
"WE ARE STARDUST"

We are star dust, reaching out to the universe. The 15th Symphony of Science video featuring Neil DeGrasse Tyson, Richard Feynman and Lawrence Krauss.
From https://www.youtube.com/watch?v=8g4d-rnhuSg

65%
O
Oxygen

18.5%
C
Carbon

9.5%
H
Hydrogen

3.2%
N
Nitrogen

1.5%
Ca
Calcium

1%
P
Phosphorus

0.4%
K
Potassium

0.3%
S
Sulphur

0.2%
Na
Sodium

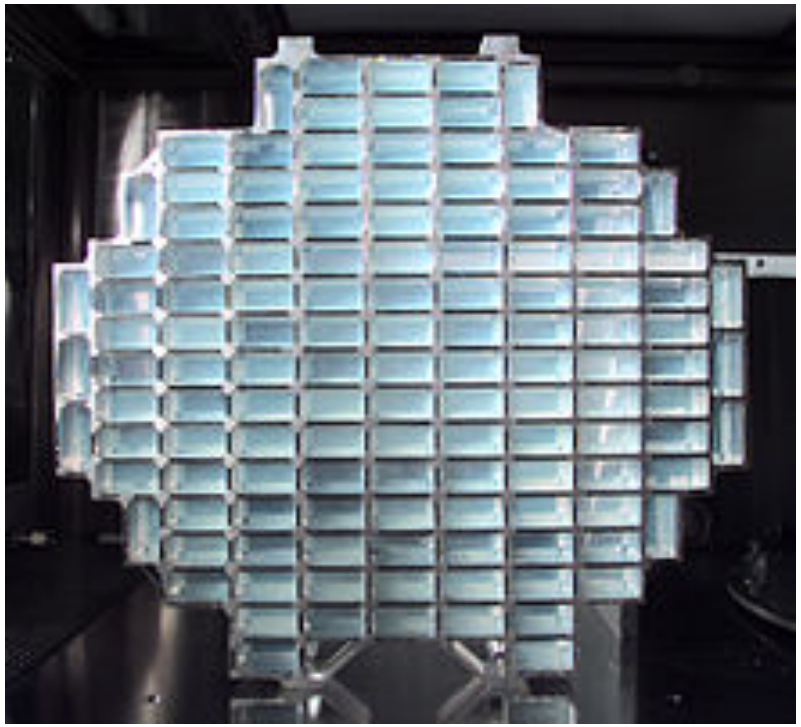
0.2%
Cl
Chlorine

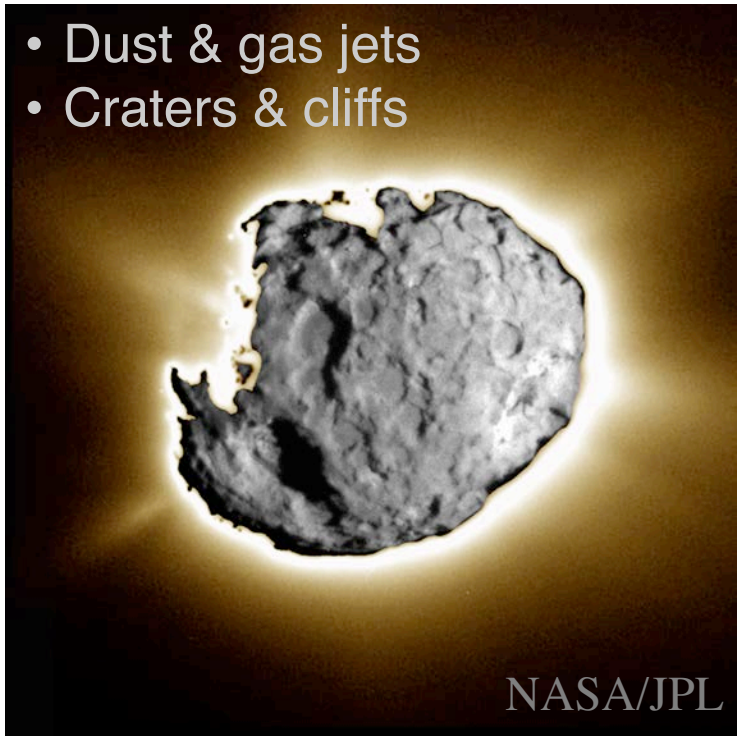
0.1%
Mg
Magnesium

Trace elements less than 1%: **B** Boron, **Cr** Chromium, **Co** Cobalt, **Cu** Copper, **F** Fluorine, **I** Iodine, **Fe** Iron, **Mn** Manganese, **Mc** Molybdenum, **Se** Selenium, **Si** Silicon, **Sn** Tin, **V** Vanadium, **Zn** Zinc

星尘号(1999–2006)

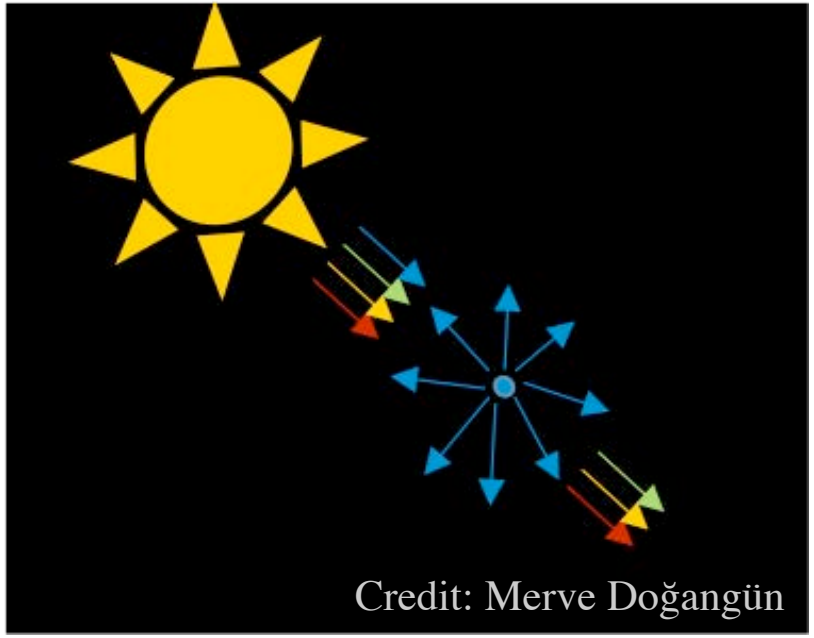
- 探测维尔特二号彗星 (comet Wild 2)。首次完成从彗星采样返回任务。

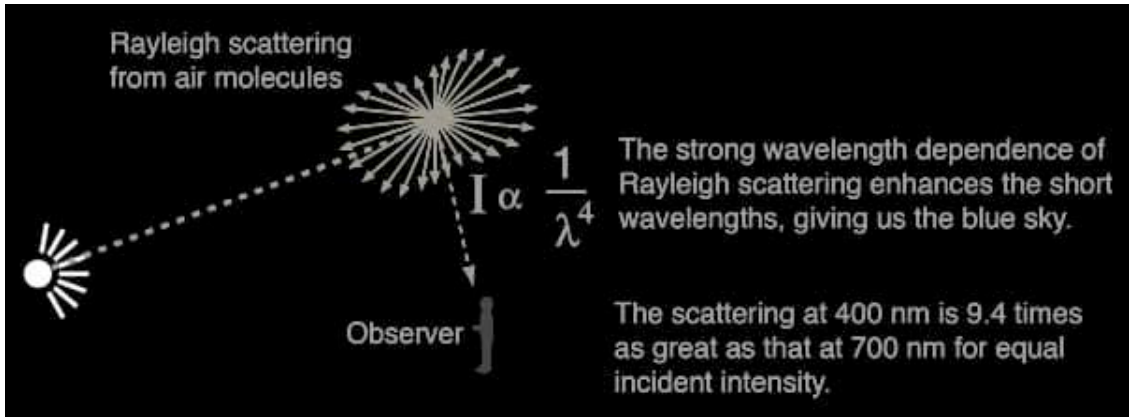


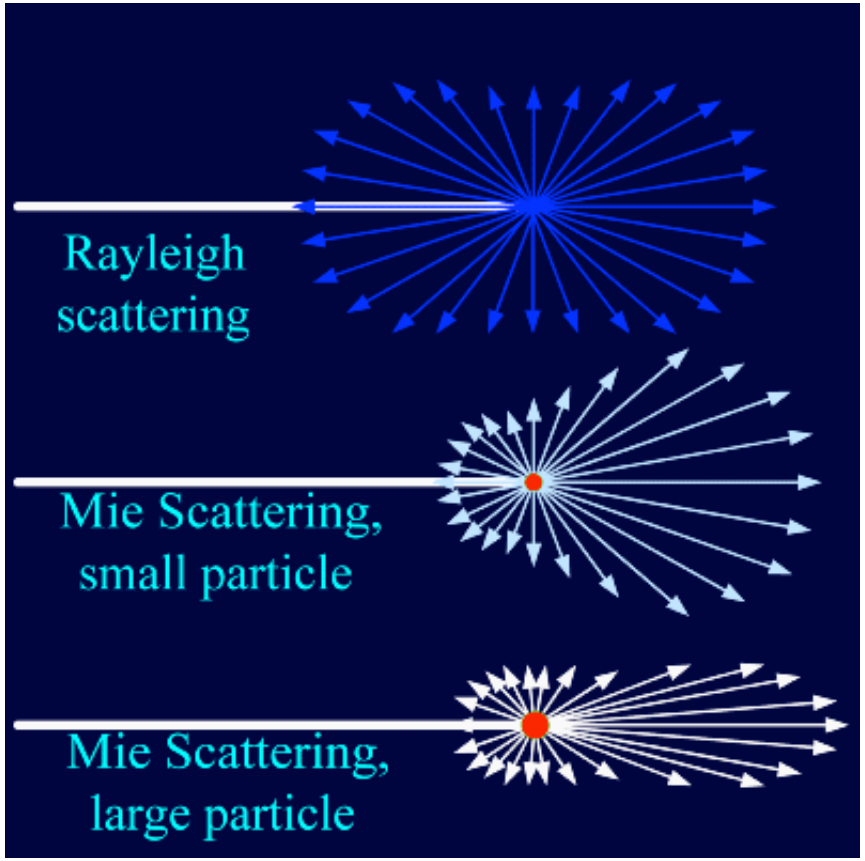


最轻的固体气凝胶“蓝烟”：當彗星微粒撞擊到氣凝膠時，會直接埋入其中，氣凝膠則會因為撞擊形成三角錐狀的長形洞穴，減緩微粒飛行的速度，使微粒停止運行，不會因為撞擊而遭破壞。並且在透明的氣凝膠中可直接進行觀測，以確定其飛行的方向。最後，再把微粒帶回地球做進一步的分析。From https://scitechvista.nat.gov.tw/c/s9s0.htm

Rayleigh Scattering – blue color

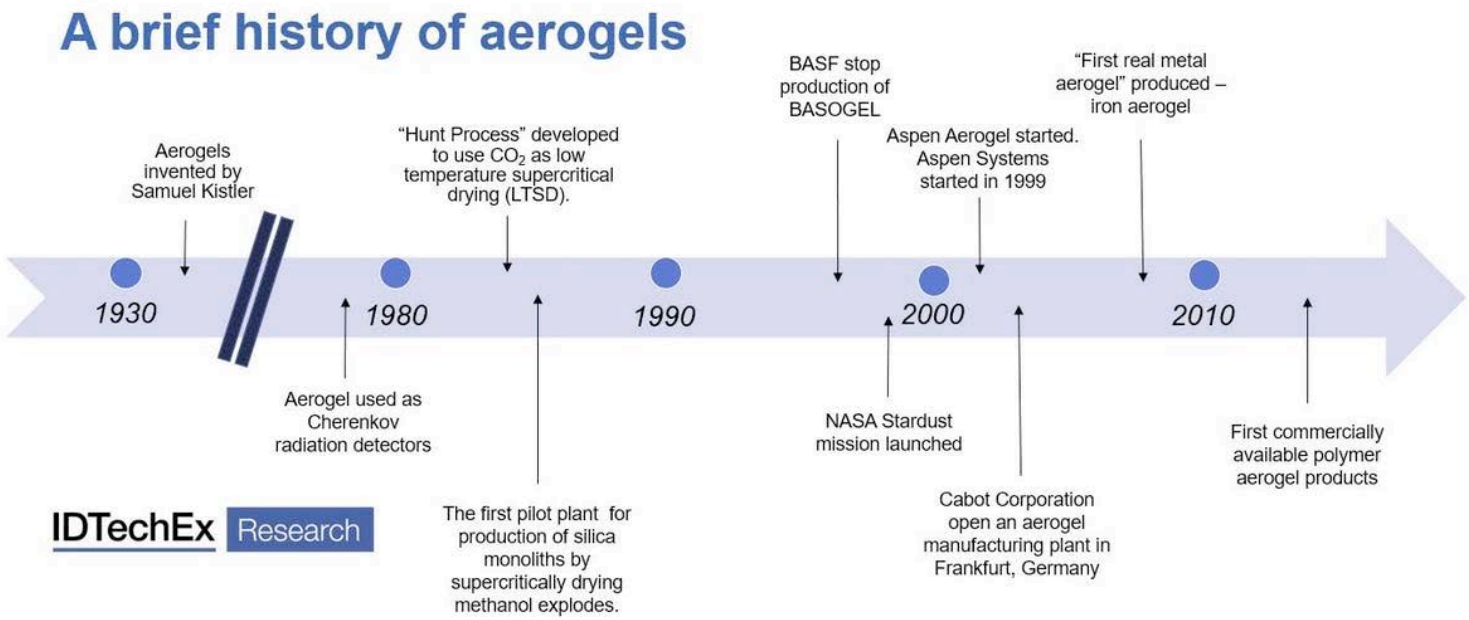






气凝胶 (from Wikipedia)

- 氣凝膠（Aerogel）是目前已知密度僅次於全碳气凝胶的物質。它是由氣體取代液體在凝膠中的位置製造而成。
- Samuel Stephens Kistler在1931年發明氣凝膠。而這一切是因為他與Charles Learned之間的賭注。他們二人當時正比賽誰先將凝膠裡的液體成分用氣體取代卻不使發泡的間壁收縮崩塌。最後Kistler辦到了。
- 物理性质：易碎而坚固的固体、隔热性良好、吸湿



太阳和恒星光谱
内容介绍

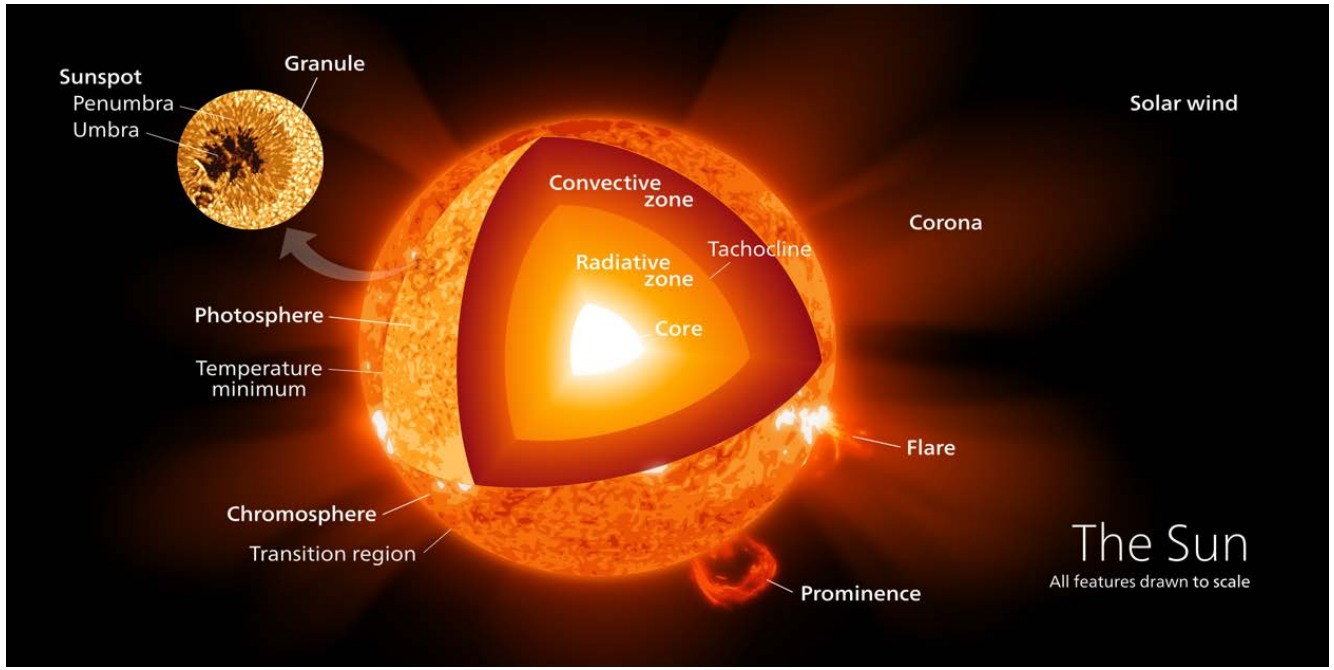
1. 太阳结构，光谱，活动周期
2. 恒星 HR 图，恒星演化
3. 恆星核聚变，超新星爆发和元素起源

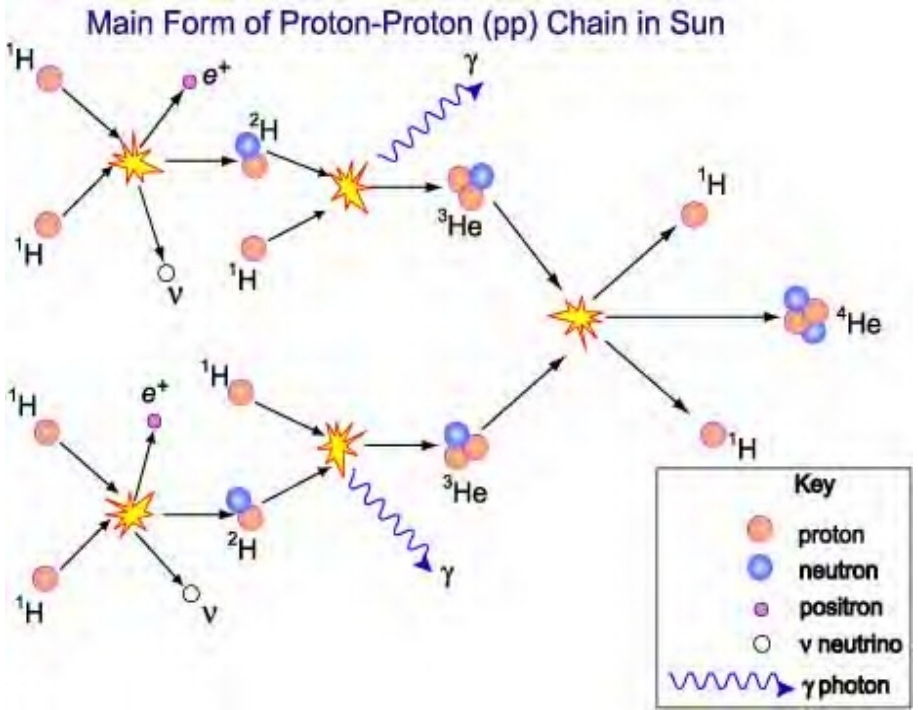
1. 太阳简介

- 太阳系位置：距离银河系中央大约2.5万光年，位于猎户臂，在人马臂和英仙臂之间
- 太阳光谱：G2 型主序星（表面温度5,505°C）

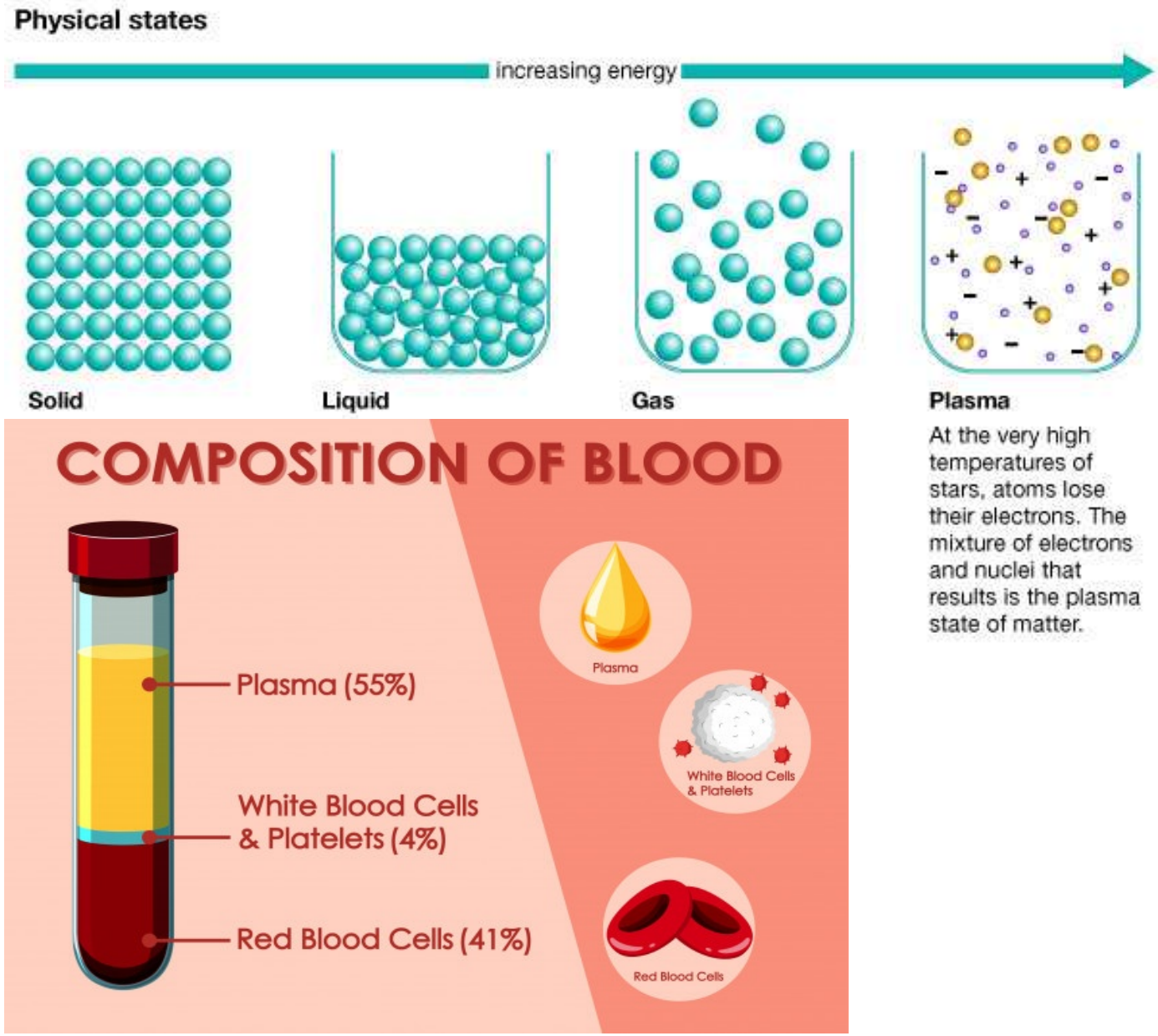
1. 太阳结构

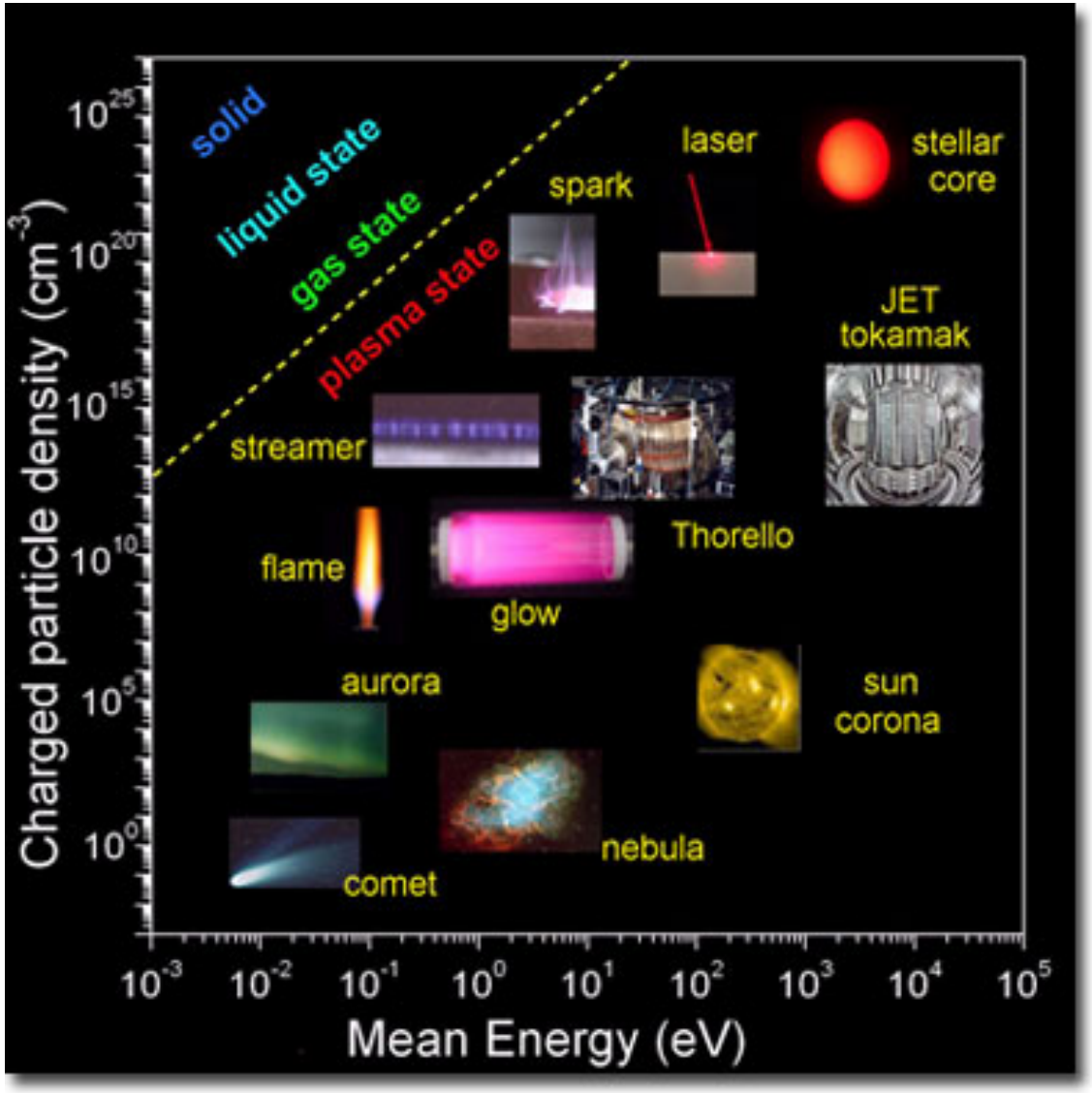
- 化学组成：74% H + 25% He +少量 O, C, Ne, Fe…
- 核 (1,500万K): 致密等离子体
  - 核聚变，产生99% 的太阳能: 功率密度较小，但总功率相当于每秒鐘产生9.192×10^{10} 百万吨TNT炸药爆炸的能量
  - Hydrostatic state: gravity = Gas pressure
- 光球： 太陽可見（对可见光不透明）的表面 ~10–100 km 厚.



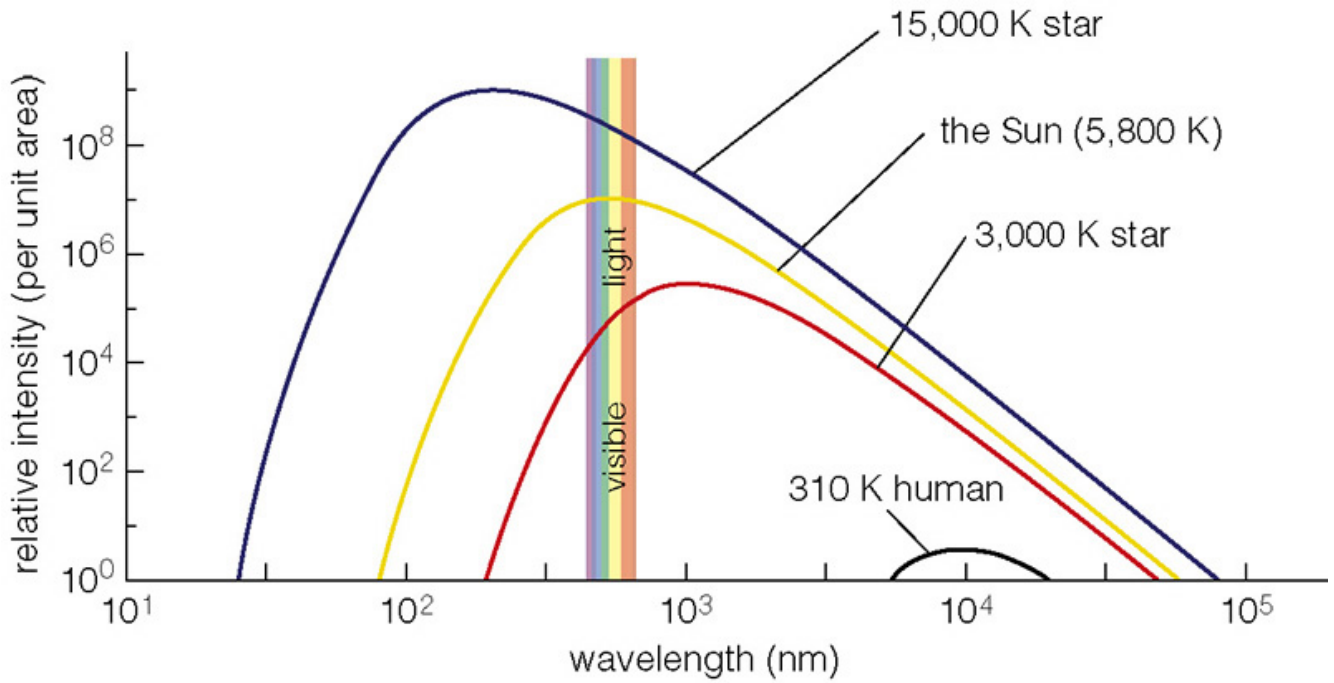


等离子体/电浆 (Plasma)



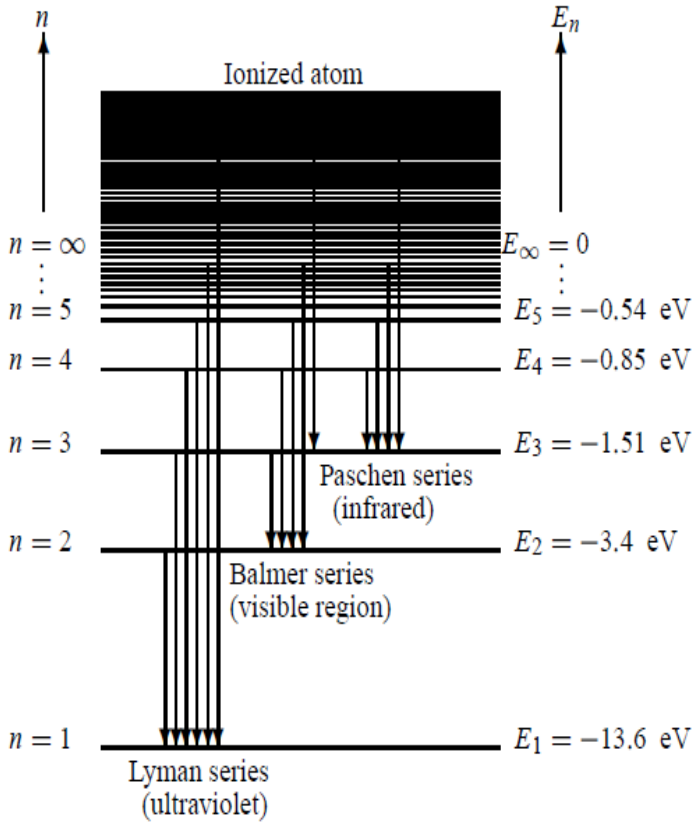


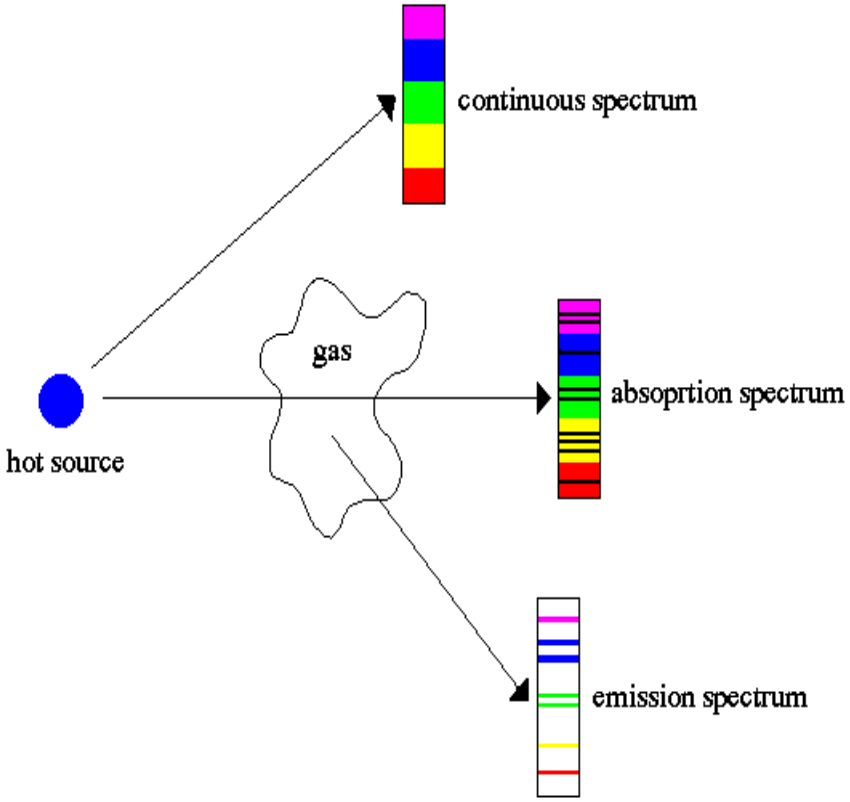
1. 太阳光谱



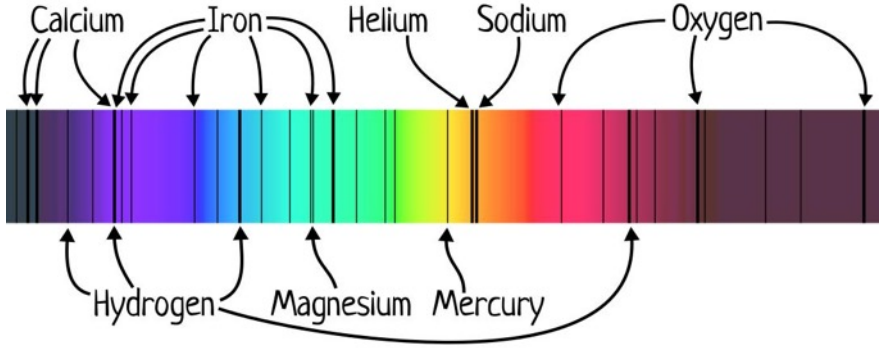
- 黑体：对任何波长的外来辐射完全吸收而无任何反射的物体
- 理想黑体可以吸收所有照射到它表面的电磁辐射，并将这些辐射转化为热辐射，其光谱特征仅与该黑体的温度有关，与黑体的材质无关。
- 普朗克(黑体)辐射定律： $I_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1};$

1. 太阳光谱：吸收线、发射线以及He 的发现





In 1814, **Joseph von Fraunhofer** studied and measured the **dark lines** in the solar spectrum. 45 years later, it was noticed that the lines coincide with the **emission lines** in the spectra of heated elements. The discovery allows us to determine the **composition of the Sun**.

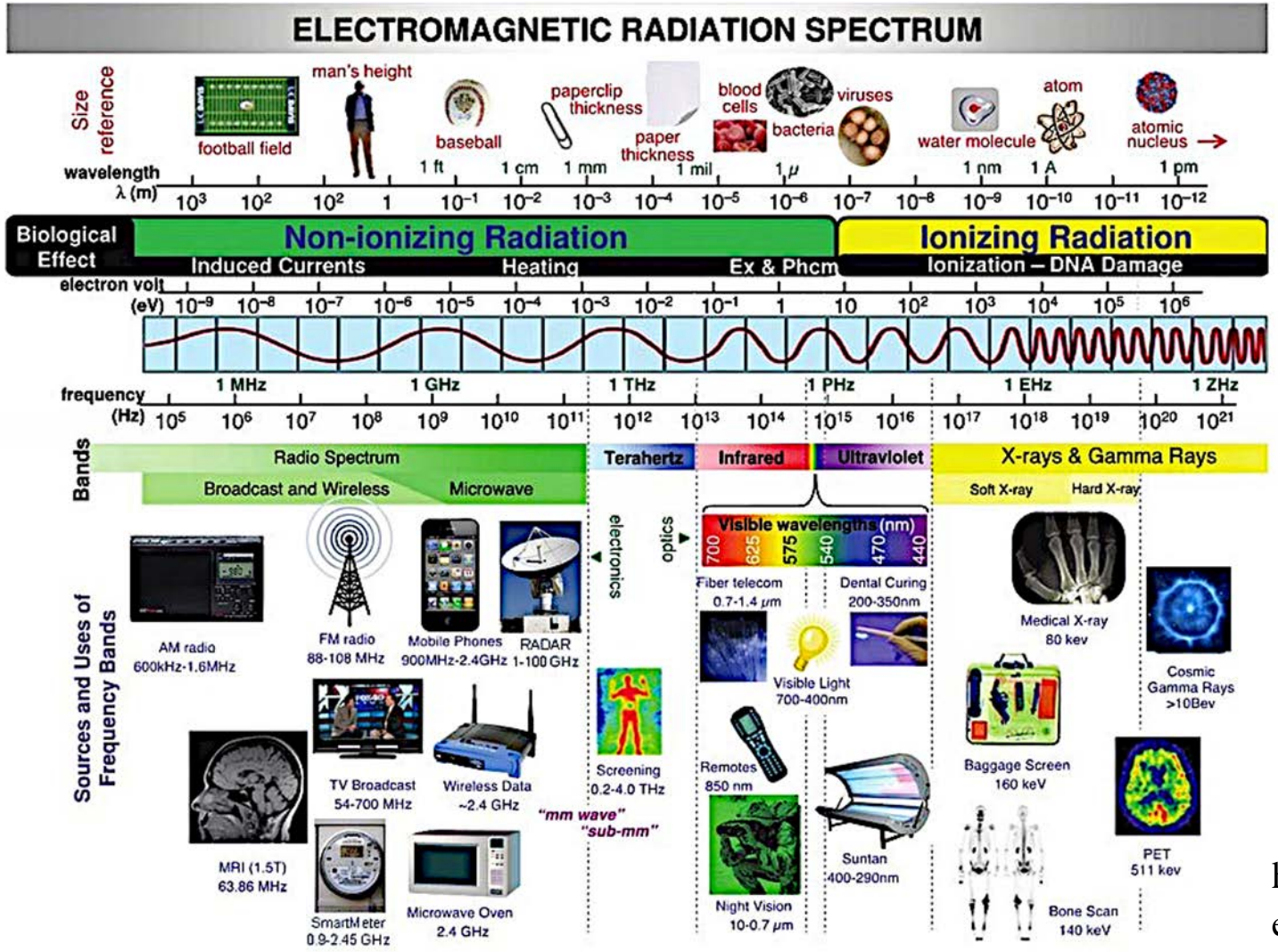


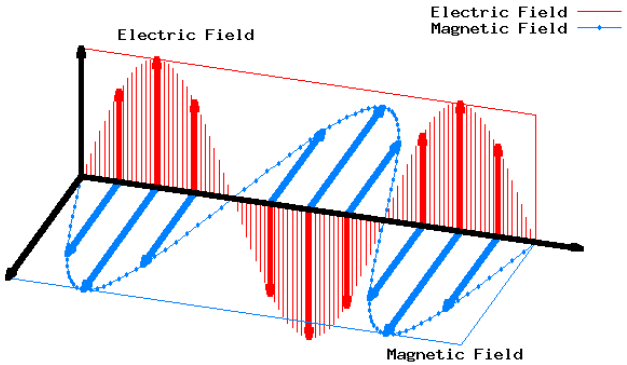
Flat-Earthers are often seen saying that it is impossible to determine the **composition of the Sun** because nobody has visited the Sun before. They are wrong. **Spectroscopy** allows us to study the **composition of the Sun** and other distant celestial bodies **without going there physically**.

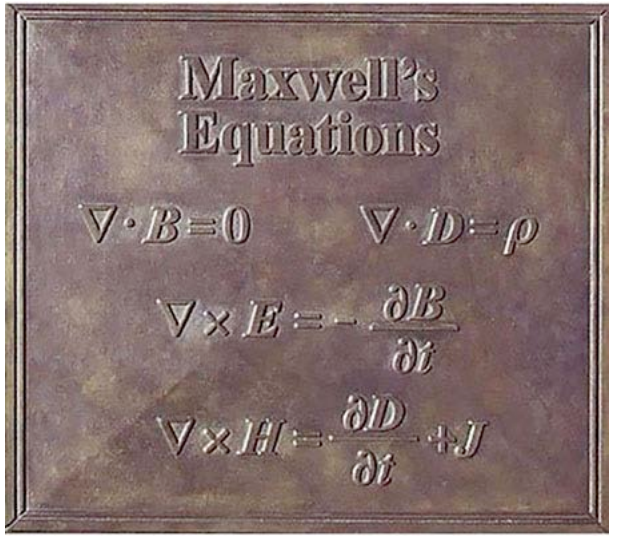
FlatEarth.ws/fraunhofer-lines
Debunking Flat Earth Misconceptions

1. 电磁波 $E = h\nu$

- 光既是一种高频的电磁波，又是一種由称為光子的基本粒子組成的粒子流。因此光同时具有粒子性与波动性，或者说光具有“波粒二象性”

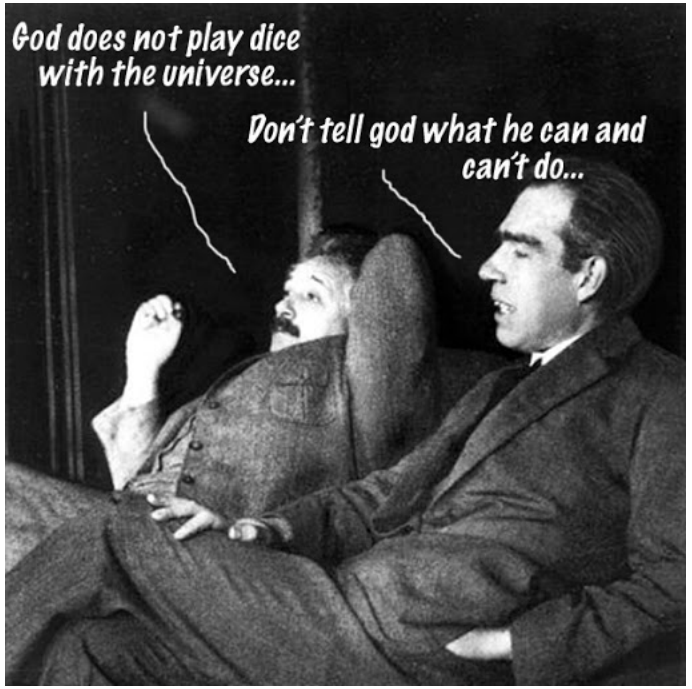






https://steemit.com/steemstem/@alex18/need-for-electromagnetic-radiation-in-daily-life

Great Einstein-Bohr Debate

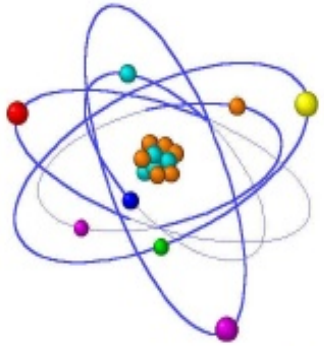


Copenhagen Interpretation

Developed by Niels Bohr in Denmark

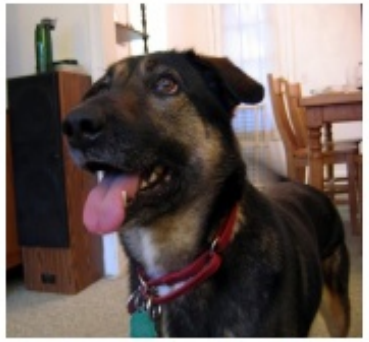
Absolute division between scales

Microscopic:
electrons, atoms, molecules



Obey quantum rules
superposition states

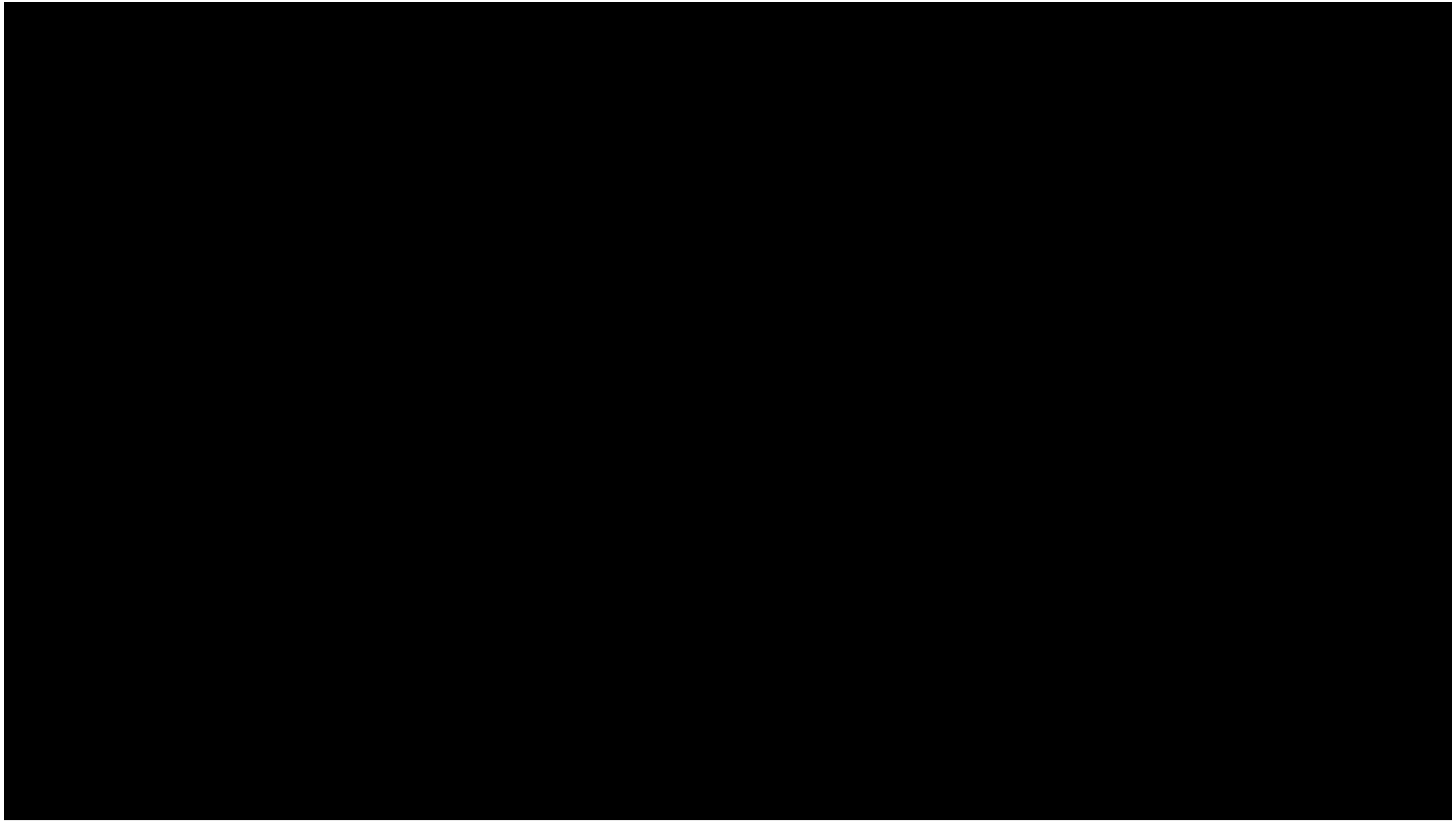
Macroscopic:
dogs, cats, physicists, steak



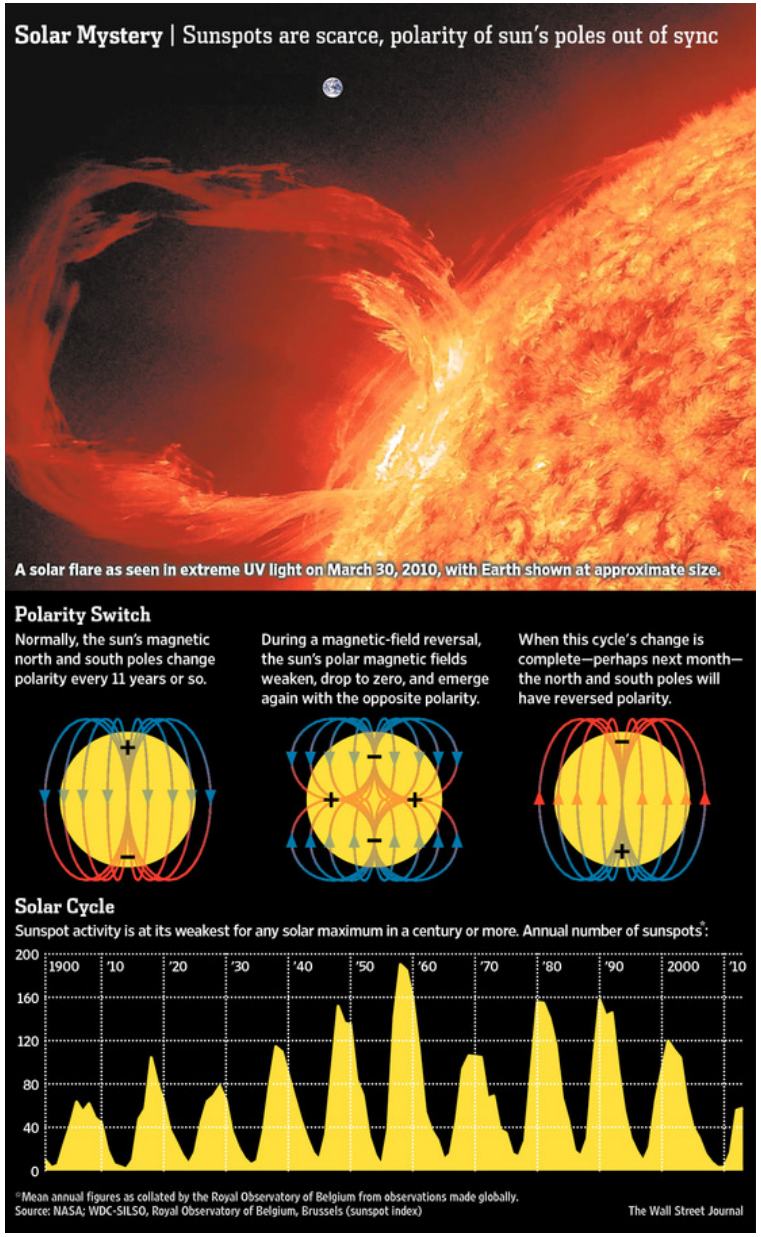
Obey classical rules
no superposition states

UNION COLLEGE

1. 太阳内部的光子运动

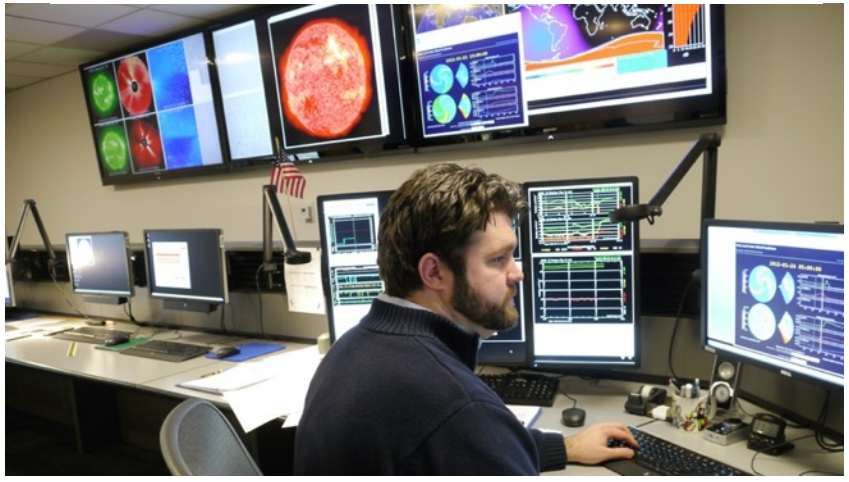


1. 太阳磁场倒转和太阳周期



Space Weather Impact Examples

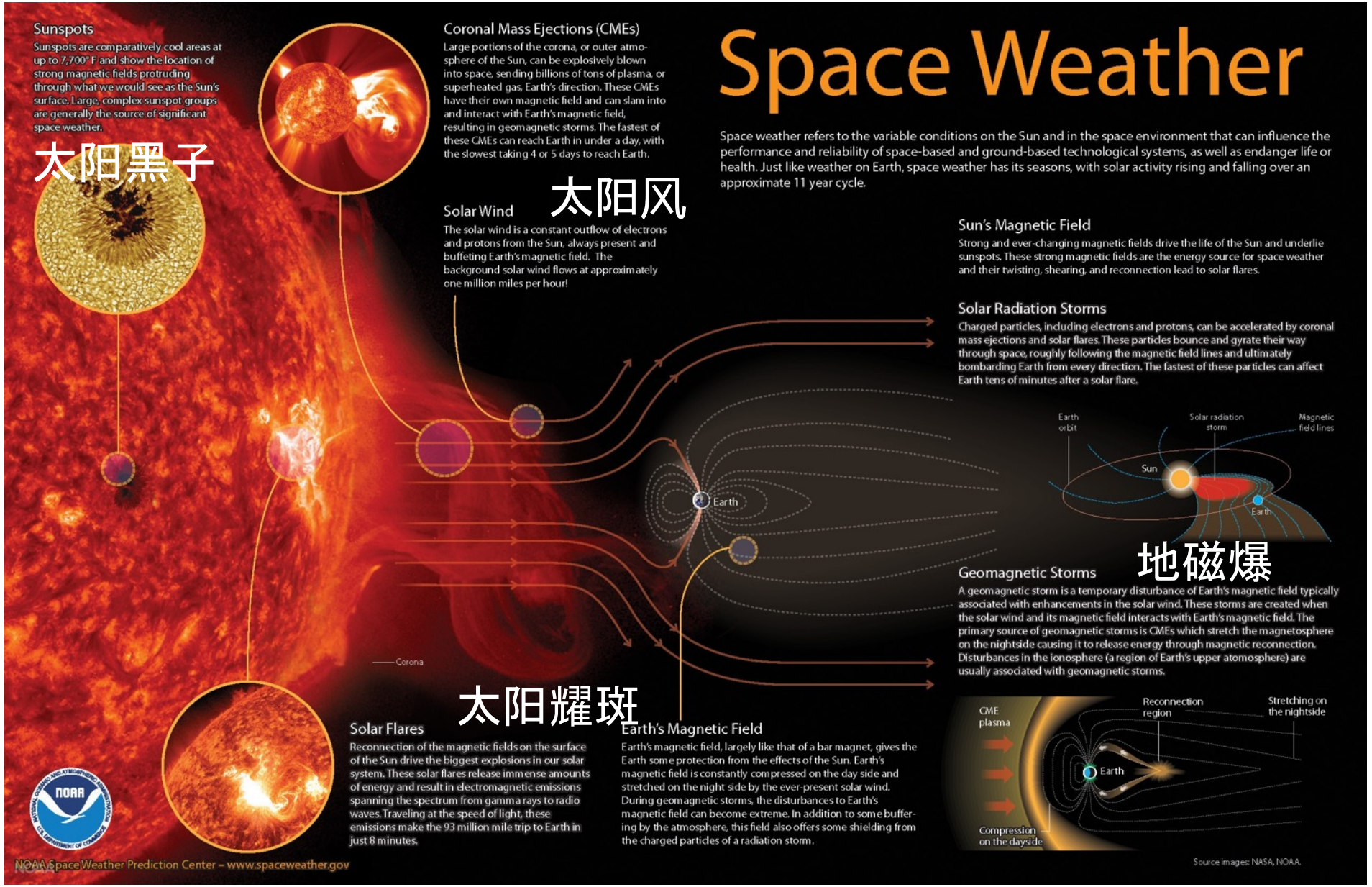
- **1859 (Late August-early September):** The Carrington Event, named for astronomer Richard Carrington who observed the solar flare preceding an historic geomagnetic storm. The storm disrupted telegraph communications around the world and produced aurora seen as far south as Hawaii and Central America.
- **1989 (March):** Quebec plunged into darkness for 9 hours as power grid overwhelmed by geomagnetic storm.
- **2003 (October):** "Halloween Storms" resulted in a 30 hour outage of the Federal Aviation Administration's Wide Area Augmentation System (WAAS), which provides GPS navigation support to aircraft.
- **2005 (January):** United Airlines diverted 26 flights from polar routes to avoid radio blackout potential.
- **2013 (March):** Three separate CME arrivals in March resulted in three separate satellite outages lasting from hours to days.



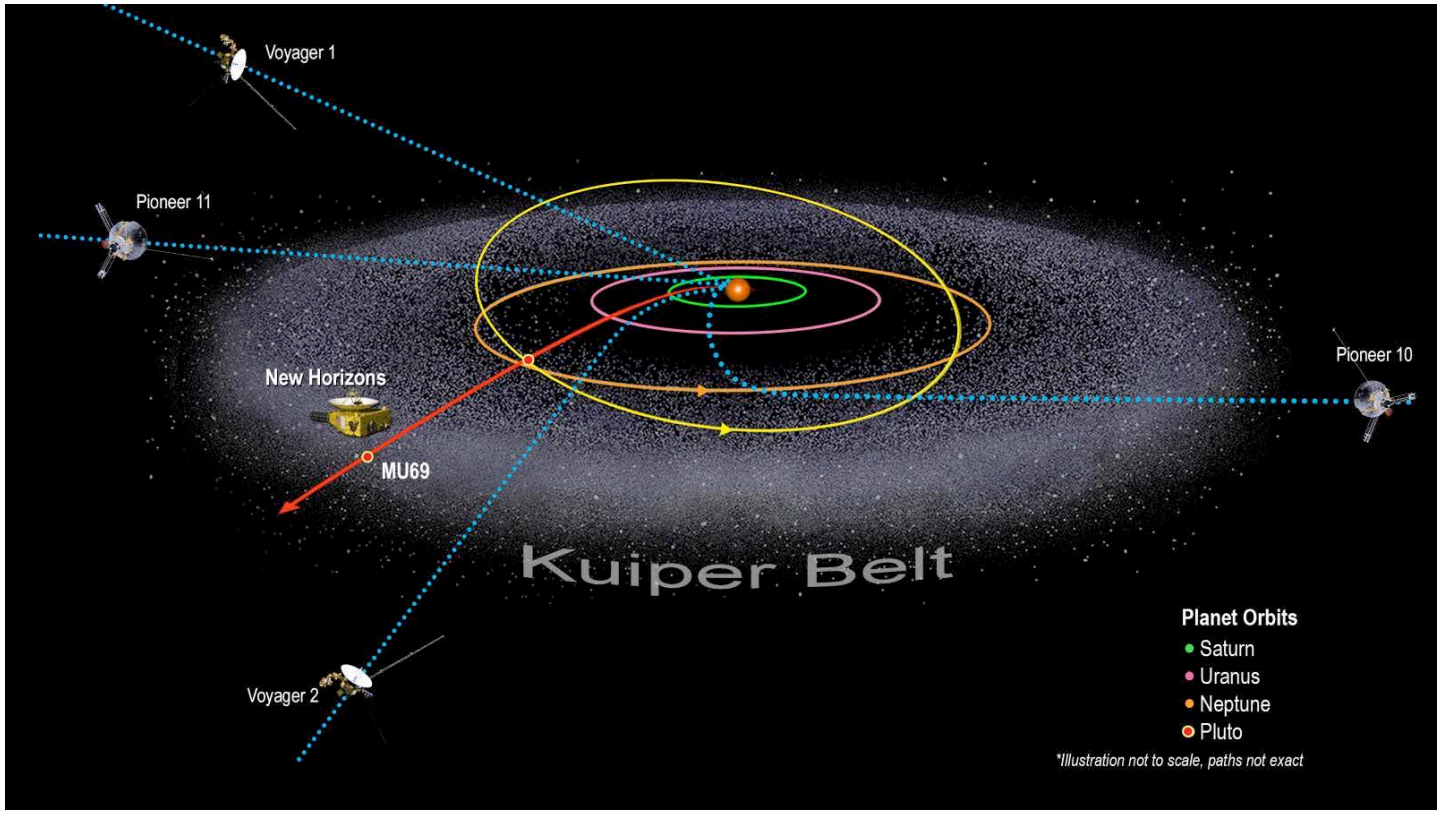
https://www.noaa.gov/explainers/space-weather-storms-from-sun

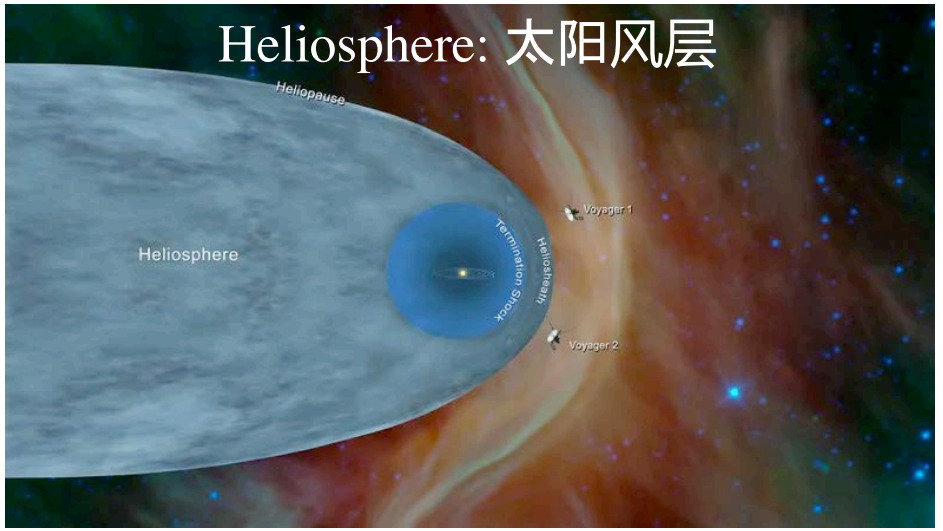
Space Weather

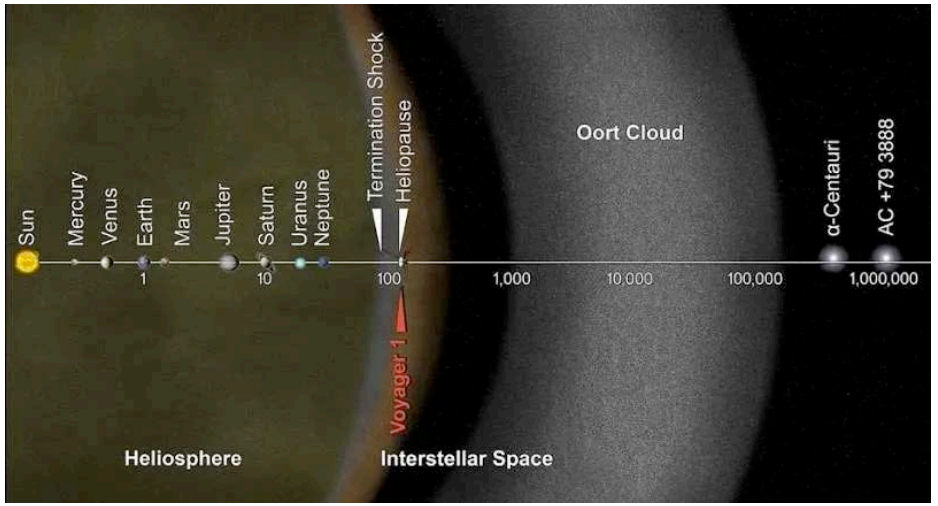
日冕物质抛射



星际空间探测







- Five space probes leaving the solar system, https://ourplnt.com/space-probes-leaving-solar-system/

2. 恒星的种类和演化

恆星是一种天体，由引力凝聚在一起,核心正在进行核聚变的一颗球型发光等离子体

恒星分类：HR 图-光度

- 光度L：恒星单位时间辐射出的总能量
- $L = 4\pi r^2 \sigma T^4$
- 绝对星等M：假定把恒星放在距离地球32.6 光年的位置测得恒星亮度。
- 视星等/视亮度

$$M_{\mathrm{bol},\star} - M_{\mathrm{bol},\odot} = -2.5 \log_{10}\left(\frac{L_\star}{L_\odot}\right)$$

该式逆变换得到：

$$\frac{L_\star}{L_\odot} = 10^{0.4\left(M_{\mathrm{bol},\odot} - M_{\mathrm{bol},\star}\right)}$$

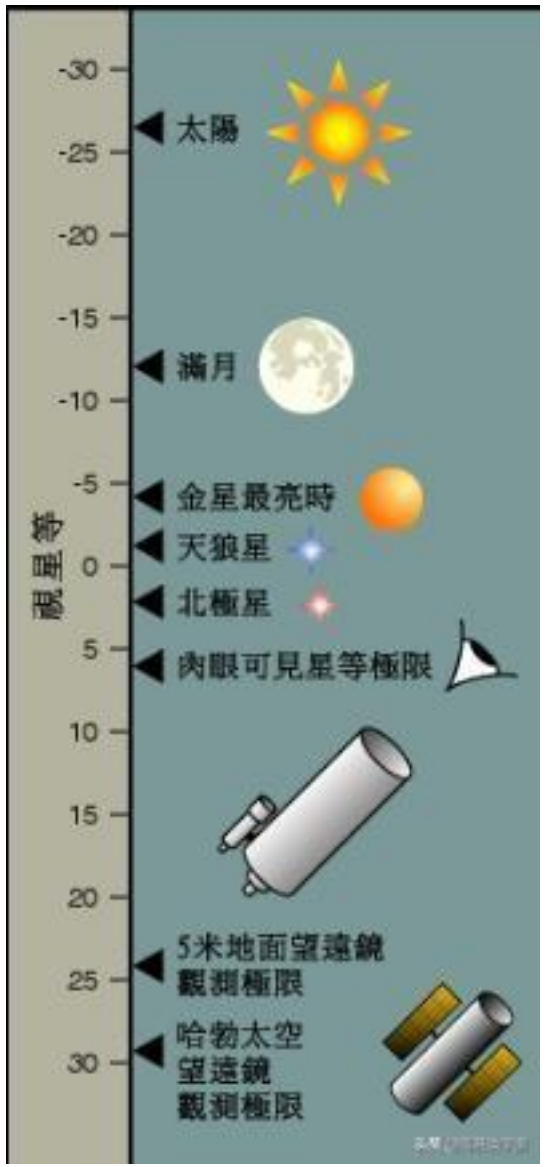
此處

$L_\odot$是太陽的光度（全波段光度）

$L_\star$是恆星的光度（全波段光度）

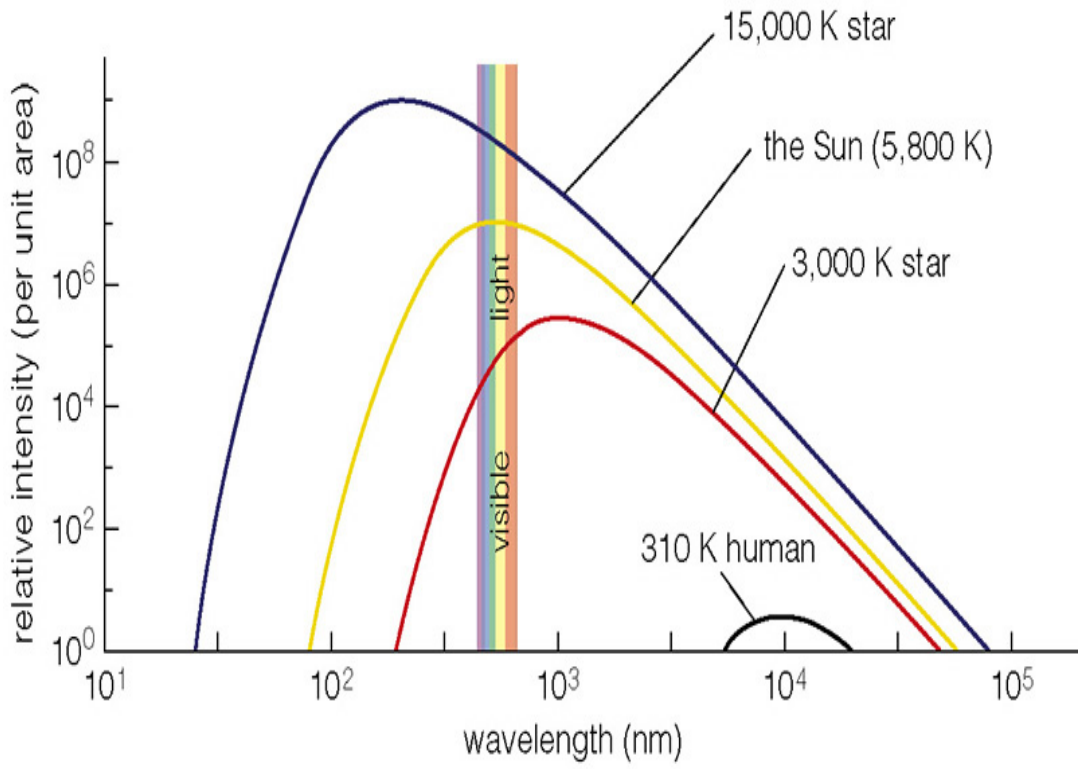
$M_{\mathrm{bol},\odot}$是太陽的全波段星等

$M_{\mathrm{bol},\star}$是恆星的全波段星等。



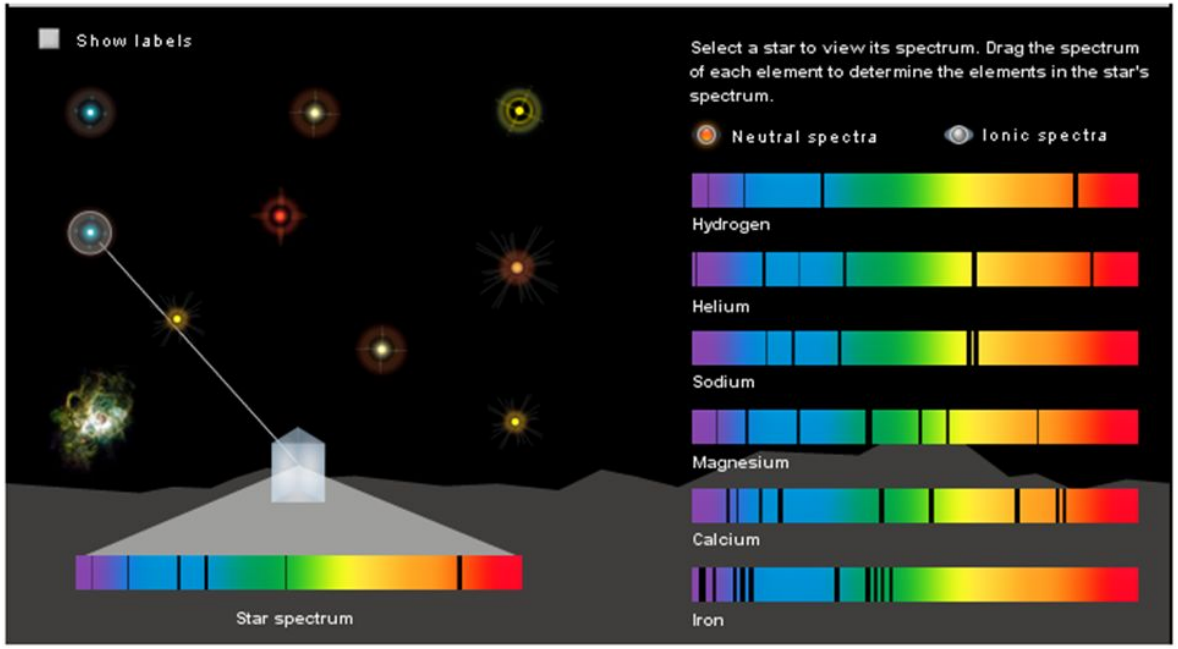
恒星分类：HR 图-表面温度

- Black-body thermal radiation spectrum
- Or use spectrum of the star

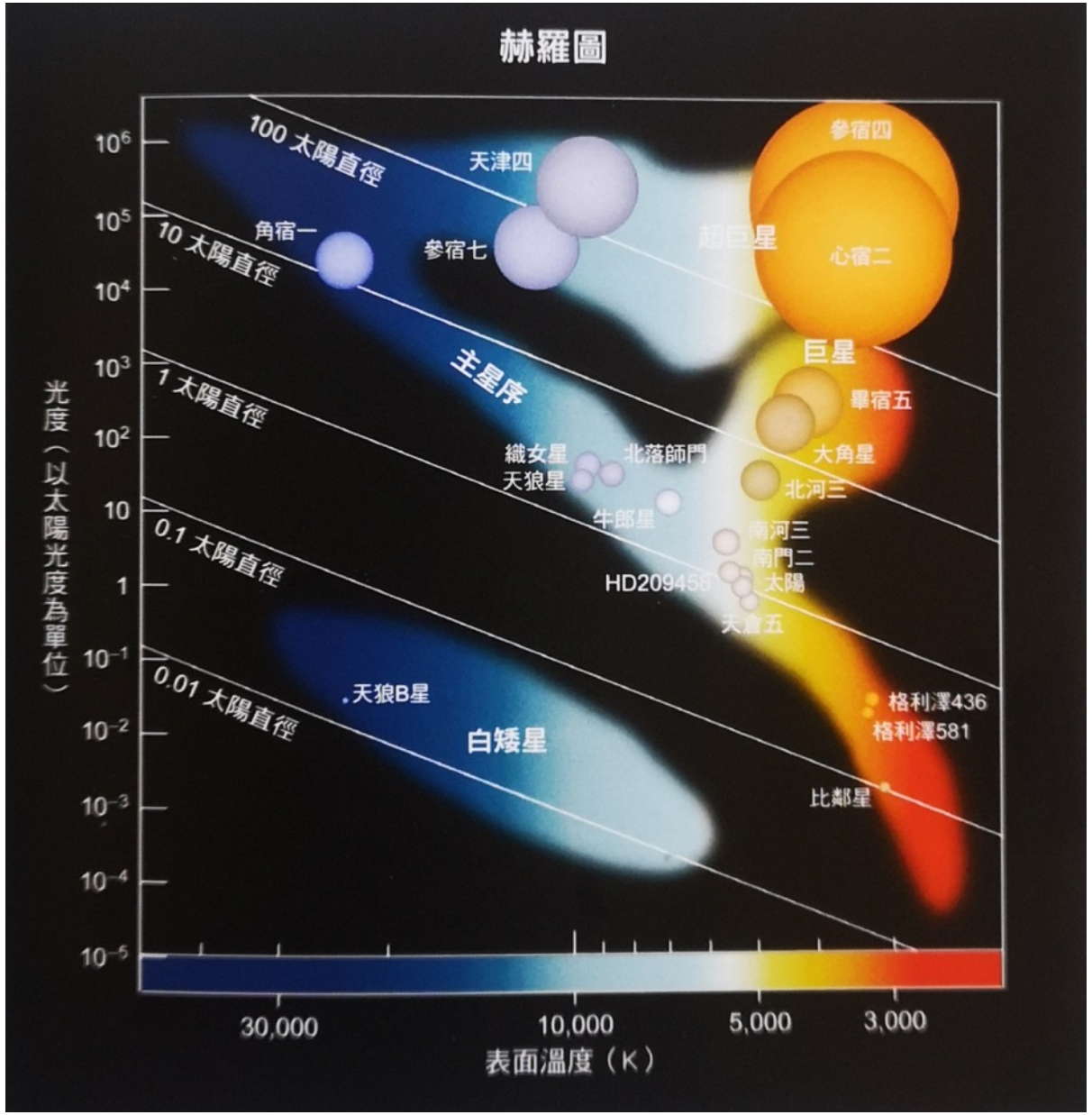


Star Spectrum

- Star spectra contain specific spectral lines. These provide evidence of the elements in the star



恒星分类



Spectral Type	Color	Temperature (K)*	Spectral Features
O		28,000-50,000	Ionized helium,especially helium
B		10,000-28,000	Helium, some hydrogen
A		7,500-10,000	Strong hydrogen, some ionized metals**
F		6,000-7,500	Hydrogen and ionized metals such as calcium and iron
G		5,000-6,000	Both metals and ionized metals, especially ionized calcium
K		3,500-5,000	Metals
M		2,500-3,500	Strong titanium oxide and some calcium

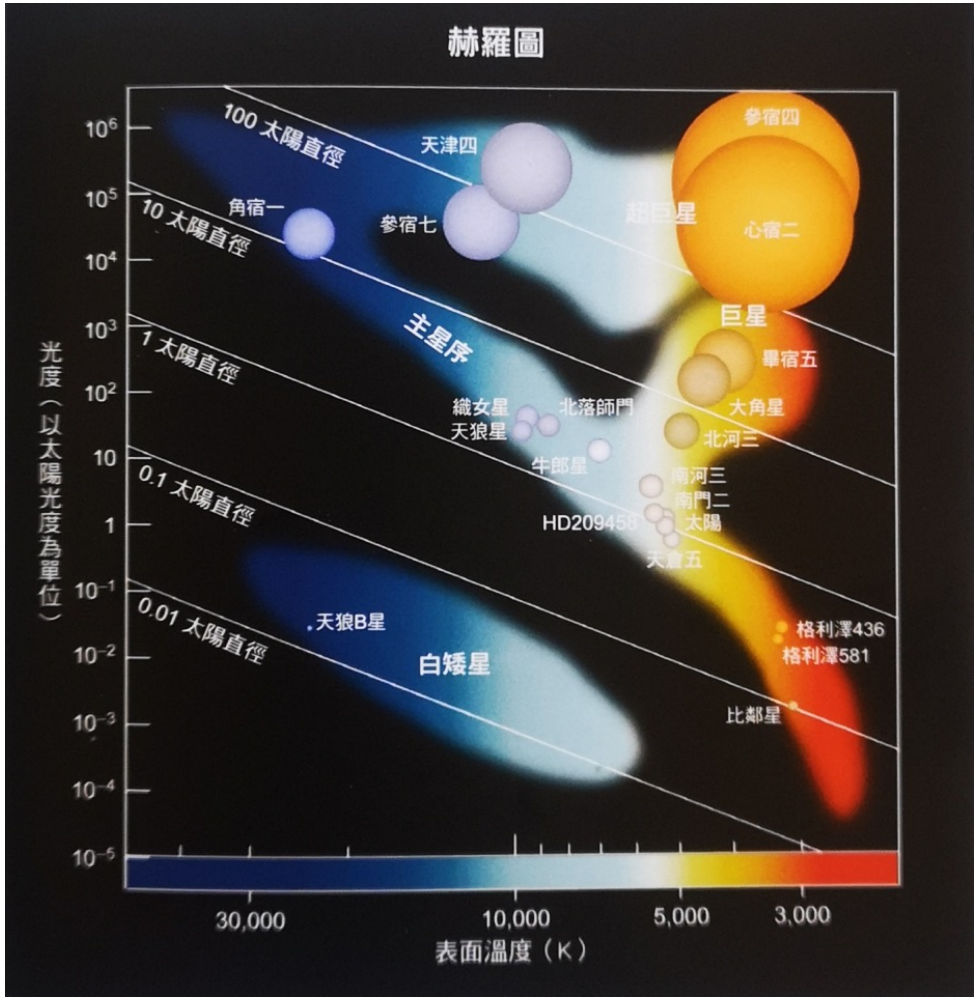
* To convert approximately to Fahrenheit, multiply by 9/5.

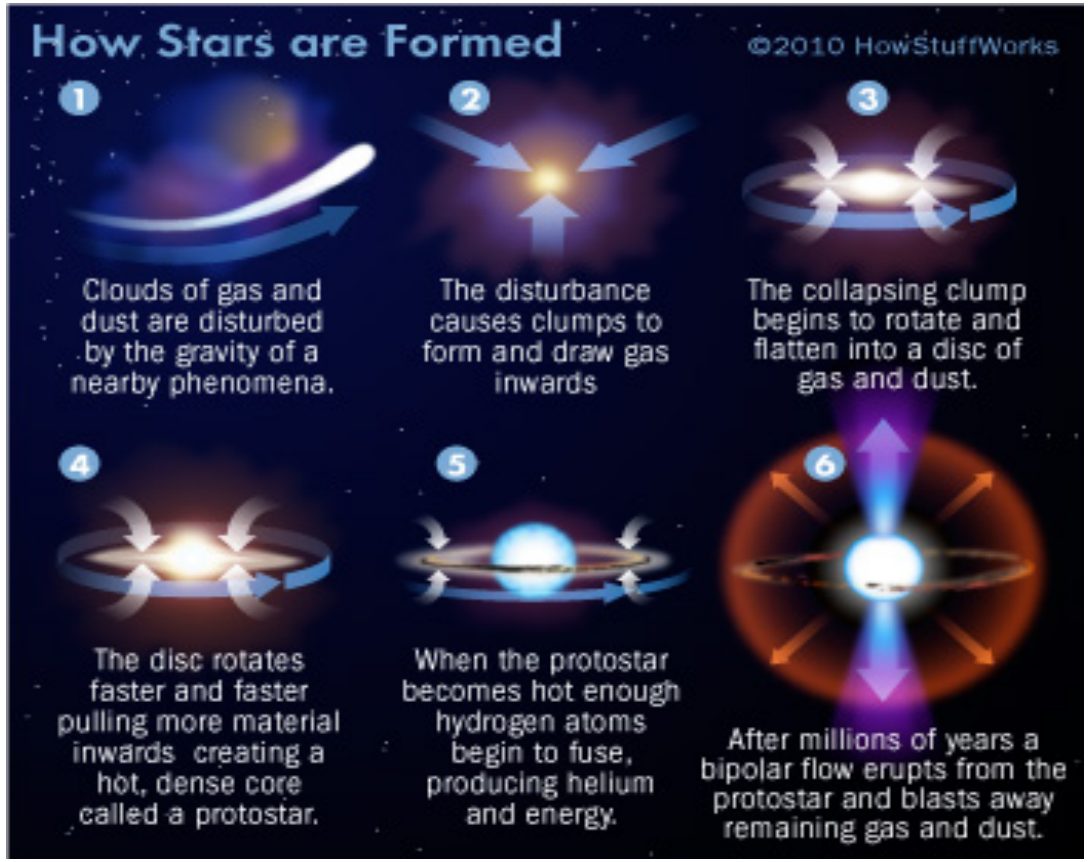
** Astronomers regard elements heavier than helium as metals.

- $L = 4\pi r^2 \sigma T^4$

主星序和恒星的产生

- 在赫羅圖上的恆星絕大多數都位於主序帶的曲線上
- 以氫燃燒為主
- 恆星的生命活躍期幾乎都耗費在這個階段





主序星寿命

估计恒星寿命 T

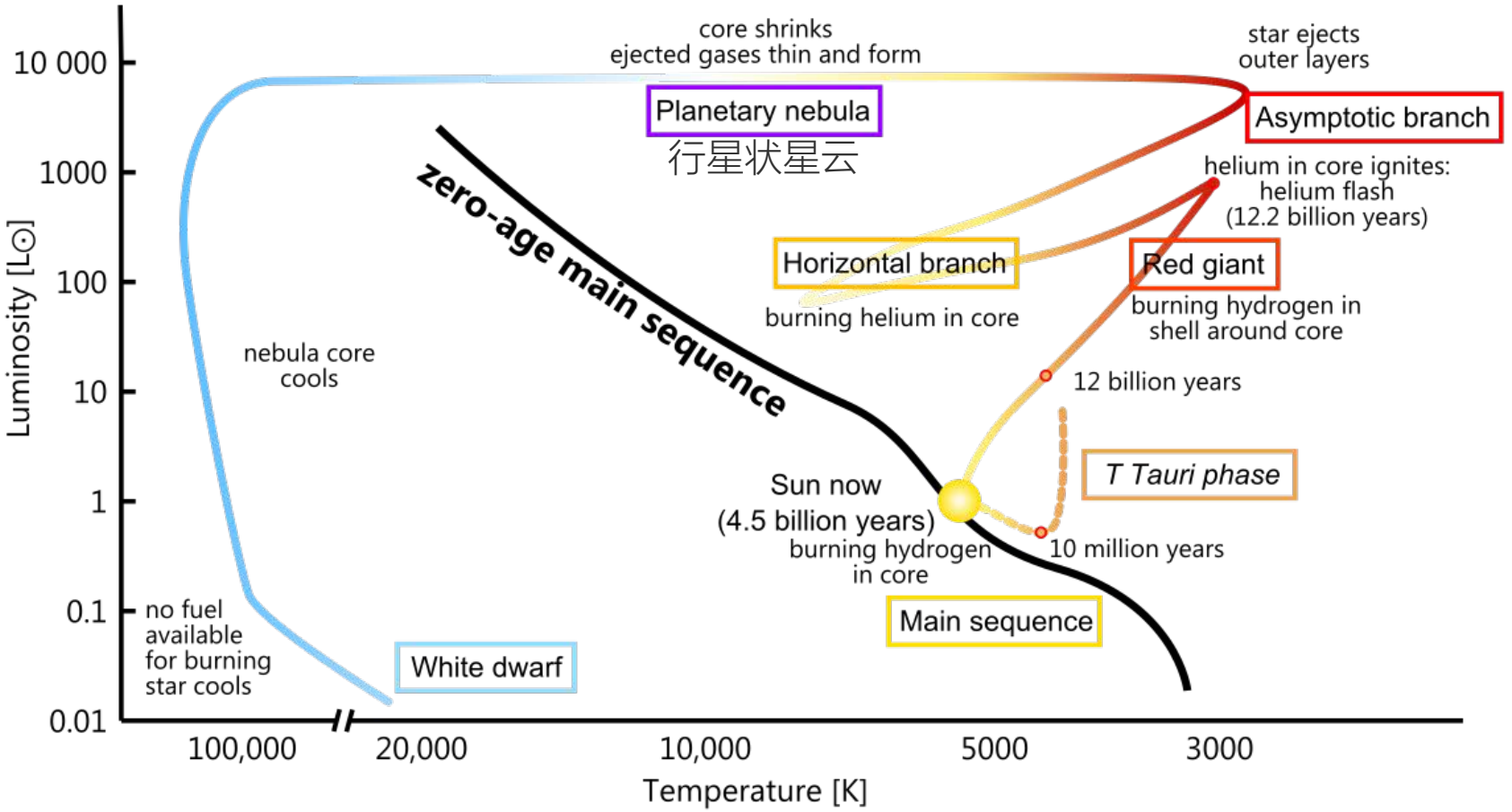
- 燃料是恒星质量：M
- 消耗燃料的速度：光度*L*
- 已知恒星质光关系：$L \propto M^{3.5}$

$\rightarrow T = M/L \propto M^{-2.5}$

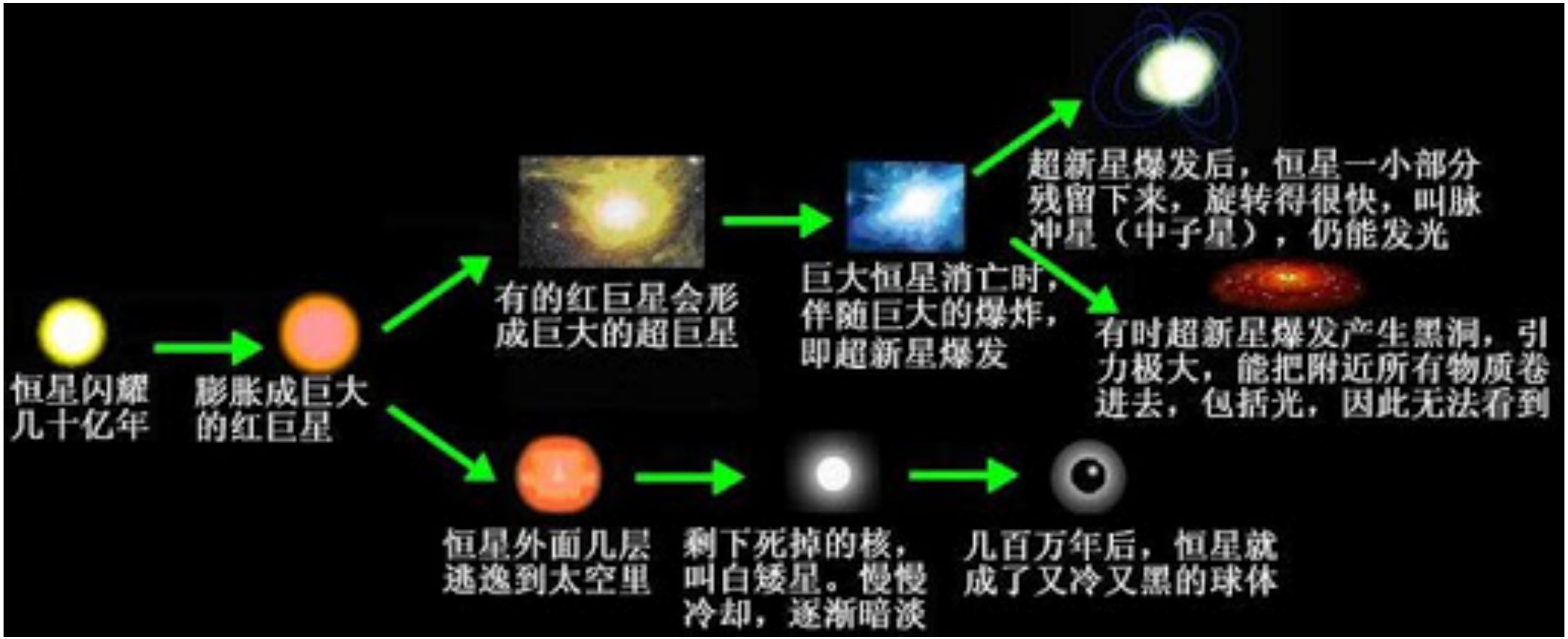
即恒星的质量越大，消耗约快（光度越大，表面温度越高），其主序星寿命越短。

恒星的演化: 太阳的演化

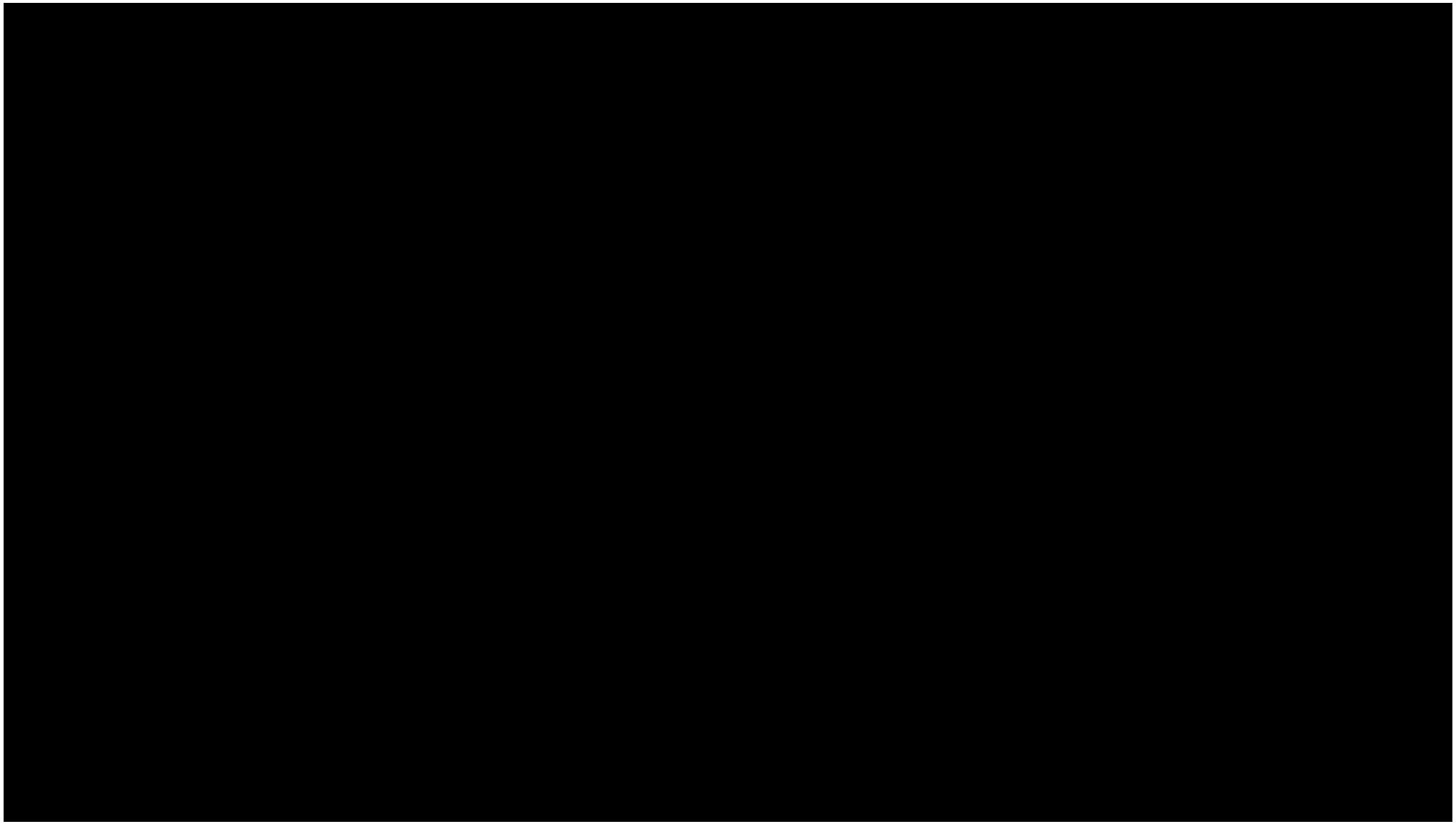
	~9 Ga		~1 Ga		~100 Ma		~10 000 a		
Stage:	Main sequence	>	Red giant	>	Horizontal branch	>	Planetary nebula	>	White dwarf
Sun's age:	4.5 Ga (now)		12.2 Ga		12.3 Ga		12.3305 Ga		12.3306 Ga



恒星演化


恒星闪耀
几十亿年
膨胀成巨大
的红巨星
有的红巨星会形
成巨大的超巨星
巨大恒星消亡时，
伴随巨大的爆炸，
即超新星爆发
超新星爆发后，恒星一小部分
残留下来，旋转得很快，叫脉
冲星（中子星），仍能发光
有时超新星爆发产生黑洞，引
力极大，能把附近所有物质卷
进去，包括光，因此无法看到
恒星外面几层
逃逸到太空里
剩下死掉的核，
叫白矮星。慢慢
冷却，逐渐暗淡
几百万年后，恒星就
成了又冷又黑的球体

恒星演化



恒星演化周期：从星尘到星尘

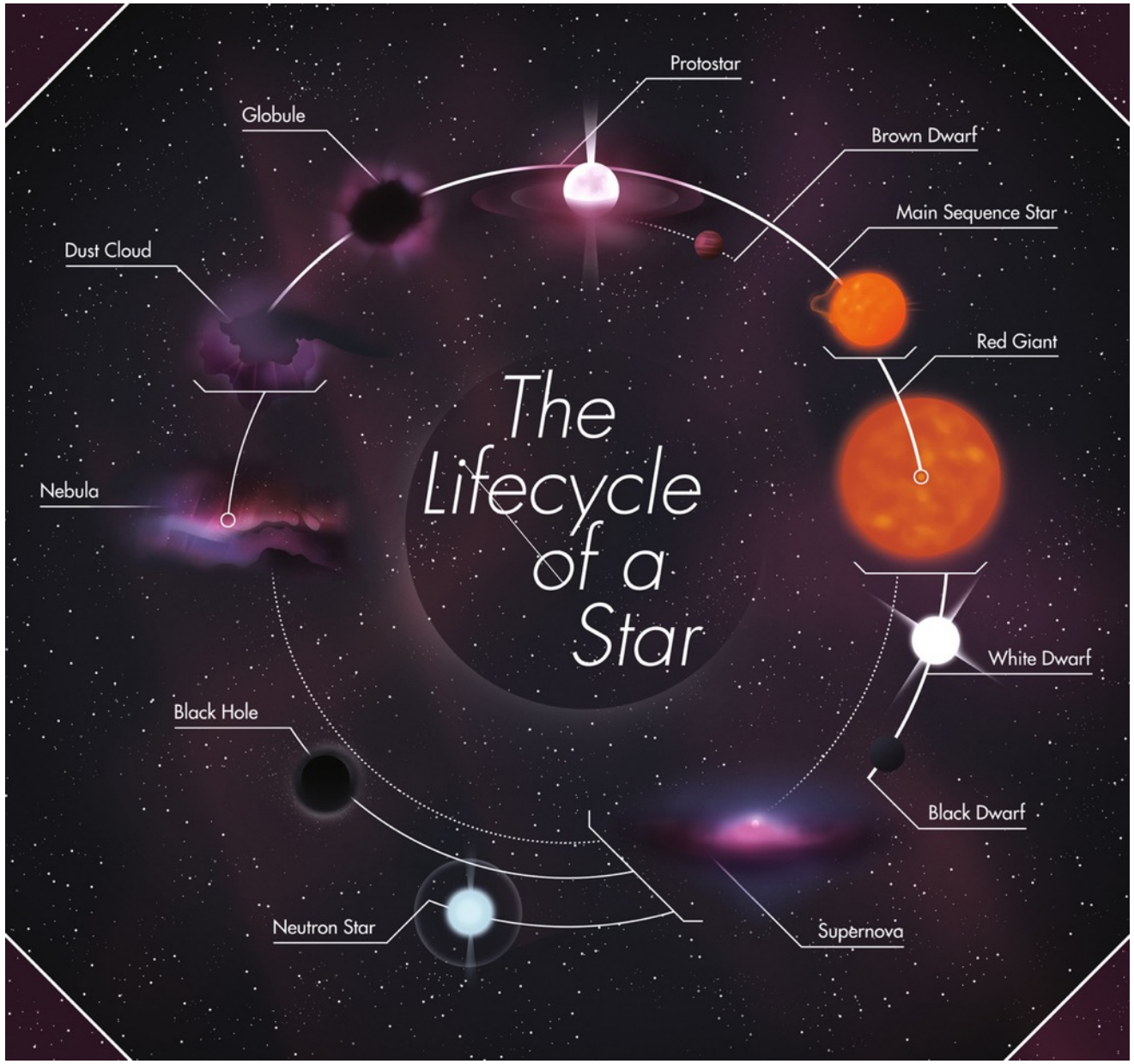
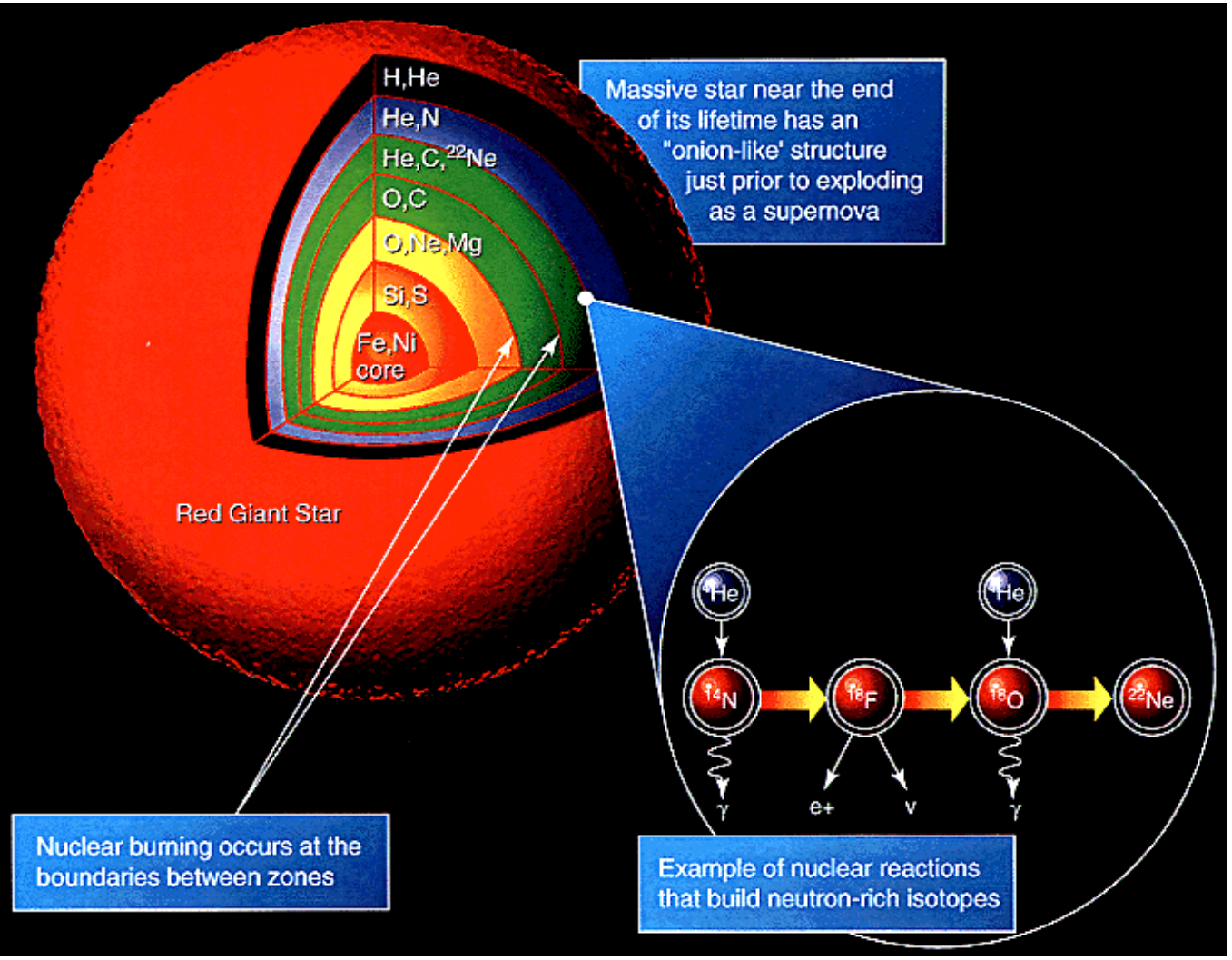


Image: Jack Hughes /Twitter: @jackmrhughes

恒星核聚变

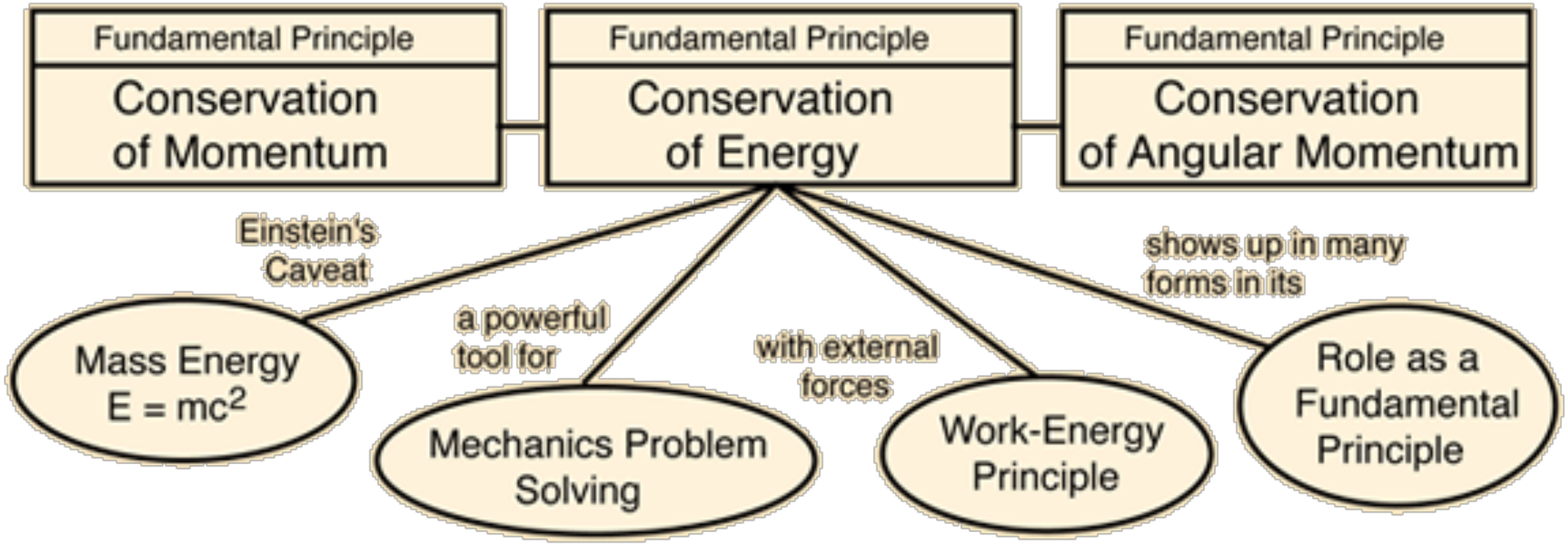


恒星演化时发生的核反应种类与其质量的关系

质 量	发生的核反应
0.08个太阳质量	不发生
0.3个太阳质量	氢燃烧
0.7个太阳质量	氢、氦燃烧
5.0个太阳质量	氢、氦、碳燃烧
10个太阳质量	发生所有的核反应

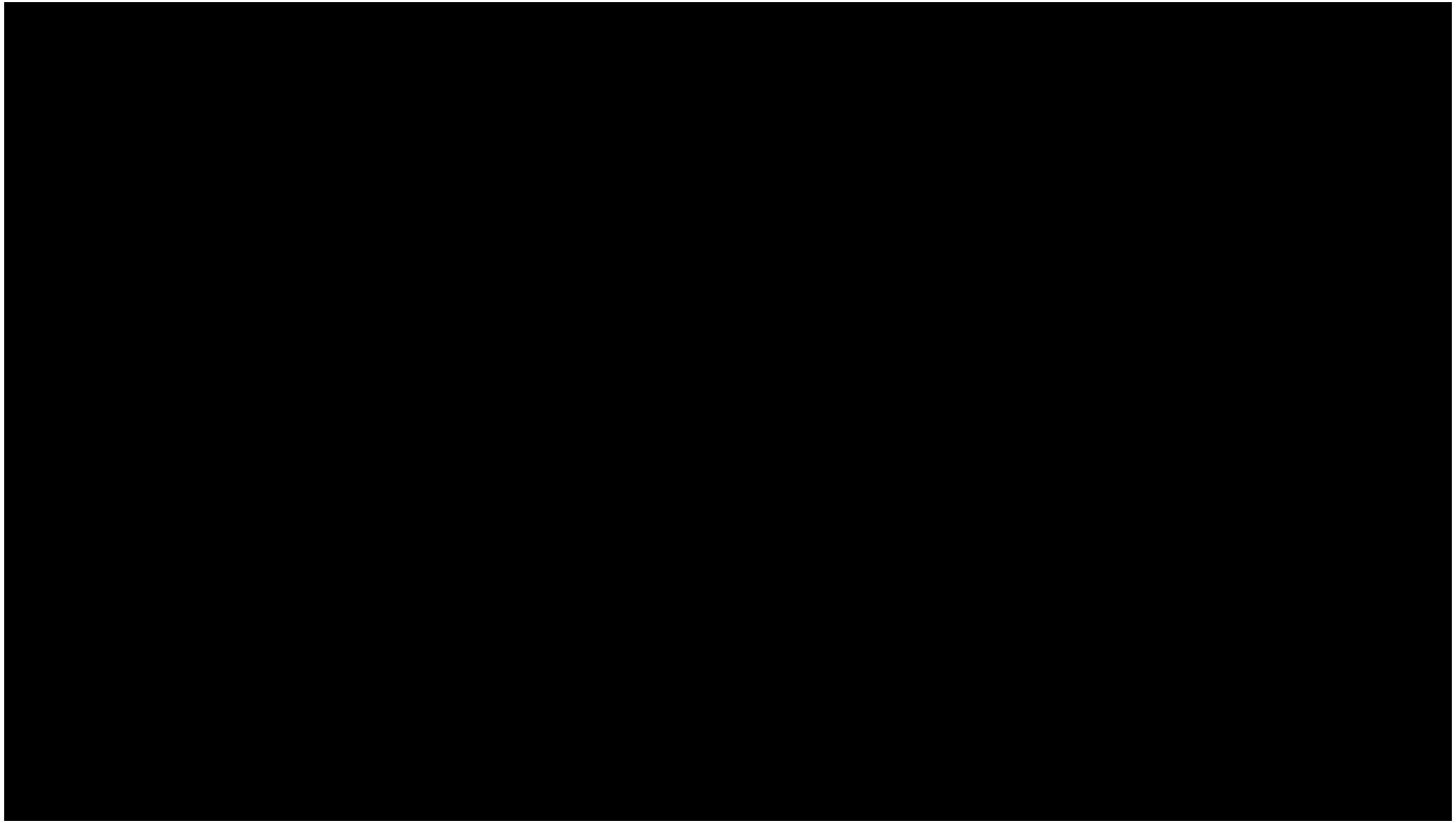
https://www.slideserve.com/patch/agb

守恒定律

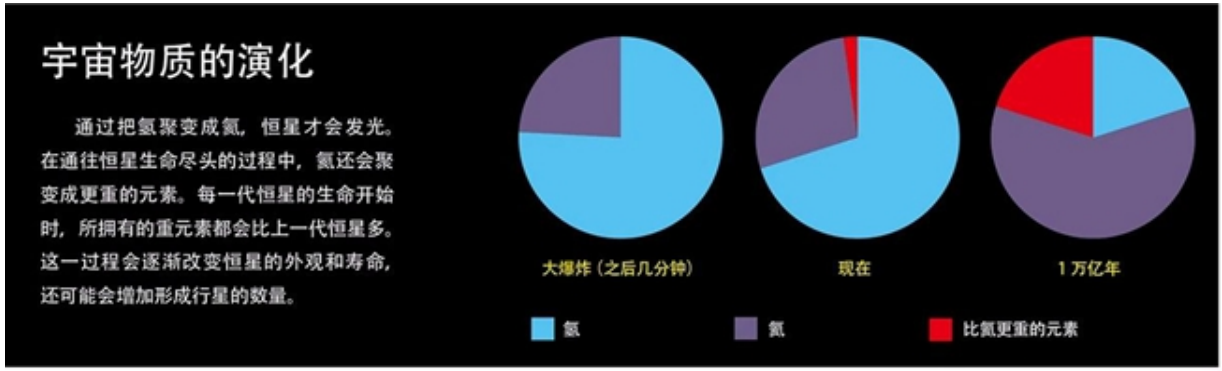


http://hyperphysics.phy-astr.gsu.edu/hbase/conser.html

超新星爆发

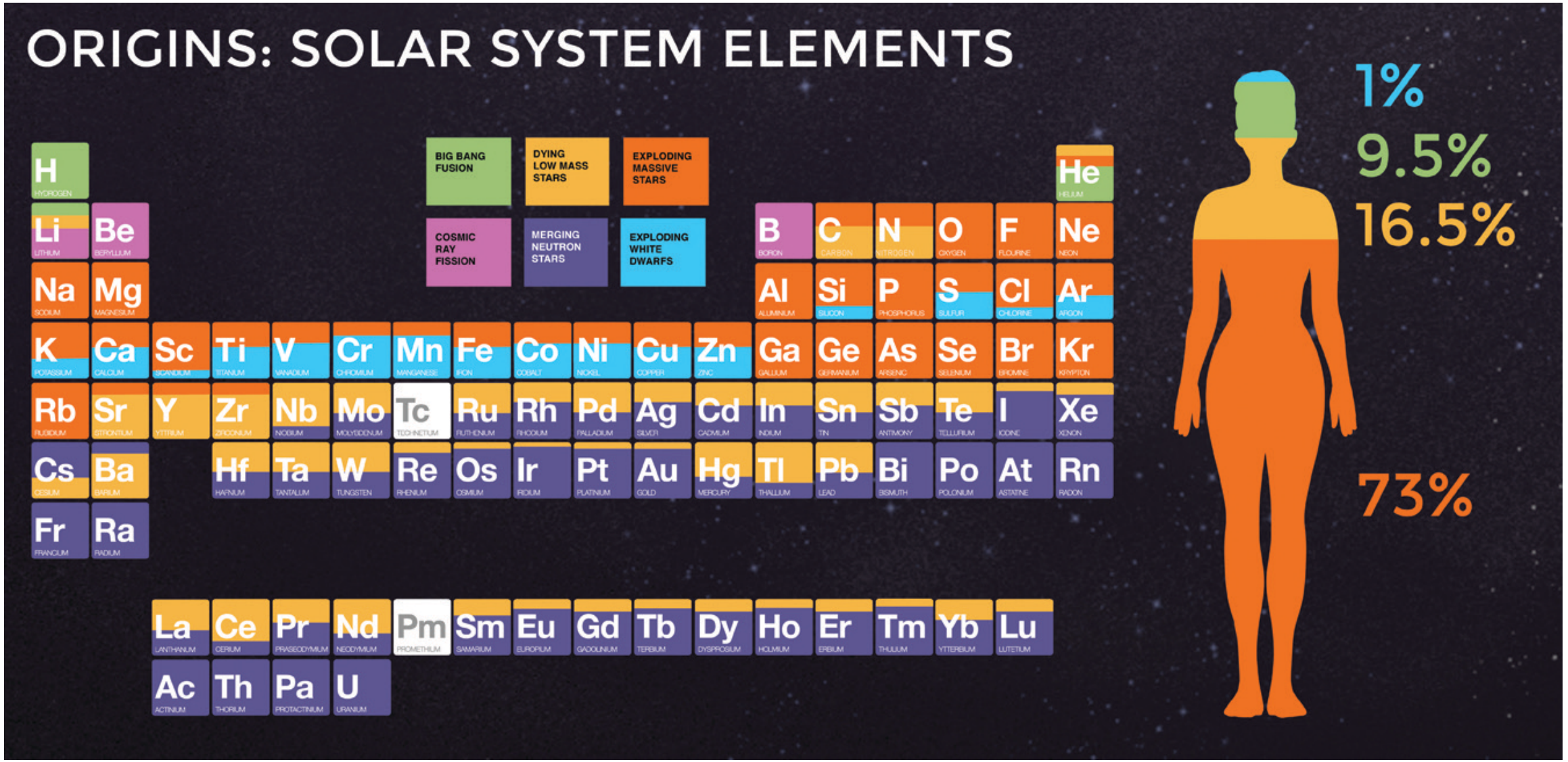


宇宙元素的来源



https://www.meta-synthesis.com/webbook/32_n-synth/nucleosynthesis.html

Conclusion: We Are Stardust



Periodic Table of Elements. Credit: NASA/CXC/K. Divona; Reference: SDSS blog, J. Johnson

Conclusion: 你我皆星尘

- *"The amazing thing is that every atom in your body came from a star that exploded. And, the atoms in your left hand probably came from a different star than your right hand. It really is the most poetic thing I know about physics: You are all stardust. You couldn’t be here if stars hadn’t exploded, because the elements - the carbon, nitrogen, oxygen, iron, all the things that matter for evolution - weren’t created at the beginning of time. They were created in the nuclear furnaces of stars, and the only way they could get into your body is if those stars were kind enough to explode. So, forget Jesus. The stars died so that you could be here today."——Lawrence M. Krauss『A Universe from Nothing』*

Home Activities

- **Citizen Science: https://www.zooniverse.org/projects?discipline=astronomy&page=1&status=live**
- **Apollo 13 in Real Time: https://apolloinrealtime.org/13/**

Credit:NASA, ESA and the Hubble Heritage Team (STScI/AURA)-ESA/Hubble Collaboration

Butterfly emerges from stellar demise in planetary nebula NGC 6302
Credit:NASA, ESA and the Hubble SM4 ERO Team

References

1. 未注明出处图片来自 Wikipedia
2. Welcome to the Universe: An Astrophysical Tour, by Neil deGrasse Tyson, Michael Strauss, J. Richard Gott

Videos

1. 科学交响曲 我们都是星尘 We Are Star Dust https://www.bilibili.com/video/av15393792/
2. Sunlight is older than you think, https://www.youtube.com/watch?v=Z-UO-RZBQ3U
3. 【天文17】氦闪是什么？太阳的宿命会是黑洞吗？恒星的演化过程 https://www.youtube.com/watch?v=w93inHZt32I
4. 【天文18】什么是超新星爆发？重元素从何而来？消失的中子星之谜 https://www.youtube.com/watch?v=qResw4tuqns
5. 薛定谔的猫：量子力学里的理想试验 https://www.ted.com/talks/chad_orzel_schrodinger_s_cat_a_thought_experiment_in_quantum_mechanics/transcript?language=zh-cn#t-145764