Frontier Science and the ILC

US-Japan Advanced Science and Technology Symposium

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UC Berkeley, Lawrence Berkeley Laboratory, U. Tokyo

April 30, 2013

How did the Universe begin?

What is its fate?

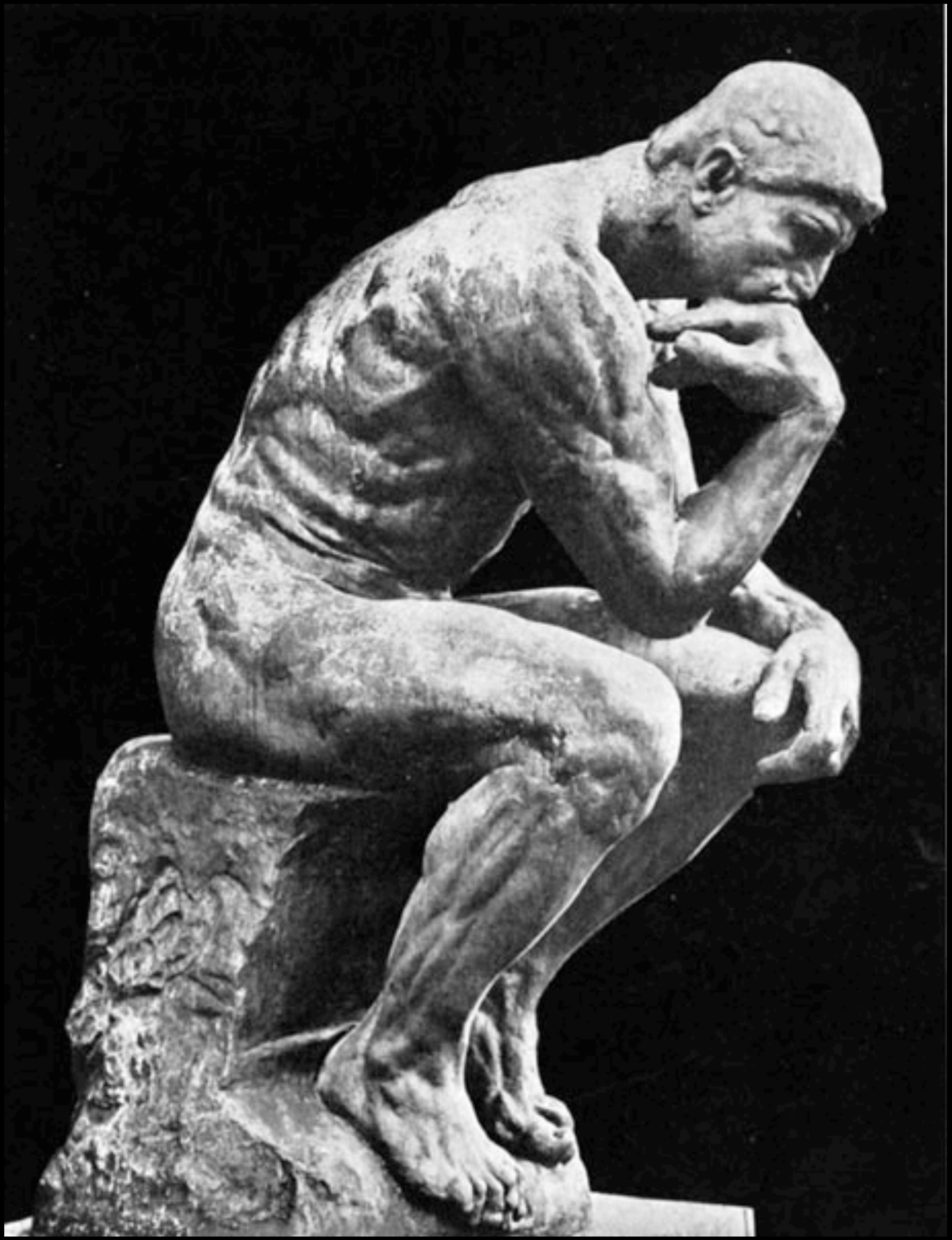
What is it made of?

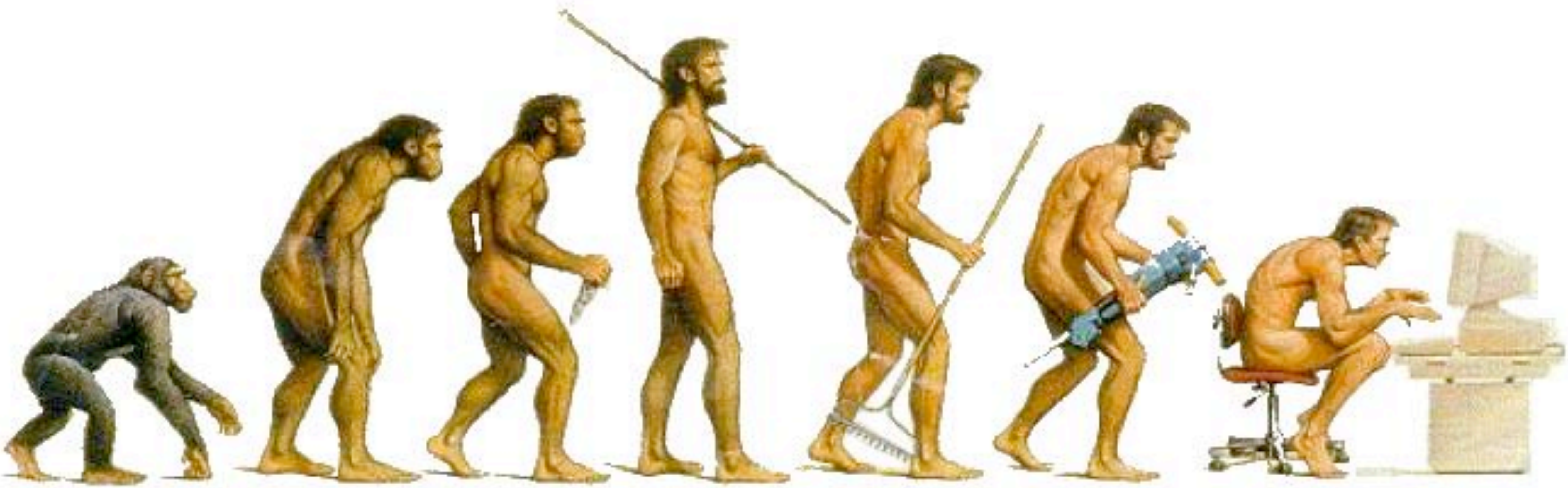
What are its fundamental laws?

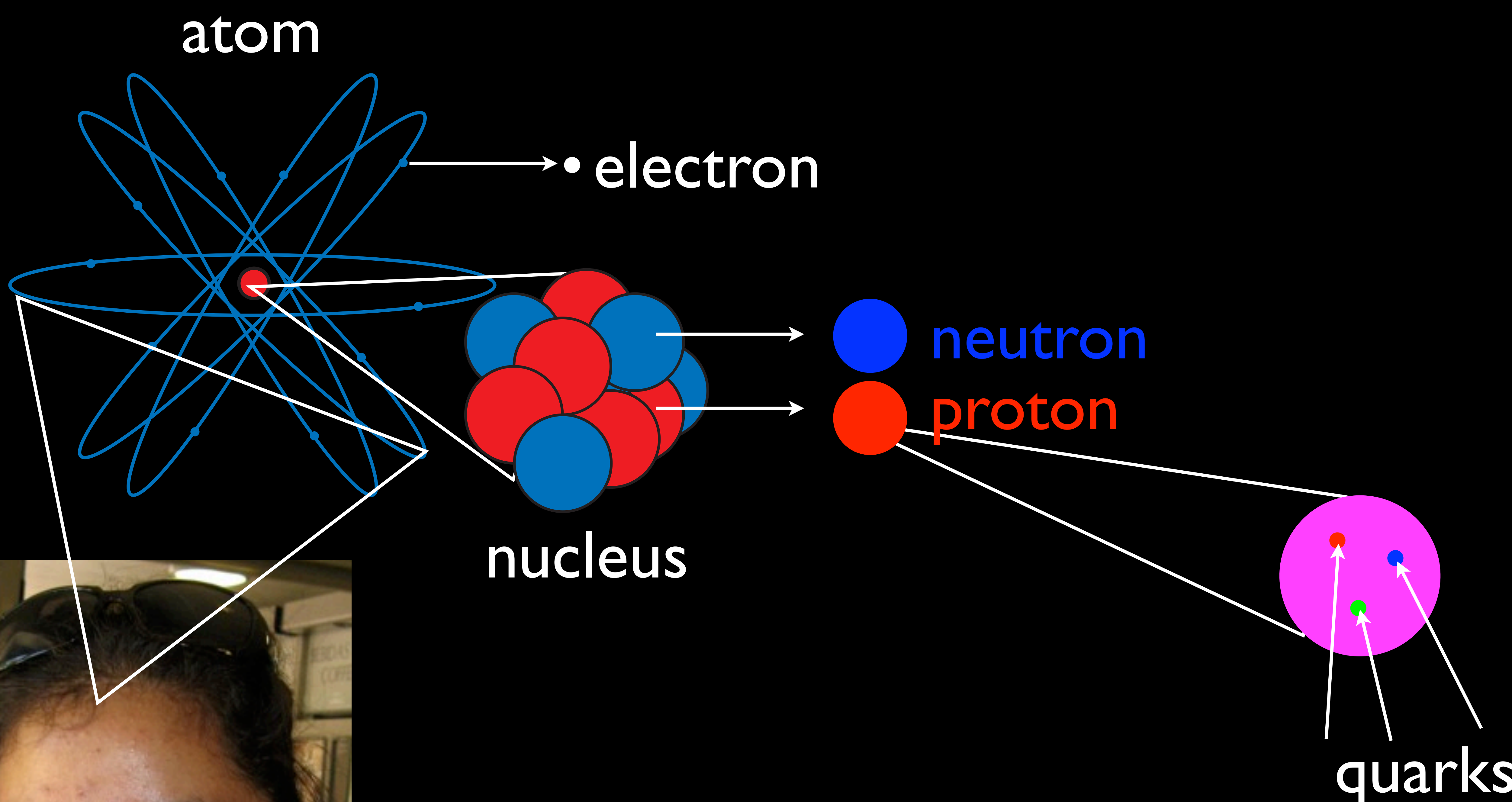
Why do we exist?





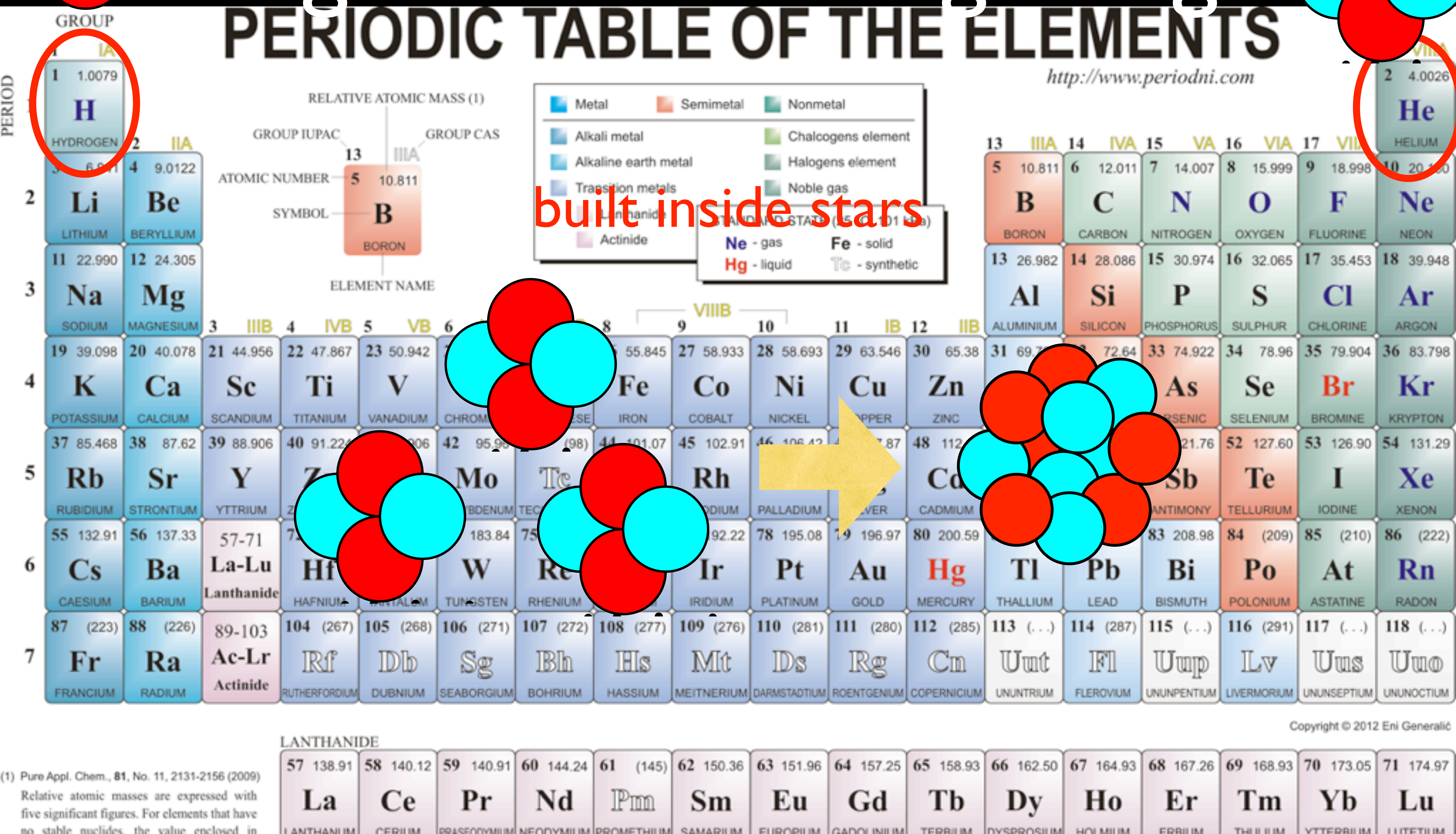






number of protons determines the chemical element

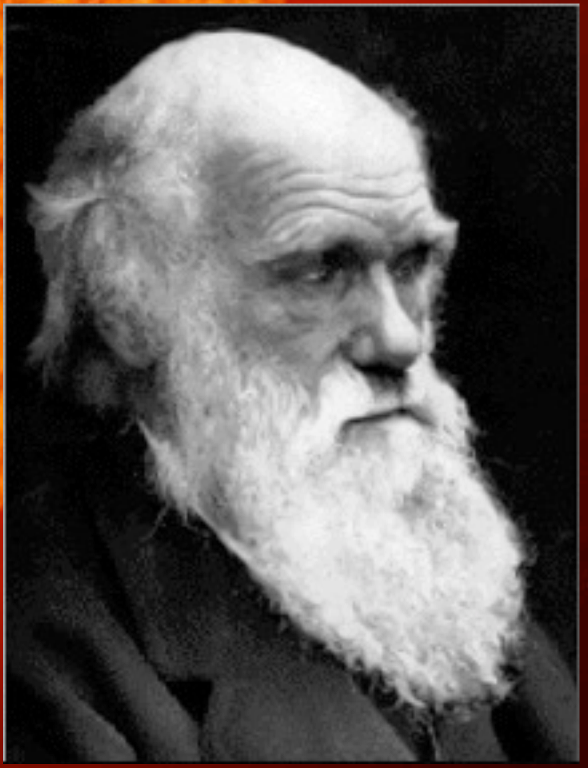
only hydrogen and helium right after the Big Bang



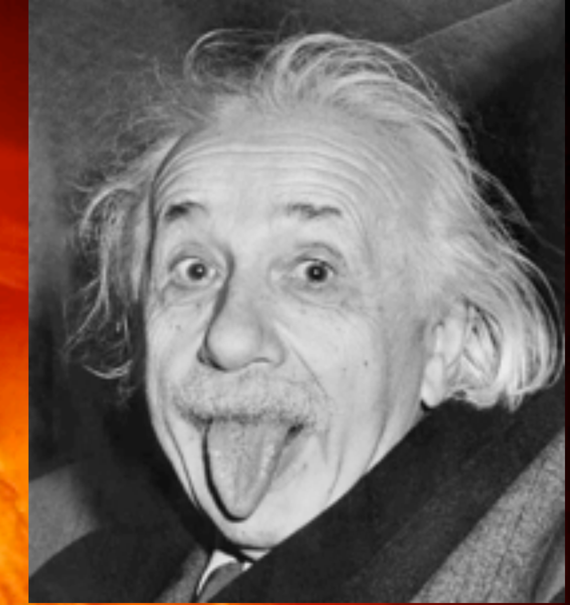
Why does the Sun shine?

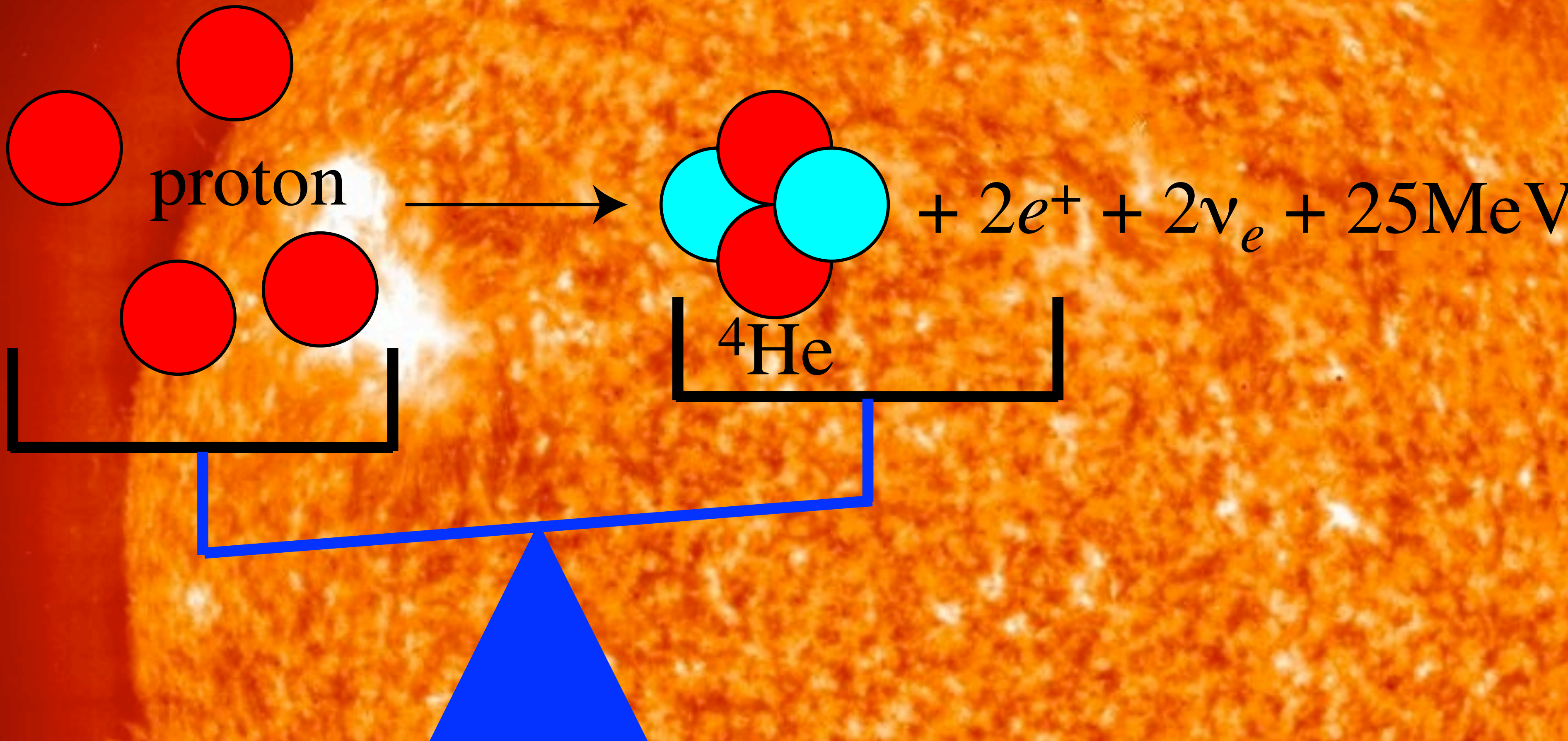
Lord Kelvin:
the Sun can't possibly shine more than 20 thousand years

Darwin:
given geological information and evolution of life, it must be older than 300 million years



burning atoms?



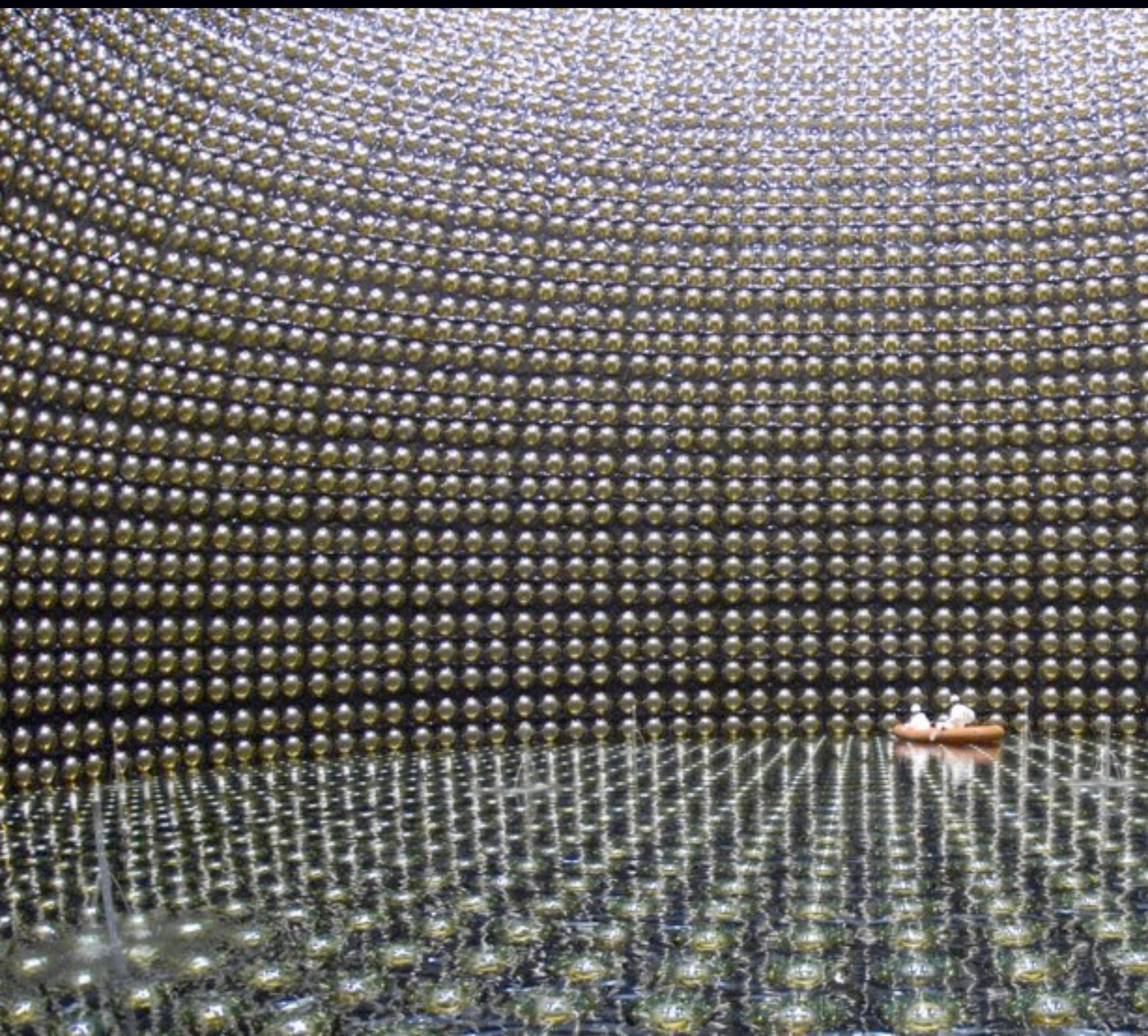


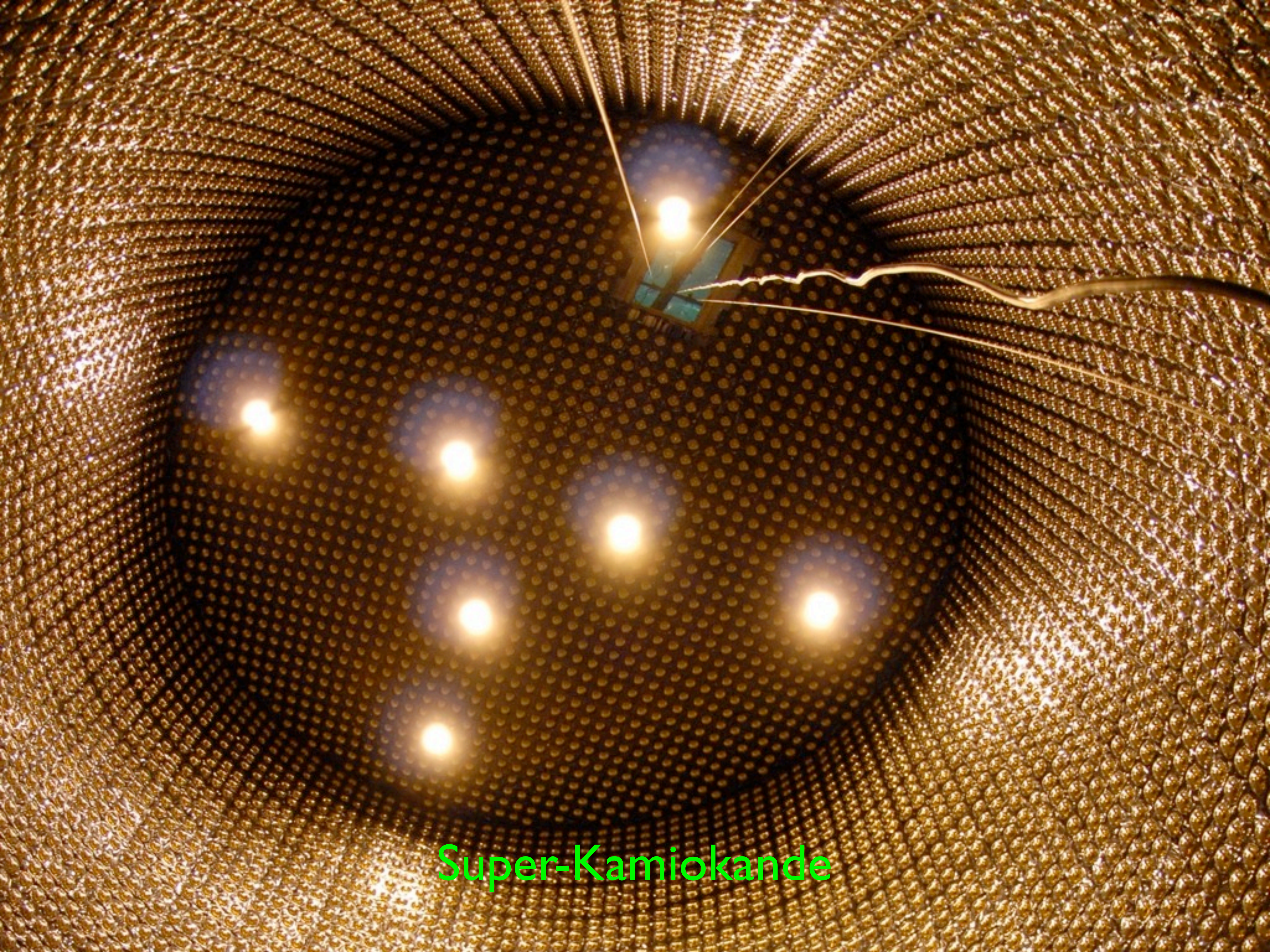
E=mc^2

the Sun is getting lighter by 4 million tons every second

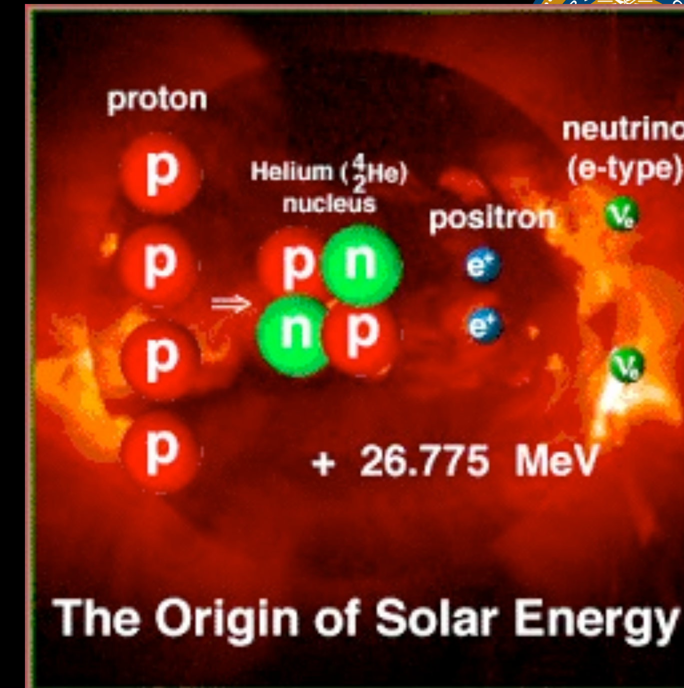
a hundred trillion neutrinos go through our body every second

How to s
invisible neut



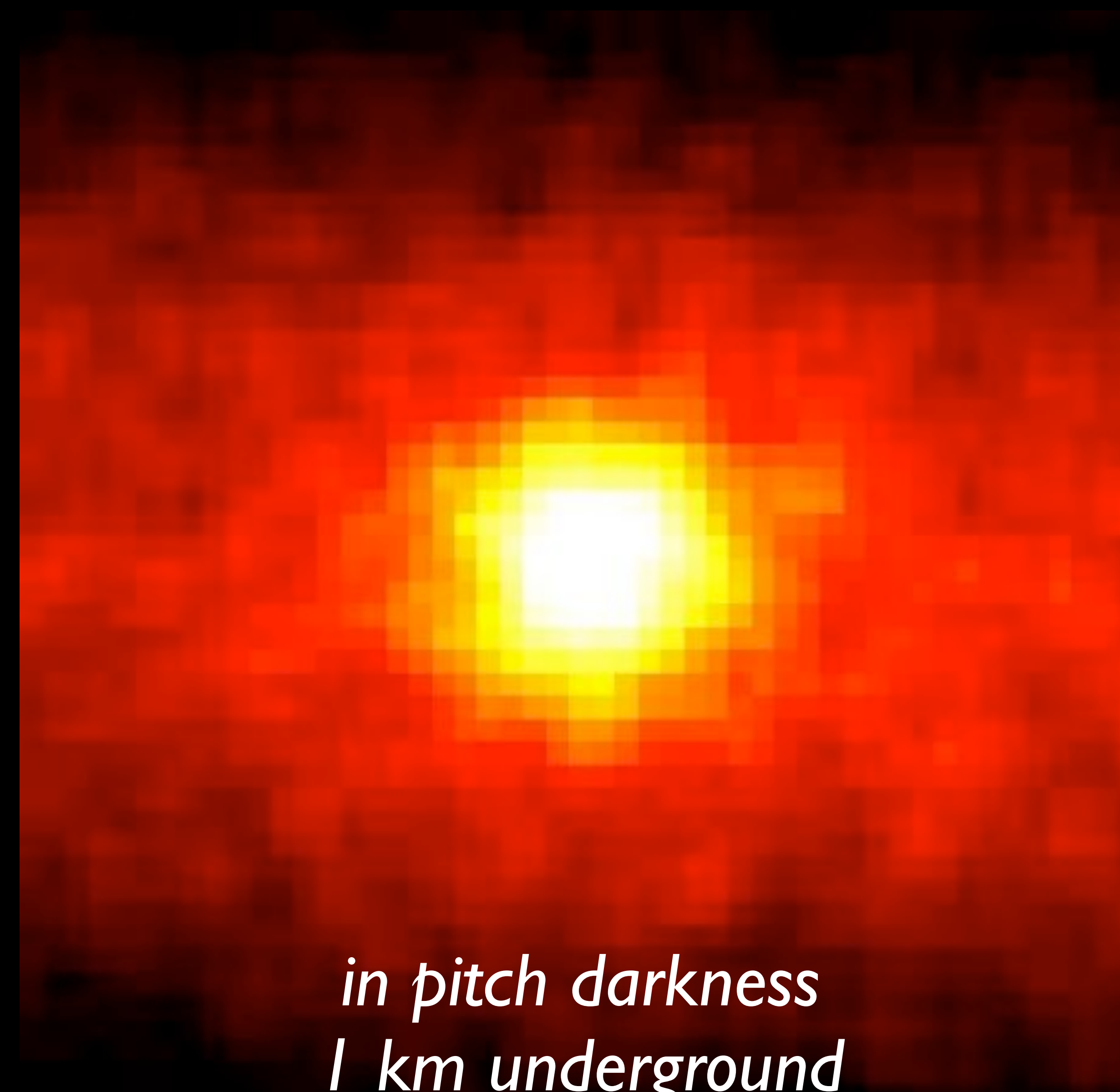

Super-Kamiokande

evidence



burning atoms in the Sun produces neutrinos

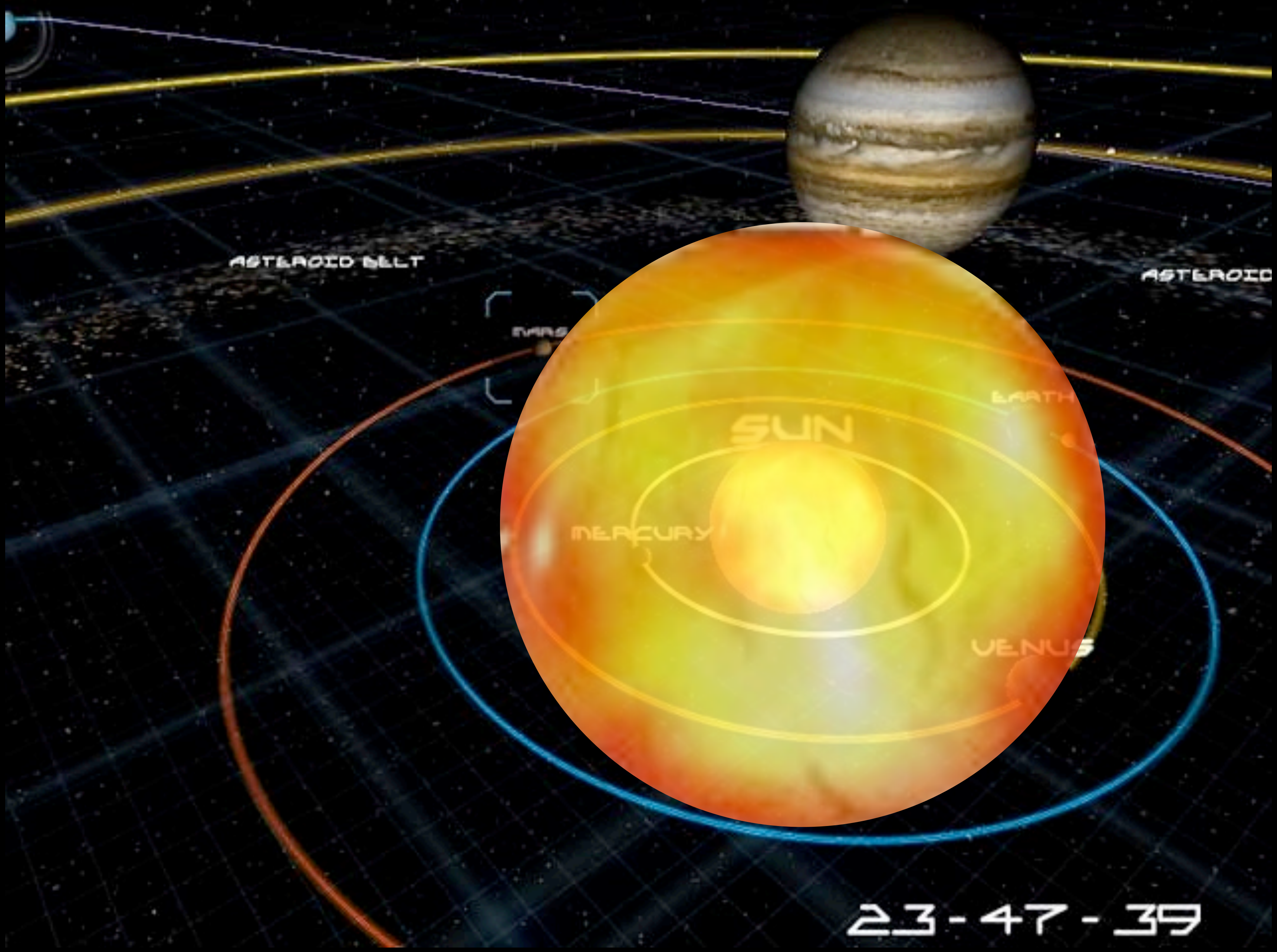
trillions through our body every second



in pitch darkness

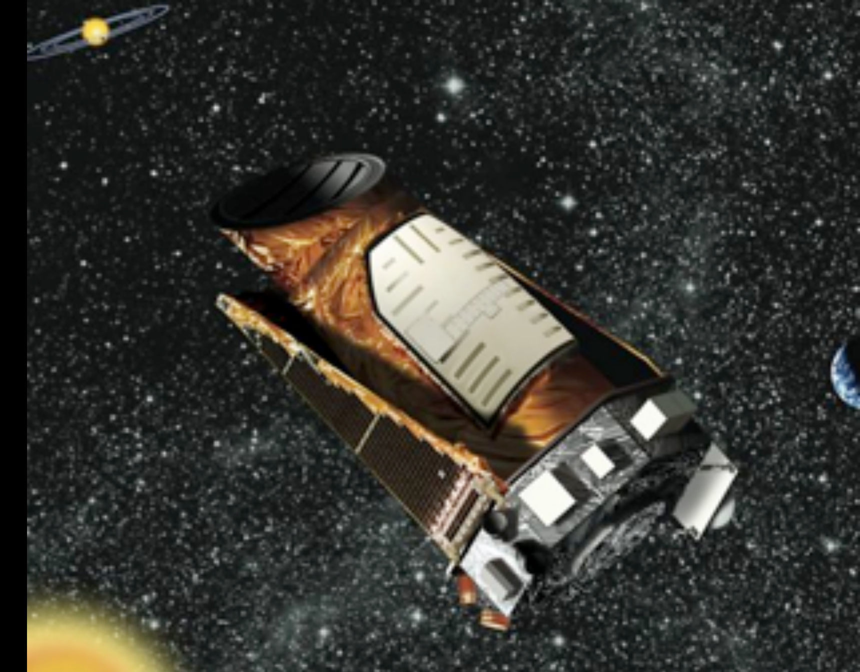
1 km underground

fate of the Sun



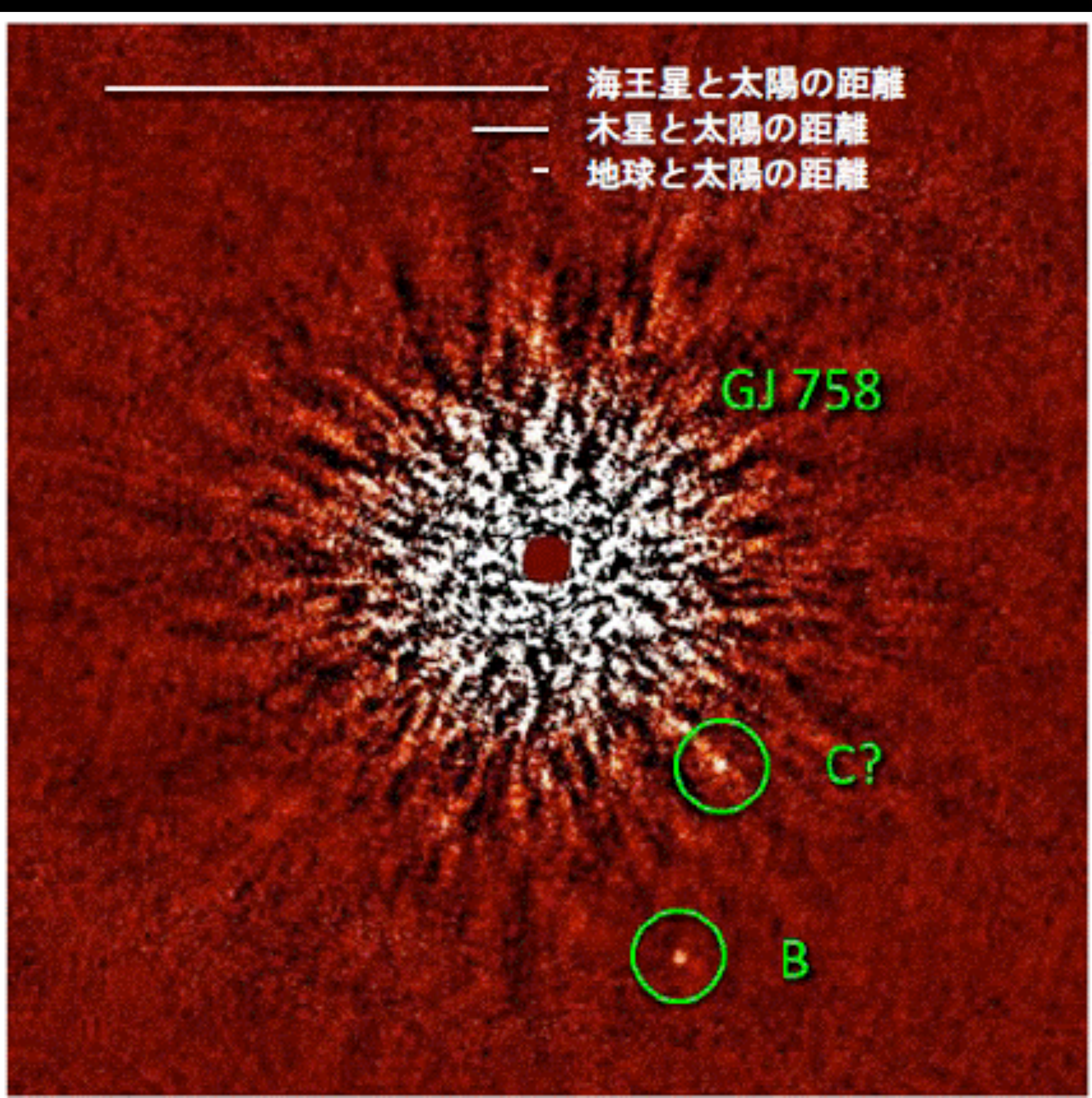

宇宙戦艦
ヤマト

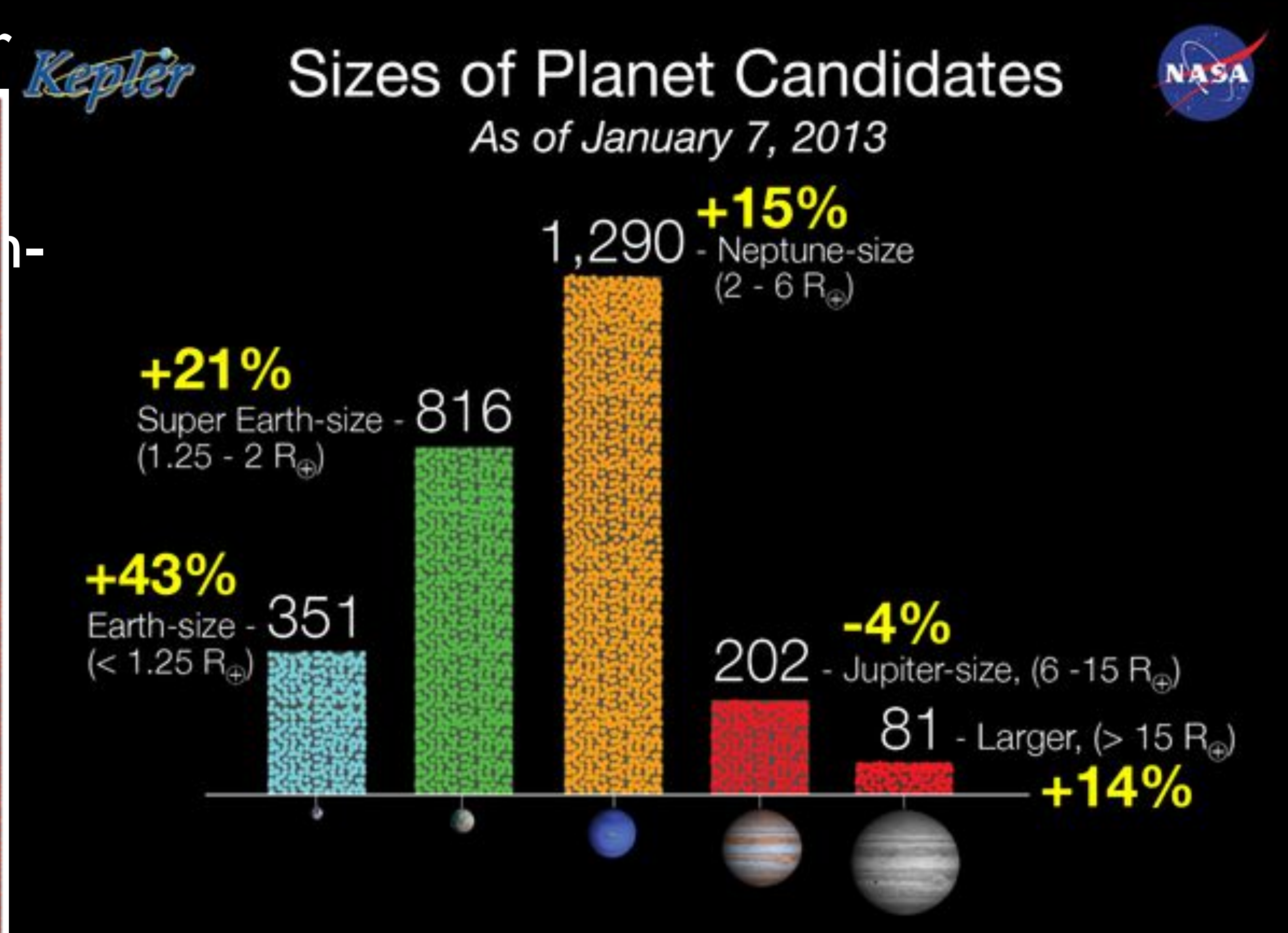
new stars are born



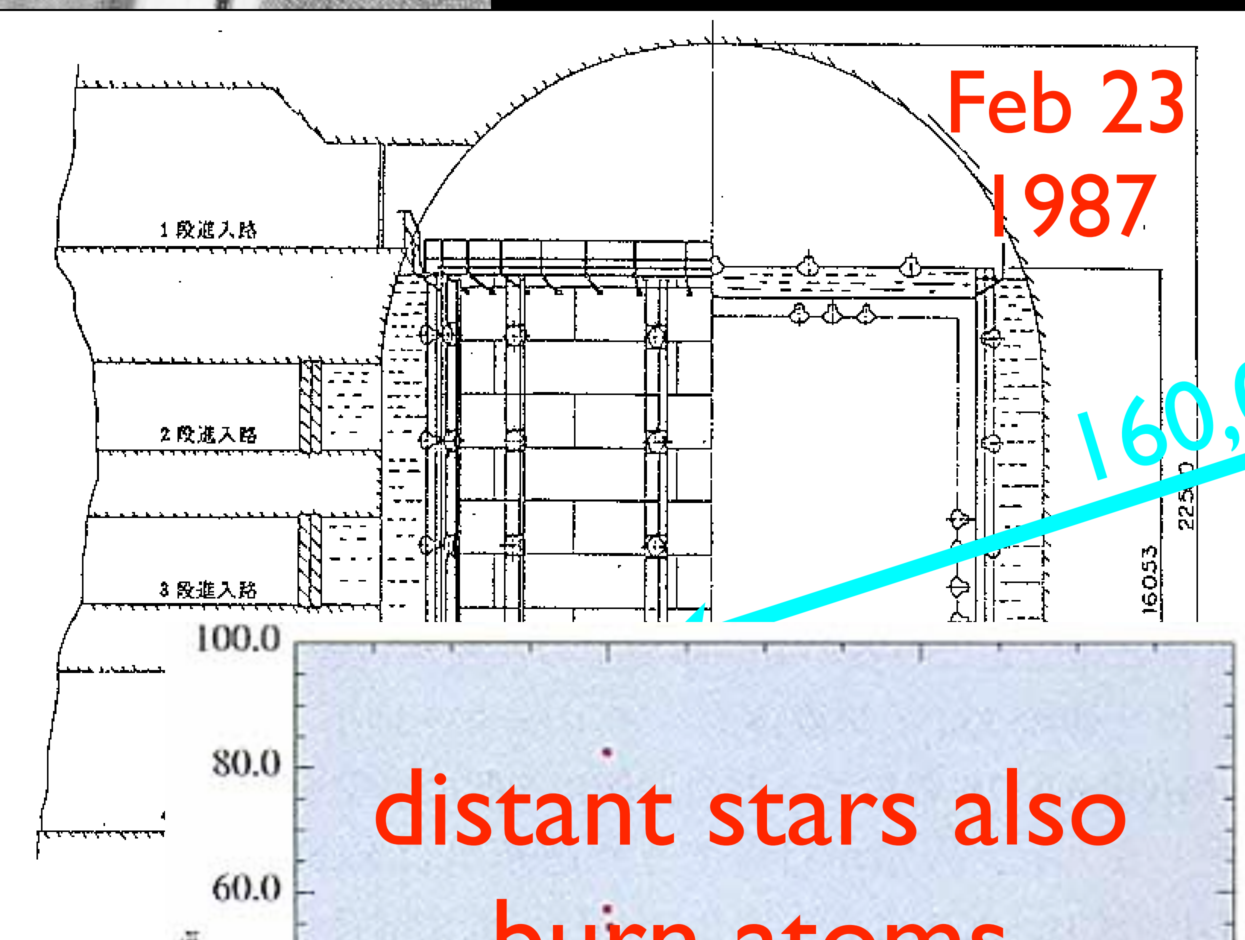
planets

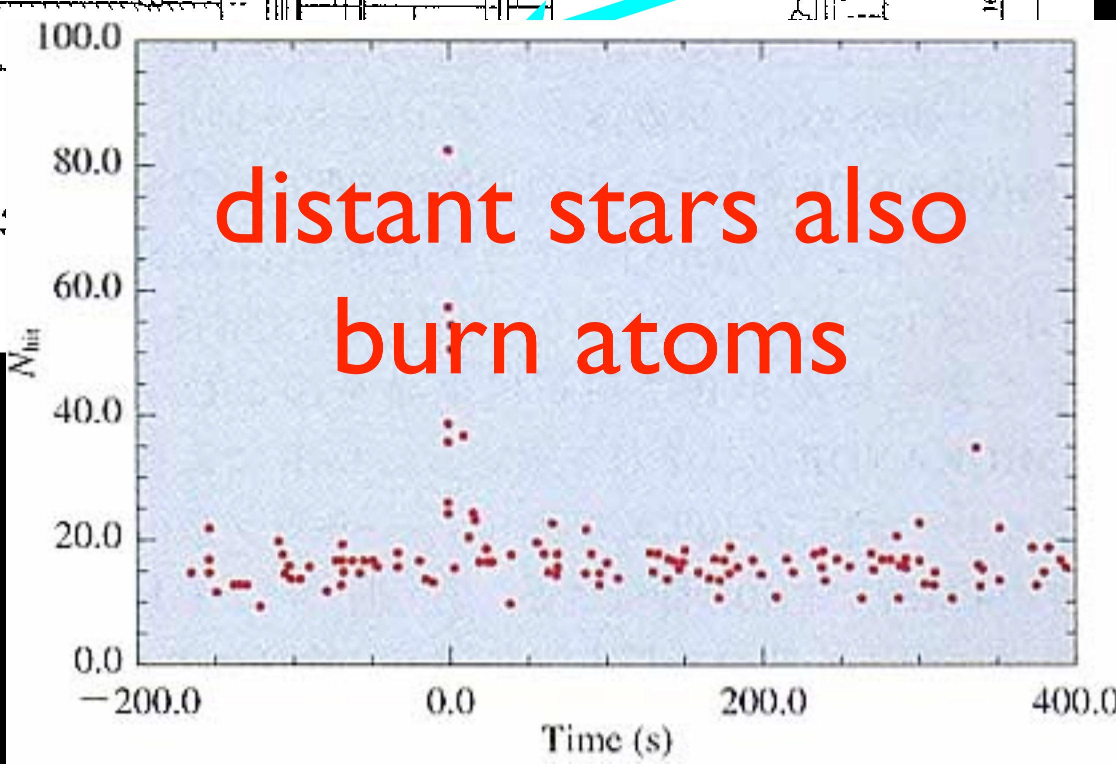
- more than 2000 candidate extrasolar

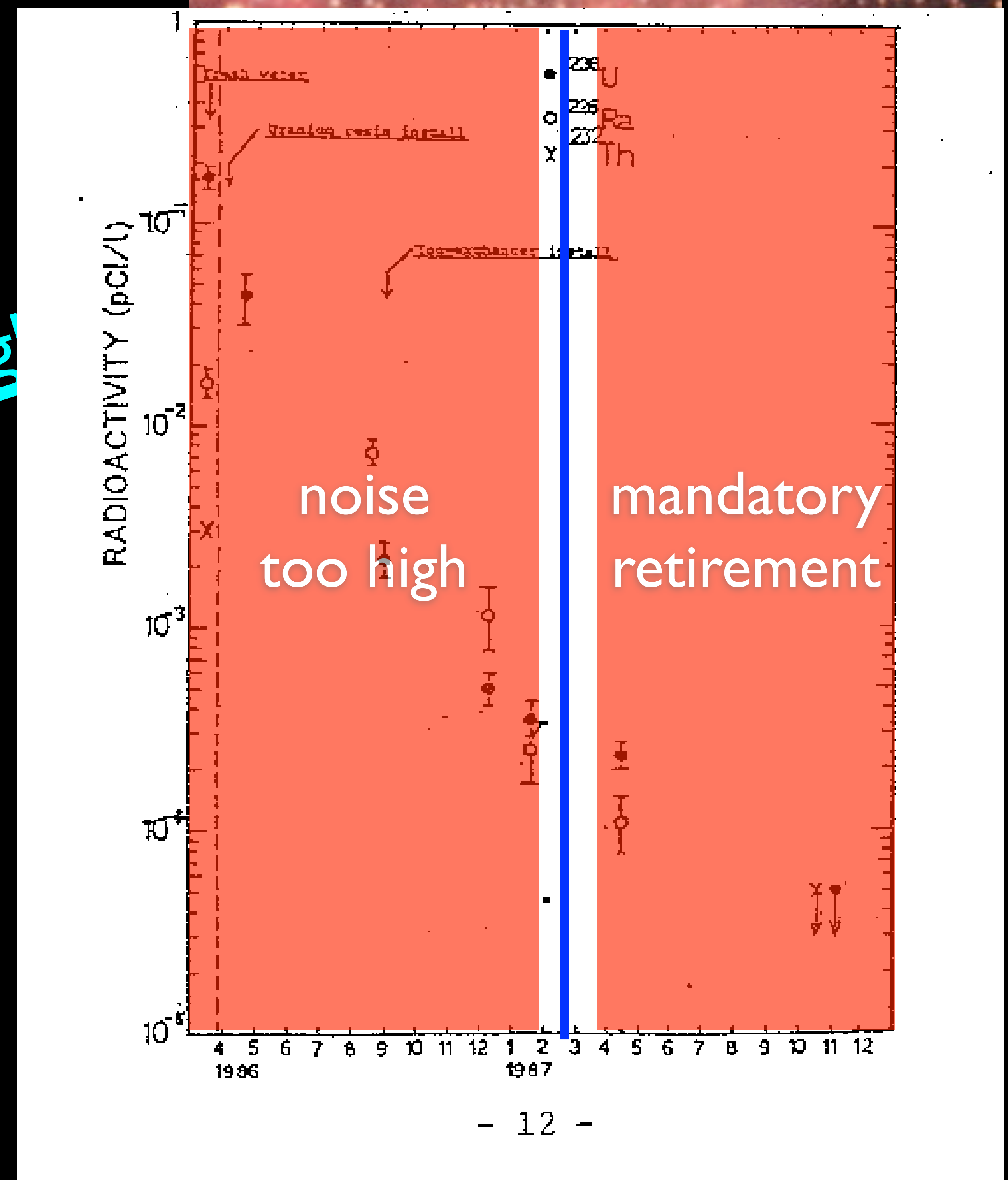




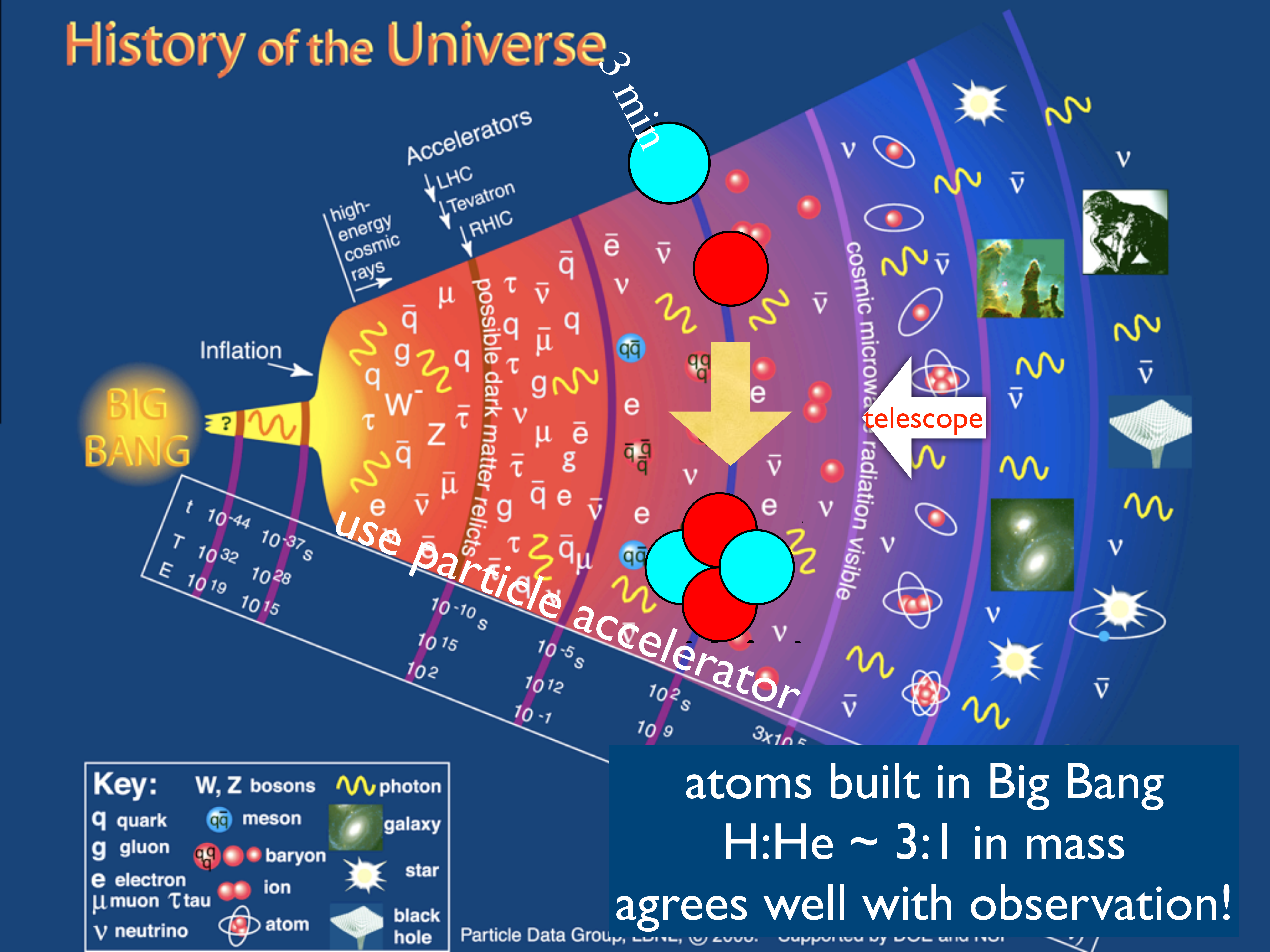
tremendous luck







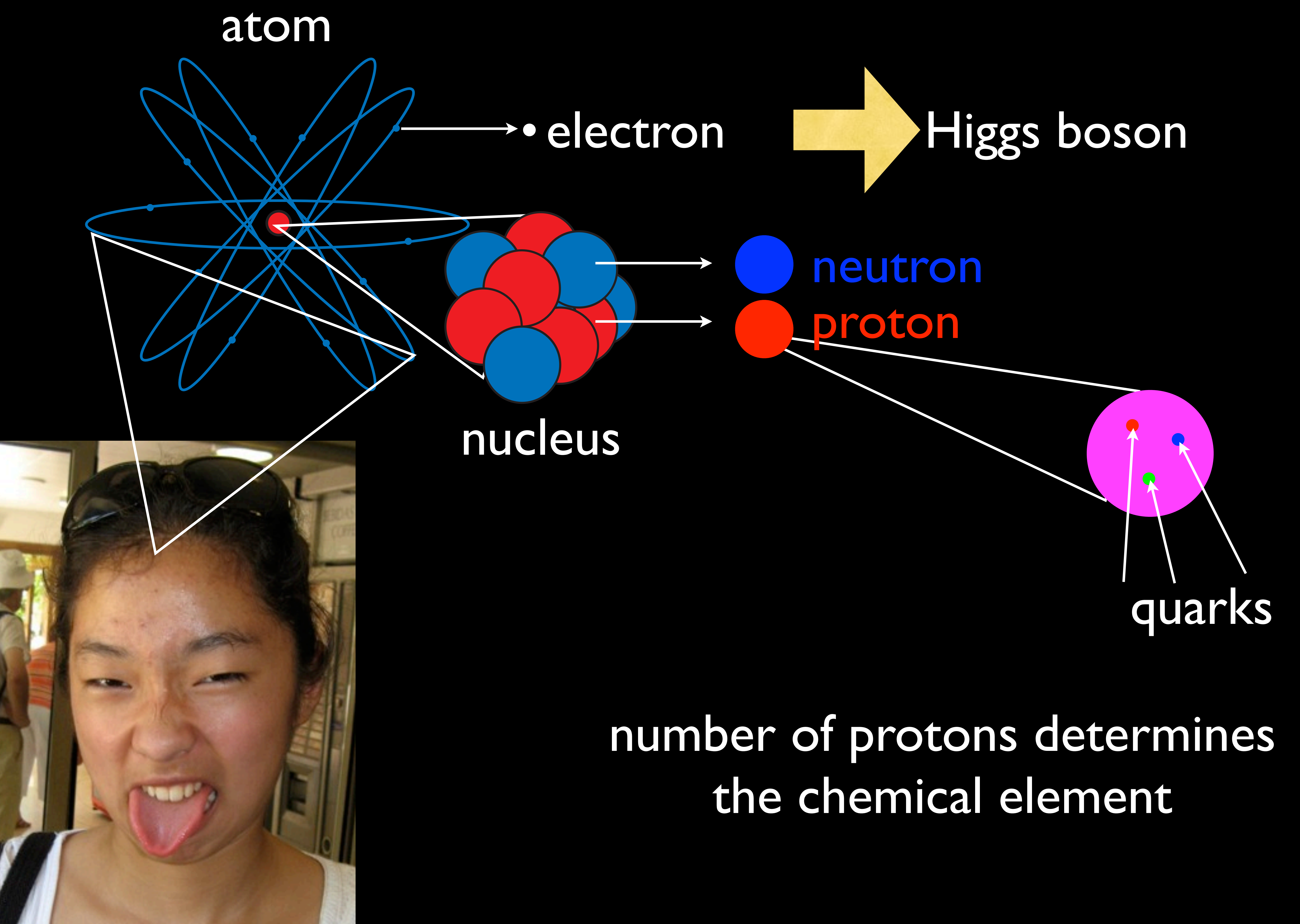

hydrogen
helium
carbon
nitrogen
oxygen
iron
neutrinos
160,000 light years
© Anglo-Australi
We are star dust



atoms built in Big Bang

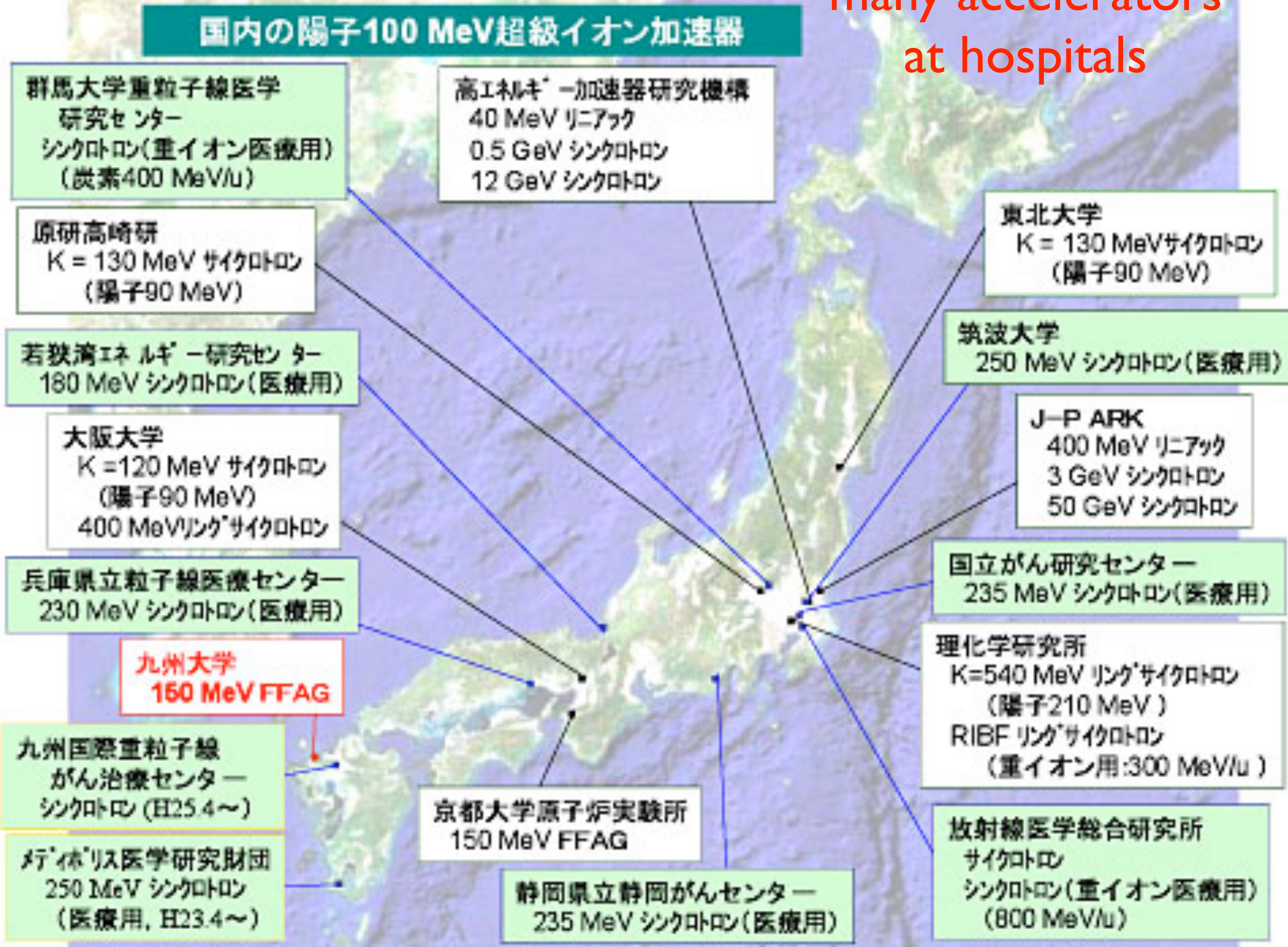
H:He ~ 3:1 in mass

agrees well with observation!


atom
electron
Higgs boson
neutron
proton
nucleus
quarks
number of protons determines
the chemical element

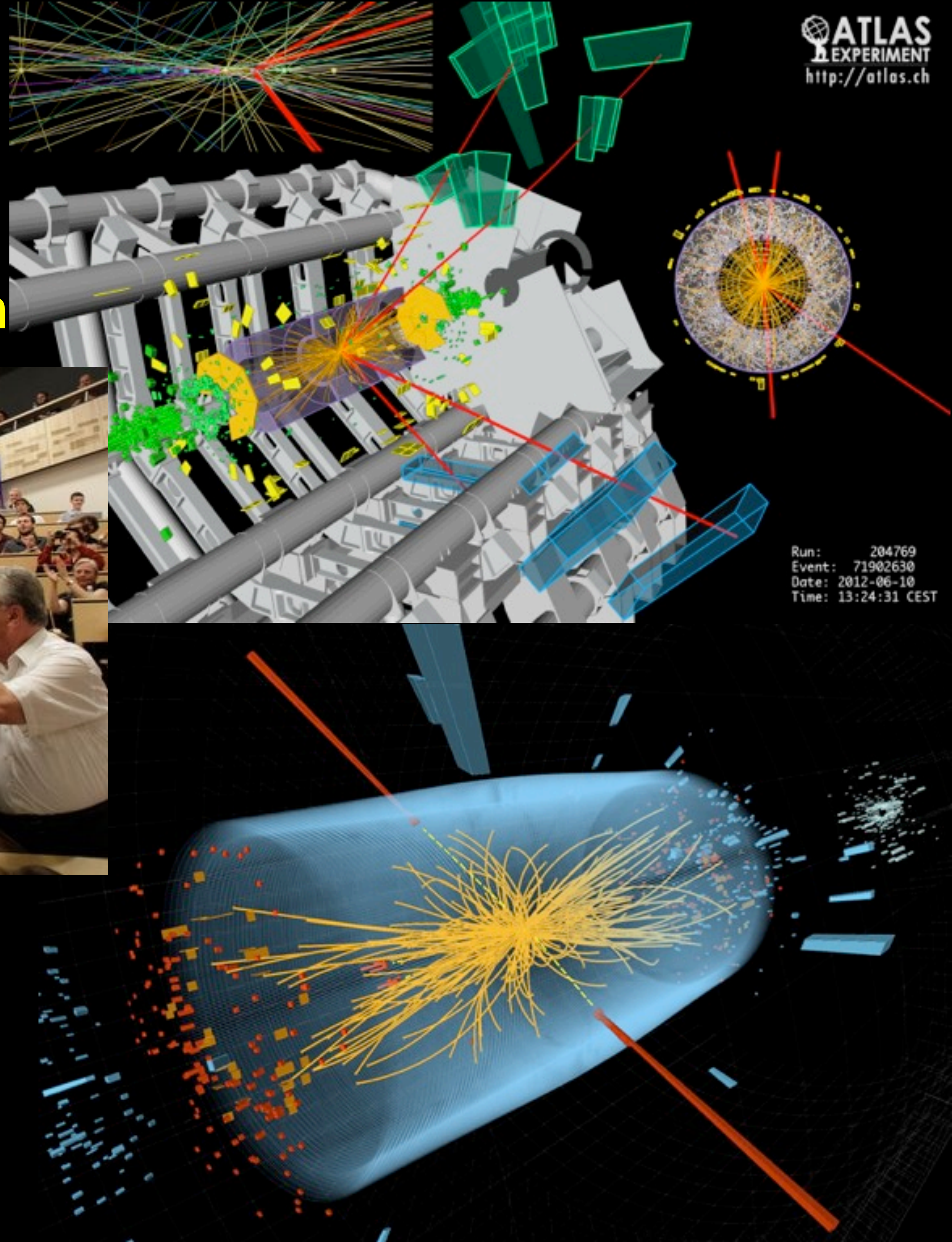
LHC

many accelerators at hospitals



2012.7.4

discovery of Higgs boson



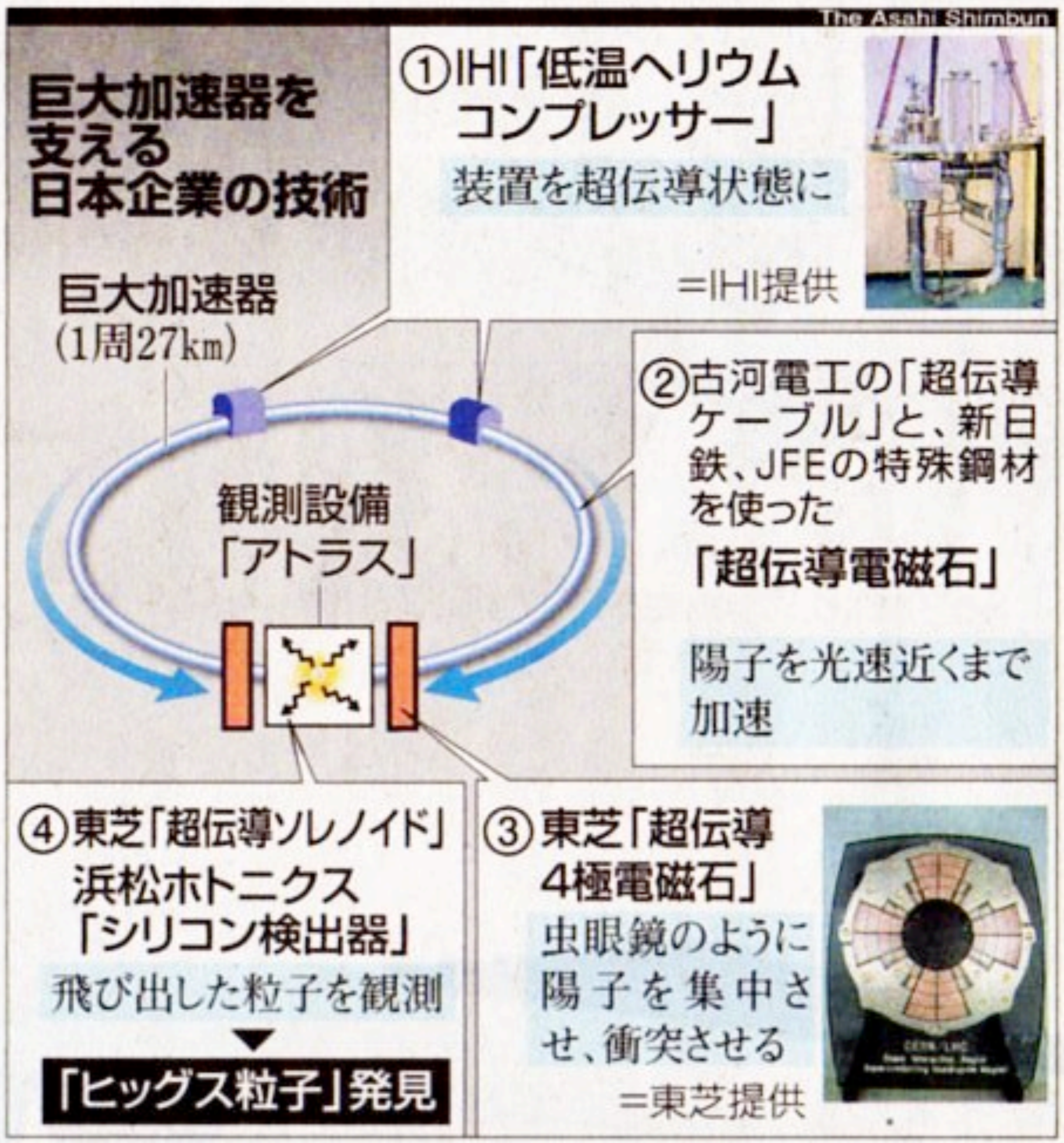
theory：1964

design：1984

construction：2001

ヒッグス粒子研究に日本の技術

CERNの巨大加速器支える



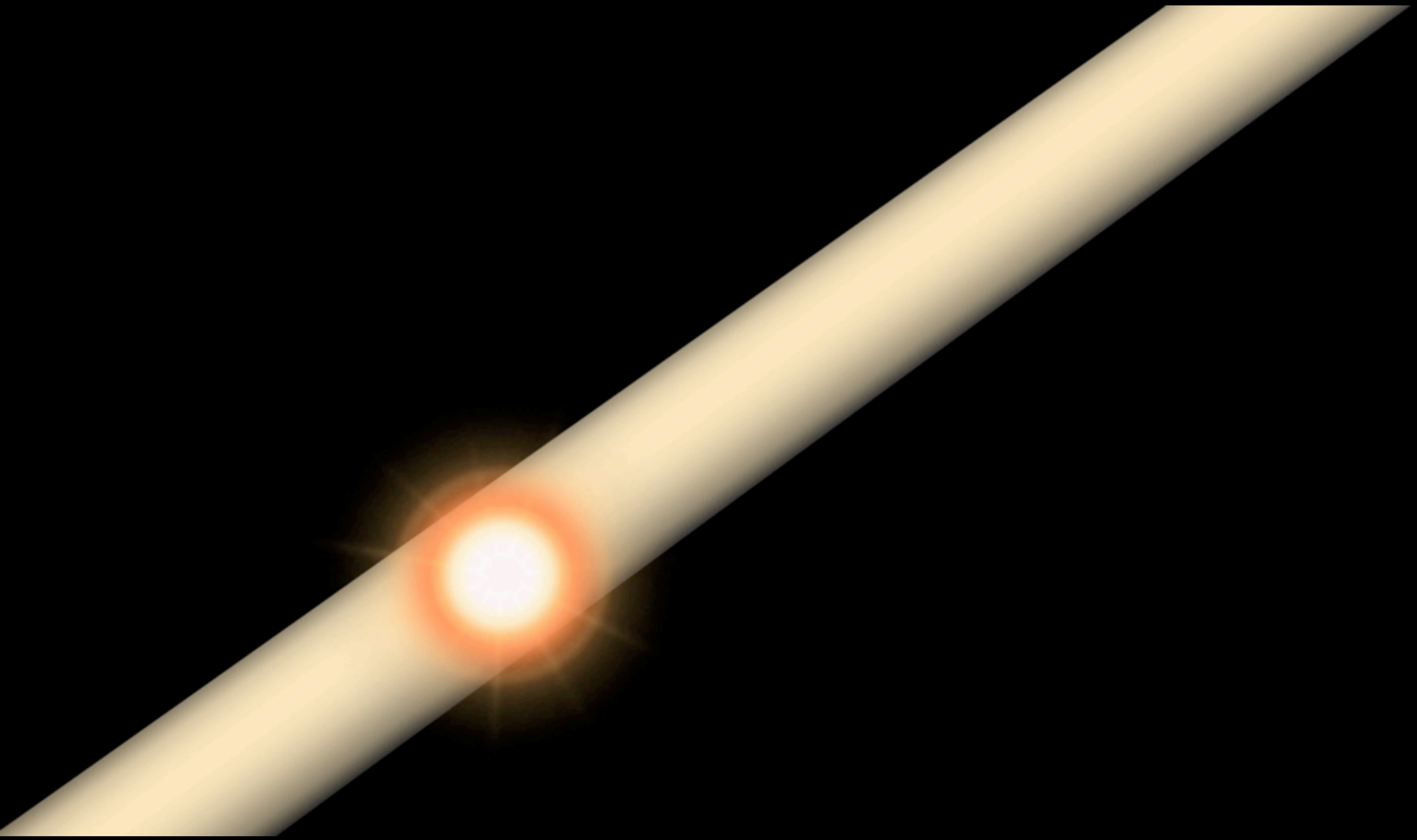
　万物に質量（重さ）を与えるという「ヒッグス粒子」とみられる新粒子の発見。その舞台となった欧州合同原子核研究機関（CERN）の巨大加速器には、東芝や古河電工など日本企業の先端技術がつめ込まれている。世界的な発見は、日本の技術力なしでは実現しなかった。

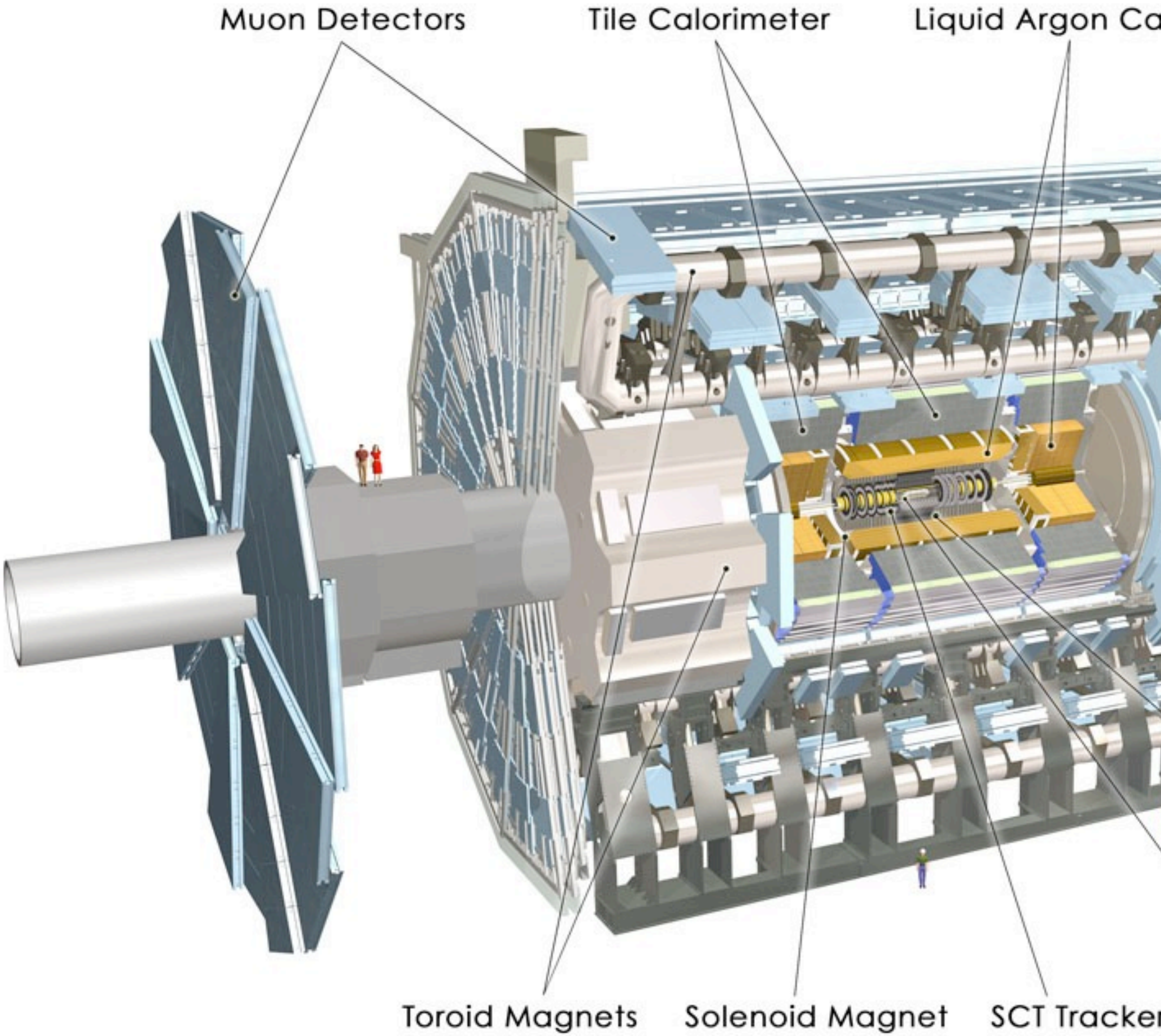
　加速器は、陽子を光に近い速さにして衝突させる。すると、ヒッグス粒子が出現するという理屈だ。

　その衝突を実現するのが、東芝の「超伝導4極電磁石」だ。陽子に強い磁力を加え、虫眼鏡で光を集めるように絞り込み、陽子どうしを正確にぶつける。全長27キロという巨大な装置の心臓部といえる。

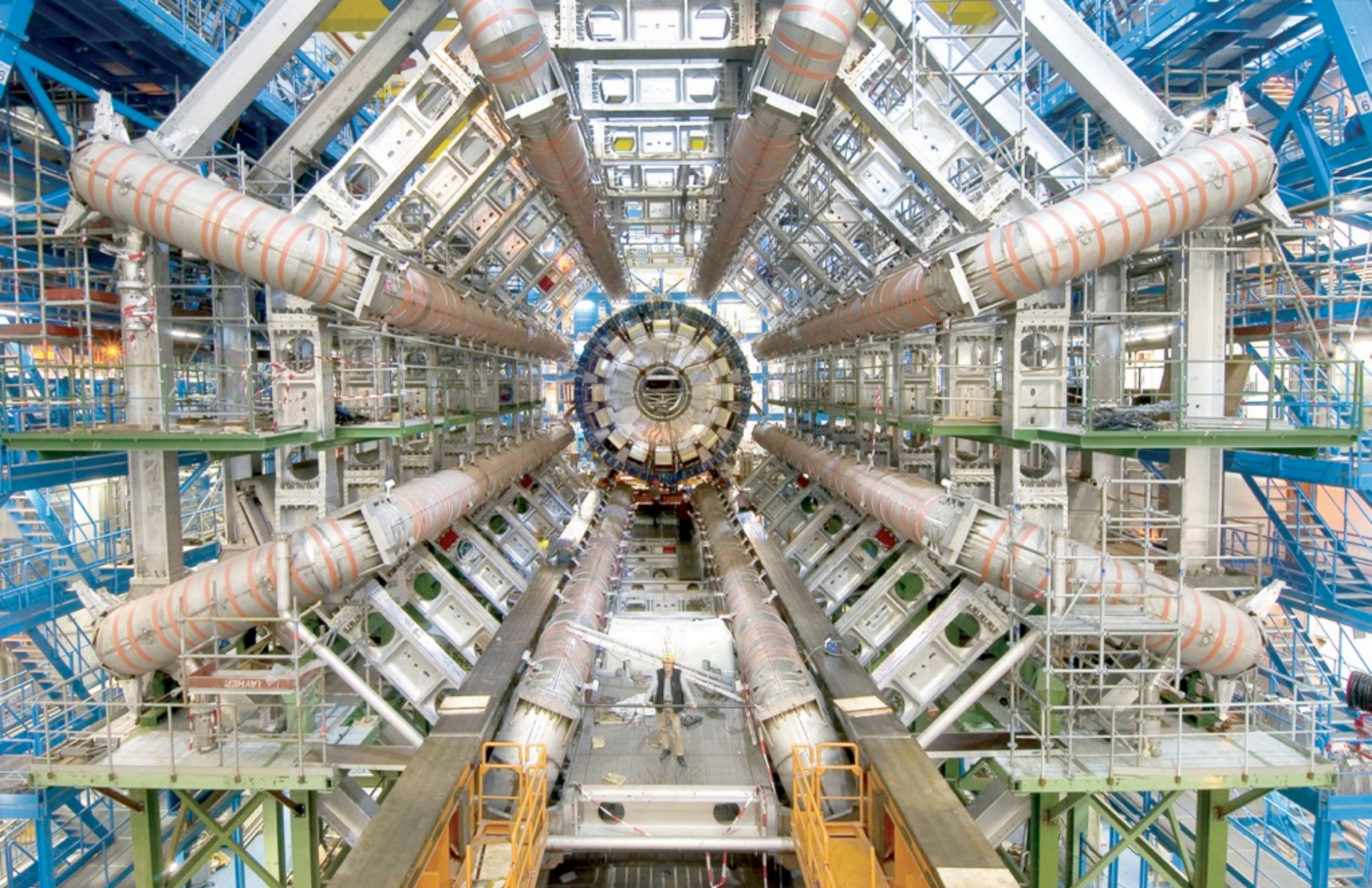
　衝突で飛び出した粒子を観測するのが、観測設備「アトラス」。粒子に磁場をかけ、進む方向がどう変わるかで粒子の質量やスピードを割り出す。この磁場をつくるのも東芝の装置

conceived back in 1984





ATLAS detector

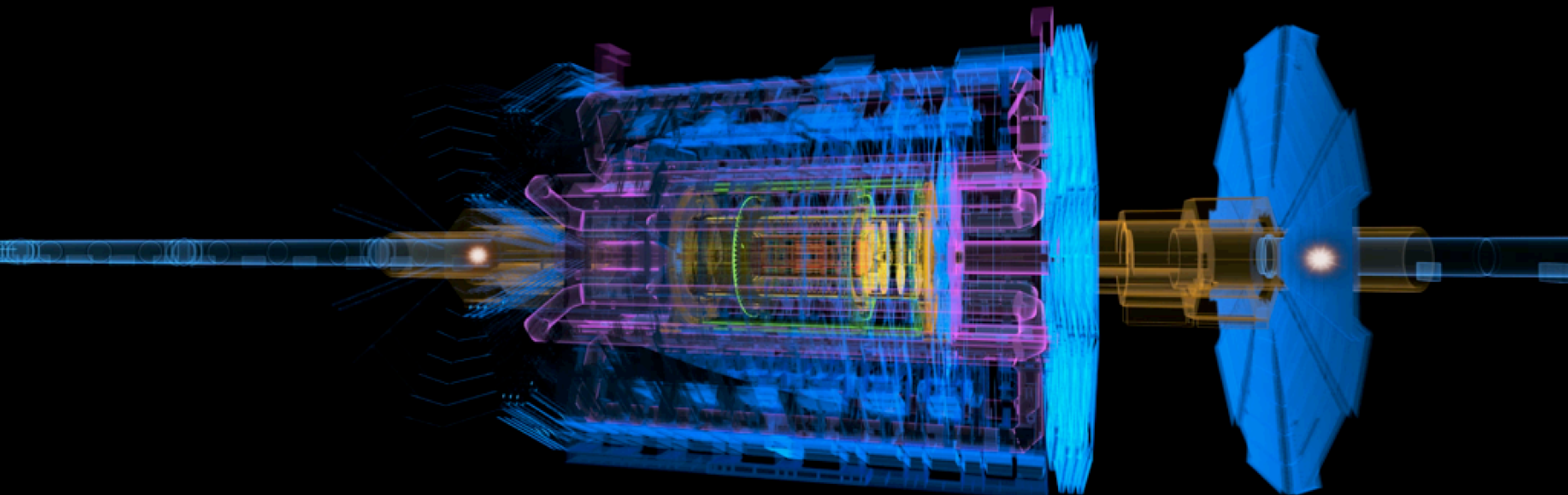


ATLAS detector

collision of protons

ATLAS experiment

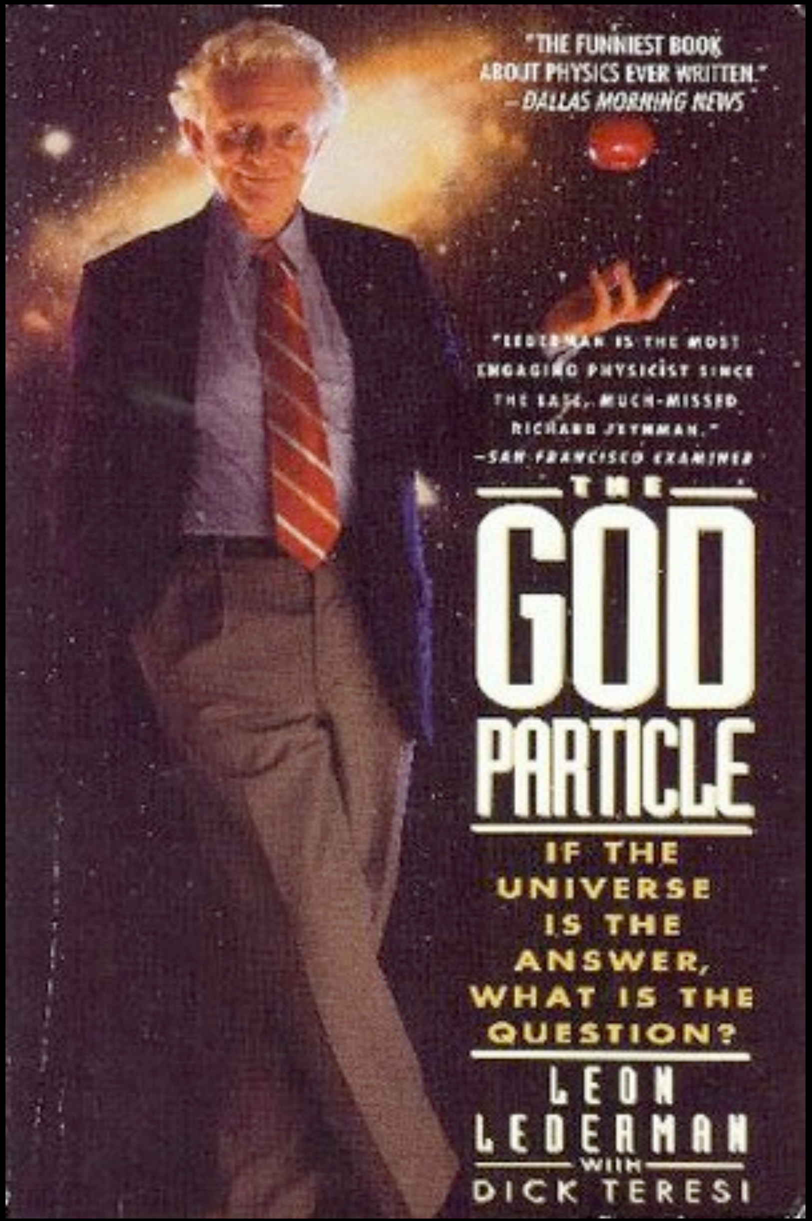
look for tens of cases out of a quadrillion collisions



Peter Higgs blessing leader of the ATLAS group

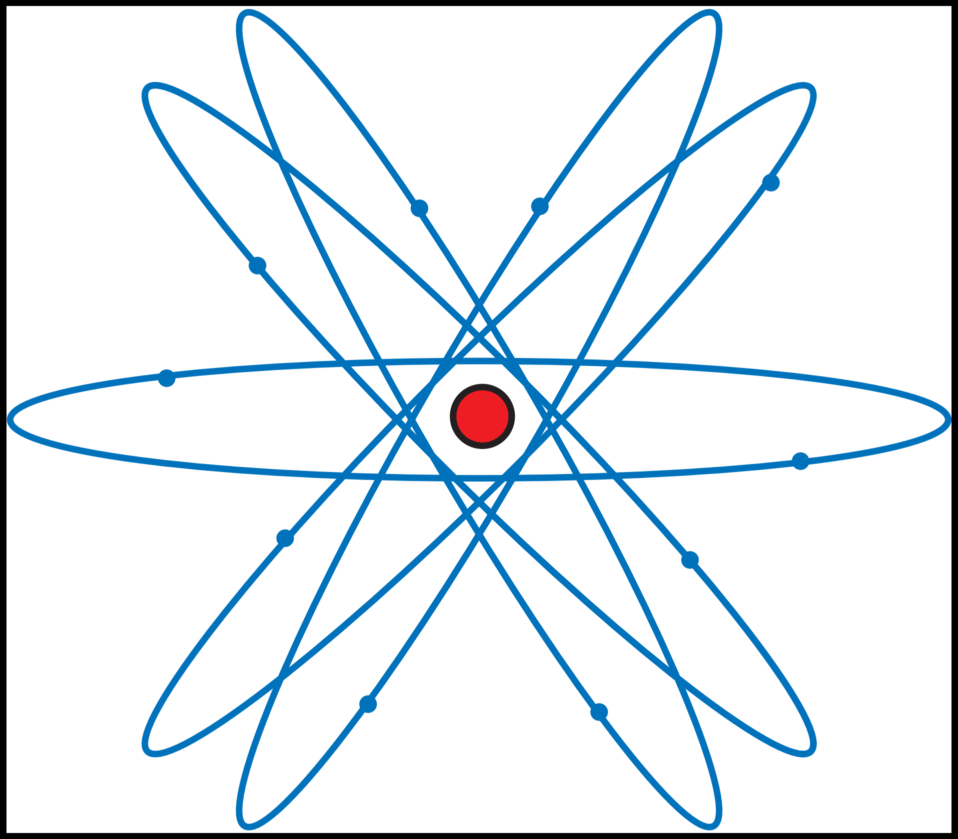
Fabiola Gianotti

God particle?

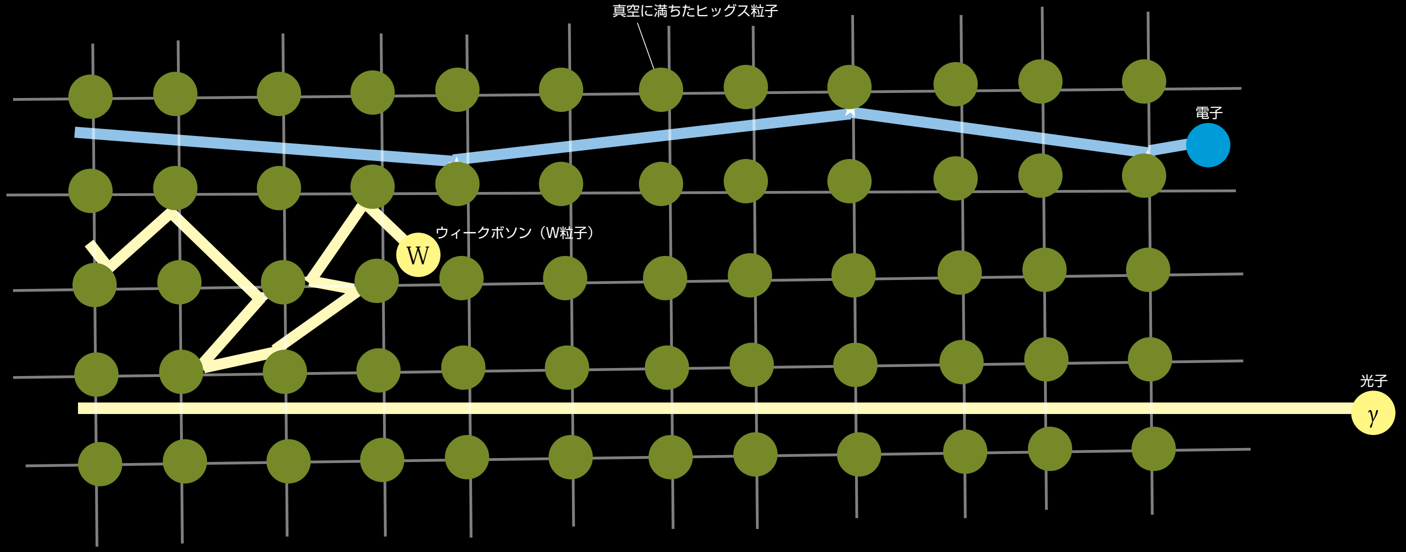


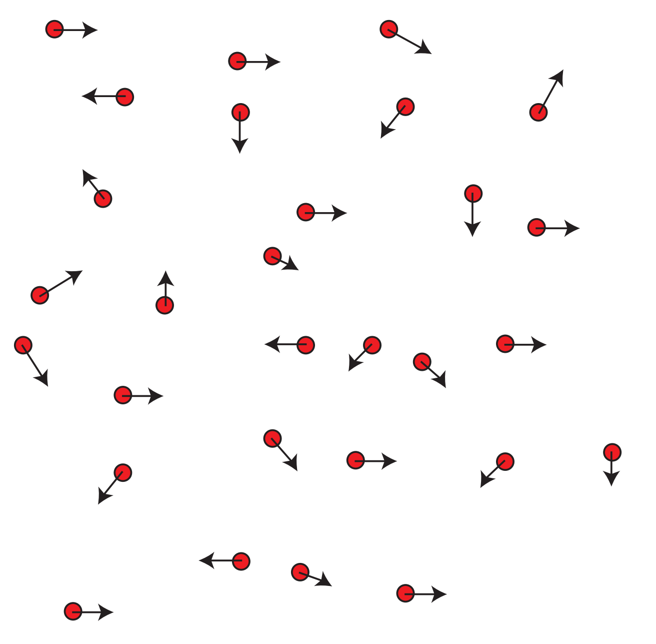
Goddamn particle!

Universe is filled with Higgs



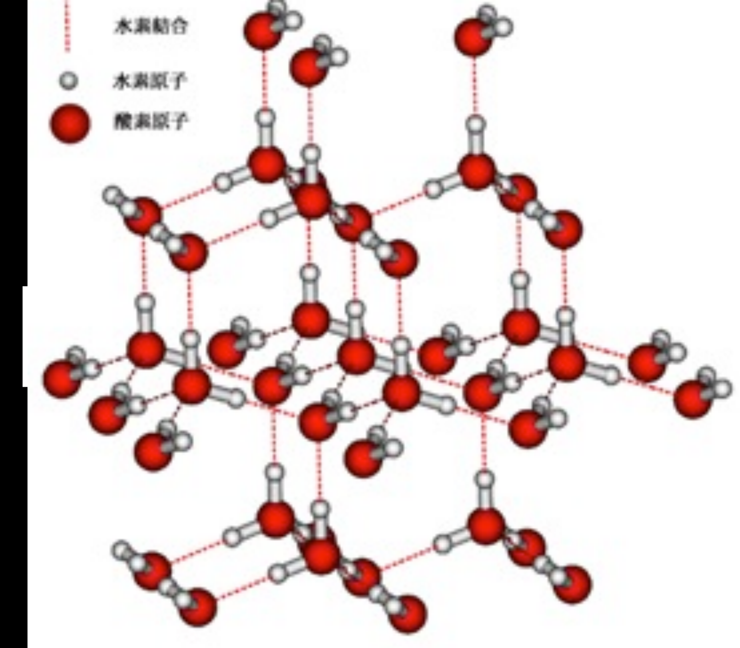
- Higgs bosons fill up space
- slows down every elementary particles from speed of light
- otherwise no atoms, no us!
- without it we evaporate in a nanosecond
- created *order* in the Universe
- our existence relies on it
- *What is it exactly??*
  we got only started with this question





verse got cooler

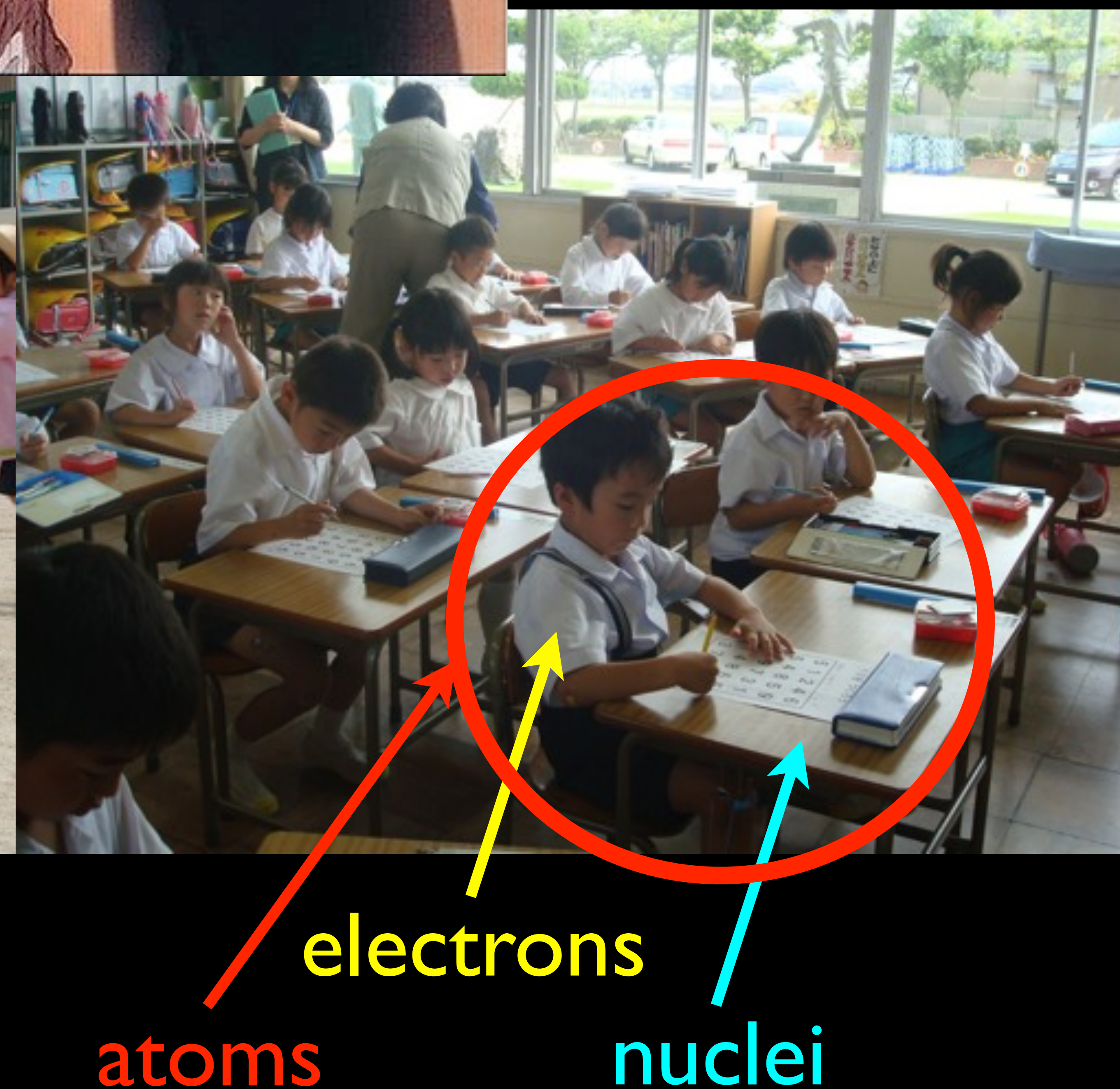
4 quadrillion degrees

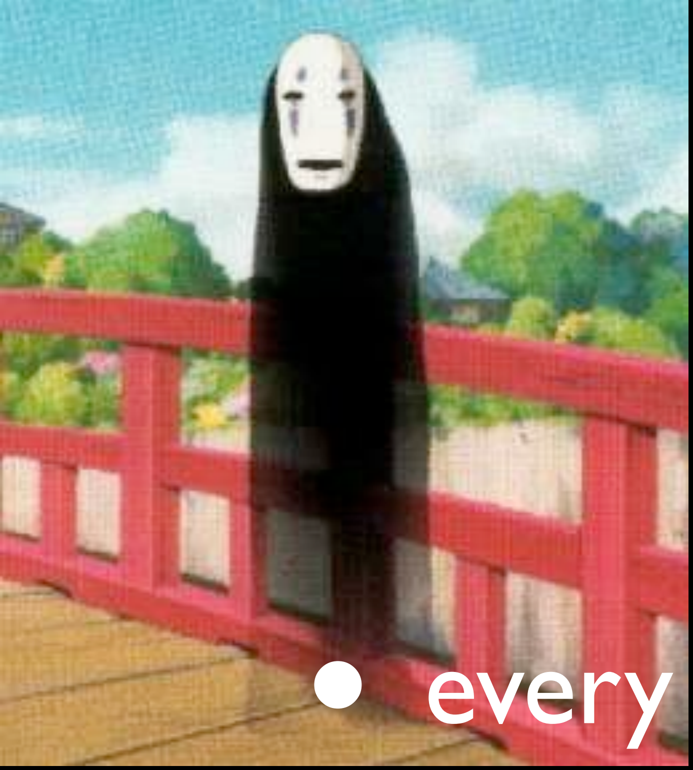


disorder ⇒ order

Why don't we notice?

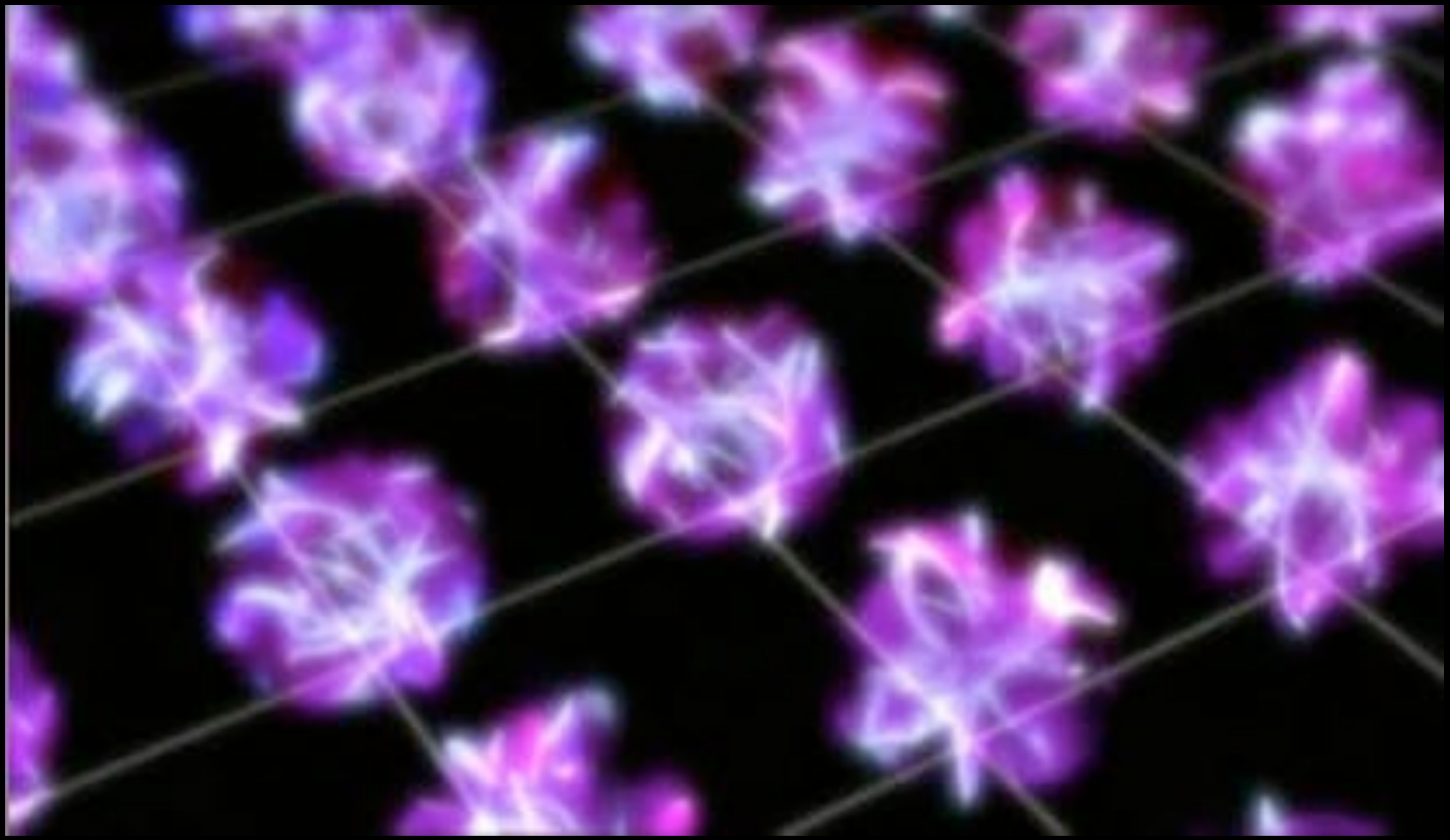
- just like the air
- ancient people didn't know that we live in the air
- flow = wind makes us notice something is there
- but can't make the Higgs bosons flow because they are frozen rigidly
- the only way: strike it hard to take one out


electrons
atoms
nuclei

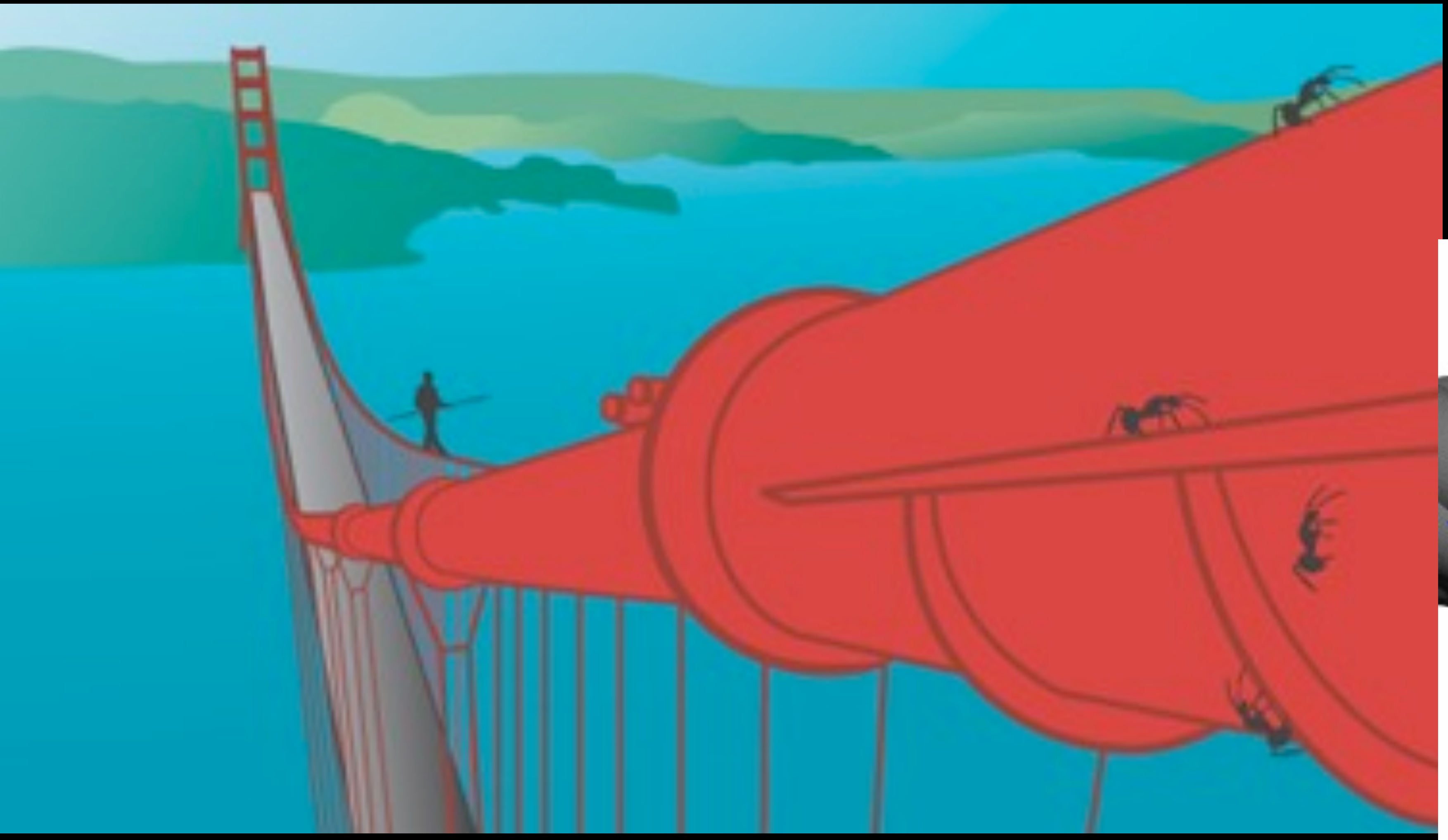


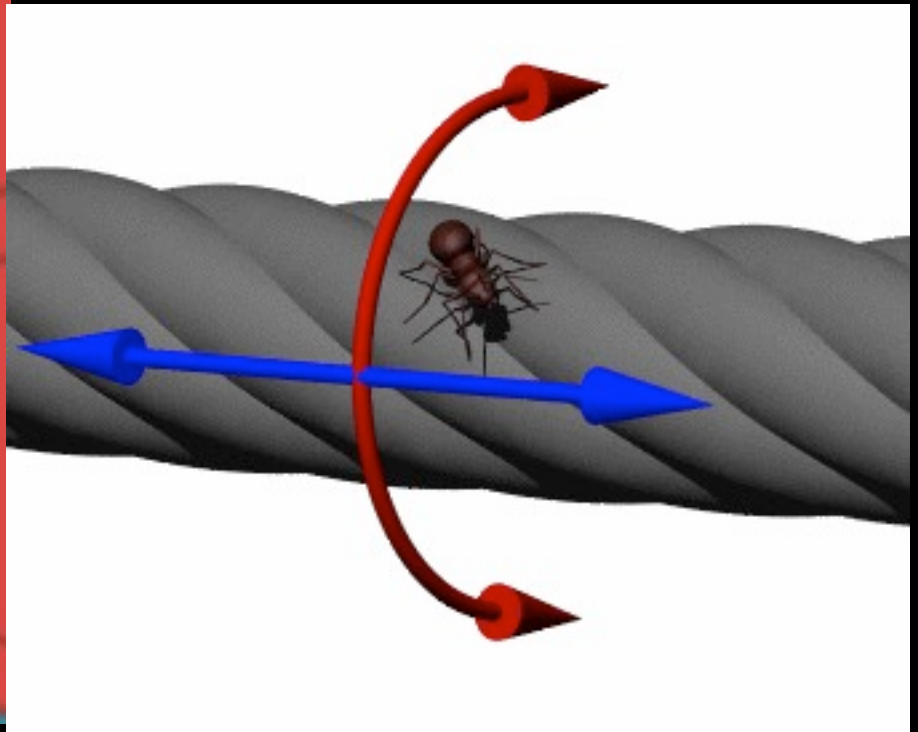
Spin

- every elementary particles spin forever
- electrons, photons, quarks, ...
- only Higgs boson doesn't spin
- faceless!
- I had proposed "Higgsless theories"
- spooky particle
- does it have siblings? relatives?
- maybe composite?
- why did it freeze in?

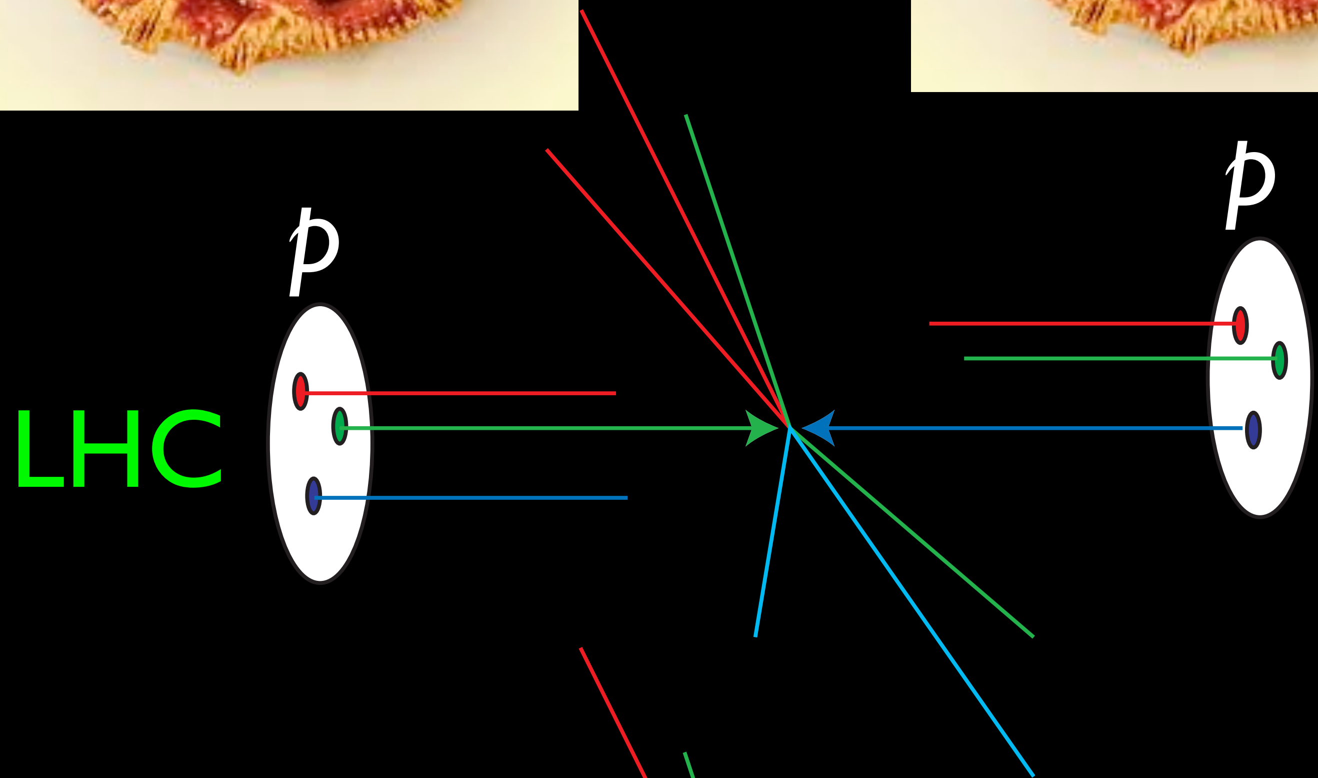


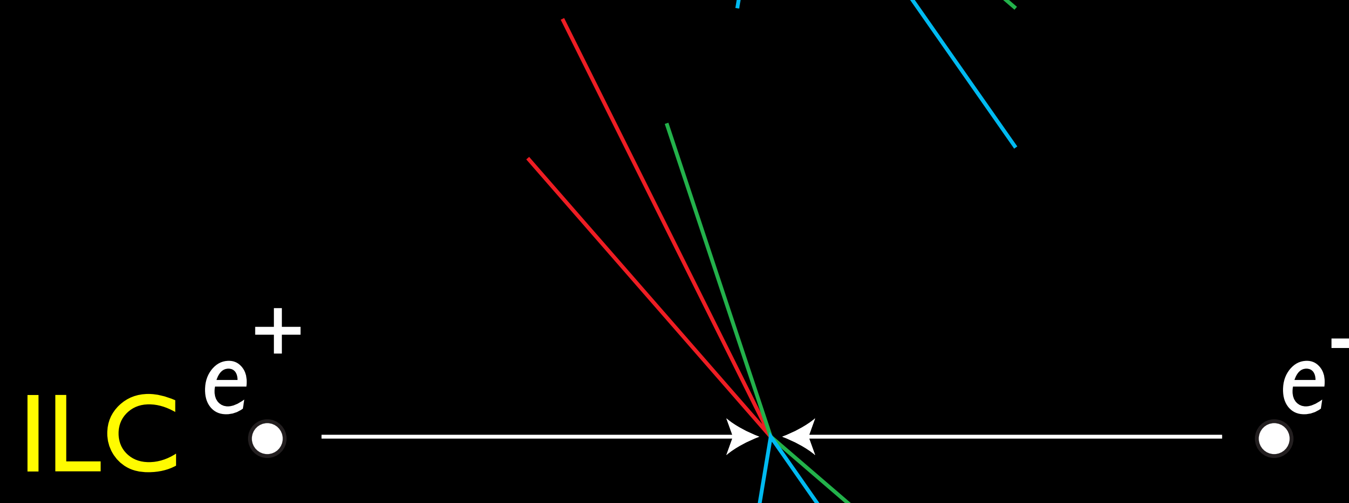
maybe Higgs boson spins in extra dimensions of space?



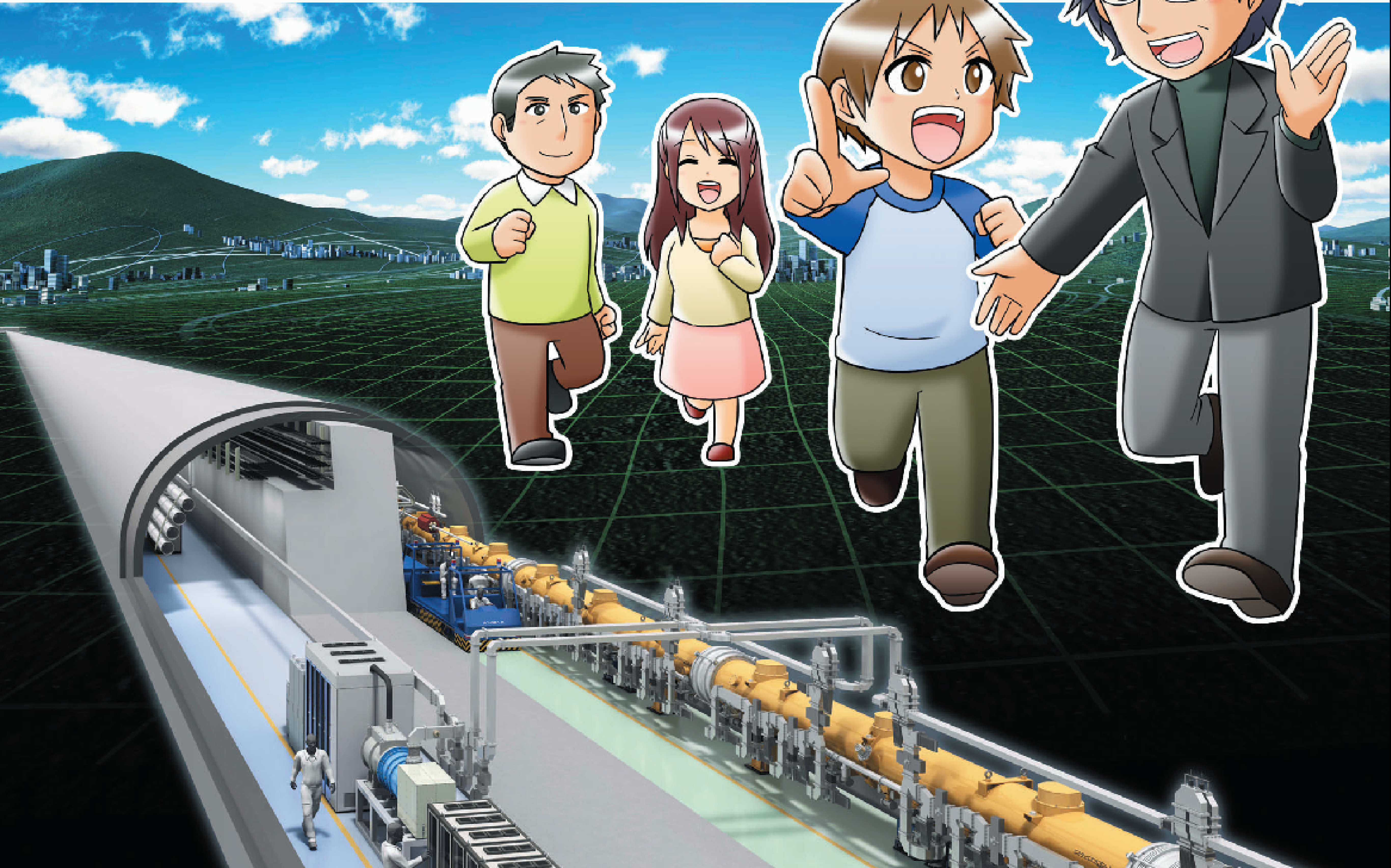



- elementary particles
- well-defined energy, angular momentum
- uses its full energy
- can produce particles democratically
- can capture nearly full information





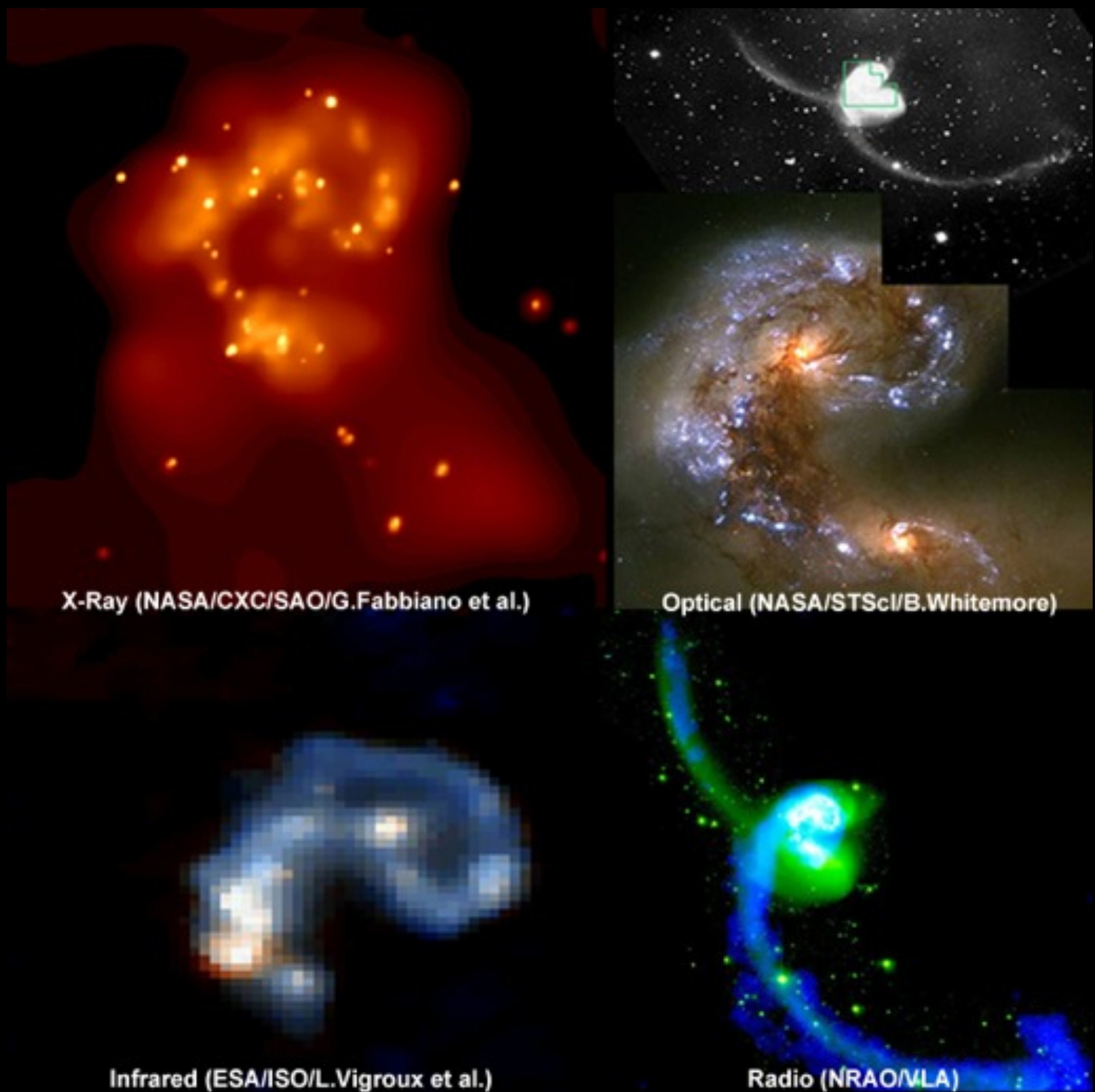

企画　大学共同利用機関法人　高エネルギー加速器研究機構
監修　村山　斉（カリフォルニア大バークレイ教授、東大カブリ数物連携宇宙研究機構 機構長、リニアコライダー・コラボレーション副ディレクター）
制作　うるののクリエイティブ事務所




そのヨーロッパの加速器じゃダメなのか？
それは……
……陽子がこのチェリーパイだとすると……
……中のサクランボが素粒子……
我々は、この素粒子＝サクランボ同士がぶつかったときに何が起こるのかを知りたい……
そこで……
ぶつけるっ!!
めしゃっ
!!
どっせい!!
わぁああああ!!


……でもチェリーパイをぶつけると、パイ皮とかジャムとか余計なものまで飛び散ってしまうんですよねぇ。
この状態の中からサクランボ同士のぶつかり方だけをチェックするのがＬＨＣの方法なんだけど……
むちゃくちゃ大変だな……
つ～か散らかすなっ!!
そう！　それでＩＬＣなんです！ＩＬＣは陽子じゃなくて電子と陽電子という一番小さい素粒子を使う加速器だから、余計なモノを散らかさないでサクランボとサクランボをぶつけられるわけです！
……とにかく散らかさないで。
でも、なんでＩＬＣは真っ直ぐなんだ？セルンの加速器とかは丸いのに……
おっ、いい質問ですねっ！
円形加速器は、円周上をグルグルと周回させることで長い加速距離を得られるのですが、そのためには粒子を曲げて飛ばさなければなりません。
■円形加速器（サイクロトロン）
■円形加速器

Multiple Wavebands in Astronomy


X-Ray (NASA/CXC/SAO/G.Fabbiano et al.)
Optical (NASA/STScI/B.Whitemore)
Infrared (ESA/ISO/L.Vigroux et al.)
Radio (NRAO/VLA)

Telescopes vs Accelerators

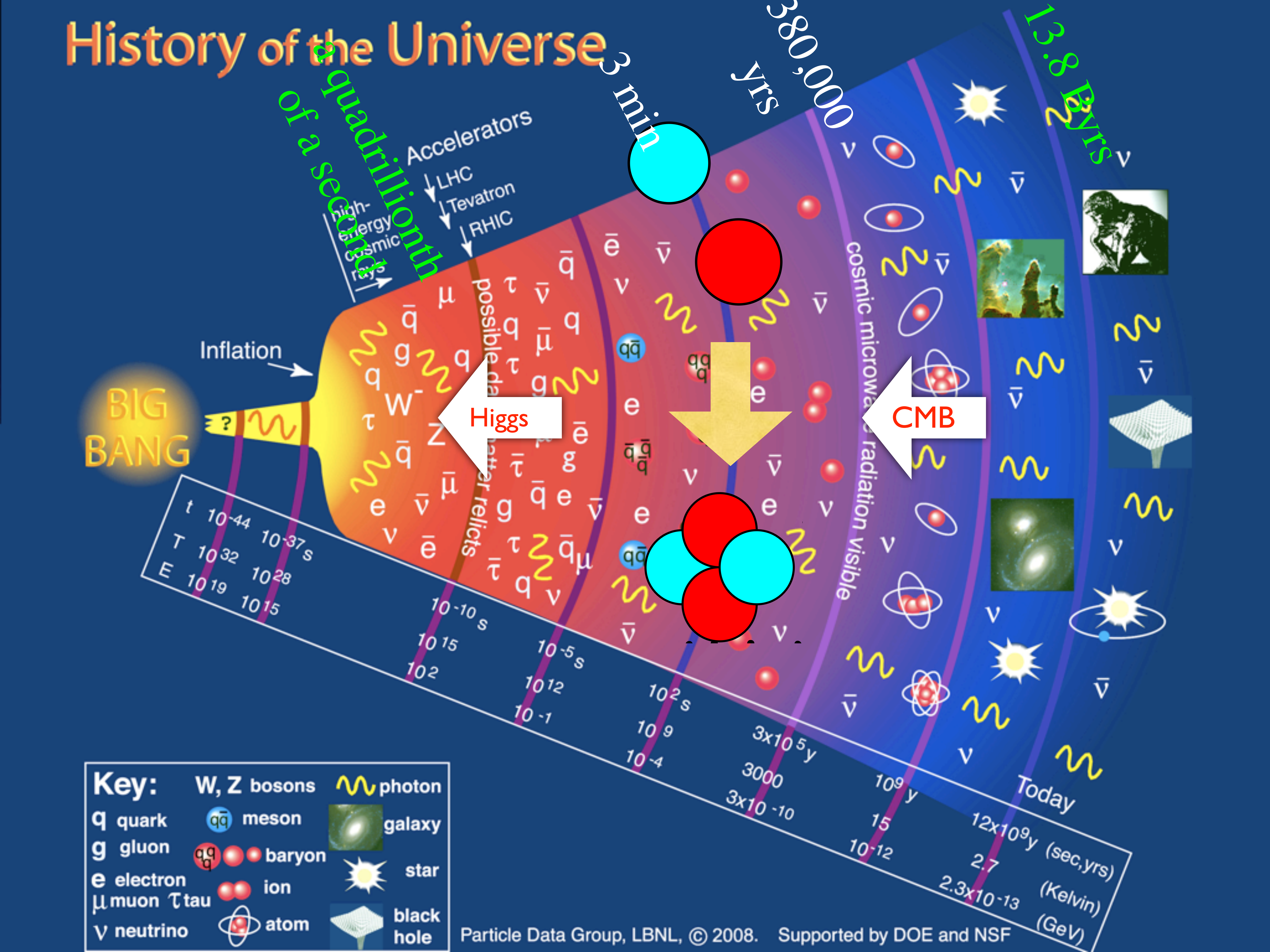
aim	need	telescopes	accelerators
probe deeper	better resolution	better mirrors, CCD	higher energy
better image	better exposure	larger telescopes, more time	more powerful beams
full understanding	multiple probes	visible, radio, infrared, UV, X-ray, gamma	protons, electrons, neutrinos

LHC vs ILC
(oversimplified)

total energy	14TeV	0.5-1 TeV
usable energy	a fraction	full
beam	proton (composite)	electron (point-like)
signal rate	high	low
noise rate	very high	low
analysis	easy to spot particles	nearly all particles
events	lose info along the beams	capture the whole
status	being upgraded	finished design

Lyn Evans
the man who
built the LHC

Mar 27, 2013


History of the Universe
a quadrillionth of a second
3 min
380,000 yrs
13.8 Byrs
Accelerators
LHC
Tevatron
RHIC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
Higgs
CMB
t 10^-44 10^-37 s
T 10^32 10^28
E 10^19 10^15
10^-10 s 10^15 10^2
10^-5 s 10^12 10^-1
10^2 s 10^9 10^-4
3x10^5 y 3000 3x10^-10
10^9 y 15 10^-12
Today 12x10^9 y 2.7 2.3x10^-13
(sec,yrs) (Kelvin) (GeV)
Key:
W, Z bosons
photon
q quark
meson
galaxy
g gluon
baryon
e electron
star
µ muon τ tau
ion
ν neutrino
atom
black hole
Particle Data Group, LBNL, © 2008. Supported by DOE and NSF

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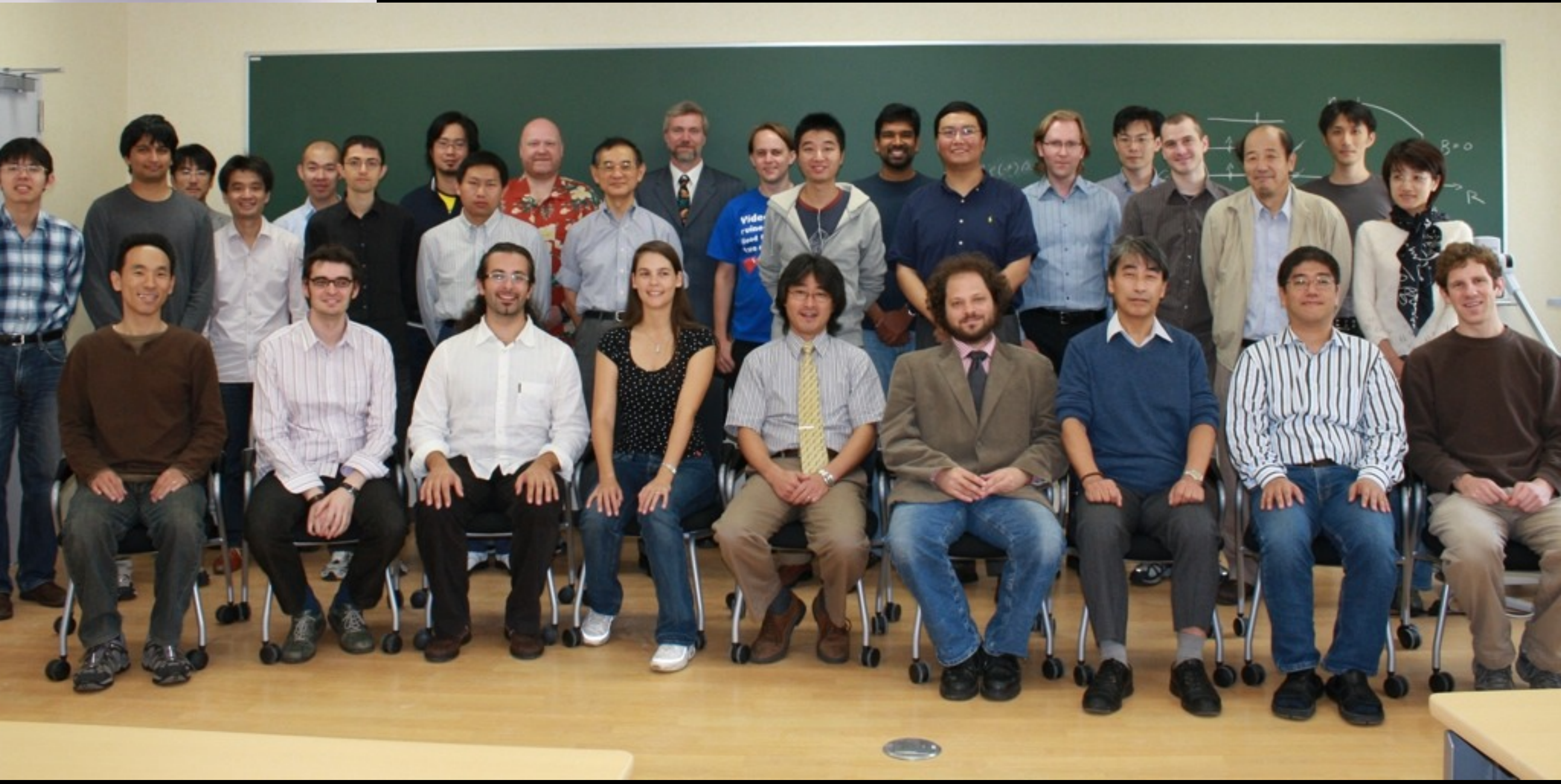
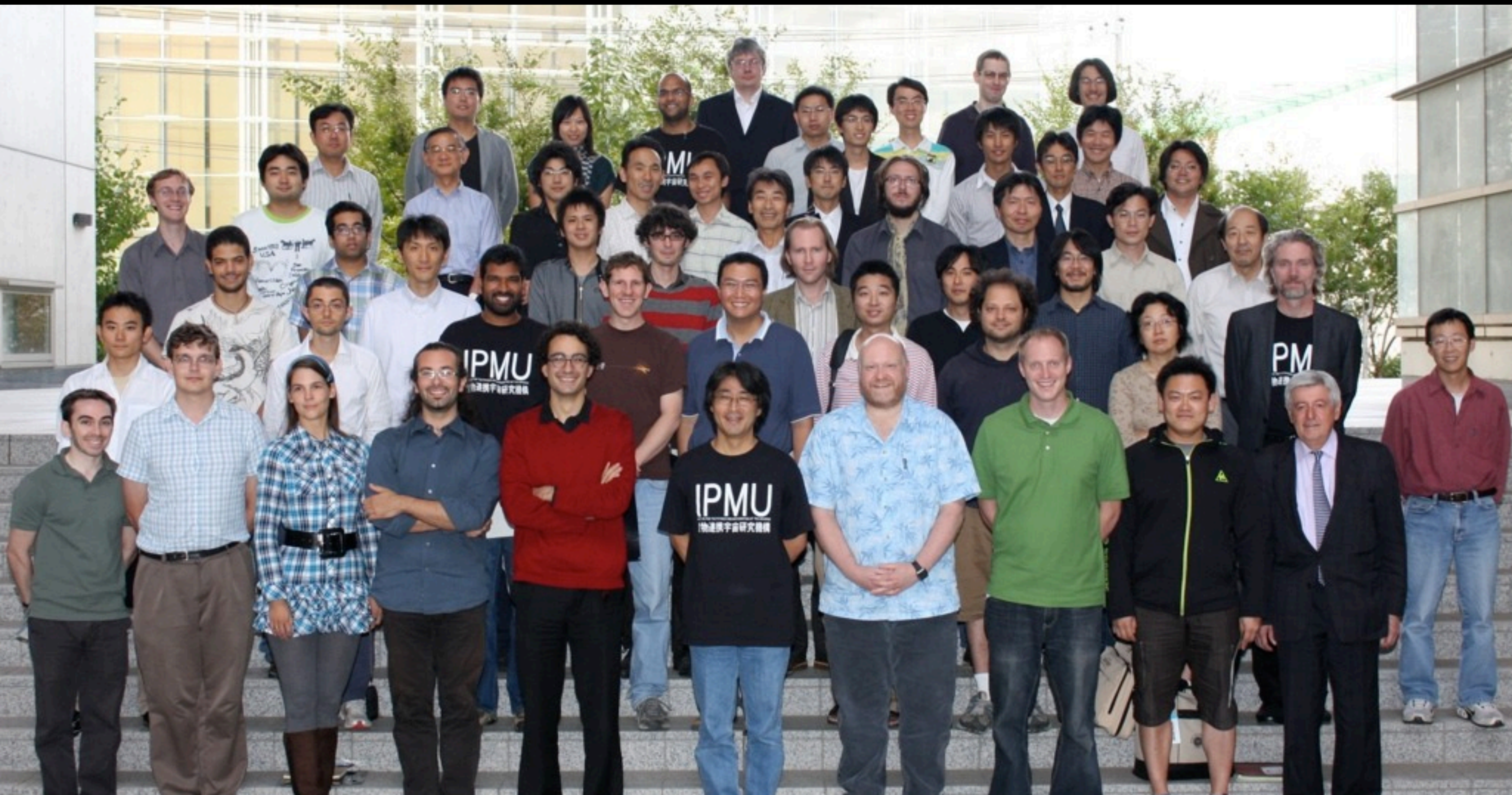
since Oct 2007

Oct 2007

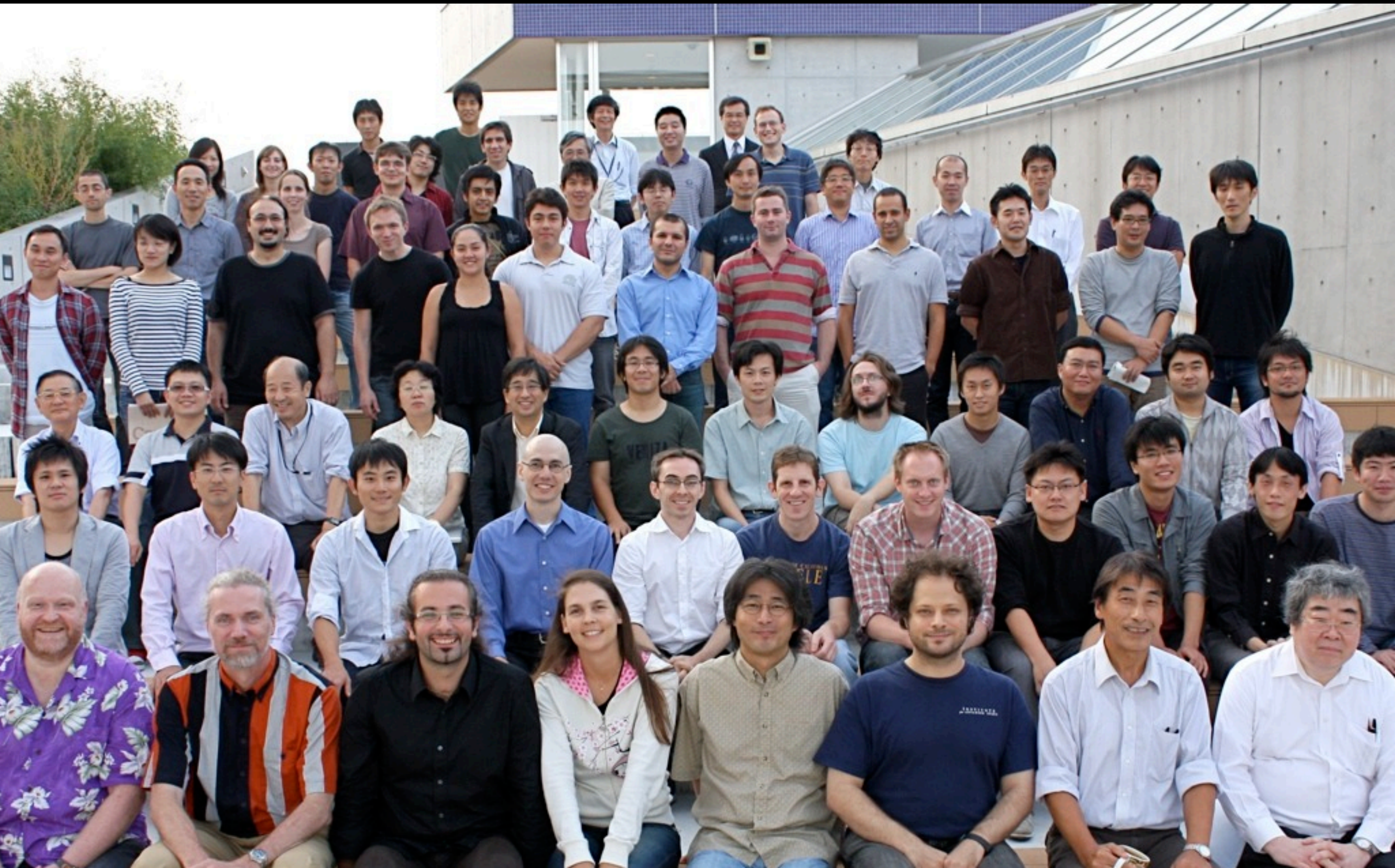
Oct 2008



Oct 2009



Oct 2010



Oct 2011

Oct 2012

Asahi TV

How did the Universe begin?

What is its fate?

What is it made of?

What are its fundamental laws?

Why do we exist?

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