光赤外線天文学特論 III（高遠）レポート問題

Answer to at least three out of the five problems below and send your report via e-mail to takato@naoj.org **by the end of Jan. 25 (Fri.), 2019 (JST)**. The report should be written in English or Japanese (a scan of hand-written report is acceptable if it is readable to me) and converted to a single PDF file (no larger than 10 MB).

I will send back an acknowledgement, but if you don't receive the acknowledgement within three business days after you turned in, please contact me via e-mail again and also contact to jimu-astron.s@gs.mail.u-tokyo.ac.jp（天文学専攻事務室）. Good luck!

2019.01.13

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1. You are observing under the condition of seeing size of 1.0 arcsec (to the zenith, at wavelength λ of 0.5 μm).

(1) Estimate the Fried parameter at $\lambda = 0.5\,\mu$m

(2) What seeing size do you expect at K- band (center wavelength is 2.2 μm)?

(3) What seeing size do you expect at zenith angle 60° at $\lambda = 0.5\,\mu$m?

2. At one night, you saw (by naked eyes) a star, Mars, and Jupiter in almost the same direction in the sky, and noticed that the star and Mars twinkled but Jupiter looked no twinkling. In the next night, you observed the same objects again and noticed that the star twinkled but Mars and Jupiter did not. The seeing sizes were the same in both nights. Discuss about the difference in the vertical profile of the turbulence through which you observed at each night.

3. An observatory has 10-m diameter telescope with perfect adaptive optics system, and they are conducting an exo-planet survey by direct imaging in J- band (λ=1.25 μm) down to 10^6 contrast (i.e. the intensity ratio of planet to primary star is 10^{-6}). However, they are facing severe budget-cut and they couldn't perform recoating the primary mirror of their telescope frequently, resulting in accumulation of dusts on it. They observed the surface of the mirror and found that the dusts on the mirror were about 0.1 mm in diameter and distributed 100 particles per 1 cm^2 on average.

Estimate the amount of the scattered light by the dusts and evaluate if the observatory needs to clean up the mirror for their exo-planet survey.

4.

(1) Explain why allmost all the adaptive optics system of ground-based telescope for astronomy correct only the phase of the wave-front.

(2) Using wave structure function $D(r) = 6.88(r/r_0)^{5/3}$ (rad^2), estimate the root-mean-square (rms) of "dancing" size of a star motion due to the atmospheric turbulence by following the procedure below.

(2-1) Because of 4.(1), D(r) is considered as the phase structure function. What is the edge to edge phase difference (rms) of the aperture diameter D.

(2-2) Calculate the rms tilt of the two points across the diameter. Note that the unit of D(r) is in rad^2, so you need to take squre-root and multiply by $\lambda/2\pi$ to obtain wave height.

(2-3) (2-2) is a good approximation of the mean tilt of the wave-front. Evaluate expected rms tilt of the wave-front ("dancing") when r_0 = 0.1 m (at λ=0.5μm) and observe at λ=0.5μm using a telescope with diameter of (a) 10 m and (b) 10 cm.

5. For the following questions, consider an incoherent light source.

(1) Calculate the optical transfer function (OTF) of a perfect lens with a square aperture of the length D each side and the focal length of f.

(2) Calculate the OTF in the case that half of the square aperture is covered by a thin, transparent film which has the thickness of d and the refractive index of n (assume d and n are spatially constant). Plot $|OTF(\nu_u, 0)|$.

(The magnitude of OTF ($|OTF(\nu_u, \nu_v)|$) is called MTF (Modulation Transfer Function))

(3) If the thickness of the film is $nd/\lambda = \pi$, what is the intensity at the focal point (i.e. intersection of the focal plane and the optical axis) when illuminating the aperture with a plane wave of wavelength λ perpendicularly to the aperture? [use Babinet's principle]