

Astronomical Observing Techniques 2018:

Exercises on Atmospheric Effects

(Due on 5 February 2018 at 11:00)

January 28, 2018

1 Airmass

The flux of a star is reduced by absorption in the Earth's atmosphere: $I = I_0 e^{-\tau}$, with $\tau = A \int \rho(z) \kappa(z) dz$. A is the airmass, κ the absorption coefficient and z the altitude. The airmass is given by $1/\cos(\theta)$, with θ the zenith angle. The optical depth, τ , is difficult to calculate in practice as $\rho(z)$ and $\kappa(z)$ are not precisely known. Show that we can find I_0 , i.e. the flux before the star light enters the Earth's atmosphere, if we carry out two measurements of the received flux (I_1 and I_2) at different airmasses (A_1 and A_2), assuming the properties of the atmosphere do not change between the two measurements.

2 Sky Background

1. Calculate the spectral radiance (at zenith) of the sky background in the L band ($3.4\mu\text{m}$). Assume that the optical depth is $\tau = 0.15$, which is much smaller than 1. Use wavelength units and assume that the average temperature of the atmosphere is $T = 250$ K.
2. Calculate the sky brightness in mag arcsec⁻². For $\text{mag}_L = 0$, the spectral irradiance is $8.1 \cdot 10^{-11}$ W m⁻² μm^{-1} .

3 Refraction

The direction of light passing through the atmosphere changes because of the changing index of refraction with height. The amount of change is given by Snell's law: $n_1 \sin(z_1) = n_2 \sin(z_2)$. Let z_t be the true zenith angle, z_0 the observed zenith angle, z_i the observed zenith angle at layer i in the atmosphere, $n_0(\lambda)$ the index of refraction at the surface, and $n_i(\lambda)$ the index of refraction at layer i ($i = 1 \dots N$).

1. Show that the refraction only depends on the index of refraction near the Earth's surface.
2. We define astronomical refraction, R , to be the angular amount that the object is displaced by the refraction of the Earth's atmosphere. Derive the following approximation to the refraction $R(z_0)$ as a function of the observed zenith angle z_0 :

$$R = (n - 1) \tan(z_0)$$

(Hint: Use $\sin(u \pm v) = \sin(u) \cos(v) \pm \cos(u) \sin(v)$ and $R \ll 1$).

3. How large is this effect for an object observed at a zenith angle of 45° ? Take a typical index of refraction of 1.00029.
4. We want to observe a source in the L band ($\lambda = 3.45\mu\text{m}$, bandwidth = 472 nm) with a diffraction-limited 15-m telescope. Do we need to worry about distortion due to the dispersion for a zenith angle of 45° ? And for 85° ? Hint: the diffraction limit of a telescope is given by $1.22\lambda/D$.