

PILED HIGHER & DEEPER

TRUE TALES

DARK MATTERS

A CONVERSATION WITH DANIEL
WHITESON AND JONATHAN FENG

BY JORGE CHAM

WWW.PHDCOMICS.COM

WE'VE BEEN
STUDYING MATTER
FOR A COUPLE
HUNDRED YEARS...

...AND WE HAVE A
FINE UNDERSTANDING
OF CHEMICALS, ETC...

AND ALL OF A SUDDEN WE
DISCOVER THAT ALL THAT
WORK WE'VE BEEN DOING,

IS ONLY ON A
TINY FRACTION
OF WHAT THE
UNIVERSE IS
MADE OUT OF!



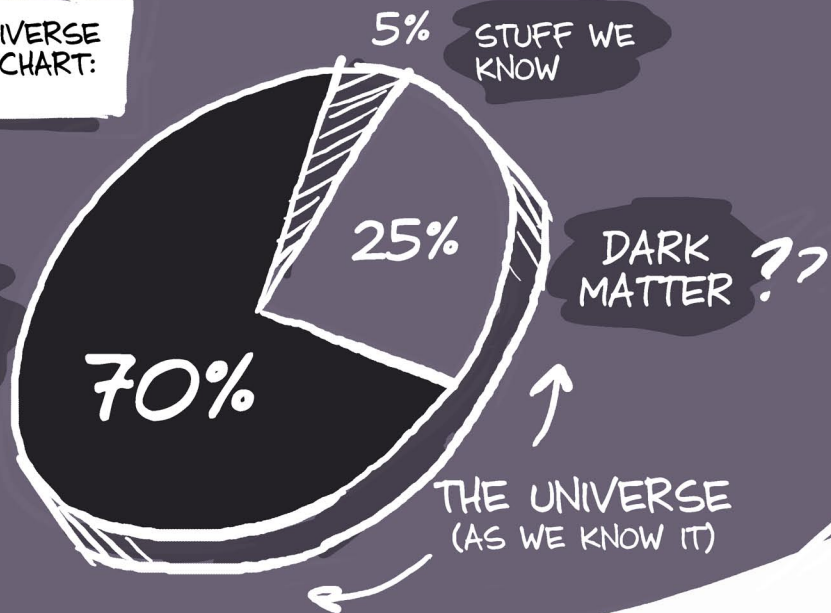
IT'S LIKE YOU'VE BEEN
STUDYING AN ELEPHANT'S
TAIL FOR TWO HUNDRED
YEARS AND YOU DISCOVER...

IT'S ONLY THE TAIL!



IF YOU LOOK AT WHAT THE UNIVERSE IS MADE OUT OF, LIKE A PIE CHART:

WE HAVE
NO IDEA



DARK MATTER IS 5 TIMES AS HEAVY AS ALL THE MATTER WE KNOW ABOUT,



THERE ARE HUGE MASSIVE BLOBS OF STUFF OUT THERE...

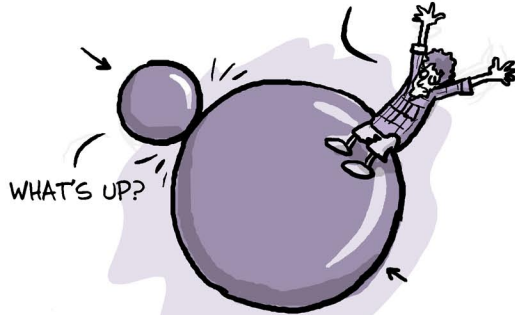
IT'S
HUGE

IT'S **EVERYWHERE.**

WE JUST CAN'T REALLY INTERACT WITH IT VERY MUCH.

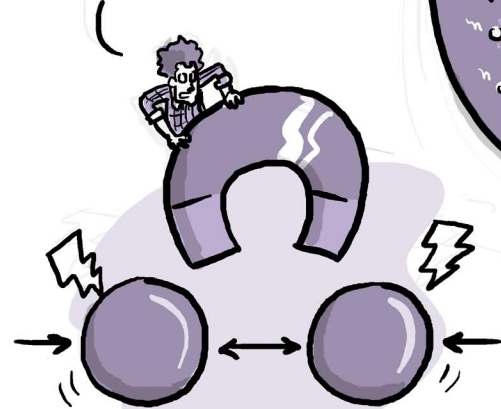
THERE ARE 4 MAJOR WAYS
THAT THINGS INTERACT:

IF YOU HAVE ANY
MASS AT ALL, THINGS
GET ATTRACTED.



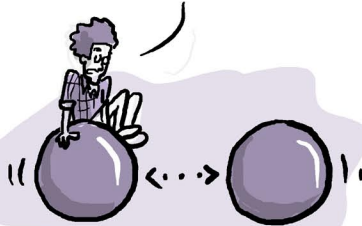
GRAVITY

TWO CHARGES ATTRACT
OR REPEL EACH OTHER.



ELECTRO-MAGNETISM

IT'S LIKE ELECTRO-
STATIC FORCES, BUT
MUCH, MUCH WEAKER.



WEAK FORCE

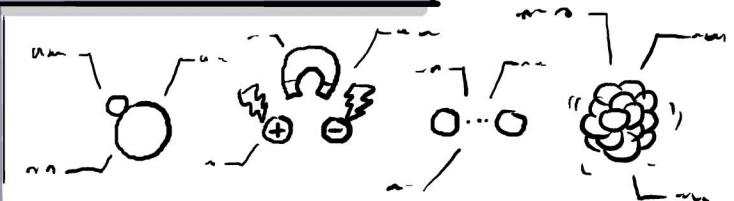
IT'S WHAT BINDS
THE NUCLEUS
TOGETHER.



STRONG FORCE

ALL THESE THINGS ARE
JUST DESCRIPTIVE.

IT'S A SUMMARY OF THE THINGS
WE'VE SEEN. LIKE BOTANY.



WHAT WE KNOW

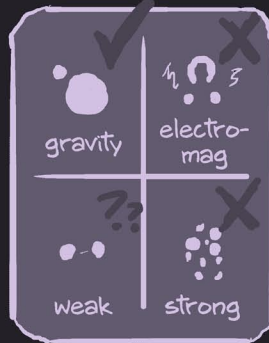
SO FAR, WE CAN EXPLAIN EVERY
EXPERIMENT IN TERMS OF THESE
FOUR KINDS OF INTERACTIONS.

DARK MATTER HAS MASS...

BUT IT DOES NOT HAVE ELECTRO-STATIC INTERACTION...

WHICH IS WHY WE CAN'T

SEE IT.



IT DOESN'T REFLECT LIGHT...

OR GIVE OFF LIGHT.

FOR A WHILE, PEOPLE THOUGHT MAYBE DARK MATTER WAS JUST A LOT OF NEUTRINOS.

BUT IT'D HAVE TO BE AN

ENORMOUS

NUMBER OF NEUTRINOS...

(NEUTRINOS ARE SIMILAR TO ELECTRONS, BUT CARRY NO CHARGE AND HAVE VERY LITTLE MASS)

A

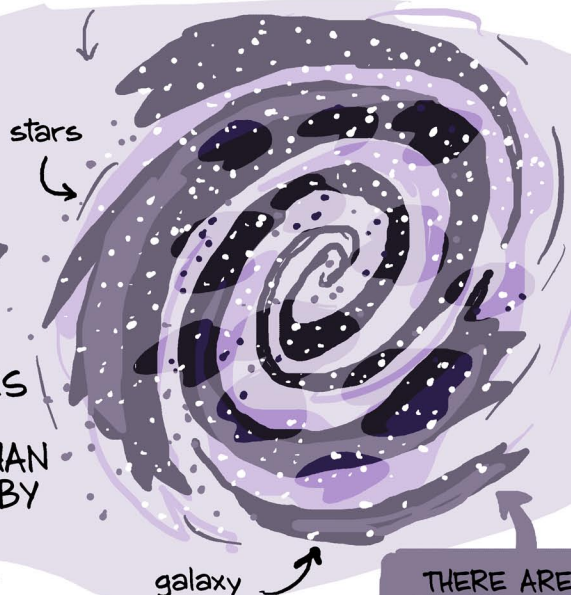
RIDICULOUS NUMBER!

(PLUS THEY ARE GOING TOO FAST)

WAYS WE KNOW DARK MATTER IS THERE

THERE'S TWO CLASSES OF WAYS WE HAVE EVIDENCE FOR DARK MATTER:

ONE WAY TO "SEE" DARK MATTER IS WHEN THINGS DON'T SPIN THE WAY THEY SHOULD:



THE STARS ROTATE FASTER THAN ALLOWED BY VISIBLE MATTER.



THERE ARE OBVIOUSLY BIG CLUMPS OF... MORE MATTER.

THERE'S ANOTHER WAY THAT WE CAN "SEE" DARK MATTER. IT'S CALLED...

STRONG LENSING

YOU LOOK UP AT A GALAXY...

LIGHT FROM IT
COMES ONE WAY...

AND GETS BENT
BY THE DARK
MATTER'S GRAVITY...



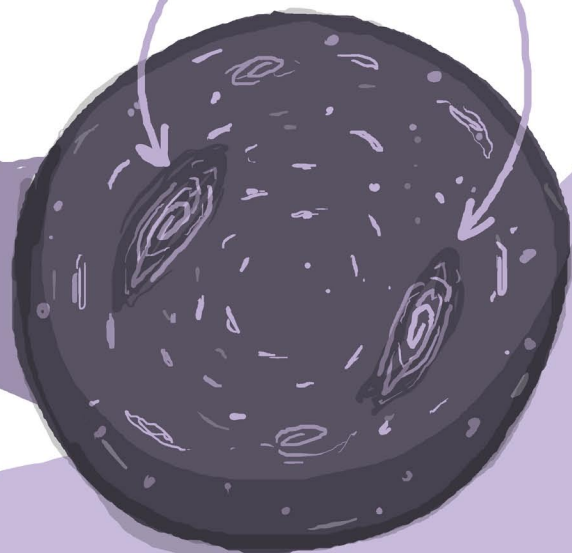
BUT IT ALSO
COMES AROUND
THE OTHER WAY...

YOU SEEM TO SEE
A GALAXY IN TWO
DIFFERENT DIRECTIONS...

YOU



BUT IT'S ACTUALLY
THE SAME GALAXY!



GRAVITY
IS THE
BIGGEST WAY
WE'VE SEEN
DARK MATTER
(BECAUSE IT FEELS IT)

THAT'S WHY IT'S CALLED
"MATTER"



IT HAS STUFF TO IT.

IT'S ONE OF THE
ONLY THINGS WE
KNOW ABOUT IT!



WE'VE ALSO SEEN MORE DIRECT EVIDENCE FOR DARK MATTER:

WE SAW TWO GALAXIES COLLIDE!

EACH GALAXY HAD
NORMAL MATTER...

...AND DARK
MATTER.

THEN THEY
COLLIDED!

THE NORMAL
MATTER SLAMMED
INTO EACH OTHER

THE DARK MATTER
JUST WENT RIGHT
THROUGH ITSELF!

(it doesn't feel
electrostatic forces,
remember?)

ENORMOUS GALACTIC-SIZED
PIECES OF MATTER PASSED
RIGHT THROUGH EACH OTHER!



THE BULLET CLUSTER

THIS IS WHAT'S SO COOL ABOUT IT...

IT'S A CLASH OF WORLD VIEWS:

FOR A LONG TIME, PARTICLE PHYSICISTS

HAVE BEEN DRILLING DOWN INTO SMALLER AND SMALLER LENGTH SCALES.

the whole universe

milky-way

solar system

atom

nucleus

quarks

ASTRONOMERS
LOOKING FURTHER AND FURTHER OUT...

THEN COMPLETELY SEPARATE, YOU HAD

JUST RECENTLY, THESE TWO SUCCESSFUL WAYS OF DOING SCIENCE SORT OF... CLASHED.

WHAT ARE YOU LOOKING AT?

THERE USED TO BE A JOKE THAT IN COSMOLOGY A FACTOR OF 100 WAS "PRECISION" COSMOLOGY.

100... or 10,000.



BUT LITTLE BY LITTLE, PARTICLE PHYSICISTS HAD TO START ADMITTING...

DARK MATTER



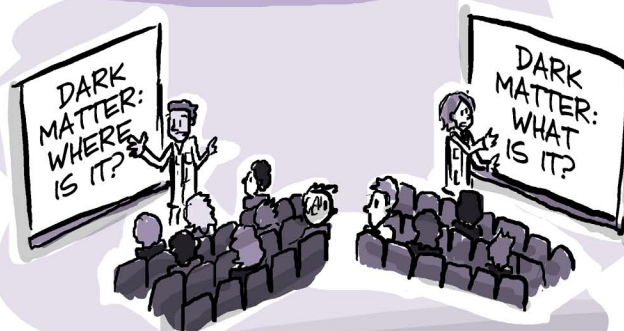
THESE GUYS ARE DOING SOMETHING IMPORTANT...



NOW THE PARTICLE PHYSICISTS REALLY WANT TO KNOW WHAT THE OTHERS FIND OUT.



WE HAVE TO GO TO THEIR CONFERENCES ...



AND LITTLE BY LITTLE THEY ARE COMING TO OURS TOO!

THERE'S BEEN A MELDING OF CULTURES!

WE'RE REALLY EXPLORING HERE... AND WE'RE IN THE EARLY DAYS



TOO MANY PEOPLE THINK...

"YEAH, SCIENTISTS MOSTLY HAVE IT FIGURED OUT..."

THEY'RE DOWN STUDYING THE DETAILS OF THE DETAILS OF THE DETAILS.

WE'RE ONLY NOW, BY LOOKING AT THE DETAILS, REALIZING WHAT THE

QUESTIONS

WE SHOULD BE ASKING

ARE!

BUT WE HAVE **NO IDEA!**

DID YOU EVER FEEL WHEN YOU WERE LEARNING ABOUT THE EXPLORERS IN ELEMENTARY SCHOOL...

MAN, THAT WOULD HAVE BEEN COOL...

BUT IT'S ALL USED UP!

THERE ARE NO MORE CONTINENTS TO DISCOVER...

IT'S NOT TRUE!

THERE'S A

HUGE

AMOUNT OF EXPLORATION

LEFT TO DO!

LEWIS & CLARK

AT **CERN**, WE'RE ABOUT TO ILLUMINATE A LARGE PORTION OF THE UNIVERSE NOBODY HAS LOOKED AT BEFORE.

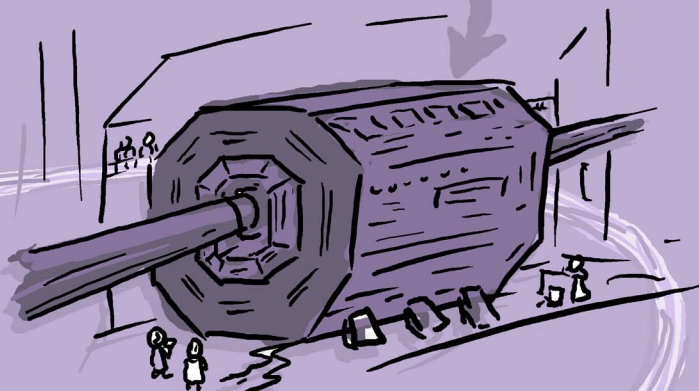


SIMULTANEOUSLY, WE KNOW WE KNOW VERY LITTLE...



...SO WE KNOW WHERE TO LOOK.

AND, WE BUILT THIS NEW COLLIDER.



THE MAGIC OF A COLLIDER IS THAT YOU CAN MAKE KINDS OF MATTER THAT YOU DON'T HAVE AROUND. IT'S THIS AMAZING QUANTUM MECHANICAL MAGIC THAT'S JUST TURNED ON.

THESE TWO THINGS ARE COMING TOGETHER

RIGHT NOW



Now

PEOPLE COULD LOOK BACK IN 200 YEARS AND SAY...

THIS WAS THE PERIOD THAT REDEFINED
OUR UNDERSTANDING OF THE UNIVERSE.

WHAT YOU SHOULD
TAKE AWAY FROM
ALL OF THIS IS...

WE DON'T KNOW WHAT
THE REST OF THE
ELEPHANT LOOKS LIKE...

AND YOU SHOULD BE
READY FOR SOME

SURPRISES.

THE
END?