HIGH ANGULAR RESOLUTION WITH ROTATION SHEARING INTERFEROMETERS: PRELIMINARY RESULTS AND FUTURE POTENTIALS.

F. Roddier* and C. Roddier*
Université de Nice - Département d'Astrophysique de l'I.M.S.P.
E.R.A. 669 du C.N.R.S. - Parc Valrose F-06034 NICE CEDEX
(*) Visiting Astronomer, Canada-France-Hawaii Telescope

Compared to speckle-interferometry, amplitude-interferometry has the following advantages:
(1) The amplitude of the object Fourier components is insensitive to both turbulence and telescope induced aberrations, permitting an accurate calibration of visibility curves,
(2) Interferograms are free from speckle noise, permitting a better signal-to-noise ratio on bright sources,
(3) Information can be retrieved from fewer exposures (including complete image reconstruction),
(4) Accurate visual measurements of stellar diameters and of the angular spacing of binary stars can be easily performed.

In the classical two-aperture Michelson scheme, the image Fourier components are measured sequentially. In order to take full advantage of amplitude interferometry, they have to be measured simultaneously (as in speckle-interferometry). This can be achieved by means of shearing interferometers. Among all possible techniques, rotation-shearing interferometry seems the most promising (Roddier, 1979; Roddier and Roddier, 1979). Fringes are observed on the telescope pupil plane, inside the common part of two pupil images, one being rotated at a given angle β with respect to the other. Thus a fairly good coverage of the two dimensional spatial frequency plane is obtained up to a cut-off frequency, which is a function of the chosen rotation angle β. The maximum angular resolution is obtained for a 180° rotation, allowing interferences over a base-line equal to the telescope diameter. Optimum balance between resolution and signal-to-noise ratio is achieved by properly choosing the rotation angle.

This technique is often called incoherent holography or twin-image holography since the fringe pattern recorded on a photographic plate behaves like a hologram. A reconstructed image is indeed observed in the diffraction pattern of the plate, when inserted into a coherent laser beam. In order to record fringes through turbulence, the exposure time must be short enough to freeze wavefront aberrations (as in speckle-interferometry). The recorded fringes are distorted, without any loss

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of visibility. The visibility function can therefore be estimated from a single hologram. Practically it is obtained by properly averaging the fringe visibility over a few holograms, allowing for stellar scintillation effects. The phase can also be recovered by averaging the position of each fringe over a larger number of holograms, thus permitting complete image reconstruction.

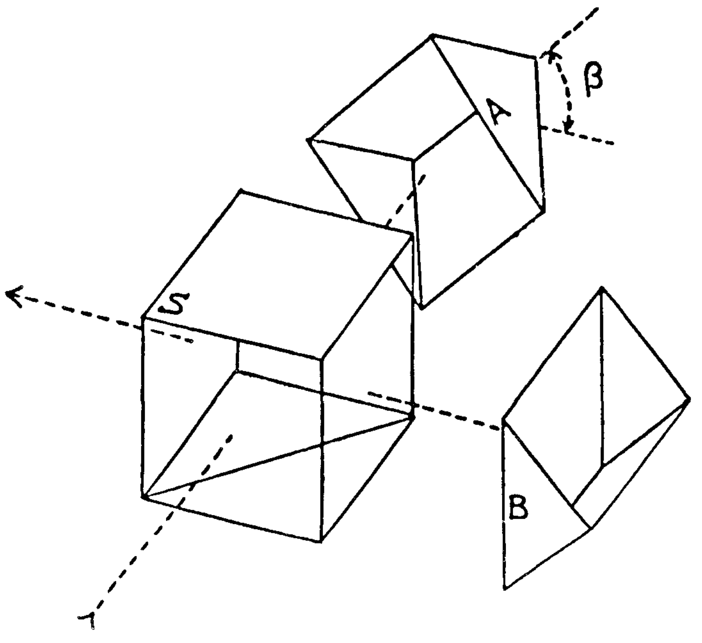

Figure 1. Perspective view of a rotation shearing interferometer - A : Rotatable roof-prism ; B : Fixed roof-prism : S : Beam splitter.

A rotation-shearing interferometer has been specially devised and successfully implemented for astronomical applications (Fig. 1). It is made of a beam-splitting cube and two phase-compensated roof-prisms giving high contrast, high luminosity fringes at any rotation angle (Roddier et al., 1978). A chromatic lens system gives a pupil image with a magnification proportional to the inverse of the wavelength thus permitting the use of large optical bandwidths (Roddier et al., 1980); the bandwidth is limited by turbulence to a few hundred Angstroms as in speckle-interferometry.

Our interferometer has been operating at the coudé focus of the C.F.H. telescope in Hawaii during six nights in November 1980. Table 1 gives visual estimates of the diameter of the star Betelgeuse (α Ori) at 10 wavelengths. The stellar diameter was estimated, by three independent observers, by measuring the rotation angle β at which fringe disappearance occur at the edge of the telescope pupil. Assuming a

λ (Å)	5000	5085	5350	5460	5560	5893	6210	6330	6400	6560
$\Delta\lambda$ (Å)	500	100	90	100	95	100	60	100	500	100
ϕ (milli-arcsec)	59±2	61±9	56±1	52±2	55±2	58±6	69±3	55±3	55±1	54±2

Table 1 : Visual estimations of the diameter of Betelgeuse. The spectral window at 5 350 Å was selected within a uniform continuum whereas the window at 6 210 Å was selected within a TiO absorption band. The indicated uncertainty is an estimation of the reproducibility of individual measurements. The diameters are presumably over estimated by a factor 1.3 (see text).

stellar disk of uniform brightness, the related baseline was taken as the abscissa of the first zero of an Airy function. The wavelength was selected by means of interference filters. The indicated bandwidth is the full width at half maximum of the filter transmission function. Two filters were specially selected for these measurements. One, centered at λ = 5350 Å, provides a spectral window ($\Delta\lambda$ = 90 Å) entirely located in a continuum part of the stellar spectrum. The other one, centered at λ = 6210 Å, provides a spectral window ($\Delta\lambda$ = 60 Å) entirely located inside a TiO absorption band. Viewed through the absorption band, Betelgeuse clearly appears to be larger by a factor 1.18 than viewed through the continuum. The indicated uncertainty is the total dispersion of individual measurements. Surprisingly, it strongly depends upon the wavelength. It has been found to be related with the variation of the stellar absorption coefficient with wavelength, inside the spectral window (Foy). The largest variations occur inside the 100 Å spectral window, centered at λ = 5085 Å, blurring the stellar limb, and thus explaining the large uncertainty on the stellar diameter measured at this wavelength. On the other hand, a sharp stellar limb is expected to be viewed through the continuum as confirmed by the small uncertainty (5%) on the stellar diameter at λ = 5350 Å.

Fringes were recorded on tri-X film through a 4 stage magnetically focussed E.M.I. image intensifier. Fig. 2 is a frame, obtained under good seeing conditions, showing fringes produced by Betelgeuse at λ = 5350 Å ($\Delta\lambda$ = 90 Å). On this frame β = 30°, providing a baseline varying from 30cm, near the secondary mirror, up to 90cm at the edge of the telescope pupil. Similar records were obtained with smaller or larger values of β. The films were photometrically calibrated. They are now analysed with a P.D.S. microdensitometer at the "Centre de Dépouillement des Clichés Astronomiques" (Nice Observatory).

A preliminary plot of the fringe visibility as a function of the baseline, estimated from the analysis of a few frames, reveals a steep decrease of visibility over the first few tens of centimeters, together

Figure 2 - Interferogram of Betelgeuse at $\lambda = 5\ 350\ \mathring{A}$ ($\Delta\lambda = 90\ \mathring{A}$). The rotation angle was 30°.

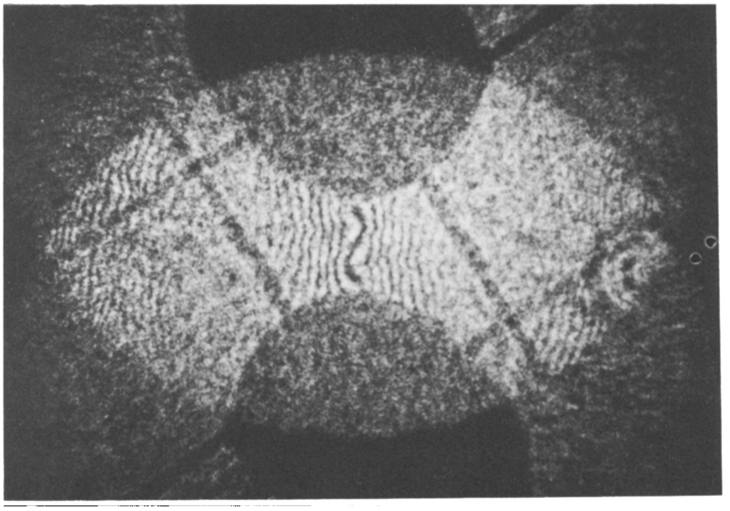

Figure 3 - Interferogram of Capella at $\lambda = 6\ 400\ \mathring{A}$ ($\Delta\lambda = 500\ \mathring{A}$) The rotation angle was 180°.

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with a more gentle fall off. It can be interpreted as produced by a uniform disk of about 40 milliarcsec diameter surrounded by an envelope which may tentatively be attributed to the dust shell surrounding Betelgeuse. This result is in agreement with the recent findings of Ricort et. al., (1981). At least 20% of the light appears to come from the envelope which apparently extends up to several stellar radii. We are presently attempting to reconstruct an image of this envelope from our data. From the visibility curve, we also conclude that the stellar diameters listed in Table 1 are presumably overestimated by a factor of 1.3.

The following stars have also been observed: Capella (α Aur), Aldebaran (α Tau) and Deneb (α Cyg). Fig. 3 shows fringes produced by Capella at $\lambda = 6400$ Å ($\Delta\lambda = 500$ A). In this case, the rotation axis was off-centered slightly from the secondary mirror. The rotation angle was 180° producing two pupil images with a two-fold symmetry with respect to this axis. The deep modulation of the fringe visibility clearly reveals the binary structure of Capella. From fifty such frames recorded on December 1st, 1980 at 8:00 (U.T.), the angular distance of the two components and the position angle were estimated to be respectively $\rho = 53.5 \pm 1.5$ milliarcsec and $\theta = 189.5^{\circ} \pm 2^{\circ}$.

Visual examination of the fringes recorded on Aldebaran reveals a slight decay of the visibility over a 3.6m baseline, showing that the star is barely resolved. A photometric analysis of the data has not yet been attempted. Finally fringes recorded on Deneb show that the star is not resolved, as expected. They will serve as a reference in order to check our data reduction process.

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