Exercises Astronomical Observing Techniques, Set 2 (homework)

19 September 2012

Exercise 1

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

a Show that the refraction depends only the index of refraction near the earth's surface.

b In which direction does an object move by refraction (away or towards the zenith)?

c We define astronomical refraction, R, to be the angular amount that the object is displaced by the refraction of the Earth's atmosphere. Derive that the refraction as function of observed zenith angle $R(z_0)$ is (approximately) given by $R = (n-1)\tan(z_0)$. (Hint: you can use that $\sin(u \pm v) = \sin(u)\cos(v) \pm \cos(u)\sin(v)$, and that $r \ll 1$).

d How large is this effect for an object observed at a zenith angle of 45°? Take a typical index of refraction of 1.00029.

e Now suppose we want to observe a source in the L band ($\lambda = 3.45\mu$m, bandwidth = 472 nm) with a diffraction limited 15 m telescope. Will you see distortion for a zenith angle of 45°? And for 85°?