Quasi-Speckle Measurements of Close Double Stars With a CCD Camera

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Abstract: CCD measurements of visual double stars have been an active area of amateur observing for several years now. However, most CCD measurements rely on "lucky imaging" (selecting a very small percentage of the best frames of a larger frame set so as to get the best "frozen" atmosphere for the image), a technique that has limitations with regards to how close the stars can be and still be cleanly resolved in the lucky image. In this paper, the author reports how using deconvolution stars in the analysis of close double stars can greatly enhance the quality of the autocorellogram, leading to a more precise solution using speckle reduction software rather than lucky imaging.

1. Introduction

For about a year now I have been measuring double stars with a CCD and a C-11 SCT telescope (Harshaw, 2016A, 2016B, 2016C). As a general rule, the CCD gives good results for wider and brighter pairs, but is not as efficient an instrument on close and fainter pairs.

For instance, the CCD can do speckle interferometry well (Harshaw, 2015; Anton, 2015). But speckle requires short integration times (usually 40 ms or less) and this means the Skyris 618C I have been using is limited to about 7.50 magnitude for the stars to register on the chip at such short integration times.

Speckle also requires both stars to be in the same isoplanatic patch, which means they must be normally 5 arc seconds or closer (perhaps up to 7" on nights of superb seeing).

Fainter pairs, of course, require longer integration times—up to 2 seconds for an 11.00 magnitude star. Such integration times are far too long for speckle interferometry, and, for that matter, lucky imaging.

However, I use David Rowe's "The Speckle Toolbox" for my data reductions and image measurements, even for those pairs too faint or wide for speckle.

The Speckle Toolbox (STB) contains many powerful tools for speckle analysis of a double star, but it can also render excellent solutions for CCD measurements. When making a speckle measurement, I normally capture 1000 frames (which are compiled into a FITS cube) of the target star, and then capture 1,000 frames of a nearby single star that is used to deconvolve the target star image. Deconvolution is a process that computes the Fourier Transform of a single star, which of course includes the telescope's optical behavior, and applies that solution for that single star to the image of a close double star. The result is a cleaner final image that is normally very easy to measure with STB.

As an example, consider the autocorellograms of a speckle pair, BU 560 (a 7.77, 8.24 magnitude pair, 1.702" rho) shown in Figure 1.

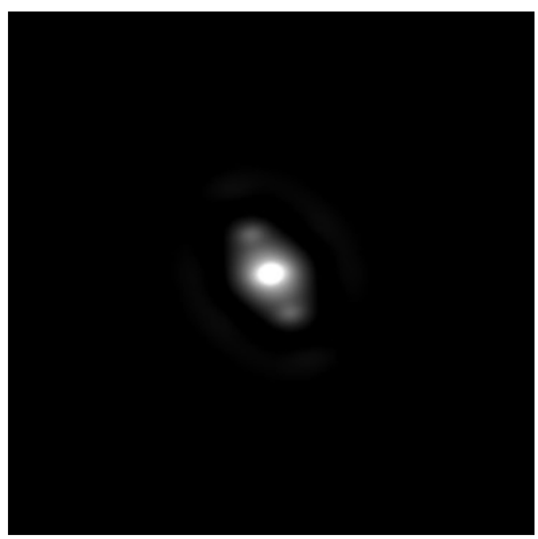

Figure 1: Bu 560 Autocorellogram without Deconvolution

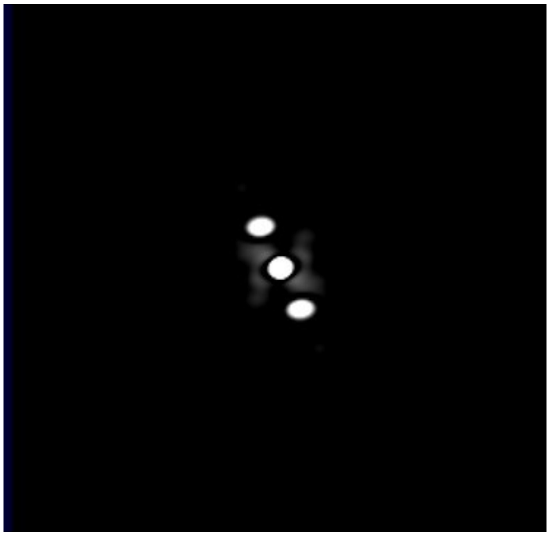

Figure 2: Bu 560 with Deconvolution

Figure 2 shows the same star with the deconvolution star processed in the autocorellogram.

Obviously, deconvolution can vastly improve an autocorellogram, letting one make precise measurements without ambiguity.

And after reading a paper in the 2013 issue of JDSO (Wiley, 2013), I began to wonder if the speckle analysis functions of STB, including using deconvolution stars, could be used to provide a better analysis of a pair than lucky imaging, even for pairs with integration times far longer than are acceptable for speckle.

For comparison purposes, Figure 3 is a lucky image rendered by Reduc, a powerful analytical program by Florent Losse.

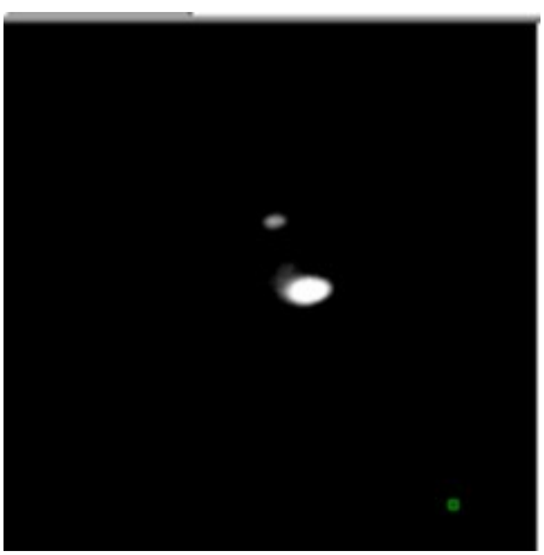

Figure 3: Lucky Image of Bu 560.

2. Equipment Used

The camera I used for these tests is a Skyris 618C color CCD camera sold by Celestron (but built by the German firm The Imaging Source). The Skyris was mounted downstream of a Televue 2.5x PowerMate mated to one arm of a flip mirror, the other arm directing starlight to the acquisition eyepiece. A picture of the setup is shown in Figure 4.

The camera was controlled with FireCapture 2.5 Beta, a very utilitarian program by Torsten Edeleman of WonderPlanets (www.wonderplanets.de). The telescope was controlled by a Lenovo computer running Windows 10 via TheSky 6.0 software. Images were saved to a 2 TB external hard disk drive that could be detached after the observing run and taken indoors for processing and analysis later.

3. Methodology

When doing speckle work, I take 1,000 frames (a "FITS cube") of both the target pair and the deconvolution star (a star that is within 4 degrees of the target pair and nearly the same in magnitude). I usually take several 1,000 frame FITS cubes of each target, but only one set for the deconvolution star.

However, when I am doing CCD imaging (not speckle)— mainly for pairs that are wider than 5 arc seconds in rho or fainter than 7.5 magnitude— I make files of 200 frames each for the target pair and the deconvolution star. Whereas a typical integration time for speckle might be in the neighborhood of 30 ms, integration times for fainter pairs may run as high as 1.75 seconds or even longer.

Losse's Reduc program is then used to select the best 25% of the Signal-to-Noise ratio frames. These frames are then bound into a small FITS cube of 50 frames. These mini-cubes are then pre-processed by

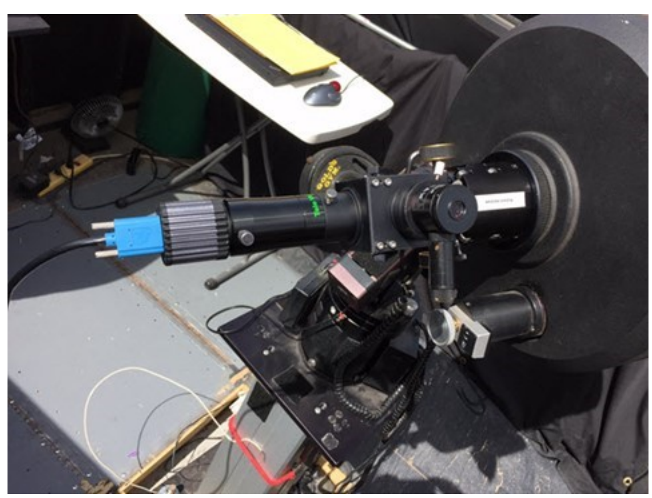

Figure 4: The Skyris 618C attached to the C-11 SCT.

Table 1: The Target Pairs and Their Deconvolution Stars

Pair	Discoverer Code	Deconvolution Star
1	STF 170	SAO 4541
2	STF 182	SAO 12065
3	STF1413	SAO 99004
4	STF1476	SAO 137795

STB and, after pre-processing, analyzed using STB's speckle analysis routine, in which the target pair file is chosen and the deconvolution star is also selected.

Once STB generates the autocorellogram, it is a simple matter to use STB's astrometry function to make the measurements for theta and rho. STB can render values to the nearest thousandth in both degrees and arc seconds, and it does so with a little higher accuracy than measuring a lucky image.

Four pairs were imaged and analyzed as shown in Table 1.

4. Results

In Figures 5 through 8, I present, side by side, the autocorellograms for each of the four pairs of Table 1. In all but one case (STF 182), the deconvolution star improved the autocorellogram, resulting in a better measurement.

Table 2 shows the resulting measuements with and without deconvolution.

5. Discussion

The data sample is too small to draw general conclusions, but it does suggest that significant differences are to be found between deconvolved autocorellograms and those made without deconvolution.

6. Conclusion

This brief experiment shows that deconvolution stars can help generate quality autocorellograms for double stars even when they are not being measured as speckle candidates (due to their faint magnitudes pushing the integration times beyond the 40 ms guideline considered the upper limit for speckle interferometry). In all four cases, STB was not able to lock onto the companion star to obtain a measurement in the autocorellograms made without deconvolution, but could lock onto the companion in every deconvolved autocorellogram (except STF 1413).

It is my plan going forward to obtain deconvolution star images for all close pairs that are too faint for speckle.

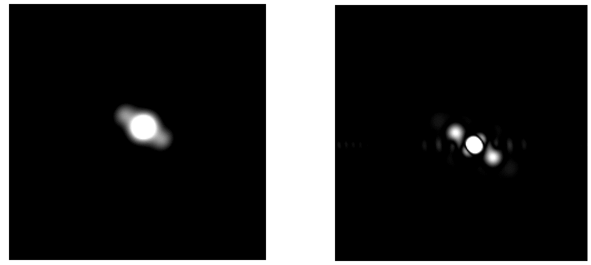

Figure 5. STF 170. Without deconvolution (left image), and with deconvolution.

Figure 6. STF 182, without deconvolution (left) and with deconvolution.

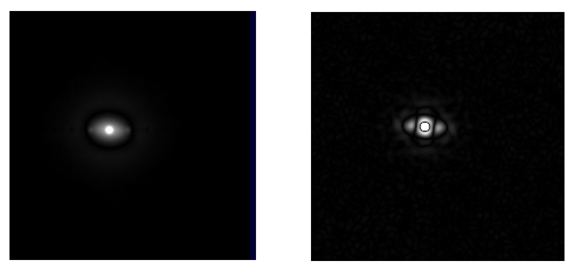

Figure 7. STF 1413, without deconvolution (left) and with deconvolution.

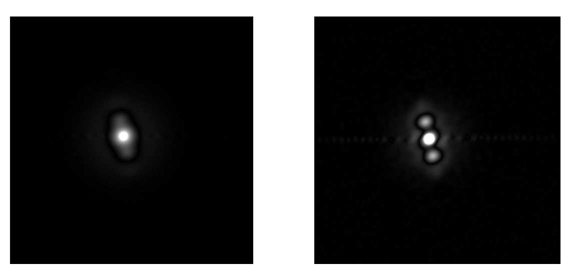

Figure 8. STF 1475, without deconvolution (left) and with deconvolution.

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Table 2: Measured Theta and Rho With and Without Deconvolution

Star	Last Theta	Last Rho	Theta No	Theta Yes	Diff	Rho No	Rho Yes	Diff
STF 170	243	3.1	244.335	244.406	-0.071	3.0126	3.1400	-0.1274
STF 182	124	3.6	126.876	124.113	2.763	2.9440	3.7080	-0.764
STF1413	271	1.8	n/a	270.868	—	n/a	2.0120	—
STF1476	16	2.3	17.167	17.859	-0.692	2.4250	2.3700	0.055

7. Acknowledgements

This research has made use of the Washington Double Star Catalog maintained at the U.S. Naval Observatory.

8. References

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