

# *The Prague Astronomical Clock*

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## *Introduction*

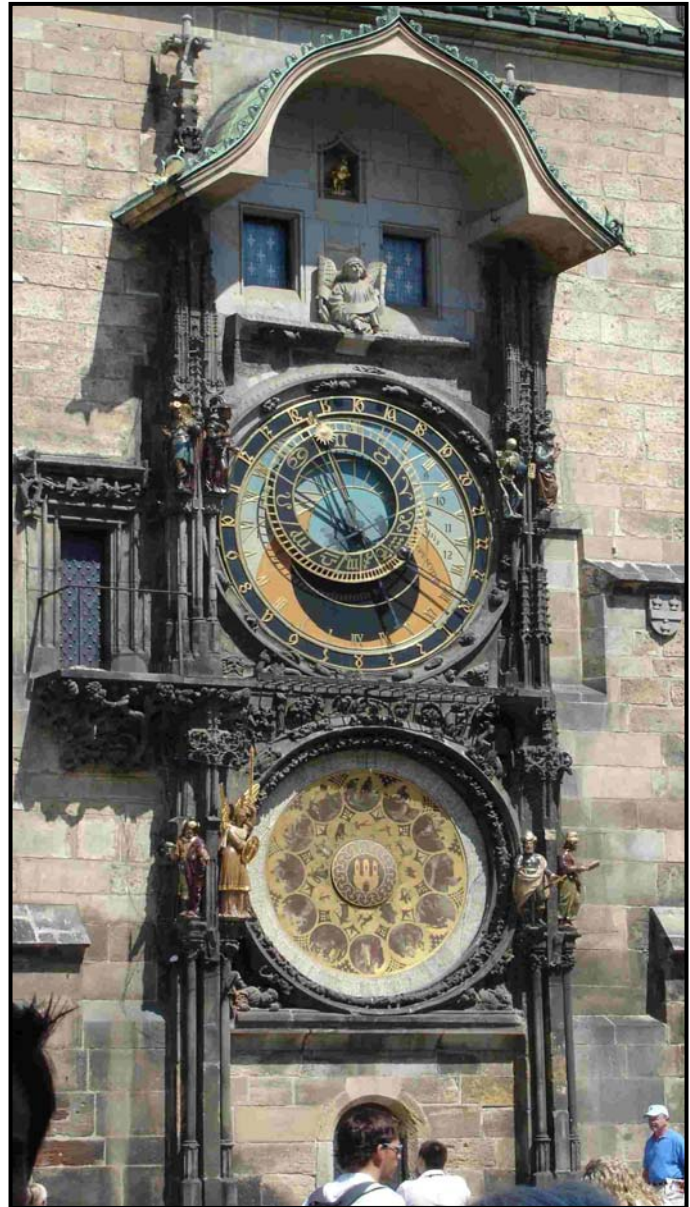
This clock is truly amazing, more so when you consider that it was built in 1410 when the world still believed that the Earth was the center of the universe. When you first look up at it, you are overwhelmed by its artistic beauty and its apparent technological sophistication. It's only after looking at it for a while that you can begin to appreciate this truly magnificent monument to man's fascination with the heavens.

The first time I saw the clock, I had no idea what all the dials, hands, colors, circles, and curved lines on the clock face signified. I couldn't even tell what time it was! I imagine that most people feel the same way when they first see the clock. It is unfortunate that the vast majority of people who wait patiently for the clock to strike, for the two blue windows on the clock tower open and show the processions of the apostles, for the sculptures of the figures around the clock move, and see only that. They miss completely the beauty and intricacies of the clockworks that keep pace with the motions of the Earth, Moon, Sun, and stars. They don't think of the genius embedded in its gears that show how the Sun moves through the Zodiac, how the Moon and the Sun move in the sky above them, the times of sunset, sunrise, moonset and moonrise, the height of the sun at midday, the times of the solstices and equinoxes, and yes, even the time of day in three different ways.

## *Some Preliminaries*

The clock face shows the Earth (Prague) in the center with the Sun, Moon, and the stars rotating around it. It wasn't until 1530, 120 years after the clock was built, that Nicolas Copernicus postulated in his *De Revolutionibus* that the Sun, not the Earth, was the center of our solar system. The world was slow to accept this now universally accepted fact.

The clock has two hands. A black and silver spherical moon is attached to one and a gold sunburst to the other. As the hands rotate, both are free to slide up and down the hands so they are always on the annulus with the zodiac signs. The only function of the moon hand is to keep the moon in its proper position. The sunburst hour hand also has a gold hand at its tip, barely discernable at this time of year when the sunburst partially obscures it, which is the pointer for telling time. At this time of year also, the zodiac annulus obscures the Roman numeral



**The Prague Astronomical Clock on the  
Town city Hall at the Old Town Square**

dial near the gold hand. In such cases, the time is more easily read at opposite end of the sunburst hand on the repeated Roman numeral dial. The hour hand makes one complete revolution in 24 hours. The clock has no minute hand.

### **Sun (Solar) Time**

The length of a solar day is the time between two consecutive meridian transits of the Sun. A meridian transit is defined as the instant the sun reaches its greatest altitude observed from a point on the earth's surface for that day, viz., local apparent noon. At that instant, it is due south of an observer (in Prague). The length of such a solar day varies slightly from day to day but its average (mean) value is 24 hours.

### **Star (Sidereal) Time**

The length of a star day is the time between two consecutive meridian transits of a star. A sidereal day is a little shorter than a solar day and equal to  $23^{\text{h}} 56^{\text{m}} 04^{\text{s}}$ . This is because the earth is moving around the sun as it spins on its axis and must turn a little bit more than 360 deg to again reach the Sun's meridian transit starting point. Stars are so far away compared to the Sun that the Earth's orbital motion has no effect on the time of a star's meridian transit.

### **Declination of the Sun**

The Earth's axis is tipped  $23\frac{1}{2}$  deg relative to the plane containing the Earth and the Sun. As the Earth moves around its year-long orbit around the Sun, this tilt causes the declination (altitude above the equator) of the Sun to vary from about  $23\frac{1}{2}$  deg below the equator to  $23\frac{1}{2}$  deg above the equator. The sun's highest declination, marked on the Earth by the Tropic of Cancer, occurs on June 21. This is the Summer Solstice and north of the equator on this day there is more daylight than on any other day. The sun is at its lowest position, marked on the earth by the Tropic of Capricorn, on December 21, the Winter Solstice. This day has the least daylight. The Vernal and Autumnal Equinoxes occur on March 21 and September 23, respectively. On these days, the lengths of day and night are equal.

### **The Ecliptic and the Zodiac**

As the Earth travels around the Sun, the Sun appears to be rising from a celestial background that changes over the course of the year. The apparent path of the Sun through the sky is called the ecliptic. The Moon and principal planets also appear to move on or near the ecliptic. Ancient astronomers divided the ecliptic into twelve equal parts, named each part after its background constellation, and called it the Zodiac. The constellations of the Zodiac and their signs beginning on the Vernal Equinox are: Aries  $\text{♈}$ , Taurus  $\text{♉}$ , Gemini  $\text{♊}$ , Cancer  $\text{♋}$ , Leo  $\text{♌}$ , Virgo  $\text{♍}$ , Libra  $\text{♎}$ , Scorpius  $\text{♏}$ , Sagittarius  $\text{♐}$ , Capricorn  $\text{♑}$ , Aquarius  $\text{♒}$ , and Pisces  $\text{♓}$ .

### *Reading the Clock*

#### **Bohemian Time**

Past civilizations have used days that start at different times. For example, the Bohemian day begins at sunset and is made up of 24 equal hours. (Prague is in the region of the Czech Republic called Bohemia.) The outermost scale on the astronomical clock, inscribed with gold Gothic numbers, keeps Bohemian time. That is, the gold hand on this scale indicates the time elapsed  $\{\sim 18\frac{3}{4} \text{ hours}\}$  from sunset. Since the time of sunset varies throughout the year, the Bohemian time scale on the clock rotates a small increment each day to stay synchronized with the time of sunset in Prague.

#### **European Central Time**

Nowadays, throughout the world, a day begins at midnight. The gold hand read on the scale inscribed with gold Roman numerals, tells European Central Time  $\{\sim 3:00 \text{ PM}\}$  ... the same time as clocks in Prague. The clock cannot be adjusted to tell daylight savings time.

## Declination of the Sun

At the center of the clock face is a painting of a projection of part of the Earth's surface. The edge of that painting represents the Earth's horizon as seen from Prague. Around this image are three gold circles. The circle just touching the tops of the Roman numeral scale represents the Tropic of Cancer; the next circle towards the center, the Equator; and the innermost circle, the Tropic of Capricorn. The position of the gold sunburst relative to these circles indicates the declination of the sun on that day. On the Summer Solstice, the Sun will reach the outermost, Tropic of Cancer, circle; on the equinoxes it will be at the equator circle; and on the Winter Solstice it will be on the innermost, Tropic of Capricorn, circle. {About 23 deg north (Actual declination was 23°20' N), almost at the Tropic of Cancer.}



**The Clock Face at 3:00PM European Central Time on June 16, 2006.**

The bracketed { } examples in the text were taken from this photograph.

## Sunrise and Sunset

The clock face has three regions of different color: blue, brown, and black. When the gold sun is in the blue region, it is daylight; when in the brown region, it is dawn or dusk; and when it is in the black region, it is nighttime. The boundaries of the blue and brown regions give the times of sunrise (ORTUS) and sunset (OCCASUS) at the latitude and longitude (50°05' N, 14°25' E) of Prague for any day of the year. {~4:05 AM and ~7:55 PM for sunrise and sunset, respectively.}

## Babylonian Time

Babylonian time divides the time between sunrise and sunset into twelve equal hours as do the curved gold lines between the Tropics of Capricorn and Cancer on the clock face. The length of a Babylonian

hour depends on the season. Near the Summer Solstice, a Babylonian hour is 81 minutes long; near the Winter Solstice only 41 minutes long. Babylonian time is shown by the position of the sunburst relative to the curved lines and is read with the black Arabic numbers inside the gold Roman numeral scale. {8½ hours}.

### **The Signs of the Zodiac**

The zodiac annulus at the center of the clock, marked with the twelve symbols of the Zodiac, does not rotate about its center but instead is offset. The offset is chosen so that the sunburst, constrained to be on but not attached to the Zodiac annulus, shows the correct declination and is in the proper sign of the Zodiac throughout the year. The Zodiac circle makes one complete revolution in a star day (23<sup>h</sup> 56<sup>m</sup> 04<sup>s</sup>). Thus, the zodiac circle rotates about 1 deg more each solar day than does the sunburst attached to the hour hand. This causes the sun to move slowly from one sign of the Zodiac to the next and its declination to vary until after one year it has completed its circuit. {The Sun is in Gemini. It will be in Cancer on June 21.}

### **The Position of the Moon**

Just like the Sun, the Moon slides on its hand so that it always lies on the Zodiac circle. It makes one complete revolution in 24<sup>h</sup> 50<sup>m</sup> 28<sup>s</sup>. The time between two consecutive full moons, a lunar month, is 29½ days. Over this time, the relative positions of the Sun and the Moon as they appear in the sky above Prague are represented by their relative positions on the clock face. As with the sunburst, when the moon is in a brown or black region of the clock face, it is below the horizon and cannot be seen. {The Moon has not yet risen.}

### **The Phases of the Moon**

Half of the moon sphere is silver, the other half black. The phases of the Moon during the lunar month are indicated by the silvered part of the moon that faces forward. {The Moon is in its last quarter.}

### **The Equinoxes and Solstices**

The Zodiac annulus is attached to the clock by two segmented bars: One between Aries and Libra; the other, between Cancer and Capricorn. The Summer Solstice occurs when the sunburst is on the long segment of the long bar in Cancer; the Winter Solstice when it is on the short segment of the long bar in Capricorn. The Vernal Equinox occurs when the Sun is on the short bar in Aries and the Autumnal Equinox when it is on the short bar in Libra. {The Summer Solstice will occur in five days.}

### **Sidereal Time**

The little gold star attached to the outside of Zodiac annulus at Aries keeps star time when read on the Roman numeral dial.

My goal here is to provide only enough of the rationale behind the clock's dials, hands, and markings to allow one to better appreciate this remarkable work and to be able to tell the time and the current positions of the Sun and Moon. (A complete description of all aspects of the clock's history and operation is in Jakub Mulina's *The Prague Horologe*.)

You can find more information on this and other astronomical clocks with the links below:

[http://en.wikipedia.org/wiki/Astronomical\\_clock](http://en.wikipedia.org/wiki/Astronomical_clock)

<http://www.tp178.com/mh/besancon/besancon.html>

<http://www.keenzo.com/showproduct.asp?M=CAMBRIDGE-UNIVERSITY-PRESS&ID=3473859&ref=GB>

<http://www.nicholaswhyte.info/row.htm#24n>

[http://www.allbookstores.com/Science/Astronomy/Astronomical\\_Clocks.html](http://www.allbookstores.com/Science/Astronomy/Astronomical_Clocks.html)

<http://www.ras.ucalgary.ca/~stil/dial.html>

[http://www.britishmuseum.org/explore/highlights/highlight\\_objects/pe\\_mla/a/astronomical\\_table\\_clock\\_by\\_he.aspx](http://www.britishmuseum.org/explore/highlights/highlight_objects/pe_mla/a/astronomical_table_clock_by_he.aspx)