VERA COOPER RUBIN

Vera Cooper Rubin was an American **astronomer**, a pioneer in measuring the rotation of stars within a galaxy. Her measurements revealed that the stars at the edges were moving as fast as those in the center, violating Newton's laws of motion (which also regulate how planets revolve around the Sun). These measurements are the most direct and robust evidence for the existence of **dark matter**. She was the **only woman** to graduate from Vassar College in astronomy in 1948 and was **unable to study for her doctorate** in astronomy at Princeton because the institution **did not admit women** at the time. She obtained her PhD from Georgetown University, becoming a fighter for the presence of women in science.

"Science progresses better when our observations force us to change our preconceptions"

Dark Matter

Almost four decades after Rubin's observations, we now know that **dark matter makes up about 84% of the matter content** of our Universe, although we do not know what it is made of. In 2013, the Planck Satellite measured the Universe's dark matter content through observing the microwave background radiation – the radiation left by the Big Bang and that permeates the entire Universe. The result showed that dark matter first clumped together, attracting ordinary matter and forming galaxy clusters. "**This is fundamental to our current understanding of astrophysics**," says Emily Levesque, an astronomer at the University of Washington. **Rubin passed away on December 25, 2016**, 88 years old, **without the Nobel Prize that her peers and colleagues believe she rightfully deserved.**

More information

NASA: Dark matter, Dark energy

Meet Vera Rubin What is Dark matter? Vera Rubin and Dark Matter

Experiment: In Search of Dark Matter

Here we list two experiments to illustrate how we realized that dark matter exists in the Universe.

a) Paper Plates

What you need

Paper plates A pen or pencil 8 small weights Transparent tape A ruler

Procedure

Find the center of one of the plates and make a very small hole there. Draw a diameter line across the plate. On each side of the center, place three weights on the line. Use your ruler to make sure they are evenly spaced, and tape them to the plate. Now decide where to place the seventh weight (note: try placing it relatively far from the center). Glue a second plate on top of the first, sandwiching the weights between the plates.

Take a third plate and make a hole in the center like you did to the first plate. Insert the pencil tip into the hole and spin the plate – now describe the motion. This case represents a galaxy with only regular matter. Place the final mass somewhere towards the border of the plate, tape it down, and spin it again. This plate represents what Rubin saw – how does this behavior differ from before? Finally, spin the plate with the other masses and describe it – this represents the rotation of the galaxy with both dark matter and regular matter.

a) Water Bottles

What you need

2 bottles of water or transparent jars with tape Loose change Washers or nuts and bolts Water

Procedure

Fill both bottles decently full with the loose materials. Fill only one bottle with water, leaving no room for air when capped. How do you know for sure that there is water inside one of the bottles, even if it is "invisible" (in this case, transparent)? One possible explanation would be one of the bottles is heavier than the other, despite having no extra "visible mass." That is how we represent dark matter. Also, if we turn the bottles upside down the material will move differently in each bottle, and the bottle with water (the "dark matter" analog) bends the light differently, distorting the objects inside and behind – similar to a gravitational lens.

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