Occultation Newsletter

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Occultation of Saturn

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ON THE COVER: Image of the occultation of Saturn on 2002 February 20. This image was taken by Joan and David Dunham.

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Lunar Occultation Workbench 3.1: stellar occultations tailor-made to your needs

Eric Limburg
elimburg0@cs.com

The Lunar Occultation Workbench (LOW) is a freeware program that has been available since 1995. In the course of the years LOW has become a popular and powerful program for the calculation of lunar occultations of stars and planets. It also allows the observer to record his observations and export them in the ILOC format. Versatile views of the moon and the occulted star or planet can be shown. Views of the lunar limb profiles give the user a clearer idea of what can be/has been observed. In August 2001 LOW version 3.0 was presented at the European Symposium on Occultation Projects (ESOP XX) in Barcelona, Spain. In the following article a brief description is given of LOW's history, current functionality and future direction.

A brief history of LOW

In August 1993, I attended ESOP XIII in Roden, the Netherlands. I had become an amateur astronomer again. A few years before I had been working professionally at e.g. the European Southern Observatory (ESO) in Chile, and at the National Optical Astronomy Observatories (NOAO) in Tucson, AZ. After having gone into business, and settling in the Netherlands again, my old passion for observing occultation phenomena came back to me again. I attended ESOP to find out what the latest developments in the field of occultations were. And so I found myself listening to presentations about and demonstrations of the various software programs that were being used to calculate predictions of stellar occultations. The programs presented ran on PC, Atari, VAX VMS or Unix computers. In most cases the programmer of the program was its only user. Only the Evans program was publicly available. Unfortunately it needed to be treated to an annual floppy feed to update its (Besselean Element) data. This process I thought rather cumbersome and limiting: a user could only calculate predictions for the coming year. Most user interfaces that were shown, I found rather rudimentary and not very user friendly. I discovered that there wasn't a single program running under the world's most proliferated operating system - Windows! I had discovered the proverbial 'hole in the market'.

I believed that a program satisfying the following criteria would meet the needs of many interested in (observing) stellar occultations:

- Allow many different users to compute the most accurately possible predictions, and easily record and send away their observations of stellar occultations
- Give users the greatest amount of freedom due to as little dependence on the programmer as possible. (As a pleasant side effect, this would allow me, the programmer, to have a more quiet life too.)
- Be easy to install, user-friendly, employ an intuitively easy to use graphical user interface (GUI), and be graphically appealing (slick!) to the user
- Be flexible enough to allow users to calculate only those predictions they are interested in, and create views that show only those elements which the user feels are relevant to him
- Have an appeal to both novices as well as to the experts in the field
- Make use of accurate and the fast algorithms for calculating the positions of the sun, earth, moon and the planets. Select algorithms that allow for computations over large periods of time
- Make use of the best available star catalogs and lunar limb profile databases
- Run stable on a PC under all 32-bit varieties of Windows (95, 98, Me, NT, 2000, XP) or on other systems with Windows emulators
- Be written in an object-oriented language that delivers highly structured, reliable and fast code.

My answer to the above has been the Lunar Occultation Workbench, or LOW (built in the LOWlands, as the Netherlands are sometimes referred to). LOW has been written in Microsoft Visual C++, a language in which many popular programs such as Windows and Word have been written too. The object oriented language enables highly structured, robust, clear and clean coding practices. LOW has the advantage of much greater speed over those PC occultation programs written in Basic. To calculate a LOW ephemeris of the sun, earth and moon for every three hours for a whole year requires a mere 5 seconds on a 1.4 GHz AMD Athlon PC. Compare that to the 30 seconds it used to take a good old BBC computer some 20 years ago to compute only one single position of the moon, and you'll appreciate how far computer technology has come in such a relatively short period of time!

LOW got a head start when Adri Gerritsen allowed me to use the C-code that he had developed to calculate predictions of stellar occultations on his Atari computer. Adri had built a reliable and robust prediction engine, so to speak, and I turned it into a highly tunable racing engine and built a Formula 1 racing car around it. LOW 1.0 was developed on a 386 laptop and presented during ESOP XV in Plzen, Czech Republic in 1995. In September 1997 version 2.0 became available and on January 29, 1998, users were able to download the program from the Internet for the first time. An estimated 40.000 downloads have been made from the ftp-site since. LOW was reviewed in Sky and Telescope, and included in the book 'Software and data for practical astronomers, the best of the Internet' which was edited by Patrick Moore. Based also on suggestions for further improvement from some 20 users from all over the world a third version was made. It became available in October 2001 and consists of more than 100.000 lines of C++ code and 350 source files. Judging by the number of downloads this version is proving to be even more popular than the previous one by a factor of five... LOW does indeed appear to fill that 'hole in the market' that I mentioned before.

Where's the beef?

For many a reader of ON LOW is nothing new. It has been mentioned and referred to every now and then, but a more lengthy description of it capabilities, and specifically those of version 3.1, has not been given until now. Below a short description is given of the algorithms and data that are used behind the scenes. It is followed by a longer description of the major menu bar options: settings, predictions, observations, views, files and other features. And so here's the beef:

Algorithms

From the following theories, algorithms have been derived that have gone into LOW:

- ELP2000-85 Theory of Lunar Motion (Chapront)
- VSOP87 Theory of Planetary Motions (Bretagnon, Francou)
- IAU Theory of Nutation 1985
- Theory of Libration

Most of these algorithms produce angles that have errors in the milliarcsecond range. Many, many algorithms that Jean Meeus has described in his classical book 'Astronomical Algorithms' have also been used.

Data

The following two star catalogs have been used:

- The XZ80P star catalog, containing 53.933 stars, 21.8% of which are Hipparcos stars
- A zodiacal subset of the Guide Star Catalog (GSC) version 1.1, which contains some 476.579 stars, is used to complement the XZ catalog. The combination of both catalogs is complete up until magnitude 13.0. This might appear an unusually high value, but it is based on practical experience. On January 9, 1982 I observed some ten occultations with my 20 cm (8") Newton telescope during the totality phase of a lunar eclipse. Of those only two could be identified at the time (Little did I know then that one day I'd write a program that would allow me to identify these stars myself.). It turned out that the weakest star shined at magnitude 12.3! By using this combination of catalogs I believe that LOW is the first program that allows for the identification of those many 'unidentified stars' that observers have seen occulted by the moon through the years. Put differently: no user will ever have to observe occultations of stars that haven't been predicted. And because many observers go outside to observe what shows up in their prediction list, it means that those same observers could make more observations.

  The older 1.1 version of the GSC is used because it includes proper motion data. The newer, more accurate GSC 2.2.01, which includes the Tycho-2 catalog, has more accurate positions of many more objects, but contains currently no proper motion data. Sometime in 2002 the GSC II will become available and it will make up for this shortcoming of the GSC 2.2.01. In the next version of LOW the GSC II will most likely be used. The story of programs such as LOW having to be continuously updated to make use of more accurate star catalogs is likely to end sometime after 2014. ESO's GAIA satellite is supposed to be launched then. GAIA should provide the data to create a complete star catalog down to magnitude 22 with a positional accuracy in the order of several to tens of microarcseconds (!) and proper motion data to go with it. That to me would be the ultimate catalog for stellar occultation purposes. I wish it were available now... Anyway, back to the present.

  LOW 3.1 is available in two editions: lite and professional. The former one comes without the GSC stars, but has all other functionality that the professional edition (with GSC) has to offer.

The following lunar limb profile databases can be used:

- Watts database. This old and well-known database is based on photographs of the moon. Its accuracy varies and is especially bad in the so-called Cassini region. This database is 25.3 MB in size. In the lite edition a condensed version of the Watts database (only 829 KB in size) is included. For predictions of total occultations the loss in accuracy is acceptable.
- MoonLimb. This newer database, also 25.3 MB in size, is an improvement over the Watts database and it's based on corrections made to the Watts database and reductions of thousands of accurate occultation observations.
- ALCPPP. The ALCPPP database (version of June 1, 2001) contains the results of some 809 grazing occultation expeditions. It provides valuable information in addition to that of the previous two databases when planning an expedition to observe a grazing occultation. This database is included in both editions of LOW.

One of the most important errors in calculating the time of a total occultation, is that of the lunar limb profiles. To minimize this error the first thing to do is use the MoonLimb database. In addition to using such a 'complete' (i.e. not condensed) database, the algorithm to determine the limb correction is of importance. In LOW a fifth order polynomial interpolation of some 16 height values at varying Watts angle and libration longitude and latitude combinations is used.

A final piece of data that is important for occultation prediction purposes is Delta T. LOW 3.1 offers users the possibility to regularly and automatically update LOW's

Delta T table by downloading data from the USNO ftp-site. In the past users often forgot, or did not know about the need to update this table every now and then in order to continue to calculate the most accurately possible predictions. This problem no longer existed with LOW 3.0 until the USNO recently decided to stop providing the Delta T data! LOW users would then have to update the table again manually. So version 3.1 (where did I see that number before?) was created to solve this particular problem and made available in February 2002.

After having had this brief look under the hood of the racing car, it's time to have a look at LOW's dashboard.

Settings

The settings consist of data describing the observers, telescopes, stations and timing methods.
The user can enter a theoretically unlimited number of each of these. You can specify the optical assembly of the telescope, including eyepieces, accessories and filters. It is important to know that each telescope needs to be linked to an observer and to a station. Simply adding a telescope to the list of telescopes and assuming that LOW 'knows' to which station it is to be linked, will not work, as some users have found out. Until at least one complete set of such settings has been defined, the user cannot calculate any predictions. The data entered are also used later for the observations that the user records.

Predictions

This is where the great strength and flexibility of LOW lies. The user can define the following parameters in or via the 'New Predictions' dialog window:

- Occulted objects. The user can define whether calculations for stars and/or planets need to be made. In addition, the user can specify whether the complete XZ catalog and possibly the GSC catalog are to be used, or whether a list of only one or more stars, or one or more planets should go into the prediction calculations. In short, the number of occulted objects can vary from one single star or planet, to the full XZ80P and GSC catalogs and the eight planets.
- Period. The time period for which the occultations are to be calculated can be defined up to the minute, and may lie anywhere between 4000 BC and 8000 AD
- Time. The time in which the predictions are expressed can either be in UTC or local (daylight savings) time.
- Observer, Telescope and Station combination. Defined earlier in the settings, the user can select for which combination predictions are to be calculated. In case the user would like to create predictions for more combinations, he simply has to make several predictions, one after the other, and save the results in different files.
- Filtering. Some 20 different parameters can be tweaked with to create tailor-made predictions. I won't describe them here in full detail; LOW's help file (press F1) can do that for you. The observer's experience and telescope aperture and optical efficiency can be changed. They determine, in part, whether an occultation is likely to be observable or not. For each occultation namely a value for the expected minimum telescope diameter that is required in order to be able to observe the occultation, is calculated. When using the 'Default' and 'Custom' algorithms, any predictions with minimum telescope diameters that are greater in size than that of the telescope aperture defined by the user, are automatically filtered out. If you use the 'Maximum Aperture' algorithm, all predictions that can be observed with a 100 cm (40") telescope are calculated. When the 'No filtering' algorithm is selected even the unobservable ones are no longer filtered out anymore... So although LOW has the capability the produce great numbers of (unobservable) occultations, it's the user who determines what is really calculated.

A nifty parameter is the local horizon. Many observers have stations for which parts of the heavens are permanently obscured by objects of some sort or another. As a part of their station they can define in intervals of 10º in azimuth above which altitude they have a clear view of the sky. When this parameter is switched on, occultations that occur below the local horizon are filtered out. So there's no longer any need to get ready to observe something that can't be seen anyway!

Whether or not and if so, which lunar limb profile database to use to calculate the correction for the lunar limb, is something the user can select. Another nifty parameter allows for predictions to be calculated during lunar eclipses only (or not). Considering the fact that:

- relatively few occultations are observed around full moon,
- that during lunar eclipses many occultations can be seen in a short period of time with modest sized telescopes, and
- that LOW can now calculate these occultations of faint stars,

then you'll appreciate that the prospects for increased observing of such valuable occultations have become brighter.

The limiting magnitude for which occultations are to be calculated is yet another parameter. Or actually, there are three parameters: one for the daytime, one for the night time bright limb and one for the dark limb. Depending on the telescope aperture, pressing the 'Default' algorithm button will fill in values for these limiting magnitudes. That way LOW won't be doing any unnecessary number crunching for you.

> Grazes can be played with too. The user can calculate grazing occultations with or without total occultations as well. The maximum distance from the selected station to the graze can be defined by the user, as well as the distance between the points along the graze line that are to be calculated. A final and handy parameter is the graze station height. By default this is the height of the selected station, but in hilly country one can (and should) fill in the height of the expedition site in order to get more accurate graze points.

Users can now answer questions like the following in a very short period of time: when is the next lunar eclipse and are there any grazing occultations that occur during totality within a distance of 100 km (60 miles) from my station? When is the next grazing occultation of a star of magnitude 3 or brighter near my home? How often is Aldebaran occulted in the period from 2000 to 2020? It's this type of flexibility that has led to the name Lunar Occultation **Workbench**.

Though it might appear from the foregoing that the user has a lot to select before a single prediction can be calculated, quite the opposite is true. All parameters have default values such that nothing needs to be changed by the user. That way the novice needn't worry at all about things he might not be familiar with. He can simply click 'Continue' to go to the 'Computing Predictions' dialog window and 'Start' the number crunching. The dialog will show the progress that has been made: the percentage completed, the number of predictions found, the time spent computing so far and the estimated time to completion. At any time the user can abort the calculations by pressing the 'Cancel' button. Once finished, the 'View Predictions' screen pops up and the list of predictions found is shown. A row of buttons at the top allows the user to add or delete one or more predictions, show only a selection of the list, see the details of a single prediction, look at the various statistics, go to the next occultation that will occur, or look at the observation information of an occultation that has been predicted and for which observation information has been recorded.

When looking at the 'Prediction Details' you'll see that 38 information fields are shown, though not all of them need to have a value. One of particular interest is the 'Flashes/Blinks' field. As reported by Richard Nugent (see ON, volume 8, number 3, page 6), some 'total' occultations can display flash and blink phenomena that one usually associates with grazing occultations. I first observed this type of phenomenon some 20 years ago, and have called them flank occultations. Assuming that we're dealing with a single, or very close double star, there usually, though not exclusively, tends to be a series of one or more dis- and reappearences that occur along the slope of a lunar hill or mountain. In case the occultation occurs not too far away from the graze line one can see dis- and reappearences due to more than one hill or mountain. Using the aforementioned 'Selection' button, one can even select these phenomena and have only them shown in the predictions list. The 'Flashes/Blinks' value can be either 'unlikely', 'possible' (when it occurs in the Cassini region), or 'likely' when not in the Cassini region, followed by the possible number of events. These phenomena are pretty rare, as one might expect. For my 25 cm (10") telescope located in Switzerland I found for the year 2002 some 7 'likely' flank occultations out of a total of 2129 predictions, or 0.3%. Most of them are several tens of kilometers from the graze line. With LOW you can view these phenomena by selecting 'Lunar Limb Profiles' from the 'View' menu. In figure 1 an example hereof is given. The trail of the star can be seen to cross the lunar limb profile on three occasions. A word of caution however: the errors in the lunar limb profiles are currently such that a flank occultation can only be predicted as occurring to be 'likely' and nothing more. I know of a few situations where an observer did indeed report seeing a predicted flank occultation. I'm curious to receive more such (positive or negative) reports from observers.

(Figure 1 text caption: Flank occultation of XZ 9898 on March 22, 2002, visible from Boswil, Switzerland.)

In the same 'Prediction Details' window pressing the 'Graze Details' button show date, time of conjunction, longitude and latitude, Watts angle, cusp angle and the required minimum telescope diameter in order to be able to observe the graze. As the minimum diameter depends strongly on the distance to the bright limb, having this information can help to chose a better graze site.

To make life even easier for the user/observer, there's the 'Tonight' function. Based on the settings (see below) LOW will calculate the predictions for the coming two nights, and highlight the next occultation to occur. To make things even easier, it is possible to have LOW automatically reload the last used file at startup and position it at the next occultation to occur. If no such prediction is available, 'Tonight' is automatically called. That way you can immediately see 'what's up tonight' after you've started the program, without having pressed a single button or having clicked your mouse!

For completeness sake it should be mentioned that before any predictions can be made an ephemeris needs to be made for all months that lie within the desired period. If one or more 'months' are missing, the user is prompted whether or not to compute these. If so, LOW then creates one or more ephemeris files and they are stored on the hard disk for future reference. Immediately after that the predictions can be calculated. A year's worth of ephemeris data requires a little less than 0.5 MB of disk space.

Observations

Once an observer has timed an occultation, he can then use LOW to record it. In the 'New Observations' window two lists are visible: one with the predictions, and one with the observations. The user can simply 'Select' a prediction from the list (or double-click on it), or press the 'Unidentified Star' button in case no prediction of his observation is present. In all these cases a new observation is created. The following data are copied from the prediction to the observation: the date, time, phenomenon, (dis- or reappearance, etc.), phenomenon position (dark or bright limb, umbra during lunar eclipse), observer, telescope and station. In case an observation was made less than three hours prior to the current observation, then the following data are copied from this older observation: seeing, transparency, temperature, and some remarks such as 'dark limb visible'. What remains for the observer to do is fill in the exact time of the occultation (editing the seconds field), the reaction time, and an estimation of the accuracy. LOW checks the time of occultation for plausibility. In case the difference between the predicted and observed times is larger than what one would expect theoretically, the user is asked for confirmation of the observed time. All in all recording an observation in LOW is something that takes less than a minute to do. How different the situation used to be in the past when observers (like me) had to fill in those coded ILOC forms. Not only was more work involved in doing this, but also the chances of making errors were far greater. Based on observations reported to the Dutch Occultation Association the percentage of errors was estimated to lie around 10%. Since all Dutch observers now use LOW that error percentage has dropped to a verified 0%. On a world scale several hundreds of observations per year could be(come) useful if observers were not to use such forms, but programs such as LOW and export their data (see below) instead.

A nice little feature of LOW is that it can be used to time occultation events. This is an alternative to using a stopwatch. Your PC or, more likely, laptop needs to be equipped with time signal receiver that frequently synchronizes the system clock, and you need to be able to press the 'Time!' button or use a mouse to click on it once you've seen the event in order to get the time. Immediately after pressing/clicking you're sent to the 'Edit Observation' screen where you can fill in the details of your observation.

There comes a time when the observations need to be sent away. There are two ways of doing this; either by exporting the observations to a file in the ILOC format, or by printing them. In the former, preferred case, one would send them away by e-mail. In the latter case ordinary mail would be used. The disadvantage of the latter is that though the observation data on the ILOC form are correct, transcription errors can still occur at the ILOC.

Views

What generally makes an astronomy program appealing to many users are its graphical capabilities. It simply has to 'look good'. In LOW this has been translated into the possibility to change the many aspects of the views that can be shown, as personal taste and needs differ considerably. There are two types of views that can be created: one with the moon and the star or planet that's being occulted (the so-called Moon View), and one with the lunar limb profiles. The following options are available to change the appearance of these views.

Moon view

First of all one can choose the source of the occultation information, i.e. either the predictions or the observations. Next, one can center the image on the moon or the star/planet. Then the dark side of the moon can be made visible, as a kind of earthshine effect, or not. Instead of an image of the moon one can create a transparent circle and terminator line and 'see' the stars that happen to be behind the moon at the moment of occultation. In case the dis- and reappearance of an occultation appear in the prediction list one can show both phenomena. The view becomes truly appealing when the star field is made visible. The number of stars visible becomes surprisingly large when one selects the option to also include the GSC stars in the view. Should the question "which star is that?" arise, then one can choose to select the option to display their names and XZ or GSC ID. The orientation of the image can changed in many ways too. One can select which direction is up: zenith, north or south. In addition all combinations of image rotation and mirroring are available. This way the view will show what one can see either with the naked eye or through a telescope. To make the telescope view even more realistic, one can select the option with exactly that name together with a magnification. The resulting image (see figure 2) gives a fairly good impression of what the occultation would look like when seen through a telescope eyepiece. Such a view should help observers locate the position of the occulted star. Note that the brightness of the occulted star is exaggerated in LOW in order to help the user determine which star is really being occulted. If unsure which one it is, simply switch off the star field and only the occulted one will be shown. To complement the view even further occultation details, similar to the prediction details described above, can be shown. One can even select which of the 41 fields of information are to be displayed. Additionally a coordinate grid with selectable grid spacing and a position angle circle around the moon can be thrown in (see figure 3). The final option is to display a small section of the lunar limb profile around the star/planet. This can be done for total and/or grazing occultations, or neither (see figure 4).

Lunar limb profile view

The lunar limb profiles of one or more of the available databases (Watts, MoonLimb and ALCPPP) can be shown and explored in more detail. On the lower horizontal axis the Watts angle values are displayed. The vertical axis shows the limb correction value in arcseconds to the left, and optionally the height on the moon (in km or miles) to the right. The profiles may be either the raw data of the databases, or interpolated Watts and/or MoonLimb data in the case of predictions. In the case of a prediction it depends on whether we're dealing with a total or a grazing occultation what will be displayed on the vertical axis to the right of the profile, and the horizontal axis above it. In the case of a total occultation, the height on the moon is displayed to the right, and the distance of the moon at the top. For a grazing occultation the distance on earth and the time with respect to the time of conjunction (in minutes) are shown. It's possible to (not) display the axes, values and grids of or more of these six dimensions. An important option is the one that allows the trail of the star or planet to be shown. The trail is only shown for total occultations and it gives one a clue whether a flank occultation (see figure 1) might occur or not. Different colors are used to depict the various sources and types profile data and switching on the legend will help identify which is which. There are different colors for the three databases, and in addition data from either the Watts or MoonLimb database that lie in the Cassini region are shown again in a different color. The colors of the ALCPPP data vary from yellow to brown. The brighter the color, the more recent the grazing occultation from which the data were taken. To see exactly when those grazing occultations occurred, the occultation details can be switched on again. Make sure to select the ALCPPP field! See figure 4 for an example hereof.

In addition to the view it is possible to have a look at the profile data itself. From the 'View' menu option, select 'Lunar Limb Profiles' and then 'Data'. For every 0.2º in Watts angle the limb correction value is shown for a particular value of the libration longitude and latitude. One can choose the source of the data to be either the Watts or the MoonLimb database.

A final interesting view is that of the 'Reaction Time Test'. From the 'Options' the user can select a prediction. An image of the moon and a star (in the case of a disappearance) are shown. When 'Start' is pressed the star is shown and it flickers and moves, just like in the real world! (Set the seeing to 3" and things become very realistic.) As soon as the star disappears the user presses the left mouse button and is asked what his estimated reaction time was. After having repeated this experiment the number of times that have been specified, a list of results is shown. In the left column one sees the time difference between the moment the star disappeared and the moment the left mouse button was clicked, and to the right the estimated reaction time of the user. This way the user gets a better feeling for how well he is able to guestimate his reaction time.

Files, Help and other features

In the obligatory ‘File’ menu there are four specific LOW options: ‘Directories’, ‘Export’, ‘Options’ and ‘Reports’. In the 'Directories' dialog window the names of the directories for the Delta T file, ephemeris files, export files and lunar limb profiles files are given. Though the default values for these directories enable trouble free usage of LOW, more advanced users might like to change these values. LOW, being a program, is often installed in the C:\Program files\LOW directory, and users often have a D: or another drive that they use to store their data. And hence they might want to save the ephemeris files, as I do, in e.g. the D:\LOW\Ephemeris directory.

LOW can export both prediction and observation data. The user can select which of the 38 fields of information available for prediction data are to be exported. A tab character in the exported file separates the fields so that they can be imported and neatly organized in columns in spreadsheet programs such as Excel. The observation data are exported in the 76-character ILOC format. The exported file can be sent by e-mail either to your local coordinator or directly to the ILOC for (preliminary) reduction.

The ‘Options’ dialog window has three options that are important at the startup of LOW. The first one is whether the last used LOW file should be reloaded at the startup of the program or not. If so, then the second and third option become of interest. Enabling the second one will show the predictions list after startup and select the next occultation to occur, if it exists. In case it doesn’t exist, the third option starts the ‘Tonight’ function described above, and predictions in a time period starting one day before the current system time and ending two days later are calculated and shown. The next occultation to occur is highlighted.

The following ‘Reports’ can be printed in LOW:

- Predictions. The user can select one or more predictions to be printed. That way the user needn’t print out a long list of which only a few predictions are of interest. Just as with exporting prediction data here too a selection of the fields can be made.
- Grazes. The same selection possibilities mentioned above apply to the grazes too. Apart from a line, which shows the prediction data, the graze details (date, time, longitude, latitude, Watts angle, cusp angle, and minimum diameter) are printed for each graze point.
- Observations. The form, similar in layout to the old ILOC form can be printed too. It can then be sent to either the local occultation coordinator or directly to the ILOC. It is recommended only when a user doesn’t have the possibility to export his data and send them off by e-mail.

In order to be able to print one or more of these reports the view that shows the LOW file summary should be active.

The lunar limb profiles can be printed too when the lunar limb profile view is active. In the lunar limb profiles ‘Options’ dialog window the user can specify whether the output should be in black & white or color. In addition the number of profiles per page, either one or four, can be selected.

The moon views can’t be printed. However, by using the 'Capture' function of e.g. Paint Shop Pro or some other graphics package and using its printing capabilities it is possible to get a hard copy of a moon view.

Help

Despite or perhaps due to the length of this article, a user might need additional help. LOW comes with a context-sensitive help function. Simply press F1 and relevant help will appear on the screen. An alternative is to search the help index with over 160 different entries to find a specific piece of information. And if that doesn't help, please feel free to contact the author.

Back to the future

There will definitely be a version 4.0 of LOW. Whether it will appear this year or next year I cannot say at this moment in time. There's a list with over 50 further improvements that can be made to either enhance the capabilities or the user-friendliness of LOW. Should you happen to have suggestions for further improvement, please let me know.
Considering the fact that the Internet is 'the way to go', creating a simple Internet version of LOW would seem the next logical step. People at ESO have even already offered to host such an application... I believe that such an application could interest (many) more people than the ones that now visit the Dutch Occultation Association web-site to download LOW (see below). Perhaps this is the next 'hole in the market'...

Thanks...

It is the combined knowledge and effort of so many individuals that has made the production of the Lunar Occultation Workbench possible. I'd especially like to thank: Adri Gerritsen, Jean Meeus, David Dunham, Mitsuru Soma, Wayne Warren, Wolfgang Zimmermann, Prof. dr. Hans Cuno, Dietmar Büttner, Rheinhold Büchner, Dr. Michelle Chapront-Touzé, Dr. Jean Chapront, Dr. Pierre Bretagnon, Dr. Jean-Louis Simon, Dr. C.B. Watts, all LOW testers/users and ESOP participants that provided me with suggestions for improvement. Their priceless effort humbles me considerably. It is to them and to all LOW users that I have dedicated this program.

How do I get LOW?

LOW can be downloaded for free via: http://home.plex.nl/~gottm/doa/. It is also available on CD-ROM and can ordered from Harrie Rutten, Boerenweg 32, 5944 EK Arcen, the Netherlands. Please send him either $ 5 or € 5 to cover for the expenses. You may copy and distribute LOW freely ■

The GAIA Mission: Main Scientific Goals and Contributions to Occultation Programs

David Fernández
Departament d'Astronomia i Meteorologia,
Universitat de Barcelona
Av. Diagonal 647, E-08028 Barcelona, Spain
dfernand@am.ub.es

Abstract

The GAIA mission will provide unprecedented astrometric and radial velocity measurements with the accuracy needed to produce a stereoscopic and kinematic census of about one billion stars in our Galaxy and the Local Group. The GAIA output catalogue will be complete down to V=20 mag. Astrometric data at 10 microarsecond level at V=15 mag will ensure great accuracy for occultation programs and stellar distances with an uncertainty of 10% for stars as far as the Galactic Center. These data, combined with broad-band and intermediate-band photometry also obtained by GAIA, will yield reliable temperatures, intrinsic luminosities, chemical composition and thus evolutionary status for this huge amount of stars. Large numbers of galaxies and quasars will also be surveyed by GAIA, making unique contributions to extragalactic astronomy. Thousands of extrasolar planets will be detected and valuable inputs for tests of Relativity and Cosmology will be provided.

A new perspective to the Solar System will be opened. It is expected that more than 105 NEOs and Kuiper Belt objects will be discovered. For the known asteroids, the predicted ephemeris errors based on the GAIA observations alone 100 years after the end of the mission will be over a factor of 30 better than the predicted ephemeris errors computed from the whole set of past and future ground-based observations. Measuring the tiny gravitational perturbations that asteroids experience in case of mutual close approaches, GAIA will allow more than 100 asteroid masses to be determined accurately.

The GAIA mission

GAIA was approved in October 2000 as the 6th Cornerstone Mission of ESA's Horizon 2000+ programme, with a tentative launch date not later than 2012. GAIA is scheduled to be launched by an Ariane 5 rocket. After a 220-240 day transfer orbit, the spacecraft will position itself in a Lissajous-type orbit around the outer Lagrange point L2 of the Sun-Earth system (at 1.5·106 km from Earth). GAIA will carry out a continuous sky scanning with a scan rate of 120 arcsecs-1. The estimated lifetime is 5 years, with 4 years of observation time. The final astrometric parameters will be obtained through a global iterative solution (Lindegren & Perryman 1997) at the end of the mission. However, all along the mission, GAIA will produce astrometric, photometric, and radial velocity data in a quick look mode thus making possible the detection and on ground follow-up observations of supernovae, transient objects or fast moving objects such asteroids or NEOs.

The payload design consists of two identical astrometric instruments. Each of these comprises a three-mirror telescope of 1.7 x 0.7 m2 primary mirror and a field of view of 0.32 deg2) separated by a 106º basic angle, as well as a spectrometric instrument (0.8 x 0.7 m2 primary mirror and a field of view of 4 deg2; it is composed by a radial velocity spectrograph and photometer) which share the focal plane of a third viewing direction.

The accuracy goal is to reach 10 µas astrometry for stars of V=15 mag. This accuracy falls to about 20-40 µas for stars of V=17-18 mag and to 100-200 µas for stars of V=20 mag, due to photon statistics. For brighter stars (V<10-11 mag), the accuracy is limited by systematic effects to 3-4 µas. This can be compared with the astrometric precision of Hipparcos satellite data for stars with V=9 mag: 1 miliarcsecond (mas), i.e. 1000 µas.

The GAIA satellite will operate, as Hipparcos did, in a continuous scanning mode. This mode is optimally suited for a global, survey-type mission with an impressive number of targets. The sky scanning follows a pre-defined pattern in which the rotation axis describes a precession motion around the solar direction at constant speed with respect to the stars. An on-board object detection system will ensure a complete and unbiased survey, ranging from near-Earth objects to galaxies in the nearby universe. At this level of precision, not only the stars in our galaxy but also those in the nearby ones will be seen to move, provided they are bright enough. These measuring capabilities make GAIA unique. GAIA will observe more than one billion stars in our Galaxy, producing the first statistically significant census.

Main scientific goals

The scientific case for GAIA has been extensively described in ESA (2000) and we will not discuss it in detail here. A short summary is given as follows:

1. Structure and Evolution of the Milky Way. The main goal of the GAIA mission is to clarify the origin and history of the Galaxy through the observation of about 1% of the entire stellar population (1 billion stars). An unbiased survey of the stellar populations and accurate kinematics of their members will allow to trace a complete scenario of galactic formation and evolution. Deep insights into the physical characteristics of bulge and halo are expected.

2. Stellar Astrophysics. Distances better than 1% for 18 million stars up to 2.5 kpc providing a luminosity calibration throughout the HR diagram and including all types of stars, even those in rapid evolutionary phases. Absolute luminosities of Cepheids and RR Lyrae in the Galaxy and LMC/SMC, luminosity functions, mass functions, color-magnitude diagrams for open and globular clusters, and an impressive number of white dwarf (about 200 000) discoveries, are some of the topics that GAIA will address.

3. Binaries, Brown Dwarfs and Planetary Systems. GAIA will detect a huge amount of the binaries closer than 250 pc from the Sun, and an important fraction out to 1 kpc. Although uncertain, the total number of observed binaries is estimated in 100 million. On the other hand, one expects to discover about 50 000 brown dwarfs. Although Earth-like planets are beyond the observational capabilities of GAIA, its contribution in planetary system detection will be the potential discovery of about 50 000 giant planets, the determination of orbits for many of them and an unbiased survey of periods between 2 and 9 years.

4. Solar System. A deep and uniform detection of minor planets is expected. Some thousands of new objects can be discovered. NEOs and Kuiper belt objects are the key objectives. These minor bodies provide a record of the conditions in the proto-solar nebula, and therefore shed light on the formation of planetary systems.

5. Galaxies, Quasars and the Reference Frame. Geometric distances for nearby galaxies, internal dynamics of Local Group Dwarfs. An unbiased survey of several millions of galaxies and about 500 000 quasars.

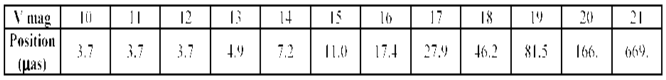
6. Fundamental Physics. The most important relativistic effect in the astrometric measurements of GAIA is gravitational light bending. The study of the residuals of the astrometric data for some ten million stars can provide a precision of 5·10-7 in the determination of .. An upper bound for changes in the gravitational constant G can be established by observing a large number of white dwarfs as GAIA will do.

Benefits for occultation programs

In this Section we discuss the potential contributions of GAIA data to occultation programs. The data with a direct application to this kind of programs can be divided into two groups: astrometric data of stars, which will allow an unprecedented precision on stellar positions, and astrometric data for asteroids (previously known or new bodies), which will result in the best orbits ever determined for these objects.

Stellar positions: an unprecedented precision

As previously discussed, GAIA will observe all stars brighter than about 20-21 mag. This follows in 26 million stars observed down to V=15 mag, 250 million stars to V=18 and 1 billion stars to V=20 mag. There exists a bright limit for stars with V<7 mag, which will not be observed by GAIA. In other words, GAIA will enhance the Hipparcos results by a factor 104 in number of stars. In astrometric accuracy, this enhancement factor is about 100-1000, depending on the stellar magnitude and colours. Obviously, the astrometric precision will be very important for occultation predictions, especially for relatively faint stars, namely V=10-15 mag, which presently have fairly poor (and very inhomogeneous) astrometric data. In Table 1 the astrometric accuracy is shown as a function of stellar magnitude.



V mag	10	11	12	13	14	15	16	17	18	19	20	21
Position (μas)	3.7	3.7	3.7	4.9	7.2	11.0	17.4	27.9	46.2	81.5	166.	669.

Table 1: Astrometric accuracy vs. V magnitude for G2V stars (ESA 2000)

The asteroid data: precision in orbits and discovery of new objects

Solar System objects present a challenge to GAIA because of their significant proper motions, but they promise a rich scientific reward. Minor planets in the main asteroid belt between Mars and Jupiter provide important information about the gradient of mineralogical composition of the early planetesimals as a function of heliocentric distance. For this reason, the main physical properties of asteroids (including masses, densities, sizes, shapes, and taxonomic classes, all as a function of location in the main belt and in the Trojan clouds) are very important to any study of the origin and evolution of the Solar System.

GAIA will derive more than 100 accurate asteroid masses from measuring the tiny gravitational perturbations that asteroids experience in case of body-body encounters. On the other hand, taking into account the resolving power of around 200 mas for extended sources, GAIA should be able to measure directly about 1500 asteroid diameters. These observations, which will constitute the first catalogue of asteroid sizes directly measured, will allow to calibrate the IRAS Minor Planet Survey (IMPS), which is currently the major database on asteroid sizes. As GAIA will observe each asteroid several times, at different geometrical configurations with respect to the rotation axis, it will derive different values of angular diameters, depending on the area as seen from the satellite. In this way, GAIA will also derive shape estimates and also permit the identification of binary objects from the deformation of the image for bright targets.

For direct orbit determinations, simulations for more than 6000 asteroids have shown that the predicted ephemeris errors based on the GAIA observations alone 100 years after the end of the mission are more than a factor 30 better than the predicted ephemeris errors corresponding to the whole set of past and future ground-based observations. Therefore, GAIA will provide such good quality asteroid orbits that ephemeris for asteroidal occultations will be extremely accurate, contrary to what we are presently accustomed.

In addition to known asteroids, GAIA will discover a very large number of new objects, of the order of 10 000 or 100 000 (65 000 bodies are currently known). GAIA will yield high-accuracy orbits for all these objects, since each of them will be observed many times during the mission lifetime. For example, GAIA will detect a very high number of NEOs (about $2 \cdot 10^4$ objects are expected), the detection limit being down to bodies of 260-590 m at 1 AU (Perryman 2000, Zappalà & Cellino 2000). Virtually all the objects above 1 km will be observed, whereas those with diameters of around 500 m will have a detection probability of ~20%.

The advantage of using space-based instruments is particularly evident for some particular classes of NEOs, like Atens and Arjunas. These spend all or most of the time at heliocentric distances smaller than 1 AU, which makes their observation very difficult from ground-based telescopes.

Finally, GAIA should discover about 130 bodies in the Edgeworth-Kuiper Belt, the so-called KBOs. These objects are orbiting the Sun at heliocentric distances of about 30-50 AU, with an apparent distribution about the ecliptic of ~30º.

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Lindegren L., Perryman M.A.C., 1997, ESA SP-1200 (Vol. 3), 483

Perryman, M.A.C., 2000, GAIA Technical Report SAG-MP-002, ESTEC

Zapallà, V., Cellino A., 2000, GAIA Technical Report SWG-VZ-001, Torino Astronomical Observatory ■

Welcome Our New Members

Art Lucas, Secy/Treas

In the flurry of communication with the members it's easy to overlook a new one if you're not careful. I found at least 4 and urge you to welcome them.

Curtis and Sandra Tooley in East Peoria, IL

Mitch Brumbelow in Snyder, TX (a bit west of Abilene and close to the sky)

Jim Moravec in Denver, CO (a high school with 5 telescopes to die for and closer yet)

John Duchek in St. Louis, MO ■

The Detection of Close Stars by Occultations

Jean Bourgeois
jb.astro@worldonline.be

The occultation of a star by the Moon is always an impressive event, giving to the observer a feeling of fulfillment. This is not surprising when we realize that an occultation needs an observer to be called an event at all. Actually, an occultation necessitates the perfect alignment of a star, the Moon's limb and the observer's eye or his detector. Without an observer, no occultation can occur !

An occultation is a rapid event, usually lasting a matter of milliseconds. The stars' apparent diameters are often so tiny that this would be instantaneous if the physical nature of the light wasn't what it is, giving to the light curve an oscillating pattern due to diffraction effects (Sky & Telescope, Sept. 1977).

A visual observer is not able to follow the rapid fluctuations of the star's light during an occultation. The event seems to him to be purely instantaneous. Nevertheless some occultations appear not instantaneous but gradual. This could be due to the apparent diameter of the star or to the particular aspects of the occultation, for instance when the path of the Moon's limb is nearly grazing the star.

A particular class of double stars

It happens sometimes that the observer captures a step event. When observing a disappearance for instance, he sees the star's brightness suddenly dropping temporarily to a fainter intensity before totally disappearing. The observer may be sure to have observed the occultation of a double star he could not have separated otherwise. It is a surprising event, about which the uninformed observer might have doubts, thinking this was only a false impression. Very often we are not sure0 of the reality of something we are not prepared to see, avoiding to communicate an observation that would be perhaps of prime importance.

A double star that can't be separated with your telescope gives a step event often lasting only a fraction of a second. A rule of thumb to be remembered is that a 0.2 second step event indicates a double star separation of 0.1 arcsecond, if the occultation is nearly radial. A near grazing occultation will give a longer step event for the same separation, of course. How fast a step event can be detected by the eye and brain system ? Systematic comparisons between simultaneous visual and videographic observations allow me to say that an experienced observer can detect step events as fast as 0.1 second or a bit less. This means that he can detect double stars with separations as close as 50 milliarcseconds ! This is very impressive isn't it ?
A new class of double stars is accessible through lunar occultations. The visual double stars are seldom separated by less than 0.3 arcsecond, while spectroscopic double stars need to be separated by less than 0.05 arcsecond. The window between visual and spectroscopic double stars is open to the occultation double stars.

Some double stars are discovered through grazing occultations, but more and more others are discovered too by ordinary occultations, erroneously called total occultations.

Up to now, more than a thousand occultation double stars have been discovered, some of them photoelectrically by professionals, and many others by visual and video observations done by amateurs. All these observations are entered in a special catalog yearly updated (see address below), and the list is increasing year after year. A new double star candidate is put in the catalogue with the mention "doubtful" or "probable". It becomes an official new double star candidate when another observer confirms the first observation. Along with the star's name, the catalog mentions the date of the discovery, the names of the discoverer and the observer(s) who confirmed the star's duplicity or multiplicity, the estimated magnitudes of both components, the step duration and the position angle of the lunar limb where the occultation occurred.

What about the orbit elements?

A visual double star observer notes two parameters to define the relative positions of the components, their separation in arcseconds and the position angle of the fainter companion, measured east from north. In the case of an occultation double star we can't separate the two components, and we have to define different parameters to characterize our observation. Actually, in addition to the estimated magnitudes of both components, we note only the time duration of the step event.

We can calculate the projected separation of the binary components at the lunar limb, which is the component of the separation perpendicular to the limb. Let's consider the triangle ACD in figure 1. If μ is the lunar speed expressed in arcseconds per second, P_μ its direction and Δt the time duration of the step event in seconds, the projected separation in arcseconds is :

$$\rho_{pr} = \mu \cdot \Delta t \cdot \cos(P_\mu - PA)$$

μ and P_μ can be found in astronomical softwares. Personally I use Guide 7 from Project Pluto. The values can be found in "Ephemeris items". This is all we can know from a single observation.

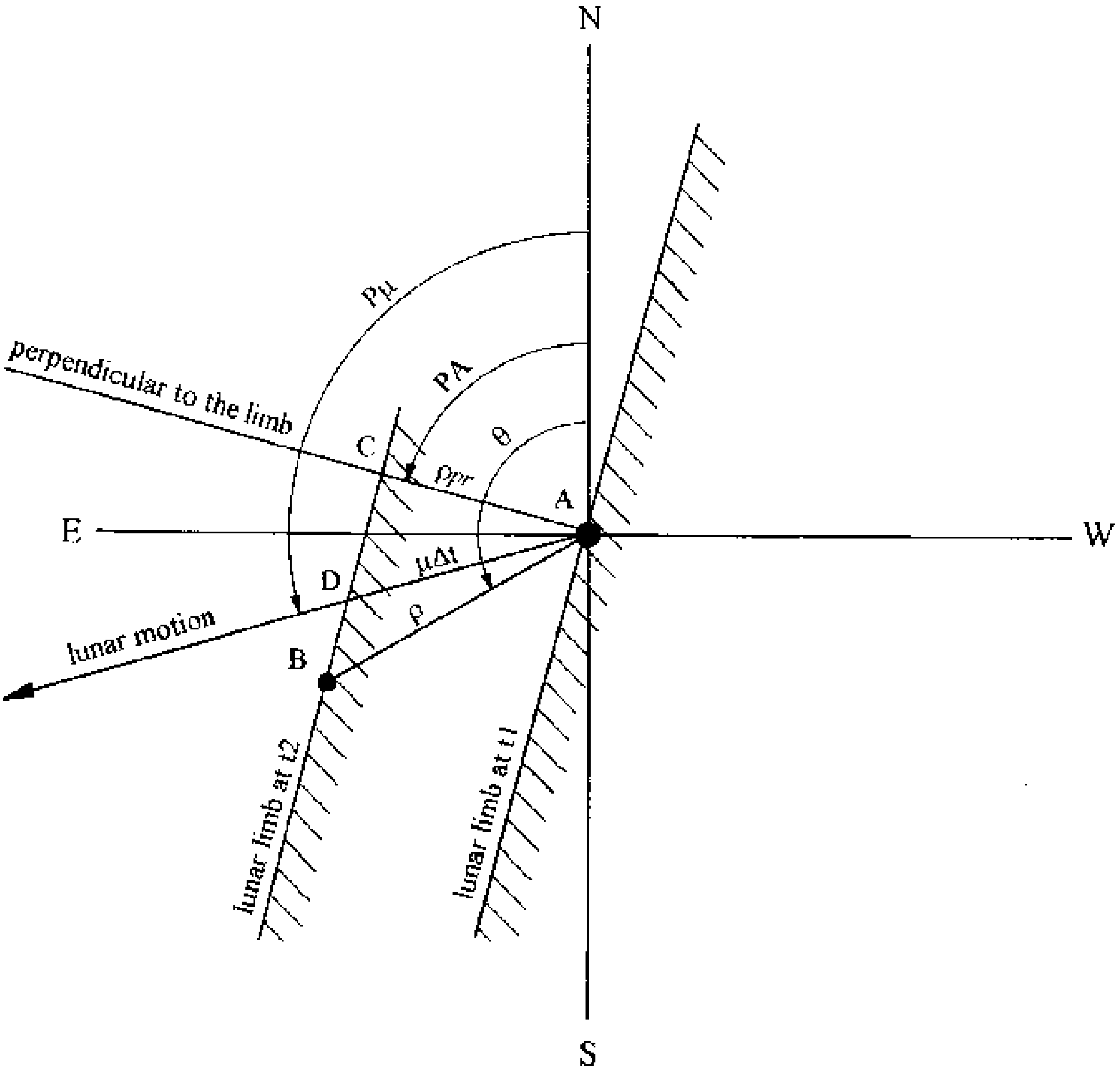

Figure 1: The binary components A and B are separated by ρ arcsec, with a position angle θ.
The lunar limb occults A and B at times t1 and t2, with $\Delta t = t1 - t2$.
The lunar motion along the position angle P_μ is μ arcsec/sec.
The brightness step duration is $\mu \cdot \Delta t$.
ρ_{pr} is the projected separation of ρ on the perpendicular to the limb.

But if we consider the triangle ABC in figure 1, we can write

$$\rho_{pr\,=}\ \rho\ \cos(\theta = PA)$$

where ρ and θ are the values we are looking for. If another observation is done on the same night from another place with a different position angle at the lunar limb, we obtain 2 more equations. It is now possible to calculate the true separation ρ and the position angle θ of the binary's component. If no simultaneous observation is available, we can combine two or more observations made at different dates, provided the binary components have not significantly changed their mutual position in the meantime. How to calculate these values graphically or mathematically can be found in Occultation Newsletter (Vol VI, nø11, September 1996).

When the observations are repeated over a long range of time, it would be possible to define the orbital elements, which can give us important data like the mass of the system.

How many new double stars could we discover?

I personally found out that about 10% of the 5000 occultations I have observed in 25 years were non-instantaneous events. Some occultations were gradual, others occurring with brightness steps. Among all these 500 non-instantaneous events I could detect about 150 step events, more than half of them from double or triple stars unknown before. It results that I could discover a new double star every 65 occultations, or three new ones every year. This is the conclusion of 25 years of assiduous research, in one of the least favourable climates for astronomy, here in Belgium. Perseverance pays off!

What to do with gradual occultations?

We have seen that, among all the non-instantaneous events, a gradual occultation can be explained by a stellar diameter effect or an interference effect. Should we infer that all the visual observations of gradual occultations are not imputable to double stars ? It is not so.

G.M. Appleby, from Greenwich Observatory, has examined 361 non-instantaneous events from 80,000 occultations reported from 1943 to 1977 to the HMNAO. These events were reported as "star fading", non-instantaneous" or "step event". His study showed that 160 of them were imputable to known unresolved double stars. His conclusion is that both gradual and step events can indicate a double star! He could deduce that a close double star occultation is seen as "gradual" when the difference in brightness between the components is less than 1 magnitude, and as a "step event" when the difference is more than 1.5 magnitude, and this with no dependence on duration.

This author could also conclude that if a gradual event has a duration longer than 0.1 second, the cause is probably not due to a stellar duplicity. His study showed that 130 stars from the list were probably newly discovered double stars. Some of them have already been confirmed since then.

It results from this authorized research that gradual events should be included in the DSFILE catalog, with a special mention like "doubtful" or "gradual". The question is now to investigate what is to be considered as a gradual event when the observer uses the more impersonal videographic method. With a sampling of 60 (or 50) fields per second, we never observe a truly instantaneous occultation, because of the classic interference effect. My experience is that most of fast events take 3 fields on a CCD camera record (one and a half frame). My opinion is that we might consider positively a possible double star detection if a gradual event has a duration between 0.08 and 0.12 second, but not shorter. Having done numerous simultaneous visual and video observations, I can claim that a visual observer is able to detect gradual events as short as 0.08 second.

What about the scientific value?

The study of close double stars is of crucial interest (Sky & Telescope Nov. 1996). Good orbital elements, combined with an estimation of the star's distance, are necessary to deduce the stellar masses. Moreover stars duplicity seems to have a particular signification is star formation. Andrea Richichi, from Arcetri Observatory, who specializes in photometric observations of occultations thinks that most of young stars are born in close multiple systems. More observations are needed to validate this hypothesis.

Visual binaries have very slow orbits, a matter of years or centuries, while spectroscopic binaries have very fast ones, in hours or days. There is a need to fill the gap between them.

For this purpose some professionals use fast photometry of occultations. Others speckle interferometry. They need giant telescopes. Great projects of optical interferometers like CHARA on Mount Hamilton and the ESO multiple telescope on Mount Paranal are under construction. They will reach resolutions never dreamed before. All these sophisticated techniques are powerful tools, giving the angular separation, the position angle and the magnitudes of the components. Moreover they can be used everywhere in the sky, while lunar occultations are limited in the zodiacal zone. But there is a price to be paid. Speckle interferometry with a 4 meter telescope, for instance, can only give satisfactorily results on stars whose components are brighter than 8th magnitude, while a visual observer can observe occultations down to 11th magnitude stars with his backyard 20 cm telescope.

A good provisional catalog of close double stars is necessary, and here is the interest in pursuing the search of binaries by occultations. The professionals will include the binaries discovered by occultations in their research program. It's already so for speckle interferometry and fast occultation photometry. In the future, these stars will be included in the interferometric projects too.

Amateur observations are not obsolete! Every good observation has its own value, and must be compared with those obtained by other methods. If they are in good agreement, it's nice. Otherwise something is wrong somewhere, and a positive conclusion can be elaborated.

Moreover, the quest of close double stars with a backyard telescope is fun. Keep in mind that every occultation is potentially able to offer a new vista on the star's properties.

Personal Equation Comparison

Jan Mánek
Štefánik Observatory,
Petrín 205, 118 46 Praha 1,
Czech Republic
jan.manek@worldonline.cz

Abstract: Comparison of personal equation from real observation and event simulation is given.

In the night of October 20./21., 2001 the waning Moon crossed region of open cluster M44. This resulted in possibility of observing several dozen reappearances during few hours. I've used this opportunity to test how reliable are personal equation estimates based on computer simulation of the event compared to real personal equation.

I've set up a video camera Oscar OS-45D (nominal sensitivity 0.02lux) in prime focus of my motor driven Newton of diameter 203mm (F ratio 1:4) and connected the camera output to a borrowed Mitsubishi videorecorder. As a time base was used Mr. Cuno's time inserter. The telescope was at located at my home at Barrandov settlement (part of Prague southwest of city downtown), on balcony at 7th floor, where the view is free from East to Southwest, just ideal for this event. All events were besides videorecording observed directly on the TV set screen and timed in usual manner with digital stopwatch controlled with DCF time signal.

During ~6 hours of the first night (plus 2 R's next nights) I've been able to time a total of 37 events of which for 25 events was possible to successfully determine precise occultation times from video. These 25 common events covered events in magnitude range 6.3 – 10.0 (in V band).

Simon[1] by Ludek Vašta was used for computer simulation. According to my earlier experience I've performed three sets of measurements of personal equation at times when no occultations occured, each set being for various range of star brightness and each set had 4 attempts. First set (P.E = -0.30 second) was then applied to visual timings of stars of magnitude range ~6.3-8.0, second set (P.E.= -0.35 second) for event timings of stars in range ~8.1-9.5 and the last set (P.E.=-0.39 second) for stars fainter than ~9.5 magnitude.

The given limits are not strict, for some stars on the borders were occassionally applied values from the neighbor set because the fact that the camera is red sensitive and due to star color this may change the feeling of the brightness. The graph (Figure 1) shows the final results of comparison for the whole magnitude range.

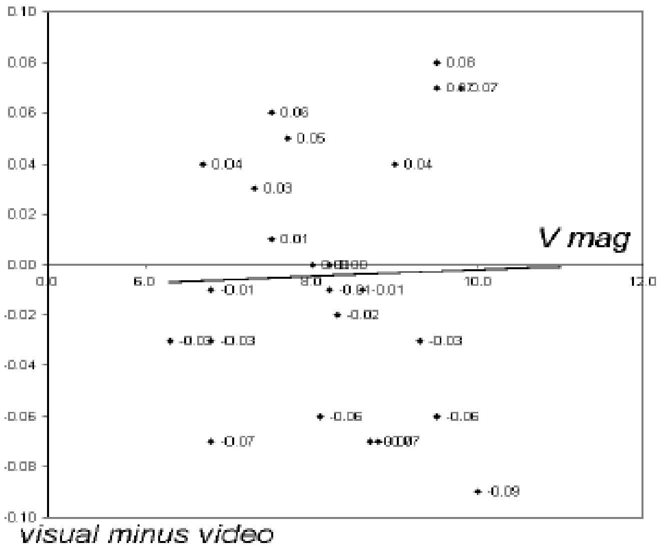

Figure 1: Final results graph. On X axis is V magnitude of star (bright on left, faint on right), while on Y axis is final residuum after substraction of video timing from final visual timing is seconds. The thicker line in the graph is the remaining trend of the results. Remaining differences are small enough to be neglected.

Checking the graph leads to the final conclusion – applying personal equation obtained by a computer simulation to visual timings is worth of the results. If possible try to find your instant reaction times for total occultations during your observation runs. But be sure to have a computer program at least as good as Simon. Due to the fact that human is not a machine, there remains still some scatter in visual data compared to real data, but if you will use such computer simulation, it will give you the guarantee you have done maximum to eliminate one of the known human errors affecting visual timings of occultations. ■

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[1] Simon v1.1 was used. This program allows to select brightness of star, its position angle, type of event (D,R) and Moon phase before performing the personal equations measurement.

The February 16, 2001 Asteroid (83) Beatrix Occultation

H. Povenmire[1] and R. Bookamer[2],

[1]Florida Institute of Technology,
215 Osage Dr.
Indian Harbour Bch., FL 32937
(cpovenmire@cfl.rr.com),

[2]Micco Observatory,
9310 Fleming Grant Rd.
Micco, FL 32976
(nukerb@aol.com).

Introduction: On April 26, 1865, astronomer A. de Gasparis of Naples, Italy discovered a bright main-belt asteroid, which was subsequently named (83) Beatrix. On June 15, 1983, a stellar occultation by Beatrix was observed at McDonald Observatory. Another occultation was observed on March 13, 1990 from Bologna, Italy. From these events the diameter was estimated at 81.4 km.

Florida occultation: On February 16, 2001, Beatrix was predicted to occult a magnitude +9.09 star on a path across Florida, south Texas and northern Mexico. The star, TYC 1936-00758-1, or SAO 80084, is an F5 spectral class star, and is not a known binary.

Unlike lunar grazing occultation paths, most asteroid occultation paths go from east to west. This path contacted the East Coast near Stuart, Florida. The conditions were favorable as there was no Moon in the sky and the altitude of the occultation was almost in the zenith. The occultation star was 39' NNW of Chi Cancri.

We made the 90 minute drive to just west of Palm City, FL and set up two stations approximately 12 km apart in a north-south direction perpendicular to the occultation path. The predicted time of occultation was 04:24:30 UT. Instead of snapping out, the star dimmed and flickered for approximately 1.1 seconds at the northern station and a lesser amount at the southern station. After occultations of 7.1 and 8.8 seconds at the respective stations, the star reappeared fairly suddenly.

Explanation of dimming phenomena: It is difficult to determine what caused the dimming phenomena. The most likely answer is that the star is a previously undetected binary star. Other possibilities are that Beatrix is irregularly shaped, is a binary asteroid, or that the northern station may have caught the star in a grazing situation. Diffraction was not likely a factor. Astronomers doing speckle interferometry are checking on this star at the present time. No secondary blinks were observed from either station, which might have been caused by minor satellites of Beatrix. Another experienced observer, Chris Stephan of Sebring, FL also observed this event and noted the flickering on the disappearance.

Technical data:

Povenmire station :
long. 80º 20' 26.4" W., lat. 27º 12' 19.08" N. elev. 10m

1. Dimming - Flickering 4:24:31.5 - 32.6
2. Disappearance 4:24:32.6
3. Reappearance 4:24:38.6

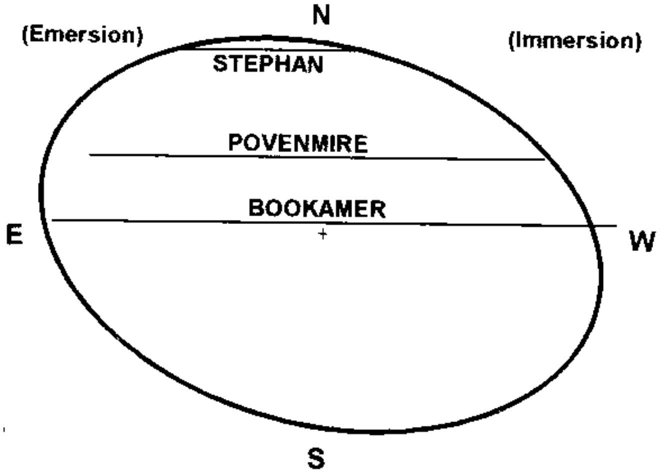
Bookamer station:
long. 80º 19' 09.4" W., lat. 27º 04' 46.98" N. elev. 10m

1. Disappearance 4:24:30.0 slow event
2. Reappearance 4:24:38.8

Stephan station:
long. 81º 20' 45.0" W., lat. 27º 26' 45.0" N. elev. 14m

1. Disappearance 4:24:46.45 slight flickering
2. Reappearance 4:24:49.17

All times are UT and the personal correction has been applied.



Profile of (83) Beatrix: Elliptical fit; visual chords fixed, radial residuals minimized. Radius: 35.9 km.

The Discovery of the Binary Star 64 Orionis

The star 64 Orionis is a magnitude +6.2, blue star of spectral class B8. It is also known as SAO 95166, Zodiacal Catalog 913, and BD +19 1136.

On the evening of March 10, 1976, a grazing occultation of this star was predicted to cross over Miami, Florida. The conditions were fairly favorable as the Moon was waxing and 59 percent sunlit. The star would graze almost 14 degrees on the dark northern limb.

At this time I was teaching astronomy at Satellite High School near Cape Canaveral. I mentioned this graze to one of my students, David Wavra, and he stated that if I tried it he would like to go along. Miami is about a 3-hour drive and many of the sections are bad neighborhoods. We selected an area near a Catholic church. I set up my telescope behind the statue at the entrance of the church and David set up several hundred yards away. Problems began when cirrus clouds came through near the beginning of the graze. Then the U.S. government time signal, WWV, began to fade on all frequencies. We turned on our tape recorders and began to observe the graze. As soon as the star disappeared we knew that something was unusual. Instead of the star blinking out sharply, it disappeared in a stair step fashion. This almost certainly means that the star is a previously unrecognized or undiscovered binary star. The star reappeared normally. Since each observation is completely independent of the other, it is an important means to confirm each others' observations. David also observed the dimming.

When the observation was reduced, it was reported to the proper agencies to be confirmed. These agencies are the U.S. Naval Observatory, IOTA, and H.M. Nautical Almanac Office in England. There the observation resided without confirmation.

Now comes to the rescue, the Center for High Angular Resolution in Astronomy (CHARA). CHARA is based out of Atlanta, Georgia and is part of Georgia State University. They use the method of speckle interferometry to resolve close binary stars. On February 2, 1993, CHARA observed this star and clearly resolved it into separate stars each having a magnitude of approximately +6.6.

There are no honors or parades given to the discoverers of new binary stars, but it is an important part of astronomy to make these minor discoveries and to have them properly confirmed. It is also fun to remember an interesting night of observation and to know that your work contributed to this new bit of information about our Universe.

Hal Povennire

The New Binary Star, 36 Sextantis

The Zodiac covers 12 constellations. The Moon's orbit is inclined to the ecliptic by almost six degrees, so that it extends the area where a star can be occulted. This was the case on May 11, 1973 when a grazing occultation of 36 Sextantis occurred over south Florida. This star is also known ad BD +03 2408, ZC 1566 and SAO 118473. 36 Sextantis is magnitude +6.6 and spectral class K2.

This graze was important, as it occurred in an area called the northern transitional Cassini area of the Moon. These are areas which cannot be observed well from Earth, but can be seen by silhouette during an occultation. This was also a difficult graze, as it occurred in the middle of the school night about two hours' drive from the Cape. There were also problems with the local police prior to the graze.

The star appeared normal when it snapped out, but about three seconds later, flashed on. When it came on, it was only 50 percent brilliance. This lasted about one second. This is almost certain evidence that the star is a binary. Most of the other events were normal except for another disappearance, which took 0.9 seconds to occur. It was almost certain that this observation had found a previously undetected binary. I reported this observation to the U.S. Naval Observatory, IOTA, H.M. Nautical Almanac Office, and to the Smithsonian Astrophysical Observatory. They reported this discovery on Astronomical Circular No. 2545.

I then found that another graze team had observed this graze from Texas. They had too much wind to note the dimming phenomena, but still got some good limb data. It happened that a program for observing occultations by photoelectric photometry was in progress at the McDonald Observatory near Ft. Davis, Texas. They had recorded the occultation but did not immediately examine it closely. When they did, they determined that this star was a spectroscopic binary. This means that the star is a binary, but the components are very close.

It is not easy to get out of bed to chase a graze a hundred miles away in the middle of the night, but when a discovery is made, it makes the effort worthwhile.

Hal Povenmire
Canaveral Area Graze Observers
215 Osage Dr.
Indian Harbour Beach, FL 32937

IOTA's Mission

The International Occultation Timing Association, Inc. was established to encourage and facilitate the observation of occultations and eclipses. It provides predictions for grazing occultations of stars by the Moon and predictions for occultations of stars by asteroids and planets, information on observing equipment and techniques, and reports to the members of observations made.

The Offices and Officers of IOTA

President	David Dunham, Dunham@erols.com
Executive Vice-President	Paul Maley, Paul.D.Maley1@jsc.nasa.gov
Executive Secretary	Richard Nugent, JackiesDad@weblore.com
Secretary & Treasurer	Art Lucas, ALucas0217@aol.com
Vice President for Grazing Occultation Services	Dr. Mitsuru Soma, SomaMT@cc.nao.ac.jp
Vice President for Planetary Occultation Services	Jan Manek, Jmanek@mbox.vol.cz
Vice President for Lunar Occultation Services	Walt Robinson, Robinson@sky.net
Editor for *Occultation Newsletter*	John A Graves, starparty@nashville.com
IOTA/ES Section President	Hans-Joachim Bode, Bode@kphunix.han.de
IOTA/ES Secretary	Eberhard H.R. Bredner, VHS113-Hamm@t-online.de
IOTA/ES Treasurer	Klaus-Peter Herrmann
IOTA/ES Research & Development	Wolfgang Beisker, Beisker@gsf.de
IOTA/ES Public Relations	Eberheard Riedel, 100756.3510@compuserve.com

IOTA European Service (IOTA/ES)

Observers from Europe and the British Isles should join IOTA/ES, sending a Eurocheck for DM 40,00 to the account IOTA/ES; Bartoldknaust Strasse 8; D-30459 Hannover, Germany; Postgiro Hannover 555 829-303; bank code number (Bankleitzahl) 250 100 30. German members should give IOTA/ES an "authorization for collection" or "Einzugs-Ermaechtigung" to their bank account. Please contact the Secretary for a blank form. Full membership in IOTA/ES includes one supplement for European observers (total and grazing occultations) and minor planet occultation data, including last-minute predictions; when available. The addresses for IOTA/ES are:

Eberhard H. R. Bredner
IOTA/ES Secretary
Ginsterweg 14
D-59229 Ahlen 4 (Dolberg)
Germany
Phone: 49-2388-3658 (in Germany 0-2388-3658)
Fax: 49-2381-36770 (in Germany 0-2381-36770)

Hans-Joachim Bode
IOTA/ES Section President
Bartold-Knaust-Str. 8
D-30459 Hannover 91
Germany
Phone: 49-511-424696 (in Germany 0-511-424696)
Fax: 49-511-233112 (in Germany 0-511-233112)

IOTA on the World Wide Web

(IOTA maintains the following web sites for your information and rapid notification of events.)

IOTA Member Site
http://www.occultations.org

This site contains information about the organization known as IOTA and provides information about joining IOTA and IOTA/ES, topics related to the *Occultation Newsletter*, and information about the membership--including the membership directory.

IOTA Lunar Occultations, Eclipses, and Asteroidal and Planetary Occultations Site
http://www.lunar-occultations.com

This site contains information on lunar occultations, eclipses, and asteroidal and planetary occultations and the latest information on upcoming events. It also includes information explaining what occultations are and how to report them.

IOTA's Telephone Network

The Occultation Information Line at 301-474-4945 is maintained by David and Joan Dunham. Messages may also be left at that number. When updates become available for asteroidal occultations in the central USA, the information can also be obtained from 708-259-2376 (Chicago, IL).