angle of incidence (i), angle of emittance (e), phase angle (g), with respect to surface normal (N)
These are irradiance spectra for a clear sky. Note the difference in scales. Moonlight is more than a million times less intense than midday light. Peaks in spectra of a moonless night are part of the airglow from the earth’s atmosphere (big peak at 558 nm is the green aurora line).
Radiometry

Spectral irradiance distribution: $E_s(\lambda)$

Irradiance: $E_\nu = \int E_s(\lambda) d\lambda$

Spectral radiance distribution: $L_s(\lambda)$

Radiance: $L_\nu = \int L_s(\lambda) d\lambda$

Radiometry concerns the physical measurement of light intensity.
Reflectance spectra of some natural materials. From Krinov (1947).
Surface Reflectance

Spectral reflectance distribution:

\[ \rho(\lambda, i, e, g, h) \]

Spectral radiance distribution:

\[ L_s(\lambda) = \frac{1}{\pi} E_s(\lambda) \rho(\lambda, i, e, g, h) \cos(i) \]
Photons and the Randomness of Light

Energy of a photon:

\[ J = \frac{ch}{\lambda} \]

Photon inter-arrival time:

\[ P[W \leq t] = 1 - e^{-\alpha t} \]

Number of photons in a fixed time interval:

\[ p(z) = \frac{e^{-\alpha} \alpha^z}{z!} \quad z = 0, 1, 2, \ldots \]

\[ \alpha = \gamma t \]
Photometry

Spectral illuminance distribution: \( E(\lambda) = K_w V(\lambda) E_s(\lambda) \)

Illuminance: \( E = \int K_w V(\lambda) E_s(\lambda) d\lambda \)

Spectral luminance distribution: \( L(\lambda) = K_w V(\lambda) L_s(\lambda) \)

Luminance: \( L = \int K_w V(\lambda) L_s(\lambda) d\lambda \)

Photometry concerns the physical measurement of light intensity, but with scaling for the approximate sensitivity of the human visual system.

**Colorimetry**

XYZ color matching functions: $\bar{x}(\lambda), \bar{y}(\lambda), \bar{z}(\lambda)$

Tristimulus values:

\[ X = \int K_w \bar{x}(\lambda) L_v(\lambda) d\lambda \]
\[ Y = \int K_w \bar{y}(\lambda) L_v(\lambda) d\lambda \]
\[ Z = \int K_w \bar{z}(\lambda) L_v(\lambda) d\lambda \]

Chromaticity coordinates:

\[ x = \frac{X}{X + Y + Z}, \quad y = \frac{Y}{X + Y + Z} \]

Luminance:

\[ L = Y \]
The conditional means of the RGB values, based on $10^{10}$ sample points from natural outdoor images. These plots give the first conditional moment of the posterior probability distribution of one color value given the other two. These conditional means are the optimal estimate when the goal is to minimize squared error with the true value.

For more information and databases see: www.cps.utexas.edu/natural_scenes/