X-Ray Attenuation through the Upper Atmosphere

The Fundamentals and Intuition Behind Detecting a Nuclear Explosion from Space

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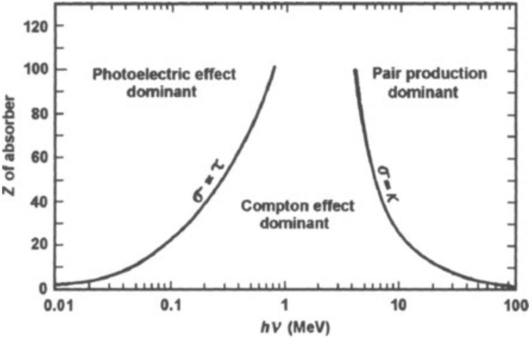
X-Ray Production

- 35-45% Energy released as thermal radiation
- Produces fireball with extremely high temperatures (100 million C)
- Fireball acts as a blackbody and radiates in the x-ray spectrum

X-Ray Attenuation

- Compton-effect
- Photoelectric-effect
- Pair-production



- Together, these form the attenuation coefficient for a particular medium

X-Ray Attenuation Coefficient

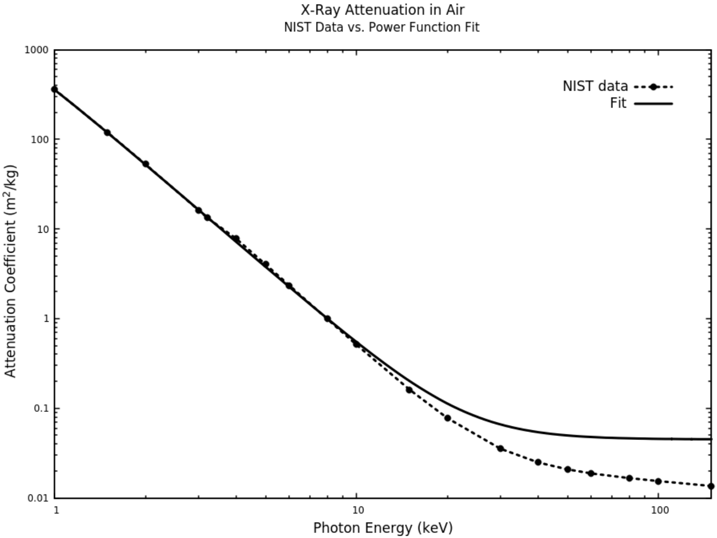


Figure: X-Ray Attenuation Coefficient Fit

Attenuation Equation

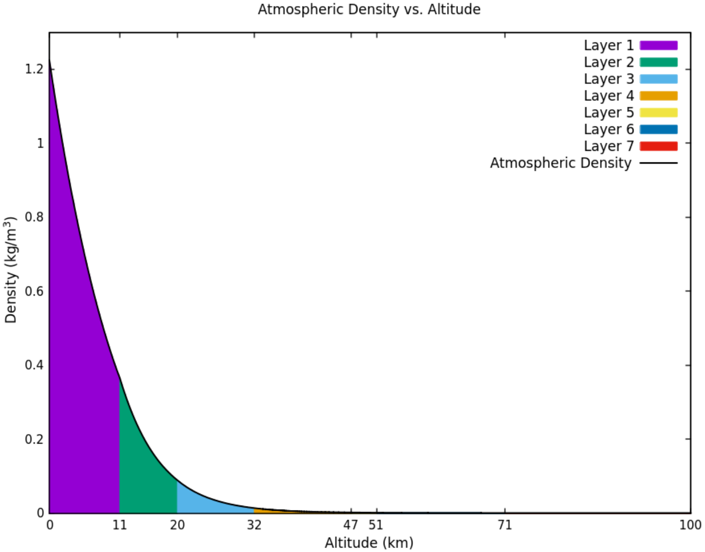
Attenuation follows the form:

$$e^{-\sigma \rho x}$$

Where:

- σ = Attenuation coefficient
- ρ = Density of medium
- x = Distance traveled through medium

Atmospheric Density



Barometric Formulas

- $\rho = \rho_b \cdot \left[\dfrac{T_b}{T_b + L_b \cdot (h - h_b)} \right]^{\left(1 + \frac{g_0 \cdot M}{R^* \cdot L_b}\right)}$
- $\rho = \rho_b \cdot \exp \left[\frac{-g_0 \cdot M \cdot (h - h_b)}{R^* \cdot T_b} \right]$

Calculating Attenuation

Modifications to the formula:

- $e^{-\sigma \rho x}$

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- $e^{-\sigma \rho x}$
- $e^{-\sigma \rho (b-a)}$

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- $e^{-\sigma\rho(b-a)}$
- $e^{-\sigma\frac{\int_a^b \rho(h)dh}{b-a}(b-a)}$

Calculating Attenuation

Modifications to the formula:

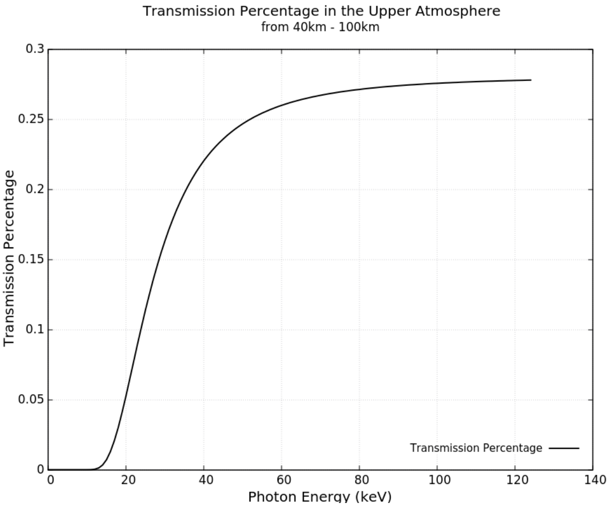
- $e^{-\sigma\rho x}$
- $e^{-\sigma\rho(b-a)}$
- $e^{-\sigma\frac{\int_a^b \rho(h)dh}{b-a}(b-a)}$
- $e^{-\sigma\int_a^b \rho(h)dh}$

This allows for calculation of attenuation over an interval while incorporating a variable density

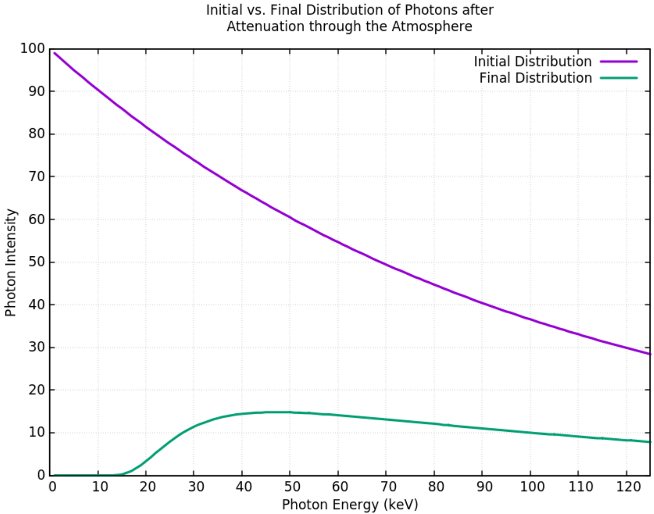
Photon Distribution

- Create bins of photons with different energy
- Fill bins according to some photons distribution such as an exponential decay function
- Multiply bin intensity buy transmission percentage for the particular interval

Transmission Percentage



Distribution Evolution



Distribution Surface Evolution