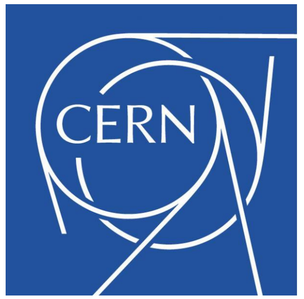
ALICE

A JOURNEY OF DISCOVERY



WHAT MATTERS FOR ALICE:
PRIMORDIAL MATTER

-13.819 BILLION YEARS

THE FIRST HOMINIDS ON EARTH (TOUMAI)- 7 MILLION YEARS

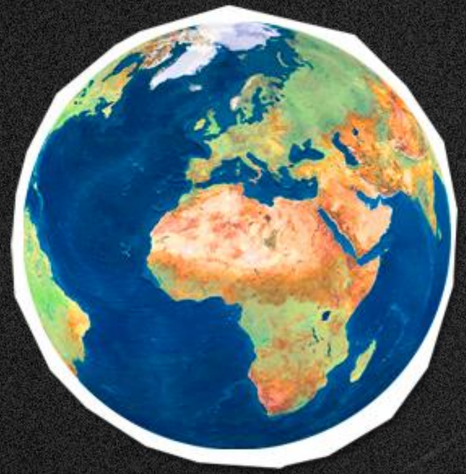
MORE THAN 1’000 BILLION DEGREES

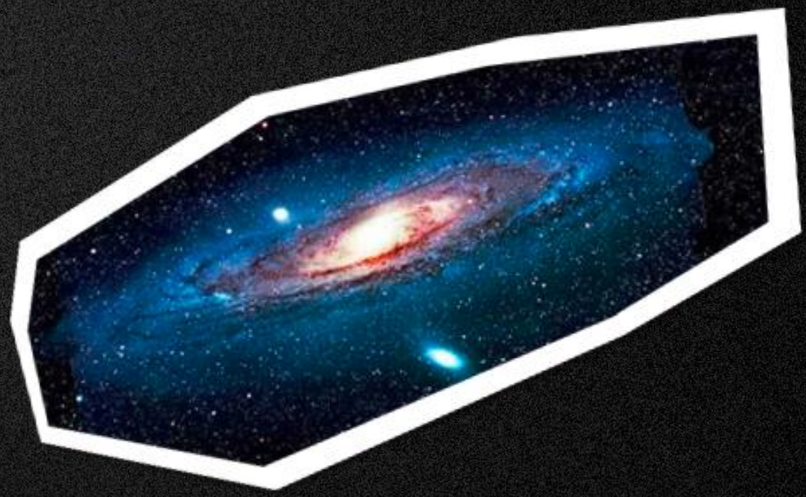
TEMPERATURE OF THE SUN:15 M

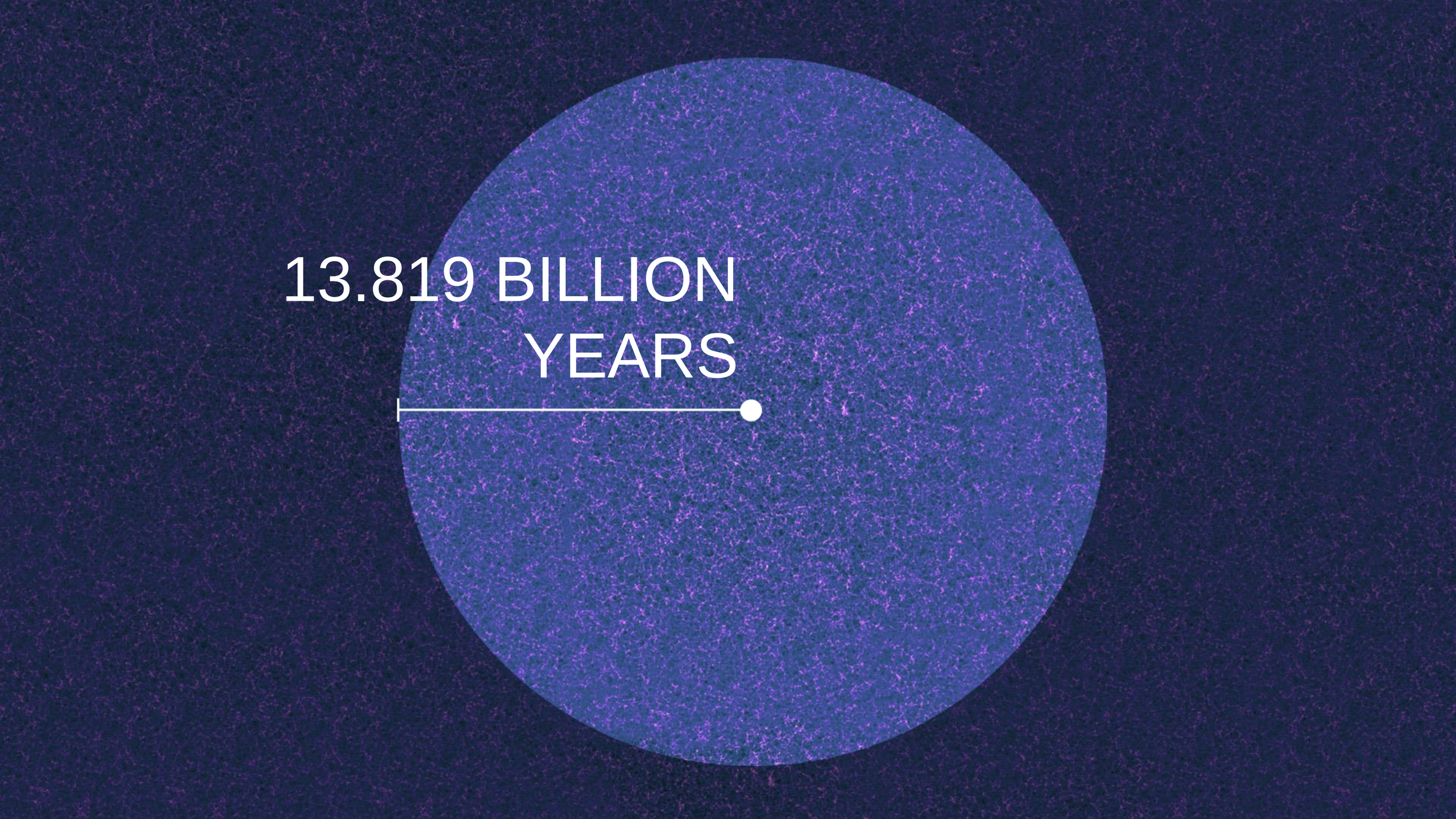
200 MILLION TONS PER cm^3

THE PYRAMID OF KHEOPSIN A PIN’S

MATTER IS WHAT EVERYTHING THAT HAS A
UNDERSTANDING WHAT THINGS ARE MADE O
TANGIBLE REALITY IS COMPOSED OF






13.819 BILLION
YEARS


UNIVERSE
>10^26m

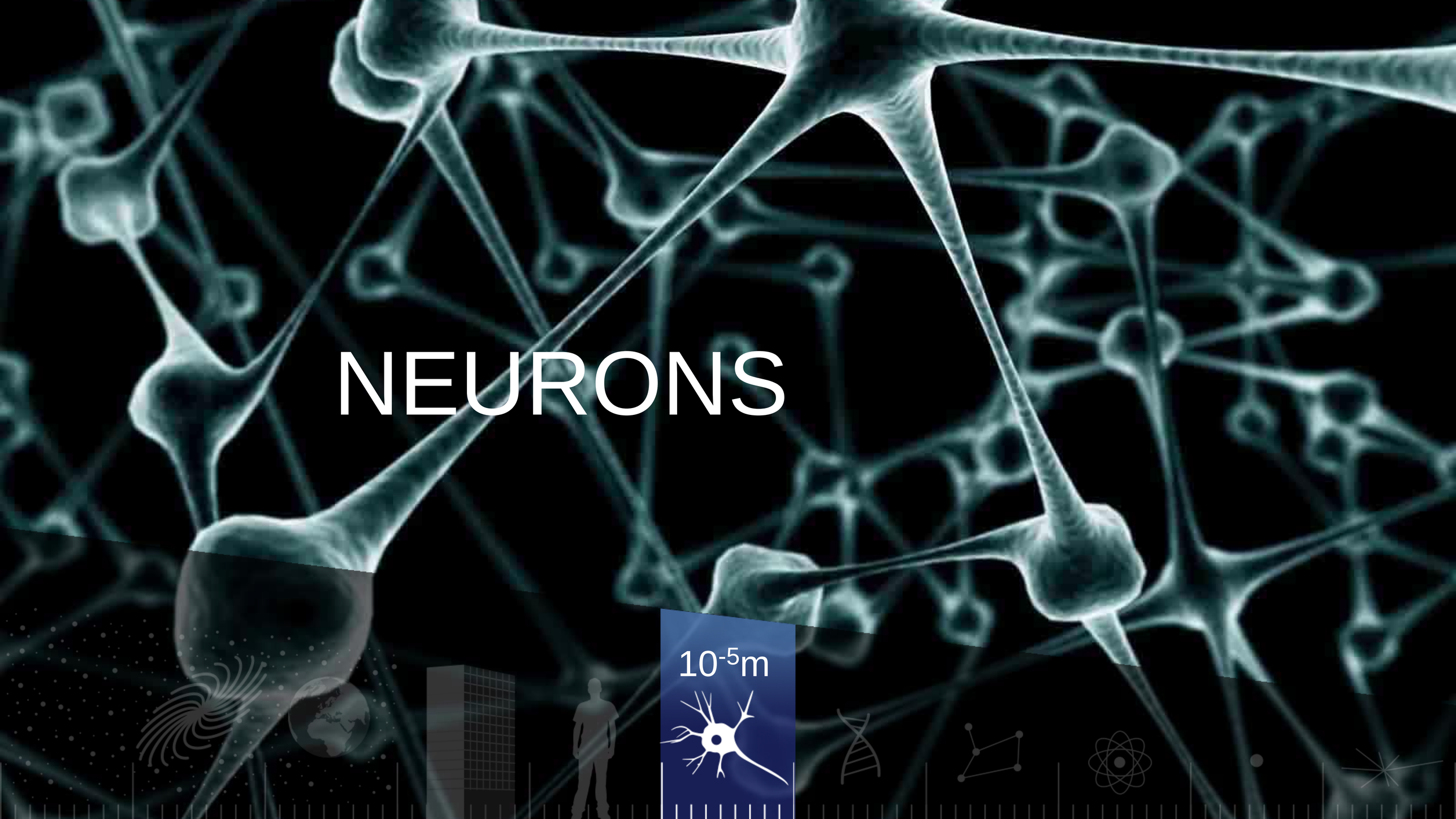

GALAXY
~10^21m

SOLAR SYSTEM


BUILDING
Square GALILEO GALILEI
Accelerating Science
Accélérateur de science
10^2m

MAN

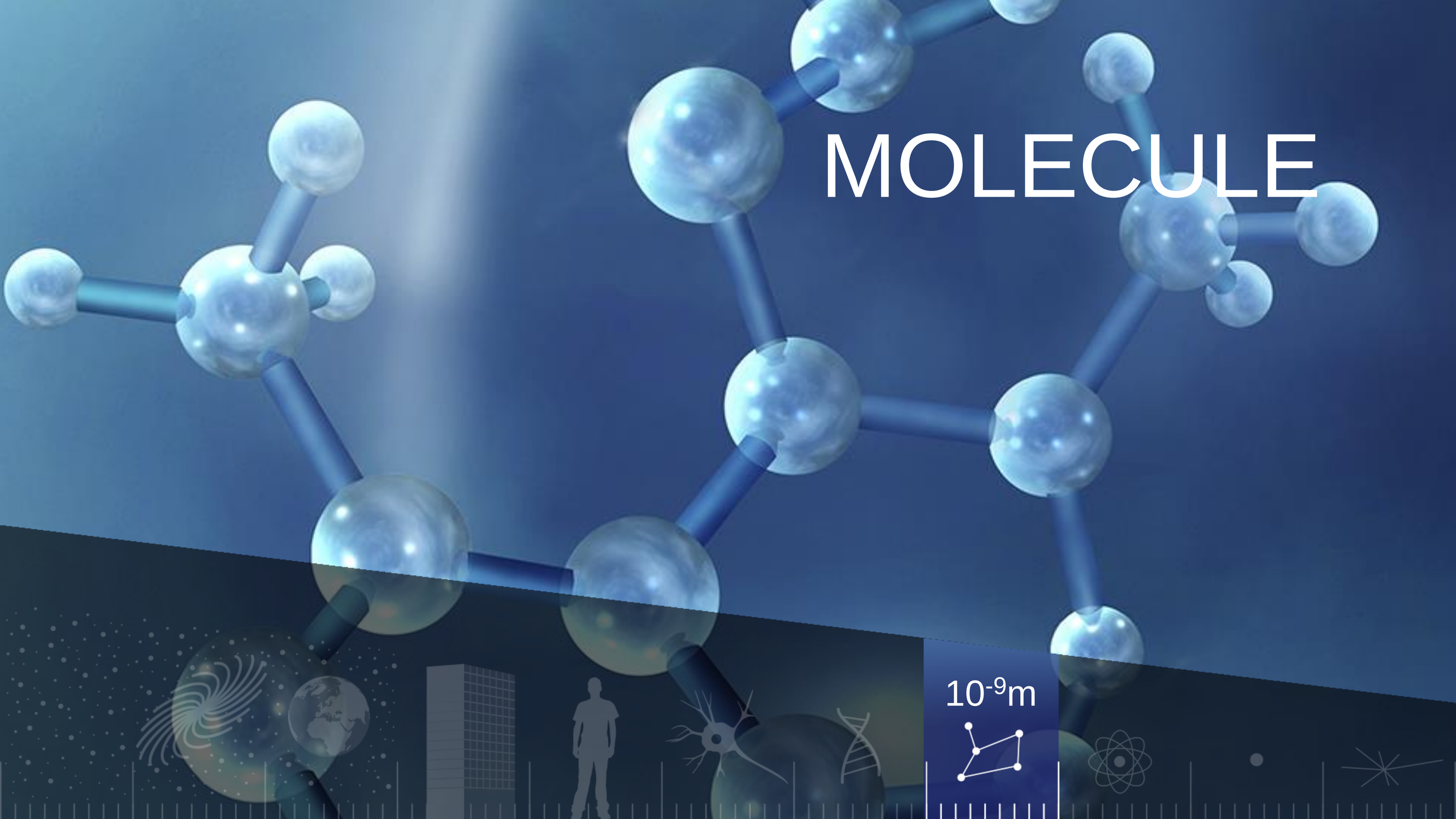
NEURONS



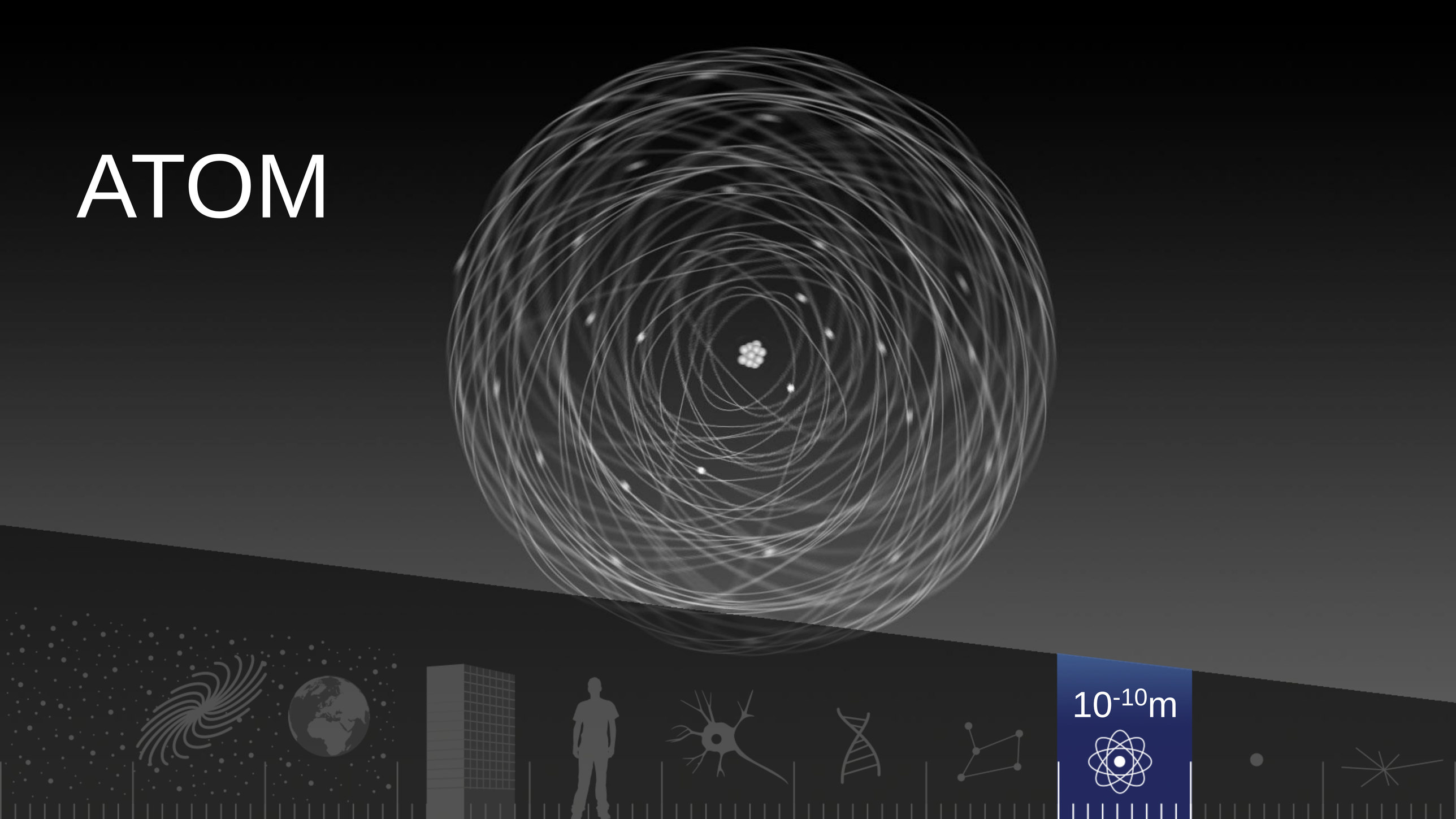

DNA
10^{-9}m

MOLECULE

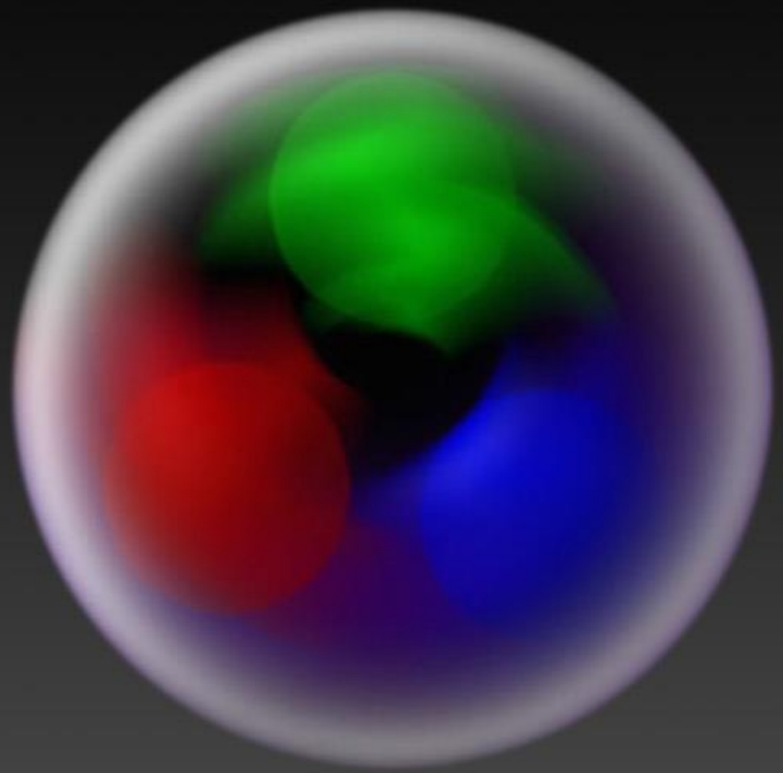
10^{-9}m



ATOM

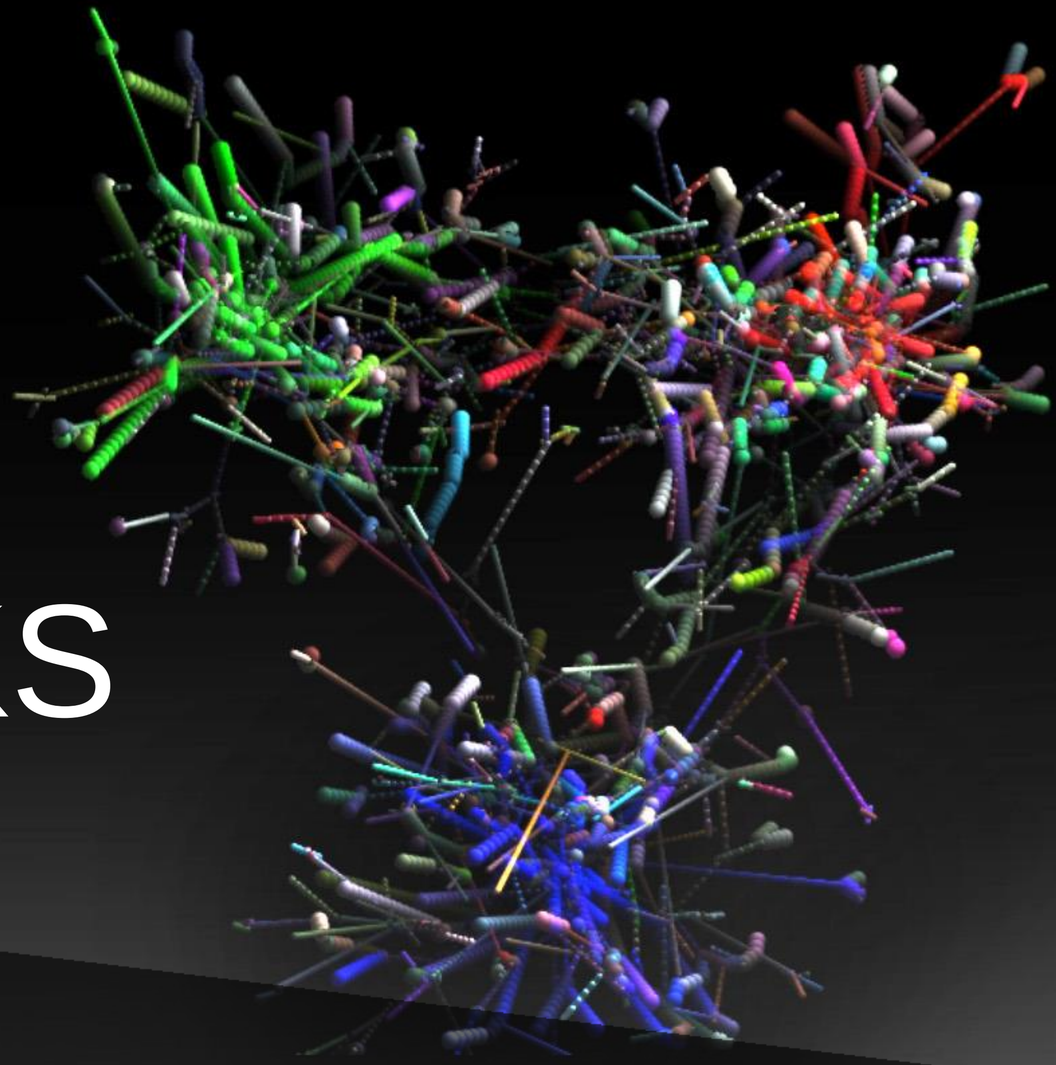


PROTON

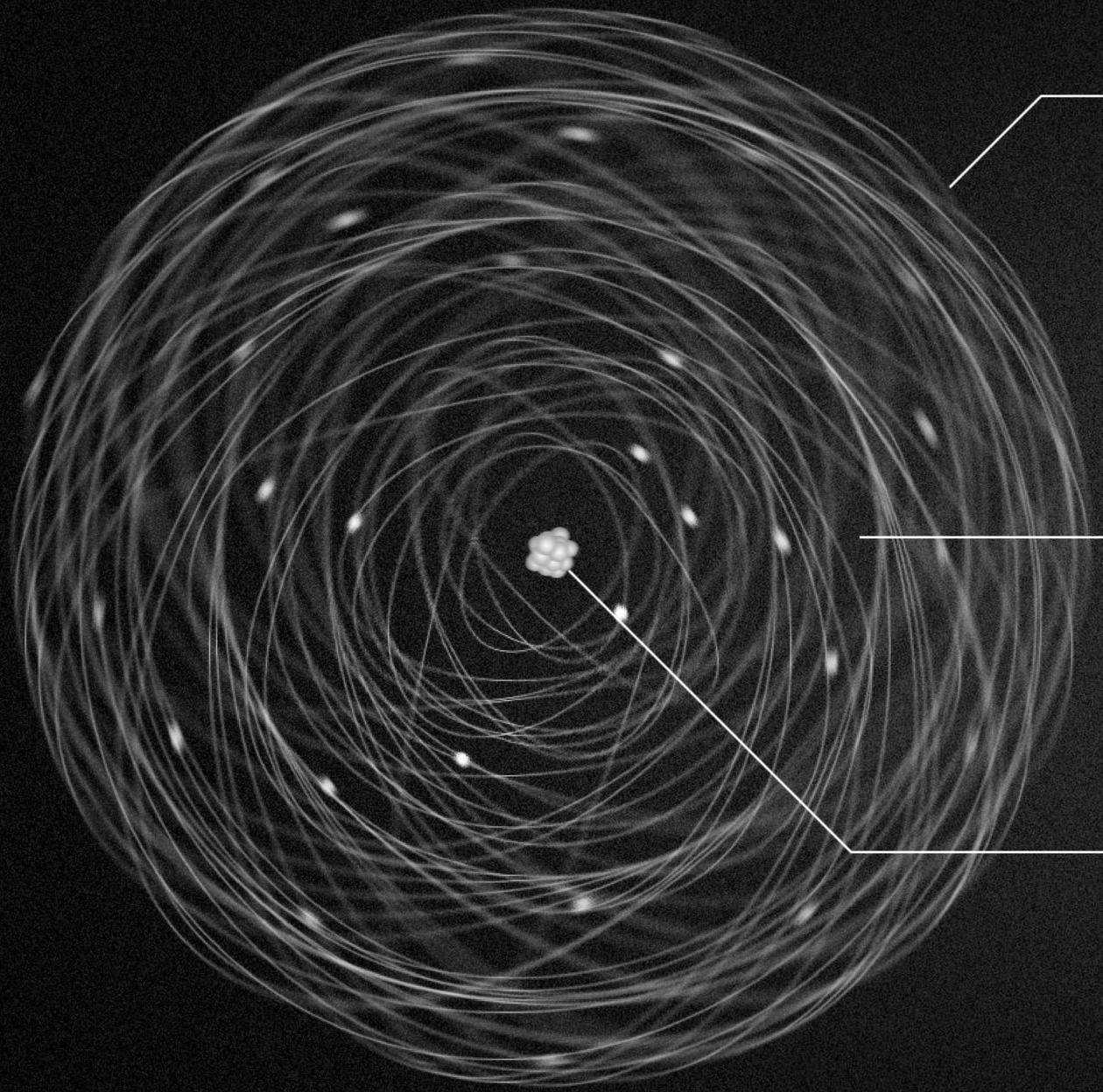


10^{-15}m

QUARKS



10^{-18}m



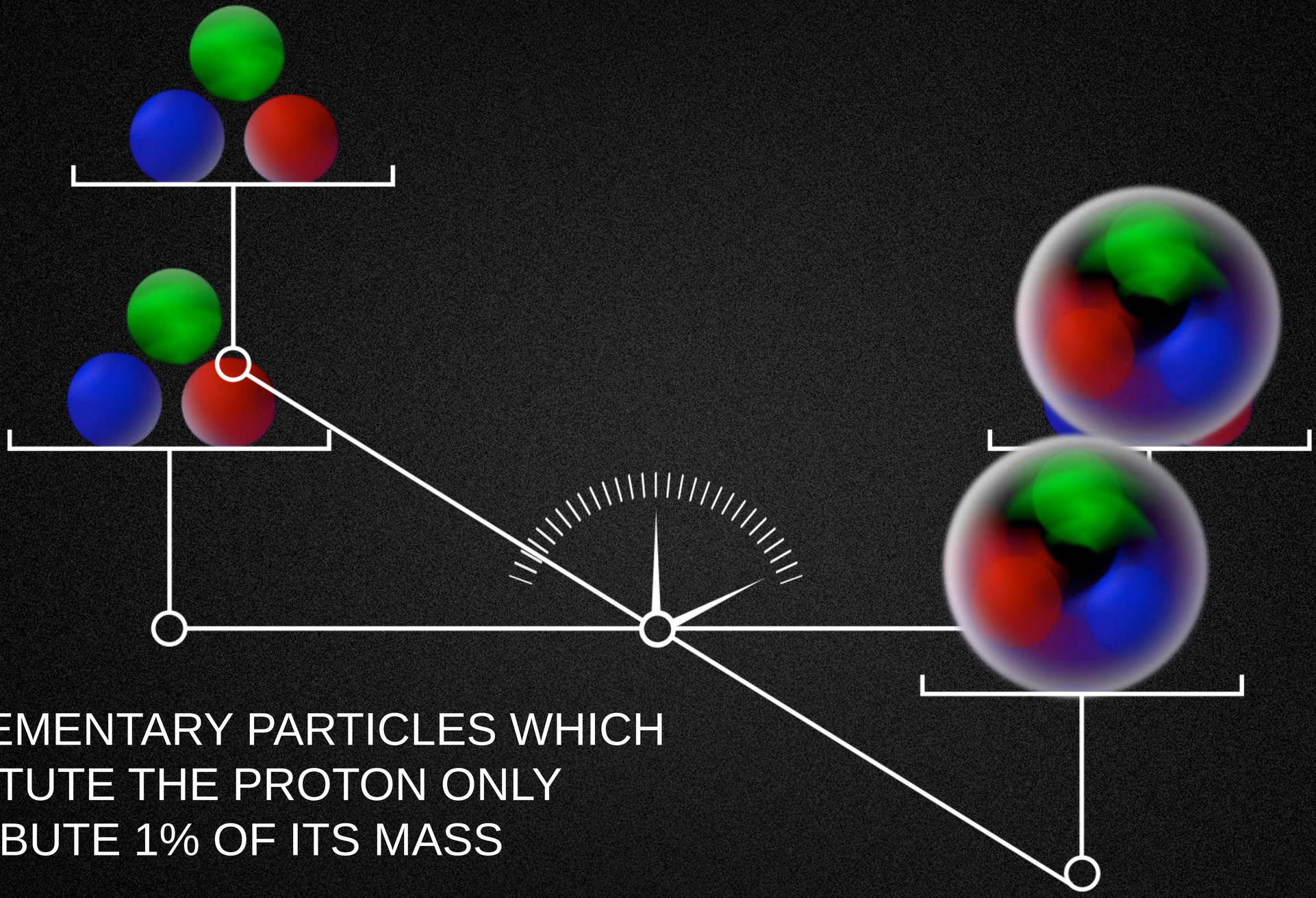
THE ATOM IS
100’000 TIMES
LARGER THAN
THE NUCLEUS

99,99999999999999%
IS VACCUM

99,995%
OF THE
ATOM MASS

WHAT DO WE KNOW ABOUT MATTER?

MATTER IS MADE OF VACUUM



THE ELEMENTARY PARTICLES WHICH CONSTITUTE THE PROTON ONLY CONTRIBUTE 1% OF ITS MASS

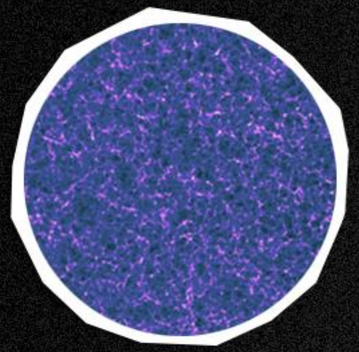
WHAT DO WE KNOW ABOUT MATTER?

MATTER IS IMMATERIAL

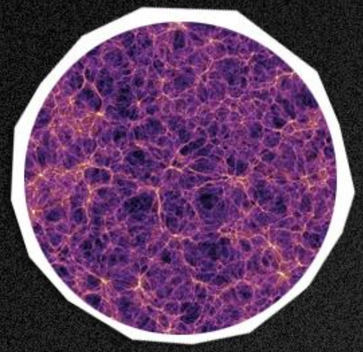
MATTER IS MADE OF VACUUM

THE FORCES STRUCTUREMAT TER

THE GRAVITATIONAL FORCE



UNIVERSE



WALLS
AND VOIDS

CLUSTERS -
SUPERCLUSTERS

GALAXY

$$R_{\mu\nu} - 1/2\, R g_{\mu\nu} = 8\pi G T_{\mu\nu}$$

$$-\frac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac{1}{4}g_s^2 f^{abc}f^{ade}g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \frac{1}{2}ig_s^2(\bar{q}^\sigma_i\gamma^\mu q^\sigma_j)g^a_\mu + \bar{G}^a\partial^2 G^a + g_s f^{abc}\partial_\mu \bar{G}^a G^b g^c_\mu - \partial_\nu W^+_\mu \partial_\nu W^-_\mu - M^2 W^+_\mu W^-_\mu - \frac{1}{2}\partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \frac{1}{2c_w^2}M^2 Z^0_\mu Z^0_\mu - \frac{1}{2}\partial_\mu A_\nu \partial_\mu A_\nu - \frac{1}{2}\partial_\mu H \partial_\mu H - \frac{1}{2}m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^- - M^2\phi^+\phi^- - \frac{1}{2}\partial_\mu \phi^0 \partial_\mu \phi^0 - \frac{1}{2c_w^2}M\phi^0\phi^0 - \beta_h[\frac{2M^2}{g^2} + \frac{2M}{g}H + \frac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)] + \frac{2M^4}{g^2}\alpha_h - igc_w[\partial_\nu Z^0_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - Z^0_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + Z^0_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - igs_w[\partial_\nu A_\mu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu(W^+_\mu\partial_\nu W^-_\mu - W^-_\mu\partial_\nu W^+_\mu) + A_\mu(W^+_\nu\partial_\nu W^-_\mu - W^-_\nu\partial_\nu W^+_\mu)] - \frac{1}{2}g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \frac{1}{2}g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu) + g^2 s_w^2(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu) + g^2 s_w c_w[A_\mu Z^0_\nu(W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu] - g\alpha[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-] - \frac{1}{8}g^2\alpha_h[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2] - gMW^+_\mu W^-_\mu H - \frac{1}{2}g\frac{M}{c_w^2}Z^0_\mu Z^0_\mu H - \frac{1}{2}ig[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)] + \frac{1}{2}g[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)] + \frac{1}{2}g\frac{1}{c_w}(Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w}MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_w MA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w}Z^0_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) + igs_w A_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac{1}{4}g^2 W^+_\mu W^-_\mu[H^2 + (\phi^0)^2 + 2\phi^+\phi^-] - \frac{1}{4}g^2\frac{1}{c_w^2}Z^0_\mu Z^0_\mu[H^2 + (\phi^0)^2 + 2(2s_w^2-1)^2\phi^+\phi^-] - \frac{1}{2}g^2\frac{s_w^2}{c_w}Z^0_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) - \frac{1}{2}ig^2\frac{s_w^2}{c_w}Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac{1}{2}g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) + \frac{1}{2}ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - g^1 s_w^2 A_\mu A_\mu\phi^+\phi^- - \bar{e}^\lambda(\gamma\partial + m^\lambda_e)e^\lambda - \bar{\nu}^\lambda\gamma\partial\nu^\lambda - \bar{u}^\lambda_j(\gamma\partial + m^\lambda_u)u^\lambda_j - \bar{d}^\lambda_j(\gamma\partial + m^\lambda_d)d^\lambda_j + igs_w A_\mu[-(\bar{e}^\lambda\gamma^\mu e^\lambda) + \frac{2}{3}(\bar{u}^\lambda_j\gamma^\mu u^\lambda_j) - \frac{1}{3}(\bar{d}^\lambda_j\gamma^\mu d^\lambda_j)] + \frac{ig}{4c_w}Z^0_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{e}^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(\frac{4}{3}s_w^2 - 1 - \gamma^5)u^\lambda_j) + (\bar{d}^\lambda_j\gamma^\mu(1 - \frac{8}{3}s_w^2 - \gamma^5)d^\lambda_j)] + \frac{ig}{2\sqrt{2}}W^+_\mu[(\bar{\nu}^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + (\bar{u}^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)] + \frac{ig}{2\sqrt{2}}W^-_\mu[(\bar{e}^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar{d}^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+\gamma^5)u^\lambda_j)] + \frac{ig}{2\sqrt{2}}\frac{m^\lambda_e}{M}[-\phi^+(\bar{\nu}^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar{e}^\lambda(1+\gamma^5)\nu^\lambda)] - \frac{g}{2}\frac{m^\lambda_e}{M}[H(\bar{e}^\lambda e^\lambda) + i\phi^0(\bar{e}^\lambda\gamma^5 e^\lambda)] + \frac{ig}{2M\sqrt{2}}\phi^+[-m^\kappa_d(\bar{u}^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + m^\lambda_u(\bar{u}^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j] + \frac{ig}{2M\sqrt{2}}\phi^-[m^\lambda_d(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m^\kappa_u(\bar{d}^\lambda_j C^\dagger_{\lambda\kappa}(1-\gamma^5)u^\kappa_j] - \frac{g}{2}\frac{m^\lambda_u}{M}H(\bar{u}^\lambda_j u^\lambda_j) - \frac{g}{2}\frac{m^\lambda_d}{M}H(\bar{d}^\lambda_j d^\lambda_j) + \frac{ig}{2}\frac{m^\lambda_u}{M}\phi^0(\bar{u}^\lambda_j\gamma^5 u^\lambda_j) - \frac{ig}{2}\frac{m^\lambda_d}{M}\phi^0(\bar{d}^\lambda_j\gamma^5 d^\lambda_j) + \bar{X}^+(\partial^2 - M^2)X^+ + \bar{X}^-(\partial^2 - M^2)X^- + \bar{X}^0(\partial^2 - \frac{M^2}{c_w^2})X^0 + \bar{Y}\partial^2 Y + igc_w W^+_\mu(\partial_\mu\bar{X}^0X^- - \partial_\mu\bar{X}^+X^0) + igs_w W^+_\mu(\partial_\mu\bar{Y}X^- - \partial_\mu\bar{X}^+Y) + igc_w W^-_\mu(\partial_\mu\bar{X}^-X^0 - \partial_\mu\bar{X}^0X^+) + igs_w W^-_\mu(\partial_\mu\bar{X}^-Y - \partial_\mu\bar{Y}X^+) + igc_w Z^0_\mu(\partial_\mu\bar{X}^+X^+ - \partial_\mu\bar{X}^-X^-) + igs_w A_\mu(\partial_\mu\bar{X}^+X^+ - \partial_\mu\bar{X}^-X^-) - \frac{1}{2}gM[\bar{X}^+X^+H + \bar{X}^-X^-H + \frac{1}{c_w^2}\bar{X}^0X^0H] + \frac{1-2c_w^2}{2c_w}igM[\bar{X}^+X^0\phi^+ - \bar{X}^-X^0\phi^-] + \frac{1}{2c_w}igM[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + igMs_w[\bar{X}^0X^-\phi^+ - \bar{X}^0X^+\phi^-] + \frac{1}{2}igM[\bar{X}^+X^+\phi^0 - \bar{X}^-X^-\phi^0]$$

WHAT DO WE KNOW ABOUT MATTER?

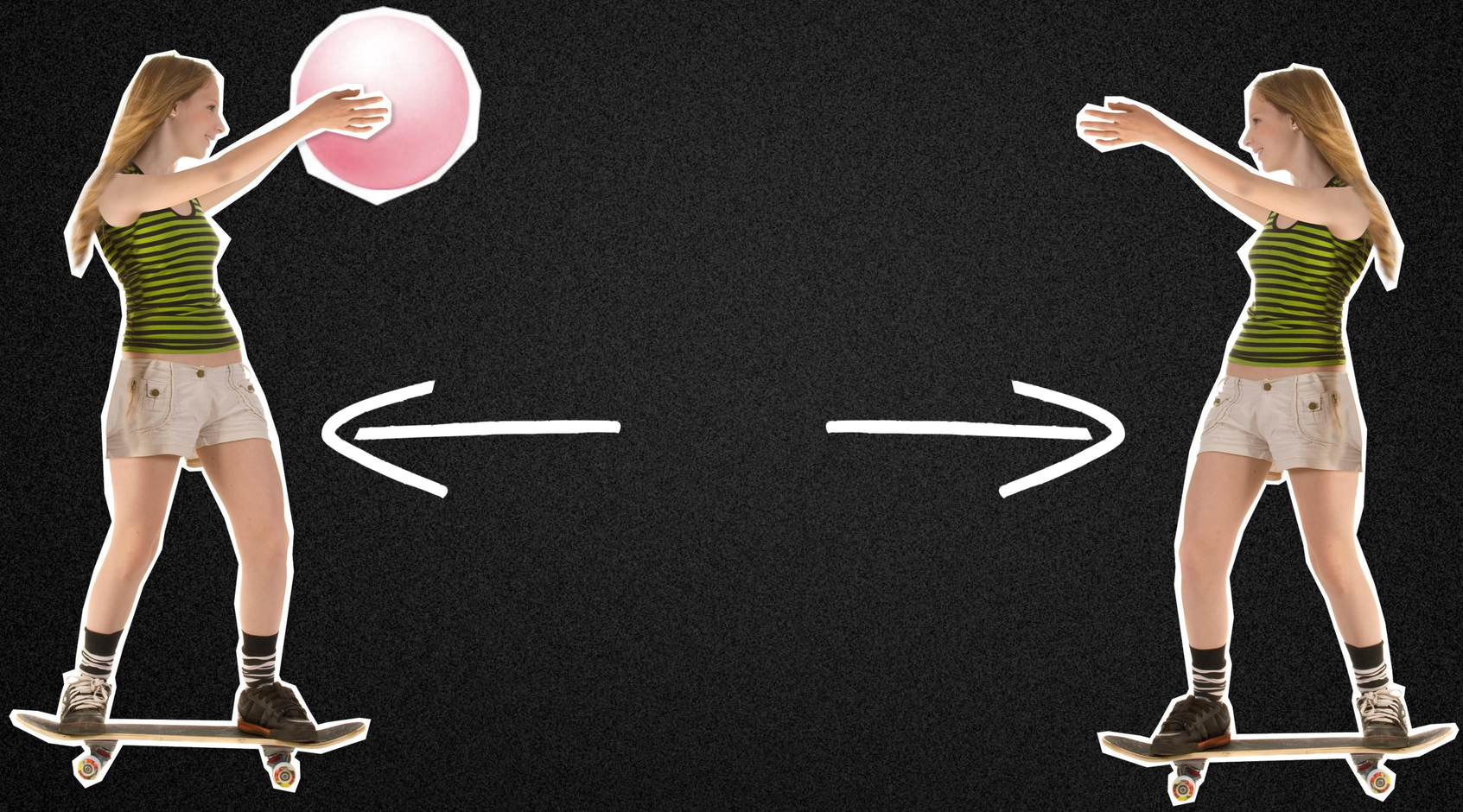
MATTER IS MADE OF VACUUM

MATTER IS IMMATERIAL

MATTER IS STRUCTURED BY 4 FORCES

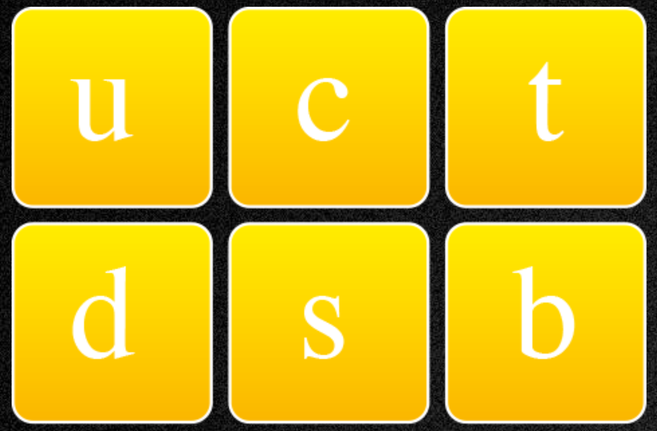
THE PARTICLES INTERACT BY EXCHANGING PARTICLE-MESSENGERS

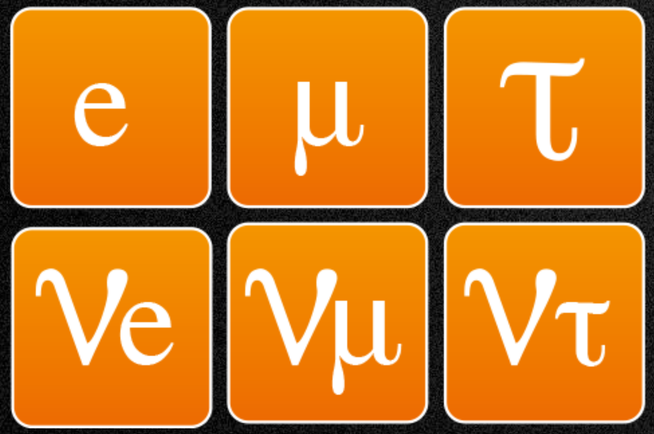
REPULSIVE INTERACTION



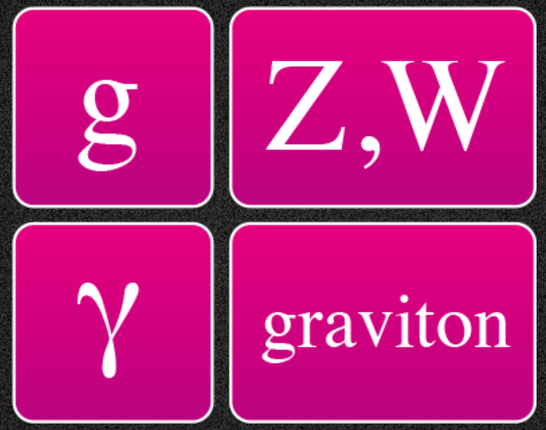
ATTRACTIVE INTERACTION

QUARKS





LEPTONS



MESSENGERS

QUARKS

u c t

d s b

e μ τ

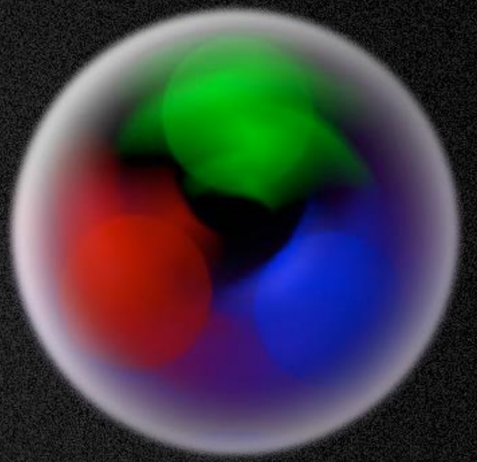
νe νμ ντ

LEPTONS

g Z,W

γ graviton

MESSENGERS



HADRONS

QUARKS

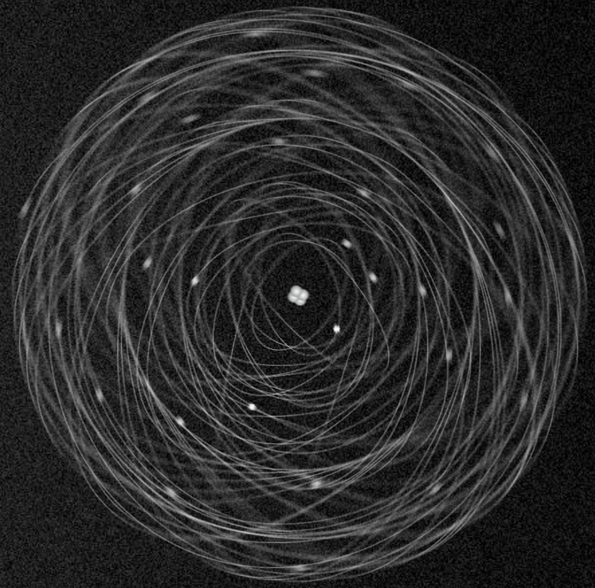
u	c	t
d	s	b

e	μ	τ
ν_e	ν_μ	ν_τ

LEPTONS

g	Z,W
γ	graviton

MESSENGERS



QUARKS

u	c	t
d	s	b

e	μ	τ
ν_e	ν_μ	ν_τ

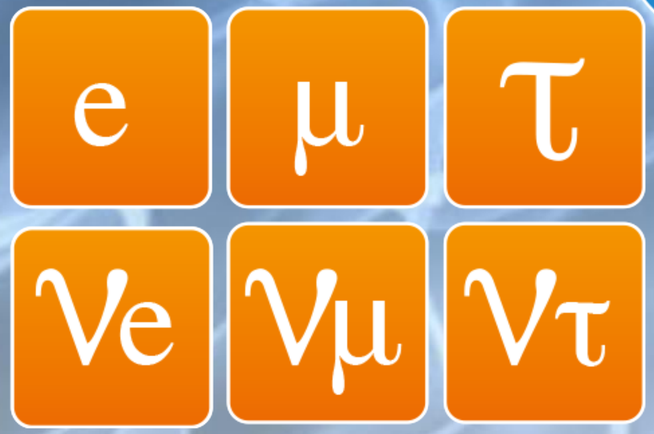
LEPTONS

g	Z,W
γ	graviton

MESSENGERS

QUARKS

MESSENGERS



LEPTONS

WHAT DO WE KNOW ABOUT MATTER?

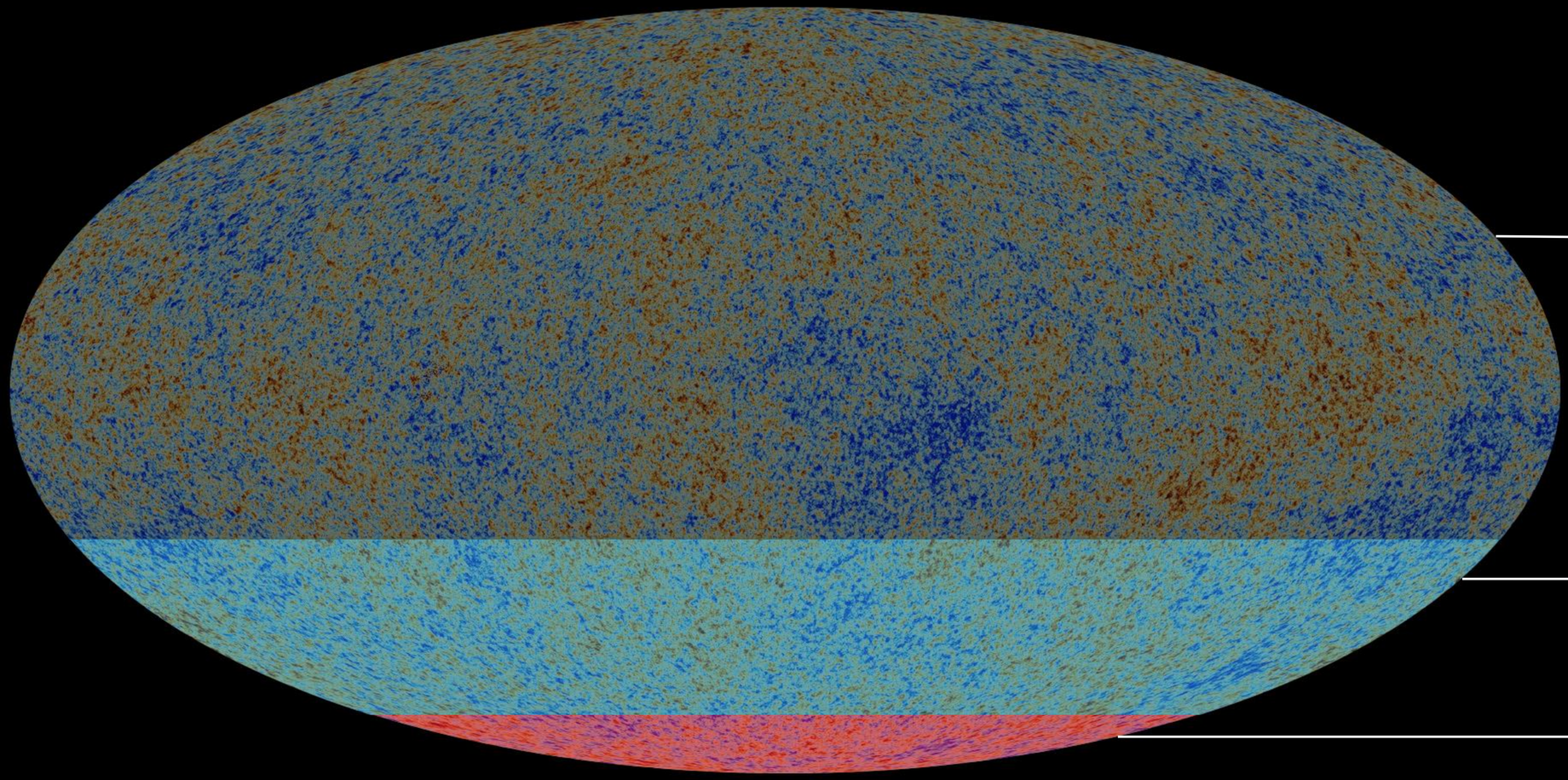
4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...

MATTER IS MADE OF VACUUM

MATTER IS IMMATERIAL

MATTER IS STRUCTURED PAR 4 FORCES

MOST ANCIENT PHOTO OF THE UNIVERSE:
380’000 YEARS AFTER THE BIG BANG, LUKEWARM ...
2700°C, FORMATION OF THE FIRST ATOMS



69,4%
DARK
ENERGY

25,8%
DARK MATTER

4,8%
VISIBLE
MATTER

WHAT DO WE KNOW ABOUT MATTER?

ORDINARY MATTER REPRESENTS 4.8% OF THE UNIVERSE

MATTER IS MADE OF VACUUM

MATTER IS IMMATERIAL

MATTER IS STRUCTURED BY 4 FORCES

4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...

COSMOLOGY PLACES THE BIG BANG
AT -**13.819 BILLION YEARS**

3 minutes LATER 99 % OF CURRENT MATTER IS CREATED OUT OF ELEMENTARY PARTICLES (PRIMORDIAL NUCLEOSYNTHESIS)

100 million YEARS LATER HEAVY ELEMENTS (C, O, FE,...) ARE SYNTHETIZED IN THE HEART OF THE FIRST STARS

WHAT DO WE KNOW ABOUT MATTER?

99% OF CURRENT MATTER HAS BEEN CREATED IN 3 MINUTES

MATTER IS MADE OF VACUUM

MATTER
IS IMMATERIAL

MATTER IS STRUCTURED BY 4 FORCES

4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...

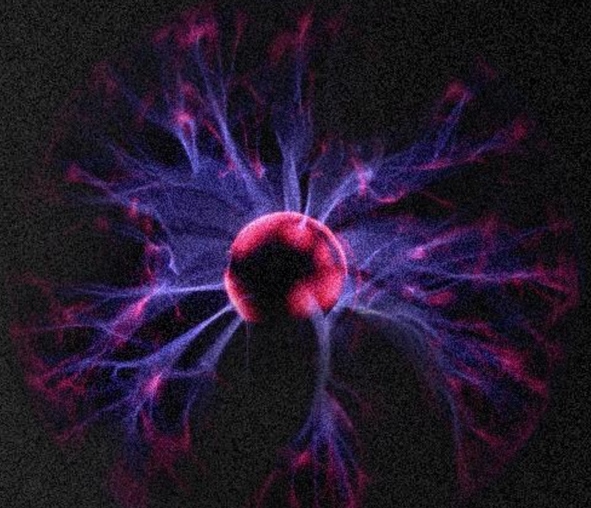
ORDINARY MATTER REPRESENTS 4,8% OF THE UNIVERSE

MATTER IN ALL ITS STATES

SOLID

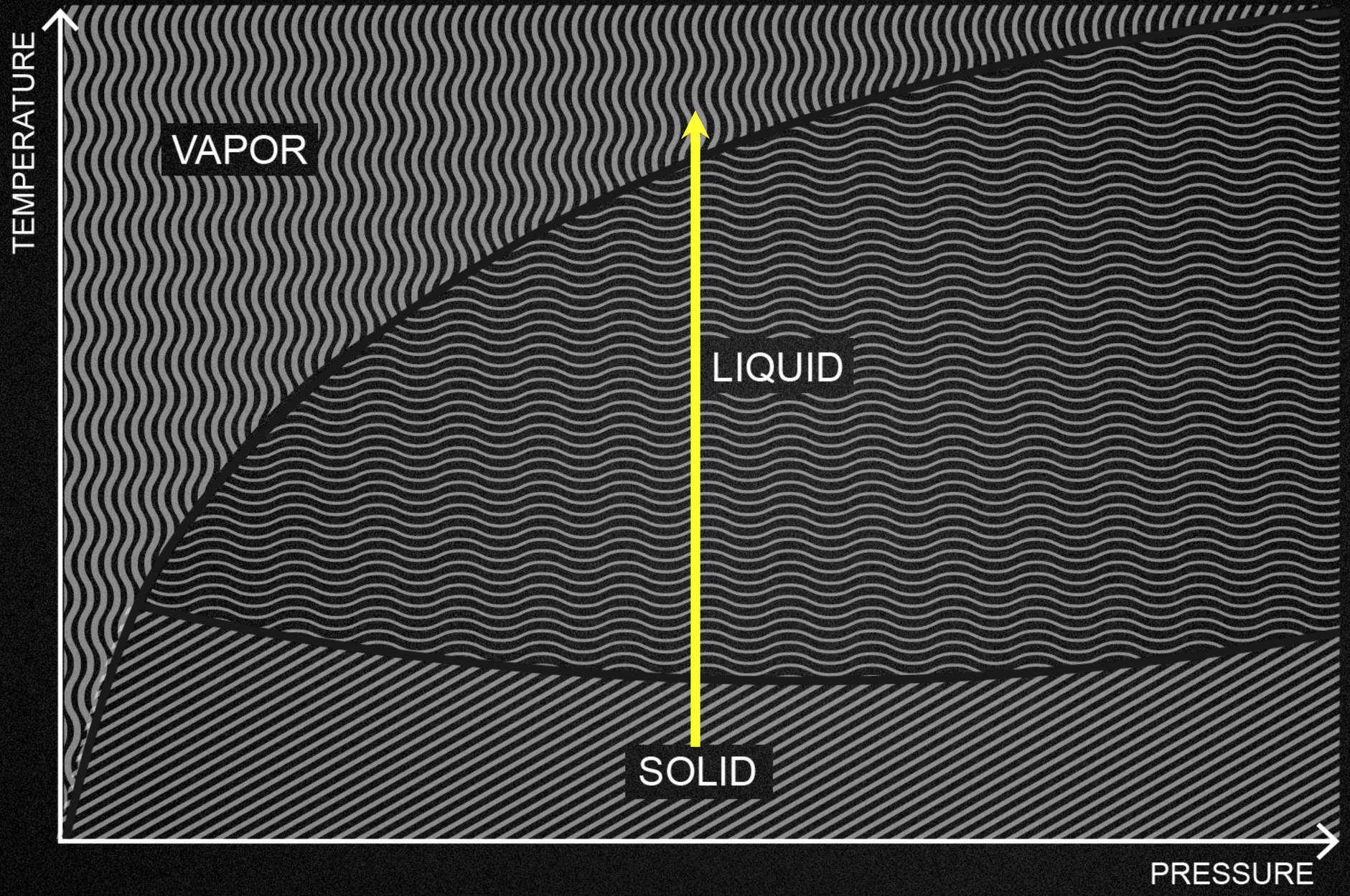
LIQUID

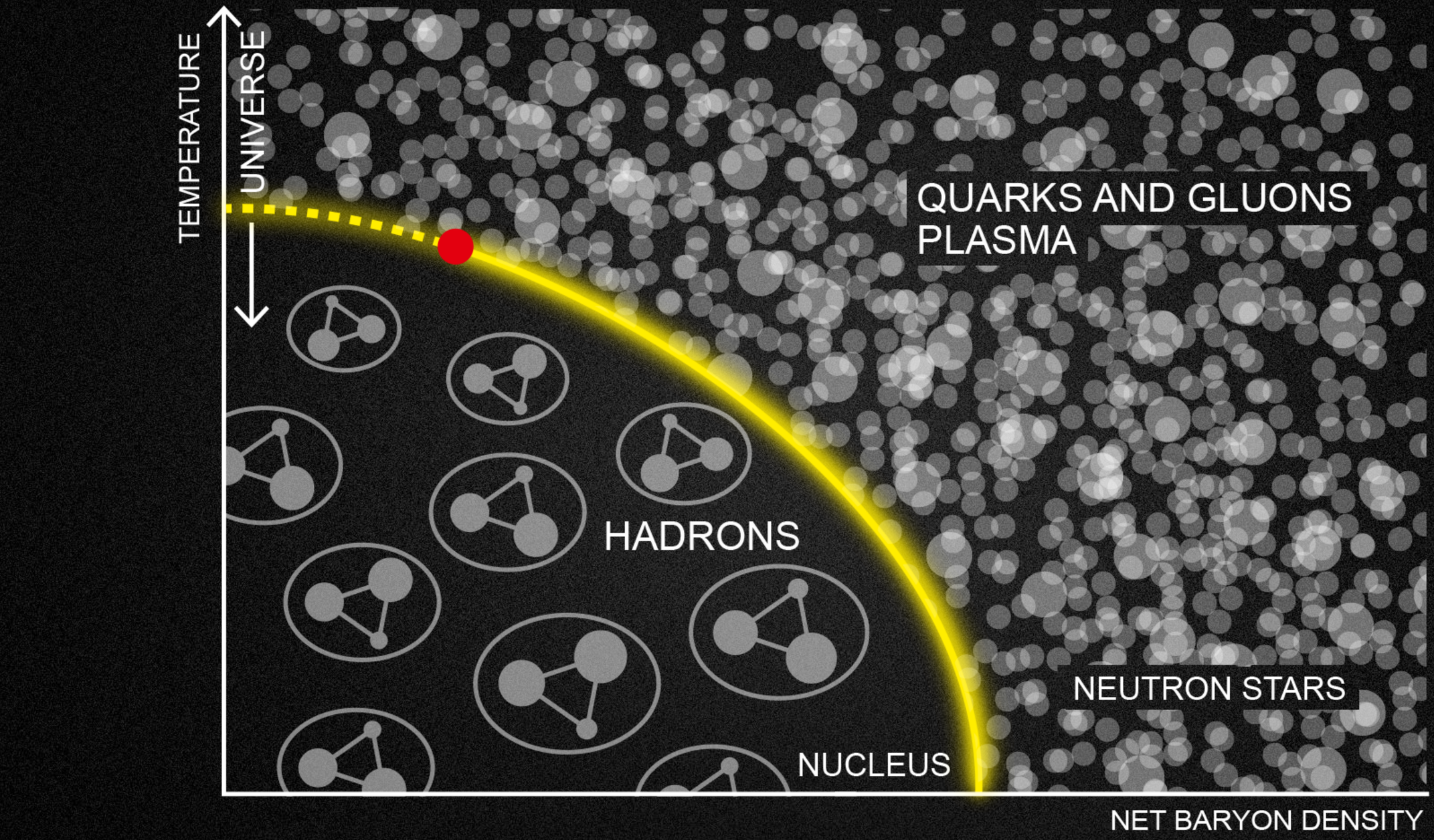
VAPOUR



PLASMA

MATTER CAN TRANSFORM


TEMPERATURE
VAPOR
LIQUID
SOLID
PRESSURE


TEMPERATURE
UNIVERSE
QUARKS AND GLUONS
PLASMA
HADRONS
NEUTRON STARS
NUCLEUS
NET BARYON DENSITY

WHAT DO WE KNOW ABOUT MATTER?

MATTER HAS ACQUIRED STRUCTURE STARTING FROM A PLASMA OF QUARKS AND GLUONS

MATTER IS MADE OF VACUUM

MATTER IS IMMATERIAL

MATTER IS STRUCTURED BY 4 FORCES

4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...

ORDINARY MATTER REPRESENTS
4,8% OF THE UNIVERSE

99% OF CURRENT MATTER HAS BEEN MADE IN 3 MINUTES

HOW CAN WE RECREATE PRIMITIVE MATTER?

ACCELERATES LEAD NUCLEI AT
99.9999997% OF THE SPEED OF LIGHT

WHEN TWO LEAD NUCLEI COLLIDE

ALICE

BIG BANG

LITTLE BIG BANG

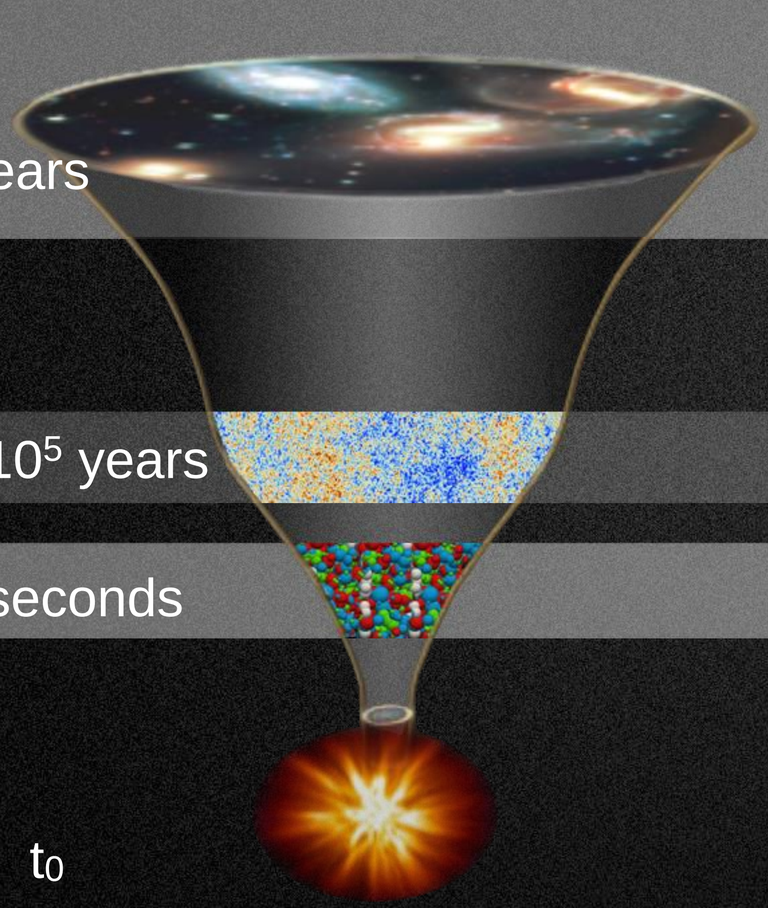
$t_0 + 13.8\times10^9$ years

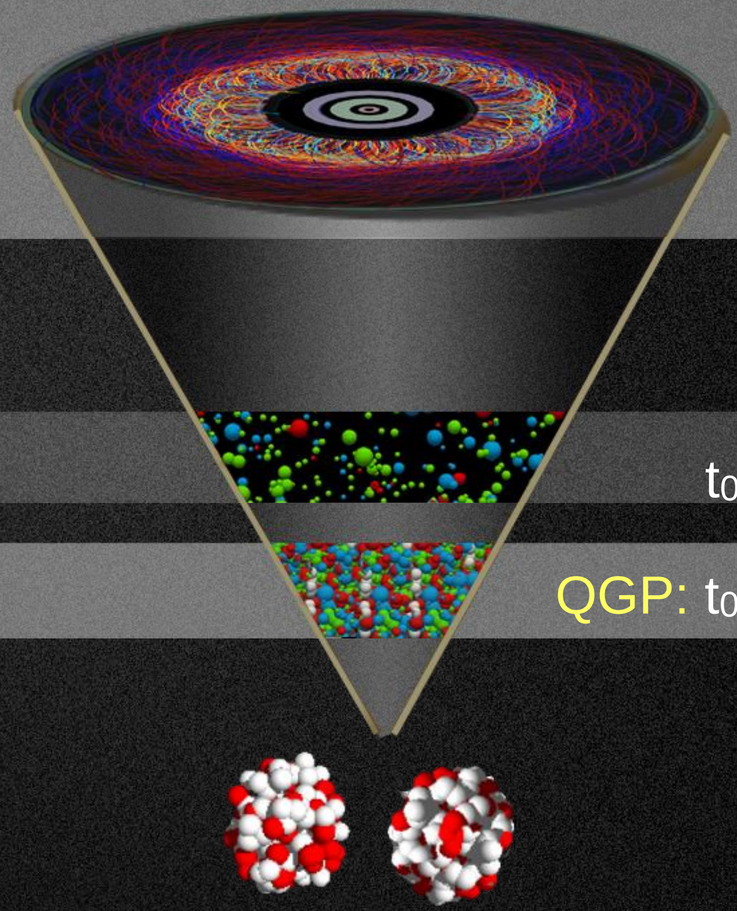
CMB: $t_0 + 3.8\times10^5$ years

QGP: $t_0 + 10^{-6}$ seconds

hadron gas:
$t_0 + 10^{-23}$ seconds

QGP: $t_0 + 10^{-24}$ seconds



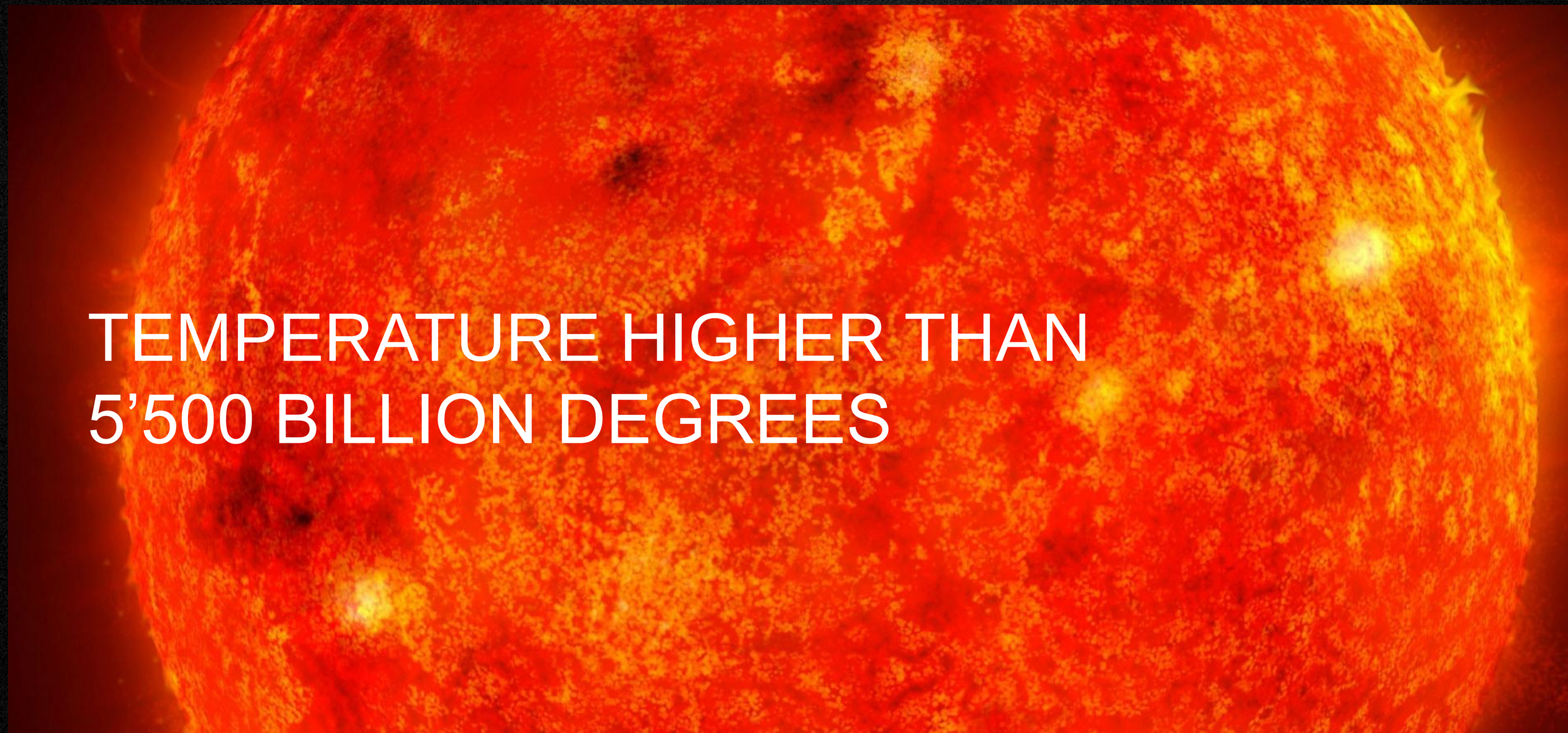


t_0

t_0

WHAT HAVE WE LEARNED UP TO NOW?

NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS



NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT EXTENDS IN A MICROSCOPIC VOLUME 10^{35} TIMES SMALLER THAN THE SIZE OF THE PRIMORDIAL UNIVERSE

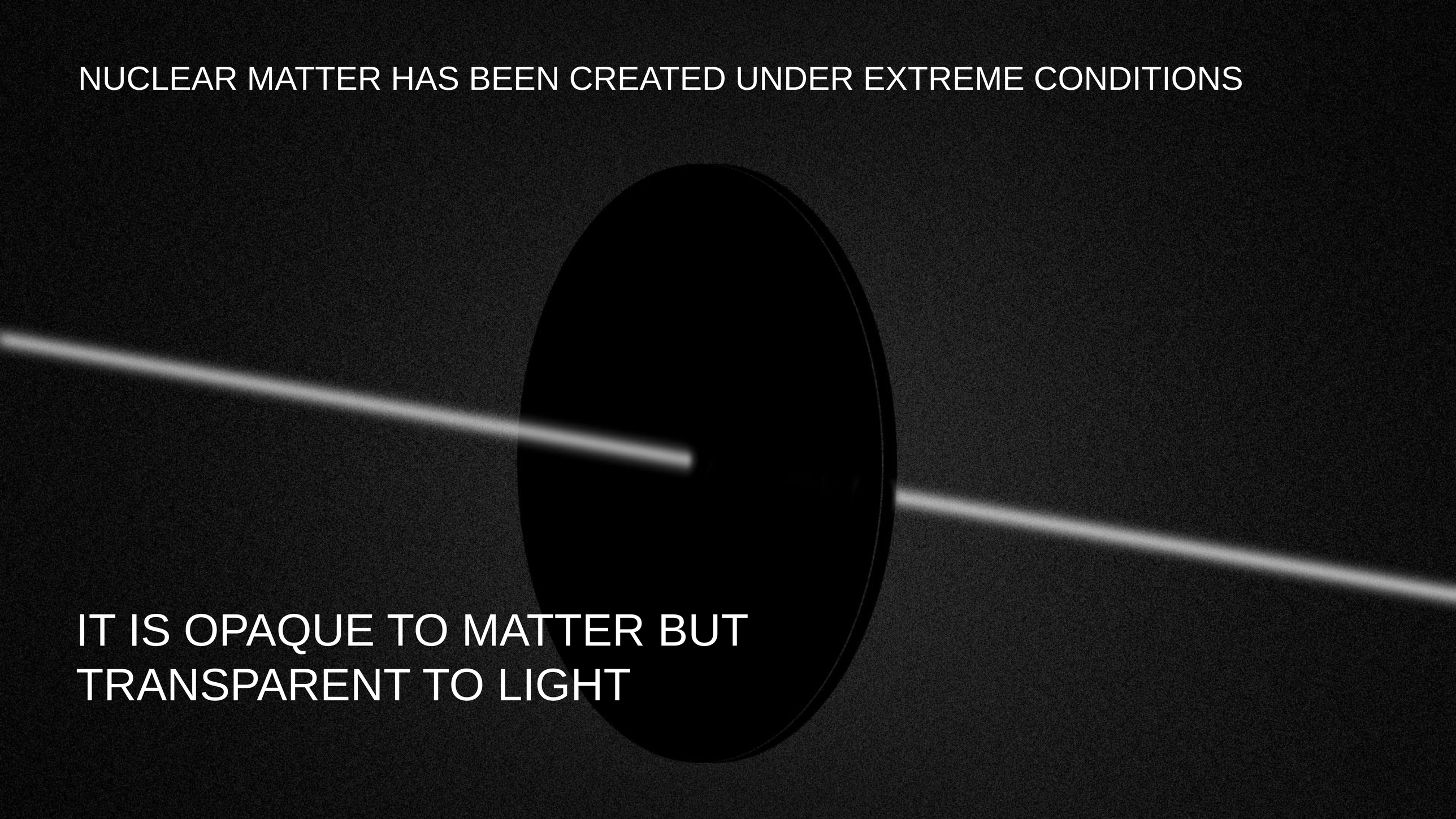
NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT LASTS AN INFINITELY SHORT TIME, 10^{17} TIMES SHORTER THAN THE PRIMITIVE MATTER OF THE BIG BANG

NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS

IT HAS THE PROPERTIES OF A PERFECT LIQUID (ZERO VISCOSITY)

NUCLEAR MATTER HAS BEEN CREATED UNDER EXTREME CONDITIONS



IT IS OPAQUE TO MATTER BUT
TRANSPARENT TO LIGHT

WHAT DO WE KNOW ABOUT MATTER?

MATTER IS MADE OF VACUUM

MATTER IS IMMATERIAL

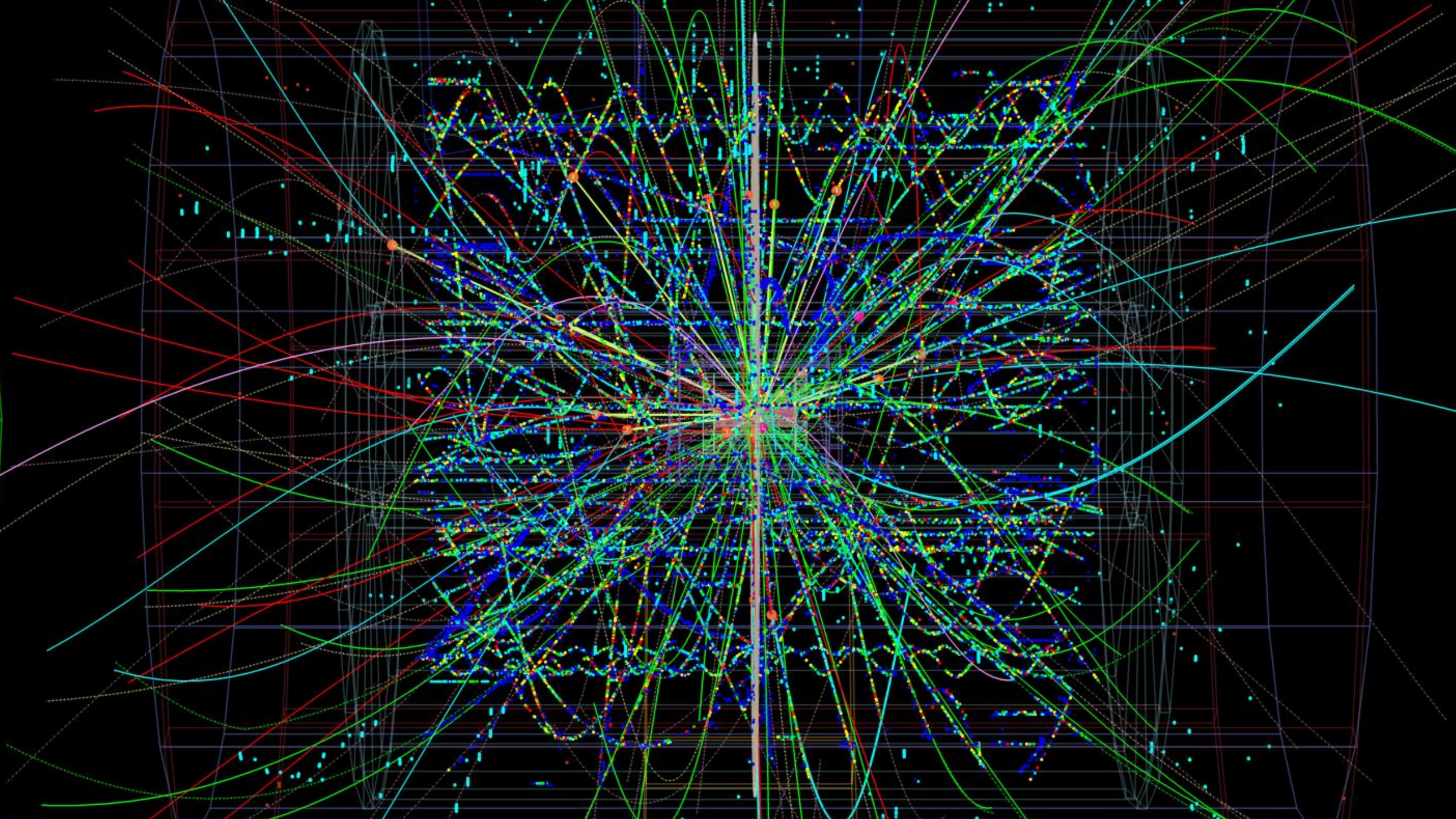
MATTER IS STRUCTURED BY 4 FORCES

4 ELEMENTARY PARTICLES CONSTITUTE ORDINARY MATTER...

ORDINARY MATTER REPRESENTS
4,8% OF THE UNIVERSE

99% OF CURRENT MATTER HAS BEEN MADE IN 3 MINUTES

MATTER HAS ACQUIRED STRUCTURE STARTING FROM A PLASMA OF QUARKS AND GLUONS



ALICE

A JOURNEY OF DISCOVERY