PATH OF THE NORTH POLE

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Abstract

The angle between the axis of the Earth and the plane of the orbit is approximately constant. Instead of that, the orientation of the axis is chancing. The axis seems to go along the surface of the cone. Hipparchus discovered this motion, called precession, over two thousands years ago. The movement of the axis is very slow, one cannot see any change in the period of few years or decades, but compared with observations made thousands of years ago, the change of the location is remarkable.

In this workshop we will construct a model, which help us to percept the movement of the North Pole in the night sky. We start by calculating the coordinates of the most famous points in time. Then the scale in the sky map has to be determined. After drawing the coordinates of the test points, we can determine the central point of the circle of North Pole's path. Then we draw the circle. It is interesting to look for some dates and realise on which constellation the pole is at that time.

With this new model, we can demonstrate the precession of the Earth's axis. A wooden or plastic ball may represent the Earth, and a grill stick represents the axis. Small pieces of iron or other heavy material can be fixed in the area of the equator. Then we will try to put the Earth in the rotating motion, like a gyroscope.

INTRODUCTION

The apparent motion of the Sun along the ecliptic is a consequence of Earth's orbital motion around the Sun. The seasons are resulted from the inclination of Earth's rotation axis to the orbit plane. In the point of the summer solstice the Earth's North Pole points nearly toward the Sun. The opposite situation is true in the winter solstice. The vernal and autumnal equinoxes are the points in the Earth's orbit where the axis is perpendicular to the Earth-Sun line.

In the summer solstice, near 21st June, the Sun is at its northernmost point above the celestial equator. This period corresponds to the longest days of the year in the Northern Hemisphere. At the southernmost point below the celestial equator, the Sun is near the 21st December in the winter solstice, and this corresponds to the shortest days of the year in the Northern Hemisphere.

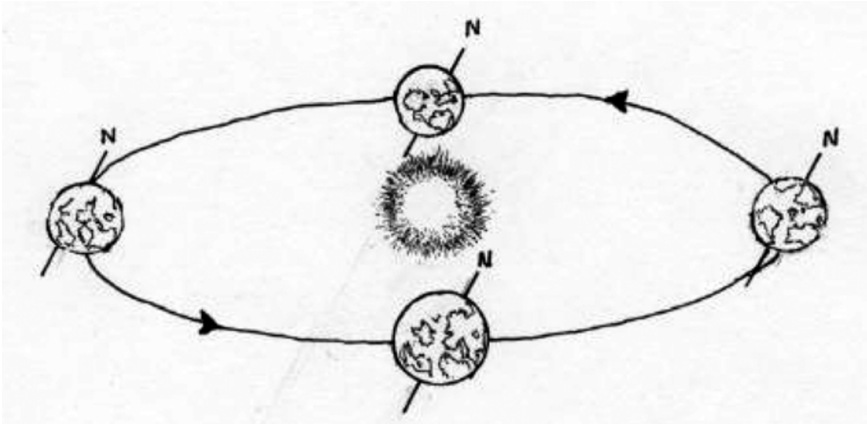

Figure 1. Seasons (Chaisson, p. 10, VH)

In Figure 2, seen face on, the Earth's orbit around the Sun is illustrated as a perfect circle as it almost is. The difference from the circle is not remarkable. The distance from the Earth to the Sun varies only slightly in the year, being the farthest in the middle of the summer and the shortest in the middle of the winter. But, it is very sure that this is not the cause of the seasonal variations on the Earth.

The two points where the ecliptic intersects the celestial equator and where the Earth's axis is perpendicular to the Earth-Sun line are called equinoxes. Then the day and the night are equal of duration. In the autumnal equinox, on the 21st September, the Sun crosses from the northern celestial hemisphere into the southern one. The opposite is occurring in the vernal equinox, on or near the 21st March, when the Sun crosses the celestial equator moving north.

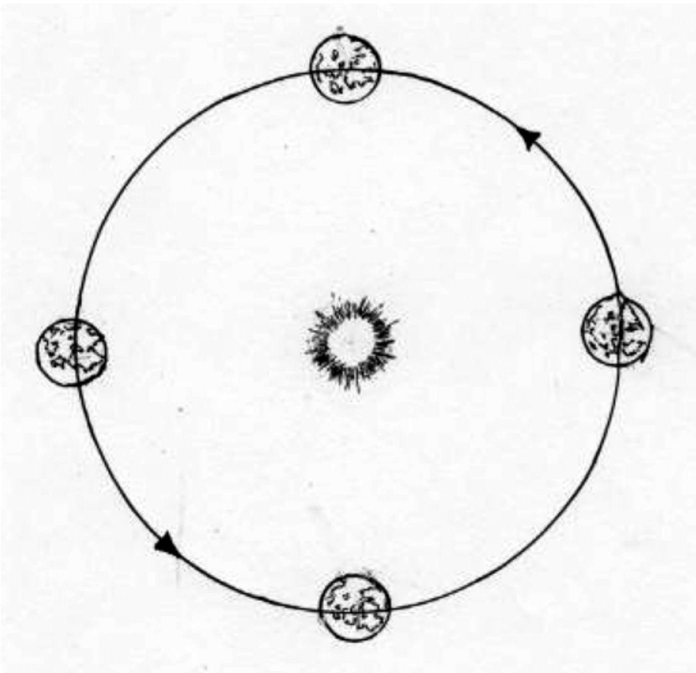

Figure 2. Earth's Orbit (Chaisson, p. 10, VH)

The vernal equinox is very important in timekeeping. The interval of time between two vernal equinoxes is called a tropical year - 365,242 solar days. The time the Earth requires for one orbit around the Sun relative to the stars, the revolution time, is called a sidereal year with 365,256 solar days. The slight difference is a consequence of the phenomenon known as *precession*.

In Figures 3 and 4 is seen that the gyration of both the gyroscope and the axis of the Earth are very similar. The Greek astronomer Hipparchus (ca.100 BC) discovered this motion as early as two thousand years ago. The motion is very slow; it cannot be recognised in a few years or decades. By comparing the ancient observations with the recent ones, the precession has to be taken into consideration.

Figure 3. Precession illustrated as a gyration (Karttunen 2002, p. 61, VH)

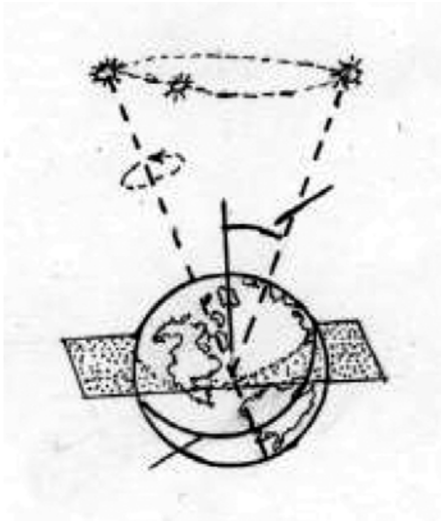

Figure 4. Precession of the Earth (Chaisson, p. 11, VH)

The direction, which the Earth's axis currently points toward, is called the North Pole. The stars seem to go around it in a day. Nowadays the North Pole is situated near the star Stella Polaris and is going towards it until 2115. Some 12000 years from now, Earth's axis will point toward the bright star Vega, which will then be the North Pole. One complete cycle of precession takes about 26000 years. When the Egyptians build their pyramids about five thousand years ago, the North Pole pointed towards the star Thuban in the constellation Draco.

The precession does not change the places of the stars. However, it is of great consequence which part of the sky is visible in some moment in the certain place. In addition to that, the precession changes coordinates of the stars in the star-maps and catalogues. At this time, the coordinates of the year 2000 are used in the star-maps. The impact of the precession is seen also in the frames of the constellations. The frames are determined using the coordinates of the year 1875. That's why they seem to be tilted in the maps of the year 2000.

ACTIVITIES

1. Demonstration of the gyration

a) Take a small ball of Styrofoam and stick some pins or small nails of metal in the equator circle.
b) Stick the toothpick through the centre of the ball and perpendicular the equator level. The toothpick will represent the axis of the Earth.
c) Put the gyroscope in the rotating motion. Explore the motion of the axis. If possible, take the photo of a long exposure time or videotape a clip of the gyration.

2. Star-map

a) Look at the star map of the northern polar area. Find the most common constellations around the North Pole. The stars that belong in these constellations are called the circumpolar stars.

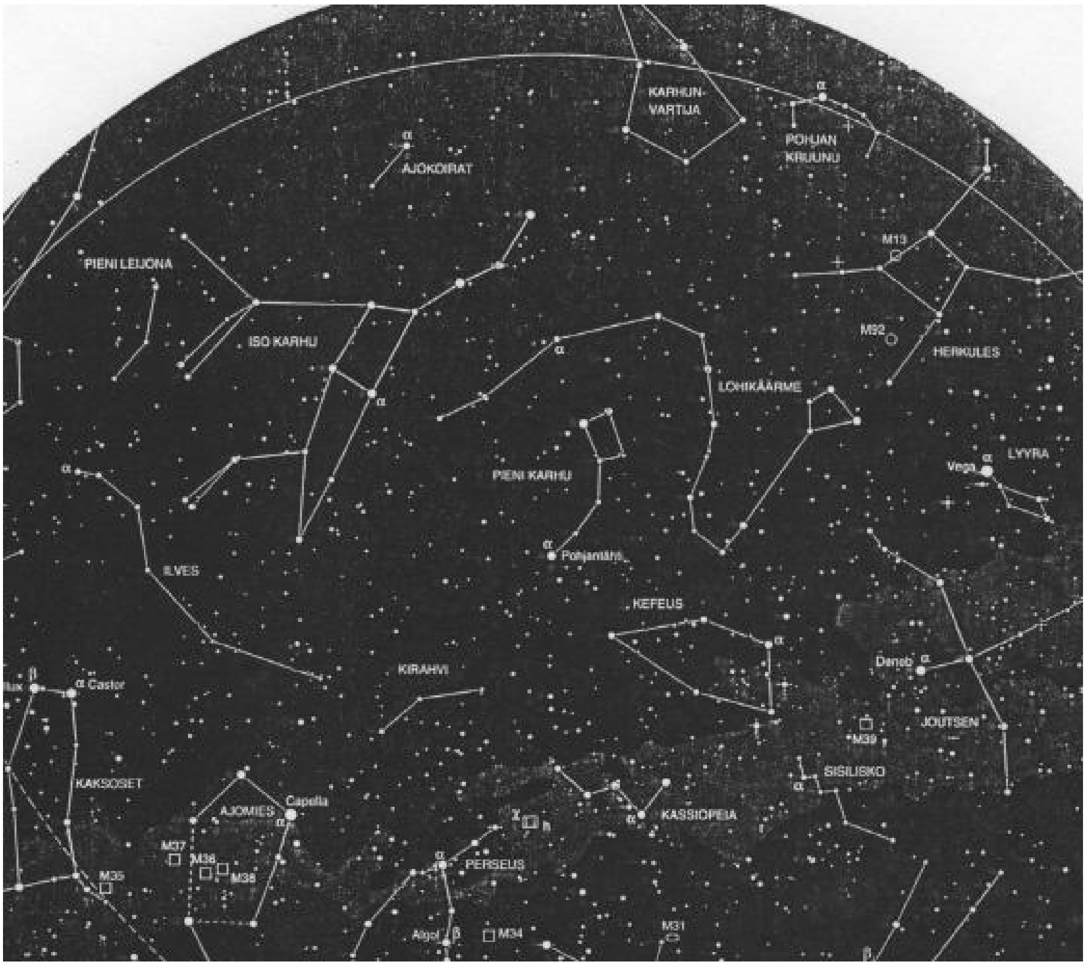

Figure 5. The star map of the northern polar area (Karttunen, 2000)

b) Take a photocopy of negative format about the circumpolar stars. The background is white and stars are marked as black. The reason to use this kind of format is very human: it is easier to read black text on the white background than to do it in the opposite situation.

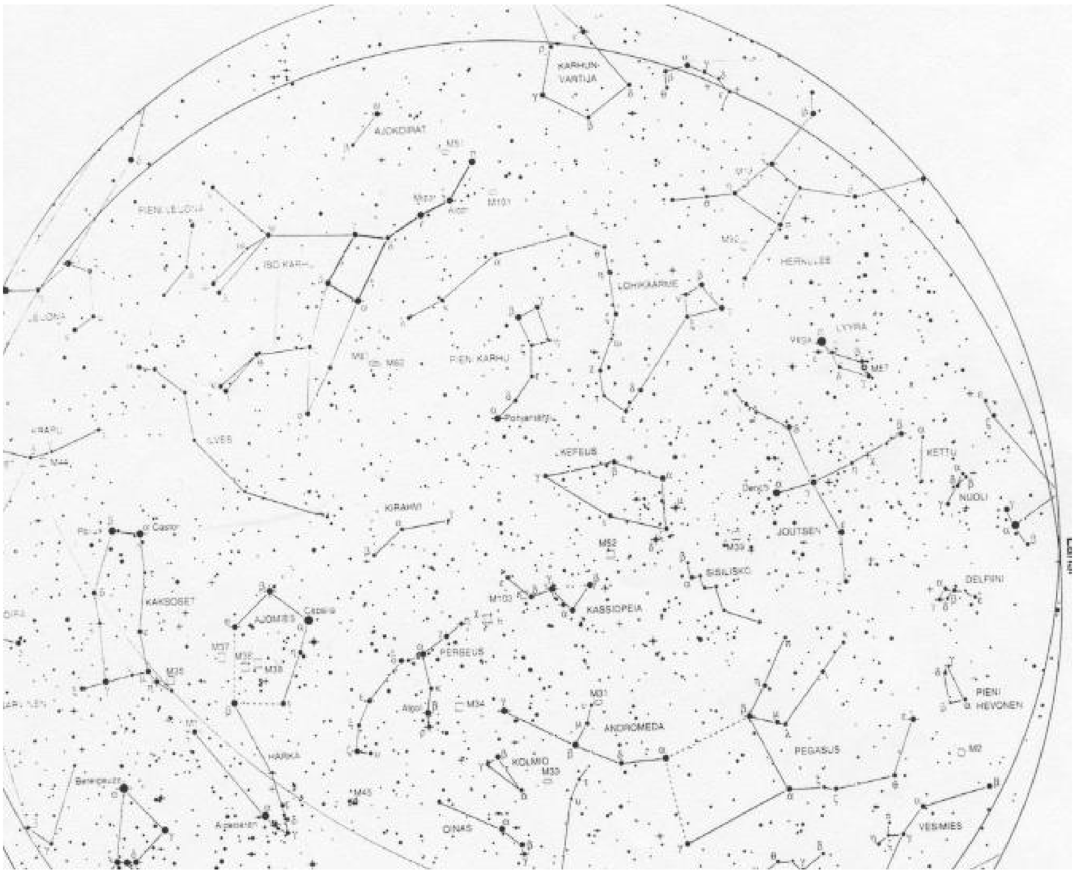

Figure 6. A star map of the circumpolar constellations as negative format (Karttunen, 2000)

c) Draw the figures of the familiar constellations near the North Pole and Stella Polaris in bold and add the names of the constellations in Latin. Write also the names of the famous well-known stars on the map.

3. Path of the North Pole

a) Find in the map the star Thuban in the constellation Draco. (A)
b) Find the Stella Polaris in the constellation Ursa Minor. (B)
c) Find the neighbour star of σ-Herculis, by name Hercules in this activity, in the constellation Hercules (C)
d) Use these three stars as fixed points being situated in the ring. Find the centre of the circle using a simple geometric method. Draw two perpendicular lines on the segments of a line AC and BC. The centre of the circle will be in the intersection of those two perpendicular lines.
e) Draw the circle and make sure that the stars Thuban, Stella Polaris and Hercules are situated in the ring.
f) Divide the ring in 26 pieces as exactly as possible. Start by calculating the angle of one sector and then use a ruler in dividing work. One arc in the ring will represent one thousand years.

g) Mark the known years in the ring: Stella Polaris the year 2000 AD, Thuban about the year 2500 BC, and Vega about the year 14000 AD. The year 1 AD (or 0 AD) is easy to find and mark; it is the moment when a timekeeping has started.

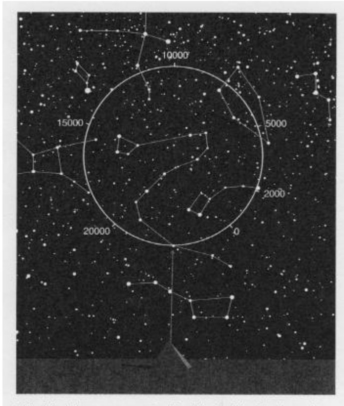

Figure 7. The circle shows the precessional path of the North Pole among some prominent Northern stars (Chaisson, p. 11)

Figure 7 shows approximately the path of the North Pole. In the workshop the ring will be explored and sketched in the very exact and specified way.

References

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