

SPECIAL FEATURE

PDF Version   

The Muon $g-2$ Anomaly Explained

April 7, 2021 • *Physics* 14, 47

Jorge Cham, aka, PHD Comics, illustrates the excitement over the muon anomaly results in a set of cartoons he made for *Physics*.

THE MUON $g-2$ ANOMALY EXPLAINED

THE MUON IS THE ELECTRON'S HEAVIER COUSIN. JUST LIKE THE ELECTRON, IT HAS A MAGNETIC MOMENT THAT COMES FROM ITS CHARGE AND QUANTUM SPIN.

'Sup, cuz!

LIKE ALL CHARGED PARTICLES, IT TENDS TO INTERACT WITH ITSELF IN A MAGNETIC FIELD, AND IN THE PROCESS IT CREATES OTHER PARTICLES THAT EXIST FOR A BRIEF MOMENT IN TIME. IT DOES THIS IN A QUANTUM MECHANICAL WAY, WHICH MEANS IT CREATES MANY COMBINATIONS OF PARTICLES ALL THE TIME, AND ALL AT THE SAME TIME.

Whoa.

THAT MEANS THAT WHEN YOU LOOK AT A MUON, YOU DON'T JUST SEE THE MUON; YOU ALSO SEE THE INFINITE NUMBER OF VIRTUAL PARTICLES IT IS CONSTANTLY CREATING. EACH OF THESE PARTICLES AFFECTS THE MUON'S MAGNETIC MOMENT IN A MEASURABLE WAY, CHANGING ITS VALUE.

I don't know who you are any more.

$g = 2$ $g \neq 2$

BY USING OUR CATALOG OF KNOWN PARTICLES, WE CAN PREDICT WHAT THIS CHANGE SHOULD BE... ...AND COMPARE IT TO EXPERIMENTAL MEASUREMENTS OF IT.

$g = 2.000001!$ $g = 2.000002!$

BUT WHAT IF THOSE TWO NUMBERS ARE NOT THE SAME? COULD WE BE WRONG ABOUT WHICH PARTICLES THE MUON CAN CREATE? OR IS OUR WHOLE FORMULATION OF PHYSICS INCORRECT? You're wrong! No, you're wrong!

THAT IS THE MYSTERY OF THE MUON'S MAGNETIC MOMENT. 20 YEARS AGO, BROOKHAVEN NATIONAL LAB MEASURED IT, AND FOUND IT TO BE DIFFERENT THAN THE THEORETICAL VALUE BY 2.7σ .

$g_{\text{Brookhaven}} = 2.00233184178 \pm 0.00000000126$

IT IS ONE OF THE MOST PRECISELY TESTED PHYSICAL QUANTITIES IN HUMAN HISTORY.

SINCE THEN, THE THEORETICAL VALUE HAS GOTTEN MORE PRECISE, AND NOW FERMI NATIONAL LAB HAS MADE AN EVEN MORE ACCURATE MEASUREMENT OF IT:

MUONS SPIN AROUND INSIDE A STORAGE RING. DETECTORS CATCH THE MUONS AS THEY DECAY INTO ELECTRONS. THE ENERGY OF THE ELECTRONS DEPENDS ON THE DIRECTION OF THE MUON'S MAGNETIC MOMENT.

WHEN THE MOMENT IS POINTING FORWARDS, THE DECAYING ELECTRONS HAVE MORE ENERGY... ..AND WHEN IT'S POINTING BACKWARDS, THEY HAVE LESS ENERGY.

THE FLUCTUATIONS IN THE ENERGY OF THE ELECTRONS COMING OFF THE RING TELL YOU THE VALUE OF THE MUON'S MAGNETIC MOMENT.

FERMILAB SHIPPED THE GIANT MAGNET FROM BROOKHAVEN, NEW YORK TO CHICAGO, UPGRADED THE EXPERIMENT SIGNIFICANTLY, AND REPEATED IT WITH MORE MUONS. WITH THIS NEW MEASUREMENT, THE DIFFERENCE IN g IS NOW 4.2σ , PROVIDING STRONGER EVIDENCE THAT SOMETHING IS AMISS. Maybe we're both right...

COULD IT BE THAT THE MUON IS CREATING PARTICLES WE DON'T KNOW ANYTHING ABOUT, BUT WHICH MIGHT SOLVE OTHER MYSTERIES IN PHYSICS? DARK MATTER? NEW FORCES?

IT'S ALL PART OF OUR SEARCH TO DISCOVER HOW THE UNIVERSE WORKS. WE ALL LOOK AROUND AND WONDER: HOW CAN THIS ALL BE? WHY DO WE EXIST?

ONE THING IS FOR SURE: THE HUNT IS ON, AND NEW DISCOVERIES ARE ON THE HORIZON.

APS physics
Written and drawn by Jorge Cham for Physics Magazine physics.aps.org Thanks to Chris Polly and Fermilab.

Recent Articles

A Lightweight Among Heavyweights

Researchers have observed the lightest uranium isotope to date, offering insight into models of nuclear structure. [Read More »](#)

Laser-Cooled Atoms and Molecules Collide in a Trap

An experiment shows the circumstances under which ultracold atoms are quick to kick molecules out of a trap, providing clues for how to use atoms as a refrigerant for molecules. [Read More »](#)

Electron Chemical Potential Measured for Graphene

Researchers demonstrate a method for measuring the chemical potential in a many-electron system, providing a way to validate numerical calculations. [Read More »](#)

[More Recent Articles »](#)

—Jorge Cham

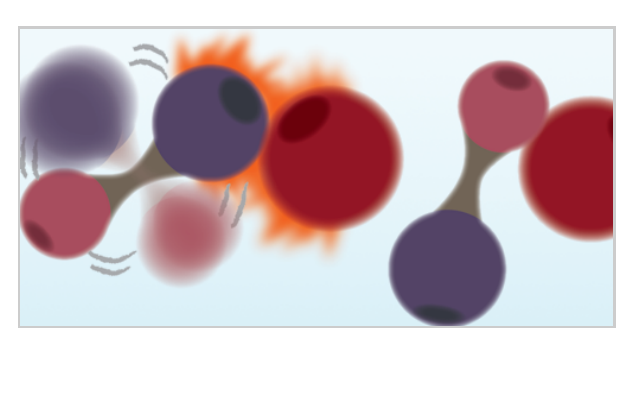
Recent Articles



NUCLEAR PHYSICS

A Lightweight Among Heavyweights

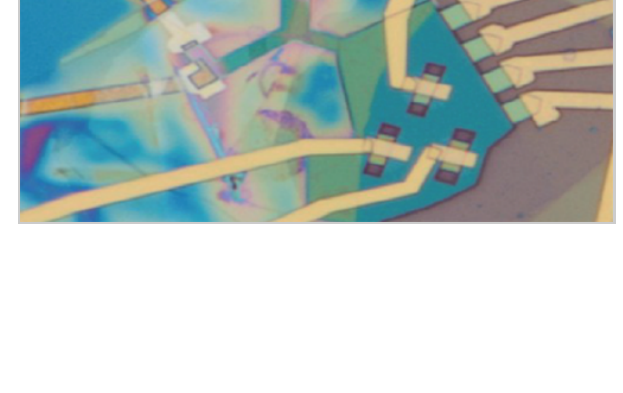
April 14, 2021
Researchers have observed the lightest uranium isotope to date, offering insight into models of nuclear structure. [Read More »](#)



ATOMIC AND MOLECULAR PHYSICS

Laser-Cooled Atoms and Molecules Collide in a Trap

April 13, 2021
An experiment shows the circumstances under which ultracold atoms are quick to kick molecules out of a trap, providing clues for how to use atoms as a refrigerant for molecules. [Read More »](#)



GRAPHENE

Electron Chemical Potential Measured for Graphene

April 13, 2021
Researchers demonstrate a method for measuring the chemical potential in a many-electron system, providing a way to validate numerical calculations. [Read More »](#)

[More Articles](#)

Sign up to receive weekly email alerts from *Physics*.

Enter your email [Sign Up](#)

APS JOURNALS

- About
- Authors
- Referees
- Subscriptions
- STUDENTS
- Physics
- PhysicsCentral
- Student Membership
- APS MEMBERS
- Subscriptions
- Article Packs
- Membership
- FAQ
- APS News
- Meetings & Events