HW 2

1.) $V_r = 5000$ km/s

$$Z = \frac{V_r}{c} = \frac{5000 \text{ km/s}}{3\times10^5 \text{ km/s}} \Rightarrow \boxed{Z = 0.016 = Z_{doppler}}$$

J-band ranges from: 11000 Å – 13000 Å

left edge:

$$Z_{cosmo} = \frac{\lambda_{stretch}}{\lambda_{emit}} - 1 = \frac{11000\text{Å}}{4861\text{Å}} - 1 = 1.263$$

right edge:

$$Z_{cosmo} = \frac{13000\text{ Å}}{4861\text{ Å}} - 1 = 1.674$$

total redshift

$$Z = (1+Z_{cosmo})(1+Z_{doppler}) - 1 =$$
$$(2.263)(1.016) - 1 = 1.3$$

$$Z = (2.674)(1.016) - 1 = 1.7$$

$\boxed{\text{J-band range: } Z \approx 1.3 - 1.7}$

H band ranges from: 15000 Å – 18000 Å

left edge:

$$Z_{cosmo} = \frac{15000\text{Å}}{4861\text{ Å}} - 1 = 2.085$$

right edge:

$$Z_{cosmo} = \frac{18000\text{Å}}{4861\text{ Å}} - 1 = 2.703$$

total redshift

$$Z = (3.085)(1.016) - 1 = 2.13$$
$$Z = (3.703)(1.016) - 1 = 2.76$$

$\boxed{\text{H-band range: } Z \approx 2.13 - 2.76}$

K band ranges from 20000Å-23000Å

left edge

$$z_{cosmo} = \frac{20000\ Å}{4861\ Å} - 1 = 3.11$$

right edge:

$$z_{cosmo} = \frac{23000\ Å}{4861\ Å} - 1 = 3.73$$

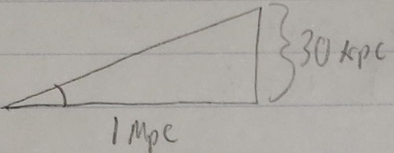
total redshift

$$z = (4.11)(1.016) - 1 = 3.17$$

$$z = (4.73)(1.016) - 1 = 3.8$$

$\boxed{\text{k-band range: } 3.17 - 3.8}$

2)



$$\tan\theta = \frac{30\ kpc}{1\ Mpc} = 0.03°$$

$$0.03° \cdot \frac{60'}{1°} \cdot \frac{60''}{1'} = \boxed{108''}$$

3) Prime focus

$$p = \frac{0.5''}{2} = 0.25''$$

$$R = f/D = 3 \cdot 8\,m \cdot 10^6\ \mu m/m = 24 \times 10^6\ \mu m$$

$$\text{platescale} = \frac{206265''}{24 \times 10^6\ \mu m} = 0.00859''/\mu m$$

$$p = \frac{0.25''}{0.00859''/\mu m} = \boxed{42.44\ \mu m}$$

Nasmyth focus

$$R = f/D = 12 \cdot 8\,m \cdot 10^6\ \mu m/m = 96 \times 10^6\ \mu m$$

$$\text{platescale} = \frac{206265}{96 \times 10^6} = 0.00214''/\mu m$$

$$p = \frac{0.25''}{0.00214''/\mu m} = \boxed{116.822\ \mu m}$$

Field of view

$$FOV = p \cdot N_{pix} = 0.25'' \cdot 2048 = 512'' = \boxed{8.5'}$$

4.) $f_\nu = F_{vega,0} \, 10^{-0.4m}$ in B-band, $F_{vega,0} = 4440$, $\lambda_{eff} = 0.44\mu m = 0.44\times10^4$ Å

4.4×10^3 Å

$$= 4440 \cdot 10^{-0.4 \cdot 9.5} = \boxed{0.7 \, Jy}$$

$1 \, Jy = 10^{-23} \, erg/s/cm^2/Hz$

$0.7 \, Jy = 7\times10^{-24} \, erg/s/cm^2/Hz$

$$f_\lambda = f_\nu \frac{\delta\nu}{\delta\lambda} = 7\times10^{-24} \, erg/s/cm^2/Hz \left(1.55\times10^{11} \frac{Hz}{Å}\right) = \boxed{1.085\times10^{-12} \, erg/s/cm^2/Å}$$

$$\frac{\delta\nu}{\delta\lambda} = \frac{c}{-\lambda^2} = \frac{3\times10^{18} \, Å/s}{(4.4\times10^3 Å)^2} = -1.55\times10^{11} \, Hz/Å$$

$h = 6.624\times10^{-27} \, erg \cdot s$

$$1ph = E = h\nu = h\frac{c}{\lambda} = 6.624\times10^{-27} \, erg \cdot s \cdot \frac{3\times10^{18} \, Å/s}{4.4\times10^3 Å} \quad 4.51\times10^{-12} \, erg$$

$$f_{phot} = \frac{1.085\times10^{-12} \, erg/s/cm^2/Å}{4.51\times10^{-12} \, \frac{erg}{ph}} = \boxed{0.24 \, ph/s/cm^2/Å}$$

5.) $m_{AB} = 26$

$\lambda = 5500$ Å

$$f_\nu = 36315 \cdot 10^{-0.4 m_{AB}} = 36315 \cdot 10^{-0.4 \cdot 26} = 3.631\times10^{-5} \, Jy$$

Convert to Johnson V mag:

$f_V = F_{vega,0} \, 10^{-0.4m}$

for V band:

$f_V = 3540 \, 10^{-0.4m}$

$$\frac{3.6\times10^{-5}}{3540} = 10^{-0.4m} \Rightarrow \frac{\log\left(\frac{3.6\times10^{-5}}{3540}\right)}{-0.4} = m = \boxed{19.98} = m_{V band}$$

for ph/s/cm^2/Å :

convert Jy to erg/s/cm^2/Hz

$$f_\nu = 3.631 \times 10^{-5}\ \text{Jy}$$
$$= 3.631 \times 10^{-28}\ \text{erg/s/cm}^2\text{/Hz}$$

Convert to f_λ

$$f_\lambda = f_\nu \frac{\delta \nu}{\delta \lambda}$$

$$\frac{\delta \nu}{\delta \lambda} = \frac{c}{-\lambda^2} = \frac{3\times10^{18}\ \text{Å/s}}{-(5500\text{Å})^2} = 9.9\times10^{16}\ \text{Hz Å}^{-1}$$

$$f_\lambda = 3.631\times10^{-28}\ \text{erg/s/cm}^2\text{/Hz} \cdot 9.9\times10^{10}\ \text{Hz/Å} = 3.6\times10^{-17}\ \text{erg/s/cm}^2\text{/Å}$$

$$1\ \text{phot} = \frac{hc}{\lambda} = 6.624\times10^{-27}\ \text{erg s} \cdot \frac{3\times10^{18}\ \text{Å/s}}{5500\text{Å}} = 3.6\times10^{-12}\ \text{erg}$$

$$f_\lambda = \frac{3.6\times10^{-17}\ \text{erg/s/cm}^2\text{/Å}}{3.6\times10^{-12}\ \text{erg}} = \boxed{9.95\times10^{-6}\ \text{ph/s/cm}^2\text{/Å}}$$

6.) $I_\nu = \frac{1\ \text{MJy}}{\text{Sr}}$ at 5500 Å

Convert into erg/s/cm^2/Hz/arcsec^2

$$1\ \text{MJy} = 1\times10^{6}\ \text{Jy} = 1\times10^{-17}\ \text{erg/s/cm}^2\text{/Hz}$$

$$1\ \text{sr} = \left(\frac{180^\circ}{\pi}\right)^2 = 3282.8\ \text{deg}^2 = 3282.8\ \text{deg}^2 \left(\frac{60'}{1^\circ}\right)^2 \left(\frac{60''}{1'}\right)^2 = 4.25\times10^{10}\ \text{arcs}$$

$$\frac{1\times10^{-17}\ \text{erg/s/cm}^2\text{/Hz}}{4.25\times10^{10}\ \text{arcsec}^2} = \boxed{2.35\times10^{-28}\ \text{erg/s/cm}^2\text{/Hz/arcsec}^2}$$

Convert into erg/s/cm^2/Å/arcsec^2

$$f_\lambda = f_\nu \frac{\delta \nu}{\delta \lambda} \qquad \frac{\delta \nu}{\delta \lambda} = \frac{c}{-\lambda^2} = \frac{3\times10^{18}\ \text{Å/s}}{-(5500\text{Å})^2} = 9.9\times10^{10}\ \text{Hz/Å}$$

$$f_\lambda = 1\times10^{-17}\ \text{erg/s/cm}^2\text{/Hz} \cdot 9.9\times10^{10}\ \frac{\text{Hz}}{\text{Å}} = 9.9\times10^{-17}\ \text{erg/s/cm}^2\text{/Å}$$

$$I_\lambda = \frac{9.9\times10^{-17}}{4.25\times10^{10}} = \boxed{2.33\times10^{-27}\ \text{erg/s/cm}^2\text{/Å/arcsec}^2}$$

Convert to mag/arcsec^2

$$m_{AB} = -2.5 \log(f_\nu) + 8.9 = -2.5 \log(1\times10^6) + 8.9 = -6.1$$

m_{AB} = Source H $\quad F_\nu = 1\times10^6$ Jy

$$\frac{-6.1}{4.25\times10^{10}\ \text{arcsec}^2} = \boxed{-1.43\times10^{10}\ \frac{\text{mag}}{\text{arcsec}^2}}$$

Convert to ph/s/cm^2/Å/arcsec^2

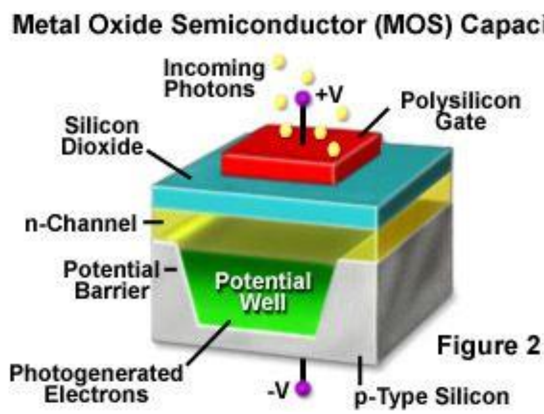
$$1\,\text{ph} = 3.6\times10^{-12}\ \text{erg}$$

$$f_{phot} = \frac{9.9\times10^{-17}\ \text{erg/s/cm}^2\text{/Å}}{3.6\times10^{-12}\ \text{erg/ph}} = 2.74\times10^{-5}\ \text{ph/s/cm}^2\text{/Å}$$

$$I_{phot} = \frac{2.74\times10^{-5}\ \text{ph/s/cm}^2\text{/Å}}{4.25\times10^{10}\ \text{arcsec}^2} = \boxed{6.44\times10^{-16}\ \text{ph/s/cm}^2\text{/Å/arcsec}^2}$$

How do telescopes detect light? As the telescope is pointed to the sky, light comes in from space and enters the telescope. From there, the light is absorbed by a CCD. What exactly is a CCD? A CCD is a charged couple device used in telescopes with mostly optical detectors and allows astronomers to measure how much light is coming from space.

What are CCDs made of? They are made of Silicon, and this is due to the nature of silicon and how it is very effective at absorbing light in the visible wavelength part of the spectrum. Each pixel that the CCD is composed of, is made of a metal-oxide-semiconductor capacitor (MOS), this is the basic element of a CCD. The MOS is laid out in a 3-layer sandwich style. The first layer being the p-type semiconductor, which is made of Silicon. However, the semiconductor has impurities. Silicon has 4 valence electrons, so the semiconductor is made with metals such as Boron or Aluminum, which have 3 valence electrons. This creates “holes” in the semi-conductor that allow electrons to move around. So, as light hits the semiconductor, it transfers its energy to the electrons, causing them to break free from their atom (ionization) and stream towards the insulator and stay there. The insulator acts as well to store the electrons during this process. A full well is the total number of electrons that can be stored and is determined by pixel size.



Each well can be laid out in a grid with rows and columns, with a section of wells that have been exposed to light, and those that haven’t been. Now that each well has electrons stored in it, the voltage can be clocked to read out CCD one column at a time. The packets of charge can be passed in serial fashion electronics to measure voltage. This is done by amplifying the signal, converting the voltage to a digital signal using an ADC (analog-digital-converter), and are then stored on a computer’s memory. We can then determine how many electrons it takes to produce one analog-digital unit (ADU).