



# MULTIPLE MIRROR TELESCOPE OBSERVATORY

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MMTO Internal Technical Memorandum 85-5

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Re: Autoguiding Techniques

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In this memorandum, possible combinations of automatic guiding techniques are reviewed, priorities are assigned for the implementation of the more useful techniques, and a schedule is proposed for offering these features in routine operation.

## I. Techniques

The attached table shows 13 possible autoguiding configurations, some of which are more usable than others. There are four basic techniques:

A. Mount only. This method measures common mode tracking error only and sends the corrections either to the mount or to the secondaries. If the corrections are sent to the mount, they must be sent over the link from the TCS computer to the mount computer. There is sufficient range of motion of the secondaries that they will not reach their stops for an estimated integration time of at least 30 minutes. The main problem with this method is that there are no flexure coefficient corrections; however, short term errors are predominantly common mode.

This method can be used with the field rotating or not rotating, with stacked or unstacked images, with spillover light from stacked or unstacked images, and with any instrument having a reflecting surface at the focal plane. The situation in which this method is most likely to be used is when the images from individual telescopes are so faint that the combined light from all 6 telescopes must be used to produce a bright enough image for autoguiding.

Software exists for this method.

B. Rotating sector. This method uses a mask at the pupil plane so that only nonadjacent images are relayed in sequential groups to the acquisition TV. Corrections for the individual images can then be measured sequentially and sent to the secondaries. Both common mode and differential corrections are determined as before.

Current hardware limits moving from one sector to the next in less than 3 seconds. If one allows 2 seconds for measuring image position, then each image will be updated twice a minute if one image is sectored at a time or four times a minute if two images are sectored at a time. This is too slow to correct for the bulk of common mode tracking error. Increasing this speed will require rebuilding the pupil wheel drive.

This method may be used for stacked and unstacked images, for spilled light or guide stars, and for rotating and non-rotating top box, though the

logical situation in which to use it is when the field is too dense for prism wheel autoguiding or when the object is very faint. Since the sky from only the telescopes selected by the sector pass through to the acquisition TV, this method provides slightly better contrast for individual images than when all 6 "skies" are combined.

A software loop to operate this method does not exist, though it can be quickly put together from subsets of existing loops.

C. Stacker. The images are spread out in a line for this method so that corrections can be measured for each image simultaneously without having to sector or use the prisms. The images must be far enough apart that a centroiding box may be placed over each image without receiving light from a neighboring image. Both common mode and differential errors are sent to the secondaries, though the common mode errors could in theory be sent to the mount.

This technique may be used with a guide star or with spillover light with a rotating or nonrotating top box. It may not be possible to use this method with the echelle because its stacker apertures are so close together.

Software exists for this method. The top box is not rotated when the stacker is used, so no rotation is required for this method as long as the stack is on axis. The TCS software holds the image positions constant on the acquisition TV so that field rotation is taken out with commands to the secondaries. Procedures for using guide star images have not yet been worked out.

D. Pupil prisms. Prisms may be inserted at the pupil plane to divert images from the location where they would normally fall on the acquisition TV. Where the images are stacked, the images at the acquisition TV will appear spread so that individual image corrections can be measured simultaneously. Common mode and residual corrections are both determined. The prisms cause all stacked images in the field to be spread so that images from the guide star may overlap a neighboring star, in which case this method cannot be used.

There isn't any point in using this mode in good seeing with the stacker when the images are already spread out sufficiently to be measured individually. But, when the seeing gets bad enough ( $> 3$  arcseconds), the prism wheel can help ensure that images do not overlap.

The prism wheel may be used with no extra complication as long as the top box is not rotating. When the top box is rotating, the pupil wheel is rotating so that each deflected image from a prism will describe a circle around a center defined by the point where the image would fall on the acquisition camera if the prism were removed. If the images are coaligned at the MMT focal plane, the deflected images will rotate about a common center. If the images are not coaligned, each will describe a circle with a different center.

Software exists for using the pupil prisms for autoguiding. When the top box derotates the field, the software forces a rotation of the deflected images in lock-step with the instrument rotator. At the moment, this rotation is done with software rather than by physically rotating the acquisition TV, although the hardware exists to rotate the TV under computer control. In fact, rotation of the acquisition TV can only be used when the center of the image rotation is coaxial with the MMT optical axis.

## II. Priority

Six techniques in table 1 are judged important enough to have an assigned priority. Prism wheel autoguiding is the general case so it has the highest priority. In fact, all other techniques are exceptions to prism wheel autoguiding: "mount only" may be used for very faint objects, and "rotating sector" may be used for faint objects or dense field problems when neighboring images overlap. "Stacker" guiding (using spillover light and no prism wheel) has been developed as a simplification, but it offers no real advantage over the same procedure used with the prism wheel, and it has the disadvantage of being usable only with the MMT spectrograph with seeing better than about 3 arcseconds.

## III. Status of Autoguiding

Spillover light or "stacker" autoguiding is scheduled for implementation as a routine procedure for the MMT spectrograph on January 2. Stacker autoguiding can be quickly expanded for use with the echelle stacker and with single aperture spillover light autoguiding with the the MMT spectrograph since no top box rotation and, consequently, no prism wheel rotation is required.

Known problems remaining are:

1. Common mode tracking errors of 0.5 arcseconds amplitude and 5 to 10 seconds duration. The coefficients of the terms in the tracking algorithm are the first place to look.
2. Drift in the Grinnell. A new sync interface board for the Grinnell has been requisitioned and is supposed to correct the problem.
3. Bandwidth. Some tests showed that the time constant of the system even with the I-CCD is a substantial part of a second. This needs to be tested and, if necessary, remedied.

Testing of autoguiding with rotating prisms or sectors in the pupil plane and with offset guide stars requires that the top box have computer control.

The following tasks must be completed for this control:

1. Guide stars. Software for the selection and use of a guide image using the AWP's must be written and tested.
2. Software. Software must be tested on the spare computer configuration before implementing the routines on the TCS computer. Top box I/O hardware and software will be moved at the same time from the spare computer to the TCS computer.

This work could go very quickly but unforeseen problems requiring extensive sky testing could result in several months more of development work. Eventually, the correction rate should be tested at 10 Hz to determine the practicality of image shrinking.

AUTOGUIDING TECHNIQUES

December 1985

Technique	Light Source		Node		Instrument			Derotation Permitted?	Priority	Notes
	Spilled Light	Guide Star	Single	Stacker	MNT-SG	ECH-SG	Imager			
"Mount Only"	1	X		X		Y	N	n.a.	Y	— SG: if tracking error > 0.5".
	2		X	X		Y	N	Y	Y	4 SG: invisible objs, faint guide *.
	3	X			X	Y	Y	n.a.	N	XXL Use scheme 5 instead.
	4		X		X	Y	Y	n.a.	N	XXL Rarely possible.
Stacker	5	X			X	Y	?	n.a.	N	2 Guide individual secondaries.
Rotating Sector	6	X		X		Y	N	n.a.	Y	— SG: for faint, visible objects.
	7		X	X		Y	N	Y	Y	5 Crowded field autoguiding.
	8	X			X	Y	Y	n.a.	N	— SG only. For faint objects.
	9		X		X	Y	Y	n.a.	N	XXL Rarely possible.
Pupil Prisms	10	X		X		Y	N	n.a.	Y	3 For bright objects, holes close together.
	11		X	X		Y	N	Y	Y	1 CCD, IR, Speckle, prove concept.
	12	X			X	Y	Y	n.a.	N	6 ECH: always; SG: bad seeing.
	13		X		X	Y	Y	n.a.	N	XXL Rarely possible.