Mateo Vasquez Obs HW 3

1. show 3% in flux is equivalent to 0.03 mag error

$f = f_0(1 \pm 0.015)$

$\Delta m = -2.5 \log\left(\dfrac{f_0 \cdot (1 \pm 0.015)}{f_0}\right)$

$= -2.5 \log(1 \pm 0.015)$

$= -0.037, 0.037 \leftarrow m = m_0 \pm 0.037$ ✓

2. source has $\mu_\nu = 1\,MJy\,sr^{-1}$ @ 5500Å, if observed thru V filter w/ CCD on 2.3 m telescope, #$\gamma\,s^{-1}\,pix^{-1} = ?$ for 1 pix = 1 arcsec^2 & typical V bandwidth assume $N_{tot} = 1$

$\mu_\nu = 1\,MJy\,sr^{-1} \cdot \dfrac{10^6\,Jy}{1\,MJy} \cdot \dfrac{10^{-23}\,erg\,s^{-1}\,cm^{-2}\,Hz^{-1}}{Jy}$

$= 10^{-17}\,erg\,s^{-1}\,sr^{-1}\,cm^{-2}\,Hz^{-1}\left(\dfrac{\pi\,rad}{180°}\right)^2\left(\dfrac{1°}{3600''}\right)^2\dfrac{arcsec^2}{pix}$

$= 2.35 \cdot 10^{-28}\,erg\,s^{-1}\,pix^{-1}\,cm^{-2}\,Hz^{-1}$

$\mu_\lambda = \mu_\nu\left|\dfrac{\partial \nu}{\partial \lambda}\right| = 2.35 \cdot 10^{-28}\left|-\dfrac{3 \cdot 10^{18}\,Å/s}{(5500Å)^2}\right|$

$= 2.33 \cdot 10^{-17}\,erg\,s^{-1}\,pix^{-1}\,cm^{-2}\,Å^{-1}$

$E_\lambda = \dfrac{hc}{\lambda} = \dfrac{6.624 \cdot 10^{-27}\,erg\,s\,(3 \cdot 10^{18}\,Å/s)}{5500\,Å} = 3.61 \cdot 10^{-12}\,erg/\gamma$

$\mu_\gamma = \dfrac{2.33 \cdot 10^{-17}\,erg\,s^{-1}\,pix^{-1}\,cm^{-2}\,Å}{3.61 \cdot 10^{-12}\,erg/\gamma} = 6.46 \cdot 10^{-6}\,\gamma\,s^{-1}\,pix^{-1}\,cm^{-2}\,Å^{-1}$

$R_s = N\Delta\lambda A \mu_\gamma$

$= (1)(1500\,Å)\left(\dfrac{2.3\,m}{2} \cdot \dfrac{10^2\,cm}{1\,m}\right)^2 (6.46 \cdot 10^{-6}\,\gamma\,s^{-1}\,pix^{-1}\,cm^{-2}\,Å^{-1})$

$= 402\,\gamma\,s^{-1}\,pix^{-1}$

3. gxy @ $d = 10\,Mpc$, $L = 10^{38}\,erg\,s^{-1}\,Å^{-1}$ over optical pt of the spectrum, #$\gamma\,s^{-1} = ?$ for 2.3 m telescope in V filter, assume $N_{inst} = 0.5$, $X = 2$ airmasses

$f_\lambda = \dfrac{L_{tot}}{A_{tot}} = \dfrac{10^{38}\,erg\,s^{-1}\,Å^{-1}}{4\pi\left(10\,Mpc \cdot \dfrac{10^6\,pc}{1\,Mpc} \cdot \dfrac{3.086 \cdot 10^{18}\,cm}{1\,pc}\right)^2} = 8.36 \cdot 10^{-15}\,erg\,s^{-1}\,cm^{-2}\,Å^{-1}$

$f_\gamma = \dfrac{8.36 \cdot 10^{-15}\,erg\,s^{-1}\,cm^{-2}\,Å^{-1}}{3.61 \cdot 10^{-12}\,erg/\gamma} = 2.32 \cdot 10^{-3}\,\gamma\,s^{-1}\,cm^{-2}\,Å^{-1}$

from #2 $\Rightarrow 3.61 \cdot 10^{-12}\,erg/\gamma$

$R_s = N_{tot}\Delta\lambda A f_\gamma$

$= (0.5 \cdot 2.5^{-2})(1500)\left(\dfrac{2.3}{2} \cdot 10^2\right)^2 (2.32 \cdot 10^{-3})$

$= 4.51 \cdot 10^5\,\gamma\,s^{-1}$?

4. point source has $R_s = 0.2\ \gamma\,s^{-1}$, $R_B = 0.5\ \gamma\,s^{-1}\,pix^{-1}$, $R_D = 10\ e^-\,hr^{-1}\,pix^{-1}$
$N_R = 5\ e^-$, how many 1 min exposures for $S/N = 100$? ($n_{pix} = 4$)

$$\frac{S}{N} = \frac{R_s t}{\sqrt{R_s t + n_{pix}(R_B t + R_D t + N_R^2)}}$$

$*R_D = 10\ e^-\,hr^{-1}\,pix^{-1} \cdot \frac{hr}{3600\,s}$

$$100 = \frac{0.2t}{\sqrt{0.2t + 4(0.5t + \frac{1}{360}t + 5^2)}}$$

$= \frac{1}{360}\ e^-\,s^{-1}\,pix^{-1}$

↳ plot to determine $t = 5.5 \cdot 10^5$ $s = 9.2 \cdot 10^3$ min

(exposures)

5.

5. w/ a 2.3m f/2.1 telescope w/ 13.5 μm pixels @ WIRO, & $X = 1$, $QE = 0.9$,
$N_{tele} = 0.7$, $t = ?$ for $S/N = 100$ on $m_V = 22$ mag, 1.1" seeing, $N_R = 4.5\ e^-\,pix$
$R_D \approx 0$ on a full moon ($\mu_V = 20$ mag arcsec^{-2})? on a new moon (μ_V
($\mu_V = 22$ mag arcsec^{-2})? detector, source, or background lim?

$f_\nu(Jy) = F_{0\,pix}\,10^{-0.4m}$

$= 3540 \cdot 10^{-0.4(22)}$

$= 5.61 \cdot 10^{-6}\ Jy \cdot \frac{10^{-23}\ erg\,s^{-1}\,cm^{-2}\,Hz^{-1}}{Jy}$

$= 5.61 \cdot 10^{-29}\ erg\,s^{-1}\,cm^{-2}\,Hz^{-1}$

$f_\lambda = f_\nu \left| \frac{\partial \nu}{\partial \lambda} \right| = 5.61 \cdot 10^{-29} \left| -\frac{3 \cdot 10^{18}\ Å/s}{(5500\,Å)^2} \right| = 5.56 \cdot 10^{-18}\ erg\,s^{-1}\,cm^{-2}\,Å^{-1}$

$E_\lambda = 3.61 \cdot 10^{-12}\ erg$ (problem #2)

$f_\lambda = \frac{5.56 \cdot 10^{-18}\ erg\,s^{-1}\,cm^{-2}\,Å^{-1}}{3.61 \cdot 10^{-12}\ erg/\gamma} = 1.54 \cdot 10^{-6}\ \gamma\,s^{-1}\,cm^{-2}\,Å^{-1}$

$R_s = N_{tele}\ \Delta\lambda\ A\ f_\lambda$
$= (0.7)(0.9)(1500Å)\left(\pi\left(\frac{2.3m}{2}\frac{10^2\,cm}{1m}\right)^2\right)\left(1.54 \cdot 10^{-6}\ \gamma\,s^{-1}\,cm^{-2}\,Å^{-1}\right)$
$= 60\ \gamma\,s^{-1}$

full moon:
$f_\nu = 3540 \cdot 10^{0.4 \cdot -20} = 3.54 \cdot 10^{-8}\ Jy\,arcsec^{-2}\,\frac{10^{-23}\ erg\,s^{-1}\,cm^{-2}\,Hz^{-1}}{Jy}$
$= 3.54 \cdot 10^{-28}\ erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}\,Hz^{-1}$

$f_\lambda = f_\nu \left| \frac{\partial \nu}{\partial \lambda} \right| = f_\nu \left| -\frac{c}{\lambda^2} \right| = 3.54 \cdot 10^{-28} \left| -\frac{3 \cdot 10^{18}}{5500^2} \right|$

$= 3.51 \cdot 10^{-17}\ erg\,s^{-1}\,cm^{-2}\,Å^{-1}$

↗ $3.61 \cdot 10^{-12}\ erg/\gamma$ $= 9.72 \cdot 10^{-6}\ \gamma\,s^{-1}\,cm^{-2}\,arcsec^{-2}$

from
#2 ⟶ $R_B = (0.7)(0.9)(1500)\left(\pi\left(\frac{2.3}{2}10^2\right)^2\right)(9.72 \cdot 10^{-6}) = 38.2\ \gamma\,s^{-1}$

for npix:

$f = RD = (2.5)(2.1) = 5.25$ m

$s = \dfrac{206265}{f} \left[\text{''/mm}\right] = \dfrac{206265''}{5.25 \cdot 10^3 \text{mm}} \cdot \dfrac{1\text{mm}}{10^3 \mu\text{m}} = 3.93 \cdot 10^{-2} \text{''}/\mu\text{m}$

$= 3.93 \cdot 10^{-2} \text{''}/\mu\text{m} \cdot \dfrac{13.5 \mu\text{m}}{1 \text{ pix}} = 0.530 \text{ ''/pix} \rightarrow \dfrac{1}{0.530} = 1.89 \text{ pix/''}$

$1.89 \text{ pix/''} \cdot 1.1'' = 2.07 \text{ pix} \rightarrow 4 \text{ pix total}$

$\dfrac{S}{N} = \dfrac{R_\delta t}{\sqrt{R_s t + n_{pix}(R_{13} t + R_0 t + N_R^2)}}$

$100 = \dfrac{60 t}{\sqrt{60 t + 4(382 t + 0 + 4.5^2)}}$

↳ plot to determine $t = 4411 \text{ s} \approx 74 \text{ min}$

new moon:

$f_\nu = 3540 \cdot 10^{-0.4 \cdot 22} = 5.61 \cdot 10^{-6} \text{ Jy arcsec}^{-2} \cdot \dfrac{10^{-23} \text{ erg s}^{-1} \text{cm}^{-2} \text{Hz}^{-1}}{\text{Jy}}$

$= 5.61 \cdot 10^{-29} \text{ erg s}^{-1} \text{cm}^{-2} \text{arcsec}^{-2} \text{Hz}^{-1} \cdot \left| \dfrac{3 \cdot 10^{18}}{5500^2} \right| \text{Jy}$

$= \dfrac{5.56 \cdot 10^{-18} \text{ erg s}^{-1} \text{cm}^{-2} \mathring{A}^{-1}}{3.61 \cdot 10^{-12} \text{ erg/} \gamma} = 1.54 \cdot 10^{-6} \gamma \text{ s}^{-1} \text{cm}^{-2} \text{arcsec}^{-2} \mathring{A}^{-1}$

$R_{13} = (0.7)(0.9)(1500)\left(\pi \left(\tfrac{2.3}{2} 10^2\right)^2\right)(1.54 \cdot 10^{-6})$

$= 61 \gamma \text{ s}^{-1}$

$100 = \dfrac{60 t}{\sqrt{60 t + 4(60 t + 0 + 4.5^2)}}$

↳ plot to determine $t = 833 \text{ s} \approx 14 \text{ min}$

after plotting the different limiting cases, I think this is a background limited case. This makes sense considering the star is so dim.

6. @ Keck (10 m tele), QE = 0.8 to observe a star w/ S/N = 50 in 10 min thru filter of width 50 Å. t = ? to get S/N = 50 @ WIRO w/ QE = 0.95

$\dfrac{S}{N} = \sqrt{R_s t} = \sqrt{\eta \Delta\lambda A f_\lambda t}$

↳ $f_\lambda = \dfrac{(S/N)^2}{\eta \Delta\lambda A t} = \dfrac{(50)^2}{(0.8)(50)\left(\pi\left(\tfrac{10}{2}10^2\right)^2\right)(10 \cdot 60)} = 1.33 \cdot 10^{-7} \gamma \text{ s}^{-1} \text{cm}^{-2} \mathring{A}^{-1}$

$t = \dfrac{(S/N)^2}{\eta \Delta\lambda A f_\lambda} = \dfrac{(50)^2}{(0.95)(1500)\left(\pi\left(\tfrac{2.3}{2} \cdot 10^2\right)^2\right)(1.33 \cdot 10^{-7})}$ (assuming equal airmass)

$= 598 \text{ s} \approx 10 \text{ min}$