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IMAGING INTERFEROMETRY WITH NON-REDUNDANT ARRAYS

J. B. Zirker
National Solar Observatory
National Optical Astronomy Observatories[1]

The performance of a set of non-redundant arrays, that convert an existing telescope to an interferometer, has been simulated.

Each array is a perforated mask, placed at an image of the objective. Each pair of holes in a mask transmits a unique spatial frequency that is present in the target; hence the term "non-redundant." Each mask produces a fringe I(f) in the focal plane that is the product of the Fourier transforms of the object and the optical transfer function S(f):

$$I(f) = O(f) \cdot S(f)$$

Seeing disturbs the phase and amplitude of the fringe I(f), but since each spatial frequency (f) corresponds to a unique pair of holes, and since each hole pairs with all the others, it is possible to solve algebraically for the atmospheric phase shift at each hole and thus eliminate seeing. With sufficient S/N the phase and amplitude of the object, O(f), can be recovered at each resolvable spatial frequency in the continuous spatial spectrum, out to the diffraction limit. Inverse Fourier transformation then yields an image of the objective.

We require two masks if the wavefront is parallel to each hole, or three masks if, as is more likely, the wavefront is tilted differently at each hole. In the simulation, I use three one-dimensional masks with spacings (0,1,4,6), (0,2,3,7), and (0,1,3,7), in units of a basic spacing, p. Each mask is non-redundant, but the masks have many spacings in common. In practice the hole diameters should not exceed the Fried parameter, r_0, during a short (~ 8ms), narrow-band (~ 50 Å) exposure. I used 6-cm holes, which correspond to 1.5" seeing. As a target, I chose the limb of the Sun. A field stop, 2.4 arcseconds in diameter, limits the field-of-view.

Figure 1 shows the fringe mask 1 would produce (a) with no atmosphere and (b) with randomly-tilted wavefronts. I added random noise in varying amounts to the fringe and followed Rhodes'[2] procedure (1972) to solve for the target's amplitudes and phases.

Figure 2 shows (a) the original target's intensity profile, (b) the reconstructed image, with fringe noise of 3%, and (c) the image that the telescope would form without the masks. The maximum hole spacing (e.g., spatial resolution) in this simulation corresponds to .25 arcseconds.

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[1]Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation
[2]W. T. Rhodes, Dissertation, Stanford University, 1972.

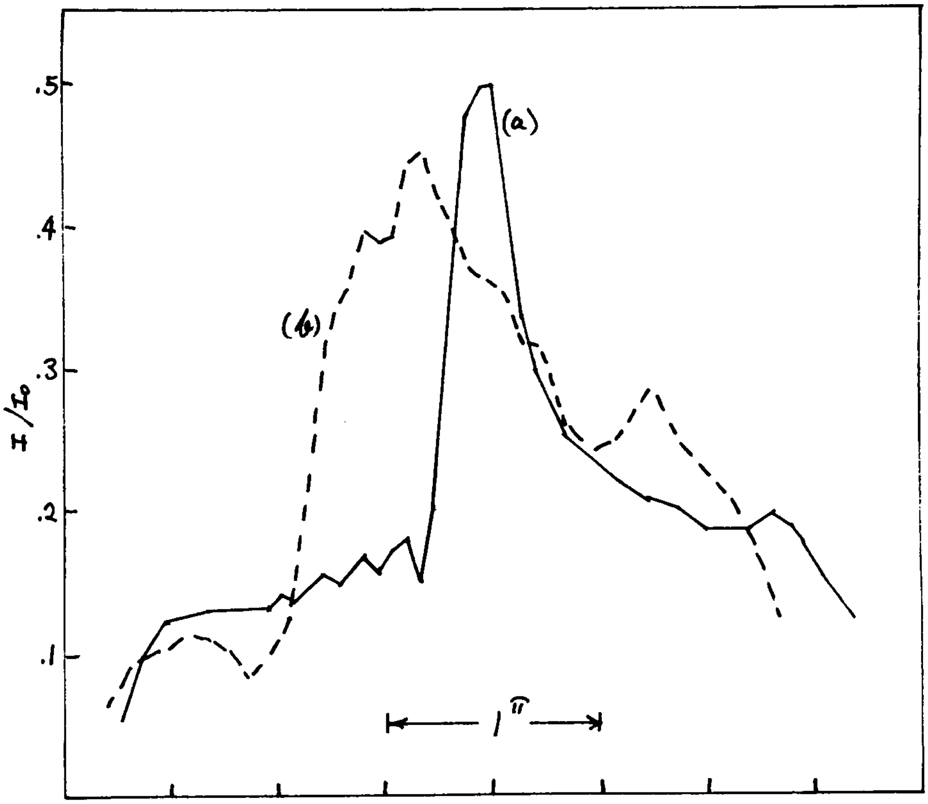

Figure 1

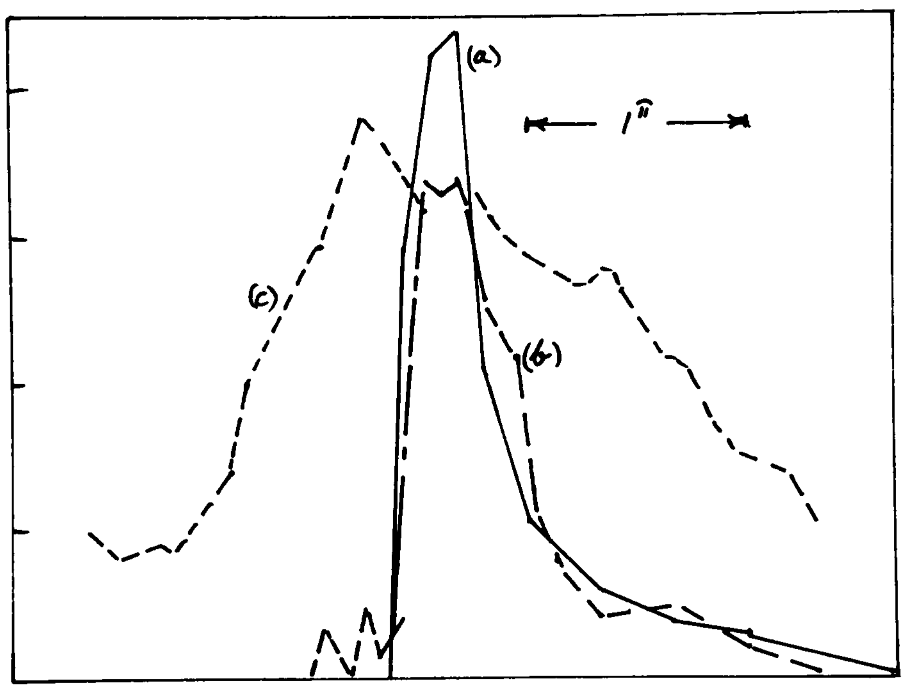

Figure 2

Thus the simulation suggests that diffraction-limited images, at least of high-contrast objects, can be reconstructed from moderately noisy observations in the presence of mediocre (1.5 arcsecond) seeing.