

Compared to the people I met at the 2023 NASS Conference in Ann Arbor I feel like an accidental dialist. Given your dedication to sundialing, the kind interest you showed in my story is inspirational for me. Thank you again.

Preliminary Notes from the Field and the Axial Sundial

My mother was interested in Heinrich Schliemann. Heinrich suspected the writings of Homer were literally true. In 1868 he went to the Eastern Mediterranean and, following Homer's indications, began digging. For starters, he found Troy.

Schliemann's story encouraged me to honor similar notions of my own. One such notion was: to understand Stonehenge, stand in a clearing and watch the sky.

I finally got around to it sixteen years ago. The idea was to build on personal observation and to avoid or at least be aware of secondhand knowledge. I did not see I was stepping into something so alive. As Skip McCoy said in the movie *Pickup on South Street*, "Sometimes you look for oil, you hit a gusher." Gusher indeed. Every insight I grasp bursts free into something more complicated and runs on ahead.

Preparing this talk has refreshed my surprise that these insights have been cultural

as much as they have been astrophysical. Richard Rorty in his book *Contingency, Irony, and Solidarity* had long since convinced me “Truth is made not found,” so maybe that should not have been such a surprise.

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Intuitively it seemed reasonable, if that makes any sense, to start by fixing a location with a post – a gnomon, and to define a field around it. Maybe I am giving myself too much credit, but a circle just seemed like the right thing.

The coldest part of most days is at sunrise. There is always a lot of bird activity – small groups, higher than usual, longer overflights. It's an inspirational time. The eastern horizon is a gradient from pale sky through increasingly dense black branches down to a solid band of shrubbery. The intense brilliance of the sun can pierce through this band at unsuspected low levels.



Summer Solstice 2019 Sunrise, 6:15 EDT.

The first glimpse of sun is just off the handle of the spoon in my coffee cup on top of the gnomon. The circular plate attached to the gnomon is a transit quadrant. The sighting device is a ½" copper tube.

I stand on the circumference sighting over the gnomon where I expect the sun to rise and rock from side to side to coax a flash of sunlight through the leaves and branches. Sometimes I catch a flash and wonder to myself, "Is that a patch of bright sky or is that the sun"? I don't know how many times I have relearned that if there is any question at all, it's not the sun. At its first sight, in line with the sun and the gnomon I place a stone at my feet.

Simple insights you might anticipate into Stonehenge came fast. For instance, after accidentally kicking yet another carefully set stone out of place, I said, "That's enough of

that! I want some big damn stones!" Stonehenge's ring of lintels made sense as an artificial horizon after I saw how much the seasonal foliage on trees and bushes altered the level of the horizon.

Information derived in the circle was to be stored strictly in the circle's configuration. No notes scribbled on the stones, no legends recorded back in the house, no diagrams. Although I didn't foresee it, this lack of documentation brought what I was doing closer to my original intent than anything else. It brought me into the circle on an immediate emotional level.

But there are many different ways to look at the stone circle. It can be very disorienting. Some days I walked into the circle and I was totally confused. What am I trying to do here? Is this a projection of the sky? Is it a reflection? Have I been seeing the circle as the azimuth or as the ecliptic, or what? The answer is always "yes!", which you might notice doesn't help at all.

For me there is a limit to the amount of information a stone can hold. It slowly dawned on me that the only way the flood of unending and overwhelming observations can be carried forward is in the meaning of a story, a metaphor that bumps perspective up a conceptual level.

The notion of story is very interesting. It is a form of memory. It is synchronic in itself in the same way the memory of, say, a close friend is. When I remember a friend the memory arises whole and instantly. I have never had the sense of a memory as a sequential download.

I haven't found a good place to fit this remark in, so I'm just going to say it now: there is nothing about sundial time that implies clock time. Sundial time is synchronic in itself, the same way a story is. Clock time is perfectly diachronic. But just as we "tell" clock time, we can "tell" a story.

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The stone circle provides an excellent image for the notion of a cycle. Over the course of a few years the length of a trammel has been refined to measure out the distance a stone representing the sun moves along the circumference each day in a yearly cycle. Currently it is 7 – 1/16" long.

For years I have also adjusted the length a lunar trammel to advance the lunar stone. It is currently 98 – 3/4" long. Occasionally it measures a synodic month perfectly – but only occasionally. Often the moon stone requires a reset at some identifiable point in the moon's orbit. I don't know what to do about that yet, but I savor the mystery. These two stones bear an imprecise but interesting relation to the actual positions of the sun and moon in the sky.

Accuracy is a constant issue in the stone circle. I have to remind myself that there are two kinds of numbers: flock numbers and field numbers. Flock numbers are: how many sheep are in that flock? Or, how many moons does earth have? Field numbers are different: how big is that field? What is the size of that angle? Well, that depends: how close are you going to cut it?

When I get carried away regarding accuracy I remind myself I'm not even sure how long a year is yet, although I do assume there is something like a year and it's somewhere around 360 days. If you think counting the days in a year should be a simple task, I suggest you try it. Are you absolutely sure you have not missed taking your medications even in the last week? Is taking your pills complicated by the weather?

You might be tempted to assume that the equinoxes divide the yearly cycle in half. But observation will not show that at all. So, where did that discrepancy creep in? Is it an observational error or is it something significant? A doubt, a lapse of attention, a questionable stone is very expensive: checking could easily cost another year.

On the other hand, a very early observer might not have been tempted by such assumptions and projections. What was there

for the early observer except another observation?

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It did not take long for the sporadic appearances of the moon to distract my attention. Since I know so little about lunar mechanics it has provided the purest test of this stand-in-a-clearing-and-look-at-the-sky exercise.

Marking the times of the new and full moon seemed immediately worthwhile. Direct observation of the new moon isn't possible and fullness is not all that easy to determine either. I tried to understand the moon's movement by pointing at the sun and moon and then, trying to keep my arms fixed at that angle, turn to the stones for some correlation.

One spring I got the idea of measuring the moon's daily approach to conjunction with the sun and then measuring its daily departure. Using that information I hoped to infer backward to where the new moon had happened. But these measurements required more precision than the "holding arms at an angle" method. By chance I was standing next to a good-sized mullein stalk . I used it to maintain the spread of my outstretched arms when my index fingers touched the sun and moon. It worked great.

I marked successive day's positions on the stalk and from that determined a rate of movement. It took a while to learn to how to hold the stalk and how to sight on it with repeatable results. But it can be done quite accurately. For instance, I know that within 4 days either side of the sun, the moon moves around 13 cm on the stalk each day. A stone to mark the new moon can be placed with some confidence.

Another difficulty is that the moon's motion does not follow the ecliptic exactly. How it deviates requires a lot of altitude measurements. If I hold the staff vertically at a careful arm's length in front of myself, touching on level ground facing the moon or sun, staring first straight ahead at the horizon and then, holding my head still, look up along the staff to the sun or moon, I can mark a surprisingly accurate altitude. Being careful to compare altitudes taken at similar hour angles reveals relative declinations of the sun and moon. A stone can be placed to mark the rough estimate of a node passage.

Still, it is incredibly easy for me to lose track of the moon. How many of you know where the moon is in the sky right now? Its altitude relative to the sun? Rough rising or setting points?

But it was the significance of the staff that hit me like a lightning bolt. I am sure the staves depicted in ancient art were loaded with

information. This information was accessible only on a personal level: one's height, the length of one's arms, the idiosyncratic use of one's eyes, one's own private way of marking the observations: one's personal story.

The very interesting book ***Dividing the Circle***, *The Development of Critical Angle Measurement in Astronomy 1500 – 1850* by Alan Chapman, 1995, Praxis Publishing, makes the point that it was not the invention of the telescope that ushered in the great revolution in astronomy and cosmology in the mid sixteenth century, but the development of tools and skill for measuring angles. Tycho Brahe's records revealed the 8 minute discrepancy between Kepler's theoretical computation of Mars' position and where Brahe had measured it to be. Kepler's solution gave the elliptical shape of Mars' orbit.

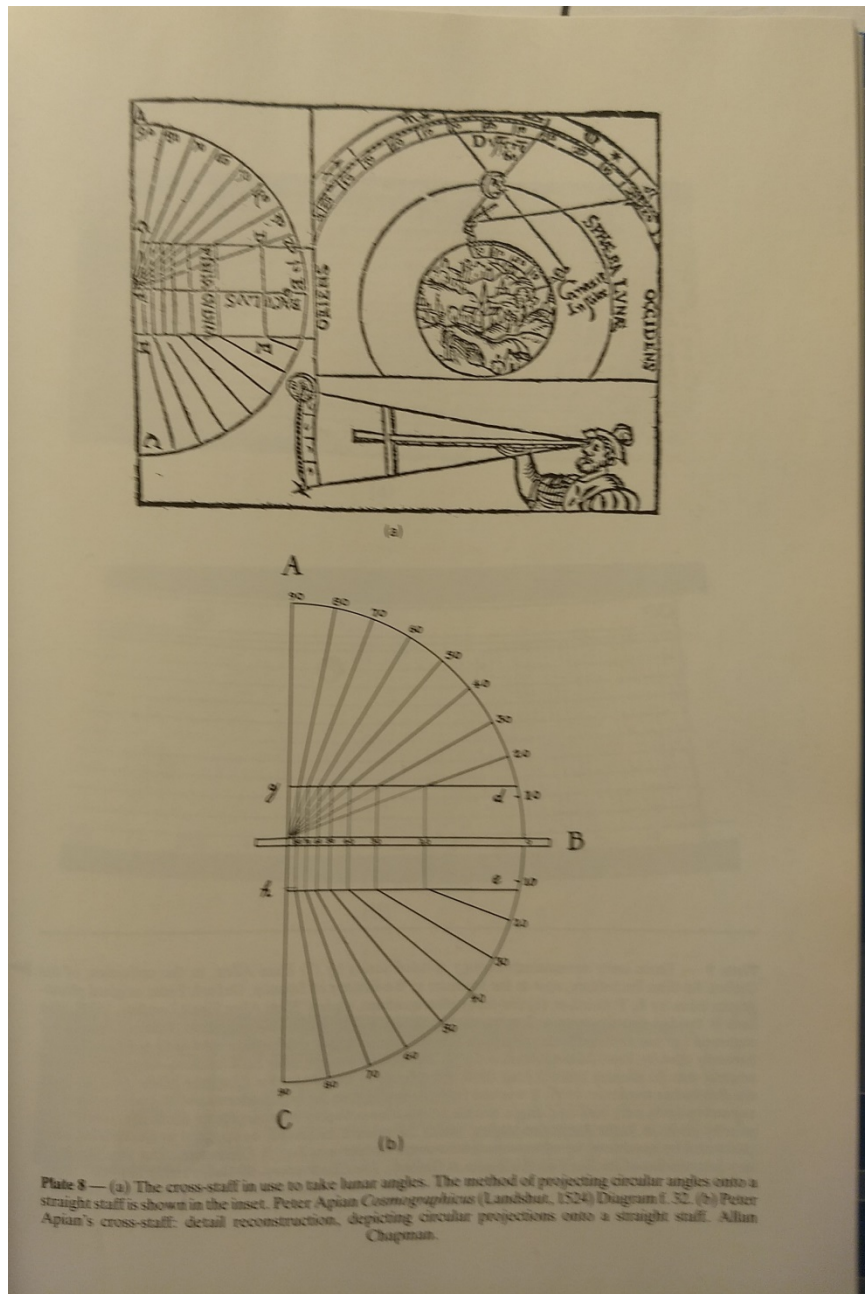


Plate 8 — (a) The cross-staff in use to take lunar angles. The method of projecting circular angles onto a straight staff is shown in the inset. Peter Apian *Cosmographicus* (Landsbat, 1524) Diagram I. 32. (b) Peter Apian's cross-staff: detail reconstruction, depicting circular projections onto a straight staff. Allan Chapman.

The Cross-Staff from *Dividing the Circle* by Chapman

Chapman documents the cross-staff as one such development. Its chief virtue you might guess is that it is not as idiosyncratic as a mullein stalk. But Chapman praises it because it uses a simple linear scale to arrive at angular measurement through trigonometry. Accurate

circular scales were more desirable but producing them was very problematic.

Early staves, however, were beyond instruments. They symbolized entire life stories of culturally foundational significance.

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It didn't take long for me to get distracted by the turning of the stars either. It's easy to be drawn to Polaris. I assumed the small spread of stones I had placed to mark Polaris relative to the gnomon was due to sighting errors on my part. For objects that don't cast a shadow, it is difficult to get my eye close enough to the ground to accurately sight over the top of the gnomon. For those sightings I use a mirror placed on the ground. Using a mirror to sight Polaris more carefully only confirmed the previous discrepancy. I was surprised that the offset of Polaris from the celestial pole, less than one degree, was something I could resolve.

A string stretched from the top of the gnomon to the middle of Polaris' projection points made the earth's axis visible. Imagine my satisfaction at such incredible good luck! The axis of the entire universe went exactly across the top of my gnomon!

A story critical to the realization of the axial sundial was a second string from the base of the gnomon perpendicular to the axis string. It revealed the equatorial plane – paralleled by

the daily paths of the sun, the moon and all the stars across the sky!

It was a revelation to see that for all I had heard about the angle of the sun's rays changing throughout the year, the angle of the sun's passage does not change. It's the origin, the place of sunrise, that changes and that affects the ultimate altitude of the sun. The yearly path of the sun is actually a helix, but the movement I experience on a daily basis seems planar. This was a big breakthrough. I felt an internalization of the axis in my understanding.

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Early spring of 2020, the first COVID year, my wife and I were driving to an early morning nerve wracking get-in-and-get-out-fast grocery shopping run. Driving by a high school I saw patches of the first sunlight on the sides of an unusually large diameter light post next to the athletic field – and that was it: the entire stone circle appeared as one clear story in that instant: the complete sense of an axial sundial.



The epiphanigenic light pole

But it was a feeling, not a design of parts. It took three years to bring it into form. How to begin was a search. Even after it seemed to be on the right track and was coming along well enough I would discover that I was completely misunderstanding it. But it worked anyway! That's the part that gets me! It took a long time for me to realize, for instance, that the central cylinder of scales does not rotate.



An early attempt to realize the axial design

Mixed in with all this was the sense that it should work in a straightforward manner anywhere on earth. Do you know that all of China is one time zone? That stumped me for a while. And I hate daylight savings. My first daylight savings adjustment to the dial was in the wrong direction. When I complained to a friend he comforted me. He said, "Don't worry,

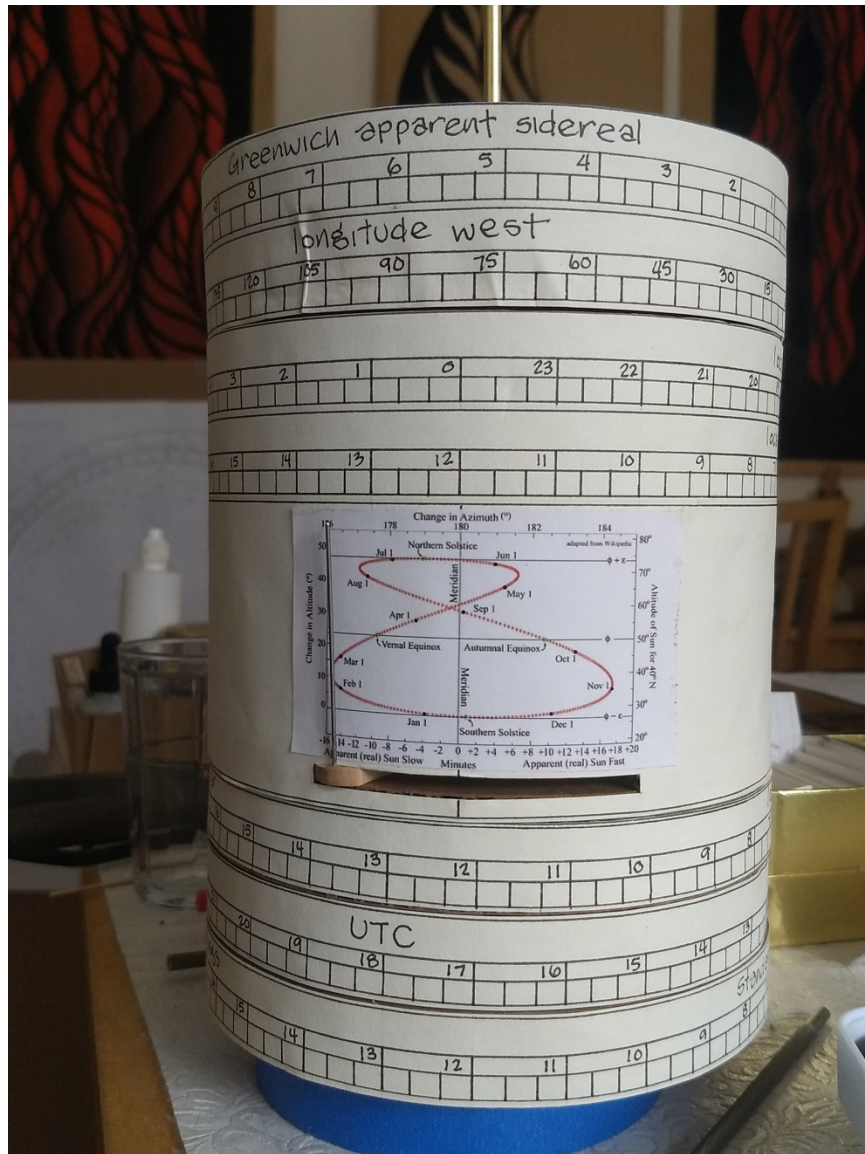
daylight savings is always in the wrong direction.”

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So, here is what I found out by standing in a field and watching the sun come up. The stone circle is somewhere past 16 years old now, its information thoroughly overwhelming: plenty of material for a good story. It begins with a 6' gnomon surrounded by a 72' diameter circular path and the placement of hundreds of stone markers. A more accurate description is to simply admit it took on a life of its own.

Although I couldn't have articulated it at the time, I needed this story to get hold of what was happening in the stone circle. In a deeply satisfying fashion this sundial is the dialectical product of the stone circle and myself. It is a memory storage device. I just never expected it to be anything like this.

This sundial will work anywhere on Earth, first by inclining the axis to the location's latitude using the scale on the Latitude Cradle. Then the central cylinder is turned to put the location's longitude under the wire index at the superior meridian. The central cylinder is analogous to the plate of a planar sundial.



The Central Cylinder

The cylinder is shown set for 82W. The 3rd and 4th unlabeled bands are Local Sidereal and Local True Solar times. The Analemma Lever is set at maximum slow Equation of Time correction which has rotated the Local Mean Solar band directly below it approximately 15 minutes ahead. The UTC band and the Standard Time band below it are incorrectly set. They should show 17:30 and 12:30 at the meridian respectively.

Starting from the top, the two upper dial scales, Greenwich Apparent Sidereal and

Longitude essentially show the same thing and are in a fixed relationship.

The next lower two scales, Local Sidereal and Local True Solar times, are also in a fixed relationship. They are turned to place zero Local Sidereal and Local True Solar Noon at the superior meridian index wire.

The meridian of the Equation of Time Analemma band is permanently aligned to the superior meridian index wire. These five scales are locked to each other and to the axis. Once set they do not rotate. The scales below the Analemma band do rotate slightly to add or subtract for the Equation of Time.

The untitled band below the Analemma band is the Local Mean Solar band. It is connected to the Analemma band so that Noon Local Solar is under the Meridian Wire when the Analemma lever is set at zero plus or minus Equation of Time. To allow an Analemma Figure large enough to be easily readable the effect of the Analemma Lever travel is reduced through a linkage to rotate the time Local Mean Solar time band the proper amount.

The UTC and Standard/Daylight Savings scales below the Local Mean Solar scale can be set to accommodate any time zone and daylight savings scheme and then are locked up to the Local Mean Solar band.

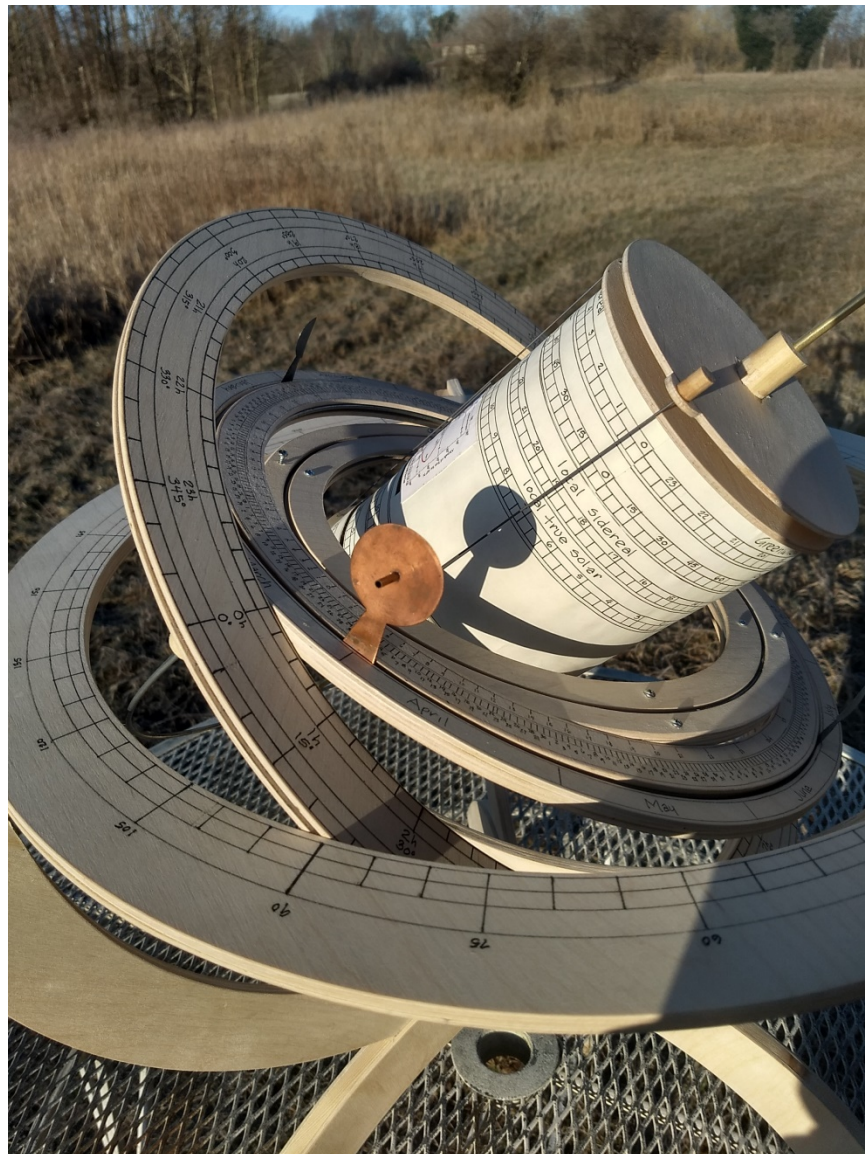
The largest ring is the Horizon Ring and shows Azimuth. Turning within the Horizon Ring is the Celestial Equator Ring showing RA in both hours and degrees. This Equatorial Ring is connected to and turns the umbrella-like representation of the Celestial Sphere at the top. The Sphere, configured here for the northern hemisphere, has icons of the Big Dipper and Polaris, allowing the dial to be functional at night. The extent of the Sphere is the tropic of the handle end star, Alkaid.

The Ecliptic Ring is fixed at a 23° angle within the Equatorial Ring. The sun token with the oculus tube is in a track that allows it to be advanced manually to daily positions labelled along the Ecliptic. The oculus tube is the gnomon of this dial. Three tokens showing the phases of the moon progress with the sun token.

Similarly, the moon token is in a track within the Lunar Ring and is manually advanced day by day using a week long template. The Lunar Ring is angled 5° to the Ecliptic. To update the location of lunar node passage the Lunar Ring's connection to the Ecliptic Ring can be turned to align with monthly positions marked by a year-specific template on the Ecliptic Ring.

In use, the axis is oriented north-south and the Horizon Ring is adjusted to be level. The Analemma lever is aligned to the time of year and with the sun icon set at the current date,

the Equator Ring is rotated until the spot of light shining through the oculus tube comes into sharp focus on the central cylinder. An index wire can be rotated to pass through the spot of light and extend along the cylinder through the various time scales. Solar times work from the moment of sunrise to sunset.



The Axial Dial debut, April 2, 2023

Sidereal times are read directly by sighting radially through the First Point of Aries onto the

Greenwich and Local Sidereal time bands.
Orientation of the Big Dipper icon to the
constellation itself advances the Sun token
which by its position still functions to indicate
time at night.

It is revealing to see how the solar day
moves slowly ahead of the sidereal day over
the course of a year. It is interesting to set the
sundial to 90° latitude and explore the
mechanics of the midnight sun, or set to the
Equator to see how the lengths of days and
nights remain about the same throughout the
year, but that the sun becomes a tricky cue for
finding direction.

The interactive aspect of the axial sundial is
essential – the same way stepping into the
stone circle is.