Lunar Sights

Objectives : How to input and interpret Lunar Distance, “Lunars”

Topics:

- Lunars Objective - To Tell Time at Greenwich Meridian (now UTC)
- Historic Background
- Accuracy Achieved
- Relevance Today
- Process Steps
- How to Input Lunar Sights into Celestial Navigation, an example
- Backyard Lunars
- What comes after Lunars tells Time at Greenwich Meridian
- Which Celestial Bodies paired with Moon make great Lunars sights.
- Tips to improve your Lunar accuracy
- Theory and Logic
- How to Analyze Lunar Sights using Celestial Navigation’s Calculate form

Lunar Distancing Background

- Objective of Lunars was to determine Time at a Baseline Meridian, Greenwich. The baseline time is now UTC.
- Navigators (and before that, Greeks and Babylonians) theorized the Moon could be used as a giant clock in the sky. The theory was that anyone on Earth could tell the same event baseline meridian time by measuring the Moon's "distance" to another celestial body. The "distance", an angle called, Lunar Distance. And then determine Longitude using local apparent time.
- 16th century mathematicians and astronomers advanced Spherical Triangles (aka Navigator's triangle) to the point where the math could be used to tell time by measuring the distance of the Moon to the Sun, planets, and stars.
- It takes the moon 27.32166 days to complete a full orbit around the earth respect to the background stars (Moon Sidereal month). Thus the Moon moves Eastward relative to the background celestial bodies at almost 13.2° per day which translates to 0.2 arc-min per ~22 seconds or 0.1 arc-min per roughly ~11 seconds.
- You need a high quality sextant! If the navigator could measure 0.1 arc-min, then time accuracy would be no better than 11 seconds Since 4 seconds in time is 1 nm at the equator, 11 seconds in time is approximately ~3 nm. That's the limit for Lunar distance accuracy with a Maritime Sextant.
- The maritime sextant was designed to meet the need to measure Lunar Distance. Double reflecting sextants to measure 120° angles or more. Higher magnification to determine more precisely when the celestial body touches the Moon (today 7x are common). Shades over the Horizon mirror for Sun-Moon distances. Eventually vernier next to micrometer drum to more precisely distinguish 0.1 - 0.2 min. of arc.
- Meanwhile, Mathematician, Astronomers worked on the position of the celestial bodies problem. Isaac Newton theory of gravity was crucial to initially calculating the Moon and other celestial body positions. But, it took more time to figure out sufficient accuracy. In 1752-1762, Johann Tobias Mayer calculated Lunar Distance tables (and altitude corrections) and was a Longitude prize winner. In 1767, Nevil Maskelyne included lunar distance tables in the first Nautical Almanac.

Lunar Distancing Background (continued)

- Then, John Harrison's H1 Chronometer was demonstrated 1736. And then successfully tested on a voyage to Jamaica in 1761. He won the largest share of the Longitude prize. An accurate Chronometer would be set for Greenwich Time which then was used to determine Longitude.
- In 1802, Nathaniel Bowditch's American Practical Navigator contained Lunar Distance Tables and simplified procedures to clear the Lunar Distances. This made the method more accessible to everyday navigators. He was an advocate for both Chronometer and Lunars. Don't rely on one method!
- And the traditional practice was to make note in the Log the Lunar's derived time and then use judgement to determine Chronometer error rate (Fast or Slow). The common practice even today is that no one directly changes the Chronometer Time.
- You'd think that shortly after 1761, Lunar Distancing method would die-off. But, chronometers weren't widely available because an entire industry needed to be created to mass produce affordable chronometers.
- Captain Cook's first Pacific voyage (1768 - 1771) didn't have a chronometer and he charted much of the Pacific aided by Lunar Distancing as one of his tools. Captain Bligh (1789) used Lunar Distancing. Navigators on multi-year voyages would use Lunars to double check their chronometer if they had one.
- Lewis and Clark had a chronometer, sextant, artificial horizon equipment when they surveyed the Louisiana purchase (1804-6). John C. Fremont on his first expedition to California (1842) took a high quality sextant. They must have used a sextant for position and possibly used it for Lunars on land.
- Up to the 1850s, many ships lacked Chronometers. Too few, too expensive. Chronometer improvements were made; adoption was slow, but inevitable. Eventually Lunars fell out of use. Bowditch Practical American Navigator reduced emphasis on Lunars in 1882, tables dropped 1912. Nautical Almanac last published Lunar tables in 1907.

After Lunar Distancing, what's next?

- After computing Time (Greenwich Time,…GMT….UTC), calculate Longitude. Calculate Latitude using a Meridian Transit. Evaluate chronometer's error rate (number of min-sec fast or slow) for future sights.

How accurate was it in the 1700s?

- The Longitude Prize was awarded if you could demonstrate a solution better than .5° longitude accuracy. Harrison was the big winner. And Tobias Mayer won some prize money for his work on Lunars. The .5° was not the estimated accuracy, it was a threshold or goal for the award. If there is statistical analysis that identified accuracy, that would be beneficial.
- Ship Logs indicate that it was trusted.
- For over 100 years after Chronometers were introduced, Navigators found it to be a valuable tool.

How accurate is it Today?

- With a good quality sextant, well adjusted, and used with skill, the goal for your Lunar Distance Observation should be consistently +/- 0.2' accuracy. The limitation is your skill given the vessel you are on, or on land.

Is Lunars relevant today?

- Lunar gives the Celestial Navigator the opportunity to practice using their Sextant. The more practice the better you become. Not only for Lunars, but for all sights. Practice makes perfect. Lunars can be done anywhere. At home in your backyard, near the water, on the water. You can do it during twilight, during the day, in the middle of night. Do it any time the Moon is visible, day or night. And of course, off shore. The Celestial Navigation Plugin was designed to support practicing Lunar sights, UTC determination. Including "in the backyard".
- Do you want to verify your Sextant's arc error? or Calibrate it? Lunar Sights can help.
- OpenCPN's Celestial Navigation's plugin for Lunars is quick and easy. Input the sight and get immediate results. Change data and instantly see the TIME results change.

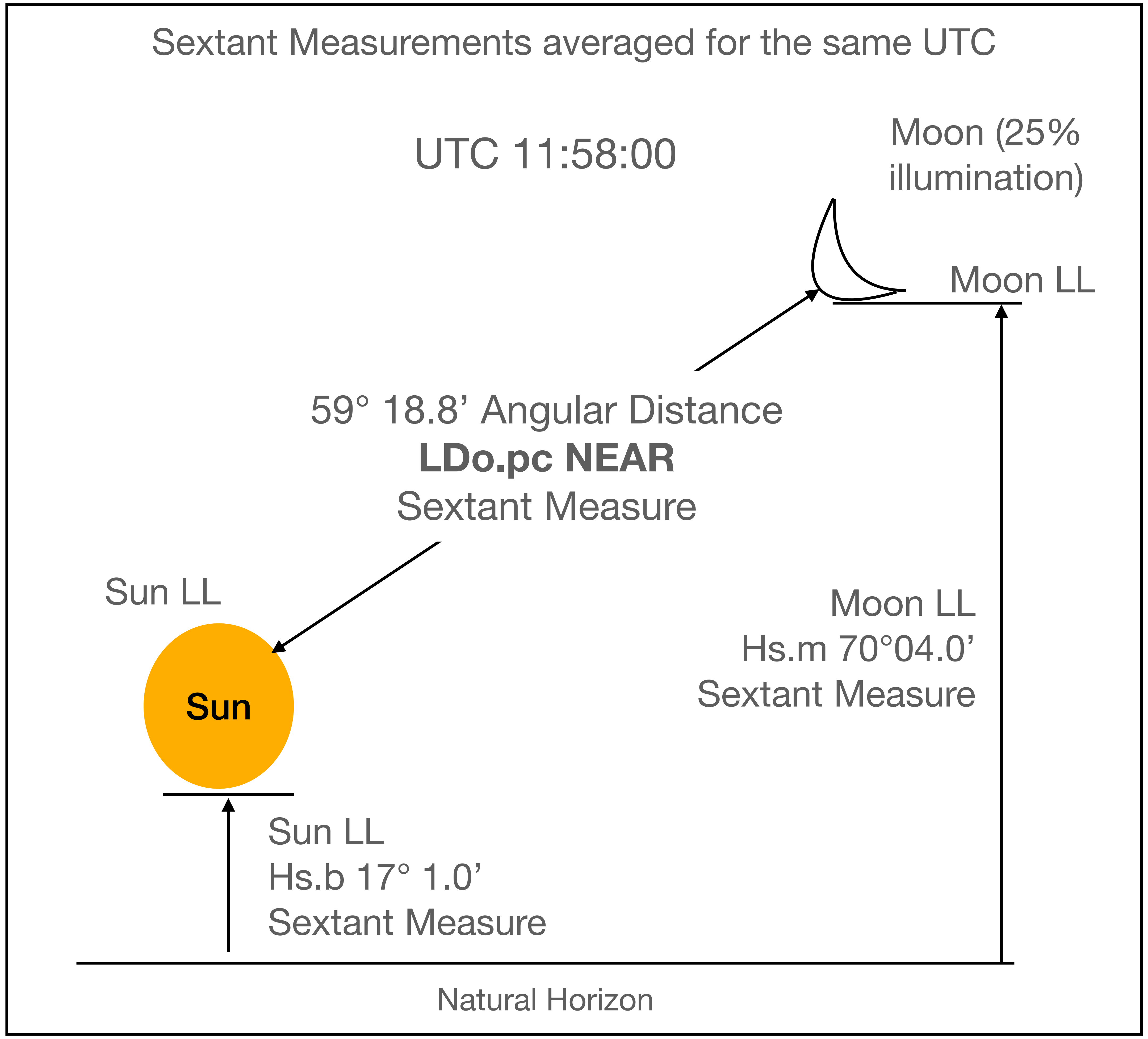
What are the Process steps to do Lunars on board Ship?

1. Measure an Altitude Sight of the Moon. One Sight.
2. Measure the Altitude Sight of the Celestial Body. One Sight.
3. Measure the Lunar Distance Angle of the Moon to your selected Celestial Body. Four Sights.
4. Hold the Sextant at an angle. The horizon mirror point to one object, and index mirror pointed to the other. Make sure the mirror that points to the sun has shades on to protect your eyes. Measure “edge” to “edge”.
5. Measure the Altitude Sight of the Celestial Body. Note the reverse order. One Sight.
6. Measure an Altitude Sight of the Moon. One Sight.
7. Average the Lunar Distance Angle/Time. Average the Moon Altitude Sight/Time. Average the Celestial Body Altitude Sight/Time. After averaging the Average Time for the 3 sets of sights should be roughly the same.
8. Input the average measurements into the Celestial Navigation Plugin.
9. Input your DR Position (Open CPN’s “Boat position” is the default, which can be changed).
10. Input the average Ship’s Time in UTC Time
11. Press the “TIME” Button to see the results of the calculations.

What are the Process Steps to do Lunars in your backyard?

You can eliminate Steps 1, 2, 5, and 6. You need to do Step 8 for the 3 sets of sights. When inputting Altitude for the Moon and for the Celestial Body, use Celestial Nav plugin’s Estimated Altitude. But you’ll need to have a Latitude and Longitude in order to estimate the Altitude (Hs) of the Moon and Celestial Body. After all, the 2 bodies need to be above the horizon for the estimated altitude to compute.

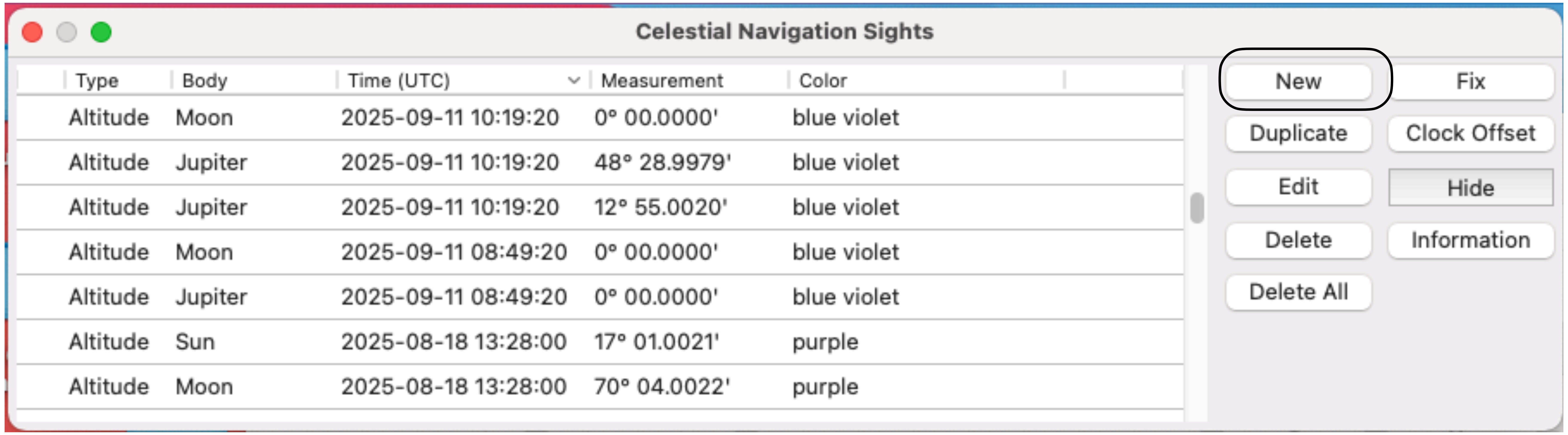
How to input this Lunar Sight



Observer Location (DR): N43°16.1’, W 076° 58.8’
Date: Aug 18, 2025 (at UTC)
UTC: 11:58:00 (at UTC) an estimated time
Height of Eye (HOE): 2.44m (8 ft).
IE (Index Error): -0.8’
Temperature: 17 in °C (63 F)
Pressure: 1013 in mb (29.92” Hg)

Select Celestial Navigation Icon from Open CPN Menu

The Celestial Navigation Sights form opens with existing sights



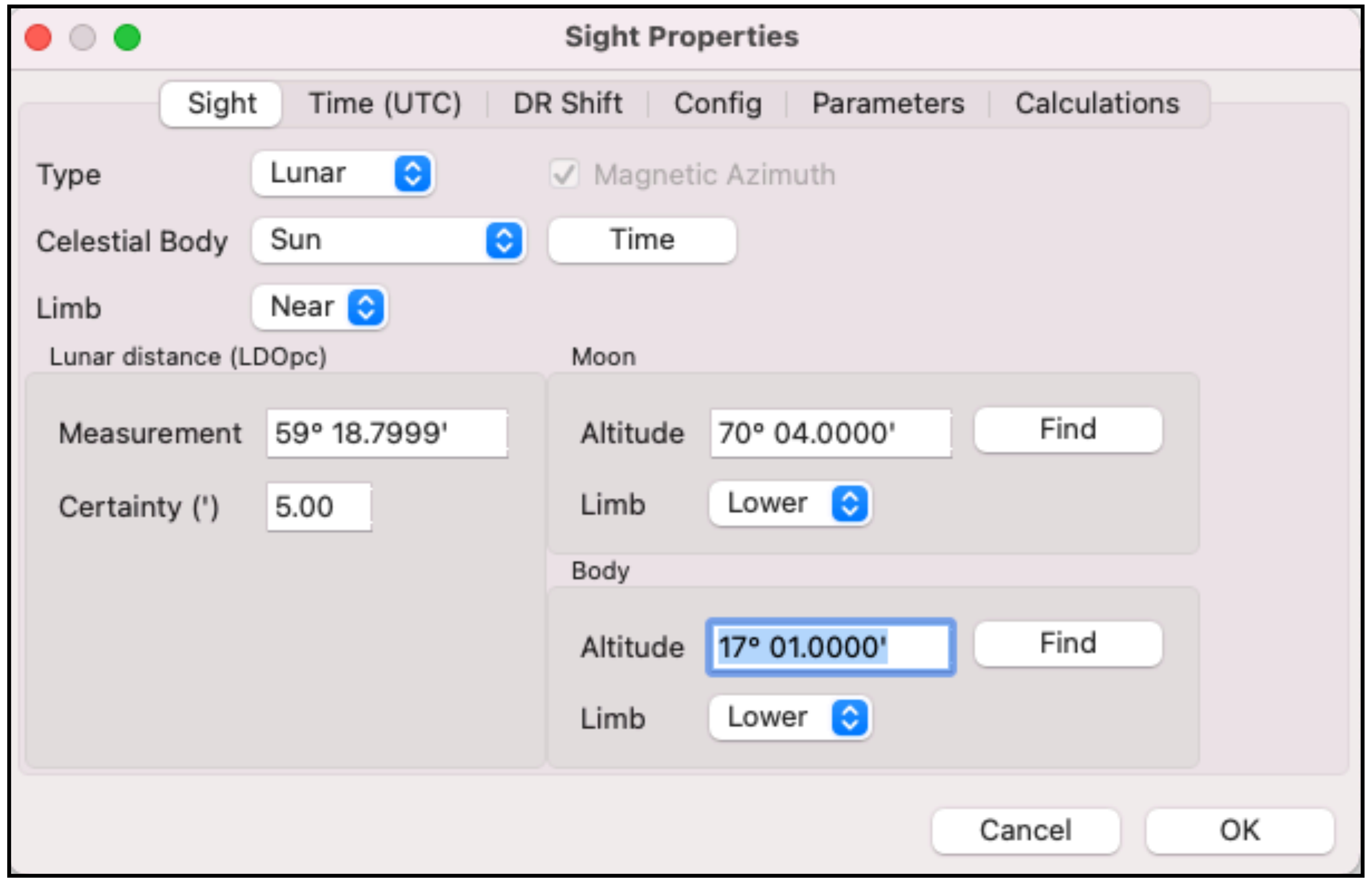
To input a new sight, select one of 2 options.

New or

Duplicate. and then Edit the Duplicated Sight

Input the Measurements

For Lunars, there are 3 measurements to input. The angle between the Moon and the Celestial Body, the Altitude of the Moon (w/Limb) to the Horizon. The Altitude of the Body (only the Sun has a Limb) to the Horizon.



Sight Properties Form.

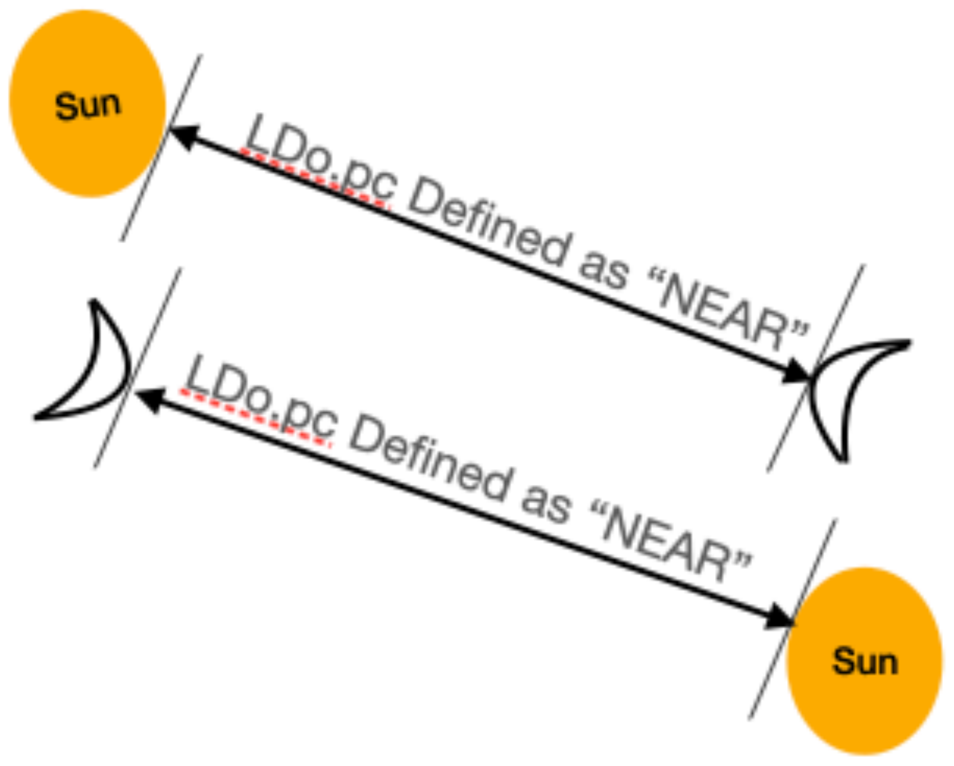
Select type: Lunar.
And Measurement. Lunar Distance Angle between the Moon and the Celestial Body

Select Limb: Near or Far

- Refer to the next illustration for examples of Near or Far.
- The body is **Near** when the closest edge of a celestial body (Sun, Star, Planet) is brought to the nearest visible edge of the moon.
- The body is **Far** when bringing the nearest edge of the body across the moon's face to the far side of the moon.

New Feature - Sextant Measurements can be input in any of 3 OpenCPN supported "angles". Decimal Degrees, Degrees-Min, Degrees-min-sec. They will be redisplayed per display preferences. You can change preferences and sights are displayed in the changed preference

Near versus Far Supported by Lunars



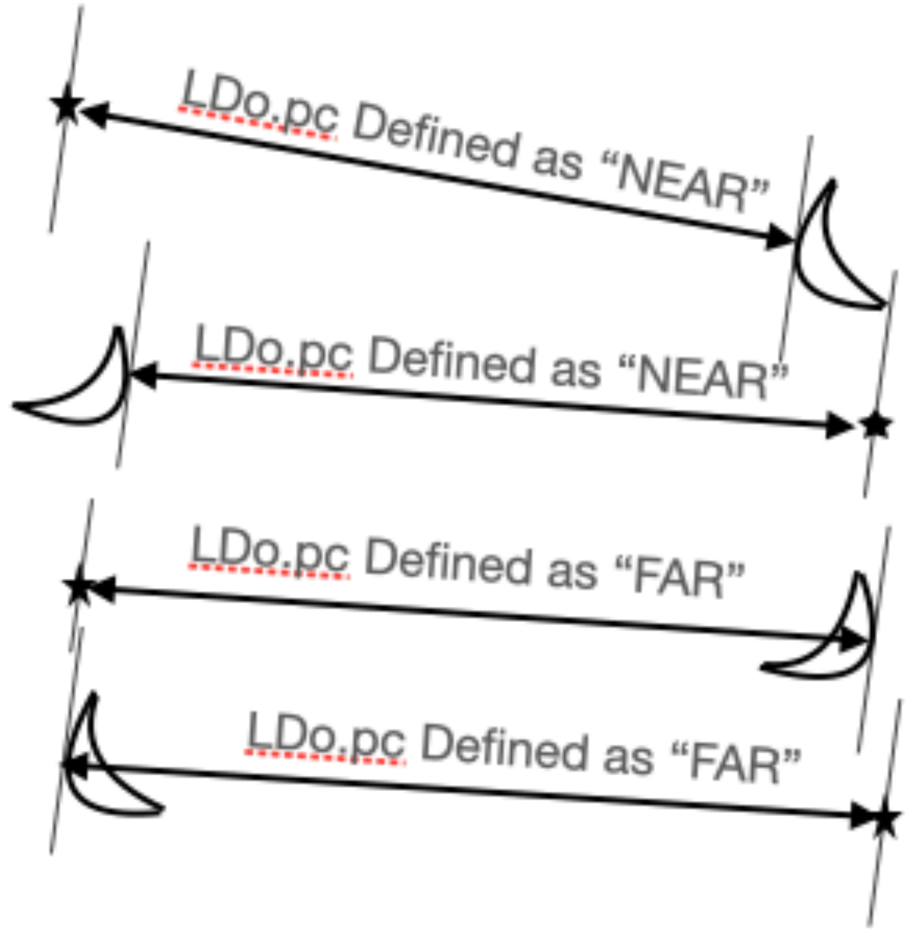
Sun Cases

Horns of the Moon are perpendicular to and point away from the Sun

NEAR equation for Sun

LDo = LDo.pc (incl IC) + SDs PLUS SDm

Note: LDo has no dip adjustment



Star and Planet Cases

NEAR equation

LDo = LDo.pc (incl IC) **PLUS** SDm

(Assume SD=0 for planets)

Note: LDo has no dip adjustment

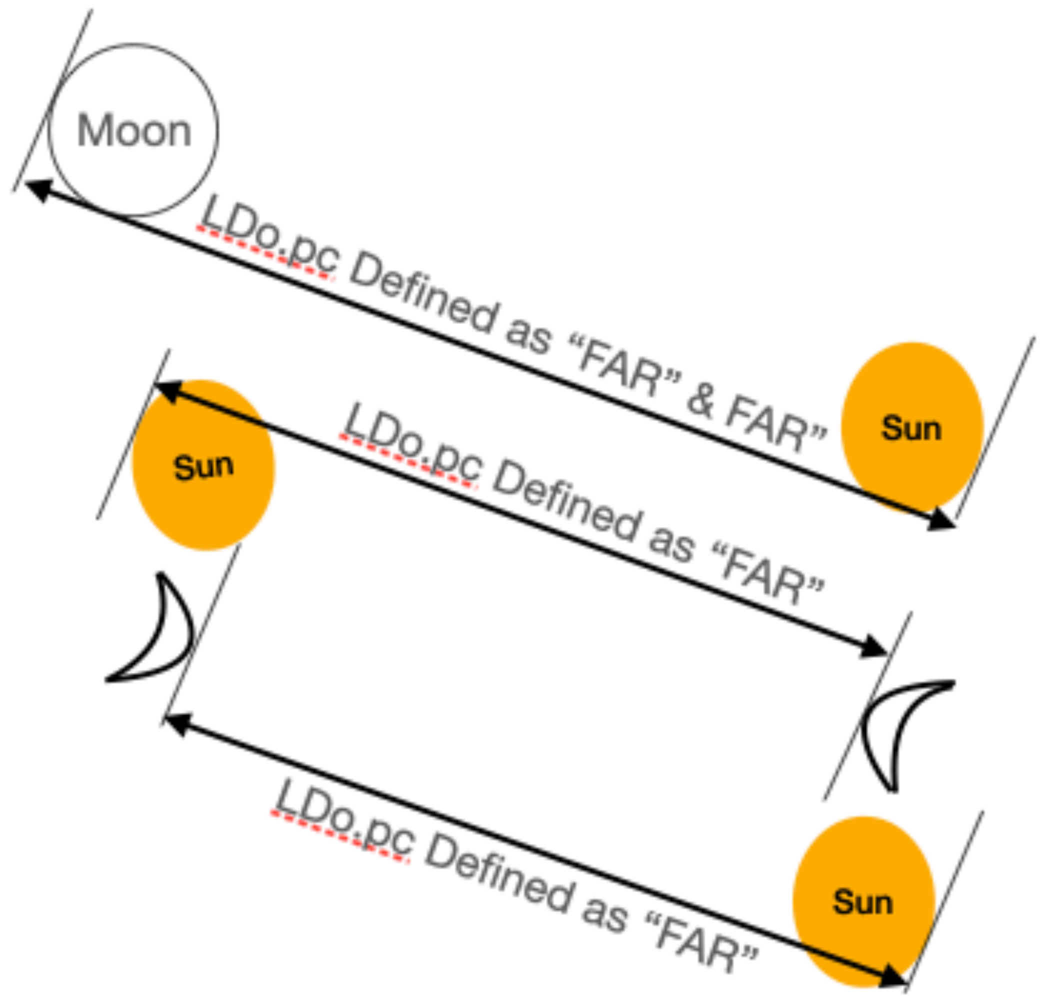
FAR equation

LDo = LDo.pc (incl IC) **Minus** SDm

(Assume SD=0 for planets)

Note: LDo has no dip adjustment

Near versus Far NOT Supported by Lunars



Sun Cases (not supported)

Horns of the Moon are perpendicular to and point away from the Sun

FAR Edge of Moon to FAR edge of Sun

LDo = LDo.pc (incl IC) MINUS SDs MINUS SDm

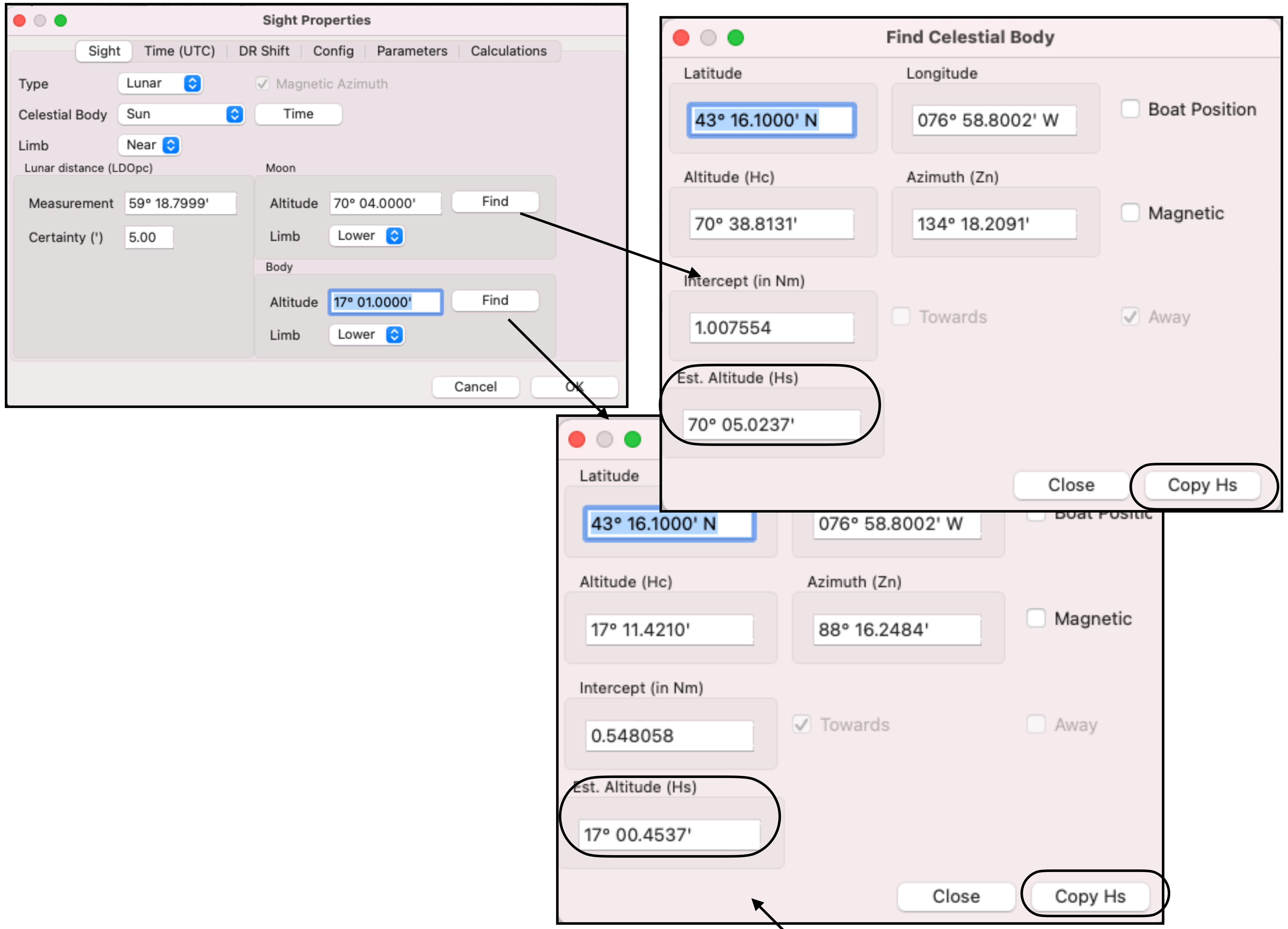
Reason: Only can happen for Full Moon (1 day/mo)
Full Moon is 180° distant from Sun.
No marine sextant can measure more than 133 - 135°

Near Edge of Moon to FAR edge of Sun

LDo = LDo.pc (incl IC) MINUS SDs PLUS SDm

Reason: not able to see Near Edge of Moon On Far Edge of the very bright Sun

Find Celestial Body to input Lat/Longitude & for Backyard Lunars



Backyard Lunars enabled by
Est. Altitude and Copy Hs

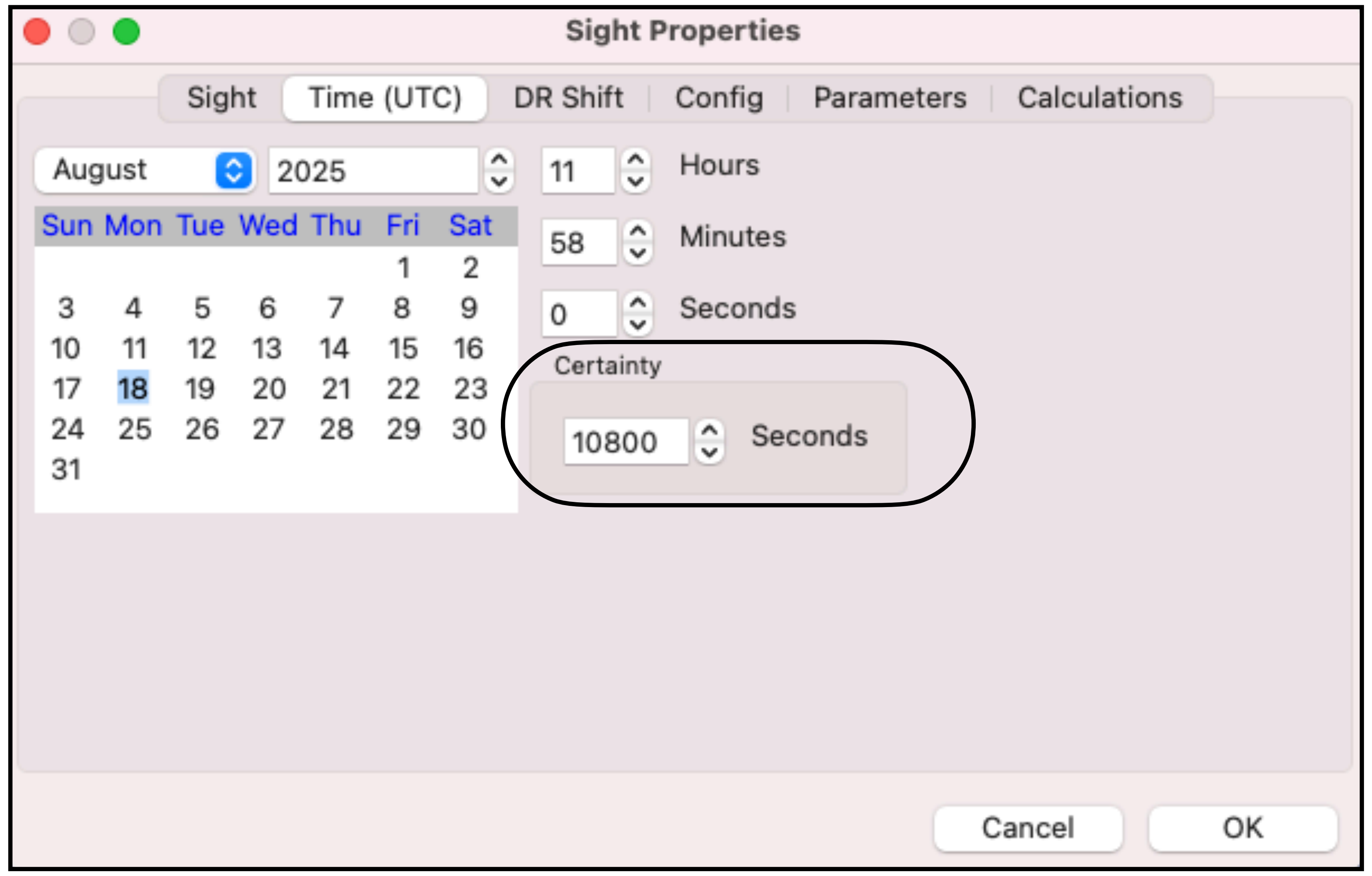
Latitude and Longitude defaults to "Boat Position". Change Latitude or Longitude to your DR position. **New features** (1) Cel Nav is using OpenCPN's standard angle formats (decimal degrees, degrees-min, degrees-min-seconds). It displays per your OpenCPN Display settings. (2) Latitude and Longitude saved with the sight in decimal degrees. Caution for Longitude, input E or W. Do not rely on negative Longitude for West, positive Longitude for East. Future OpenCPN release fixes this limitation.

Est. Altitude (Hs). **New Feature.** Cel Nav estimates an Hs by considering altitude adjustments (IE, Dip, SD/Limb, Refraction, Parallax, Augmentation). It serves three purposes.

1. Validate your sight measurement,
2. Plan your sights,
3. Enables you to do Lunars in the backyard or when you can't see the horizon.

Press **Copy Hs** button to copy it to your Altitude Sight.

Caution estimate is within +/- 0.2' altitude from 1.5° to 90. It is not calculated for negative angles which happens when the body is below the horizon.

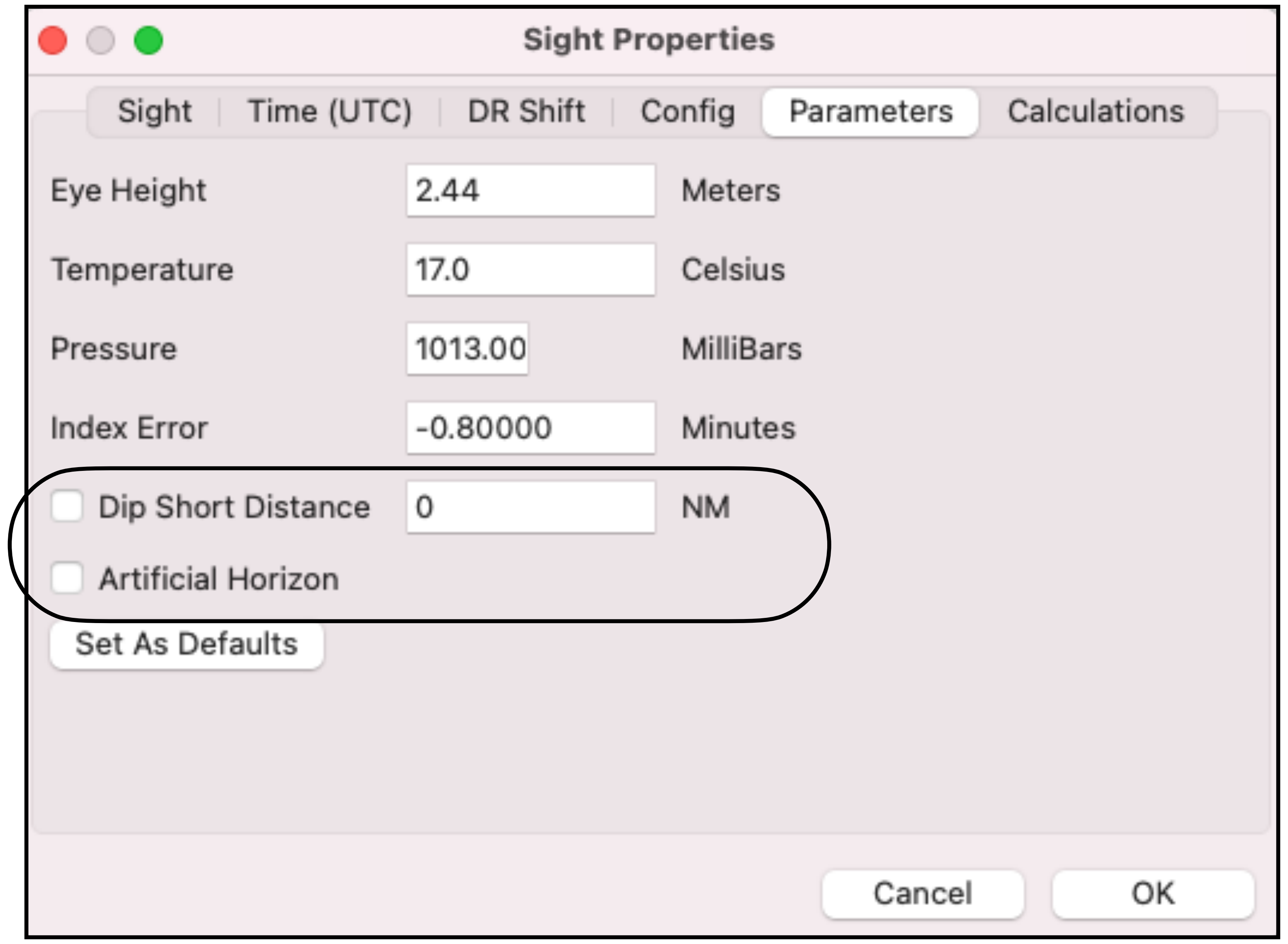


Time (UTC)

Input UTC like normal Altitude Sights.

Certainty. has always been part of the Cel Nav plugin and for altitude sights, it gives a visualization of Time uncertainty. Certainty is used by Lunar's algorithm to interpolate and find an estimated UTC. When Lunar Distance Tables were first published, Time to Lunar Distance table was reported every 3 hours, or 10800 seconds. For Lunars only, Certainty defaults to 10800 seconds.

Try a smaller number. It must bracket the True UTC time. Recalculation is instantaneous.



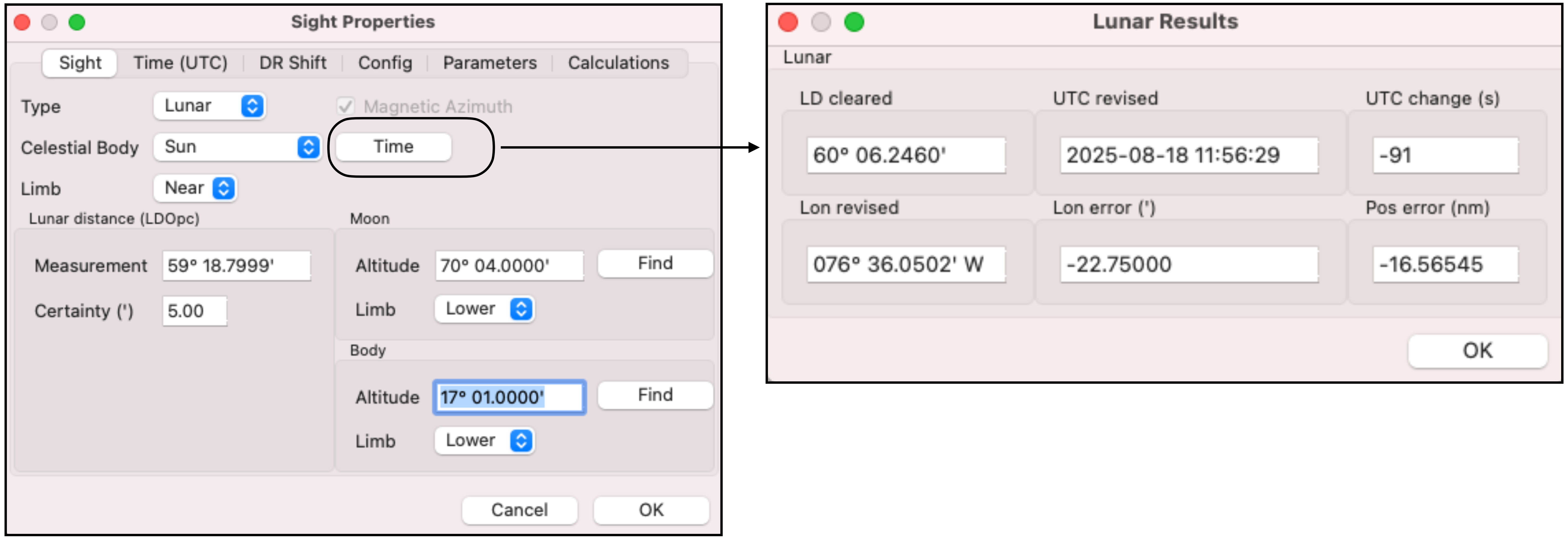
Parameters

No changes for Eye Height, Temperature, Pressure, Index Error. **New** Notice more significant digits. Useful if you converted from imperial

New Feature. Cel Nav allow sights for Dip Short or Artificial Horizon. This feature is meant for Altitude Sights (not Lunars)

Dip Short is intended for regular Altitude sights where you can't see the natural horizon. For Lunars, you can use Dip Short Distance if the altitude sights for the Moon and Celestial Body have the same Dip Short Distance (they won't generally). If they are greatly different, use with caution. It is better to use Eye Height = 0 and use the Estimated Hs for Lunars if you can't see the horizon.

For Lunar Distance Calculated UTC Time, Press TIME in Sight Properties Form



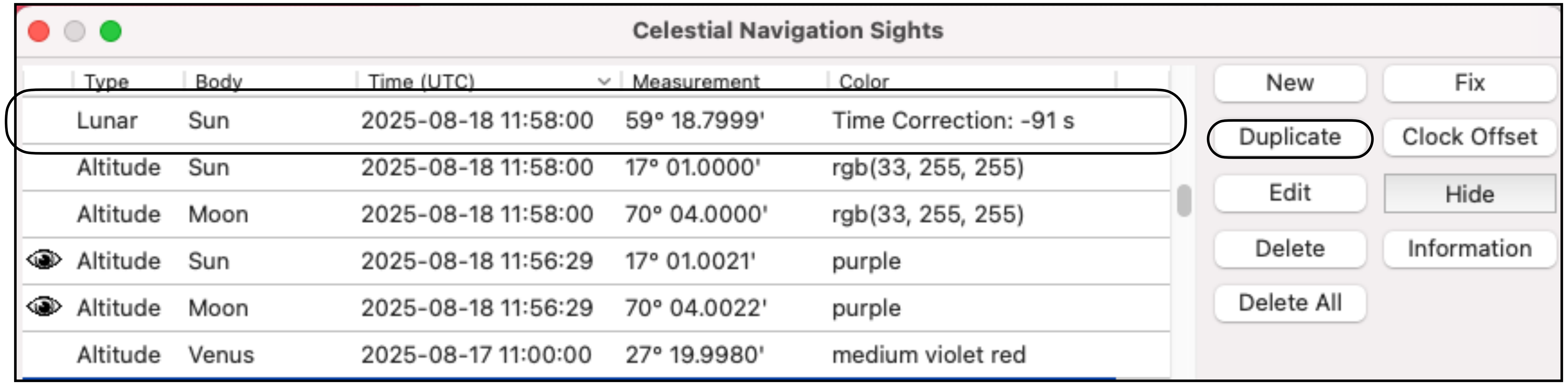
Lunar Distance Cleared. First output of the Lunars Calculation. Similar meaning as Hc (Altitude Computed). It includes altitude adjustments: Index Correction, Limb, Refraction, Parallax, Augmentation. See Theory and Logic section.

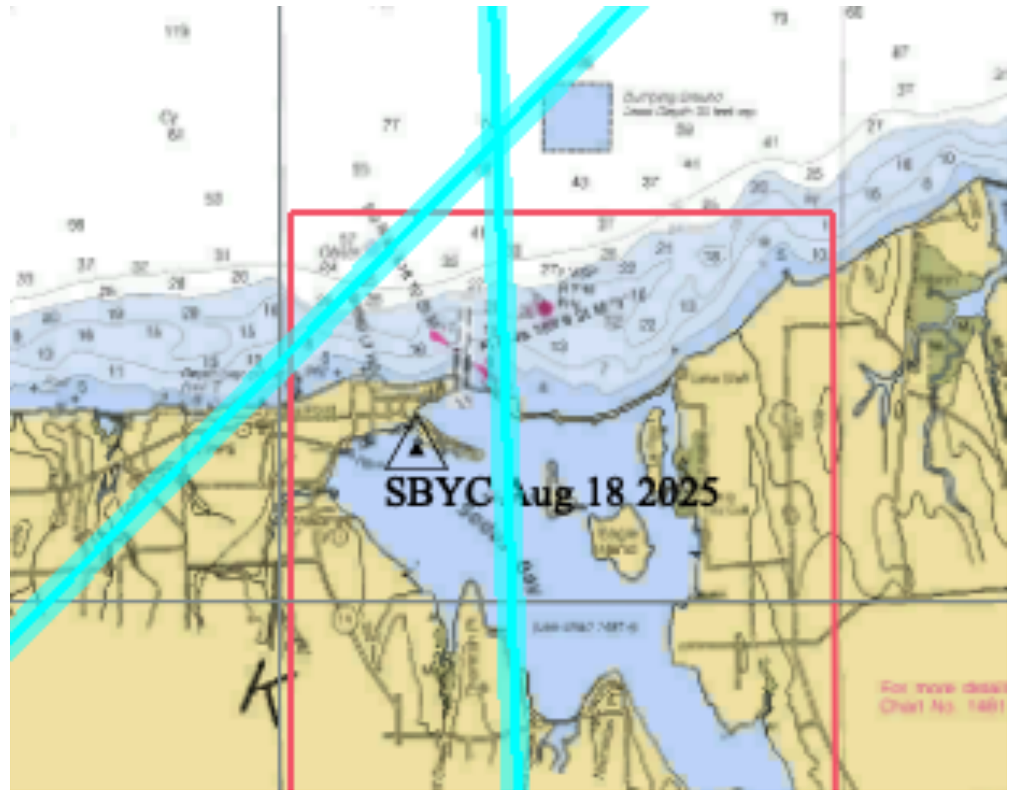
UTC revised is derived from Lunar Distance Cleared. It is the Time uniquely determined for the Lunar Distance Cleared.

UTC change (s) The difference between UTC that was input for the sight and the UTC derived from Lunar Distance Cleared.

The next outputs are simple heuristics. Earth revolves around the Mean Sun at .25 arc-min per second (15° per hour). -91 seconds is -22.8 arc-minutes change in Longitude. Position error is Longitude Error x Cos (Latitude) or -16.6nm.

After Calculating Time, calculate Longitude. That's the traditional Lunars next step!





Celestial Navigation Plugin offers an alternative way to analyze your position.

The Sun and a 1st qtr or 3rd qtr Moon (50% illumination) is known to make a great 2 body fix. The Sun and half Moon was the most frequent done Lunar sight. With Cel Nav, use the Sun LL and Moon LL altitude sights. "Duplicate" the Lunar sight, then EDIT to change the type to "Altitude" and change the UTC time or keep UTC the same. The above illustrates 4 sights created by using "Duplicate". Two of the sights have the "eyeball" icon turned on. See 2 intersecting Line of Positions are plotted for those 2 sights? Is this a good 2 body fix? **Hint** - Open "Find Celestial Body" form and look at the Azimuth for the Sun and then for the Moon. What is the angle difference? Moon 25% illuminated.

Caution - A 2 body fix still has position risks. Try sensitivity analysis and change the Hs of the 2 bodies. Did you see the Fix drift? Celestial Nav plugin recalculates quickly.   A 3 body to 4 body fix each at a minimum 60° spread is better. A Pinwheel is the best. Consider an additional sight for a running-fix. If the Lunar sight was done earlier in the morning (9am local time), a Meridian Transit will give you Latitude.   The meridian transit plus the Sun-Moon could give a Running fix.

Notice - Measurement is shown at 4 significant digits for minutes. The angles are stored in decimal degrees to 6 significant digits in a file called, "sights.xml". When converting from one standard to another, there is minor rounding for certain angles. The small rounding can be ignored because they are immaterial in the sight reduction calculations.

Which Celestial Bodies paired with the Moon make a great Lunar?

#1 **Sun and 1st Qtr or 3rd Qtr (50% illumination) Moon**

- The most frequent Lunars pair. It doesn't literally have to be 1Q/3Q Moon. The example was 25% illum. Use judgement
- With 1st or 3rd quarter Moon, after calculating time, you have an excellent 2 body fix.

#2 **Planets (Venus, Mars, Jupiter, Saturn) and Moon**

- Venus, Mars, Jupiter, Saturn travel along the Ecliptic plane. They make for a good pair with the Moon.
- In the Evening and through Twilight Morning and Evening, there is almost always at least 1 visible major planet.

#3 **Bright Stars on the Ecliptic Plane with the Moon**

- There were 9 bright stars known as "Lunar Stars" Bright, close to the Ecliptic Plane, spread 360° East to West, and North to South. Lunar Distances were pre-calculated in the Nautical Almanac and Bowditch American Practical Navigator. There are a few others. Scored lower in the Lunar criteria. Vega and Deneb isn't on the list. That's because they aren't remotely close to the Ecliptic. They'd be poor selections to pair with moon to tell time.

Lunar Stars	SHA	Dec.
Aldebaran	291°	N17°
Altair	027°	N 9°
Antares	112°	S27°
Fomalhaut	015°	S30°
Hamal	328°	N24°
Markab	013°	N15°
Pollux	243°	N28°
Regulus	208°	N12°
Spica	158°	S11°

Others	SHA	Dec.
Arcturus	146°	N19
Enif	034°	N10°
Nunki	075°	S26ª
Procyon	244°	N5°
Riegel	281°	S8°
Sirius	248°	S17°

SHA or Sidereal Hour Angle. Shows 360° spread
DEC or Declination. Shows North vs South Hemisphere stars

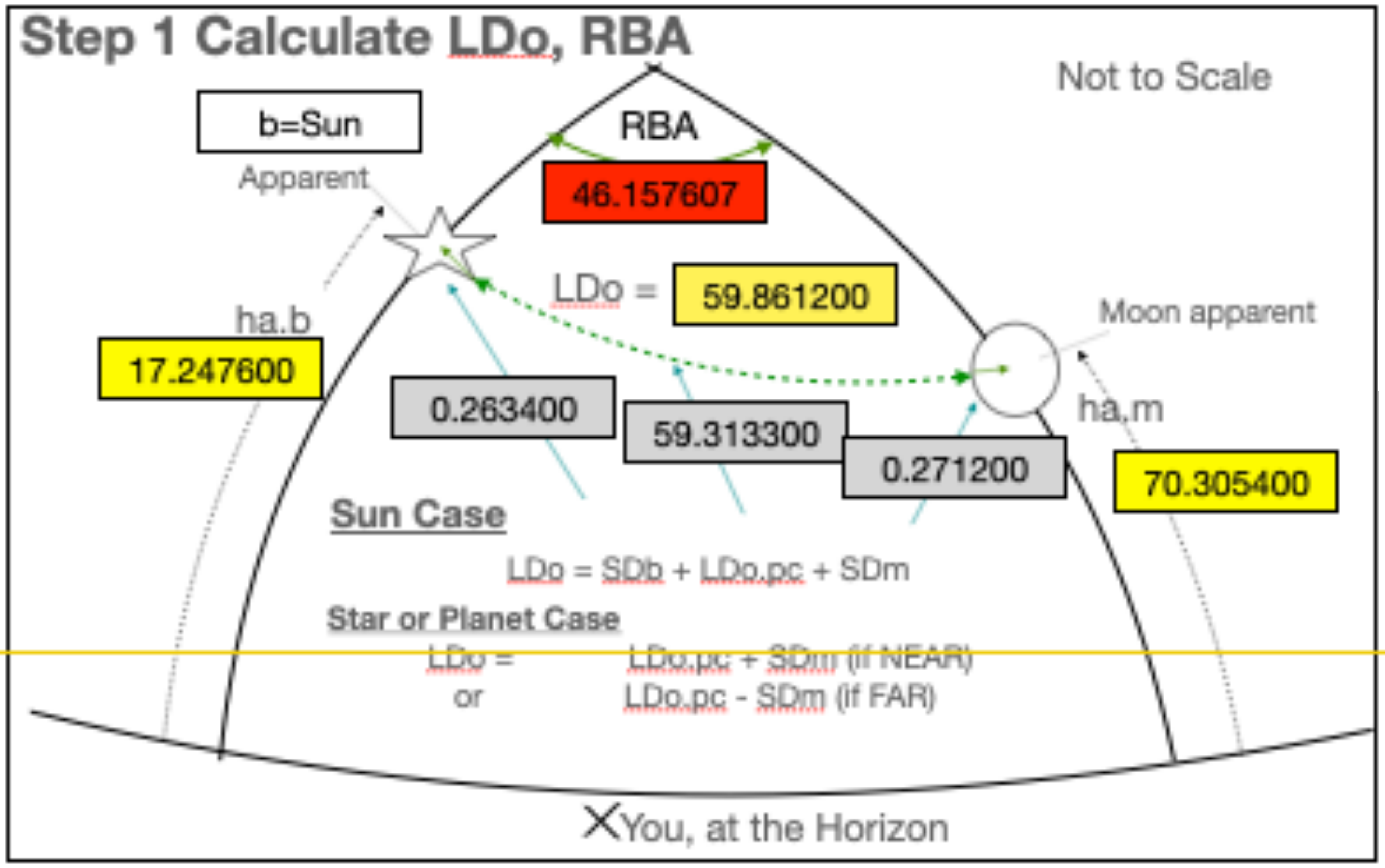
#4 **Selection and what LD measurement to target**

- While outdoors, pick a star/planet on the Moon's trajectory/path. Pick the one that is NOT close to the Moon.
- If Lunar Distance is small, then the Lunar Distance cleared and time will be less accurate.
- If large (i.e. > 100°), it gets hard to sight the body with the moon. Although practice makes perfect.
- A good LD Range is 60° - 100°. 90° was considered optimal

#5 **Full or almost Full Moon and a Star or Planet.** Difficult to Measure LD at night. Moon's glow washes out most stars

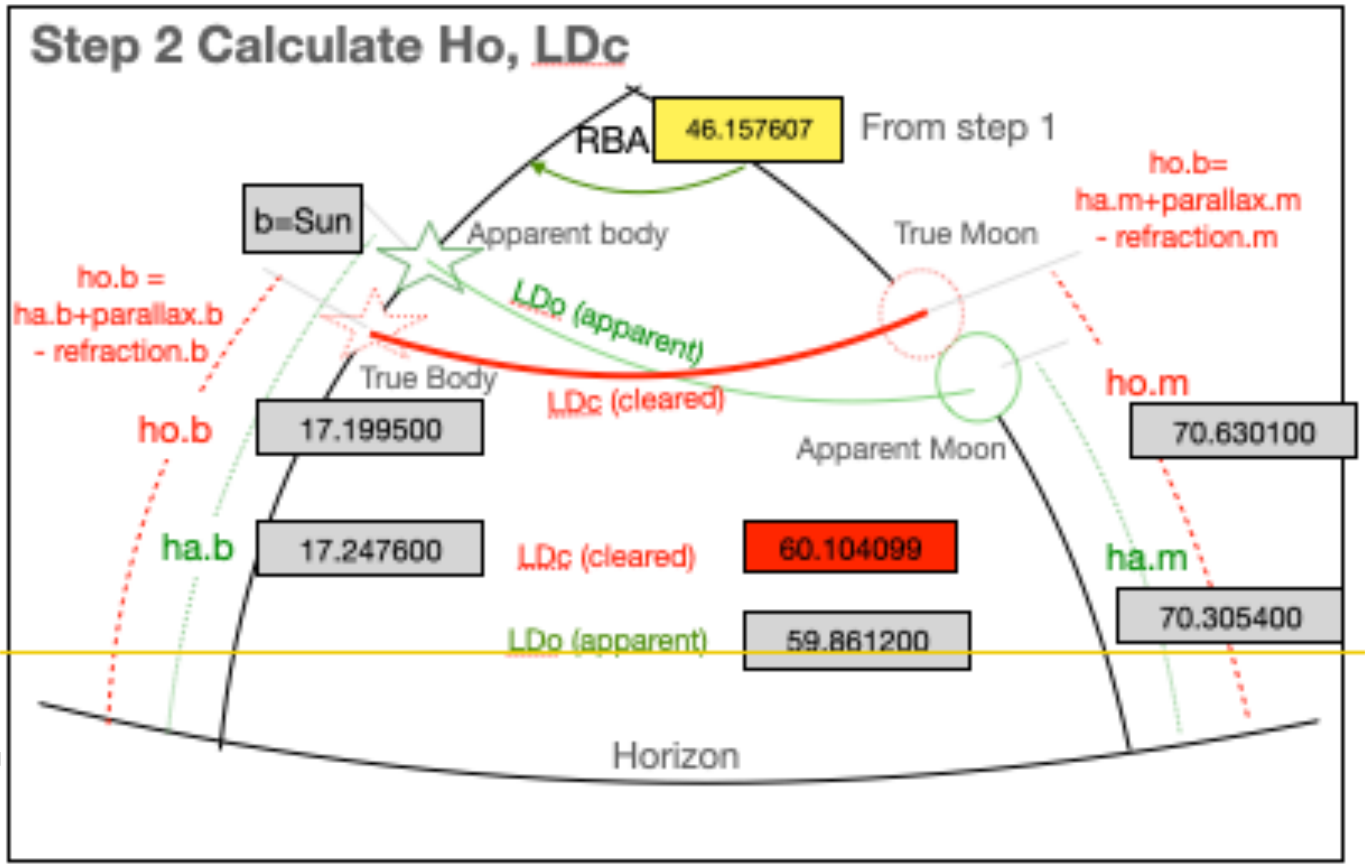
Theory and Logic - Spherical Triangle Method

Calculations for Lunars is available to view in the Calculations form.



Step 1 illustrates LDO apparent and Ha altitude sights

Step 2 illustrates Ho and LD Cleared of the effect of Parallax, and Refraction. Center of the bodies to Center of the Earth



Step 3 Interpolate UTC

UTC from Predicted LDc at time 10:28, 13:28. interpolation is using the UTC form's "certainty" field.

Make the "certainty" smaller, but don't make it too small that the derived UTC is outside the range.

	UTC	LDc °
	10:28:00	60.9026
Derived UTC ⟶	11:56:29	60.1041
	13:28:00	59.2784

What expectation should you have for Accuracy?

- A high quality Sextant. Then minimize all adjustable Sextant Errors. They should be as close to 0 as possible.
- Your initial goal is to consistently achieve better than +/- 0.3’ LDo measurement accuracy.
- Experienced Navigators can achieve between +/- 0.1’ to +/- 0.2 LDo measurement accuracy. Which is between 3’ to 6’ Longitude.

    Easier to achieve LDo measurement accuracy than Altitude sight measurement accuracy. Why? Because LDo measurements have no DIP! And the problem with DIP adjustment is the uncertainty in the Height of Eye due to your vessel bobbing up and down, timing the swells when sighting the horizon, and special weather refraction situations.

    None of this DIP uncertainty exists when measuring Lunar Distance LDo. There is no DIP!

- You’ll be shooting 2 Altitude Sights for Lunars. The purpose is to determine Parallax, Refraction, and Limb corrections. And for Lunars, these altitude sights don’t need to be “spot on”.

    But, Altitude Sights can afterwards be used for a 2-body fix. Your Altitude Sight goal should initially be 1’ or less “sight error”. Sextant professionals consistently get no more than .5’ sight error. A few Navies are working towards .25nm position error. That gives you an idea of your runway for improvement. Dip correction uncertainty is the cause of some of the “Sight error”, and the error depends on ship size and stability. So there is judgement to what goal is achievable.

- In the 1700’s, Celestial mechanics was good enough for the times, but not perfect. Now the Commercial Edition of the Nautical Almanac is accurate mostly 0.0’ error but occasionally 0.1’ error. And U.S. Navy Observatory Celestial Data is better than that. Celestial Nav’s error against the Commercial Edition of the Nautical Almanac is +/- 0.1 at 1 Standard Deviation. At least 50% of the time, it is 0.0’.
- The Lunar measurement in this example was off by 0.6’. Room for improvement! Try the following tips.

Tips to improve Lunar Accuracy

- A high quality metal sextant with good inspection report. No arc errors throughout the range.
- The higher the magnification, the better. 7X is readily available.
- Well Adjusted. Perpendicularity, then side and index error. Goal is as close to 0.0 as you can get because the errors really impacts Lunar Distance accuracy.
- The very best Lunar Distance Observation you can get. Altitude sight accuracy is not as important for TIME.
- Practice-Practice-Practice. Ship Navigators took sights almost daily. That's why they are so good.
- Select a celestial body that is traveling along the same trajectory plane as the Moon, as if they'd collide.
    - Start off with Sun, it gives the best result.
    - Then try Planets because they travel close to the Moon's trajectory.
    - Then "Lunar Stars". They were bright and close to the ecliptic (some closer than others).
- Don't select a celestial body near the Moon. The Cleared Lunar Distance and Time won't be as accurate.
- Select a body who's LD is between 60° to 100°. 90° is considered optimal. Larger LDo fixes problems when Moon travel path doesn't look like it will "collide" with the paired Lunar celestial body.
- Don't select a star that is far off the moon's path or far off the ecliptic (e.g. Vega).
- Ensure the sharpest focus. You want to see a clear outline of the Moon and Sun.
- Hold the sextant frame with both hands to avoid wobbling. Do small micrometer adjustments.
- Make sure the body is aligned (an imaginary line) to the center of the Field of View. That way, the sextant frame is aligned to the plane of the bodies. You'll be rocking your sextant to ensure the touch is tangent.
- Preset the sextant to the expected Lunar Distance. Then wait for the body to touch the Moon.
- In the Lunars chapter of Bowditch's American Practical Navigator, the editors recommended that the center of the body (planet, star) touches the moon. This indicates that the navigators used sextants with good magnification.
- Try not to do "live" adjustments to the micrometer. You'll be more successful by setting up your sextant to the predicted LD, then patiently wait for the "touch" to occur, and then MARK. And then for the next sight, turn the micrometer a little ahead for the next MARK and then wait.

Tips to improve Lunar Accuracy (continued)

- Bowdich chapter on Lunars has a lot of practical advice.
- Average the run of Sights

How to do a Run of sights for Lunars on the Ocean

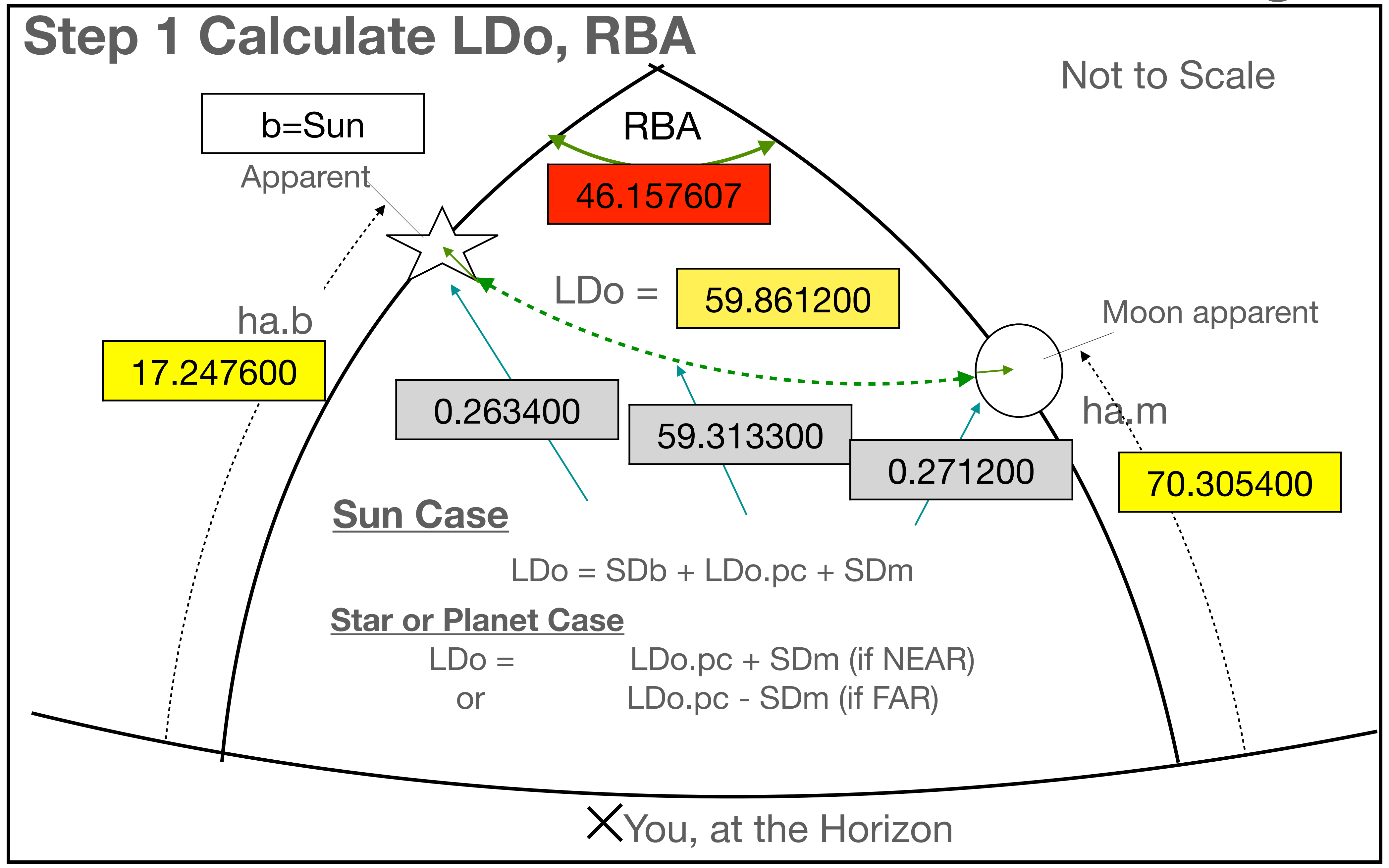
A run of Sights that average to the same Time. Using a calculated average time and average measurement often results in better accuracy. Assuming the time between sights is say 1 minute, then sighting in this order will result in about the same average time for the 3 sets of sights. For example 8 observations

1. Altitude Sight for Moon
2. Altitude Sight for Celestial Body
3. Lunar Distance Observation 1
4. Lunar Distance Observation 2
5. Lunar Distance Observation 3
6. Lunar Distance Observation 4
7. Altitude Sight for Celestial Body
8. Altitude Sight for Moon

- Average the Moon Altitude Sights 1 & 8
- Average the Celestial Body Altitude Sights 2 and 7
- Average the Lunar Distance Observations for 3, 4, 5, 6.
- If Average TIME for the Sight data is roughly the same, use it for the Lunar Sight Reduction.

You don't have to be as systematic as the first option. You can plot the run of Hs sights for the 2 bodies and DLo measurements against elapsed minutes. Fit a line through the data, choose a common elapsed minutes time and read the Hs or DLo angles that are on the fitted line.

Step 1- Calculate LDo and Relative Bearing Angle



Cos (LDo) = sin (ha.m) * sin (ha.b) + cos(ha.m)*cos(ha.b)*cos(ΔZ)

Or

Cos (RBA) = Cos (LDo)/Cos (ha.m)/cos(ha.b) - tan (ha.m)*tan (ha.b)

Cos (RBA) = 0.502096 / 0.337007 / 0.955032 - 2.793721 * 0.310462

Cos (RBA) = 0.692677 RBA = 46.157607 degrees

The Celestial Nav's Calculate Form Shows the calculation

These calculations are shown in the Calculate Form

RBA	Relative Bearing Angle between the Moon & body
LDo.pc	LDo pre-cleared. hs Lunar Distance°

Apparent Altitude Corrected

ha.b*	Body apparent Alt = hs.b +/-IC - dip +/-limb.b
ha.m*	Moon apparent Alt= hs.m +/- IC - dip +/- limb**.m
	**Limb incl augmentation
LDo	If Body = Sun AND Limb="NEAR"
	then LDo.pc +/- IC + SDm + SDb
	If Body = star or planet & Body = NEAR
	then LDo.pc +/- IC + SDm
	If Body = star or planet & Body = FAR
	Then LDo.pc +/- IC- SDm
SDm	Semi-Diameter of Moon. Positive number.
SDb	Semi-Diameter of Sun. Positive number
	SD for stars and planets is 0.

Notes:

* ***Refraction and Parallax/augmentation is not part of RBA in step 1***

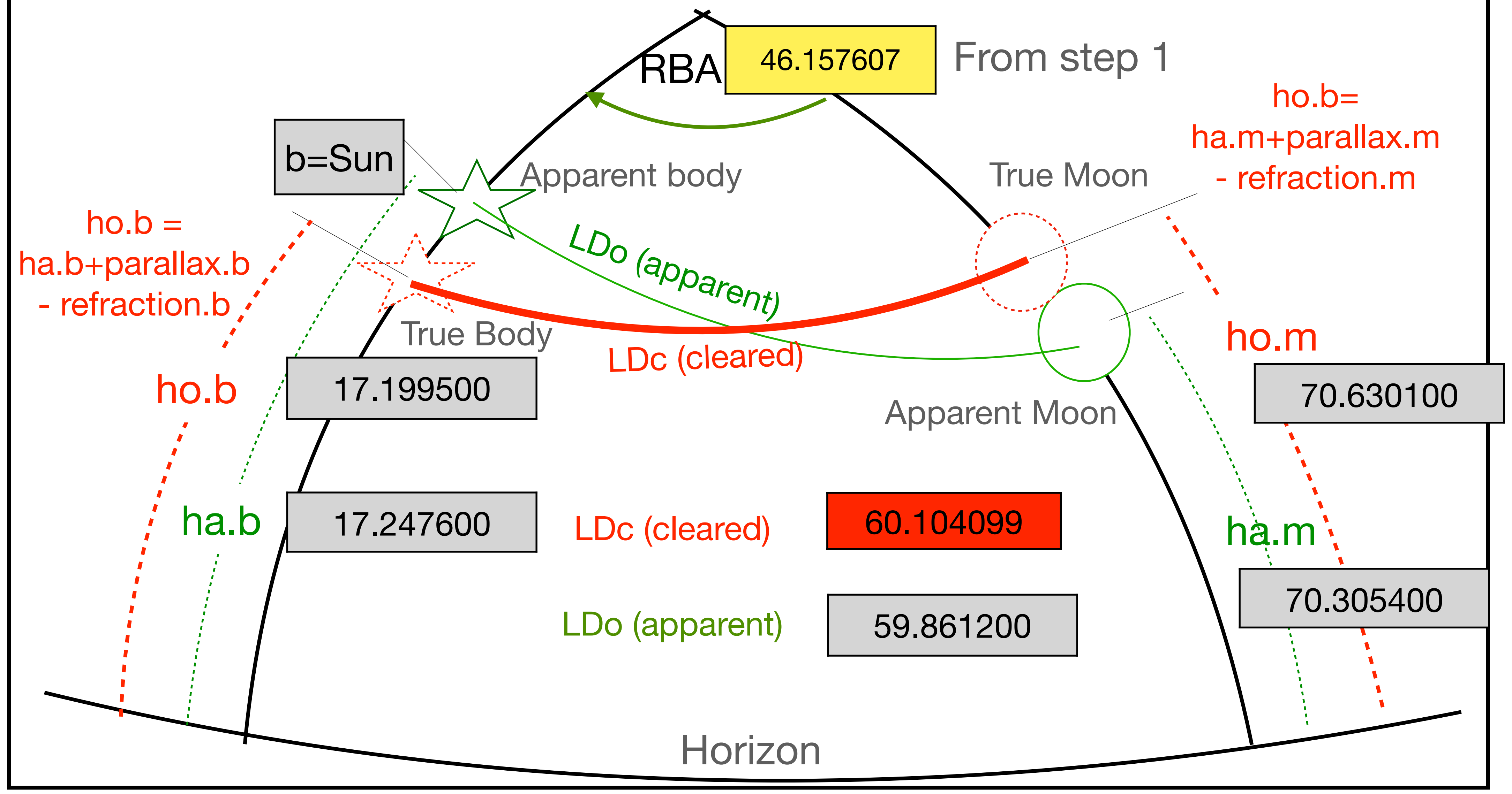
** ***SD for LDo calculation of planets assumed to be 0***

INPUTS

	LDo	ha.m	ha.b
			b=Sun
LImb	NEAR	LL	LL
LDO.pc, hs	59.313300	70.066700	17.016700
IC	0.013300	0.013300	0.013300
- dip		-0.045800	-0.045800
Limb (SD)		0.271200	0.263400
LD SDm	0.271200		
LD SDb	0.263400		
LDo/ha	59.861200	70.305400	17.247600
Radians	1.044775	1.227061	0.301027
Cos	0.502096	0.337007	0.955032
Tan	1.722401	2.793721	0.310462

Step 2- Calculate LD Cleared using Law of Cosines

Step 2 Calculate Ho, LDc



RBA	Relative Bearing Angle solved in Step 1
LDo-pc	Pre-cleared Lunar Distance Sextant measure
LDo	Lunar Distance observed
ha.b	Body apparent altitude= hb +/-IC -dip +/-limb
ha.m	Moon apparent altitude= hm +/- IC - dip +/- limb
ho.b	ha.b + parallax.b - refraction.b
ho.m	ha.m + parallax.m* - refraction.m
LDc	Cleared Lunar Distance

* Note: parallax for Moon includes augmentation as an additional altitude correction.

Recap Step 1

Cos (RBA) = 0.502096 / 0.337007 / 0.955032 - 2.793721 X 0.310462

Cos (RBA) = 0.6926770 RBA= 46.157607

Step 2 Calculate LD

Cos (LDo) = sin (ho.m) * sin (ho.b) + cos(ho.m) * cos(ho.b) * cos(RBA)

Cos (LDc) = 0.943397 X 0.295700 + 0.331666 X 0.955281 X 0.692677

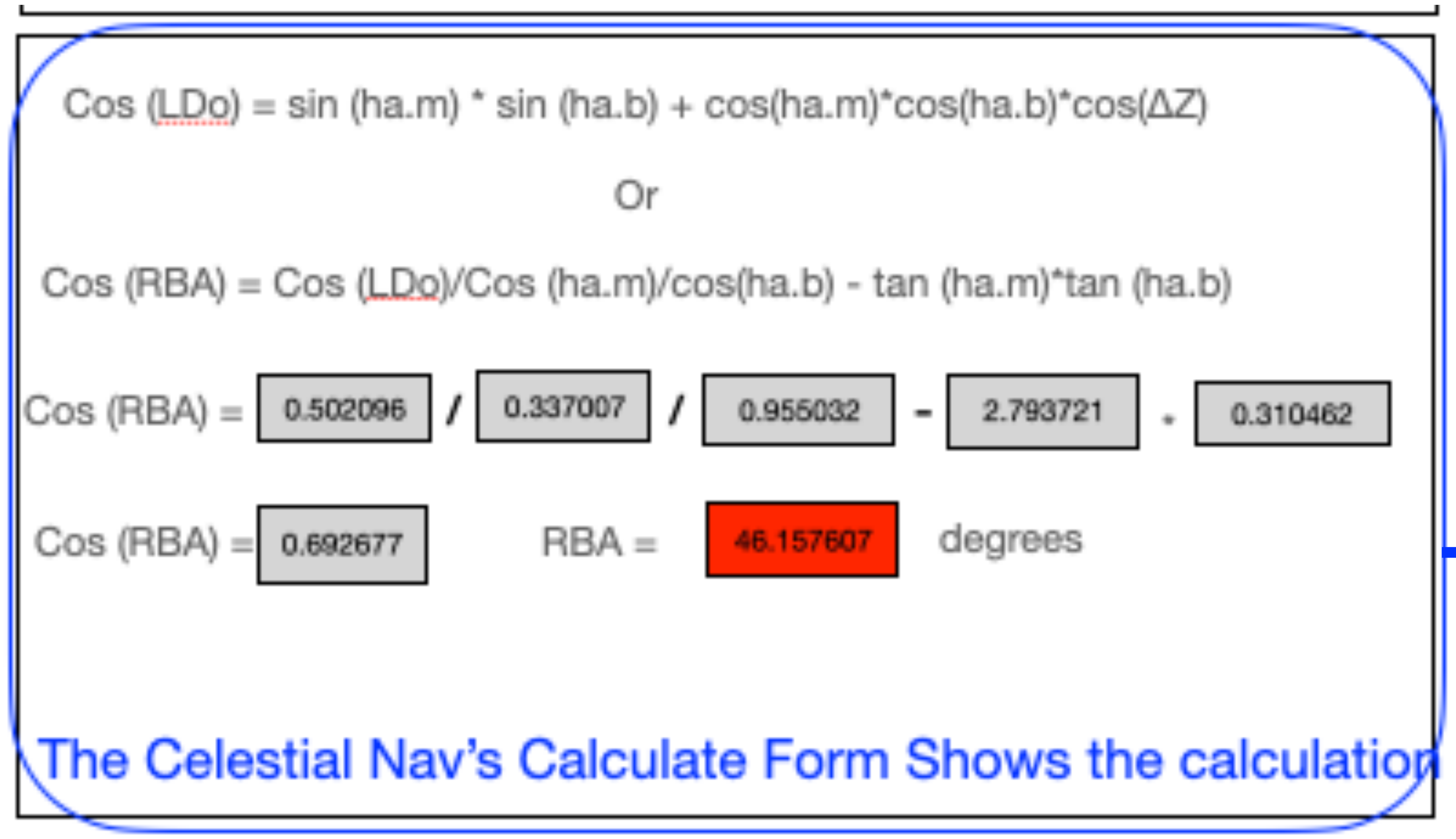
Cos (LDc) = 0.498426

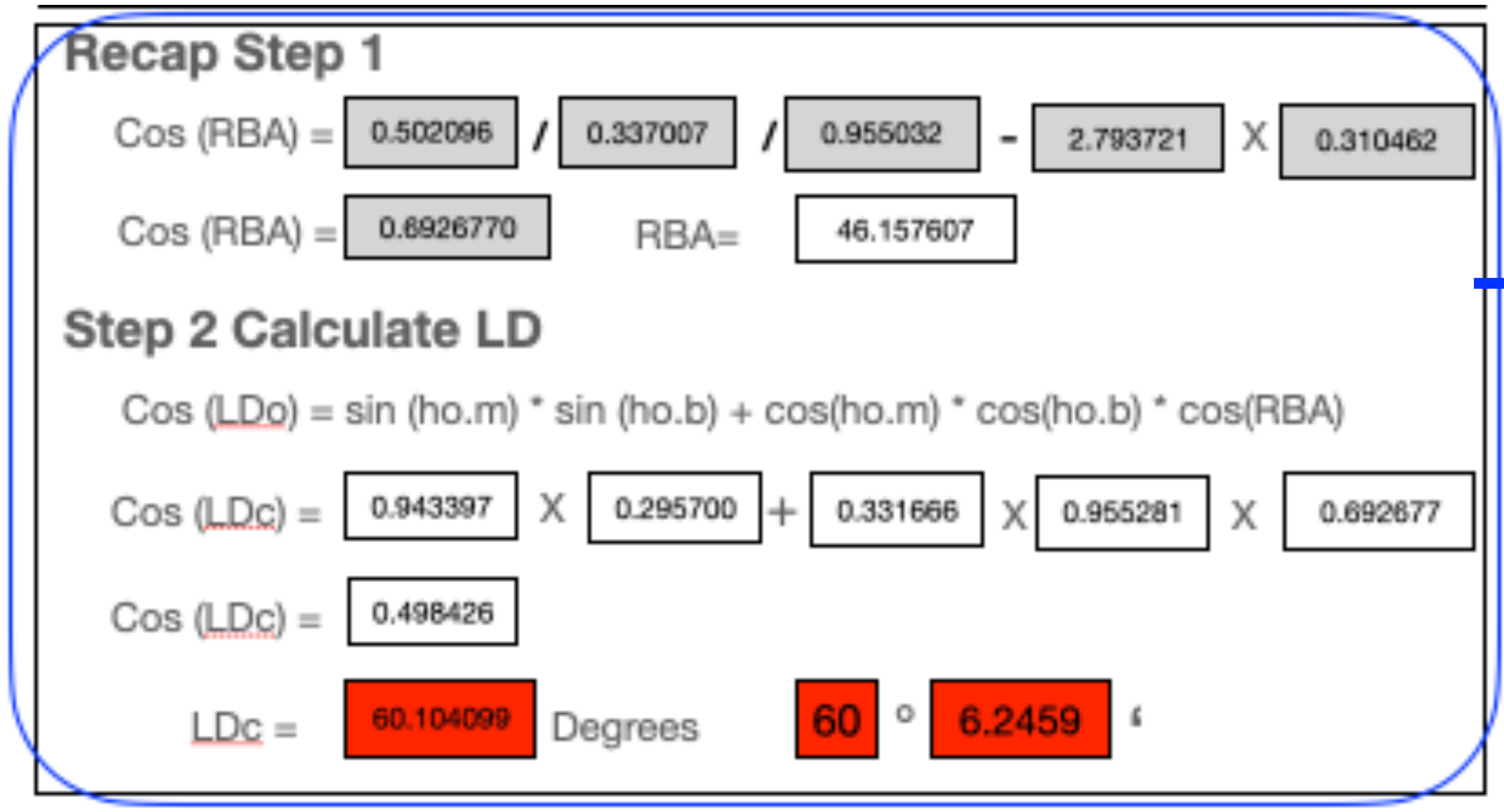
LDc = 60.104099 Degrees 60 ° 6.2459 ‘

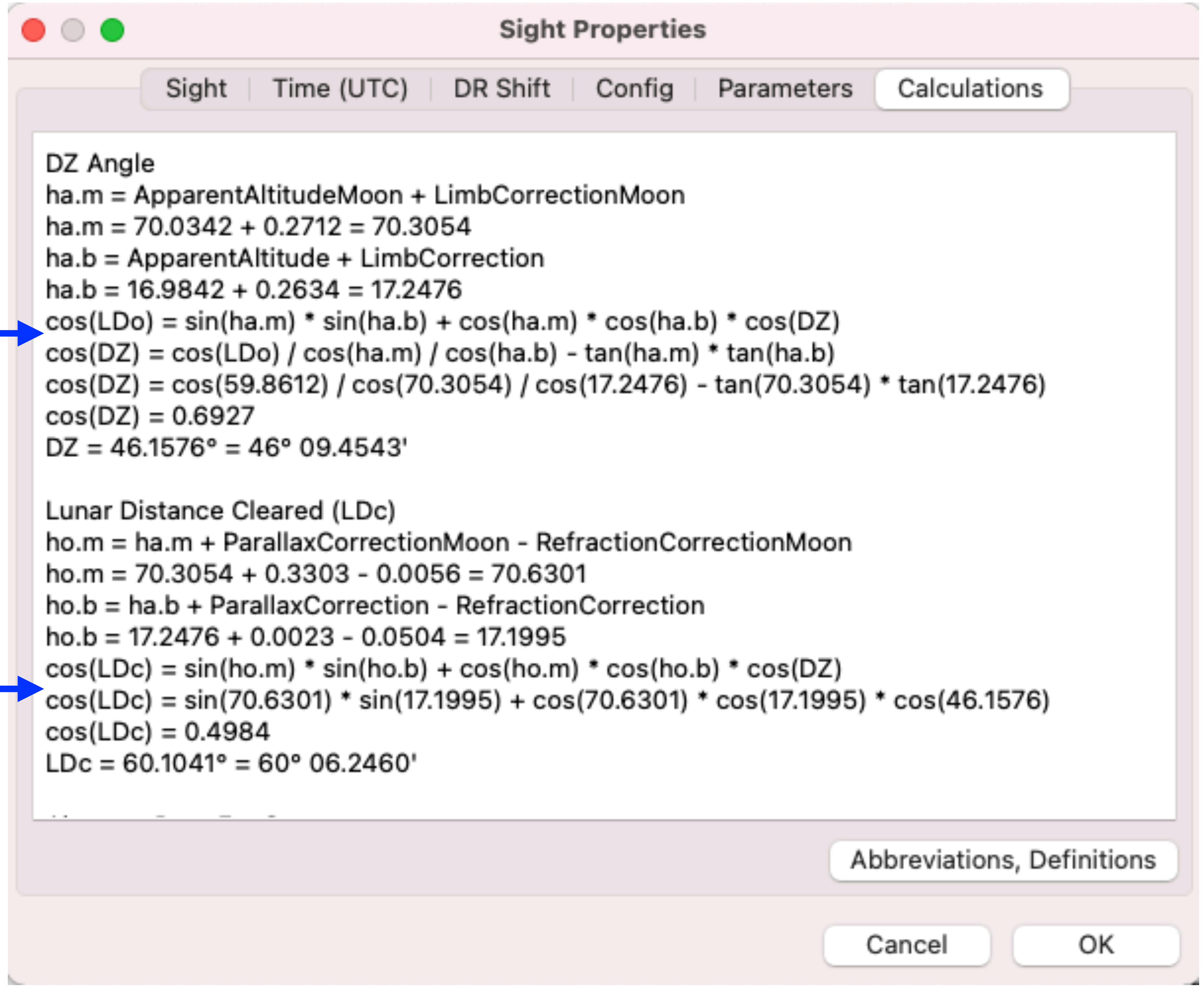
	LDo	h.m	h.b
Body			b=Sun
LImb	NEAR	LL	LL
LDo.pc/hs	59.313300	70.066700	17.016700
IC	0.013300	0.013300	0.013300
- dip		-0.045800	-0.045800
Limb		0.271200	0.263400
LD Limb.m	0.271200		
LD Limb.b	0.263400		
LDo/ha	59.861200	70.305400	17.247600
Radians	1.044775	1.227061	0.301027
Cos	0.502096	0.337007	0.955032
Tan	1.722401	2.793721	0.310462
Refraction		-0.005600	-0.050400
Parallax		0.330300	0.002300
dh		0.324700	-0.048100
ho		70.630100	17.199500
Radians		1.232728	0.300188
Cos		0.331666	0.955281
Sin		0.943397	0.295700

Step 1 and 2

Calculations Form show the derivation details







New Feature - Angles are shown in Decimal Degrees <u>and</u> Degrees and Minutes to make it easier to use.
Calculations are done in Decimal Degrees, 4 significant digits shown, but carried out using more digits

Step 3 Calculate UTC

Calculations Form show the calculations details

Step 3 Interpolate UTC
UTC from Predicted LDc at time 10:28, 13:28. interpolation is using the UTC form’s “certainty” field.
You can make the “certainty” smaller, but don’t make it too small that the derived UTC is outside the range.

	UTC	LDc °
	10:28:00	60.9026
Derived UTC →	11:56:29	60.1041
	13:28:00	59.2784

Sight Properties

Sight | Time (UTC) | DR Shift | Config | Parameters | Calculations

Lunar Distance Cleared (LDc) prediction for 2025-08-18 10:28:00
cos(LDc) = sin(dec.m) * sin(dec.b) + cos(dec.m) * cos(dec.b) * cos(Dgha)
cos(LDc) = sin(28.5424) * sin(12.9387) + cos(28.5424) * cos(12.9387) * cos(296.2978)
cos(LDc) = 0.4863
LDc = 60.9026° = 60° 54.1530'

Lunar Distance Cleared (LDc) prediction for 2025-08-18 13:28:00
cos(LDc) = sin(dec.m) * sin(dec.b) + cos(dec.m) * cos(dec.b) * cos(Dgha)
cos(LDc) = sin(28.5793) * sin(12.8981) + cos(28.5793) * cos(12.8981) * cos(61.8317)
cos(LDc) = 0.5109
LDc = 59.2784° = 59° 16.7011'

Interpolating Lunar Distance Cleared to find out UTC
UTC = time.start + (LDc - LDc.start) * (time.end - time.start) / (LDc.end - LDc.start)
UTC = 2025-08-18 10:28:00 + (60.1041 - 60.9026) * (2025-08-18 13:28:00 - 2025-08-18 10:2
UTC = 2025-08-18 11:56:29

Time correction -91 seconds

Abbreviations, Definitions

Cancel OK

Calculate Lunar Distance Cleared by interpolating LDc from Certainty Seconds /2 (10800/2) before the UTC Time and Certainty Seconds/2 after the UTC Time.