HW2 Obs Astro ASTR 8060: Obs Astro Wed 20 Sep 2023 Levi Schult | 1

1) $V = 5000 \frac{km}{s}$ $H\beta$ line $\Rightarrow$ $486.135 \times 10^{-9} m$

Assuming J, H, + K filters can detect this line within FWHM centered on Effective λ midpoint

Filter	Eff. λ (nm)	FWHM (nm)		Total λ range (nm)
J	1220	213	$\rightarrow$	1113.5 – 1326.5
H	1630	307	$\rightarrow$	1476.5 – 1783.5
K	2190	390	$\rightarrow$	1995 – 2385

$$1 + z_{dop} = \sqrt{\frac{1 + v_r/c}{1 - v_r/c}} \rightarrow z = \sqrt{\frac{1 + \frac{5\times10^6 m/s}{3\times10^8 m/s}}{1 - \frac{5\times10^6 m/s}{3\times10^8 m/s}}} - 1$$

$z_{dop} = 1.68 \times 10^{-2}$

$$1 + z = (1 + z_{dop})(1 + z_{cosm}) = \frac{\lambda_{obs}}{\lambda_{emit}}$$

$$1 + z_{cosm} = \frac{\lambda_{obs}}{\lambda_{emit}(1 + z_{dop})} \longrightarrow z_{cosm} = \frac{\lambda_{obs}}{\lambda_e(1 + z_d)} - 1$$

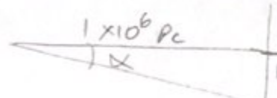
$$z_{cosm} = \frac{\lambda_{obs}}{\lambda_e(1 + z_d)} - 1$$

J| $\lambda_{obs} = 1113.5\ nm,\ 1326.5\ nm \Rightarrow z_{cosm} = 1.25 - 1.68$

H| $\lambda_{obs} = 1476.5\ nm,\ 1783.5\ nm \Rightarrow z_{cosm} = 1.98 - 2.61$

K| $\lambda_{obs} = 1995\ nm,\ 2385\ nm \Rightarrow z_{cosm} = 3.04 - 3.82$

2)



$$\alpha = \tan^{-1}\left(\frac{15\times10^3 pc}{1\times10^6 pc}\right) = 0.0150 \text{ rad}$$
$$= 0.859^\circ$$

Total $\measuredangle$ size $= 2\cdot\alpha = 0.03$ rad $= 1.72^\circ$

3) 8 m diam. f/3 prime f/12 Nasmyth

$\rightarrow$ $f_0 = 24\ m$, $96\ m$

Plate Scale $= \frac{\theta}{F_0} \rightarrow \frac{206265}{24\times10^3 mm} = 8.59''/mm$ OR $2.14''/mm$

So pixels to get $.5''/2 = 0.25''$

Pixel size: $\frac{0.25''}{8.59''/mm} = .0291 mm$ OR $\frac{0.25''}{2.14''/mm} = 0.117\ mm$

$$FOV = P \cdot N_{pix} = 0.25'' \cdot 2048 = 512'' = 8.53'$$

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$B = 9.5$ mag @ $\lambda_{eff} = 445$ nm $= 4450$ Å $f_{\nu,0}(Jy) = 4440$ from notes

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

$f_\nu(Jy) = 4440\ Jy \cdot 10^{-0.4 \cdot 9.5} = \boxed{0.704\ Jy}$

$0.704\ \cancel{Jy} \cdot \dfrac{10^{-26}\ \cancel{W}\, m^{-2}\, Hz^{-1}}{\cancel{Jy}} \cdot \dfrac{10^{7}\ erg\ s^{-1}}{\cancel{W}} \cdot \dfrac{m^2}{10^4\ cm^2} \cdot 1.51\times10^{11}\ Hz\ Å^{-1}$

$= \boxed{1.06 \times 10^{-12} \dfrac{erg}{s\ cm^2\ Å}}$

$\dfrac{\delta\nu}{\delta\lambda} = \dfrac{c}{\lambda^2} = \dfrac{3\times10^{18}\ Å/s}{(4450\ Å)^2}$

$h = 6.624\times10^{-27}$ erg·s $E = h\nu = \dfrac{hc}{\lambda} = 6.624\times10^{-27}\ erg\cdot s \cdot \dfrac{3\times10^{18}\ Å/s}{4450\ Å}$

$E = 4.47\times10^{-12} \dfrac{erg}{Photon}$

$1.06\times10^{-12} \dfrac{erg}{s\,cm^2\,Å} \cdot \dfrac{Photon}{4.47\times10^{-12}\ erg} \Rightarrow \boxed{2.38\times10^{-1} \dfrac{photon}{s\ cm^2\ Å}}$

5) $m_{AB} = 20$ @ 5500 Å

$f_\nu(Jy) = 3631\ Jy\ 10^{-0.4 m_{AB}} \to 3631\ Jy\ 10^{-0.4\cdot20} = \boxed{3.63\times10^{-5}\ Jy}$

$f_\nu(Jy) = F_{vega,0}\, 10^{-0.4m}$ 5500 Å = 550 nm $\Rightarrow V$

$f_\nu \cdot F_{vega,0} = 10^{-0.4m} \to \log(f_\nu \cdot F_{vega,0}) = -0.4m$

$m = \dfrac{\log(f_\nu \cdot F_{vega})}{-0.4} = \dfrac{\log_{10}(3.63\times10^{-5}\ Jy \cdot 3540\ Jy)}{-0.4} = \boxed{2.23}$

$3.63\times10^{-5}\ Jy \cdot \dfrac{10^{-26}\ W\,m^{-2}\,Hz^{-1}}{Jy} \cdot \dfrac{10^{7}\ erg\ s^{-1}}{W} \cdot \dfrac{m^2}{10^4\ cm^2} \cdot \dfrac{3\times10^{18}\ Å/s}{(5500\ Å)^2 \to Å} \cdot \dfrac{Photon \quad 5500\ Å}{6.624\times10^{-27}\ erg\cdot s \cdot 3\times10^{18}\ Å/s}$

$= \boxed{9.96\times10^{-6} \dfrac{photon}{cm^2\ s\ Å}}$

$1 \frac{MJy}{Sr}$ @ $5500\,Å$ $\qquad 1\,Sr = 1\,rad^2 = 206265\,''^2 / rad^2$

$$\frac{1\,MJy}{Sr} \cdot \frac{Sr}{(206265\,'')^2} \cdot \frac{10^{-26}\,W\,m^{-2}\,Hz^{-1}}{Jy} \cdot \frac{10^{7}\,erg\,s^{-1}}{W} \cdot \frac{m^2}{10^4\,cm^2}$$

$$= \boxed{2.35\times10^{-38} \frac{erg}{s\,cm^2\,Hz\,(as)^2}}$$

$$2.35\times10^{-38} \frac{erg}{s\,cm^2\,Hz\,(as)^2} \cdot \frac{3\times10^{18}\,Å/s}{(5500\,Å)^2} = \boxed{2.33\times10^{-17} \frac{erg}{s\,cm^2\,Å\,(as)^2}}$$

$$2.33\times10^{-17} \frac{erg}{s\,cm^2\,Å\,(as)^2} \cdot \frac{Photon}{6.624\times10^{-27}\,erg\cdot s} \cdot \frac{5500\,Å}{3\times10^{18}\,Å/s} = \boxed{6.45\times10^{-6} \frac{Photon}{s\,cm^2\,Å\,(as)^2}}$$

7) Imagine several bucket brigades trying to measure the amount of rainfall from a storm. They stand holding empty buckets under the storm for an amount of time that allows the buckets in the heaviest downpour to almost fill up. They then use umbrellas to block more rain from collecting before they pass their buckets down the line to the brigade on the end of the grid. This last brigade is oriented perpendicularly so they can pass each bucket, one at a time, to the person who measures each bucket's water. In the stronger storms, they don't have to collect water very long to get enough water for measurement. In weak storms, they wait for longer. They also often stand under an artificial waterfall, so they can see if anyone who is supposed to be in the grid is absent, resulting in no collection bucket. They will also calibrate by checking if anyone has a trick bucket that is always full of water, distorting measurements. When they pass the buckets down the brigade in the measurement reading process, sometimes rain falls in or spills out leading to some more noise.