



MULTIPLE MIRROR TELESCOPE OBSERVATORY

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MMTO Technical Memorandum 86-1

Re: Offset Autoguiding with the SAO-CCD

From: C. Janes and J. Montgomery

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Offset autoguiding was first used successfully at the MMT for recording automatically coaligned images of faint optical objects by Drs. Rudy Schild and Peter Eisenhardt on June 9th and 10th, 1986. This is a report on that observing run from an engineering viewpoint. The reader not familiar with the top box and autoguiding procedure should review MMTO Publications 86-9, 86-10, and MMTO Internal Technical Memorandum 85-5.

The Setup

The instrument used for the experiment was the SAO-CCD, more commonly used at the Whipple 24" telescope. The camera consists of a dewar-mounted RCA CCD (512 x 320) with a focal plane aperture of approximately 2 x 3 1/2 arc-minutes. The reflectivity of a beam splitter at the focal plane is 4% across the aperture. The remainder of the focal plane is aluminized for roughly 90% reflectivity. SAO software was used on the MMT instrument computer to collect and display the images via the instrument Grinnell. The data were recorded on magnetic tape and will be analyzed in detail in Cambridge. Resolution of the SAO-CCD is 0.3 arcseconds per pixel.

The MMT top box and the Telescope Coalignment System (TCS) were used for the autoguiding control. The MMT intensified CCD (I-CCD) had failed prior to this run, so it was necessary to borrow the I-CCD from the 24" and install it in the top box. Otherwise the top box configuration was as described in previous memoranda.

The Whipple I-CCD

The Whipple I-CCD fits readily in the MMT top box. D. Blanco had made an adapter flange to match the bolt hole patterns. The electronics package and power supply were fastened to a door off the old top box and installed on the new top box. The intensifier for the Whipple CCD is controlled with a remote paddle which connects to the camera via a standard coaxial cable. The levels of the composite video from the Whipple CCD were sufficiently different from the MMT CCD that the CVI sync stripper required to feed timing to the TCS Grinnell had to be replaced with a different model.

The camera rotator motor had insufficient torque to turn the camera, possibly because of the short stiff cables connected to the camera. The axes were aligned by hand instead.

The sensitivity of the Whipple CCD seemed to be less than that of the MMT intensified vidicon. The process of making the SAO-CCD and the top box confocal called for placing a piece of newsprint at the focal plane. The newsprint was resolvable with the vidicon but not by the Whipple CCD. As a result, it was necessary to focus the vidicon to the newsprint, then focus the star images to the vidicon using the secondary focus control, and finally focus the Whipple CCD to the star images using the focusing sleeve on the CCD. A crosscut of a stacked image taken with the SAO-CCD showed the focus was good; i.e., the image width was about 1 arcsecond with a smooth Gaussian distribution of intensity showing no sign of multiple images.

The fixed pattern noise on the Whipple CCD was very pronounced. A crosscut of an SAO star (approximately 9 magnitude) showed peak-to-valley excursions as a result of the clocking artifact equal in magnitude to one-half the intensity amplitude of the star image. And this was with the 5 mHz filter in place commonly used with the old I-CCD. This fixed pattern noise may have slightly compromised the centroiding algorithm for stacking and autoguiding, reduced sensitivity for star acquisition, and may have caused the elongation of images reported by the observer in the RA (horizontal) axis. The vidicon was used for stacking, but the CCD must be used for autostacking measurements because of the placement of the pupil wheels and AWP's.

Also noticed was a persistence of several seconds, probably the result of the phosphor selection for the image intensifier used with the I-CCD. Persistence can compromise the centroiding calculation during point stacking if sufficient settling time is not provided before the measurement.

Bright pixels came and went, occasionally interfering with the centroiding calculation. The ability to reduce the size of the centroiding boxes helped overcome this problem and one problem with crowded fields.

Pupil Alignment

The pupil alignment was checked with the I-CCD, the 28 mm lens, and the Fresnel lens at the pupil (See MMTO Tech Memo 85-6). The pupils were off by a distance nearly equal to a pupil diameter. The SAO-CCD instrument housing was shimmed nearly 1/4" on one side to align the pupils with the wedge prisms. A nodding operation of the images confirmed that the motion of a single secondary could only be observed on a single image at the I-CCD. Dr. Rudy Schild made a note of the pupil alignment problem and plans to modify the instrument to permit minor adjustments to the focal plane.

Autoguiding Procedure

The 4% reflectivity of the beam splitter limits use of this portion of the focal plane to stars several magnitudes brighter than the usual 17 magnitude limit for autostacking and autoguiding operations. Most fields of interest for observing did not include a star this bright, so it was necessary to develop an observing method that placed a guide star on the reflective portion of the focal plane while still keeping the object within 30 arcseconds of the field center. This was done by entering fictitious coordinates for the object which offset the object but forced the guide star to the reflective region. The instrument rotator was positioned so that RA was along the long axis of the chip.

The autoguiding procedure initially developed was to steer the guide star to the center of the I-CCD using the achromatic wedge prisms (AWP's). (The 200 mm re-imaging lens was used to achieve the 6 pixel/arcsecond resolution required for autoguiding, but this lens limits the field of view to 90 arc-

seconds.) Then, a point stack was performed, the wedge prisms moved into the pupil plane to diverge the images, the centroiding boxes positioned over the images, and autoguiding begun. It immediately became obvious that the focus was not uniform across the telescope field. Objects close to the guide star were properly assembled, but it was possible to see portions of the 6 individual images on objects as close as 2 arcminutes away.

The procedure was changed so that point stacking was performed on a nearby SAO star (called the "stack" star) on the optical axis using the I-CCD, then the mount was offset to the field of interest, the AWP's rotated and wedge prisms inserted, and autoguiding begun. A second problem emerged: it took so long to move the AWP's into position that the stack was beginning to fall apart by the time autoguiding was started.

The procedure that was finally adopted was to acquire the "stack" star and do a point stack, then go to the fictitious object coordinates. The guide star was then centered on the I-CCD with the AWP's. The guide star was positioned on the 90% reflective beam splitter region by moving the mount and fictitious object coordinates updated accordingly. Without moving the AWP's, the telescope was offset to the "stack" star and a fresh point stack done with the I-vidicon, then the telescope offset back to the guide star, the I-CCD selected, the guide cursor positioned over the star, the prism wheel inserted, and autoguiding begun.

An important hazard of the observing procedure is that it is easy to lose track of which camera is being displayed; only one camera video is displayed at a time. One could easily turn up the intensity of the camera not being displayed and burn out the intensifier if that camera happened to be looking at a bright object. An interlock that automatically closes the shutter of the unused camera needs to be added.

Setting up on a new object takes nearly 15 minutes with the observing procedure even though the observer had defined coordinates for object offsets, guide stars, and "stack" stars prior to the run. For continued use of the autoguiding procedure, this time needs to be cut to 5 minutes at the most. Speeding up the AWP's would make a major improvement; fast AWP action would eliminate the need to switch cameras as well as reduce the time to steer the guide star. A means of transmitting coordinates from the mount to the TCS so that they only have to be typed in once will also save some time. Filter changes on the instrument must be done manually now; the ability to select filters remotely would save a little time. Speeding the derotator up to the speed of the building would help. Improving the quality of the acquisition video would also help. Documentation of the procedure and practice will make a difference.

Dr. Peter Eisenhardt suggests that the observer select the following three coordinates prior to observing:

1. Stack star: a nearby star 14 magnitude or brighter.
2. Guide star: a star 17 magnitude or brighter (a function of sky conditions and acquisition camera sensitivity) which is less than 2 arcminutes away in declination and less than 1 arcminute away in RA, assuming RA is on the long axis of the chip. (The RA and declination position requirements can be swapped by rotating the instrument 90°.)
3. Fictitious object: coordinates with the correct RA but a declination 70 arcseconds from the true coordinates of the guide star. (Again, RA and declination can be swapped.)

If it is necessary to stop autoguiding, restack, and start again on the same field, the time required is only a little over 1 minute. This procedure

is necessary, for example, if the I-CCD gain must be turned down between exposures.

Evaluation of System

Dr. Peter Eisenhardt reports:

I was very pleased with the success of the run. We obtained good to excellent quality images in blue, red and narrow band filters of four galaxies with redshifts from 0.75 to 1.13. These objects have previously measured V magnitudes in a 7 arcsecond aperture of typically 21.5 and were readily visible in 20 minute exposures. The narrow band filters were centered on the redshifted [OII] 3727 feature, and the galaxies were detected in three of the four cases. The non-detection may be due to uncertainty in that object's redshift. The highest redshift object, 3C368, showed very peculiar structure, somewhat like an "integral sign" Sc, and had spectacular 3727 emission. The stellar image sizes near the field center ranged from 0.9 arcseconds FWHM to 2 arcseconds, most of which variation is due to seeing.

This procedure worked well most of the time, although in a few frames the integrated images showed poor stacking for reasons that are unclear. Also, the horizontal (RA) axis was invariably more extended than the vertical, typically 5 pixels FWHM horizontally versus 4 vertically. I suspect this is caused by the interline regions on the Fairchild CCD.

The observations were judged useful because a crosscut measurement of the intensity distribution of stellar objects near the center of the field showed a Gaussian shape with no lumps caused by images not precisely overlapped and because the FWHM of the images were equal to seeing measurements of freshly stacked stars, even after 20 minutes of integration and up to 30° of field rotation.

The wind velocity into the chamber was up to 12 mph during some of the observing but with little gusting. No wind buffeting disturbances to tracking were observed, even though the light baffling shroud was mounted on the OSS.

Focusing Problems with Interference Filter

An interference filter in the instrument caused the image at the SAO-CCD to be slightly out of focus. An attempt was made to focus to the SAO-CCD using the focus control on the secondaries, then correct the focus to the acquisition TV using the top box Beseler lens. It became apparent that it would take too long for the iterations necessary to focus on the SAO-CCD, so this idea was dropped for the time being.

Derotator

Concern was expressed prior to this run that the motion of the derotator had insufficient resolution for subarcsecond positioning of the focal plane. An error in derotator motion would show up as trails on objects near the field perimeter. This effect was not noticed, but if it existed, it would be

obscured by the focusing problem at the perimeter, seeing greater than 1 arcsecond, optics good only to 0.5 arcseconds, and tracking good only to 0.2 arcseconds rms.

Further Development

1. An I-CCD acquisition camera and a spare must be developed as soon as possible.
2. The setup procedure needs to be speeded up. Documentation, practice, and adding the ability to send coordinates to the TCS from the mount are the most promising areas for improvement. Longer term improvements are speeding up the AWP's, motorizing the instrument filters, and speeding up the derotator.
3. The observer should modify the SAO-CCD instrument to permit adjustment of the focal plane and to correct the focusing problem with the interference filter.
4. The apparent distortion of the telescope field should be studied and corrected, if possible.
5. The effect of error in derotator motion should be understood better and corrected, if necessary.
6. An interlock should be provided to prevent damage to the intensifier on cameras not being displayed.