CTA200H 2023 One Week Project

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Task 1

First the function $dE_\nu = I_\nu * cos(\theta) * dA * d\omega * d\nu * dt$ was defined. This function outputs the amount of energy (dE_ν) entering a solid angle $d\omega$ in a frequency interval $d\nu$ within time dt per surface area element dA. The energy is a function of I_ν with radiation coming in at an angle θ with respect to the area the radiation is passing through, A.

Next the flux-intensity relation was defined to be $F = \pi I$, using the assumption that the incoming intensity is isotropic in order to disregard the more complex flux intensity relation involving integrals. Finally the equation for flux as a function of the luminosity of the source and distance from the source was defined as $F = \frac{L}{4\pi d^2}$.

Multi-epoch g-band and r-band observations corresponding to CCD number 24 and field number 1 were downloaded, and the sources with the minimum modified Julian date observed for each catalogue were selected. Their distributions in the sky in equatorial coordinates were then plotted, as shown in Figure 1.

(a) g-band distribution
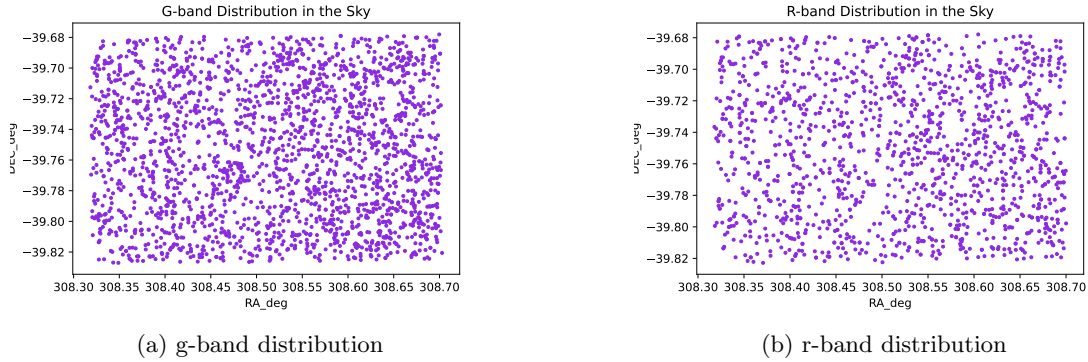

(b) r-band distribution

Figure 1: HOWVAST g-band and r-band distributions in the sky in equatorial coordinates.

The instrumental magnitudes of the data were then computed as a function of the PSF-based fluxes using the equation $mag = -2.5log(\frac{F}{t_{exp}}) - a - kX$, where F is the PSF-based flux, t_{exp} is the exposure time, a is a photometric zero point, k is a first-order extinction coefficient, and X is the airmass. For the g-band, a = -25.34 and k = 0.2, and for the r-band a = -25.45 and k = 0.1. For the g-band, the mean magnitude was found to be 22.194945 with a standard deviation of 2.068801. For the r-band the mean magnitude was found to be 20.382472 with a standard deviation of 1.978184. Histograms of the magnitude values for each band are shown in Figure 2 below. A concentration of magnitude values can be seen from   22-24 for the g-band and 20-22.5 for the r-band.
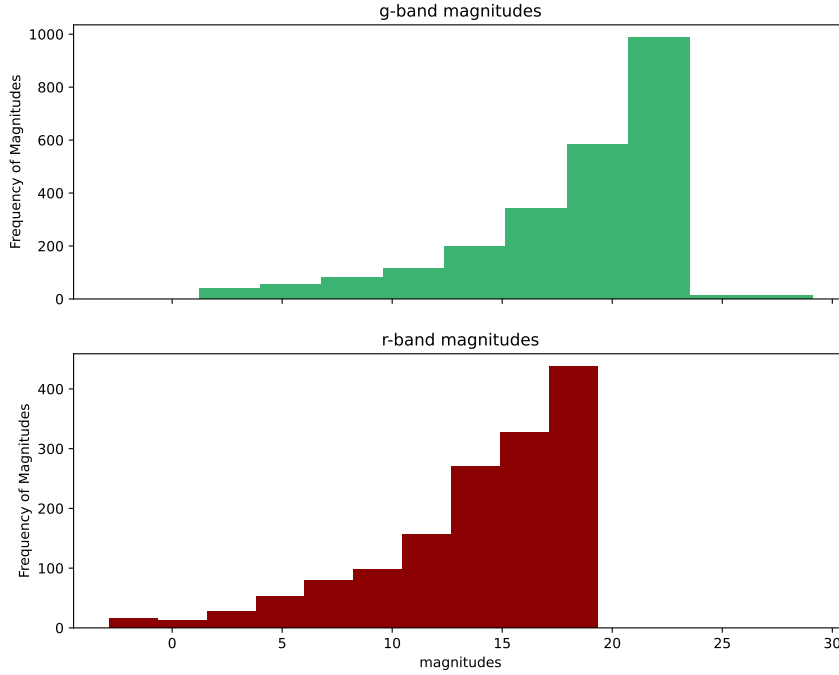
Figure 2: Histogram of calculated instrumental magnitudes for the g-band and r-band.

Task 2

Next data was retrieved from the NSC database using ADQL, using right ascension (ra) and declination (dec) values to limit the data. These values were the global minimum and maximum ra and dec values between both the g-band and r-band HOWVAST data.

Some columns available in the NSC table include ra and dec values along with their respective raerr and decerr, which will be useful for cross-matching with HOWVAST RA_deg and DEC_deg values to find potential matches between the catalogues. The mjd column can also be compared with HOWVAST's MJDObs column, to compare the times at which the data was observed. The gmag and rmag columns with their respective gerr and rerr data would also be helpful for comparing with our calculated g and r magnitudes for the HOWVAST data. The class_star column will be help in limiting the NSC data, as it determines whether something is a star or a galaxy depending on whether it's class_star value is closer to 1 or 0.

A cross-match was then performed between the HOWVAST and NSC data, based on equatorial coordinates. First all the NSC data that had g or r magnitudes equal to 99.99 were limited out, as these 99.99 values were equivalent to missing data. Then the NSC data was limited further in order to make sure that the data only contained stars and not galaxies. This was done by limiting the class_star column to values greater than 0.85, as values close to one are likely to be stars and values close to zero are likely galaxies. The HOWVAST calculated magnitudes were also limited to be less than 23, as the magnitude uncertainties increase as the magnitudes become fainter and this was taken to be the cutoff point where the errors became too high. The magnitude uncertainties themselves were also limited to be less than 0.1.

Then the r-band and g-band HOWVAST catalogues were cross-matched using SkyCoord from astropy, in order to make them the same shape. This cross-match was done by matching equatorial coordinates (ra and dec values). Then the HOWVAST and NSC data were cross-matched in the same way, and because the r-band and g-band data from HOWVAST had already been cross-matched, the matching values could

ra	dec	rmag	RA_deg	DEC_deg	mag_r
308.3199815157328	-39.74382571463147	21.343632	308.32001608576167	-39.74384056542559	21.447233589694743
308.32191564303275	-39.74569709506943	21.355093	308.3219156711253	-39.74567891613083	21.475259052975034
308.31976394843497	-39.73769648446402	20.624195	308.3197595478313	-39.73771249522027	20.78218591688039
308.32463524933576	-39.7397136514464	20.663216	308.32464752773564	-39.73974360095482	20.752765757645363
308.3277821120881	-39.74191975250112	15.746295	308.3277688768264	-39.7419723864803	15.891395714449835
308.323668519267	-39.78843478930611	20.98415	308.3236692617301	-39.78845080272856	21.076242475135036
308.3263659268317	-39.79730484727615	19.916483	308.3263747971646	-39.79731313603296	20.00293972512703
308.3359846562108	-39.79946088055532	21.039448	308.33600356647145	-39.79950429207855	21.099460237419855
308.33397811953824	-39.78349216603588	19.414886	308.3339833259193	-39.78350806393074	19.55387001689415
308.3391014497509	-39.79332240231385	19.423096	308.3391128973188	-39.793338585407135	19.54560498325442

Table 1: Crossmatched HOWVAST and NSC data. This table contains ra, dec, and r magnitude values.

be called for both of them at the same time without having to match them seperately to the NSC data. The best cross-matched pairs were defined by whether the distance between the stars was less than 0.5 arc-seconds. There were a total of 516 matches. An example of the some of the crossmatched data can be seen in Table 1. This table contains a limited selection of crossmatched NSC and HOWVAST data, and contains NSC and HOWVAST right ascension, declination, and r-magnitude information. The ra and dec values are quite similar, but the magnitudes are less so. This is most likely because the NSC data is already calibrated, whereas the HOWVAST data is not.

Task 3

Then colour magnitude diagrams were built from the cross-matched HOWVAST and NSC data, as shown in Figures 3 and 4. Figure 3 shows g versus g-r colour (a) and g-r versus r colour (b) for the NSC data, with the uncertainties being taken and propagated from the g_err and r_err columns of the NSC data. Then Figure 4 shows the same plots, but this time for the HOWVAST data. The errors on these graphs were propagated from the flux uncertainties in each band, using the equation $-2.5\frac{uflux}{log(flux)}$, where uflux is the uncertainty in the flux from the base_PsfFlux_fluxSigma column and flux is from the base_PsfFlux_flux column. All of these plots are very zoomed in, as can be seen from the scale of the axes. This explains why no clear shape can be seen in either the g-band or r-band data. It seems like there are higher uncertainties in the r-band plots, and that the uncertainties seem to be slightly larger for the HOWVAST data, such as for the lowest g-r values and dimmest r-values in Figure 3 b) versus Figure 4 b). The HOWVAST and NSC colour magnitude diagrams also have slightly different concentrations of data points, even though they have been cross-matched. For example, in Figure 4a) there is more of a concentration of points near the highest g-r values than in Figure 3a), and the data with the brightest r magnitude values in Figures 3b) and 4b) trail off differently depending on whether they are from the NSC or HOWVASt catalogues. This is reasonable, as the NSC data has already been calibrated, whereas the HOWVAST data has not so seeing some differences is not unexpected.

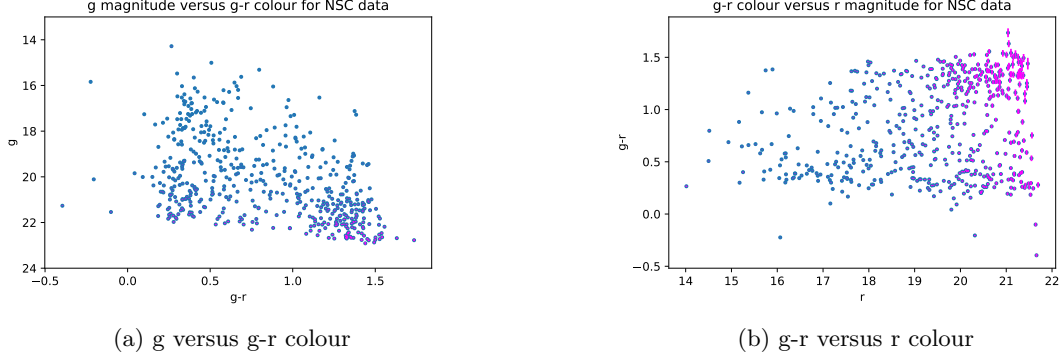(a) g versus g-r colour

(b) g-r versus r colour

Figure 3: Colour magnitude diagrams for NSC data, using the g-band and r-band. The pink indicates uncertainties.

(a) g versus g-r colour
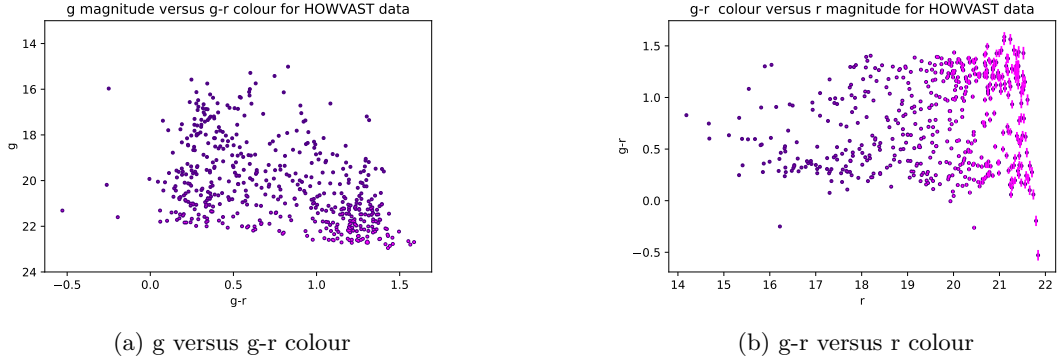

(b) g-r versus r colour

Figure 4: Colour magnitude diagrams for HOWVAST data, using the g-band and r-band. The pink indicates uncertainties.

Then the magnitudes for the catalogs in each pass-band were compared. This was done by plotting the difference in magnitudes (NSC data - HOWVAST data), versus the magnitude for each catalogue. These plots can be seen in Figures 5 and 6.

The difference in magnitudes seems to be greatest at fainter magnitudes, and decrease with higher magnitudes. This makes sense, as the NSC data is calibrated whereas the HOWVAST data is not, and the dimmer stars have higher uncertainties associated with them because they are not as easy to detect precisely as brighter stars. Examining the plots, we can see what looks like a mild negative linear correlation between magnitude and magnitude difference. With a larger data set, we may be able to see this correlation more distinctly and fit the relation to solve for the slope and the constant.
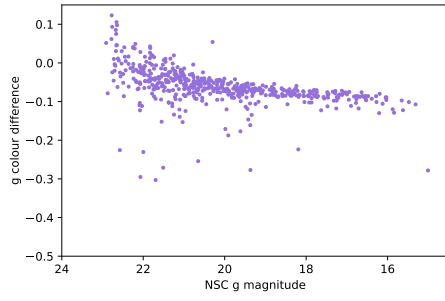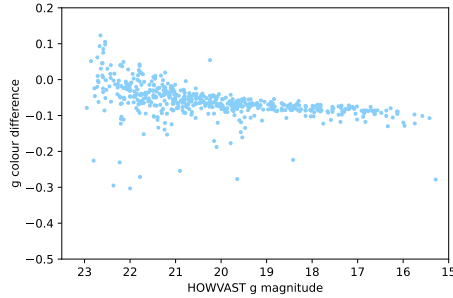
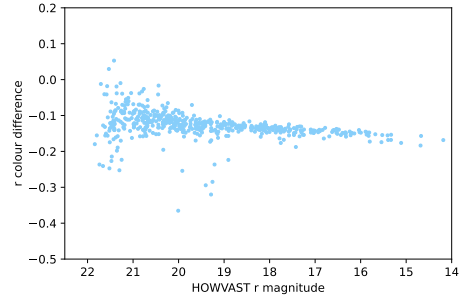(a) g magnitude differences versus NSC g colour
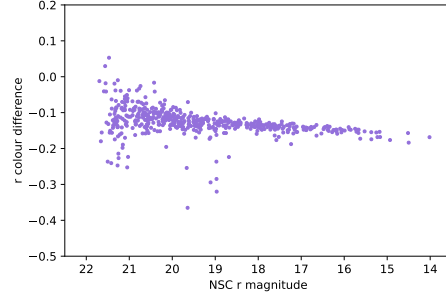
(b) r magnitude differences versus NSC r colour

Figure 5: colour differences between NSC and HOWVAST data, as a function of NSC colour.

(a) g magnitude differences versus HOWVAST g colour

(b) r magnitude differences versus HOWVAST r colour

Figure 6: g-colour differences between NSC and HOWVAST data, as a function of HOWVAST colour.

Optional Task

Information was taken from the Gaia database about the HOWVAST targets, again using the minimum ra and dec values from HOWVAST to limit the data. Similarly to the NSC data, ra, dec, ra_error and dec_error would be helpful if we wanted to cross-match with the HOWVAST data. Gaia also has phot_g_mean_flux, with a phot_g_mean_flux_over_error, as well as the same for the r band (the same but rp), which could be useful for comparing calculated magnitudes and errors as Gaia data is calibrated. However, we would need to check that the bands used are the same or similar enough to correct for differences. There are also phot_g_mean_mag values, and the equivalent for rp, wit which we could also compare magnitudes. CMDs could also be plotted as the g_rp column is equivalent to G-RP colour.

However, there are many Gaia data points that have high errors, for example phot_g_mean_flux_over_error values of 6.64. In order to perform data quality cuts, we can limit the data to only contain reasonable errors before cross-matching it. For example, we could limit the phot_g_mean_flux_over_error column, the contaminated transit columns, the astrometric excess noise column, and the ruwe (renormalized unit weight error) column to only contain data with reasonable errors.