



MULTIPLE MIRROR TELESCOPE OBSERVATORY

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MMTO Technical Memorandum 84-1

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Subject: Open Loop Flexure Coefficients for MMT Phasing

- (1) During the December 14-16 DSI observing run we used the optical coherent beamcombiner, which is stepper motor controlled for path-length adjustment (1 step = $0.18 \mu\text{m}$ change in pathlength), and which is now interphased to the TCS computer for open-loop adjustment. Goring and Quast provided the interfacing to the TCS computer and Montgomery and Hege developed the software for open-loop control with elevation change. During this observing run we set out to test this open-loop control of the MMT pathlengths which included the determination of the open-loop phasing coefficients. This memo describes the results, the problems encountered, and future procedures.
- (2) Before giving the measurements, we point out again the close inter-relation between telescope pointing and phasing. Take two telescopes with a separation of D ($D = 5$ meters for telescope pairs A and D, B and E, and C and F). If the MMT mount is offset by 1 arc second in the direction connecting the two telescope centers, and if this offset is compensated by tilting the secondaries of the two telescopes, the pathlength difference between the two telescopes changes by $D/206500$ which for $D = 5$ meters corresponds to $\approx 25 \mu\text{m}$ or ≈ 150 steps. This major change stresses the significance of the complex interaction between telescope phasing and pointing. Before phasing measurements can be made satisfactorily it is necessary to define a clear, precise, repeatable procedure for the pointing of the six MMT telescopes. Using that procedure the open-loop coefficients should be measured and then the same procedure should be followed during the observing run.
- (3) We identify now the following possible procedures:
 - (a) Always point the MMT to the object under study with the guide telescope to a precision of ~ 0.1 arc sec. Adjust the secondaries to put the images at the desired position in the field of view. The problem with this is that the guide telescope can only see stars with $V = 5$ and brighter.
 - (b) Use one of the MMT telescopes as the guide telescope as described above. It's secondary is therefore never adjusted in tilt (and focus) and its image is used to point the telescope. We tried this mode with partial success but gave up after the azimuth/wind direction induced pointing errors were discovered (see Technical Memo 84-2).

- (c) Use the average position of the six star images as the pointing direction of the MMT. The TCS autostack routines as they existed did not allow to do an autostack on the average position. We therefore estimated by eye the location of the average star position, then centered the Z-box on it and auto-stacked on it. This method failed because the error involved in doing this was too large (≈ 1 arc second). Repeating this procedure led to a continuing increase in this error. We hope that at the next DSI run the stacking at CG is available in such a way that the error is < 0.1 arc second and does not increase in repeated stacking.
- (d) Use the mount pointing as is to point the six MMT telescopes. This pointing can be 1 arc sec out so that $25 \mu\text{m}$ phasing errors may occur. This is the procedure used ultimately to determine the open-loop pointing coefficients.
- (4) Using procedure (d) above, we measured the pathlength difference between each of telescopes B,C,D,E, and F with respect to telescope A as a function of elevation while moving up and down in the sky. We measure this in steps of the stepper motor used to adjust the translation of the BK 7 optical wedges. Each step corresponds to a $2 \mu\text{m}$ motion of the 10° wedge or a pathlength change as a function of wavelength equal to:

$\lambda(\text{nm})$	1 step =
405	0.184 μm
436	0.183
480	0.182
486	0.182
546	0.180
587	0.179
644	0.179
656	0.179
707	0.178

The wavelength used was selected by a 650 nm, 30 nm bandwidth interference filter.

Figures 1-5 show the measured pathlength difference between telescope A and the other telescopes ($P_A \equiv$ pathlength of telescope A; if $P_A - P_B$ shown in steps is positive, the pathlength in telescope A is longer thus requiring a thinner combination of wedges in that telescope, which means moving the translatable wedge upward). The observations cover a total period of 2 hours. One notices the following:

- (a) The scatter between the observations is quite large amounting to ~ 270 steps or $48 \mu\text{m}$ Peak to Peak or ~ 90 steps = $16 \mu\text{m}$ RMS. This is about the variation which may be expected from the pointing precision of the MMT (1 arc seconds results in $25 \mu\text{m}$ error for $P_A - P_D$; $22 \mu\text{m}$ for $P_A - P_C$ and $P_A - P_E$, and $13 \mu\text{m}$ for $P_A - P_B$ and $P_A - P_F$) and from the effects of thermal variations of the OSS (typically $\sim 0.3^\circ\text{C}$ resulting in a $26 \mu\text{m}$ pathlength change). In an earlier determination of $P_B - P_E$ (MMTO Technical Memo 83-) the scatter was much less ($\sim 4 \mu\text{m}$ RMS) because of a better pointing algorithm which can only be used for 2 or 3 telescopes.

- (b) From these figures one derives the following linear gradients in the pathlength difference vs elevation:

$P_A - P_B$: + 22 steps/degree in elevation
 $P_A - P_C$: + 7 steps/degree in elevation
 $P_A - P_D$: + 16 steps/degree in elevation
 $P_A - P_E$: + 2 steps/degree in elevation
 $P_A - P_F$: - 2 steps/degree in elevation

Although the open-loop correction algorithm allows for a second order term ($P_A - P = C_0 + C_1 \cdot EL + C_2 \cdot EL^2$) the measurements do not allow a meaningful determination of C_2 .

- (c) The scatter in the data do not allow an accurate assessment of the hysteresis effects. We estimate the following amounts of hysteresis:

$P_A - P_B$ 70 steps or 13 μm
 $P_A - P_C$ <30 steps or <5 μm
 $P_A - P_D$ <30 steps or <5 μm
 $P_A - P_E$ <50 steps or <9 μm
 $P_A - P_F$ <50 steps or <9 μm

- (5) Since we believe that the pointing procedure causes most of the scatter in our observations we plan to use a different procedure during our next observing run. We will try to use both procedures (a) and (c) described in section 2 above.

