Testing of the McMath-Pierce 0.8-Meter East Auxiliary Telescope's Acquisition and Slewing Accuracy

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Abstract Following mediocre results with pointing tests of the McMath-Pierce 0.8-meter East Auxiliary Telescope in April 2014, a team of astronomers/engineers met again in May 2014 to test other pointing models and assess the telescope's ability to point with enough accuracy to permit the efficient use of speckle interferometry. Results show that accurate collimation is a pre-requisite for such accuracy. Once attained, the telescope performs extremely well.

Definition of the Problem

Speckle interferometry requires large aperture at very high focal ratios. The 0.8-meter East Auxiliary telescope at the McMath-Pierce Solar Observatory on Kitt Peak in Arizona certainly qualifies as a suitable aperture, given its objective and focal length (f50). The question is, does this telescope have the ability to acquire stars with enough accuracy to make placing the light of a double star on the small chip of an EMCCD camera?

To test this question, a team of six astronomers convened at the McMath-Pierce 0.8-meter telescope in late May 2014 to run engineering tests and one speckle test of the instrument for possible uses as a speckle imaging system. The team is shown in Figure 1.

Past Experiences With the 0.8-Meter

One of the team members (Harshaw) was a member of a team that investigated this telescope in April 2014 (Wiley et al. 2014). During that engineering and observing run, the investigating team (Wiley, Harshaw, Boyce, Branston, Green, Genet, and Rowe) found consistent but minor pointing problems with the telescope, most acquisitions being slightly off center when the telescope was instructed to slew to a particular target.

Since the placement of the target star tended to be consistently off by the same general quadrant and angular distance, the possibility existed that the April 2014 setup was slightly off-center of the telescope's optical axis—that is, slightly off collimation. Therefore, collimation of the observation optical bench with the telescope's optical axis was the first priority for this run of tests.

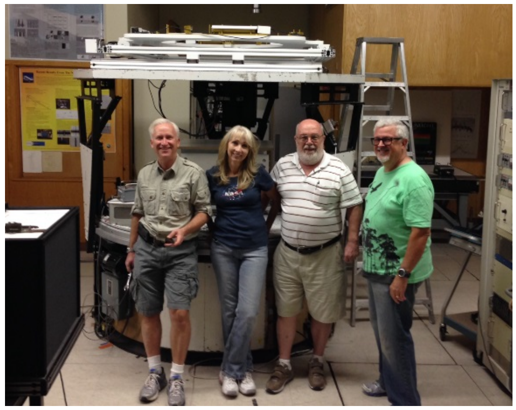

Figure 1. Engineering Test Team (Ray, Prause, Douglass, Harshaw; not pictured: Branston, Genet).

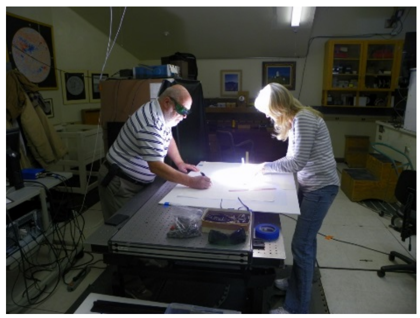

Figure 2. Douglass and Prause put the final touches on the collimation rig.

Constructing the Pointing Accuracy System

The team set about building a test rig for the pointing accuracy tests. This rig consisted of a sheet of foam core with quadrille graph paper (5 squares to the inch) affixed with Mastic. A small crosshair was drawn on the graph paper at the center of the collimated light path from the telescope and a small low-lux camera (a ZWO ASI120MC) was affixed to a magnetic mount on a steel pole near the telescope's ceiling port. This would allow us to view a target star's proximity to the crosshair from the nearby observing control room, letting us keep the observing room (Figure 2) totally dark.

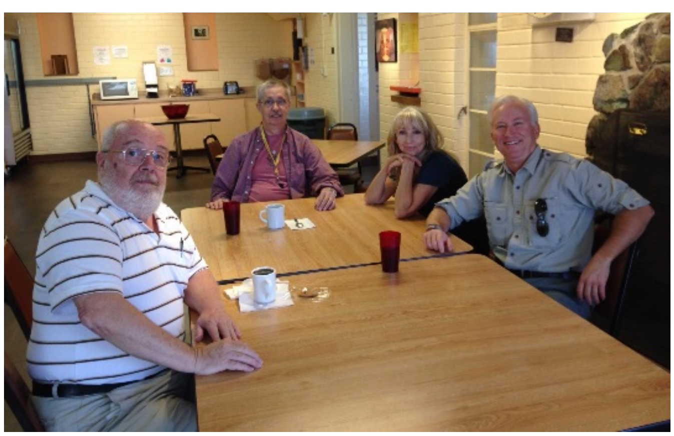

Figure 3. Douglass, Green, Prause, Ray at the Dining Hall.

The Pointing Accuracy Tests

Once the pointing test rig was completed, we waited for dark, having dinner in the Kitt Peak Lodge Dining Hall in the meantime (Figure 3). (Wayne Green, a spectroscopist from our April observing run, joined us as he was doing differential radial velocity measurements of double stars at the Coude Feed housed in the 2.1 meter telescope building.)

We began our pointing tests by aiming the telescope at Arcturus. (The East Auxiliary telescope, while controlled directly by a DFM computer system, is aimed using Software Bisque's TheSky (version 4) as the user interface. This makes issuing pointing commands as easy as finding the target in TheSky and issuing a slew command.)

Once centered on Arcturus, we issued a "Sync" command through TheSky (this command tells the DFM computer that we were precisely on Arcturus, allowing the DFM computer to reset the encoder readings). From Arcturus we then issued commands to slew the telescope 2° north of Arcturus, then return, noting the aiming error by measuring the offset of the star from the crosshair on our rig. We then slewed 2° south and repeated the return to Arcturus. We then did slews 6° north and south, and finally 15° north and south.

We then directed the telescope to Spica to repeat the tests, but as soon as we acquired Spica, we realized that we had a similar problem to what we encountered in April—the stars were always close to the crosshair, but never exactly on it. This suggested that our problem may have more to do with collimation than telescope control.

The results of our aiming tests are summarized in Table 1, where the offsets from the crosshair are measured in grid squares north, south, east, and west of the crosshair. (At the image scale of the East Auxiliary telescope, 0.2 inches—the size of the quadrille squares—is approximately 36.6″ of angular displacement.) Once the primary star (Arcturus or Spica) was acquired, a Sync command was issued to align the DFM computer with the sky, but no syncs were issued during the slews from the north or south.

Star	Direction of Slew	Acquisition Error	True Error
Arcturus	2° from the north	9N, 4W	71" @ 336°
	2° from the south	11N, 3 W	82" @ 345°
	6° from the north	12N, 4 W	91" @ 342°
	6° from the south	14N, 4W	105" @ 344°
	15° from the north	15N, 5W	114" @ 342°
	15° from the south	19N, 5 W	141" @ 345°
Spica			
	2° from the north	2N, 1W	16" @ 333°

Table 1. Preliminary Pointing Test Results for the East Auxiliary Telescope.

As can be seen, without syncing between slews, the system errors seem to accumulate. However, it is of some comfort to see that the errors always lie on the same side of the crosshair, suggesting that a good pointing model can be built that would compensate for the errors.

Collimation of the 0.8 Meter Telescope

A group discussion the next morning led to the possibility that we were not precisely aligned with the East Auxiliary's true optical axis—in other words, we were not precisely collimated. With the assistance of Detrick Branston, chief operator of the McMath-Pierce complex, we were able to set up as accurate a collimation as was possible the next afternoon. Figure 4 shows Prause, Ray, and Branston checking collimation using skylight in a darkened observing room.

The collimation process involved reflecting the light coming down through the ceiling view port of the telescope off a 5-inch diameter optical flat to a vertical sheet of foam core board located approximately 150 cm away. A pinhole was placed in the foam core and the telescope's collimating motors operated until the heliostat was perfectly centered in the tertiary mirror as seen through the pinhole. This setup took a little over an hour to complete. Once collimation was completed, we had to wait until dark to start testing the telescope's acquisition accuracy using stars.

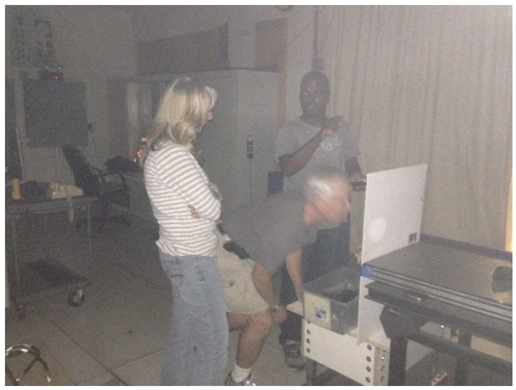

Figure 4. Prause, Ray (kneeling), and Branston during collimation.

Combining Pointing Tests With Speckle

As the afternoon progressed, the weather forecast for the following night—the night we had planned to devote 100% to speckle acquisition—deteriorated, so we had to move our speckle tests up one night. This meant we would have to combine slewing accuracy tests with speckle acquisition in one long run.

That being the case, our afternoon was a hectic one in which our chief optician, Jimmy Ray, worked on building an optical bench that would allow for both fast target acquisition and facilitation of speckle image capture.

After experimenting with a few setups that were not successful, Ray ended up around midnight with a good setup. Figure 5 shows Ray and Prause building our optical bench.

The optical bench we settled on used a 5-inch optical flat to reflect light from the ceiling port of the East Auxiliary to a flip mirror on which was mounted a 20mm eyepiece (giving us an estimated field of view of about 3 arcminutes). With the flip mirror raised, light could then be routed to the science camera's CCD chip, which consisted of the ZWO camera for initial testing.

Due to the less than perfect pointing experienced in earlier tests, we elected to use a procedure where we pointed to a bright star as near as possible to the our target star. The telescope was then aligned with the bright star (after we centered the star on the camera) and synced with TheSky. Then the telescope was moved to the target star (be it a reference star for deconvolution or the actual double we wanted to study).

In all cases, the bright star, as well as the deconvolution star, were acquired using catalog numbers (SAO or HIP). However, when slewing to the final target double, J2000 coordinates were used.

As mentioned previously, pointing is done using Software Bisque's TheSky 4. Using TheSky to point to known names or object ID's generated good pointing results. However, pointing to coordinates proved problematic. General observation of TheSky screens, along with digitized sky survey images of the immediate area of the target and visual confirmation from the eyepiece observer (Ray), provided adjustments necessary to find the targets.

The problem was later identified. TheSky V4 was released by Software Bisque in 1996. Correspondence between Douglass and the Bisque team confirmed that TheSky 4 used B1950 coordinates. The coordinates we were using were J2000. Thus, the problem.

A quick test of acquisition ability using Mars, then Saturn, then Spica, and Arcturus showed that the East Auxiliary consistently put the target in the eyepiece field of view, allowing Ray, the acquisition operator, to center the star for the science camera. A turn of the flip mirror put the star (or planet) on the camera's chip! We had solved our aiming problem, and it turned out to be a combination of collimation and final coordinates.

Beginning about 1:00 AM on Wednesday morning, May 28, we switched out the ZWO camera for the Andor Luca R EMCCD camera and began doing speckle (at least until the seeing deteriorated so badly, around 3:30 am local time, that we had to stop). The results of our speckle run are reported in a separate paper.

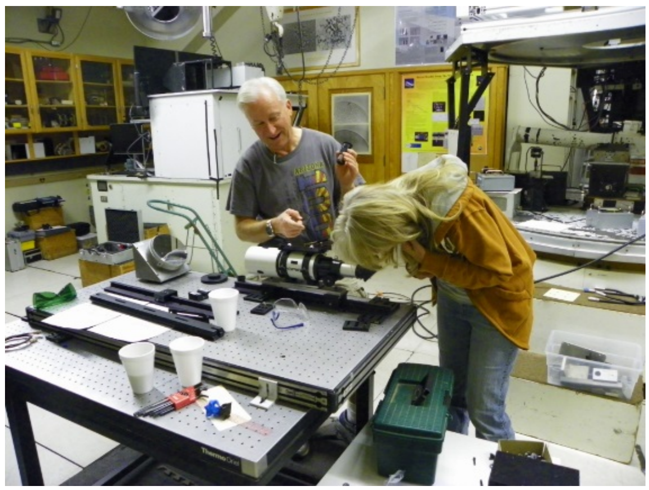

Figure 5. Ray and Prause building the optical bench.

A Solution for the Coordinate Problem

The following day, Douglass did an extensive search for utilities to convert J2000 data to B1950. Although many utilities exist and are available for converting from B1950 to J2000, the opposite was not true. Several educational papers exist on the web for how to do the calculations, but only one working utility was found, and it was available for on-line use. Several sets of coordinates have been tested with this utility, and the conversions all appear to be good.

The author of the utility, Robert Martin Ayers, a former member of the Lowell Observatory Advisory Board, has given his permission for us to co-host his utility, and provided the code for the conversion utility. (See *www.robertmartinayers.org/tools/coordinates.html* for Ayers' original posting, or *www.az-dahut.net/ACCTool.html,* where Ayers has graciously allowed us to set up this backup page.) Thus, we will be able to continue using the existing software at the McMath, along with our existing J2000 coordinate information, and resolve the final accurate pointing issue. With good coordinate information, the final pointing to the target should be very accurate, thus eliminating the final search for the actual target. It is also possible that giving TheSky 4 the HIP or SAO number of the primary of the pair we wish to study will result in better acquisition too. Both approaches will be tested on our next observing run on the McMath-Pierce 0.8 meter East Auxiliary.

Conclusion

When properly collimated, the McMath-Pierce 0.8 meter East Auxiliary Telescope can render adequate pointing performance, a vital requirement for efficient speckle interferometry image acquisition.

Recently, the East Auxiliary DFM interface was made accessible on-line so operators could access the East Auxiliary using the internet from any location in the world. This opens the doors to new possibilities, provided the telescope has been properly collimated and a standardized optical bench set in place by a telescope engineer prior to the observing run (a mode sometimes known as remote control/operator assisted). If a protocol can be worked out for using the East Auxiliary in this manner, a whole new universe of possiblities opens for its use as an instrument for stellar astronomy.

Acknowledgments

The authors wish to thank the National Solar Observatory and Kitt Peak National Observatory for use of the East Auxiliary telescope for these tests.

References

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