What was the next day after Thursday October 4th, 1582?

A. Friday October 5th, 1582
B. Friday October 5th, 1583
C. Monday October 5th, 1582
D. Friday October 15th, 1582
E. Sunday October 6th, 1582

What was the next day after Thursday October 4th, 1582?

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Strange but true! The dates October 5 through October 14 were "skipped" that year! The month of October that year had only 20 days. Why? Read on…

Precession

subtle slo-mo

the Visible Sky

I. Stars and Celestial Sphere
Constellations & Coordinates

II. Sun
Time, Seasons, **Precession**

III. Moon
Phase, Orbit, etc.

IV. Eclipses
Solar & Lunar

The student will be able to:		HW:
1	Explain and utilize constellations and asterisms as means of mapping and organizing the stars.	1 – 4
2	Explain and utilize the concept of the celestial sphere as a means of understanding the appearance of the universe as seen from Earth.	
3	Explain the significance of the pole star, Polaris, and its connection with the apparent motion of the celestial sphere.	
4	Explain, define, and utilize the celestial equatorial coordinate system of right ascension and declination, celestial equator and celestial poles.	
5	Describe changes in position and appearance of the stars through time and explain in terms of the actual motion and position of the Earth.	5
6	Define, apply, and relate to astronomical events or cycles the following time concepts: sidereal and solar day, sidereal and tropical year, mean solar time, standard time, daylight savings time, and universal time.	6
7	Use a planisphere to locate celestial objects for a particular date and time and/or determine the date and time of certain celestial events.	7 – 8
8	Describe changes in position and appearance of the Sun through time and explain in terms of the actual motion and position of the Earth.	9
9	State the constellations of the zodiac in order and explain the relation between the zodiac and the Sun.	10 – 14
10	Explain, define, and utilize the concept of the ecliptic and the ecliptic plane.	
11	Illustrate and describe the connection between the seasons and the motion and orientation of the Earth in its orbit.	15
12	Explain the cause and effect of Earth's precession and state and apply the period of this cycle to solve problems.	16
13	Describe changes in the appearance of the Moon over the course of one day and night, from one night to the next, from one week to the next, from one month to the next, and from year to year.	17 – 20
14	Explain the apparent motion and changing appearance of the Moon in terms of the actual motions of the Earth and Moon relative to the Sun.	
15	Explain and illustrate how the motion and position of the Moon relative to the Earth and the Sun result in the phases: new Moon, waxing crescent, first quarter, waxing gibbous, full Moon, waning gibbous, third quarter, and waning crescent.	
16	Define, apply, and relate to astronomical events or cycles the following concepts: sidereal month, synodic month, lunar sidereal and solar days.	21 – 22
17	Explain and illustrate how the motions and positions of the Earth, the Sun, and the Moon result in lunar and solar eclipses – partial, total, and annular.	23
18	Explain and illustrate the concepts of umbra and penumbra in relation to eclipses.	24

Long Term Changes

- Certain aspects of the celestial sphere change very slowly over time.
- The celestial north and south poles are not fixed relative to the stars.
- The equinoxes and solstices “drift” along the ecliptic and move through different constellations.
- The coordinates (*RA* and *dec*) of any particular star change over time.

2000 AD

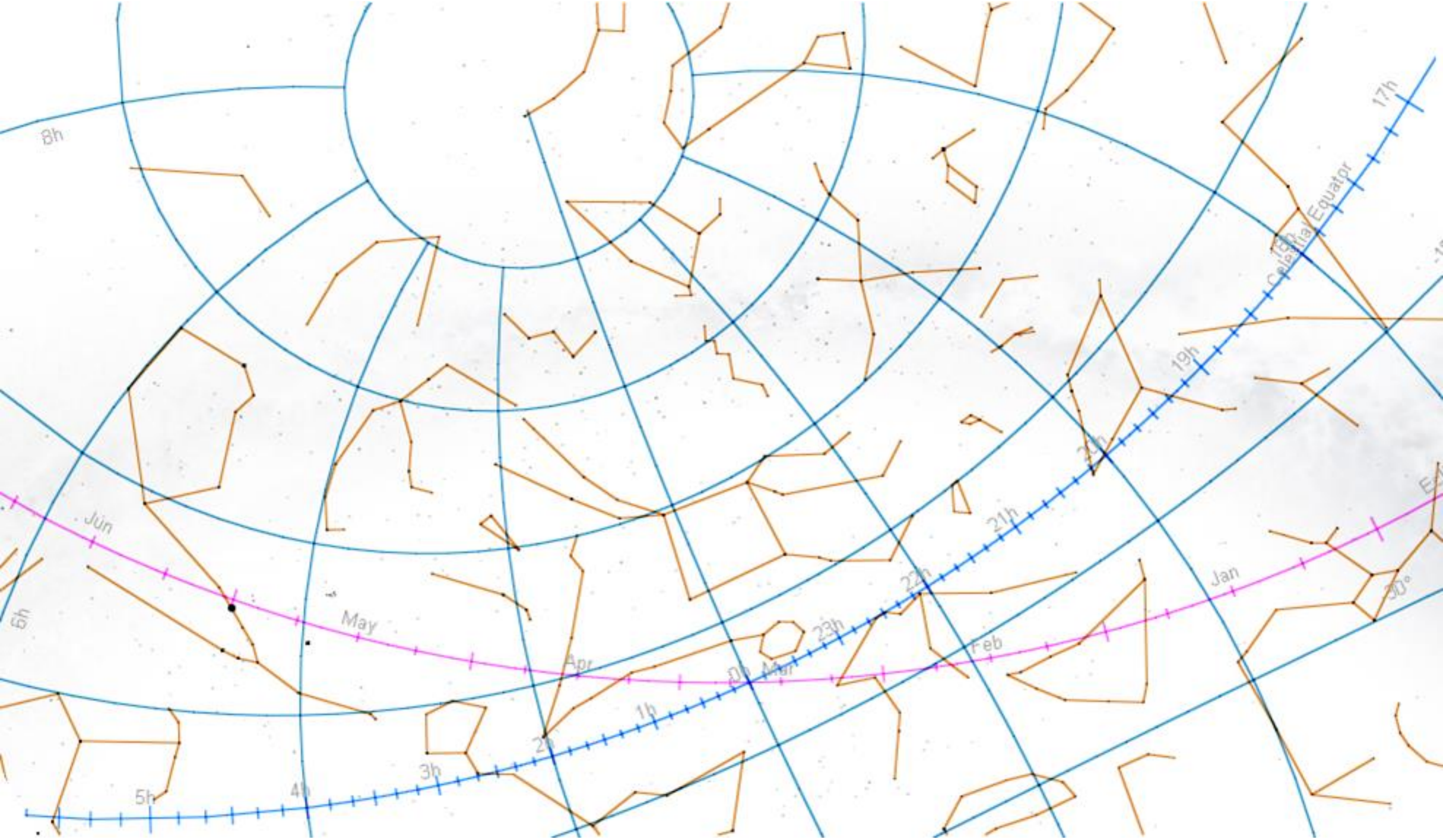
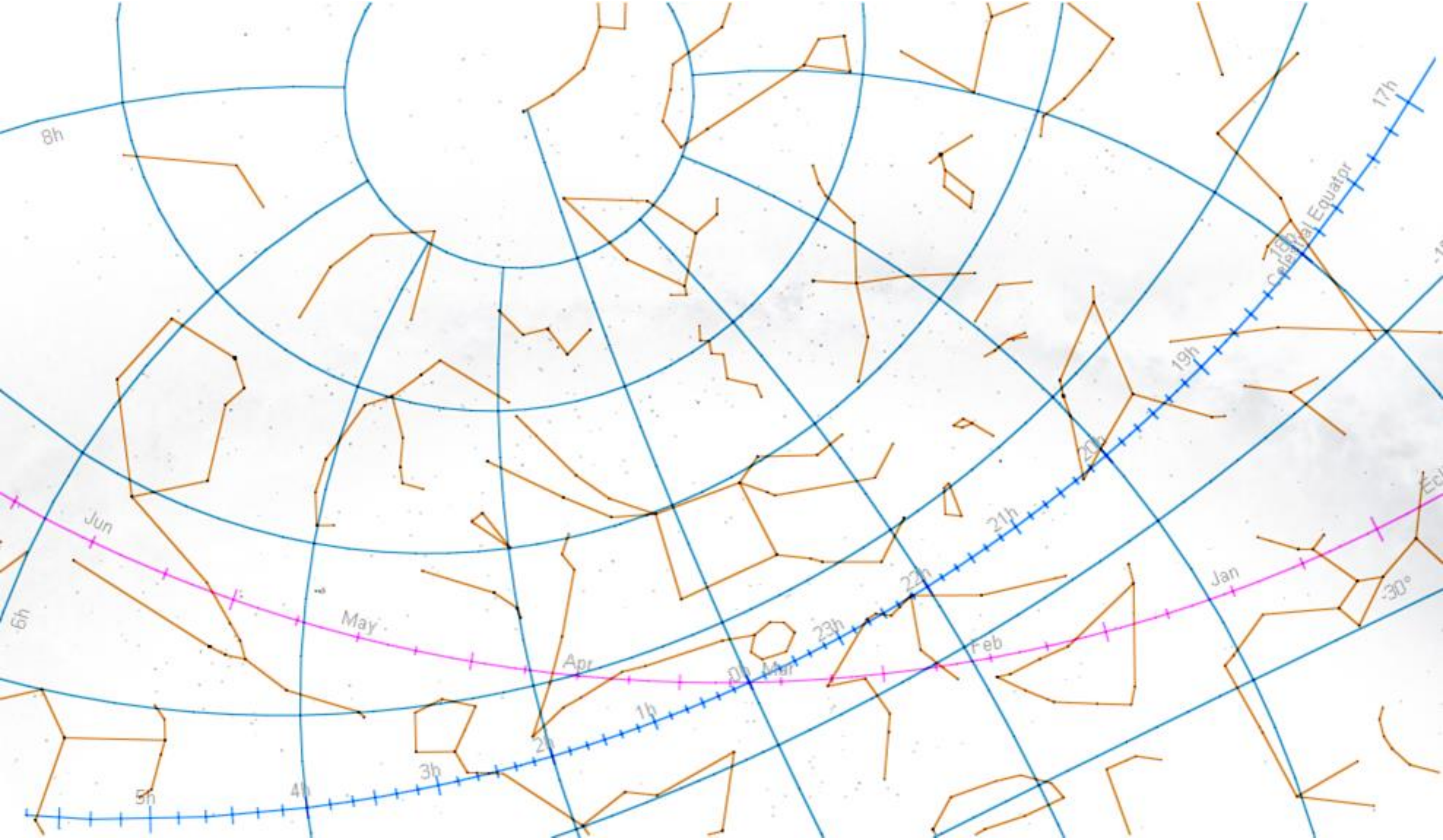


image: Starry Night

2100 AD



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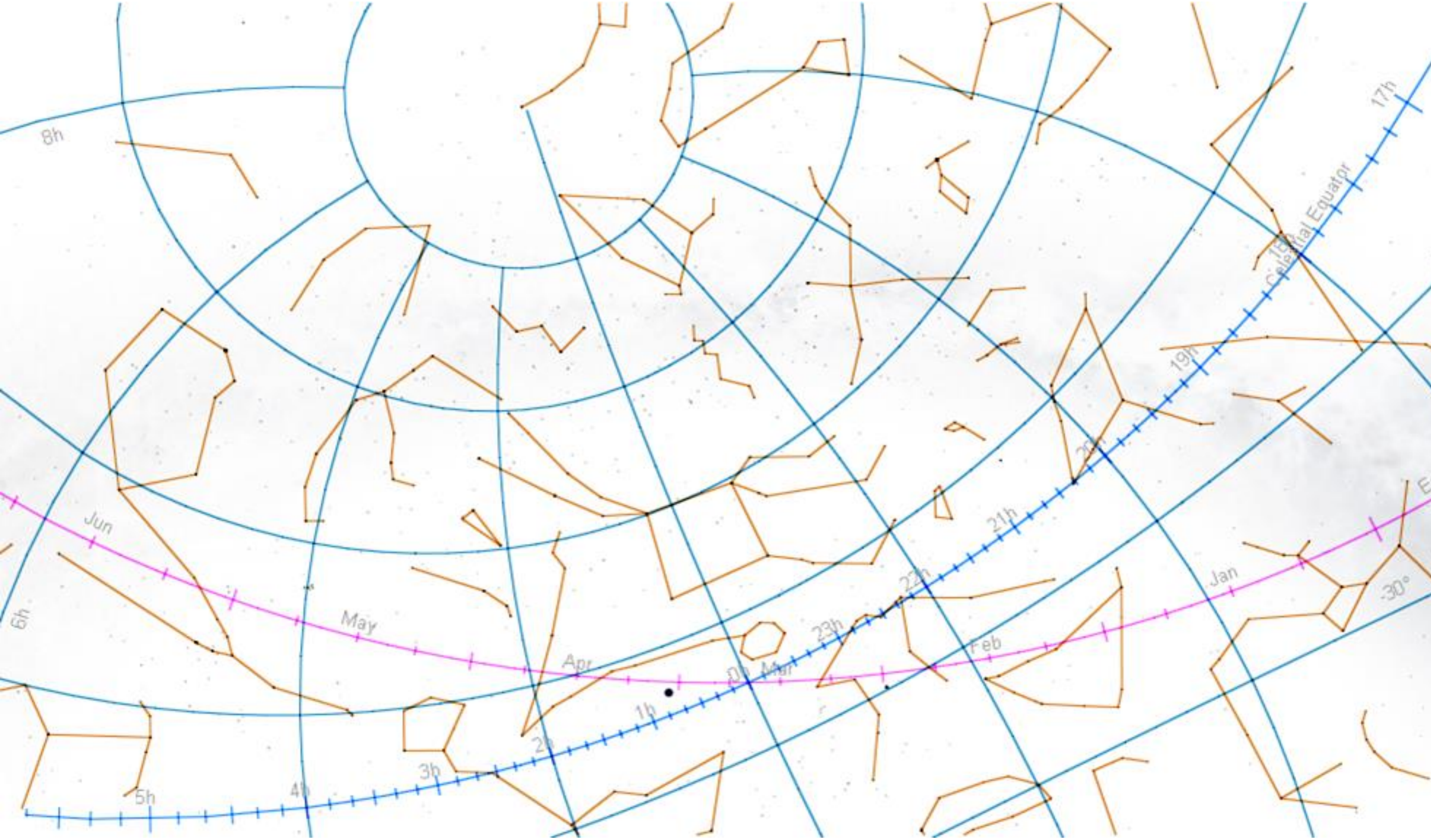
2200 AD



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2300 AD

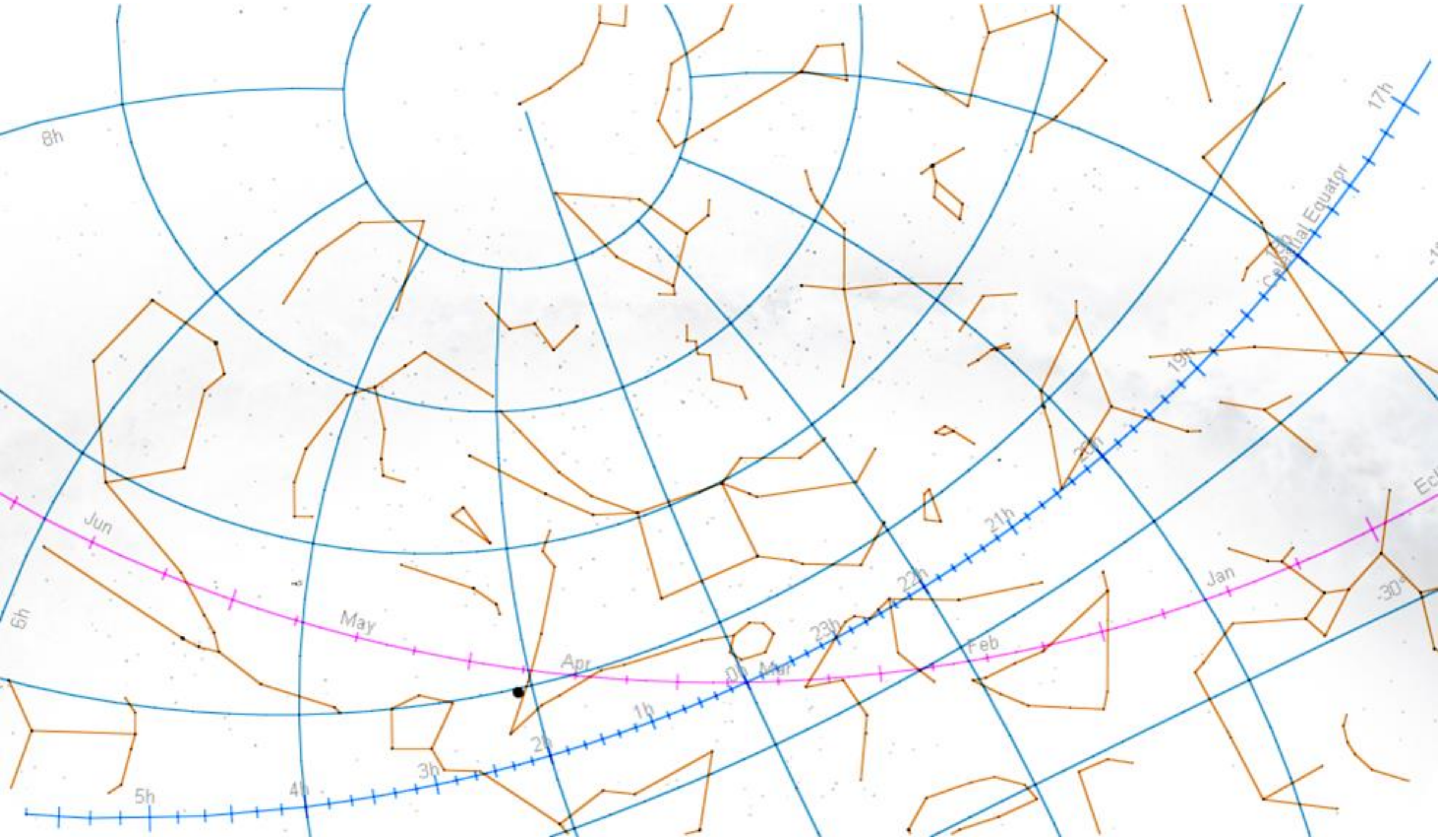


image: Starry Night

What is changing?

And what *isn't* changing?

To best appreciate and understand the charts shown here you should arrange so that you can flip through the pages by clicking of tapping "page down". In other words don't *scroll* through all these charts – *jump instantly* from one to the next like stepping through a movie one frame at a time.

Check out the previous 4 charts and the next 15 charts in this way – note the year depicted by each chart. You are observing changes that are only apparent and significant over very long periods of time…

2000 AD

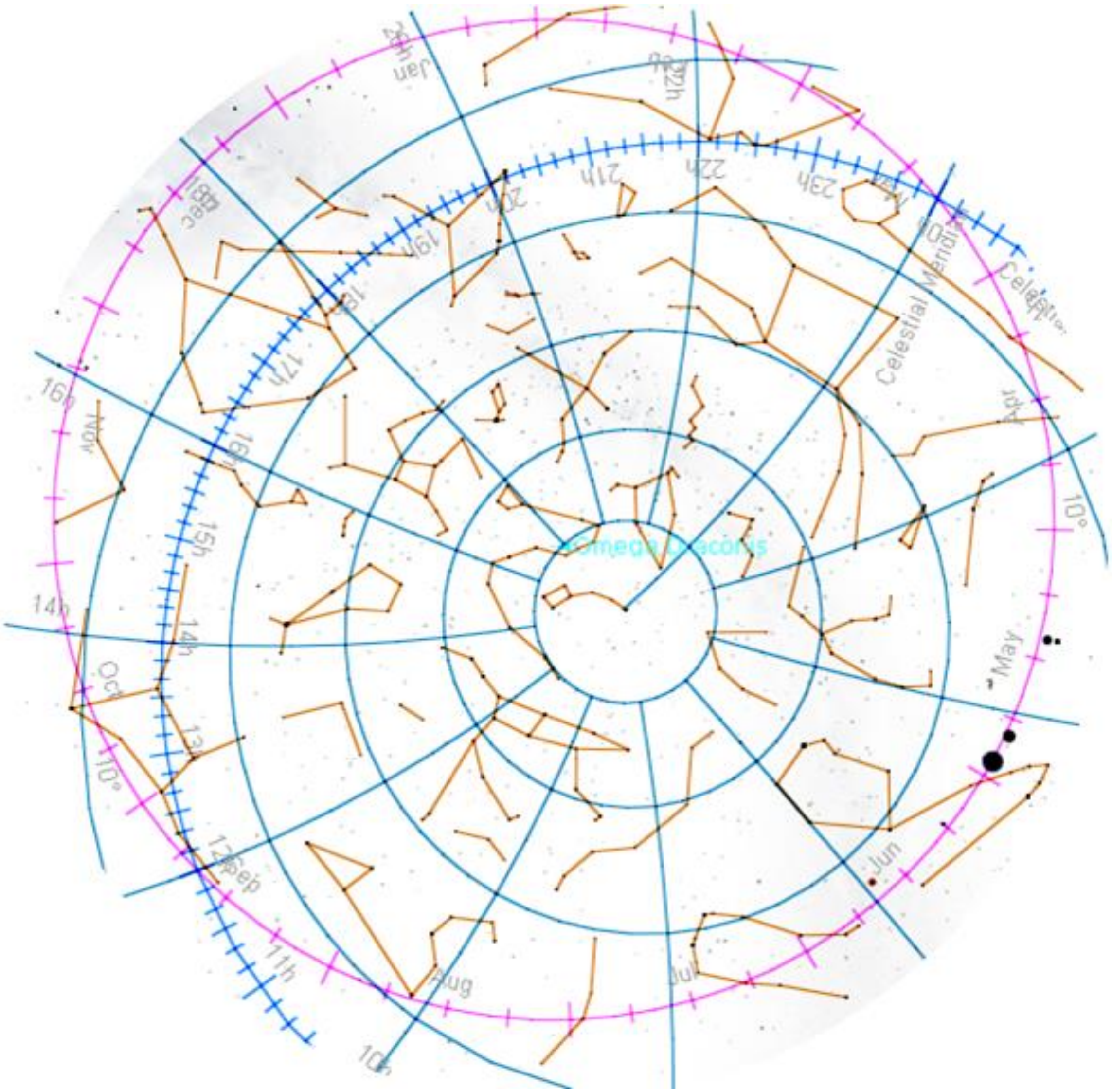


image: Starry Night

3000 AD

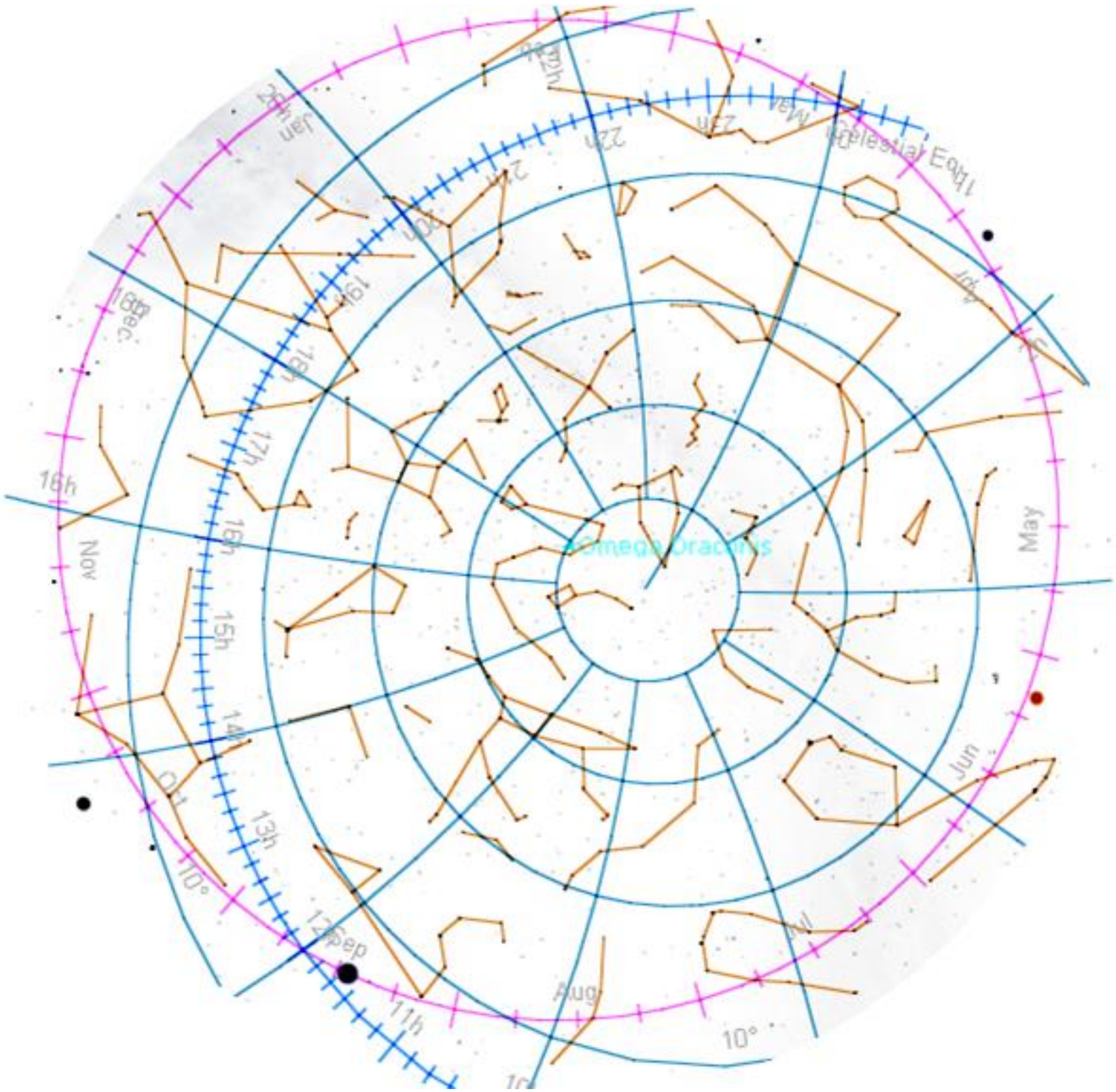


image: Starry Night

4000 AD

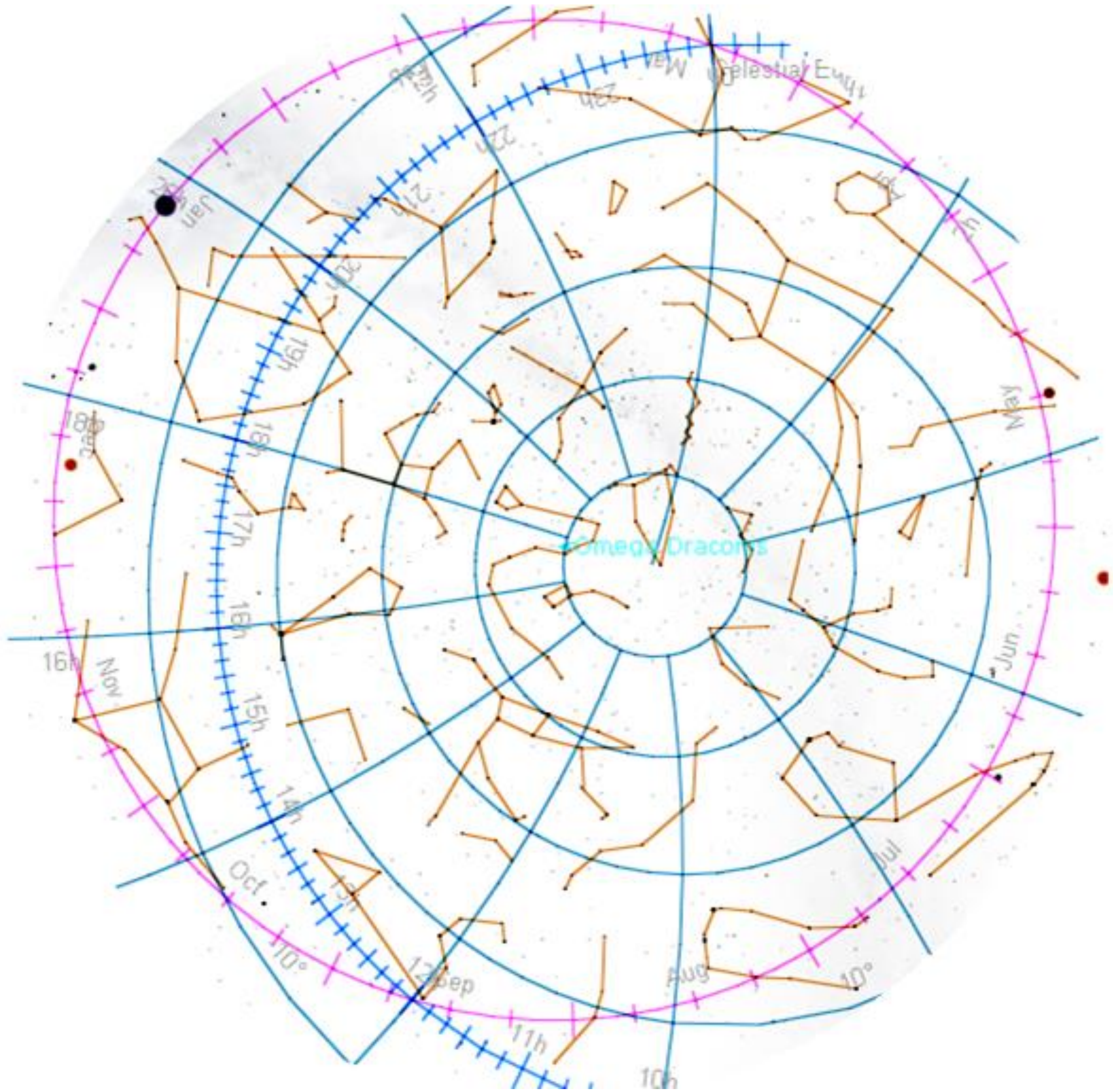


image: Starry Night

5000 AD

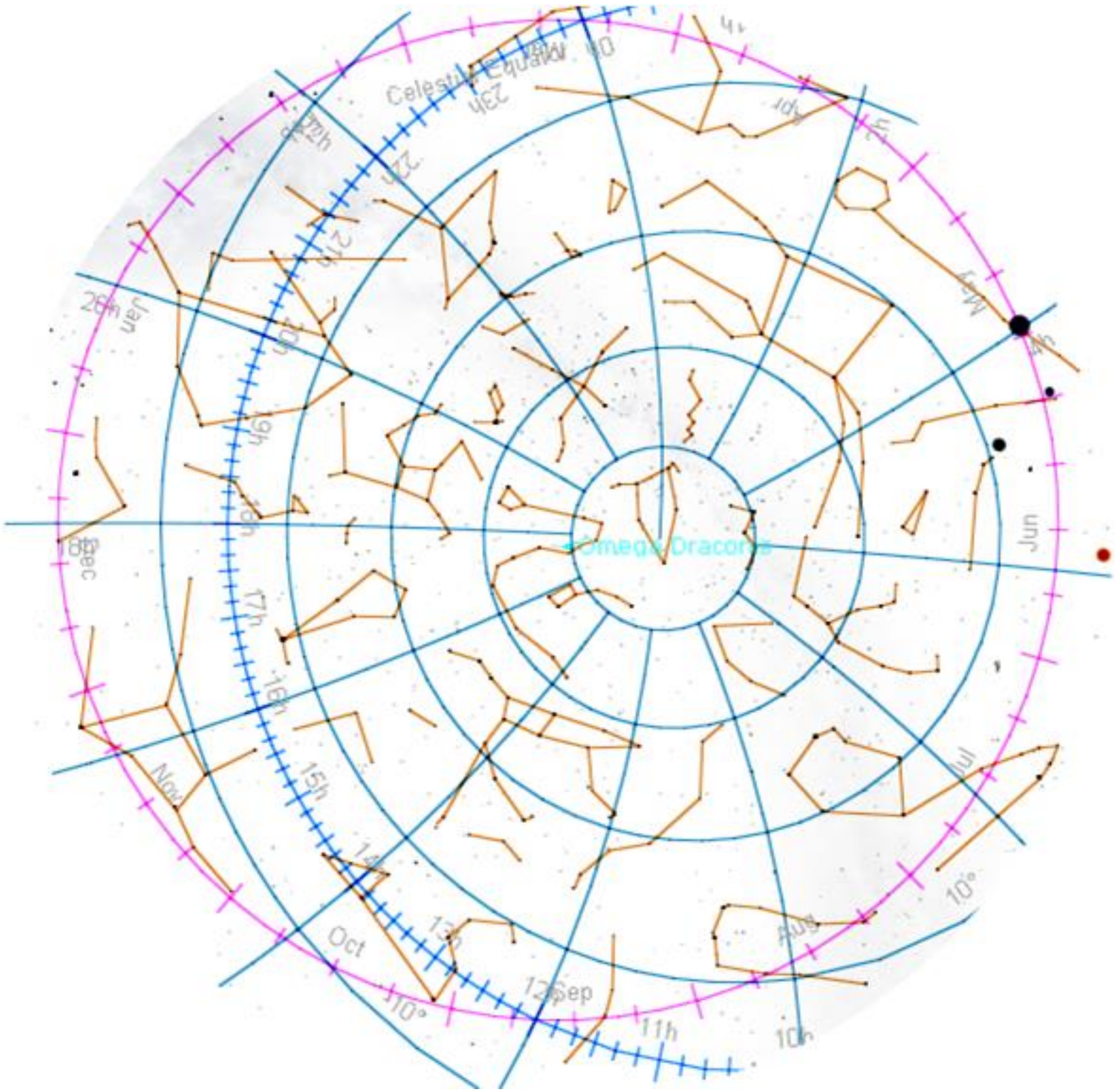
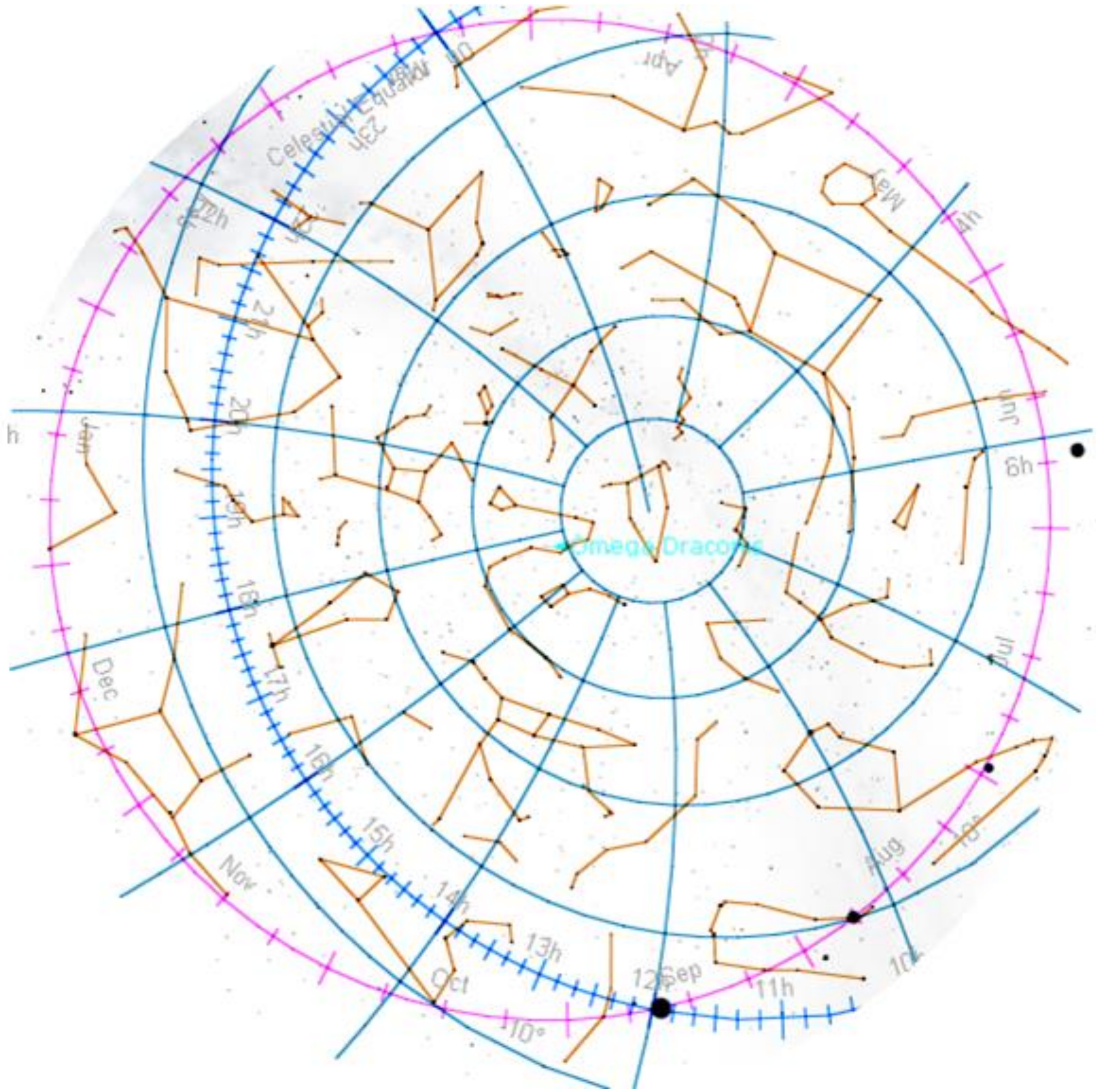


image: Starry Night

6000 AD



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7000 AD

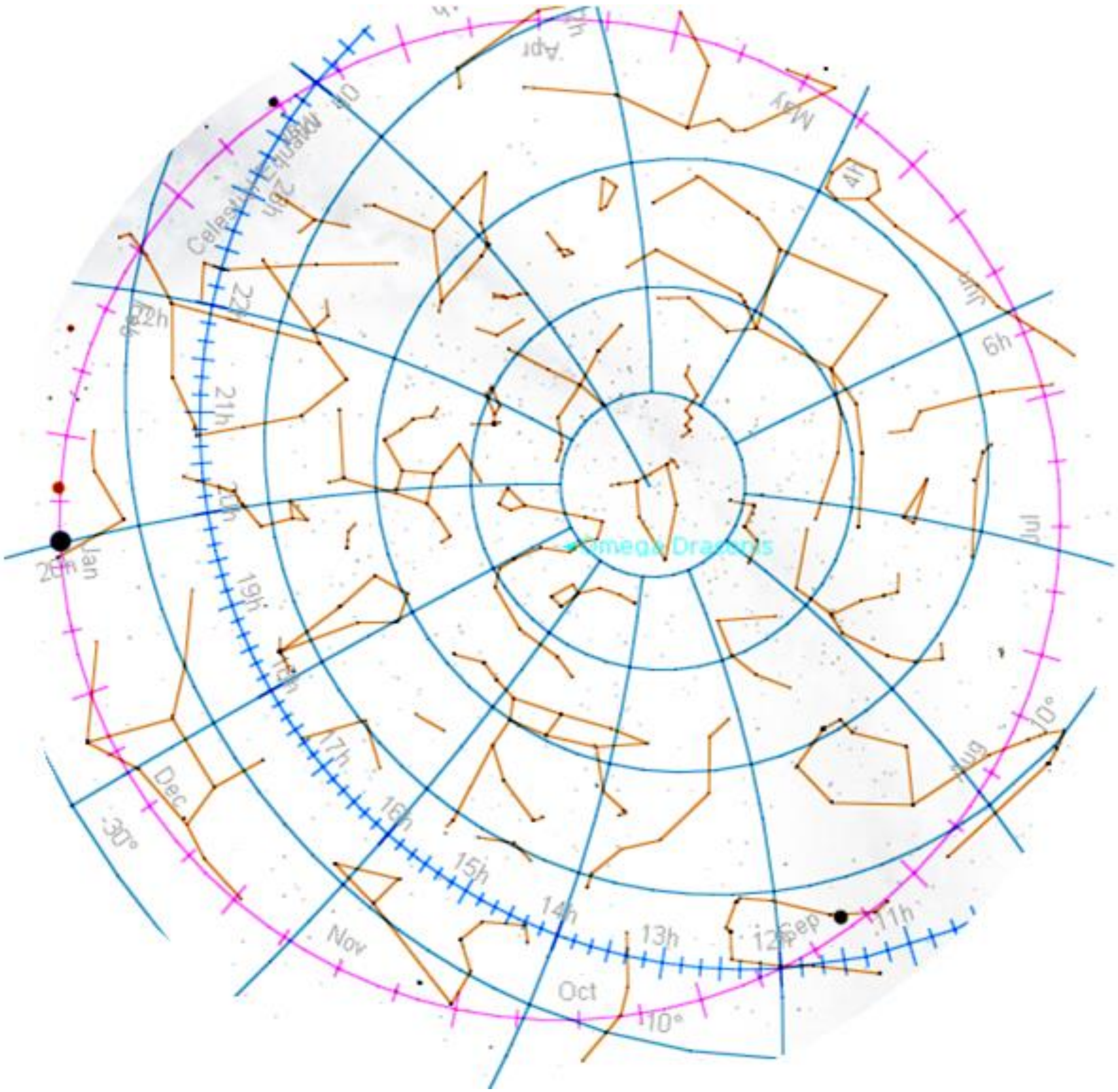
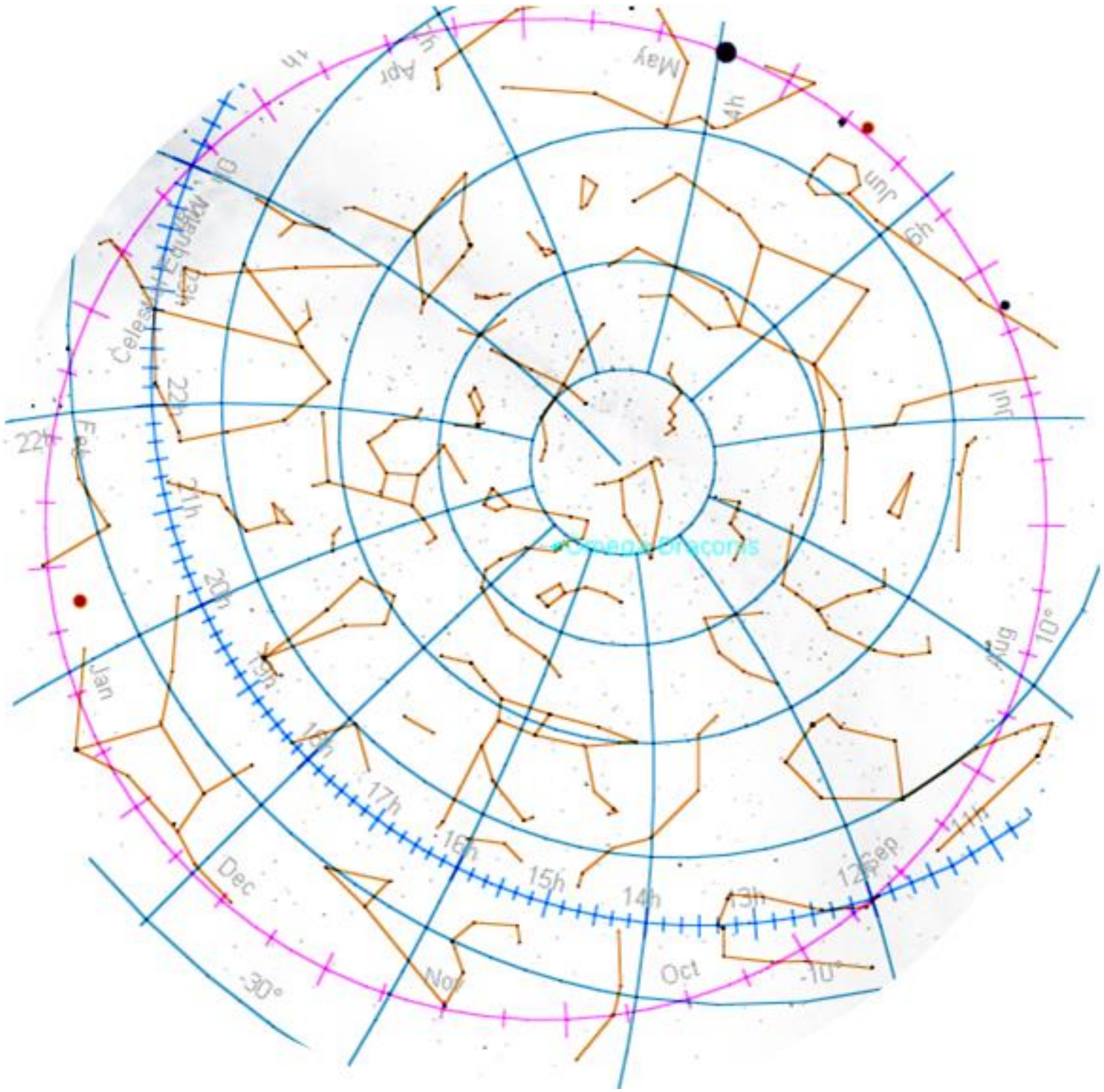


image: Starry Night

8000 AD



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9000 AD

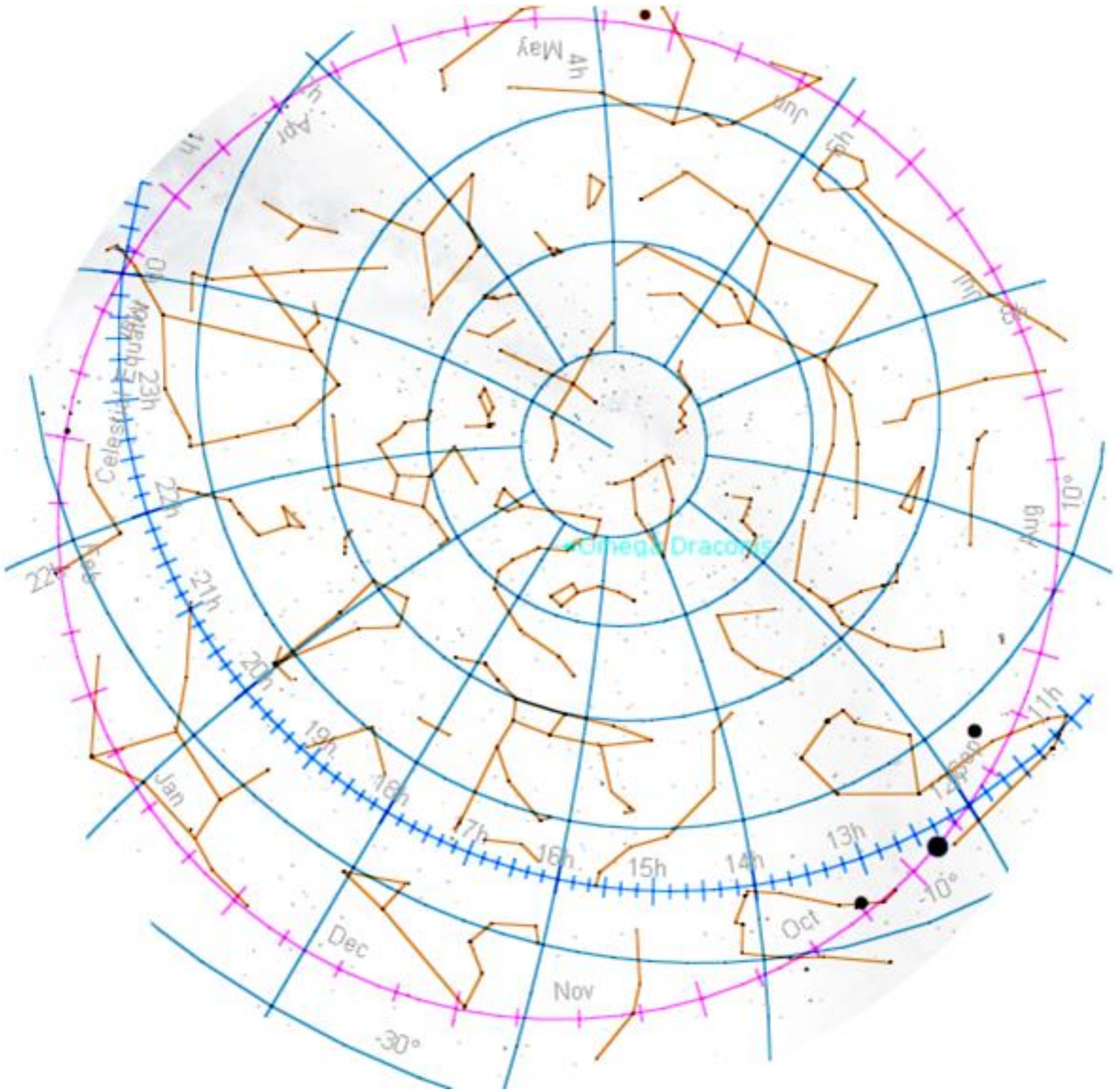


image: Starry Night

10000 AD

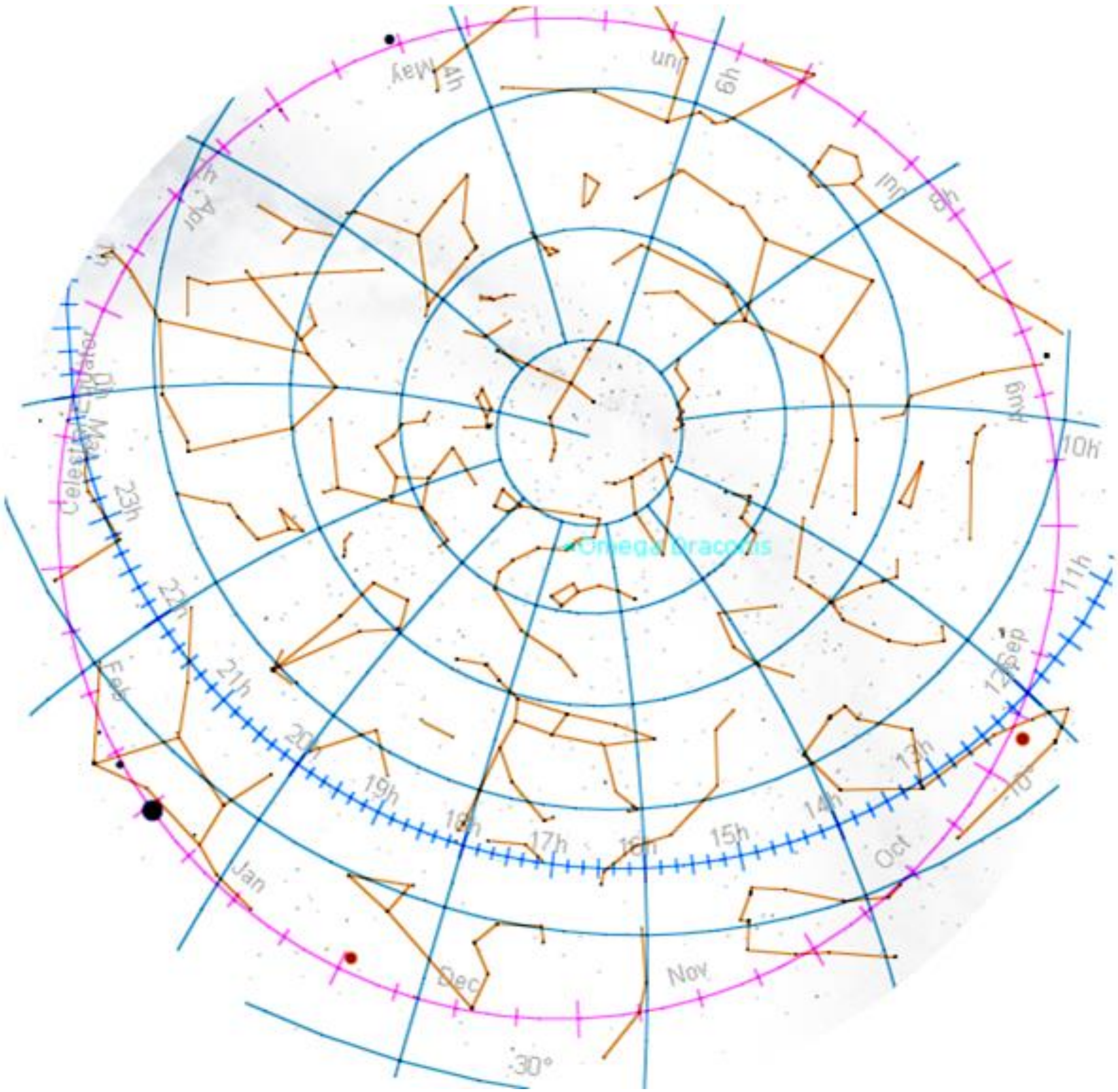
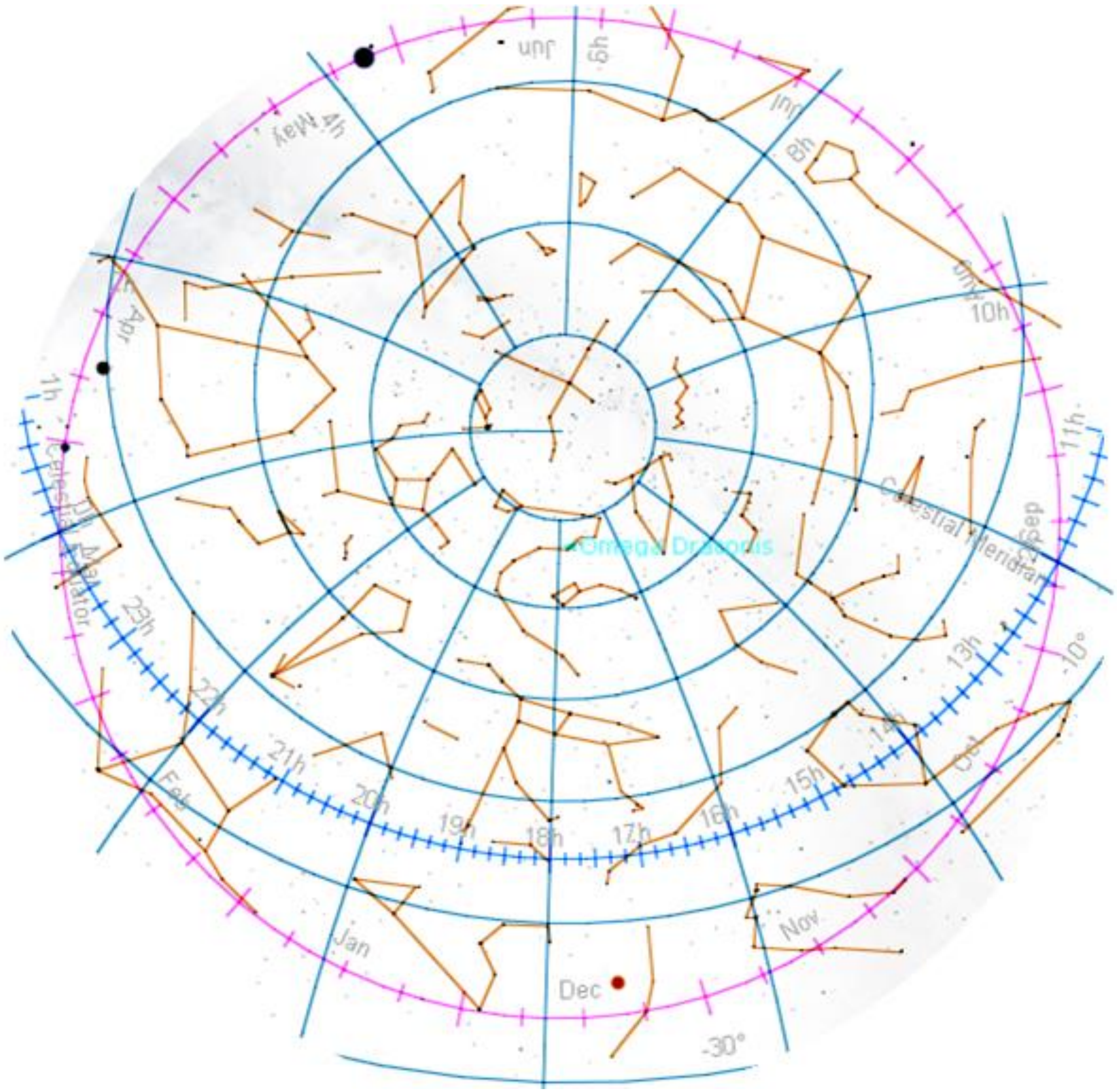
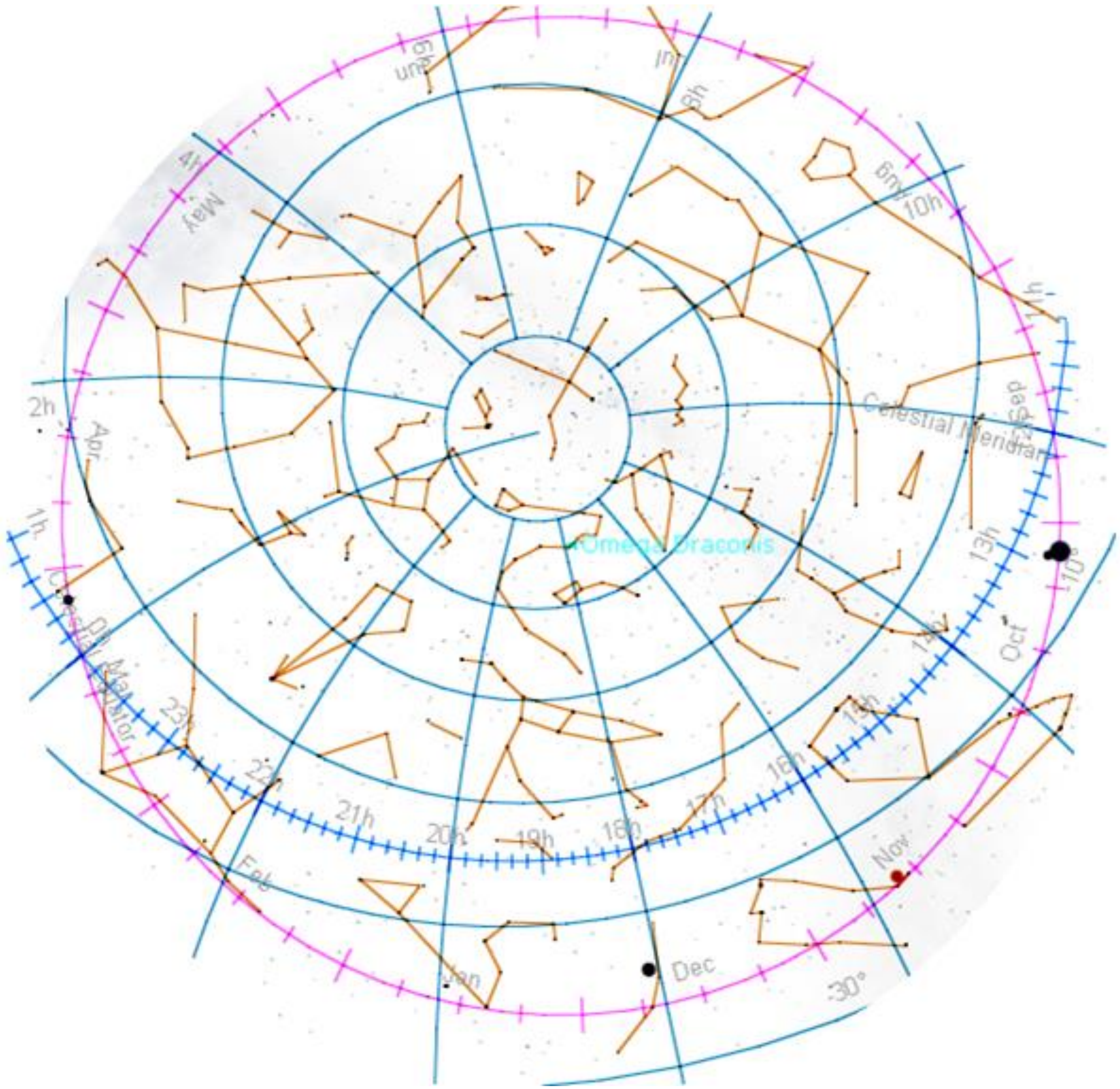


image: Starry Night

11000 AD


Jun
6h
Jul
4h May
8h
Aug
10h
Apr
1h
11h
Celestial Equator
Mar
Celestial Meridian
Sep
Omega Draconis
23h
13h
10°
22h
14h
Oct
21h
15h
Feb
20h
19h
18h
17h
16h
Nov
Jan
Dec
-30°

12000 AD



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13000 AD

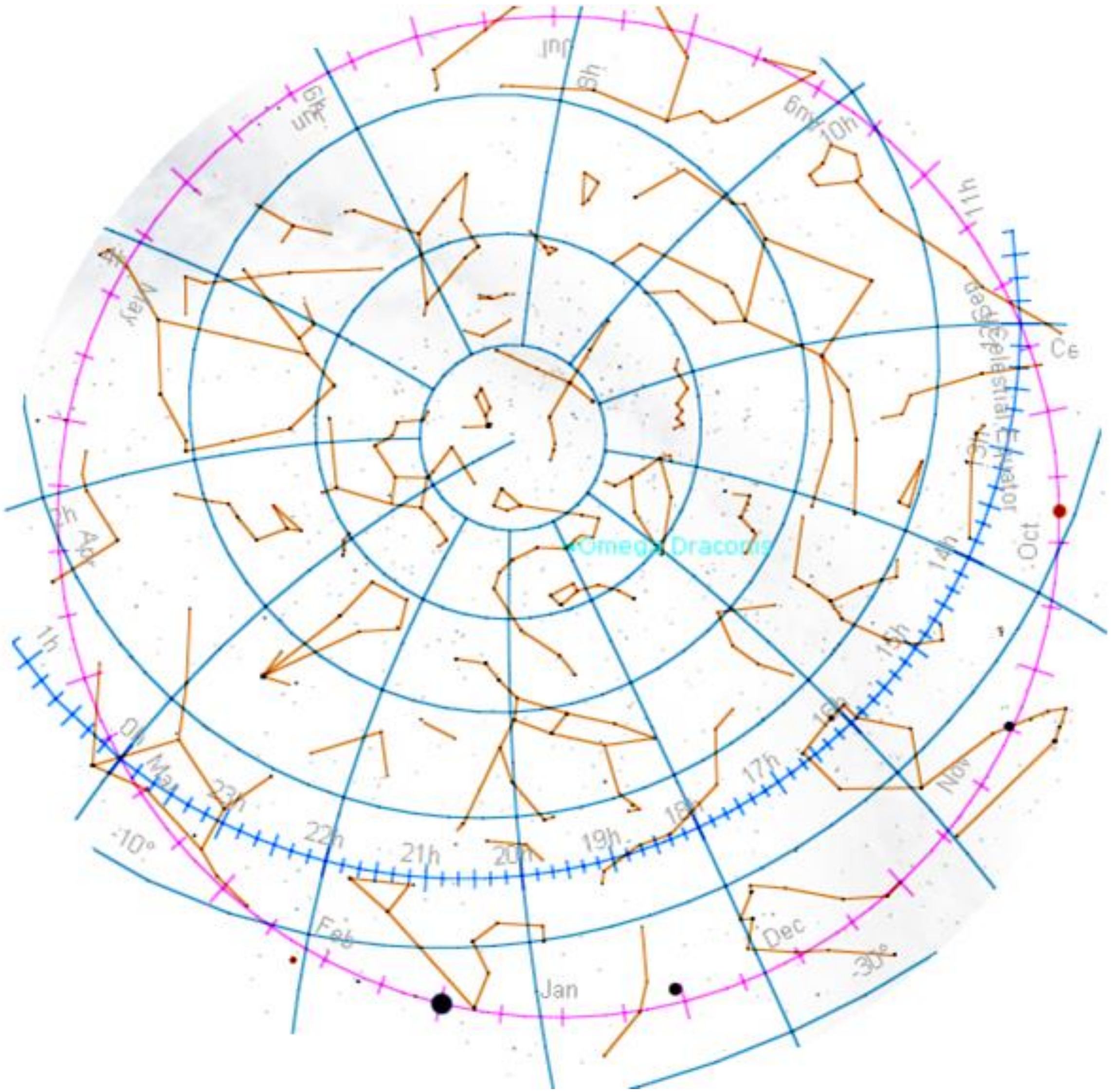


image: Starry Night

14000 AD

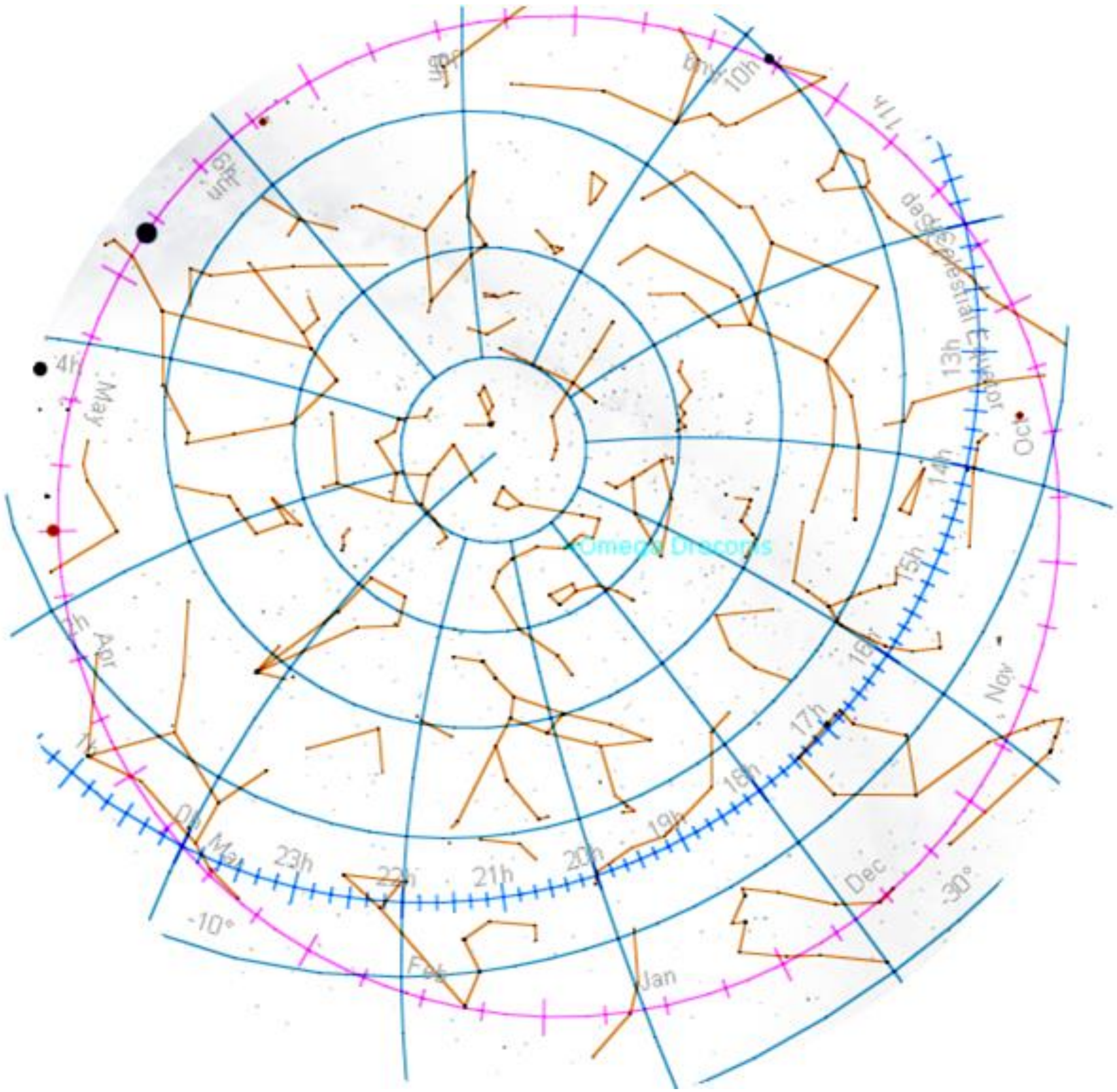


image: Starry Night

15000 AD

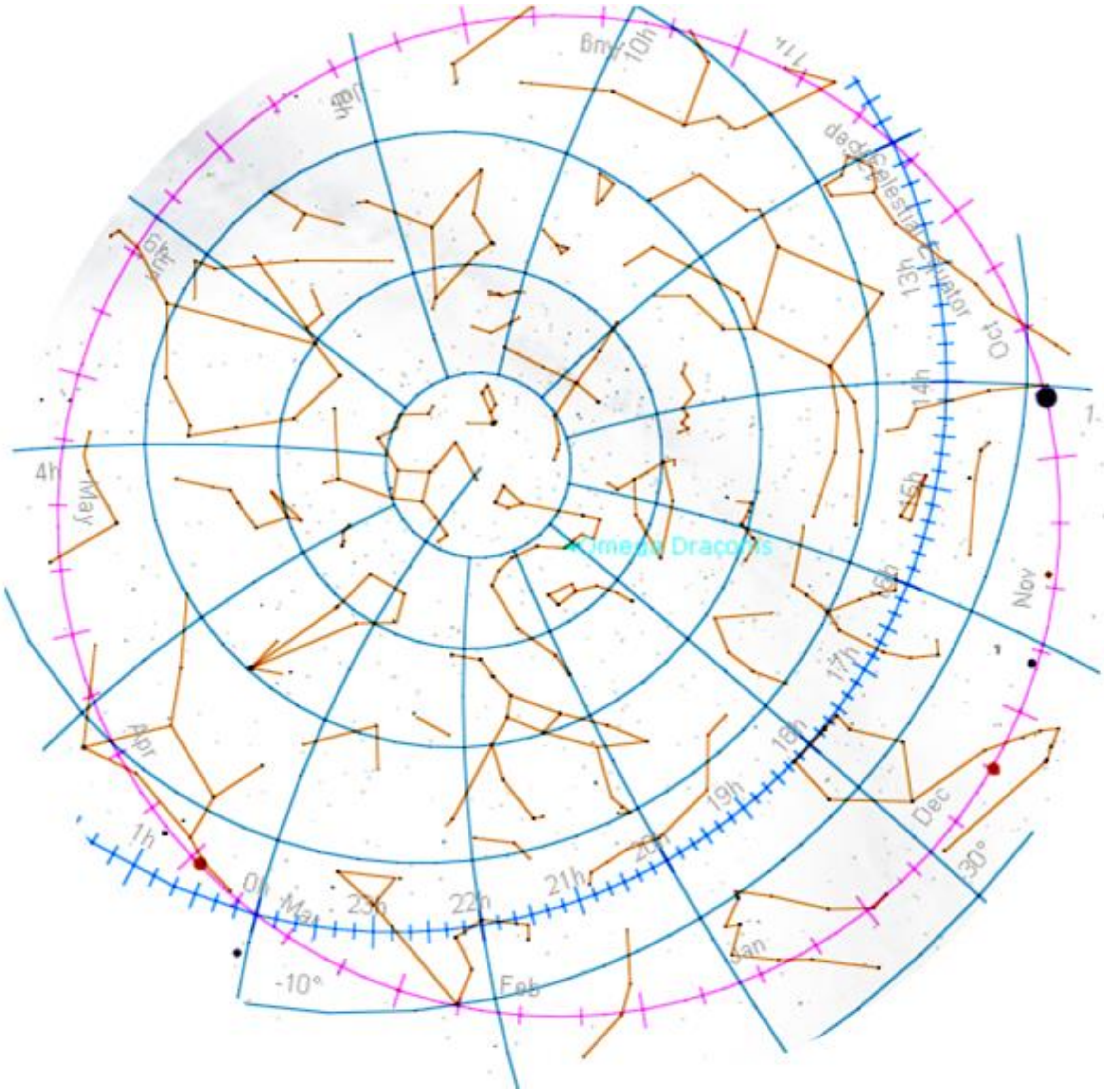
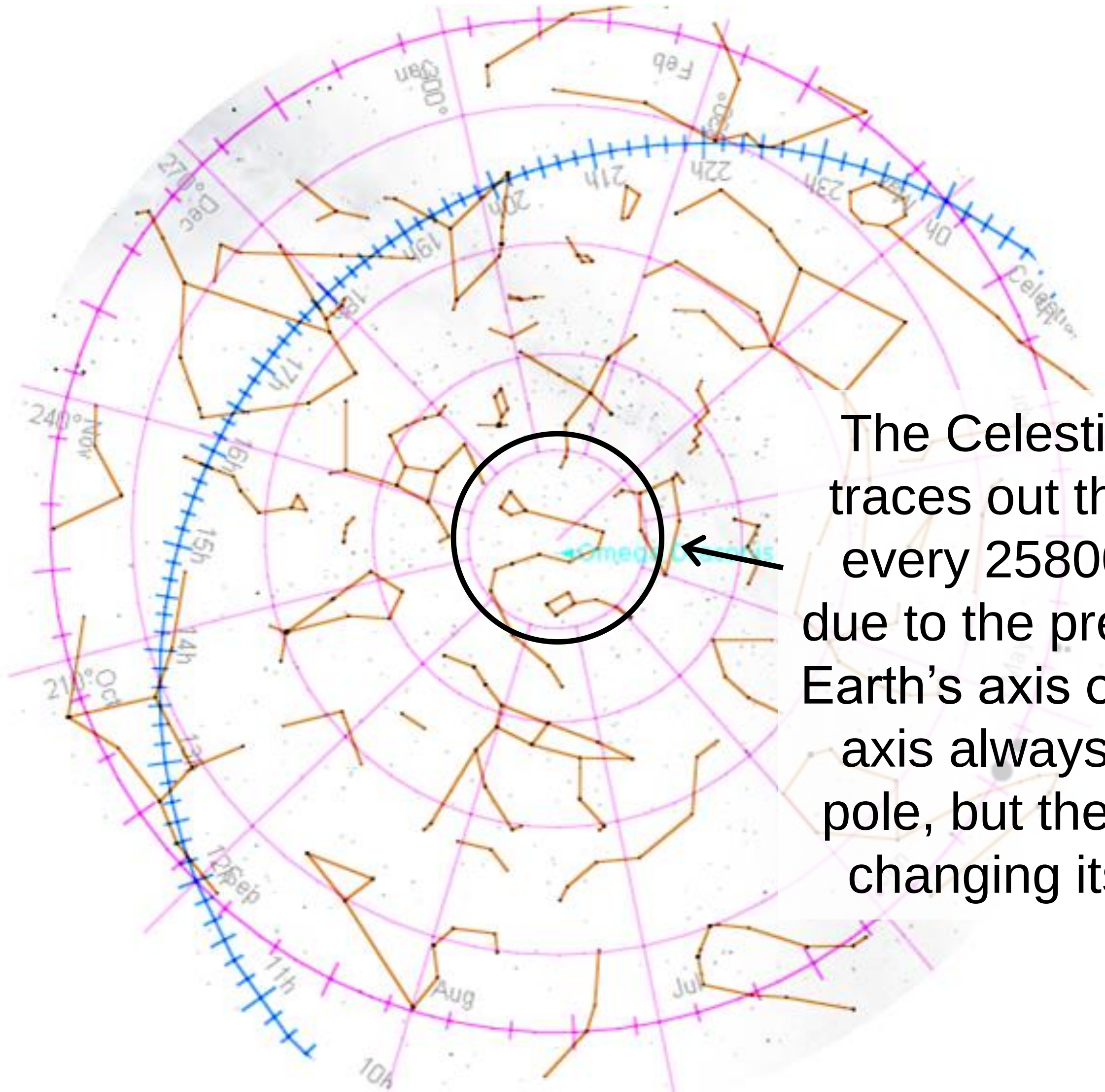


image: Starry Night

Precession

- These long term changes are caused by the precession of the Earth.
- Precession is a slow "wobble" of the Earth's axis of rotation – much like that of a spinning top or gyroscope.
- The Earth's axis completes one wobble in about 25800 years.
- The amount of tilt in the Earth's axis does not change, but the direction it points in space does change because of precession.

2000 AD



The Celestial North Pole traces out this circle once every 25800 yrs. This is due to the precession of the Earth's axis of rotation – the axis always points to the pole, but the axis is slowly changing its orientation.

image: Starry Night

2000 AD

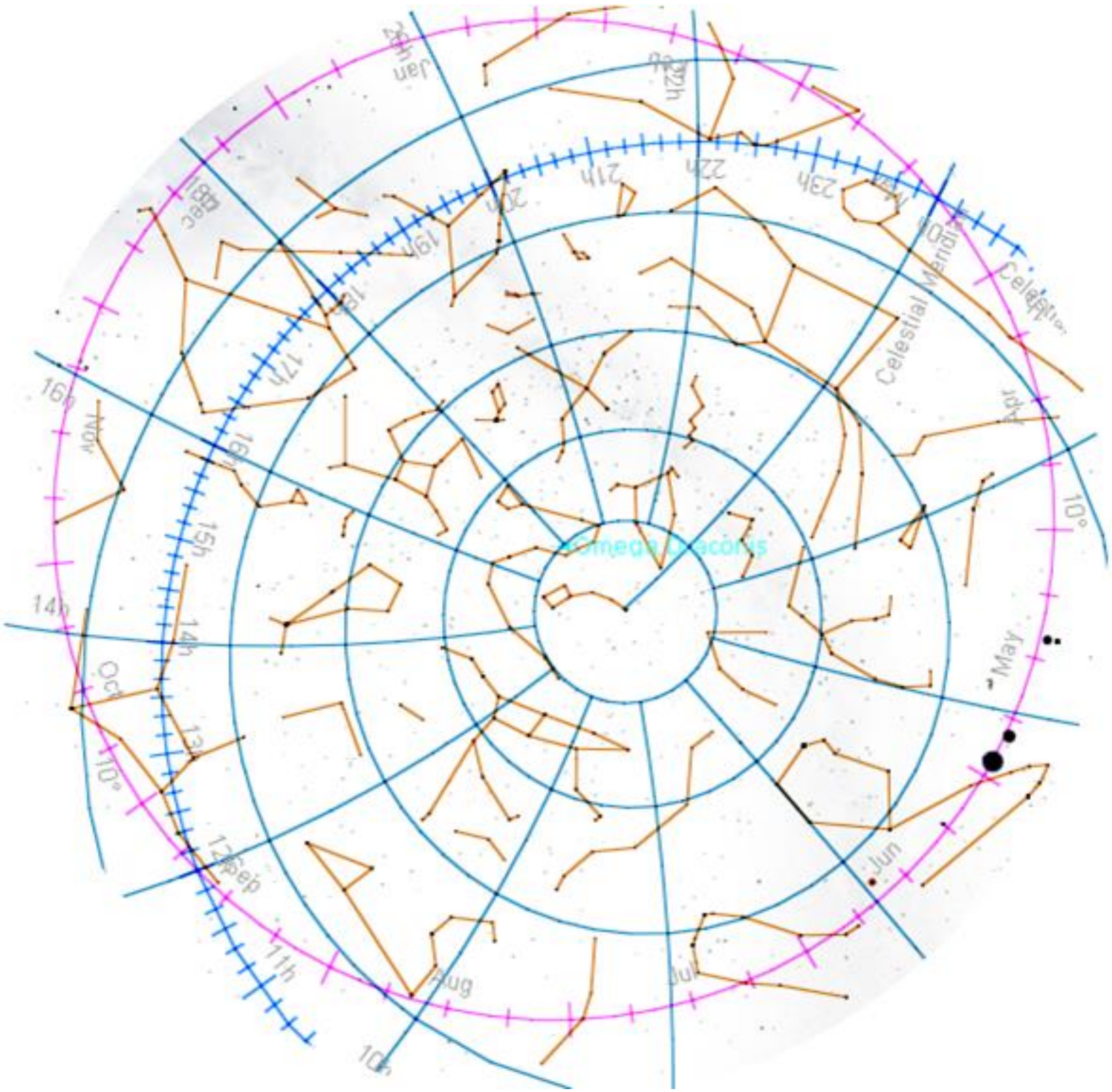
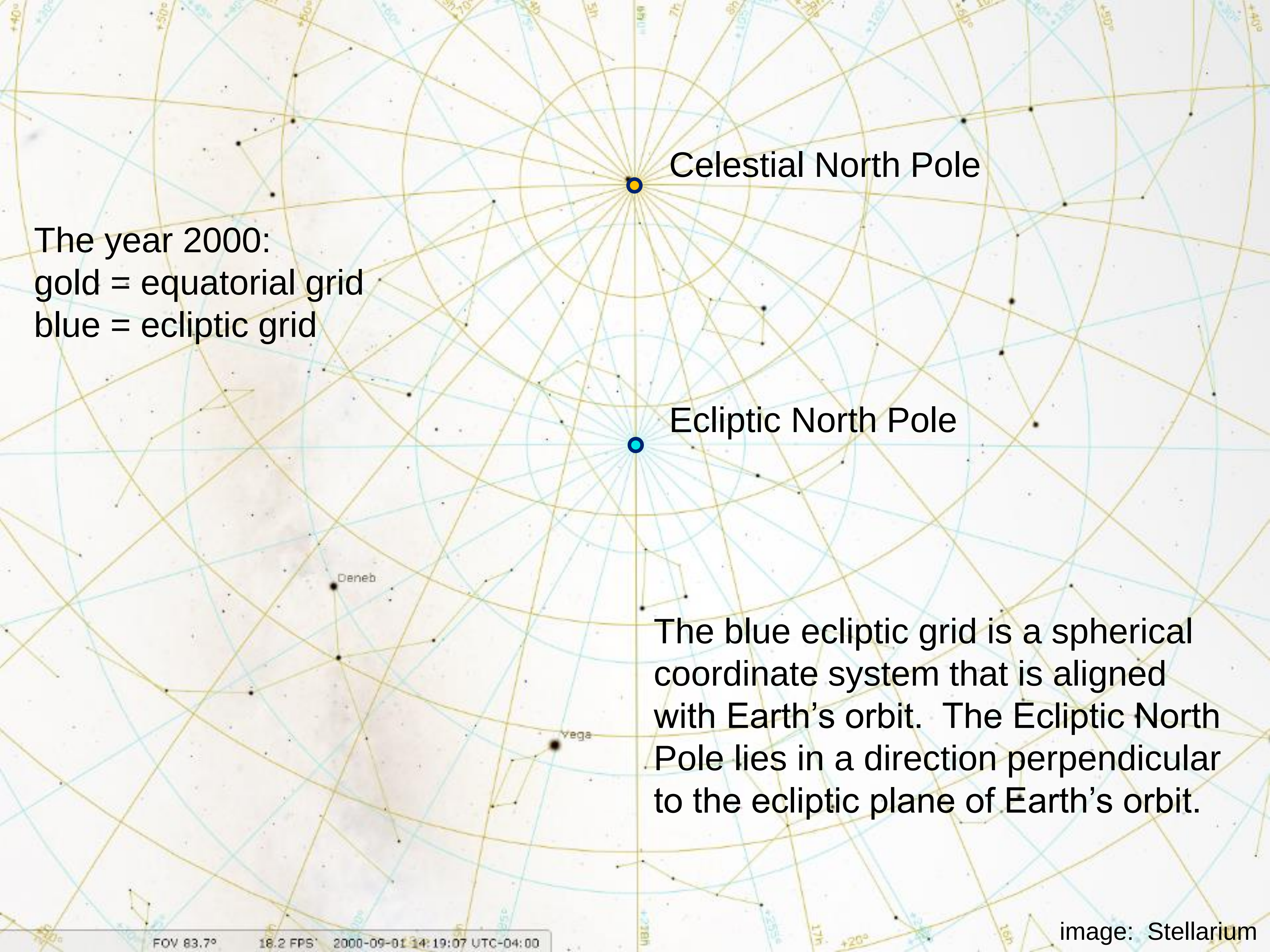
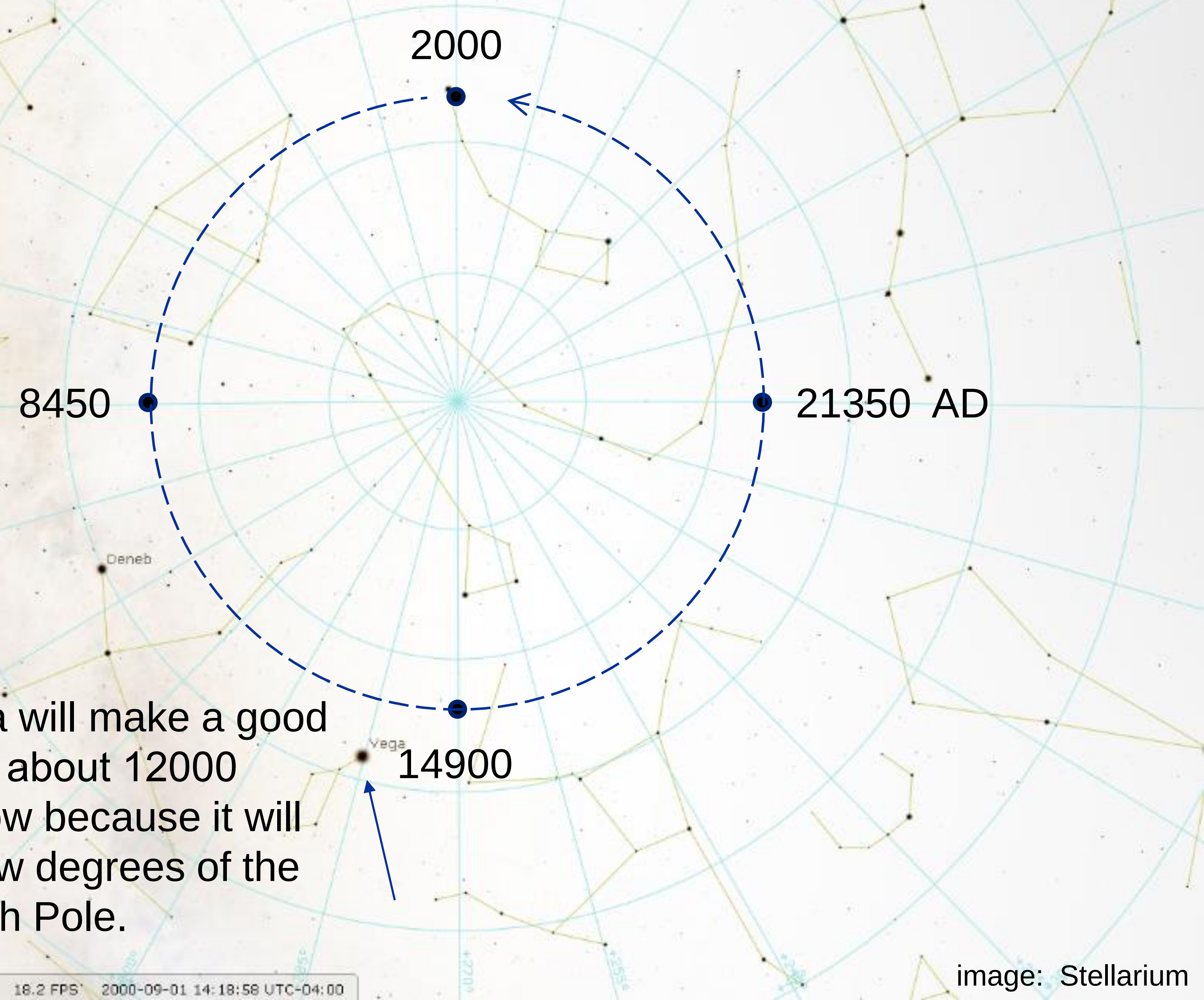


image: Starry Night

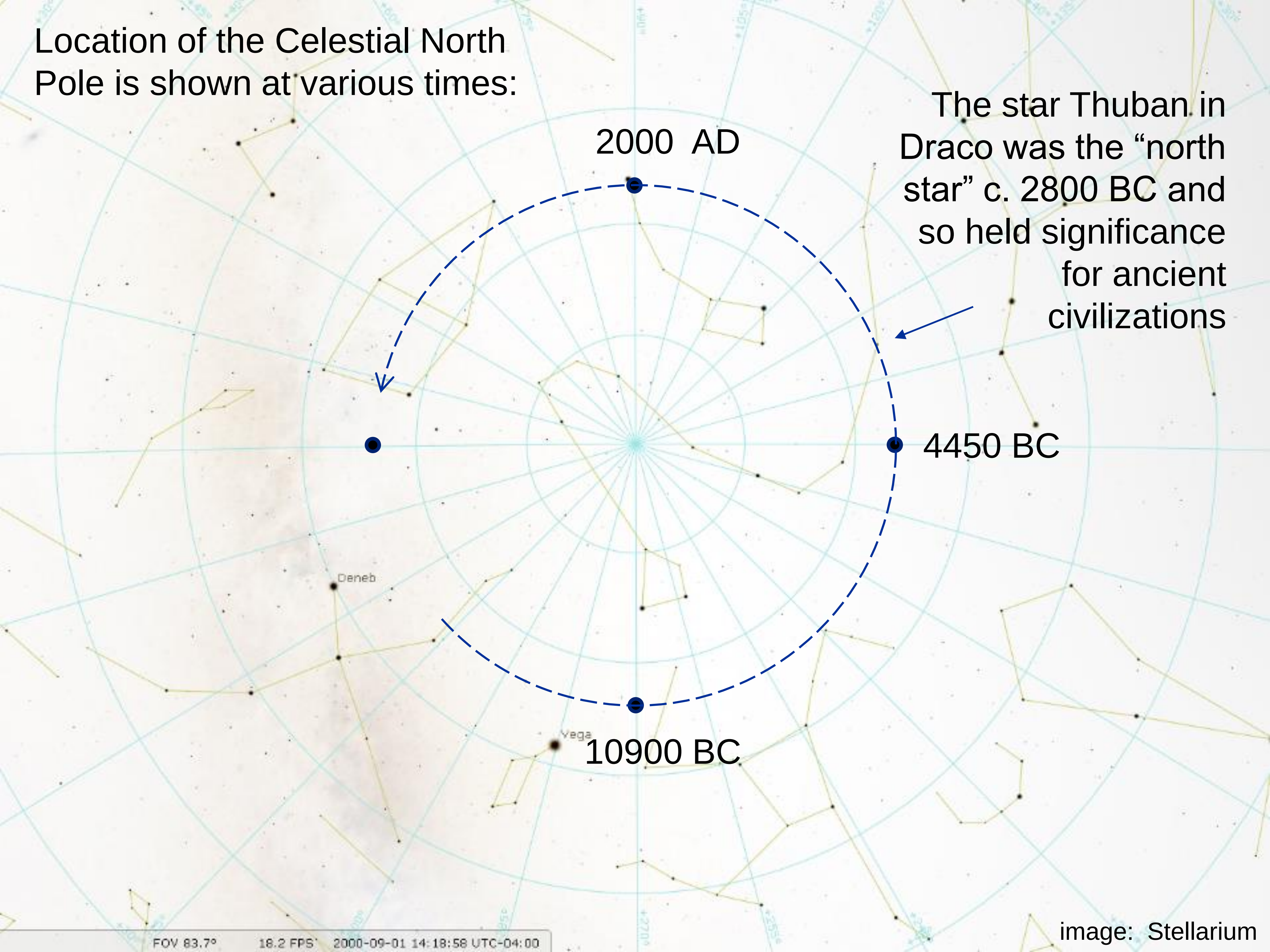

Celestial North Pole
The year 2000:
gold = equatorial grid
blue = ecliptic grid
Ecliptic North Pole
Deneb
Vega
The blue ecliptic grid is a spherical coordinate system that is aligned with Earth's orbit. The Ecliptic North Pole lies in a direction perpendicular to the ecliptic plane of Earth's orbit.
FOV 83.7°
18.2 FPS
2000-09-01 14:19:07 UTC-04:00
image: Stellarium

Location of the Celestial North Pole is shown at various times:



The star Vega will make a good “north star” in about 12000 years from now because it will be within a few degrees of the Celestial North Pole.

image: Stellarium


Location of the Celestial North Pole is shown at various times:
The star Thuban in Draco was the "north star" c. 2800 BC and so held significance for ancient civilizations
2000 AD
4450 BC
10900 BC
Deneb
Vega
FOV 83.7°
18.2 FPS
2000-09-01 14:18:58 UTC-04:00
image: Stellarium

The Effects of Precession

- The Earth's orbit about the Sun is not affected by precession.
- Therefore the ecliptic does not change.
- However, the orientation of the Earth's equator changes; it wobbles like a hula-hoop!
- The precession of Earth's equator causes the equinoxes and solstices to shift along the ecliptic.

2000 AD

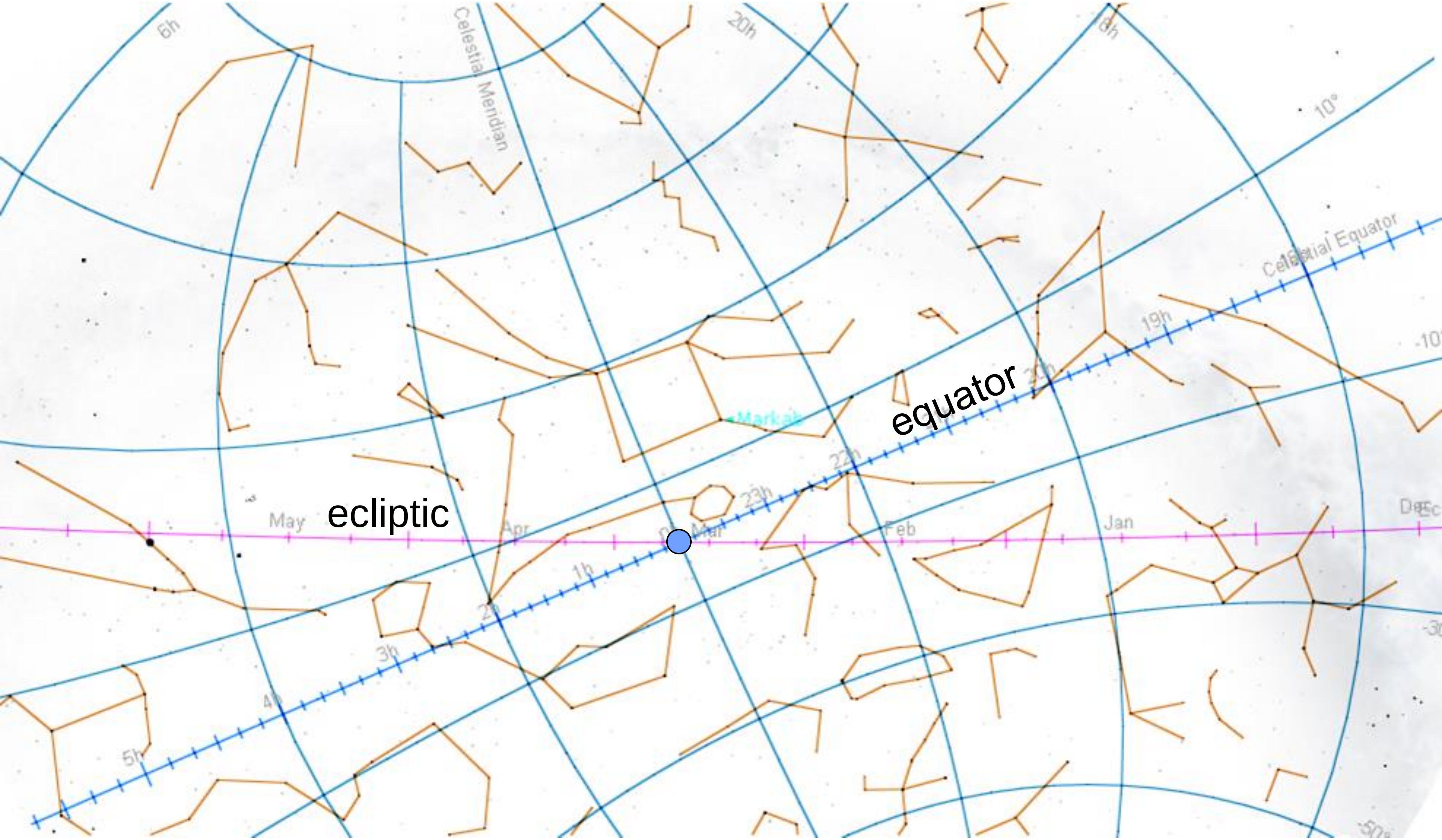


image: Starry Night

3000 AD

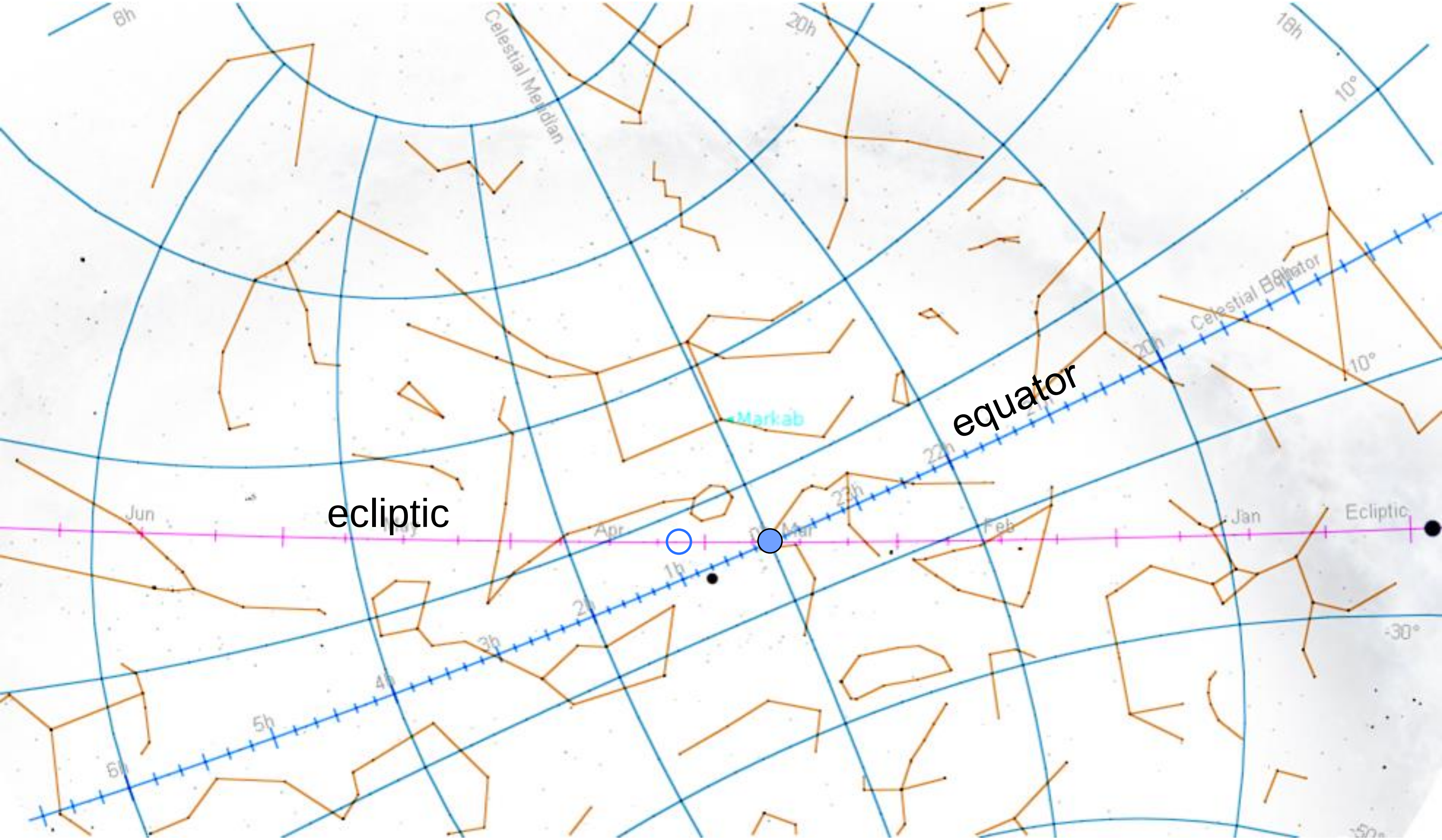


image: Starry Night

4000 AD

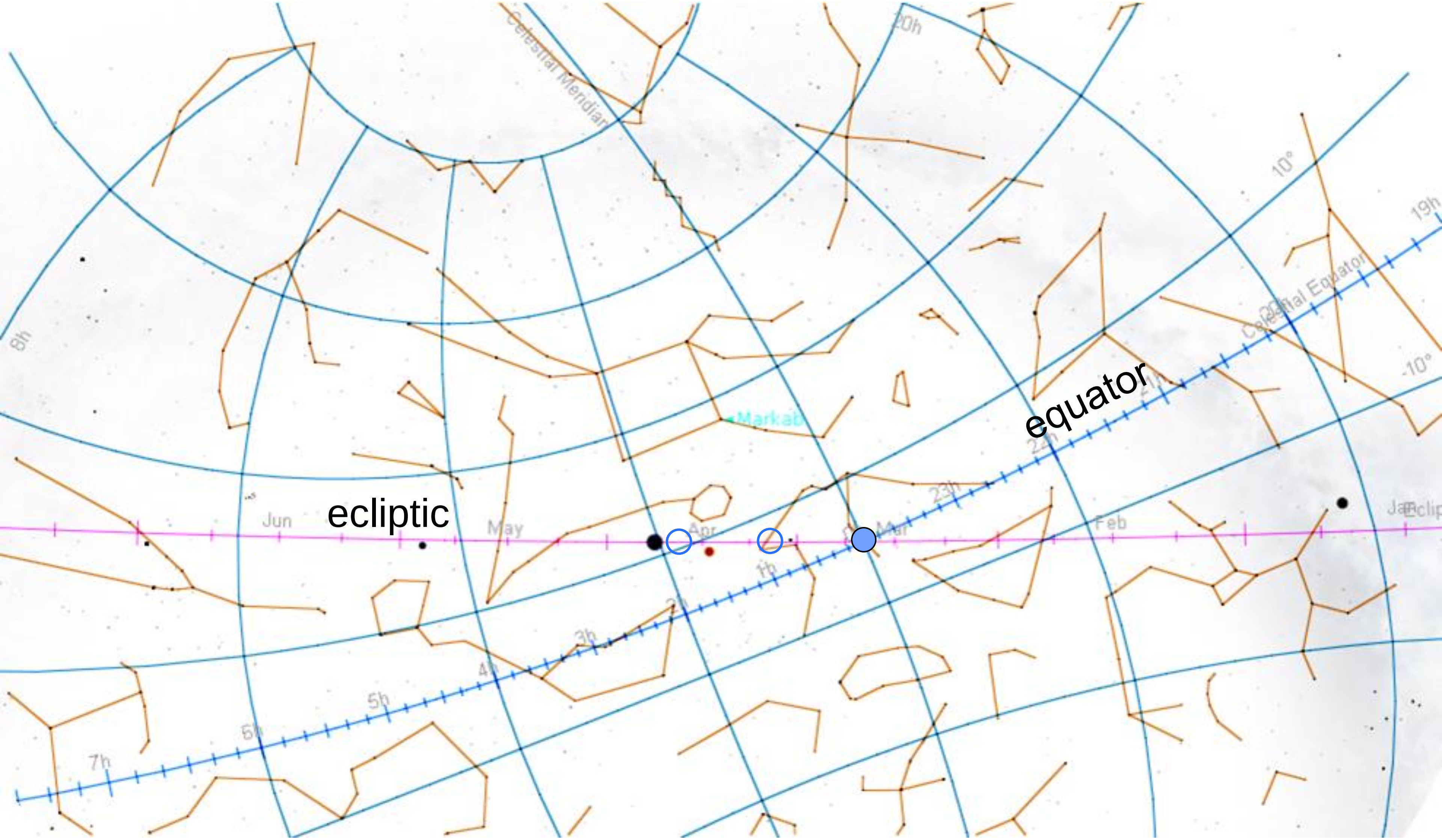


image: Starry Night

5000 AD

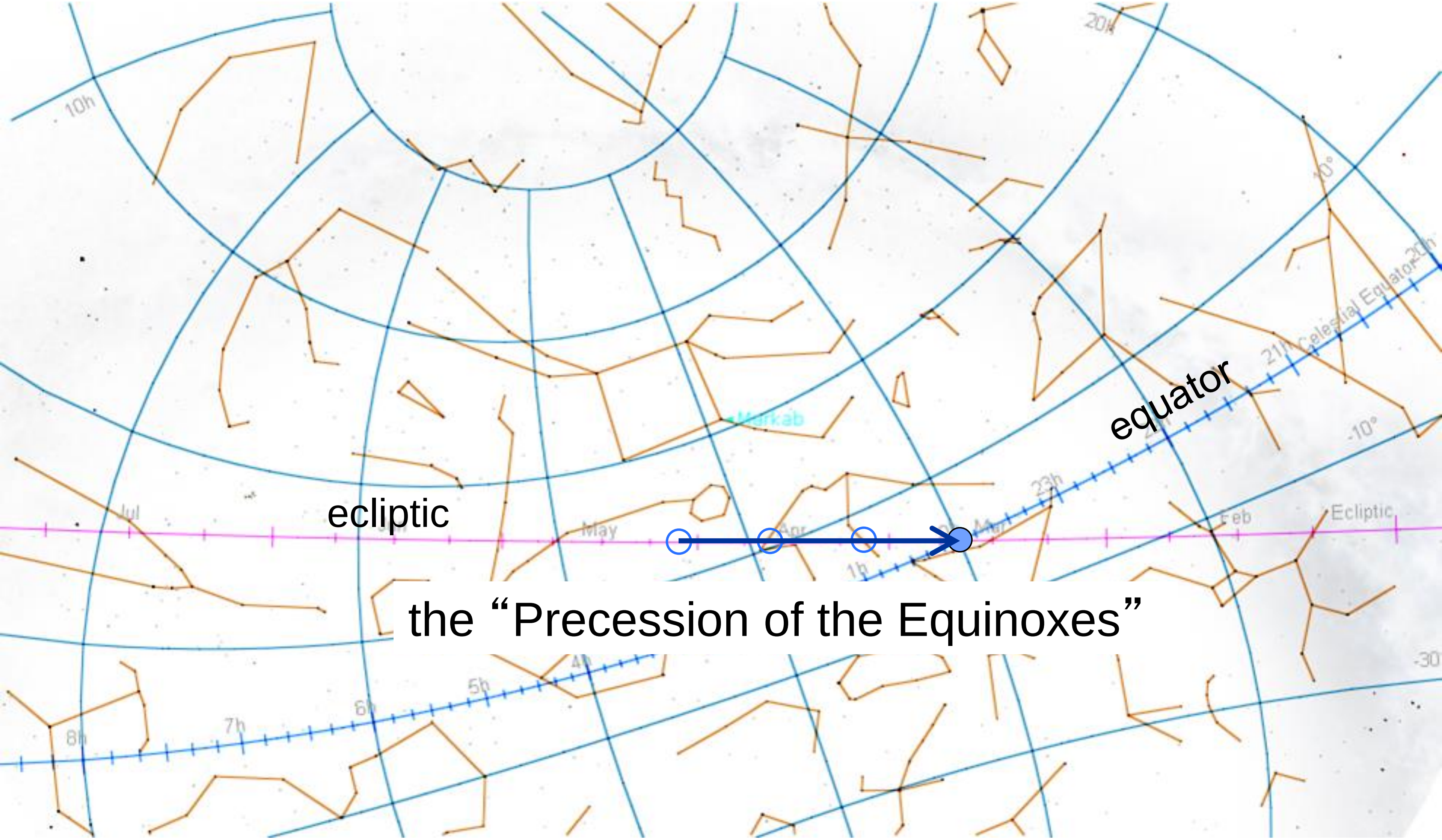


image: Starry Night

Precession Historical Trivia

- The Greek astronomer Hipparchus (c. 150 BC) first discovered precession by noting that the right ascension of stars increased slightly over time.
- Thousands of years ago the vernal equinox was in Ares – sometimes referred to as the "first point of Ares".
- Thousands of years ago the solstices were found in Cancer and Capricorn.

What is one year?

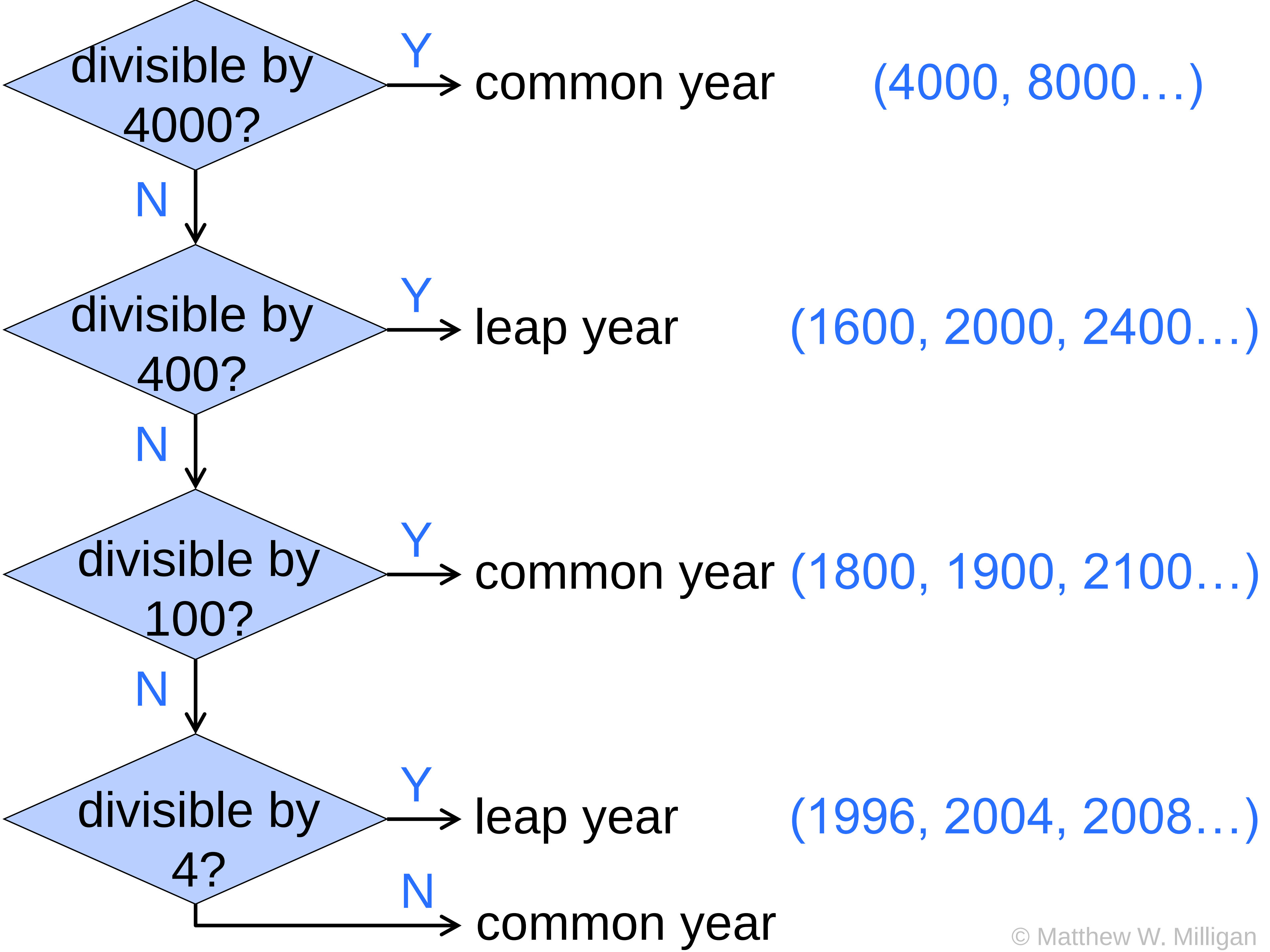
- Sidereal year = 365.2564 days,
which is the time for Earth to complete one orbit relative to the stars.
- Tropical year = 365.2422 days,
which is the time for the Sun to complete one trip through the tropics, *i.e.* the time to go from one vernal equinox to the next.
- Our calendar and system of leap years is based on the tropical year – the precise time for one complete set of seasons.

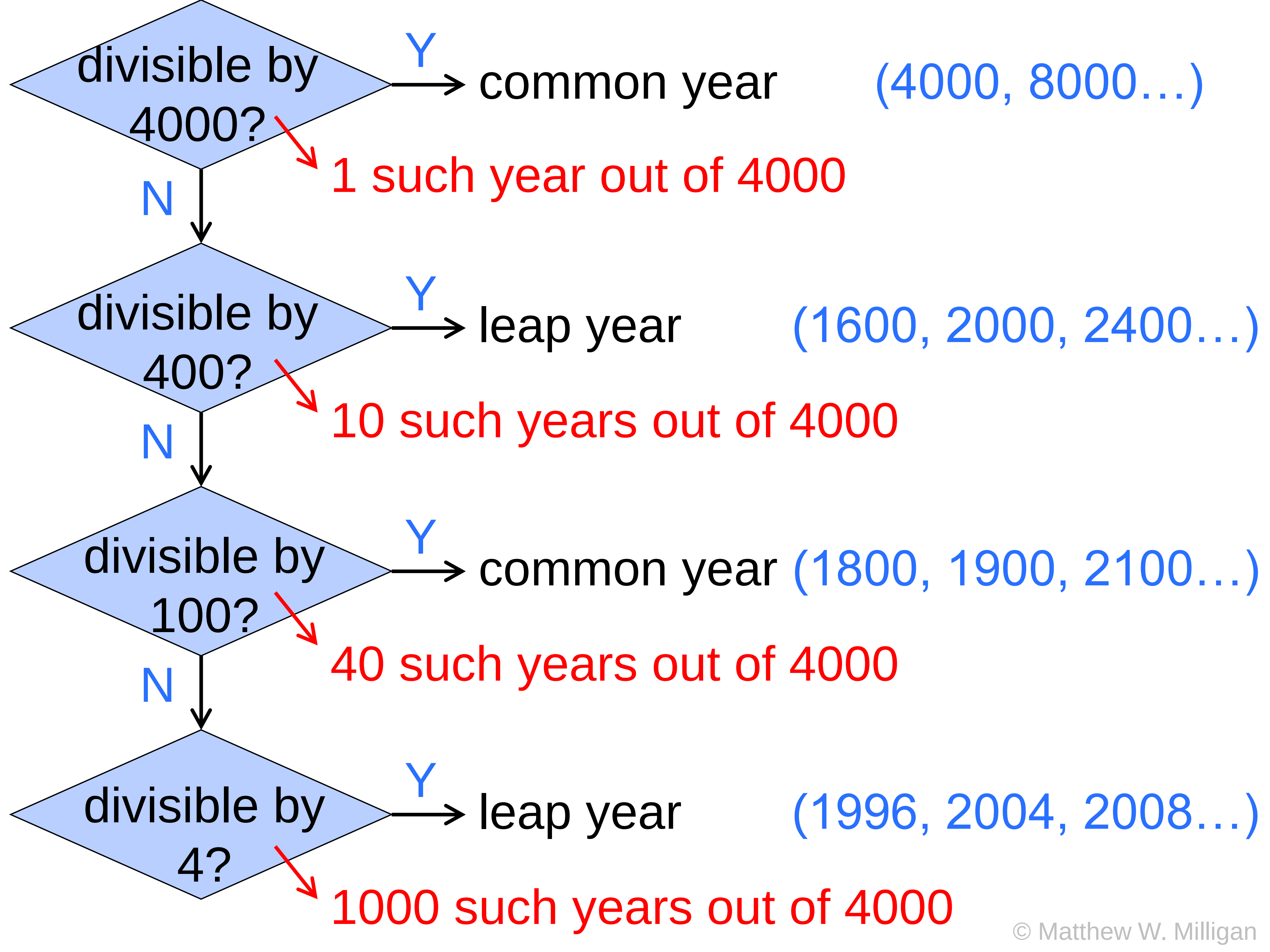
Leap Years

- Because there are not an exact integer number of days in a year, seasons would not occur during the same months if there were 365 calendar days **every** year.
- Leap Year = 366 days
  Common Year = 365 days
- Julian Calendar = add an extra day, a "leap day", every four years.
- Started in 46 BC. 67 extra days were inserted that year to "set things right".

Gregorian Calendar

- Because the fractional part of the year is not *exactly* one quarter of a day, the Julian Calendar was not *exactly* correct.
- In 1582, 10 days were omitted from the calendar and the day after October 4^{th} was October 15^{th} by decree of Pope Gregory XIII. October 5^{th} – 14^{th} did not occur!
- In the "Gregorian Calendar" certain years that are divisible by 4 are common years instead of leap years.


divisible by 4000?
Y
common year
(4000, 8000…)
N
divisible by 400?
Y
leap year
(1600, 2000, 2400…)
N
divisible by 100?
Y
common year
(1800, 1900, 2100…)
N
divisible by 4?
Y
leap year
(1996, 2004, 2008…)
N
common year



divisible by 4000?
Y
common year
(4000, 8000…)
1 such year out of 4000
N
divisible by 400?
Y
leap year
(1600, 2000, 2400…)
10 such years out of 4000
N
divisible by 100?
Y
common year
(1800, 1900, 2100…)
40 such years out of 4000
N
divisible by 4?
Y
leap year
(1996, 2004, 2008…)
1000 such years out of 4000
© Matthew W. Milligan

Out of Every 4000 Years:

- There are 969 leap years:
(1000 – 40 + 10 – 1 = 969)
- There are 3031 common years:
(4000 – 969 = 3031)
- There are 1,460,969 days:
(3031·365 + 969·366 = 1460969)
- Average length of a year: 365.24225 days
(1460969 ÷ 4000 = 365.24225 days)
- This closely matches the tropical year:
(1 cycle of seasons = 365.24219 days)
- Note: the years counted by our calendars are <u>not</u> sidereal years! Technically speaking the Earth does <u>not</u> complete an orbit in a calendar year (*i.e.* the tropical year)! <u>If</u> the calendar was based on the sidereal year (and the number of complete orbits) the seasons would shift – eventually summer would occur in December!

What was the next day after Thursday October 4th, 1582?

Because the Julian calendar in use before 1582employed a year equal to 365.25 days it did not precisely correspond to the length of the seasons. The dates October 5 through 14 were skipped to get the seasons back in the right place on the calendar!

D. Friday October 15th, 1582

E. Sunday October 6th, 1582