

THE OUTLOOK FOR FUNDAMENTAL PHYSICS

DAVID GROSS

Particle Physics and Cosmology after the discovery of Higgs boson

Oct. 21, 2013.

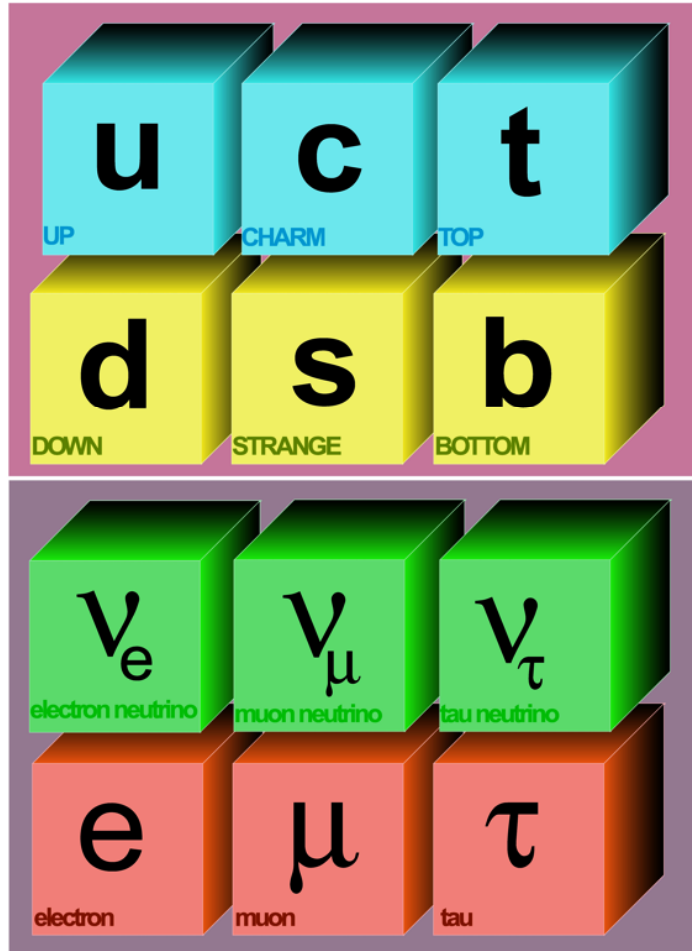
Tohoku Forum for Creativity

Kavli Institute
for
Theoretical
Physics



The Standard THEORY Elementary Particles

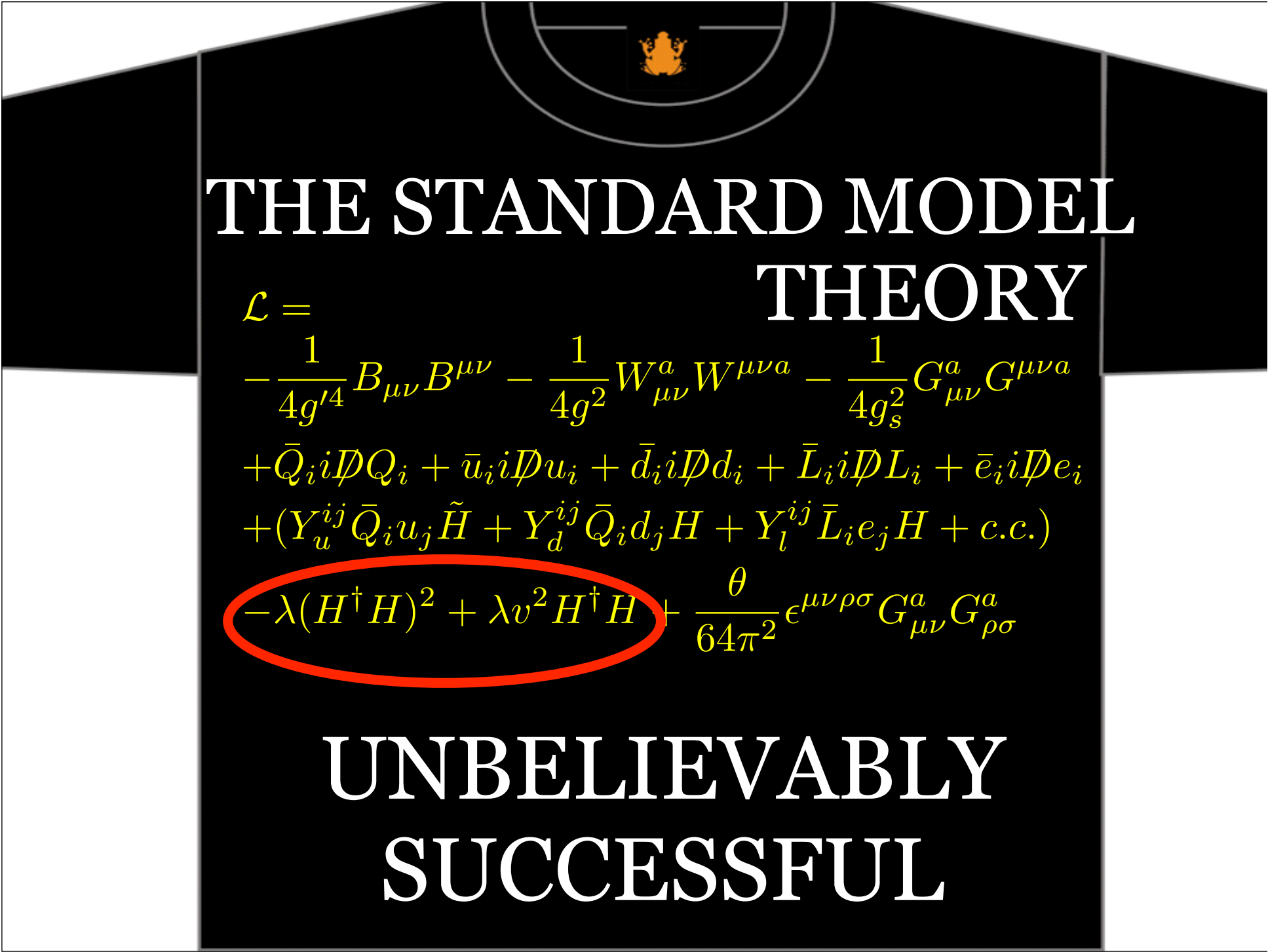
leptons *quarks*



force carriers

- 1 E & M
- 2 WEAK
- 3 STRONG

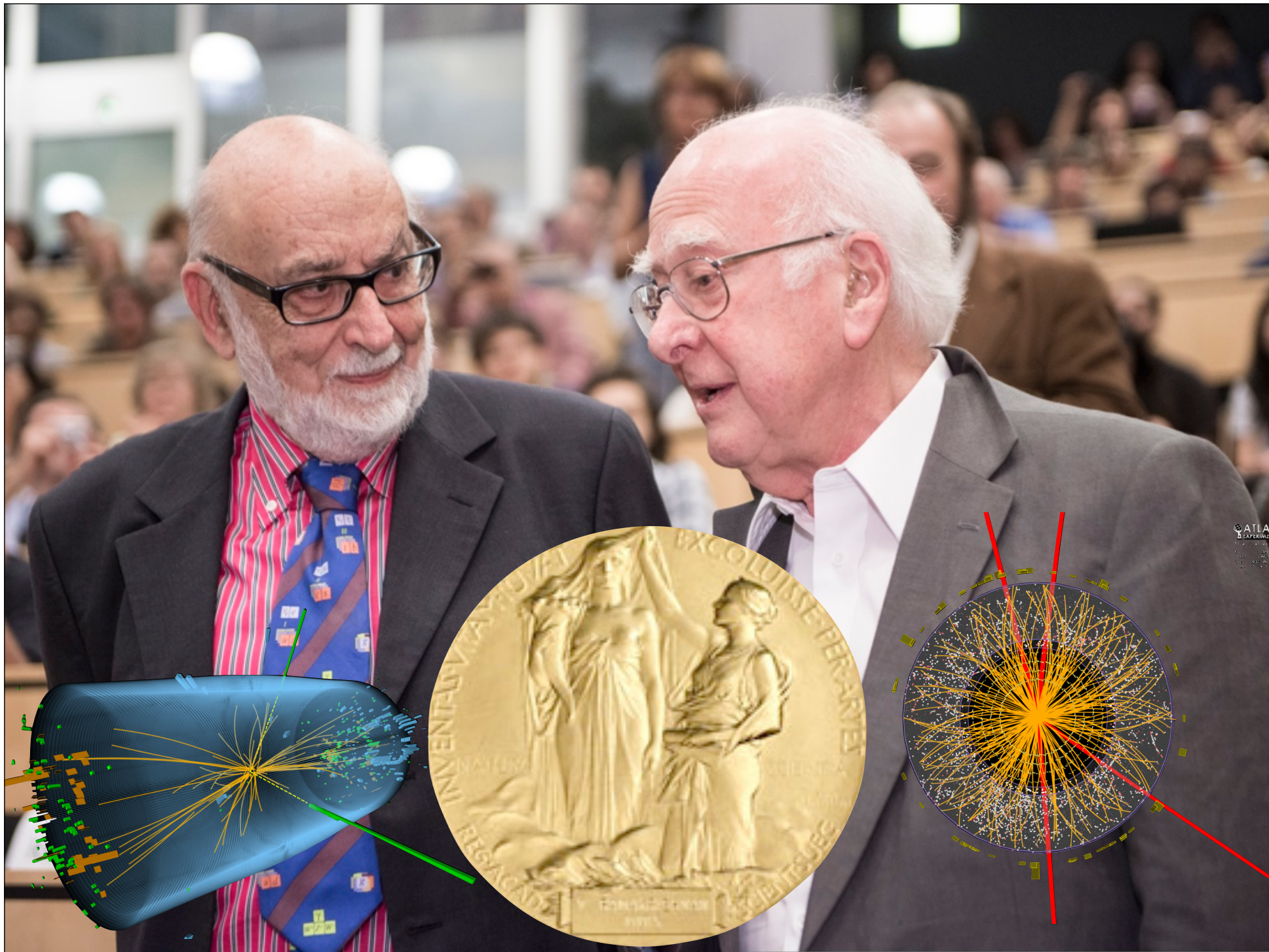
HIGGS



THE STANDARD MODEL THEORY

$$\begin{aligned}\mathcal{L} = & -\frac{1}{4g'^4} B_{\mu\nu} B^{\mu\nu} - \frac{1}{4g^2} W_{\mu\nu}^a W^{\mu\nu a} - \frac{1}{4g_s^2} G_{\mu\nu}^a G^{\mu\nu a} \\ & + \bar{Q}_i i \not{D} Q_i + \bar{u}_i i \not{D} u_i + \bar{d}_i i \not{D} d_i + \bar{L}_i i \not{D} L_i + \bar{e}_i i \not{D} e_i \\ & + (Y_u^{ij} \bar{Q}_i u_j \tilde{H} + Y_d^{ij} \bar{Q}_i d_j H + Y_l^{ij} \bar{L}_i e_j H + c.c.) \\ & - \lambda (H^\dagger H)^2 + \lambda v^2 H^\dagger H + \frac{\theta}{64\pi^2} \epsilon^{\mu\nu\rho\sigma} G_{\mu\nu}^a G_{\rho\sigma}^a\end{aligned}$$

UNBELIEVABLY
SUCCESSFUL



BEYOND THE ST_h

- Dark Matter ✓
- Neutrino Masses
- Baryon Asymmetry
- Cosmic Acceleration

Exp

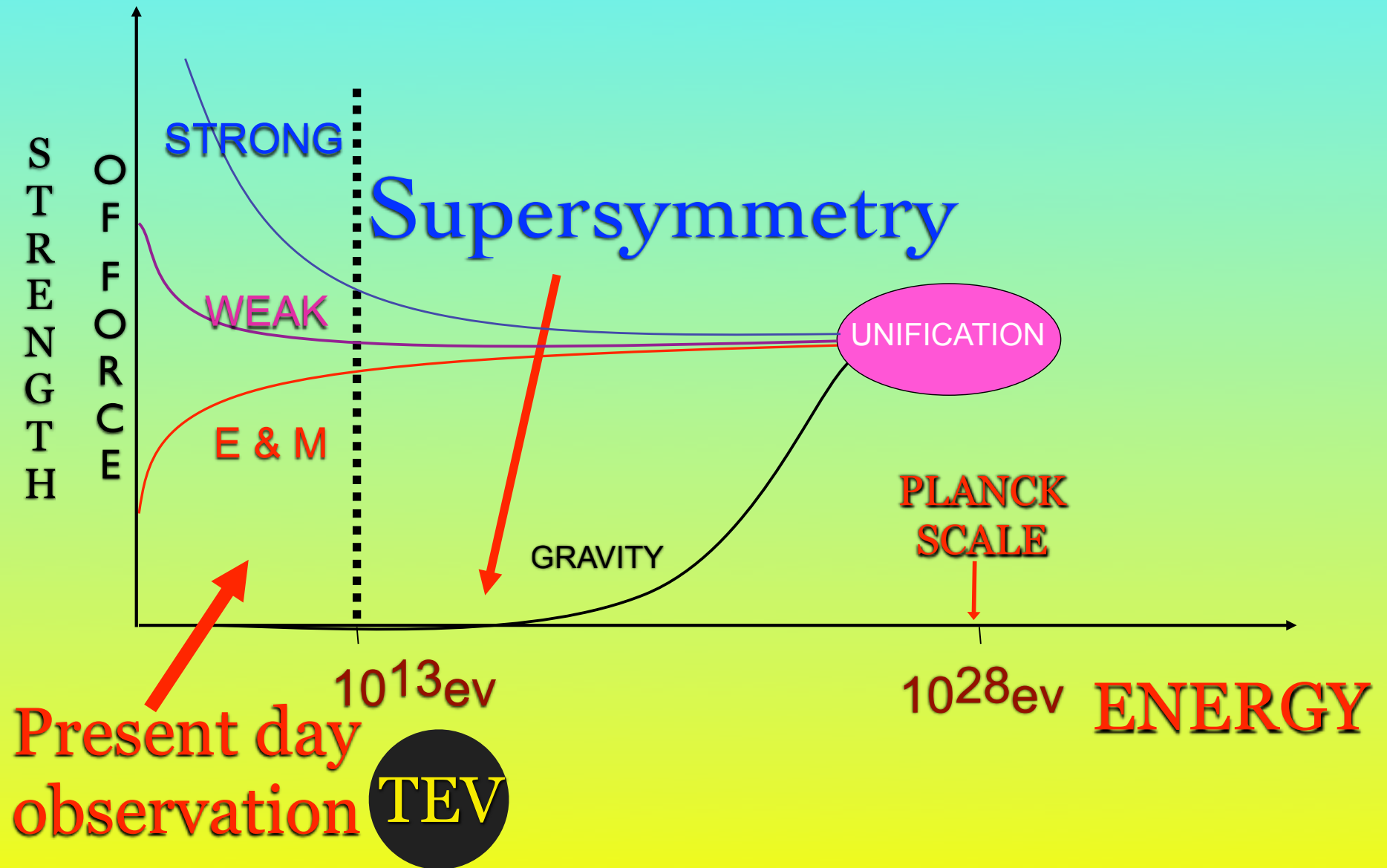
TEV

- Unification ✓
- Electroweak scale, “hierarchy” ✓
- Flavor masses, mixings, generations
- Cosmology, inflation, vacuum energy

Th

SUSY = QUANTUM
DIMENSIONS of SPACE TIME

BEYOND THE STANDARD MODEL



AN IMPORTANT CLUE
FOR UNIFICATION

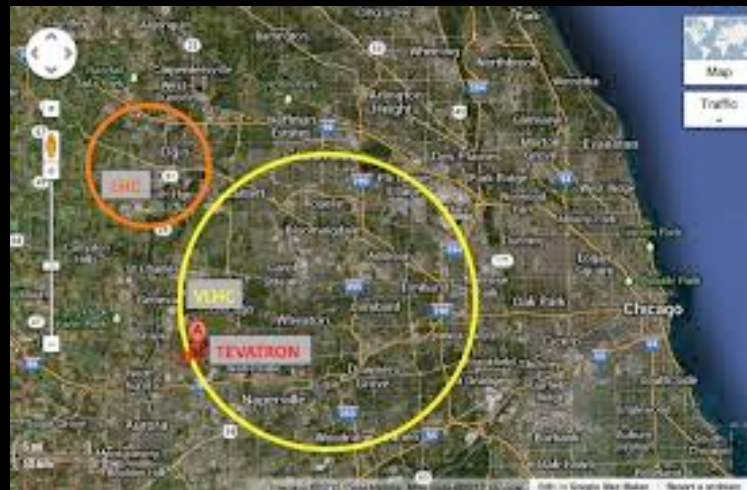
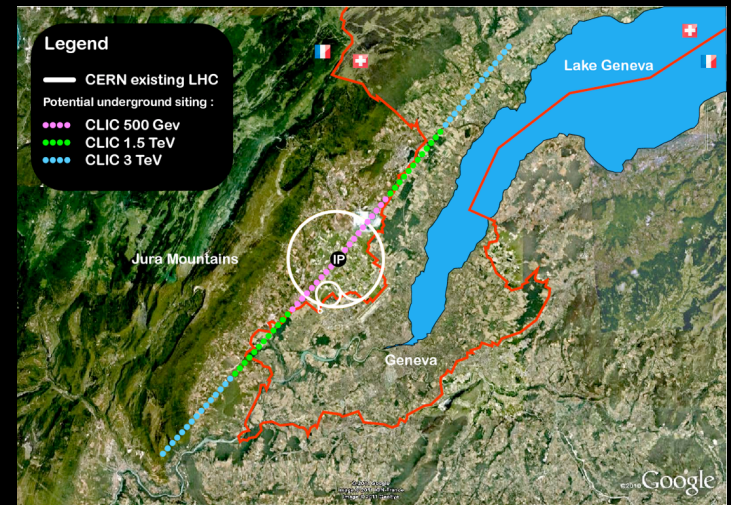
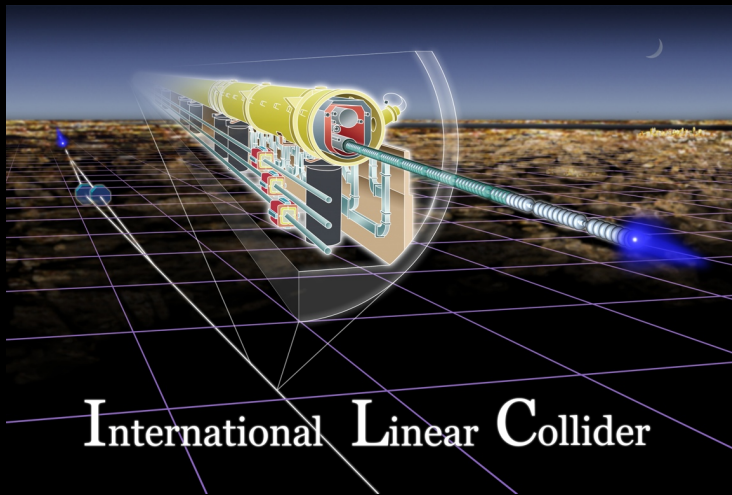
(INCLUDING GRAVITY)

AND SUSY AT $\sim$ TEV

OR

A COINCIDENCE

WE MUST FULLY EXPLORE THE 10-100 TEV ENERGY RANGE



私たちは

国際リニアコライダー

計画を**応援**しています。

We support the International
Linear Collider Project.

一関商工会議所／岩手県ILC推進協議会

THE FUTURE

2 EXTREME SCENARIOS



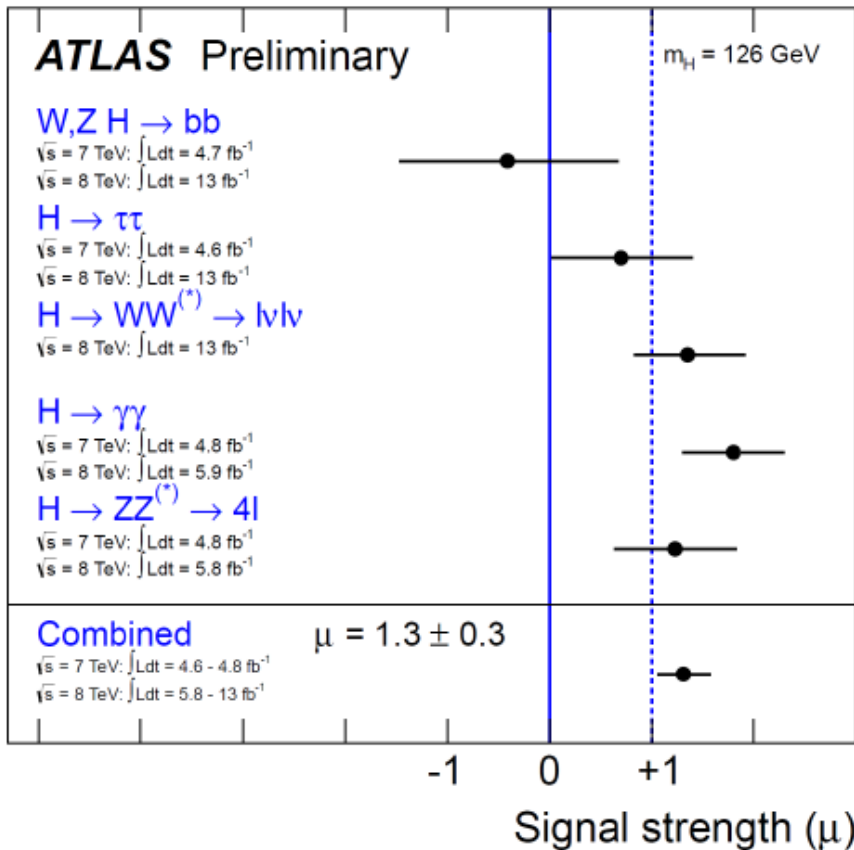
OPTIMISM



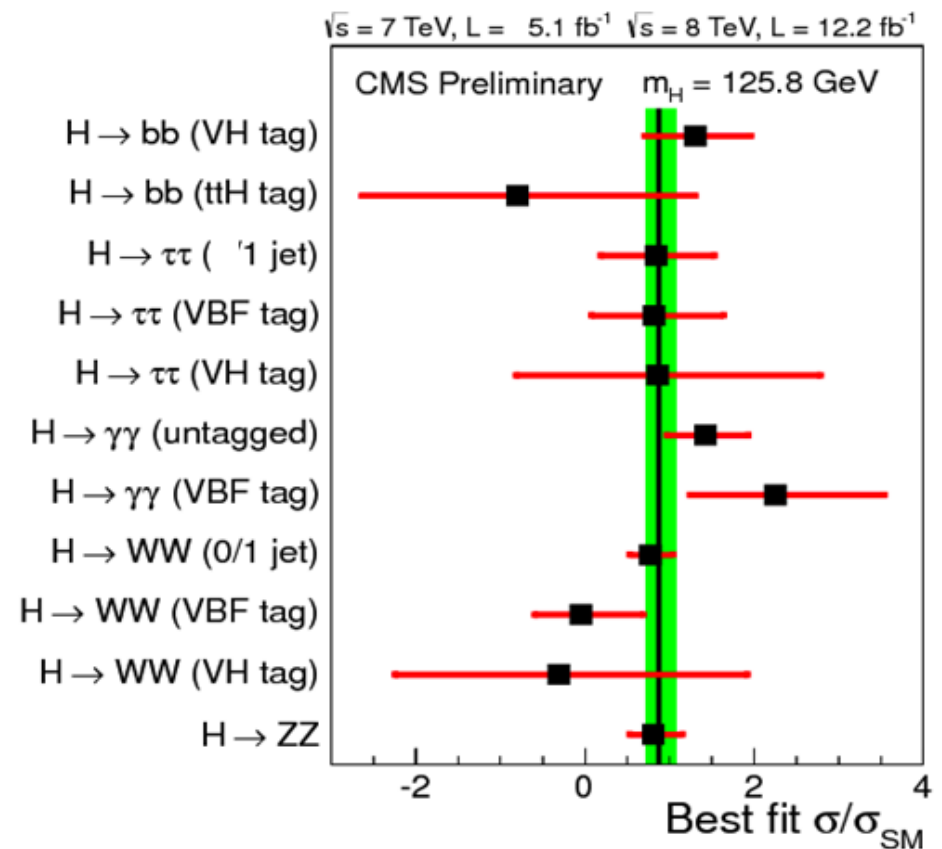
PESSIMISM

The Extreme Pessimistic Scenario

Best-fit Higgs mass m_H :
 126.0 ± 0.4 (stat) ± 0.4 (syst) GeV



• $M = 125.8 \pm 0.4$ (stat) ± 0.4 (syst) GeV



• $\sigma/\sigma_{SM} = 0.88 \pm 0.21$

- ★ The Higgs(-like) boson = SM Higgs.
- ★ No direct signal for SUSY (or anything else) .
- ★ No detection of Dark Matter, in the sky, underground or at the LHC.
- ★ No direct indication of the next threshold!
Maybe 10^{10} -- 10^{19} GeV

WHAT TO DO ?

The Extreme Optimistic Scenario

- ★ The Higgs(-like) boson $\neq$ SM Higgs
- ★ Direct production of SUSY particles
- ★ Detection of Dark Matter, in the sky, underground and at the LHC
- ★ Strong guidance for the next steps!

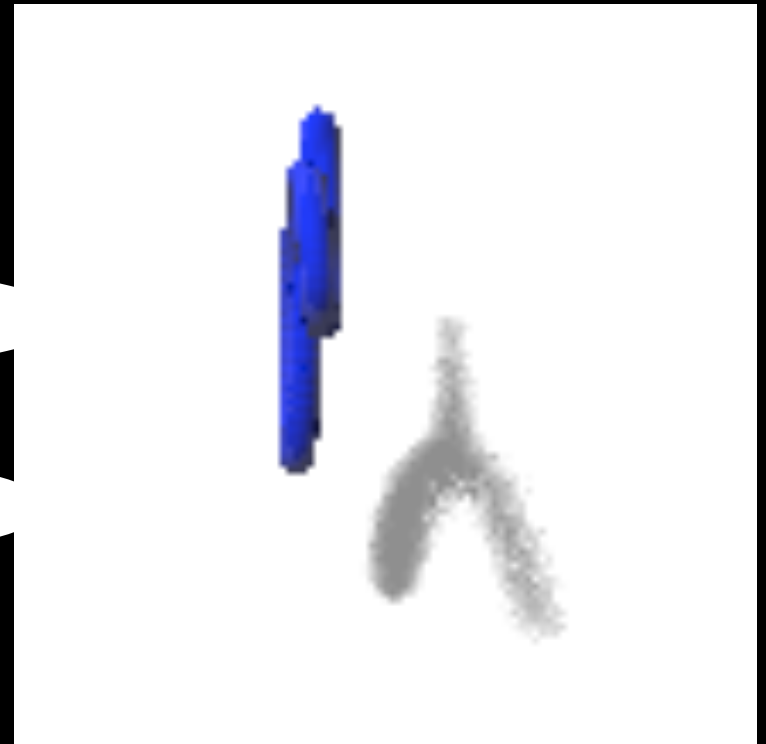
ILC, CLIC, HL-LHC, VHE-LHC, HHC, ...

WE MUST
FULLY
EXPLORE
THE 10-100 TEV
ENERGY RANGE

The Framework of Theoretical Physics

QUANTUM
FIELD
FRAMEWORK

Standard Theory

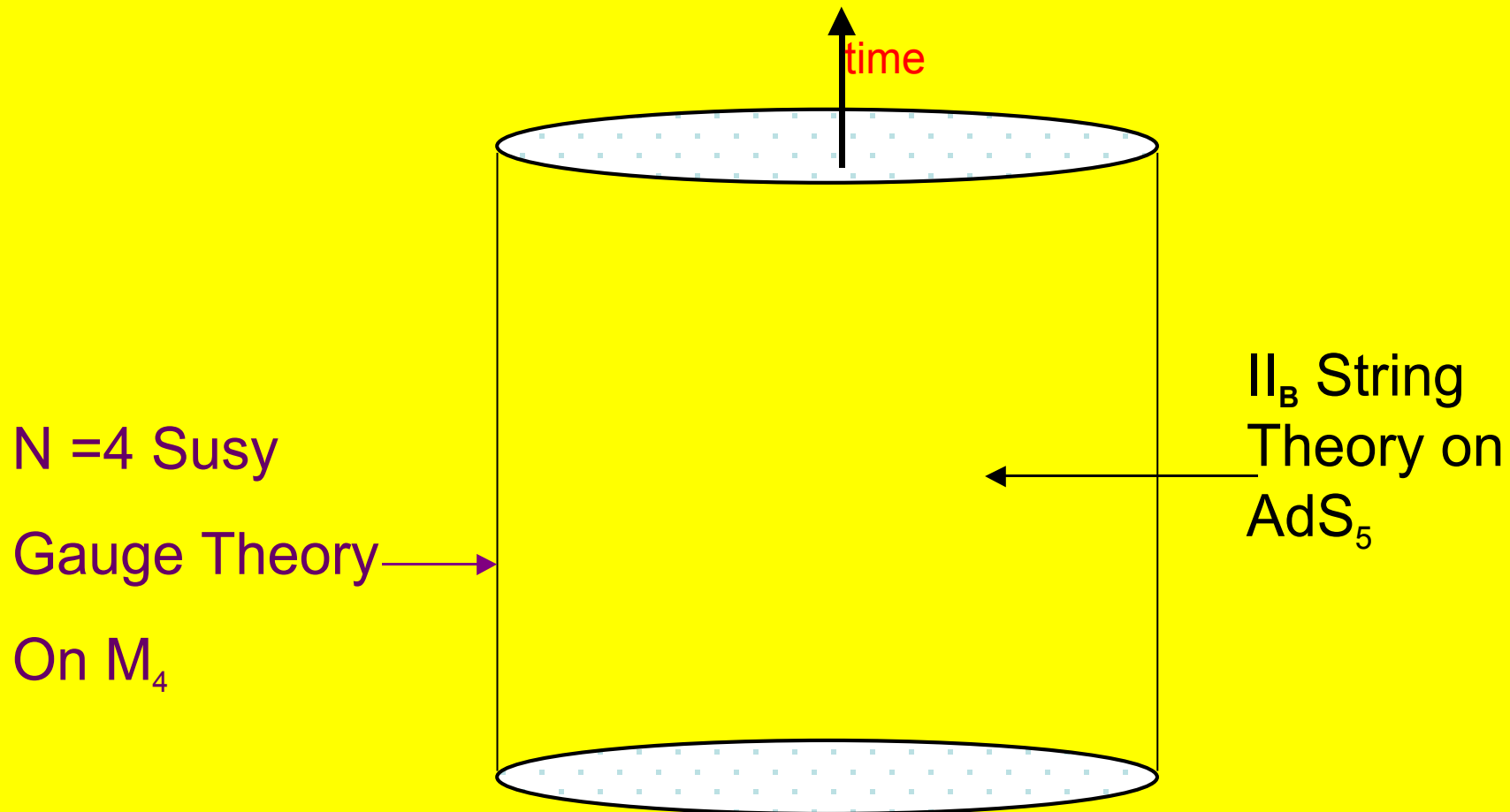


The Framework of Theoretical Physics

An incredible
FRAMEWORK

that includes strings, branes,
all consistent field theories
and quantum gravity.

GAUGE--STRING DUALITY



NEW INSIGHTS INTO GAUGE THEORY

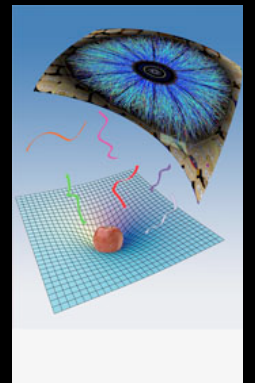
STRING THEORY OF QCD

TRANSPORT COEFFICIENTS

QUARK-GLUON FLUID

QUANTUM PHASE TRANSITIONS IN
STRONGLY CORRELATED SYSTEMS

RESOLUTION OF THE PUZZLES
OF QUANTUM GRAVITY



NEW CONCEPTS OF SPACE-TIME

WHAT FIXES THE
DYNAMICS?

WHAT FIXES THE INITIAL
(FINAL) STATE ?

SPACE-TIME

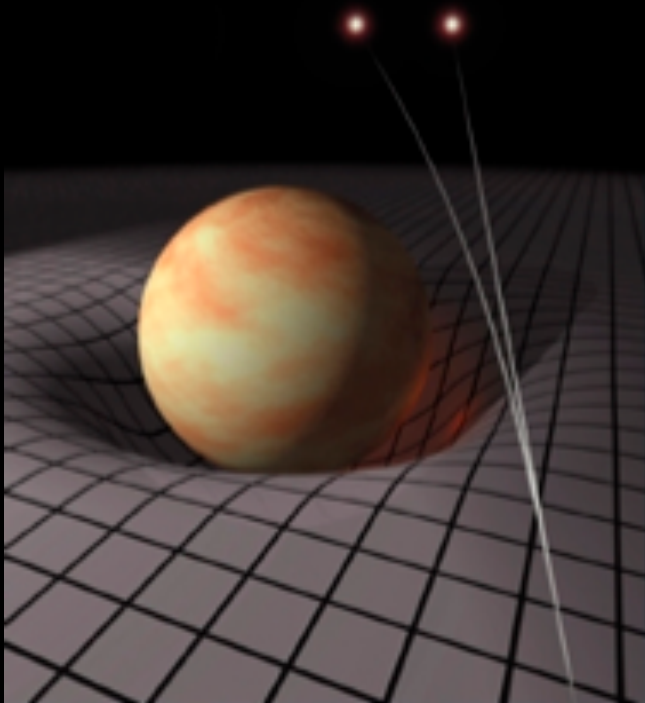
Smooth Manifold

Fixed Topology

Fixed Number of Dimensions

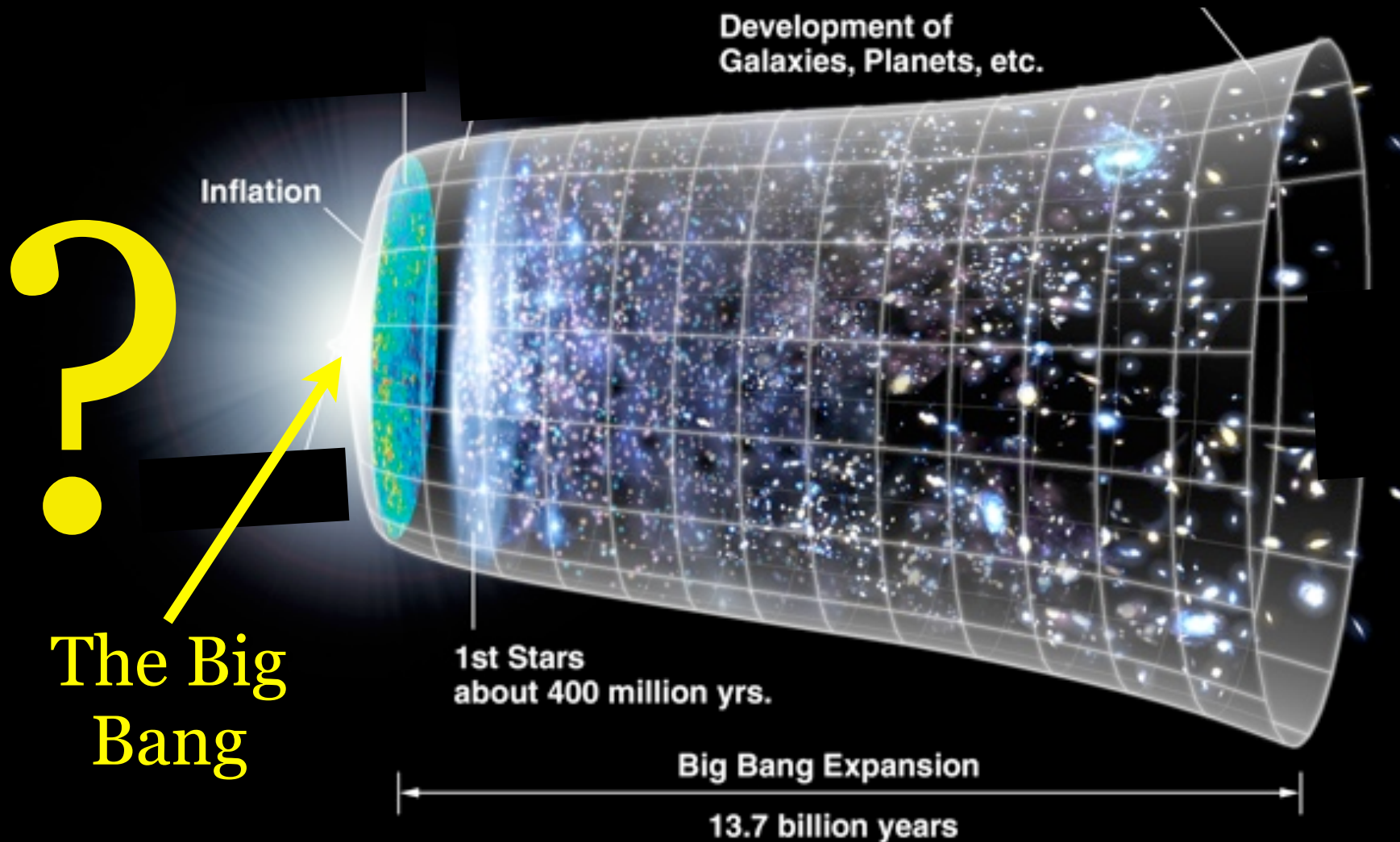
What are the rules of physics
without spacetime?

IS ALL OF SPACETIME
EMERGENT?



IS GRAVITY
EMERGENT?

THE UNIVERSE



Λ

De Sitter space
Eternal Inflation...

THE END

B
O
U
N
D
A
R
Y

THE
UNIVERSE

=

SPACETIME
HISTORY

WHAT ARE THE
OBSERVABLES?

WHAT ARE
THE RULES ?

THE BEGINNING

WE HAVE A WONDERFUL
THEORY OF ELEMENTARY
PARTICLES

BUT THE MOST EXCITING
QUESTIONS REMAIN TO BE
ANSWERED

NEW EXPERIMENTS AND
NEW ACCELERATORS
ARE COMING SOON

EXCITING NEW
DISCOVERIES ARE
AROUND THE CORNER

THE BEST
IS YET
TO COME

Congratulations !

TOHUKO FORUM
FOR CREATIVITY

GOOD LUCK

THE

END