

HW 3

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

Two cases:

$$\textcircled{1} \quad \frac{F_1}{F_2} = 1.03 \Rightarrow m_1 - m_2 = -2.5102[1.03]$$

$$= -0.032 \Rightarrow \text{m2 low by .03 if F37 too high}$$

$$\textcircled{2} \quad \frac{F_1}{F_2} = .97 \Rightarrow m_1 - m_2 = -2.5102[.97]$$

$$= 0.033 \Rightarrow \text{m2 high by .03 if F37 too low}$$

In either case, our error ~.03 mags

$$2.) R = n_{\text{total}} \Delta \lambda_{\text{bandpass}} A_{\text{surface}} f_{\lambda} \left(\frac{F_h}{r} \right)$$

$$= n_{\text{total}} \Delta \lambda_{\text{bandpass}} A_{\text{surface}} f_{\lambda} \left(\frac{F_h}{r^2 F_h} \right)$$

$$= (1900 \text{\AA}) (\pi (1.15 \text{m})^2) (6.457 \times 10^{-3} \frac{F_h}{\text{cm}^2 \text{Hz} \text{nm}^2}) \left(\frac{1 \text{nm}^{-1}}{1 \text{nm}^2} \right) \left(\frac{100 \text{cm}^2}{1 \text{m}^2} \right)^2$$

$$= 241 \frac{F_h}{\text{cm}^2}$$

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

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

$$I_{\lambda} = 6.457 \times 10^{-3} \frac{F_h}{\text{cm}^2 \text{Hz} \text{nm}^2}; \text{from HW 2}$$

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

$$= (1.346)(900 \text{\AA}) (\pi (1.15 \text{m})^2) (23.54 \frac{F_h}{\text{cm}^2 \text{\AA}})$$

$$\approx 30,410 \frac{F_h}{\text{cm}^2}$$

restriction set R for
V-band from table next

$$n_{\text{total}} = 507 = 5 \times (2.5 \frac{1.346}{\text{nm}^{-1}})^2 = 1.346$$

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

$$f_{\lambda} = \frac{L_{\lambda}}{4\pi d^2} = \frac{10^{32} \frac{\text{W}}{\text{sr}}}{4\pi (10 \text{Mpc})^2}$$

$$= 7.958 \times 10^{-34} \frac{\text{sr}}{\text{cm}^2 \text{Hz} \text{\AA}^2} \times \left(\frac{1 \text{Mpc}}{3.086 \times 10^{22} \text{m}} \right)^2$$

$$= 8.356 \times 10^{-11} \frac{\text{sr}}{\text{cm}^2 \text{Hz}^2} \times (3.5 \times 10^{-12} \frac{\text{sr}}{\text{Hz}})^{-1} \quad \left[E_{\text{rh}} = \frac{h c}{\lambda} = (6.626 \times 10^{-34} \text{Jsr}) (3 \times 10^8 \frac{\text{m}}{\text{s}}) (56 \times 10^{-9} \text{m})^{-1} = 3.5 \times 10^{-12} \frac{\text{sr}}{\text{Hz}} \right]$$

$$= 23.54 \frac{F_h}{\text{cm}^2 \text{\AA}}$$

$$4.) \sqrt{N} = \frac{R_s t}{\sqrt{R_s t + n_{pix}(R_s t + R_s t + N_b)}}$$

$$100 = \frac{1.2 \frac{\text{e}^-}{\text{sr}} \text{ s}}{\sqrt{(1.2 \frac{\text{e}^-}{\text{sr}} \text{ s}) + 4 \pi (5.7 \frac{\text{Hz}}{\text{sr}}) \cdot 0.012 \frac{\text{J}}{\text{Hz}} + 5 \frac{\text{e}^-}{\text{pix}}}}$$

(cancel)

$$\Rightarrow t = 552809 \text{ s}$$

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

$$\sqrt{N} = 100$$

$$R_s = .2 \frac{\text{e}^-}{\text{sr}}$$

$$R_b = .5 \frac{\text{e}^-}{\text{sr pix}}$$

$$R_b = 10 \frac{\text{e}^-}{\text{sr pix}} \times \frac{1.2 \frac{\text{e}^-}{\text{sr}} \text{ s}}{3600 \text{ s}} = .0028 \frac{\text{e}^-}{\text{sr pix}}$$

$$n_{pix} = 4 \text{ pix}$$

$$N_b^2 = 5 \frac{\text{e}^-}{\text{pix}}$$

$$5.) \sqrt{N} = \frac{R_s t}{\sqrt{R_s t + n_{pix}(R_s t + R_s t + N_b)}}$$

$$100 = \frac{21.7 \frac{\text{e}^-}{\text{sr}} \text{ s}}{\sqrt{(21.7 \frac{\text{e}^-}{\text{sr}} \text{ s}) + 4 \pi (62.12 \frac{\text{Hz}}{\text{sr}}) \cdot 0.012 \frac{\text{J}}{\text{Hz}} + 5 \frac{\text{e}^-}{\text{pix}}})} \quad \text{cancel}$$

$$100 = \frac{21.7 \frac{\text{e}^-}{\text{sr}} \text{ s}}{\sqrt{(21.7 \frac{\text{e}^-}{\text{sr}} \text{ s}) + 4 \pi (62.12 \frac{\text{Hz}}{\text{sr}}) \cdot 0.012 \frac{\text{J}}{\text{Hz}} + 5 \frac{\text{e}^-}{\text{pix}}})}} \quad \boxed{t_{new} = 8635.29 \text{ s} \times \frac{1 \text{ sr}}{3600 \text{ s}} = 2.4 \text{ hr}}$$

; We are basically background-limited since R_b / n_{pix} is much larger than our source, dark current, &

$$t_{new} = 1622.23 \text{ s} \times \frac{1 \text{ sr}}{3600 \text{ s}} = .47 \text{ hr}$$

$$R_s = n_{pix} A_{\text{lambda, bandpass}} F_\lambda$$

$$= .524 (900 \text{ \AA}) (4.155 \text{ m}^2) (5.367 \times 10^{-19} \frac{\text{erg}}{\text{sr \AA}})$$

$$= 1.0927 \times 10^{-10} \frac{\text{e}^-}{\text{sr}} \times (3.5496 \times 10^{-12} \frac{\text{e}^-}{\text{sr}})^{-1}$$

$$= 2.7 \frac{\text{e}^-}{\text{sr}}$$

read noise our new moon exposure time is much longer than full moon, which makes sense! The light from the full moon will contribute pretty significantly to our background noise.

$$\begin{aligned} n_{pix} &= (QE)(\text{efficiency})(\text{fano}) \\ &= .9(.7)(2.5)^{(\text{background})/(\text{background})} \\ &= .524 \end{aligned}$$

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

$$A_{\text{lambda, bandpass}} = \pi (1.15 \text{ m})^2 = 4.155 \text{ m}^2$$

$$\begin{aligned} F_\lambda &= F_r \left| \frac{\delta V}{\delta \lambda} \right| \\ &= (5.611 \times 10^{-25} \frac{\text{erg}}{\text{sr m}^2 \text{ Hz}}) / (9.566 \times 10^{10} \frac{\text{Hz}}{\text{A}}) \\ &= 5.367 \times 10^{-19} \frac{\text{erg}}{\text{sr m}^2 \text{ \AA}} \\ &\quad \text{from chart notes!} \\ F_r &= 35490 \text{ Jy} \times 10^{-22} \text{ (22)} \\ &= 5.611 \times 10^{-6} \text{ Jy} \times 10^{-16} \frac{\text{Hz}^{-1}}{\text{m}^2 \text{ Hz} \text{ Jy}} \times 10^7 \frac{\text{erg}}{\text{J}} \\ &= 5.611 \times 10^{-25} \frac{\text{erg}}{\text{sr m}^2 \text{ Hz}} \\ \left| \frac{\delta V}{\delta \lambda} \right| &= \frac{C}{\lambda^2} = (3 \times 10^8 \frac{\text{Hz}}{\text{\AA}}) / (.56 \times 10^{-5} \text{ m})^{-2} \\ &= 9.566 \times 10^{20} \frac{\text{Hz}}{\text{m}} \times \frac{10^{10} \text{ Hz}}{\text{\AA}} \\ &= 9.566 \times 10^{\frac{20}{\text{m}}} \frac{\text{Hz}}{\text{\AA}} \end{aligned}$$

$$F_r = \frac{16}{\lambda} = (16.626 \times 10^{-27} \text{ erg sr p}) [3 \times 10^8 \frac{\text{Hz}}{\text{\AA}}] / (.56 \times 10^{-5} \text{ m})^{-1} = 3.549 \times 10^{-11} \frac{\text{erg}}{\text{sr}}$$

[FVII]

$$\begin{aligned}
 R_b &= \eta_{\text{int}} \Delta A_{\text{v, bandpass}} A_{\text{eff}} \epsilon_{\text{rec}} F_A \\
 &= (3.24) (900 \text{ A}^2 / (4.155 \text{ m}^2)) (3.386 \times 10^{-13} \frac{\text{eV}}{\text{sr m}^2 \text{ Hz} \text{ arcsec}^2}) (3.549 \times 10^{-11} \frac{\text{Hz}}{\text{sr}})^{-1} \\
 &= 187.11 \frac{\text{sr}}{\text{arcsec}^2} \times .332 \frac{\text{arcsec}^2}{\text{pix}} \times 12 \text{ pix} \\
 &= 746.28 \frac{\text{sr}}{\text{pix}}
 \end{aligned}$$

$$\begin{aligned}
 \eta_{\text{int}} &= (\text{QE})(\text{Efficiency}) (\eta_{\text{aimo}}) \\
 &= .9 (.7) (2.5 \frac{\text{Signal}}{\text{Noise}})^{-1}
 \end{aligned}$$

$$= .524$$

$$\Delta A_{\text{v, bandpass}} = 900 \text{ A}$$

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

$$F_A = F_r / \left| \frac{\delta y}{\delta \lambda} \right|$$

$$= (3.54 \times 10^{-11} \frac{\text{sr}}{\text{m}^2 \text{ Hz} \text{ arcsec}^2}) (9.566 \times 10^{10} \frac{\text{Hz}}{\text{A}})$$

$$= 3.386 \times 10^{-13} \frac{\text{sr}}{\text{m}^2 \text{ A} \text{ arcsec}^2}$$

from slide notes

$$F_r = 3549 \text{ Jy} = 10^{-21} \text{ W}$$

$$= 3.34 \times 10^{-5} \frac{\text{W}}{\text{arcsec}^2} \times 10^{-16} \frac{\text{Jy}^{-1}}{\text{m}^2 \text{ Hz} \text{ Jy}} \times 10^7 \frac{\text{W}}{\text{Jy}}$$

$$= 3.34 \times 10^{-21} \frac{\text{W}}{\text{sr m}^2 \text{ Hz} \text{ arcsec}^2}$$

$$\left| \frac{\delta y}{\delta \lambda} \right| = \frac{C}{\lambda} = (3 \times 10^8 \frac{\text{m}}{\text{s}}) / (.56 \times 10^{-4} \text{ m})^2$$

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

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

$$E_{rh} = \frac{hC}{\lambda} = (16.626 \times 10^{-34} \text{ erg s}) (3 \times 10^8 \frac{\text{m}}{\text{s}}) (.56 \times 10^{-4} \text{ m})^{-1}$$

$$= 3.549 \times 10^{-11} \frac{\text{sr}}{\text{rh}}$$

$$\frac{\text{background}}{\text{total flux}} = .577 \frac{\text{arcsec}^2}{\text{pix}}$$

$$F = RD = 2.1(2.3 \text{ m}) = 4.83 \text{ m}$$

$$f = \frac{206265}{4.83 \text{ m} \times \frac{10^3 \text{ mm}}{1 \text{ m}}} = 42.7 \frac{\text{arcsec}}{\text{mm}}$$

$$1 \text{ pix} = 42.7 \frac{\text{arcsec}}{\text{mm}} \times 19.5 \text{ mm} \times \frac{10^3 \text{ mm}}{10^6 \text{ m}}$$

$$= 577 \text{ arcsec}$$

$$\eta_{\text{pix}} = 3.8 \frac{\text{arcsec}^2}{\text{pix}} \times (577 \frac{\text{arcsec}}{\text{pix}})^{-2}$$

prepared by 16 wide pix

$$= 11.42 \text{ pix} \approx 12 \text{ pix}$$

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

[Assume circle & aperture radius = seeing]

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

$$N_r^2 = 4.5 \frac{\text{e}^-}{\text{pix}}$$

[now]

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

$$\begin{aligned} &= 29.7 \frac{r_h}{\text{arcsec}^2} \cdot 332 \frac{\text{arcsec}^2}{\text{pix}} \\ &= 9,888 \frac{r_h}{\text{pix}} \end{aligned}$$

same calc as R_s b6 $M_p = 22$!

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

$$b.) \sqrt{N} = \frac{R_s t}{\sqrt{R_s t + \eta_{101} (R_s t + R_d t + N_d)}}$$

$$\sqrt{N} = \sqrt{R_s t}$$

[Assume source-limited]

$$50 = \sqrt{R_s t / 600} \Rightarrow R_s = 4.167 \frac{r_h}{\text{arcsec}^2} \quad [t = 10 \text{ min} \cdot \frac{60 \text{ s}}{1 \text{ min}} = 600 \text{ s}]$$

$$50 = \sqrt{R_s t} = \sqrt{4.167 / 4 t} \Rightarrow t = 531 \text{ s} \cdot \frac{1 \text{ min}}{60 \text{ s}} = 8.84 \text{ min}$$

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

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

[telescope: 10 m diameter]

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

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

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

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

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

$$= .95(900 \text{ \AA})(1.325 \pi \text{ m}^2)(1.326 \times 10^{-3} \frac{r_h}{\text{cm}^2 \text{\AA}})$$

$$= 4.7119 \frac{r_h}{\text{arcsec}^2}$$

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

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

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

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

[Assume same flux densities]