

Topics in Magnetohydrodynamics

Brief review of plasma

What is plasma?

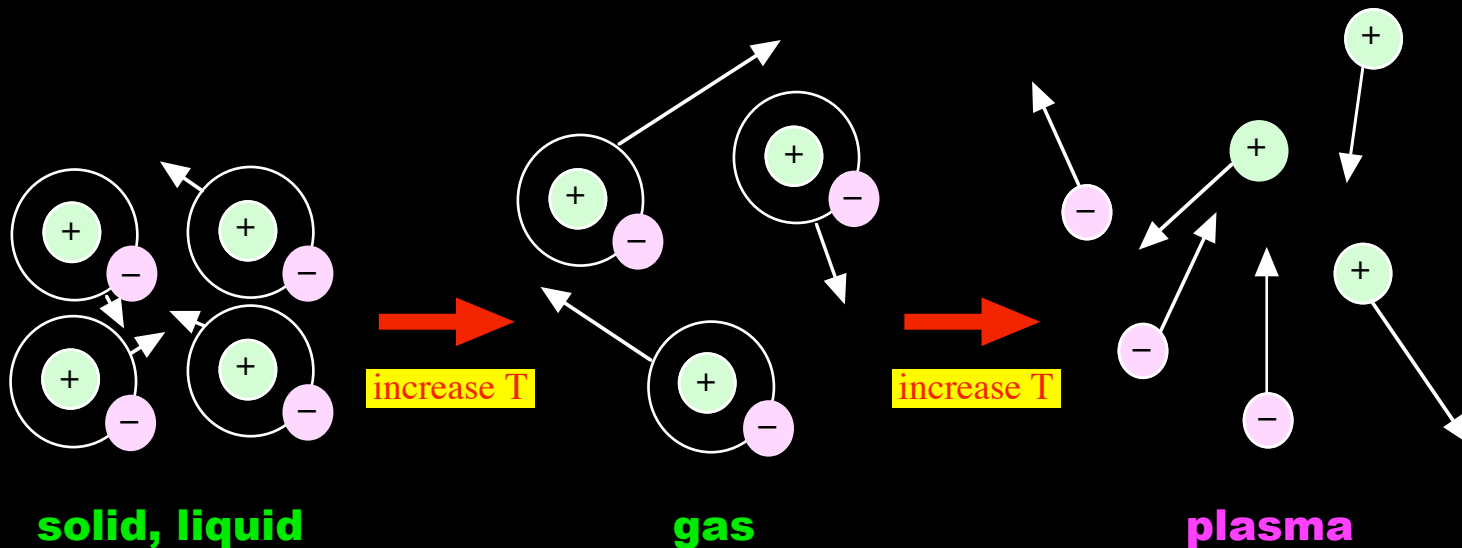
Plasma...

the 4th-state of matter, following **solid**, **liquid**, and **gas**

High temperature (e.g. $T \geq 10^4$ K for hydrogen atom)

→ neutral particles are **dissociated** into positive ions and negative electrons (**ionization**)

plasma



Two types of plasma

Cold plasma (partially ionized plasma)...

low temperature, only *part* of neutral particles are ionized

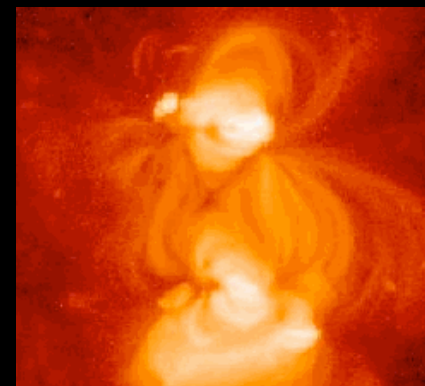
$T \sim \text{several thousands K for hydrogen atom}$



Hot plasma (fully ionized plasma)...

high temperature, *all* neutral particles are ionized

$T \gg 10^4 \text{ K for hydrogen atom}$



Examples of plasmas

Plasmas in our daily life (cold plasma)



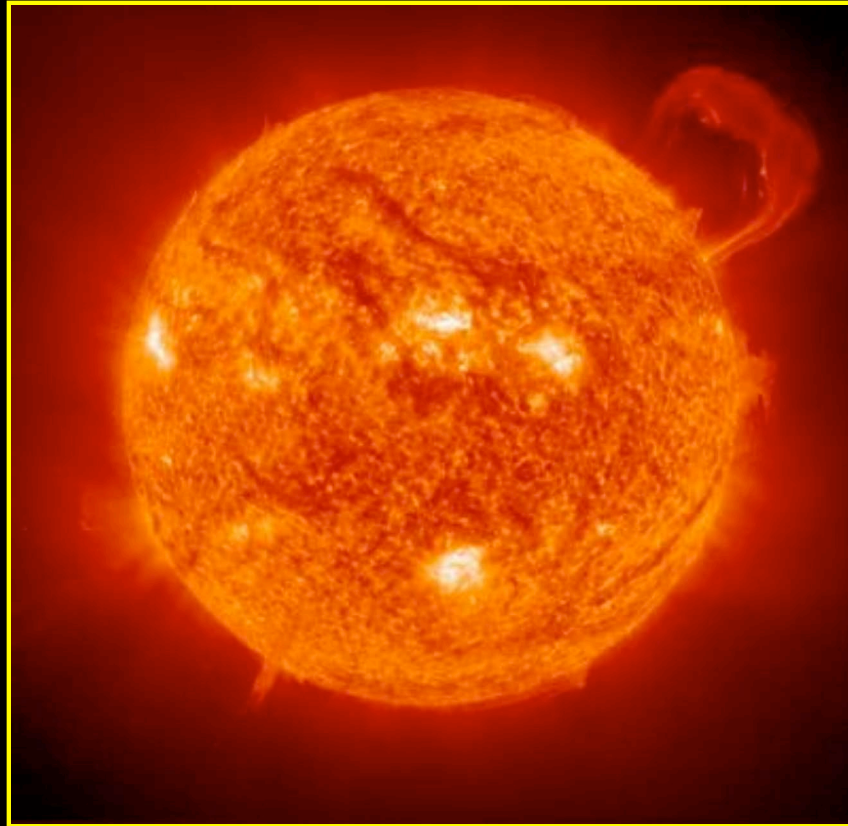
plasma television



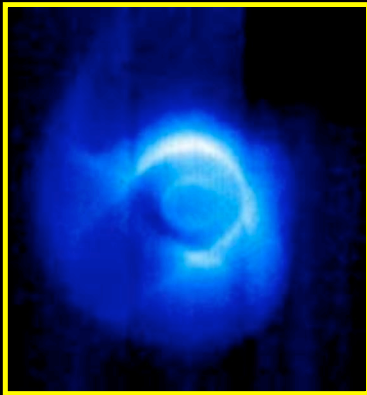
fluorescent lamp

Plasmas in the universe (hot plasma)

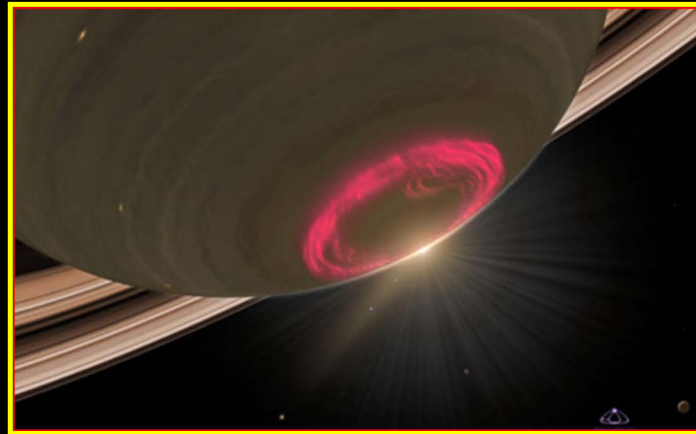
**Solar atmosphere
(chromosphere)**



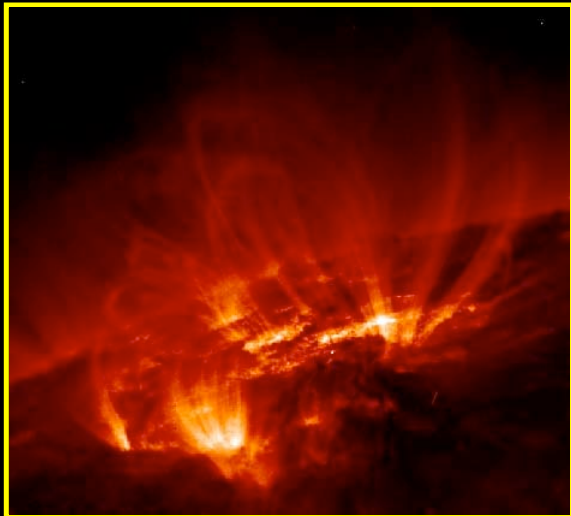
Temperature is higher than 10,000 K.



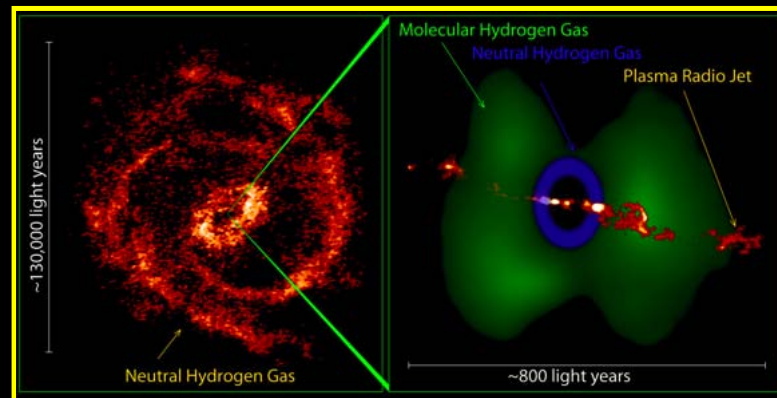
Magnetosphere



Saturn



Active region on the Sun



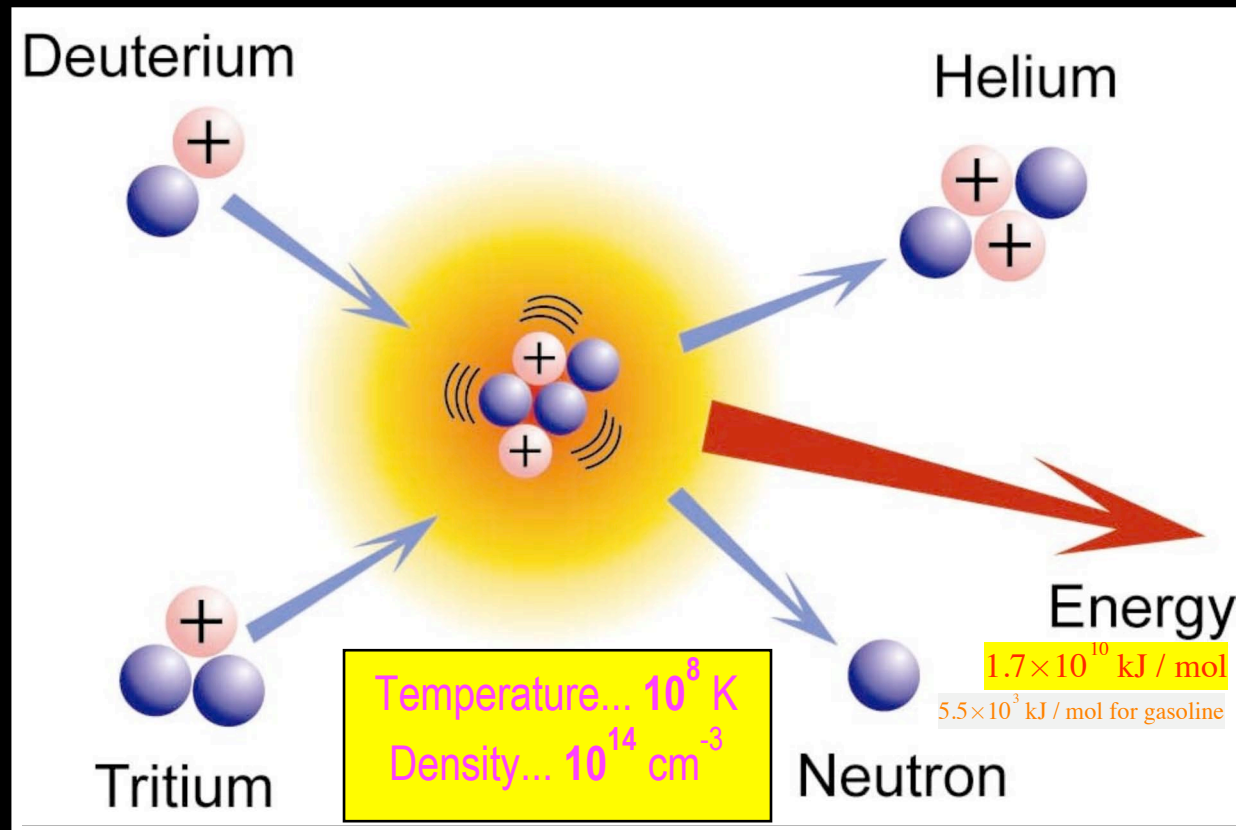
Jet from an active galactic nucleus (AGN)

Laboratory plasma (hot plasma)



tokamak

Plasmas... future energy resource (via nuclear fusion)



Solar center

$$T_{\text{solar center}} \sim 1.5 \times 10^7 \text{ K}$$

$$n_{\text{solar center}} \sim 10^{26} \text{ cm}^{-3}$$

Earth's surface

$$T \sim 300 \text{ K}$$

$$n \sim 10^{19} \text{ cm}^{-3}$$

How can we confine a 100,000,000 K plasma?

Even for the **matter that has the highest melting point**, it is less than 4000 K ('**tungsten**' whose melting point is about 3695 K).

This means that even if **tungsten** is used for **plasma confinement**, it will be **melted** and **vaporized** immediately.

Therefore, we cannot use any solid material to confine a plasma.

Instead, we use **magnetic field** to confine it.