5-2019

Investigating Milky Way Structure with Gaia

Mary Geer Dethero
Lehigh University

Investigating Milky Way Structure with Gaia

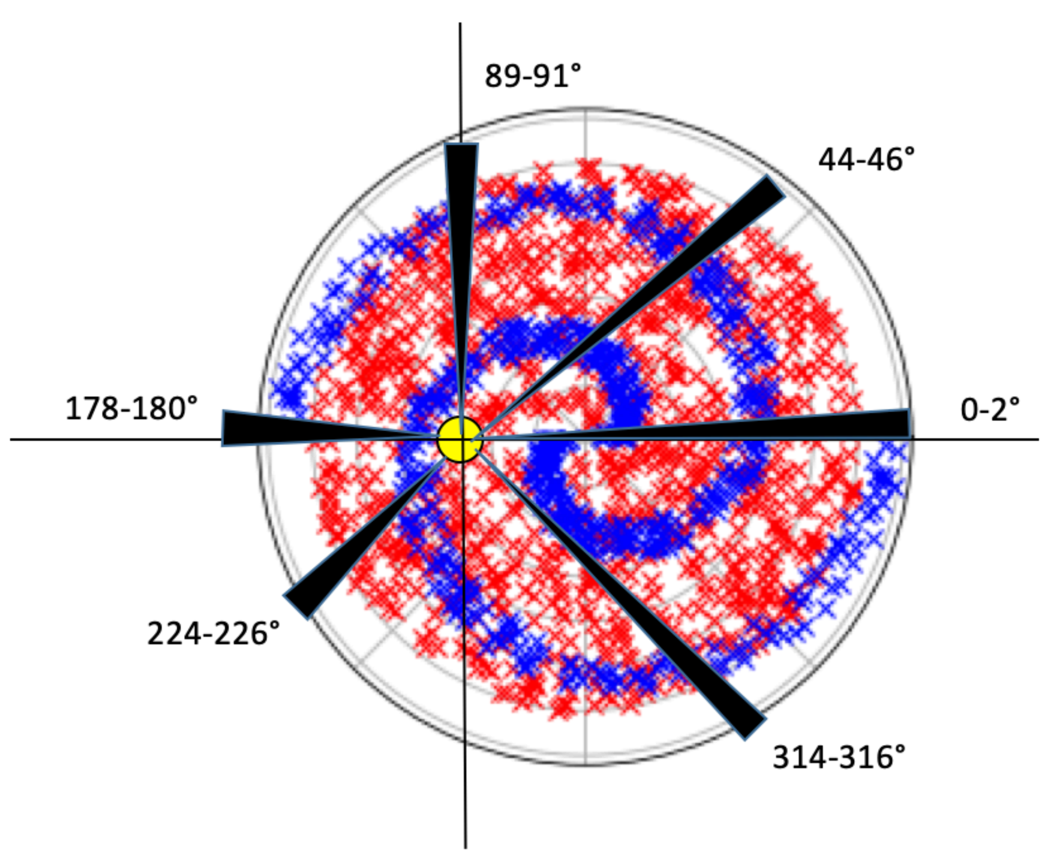
Mary Geer Dethero & M. Virginia McSwain, Department of Physics, Lehigh University

Abstract

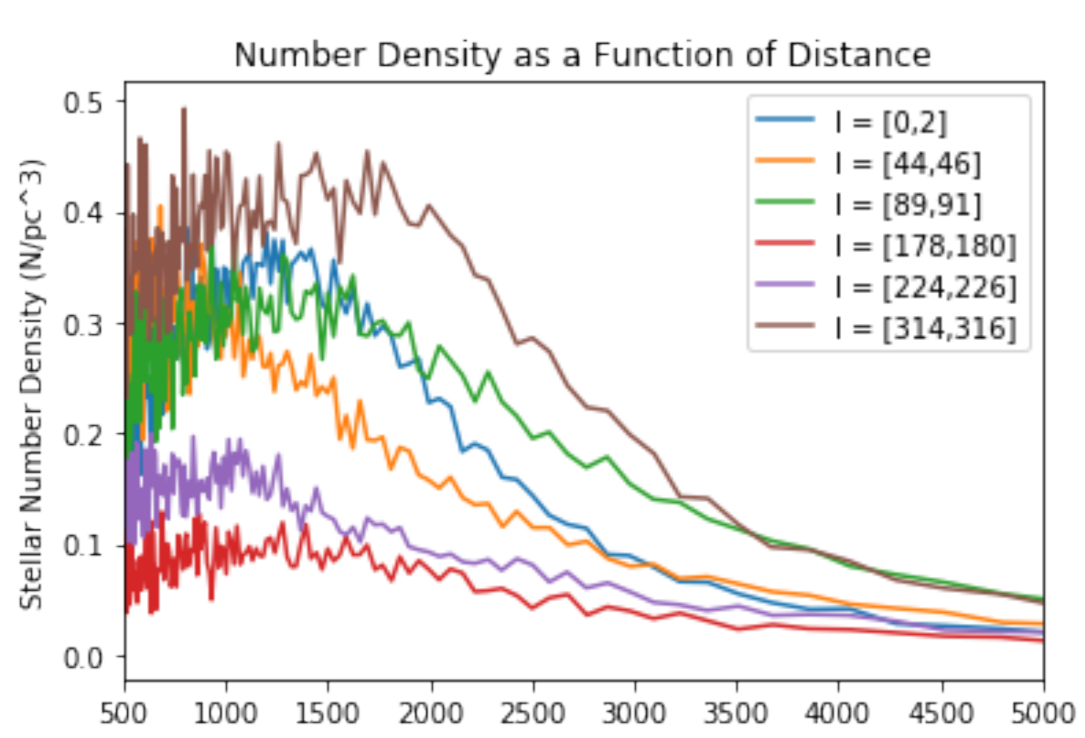
We present an investigation of the structure and characteristics of the Milky Way Galaxy using data from the Gaia mission's second data release (DR2). We began by plotting the spatial distribution of stars in a variety of directions around the Galactic plane. Using Python, we have generated several random populations of stars with different distributions. The stars in each model are assigned a random mass, M, according to the Salpeter initial mass function, and we assign a luminosity, L, by assuming a simple power law, L ~ M^3, to account for their visibility. Finally, we compare the modeled stellar density distributions to the observed distribution within the Milky Way.

Introduction

The Gaia spacecraft is collecting data on the positions of one billion stars in the Milky Way, making up about 1 percent of the Galactic population. As the spacecraft orbits the Sun, it observes parallax, which indicates the distance to a star. We can plot the distances of each star and consider trends in their physical distribution. In this research, we examine the distribution of stars for 6 different pointings, shown in Figure 1.



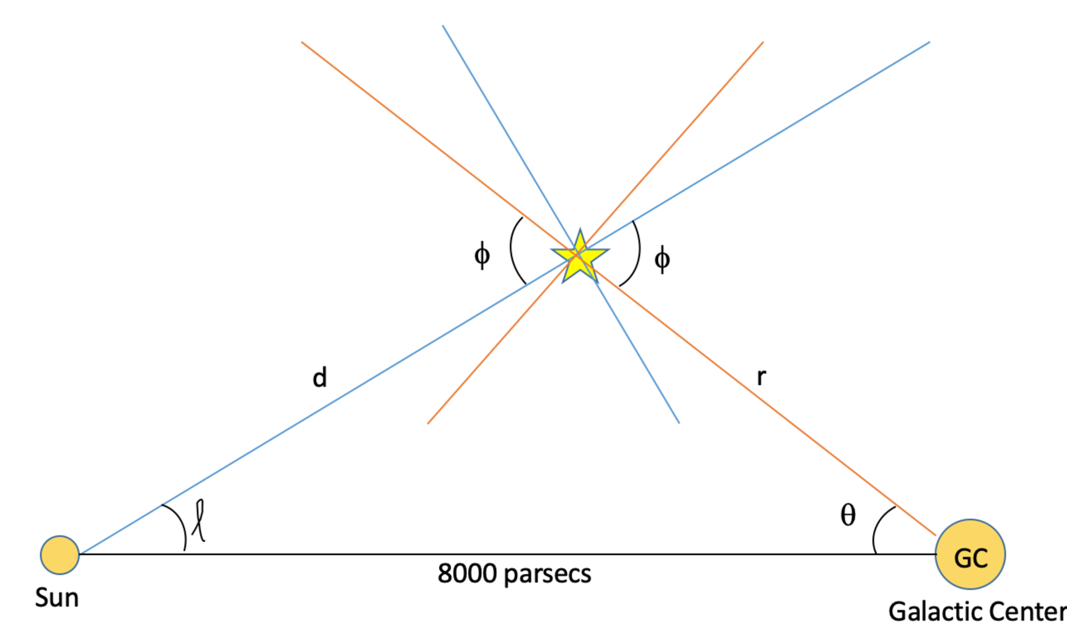
- Figure 1: Above is a schematic plot of the Milky Way assuming a uniform density of stars in the disk as well as a preliminary spiral arm configuration. The black wedges represent each direction we studied with Gaia with the indicated galactic longitude ℓ and galactic latitude 0° < b < 2°.



- Figure 2: The observed stellar number density as a function of distance from the Sun for each pointing. The density is generally higher for directions closest to the Galactic Center, while the lowest densities are observed toward the Anticenter. However, we note that the highest observed density corresponds to the direction 314° < ℓ < 316°, which probably corresponds to a spiral arm.

Procedure

- Using Python, we imported the Gaia data for six different pointings. Each pointing is limited by Galactic coordinates, ℓ and b. The Galactic latitude, b, is fixed between 0° and 2° for each pointing, and the Galactic longitude, ℓ, always has a range of 2°.
- We created four models, each with a population of 200 billion stars, by randomly distributing stars according to four different functional shapes: a uniform density model, an exponential model, a normal (Gaussian) model, and a linearly decreasing model.
- Using basic geometry, each star's position was transformed from the Galactocentric coordinate system to the Sun-centered Galactic coordinate system. From here, we can compare the models to the observed stellar density in the Milky Way.



$$d_{mod} = \sqrt{8000^2 + r_{mod}^2 - 2(8000)r\cos\theta}$$

$$l_{mod} = \cos^{-1}\left(\frac{d^2 + 8000^2 - r_{mod}^2}{2 * 8000 * d_{mod}}\right)$$

- To model the visibility of stars in each distribution, we assigned each star a random mass according to the Salpeter initial mass function:

$$\zeta(m) = \zeta_0 m^{-2.35}$$

- We assumed a very simple power law relation to assign a luminosity to each star according to the following relationship:

$$L \propto m^3$$

- Since the visibility of stars follows an inverse square law, we can set an arbitrary threshold for detection using :

$$visibility \propto \frac{L}{d^2}$$

Acknowledgements

This work has made use of data from the European Space Agency (ESA) mission Gaia (https://www.cosmos.esa.int/gaia), processed by the Gaia Data Processing and Analysis Consortium (DPAC, https://www.cosmos.esa.int/web/gaia/dpac/consortium). Funding for the DPAC has been provided by national institutions, in particular the institutions participating in the Gaia Multilateral Agreement.

Results

Figure 3: Comparing stellar density as a function of distance from the Galactic Center for all four models.

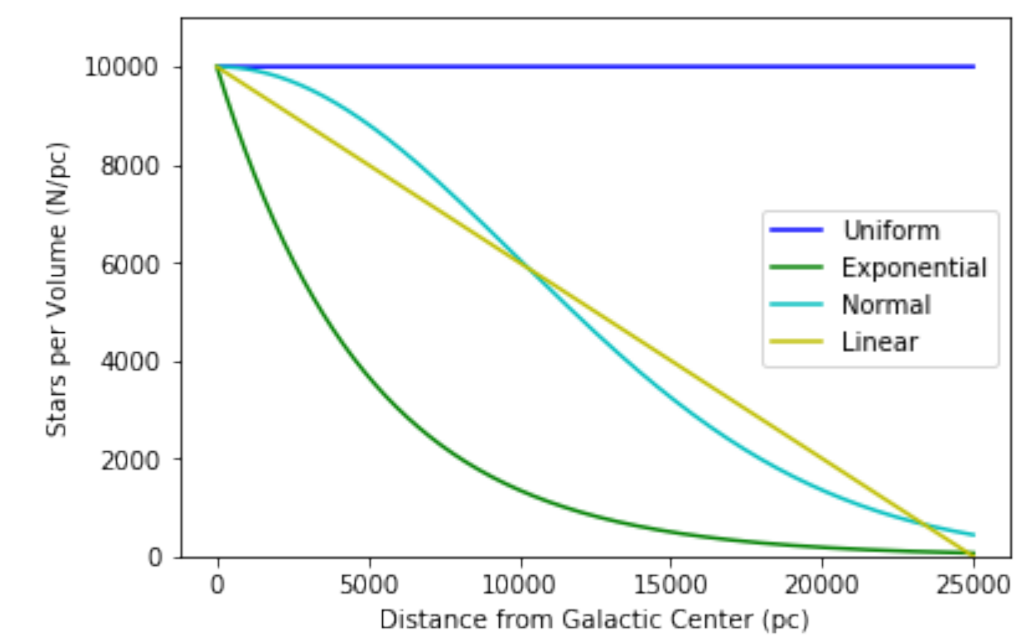


Figure 4: For each model, we plot the total number of stars as a function of distance from the Sun for ℓ = [0°, 2°].

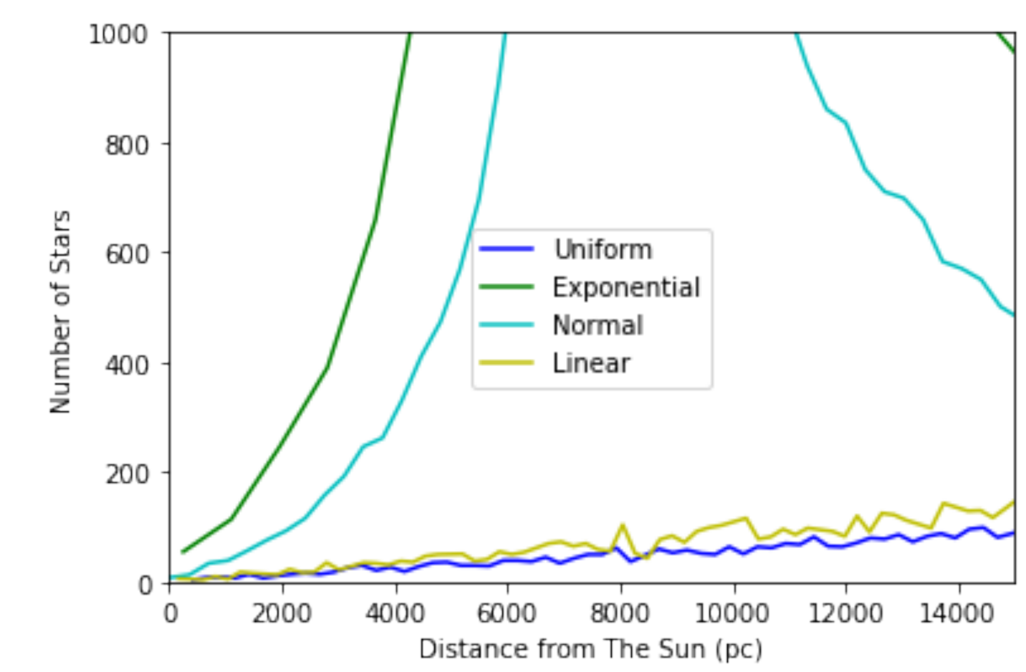
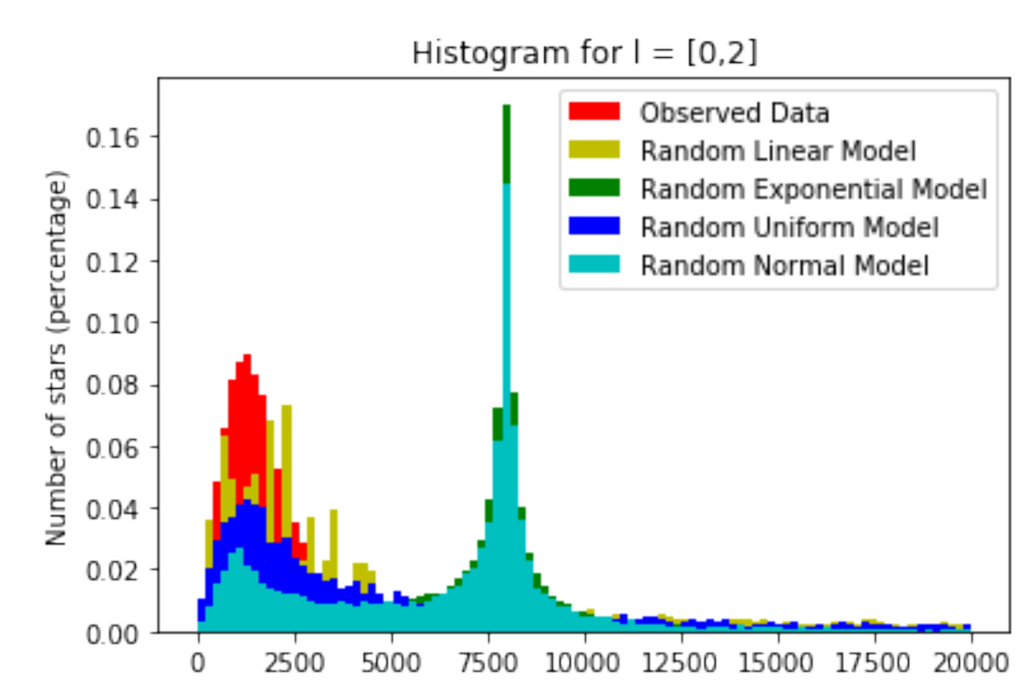


Figure 5: We compare the stellar density for each model, with an arbitrary detection threshold, to the observed data for ℓ = [0°, 2°].



Conclusion

We modeled the stellar density of the Milky Way using several very naïve and unphysical functions for simplicity. This allowed us to gain experience exploring Gaia data, Python programming techniques, and random number generation without being too concerned with a precise fit. Future work will consider more physical models of the stellar distribution as well as the spiral arms.