

THE EQUIVALENCE PRINCIPLE UNDER A MICROSCOPE

FOR TWO AND A HALF YEARS, A SMALL FRENCH SATELLITE NAMED **MICROSCOPE*** FLEW OVER THE NORTH POLE EVERY 99 MINUTES.

ITS JOB: TO TEST THE WEAK EQUIVALENCE PRINCIPLE (WEP), ONE OF THE FOUNDATIONS OF EINSTEIN'S THEORY OF GRAVITY.

**MICRO-SATELLITE À TRAÎNÉE COMPENSÉE POUR L'OBSERVATION DU PRINCIPE D'EQUIVALENCE*

PHYSICS HAS TWO KINDS OF MASS:

INERTIAL MASS, THE MEASURE OF AN OBJECT'S RESISTANCE TO BEING MOVED...



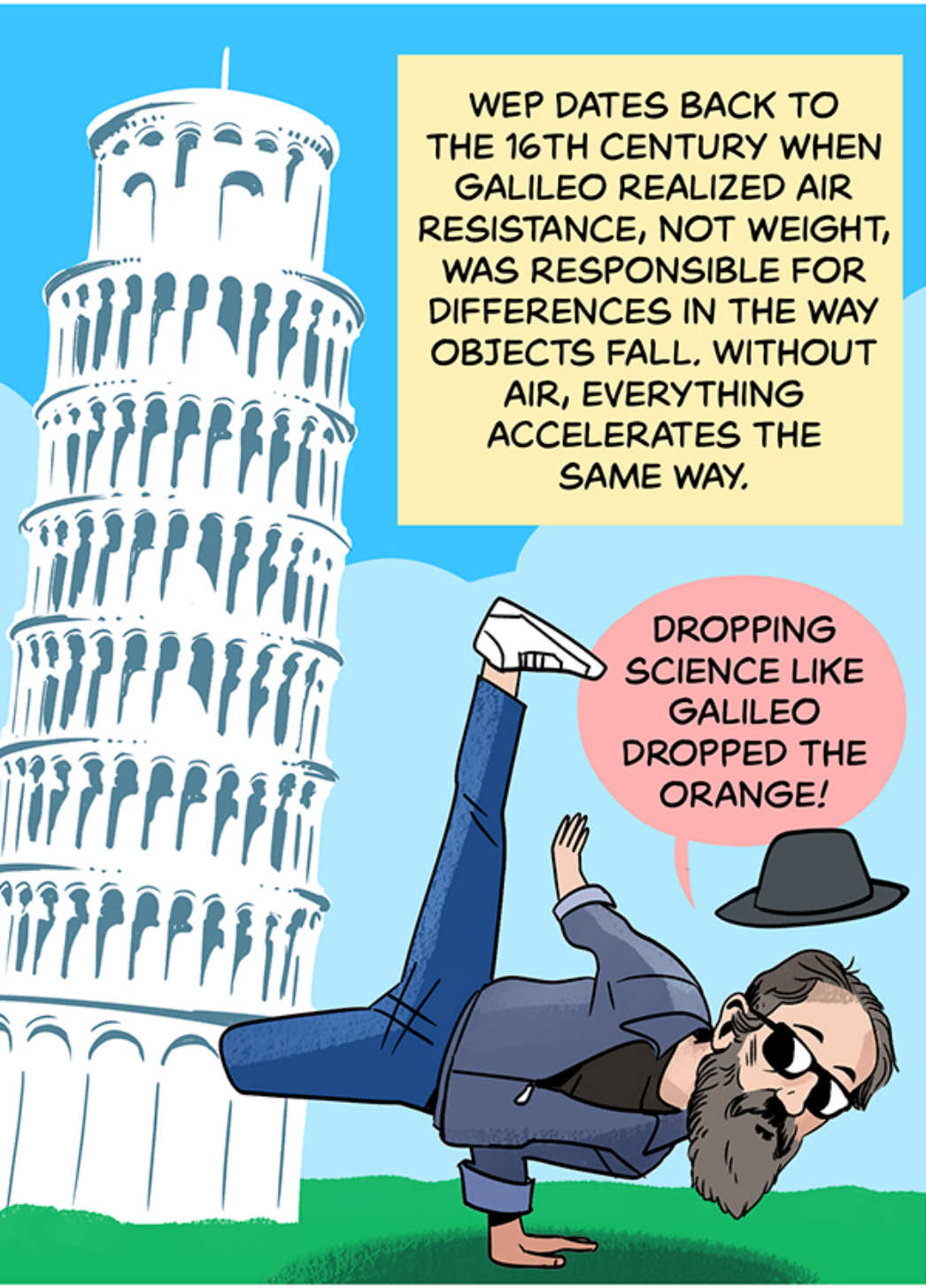
MOVING AN ASTRONAUT IN DEEP SPACE DEPENDS ONLY ON INERTIA.

...AND GRAVITATIONAL MASS, WHICH DETERMINES HOW MUCH GRAVITY A BODY FEELS.



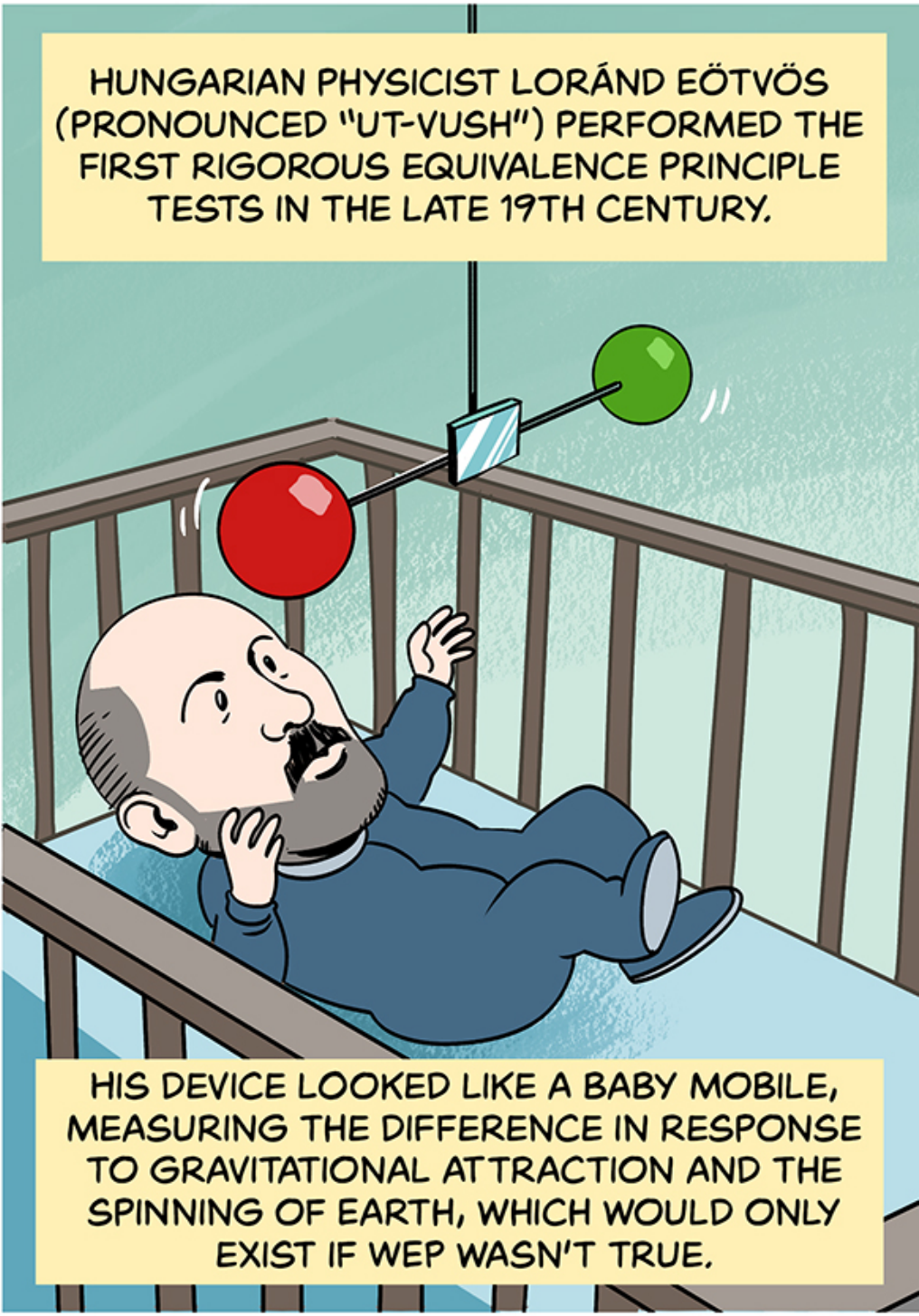
GRAVITY PULLS BOTH THE AIRPLANE AND THE PERSON DOWN.

WEP SAYS THESE TWO TYPES OF MASS ARE EQUIVALENT--A RADICAL IDEA, SINCE IT IMPLIES A SPECIAL RELATION BETWEEN GRAVITY AND MASS THAT OTHER FORCES DON'T HAVE.



WEP DATES BACK TO THE 16TH CENTURY WHEN GALILEO REALIZED AIR RESISTANCE, NOT WEIGHT, WAS RESPONSIBLE FOR DIFFERENCES IN THE WAY OBJECTS FALL. WITHOUT AIR, EVERYTHING ACCELERATES THE SAME WAY.

DROPPING SCIENCE LIKE GALILEO DROPPED THE ORANGE!



HUNGARIAN PHYSICIST LORÁND EÖTVÖS (PRONOUNCED "UT-VUSH") PERFORMED THE FIRST RIGOROUS EQUIVALENCE PRINCIPLE TESTS IN THE LATE 19TH CENTURY.

HIS DEVICE LOOKED LIKE A BABY MOBILE, MEASURING THE DIFFERENCE IN RESPONSE TO GRAVITATIONAL ATTRACTION AND THE SPINNING OF EARTH, WHICH WOULD ONLY EXIST IF WEP WASN'T TRUE.

ALBERT EINSTEIN BUILT HIS THEORY OF GENERAL RELATIVITY ON WEP IN 1915, IMAGINING A SCENARIO FROM THE DAYS BEFORE SKYDIVING:

BECAUSE FOR AN OBSERVER IN FREE FALL FROM THE ROOF OF A HOUSE, THERE IS--

--AT LEAST IN HIS IMMEDIATE VICINITY--

--NO GRAVITATIONAL FIELD.

ANY EXPERIMENT PERFORMED DURING FREE FALL WILL BEHAVE LIKE IT WOULD IN A SITUATION WITH NO GRAVITATIONAL FORCES ACTING ON IT AT ALL!

BUT IS WEP TRUE?

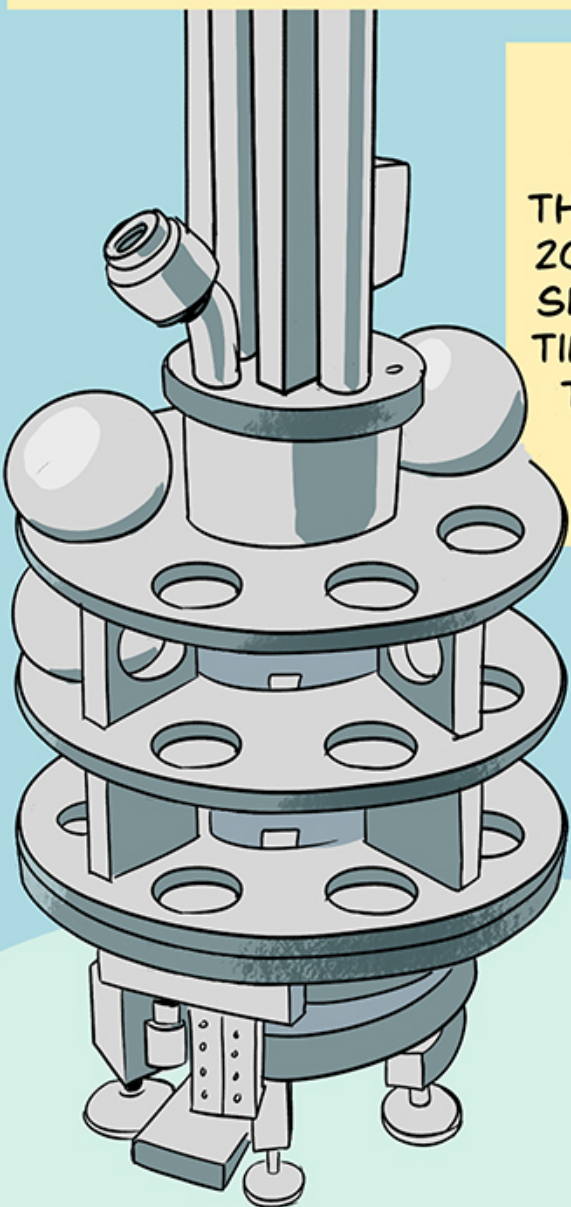
MOST OF THE ATTEMPTS TO GO BEYOND GENERAL RELATIVITY SUGGEST NEW INTERACTIONS [THAT] GIVE RISE TO APPARENT VIOLATIONS OF THE WEP.

MANUEL RODRIGUES
SCIENCE CO-INVESTIGATOR
OF MICROSCOPE



THE EÖT-WASH (PRONOUNCED "UT-WASH") EXPERIMENT AT THE UNIVERSITY OF WASHINGTON WAS A SOPHISTICATED UPDATE OF THE MOBILE-TYPE TEST.

IT RAN FROM THE LATE 1990s THROUGH THE EARLY 2000s, REACHING A SENSITIVITY 10,000 TIMES BETTER THAN THAT OF EÖTVÖS' ORIGINAL.



BUT TESTING WEP ON EARTH IS HINDERED BY THINGS LIKE GROUND VIBRATIONS AND TEMPERATURE VARIATIONS. ACHIEVING HIGHER SENSITIVITY REQUIRES...



GOING TO SPACE!

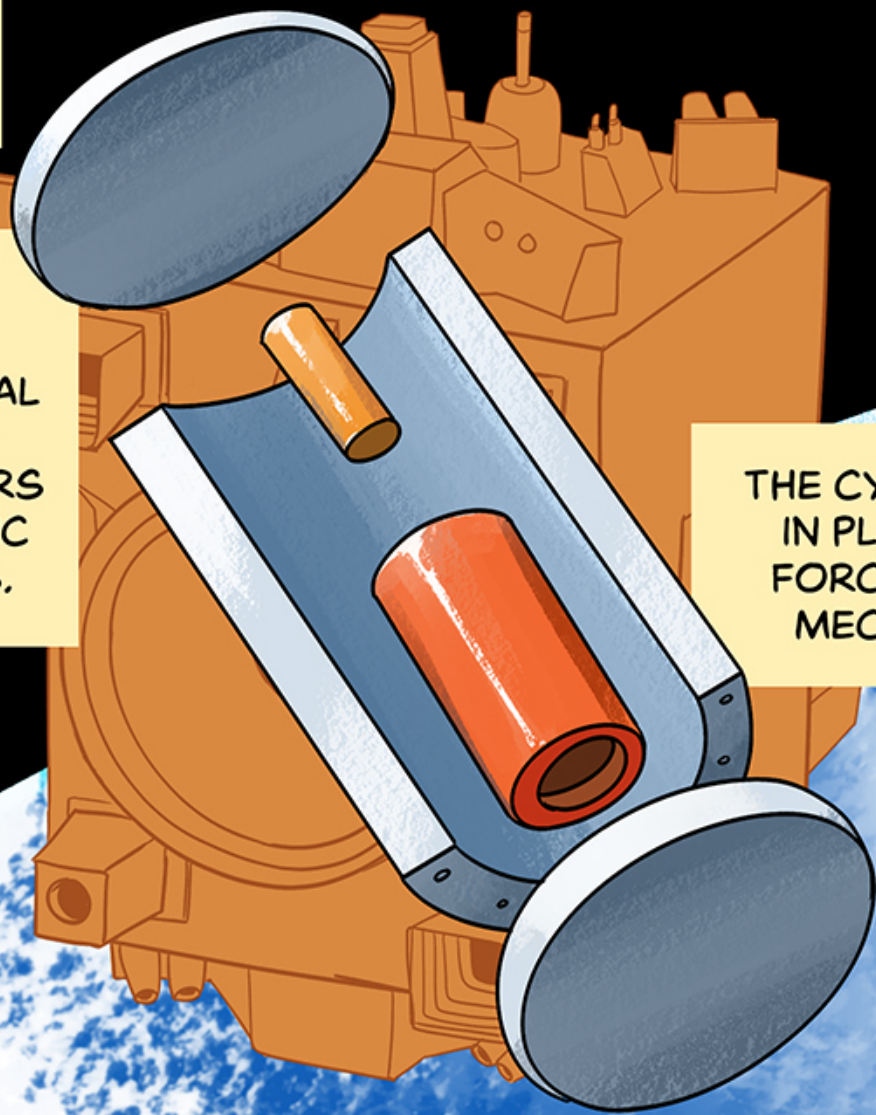
THE MICROSCOPE SPACECRAFT CARRIES FOUR HOLLOW CYLINDERS, NESTED IN PAIRS.

ONE PAIR IS MADE OF DIFFERENT MATERIALS TO TEST WEP...

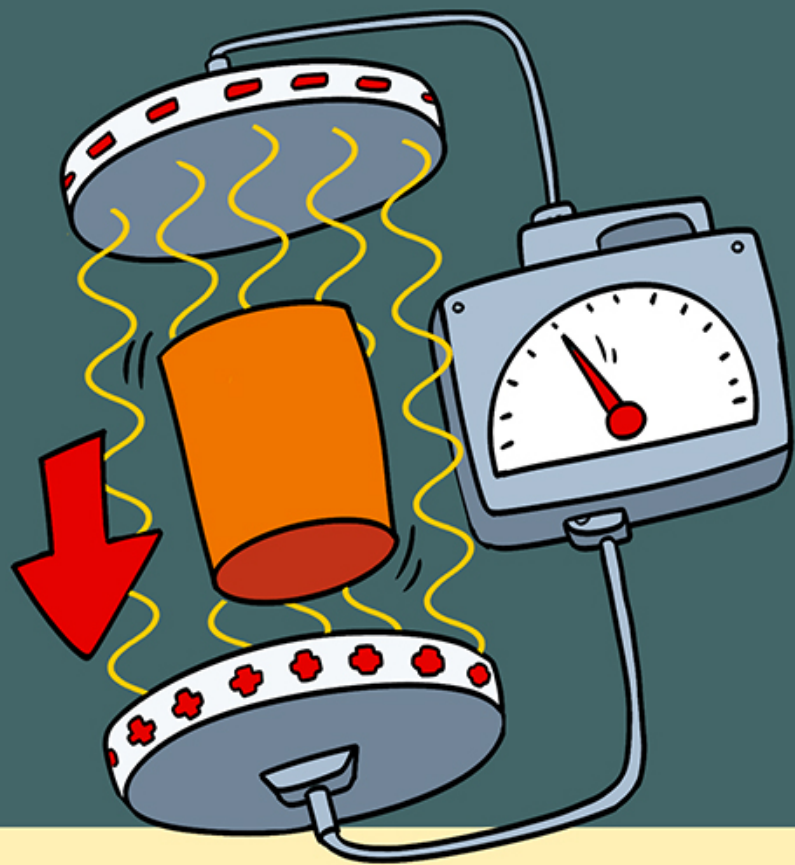
...WHILE THE OTHER PAIR IS MADE OF IDENTICAL MATERIALS TO ELIMINATE FACTORS THAT MIGHT MIMIC WEP VIOLATIONS.

THE CYLINDERS FLOAT, HELD IN PLACE BY ELECTRICAL FORCES TO REMOVE ANY MECHANICAL CONTACT.

AS MICROSCOPE ORBITS EARTH, ITS SENSORS MEASURE THE FORCES REQUIRED TO KEEP THE CYLINDERS CENTERED INSIDE THE SPACECRAFT.



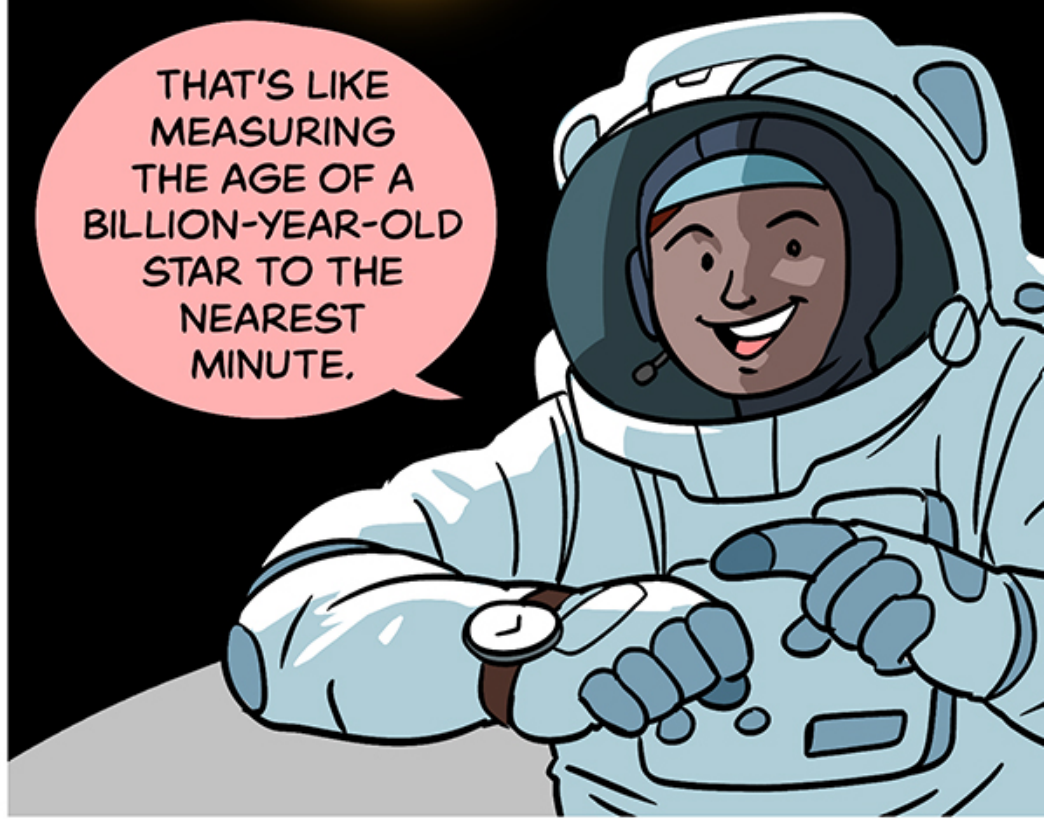
IF THE FORCES BETWEEN THE TWO SETS OF CONCENTRIC CYLINDERS ARE THE SAME, THEN WEP HOLDS TRUE.



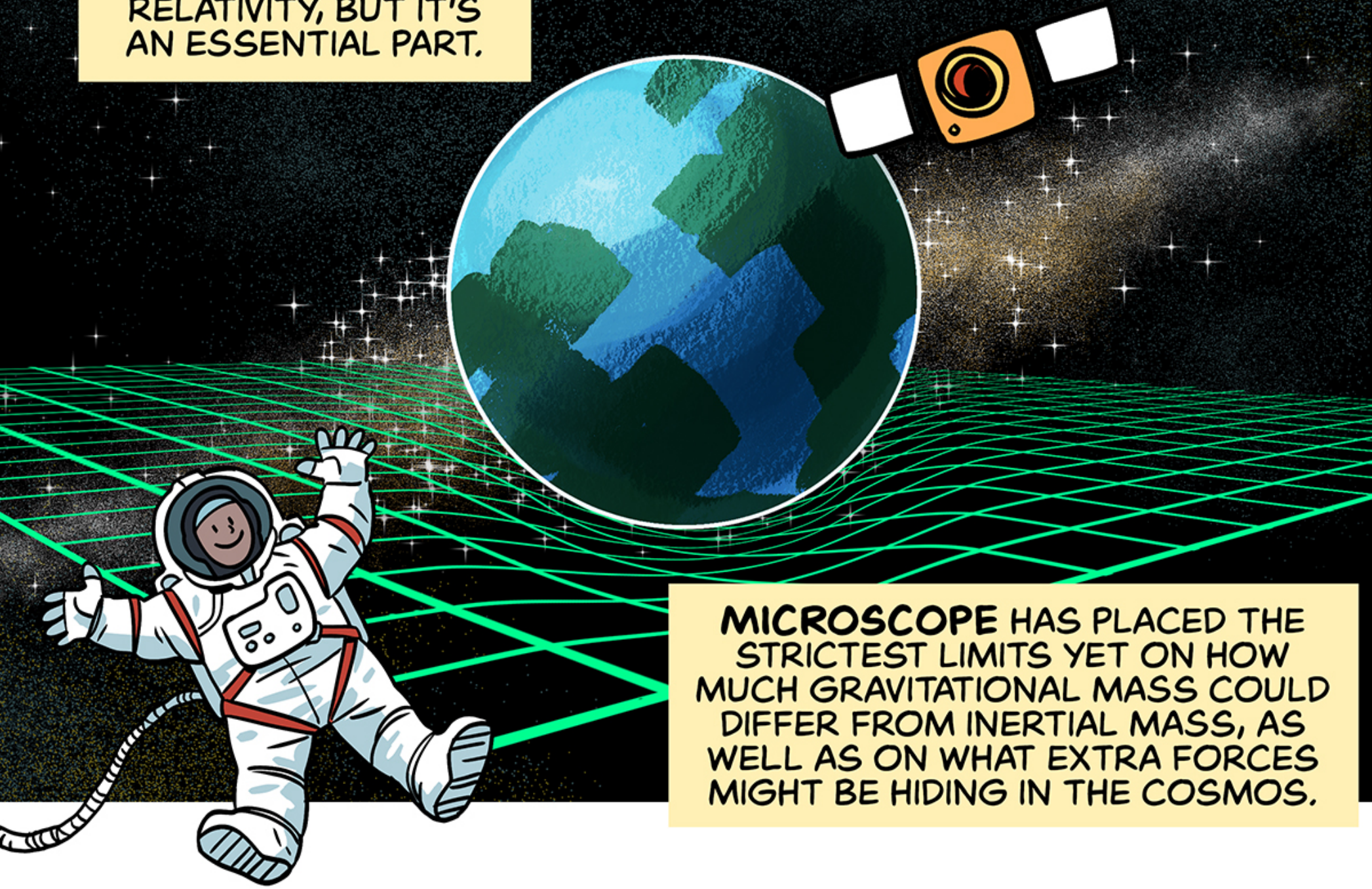
IF THE FORCES ARE DIFFERENT, THEN EITHER WEP IS ONLY APPROXIMATELY TRUE OR A NEW TYPE OF FORCE IS ACTING ON THEM, POSSIBLY BECAUSE OF THE DIFFERENT NUCLEAR COMPOSITION OF THE CYLINDERS.

HOWEVER, THE **MICROSCOPE** EXPERIMENT--WHICH JUST RELEASED ITS FINAL RESULTS--CONFIRMED WEP TO APPROXIMATELY ONE PART IN 10^{15} .

THAT'S LIKE MEASURING THE AGE OF A BILLION-YEAR-OLD STAR TO THE NEAREST MINUTE.



WEP IS ONLY ONE PART OF GENERAL RELATIVITY, BUT IT'S AN ESSENTIAL PART.



MICROSCOPE HAS PLACED THE STRICTEST LIMITS YET ON HOW MUCH GRAVITATIONAL MASS COULD DIFFER FROM INERTIAL MASS, AS WELL AS ON WHAT EXTRA FORCES MIGHT BE HIDING IN THE COSMOS.

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