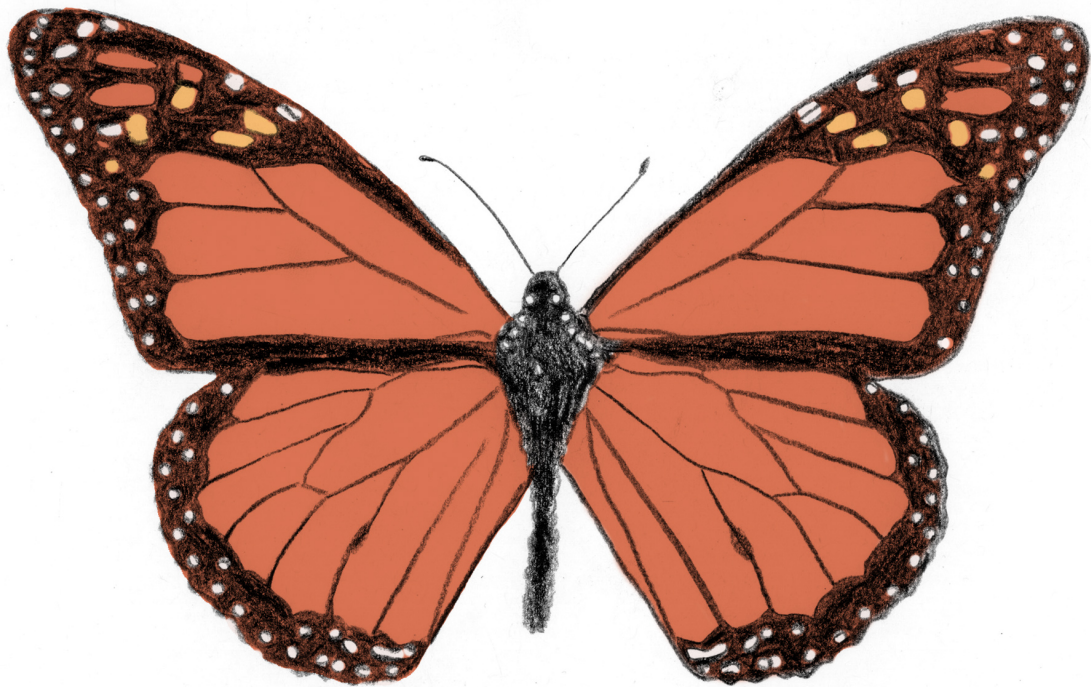


SYMMETRY IN PHYSICS



BY PAGE BIERSDORFF
& DR. LAURA JEANTY

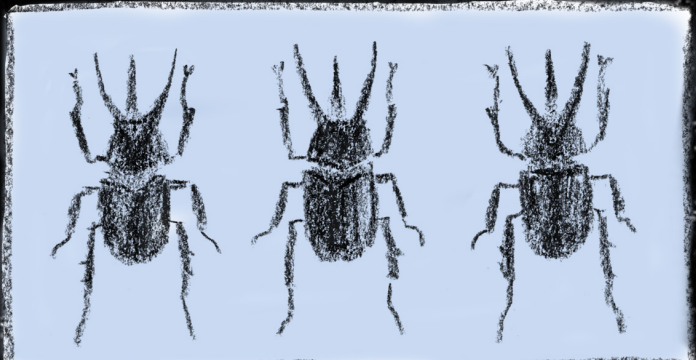
CREATED THROUGH THE UNIVERSITY OF OREGON:
COMICS & SCIENCE FELLOWSHIP PROGRAM

MANY KINDS OF SYMMETRY
ARE FOUND IN NATURE

FOR EXAMPLE:

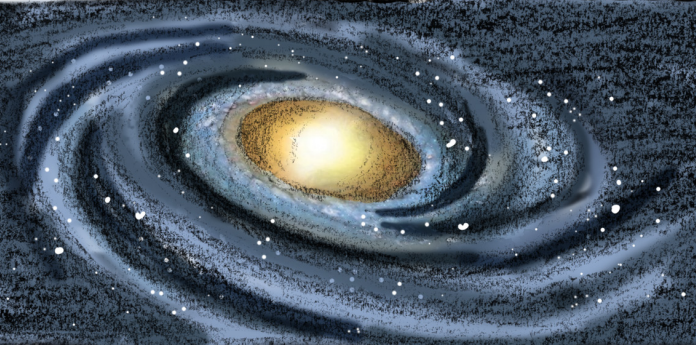


THE TRANSLATIONAL
SYMMETRY OF HONEYCOMBS



OR THE BILATERAL SYMMETRY
OF HORNED BEETLES

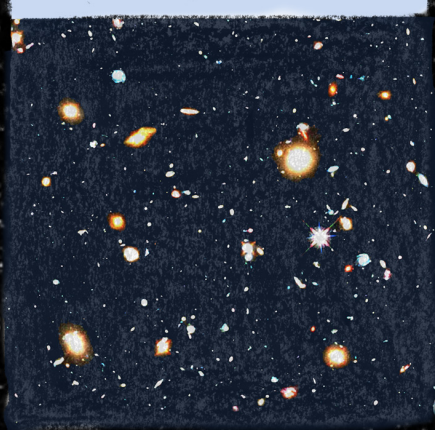
OR THE MILKY WAY'S ROTATIONAL SYMMETRY.



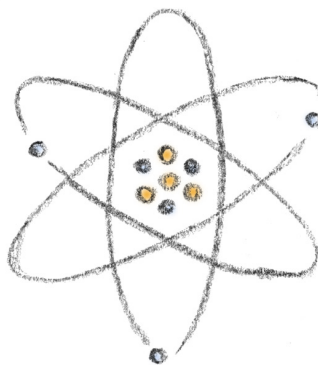
PB21

DO SYMMETRIES EXIST AT THE SCALE OF...

THE UNIVERSE?

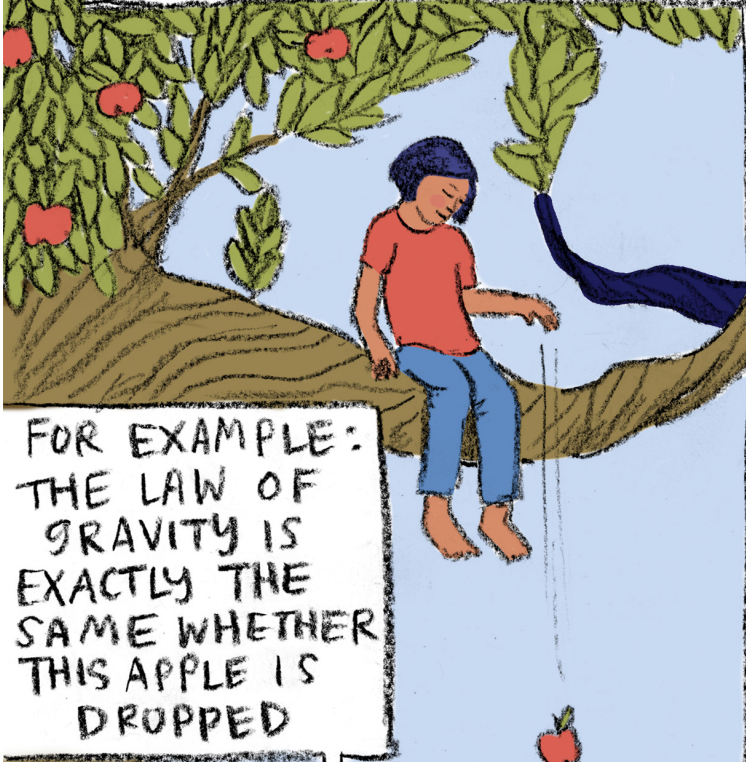


OR ATOMS?



OR THE
FUNDAMENTAL
PARTICLES
WHICH MAKE
UP ATOMS AND
EVERYTHING
ELSE?

PHYSICISTS FIND SYMMETRY IN THE LAWS OF NATURE WHICH DESCRIBE FUNDAMENTAL INTERACTIONS. THERE ARE DIFFERENT FORMS OF SYMMETRY IN PHYSICS... A FORM OF **EXACT SYMMETRY** IS FOUND IN THE LAWS OF NATURE AS WE MOVE THROUGH TIME.

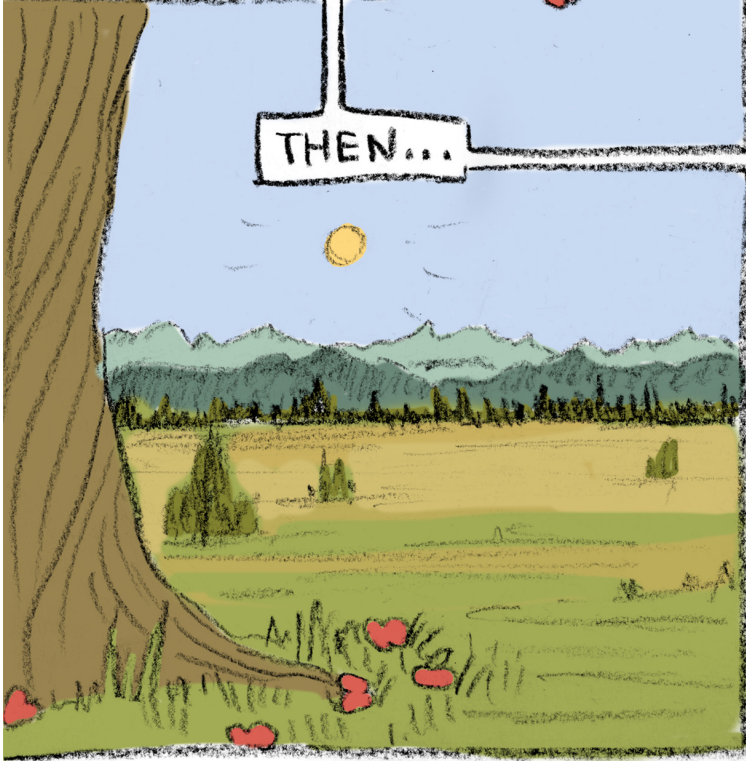


FOR EXAMPLE:
THE LAW OF
GRAVITY IS
EXACTLY THE
SAME WHETHER
THIS APPLE IS
DROPPED

THEN...



OR NOW.



THE FACT THAT
PHYSICAL LAWS
STAY CONSTANT
AS TIME PASSES
IS AN **EXACT
SYMMETRY.**



THROUGH SYMMETRY WE DETERMINED
THAT EVERY PARTICLE HAS AN ANTI-
MATTER MIRROR SELF (CALLED
CHARGE PARITY (CP) SYMMETRY.)

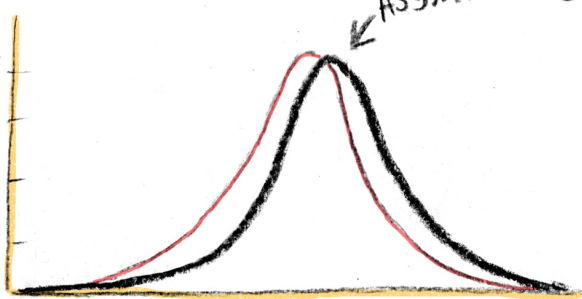
THE PARTICLE/ANTI-
PARTICLE PAIRS BEHAVE
ALMOST IDENTICALLY,
BUT NOT QUITE, SO
THIS SYMMETRY IS
CONSIDERED BROKEN
OR ASYMMETRIC

What a
paradox!

MATTER					ANTI-MATTER				
u	c	t	b	H	$\bar{u}$	$\bar{c}$	$\bar{t}$	$\bar{b}$	$\bar{H}$
d	s	b	γ		$\bar{d}$	$\bar{s}$	$\bar{b}$	$\bar{\gamma}$	
e	μ	τ	Z		$\bar{e}$	$\bar{\mu}$	$\bar{\tau}$	$\bar{Z}$	
ν_e	ν_μ	ν_τ	W		$\bar{\nu}_e$	$\bar{\nu}_\mu$	$\bar{\nu}_\tau$	$\bar{W}$	

OPPOSITE CHARGE

CP VIOLATION:

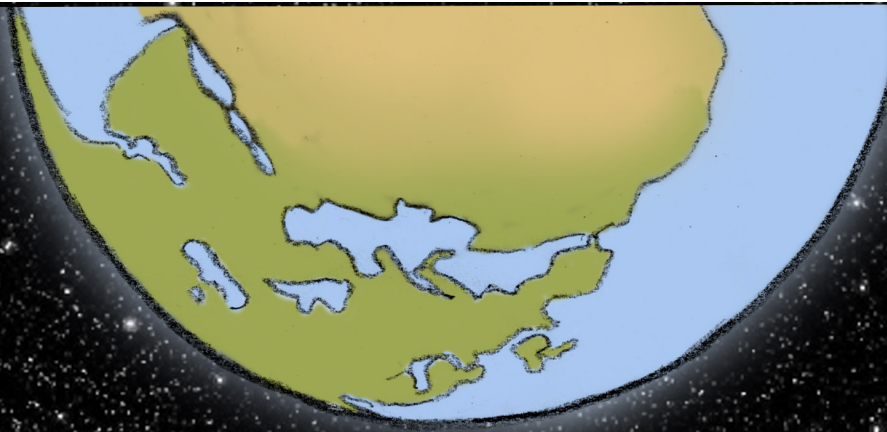


OUR ENTIRE EXISTENCE
DEPENDS ON EXACT
SYMMETRIES AS WELL
AS ASYMMETRIES...

CERN

IF SYMMETRY BETWEEN MATTER AND ANTI-MATTER WERE NOT SLIGHTLY BROKEN OR ASYMMETRICAL, THEN ALL OF MATTER WOULD HAVE BEEN ANNIHILATED BY ANTI-MATTER AFTER THE BIG BANG.





FOR EXAMPLE, IF AN UPQUARK (u) INTERACTED WITH AN ANTI-UPQUARK ($\bar{u}$) THEN THEY WOULD CANCEL EACH OTHER OUT, CREATING ENERGY IN THE FORM OF PHOTONS. YET, MYSTERIOUSLY THEY DIDN'T ALL CANCEL OUT, AND SOME MATTER REMAINED. THAT REMAINING MATTER TURNED INTO ALL OF THE STARS IN THE UNIVERSE, OUR SOLAR SYSTEM, AND US!





FERMILAB

PB21

ANOTHER KIND OF SYMMETRY
IS THE THEORY OF
SUPERSYMMETRY.

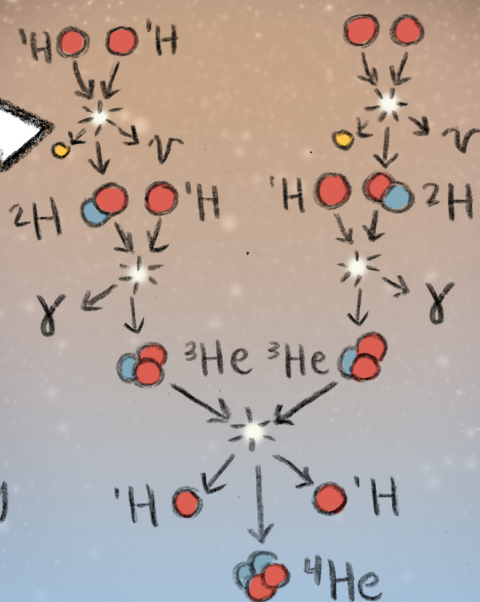
THIS THEORY OFFERS SOLUTIONS TO
HOW GALAXIES ARE FORMED...

SUPERSYMMETRY
COULD EXPLAIN DARK
MATTER WHICH IS
NEEDED TO PREDICT
GALAXY EVOLUTION.

...OR HOW THE
SUN SHINES

AKA HYDROGEN FUSION:

SUPERSYMMETRY
COULD EXPLAIN
WHAT MAKES
THIS STEP
POSSIBLE.



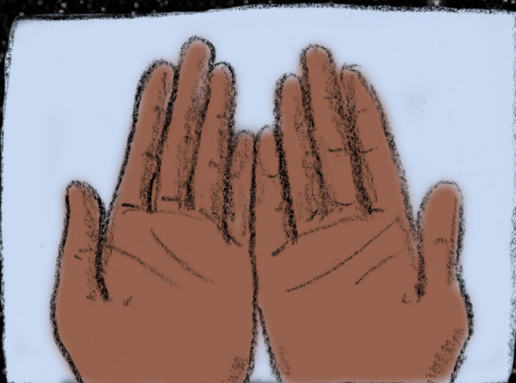
THERE ARE STILL OUTSTANDING QUESTIONS ABOUT SYMMETRY IN PHYSICS AND IN NATURE, INCLUDING WHETHER OR NOT SUPERSYMMETRY ACTUALLY EXISTS, AND IF IT DOES EXIST, HOW ASYMMETRIC IT IS.



PB21

COURTESY CERN

THESE QUESTIONS ARE BEING EXPLORED BY ACCELERATING PARTICLES AT THE LARGE HADRON COLLIDER AND STUDYING THE PARTICLES WHICH ARE PRODUCED FROM THE COLLISIONS USING THE ATLAS DETECTOR.



$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\psi}\not{D}\psi + h.c. + \bar{\psi}_j\gamma_j\psi_j\phi + h.c. + |D_\mu\phi|^2 - V(\phi)$$

STANDARD
MODEL
LAGRANGIAN
~

SHIVA STATUE AT CERN
"THE METAPHOR FOR THE COSMIC
DANCE UNIFIES ANCIENT
MYTHOLOGY, RELIGIOUS ART
& MODERN PHYSICS."

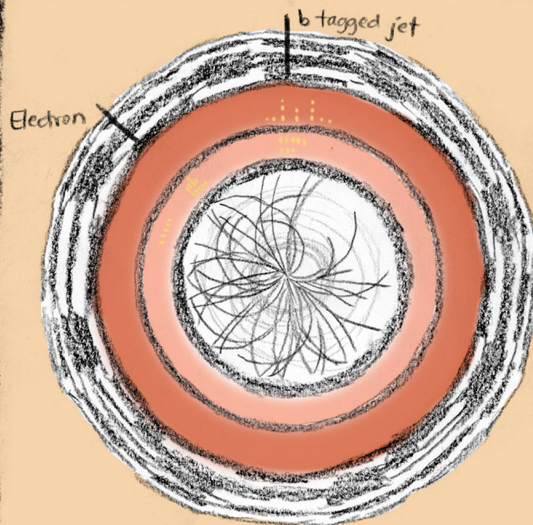
-FRITJOF CAPRA



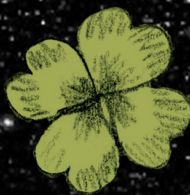
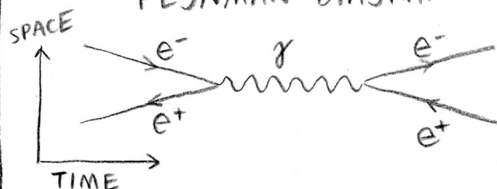
FIRST DETECTION OF
ANTI-MATTER
1932

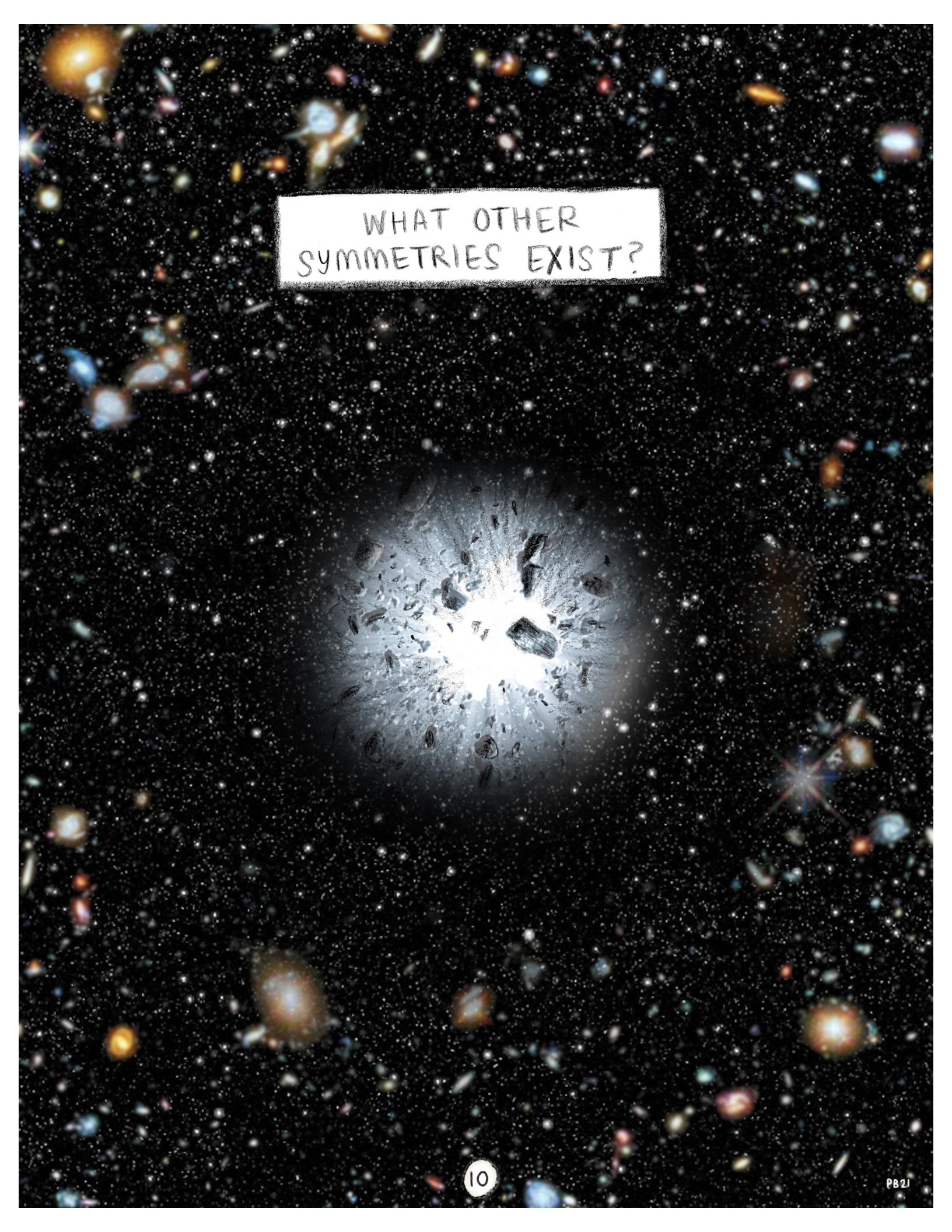
LEAD PLATE

IMAGE OF DEBRIS FROM
PROTON-PROTON COLLISION



FEYNMAN DIAGRAM



The background of the entire page is a deep space image filled with numerous galaxies of various shapes and colors (blue, orange, white) against a black field of stars. In the center of the page, there is a large, bright, circular cluster of galaxies, possibly a galaxy core or a dense cluster, with a very bright white center and a surrounding glow of smaller galaxies and stars.

WHAT OTHER
SYMMETRIES EXIST?