A Practical Guide to Asteroid Chasing for the Amateur Astrometrist

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So, you are interested in Asteroid chasing and learning how to perform Astrometry on these objects? Within this guide, we want to introduce you to this fascinating world. But be warned, Astrometry can be an addiction!!

This is a general guide to perform and organize an Asteroid study session and might change in some aspects due to astronomer experience, instrument setups, sky conditions, observatory characteristics and the type of object being observed. Nevertheless, this guide could be a useful aid to accelerate or improve the observing experience. Knowledge and certain skill using some astrometric software and planetarium programs are recommended when using this guide.

INTRODUCTION

Asteroids are a class of astronomical bodies or objects that orbit around the sun. The term "asteroid" comes from the Greek word meaning "star like" used in a common way to indicate the bodies are "wandering" around in the Solar System. The International Astronomical Union prefers to call them Minor Planet Bodies. They are also known as Planetoids ("planet-like") and more actually as Small Solar System Bodies (SSSB). This last term includes Comets, Centaurs, Trans Neptunian and other objects also. Today, the largest minor planets are called “Dwarf Planets”

Ceres was the first Asteroid discovered and it is the largest known to date. According to what we said before regarding the "largest minor planets", it is considered as a Dwarf Planet. It was discovered in 1801 by the director of the observatory of Palermo in Sicily, Giuseppe Piazzi. Notable asteroid hunters of this early era were J. R. Hind, Annibale de Gasparis, Robert Luther, H. M. S. Goldschmidt, Jean Chacornac, James Ferguson, Norman Robert Pogson, E. W. Tempel, J. C. Watson, C. H. F. Peters, A. Borrelly, J. Palisa, Paul Henry and Prosper Henry and Auguste Charlois. The pioneer on using photograph methods for Asteroid discovering was Max Wolf in 1891.

Asteroids come from different Solar System zones and they are identified according to these zones as follow:

MAIN BELT ASTEROIDS: They reside in a band between Mars and Jupiter orbits and are the most common and numerous of the asteroids.

NEA's (Near Earth Asteroids): Are those having orbits near to our planet. More than 4000 NEA's are known to date and are sub-divided into three groups: Amor, Apollo and Aten. The Amor group crosses Mars' orbit but not the Earth Orbit. Apollo and Aten Asteroids are crossing the Earth orbit in different periods: Apollo cross the Earth orbit in more than one year period. Aten asteroids do the same in less than a year.

JOVIANS: The Jovian Asteroids have orbits around the Sun following planet Jupiter.

CENTAURS: Orbit between Jupiter and Neptune.

TRANSNEPTUNIAN: Objects crossing Neptune orbit (very distant).

Nevertheless, Asteroids are classified into groups based on the characteristics of their orbits and on the details of the spectrum of sunlight they reflect.

These groups are known as "families" and are defined this way because they are sharing similar orbital elements, such as semi axis, eccentricity, and orbital inclination. It is customary to name a group of asteroids after the first member of that group to be discovered. Also, "cratering families" are distinguished and they are formed by ejecting fragments from Asteroid impacts. Thus we have families as Themis, Eos, Nemesis, Maria and others. The spectral classifications are defined by the Asteroid's physical characteristics as colors, albedo, materials composition and spectral shape. They are known as taxonomic properties. The spectral classification was introduced by Clark Chapman, David Morrison, and Ben Zellner in 1975.

The near-Earth asteroid 433 Eros had been discovered as long ago as 1898, and the 1930s brought a flurry of similar objects. In order of discovery, these were: 1221 Amor, 1862 Apollo, 2101 Adonis, and finally 69230 Hermes, which approached within 0.005 AU of the Earth in 1937. Astronomers began to realize the possibilities of Earth impact. (Wikipedia)

All the Small Solar System Bodies (asteroids or comets), which are approaching within 1.3 astronomical units of the Sun (150 Millions Km or 96 millions Miles), are called and considered Near Earth Objects or NEOs.

Two events in later decades increased the level of alarm: the increasing acceptance of Walter Alvarez' theory of dinosaur extinction being due to an impact event, and the 1994 observation of Comet Shoemaker-Levy 9 crashing into Jupiter. The U.S. military also declassified the information that its military satellites, built to detect nuclear explosions, had detected hundreds of upper-atmosphere impacts by objects ranging from one to 10 meters across. All of these considerations helped spur the launch of highly efficient automated systems that consist of Charge-Coupled Device (CCD) cameras and computers directly connected to telescopes. Since 1998, a large majority of the asteroids have been discovered by such automated systems. (Wikipedia)

In spite of all the existing automated searching systems installed around the world and the well documented discovers until date, Asteroid searching and study continues within an area in which the Amateur astronomers have the opportunity to contribute and interact in a direct way with the professional Astronomy world.
The most collaborative practice today is Asteroid's light curves. With them we can detect the way the Asteroids moves in the space, including its rotation movement. Asteroids can be grouped in systems of two and even three bodies interacting between them. These studies are a conjunction of Astrometry and Photometry given a more interesting fact to the Asteroid chasing world, but this kind of work demands more instrument power. More on Photometry can be found at the Palmer Divine Observatory

Hope you enjoy and find this guide very useful.

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Chapter 1: INTRODUCTION TO ASTROMETRY

It is very important to understand how to work well with all the pieces that allows a successful astrometry session. This includes our instruments, cameras, software, and knowledge. You would need to investigate and make some calculations to determine some of these points in detail. The following is a briefing of things that we must understand to have a "soft" introduction to Astrometry. Remember, the most important things to add to this list is patience, perseverance, and fun!

As a checklist, we could have the following points:

Completely understand what your instrument is capable of doing, considering the optical configurations that can be configured and their parameters. You can use many calculation formulas and software that is available on the Internet for this. Here is an application (eyepiece calculator) by Marcelo Saavedra that contains the most common formulas: http://www.snapdrive.net/files/323779/Astronomy/EPC.zip

In the same line, you will need to know your camera's capabilities and characteristics, and how it (they) conforms a unit jointly to your instrument. To have this information always handy, it is a good idea to build an Excel spreadsheet with your cameras specifications as pixel size, pixel array size, total pixels, full well capacity, typical read noise among others and which image scales and FOV you can reach with different optical configurations. A very good and useful tool to know you CCD/Telescope performance is the free Ron Wodaski's CCD Calculator. You can find it here: http://www.newastro.com/newastro/book_new/camera_app.asp

Regarding the setup operation, you will need to practice how to locate a specific celestial field in your telescope/ccd. In spite of the use and connection using a computer between planetarium software and your telescope, tangent boxes and integrated firmware's into the telescope control boards can be used also to locate the fields. Also, you should have a good idea on how accurate your telescope/mount can aim to the field center. By using star charts or software you should be able to identify that what you are seeing with your CCD, is that same field showed in these charts. Once done, then the magnitudes you are reaching with your "seeing conditions" must be estimated. Astrometry procedures can be applied to define the limited magnitudes also but this should be explained in another guide. This will give you an idea of what you can expect to reach, follow and find.

Depending on your mount accuracy, you could need to do auto-guiding by using any known method in order to achieve the wanted exposure length. This will require some expertise and experimenting with your particular setup and we would recommend doing a mount test to define this. You can use any software with auto-guiding capabilities and use the guiding log to trace and analyze your mount behavior in an Excel graph. A very good couple of free software that you can use to do this are PHD (guiding software) and PEAS (periodic error analyzer). With both you can determine your mount characteristics very well.
PHD http://www.stark-labs.com/phdguiding.html
PEAS http://web.telecom.cz/elektro-metal/peas_a.htm

The last point of this very short and summarize list involves the use of your CCD and the related imaging and Astrometry software. You must be very clear on how and when to take Bias, Flats and Dark shots and how to do a good images calibration. This is very important because dark/cold pixels, cosmic ray hits and other artifacts can produce false identifications and detections, so you would be very sure to reduce these possibilities to their minimum. Many imaging software programs are capable to do astrometry reductions, blinking and stacking. It is important to read the software manuals and tutorials in depth. Play with them; investigate the terms and functions in your software that you are not sure about in order to feel comfortable and confident handling them.

This "load" of information may sound very complicated and confusing, but after reading through this guide and working with your equipment to produce your own astrometry, all of this information will become clear.

Chapter 2: PREPARING FOR AN OBSERVING SESSION

1. By using planetarium software and MPC data, prepare your observing session.

2. If you are beginning in this passionate world, it is better to go for slow and brighter objects first. MPC requires the observing and measuring of objects numbered in the catalogs between 400 and 40,000 to obtain an observatory code number. They are slow and bright enough to obtain observing experience. Low numbered objects (0 to 399) already have well established orbits and additional data really does no good. By asking to go for higher numbered asteroids, a dual purpose is served: first, to check on the quality of the measurements and, second, to contribute useful data. But, the lowered numbered asteroids are not ignored entirely. They are often picked up by most surveys and caught during regular work by others from time to time. The surveys report data from all detected objects.

3. If you have some experience in Astrometry, then you would want to choose targets that actually need observations and they would be in the observer’s best interest. This process is commonly called “follow-ups” and requirements of them can be found on the MPC - Minor Planet Center Web site.

4. On a typical night doing follow-up observations, you could start out with a list of say, 10 potential targets to have a good inventory of them. Depends on the time needed to get the data for each one, maybe you will not be able to cover all of them, or you may have the opportunity to go for 2 or 3 more. A fast bright object could require less imaging time then say faint and slow moving objects.

   NOTE: If you are planning to observe slow objects, select 3 or 4 other objects in "near" field areas around the main target to perform a slew between them during the observing session. Giving enough time for the objects to move is a general rule in astrometry

5. It is better to locate the target fields with enough separation to do comfortable work and with enough time between them during the whole observation period.

6. Make sure to calculate the correct optical path to be used to guarantee a good pixel scale (MPC recommend a 2 arc seconds per pixel scale or 3 on the worst of cases) but you must be sure that your used configuration will allow you a correct “seeing” of the objects to be studied and a good PSF (Point Spread Function).
   Take in mind that the MPC’s pixel scale is a recommendation and will vary based

on your site seeing. You have to determine the best spatial sampling for your particular site.

Since most amateur sites have seeing in the range of 4” to 5” the 2 arc seconds per pixel works out well on average and was selected because this scale fits the seeing disk at most of them. Some sites actually have better seeing and can select a different scale.

To go more in depth into this topic we could recommend excellent Herbert Raab's article “Detecting and measuring faint point sources with a CCD” reading.

7. Another aspect that should be taken into account is the computer time accuracy. It is fundamental that the computing time error be less than 1 second. You must be sure to synchronize the PC clock with a NPT server around the world by using the internet before and during your session. Also, you will be sure that the time stored in you FIT image header will be in UTC format and not local. This is very important! Consult your software manual.

Chapter 3: AT THE TELESCOPE

AN EXAMPLE / PRACTICE SESSION

1. To prepare the telescope checking if necessary, the perfect polar alignment and a clean optic. Windex cleans the lens well and dries with no smears, but check with your telescope manufacturer for specifications on this.

2. Make sure to have all the tools to make a good image calibration, taking Bias (if you normally use them), Flats and Darks frames. You will need the best possible images and this step is a must.

3. Check the correct telescope slewing and centering of known objects within the FOV.

4. Slew the telescope to the first selected field to be studied and verify the scope is in the correct location. This can be done with data reduction with astrometric programs or compare with your planetarium program.

5. Take a moment to get perfect focus in both, guiding and imaging setups.

6. Calibrate the guider system and begin auto-guiding (if needed). If the object is bright and your telescope system is capable of 30 to 45 second exposures without auto-guiding, then an auto-guider may not be needed at this point. Most faint objects will require auto-guiding when using the "average" amateur based telescope and equipment.

7. Select the maximum exposure time to avoid any star trailing or asteroid trailing in the resulting images. You must achieve maximum exposure time appropriated to obtain the desired magnitude.

8. Once determined and the exposure time is set, begin the exposures - saving the images in a pre-determined folder of your choice.

9. After a 15 minute time frame and by using you astrometry software, blink the obtained images and try to locate the target(s) by their movement in the FOV (Field of View).

NOTE: 15 minutes is taken as a reference time and be aware that imaging time will vary depending on the objects speed and the instrument being used. The main idea here is that some exposing time has passed and motion can be seen from the object.

10. You are now sure that the current field of view is properly aligned and the object is near centered. If the object(s) of interest are near the image center and away from any bright stars, continue exposing, guiding, and auto-saving the images for a period of at least one hour (unless the object is moving very fast). Checking the targets path with planetarium software will help avoid star interference also. If this interference exists, come back to the object once it has cleared the star.

11. Now you have captured the light from the object. These images can be stacked in your astrometry software according to the objects motion (xxx"/min and P.A. yyy). At this step, you can be on presence of two different cases depending on what you are looking for: slow moving objects or fast moving objects (normally NEOs - Near Earth Objects).

a. Slow moving objects: Since this object is moving so slow, you may (or may not) slew to and measure other objects, coming back to the original target for more images making an observation/imaging cycle and waiting for a significant movement from the object. If the object is slow, this leaves a lot of time to leave the field and return only after the object has moved a significant amount of arc. It would take a particular object an hour or more to move even a few pixels for a given setup. You could image a lot of sky somewhere else in that amount of time. It's normally more efficient to image other objects and come back to it.

b. For a fast mover: it might be better to get all the frames at once since the object has moved enough arc to get 3 good positions. Take them and move on to the next object. You can still stack these altogether and look for other fast movers streaking across your field but at least you have 3 good positions to submit. We will see this case later because it is considered as an “advanced astrometry” procedure.

12. Finally, VERIFY darks, flats, and bias - these are a must!!! Darks, flats, and bias images may be taken and saved prior to the observing session to save time while actually working at the scope. Calibration frames: flats and darks are a must.

13.You are now ready for the data reduction.

Chapter 4: AT THE COMPUTER

DATA REDUCTIONS

A common and very useful process for fast moving asteroid searching is the “track and stack”.

The track and stack technique allows you to align and then stack the images in two different ways. You can stack the images by aligning the stars, or you can stack the images by using the motion ("/min and P.A.) of the object - causing the stars to "trail". (not all astrometry software will align the images before stacking. In this case you can use your imaging software to pre align the images and use them to stack).

Normally you can “manipulate” the stacking speed and direction. Speed means how much one image is separated from the consecutive ones in pixels causing the “static” stars to appear as trailed lines. The Direction is known as “Position Angle” or P.A. for short. It allows you to set the movements directions of the images. If both parameters (speed and P.A) are shifted, you would see the stars as a trails and the minor planets as a static point. If Speed and P.A are set to 0 then the stars will appear as a point and the minor planets as trails. We use both cases together to detect the minor planets but giving a correct speed and P.A. to the image set will add (or average or median) the asteroids signal in our set and then possible unappreciable minor planet in one image can be seen in the “stacked and tracked” image. Normally, when a series of images are stacked using this procedure, the astrometry software will produce better measurements.

Here is an example of an Stacked images without tracking (Speed=0). Note the trace made for the 66MAJA Asteroid at the bottom left:

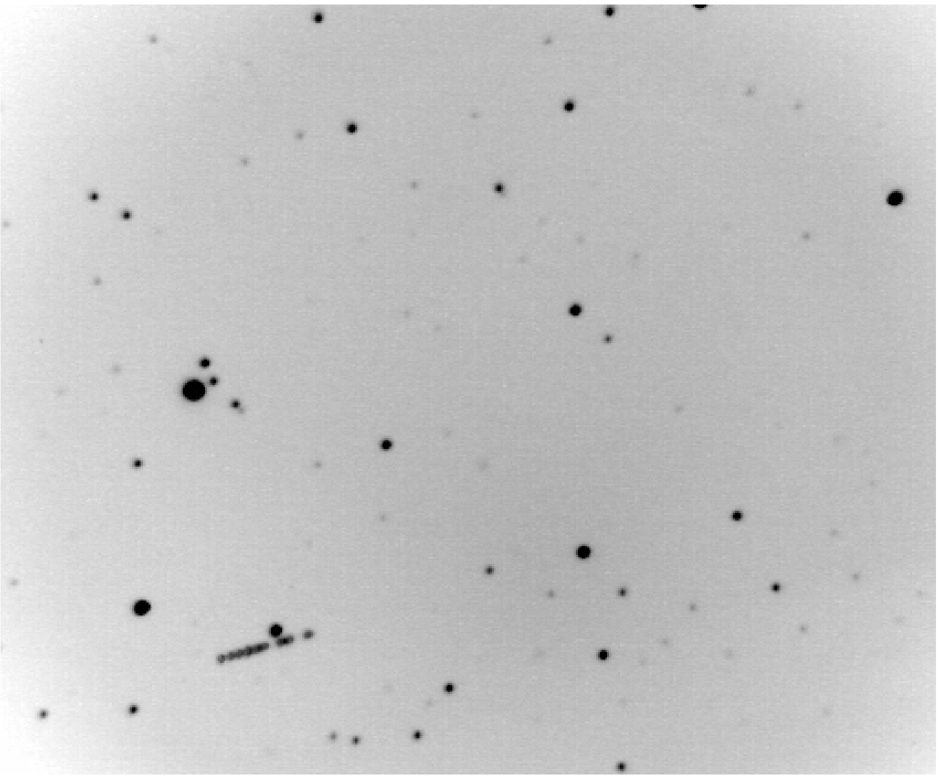

Image of Asteroid 66-MAJA by Marcelo Saavedra

Now, the same image with Speed=0,63 and PA=287,3. Note that 66MAJA appears as a static point and the stars as tracks:

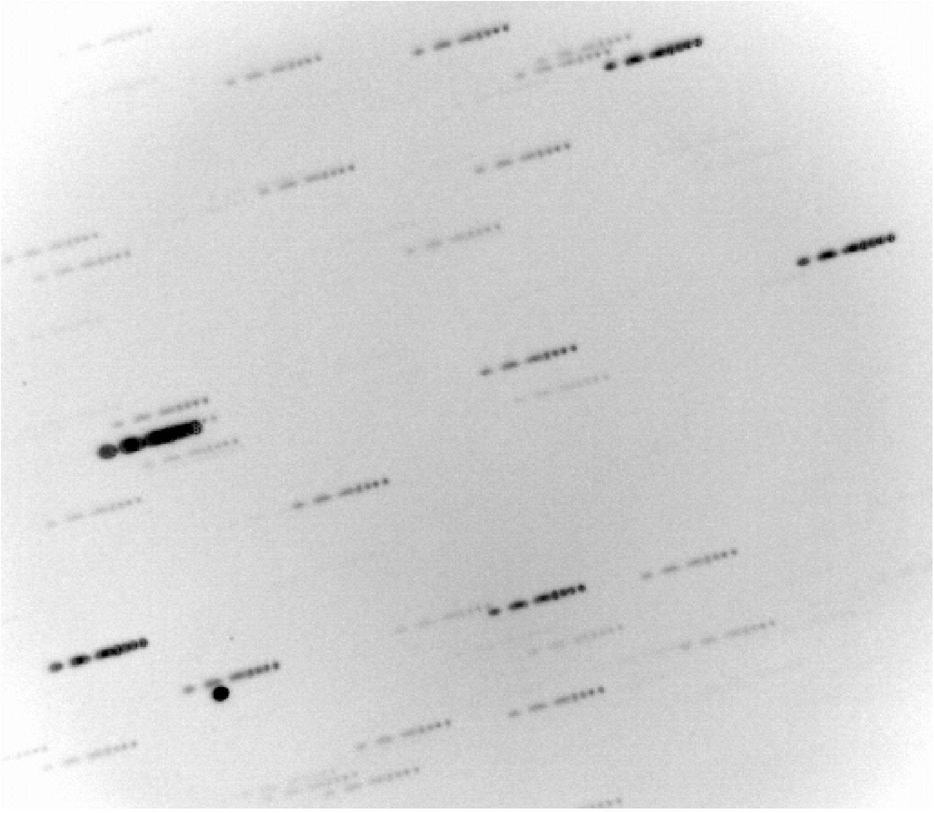

Image of Asteroid 66-MAJA by Marcelo Saavedra
Both Images taken with a 0.2 m SCT Telescope
CCD ST237A at -7 Degrees
20 Subs 3minutes each.
Binning 1x1

In order to explain some things more in a practical way, suppose that we have taken 40 images in one hour with 1.5 min exposure each.

Considering our example, you have a total exposure time of 60 minutes. You would stack all 60 exposures with 0"/min and a P.A. of 0. Very faint stars will appear in the finished image, and faint trails will appear from any bright moving objects! Faint "moving" objects normally do not appear in stacked images using the average equipment.

NOTE: In the practice, you can detect any object at any exposure length depending on the object’s brightness and motion. However, very fast and faint objects will often not be detected in a single short exposure unless you have an extremely large aperture.

Another way to detect moving objects is using the “Blink” feature. It is like the “old” movie composed by photograph frame, passed one after another with a given speed to create a movement effect. In our image set, If the moving object is bright enough to appear in each (or some) images, blinking them could be useful to determine the motion speed and angle. If not, track and stacked should be used with an empiric values for Speed and P.A., trying to locate the object.

In conclusion, if no trails are noticed in the images, then you can try re-stacking the images at various speeds and different P.A.s to search for faint objects. One possible method to avoid wasting your time doing a “try and error” on the Speed and P.A. could be start by stacking and shifting the frames based on the object’s known motion. Take present that if you are trying the “Main Belt Asteroids” or MBAs, the movement on these objects could be very slow. In that cases, the detection can be done by just imaging an area long enough to detect the object and then measure it. If there is an MBA in the field and is bright enough to detect it you’ll find it without the images shift.

A good practice is to divide the total images in equaled slices for track and stacking. For our example, if 40 images were taken in one hour with 1.5 min exposure each then 4 stacks of 10 subs of 1.5 minute exposures would be stacked according to the objects motion so that it would "bring out" the light of the asteroid.

You would load and stack the first 10, then the next 10, and so on until you have four "staked", reduced images blocks with increased asteroid signal on each of them, made from our supposed 40 images collected.

Next, they would be blinked to re check and extract some useful information needed. In the blinking window, you would do the measurements and name the identified objects. If you found an unknown object or other than one on the NEOCP, you would assign your own name to it such as **NAME015** as a temporary name but MPC will assign the name they considers correct.

Note: If a new object was found, you should take measures in at least two different nights, covering no less than 30 minutes of observation on each one. But, if the object appears to be an unknown FMO (Fast Moving Object), then a number of measurements should be taken and the object can be reported as a "one nighter".

NOTE: The name submitted to the Minor Planet Center must contain 6 or 7 characters for their computers to recognize it as observations.

Once your images reduction is done and you feel that a new object is on your images set, first check the MPCChecker.
Typically the MPCChecker is used when you have already detected something you think is new and are trying to eliminate a know object as being new. Also if your astrometry software has an option to make an overlay of your image with star catalogs you can use this option to look for unknown objects.

Finally, you would report the object to MPC by using the report option in your astrometry software or by sending an email in PLAN TEXT (no HTML) to the MPC using its normalized format (take a look here for more details: http://cfa-www.harvard.edu/iau/info/Astrometry.html).

Hopefully this will produce new objects, and at the same time produce follow-up observations on known objects. A new discover while imaging other known objects could happen but some astronomers could think that if you want to find a new object then start looking in other unexplored fields.”

Chapter 5: HOW TO OBTAIN AN OBSERVATORY CODE

Obtaining an observatory code should be a goal set by anyone who is interested in building their own permanent observatory or plan to observe from the same location every viewing session. The primary purpose for obtaining an observatory code is to document specific details about your observing site and the types of instruments used within your observatory. This will not only tell the Minor Planet Center where you are at or what equipment you use, it will also "announce" to many astronomical centers and stations worldwide that there is an active observatory at this particular location. Obtaining an observatory code takes a little experience in astrometry, a telescope capable of tracking objects for short (or long) periods of time with a CCD camera, astronomical software to accurately measure the object, and a lot of patience. I'll later explain the steps that I took, in as much detail as possible, in hopes to give a general idea of "what can be done" to achieve this.

Part 1: Getting Started

Telescope:
The proper telescope needed to perform astrometry should be capable of guiding for a period of time usually no less than 30 seconds for the average object. The "go-to" telescope works very well for this and if purchasing a new telescope it should be took into consideration. Below is a list of telescope companies.

Meade
Celestron
Orion

CCD:
A lot of technical details can be brought into consideration when discussing CCD imagers, so this explanation will be kept as simple as possible for a newcomer to CCD astrometry. CCD imagers come in a variety of styles with the most common probably being the SBIG (Santa Barbra Instruments Group) CCD cameras and the Apogee CCD cameras. Below is a list of CCD Imagers that may be used for astrometry.

Apogee
SBIG
Starlight Express

Software:
The software used will be according to the person who will be performing the astrometry. Also needed is a synchronizing program to keep the time clock on the computer extremely precise. Here are some links to various software packages for producing astrometry:

Astrometrica
MPO Software
CHARON Project Pluto
FindOrb

Part 2: Minor Planets to Observe

Once you have your telescope, CCD, and Software packages of your choice, you are now ready to prepare for your astrometric imaging session. The Minor Planet Center requires that you observe a number of "low-numbered" minor planets (400 - 40,000) each on pairs of nearby nights and try to observe objects of various brightness. They are not very specific with an exact number of objects to work on but I would recommend at least 3 objects over a period of 2 nights to produce good results. But, the objects should be well within the limits of your equipment. You should also take into consideration the speed of the objects to measure. You wouldn't want to try astrometry for the first time on a fast moving object.

These objects can be found in nearly any planetarium program capable of loading asteroids and comets. Some planetarium programs are listed below.

Hallo Northern Sky
Cartes du Ciel
The Sky

Other ways to determine object selection can be found here:

http://www.cometary.net/asteroid_hunting_tips1

Some examples of asteroids to image would be:

(817) Annika 15.6 magnitude on 20070226
(478) Tergeste 13.7 magnitude on 20070226
(1145) Robelmonte 16.8 magnitude on 20070226
(529) Preziosa 15.6 magnitude on 20070226

Remember, these objects will vary accordingly to the equipment being used for the measurements.

Part 3: Imaging the objects

To many people, this is the toughest part. The position of the object has to be determined and centered accordingly. It is very irritating to spend time on imaging an area only to find that the object is just outside the FOV. After many nights of doing this one can loose interest and finally give up. But, by spending a little time learning how to operate your telescope, CCD, and software, this can be easily overcome. For example: If you have a go-to scope such as the Meade LX200 GPS, an SBIG CCD imager, and CCDSoft, you can use the CCD to center the scope on an object. The telescope can be slewed to a brighter star very near the object to be imaged, and then center the star in the FOV by using the auto-center function in CCDSoft (right click on the star in the image). Once the star is centered in the FOV, simply sync the telescope on that star. If the drives are "decent" in the scope, you should be able to accurately slew to the exact location of the object and begin the auto-guide sequence (if needed). Focus the telescope, take your images, save them to a predetermined file, and slew to the next object. Also, collect flat fields and dark frames according to your telescope/CCD combination, CCD temperature, and focal length.

Part 4: The Astrometry

This is the fun part. Everyone has their own special techniques that they do to perform astrometry. I guess this could be considered a “customized” area of astrometry. But the main goal is to produce correct, accurate results.

Currently, there are several programs that are available for producing astrometry. They are used to calculate the stars in a field, and “align” your images with these stars. Once the program has determined the reductions on the images, positions and magnitude estimates can be performed on any objects within the FOV. The techniques used to process your images will be determined by the technique you prefer and the quality of equipment and images you collect.

Here’s a quick example on performing astrometry on an object in your images.

1. Load the Astrometry program.

2. Load your images containing the object.

*These may be single exposed, stacked, have the flats and darks removed, etc…

3. Command the Astrometry program to perform a data reduction on the images. Here you will need to know the center position of the FOV in R.A. and Decl.

4. Click on the object in each of the frames to allow the program to “mark” the object with proper position and magnitude. Assign the object a “user defined” name that contains 6 or 7 characters (letters and numbers). (Ex.000001, 0000001, A00001, 100000A) Just remember to assign one unique identification per object to prevent confusion in the calculations.

5. Check your residuals by using a program such as FindOrb.

6. Use XXX for the observatory code when submitting your first set of measurements and /or while awaiting for approval and official code assignment from the MPC. This informs the Minor Planet Center's computers that these reports are coming from a new (unregistered) station and a code is being requested.
You could continue sending reports under XXX code but once you reported your first set of positions for the code, you would want to wait until confirmation from the MPC until you report any more observations. This way you would verify that everything is acceptable. You could gather the images and collect the measurements while waiting for the code.

Upon receiving your measurements, the Minor Planet Center will review your report for errors. If your report and measurements pass, they will assign your observatory code within a few days.

Here are some of the original positions that was sent to the MPC for Observatory Code H68.

Tomeileen (2443)
0TOMEI C2006 08 03.08950 15 08 24.94 -07 12 53.8 17.2 V XXX
0TOMEI C2006 08 03.09958 15 08 25.20 -07 12 59.3 17.0 V XXX
0TOMEI C2006 08 03.13052 15 08 26.20 -07 13 12.9 16.7 V XXX

Mercedes (1136)
0MERCE C2006 08 03.11436 15 01 32.70 -10 26 40.3 15.9 V XXX
0MERCE C2006 08 03.13689 15 01 33.51 -10 26 45.5 16.4 V XXX
0MERCE C2006 08 03.14758 15 01 34.11 -10 26 47.0 16.3 V XXX

Krylov (5247)
0KRYLO C2006 08 03.16440 16 45 48.95 +08 04 29.0 16.0 V XXX
0KRYLO C2006 08 03.17800 16 45 49.41 +08 04 24.4 16.1 V XXX
0KRYLO C2006 08 03.19873 16 45 49.98 +08 04 17.8 16.1 V XXX

Useful links: Guide to Minor Body Astrometry - Minor Planet Center

Chapter 6: HOW TO IMAGE FAST MOVING OBJECTS

Fast moving objects (FMOs) are a little more difficult to image than slow moving objects (SMOs), but it’s still easily done with the proper procedures and techniques. How do you define a fast moving object? Actually, FMOs are usually not moving any faster than SMOs but are merely closer to Earth – they only “appear” to be moving faster. In a long (or sometimes short) exposure of a field of stars, galaxy, or nebula, you will see a “streak” of light that appears. This could be a long streak produced by a FMO or a very short streak (if any) produced from a SMO. It's all according to the length of the exposure and how fast the object appears to be moving. Often you will notice bright streaks that will appear to move completely across the field of view and sometimes ruin your astro-photo. These are Very Fast Moving Objects (VFMOs) - or usually man-made satellites. The average asteroid moves at an absolute rate of about 20 kilometers per second. The motion/movement that we see in our images that appear as streaks of light or points of light from the asteroids is mostly determined by the “distance” between the asteroid and your position on the Earth.

Things you need to know to image a FMO.

1. What is the objects speed/motion? This is determined by checking the “/min or “/hour. Most commonly, “/min is used. An example of a FMO would be 10.2”/min. This means in one minute, the asteroid will appear to move 10.2 seconds (in distance) across the sky.

2. What is the P.A. (Position Angle) of the object? The P.A. is referenced to the direction in which the object appears to travel. This is determined by checking the P.A.

An example of the P.A. of an object would be P.A. 253.2

3. What is the magnitude of the object? This is usually listed as a “V”.

An example for magnitude would be V = 17.9

Below is how the magnitude and motion would be shown.

V	Motion "/min	P.A.
17.9	10.06	253.2

Note: To convert 10.06"/min into "/sec use this formula.

"/min / 60 = "/sec 10.06"/min / 60 = 0.17"/sec

*Although much detail can be written here, it will be kept short and simple as it is written for the beginner.

The equipment used will determine how long the exposure length should be. Common equipment consists of an 8” to 16” computer operated telescope capable of guiding, and an astronomical grade CCD imager. The telescope can be set at a large range of focal lengths but most commonly a lower focal length is used (f/3 – f/8).

Once you determine the length it takes for an object to move across your telescope/CCD combination, you are ready to begin imaging the object.

Whatever software package you use to produce astrometry must be capable of stacking multiple images according to the motion of the object to get accurate measurements of the object (unless you are using a Very Large telescope and you are capable of detecting faint objects with very short exposures).

Example Observation:

Example Equipment: 14" Meade SCT working at a focal length of f/5 and an ST-8 SBIG camera.

SCT - 350mm f/5 = 1750 mm ST-8 CCD Pixel 9 x 9 micron 1530 x 1020

Arc-Seconds per Pixel 1.06 FOV in Arc-Minutes 18' x 27'

1 x 1 Binning (Un-binned)

Example Object: Object A123456 on the Near Earth Object Confirmation Page (NEOCP) with a motion of 10.06"/min (0.17"/sec) and a P.A. of 253.2 and a magnitude of 17.9.

1.06 * 2 / 0.17"sec = 12.46 second exposure

1.06 (Arc-Seconds per Pixel)

2 (movement across 2 pixels)

0.17"sec (speed of object in seconds)

12.46 (total exposure time)

This object is moving at a fast rate, but it is fairly bright for the telescope being used. Using the formula above, it shows that a maximum exposure length of 12.46 seconds can be taken. This will allow the object to move across 2 pixels (which is normally the "target" of movement).

Now you have your exposure length!

Assuming the positions from the NEOCP are precise, calculate a position to where the object will be in ~30 minutes. This is the point to where you will slew and center your scope. The reason for this: since this is an unknown NEO, you will want to report at least an hour of movement on it. If you center 30 minutes ahead of the target and image it for one hour, it should be centered in your field of view - midway through the session. Therefore, giving you positions - 30 minutes ahead and behind center field of view.

Center the scope on the R.A. and Decl. - begin auto-guiding - begin your series of images taken at 12.46 seconds.

**Recommended settings during exposures --- have the imaging camera pause for 5 to 10 seconds between image download and the next frame (if your camera has a built-in auto-guiding camera). This will allow the auto-guider time to realign the telescope (if needed) after the shutter is closed and the light image has been downloaded. **Also, DOUBLE CHECK the computer clock to verify it has been synchronized and accurate!!! If your clock is off, your measurements will be incorrect!!

If you calculate about 3 exposures per minute times 60 minutes, you will have a total of about 180 - 12.46 second exposures of this new NEO (the more the better). Now it's time to process and stack the images and measure the object.

When a new fast moving object has been discovered, it is a good idea to report 5 to 6 measurements of that object over a period of at least an hour. This "example object" should have traveled around 600" (10') in this hour of imaging. This is plenty of movement across the 18' x 27' field of view of the SBIG ST-8 CCD and reporting 6 positions will not be too many measurements.

With stacking techniques, we can detect fainter objects whether they are stars, comets, asteroids, galaxies, nebula, etc... When stacking images on stars or galaxies (objects that do not appear to move), you simply align the stars and stack the images. When stacking images on asteroids, the images have to be aligned on the asteroids movement - then stacked. There are a number of programs available that can do this.

Example Stacking:

You have successfully collected 180 - 12.46 second exposures of this object over a period of an hour and you want to obtain 6 positions. To allow for any possible error, obtain 9 positions and eliminate the 3 worse. Divide 180 images by 9 positions and this comes to a total of 20. So, with this you will make 9 stacks of 20 images.

Using your astrometry program, load the first 20 images to stack and prepare the data reduction. You will be prompted to enter information for data reduction (R.A. and Decl – object motion). Enter the R.A. and Decl. for the center of the field of view and enter the motion of this object which is 10.06”/min and P.A. of 253.2. The astrometry program will then query the star catalog for that particular R.A. and Decl. and get a data reduction on your image. Once it does this, it will align all 20 images according to the motion of the object (10.06"/min – P.A. 253.2) and create a "master image" of the stacked 20 images. Finally, you will see an image of trailed stars, and the asteroid will show as a single point of light. Do not close this image and repeat this step for all 180 images until you have the 9 "stacked images". Now you are ready to measure the positions of the object.

The easiest way to measure the object in all 9 stacked images is to blink the set of images so you will be able to see the movement of the object and also have the capability to "pause" the blinking process. Proceed to the first stacked image and click on the object. The position of the object, and the time (center of exposure time) will show. Now, you can list the name of the object as it is titled in the NEOCP – A123456. This will be entered when requested by the program. Blink to the next image and do the same, remembering to list the objects name A123456 for each entry until it has been measured in all 9 stacked images. When you finish, you will have a complete report to send to the MPC that contains measurements for the new NEO.

To check the positions, load an orbital configuring program that is capable of calculating residuals from a set of measurements. Once the program is loaded, have it to check your measurements for accuracy. Perfect measurements will have residuals of 0.00 but this is nearly impossible. Select your three measurements with the highest residuals and remove them from the list. This will leave you with 6 positions over the period of an hour. Reload your 6 positions, and you should now have a set of measurements with low residuals that will be accepted from the Minor Planet Center.

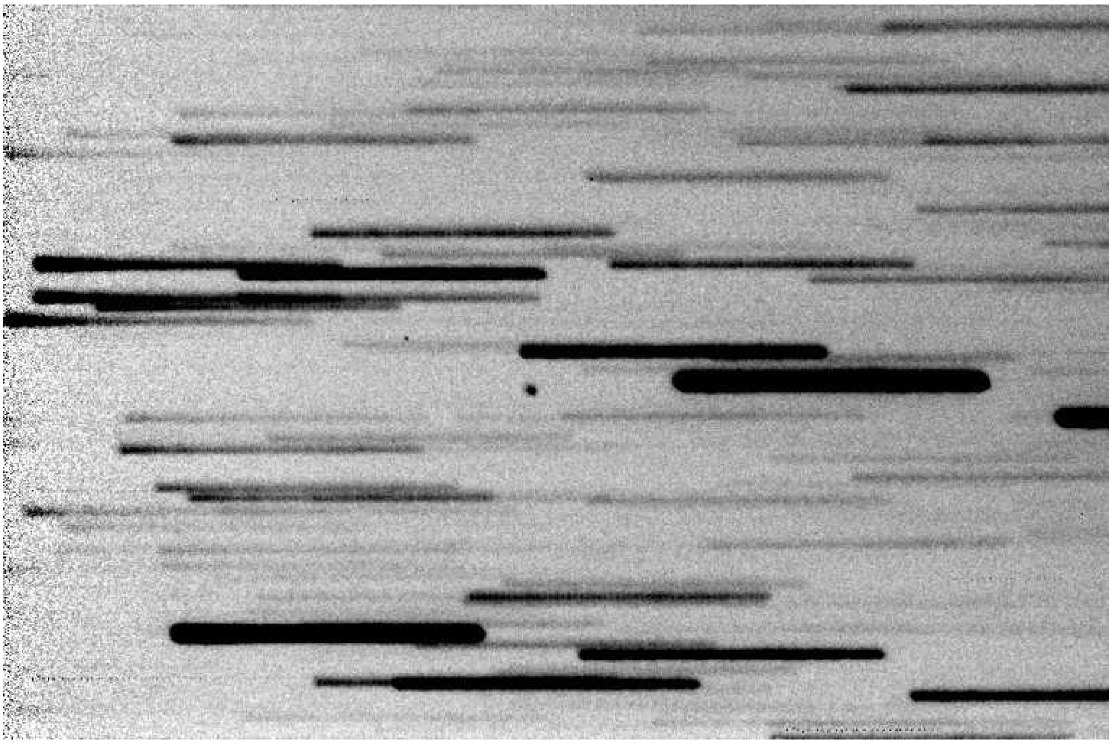

Image of Potentially Hazardous Asteroid (86039) 1999 NC43
6.30"/min P.A. 092.7

Image Information:
Taken by Steve E. Farmer Jr.
Red Barn Observatory H68

Date and Time: 20070308 (01:21:01) UT
Image Center: R.A. 04:59:22 Decl. +15:43:07
Telescope: 0.30m Meade LX200 SCT @ f/5
Camera: SBIG ST7
50 - 30 second exposures stacked in Astrometrica.
CCD temperature: -10c
Exposure Time: 30 seconds
Binning: 1x1

NOTES:

Pixel Scale is a measure of the amount of sky that fits on a pixel (in angles) The amount of sky falling on each pixel will depend on how big the pixel is (pixel size) and how much the object was magnified before it got to the pixel. Since the focal length of the telescope determines magnification, the focal length and the pixel size together determine the pixel scale.

**This Guide is still in the developing and correcting stage and will continue to develop as time passes. Please report any errors found to sefarmer[at]cometary[dot]net or caracasastronomica[at]gmail[dot]com

End of the Astrometry guide first version.