AL-FARABI KAZAKH NATIONAL UNIVERSITY

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ENGLISH FOR PHYSICS AND ASTRONOMY

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The teaching material is intended for 1-2 year students of Physical and technical departments, specialty physics and astronomy and it can also be used as supplementary material for self-study assignments. Methodical development of the texts in Astronomy has been prepared on the basis of authentic texts.

The purpose of this teaching material is to teach students to understand texts in their specialty, to familiarize with the terminology. Lexical and grammar tasks allow texts to remove difficulties in understanding the content of the texts and adapt their grammatical structure.

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INTRODUCTION

The present teaching material is designated for learners of Pre-Intermediate/Intermediate level students at higher educational institutions.

The aim of the teaching material is to teach students how to extract information from the text, to understand its main content and to develop elementary skills of speaking on speciality.

The teaching material includes texts followed by exercises, texts for supplementary reading, lexical-grammar tests and description of the technique of working at texts.

The work on vocabulary and phrases from the text assumes removal of some difficulties while working at the text. The way of introducing grammar makes it possible to facilitate the work at certain speech tasks. Other types of exercises include word formation, choice of synonyms and antonyms, substitution tables, filling the gaps, translation from English into Russian/Kazakh and from Russian/ Kazakh into English and answering the questions.

The purpose of primary reading is to understand the main content of the text, which develops some skills of a purposeful intelligent reading.

It is not recommended to translate the text in details as sometimes it is not considered as one of the effective ways of working at the text. The work before reading the text and translation of some sentences considerably facilitate the process of mastering the language material.

Control and choice of texts for independent work are carried out at a teacher's discretion.

At the final stage of work it is possible to speak on the topic chosen by learners or a teacher.

UNIT 1

Grammar: Present Simple and Continuous.
Texts: 1. Observing the sky with unaided eye
2. The Moon

Present Simple (I work) or Present Continuous (I'm working)

Compare the Present Simple and the Present Continuous:

Present Simple	**Present Continuous**
We use the Present Simple for things that are true at any time. We use it for a general truth, or a fact: *Things fall to the ground because of gravity.*	We use the Present Continuous to say that an action is in progress now, at the time we speak: *Look! The leaves are falling from the trees.*
We use the Present Simple when we talk about a permanent situation, or an activity that is repeated again and again. We think that it will continue for an unlimited time: *I work for a company that makes computers. We sell them all over the world.* *Mary usually studies in the library*	We use the Present Continuous to describe a current activity or situation that is unusual or temporary. We know it will continue for a limited period of time from now: *I don't usually work at the weekends, but I'm working on Saturdays at the moment.* *Mary is studying at home. The library is shut.*
We use the Present Simple with words like always, usually, often etc. when we talk about how often we do something: *Tom sometimes studies at home, but he usually works in the library.*	We can use the Present Continuous with always to say that something happens too often: *Tom is always asking stupid questions.* *They are always complaining.*

Look at this table.

Name	Home	Job	Current project	Project location
Mike	Glasgow	engineer	bridge design	Aberdeen
Sally	London	conference organizer	congress	Dublin
Philip	Leeds	salesman	trade fair	Birmingham
Jenny	Brighton	accountant	head office	London

Exercise 1. Use these verbs in the Present Simple or the Present Continuous: live, work, stay.

0 Mike lives in Glasgow and he works as an engineer.

0 At the moment Mike is staying in Aberdeen because he is working on a bridge design there.

1. Sally ______________ in London where she ______________ as a conference organizer.
2. At the moment Philip ____________ in Birmingham because he _____________ at a trade fair there.
3. At the moment Sally ___________ in Dublin because she ___________ at a congress there.
4. Jenny _____________ in Brighton where she ____________ as an accountant.
5. Philip _____________ in Leeds where he _____________ as a salesman.
6. At the moment Jenny ___________ in London because she ___________ at head office.

Exercise 2. Use the words in brackets () to complete the dialogues. Use Present Continuous or Present Simple.

0 (The sun/rise/in the east.)

The sun rises in the east.

1. Sam: (Why/that machine/not /work/at the moment?)

____

Chris: (I don't know, but a mechanic/mend /it)

____

Sam: (What/the machine/do/in fact?) (it/make/boxes?)

____

Chris: (Yes, it/make/boxes of all size)

____

2. Mary: (Look! The Forsters/work/in their garden.)

____

(They/not/usually/work/on Sundays.)

____

Exercise 3. Put the verbs into the correct form, present continuous or present simple.

1. Are you hungry? ________________ something to eat? (you/want)
2. Don't put the dictionary away. I ________________ it. (use)
3. Don't put the dictionary away. I ________________ it. (need)
4. Who is that man? What __________________? (he/want)
5. Who is that man? Why __________________at us? (he/look)
6. George says he's 80 years old but nobody _________________ him. (believe)
7. She told me her name but I _____________________ it now. (not/remember)
8. I ____________________ of selling my car. (think) Would you be interested in buying it?
9. I____________________ you should sell your car. (think) You _________________ it very often (not/use)
10. I used to drink a lot of coffee but these days I ________________ tea. (prefer)
11. Air _____________________ mainly of nitrogen and oxygen. (consist)
12. Jill is interested in politics but she ___________________ to a political party. (not/belong)
13. Jim is very untidy. He _________________ (always/leave) his things all over the place.
14. The train is never late. It _________________ (always/leave) on time.

Exercise 4. Discuss the following questions, what do you think?

1. What is the universe composed of?
2. What is the relationship between the billions of objects in the universe?
3. What happens inside these objects?
4. How was the universe created?
5. What will happen to the universe in the future?

Exercise 5. Now read the text and check your answers

OBSERVING THE SKY WITH THE UNAIDED EYE

Astronomers carry out observations and perform calculations. Observations are carried out either with **telescope**s or with the unaided eye. Everybody is an astronomer in fact, since everybody looks at the sky. Looking at the **sky** with an unaided eye reveals several objects.

Since the sunlight covers the entire sky, it is impossible to make clear **observation**s in the sky during the daytime. Observations must be carried out nighttime in order to see celestial objects. The most obvious one of these objects is the Moon with its dimensions apparently the same as the Sun.

Now get ready for the show of light in the night sky. The twinkling, point-like light sources are **stars**, many of which are just like our **Sun**, but appearing very small and faint due to the very large distances over which their light travels to reach us. Some stars are even more gigantic than the Sun and there are stars so colossal that they are a million times brighter than the Sun.

There are also a few other objects that have the appearance of a star, but they do not twinkle. These objects are the planets of our solar system. It is not possible to see all the planets with the unaided eye. A careful observer can make out five planets of our solar system: Mercury, Venus, Mars, Jupiter, and **Saturn**.

An observer may see a broad, diffuse band of light through the sky on a clear moonless night. This band is the Milky Way **galaxy** that consists of about 400 billion stars, and clouds of interstellar gas and dust. There are billions of galaxies in the universe, but not all are visible with the naked eye. **Meteor**s are occasional visitors, which may be observed with the naked eye.

They are seen as brief, falling flashes of light. The other occasional members of our sky are comets. Comets revolve around the Sun with constant periods. The most famous comet is the Halley's **Comet**, which passed very close to the Earth in 1986.

'The entire **universe** is rotating around **the Earth**!' This debate persisted during the ancient times based on the idea that the Earth was at the centre of the universe. Now it is known that the Earth is not at the centre of the universe but only appears to be rotating around the Earth. The motion is actually that of the Earth around its axis, so the universe is rotating relative to the Earth. Since we are making our observations in the reference frame of the Earth, we perceive the universe to be in motion.

Each revolution of the Earth around its rotational axis corresponds to one revolution of the objects in the sky around the Earth. A long exposure photograph clarifies this motion. We can conclude that the entire universe appears to be in circular motion around the Earth. During the Earth's rotation, we observe that the Sun is also in circular motion around us.

But it is not as simple as it appears to be. There are too many objects that have their own motion through the sky, and the objects have relative motions with respect to each other. One of the most famous of these relative motions is the retrograde motion of Jupiter.

New words

twinkle	жылтылдау	мерцать
gigantic	алып, аса зор	гигантский (-ая; -ое)
colossal	аса ірі, зор, үлкен	колоссальный (-ая; -ое)
night time	түнгі уақыт	ночное время
apparently	бәлкім, мүмкін, сірә	по-видимому
brief	қысқа	кратко
persisted	сақтау	сохранять
conclude	қорту, аяқтау	заключить
retrograde	кертартпа, кертартпалық	ретроградный (-ая; -ое)

Exercise 6. Translate the following word combinations into Kazakh (Russian)

To perform calculations, to reveal several objects, entire sky, celestial objects, the show of light in the night sky, point like light sources, a million times brighter than the Sun; a broad, diffuse band of light, clouds of interstellar gas and dust, occasional visitors, naked eye, falling flashes of light, rotating around the Earth, the ancient times, rotational axis, a long exposure photograph, circular motion around the Earth, relative motions.

Exercise 7. Match the highlighted words with the definition

1. ______________________ a scientist who studies astronomy
2. ______________________ a piece of equipment shaped like a tube, containing lenses, that you look through to make objects that are far away appear larger and nearer.
3. ______________________ a large ball of burning gas in space that we see as a point of light in the sky at night
4. ______________________ the star that shines in the sky during the day and gives the earth heat and light
5. ______________________ the system of stars that contains our sun and its planets seen as a bright band in the night sky.
6. ______________________ a piece of rock from outer space that makes a bright line across the night sky as it burns up while falling through the earth's atmosphere.
7. ______________________ a mass of ice and dust that moves around the sun and looks like a bright star with a tail.
8. ______________________ the whole of space and everything in it, including the earth, the planets and stars.
9. ______________________ the world; the planet that we live on.
10. ______________________ a large planet in the solar system that has rings around it and is 6^{th} in order or distance from the sun.
11. ______________________ The space above the earth that you can see when you look up, where clouds and the sun, moon and stars appear.
12. ______________________ The act of watching somebody or something carefully for a period of time, especially to learn something

Exercise 8. Read and translate the following text using the words below:

New words

targets	нысана, мақсат, мүдде	Цель
amateur	әуесқой	любительский
equal	тең, бірдей	Равно
the angle	бұрыш	Угол
measure	өлшем	измерение
synodic	синодикалық	синодический
alignment	тегістеу, туралау	выравнивание
emit	нұр шашу, сәуле тарату	излучать
reflect	қайтару, дарыптау	отражать
new moon	жаңа ай	новолуние
full moon	толған ай	полная луна
circle	шеңбер, дөңгелек	круг, круглый
first quarter	бірінші ширек	первая четверть
the thickness	жуандық, толықтық	толщина
Waxing	үдемелі, өскелең	растущая

THE MOON

The Moon is the brightest object in the nighttime sky. Thus, it is one of the first observation targets of amateur astronomers. Its motion through the sky is not simple; however, it is easily observed due to its rapid motion and close proximity to the Earth. Apart from daily rotation together with the entire universe, the Moon moves about 1° across the sky (with respect to the stars) every 2 hours; it moves nearly 12° every day. Taking its angular diameter, to be 0.5° we can conclude that it moves a distance (with respect to the stars) of about equal to its own diameter every hour.

The angle between the plane of the orbit of the Moon around the Earth and the plane of the orbit of the Sun around the Earth (the ecliptic) is 5°. Since the angle is small, it causes the Moon to stay near the ecliptic as observed from the Earth. The ecliptic is the plane of the virtual orbit of the Sun around the Earth (recall that the Sun appears to revolve around the Earth when it is observed from the Earth). It takes the Moon a little more than 27 days to revolve around the Earth once, in the reference frame of the distant stars (fixed stars). This period is called the side- real period. Observing from the Earth, we will measure about 29.5 days for the Moon to complete its full cycle of phases. For example: The time needed from one full Moon phase to the next is about 29.5 days. This period is called the synodic periodor the lunar month. The phase of the Moon depends on the relative alignment of the Moon, Earth and Sun. After one complete circle around the Earth (one lunar month) is completed, the Moon requires extra time to reach the initial Moon – Earth – Sun alignment because of the motion of the Earth around the Sun. From Earth's surface we can only observe the same side of the Moon; the other side of the moon is not visible from Earth. Since the rotation period of the Moon about its own axis is equal to its period of revolution around the Earth. This type of motion is common in the universe and is called synchronous rotation.

a. The Phases of the Moon

One more difference between the Moon and the stars in the sky is that the Moon does not emit its own light, instead it reflects the sunlight. Thus we can only see the portion of the Moon that is able to reflect sunlight. This makes the Moon appear to take on different shapes which are called the phases of the Moon. We have a moonless night when the Moon is between the Sun and the Earth, because the Moon is unable to reflect the sunlight. This phase of the Moon is called the new moon. If you want to observe the true shape of the Moon, you have to wait until the Moon is directly opposite the Sun. This phase, in which the full shape of the Moon is observed is called the full moon. The position of the moon relative to Earth and the Sun. We always observe the same side of the Moon from Earth. When the moon is opposite the Sun it is said to be in opposition, when the Moon is between the Earth and the Sun, the configuration is called the conjunction. The configuration in which the Moon is in a position 90° from the Earth-Sun line is said to be in quadrature. In one complete cycle there is one opposition, one conjunction and two quadratures. Exactly half of the Moon is observable in quadrature. If the observable portion of the Moon is less than half, it is called a crescent, and if more than half is observable it is called gibbous. If the Moon is observed to be exactly one half of a circle, it will either be the first quarteror third quarter. From the new moon phase to the full moon phase, the thickness of the observed portion of the moon increases, and starts to decrease from the full moon until the new moon. Starting from the new moon; the phases of the Moon are: new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, third quarter, waning crescent, and finally, new moon.

Exercise 9. Answer the following questions:

1. Define the motions of the Moon and the Sun with respect to the entire sky?
2. What is the difference between the sidereal period and the synodic period of the moon?
3. What are the phases of the Moon?
4. Why don't we see eclipses every month?

Exercise 10. Read the text and mark the sentences T (true) or F (False)

1. It takes the Moon a little more than 29 days to revolve around the Earth once.
2. Observing from the Earth, we will measure about 29.5 days for the Moon to complete its full cycle of phases.
3. The phase of the Moon depends on the relative alignment of the Moon, Earth and Sun.
4. From Earth's surface we can only observe the same side of the Moon.
5. The Moon does not emit its own light, instead it reflects the sunlight.
6. The phase, in which the full shape of the Moon is observed is called the full moon.
7. We have a moonless night when the Moon is between the Sun and the Earth.
8. If the observable portion of the Moon is less than half, it is called a crescent.
9. The configuration in which the Moon is in a position 80° from the Earth-Sun line is said to be in quadrature.
10. Exactly quarter of the Moon is observable in quadrature.

Exercise 11. Translate the following word combinations into Kazakh (Russian)

the brightest object, rapid motion, close proximity to the Earth, angular diameter, the distant stars, the side real period, observing from the Earth, full cycle of phases, synodic period or lunar, extra time, observe the same side of the Moon, is not visible from Earth, period of revolution, around the Earth, synchronous rotation, the portion of the Moon, to reflect sunlight, different shape, a moonless night, unable to reflect the sunlight, the true shape of the Moon, half of the Moon is observable, to decrease from the full moon, waxing gibbous, waning gibbous, waning crescent.

Exercise 12. Make the sentences interrogative and negative:

1. There are billions of galaxies in the universe.
2. Everybody is an astronomer in fact.
3. A careful observer can make out five planets of our solar system: Mercury, Venus, Mars, Jupiter, and Saturn.
4. The Milky Way galaxy consists of about 400 billion stars.
5. The entire universe is rotating around the Earth!
6. Meteors are occasional visitors, which may be observed with the naked eye.
7. The Moon is the brightest object in the nighttime sky.
8. The phase of the Moon depends on the relative alignment of the Moon, Earth and Sun.
9. From Earth's surface we can only observe the same side of the Moon.
10. We always observe the same side of the Moon from Earth.

Exercise 13. Underline examples of Present Simple and Continuous in each text.

Exercise 14. Translate into Kazakh (Russian)

The universe consists of clusters, which includes billions of galaxies, whereas there are billions of stars in an ordinary galaxy. Some stars have planets revolving around them, satellites revolve around the planets. Even without a telescope, an observer with his naked eye can see the Sun, the Moon, some stars, five of the planets, comets and meteors.

We need the concept of the celestial sphere in order to define the positions of the objects in the sky. We use astronomical coordinate systems to define these positions in the celestial sphere. The first target of observers using their naked eye is the Moon. We can determine many properties of the Moon during such an observation. We can define two periods for the Moon: the sidereal period for a complete cycle with respect to the stars and the synodic period for a complete cycle with respect to the Earth-Sun line.

The type of motion the Moon undergoes is called synchronous motion, that is, the Moon revolves around the Earth always displaying it's same side to the Earth. The apparent shape of the Moon changes in phases, which have various shapes. The apparent dimensions of the Sun and the Moon are the same, thus either one of them can prevent light reaching Earth from each other. These phenomena are called a solar eclipse and a lunar eclipse.

Exercise 15. Write not less than 7 questions to the text and be ready to answer them.

UNIT 2

Grammar: Past tenses: Simple, Continuous, Perfect.
Texts: 1. Ancient astronomy
2. Astronomy after the 20th century.

Past Simple (I waited) or Past Continuous (I was waiting)

Compare the Past Simple and the Past Continuous

We use the Present Simple to talk about a complete event in the past: *Last Saturday morning, Paul played football in the park.* *On Sunday, I made a cake.* *It rained a lot on Monday morning.*	We use the Past Continuous to talk about an action that was in progress, when something else happened: *Last Saturday, Paul was playing football in the park when he saw Jane.* *The phone rang while I was making a cake.* *It was raining when we left home.*

We often use the Past Simple to talk about one event that fallowed another event: *When Ann James left university, she went to work for a bank. She left the bank after five years, and wrote a book which….*	In a story we often use the Past Continuous to say what was in progress, when something happened: *The sun was shining. People were sitting under the trees or walking around the park. Suddenly a car drove into the park ….*

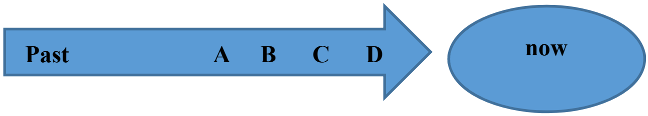
Past Perfect (I had eaten)

When we talk about an event or situation in past time we use the Past Simple (e.g. flew); if we talk about an event before that time, we use the Past Perfect (e.g. had been). Here is example.

Last Saturday at the cinema: Mary: *We don't need to queue because I've already bought the ticket.* Now: Mary: *We didn't need to queue because I* ***had*** *already* ***bought*** *the ticket.*

1. If we talk about a series of past events in order, we use the Past Simple:

A I saw a beautiful bird in my garden. **B** I went to get my camera. **C** The bird flew away. **D** I returned with my camera.



2. We need the Past Perfect to make it clear that one of the events is not in order: **D** I returned with my camera. **C** The bird had already flown away. (The bird had gone before I returned.)

Also, compare these sentences using when:

Past Perfect: *When I returned with my camera, the bird had flown away.* (The bird went before I returned.)

Past Simple: *When I returned with my camera, the bird flew away*. (The bird went after I retuned.)

3. The Past Perfect is used in reported speech:

'I have suffered from asthma for many years.' She told the doctor that she ***had suffered*** *from asthma for many years.*

Exercise 1. Use the Past Simple and Past Continuous to make sentences from the words in brackets.

0 (The police/arrive/while/I/have/breakfast)

<u>The police arrived while I was having breakfast.</u>

1. (The storm/start/while/they/drive/home)

____

2. (I/see/an accident/while/I/wait/for the bus)

____

3. (Mary/go/to several concerts/while/she/stay/in London)

____

4. (My father/cook/the dinner/when/he/burn/his fingers)

____

5. (The soldiers/prepare/to leave/when/the bomb/explode)

____

Exercise 2. Complete these texts using the Past Simple or the Past Continuous of the verbs in brackets.

0 Beethoven *wrote* nine symphonies; he *was writing* (write) another symphony when he died.

1. Last Saturday Tom wanted to make two salads. He _____________ (make) the first one in five minutes. He ___________ (make) the second one when his guests ____________ (arrive), and they ____________ (help) him to finish it.
2. The artist Gaudi ___________ (design) several houses in Barcelona, Spain. Later he ___________ (start) work on a church. He ___________ (work) on the church when he __________ (die).
3. Last month a bank robber ____________ (escape) while the police __________ (take) him to prison. Later they __________ (catch) him again, and this time they ___________ (lock) him up without any problem.
4. Philip's football team were lucky last Saturday. After 20 minutes they __________ (lose), but in the end they ___________ (win) the game by 4 goals to 2.
5. John Lennon __________ (sing) and __________ (play) on many records with the Beatles. After that he _________ (record) several songs without the Beatles. He __________ (prepare) a new record when Mark Chapman ____________ (shoot) him.
6. The evening was getting darker; the street lights _________ (come) on. People _________ (hurry) home after work. I __________ (stand) in a queue at the bus stop. Suddenly somebody __________ (grab) my bag.

Exercise 3. Write sentences about what these people had already done or had never done before. Use the Past Perfect, and already or never.

0. Last summer Mary won a gold medal for the third time.
<u>She had already won two gold medals</u>__________before that.

1. Last weekend Tom rode a horse for the first time.
He______________________________________before that.

2. Last summer Jeff ran in a marathon for the sixth time.
He ____ before that.
3. Last week Susan wrote a poem for the first time.
She ____ before that.
4. Last week Ann appeared on TV for the first time.
She ____ before that.

Exercise 4. Discuss the following questions, what do you think?

1. When was first astronomical recorded?
2. Who was the first person to realize that the Earth was round?
3. Who advocated the idea of geo-centric universe?

Exercise 5. Now read the text and check your answers

Text 1. ANCIENT ASTRONOMY

Babylonians first recorded astronomical **data** upon thousands of stone **tablets**. They recognized the motion of the Sun, and they divided the path of the sun ecliptic into twelve parts. The length of the year was determined to within 4 minutes accuracy. However they thought the sky was a dome supported by mountains. The early Greeks also thought that the sky was **a dome** of the heavens and that the Earth was a disc-like structure floating on water. Pythagoras was the first person to realize that the Earth was round and that the paths of **the heavens** were circular. Anaxagoras discovered that the Moon did not emit its own light, instead it reflects the sunlight.

Plato claimed that all objects were spherical and that they all had perfect spherical motions. Aristotle claimed that the Earth was composed of four elements; Earth, wind, fire and water. He also said that the objects in the sky were made of a fifth element which he called either. He thought that both the Earth and the universe were spherical and that the Earth was at the centre of the universe. The Earth was thought to be at the centre of the universe until about the 3rd century B.C. After this the Sun was thought to be at the centre of the universe. This was first noted by Aristarchus, who tried to calculate the relative sizes and distances of the Moon and the Sun, however, his measurements were not accurate enough. However, he was correct in his **assumption** that the Sun was much larger than either the Earth or the Moon. Aristarchus was unsuccessful in measuring the relative distances and sizes of the Sun and the Moon but Eratosthenes managed to determine the size of the Earth, assuming that the Sun was far enough; he measured **the angles** of incidence of sunlight from two different locations called Alexandria and Syene. Their difference of 7° helped Eratosthenes to calculate the size of the Earth to more than 98% accuracy. By the third century B.C. the idea of epicycle was developed to explain planetary motion. Sometimes planets make retrograde motion as discussed earlier. **Theories** about the motions of the heavens could not explain retrograde motion, but the idea of an epicycle model helped to explain some planetary motions. Hipparchus, who had an observatory on the island of Rhodes, laid down many of the **foundations** of astronomy. One of his most important **inventions** was the stellar magnitude system used to estimate star brightnesses. Hipparchus advocated the idea of a geo-centric universe i.e. Earth centred Universe. Ptolemy tried to summarise all knowledge of astronomy up until that time in his 'Almagest' consisting of 13 published books. Chinese astronomical thought was not as complex as Greek astronomy. They simply thought that the universe was the sphere of the sky (celestial sphere), which rotates daily. The Mayas in America developed a very accurate **calendar** which was based on the idea of a universe which consisted of layers both above and below the Earth. In the 13th century new tables (Alfonsine tables) of planetary motion were developed and used for 3 centuries.

New words:

Babylonians	Вавилондықтар	Вавилонцы
accuracy	анықтық, дәлдік	точность
the heavens	аспан, әуе, көк	небеса
claim	бекіту, нандыру, сендіру	утверждать
aether	әуе, аспан, кеңістік	эфир
measurements	өлшем, шама	измерения
assumption	болжам, шамалау	предположение

Exercise 6. Translate the following word combinations into Kazakh (Russian)

An astronomical data, stone tables, the length of the year, a dome of the heavens, a disc-like structure floating on water, the Earth was composed of four elements, the centre of the universe, the relative size and distances of the Moon, not accurate enough, the angles of incidence of sunlight, the idea of epicycle, planetary motion, theories about the motions of the heavens, the island of Rhodes, the stellar magnitude system, to estimate star brightnesses, the idea of a geo-centric universe.

Exercise 7. Match the highlighted words with the definition:

1. ____________________ facts or information, especially when examined and used to find out things or to make decisions.
2. ____________________ a flat piece of stone that has words written on it, especially one that has been fixed to a wall in memory or an important person or event.
3. ____________________ a round roof with a circular base.
4. ____________________in some religions) the place believed to be the home of God where good
5. ____________________ the ability to have new and interesting ideas.
6. ____________________ a system by which time is divided into fixed periods, showing the beginning and end of a year.
7. people go when they die.
8. ____________________ a belief or feeling that something is true or that something will happen, although there is no proof.
9. ____________________ a spirit who is believed to be a messenger or servant of God.
10. ____________________ a formal set of ideas that is intended to explain why something happens or exists.
11. ____________________ a principle, an idea or fact that something is based on and that it grows from.

Exercise 8. Read and translate the following text using the words below:

New word:

1	2	3
coincide	бір	совпадать
constellation	жұлдыздар тобы, шоқ жұлдыз	созвездие
nebula	тұмандылық, бұлыңғыр	туманность

1	2	3
probe	зонд	зонд
explore	зерттеу	исследовать
margin	айырмашылық, өзгешелік	разницы
error	қате	ошибка
pursued	жасау, жүзеге асыру	осуществлять (-ся)
due to	себепті, себебімен	в связи с

Text 2. ASTRONOMY AFTER THE 20th CENTURY

Like any other science, the fastest development in astronomy occurred in the 20th century. This was due to developments in atomic physics, which lead to the construction of sophisticated devices and a better understanding of events in the universe. Thus, astronomers began studying the Universe as a whole and the properties of individual celestial bodies. The history of the Universe was clarified in the 20th century. The most important developments in astronomy in the 20th century were: German scientist Bunsen discovered that flames of each element emit light only at specific wavelengths. Bunsen noticed that the Sun's spectral lines, which were determined by Fraunhofer, coincide exactly with the spectral lines of particular elements on Earth. Bunsen concluded that some elements on Earth also existed in the Sun. This was a very important clue to the origin of the Universe. More information of this phenomenon will be given in the next chapter. Edwin Hubble made one of the most important discoveries in science in 1924. Hubble carried out observations on the fuzzy light source in the constellation of Andromeda and discovered that the light source was not a nebula, but a galaxy, containing billions of stars, which was receding us. In 1929, Hubble discovered the universal fact that the receding speed of a galaxy is proportional to the distance away of the galaxy. Edwin Hubble's discovery lead to much scientific activity and research into this fact, with the result that, today, much information about the history of the Universe has been revealed. The Big Bang Theory has been refined since the 20th century. The first space probe was sent on October 4, 1957. It didn't manage to get into orbit, although it was very close. Just one month later another probe carrying a dog, whose name was Layka, was set into orbit. The dark side of the moon was first photographed on October 7, 1959. The first visit into outer space by mankind took place in 1961; Russian astronaut Yuri Gagarin was the first man to go in to space. Mariner 4 probe first managed to take photographs from the surface of Mars in 1965, whereas the Venera 3 probe succeeded in entering the atmosphere of Venus and took photographs of its surface. With the Apollo missions, mankind landed on the surface of the Moon six times. The first Apollo mission (Apollo 11) was on July 20, 1969. Neil Armstrong was the first man to land on the surface of the Moon. Five more Apollo missions took place, the last of which occurred in 1972. In 1977 the Voyager missions began to explore the planets of our solar system more closely. Voyager probes managed to take close photographs from surfaces of planets. Today we know much about all the members of solar system and about any other object in the sky. But still some calculations are within a 30% margin of error. This means we need more sophisticated instruments to make more accurate observations and calculations. We need more specific research to learn more about the universe. In conclusion, the history of astronomy is not over, but being pursued faster than ever.

Exercise 9. Answer the following questions:

1. What is the reason ancient astronomers made incredible mistakes concerning the nature of the universe?
2. The entire universe seems to revolve around us, but the planets don't. What was the first idea that explained planetary motion?
3. What is Tycho Brahe's most striking discovery? What is the important result of this discovery? The History of Astronomy

Exercise 10. Translate the following word combinations into Kazakh (Russian)

Atomic physics, the construction of sophisticated devices, the properties of individual celestial bodies, the spectral lines of particular elements on Earth, a very important clue, the origin of the Universe, carried out, the fuzzy light source, a galaxy containing billions of stars, the receding speed, the distance away of the galaxy, outer space, the first man to go into space, the surface of Mars, the atmosphere of Venus, mankind landed on the surface of the Moon six times, the members of solar system, to make more accurate observations and calculations.

Exercise 11. Read the text and mark the sentences T (true) or F (False):

1. The fastest development in astronomy occurred in the 20th century.
2. The history of the Universe was clarified in the 21th century.
3. Bunsen concluded that some elements on Earth also existed in the Sun.
4. In 1939, Hubble discovered the universal fact that the receding speed of a galaxy is proportional to the distance away of the galaxy.
5. The first space probe was sent on October 4, 1957.
6. Russian astronaut Yuri Gagarin was the first man to go in to space.
7. Five more Apollo missions took place, the last of which occurred in 1978.
8. In 1977 the Voyager missions began to explore the planets of our solar system more closely.
9. Voyager probes managed to take close photographs from surfaces of planets.
10. But still some calculations are within a 40% margin of error.

Exercise 12. Give the forms of the following verbs:

To record, to recognize, to divide, to think, to calculate, to begin, to give, to lead, to send, to go, to take, to know, to mean, to make, to learn.

Exercise 13. Make the sentences interrogative and negative:

1. Babylonians first recorded astronomical data upon thousands of stone tablets.
2. Pythagoras was the first person to realize that the Earth was round.
3. Plato claimed that all objects were spherical and that they all had perfect spherical motions.
4. Edwin Hubble made one of the most important discoveries in science in 1924.
5. In 1929, Hubble discovered the universal fact that the receding speed of a galaxy is proportional to the distance away of the galaxy.
6. Russian astronaut Yuri Gagarin was the first man to go in to space.

7. In 1977 the Voyager missions began to explore the planets of our solar system more closely.

8. Voyager probes managed to take close photographs from surfaces of planets.

Exercise 14. Translate into Kazakh (Russian)

Astronomy is one of the oldest sciences. Human beings have been interested in the unique beauty of the universe and have wondered about the heavens since time immemorial. Babylonians recognized the motion of the Sun, and they divided the path of the Sun into twelve parts, which are still useful for some purposes in astronomy. Ideas in Greek astronomy were affected by philosophy and religion more than observation and calculation, that is why fantastic ideas, like the sky being a dome supported by mountains, were supported by Greek astronomers. The Earth and the Sun was thought to play a key role in the universe. The Earth was thought to be at the center of the universe and it was thought that the entire universe was revolving around the Earth. Planets did not obey the rule that everything revolved around the Earth; this lead to the idea of epicycle. However, the idea of epicycle was inadequate in explaining the motions of all the planets.

Exercise 15. Write not less than 7 questions to the text and be ready to answer them.

UNIT 3

Grammar: Comparatives and Superlatives.
Texts: 1. The Solar system in general
2. Member of the Solar system

Comparing adjectives

adjective	comparative	Superlative
one syllable: hard	adjective+ -er: harder	the + adjective + -est: the hardest
one syllable ending in –e: nice	adjective+ -r: nicer	the + adjective+st: the nicest
one syllable ending in vowel + consonant: fat	adjective with last consonant doubled + -er: fatter	the +adjective + consonant doubled + est: the fattest
two syllable ending in –y: happy	adjective –y+ -ier: happier	the + adjective –y+iest: the happiest
two or more syllables: enjoyable	more + adjective: more enjoyable	the most + adjective: the most enjoyable
Irregular: good, bad, far	better, worse, further/farther	the best, the worst, the furthest/farthest

Comparative adjectives

We use comparative adjectives to compare two or more things, people or places:

Younger runners will always be faster than older runners will.

or the same thing, person or place at two different times.

I'm much fitter than I was last year.

We use than after comparative adjectives to say what we are comparing something with. Sometimes we leave out the than clause if it is clear from context what we are comparing something with: *Older athletes are getting faster and fitter.* (than in the past)

We can say two things are the same or similar with as + adjective + as:

My car ***as old as*** *yours.* = (the two cars are the same age)

We can say two things are different with not as + adjective + as

While they may ***not*** *be* ***as fast as*** *their younger counterparts …*

We use the + comparative + the + comparative to show that two things vary or change at the same time.

It would seem that ***the longer*** *athletes keep competing* ***the greater*** *their chances of setting new records are.*

Superlative adjectives

We use superlative adjectives to compare one thing in a group with all the other in the group:

The Olympics is probably the most exciting sports event in the sport calendar.

We can modify superlative with

– one of the/ some of the + superlative + plural noun:

It's one of the few chances we get to see ***some of the best*** *athletes in the world competing against each other.*

– ordinal nimbers

Our team was ***the third*** *best in the competition.*

We can replace ***the*** with a possessive:

my *best friend*

his *greatest achievement*

Exercise 1. Fill in gaps with the adjectives in the box in a comparative or superlative form.

brave effective exciting expensive fast happy good heavy small

1. I travelled through Turkey by train because it was <u>*the fastest*</u> way to cross the country.
2. Scientists have discovered a tiny bacteria living in the deep ocean. They say it is …………….living organism known to man.
3. It is almost impossible to find a parking space in the city centre so it is ………………. to travel by public transport if you need to go there.
4. Painkillers are much ……………… now so they reduce pain a lot faster than in the past.
5. I like all kinds of sports, but I think football is ………………….. game to watch because it is so fast-moving.

6. Nick did a bungee-jump, but I was too scared. He's much ………………… than me.

7. I think people from the north of my country are ………………………than people from the south. In the south no one ever seems to smile, but it's opposite in the north.

8. The website listed hotels in a wide price range. I was amazed that the ………………….one cost over $500 a night.

9. Weightlifters these days are lifting ………………. weights than ever before.

Exercise 2. Fill in gaps with the words in the brackets in a comparative or superlative form.

Teacher: What are (1) <u>*the most obvious*</u> (*obvious)* difference you have noticed between your own country and this one?

Student: Oh there are so many! In my country people are (2) not as interested (not/interested) in foreigners as people here, who are much (3) ……………….(friendly). They are always as kind and welcoming. Also, the weather is very different. It's much (4) ……………. (hot) in my country. It's only autumn but I am feeling cold here already and it's getting (5) …………….. (cold) every day. I don't like that. Then there's the food. Your food is (6) ……………….. (not/good) ours. Our food is (7) ……………… (spicy) and (8) ………………. (delicious). I think it's (9) ……………… (good) in the world! It is (10) ………………….. (not/expensive) either. I've also noticed that people here eat slightly (11)………….. (early) and they eat their meals (12)……………… (quickly). And I am beginning to change my own habits too! (13) …………………(long) I stay here (14) ……………. (fast) I seem to be eating.

Exercise 3. Discuss the following questions, what do you think?

1. What does the solar system consist of?
2. Which is the dominant body in the solar system and why?
3. What is the age of the solar system?
4. What is the Astronomical Unit (AU) of distance?

Exercise 4. Now read the text and check your answers:

Text 1. THE SOLAR SYSTEM IN GENERAL

Our solar system is a small family of celestial objects in the universe. It consists of a star (the Sun), 9 planets (From the nearest to the farthest one from the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, Pluto), asteroids, comets, satellites and interplanetary dust (spread out over the entire Solar system).

About 5 billion years ago, our solar system was a gas and dust cloud. As it became smaller its temperature increased simultaneously. The force of gravitation caused all the nearby matter to gather together, increasing the pressure inside this cloud. Due to symmetry, the gas and dust cloud took on a spherical shape. As very high temperatures and pressures existed nuclear reactions began. These made the Sun capable of radiating the energy resulting from these reactions. Any material which did not gather to form the Sun formed the planets of our solar system.

More than 99 % of the mass of the solar system belongs to the Sun; this makes it the largest object in the solar system. The planets, asteroids, and comets revolve about the Sun. They all have adjacent orbits on the same plane as the ecliptic; with some exception of course. The satellites do not revolve around the Sun directly; they revolve around the planets.

The dimensions of Earth are very small compared to the dimensions of the solar system, and the dimensions of the solar system are miniscule compared to the dimensions of the universe. So we cannot use the same units that we use on Earth; for measuring the distances in the solar system and universe astronomers use astronomical units (AU), or light years (Ly) or parsecs (pc) in order to represent actual distances.

The astronomical unit (AU) is the average distance of Earth from the Sun. One AU is about 149 600 000 km. The orbit of the Earth is elliptic but the Sun is not exactly as its centre. That is, the distance between Earth and the Sun along the semi-major axes is not constant, but varies a little between a minimum value of some 147 million km and a maximum value of some 151 million km. The point at which a planet is closest to the Sun is called the perihelion, and the point at which it is farthest is called the aphelion. The nearest planet to the

Sun, mercury, is about 0.4 AU from the Sun, Pluto, the farthest planet, is about 40 AU from the Sun.

New words:

adjacent	іргелес, көршілес, шектес	смежный
average	орташа	средний
dimension	өлшем	измерение
force	күш	сила
nearby	жанында	рядом
nuclear	ядролық	ядерный
pressure	қысым	смежный
simultaneously	бір мезгілде, бір уақытта	одновременно
solar	күн, күнгей	солнечный
universe	бүкіл әлем, жер жүзі	вселенная
Venus	Шолпан	Венера

Exercise 5. Translate the following word combinations into Kazakh (Russian):

Solar system, interplanetary dust, a gas and dust cloud, temperature increased simultaneously, the force of gravitation, due to symmetry, increasing the pressure, a spherical shape, nuclear reactions, mass of the solar system, adjacent orbits, some exception, the dimensions of Earth, dimensions of the solar system, measuring the distances, astronomical units, light years, semi-major axes, minimum value.

Exercise 6. Read the text and mark the sentences T (true) or F (False):

1. Our solar system is a small family of celestial objects in the universe.
2. About 6 billion years ago, our solar system was a gas and dust cloud.
3. More than 99 % of the mass of the solar system belongs to the Sun
4. The astronomical unit (AU) is the average distance of Earth from the Sun.
5. One AU is about 149 000 000 km.

6. The orbit of the Earth is elliptic but the Sun is exactly as its centre.

7. The point at which a planet is closest to the Sun is called the aphelion,

8. The nearest planet to the Sun, mercury, is about 0.6 AU from the Sun

Exercise 7. Read and translate the following text using the words below:

1	2	3
carbon	көмірсу	углерод
core	өзек, ядро	ядро
density	тығыздық	плотность
denser	тығыздау, тығыздату	плотнее
faint	әлсіз, күшсіз	слабый
Jovian	Юпитер	Юпитер
liquid	сүйықтық	жидкость
methane	метан	метан
properties	жабдықтар, қасиет	свойства
rocky	жартасты, құзды	скалистый
solid	қатты, тұрақты	твердый
terrestrial	жер	земной
thin	жұқа, жіңішке	тонкий
appear	көріну, пайда болу, шығу	появляться
approach	амал, тәсіл, ыңғай	подход
boundary	шекара	граница
collision	қақтығысу, соғылысу	столкновение
deduced	шығу тегін білу	расшифрована,установить происхождение
dust	шаң, тозаң	пыль
elongated	созылған, ұзартылған	вытянутый
fixed	белгіленген, тіркелген	фиксированный
a halo	сәуле жиек	ореол
notably	әсіресе, ерекше, айрықша	особенно
observe	байқау, бақылау, қарау	наблюдать

1	2	3
protrude	шығып тұру	выступать
recognize	мақұлдау, мойындау, тану	признавать
shell	қабық, қабықша, сырт, тыс	Оболочка
tail	құйрық, соңы	хвост
wipe out	жою, жайпау, құрту	уничтожать
composition	құрам	состав
twin	егіздер	близнец
voyager	саяхатшы	путешественник

MEMBERS OF THE SOLAR SYSTEM

a. Planets

There are nine planets in the solar system. The nearest one to the Sun is Mercury. Then comes Venus and Earth, Mars, Jupiter Saturn, Uranus, Neptune, and Pluto. The first four planets (Mercury, Venus, Earth, and Mars) are called terrestrial planets, and the next four (Jupiter, Saturn, Uranus, and Neptune) are called Jovian planets. Planets in the same group have common or similar properties. Pluto, the last planet, is not similar to any of the planets in these two groups.

Terrestrial planets are closer to the Sun and smaller than the Jovian planets. The density of terrestrial planets (about 3-4 g/cm^3) is larger than Jovian planets (1-1,5 g/cm^3). They have rocky surfaces but their cores are (or were) molten. This means that denser materials have sunken to the centres of these planets. Venus, Earth and Mars have atmospheres over their rocky surfaces. Their atmospheres contain nitrogen, oxygen, and carbon. Hydrogen and helium is also present, but only in very small quantities, since they can easily escape the low gravity of the terrestrial planets. Mercury does not have an atmosphere because its surface gravity is not great enough to hold atmospheric gases over its surface.

Jovian planets are larger than terrestrial planets, also as they are gaseous they don't have rocky surfaces, and are of lower density. Jovian planets do have a small solid core and are composed of liquid under their gaseous surface. They have atmospheres consisting of the same elements as the terrestrial planets; since, hydrogen and helium cannot escape the high gravity of these giant planets.

Pluto is a small, faint planet, which is very hard to observe. It consists of ice and rock and its surface is thought to be composed of solid nitrogen and methane. It is also thought that Pluto has a thin atmosphere.

b. Comets

In 1986 an object passed very close to Earth but, fortunately, no collision occurred. If a collision had occurred, it would have wiped out life on Earth. The object which nearly collided with Earth is actually a very well known comet called Halley's Comet. It is named after Edmund Halley who recognized that the comet had been observed and recorded many times in history; notably in 1456, 1531, and 1607. He realized that it was the same comet as one observed in the 3^{rd} century B.C. and also the same as one observed in the 5^{th} century B.C. He deduced that Halley's Comet orbits the Sun. He then calculated the comet's orbit and period. The period is 76 years.

It is not only Hailey's Comet which orbits the Sun, other comets also orbit the Sun in elliptical orbits having fixed periods of revolution. The orbits of the comets are more elongated, so they appear more elliptical than that of the planets. Planetary orbits, although also elliptic are much closer to circles.

Just like the planets comets reach their maximum speed at the perihelion and slow down to a minimum speed at the aphelion.

The most exciting characteristic of comets is their tails. A comet does not have a tail when it is far from the Sun, however, when it approaches the Sun, its temperature increases. Heated gas and dust from the comet forms a cloud called a halo. This gas and dust is blown away from the Sun because of the solar wind. This motion causes long tails of hot gas and dust to protrude from the comet. Comet's tails always point away from the Sun.

There are two types of comets which are categorised according to their periods and the elongation of their orbits.

Some comets orbit the Sun close to the ecliptic plane. These comets have shorter periods of revolution. It is thought that there is a cloud of comets, called the Kuiper Belt, just outside the planetary orbits. The short period comets are thought to have originated from this belt.

The other groups of comets have much longer periods, approaching millions of years. This second type of comet has very elongated orbits. Which make large angles with the ecliptic (Earth's plane of orbit). The boundary of the solar system is thought to be a spherical shell, called the Oort cloud, from which the long period comets are thought to have originated.

c. Satellites

Satellites are objects which revolve around the planets, not the Sun. They are generally much smaller than the planet they are revolving around. Each satellite has its own composition of materials.

Earth has only one satellite, the Moon.

Mars has two satellites named Phobos and Deimos.

The largest four satellites of Jupiter were discovered by Galileo at the beginning of the 17^{th} century they are termed ‘Galilean satellites’ after him. These four satellites can be seen with the naked eye. The largest of them is Ganymede, and the others are Callisto, lo, and Europa in order from the largest to the smallest. Jupiter has 12 more which are smaller and unobservable with the naked eye.

Titan is the largest satellite of Saturn. It is even larger than the planet Mercury, it is large enough to hold onto an atmosphere like a planet. The following 7 satellites are smaller than Titan but larger than the other 10 small satellites: These 7 satellites are Rhea, Lapetus, Dione, Tethys, Enceladus, Mimas, and Hyperion in order from the largest to the smallest.

Five of the fifteen satellites of Uranus are observable from Earth. The other 10 satellites were discovered by Voyager. The largest five satellites are called Titania, Oberon, Umbriel, Ariel, and Miranda in order from the largest to the smallest.

Neptune has two major satellites, Triton and Nereid and 6 smaller satellites which were discovered by Voyager. The direction of revolution of Triton is opposite that of Neptune.

One of the most interesting satellites is Pluto's satellite, Charon. Pluto and Charon are called twin planets because they nearly have the same dimensions. Charon does not orbit Pluto instead they both revolve around their centre of mass.

Exercise 8. Answer the following questions:

5. What is the name, of the most famous comet?
6. Which planets do not have satellites?
7. Which planet is the hottest on average? Why?
8. Which planetary satellites are larger than mercury?

Exercise 9. Translate the following word combinations into Kazakh (Russian)

The first four planets, terrestrial planets, Jovian planets, similar properties, the density of terrestrial planets, rocky surfaces, the low gravity, to hold atmospheric gases, small solid core, composed of liquid, gaseous surface, giant planets, faint planet, very hard to observe, ice and rock, solid nitrogen and methane, a thin atmosphere, very close to Earth, no collision occurred, wipe out life on Earth, a very well known, observed and recorded, many times in history, the same comet, calculated the comet's orbit and period, elliptical orbits, fixed periods of revolution, most exciting characteristic, heated gas and dust, solar wind, long tails of hot gas and dust, to protrude from the comet, point away from the Sun, elongated orbits, the boundary of the solar system, a spherical shell, composition of materials, were discovered by Galileo, known satellites, unobservable with the naked eye, observable from Earth, major satellites, direction of revolution of Triton, twin planets, they nearly have the same dimensions, revolve around their centre of mass.

Exercise 10. Complete the following sentences with the words given.

Mars	Galileo	tails	the Sun	Nereid	twin
Satellites	Terrestrial	atmosphere		faint planet	

1. __________________ planets are closer to the Sun and smaller than the Jovian planets.
2. Venus, Earth and _____________ have atmospheres over their rocky surfaces.
3. Mercury does not have an _____________________
4. Pluto is a small, ____________________, which is very hard to observe.
5. The most exciting characteristic of comets is their ________________.

6. Comet's tails always point away from _______________.
7. ________________are objects which revolve around the planets, not the Sun.
8. The largest four satellites of Jupiter were discovered by ________________ at the beginning of the 17^{th} century
9. Neptune has two major satellites, Triton and _____________________
10. Pluto and Charon are called ____________ planets because they nearly have the same dimensions.

Exercise 11. Give degrees of comparison of the adjectives:

Near, close, small, large, near, far, thin, long, hot, interesting, different, tall, new, great, necessary, easy, beautiful, narrow, wide.

Exercise 12. Form adjectives from the nouns:

Gas, excitement, sphere, astronomy, elliptic, interest, observation, use, base, space, purpose, care, science.

Exercise 13. Translate into Kazakh (Russian)

The largest object in the solar system is the sun with more than 99% of the total mass. The planets, asteroids and comets revolve around the Sun.

The semi-major axis of Earth is used as a unit of length called the astronomical unit (AU) for measurements in the solar system. One AU is about 150 million kilometres. The distances involved in our solar system are very small compared to those of the entire Universe. The AU is not a useful unit of length for distances out of our solar system; larger units of distances (light-year, parsec) are needed.

The nine planets of our solar system can be classified into three groups; terrestrial planets (the inner four planets), Jovian planets (next four from inner to outer), and Pluto itself. Planets in the same group have similar properties.

Asteroids are small, metallic, rocky objects, which revolve around the Sun in an orbit between that of Mars and Jupiter.

Comets have highly elongated orbits. The most popular comet is the one named after its discoverer, Edmund Halley. Halleys comet revolves around the Sun with a period of about 76 years.

Satellites are objects that revolve around the planets, not the Sun. Mercury and Venus do not have satellites, whereas other planets have at least one satellite.

Exercise 14. Write not less than 7 questions to the text and be ready to answer them.

UNIT 4

Grammar: Future forms. First and second conditionals.
Texts: 1. General properties of the Sun.
2. Where does this much energy come from?

Future: will, be going to, Present Continuous and Simple

1. We can talk about future time with different verb forms, for example:

– **will**: I'**ll come** with you.

– **be going to**: He'**s going to come** with us.

– **Present Continuous**: We'**re coming** tomorrow.

2. When we talk about events in the future that we expect to happen but that are not in our control, we can use **will** or **be going to**:

Ann ***will be*** *(or* ***is going to be****)12 next week.*

We ***won't see*** *(or* ***aren't going to see****)those birds again until next spring.*

Will *they* ***finish*** ***(Are*** *they* ***going to finish****) the building soon?*

3. When we talk about events in the future that are in our control (for example: we can decide what will happen), we use **will** differently from **be going to.** We use **will** at the time we decide what to do; we use **be going** after we have decided what to do. Look at these examples:

John: *Can somebody help me, please?*

Helen: *Yes, I'****ll help*** *you.* (Here Helen decided after John asked)

Now compare

Carol: *John needs some help.*

Helen: *I know. I'****m going to help*** *him.* (Here Helen had decided before Carol spoke).

4. When a sentence has two parts that refer to the future, we use the Present Simple after **if, when, before, after, as soon as** and **until**, and in the other part of the sentence we use **will** or **be going to**:

When/ **after** etc. + Simple Present + **will/be going** to
After *it* ***finishes****, we'****ll have*** *lunch.*

5. We use the Present Continuous to talk about a future arrangement that we have made with someone else:

A: *Can you come and see us this evening?*

B: *I can't. I'***m playing** *squash with Sam.*

*Peter can't come to the cinema with us tonight because he***'s meeting** *Jane for dinner.*

Exercise 1. Look at this table and then use will and verbs; beat, draw with, lose to.

Bob foster's forecast for next Saturday's big football matches:		
Arsenal 1, Liverpool 1	Leeds 2, Everton 1	Chelsea 1, Luton 2
Ipswich 3, Millwall 3	Brighton 2, Oxford 1	Portsmouth 0, Preston 2

Bob Foster thinks that:

0 Arsenal will draw with Liverpool.

1. Leeds ____________ Everton.
2. Chelsea ____________ Luton.
3. Ipswish ____________ Millwall.
4. Brighton ____________ Oxford.
5. Portsmouth ____________ Preston.

Exercise 2. In each situation, think about when the person decided to do something. Then complete the sentences using will or be going to and one of the phrases from the box.

take it to the car wash	see her	
go to the hairdresser's	have a shower	make some tea

0 Mary: Philip, I'm very thirsty.

Philip: I am too. I'm going to make some tea. I've already put the kettle on to boil.

1. Jack: Is your toothache better?

Jill: No, but I've phoned the dentist. I _______________ at 10.30.

2. Jane: Do you think my hair is all right?

Sam: No, I'm sorry, I don't think it needs a cut.

Jane: OK I _____________________ this afternoon.

3. Ann: Where is Tom?

Mike: He's just gone into the bathroom. He ________________ .

4. John: Where have you been with the car? It's very dirty.

Rose: Is it? OK, I ________________________________ .

First Conditional

If + present simple + will (or'll)

We use if + Present Simple + will to talk about things that are possible in the future:

We will go to the beach this Saturday if the weather is hot enough. (= It's possible it will be hot.)

We can use unless to mean «If ….. not»: We will go the mountains on Sunday unless it rains. (= … if it doesn't rain.)

Unless you pay for the broken window, I'll phone the police. (= If you don't pay…)

Second Conditional

If + past simple + would (or'd)

We use if + Past Simple + would to talk about the present, and to imagine something different from the real situation now:

If Shakespeare was alive today, what would he write about? (Shakespeare isn't alive today.)

If animals could speak, we would be able to discover what they think. (We aren't able to discover what animals think, because they can't speak.)

Exercise 3. Complete the conversation. Put in the correct form of the verb. You may need to use will or would.

Matthew: I haven't forgotten your birthday, you know. If you like (0) I'll book (I/book) a table for Thursday at our favourite restaurant.

Emma: My birthday is on Wednesday, Matthew. You're playing basketball then, aren't you? If you cared for me, (1) ………………………. (you/not/play) basketball on my birthday.

Matthew: What's the difference? If (2) ………………………. (we/go) out on Thursday, it'll be just the same. If (3) ……………………. (I/not/play), I'd be letting the team down.

Emma: Yes, I suppose (4) ……………………… (it/be) a disaster if you missed one game. Well, if (5) ……………………… (you/think) more of your friends than you do of me, you can forget the whole thing.

Matthew: I just don't understand you sometimes, Emma.

Emma: If (6) ………………………. (you/think) about it, you'd understand. And I think (7) ………………………… (it/be) better it we forget all about my birthday.

Matthew: Don't be silly, Emma. If you get into one of your bad moods, (8)…….. ……………………… (it/not/do) any good.

Emma: If you were interested in my feelings (9) …………………… (I/not/get) into a bad mood.

Exercise 4. Discuss the following questions, what do you think?

1. What does the Sun consists of?
2. What is the surface temperature of the Sun?
3. What is hydrostatic equilibrium?
4. What can shine more brightly than the Sun in the daytime?

Exercise 5. Now read the text and check your answers:

Text 1. GENERAL PROPERTIES OF THE SUN

The Sun is unique in our solar system, since it is a star. However there are billions of stars in our galaxy, the Milky Way, and billions of galaxies each containing billions of stars. Its properties, which include mass, temperature and luminosity make the Sun an ordinary star. If we study the Sun we will gain a basic knowledge about the general properties of other stars.

More than 73% of the mass of the Sun is hydrogen, the remaining mass is composed of 25% helium and the remaining 2% of the mass is composed of carbon, iron, oxygen, nitrogen and many other elements. This composition of elements is the same as that of the planets, indicating that the entire solar system was formed from the same material.

The surface temperature of the Sun is 5600 °K while it reaches 15.000.000 °K at the core. The thermal pressure is also very high at the core, giving rise to very high densities in this region of more than

100 g/cm^3 while the Sun itself only has an average density of 1.4. Despite the high pressure, the Sun is not solid; it remains gaseous, since the temperature at the core is also very high. This high pressure however, does cause the atoms (completely ionised at the core and partially ionised at the surface) to exert an outward force upon each other. For the Sun to be held together an equal but opposite force balances this outward force. This equal but opposite force is the gravitational force which acts to pull the atoms towards the centre. The equilibrium between gravitational force and the pressure is called hydrostatic equilibrium. Deeper into the Sun the amount of material available increases, thus, gravitational force increases, but the pressure also increases in the same proportion. As a result this equilibrium is maintained everywhere inside the Sun. Hydrostatic equilibrium is vital for a star to survive. The life of a star would end unless this equilibrium was maintained.

The brightness of the Sun makes everything in the sky clear. Nothing can shine more brightly than the Sun in the daytime. What makes the Sun emit this much light? Are there any other objects which are as bright as, or brighter than the Sun?

The luminosity of the Sun is about 3.8 x 10^{26} J/s. A 100 watt light bulb emits 100 J/s. Thus, the energy emitted by the Sun in 1 second, is enough to allow 8 000 of these light bulbs to have shone since the beginning of the universe.

New words:

Daytime	күндізгі уақыт	дневное время
Despite	бұған қарамастан	несмотря на
Exert	Шақыру	Вызывать
Entire	бәрі, бүкіл, барлығы	Весь
Gain	алу, алып тұру	Получить
Galaxy	галактика, жұлдыздар жүйесі	Галактика
Luminosity	айқындылық, анықтық	Яркость
the Milky Way	Құс Жолы	Млечный Путь
Outward	сыртқа, тысқа, көрнеу	Наружу
Pull	сүйреу, тарту	Тянуть
Vital	өмірлік маңызды, өте маңызды	жизненно важный

Exercise 6. Read and discuss these sentences. In pairs or small groups, answer the questions for each prediction, using *I think so, I do not think so, probably, I am sure it will, perhaps, maybe.*

1. If we study the Sun we will gain a basic knowledge about the general properties of other stars.

2. The life of a star would end unless hydrostatic equilibrium was maintained.

Do you think it will happen in the future?
Do you think it will be a good thing or a bad thing?

Exercise 7. Translate the following word combinations into Kazakh (Russian)

Gain a basic knowledge, the remaining mass, composition of elements, thermal pressure, very high densities, average density, Despite the high pressure, opposite force, hydrostatic equilibrium, light bulb.

Exercise 8. Complete the following sentences with the words given.

hydrogen the Sun elements vital hydrostatic increases helium proportion

1. More than 73% of the mass of the Sun is _____________, the remaining mass is composed of 25% ______________and the remaining 2% of the mass is composed of carbon, iron, oxygen, nitrogen and many other ______________.
2. The equilibrium between gravitational force and the pressure is called ___________________ equilibrium.
3. Deeper into the Sun the amount of material available ________________, thus, gravitational force increases, but the pressure also increases in the same__________________.
4. Hydrostatic equilibrium is _________________ for a star to survive.
5. Nothing can shine more brightly than ________________ in the daytime.

Exercise 9. Read and translate the following text using the words below:

New words:

Countless	есепсіз, өлшеусіз, сансыз, мөлшерсіз	бесчисленный
Current	Ток	Ток
Generate	тудыру, жасап шығару	Генерировать
Granulation	Үсақталу	Грануляция
Occur	болу, шығу	Происходить
Penetrate	ену, кіру, өту	Проникать
Photosphere	Фотосфера	Фотосфера
Random	Кездейсоқ	Случайный
Transmit	беру, табыс ету, тапсыру	Передавать
Vast	зор, үлкен	Огромный

Text 2. Where does this much energy come from?

The energy of the Sun is produced in its core as a result of nuclear reactions taking place there. High temperatures and pressures cause nuclear reactions to occur simultaneously and vast amounts of energy are generated. The core is at the centre of the Sun and has a radius of 25% of the sun's radius.

Thus, a radiative zone extends from 25% of the radius of the Sun up to 85% of its radius. A convective zone then extends from the end of the radiative zone almost up until the surface of the Sun. There is a very thin final layer which extends right up onto the sun's surface called the photosphere.

Most of the energy is created by y-rays which are generated in the core. These very energetic rays can penetrate through the radiative zone, convective zone, and then photosphere and travel outside the surface of the Sun itself.

The rays travel in random directions in the radiative zone. Each photon is absorbed (recall that the density is very high so there are an enormous number of atoms per unit volume) and then reemitted in a very short time (it is impossible to measure this short a time). Fortunately the direction of reemission is also random. Randomly directed re-emission causes the photon to be absorbed and emitted many times (it is impossible to count or to express this number, it can only be described as countless. The radius of the Sun is about 700 000 km and it takes less than 3 seconds for electromagnetic radiation to travel this distance normally, however, the vast amount of random absorptions and re-emissions results in gamma rays taking thousands of years to reach the surface of the Sun. By this time the highly energetic y- rays, lose most of their energy, and have turned into visible rays on the surface of the Sun. Now, since y-rays are much more energetic than visible light rays, the energy lost is converted into heat energy inside the Sun. This is the source of the high temperature of the Sun, which heats our solar system and our Earth.

The convective zone has this name because it transmits the gamma ray photons by convection. The deeper, hotter gas flows towards the outer, cooler gas. Convection currents cause a phenomenon called **granulation** on the surface of the Sun.

Exercise 10. Answer the following questions:

1. What are the extraordinary properties of the Sun compared to the other stars?
2. What is the chemical composition of the Sun?
3. What is hydrostatic equilibrium and what is the importance of hydrostatic equilibrium in the interior of the Sun?
4. How can the Sun emit such a massive amount of energy? How is it produced?
5. Which nuclear reaction takes place in the core of the Sun?

Exercise 11. Translate the following word combinations into Kazakh (Russian)

Vast amounts of energy, the sun's radius, a very thin final layer, photon is absorbed and then reemitted, electromagnetic radiation, highly energetic y- rays, visible rays on the surface of the Sun, converted into heat energy, transmit the gamma ray photons by convection, convection currents cause a phenomenon called granulation, cooler gas.

Exercise 12. Read the text and mark the sentences T (true) or F (False):

1. The core is at the centre of the Sun and has a radius of 28% of the sun's radius.

2. There is a very thin final layer which extends right up onto the sun's surface called the photosphere.
3. Most of the energy is created by x-rays which are generated in the core.
4. Each photon is absorbed and then reemitted in a very short time.
5. The radius of the Sun is about 750 000 km.
6. The convective zone has this name because it transmits the gamma ray photons by convection.
7. The vast amount of random absorptions and re-emissions results in gamma rays taking hundreds of years to reach the surface of the Sun.
8. Convection currents cause a phenomenon called granulation on the surface of the Sun.

Exercise 13. Translate into Kazakh (Russian):

The Sun is the only star of our solar system. It is the closest star to Earth, which is why it is the star, about which we have the most detailed information.

Research into the Sun provides clues about other stars as well. What we learn about the Sun soon becomes a key to the other stars.

More than 73% of the mass of the Sun is hydrogen, 25 % is helium and the remaining 2% is composed of carbon, iron, oxygen, nitrogen and many other elements.

Equilibrium between the gravitational force and the pressure is called hydrostatic equilibrium. This equilibrium is maintained everywhere inside the Sun. Hydrostatic equilibrium is vital for a star to survive.

The Suns energy source is obtained from a nuclear fusion reaction called the proton-proton chain reaction in which hydrogen atoms combine to form helium.

The Solar atmosphere consists of several layers: the chromospheres, and the corona.

Exercise 14. Write not less than 7 questions to the text and be ready to answer the

UNIT 5

Grammar: Passive: be + past participle
Texts: 1. Why do we need telescopes?
2. Visible Light Telescopes

A passive verb is a form of be + a past participle, e.g. is baked, was worn. Some participles are irregular.

	ACTIVE	PASSIVE
Present Simple	We bake the bread here.	The bread is baked here.
Present Continuous	We are baking the bread.	The bread is being baked.
Present Perfect	We have baked the bread.	The bread has been baked.
Past Simple	We baked the bread yesterday.	The bread was baked yesterday.
Past Continuous	We were baking the bread.	The bread was being baked.
Past Perfect	We had baked the bread.	The bread had been baked.

We form negative and questions in the same way as in active sentences.

The bread isn't baked in a factory.

Where is the bread baked?

The future and modal verbs in the Passive

We use **be** + a past participle after **will, be going to, can, must, have to, should,** etc.

The gates ***will be closed*** *this evening.*
The machine ***has to be repaired.***
Seats ***may not be reserved.***
This rubbish ***should be thrown*** *away.*
The news ***might be announced*** *soon.*
How ***can*** *the problem* ***be solved****?*

Exercise 1. Complete the information about Barford Hall. Put in the correct form of these verbs.

► **build** (Past Simple)	2 **use** (Past Continuous)	4 **not look** (Past Perfect)	6 **use** (Present Simple)
1 **own** (Present Simple)	3 **buy** (Past Simple)	5 **do** (Present Perfect)	

The building at the end of the High Street is Barford Hall, which (►) was built in 1827. Today the Hall (1) …………………… by Bardale Council. It (2) …………………… as a warehouse when it (3)……… ……………………….. by the Council in 1952, and it (4)…………… ………………. after very well. Since then a lot of work (5)………… …………………… on it, and these days the Hall (6) ……………….. as an arts centre.

Exercise 2. A press conference is being held. Put in the correct form of the verbs.

1. Reporter: Are you going to do any more tests on the drug?
Professor: Yes, further tests ………………………………….. soon.
2. Reporter: What …………….. the drug ……………………..?
Professor: It will be called Bio-Meg.
3. Reporter: Can people buy the drug now?
Professor: No, it ……………………….. by the public yet.
4. Reporter: Do you think the company should sell this drug?
Professor: Yes, I think Bio-Meg ……………………………. to anyone who wants it.

Exercise 3. Discuss the following questions, what do you think?

1. What is a telescope?
2. What does it consists of?
3. What is called resolution?

Exercise 4. Now read the text and check your answers:

WHY DO WE NEED TELESCOPES?

Astronomers need to collect as much light as possible from objects in order to extract all the information available. The more light collected, the better the information received. Many celestial objects are not even observable with the unaided eye, but can be detected by telescopes. **The radius** of the eye is several **millimetres** but modern telescopes have radius of many metres. This means that telescopes have **the capacity** to collect much more light than the eye. Since the light collected is proportional to the area of **the receiver** surface and since the receiver area is circular, the light collected is proportional to the square of the radius of **a circle**, a telescope can receive some ten thousand times more light than the eye. By bringing much more light to a focus, telescopes open the doors to a dark universe.

The collected light is analysed by instruments which are connected to telescopes. The light focused is converted to data and transferred to sophisticated computers so that astronomers can study this data. **Equipment** is also available to increase the intensity of collected light. Long exposure photographs for example can be taken through a telescope, this means photographs are exposed to light for a longer time period. A photograph taken in one hour for example collects thousands times more light than an ordinary photograph taken in **a fraction** of a second. Combining these two (much larger areas of a telescope and the option of longer exposure times) properties of telescopes; an astronomer can detect an object which is more than a billion times fainter than that observed with the naked or unaided eye. Eyes collect only a very small portion of light reflected off objects. However, this is not the only **disadvantage**, eyes cannot differentiate objects which have small angular separations. (Actual distances are not important for large distance measurements since angular separations are measured as an indication of distance. Angular separations are measured in angular units in the celestial sphere). Stars which are close to each other in the celestial sphere appear to be a single object. The ability to differentiate two objects is called resolution. The higher the resolution, the smaller the angle between two recognised objects. Take two pens for example, and separate them by a few millimetres and then press them into somebody's back. They will feel that they were touched with a single object, now ask then to close their eyes and press both pens against their tongue, they will recognise that there are two different objects. Similarly the human eye can resolve an angular separation of 1,5 arcminutes. However, a telescope may reach a resolution of 0.05 arcseconds for visible light. This means that for a person to differentiate two objects their angular separation must be at least 90 arcseconds, if the angle is smaller than this the objects will appear as a single object. Using telescopes, however, a distance of 0.05 arcsecondsmay be enough to differentiate these two objects. One observes a ship on the horizon as a single object for example, but its masts, flag, and sails cannot be resolved separately, unless you use **binoculars**. Additionally, the resolution is proportional to the observed wavelength. One important advantage of telescopes, binoculars and other optical instruments is that, not only do they magnify objects but they increase the resolution of our eyes. In addition to improving resolution by using telescopes with large surface areas and long exposure times to collect more light, telescopes can also be used in groups (like the very large array in New Mexico) to improve resolution. The radiation collected by each telescope is overlapped to produce an interference pattern, which is analysed. This technique vastly improves the resolution and is called interferometry.

New words:

extract	сығып шығару	извлечение
square	шаршы	квадрат
converted	айналдырылған, өзгертілген	преобразованный
transferred	беру, алып беру	передается
equipment	жабдықтау, құрал	оборудование
fraction	үлес, пай	доля
differentiate	диференциалау, саралау	дифференцировать
resolution	рұқсат беру, шешімін табу	разрешение
resolve	шешу, үйғару, қортынды шешім	решить
binocular	дүрбі	бинокль
wavelength	толқынның ұзындығы	длина волны
vastly	айтарлықтай, біраз, бірталай	значительно
interferometry	интерферометрия	интерферометрия

Exercise 5. Translate the following word combinations into Kazakh (Russian):

The information available, the radius of the eye, the receiver area is circular, the intensity of collected light, properties of telescope, detect an objects, small angular separations, angular unites, press both pens against their tongue, optical instruments, large surface areas, to produce an interference pattern.

Exercise 6. Match the highlighted words with the definition:

1. _________________ a straight line between the centre of a circle and any point on its outer edge.
2. _________________ a unit for measuring length; a 1000^{th} of a meter.
3. _________________ the size or power of a piece of equipment, especially the engine of a vehicle.
4. _________________ a piece of radio or television equipment that changes broadcast signals into sound or pictures.
5. _________________ 1. a completely round flat shape. 2. The line that encloses a circle.
6. _________________ the things that are needed for a particular purpose or activity.
7. _________________ 1.a small part or amount of something 2. A division of a number.
8. _________________ something that causes problems and tends to stop somebody or something from succeeding or making progress.
9. _________________ an instrument, like two small telescope fixed together, that makes object that are far away seem nearer when you look through it.

Exercise 7. Read and translate the following text using the words below:

New words:

Intensities	қарқындылық, үдемелілік	интенсивность
Dimension	өлшем, шама	измерение
Dispersion	бытырау, шашылу, шашырау	дисперсия
Decrease	азаю, кему	уменьшение
Absorb	жұту, сорып алу, сіңіру	поглощать
Thickness	қалыңдық, жуандық	толщина
Layer	қабат, текше	слой
Distort	Бұрмалау	искажать
Purity	тазалық, қоспасыз	чистота
Altitude	теңіз деңгейінен жоғарғы биіктік	высота над уровнем моря

Visible Light Telescopes

The oldest type of telescope is the visible light telescope. There are two types of visible telescopes: Refracting telescope and Reflecting telescopes.

In refracting telescopes lenses are used to focus light at a point by refraction. The light first reaches a large lens called the objective – the primary lens – and is then brought to a focus by it. The objective is a large at the input end of the telescope. At the output end of the telescope there is a smaller lens which magnifies the image for observation by the human eye. The larger the objective is, the more light that is gathered by the telescope, the greater the light gathered, the more powerful the telescope becomes. Powerful telescopes are needed to observe very faint objects.

Mirrors are used instead of lenses in reflecting telescopes. The light is focused by reflection on a spherical mirror. Some reflecting telescopes may have only one mirror but, in some telescopes one or more plane mirrors may be used in order to direct the focused light to a point outside the telescope.

The focused light is sorted according to wavelength and the spectrum is then recorded by devices called cameras. These take photographs at different wavelengths using filters. Another procedure is to record the light intensities using electronic detectors. Astronomers make calculations and reach conclusions by using this stored, recorded information.

Both the reflecting telescopes and the refracting telescopes are used by astronomers in different situations by comparing their advantages and disadvantages with respect to each other. The advantages of reflecting telescope with respect to refracting telescopes are:

- Reflecting telescopes can be constructed of much larger dimensions than refracting telescopes. This property makes reflecting telescopes more powerful than refracting telescopes.
- Lenses refract each wavelength at different angles of refraction (dispersion). This makes the incident light spread and makes it harder to focus the light to a single point. There is no dispersion in reflection, the wavelengths are reflected at the same angle, so it is much easier to focus the light by reflection.

Reflecting telescopes also have disadvantages:

- The incident light is reflected back, so the focus coincides with the light incident on the main mirror. To make focused light observable, either the light should be directed outside the telescope with auxiliary mirrors or the astronomer should be located inside the telescope to observe the focused light in person. This means the incident light has to be blocked with an instrument at the focal point. However, blocking a portion of light decreases the power of the telescope.
- The geographical location of telescopes is very important. If the telescope is built on a high mountain, the effect of the atmosphere will be minimised. The atmosphere absorbs incoming light, so the thickness of the atmospheric layer should be reduced as much as possible.
- Telescopes should be located far away from cities, because the lights of a city may interfere with the incoming light and distort the information. The purity of the atmosphere should also be taken into consideration.

a. Infrared Telescopes

The working principle of infrared (IR) telescopes is the same as that of visible telescopes. The radiation is focused to a point and then recorded and analysed for information about the source. It is difficult to detect the radiation. The Earth's atmosphere does not allow IR radiation to penetrate 100 percent. Some IR wavelengths are absorbed by Earth's atmosphere, thus, telescopes must be placed above the atmosphere. High altitude telescopes or satellites can be used as IR telescopes in order to cover the IR portion of the electromagnetic spectrum.

However, some IR wavelengths can penetrate the Earth's atmosphere, and this has led to some observatories making observations on Earth.

Exercise 8. Answer the following questions:

1. What are the main advantages of using a telescope compared with observation by the naked eye?
2. How can we collect more intense light?
3. What is the relationship between the resolving power and the smallest detectable angle?

4. What is interferometry?
5. What types of wavelength-dependent telescopes are there?
6. What types of visible light telescopes are there? Why do astronomers use each type?

Exercise 9. Translate the following word combinations into Kazakh (Russian)

To observe very faint objects, plane mirrors, to record the light intensities, make calculations, reach conclusions, advantages and disadvantages, different angles of refraction, dispersion in reflection, the purity of the atmosphere, take into consideration, to emit electromagnetic radiation at short wavelengths, to reflect x-ray radiation, to observe explosions and very energetic phenomena, to provide greater resolution, specific wavelength ranges, to focus light at a point, magnifies the image, powerful telescopes.

Exercise 10. Make the sentences interrogative and negative:

1. The collected light is analysed by instruments which are connected to telescopes.
2. In refracting telescopes lenses are used to focus light at a point by refraction.
3. Mirrors are used instead of lenses in reflecting telescopes.
4. The light is focused by reflection on a spherical mirror.
5. The focused light is sorted according to wavelength and the spectrum is then recorded by devices called cameras.
6. Reflecting telescopes can be constructed of much larger dimensions than refracting telescopes.
7. Telescopes should be located far away from cities.
8. High altitude telescopes or satellites can be used as IR telescopes in order to cover the IR portion of the electromagnetic spectrum.

Exercise 11. Read the text and mark the sentences T (true) or F (False):

1. The oldest type of telescope is the visible light telescope.
2. There are three types of visible telescope.
3. The objective is a large at the input end of the telescope.
4. Mirrors are used instead of lenses in reflecting telescopes.

5. Lenses refract each wavelength at the same angle of refraction (dispersion).

6. If the telescope is built on a high mountain, the effect of the atmosphere will be maximised.

7. The working principle of infrared (IR) telescopes is not the same as that of visible telescopes.

8. The Earth's atmosphere does not allow IR radiation to penetrate 100 percent.

Exercise 12. Translate into Kazakh (Russian):

Telescopes are used for collecting the vital information carrier, light. The more light collected, the more knowledge that can be obtained. The purpose of using a telescope is not to magnify the observed object but to collect more light and to increase resolution.

Many types of telescopes are used. Each type is used to analyse a specific portion of the electromagnetic spectrum. IR telescopes are used to analyse infrared waves, which are received from a star for example.

There are two types of visible-light telescopes: reflecting telescopes and refracting telescopes. The aim of both telescopes is to focus all light at a point. Reflecting telescopes use mirrors; refracting telescopes use lenses in order to focus the light.

The ability of a telescope to differentiate between two objects is called resolution. The higher the resolution, the clearer the observed object. Higher resolution provides more careful and more correct observations. The quality of a telescope is measured by its resolution.

Interferometry, overlapping radiation patterns collected by different telescopes, is used to increase the resolution of telescope.

Exercise 13. Write not less than 7 questions to the text and be ready to answer them.

SUPLEMENTARY READING

ASTRONOMY
Our Picture of the Universe

What do we know about the universe, and how do we know it? Where did the universe come from, and where is it going? Did the universe have a beginning, and if so, what happened *before* then? What is the nature of time? Will it ever come to an end? Can we go back in time? Recent breakthroughs in physics, made possible in part by fantastic new technologies, suggest answers to some of these longstanding questions.

As long ago as 340 BC the Greek philosopher Aristotle, in his book *On the Heavens,* was able to put forward two good arguments for believing that the earth was a round sphere rather than a flat plate. First, he realized that eclipses of the moon were caused by the earth coming between the sun and the moon. The earth's shadow on the moon was always round, which would be true only if the earth was spherical. If the earth had been a flat disk, the shadow would have been elongated and elliptical, unless the eclipse always occurred at a time when the sun was directly under the center of the disk. Second, the Greeks knew from their travels that the North Star appeared lower in the sky when viewed in the south than it did in more northerly regions. (Since the North Star lies over the North Pole, it appears to be directly above an observer at the North Pole, but to someone looking from the equator, it appears to lie just at the horizon). The Greeks even had a third argument that the earth must be round, for why else does one first see the sails of a ship coming over the horizon, and only later see the hull?

Aristotle thought the earth was stationary and that the sun, the moon, the planets, and the stars moved in circular orbits about the earth. He believed this because he felt, for mystical reasons, that the earth was the center of the universe, and that circular motion was the most perfect.

Another model, however, was proposed in 1514 by a Polish priest. Nicholas Copernicus. His idea was that the sun was stationary at the center and that the earth and the planets moved in circular orbits around the sun. Nearly a century passed before this idea was taken seriously. Then two astronomers – the German, Johannes Kepler, and the Italian. Galileo Galilei – started publicly to support the Copemican theory, despite the fact that the orbits it predicted did not quite match the ones observed. The death blow to the Aristotelian/Ptolemaic theory came in 1609. In that year, Galileo started observing the night sky with a telescope, which had just been invented. When he looked at the planet Jupiter, Galileo found that it was accompanied by several small satellites or moons that orbited around it. This implied that everything did not have to orbit directly around the earth, as Aristotle and Ptolemy had thought. At the same time, Johannes Kepler had modified Copernicus's theory, suggesting that the planets moved not in circles but in ellipses (an ellipse is an elongated circle). The predictions now finally matched the observations.

In 1687 Sir Isaac Newton published his *Philosophise Naturalis Principia Mathematica,* where he postulated a law of universal gravitation according to which each body in the universe was attracted toward every other body by a force that was stronger the more massive the bodies and the closer they were to each other. It was this same force that caused objects to fall to the ground. Newton went on to show that, according to his law, gravity causes the moon to move in an elliptical orbit around the earth and causes the earth and the planets to follow elliptical paths around the sun.

It is an interesting reflection on the general climate of thought before the twentieth century that no one had suggested that the universe was expanding or contracting. It was generally accepted that either the universe had existed forever in an unchanging state, or that it had been created at a finite time in the past more or less as we observe it today.

But in 1929, Edwin Hubble made the landmark observation that wherever you look, distant galaxies are moving rapidly away from us. In other words, the universe is expanding. This means that at earlier times objects would have been closer together. In fact, it seemed that there was a time, about ten or twenty thousand million years ago, when they were all at exactly the same place and when, therefore, the density of the universe was infinite. This discovery finally brought the question of the beginning of the universe into the realm of science.

Hubble's observations suggested that there was a time, called the big bang, when the universe was infinitely small and infinitely dense.

The eventual goal of science is to provide a single theory that describes the whole universe. Today we still yearn to know why we are here and where we came from. Humanity's deepest desire for knowledge is justification enough for our continuing quest. And our goal is nothing less than a complete description of the universe we live in.

Space and Time

Einstein made the revolutionary suggestion that gravity is not a force like other forces, but is a consequence of the fact that space- time is not flat, as had been previously assumed: it is curved by the distribution of mass and energy in it. Bodies like the earth are not made to move on curved orbits by a force called gravity; instead, they follow the nearest thing to a straight path in a curved space, which is called a geodesic. A geodesic is the shortest (or longest) path between two nearby points. For example, the surface of the earth is a two-dimensional curved space. A geodesic on the earth is called a great circle, and is the shortest route between two points.

In general relativity, bodies always follow straight lines in four-dimensional space-time, but they nevertheless appear to us to move along curved paths in our three-dimensional space. (This is rather like watching an airplane flying over hilly ground. Although it follows a straight line in three-dimensional space, its shadow follows a curved path on the two-dimensional ground.)

The mass of the sun curves space-time in such a way that although the earth follows a straight path in four-dimensional space-time, it appears to us to move along a circular orbit in three-dimensional space.

Light rays too must follow geodesics in space-time. Again, the fact that space is curved means that light no longer appears to travel in straight lines in space. So general relativity predicts that light should be bent by gravitational fields. This means that light from a distant star that happened to pass near the sun would be deflected through a small angle, causing the star to appear in a different position to an observer on the earth. Of course, if the light from the star always passed close to the sun, we would not be able to tell whether the light was being deflected or if instead the star was really where we see it. However, as the earth orbits around the sun, different stars appear to pass behind the sun and have their light deflected. They therefore change their apparent position relative to other stars. It is normally very difficult to see this effect, because the light from the sun makes it impossible to observe stars that appear near to the sun the sky. However, it is possible to do so during an eclipse of the sun, when the sun's light is blocked out by the moon.

Another prediction of general relativity is that time should appear to slower near a massive body like the earth. This is because there is a relation between the energy of light and its frequency (that is, the number of waves of light per second): the greater the energy, the higher frequency. As light travels upward in the earth's gravitational field, it loses energy, and so its frequency goes down. (This means that the length of time between one wave crest and the next goes up.)

To someone high up, it would appear that everything down below was making longer to happen. This prediction was tested in 1962, using a pair of very accurate clocks mounted at the top and bottom of a water tower. The clock at the bottom, which was nearer the earth, was found to run slower, in exact agreement with general relativity.

Newton's laws of motion put an end to the idea of absolute position in space. The theory of relativity gets rid of absolute time. Consider a pair of twins. Suppose that one twin goes to live on the top of a mountain while the other stays at sea level. The first twin would age faster than the second. Thus, if they met again, one would be older than the other. In this case, the difference in ages would be very small, but it would be much larger if one of the twins went for a long trip in a spaceship at nearly the speed of light. When he returned, he would be much younger than the one who stayed on earth. This is known as the twin's paradox, but it is a paradox only if one has the idea of absolute time at the back of one's mind. In the theory of relativity there is no unique absolute time, but instead each individual has his own personal measure of time that depends on where he is and how he is moving.

Before 1915, space and time were thought of as a fixed arena in which events took place, but which was not affected by what happened in it. This was true even of the special theory of relativity. Bodies moved, forces attracted and repelled, but time and space simply continued, unaffected. It was natural to think that space and time went on forever.

The situation, however, is quite different in the general theory of relativity. Space and time are now dynamic quantities: when a body moves, or a force acts, it affects the curvature of space and time – and in turn the structure of space-time affects the way in which bodies move and forces act. Space and time not only affect but also are affected by everything that happens in the universe. Just as one camiot talk about events in the universe without the notions of space and time, so in general relativity it became meaningless to talk about space and time outside the limits of the universe.

In the following decades this new understanding of space and time was to revolutionize our view of the universe. The old idea of an essentially unchanging universe that could have existed, and could continue to exist, forever was replaced by the notion of a dynamic, expanding universe that seemed to have begun a finite time ago, and that might end at a finite time in the future. That revolution forms the subject of the next chapter. And years later, it was also to be the starting point in theoretical physics. Einstein's general theory of relativity implied that the universe must have a beginning and, possibly, an end.

The Expanding Universe

In the 1920s, when astronomers began to look at the spectra stars in other galaxies, they found something most peculiar: there were the same characteristic sets of missing colors as far stars in our own galaxy, but they were all shifted by the same relative amount toward the red end of the spectrum. At that time most people expected the galaxies to be moving around quite randomly, and so expected to find as many blue-shifted spectra as red-shifted ones It was cube a surprise, therefore, to find that most galaxies appeared red-shifted nearly all were moving away from us! More surprising still was the finding that Hubble published in 1929: even the size of a galaxy's red shift is not random, but is directly proportional to the galaxy's distance from us. Or, in other words, the farther a galaxy is, the faster it is moving away! And that meant that the universe could not be static, as everyone previously had thought, is in fact expanding; the distance between the different galaxies is changing all the time.

The discovery that the universe is expanding was one of the great intellectual revolutions of the twentieth century.

With hindsight, it is easy wonder why no one had thought of it before. Newton, and others should have realized that a static universe would soon start to contract under the influence of gravity. But suppose instead that the universe is expanding. If it was expanding fairly slowly, the force of gravity would cause it eventually to stop expanding and then to start contracting. However, if it was expanding at more than a certain critical rate, gravity would never be strong enough to stop it and the universe would continue to expand forever. This is a bit like what happens when one fires a rocket upward from the surface of the earth. If it has a fairly low speed, gravity will eventually stop the rocket and it will start falling back. On the other hand, if the rocket has more than a certain critical speed (about seven miles per second), gravity will not be strong enough to pull it back, so it will keep going away from the earth forever.

In 1965 two American physicists at the Bell Telephone Laboratories in New Jersey, Arno Penzias and Robert Wilson, were testing a very sensitive microwave detector. (Microwaves are just like light waves, but with a wavelength of around a centimeter.) Penzias and Wilson were worried when they found that their detector was picking up more noise than it ought to. The noise did not appear to be coming from any particular direction.

The extra noise was the same whichever direction the detector was pointed, so it must come from *outside* the atmosphere. It was also the same day and night and throughout the year, even though the earth was rotating on its axis and orbiting around the sun. This showed that the radiation must come from beyond the Solar System, and even from beyond the galaxy, as otherwise it would vary as the movement of earth pointed the detector in different directions.

In fact, we know that the radiation must have traveled to us across most of the observable universe, and since it appears to be the same in different directions, the universe must also be the same in every direction, if only on a large scale.

At roughly the same time as Penzias and Wilson were investigating noise in their detector, two American physicists at nearby Princeton University, Bob Dicke and Jim Peebles, were also taking an interest in microwaves. They were working on a suggestion, made by George Gamow (once a student of Alexander Friedmann), that the early universe should have been very hot and dense, glowing white hot. Dicke and Peebles argued that we should still be able to see the glow of the early universe, because light from very distant parts of it would only just be reaching us now. However, the expansion of the universe meant that this light should be so greatly red-shifted that it would appear to us now as microwave radiation.

According to Friedmann's model, all the galaxies are moving directly away from each other. The situation is rather like a balloon with a number of spots painted on it being steadily blown up. As the balloon expands, the distance between any two spots increases, but there is no spot that can be said to be the center of the expansion. Moreover, the farther apart the spots are, the faster they will be moving apart. Similarly, in Friedmann's model the speed at which any two galaxies are moving apart is proportional to the distance between them. So it predicted that the red shift of a galaxy should be directly proportional to its distance from us, exactly as Hubble found.

Although Friedmann found only one, there are in fact three different kinds of models that obey Friedmann's two fundamental assumptions. In the first kind (which Friedmann found) the universe is expanding sufficiently slowly that the gravitational attraction between the different galaxies causes the expansion to slow down and eventually to stop. The galaxies then start to move towaid each other and the universe contracts.

In the second kind of solution, the universe is expanding so rapidly that the gravitational attraction can never stop it, though it does slow it down a bit.

Finally, there is a third kind of solution, in which the universe is expanding only just fast enough to avoid recollapse.

But which Friedmann model describes our universe? Will the universe eventually stop expanding and start contracting, or will it expand forever? To answer this question, we need to know the present rate of expansion of the universe and its present average density. If the density is less than a certain critical value, determined by the rate of expansion, the gravitational attraction will be too weak to halt the expansion. If the density is greater than the critical value gravity will stop the expansion at some time in the future and cause the universe tore collapse.

Texts on astronomy for supplementary reading

Our Place In Space

The Solar System

The first stop in a tour of our Solar System is the Moon, which lies about a quarter million miles from the Earth, or about thirty Earth diameters away. If we were to use a miniature model of the Solar System, in which the Earth is only about an inch across (about 500 million times smaller than its actual size), the Moon would be a quarter-inch diameter ball, only about two and a half feet away.

On this scale, the Sun, which is around 93 million miles from the Earth- Moon system, or about four hundred times further than the Moon, would be a ball approximately ten feet in diameter, a thousand feet away from the inch and quarter-inch balls which represent the Earth and Moon.

Lying somewhere within the thousand foot radius circle which approximates the orbit of the Earth would be another one-inch ball, representing Venus, and another ball, a little less than half an inch in size, representing Mercury. Mercury's half-inch model would be three to five hundred feet from the Sun, depending upon where it was in its somewhat eccentric orbit, while Venus would be about seven hundred feet from the Sun.

If passing between the Earth and Sun, it would be three hundred feet from us, but if on the other side of the Sun, it would be seventeen hundred feet away.

Now think about what these objects would look like, as seen from the inch-wide Earth. The Moon, although only a quarter-inch across, is only two and a half feet away, and as a result, would be seen as a small ball, about half a degree in size. The Sun, although much further away, is much larger than the Moon, and would appear to be about the same half degree in size. (Which is the way they look in our sky.)

Mercury and Venus, however, being not much larger than the Moon and smaller than the Earth, would be so tiny, given their huge distances from us, that they would only be dots as seen from the Earth, unless viewed with some kind of magnifying device (e.g., a telescope). And when we look at the night sky, that is exactly how we see them and every other individual object in the Universe, save for the Moon and Sun. Only the planet we live on, its satellite, and the star it orbits are big enough or close enough for us to see them as anything other than infinitesimal dots, without optical aid.

Black Holes

A Cambridge don, John Michell, wrote a paper in 1783 in the *Philosophical Transactions of the Royal Society of London* in which he pointed out that a star that was sufficiently massive and compact would have such a strong gravitational field that light could not escape: any light emitted from the surface of the star would be dragged back by the star's gravitational attraction before it could get very far. Michel 1 suggested that there might be a large number of stars like this. Although we would not be able to see them because the light from them would not reach us, we would still feel their gravitational attraction. Such objects are what we now call black holes, because that is what they are: black voids in space.

To understand how a black hole might be formed, we first need an understanding of the life cycle of a star. A star is formed when a large amount of gas (mostly hydrogen) starts to collapse in on itself due to its gravitational attraction. As it contracts, the atoms of the gas collide with each other more and more frequently and at greater and greater speeds -the gas heats up. Eventually, the gas will be so hot that when the hydrogen atoms collide they no longer bounce off each other, but instead coalesce to form helium. The heat released in this reaction, which is like a controlled hydrogen bomb explosion, is what makes the star shine. This additional heat also increases the pressure of the gas until it is sufficient to balance the gravitational attraction, and the gas stops contracting. It is a bit like a balloon – there is a balance between the pressure of the air inside, which is trying to make the balloon expand, and the tension in the rubber, which is trying to make the balloon smaller. Stars will remain stable like this for a long time, with heat from the nuclear reactions balancing the gravitational attraction. Eventually, however, the star will run out of its hydrogen and other nuclear fuels. Paradoxically, the more fuel a star starts off with, the sooner it runs out. This is because the more massive the star is, the hotter it needs to be to balance its gravitational attraction. And the hotter it is, the faster it will use up its fuel. Our sun has probably got enough fuel for another five thousand million years or so, but more massive stars can use up their fuel in as little as one hundred million years, much less than the age of the universe. When a star runs out of fuel, it starts to cool off and so to contract. What might happen to it then was first understood only at the end of the 1920s.

In 1928 an Indian graduate student, Subrahmanyan Chandrasekhar, set sail for England to study at Cambridge with the British astronomer Sir Arthur Eddington, an expert on general relativity. During his voyage from India, Chandrasekhar worked out how big a star could be and still support itself against its own gravity after it had used up all its fuel. The idea was this: when the star becomes small, matter particles get very near each other, and so according to the Pau 1 exclusion principle, they must have very different velocities. This makes them move away from each other and so tends to make the star expand. A star can therefore maintain itself at a constant radius by a balance between the attraction of gravity and the repulsion that arises from the exclusion principle, just as earlier in its life Chandrasekhar realized, however, that there is a limit to the repulsion that the exclusion principle can provide. The theory of relativity limits the maximum difference in the velocities of the matter particles in the star to the speed of light. This means that when the star got sufficiently dense, the repulsion caused by the exclusion principle would be less than the attraction of gravity. Chandrasekhar calculated that a cold star of more than about one and a half times the mass of the sun would not be able to support itself against its own gravity. (This mass is now known as the Chandrasekhar limit.) A similar discovery was made about the same time by the Russian scientist Lev Davidovich Landau.

This had serious implications for the ultimate fate of massive stars. If a star's mass is less than the Chandrasekhar limit, it can eventually stop contracting and settle down to a possible final state as a «white dwarf' with a radius of a few thousand miles and a density of hundreds of tons per cubic inch. A white dwarf is supported by the exclusion principle repulsion between the electrons in its matter. We observe a large number of these white dwarf stars. One of the first to be discovered is a star that is orbiting around Sirius, the brightest star in the night sky.

Landau pointed out that there was another possible final state for a star, also with a limiting mass of about one or two times the mass of the sun but much smaller even than a white dwarf. These stars would be supported by the exclusion principle repulsion between neutrons and protons, rather than between electrons. They were therefore called neutron stars. They would have a radius of only ten miles or so and a density of hundreds of millions of tons per cubic inch. At the time they were first predicted, there was no way that neutron stars could be observed. They were not actually detected until much later.

Stars with masses above the Chandrasekhar limit, on the other hand, have a big problem when they come to the end of their fuel. In some cases, they may explode or manage to throw off enough matter to reduce their mas below the limit and so avoid catastrophic gravitational collapse, but it was difficult to believe that this always happened, no matter how big the star. How would it know that it had to lose weight? And even if every star managed to lose enough mass to avoid collapse, what would happen if you added more mass to a white dwarf ‘or neutron star to take it over the limit? Would it collapse to infinite density? Eddington was shocked by that implication, and he refused to believe Chandrasekhar’s result. Eddington thought it was simply not possible that a star could collapse to a point. This was the view of most scientists: Einstein himself wrote a paper in which he claimed that stars would not shrink to zero size. The hostility of other scientists, particularly Eddington, his former teacher and the leading authority on the structure of stars, persuaded Chandrasekhar to abandon this line of work and turn instead to other problems in astronomy, such as the motion of star clusters. However, when he was awarded the Nobel Prize in 1983, it was, at least in part, for his early work on the limiting mass of cold stars.

Chandrasekhar had shown that the exclusion principle could not halt the collapse of a star more massive than the Chandrasekhar limit, but the problem of understanding what would happen to such a star, according to general relativity, was first solved by a young American, Robert Oppenheimer, in 1939. His result, however, suggested that there would be no observational consequences that could be detected by the telescopes of the day. Then World War II intervened and Oppenheimer himself became closely involved in the atom bomb project. After the war the problem of gravitational collapse was largely forgotten as most scientists became caught up in what happens on the scale of the atom and its nucleus. In the 1960s, however, interest in the large-scale problems of astronomy and cosmology was revived by a great increase in the number and range of astronomical observations brought about by the application of modern technology. Oppenheimer's work was then rediscovered and extended by a number of people.

BLACK HOLES (II)

Further encouragement for the existence of black holes came in 1967 with the discovery by a research student at Cambridge, Jocelyn Bell-Burnell, of objects in the sky that were emitting regular pulses of radio waves. At first Bell andher supervisor, Antony Hewish, thought they might have made contact with an alien civilization in the galaxy! Indeed, at the seminar at which they announced their discovery, I remember that they called the first four sources to be found LGM 1 – 4, *LGM* standing for «Little Green Men». In the end, however, they and everyone else came to the less romantic conclusion that these objects, which were given the name pulsars, were in fact rotating neutron stars that were emitting pulses of radio waves because of a complicated interaction between their magnetic fields and surrounding matter. This was bad news for writers of space westerns, but very hopeful for the small number of us who believed in black holes at that time: it was the first positive evidence that neutron stars existed. A neutron star has a radius of about ten miles, only a few times the critical radius at which a star becomes a black hole. If a star could collapse to such a small size, it is not unreasonable to expect that other stars could collapse to even smaller size and become black holes.

How could we hope to detect a black hole, as by its very definition it does not emit any light? It might seem a bit like looking for a black cat in a coal cellar. Fortunately, there is a way. As John Michell pointed out in his pioneering paper in 1783, a black hole still exerts a gravitational fierce on nearby objects. Astronomers have observed many systems in which two stars orbit around each other, attracted toward each other by gravity. They also observe systems in which there is only one visible star that is orbiting around some unseen companion. One cannot, of course, immediately conclude that the companion is a black hole: it might merely be a star that is too faint to be seen. However, some of these systems, like the one called Cygnus X-l are also strong sources of X-rays.

The best explanation for this phenomenon is that matter has been blown off the surface of the visible star. As it falls toward the unseen companion, it develops a spiral motion (rather like water running out of a bath), and it gets very hot, emitting X-rays.

For this mechanism to work, the unseen object has to be very small, like a white dwarf, neutron star, or black hole. From the observed orbit of the visible star, one can determine the lowest possible mass of the unseen object. In the case of Cygnus X-l, this is about six times the mass of the sun, which, according to Chandrasekhar's result, is too great for the unseen object to be a white dwarf. It is also too large a mass to be a neutron star. It seems, therefore, that it must be a black hole.

The Origin of the Universe

At the big bang itself the universe is thought to have had zero size, and so to have been infinitely hot. But as the universe expanded, the temperature of the radiation decreased. One second after the big bang, it would have fallen to about ten thousand million degrees. This is about a thousand times the temperature at the center of the sun, but temperatures as high as these are reached in H-bomb explosions. At this time the universe would have contained mostly photons, electrons, and neutrinos (extremely light particles that are affected only by the weak force and gravity) and their antiparticles, together with some protons and neutrons. As the universe continued to expand and the temperature to drop, the rate at which electron/antielectron pairs were being produced in collisions would have fallen below the rate at which they were being destroyed by annihilation. So most of the electrons and antielectrons would have annihilated with each other to produce more photons, leaving only a few electrons left over. The neutrinos and antineutrinos, however, would not have annihilated with each other, because these particles interact with themselves and with other particles only very weakly. So they should still be around today. If we could observe them, it would provide a good test of this picture of a very hot early stage of the universe. Unfortunately, their energies nowadays would be too low for us to observe them directly.

However, if neutrinos are not massless, but have a small mass of their own, as suggested by some recent experiments, we might be able to detect them indirectly: they could be a form of «dark matter», like that mentioned earlier, with sufficient gravitational attraction to stop the expansion of the universe and cause it to collapse again.

About one hundred seconds after the big bang, the temperature would have fallen to one thousand million degrees, the temperature inside the hottest stars. At this temperature protons and neutrons would no longer have sufficient energy to escape the attraction of the strong nuclear force, and would have started to combine together to produce the nuclei of atoms of deuterium (heavy hydrogen), which contain one proton and one neutron. The deuterium nuclei would then have combined with more protons and neutrons to make helium nuclei, which contain two protons and two neutrons, and also small amounts of a couple of heavier elements, lithium and beryllium. One can calculate that in the hot big bang model about a quarter of the protons and neutrons would have been converted into helium nuclei, along with a small amount of heavy hydrogen and other elements. The remaining neutrons would have decayed into protons, which are the nuclei of ordinary hydrogen atoms.

Within only a few hours of the big bang, the production of helium and other elements would have stopped. And after that, for the next million years or so, the universe would have just continued expanding without anything much happening. Eventually, once the temperature had dropped to a few thousand degrees, and electrons and nuclei no longer had enough energy to overcome the electromagnetic attraction between them, they would have started combining to form atoms. The universe as a whole would have continued expanding and cooling, but in regions that were slightly denser than average, the expansion would have been slowed down by the extra gravitational attraction. This would eventually stop expansion in some regions and cause them to stall to recollapse. As they were collapsing, the gravitational pull of matter outside these regions might start them rotating slightly. As the collapsing region got smaller, it would spin faster – just as skaters spinning on ice spin faster as they draw in their anus. Eventually, when the region got small enough, it would be spinning fast enough to balance the attraction of gravity, and in this way disk like rotating galaxies were born. Other regions, which did not happen to pick up a rotation, would become oval-shaped objects called elliptical galaxies. In these, the region would stop collapsing because individual parts of the galaxy would be orbiting stably round its center, but the galaxy would have no overall rotation.

As time went on, the hydrogen and helium gas in the galaxies would break up into smaller clouds that would collapse under their own gravity. As these contracted, and the atoms within them collided with one another, the temperature of the gas would increase, until eventually it became hot enough to start nuclear fusion reactions. These would convert the hydrogen into more helium, and the heat given off would raise the pressure, and so stop the clouds from contracting any further. They would remain stable in this state for a long time as stars like our sun, burning hydrogen into helium and radiating the resulting energy as heat and light. More massive stars would need to be hotter to balance their stronger gravitational attraction, making the nuclear fusion reactions proceed so much more rapidly that they would use up their hydrogen in as little as a hundred million years. They would then contract slightly, and as they heated up further, would start to convert helium into heavier elements like carbon or oxygen. This, however, would not release much more energy, so a crisis would occur, as was described in the chapter on black holes. What happens next is not completely clear, but it seems likely that the central regions of the star would collapse to a very dense state, such as a neutron star or black hole. The outer regions of the star may sometimes get blown off in a tremendous explosion called a supernova, which would outshine all the other stars in its galaxy. Some of the heavier elements produced near the end of the star's life would be flung back into the gas in the galaxy, and would provide some of the raw material for the next generation of stars. Our own sun contains about 2 percent of these heavier elements, because it is a second- or third-generation star, formed some five thousand million years ago out of a cloud of rotating gas containing the debris of earlier supernovas. Most of the gas in that cloud went to form the sun or got blown away, but a small amount of the heavier elements collected together to form the bodies that now orbit the sun as planets like the earth.

The Arrow of Time

There is a big difference between the forward and backward directions of real time in ordinary life. Imagine a cup of water filling o fa table and breaking into pieces on the floor. If you take a film of this, you can easily tell whether it is being run forward or backward. If you run it backward you will see the pieces suddenly gather themselves together off the floor and jump back to form a whole cup on the table. You can tell that the film is being run backward because this kind of behavior is never observed in ordinary life. If it were, crockery manufacturers would go out of business.

The explanation that is usually given as to why we don't see broken cups gathering themselves together off the floor and jumping back onto the table is that it is forbidden by the second law of thermodynamics. This says that in any closed system disorder, or entropy, always increases with time. In other words, it is a form of Murphy's law: things always tend to go wrong! An intact cup on the table is a state of high order, but a broken cup on the floor is a disordered state. One can go readily from the cup on the table in the past to the broken cup on the floor in the future, but not the other way round.

The universe would have started off with a period of exponential or «inflationary» expansion in which it would have increased its size by a very large factor. During this expansion, the density fluctuations would have remained small at first, but later would have started to grow. Regions in which the density was slightly higher than average would have had their expansion slowed down by the gravitational attraction of the extra mass. Eventually, such regions would stop expanding and collapse to form galaxies, stars, and beings like us. The universe would have started in a smooth and ordered state, and would become lumpy and disordered as time went on. This would explain the existence of the thermodynamic arrow of time.

But what would happen if and when the universe stopped expanding and began to contract? Would the thermodynamic arrow reverse and disorder begin to decrease with time? This would lead to all sorts of science-fiction-like possibilities for people who survived from the expanding to the contracting phase. Would they see broken cups gathering themselves together off the floor and jumping back onto the table? Would they be able to remember tomorrow's prices and make a fortune on the stock market? It might seem a bit academic to worry about what will happen when the universe collapses again, as it will not start to contract for at least another ten thousand million years.

At first, I believed that disorder would decrease when the universe recollapsed. This was because I thought that the universe had to return to a smooth and ordered state when it became small again. This would mean that the contracting phase would be like the time reverse of the expanding phase. People in the contracting phase would live their lives backward: they would die before they were born and get younger as the universe contracted.

To return to the arrow of time, there remains the question: why do we observe that the thermodynamic and cosmological arrows point in the same direction? Or in other words, why does disorder increase ^ the same direction of time as that in which the universe expands? if one believes that the universe will expand and then contract again as the no boundary proposal seems to imply, this becomes a question of why we should be in the expanding phase rather than the contracting phase.

One can answer this on the basis of the weak anthropic principle Conditions in the contracting phase would not be suitable for the existence of intelligent beings who could ask the question: why is disorder increasing in the same direction of time as that in which the universe is expanding? The inflation in the early stages of the universe, which the no boundary proposal predicts, means that the universe must be expanding at very close to the critical rate at which it would just avoid recollapse, and so will not recollapse for a very long time. By then all the stars will have burned out and the protons and neutrons in them will probably have decayed into light particles and radiation. The universe would be in a state of almost complete disorder. There would be no strong thermodynamic arrow of time. Disorder couldn't increase much because the universe would be in a state of almost complete disorder already. However, a strong thermodynamic arrow is necessary for intelligent life to operate. In order to survive, human beings have to consume food, which is an ordered form of energy, and convert it into heat, which is a disordered form of energy. Thus intelligent life could not exist in the contracting phase of the universe.

This is the explanation of why we observe that the thermodynamic and cosmological arrows of time point in the same direction. It is not that the expansion of the universe causes disorder to increase. Rather, it is that the no boundary condition causes disorder to increase and the conditions to be suitable for intelligent life only in the expanding phase.

Critical Observations Homogeneity and Isotropy

Until a few hundred years ago, the Solar System and the Universe were equivalent in the minds of scientists, so the discovery that the Earth is not the center of the Solar System was an important step in the development of cosmology. Early in the 20th century Shapley established that the Solar System is far from the center of the Milky Way. So by the 1920's, the stage was set for the critical observational discoveries that led to the Big Bang model of the Universe.

In *1929* Hubble published a claim that the radial velocities of galaxies are proportional to their distance. The redshift of a galaxy is a measure of its radial velocity, and it can be measured using a spectrograph to determine the Doppler shift.

The linear distance-redshift law found by Hubble is compatible *with* a Copernican view of the Universe: our position is not a special one. *First* note that the recession velocity is symmetric: if A sees B *receding*, *then B sees* that A is receding too.

The Hubble law generates a homologous expansion which does not *change the shapes of* objects, while other possible velocity-distance *relations lead to* distortions during expansion.

The *Hubble law* defines a special frame of reference at any point *in the Universe. An* observer with a large motion with respect to the Hubble flow would measure blueshifts in front and large redshifts behind, instead oi the same redshifts proportional to distance in all directions. Thus we can measure our motion relative to the Hubble flow, which is also our motion relative to the observable Universe. A commoving observer is at rest in this special frame of reference. Our Solar System is not quite commoving: we have a velocity of 370 km/sec relative to the observable Universe. The Local Group of galaxies, which includes the Milky Way, appears to be moving at 600 km/sec relative to the observable Universe.

The case for an isotropic and homogeneous Universe became much stronger after Penzias and Wilson announced the discovery of the Cosmic Microwave Background in 1965. They observed an excess flux at 7.35 cm wavelength equivalent to the radiation from a blackbody with a temperature of 3.5+/-1 degrees Kelvin. The Kelvin temperature scale has degrees of the same size as the Celsius scale, but it is referenced at absolute zero, so the freezing point of water is 273.15 K. A blackbody radiator is an object that absorbs any radiation that hits it, and has a constant temperature. Many groups have measured the intensity of the CMB at different wavelengths. Currently the best information on the spectrum of the CMB comes from the FIRAS instrument on the COBE satellite.

The temperature of the CMB is almost the same all over the sky. Thus the microwave sky is extremely isotropic. These observations are combined into the Cosmological Principle: The Universe is Homogeneous and Isotropic.

Another piece of evidence in favor of the Big Bang is the abundance of the light elements, like hydrogen, deuterium (heavy hydrogen), helium and lithium. As the Universe expands, the photons of the CMB lose energy due to the redshift and the CMB becomes cooler. That means that the CMB temperature was higher in the past. When the Universe was only a few minutes old, the temperature was high enough to make the light elements by nuclear fusion. The theory of Big Bang Nucleosynthesis predicts that about 1/4 of the mass of the Universe should be helium, which is very close to what is observed. The abundance of deuterium is inversely related to the density of nucleons in the Universe, and the observed value of the deuterium abundance suggests that there is one nucleon for every 4 cubic meters of space in the Universe.

IV. Translate at sight

The Realm of the Stars

Beyond the Solar System, tens of thousands and more miles from us, in our model, and hundreds of millions of miles in the vastness of real space, lie the stars. Each of the stars that we see in our skies is a Sun, like ours. Most are smaller and fainter than our Sun, but almost all seen without optical aid are larger and brighter, and in some cases, much larger and brighter than the Sun. Polaris, for instance, appears as a very live in brightly-lit city skies (which is, of course, most of the people in the world). This is partly because it is relatively far away, compared to the closest stars, and partly because *all* stars are far away, in any normal conception of distance. The nearest star we know of, Proxima Centauri, is two hundred fifty thousand times further than the Sun, or in our scale model, fifty thousand miles. Other stars are scattered through the vastness of space at similar or larger distances from each other, so that each star's nearest neighbors are tens of thousands of miles away in our model, and hundreds of millions of millions of miles away, in space.

Because the stars are so far away, using AU's, or miles, or kilometers, is ridiculous. Instead, we invent new units. The first such unit was the Light Year (LY).

Light goes 186,400 mi/sec, or 300,000 km/sec, or, since there are 31,000,000 sec/yr, about 6 trillion miles, or 10 trillion km, in one year. That makes it a good yard-stick for stars.

The nearest star, other than the Sun, is alpha Centauri, which is a little over 4 light years away. Polaris is about 1000 light years away. Rigel, in Orion, about 2000 light years away. Most of the stars in the night-time sky are a few tens or hundreds of light-years away, and a very few are just a few LY away, or thousands of LY away.

LIGHT YEARS are nice, because they are easy to understand AND because when you look out into space, you are looking back into time We see the Sun as it was, 8 minutes and 20 seconds ago. We see Jupiter as it was somewhere between 35 minutes and 50 minutes ago.

If you look at a star, you see it as it was, as many years ago, as its distance in LY. NORMALLY, this makes no difference. Stars don't change much, in times that are short compared to millions or billions of years. But occasionally, it can make a difference.

THIS IS PARTICULARLY TRUE, if we look at things that are VERY far away, such as GALAXIES. However, we also use a different unit, the PARSEC, to measure large distances, for reasons we'll discuss later in the book.

V. Retell the text.

Age of the Universe

There are at least 3 ways that the age of the Universe can be estimated.

- The age of the chemical elements.
- The age of the oldest star clusters.
- The age of the oldest white dwarf stars.

The age of the Universe can also be estimated from a cosmological model based on the Hubble constant and the densities of matter and dark energy. This model-based age is currently 13.7 +/- 0.2 billion years old. But this Web page will only deal with actual age measurements, not estimates from cosmological models. The actual age measurements are consistent with the model-based age which increases our confidence in the Big Bang model.

The Age of the Elements

The age of the chemical elements can be estimated using radioactive decay to determine how old a given mixture of atoms is. The most definite ages that can be determined this way are ages since the solidification of rock samples. When a rock solidifies, the chemical elements often get separated into different crystalline grains in the rock. For example, sodium and calcium are both common elements, but their chemical behaviors are quite different, so one usually finds sodium and calcium in different grains in a differentiated rock.

When applied to rocks on the surface of the Earth, the oldest rocks are about 3.8 billion years old. When applied to meteorites, the oldest are 4.56 billion years old. This very well determined age is the age of the Solar System.

When applied to a mixed together and evolving system like the gas in the Milky Way, no great precision is possible. One problem is that there is no chemical separation into grains of different crystals, so the absolute values of the isotope ratios have to be used instead of the slopes of a linear fit. This requires that we know precisely how much of each isotope was originally present, so an accurate model for element production is needed. One isotope pair that has been used is rhenium and osmium: in particular, Re-187 which decays into Os-187 with a half-life of 40 billion years. It looks like 15% of the original Re-187 has decayed, which leads to an age of 8-11 billion years. But this is just the mean formation age of the stuff in the Solar System, and no rhenium or osmium has been made for the last 4.56 billion years. Thus to use this age to determine the age of the Universe, a model of when the elements were made is needed. If all the elements were made in a burst soon after the Big Bang, then the age of the Universe would be t_o = 8-11 billion years. But if the elements are made continuously at a constant rate, then the mean age of stuff in the Solar System is t = 11.5-17.5 billion years.

Famous physicists

ALBERT EINSTEIN

Einstein's connection with the politics of the nuclear bomb is well known: he signed the famous letter to President Franklin Roosevelt that persuaded the United States to take the idea seriously, and he engaged in post war efforts to prevent nuclear war. But these were not just the isolated actions of a scientist dragged into the world of politics. Einstein's life was, in fact, to use his own words, «divided between politics and equations».

Einstein's earliest political activity came during the First World War, when he was a professor in Berlin. Sickened by what he saw as the waste of human lives, he became involved in antiwar demonstrations. His advocacy of civil disobedience and public encouragement of people to refuse conscription did little to endear him to his colleagues. Then, following the war, he directed his efforts toward reconciliation and improving international relations. This too did not make him popular, and soon his politics were making it difficult for him to visit the United States, even to give lectures.

Einstein's second great cause was Zionism. Although he was Jewish by descent, Einstein rejected the biblical idea of God. However, a growing awareness of anti-Semitism, both before and during the First World War, led him gradually to identify with the Jewish community, and later to become an outspoken supporter of Zionism. Once more unpopularity did not stop him from speaking his mind. His theories came under attack; an anti-Einstein organization was even set up. One man was convicted of inciting others to murder Einstein (and fined a mere six dollars). But Einstein was phlegmatic. When a book was a fished entitled *100 Authors Against Einstein,* he retorted, «If I were wrong, then one would have been enough!»

In 1933, Hitler came to power. Einstein was in America, and declared he would not return to Germany. Then, while Nazi militia aided his house and confiscated his bank account, a Berlin newspaper displayed the headline «Good News from Einstein – He's Not Coming Back» In the face of the Nazi threat, Einstein renounced pacifism, and eventually, fearing that German scientists would build a nuclear bomb proposed that the United States should develop its own. But even before the first atomic bomb had been detonated, he was publicly warning of the dangers of nuclear war and proposing international control of nuclear weaponry.

Throughout his life, Einstein's efforts toward peace probably achieved little that would last – and certainly won him few friends. His vocal support of the Zionist cause, however, was duly recognized in 1952, when he was offered the presidency of Israel. He declined, saying he thought he was too naive in politics. But perhaps his real reason was different: to quote him again, «Equations are more important to me, because politics is for the present, but an equation is something for eternity».

GALILEO GALILEI

Galileo, perhaps more than any other single person, was responsible for the birth of modern science. His renowned conflict with the Catholic Church was central to his philosophy, for Galileo was one of the first to argue that man could hope to understand how the world works, and, moreover, that we could do this by observing the real world.

Galileo had believed Copernican theory (that the planets orbited the sun) since early on, but it was only when he found the evidence needed to support the idea that he started to publicly support it. He wrote about Copernicus's theory in Italian (not the usual academic Latin), and soon his views became widely supported outside the universities. This annoyed the Aristotelian professors, who united against him seeking to persuade the Catholic Church to ban Copernicanism.

Galileo, worried by this, traveled to Rome to speak to the ecclesiastical authorities. He argued that the Bible was not intended to tell us anything about scientific theories, and that it was usual to assume that, where the Bible conflicted with common sense, it was being allegorical. But the Church was afraid of a scandal that might undermine its g t against Protestantism, and so took repressive measures. It declared Copernicanism «false and erroneous» in 1616, and commanded Galileo never again to «defend or hold» the doctrine. Galileo acquiesced.

In 1623, a longtime friend of Galileo's became the Pope. Immediately Galileo tried to get the 1616 decree revoked. He tailed, but he did manage to get permission to write a book discussing both Aristotelian and Copernican theories, on two conditions: he would not take sides and would come to the conclusion that man could in any case not determine how the world worked because God could bring about the same effects in ways unimagined by man, who could not place restrictions on God's omnipotence.

The book, *Dialogue Concerning the Two Chief World Systems,* was completed and published in 1632, with the full backing of the censors – and was immediately greeted throughout Europe as a literary and philosophical masterpiece. Soon the Pope, realizing that people were seeing the book as a convincing argument in favor of Copernicanism, regretted having allowed its publication. The Pope argued that although the book had the official blessing of the censors Galileo had nevertheless contravened the 1616 decree. He brought Galileo before the Inquisition, who sentenced him to house arrest for life and commanded him to publicly renounce Copernicanism. For a second time, Galileo acquiesced.

Galileo remained a faithful Catholic, but his belief in the independence of science had not been crushed. Four years before his death in 1642, while he was still under house arrest, the manuscript of his second major book was smuggled to a publisher in Holland. It was this work, referred to as *Two New Sciences*, even more than support for Copernicus, that was to be genesis of modern physics.

ISAAC NEWTON

Isaac Newton was not a pleasant man. His relations with other academics were notorious, with most of his later life spent embroiled in heated disputes. Following publication of *Principia Mathematica* – surely the most influential book ever written in physics – Newton had risen rapidly into public prominence. He was appointed president of the Royal Society and became the first scientist ever to be knighted.

Newton soon clashed with the Astronomer Royal, John Flamsteed, who had earlier provided Newton with much-needed data for *Principia,* but was now withholding information that Newton wanted. Newton would not take no for an answer: he had himself appointed to the governing body of the Royal Observatory and then tried to force immediate publication of the data. Eventually he arranged for Flamsteed's work to be seized and prepared for publication by Flamsteed's mortal enemy, Edmond Halley. But Flamsteed took the case to court and, in the nick of time, won a court order preventing distribution of the stolen work. Newton was incensed and sought his revenge by systematically deleting all references to Flamsteed in later editions of *Principia.*

Amore serious dispute arose with the German philosopher Gottfried Leibniz. Both Leibniz and Newton had independently developed a branch of mathematics called calculus, which underlies most of modem physics. Although we now know that Newton discovered calculus years before Leibniz, he published his work much later. A major row ensued over who had been first, with scientists vigorously defending both contenders. It is remarkable, however, that most of the articles appearing in defense of Newton were originally written by his own hand – and only published in the name of friends! As the row grew, Leibniz made the mistake of appealing to the Royal Society to resolve the dispute. Newton, as president, appointed an «impartial» committee to investigate, coincidentally consisting entirely of Newton's friends! But that was not all: Newton then wrote the committee's report himself and had the Royal Society publish it, officially accusing Leibniz of plagiarism. Still unsatisfied, he then wrote an anonymous review of the report in the Royal Society's own periodical. Following the death of Leibniz, Newton is reported to have declared that he had taken great satisfaction in «breaking Leibniz’s heart».

During the period of these two disputes, Newton had already left Cambridge and academe. He had been active in anti-Catholic politics at Cambridge, and later in Parliament, and was rewarded eventually with the lucrative post of Warden of the Royal Mint. Here he used his talents for deviousness and vitriol in a more socially acceptable way, successfully conducting a major campaign against counterfeiting, even sending several men to their death on the gallows.

Constellations and Legends

Constellations and Asterisms

Constellations are groups of stars which have been designated as representing a particular figure in the sky. Different cultures have done this in different ways, and many ancient and modem constellations are no longer in use. Eighty-eight of the traditional and modem Western constellations have been designated as «official» constellations by the IAU (the International Astronomical Union).

Constellations can be represented by stick figures, some of which are traditional, and others which are created by the illustrator of one book or another. In the past, constellations were usually depicted by artistic drawings based on allegorical figures, and different books typically had different drawings, which didn’t always include exactly the same stars. In 1930, the IAU defined constellation boundaries which enclose the regions traditionally occupied by allegorical figures, so that every part of the sky is inside some constellation, or another. Stars which are inside the boundary of a constellation are usually said to be «in» that constellation, meaning that they are in a direction enclosed by that boundary.

Asterisms are groups of stars, such as the Little Dipper, Big Dipper, and the Pleiades, which are not constellations, but have well- known names of their own. The Big and Little Dippers are part of the Big and Little Bears. The Pleiades are an example of a *cluster* of stars, which happens to be visible to the eye, in the constellation of Taurus.

Andromeda

The Chained Lady Cassiopeia, Andromeda's mother, boasted that she was the most beautiful woman in the world, even more beautiful than the gods. Poseidon, the brother of Zeus and the god of the seas, took great offense at this statement, for he had created the most beautiful beings ever in the form of his sea nymphs. In his anger, he created a great sea monster, Cetus (pictured as a whale) to ravage the seas and sea coast. Since Cassiopeia would not recant her claim of beauty, it was decreed that she must sacrifice her only daughter, the beautiful Andromeda, to this sea monster. So Andromeda was chained to a large rock projecting out into the sea and was left there to await the arrival of the great sea monster Cetus. As Cetus approached Andromeda**,** Perseus arrived (some say on the winged sandals given to him by Hermes). He had just killed the gorgon Medusa and was carrying her severed head in a special bag. When Perseus saw the beautiful maiden in distress, like a true champion he went to her aid. Facing the terrible sea monster, he drew the head of Medusa from the bas and held it so that the sea monster would see it. Immediately, the sea monster turned to stone. Perseus then freed the beautiful Andromeda and, claiming her as his bride, took her home with him as his queen to rule.

Aquarius – The Water Bearer

The name most often associated with the constellation Aquarius is that of Ganymede, son of Tros, King of Troy. Ganymede was an extremely handsome young man, the most handsome the gods and goddesses had ever seen. While attending to his father's flocks on Mount Ida, Ganymede caught the attention of Zeus. Zeus sent his messenger eagle, Aquila, down to earth with instructions to bring Ganymede back up to Mount Olympus. On Mount Olympus, Ganymede served the gods by bringing them water whenever they needed it. He also served as cup bearer to Zeus. He was honored for his service by Zeus, who placed a constellation called Aquarius, which means water carrier, among the stars.

According to the Greeks, Bootes was pictured as a mighty man. In his right hand he holds a spear, and with his left, two hunting dogs.

Since he appears to be pursuing the Great Bear (Ursa Major) around North Pole-Bootes was called «The Bear Driver». The ’key’ star, Arctures. can be easily found by following the curved line formed by the handle of the Big Dipper outward to the first bright star. Without doubt Arctures was one of the first stars to be named. It was one of the few stars mentioned in the Bible, where it is referred to in the book of Job. thus giving it the name «Job’s star».

«Cancer – The Crab»

According to Greek mythology, Hercules, Zeus’ son, was given 12 labors by Hera, Zeus’ wife, which would each test his strength and courage. Hera hoped these 12 labors would prove to Zeus that Hercules was unworthy of his love. The second of these 12 labors was to kill the Lernean Hydra, which had a long snake or dragon-like body and nine heads. If anyone succeeded in cutting off one of its heads, it would grow another one in its place. In order to make sure that Hercules failed at this task (Hera was very jealous of Zeus’ love for Hercules), Hera sent a large crab to grab Hercules by the heel and distract him while he was fighting the Hydra. During the fight with the Hydra, Hercules, who took his nephew Iolas along, would cut off one of the Hydra’s heads and Iolas would sear that neck with a torch so that no new head could grow back. Fearing that Hercules might indeed defeat the Hydra, Hera sent in the crab to grab Hercules’ foot. However, as the crab grabbed his foot, Hercules stomped down with his other foot and crushed the crab. He then cut the final head of the Hydra off and Iolas seared it, thus defeating the Hydra and Hera. To honor Hercules’ great victory and to remind Hera of her failure, Zeus placed the constellation of Cancer the Crab in the sky.

Casseopia – Queen of the Night Sky

Queen Casseopia, wife of King Cephus and mother of Andromeda, was very beautiful. She boasted that she was the most beautiful woman in the kingdom. As time went by, she began to say that she was the most beautiful woman in the world. Eventually, her boasting proclaimed that her beauty even exceeded that of the gods. Poseidon, the brother of Zeus and the god of the sea, took great offense at this statement, for he created the most beautiful beings ever in the form of his sea nymphs.

In his anger, he created a great sea monster, Cetus (also described as a great fish or whale), to ravage the seas, sinking ships, killing the sailors, and destroying towns and villages along the seacoast. This created great fear among the people of Casseopia's country. In an effort to stop this tremendous destruction, the people when to Poseidon and asked what could be done to stop this monster. Poseidon replied that if Casseopia would admit that his sea nymphs were indeed more beautiful than she, he would stop the monster. But Casseopia refused. The people asked Poseidon if there were any other way to stop the destruction. He replied that if the beautiful Andromeda, Casseopia's only daughter, were to be sacrificed to Cetus the destruction would stop. The people took Andromeda and chained her to a rock which projected out into the sea to be sacrificed to Cetus. However, she was saved by Perseus, and Cetus was turned to stone. Poseidon and his brother Zeus decreed that Casseopia be placed in the sky as a constellation, and as punishment for being so conceited about her looks, she would suffer the humiliating position of being upside down in the sky during the fall of the year when her constellation is best seen. Cephus – The King Cephus, the legendary king of Ethiopia, was placed in the night sky just ahead of his wife, Casseopia, as they rotate around the North Star, Polaris. He must have been a weak king allowing his wife to continually boast of her beauty and in the end be willing to let Casseopia sacrifice their own daughter, Andromeda, to Cetus the sea monster. Since he did not stop Casseopia from her continual boasting of her beauty, Cephus was placed next to her in the sky where he must listen for all time to her boasting. His constellation was given faint stars which are somewhat difficult to see.

Another story relates that Cephus was one of the Argonauts, the valiant band of heroes that sailed the ship Argo in quest of the Golden Fleece. According to this legend, Cephus was changed into a constellation at his death in the night sky.

Gemini – The Twins

Castor and Pollux were twin brothers, the sons of Zeus and Leda, the wife of Tyndarus, king of Sparta. They sailed with Jason and the

Argonauts in search of the Golden Fleece. They were invincible fighters with unparalleled courage. Pollux distinguished himself as a great boxer or fighter and Castor as a great wrestler. Some stories say Castor was a great horseman. These two were inseparable companions and fought their best when they were near each other. Because of the help they gave their fellow Argonauts during a storm which threatened to sink their ship, the constellation Gemini was considered a favorable sign to sailors when they saw it. To commemorate their great feats and the help they gave to the sailors, and because of their great love for each other, Zeus placed their constellation, Gemini, in the sky after their deaths. Today, Gemini can be seen between the constellations of Orion and Cancer, near Leo.

Hercules – The Strong Man

Hercules was the son of Zeus and Alcmene. He was the favorite son of Zeus, who had made special preparations for Hercules' birth so that he would be the mightiest of all the heroes. In keeping with this plan, Hercules would spend the first part of his life living among, and even serving, mortals. He would learn how they lived and what was important in their lives. Then, he would be brought up to Mount Olympus to join the Olympians there, and having lived among the mortals, could help the gods in their discussions and plans. Hercules was known for his great strength, courage, and agility. He was also known for his Twelve Labors, which he undertook as a result of Hera's scheming. Hera tried many times to get Hercules to fail at some *ta** and as a result, fall out of favor with his father Zeus. However, Hercules not only completed these twelve tasks, but did them in such a way as to win even more favor from his father, and at the same time make Hera look bad. In addition to these famous Twelve Labors, he also sailed with Jason and the Argonauts in search of the Golden Fleece, took part in the war between the gods and the giants and still had time to sack Troy. Zeu commemorated all the mighty acts of Hercules by his constellation in a very prominent place in the sky.

Leo – The Lion

According to Greek mythology, Leo was a ferocious lion who fell t *d* the earth in the forests of Nemaea. He feasted on the animals of the forest and also caught and ate many human beings. Many brave men lost their lives trying to kill this giant lion, for its skin was so tough that no arrow or spear could pierce it. Hercules was given the first of his Twelve Labors, that of killing the terrible lion, by Hera the jealous wife of Zeus. She hoped that he would fail and thus loose the love of his father, Zeus. Knowing that no spear or arrow could pierce the lion's skin, Hercules entered the lion's cave and was able to strangle the terrible lion. Hercules then reappeared at the cave's entrance wearing the lion's skin as a robe. Hercules had saved the people of Nemaea. This great act of heroism was commemorated by Zeus, when he placed the picture of the defeated lion (Leo) in the night sky.

The Pleiades – Seven Sisters

Of all the constellations in the sky, no group of stars has been known longer nor had more different stories, legends, or myths told about it than the Pleiades. There are at least 43 different stories or names for them. However, there are only two that are closely related to the Greek heroes or gods.

The Pleiades, according to the first Greek myth, were the seven daughters of Pleione and Atlas, the giant who bears the world upon his shoulders. These seven maidens, along with their sisters the Hyades, (these are the small stars forming the face of Tams) were transformed into stars because of their «amiable virtues and mutual affection» and because of their great sorrow at the burden imposed upon their father, Atlas.

Scorpio – The Scorpion

This is the famous Scorpion, which came up out of the ground and was commanded by Artimus to sting Orion, the mighty hunter, and caused him to die. That was the punishment Orion received because he had killed so many animals for no reason, except to try to impress her. Scorpio was then placed into the sky on the opposite side of the world from Orion so as to avoid any further conflict. It was also placed in the sky to remind all of us that it is okay to kill animals for food, but it is wrong to kill them just for the fun of it.

Ursa Major – The Big Bear (Dipper) and Ursa Minor – The Little Bear (Dipper)

Ursa Major is one of the oldest known constellations and has more named stars in it than any other constellation. It has been known by many names, but the form of the bear has become the most common, even though it's quite difficult to see this image in the stars. In Greek mythology, Zeus had many human girlfriends, but his favorite was the beautiful nymph Callisto. His secret visits to earth to meet with her only added to Hera's jealousy and determination to get revenge against these women. One day, as Zeus was walking through the forest with Callisto, he saw his wife Hera coming. Unable to hide Callisto in time, he turned her into a large brown bear. When Hera arrived, she saw only Zeus walking by himself through the forest. She looked around, searching for someone with Zeus, but saw only an old brown bear. She still did not trust Zeus and insisted that he return to Mount Olympus. Zeus did not want to go because he wanted to change his girlfriend Callisto back into her human form before leaving. But Hera insisted. So Zeus went with Hera, leaving Callisto as a large brown bear. Unknown to Zeus, Areas, Callisto's son who was a great hunter, was out in the woods hunting that day. As chance would have it, he saw this great big brown bear. He put an arrow to his bow, took careful aim, and shot that great bear through the heart. Right before his startled eyes, Areas watched the bear as it died change back into the form of his mother Callisto with an arrow through her heart. Areas began to cry loudly for his mother and what he had done to her. When he realized that it was Zeus that had changed her into the bear, he grew even angrier. Zeus, fearing that Hera might hear the cries, went down to earth to try to appease Areas. In order to hide what he had done, Zeus changed Callisto back into a bear and placed her form, as a constellation, into the northern sky as the Big Dipper. He then fringed Areas into the small bear (the Little Dipper). As Arcas was being placed into the sky, he turned to look at his mother Callisto (now the Big Dipper). That is why the Little Dipper is curved toward the Big Dipper, so that Arcas can watch over his mother Callisto for all eternity.

The Origin of the Solar System (Stellar Formation)

Stars start out as interstellar clouds of gas and dust. If you were inside such a cloud, you probably couldn't tell that there was anything at all there, because the gases which make up the clouds are incredibly thin. Each cubic inch of these clouds contains only a few dozen to a few hundred atoms, while each cubic inch of our atmosphere contains almost a billion trillion atoms. If you had to expand a single cubic inch of our atmosphere until it was as thin as the gases in an interstellar cloud, it would be almost 200 miles on a side.

Although the clouds are incredibly rarefied, they are also incredibly big. Stretching for trillions of miles in all directions. Because of their huge size, even though there is practically nothing at any given place within them, the huge extent of practically nothing adds up to substantial masses, hundreds of thousands of times greater than the mass of the Earth, like that of the Sun.

Because the material of the cloud is spread out over such a huge volume of space, the gravity caused by its mass is incredibly small, and under normal circumstances, it cannot force the cloud to contract to a smaller size. But under some circumstances, the clouds ARE forced to contract to smaller sizes. During such contractions, gravity gradually increases, and if its force becomes large enough, the thin gases within the cloud will not be able to exert enough outward pressure to prevent the gravitational pull from contracting the cloud to still smaller sizes, and so the cloud will continue to contract.

Although gravity is trying to make the cloud smaller, the pressure *oi* the gases within the cloud is trying to stop the contraction. At first the pressure is negligible, since the gases are so incredibly thin, but as the cloud gets smaller, the gases become denser and hotter. The inward pull of gravity tries to make the gases move inward with greater and greater speeds, but random collisions between the atoms of the gas tend to convert this inward motion into a random sub-microscopic movement, which we perceive as heat. As the cloud contracts, greater and greater amounts of inward movement are converted into faster and faster microscopic motions, or greater and greater amount of heat. The greater temperatures which result, combined with the greater density of the gas, create a continually increasing pressure, which fights against gravity.

As the heat generated by the contraction of the gases increases, pressure gradually rises, until it equals the gravitational forces, stopping the inward motion of the cloud. If this occurs while the cloud is still very large, and not very warm, no further contraction will occur. But if this balance does not occur until the cloud has contracted a long way, and has therefore generated a large amount of heat, some of the heat will be radiated away in the form of infrared light. The heat lost in this way reduces the ability of the gas to hold up against the pull of gravity, and causes a slow, semi-equilibrium contraction of the cloud. At each stage of the contraction, pressure and gravity are in balance, and if no more heat were radiated away, the contraction would stop, but the continual radiation of infrared light at the outside of the gradually warming cloud prevents this, and allows gravity to have a slow but steady victory over pressure.

Although the loss of heat at the outside of the cloud forces it to contract, there is a limit to how far the contraction can go. As the cloud continues to contract temperatures within the cloud continue to rise By the time that the cloud is as small as a star like the Sun the central temperatures have risen to many millions of degrees and of hydrogen to helium begins, in a process known as thermonuclear fusion. At first, this conversion is slow, and produces only a small amount of energy, but as the star continues to contract, the rate of nuclear fusion increases, producing more and more energy. The heat generated by this fusion helps replace the heat being lost at the outside of the star, slowing the rate of contraction. The closer the star gets to a stable size, the closer the core approaches an equilibrium temperature at which the nuclear reactions produce exactly as much heat as is being lost on the outside. When the star reaches that temperature, there is no longer any net loss of heat, and so the star’s contraction finally ends.

The Formation of the Solar Nebula

A cloud which is trying to contract to become a star has several problems to overcome before it can do so. One of these is the outward pressure, discussed above. In this case, the solution to the problem is to heat the cloud to a high enough temperature so that some of the heat is being continually radiated away, reducing the amount of heat left over to create pressure.

Another problem is angular momentum. Even while the cloud is huge, it must have some tiny amount of rotational motion. The random motions which occur in different parts of the cloud will probably nearly cancel each other out, so that any overall motions are small, but it is not likely that they will exactly cancel, and so some tiny rotational motion is to be expected.

In many cases, the rotational motion of the cloud may be so large that it is impossible for the gravity of the cloud to overcome it, and the cloud remains as a large cool blob of gases, but the existence of so many stars in our Galaxy shows that there must be various ways in which stars can overcome this problem. One way is for the cloud to break up into two or more blobs, revolving around each other-a binary or multiple star system. Such systems are in fact quite common. Between one-third and one-half of all the stellar systems in our Galaxy are thought to consist of such multiple stars.

Since we do not know of any companions to the Sun, it seems that our Solar System solved the problem in a different way. Presumably the amount of rotation in the cloud was fairly small, and as a result, those parts of the cloud which happened to have a smaller amount of rotation could fall inwards more-or-less uniformly, forming a large, roughly spherical ball near the center, which became the Sun, while those parts of the cloud which were rotating the fastest formed a flattened circular disk rotating around the central ball, the Solar Nebula. As the cloud contracted, parts of it which were moving parallel to the axis of rotation (getting closer to the plane of rotation) would not have had their inward motion affected by the rotation, but parts which were moving in the plane of rotation (getting closer to the axis of rotation) would have gradually increased their rotational speeds just as, just as ice skaters spin faster by pulling their arms towards their bodies. The same thing can be seen in the motion of the planets around the Sun; Kepler’s Law of Areas is mathematically equivalent to the Law of Conservation of Angular Momentum which determines how rotating objects speed up as they get closer to their axis of rotation.

The Age of the Solar System and Its Early History

The Sun and planets must have been formed about 4.5 billion years ago. This date is determined by studying the characteristics of rocks which contain small amounts of radioactive substances. It the mineral grains which contain such materials have not been altered significantly since their formation, the decay products will be trapped in those minerals, but the decay products do not have the same chemistry as the original radioactive materials, and so they stick out like a sore thumb when detailed chemical and physical studies of the minerals are made. By comparing the fraction of radioactive materials which have already decayed to the total amount of such materials, and measuring the rate at which such materials decay in the laboratory, it is possible to determine the «age» of the rock. Of course, this is only an estimate in many cases, and if the rock has been altered in some significant way since the minerals were first formed, it may not be an accurate indication of how long ago that was, but if we look at many samples from various places, the overall results are almost certainly correct.

The age of the Solar System is determined by the study of Earth rocks, Moon rocks, and meteorites. The oldest rocks which we have discovered on the Earth only date back to 3.8-3.9 billion years ago The Earth itself must be somewhat older than that, as these rocks are all sedimentary and metamorphic rocks, meaning that they were formed from the compression and alteration of sediments derived from the weathering and erosion of still older rocks but no samples of those older rocks are known to still exist. It is therefore difficult to estimate the true age of the Earth from direct study of Earth rocks, but calculations based on the relative distribution of the decay products of radioactive materials in rocks of various ages seem to imply an age somewhere in the range of 4 to 5 billion years.

The rocks which the Apollo astronauts brought back from the Moon give us a slightly more accurate estimate of the actual age of the solar system. Most of these rocks are basaltic lavas from the lunar maria, and date only to 3.3 to 3.8 billion years ago, but some of them are heavily fractured granitic rocks which appear to have been blasted off the lunar highlands, and date to over 4.3 billion years ago. This implies that the Moon must have formed a little earlier than that, but again just how much earlier could be difficult to estimate.

The best estimates of the age of the solar system seems to come from certain primitive meteorites, which appear not to have been significantly altered since they were formed. They exhibit a range of ages, but most of their ages cluster closely about a value of 4.5 billion years ago. Since this is in reasonable agreement with the best estimates that we can make from the Earth and the Moon, we believe that this is the true age of the Solar Nebula, the Sun, and all the other bodies in the solar system.

The total history of the accumulation of the planetesimals into planets and other solid bodies probably did not encompass more than a few million years, and in comparison to the 4500 million years or so back to the beginning of the solar system, represents only an instant. So we should probably consider all of the bodies which we now see as being of essentially the same age.

Towards the end of their formation, the planets must have undergone a period of melting. Certainly the differentiation of the Earth, with its heavy metallic core, and lighter rocky mantle, requires some such period of melting. The exact time that this occurred can only be estimated, but probably was very close to the initial formation of the planets, as even the Moon seems to have completed such a molten state at a very early date. Like the Earth, the Moon has a differentiated crust, with a low-density granitic «slag» forming the bulk of the highland surface of the Moon. This implies that the Moon must have melted, differentiated, and then begun to re-solidify before the date, 4.3 to 4.4 billion years ago, which we determine as the «age» of the rocks which were recovered from the Moon. This means that the period of melting must have been within the first 100 million years after the formation of the planetary bodies.

The heat required to produce this melting appears to have been caused by the decay of short-lived radioactive materials. These materials are created inside supernova explosions, and one or more such explosions must have occurred in the region near the interstellar cloud which became the solar system within the last few tens of millions of years prior to the formation of the solar system, in order for any significant amounts of such radioactive substances to have still existed at the time that the solar system formed. But this would not be surprising, as we believe that the Sun, like most stars, probably formed in a group or cluster of stars, and if any of those were much more massive than the Sun, they could easily have formed, lived out their lives, and died, all during the time that the could which became our solar system was hovering on the edge of contraction. In fact, some primitive meteorites have unusual abundances of very heavy atoms which are, as a result, thought to be at least partly the decay products of extremely heavy atoms which cannot normally exist in nature, except for short times after they are created in supernova explosions, and before they have had a chance to decay. As a result, we feel certain that at the time the planets were forming, they contained significant amounts of short-lived radioactive substances which would soon decay and disappear. If those substances were permanently trapped inside small bodies, such as the primitive meteorites, then the heat generated by the decay of these materials would easily leak to the surface and be radiated away into interplanetary space, but if they were trapped inside larger bodies, such as the asteroids or planets, it would take a long time for the heat to leak through the thicker layers of rocky materials, and so heat would build up inside the larger bodies.

According to current estimates of the amounts of such radioactive substances in the early solar system, any bodies more than 50 to 100 miles in diameter would soon accumulate so much heat that they would start to melt, allowing the heavier metals to sink to the bottom and the lighter rocky materials to rise to the top. As a result, all of the Terrestrial planets, the Moon, and even the half dozen or so largest asteroids must have become completely molten differentiated objects. As the short-lived radioactive materials died out the heat created by their decay would also die out, and the molten bodies would gradually solidify. The crustal materials, being exposed directly to the relatively low temperatures of interplanetary space, would solidify first, while the rocky mantles, insulated by hundreds or thousands of miles of the overlying materials, would take considerably longer. So the crust of the Moon could easily have formed within the 200 million years or so allowed by our current knowledge of the ages of highland rocks, but the deep interior of the Moon might well have still been molten at the time (in fact, «fossil» magnetism inside Moon rocks implies that it did have a molten core, and a magnetic field created by that core, for at least a short period of time).

Looking at the highland surface of the Moon, we can see that at the time that it solidified, not all of the rocky material in the inner solar system was inside the Moon and planets. At least some small fraction of the planetesimals must have still been moving around in independent orbits and as these objects ran into the now-solid surfaces of the cooling planets, they blasted out huge craters. The number of objects left in between the planets must have been only a small fraction of the mass of the planets themselves, or else heat generated by the violence of their collisions would have re-melted the surfaces of the planets, but there must still have been a huge number of them, since all the truly ancient planetary surfaces still visible to us, such as the surfaces of our Moon, Callisto and Mercury, are completely covered with craters tens or hundreds of miles in diameter.

Eventually, of course, this stage of bombardment of the early planetary surfaces must have come to an end. As the planets gradually swept up the objects not yet in them, the numbers of such objects which were still left would have gradually declined, and so there would be fewer and fewer objects left to cause still other collisions. By around 4 billion years ago, about half a billion years after the start of the solar system, there were so few objects left that the early period of intense bombardment had essentially ended, and surfaces which are younger than that are relatively unscathed by cratering.

The Big Bang

Based on the Hubble redshift observed for distant galaxies, the Universe is believed to have started out, about 15 billion years ago, as a very small, dense, hot blob, which expanded violently outwards in all directions, in an explosion which we call the Big Bang. In the first few moments of the expansion, the temperatures and densities were so high that matter as we know it could not exist. As the expansion proceeded, temperatures and densities dropped very rapidly, and within a very short time, the primordial stuff of the Universe was transformed into hydrogen nuclei, electrons, photons, and neutrinos. For a little while after this, hydrogen was fused into helium through the same proton-proton cycle still used in stars like the Sun, until only 3/4 of the weight of the Universe remained as hydrogen, and 1/4 was helium. Not much later, as the expansion cooled off the gases, the temperature dropped so that hydrogen fusion could no longer occur and the gas simply expanded more and more, causing temperature and density to continually decrease. For a few hundred thousand years the gas was so dense that photons of light were continually running into other particles (the gas was *opaque*, as in the interior of a star), but as the gas expanded, the light was able to move further and further without interference. Eventually the gas became so rarefied that most light could keep going through space forever without running into anything. The early stage where the Universe was opaque, and light could not get very far, is referred to as the Cosmic Fireball. Once the Fireball had expanded to the stage where it became transparent and light could travel freely through the Universe, the Big Bang was over.

Origin of the Galaxy

Eventually, as the hot gases from Big Bang cooled, electrons combined with protons to make neutral hydrogen gases, and gravity began to pull gases together, forming galaxies, and within the galaxies, stars.

When the gases that become our Galaxy were still spread out over hundreds of thousands of light years, the density would have been relatively low, making it difficult to get denser clumps of gas which could form into stars. The large distances between halo stars (low star density) presumably mirrors the low formation rate at that time.

As the gases contracted towards the center of the Galaxy the became denser, making it easier to get dense clumps of gas which could form clusters of stars. The smaller distances between stars closer to the nucleus presumably mirrors the higher formation rate at that time.

As the gases contracted to form the nucleus of the Galaxy, the still greater gas densities made star formation faster and faster, so there are more and more stars closer and closer to the nucleus.

At the end of the formation, large amounts of gas may have formed into huge numbers of stars, or they may have collapsed to supermassive black holes. Most of the stars in the Galaxy probably formed within a billion years or two after the start of the Galaxy's formation, over 12 billion years ago. Since then, star formation has been much slower, since most of the gas had already been turned into stars There are very few places where there is much gas left to make into new stars (mostly in the spiral arms).

Stars formed during this early stage have very few heavy atoms in them while stars formed later on have more and more heavy atoms in them, because the heavy atoms are not formed in the Big Bang, but in massive stars. During the formation of the Galaxy, there was a lot of gas left, and very few stars, even massive ones, had had time to die and spread their ashes around. Later on, there was less gas left, and more ashes from dead stars, so the ratio of heavy atoms to light ones gradually increased (to about 4% by weight today).

Background: Structure of the Galaxy

The Sun is about 25000 light years (LY) from the center of our galaxy. The nucleus of the Galaxy is roughly spherical, about 10000 LY in diameter, and contains about 100 billion solar masses. Superimposed on this is a flattened rotating disk which is about 100000 LY in diameter, 2000 LY thick, and also contains about 100 billion solar masses. Superimposed on both of these is the halo, which is roughly spherical, between 200000 and 500000 LY in diameter, and contains between 100 billion and 500 billion solar masses. Our Galaxy probably looks very much like the Andromeda Galaxy, but is probably only 70-80% as large.

Most of the stars in the galaxy are very old, which means they are very faint, since bright stars cannot last very long. In the nucleus, the stars are only a few light weeks or months apart, but in the disk they are several light years apart, and in the halo they are tens of light years apart. Because the stars are thickly clustered in the nucleus, even though they are individually faint, their combined light can be easily observed, even at the distance of other galaxies. But in the disk and halo, the larger distance between the stars mean that even their combined light is usually too faint to observe.

There are, however, regions in the disk of the Galaxy which contain large amounts of gas and dust, out of which new stars are continually forming. Some of these stars are massive, hot, large, bright stars and they light up the space around them, making it easy to see the regions where they have just formed. The places where gas and dust are common usually have a spiral distribution, so they are called spiral arms. In these regions, new stars can continually form out of gas and dust, or Interstellar Medium.

Initial Conditions For Forming Stars: The Interstellar Medium

Clouds of gas and dust in interstellar space are very large (often tens or hundreds of thousands of AUs in size), but very rarefied with only a few tens or hundreds of atoms (mostly hydrogen and helium) per cubic inch. Considering that a cubic inch of air contains almost a billion trillion molecules of nitrogen and oxygen, a typical interstellar cloud has almost nothing in it at all. In fact, if you were inside such a cloud, unless you had sensitive measuring devices, you wouldn't be able to tell that it was even there. However, despite the small amount of material in any given area, the clouds are so large that they can contain substantial masses, comparable to, or even larger than, the mass of our Sun.

In order to form a star, something has to happen to make this incredibly large, incredibly thin gas collapse to a very small, very dense object: a Main Sequence star. That requires some kind of force which can compress the gas, and make it smaller and smaller.

Sometimes, the force that accomplishes this is simply the force of gravity. If, in some way, gravity can overcome whatever forces keep the cloud at its current size (to be discussed in more detail below) then, as the cloud decreases in size, the gravitational force will increase, since it depends upon the inverse square of the distance between the various parts of the cloud. As the cloud shrinks, the various parts get closer together, so the gravitational attraction between them increases, happens, it should become easier and easier for gravity to pull things still closer together, and if there weren't any other problems, the cloud would shrink, faster and faster, as its parts pull closer and closer together and exert larger and larger forces on each other.

The only trouble with this idea is that there are various problems overcome. One of them is a tendency for the cloud to rotate, faster and faster, as it gets smaller. However, that has been dealt with earlier (in the discussion of the origin of the Solar System), and in any event, not a serious problem until the cloud becomes much smaller than its original size. There can also be problems with a gradual increase in the magnetic field which runs through interstellar space. Although it is very weak, it will become stronger as the cloud contracts, and it can. to a certain extent, oppose the contraction of the cloud, well. However, to a certain extent, as in the case of rotation, the magnetic field simply makes the cloud contract in certain ways, rather than preventing it from contracting at all, and in any case, the physics involved is well beyond what can be easily explained at an introductory level, so we will ignore it, as well, in this «simple» discussion.

There is, however, one problem which cannot be ignored, in discussing the formation of stars, namely the fact that, in addition to gravitational forces which are trying to contract the cloud, there will be an internal pressure, due to the motions of the gas particles, which is trying to expand it. This pressure will be extremely small at any given place, because it depends upon the density and temperature of the gases, which are both very low. As already mentioned, the gas is millions of trillions of times thinner than air, so the density is incredibly low, and the temperature of a typical interstellar cloud is also very low, typically no more than 100 Kelvins above absolute zero, or more than 250 degrees below zero, on the Fahrenheit scale. With both a low density and a low temperature, the gas pressure is very close to zero, so it would be easy to ignore it, at first thought.

Even if it has a mass like that of the Sun, since it is millions, or even tens of millions, of times larger than the Sun, its gravity would be that amount SQUARED, or many trillions, or hundreds of trillions, of times less than the Sun's gravity. As a result, BOTH the gas pressure and the gravity are very small, and in point of fact, under normal circumstances, they must be more or less equal. If this were not true, then clouds would always be fairly rapidly contracting to form stars (if gas pressure is more than gravity). The fact that, over 12 billion years since our Galaxy, where as much as half the mass is in the form of clouds of gas and dust, means that most of the time, interstellar clouds must be in a state of quasi-equilibrium in which gas pressure and weight are more or less in balance.

How do brown dwarfs die?

Brown dwarfs can't die, because they are, so to speak, already dead.

As you move down the Main Sequence, the density of stars increases, because the lower mass stars have to contract more in order to achieve a given temperature, than the higher mass stars do. Is means that when they begin nuclear burning, they are much fainter, and therefore, don't need to produce as much heat in order to stop their contraction. As a result, they are not only much denser, but also, much cooler (in relative terms) than higher mass stars.

As an example, a massive star may have central temperatures in excess of 30 million Kelvins, and central densities only a little greater than that of water, whereas the Sun has a central temperature of less than 15 million Kelvins, and a central density more than 100 times that of water. By the time you get to the bottom of the Main Sequence, the lowest mass stars have central densities of thousands of times that of water, and central temperatures of only 6 or 7 million Kelvins.

The higher densities of low mass stars mean that their electrons are pushed closer together, and their lower temperatures mean that the electrons act bigger, because of the Uncertainty Principle, than in high mass stars. As you go to lower and lower masses, the decrease in distance between the electrons, and the increase in electron «size» means that the space between the electrons rapidly decreases.

Once the mass gets low enough, it becomes so hard for the faint, cool protostar to increase its temperature that, as it contracts, ^electrons begin to fill up its entire interior, and to act like a liquid, it i_s technically known, an electron-degenerate gas. This is exactly the same situation which white dwarfs achieve, but at much higher densities, because they are much hotter, so that their electrons «act» smaller.

So if the mass of a would-be star is small enough (somewhere below 1/10th the mass of the Sun), as it contracts toward the Main Sequence, the electron gas begins to act like a liquid. At first, the electron degeneracy is small, and the protostar continues to shrink more or less as it previously did. But as the protostar continues to shrink, and the electron degeneracy grows, any further loss of heat becomes less and less important, and it shrinks more and more slowly. Eventually, once the electrons are completely degenerate, and the electron gas behaves like a liquid, the protostar stops shrinking.

At this point, the protostar has no heat source save the heat stored inside it during its contraction. As that heat is slowly radiated away, the star cools off, and becomes gradually fainter and fainter. Such stars are already so cool that most of their heat is in the infrared, and as they cool off further, they become almost impossible to observe at interstellar distances, save through their infrared radiation. Once that happens, they are called brown dwarfs.

So, in a sense, brown dwarfs never have a life, in the sense that the Sun has, as a Main Sequence star. Instead, they are «stillborn», and «die» without ever having lived.

THE LIST OF IRREGULAR VERBS

Infinitive	Past Simple	Past Participle	Перевод
1	2	3	4
Be	was, were	been	быть, являться
Beat	Beat	beaten	бить, колотить
become	Became	become	становиться
Begin	Began	begun	начинать
Bend	Bent	bent	Гнуть
Bet	bet	bet	держать пари
Bite	bit	bitten	Кусать
Blow	blew	blown	дуть, выдыхать
Break	broke	broken	ломать, разбивать, разрушать
bring	brought	brought	приносить, привозить, доставлять
build	built	built	строить, сооружать
Buy	bought	bought	покупать, приобретать
catch	caught	caught	ловить, поймать, схватить
choose	chose	chosen	выбирать, избирать
come	came	come	приходить, подходить
cost	cost	cost	стоить, обходиться
cut	cut	cut	резать, разрезать
deal	dealt	dealt	иметь дело, распределять
dig	dug	dug	копать, рыть
do	did	done	делать, выполнять
draw	drew	drawn	рисовать, чертить
drink	drank	drunk	пить
drive	drove	driven	ездить, подвозить
eat	ate	eaten	есть, поглощать, поедать
fall	fell	fallen	падать
feed	fed	fed	кормить
feel	felt	felt	чувствовать, ощущать
fight	fought	fought	драться, сражаться, воевать
find	found	found	находить, обнаруживать
fly	flew	flown	летать
forget	forgot	forgotten	забывать о (чём-либо)
forgive	forgave	forgiven	прощать
freeze	froze	frozen	замерзать, замирать
get	got	got	получать, добираться
give	gave	given	дать, подать, дарить

1	2	3	4
go	went	gone	идти, двигаться
grow	grew	grown	расти, вырастать
hang	hung	hung	вешать, развешивать, висеть
have	had	had	иметь, обладать
hear	heard	heard	слышать, услышать
hide	hid	hidden	прятать, скрывать
hit	hit	hit	ударять, поражать
hold	held	held	держать, удерживать, задерживать
hurt	hurt	hurt	ранить, причинять боль, ушибить
keep	kept	kept	хранить, сохранять, поддерживать
know	knew	known	знать, иметь представление
lay	laid	laid	класть, положить, покрывать
lead	led	led	вести за собой, сопровождать, руководить
leave	left	left	покидать, уходить, уезжать, оставлять
lend	lent	lent	одалживать, давать взаймы (в долг)
let	let	let	позволять, разрешать
lie	lay	lain	лежать
light	lit	lit	зажигать, светиться, освещать
lose	lost	lost	терять, лишаться, утрачивать
make	made	made	делать, создавать, изготавливать
mean	meant	meant	значить, иметь в виду, подразумевать
meet	met	met	встречать, знакомиться
pay	paid	paid	платить, оплачивать, рассчитываться
put	put	put	ставить, помещать, класть
read	read	read	читать, прочитать
ride	rode	ridden	ехать верхом, кататься
ring	rang	rung	звенеть, звонить
rise	rose	risen	восходить, вставать, подниматься
run	ran	run	бежать, бегать
say	said	said	говорить, сказать, произносить
see	saw	seen	видеть

1	2	3	4
seek	sought	sought	искать, разыскивать
sell	sold	sold	продавать, торговать
send	sent	sent	посылать, отправлять, отсылать
set	set	set	устанавливать, задавать, назначать
shake	shook	shaken	трясти, встряхивать
shine	shone	shone	светить, сиять, озарять
shoot	shot	shot	стрелять
show	showed	shown, showed	показывать
shut	shut	shut	закрывать, запирать, затворять
sing	sang	sung	петь, напевать
sink	sank	sunk	тонуть, погружаться
sit	sat	sat	сидеть, садиться
sleep	slept	slept	спать
speak	spoke	spoken	говорить, разговаривать, высказываться
spend	spent	spent	тратить, расходовать, проводить (время)
stand	stood	stood	стоять
steal	stole	stolen	воровать, красть
stick	stuck	stuck	втыкать, приклеивать
strike	struck	struck, stricken	ударять, бить, поражать
swear	swore	sworn	клясться, присягать
sweep	swept	swept	мести, подметать, смахивать
swim	swam	swum	плавать, плыть
swing	swung	swung	качаться, вертеться
take	took	taken	брать, хватать, взять
teach	taught	taught	учить, обучать
tear	tore	torn	рвать, отрывать
tell	told	told	рассказывать
think	thought	thought	думать, мыслить, размышлять
throw	threw	thrown	бросать, кидать, метать
understand	understood	understood	понимать, постигать
wake	woke	woken	просыпаться, будить
wear	wore	worn	носить (одежду)
win	won	won	победить, выиграть
write	wrote	written	писать, записывать

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