

Midterm Topics (next Monday, Sept. 23)

1. Scientific units, notations
2. Exponents, trigonometry
3. Length scales in the universe, astronomy units
4. Eratosthenes: radius of the Earth
5. Retrograde motion of the planets, epicycles
6. Earth's axis tilt, seasons, precession
7. Important stars and constellations
8. Kepler's Laws
9. Galileo's & Newton's contributions
10. Newton's laws
11. Conservation laws: Energy, momentum, angular momentum
12. Kinetic & Potential Energy

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11. Conservation laws: Energy, momentum, angular momentum
12. Kinetic & Potential Energy
13. Gravity
14. Circular Motion
15. Escape velocity
16. Tides
17. Electromagnetic waves
18. Electromagnetic spectrum
19. Blackbody radiation
20. Photons
21. Electronic structure of atoms
22. Spectroscopy
23. Doppler effect
24. Today's topics

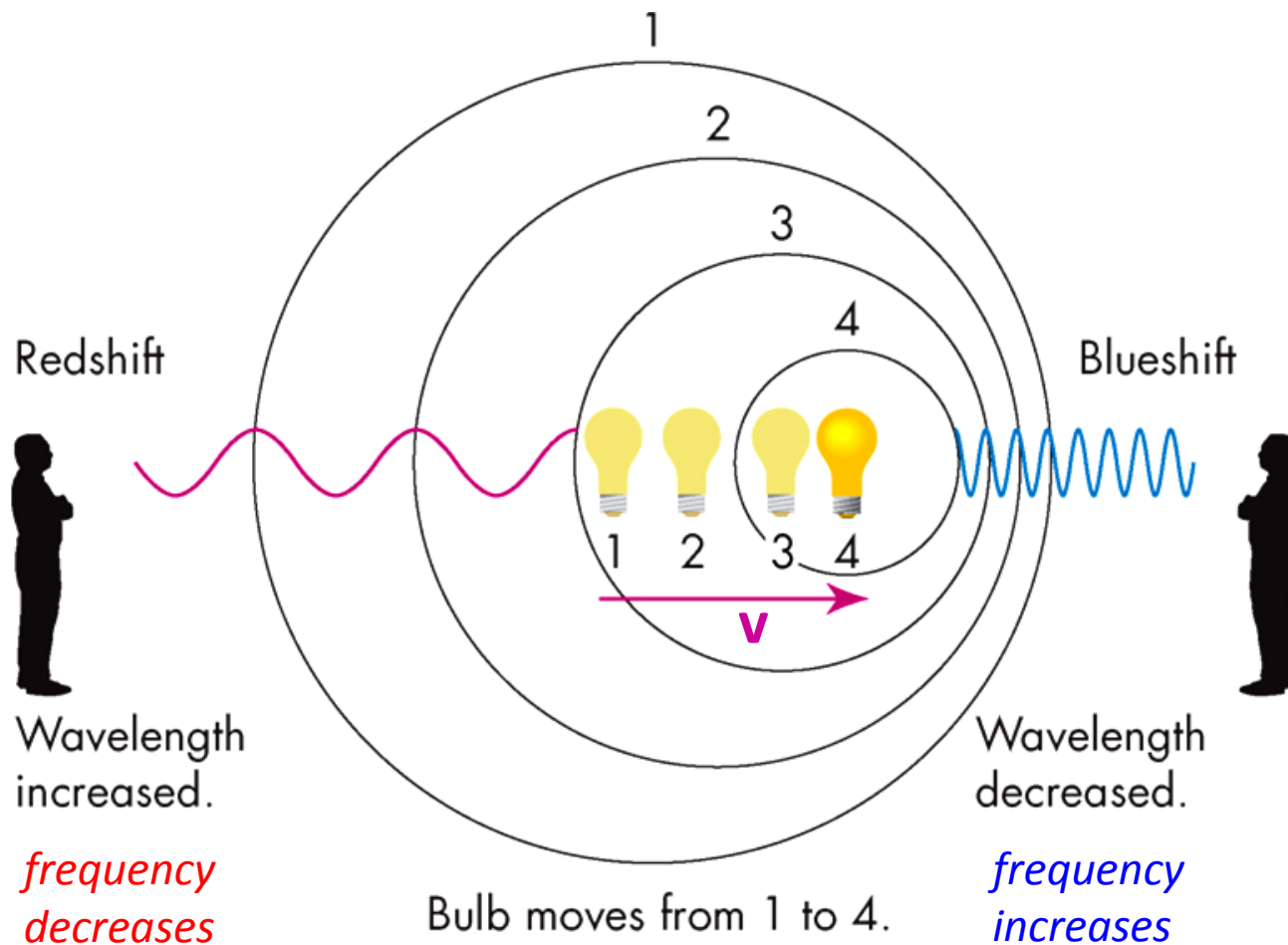
Today's Topics

Friday, September 20, 2019 (Week 3, lecture 10) – Chapter 5, 16.1-2.

1. Doppler Effect
2. Nuclear Particles, Isotopes
3. Solar fusion basics

Doppler Effect

A **moving source** cannot change the speed of its emitted light, but it does change its **frequency & wavelength**.



Doppler Shift Calculation

The Doppler effect shifts the light's frequency: $f' = f + \Delta f$

perceived frequency
of moving source

frequency of
stationary source

Doppler shift

The diagram shows the equation $f' = f + \Delta f$ with three labels and arrows. A purple arrow points from the text 'perceived frequency of moving source' to the variable f' . A green arrow points from the text 'frequency of stationary source' to the variable f . A purple arrow points from the text 'Doppler shift' to the variable Δf .

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Doppler shift

Doppler frequency shift:
$$\frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v}{c}$$

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Doppler frequency shift: $\frac{\Delta f}{f} = -\frac{\Delta \lambda}{\lambda} = \frac{v_{\parallel}}{c}$

velocity component
along line-of-sight

If source is moving towards you, then light is blue shifted.

$$v > 0$$

$$\Delta f > 0, f' \text{ goes up}$$

$$\Delta \lambda < 0$$

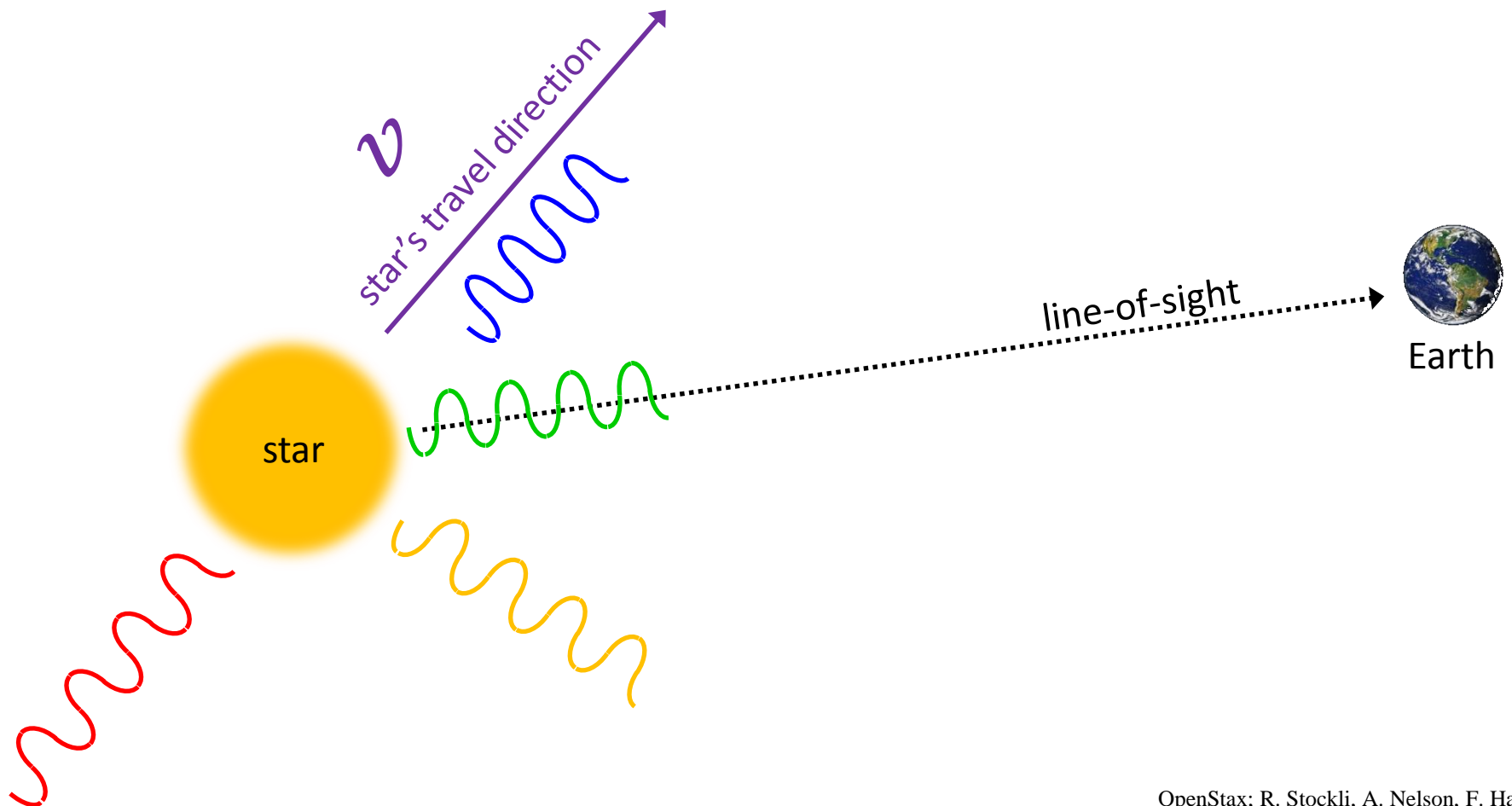
If source is moving away from you, then light is red shifted.

$$v < 0$$

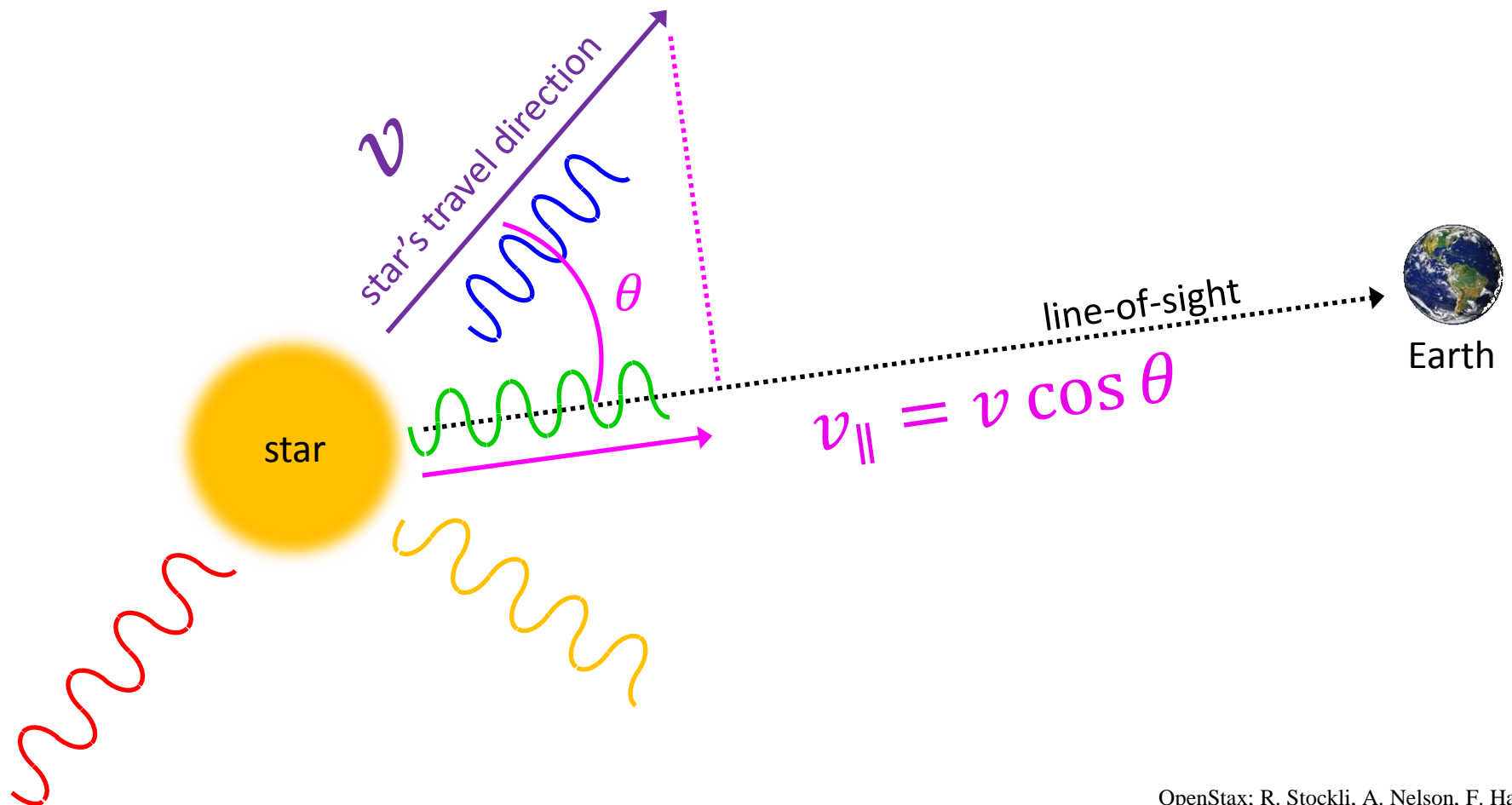
$$\Delta f < 0, f' \text{ goes down}$$

$$\Delta \lambda > 0$$

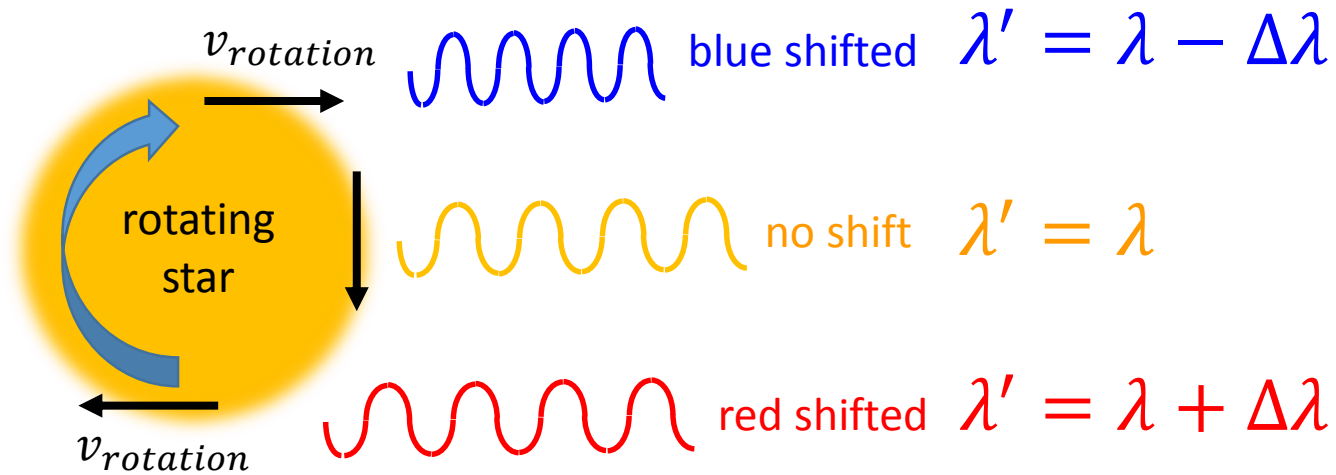
Doppler Shift is for Line-of Sight Velocity Component



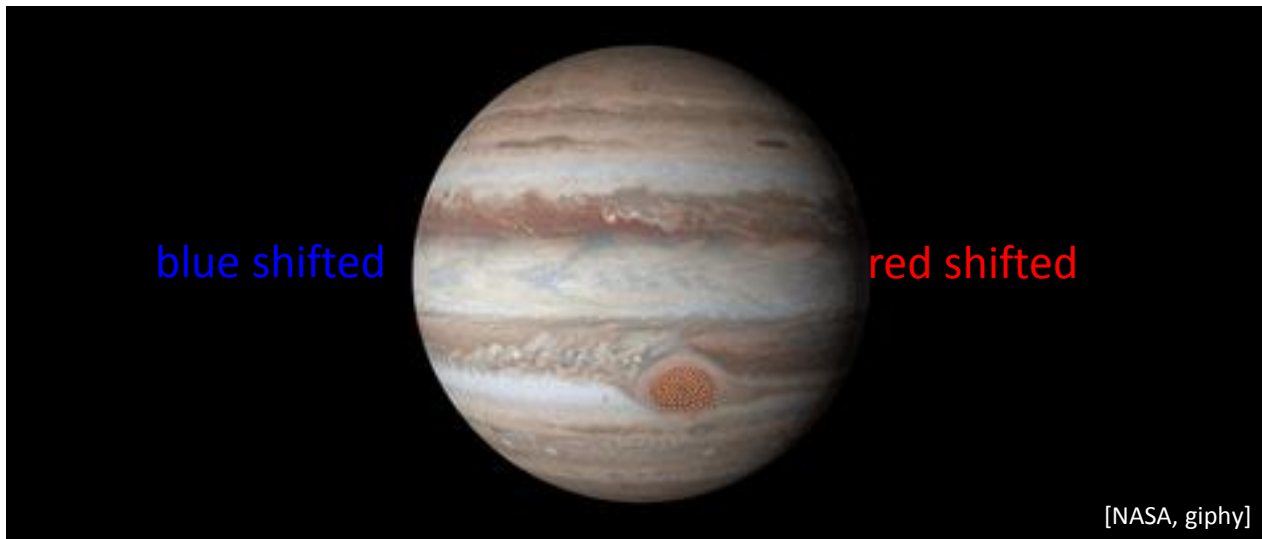
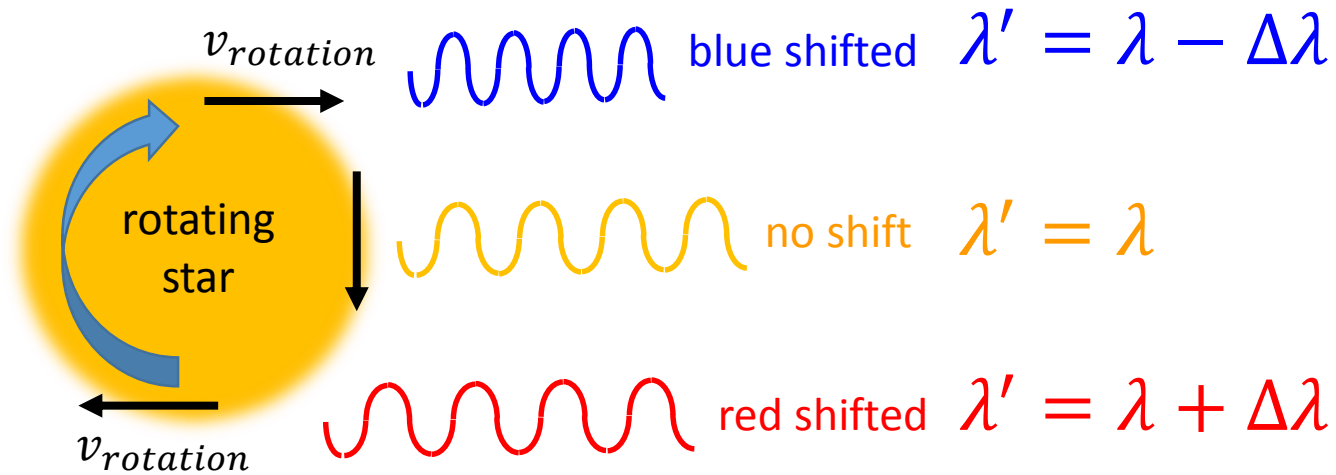
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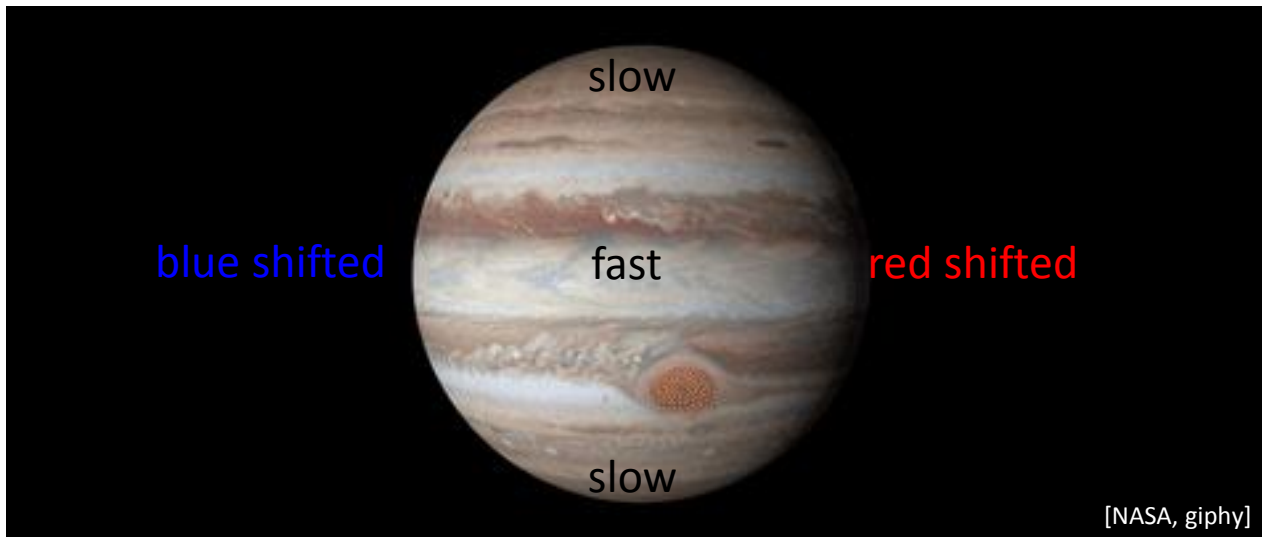
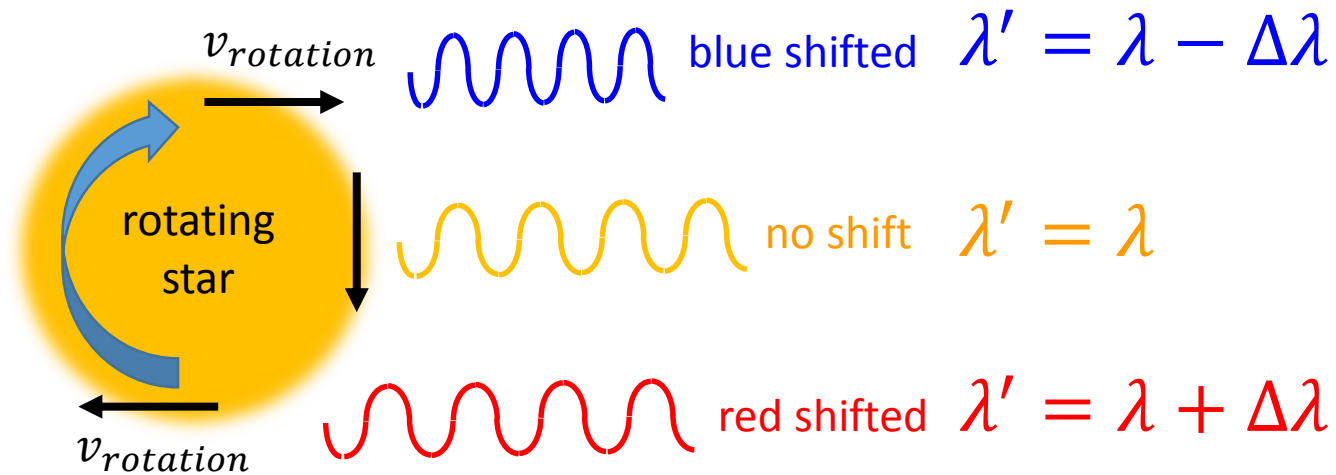
Doppler Shifts for Rotating Sources



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Doppler Shifts for Rotating Sources



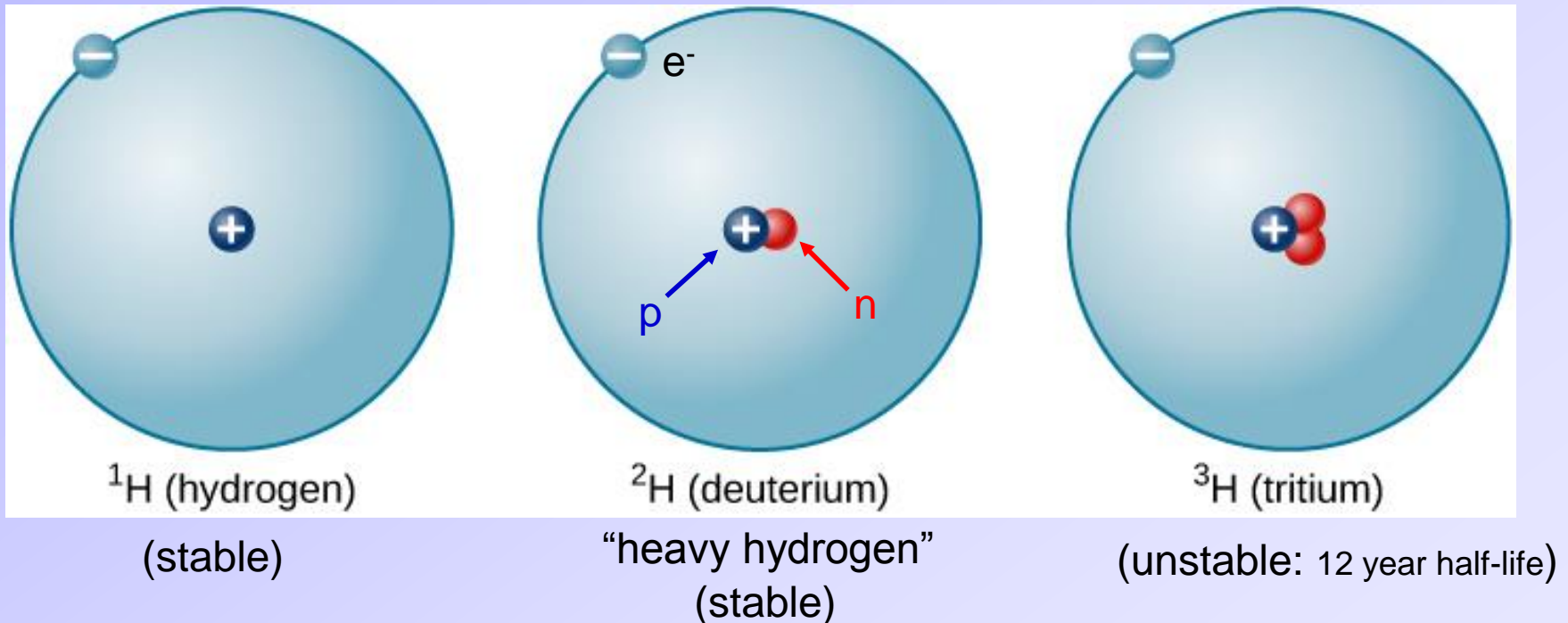
Nuclear Particles

Photons are the easiest particles with which to view space, but they are not the only ones

- Protons (p or p^+), electrons (e or e^-), neutrons (n)
- Alpha particles (α)
- Neutrinos (ν)
- Anti-particles: Positrons (e^+) & anti-protons (p^-)
- Cosmic rays (high energy p^+ , p^- , e^+ , e^- , α , etc)

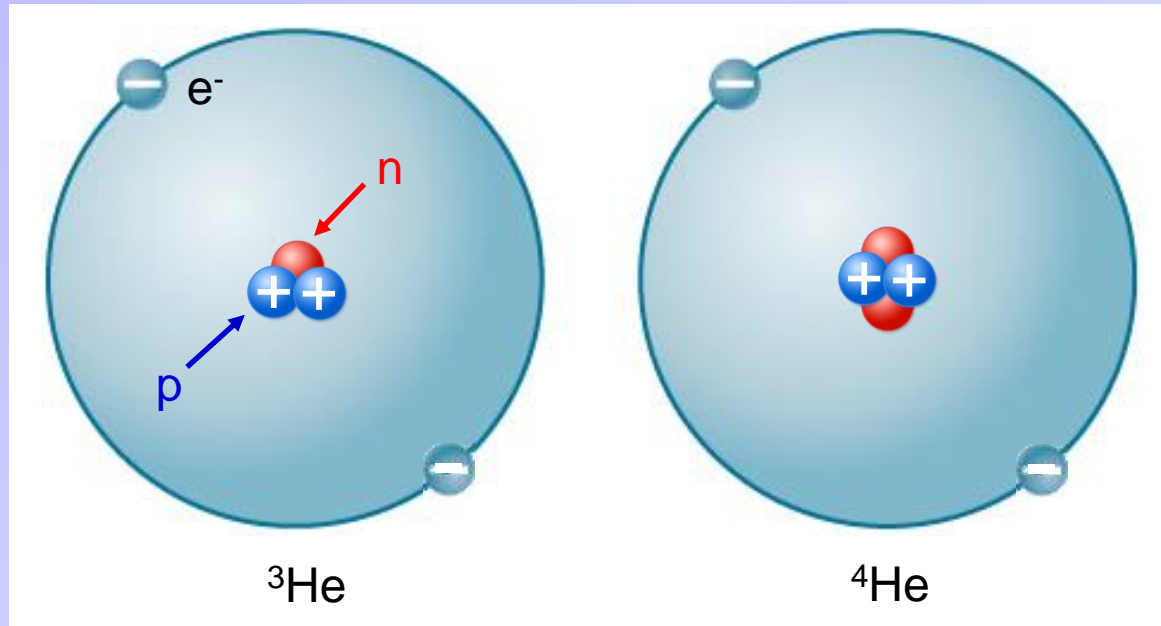
Nuclear Isotopes: hydrogen

- Number of neutrons affects the properties of nucleus, but not chemistry.
- 3 hydrogen isotopes:



Nuclear Isotopes: helium

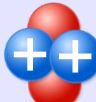
2 stable isotopes of helium:



[OpenStax: Astronomy]

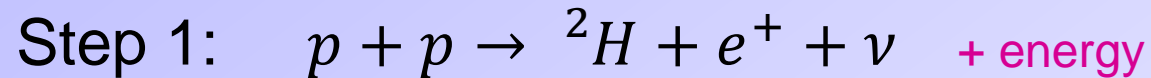
1 neutron
2 protons

2 neutron
2 protons

Note: an alpha particle (α) is a helium-4 nucleus \longrightarrow 

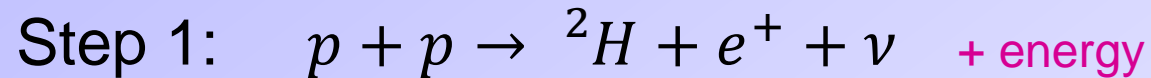
Solar Nuclear Fusion

The Sun generates its heat primarily by nuclear fusion in a 3 step “proton-proton chain”:



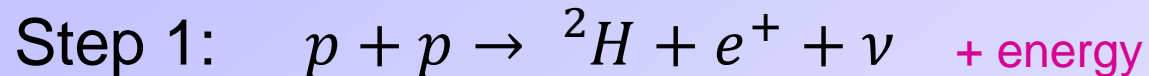
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Particle Properties

Particle	Mass (kg)	Electric charge	Forces
Proton	1.67265×10^{-27}	+1	Strong, EM, weak, gravity
Neutron	1.67495×10^{-27} <i>$m_n \sim m_p$</i>	0	Strong, weak, gravity
Electron	9.11×10^{-31} <i>$m_e \sim 1/2000$ of m_p</i>	-1	EM, weak, gravity
Neutrino	$< 2 \times 10^{-36}$	0	weak, gravity

 barely interacts with anything !!! (very hard to detect)

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Fundamental forces

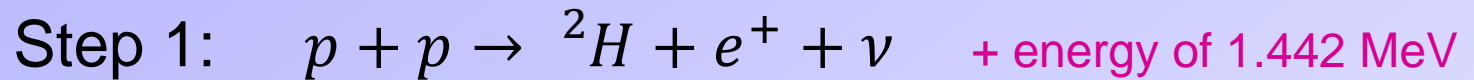
There are only 4 fundamental forces that we know of:

Strong nuclear force, **electromagnetic force**, **weak nuclear force**, **gravity**.

(holds nucleus together)
[short range]

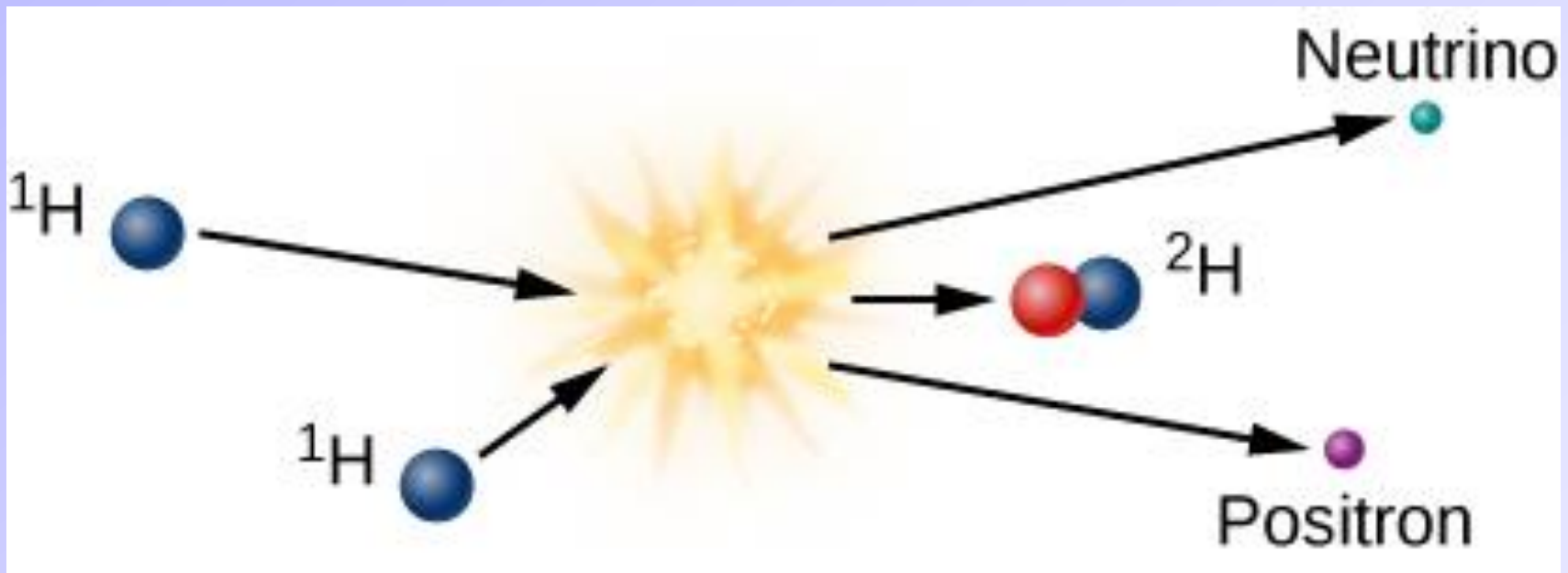
(generates radioactive decay) (very very weak)
[short range]

Step 1: p + p




weak force

Note: 1 eV = 1.602×10^{-19} J

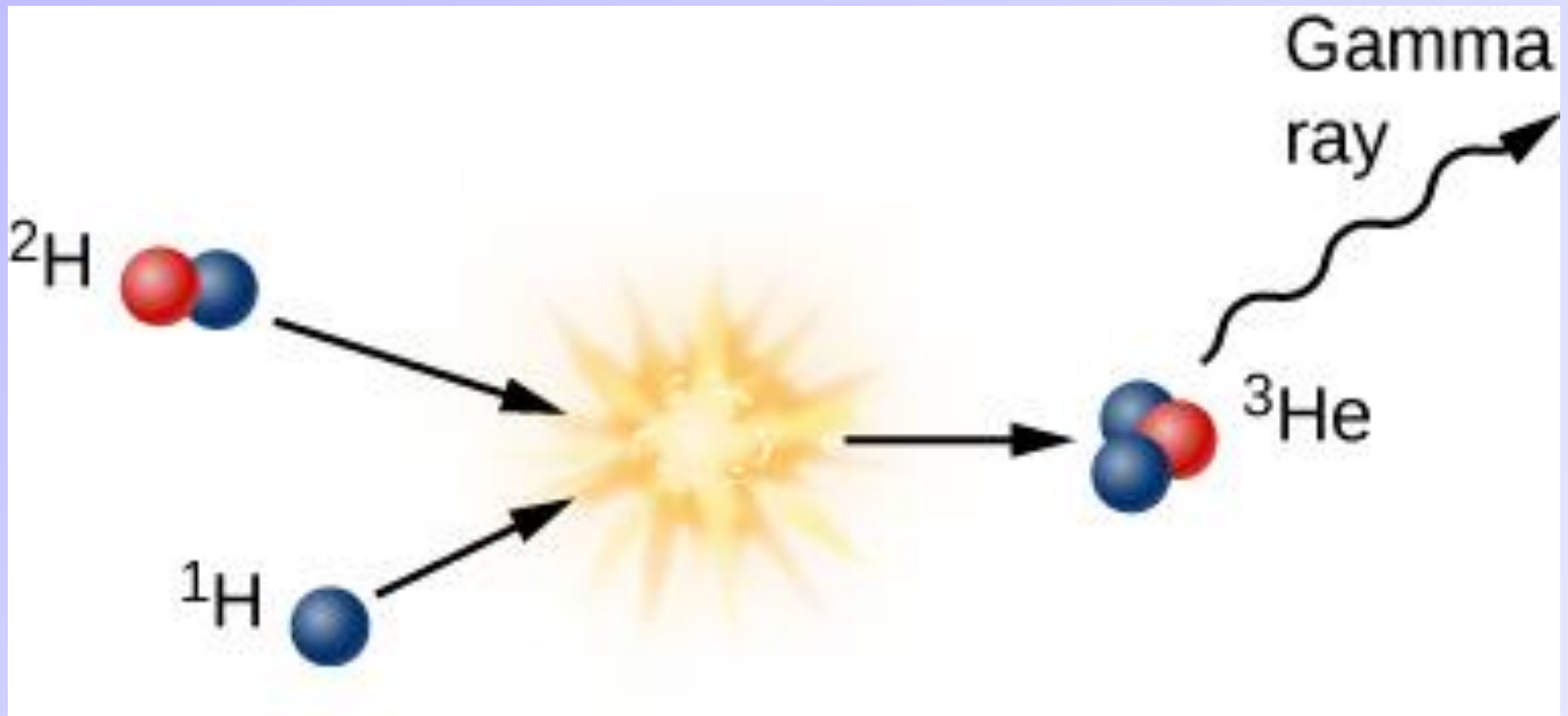


Note: This reaction is very slow ... protons are estimated to wander around for 9 billion years (on average) in Sun's core before this process occurs.

Step 2: ${}^2\text{H} + \text{p}$




strong force

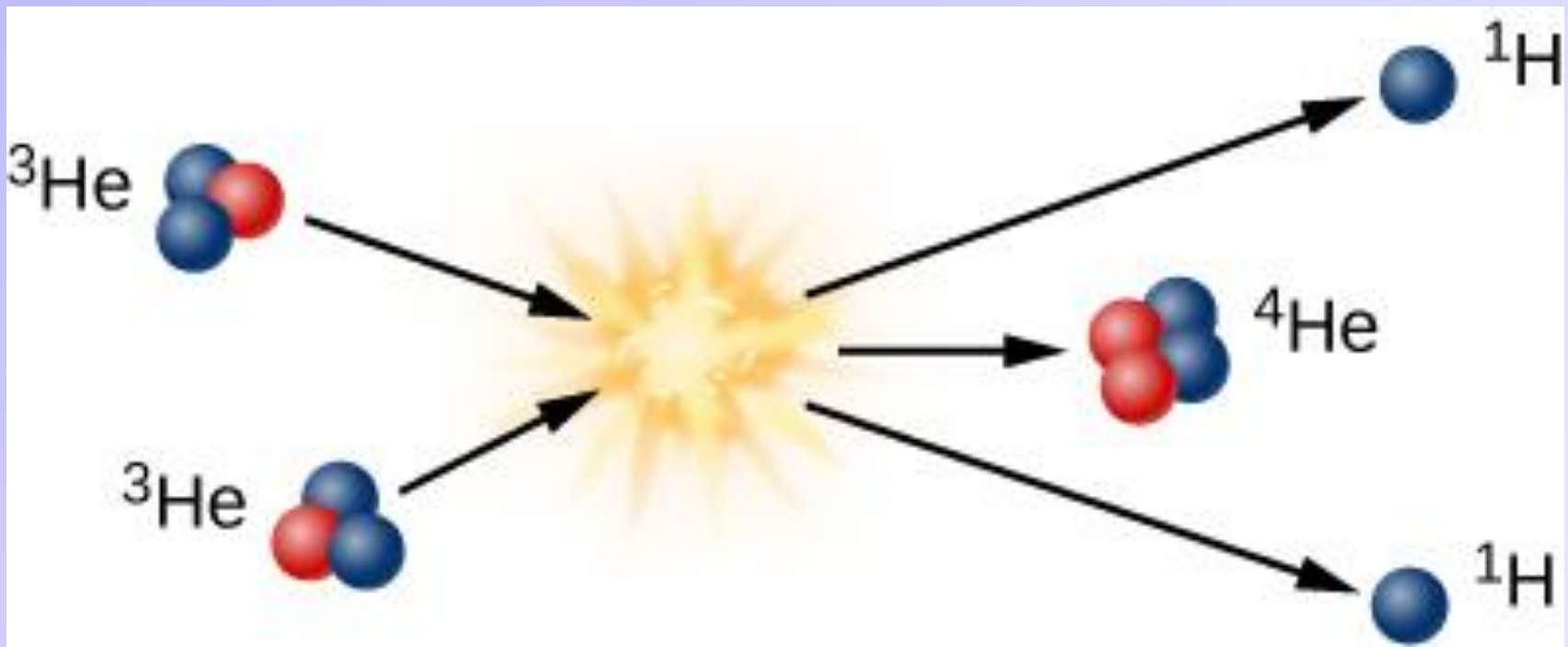


Note: This reaction is very fast ... each ${}^2\text{H}$ nucleus lasts about 4 seconds.

Step 3: ${}^3\text{He} + {}^3\text{He}$

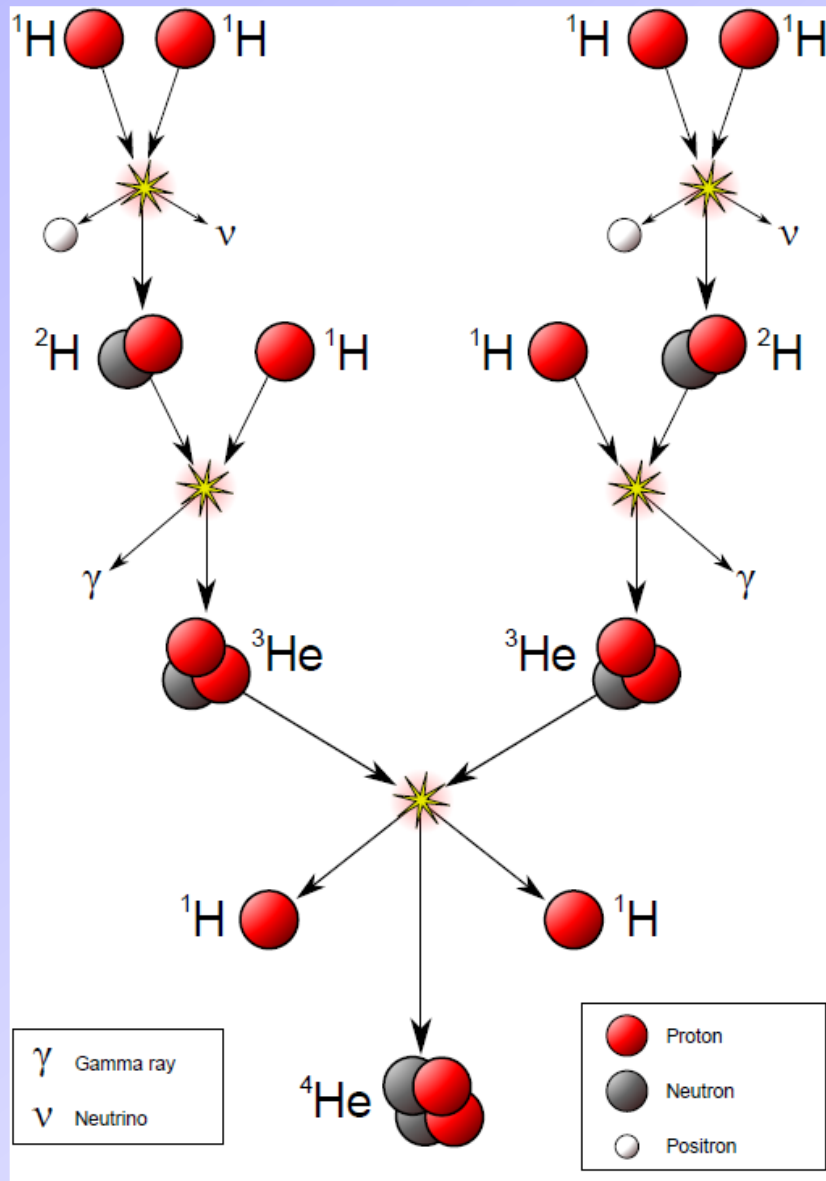
Step 3: ${}^3\text{He} + {}^3\text{He} \rightarrow {}^4\text{He} + p + p$ + energy of 12.86 MeV


strong force



Note: each helium-3 nucleus lasts about 400 years in the Sun's core.

Summary of proton-proton chain



$$2 \times 1.442 \text{ MeV}$$

$$+ 2 \times 5.49 \text{ MeV}$$

$$+ 12.86 \text{ MeV}$$

$$= 26.7 \text{ MeV total}$$

$$= 4.28 \times 10^{-12} \text{ J}$$