Stars and Galaxies

Observational Techniques Homework Set 2

1) *(i)* If we consider the 24 pixels around the central pixel, then the mean is 999 and square-root of the mean is 32 (alternatively, the standard deviation is 35 which will give similar results). Therefore, if the background is the only signal source, then we expect the following probabilities:

$1031 = \text{mean} + 1\text{-}\sigma$	68%
$1063 = \text{mean} + 2\text{-}\sigma$	95%
$1095 = \text{mean} + 3\text{-}\sigma$	99.7%
$1127 = \text{mean} + 4\text{-}\sigma$	99.9%

The output of the pixel is 1100, therefore there is approximately a 0.3% probability that this occured because of chance.

(ii) We have already shown that the probability of a value of 1100 is 0.3%, so by random chance, if there are 1000 pixels, 3 are expected to have values > 1100. [1 mark]

2) *(i)* $\frac{S}{N} = \frac{\sum \dot{N}_\gamma}{(\sum[\dot{N}_\gamma + \dot{N}_{sky} + R^2 + \dot{N}_d])^{1/2}}$ where $\dot{N}_\gamma$ is the photon count rate from the object, N_d is the dark noise, N_{sky} is the sky noise and R is the read noise. [1 mark]

(ii) For sky limited case, $\dot{N}_{sky} >> \dot{N}_d >> R^2$ and so $\frac{S}{N} \sim \frac{\sum \dot{N}_\gamma}{(\sum \dot{N}_{sky})^{1/2}}$

For read-noise limited case, $R^2 >> \dot{N}_{sky} >> \dot{N}_d$ and so $\frac{S}{N} \sim \frac{\sum \dot{N}_\gamma}{(\sum R^2)^{1/2}}$

For dark-noise limited case, $\dot{N}_{dark} >> R^2 >> \dot{N}_{sky}$ and so $\frac{S}{N} \sim \frac{\sum \dot{N}_\gamma}{(\sum \dot{N}_d)^{1/2}}$ [1 mark]

(iii) Use $\frac{S}{N} = \frac{\sum \dot{N}_\gamma}{(\sum \dot{N}_{sky})^{1/2}}$ with $\dot{N}_{sky} = 20$, and $t = 600$ gives $\underline{\mathrm{S/N} = 54.7}$

3) There is no unique solution – it's up to you to design this experiment. However, some things we need to know / use:

For 1% precision, this implies we require a signal-to-noise ratio of S / N = 100.

From the webpage, you can see that FORS2 is an optical instrument that operates between 400–900 nm. A G-type star, like the Sun, has a spectrum that peaks at about 550 nm (which is why the Sun is orange), and so will be brightest in the V-band.

Lets assume we are observing in average conditions for the VLT, which is median seeing $= 0.8''$ (you can check what happens to the exposure time and limiting magnitude as you improve / degrade the seeing).

The sky is darkest when there is no moon (i.e. 0 days from new moon), so for the best results, this is when we would take out observations.

To search for the transit of a planet as it passes in front of a star, we'd probably want to start a new exposure about every 10 minutes. This will give us about 50 individual images from which we can search for a systematic change in the magnitude caused as a planet passes in front of the star.

By changing the magnitude of the star in the exposure time calculator, for these conditions, a signal-to-noise of 100 (total summed over all pixels covering the area subtended by the star) is reached in 900 seconds for a star with magnitude of $V = 21.8$. [4 marks]

Any other sensible answer is also fine (depending on your choice of seeing, brightness of the moon, observing band, etc). [4 marks]