

# A-Team Tutorials

## Level 1 with Astrometrica

### Targets and Priorities

Which object should you select for a measurement? Of course, this will depend on your own interests for example:

- Easy asteroids or comets to practice using Astrometrica.
- Asteroids for which the Minor Planet Center (MPC) or European Space Agency (ESA) require measurements.
- Recent discoveries not yet confirmed.
- Recovery of objects that have not been seen for a long time.

If you are new to asteroid observing then it is best to start with some bright, slow-moving, easy ones and these can be found at the “What’s Observable” website or using your own planetarium software.

### *What’s Observable?*

The easiest place to find what’s observable tonight is the [What’s Observable?](#) website. Go to the site and set up the search:

- Edit *Observer Location* to a Slooh observatory code. Press *Edit*, put G40 (Canaries), W88 (Chile) or E62 (Australia) in the *Lookup the Specified Location* box and press Search.
- Change the *Observation time* to a time when you believe there will be some free mission slots at your chosen telescope. This does not have to be precise, any time around the middle of the night will be OK.
- Set the *Min elevation angle* to 40 degrees to ensure you will have a good view of the objects.
- Move the slider next to Visual Magnitude and enter 13 – 16. That will give you a list of objects that are a reasonable brightness for this exercise.
- You can usually leave the rest of the constraints to the default.
- Select “Retrieve Data” (it may take some time).

Home / What's Observable?

The API service provides programmatic access to the tool.

Observer Location: **Slooh.com Canary Islands Observatory** [code: G40]

**Observer Constraints**

Use the panel below to specify the observer constraints. Optional constraints can be activated/deactivated using the corresponding toggle switches. If a field is empty, the constraint is not considered active even if the toggle switch is on.

When ready, click the "Retrieve Data" button below to load the list of observable objects.

Observation type: **Optical**

Observation time (UT/JD): **2021-10-17 00:00:00**

End of observation (UT/JD):

Min. elevation angle (deg): **40** ☐

Min. exposure time (min): **5** ☐

Solar elongation (deg):  -  ☐

Visual magnitude: **14** - **17** ☐

Dist. to galactic plane (deg):  -  ☐

Heliocentric range (au):  -  ☐

Topocentric range (au):  -  ☐

R.A./dec. output format: **Sexagesimal**

Require magnitude: ☒

Max. output: **100** Sort by: **Object name** **Asc**

**Retrieve Data**

+ Limit by Object Kind/Group

+ Limit by Orbit Class

+ Custom Object/Orbit Constraints

*Set up What's Observable? query.*

You will get a list of objects like this:

Home / What's Observable?

102 Minam (A806 UA)	05:43	08:42	12:04	00:24	09:21:00	+10 32'
132 Aethra (A873 LA)	15:45	18:21	20:57	01:04	18:57:37	-04 37'
136 Austria (A874 FA)	03:09	06:31	09:53	02:38	07:09:33	+11 36'
146 Lucina (A875 LC)	05:17	08:57	12:37	00:30	09:36:08	+21 44'
147 Protogeneia (A875 NA)	00:45	04:27	08:09	05:02	05:04:57	+23 06'
158 Koronis (A876 AA)	04:22	07:57	11:32	01:25	08:35:28	+18 30'
161 Athor (A876 HA)	04:11	07:59	11:48	01:36	08:38:04	+27 48'
189 Phthia (A878 RA)	05:37	08:55	12:13	00:10	09:33:43	+09 41'
197 Arete (A879 KA)	01:03	04:38	08:14	04:45	05:16:19	+18 58'
207 Hedda (A879 UA)	02:37	06:23	10:09	03:10	07:01:36	+26 10'
208 Lacrimosa (A879 UB)	19:25	21:18	23:11	03:18	21:55:16	-13 31'
215 Oenone (A880 GA)	05:25	08:56	12:26	00:22	09:34:29	+16 00'
223 Rosa (A882 EA)	22:06	01:28	04:50	06:44	02:05:38	+11 48'
225 Henrietta (A882 HA)	01:40	04:43	07:45	04:07	05:20:43	+03 42'
235 Carolina (A883 WA)	04:47	08:29	12:12	01:00	09:08:11	+23 08'
251 Sophia (A885 TA)	20:19	22:25	00:32	04:12	23:02:27	-11 11'
252 Clementina (A885 TB)	04:37	07:53	11:09	01:10	08:31:42	+08 49'
254 Augusta (A886 FA)	03:51	07:34	11:18	01:57	08:13:00	+24 23'
255 Oppavia (A886 FB)	05:10	08:52	12:35	00:37	09:31:16	+23 37'
257 Silesia (A886 GB)	01:55	05:41	09:28	03:52	06:19:35	+26 12'
260 Huberta (A886 TA)	23:09	02:26	05:44	06:35	03:04:08	+09 38'
262 Valda (A886 VA)	02:46	06:35	10:24	03:01	07:13:46	+28 19'

Showing 1 to 25 of 100 entries 1 row selected

Previous **1** 2 3 4 Next

SSD Site Map Privacy Policy Contact Us Site Manager: Ryan Park

*List of objects*

The list will contain lots of objects visible from your chosen observatory. Look for some that have convenient rise/set times.

- Check the Object-Earth-Moon angle (deg). This tells you how far away from the Moon the object will be in the sky. It's best to go for objects that are at least 60 degrees away from the Moon otherwise stray light from the Moon can ruin your images.

You can see lots of technical details about an object by clicking on its name.

Select a few of the objects you might be interested in and make a note of their names or numbers.

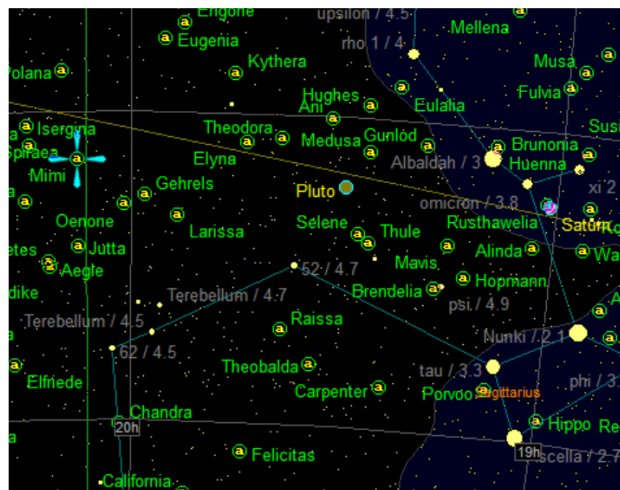
## Planetarium software

You will sometimes need to use planetarium software to display star (and asteroid) maps. There are lots of commercial and free packages available and you may already have your own favourite. Make sure you are familiar with the functions to download asteroid data, filter asteroids by magnitude and display them on the map.

(I am currently using C2A because of its flexible handling of comets and asteroids – and it's free!)

A star map showing asteroids can be a convenient way of selecting interesting observation targets. Set up the map for a time near the availability of Slooh missions and set to one of the Slooh observatory locations.

Filter your asteroid database to magnitudes 13 to 16. Examine the map for objects that are not too near the horizon and not too near the Moon.



*Asteroids in a C2A chart.*

## Visibility and Missions

Now it is time to make a final decision on which object you are going to target, obtain its exact coordinates, set up the missions and (weather willing!) a few hours later download the results.

## JPL Horizons or MPC?

You need to get detailed information about an object's visibility to the Slooh telescopes. Some Slooh members may already be familiar with using [JPL Horizons](#) to obtain this data. There is no reason why they should not continue to do so if they find that system easier to use. However, it may be worth learning to use the MPC (Minor Planet Centre) Ephemeris pages (described below) because:

- You can copy and paste a plain text candidates list directly into the selection page.
- You can get information for all your candidates at the same time.
- You get information about whether new observations are needed and the uncertainty of the position.
- All the information needed to assess the viability of a mission is immediately available.

The [MPC Site](#) has many pages and navigating within the site can be complicated. For Level 1 you will only need to select [Observers/Ephemeris Service](#) but it is worth spending a bit of time exploring other parts of the site as they will be needed in due course.

### *Ephemeris*

“Ephemeris” is a fancy word for a list showing the coordinates of an object at different times.

At this stage I am assuming you have a few names or numbers of potential targets, and you know what missions are available for one of the Slooh Telescopes. Go to the [MPC Ephemeris page](#), enter the list of targets into the objects box (you can copy and paste the entire list into the box as long as it just contains object names, numbers or designations each on a separate line.)

The MPC will recognise an object in several ways:

- For an un-numbered object use its Provisional Designation (e.g., 2014 ER48).
- For a numbered object use its number (e.g., 12711), its name (e.g., Tukmit) or the Provisional Designation it had before it received a number (e.g., 1991 BB). 12711, Tukmit and 1991 BB all refer to the same object.

Elsewhere on the Ephemeris page:

- Make sure “Return Ephemeris” is selected as the option.
- Enter ephemeris start date/time (e.g., 2018 12 26 22:00).
- Enter Number of dates to output (say 18).
- Enter Ephemeris Interval and select units (say 30, minutes).
- Enter Observatory code (G40 for Canary Islands, W88 for Chile or E62 for Australia).

Leave other fields as default and press “Get ephemerides/HTML page”. You will see something like the page below for each object in the candidates list.

(12711) Tukmit

[Display all designations for this object](#) / [Show naming citation](#) / # of variant orbits available = 3

Perturbed ephemeris below is based on 15-opp elements from MPO 416849. Last observed on 2017 Sept. 18. Object has been observed on only

Discovery date : 1991 01 19  
 Discovery site : Palomar  
 Discoverer(s) : Mueller, J. E.

12711 Date	UT h m s	[H=15.8] R.A. (J2000)	Decl.	Delta	r	El.	Ph.	V	Sky Motion "/min	P.A.	Object Azi. Alt.	Sun Alt.	Moon Phase	Dist.	Alt.
2017 08 21 040000	05 26 09.5	+63 59 55	1.247	1.307	69.8	46.6	18.6	1.39	070.0	210	+34	-32	0.00	064	-25
2017 08 21 043000	05 26 15.4	+64 00 09	1.247	1.307	69.8	46.6	18.6	1.39	070.1	209	+38	-27	0.00	065	-19
2017 08 21 050000	05 26 21.4	+64 00 23	1.247	1.307	69.8	46.6	18.6	1.38	070.1	208	+41	-21	0.00	065	-14
2017 08 21 053000	05 26 27.3	+64 00 37	1.247	1.307	69.8	46.6	18.6	1.38	070.2	206	+44	-15	0.00	065	-08
2017 08 21 060000	05 26 33.2	+64 00 51	1.247	1.307	69.8	46.6	18.6	1.38	070.2	203	+47	-09	0.00	065	-02
2017 08 21 063000	05 26 39.1	+64 01 05	1.247	1.307	69.9	46.6	18.6	1.37	070.3	200	+49	-03	0.00	065	+04
2017 08 21 070000	05 26 45.0	+64 01 19	1.247	1.308	69.9	46.6	18.6	1.37	070.4	196	+51	+04	0.00	066	+10
2017 08 21 073000	05 26 50.9	+64 01 32	1.247	1.308	69.9	46.6	18.6	1.37	070.5	191	+53	+10	0.00	066	+17
2017 08 21 080000	05 26 56.8	+64 01 46	1.247	1.308	69.9	46.6	18.6	1.37	070.7	186	+54	+17	0.00	066	+23
2017 08 21 083000	05 27 02.7	+64 02 00	1.247	1.308	69.9	46.6	18.6	1.36	070.8	181	+54	+24	0.00	066	+29

These calculations have been performed on the [Tamkin Foundation Computing Network](#).

### Ephemeris for Tukmit

The page shows the number and name (or Provisional Designation), information about when it was discovered and last observed, comments about whether more observations are required and a table of times and coordinates.

There are several things to check:

- Check “V” (magnitude). Anything brighter than about 16.0 should give you an easy target for measurement.
- Check “Object Alt.” (altitude above the horizon). Go for objects that are above 40 degrees from the horizon at the time of the mission. Closer to the horizon and haze or atmospheric disturbance can reduce the quality of images.
- Check “Sky motion “/min”. Fast objects will leave faint trails and will be difficult to measure. Ideally the object should not move more than about 2 or 3 pixels during the exposure. In practice, speeds up to around 4 or 5 arcseconds per minute should be fine.
- Check the Moon. Phase (a percentage of full), Alt (distance above the horizon) and Dist. (angular distance between the object and the Moon). For a full Moon I would want to be 90° away from the Moon and at first/last quarter 60° away. Slooh will not allow a reservation if it thinks the Moon is too close.

For information:

- “Delta” is the object’s distance from Earth in AU.
- “r” is the object’s distance from the Sun in AU.
- “El.” is “elevation”, the angular distance of the object from the Sun.
- “Ph” is “phase” that specifies the percent illumination of the object (like a Moon phase).
- There may be additional information on the right of the table showing Uncertainty. This is included if the position of the object is unsure (this will be important later in the Tutorial).

The R.A. and Decl columns tell you where the object should be at different times. Keep the ephemeris page open while you look for suitable mission times.

### ***Missions***

When you have an object that satisfies all your criteria, reserve the missions.

You should use the T1HM, T2WF, C2WF or A1 systems for your missions. When it comes to measurement you will want at least three images spread out over half-an-hour to see that the object has moved. Schedule the missions spread 10-15 minutes apart. Select the mission times and get the coordinates from the ephemeris.

- Remember you can “hold” missions on the Slooh reservation system so look through the available slots, decide on the set of missions you want and “hold” them until you are ready to finalise them.

If you have scheduled missions spread over half an hour or so, your object will not move far across the field of view. It is best to set up all the missions using the coordinates where the object will be half-way through your group of missions. That way all the images will align together showing the same field of view and the object will appear to move through the centre of the images when you “blink” them later. This will also reduce the effect of any defects in the CCD as different pixels will be showing the object in each mission.

Enter the coordinates into the Slooh reservation slots. We normally use the Multi-Luminance 50s processing recipe for asteroid hunting as this gives multiple 50-second luminance images for each mission. However, for Level 1 it does not matter too much if you use the Generic mission recipe.

### ***Retrieve the FITS***

FITS (Flexible Image Transport System) files contain detailed information from the camera. This high precision data is needed to make accurate measurements of position and magnitude. FITS files are generated over a period of hours after the end of missions each night.

In the Slooh Desktop, go to My Past Missions and check that your missions ran OK. Select “view mission log”. When the FITS files are available a FITS button will appear. Click on that button for a list of FITS Files available. For systems like Canary Two, there will be two sets of FITS, one from each of the two telescopes mounted on that pier. You will be interested only in the first group of FITS in the list.

Select the download symbol for each of the required FITS files. The files will appear in your Downloads folder. It’s a good idea to set up a hierarchy of folders for your FITS files, notes and measurements because you will collect a great many of them eventually. Set up a folder to hold your images of this object and move the FITS into it.

### *Filenames*

Filenames of FITS files look like this:

112356m055032\_20140406\_213041\_0\_abcdef\_l\_cal.fit

112356m055032\_20140406\_213341\_3\_abcdef\_r\_cal.fit

The filenames are made up of the following parts:

- The coordinates of the mission: RA=11h 23m 56s, Decl= -05° 50' 32". If the Dec is positive, then the "m" will be a "p". These are the coordinates used to plan the mission they are only an approximation of where the telescope was pointing. The precise coordinates of the centre of the image will be measured later by comparison to a star catalog.
- The date (yyyymmdd): 2014 04 06 and the time (hhmmss): 21:30:41 or 21:33:41. This is the timestamp from when the image file was created and is not a precise indicator of the time the exposure happened. The start of the exposure is contained in "FITS Header" information embedded within the file.
- A sequence number of images within the mission.
- A "random" 6-character string to ensure the name is unique.
- A letter indicating which filter was used:
  - l – luminance.
  - r – red.
  - g – green.
  - b – blue.
  - e – photometric visual.
  - d – photometric infrared.
  - v – photometric red.
- "cal" indicates the image has been calibrated.
- ".fit" is the file type

## **Identify and Measure**

We will need some specialised software to process the images and generate observations.

### ***Application Choice***

The initial challenge is to install the necessary software application and develop some skill at using it. The programs have help and tutorials, so I am not going to repeat the fundamentals here but concentrate on "best practice" as applied by the A-Team using Slooh telescopes.

There are two applications available. Astrometrica and Tycho Tracker.

- [Astrometrica](#) is a well-established and stable software package that runs on MS Windows. It has been "the standard" for amateur observers for many years. The workflow when using it is quite straight forward and the measurement results are of high quality.

- [Tycho Tracker](#) is a relatively recent (2018) introduction but is becoming increasingly popular. It runs on Windows or MAC and offers a much wider range of functions and options. This can make it somewhat more complex to learn and use. It produces high quality results and is much faster than Astrometrica.

I suggest you study the websites of these applications and decide which one to go with. Of course, if you are a MAC user the only choice is Tycho Tracker.

From this point, this Level 1 Tutorial is tailored to Astrometrica.

## Astrometrica

The initial challenge is to install Astrometrica and develop some skill at using it. The program has built-in help and tutorials, so I am not going to repeat the fundamentals here.

Astrometrica will be used to:

- Open the FITS files and display the images.
- Perform “Data Reduction” (also known as “Plate Solve”) to match the stars in the images to a star catalogue so that the exact sky coordinates of each pixel can be calculated.
- Show “known objects” where asteroids and comets with known orbits are indicated in the image.
- “Blink” the images so that we can clearly identify movement of the target.
- Measure the position and magnitude of the target.

## Installation

Astrometrica is a major piece of software, and you will need to be prepared to spend some time learning how to use it. It is also not free – but you get 100 days to play before you pay and at €25 it is well worth it!

The [home page](#) of Astrometrica has some introductory information and links to a download page. Download the full installation package, “Current Version with ADES format output”, including tutorials and follow normal instructions to install it. You do not need to download a star catalogue as we will access the main catalogues online. Have a look through the Help topics and get an idea of what all the menu items are about. Do at least Tutorial I. There are lots of discussions about Astrometrica on the web and you may like to watch a tutorial on [YouTube](#).

Before attempting to go any further with images from Slooh telescopes you will need to get some configuration files for the Slooh telescopes.

Firstly, open Astrometrica and go to Settings/Environment tab. There you will see three directories named. Make a note of the one called

MPCOrb. This is where your Astrometrica has decided to keep its copy of MPCORB.DAT (the orbits database).

### ***Settings and Configuration Files***

Astrometrica needs to be specifically configured for the telescope and camera system being used. The Files/Settings menu item leads to a set of tabs containing information about you, the telescope, camera, filter, star catalogue and other options. Settings are saved in configuration files. You will eventually accumulate lots of configuration files for the various telescopes and types of images. So, set up a folder to hold them.

As the configuration settings vary from time to time, you should get an initial set of current files from your A-Team tutor and tailor them for yourself.

The configuration files will arrive in an email. Set up a suitably named folder for them and save them.

Start Astrometrica and select File/Settings/Open and select one of the supplied configuration files.

Go to the Observing Site tab and replace the name with your own name.

- The format of the name is important. Observations submitted to the Minor Planet Centre will eventually be published in official scientific documents and your name will be indexed in the NASA Astrophysics Data System (<http://cdsads.u-strasbg.fr/>) (ADS).
- The format must be first initial, full-stop, blank, (second initial, full stop, blank), surname.

Program Settings - Canary Two Wide-Field - Gaia - ADES.cfg

Observing Site | CCD | Program | Environment | Catalogs | Internet

**Location**

MPC Code: G40

Name: Slooh.com Canary Islands Observatory

Longitude: 16.5083 \* ☐ East ☒ West

Latitude: 28.2997 \* ☒ North ☐ South

Height: 2372.3 m

**Details**

Submitter: A. J. Evans

Observer: A. J. Evans

Measurer: A. J. Evans

**Telescope**

Design: Corrected Dall-Kirkham

Aperture: 0.43 m Focal Ratio: 6.80

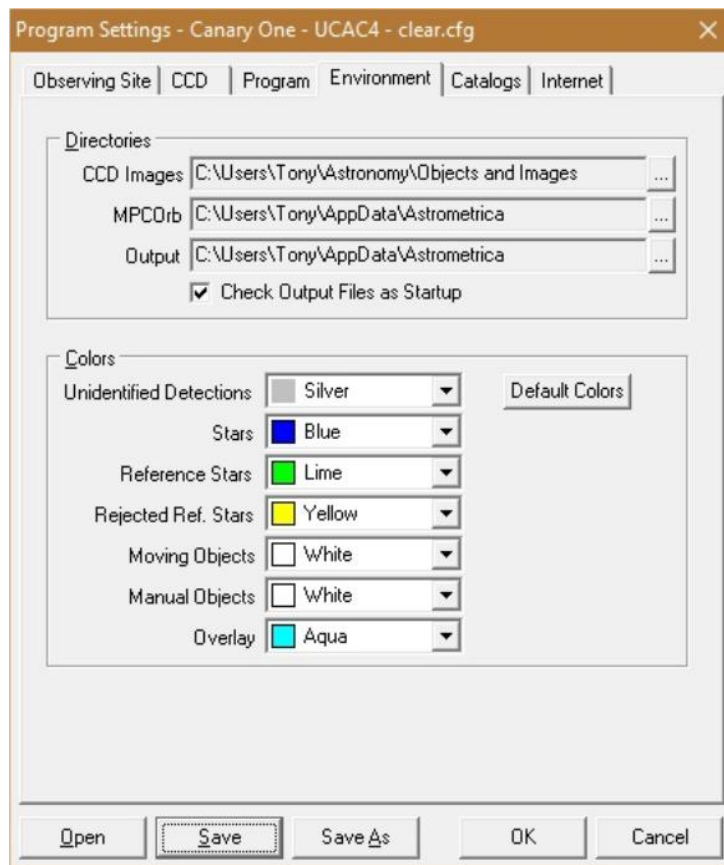
Detector: CCD (Charge oupled Device)

Open Save Save As OK Cancel

### *Observing Site Tab*

Go to the Environment tab and change the directories to those in your installation. You set each directory by selecting the [...] browse button and navigating to the required folder.

- CCD Images: Set the folder you want Astrometrica to open when you select File/Load images.
- MPCOrb: select the folder in which Astrometrica keeps its copy of MPCORB.DAT. Hopefully, you will have made a note of this earlier but if not, it can usually be found at C:/Users/(username)/AppData/Astrometrica.
- Output: This is where Astrometrica puts its output reports. The default is usually OK.



### *Environment Tab*

You can now “Save-as” the modified configuration file, giving it your own name and folder location.

Repeat the same process for each of the configuration files supplied by your tutor.

### **MPCOrb**

MPCOrb is a file containing information about the orbits of all known asteroids. Astrometrica uses the information in this file to work out

where the “known objects” should be in your images. It is necessary periodically to download a new copy of MPCOrb to ensure you have current information about recently discovered objects. This can be achieved in Astrometrica selecting Internet/Download MPCOrb. If you have not done that recently, do it now.

Now you are ready to process Slooh images.

## Identify & Measure

### *Data Reduction*

The objective of Data Reduction is for Astrometrica to match the pattern of the stars in your image to a star catalogue that contains precise details of their position and magnitude. Having done that, Astrometrica works out some figures that allow it to calculate the coordinates of each pixel in the image and to estimate the magnitude of any group of bright pixels.

### *Process the first image*

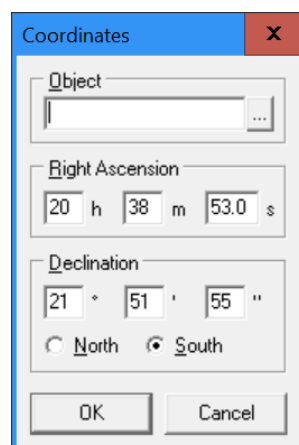
Open Astrometrica and check that you have the right configuration file loaded for the telescope and filter used for the image. (Configuration file-name is shown bottom right).

File/Load one of the FITS images from your first mission. (The Luminance image if you used Generic).

If Astrometrica shows you the FITS date/time stamp do not change it, just press OK. (The time stamp in the FITS header is accurate to about 0.1 second but the time in the file name is only approximate.) (You can switch off seeing the time stamp in File/Settings/CCD/Skip checking of Time after Loading.)

Select Astrometry/Data Reduction. Astrometrica needs to know the approximate coordinates of the centre of the image. You should enter the RA and Dec from the file name of the image and press OK. This is always the best way to set the coordinates and works regardless of whether your target is near the centre of the image or not.

- (Remember to select South if the Decl is negative).



*Set coordinates from the file name.*

Select OK and Astrometrica will download part of a star catalogue and try to match the stars in the catalogue to the image. If it is successful, you will see a Data Reduction Results window containing information about what was found.

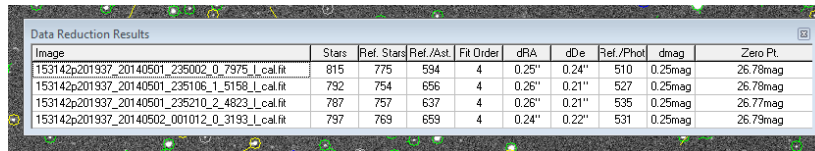


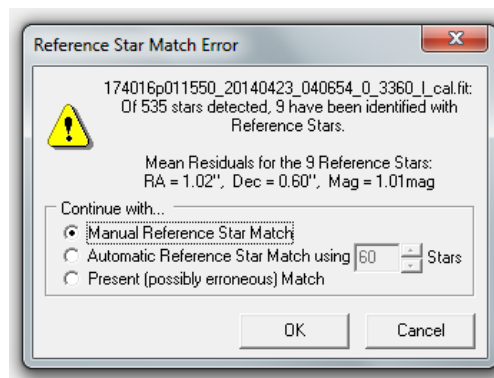
Image	Stars	Ref. Stars	Ref./Ast.	Fit Order	dRA	dDe	Ref./Phot	dmag	Zero Pt.
153142p201937_20140501_235002_0_7975_l_cal.fit	815	775	594	4	0.25"	0.24"	510	0.25mag	26.78mag
153142p201937_20140501_235106_1_5158_l_cal.fit	792	754	656	4	0.26"	0.21"	527	0.25mag	26.78mag
153142p201937_20140501_235210_2_4823_l_cal.fit	787	757	637	4	0.26"	0.21"	535	0.25mag	26.77mag
153142p201937_20140502_001012_0_3193_l_cal.fit	797	769	659	4	0.24"	0.22"	531	0.25mag	26.79mag

### Data Reduction Results

At this stage you should only be concerned that there at least a few tens of Ref.Stars and that Fit Order is not red!

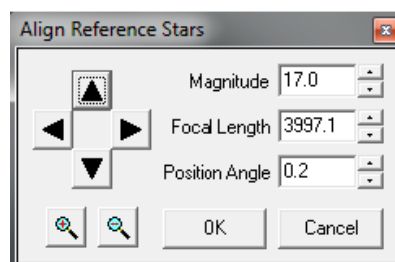
### Data Reduction problem?

If there is a problem with Data Reduction you will see a message like this:



### Data Reduction Error

Select OK and you will see another dialog like this:



*Adjust for a star match.*

Use the arrows to shift the circles around until they fit over the stars. You can try using the other adjustments as well to see what the effect is. When all the circles and stars are well aligned, press OK and you should see the expected data reduction results.

- Data reduction problems can happen if the telescope is not pointing accurately or after a maintenance visit when the camera has been moved.

If you cannot get a match, check you really have the correct configuration file loaded. Start again and repeat the procedure. If still no success, ask for help!

### ***Complete data reduction***

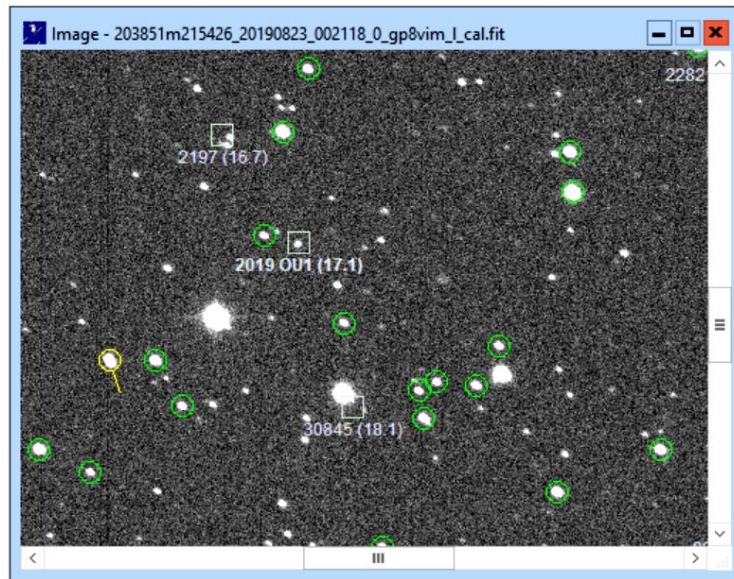
Assuming you have completed data reduction for the first image, File/Load one image from each of the other missions (leaving the original one open in Astrometrica). Repeat Data Reduction for these images.

Notes:

- You can load multiple images and try to do Data Reduction on them at the same time. This may work but it depends how consistent the telescope pointing was from image to image.
- If you try to do Data Reduction with the wrong configuration file loaded, it won't work! If you then load a different configuration file and try Data Reduction again it probably will still not work! You need to close Astrometrica and start again!
- If you used the Multi Luminance 50s recipe for your missions, you will have several luminance images for each mission. It does not matter which one you use for this exercise, but you only need one from each mission.
- If you cannot make it work, ask for help.

### ***Identify the Target***

With Data reduction completed for all three images, select Tools/Known Object Overlay. Astrometrica will search the database (MPCOrb) and work out which objects should be showing in your images. It will draw a little box round them. You can use zoom to inspect closely.



### *Known Objects*

In my example, the green circles are stars used as references and white boxes are known objects. You can select Image/Select Markings to change what is shown and Settings/Environment to change the colours used.

You should see your target object marked somewhere near the middle of the image.

There may be other known objects in the image and, depending on their magnitude, they may be visible. (You can measure them too if you like).

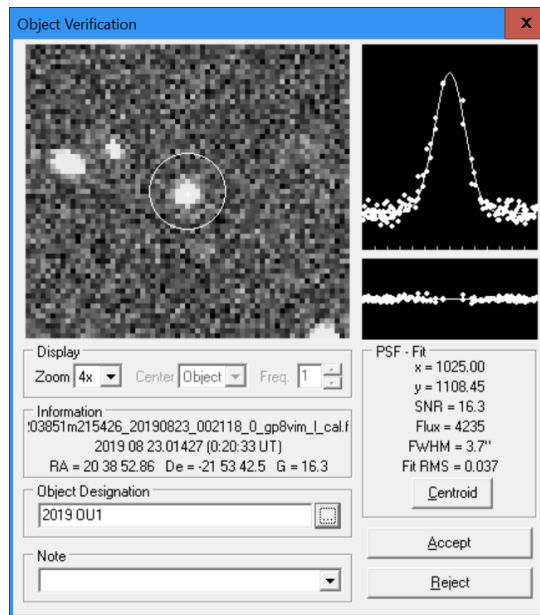
The “known object” box is sometimes not very well positioned relative to the object in the image. Do not worry too much about that. The main thing is to identify your object by seeing it move when “blinking”.

### *Blinking*

Select Tools/Blink. This will create a new window with the three images “blinking” and clearly showing movement. You can create an animation using any screen capture software you may have. (I find Screen-to-gif convenient for this). Post the results in the Slooh Workspace if you like. (You will see lots of examples in the A-Team and Comets Workspaces).

### *Measure*

The last stage of the process is to measure the position and magnitude of your target. Having carefully located its position (use the magnify window if it helps) click on it and the Object Verification window will open. Click on the [...] button next to Object Designation and a list of likely objects will appear. Select the correct one and OK.



Object Verification

Repeat the measurement for all three images, then select File/View ADES Report File. You will see something like this:

```
# version=2017
# observatory
# mpcCode 040
# name Slooh.com Canary Islands Observatory
# submitter
# name A. J. Evans
# observers
# name A. J. Evans
# measurers
# name A. J. Evans
# telescope
# design Corrected Dall-Kirkham
# aperture 0.43
# fRatio 6.8
# detector CCD
# software
# astrometry Astrometrica 4.12.0.448
# photometry Astrometrica 4.12.0.448
permID | provID | trkSub | mode | stn | obsTime | ra | dec | rmsRA | rmsDec | astCat | mag | rmsMag | band | photCat | p
2019 001 | | CCD | 040 | 2019-08-23T00:20:33Z | 309.72023 | -21.89513 | 0.07 | 0.07 | Gaia2 | 16.3 | 0.08 | G1 | Gaia2 |
2019 001 | | CCD | 040 | 2019-08-23T00:23:44Z | 309.71883 | -21.89892 | 0.08 | 0.08 | Gaia2 | 16.3 | 0.08 | G1 | Gaia2 |
2019 001 | | CCD | 040 | 2019-08-23T00:26:31Z | 309.71758 | -21.90231 | 0.09 | 0.09 | Gaia2 | 16.2 | 0.08 | G1 | Gaia2 |
```

ADES Report

What this all means is beyond the scope of level 1. Suffice to say that this file contains details of the measurements you have just made in the official Astrometry Data Exchange Standard (ADES) format.

## Residuals and Quality

### What are Residuals?

A “Residual” is the difference between where an object should be according to its orbit and where an observation measures it to be. There is almost always some difference because:

- The images we use for measuring suffer from the effects of “seeing” and the position of the object is estimated by trying to fit a nice smooth theoretical brightness curve (Point Spread Function – PSF) to a set of square pixels with values that include quite a lot of noise.
- The images have been calibrated using the measured positions of stars (same problem as measuring the position of the asteroid)

and the recorded position of stars in a catalogue that may have some random or systematic errors in it.

- The predicted position of the object is only as good as the accuracy of the orbit data, and this has been estimated using lots of earlier observations all of which had similar deficiencies as ours.

For now, we just want to have an idea that our measurements are reasonably consistent with the known orbit of our target.

### Find Orb

Find\_Orb is a piece of software that will calculate an orbit from observations and show the residual of each observation. We will install and use the Windows version of Find\_Orb in a later tutorial but meanwhile we can use an on-line version.

The on-line version of Find\_orb has limitations in its ability to solve some orbits and lacks the controls and settings available in the desktop version. We will tailor the input to on-line Find\_Orb to give it best chance of working properly.

### Prepare an observations file

Go to [MPC Observations Database](#), enter the number or designation of your object in the textbox and press Show.

### MPC Observations Database

A page will display showing lots of information about the object. Scroll down to the list of observations and select the “download” link.

Date (UT)	J2000 RA	J2000 Dec	Magn	Location	Ref
2021 02 20.469150	16 37 41.18	+68 39 35.1	17.80 G	703 - Catalina Sky Survey	MPS 1351544
2021 02 20.479987	16 36 56.76	+68 37 42.0	17.99 G	703 - Catalina Sky Survey	MPS 1351544
2021 02 20.485404	16 36 34.71	+68 36 45.2	17.68 G	703 - Catalina Sky Survey	MPS 1351544
2021 02 20.529215	16 33 35.18	+68 28 47.1	17.63 G	152 - Steward Observatory, Mt. Lemmon Station	MPS 1351544
2021 02 20.529461	16 33 34.17	+68 28 44.4	17.68 G	152 - Steward Observatory, Mt. Lemmon Station	MPS 1351544
2021 02 20.529706	16 33 33.16	+68 28 41.6	17.87 G	152 - Steward Observatory, Mt. Lemmon Station	MPS 1351544
2021 02 20.529952	16 33 32.16	+68 28 38.9	17.80 G	152 - Steward Observatory, Mt. Lemmon Station	MPS 1351544

### Observations list

This will take you to a plain text version of the observations list which you can save as a text file.

Open the text file and see what has arrived. If you have selected a low-number object, there could be a very large number of observations going back many decades. This will give Find\_Orb indigestion! Delete all the observations further back than the last two or three oppositions or a few hundred observations over the last few years.

When you have cut your observations file down to size, copy the entire ADES Report from Astrometrica and paste it to the bottom of the observations file, then save.

### *Calculate Residuals*

Go to [On Line Find\\_Orb](#).

Best not to get too worried about most of the stuff on this page. Go to the area where there is a Choose File button. Use that to select the file of observations you have prepared and select "Compute Orbit and Ephemeris".

Find\_Orb will now try to find an orbit that is optimised to satisfies all the observations as closely as possible. Output will be like a Minor Planet Electronic Circular (MPEC) – a document published by the MPC when it announces new discoveries, orbit updates and observations.

Scroll down to the section on "Residuals in arcseconds". You should see your observations (from G40, W88 or E62) near the end of the list. The two numbers next to them are your residuals in RA and Decl.

190729 F52	.05-	.18+	190811 595	.28+	.76-	190822 G96	.05+	.00
190729 F52	.06-	.13+	190812 595	.52-	.92-	190822 L06	.35-	.53+
190729 F52	.14-	.08+	190812 595	.51+	.10+	190822 L06	.25+	.61+
190729 F52	.03-	.06+	190812 291	.04-	.30+	190822 L06	.44+	.40+
190803 Q63	.78+	.21-	190812 291	.09-	.22+	190823 G40	.01+	.08-
190803 Q63	.49+	.14-	190812 291	.06-	.32+	190823 G40	.06-	.05-
190803 Q63	.33+	.27-	190819 691	.26-	.32+	190823 G40	.01-	.09-
190803 Q63	.31+	.11-	190819 691	.23-	.30+	190823 G40	.03+	.10-
190804 H21	.13-	.05-	190819 691	.11-	.31+	190823 G40	.05+	.03+
190804 H21	.02+	.13+	190819 K93	.12+	.13+	190823 G40	.04+	.10+
190804 H21	.55-	.31+	190819 K93	.00	.12+			
190806 474	.11-	.06-	190819 K93	.13-	.19-			

### *Residuals for G40*

When you have reached this stage copy the Pseudo MPEC page into a file and email it to your A-Team tutor together with comments about why you chose that object, any problems experienced or questions. You will get feedback on the measurements as soon as possible.

### *Quality*

If everything has gone reasonably well your residuals should be less than 1.0" . If they are less than 0.5" , well done!

If they are all consistently over 1" there may be a good reason. If they are scattered (large and small, positive and negative), try doing the measurements again.

There will be lots more discussion in later tutorials about the quality of observations as demonstrated by their residuals.

## Conclusion

Now you have completed the basic workflow, practice with a variety of objects and using different Slooh telescopes.

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*Tony Evans*