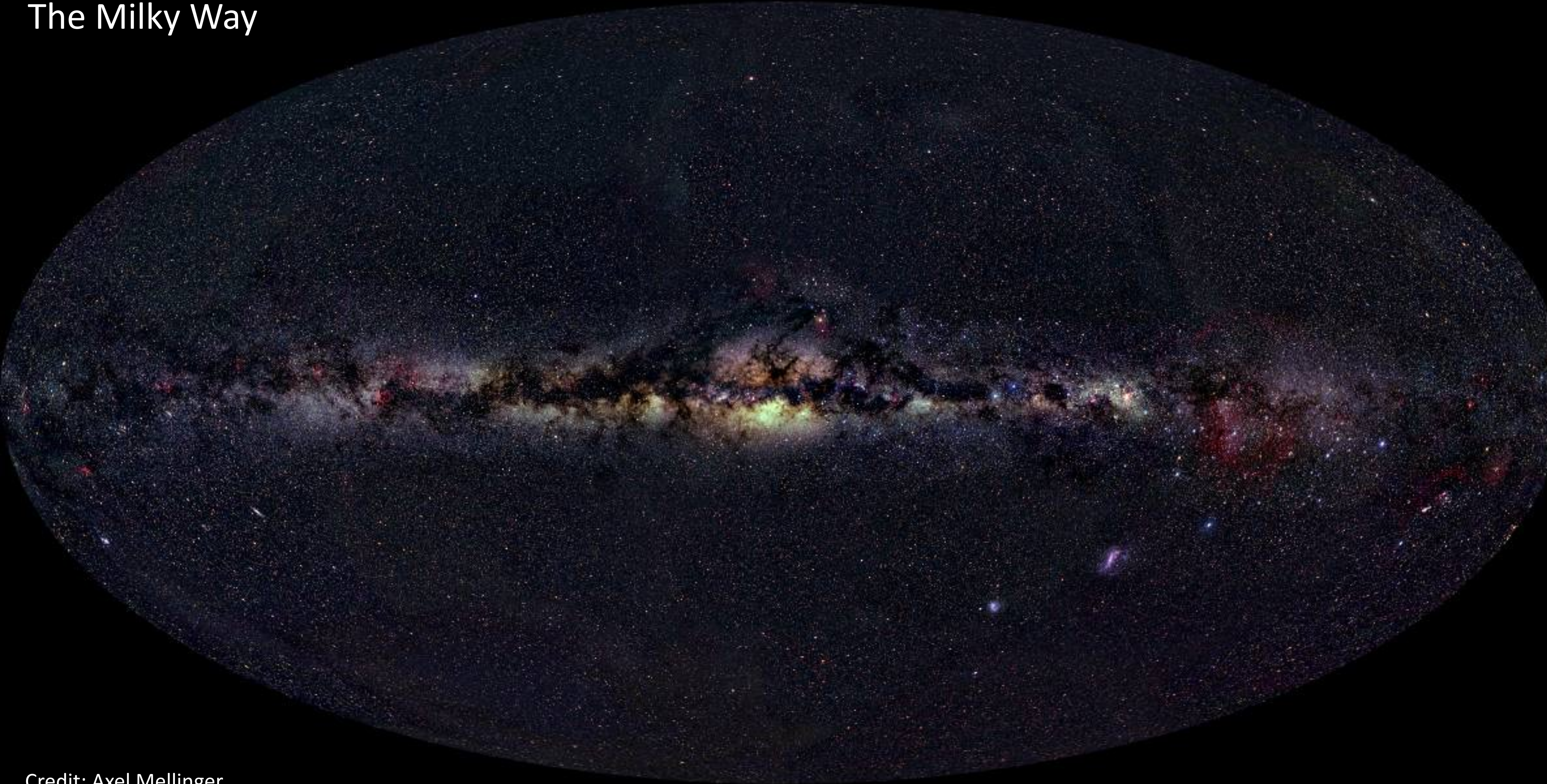
The Milky Way

Credit: NOIRlab

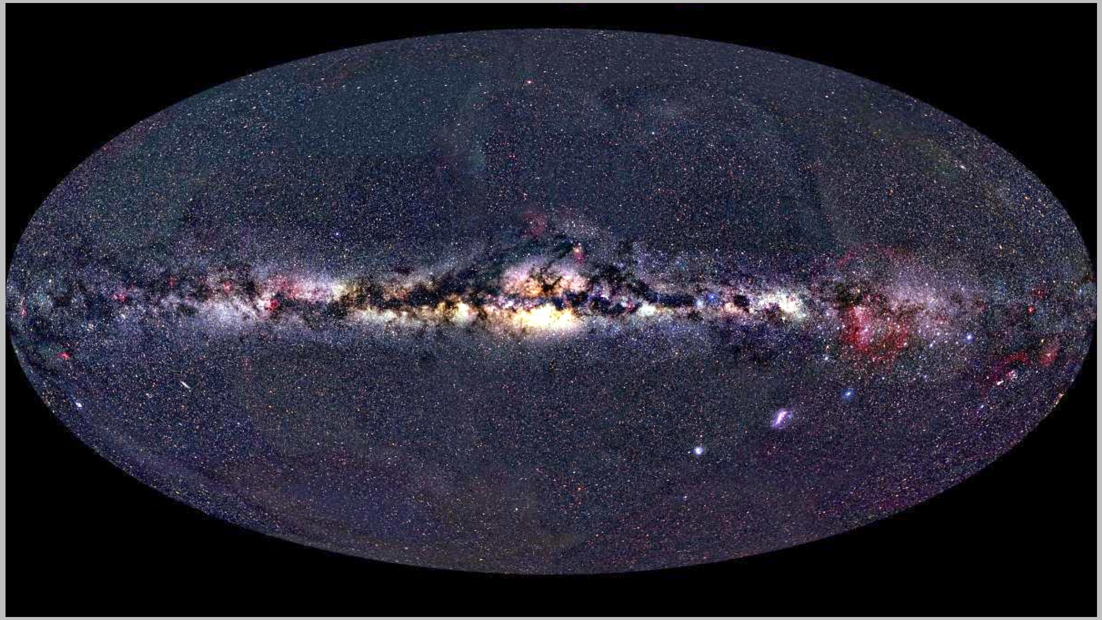
The Milky Way



Credit: Axel Mellinger
https://www.milkywaysky.com/

The Milky Way: Early studies

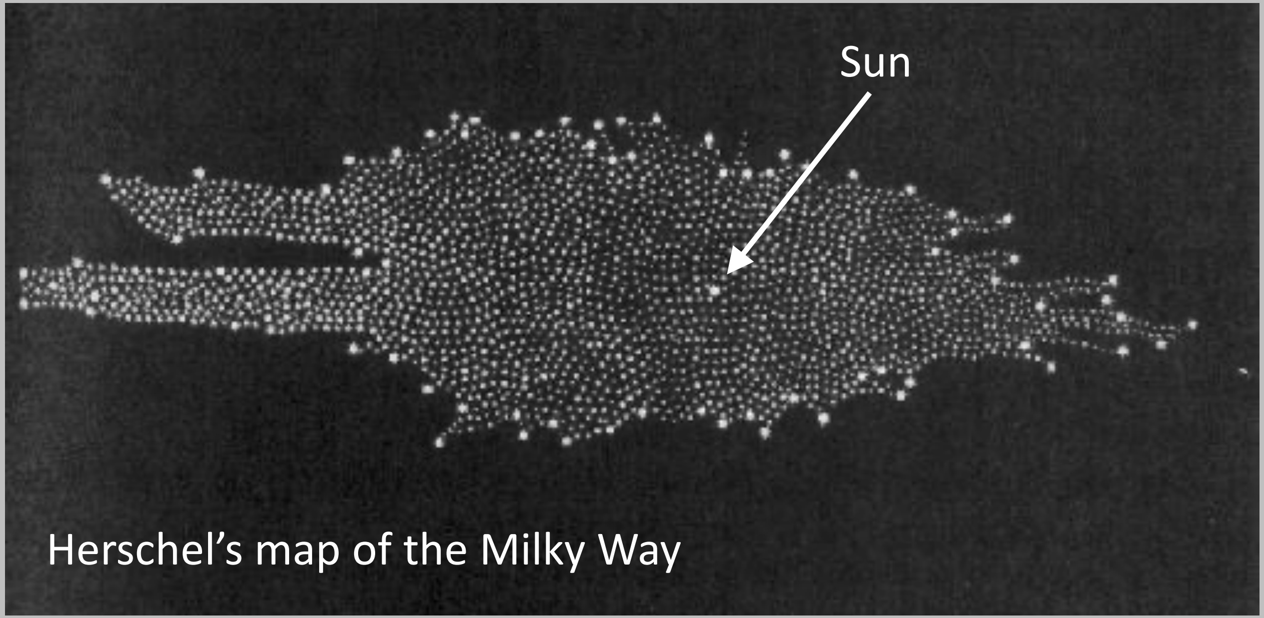
1755: Immanuel Kant proposes that the Galaxy is a disk of stars (including our Sun) and that there might be "island universes" of other galaxies like our own.



1785: Wiliam Herschel uses star count data to map the Milky Way. He assumes:

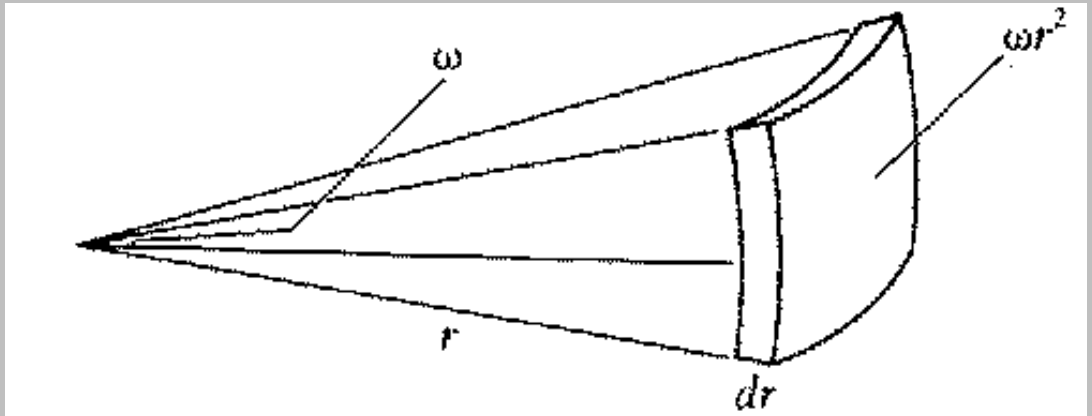
- all stars have the same brightness
- the galaxy has a uniform density
- we can see to the edge

Herschel's map of the Milky Way puts the Sun very near the center of the Galaxy.



Herschel's map of the Milky Way

Studying Star Counts in the Galaxy



If we choose stars which are all the same absolute magnitude, we can use their apparent magnitude as a substitute for distance. So let's look at **star counts as a function of apparent magnitude**.

Volume of a shell at distance r is given by $dV = \omega r^2 dr$

So the number of stars in the shell is given by $\rho\omega r^2 dr$

If the galaxy has a uniform density of stars (given by ρ), and we integrate over radius, we get the total number of stars **between us and r**:

$$N(r) = \rho\omega \int_0^r r^2 dr = \frac{1}{3}\omega\rho r^3$$

We can use the distance modulus equation to solve for r, given the apparent magnitude m:

$$m - M = 5\log r - 5 \;\dashrightarrow\; r = 10^{[0.2(m-M)+1]}$$

Plugging that into N(r), we get N(m) the number of stars **brighter than** some apparent magnitude m:

$$N(m) = 10^{(0.6m + C_1)} \quad \text{or} \quad \log N(m) = 0.6m + C_1$$

So for every magnitude fainter that we look, we ought to see $10^{0.6} \approx 4\times$ as many stars. ***That's not what we see!***

But it gets worse! Lets look at how much light we'd get from all those stars.....

If an $m = 0$ star has a brightness given by l_0, then a star of magnitude m has a brightness $l(m) = l_0 10^{-0.4m}$.

The total amount of light coming from stars of magnitude m is given by

$$dL(m) = l(m)\frac{dN(m)}{dm} = C_2 \times 10^{0.2m}$$

So the total amount of light coming from all stars brighter than an apparent magnitude m is given by:

$$L_{tot}(m) = \int_{-\infty}^{m} dL(m)dm = C_2 \int_{-\infty}^{m} 10^{0.2m} dm = C_3 10^{0.2m}$$

As we look fainter and fainter ($m \to \infty$), the amount of light diverges ($L_{tot} \to \infty$).

This result is known as **Olber's paradox: If the Galaxy was infinite in size and homogenous in density, the night sky should be infinitely bright!**

What's wrong with our assumptions?

Turn the problem around: use the observed N(m) to work out $\rho(r)$, and figure out the density structure of the Galaxy.