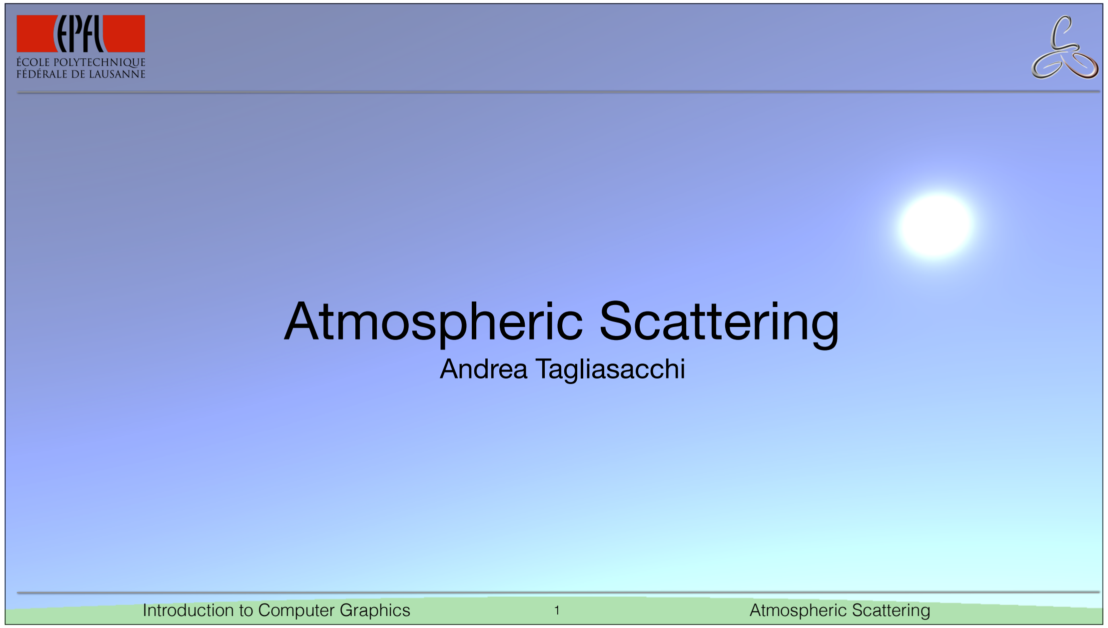
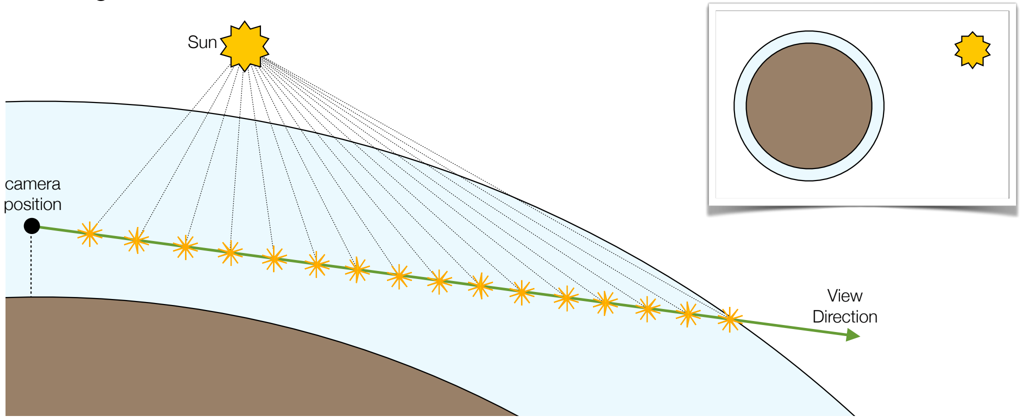


Material prepared from this chapter of GPU Gems 2:
http://http.developer.nvidia.com/GPUGems2/gpugems2_chapter16.html

Atmospheric Model

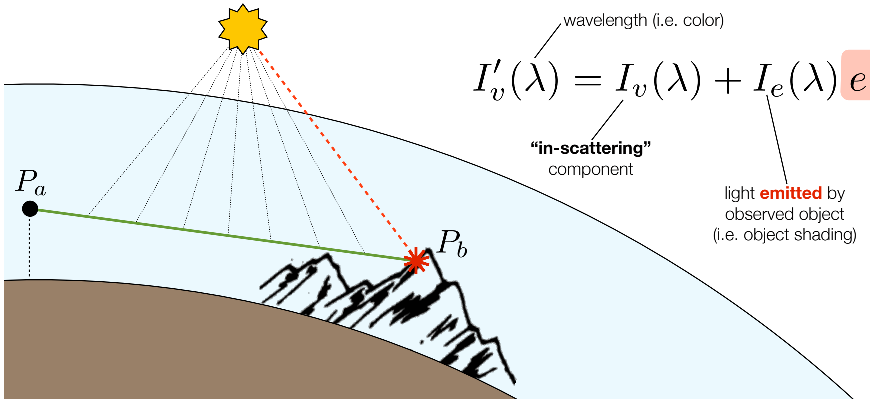
Particles along the view ray reflect a **portion** (not 100% of it.. thus “scattering”) of the light toward the camera.



planet: earth radius + atmosphere radius
observer: height + view direction (angle)
sun: position (or direction assuming far-field approximation)

Are you looking at an object?

we must also take into account that some of the light reflected by the object will be scattered on the way to the camera



$$I'_v(\lambda) = I_v(\lambda) + I_e(\lambda)\, e^{-t(P_a P_b, \lambda)}$$

wavelength (i.e. color)

"out scattering"
t(a,b,c)

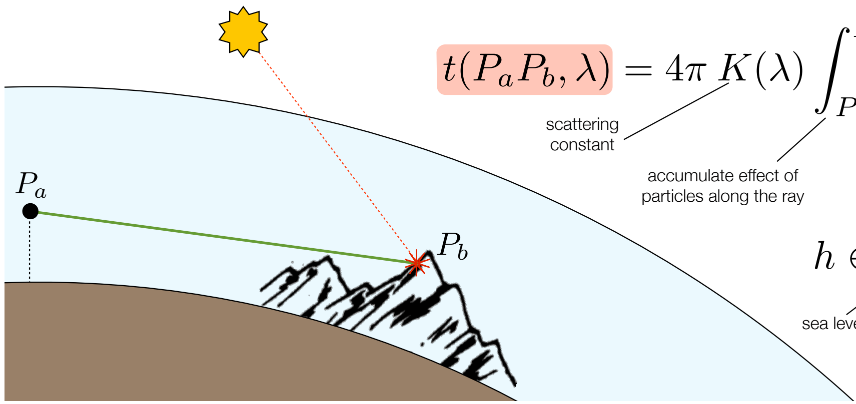
"in-scattering" component

light **emitted** by observed object (i.e. object shading)

how much light will be scattered along the view ray

“Out Scattering” Equation

“weighting factor” based on **how many** air particles **(integrate)** are in the path of the light along the ray



$H_0 = .25$
h of average density

$$t(P_a P_b, \lambda) = 4\pi \, K(\lambda) \int_{P_a}^{P_b} e^{-h/H_0} ds$$

scattering constant

accumulate effect of particles along the ray

atmospheric density

$$h \in [0, 1]$$

sea level

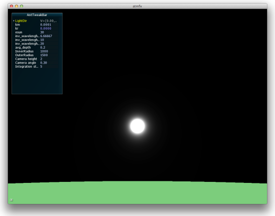
“top” of atmosph.

Essentially density of particles is assumed proportional to the height
The scattering constant “K” is different for {Mie, Rayleigh} scattering

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

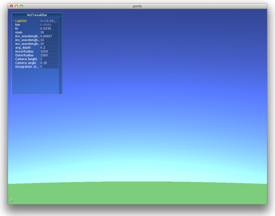
Rayleigh v.s. Mie Scattering

Mie Scattering



Caused by aerosol particles (e.g. dust)
Acts equally across wavelengths
Effect: gray sky on rainy days
Effect: sun halo on cloudy days

Rayleigh Scattering



Scattering of (small) molecules in air
Affects more short wavelengths
Effect: blue daylight sky
Effect: red sunset

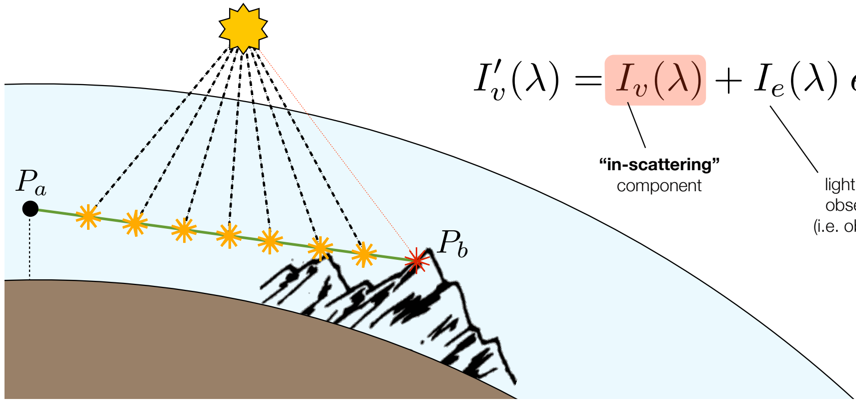
Mie: particles around size of wavelength
Rayleigh: particles much smaller than wavelength

Rayleigh (blue -> green -> red)

wiki: The reddening of sunlight is intensified when the sun is near the horizon, because the volume of air through which sunlight must pass is significantly greater than when the sun is high in the sky. The Rayleigh scattering effect is thus increased, **removing virtually all blue light** from the direct path to the observer. The remaining un-scattered light is mostly of a longer wavelength, and therefore appears to be orange.

Atmospheric Scattering

we must also take into account that some of the light reflected by the object will be scattered on the way to the camera



"out scattering"
t(a,b,c)

$$I'_v(\lambda) = \boxed{I_v(\lambda)} + I_e(\lambda)\, e^{-t(P_a P_b, \lambda)}$$

"in-scattering" component

light **emitted** by observed object (i.e. object shading)

“In Scattering” Equation

$$\underbrace{I_v(\lambda)}_{\text{final color}} = I_{\text{sun}}(\lambda)\, K(\lambda) \int_{P_a}^{P_b} F(\theta, g)\, \underbrace{e^{-h/H_0}}_{\text{atm. density}}\, e^{-t(PP_c,\lambda)}\, e^{-t(PP_a,\lambda)}\, ds$$

final color

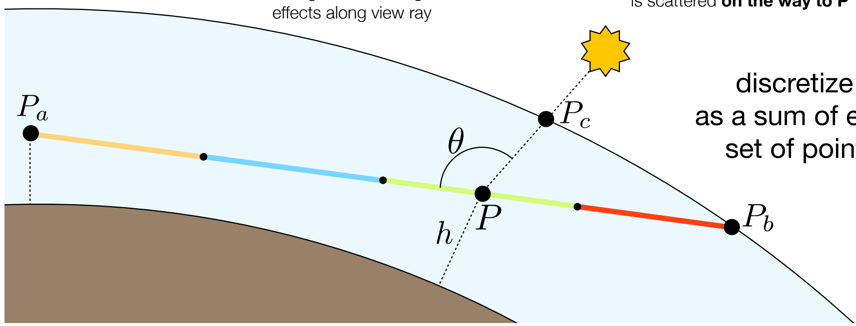
integrate scattering effects along view ray

“phase function” (Mie v.s. Rayleigh)

atm. density

how much of the **sunlight** is scattered **on the way to P**

how much of the **light at P** is scattered **toward camera**



discretize the integral as a sum of evaluations at a set of point locations P

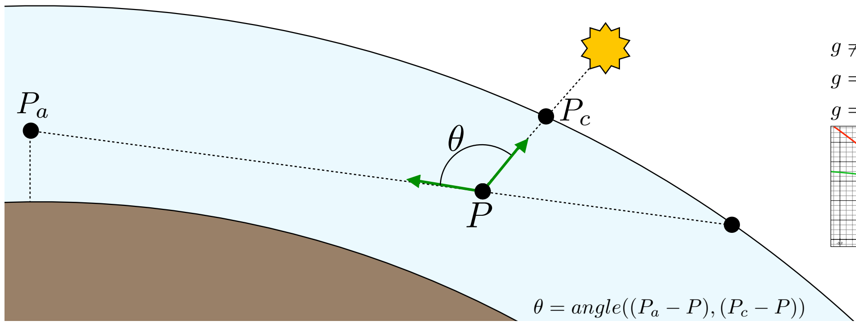
The parameter “g” of the phase function changes for {Mie, Rayleigh} (see next slide)
You can think of “atm. density” here as the “shading” of air around P

The Phase Function "F"

how much light is scattered in the direction of the camera (w.r.t. **angle**)

$$I_v(\lambda) = I_{\text{sun}}(\lambda)\, K(\lambda) \int_{P_a}^{P_b} F(\theta, g)\, e^{-h/H_0}\, e^{-t(PP_c,\lambda)}\, e^{-t(PP_a,\lambda)} ds$$

$$F(\theta, g) = \frac{3(1-g^2)}{2(2+g^2)} \frac{1+cos^2(\theta)}{(1+g^2-2g\cos(\theta))^{\frac{3}{2}}}$$

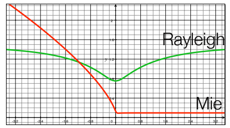


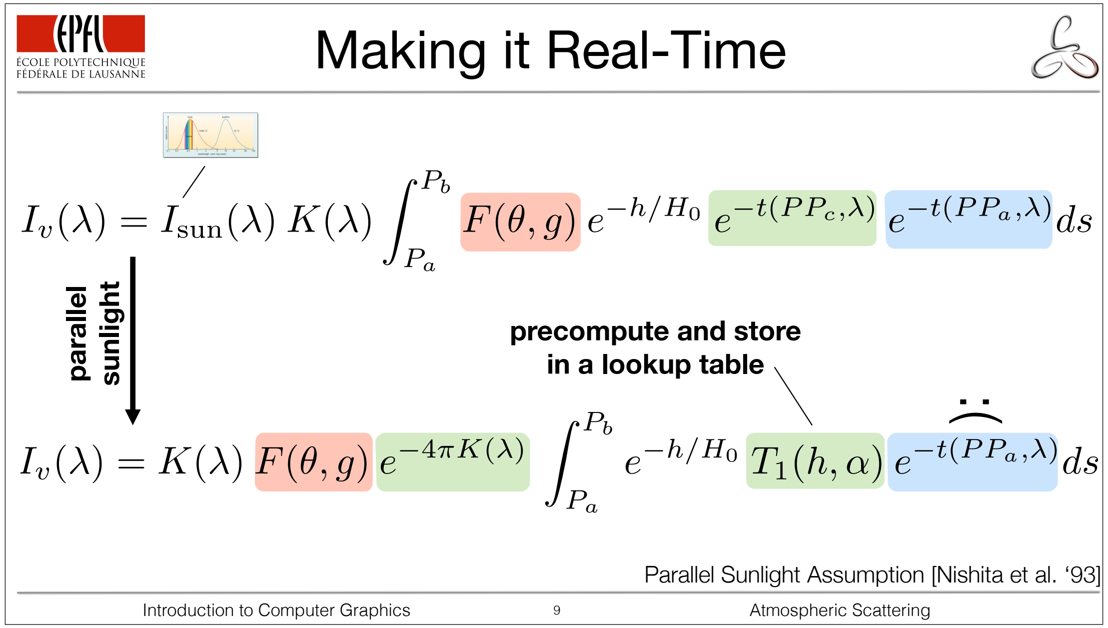
$\theta = angle((P_a - P), (P_c - P))$

$g \neq \{-1, +1\}$

$g = [-.99, -.75]$ (Mie)

$g = 0$ (Rayleigh)





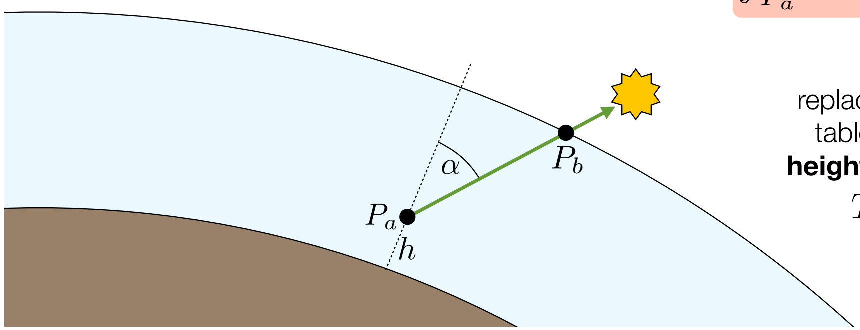
The evaluation of the outer integral is "ok" (...necessary).
But can we do something about the inner integral?
Otherwise the cost is 300 computations per-fragment
(and that just discretizing integral with 5 samples!).

Parallel sun rays: "This makes it possible to calculate a lookup table that contains the amount of out-scattering for rays going from the sun to any point in the atmosphere. This table replaces one of the out-scattering integrals with a lookup table whose variables are altitude and angle to the sun. Because the rays to the camera are not parallel, the out-scattering integral for camera rays still had to be solved at runtime."

Using a Lookup Table

likely the reasons for which this was named "t" (as in lookup-**t**able)

$$t(P_aP_b, \lambda) = 4\pi\, K(\lambda) \boxed{\int_{P_a}^{P_b} e^{-h/H_0}\, ds}$$



replace with lookup table indexed by **height** and an **angle**

$$T_1(h, \alpha)$$

[O'Neil et al. '04]

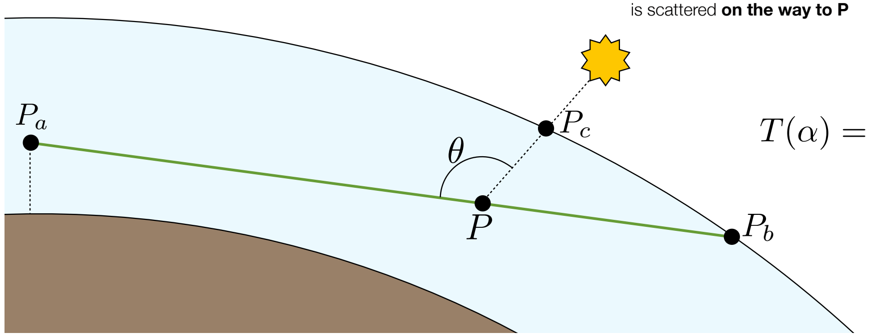
Read _VERY_ carefully the 2nd part of Section 16.3.
You have to make a few important tweaks to use the lookup table

(Over)simplifying Assumptions

$$I_v(\lambda) = I_{\text{sun}}(\lambda)\, K(\lambda) \int_{P_a}^{P_b} F(\theta, g)\, e^{-h/H_0}\, e^{-t(PP_c,\lambda)}\, e^{-t(PP_a,\lambda)}\, ds$$

how much of the **sunlight** is scattered **on the way to P**

how much of the **light at P** is scattered **toward camera**



$$T(\alpha) = H_0\, e^{-\alpha^3}$$

[GPU Gems 2, Ch.16]

Read _VERY_ carefully section 16.4.1 of the tutorial

Final Result