AIP4Win 2.0 Astrometry Tutorial (Rev. 4-27-06)

This tutorial demonstrates how to use ***AIP4Win*** to make precise positional measurements of objects in your CCD images. The files for it are located in the Astrometry subdirectory of the Tutorials directory on the CD-ROM.

In recent years a number of ever more accurate astrometric databases has become available, making it easy to precisely determine the celestial coordinates of objects in electronic images. ***AIP4Win*** supports several CD-ROM databases including:

- The Hubble *Guide Star Catalog* (*GSC*), the first of the CD-ROM databases to become widely available.
- The *United States Naval Observatory A2.0* database, which was created by scanning the Palomar Sky Survey (POSS) plates, and precisely locating the stars on each plate using data from the Hipparcos satellite.
- The subsampled version of the *A2.0* database, the *SA2.0*.
- The *MegaStar* CD-ROM, which is based on the *GSC*.

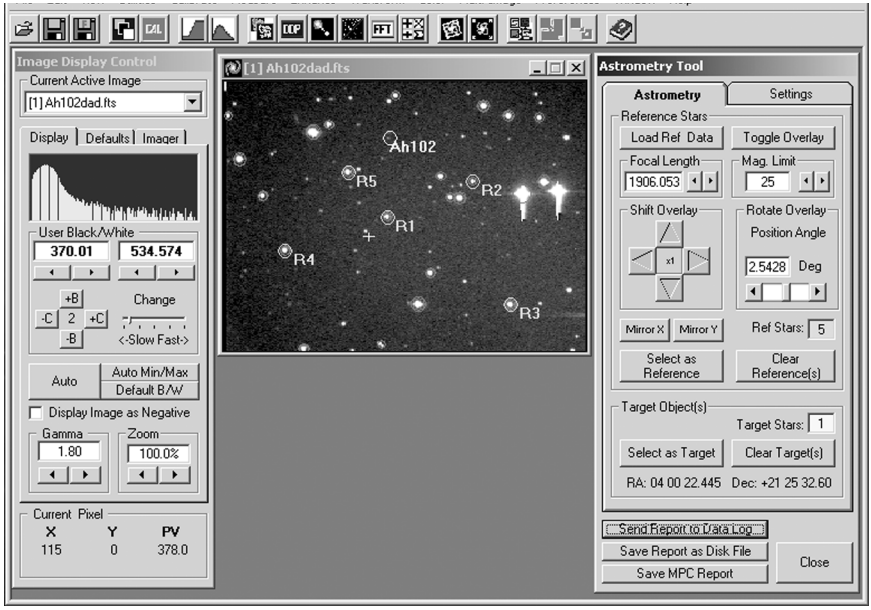
Knowing the coordinates of the center of your image, you can generate an overlay of known stars from any of these databases and, once the overlay is registered to the image, determine the precise coordinates and stellar magnitude of any object in it.

You can also use *MegaStar* to find the coordinates of your image and save a list to disk of all the stars in its immediate vicinity for use as an overlay.

In this tutorial, you will load a CCD image in which there are several asteroids, and then load a pre-generated reference star data file corresponding to that image. You will then generate and align the overlay to it, select a set of reference stars from the overlay, and then determine the coordinates and magnitude of the asteroids on the image.

Step 1: Load the Image. If any images are currently open, click the *Window|Close all Images* menu item to close them. You can also click the *Window|Close all open Tool Windows* menu item to close any tools you may have left open. These features are handy for quickly clearing your screen of old tools and images.

Load the image "Ah102dad.fts." Click the *Measure|Astrometry...* menu item and the Astrometry Tool will appear. Drag it to a convenient location on the screen.



Astrometry enables you to determine precise right ascension and declination coordinates for any object in a image. The first step is to link reference stars in your image to reference star coordinates. The next step is to designate a target, and the last step is to solve for the coordinates of the target object.

Step 2: Create an Overlay. For this tutorial, several reference star files have been prepared for this image, one using the Hubble *GSC* (via *MegaStar*) and one using the *USNO SA2.0*. The first one you will load will be the *GSC* version.

Before you load the reference data, you want to input the telescope focal length in mm in the **Focal Length** text box. This will scale the generated overlay so that it matches the scale of the image. For some images you may also need to use the **Mirror X** and/or **Mirror Y** buttons to reorient it so that north is to the top (roughly) and east is to the left, to match the overlay.

The telescope used to make this image had a focal length of approximately 1,909 mm. Input this value in the **Focal Length** text box. Later, the software will determine a precise value for the focal length.

It is not necessary to mirror this image about either axis.

Now you can create the overlay. Click on the **Load Ref Data** button and the Select Overlay window will appear. At the top you will see a set of five radio buttons corresponding to the different database types that ***AIP4Win*** can read. In addition to the four CD-ROM databases, there is a **Reference File** button. Click it and click **OK,** and a dialog box will appear. Navigate to the Astrometry subdirectory, select the file "Ah102.ref" and click **Open**; the reference data file will be loaded and an overlay will be generated.

To use an astrometric catalog stored on CD-ROMs, select the appropriate database; and input the Right Ascension and Declination of the field center along with the size of the field. ***AIP4Win*** will prompt you for the correct CD-ROM and create a list of all the stars in the selected region brighter than the magnitude limit set in the **Magnitude Limit** text box. You are then prompted to save the generated list—that is how the reference data files for this tutorial were generated. Chapter 9 provides information on obtaining these databases.

Click the **Toggle Overlay** button until the overlay appears. It will appear as a collection of red circles, with a blue cross marking the center of the field.

Step 3: Align the Overlay. For this image, the overlay needs to be shifted to line up with the stars. Look for a conspicuous trapezoid of stars just above and to the right of center. Just above and to the left of the trapezoid, you will see a set of four circles in a matching trapezoidal pattern.

In the Shift Overlay frame you will see a set of four arrowed buttons grouped around a center button marked **X1**. Click the **X1** button, and it will show **X10**; this is the rate at which the arrow buttons will shift the overlay. Click the left arrow button twice and the down arrow button twice; the overlay will shift so that the trapezoid of circles nearly overlays the trapezoid of stars. Click the **X10** button so that it shows **X1,** and refine the position with the arrow keys until the overlay matches the stars as closely as possible.

At this point you will notice that the trapezoid matches the overlay, but many of the other stars do not. This is because the image is slightly rotated with respect to the overlay. Correct this by typing 2.5 in the **Parallactic Angle** textbox, or use the associated slider. A few clicks of the **Shift Overlay** arrow buttons and the overlay and the image will come into perfect alignment. Once you identify the reference stars in the field, the overlay can be brought into perfect alignment automatically.

Step 4: Select a set of Reference Stars. Select the circled star in the center of the image with the mouse and click the **Select as Reference** button. A green circle will surround the star with the label **R1** below and to the right of it. This marks the star as a reference for measurement. When selecting a reference star, try to pick a clean star image that will give a good centroid. Avoid selecting stars in the middle of nebulosity or ones that show blooming trails. Clean star images will yield more accurate position and brightness measurements.

Select two more reference stars. Use the top right one in the trapezoid and the bottom right one in the image. Remember only to select stars that appear on the overlay. If you attempt to select a star that doesn't appear on it, an error message will appear, prompting you to try again.

As soon as all three reference stars are selected, the program will automatically refine the overlay alignment to sub-pixel accuracy. You will see that the telescope focal length is updated to about1906 mm and the parallactic angle is updated to about 2.46 degrees. (This is a useful way to determine the focal length of your telescope/CCD camera configuration very accurately, by the way.) The program will continue to refine the overlay as each additional rreference star is added.

Select a few more reference stars. You will need at least four in order for *AIP4Win* to calculate a set of residuals associated with the calculated plate constants for the CCD image. You will see that as soon as a set of plate constants is calculated, the RA and Dec of the cursor position is updated at the bottom of the Astrometry Tool window whenever the cursor is moved over the image. As you add more refernce stars the accuracy of the solution increases.

Step 5: Select the Object to be Measured. In this image there are three asteroids. One of them, ah102, is at X = 115, Y = 45. Click on this faint object with the left mouse button. Click the **Select as Target** button, and the Enter Target Name window will appear. Enter the name "Ah102" for the target and click **OK**, and a yellow circle will appear around the target with the label "Ah102" below and to the right. If the circle centers on the brighter star below this object, click the **Clear Target(s)** button and try again. It might help either to reduce the search radius using the **Search Radius** slider on the **Settings** tab, or position the circle so that it includes the asteroid but not the star. Your cursor position doesn't have to be accurately centered; *AIP4Win* will find the centroid of the object inside the search radius and align to it automatically. If two objects are inside the search radius, *AIP4Win* may attempt to center on their common "center of mass."

Step 6: Generate a Report. Now click the **Send Report to Data Log** button. If it is not already visible, open the Data Log window from the taskbar. In it you will see the a report on the object, containing a list of the reference stars used and the calculated RA and Dec of the object, the error for both RA and Dec, and the magnitude of the object.

If you wish to generate a report file, click the **Save Report as Disk File** button and the Enter Astrometry Report Data window will appear. You are presented with two options here: a verbose (multi-line) report, or a single-line report in the form required by the Minor Planet Center (MPC). Select the verbose format and type in an object name, and an arbitrary time and date. Click **OK**, and you will be prompted for a location to save this report. Choose a convenient place (not on the CD-ROM!), and click **Save** to save it.

You can examine the report if you click the *File|Open Log (text) File…* menu item. This will open a file select dialog. Select the file you saved and it will be displayed in a small text window. You can also examine or edit this file with any ASCII text editor.

You can clear the reference stars and targets and select a new overlay if you want to experiment further. Try using the file "ah102.gsc." It was generated from the *USNO A2.0* database. This is a phenomenally deep database with more than half a billion stars in it. You will see that the overlay includes nearly every object in the image, with the exception of the three asteroids.

This concludes the astrometry tutorial.