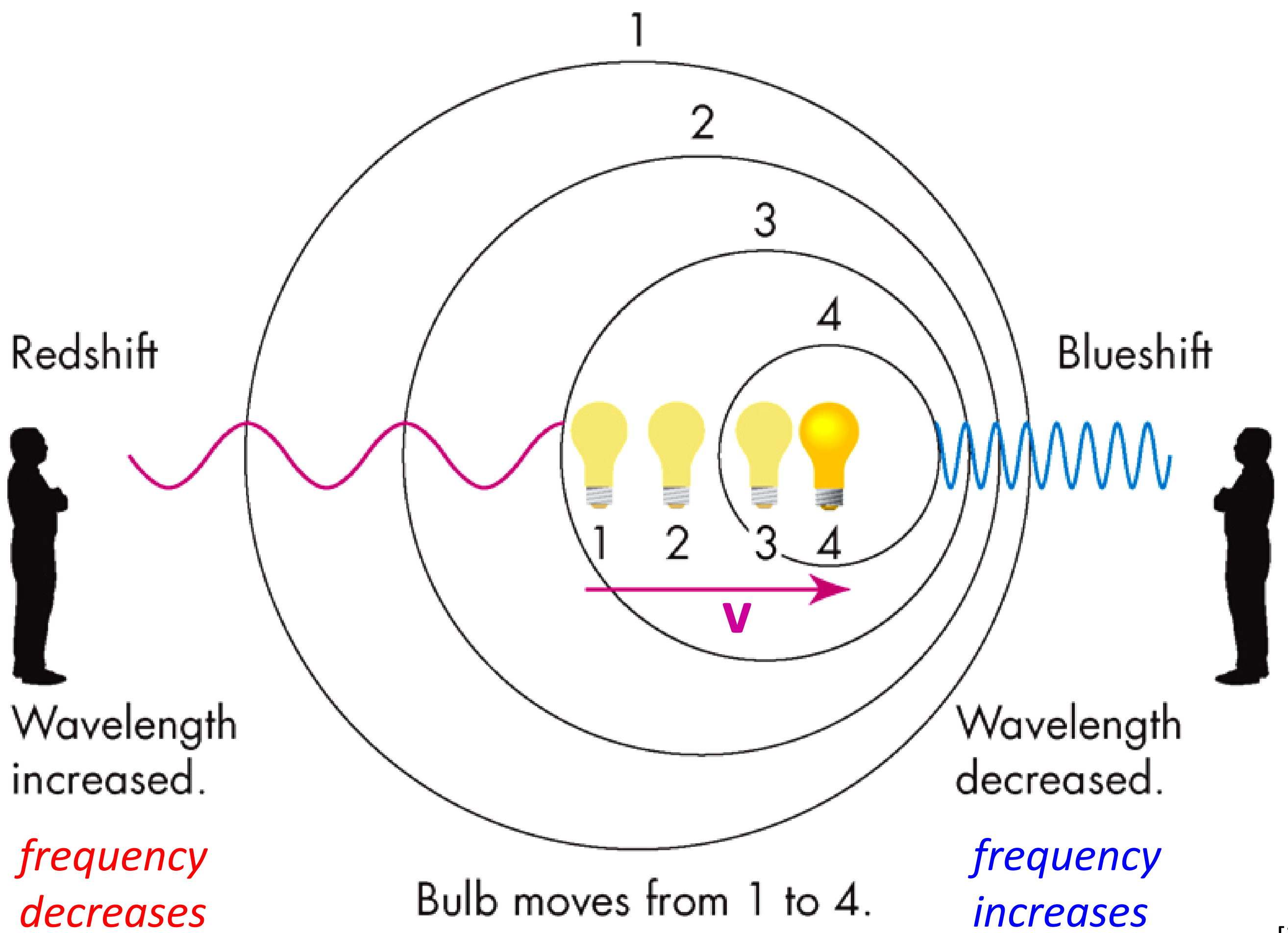
Today's Topics

Wednesday, September 9, 2020 (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**.



[image source: J. Nelson]

Doppler Shift Calculation

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

perceived frequency of moving source → f'

frequency of stationary source → f

Doppler shift → Δf

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Doppler shift

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frequency of stationary source (f)

Doppler shift (Δf)

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velocity component along line-of-sight ($v_{\parallel}$)

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

$v > 0$ | $\Delta f > 0$, f' goes up

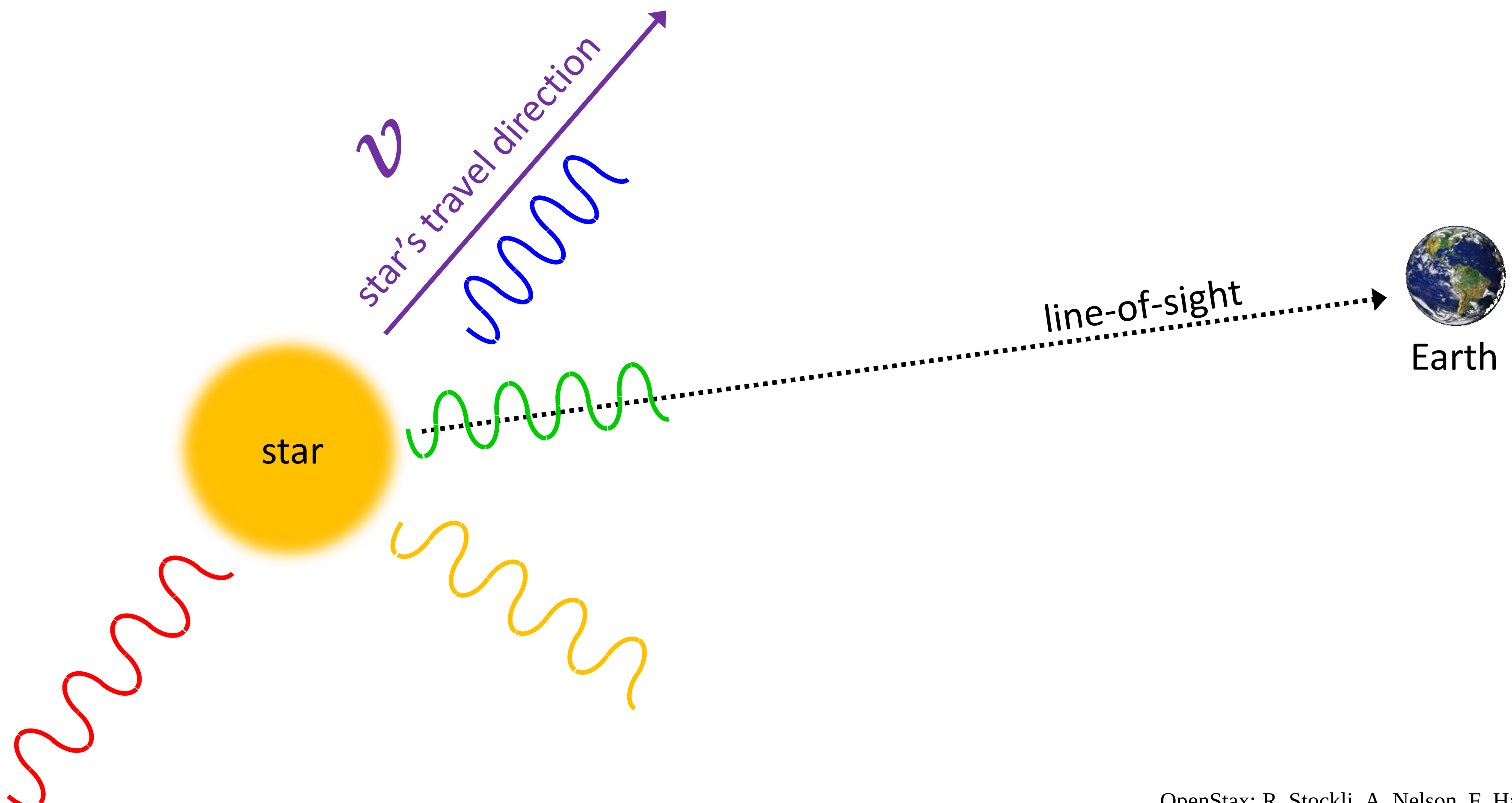
$\Delta\lambda < 0$

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

$v < 0$ | $\Delta f < 0$, f' goes down

$\Delta\lambda > 0$

Doppler Shift is for Line-of Sight Velocity Component



OpenStax; R. Stockli, A. Nelson, F. Hasler, NASA/GSFC/NOAA/USGS)

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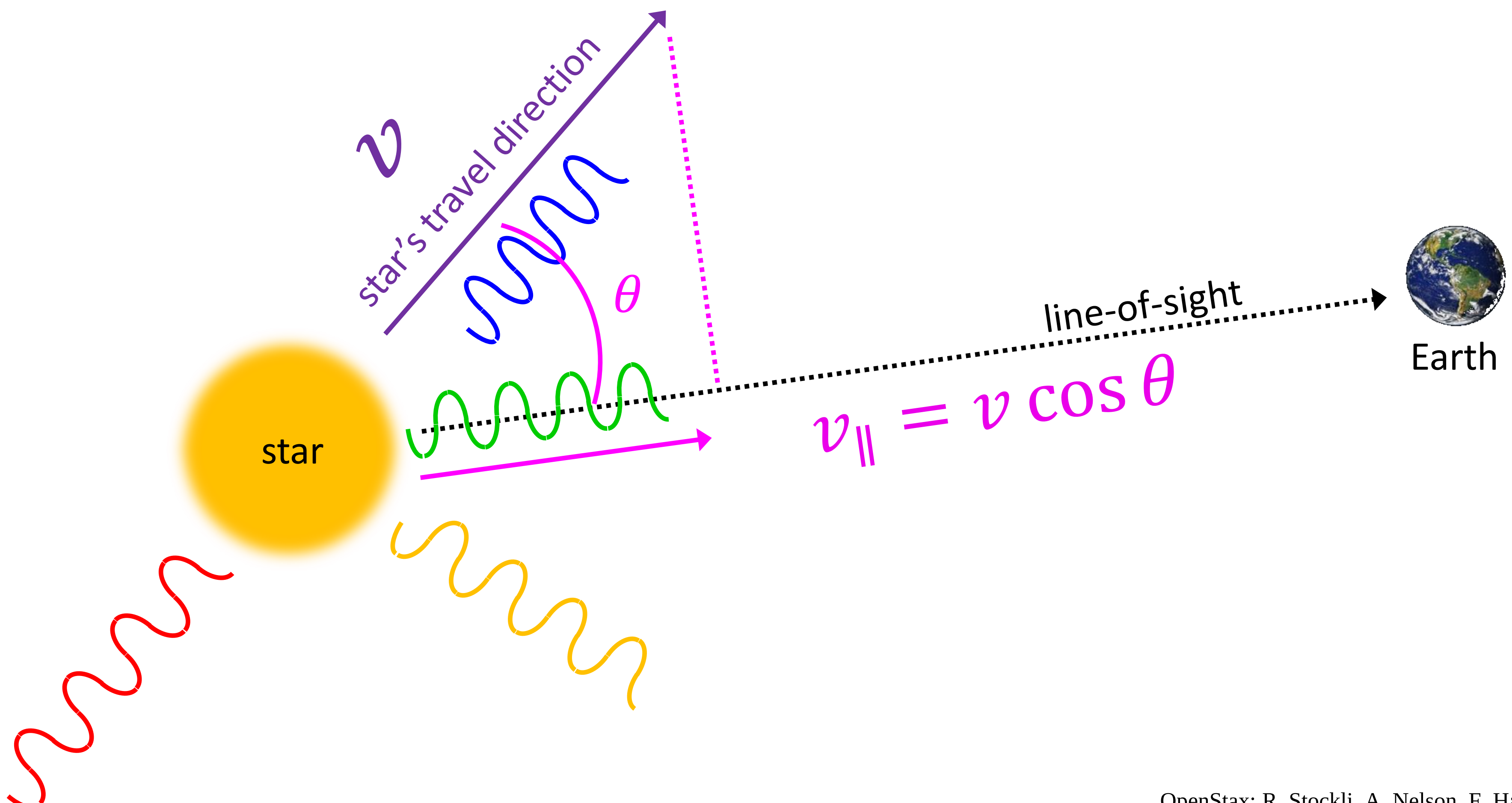

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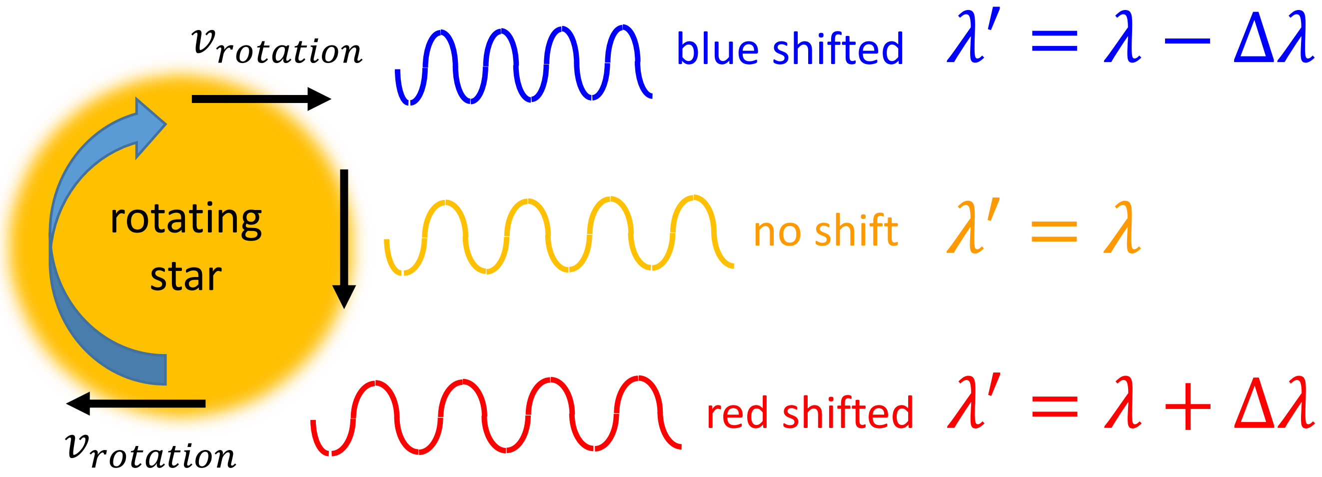
Doppler Shifts for Rotating Sources



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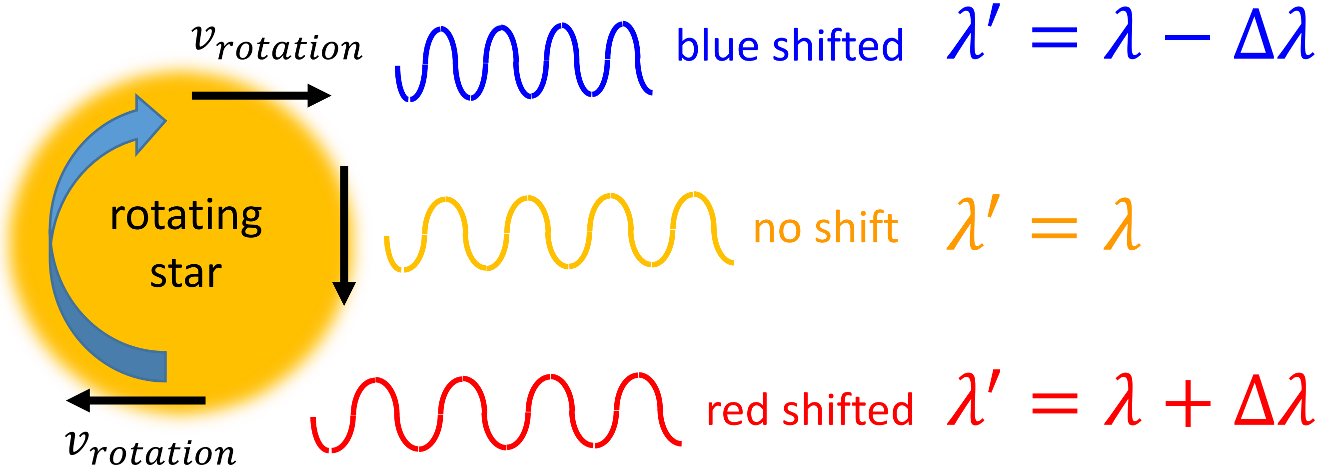

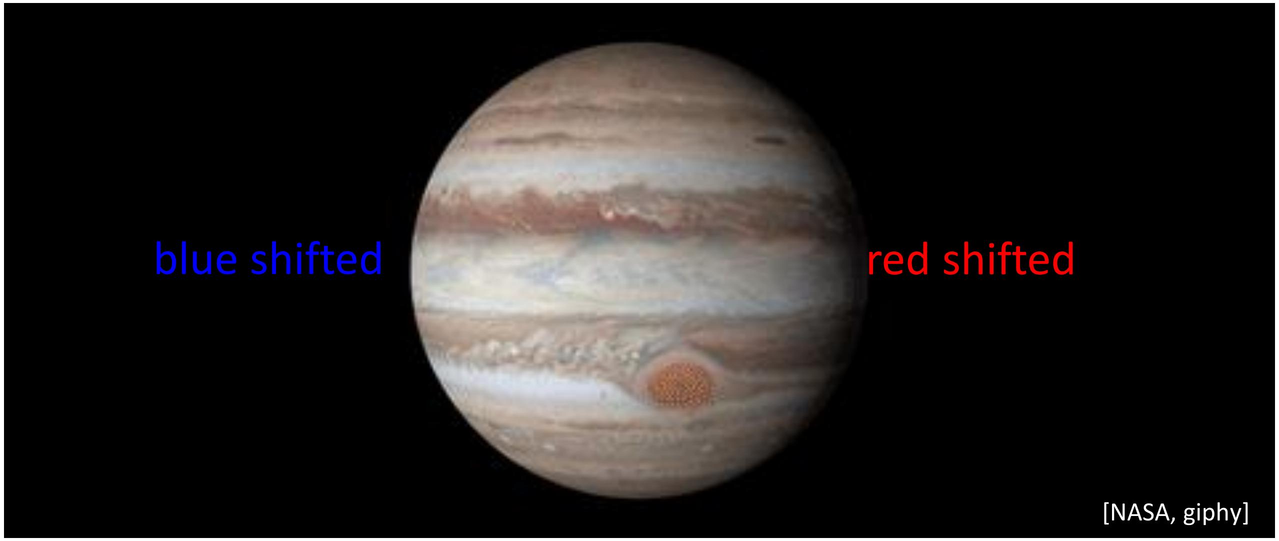

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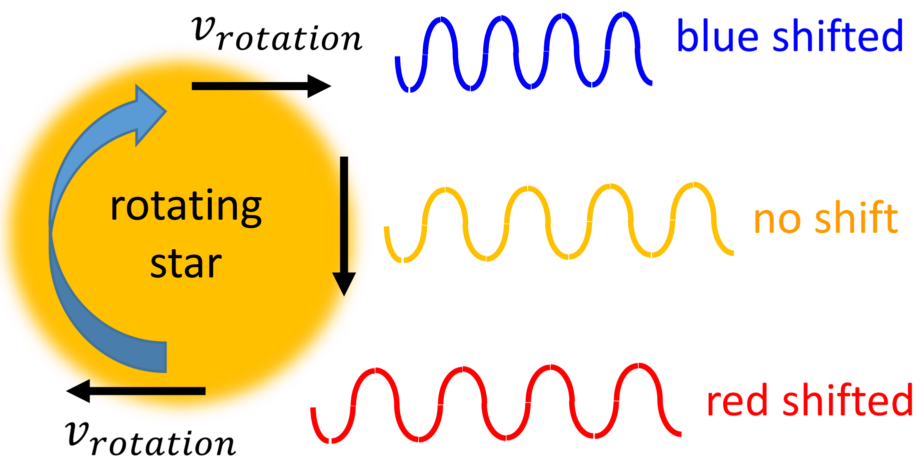
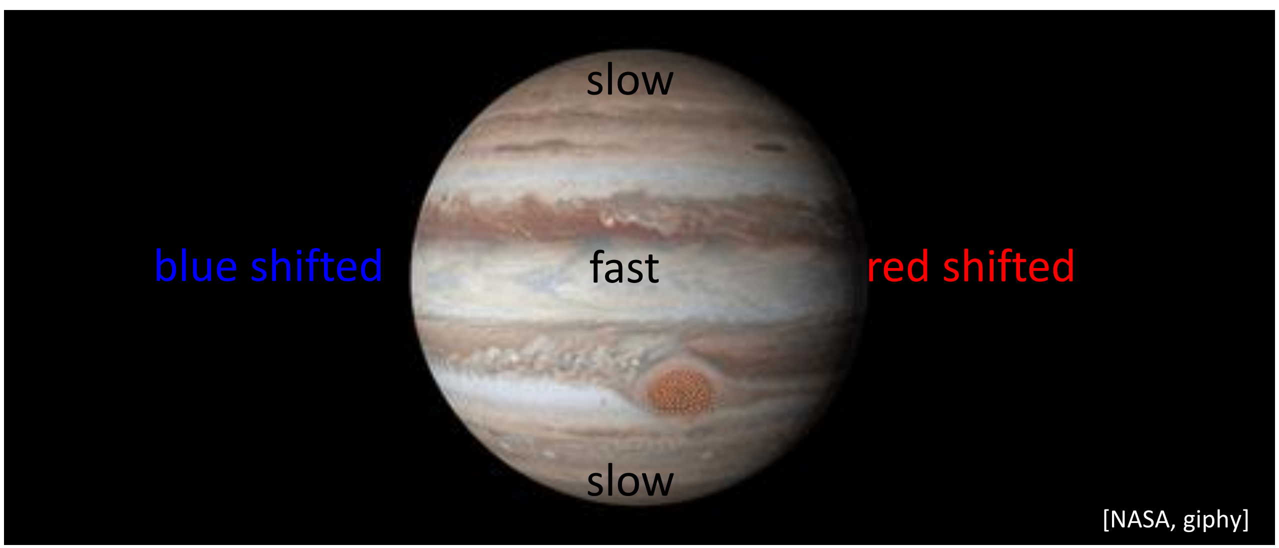


$$\lambda' = \lambda - \Delta\lambda$$

$$\lambda' = \lambda$$

$$\lambda' = \lambda + \Delta\lambda$$



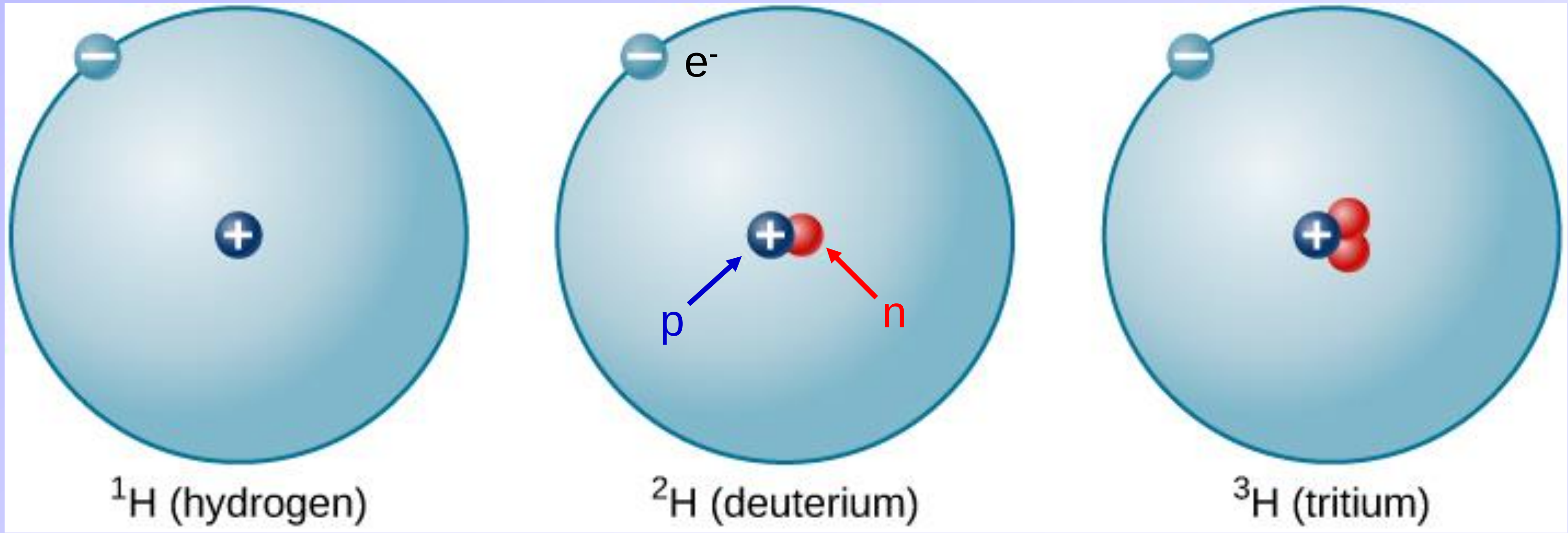
Nuclear Particles

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:



(stable)

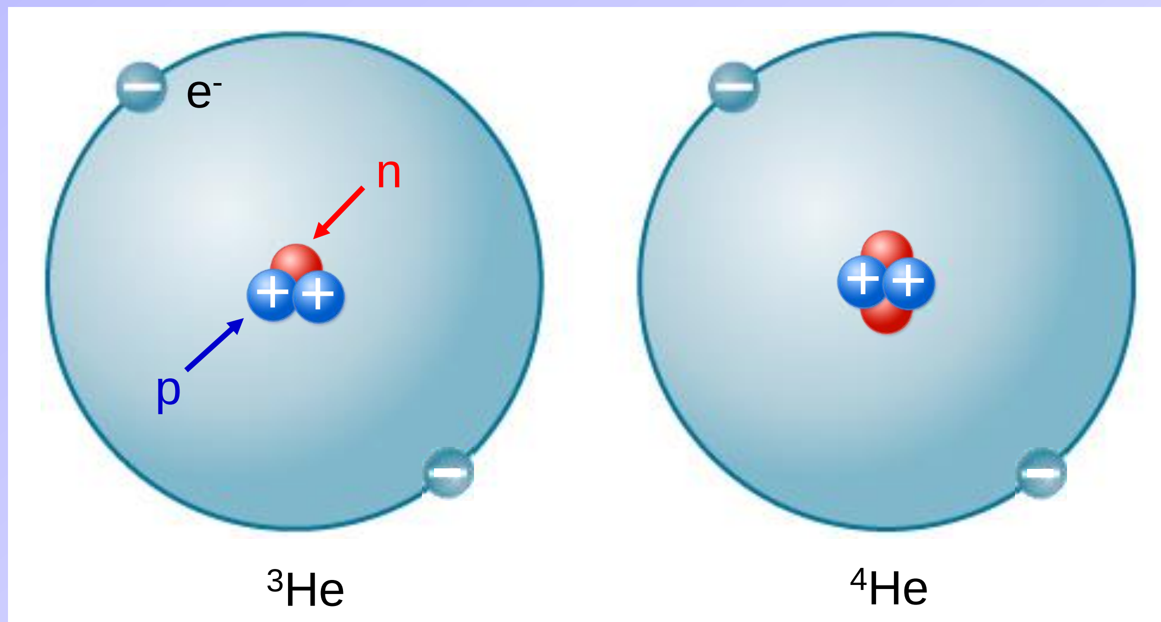
"heavy hydrogen" (stable)

(unstable: 12 year half-life)

[OpenStax: Astronomy]

Nuclear Isotopes: helium

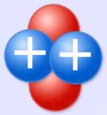
2 stable isotopes of helium:



[OpenStax: Astronomy]

1 neutron
2 protons

2 neutron
2 protons

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

Solar Nuclear Fusion

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

Step 1: $p + p \rightarrow {}^{2}H + e^{+} + \nu$ + energy

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Step 3: ${}^{3}He + {}^{3}He \rightarrow {}^{4}He + p + p$ + energy

Particle Properties

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

Strong nuclear force: (holds nucleus together) [short range]

Weak nuclear force: (generates radioactive decay) [short range]

Gravity: (very very weak)

Solar Fusion

Proton-proton chain

Step 1: $p + p \rightarrow {}^{2}H + e^{+} + \nu$ + energy

Step 2: ${}^{2}H + p \rightarrow {}^{3}He + \gamma$ + energy

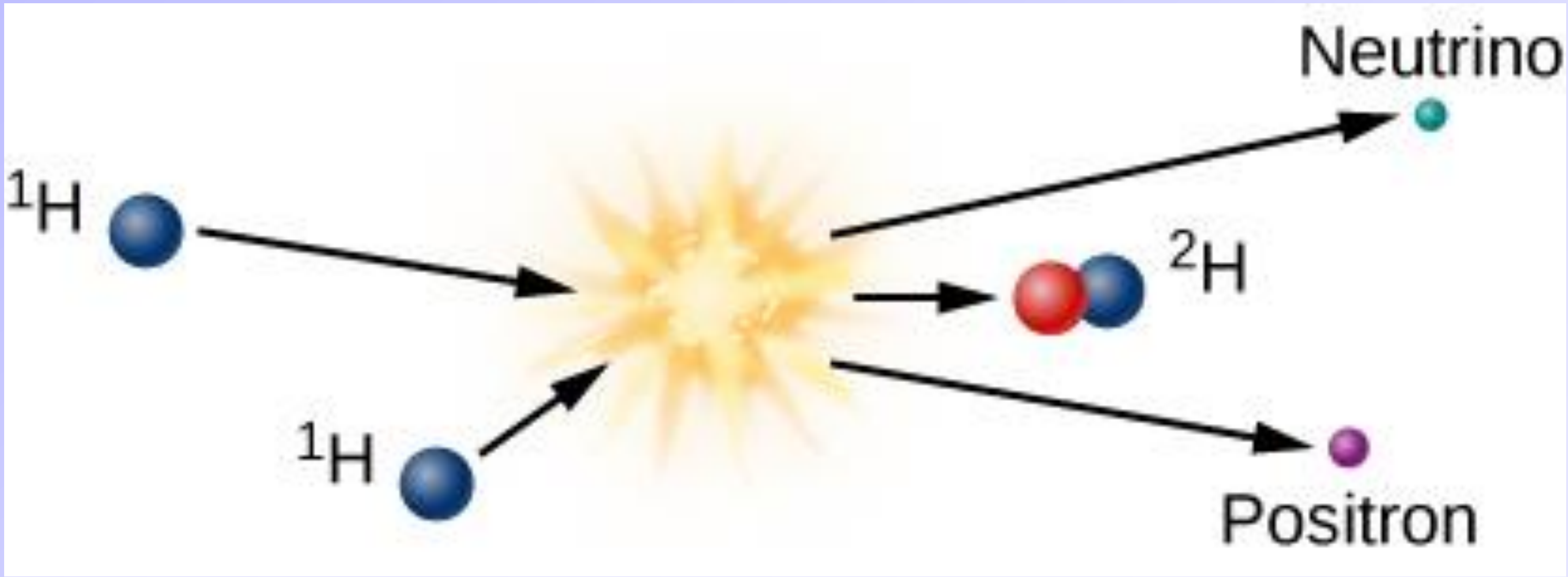
Step 3: ${}^{3}He + {}^{3}He \rightarrow {}^{4}He + p + p$ + energy

Step 1: p + p

Step 1: $p + p \rightarrow {}^{2}H + e^{+} + \nu$ + energy of 1.442 MeV

weak force

Note: 1 eV = 1.602×10^{-19} J

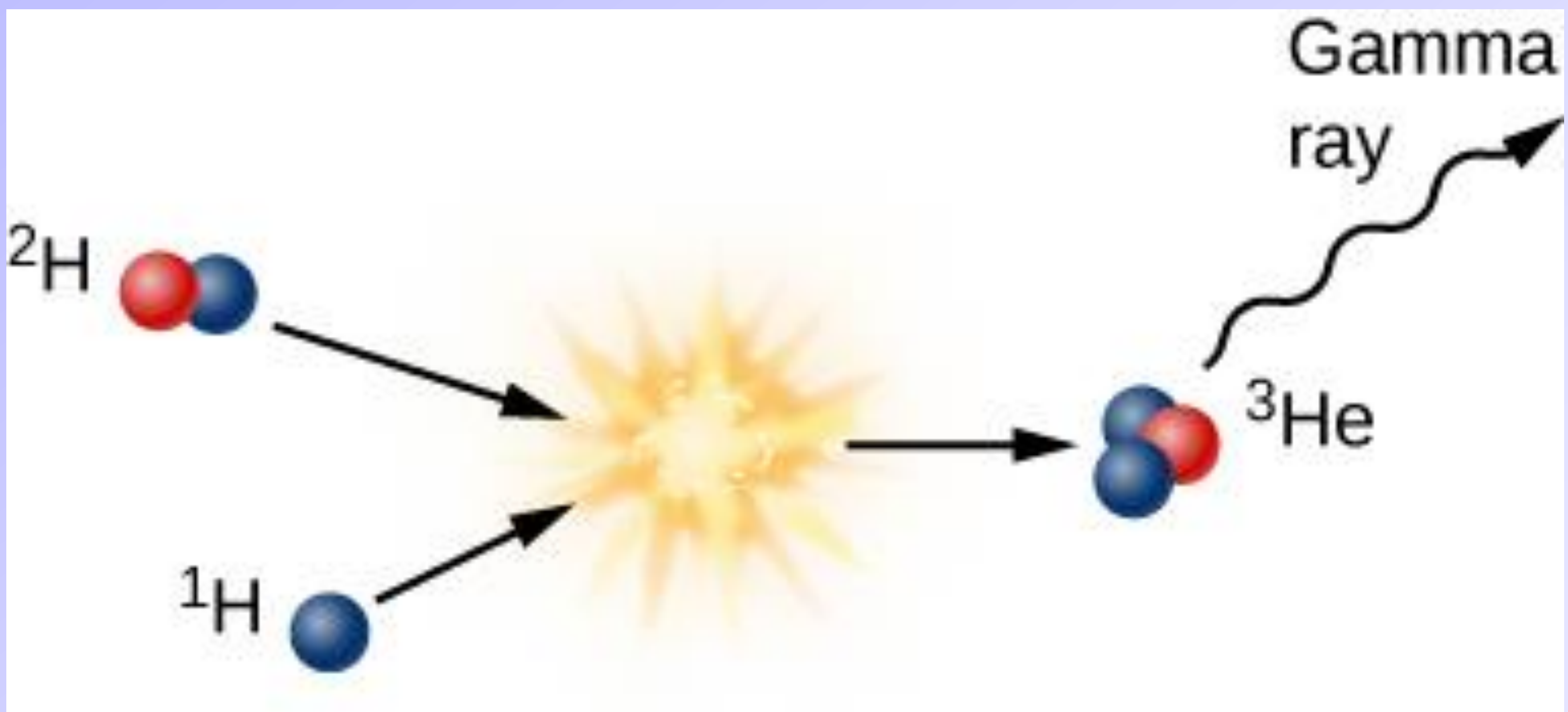


Note: This reaction is very slow … protons are estimated to wander around for 9 billion years (on average) in Sun's core before this process occurs.

Step 2: $^2H + p$

Step 2: $^{2}H + p \rightarrow {}^{3}He + \gamma$ + energy of 5.49 MeV

strong force

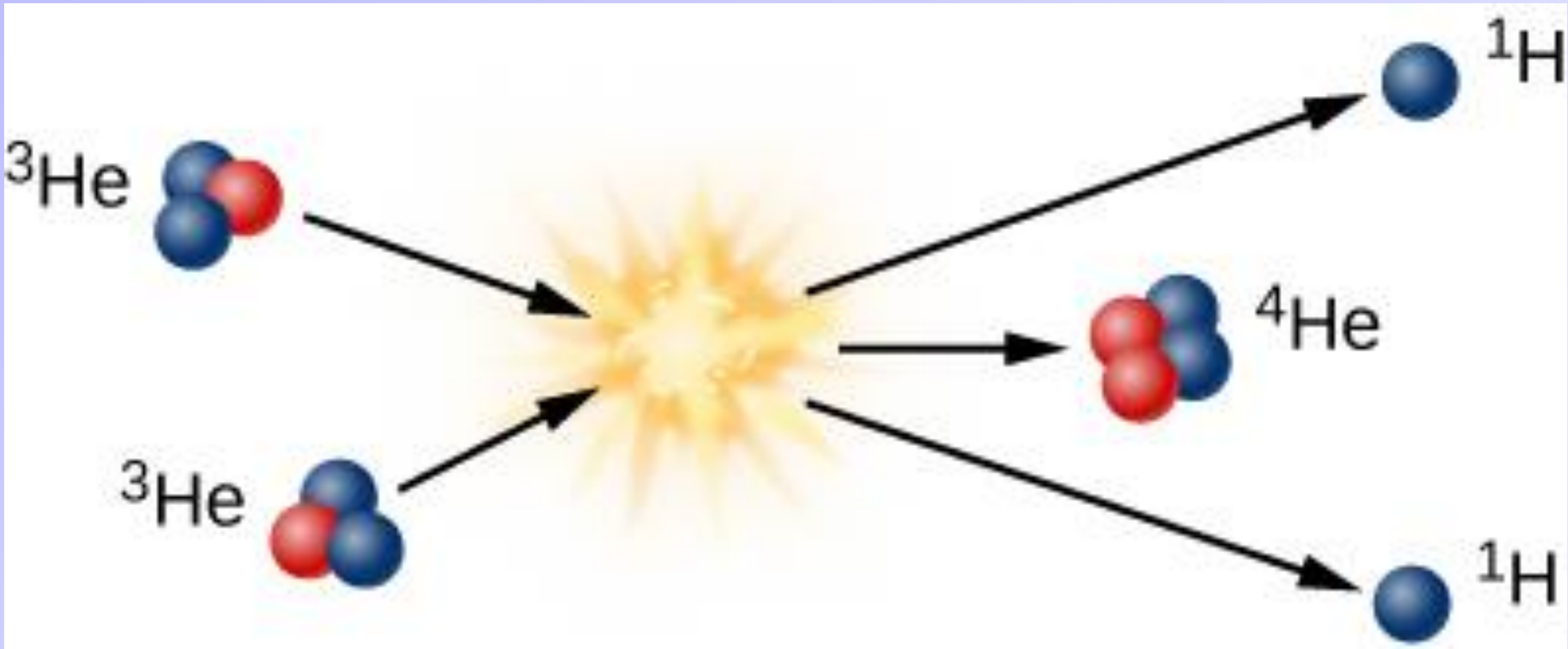


Note: This reaction is very fast … each ^{2}H nucleus lasts about 4 seconds.

Step 3: ^{3}He + ^{3}He

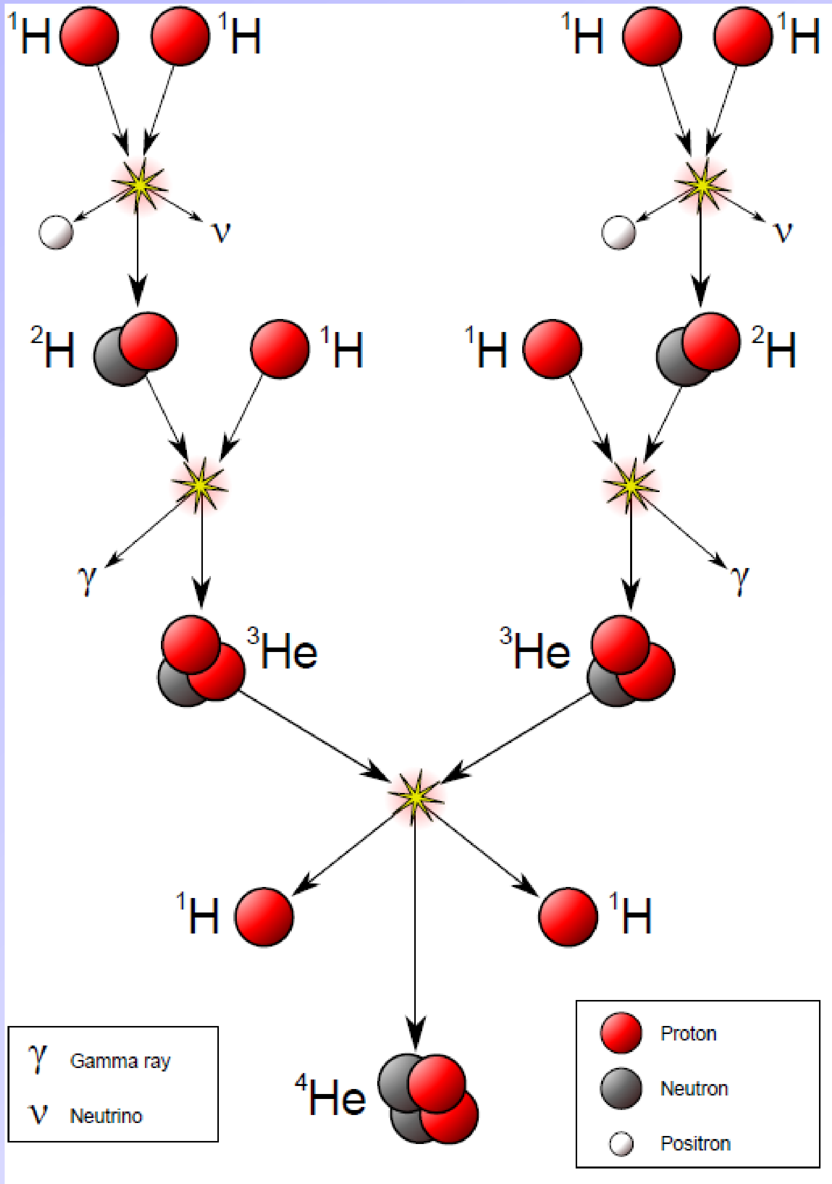
Step 3: $^{3}He + {}^{3}He \rightarrow {}^{4}He + p + p$ + energy of 12.86 MeV

strong force



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

Summary of proton-proton chain



2×1.442 MeV

$+ \quad 2 \times 5.49$ MeV

$+ \quad 12.86$ MeV

= 26.7 MeV total

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

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