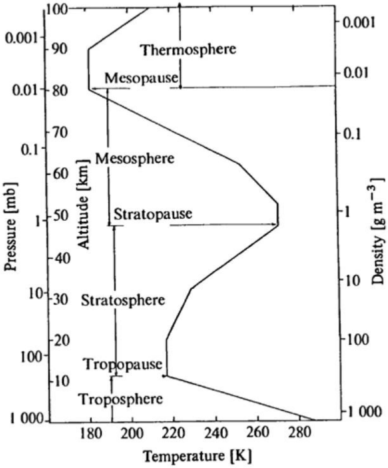
Astronomical Techniques I

Lecture 5

Yogesh Wadadekar

Jan-Feb 2015

Temperature/Pressure/Density in the lower atmosphere



Sources of atmospheric attenuation

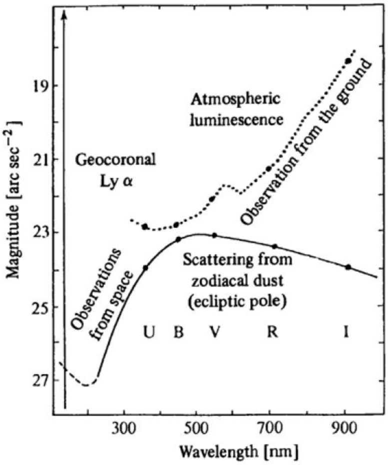
- molecular: rotational, rotational-vibrational, electronic
- atomic: electronic

atomic and molecular physics allows for the calculation of absorption coefficients and cross-sections of the various transitions for the various atmospheric species. Telluric bands can severely affect infrared spectroscopy.

Sources of atmospheric emission

- flourescense (airglow) at $\sim$100 km altitude caused by
  - recombination of ions which were photoionized by the sun during the day
  - luminescence caused by cosmic rays striking the upper atmosphere
  - chemiluminescence caused mainly by oxygen and nitrogen reacting with hydroxyl ions at heights of a few hundred kilometers.
- below 60 km, atmosphere is dense enough that collisions are frequent to keep it in local thermodynamic equilibrium, therefore thermal emission.

Emission dependence on wavelength



Advantage of space based optical observatory!

Question

Why is thermal emission from the atmosphere not much of a concern at optical wavelengths?

Atmospheric scattering

has contributions from

1. air molecules cause elastic scattering of photons (Rayleigh scattering) $\propto \lambda^{-4}$

Atmospheric scattering

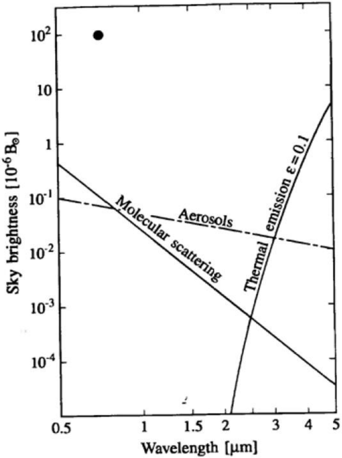
has contributions from

1. air molecules cause elastic scattering of photons (Rayleigh scattering) $\propto \lambda^{-4}$
2. aerosols - content and concentration depends on winds, industrial pollution, volcanic eruptions, and is therefore very difficult to model. Particles are much larger than molecules. So, Mie theory applies. For details see: *Light scattering by small particles* by van de Hulst.

Question

Telescope time allocation commitees like to give dark time to optical observations and bright time to infrared observations. Why?

Scattering dependence on wavelength



Daytime observations at sub mm. wavelengths routine.

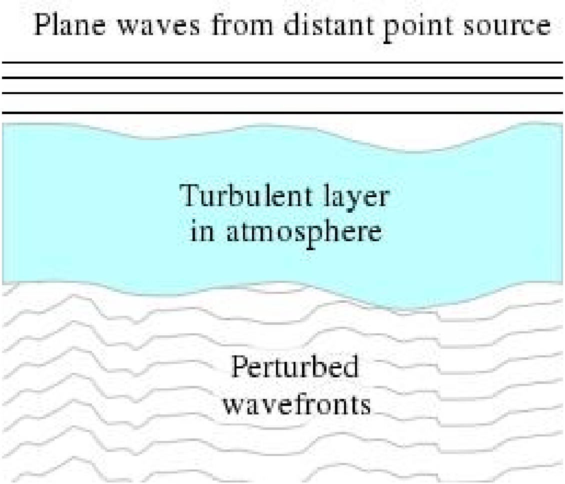
Modeling atmospheric absorption and emission - MODTRAN

The MODTRAN5 software (developed by the US airforce in collaboration with a private company) is the state-of-the-art atmospheric band model radiation transport model. The software implements a correlated-k algorithm which facilitates accurate calculation of multiple scattering. This permits MODTRAN5 to act as a 'true Beer-Lambert' radiative transfer code, with attenuation/layer having a physical meaning. More accurate transmittance and radiance calculations will greatly facilitate the analysis of hyperspectral imaging data. The other major addition to MODTRAN has been to provide sets of Bi-directional Radiance Distribution Functions (BRDFs) that permit the surface scattering to be other than Lambertian. The combination of correlated-K and BRDFs has greatly improved the scattering accuracy, as has the implementation of azimuthal asymmetries.

The turbulent sky as seen by the Infrared Sky Camera

Show video

Effect on plane wavefronts



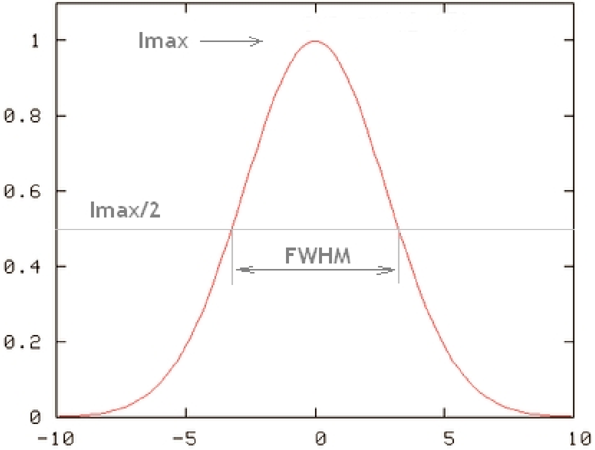
characterised by Fried parameter r_0 (5-20cm) and timescale t_0. Details gory - Kolmogorov (1941) theory of turbulence.

Question

Plot telescope resolution versus telescope size if Fried parameter is r_0

In adaptive optics systems r_0 determines the spacing between actuators and t_0 the frequency of wavefront correction.

Gaussian like Point Spread Function

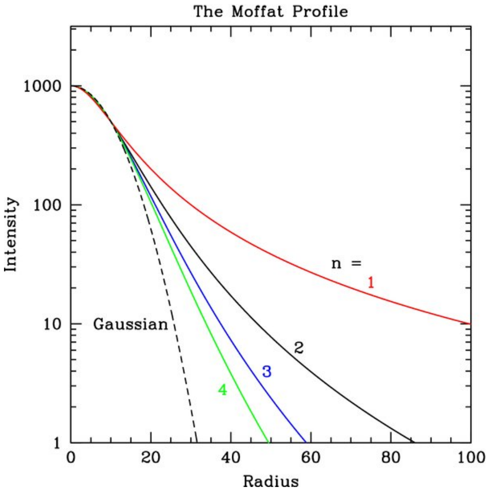


The Moffat function for nuclear source and PSF

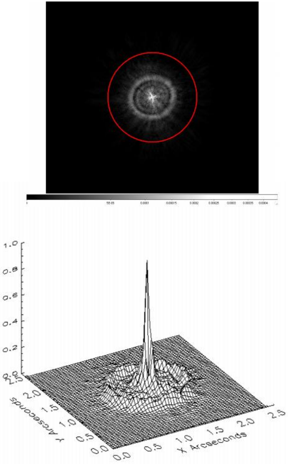
$$\Sigma(r) = \frac{\Sigma_0}{[1 + (r/r_d)^2]^n}$$

r_d is related to FWHM and n=4.765 (for ground based observations)Why?. For $n \to \infty$ it becomes a Gaussian.

The Moffat profile



The Point Spread Function - Diffraction



How large is the atmospheric deterioration?

At Mauna Kea, where the 10 m Kecks are located the median FWHM of the see ing disc is 0.8 arcsec at 500 nm. How does this compare with the Airy disk for this telescope?

How large is the atmospheric deterioration?

At Mauna Kea, where the 10 m Kecks are located the median FWHM of the see ing disc is 0.8 arcsec at 500 nm. How does this compare with the Airy disk for this telescope?

Therefore, Adaptive Optics!

How adaptive optics works

Show video

How to quantify improvement due to adaptive optics?