

Occult v4 Overview

April 2019

Steve Preston

1 INTRODUCTION

The program Occult is designed to generate predictions and analyze observations for a variety of astronomical occultation phenomena. Occult can predict the circumstances of lunar occultations, asteroidal occultations, solar eclipses, lunar eclipses, occultations of planetary satellites, and more related events. This overview document will provide a basic introduction to Occult's user interface and some suggestions for configuring Occult.

Occult has an extensive help file which is a good source of detailed information on Occult. However, Occult's help file is very large and might be daunting to first time users. This is an introduction to the user interface of Occult and will provide suggestions for how to get started with some basic operations.

If you are not familiar with the basic attributes of occultations and how to observe them, I suggest that you review some of the materials posted on www.occultations.org. In particular, the IOTA Observer's Manual provides a lot of relevant information.

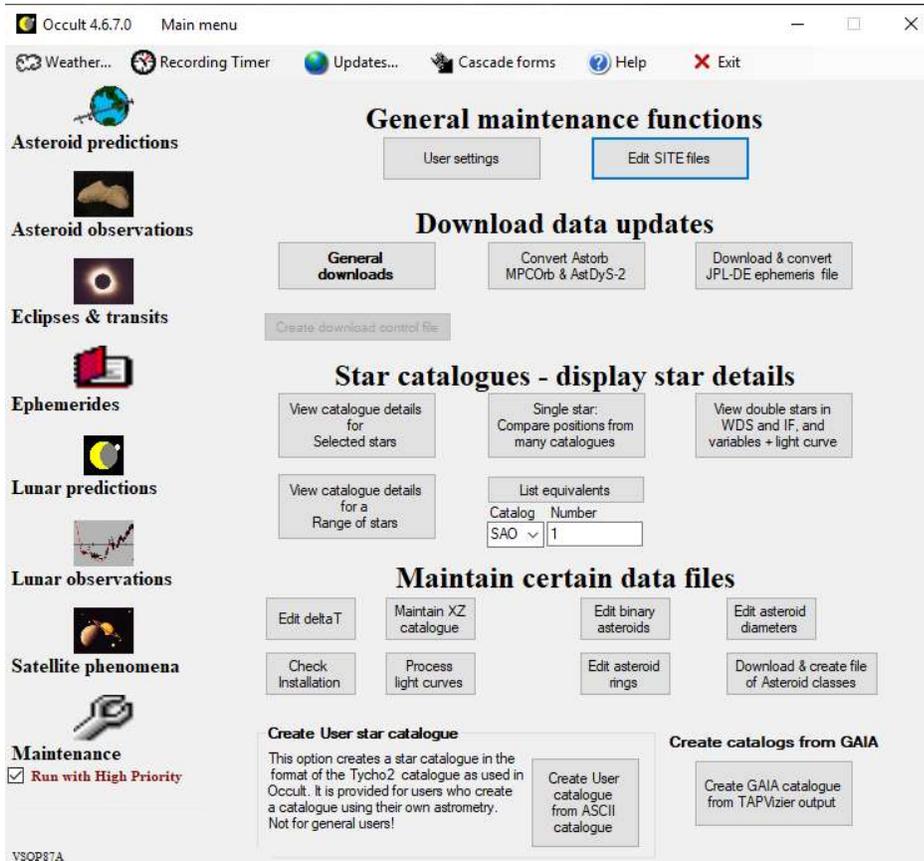
2 INSTALLING OCCULT

The software section of the IOTA website (www.occultations.org) will include a link to the download page for Occult. The download page includes instructions for installing Occult and how to initialize the basic settings. This document provides information on additional settings and some basic instructions for using Occult to predict the circumstances lunar and asteroidal occultations.

3 OCCULT'S MAIN MENU

When you start Occult, Occult displays the Main Dialog which should look like the following screen shot.

Figure 1 Occult Main Menu : Maintenance Module



The Main Dialog is divided into two sections: the left column of labeled icons is the navigation section and the right two-thirds of the dialog is the module section. The left section is a list of the main Modules of Occult: Asteroid predictions, Asteroid observations, Eclipses & transits, Ephemerides, Lunar predictions, Lunar observations, Satellite phenomena, and Maintenance. If you click one of these modules listed in the left column, that module become the currently selected module in Occult. The module section of the Main Dialog always displays the functionality for the currently selected Module. In the screen shot above, the Maintenance module is the currently selected module. Therefore, the module section of the main dialog shows the options for the Maintenance functions. If you click on “Asteroid prediction”, the module section will show the options for the Asteroid prediction module. When you exit Occult and start it up again, Occult will start up in the same main module that was active when you exited Occult.

In general, when you select a module, the module section of this Main dialog will show several “buttons” for various capabilities (e.g. the “General Downloads” button in the screen shot above). When you select one of these buttons, Occult will display a new dialog. In most situations I will start up only one module level dialog at a time (and close it after I have finished using that dialog). However, it is

sometimes possible to have more than one of these module level dialogs active at a time (possibly from different modules).

4 MAINTENANCE MODULE

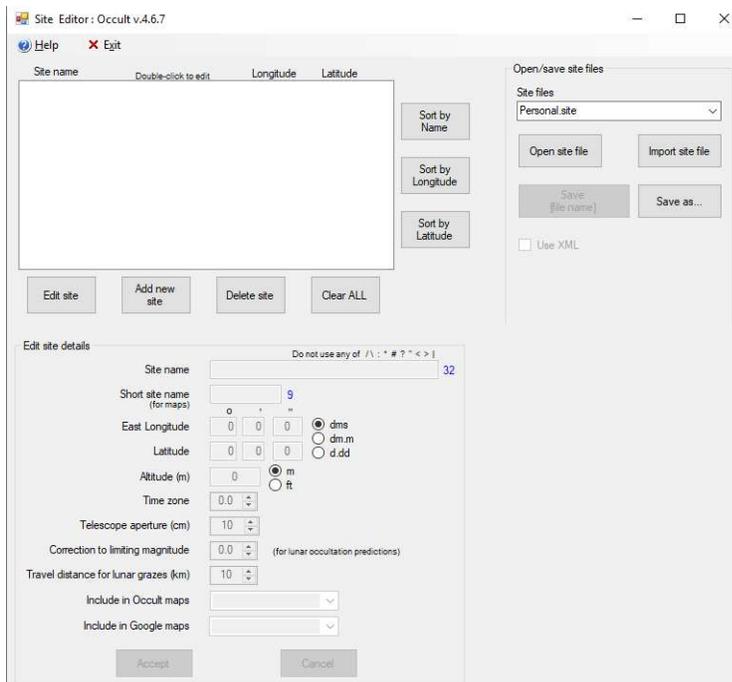
As implied by the name of the module, the maintenance module is where you specify various settings for the program and where you download any data files which might be required for predicting or analyzing occultations. Most observers should only be concerned with the buttons in the top two sections of this dialog: “User settings”, “Edit Site Files”, “General downloads”, and “Convert Astorb MPCOrb & AstDys-2”. I will discuss the functionality of each of these buttons below.

4.1 EDIT SITE FILES

Site files are an important input for Occult. Occult predicts the circumstances of occultations at a location. Site files specify the position of one or more sites (locations) on the earth. The Occult install process will setup several preconfigured site files which define “sites” for various cities across the globe. The “World Main” site file includes major world cities. The “WorldPlots” site file includes many more cities worldwide. And there are site files for various regions: North America, Europe, Asia, etc. Since most observers are primarily interested in knowing the circumstances from their home location, I recommend that observers setup a new site file which contains only the locations they might use on a regular basis: home, dark sky observing site, etc. For my purposes, I have a site file called “SteveP.site” and it contains a “site” for my home location and two other locations which I regularly use for observing.

When you select the “Edit Site Files” option from the Maintenance module, Occult displays the “Site Editor” dialog. This dialog has three sections: List of Sites, the Open/Save Site File section, and Site Details section. The List of Sites section is in the upper left part of the dialog. The Open/Save Site file section is in the upper right. And the Site Details section is in the lower left part of the dialog. When you start the Site Editor, the List of Sites will be empty.

Figure 2 Site Editor



4.1.1 Creating a new site file

Since I recommend that observers create a new site file with their own personal observing location, here are the steps for creating a site file called “personal.site” that contains the location “home”.

1. Start the Site Editor
2. Click on the Add New button in the List of Sites section
3. In the Site Details section, set Site Name and Short Site name to “home”. Set the Longitude, Latitude, and Altitude for your home location. Note: West Longitude is specified as a negative Longitude.
4. Now set the time zone.
5. Set the telescope aperture. I recommend using a value larger than the largest aperture you plan to use. When searching for lunar occultations, Occult will show more events rather than fewer.
6. The other elements of the site details are optional for now. But if you know what values you want to use, go ahead and set them now.
7. Hit the Accept Button in the Site Details section. The “home” site should now appear in the List of Sites section.
8. In the Open/Save Site files section, select “Save As...” and tell Occult to save this site file as “personal.site” (or whatever name you wish to use).

4.1.2 Editing an existing site file

Editing an existing site file is a four-step process:

1. Start the Side Editor.
2. Load the site file you wish to change. In the Open/Save site Files section, select Open Site file and select the file you wish to change.
3. Change or Add a site. You can now select a site in the List of Sites section and hit “Edit Site” to make changes. Or you can choose the “Add new Site” button in the List of Sites section to create a new site, fill in the site details, and accept it.
4. Save the changes. In the Open/Save site files section, select the Save “filename” button (or Save As if you wish to save these changes to a new site file).

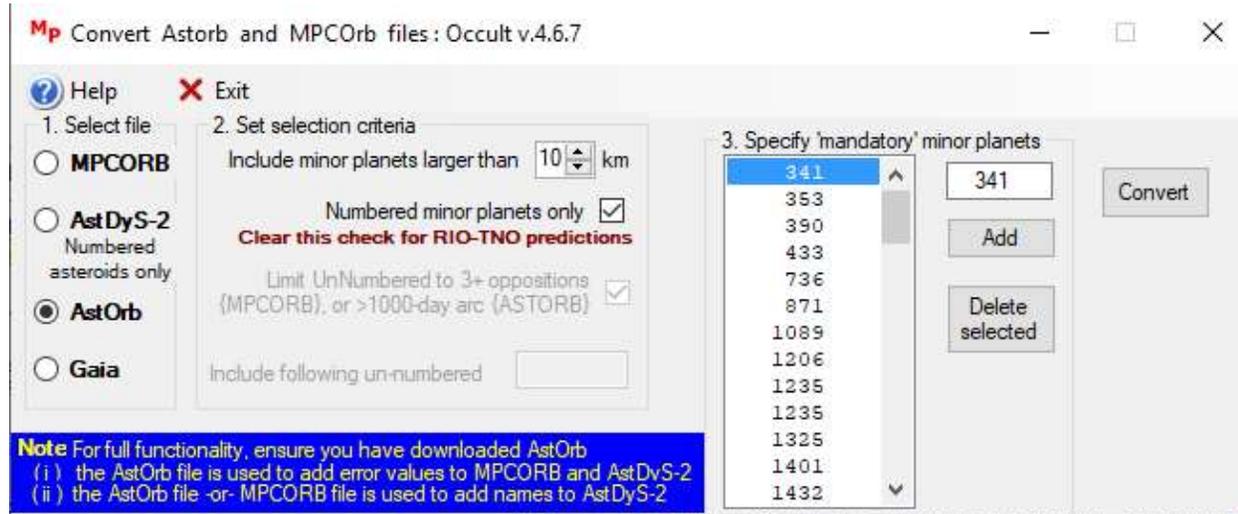
4.2 GENERAL DOWNLOADS

With the General Downloads dialog, you can download the data files which might be used by Occult. The list of data files is long. Some of these data files should only be downloaded one time. But many of these data files should be downloaded on a regular basis to include the latest data. In the General Downloads dialog, Occult will flag the files which are ready for an update (new download). These datafiles are not large in the context of the size of hard drives today. But you don't need to download everything. Here are my recommendations for downloading Occult data files.

1. General downloads (items 1 – 19): download all these files
2. Files for Asteroid Predictions/ reductions:
 - a. FutureALL.xml – This is the current file of asteroidal occultation path predictions posted at asteroidoccultation.com. Download this file if you want to review a path prediction with Occult. This file is updated about twice a month on asteroidoccultation.com. Since

these path predictions are already posted to asteroidoccultation.com and OccultWatcher, most people won't need to download this file.

- b. TNOS_RIO.dat – This is the current file of asteroid occultation predictions by the RIO group. Since these path predictions are also available in OccultWatcher, most people won't download this file.
- c. MPCorb , AstDyS-2, and Astorb. – These data files are catalog of orbits for asteroid. Occult will use these orbits when searching for possible asteroid occultation events. If you think you will be working with asteroid occultations predictions, I recommend that you download Astorb and MPCorb. Occult will bring up the “convert” dialog (below), after downloading each file. Occult access asteroids from an internal data file. The “convert” dialog copies orbit data from the input orbit catalog (e.g. Astorb.dat) into Occult's internal orbit catalog file. To update the internal orbit catalog file, download Astorb first, then convert it. Then download MPCorb and convert it. For both conversions I recommend that you set the minimum diameter to 10km in section 2 and check the box for Numbered minor planets only. Otherwise, your internal catalog of orbits will include many more asteroids than necessary.



- d. Gaia (option 24a): don't bother with this one.
 - e. ISAM Asteroids. Download this one.
3. Static data files
- a. Download the Historical file of lunar occultations, the XZ catalog and the LOLA lunar limb data.
 - b. Download star diameters, the Tycho2 catalog, the Kepler2 target stars and the JPL Planetary ephemeris. But you will probably not need the JPL 6000 year ephemeris. Or the EOP series before 1962.
 - c. Download the crater coordinates, Phoebe ephemeris, and Google Map templates.
 - d. Download the Gaia14_ xxx catalog. You will only need this catalog if you are planning to search for asteroidal occultations. Since IOTA already provides predictions for many worldwide asteroidal occultations, most users will not need this catalog download. As of Apr 2019, this catalog is based on the DR2 release of Gaia. It will likely be updated to use DR3 data in the future. This is a large download but should not take long with a good internet connection.

- e. Download the SAO catalog.

4.3 USER SETTINGS

The basic install instructions for Occult provide suggestions for the User Settings dialog. These default settings should work for most purposes. But I suggest that you review the options in the dialog so you will know what options exist in case you want to make changes later.

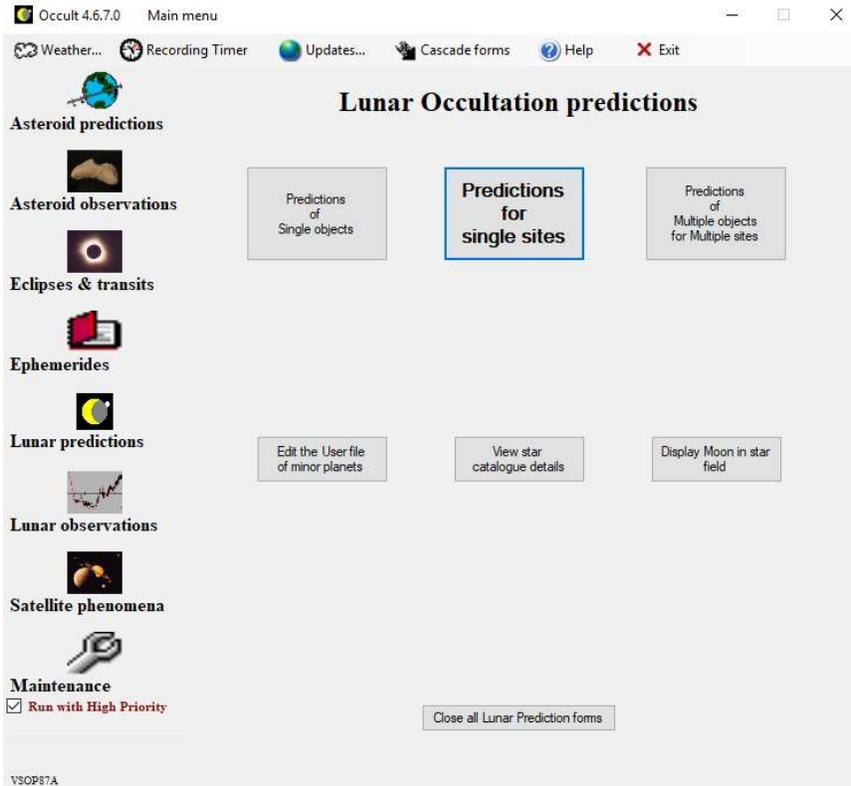
4.4 CONVERT ASTORB, MPCORB & ASTDYS-2

This button on the Maintenance module dialog brings up the Convert Astorb and MPCorb dialog mentioned earlier in this document. In most situations you will only use the Convert dialog as part of downloading a new set of orbit element. I only access the Convert dialog via this button on the Maintenance module when I need to add a new asteroid to Occult's internal catalog of orbits. To control the size of the internal orbit catalog, we normally only import (convert) orbits for asteroids of a certain minimum size (e.g. 10km). But you may want to add smaller asteroids for a special purpose search. You can do so by adding the asteroid number to the list in section 3 of the "Convert Dialog".

5 LUNAR OCCULTATIONS

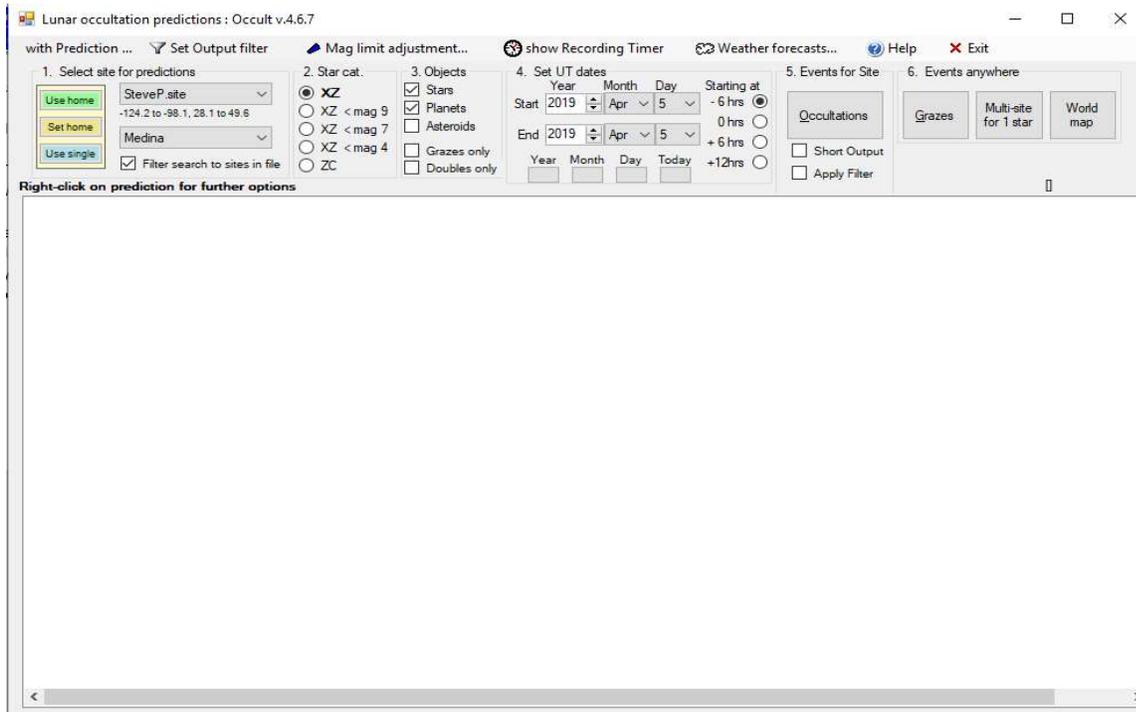
The Lunar predictions module of Occult provides detailed information on both total and grazing lunar occultations. If you select the Lunar predictions module the main dialog will show the following options.

Figure 3 Lunar Occultation Predictions module main dialog



Most users will only be interested in the “Predictions for single sites” dialog which generates predictions of lunar occultations near a specific site. Here is a screen shot of the single site predictions search dialog.

Figure 4 Lunar Occultations Predictions dialog (single site):



This search dialog will create a list of all total lunar occultations visible from the specified site. And it will list any grazing occultations which happen within a “travel distance” from the specified site. The travel distance for grazing events is one of the settings in the User Settings dialog of the Maintenance module. Total lunar occultations are typically visible over a large part of the globe. However grazing occultation events are only seen from a narrow strip a few kilometers in width. Thus, you must plan on traveling to the “graze path” when trying to observe events in a lunar grazing occultation. Occult provides detailed mapping support for determining where to setup for a lunar grazing occultation.

5.1 TOTAL LUNAR OCCULTATIONS AT A SINGLE SITE

In this section I will provide a brief description of the steps I follow when using Occult to plan for observing total lunar occultations. Hopefully this description will provide a reasonable introduction to the lunar occultation dialog. Occult provides many output options and you may determine that a different approach works better for you.

With the Lunar occultations predictions dialog, you can search for lunar occultation events which are visible from a specified location over a range of dates. This dialog has six sections of controls across the top of the dialog. Sections 1 through 4 set the input parameters for the search and the “Occultations” button in section 5 starts the search function. As the search proceeds, the lunar occultation events observable from the specified site are listed in the lower two thirds of the dialog.

For total lunar occultations I generally only search for one night at a time (usually earlier in that day). Here are the steps I follow.

1. Set the observing site in section 1. The upper drop-down box selects the site file and the lower drop-down box selects a specific site from the site file. You can set the current site as your "home" site using the "set home" button on the left. Then you can select the home site use the "home" button on the left.
2. Section 2: Star Catalog. I just leave this set to XZ.
3. Section 3: Objects: I generally just select Stars. Lunar occultations of planets are not frequent and the circumstances are usually already posted to an IOTA website.
4. Section 4: Search Dates. I enter the same day for the star and end date. Note that these dates are UT and this section includes options to start the search at either -6hrs, +0hrs, +6hrs, or +12hrs from the start of the day. Since I live in Western North America with an offset of -8 hrs from UT, I generally select the -6 hrs option. Thus, my search will start at 18hrs on the day BEFORE the date I select and end at 18hrs on the day I select.
5. Section 5: Start the search by hitting the Occultations button. There are checkboxes to apply a filter or use a short form of output. I generally leave those options OFF. These options make more sense when conducting a longer search (over many days).

And here is a screen shot showing the results of a search for lunar occultations visible from my home location on 2019 Apr 13.

Figure 5 Lunar Occultation Predictions dialog :

Right-click on prediction for further options

Occultation prediction for Medina
 E. Longitude -122 14 13.2, Latitude 47 38 20.4, Alt. 30m; Telescope dia 40cm; dMag 0.0

day	Time	P	Star	Sp	Mag	Mag	%	Elon	Sun	Moon	CA	PA	VA	AA	Libration	A	B	RV	Oct	durn	R.A. (J2000)	Dec	Mdist	SV								
y	m	d	h	m	s	No	D	v	x	V	l11	Alt	Alt	As	o	o	L	B	m/o	m/o	"/s	o	sec	h	m	s	o	m	s	Mm	m/s	
19	Apr	13	3	12	28.7	D	79818SG5	7.3	54+	94	-4	63	195	29N	41	30	28	-4.4	-0.2	+2.2	+3.0	.215	59.3	7	57	5.8	20	58	1	365.9	747.2	
79818 is triple: AB 7.32 9.46 0.75" 134.3, dT = -0.22sec : AC 7.3 13.0 9.0" 155.0, dT = -19sec																																
79818 is a close double. Observations are highly desired																																
19	Apr	13	3	30	8	Gr	79818SG5	7.3	54+	95	-6	59	**	GRAZE: CA -1.0N; Dist.275km in az. 16deg. [Lat = 50.22-0.20(E.Long+122.24)]																		
19	Apr	13	3	32	17.9	d	X106281	9.9	8.8v	54+	95	-7	62	204	6N	77	60	64	-4.4	-0.2	+1.8	+0.1	.389	23.5	7	58	3.5	20	47	47	365.9	753.3
X106281 = ASAS J075804+2047.8, 9.84, range 0.11, V, Type MISC, Period 49.032679 days, Phase 39%																																
19	Apr	13	3	52	18.6	D	79830 A0	8.6	8.5	54+	95	-10	60	213	76S	115	92	103	-4.5	-0.2	+1.4	-1.4	.416	-14.2	7	58	34.3	20	35	32	365.9	761.8
19	Apr	13	4	5	8.4	d	79834 K5	9.8	9.2	54+	95	-12	59	218	71S	120	94	108	-4.5	-0.2	+1.3	-1.7	.410	-18.8	7	58	54.6	20	33	11	366.0	768.4
19	Apr	13	4	13	47.5	d	79840 M0	9.2	8.4v	54+	95	58	221	63S	128	100	115	-4.5	-0.2	+1.2	-2.0	.391	-26.1	7	59	5.2	20	30	38	366.0	773.3	
79840 = ASAS J075905+2030.6, 9.27, range 0.13, V, Type MISC, Period 1. days, Phase 50%																																
19	Apr	13	4	30	17.0	d	79845 G5	9.2	8.6	54+	95	56	227	59S	133	101	120	-4.5	-0.2	+1.0	-2.3	.381	-30.4	7	59	31.9	20	28	5	366.1	783.9	
19	Apr	13	4	32	31.0	D	79846 K0	7.7	7.3	54+	95	56	228	34N	45	13	32	-4.5	-0.2	+2.2	+1.6	.240	57.2	7	59	33.9	20	50	38	366.1	785.5	
19	Apr	13	5	6	10.1	d	X 12048 A0	9.7	9.6	54+	95	51	238	73S	119	81	106	-4.6	-0.2	+1.0	-1.8	.439	-15.7	8	0	48.7	20	27	47	366.3	810.9	
19	Apr	13	5	32	5.6	d	79871cG5	9.0	8.6	55+	95	47	245	80S	112	71	99	-4.6	-0.2	+0.9	-1.7	.464	-8.4	8	1	42.3	20	26	50	366.5	834.1	
79871 is double: ** 9.6 5.6 0.10" 318.0, dT = -0.15sec																																
79871 has been reported as non-instantaneous (OCc 805). Observations are highly desired																																
19	Apr	13	6	27	49.3	D	79899 G5	7.0	6.5	55+	96	38	258	79S	112	68	99	-4.7	-0.2	+0.6	-1.8	.495	-8.6	8	3	34.1	20	20	19	367.1	892.0	
19	Apr	13	7	6	19.5	d	79919 A2	8.9	8.9	55+	96	32	265	73S	119	73	105	-4.7	-0.2	+0.3	-1.9	.508	-14.8	8	4	52.6	20	13	59	367.6	937.1	
19	Apr	13	7	7	48.9	d	79912cF5	8.6*	8.5	55+	96	32	266	27S	165	119	152	-4.7	-0.2	-0.5	-3.7	.252	-61.4	8	4	13.4	20	5	52	367.7	939.7	
79912 is double: ** 9.3 9.3 0.10" 301.0, dT = -0.28sec																																
79912 has been reported as non-instantaneous (OCc 804). Observations are highly desired																																
19	Apr	13	7	20	20.3	d	79925cA3	8.6	8.4	55+	96	30	268	37N	49	3	35	-4.7	-0.2	+1.1	-0.1	.306	55.1	8	5	14.9	20	30	43	367.8	954.8	
79925 is double: ** 9.4 5.4 0.10" 135.0, dT = +0.02sec																																
79925 has been reported as non-instantaneous (OCc 784). Observations are highly desired																																

In this example, Occult lists many events including several events with double stars where "Observations are highly desired". For a more detailed description of the information on these lines you can review the Help information in Occult and Chapter 4 of the IOTA Observer's manual (free PDF posted on occultations.org).

If you right-click on one of the lines in this list, Occult will display menu with options for more information on the event. The two options which I sometimes use are the Moon map and the Star Details. The moon map displays a map of the moon showing the location of the star along the edge of the moon at the time of the event (and labels the star with the time of the event). You can change the N/S or E/W orientation to match the field of view from your scope/camera. This might be very useful if you typically have a computer nearby while observing. Or you could print out the moon map to have with you while observing. It is also possible to plot multiple stars from the list on the moon map.

Alternatively, some observers might wish to use the Lunar Occultations Predictions dialog to search for specific types of lunar occultations over a larger range of dates – as a long-range planning tool. For example, you could select the $XZ < 4$ option in section 2 and search for all bright star events visible from your location in the month of April. Or, you could use the “Set Output filter” menu option to tell occult “Exclude events that do not include a double star or K2 star” and set the Apply Filter option in section 5 – this search will show only the events with double stars.

5.2 LUNAR GRAZING OCCULTATIONS NEAR A SITE

Observing a grazing lunar occultations requires more planning than a total lunar occultation. The circumstances of grazing occultations vary significantly. If you are not already familiar with lunar grazing occultations, I suggest that you review Chapter 5 of the IOTA Observers Manual (free PDF posted at www.occultation.org). Now that we have the Gaia star catalog for star position and the LOLA data for the lunar limb, grazing occultations are not likely to yield unique information about the star or the moon. For this reason, I recommend that observers pursue grazes for the fun of seeing multiple events. Grazes can be a good group activity for classes or outreach.

When deciding whether to attempt to observe a graze, you will likely consider the travel distance to the graze path, the cusp angle of the star, the altitude of the moon, the magnitude of the star, and the number of “events” likely to be seen during the graze. Once you have determined that you do want to observe a specific graze, you must determine the exact location of the graze path and where you wish to setup within the graze path. Occult provides good support for mapping the graze path, but you may also need to consider corrections for altitude when finalizing your map.

Because of the amount of work involved with planning a graze, I recommend that you review the nearby grazes well ahead of time to determine which ones might be interesting. As an example of reviewing grazes as potentially interesting candidates to observe, here is a screenshot of all the grazes nearby my home location in Apr 2019. To generate this list, I selected the “grazes only” option in section 3.

Figure 6 Lunar Occultation Predictions dialog: (grazes only)

The screenshot shows the 'Lunar occultation predictions: Occult v.4.6.7' dialog box. The '3. Objects' section has 'Grazes only' selected. The '5. Events for Site' section has 'Occultations' selected. The main window displays a table of predictions for Medina, with the following data:

Grazing Occultations near Medina																		
E. Longitude -122 14 13.2, Latitude 47 38 20.4, Alt. 30m; Telescope dia 40cm; dMag 0.0																		
y	m	d	h	m	s	P	Star No	Sp D	Mag v	Mag r	Mag V	% ill	Elon Alt	Sun Moon Alt	Cusp angle	Distance km	Azimuth	Path formula
19	Apr	8	2	46	26	Gr	464cK0		6.1	5.6		7+	32	-1 25	**	GRAZE: CA -8.4N; Dist.220km in az. 187deg.	[Lat = 45.65-0.08(E.Long+122.24)]	
19	Apr	8	4	0	21	Gr	93353 G0		5.4	8.9		8+	32	-11 13	**	GRAZE: CA 6.9S; Dist.279km in az. 13deg.	[Lat = 50.22-0.15(E.Long+122.24)]	
19	Apr	12	3	54	58	Gr	78905 A2		8.7	8.5		43+	82	-11 54	**	GRAZE: CA -0.3N; Dist. 66km in az. 199deg.	[Lat = 47.01-0.24(E.Long+122.24)]	
19	Apr	12	4	24	28	Gr	78919cK2		8.3	7.7		43+	82	48	**	GRAZE: CA 0.0S; Dist.169km in az. 22deg.	[Lat = 49.28-0.27(E.Long+122.24)]	
19	Apr	13	3	30	8	Gr	79819SG5		7.3			54+	95	-6 55	**	GRAZE: CA -1.0N; Dist.275km in az. 16deg.	[Lat = 50.22-0.20(E.Long+122.24)]	
19	Apr	14	4	53	2	Gr	1343 H4		6.3	5.5v		66+	108	60	**	GRAZE: CA -2.0S; Dist.293km in az. 209deg.	[Lat = 44.62-0.38(E.Long+122.24)]	
19	Apr	14	7	16	42	Gr	1350kG		5.2	8.9		67+	109	39	**	GRAZE: CA 2.8N; Dist.276km in az. 219deg.	[Lat = 44.42-0.55(E.Long+122.24)]	
19	Apr	15	3	51	48	Gr	1459 P5		7.4	6.9		76+	122	-9 54	**	GRAZE: CA 0.5S; Dist.217km in az. 20deg.	[Lat = 49.72-0.25(E.Long+122.24)]	
19	Apr	15	4	16	46	Gr	1464 P5		7.5	7.0		76+	122	59	**	GRAZE: CA 0.5N; Dist.139km in az. 205deg.	[Lat = 46.26-0.31(E.Long+122.24)]	
19	Apr	23	11	53	11	Gr	185506 H4		7.8	6.8v		81-	129	-11 20	**	GRAZE: CA 8.0S; Dist. 86km in az. 22deg.	[Lat = 48.28-0.27(E.Long+122.24)]	
19	Apr	27	11	9	12	Gr	3078cA5		4.9			45-	84	7	**	GRAZE: CA 8.8S; Dist.184km in az. 205deg.	[Lat = 45.81-0.32(E.Long+122.24)]	

When reviewing this list for possible grazes to observe, I first look at the cusp angle. A negative cusp angle means the star will graze along the sunlit portion of the lunar limb. I generally only consider events with a larger positive cusp angle where the star will be occulted by the “dark” portion of the

lunar limb. In the listing above, I found three potentially interesting grazes: a graze on Apr 8 with a cusp angle (CA) of 6.9S, a graze on Apr 23 with CA = 8.0S and a graze on Apr 27 with CA = 8.8S. And I note that the travel distances for these grazes are 279km for the Apr 8 graze, 66km for the Apr 23 graze, and 184km for the Apr 27 graze. However, I also note that the altitude of the moon will only be 7 deg for the Apr 27 graze. The next step is to explore the details for each of these grazes. To explore the details of a graze in Occult, you must do the search again but for a time span of only one day. For the example above I will start with a search for lunar occultations on Apr 8. After doing this search the list of occultations shows only the two grazes on Apr 8. I now right-click on the graze of with CA=6.9S and select "compute graze". After this step the contents of the lower two-thirds of the dialog changes to include information for this specific graze. Here is the information displayed for this graze. There is a table of circumstances for various locations in the graze path and a table of limiting magnitudes for various telescope apertures.

Grazing Occultation of 93353 GO Magnitude 9.4 [Red = 8.9]
 Date: 2019 Apr 08 3h 59m, to 2019 Apr 08 4h 1m

Nominal site altitude 30m

E. Longit.	Latitude	U.T.	Sun	Moon	TanZ	PA	AA	CA
o ' "	o ' "	h m s	Alt	Alt Az		o	o	o
-125 0 0	50 37 16.2	3 59 12	-9	15 272	3.79	165.4	179.95	7.18S
-124 45 0	50 35 11.6	3 59 18	-10	15 272	3.83	165.5	179.98	7.15S
-124 30 0	50 33 5.8	3 59 25	-10	14 273	3.88	165.5	180.00	7.13S
-124 15 0	50 30 58.8	3 59 31	-10	14 273	3.93	165.5	180.03	7.10S
-124 0 0	50 28 50.6	3 59 38	-10	14 273	3.99	165.5	180.05	7.07S
-123 45 0	50 26 41.2	3 59 44	-10	14 273	4.04	165.6	180.08	7.05S
-123 30 0	50 24 30.7	3 59 51	-11	14 273	4.09	165.6	180.10	7.02S
-123 15 0	50 22 19.0	3 59 57	-11	14 274	4.15	165.6	180.13	7.00S
-123 0 0	50 20 6.1	4 0 3	-11	13 274	4.21	165.6	180.16	6.97S
-122 45 0	50 17 52.0	4 0 9	-11	13 274	4.27	165.7	180.18	6.95S
-122 30 0	50 15 36.8	4 0 15	-11	13 274	4.33	165.7	180.21	6.92S
-122 15 0	50 13 20.4	4 0 21	-11	13 275	4.39	165.7	180.23	6.90S
-122 0 0	50 11 2.9	4 0 27	-12	13 275	4.45	165.7	180.26	6.87S
-121 45 0	50 8 44.2	4 0 32	-12	12 275	4.52	165.8	180.28	6.85S
-121 30 0	50 6 24.4	4 0 38	-12	12 275	4.59	165.8	180.30	6.82S
-121 15 0	50 4 3.4	4 0 44		12 275	4.66	165.8	180.33	6.80S
-121 0 0	50 1 41.3	4 0 49		12 276	4.73	165.8	180.35	6.77S
-120 45 0	49 59 18.0	4 0 55		12 276	4.80	165.9	180.38	6.75S
-120 30 0	49 56 53.6	4 1 0		12 276	4.88	165.9	180.40	6.73S
-120 15 0	49 54 28.1	4 1 5		11 276	4.96	165.9	180.43	6.70S
-120 0 0	49 52 1.4	4 1 11		11 276	5.04	165.9	180.45	6.68S

Path coordinates are referred to WGS84 (as used by GPS), with the nominal site altitude being referenced to Mean Sea Level. The path is adjusted for the effects of refraction at low moon altitudes.

Librations Long -6.24 Lat +6.28
 P +179.49 D +6.57
 Illumination of moon 8%+
 Elongation of Moon 32
 Vertical Profile Scale approx. 2.16 km/arcsec at mean distance of moon
 Horizontal Scale Factor 1.91 deg/min

At longitude -122.50:

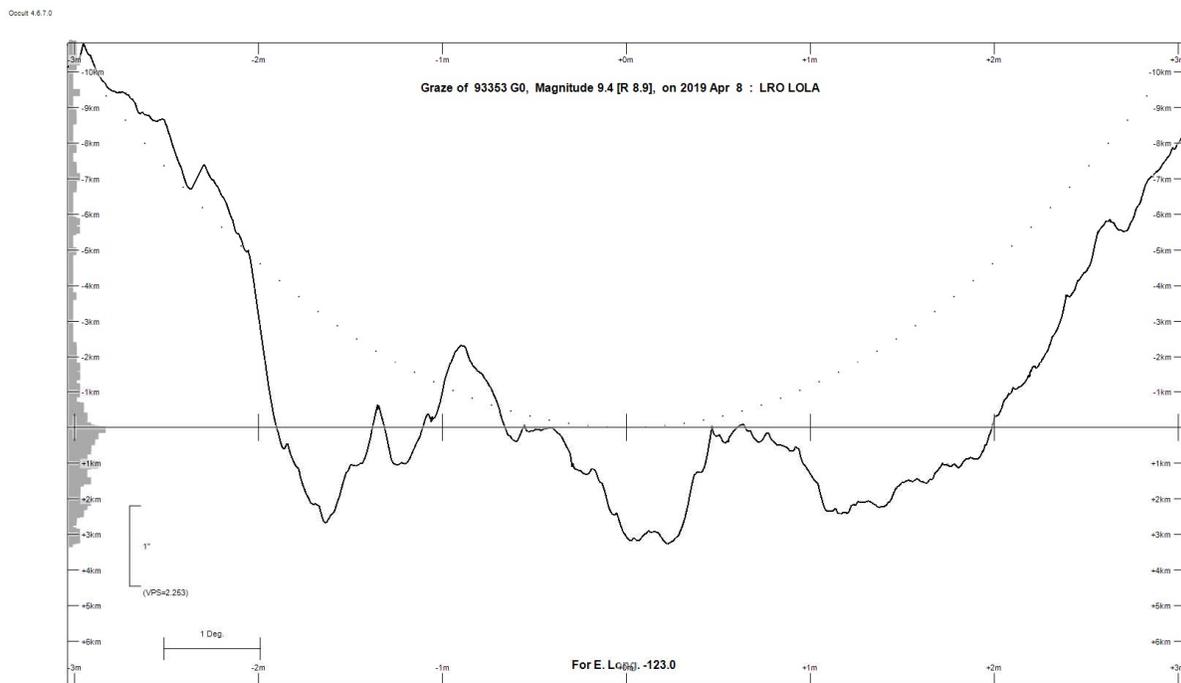
Limiting Magnitudes for various telescope apertures (in cm)

CA\Tdia	5	10	15	20	25	30	35
2.9	6.6	8.1	8.9	9.4	9.7	10.0	10.2
4.9	6.6	8.1	8.9	9.4	9.8	10.0	10.2

6.9	6.7	8.1	8.9	9.4	9.8	10.1	10.3
8.9	6.7	8.1	9.0	9.5	9.8	10.1	10.3
10.9	6.7	8.2	9.0	9.5	9.9	10.1	10.4

Since the star for this graze is roughly 9th magnitude and CA is 7 deg, the table says I will need a 20cm (8" scope) to observe the graze. The next piece of information of interest is the "graze profile" which shows the lunar profile which will occult the star. Examining the graze profile will give me some idea of the number of events (disappear and reappear) likely to be recorded for this graze. To see the graze profile, I right-click on one of the lines in the table of locations in the graze details and select "graze profile" to get the dialog/chart show below. For this chart I also selected some options from the "with Profile" menu option on the chart dialog. I selected "Show LOLA high resolution limb" and turned off all other LOLA and Kaguya options. Then I selected "Event #s by path distance – high resolution". You can bring up Occult's context sensitive help menu when viewing this graph to learn about the details. But, at this stage, my primary interest is the histogram along the left vertical axis. This histogram shows the number of events possible from the given offset from the nominal graze line. From this histogram, we see that the graze might generate 10 or more events from a location near the nominal graze line.

Figure 7 Graze Profile plot:



Next, I run the graze search for each of the other two days and examine the profile for the other two grazes. The Apr 23 graze has CA = 8.0S with a mag 8 star and an 81% illuminated moon. The limiting magnitude table tells me that I need an aperture of more than 35cm, so this graze is not an option for me. The Apr 27 graze has CA= 8.0S and a mag 4.9 star. The limiting mag table says I will need an aperture of only 10cm, so this graze is an option. And the graze profile shows a possibility of as many as eight events.

I know have two potential grazes to consider: Apr 8 and Apr 27. The Apr 27 is a much brighter star and the travel distance is 100km closer than Apr 8. However, the Apr 27 event occurs early in the morning with the moon at an altitude of only 7 deg. With these factors in mind, the Apr 8 event is the only one I would consider trying to observe.

Assuming that you have identified a specific graze you wish to observe, you must then determine the exact location where you will observe the graze. Here are the steps I would follow. The process is a bit convoluted due to altitude corrections.

1. The first step is to go back to the Lunar Predictions dialog and generate the list of occultations for the day of the graze.
2. Then right-click on the line for the graze of interest and select "View in GoogleEarth" (install Google Earth first). This will show the entire path of the moon's "shadow" – including the nominal graze line as the edge of the moon's shadow.
3. Review the path of this nominal graze line, in GoogleEarth, to identify a general area where you think you might be able to observe the graze. Since the location of the graze line changes with altitude it is best to pick an area of relatively constant altitude. Note the latitude, longitude and altitude of a location near the middle of your prospective observing area. You can now close Google Earth (without saving the graze line data).
4. Graze Site file. Now you must setup a new site file and site for this location in the observing area. I tend to use a site file name of yyyy_mm_dd_graze.site where yyyy_mm_dd is the year, month, and day of the graze. Then it is easier to identify this site file as specific to one graze (and delete it when I no longer need the site file).
5. In the Lunar predictions dialog, select your new site file and site in section 1 of the dialog. And once again, generate the list of occultations for the day of the graze.
6. Right-click on the entry in the list for your graze of interest and select "Compute Graze". The resulting graze details will now be specific to the altitude of your actual planned observing area.
7. Right-click on a path coordinate entry in the graze details and select "graze profile". Review the profile to confirm the offset from the nominal graze line which to maximize the number of events.
8. Close the graze profile window. Right-click on a path coordinate and select "View in GoogleEarth". The path line that now appears in GoogleEarth will be a shorter version of the nominal graze line which now covers only the area near your prospective observing location. Note: this nominal graze line may not match the line plotted in Step 2 above due to altitude corrections. Keeping in mind your desired offset from this "altitude corrected" nominal graze line, you can now look for an exact location from which to observe.

6 ASTEROIDAL OCCULTATIONS

Observers can use Occult's "Asteroid Predictions" module to search for asteroidal occultations visible from the earth and display the circumstances (e.g. maps) of these occultations. In contrast to lunar occultations, asteroidal occultations are more difficult to predict and observe. Asteroids subtend a very small angular area of the sky. For many asteroids, the uncertainty of the asteroid's position based on current orbit solutions is often a significant fraction of the asteroid's angular diameter. As a result, the uncertainty in the location of the path for an asteroid occultation is often large enough that observers cannot be certain of seeing the occultation from any specific location. Given this consideration, most observers should rely on the asteroidal occultation path predictions from IOTA sources listed on IOTA's website: <http://occultations.org/observing/occultation-predictions/>. However, some observers will be interested in using Occult to search for asteroidal occultations or view the circumstances using Occult. In this document I will describe the basic elements of predicting and displaying the circumstances of asteroidal occultations.

Occult also includes an "Asteroid Observations" module for examining IOTA's database of worldwide observations of asteroidal occultations. IOTA collects asteroid occultations from observers worldwide and publishes a database of these observations. Occult's "Asteroid Observations" module provides a convenient means of exploring this database of observations. For most observers Occult is the best method for reviewing the observational results of asteroidal occultations.

6.1 ASTEROIDAL OCCULTATION PREDICTIONS

The "Asteroid Predictions" module has two primary functions: searching for asteroid occultation events and displaying (plotting) the path of an occultation event. If you select the Asteroid Predictions module, the main dialog will display several buttons for accessing the dialogs of this module. The two primary dialogs are: "Search for & list occultations" and "List & Display occultations". Most observers will use only a few other buttons from the Asteroid Predictions main dialog: "Convert Astorb, MPCOrb & AstDys-2" and the "Preston files" download buttons in the Download Prediction files group.

6.1.1 Search and Display: Overview

Occult searches for asteroid occultations by comparing asteroid positions over time to star positions from a star catalog. When you search for asteroid events, you specify (a) a catalog of asteroid orbits (b) a star catalog (c) a timeframe over which to conduct the search for events (d) a set of one or more asteroids for which to do the search for events. For each asteroid specified, Occult then conducts a search for asteroidal occultation events visible from locations on, or near, the earth. If Occult finds events during the search process it outputs a file containing the primary "elements" for each occultation event found. This output file of occultation elements is called the "occelmnt" file (short for occultation elements). Ocelmnt files may contain elements for more than one occultation event and serve as the underlying file type for occultation predictions in Occult. The ocelmnt file is the input file for displaying the circumstances of an occultation event. When you open an ocelmnt file with the List&Display dialog, then select an event, Occult will plot the predicted path of the occultation on a map of the earth and provide additional circumstances for the event.

6.1.2 Searching for asteroidal occultations

Occult's search dialog is reached via the "Search for & list occultations" button in the main dialog of the Asteroid Predictions module.

Figure 8 Search for Planetary occultations Dialog :

The screenshot shows the 'Search for occultations by Asteroids, or by Planets' dialog box in Occult v.4.6.7. The window title is 'Search for occultations by Asteroids, or by Planets [including Pluto] : Occult v.4.6.7' and the user is 'VSOP87A'. The dialog is organized into five numbered sections:

- 1. Set the date range for the search:** Includes fields for Start Year, month & day (2019, 5, 1) and End Year, month & day (2019, 6, 1). Buttons for 'Year', 'Month', and 'Now' are available, along with a 'Add 1 day =>' button.
- 2. Select the star catalogue for the search:** Radio buttons for 'Gaia' (selected), 'UCAC5', 'Tycho2 (pre Gaia)', 'UCAC4', 'User catalog', 'PPMXL', and 'User star'. A 'Select the Gaia file to use' list shows 'Gaia14_DR2', 'Gaia14', and 'TychoGaia'. Filter options include 'Exclude stars fainter than mag 14.5', 'Exclude if mag drop smaller than 0.30', and 'Limit to Kepler2 stars'.
- 3. Select asteroids to search, or planets [including Pluto] to search:** Radio buttons for 'Asteroids' (selected) and 'Planets'. Shows '1 Ceres <=> 523800 2017 KZ31 (5254 asteroids)'. Includes options for 'use USER file of elements', 'Exclude minor planets smaller than 15 km', and 'Exclude if duration less than 0.2 secs'. A 'Binary asteroid ephemerides available from Miriade' section includes a list of numbers (22, 41, 45, 87, 93, 107) and options for 'Do not use Miriade ephemerides' and 'Limit output to first (= best) orbit'.
- 4. Set the file to save the occultation elements from the search:** Includes a 'Set output file' button, a checked 'Automatically save the search results' checkbox, and an unchecked 'Sort the file by date' checkbox. The file path is 'C:\Occult 4\Generated Files\Occelmnt20190501.xml'.
- 5. Do the search:** Includes a field for 'Adjust asteroid position (in mas) by RA 0 Dec 0', an 'Increase Earth miss distance by 4 Earth radii' field, and a checked 'Clear the previous results from memory' checkbox. The 'Star catalogue' is 'Gaia14_DR2' and the 'Orbit source' is 'Astorb 2019Apr04'. A 'Search' button is present.

At the bottom, there is a 'Note: Search must be within the interval covered by the depressed buttons. Press buttons as needed.' and a grid of date range buttons:

1831 Jul 02 == 1858 Nov 17	1913 Aug 21 == 1941 Jan 06	1995 Oct 10 == 2023 Feb 25	2077 Nov 28 == 2105 Apr 16
1858 Nov 17 == 1886 Apr 04	1941 Jan 06 == 1968 May 24	2023 Feb 25 == 2050 Jul 13	
1886 Apr 04 == 1913 Aug 21	1968 May 24 == 1995 Oct 10	2050 Jul 13 == 2077 Nov 28	

Before conducting a search, be sure that you are using a good set of asteroid elements. You can download a current set of orbital elements via the maintenance dialog as described in the early sections of this document. You can also access this functionality via the "Convert Astorb, MPCOrb & AstDys-2" button on the main dialog of the Asteroids Predictions module.

To conduct a search for occultation events, you must set parameters in each of the five sections of this dialog.

Section 1: Date range for Search. Keep the date range as small as possible. Searching over an entire month can take a long time and generate a lot of events.

Section 2: Star Catalog. Choose the catalog based on the most recent Gaia catalog and with a limiting magnitude matching your needs. In the bottom part of this section, you should also set the limiting star magnitude and limiting magnitude drop. These options will speed up the search and limit the size of the output file.

Section 3: Asteroids/Planets. These settings will have the biggest impact on the time required for the search. Minimize the number of asteroids in the search. Exclude events which are too short in duration for the time resolution of your equipment. For most observers, any less than 1 second is difficult and less than 0.5 seconds is impractical. When possible, exclude smaller asteroids.

Section 4: Output. Set a filename. When you start the Search dialog it will default to a filename based on the current year, month and day. Check the box to automatically save the search results and avoid accidentally losing the results of a long duration search (a good default setting).

Section 5: Do the search. Set the Earth miss distance – 2 or 3 earth diameters is good enough for most asteroids.

When the search is finished, Occult will display a list of all the occultation events found in a “List&Display” dialog (described in the next section). If you have checked the box for “Automatically save search results”, Occult will have saved these events to the ocelmnt file name you specified in section 4.

6.1.3 Displaying asteroidal occultations

Users can display the circumstances of an occultation event by opening an occultmnt file from Occult's List & Display dialog and selecting the event. Also, after searching for events with the Search dialog, Occult will automatically start the List & Display dialog showing the events found in a search. Here is a snapshot of the List&Display dialog showing a list of events from an occultmnt file. In the top portion of this dialog, the user has options for specifying several criteria for filtering the events from an occultmnt file to list only events which meet these criteria.

Figure 9 The List and Display Dialog:

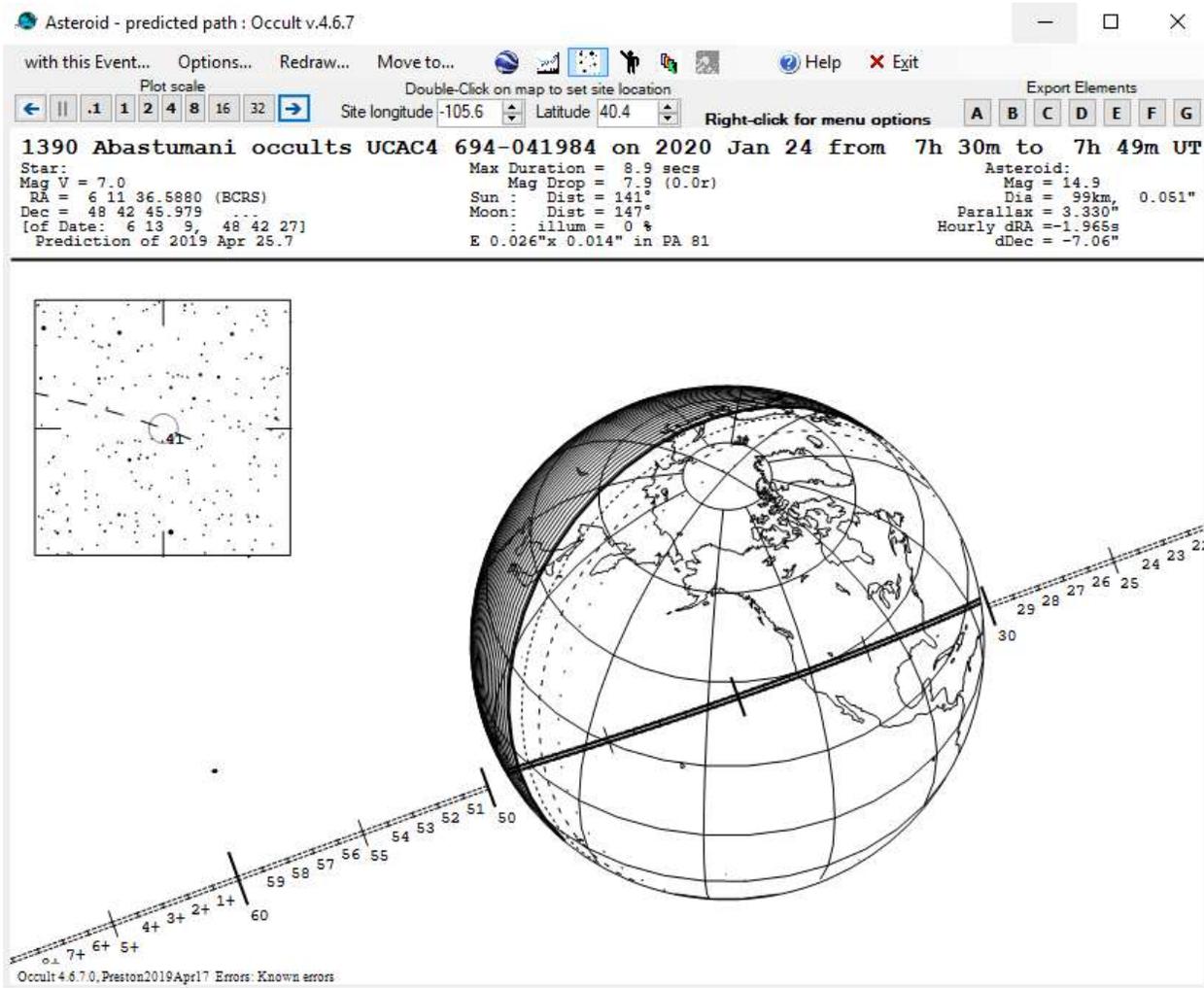
The screenshot shows the 'List & Display' dialog box with the following sections:

- File... Sort events... Generate predictions for all listed events**
- Selection filters:**
 - Magnitude drop > 0.5
 - Star mag < 14
 - Maximum dum > 1.0 sec
 - Diameter > 25 km
 - Solar elongation > 20°
 - Path crosses
 - Major planets [Jupiter]
 - Asteroids with a shape model - §
 - Asteroids with moons - <
 - Asteroids with rings - ⊕
 - Uncertainty < 0.6 Earth radii
 - Exclude if in Future(All).xml
- Global summary of events - sorted by Date**

Date	U.T.	Diameter	Durn	Star	Mag-Drop	Elon	%	Star	d	Planet	Min	Moon	§	R.A. (J2000)	Dec.	
y m d	h m	km	sec/m	mag	V	R	o	Ill	No.	No Name	D	Error	Dist	ill	h m s	
2020	Jan 1	7 59.2	144 0.129	12.3s 12.5	.25	176		UCAC4 582-034437	144	Vibilia	0.32	±0.00	113 33	§	6 55 59.803	26 13 24.10
2020	Jan 1	9 50.4	77 0.066	7.4s 12.0	1.6	151		UCAC4 438-040785	329	Svea	0.65	±0.00	122 33	§	7 44 16.298	- 2 28 4.87
2020	Jan 1	11 3.1	54 0.063	6.3s 10.0	1.3	169		UCAC4 583-021895	563	Suleika	0.02	±0.01	99 34		5 59 37.854	26 33 48.39
2020	Jan 1	11 26.1	43 0.040	5.9s 12.1	1.1	114		TYC 4919-00728-1	582	Olympia	0.17	±0.01	161 34	§	10 44 43.967	- 6 10 33.24
2020	Jan 2	2 25.6	34 0.030	3.3s 12.3	1.5	159		UCAC4 579-041371	131	Vala	0.40	±0.00	122 40		8 17 56.518	25 43 18.34
2020	Jan 2	3 47.7	144 0.129	12.3s 12.4	.28	176		UCAC4 582-034287	144	Vibilia	0.31	±0.00	103 40	§	6 55 5.256	26 16 2.06
2020	Jan 2	5 53.5	124 0.105	11.0s 12.5	0.6	167		UCAC4 628-035919	127	Johanna	0.71	±0.00	99 41	§	6 42 59.459	35 26 56.28
2020	Jan 2	11 20.4	99 0.077	7.3s 11.8	1.4	177		TYC 1356-01708-1	412	Elisabetha	0.33	±0.01	100 43		6 59 11.023	21 22 47.68
2020	Jan 2	12 29.9	136 0.062	3.8s 10.4	3.8	56		TYC 5229-01055-1	283	Emma	0.25	±0.01	29 44	§	22 26 19.591	- 4 0 51.33
2020	Jan 2	16 38.2	93 0.076	8.1s 12.1	0.5	148		UCAC4 451-044825	148	Gallia	0.28	±0.00	118 45		8 23 16.983	0 11 27.99
2020	Jan 2	20 36.2	116 0.095	12.3s 12.2	0.8	162		UCAC4 570-017952	86	Semele	0.16	±0.01	76 47		5 34 4.001	23 53 25.97
2020	Jan 2	22 17.7	35 0.020	5.8s 9.9	6.4	134		TYC 0239-00693-1	1408	Trusanda	0.87	±0.01	135 47		9 42 21.810	2 56 53.79
2020	Jan 2	22 20.6	66 0.035	5.2s 11.7	3.8	143		TYC 5426-01396-1	1051	Merope	0.39	±0.01	112 47		8 10 33.118	- 8 37 49.66
2020	Jan 3	11 58.4	31 0.026	3.0s 8.6	5.6	8.2	176	TYC 1341-1154-1	1003	Lilofee	0.17	±0.01	83 53		6 36 25.928	21 18 26.57
2020	Jan 3	18 36.5	54 0.029	3.5s 12.4	1.5	176		UCAC4 569-037540	222	Lucia	0.56	±0.01	87 55	§	7 10 43.475	23 42 56.15
2020	Jan 3	19 40.4	93 0.060	6.8s 11.7	2.0	170		TYC 2442-01511-1	567	Eleutheria	0.60	±0.01	87 56	§	7 11 42.676	32 17 42.61
2020	Jan 4	0 14.6	29 0.023	2.3s 8.0	5.8	5.9	158	HIP 39219	1659	Punkaharju	0.51	±0.01	94 58	§	8 1 19.555	40 24 2.38
2020	Jan 4	14 31.9	144 0.129	12.4s 11.3	0.6	176		TYC 1902-00635-1	144	Vibilia	0.58	±0.00	73 63	§	6 52 23.911	26 23 29.88
2020	Jan 4	16 0.6	107 0.040	3.6s 7.8	7.5	65		HIP 72339	780	Armenia	0.78	±0.01	166 64		14 47 32.554	- 0 16 56.13
2020	Jan 4	17 19.8	61 0.028	7.5s 11.6	4.5	103		TYC 4938-00229-1	1240	Centenaria	0.34	±0.01	148 64		11 54 29.875	- 3 41 9.82
2020	Jan 4	23 42.9	73 0.056	8.1s 12.2	1.9	148		UCAC4 537-048604	112	Iphigenia	0.25	±0.00	102 67	§	9 15 14.996	17 14 42.98
2020	Jan 5	1 50.7	54 0.064	6.7s 11.0	0.8	165		UCAC4 585-021243	563	Suleika	0.12	±0.01	55 68		5 56 11.318	26 55 37.69
2020	Jan 5	5 17.0	43 0.028	7.2s 12.0	1.8	138		UCAC4 497-054018	125	Liberatrix	0.19	±0.00	109 69	§	9 47 15.520	9 18 44.87
2020	Jan 5	5 53.9	27 0.025	3.8s 8.7	6.4	6.7	155	TYC 1396-728-1	1125	China	0.10	±0.01	92 69	§	8 46 48.607	19 50 6.62

To display the path and other circumstances of an event listed in the dialog, you click on the event in this list. Occult will then display the occultation path plot dialog for the event. The Occult help file provides detailed descriptions of all aspects of this dialog. And you can find descriptions of the basic information and functionality of the dialog in the IOTA Observers manual posted on the IOTA website. In this document I will describe a few of the more useful features of this dialog (show below).

Figure 10 Occultation Path Plot dialog



Plot Scale: The plot generally starts up a scale showing the entire earth. Zooming out is easily accomplished via the "Plot Scale" buttons in the upper left of the dialog. But zooming in requires that you set a center location for the zoom. You can set the center via the Site longitude, Latitude fields in the top middle of this dialog. Or you can set the center by double-clicking a location on the plot. After setting the plot center, change the plot scale via the buttons in the upper left.

Export Elements: In many cases you will open and review an occultation file containing many events. But you may wish to "save" only certain events to separate file. When you click on one of the Export Elements buttons in the upper right, Occult will save the elements for the current event to a file with the same name as the current input file AND a suffix of "-A", "-B", ... or "-G".

Export to Google Earth: From the "with this Event..." menu item of this dialog, you can access an option to save the path of this event to a GoogleEarth KMZ file. You can open this file with Google Earth to see the path on a satellite view of the globe.

List WDS, Interferometric catalog, etc: If you right-click on the plot, Occult will display a dialog with several options, including an option to list any relevant entries in the WDS (Washington Double Star) catalog and other catalogs which provide additional information about the star. Before observing an event, it is good to check for possible double stars which might complicate the observations. The later releases of Gaia data may replace this capability. But it will probably be good to check anyway.

Pre-point stars: If you are pre-pointing a telescope for your observation. Occult can display a list of pre-point stars with times. You can access this list via the “with this Event...” menu item.

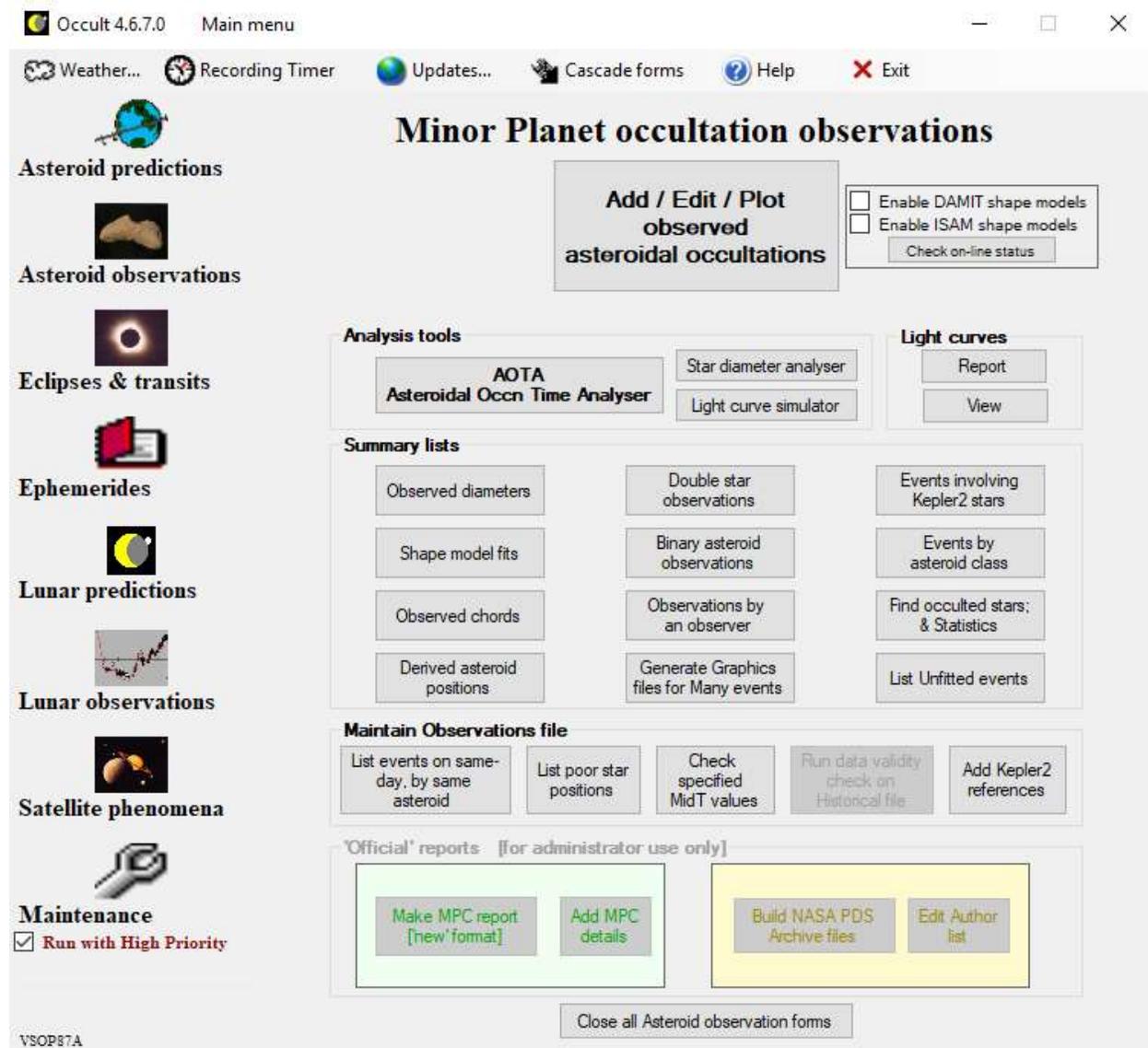
6.1.4 Download Predictions

The Download Prediction files section in the main dialog of the Asteroid Predictions module can download existing files containing occultation path predictions. Most observers will only be interested in downloading the FutureAll.xml file. FutureAll.xml is an ocelmnt file containing the full set of path predictions posted on asteroidoccultation.com. future.xml is a subset of FutureAll containing only the events in the “current events” list of asteroidoccultation.com. But FutureAll is not a large download with current internet connections so most observers should just download FutureAll. Occult will place the FutureAll.xml file in the \Generated Files sub-directory of the Occult install directory. After downloading FutureAll, you can open the file with the “List & Display” dialog and review any specific events in the file.

6.2 ASTEROIDAL OCCULTATION OBSERVATIONS DATABASE

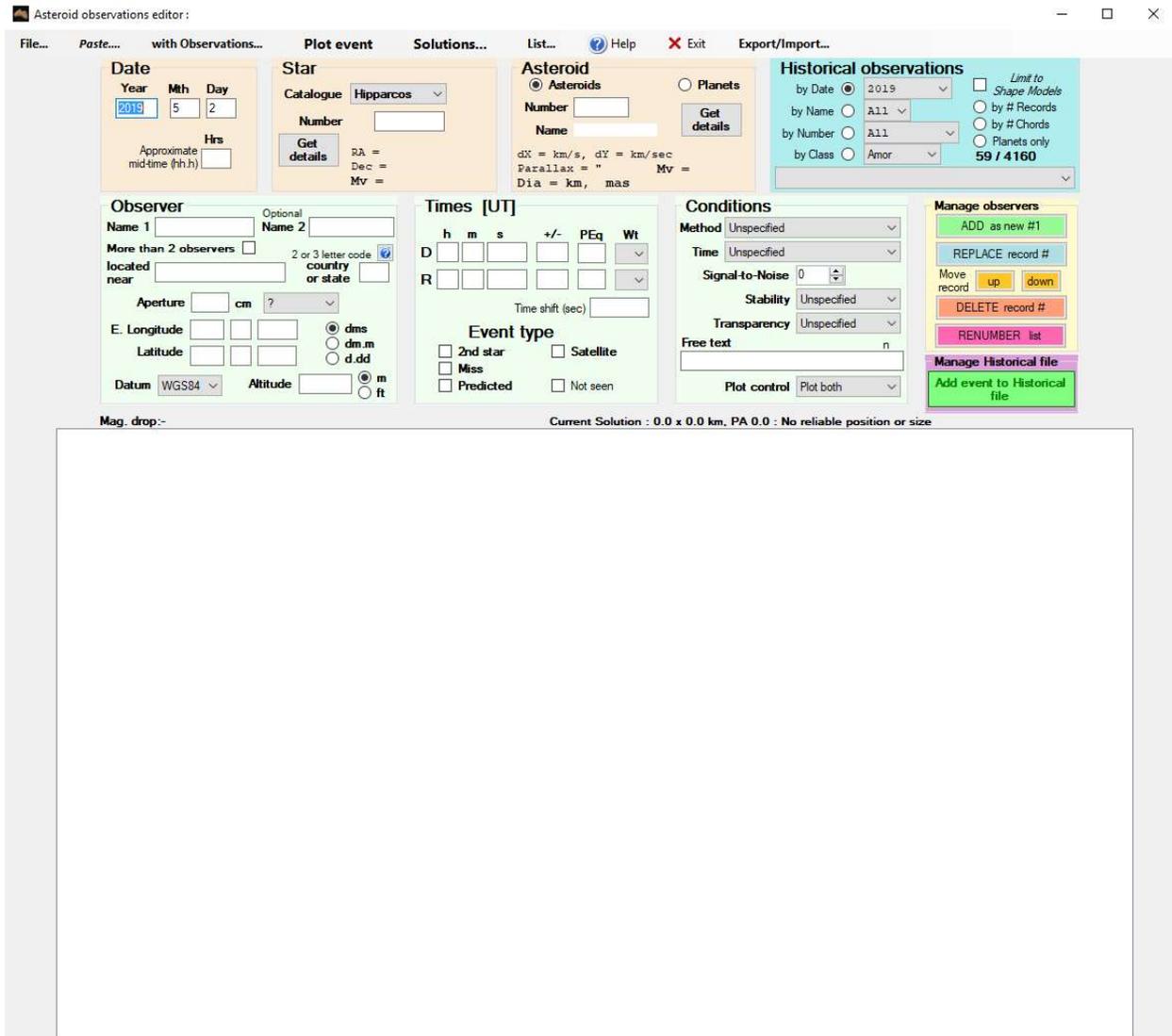
You can view the database of historical asteroidal occultation observations via the “Asteroid Observations” module in Occult. Before reviewing the database, download the latest dataset via Occult’s Maintenance module (show below). Most observers will only access the Summary lists or browse the database via the “Add / Edit / Plot observed asteroidal occultations” dialog.

Figure 11: Asteroid Observations module



The summary lists are either self-explanatory or described in the Occult help file. This document will focus on the “Add/Edit/Plot” dialog. Despite the “Add” and “Edit” in the name, most observers will only be interested in “Plotting” (reviewing) the observations in the database. When you select the “Add/Edit/Plot” dialog from the main menu of the Asteroid Observations module above, Occult will bring up two dialogs: “Asteroid Observations Editor” dialog and “Plot event observations” dialog. To review the observations for a specific event, you will start with the Asteroid Observations Editor dialog.

Figure 12: Asteroid Observations Editor



The controls in the “Historical Observations” section of the upper left part of this dialog provide options for searching for events via date, asteroid name, asteroid number or class of asteroid. Use these controls to select an event. Occult will then fill in this form with the observation details and plot the observation profile in the “Plot event observations” dialog.