VISUAL OBSERVATION OF MINOR PLANETS

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The author describes the processes for identifying minor planet targets, observational planning, identification criteria, and record keeping. He presents his lifetime observational totals from 50+ years of observing.

A worthwhile challenge for amateur astronomers is hunting asteroids. Since they are constantly on the move, they can be more difficult to locate than most other celestial objects. To be successful, the amateur needs to identify targets, prepare charts, observe, and keep good records.

Identifying Potential Targets

There are several sources a minor planet observer can use to identify potential targets. One such resource is maintained by Brian Warner (*http://www.MinorPlanet.info*). By clicking "Observation Planning" on the main menu, one can access the "Ephemeris Generator" page, which allows the user to select parameters such as month and year, magnitude limit, declination limits, etc. Once these parameters are entered, the site produces a list of minor planets ordered by date of brightest appearance. The output includes the dates of closest approach and opposition, minimum distance, brightness, declination, etc.

This list is a starting point; the user will need to cull objects from this list based on personal criteria. A useful second step is to access the Minor Planet and Comet Ephemeris Service web site of the IAU Minor Planet Center

http://minorplanetcenter.net/iau/MPEph/MPEph.html

Entering the minor planet numbers from the list, and the desired date range, the IAU website will then provide an ephemeris for each selected minor planet for the desired range of dates. This information can be used to further cull the list of potential targets.

Observational Preparation

Next, the observer must prepare a chart for each target. The author has used two different methods for producing charts.

The first is the *Minor Planet Observer Asteroid Viewing Guide* (Warner, 2018). This software package will produce a sky chart showing the path of the minor planet on selected dates. The user can select the minor planet, chart scale, magnitude limit of the background stars, and dates. Another useful source is the AAVSO site (*http://aavso.org/apps/vsp*). Like the *MPOAVG*, users can select the scale and magnitude limits, but this software does not produce a path track.

Finally, the user needs to select the targets for observation on a given night. In the author's youth he would select up to 30 targets for a single night, but as his stamina declined with age he limited it to just 10 or so. Observing minor planets visually can be hard work, and an observer needs to understand his limitations.

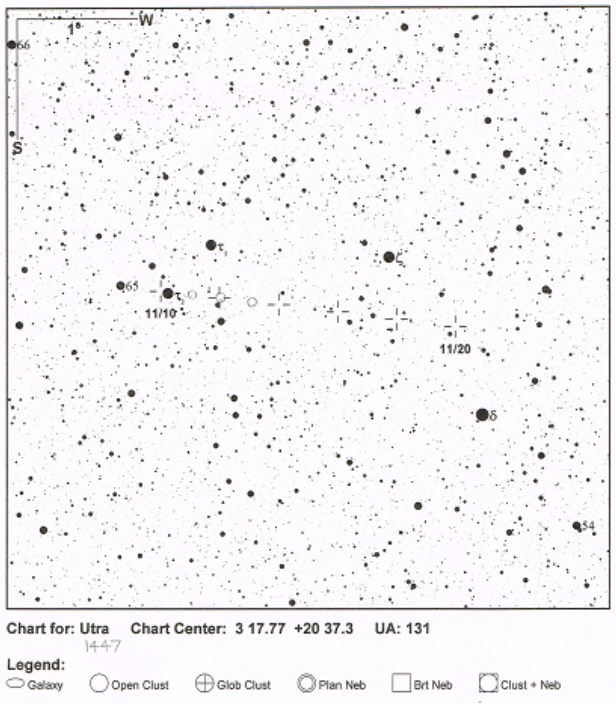

Figure 1. Chart of the path of 1447 Utra, produced from the *Asteroid Viewing Guide* on 2001 Nov 10. The hand-drawn circles along the path show the positions during times of observation. North is up.

Figure 2. Motion of 1447 Utra recorded by the author at the telescope on 2001 Nov 10. Positions "A" and "B" correspond to local times 22:20 and 23:25 EST respectively (03:20 and 04:25 UT on 2001 Nov 11). North is to the lower right. [The image was digitally enhanced during production to increase contrast – Editor].

Once the observer has selected a list of targets and produced star charts (with tracks plotted on them) for each one, he is ready to observe. If the observer has a "go-to" telescope with RA and Dec inputs, then he can locate the star field quickly. Otherwise, he must identify the bright stars on the chart and locate them in the sky with a good quality atlas. The author uses the *Atlas of the Heavens* (Becvar, 1962), *Sky Atlas 2000* (Tirion and Sinnott, 1998), or the *Sky & Telescope Pocket Atlas* (Sinnott, 2006), depending on the brightness of the targets. Standard star-hopping techniques can be used to find the target.

When observing, one should record the telescope aperture, magnifications used, date and time, transparency, seeing, and other relevant factors such as moonlight. Once a target is located in the telescope, the observer draws the relevant field of view, and

identifies suspected targets. This drawing must be sufficiently accurate that a motion of 0.5 arc minutes would be noticeable. The less accurate the drawing, the greater the motion must be to be noticed and, therefore, the longer the wait until that motion becomes clear. The author has found that eyepieces producing a field of view of 10 to 20 arc minutes are most helpful. Figure 1 shows a target path created from the *Asteroid Viewing Guide*, and Figure 2 shows the drawing of the visual field made by the author at the eyepiece.

After sufficient time has passed for the motion of the suspect to be identified, the observer must re-observe the field of view and note the second position of the target, if it has moved. If no motion is detected, then either the target was not seen at all, or the time interval to detect its motion was insufficient. Most minor planets move at least 0.5 arc minutes per hour, although some may be slower, particularly near stationary points. Like the outer planets, nearly all minor planets will retrograde at opposition, but they can be near a stationary point several weeks before or after opposition. Thus, the middle of the opposition is the best time to observe any given minor planet because the motion will be most obvious and the target will be at or near its brightest.

Once the observer has confirmed the observation of the minor planet by showing it at two different locations at two different times on the same night, the observation needs to be logged and recorded. The author recommends making a visual estimate of the object's magnitude.

In the early years, the author came to realize that drawings can be imperfect and errors of identification can be made. For example, multiple faint stars very near the target can cause the observer to misidentify the target, especially if the transparency changes between the first and second observations. For this reason, the author does not consider the observation of the minor planet to be fully confirmed until additional observations can be made on subsequent nights. This is the "three observations" rule: the object should be seen on two different nights and at least twice on one of those nights. This rule was always followed when observing a minor planet for the first time, but eventually it was relaxed when observing brighter asteroids (V < ~13) at second and subsequent oppositions.

Record Keeping

It is critical that clear records be maintained. Besides the actual drawings and notes made at the eyepiece, there is a need for a summary record, generally digital. The author has kept all of his notes and drawings since 1965, and also maintains several digital records covering the last 50+ years. Microsoft Excel® is useful for this purpose since pivot tables can be constructed that allow slicing the data by minor planet number (or groups of numbers), month or year, and other parameters. Of course, Microsoft Excel® did not exist when the author started observing, but he began converting paper records to digital form in the 1990s.

Successful minor planet observing requires all the aforementioned processes, and some skill at the eyepiece, but also the discipline to keep observing night after night. One will not find any minor planets by staying indoors on cold winter nights or on sweltering hot summer evenings. The author has endured hundreds of bitterly cold nights in an effort to identify as many asteroids as possible. Largely because of this persistence, he has accumulated over 28,000 visual observations of nearly 2,900 distinct objects.

Seasonality

The orbits of the main-belt asteroids lie between the orbits of Mars and Jupiter. These will account for more than 90% of all minor planets observed. Jupiter's orbit has an eccentricity of 0.049, meaning that the aphelion is more than 10% further from the Sun than the perihelion. Consequently perihelic oppositions of Jupiter (around October) are noticeably brighter than aphelic oppositions (around April). Due to its great mass, Jupiter perturbs the orbits of the minor planets, with the effect that many of their orbits line up their perihelia in the same general direction as Jupiter's perihelion. Thus, asteroids at opposition in October tend to be brighter on average than those at opposition in April. This creates a distinct seasonal pattern.

This pattern is abundantly clear in the author's data. About 67% of all minor planets were first identified in the six-month period of August through January, leaving only 33% in the six-month period of February to July. In terms of total observations, 62% were made in August to January and 38% in February to July. These patterns are shown in Figure 3.

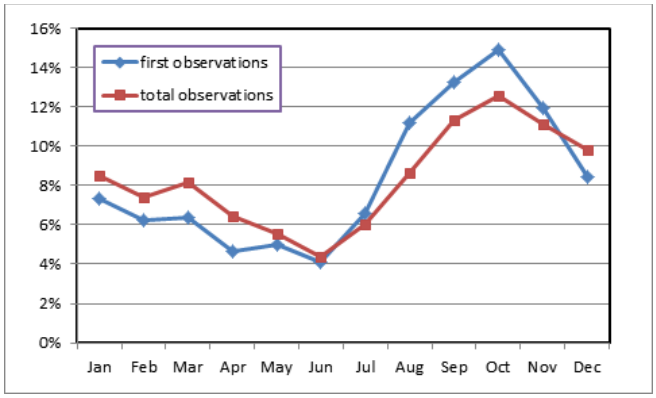

Figure 3. Monthly distribution of first sightings of each object (2,894 total) and of total observations (28,012 total) over the period 1966 to 2018.

Any observer setting out to capture minor planets in his telescope is likely to see a similar pattern. There will be far more available targets in the second half of the year than in the first half.

Although the lines of apsides of the minor planets are not randomly distributed around the ecliptic, the positions of these objects in their orbits are random. Since most main-belt asteroids have orbital periods ranging from three to six years, with most having orbital eccentricities of at least 0.10, they will have both aphelic and perihelic oppositions. A typical object will be a full magnitude or more fainter at aphelic than at perihelic opposition. Thus, many potential targets may be visible only near perihelion. Consequently, in order to capture as many objects as possible, an observer must commit to an observing program lasting up to six years. The author is nearing completion of his fifth six-year program since building his observatory in 1990.

Summary of Results

The author's lifetime totals are included in Table 1, showing the number of distinct objects, the number of oppositions, and the number of observations. Note that the recently classified dwarf planets Ceres and Pluto have been removed from the minor planet subtotal and listed separately.

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ASTEROID NUMBER	TOTAL SEEN	TOTAL OPPNS	GROSS OBSNS
2 - 200	199	2,056	6,312
201 - 400	200	1,330	3,905
401 - 600	199	1,026	3,019
601 - 800	194	796	2,326
801 - 1000	191	593	1,749
1001 - 1300	260	642	1,955
1301 - 1600	240	504	1,580
1601 - 2000	244	457	1,474
2001 - 3000	373	585	1,949
3001 - 5000	378	539	1,866
5001 - 10000	236	293	1,054
10001 -	180	197	823
MINOR PLANETS	2,894	9,018	28,012
COMETS	58	62	416
DWARF PLANETS			
Ceres	1	26	88
Pluto	1	22	180
GRAND TOTAL	2,954	9,128	28,696

Table I. Lifetime total observations of minor planets, comets, and dwarf planets as of 2018 June 30. Ceres was upgraded from minor to dwarf planet in 2006 (observed from 1966 to 2018). Pluto was downgraded from major to dwarf planet in 2006 (observed from 1987 to 2008).