Chapter 3: Observing with an Aligned Telescope and CCD Camera

Hopefully, by the time you are ready to do all of the labs after Lab 1, the telescope is close to aligned with the North Celestial pole. If so, you can follow these directions.

Remember, you will never align the telescope perfectly. We want to get close enough that the software can find a pointing solution that corrects for any errors.

In these instructions, we will assume you will be using the SBIG CCD camera with filter wheel and tip/tilt adaptive optics attached. Do not drop the camera!! Be aware of the wires. And make sure you aren't asking the telescope to observe an object where the CCD camera won't fit, for example we can't observe Polaris.

Also, remember that the longer your camera integrations, the more important alignment will be. If it is not polar aligned, you will see streaks in your field as it will be rotating incorrectly. I define polar aligned as going to objects and being with an eyepiece field of view of the objects. However, for most students in this class, close polar alignment is usually good enough.

1. Unlock and open dome to the North.
2. Remove the combination bike locks from the telescope: 1420 is the code.
3. Do not power on the telescope.
4. Uncover the main mirror and the finder scope.
5. Screw on the fine focuser, and plug it in (secure the cord.)
6. Before you use the CCD camera you MUST verify that everything is working with your eyepiece. So, we start the same as before.
7. Attach diagonal (90 degree component) to the fine focuser. Do not overtighten the finger screws.
8. Attach the 26 mm eyepiece to the diagonal. Do not overtighten the finger screws.

9. Make sure the telescope is balanced for this configuration. Someone could be using the camera before you and that changes the balance a lot!
   a. Unlock the RA and DEC locks.
   b. Then, point the telescope straight up (i.e. vertical) with the mirror and equipment at the bottom (see Figure 1).

   Figure 1: Arrows show the two weights to screw on or off to correct for offsets of mass while pointing straight up.

   c. You want to balance it so that it stays in this position. You will do this by screwing on/off the weights pointed at by the arrows in Figure 1.
   d. Holding the telescope straight up, see what way the telescope wants to move and counteract with the counterweights.
   e. For example, if the telescope moves to the left in Figure 1, then first screw the left weight toward the telescope. When, screwed all the way in, screw out the weight on the right side until the telescope is balanced, i.e. when you let go of it, it stays pointing up.

f. Next, move the telescope so that it is pointing horizontal (Figure 2).

Figure 2: What a horizontally pointing telescope looks like. Now, we have to move the entire weight assembly along the rail shown in this image running along the top of the telescope (and along the bottom). Be careful, they can fall off the rail so loosen carefully while moving these, while a teammate holds the telescope.

g. Now, to balance in this direction, we need to move the entire weight assembly left or right to balance. Do not screw/unscrew the weight up or down since that will affect the balance of the vertical direction.
h. Holding the telescope carefully in the horizontal direction, see which way the telescope moves.
i. Unscrew (carefully) the weight assembly that moves left/right (horizontally) along the telescope tube. You can move either one, but it is best to move them together.
j. For example, if the telescope moves mirror down (counter clockwise), then you will need to shift the two weight assemblies to the right to counter.
k. Once you have the vertical and horizontal balanced, you should be able to move the telescope arbitrarily and when you let go, it should not move too much. If it moves fast, then you did not balance the telescope.
l. Remember the better balanced, the better the telescope will track and the easier it is to use the telescope overall. It is worth your time to balance it.

10. Go to a bright star with the scope still powered off.
11. Verify the finder scope is aligned with the eyepiece, i.e., pointing at the same place. This will be essential later!
12. With a balanced telescope and an aligned finderscope, move the telescope back to the approximate location where you found it. Leave the motors unlocked (i.e. loose).
13. Turn on the telescope. Tell it to go to a bright star that you are know the position of.
14. Let the motors go where they think it is located.
15. Once the drive settles, move the telescope to that location manually. Manually align the eyepiece to point at that star. Do NOT use the hand-paddle. If you use the hand-paddle you are moving where the telescope thinks it is. We want to move to that star where the drive thinks it is pointing to regain our alignment and not move the drive. This is an important point.
16. Lock the motors, and tell it to go to another nearby star. It should move there or else you wrapped the RA/DEC too many times and it is at a hard stop. To fix that, unwrap the motion.
17. When you have the star centered (it better be the right star), then press and hold the ENTER button on the hand-paddle until it beeps and request you to press ENTER again. Now, you are re-aligned.
18. Test this by going back to the first star. It better be aligned in the eyepiece or something wrong happened. If not, then you will likely need to redo the polar alignment procedure or Lab 1. But that is very unlikely. First, try to start alignment at Step #24 in Chapter 2. If that does not work, then you likely have to redo the fulll alignments-- again very unlikely.
19. Assuming everything is okay. Go to a bright star and prepare for the CCD camera installation. Press and hold the ENTER button on the hand-paddle until it beeps and request you to press ENTER again. You are perfectly aligned with the star. We are about to remove the eyepiece and replace it with the camera, you better make sure your

finderscope is aligned or at least where the star has to go back to once you no longer have an eyepiece.

20. Unlock the RA and Dec.
21. Remove the eyepiece and diagonal.
22. Move manually the telescope to point to zenith (straight up).
23. Attach the CCD camera to the telescope, tightening carefully while holding the camera.
24. Do not power on the camera yet!! Connect the power cable and the USB cable to the camera. You may plug in camera USB to laptop.
25. Once the telescope is attached, we will need to move the counterweights to counterweight the weight of the camera hanging off the back end. This will give a better tracking performance. This is a two person job. Be careful and work slowly, the telescope can move REALLY quickly when it is out of balance with CCD camera.
    a. Unlock the RA and DEC locks.
    b. Then, point the telescope straight up (i.e. vertical) with the mirror and equipment at the bottom (see Figure 1).
    c. You want to balance it so that it stays in this position. You will do this by screwing on/off the weights pointed at by the arrows in Figure 1.
    d. Holding the telescope straight up, see what way the telescope wants to move and counteract with the counterweights.
    e. For example, if the telescope moves to the left in Figure 1, then first screw the left weight toward the telescope. When, screwed all the way in, screw out the weight on the right side until the telescope is balanced, i.e. when you let go of it, it stays pointing up.
    f. Next, move the telescope so that it is pointing horizontal (Figure 2).
    g. Now, to balance in this direction, we need to move the entire weight assembly left or right to balance. Do not screw/unscrew the weight up or down since that will affect the balance of the vertical direction.

h. Holding the telescope carefully in the horizontal direction, see which way the telescope moves.
i. Unscrew (carefully) the weight assembly that moves left/right (horizontally) along the telescope tube. You can move either one, but it is best to move them together.
j. For example, if the telescope moves mirror down (counter clockwise), then you will need to shift the two weight assemblies to the right to counter.
k. Once you have the vertical and horizontal balanced, you should be able to move the telescope arbitrarily and when you let go, it should not move too much. If it moves fast, then you did not balance the telescope.
l. Remember the better balanced, the better the telescope will track and you will get better images on the CCD camera.

26. Now you are balanced, we need to setup the camera. Follow the order precisely in order to not damage the camera. Do not power up until the end.
27. Turn on a laptop: User: Obs Pass: Obs1420
    Setup wireless if you want, but not necessary. If you want to use your own laptop, that is fine (these are really old and slow!). You need to download the CCDOps program from https://www.sbig.com/support/software/
28. Run CCDOps (from desktop)
29. Verify power adaptor is switched off and plugged into line voltage.
30. Verify that Camera USB is plugged into laptop.
31. Turn power adaptor on to supply power to camera.
32. After a short delay, the fan and the LED light on the back of the camera should turn on. This verifies that the drivers are working properly. Make sure to wait for this.
33. CCDOps Menu: MISC → Graphics/Com Setup (Use this to verify camera is set to USB)
34. In CCDOps go to
    Menu: Camera → Establish Com Link
    After a brief delay, the camera link should show up on the bottom left of CCDOps window

35. If you have the adaptive optics module setup too (the AO-8), the software will ask about calibration setup. Chose the default calibration with power cords facing different directions.
36. If the filter wheel is connected, then
    Filter → Filter Setup
37. In the first drop down, choose CFW9
38. The other fields should be set to the defaults.
39. The software will move to the clear filter position.
40. Next, we need to start the Peltier cooler.
    Camera → Setup
    At the top of this pop up menu, we can turn on active cooling and the temperature set point. Down to about -23°C, we gain sensitivity; however the Peltier devices can cool down to 30°C lower than ambient temp. Keep that in mind when setting the target temperature. On the other hand, we want the temp to be stable so that our noise is stable, which means that we want to use the cooler at 75-85% of its max capability. (Look at the bottom right of the CCDOps window to see capacity once it reaches the target temp.) Adjust temp to best optimal setting. Allow 10-20 mins for camera to stabilize before making optimal determination.
41. Now you should be ready to observe. At all times mind the wires. They should not get too taut.
42. Use your finderscope to move the telescope back to the bright star that your drive thinks it is still tracking. Lock the RA/DEC.
43. The CCD camera is really far out in the back focus of the telescope, so it will be **really** out of focus. I mean a lot! It is so far out of focus that it makes a huge doughnut shape in the focal plane. So huge that you may not see any light-- too spread out in the focal plane. So, first we need to focus our camera.
44. Set the CCDOps to focus mode. This is most easily found on the main button panel.

45. The software will do quick exposures that allow you to focus. You will most likely see **nothing** since it is so out of focus.
46. Checking that the focus is not locked, start playing with the main focus until you eventually see the star. This may take a **while**. You will probably go the wrong direction at first.
47. When it is as best focused as you can get-- check the average peak brightness given in counts in the software. You will want to use the fine focus to get even better. It does make a difference. Lock down the rough focus and switch to the fine focuser on the paddle.
48. Once you have the focus close, go ahead and center the star in the field with your hand paddle.
49. Press and hold ENTER for a few seconds then release. This tells the telescope to align at this location for the star. Press enter to verify.
50. To get to the object you want to observe. I recommend taking baby bootstrap steps. Go about 20 degrees to another star on the way to you source and as you go, center the star on the CCD using the Enter align trick. Then, go to a star that is very close to your object-- but not as bright. Center that star, then do a really good job of fine focusing. Might be hard to well focus bright objects compared to dim objects-- so it depends on what your target is.
51. Now move to the object you want to observe.
52. You can run a simple grab to check out the object.
53. See the CCDOps manual for how to setup color images. You basically want to take observations at all colors with similar exposure times.
54. See the CCDOps manual for how to take flat field images. You will need one per filter.
    a. I have two white poster board to use for this.
    b. You should shine a flashlight onto 1 board, then reflect it to the second in front of the telescope. Or try another method.

55. If you want to use the tip/tilt or the guide function of the adaptive optics, read the CCDOps manual too, but it can be tricky. You will need to find a star that aligns on the second CCD chip in the camera. To make that happen, you will have to rotate the camera. This will mess up the counterweights maybe and make the focus change, so use carefully.
56. Observe your targets.
57. To Shutdown, go to Camera → Shutdown (select Warm and Wait). Wait for the camera to reach ambient temp (then remove USB cable, then turn off power switch, and unplug power from the camera).
58. You can either choose to park the telescope or just turn off the drive. In this class most people will just turn off the drive. If you are the next group to use it, you can also park which will save time later.
59. If you park the telescope, it will be faster next time. On your paddle do UTILITIES-PARK.
60. The telescope will move to the PARK position, then request you to turn off the drive.
61. When you start the telescope next time, it is ready to go, unless someone messed with it.