INTERFEROMETRY FOLLOWING ADAPTIVE OPTICS

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ABSTRACT

Adaptive optics systems on single big telescopes correct many modes, allowing imaging in the infra red. At the same time, visible photons can be used as well, especially when infra red light is also employed for wave front sensing. It is argued that pupil-plane interferometry is the most useful application for high-resolution imaging. This is because the isoplanatic patch area and the integration time are larger after correction, and they afford enhanced signal collection in the aperture plane. In contrast, speckle imaging methods only gain indirectly from this enhancement.

The improvement of the wave front

Assume that all aberrations, up to the highest correctible by the adaptive optics system, are almost nulled. The fractal spectrum of aberrations is well described by the Kolmogorov-von Karman statistics. The small deviation near the adaptive optics cut off is due to aliasing effects and to non-circular optics, such as in the primary mirror or the deformable mirror.

Residual errors

The region in which atmospheric aberrations are still not corrected is between r0 and r0, the scales of Fried’s parameter and the element size of the deformable mirror or wave front sensor. For different telescopes this range can be between 5-40 cm and 30-100 cm (in the visible) according to the quality of the site, which also sets the decision of the scale of r0.

Fried’s coherence length, over which the standard deviation of the wave front does not exceed 1/2 π r0 nm, will grow because of the partial correction of the wave front. Call it the compensated Fried’s parameter, ρ0, where ρ0 > r0, with a similar effect in integration times. The Greenwood frequency ωG, after the wave front, is

\[ \omega_G = 2 \pi r_0 / D \]

where D is the aperture diameter.

The isoplanatic volume is the product of the patch area and integration time, and grows as

\[ \rho_0 / \rho_0 + \cos \theta \]

and ρ0 sets the maximum detector pixel size and, with ∆t, the maximum integration time.

For j (j > 10) corrected Zernike modes, the modified coherence length is

\[ \rho_0 = 1.25 j^{1/10} \rho_0 \]


As a result, the photon flux inside an isoplanatic volume (patch area and duration) grows, as compared to the uncorrected case, by 1.95 j^{1/10}.

Speckle imaging and interferometry

If indeed the effective isoplanatic patch size grows, speckle imaging and interferometry become easier (spectroscopy and similar methods are similar in behaviour). It now depends whether the camera is integrating or taking fast frames. In the latter case:

- In speckle imaging, the number and size of pixels depend mainly on the telescope resolution, and are not changed much. But processing in the Fourier domain can be performed over coarser pixels.
- In pupil plane interferometry, the pixel size and integration time can be extended with ρ0.

Phase closure

It is possible to obtain directly and continuously phase closure or phase integration in pupil plane interferometry, as shown for the interferogram and for the corresponding aperture points. At left is phase closure at 21,3, and at right nearly at 17. (E. Ribak, Appl. Opt. 26, 194-8, 1987; Proc. ESO 29, 271-80, 1989). The latter allows Knox-Thompson integration in the pupil (A. Cheill and J. M. Mariotti, A&A 157, 372-82, 1986).

Comparison

What can be gained by using different methods after partial correction: