# ASTRON USER NOTES (V1.13)

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## 1. INTRODUCTION

Astron (ἄστρον – Greek for Star) is an Excel programmed worksheet for sextant users. Its primary objective is to combine almanac calculations, apparent body position calculations and sextant altitude corrections into an easy to use single sheet utility. Astron is a large spreadsheet and may load or run slowly on older machines. In fact, it was the predominance of Greek characters in the many formulae used that inspired the name Astron.

* As an almanac, Astron will, for an entered date and time, calculate the GHA, Dec, HP & SD of a body selected from a list of the 57 navigational stars, Polaris, Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn. In context, it also calculates Sun and star rise and set times, Moon phase, body magnitudes and twilight times. Although intended for practical use in the present era, dates between 1905AD and 2999AD may be entered.
* If an assumed position is also entered, Astron will also calculate the Azimuth and Altitude of the selected body. (If the body is unidentified, a sidebar utility can identify it given its approximate azimuth and altitude.)
* If a sextant altitude is also entered, together with instrument correction, height of eye, temperature, pressure and observed limb, Astron will also calculate the Azimuth and Intercept from the assumed position.
* Several supplementary features, such a sight planner, are also included.

## 2. CAUTION

Astron is free software that has been produced by enthusiastic amateurs. Whilst every effort has been taken to eliminate errors and inaccuracies, including cross checking with commercial software, almanacs and other printed publications, some errors and inaccuracies undoubtedly exist. Astron should never be used as a source of navigational information. On commercially licenced vessels, it should never even be installed on any ship’s equipment as such action could invalidate the vessel’s certification.

## 3. COMPATIBILITY

Astron is an Excel program and it requires Microsoft Excel to run it. The author chose Excel rather than a compiled programming language such as C++ (his favourite) as Excel is now available on many platforms. Additionally, because macros are never used, Astron cannot create any risk to the user of downloading malicious code (and should never give rise to any warnings of such possible risk.)

* For Windows PC users. Astron was developed using Excel 2016 and has been tested on Windows 8/10 desktops, laptops and Microsoft Surface / Surface Pro 3 tablets, all running fully licenced Excel versions from 2007 upwards. Some formatting features display incorrectly with Excel 2007 and Excel 2010 or later is recommended.
* For Apple Mac users. Astron has been tested on a modern Apple Mac running Excel for Mac V14.7.1.
* For iPad users. Astron has been tested (and very successfully compared with tabular results) on an Atlantic crossing using an iPad running Microsoft Excel Mobile for iPad. (Free as at Sept 2016)
* For Android tablet users. Astron has been modified (V1.10) and tested to run under Microsoft Excel Mobile for Android. (Free as above).
* For Windows tablet users. Microsoft state that, provided the tablet screen diagonal is 10.1 inches or less, Astron should run using (similarly free) Excel Mobile for Windows, but has not been so tested yet. On screens larger than 10.1 inches, Microsoft state that many user features are inhibited and therefore this version of Excel is not suitable to run Astron. Maybe they want you to buy the full version! However, the author tried using Excel Mobile for Windows on his Microsoft Surface Pro 3 (with 12” diagonal screen) and it worked just fine, not only on the tablet itself but on an external 23” screen also. Perhaps the simultaneous presence of a licensed version of the (full) Excel 2016 on that machine caused this to happen.
* For smart phone users. The above three Mobile versions of Excel will run Astron “in a fashion” on their respective platforms, but the small screen size requires excessive scrolling and is thus not recommended for practical use. Those who persist with the scrolling will find that the results are correct! Because of the size of Astron, we also suggest that you save it to your SD card to save time and charges.
* For newcomers to Astron. If you have not yet used Astron, don’t have Excel on your device and just want to get the look and feel of it, try Microsoft Excel OnLine. This is found and accessed through your internet browser and works with many platforms. Astron runs, but some forced cell format, colour and size changes impair the design and ease of use. Also, of course, an online version is of no use if you are at sea! (You need to press the “Edit on Line” button to start.)
* For Open Office Users. Alas, free Open Office Calc (V4.1.2) does not run Astron in .XLSX format. It does work with a worksheet exported in .XLS format, but then too many features depending upon cell colour and conditional formatting are lost to justify issuing a separate worksheet to run under Open Office.
* For Libre Office Users. Astron runs adequately under free (suggested donation US$10) Libre Office Calc (V5.1.5.2). Some conditional formatting is missing (such as the highlighting of the selected time input mode and the yellow override during daylight on the Sight Planner) but in general it is an adequate alternative if you don’t have a licenced copy of Microsoft Excel. (On first use of the settings sheet, it displays and interprets 0.0 as “FALSE” and any other number as “TRUE” – until you have entered “TRUE” or “FALSE” into all options) Also, upon your first saving of this, set the default to .ODS format, thus preserving the original .XLSX format file for future use with Excel.
* Microsoft Excel Viewer Users. This is just a viewer, you can’t input values and it is not suitable.

## 4. INSTALLATION.

We suggest that you install Astron somewhere on your local drive, maybe on your desktop, but not in a folder that is synchronised with a ‘cloud’ service such as Dropbox, Google Drive or OneDrive. This is to avoid the possibility of the workbook not loading because it is trying to synchronise whilst your vessel is beyond Wi-Fi and cellular data range.

## 5. GENERAL NOTES

5.1. Ensure that ALL main input fields are correct before using result. Fields coloured  are intermediate calculations for information only, whilst results are coloured . Additional supplementary utilities, such as body identification, have their text in a subdued grey, optional input fields shown as  and results shown as .

5.2. A: There is one main working sheet, COMPUTER ALMANAC, selected from the tabs located at the bottom left of any sheet. This handles both the almanac processes of calculating the geographic position of the body at the instant of observation and the subsequent sight reduction.

B: There is a supplementary working sheet, MANUAL ALMANAC, for those who prefer to use a printed almanac and just want Astron to calculate the apparent position and perform the sight reduction.

There are three additional sheets, similarly selected by the tabs located at the bottom left of any sheet.

C: The SIGHT PLANNER. See section 15 below for details.

D: SETTINGS. See Section 16, USER CONFIGURABLE ITEMS, below for details.

E: STAR INFORMATION. This sheet lists permanent star data sorted in various orders.

5.3. Astron is a spreadsheet and it recalculates all dependent fields whenever any field is changed. There is no ‘calculate’ button, but you do need to mouse click away from the last entered field (or press enter) to initiate the final calculation. Do not use any result until you are sure that you have correctly entered all input fields … intermediate results may appear incongruous! If you press “Save” (or set auto save on), the last entered data and settings will be recalled upon next use.

5.4. Some rows and columns and several other sheets are hidden for clarity. These are all for intermediate processes only. If you wish to view or indeed tinker with these, see Section 21, MODIFYING ASTRON, near the end of these notes.

5.5. This software is intentionally ‘verbose’. It could have been written with just the input fields and an output display of only azimuth and intercept. However, the author hopes that the intermediate data displayed is helpful in both understanding the processes and avoiding errors. Some intermediate results are also useful when using the software for indirect or unintended purposes.

5.6. Astron has various user configurable settings. In a release version, these are initially set to the default settings as described in section 16 of these notes. Similarly, units for height, temperature and pressure are set to metres, °C and hPa. If you receive Astron from another person, these settings may have been changed. These notes, to avoid repetition, assume that the default settings are used.

5.7. The following symbols are used to abbreviate some on-screen legend.

Sun **☉**, Moon **☾**, Any star **☆**, Venus **♀**, Mars **♂**, First Point of Aries ♈.

## 6. GENERAL CALCULATION NOTES

**Numbers:** These are displayed rounded to whole numbers or to1 decimal place; however, all calculations are carried out using 15 significant figures. In some instances, optional entries of greater accuracy are permitted (and used, but not displayed). (EG 0.14' can be entered as Sun horizontal parallax on the Manual Almanac sheet, but will be displayed as 0.1')

**Cell Rounding:** If the calculation result is (say) 12° 59.96', Excel will (alas) round this to display 12° 60.0'. This should be interpreted as 13° 00.0'. If anyone has a fix for this, (without recourse to undesirable macros), please speak up!

**Division by zero:** Exceedingly rare cases may occur (usually involving chance interim values of exactly 0 or 90 degrees) which give a #NUM! or #DIV0! error. Work around by changing (say) input time by 1 second.

## 7. NOTES when using the COMPUTER ALMANAC sheet.

This sheet has two supplementary utilities (with blue borders) below the main display. The intention is that only the top display with cream border is normally visible – but you may need to adjust your zoom setting (pinch gesture or Ctrl + mouse wheel) to achieve this.

**Enter Time and Date**:

1. The default method is to enter date and time in Ship’s Watch Time. The header “Watch Date/Time in Ship’s Time” should be visible above the date/time entry fields. Some users prefer to enter date/time as GMT and this is available as an alternative mode described in the section 16.1 (USER CONFIGURABLE ITEMS). Which mode you use is entirely your choice. However, to avoid explaining both methods repetitively, except where specifically stated, date/time input in Ship’s Watch Time is assumed and described in these notes.
2. So, enter your ship’s watch date and time of observation. Invalid dates (say 31st April) give an error message and Astron calculates assuming (say 1st May) was intended.
3. Then enter your Watch Correction. If your watch is (say) 15 seconds slow, enter +15. (-15 if fast.) Values between -60 and +60 seconds are permitted. Do not confuse with the term Watch Error which is of opposite sign. Note that entering a Watch Correction does not change the time display that you have entered on the input line, but the corrected time is displayed (in both GMT and Ship’s Time) on the right of the screen. Of course, if you always adjust mentally, just enter zero.
4. See also the paragraph “Time Zones / Zone Descriptions / Daylight Saving” below. These fields MUST be also be entered for Astron to function correctly in either time entry mode.

**A note on obtaining accurate time**. If you seek very high accuracy, beware of setting your chronometer from time signals on digital radio, digital TV, GPS and the internet. A delay of around two seconds is common on audible/visual output of digital transmissions. There are also unverified internet reports of some analogue radio transmissions being reworked as ‘relays’ of the digital signal, thus questioning their accuracy too. Time displayed on a GPS may also be delayed even though the unit knows time within a few nanoseconds, especially within 15 minutes of switch on but also if the time display driver subroutine has a low priority with a busy processor. Several websites have feedback mechanisms that measure and correct for internet time delays, claiming accuracies of hundredths of a second. However, your computer display has its own delays, especially when caches are used. The author has tested several such websites and found differences between them of up to 4 seconds. Try for yourself running two or more in separate windows and another on your smartphone. [www.time.is](http://www.time.is) seems to have been designed to minimise this screen display delay effect.

**Time Zones / Zone Descriptions / Daylight Saving:**

Astron can be configured to work using either Time Zones or Zone Descriptions. See 16.2 (USER CONFIGURABLE ITEMS). Time Zones are positive East of Greenwich, whilst Zone Descriptions are negative East of Greenwich. Time zones between -12 and +14 may be entered. (ZDs between -14 and + 12.) Please set the method you prefer. These notes describe the Time Zone method only to avoid repetition.

A section on the upper right of the Computer Almanac sheet asks you to enter the Time Zone offset that you are using (+E/-W) and also a Daylight Saving hour if applicable. Astron displays both GMT and Ship’s Time adjacently to the time zone entry fields, with a caret (>>) and green background beside the one which is the current date/time entry mode. Note that Time Zones and Daylight Saving not only affect the hour, they can also affect the day, the month and possibly even the year. The prime purpose of displaying both times, including day of the week, is to allow you to cross check that the intended time has been entered. Time Zones are positive East of Greenwich. Partial hours are permitted as decimals, so for India (5h 30m ahead of GMT) enter +5.5. Times of sunrise, sunset and twilight observation window on the computer almanac sheet are always given in Ship’s Time. As an example, if you were about to depart from New Zealand in their summer, your ship’s clock would probably be set to New Zealand summer time. (GMT+12 + 1 hour daylight saving time.) So 06:00 Ship’s Time would be 17:00 GMT the previous day.

See also Section 19, DISCUSSION ON TIME ENTRY METHOD, later in these notes.

**Select Body:** Click on the displayed body name. Then click on the arrow that appears on the right of that cell and use the pick list to select the required body. Sun, Moon and planets are first on the list, then stars in alphabetical order. Stars whose names are in UPPER CASE are all first magnitude (<=1.5). (Depending on your system, you may need to use the up/down arrows beside the pick list if mouse scrolling doesn’t work.) Bodies whose names are followed by a period(.) are the only ones considered by Astron for the lunar distance pop-up. See 18.1.

**Additional Sun Features:** If the Sun is the selected body, additionally…

1. Astron displays the value of the equation of time at the user entered instant. If the sign is +ve, this indicates that the ‘true’ Sun is ahead of the ‘mean’ Sun and thus the Sun’s meridian passage will be that time interval before 12:00 local mean time. Vice versa for a -ve sign. (LMT = GMT +E/-W Longitude (in degrees) / 15).
2. The times of sunrise and sunset at the assumed position are displayed. (These are always given in Ship’s Time). Of course, the time zone and daylight saving fields must have been correctly entered. In that hemisphere’s winter in high latitudes, the Sun may not rise at all that day. Conversely, in summer, the Sun may not rise because it is above the horizon all day. In these cases, “None” or “H24” is displayed. These sunrise and sunset times use an abbreviated formula and are based on the upper limb rise/set for a sea level observer in standard conditions. In latitudes below 66 degrees, they are believed to be accurate to within 3 minutes. (2 minutes calculation plus 1 minute due to the refraction anomalies). In polar latitudes, refraction anomalies have a greater effect on the rise/set time. See Indirect Uses (17.1) for a more accurate sunrise / meridian passage / sunset method.

**Additional Moon Feature:** If the Moon is the selected body, additionally…

1. The Moon’s phase is displayed, indicated as a percentage of full Moon illumination. A “+ve” sign indicates that the Moon is waxing, a “-ve” sign indicates waning. For times of Moon rise/set, see Indirect Uses (17.1).

**Additional Moon, Star and Planet Features:** If any body other than the Sun is selected, additionally…

1. The magnitude of the body (except for Moon) is displayed.
2. Star and planet sights can normally only be taken during an observation window before sunrise and after sunset when the light levels are such that both stars and horizon are visible. Astron displays the Ship’s Times of the AM and PM Observation Windows for the assumed position. Of course, the time zone and daylight saving fields must have been correctly entered. The default window is based on the time when the centre of the Sun is between 3° and 9° below the celestial horizon. However, you may prefer different values and, if so, you can change these using the “Settings” sheet as explained in Section 16.5, User Configurable Items. In that hemisphere’s winter in high latitudes, there may be no window as the Sun may remain too low all that day. Conversely, in summer, there may be no window as the Sun may remain too high all day. In both cases, “None” is displayed. These times use an abbreviated method and are believed accurate to within 5 minutes in latitudes below 66 degrees. These observation window times do not indicate that the selected body will be visible.

**Additional Star Feature:** (New V 1.13)

The ship’s times of rise, upper meridian passage and set of the selected star are displayed in the lower right hand corner, based on the height of eye, temperature and pressure that you have set in Sextant Altitude Corrections. These are the times when these three events occur on the selected (ship’s time) date, so, for an evening star rise, say 1900, the displayed set time would be for when it previously set on the morning of that day, not for the set the following morning. Occasionally an event can occur twice on a given day, just after and just before midnight, in which case, the later event time is shown in the border below the earlier one. If the star does not rise or set that day, NONE is displayed. The time of upper meridian passage is always displayed, even if the star is below the horizon. Calculation accuracy is believed to be within 5 seconds, except for near circumpolar situations. Due to refraction anomalies, such accuracies are unrealistic but have been retained as the author is doing some personal research on ‘extinction’, the reduction in apparent magnitude of setting stars as they near the horizon. (If using GMT input mode, note that the times will be for the present day in ship’s time, which may be different from the entered GMT day.)

**Planets:** Although not normally listed in navigation almanacs, Mercury is included in Astron as its apparent magnitude exceeds even that of Sirius for a few days once or twice on each 116-day apparent orbit. For times of Planet rise, meridian passage and set, see Indirect Uses (17.1).

**Polaris:** Treat as any other star and plot intercept. GHA may be up to 1.5' in error due meridian convergence near the pole, but azimuth and intercept calculation accuracy remains <0.2'/0.2nm unless Ass Lat is North of 75°N. Observation inaccuracies are greater than calculation inaccuracies.

## 8. NOTES when using the MANUAL ALMANAC sheet.

This (lesser used) sheet has a blue border to avoid confusion with the Computer Almanac sheet.

**Entering Data for Sun, Moon or a planet**: Enter the GHA and Declination from the Almanac for the exact time of observation. Enter 0.0 in the field headed SHA. (Please note that 0.0 is not the body’s actual SHA, but this method avoids having a separate entry format for a star.)

**Entering Data for a star**: Enter the GHA of Aries from the Almanac for the exact time of observation. Enter the Almanac SHA and Declination for the star in the appropriate fields.

**Entering Horizontal Parallax**: For the **Moon,** all almanacs list HP which must be entered. For the **Sun,** normally enter 0.14 minutes. (Your almanac may list Sun HP values in the notes section.) For **Venus** and **Mars**, most almanacs list this as a single entry on each multi day page. For **other planets** and **stars**, enter 0.0.

**Entering Semi Diameter**: For the **Sun** and **Moon,** all almanacs list semi diameter which must be entered. For planets and stars, normally enter 0.0 and observe the centre of any discernible shape.

## 9. ASSUMED LATITUDE & LONGITUDE NOTES (both worksheets)

* Unlike when using sight reduction tables, there is no need to specify specific values to facilitate table look up methods. Choosing whole degree values nearest to your DR position usually simplifies plotting of the subsequent line of position. (However, if you are using Astron to cross check a tabular sight reduction, then you will need to input the same assumed latitude and longitude that you were obliged to use for table look up.)
* Input of exactly 180° longitude and 90° latitude is prohibited. If required, use 179° 59.9’, etc.
* Input of N or S, E or W can be in UPPER or lower case.

## 10. SEXTANT ALTITUDE CORRECTION NOTES (both worksheets)

**Sextant Reading (Hs):** The maximum permitted value is 149° 59.9’. Values over 90° are to cater for sextants using an artificial horizon and for back “over the top” sights. For real horizon sights, avoid angles close to 90° for plotting accuracy and limb ambiguity reasons. (See Indirect Uses section 17.6 for artificial horizon sights and 17.7 for back “over the top” sights.)

**Index Correction (IC):** When zeroing your sextant on a distant object, an “off the arc” calibration reading is deemed a positive index correction. (H1 = Hs + IC). Do not confuse with often used Index Error (IE) which is of opposite sign. (Beware of a not infrequent error when reading ‘off the arc’ values – an off arc reading of 0.2’ (IC = +0.2’) will show on the main scale between 0° and -1°, but on the vernier as 0.8’.)

**Selectable units for HoE, Temperature and Pressure.** To change units, click on the amber coloured field saying (say) “Metres”, then use the “pick list” to select your preferred units.

**Height of Eye (HoE):** Enter the accurate height of the observer’s eye above sea level. The units are user selectable between feet and metres. A platform midway fore and aft reduces HoE variations due to pitching. A low and on-centreline platform reduces HoE variations due to rolling. A higher platform reduces horizon wave effects whilst a low platform reduces refraction anomalies for low altitude sights (and can sometimes give a horizon with a distant fog bank.) Minimising HoE variations due to vessel’s heaving is a personal observer skill.

**Temperature and Pressure Corrections for refraction.** Enter the ambient air temperature and pressure. The units (°F or °C and Inches Hg or hPa) are user selectable. (The millibar was internationally renamed hectopascal in 1971. Entries in hPa display with superfluous decimals as these are needed for Inches Hg.)

Beware of results when Hs is less than 5° due to natural anomalies from the computed normal corrections for the input temperature and pressure. Exactly on the visible horizon, some authors record measuring anomalies of up to 20', equivalent to up to 20 nm error in position line. However most of these reports were measured from platforms of significant elevation, such as cliff tops and even mountain observatories, often over intermediate terrain and usually with a distant sea horizon. Most of the reported natural anomaly is usually attributable to temperature variation of the air mass below the level of the observer. Computer and tabular methods usually treat that part of the refraction (below the sensible horizon) as part of the HoE correction and do not include any provision for non-standard below sensible horizon atmospheric effects. For an observer on the deck of a small vessel well away from the influence of land, these anomalies are usually far smaller.

**Limb:** Computer Almanac calculates semi diameter for Sun, Moon and planets. For Sun and Moon, enter U, L or C as appropriate. For stars, semi diameter is zero, so enter any value. For planets, normally use "C" and observe centre of planet. However, Venus’ aspect (like the Moon) is seldom vertical and the apparent centre is seldom the true centre. (The Nautical Almanac listed positions for Venus are pre-adjusted for the apparent centre – with Astron, if you select “L” or “U” for any planet and observe accordingly, it will correct for semi diameter.)

**Correction for parallax:** In addition to the usual corrections for horizontal parallax, Astron also includes a further correction to allow for the oblateness of the earth. (Reducing earth radius as latitude increases.) For the Moon, this further correction is 0' at the equator, decreasing to -0.2' at the poles and is negligible for other bodies.

**Correction for semi diameter:** In addition to correcting for SD, for a Moon sight only, Astron also applies a further correction for augmentation. (Increased apparent Moon semi-diameter when overhead because you are an earth’s radius closer to it.) This is 0' on the horizon increasing to +0.26' at the zenith.

## 11. UNIDENTIFIED BODY UTILITY (On Computer Almanac sheet only)

First enter Date, Time and Ass Lat/Lng.

Then enter Observed Altitude and TRUE bearing in the fields near the right edge of the screen.

Note that only the listed bodies can be identified. (Sun, Moon, Mercury, Venus, Mars, Jupiter, Saturn, the 57 navigational stars and Polaris). Other bright stars, such as Castor or Becrux, will not be found. Like the main display, the logic continues to work for bodies below the horizon and ignores invisibility in daylight. You may prefer to use the Sight Planner sheet which gives azimuth and altitude information on all above-horizon listed bodies for the selected date, time and assumed position.

## 12. CONVERSIONS

This facility was withdrawn on the Computer Almanac sheet in V1.13 as user selectable units were added to the main display. It is retained for the time being on the Manual Almanac sheet where Astron uses only metres, °C and hPa for height of eye, temperature and pressure respectively.

## 13. LATITUDE FROM LOCAL UPPER MERIDIAN PASSAGE OF ANY BODY.

Traditionally a separate procedure is used to calculate latitude from an observation of a body at its maximum altitude, usually on the grounds that it is simpler than calculating and plotting a standard sight reduction. With Astron, the author suggests that, if you have accurate time, it is easier, and more consistent, to treat this as any other sight and plot the resulting (East/West) position line. However, in respect of the traditional method, (especially to finding latitude with inaccurate time), Astron replicates this method and makes a direct calculation of latitude (and approximate longitude) for such a sight. This is on the Computer Almanac sheet only and works as follows -

* Pop-up display. Whenever the entered data results in a local hour angle near to 360 degrees, Astron thinks that you may be trying to resolve an upper meridian passage sight. It therefore shows a ‘pop-up’ display entitled “Upper Meridian Passage Sight?” and, below it, the observer’s latitude and longitude assuming that:-
  + (a) the entered sextant altitude (Hs) was the measured maximum altitude of the body and
  + (b) the entered date/time was the exact time of that event. If not an upper meridian passage sight, just ignore this display.
* Latitude calculation. The assumed latitude MUST be in the correct sense. By this, we mean that if you were facing South to take the sight, then you were North of the body and the assumed latitude MUST be North of the declination of the body, and vice versa. With this important proviso, the accuracy of the assumed latitude has no other effect as the latitude is calculated using the declination at the entered time of meridian passage and the maximum sextant altitude. (For a star, latitude accuracy is not influenced by time accuracy – for Sun, Moon and, to a lesser extent, planets, the declination varies with time and latitude accuracy is influenced by time accuracy.)
* Longitude calculation. The accuracy of the assumed longitude need only be within 10 degrees of your actual position (to trigger the pop-up display) but the accuracy of the time of maximum altitude is critical to this calculation of longitude. However, such observation time is unlikely to be accurate as the exact time of maximum altitude is difficult to observe.
* If the time of maximum altitude is more accurately determined by the median time of observations of equal altitude, then the calculated longitude will be more accurate, but still lacks corrections for ship’s run and (except for star observations) the change of body declination between the observations.

## 14. ADVANCED LINE OF POSITION. (New V1.07)

This utility (located below the main display on the computer almanac sheet only) will hopefully assist in plotting a fix from multiple observations whilst under way. It only works if you choose a fix time that is equal to, or later than, the time of the last of the observations. Your COG and SOG must be constant throughout the period.

* For each entered observation in turn, enter (or check) the chosen fix time, course over ground (COG) and speed over ground (SOG). Astron will display the distance that the line of position (LOP) from this observation needs to be advanced (in the direction of the COG) to advance the LOP to the fix time. Many navigators prefer to work this way, plotting both the LOP at the observation time and the advanced LOP at the fix time.
* Some, however, prefer to advance the assumed position(s) and plot only the advanced LOP’s. So, for those who do this, Astron also calculates the advanced assumed latitude and longitude from which you should plot the calculated azimuth and intercept, assuming rhumb line course and speed were held. (The azimuth and intercept values for the current sight are repeated here for convenience.) If you prefer the former method, just note the COG and the distance to advance and ignore the rest. Note that, if you have used the same assumed position for sights taken at different times, the advanced assumed positions will not be the same.
* You will need to record (or plot) the outputs for each observation before using Astron for the next observation.
* Fix times earlier than the sight time (retired LOP’s) are not supported. This is to allow for sights over midnight - Astron assumes that an ‘earlier’ entered fix time is on the following day. (You can cheat by temporarily reversing the times and entering the reciprocal of the COG!)
* Astron uses time after watch correction for these calculations.
* Effectively, this is just a DR calculator and it can be used for other rhumb line calculation purposes.

## 15. SIGHT PLANNER. (New V1.08)

This separate sheet, accessed using the tabs located at the bottom left of any sheet, will hopefully help you choose suitable bodies for a multiple body fix. It can also be used as a star (and planet) recognition aid as it lists the azimuths and altitudes of all visible bodies in clockwise azimuth order.

* The SIGHT PLANNER is linked to the body, time and assumed position set on the Computer Almanac sheet. You can only change these by temporarily revisiting that sheet. Both this sheet and the Computer Almanac sheet list the Ship’s Times of the AM and PM observation windows which may be of help in choosing your planned observation time.
* The first three columns list the azimuths and altitudes of all above horizon bodies at the chosen time as would be observed from the assumed position. Values are rounded to the nearest whole degree. The list is in order of AZIMUTH (i.e. true bearing) clockwise from North. Bodies with a poor observational altitude (but maybe still useable) are shown in pale grey. (These three columns with more detailed values of Azimuth and Altitude are repeated if you scroll right on the Sight Planner sheet.)
* The columns headed “2”, “3” & “4” are for two, three and four body fixes respectively. Within these columns, bodies with good altitudes and good angular separations from the reference body are shown with their azimuth difference (+ve clockwise) from the reference body displayed. For a good two body fix, choose bodies with azimuth differences of +/- 90 degrees. For a three body fix, use +/- 60/120 degree differences and for a four body fix use +/- 45/90/135 degree differences. Remember not to choose bodies that are 180 degrees apart, i.e. near 135 & -45, etc.
* If the Sun is above the horizon, a yellow warning is given. Only the Sun, perhaps the Moon and possibly Venus could be visible! The Sun is deliberately included in the list of bodies to cater for possible Sun/Moon/Venus daylight sights. The altitude of the Sun is shown in the explanatory text.
* The NORMAL METHOD OF USE is to start on the Computer Almanac sheet and select your expected latitude, longitude and a time within the observation window. Then view the Sight Planner sheet, use the information to choose a bright reference body with a good altitude, revisit the Computer Almanac sheet to select that body and then return and make your choices of other bodies. A red warning is given if you have selected a reference body that is below the horizon and an amber warning if it has a poor observational altitude.
* If the suggested bodies are too few, obscured or just not bright enough, try a different reference body.
* A separate area allows you to adjust certain settings to your own preference. These affect the display of the indicators of daylight, below horizon bodies, good body altitude and good angular separation. Any changed settings will be remembered only if you save before you exit Astron.
* Some other factors that may influence your choice are body magnitudes (1st magnitude stars are in CAPITALS), cloud and horizon conditions, proximity of the Moon, bodies obscured by sails, stars that you are sure you can recognise and the need to observe faint bodies first as soon as the horizon is visible before sunrise.
* Of course, overriding navigation criteria may dictate a totally different choice. For example, if you need to clear an isolated reef, you will mainly be interested in cross track accuracy and you will bias your choice towards bodies with an azimuth near to 90 degrees to your track.
* By way of example, first set the following values on the Computer Almanac sheet. (Ship’s Time entry mode). Date: 2016 January 2nd.Ship’s Time: 04:45:00 Body: VENUS Lat: **S**29° 00.0’. Long: **E**168° 00.0’. Time Zone: +11.5. Daylight Saving: 0. Note that the proposed time falls within AM observation window. Then move to the Sight Planner and observe that:
  + The two body column suggests three alternatives, of which you would probably choose Jupiter (-87 degree intersect to your chosen reference body Venus.)
  + The three body column suggests either the Moon or Arcturus (both about -60 degrees to Venus) and one of the (+60 degrees) RIGIL KENT, HADAR or ACRUX. (Not CANOPUS as it is opposite Arcturus/Moon). Five second magnitude stars also fall within the suggested range.
  + The four body column suggests Jupiter (near -90), ARCTURUS (near -45) and RIGIL KENT or HADAR (near +45), Three second magnitude stars also fall within the suggested range.
  + You may like to try selecting a different reference body, (say Canopus or the Moon) and noting the changes in the suggested combinations. Also try temporarily changing the value of (say) the four body range parameter (from 10 to 5) to see how the number of possibilities reduces.

## 16. USER CONFIGURABLE ITEMS

These settings are all on the sheet “Settings” accessed from a tab on the lower left of any screen. Any changes you make will be preserved if you press “Save” on exit.

### 16.1. GMT INPUT MODE. (Revised V1.09)

The default setting is FALSE. As stated earlier in these notes, the default method is to enter date and time as Ship’s Time. The header “Enter Date/Time in Ship’s Time” should be visible above the date/time entry fields. However, if you set this to TRUE, the computer almanac sheet header will change to “Enter Date/Time in GMT” and Astron will accept date/time inputs in GMT. Note that in either mode, Astron always displays both GMT and Ship’s Time on the right hand side of the screen, with a caret (>>) and green background to the one which is the current date/time entry mode. This is to enable you to check that the date/time inputs are as intended. (Strictly speaking, the term Universal Time (UT) should be used, rather than GMT, but the difference is always less than one second and GMT is so well established that this term is used throughout this workbook.)

### 16.2. USE ZONE DESCRIPTIONS. (New V1.13)

The default setting is FALSE and Astron uses Time Zones to convert between ship’s time and GMT. Time zones are +ve East of Greenwich and are set by international agreements.

Many high seas sailors use Zone Descriptions which are -ve East of Greenwich and are defined as strictly dependent on longitude bands. (EG A ZD of +1 applies to the band between W007° 30’ and W022° 30’). Astron uses a looser definition to allow for values of minus 13 and minus 14 (for Samoa and the Line Islands) and for decimal values. Set this field to TRUE if you wish to use Zone Descriptions rather than Time Zones. Your previous value will need to be updated if you change this setting, usually just by changing the sign. The ‘legend’ to the input fields will change accordingly.

### 16.3. SHOW RIGHT ASCENSION.

The default setting is FALSE. This feature is provided for telescope users with Right Ascension equatorial mounts. If set to TRUE, the Right Ascension of the body will be displayed instead of its SHA. Note that this is the Right Ascension of the body at the exact input time. It will differ from a star catalogue value (often at J2000.0) as Astron has corrected the RA for proper motion, precession, nutation and aberration since the catalogue datum.

### 16.4. ARTIFICIAL HORIZON.

The default setting is FALSE. If you are reducing a sight using an artificial horizon, first set this to TRUE. See INDIRECT USES (17.6) below.

### 16.5. ADJUST TWILIGHT OBSERVATION WINDOW TIMES. (New V1.13)

As explained in Section 7 (Additional Moon, Star and Planet Features), the times shown here are the times when the Sun centre is between two selected angles of depression below the celestial horizon. These default angles are -3° and -9°. You can change these values (within certain limits) to suit your personal observation methods by changing the values of TOO LIGHT SUN DEPRESSION and/or TOO DARK SUN DEPRESSION.

## 17. INDIRECT USES

These are indirect ways of using Astron for purposes other than its design objective of sight reduction. Some of them can be accomplished more easily with other dedicated software, but are listed here just in case you do not have such software handy. Please familiarise yourself with the normal (preceding) uses of Astron before experimenting with these indirect uses or, indeed, any other uses that you invent yourself.

(Where ‘adjust’ is mentioned, please see 17.9, NOTES TO INDIRECT USES, at the end of this section).

### 17.1A. Calculate time of rise or set of any body at any location.

* For stars, this information is already displayed on the Computer Almanac sheet (accuracy within 5 secs). For the Sun, this information is also displayed, but only to an accuracy of about 3 minutes. For Moon, planets and more accurate Sun information proceed as follows.
* Enter Year, Month, Day, approximate Ship’s Time, chosen body, Location Lat & Long, Hs=0, IC = 0, Act HoE, Temp, Press & (usually) Upper Limb. Watch correction should be zero and Time zone and daylight saving time must also be correctly entered.
* Then ‘adjust’ Hour, Minute and eventually Second to give an intercept value of 0.0nm. This is Ship’s Time of the event. GMT time (and date) is also given.

Note 1: Do not adjust to give a Hc of 0.0 – it must be the intercept of 0.0 to allow for refraction, etc.

Note 2. Inability to converge to an intercept of 0.0 indicates that the body does not rise (or set) that day.

* If azimuth <180°, this is body rising time. Otherwise, it is setting time.
* Calculation accuracy using this method is believed to be well within 5 seconds provided the difference in latitude and declination is within 60 degrees. However, because of natural variations in refraction at very low observed altitudes, do not expect accuracies of less than 1 minute.

### 17.1B. Calculate time of upper meridian passage of any body.

* This is similar to 17.1.A, but ‘adjust’ time to give a Local Hour Angle of 000° 00.0’. In the case of the Sun, the value shown in Equation of Time may help save a few steps. (Lower meridian passage is similar, but ‘adjust’ to give a LHA of 180°.)

### 17.2. Compass check. (Traditionally naked eye bearing at sunrise or sunset)

* Record pelorus bearing of event.
* Input body, exact ship’s time of naked eye body rise/set, Act Lat & Long, Hs=0, IC=0, Act HoE, Act Temp, Act Press and Limb. Time zone and daylight saving time must also be correctly entered. The resulting Intercept value should be near to zero.
* Compare Astron’s Azimuth with recorded bearing, allowing for variation and deviation (unless a gyro compass).
* This procedure is also valid for any visible body at any low altitude, not just at set/rise. In this case, record Ship’s Time and pelorus bearing and measure the (low) altitude with your sextant, entering Ship’s Time, measured Hs, IC, HoE, temperature, pressure and limb.
* After a naked eye sight, remember to reset IC to your usual value.

### 17.3. Latitude from Local Lower Meridian Passage of any circumpolar body. (IE body at minimum altitude)

* Enter Hs, Ship’s Time of minimum altitude, Ass Lat/Lng and other parameters as for a normal sight. Time zone and daylight saving time must also be correctly entered.
* The azimuth will be near to 000° (body N of observer) or 180°. Plot azimuth/intercept as normal.
* Alternatively, ‘adjust’ your assumed Longitude to give a **LHA** of exactly 180, then ‘adjust’ Assumed Latitude to give intercept of zero. This is your Latitude.
* NOTE 1. In theory, the adjusted assumed longitude is also your true longitude, but this is unlikely to be accurate as the exact time of minimum altitude is difficult to observe.
* NOTE 2. If the time of minimum altitude is more accurately determined by the median time of observations of equal altitude, then the adjusted assumed longitude will be more accurate, but still incorrect due to ship’s run and (except for star observations) the change of body declination between the observations.
* NOTE 3. Refraction anomalies could reduce accuracy in latitude if the body altitude is low. Longitude accuracy with a ‘bracketed’ sight should not be affected, provided atmospheric conditions do not change between sights.
* Read also (in reverse context) notes in 13 above re LATITUDE FROM LOCAL UPPER MERIDIAN PASSAGE OF ANY BODY.

### 17.4. Sextant damaged or overboard! (but chronometer ok)

* Observe rise or set of any body to obtain a line of position. Input body, exact Ship’s Time of rise or set, Ass Lat & Long, Hs=0, IC=0, Act HoE, Act Temp, Act Press and Limb. Time zone and daylight saving time must also be correctly entered.
* Plot line of position from Azimuth/Intercept result. Repeat with other bodies with maximum possible difference in declination, transferring lines of position for ship's run. (Aim for at least 50° difference in declination.)
* Star/planet rise/set observations can be made all night, not just during twilight.
* For Sun or Moon rise / set observation, also note time of rise/set of LOWER limb. Useful as a cross check and (for set) in case the subsequent upper limb event is obscured.
* See comments in 17.1 above re corrections for refraction. Don’t expect great accuracy from this, but you should still find an island the size of Barbados. (In 1975 Leslie Powles ended up in Brazil rather than Barbados with a perfectly serviceable sextant, using just the Sun upper meridian passage for latitude. Alas, he made a repetitive error in this (allegedly) straightforward method, by not changing the sign of the Sun’s declination after the autumnal equinox. This is why the author favours just using one method for all sights, rather than having one for normal circumstances, one for meridian passages and a third for Polaris.)

### 17.5. Exact time of full or new Moon.

* Select “Moon”.
* Enter approximate date.
* ‘Adjust’ day, hour, minute and eventually second whilst watching the waxing/waning +/- indicator. When this changes from + to – with a tiny time increment, this is the time of full Moon. (From – to + is new Moon.) (Using the +/- is more accurate than using the change in phase from 99% to 100%)

### 17.6. Artificial horizon sights. (New V1.08)

To use Astron for sights taken using an artificial horizon, you first need to set ARTIFICIAL HORIZON to TRUE. This is explained in 16.4 above. Having done so, note a warning “CAUTION: ARTIFICIAL HORIZON MODE” appears. The following example shows how Astron treats such a sight.

* Sextant reading 123° 45.6’. Index Correction +0.4. HoE 4.0m.
* Enter 123° 45.6’ in the Hs fields.
* Enter 0.4’ in the Index Correction field. Display is 123° 46.0’. All normal so far!
* Enter any value you like in HoE field! Display reads 61° 53.0’ regardless as HoE has no effect with an artificial horizon. The information value below the HoE field is exactly half the index corrected result.
* Enter Temperature & Pressure as normal.
* Take care determining which limb is observed. If the bottom of double reflected image touches the top of the image seen in the mirror or liquid, this is a LOWER limb sight. Even greater care is necessary if you are using an inverting telescope! If in doubt, overlap both images and enter “C” in the limb field.
* Ensure other input fields are all entered correctly and plot azimuth and intercept as normal.

### 17.7. Back (“over the top”) sights. (New V1.08)

Sometimes, when the nearer horizon is obscured or indistinct, a back sight can be taken. (The author’s Henry Hughes’ sextant reads up to 130°). If you insert a value for Hs greater than 90 degrees, (provided ARTIFICIAL HORIZON is not set to TRUE), Astron assumes that this is a back sight. The following example shows how Astron treats such a sight.

* Sextant reading 123° 45.6’. Index Correction +0.4. HoE 4.0m. Lower limb as observed in sextant.
* Enter 123° 45.6’ in the Hs fields. Note a warning “CAUTION: BACK SIGHT MODE” appears.
* Enter 0.4’ in the Index Correction field. Display is 123° 46.0’. All normal so far!
* Enter 4.0m in HoE field. Display reads 56° 17.5’. Note now that the altitude from the opposite horizon is displayed below this field. It has been corrected for dip, but by addition rather than the usual subtraction. (A sketch would show you why the dip must be reversed.) (180° - 123° 46.0’ plus 0° 03.5’ dip = 56° 17.5’)
* Enter Temperature & Pressure as normal.
* For a Sun or Moon sight, reverse the limb. If you observed the lower limb to be on the horizon, this looks like a lower limb sight, but you must enter it as an upper limb sight, because you are now measuring it from the opposite horizon. If in doubt, take and rework an additional approximate cross check sight using the centre of the body and enter “C” in the limb field – if the resulting intercept differs by about 30 miles you have chosen the wrong limb!
* Ensure other input fields are all entered correctly and plot azimuth and intercept as normal.

### 17.8. Latitude from simultaneous sights of two stars. (Sextant OK, inaccurate timepiece.)

Ensure you are very familiar with ‘adjusting’ entries as described in 17.9 below before getting bogged down with the following use. If you are interested in the Polynesian skill of wayfinding distant islands without a sextant (and also without compass, watch, almanac, log, logbook or charts), read all about it at <http://www.hokulea.com> and associated links.

The principle is that, within the limitations below, there is ***only one latitude at which two given stars simultaneously have two specific altitudes.*** It is independent of accurate time – just the simultaneity of observation time matters.

* Do not use in latitudes higher than 60°
* You can’t use any pair of stars! They both must have (a) azimuths within 45 degrees of 270 (setting) or 090 (rising), (b) altitudes below 70°, (c) altitude difference not more than 40° and (d) a declination difference of at least 30°. The example below was chosen as a test as it is quite close to limits a, b and d above. (Vega’s Azimuth of 310°, Altair’s altitude of 67° and declination difference of 30°). A star/planet combination also works within these limits, provided date is correct. Two planet combinations cannot conform to c) and d). Don’t use the Moon.

Assume you are approaching the US Virgin Islands on 11 Nov 2016. (The exact date has little effect, but we must enter something!) During evening twilight, you take the following simultaneous observations. (One sight must be an interpolated bracketed pair, but that is mere detail.)

**Hs ALTAIR 67° 04.6’ Hs VEGA 49° 13.7’**. IC=0, Hs=3m, T=25C, P=1010 hPa.

Approx Lat 17° 30’N. Ass Long 64° 00.0W. Approx Time 18:00:00. Ship’s Time Mode. Time Zone GMT -4. DS=0.

Use Astron to find the times when these altitudes would occur at 17° 00.0N 064° 00.0W.

1. Enter ALTAIR, Hs 67° 04.6’, sextant corrections as above. Adjust Time to give intercept of 0.0. (18:10:05)
2. Ditto VEGA, Hs 49° 13.7’ (18:06:23)

Now find the times for 18°N.

1. Ditto ALTAIR, Hs 67° 04.6’. (18:08:39)
2. Ditto VEGA. Hs 49° 13.7’. (18:09:53)

From 1 and 2, at 17N, VEGA’s Hs was 49° 13.7’ 3m 42s (222 secs) before ALTAIR’s Hs was 67° 04.6’.

From 3 and 4, at 18N, VEGA’s Hs was 49° 13.7’ 1m 14s ( 74 secs) after ALTAIR’s Hs was 67° 04.6’.

So they would have been at their respective measured altitudes simultaneously at 222/296 of 60 minutes North of 17N. This is N17° 45.0’.

As a check, enter N17° 45.0’. into Astron, re-enter ALTAIR, Hs 67° 04.6’ and adjust time to a zero intercept. (18:09:01). Now, without changing time, re-enter VEGA. Hs 49° 13.7’ and, isn’t science wonderful, the intercept is also zero.

This method is certainly laborious, as are many of these ‘indirect’ uses of Astron. But it is a possible method of finding latitude without an accurate watch if you have missed a meridian passage sight because of cloud.

### 17.9. NOTES TO ABOVE INDIRECT USES.

Some of the uses refer to ‘adjusting’ an entry. This is best done by ‘guessing and halving’ as the following example (in Ship’s Time entry mode) shows. Changes on each iteration are shown in RED. The example is to find the Ship’s Time of the rise of Mercury on 2nd January 2016 (Ship’s Time date) at a position 6 miles North West of Norfolk Island. (S29° 00.0’ E168° 00.0’.) Time Zone is +11h 30m with no daylight saving. The answer is 06:51:20. (19:21:20 GMT the previous day.) Alas, after all your efforts, this was after sunrise and the rise of Mercury would not have been visible! It looks complicated, but once you have done it a couple of times and get the hang of it, you can usually get the result in less than 15 seconds.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **INITIAL SETTINGS** | | Time Zone  **11.5** | Daylight Saving  **0** | (SHIP’S TIME ENTRY MODE) |  |  |  |  |
| BODY | ALAT | ALNG | Hs | IC | HoE | T | P | Limb |
| MERCURY | S 29 00.0 | E 168 00.0 | 0 | 0 | 5.5m | 28C | 1025 hPa | C |
|  |  |  |  |  |  |  |  |  |
| **YEAR** | **MONTH** | **DAY** | **HOUR** | **MIN** | **SEC** | **AZIMUTH** | **INTERCEPT** | **COMMENT** |
| 2016 | 1 | 2 | 12 | 0 | 0 | 076.1 | 3957.9A | Initial guess. Long way off. Subtract 6 hours. |
|  |  |  | 06 |  |  | 121.1 | 596.8T | Now 600 off. Try another hour earlier. |
|  |  |  | 05 |  |  | 130.6 | 1235.8T | Wrong way! Try 07:00 |
|  |  |  | 07 |  |  | 113.2 | 104.1 A | A little too far. Try 15 mins earlier. |
|  |  |  | 06 | 45 |  | 115.1 | 75.5 T | Not enough. Try 7 mins later. |
|  |  |  |  | 52 |  | 114.2 | 8.0 A | Getting closer. Just a little too far. Try 51 mins. |
|  |  |  |  | 51 |  | 114.3 | 4.0 T | 51 mins not enough, 52 too many. Try 30 seconds. |
|  |  |  |  |  | 30 | 114.3 | 2.0 A | Too much. Halve it. Try 15 secs. |
|  |  |  |  |  | 15 | 114.3 | 1.0 T | Too little. Halve the difference. Try 22 secs. |
|  |  |  |  |  | 22 | 114.3 | 0.4 A | Too much. Try 19 secs. |
|  |  |  |  |  | 19 | 114.3 | 0.2 T | Nearly there. Add 1 sec. |
|  |  |  |  |  | 20 | 114.3 | 0.0 | QED. |
| **2016** | **1** | **2** | **06** | **51** | **20** |  |  | **Answer in Ship’s Time.** |
| 2016 | 1 | 1 | 19 | 21 | 20 |  |  | Answer in GMT |

PS. “Why Norfolk Island?” The author happened to be a jetlagged passenger on an aircraft near Norfolk Island before dawn on that local date. I did not see the lights of Norfolk Island, but there was a lovely view of Venus in the East. This inspired me to use Astron to see when Mercury would rise. This example also demonstrates the use of a time zone that is not a whole hour offset from GMT. Also, you may like to read “Alone over the Tasman Sea” by Sir Francis Chichester. An extraordinary example of solo navigation to find this tiny and remote island in 1931 in a Gipsy Moth biplane fitted with floats, using only a marine sextant and with no fuel to go anywhere else and no autopilot. He practiced taking Sun sights whilst pedalling a bicycle along a coast road.

## 18. LUNAR DISTANCES (New V1.12)

### 18.1. OBSERVED LUNAR DISTANCE POP-UP

Astron, like old Almanacs, can display the lunar distance between the moon and the currently selected body for the selected location and time. Almanacs used to list the geocentric lunar distance (the angle between the centres of the two bodies as would be measured by an observer at the centre of the Earth) for selected bodies at 3 hour intervals. However, Astron shows the calculated “Observed Near Limbs Lunar Distance” which is the actual apparent arc between the near limbs of the two bodies as would be measured by an observer at the assumed position and GMT. It is a ‘pop-up’ on the Computer Almanac sheet, below the unidentified body utility. It will be displayed only when all the following criteria are valid.

* The selected body is the Sun, a planet or a star located close to the ecliptic plane. Such bodies have a period (.) after their name on the body selector list and elsewhere. (Sun, Mercury, Venus, Mars, Jupiter, Saturn, Aldebaran, Altair, Antares, Denebola, Fomalhaut, Hamal, Menkar, Nunki, Pollux, Regulus, Spica & Zuben'ubi)
* The (geocentric) lunar distance arc is between 10° and 140°.
* The Moon and the selected body are both at altitudes above 10°.
* If the Sun is above -6° below the horizon, the selected body is the Sun or Venus.

Not all bodies are suitable: they must be within a small angle of the moon’s path. Bodies very near the Moon are tempting, but seldom meet the small angle requirement. Therefore, Astron omits bodies closer than 10° to the Moon – however any value less than 30° should be used with caution. Similarly, because of refraction anomalies, Astron only displays if both bodies are more than 10° above the horizon - but use caution if either are below 20°.

The main purpose of this pop-up is to indicate if a ‘lunar’ (see 18.2) is possible with the chosen body at the selected time and location.

### 18.2. FIND POSITION AND GMT FROM LUNAR DISTANCE (LUNARS)

This section is new in V1.12 and is still under Beta test. Use with caution. As with many indirect uses in the previous section, lunars can be accomplished more easily with other dedicated software available in the public domain.

Lunars are a traditional method of finding GMT (and hence longitude) from the observed lunar distance (sextant measured angle) between the Moon’s illuminated limb and another body near to the plane of the moon’s path. It was used extensively in the 17th and 18th centuries before the invention of accurate chronometers. (Book and TV Series “Longitude” – the story of John Harrison.) The calculations were very complicated and many vessels are thought to have foundered due to calculation or method rather than observation errors.

The basic principle is that the Moon moves Eastward relative to the background of stars at a predictable rate. Effectively, the zodiacal stars (those near the Moon’s path) are the hour markings of a clock in the sky and the Moon is the hand of the clock. By measuring the angle between the Moon and a known star (in addition to the star’s altitude) the GMT and longitude of that observation can be calculated. The Moon orbits the Earth once every 27 days or so, which is only about one Moon diameter (30 minutes of arc) per hour. If you can measure the lunar distance to an accuracy of 0.5 minutes of arc you can deduce the time to an accuracy of one minute and hence longitude to within 15 miles. The Sun or a planet can be used instead of a zodiacal star as Astron compensates for their individual apparent motion against the fixed background of stars. The accuracy of the Moon/body distance measurement is paramount – drawing a graph of several sights and using best fit values is common practice. In the hands of expert navigators, lunars provided surprising accuracy. Lieutenant James Cook, on his first great voyage in 1770, charted the longitude of what he called “Cape North”, the most North Eastern point in New Zealand, as W186° 53’. To us that is E173° 07’, only 4 miles from Google Earth’s calculations. His longitude for the most Southerly point of New Zealand (“Cape South” on Stewart Island) was even more accurate.

Astron’s implementation attempts to integrate lunars with its normal sight reduction function, thereby hopefully avoiding duplication of entries. The entry form is at the bottom of the computer almanac page, so you will need to scroll down the page to see it.

**SIMPLE EXAMPLE.** Let’s start with a simple example, showing the method with some explanations. You are stranded on an island with the unlikely combination of a friend, cloudless skies, two sextants, a computer with Astron (but no internal clock!), a solar panel charger and an old tin clock that seems to work ok when wound up.

INITIAL PREPARATION.

* Set Astron in GMT input mode (see 16.1) and set Watch Correction to 0. Because of the iteration in stage 4, you must work in strict GMT.
* Enter Astron with your guess of GMT date (2017 Dec 25), latitude (S10° 00.0’) and longitude (E105° 00.0’). Choose the nearest multiple of 15 for your assumed longitude. Then you know that you are (in this case) 7 hours ahead of GMT and as it is about 10 o’clock local time, so enter 03:00:00 into Astron. (Entering +7 in the time zone field (or -7 if set to ZD) will give meaningful local sun rise/set times.)

STAGE 1. Find your latitude.

* You choose to determine your latitude using the Sun’s upper meridian passage method (Section 13).
* Measure the Sun’s lower limb maximum altitude (76° 56.8’) as your friend simultaneously sets your tin clock to 05:00:00.(Noon – 7 hours.) Don’t bother with allowing for the equation of time – such detail will come out in the wash.
* Select the Sun as body, enter 05:00:00 as GMT and the observed Sun’s maximum altitude of 76° 56.8’, together with the sextant altitude correction data of IC=0, HoE=2.4, T=25, P=1010 and limb=Lower.
* Astron’s Upper Meridian Passage side display shows your latitude (S10° 33.3’) which you enter in the Assumed Latitude fields. The displayed longitude is meaningless as the time is just a guess, so leave Assumed Longitude as E105° 00.0’. (If the Upper Meridian Passage display is not visible, try another assumed longitude or assumed time.)

PREPARATION FOR STAGES 2 and 3.

Soon you notice the Moon in the East, too low for an accurate sight as the recommended minimum altitude is 20°. Time to prepare for the next stage. You will need to take two sights simultaneously, so you are fortunate to have a friend and two sextants. (There are, of course, ways with a single observer and sextant, but we are trying to simplify things!) One sight will be the Sun’s altitude, the other the angle between the Moon’s illuminated limb and the Sun’s nearer limb to the Moon. The Moon’s illuminated limb is (always) the one nearer the Sun. As the Moon gains altitude, you do a few practice simultaneous sights and finally settle for the following values. Tin Clock Time 08:05:06, Sun (lower limb) Altitude 40° 49.6’, Sun (near limb) Lunar Distance 77° 36.1’.

STAGE 2. Synchronise assumed longitude with assumed time.

You now know your latitude (S10° 33.3’). If you now assume, for the time being, that your guess of GMT was correct, you can obtain a line of position from your Sun altitude measurement. Where this intersects your latitude would be your position. However, if your time guess had been (say) exactly one hour earlier, this same altitude would have given your position as 15 degrees further East. There is a relationship between longitude and time and this synchronisation needs to be established because your initial guesses of time and longitude were both arbitrary. So, proceed as follows:

* Set GMT to 08:05:06
* Set the Sextant Altitude (Hs) fields to 40° 49.6’
* Check latitude remains as S10° 33.3’, Longitude as E105° 00.0’
* For simplicity, all sextant altitude corrections are assumed unchanged from stage 1. (If not, change them!)
* Note Astron gives the Sun’s Azimuth as 247.6° and the Intercept as 187.5nm Away.
* You could plot this to find where the line of position intercepts your latitude. However, you can do this with Astron without any plotting. You are going to ‘adjust’ your assumed longitude to get an intercept of 0.0. (Section 17.9 explains the principle of ‘adjusting’). Below is a typical sequence for this situation.
* E110° 85.9T
* E108° 23.6A
* E109° 31.1T
* E108° 30.0’ 3.7T
* E108° 20.0’ 5.4A
* E108° 26.0’ 0.1T
* E108° 25.9’ 0.0 It looks time consuming, but only takes 20 secs!
* So, if your assumed GMT had been correct, you would have been at longitude E108° 25.9’. You have now synchronised your assumed longitude to your assumed time.

STAGE 3. Use the lunar sight to determine GMT and longitude.

As explained in the introduction, you can now use the measured lunar distance to calculate GMT and longitude.

* Scroll down the page to the section FIND POSITION AND GMT FROM LUNAR DISTANCE (LUNARS)
* Enter 77° 36.1’ in the Measured Lunar Distance fields.
* Enter ‘N’ (Near) in both limb fields.
* Observe the pre-set index correction display. This is to remind you that if this (or any other correction) is different from that in stage 2, you must change it accordingly in the main display.
* Write down the revised Date (no change), Time (08:14:37) and Longitude (E106° 03.2’).
* Observe the Difference value is 5.38’.

STAGE 4. Iteration.

As part of the process of the stage 3 calculations, Astron must adjust for lunar parallax and make some other lesser corrections. Lunar parallax itself varies significantly with longitude, so the above values are not your actual longitude and GMT. You need to change the longitude and GMT (and sometimes the date) in the main section to these values to get a more accurate result. You may need to do this more than once – repeat until the Difference falls to 0.10’. (Unlike spreadsheets, programs written in compiled languages such as C++ can easily do this stage for you!)

* Enter 08:14:37 in the GMT fields.
* Enter E106° 03.2’ in the longitude fields. (Iteration 1)
* Enter both values before revisiting the lunar section, lest you break the synchronisation established in stage 2.
* 08:15:54 105° 44.0’ 0.72’ (Iteration 2)
* 08:16:04 105° 41.5’ 0.10’ (Iteration 3)
* 08:16:05 105° 41.1’ 0.01’ These last two iterations are academic only.
* 08:16:05 105° 41.0 ‘ 0.00’ Accuracies better than 0.1’ of arc are a pipe dream.

So, at the instant of the ‘simultaneous’ lunar and altitude sights, the actual GMT was 08:16:05 and your position was S10° 33.3’ E105° 41.0’. Your tin clock read 08:05:06, so it was 10 minutes 59 seconds slow. (Have a quick look at <https://www.google.co.uk/maps/@-10.5326642,105.7323764,10.73z> to see where this position is.)

(The actual position was S10° 33.3’ E105° 39.7’ at 08:16:11 GMT. The very small calculation differences are due to rounding errors - inputs only being to the nearest 0.1’.)

**DEVELOPMENT OF THE METHOD.** We shall now discuss real world variations to the simplified example.

Single observer. To obtain the altitude of the sun (or other body) simultaneously with the lunar sight, you can take sights before and after the lunar sight, noting the tin clock times of both sights, then interpolate to the lunar sight time accordingly.

Latitude measurement. Measuring latitude by the upper meridian passage of the Sun is a good method and gives you a clue as to (local) time. The sun’s declination varies with time and, at an equinox, can be as much as 1’ per hour. However, this will only affect the result if your guess of GMT was substantially in error. Latitude can also be measured by the upper or lower meridian passage of any body (except the Moon), but only during twilight. Polaris sights create a problem as the corrections depend upon time and longitude, both of which are unknown. (The solution for a Polaris latitude is to rework all four stages starting with your newly found longitude and time.)

Ship’s run. The above example using an island eliminated the need to DR ahead from the time of your latitude sight (normally local midday) to the time of the lunar sight. However, this will normally be necessary. You can either plot it or use the ADVANCED LINE OF POSITION utility (Section 14). Only enter the advanced latitude into Astron as you are going to change the longitude in stage 2 regardless.

Choice of body for lunar distance measurement (Stage 3). Normally, the appearance of the lunar distance pop-up will indicate that the chosen body may be suitable for a lunar. Section 18.1 lists the conditions for this. For the lunar sight, suitable Sun/Moon positions only occur on about 9 days each lunar month. At other times, you must use a star or planet which normally restricts your observation times to twilight. Astron’s Sight Planner sheet may help with your choice. A lunar sight can be taken all night, but the need for a simultaneous altitude sight usually negates this. Some skilled observers can tell when an apparent moonlit horizon is genuine – if you are confident of this, use it.

Choice of body for simultaneous altitude measurement (Stage 2). Section 18.1 does not consider the suitability of the chosen body for the Stage 2 altitude measurement. The purpose of stage 2 is to synchronise your assumed longitude with your assumed time. To do this the body’s altitude must be below (say) 50° and the azimuth as near to 090° or 270° as possible, to obtain a line of position that intersects your latitude at a good angle. To achieve this, it is often preferable to use a different body rather than the body used for the lunar distance – just remember to select the correct bodies in Astron at each stage. Astron’s Sight Planner sheet may help with this too.

Selection of limbs. The illuminated limb of the Moon is always the one nearer the Sun, but it is not necessarily the one nearer the body you are using! For a Sun/Moon sight, it is usual to use the near limb (N/N) but Astron permits you to use the Sun’s far one (F/N). Stars have a zero semi-diameter correction so select either F or N. For planet/Moon sights, planets may have a discernible disc or crescent, especially if you are using the telescope eyepiece, so all four combinations are possible. (Jupiter can have a semi diameter up to 0.3’ – up to a 9 mile error in longitude if the centre of the planet is used instead of the correct limb.) Take great care identifying which limbs you are using – the crescent of Venus externally kissing the crescent of the Moon looks like a near/near sight, but could be a far/far one.

Note 1. Traditionally the observed lunar distance was ‘cleared’ to a geocentric lunar distance before interpolation with the almanac’s listed (three hourly) geocentric lunar distances. In Astron, the reverse (mathematically simpler) method is used – the geocentric distance for the subject time is calculated and then ‘un-cleared’ to give a theoretical observed lunar distance for the assumed location which is directly compared with the measured distance.

Note 2. The lunar display section will give an inaccurate position and time if an unsuitable body is selected, but you can nevertheless use the calculated observed lunar distance value for practice or sextant scale error checks.

## 19. DISCUSSION ON TIME ENTRY MODE.

In Astron, the default mode of time (and date) entry is in Ship’s Time, but optionally may be entered in GMT. We suggest that you choose one mode and stick with it rather than switching between modes.

a). We express no opinion on whether GMT or Ship’s Time entry mode is preferable – it is your choice. The default is Ship’s Time mode, but only because we had to settle for one or the other!

b). Astron always shows both GMT and Ship’s Time on the right side of the computer almanac screen. Having entered the date/time in your chosen mode, we recommend the habit of checking that the GMT date/time and the ship’s date/time agree with your intentions.

c). Regardless of which mode you are using, the Time Zone (or ZD) and Daylight Saving fields should always be entered.

## 20. RECENT REVISION HISTORY.

1.13 Times of Rise, Meridian Passage and Set for selected star now displayed.

User can now use Zone Descriptions if preferred to Time Zones.

Watch Correction field now always visible.

‘Twilight’ observation window times now user adjustable.

1.12 Sight Planner: Extra columns added for accuracy verification against US Naval Observatory data.

Lunar Distances calculator added. (Beta test only.)

Lunar distances now only pop-up in usable circumstances.

1.11 Lunar Distances pop-up added.

1.10 Sight Planner presentation improved.

Now compatible with recent Android tablets running Excel Mobile for Android.

Optional entry of watch correction added.

1.09 Date range changed. Now 1905AD to 2999AD.

1.09 Optional GMT date/time entry mode added as a User Configurable item.

1.09 Default date/time entry mode now in Ship’s Time.

1.08 Back sight mode now automatic if Hs + IC > 90 degrees.

1.08 Artificial Horizon mode added to settings.

1.08 Sight Planner added.

1.07 Advance line of position utility added. Contents page and acknowledgements paragraph added to user notes.

1.06 User configurable items improved and documented. Back sight indirect use added to notes.

1.06 Time zone input now permits decimal hours. (EG +5.5 for India)

1.05 Now compatible with recent iPad tablets running Excel Mobile for iPad.

1.05 Rigil Kent. inaccuracy note deleted.

1.05 Star position / proper motion data revised using data from SIMBAD4 Revision 1.5 24th March 2016.

## 21. ACKNOWLEDGEMENTS.

Astron was developed from many of the spreadsheets published on <http://www.navigation-spreadsheets.com/> with the permission of, and thanks to, the developer. Although much reformatted and hidden, those spreadsheets provide the ‘drivers’ for many of the results shown on the visible pages of Astron and remain the source of lunar and planetary motion data. The stellar data source is now SIMBAD4 Revision 1.5. The visible sheets, including unidentified body finder, LOP advance, choice of time and zone entry modes, Sun and star rise/set times, observation window times, Sight Planner, back sight mode, artificial horizon mode, upper meridian passage pop-up and lunars are original coding. The classic reference book “Astronomical Algorithms” by Jan Meeus has been used to cross check many of the formulae used. Delta T predictions to 2999AD are taken from NASA’s website <http://eclipse.gsfc.nasa.gov/SEhelp/deltatpoly2004.html>. The section on lunars was coded using the logic described in “Longitude by the Method of Lunar Distance” by Wendel Brunner, PhD, MD. <https://www.starpath.com/resources2/brunner-lunars.pdf> . Astron has also been cross checked against the examples in chapter 20 of the 2002 edition of The American Practical Navigator, against data from the US Naval Observatory and against other digital and tabular sources with results listed in Section 23, Accuracy and Tests.

## 22. MODIFYING ASTRON.

Many supplementary sheets are hidden for clarity. These are all for intermediate processes only. Also, some rows and columns on the visible sheets are also hidden. If you wish to view or indeed tinker with these, please read on. The following assumes that you are using a fully licenced version of Excel 2016. Earlier versions, mobile versions, on-line versions and alternatives may have different or reduced capabilities.

1. The first move is to make a copy of Astron, rename it and only tinker with that copy.

So, step 1 is *{File/SaveAs/AstronCopy.xlsx}*.

1. The whole workbook is protected. To unprotect the workbook: *{Review/UnProtect Workbook}*. No password is required.
2. To view a hidden sheet: *{Home/Format/Hide & Unhide/Unhide Sheet}*. Then select the sheet you wish to view. Each sheet must be unhidden individually, the author cannot find an Excel ‘unhide all’ facility.
3. All sheets are individually protected. To allow any changes, or indeed to see the underlying formulae, you must unprotect that sheet: *{Review/Unprotect Sheet}.* Again, no password is required.
4. Some rows and/or columns on the visible sheets are also hidden for clarity – these also contain only intermediate working data. You can identify such a row or column by the missing letters or numbers in the headers. To reveal a hidden row, select the two adjacent cells in the header row (or column), right click and press unhide. (When unhidden, hidden rows/columns have a “H” in the left/top cell – so you know which to hide to return to the normal (hopefully uncluttered) display.)

If you do delve around, you will see how large Astron really is. (17 sheets, 13 of them hidden.) All code is standard Excel coding, deliberately avoiding macros. There is much use of Styles, Defined Names, Cell formatting, Conditional Formatting, Data Validation and Hiding of sheets, rows and columns containing only intermediate calculations. Comments were written for the benefit of the author and any successor, not with an audience in mind! Good luck with it – and please, don’t change the original, work on a renamed copy!

## 23. ACCURACY AND TESTS.

**Introduction.** General body position calculation accuracy for the present era (and corrections for parallax and semi diameter) has nearly always been found to be within 0.2’ of the positions extracted from a nautical almanac. Similarly, sight reduction accuracy has nearly always been found to be within 0.2nm of the results when using sight reduction tables with the same inputs. (Lesser accuracies for Polaris, low altitude sights, sunrise, sunset and am/pm observation windows are discussed in context above.) Details of some tests where Astron has been validated against other software and tabular methods are given below. This includes (23.6) a sample of calculated altitudes and azimuths of above horizon bodies at a quoted instant and location, compared with the US Naval Observatory data for the same instant and location. These are usually identical and the author has yet to find a disagreement greater than 0.1’. Indeed, the fact that more than 90% are identical infers, bearing in mind that both data sources are rounded to 0.1’, that both sources usually agree to within 0.02’. In general, observation inaccuracies (and meteorological anomaly effects for low altitude sights) are far greater than Astron’s calculation inaccuracies.

**23.1. Test Astron’s Almanac calculations against other references.**

X-Check GHA and Dec values for 1994.06.16. UT 08.15.23

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Astron Version 1.07** | | **Nathaniel Bowditch**  **American Practical Navigator** | |  | |
| Sun | 303° 42.1' | N23° 20.6' | 303 42.1 | N 23 20.5 |  |  |
|  |  |  | **Henning Umland** | |  | |
|  |  |  | **www.celnav.de** | | **StarPilot PC** | |
| Sun | 303° 42.1' | N23° 20.6' | 303° 42.1' | N23° 20.6' | 303° 42.1' | N23° 20.6' |
| Moon | 220° 27.7' | N00° 07.6' | 220° 27.7' | N00° 07.6' | 220° 27.6' | N00° 07.5' |
| Mercury | 289° 42.3' | N21° 15.7' | ~~~~~~~ | ~~~~~~ | 289° 42.6' | N21° 15.8' |
| Venus | 264° 18.5' | N21° 48.7' | 264° 18.5' | N21° 48.7' | 264° 18.3' | N21° 48.7' |
| Mars | 343° 10.7' | N16° 26.1' | 343° 10.7' | N16° 26.1' | 343° 10.3' | N16° 26.1' |
| Jupiter | 174° 56.1' | S12° 02.8' | 174° 56.1' | S12° 02.8' | 174° 55.8' | S12° 02.8' |
| Saturn | 043° 48.5' | S08° 31.8' | 043° 48.5' | S08° 31.85' | 043° 48.1' | S08° 31.8' |
| Acamar | 343° 42.7' | S40° 19.5' | 343° 42.6' | S40° 19.5' | 343° 42.5' | S40° 19.5' |
| Sirius | 286° 59.8' | S16° 42.6' | 286° 59.8' | S16° 42.6' | 286° 59.7' | S16° 42.6' |
| Polaris | 351° 52.6' | N89° 14.1' | 351° 52.6' | N89 14.1 | 351° 52.4' | N89° 14.1' |
| Aries | 028° 13.2' | ~~~~~~~~ | 028° 13.2' | ~~~~~~~~ | 028° 13.1' | ~~~~~~~ |

**23.2. Test Astron’s almanac and sight reduction.**

Compare with Bowditch P303 for a low altitude hot temp low pressure example.

X-Check values for 1994.06.16. UT 08.15.23 Lat 30N Long 44 42.1W

Sun Upper Limb.

Hs 03 20.2, IE 0 , HoE 5.5, T 31C, hPa 982.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Astron V1.01** | **Bowditch** | **Umland** | **StarPilot** |
| GHA | 303° 42.1’ | 303° 42.1’ | 303° 42.1’ | 303° 42.1' |
| Dec | N23° 20.6’ | N23° 20.5’ | N23° 20.55’ | N23° 20.6' |
| Hc | 02° 39.6’ | 02° 39.6’ | 02° 39.5’ |  |
| Zn | 064.5° | 064. 7° | 064.45° | 064.5° |
| Ho | 02° 48.2’ | 02° 48.1’ | 02° 48.2’ |  |
| Int | 8.6T | 8.5T | 8.6T | 8.7T |

**23.3. Check of Greenwich Apparent Sidereal Time calculations.**

Astronomical algorithms by Jan Meeus P84 line 10

Example in http://www2.arnes.si/~gljsentvid10/sidereal.htm above, about 4/5 way through.

1994.06.16. UT 18.00.00

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Meeus** | **Astron** | **Umland** | **ICE (The Gospel)** |
|  | **Example** | **V1.01** |  |  |
| GAST degrees | 174.774570 | 174.774573 | 174.774583 | 174.774573 |
| Difference from ICE (Deg) | -0.000002 | 0.000000 | 0.000011 | 0.000000 |
| ditto (mins of arc) | -0.00012 | 0 | 0.00066 | 0 |

**23.4. Compare against tabular methods for Moon, Sun, a planet and a star.**

2016 Almanac from <https://www.thenauticalalmanac.com>

Sight Reduction Tables from <https://www.celestaire.com/pubs/category/2-pub-229.html>

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Body | Limb | Date | GMT | Hs | IC | Ass Lat | Ass Long | °C | hPa | HoE(m) |
| **Moon** | L | 2016:11:12 | 19:53:56 | 22 27.7 | 0.7 | N20° 00.0’ | W033° 30.6’ | 20 | 1034 | 6 |
| **Astron 1.07** | Azimuth | Intercept | **Tabular** | Azimuth | Intercept |  |  |  |  |  |
|  | 091.2° | 40.7T |  | 91.2° | 40.9T |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Body | Limb | Date | GMT | Hs | IC | Ass Lat | Ass Long | °C | hPa | HoE(m) |
| **Sun** | U | 2016:11:12 | 20:17:19 | 40 54.2 | 0.6 | S30° 00.0’ | E179° 43.9’ | 20 | 1010 | 2.4 |
| **Astron 1.07** | Azimuth | Intercept | **Tabular** | Azimuth | Intercept |  |  |  |  |  |
|  | 088.0° | 49.6A |  | 088.1° | 49.8A |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Body | Limb | Date | GMT | Hs | IC | Ass Lat | Ass Long | °C | hPa | HoE(m) |
| **Venus** | C | 2016:11:12 | 19:43:19 | 24 33.7 | 0.6 | N20° 00.0’ | E028° 22.6’ | 20 | 980 | 2.4 |
| **Astron 1.07** | Azimuth | Intercept | **Tabular** | Azimuth | Intercept |  |  |  |  |  |
|  | 228.2° | 23.0T |  | 228.2° | 23.2T |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Body | Limb | Date | GMT | Hs | IC | Ass Lat | Ass Long | °C | hPa | HoE(m) |
| **Acrux** | C | 2016:11:12 | 16:43:58 | 2 02.2 | 0.3 | N15° 00.0’ | W170° 21.0’ | 10 | 1010 | 2.4 |
| **Astron 1.07** | Azimuth | Intercept | **Tabular** | Azimuth | Intercept |  |  |  |  |  |
|  | 158.6° | 15.2T |  | 158.5° | 15.2T |  |  |  |  |  |

**3.5. General cross check for any place and time against US Naval Observatory data.**

Website <http://aa.usno.navy.mil/data/docs/celnavtable.php> displays computed altitudes and azimuths for all listed above horizon bodies for an entered latitude, longitude, date and time. A check using GMT/UT 2016 Jan 1 00:00:00 ALat S29° 00.0’ ALong E168° 00.0’ shows Astron (V1.10) giving identical results to the USNO data for all listed bodies and, as stated in the introduction, for the present era we have yet to find a difference of more than 0.1’. The first 8 are reproduced below.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **~~~~~Azimuth~~~~~** | | | **~~Observed Altitude~~** | | |
| **Body** | **Astron** | **USNO** | **Diff.** | **Astron** | **USNO** | **Diff.** |
| Sun | 65.5 | 65.5 | 0 | 077° 05.5' | 077 05.5 | 0 |
| Venus | 286.1 | 286.1 | 0 | 062° 41.9' | 062 41.9 | 0 |
| Mars | 275.7 | 275.7 | 0 | 029° 53.8' | 029 53.8 | 0 |
| Saturn | 293.1 | 293.1 | 0 | 071° 23.4' | 071 23.4 | 0 |
| ACHERNAR | 150.3 | 150.3 | 0 | 011° 17.6' | 011 17.6 | 0 |
| ACRUX | 210.8 | 210.8 | 0 | 029° 32.1' | 029 32.1 | 0 |
| Al Na'ir | 128.8 | 128.8 | 0 | 037° 52.7' | 037 52.7 | 0 |
| Alphecca | 326.2 | 326.2 | 0 | 025° 22.3' | 025 22.3 | 0 |

If you wish to do your own testing, you can use the more detailed values of Azimuth and Altitude that are repeated if you scroll right on the Sight Planner sheet. Using GMT mode, insert same date, time and assumed position into Astron and the above site and compare results. Only above horizon bodies are shown and these may be in daylight and not visible. USNO bodies are in alphabetical order - Astron in Zn order. So it is easier to compare from Astron to USNO rather than the other way around.

Astron’s altitude corrections can also be cross checked against the USNO altitude corrections and these similarly always seem to agree within 0.1’. If you wish to do this, set IC to 0, HoE to 0, Temp to 10°C, Press to 1010 hPa and limb to ‘L’ (Sun/Moon) else ‘C’. Then adjust Hs to make Ho the same value as Hc. Because of rounding of individual corrections, just compare Astron’s total correction (Ho-Hs) with the USNO’s ‘sum’ field.

**23.6 Lunars cross check against example in** <https://www.starpath.com/resources2/brunner-lunars.pdf>

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | OLD  (Page 10) | ACT LONG | DEDUCED LONG | DIFF | ACT GMT | DEDUCED  GMT | DIFF |
| Brunner | 51° 51.4’ | W122° 23.9’ | 122° 28.9’ | 5.0’ | 23:24:00 | 23:24:08 | 8s |
| Astron 1.12 | 51° 51.6’ | W122° 23.9’ | 122° 23.4’ | 0.5’ | 23:24:00 | 23:23:58 | 2s |

**23.7. Test of times of Star Rise, Meridian Passage and Set.**

These times are normally only listed to the nearest minute, but for reasons given in 17.10 Astron quotes times to one second, with a believed (calculation) accuracy of 5 seconds (except for near circumpolar situations). We cannot find a separate source to make accurate comparisons. The USNO Celestial Navigation Data omits bodies with an Ho below +1°, so we have compared times when the star is just above 1°.

A: 2016 Mar 03 Sirius 30N 179 59.9E TZ+12. DS +1 HoE 3m T 10C P 1010hPa.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SIRIUS after RISE15:45:33 (02:45:33 UTC) | | | | |
|  | Hc | Hs | Corr | Ho |
| USNO | 1 00.1 | 1 21.8 | 21.7 | 1 00.1 |
| Astron | 1 00.1 | 1 21.9 | 21.8 | 1 00.1 |

|  |  |  |
| --- | --- | --- |
| **SIRIUS on 03 Mar Ship's Time** | | |
| **Rise** | **Mer Passage** | **Set** |
| **15:37:33** | **20:59:46** | **02:25:55** |
|  |  |  |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| SIRIUS before set. 02 17:33 (13:17:33 UTC D-1). | | | | |
|  | Hc | Hs | Corr | Ho |
| USNO | 1 04.4 | 1 25.7 | 21.3 | 1 04.4 |
| Astron | 1 04.4 | 1 25.7 | 21.3 | 1 04.4 |

|  |  |  |  |
| --- | --- | --- | --- |
| SIRIUS 20:59:46 (07:59:46 UTC) Mer Passage | | | |
|  | GHA | Hc | Zn |
| USNO | 180 00.2 | 43 15.3 | 180.0 |
| Astron | 180 00.2 | 43 15.3 | 180.0 |

* 1 sec earlier GHA 179 59.8

B: Try other side of 180 meridian. Change to 179 59.9**W -12 DS +1** (same ship’s time date of 3 March.)

|  |  |  |
| --- | --- | --- |
| SIRIUS on 03 Mar Ship's Time | | |
| Rise | Mer Passage | Set |
| 15:33:36 | 20:55:49 | 02:21:58 |

These are all 3m 57’ earlier, correctly so because this observer is seeing the events of 24 hours later.

C: Now try for Tivalu, or rather an imaginary place at 179 59.9W, but with time zone of +14 (yes, plus 14) (DS 0)

|  |  |  |
| --- | --- | --- |
| SIRIUS on 03 Mar Ship's Time | | |
| Rise | Mer Passage | Set |
| 16:37:32 | 21:59:45 | 03:25:54 |

These are same as A above, but exactly one hour later as one would expect. (GMT + 14 i/o GMT + 13.)

D. Now 02 Feb to test display of a double same day event.

|  |  |  |
| --- | --- | --- |
| SIRIUS on 02 Feb Ship's Time | | |
| Rise | Mer Passage | Set |
| 18:35:29 | 00:01:38 | 05:23:52 |
|  | 23:57:43 |  |