ASTP 613 Exam Practice Question – Nova Solvason

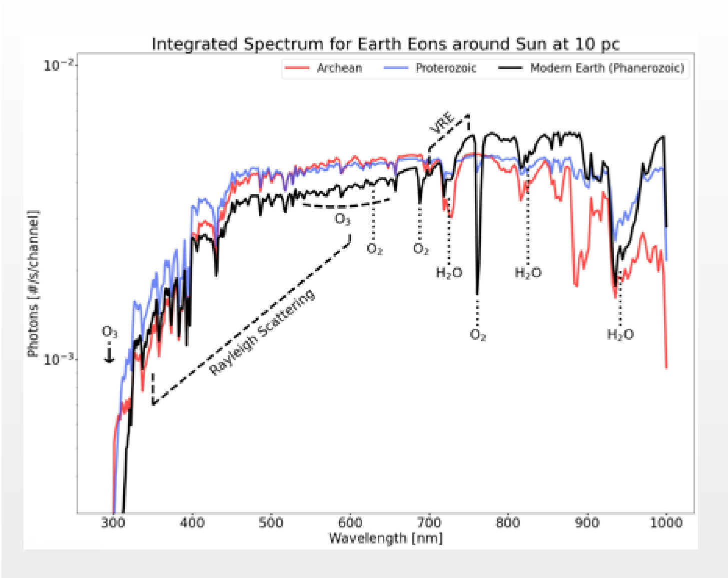

Figure 1 - Simulated Spectrum of Earth if it were observed from 10pc. Credit: Edwin Alexani, CfD.

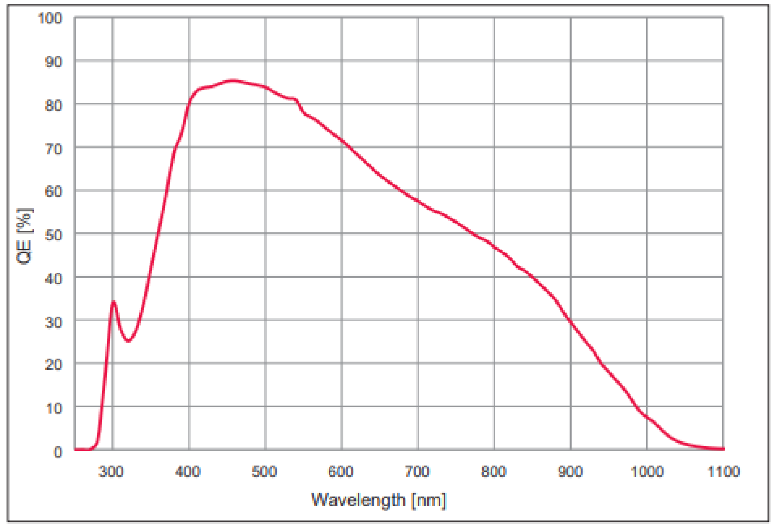

Fig. 2-3. QE curve

Figure 2 - Hamamatsu Orca Quest camera technical note document.[2] Hamamatsu.com

Suppose you are planning to do some exoplanet research with an exceptionally low noise CMOS camera such as the [2]*Hamamatsu Quest™*. Considering the atmosphere of modern earth, a good absorption line to look for is the Oxygen A-band at ~762nm[1]. The Hamamatsu Quest has an area of 4096pix x 2304pix. [per channel can be interpreted as per pixel]

a. Looking at the simulated spectrum and quantum efficiency seen above, what signal would you be able to measure with an exposure of 1 second [electrons]?

b. [2]Given a dark current of 0.006 electrons/s/channel and a readout noise of 0.27 $electrons_{rms}$/channel, estimate the SNR of your measurement.

c. To know if there is an actual absorption line at this wavelength, we need a baseline. Estimate the measured signal and SNR you would expect to see at 800nm.

1. Molecular Oxygen – A band absorption
2. Hamamatsu Quest Technical Note
3. Hint: Info on SNR can be found in the lecture notes

d. Given this difference in signal and an estimate of the accuracy of these measurements, would you be able to definitively claim there is a presence of O_2 in the simulated exoplanet?

e. Suppose we wanted a higher signal. If the effective temperature of this exoplanet is 255K, what is the peak blackbody wavelength emitted?

f. Would you be able to make observations in this range with the Hamamatsu Quest™?

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Solutions

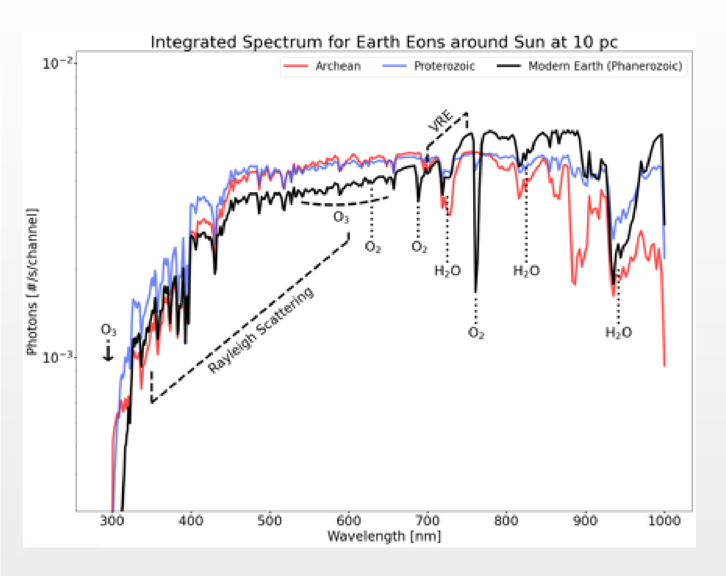

Figure 3 - Simulated Spectrum of Earth if it were observed from 10pc. Credit: Edwin Alexani, CfD.

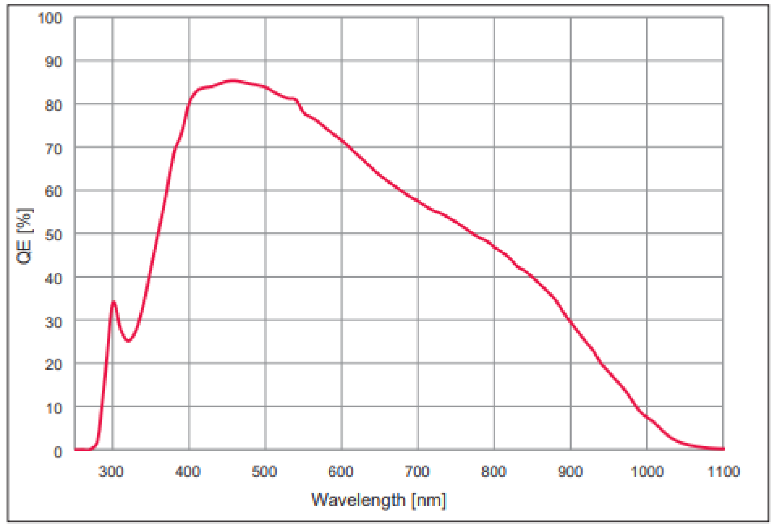

Fig. 2-3. QE curve

Figure 4 - Hamamatsu Orca Quest camera technical note document. Hamamatsu.com

Suppose you are planning to do some exoplanet research with an exceptionally low noise CMOS camera such as the *Hamamatsu Quest™*. Considering the atmosphere of modern earth, a good absorption line to look for is the Oxygen A-band at ~762nm[1]. The Hamamatsu Quest has an area of 4096pix x 2304pix.

a. Looking at the simulated spectrum and quantum efficiency seen above, what signal would you be able to measure with an exposure of 1 second [electrons]?

Incoming photons: .5x10^{-3} photons/s/channel
Integration: 1s * QE
Quantum Efficiency: 50%, 0.5 e^-/photon
n_{pix} = 4096 * 2304 = 9437184 pixels (channels)

Measured Signal: photons * integration * QE + n_{pix} = 0.5x10^{-3} * 1 * 0.5 * 9.4x10^6 = 2359 e^-

b. Given a dark current of 0.006 electrons/s/channel and a readout noise of 0.27 electrons_{rms}, estimate the SNR of your measurement. (assume no sky signal)

$$SNR = \frac{Signal}{\sqrt{Signal + (Dark\ Current * n_{pix} * t) + Read\ Noise^2 * n_{piz}}}$$

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Solutions

$$= \frac{2359}{\sqrt{2359 + (0.006 * 9.4x10^6 * 1s) + 0.27^2 * 9.4x10^6}} = 2.73 \text{ (yikes!)}$$

c. To know if there is an actual absorption line at this wavelength, we need a baseline. Estimate the measured signal and SNR you would expect to see at 800nm.

Measured Signal: photons * integration * QE + n_{pix} = $5.0x10^{-3}$ * 1 * 0.475 * $9.4x10^6$ = 22413 e^-

$$SNR = \frac{Signal}{\sqrt{Signal + (Dark\ Current * n_{pix} * t) + Read\ Noise^2 * n_{piz}}}$$
$$= \frac{22413}{\sqrt{22413 + (0.006 * 9.4x10^6 * 1s) + 0.27^2 * 9.4x10^6}} = 25.592 \text{ (better!)}$$

d. Given this difference in signal and an estimate of the accuracy of these measurements, would you be able to definitively claim there is a presence of O_2 in the simulated exoplanet?

I would say yes, though the SNR leaves much to be desired, the difference in measured signal is not bad, and we would be able to definitively define a dip in signal at that wavelength. I would say with these approximations, you would not be able to definitively make statements about the abundances, but it would be clearly present in some amount.

e. Suppose we wanted a higher signal. If the effective temperature of this exoplanet is 255K, what is the peak blackbody wavelength emitted?

Wien's Law: λ_{max} = 2898 [μm*K] / T_{eff} [K] = 2898 / 255 ~11 μm

f. Would you be able to make observations in this range with the Hamamatsu Quest™?

No… it's a silicone detector, where the bad gap is about 1.1eV or 1μm

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