# ASTRON USER NOTES

# (V1.05 – revision history is listed at the end of these notes)

## INTRODUCTION

Astron (Aστρον – Greek for Star) is an Excel spreadsheet for sextant users. Its objective is to combine almanac calculations, apparent body position calculations and sight reduction into an easy to use single sheet utility.

* 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 moon rise and set times, moon phase, body magnitudes and twilight times. Although intended for practical use in the present era, dates between 2000BC and 3000AD may be entered. (Dates entered before 1752AD are assumed to be on the Julian calendar.)
* 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 error, height of eye, temperature, pressure and observed limb, Astron will also calculate the Azimuth and Intercept from the assumed position.

Astron was written using Excel 2016. It has backward compatibility to at least Excel 2010. It has not yet been tested on Open Office Calc, nor on operating systems other than Windows 8/10. It is a large spreadsheet and, on account of the many calculations, will probably run very slowly on older machines. In fact, it was the predominance of Greek characters in the many formulae used that inspired the name Astron.

## GENERAL NOTES

1. Ensure that ALL input fields are correct before using result. Other fields cannot be changed. Fields coloured  are intermediate calculations for information only, whilst results are coloured 

2. There are two working sheets, selected by the tabs on the bottom left of the sheet.

A. The COMPUTER ALMANAC that handles both the process of calculating the geographic position of the body at the instant of observation and the subsequent sight reduction.

B. The MANUAL ALMANAC that asks you to enter the body’s geographic position from elsewhere (typically from a printed almanac) and then calculates the apparent position and performs the sight reduction.

C: A third sheet, for reference purposes only, gives permanent star data sorted in various orders.

3. Remember to save when exiting Astron so that the last entered data will be recalled on next use.

4. General body position calculation accuracy, including corrections for parallax and semi diameter has usually been found to be within 0.2 minutes / 0.2nm when compared with nautical almanac positions. Low altitude sights, sunrise, sunset and twilight accuracies are noted below.

5. There are several other sheets for intermediate processes. These are all protected and hidden, but can be revealed individually by the curious. {Home/Review/Unprotect workbook/Home/Format/Hide & Unhide}. A password is not required to unprotect sheets nor workbook. If you wish to view or change any hidden data, it is suggested that you make a copy of Astron, rename it and ONLY delve around with your copy. Some parts of the visible sheets are also hidden for clarity – these also contain only intermediate working data.

## CALCULATION NOTES

**Cell Rounding:** If answer is (say) 12° 59.96', Excel will (alas) round this to 12° 60.0'. Interpret this as 13° 00.0'. If anyone has a fix for this, (without recourse to undesirable macros), please speak up!

**Division by zero:** Rare cases may occur (usually involving interim values of exactly 0 or 90 degrees) which give a #NUM! error. Work around by changing input by 0.1 minutes.

**Numbers:** These are displayed rounded to 0 or 1 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')

## NOTES when using the COMPUTER ALMANAC

**Enter Time and Date**: Always enter GMT time and date. See paragraph “Time Zones” below. (Strictly speaking, the term Universal Time (UT) should be used, but the difference is always less than one second and GMT is so well established that it is used throughout this workbook.)

**Select Body:** Click on the current 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.) Alternatively, just enter in the (correctly spelled) name of the body.

**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 meridian passage will be that time interval before 12:00 local mean time. (LMT = GMT + Longitude (in degrees) / 15). Vice versa for a -ve sign.
2. The times of sunrise and sunset at the assumed position are displayed. These are ship’s times. 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, so much so that at a pole, a refraction anomaly of just 10’ can result, at an equinox, in an error of ten hours!

**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. A “+ve” sign indicates that the moon is waxing, a “-ve” sign indicates waning.

**Additional Star and Planet Features:** If any star or planet is selected, additionally…

1. The magnitude of the body is displayed.
2. The ship’s times of the beginning and end of morning and evening twilight at the assumed position are displayed. Of course, the time zone and daylight saving fields must have been correctly entered. In that hemisphere’s winter in high latitudes, there may be no twilight as the sun may remain below -6 and/or -12 degrees all that day. Conversely, in summer, there may be no twilight at all as the sun is above -6 and/or -12 degrees all day. In both cases, “None” is displayed. These times use an abbreviated formula and times are believed accurate to within 5 minutes in latitudes below 66 degrees. Twilight in this context is the time when the centre of the true sun is between 6 and 12 degrees below the horizon. This is the typical time when it is dark enough for star and planet sights to be taken whilst the horizon is also visible.

**Planets:** Computer Almanac calculates semi diameter for planets – normally use "C" and observe centre of planet. However, Venus’ phase aspect (like the moon) is rarely vertical and the apparent centre is not necessarily the true centre.

**Polaris:** Treat as any other star and plot intercept. GHA may be up to 1.5' in error due meridian convergence near the pole. Azimuth and intercept calculation accuracy remains <0.2'/0.2nm unless Ass Lat is North of 75N. Note that 1 second error in time (hardly avoidable) equals 0.25nm in position. Observation inaccuracies are greater than calculation inaccuracies,

## NOTES when using the MANUAL ALMANAC

**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 SHA fields.

**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 centre of any discernible shape.

## SIGHT REDUCTION NOTES (both worksheets)

**Index Correction:** An off scale reading is deemed positive. (H1 = Hs + IC). Do not confuse with oft used Index Error (IE) which is of opposite sign. (Changed from IE to IC in V1.01)

**Corrections for refraction.** Beware of results when Hs is less than 5° due to natural variations from the normal for the input temperature and pressure. Exactly on the horizon, these variations can be up to 20', equivalent to up to 20 nm error in position line, though usually less away from land influence. (In mirage conditions, much larger variations may occur.)

**Correction for parallax:** This also includes a further latitude correction to HP to allow for oblateness. (Reducing earth radius as latitude increases. For the moon, this is 0' at the equator, decreasing to -0.2' at the poles. The latitude correction to HP is negligible for other bodies)

**Correction for semi diameter:** In addition to SD correction, for a moon sight only, a further correction for augmentation is included. This is 0' on the horizon increasing to + 0.26' at the zenith.

**Artificial horizon:** If bottom of double reflected image touches top of image seen in mirror or liquid, this is a LOWER limb sight. Either way, add index correction, then half result to get Hs. Set IC and HoE to 0.

## UNIDENTIFIED BODY (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 (EG Castor and Becrux) will not be found.

## CONVERSIONS

This software uses metres, °C and hPa for height of eye, temperature and pressure respectively. If you normally work in feet, °F or Inches of Mercury, use the converter at lower right of the screen.

## TIME ZONES (On Computer Almanac sheet only)

A section on the right of the Computer Almanac sheet allows you to enter the Time Zone offset that you are using (+E/-W) and a Daylight Saving hour if applicable. It calculates ship’s time from the GMT that you have entered. The prime purpose is to allow you to cross check that the correct GMT has been entered. Note that Time Zones not only affect the hour, they can also affect the day, the month and possibly even the year. Time Zones are positive East of Greenwich. For simplicity, only whole hours are accepted – sorry India, Marquesas Islands and parts of Australia! Be aware that high seas sailors often use Zone Descriptions (ZD) which are strictly longitude dependant and of opposite sign. Times of sunrise, sunset and twilight on the computer almanac sheet are given in ship’s time.

As an example, if you were at 40S 170E soon after departing from New Zealand in their summer, your ship’s clock would probably be set to New Zealand time. (GMT+12 + 1 hour daylight saving time.) So 12:00 GMT would be 01:00 ship’s time the following morning. Note that, at that same moment (GMT 12:00), the true local mean time (LMT) would be 12:00 + 170/15 = 23:20. (A chronometer used for astro work should not be adjusted for time zones or any other reason.)

**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 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, a direct calculation of latitude (and approximate longitude) from such a sight has been added to Astron in version 1.04. This 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. It therefore shows a ‘pop-up’ display entitled “Upper Meridian Passage Sight?” and, below it, the observer’s latitude and longitude assuming that the Hs was the maximum altitude and that 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 accuracy of the assumed latitude is not important, but it 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. With this proviso, the latitude is calculated from the body declination (which, except for stars, is itself time dependent) and the observed maximum altitude.
* Longitude calculation. The accuracy of the assumed longitude is not important – within 20 degrees is ok - but the accuracy of the time of maximum altitude is critical to this calculation of longitude. However, the observation time is unlikely to be accurate as the exact time of maximum altitude is difficult to observe, especially so when the body is within 20 degrees of overhead.
* If the GMT of maximum altitude is more accurately determined by the median time of bracketed observations of equal altitude, then the calculated 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 bracketed observations. The author suggests that, with Astron, if you need longitude as well, it is easier just to take two or more observations at opportune times (over at least six hours) and plot a transferred position line fix.

## INDIRECT USES (please see separate note at end of this section)

**1. Calculate time of rise or set of any body at any location.**

* Input Year, Month, Day, approximate GMT, chosen body, Location Lat & Long, Hs=0, IC = 0, Act HoE, Temp, Press & Limb (☉ ☾).
* Then adjust Hour, Minute and eventually Second to give an intercept value of 0.0nm. This is GMT. Ship’s time (and date) is also given, provided time zone and daylight saving time are correctly entered. (Do not adjust to give a Hc of 0.0 – it must be the intercept of 0.0 to allow for refraction, etc.)
* If azimuth <180, this is body rising time. Otherwise, it is setting time.
* Calculation accuracy using this method is believed to be within 5 seconds in latitudes below 66 degrees. However, because of natural variations in refraction at very low observed altitudes, do not expect accuracies of less than 1 minute. This method is more accurate than the rise/set/twilight times that are automatically calculated on this sheet which use an abbreviated method.
* If more accurate twilight times are sought, use this method but first set Hs to give an Ho of -6.0/-12.0/-18.0 degrees for civil, nautical or astronomical twilight as appropriate.

**2. Compass check. (Traditionally at sunrise or sunset)**

* Record pelorus bearing of event. Input body, exact time, Act Lat & Long, Hs=0, IC = 0, Act HoE, Act Temp, Act Press, Limb = "U" (☉ ☾ only). (Intercept should be near to zero,)
* Compare 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.

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

* Enter Hs, GMT, Ass Lat/Lng and other parameters as for a normal sight.
* 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 GMT of minimum altitude is more accurately determined by the median time of bracketed 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 bracketed observations. The author suggests that, with Astron, if you need longitude as well, it is easier just to take two or more observations at opportune times (over a six-hour period) and plot a transferred position line fix.
* 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.

**4. Sextant damaged or overboard!**

* Observe rise or set of any body to obtain a position line. Input body, exact GMT of rise or set, Ass Lat & Long, Hs=0, IC = 0, Act HoE, Act Temp, Act Press, Limb = "U" (☉ ☾ only).
* Plot position line from Azimuth/Intercept result. Repeat with other bodies, transferring position lines for ship's movement.
* Choose bodies with maximum possible difference in declination.
* 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 note 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 chronometer and sextant, using the sun upper meridian passage / latitude sailing method. Alas, he did not change the sign of the sun’s declination after the equinox.)

**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%)

**Notes to above indirect uses.**

1. These are indirect ways of using Astron for purposes other than its design objective. All 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.
2. Some of the uses refer to ‘adjusting’ an entry. This is best done by ‘guessing and halving’ as the following example shows. Changes on each iteration are shown in RED. The example below is to find the GMT of the rise of the planet Mercury on 1st January 2016 at a position 6 miles North West of Norfolk Island. (S 29 00.0 E168 00.0) The answer is 19:21:20 GMT on 1st Jan 2016. (Setting Time Zone to +11 gives a ship’s time of 06:21:20 on 2nd January – a useful reminder that you may have chosen the wrong start date!) As it is mid- summer, the sun will have risen at 04:53 and, alas, after all your efforts, the rise of Mercury was not visible!

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **INITIAL SETTINGS** | |  |  |  |  |  |  |  |
| BODY | ALAT | ALNG | Hs | IC | HoE | T | P | Limb |
| MERCURY | S 29 00.0 | E 168 00.0 | 0 | 0 | 5.5 | 28 | 1025 | C |
|  |  |  |  |  |  |  |  |  |
| **YEAR** | **MONTH** | **DAY** | **HOUR** | **MIN** | **SEC** | **AZIMUTH** | **INTERCEPT** | **COMMENT** |
| 2016 | 1 | 1 | 0 | 0 | 0 | 083.0 | 3561.2 A | Initial time guess. Long way off. Add 12 hours. |
|  |  |  | 12 |  |  | 209.5 | 2017.0 T | Still long way off. Add 6 hours. |
|  |  |  | 18 |  |  | 125.6 | 925.9 T | Now 900 off. At least 1 hour. |
|  |  |  | 19 |  |  | 117.0 | 252.5 T | Now 200 off. Try 30 minutes. |
|  |  |  | 19 | 30 |  | 113.2 | 104.1 A | Too far. Try 15 mins. |
|  |  |  |  | 15 |  | 115.1 | 75.5 T | Not enough. Try 22 mins. |
|  |  |  |  | 22 |  | 114.2 | 8.0 A | Getting closer. Just a little too far. Try 21 mins. |
|  |  |  |  | 21 |  | 114.3 | 4.0 T | 21 mins not enough, 22 too many. Try 30 seconds. |
|  |  |  |  | 21 | 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. |

PS. “Why Norfolk Island?” Read “Alone over the Tasman Sea” by Sir Francis Chichester. A wonderful example of navigation to find this remote tiny island in 1931 in a Gipsy Moth biplane fitted with floats, using only a sextant and with no fuel to go anywhere else and no autopilot. He practiced taking sun sights whilst riding a bicycle along a coast road!

**Revision history.**

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.

1.04 Upper Meridian passage ‘pop-up’ feature added.

1.03 Times of twilight added when sun is not the selected body.

1.02 Times of sunrise, sunset and equation of time added when sun is selected body.

1.01 Index correction now used i/o index error. (User request)

1.01 Time zone and daylight saving fields highlit as input fields.

1.00 Initial release version. All sheets with no user input now hidden, also certain intermediate calculation parts of user sheets hidden. Workbook and worksheets protected (without password).