

Astrarium — User Manual (Android)

For version 1.3

7 September 2026

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1. Introduction

Astrarium is a planisphere and astronomical simulator for Android phones and tablets. It shows the sky as it is now, but it also lets you drive the clock freely — back into the past, forward into the future — and it puts planetary phases, eclipses, meteor showers and comets on the same chart.

Satellites here means the **space stations** — the ISS and Tiangong — which it draws on the chart and predicts visible passes for (chapter 11).

AR — the chart drawn over the live camera — is here too. Hold the device up and the constellations in that direction line up on screen (chapter 11).

Positions come from the JPL DE421 ephemeris, the IAU precession and nutation models and IERS Earth-orientation data, and are accurate enough to plan real observing sessions with.

1.1 Requirements

Devices	Android phones and tablets (Android 8.0 or later)
Orientation	Portrait and landscape both supported
Price	Free. No in-app purchases, no advertising
Network	The chart and all the astronomy run on the device — it works offline
Data collection	None. Your site and settings stay on the device

An internet connection is needed only to **update** three things:

- satellite orbital elements (TLEs, from Celestrak),
- comet and asteroid elements (from the MPC and JPL),
- your current position (this uses location services, not the network). When the permission dialog appears, choose **Precise**: an approximate position can be kilometres out, and that changes what is visible near the horizon.

1.2 First steps

1. On launch, the app shows the sky over Tokyo at the present moment.
2. Press  in the top bar and allow the use of your location. Astrarium switches to your position and tells you the nearest registered site and how far away it is. If you would rather not share your location, pick a site from the list or type in coordinates (chapter 3).
3. Outdoors, press  (night vision). The whole interface turns red so that it does not spoil your dark adaptation.

2. The screen

The screen is divided into five bands, from top to bottom.

	Band	Where	What it does
Top bar		Top	Clock, observing site, location, panel, language, night vision
Chart		Middle	The sky itself — driven with your fingers
Quick bar		Below the chart	Magnitude slider and the common toggles (two

Band	Where	What it does
		rows)
Time bar	Below that	How the sky is shown (all-sky, horizon, AR) and the grids; moving and playing the clock (three rows)
Signature	Bottom	Logo and author, both links

The three rows of the time bar are, from the top,

1. **All-sky / Horizon / AR / Grids** — how the sky is shown
2. **–syn –1d –1h –1m / +1m +1h +1d +syn** — moving the clock
3. **Date button / time / Now / ◀ ■ ▶** — the date and time themselves

Pressing the date button opens a calendar; the time field can be typed into.

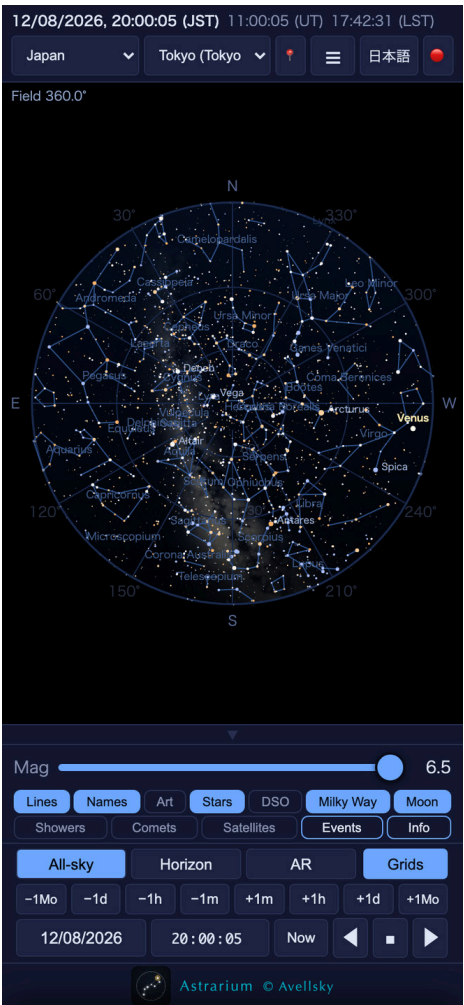


Figure 1. The all-sky view (Tokyo, 12 August 2026, 20:00)

2.1 The top bar

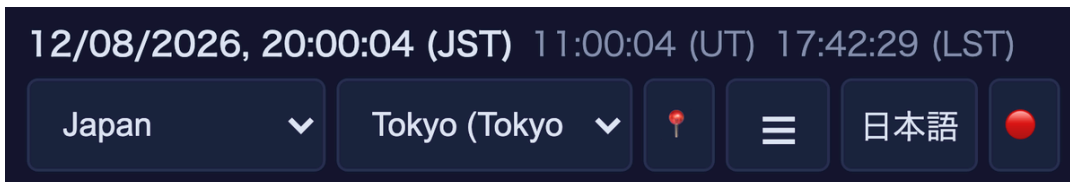


Figure 2. The top bar: site category and site, location, panel, language, night vision

- **Clock** — local time at the observing site, Universal Time (UT) and Local Sidereal Time (LST) side by side. LST tells you which right ascension is on the meridian right now, which is what you need when pointing a telescope.
- **Site category** — Japan (the 47 prefectural capitals), Japanese dark-sky sites, observatories, major cities other than capitals, the capitals of each continent, and the Antarctic research stations. Observatories at home and abroad are one list. Each menu is named for exactly what is in it: “Asia · capitals” holds one national capital per country. Choosing observatories adds a second **Region** menu so you can narrow the list down by continent.
- **Site** — the place itself. The prefectures and the dark-sky sites run north to south; the world cities are alphabetical, by the reading of the name when the app is in Japanese.
- 📍 — use your current position.
- ☰ — open or close the detail panel (six tabs).
- **EN / 日本語** — switch language. Object names, constellation names and every description change with it.
- 🔴 — night vision; press again to return to normal colours.

2.2 The signature line

The logo at the bottom opens the Astrarium home page and © Ave11sky opens the author’s page, both in the browser.

3. Choosing where you are

Pick a place from the category and site menus in the top bar, or press 📍 to open the **site screen**, which holds a map, coordinate entry and your saved places on one panel.

Pick it from the list

Use the category and site menus in the top bar. The app carries the capital of each of the 47 Japanese prefectures — “Sapporo (Hokkaido)”, named with its prefecture — recommended dark-sky sites in Japan ordered by prefecture from the north, every national capital named with its country, the

major cities that are not capitals, the Antarctic research stations, and the world's observatories with their MPC codes. Each place appears in one menu only.

Open the site screen

Press . Nothing moves the moment you press it.

- **Get current position** — choose “While using the app”, and **Precise**, when Android asks (an approximate position can be kilometres out, which changes what sits on the horizon). Tick “Get position at launch” and it will do this on every start.
- **Map** — drag the map (OpenStreetMap) until the centre mark is on the spot; + and – zoom.
- **Latitude, longitude, altitude** — type degrees, minutes and seconds, and the altitude; the arrows step one unit at a time. “Use this position” applies it.
- **List** — save up to **ten** places by name and tap a row to go there.

Changing the site updates the clock, the rise and set times and the whole geometry of the chart together.

4. Driving the chart

4.1 All-sky and horizon views

Switch with **All-sky** and **Horizon** at the left of the time bar.

- **All-sky** — the whole sky as a circle centred on the zenith, north up and east to the left, exactly as on a cardboard planisphere. The Milky Way is drawn in this view.
- **Horizon** — part of the sky drawn as you would actually see it looking out. The menu beside the button chooses which way you face: **N**, **E**, **S**, **W**.

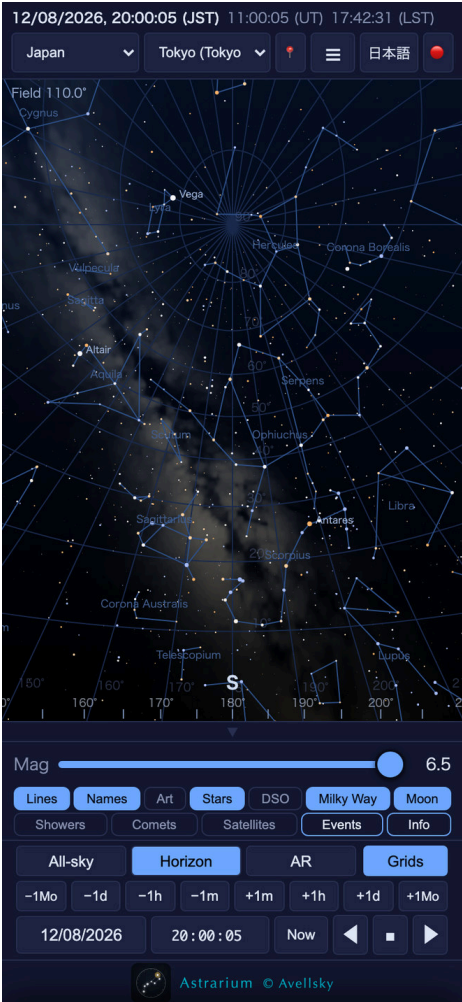


Figure 3. Horizon view, facing south, 110-degree field

4.2 Gestures

Gesture	All-sky	Horizon
One-finger drag	Diurnal rotation — the sky turns about the celestial pole and the clock follows your finger	Pans the view
Two-finger pinch	Zoom about the point between your fingers	The same
Double tap	Recentre on the zenith	—
Tap an object	Opens its information popup	The same
Mouse wheel	Zoom	Zoom
SHIFT + drag	Pans the view centre without rotating	—

Dragging in all-sky view is the planisphere gesture: the dial turns and the simulated time turns with it, so you can feel out how high Orion will be in two hours' time with a fingertip.

4.3 What a tap tells you

The popup gives the name, right ascension and declination, azimuth and altitude and the magnitude, with buttons underneath. **The readings follow the clock while the card is open.** Azimuth and altitude are recomputed twice a second, α and δ , distance, elongation and phase angle each time the sky is refreshed, and the rise, transit and set times when the local date turns over. “(below the horizon)” is added once the object has set.

The Sun, the Moon, the planets and the moons drawn in the zoom view also carry a sentence or two on what they are, and every card gives the **distance** — in astronomical units for the solar system (kilometres for the Moon) and in light years for the stars, from the Hipparcos parallaxes.

Close a card with the **pin (📌)** in its **top-right corner**. Tapping the body of the card does not close it, so a long description can be read without it vanishing under your finger.



Figure 4. Saturn tapped: coordinates, magnitude, rise and set, and two buttons

-  **Zoom in** — puts the object in the middle of the screen, zooms in and starts **tracking** it. While tracking, the object stays centred as the clock runs. Release it with the **Release** button on the chart or the `Esc` key; panning the view does not break the tracking.
-  **Details** (Sun, Moon and planets) — opens a window that draws the body as a disc, recomputed every five seconds so its distance, elongation, phase angle and libration follow the clock too. The figures include the **physical data** — diameter, mass, mean density, rotation period, axial tilt and surface gravity — and scroll inside the window when there are more than it can show.
-  **Polar alignment** (Polaris only) — opens the polar scope's field, with Polaris on an hour-angle ring that follows the clock. The red button in that window switches night vision on and off. The Moon comes with its age, illuminated fraction, libration and popular name (Pink Moon, supermoon and so on); Jupiter with the four Galilean moons; Saturn with the rings and Titan; Mars with Phobos and Deimos. You can drag inside the window.



Figure 5. The zoom view of Saturn, with the rings and its moons

Picking a deep-sky object brings up a photograph and a short description; a comet or asteroid brings up its orbital elements and estimated brightness. Deep-sky names, constellations and descriptions are available in both languages; an object with no Japanese name is listed by its catalogue number in Japanese, with the English name beside it.

Tapping a meteor shower's radiant gives its azimuth and altitude as well as its coordinates, and these follow the clock — so you can see at a glance whether the radiant is up yet.

With constellation art switched on, tapping one of the twelve zodiacal constellations shows the corresponding astrological sign and its birth dates, together with a note that precession has moved the signs about a month away from where the Sun really is.

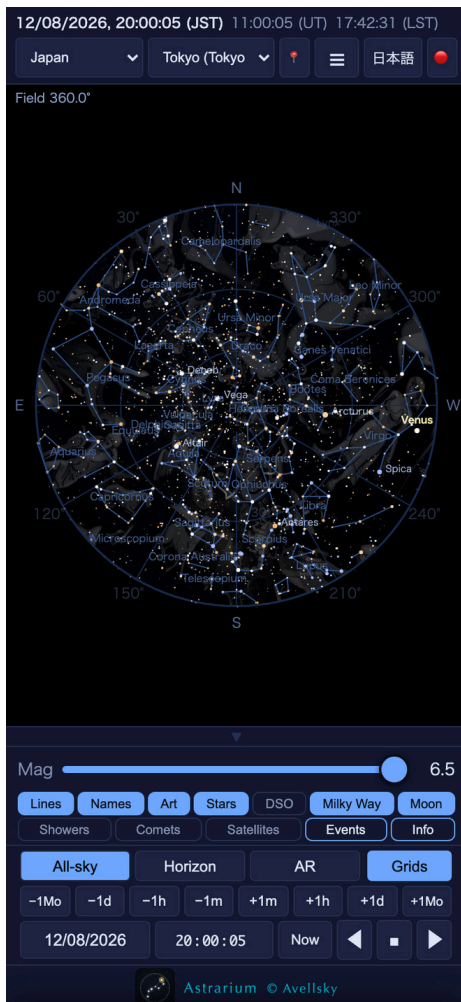


Figure 6. The whole sky with the constellation figures drawn

5. Moving through time

The lower two rows of the time bar do this.

5.1 Steps and playback

Control	What it does
–syn / +syn	Back or forward one synodic month (29.53 days) — the same lunar phase
–1d / –1h / –1m	Back one day, hour or minute
+1m / +1h / +1d	Forward one minute, hour or day
Date button	Opens a calendar. Picking a day keeps the time of day and moves the date
Time field	Type 21:30 and the clock goes to that time on the same day
Now	Return to the present

Control**What it does**

Play backward / forward; each press steps $\times 1 \rightarrow \times 60 \rightarrow \times 600 \rightarrow \times 6000$ and round again



Hold the clock still; press again and it runs from where it stopped

Rate

The speed it is running at — “stopped” when held, “real time” when idle

While it runs the arrow carries the rate in its heads: $\blacktriangleright \times 1$, $\blacktriangleright\blacktriangleright \times 60$, $\blacktriangleright\blacktriangleright\blacktriangleright \times 600$, $\blacktriangleright\blacktriangleright\blacktriangleright\blacktriangleright \times 6000$, and a minus sign on the rate when running backwards. At $\times 600$ one second of yours is ten minutes of sky.

■ also detaches the chart from real time. Idle, the sky still moves at the rate the real sky moves; **■** stops it dead. Stepping the clock still works while it is held, and it stays wherever you step it to.

With a keyboard, $\leftarrow$ and $\rightarrow$ move ± 10 minutes, with `shift` ± 1 day, with `Alt` ± 1 minute, and $\uparrow$ $\downarrow$ move ± 1 hour.

Every date and time is the time at the observing site. Choose a site abroad and the clock, the date button and the time field all switch to that place’s time — not the device’s. The zone abbreviation (JST, GMT and so on) follows the clock in brackets.

In the horizon view the altitude lines run all the way to **90° (the zenith)**, numbered like the rest. In the whole-sky view 90° is a point, not a line.

5.2 Grids

The **Grids** button opens a menu of overlays; you can have several at once.

Overlay**What it is**

Alt-Az grid

Horizontal coordinates — azimuth and altitude

RA-Dec grid

Equatorial coordinates, the system star catalogues use

Ecliptic grid

Ecliptic coordinates; the planets and the Moon keep to this band

Galactic grid

Galactic coordinates; the Milky Way lies along latitude 0°

Celestial equator

Drawn as a single great circle

Overlay

Ecliptic

Galactic plane

Meridian

What it is

The Sun's path, likewise

The great circle at galactic latitude 0° — the centre line of the Milky Way

The north–south great circle objects transit

The spacing of the lines and the precision of the labels follow the zoom level.

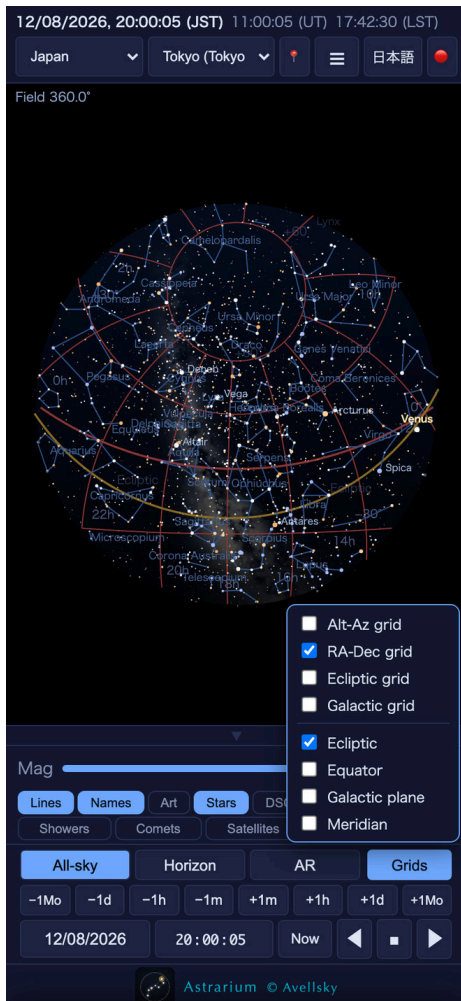


Figure 7. The grid menu, with the RA-Dec grid and the ecliptic drawn

6. What the chart shows

6.1 The quick bar

The slider on the left is the **magnitude limit**. Lower it and the faint stars go, which is much closer to a city sky; raise it and the chart goes to magnitude 6.5, the naked-eye limit.

The first row controls the chart itself, the second the kinds of object.

Button	Shows
Lines	The figures of the 88 constellations
Names	Constellation names
Art	Constellation drawings (86 of them; shown whatever the magnitude limit)
Stars	Names of the named stars
DSO	Messier and Caldwell objects
Milky Way	The Milky Way — drawn in the all-sky view, unbroken down to the horizon
Moon	Sky brightness from moonlight
Showers	Radiants and expected rates of the active meteor showers (chapter 7)
Comets	Every comet currently bright enough (fetches elements the first time)
Satellites	The space stations on the chart (fetches elements the first time; chapter 11)
Events	Opens the Events tab
Info	Opens the Info tab

AR, in the first row of the time bar, draws the chart over the camera image (chapter 11).

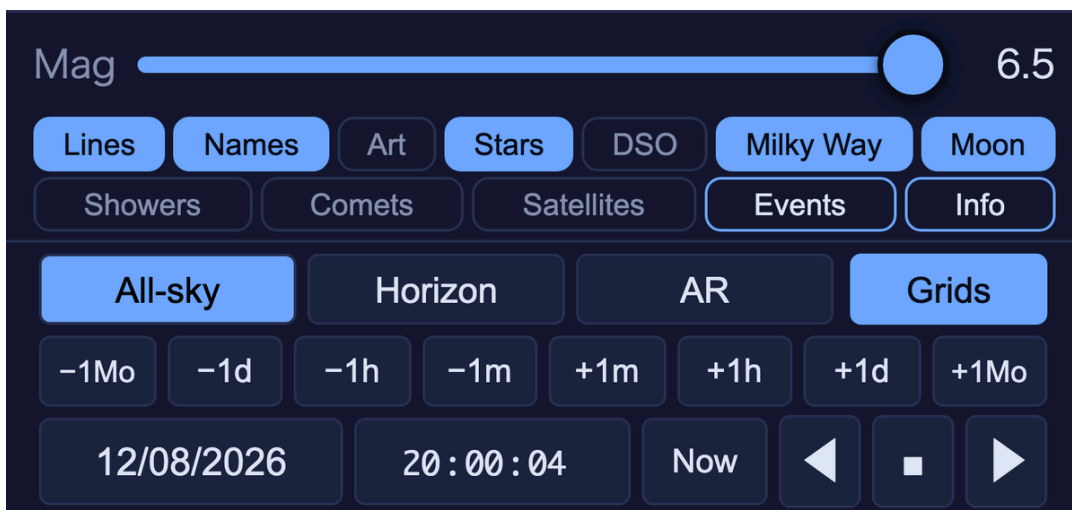


Figure 8. The quick bar and the time bar

6.2 The View tab ($\equiv \rightarrow$ View)

Everything the quick bar does not carry lives here.

- **Sun, Moon & planets** — show or hide them.
- **Stars** — show or hide the stars. Switch them off and the constellation lines stand on their own.
- **Sunlight** — daylight and twilight. Switch it off to draw the sky as if it were always dark, which is how you check where the stars are in the daytime.
- **Moonlight** — the wash of a bright Moon. It switches separately from sunlight, so you can leave the daytime sky as it is and take out only the moonlight to see what the stars would do.
- **Mirror** — flips the image for a telescope finder that inverts.
- **Star trails** — leaves a trail behind moving objects during playback, so diurnal motion and satellite passes are drawn as lines.
- **Long exposure** — keeps the trails instead of letting them fade, so the tracks build up as they would on film (switching it on switches trails on too).
- **FOV frames** — rectangles for a camera field or circles for an eyepiece, laid over the chart. “Add frame”, then give it a sensor size and focal length, or an apparent field and a magnification. Drag the centre to move the frame, click the centre to zoom to it, drag a corner to rotate. Useful for framing a photograph, or for seeing what will fit in the field.
- **Mag limit** — the same slider as on the quick bar.

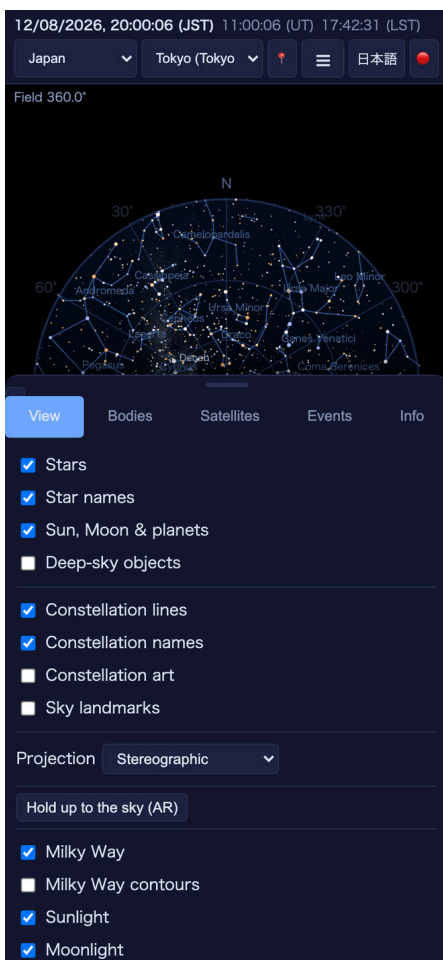


Figure 9. The View tab

6.3 Export as PNG or PDF

Saves the chart for the current time and site as an image. Because these are meant to be printed and taken outside:

- the background is white paper and the stars and lines are black,
- sky brightness (sunlight and moonlight) is left out,
- the Milky Way is drawn **as contours only**, not filled,
- the date, time and Astrarium © Avellsky appear in the bottom right corner.

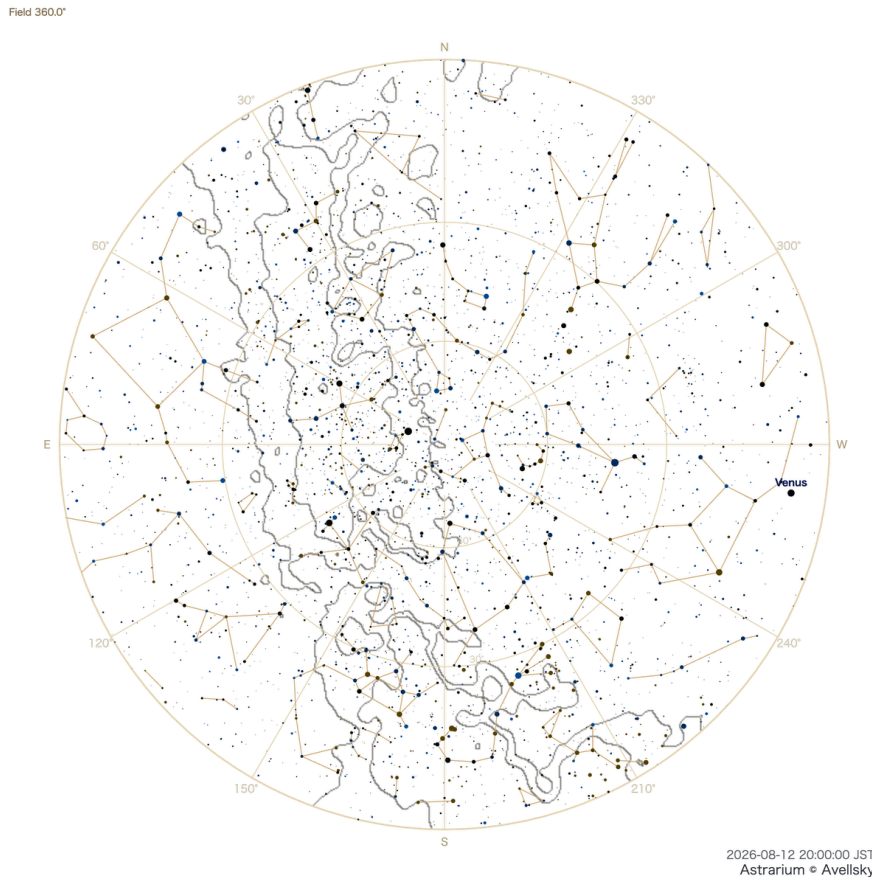


Figure 10. An exported chart: the Milky Way drawn as contours on white paper

Where files are saved

Output	Goes to
PNG (chart)	Pictures/Astrarium
AR capture (JPEG)	Pictures/Astrarium
PDF	Download/Astrarium

The PNGs and JPEGs show up in your photo app; the PDFs open from the Downloads folder of a file manager.

These live in shared storage, so **they remain after Astrarium is deleted**. Remove them from the photo or file app when you no longer want them. (The settings the app keeps for itself — site, language, display switches — do go when the app does.)

6.4 Demo and recording

Demo is a tour of a few minutes. It plays without sound; each scene is described in captions below the chart. It runs through twilight, the Milky Way and moonlight, the apparent size of a planet, Saturn's rings and moons, FOV frames, the Moon's libration, deep-sky objects with photographs, a meteor shower, a long exposure, the language switch and diurnal motion. Touching the screen ends the tour and restores what you had.

It takes a moment to get ready before the first scene appears — a note under the button says so. While it runs, the button turns red and reads **Stop demo**, so you can end it at any point.

Record saves the moving chart as a video (if the device cannot do it, the button says so). Start recording during the demo and the file saves itself when the tour ends.

7. Meteor showers

Use the **Bodies** tab or the **Showers** button on the quick bar.

7.1 The list

The menu holds the principal showers of the year, sorted by **how close their maximum is to the date on the chart**. Choosing one moves the clock to **the moment of that maximum** and opens the details; where the maximum falls in daylight, it moves to about 1 a.m. that night instead. Clicking the radiant on the chart itself leaves the clock where it is.

Field	Meaning
Maximum	Given both in Universal Time and in the local time of your site
Radiant	Right ascension and declination, with its altitude at maximum and now
Entry speed	How fast the meteoroids meet the atmosphere

Field	Meaning
Population index r	The proportion of bright meteors; the smaller, the brighter
Parent body	The comet or asteroid the stream came from
Expected rate	Meteors per hour, from the model below

7.2 How the rate is worked out

The figure in “per hour” is not the ideal ZHR — it is **what you can expect from your site at that moment**. Four factors are multiplied together:

1. **Distance from the maximum.** A Gaussian profile: about a day either side the rate has fallen to the sporadic background, and outside the activity period nothing is shown at all.
2. **Radiant altitude.** The lower the radiant, the fewer meteors; below the horizon, none.
3. **Twilight.** Zero between sunrise and sunset, reduced during twilight in proportion to how bright the sky is.
4. **Moonlight.** Reduced according to the Moon’s phase and altitude.

Active showers are also listed in an orange box at the top of the chart. Tapping a name in the box opens its details; **Release** clears the box (and turns off the Showers button on the quick bar with it).



Figure 11. The Perseid maximum (13 August, 3 a.m., 72 per hour expected)

8. Comets and asteroids

The lower half of the **Bodies** tab.

- **List bright now** — the comets and asteroids in the sky, brightest first.
- **Search** — by any part of a name or designation. If the object is not in the local data, Astrarium asks JPL for it and adds it (needs a connection).
- **All / Comets / Asteroids** — filters the list.
- **Selected** — the objects drawn on the chart. Anything you put here is plotted.
- **Update from MPC** — fresh comet elements from the Minor Planet Center and asteroid elements from JPL. The date of the last fetch is shown underneath.

Tapping a comet on the chart gives its distance from the Sun and from the Earth, phase angle, estimated diameter, orbital elements, period and epoch.

9. Events

The **Events** tab lists eclipses, oppositions and conjunctions, solstices and equinoxes, meteor maxima, close approaches of the Moon and planets, and occultations.

- **Period** — what is next, the next 7 days, 30, 90 or 180 days, 1, 5 or 10 years. “What is next” looks up to 90 days ahead and shows **the next event only**.
- **Direction** — upcoming, past, or both (fixed to upcoming for “what is next”).
- **Kind** — one at a time:
 - **All astronomical events** — eclipses, oppositions, conjunctions and stations, the solstices and equinoxes, the Moon’s phases, perigee and apogee, the meteor maxima.
 - **Occultations** — the Moon passing in front of a star, with immersion or emersion, dark or bright limb, and the star’s magnitude.
 - **Naked-eye satellites** — visible passes of the ISS and the CSS.
 - **Eclipses** — with local circumstances (magnitude and times for your site). The last three list only what can actually be observed from your site — above the horizon and in a dark enough sky. Where nothing qualifies, the tab says how many fell in daylight or below the horizon. “All astronomical events” is not filtered.
-  **Search** starts the scan. While it runs the button reads “🕒 searching 12s — press to stop” and pressing it does stop; the list below is dimmed so that the previous answer is not mistaken for this one.
- Tap a row and **the chart jumps to that moment**; the panel closes so the chart is in front of you.

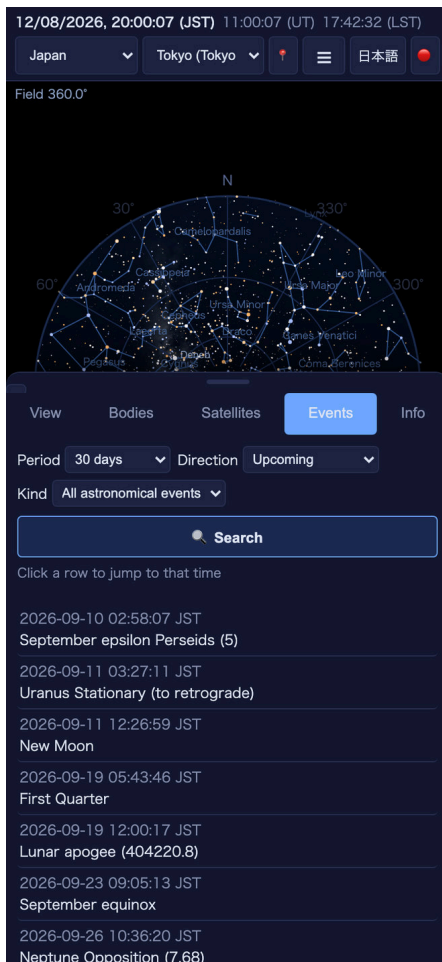


Figure 12. The Events tab

10. The Info tab

- **The sky for the date and place you have chosen** — sunset and sunrise, the beginning and end of twilight, the dark window, moonrise, moonset and lunar age, the transits of the Sun and Moon, the traditional lunisolar date and solar term, and local sidereal time. The heading names them both — “Tokyo — 22 August 2026” — and moving the clock to another date changes the table with it.
- **Selected object** — the position and rise/set times of whatever you last tapped on the chart.
- **Credits and sources** — every catalogue, ephemeris, image and library the app uses, with its source, its licence and the date it was last checked. It follows the language setting.

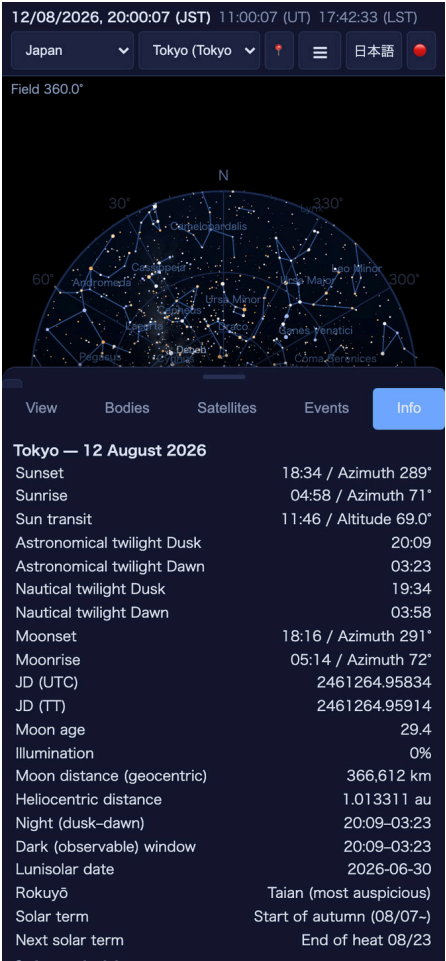


Figure 13. The Info tab, “Tonight’s sky”

11. Satellites and AR

11.1 Satellites (the space stations)

What this shows are the **space stations** — the International Space Station (ISS) and Tiangong, together with the craft docked to them. They cross the evening and morning sky faster than an aircraft, and without blinking.

Open ≡ → **Satellites**, or the **Satellites** button in the quick bar.

- 1. Press **Download / update TLEs** to fetch the orbital elements (this needs the network, once; everything after that is computed on the device).
- 2. Tick **Show on chart** and the stations above your horizon are drawn.

Control	What it does
Projection	All-sky or horizon — the same two views as the time bar
Magnitude limit	4 by default; anything fainter is not drawn

Control

Sunlit only

What it does

Only craft outside the Earth's shadow, i.e. lit by the Sun. Those are the only ones you can actually see

The list in the tab holds whatever is up right now, highest first. **Press a row and you get its coming visible passes** — when it rises, from which bearing, how high it climbs, where it sets and how bright it gets — with the track drawn across the chart. Pressing the craft on the chart does the same.

Choosing **Naked-eye satellites** under **Kind** in the Events tab puts the same predictions in the events list, alongside everything else.

Above $\times 600$ the display of satellites pauses: the calculation cannot keep up.

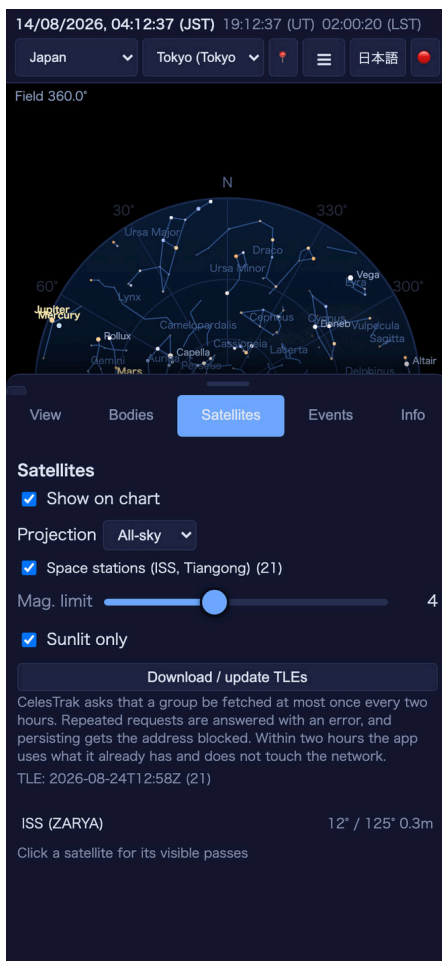


Figure 14. The Satellites tab: the space stations, and whatever is up right now

About the fetch interval. Celestrak asks for no more than one fetch per group every two hours, which is how often the elements are updated. Fetching faster than that returns an error, and persisting gets the connection cut. Astrarium records when it last fetched and,

within two hours, answers from the stored copy without using the network at all. This is not thrift — it is how the block is avoided.

11.2 AR — the chart over the live camera

Press **AR** in the first row of the time bar and the chart is drawn over the rear camera image. Hold the device up to the sky and the constellations in that direction line up on screen. The first time, Android asks for camera permission.

On Android there is no north to line up by hand. The device reports its orientation against true north, so the chart is already aligned the moment AR opens. (On the iPhone the magnetic declination sometimes has to be nudged out with the bearing slider.)

The control panel at the bottom has four rows.

Row	What is in it
1	Field of view and bearing sliders, night mode
2	What to draw: stars / constellation lines / names / art / landmarks / Milky Way / Sun / Moon and planets / alt-azimuth / equatorial / equator / ecliptic
3	The magnitude slider
4	Date and time, Now , Reset , the bearing and altitude you are facing, Shoot (twilight, Moon, stars) and Exit AR

- A button lights up when it is on, so what is being drawn is visible at a glance.
- The **bearing** slider is there to nudge the chart when magnetic interference has put it off. You will not normally need it (north comes from the device, as above) — only near steel or magnets, where you line it up on a bright star. **Reset** throws the nudge away and goes back to the sensors.
- **Shoot** combines the camera image and the chart into one picture (**Pictures/Astrarium**). The three buttons are exposure presets (twilight, Moon, stars): the darker the subject, the longer it stacks. Leaving a little of the landscape in the frame, or turning the alt-azimuth grid on, makes the bearing readable afterwards.
- **Exit AR** restores the display settings you had before entering.

12. If something looks wrong

Location does not work

Settings → Location → App location permissions, set Astrarium to “Allow only while using the app”, and turn **Use precise location** on. You can also skip location altogether and type coordinates into the Info tab.

I cannot find what I exported

Charts and AR captures go to **Pictures/Astrarium**, PDFs to **Download/Astrarium**. They can take a moment to appear in the photo app.

No comets appear

The Comets button shows nothing when no comet is brighter than the limit, and fetching current elements needs a connection.

No meteor rate is shown

You are more than a day from the maximum, or outside the activity period. The rate is also zero in daylight.

Too few or too many stars

Move the magnitude-limit slider. To match a real sky, a city is about 4, the suburbs 5-something, and a dark mountain site 6.5.

No satellites appear

Either the orbital elements (TLEs) have never been downloaded, or playback is faster than $\times 600$. With “Sunlit only” ticked, craft in the Earth’s shadow are hidden.

TLEs will not download, or the address has been blocked

CelesTrak answers a caller that fetches the same group more often than every two hours with an error, and blocks the **IP address** if it continues. The block is against the connection, not against your device or account, so:

1. Stop fetching and leave it alone for a while. Astrarium does not touch the network within two hours of a fetch, so ordinary use will not get you blocked.
2. Switching networks (Wi-Fi to mobile data, or the other way) changes the address and often works. On shared Wi-Fi the cause may be someone else on the same connection.
3. If it does not clear, ask CelesTrak (celestrak.org) to lift it.

While blocked, **the elements you have already fetched still work**. They lose accuracy over a few days, but the chart and the pass predictions keep running without a connection.

The event list is slow

Only the first 5- or 10-year scan, which takes a few minutes. It runs in the background and fills in when it finishes; the result is cached, so the next one

is immediate.

In AR the chart does not line up with the sky

Steel-framed buildings and cars upset the compass. Step outside and press **Reset**, or correct it by hand with the **bearing** slider.

13. Glossary

Term	Meaning
Magnitude	Brightness; smaller is brighter, and one magnitude is a factor of about 2.5
Azimuth / altitude	Direction round the horizon (north 0°, east 90°) and angle above it
RA / Dec	Coordinates fixed to the sky — the system star catalogues use
Local sidereal time	The right ascension currently on the meridian
Universal Time	Time at longitude 0°
Moon age	Days since new Moon; 0 is new, about 14.8 is full
Illumination	The fraction of the Moon's disc that is lit
Airmass	Thickness of atmosphere, 1 at the zenith; the larger, the worse the seeing
ZHR	Meteors per hour with the radiant overhead and a 6.5-magnitude sky
Radiant	The point the meteors of a shower appear to come from
TLE	A satellite's orbital elements; they go stale in a few days and need refreshing

14. Credits and contact

Every source Astrarium computes from is listed in the app under **Info** → **Credits and sources**. The principal ones are:

- Planetary ephemeris: JPL DE421
- Stars: Yale Bright Star Catalogue, Tycho-2

- Deep sky: the Messier and Caldwell catalogues; photographs from Wikimedia Commons (freely licensed images only)
- Satellites: Celestrak (TLEs), SGP4/SDP4
- Comets and asteroids: Minor Planet Center, JPL Small-Body Database
- Earth orientation: IERS finals2000A

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