A-Team Tutorials
Level 3 with Astrometrica

Targets and Priorities

NEOFixer is the main source of NEO observing priorities. We should also consider unconfirmed objects and various other targets.

Near Earth Object Confirmation Page (NEOCP)

The Near Earth Objects Confirmation Page contains objects that have been recently discovered and require confirmation. Its focus is on objects that could be NEOs. Each object on this page has a "score" indicating how likely it is to be a NEO based on the observations so far.

NEOCP webpage

Objects on the list have Temporary Designations assigned by the discoverer. When sufficient observations have been acquired to confirm the existence of an object and generate an initial orbit, the MPC assigns a Provisional Designation (which it retains until it becomes a Numbered Object) and publishes a Minor Planet Electronic Circular (MPEC) announcing it.

NEOCPs are usually desirable targets but many have only a handful of observations and uncertain orbits. Bill Gray (developer of Find Orb) provides a summary of NEOCP objects that gives additional information derived from Find Orb automated processing. This can help identify viable targets.

When an object disappears from the NEOCP it may be found, with its new Provisional Designation, at:

Previous NEOCP Objects

This list also carries comments like "was not confirmed" or "was not a minor planet" for objects that were never confirmed, were lost, or turned out to be a satellite.

The ESA provides similar data in its NEOSCAN page.

Potential Mission Destinations

A selection of objects has been designated potential destinations in the Near-Earth Object Human Space Flight Accessible Targets Study (NHATS). There is a customisable list of these objects at:

NHATS.

Lowell Observatory

Various lists and query functions are provided at Asteroid Observing Services.

Sentry Risk Table

The NASA Sentry system monitors the probability of Earth impact of NEOs. All risk-related objects are listed but there are no facilities to select observable ones.

The NEODyS website lists the currently observable risk-related objects.

If a new object is discovered and is considered to have an impact risk, it is placed on the Sentry list, and the status of "Virtual Impactor (VI)" will appear against it in the MPC Ephemeris pages. It will also appear as urgent in priority lists.

Approachers

Regardless of urgency, objects making a close approach are often interesting and in the news. ESA publishes lists of "forthcoming and recent" objects approaching the region inside 0.05 AU of Earth.

Comets

At Level 3 we include comets in the candidates. Although the MPC maintains a database of comet observations there is much less emphasis on providing observation priority or guidance.

If a comet is considered a Near Earth Object, it will appear in NEOFixer listings the same as an asteroid. The PCCP (Potential Comet Confirmation Page) lists objects that are suspected of being comets but need confirmation observations.

The main exercise for Level 3 is to obtain an accurate position measurement for a big, bright, fuzzy comet. Please refer to the separate tutorial on comet observing.

Discovery

There is, of course, the alternative of trying to discover new objects. This is a highly competitive sport, especially with several well-equipped professional survey teams continually scanning the sky. There is one source of assistance at the Sky Coverage Plot. This MPC tool generates a map of where the major surveys have been imaging recently. It can be a starting place to find where not to look!

Visibility and Missions

Uncertainty

You are already experienced in finding coordinates and setting up missions for most objects, but we need to consider the situation when the coordinates are uncertain.

NEOCPs may have very few observations and their ephemeris may have an uncertainty that renders them difficult to observe. Some NEOs have few observations from years ago. You need to obtain the best possible coordinates for your missions and may need to plan several missions to search for an object.

The MPC Ephemeris page may include specific uncertainty information and an "uncertainty map" but this can be unreliable. Be particularly wary if you see a "One Opposition" object with no uncertainty map. It is probably "lost".

Find_Orb Ephemeris

A good way to get ephemeris and uncertainty information is to use the ephemeris-generating function of Find_Orb. Details of how to do this are described in the Find_Orb tutorial. Unfortunately Find_Orb is a Windows application but MAC-users with Tycho Tracker have a limited-function version attached to the Session Planning modules that "may" produce useful ephemeris.

Fast movers

The 20-second Multi-luminance recipe can be used to observe faster moving objects provided they are bright enough to provide sufficient SNR with the short exposures. The timestamps on images from Slooh telescopes are generally accurate to +/- 0.1 second. This translates to an error of +/- 0.25" for an object moving at 150"/m. So, in theory, a reasonable measurement could be made of an object moving at that speed.

However, such an object would cover a distance of 50" during a 20s exposure. So, the challenge is more related to accuracy of measuring a long streak rather than timing precision.

For extremely bright objects, you can try the photometric 10s or 4s recipe.

Identify and Measure

The basics of data reduction and measurement have already been covered in previous levels but here we need to look at some more difficult situations.

Close to Star

If you target is close to a bright star, the centroid may be dragged towards that star and give wrong position and magnitude. Use the Centroid button to examine the situation and find an aperture that

will fit the target and avoid most of the star. Go into settings and change the aperture to that size (do not save!). Then try to obtain a measurement using the small aperture.

Set the "close to star" note for this observation and make sure to check residuals.

Crowded field

If your target has a lot of background stars it may be difficult to isolate it against all the star trails. Visibility can sometimes be improved by using a Median stack rather than an average. Some of the trails will be removed or thinned out.

You can also examine your individual images and select just those where your target is clear of stars.

Fast movers

If an object is moving fast, it may produce a streak or trail in the image. Short streaks of up to 4 or 5 pixels may not cause Astrometrica a problem; simply click in the middle of the streak and check the PSF curve. Examine the way in which the centroid has positioned itself. Has it clearly looked for the centre of the streak in terms both of width and length? If not, you can try to enlarge the centroid:

- Use the Centroid Button and adjust the centroid size until it neatly contains the entire trail. Do not confirm this measurement but just use it to measure the size of the trail.
- Temporarily increase the Aperture Radius in Settings to match the required size.
- Try clicking in the middle of the trail and check if the positioning looks good.
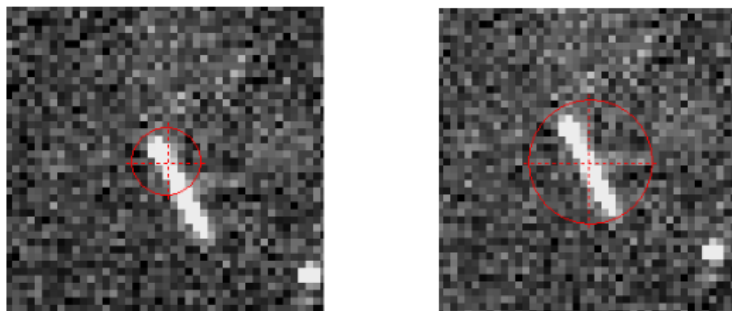
Measuring a trail

Reference stars

If your coordinates are in some regions of the sky, there may be too few stars for Astrometrica to use as references. In other areas there

are so many stars that Astrometrica gets confused and data reduction fails. To handle these situations be aware of the various catalogs that can be used and the Settings of Upper and Lower magnitude limit.

Settings/Program/Star Catalog determines the selection of catalogue and the range of magnitudes to be used. If data reduction seems to be overwhelmed by stars, or has too few stars to work with, you may want to consider using a different catalogue or magnitude range.

Catalogues
There is an outline of the various catalogs that can be used with Astrometrica at:

> [Star Catalogs for Astrometrica](#)

The most recent release of data from the Gaia satellite is now available (DR2 or DR3) and it has extremely accurate positions to quite faint magnitudes. When using Gaia, the Settings should be adjusted to

- Catalog: Gaia DR2 or DR3
- Color: Gaia Broadband
- Filter: Clear/None

Magnitude Limits
Associated with Catalogue-selection are Upper and Lower limits of magnitude. This controls the range of stars used for matching the catalogue to the stars in your image. It is sometimes necessary to adjust these limits:

- The Upper limit should be set so that there is no danger of Astrometrica trying to use stars that are saturated in the image.
- The Lower limit should be set so that that there are enough stars for matching but not so many that Astrometrica gets confused.

Focal length and rotation
Astrometrica relies on the Settings having correct values for focal length and field rotation. After a servicing visit (or extreme temperatures) these figures can change or drift.

Changes to focal length or rotation are periodically mentioned in the A-Team Club but if you are having trouble getting your images to register during data reduction:

Look in the log file of Astrometrica (File/View Log File.)

- Find where it states the focal length and field rotation for each successfully registered image.
- Average out the focal length and rotation it actually found for a few images and put these numbers in the Focal Length and Position Angle in the Settings.

Stacking Uncertain Objects

Normally, when doing Stack and Track you get the Motion and PA from the Ephemeris or allow Astrometrica to calculate it automatically using MPCORB. However, NEOCPs and new discoveries are not in MPCORB and the motion/PA data for objects with a high positional uncertainty may be quite wrong. For NEOCPs and other recoveries or discoveries:

- Use Find Orb with whatever observations are available to generate an ephemeris with motion and PA.
- Run Stack & Track with this motion and PA.
- Make a set of measurements, add these to the old observations, re-run Find Orb and make new ephemeris.
- If there is a big difference between your original motion and the that shown in the new ephemeris, repeat Stack & Track using the new figures and remeasure the object.

'Known Objects Box' problems

There are several reasons why an object may not appear in its known-objects Box.

- An object's orbital elements may have uncertainty. If the uncertainty is moderate the object will be seen (when blinking) moving close to its box or off-centre in its box. This is perfectly normal. Measure and report its position as usual.
- Sometimes you will see boxes for objects that should be bright enough to be visible – but no object. Check its uncertainty in the MPC Ephemeris and Observation DB. If it had only a handful of observations a few years ago, it is probably lost and could be anywhere. Astrometrica has calculated where to put the box based on the orbit described in MPCOrb, but that orbit is just a guess!
- If your copy of MPCORB is old, it will not include recently discovered objects. You will need to update MPCORB.
- If you are processing an old image, then the epoch of a recent MPCORB may be a long way from the date of the image and Astrometrica will put the box in the wrong place (possibly not in the FOV).

In the case of a recently discovered NEO undergoing a close approach, downloading a new copy of MPCORB may not provide an

accurately positioned box due to the way in which the MPC only recalculates obits periodically. You can fix this with Internet/Update MPCORB/Near Earth Objects (but this is quite slow).

NEOCPs

For NEOCP objects proceed with data reduction as usual and request Known Objects. This is to identify the known objects in the image and not mistake one of them for the NEOCP.

The NEOCP itself will not have a Known Objects box (because it is not a known object!). You will need to be exceptionally careful to check you have the right object and that it is not a false alarm (see below). The target may be some distance from the coordinates originally computed especially if there are few prior observations. In the Object Verification dialog enter the NEOCP designation in the Object Designation box. Be sure to enter it exactly as shown on the NEOCP page.

Check your residuals in the normal way to ensure your observations fit properly with the existing ones.

It is as well to check the NEOCP page at the MPC to see that the object is still there. If it has been promoted to a designated object you will need enter its new Provisional Designation instead.

You can find a list of newly assigned designations here.

Moving object detection

If your objective is to discover new objects, then proceed as normal with data reduction and display of known objects. You can try using Astrometrica's Moving Object Detection tool – it may come up with something. The tool works with a minimum of 3 and a maximum of 6 images.

The alternative is to blink the images and study them carefully. You will immediately "see" lots of things moving about.

False alarms

Most, (usually all) of the apparently moving objects in the image will be false alarms.

- Hot pixels are pixels that have "stuck" with the maximum value and appear as single pixel-sized points of brightness. They may appear to move from image to image because the telescope pointing has moved. Under magnification it is clear that the brightness has sharp edges, not like a real object that is smoothly spread by the PSF. However, there is a danger that hot

pixels get to look like real objects after tracking and stacking multiple images.

- Cosmic Ray (CR) hits are individual or small groups of pixels that have been brightened by the impact of a cosmic ray particle. The extent of the brightness varies according to the particle energy and its direction of impact. The bright region usually has sharp edges that do not look like a real object spread by the PSF. An individual CR hit will not "move" but it is easy for your eyes to deceive you into believing that different CR hits on consecutive images come from a moving object. There are lots of CR hits in most images.

- Satellites can sometimes appear as moving objects. Most move quickly and will be obvious. There are some satellites in higher orbits that regularly get "rediscovered" and appear for a while in the NEOCP. Subscribe to the groups.io MPML where these objects are often discussed.

- Beware also of internal reflections (e.g., from Moon light), dust motes (donuts), spots of condensation (usually the domes are closed before that can happen) and ghost images (typically Jupiter from the previous mission).

Temporary Designations

If you still think you have found something you will need to invent a temporary designation for it. Typically use your initials followed by a sequence number. (The professional surveys use complicated structures as seen in the NEOCP designations). The main rule for temporary designations is that they must not look like the name, number, or designation (full or packed) of a known object.

Measure the object in the normal way putting your temporary designation in the Object Designation field.

Use the MPChecker to make sure it is not already known. It may be worth checking the NEOCP list to see if someone else has reported it. You may also want to use the NEOChecker to get a score for it and decide if you want to submit it as a new NEO.

A minimum of 3 (preferably 4) images, showing the object moving with consistent speed and direction, should be obtained before believing you have found something.

Check the residuals to ensure the discovery is moving in a straight line with consistent motion.

Reports and Publications

At Level 3 there is no separate tutorial on Residuals and Quality. You have Find_Orb and it is up to you to decide whether you think your observations are good enough to submit. This applies to asteroids, comets, close approaches, NEOCPs etc.

A-Team Report

As in the previous levels, please post a report to the tutor or A-Team Club containing:

- A description of the target and why it is important.
- Comments about any problems with imaging or measuring.
- The .psv file you propose to submit.
- Find Orb residuals of the observations you propose to submit.

You may like to post an animated gif of the observations in the A-Team Club as do several other A-Team members.

MPC Report

The basic structure of the MPC report has been discussed before. The MPC Submissions page has some additional indicators. Do not mix up different kinds of objects in the same submission.

- NEOCP – Observations of an object on the NEOCP/PCCP.
- New NEO Candidate – Check this if you think your observations are the discovery of a new NEO.
- NEO – Observations of a known, designated, NEO.
- New Comet – Check this if you have discovered a new comet.
- Comet – Observations of an existing comet.
- TNO – Observations of a distant object.
- ARTSAT – Observations of a known Artificial Satellite.

The MPC will respond to a NEOCP report, usually within a minute or two, confirming the identity of the object. Your observations will appear in the observations list also within a few minutes. Your observation and name will appear in the announcement MPEC if the object is confirmed as a NEO.

If your target is a PCCP or you believe you can see cometary features, then you should use the MPCs special report page in addition to the normal ADES submission.

https://minorplanetcenter.net/mpcops/submissions/cometary/

The form is self-explanatory, and you must use it if you want your comments to appear in the MPEC. You must not use it for any known (designated) comet.

Discoveries

A potential discovery raises the question as to whether to report it immediately (and you may be wrong) or wait for a confirmation (and someone else may report first). There are some considerations:

- Are you sure it is a moving object and not an image artefact?
- Has a survey recently checked this region of sky? If so, is it reasonable that you have spotted something they missed?
- Have you used the MPC Checker, Comet Checker and/or Distant Satellite Checker to check for a known object?

Use the NEO Rating tool at the MPC to obtain a "score" showing how likely it is that your object is a NEO. If it has a score of more than 50 then mark it as "New NEO Candidate" in the submission form.

At the end of the day, if you are feeling reasonably confident, send the report and see what happens.

Try to follow up as quickly as possible. Use Find_Orb to predict where it will be tomorrow night or later today at another Slooh telescope.

Note you will not be officially credited with being the "discoverer" until the object becomes numbered, and it is confirmed that you provided the earliest observations as defined in MPEC 2010-U20. Sadly, it is very unlikely these days that you will get credit because the big surveys, with years of images, can probably show they saw it first. There is more information here.

Submissions

If approved by your tutor, send the report to the MPC.

Once you have demonstrated the ability to execute the complete workflow reliably a few times, with a range of object types and good judgement regarding your residuals, you will "graduate" and be authorised to send reports without needing to check with anyone. However, I hope you will continue as an active member of the A-Team:

- Post information in advance about you targets so we don't duplicate our efforts.
- Post results and experiences because we are all interested in seeing who is observing what.
- Occasionally post a gif and report as an "Observation" so that all members can see what we are up to.

Publications

MPC Publications remains the best places to look for your observations. You can also find them in the NEODyS or AstDyS

systems with their residuals and indicators as to whether they were used as part of the orbital solution.

ADS (SAO/NASA Astrophysics Data System)

ADS is a formal bibliographic reference and abstract database for matters relating to astronomy and physics. The checks made by the MPC constitute "peer review" of your observations and after publication they are eligible for inclusion in the ADS service. Entry to the service is at:

[ADS Query Form](#)

You can search using your name (last name, first initial) and in the title field put "Observations and orbits of comets".

Congratulations! You are now a named (co)author of a formal scientific document! Note, however that it may take some time before your name (as co-author of an MPEC) begins to appear in the ADS listings.

Conclusion

This is the end of the A-Team Tutorials. I hope it was challenging but enjoyable.

<div align="center" style="color:red">Congratulations on getting this far!</div>

But now – we need your help to improve these tutorials for the next generation of students. Please provide comments and suggestions and any additional notes about special techniques you know.

Now you are a fully-fledged A-Team member, and you can research topics of your own. Have fun!

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