

HW 3

$$1.) m_1 - m_2 = -2.5102 \left(\frac{F_1}{F_2} \right)$$

Two cases:

$$\textcircled{1} \frac{F_1}{F_2} = 1.03 \Rightarrow m_1 - m_2 = -2.5102(1.03)$$

$$= -0.032 \Rightarrow \text{mag low by } .03 \text{ if } F \text{ 3\% too high}$$

$$\textcircled{2} \frac{F_1}{F_2} = .97 \Rightarrow m_1 - m_2 = -2.5102(.97)$$

$$= 0.033 \Rightarrow \text{mag high by } .03 \text{ if } F \text{ 3\% too low}$$

in either case, our error ~.03 mag

$$2.) R = n_{\text{total}} \Delta \lambda_{\text{bandpass}} A_{\text{telescope}} f_{\lambda} \left(\frac{F_{\lambda}}{f_{\text{pix}}} \right)$$

$$= n_{\text{total}} \Delta \lambda_{\text{bandpass}} A_{\text{telescope}} I_{\lambda} \left(\frac{F_{\lambda}}{f_{\text{pix}}} \right)$$

$$= (1900 \text{ \AA}) (\pi (1.15 \text{ m})^2) (6.457 \cdot 10^{-14} \frac{\text{W}}{\text{cm}^2 \text{ \AA}}) \left(\frac{1000000}{1 \text{ pix}} \right) \left(\frac{100 \text{ cm}}{1 \text{ m}} \right)^2$$

$$= 291 \frac{\text{ph}}{\text{pix}}$$

$$n_{\text{total}} = 1007 \approx 1$$

$$\Delta \lambda_{\text{bandpass}} = 900 \text{ \AA}; \text{ technical graph \& FWHM}$$

$$I_{\lambda} = 6.457 \cdot 10^{-14} \frac{\text{W}}{\text{cm}^2 \text{ \AA}}; \text{ from HW 2}$$

$$3.) R = n_{\text{total}} \Delta \lambda_{\text{bandpass}} A_{\text{telescope}} f_{\lambda}$$

$$= (.346) (900 \text{ \AA}) (\pi (1.13 \text{ m})^2) (23.54 \frac{\text{ph}}{\text{m}^2 \text{ \AA}})$$

$$= 304 \cdot 10^3 \frac{\text{ph}}{\text{s}}$$

$$n_{\text{total}} = 50\% = .5 \pi \left(2.5 \frac{(1.2 \frac{\text{nm}}{\text{nm}}) (2)}{1} \right)^2 = .346$$

$$\Delta \lambda_{\text{bandpass}} = 900 \text{ \AA}; \text{ technical graph \& FWHM}$$

$$f_{\lambda} = \frac{L_{\lambda}}{4\pi d^2} = \frac{10^{36} \frac{\text{erg}}{\text{s}}}{4\pi (10 \text{ pc})^2}$$

$$= 7.958 \cdot 10^{-14} \frac{\text{erg}}{\text{m}^2 \text{ \AA}} \cdot \left(\frac{1 \text{ W}}{10^7 \text{ erg/s}} \right) \cdot \left(\frac{1 \text{ m}}{3.086 \cdot 10^{16} \text{ m}} \right)^2$$

$$= 8.356 \cdot 10^{-11} \frac{\text{erg}}{\text{m}^2 \text{ \AA}} \cdot \left(3.5 \cdot 10^{-12} \frac{\text{erg}}{\text{ph}} \right)^{-1} \left[E_{\text{ph}} = \frac{hc}{\lambda} = (6.626 \cdot 10^{-27} \text{ erg s}) / (3 \cdot 10^8 \frac{\text{m}}{\text{s}}) \right] (56 \cdot 10^{-4} \text{ m})^{-1} = 3.5 \cdot 10^{-12} \frac{\text{erg}}{\text{ph}}$$

$$= 23.54 \frac{\text{ph}}{\text{m}^2 \text{ \AA}}$$

$$4.) \sqrt{N} = \frac{R_s t}{\sqrt{R_s t \cdot \eta_{pix} (R_{B1} \cdot R_{B2} \cdot R_{B3} \cdot N_{B1})}} \\ 100 = \frac{1.2 \frac{e^-}{\mu s}}{\sqrt{1.2 \frac{e^-}{\mu s} \cdot 0.9 \cdot 10^{-4} \cdot (5 \frac{e^-}{\mu s} \cdot 0.001 \frac{e^-}{\mu s} \cdot 5 \frac{e^-}{\mu s})}}$$

$$\Rightarrow t = 552809 \mu s$$

$$\text{if we have 60 exposures, we will need: } N = 552809 \mu s \times \frac{1 \text{ exposure}}{60 \mu s} = 9213 \text{ exposures}$$

$$\sqrt{N} = 100$$

$$R_s = .2 \frac{e^-}{\mu s}$$

$$R_B = .5 \frac{e^-}{\mu s \cdot \mu s}$$

$$R_B = 10 \frac{e^-}{\mu s \cdot \mu s} \times \frac{1 \mu s}{3600 \mu s} = .0028 \frac{e^-}{\mu s \cdot \mu s}$$

$$\eta_{pix} = 0.9$$

$$N_B = 5 \frac{e^-}{\mu s}$$

$$5.) \sqrt{N} = \frac{R_s t}{\sqrt{R_s t \cdot \eta_{pix} (R_{B1} \cdot R_{B2} \cdot R_{B3} \cdot N_{B1})}}$$

$$100 = \frac{17.7 \frac{e^-}{\mu s}}{\sqrt{17.7 \frac{e^-}{\mu s} \cdot 12 \mu s (62.12 \frac{e^-}{\mu s} \cdot 0.95 \frac{e^-}{\mu s})}} \Rightarrow t_{full} = 8635.24 \mu s \cdot \frac{1 \mu s}{3600 \mu s} = 2.4 \mu s$$

$$100 = \frac{17.7 \frac{e^-}{\mu s}}{\sqrt{17.7 \frac{e^-}{\mu s} \cdot 12 \mu s (9.11 \frac{e^-}{\mu s} \cdot 0.95 \frac{e^-}{\mu s})}} \Rightarrow t_{new} = 1682.23 \mu s \cdot \frac{1 \mu s}{3600 \mu s} = .47 \mu s$$

We are basically background-limited since $R_B \cdot \eta_{pix}$ is much larger than our source, dark current, & read noise. Our new moon exposure time is much lower than full moon, which makes sense! The light from the full moon will contribute pretty significantly to our background noise.

$$R_s = \eta_{pix} \Delta \lambda_{bandpass} A_{telescope} F_{\lambda} \\ = .524 (900 \text{ \AA}) (4.155 \text{ m}^2) (5.367 \cdot 10^{-19} \frac{\text{erg}}{\text{cm}^2 \text{ \AA}}) \\ = 1.0327 \cdot 10^{-10} \frac{\text{erg}}{\text{s}} \times (3.5996 \cdot 10^{-12} \frac{\text{erg}}{\text{ph}})^{-1} \\ = 27.7 \frac{\text{ph}}{\text{s}}$$

$$\eta_{pix} = (QE) (CH_{efficiency}) (\eta_{atmo}) \\ = .9 (1.7) (2.5^{(1000 \text{ nm} / 1.2 \text{ nm})})^{-1} \\ = .524$$

$$\Delta \lambda_{bandpass} = 900 \text{ \AA}$$

$$A_{telescope} = \pi (1.15 \text{ m})^2 = 4.155 \text{ m}^2$$

$$F_{\lambda} = F_{\nu} \left| \frac{c}{\lambda^2} \right| \\ = (5.611 \cdot 10^{-25} \frac{\text{erg}}{\text{cm}^2 \text{ Hz}}) (9.566 \cdot 10^{10} \frac{\text{Hz}}{\text{ \AA}}) \\ = 5.367 \cdot 10^{-19} \frac{\text{erg}}{\text{cm}^2 \text{ \AA}}$$

$$F_{\nu} = 359077 \cdot 10^{-9(22)}$$

$$= 5.611 \cdot 10^{-6} \text{ erg} \cdot 10^{-18} \frac{\text{erg}^{-1}}{\text{m}^2 \text{ Hz}} \cdot 10^7 \frac{\text{erg}}{\text{s}}$$

$$= 5.611 \cdot 10^{-25} \frac{\text{erg}}{\text{cm}^2 \text{ Hz}}$$

$$\left| \frac{c}{\lambda^2} \right| = \frac{c}{\lambda^2} = (3 \cdot 10^8 \frac{\text{m}}{\text{s}}) (5.6 \cdot 10^{-6} \text{ m})^{-2} \\ = 9.566 \cdot 10^{10} \frac{\text{Hz}}{\text{ \AA}} \cdot 10^{-10} \frac{\text{ph}}{\text{ \AA}}$$

$$= 9.566 \cdot 10^{10} \frac{\text{Hz}}{\text{ \AA}}$$

$$F_{ph} = \frac{hc}{\lambda} = (6.626 \cdot 10^{-27} \text{ ergs}) (3 \cdot 10^8 \frac{\text{m}}{\text{s}}) (5.6 \cdot 10^{-6} \text{ m})^{-1} = 3.599 \cdot 10^{-11} \frac{\text{erg}}{\text{ph}}$$

[Full]

$$R_D = \eta_{int} A \lambda_{bandpass} A_{telescope} f_\lambda$$

$$= (.324) (900 \text{ \AA}) (4.155 \text{ m}^2) (3.386 \times 10^{-10} \frac{\text{erg}}{\text{cm}^2 \text{ \AA} \text{ arcsec}^2}) (3.549 \times 10^{-11} \frac{\text{erg}}{\text{ph}})^{-1}$$

$$= 187.11 \frac{\text{ph}}{\text{arcsec}^2} \times .332 \frac{\text{arcsec}^2}{\text{pix}} = 12 \text{ ph}$$

$$= 746.28 \frac{\text{ph}}{\text{s}}$$

$$\eta_{int} = (QE) (\text{efficiency}) (\eta_{atmo})$$

$$= .9 (.7) (2.5^{(1.05 \log(10 \frac{\text{m}}{\text{diameter}}))})^{-1}$$

$$= .324$$

$$\lambda_{bandpass} = 900 \text{ \AA}$$

$$A_{telescope} = \pi (1.15 \text{ m})^2 = 4.155 \text{ m}^2$$

$$f_\lambda = f_\nu \left| \frac{d\nu}{d\lambda} \right|$$

$$= (3.54 \times 10^{-15} \frac{\text{erg}}{\text{m}^2 \text{ Hz arcsec}^2}) (9.566 \times 10^{10} \frac{\text{Hz}}{\text{ \AA}})$$

$$= 3.386 \times 10^{-10} \frac{\text{erg}}{\text{m}^2 \text{ \AA} \text{ arcsec}^2}$$

$$f_\nu = 3540 \text{ Jy} = 10^{-12} \text{ W/m}^2$$

$$= 3.54 \times 10^{-15} \frac{\text{Jy}}{\text{arcsec}^2} \times 10^{-18} \frac{\text{J}}{\text{m}^2 \text{ Hz}} \times 10^7 \frac{\text{erg}}{\text{J}}$$

$$= 3.54 \times 10^{-15} \frac{\text{erg}}{\text{m}^2 \text{ Hz arcsec}^2} \quad \text{from circle noise!}$$

$$\left| \frac{d\nu}{d\lambda} \right| = \frac{c}{\lambda^2} = (3 \times 10^8 \frac{\text{m}}{\text{s}}) (3.6 \times 10^{-10} \text{ m})^{-2}$$

$$= 9.566 \times 10^{10} \frac{\text{Hz}}{\text{m}} \times \frac{10^{-10} \text{ m}}{\text{ \AA}}$$

$$= 9.566 \times 10^{10} \frac{\text{Hz}}{\text{ \AA}}$$

$$f_{ph} = \frac{hc}{\lambda} = (6.626 \times 10^{-27} \text{ erg s}) (3 \times 10^8 \frac{\text{m}}{\text{s}}) (3.6 \times 10^{-10} \text{ m})^{-1}$$

$$= 3.549 \times 10^{-11} \frac{\text{erg}}{\text{ph}}$$

$$\text{background rate per pixel} = .577 \frac{\text{arcsec}^2}{\text{pix}}$$

$$f = R_D = 2.1 (23 \text{ m}) = 4.83 \text{ m}$$

$$s = \frac{200265}{4.83 \text{ m} \times \frac{10^3 \text{ mm}}{1 \text{ m}}} = 42.7 \frac{\text{arcsec}}{\text{mm}}$$

$$1 \text{ pix} = 42.7 \frac{\text{arcsec}}{\text{mm}} \times 13.5 \text{ mm} \times \frac{10^3 \text{ \mu m}}{10^3 \text{ \mu m}}$$

$$= 577 \text{ arcsec}$$

$$\eta_{pix} = 3.8 \text{ arcsec} \times (1.577 \frac{\text{arcsec}}{\text{pix}})^{-2}$$

$$= 11.42 \text{ pix} \approx 12 \text{ pix} \quad \text{rounded up to whole pix}$$

$$A = (1.1 \text{ arcsec})^2 \pi$$

[Assume circle & aperture radius = seeing]

$$= 3.8 \text{ arcsec}^2$$

$$N_R = 4.5 \frac{\text{ph}}{\text{pix}}$$

[now]

$$R_o = \eta_{101} \Delta \lambda_{\text{bandpass}} A_{\text{telescope}} f_A$$

$$= 27.7 \frac{\text{ph}}{\text{arcsec}} \cdot .332 \frac{\text{arcsec}^2}{\text{pix}}$$

$$= 9.888 \frac{\text{ph}}{\text{pix}}$$

same calc as R_r bc $\mu_v = 22!$

Use $1 \text{ pix} = .577 \text{ arcsec}$ from above calc!

$$b.) SN = \frac{R_r t}{\sqrt{R_r t + n_{\text{pix}}(R_{\text{ot}} + R_{\text{at}} + N_{\text{d}}^2)}}$$

$$SN = \sqrt{R_r t}$$

[Assume source-limited]

$$50 = \sqrt{R_r (600s)} \Rightarrow R_r = 4.167 \frac{\text{ph}}{s}$$

$$[t = 10 \text{ min} \cdot \frac{60s}{1 \text{ min}} = 600s]$$

$$n_{50} = \sqrt{R_r t} = \sqrt{4.167 \cdot 600} \Rightarrow t = 531s \cdot \frac{1 \text{ min}}{60s} = \boxed{8.84 \text{ min}}$$

$$R_r = \eta_{101} \lambda_{\text{bandpass}} A_{\text{telescope}} f_A$$

$$4.167 \frac{\text{ph}}{s} = .8 (50 \text{ \AA}) (\pi (5m)^2) f_A$$

[Check: 10 m diameter]

$$\Rightarrow f_A = 1.326 \times 10^{-3} \frac{\text{ph}}{\text{cm}^2 \text{ \AA}}$$

$$\eta_{101} = QE = .8$$

$$\Delta \lambda_{\text{bandpass}} = 50 \text{ \AA}$$

$$A_{\text{telescope}} = \pi (5m)^2 = 25 \pi m^2$$

$$R_r = \eta_{101} \lambda_{\text{bandpass}} A_{\text{telescope}} f_A$$

$$r = .95 (900 \text{ \AA}) (1.3225 \pi m^2) (1.326 \times 10^{-3} \frac{\text{ph}}{\text{cm}^2 \text{ \AA}})$$

$$= 4.7119 \frac{\text{ph}}{s}$$

$$\eta_{101} = QE = .95$$

$$\lambda_{\text{bandpass}} = 900 \text{ \AA}$$

$$A_{\text{telescope}} = (1.15m)^2 \pi = 1.3225 \pi m^2$$

$$f_A = 1.326 \times 10^{-3} \frac{\text{ph}}{\text{cm}^2 \text{ \AA}}$$

[Assume same flux densities]