**WORKSHEET**

**DARK MATTER & DARK ENERGY (Part 1)**

**MATERIAL**

Part 1: stretchy sheet, washbowl, heavy marble, light marble, elastic string.

Part 2: Set A and B

Part 3: Intact balloon, punctured balloon,

**ACTIVITY**

**Part 1: What is gravity?**

1. Cover a stretchy sheet on a large round bowl. Surface of the sheet is like a small portion of space in 2 dimensions (space surrounds us everywhere in all directions).

2. Place a heavy marble on the sheet. Observe there is a curvature due to the mass of the marble. Then roll a lighter marble on the sheet so that the light marble moves toward the heavier one and circles around it.

→ Any object has mass can distort space like the marble does to the stretchy sheet, causing objects to be attracted to each other. This effect is called **gravity, which is the bending of space.**

**Part 2: The discovery of dark matter (15 min)**

*1.* Like the marbles, stars and planets bend space, creating gravity, which causes them to orbit each other and organize into galaxies and galaxy clusters.

So gravity of a cluster reflects the mass of everything in the cluster, all the stars, planets, galaxies and other things (because more mass, more curve, more gravity).

→ Based on this knowledge, you will solve the mystery of whether an invisible matter exists in space.

2. You are acting as astronomers who study the mass and gravity of a galaxy cluster. The curve of the sheet represents gravity of the galaxy cluster.

Washbowl set A represents what the gravity of the galaxy cluster should be like in theory. And set B is actual observation. You need to find out if sets A and B are just the same galaxy cluster (consisting of same galaxies) and why there is a difference.

3. Record your observation for the 2 setups in the following table.

*Note: Do not remove sheet from washbowl. And once you finish with a set, put everything (all marbles) back to how it was in the beginning so that other groups can work with the set.*

|  |  |  |  |
| --- | --- | --- | --- |
| **Set** | **Gravity**  **(Compare set A and B)** | **What should you measure to explain the difference in gravity between set A and B?**  **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_** | **Extra note (Strange observation)** |
| A |  |  |  |
| B |  |  |  |

4. Are set A and B representing the same ‘galaxy cluster’, consisting of the same ‘galaxies’ (marbles)?

5. What should the gravity (i.e. sheet curvature) created by ‘galaxy cluster’ in set B be like?

6. Why is there a difference in gravity between them?

**Part 3: Dark energy**

1. Dark energy is discovered from an unexpected observation, different from the facts that we already know.

*Fact 1: The Universe continually expands since its formation. It’s like an expanding balloon.*

2. Slightly inflate a balloon with some dots drawn on it. This is our Universe at birth, everything is compact (the dots are close together). Continue to blow the balloon and the dots on the balloon move far away from each other. This is like our Universe, it has been expanding and the dots are like the galaxies moving apart in our expanding Universe.

3. *Fact 2: Gravity of dark matter and normal matter holds everything in Universe together.*

Despite this effect of gravity, Universe has been expanding and galaxies fly away from each other. This is like blowing a balloon with a puncture. Blow intact and punctured balloons to see that the punctured balloons cannot expand as easily. So similar to the balloon observation, scientists expected that Universe should eventually be slowed down by gravity.

4. In fact Universe expansion has become faster (Universe acceleration). Use the balloon to represent this Universe acceleration with the balloon.

5. As scientists observed faster Universe expansion, this must be the effect of something else that exists in more quantity and opposes the gravity caused by the normal matter and dark matter. They called it dark energy. (Don’t be confused by the name, it’s not related to dark matter at all).