NASSP Class Test – 2008 April 7th

Answer FOUR questions from section A (10 marks and approximately 10 minutes each) and FIVE questions from section B (20 marks and approximately 20 minutes each). The marks allocated to each part question are indicated in brackets.

Section A

1. BASICS

   (a) Describe the **second equatorial system of co-ordinates** (Right Ascension and Declination) by defining the **fundamental circle, poles and origin** of the system. Sketch the system to indicate the angles α and δ (R.A. and Dec.). **(6)**

   (b) Explain what is meant by **sidereal time** and indicate why it is important to the equatorial system of co-ordinates. **(4)**

2. BASICS

   (a) Write down an expression relating the difference in apparent magnitude of two stars to their observed flux intensities. **(1)**

   (b) Define **absolute magnitude** and use the inverse square law to derive a relation linking the apparent magnitude, absolute magnitude and distance of a star. **(7)**

   (c) Define the **effective temperature** of a star. **(2)**

3. BASICS

   (a) Explain, with the aid of a sketch, what is meant by the **annual parallax** of a star. **(3)**

   (b) Define the **astronomical unit** and the **parsec** and show that, using these units, the parallax of a star (π) is related to its distance (r) by: **(5)**

   $$\pi = \frac{1}{r}$$

   (c) In principle, you can measure the parallax of a star in the ecliptic plane by making two sets of measurements, 6 months apart. Give two reasons why it is good practice to make many measurements over several years. **(2)**

4. BASICS

   (a) Explain why the strength of the Balmer series of Hydrogen varies with temperature, and hence explain why the spectral type sequence **OBAFGKM** is principally a temperature sequence. **(5)**

   (b) Briefly describe two processes occurring in stellar atmospheres which allow us to separate stars into luminosity classes by examining their spectra. **(5)**

5. BASICS

   (a) Explain what is meant by the **Equation of time** including a description of the two main periodic terms which cause it. **(7)**

   (b) Explain why a Julian Date would require a **heliocentric correction**. Under what circumstance might a **barycentric** correction be required ? **(3)**

Section B

6. TELESCOPES

   (a) Explain, using sketches, **chromatic aberration** in lenses and the effect of **spherical aberration** in lenses or mirrors. Indicate how both effects can be corrected. **(9)**

   (b) Sketch the layout of a **Schmidt telescope** indicating the key components and list the advantages of such telescopes for wide-field survey work. **(7)**

   (c) List four reasons why the **vacuum-deposition** of aluminium has been such a valuable method of coating astronomical mirror surfaces. **(4)**

7. TELESCOPES

   (a) Give four reasons for siting large telescopes at high altitudes **(4)**

   (b) Using sketches where necessary, describe how the **Shack-Hartmann** wavefront sensor works, briefly describing key parts of the sensor. **(10)**

   (c) Sketch the layout of a typical astronomical **adaptive optics system**, labelling the key elements. **(6)**

8. SALT

   (a) List the 5 most important differences between SALT and a classical 2-mirror telescope? **(5)**

   (b) How does SALT achieve a large cost-saving compared to other telescopes of the same sized primary mirror? **(5)**

   (c) What are the most important limitations on SALT compared to a classical 2-mirror telescope? **(4)**

   (d) Describe how SALT tracks stars as they move across the sky. **(6)**

9. DETECTORS

(a) Explain the terms **quantum efficiency (QE), detective quantum efficiency (DQE), upper and lower thresholds** and **dynamic range** as applied to astronomical detectors. **(5)**

(b) Sketch a typical **photomultiplier tube**, briefly describe the key components and indicate how a photomultiplier turns light into a measurable quantity for photon counting. **(12)**

(c) Explain what is meant by the **dark count** of a photon detector and list two possible sources of this in photomultipliers. **(3)**

10. CCDs

Using sketch diagrams as appropriate:

(a) Define the concept of depletion regions in CCDs with reference to both surface channel and buried channel CCDs, describing the advantages of the latter. **(4)**

(b) Discuss the advantages and disadvantages of back-illuminated CCDs and what processes can be used to improve their performance. **(4)**

(c) Describe/sketch how accumulated charge is stored and read out in a 3-phase CCD and define the concept of Charge Transfer Efficiency (CTE). **(4)**

(d) Describe the nature of a Frame Transfer CCD and an Electron Multiplication CCD (EMCCD), how they are operated and what advantages they have in astronomy. **(4)**

(e) Discuss three types of cosmetic defects experienced with CCD detectors and how they are removed. What are the three regimes of the Signal-to-Noise (S/N) equation as applied to CCDs. **(4)**

11. PHOTOMETRY

(a) List three principal absorption or scattering processes which contribute to **atmospheric extinction** in the visible and near infrared and indicate what causes each. **(6)**

(b) Show that a simple correction of the form kX (where X is the air mass of the observation and k is a constant) is required to correct observed magnitudes for **atmospheric extinction**. **(6)**

(c) Explain what is meant by **colour equations** in the context of a photometric system and why these are necessary. **(4)**

(d) Explain what is meant by **standard stars** and why these are important in stellar photometry. **(4)**

12. PHOTOMETRY

(a) Write down the expression for the **Fourier transform**, $F(\nu)$, to frequency space of a time series function, $f(t)$. **(2)**

(b) Hence show that the Fourier transform of a **boxcar** or **rectangle function** (unity between $-T/2 < t < T/2$ and zero elsewhere) is a *sinc* function. **(8)**

(c) Explain what is meant by the term **"differential photometry"** and indicate under what circumstances it is useful. **(5)**

(d) What is meant by **"aliasing"** in the context of variable star observing and how might the effect be reduced ? **(5)**