Title: Physics in Nature Presentation: Why is the Sky Blue?

Date: Aug 19, 2011 01:30 PM

URL: http://pirsa.pi.local/11080101

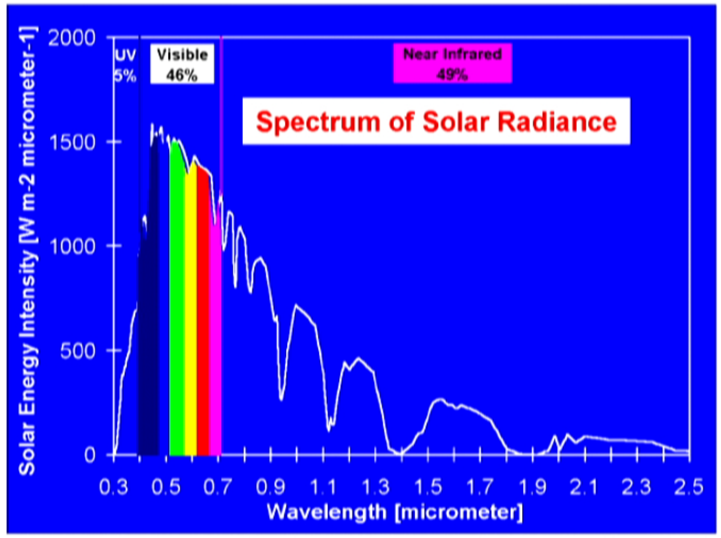
Abstract:

Why why?

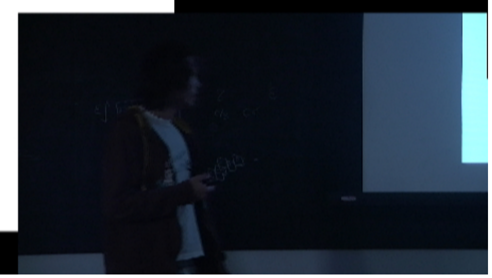
- interesting
- relations to other phenomena involving colour
- tests of the theory

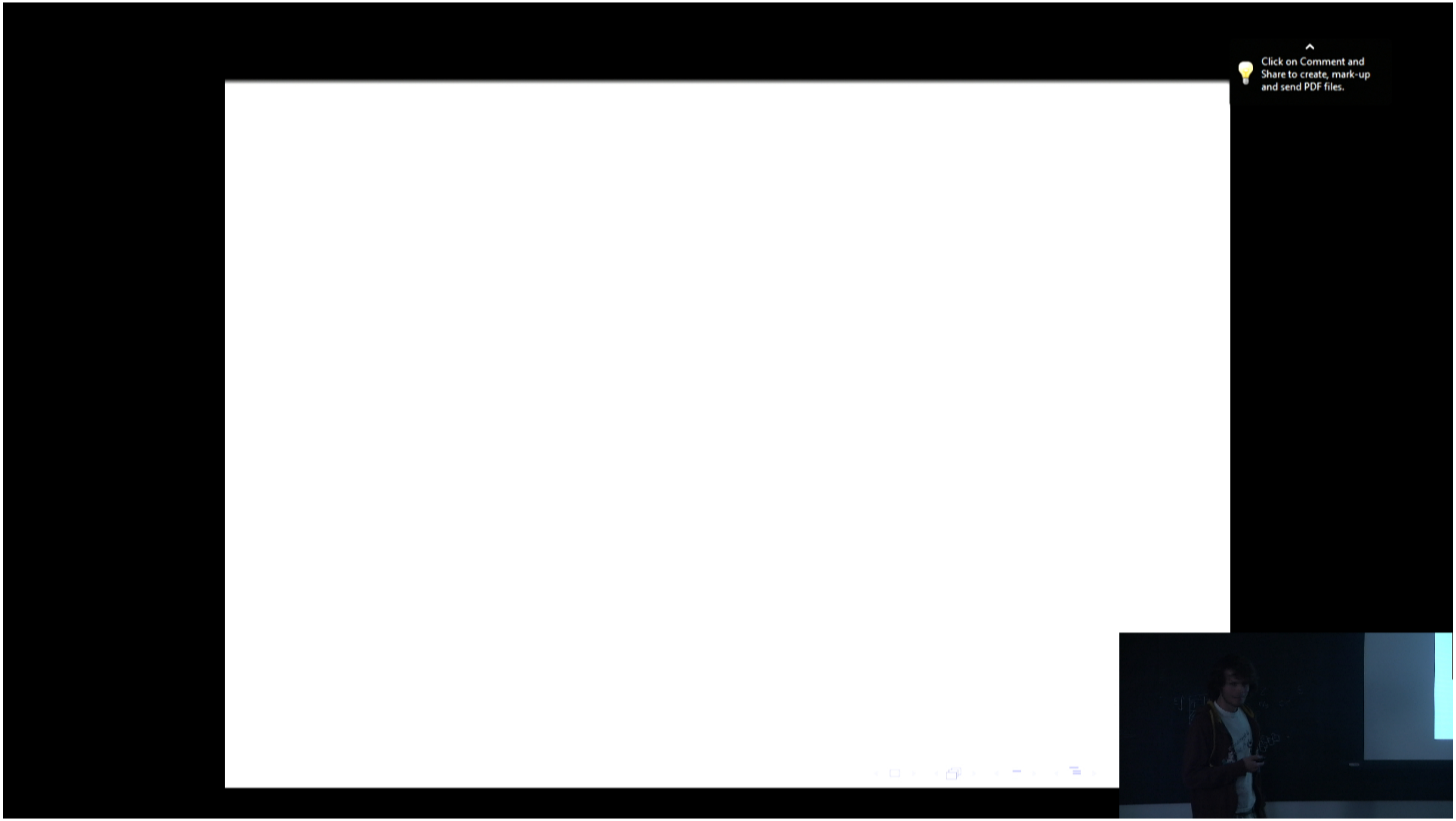
Click on Comment and Share to create, mark-up and send PDF files.

The solar spectrum



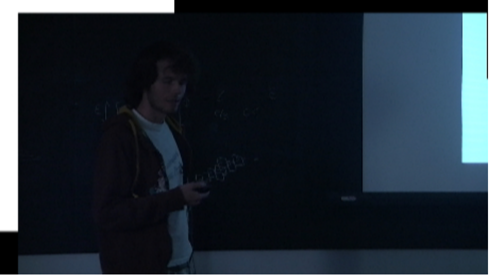
- maximum at visible wavelengths
- all colours represented about equally




Click on Comment and Share to create, mark-up and send PDF files.

Sky = Atmosphere

molecule	percentage	molecule size
N_2	78%	110 pm
O_2	21%	121 pm
Ar	1%	106 pm



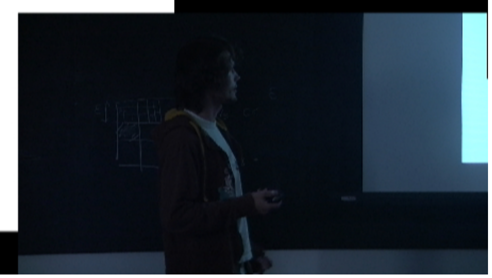
The model

- molecule = harmonic oscillator in electric field

$$\ddot{\mathbf{x}} + \omega_0^2 \mathbf{x} = \frac{q}{m} \mathbf{E} e^{i\omega t}$$

$$\Rightarrow \quad \mathbf{x}(t) = \frac{q\mathbf{E}}{m(\omega_0^2 - \omega^2)} e^{i\omega t}$$

$$\Rightarrow \quad \langle a^2 \rangle = \frac{q^2 E^2 \omega^4}{2m^2(\omega^2 - \omega_0^2)^2}$$



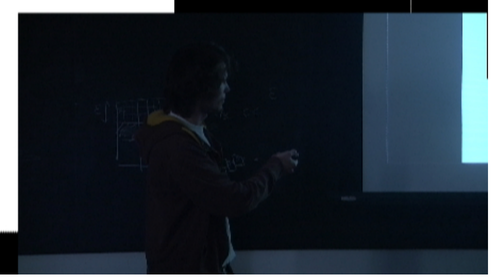
The model

- molecule = harmonic oscillator in electric field

$$\ddot{\mathbf{x}} + \omega_0^2 \mathbf{x} = \frac{q}{m} \mathbf{E} e^{i\omega t}$$

$$\Rightarrow \quad \mathbf{x}(t) = \frac{q\mathbf{E}}{m(\omega_0^2 - \omega^2)} e^{i\omega t}$$

$$\Rightarrow \quad \langle a^2 \rangle = \frac{q^2 E^2 \omega^4}{2m^2(\omega^2 - \omega_0^2)^2}$$



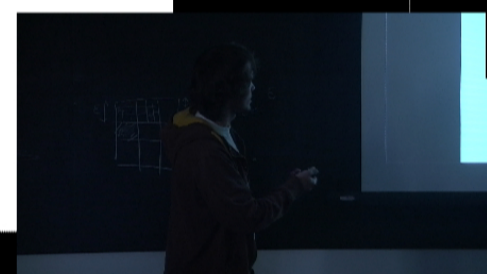
The model

- molecule = harmonic oscillator in electric field

$$\ddot{\mathbf{x}} + \omega_0^2 \mathbf{x} = \frac{q}{m} \mathbf{E} e^{i\omega t}$$

$$\Rightarrow \quad \mathbf{x}(t) = \frac{q\mathbf{E}}{m(\omega_0^2 - \omega^2)} e^{i\omega t}$$

$$\Rightarrow \quad \langle a^2 \rangle = \frac{q^2 E^2 \omega^4}{2m^2(\omega^2 - \omega_0^2)^2}$$

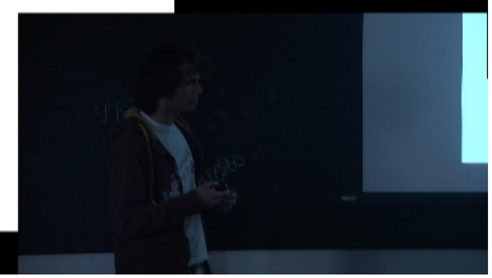


Rayleigh scattering

- molecule size $\ll \lambda \quad \Rightarrow \quad \omega_0 \gg \omega$
- radiated power

$$\begin{aligned}\langle P \rangle &= \frac{q^2}{6\pi\varepsilon_0 c^3} \langle a^2 \rangle \\ &= \frac{q^4 E^2}{12\pi\varepsilon_0 m^2 c^3} \left(\frac{\omega}{\omega_0} \right)^4\end{aligned}$$

- $\langle P \rangle \propto 1/\lambda^4$, so the sky is blue!



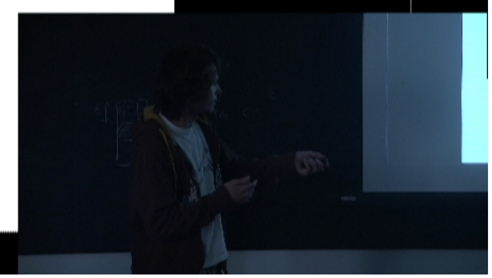
The model

- molecule = harmonic oscillator in electric field

$$\ddot{\mathbf{x}} + \omega_0^2 \mathbf{x} = \frac{q}{m}\mathbf{E}e^{i\omega t}$$

$$\Rightarrow \quad \mathbf{x}(t) = \frac{q\mathbf{E}}{m(\omega_0^2 - \omega^2)}e^{i\omega t}$$

$$\Rightarrow \quad \langle a^2 \rangle = \frac{q^2 E^2 \omega^4}{2m^2(\omega^2 - \omega_0^2)^2}$$

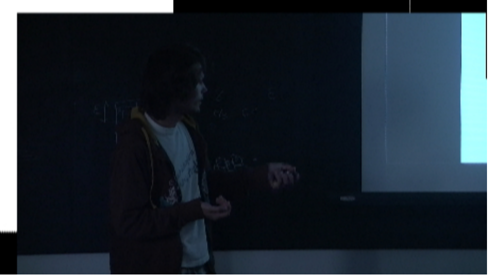


Rayleigh scattering

- molecule size $\ll \lambda \quad \Rightarrow \quad \omega_0 \gg \omega$
- radiated power

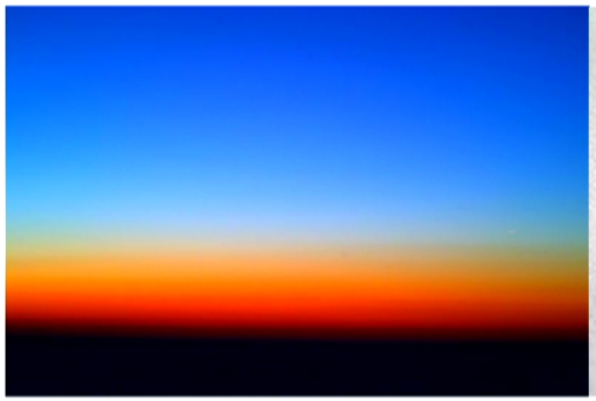
$$\langle P \rangle = \frac{q^2}{6\pi\varepsilon_0 c^3}\langle a^2 \rangle$$
$$= \frac{q^4 E^2}{12\pi\varepsilon_0 m^2 c^3}\left(\frac{\omega}{\omega_0}\right)^4$$

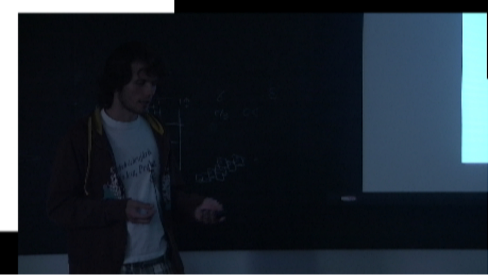
- $\langle P \rangle \propto 1/\lambda^4$, so the sky is blue!



Why is the sunset red?

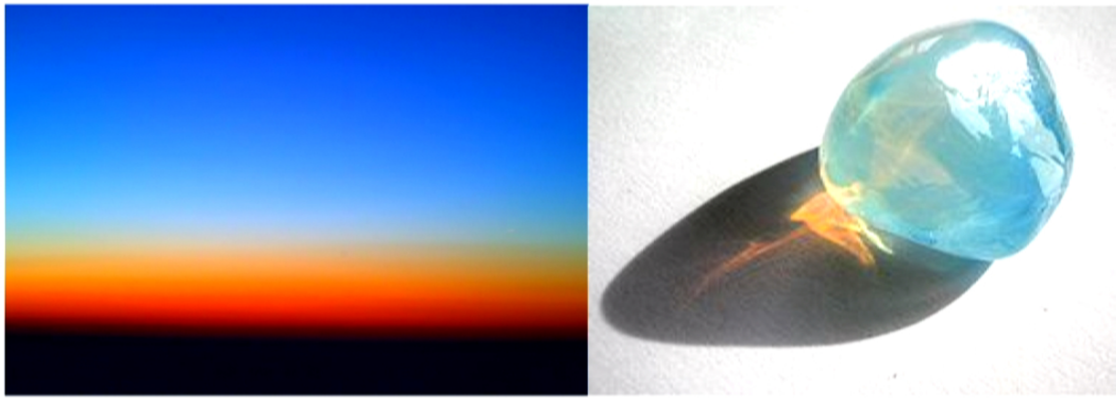
- blue light scatters away $\Rightarrow$ left with red light

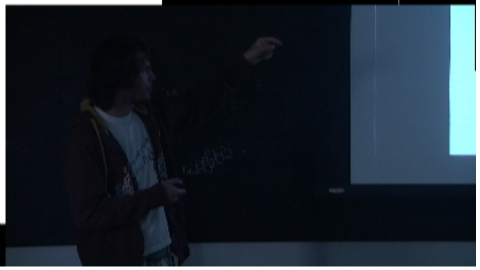




Why is the sunset red?

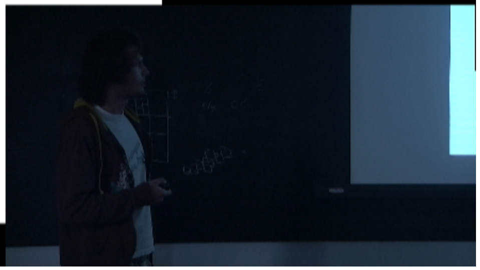
- blue light scatters away $\Rightarrow$ left with red light





Bonus: Why are clouds (white)?

- condensation $\Rightarrow$ constructive interference
- works until droplet size $\approx \lambda$
- red light $\Rightarrow$ larger droplets allowed to contribute

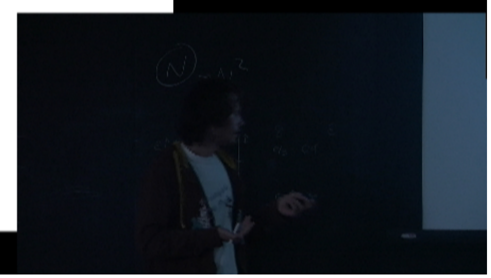


Bonus: Why are clouds (white)?

- condensation $\Rightarrow$ constructive interference
- works until droplet size $\approx \lambda$
- red light $\Rightarrow$ larger droplets allowed to contribute

Improvements

- do not neglect molecule size - Mie theory
- more realistic model of the molecule - QM
- polarization



Why is the sunset red?

- blue light scatters away ⇒ left with red light