Mt. Wilson 100-inch Speckle Interferometry Engineering Checkout

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Abstract The historic 100-inch Hooker telescope at Mt. Wilson Observatory has been brought back to operational status. Its use for speckle interferometry at its new relayed optical focus was evaluated with an Andor Luca emCCD camera. While useable speckle images were obtained, there was some electromagnetic interference from powerful nearby transmitters that shielding and other EMI reduction measures should handle.

Introduction

Speckle interferometry allows close visual double stars to be observed with separations well below the time-averaged seeing limit. While smaller telescopes, equipped with high-speed, low-noise cameras, have worked well for separations down to about 0.5″, it takes larger telescopes to observe short-period binary stars which have smaller separations.

Our group has observed close visual double stars with separations down to 0.1″ during two week-long runs on the 2.1-meter telescope at Kitt Peak National Observatory. Prior to our first run, we brought our instrumentation for an in-person checkout on the telescope. The 2.1-meter telescope, no longer available for general use, is now being used full time by the California Technical Institute for automated adaptive optics observations. Thus we needed to locate another large telescope to continue our observations of double stars too close for our smaller telescopes to handle.

Since our group is primarily located in Southern California, it was only natural that we should consider the newly revived 100-inch (2.5-meter) Hooker telescope at Mt. Wilson Observatory. This historic telescope, used by Edwin Hubble to discover both the size and expansion of the universe, is back in operation with the focal plane relayed to a convenient location below the primary mirror.

The Hooker telescope has been used in the past for speckle interferometry observations of close double stars by Brian Mason and Bill Hartkopf from the US Naval Observatory, along with Hal McAlister from the Center for High Angular Resolution Astronomy. They used a double slit—similar to Young's famous double-slit experiment —placed at the top of the telescope to provide calibration of their pixel (plate) scale. In a visit to Mt. Wilson by Genet, Nils Turner kindly looked around the dome to see if the slits were still available. They were. Made of lightweight aluminum tubing, the two slits are precisely located on the top of the telescope with pins. A piece of dark cloth, also still available, is stretched between the two slits and fastened to the slits with Velcro, while two other pieces of cloth are installed between the slits and the outer edges of the telescope.

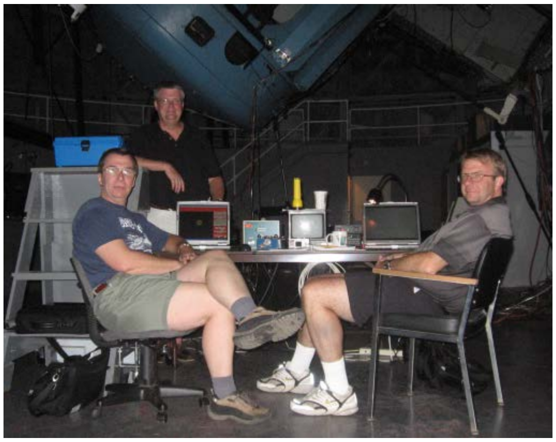

Figure 1. Left: Bill Hartkopf, Hal McAlister, and Brian Mason pose during a close double star observing run on the 100-inch telescope a number of years ago. Right: Nils Turner holds one of the two slits used by Hartkopf et al. for speckle interferometry calibration.

Instrumentation

At earlier observing runs on a 0.5-meter telescope at Dave Rowe's Pinto Valley Observatory, as well as the runs on the 2.1-meter telescope at Kitt Peak National Observatory, our operation of the telescope was from a nearby warm room. The installation at Pinto Valley observatory (Figure 1, left), consisted of a Van Slyke slider which switched the optical path between an SBIG ST-402 wide-field acquisition camera and the optical path through a Barlow lens and motorized filter wheel to the narrow-field Andor Luca S emCCD camera.

The installation on the 2.1-meter telescope at Kitt Peak was somewhat different, as it did not require an acquisition camera since we were able to use the acquisition-guider unit already installed on the telescope with its intensified CCD camera for both target acquisition and centering.

For our Engineering checkout run at Mt. Wilson, our optical system consisted of a 25 mm eyepiece, the Andor Luca EMCCD camera, and a manual flip mirror by which the incoming light could be directed to either the eyepiece or to the camera. We inserted the flip mirror into the eyepiece holder of the optical extension used for visual observing through the 100-inch telescope. For the checkout we did not include a Barlow lens or filter wheel, in order to keep things as simple as possible. The telescope was pointed by the telescope operator, using the standard systems of the 100-inch telescope. The targets were relayed to the operator by their SAO or GSC identities; the telescope operator then used TheSky to determine the current-epoch celestial coordinates, and directed the telescope to the indicated position.

The visual-optics system swing pretty dramatically as the telescope is pointed. When the telescope is aimed at the zenith, the eyepiece holder is about 5 feet above the observing floor; as the telescope is aimed lower in the sky, the eyepiece holder (holding our camera assembly) swings up and out in a large arc.

Our control computer was set up on the observing floor, roughly beneath the camera; and power and USB cables dangled from the camera location down to the computer table. The limited length of the cables meant that whenever the telescope was re-aimed, we also had to move the table.

After the telescope was pointed (based on celestial coordinates of the target), the observer would climb a ladder so that he could look into our eyepiece, and center the target in the field of view. It turned out that the pointing accuracy of the telescope was not good enough to put the target reliably into the field of the eyepiece, so a manual search was done with the observer's slow-motion control to find the target, and bring it to the center of the field. The flip mirror was then flipped, to aim the light into the Andor camera. This was a meticulous but successful method—the target always appeared near the center of the Andor image and could be easily maneuvered using the observer's slow-motion control.

Figure 2. Left: close-up of the speckle camera for the 100-inch checkout with its Andor EMCCD camera, Orion flip mirror, and eyepiece. Light from the telescope entered from the right. Right: the camera installed on the 100-inch telescope at the end of the white optical extension.

For runs on the 100-inch telescope in the future, we plan to improve the effectiveness by:

- replacing the finder-eyepiece with a wide-field-of-view camera (probably a DSLR), to eliminate the need for repetitively climbing the ladder in the dark;
- replacing the manual flip mirror with a motorized (remotely-actuated) mechanism;
- inserting a Barlow lens in the path to the Andor camera, to improve the image scale (at the expense of reduced field-of-view but improved speckle interferometry performance);
- including a remotely-controlled filter wheel in the optical path to the EMCCD camera;
- changing the camera-to-computer link to Ethernet (to be compatible with long cable runs), dressing the cables along the Dec and RA axes, and placing the computer table near the south bearing of the telescope mount, where it can stay regardless of the direction the telescope is aimed.

Observations

Engineering checkout observations with our speckle interferometry camera were made on the evening of December 4, 2015. Mt. Wilson's Director, Tom Meneghini, operated the telescope from the control console on the second level.

Figure 3. The control station in a photo taken by Genet much earlier.

The control console, physically, is little changed from Hubble's days, although precision encoders have been added to the telescope's axes. Given the target's coordinates, the operator uses push buttons to slew the telescope to the approximate target coordinates, and then uses fine-motion controls to move the telescope until the desired coordinates are displayed. The telescope operator, as in Hubble's days, is part of the feedback loop.

Fine motion in Declination is via a tangent arm. For fine Dec motion, the telescope must be unclutched from the Dec worm gear, and then re-clutched to the tangent arm. The very loud clutches help keep everyone awake when they pop.

Figure 4. Left: Dave Rowe centers a double (binary) star using slow motion controls. Right: Russ Genet operates the EMCCD camera from a laptop using Andor's Solis software.

Results

Two double stars and two single stars were observed. A cold front had just passed through, clearing in late afternoon. Thus the seeing was very poor—not at all typical of Mt. Wilson where 0.5″ seeing is not unusual—so we observed somewhat wide (for speckle interferometry on a large telescope) doubles.

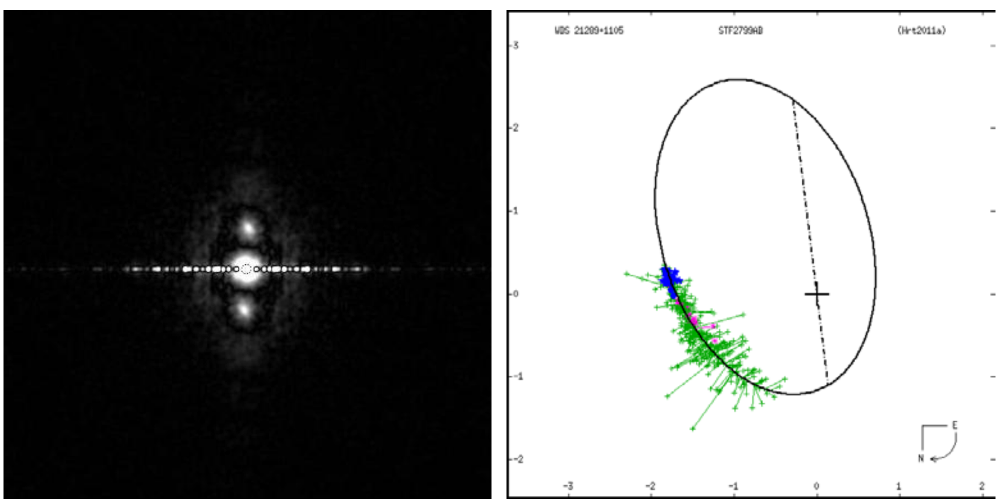

Figure 6. Left: Autocorrelogram of WDS 21289+1105. Right: Orbital plot of past observations.

Shown in Figure 6 (left) is the autocorellogram we obtained from our observation of WDS 21289+1105 (STF 2799 AB) using Dave Rowe's PS3 reduction program. The last reported separation (2014) of this binary pair was 1.93″. We did not determine the current separation (or position angle), as calibration—which can be quite time consuming—was not intended to be part of our short, single-evening engineering checkout. A nearby single star was used for deconvolution.

The horizontal artifact in the image may be due to electromagnetic interference (EMI) from the nearby high-power television transmitters on Mt. Wilson. The interference filter on PS3 was used to reduce these effects, but they could not be eliminated entirely. The dome was pointed toward the south. We expect that the interference would have been worse had the dome been pointed west toward the transmitters, but would have been less had it been pointed toward the east away from the transmitters, although we did not check this assumption. Targets could be observed on the meridian or before they reach the meridian, thus avoiding moving the dome to the west.

Discussion

Prior to the engineering checkout we had formulated eight questions we wanted to answer:

- What would be the physical interface between our camera system and the telescope?
- Would there be sufficient backfocus for our instrument?
- Would we be able to acquire targets with our acquisition camera?
- Would EMI from the nearby high-power TV transmitters cause undue interference with our sensitive EMCCD camera?
- How should we configure our speckle camera for operation on the 100-inch telescope?
- What would be the best way to set up our equipment?
- Would semiautomatic operation of our camera be possible?
- Could a semiautomatic camera system be interfaced with the telescope's control system?

Physical Interface

The 100-inch telescope is equipped with a very solid focuser that accepts 2.75-inch OD male eyepieces or instruments. This can be easily reduced with inserts to 2.0- or 1.25 inches

Backfocus

There are, in essence, no (reasonable) backfocus limits, as the telescope's motorized secondary mirror can move the focus of this f/11.X telescope to any desired position. The manual focuser near the instruments (or eyepiece) can also be used for focus adjustments.

Target Acquisition

We were not able to directly acquire targets with a 25 mm eyepiece. However, searching the nearby field with the fine motion controls, while looking through the eyepiece, we did (perhaps luckily) locate targets fairly expeditiously. The telescope's mathematical mount model is being refined. It is expected that these refinements will result in the displayed RA and Dec coordinates being considerably closer to the telescope's actual position. This may take care of this potential problem. We have not yet compared the field-of-view of the 25-mm eyepiece used in the engineering checkout with the expected field-of-view of our acquisition camera—perhaps a DSLR or large format CCD camera.

Electromagnetic Interference (EMI)

We were very concerned that EMI from the powerful, nearby TV station transmitters would induce irreparable pattern noise. At its heart, speckle interferometry sensitively looks for any patterns, and is thus unusually sensitive to repetitious noise, even if at a very low level. We were relieved that EMI (if that is what the horizontal pattern noise was) was at a tolerably low level. However, we plan on further investigations with respect to noise and remedial actions such as adding shielding, ferrite coils, etc. It might be noted that if we run a much longer cable between the emCCD camera and its control PC (including conversion from USB to Ethernet and back to USB), this could introduce additional problems, although we are currently planning on using a fiber-optic cable.

Eventual Camera Configuration

While we were able to acquire the targets visually with an eyepiece (with some searching), and manually changed the optical path between the eyepiece and the EMCCD camera, the eventual camera system would include an acquisition camera and remote (computer) control of the optical path. Orion Telescopes makes a low-cost two-port instrument selector that could be modified for remote control, Optec makes a four-port instrument selector (Perseus) that precisely moves the optical path between the four ports, and there are other possibilities. If a target is centered on a wide-field acquisition camera, one can be confident that it will still be centered when the optical path is switched to a very narrow-field EMCCD camera (behind the Barlow lens).

Equipment Setup

A table could be set up on the floor under the telescope off to one side just below the telescope control console. The camera operator, run (log) manager, and assistants could set up their PCs on this table. A Cat-6 cable could connect the instruments on the telescope with the PCs on the table with appropriate USB-to-Ethernet conversion on each end. In previous runs, we found that it was necessary to run a separate cable for the camera. Whether, with new equipment, this will still be necessary remains to be determined.

Semiautomatic Operation

Speckle interferometry of close visual double stars is a very intense, fast-paced operation. At both the Pinto Valley and Kitt Peak observatories we were able to slew to, acquire, center, and gather 1000 images of our targets in, on the average, only four minutes. This required close (practiced) coordination between the camera operator, the log master, and the telescope operator. Semi-automation of the speckle camera portion of this process could significantly improve the efficiency of observations with the 100-inch telescope. Automated control of the acquisition and speckle cameras, switching the optical path between the two, fine RA and Dec motions, fine focus, and filter selection may all be possible. Efficiency could also be enhanced by automating the target selection process. Given a large number of targets (certainly the case), it should be possible to park the dome facing due south and catch the targets as they move within the slit without moving the dome. Furthermore, a smart target selection program could also reduce both the RA and Dec motions of the telescope.

Telescope Interface

Semi-automatic speckle camera operation would require an interface between the camera control PC and the telescope's control system. The current telescope control paddle (on a long cable), which contains the RA and Dec slow motion controls as well as fine focus control, is being replaced with a small control panel on the telescope near the "eyepiece position" of the telescope. This will facilitate visual observations. A separate control box will be available for engineering or other purposes on the floor. Discussions with Bill Leflang, a JPL retiree who is upgrading the telescope's control system, suggested that it should not be difficult to add a connector to the floor control box that would accept TTL-level discretes from the speckle control computer to control fine telescope motions and focus.

Conclusions

The revitalized 100-inch Hooker telescope at Mt. Wilson Observatory appears to be well suited for speckle interferometry observations of visual double stars with small separations well below the seeing limit. Seeing at Mt. Wilson is often excellent, improving the quality of speckle observations. The somewhat bright skies at Mt. Wilson are not of concern, given our relatively bright objects and short integration times. Our Kitt Peak observing runs were both bright time runs (near full moon, a lunar eclipse actually occurred in the middle of our second run). Significant time will be available on the 100-

inch telescope, particularly bright time during week nights (the telescope is primarily used for visual observations during dark time on weekends).

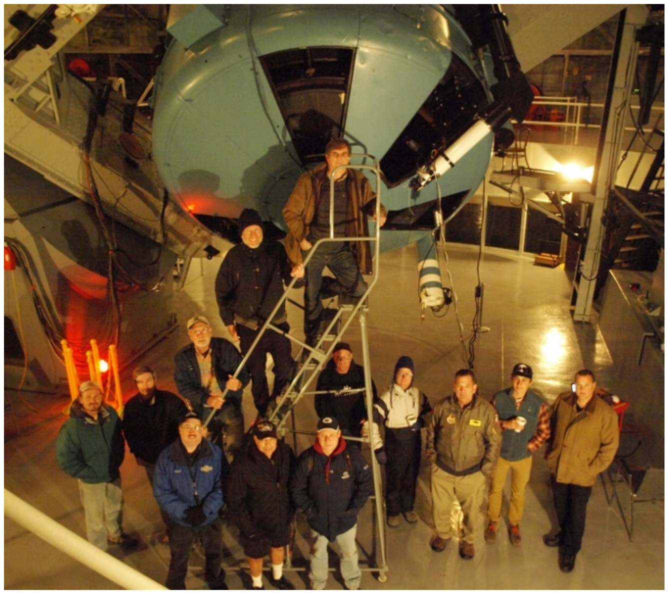

Figure7. Observational team and Mt. Wilson staff poses at the end of the engineering checkout.

The engineering checkout of our speckle camera system on the 100-inch telescope has given us sufficient confidence to move forward. We plan to proceed with development of a speckle camera system capable of semi-automation, devise a multi-objective science observing program with significant student participation, and obtain funding for telescope time and other expenses. We hope to have a full two-night run as early as May 2016.

Acknowledgments

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