6.2 Stars and the Universe

Name: _____ Class: _____ Date: _____ **Total: 21 marks**

0 Vocabulary

Word	Example
dust /dʌst/ 尘埃	The planets formed from gas and **dust**. 行星由气体和**尘埃**形成。
element /ˈelɪmənt/ 元素	Each **element** of the array holds one value. 数组的每个**元素**保存一个值。
star /stɑː/ 恒星	The Sun is a **star**. 太阳是一颗**恒星**。
hydrogen /ˈhaɪdrədʒn/ 氢	Water contains **hydrogen** and oxygen. 水含有**氢**和氧。
helium /ˈhiːlɪəm/ 氦	An alpha particle is a **helium** nucleus. α 粒子是一个**氦**原子核。
electromagnetic spectrum 电磁波谱 /ɪˌlektrəʊməgˈnetɪk ˈspektrəm/	Radio waves and X-rays are both in the **electromagnetic spectrum**. 无线电波和 X 射线都属于**电磁波谱**。
nuclear reaction 核反应 /ˈnjuːklɪə rɪˈækʃn/	A **nuclear reaction** changes one nucleus into another. **核反应**将一种原子核变成另一种原子核。
nuclear fusion 核聚变 /ˈnjuːklɪə ˈfjuːʒn/	**Nuclear fusion** powers the Sun. **核聚变**为太阳提供能量。
galaxy /ˈgæləksi/ 星系	Our **galaxy** is the Milky Way. 我们所在的**星系**是银河系。
Milky Way /ˈmɪlki weɪ/ 银河系	Our Sun is one star in the **Milky Way**. 太阳是**银河系**中的一颗恒星。
light-year /laɪt jɪə/ 光年	A **light-year** is the distance light travels in a year. 一**光年**是光在一年内传播的距离。
diameter /daɪˈæmɪtə/ 直径	Measure the **diameter** of the wire with a micrometer. 用千分尺测量金属丝的**直径**。

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Word	Example
Universe /ˈjuːnɪvɜːs/ 宇宙	The **Universe** is about 13.8 billion years old. **宇宙**的年龄约为 13.8 billion 年。
interstellar cloud 星际云 /ˌɪntəˈstelə klaʊd/	Stars form inside an **interstellar cloud** of gas and dust. 恒星在由气体和尘埃组成的**星际云**中形成。
protostar /ˈprəʊtəʊstɑː/ 原恒星	A **protostar** is a young star that is still forming. **原恒星**是一颗仍在形成中的年轻恒星。
stable /ˈsteɪbl/ 稳定	A **stable** sort keeps equal items in the same order. **稳定**的排序会保持相等元素的原有顺序。
fuel /ˈfjuːəl/ 燃料	Hydrogen is the **fuel** for most stars. 氢是大多数恒星的**燃料**。
red giant /red ˈdʒaɪənt/ 红巨星	The Sun will become a **red giant**. 太阳将会变成一颗**红巨星**。
nebula /ˈnebjʊlə/ 星云	New stars form inside a **nebula**. 新的恒星在**星云**内形成。
white dwarf /waɪt dwɔːf/ 白矮星	A **white dwarf** is about the size of the Earth. **白矮星**的大小与地球差不多。
red supergiant 红超巨星 /red ˈsuːpədʒaɪənt/	A **red supergiant** may end as a supernova. 一颗**红超巨星**最终可能成为超新星。
supernova /ˌsuːpəˈnəʊvə/ 超新星	A **supernova** can be brighter than a whole galaxy. 一颗**超新星**可能比整个星系还亮。
neutron star /ˈnjuːtrɒn stɑː/ 中子星	A **neutron star** is very small and very dense. **中子星**体积很小，密度很大。
black hole /blæk həʊl/ 黑洞	Not even light can escape from a **black hole**. 即使是光也无法逃离**黑洞**。
receding /rɪˈsiːdɪŋ/ 退行	Distant galaxies are **receding** from us. 遥远的星系正在**退行**，远离我们。
wavelength /ˈweɪvleŋθ/ 波长	The **wavelength** is the distance from one crest to the next. **波长**是相邻两个波峰之间的距离。
redshift /ˈredʃɪft/ 红移	The **redshift** shows the galaxy is moving away. **红移**表明星系正在远离我们。
expanding /ekˈspændɪŋ/ 膨胀	The universe is **expanding**. 宇宙正在**膨胀**。
Big Bang /bɪg bæŋ/ 大爆炸	The universe began with the **Big Bang**. 宇宙起源于**大爆炸**。

Word	Example
microwave /ˈmaɪkrəʊweɪv/ 微波	A **microwave** can carry a signal to a satellite. **微波**可以向卫星传送信号。
radiation /ˌreɪdɪˈeɪʃn/ 辐射	**Radiation** from the source can damage cells. 辐射源发出的**辐射**可能损伤细胞。
cosmic microwave background radiation 宇宙微波背景辐射 /ˈkɒzmɪk ˈmaɪkrəʊweɪv ˈbækgraʊnd ˌreɪdɪˈeɪʃn/	The **cosmic microwave background radiation** comes from the early universe. **宇宙微波背景辐射**来自早期宇宙。
Hubble constant 哈勃常数 /ˈhʌbl ˈkɒnstənt/	The **Hubble constant** links a galaxy's speed to its distance. **哈勃常数**将星系的速度与距离联系起来。

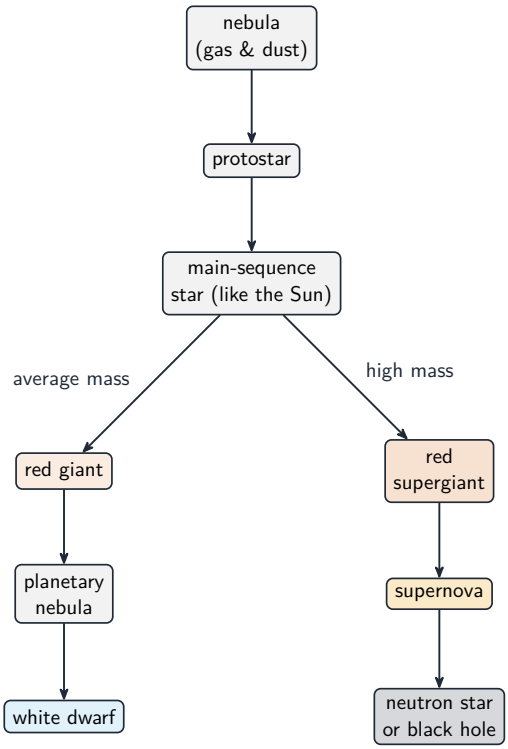
1 Key knowledge and worked examples

Study these first. Each one shows the method for a question type used later: follow the steps and you can do the Practice and Exam-style questions yourself.

■ The Sun and the galaxies

- The Sun is a medium-sized star, powered by **fusion** of hydrogen nuclei into helium. It radiates most of its energy as infrared, visible light and ultraviolet.
- A **galaxy** is a huge group of billions of stars held together by gravity; the Solar System is in the **Milky Way**.
- A **light-year** 光年 is a **distance**: how far light travels in one year, about 9.5×10^{15} m.

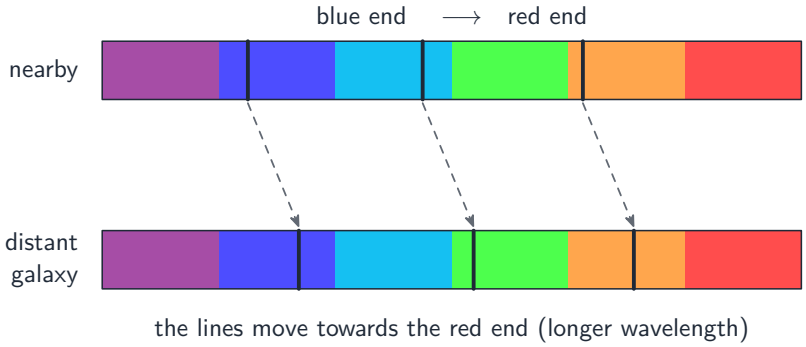
The life cycle of a star



Every star begins in a nebula; a heavy star ends in a supernova → neutron star or black hole

1. A cloud of dust and gas (**nebula**) collapses under gravity into a **protostar**.
2. It becomes a **stable star** when fusion starts and the outward force from the hot core balances the inward pull of gravity.
3. When the hydrogen runs out it swells into a **red giant** (Sun-like star) or a **red supergiant** (much more massive star).
4. A red giant throws off a **planetary nebula** and leaves a **white dwarf**. A red supergiant explodes as a **supernova**, leaving a **neutron star** or, for the most massive, a **black hole**.

■ Redshift and the Big Bang



Light from receding galaxies is redshifted; the farther the galaxy, the bigger the redshift

- **Redshift** 红移: light from a galaxy moving away is observed at a **longer wavelength** than it was emitted.
- The further away a galaxy is, the faster it recedes. The **Hubble constant** is the ratio of speed to distance, $H_0 = \dfrac{v}{d}$.
- Running the expansion backwards gives a start, the **Big Bang**: age of the Universe $\approx \dfrac{1}{H_0}$. The cosmic microwave background radiation (CMBR) is further evidence.

■ Worked example: the age of the Universe

A galaxy 5.0×10^{24} m away recedes at $1.1 \times 10^{7}\ \dfrac{\text{m}}{\text{s}}$. Estimate the age of the Universe.

1. Hubble constant: $H_0 = \dfrac{v}{d}$.

$$H_0 = \frac{v}{d} = \frac{1.1 \times 10^{7}\ \frac{\text{m}}{\text{s}}}{5.0 \times 10^{24}\ \text{m}} = 2.2 \times 10^{-18}\ \text{s}^{-1}$$

2. Age $\approx \dfrac{1}{H_0}$:

$$\text{age} \approx \frac{1}{H_0} = \frac{1}{2.2 \times 10^{-18}\ \text{s}^{-1}} = \mathbf{4.5 \times 10^{17}}\ \text{s}$$

2 Practice

2.1 State the nuclear reaction that powers the Sun. [1]



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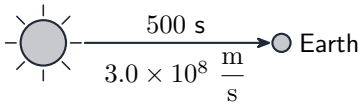
2.2 State what a light-year measures. [1]

light-year

2.3 State what is meant by a galaxy, and name the galaxy that contains the Solar System. [2]

galaxy

2.4 Light travels at $3.0 \times 10^8 \ \frac{\text{m}}{\text{s}}$. Light from the Sun takes 500 s to reach the Earth. Find the distance from the Sun to the Earth. [2]



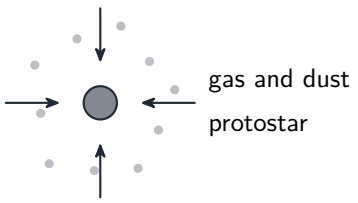
3 Exam-style questions

3.1 Redshift of light from distant galaxies is evidence that the Universe is: [1]

redshift

- ☐ **A** shrinking
- **B** expanding
- **C** unchanging
- **D** rotating

3.2 State the condition required for a protostar to become a stable star. [1]



3.3 A medium-mass star like the Sun runs out of hydrogen fuel.

Describe what it becomes, in order, after this. [3]

medium-mass star

hydrogen used up

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3.4 Describe what happens to a star with a much greater mass than the Sun after it has become a red supergiant. [3]

red supergiant

3.5 The Hubble constant is about $H_0 = 2.2 \times 10^{-18}\ \text{s}^{-1}$.

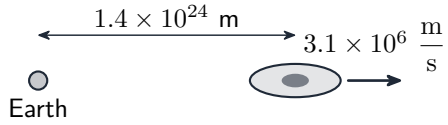
(a) Estimate the age of the Universe in seconds. [2]

$H_0 = 2.2 \times 10^{-18}\ \text{s}^{-1}$

(b) State one other piece of evidence for the Big Bang. [1]

3.6 A distant galaxy is 1.4×10^{24} m from the Earth and is moving away at $3.1 \times 10^{6}\ \frac{\text{m}}{\text{s}}$.

(a) Use these values to calculate the Hubble constant H_0. [2]



(b) Explain how the redshift of light from galaxies at different distances supports the Big Bang theory. [2]

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Solutions

Each answer shows the steps, then the **result**.

2.1

- nuclear fusion (of hydrogen nuclei into helium)

2.2

- distance (the distance light travels in one year)

2.3

- a galaxy is a very large group of (billions of) stars held together by gravity
- the Milky Way

2.4

- distance = speed × time, $d = vt$

$$d = vt = (3.0 \times 10^8 \ \frac{\text{m}}{\text{s}})(500 \text{ s}) = \mathbf{1.5 \times 10^{11}} \text{ m}$$

3.1 B

- redshift shows galaxies are receding – the Universe is expanding

3.2

- the outward force from the hot core (fusion) balances the inward force of gravity

3.3

- it swells into a red giant
- throws off its outer layers as a planetary nebula
- leaving a white dwarf

3.4

- it explodes as a supernova
- forming a nebula containing hydrogen and new, heavier elements
- leaving a neutron star or, for the most massive stars, a black hole

3.5

(a) age $\approx 1/H_0$

$$\text{age} = \frac{1}{2.2 \times 10^{-18} \text{ s}^{-1}} = \mathbf{4.5 \times 10^{17}} \text{ s}$$

(b) the cosmic microwave background radiation (CMBR)

3.6

(a) $H_0 = v/d$

$$H_0 = \frac{v}{d} = \frac{3.1 \times 10^6 \ \frac{\text{m}}{\text{s}}}{1.4 \times 10^{24} \text{ m}} = \mathbf{2.2 \times 10^{-18}} \text{ s}^{-1}$$

(b) the light from distant galaxies is redshifted, so they are moving away from us

- the further away the galaxy, the greater the redshift and the faster it recedes, so the Universe is expanding from a single starting point

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