**Deriving M101 Properties: Surface Brightness and Color Profile**

**Remember what you did in HW #2 for M84:**

- Image in one filter (V)
- Binned pixels by radius, got median pixel intensity ($I_{med}$) as a function of radius
- Turned pixel intensity into magnitude using 1-band photometric solution:

$$m = -2.5\log(I_{med}) + 28.60$$

- Turned magnitude into surface brightness given the area of an individual pixel:

$$\mu = m + 2.5\log(1.45^2)$$

**But for the M101 data it's *different*:**

- Images in two filters (B and V)
- Bin pixels by radius, get average/median pixel intensity for each image ($I_{med,B}$ and $I_{med,V}$) as a function of binned radius
- Turn pixel intensities into magnitude and color using the 2-band photometric solution function we worked out in class (See the Photometry.ipynb worksheet on the M101 Lab page)
- Turn magnitude into surface brightness given the area of an individual pixel:

$$\mu = m + 2.5\log(1.45^2)$$

*The answer is shown in Mihos et al (2013), so you know what you are aiming for.*

**Deriving M101 Properties: Scale length and central surface brightness**

Remember that M101 is a spiral galaxy, and we characterize its light profile as an exponential: $I(r) = I_0 e^{-r/h}$

Rewritten using surface brightness this becomes $\mu(r) = \mu_0 + \frac{2.5}{h \ln 10} r$

Fit a straight line to your surface brightness profile (decide what range of radii is best to fit and explain/justify your choice!) and use the fit to derive the central surface brightness ($\mu_0$) and scale length ($h$).

**Deriving M101 Properties: Total Apparent Magnitude**

With your fitted values of central surface brightness ($\mu_0$) and scale length ($h$), derive the total apparent magnitude of M101: $m_{tot} = \mu_0 - 2.5\log(2\pi h^2)$. *(We worked this out in one of the ASTR 323 Homeworks!)*

**Deriving M101 Properties: Physical Parameters**

Use the distance to M101 (cite your source!) to convert observed properties (apparent magnitude, scale length in arcminutes, etc) into physical properties (absolute magnitude, luminosity, scale length in kiloparsecs).

## Handling Uncertainties

### Quantitative: Propagating Random Errors

Use the uncertainties in your fits (slope, intercept) to derive uncertainties in your scale length ($h$) and central surface brightness ($\mu_0$).

Use the uncertainties in $h$ and $\mu_0$ to derive uncertainty in total apparent magnitude ($m_{tot}$).

### Qualitative: Discussing Systematic Errors

Systematic errors are much more difficult to quantify. Instead, I want you to think and discuss sources of systematic errors and how they might (qualitatively) change your results.

**Thinking, Discussion, and Interpretation**

Compare your fitted parameters and colors/profiles to those published in the scientific literature, both for M101 specifically and for spiral galaxies more generally. *I want to see more than just a comparison to Mihos et al 2013!*

Think about what it means that you see a particular color profile. What's happening in the galaxy to give these colors? Why might it change with radius?

Think about / discuss the morphology of M101 as seen in your images: its shape, spiral structure, asymmetry, structure in the inner parts vs the outskirts, presence/absence of a central bulge, etc.

Discuss these issues in the context of galaxy evolution (inside-out galaxy formation, disk galaxy evolution, galaxy interactions, etc).

**Research Starting Points *(but not ending points!):***

- My galaxies classes (ASTR 222 and ASTR 323)
- Bill Janesh's galaxies class (ASTR 222)
- van der Kruit and Freeman review paper "Galaxy Disks", in the Annual Review of Astronomy and Astrophysics (ARAA)
- Blanton and Moustakas review paper "Physical Properties and Environments of Nearby Galaxies" in ARAA
- Mihos et al (2013): "The Extended Optical Disk of M101"