Homework 7: Due March 16

1. Problem 3.5

“Ground-based measurements of solar radiation are fundamentally incapable of giving such absorption direction and without assumptions, since.....attenuation of solar radiation by absorption and by scattering are indistinguishable, and only attenuation can be measured at the ground”

2. Read and summarize “Can Cirrus Clouds Produce Glories?” and “Gustav Mie and the Evolving Discipline of Scattering by Particles” available under resources on the 6680 main page. Any added insights you care to add (especially on the glories paper) are great.

3. Discuss possible opportunities and challenges for the assessment of cloud and aerosol properties using ground or space-based lidar. Your answers should address the concepts dealt with in Chapter 3 of the text. Is there complementary information that might be used to constrain a retrieval problem? If so, how?

4. Problem 4.51

Let \( n \) be the number of photons per unit volume with energy \( h\nu \) per unit energy interval. All photons have the same speed \( c \). If the radiance is isotropic, then \( n/4\pi \) is the number of photons streaming in each direction per unit solid angle. The rate at which these photons carry energy is \( c h\nu \). Thus

\[
L = \frac{n h\nu c}{4\pi}
\]

But \( u = n h\nu \) so

\[
u = \frac{4\pi}{c} L
\]

5. Problem 4.52
The momentum of a photon is \( h \nu / c \). The component of momentum of a photon making an angle \( \vartheta \) with the normal to the wall is \( h \nu \cos \vartheta / c \). In a specular reflection with 100% reflectivity, every such photon undergoes a change in momentum equal to \( 2h \nu \cos \vartheta / c \). A change in momentum causes a force. A force per unit area is a pressure. The rate at which photons (isotropic radiation field) are streaming across unit area in any direction per unit solid angle is \( nc/4\pi \) (where \( n \) is the number density of photons per unit frequency interval). Multiply this by the previous number for the momentum transfer to obtain

\[
nh \nu \cos \vartheta / 2\pi
\]

Now just do the usual kind of integration to obtain an irradiance from a radiance, except applied to the momentum transfer, which is a pressure

\[
p = \frac{1}{2\pi} \int_0^{2\pi} \int_0^{\pi/2} nh \nu \cos \vartheta \cos \vartheta \sin \vartheta d\vartheta d\varphi = nh \nu / 3 = u/3
\]

6. Problem 4.53

From the previous two problems we have

\[
L = \frac{3cp}{4\pi}
\]

One atmosphere in SI units is about \( 10^5 \) Pa. The speed of light is \( 3 \times 10^8 \) m/s, so the radiance \( L \) is about \( 10^{15} \) Wm\(^{-2}\) sr\(^{-1}\). The solar radiance is about \( 10^7 \) Wm\(^{-2}\) sr\(^{-1}\).