The Space Explorer's Guide

Teacher's Handbook

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Contents

1 The "Space Exploration" activity cycle

1.1 Some Introductory comments

This activity cycle is named "Space Exploration" because we envision it as a journey to an unknown land. We start this adventure without knowing our exact destination, but with each step we are learning how to use our tools and how to take in all the wonders we are witnessing.

This "Space Explorer's Guide" describes our path, activity after activity, showing us directions to look at and questions to pose. It is therefore a book which aims to present basic astronomical concepts by means of practical activities.

This handbook is thought as one of the main tools of the *GalileoMobile Constellation* project, which runs during 2015 in several schools in different countries in SouthAmerica. Nevertheless it is designed in such a way to be used also by a wider audience.

The main objective of this activity cycle is to show students the scientific method, where a hypothesis is tested by experiment. This is the so-called "inquiry based" method, which rely on a dynamical exchange between teacher and students, an interplay in which both of the parts play together to achieve the same goal, namely a deeper comprehension of an astronomical phenomenon.

Another central goal is to show students the way the scientific community operates: by collaboration, healthy scepticism and dialogue. This will teach them that the way to a scientific truth is not a privilege of the few, but a fun and intellectually fulfilling activity for every human being.

1.2 About the activities

The activities target an adolescent or pre-adolescent audience, but are not limited to that age range. Some knowledge of mathematics is required, but nothing more advanced than simple arithmetics and trigonometry.

Each activity is short and concisely written to leave maximum margin for the individual ideas of the teacher and the students. At the beginning we provide a short introduction and a suggested list of materials we expect will be needed. We also list the possible subjects for discussion that may arise during of after the activity.

We have divided the handbook in two sections. In the first one we have put the activities we will propose during the GalileoMobile Constellation project in 2015.

In the second part we have prepared some bonus activities for those students and teachers who want to explore the sky a bit further.

We wish you all enjoy this journey we are embarking on together!

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Part I

Activities

2 The Earth, the Moon, and the Sun

The activities of this chapter deal with the sizes and properties of the Earth, the Sun and the Moon. Apart from getting to know our immediate neighborhood, here we are going to get a first taste of the methods scientists use or have used to determine the basic properties of celestial objects. We are, in the process, going to discover that it is not always elaborate or expensive instruments that we need in order to explore space, but imagination and skill.

2.1 Activity 1: How to measure the size of the Earth

Introduction

How big is the Earth? How do we know its size?

A very interesting, easy and educational measurement one can make using simple materials is to find the radius of the Earth. In ancient Egypt, in the third century BC, a variation of this method was used by Eratosthenes, who derived a remarkably accurate estimate of the size of our planet.

The version we present here is more fun, because we can calculate the radius of the Earth by collaborating with someone far away. In fact, you can ask one or more nodes of the network to exchange their measurements with you and see if more measurements give you a more accurate number!

Figure 2.1 illustrates the concept. We are trying to measure the angle α enclosing two places, A and B. If the distance between A and B is, say l, then:

$$\frac{\alpha}{360^o} = \frac{l}{2\pi R} \tag{2.1}$$

where R is the radius of the Earth. In other words, α is a fraction of the 360^o in a circle, and l is the same fraction of the total circumference of the Earth.

But how do we find the angle α between these two places? You can tell from Figure 2.1 that α is the difference between the angles θ_1 and θ_2,

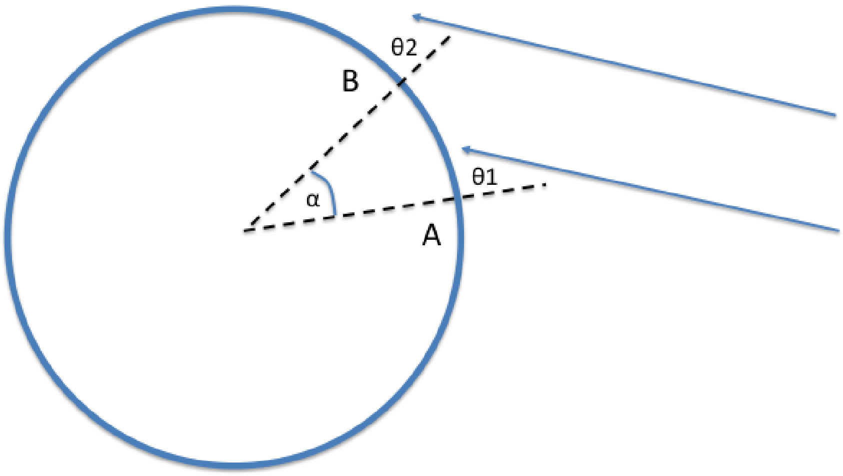


Figure 2.1: The angle α is the latitude difference between two places, A and B. It is equal to the difference of the two angles θ_1 and θ_2 formed at each location by the parallel rays of light.

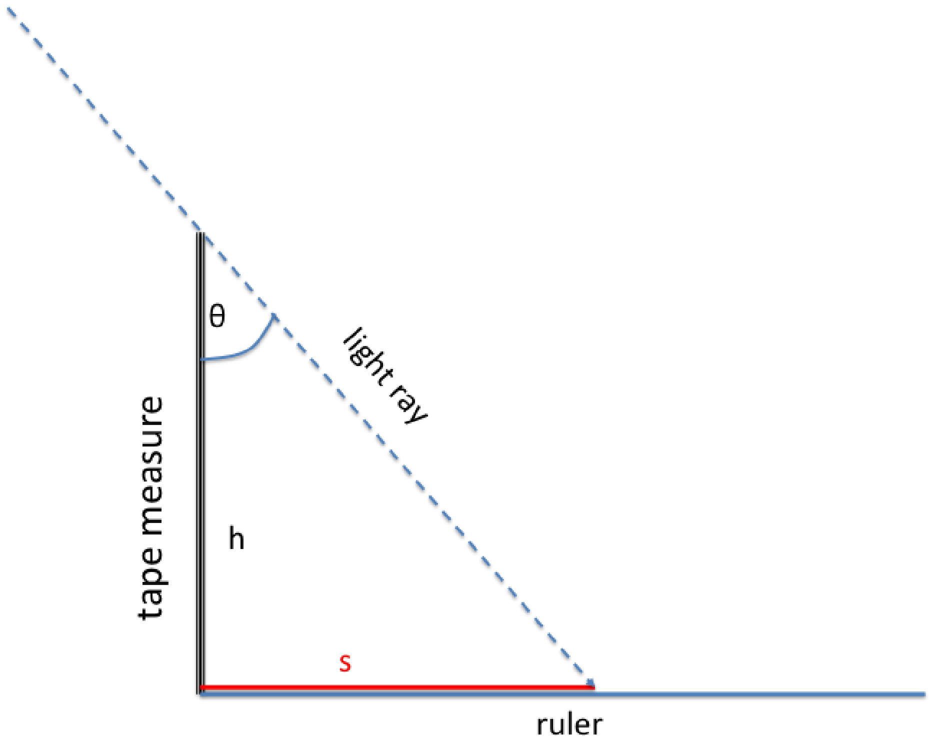


Figure 2.2: The tangent of the angle θ is equal to the length of the shadow, s, divided by the length of the rod or tape measure that casts the shadow.

formed by the parallel rays of light and the vertical to the Earth's surface at each place. Now maybe you begin see what our experiment will be like!

Figure 2.2 shows a way to measure the angle θ at your location. You will need a partner at another location, at a known distance, to make the same measurement at roughly the same date, and then you can use Equation (2.1) to calculate the Earth's radius R by combining your measurements.

Material and duration

- A tape measure or an object of known length
- A large ruler or a second tape measure
- Duration: About 1-2 hours for the activity itself, plus preparation and follow-up activities

This activity is a good chance to

- Introduce the concept of a spherical planet and its relative position to the Sun
- Discuss distances and sizes on large scales
- Familiarize ourselves with the scientific method
- Practice geometry in a fun way and explore the relation between Math and Nature
- Collaborate with others far away from us to get to an interesting result!

Preparation

It is evident that some knowledge of trigonometry is required for the students to appreciate this calculation. But the real beauty in this and such experiments lies in its simplicity and the imagination that went into its design. Before commencing the introduction to the activity, engage in a discussion with the classroom on measuring distances. For example, how do we know the size of our city, or of our continent? How easy or difficult was it to know where we are when there were no satellites, or even maps? How would you measure the radius of the Earth? Allow the students a couple of days to research and come up with different answers. Ask the other nodes to do the same. Would you be able to collaborate? Record the answers and exchange ideas.

After this process you can introduce the original experiment by Eratosthenes, as well as the method to be used for this activity. Try to derive the formulas together with your students!

The Activity

We introduced the essence of the method in the Introduction: Following Figure 2.2, you will need to place a tape measure or a rod of known length vertical to the ground close to noon. Your partner at a remote location should do the same!

You should place a ruler on the ground to measure the length of the shadow. Then you can calculate the tangent of the angle θ by dividing the length of the shadow by the length of the object casting the shadow. The measurement of your local angle $\theta = atan(s/h)$, will be combines with a partner's measurement at another location to calculate the difference in angle, α.

You will need to make sure at least one more node is taking measurements on the same dates as you. Find a partner school (or several) with which you will collaborate.

For the measurements themselves, keep in mind that it is good practice to take a lot of data. Start by separating the classroom into groups of 2-3 students. Each team should have a tape measure and a ruler to make their own measurements.

Ask the students to keep a log with the date and time the data were taken. Point out that they should be careful to place the rod vertical to the surface of the Earth. It is important to do this close to noon, when the Sun is highest on the sky.

Each team should calculate the angle over a period of 2-3 days. Gather all the measurements and try to find the mean value and the variance in the angles measured. Note any evolution of the length of the shadow by date.

Follow-up activities and sharing

This is a result you should share with the other nodes as soon as you have gathered your data! Then with pairs of angles θ_1 and θ_2 you can calculate the angle α formed by your locations and the center of the Earth. And knowing the distance separating your schools, you can calculate the Earth's radius!

First discuss with the students the measurement process itself. Why aren't all the measurements the same? You can discuss what a "mean" value and a "deviation" mean.

Then discuss the result with the students. What does this number mean for us? How long would it take to go around the Earth in a car, traveling continuously? In a plane? Is the Earth's radius the same everywhere? You can also check for the more accurate number. How do you think this more accurate answer was obtained?

A slightly more advanced conversation subject is to question the assumptions that go into this measurement. The core assumptions behind this experiment is that the Earth is round and that the Sun is far away from the Earth, so it casts parallel shadows. What if the Sun was actually close to the Earth? What would your measurements mean if the Earth was flat? You can try to draw such a model. (Hint: if the Earth was flat, your collaborators at a different location would see it larger, or smaller. Do they?)

Further reading

- More on the Eratosthenes measurement:
  http://difusion.df.uba.ar/Erat/InstructivoEratostenes2012.pdf

- There is a global collaboration for the Eratosthenes measurement for the International Year of Light!
  http://df.uba.ar/actividades-y-servicios/difusion/proyecto-eratostenes/eratostenes-2015

2.2 Activity 2: The apparent motions of the Sun and the Moon in the sky

Introduction

Not surprisingly, the motion of the Sun and the Moon on the sky are among the first natural phenomena to be studied by mankind. Many civilizations built their calendars according to this perpetual and repeated change of the sky's appearance, day and night, seasons, and the Moon's phases. The calendar we use today is itself mostly based on these motions.

We know now that the alteration of day and night is due to the rotation of the Earth around an imaginary axis. The change of seasons and the apparent change of position of the Sun and the Moon on the sky are also a result of this motion: distant stars do not change their relative positions on the sky, while close-by objects move faster and are hence projected onto what we interpret as constellations.

The Moon is the Earth's only natural satellite. It moves on an almost circular orbit around our planet, with an orbital period the same as its rotation period and equal to 27.322 days.

This synchronous motion means that, unless we employ space travel, we can only ever observe half of its surface.

We may always see the same face of our satellite, but its relative position with respect to the Sun changes as it rotates around the Earth. This causes a phenomenon known as "phases", where we see a different portion of the Moon illuminated as it completes an orbit.

The motion of the Moon on the sky (meaning in which constellation we can see its projection in the course of one year), contrary to that of the Sun, is very complex. It actually took astronomers centuries of careful observations to work out analytic formulae for this motion. This is, of course, due to the complicated dynamics of the combined motion of the Earth around the Sun and that of the Moon around the Earth.

In this activity we are going to study these motions and try to connect them with time keeping and calendars. A useful astronomical software for this and other activities, is called Stellarium and it can give you a view of the sky on your computer with information about several objects:
http://www.stellarium.org (English)
http://www.stellarium.org/es/ (Spanish)
http://www.stellarium.org/pt_BR/ (Portuguese)

Material and duration

- Pencil and paper, or a journal
- According to how far you feel like taking this activity, it may take from one month up to one year.

This activity is a good chance to:

- Discuss calendars and time keeping
- Talk about gravity and orbits
- Connect to ancient civilizations through studying and discussing their astronomical calendars

Preparation

Ask your pupils how they understand day and night. Ask them about sunrise and sunset. Do they always occur at the same time? Or at the same location? How about the duration of day and night? If the Earth always rotates at the same speed, how come day and night vary in duration?

Discuss the Moon in the classroom. What are the theories your students know about its origin? Have they observed any changes in its appearance? In its position? What do they know about the Moon's phases? Note: It is a good idea to combine this activity with the next one, Activity 2.3.

The Activity

This activity is largely an observational activity and it can be done without a telescope. It requires very little material, but a lot of dedication.

Ask your students to form teams. Some teams will be observing the Sun and others will be observing the Moon. There can be various teams for each and take turns observing.

The teams observing the Moon should keep track of its position. This in rough terms entails the following:

- They should keep a journal with the date and time of the observation.
- In this journal they can prepare identical circles, in which they should try to illustrate the phase of the Moon as they see it by shadowing the corresponding portion of the circle.
- They should take note of the time of moon-rise and moon-set, if known.
- They should take note of the constellation on which the Moon is projected.
- If the students are familiarized with celestial coordinates, or if they are using a software like Stellarium, they should also register its precise coordinates.

The teams observing the Sun should keep a similar journal, if possible over the course of several months: They should :

- Design and keep a journal with the date and time of the observations.
- Choose and register their point of observation (photographs would be excellent) very carefully and have exact points of reference.
- Observe the times of sunrise and sunset.
- Register the exact position where this happens.

Since these phenomena usually happen outside school hours, all this can be difficult for practical reasons. In this case you can use astronomical software. If using such software, the students can also document the constellation in which the Sun is projected during that period.

Follow-up activities and sharing

The Moon's motion: did you observe differences in the time of moon-rise and moon-set in the course of the month? Does it correlate with the Moon's phases? What about the position of the Moon on the sky? Does the Moon ever appear during daytime? How much does the Moon's position change in the course of a night? And in a month? If you observed it for longer, comment on its longer-term motion.

The Sun's motion: Does the duration of the day and night change in your calendar? How about the position of the Sun with respect to the distant stars that form the constellations? The points of sunrise and sunset?

Discuss what this means. Why do the Sun and Moon appear to be changing position? Why does the position of sunrise and sunset change, if they do? (The same with the duration of day and night.)

Do you know any local myths, or fairy tales concerning the Sun and the Moon? How would you keep time using these motions? Can you think of calendars using the motions of the Sun and the Moon, nowadays or in older times? Share your findings, your inspirations and your thoughts with the other nodes!

2.3 Activity 3: Observing the phases of the Moon

Introduction

We read in activity 2.2 that the Moon is on an almost circular orbit around our planet, with an orbital period that is the same as its rotation period and equal to 27.322 days. This means that the Moon always shows us the same face. But, can we prove this? The Moon is, along with the Sun, the celestial objects with the largest apparent size on the sky. We can therefore test whether it always shows the same face to the Earth, or if its aspect changes, by means of observations. We can also measure the duration of a lunar cycle.

Material and duration

- A telescope
- A journal, a pencil
- According to how far you feel like taking this activity, it may take from two months up to one year.

This activity is a good chance to:

- Discuss calendars and time keeping
- Talk about the phases of the Moon.
- Learn how to study an astronomical phenomenon.
- Explore the lunar surface.

Preparation

This is an activity that can be performed both during daytime and nighttime. Ask the students to form observing groups of 3 or 4. The goal of the observations is to describe as many features of the Moon as possible. In particular, the first questions we want to answer are: How long is the lunar cycle? and, does the moon always show us the same face? If you have already performed Activity 2.2, the preparation is pretty much the same.

The Activity

Each team should take notes of the position of the Moon in the sky whenever it is visible. For instance, they should note when there is a full Moon, half Moon, or New Moon. The students will have to discuss about the exact date when the Moon is full, half, or new.

They will also have to observe the Moon, which can be done with a naked eye or with a telescope. If the school only has one telescope, the teams will have to share the time they can use the telescope. This is also how real scientists do it! There are lots of astronomers in the world, a lot of theories to be tested and celestial bodies to be investigated, but there are only few large telescopes! So, have to request a few hours or days every year to use a big telescope.

Each team will therefore observe the Moon with a telescope. This can be done during the night as well as during the day, depending on the logistics of each school and the availability of the students. Each team will produce a drawing of the what they observe. Since there are many tasks for each team, each of the students should have a well-defined task. For example, one could be responsible for mounting and pointing the telescope, another for writing down the date and time of the observation, and another for booking the telescope for the observations. One, two, or all the them, should observe and make sure they draw as many details as possible and in the most accurate way.

Nowadays there are cameras for studying the sky, but this is quite a new invention. Do you know that the first detailed map of the Moon was compiled by an astronomer called Gian Domenico Cassini? He observed the Moon from the Observatory of Paris and drew the first detailed map of its surface in 1692.

Follow-up activities and sharing

As we said, this is a long term activity which will take at least two months. Nevertheless, it would be a good habit to discuss your observations, methods and best practices once per week. Did every team produce some drawings? How about the measurements of the phases of the Moon? Each team will likely have slightly different results. Is there any result that is prevalent? How do they decide which result is the most accurate? Can they provide details of the procedure they have followed when doing observations?

Once more, this is how real scientists work: each research team usually accomplished results which are different from those of other teams. Therefore it is of utmost importance they can compare their results and discuss them in details, as much as possible.

A very interesting follow-up activity is to ask the students to draw the relative position of the Earth, the Sun and the Moon according to the lunar phases. This is a very good opportunity for them to realize that the rest of the Moon is actually in its night-time.

How about the maps of the Moon? Is there any recurrent feature in the drawings of the surface? At the end of the two months the students will present their final results, consisting of their measurements and the maps they have drawn. If nobody before you has followed this procedure, these will be the first lunar maps produced in your school!

Further reading

- Historical lunar maps:
  http://brunelleschi.imss.fi.it/galileopalazzostrozzi/object/GalileosMoons.html

2.4 Activity 4: Using sunspots to measure the rotation period of the Sun

Introduction: The Sun and sunspots

With the activities above we explored the size of our planet and its motion relative to the Sun. With this activity we will see that the Sun is more than a warm sphere. It is a fascinating object, where a lot of complex physical phenomena are taking place.

When we observe the Sun with a filter or through a projection we can appreciate features on its surface that are not discernible with the naked eye. For example we can see dark spots, called sunspots, against the bright disk of the Sun. Sunspots appear dark because they are much colder than the rest of the Sun's surface. They vary in sizes and shapes, but they usually appear in groups.

The exact mechanism for the formation of sunspots is not known, but we have observed them in detail and have a very good understanding of their physical state. In these regions the Sun's magnetic field emerges from its interior in large loops and its strength inside and around them is particularly high.

The lifetime of sunspots varies from days to weeks. Their statistics follow a very-well studied 11 year activity cycle. During this cycle, the Sun passes from a maximum to a minimum of magnetic activity. The maximum is associated with a large number of sunspots, spreading to higher solar latitudes. During a minimum the Sun produces almost no sunspots.

Since sunspots are features on the surface of the Sun, we can use them to study the surface motions of our star. By observing the solar disk over a few days, we can identify the same sunspots and see if they have moved and to what direction. With this activity we are going to discover that the Sun rotates and we are going to do that precisely by observing the motion of these features on its surface.

There are several ways to do this, and for all of them we need to have images of the Sun's surface. The most easily accessible way to get such pictures is the Internet. There are real data of solar observations online which we can download and use for this activity. We do provide such images in the Appendix of this handbook.

A slightly more involved, but very educational way is, if we have a small telescope, to observe the Sun with a filter and take photographs, or project the Sun on a piece of carton behind our telescope's objective and draw the positions of the sunspots. Care must be taken to correctly identify the sunspots from one day to the next.

This activity has been adapted from the GalileoMobile Activity Handbook [1].

Material and duration

- Images of the Sun on different dates (provided)
- Ruler
- Duration: About 1-2 hours for the activity itself, plus preparation and flollow-up activities

This activity is a good chance to

- Discuss the nature of the Sun
- Introduce the fact that the Sun is a star, a very different object than the Earth
- Introduce the notion that the Sun is not static or unchanging, in fact, quite the opposite!
- Perform a real measurement, using satellite data, with a simple instrument.

Preparation

Start a conversation about the Sun in the classroom. You can ask the students to enumerate what they know about the Sun as a star. Speak about the Sun's shape. How does it look like when we filter the excess light? You can show images of the Sun from various observatories and discuss the different filters and what part of the Sun we can see with each one. Are there sunspots on any of them? Ask the students to investigate at home about sunspots and the Sun's activity.

This activity uses the notion of constant speed to travel certain distance. Make sure that your students are comfortable with this concept by asking simple questions, like the distance covered by a car moving at speed v over a time period, t.

The Activity

In the Appendix you can find images of the Sun's surface, taken from the Solar Dynamics Observatory (SDO) (Section 10.1 of the Appendix). On these images there is the date and time they were taken and each sunspot on them is marked with a number. The numbers are given automatically to each new sunspot as it appears on the Sun's surface and they can be used to identify them from one image to the next.

Ask the students to choose two or more images of the Sun's surface and find the same sunspot in both. It's better if they work in groups of two for this. They will have to measure (with a ruler on the image) how far the sunspot travelled over the time period between the two images. The speed of the sunspot's motion is, of course, defined as:

$$v = \frac{x_2 - x_1}{t_2 - t_1} \tag{2.2}$$

where x_1 and x_2 are the positions of the sunspots at times t_1 and t_2.

The local circular trajectory of the spot, L, over half the Sun, can be calculated by measuring the width of the solar disk, d, at the latitude of the sunspot:

$$L = \pi d \tag{2.3}$$

Then it is straightforward to determine the Sun's rotation period, T, by dividing L by the sunspot speed:

$$T = \pi * L/v \tag{2.4}$$

Two images are sufficient for this calculation, but with more images the result can be derived many times for comparison.

Follow-up activities and sharing

Gather the classroom's answers on a table and share with the network. What is the typical rotation period of the Sun, according to your measurements? Find the more accurate answer online (average: 27.2753 days). Does this agree with your result, or with that of the other nodes? If not, ask your students why. Clearly, the deviation you observe comes from the fact that the surface of the Sun is not flat, and the movement of the sunspots is on average over a distance larger than what you measured. Probably the teams who chose a sunspot closer to the central parts of the solar disk got an answer closer to the accurately measured result. Also, it is important to discuss that the Sun does not rotate at the same speed at all latitudes. This is called differential rotation. You should expect to find deviations in the calculated period according to the latitudes of the chosen sunspots.

Further reading

- You can find images of the Sun observed by SDO at different wavelengths:
  http://sdo.gsfc.nasa.gov/data/
- If you want to build your own solar projection and have your images of the Sun's surface, follow the instructions here:
  http://sdo.gsfc.nasa.gov/data/

3 Planetary systems

3.1 Activity 5: Create your own planetary system!

Introduction

Given the large number of exoplanets constantly being discovered (at the time of writing more than 1500 and increasing every day), one cannot help but wonder: how are these worlds? How would it feel like to walk on their surface, if they even have a surface? This activity triggers the children's imagination about the new worlds we are discovering. At the same time, it teaches the basics of some planet-related concepts: Rotation, orbits, mass, atmosphere and it is an opportunity to discuss concepts like density, gravity and temperature. Eventually, it shows how reality can often be more complex than imagination.

Planets around distant stars can be detected using a variety of techniques. The most popular is to look for variations in the amount of light we receive from that distant star: if we see it dimming periodically, it can mean that a planet is passing between us and the star,and this partial eclipse is responsible for the observed change in luminosity. Using this and other techniques, we have discovered that many stars are surrounded by giant planets, even larger than our Jupiter, located very close to them. Also, some planets are at the same distance from their star as the Earth from the Sun, but their mass and radius are much larger.

This variety of planetary systems and the difficulty to find one similar to our own has triggered a discussion about the so-called "habitable zone" of a star. This is the range of distances from the star at which, according to a variety of factors, life could potentially develop on a planet. For more information about exoplanets and the habitable zone, look at the "Further reading" section.

Material and duration

- Colors, brushes
- Small balls
- Plastiline, Paper

- Duration: approximately 45 minutes + discussion

This activity is a good chance to

- Discuss what a planet is
- Discuss where planets are located
- Discuss planet formation, both in our solar system, and beyond!
- Discuss the characteristics of a planet
- Explore the differences between different objects in a planetary system
- Discuss physical units
- Wonder about possible worlds that can, one day, be discovered for real!

Preparation

Start a conversation about the Solar System and the different planets. Ask the students to describe each of them, or research at home and make a presentation individually or in groups. Focus on how we can know all these things about these planets: they are very close and we have been able to send spacecrafts to many of them. Then ask them about other bodies in the Solar system: asteroids, comets and satellites. What is their role? What is the relationship of each of these bodies with the Sun?

Ask the children how we could detect a planet (or more) orbiting a distant star. Then you should all discuss the exoplanet hunting and the Kepler mission. Why is it important? Discuss the different kinds of stars. Can there be planets around other types of stars (larger, smaller than our own, a white dwarf, a neutron star)?

Then you can begin the activity, which is to create a stellar system. You will need some material: small balls, colors and brushes, plastiline and small sheets of paper.

The Activity

Give a short introduction about the orbital and environmental conditions of the Earth, as they are shown in Table 3.1.

Quantity	Value	Unity
Gravity	9.8	mt/sec^2
Radius	6371	Km
Mass	$5,972 \times 10^{24}$	Kg
Surface Temperature	16	degrees Celsius
Average Distance from the Sun	149,597,887.5	Km
Orbital Period	1	Year
Liquid on the surface	70%	Water
Composition of atmosphere	Nitrogen (N_2)and Oxygen (0_2)	
Life	YES!	
Known species	2,000,000	
Satellites	1	The Moon

Table 3.1: Some characteristic of the Earth.

The students are divided in groups (in our experience, it is fun to have them name their groups). Each group has to form a planetary system, with a central star (or a binary, or triple system, however they'd like to imagine it), planets and other bodies like comets or asteroids. Each of the students in the group will take care of one of the objects which constitute the system. They will have to name the system, as well as their object. This means they will have to decide the characteristics of their object according to the choices of all the others, in order to have consistency within the planetary system.

They can list the characteristics on a sheet and they can give values in two different ways: Either using the units shown in Table 3.1, or with reference to the Earth, saying, for example: "this planet has a radius three times larger than the radius of the Earth".

Once each group agrees on how their planetary system should be and on each person's role in the construction, they are all given the prime matter out of which to create their celestial body: their small balls, colors, etc. At the same time, they have to annotate their system's characteristics on a sheet of paper.

At the end of the activity, one representative of each group will present the system to the rest of the class.

Follow-up activities and sharing

What is life like in these stellar systems, on each of their planets? Could there be life there? If so, what sort of life would it be? How long is the day, or the night on each of these worlds? Try to record the most popular sorts of stellar systems: number or type of stars, number and size of planets. Are they similar or inspired in our own Solar system? It would be ideal if the process of designing and building the stellar systems could be documented. If you have a recording device, interview the students at different phases of the construction. If not, take notes of their comments and progress. The presentations could be an event for the school: an exhibition in which to invite all the students, even outside the Astronomy Club. Share the experience with the other nodes.

Further reading

- Details on the Kepler mission, which is discovering new exoplanets http://kepler.nasa.gov/
- On the habitable zone of planets (English): https://www.e-education.psu.edu/astro801/content/l12_p4.html
- On the habitable zone of planets (Spanish): http://www.abc.es/ciencia/20150205/abci-zona-habitabilidad-estrella-201502041702.html
- The International Astronomical Union has launched an initiative called ”name Exoworlds”, in which organizations can vote names for the new worlds being discovered. GalileoMobile can be an ambassador for you if you want to participate in this or future initiatives! http://www.iau.org/news/pressreleases/detail/iau1404/

4 Stars and Constellations

4.1 Activity 6: Constellations in three dimensions

Introduction

Since ancient times, mankind has imagined people, animals and objects from their daily lives, beliefs, and culture, in the sky. They constructed these figures by connecting stars, and we call the figures constellations. Constellations and their names can be found printed on a planisphere or celestial chart. Before the time of clocks, maps and calendars, observing the sky was very important for helping people to orient themselves in time and space. The constellations were a way to find specific stars and regions of the sky, and a way to figure out your position. In the middle of the desert, the mountains, or the sea, travelers and sailors arrived at their destination guided by the stars. Whether particular stars are visible in the sky or not depends on our location on the planet, the time of day, and the time of year. Today, thanks to powerful telescopes, we know that there are many more stars in the sky than the ancients marked on their planispheres.

However, constellations are not real formations on the sky. We see the projections of stars on the sky and imagine shapes, but in reality, these stars are usually located very far from each other. A constellation is just an illusion, created by our point of view of the Universe. This activity is meant to illustrate this and remind us of the three-dimensionality of space.

This activity has been adapted from the GalileoMobile Activity Handbook [1].

Material and duration

- Wool strings
- Ruler
- Small balls

- A transparent plastic sheet (should be easy to draw holes into, but steady enough to hold)
- An outline of the Swan constellation (provided)
- Duration: approximately 45 minutes + discussion

This activity is a good chance to

- Discuss what a constellation is
- Discuss the about the meaning of different constellations in different cultures
- Discuss constellations as a means of orientation
- Talk about the role of constellations in modern Astronomy (they help astronomers refer to the position of objects on the sky)
- Understand what is the relative position of stars in a constellation
- Wonder how astronomers understand the distance of stars from our planet

Preparation

Introduce the students to what a constellation is. Discuss about the fact that constellations can be different in different cultures and traditions. A constellation is a portion of the sky in which humans that humans have connected with images coming from daily life (animals, people, places) or with local mythology.

Discuss the fact that stars at different distances from us can appear one near the other in the sky, although they are very far away from each other. This is a consequence of the fact that the sky appears to us like a surface, and we identify concepts like ”right”, ”left”, ”up’, ”down” with it. However, we cannot easily establish the distance of an object in the sky. Consider, for instance, the case of the Moon, setting behind a mountain: when the Moon is setting we see it disappearing behind a mountain, or behind the sea or behind buildings. Nevertheless, the Moon is about 370.000 km away from us, while the mountain, or the building, is usually not further than a few kilometers.

Moreover, there is also another consequence of the fact that stars are all at a different distances from the Earth: the consequence is that we see constellations as they are because of our position in the Galaxy. If the Earth sat in another area of the Galaxy, the same stars would have a different position in the sky and the constellations would look different. Discuss this with your students. You can play a game where they draw the room on a piece of paper, (in essence projecting it on a surface) and then comparing the drawings from different points of view of the classroom.

The Activity

In this activity, we'll see how to trace out the constellations and understand why they look as they do from the Earth. To do this, we'll make a three-dimensional model of a constellation known as Cygnus or "the Swan." The star corresponding to the Swan's tail is called Deneb, and is one of the brightest stars in the Milky Way. Give each student/student pair a Swan constellation template (Figure 10.7 in the Appendix), together with 8 long pieces of wool strings. Using the tape measure, cut the colored strings to the lengths indicated in the template next to each star (in cm). Attach the strings to the 8 corresponding star positions (taping them or passing them through the transparency and making a nod) Attach a bead or a paper ball or (fluorescent) plastiline to the end of each string. Look at the Swan from above. It should look like it does on the sky!

(A variation: you can reverse the distances of the stars to be able to look at the constellation from below and have it hang from the ceiling.)

Follow-up activities and sharing

If we now look at the same stars from the side, do we still see the Swan? Why or why not? We no longer see the Swan because our position in space has changed. From this new point of view, the stars are now at different distances from us compared to when we looked from above. That is to say, the shapes of the constellations we see are only apparent and relative. The strings represent the distances separating us from the stars. Each cm of string corresponds to 60 light years (5.7 followed by 15 0's kms!!) in real space, Can you calculate the distance separating us from each of the stars of the Swan constellation?

Do you know of any constellation that is a group of stars actually physically close to each other?

Activity 6b

Try the same procedure with another constellation. Choose a constellation and do search the distances of each of the main stars in it. Then draw a sketch of such constellation, writing next to each star the distance from the Earth. Then follow the same steps as in the case of Swan constellation.

Discuss, the approximate number of stars we see in the sky, and compare it with the approximate number of stars we think there are in our Galaxy. Are they different? Why? How far can we see with the naked eye?

And, if you were to imagine the schools on our "Constellation" network as stars of a real constellation (without much of a third dimension this time), what shape and name would you give it?

Further reading

- Inca constellations: http://www.fromquarkstoquasars.com/the-dark-constellations-of-the-incas/
- http://guillermoabramson.blogspot.co.uk/2013/01/la-llama-sagrada.html

4.2 Activity 7: How do we measure angles in the sky?

Introduction

In some parts of this book we speak about the motion of objects in the sky. The study of such motions has been, throughout history, of extreme importance for understanding many properties of many celestial objects, as well as for understanding the motion of the Earth itself. Nowadays technology provides us with excellent ways to measure the motion of stars, planets, satellites, as well as their positions in the sky. But in ancient times people did not have any of the modern tools. How could they measure and study the position of celestial objects in the sky? We will see in this activity an example of how to estimate angles with a few basic tools as well as with no tools.

Material and duration

- Nothing else than your arms, fingers, eyes!
- Duration: 1-2 hours

diagrams.jpg

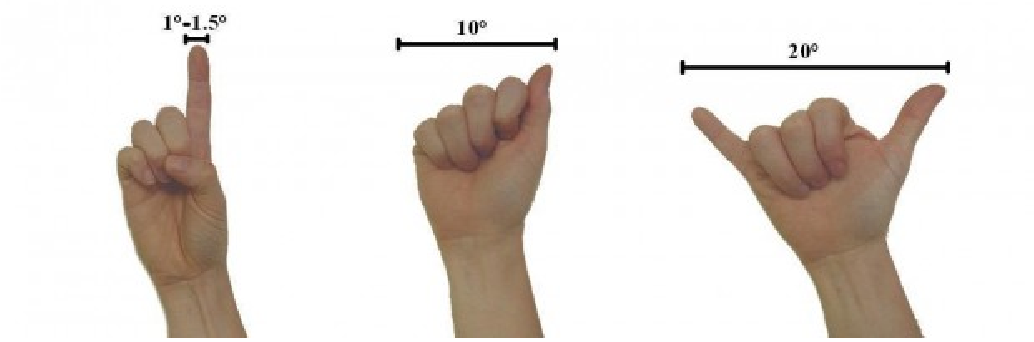


Figure 4.1: Measuring angles using your hands.

This activity is a good chance to:

- Discuss what an angle is
- Discuss about position and motion of celestial objects
- Wonder about discoveries and measurements made in ancient times

Preparation

Start with a discussion about the position of stars and the Moon in the sky. Ask the students how they think it is possible to measure the position of such objects in the sky. Discuss if it is better to measure the position in terms of linear distances or angular displacements. Choose a celestial object to measure its position. The Moon, if visible during the day, or a very luminous star during the night are good choices. Alternatively, take the top of a building or the border of a cloud as reference.

The Activity

If you measure the ratio between the size of your thumb and that of your arm, you can obtain an angle: this is the angle subtended by your thumb when your arm is completely stretched in front of you. You can do the same with your fist, for example, or with your open hand, spreading your fingers as widely as possible. This is illustrated in Figure 4.1.

The value obtained is the measure of the tangent of the angle, form which you can deduce the angle as in activity 2.1. You will see that the angle subtended by your spread hand is about 20 degrees. In such way you can measure the height of celestial objects above the horizon, in terms of an angle. You can combine both of the spread hands to obtain an angle twice as big as the one subtended by only one hand. To make sure that you are measuring correctly, you can start by measuring the angle starting from the horizon and arriving to the zenith, which is the imaginary point in the sky directly ”above” your head (its opposite, the imaginary point directly below your feet is called Nadir). This angle is 90 degrees.

In this way you can measure the angular position of a celestial object with respect to the horizon, or with respect to another celestial object. You can also measure the angular extension of a building as seen as from your position.

Follow-up activities and sharing

Compare the measurements made by different students. If you are in a big group it is likely that students will have many different measurements. This is science! Many different measurements, so which one is right? Discuss about the sources of errors and devise other ways to improve the reliability of each measurement.

Do you think that such angular measurement can help in evaluating the distance of a distant object? If you know the height of a building, can you measure its distance from your position using this method for measuring angles?

Further reading

- http://lcogt.net/spacebook/using-angles-describe-positions-and-apparent-sizes-objects

5 Colors of light

5.1 Activity 8: The colors of The Sun

Introduction

What is the nature of light? This is a very basic, but amazingly complicated matter that is of central importance for humans, both in daily life and the study of astronomy. We receive every day light from the Sun, and such light appears to be white. Nevertheless, if one sees a rainbow, this is not white! A rainbow is produced by sunlight passing through raindrops: this is one of the example which tells us that sunlight is composed of all colors of the rainbow.

To tell the truth, sunlight is composed by much more than the colors of the rainbow, but this is its only part that is visible to human eyes, and we therefore concentrate in it.

Here we present an activity that shows a method to separate light into the colors of the rainbow.

Light changes its direction of propagation when it travels from one medium to another. This phenomenon is called refraction. The angle by which the light rays are refracted is calculated by the following formula:

$$\frac{sin\theta_1}{sin\theta_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} \tag{5.1}$$

In Equation (5.1), the indices 1 and 2 refer to the media 1 and 2 in which the ray propagates. The angles θ_1 and θ_2 are measured between the light ray and the vertical on the surface of separation between the media. λ_1 and λ_2 are the wavelengths in the two media, and n_1 and n_2 are called indices of refraction and are characteristic of each material.

It is clear that, if we force white light (all wavelengths, hence all colors) to change medium, coming in with the same angle θ_1, each color will be found at a different angle θ_2 in the new medium.

This activity has been adapted from the GalileoMobile Activity Handbook [1]

Material and duration

- Plastic or glass box
- Water

- A mirror
- Duration: 30 minutes

This activity is a good chance to:

- Discuss what light is
- Discuss about the difference between different colors
- Discuss about two special colors: white and black
- Discuss about phenomena like rainbows

Preparation

Start speaking about light, and triggering a discussion among students about what they know about light, and about the light coming from the Sun. Do they know phenomena showing that light is not only white? Discuss the refraction of light.

The Activity

During a sunny day go outside and bring with you a plastic box, water and a mirror. Fill a container with water and put the mirror in the container so that the mirror can sit at an angle with respect to the bottom of the container. The mirror reflects the sunlight, which can be projected onto a screen, a flat white surface or even on your shirt! On the screen, you will see a rainbow of colors!

Follow-up activities and sharing

When a sun ray goes through the water surface, it is refracted, i.e., its direction changes according to its wavelength. Then it travels through the water until it reaches the mirror, where it is reflected, goes back and exits again crossing the surface of the water. The result of these refractions can be seen on the screen: colors!

What colors can you see on the screen? Thinking about the explanation given in the introduction on light and rainbows, can you tell what has happened in our experiment? If you do the experiment many times, will you see the colors showing up always in the same order, or in different ones? Try to draw the experiment and trace the light rays of different colors.

The colors you can see are part of the *spectrum* of the light of the Sun. You have in fact built a spectroscope. By playing with the spectroscope you can find out how it works best. Which orientation, inclination, or amount of water, gives the best results?

Part II

Bonus Activities

6 The Earth, the Moon, and the Sun

6.1 Activity 9: The shape of the Earth's orbit

Introduction

Since ancient times, we observe repetitions in the apparent motions of the Sun, the Moon, the planets and the stars. This is very good evidence to suggest that the Earth's motion is closed and periodic, since such a motion would cause us to pass from the same locations in space repeatedly. We also know that the orbits of the planets (and it is reasonable to assume that the Earth's orbit too) are smooth, meaning they don't have sharp angles, like a square, or a triangle.

By this simple reasoning, the love of many civilizations for absolute symmetry led to the idea that the planets moved in circular orbits. In fact, we now know that this philosophical view is not too far from reality. This knowledge originated from the careful observations of great astronomer Tycho Brache, which led another great astronomer, Johaness Kepler, to form his famous three laws for the motion of the planets. These laws, in fact, show that the orbits of the planets are ellipses:

This activity has been adapted from the GalileoMobile Activity Handbook [1]

1. The orbit of a planet is an ellipse with the Sun at one of the two foci.
2. A line segment joining a planet and the Sun sweeps out equal areas during equal intervals of time.
3. The square of the orbital period of a planet is proportional to the cube of the semi-major axis of its orbit.

Since Newton formulated his universal law of gravity, we now know that these relations are a direct consequence of the behavior of the gravitational force, and are valid for the motion of all satellites.

But, can we come up with a simple way to validate Kepler's very detailed result and confirm that our planet's orbit is indeed elliptical? With this activity we will not only do this, but also measure its eccentricity.

This activity has been adapted from the GalileoMobile Activity Handbook **??**.

Material and duration

- Images of the Sun 3 months apart (provided)
- Ruler
- Duration: About 1-2 hours for the activity itself, plus preparation and follow-up activities

This activity is a good chance to

- Discuss the concept of an orbit and the Universal law of gravity, very important in Astronomy
- Discuss the motion of the Earth relative to the Sun and its effect on our lives and civilization
- Introduce the scientific method: logical reasoning that leads to a plausible theory, and then test the validity of that theory

Preparation

This activity requires some prior knowledge of geometry, specifically the conical sections and the characteristics of an ellipse. In preparing the classroom for the experiment, it would be useful to mention Tycho Brache's observations and describe Kepler's laws and what they mean for the orbits of the planets.

Another key concept in this activity is the apparent magnitude. In fact, what is required here is to measure the change of the Sun's apparent magnitude at different points of the Earth's orbit. This will lead us to measure the change of distance between us and the Sun. Have a small introductory activity when the children are asked to observe one another approaching or receding. They can observe the change in the "apparent magnitude" of their friends' faces either by looking at them through a hole, or by trying to obscure them with their fingers.

This activity requires solar projections, if you wish to do your own observations. It would be useful to acquaint yourself with the use of the telescope for this purpose. If you do not feel prepared to use the telescope for this purpose, you can use the images of the Sun provided in the Appendix.

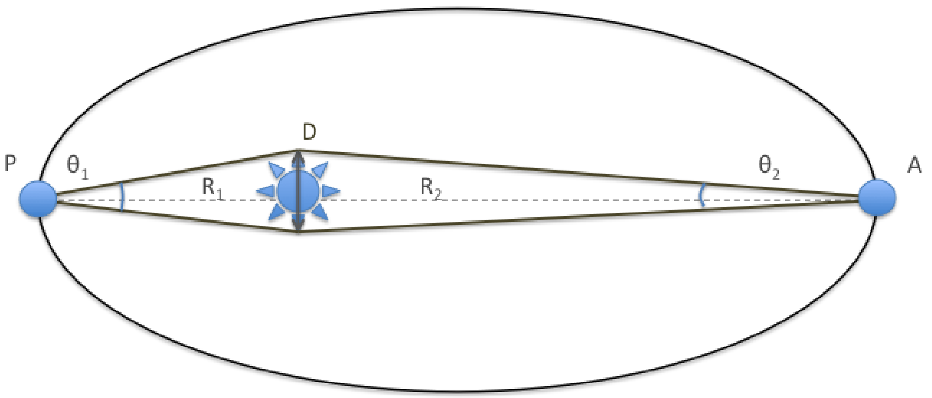


Figure 6.1: Change of the Sun's viewing angle from the Earth at opposite points of the Earth's orbit, the Perihelion (P) and the Aphelion (A). These are the point of Earth?s orbit in which the Earth is, respectively, nearest and farthest, to the Sun.

The Activity

Figures 10.1, 10.2, 10.3, 10.4 in the Appendix are 4 images of the Sun. (Alternatively, use four of your own images of the Sun, taken three months apart). First, take a careful look and describe any differences (the difference relevant for this activity is the size of the disk). Form a hypothesis for these differences.

Each of them is was taken 3 months apart, meaning they correspond to 4 equally spaced points on the Earth's orbit. You can make a drawing like Fig. 6.1 and place the points.

With a ruler or another measuring instrument measure the size of the solar disk on each image and write down your measurements along with the date for each image. When is the disk larger? By how much?

Using Figure 6.1 calculate the distances d_1 and d_2. How much larger is the distance to the Sun at the Aphelion? You can calculate the eccentricity of the Earth's orbit with the simple formula:

$$e = \frac{|d_1 - d_2|}{(d_1 + d_2)} \tag{6.1}$$

Follow-up activities and sharing

Discuss in the classroom about the significance of your result. Is the Earth's orbit close to a circle? What if the eccentricity was exactly zero, or one? Is there reason to believe the other planets have similar orbits?

There is a common misconception that the change of seasons is due to this difference of distance you just measured. Do you think this is the case? Discuss: If the distance was the reason, the seasons would fluctuate in the same way in both hemispheres. Actually, within our network there are probably schools at locations where the seasons do not change. Have the students mention what they know about the seasons, and especially the difference between hemispheres. Exchange experiences about the seasonal changes with your colleagues at different locations of the network.

Actually, the change of seasons happens due to the inclination of the Earth's rotation axis with respect to its orbital plane. These two planes form an angle of 23.5^o. During the summer in the northern/southern hemisphere, that part of the Earth is tilted towards the Sun, and it is tilted away from the Sun during the winter. Thus, sunlight enters the Earth's atmosphere almost vertically in the summer and at a large angle during the winter. The more atmosphere sunlight has to travel through, the more energy it loses, so it transfers less heat to the planet's surface. Moreover, due to the inclination of the rotation axis, we have longer days during the summer, which means longer exposure to sunlight and, therefore, more heat and higher temperatures.

Can students think of some other reason for observing the Sun varying its apparent size in the sky? How can we prove that the change of the size of the Sun is not due to an intrinsic change in the size of the Sun?

6.2 Activity 10: Measuring the distance to the Moon

Introduction

By far the most precise and reliable way of measuring distances in Astronomy is parallaxes. In the second century BC, Hipparcus calculated the distance from our planet to the Moon using its parallax. This method is based the apparent change in position of a relatively close-by object with respect to more distant objects, when observed from different points of view. Figure 6.2 illustrates the idea.

Picture a distant star; let's call it S. S is much further from the Earth

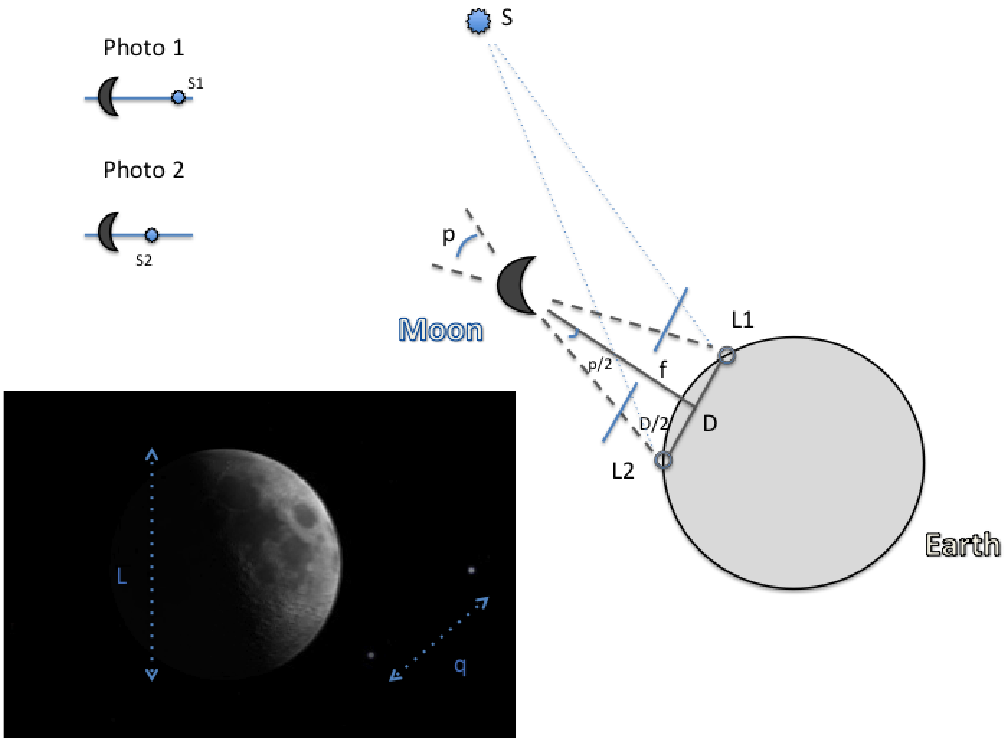


Figure 6.2: Measuring distances with parallaxes.

than the Moon is. And imagine two different observers, at locations L1 and L2, at a distance D from each other.

The angle p in Figure 6.2 is called the parallax, in this case, of the Moon. (The Moon is very close to us, so this angle is relatively large. Objects further away have smaller parallax angles.) It is clear that we can calculate the distance to the Moon, marked as f, if we know the angle p:

$$
\begin{aligned}
tan(p/2) &= \frac{D/2}{f} \Rightarrow \\
f &= \frac{D/2}{tan(p/2)}
\end{aligned}
\tag{6.2}
$$

But how can we measure this angle p? Remember the two observers we placed at L1 and L2? Let's have them take a picture of the sky at the same time. The observer at location L1 will take photograph 1 and the observer at L2 will take photograph 2. To help us imagine how these photographs would look like, grey dashed lines show how the light would travel to the observers from the Moon, while the blue dotted lines show the same thing for star S.

We can calculate the parallax p by merging Photo 1 and Photo 2 in such a way that the images of the Moon overlap (or so that the images of the stars overlap, see Figure 6.3 later in the activity). In effect, this is equivalent to rotating the point of view from location L1 to location L2 by an angle p. When we do this, we get a picture similar to the one shown at the left bottom corner of Figure 6.2. The angular distance between the two positions of the star S, S1 and S2 is the parallax p.

However, we cannot measure angular distances on a picture! The easiest way here is to use the well known angular size of the Moon, $AM = 29.3' - 34.1'$, where primes denote minutes of the arc ($1' = 1/60$ degree, so $AM \simeq 0.5$ degrees). So, if we measure the size of the Moon on the picture (in cm, for example) and call it DM and do the same for the distance between S1 and S2, and call that dm, the parallax p is calculated as:

$$\frac{dm}{DM} = \frac{p}{AM} \Rightarrow \\ p = \frac{dm \cdot AM}{DM} \quad (6.3)$$

Material and duration

- At least two images of the Moon next to a distant star, taken from different locations (provided)
- A ruler
- Duration: About 45 minutes

This activity is a good chance to:

- Discuss distances and how we measure them
- In general, bring up the complex problem of distance measuring in astronomy
- Talk about the Hipparchus satellite, which measured distances to thousands of stars!

An alternative way for measuring angles is to refer to activity 6 and proceed in a similar fashion: one can start from measuring the angular distance of the Moon from the horizon.

Preparation

Like Eratosthenes' measurement (Section 2.1), this activity obviously requires some knowledge of trigonometry, so it would be advisable to refresh that knowledge beforehand. Alternatively, this activity could be used to trigger the pupils interest in trigonometry and have them revise!

This experiment dates back to the second century BC. It would be a good opportunity to talk about that epoch with the class, discuss what humanity knew back then and what not and whether they were able to measure distances the way we do now. Ask the pupils if they know how distances are measured in general. Document the responses as best you can.

This activity requires taking either photographs of the sky or snapshots with Stellarium. In the first case, you will need a good camera and a skilled photographer to capture the Moon and at least one known star in your photograph. In the second case, you will have to have Stellarium (or other related software) installed on at least one computer. You will also need image processing software.

In either case, one needs photographs of the projected position of the Moon on the sky from (at least) two different locations. The ideal way to conduct this activity is to collaborate with at least one other school at a different location.

The Activity

Like described in the Introduction, the calculation is very straightforward. Two pictures of the sky are taken at the same time, from different locations. For this you can use a camera and take a picture of the Moon together with a known star at exactly the same time as another school of the network. Alternatively, you can arrange to print out snapshots of the same thing with Stellarium.

Then you need to merge the two pictures so that the images of the Moon overlap, or so that the stars overlap, like in our provided picture, Figure 6.3.

If you have a digital version of the photographs you can use image processing software to do this, and then print out the final result. Alternatively, you can use transparent paper to transfer one image to the other.

Measure the apparent size of the Moon on the image. This is DM in Equation (6.3). Then measure the distance between the two positions of the star (or the two positions of the Moon), which would be dm in Equation (6.3). Then use AM=0.5 degree and evaluate Equation (6.3). (If you wish, you can actually measure the angular size of the Moon by directly observing it.)

Once you have the angle p from Equation (6.3), you can use it in Equation (6.2) to calculate the distance to the Moon.

You can also share your photographs and measurements with different schools and do this calculation more than once. Then calculate the mean distance from all the measurements.

Follow-up activities and sharing

Reflect upon this calculation with the class. What does this distance mean? How much time would it take us to travel there by car? How much does light take to get there?

Hipparcus measured the distance to the Moon almost 2000 years ago. Obviously, he had no photographs or image processing equipment. How did he do it?

Can we think of other ways to measure the distance to the Moon? How far do you think an object can be until parallaxes don't work any more? What would be the limitation? Can we think of ways to measure distances where parallaxes are not possible?

- http://www.esa.int/Our_Activities/Space_Science/Hipparcos_overview

Figure 6.3: A composite picture taken for measuring parallaxes. The distances to the three locations are indicated at the bottom right. (Credits on the picture)

7 Planetary systems

7.1 Activity 11: Sending a message to the Universe: The Voyager missions

Introduction

The twin spacecrafts Voyager 1 and Voyager 2 were launched by NASA in separate months in the summer of 1977 from Cape Canaveral, Florida. As originally designed, the Voyagers were to conduct closeup studies of Jupiter and Saturn, Saturn's rings, and the larger moons of the two planets. To accomplish their two-planet mission, the spacecraft were built to last five years. But as the mission went on, and with the successful achievement of all its objectives, the additional flybys of the two outermost giant planets, Uranus and Neptune, proved possible. Eventually, between them, Voyager 1 and 2 explored all the giant outer planets of our solar system and 48 of their moons.

Material and duration

- Colors, brushes, paper, carton
- Books, magazines, media in general
- Children's imagination is really the limit of this activity: It can take as little or as much time and material as you want!

This activity is a good chance to:

- Discuss the Voyager missions
- Discuss our global culture, in the process developing a feeling of unity across humanity
- Explore the limits of communication, verbal and non-verbal, symbolic and mathematical.

Preparation

Start by asking the students the questions like the following:
"Do you believe in aliens?"
" If there are aliens out there, how far do you think we need to go in order to find them?"
" Do you thing we could ever contact them?"
To assess the preliminary knowledge of your students, continue the conversation based on the following questions:
"Do you know any cases when astronomers tried to receive messages from alien civilizations that might exist?" For this you can check online resources listed at the end of the activity, for example the SETI project and the Big Ear radio-telescope.
"Do you know if astronomers have ever tried to send a message to outer space in order to contact alien civilizations that might exist?"

Inform your students about the Voyagers and the Golden records they carry. (Some relevant links are provided at the "Further reading" section.)

You can complete the conversation with questions such as:
"If you could compile your own Voyager record, what would you put in it? What message would you like to send to outer space?" "What do you believe should be included in a record that is supposed to reach an alien civilization?"

The Activity

The activity is, essentially, planning a mission similar to the Voyager missions and sending our own messages out to space. First, ask your students to imagine that they have been selected by the world to be part of a committee that will compose the content of a record that will be sent to outer space. They should discuss what kind of information they believe they should include in their message. Encourage the students to search in books, magazines and the world around them to gather the information that they would like to put in their disk. Once all the footage is gathered have students gather for a second conference of the committee. In this conference the groups will have to present the footage gathered. The entire team will then have to filter them and decide what they want to include in their disk. Remind them that they are part of a scientific committee and that their selections should be based on solid arguments.

Once students finalize the selection process ask them to make a collage(s) (or any other type of presentation they would like) to present the footage they have collected.

Follow-up activities and sharing

You can present to the students photographs of the Golden disk and its content and explain why it is gold and what do the symbols on it mean. Why did the language have to be symbolic? How possible do you think it would be our alien friends would understand our message? Ask your students to compare the content of the disk with the footage they have collected. An interesting focus of the discussion is that the Voyager disks were sent off in 1977. Many things happened since then. What is the extra information they feel should be passed on from the last decades?

Organize a small celebration where the students get to present their collage and the footage they collected. Share your disk and your celebration photographs with the rest of the network!

Further reading

- http://voyager.jpl.nasa.gov/spacecraft/goldenrec.html
- http://voyager.jpl.nasa.gov/science/planetary.html
- http://en.wikipedia.org/wiki/Pioneer_10
- http://en.wikipedia.org/wiki/Voyager_program
- http://en.wikipedia.org/wiki/Voyager_Golden_Record
- http://voyager.jpl.nasa.gov/spacecraft/index.html
- The Big Ear radiotelescope and the WoW signal: http://paraportal.gr/index.php/na
- The SETI project: http://www.seti.org/
- "Messages from Earth": http://news.bbc.co.uk/2/hi/science/nature/613444.stm

8 Galaxies

Galaxies are enormous collections of stars, gas and dust bound together by their gravitational interaction. Their name comes from the ancient Greek name for our own galaxy, the Milky Way (”galaxias” in Greek, originating from the Greek work ”gala” for milk): the view of the millions of our galaxy’s stars from our position in the Milky Way is a whitish strand on the sky that these people imagined as dropped milk. But it took scientists several centuries more to discover that there are millions more of these objects, all around the Universe and to explore their nature.

Nowadays we know that, within a galaxy, stars are created and destroyed. We also know that galaxies are bound together in groups or large clusters and often they also interact with each other. One common interaction is the actual merging of two galaxies to create a new, larger galaxy with different properties.

8.1 Activity 12: A galaxy merger

Introduction

Galaxy mergers are a fairly common phenomenon in the Universe. We have actually observed them in various phases in various wavelengths with state-of-the-art observatories. A merger happens when two galaxies find themselves close to one another. Then the gravitational force pulls them together. Depending on the mass ratio of the two objects, they can spiral around each other one or several times, in which some of their gas and stars is tidally stripped, while in other locations it is compressed by large shocks and forms new stars. The result, typically after hundreds of millions of years, is a new galaxy, the shape and properties of which depends on the mass ratio and the properties of the two galaxies participating in the merger.

Material and duration

- At least 20 Students
- A video about galactic collisions

- An open space or a big room
- Duration: approximately 45 + discussion

This activity is a good chance to

- Discover and discuss what a galaxy is
- Discuss the meaning and origin of the word ”galaxy”, and make comparison with other languages
- Introduce to the students the elements which form a galaxy
- Wonder about how the components of a galaxy move
- Wonder about how the components of two different galaxies behave during a galactic collision

Preparation

Introduce the classroom to galaxy dynamics and collisions. It is recommended to use a video,for example the ”Cosmic Collisions” of the American Museum of Natural History. (The same video is also used in Galileo-Mobile opening talk.) Alternately, videos from actual numerical simulations of galaxy mergers are also useful.

The Activity

The goal of this interactive and fun activity is to give a basic understanding of galactic dynamics, especially the mechanism of galaxy collisions.

The first part of the activity is a ”Galaxy fair”, in which students are assigned a galaxy, like in Figure 8.1 (for example, the Milky Way and Andromeda) and choose what kind of object they want to be: a super-massive black hole at its center, a star or a cluster of stars, a nebula or a supernova, etc. It’s recommended that they get a piece of paper with information about their object. If the activity is performed in schools where there are students speaking different languages, we strongly recommend to discuss how the word ”galaxy” is translated in each of these languages. We also advice to discuss the meaning and etymology of the word, as we have briefly done with the word ”galaxy” in the introduction of this activity.

The second part would be ideally carried out at an open space. The children are placed in ”orbits” in their galaxy. The orbits can be drawn on

Figure 8.1: A Galaxy of students - GalileoMobile "BraBo" expedition, 2014

the floor with chalk. Here we can discuss internal galactic dynamics: the central black hole, star formation, and stellar orbits. Eventually, the galaxies merge (it's probably more practical to stop orbiting and only focus on the collision course). Remind the children that objects in a galaxy merger very rarely collide! The black holes at the center will probably eventually merge, the gas does collide and forms new stars, but stars either pass each other by or get tidally stripped.

Activity 6 bis -Variation

Expansion of the Universe: A larger group of students could be split to represent many galaxies. While each group belonging to the same galaxy should stay together, galaxies could slowly start moving apart. Taking pictures from above during different stages of the merger (or expansion) can be material used for discussion later.

Follow-up activities and sharing

Try to estimate the final mass of your galaxy in stars and in gas compared to the two parent galaxies. How much stars and gas did you lose from tidal stripping and how many new stars did you form from the compression of the gas? What do you think happened to the tidally stripped objects?

Discuss the time-scales of a merger compared to the orbital period of each object and to the lifetime of each object. How long will it be from now until our galaxy's merger with Andromeda is completed? Will our Sun still be around?

Try to estimate how many mergers can happen in the lifetime of a galaxy. It's actually hard to come up with a number! What clues do you need in order to make a good guess?

9 Properties of light

9.1 Activity 13: The colors of light

Introduction

This activity is some way similar to activity 5.1, so you can refer to it for the introduction. It is an activity about light and colors.

This activity has been adapted from the GalileoMobile Handbook of activity [1]

Material and duration

- Match box
- 1 used CD
- Tape
- Torch (in case of a cloudy day)
- 45 minutes

This activity is a good chance to:

- Discuss what light is
- Discuss what colors are
- Wonder about atmospheric phenomena like the rainbow

Preparation

Paint the interior of a match box black. Make a longitudinal cut, similar to figure 9.1: the observer will look at the color spectrum inside the box through that cut. Using scissors, cut a CD that you do not need into eight equal parts (to make it easier to cut, pre-cut the CD with a cutter). Glue one of them at the bottom of the box with the recording side (the reflector) upwards.

spectrum.pdf

Figure 9.1: A scheme of the spectroscope

The Activity

The activity starts when you close the box, making sure to leave just a slit open in the area opposite where you made the cut. Then you can point the match box so that sunlight (or artificial light) gets in through the open slit and look through the aperture (Figure 9.1). At this point the students can start playing with the match box to find the appropriate orientation to observe the different colors of Sunlight.

Follow-up activities and sharing

Did you manage to see the colors? What do you think happened? Like in the rainbow experiment, sunlight enters through the slit and the CD surface refracts the light, decomposing it into different colors. Why did we not have to use water in this case to split the light into the different colors of the rainbow?

We have seen that the light contains several colors. But what happens if we repeat the experiment and put a red filter (or a filter of any other color) where the light enters the spectroscope? Do we still see colors?

Also: Are these the only colors present in the light? Does any of the students know about other features of sunlight?

10 Appendix: Supplementary material

Here a list of material needed to be used to perform the activities listed in this handbook

10.1 Activity 2: The shape of the Earth's orbit

These are images taken from the Yohkoh Satellite several years ago. The Yohkoh Satellite might have suffered from eclipses (and its data are lower quality), but it moved around the Earth, so it saw the same size variations as the Earth did along its orbit.

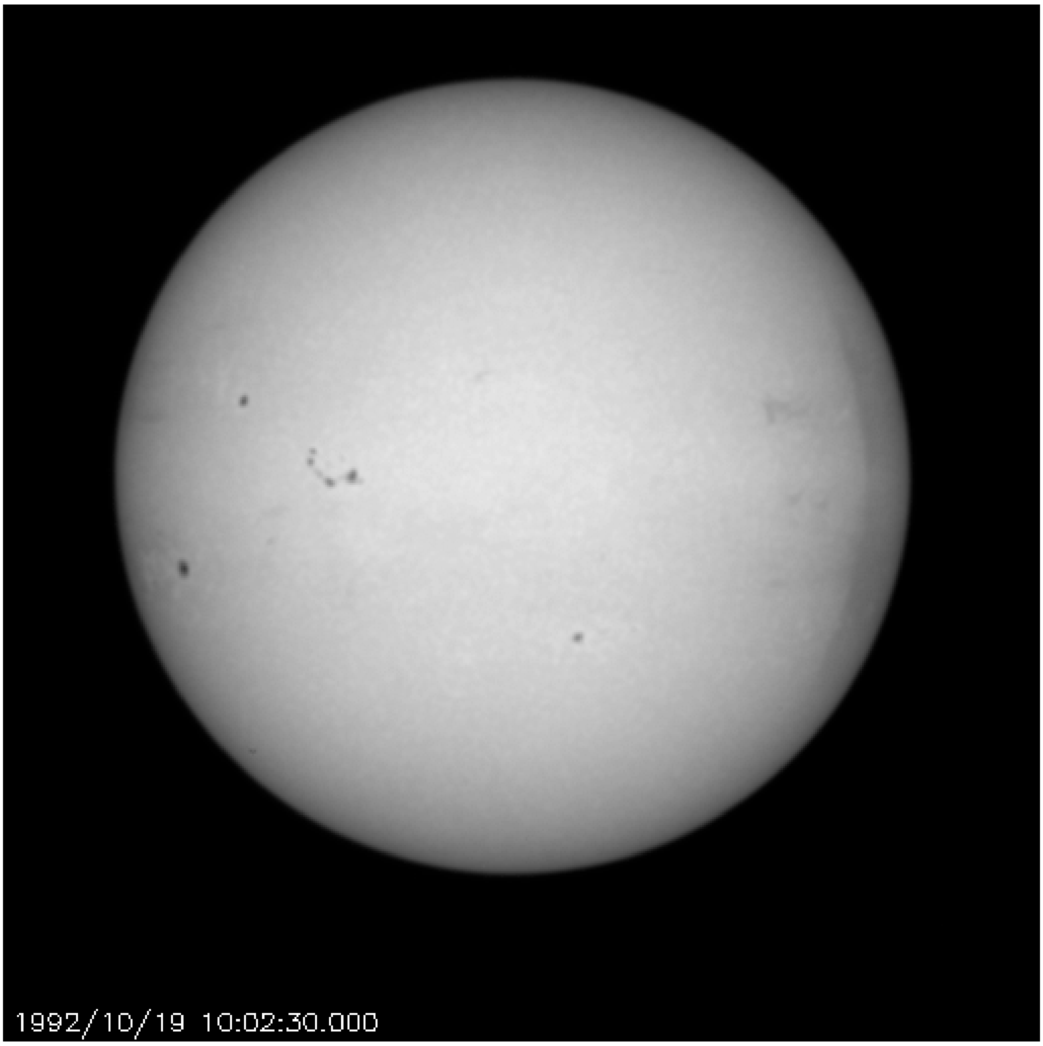


Figure 10.1: The Sun on October 19th, 1992.

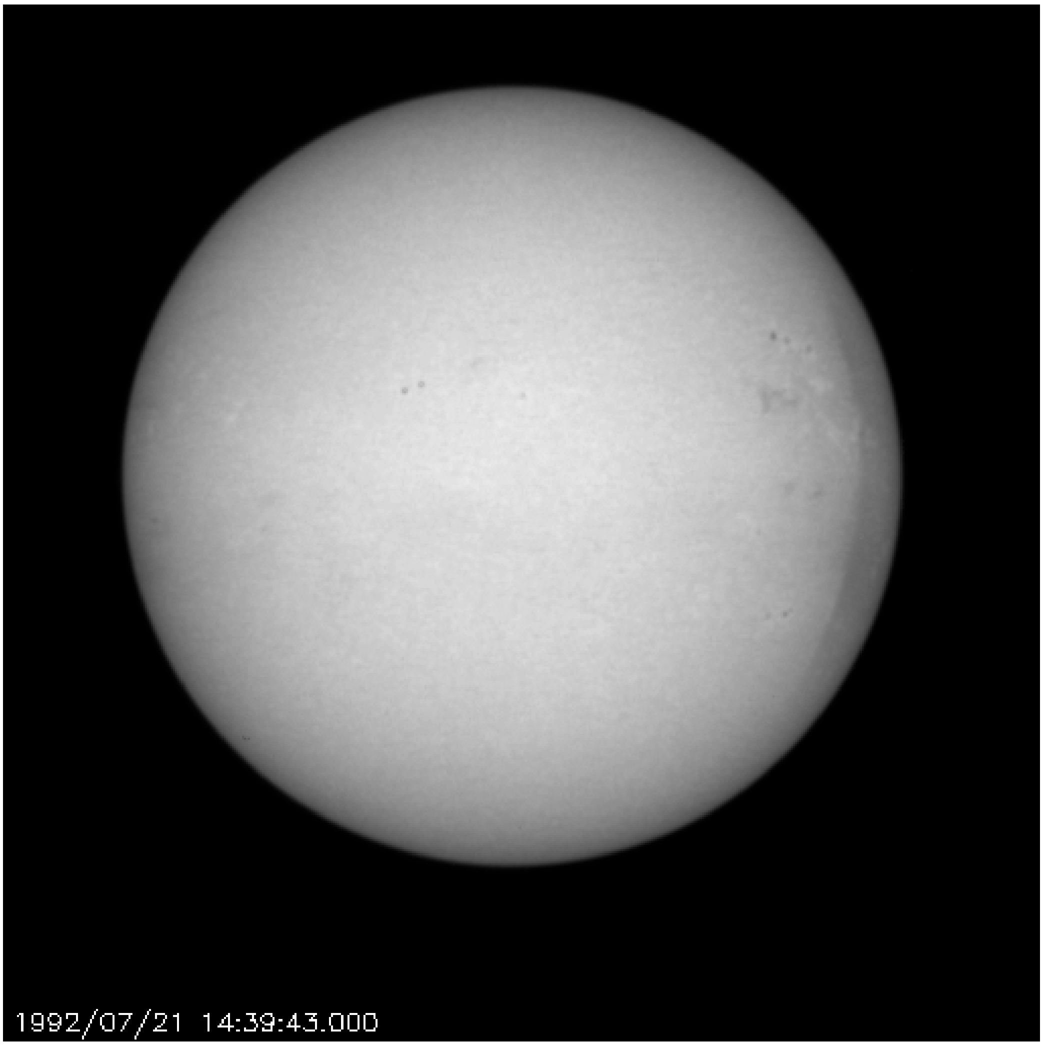


Figure 10.2: The Sun on July 21st, 1992

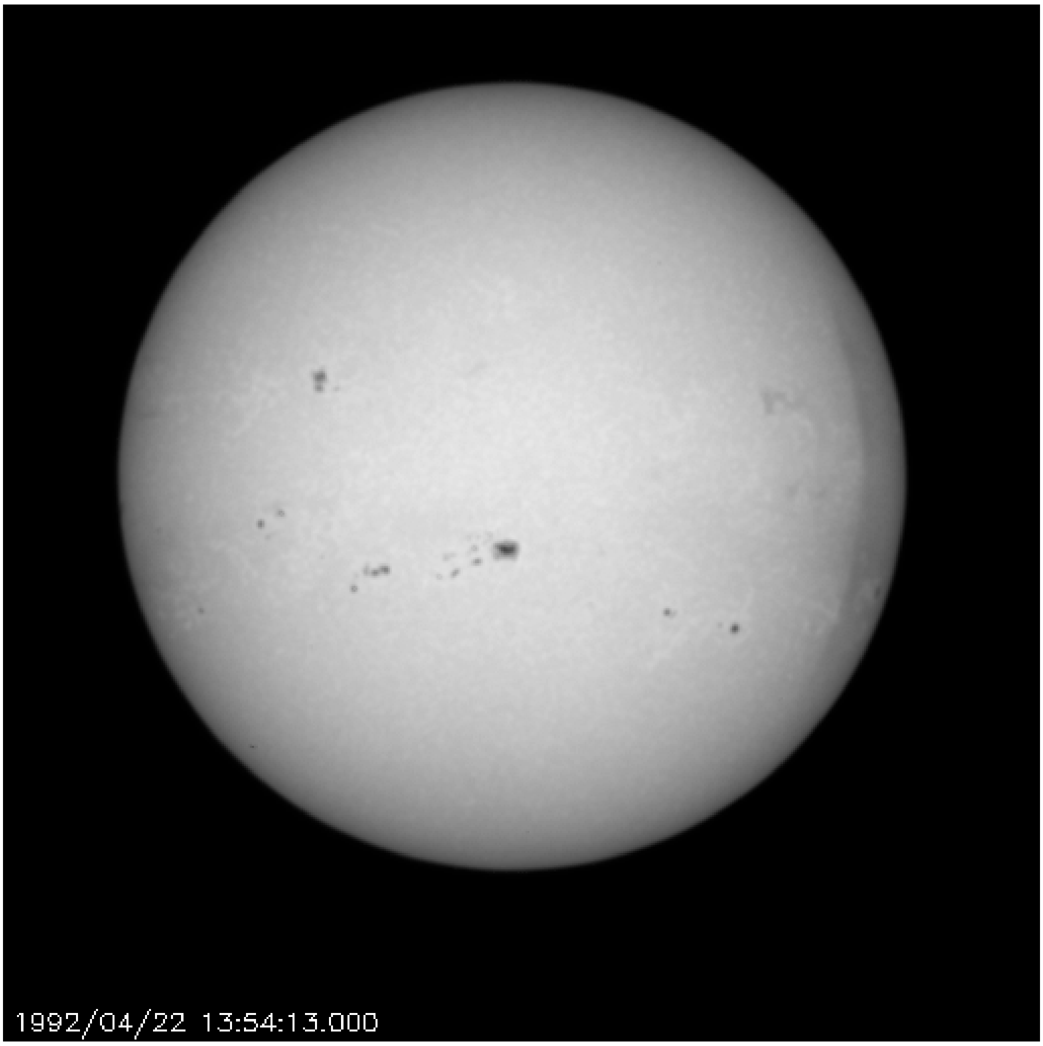


Figure 10.3: The Sun on April 22nd, 1992

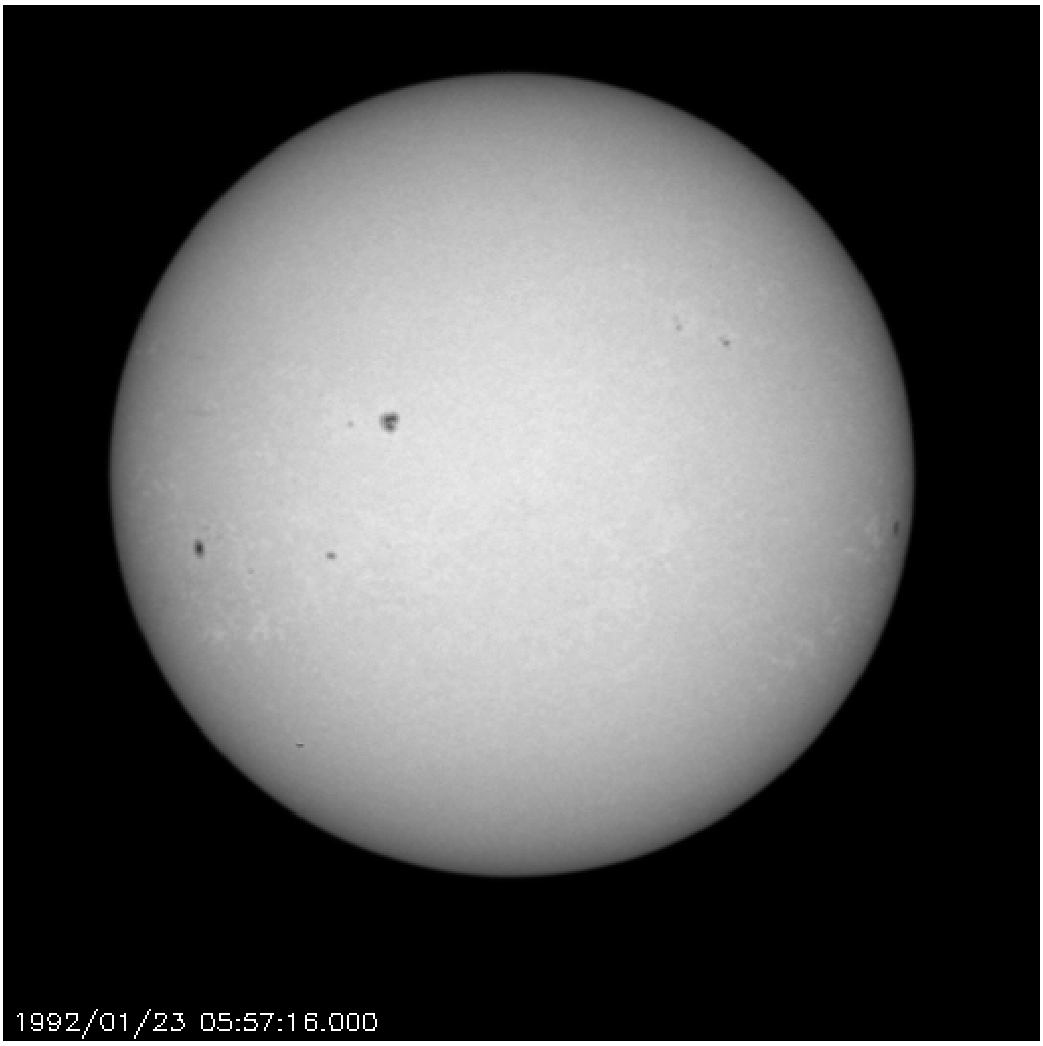


Figure 10.4: The Sun on January 23rd, 1992

10.2 Activity 3: Using sunspots to measure the rotation of the Sun

Below are several images of the Sun's surface taken by the Solar Dynamics Observatory over a period of 7 days.

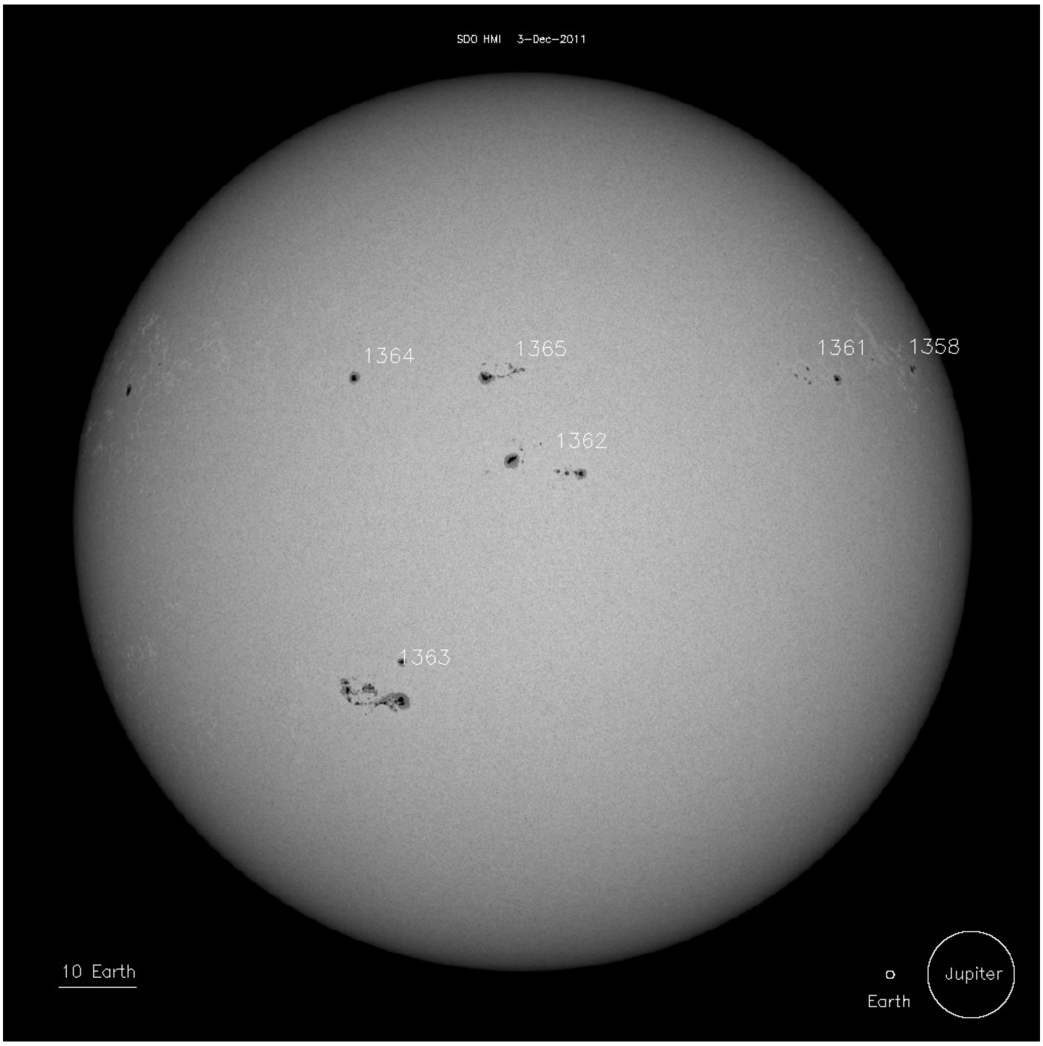
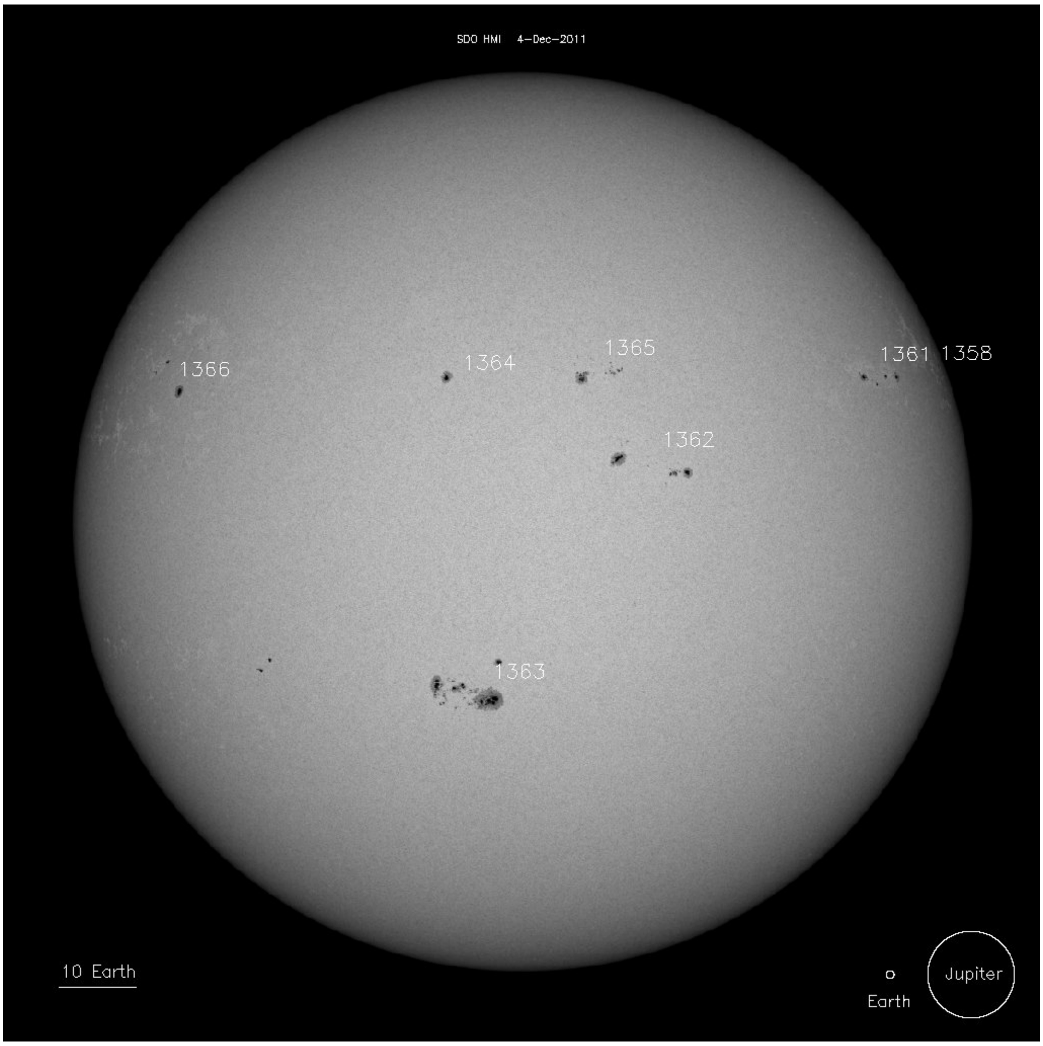


Figure 10.5: The Sun's photosphere, with the date and time. Sunspots are numbered.



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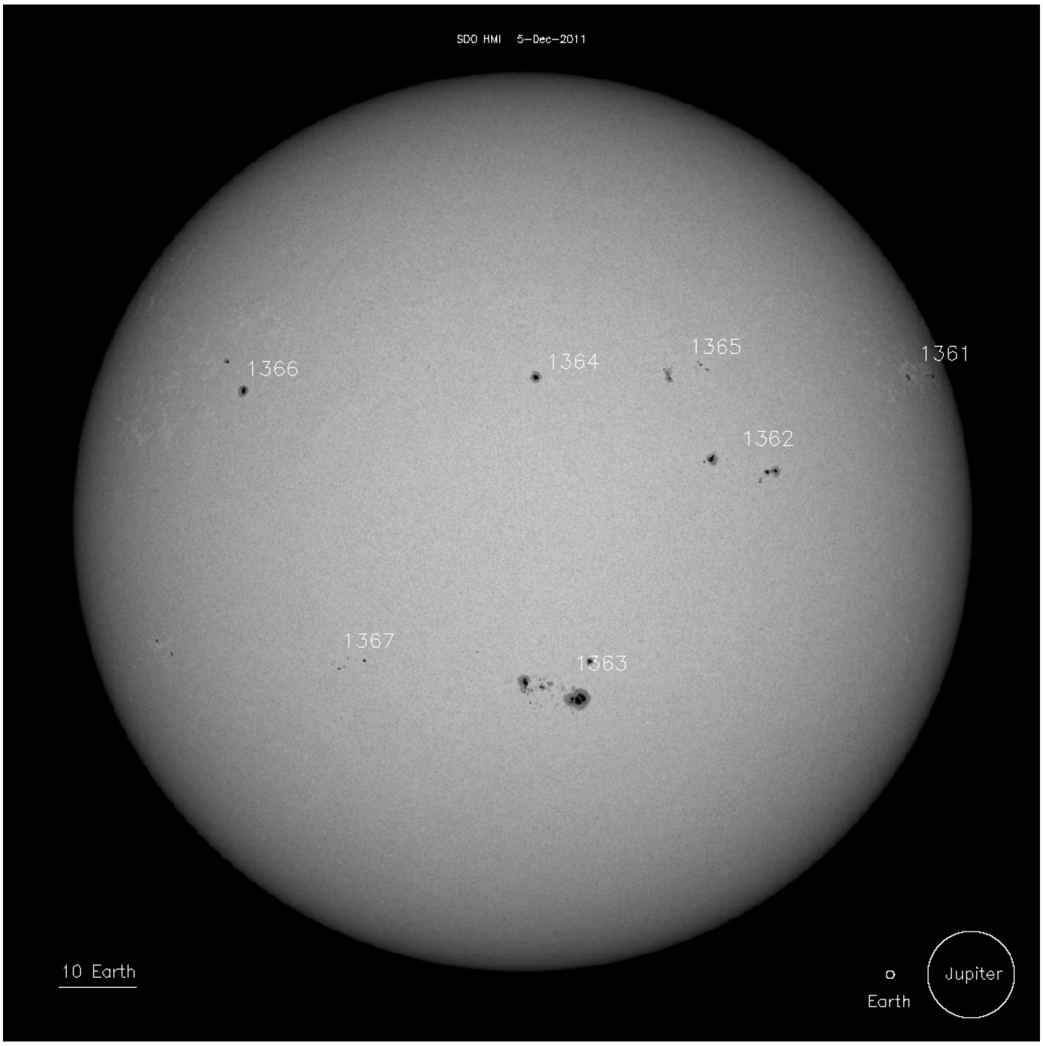
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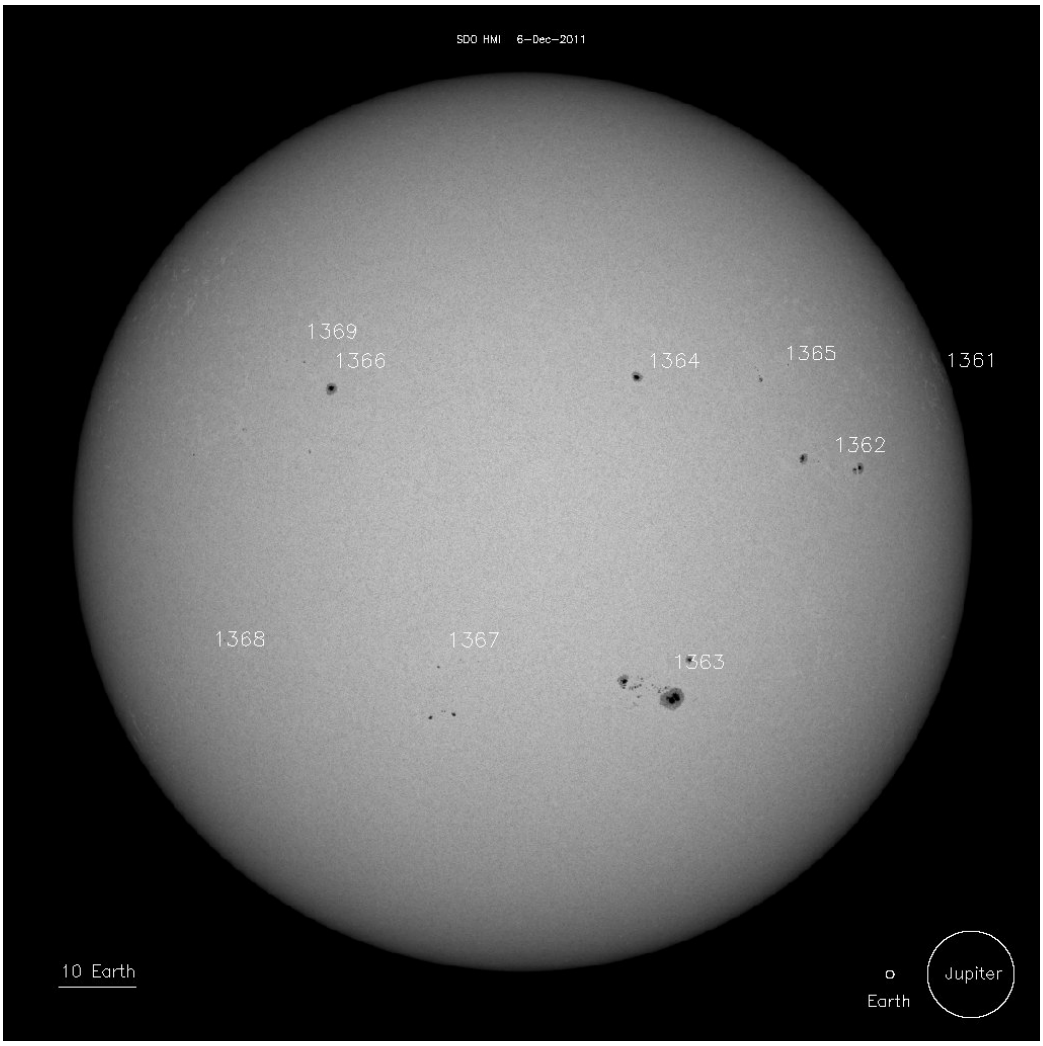
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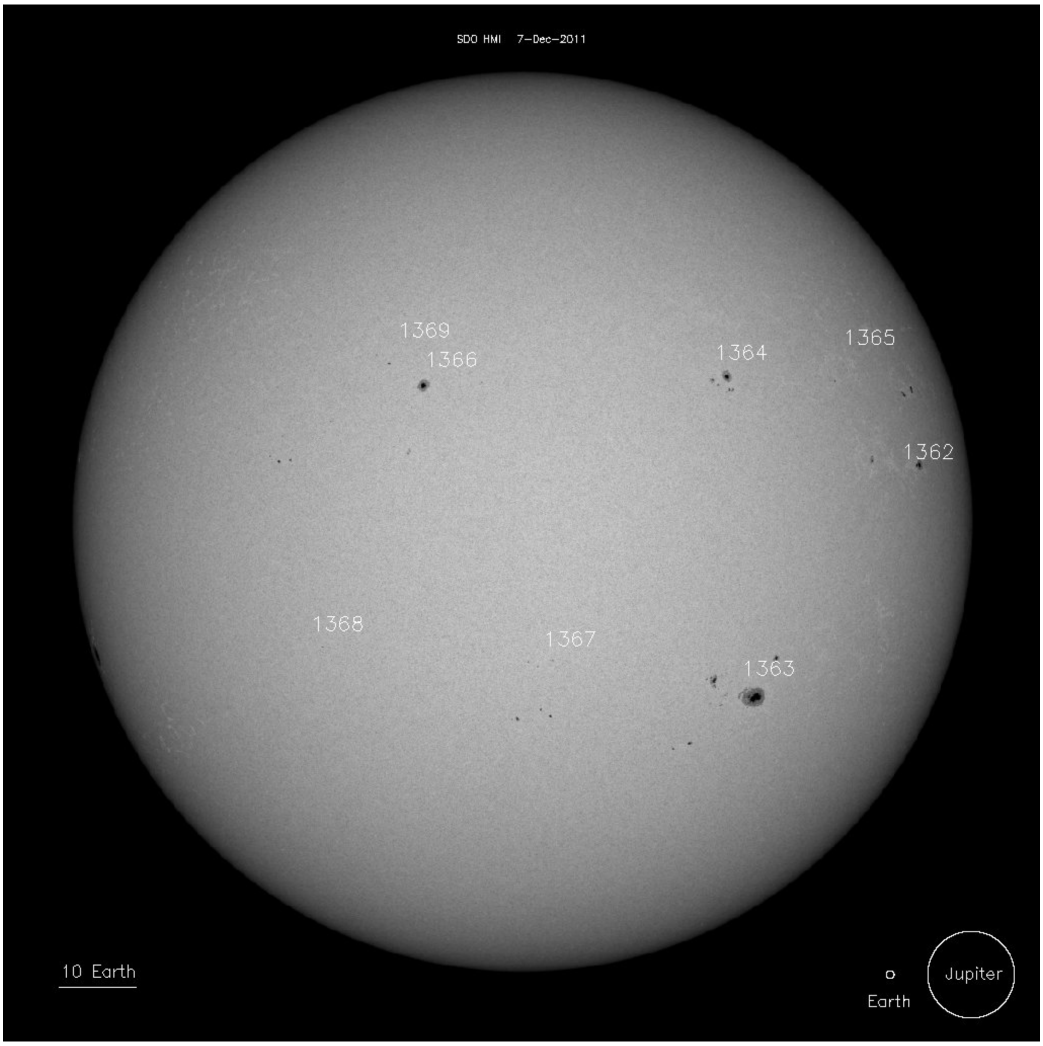
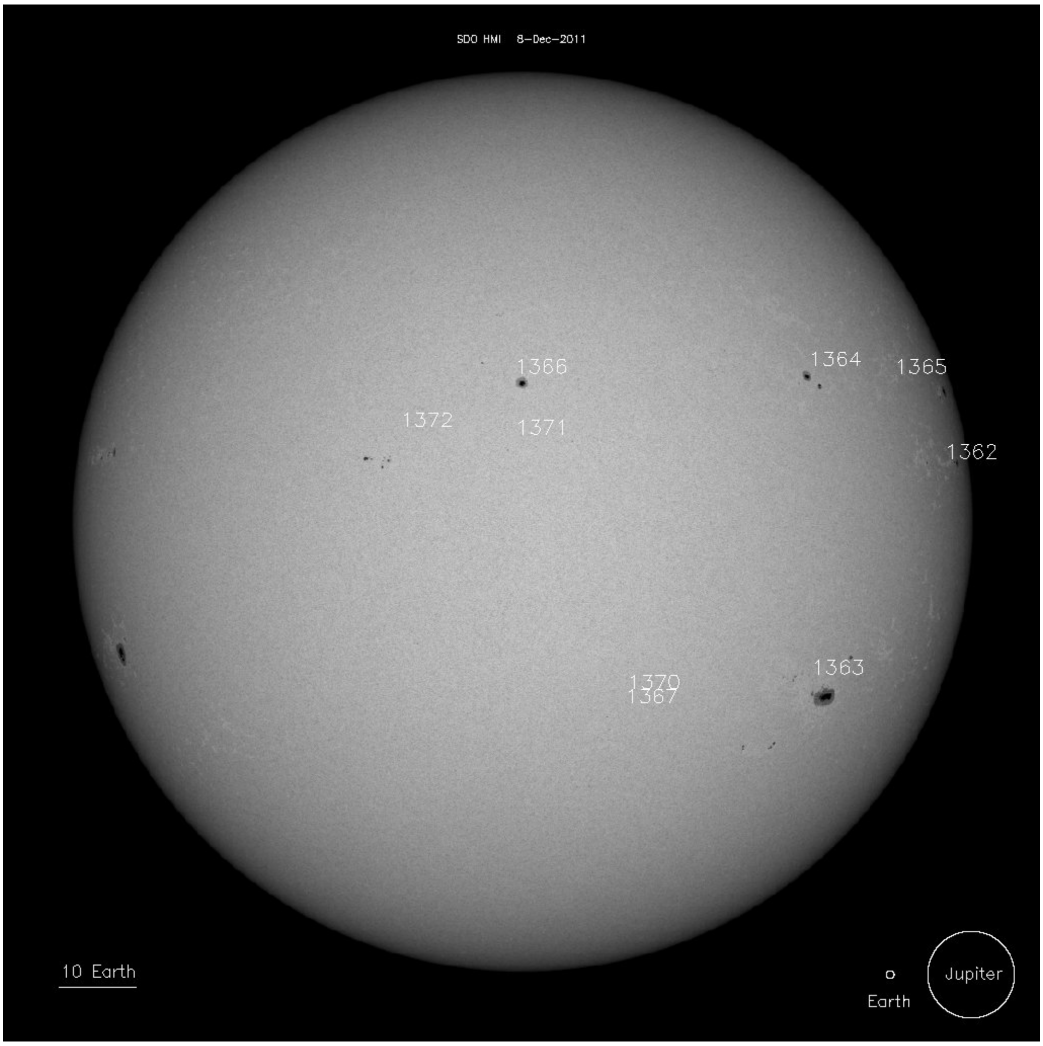


Figure 10.6: The Sun's photosphere, with the date and time. Sunspots are numbered.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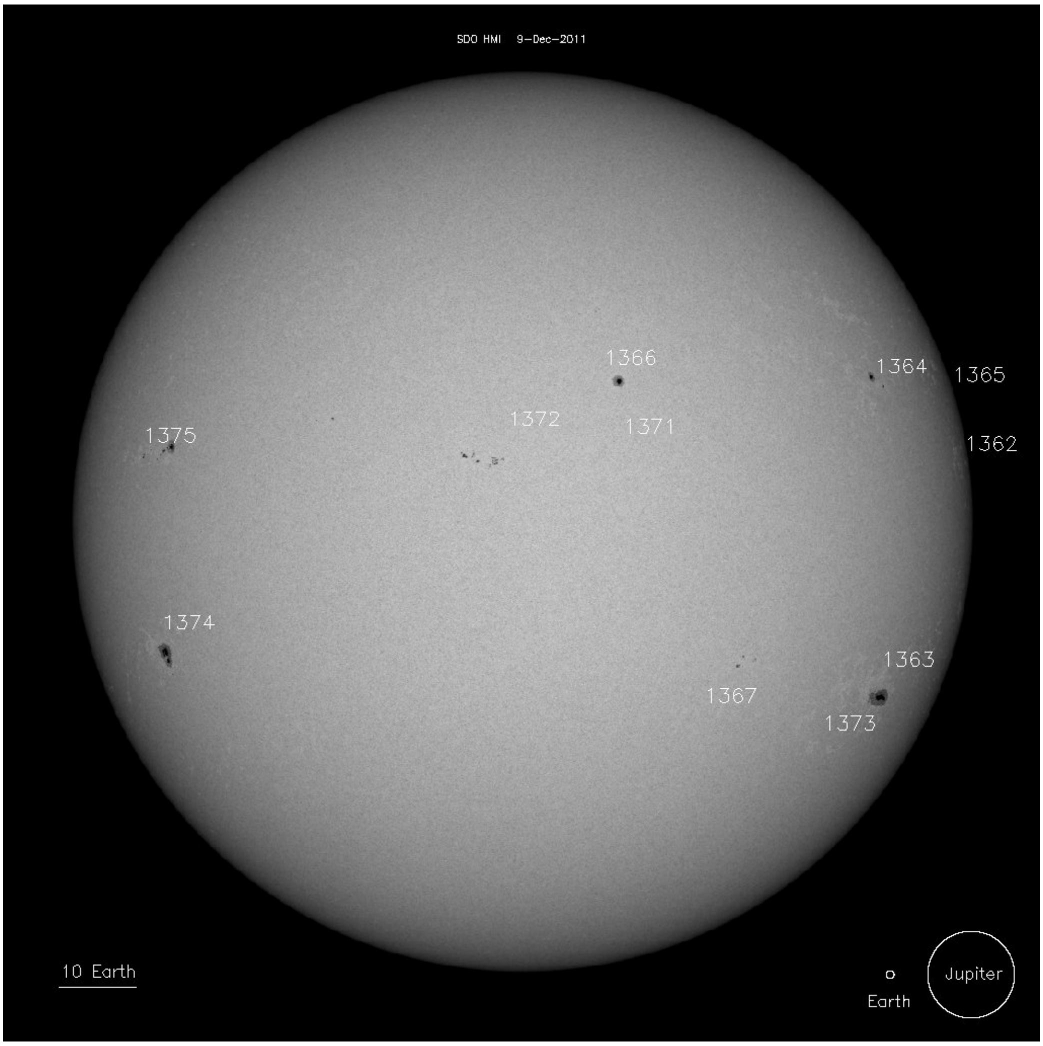
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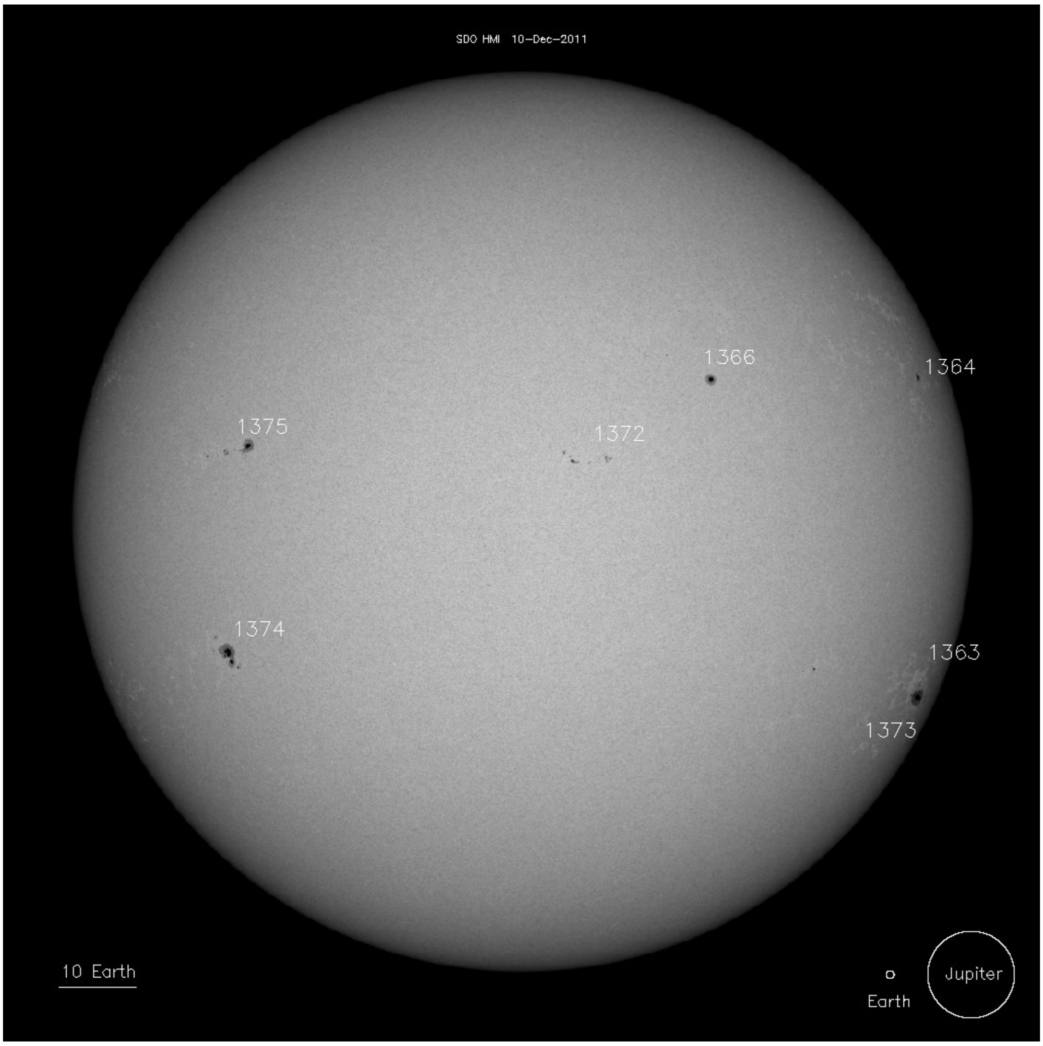
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10.3 Activity 5: Constellations in three dimensions

Below a template of the Cygnus constellation. The numbers at the positions of the stars are their distances in light years. We recommend you translate each light year to 1 cm, but you can change that according to your needs.

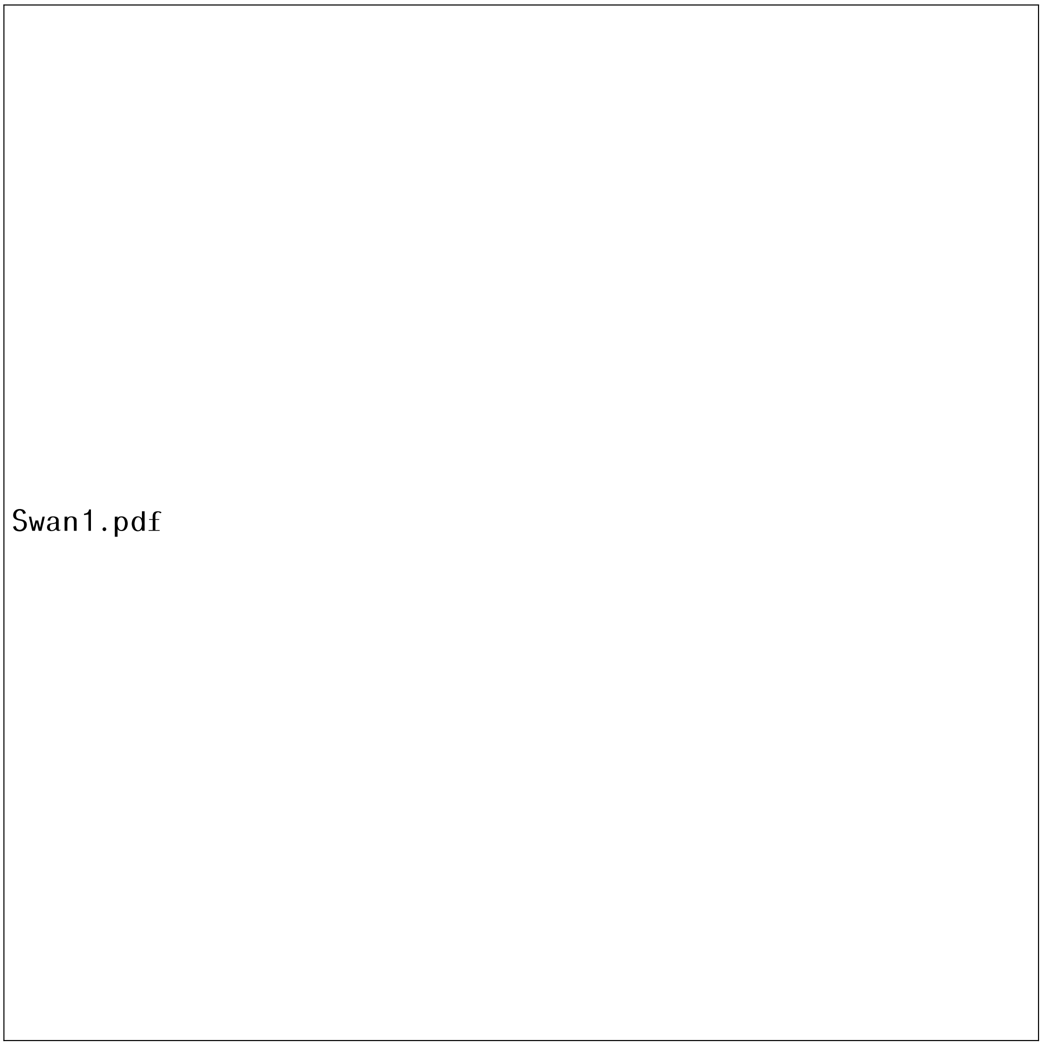

Figure 10.7: Template of Cygnus constellation.

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References

[1] GalileoMobile activity handbook, http://galileomobile.astro.ufsc.br/mediawiki/images/3/3f/Handbook_v1.4_EN.pdf