

One-Year Approach to the Astronomical Field

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In the science class of junior high schools, the third graders learn the astronomical field. In recent years, knowledge on this field has increased thanks to the evolution of observation equipment, and there are many opportunities to see the knowledge through various media coverage. At elementary schools, the students learn the movement of the sun and moon, which is socially reflected in calendars. Therefore, junior high school students feel familiar with astronomy and are really interested in it. Contrary to such a strong interest, astronomical lessons are not easy because making astronomical observations depends on weather and imaging a spatial arrangement is difficult. The one-year class should allow the third graders to learn astronomy without haste, to feel familiar with it, and to deepen their understanding.

Key Words: science education at junior high schools, astronomical field, class

I Introduction

Knowledge about celestial bodies in the solar system and the universe is increasing drastically in proportional to the recent development of observation appliances. We can get plenty of astronomical information by seeing images resulting from observations over the Internet and watching TV programs relating to the cosmos. Particularly in Japan, the spotlight is put on the asteroid explorer “Hayabusa” that has shown the worldwide performance. Elementary school students learn not only the movement of the sun and moon but constellations. In addition, the present society employs calendars affected by the astronomic field. Junior high school students feel familiar with celestial objects and are really interested in them.

Contrary to such a strong interest, astronomic lessons are not easy. The following shows the possible reasons.

The first reason is that observing actual stars is difficult. In the case of the sun, it takes one day for the sun to turn 360 degrees around the earth when viewed from the earth. Everybody knows this, but observing the motion of the sun is difficult in class because it depends on the weather of the day. Of course, we cannot do it on a cloudy day. As a result, it is necessary to set up the lesson in consultation of weather, which is difficult.

The second reason is that understanding the universe is very difficult unless students can imagine the spatial layout of stars. The universe is a significantly large three-dimensional space, but textbooks, pictorial books, and other documents present two-dimensional pictures. Understanding the universe requires them to change their positional information from the plan view to the three-dimensional view. Some students who are not good at space imaging feel that astronomy is difficult.

The objective of this one-year astronomical lesson is for the third graders to feel familiar with astronomy by observing seasonal differences and sun's motion as well as to improve their understanding by converting the cosmic space to an actual living space.

II Teaching plan

Importance is given to the actual observation of the space and the experience of cosmic space through conversion of the space to a real living space.

		Aim	Description
1		To know changes in human being's outlook on the universe.	Lecture(1) Changes in outlook on the universe[1]). From Ancient Greek to the Copernican model.
2		To understand basics of the sun. To know that temperatures can be given by optical spectra.	Lecture(2) About the sun (size and distance). About surface temperatures (black body radiation).
3		To know fusion reaction. To know what observational facts constitute the basics of the sun.	Lecture(3) Fusion reaction causing the sun shine (proton-proton chain reaction[2]). About solar corona (video).
4	(1)	To get knowledge necessary to astronomical observation. To check observation condition settings.	Lecture(4) About the celestial sphere (zenith and meridian). Preparation for observing the diurnal motion of the sun.
5		For observers to set a date and make observations.	Observation(1) Using the transparent hemisphere to observe the one-day motion of the sun on a day near to the summer solstice.
6		To make a tool for converting 3D information to 1D culmination altitudes.	Practice(1) Making a tool and method for measuring culmination altitudes according to the results of observing the transparent hemisphere.
7		To calculate the culmination altitude of the sun from a diagram created in consideration of the inclination of the earth's axis.	Lecture(5) Culmination altitude and annual motion (inclination of the earth's axis) of the sun.
8		To understand the basics of the revolution of the celestial sphere.	Lecture(6) Daily movement of stars (diurnal motion). Yearly movement of stars (annual motion).
9	(2)	For observers to make a survey while taking account of observation conditions.	Observation(2) Using the transparent hemisphere to observe the diurnal motion of the sun on a day near to the autumnal equinox.
10		To understand the relationship among the annual motion of the sun, the twelve signs of the zodiac, and the horoscope.	Lecture(7) Annual motion of the sun (twelve signs of the zodiac). Horoscope and the twelve signs of the zodiac.

11	(3)	To understand the basics of the moon.	Lecture(8) About the moon (size and distance) and a synodic month.
12		To understand the relationship between the moon and Japanese culture.	Lecture(9) About a synodic month, phases of the moon, and the name of each phase.
13		To understand the relationship between phases of the moon and calendars.	Lecture(10) About calendars including the lunar and luni-solar ones.
14		To understand the surface structure of the moon.	Practice(2) Moon's paper craft[3].
15	(4)	To understand the basics of the solar system.	Lecture(11) About the solar system and its birth.
16		To make a survey and presentation as well as to share information.	Practice (3) Survey of planets in the solar system and exchange of information on them[4].
17		To understand celestial bodies in the solar system.	Lecture(12) About terrestrial and Jovian planets. About celestial bodies at the outer edge of the solar system.
18		To set up observation conditions and make observations.	Observation(3) Use the transparent hemisphere to observe the diurnal motion of the sun on a day near to the winter solstice.
19		To understand coordinate systems and how to represent positions. To get knowledge about the equatorial coordinate system in which the earth is in the center.	Lecture(13) Equatorial coordinate system (right ascension and declination) and how to represent the positions of celestial bodies. How to use celestial globes.
20		To understand coordinate systems and how to represent positions. To get knowledge about the ecliptic coordinate system in which the sun is in the center.	Lecture(14) Ecliptic coordinate system (celestial longitude and latitude) [5] and how to represent the positions of celestial bodies. How to use the planet simulator PLMotion [6].
21		To use the planet simulator to determine the positions of planets.	Practice(4) Positions of planets (interior and exterior ones) [7].
22		To convert the whole solar system to an actual living space.	Practice(5) One-billionth scale model of the solar system [7]. Conversion of the sizes and distances of celestial bodies.
23		To convert the whole solar system to an actual living space.	Practice(6) One-billionth scale model of the solar system. Survey of the celestial longitudes of planets with the simulator.
24		To use the planet simulator to determine the position of planets.	Lecture(15) Movement of interior and exterior planets [8]. About configurations (interior and superior conjunctions, opposition, and quadrature).
25		To arrange the sun, Venus, and the earth in a one ten-billionth scale space and have a bodily sensation of phases and apparent sizes of them.	Practice(7) Movement of Venus (outdoor simulation). Phases, apparent size, and maximum digression of Venus.
26		To understand various kinds of celestial bodies.	Lecture(16) About celestial bodies out of the solar system, astronomical units, and light-years.

III Important points

○ Difficulty of observation

In the astronomical field, observations depend on various conditions and are sometimes impossible in certain situations. In the chemical or physical field, experimenters can actively define conditions to make an experiment. However, that is difficult in the astronomical field.

As an example, I describe the observation of the daily movement of the sun. The sun rises in the eastern sky and sets in the western sky. Observation is limited to such period. The most important thing is the weather. The sun does not appear unless the sky is clear—the object to be observed disappears. Observing the one-day movement of the sun requires a sunny weather throughout the day or during the observation period. If we want to observe the sun on the summer solstice, spring equinox, autumnal equinox, or winter solstice, it may not work out well. Particularly around the summer solstice, the observation is often impossible because of the rainy season. Moreover, observing the diurnal motion of the sun is impossible in the one-hour class.

Accordingly, I let the students set up how to observe the motion of the sun. They select an observation date according to weather forecasts. To do this at their own discretion, the students use the weekly weather forecast and synoptic map of the previous day. They have the ability to know how to read weather maps, to understand weather news, and to create a weather map because they learned the meteorological field in the previous year.

In addition, I give the students the following requirement: they will make observations six times or more every one hour from the morning to the afternoon. On the day, they not only make this observation but also conduct a variety of activities, such as taking other classes and attending clubs. Therefore, they have to observe the sun in their free moments.

This difficulty allows the students to know, by their own action, that simple observations are not always possible. It also creates the situation in which the students cannot help having interest in the object to be observed by asking themselves “Today, observable? What about tomorrow?” The students have to take account of conditions that they have never paid attention to, which attitude should help them sweep away the concept of “normal” — making an experiment normally—and recognize the importance of setting up conditions.

As mentioned above, we view nature as target of observation for third graders during experiment and this allows them to well understand that it is difficult to set up conditions because they have never done that. Their understanding of this makes it possible to recognize the importance of setting up experimental conditions so as to make an experiment smoothly and to get the good results.

○ Observing the sun in different seasons

The earth’s axis tilts 23.4 degrees against the vertical direction of the plane of revolution on which the earth revolves around the sun. This causes the change in the position of the sun that daily orbits day by day. However, it takes one year to complete this change, so it is very difficult for us to be aware of such daily small changes. Even in one-week or one-month observation, we hardly feel it.

In the class of junior high schools, the third graders learn four fields consisting of physics, chemistry,

biology, and earth science. In most cases, after one field is complete, the next field is taught. It takes a little less than three months to complete each lesson. Therefore, the period of the astronomical lesson in earth science is a little less than three months as well, not going beyond one season. Observations in this period make it difficult to find out the difference between the season-by-season diurnal motion of the sun.

Therefore, to address this problem, I draw up this teaching plan to hold the class over the summer solstice, autumnal equinox, and winter solstice. If the class goes over the three seasons, the teaching flow is intermittent, which situation may reduce the effect of each lesson, but the third graders of junior high schools can respond to it because they have received many lessons. If priority is given only to the period, the teaching flow becomes disrupted and expected educational effect cannot be obtained. While taking into account all these factors, the teaching plan has been prepared.

In this plan, I classify all 26 lessons into four units (1 to 4). Each unit continuously goes without any disruption. The following shows the unit titles: (1) Sun and its diurnal motion, (2) Annual motion, (3) Phases of the moon, and (4) Planets in the solar system.

I give the unit-by-unit lessons around the summer solstice, autumnal equinox, and winter solstice in consideration of the progress of lessons in the other fields.

○ Phases of the moon and calendars

The moon has been familiar to those who live in Japan since early times. They become interested in phases of the moon. Different phases had different names, which were used in past literature and became popular. As a result, calendars being used currently show annual events relating to the moon, such as a moon-viewing party and the mid-autumn full moon, which are very close to student's life.

As mentioned above, the moon is popular but hardly appears in textbooks. Many students have fragmentary knowledge about calendars and phase-by-phase moon names or graduate from junior high schools with no opportunity to learn them. Accordingly, I pick up the moon as a unit in this plan and allot four hours to it. I would like the students to observe the moon from multiple aspects to understand it comprehensively through approaches that have been little employed in science.

• Basics of the moon

Teaching materials employed relatively often include the average distance between the moon and earth, comparison in size between the moon and the earth, moon's gravity, and the rotation of the moon. Textbooks show that phases of the moon consist of new, crescent, waxing, full, waning, and new moons in order. I teach them as knowledge and move to the next lesson.

• Relationship between the moon and Japanese culture

I teach that phases of the moon were named uniquely in Japan and left a vestige of its practice. Phase-by-phase moon names appearing in old books show us correct dates and time zones in those days. People are apt to think that they do not relate directly to science, but the moon names relate closely to the rising and setting of the moon because it is based on changes in the positional relationship among the sun, the earth, and the moon. Knowing the moon names associated with our life makes it possible to understand the moon in relation to the positions.

• Synodic month and calendars

Therefore, I teach the students a synodic month in more detail. They become aware that the synodic month is a period of 29.5 days from the new moon to the next new moon via the full moon and it is different from a month used in the present calendar. Like this, the students learn the establishment of the calendar by relating it to their life. Moreover, they know that the lunar calendar based on the synodic month is inconsistent with seasons and that an intercalary month is introduced, resulting in the institution of the luni-solar calendar. As a result, the students recognize the importance of calendar and relate it to their life, and they further realize that observing the movements of the sun and moon is very meaningful.

The purpose of this lesson is to encourage students to feel the effect of moon, a familiar object, on people who live in modern age, or in other words, strong ties between the nature and human beings. Quite a few students are surprised to know that natural phenomena are incorporated into their lives to such an extent. I feel that as part of the science class, it is necessary to positively teach the relationship between the nature and human beings that is difficult to experience if teachers adhere to science only. The moon names and calendars appear in Japanese and social studies textbooks respectively, so finding out a connection with other subjects in a cross-sectional manner should make it possible to look at lessons from various angles.

○ Converting the whole solar system to an actual living space — one-billionth scale model

In the astronomical field, it is difficult to grasp a spatial extent because the universe is an infinite space. Most of documents, such as textbooks and pictorial books, compare planets size precisely but do not show the correct distance between planets. Accordingly, the students have ambiguous awareness of the distance. In addition, the universe is a three-dimensional space, so it is essential to convert objects shown in such two-dimensional documents to those of the three-dimensional space. Accordingly, the students have difficulty in understanding the universe if they cannot image the latter.

To allow the third graders to understand the distance and size sensuously as well as the extent of the universe and to help them convert the plan view to the three-dimensional view, this class uses a simple model that represents the motion and view of planets in the solar system. This is the one-billionth scale model of the solar system. The following describes procedures for using the model.

(1) Confirming the layout of planets

In the first step, how to represent the positions of celestial bodies is important. The universe has no datum point, so the vernal equinox is normally regarded as the datum point in the astronomical field. This method is used in various coordinate systems. In this class, I teach that the method of representing the positions of planets is not only one and let the students think which coordinate system is suitable. I introduce the equatorial and ecliptic coordinate systems. In the case of the former, the earth sits in the center, so it has an advantage: the students can observe the space from the earth and know that they can use an astronomical yearbook to observe celestial objects. In the daytime class, it is difficult to observe a starry sky, so the students learn how to do it with a celestial globe. Concerning the ecliptic coordinate system, they learn the heliocentric type, in which the sun sits in the center and which has an advantage: the students can view the solar system from the celestial north pole.

I use the free software “Planetary Motion Ver. 0.38(1)” that shows the position of each planet in the ecliptic coordinate system. This software allows the students to know the layout of planets on an arbitrary date, so in this practice, I instruct them to draw the planet layout of the solar system on

their birthdays on their own sheets(2) to feel familiar with it.

(2) Converting the solar system to the one-billionth scale model

The scale is one to one billion from the viewpoint of understandable and easy imagination. This one-billionth scale model can convert the vast solar system exactly to a personal living area. The word “exactly” means that the revolving orbits of planets overlap with the extent of space in which the students go to school everyday. Comparison with the daily livelihood zone makes it easy to imagine the sizes of planets and the vastness of the solar system.

(3) Converting the plan view to the three-dimensional view

Model planets(3) take a lively part in this practice. They are made manually from foamed styrene balls, marking pins, and paints. I let the students make an earth model from paper clay by themselves to realize how large it is. As a result, they can convert the solar system appearing in plane in their textbooks to the three-dimensional one that has a spatial extent. The resulting model allows the students to arrange the planets on the revolving orbits in their heads and to make conversion to the solar system viewed from the earth quickly. This practice significantly reduces the number of students who fail to convert the plan view to the three-dimensional view because they input the three-dimensional model in their heads as seeing it rather than imaging it.

○ Lesson in an extensive place rather than the class room — the motion of Venus (outdoor simulation)

In the astronomic field, it is difficult to make an experiment because we cannot pick up any object to observe. As a result, the class is dominated by lectures and apt to become one-way teaching from the teacher to the students. I change book learning to an outdoor and motional practice to let the students experience observing objects even if they are not real. This should allow some students who are not good at spatial perception to memorize the experience, resulting in acquisition of imagination. The following describes this method.

(1) Role allotment

In general, four students make an experiment as a group, but I employ a group of eight students. This is simply because the experiment requires many participants. Each student plays a role as follows:

S : Sun (in the center)

V : Venus (arranged by four students according to observer’s instructions)

E : Earth (the observer plays this role and the remaining students also wait here)

(2) Observation

Figure 1 shows the arrangement of the planets. The observer playing a role as the earth observes Venus by peeping at a transparent plotting scale sheet through a paper pipe and records the view and size of it on a note.

In this practice, I would like the students to imagine the moving Venus to a possible extent. Phases of the planet hardly change on the day because of the diurnal motion, but the students can find out that it is important to know not only the relationship between the earth and Venus but also the positional relationship with the sun. They play a role as a celestial body to re-acknowledge the importance of the meaning of positions.

References

- [1] Document(1): Changes in outlook on the universe
- [2] Document(2): <http://ja.wikipedia.org/>
- [3] Document(3): <http://www.nao.ac.jp/download/>
- [4] Document(4): Planet survey sheets
- [5] Document(5): Positions of planets in the solar system on birthdays
- [6] <http://www.moonsystem.to/soft/plmotn.htm>
- [7] <http://www.aichi-c.ed.jp/contents/rika/syotou/syol/taiyoukei/taiyoukeimokei.htm>
- [8] Document(6): Changes in the planet positions

天文分野への一年を通したアプローチ

く る び こう へい
久 留 飛 航 平

附属天王寺中学校

中学校理科では、3年生で天文分野を学ぶ。この天文分野の知見は、近年の観測機器の進歩に伴い増大し、様々なメディアで取り上げられ目にする機会も多い。また、小学校において太陽や月の動きについて学習がなされ、暦にも反映されている社会において、中学生にとって天文とは非常に身近で興味・関心も高い分野と言える。しかし授業での取り扱いは、その高い興味とは裏腹に容易なものではない。それは、天候に左右されること、空間配置をイメージすることが難しいことなどが挙げられる。一年間の授業を展開することで、気長に天体と付き合うことによって身近に天体を感じ、理解を深めることができるようになるはずである。

キーワード：中学校理科教育，天文分野，授業展開

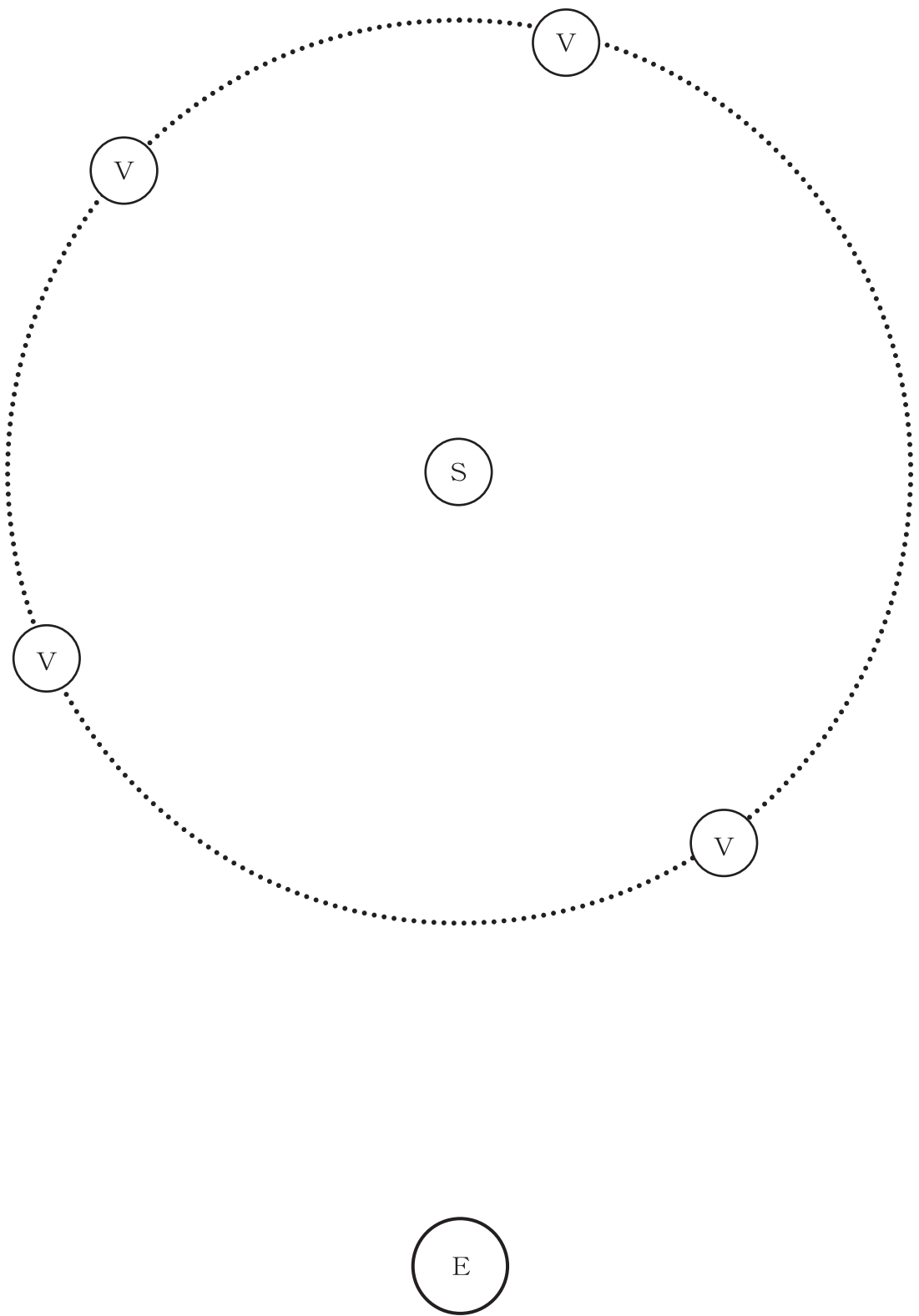
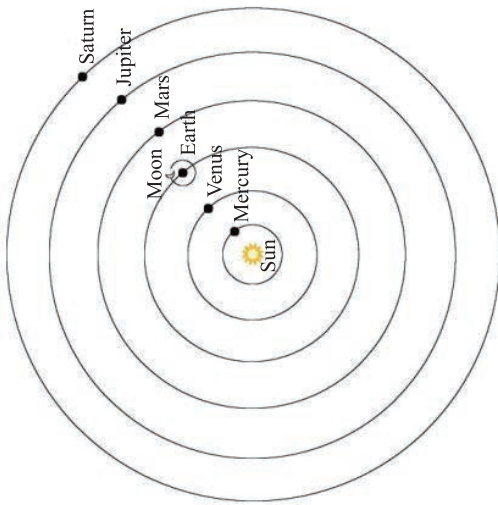
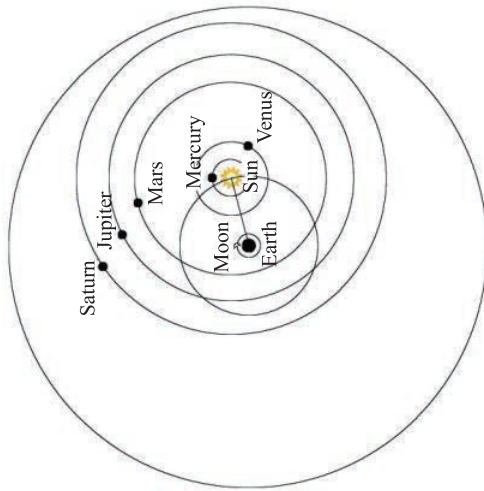


Figure 1

Document(1): Changes in outlook on the universe



Copernican heliocentric theory



Tycho Brahe model

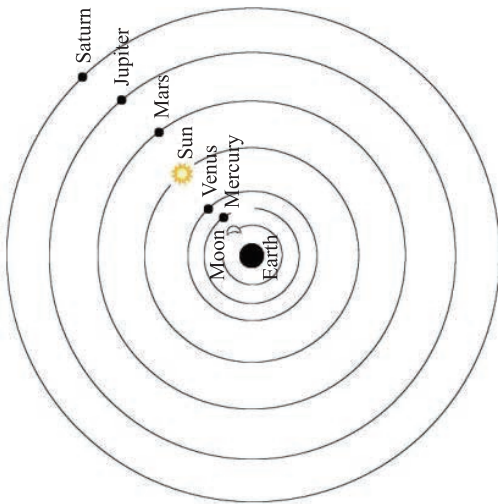
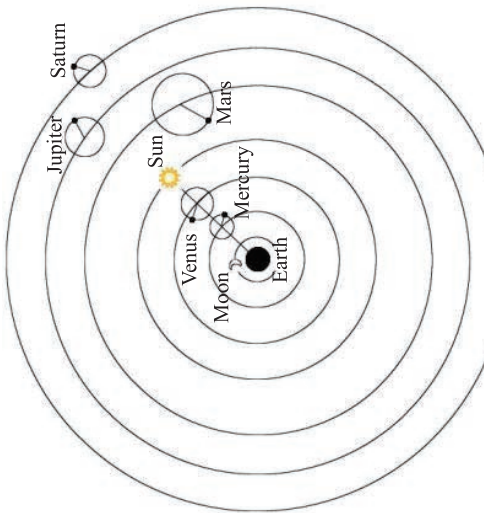
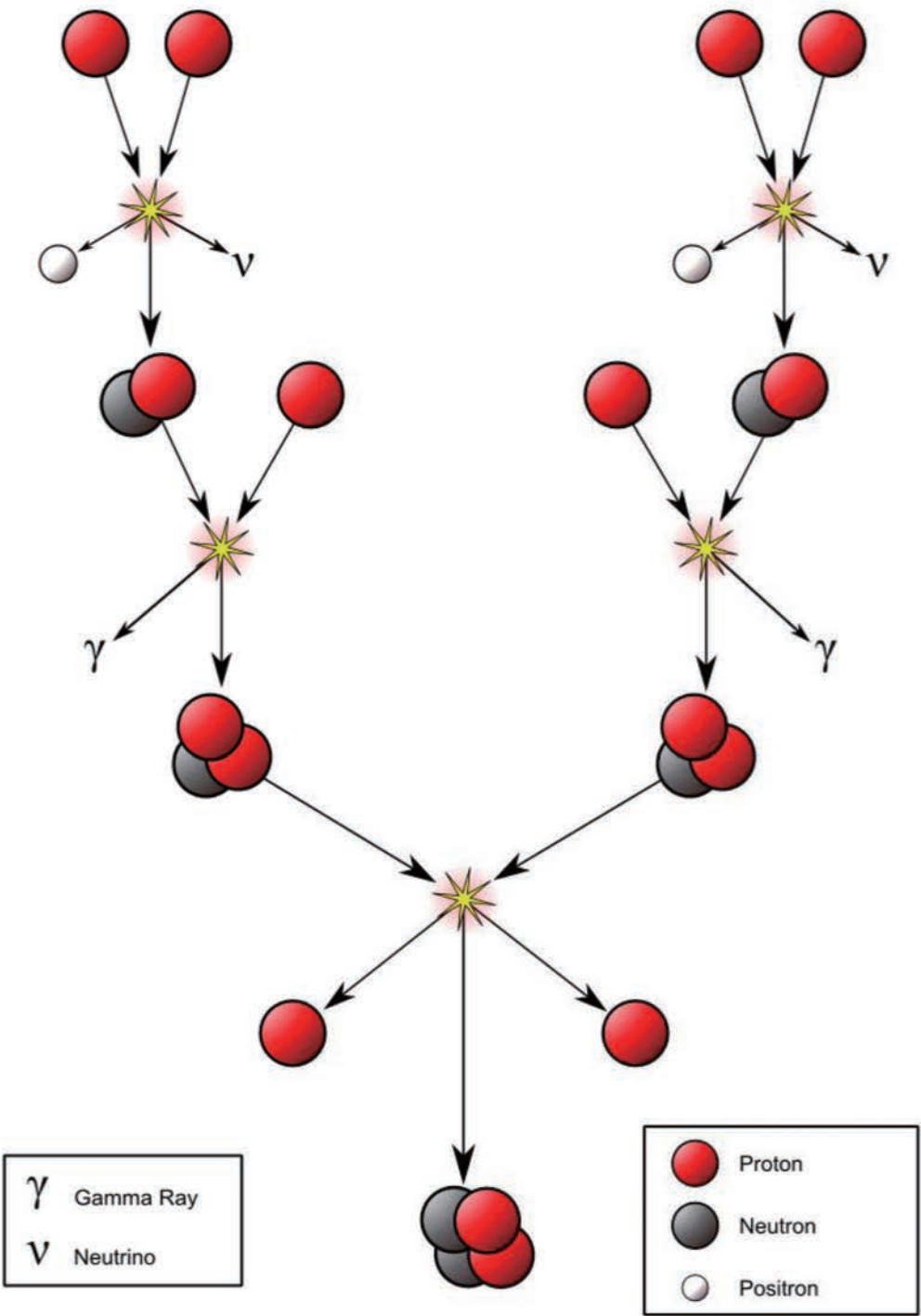


Image of the universe created by Ancient Greek



Ptolemaic geocentric theory

Document(2) : <http://ja.wikipedia.org/>



Document(4): Planet survey sheets

Planet

Basic data

Name:

Origin:

Volume:

Mass:

Mean distance:

km

AU

Equatorial radius:

which is

times longer than Earth

Density:

Main component:

Orbital period:

which is

times longer than Earth

Rotating period:

Inclination angle:

Surface gravity:

Number of satellites:

Main atmospheric component:

Features

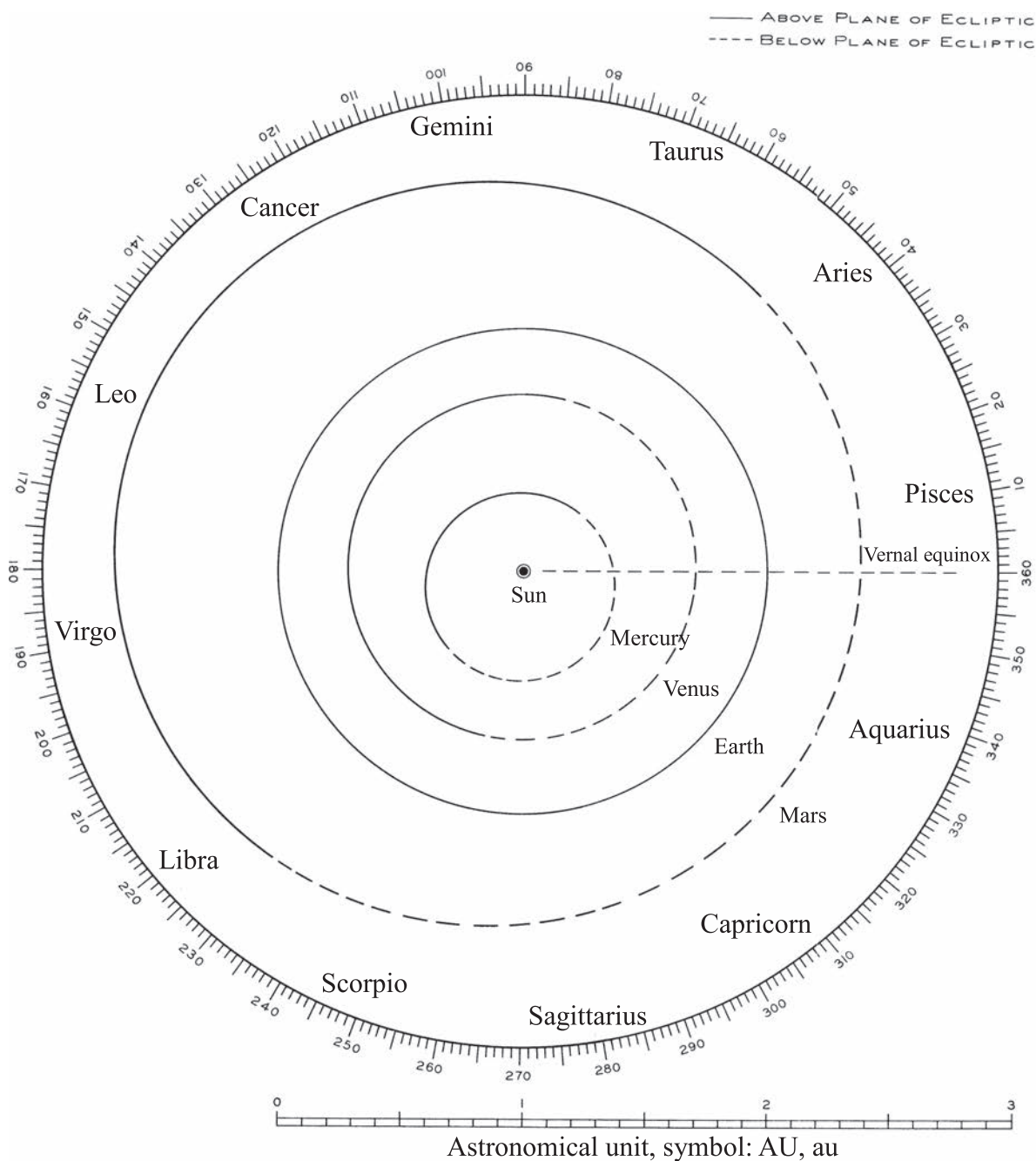
Ties with mankind

Document(5): Positions of planets in the solar system on birthdays

Positions of the Planets in the Solar System

Date: _____ ; Time: _____

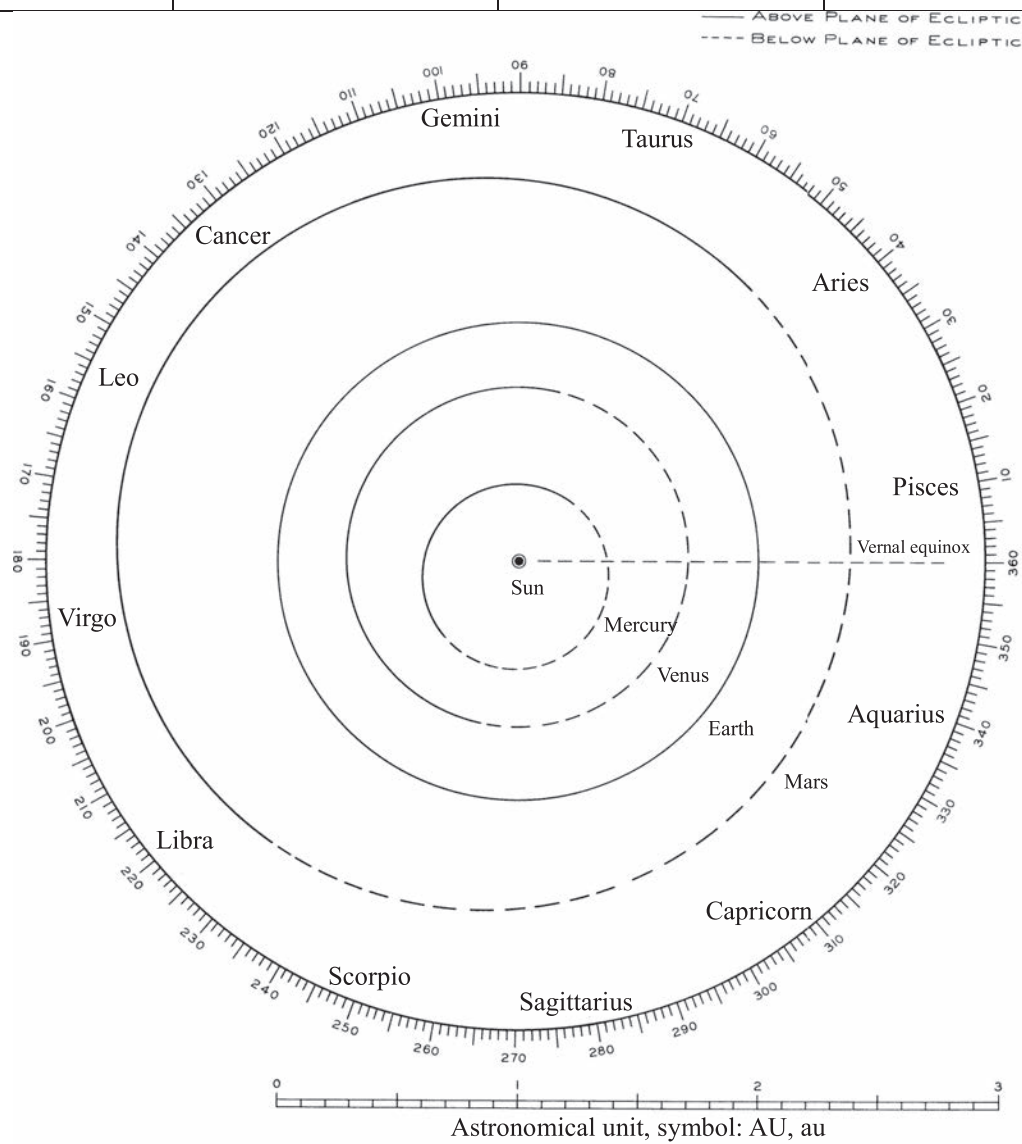
Mercury		Mars		Uranus	
Venus		Jupiter		Neptune	
Earth		Saturn		Pluto	



Document(6): Changes in the planet positions

Changes in Planet Potions

Date	Venus	Earth	Mars



<Tools>

Tool	Qt.	Application

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Figure of tester

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