CIELO
MANUAL

Contents

Figure 1: CIELO sundial

retaining ring

north pointer

meridian ring

°S 70 60 50 40

°N 70 60 50

date disc

north stopper

sun sphere

9 am LAT

south stopper

gnomon

WINTER

MAR APR MAY JUN

LONDON 52°N

PARIS 49°N

ROME 42°N

BERLIN 53°N

CAPE TOWN 34 S

ISTANBUL 41°N CAIRO 30°N MOSCOW 56°N

world cities
with latitude

south pointer

equator ring
with time scale

EQUINOX SUMMER

SEP

JUL AUG

JAN DEC NOV

[2]
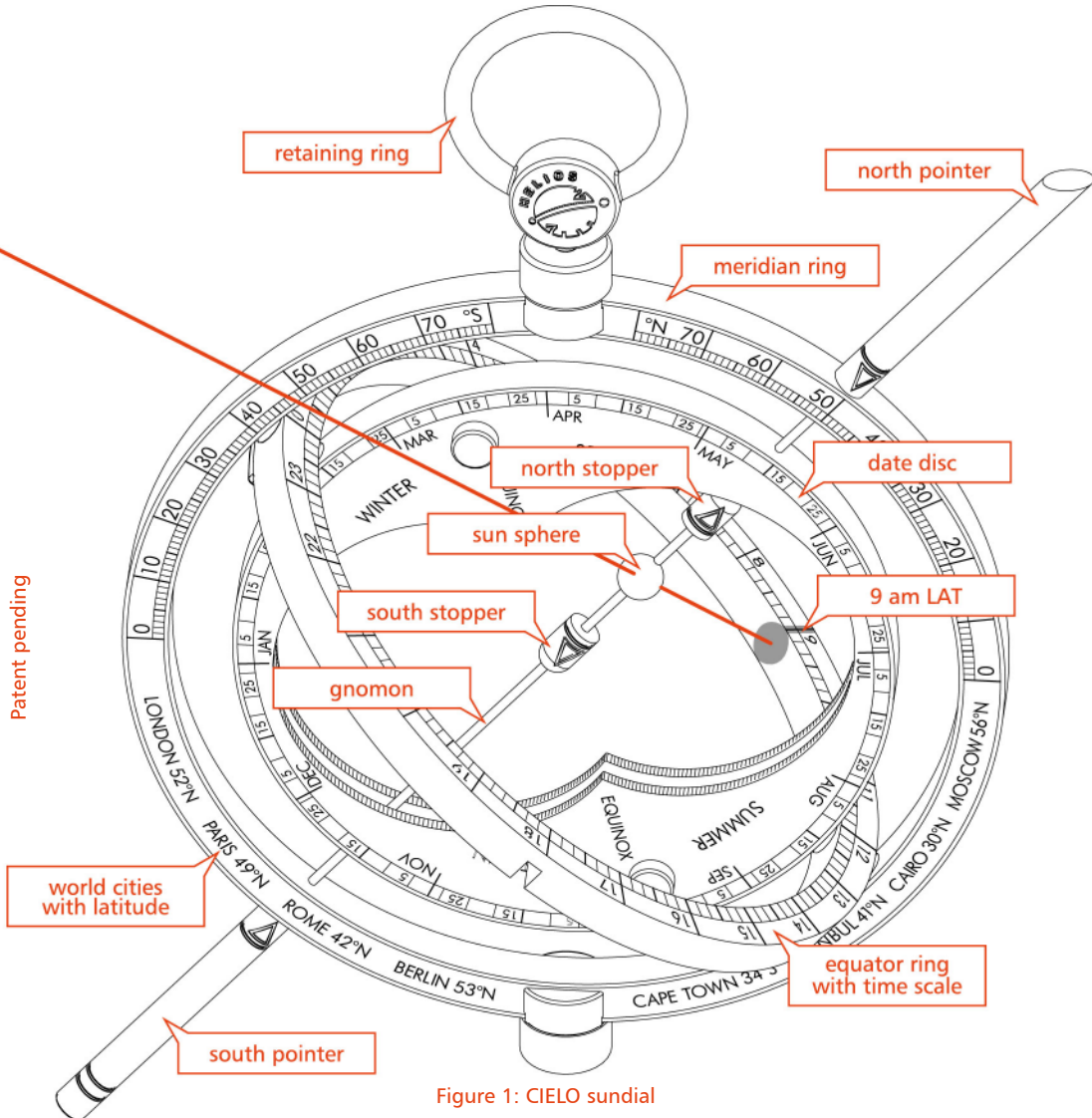
CIELO – Celestial times

The CIELO [*ital. heaven*] sundial is not only a useful instrument for telling the time, it is also a model of the celestial firmament. Our time of day is determined by the apparent celestial course of the Sun around our globe. The CIELO sundial clearly demonstrates to us how time can be understood from a cosmic point of view.

The CIELO sundial is the highest stage of development in the classic equinoctial ring sundial from the sundial's "Golden Age" between the 16th and the 18th century, when mechanical clocks were still inaccurate and expensive. The local time as measured by sundials was the official time for civic life.

The ring sundial is called the "Queen of Sundials", since it is the only portable sundial which can find due south without a compass and can be used at any latitude throughout the world. The standard construction of this instrument originated mid-17th century and has hardly changed since then. A pinhole is set to a specific date and the spot of light projected by the sunlight permits the sundial to be adjusted to a north-south direction and to display the time.

The ring sundial CIELO is the modern advancement on the "Queen of Sundials", improved in many respects. The three most important innovations are:

> When positioning towards due south, the conventional pinhole has to be turned several times so that the sunlight can fall through it. The CIELO's gnomon with its sun sphere throws a consistently visible shadow independent of direction, so that it is much easier to correctly adjust the north-south setting.

> The closely typed linear date setting is replaced by a circular date scale spread across 360°, which enables you to select a sensitive and accurate setting for the sun sphere.

> The latitudinal scale stretches from the horizon to the zenith, so that it coincides with the celestial pole's angle of altitude (figure 3). This angle is also measured with sextants at sea and corresponds exactly with the observation at the given location.

This manual will serve as a guide in helping you to use this instrument effectively. The first section explains the most important facts about measuring time with a sundial. In the second section, we explain the steps from setting and adjusting the sundial to the first time reading and in the third section we explain in detail the information which you can read off the CIELO. The appendix contains a table of the cities displayed on the sundial with useful information on how to use the CIELO for measuring time.

Measuring time by the Sun

Perhaps you have already asked yourself why the sundial which you have just discovered on a church tower does not display the same time as that on your wrist-watch. The answer is that the sundial displays a different time, i.e. local apparent time (solar time). This is nature's time, determined by the Sun's path and valid for the place at which the church is located.

When the Sun has reached its highest point and is exactly in the south, the sundial displays 12 o'clock, it is local apparent noon. If we follow this event over several days, we will notice on our watch that this happens at totally different times. The time from noon to noon is evidently not always 24 hours, the solar day is sometimes shorter, sometimes longer. The differences cumulate and result in the fact that, during the year,

the sundial may be up to 17 minutes fast or up to 15 minutes slow compared to the average. There are two explanations for this phenomenon.

Firstly, the Earth moves on an elliptical path around the Sun and is faster when near the Sun than when at a distance. Secondly, the Sun moves along the ecliptic which is at an angle of 23.44° to the celestial equator. Only that part of the Sun's path in the direction of the celestial equator is relevant for time measurement. This part is also constantly changing throughout the year.

From this, we can observe that local apparent time (LAT) is irregular time and is therefore inappropriate for time measurement with mechanical clocks. For this reason, an average time, local mean time (LMT) was introduced in the 18th century for large towns. This assumes a fictitious Sun which moves towards the celestial equator evenly and includes all locations within the same longitude. The difference between apparent and mean time is called the equation of time. Figure 2 shows how the equation of time changes during the year. The CIELO has a scale with which you can read the equation of time so that you can calculate the locally valid standard time, e.g. Central European Time (CET).
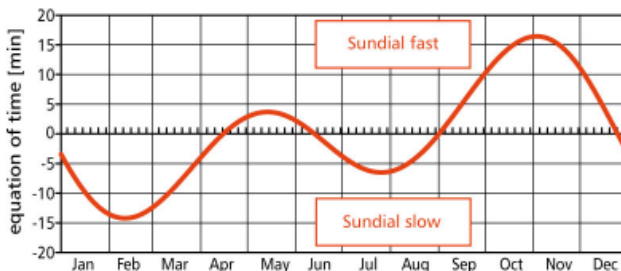

Figure 2: Equation of time

Time zones

The invention of the railway during the industrial revolution in the 19th century made it possible to travel long distance. Mainly as a result of the need for a national rail timetable a further standardisation in time took place: the introduction of standard time, valid for specific time zones, by international agreement in 1884. According to this regulation, the zero meridian passes through the Royal Observatory in Greenwich, near London, which is the reference point for the Universal Time Coordinated (UTC).

The time zones are one hour apart, exactly the amount of time which the Sun takes to move 15 degrees in longitude across the Earth. The standard time valid for most countries in Europe is Central European Time (CET). This is defined as the local mean time at longitude 15°E (east of Greenwich) and is one hour ahead of Universal Time Coordinated.

In order to determine Central European Time from the local time read off the sundial, it is important to know the length of time which the Sun requires to travel between longitude 15°E and the local meridian. We explain how to calculate this in the practical part of this manual.

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Adjusting the sundial and reading the time

The CIELO ring sundial is an accurate instrument displaying solar time. As soon as you are familiar with the adjustment options, you can set the time accurately. The following instructions use an example to describe the process in detail until you make your first time measurement.

In order to adjust the CIELO correctly, you need to know two things: the date and the latitude for your current location. For this example, we will assume that we are in Mainz on Rhine (latitude 50°N) and the date is 15 May.

Setting the latitude

After being set up correctly, the gnomon should stand parallel to the Earth's axis. This requires the gnomon's angle to the horizontal to be equivalent to the geographical latitude. From the observer's point of view, this is the altitude of the pole, since at night the celestial pole, recognisable by the Pole Star which can be found nearby, appears at this angle of altitude.

Set the latitude for your location by moving the meridian ring by the north pointer until the relevant latitude marking (in the example 50°N) is directly in line with the gnomon (figure 3).

If you are located in the southern hemisphere, you should turn the north pointer down past the equator ring, so that the south pointer is positioned in the southern latitudes on the left-hand scale (figures 4C and 4D).
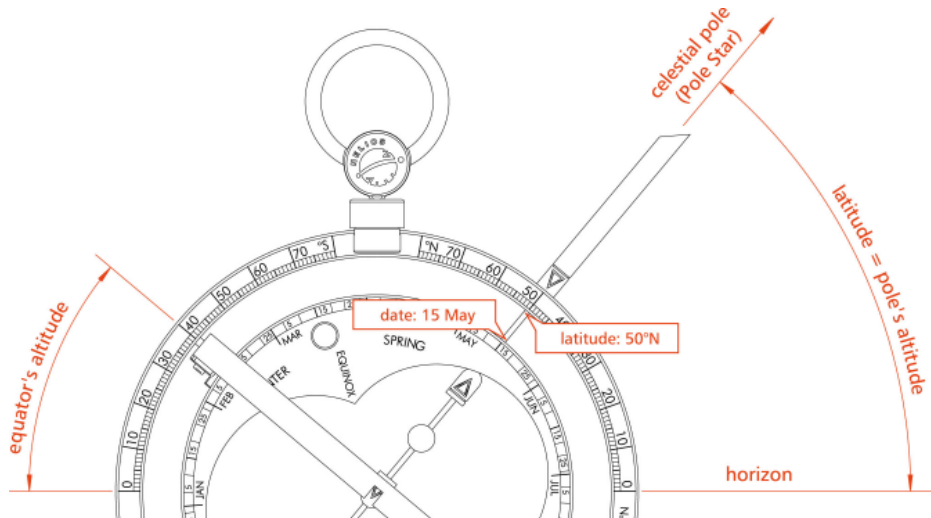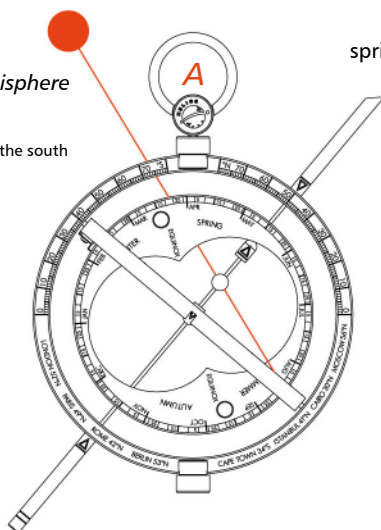

Figure 3: Setting the latitude and the date

spring/summer

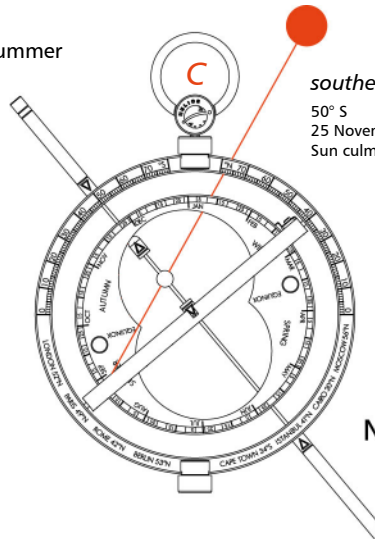*northern hemisphere*
50° N
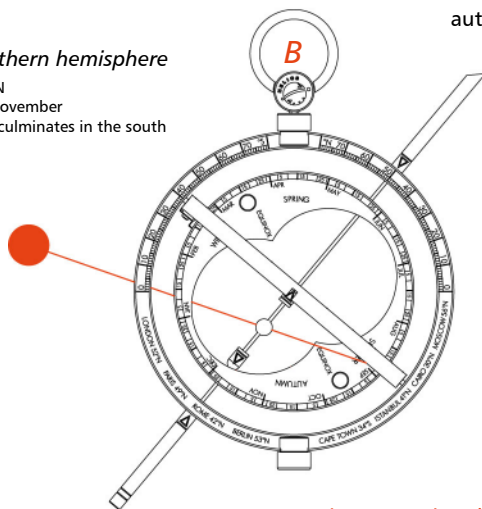15 May
Sun culminates in the south

southern hemisphere
50° S
25 November
Sun culminates in the north

autumn/winter

northern hemisphere
50° N
25 November
Sun culminates in the south

southern hemisphere
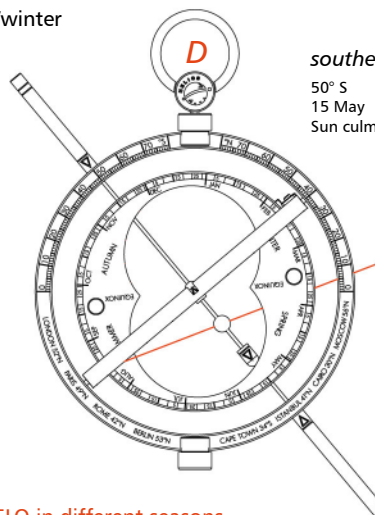50° S
15 May
Sun culminates in the north

N →

Figure 4: Using the CIELO in different seasons

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Setting the date

You can use the date disc to set the central sun sphere to the current date. The date setting is again aligned with the gnomon. Turn the date disc at the two buttons until the 15 May (example) is aligned with the gnomon on the north pointer.

Then push the gnomon upwards until the north stopper touches the frame. The sun sphere is then positioned correctly (figures 3 and 4A). In autumn and winter (25 November, for example) the Sun moves below the equator, so the date on the gnomon should be set in the area of the south pointer (figure 4B).

If you are located in the southern hemisphere, you should proceed with your settings accordingly. In this case the seasons are reversed (figures 4C and 4D).

Positioning towards the Sun

Now you have completed your preparation for time measurement and you can position the sundial towards the Sun. Open the equator ring until it hits the stop. You have already positioned the Sun's sphere correctly. In spring and summer, as in our example of 15 May, the sun sphere is located above the equator ring with the time scale. Now you need to bring its shadow in line with the inside of the equator ring. You are turned towards the Sun and are holding the CIELO in one hand from its retaining ring, so that it hangs freely and the north pointer points towards you. Now, still leaving the sundial hanging freely, you turn the sundial towards the west if it is morning and towards the east if it is afternoon.

Soon the shadow of the Sun appears on the inside of the equator ring (figure 1). The gnomon's shadow now shows you local apparent time (LAT) on the time scale. In the example in figure 1 it is 9 am LAT.

If you are using the CIELO in the autumn or winter, the sun sphere will be below the equator ring. In this case, you turn so that your back is towards the Sun and hold the sundial over your head, so that you are looking at the bottom side of the equator ring. The north pointer is pointing away from you. You can read the time resulting from your setting on the bottom side of the equator ring.

You can proceed in exactly the same way when using the CIELO in the southern hemisphere. The latitude is then set as required in the southern hemisphere. The Pole Star, toward which the north pointer points, will not be visible there at night, since it is positioned behind the Earth. Instead, the south pointer will point to the southern celestial pole, which you can find by following the vertical axis of the constellation "Southern Cross". Figure 4 shows the possible situations in both the northern hemisphere and in the southern hemisphere on 15 May and on 25 November.

At the equinoxes on 20/21 March (point of Aries) and on 22/23 September (point of Libra), the Sun is positioned directly at the level of the equator and the Sun's rays hit the side of the equator ring, so no shadow falls on the time scale. On these days the sundial cannot be used.

Important note: There are two ways you can position the CIELO so that the sphere's shadow is in alignment with the equator ring, only one of these positions is correct. If you are not sure whether it is morning or afternoon, read the time again a few minutes later from the position you have chosen. If an earlier time is now shown, i.e. time has moved backwards, then obviously the other position is correct.

CIELO – solar timepiece and navigator

Now that you know how to adjust the CIELO, this section describes in more detail the sundial's various functions and the information you can read from it.

Local apparent time (solar time)

The CIELO is the modern progression from the classic ring sundial. Like its historical role model, it displays local apparent time (LAT) for its current location. The LAT is determined directly by the Sun. It is 12 o'clock local apparent time when the Sun has reached its daily high point at noon (culmination) and passes through the local meridian.

This „natural" time reproduces the Sun's natural path daily (see figure 6). During the morning (ante meridiem = am), the Sun steadily climbs in the sky until it has culminated at 12 o'clock LAT. This event is called local apparent noon (ad meridiem = midday). Now the Sun is positioned exactly in the direction of CIELO's meridian ring and the gnomon's shadow disappears for a short time. Then the Sun lowers again, it is afternoon (post meridiem = pm).

Standard time

While local apparent time (LAT) relates to the local meridian, standard time always relates to a defined meridian, the standard meridian.

So how do you determine standard time? We will assume as an example that we are in Mainz on Rhine (50.0° N 8.25° E). The standard time in Germany is Central European Time (CET). In order to determine the standard time based on the local apparent time read off the sundial, three values are added together:

1. Local time deviation: This is the time that the Sun requires to move from the standard meridian for CET (15° E) to the local meridian (8.25° E). The Sun moves across a longitude of 15° in one hour, therefore 4 minutes per degree of longitude. So it will require 27 minutes for the 6.75 degrees that Mainz is located to the west of 15° E. If you want to calculate the local time difference for a different location and a different standard meridian, you can proceed in exactly the same manner. Please bear in mind that the local time difference is always positive when you are located to the west and always negative when you are located to the east of the standard meridian.

2. Equation of time: During the year, local mean time (LMT) is always ahead or behind the local apparent time (LAT) as read from the sundial. On the back of the date disc, you can read the equation of time* value for the current date. As an example: on 15 May, the date-dependent time difference is -4 minutes (figure 5).

3. Summer time deviation: From the end of March to the end of October, Central European Summer Time (CEST) is valid. An extra hour is added to this. This is also applicable to our example of 15 May.

In total, the deviation to be applied can be calculated as follows: 27 min +(-4) min + 1 h = 1 h 23 min. So in Mainz on 15 May at 9 am LAT, the time is 10:23 am CEST. In table 1 on page 12 you will find a list of the cities displayed on the sundial and the information required to determine the correct standard time.
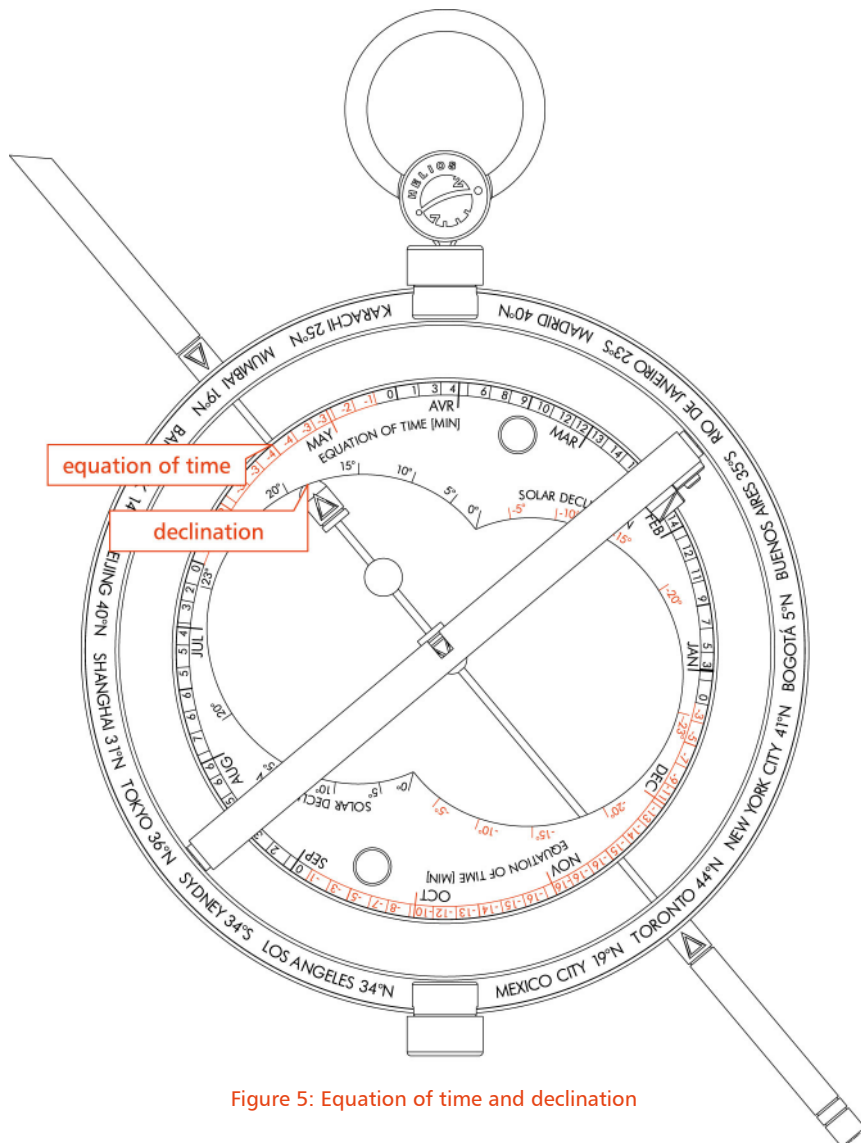
* On the sundial, a negative value is shown for the equation of time, this simplifies the calculation.

Figure 5: Equation of time and declination

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Model of the firmament

The CIELO ring sundial represents a model of the firmament with the Earth at its centre (figure 6). This geo-centric model of the universe originates in ancient times. Yet even today, it has not lost its meaning when it comes to showing the Sun's path across the skies as we perceive it from Earth.

The celestial equator is a projection of the Earth's equator on the sky and the celestial poles represent an extension of the Earth's axis. The meridian is the great circle in the sky, which goes through both celestial poles and the zenith of the observation point. At the same time, the meridian is also the „connecting link" between the equatorial and the horizontal firmament, consisting of the meridian, the horizon and the zenith.

When we succeed in aligning the CIELO in its equatorial setting with the horizontal firmament of our location, then it is in north-south alignment and displays the time. We achieve alignment with the equator by setting the latitude on the meridian ring. This means that the angle of the north pointer (in the example 50°) and of the equatorial ring (in the example 40°) are correct at the horizontal level, only the meridian ring is not yet aligned in a north-south direction. In order to accomplish this, we use the fact that the declination of the Sun (angle to the celestial equator, see figure 6) hardly changes throughout the day. The sun sphere is therefore positioned according to the declination, with the help of the date scale (in the example 15 May). If we now turn the sundial around its vertical axis (zenith) until the Sun's shadow falls on the inside of the equator ring, then the meridian ring is aligned in a north-south direction. The equator ring is positioned parallel to the equator and the north pointer points towards the celestial pole, with the Pole Star nearby. As a result, the gnomon is automatically aligned parallel to the Earth's axis.

In the same way as the Sun moves around the Earth's axis daily as the Earth turns, it also moves around the CIELO's gnomon. Since the Sun is so enormously far away (approximately 150 million kilometres), it makes no difference that we are standing on the Earth's surface with the CIELO and not at its centre. Consequently, the shadow behaves in exactly the same manner as the Sun moving across the CIELO's time scale at 15 degrees per hour and shows us local apparent time (in our example for Mainz).

Due to the fact that the sundial's co-ordinate system corresponds with that of the Earth, we are able to follow the Sun's path and the phenomena related to it on the CIELO as they are taking place in the world.

Solar compass

The CIELO can be used as a compass, since we now know that the north pointer points exactly north after being aligned with the Sun. One advantage when compared with a magnetic compass, which is aligned with the Earth's magnetic field, is that you do not need to take any magnetic declination into account and that iron objects have no influence on the reading. Of course the CIELO can only be used as a compass in good weather, since it is a sundial, which by nature „only counts the good hours", as a well-known sundial saying tells us.
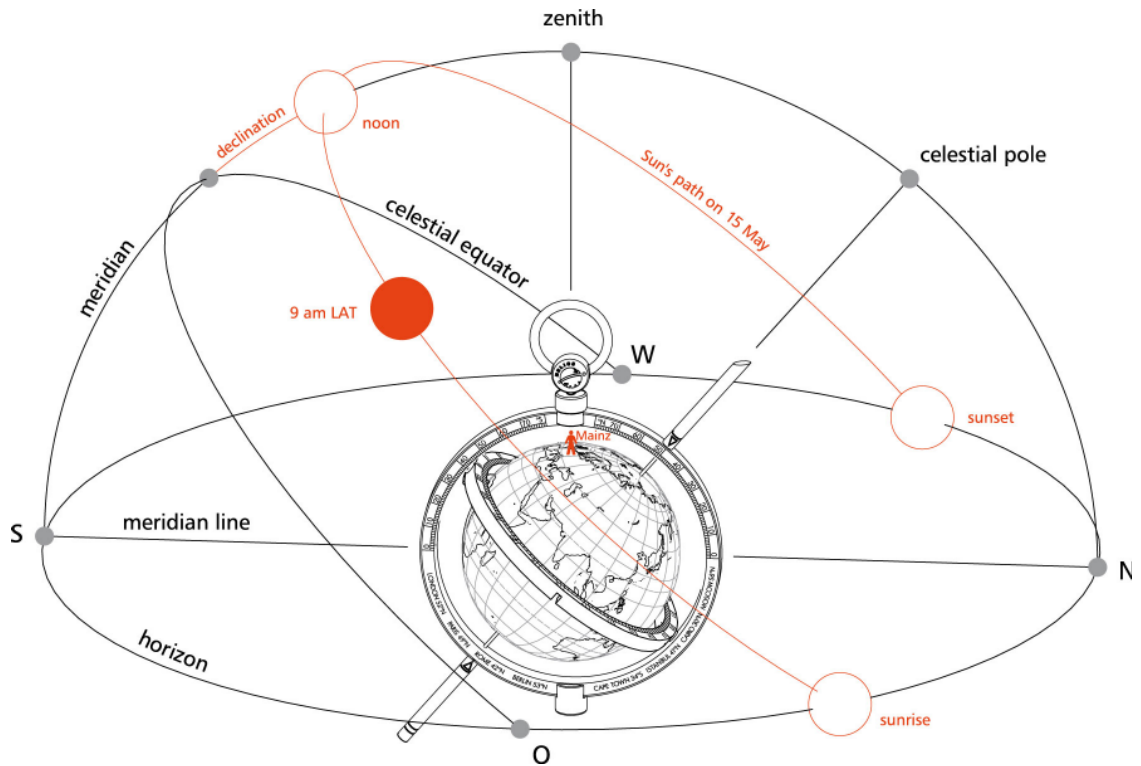
Figure 6: CIELO - model of the firmament

Support

If you have questions on the correct use of your sundial, you can reach us at the following contact address:

We wish you plenty of enjoyment with your CIELO on many sunny days.

City	Country	Latitude	Longitude	Standard time	Standard time meridian	Local time deviation	Summer time?
London	England	51.5°N	0.1°W	GMT	0°W	0.4 min	yes
Paris	France	48.9°N	2.4°E	CET	15°E	50.4 min	yes
Rome	Italy	41.9°N	12.5°E	CET	15°E	10.0 min	yes
Berlin	Germany	52.5°N	13.4°E	CET	15°E	6.4 min	yes
Cape Town	South Africa	33.9°S	18.4°E	SAST	30°E	46.4 min	no
Istanbul	Turkey	41.0°N	29.0°E	EET	30°E	4.0 min	yes
Cairo	Egypt	30.1°N	31.2°E	EET	30°E	-4.8 min	yes
Moscow	Russia	55.8°N	37.6°E	MSK	45°E	29.6 min	no
Karachi	Pakistan	24.9°N	67.0°E	PKT	75°E	32.0 min	no
Mumbai	India	19.0°N	72.8°E	IST	82.5°E	38.8 min	no
Bangkok	Thailand	13.8°N	100.5°E	ICT	105°E	18.0 min	no
Beijing	China	39.9°N	116.4°E	CST	120°E	14.4 min	no
Shanghai	China	31.2°N	121.5°E	CST	120°E	-6.0 min	no
Tokyo	Japan	35.7°N	139.8°E	JST	135°E	-19.2 min	no
Sydney	Australia	33.9°S	151.2°E	AEST	150°E	-4.8 min	yes
Los Angeles	USA	34.1°N	118.3°W	PST	120°W	-6.8 min	yes
Mexico City	Mexico	19.4°N	99.2°W	CST	90°W	36.8 min	yes
Toronto	Canada	43.7°N	79.4°W	EST	75°W	17.6 min	yes
New York City	USA	40.7°N	74.0°W	EST	75°W	-4.0 min	yes
Bogotá	Colombia	4.6°N	74.1°W	COT	75°W	-3.6 min	no
Buenos Aires	Argentina	34.6°S	58.4°W	ART	45°W	53.6 min	no
Rio de Janeiro	Brazil	22.9°S	43.2°W	BRT	45°W	-7.2 min	yes
Madrid	Spain	40.4°N	3.7°W	CET	15°E	74.8 min	yes

Table 1: Co-ordinates and local time differences for the world cities displayed

[12]