Homework #2: Dust Attenuation & Structure of Galaxies

AST386: Prof. Caitlin Casey

This assignment is due by 3pm on October 16^{th}. Send me a pdf (in a format lastname_hw2.pdf) in email to cmcasey'at'utexas.edu. It should be formatted using LaTeX, showing your work, and embedding plots as needed. You can generate the plots in any code you prefer, but please include a full description of your methods so I could reproduce your plot exactly following your instructions.

1. Download tools for this homework here: `www.as.utexas.edu/~cmcasey/ast386c/hw2tools/`
2. This problem should be considered a continuation of problem # 2 on HW#1. So use the stellar population you generated for that problem to continue the exercise here, now involving .... dust!
   (a) Plot the Calzetti attenuation of light as a function of wavelength for two different levels of dust attenuation: $E(B-V) = 0.1$ and $E(B-V) = 1.0$. What R_V values do these correspond to? The folder `hw2tools` contains the Calzetti attenuation curve in terms of $A_\lambda/E(B-V)$ in calzetti01.txt. While the definition is often given in magnitudes, plot it as a fractional attenuation in flux density (i.e. transmission). Make mindful choices of how you generate the plot (ranges on both axes and log or linear scale).
   (b) Apply these attenuation curves to all of your spectra you have generated (the stellar population synthesis spectrum that is 0-age, 500 Myr, and 1 Gyr). You should have nine different spectra in the end. Put all of the spectra on one plot for comparison. Use different colors to denote different ages and different line styles to denote different levels of attenuation.
   (c) What is the $g-r$ color for all nine of your template spectra? Use the g and r filters from Subaru that you used to complete Homework #1. How does this depend on age or dust attenuation? More generally, from your nine model spectra, is there any way to easily distinguish between the effects of dust and age?
   (d) In the `hw2tools` folder, you will also find a simple text file giving photometry for several different bands across the optical and near-IR for a sample galaxy in the rest-frame (galaxyphot.txt). Which of your nine model templates (three levels of extinction, three different ages) fits this data best? Describe how you arrive at that conclusion quantitatively. Hint: you will get different χ^2 values depending on how your template is normalized with respect to the data points. There *is* an optimal factor by which to normalize a given template to minimize χ^2 over all possible normalization coefficients. You should find that for each template, and then determine which template is best.
3. The `hw2tools` folder contains a fits image of a galaxy, NGC5055. Use ds9 (or your other favorite fits image viewer) to take a look at the galaxy. For this problem, we will conduct some basic measurements of its properties.
   (a) The pixel scale of the image I gave you is 1 arcsec/pixel[1] Using only this image, estimate the inclination angle of the disk (with an uncertainty). Describe your methods. Please, no need for detailed modeling in THIS part of the question!

[1]This information is stored in the fits header; if you poke around this value is the 'CD' 2x2 matrix multiplied by the 'CDELT' matrix, which results in a 2x1 matrix, which is the pixel scale of the image in x and y directions, in units of degrees per pixel.

(b) The surface brightness profile of disk galaxies, if viewed face on, have an exponentially declining surface brightness, such that

$$\Sigma(r) = \Sigma_{\rm cent} \exp(-r/h) \tag{1}$$

where h is a characteristics scale length of the disk such that at a radius of h, the surface brightness drops by $1/e$. Σ is the surface brightness in flux density per square arcseconds, and $\Sigma_{\rm cent}$ is the galaxy's central surface brightness. Create a very simple model image of NGC 5055 as an exponential disk at the inclination you estimated in the first part of this question and plot a figure of it alongside the image in the fits file. Note that the position angle of the semi-major axis of NGC 5055 is approximately 100 degrees (east of north).

(c) Now adjust your model in part b to be centered on NGC 5055 and the same size as NGC 5055. Generate a residual image, which is the real image of NGC 5055 with your exponential disk model subtracted. Is it a good fit? Discuss some of the features in your residual map, and estimate the scale length of the disk, h, in kpc. To convert from the angular scale of the image to physical units, you can use the distance to NGC 5055 (9.4 Mpc) and the small angle approximation (no cosmology needed).

(d) Show that any stellar system with a surface brightness given by μ in mag arcsec^{-2} has a surface luminosity density in projection on the sky of

$$\Sigma = 10^{0.4(26.4-\mu)} L_\odot \, pc^{-2} \tag{2}$$

Please neglect all cosmological effects for this problem (i.e. don't consider galaxies at high-redshift).

(e) photometry in the V-band along the major axis of NGC 5055 gives $\mu = 20.1$ at $1'$, 21.1 at $2'$, 22.7 at $4'$ and 25.25 at $8'$, where μ has units of V magnitudes arcsec^{-2}. Use these measurements to calculate h and $\Sigma_{\rm cent}$. Then use the functional form of the expoential model to calculate the total luminosity of the disk in $L_\odot$ (note that the sun has a V-band absolute magnitude of 4.83).

4. Let's start the process of thinking about your end-of-semester proposal.

(a) In your readings so far in this class, what have you found the most surprising about our knowledge of galaxies and how we obtain fundamental measurements of their properties (or use them to learn something else fundamental about astrophysics)? Why?

(b) List three topics related to galaxy formation and evolution, or galactic structure, which you think are the most important issues to solve in the next 5-10 years. Justify your choices. This can include topcis we have not yet discussed in class. Pro-tip: just because you like something / find it interesting / are working on it doesn't make it the most important problem to solve. Justify in a few sentences each of your choices!