CHARA AO commissioning run report 2014Jan

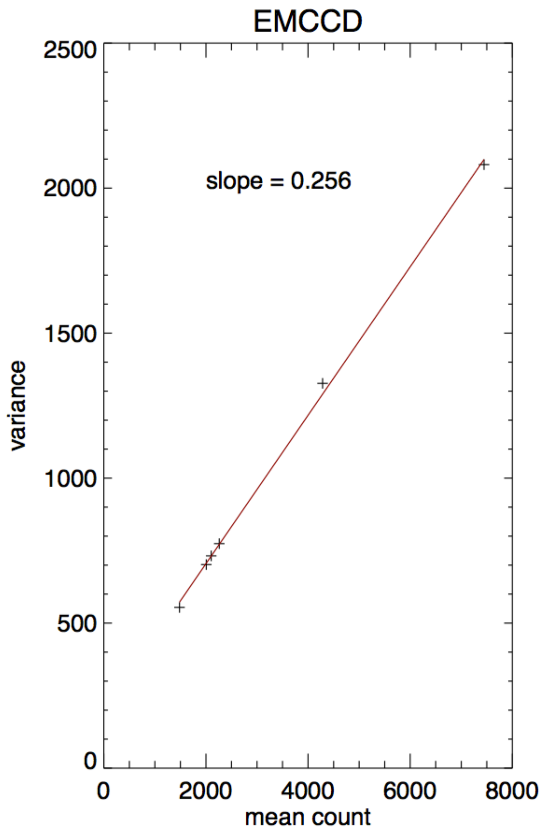
We had the second CHARA AO commissioning run from Jan. 12th – 28th 2014 to improve the control software and take test data with WFS to see the performance of the new system. Here is a report of the status of CHARA AO system.

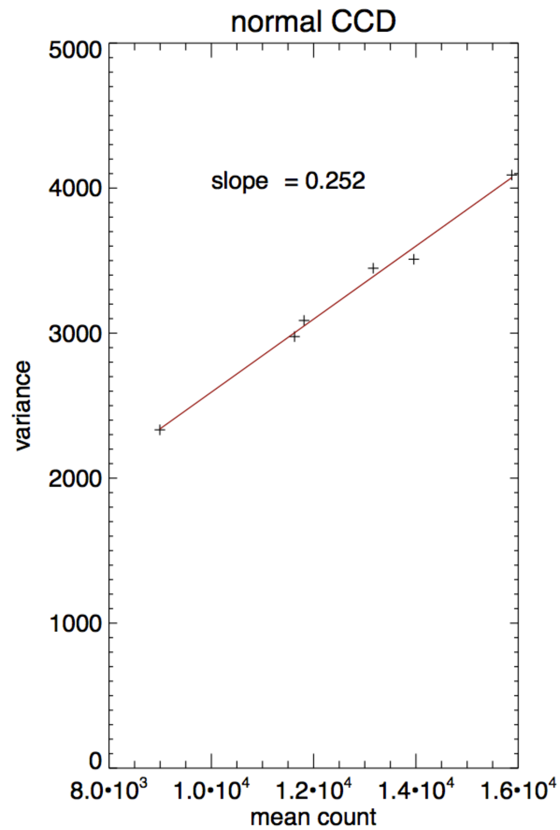
1. Locking a star with the AO system.

Ideally the observation procedure using the new system is to first use beacon to mark the reference centroids, and then build the reconstruction matrix to calculate the Zernike terms or calculate the average centroids offsets for tiptilt correction. However since the beacon is not aligned with the telescope (as shown in the following), we have to take other procedures. Right now I always use a bright star to mark the centroids at the beginning. A bright star can fulfill the hole and overflow to the edge, by balancing the light around the edge, we can mark the reference centroids pretty well. Notice the star is not locked in this step. After the reference centroids are marked, we can use these positions to lock a faint object at any place on sky. This is because the a pattern of reference centroids on WFS corresponds to a relative position of the star to the hole, once we mark the reference centroids with a bright star right in the hole, these centroids can be used for the whole sky.
This method seems to work pretty well.

2. Flat field test

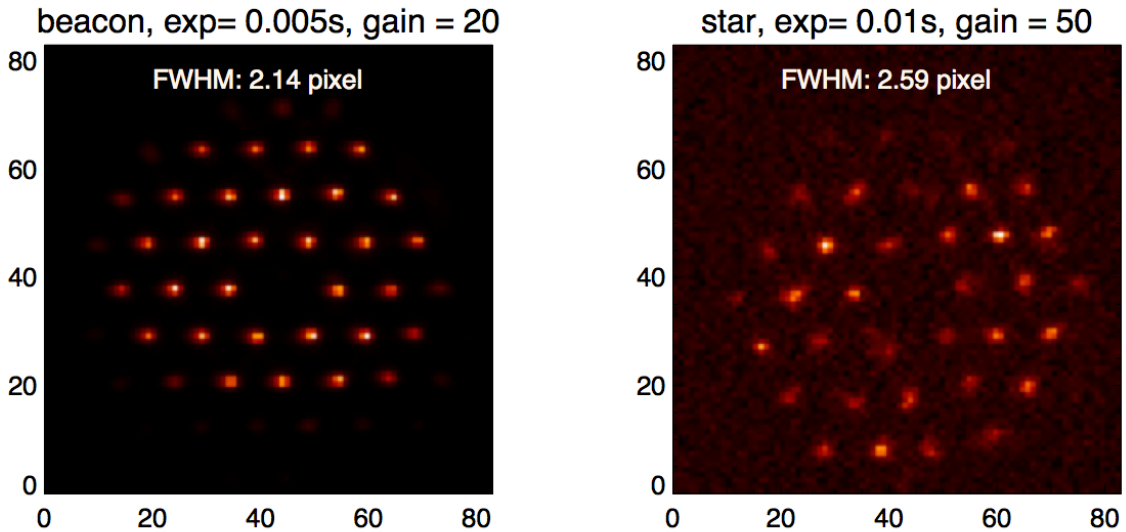
I did mean-variance test on the WFS camera. I created a flat field and took data using both EMCCD and CCD, the results agree. The camera settings are pregain = 1, EMCCD gain = 3. I increased the exposure time to change the flux level. Here is the plot with the best fitting. So the slope is about 0.25, meaning 4 electrons/ADU.





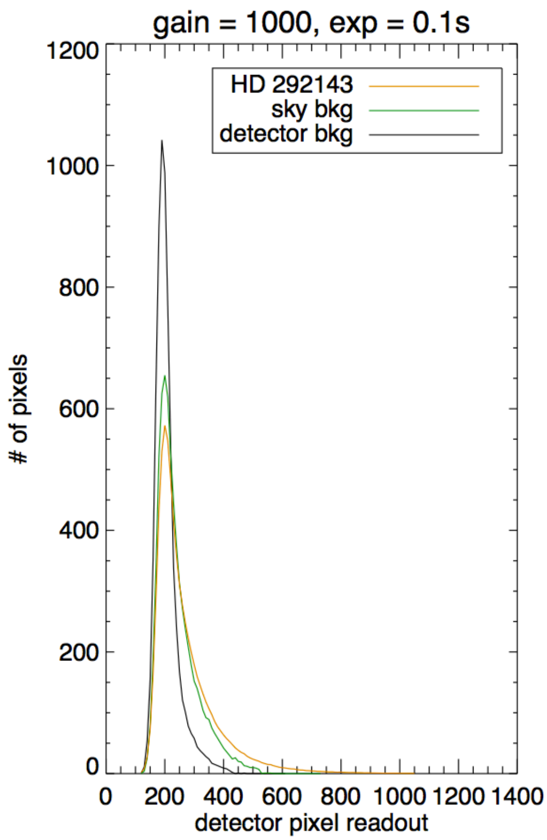
3. Image quality.

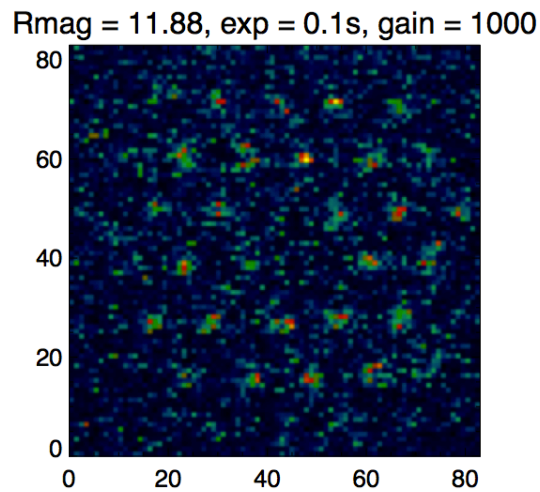
I took images with the beacon and starlight with certain exposure time and gains. The designed FWHM should be about 1.5 pixels. The measured average FWHM is 2.14 pixels using beacon and 2.59 pixels using starlight. We notice that FWHM on x direction is always larger than that on y direction using the beacon, which may have something to do with the CCD readout mechanism. Another reason the measured FWHM for the beacon is higher is probably because it is not a point source? And the reason for the starlight may be because the star is not at focus. (Images from 2014_01_26)



4. Sensitivity test.

The WFS has been able to observe stars with Rmag range from 1.5 to 12 with the bare glass that reflects 8% of light. I have observed a few star with Rmag ~ 12. One of them is HD 292143 with Rmag = 11.88 (simbad), the camera settings I used are gain = 1000, and exp = 0.1s. I attached the histogram of three cases: detector background, which is taken with camera shutter closed; sky background, which is taken with telescope pointing at a place with no visual object; HD 292143, which is taken with telescope pointing at the star locked by new AO system. The camera settings are the same for all three cases. I also attached a frame of WFS camera when the star is locked. If we believe it is approximately in photon counting mode, then we can count the number of photons by subtracting detector background from the other two cases on the Gaussian tail. I get 1820 counts for the sky background, and 2400 for the star. The difference 580 is the number of photons from the star per 0.1s. In my simulation, the number of photons should be 4.2e9 * 0.1 * 0.08 * 10^(-11.88/2.5) = 595 counts, where 4.2e9 is the zero mag flux taking into account the QE of the detector and loss on the mirrors, 0.1s is exposure time, 0.08 is the reflection rate of the dichroic. The two numbers are very close (data taken on 2014_01_23). However in the simulation, I used the wavelength range of 550 – 1000nm, but we don't have a filter in front of the camera yet. Taking that into account for a G5 star (the spectral type of HD 292143), I get 1.4 times more photons. So the prediction is 833 photons per 0.1s, a little higher than 580. This could be due to many other effects such as missing photons received by the camera but not amplified high enough to escape the core part of the Gaussian distribution in the histogram, or uncertainty on the reflection rate.





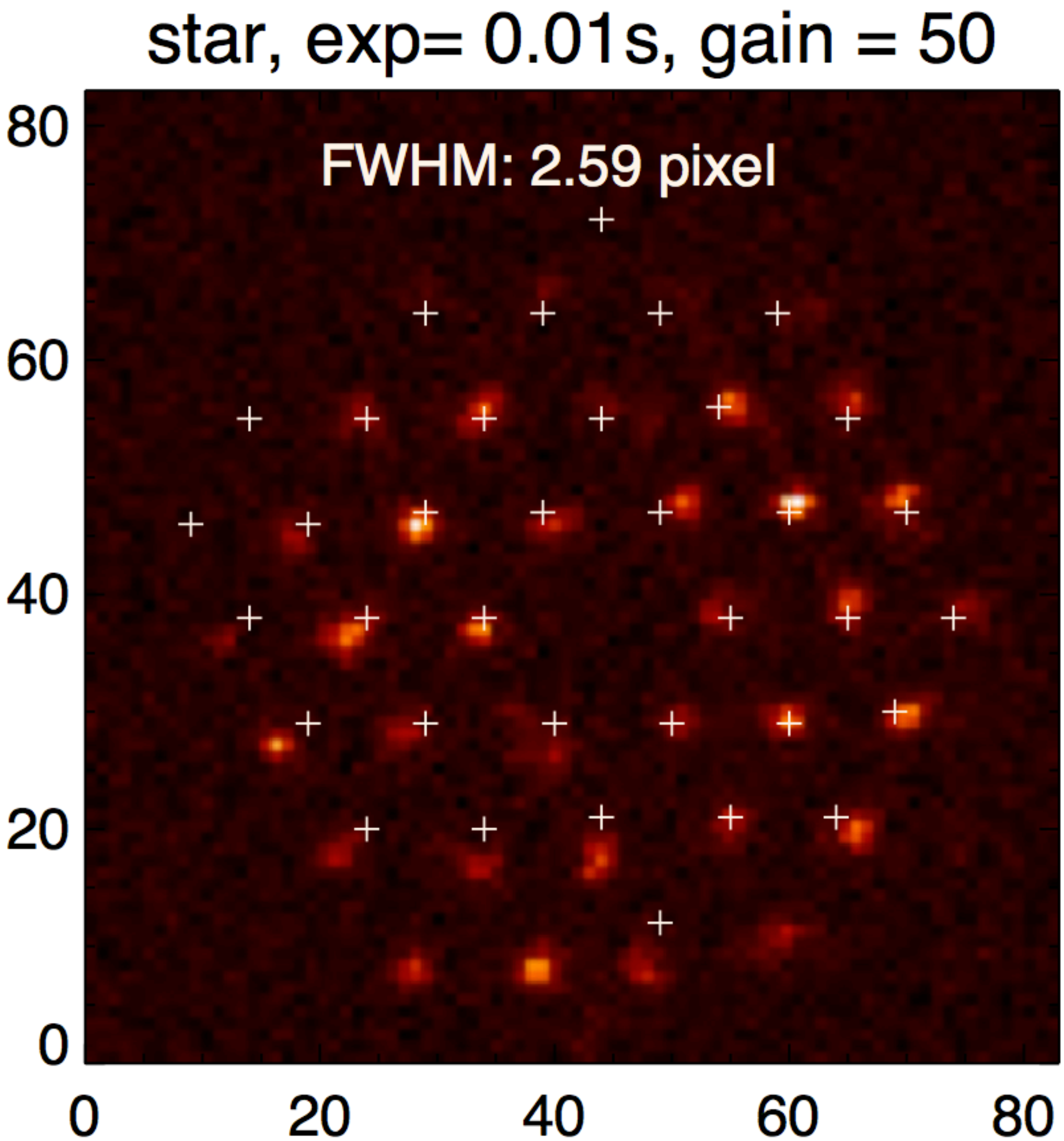
Another way to see how much the new AO system improves is to compare with the current TT system. We took data with both WFS and TT sensor on a bright star. The WFS camera setting is gain = 20, and exp = 0.01s, while the TT sensor has exp = 0.005s. I have measured the total intensity on the TT sensor to be 24,000 on average by adding the counts on four pixels. This I believe is background subtracted. Now on WFS, I measured 175,000 per frame with background subtracted. If we assume average gain = 20, 4e-/ADU, reflection on the dichroic is 8%, and correction for different exposure time by a factor of 2, then we have number of photons: 175,000 / 20 *4 *92 /8 /2 = 202,000. If we assume it is also 4 electron/ADU for TT sensor, then the photon number is 6,000. So the WFS is 33 times more sensitive than the current TT sensor, corresponding to 3.8 magnitudes (data from 2014_01_24)

5. Focal issues.

There are two issues here. Firstly the focus of the beacon doesn't agree with that of the telescope. Secondly probably neither of the foci fall into the center of the hole on the front surface of the mirror.

The existence of the first issues can be very easily proven. In the following figure, I plot the centroids (white plus) using beacon over a WFS frame looking at a star. Despite the drift of the centroid positions, we notice that the distance between centroids is larger using the starlight. Based on this difference, I estimated the distance between the beacon focus and telescope focus to be ~100 micron. To fix

this issue, one can move the parabola mirror in the beacon system in the focal direction.
The second issue is harder to fix. We could place a bright star in the hole, and move it out of the hole along a certain direction while taking data on WFS. The direction is defined as the intersected line between the focal plane and the front surface of the mirror. If the telescope focus is at the right position, then we should see a sharp drop in intensity on WFS as the stellar image moving out of the hole, and all the WFS spots should disappear at the same time. I did a similar experiment by tiptilting the secondary in AZ and El direction while taking data on WFS. Here is a link to the movie.



6. Coude alignment

Due to the imperfectness of the coude alignment, the position of the hole relative to a star locked by the current TT system changes with azimuths as can be seen on the acquisition camera. Since we aligned the WFS at stow position which corresponds to AZ = 82 degree, the overlap of the hole and a star is best at AZ ~82 degree. If a star is far away from that position, the overlap could be very little, which significantly reduces light going through the hole to the WFS. The solution is to install motorized actuators on the big dichroic so that we can tilt the dichroic to move the star into the hole.

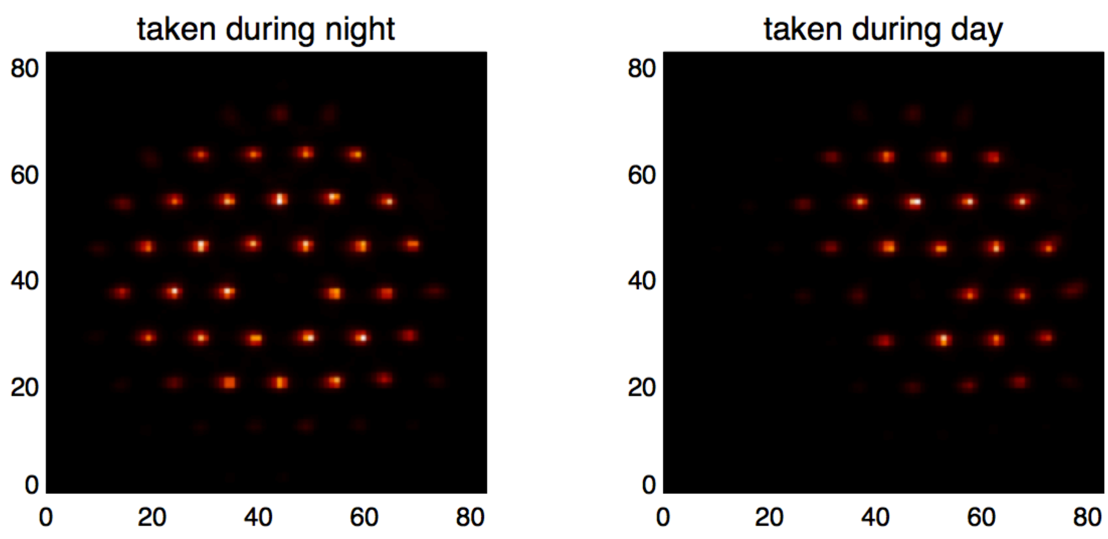
7. Temperature dependent of beacon alignment.

The alignment of the beacon on WFS and acquisition mirror seems to be dependent on temperature. Here is one supporting fact.

We aligned the beacon on the acquisition camera one day, and then aligned the WFS with beacon during the day. Then in the evening, we noticed that the image of the beacon had drifted away from the hole a little as shown in the acquisition camera, and as I checked the WFS images, they had moved and partially disappeared too. So we went to the S2 dome, and adjusted the tiptilt of one flat mirror in the beacon system to move the image back to the hole. When the adjustment was done, the WFS spots were aligned automatically.

This has kept happening every time I have checked: the WFS alignment using the beacon is different between day and night. I have attached one example of comparison. One possible theory is that the big board support all the new optics and WFS may curve a little because of the temperature variation. As the beacon goes across the board twice, the curvature of the board may have a strong effect on the alignment.

The good news is that the alignment seems stable from night to night. Once we align it during a night, it can be used for several nights without much drift.



8. Stream of frames

We have taken frames with open and close loop of the new CHARA AO system. The idea is to see if the spots are more stable with loop closed and by how much. I haven't analyzed the data yet.

9. Comparison of offset measurement from TT and WFS
We have taken data on both TT sensor and WFS simultaneously in three cases: TT locking the star; new AO system locking the star; star not locked. The measured offsets on TT and WFS should agree with each other. I haven't analyzed the data yet.

10. Big measured offset movement with WFS tracking
The WFS control software has been implemented with a display just like the current TT system, where white dots show the measured offsets and green dots show the corrections. When a star is locked by the new AO system, although the white dots move from some other places to the center of the display, but they still wander around a lot. In other words, the scattering of the white dots does not seem to be reduced after closing the loop. It could be due to the uncertainty of the true reference centroids, or the gain and leak values are not optimized.