High Accuracy Astrometry

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High Precision Astrometry is a field of astronomy that deals with measuring the observed right ascension and declination of asteroids. To obtain an accurate trajectory of an asteroid, a large compilation of data is required. The data is obtained at Table Mountain Observatory by utilizing a 2k camera attached to their 0.6 meter telescope. Highly accurate tracking software combined with data reduction makes this type of astronomy possible. For every target, five exposures are taken. Four of the exposures are offset to capture the asteroid in each corner as well as one centered photograph. Following this procedure we have the optimal probability of finding the object with a sufficient amount of reference stars. When observing is complete, the data is formatted. This process of data reduction is done by running various scripts that have already been written. If the computer finds an error from a night of observing, then the user must correct these errors before data reduction is complete. Once complete, these files are then sent out to be further analyzed by others. This data is utilized to better predict the orbits of asteroids, and to assist NASA in space navigation. Astrometry is a very important part of space exploration and is a field that has a large compilation of data that will continue to grow and improve space navigation.

Methods:

The first step in Astrometry is planning. This is done by obtaining a large file of star fields with targets in them. The targets may consist of asteroids, moons, or planets. To be able to successfully obtain an image of an object there are three conditions that must be met. We begin by looking at the star field itself. The star field must have enough stars to reference otherwise the movement of the asteroid will be unnoticeable. The second step is to look at the declination of an object, abbreviated as DEC. If the object has a declination of less than minus thirty then there is a very good chance that it is too low on the horizon and the object will be unobtainable, therefore that object would not be observed that night. The beta angle is the angle that the object makes with the sun, this is abbreviated as BT. We then make sure that the beta angle of the object to the sun is greater than 90 degrees, if any less then the object will not be viewable. Notice in figure 1 the DEC and BT are both acceptable, DEC is greater than minus 30 degrees and BT is greater than 90 degrees. When all of this is complete the files are printed and then sorted in order of right ascension. From here we create offsets for two or three different exposures that are taken for each object. We do this to obtain different reference stars near the object to more precisely calculate where the object is.

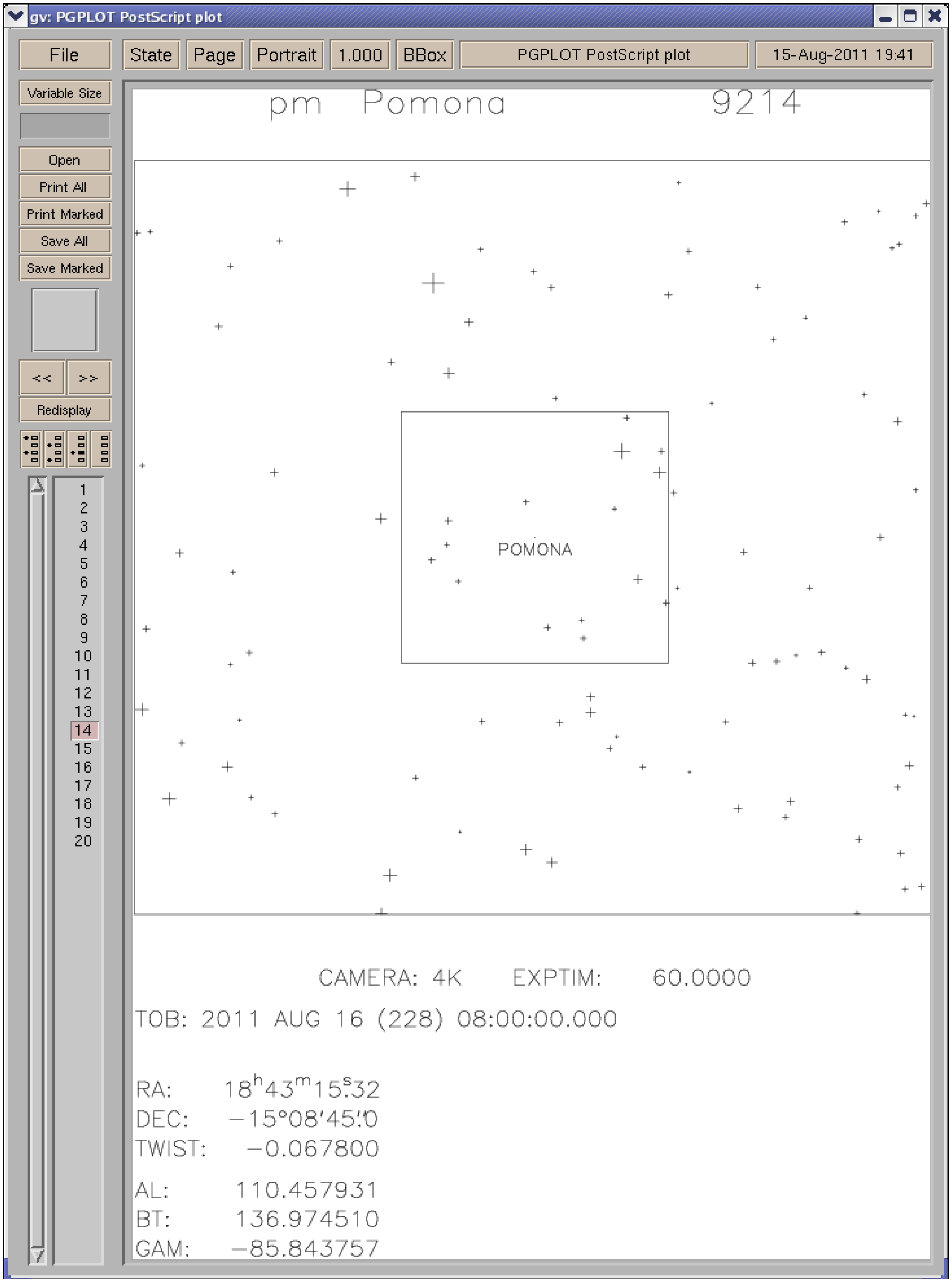

Figure 1:
A star field of the minor planet Pomona on August 16th. Notice its acceptable DEC of -15 and BT of 136.

Observing:

To observe a 0.6 meter telescope at Table Mountain Observatory is used along with a 4k CCD camera, or more recently a 2k camera. The 2k has a much smaller viewing window but does not require liquid nitrogen. An observation run spans three nights and is done in 8 to 10 hour shifts. The night begins with opening the telescope and turning on the camera. We then fill the 4K camera with liquid nitrogen to lower the temperature for optimum picture quality. Once everything is open and turned on we need to calibrate the telescope. The first step in calibration is to make sure that the telescope is centered. To do this, a three second exposure is taken of a cataloged reference star that is near the zenith. The star is then viewed as an image on the computer screen. Using the cursor and the X and Y axis coordinates we are able to measure the offset and manually correct it. The last part of prep work for the night is focusing the telescope. To do this we do a focus sweep, which is 11 consecutive exposures in 3 second intervals, while changing the focus and declination of the telescope. The result is a picture with 11 exposures of the same star in a vertical line down the screen. The most crisp and detailed version of the star is the focus that is chosen for the night.

With our preparation complete the night of observation may begin. The first picture is selected by its right ascension. The name and prefix of the asteroid is entered into the camera program. The prefix is a unique one, two, or three letter abbreviation of the name that is used by the computer to identify each unique asteroid, moon, or planet. Then the right ascension and declination are entered into the TCP (telescope control program). The TCP moves the telescope and the dome to the correct coordinates and continually tracks the object as it moves. The 4k camera program is set to a 180 second exposure that will download the image to a file. When using the 2k we set the exposure time to 90 seconds. When the exposure begins, the time of the exposure in UT is recorded in a log. Two or Three exposures are taken of every object before moving on to the next one. On the second exposure the humidity, temperature, and barometer are recorded into our log.

Every night we do one object different than others. This object is our calibration field. One of our calibration fields was M13, a bright star cluster. Five 180 second exposures are taken of this image which includes one in the center and one on each diagonal corner of the object. Other than the number of exposures the process is the same as the other exposures.

One exposure that was different than all the rest was Antiope. It was a special occultation that allowed us only one chance to take an exposure. The exposure was taken at 10:25:00 UT on July 19, 2011 for 480 seconds. Our right ascension rate was set to -566.4572 time seconds per hour and our declination rate to -8329.863 arc seconds per hour. The picture was to be taken when Antiope was supposed to occult a bright star. With the telescope tracking Antiope at this rate it created a long diagonal line from the bottom right corner of the screen to the top left. Signs of the occultation would result a dimming in the line. Unfortunately, we were too far south to observe this occultation.

When the night is complete the pictures and logs are transferred from our camera computer, TMO 4k, to our data reduction computer, Nekkar. While the files are uploading the telescope is moved back to the zenith and the dome is closed. After everything is turned off and closed up we begin data reduction.

Data Reduction:

Data reduction begins by running the script “doit”. The doit script will reformat the image, pointing and temp file while preforming center finding and reducing the image. When the script is complete other scripts may be run. The check script notifies the user if any targets were not found. Reasons for this would be a dim, unfocused, or off target image. To fix these problems the pointing file must be check for typos, once checked xrover may be ran. Xrover will allow the user to look at the image and line up an the predicted and actual positions as seen in figure 2. This will be followed by the ctrpsf script which will resolve our center finding issues. To fix problems with the reduce script one must remove all “bad” residuals. Then we must rerun the reduce and check script. When all issues are resolved the deliver script is run and the data for the night is sent out to those who request it, usually Harvard University and specific astronomers. Once sent out, the data reduction is complete.

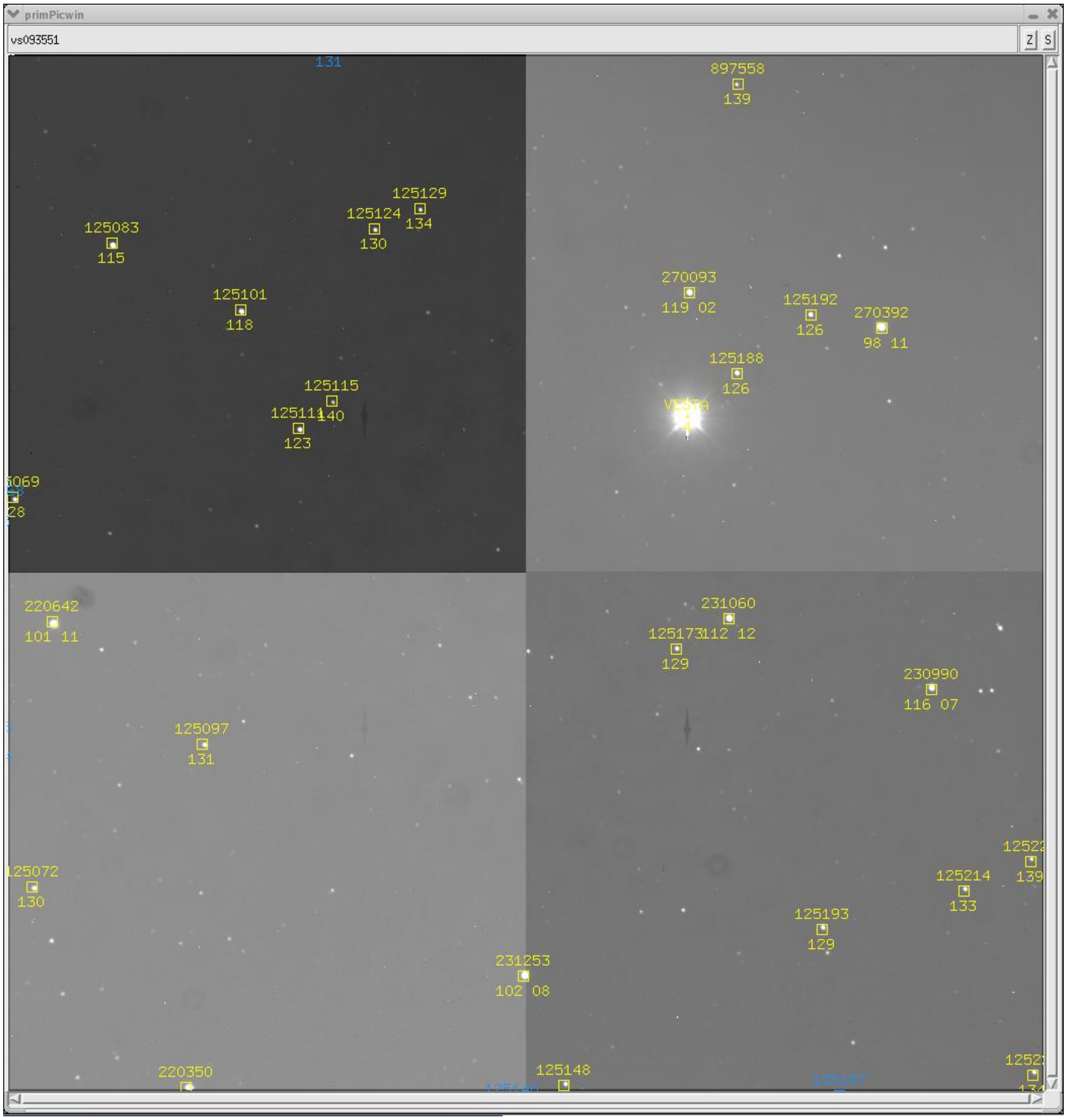

Figure 2:
Vesta, an asteroid in the top right quadrant, as seen in Xrover

Results:

My results every night give us on average 28 targets that are usable. Usually 1-2 images are unusable due to either poor viewing or human error. Results with many reference stars clearly show how the asteroid has moved from one image to the next, but they still must have the correct brightness. The biggest event I observed was Antiope's Occultation. My Antiope occultation unfortunately yielded little results for us, but with a combined effort of many other astronomers this model in figure 3 was created. Each line is a single observation from different astronomers in different locations around the world. When all of their results are combined you can see the double asteroid clearly. Notice the scale of 50 kilometers at the bottom of the figure.

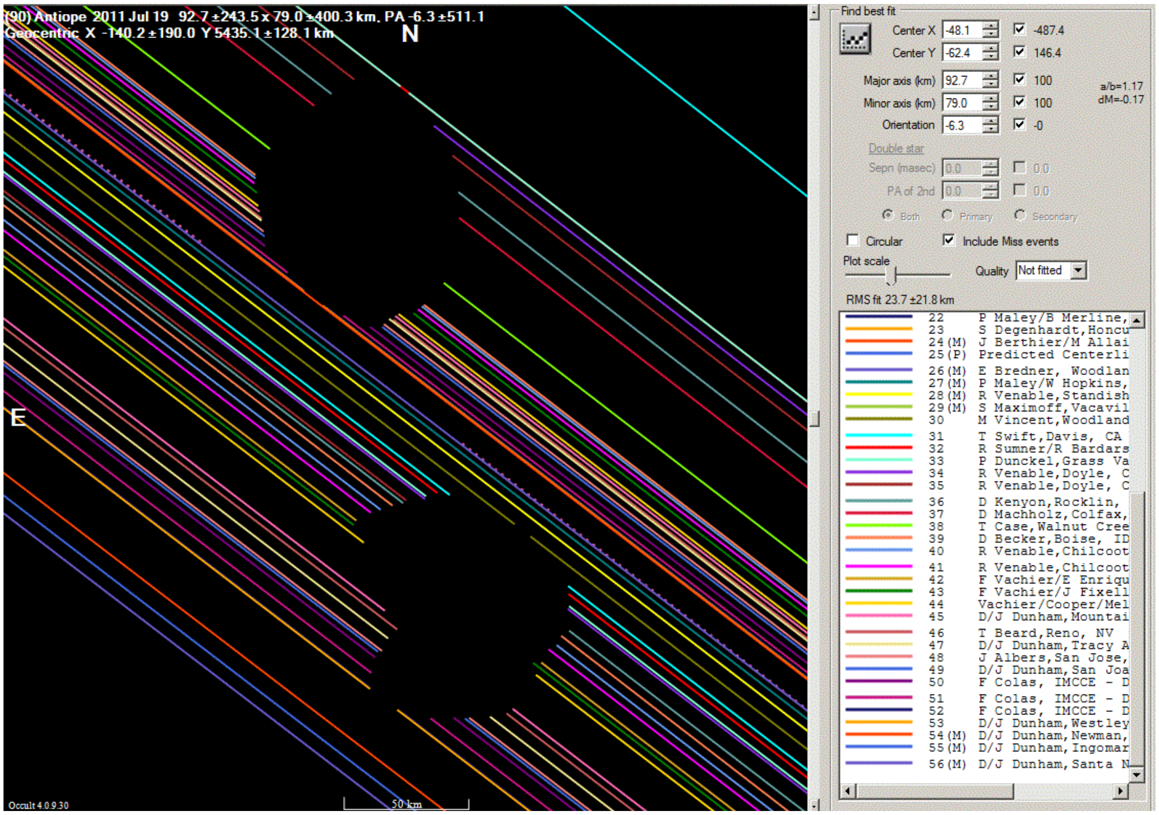

Figure 3:
A picture of the Antiope occultation. [1]"(Preston 2011)"

Though fighting many different weather conditions and natural events we were able to obtain more data than originally expected. This summer we have observed for 17 different nights and have obtained a lot of data for many different programs.

References:

1.) Preston, Steve, "2011 Asteroidal Occultation Results,"
http://www.asteroidoccultation.com/observations/Results/Data2011/20110719_AntiopeProfile2.gif

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