PHYC30019 Astrophysics

Project 1: Something

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March 20, 2016

1 Order-of-magnitude estimate 1

Are there more grains of sand on the beaches of Earth or more stars in the Milky Way?

1.1 Grains of sand

We begin by estimating the number of beaches on Earth.

$$\begin{aligned} \text{no. of continents} &= 7 \sim 10 \\ \text{no. of beaches/continent} &\sim 10,000 \\ &\Rightarrow 100,000 \text{ beaches on Earth} \end{aligned}$$

We then make an estimate of the average volume of a beach covered by sand.

$$\begin{aligned} \text{average length of beach} &= 1000\,\text{m} \\ \text{average width}^1 \text{ of beach} &= 10\,\text{m} \\ \text{average depth}^2 \text{ of beach} &= 2\,\text{m} \\ &\Rightarrow = 20.000\,\text{m}^3 \text{ of sand per beach} \end{aligned}$$

Next we estimate the number of grains of sand in a $1\,\text{cm}^3$ box to be ~ 1000.

$$\begin{aligned} &\Rightarrow 1000 \text{ grains of sand/cm}^3 \\ &\Rightarrow 10^3 \times 10^6 \text{ grains of sand/m}^3 \end{aligned}$$

We can now estimate the number of grains of sand on the beaches of Earth as

$$\begin{aligned} \text{number of grains of sand} &\sim 100,000 \text{ beaches} \times 20.000\,\text{m}^3/\text{beach} \times 10^9 \text{ grains/m}^3 \\ &\sim 2 \times 10^5 \times 10^5 \times 10^9 \text{ grains} \\ &\sim 2 \times 10^{19} \text{ grains} \end{aligned}$$

1.2 Stars

We begin by determining a rough measure of volume for the Milky Way.

$$\begin{aligned} \text{diameter of Milky Way} &\sim 100.000\,\text{ly} \\ \text{thickness of Milky Way} &\sim 2.000\,\text{ly} \\ \Rightarrow \text{volume} &= \pi \left(\frac{100.000\,\text{ly}}{2} \right)^2 \times 2.000\,\text{ly} \\ &\sim \frac{6}{4} \times 10^3 \left(10^5\right)^2 (\text{ly})^3 \\ &\sim 1.5 \times 10^{13} \, (\text{ly})^3 \end{aligned}$$

We then estimate the average distance between stars. To do this, we take the distance from the Sun to its nearest neighbour as $\sim 4\,\text{ly}$. Using this distance we then suppose that each star exists within a "starbox" of dimensions $2 \times 2 \times 2\,(\text{ly})^3$.

$$\text{Volume per star} \sim 8\,(\text{ly})^3/\text{star}$$

Now we can estimate the number of stars as:

$$\begin{aligned}\text{Number of stars in the Milky Way} &= \frac{\text{volume of Milky Way}}{\text{volume/star}} \\ &\sim \frac{1.5 \times 10^{13}}{8} \\ &\sim \frac{10^{13}}{10} \\ &= 10^{12}\,\text{stars}\end{aligned}$$

1.3 Conclusion

From the above, we claim that

$$\begin{aligned}\text{Number of grains of sand on the beaches of Earth} &\sim 10^{19} \\ \text{Number of stars in the Milky Way} &\sim 10^{12}\end{aligned}$$

From the rough order-of-magnitude calculations performed, we deduce *there are more grains of sand on the beachs of Earth than there are stars in the Milky Way.* Even though we have made many assumptions as well as liberal rounding of numbers, it is unlikely that these values are more than an order of magnitude greater or smaller than quoted.

It is validating to note that the common answer for number of stars in the Milky Way[3] is quoted as $\sim 10^{11}$.

2 Research task 1

3 Calculation 1

4 Calculation 2

5 Calculation 3

[3] See http://asd.gsfc.nasa.gov/blueshift/index.php/2015/07/22/how-many-stars-in-the-milky-way/