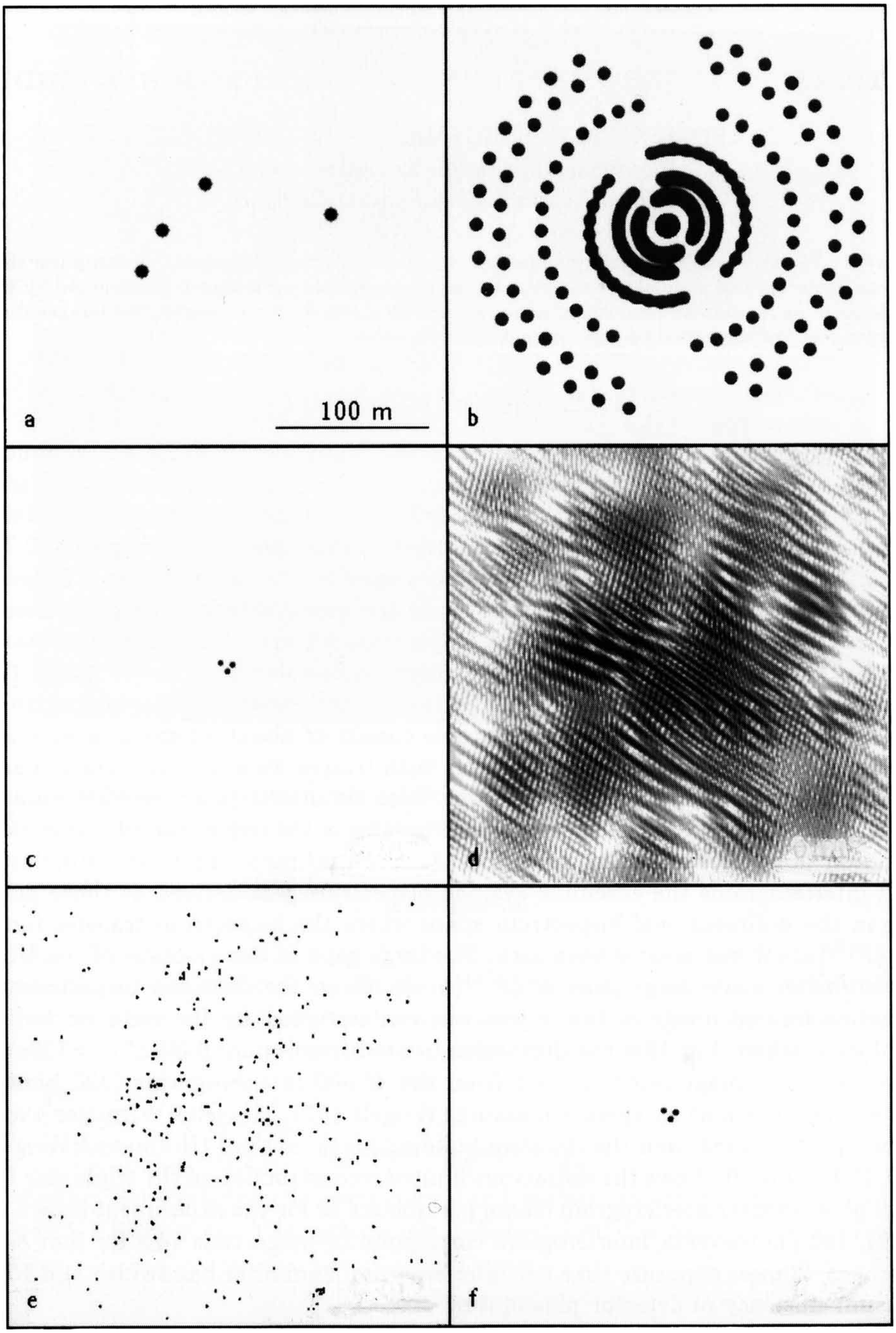


**Fig. 1. Computer simulation of optical long-baseline interferometry with the ESO VLT Interferometer (four 8-m telsecopes) in the multi-speckle mode. The diffraction-limited image (f) was reconstructed from 48 000 VLTI interferograms with photon noise of ∼300 photoevents/interferogram (see text).**

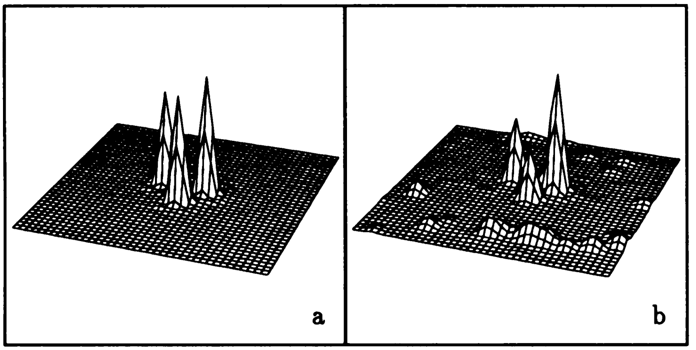


Fig. 2. Same computer simulation as described in Fig. 1, but photon noise of 100 photoevents/interferogram: (a) theoretical object, (b) diffraction-limited reconstruction derived from 48 000 VLTI interferograms.

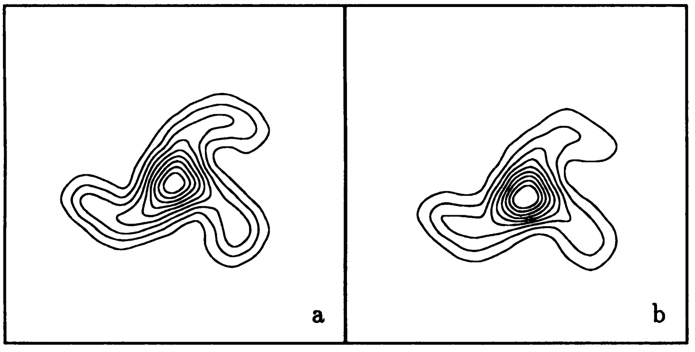


Fig. 3. Same computer simulation as described in Fig. 1, but extended object: (a) theoretical object, (b) diffraction-limited reconstruction derived from 48 000 simulated VLTI interferograms with photon noise of ~5000 photoevents/interferogram.

## References

Hofmann K.-H., Weigelt G.: 1990, 'Image Reconstruction from the Bispectrum Using an Iterative Algorithm, Applications of the Method to Astronomical Objects', in: Optics in Complex Systems, ICO 1990, eds. F. Lanzl, H.-J. Preuss, G. Weigelt, *Soc. Photo-Opt. Instr. Eng.* **1319**, 444

Hofmann K.-H., Weigelt G.: 1992, 'The Building Block Method: Image Reconstruction from the Bispectrum using an Iterative Algorithm', in: High-Resolution Imaging by Interferometry II, 14-18 Oct. 1991, eds. Beckers J.M., Merkle F., European Southern Observatory, Garching, Germany, p. 193

Lohmann A.W., Weigelt G., Wirnitzer B.: 1983, *Appl. Opt.* **22**, 4028

Reinheimer T., Weigelt G.: 1987, *A&A* **176**, L17

Reinheimer T., Hofmann K.-H., Weigelt G.: 1992, 'Computer Simulations of Interferometric Imaging with the VLT Interferometer', in: High-Resolution Imaging by Interferometry II, 14-18 Oct. 1991, eds. Beckers J.M., Merkle F., European Southern Observatory, Garching, Germany, p.827

Weigelt G.: 1977, *Optics Commun.* **21**, 55

Weigelt G., Wirnitzer B.: 1983, *Optics Lett.* **8**, 389