Chapter 2　Scientific Approach Design & Science Expression

■ Four Fundamental Rules of Calculation

Scientific Communication

Useful Expression.

「計算方法」を説明してみよう！

a ＋ b ＝ c	⇒	a plus b is （is equal to, equals to） c.
a － b ＝ c	⇒	a minus b is c.
a × b ＝ c	⇒	a times b is b.
$\frac{a}{b}$ ＝ c	⇒	a divided by b is c.　or　a over b is c.
$\frac{2}{15}$	⇒	two fifteenths　or　two over fifteen
a^2	⇒	a squared　or　a to the power of two
a^3	⇒	a cubed　or　a to the power of three
$\sqrt{a}$	⇒	the square root of a
$\sqrt[3]{a}$	⇒	the cube root of a
a ≧ b	⇒	a is greater than or equal to b
a ＜ b	⇒	a is less than b

式　: expression
代入する　: substitute
方程式を解く: solve
x と y の関数 : a function of x and y

average speed ＝ $\frac{\text{distance moved}}{\text{time taken}}$ ⇒ "distance moved" over "time taken"
or "distance moved" divided by "time taken"

Exercise 1　Explain how to solve the following equation.

5x + 2 = 3x + 6

（　　）the 3x（　　）, and 2 to the right side,（　　）5x - 3x = 6 - 2
Then 2x = 4,　（　　）x = 4/2 = 2

Exercise 2　Explain how to solve the following quadratic equation.

x + y = 3　・・・①
2x + 5y = 9　・・・②

If I（　　）the equation ①　（　　）x,　it will be　x = - y + 3 ・・・③ ,
and then　（　　）x（　　）the equation ②,
then I get　2(- y + 3) + 5y = 9
（　　）the equation, - 2y + 6 + 5y = 9
3y = 3
Therefore　y = 1

Then（　　）y=1 in the equation ③,
x = -1 +3 = 2
The answer is　x = 2, y = 1

Let's Read !

■ Universe

The characteristics of stars

Stars

A **star** is a ball of gases that **gives off** a huge **amount** of light (**electromagnetic waves**). This energy comes from **nuclear fusion** within the star. Nuclear fusion is a reaction in which several light **atomic nuclei** are put together to form heavier atomic nuclei.

When you see stars in the sky at night, most stars appear to be small spots of white light. However, if you look carefully at the stars, you will notice that there are some stars that look slightly reddish and some stars look blue-white.

Analyzing Starlight

When you shine sunlight through a prism, you will see the colors of the rainbow. This rainbow is called a **spectrum**. There are three types of spectra: **emission**, or bright-line; **absorption**, or dark-line; and **continuous**. Astronomers use **spectroscopes**, which separate light into different colors or **wavelengths**, to analyze starlight.

When you observe sunlight carefully through a spectroscope, you will notice that there is a continuous spectrum and many dark lines across it, as shown in Figure 1. This dark line is called **Fraunhofer lines** named after the German physicist Joseph von Fraunhofer（1787–1826）. Later it was noticed that all stars have these dark lines（absorption spectrum）, and a star's absorption spectrum reveals the star's **composition** and temperature.

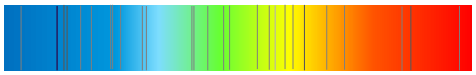


Figure 1. Solar Spectrum

The Origin of the Universe

Actual Motion of Stars

The siren of an ambulance sounds different as it passes you by. This **phenomenon** is called **the Doppler effect**. This phenomenon occurs because, when the source of sound moves toward the observer, the wavelength decreases, but when the source of sound moves away from the observer, the wavelength increases. Moreover, the greater the **motion** toward or away from the observer, the greater the Doppler shift. This phenomenon can be observed to occur with all types of waves: water waves, sound waves and light waves.

By observing a star's spectrum, astronomers can learn more about how that star is moving in space. In the part of the spectrum that can be seen, red light has the longest wavelength, and blue light has the shortest. Therefore, when a star is moving away from us in space, the light waves that reach us increases and therefore appear red, as shown in Figure 2. This increase in wavelength is called **redshift**. Distant **galaxies** have red-shifted spectra, which indicates that these galaxies are moving away from Earth.

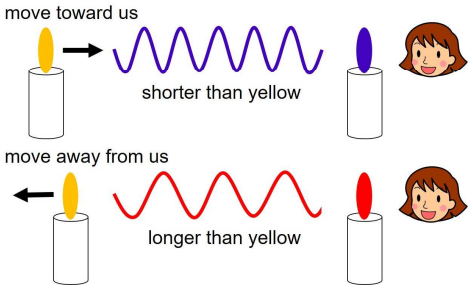


Figure 2. The Doppler effet

Hubble's Observations

Near the end of the 1920s, Hubble found that the spectra of galaxies, except for the few closest to Earth, were shifted toward the red end of the spectrum. By examining the amount of red shift and the distance of galaxies, he found that galaxies are moving away from Earth at a speed that is proportional to their distance from Earth, as shown in Figure 3. This shows that the universe is **expanding**.

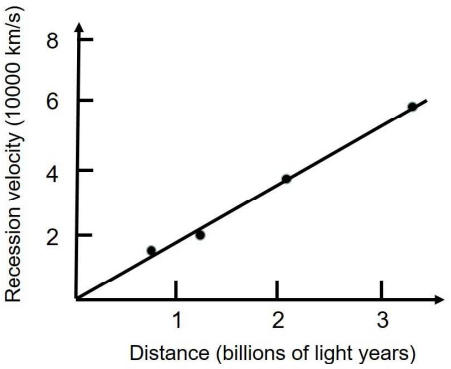


Figure 3. Hubble's distance-velocity relationship

The Big Bang Theory

If we trace our expanding universe back to the "beginning," all matter would have been close together. That means, all the matter and energy in the universe was **compressed** into an extremely small **volume**. The current and most widely accepted theory that our universe started as matter in a small volume, about 13.8 billion years ago, is called **the Big Bang**.

In 1964, astronomers have also discovered a **cosmic microwave background** (CMB). The CMB is the remains of the **thermal energy** from the Big Bang. The discovery of the CMB, predicted by the Big Bang theory, provided very strong support for the Big Bang theory.

A Universe of Surprises

Based on recent data on the CMB, the observation of **gravitational lens effects** and studies of the distant **supernovas**, astronomers now think that the universe is made up of more mass and energy than they can currently observe. The ordinary matter we know that makes up humans, the earth and the stars are made of 5% of the mass/energy of the universe. Another 27% of the universe is made up of a mysterious matter called **dark matter** that we cannot directly observe. The rest of the universe is made up of an unknown form of energy that repels gravity known as **dark energy**（68 percent）.

Understanding Main Concepts

1. What is called a nuclear reaction in which atomic nuclei combine?
   a. photosynthesis **b.** fusion **c.** magnetism **d.** fission

2. Which type of spectrum reveals the star's composition?
   a. en emission spectrum **b.** a continuous spectrum **c.** an absorption spectrum

3. What theory proposes that the universe is expanding?
   a. the steady-stage universe theory **b.** continental drift
   c. the giant impact theory **d.** the Big Bang

【Vocabulary】

本文			
star	noun	恒星	a large ball of burning gas in space that can be seen at night as a point of light in the sky
give off		発する，放つ	
amount	noun	量	
electromagnetic waves	noun	電磁波	a kind of radiation including visible light, radio waves and X-ray
nuclear fusion	noun	核融合	a reaction in which the central parts of atoms join together, which produces power without producing any waste
atomic nuclei	noun	原子核	the central part of the atom
spectrum	noun	スペクトル	a band of colored lights into which a beam of light separates when it is passed through a prism
emission spectrum	noun	線スペクトル	
absorption spectrum	noun	吸収スペクトル	
continuous spectrum	noun	連続スペクトル	
spectroscope	noun	分光器	
wavelength	noun	波長	the distance between two points on energy waves such as sound or light
Fraunhofer lines	noun	フラウンホーファー線	
composition	noun	組成	the way in which something is made up of different parts, things, or members
phenomenon	noun	現象	
Doppler effect	noun	ドップラー効果	the change in observed wavelength of a sound due to relative motion of the source and/or observer
motion	noun	動き、運動	
red shift	noun	赤方偏位	the displacement of the spectrum to longer wavelengths in the light
galaxy	noun	銀河	one of the large groups of stars that make up the universe
expanding	adj	拡大する、膨張する	
compress	verb	圧縮する	
extremely	adv	極めて	
volume	noun	体積	a measurement of the amount of space that a substance or object fills, or the amount of space in a container
the Big Bang	noun	ビッグバン	
cosmic microwave background	noun	宇宙背景放射	
thermal energy	noun	熱エネルギー	
gravitational lens effects	noun	重力レンズ効果	
supernova	noun	超新星	a very large exploding star
dark matter	noun	ダークマター	non-luminous material postulated to exist in space
dark energy	noun	ダークエネルギー	a mysterious quantity that makes up, along with dark matter, most of the mass of the universe

■ Analyzing Starlight

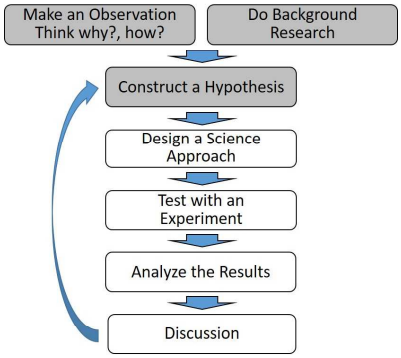
English Science

Words learned through English Science

Point!

Construct a Hypothesis

Scientific Approach



●課題を解決するための科学的手法の１つに、「検証可能な仮説を立てること」があります。科学研究は、一般に、自然事象・現象を観察（直接何らかの自然界での現象を観察したり、たまたま既存の研究内容を目にしたり）したときから始まります。そして、その自然事象・現象を通じて**「なぜ？」**という疑問が生じます。

他に情報が無い状態で、この「なぜ？」に答えることは、とても難しいことです。なぜならば、多くの場合は、答えが複雑に絡み合っているからです。それでは、どうしたら答えを見つけることができるでしょうか。

0. **観察したものを比較・分類しているとき、あるいは、これまでの経験・知識にない何か（自然事象・現象）を観察したときに、**
1. **漠然と「なぜ？ Initial Question」が生じる。次に、**
2. **何がわかっていて、何がわかっていないのかを明確にする。**
3. **そこから、何を知りたいのかという「目的」が生じる。**
4. **「なぜ？」を、まずは答えることができる簡単な「問い research question」にする。**
5. **「問い」を、実験、観察、調査等により真偽判定できる「命題」に置き換える。**

この「命題」、すなわち予想される結果が「仮説」です。

実験によって導き出されたこの仮説の答えは、一番最初に抱いた疑問の答えにはなりませんが、この最初の疑問の答えを導くための有効な知識となります。さらにそこから新たな検証可能な「問い」を導き出し、実験により答えを導き出します。これを繰り返すことにより、最終的に最初に抱いた「なぜ？」の答えを見つけることができるのです。

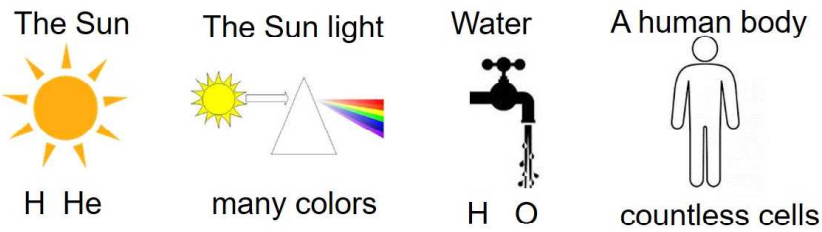
ここでは、「なせ？」から仮説を設定する過程に着目して、実験を行いましょう。

It's Your Turn -Activities with TA-

Useful Expression.

be made up of … / consist of … / be composed of … : … からできている

【Role play】



A: What is the Sun made of ?

B: The Sun is made up of hydrogen and helium.
The Sun light is made up of many colors.
Water consists of hydrogen and oxygen.
A human body is composed of countless cells.

主語
be made up of …
consist of …
もの

1a Initial Observation & Information Gathering

Drawing events

Observation Exercise1

Let's observe various lights using a spectroscope! Explain how you could see lights respectively. See Role play. Make a sketch if it is necessary to explain.

Flashlight	Alcohol lamp contains Na	Na, Hg lamp	Fluorescent light	The sky
				
(hot solid)	(thin gas)	(thin gas)	(thin gas + α)	(sunlight)
⇩	⇩	⇩	⇩	⇩
	Na	Hg		

【TAs Question】

Q1.

【Your Answer】

→ reply

I could see ...

line 線

bright 明るい　dark 暗い

continuous 連続した

in places 所々

1b Write down what you have observed and what you want to know

The scientific method starts when you ask a question about what you have observed.

Activity 1

You must have noticed something, and wonder why it happens. Now you want to know how or why it happens. Talk about what you have observed and what you think and wonder about in groups.

The first step is,

Write down exactly what you have observed.

Write down your question about what you have observed, or write down what you want to know.

Initial Question

2 Background Research

Next step is to make clear what is known, what is not known about your topic. Find out about what you want to investigate. Read books, magazines, use the Internet to research or ask professionals to learn about the area of study. In this lesson, you will learn about the spectrum as background research.

3 Aim of your research

You learned about continuous spectrum and emission spectrum. However, it is still unknown what are the dark lines seen in the solar spectrum. So, you want to investigate what are the dark lines. This will be the aim of your research.

4 Research question

Then, express your initial question in a single question and propose an answer to the question based on what you know. The question must be testable.

Activity 2

Now you want to clarify the cause of the dark lines. You found out the following property about the spectrum. In groups, think of a possible research question for the initial question below. Your research question can be tested by an experiment. You can create many research questions, many answers are possible. Activity 3 will help you to think of a research question.

Initial Question : What are the dark lines seen in the solar spectrum?
What is known : ・Atoms in a gas emit light of specific wavelengths, which create bright lines.
What is not known : Cause of the dark lines.
Aim of your research : To clarify the cause of the dark lines.

Activity 3

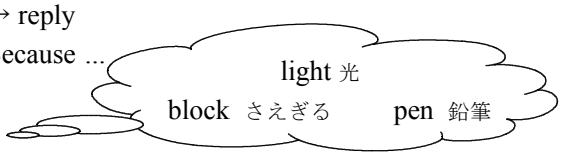
Let's make a shadow on the white paper using a pen and a flashlight!
Then discuss why the shadow is dark.

【TAs Question】

Q1.

【Your Answer】

→ reply
Because ...



What is known : ・_____ is the result of the absence or complete absorption of visible light.
・We perceive the area where there is less light as _____.
・Dark lines indicate the particular wavelengths of light are absent.

Idea & Imagination

Research questions (a single question which is testable) **:**

5 Construct a Hypothesis

When you create a research question, you will also have an expectation of the answer. This expectation is the hypothesis.

Activity 4

If you wrote a research question for the Initial Question on the Activity 2, what is the answer you would expect?

Research question : Do atoms in the gas absorb light of specific wavelengths?

Hypothesis:

Design a Science Approach & Experiment

Thinking Critically

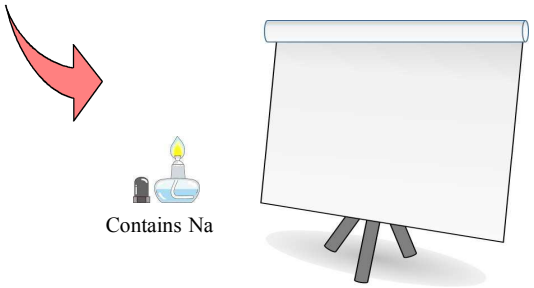
Activity 5

1 Do you think we could make a shadow of a flame? Discuss why you think yes or no. If you think yes, draw a picture how to make a shadow of the flame. See Activity 3.

Science History

・William Hyde Wollaston(1802) and Joseph von Fraunhofer (1814) found absorption spectrum in the optical spectrum of the Sun.

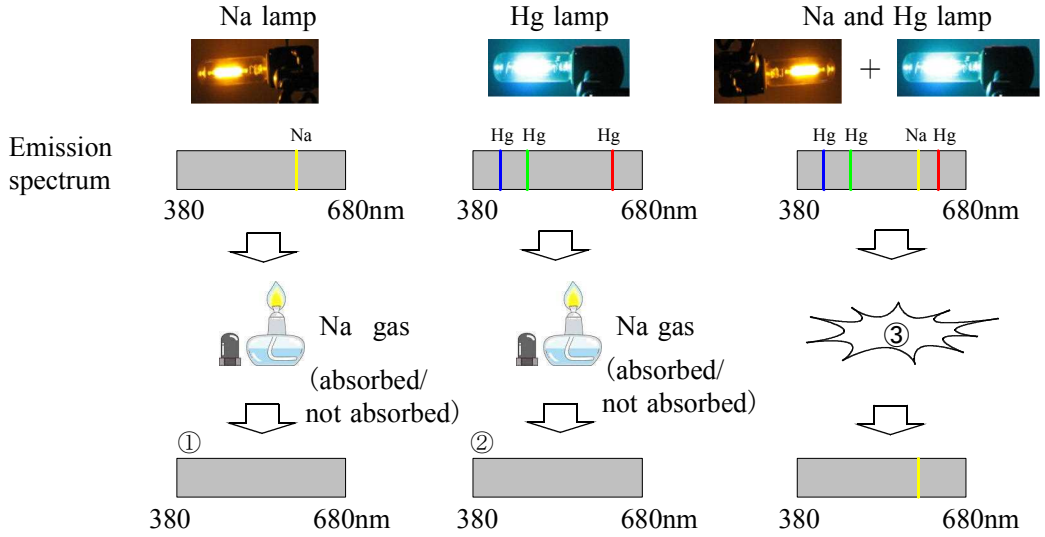
・Gustav Robert Kirchhoff and Robert Wilhelm Bunsen(1860) discoverd the relationship that the dark lines in the absorption spectrum of the light corresponded in wavelengths, with the wavelengths of the bright, sharp lines characteristic of the emission spectra of the same test materials.



2 What kind of experiment did you design to test the hypothesis? Let's try it!

Exercise 1

1. Draw an image of the spectrum on ① and ②.
2. ③ is a gas. What is it?



序論(Introduction)で使う英語表現

序論は、著者が先行研究（特定のテーマについて、何が分かっていて、何が分かっていないか）に言及して、何が重要で、どのような仮説を立てて、どのような実験を行い仮説を検証したかを簡潔に述べるところです。通常、次のような流れで書きます。

１　背景、先行研究、事例紹介：なぜこの研究が必要なのかの理由を述べる（一般化General）

...have been widely investigated., ...has already been proposed by A, This phenomenon has been widely observed., ...is well known., ...is an increasingly important issue around the world.

２　未解決の問題、新たな課題：どこまで明らかになっていて、何が明らかになっていないのか、問題点となっているのは何か、を述べる

However, the cause of ... has not yet noticed / mentioned. However, it is still unknown whether... / how..., However, most of the research on ..., There have been few examinations of ..., Little has been reported on,

３　研究の目的：自分たちの研究の目的を述べる

The aim / The purpose of this study is to clarify / examine / analyze / investigate / determine ...,
This paper clarifies / focuses on / describes ...,

４　仮説の提示：何を調べたのか、どこまで明らかにしたのかを述べる（特定化Specific）

In this study / research / paper, we tested / investigated ..., This study tested the hypothesis that X is Y. The effects of ... were also investigated. Therefore we examined whether ...

Exercise 1

In the topic above(Analyzing Starlight), and using the hypothesis constructed, along with the background information written in the "Science History", write an Introduction using the underlined parts above.

Home Work　Using the form below, write a research theme in the topic above.

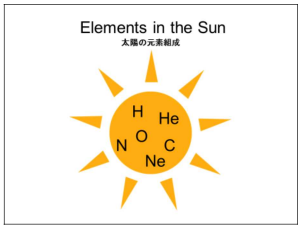
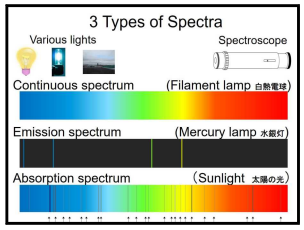
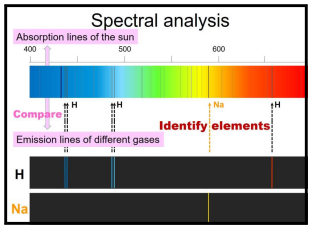
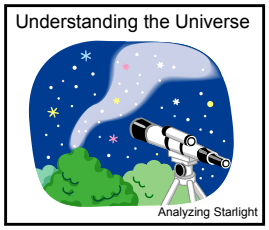
Background research -What you want to investigate（何をしたいか、問題は何か） -What is known（今までの結果、わかっていることは何か） -What is not known/Current status of issues/Why is it important?（わかっていないこと、課題の現状、なぜ問題なのか） -Ideas to solve the question（何をしたら解決できそうか、課題を乗り越えるアイディア）
Aim of research（研究の目的）
Research question and/or hypothesis（仮説）

Exercise 2

You summarized what you learned on this topic to the following points ①～⑧ and made 4 slides to explain them. Let's make scripts in Japanese by arranging the following ①～⑧ for each slide. Then translate it into English.

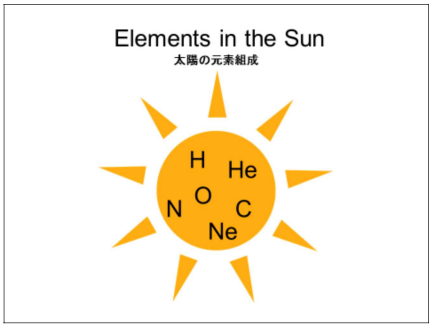
学んだ内容

〈テーマ〉
① 太陽の大気組成
〈不思議だと思ったこと〉
② どうやって太陽の大気組成を調べたのだろう。
〈学んだこと〉
③ 太陽大気の主成分は、水素とヘリウムで、その他、酸素、炭素、窒素などを少量含む（表を参照）。
④ 太陽光をプリズムに通すと（分光器で光を観察すると）、光の波長による屈折率の違いにより光の帯が見える。これをスペクトルという。
⑤ スペクトルには、連続スペクトル、線スペクトル、吸収スペクトルの３種類がある。
連続スペクトル：高温の個体が放つ光。
線スペクトル：原子の状態が変化するときに放つ特定の波長の光。
吸収スペクトル：物質が特定の波長範囲を選択的に吸収するスペクトル。
⑥ ガス成分が同じだと、線スペクトルと吸収スペクトルの波長は同じである。
⑦ 太陽の吸収線と様々な元素の線スペクトルを比較することで、太陽の大気組成がわかる。
〈学びを通して考えたこと〉
⑧ 夜空の星の光を解析することにより、もっと詳しく宇宙のことがわかるのではないか。

Introduction	**Body 1**	**Body 2**	**Conclusion**
			
Scripts:	Scripts:	Scripts:	Scripts:

【Presentation Exercise】 Let's try to have a presentation using the following slides and script.

Introduction



・My name is _____

太陽の元素組成

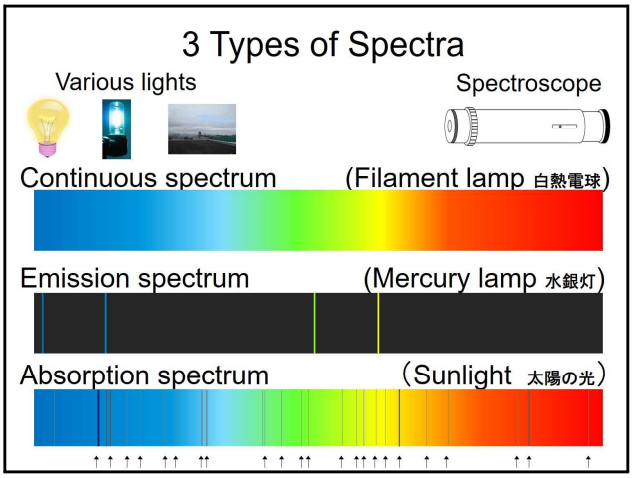
・I'm going to talk about elements in the sun.

太陽は何からできているのか

・Do you know what the sun is made of ?

・The sun is made of Hydrogen, Helium and more.

Body 1



様々な光を分光器で、

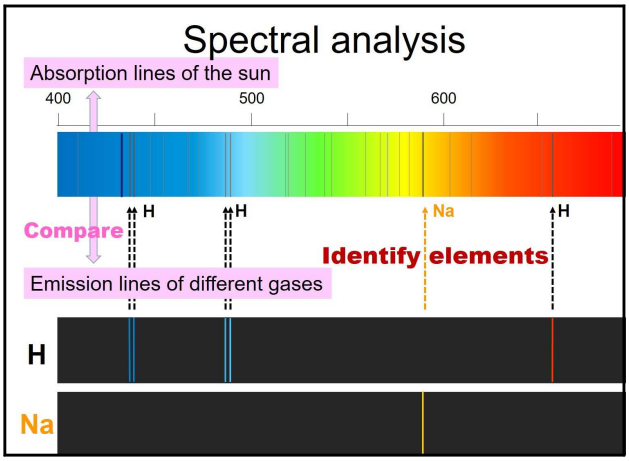
・If we observe various lights through a spectroscope, we can see three types of spectra.

連続スペクトル、線スペクトル、吸収スペクトル

・These are the continuous spectrum, emission spectrum and absorption spectrum.

・The wavelengths of the emission lines are the same as the absorption lines if the gas is the same type.

Body 2



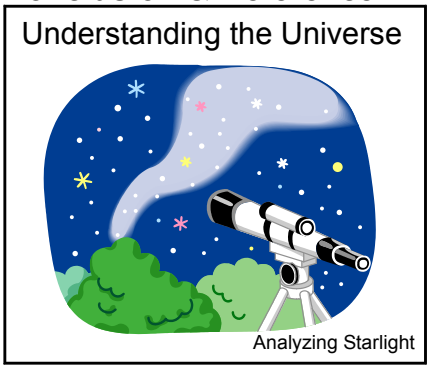
太陽の吸収線と異なるガスの輝線を比較することで、

・So, by comparing the absorption lines of the sun with the emission lines of different gases,

太陽の大気組成を同定することができます。

we can identify the elements that make up the sun.

Conclusion & Reference



・I think if we analyze starlight of the night sky, we will understand the universe more.

・Thank you for listening.