Blind Astrometry – how to find where your telescope was pointing when you took an image.

Astrometry is the science of the precise measurement of the positions of celestial objects from asteroids, planets and stars to quasars. Some of you will be familiar with and use the various software packages on the market that enable you to find the position of an asteroid or if you are lucky a supernova by aligning a digital image with a background image from a precision star catalogue. Once aligned you can then measure the position of the unknown object and the computer does the hard work of calculating the position of the object. Typical examples of this type of software include Astrometrica (http://www.astrometrica.at/), The Sky + CCD Soft (http://www.bisque.com/sc/shops/store/default.aspx) and the Starlink GAIA package (http://star-www.dur.ac.uk/~pdraper/gaia/astromcal/index.html) though readers will have their own favourites. All these products are capable of high quality astrometry but tend to require information on the field location and the plate scale (normally in arc-seconds per pixel) to allow you to start the alignment process. For those with properly aligned telescopes and CCD cameras where you know the plate scale this is fairly easy. However those who manage to take images and then realise that the position they have recorded on the sky seems to bear no relationship to the stars they have recorded help is now at hand. These images quite often only show a small area of the sky and recognising the stars is a challenge. The other group of people who will be helped by Blind Astrometry are those who use DSLR cameras with telephoto lenses on either a tracking or fixed mount to take images of the sky. Of course we all take copious notes of what we were imaging and record the results in our logbooks but in time these can get mislaid and I for one have quite a few images both in digital format and film where I have forgotten what I was attempting to image !

Perhaps I should say a little about image formats for those who may not be familiar with this aspect of the digital world we now live in. Digital cameras such as DSLRs and Point and Shoot compact cameras commonly save their images in a compressed format called JPEG. In addition to the image this quite often includes information about the time and date of the image as well as technical information such as the exposure duration the f number the lens was set to, the ISO Speed equivalent as well as the focal length of the lens. If your images are still on film they can be converted into a digital image with a film scanner – in this case they may be saves as a JPEG or possibly a TIFF image, in these cases no exposure information will be included. The specialist astronomical cameras that are used by the amateur astronomical community as well as the cameras used in professional observatories normally record their images in 'FITS' (Flexible Image Transport System') format. This format is designed specifically for astronomical images and the FITS standard together with it's WCS (World Co-ordinate System) extension define the keywords and usage that standardise how the astronomical co-ordinates are included in the file.

Locating our image on the sky is a difficult technical challenge due to the lack of approximate position or scale and of course there are a lot of stars! To

illustrate the size of the challenge the US Naval Observatory B1.0 catalogue which is commonly used for astrometry contains 1,042,618,261 objects including stars, galaxies and Quasars to magnitude V21.0. Matching the star positions in a random sky image to this number of stars may be more difficult as finding the traditional needle in a hay stack. Despite this websites now exist that can solve the 'Blind Astrometry' for an image you enter and then return you either a position, scale and list of major objects in your image or else return a FITs format image with the correct WCS co-ordinates in the header so you can view it in one of the virtual observatory tools that allow you to locate objects in the image.

The automated astrometry web sites have different ranges of capability, some sites will take a FITs format file with WCS co-ordinates that may be slightly in error and will return the file with corrected co-ordinates, the next step up in capability require that you supply approximate information either in the FITS file or via a web interface. With both of these you obviously need to have quite a good idea of what you actually imaged. However there is one site at Astrometry.net that provides the ability to take an image in a variety of formats and return the information of where the telescope was pointed and what the angular size of the image is. However a word of warning if you use this site – you need to read the terms & conditions about the rights they get to use your image carefully.

Whilst astronomy.net operate the astrometry engine that does the hard work there are a three different portals to the service in addition if you have a large computer you can download and run their software on your own machine but this is not a trivial task due to the amount of data and computing requirements.

The first portal is aimed at 'point and click' photographers, a public group pool has been set up on the photo sharing website Flickr. This is accessible at www.flickr.com/groups/astrometry/ . This website will take images in a variety of common formats except FITs due to the targeted audience. Images that are submitted to the group are marked with the location of the centre of the image as well as the field orientation, the pixel scale and the image angular size. In addition the major objects in the image are identified in the text. To allow you to identify which object is which the major objects are shown enclosed by a box with a pop-up description if you move the cursor over the image. The image itself is not labelled but the website does allow the image to be viewed in Microsoft's World Wide Telescope. Bear in mind that any images you submit are publicly visible and may well be copied by other visitors.

A second portal has been developed specially for the Royal Observatory Greenwich 'Astronomy Photographer of the Year' competition. This is very similar to the first portal above but uses a different group on Flickr. This has one improvement on the first portal in that you have to submit the date and time that the image was taken and also a description. Once again your images pass into the public domain.

The third portal involves direct interaction with the astronomy.net server via a private web page. The web interface is not yet open to the public but can apply to become an 'Alpha Tester' by emailing the address on the 'use' tab. They seem quite keen to have more testers so there should be no problems in getting access. Once you have been granted access – having read the conditions about security and the use they may make of your data you get access to a web page that allows you to upload an image to be solved. The image may be in FITs format as well as JPG, GIF or PNG. You can also submit the star positions as a table but I have not tried that. There is a limitation of 250 Mbytes on the image, which should not be a problem for compressed image files, but you may reach that with a FITs file as it is not compressed.

The JPG, GIF or PNG format files are likely to be in colour and the system is capable of accepting these and returning the image as a FITS file with three separate tables one for each primary colour. I have not tried entering FITs colour files yet but as there is no standard to define these the system is likely to be quite sensitive to the file structure. It should however accept monochrome FITs images without any problems as these are well defined. However it's this sort of problem Alpha Tester are there to find !

The web form allows you to either browse for a file to upload or to give the location as a URL.

To aid the search engine there are a couple of other parameters which while not mandatory speed up the search. The first is an indication of the width of the field – this does not have to be very accurate. If you are using a known telescope and camera combination you may well know this. If of course you are using a camera with a telephoto lens there is likely to be a much greater uncertainty. The second optional information is to supply the field 'parity' is it as you look at the sky which is what you will get from a digital camera or is it from a telescope that may provide a mirror image. There is an option to select both if you don't know but selecting the correct one reduces the workload on the server as it does not have to try the mirror patterns. However selecting the wrong one is likely to cause the astrometry process to fail.

Once you have completed the form all you need to do is to click the submit button and wait for the email to tell you the image has been solved. My experience so far is that it is very quick at present.

The only problem I have with the upload process is that there is no provision to label the image so when you get the confirmation email back you may be unsure which image has been solved. The work around at present is to ensure that the file name you use when you submit your images describe them.

In fact you get two emails – the first tells you that the server has received the job and is trying to solve it – this has a link that allows you to observe the progress. A second email follows when the identification is complete. This has

a link that allows you to access the files that the astrometry engine has produced.

One image I recently submitted is shown in Figure 1 – perhaps not the best astronomical image ever taken ! This image was taken with a Canon 40D DSLR at prime focus of a 14" Meade LX200. The image is not very good due to a combination of the sky still being light, high cirrus cloud and a nearby moon. However it provides a good test of the capabilities of the astrometry engine. I had been taking a number of moon shots and thought I would take an image of the Quasar 3C273 (mag 12.9) to see what the limiting magnitude of the combination was. The exposure was 30 s using ISO 1600. The field is supposed to contain the Quasar but I could not match the stars to the field containing the Quasar..
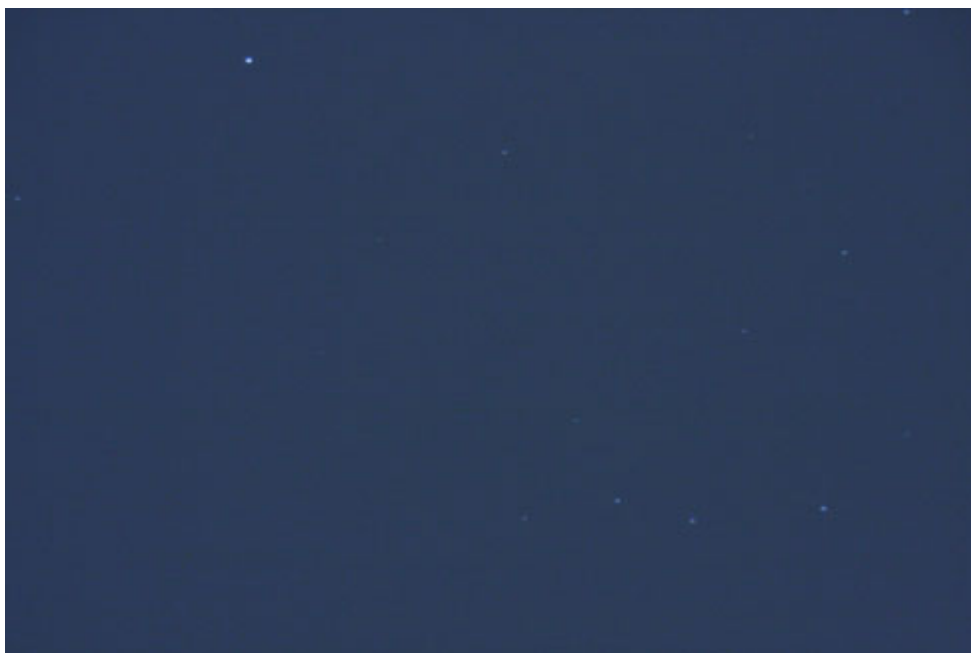

Figure 1

The results of the Astrometry Server can be found at http://live.astrometry.net/status.php?job=alpha-200905-66457948. The results page contains a combination of data, images and links to other files. The most important data is the information on the field location and the size. In the case of the image in Figure 1 this is '*Your field is at (RA, Dec) = (187.249, 1.880) degrees and spans 21.72 x 14.48 arcminutes*.' Further down the page is much more detailed information including the field orientation and the pixel scale.

There are a number of thumbnail images on the page which show the field against the star background at different scales to show where your image is located. A second image on the page which is reproduced in Figure 2 shows the objects identified in your image as the larger circles and smaller circles showing the position of stars in the astrometry database. The 4 sided figure is the identification shape that the engine used too locate the image.

The third section of the page has links to a number of files created by the Astrometry engine. There are a number of files that list the objects in the field, the WCS (World Co-ordinate System) location and size. The most useful file is a fits format image that contains your original image with a FITS WCS header that allows you to save it and then open it in programmes such as Aladin that will open the image in the correct position and then allow you to overlay data from other catalogues on it.
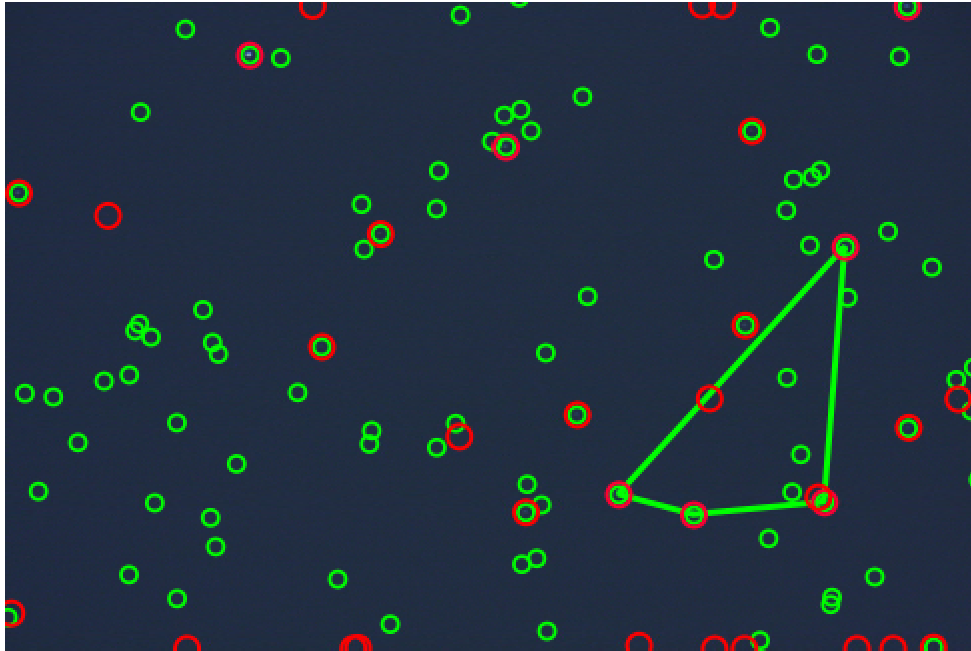

Figure 2

Examination of the resulting FITS file in Aladin showed that the image did not contain the Quasar 2C273.

In addition there are a number of files that allow you to open your image in Google Sky.

The Astrometry Engine is very useful to identify images, particularly those which have a small field of view and those where there is no recognisable part of a constellation. If you want to see the range of images that the engine can solve have a look at the Flickr web site above.

In conclusion Astrometry.net provides a useful service in identifying unknown star fields to allow you to use other tools such as Aladin to examine the objects in an image in more detail. The only downside is that your image may be published in the public domain by Astrometry.net. The system is still in development so as an Alpha Tester you have an opportunity to influence the future developments and to find the bugs.