# Order-of-Magnitude Estimation
# Black holes (Level 3)

## The Question

How many black holes are in the Milky Way Galaxy?

## Background

Stars are constantly being born and dying in our Galaxy. The star formation rate of the Milky Way is about 3 solar masses per year (the Suns worth of gas collapses into stars each ear, on average). This is distributed amongst stars according to something called the initial mass function (see next page). When a massive star (about 10 times the mass of the Sun) runs out of fuel, it collapses on itself and explodes in a brilliant supernova. All that remains is its dense core, as either a neutron star or a black hole. These last effectively forever, and so they build up over the lifetime of the Galaxy.

## Guiding Questions

Here are some things you may need to consider:

- How many stars are there in the Galaxy?

- How many are massive enough to leave behind a black hole?

- How old is the Galaxy?

## The Solution

Three solar masses worth of stars is converted into stars each year. According to the stellar initial mass function, you can think of this as 3 Sun-like stars forming each year, or $3 \times 0.01$ 10 solar mass stars forming each year. If we further assume the Galaxy is in a steady state, this means that this many 10 solar mass stars die each year. Finally, estimating that the Milky way is about 10 billion years old (of the same order of magnitude as the Universe, which is ∼14 billion years old, we find that the number of stars that have collapsed into black holes over the age of the galaxy is:

$$N_{\mathrm{bh}} = 3 \times 0.01 \times 1 \times 10^{10} = 3 \times 10^8 \tag{1}$$

This means that there are about 300 million black holes in the Milky Way (plus one supermassive one...).
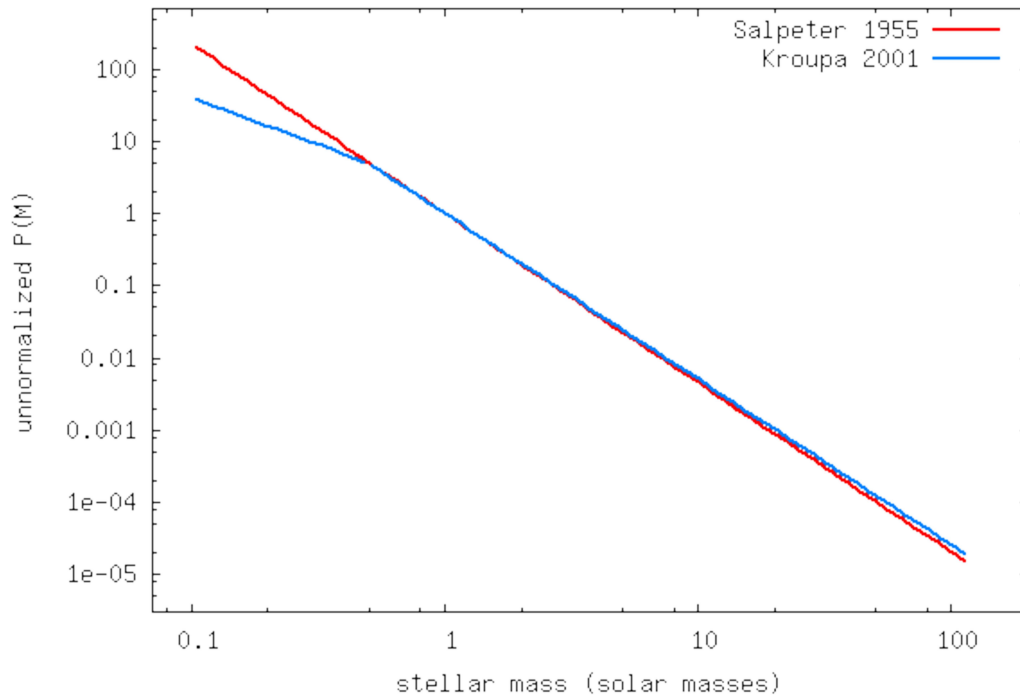
# Education Standards

This OoM Estimation problems meets the following standards in **bold**:
***Next Generation Science Standards (NGSS):***

- Physical Sciences

    - Matter & Its Interactions
    - Motion and Stability: Forces and Interactions
    - Energy
    - Waves and Their Applications in Technologies for Information Transfer

- Life Sciences

    - From Molecules to Organisms: Structures and Processes
    - Ecosystems: Interactions, Energy, and Dynamics
    - Heredity: Inheritance and Variation of Traits
    - Biological Evolution: Unity and Diversity

- Earth and Space Sciences

    - Earth's Place in the Universe
    - Earth's Systems
    - Earth and Human Activity

- Engineering, Technology, and Applications of Science

    - Engineering Design

***Common Core Standards (CSS):***

- **Counting & Cardinality**

- **Operations & Algebraic Thinking**

- **Numbers & Operations in Base Ten**

- **Number & Operations — Fractions**

- **Measurement & Data**

- Geometry

- Ratios & Proportional Relationships

- The Number System

- Expressions & Equations

- Functions

- **Statistics & Probability**