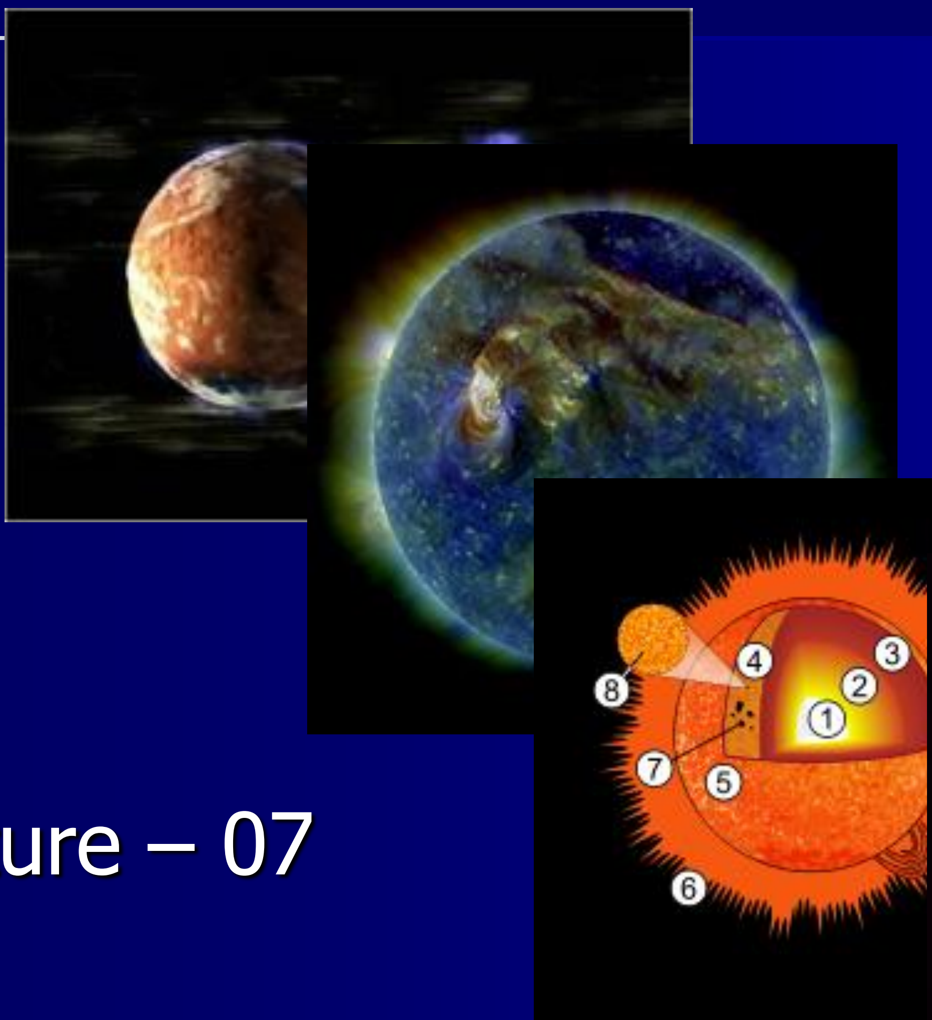
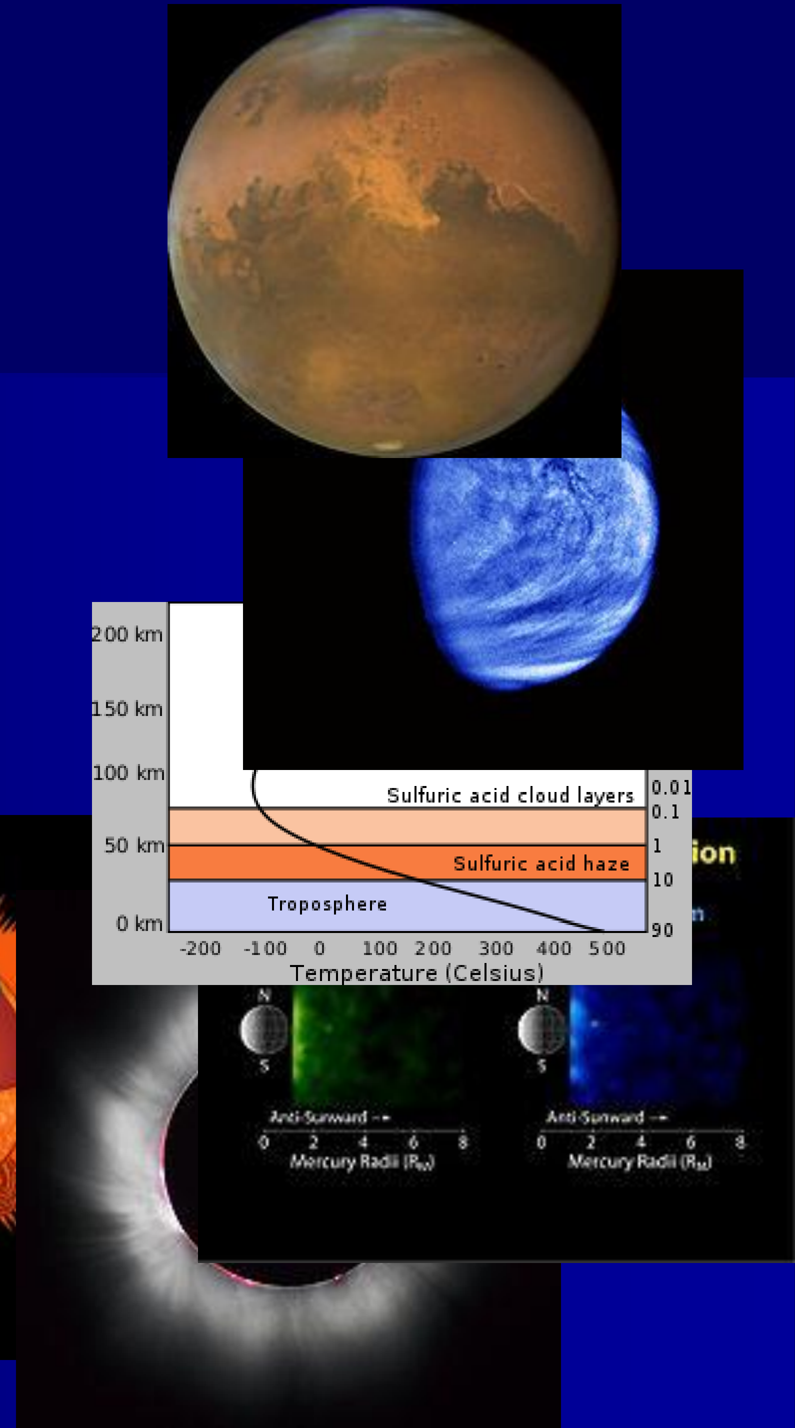
Space Physics

Space Physics





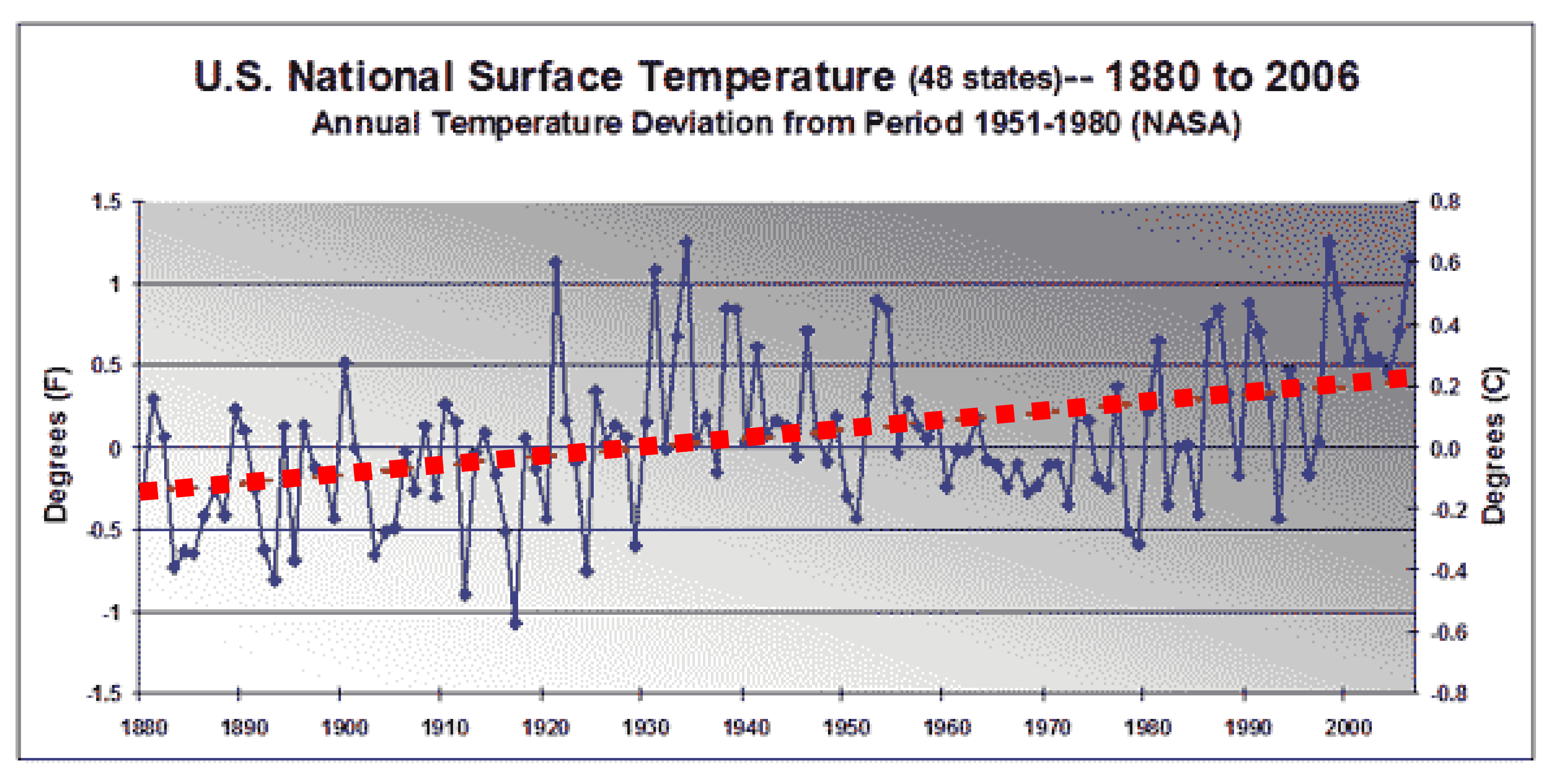
Lecture – 07

Global Warming

Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation.

Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C, with about two-thirds of the increase occurring since 1980.

Global Warming



Top 10 Things You Can Do to Reduce Global Warming

1. **Reduce**, **Reuse**, **Recycle**
2. **Use Less Heat and Air Conditioning**
3. **Change a Light Bulb** (CFL, most suitable LED Bulbs)
4. **Drive Less and Drive Smart**
5. **Buy Energy-Efficient Products** (Plasma Display, CRT Display, **LCD**, **LED, OLED**)
6. **Use Less Hot Water**
7. **Use the "Off" Switch**
8. **Plant a Tree**
9. **Get a Report Card from your Utility Company**
10. **Encourage Others to Conserve**

Share information about recycling and energy conservation with your friends, neighbors and co-workers, and take opportunities to encourage public officials to establish programs and policies that are good for the environment.

These 10 steps will take you a long way toward reducing your energy use and your monthly budget. And less energy use means less dependence on the fossil fuels that create greenhouse gases and contribute to global warming.

The Ionosphere

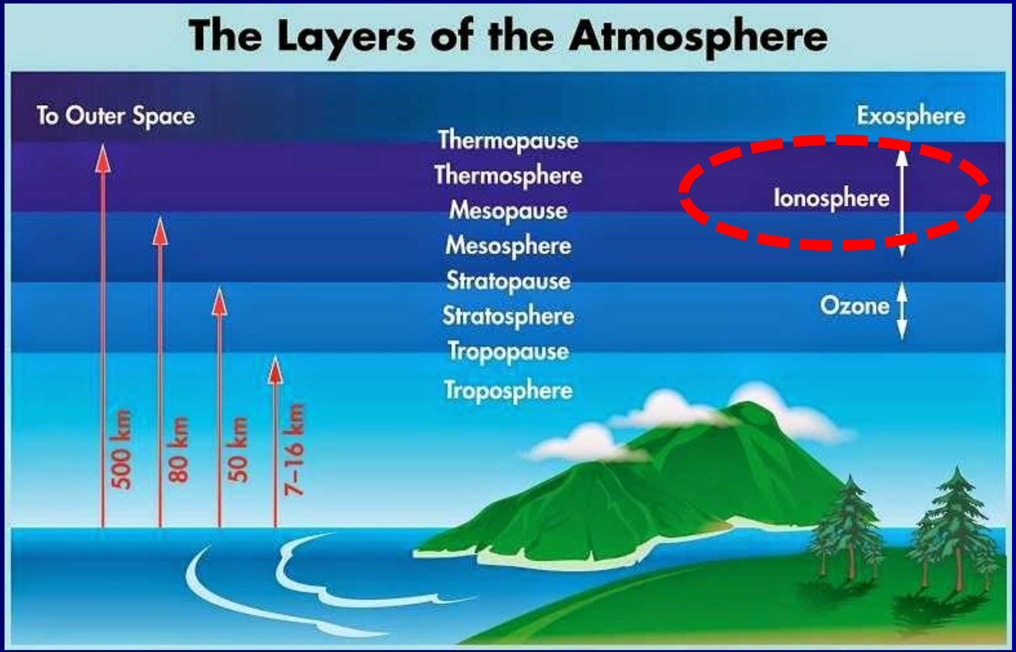
The Ionosphere

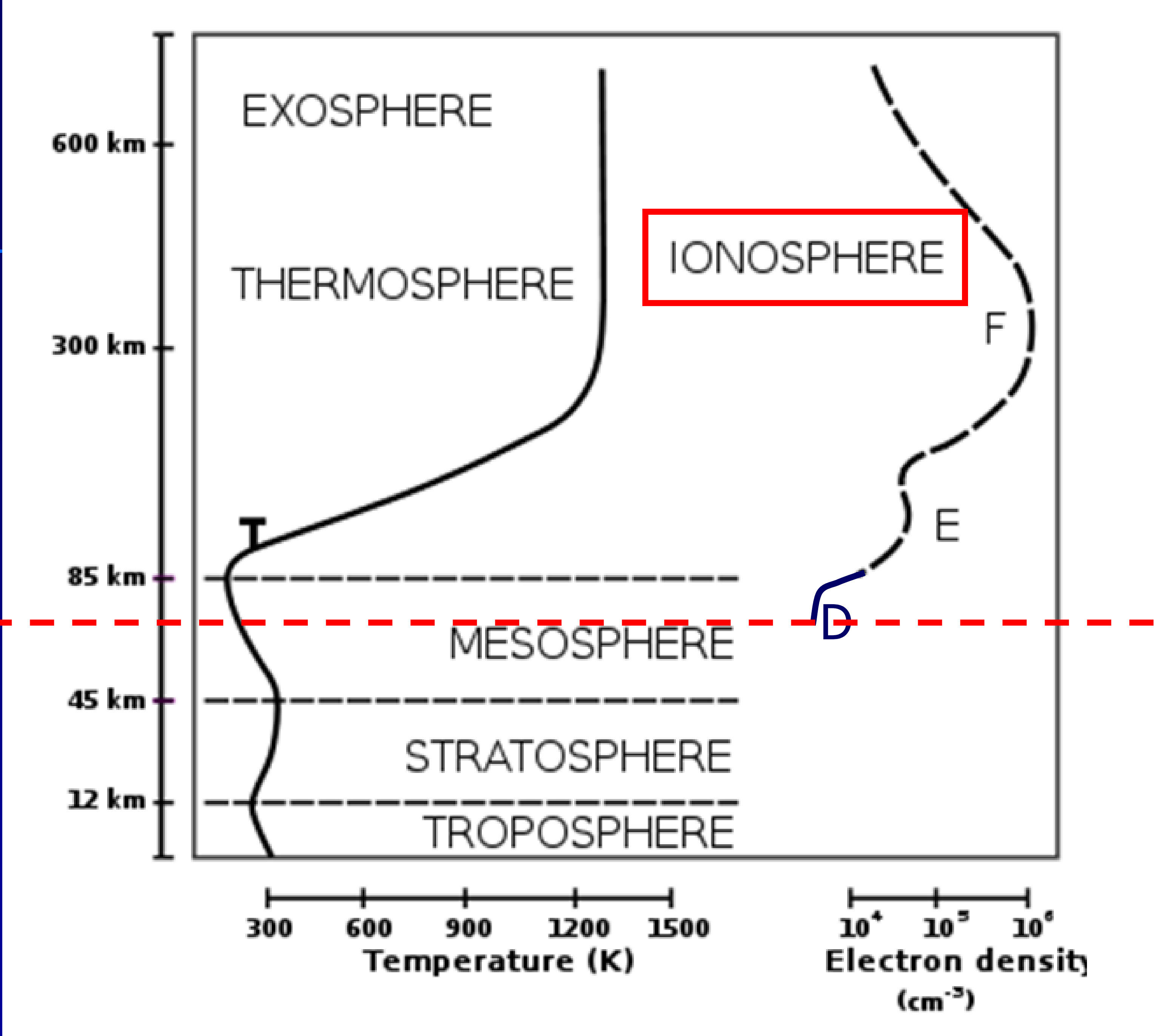
Introduction
The Chapman Layer Theory
Plasma Frequency
Collision Frequency and Absorption
The Structure of the Ionosphere and the Plasmasphere
Regular and Irregular Variations of the Ionosphere

Introduction

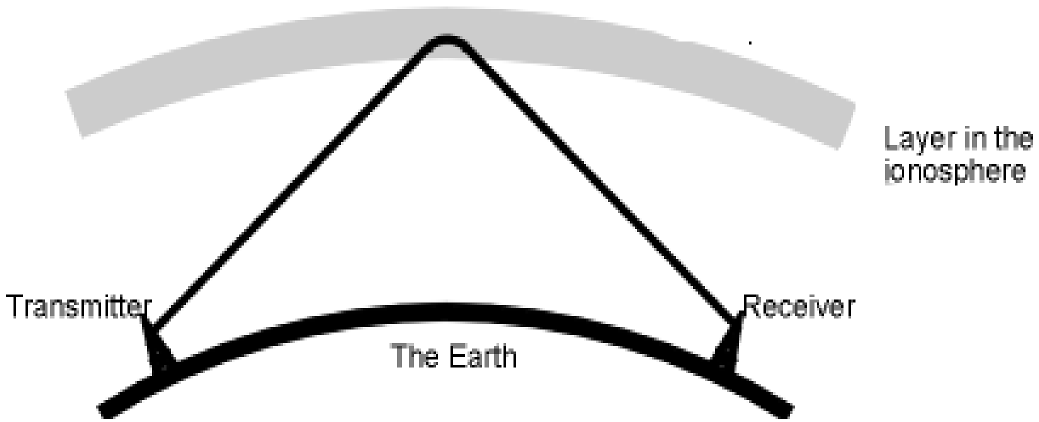
The ionosphere is a portion of the upper atmosphere, between the thermosphere and the exosphere, distinguished because it is ionized by solar radiation.

The ionosphere is a shell of **electrons** and **electrically charged atoms** and **molecules** that surrounds the Earth, stretching from a height of about 70 km on up.




EXOSPHERE
THERMOSPHERE
IONOSPHERE
F
E
D
MESOSPHERE
STRATOSPHERE
TROPOSPHERE
600 km
300 km
85 km
45 km
12 km
300
600
900
1200
1500
Temperature (K)
10^4
10^5
10^6
Electron density
(cm^{-3})

The existence of the ionosphere, as an electrically conducting region of the atmosphere, was first suggested by the Scottish meteorologist Belfour Stwart in 1883. It has practical importance because among other functions, it influences Radio Propagation to distant places on Earth.

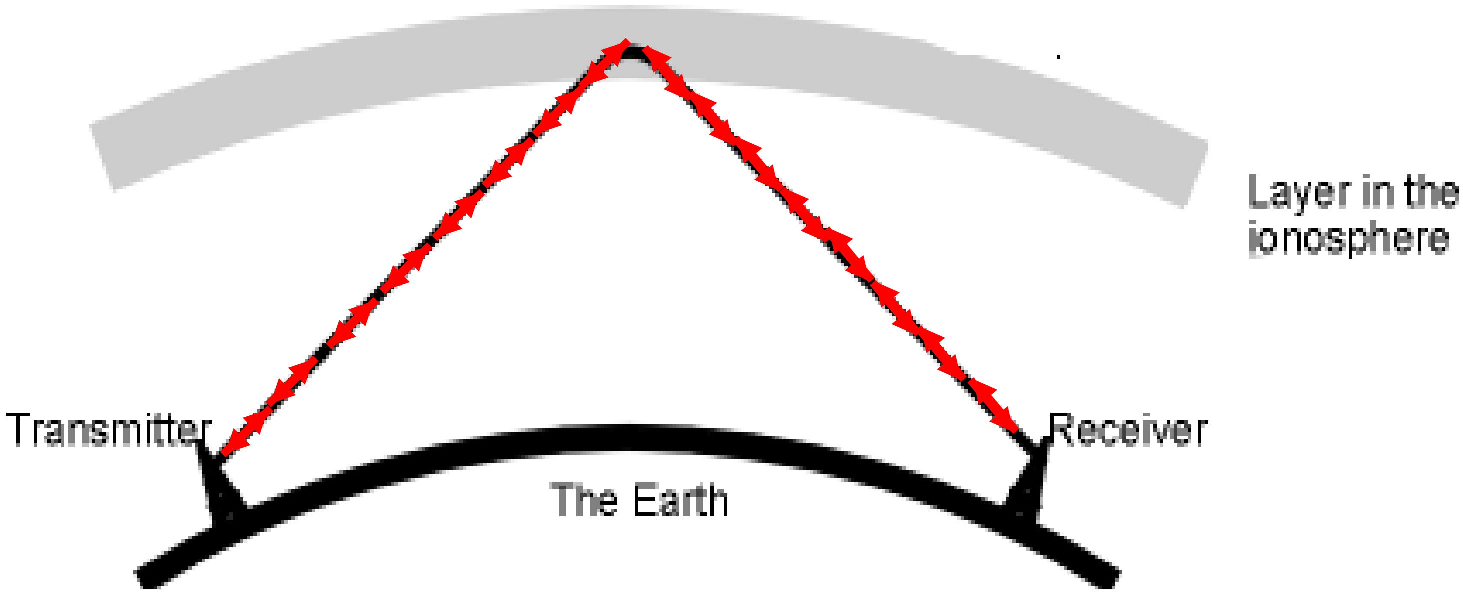


Refraction of a radio signal as it enters an ionised region

Marconi’s successful experiments in 1901 of wireless communication across the Atlantic prompted **Heaviside** and **Kennelly** to postulate independently the existence of an ionized layer in the atmosphere. This electrically conducting layer was originally called the **Heaviside** Layer and later the E-Layer because of its many free elections.

The E-layer as seen in the following figure, acts as a **reflector** and makes it possible for Radio Signals to bridge large distance over the spherical Earth. The E-layer is an altitude of approximately 110 km.

The Ionosphere acting as a reflector of radio waves making possible radio telecommunication over the horizon.

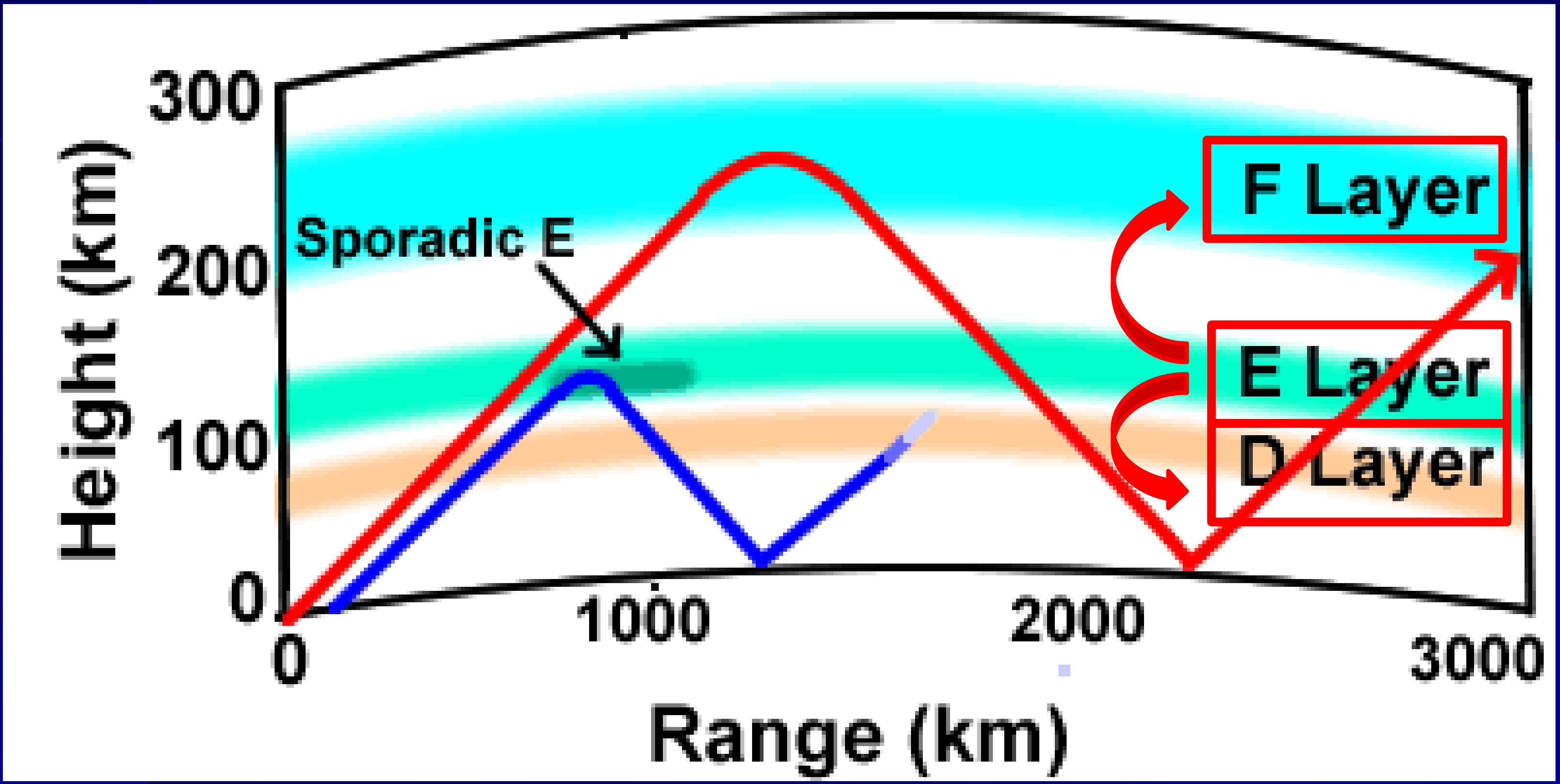


Refraction of a radio signal as it enters an ionised region

The First attempts to **study the structure of the ionosphere with Radio signals bounced back from the ionosphere** were made in **1925** by Appleton and Barnett in England.
Similar ionospheric sounding experiments were performed also in America in **1928** by Brest and Tuve.

An ionospheric sounder consists basically of a **Radio Transmitter** and a **Radio Receiver** connected in a way which allows them to **measure the time interval** between the transmission and the return of the Radio Pulse.

By multiplying one half of this time interval, which is of the order of a millisecond, with the speed of light, we obtain the **heights of the Reflection Layer.**

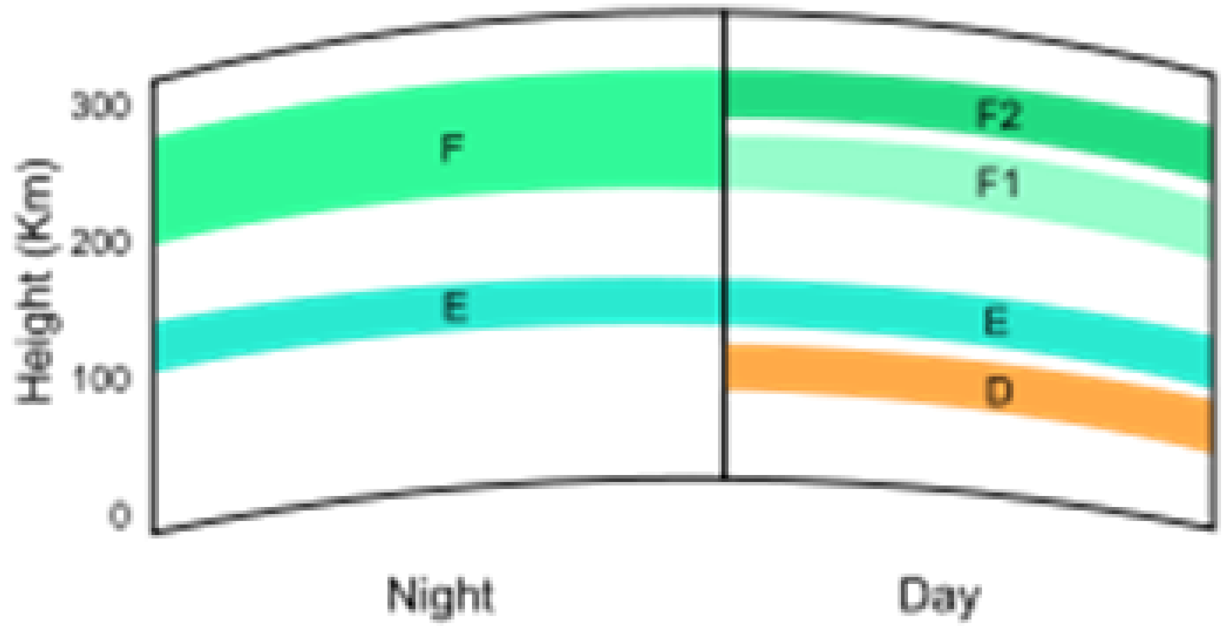

Height (km)
300
200
100
0
Sporadic E
F Layer
E Layer
D Layer
0
1000
2000
3000
Range (km)

The ionospheric layers

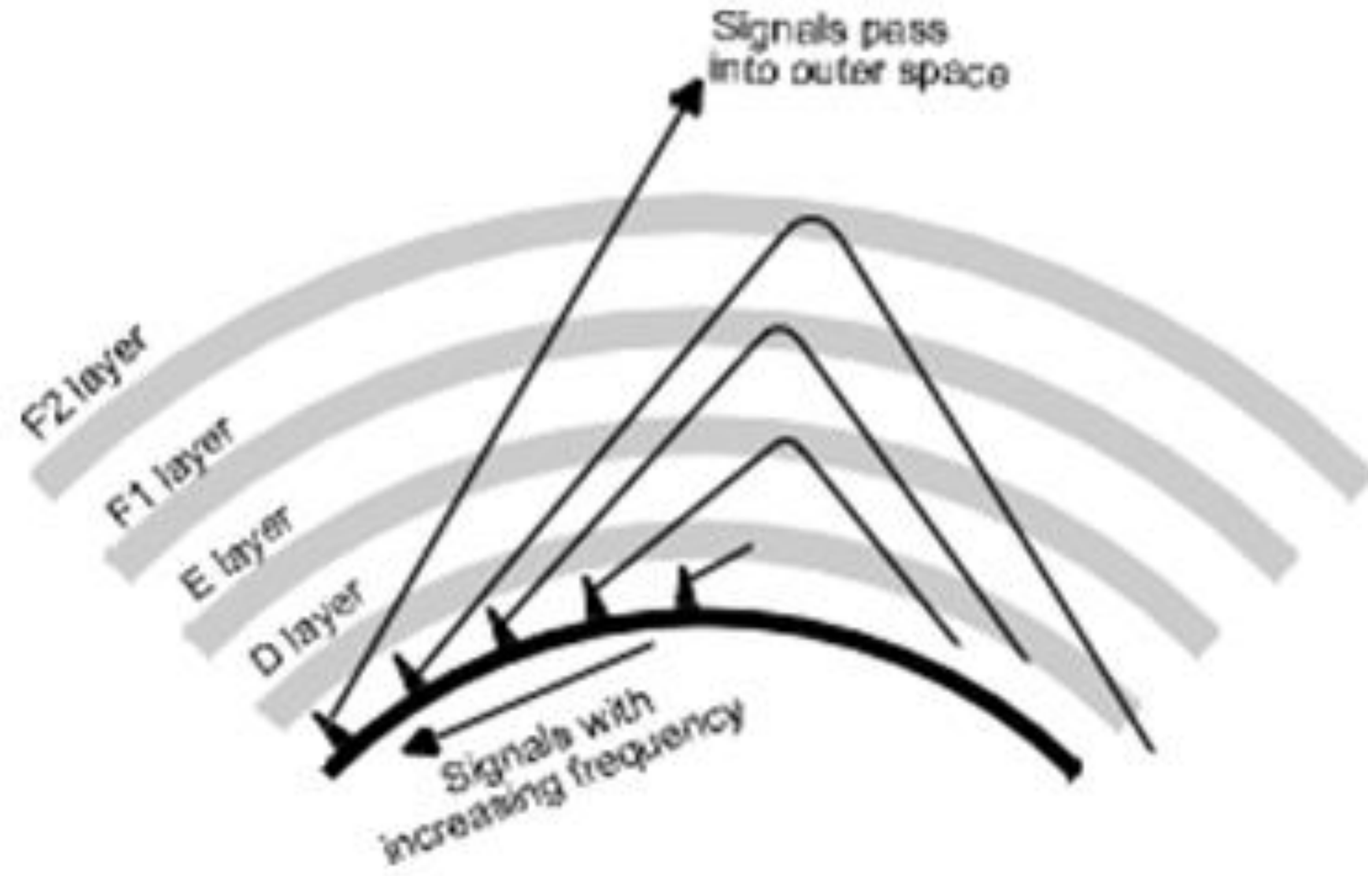
At night the F layer is the only layer of significant ionization present, while the ionization in the E and D layers is extremely low.

During the day, the D and E layers become much more heavily ionized, as does the F layer, which develops an additional, weaker region of ionisation known as the F1 layer. The F2 layer persists by day and night and is the region mainly responsible for the refraction of radio waves.

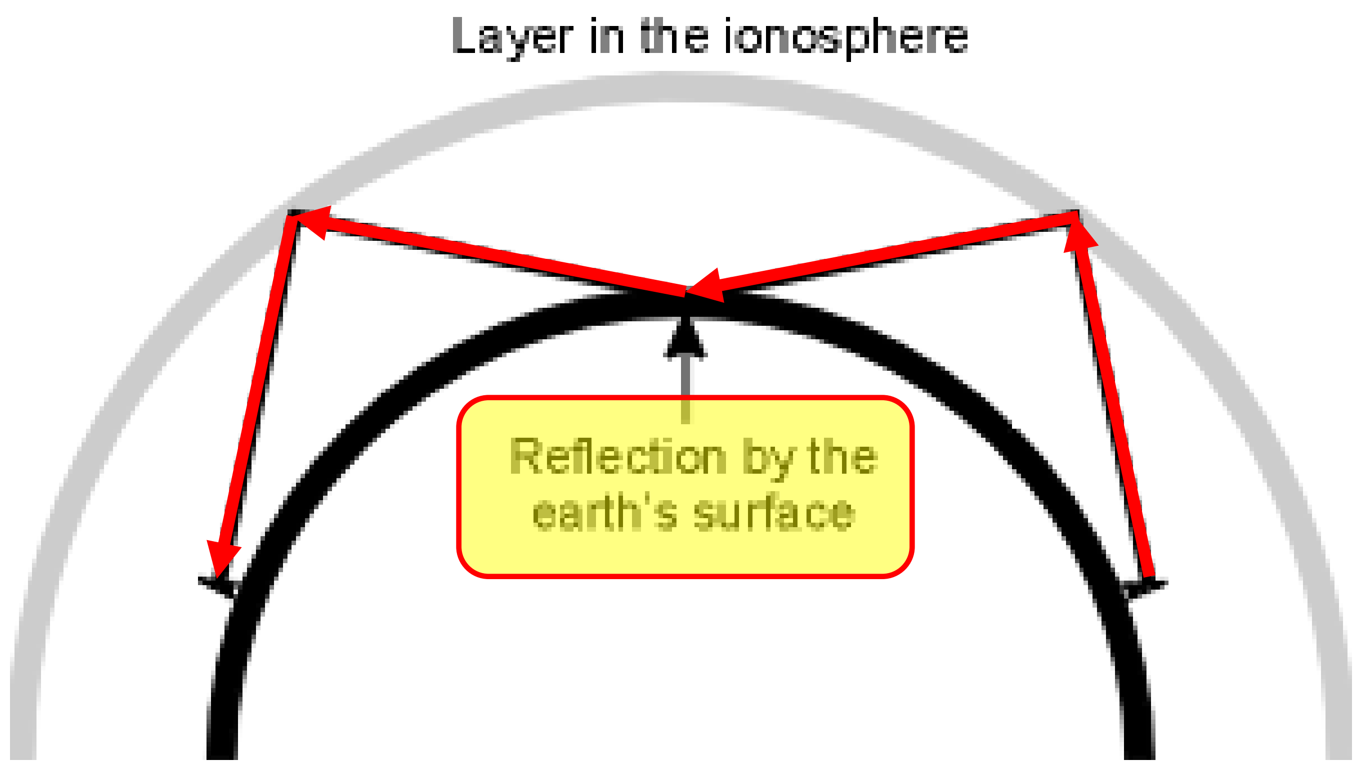
The ionospheric layers



Ionospheric layers.



Signals reflected by the E and F regions



Multiple reflections

The ionospheric layers

D-layer or D-region

The D layer is the innermost layer, 60 km to 90 km above the surface of the Earth.

Ionization here is due to **Lyman series-alpha hydrogen radiation** at a **wavelength of 121.5 nm** ionizing **nitric oxide (NO).**

In addition, with high solar activity hard X-rays ($\lambda < 1$ nm) may ionize (N_2, O_2).

During the night cosmic rays produce a residual amount of ionization.

The ionospheric layers

D-layer or D-region

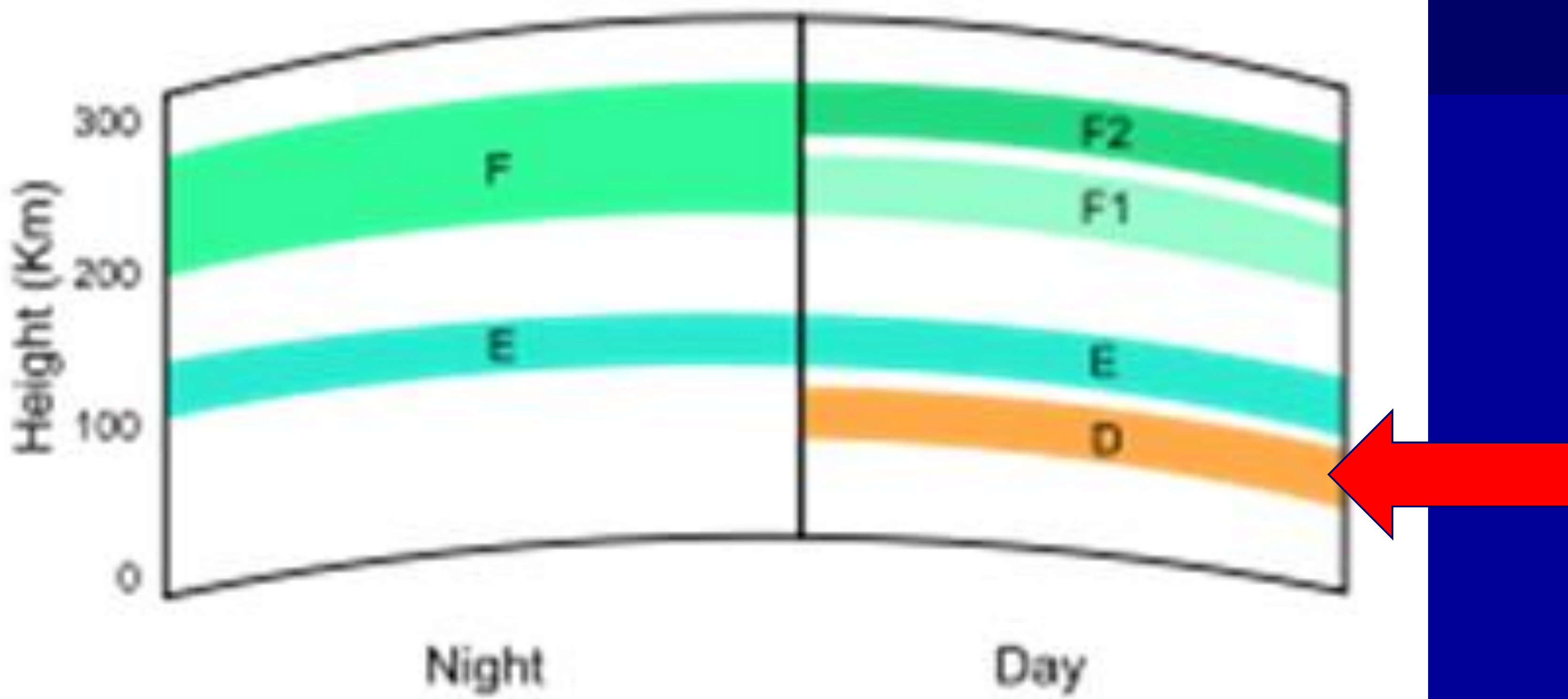
Recombination is high in the D layer, the net ionization effect is low, but loss of wave energy is great due to frequent collisions of the electrons (about 10 collisions every mili-seconds).

As a result high-frequency (HF) radio waves are not reflected by the D layer but suffer loss of energy there in.

This is the main reason for absorption of HF radio waves, particularly at 10 MHz and below, with progressively smaller absorption as the frequency gets higher.

The ionospheric layers

D-layer or D-region



Ionization is due to – Lyman series - Alpha

Ionizing of – Nitric Oxide (NO)

Also ionization due to –

Hard X – rays ($\lambda < 1$ nm)

Ionizing of – N_2, O_2

The ionospheric layers

E-layer or E-region

The E - layer is the middle layer, 90 km to 120 km above the surface of the Earth.

Ionization is due to **soft X-ray (1–10 nm)** and **far ultraviolet (UV)** solar radiation ionization of molecular oxygen (O_2).

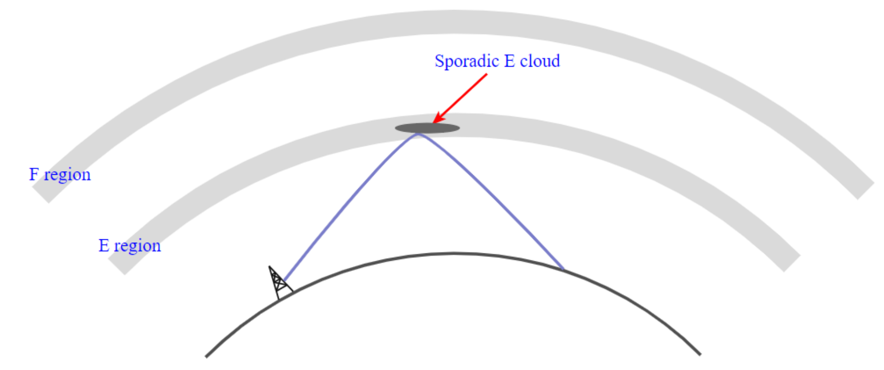
Normally this layer can only reflect radio waves having frequencies **lower than about 10 MHz** and may contribute a bit to absorption on frequencies above.

However, **during intense** (quick) **Sporadic E events, the E_s layer (Sporadic E layer) can reflect frequencies up to 50 MHz and higher.**

The ionospheric layers

E_s – Sporadic (කඩින් කඩ) layer

E sporadic is a form of **E layer** ionisation that occurs randomly in the ionosphere. It can affect frequencies normally affected by **ionospheric** propagation, but as the levels of ionisation can rise very high, it can affect frequencies much higher than would be expected by normal **E** region ionisation.

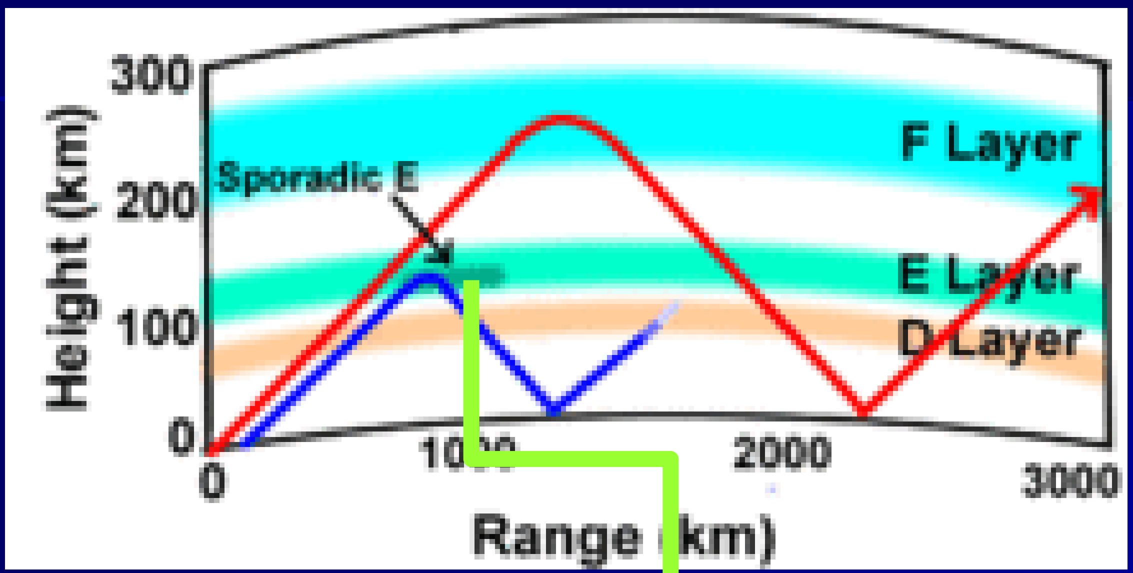


Sporadic E propagation

Sporadic E propagation bounces signals off smaller "clouds" of unusually ionized atmospheric gas in the lower E-region (located at altitudes of approx. 90 to 160 km).

The ionospheric layers

E_s – Sporadic (කඩින් කඩ) E - layer



The E_s layer is **characterized by small, thin clouds of intense ionization, which can support reflection of radio waves**, rarely up to 225 MHz. Sporadic-E events may last **for just a few minutes to several hours**. Sporadic E propagation makes radio amateurs (learner) very excited, as propagation paths that are generally unreachable can open up.

The ionospheric layers

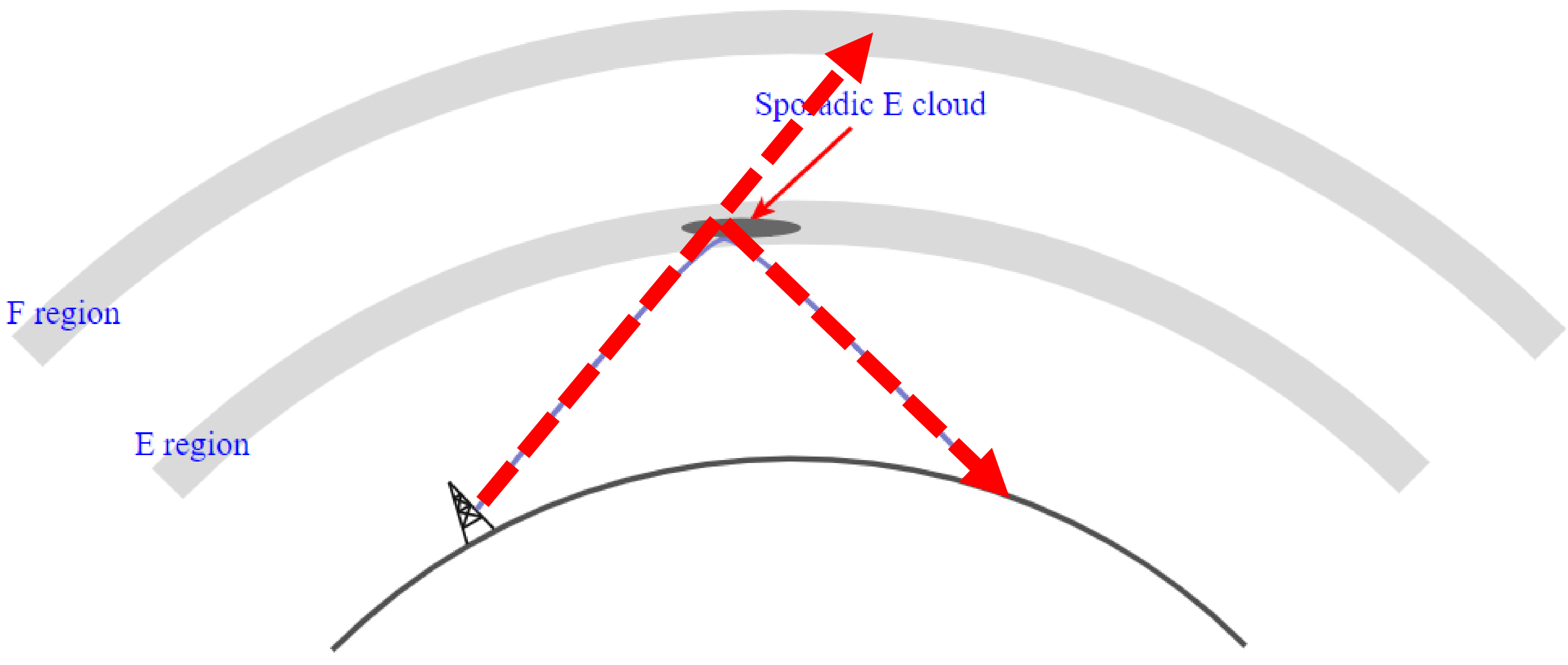
E-layer or E-region

E_s - Sporadic E - layer

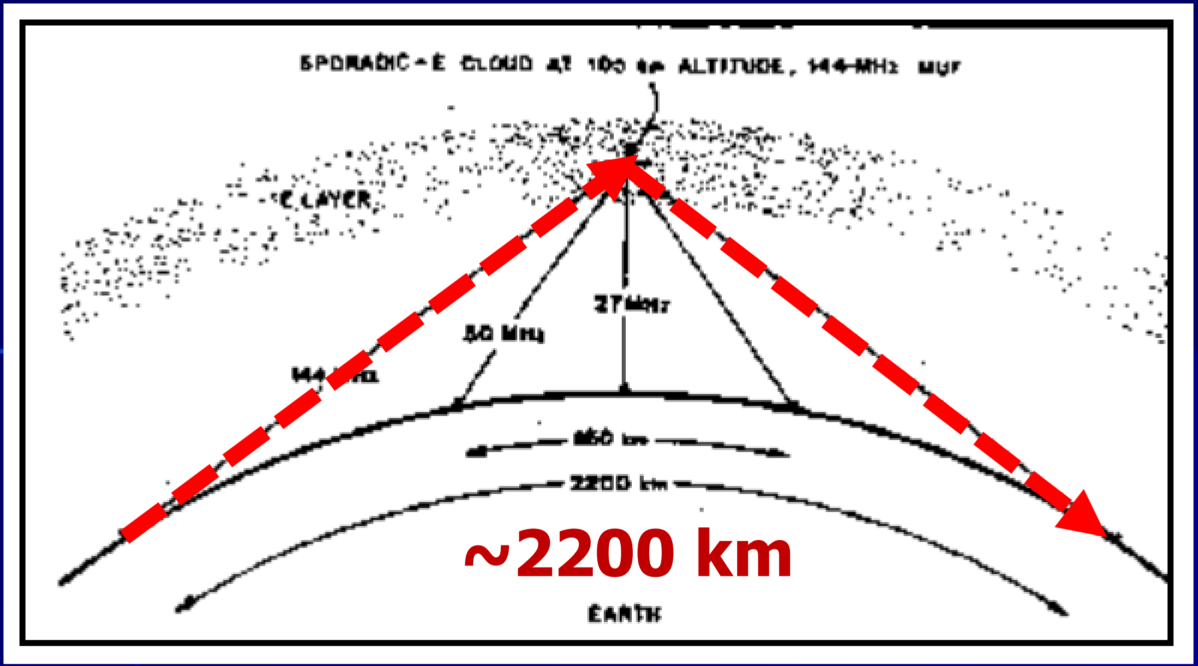
There are multiple causes of sporadic-E that are still being pursued by researchers. This propagation occurs most frequently during the summer months when high signal levels may be reached.

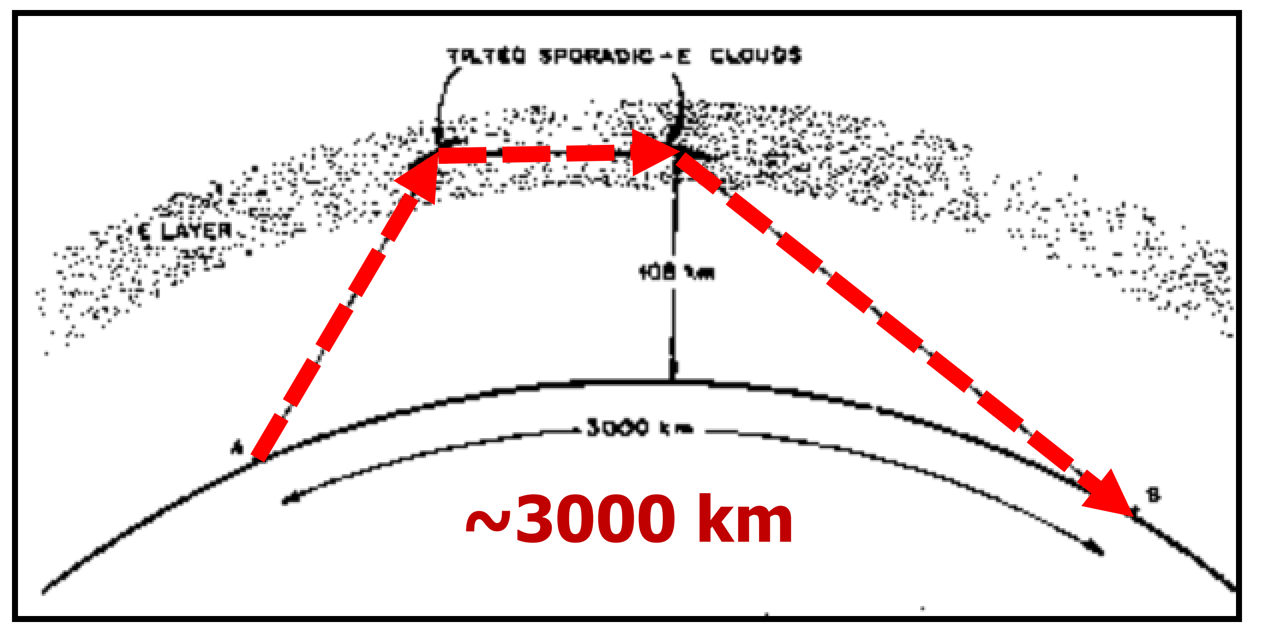
The **skip distances are generally around 1000 km**. VHF TV and FM broadcast also get excited as their signals can be bounced back to Earth by E_s.

Distances for one hop propagation can be as close as 900 km or up to 2,500 km. Double-hop reception over 3,500 km is possible too.



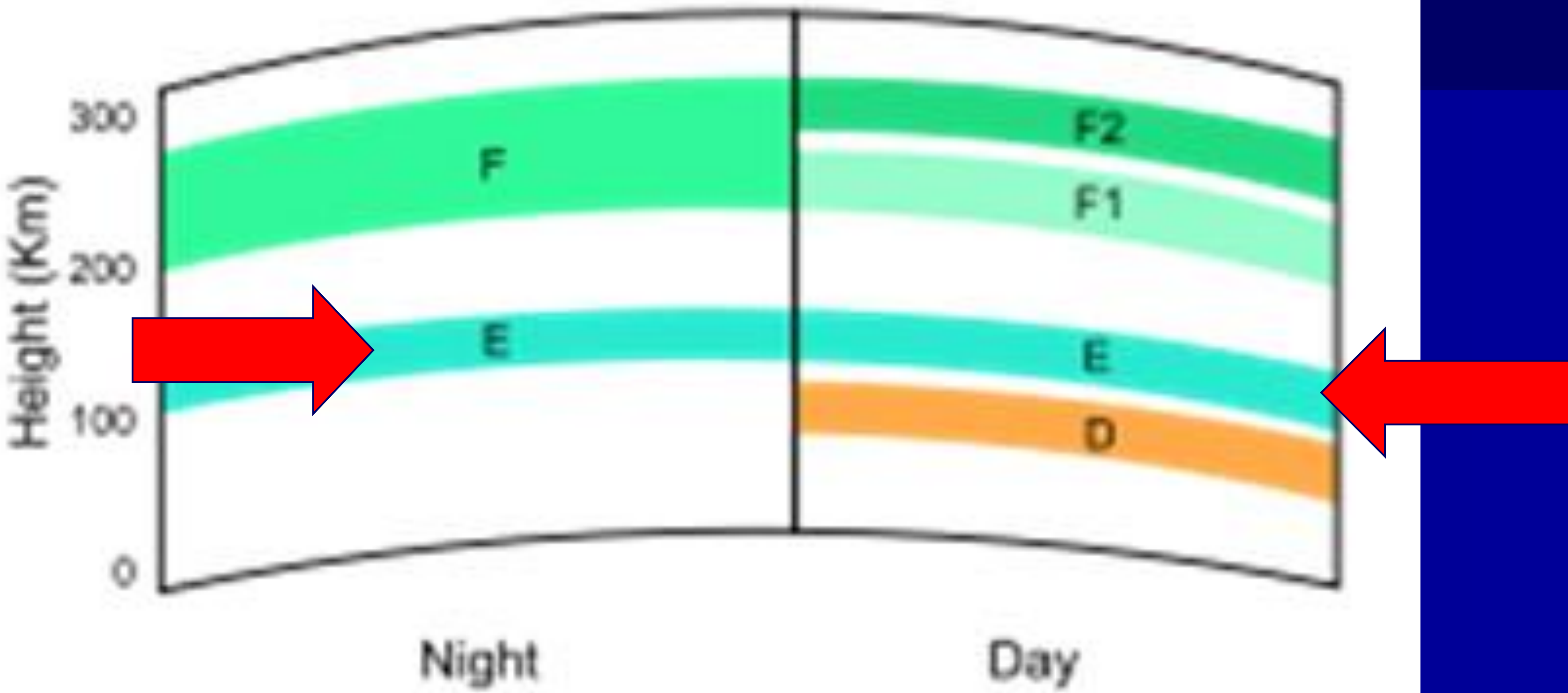
Sporadic E propagation


E LAYER
27 MHz
50 MHz
2200 km
~2200 km
EARTH


SPORADIC-E CLOUDS
E LAYER
100 km
3000 km
A
B
~3000 km

The ionospheric layers

E-layer or E-region



Ionization is due to –

Soft X – rays (λ, 1-10 nm) &

Far Ultra Violet

Ionizing of – Molecular Oxygen (O)

E_s – Sporadic E-layer

The ionospheric layers

F-layer or F-region

The F layer or F region, also known as the **Appleton layer**, extends from about 200 km to more than 500 km above the surface of Earth.

It is the **densest point of the ionosphere**, **which implies signals penetrating this layer will escape into space**.

Beyond this layer is the topside ionosphere. **Here extreme ultraviolet (UV, 10–100 nm)** solar radiation **ionizes atomic oxygen**.

The ionospheric layers

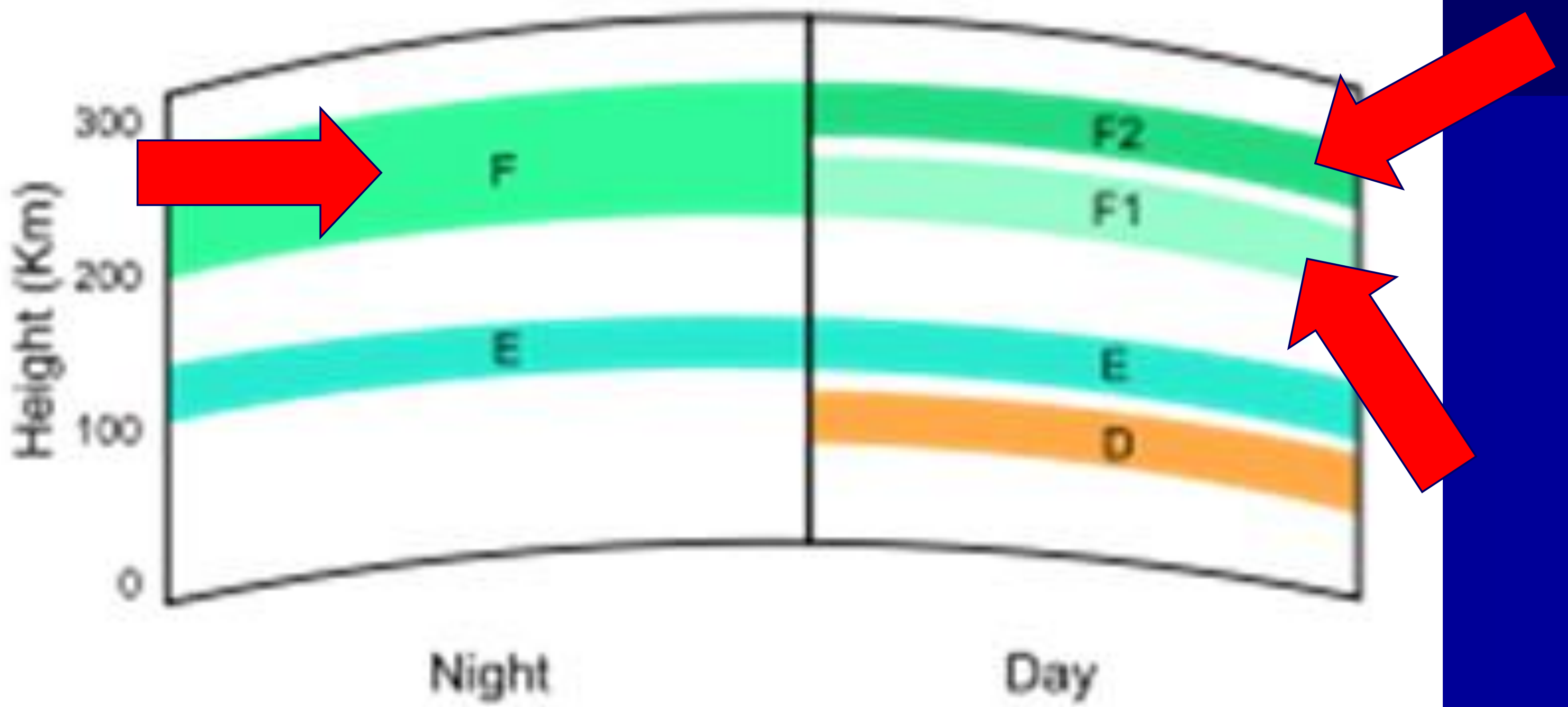
F-layer or F-region

The F layer consists of one layer at night, but during the day, a deformation often forms in the profile that is labeled F_1.

The F_2 layer remains by day and night responsible for most sky wave propagation of radio waves, facilitating high frequency (HF or shortwave, SW) radio communications over long distances.

The ionospheric layers

F-layer or F-region



Ionization is due to –

Extreme Ultra Violet

(λ, 10-100 nm)

Ionizing of – Atomic Oxygen

F_1 and F_2 - layer

Ionospheric regions

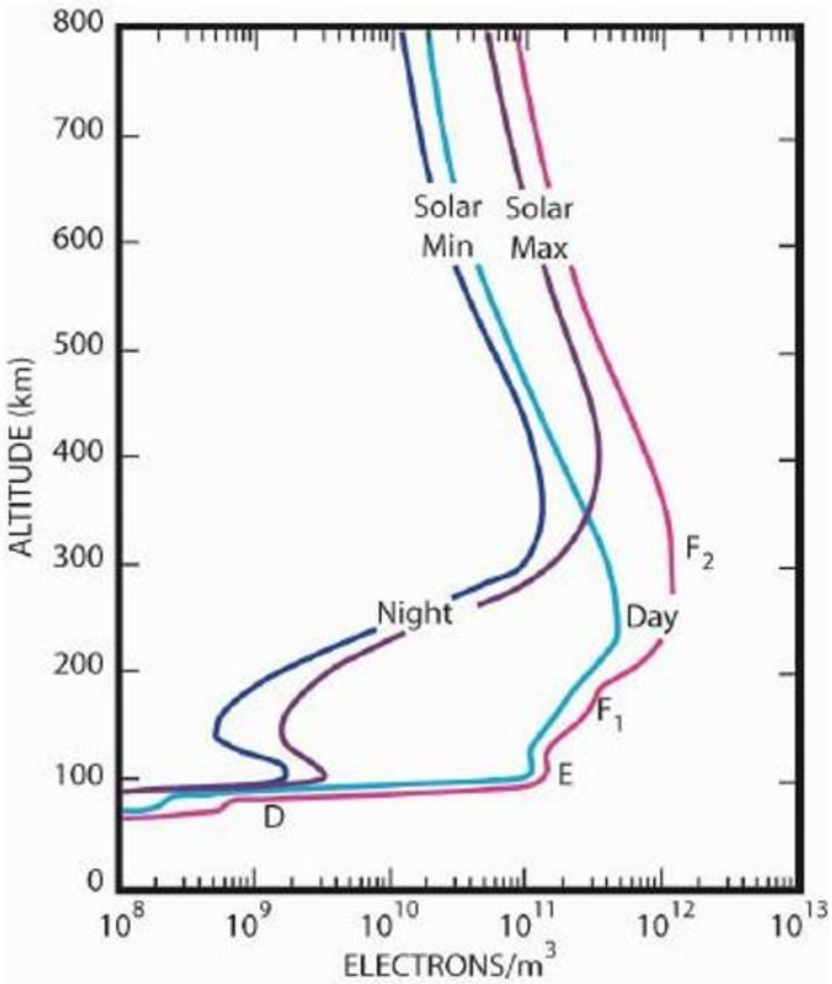


Figure: Typical ionospheric electron density profiles.

Ionospheric regions and typical daytime electron densities:

- D region: 60–90 km, $n_e = 10^8$–10^{10} m^{-3}
- E region: 90–150 km, $n_e = 10^{10}$–10^{11} m^{-3}
- F region: 150–1000 km, $n_e = 10^{11}$–10^{12} m^{-3} .

Ionosphere has great variability:

- Solar cycle variations (in specific upper F region)
- Day-night variation in lower F, E and D regions
- Space weather effects based on short-term solar variability (lower F, E and D regions)

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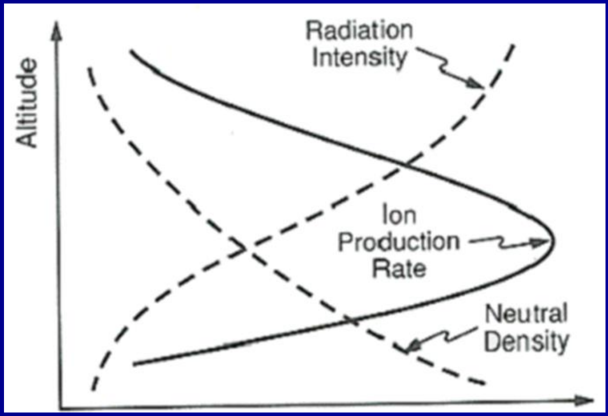
Chapman layer Theory

The Ionization of the atmosphere

The ionization of the atmosphere is produced primarily by the Sun's Ultraviolet and X-ray radiation. **The rate q at which ion-electron pairs are produced per unit volume is proportional to the intensity of the ionizing radiation I and the number density N_n of the neutral atmosphere**, i.e.:

$$q \; \alpha \; I \cdot N_n$$

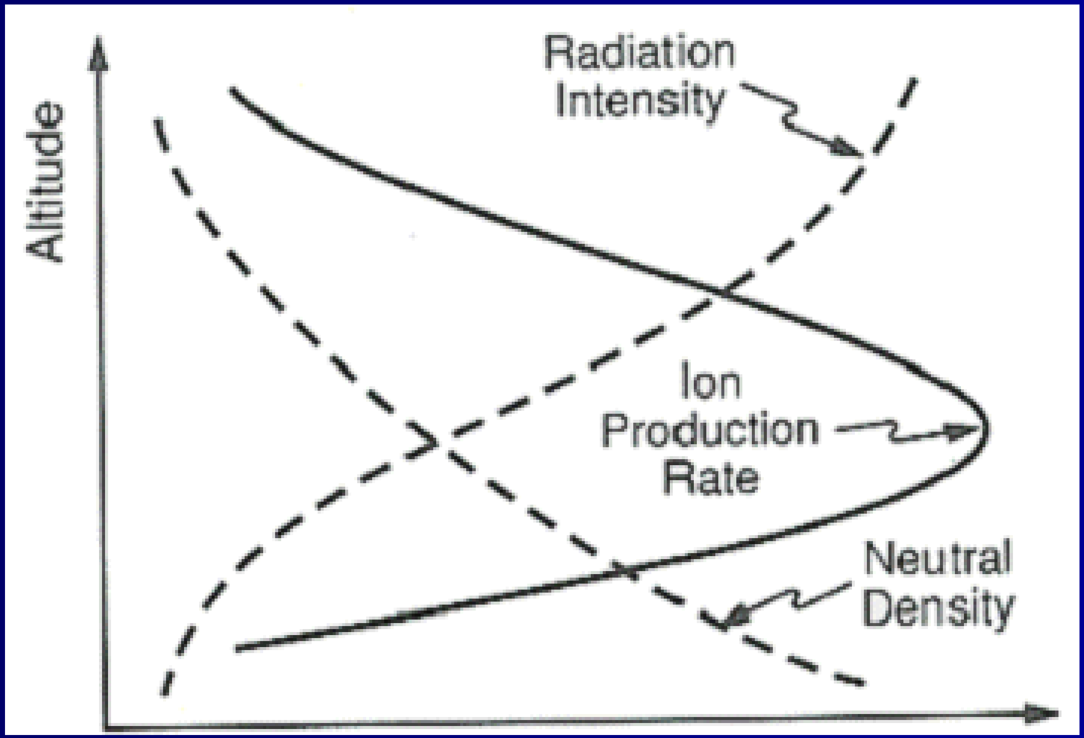
As seen from the following diagram, at high altitudes q **is very small because N_n is very small.** As the ionizing radiation penetrates deeper into the more dense layers of the atmosphere, q reaches a maximum q_m at a height h_m where I and N_n reach the best possible combination.



Chapman layer Theory

The Ionization of the atmosphere

Below this altitude, the intensity of the ionizing radiation drops rapidly because the energy is spent for the ionization of the atmosphere. As I decreases, q also decreases and finally vanishes near **70 km**.



Chapman layer Theory

The Ionization of the atmosphere

Chapman in 1931 produced a very neat theoretical treatment of the problem. In his simplified model, Chapman assumed,

- ◊ an isothermal,
- ◊ horizontally stratified atmosphere,
- ◊ composed of a single gas, which is been ionized by
- ◊ monochromatic radiation from the Sun.

It is obvious that this model is an **over simplification** of the actual conditions.

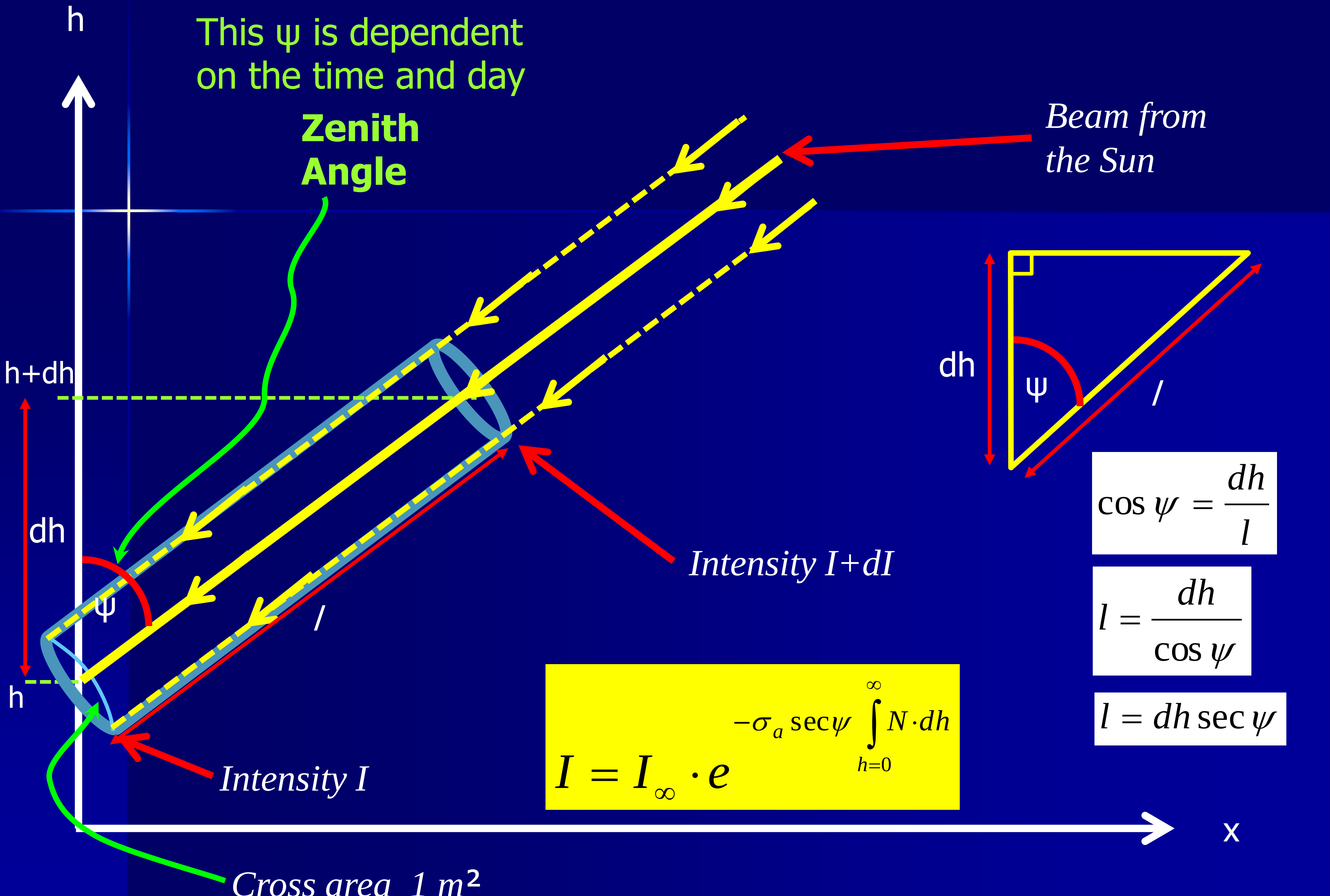
Chapman layer Theory

The Chapman Layer Theory in 1931 is a very good example of an **ingenious mathematical formulation** of a very complicated physical problem.

Intensity of Ionizing Radiation :

Let us first compute the absorption sustained by a beam of ionizing radiation at a height *h*. Let the beam have **unit cross-section** and ψ be the angle the beam makes with the vertical (called **Zenith Angle**). The energy of the beam expanded to ionized neutral particles between h and h+dh will be proportional to the intensity of the beam at this height I(h).

P.T.O



$$\cos\psi = \frac{dh}{l}$$

$$l = \frac{dh}{\cos\psi}$$

$$l = dh \sec\psi$$

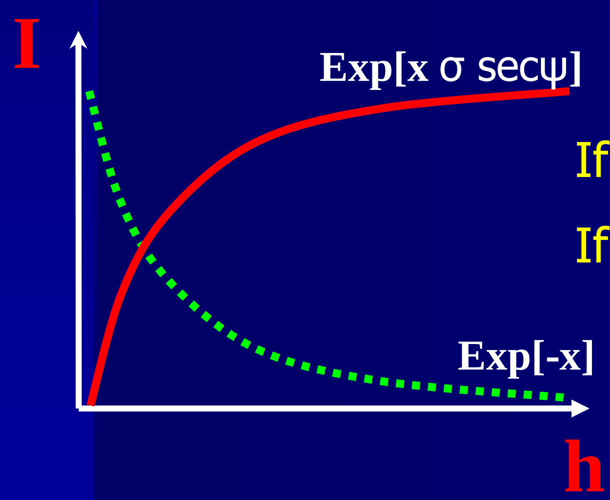
$$I = I_\infty \cdot e^{-\sigma_a \sec\psi \int_{h=0}^{\infty} N \cdot dh}$$

Chapman layer Theory

Intensity of Ionizing Radiation

$$I = I_{\infty} \cdot e^{-\sigma_a \sec\psi \int_{h=0}^{\infty} N \cdot dh}$$

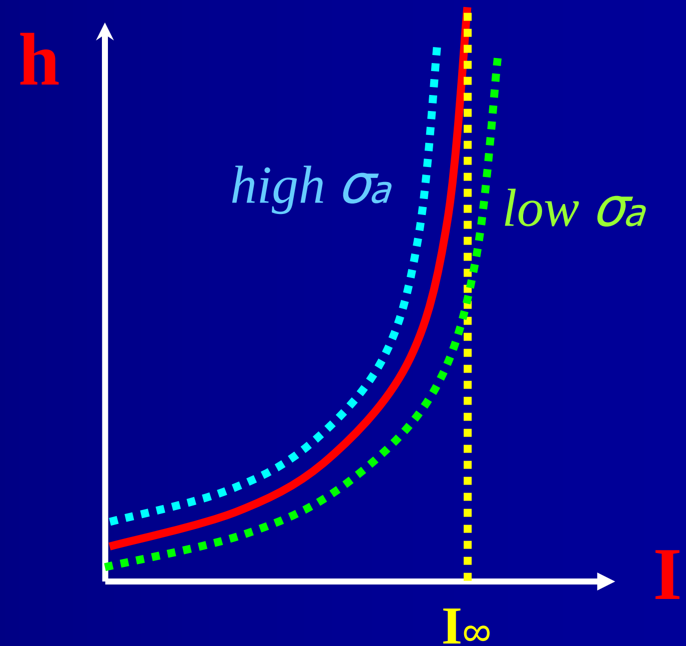
- *Intensity of Ionizing Radiation at height h*: I
- *Intensity of Ionizing Radiation at infinity*: I_{∞}
- *Absorption Cross-section*: σ_a
- *Zenith Angle*: ψ
- *Molecular Number Density*: N



If h ↑ , σ ↓ and

If h ↑ , ψ ↑

Ionization Radiation (I)



Ionization Wavelength (λ) :

Ionization of O, O_2 , NO and N_2 in the Earth atmosphere due to radiation at a particular wavelength from the Sun. This wavelength is called "Ionization Wavelength".

For Ionization

Given wavelength to ionized

$$\lambda < \lambda_i$$

Wave length that is corresponding maximum energy of ionized of a specific material

Material	Required wavelength for ionized
N_2	796 Å
O	911 Å
O_2	1118 Å
NO	1340 Å

N_2 *is the more difficult material is to be ionized !*

Ionization Efficiency (η) :

The ratio of the number of ions formed to the number of electrons or protons used in an ionization process OR no of ion-paires per unit absorbed energy.

$$\eta = \frac{No\ of\ ion - pairs\left(e^{n}s\right)}{Absorbed\ energy}$$

If $\lambda > \lambda_i$ ➡ $\eta = 0$ (Because there are no ionized irons)

If $\lambda < \lambda_i$ ➡ $\eta > 0$ (Because there are ionized irons in this case)

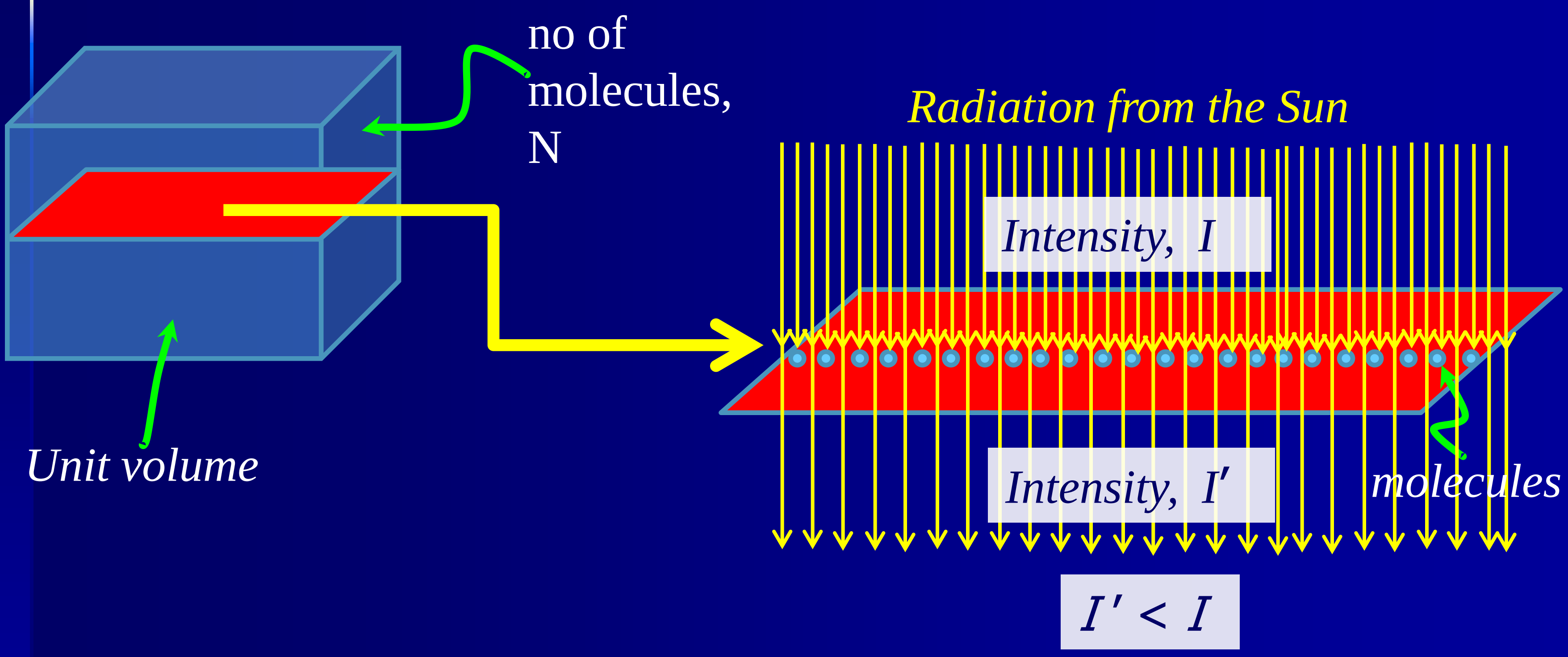
$$\eta = \frac{No\ of\ ion - pairs\left(e^{n}s\right)}{Absorbed\ energy}$$

➡ $$No\ of\ ion - pairs\left(e^{n}s\right) \quad \alpha \quad Absorbed\ energy$$

Electron Production Rate (Q)

Absorbed Intensity (*dI*)

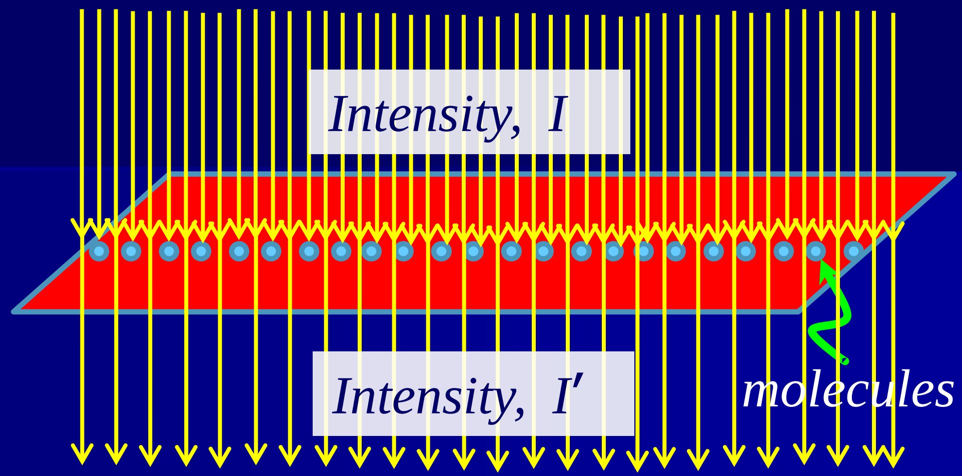
If we assume there are N no of molecules in an unit volume!



Intensity of the Radiation from the Sun (I) comes from the upside to the selected molecules layer. The intensity I' goes through that layer to the downside. $I > I'$ because the amount of $I - I'$ (= dI) radiation intensity stopped by the molecular layer.

Electron Production Rate (Q)

Absorbed Intensity (*dI*)



$I' < I$

Assume σ_a is the Absorption Cross-section area corresponding to the molecules.

Block intensity from the area $N\sigma_a$

Cross Area of the molecules in the Unit Area

$$\frac{dI}{I} = \frac{N\sigma_a}{1}$$

Where, $dI = I - I'$.

Intensity from the Sun

Intensity I comes to the cross area 1m²

Cross Area of the molecules in the Unit Area

Absorbed Intensity

$$dI = N\sigma_a I$$

Intensity of the Radiation from the Sun

Electron Production Rate (Q)

Production rate → $$Q = \eta \times dI = \eta \times N \sigma_a I$$

$$\therefore \quad Q = \frac{\eta e^{-Z}}{eH} I_\infty \cdot e^{1-\sec\psi . e^{-Z}}$$

Where N and Z are dependent variables, because

$$e^{-Z} = \sigma_a NH$$

Production rate at any point

$$Q = \frac{\eta \cdot I_\infty}{e H} e^{\left(1 - Z - \sec\psi \cdot e^{-Z}\right)}$$


Thank You !
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