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Venus Occultation - 2020 June 19

Dear reader,

Computers are an integral part of occultation work today. In this issue of *Journal for Occultation Astronomy* Marek Zawilski shows us historic solar eclipses from the 13th and 19th centuries. After intensive research of the historical archives, computer programs help us to interpret the descriptions of these celestial phenomena in the ancient documents.
The ongoing development of computer languages gives us a wide range of versatile applications in the daily work of predicting, analysing and presenting occultations. You can take first steps into coding with *Python* on your own with the assistance of Mike Kretlow's article in this issue.
Hristo Pavlov gives a first look into version 2 of the *Astronomical Digital Video* (ADV) Data Format, which will prevent data loss of occultation recordings, besides other new features.
The IOTA Annual Meeting and IOTA/ES' ESOP XXXIX would not be possible without the worldwide network of computers linking straight into our homes.
Konrad Guhl has a closer look at remote (90377) Sedna in *Beyond Jupiter* and the re-evaluation of an occultation observation in 2013.
Finally we remember the late Gordon E. Taylor, pioneer of asteroidal and planetary occultation predictions and long-time Director of the British Astronomical Association's (BAA) Computing Section.

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In this Issue:

COVER

Venus occultation by the Moon recorded in Fjellhamar, Norway. An infrared filter blocking light at wavelengths shorter than 850nm was used to darken the daytime sky and improve contrast. Two video sequences were recorded. A set of 4525 frames with 2.85 ms exposure time (best 90% stacked) to bring out lunar details. Then a set of 6169 exposures with exposure time 1 ms (best 20% stacked) to generate a sharp image of Venus which was pasted in to match the planet's location in an image taken just before the beginning of the occultation. Software used: *Autostakkert* and *iPhoto*. Celestron 8 SC-telescope with a ZWO ASI224MC camera. A video of the occultation is available here. Courtesy: Håkon Dahle

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Journal for
Occultation Astronomy

A Catalogue of Historical Solar Eclipses

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ABSTRACT: Collecting and analysing information on historical observations of solar eclipses allows us to verify the theory of the orbital motion of the Moon and Earth, as well as the rotation of the Earth and also allows us to learn about the reactions of people to this unusual phenomenon. This article describes the problems related to collecting such information, and also describes three examples of solar eclipses from the past.

Introduction

Solar eclipses, as extraordinary phenomena, have had an impact on people since time immemorial. For the most part, they were treated as announcements of bad times or even of the end of the world (a direct reference to the Bible!). In the distant past, only a few people treated them as natural phenomena and tried to use them for scientific purposes, which in time became normal. In addition, despite various astronomical theories, these phenomena were not predicted accurately enough. In ancient times there was only a possibility to predict a solar eclipse at the time of the nearest New Moon, and only from around the 14th century could more accurate ephemerides be calculated, which, however, were known to a small group of better educated people and were poorly distributed. From the 17th century we can talk about ephemerides providing reliable tracks of the central phase paths and about planning of observations, and from the 18th century about the planned verification of the path of totality (E. Halley, 1715). In the following centuries, efforts were made, rather, to study the nature of the Sun's corona, which could only be done during total eclipses.

Predicting solar eclipses with high accuracy required, of course, a modern knowledge of the movement of the Moon and Earth; after which it turned out that this is not sufficient, because one should also take into account the irregularity of the Earth's rotation, especially important for distant epochs.

This topic was dealt with by many researchers, such as S. Newcomb, J.K. Fotheringham, and F. Ginzel [1, 2, 3], who discovered that a calibration of computational algorithms is not possible without knowledge about historical observations of eclipses (both of the Sun and Moon) and selected occultations of stars by the Moon. This caused a search for historical sources. Research on this subject continues to this day (R.R. Newton, F.R. Stephenson, L.V. Morrison [4, 5, 6]). Assessing this problem, it is necessary to point out significant difficulties: early accounts of solar eclipses are found mostly not in astronomers' reports, but in narrative sources - chronicles, annals, diaries, calendars, and finally in other documents of limited historical significance, which the author had at hand. In addition, some of the potential sources of information have not survived to our times (it is enough to mention serious fire and war losses of libraries in various historical periods, and especially in 1944-1945 in Poland and Germany, when the original, not edited or copied collections, were irrevocably destroyed). Finally, so far some sources (mainly manuscripts) have still not been thoroughly searched. Let me just mention that in recent weeks, when reordering my files, I tried to supplement something and unexpectedly found some completely unknown in the literature descriptions of solar eclipses and a few others, which were published but were not known to me.

I started my search around 1990, browsing (page by page for specific dates) various sources in available libraries, feeling at the same time that I would find only a part of the information. The development of the internet has changed the situation radically. However, a surfer across the internet collections may be disappointed: only a small part of the literature and original documents is available, and only some of them are available in full. Therefore, the search engine can at most indicate a fragment of the text and on this basis it is necessary to assess whether the source should be further located and viewed. Anyway, even choosing a keyword itself is a problem: first of all, you have to use the original language of a document (but which one?), and if so, you can come across different phrases in the original texts (e.g. Latin "eclipsis solis", next to "defectus solis" and "obscuratio solis", "defunctus est sol" etc.). The located text must be understood (e.g. Portuguese and Spanish from the 14th century, or German from the 15th century, etc.), the *Google* translator will not be useful here; and what if we found an illegible manuscript? And yet it turns out that many sources are not original or the descriptions are not real and the dates are sometimes confused, and we want to know the exact place of observation and the actual phase of the eclipse, which are often missing. Sources also often remain silent for eclipses on the appropriate date, where such a description "should be" (very annoying!).

Given that historical information has different content and may interest different people, I decided to collect "all" data on solar eclipses from Europe and the Middle East up to 1905 for which something can be deduced about the observed phase of the eclipse, and all other data for phenomena for which the path of totality ran through the area mentioned above. This collection (The catalogue of the historical observations of solar eclipses for Europe and the Near East, 2020) [7] so far contains about 1200 descriptions, some of which were not already known in the

literature of the subject and, as I mentioned above, it is still being supplemented. A similar, much more modest collection, also concerns lunar occultations.
Of course, it is not possible in a short article to describe numerous phenomena from history. So, I'll start with three solar eclipses that have had a major impact on the development of astronomy. Two of them reach their jubilees in 2020.

The Longest Observed Total Eclipse in European History: 1239 June 3

A long duration total eclipse can occur primarily in the equatorial regions, but in favourable circumstances it can also occur in our latitudes. And here it happened one hot day in medieval southern Europe. Moreover, it seems to have happened completely unexpected and unpredicted, about noon on a clear day, and in addition during religious ceremonies. Mostly it ended in panic ...
The attached map marks the places from which the information about the phenomenon comes - from Portugal (Coimbra), through Spain (Toledo, Cerrato, Cardeña, Pamplona), France (Montpellier, Digne), and especially Italian Tuscany (i.a. including Lucca, Siena, Parma, Cesena, Arezzo and Florence), as well as Genoa and Split (Figure 1). During the total phase, next to the black Sun (at an angular distance of only 1° as we know today) a bright star appeared; only a few of the people were aware that it was Venus (however, at that time it had another significant name: Lucifer...). Most reports of this phenomenon are anonymous. Some observers, however, are known by name: in Montpellier the eclipse was described by King Jacob the Conqueror, in Genoa – by Giacomo da Voraggio, in Lucca by Salimbene de Adam (who also gave the names of other witnesses of the event), a little later the event from Lucca was also described by Tolomeo Fiadoni, from Arezzo we have Ristoro's quite detailed description by an eyewitness, whose description has the form of a scientific treatise (although Venus has been treated as Mercury). In Split, the eclipse was described by Archbishop Thomas, who also became the first person known by name to witness two total eclipses (the second such phenomenon was seen on October 6, 1241). It appears that the corona is clearly noticed in Coimbra and solar prominences in Cesena.
As we can say today, the maximum eclipse occurred at 11:56:55 UT in Spain between Madrid and Valladolid, and the total phase lasted there for 5^m58^s.

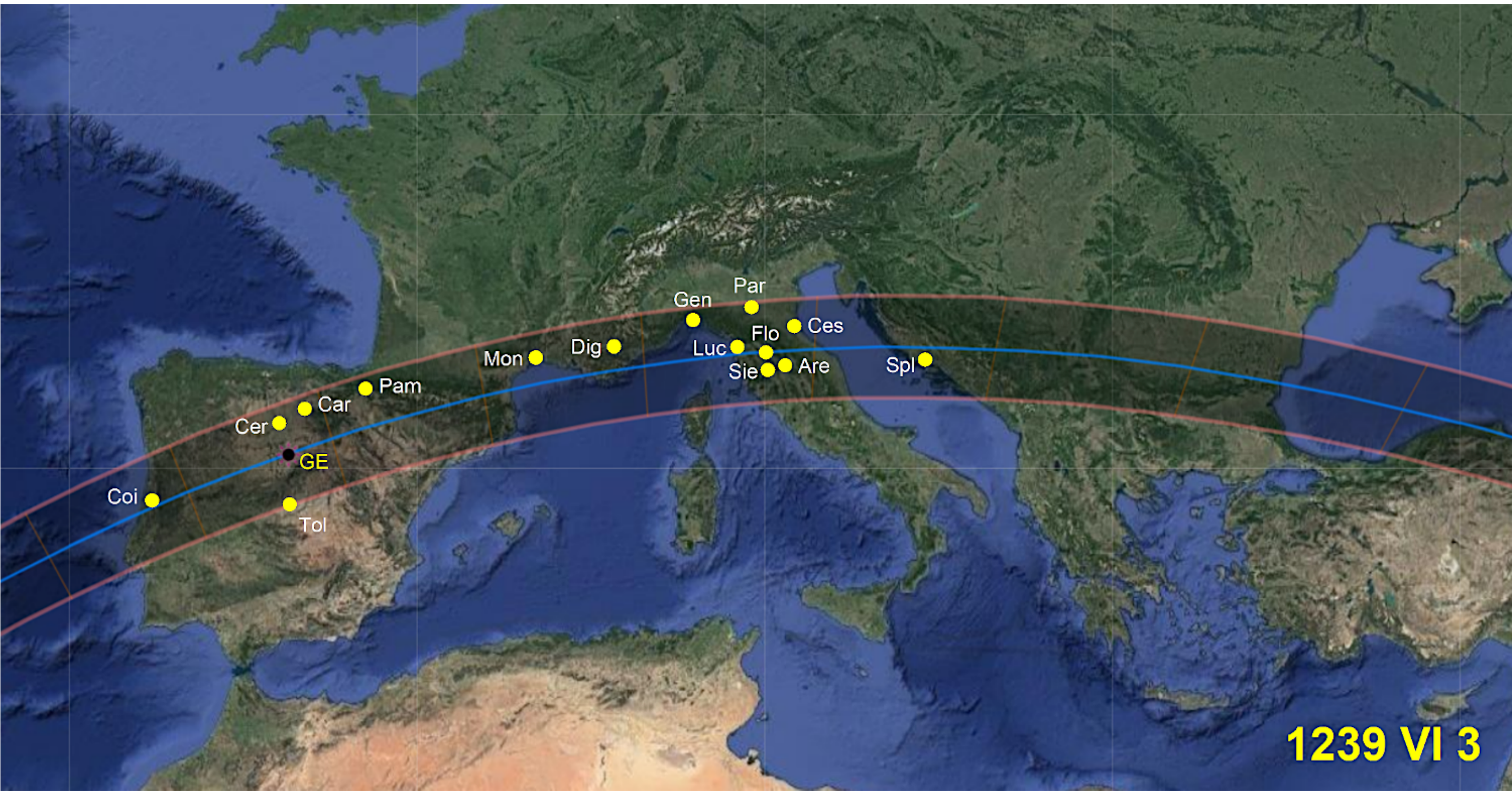


Figure 1. The track of the total solar eclipse of 1239 June 3. Main places of observation are shown. GE means the point of the greatest eclipse phase. Generic interactive Google Map for Solar Eclipses by Xavier M. Jubier [8]. http://xjubier.free.fr/xSE_GM?Ecl=+12390603

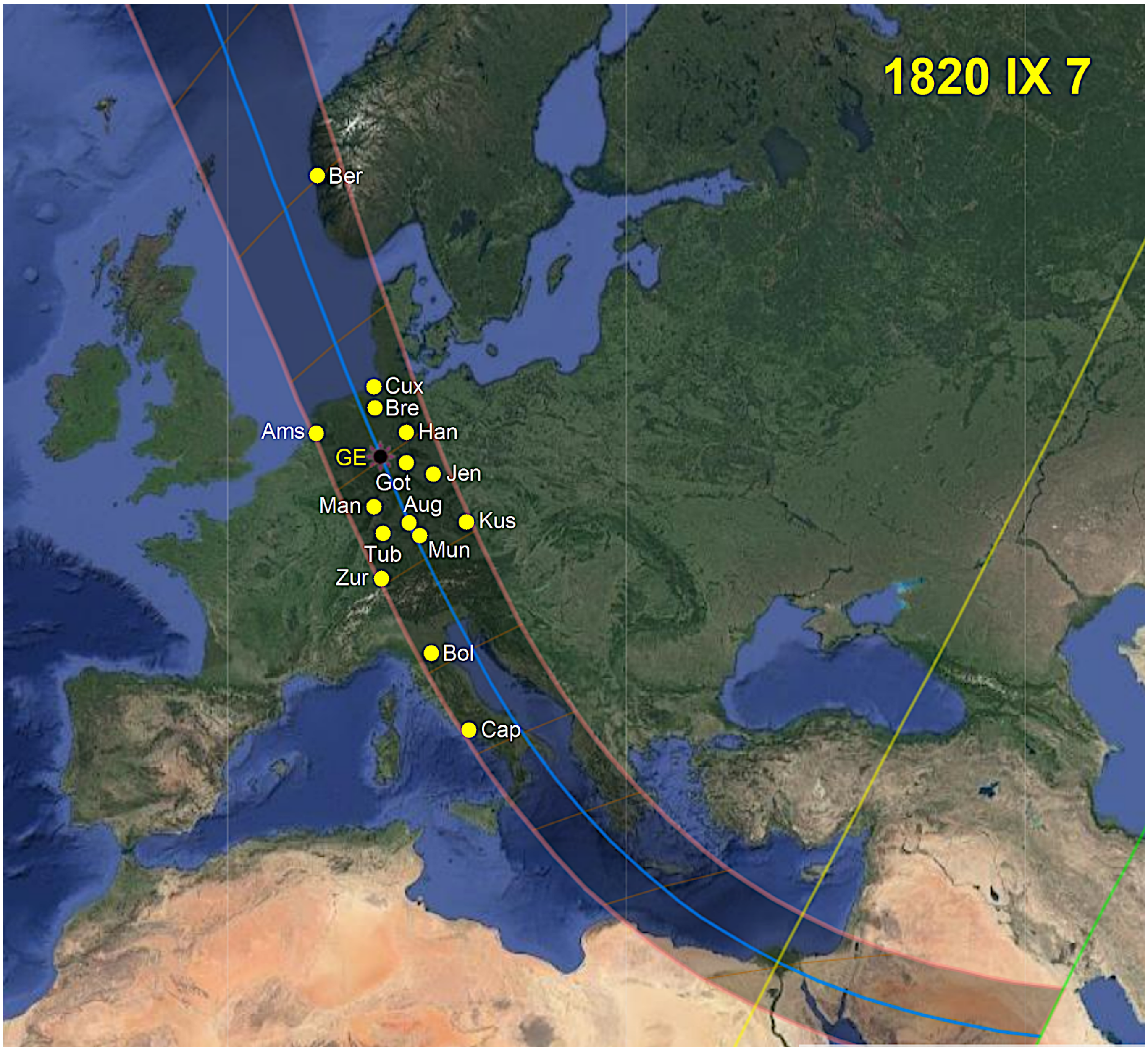


Figure 2. The track of the annular solar eclipse of 1820 September 7. Designations as in Figure 1.
Generic interactive Google Map for Solar Eclipses by Xavier M. Jubier [8]. http://xjubier.free.fr/xSE_GM?Ecl=+18200907

The Annular Eclipse of the Sun on 1820 September 7

An interesting annular eclipse occurred in Europe just 200 years ago. The maximum was around 14:00 UT in Wewelsburg in North Rhine-Westphalia, Germany, where the annular phase lasted 6^m49^s. The annular eclipse path mainly covered Germany, as well as Norway, Switzerland, Austria and Italy (Figure 2).

In the 19th century, observations of solar eclipses were primarily aimed at precisely determining contacts, and from this data also the longitude of the observation sites. Accurate observations were carried out, among others, by J.G. Tralles in Cuxhaven (recorded the annular phase of $5^m02.9^s$), who, however, then conducted a long discussion about the origin of the ring, stating its most likely origin was the Moon's atmosphere (!). In Tübingen the annular phase lasted $4^m50.6^s$, which was precisely determined by J.G.F. von Bohnberger. In Jena, on the other hand, it was observed by J.F. Posselt, who found the duration of the annulus of 4^m03^s. However, the most interesting observation was made by B. Nicolai in Mannheim [9]. He measured the annular phase duration as 4^m56^s, but then gave other details of the observation. Namely, he described in detail the formation of the solar ring at the first internal contact as a short (within 1 second) appearance as if of several "mercury drops" next to each other. He rightly attributed this to the effects of the passing of the Sun's light through the valleys on the apparent lunar edge. He also noticed a similar phenomenon during the second internal contact. Nicolai also cited a report about a similar phenomenon seen in Leipzig. Information about the perception of the "string of golden pearls" was also provided by F. von Paula Gruithuisen, observing from Kuschwarta, today on the border between Germany and the Czech Republic. It is interesting, therefore, that the phenomenon described more broadly in 1836 and 1842 by F. Baily and named after him as Baily's beads, had already been described at least 16 years earlier (it should be added, however, that a similar phenomenon was also observed in 1706 by Ch. Heinrich in Breslau (now Wrocław) and in 1780 by S. Williams in Maine, USA).

The annular eclipse had also been observed in Germany at Bremen (H.W. Olbers, 5^m18^s), at Göttingen, Speyer, Frankfurt a.M, Hannover, Augsburg, München, Apenrade, in Switzerland at Zürich (Freer 1^m35^s, Horner 1^m38^s), and in Italy at Bologna (F.X. von Zach,), Capodimonte (C. Brioschi, $3^m43.7^s$) and Modena. In Amsterdam, E.H. Greve noted the annulus only for 54^s, and J.H. van Swinden also noticed "stripes and threads" before the internal contact. Finally, at Bergen C.F.G. Bohr noted the duration of the annular phase for 4^m01^s.

Other observations worth mentioning are Böckmann's in Karlsruhe, who neither didn't notice any effects of the Moon's atmosphere, nor Baily's beads, and the chronicle account from Memmingen ("black shield against the Sun and steel-blue sky").

Total Solar Eclipse, 1870 December 22

Just 150 years ago, the famous total eclipse could be observed in southern Spain, Algeria and southern Italy (primarily in Sicily) (Figure 3). The duration of it was not long - at its maximum point off the coast of Algeria it lasted only 2^m11^s. Many observations at that time focused on heliophysics to fully explain the nature of the Sun's corona.

In Spain at Jerez, the American astronomer Ch. A. Young observed the flash spectrum of the solar chromosphere. In Malaga, a group of Spanish astronomers observed prominences, while another large group in Cadiz performed the observation of the corona, prominences and the reactions of the surrounding nature to the eclipse.

An extraordinary adventure was experienced by P.J.C. Janssen, a recent discoverer of helium (during the eclipse two years earlier in India), who, in order to observe the eclipse in 1870, escaped from the besieged Paris in a balloon and then travelled to Algeria, only to observe the cloudy sky from there. Similarly, like the British expedition led by W. Huggins in Oran, Algeria, where observers were unable to carry out planned spectroscopic observations due to the cloudy sky.

In Sicily, however, full success was achieved. State-sponsored observations were organised mainly in Palermo, Catania, Terranova, Caltagirone and Augusta as well as opposite in Capo dell'Armi on the peninsula. The corona was studied, spectroscopic observations, flash spectrum, prominence observations were

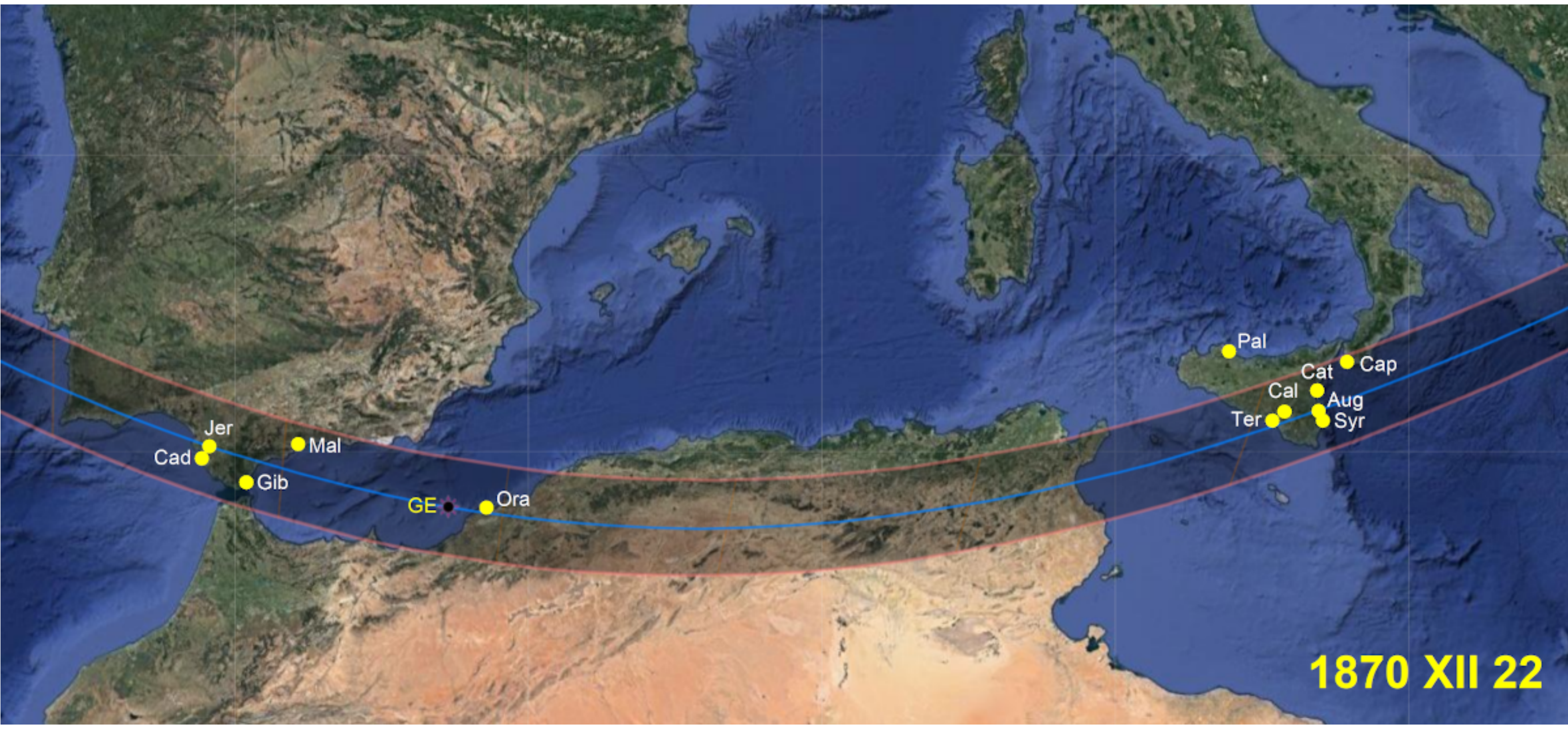


Figure 3. The track of the total solar eclipse of 1870 December 22. Designations as in Figure 1.
Generic interactive Google Map for Solar Eclipses by Xavier M. Jubier [8]. http://xjubier.free.fr/xSE_GM?Ecl=+18701222

carried out and meteorological observations and magnetic measurements were done too. Most of the results of this eclipse were published by Padre Angelo Secchi in his work "Le Soleil" [10].

A trip to Europe for this eclipse was also organised by the US Naval Observatory under the command of Admiral B.F. Sands. S. Newcomb himself chose the position in Gibraltar, where he successfully performed the planned observations (precise instants of contacts, as well as observations of the corona and prominences). At Syracuse, Sicily, observations were carried out under A. Hall to a similar extent as in Gibraltar (but through the clouds). W.M. Harkness performed thorough studies of the corona and prominences In both Gibraltar and Syracuse, a telegraph was used to send signals from chronometers to each other.

American observations have also been included in a special comprehensive report available online today [11].

Final Remarks

The author plans to publish the entire catalogue of historical solar eclipses soon. An overview of the most important historical observations can be found in the presentation specified in [7].

References

[1] Newcomb, S. Researches on the Motion of the Moon, Astron. Pap., Washington, Part I and II, 1878.
https://archive.org/details/cihm_19050
https://archive.org/details/cihm_19051

[2] Ginzel, F.K. Astronomische Untersuchungen über Finsternisse. Sitz. Math.-naturwiss.Kl. Akad. der Wissenschaften, Wien, 88, 1883, p. 629-755.
https://www.zobodat.at/pdf/SBAWW_88_2_0639-0755.pdf

[3] Fotheringham, J.K. A solution of ancient eclipses of the sun, Monthly Notices of the Royal Astronomical Society, 1920, p. 104-126.
https://ui.adsabs.harvard.edu/abs/1920MNRAS..81..104F/abstract

[4] Newton, R.R. Medieval Chronicles and the Rotation of the Earth, Baltimore, 1972.

[5] Stephenson, F.R. Historical Eclipses and Earth's Rotation, Cambridge, 1997.

[6] Stephenson, F.R., Morrison, L.V., Hohenkerk, C.Y. Measurement of the Earth's rotation: 720 BC to AD 2015, Proc. R. Soc. 2016, A 472: 20160404, http://dx.doi.org/10.1098/rspa.2016.0404

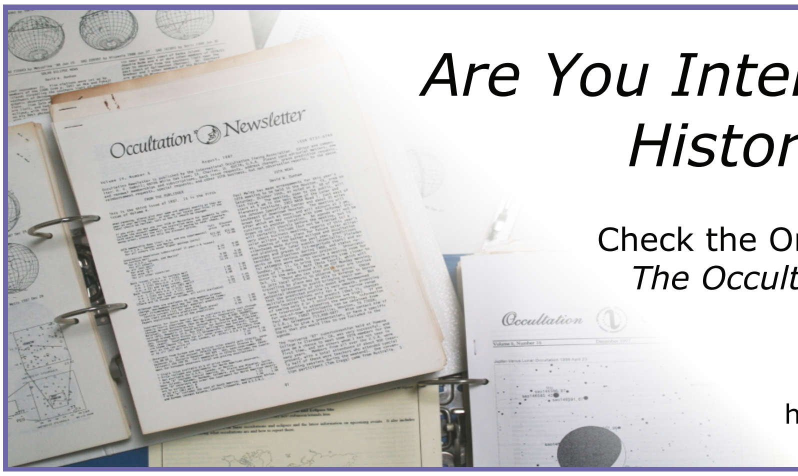
[7] Zawilski, M. The catalog of the historical observations of solar eclipses. A presentation to the Solar Eclipse Conference, Genk, Belgium, August 2-5, 2018. http://www.rvonline.be/sec2018/assets/downloads/Sunday/09_MarekZawilski.pdf

[8] Jubier, X.M. Five Millennium (-1999 to +3000) Canon of Solar Eclipses Database
http://xjubier.free.fr/en/site_pages/solar_eclipses/5MCSE/xSE_Five_Millennium_Canon.html

[9] Nicolai, B. Einige physikalische Beobachtungen angestellt bei der ringförmigen Sonnenfinsterniss am 7 Sept. 1820, Annalen der Physik, Bd. 66, 1820, p. 213
https://books.google.com/books?id=sxFDAQAAMAAJ&pg=PA213

[10] Secchi, A. Le Soleil, Paris,1875-77.
https://gallica.bnf.fr/ark:/12148/bpt6k950439.image

[11] Sands, B.F. Reports on Observations of the Total Solar Eclipse of December 22, 1870, Washington, 1871.
https://books.google.com/books?id=kDYAAAAAQAAJ&oe=UTF-8&redir_esc=y&hl=en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The Astronomical Digital Video (ADV) Data Format

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ABSTRACT: The Astronomical Digital Video (ADV) data format has been around for about a decade now and it has been used for astronomical video recording by the Astronomical Digital Video System (ADVS), *Genika* and *OccuRec*, while *Tangra* has been the primary software for data reduction. With the recent developments in digital video and the increased use of digital video cameras a number of improvements have been made to the format and it has now become more widely available. ADV can now be used with the DVTI (Digital Video Time Inserter) system and it will be available in the upcoming release of *SharpCap* version 3.3. *PyMovie* recently added support for ADV data reduction starting from version 2.6.9 and *PyOTE* from version 3.4.8. The quick addition of ADV support to these software packages was possible because of the available free and open source cross-platform C library AdvCore to read and write in ADV format and the wrappers in C# and Python. In this paper we provide more information about the recent development in ADV and also discuss the format and how it compares to other formats.

Introduction

The ADV data format was originally developed in 2011 (Figure 1) as the video recording file format for the ADVS system [1]. From the start the purpose of the ADV format was to provide a fail safe, single file recording for 16 bit video with support of extensible amount of metadata. The format allows saving all data to the disk as the frames arrive, including all timing and other frame related information, so in the event of a power cut or other unexpected failure, the observation data obtained until the moment of failure would still be available for analysis. In order for this to work the recording software or system must also of course be flushing the file data to the disk after each video frame. Apart from ADVS one other software that records in the original version 1 of the ADV Format is *Genika* [2].

After the release of ADVS the analogue video format continued to dominate among the commonly used occultation cameras, mostly because of the high price tag of digital cameras and the difficulty of reliably inserting fiducial time stamps. The release of the very sensitive WAT-910HX and WAT-910BD integrating video cameras in 2013 further led to the development of *OccuRec* [3] where in order to improve the signal to noise ratio (SNR) and to minimize the file size of the recording, *OccuRec* records a single binned video frame for any (multi-frame) integrating interval. In order to avoid data loss there was a need for a more than 8-bit video file format for *OccuRec* to use. Because ADV is actually an extensible format and is 16 bit the AAV format was created as an extension to be used by *OccuRec*. So AAV files are actually ADV files with extra metadata specific for integrated video cameras and *OccuRec*'s recording.

In 2016 a second version of ADV was released with further improvements including a Lagarith lossless compression and support for very high frame rate video. This format is formally known as ADV version 2 and the vast majority of the ADV files that exist today are of this type. At the beginning of 2020 a few additional minor improvements were made to the format, most notably adding an ROI only image layout, which will be discussed later in more detail.

ADV stands for *Astronomical Digital Video* and the file format [4] is actually built on the top of a more generic format called *Flexible Stream Transport Format* (FSTS). Basically FSTS defines the building blocks of the format such as sections, streams, frames and metadata and makes sure they are fail safe, while the ADV builds on the top of it further defining image layouts and metadata specifically for the recording of astronomical video as well as adds various levels of lossless image compression. More importantly for occultations, ADV defines a number of timestamps that can be used during the reduction, including separate external UTC timestamp, computer system timestamp and hardware clock timestamp (such as camera, CPU or transport bus).

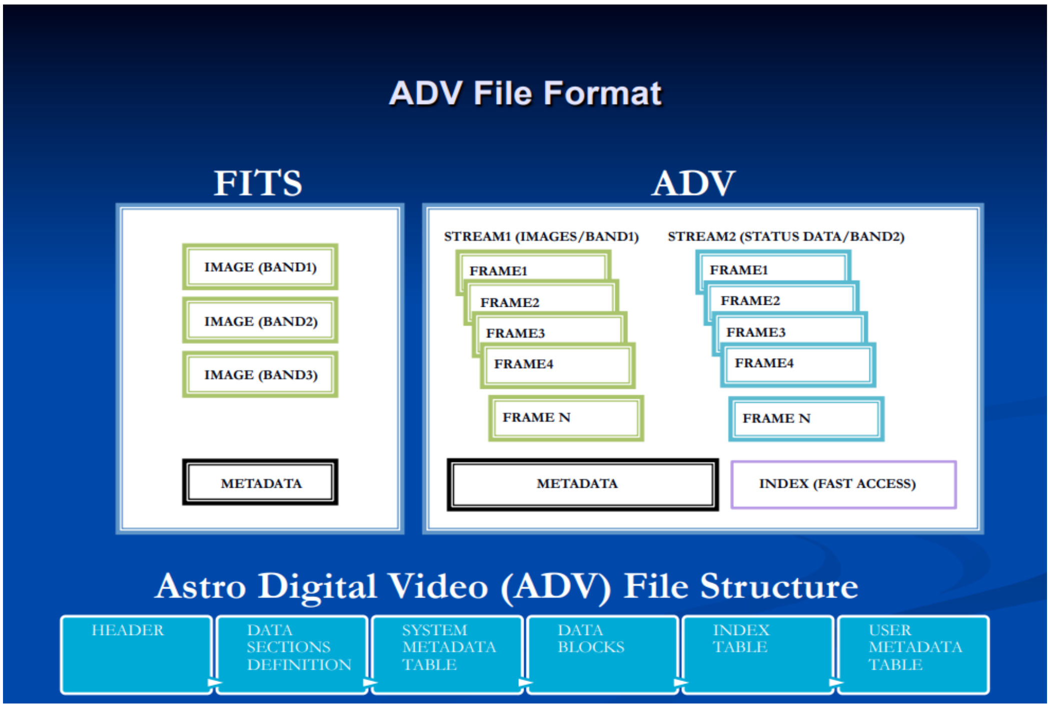

Figure 1. Visual representation of the layouts of ADV and FITS when the format was initially developed as part of ADVS.

ADV also comes with a free and open source, cross-platform C++ library for reading and writing in the ADV format called AdvCore [5]. Using the C-style interface of the library makes it possible for it to be easily used from any high level language on any platform where C++ can be compiled. Currently there are wrappers available for the library in C# and Python which makes it possible to use it on *Windows*, *Linux* and *MacOS* with these programming languages. The C# wrapper, called AdvLib [6] and the Python wrapper, called Adv2 [7], are also free and open source.
In the next sections we compare ADV with SER and FITS formats which are among the most popular formats for astronomical digital video recording.

ADV and SER

The SER file format was created to support 16-bit video recording in a single file and its original purpose was to be used for planetary imaging. SER is still probably the most commonly used video file format for planetary imaging with digital video cameras and it is supported by many video recorders. It is also widely used for occultations.
The SER format however allows only for a single timestamp to be associated with each video frame and it is embedded in the video recording at the end of the file. One issue with this is that if the recording doesn't complete gracefully e.g. because of a power cut or a software crash, then the timestamps will end up missing. This is mitigated by some SER recording software recording the timestamps separately in a text file using their own format. A second issue with the SER timestamp is that the format does not define what this timestamp represents and therefore recording software packages are free to use their own interpretation. This means that the saved SER timestamp could be either the UTC timestamps of the start of the exposure, or the middle or the end of the exposure, or a *Windows* timestamp at the time when the frame has been received or indeed it could be something else. This is the biggest drawback of the SER format when used for occultations as additional information will have to be provided at processing time to be able to correctly interpret the timestamp and observers are not always sure of what timestamp has been actually recorded by the recording software they are using. This becomes even more problematic where for example a QHY174M-GPS camera [8] may or may not have a GPS fix at a certain time. So, if a video is recorded in SER format with this camera there is the question of whether the SER timestamp is coming from the camera's GPS or is it the *Windows* timestamp when the camera does not have a GPS fix, for example.
The ADV file format has a timestamp advantage over SER because it clearly defines the timestamp reference (being the mid-frame timestamp) and for providing multiple and separate timestamp fields for a UTC timestamp, such as one from a QHY174M-GPS camera, and a separate *Windows* system timestamp. ADV also allows for additional metadata to be saved with each video frame and allows for video compression. For all these reasons we recommend ADV to be preferred over SER for occultation video recordings.

ADV and FITS

There has been a number of attempts to create a better format than FITS for scientific imaging and data storage, such as HDF5 [9], ASDF [10] and JPEG2000 [11], but none of those were successful enough for the moment to replace FITS. One of the biggest advantages of FITS is that it has been around for so long that

almost all scientific tools support it and this is not going to change anytime soon. Most of the observational astronomical community uses the FITS format for at least some stage in the life of their data [12] even if they record in a different format.
ADV is at par with FITS when it comes to support of recording information and image metadata in particular. The advantage of ADV over FITS is that it supports the recording of multiple streams of data into a single file allowing metadata at all levels - individual video frame and video streams. FITS only supports defining metadata per file and in a typical occultation recording there will be a separate FITS file for each frame in the *FITS Sequence*.
FITS also supports the recording of a so-called *FITS Cube* where a single file contains the full video recording. In this format the observation is stored as a 3-dimensional "image" in a single FITS file, where the 3rd dimension is the frame number in the sequence where constant exposure with no dead time is assumed. This format is not protected against data corruption caused by a power loss and does not support metadata for the individual frames in the cube as there is only one metadata section for the entire file. Therefore, timestamps and other frame level metadata cannot be associated directly with the individual frames inside the *Cube* as the video frames are merely a third dimension of pixels in a 3D array. Probably due to these limitations the *FITS Cube* is not a popular format for occultation recording.

While ADV is unlikely to replace FITS for scientific imaging it could provide a better alternative for the original video recording because it produces a single file and supports video compression therefore resulting in smaller and easier to manage files. Because ADV is an open format the lossless conversion of ADV files to FITS format is a trivial task. *Tangra* [13] has been offering such a conversion for a number of years already in order to supply FITS data of occultation recordings to the professional astronomers for processing. This exporting mechanism has been used successfully many times when collaborating with the *Lucky Star project* [14].

ADV Usage in DVTI

The *DVTI initiative* [15, 16] is one of the recent examples of a system adopting the ADV format for occultation video recording. The DVTI system is capable of sending only selected regions of interest (ROI) from the camera to the recording software. This can be useful for example to reduce the amount of recorded data in long recordings or to speed up the data transfer and achieve faster frame rates.
In the typical usage of this feature the user will select the ROIs (Figure 2a) which will be regions around the target star and comparison stars and then only those will be sent to the recording software. If the data is only sent for selected ROIs there is the

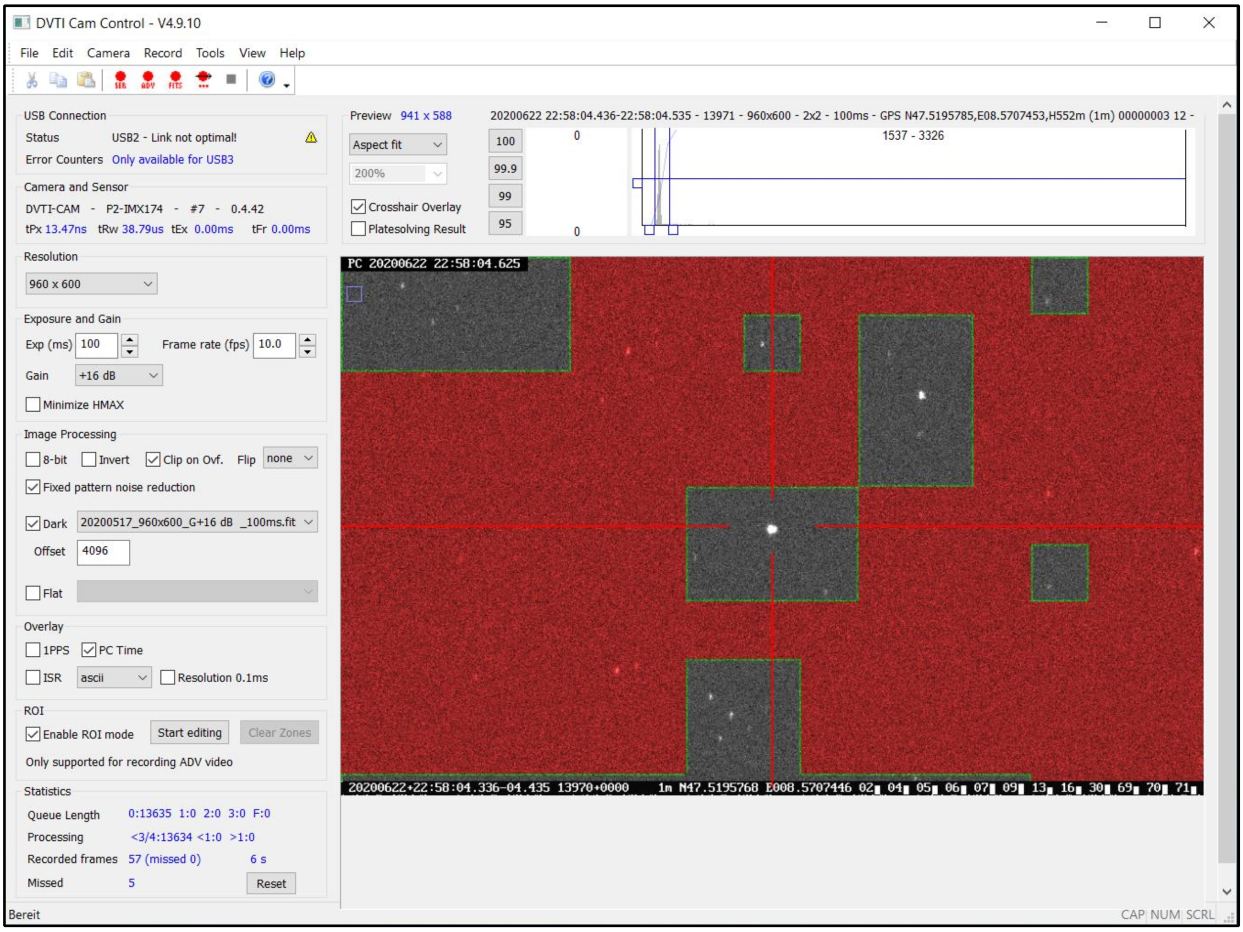

Figure 2a. Screenshot of the DVTI Tool during the occultation by (2) Pallas on 2020 Jun 23 demonstrating the ROI feature.

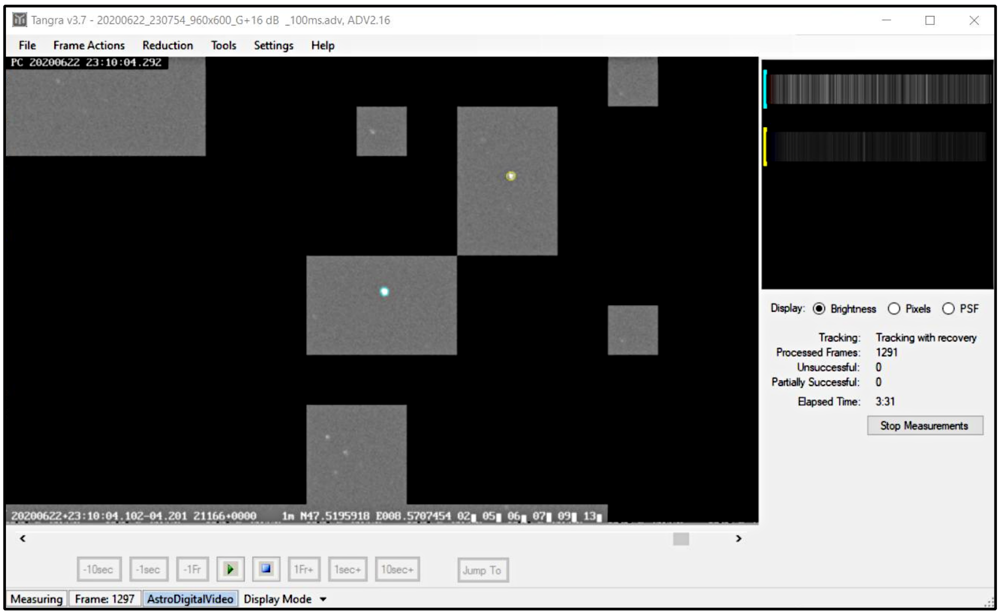

Figure 2b. The ROI-only ADV file displayed in Tangra. Only the pixels in the selected ROIs are actually saved in the ADV video recording.

valid question of why anything else should be recorded in the final video file. This is how the unique ROI-only layout was added in the last update of the ADV format and is now used by the DVTI system to produce smaller files and support its ROI feature. Figure 2b shows how the recorded ROI-only video is shown in a processing software, in this instance in *Tangra*.

Between February and June 2020 a total of 19 occultations have been recorded in the ADV format using DVTI, six of them were positive and two have been recorded in ROI mode. Figure 3 shows the *PyMovie* [17] analysis of one such occultation of UCAC4 570-011044 by (332) Siri observed on 2020 Mar 22.

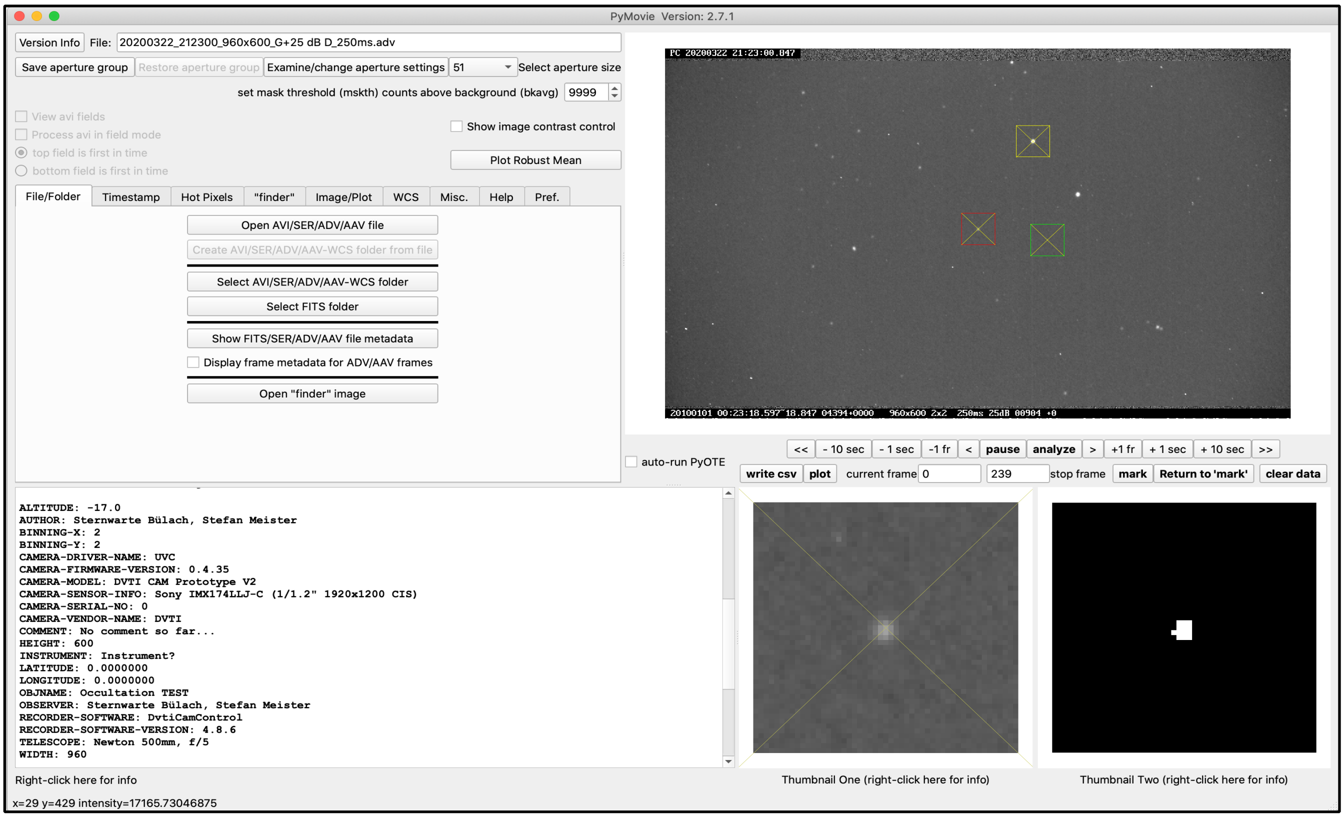

Figure 3. PyMovie analysis of an occultation recorded by a DVTI system in ADV format. PyMovie uses the AdvCore C++ library natively compiled on Mac, Linux or Windows and a Python wrapper on the top of it to read ADV files on those operating systems.

ADV Usage in SharpCap

At the time of the writing of this paper, *SharpCap* [18] version 3.3 is in alpha testing mode and is expected to be released in the near future. One of the new features in this version is the support for recording in ADV format (Figure 4) using the open source C# AdvLib. This will be particularly useful for QHY174M-GPS cameras where the camera's GPS timestamp is recorded separately from the PC timestamps and both are available in all recorded frames. *SharpCap* also records for each frame in the ADV file the full GPS statistics from the camera, including the fix status, plus additional information such as sensor temperature, gain and others.

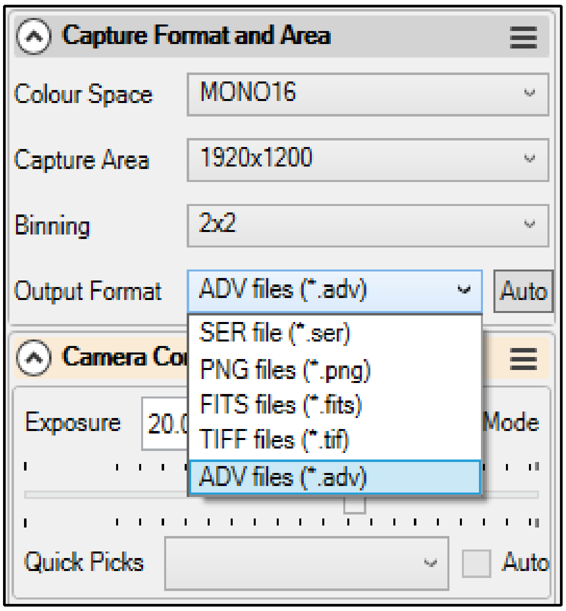

Figure 4. ADV will be soon available as an output format in SharpCap.

Summary

The ADV data format was presented and compared with other formats for occultation video recording. With the recently added support for ADV in a number of video recorders and reduction software packages, the format has now become more widely and easily available to occultation observers.

References

[1] Barry, M. Tony, A. et al. A Digital Video System for Observing and Recording Occultations, Publications of the Astronomical Society of Australia, Volume 32, id.e031 8 pp.

[2] Genika Astro http://genicapture.com/

[3] Pavlov, H. OccuRec http://www.hristopavlov.net/OccuRec/

[4] Astronomical Digital Video and the file format http://www.astrodigitalvideoformat.org/spec.html

[5] AdvCore https://github.com/AstroDigitalVideo/ADVCore

[6] AdvLib https://github.com/AstroDigitalVideo/ADVLib

[7] https://pypi.org/project/Adv2/

[8] QHY174M-GPS https://www.qhyccd.com/index.php?m=content&c=index&a=show&catid=94&id=46&cut=1

[9] Jenness, T. Reimplementing the hierarchical data system using hdf5 (2015), Astronomy and Computing, Volume 12, p. 221-228

[10] Greenfield, P. Droettboom, M. Bray, E. ASDF: A new data format for astronomy, Astronomy and Computing, Volume 12, p. 240-251

[11] Kitaeff, V. V. Cannon, A. Wicenec, A., Taubman, D. Astronomical Imagery: Considerations For a Contemporary Approach with JPEG2000,
Astronomy and Computing, Volume 12, p. 229-239

[12] Mink, Jessica D. Astronomical Data Formats: What we have and how we got here, https://arxiv.org/pdf/1507.03646.pdf

[13] Pavlov, H. Tangra http://www.hristopavlov.net/Tangra3/

[14] Lucky Star project https://lesia.obspm.fr/lucky-star/

[15] Schweizer, A. Meister, S. Presentation of DVTI at the ESOP-38 in Paris https://lesia.obspm.fr/lucky-star/esop38/doc/C1-3-A.Schweizer-S.Meister.pdf

[16] Schweizer, A. Meister, S. The DVTI Camera Project http://www.occultations.ch/equipment.html#DVTI

[17] Anderson, R. PyMovie http://occultations.org/observing/software/pymovie/

[18] Glover, R. SharpCap https://www.sharpcap.co.uk/

Journal for Occultation Astronomy

Using Python in (Occultation) Astronomy

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ABSTRACT: Python is one of the most popular programming languages and is a great tool for scientific computing. Thus, it is well suited for almost any kind of astronomical applications. In the last few years many large packages for astronomical and astrophysical work have been developed or have matured, in many cases actively maintained by professional institutions. A first, brief introduction into Python is given here and the use of Python for occultation work is demonstrated in practical examples.

Introduction

Python [1] is a high-level, general-purpose programming language, created by the Dutch programmer Guido van Rossum and first released in 1991. It is very well suited for scripting, interactive work and quick prototyping, while being powerful enough to write large applications in it. Python is open-source, and its license makes it freely usable and distributable, even for commercial use. Python runs on all major platforms like *Microsoft Windows*, *Linux* and *Mac OS*, and on various hardware.

The language was not designed (especially) for scientific computing, which was at that time the domain of high-level compiled languages like Fortran and C/C++ (later also Java) or domain-specific systems like Matlab, IDL, R, etc. But over time the language evolved, matured (and got faster), and with the availability of more and more packages (libraries) its popularity increased and vice versa. In 2005 the NumPy [2] package was released which boosted the usage of Python in numeric computing[1].

[1] Predecessor were the packages Numeric and Numarray, dating back to 1995.

Complemented by packages like SciPy, Matplotlib and Pandas, a comprehensive, easy to use and professional level tool box for scientific computing is available to the community.

Since 2018 Python is among the first three most popular programming languages according to the TIOBE index (Figure 1). Python is widely used in any kind of web applications and services, artificial intelligence (AI), machine learning (ML), computer vision, scientific computing, data science, and as a general scripting language. Many (large) companies and organizations use Python, like Wikipedia, Google, Facebook, Dropbox, CERN, NASA, and much more.

Python's design and philosophy has influenced other programming languages - for example Go, Ruby and Julia.

This article isn't meant to be a complete introduction nor a tutorial to Python. You will find plenty of free introductions and (video) tutorials on the web, probably even in your native language, as well as books on the market.

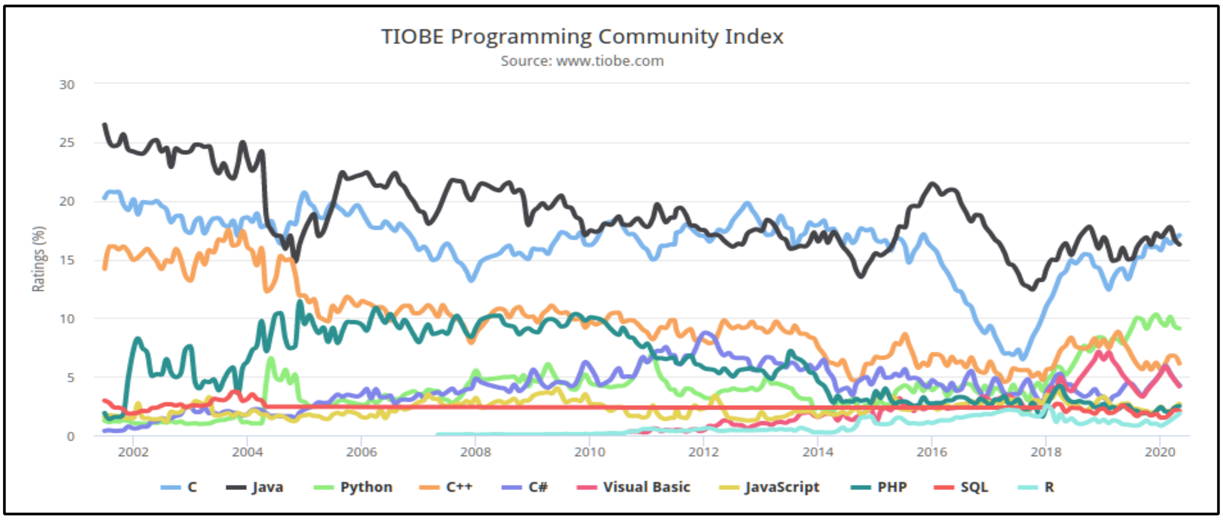


Figure 1. The TIOBE programming community index is a measure of popularity of programming languages. The rating is based on a formula that assesses searches related to programming languages in 25 search engines including Google, Baidu, Yahoo, Wikipedia, Bing.

Technical Aspects

Python is well structured and dynamically typed. Object-oriented programming and structured programming are fully supported, and many of its features support functional programming. Python is meant to be an easily readable language. Its formatting is visually uncluttered and it uses white-space indentation, rather than curly brackets or keywords, to delimit logical code blocks. So, indentation is part of the syntax. Beside the comprehensive standard library, which provides functions suited for many tasks, Python was designed to be highly extensible by third-party modules (packages), which is a main reason for its popularity (see the section "Ecosystem").

The Python language (standard) says nothing about whether the language is compiled or interpreted. It depends on the specific implementation. Compiled languages use a compiler which translates the language code directly into (hardware-specific) machine code which can be executed on the processor.

An interpreted language is any programming language that isn't already in machine code prior to run time. Translation from source code into machine code occurs at the same time as the program is being executed, this process costs execution speed. In the (official) Python implementation, CPython, the source code (.py) is compiled into a much simpler form called byte code (.pyc), which is then interpreted. In that case, Python (CPython) is neither a true compiled nor a pure interpreted language. Other Python implementations like PyPy or Python packages like Numba provide a (partly) Just-In-Time (JIT) compilation of the Python source code (or specific parts like numerical functions in the case of the Numba package).

Getting Started

First you have to install Python[2]. This can be done by downloading a Python installation package from [1] or, if you prefer another popular implementation / distribution, Anaconda Python [3] would be a good choice. *Linux* users might use their package manager for installing Python, but usually it is already installed on modern mainstream *Linux* distributions.

After installation it is possible to start a Python program with the shell command **`python filename.py`** or you can invoke the interactive shell (REPL, Read Eval Print Loop) by just entering **`python`** on the command shell. You can use the REPL for your first steps or simply as a sophisticated calculator:

Another great toolbox is the Jupyter software [4], which allows you to run various programming languages (like Python, Julia or R) inside your web browser, providing you with a sophisticated, interactive and graphical environment. This approach is very common among scientists or in education and we will use these so-called Jupyter notebooks in this article from now on. The examples presented here are available as notebooks on [5]. You can download them from GitHub or clone the repository, and run it on your local hardware. You can even run the notebooks directly on the web using Binder [6], providing the GitHub URL given before, so you just need a browser and installation work is zero.

For a more comprehensive and step-by-step description of the installation of Python, Jupyter (if you do not use Binder) and Python packages, please refer to the installation documentation and guides given on the web sites from where you got your installation packages. And by searching the web for beginner guides you will also find a lot of help going beyond the scope of this article.

Hello World

Most tutorials and books start with a very simple first program ("Hello World"). The following first example is a little bit more extensive in order to introduce some basic entities and features of the Python language at one glance. Python has different data types to store numerical values, strings, Boolean values (true and false), etc. It has sequences like lists, tuples (which are similar to lists, but the elements are immutable) and dictionaries (key-value pairs). Because of the dynamical typing you do not have to declare the data type of a variable and you can change it freely. All the features which are common to programming languages you will find in Python as well, like comparing operators and conditional statements. Some functions (like the print() function) are built-in, other functions need to be imported before they can be used. The **`log10`** function used in the following example is defined inside the **`math`** module, which is part of the Python standard-library. The hash symbol # indicates a single comment line (multi-line comments exist as well). Python has different kinds of loops. In this example we iterate over the content of a list (**`smag`**).

```
linux> python
Python 3.8.3 (default, May 17 2020, 18:15:42)
[GCC 10.1.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> 17+4*4
33
>>> from math import *
>>> acos(0)
1.5707963267948966
>>> deg2rad = 180/pi
>>> deg2rad
57.29577951308232
```

[2] Throughout the paper Python 3 is used interchangeably with Python. Python 2 has reached its EOL (end-of-life).

User defined functions are declared by the keyword **def**, followed by the function name and an optional argument list. They can return a value or a list of values (or none).
The first example defines a function to add two magnitudes. In the main part of the script a fixed value **pmag = 14.5** is defined and a list of three secondary magnitudes is stored in a list named **smag**. We loop over all values in the list and compute the combined magnitude of pmag + smag (for all values in smag) by calling our function **addmag()**, which we have defined before. As you see, the formatting is part of the syntax: the loop body is defined by its indentation level.

This simple program gives you a first impression of what Python looks like inside a Jupyter notebook. Each code cell (grey box) contains code which is executed and below the cell the output (if any) of that cell is displayed. If you are already a little bit familiar with Python you can go ahead and study the scripts given in the Example section. Otherwise I recommend you now make your first steps in Python by working through one of the many tutorials about Python you will find on the web (or by using a book).

Example 1: Adding Magnitudes

In [1]:

```
from math import log10

# This function adds two magnitude values given as arguments x and y.
# The result res is returned to the caller.
def addmag(x,y):
    res = -2.5*log10(10**(-x*0.4) + 10**(-y*0.4) )
    return res

# The main program (script) starts here
print("Hello world, this is Python\n")

# A single float value stored in a variable named pmag
pmag = 14.5

# A list of float values stored in a variable named smag
smag = [12.5, 14.5, 15.9]

# Loop over all values given in the list smag. The current value is assigned to the variable mag.
for mag in smag:

    # Compare values and execute conditional statements (assign a string to variable cmt)
    if mag < pmag:
        cmt = "star is brighter than planet"
    elif mag > pmag:
        cmt = "star is fainter than planet"
    elif mag == pmag:
        cmt = "star is equal bright as planet"

    # Compute combined magnitude of pmag and the current loop value
    cmag = addmag(pmag,mag)

    # Print result using a Format-String (f-string)
    print(f"pmag = {pmag}, smag = {mag}: combined magnitude is {cmag:0.2f} ({cmt})")

# Loop body ends here because of indentation level
print("\nHave a nice day !")
```

```
Hello world, this is Python

pmag = 14.5, smag = 12.5: combined magnitude is 12.34 (star is brighter than planet)
pmag = 14.5, smag = 14.5: combined magnitude is 13.75 (star is equal bright as planet)
pmag = 14.5, smag = 15.9: combined magnitude is 14.24 (star is fainter than planet)

Have a nice day !
```

Ecosystem and Resources

There is an overwhelming amount of resources and the Python ecosystem is huge, even if we focus on scientific computing and still even if we just consider astronomy within that domain. Many of these libraries / frameworks are mature and have been well tested for 5-10+ years.
In this section some important packages for scientific computing and for astronomical applications are presented.

Python and **PyPi**: The main website of Python [1] was already mentioned. Use it as a starting point to learn Python and to navigate to other resources. You will also find there downloads for the installation. The Python Package Index (PyPi) [7] is a repository of software for the Python programming language. Currently about 241000 (!) packages are listed at PyPi. Packages can be simply installed using the Python package installer `pip`, by typing at the command prompt:

```
pip install package_name ...
```

For example, to install NumPy, SciPy, Matplotlib and Pandas you type:

```
pip install numpy scipy matplotlib pandas
```

With `pip list` you get a list of Python packages currently installed on your system.

NumPy: As already mentioned, Python was not originally designed for numerical computing, but attracted early the attention of the scientific and engineering community. NumPy [2] adds support for large multi-dimensional arrays and matrices and a large set of mathematical functions to work very fast on these arrays (vectorised). NumPy is the base of almost any scientific application or package for Python.
SciPy: SciPy [8] is another major and important package used for scientific and technical computing. It contains modules for optimization, linear algebra, integration, interpolation, special functions, FFT, signal and image processing, ODE (ordinary differential equations) solvers and other tasks common in science and engineering.
Pandas: Pandas [9] is a library for fast, easy and powerful data analysis and manipulation.
Matplotlib: Matplotlib [10] is a comprehensive and very popular plotting library for creating static, animated, and interactive visualizations ('plots') in Python. You can use it inside Jupyter (in your browser) and the plots are of high quality ("publication ready") and can also be saved in many formats (images, PDF etc.).
Astropy: Astropy [11] is a community Python library for astronomy, containing key functionality and common tools needed for many tasks in astronomy and astrophysics. It is at the core of the Astropy Project, which aims to enable the community to develop a robust ecosystem of affiliated packages, covering a broad range of needs for astronomical research, data processing, and data analysis.

Astropython: This website [12] is the starting point if you are using Python for astronomy. It is a community-maintained knowledge base and repository with tutorials, list of astronomical related packages, wiki pages and many other resources.

Often NumPy, Pandas and Matplotlib are used together in a script and you will frequently see an import of these three packages into the main name space using an alias:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
```

Now you can access NumPy functions with `np.function()`, for example `np.sqrt(x)`.

SciPy does not recommend to import the whole package (`import scipy as sp`), but rather to import just the specific modules which are needed, for example
`from scipy import integrate`.

Examples

In the following sections I demonstrate how I use Python in my astronomical work. These few examples should give you an idea how Python can be used. It covers only a tiny fraction of what is possible. The scripts are not very sophisticated nor should they be considered as 'complete', but my intention was to make them neither too long nor too complicated. Thus, they also do not necessarily represent an elegant Python programming style.

Occultation Light Curve Analysis

The first example shows the reduction of an occultation by TNO (50000) Quaoar observed on 2019 Sep 26 in Namibia.
The photometry was done using the program *PyOTE* [13] but could also be done with other programs. The content of the light curve data (CSV) file produced with *PyOTE* looks like:

```
R-OTE
FrameNum, Time, Value, Ref1, Ref2, Ref3
0,[18:58:32.9070],2543.818182,4818.000000,7406.636364,5220.333333
1,[18:58:33.2070],1308.000000,3940.166667,7305.384615,5065.909091
2,[18:58:33.5070],2308.666667,4422.000000,6823.333333,4625.333333
3,[18:58:33.8070],2109.615385,4645.545455,7359.000000,5063.500000
…
2031,[19:08:42.2230],2276.000000,5021.000000,7292.846154,4506.000000
```

After two lines of header we have comma separated frame number, timestamp and the photometry of the target star and three reference stars.
For the fitting of a well-depth to the occultation light curve in order to derive the times of D and R of disappearance and reappearance we use the package LMFIT (Non-Linear Least-Squares Minimization and Curve-Fitting for Python) [14], which can be installed using pip with `pip install lmfit`.

The workflow is very simple (the leading number is the number of the corresponding code cell in the corresponding Jupyter notebook):
5: read the photometry from the CSV file into NumPy arrays.
7: make a first plot of the raw occultation light curve (optional step).
8: define the region on the x-axis (unit is frame number) which is outside the occultation. Calculate the intensity mean in the 'outside' region and normalize the light curve (the intensity on the y-axis is now between 0 and 1).
10: fit a rectangle model (well-depth) to the light curve. Among much other information about the performed fit, we get the fit parameter step_center1 and step_center2, which correspond to the point of D and R (in frame units). We also get uncertainties from the covariance matrix. But LMFIT is also able to explicitly calculate the confidence intervals, which is omitted here (cell 11).
12: plot the light curve together with the fit curve, which could be saved and used for publication.
With some additional code we could directly convert frame numbers (and fractions) into times (UT), which is omitted here.
We got the result : D at frame 812.06 +/- 0.23 (1-sigma) and R at frame 1216.00 +/- 0.35 (1-sigma).

Example 2: Occultation Light Curves and Fits

```
In [1]: %matplotlib inline
```

```
In [2]: # Import packages
        import numpy as np
        import matplotlib.pyplot as plt
        import matplotlib.dates as mdates

        from lmfit.models import LinearModel, StepModel, RectangleModel
```

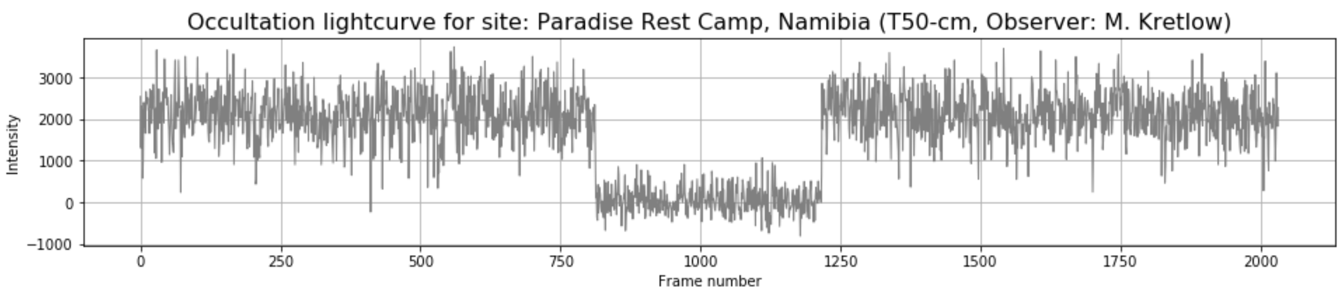
```
In [3]: # Set plot size
        plt.rcParams["figure.figsize"] = (16,6)
```

```
In [4]: # Plot settings: title
        occ_title = "Occultation lightcurve for site: Paradise Rest Camp, Namibia (T50-cm, Observer: M. Kretlow)"
```

```
In [5]: # Read data from CSV file (generated with PYOTE)
        data = np.genfromtxt('OLC_MKretlow_OTE.csv',dtype=None, encoding=None, delimiter=',', comments='#', skip_header=2,
        usecols = (0,1,2), names=['frame', 'time', 'value' ],)
```

```
In [6]: # Get number of frames in the CSV file
        num_of_images = len(data['frame'])
        print("Number of frames / images = ",num_of_images)

        Number of frames / images =  2032
```

```
In [7]: # 1st Plot: raw occultation light curve
        fig = plt.figure()
        ax1 = fig.add_subplot(211)
        ax1.plot(data['frame'], data['value'], color='gray', linestyle='-', linewidth=1, marker='')
        ax1.grid()
        ax1.set_xlabel("Frame number")
        ax1.set_ylabel("Intensity")
        plt.title(occ_title,fontsize=16);
```



In [8]:
```python
# Normalize the occultation light curve

# Define 'outside occultation' region points
l1,l2,r1,r2 = 50,750,1250,2000

xall = data['frame']
yall = data['value']

# Normalize signal using region outside occultation (trim here left and right region)
y_outside = np.concatenate((yall[l1:l2],yall[r1:r2]), axis=0)
yall = data['value'] / np.mean(y_outside)

print("# frames in outside region = ",len(y_outside), ", mean = ",np.mean(y_outside))
```

```
# frames in outside region =  1450 , mean =  2142.316924957931
```

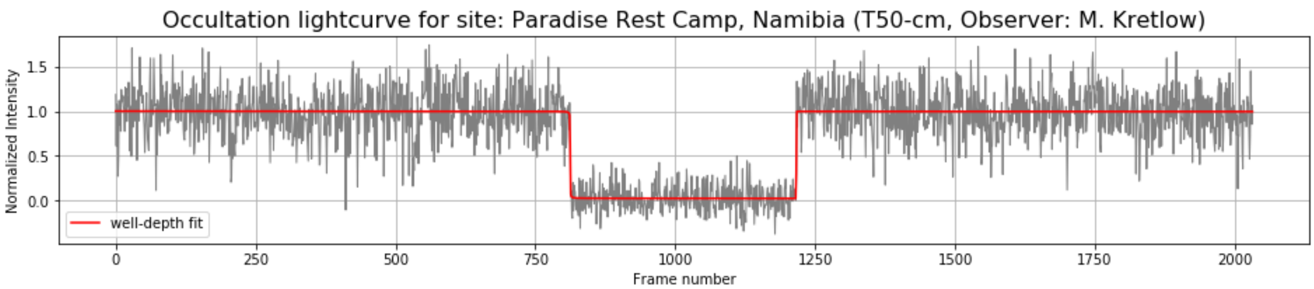
In [9]:
```python
# Slice dataset for the fit (for example just D or R region using step model)
x = xall #[800:2000]
y = yall #[800:2000]
```

In [10]:
```python
# Fit the model function (well-depth) to the light curve

step_mod = RectangleModel(form='atan', prefix='step_')
line_mod = LinearModel(prefix='line_')

pars = line_mod.make_params(intercept=y.min(), slope=0)
#pars += step_mod.guess(yy, x=x, center=800)
pars += step_mod.guess(y, x=x) #, center1=800,center2=1200)

mod = step_mod + line_mod
out = mod.fit(y, pars, x=x)

# The errors here reported are 1-sigma errors estimates from the covariance matrix of the LS fit
print(out.fit_report())
```

```
[[Model]]
    (Model(rectangle, prefix='step_', form='atan') + Model(linear, prefix='line_'))
[[Fit Statistics]]
    # fitting method   = leastsq
    # function evals   = 292
    # data points      = 2032
    # variables        = 7
    chi-square         = 121.189761
    reduced chi-square = 0.05984680
    Akaike info crit   = -5715.05781
    Bayesian info crit = -5675.74038
[[Variables]]
    line_slope:      -2.6298e-06 +/- 9.2671e-06 (352.39%) (init = 0)
    line_intercept:   1.00167922 +/- 0.01122247 (1.12%) (init = -0.3762282)
    step_amplitude:  -0.97645174 +/- 0.01419833 (1.45%) (init = 2.120912)
    step_center1:     812.062101 +/- 0.23394510 (0.03%) (init = 507.75)
    step_sigma1:      0.14333769 +/- 0.44418524 (309.89%) (init = 290.1429)
    step_center2:     1216.00038 +/- 0.36659147 (0.03%) (init = 1523.25)
    step_sigma2:      4.7334e-04 +/- 0.44369523 (93736.48%) (init = 290.1429)
    step_midpoint:    1014.03124 +/- 0.22061726 (0.02%) == '(step_center1+step_center2)/2.0'
[[Correlations]] (unreported correlations are < 0.100)
    C(step_center2, step_sigma2)      =  1.000
    C(line_slope, line_intercept)     = -0.839
    C(step_center1, step_sigma1)      =  0.820
    C(line_intercept, step_amplitude) = -0.251
    C(step_amplitude, step_sigma2)    = -0.203
    C(step_amplitude, step_center2)   = -0.203
    C(step_amplitude, step_sigma1)    = -0.202
    C(step_amplitude, step_center1)   = -0.172
```

In [11]:
```
# The lmfit confidence module allows you to explicitly calculate confidence intervals for variable parameters. For
# most models, it is not necessary since the estimation of the standard error from the estimated covariance matrix
# is normally quite good.
# But for some models, the sum of two exponentials for example, the approximation begins to fail.
# For this case, lmfit has the function conf_interval() to calculate confidence intervals directly.
# This is substantially slower than using the errors estimated from the covariance matrix,
# but the results are more robust.

# out.conf_interval()
# print(out.ci_report())
```

In [12]:
```
# Plot light curve together with well-depth fit
fig = plt.figure()
ax1 = fig.add_subplot(211)
ax1.plot(x, y, color='gray', linestyle='-', linewidth=1, marker='')
ax1.grid()
ax1.plot(x, out.best_fit, 'r-', label='well-depth fit')
ax1.set_xlabel("Frame number")
ax1.set_ylabel("Normalized Intensity")
ax1.legend(loc='best')
plt.title(occ_title,fontsize=16);
```



In [13]:
```
# Get frame number of disappearance (D) and reappearance (R), which can be converted to times
print(out.params['step_center1'])
print(out.params['step_center2'])
```

```
<Parameter 'step_center1', value=812.0621012136145 +/- 0.234, bounds=[-inf:inf]>
<Parameter 'step_center2', value=1216.0003838355685 +/- 0.367, bounds=[-inf:inf]>
```

Access Occult Watcher Feeds

The Beautiful Soup [15] package is designed for scraping web pages. It makes it easy to parse HTML tables from web pages into Pandas data frames (DF). Once the data are stored in DFs, you have a lot of possibilities to process these data (from statistics up to visualization). Example 3 shows how we parse some of the existing *Occult Watcher* (OW) feeds and display a list of events summaries. But moreover, we store these data directly into an SQLite database with only some lines of additional code. This DB (a simple file) could be used by another tool or application we could think of, if we add some code to parse the ground tracks as well. A lot of Python packages provide functionality for plotting geographical data on maps etc. That code could be used as core for your own small occultation planning application, written in Python and thus be able to run on different operating systems or even as a web application. Use a tool like the program "DB Browser for SQLite" [16] to open that data base and to browse the data.

The purpose of this script is not to demonstrate how to parse *Occult Watcher* feeds in order to build a fully functional Python client for it. OW feed format could change at any time without notice and this script could stop working in the future. The purpose of Example 3 is to show how to parse web pages and *Occult Watcher* feed sources were used as they are something with which the reader will be familiar.

Vizier Queries

In Example 4 we use the packages Astropy [11] and Astroquery [17] to make catalogue queries at VizieR (CDS). Astropy and Astroquery are large and powerful packages, check out the web sites and documentation. In this simple example we make a search around a position in the sky (RA, DE) in order to search for stars in catalogues at this position (i.e. also some kind of cross-reference). Finally, we plot their catalogue positions for comparison. So, you will get an idea of the positional scatter of different catalogues.

Example 3: https://github.com/mkretlow/JOA2020-3/blob/master/Example_3/Example_3.ipynb
4: https://github.com/mkretlow/JOA2020-3/blob/master/Example_4/Example_4.ipynb

Conclusion

Python is a great tool for data science, for astronomy and for occultation work. It is easy to learn, powerful, and many different working environments are in your hands. Depending on what's best suited for your current tasks, you run Python programs on the console, or you might want to work interactively with Jupyter notebooks or just with the REPL (in that case, IPython is recommended). You can write classical applications with GUIs (graphical user interfaces) or run your code within a web framework like Django [18]. The huge amount and diversity of packages enables you to focus on your specific task, avoiding reinventing the wheel. Because almost all packages are open source you can examine what these packages are doing, and you can copy and change the code for your purposes, if necessary. And this is all for free. Enjoy Python!

Many common concepts in the daily work of (experienced) Python users, as well as data scientists and astronomers using Python are not covered here because it would be far beyond the scope of this article. For example, virtual environments (pyenv, pipenv etc.), JIT implementations (Numba, PyPy), IPython, JupyterLab, many more packages addressing astronomical topics, or object-oriented programming.

The examples are simplified versions of my working copies in order to reduce the amount of content and complexity. For example, they do not handle exceptions (very well). But anyway, they are (hopefully) useful for the reader and with some experience they can serve as a basis or template for your own applications and tasks.

References

[1] https://python.org
[2] https://numpy.org
[3] https://anaconda.com
[4] https://jupyter.org
[5] https://github.com/mkretlow/JOA2020-3
[6] https://mybinder.org
[7] https://pypi.org
[8] https://scipy.org
[9] https://pandas.pydata.org
[10] https://matplotlib.org
[11] https://astropy.org
[12] https://astropython.org
[13] https://pypi.org/project/pyote
[14] https://lmfit.github.io
[15] https://pypi.org/project/beautifulsoup4/
[16] https://sqlitebrowser.org
[17] https://astroquery.readthedocs.io/en/latest/
[18] https://djangoproject.com

IOTA Annual Meeting & ESOP XXXIX

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ABSTRACT: Due to the COVID-19 pandemic the IOTA Annual Meeting 2020 and the 39th European Symposium on Occultation Projects (ESOP) will be held via the web. The worldwide community of occultation observers is invited to join the meetings. The technical aspects and the schedules were still under preparation by the organising teams at the date of publication of this issue of JOA.

IOTA Annual Meeting 2020

This year's annual meeting of IOTA will be held on 2020 July 25 & 26. At the current status (2020 Jun 29) the participants will meet online using the virtual meeting software *Zoom*.

Pariticipants won't need to preload any software onto their computer. Simply click on the *Zoom* access number when it is presented on the message list [1], and the participant will be asked to install a program that will connect to the meeting. The software deletes itself when you are done with it.

Roger Venable, Vice President of IOTA, has lined up the following presenters and lectures [2]:

David Dunham will talk about the best North American lunar occultations and grazes of the last year and the best North American lunar occultations and grazes coming up during the next year. He will report on his experiences of recruiting new IOTA members and observers online and of observing asteroidal events in Arizona. Steve Preston, President of IOTA, will give an outlook on the best asteroidal occultations observable from North America during the coming year.

The best-observed asteroidal occultation will be presented by two speakers. Dave Herald will show the best-observed non-North American asteroidal occultations of the last year while John Moore, IOTA's Vice President for Planetary Occultation, will have a close look at the best-observed events in North America in 2019. Steve Conard or his student will talk about a system of telescope/ camera/computer that can be left unattended without even pointing it at the sky, and it will record an occultation in a fully automated way. Tony George will speak about positive occultation observations that were initially thought to be negative, found with a new feature of Bob Anderson's *PyOTE* program. Joan Dunham, IOTA's Secretary & Treasurer, will give the IOTA Treasurer's Report. Two IOTA members are considering giving talks about some idiosyncrasies of the QHY-174M GPS camera and its firmware and software.

More lectures are awaited. The hourly schedule of the talks is still in development. For presenters who wish to practice making a presentation with the software, the organising team of the IOTA Annual Meeting plans to have a test session sometime before the meeting. In the previous test session, the *Zoom* software proved to be simple to use and well suited to the purpose.

If you would like to present a lecture or wish to attend the test session, please contact Roger Venable (for contact info see back cover of this issue).

ESOP XXXIX

The 39th European Symposium on Occultation Projects (ESOP XXXIX) was planned as an in-person meeting on location in Freiburg in Breisgau, Germany. Due to the pandemic the Board of IOTA/ES had to decide to cancel this physical meeting and instead will hold the ESOP XXXIX Web Video Conference on 2020 August 29 & 30. The technical centre for the online meeting will be located at the Archenhold-Sternwarte, Berlin, Germany. At the current status the meeting will be presented via the video conferencing tool *Jitsi*. A test session for presenters is planned. The organising team requests that participants register via the meeting's web page [3]. 47 participants have already registered (2020 July 1).

The programme itself is at an early stage. IOTA/ES encourages you to add your own contribution. First lectures are already announced:

ESA's Gaia mission and its data output for occultation work will be a topic of at least two lectures. Thomas Mashall Eubanks will look at occultations in the era of Gaia and João Ferreira will have a closer look at the performance of occultation astrometry with Gaia DR2. Mike Kretlow will present results of the 2019 stellar occultation by (50000) Quaoar and Anna Marciniak will give a talk about modelling and scaling of neglected asteroids. Andrea Richichi will report about latest developments and results at professional observatories. Constantino Sigismondi will talk about the partial and nearly grazing solar eclipse of 2020 June 21 and solar diameter measurements.

The Board of IOTA/ES wants to thank the LOC in Freiburg for all the preparations already done before the cancellation of the physical meeting took place.

References

[1] https://groups.io/g/IOTAoccultations
[2] E-mail communication, 2020 June 26
[3] https://esop39.iota-es.de

Figure 1. Home page of the web presentation of the ESOP XXXIX Web Video Conference. Please keep youself informed by having a look at this website from time to time.

Beyond Jupiter

The World of Distant Minor Planets

Since the downgrading of Pluto in 2006 by the IAU, the planet Neptune marks the end of the zone of planets. Beyond Neptune, the world of icy large and small bodies, with and without an atmosphere (called Trans Neptunian Objects or TNOs) starts. This zone between Jupiter and Neptune is also host to mysterious objects, namely the Centaurs and the Neptune Trojans. All of these groups are summarized as "distant minor planets". Occultation observers investigate these members of our solar system, without ever using a spacecraft. The sheer number of these minor planets is huge. As of 2020 June 29, the *Minor Planet Center* listed 1155 Centaurs and 2522 TNOs.

In the coming years, JOA wants to portray a member of this world in every issue; needless to say not all of them will get an article here. The table shows you where to find the objects presented in former JOA issues. (KG)

In this Issue:

(90377) Sedna

Konrad Guhl · IOTA/ES · Archenhold Sternwarte · Berlin · Germany · kguhl@astw.de

ABSTRACT: Since 2016, JOA regularly publishes portraits of objects beyond Jupiter's orbit. This short communication on the TNO Sedna tells the story of discovery, the orbit and the meaning behind its name. Size and physical properties follow data published up to 2020. A light curve from an occultation is presented and an outlook for coming stellar occultations is given.

No.	Name	Author	Link to Issue
944	Hidalgo	Oliver Klös	JOA 1 2019
2060	Chiron	Mike Kretlow	JOA 2 2020
5145	Pholus	Konrad Guhl	JOA 2 2016
8405	Asbolus	Oliver Klös	JOA 3 2016
10199	Chariklo	Mike Kretow	JOA 1 2017
15760	Albion	Nikolai Wünsche	JOA 4 2019
20000	Varuna	Andre Knöfel	JOA 2 2017
28728	Ixion	Nikolai Wünsche	JOA 2 2018
50000	Quaoar	Mike Kretlow	JOA 1 2020

No.	Name	Author	Link to Issue
54598	Bienor	Konrad Guhl	JOA 3 2018
60558	Echeclus	Oliver Klös	JOA 4 2017
90482	Orcus	Konrad Guhl	JOA 3 2017
120347	Salacia	Andrea Guhl	JOA 4 2016
134340	Pluto	Andre Knöfel	JOA 2 2019
136108	Haumea	Mike Kretlow	JOA 3-2019
136199	Eris	Andre Knöfel	JOA 1 2018
136472	Makemake	Christoph Bittner	JOA 4 2018

Figure 2. The 1.2 m Schmidt telescope. (Coutesy of Palomar Observatory/Caltech)

Figure 1. The dome of the Samuel Oschin Telecope of Mount Palomar Observatory (Courtesy of Palomar Observatory/Caltech)

The Discovery

The object was discovered on 2003 November 14th with the Samuel Oschin Telescope (Figure 1, 2), a 1.2 m Schmidt telescope at the Mount Palomar Observatory. The discovery was made by Mike Brown (California Institute of Technology), Chad Trujillo (Gemini Observatory) and David Rabinowitz (Yale University). It got the preliminary number 2003 VB_{12}. Pre-discovery images were dating back to 1990. The orbit is beyond Neptune's orbit, placing Sedna in the class of "distant detached objects" = DDO.

The Name

Because of the large distance from the sun, 2003 VB_{12} has very low surface temperatures of about -240°C. The name of the celestial body was chosen to refer to this effect and the object was named Sedna after the main god of the Inuit, Sedna. This Inuit goddess is the mother of the sea and the mother of all sea creatures. Without Sedna's blessing, hunts fail, and the people starve. She is thus one of the most important figures in Inuit legend.
Since the regulations for naming small planets stipulate that the

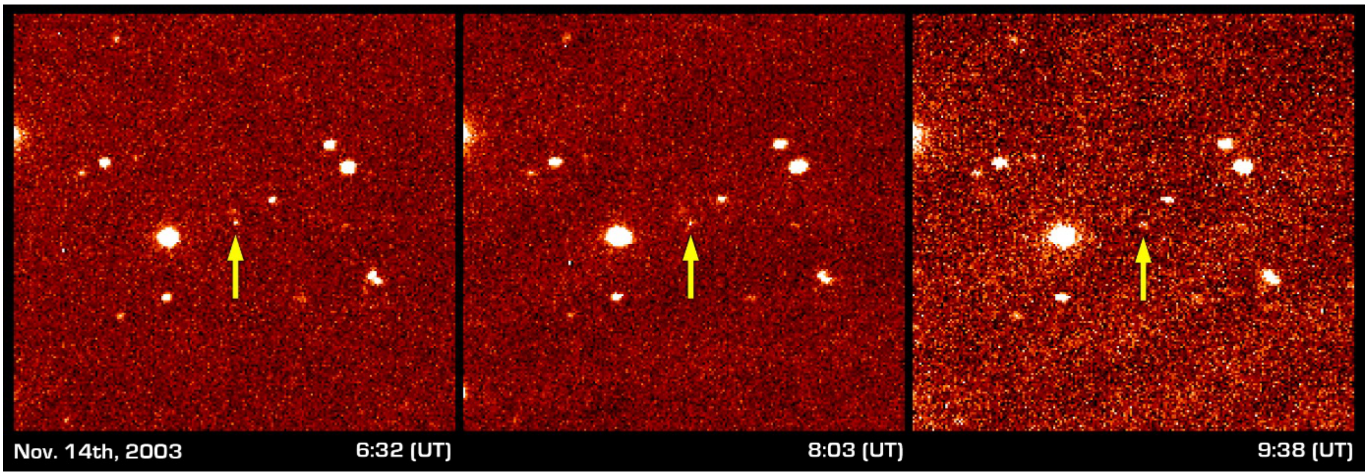


Figure 3. Three images of the discovery sequence of 2003VB12. The field of the view is 3.4 arcminutes and each pixel has a size of 1.0 arcseconds (NASA/Caltech) http://photojournal.jpl.nasa.gov/catalog/PIA05568

name should not be used before the official naming, there was a controversy about the naming of Sedna, since the discoverers had already mentioned the name in a press conference. Since there were no alternative suggestions and the naming seemed to be reasonable, the name proposal was kept like reported in the Minor Planet Center circular [1].

The Orbit

The orbit is highly eccentric (0.849) and inclined to the ecliptic by 11.9°. With a semi-major axis of 480 AU, the distance from the Sun is between 76.15 AU and 883.6 AU. The complete orbit is outside of the orbit of Pluto and has an orbital period of approx. 10,500 years. Currently, Sedna is at a distance of 85 AU (appr. 3 times the distance of Neptune) on the way to its perihelion. Sedna will be at this perihelion in 2076.
Theories explain the Sedna orbit with a close encounter of the early solar system with a passing star.

The Size and Physics

Firstly, it was observed that the sunlight reflected by Sedna changes periodically every 40 days, suggesting a rotation period of equal length.
From October 2004 to January 2005 a group of the Harvard-Smithsonian Center for Astrophysics around Scott Gaudi carried out an observation campaign that could not confirm the results of Brown et al. [2]. This group determined rotation periods of 10.273 h. The group also announced an ~18h period can fit their data but the confidence in this calculation is less [3]. Further observations are needed to determine the exact rotation period.

Figure 4. Granite sculpture from Aka Høegh, Mother of the Sea".
Source: license creativecommons.org https://creativecommons.org/

Observations of the IR radiation with the Herschel telescope yielded a diameter of 995±80 km and an albedo of p_V=0.32±0.06 [4].
Figure 6 shows the spectral distribution of the observed radiation [4]. Sedna has a higher albedo than other TNOs and radiates more strongly in the reddish colour range than other TNOs.
Sedna is classified by M. Brown as "near certainty" dwarf planet together with 9 other objects. Mike Brown explained "near certainty": "*We are confident enough in the size estimate to know*

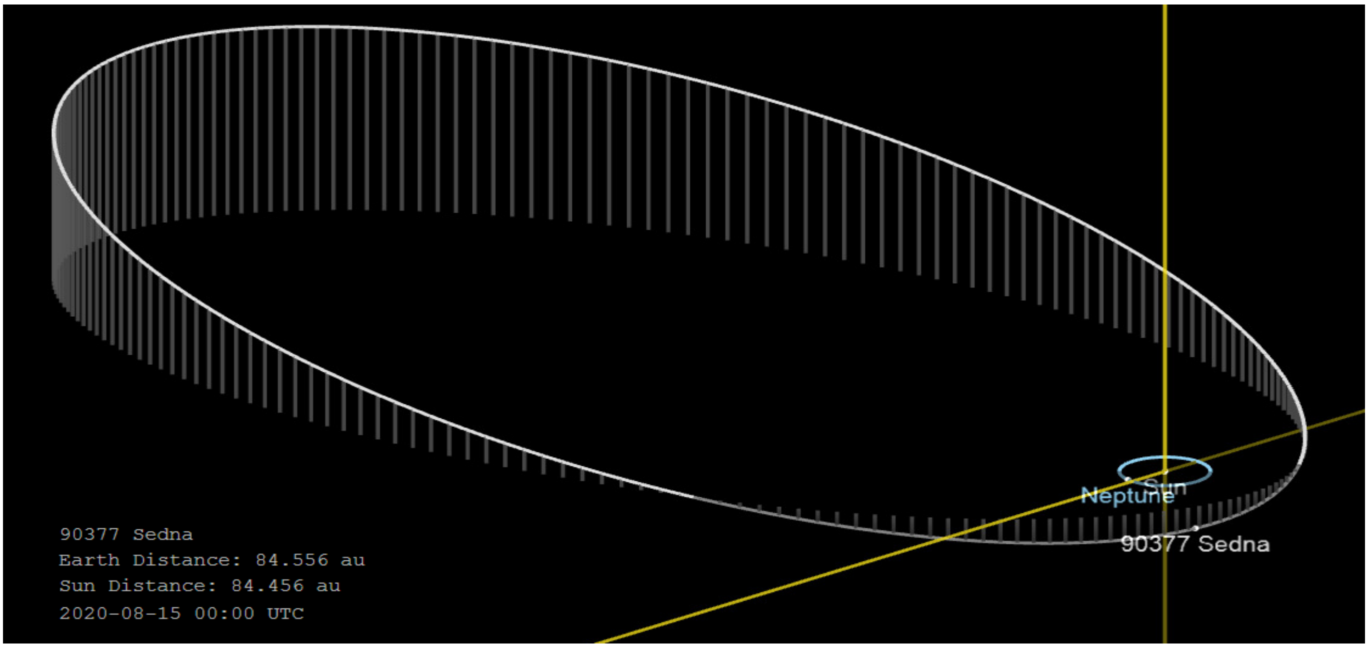


Figure 5. The orbit of (90377) Sedna. JPL Small-Body Database Browser, https://ssd.jpl.nasa.gov/sbdb.cgi?sstr=90377

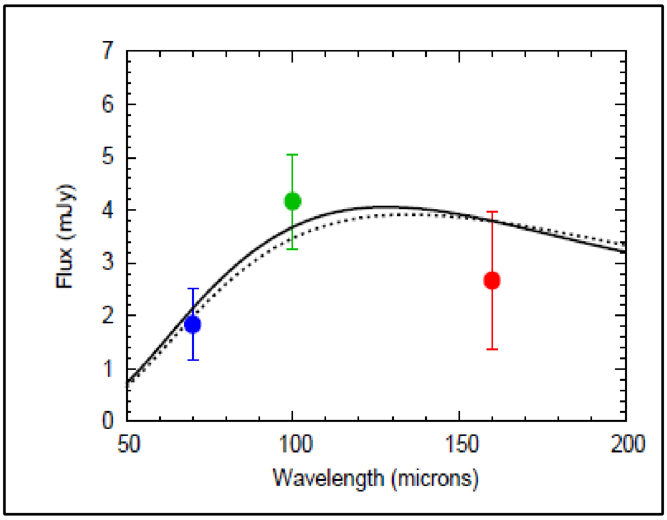


Figure 6. Thermal fluxes of Sedna derived from Herschel measurements at 70 µm (blue), 100 µm (green) and 160 µm (red) wavelength. The solid and the dashed line represents a best-fit to these data using the so-called Thermophysical Model (TPM) and the Standard Thermal Model (STM) [4].

that each one of these must be a dwarf planet even if predominantly rocky" [5].
The apparent brightness of Sedna at perihelion is 20.4 mag [6] with an absolute brightness of 1.8 mag.
To this day, there have been no moons discovered orbiting Sedna.

Occultation by Sedna

The only successful observation of a stellar occultation by Sedna so far was made by Joseph Brimacompe on 13 January 2013 in Cairns, Australia [7], (Figure 7). The video of the observation is available at https://www.flickr.com/photos/43846774@N02/8377851009/
The occulted star USNO-A2 0900-00814908 has a magnitude of 17.4 mag. Therefore an integration time of 60 s was used.

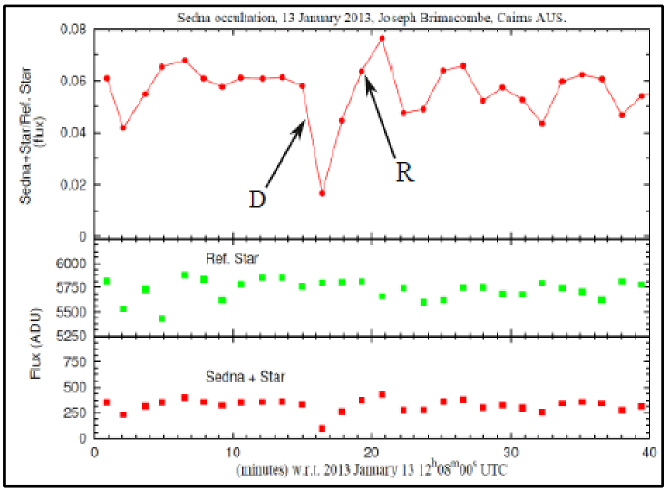


Figure 7. Light curve from the occultation by Sedna [7].

Ortiz et al. have re-evaluated this recording and a second observation made by Tim Carruthers from Cairns (longer exposure and cycle times) [8]. An important criterion in this evaluation is the question whether the first measuring point after the minimum was still partially determined during the occultation or not. Photometry of the single image leads to the assumption that this is not the case. Thus the duration of occultation is determined to 85 +/-12 s [9].

Unfortunately, Sedna is currently moving very slowly through a starless region of the sky. Therefore, no occultations are predicted for the near future [10].

References

[1] MPC Circular No. 52733
https://minorplanetcenter.net//iau/ECS/MPCArchive/2004/MPC_20040928.pdf
[2] Brown, M. E. et al. DPS Meeting 36, Louisville, KY, USA, Nov. 2004
[3] Scott Gaudi, B. et al. On the Rotation Period of (90377) Sedna https://arxiv.org/abs/astro-ph/0503673
[4] Pál, A. et al. "TNOs are Cool": A survey of the trans-Neptunian region, VII. Size and surface characteristics of (90377) Sedna and 2010 EK139 https://arxiv.org/abs/1204.0899
[5] Brown, M. E. Homepage http://web.gps.caltech.edu/~mbrown/dps.html
[6] Barkume, K. M., Brown, M. E., Schaller, E. L. Near-Infrared Spectra of Centaurs and Kuiper Belt Objects. Astronomical Journal 135, p. 55–67.
https://iopscience.iop.org/article/10.1088/0004-6256/135/1/55
[7] Brimacompe, J. Observation report in RASNZ Occultation section, CIRCULAR CN2013/1, June 2015
http://www.occultations.org.nz/planet/2013/results/20130113_90377_Sedna_Rep.htm
[8] Ortiz, J. L. (Granada team), Sicardy, B. (Lucky Star project), Braga-Ribas, F. (RIO team) and other usual collaborators Stellar Occultations by TNOs. Presentation at ESOP XXXII, Barcelona, 2013 August 24. https://www.aster.cat/mm/file/ESOP32/ESOPXXXII_Ortiz_latest.pdf
[9] E-mail conversation with F. Braga-Ribas, J. L. Ortiz and P. Santos-Sanz regarding the observation of 2013 Jan 13.
[10] E-mail from J. Desmars (Lucky Star project) to the author, 2020 May 05

Further Reading

About the Samuel Oschin telescope:
https://www.astro.caltech.edu/palomar/about/telescopes/oschin.html
About objects like TNO and Centaurs:
http://ssd.jpl.nasa.gov/sbdb.cgi
http://spacewatch.lpl.arizona.edu
http://www.minorplanetcenter.org
About Sedna:
http://web.gps.caltech.edu/~mbrown/sedna/

Gordon Ernest Taylor

1925 – 2020

(Courtesy: Violet Taylor)

It is with great sadness we report that Gordon Taylor, the pioneer of asteroidal and planetary occultation predictions, passed away on 2020 March 15. His lifelong fascination with astronomy took him from his early days as an amateur observer through to him receiving many awards for the scientific contributions of his high-quality computational work.

In 2014 Gordon wrote his autobiography for *JOA* [1] and in there we learn that in the 1940s he served as a meteorologist in the Royal Air Force, then in 1949 he joined H.M. Nautical Almanac Office in Bath, England. His initial role in the Occultation Section was to use the Occultation Machine to predict the times of total lunar occultations at various places around the world. It was a mechanical device, an analogue computer, which cast a cylindrical beam from a 'Moon' lamp onto a terrestrial globe to simulate the circumstances of lunar occultations at numerous observing locations. Gordon once hurt himself when he broke a tooth on the back of the Moon carriage. His claim for industrial injury compensation was turned down!

He devised a method for predicting grazing occultations which was programmed to run on an early electronic computer. In the 1950s he worked on predictions of lunar occultations of the brighter minor planets (Ceres, Pallas, etc.) but no successful observations were obtained. He extended these predictions to occultations of stars by asteroids, which were challenging for both the programmer and the observer because of uncertainties in the stars' positions and in the asteroids' orbits. However, this resulted in the first successful observation of an asteroidal occultation - by Pallas in 1961 from Uttar Pradesh, India [2].

At the IAU Meeting in Grenoble, 1976.
Left to right, back: Leslie Morrison (RGO), Tom Van Flandern (USNO), Dr. Orsino.
Front: Joan Dunham (IOTA), Gordon Taylor (RGO), David Dunham (IOTA), N.N. (Courtesy: Leslie Morrison)

He computed occultations of stars by planets, including the occultation of Regulus by Venus on 1959 July 7, of a 7.7 mag star by Neptune on 1968 April 7 and that Mars would occult the 3rd mag epsilon Geminorum on 1976 April 8. He also successfully predicted stellar occultations by the planetary moons Io, Ganymede and Rhea. Gordon's growing reputation led to him being elected President of the British Astronomical Association for 1968-1970.

His Presidential Address in 1969 was on 'The planet Neptune' and for his 1970 Address his theme was 'Occultations'. In 1974 he was appointed Director of the BAA's Computing Section. In addition, from 1976 to 1985 he served on IAU Commission 20 'Positions & Motions of Minor Planets, Comets & Satellites'.

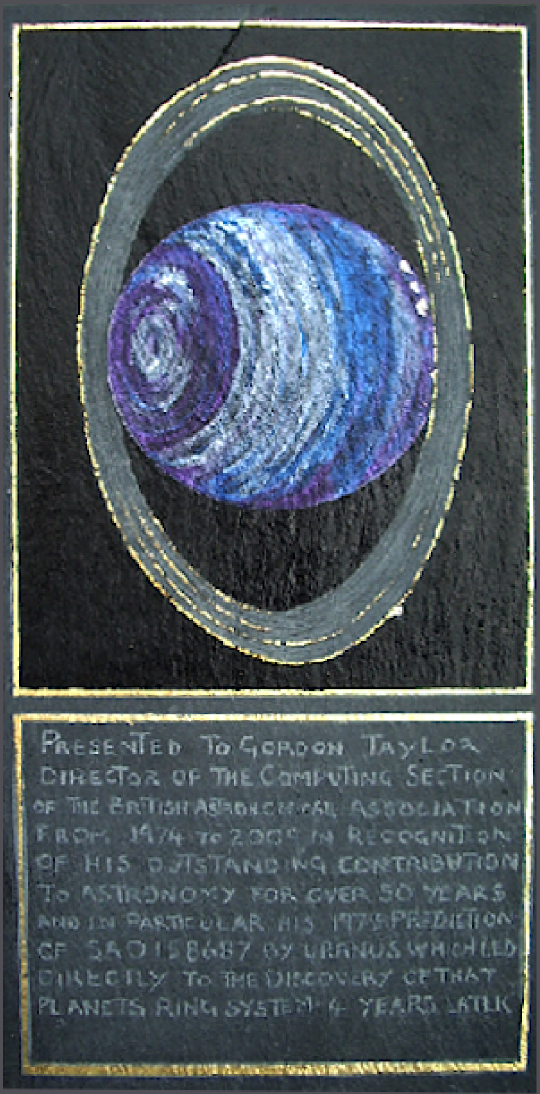
To check and refine his predictions, Gordon pioneered the technique of last-minute astrometry, where he used the astrograph at Herstmonceux to photograph the star and target object when they were in the same field. One of his most memorable predictions was when he announced that a 8.8 mag star would be occulted by Uranus on 1977 March 10. Successful observations by the Kuiper Airborne Observatory (KBO) revealed that the gas giant was encircled by at least 5 rings. In 2009 Gordon stepped down from the post of Director of the BAA's Computing Section after 35 years' service and at the following year's Annual General Meeting he was presented with a plaque depicting Uranus and its rings with the inscription "...*In recognition of his outstanding contribution to astronomy over 50 years and, in particular, his 1973 prediction of the occultation of SAO 158687 by Uranus which led directly to the discovery of that planet's ring system four years later.*"[3]

Gordon Taylor (right) is honoured by Roger Pickard, Vice President of BAA, with the BAA "outstanding contribution" award. (Courtesy: Crayford Manor House Astronomical Society)

Gordon was also an active observer. *Occult*'s historical archive lists 129 of his lunar occultation timings obtained between the years 1957-1997. It also records him participating in 3 grazing occultation expeditions. He observed the occultation of the 2nd mag. sigma Sagittarii by Venus from Mombasa, Kenya on 1981 Nov 17, but only approximate timings were obtained.

When ESOP XVI was held in Cambridge, England in 1997, IOTA/ES members specifically requested a keynote talk by Gordon. He was very helpful when I researched the history of the Occultation Machine. I updated him on the latest developments in occultation astronomy and he was most interested in the improvements in predictions we were anticipating from the Gaia datasets. It was a pleasure to have known him.

Alex Pratt
IOTA/ES, BAA, Leeds, England



The plaque of the "outstanding contribution" award (Courtesy: BAA)

His work was acknowledged by the numerous awards bestowed upon him:

The BAA's Merlin Medal and Gift in 1962 – for his work on artificial satellites and on occultations by major and minor planets [4].

The BAA's Merlin Medal and Gift in 1979
– for his work on the occultations by Neptune and Pallas [4].

A BAA "outstanding contribution" award in 2009
- for his lifetime work, including the Uranus occultation [3].

Main belt asteroid (2603) Taylor = 1981 BW1
(currently magnitude 16, near alpha Librae).

The 2014 David E. Laird Award of the International Occultation Timing Association (IOTA) for being the father of Asteroidal Occultations [5].

References:

[1] Taylor, G. An astronomical autobiography, JOA 2016-04, pp. 3-4
[2] Herald, D. The first observed asteroidal occultation, JOA 2014-04, pp. 9-12
[3] https://britastro.org/computing/history.html
[4] https://britastro.org/about-awards
[5] http://www.asteroidoccultations.com/observations/Awards/Taylor.htm

Journal for
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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.

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IOTA maintains the following web sites for your information and rapid notification of events:

www.occultations.org
www.iota-es.de
www.occultations.org.nz

These sites contain information about the organisation known as IOTA and provide information about joining.

The main page of occultations.org provides links to IOTA's major technical sites, as well as to the major IOTA sections, including those in Europe, Middle East, Australia/New Zealand, and South America.

The technical sites hold definitions and information about all issues of occultation methods. It contains also results for all different phenomena. Occultations by the Moon, by planets, asteroids and TNOs are presented. Solar eclipses as a special kind of occultation can be found there as well results of other timely phenomena such as mutual events of satellites and lunar meteor impact flashes.

IOTA and IOTA/ES have an on-line archive of all issues of Occultation Newsletter, IOTA'S predecessor to JOA.

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