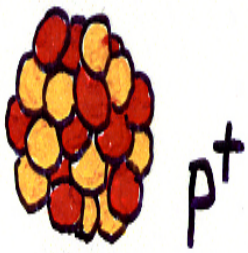
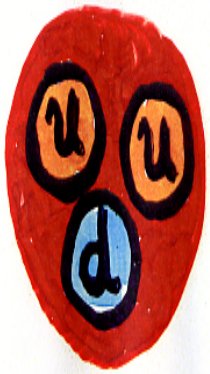
Come funziona l'universo ? Quello che il LHC può insegnarci

Alvaro De Rujula, CERN

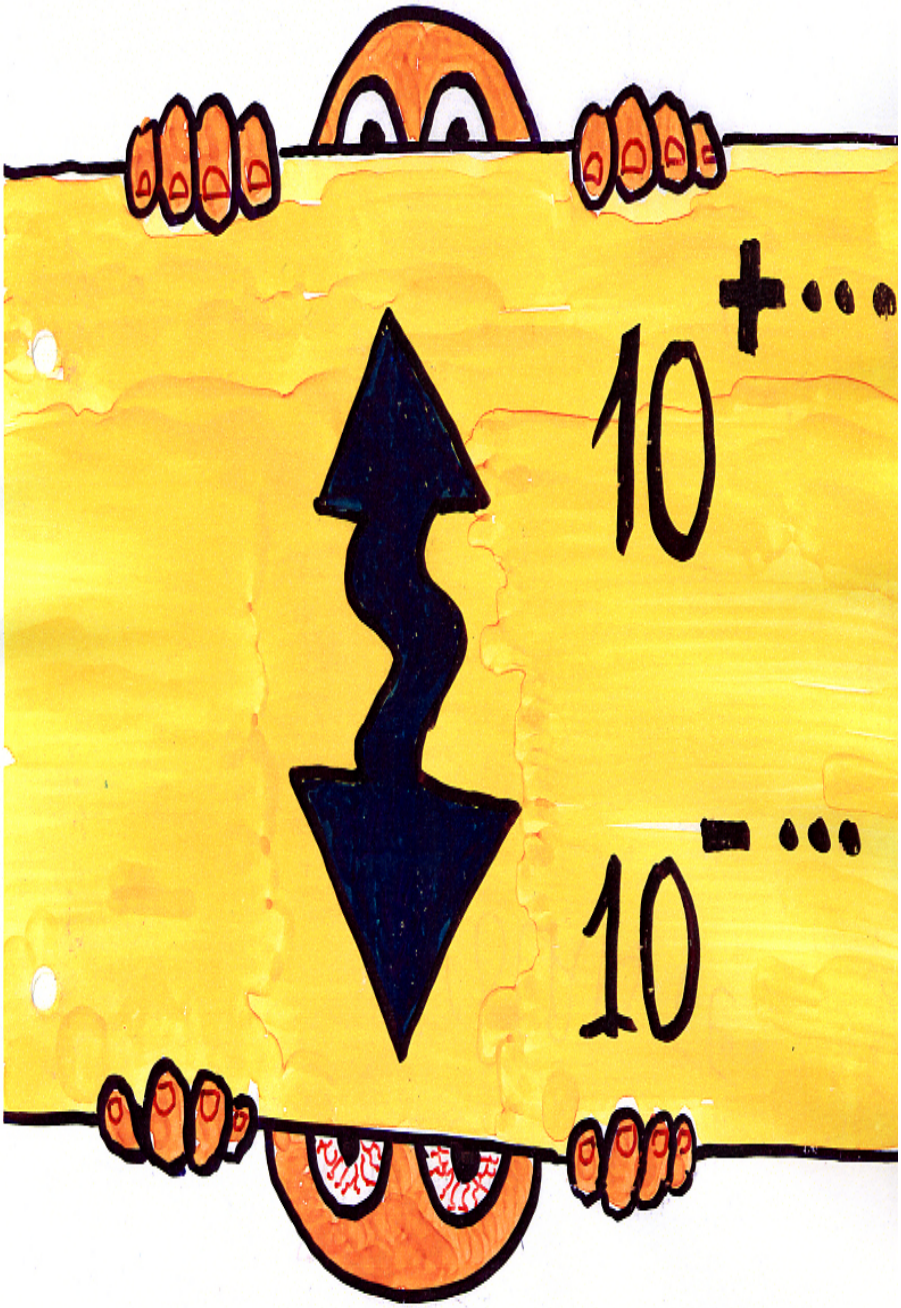
Incontri di Fisica 2008
1 Ottobre 2008
LNF, Frascati

m	OGGETTO	"FOTO"	FORZA	UTILITÀ	ESPERTO
10^{21}	AMASSI DI GALASSIE		GRAVITÀ	STARE in PIEDI	COSMOLOGI ASTRONOMI FISICI
10^{6}	STELLE E PIANETI				
1	ESSERI VIVENTI		ISTINTI SESSO	MANTENERE LA SPECIE	SOCIOLOGI BIOLOGI TASS...

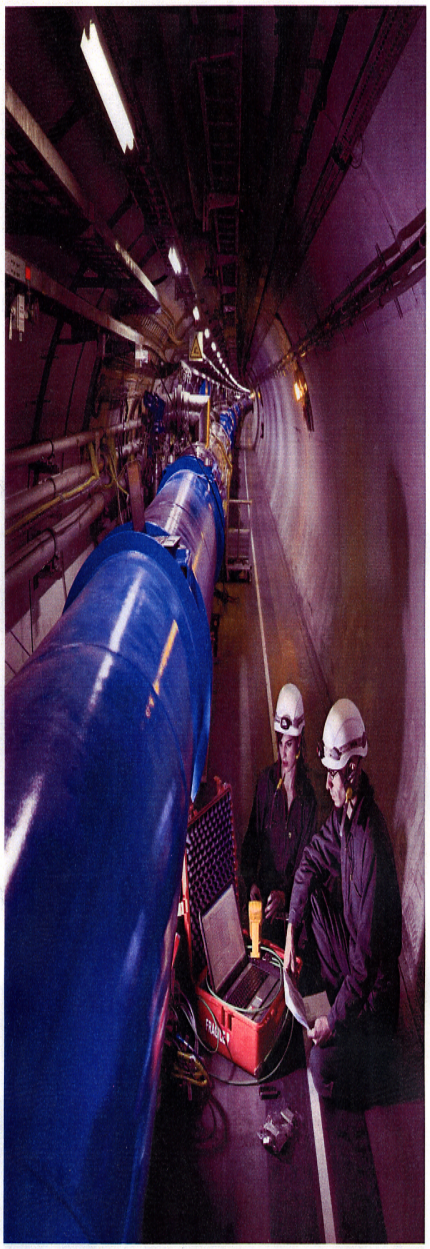
m	OGGETTO	FOTO	FORZA	UTILITÀ	ESPERTO
10^{-9}	MOLÈ-COLA		ELET-TRO-MAG-NETIS-MO	CHIMICA LUCE VITE ... COMPL.	FARMA... CHIMICO IDRAU...
10^{-10}	ATO-MO				
10^{-14}	NU-CLEO		"FORTE"	SOLE REAT.	FISICO NUCLEARE
10^{-15}	PROTONE & NEUTRONE		LA COLLA		CERN-IOTA

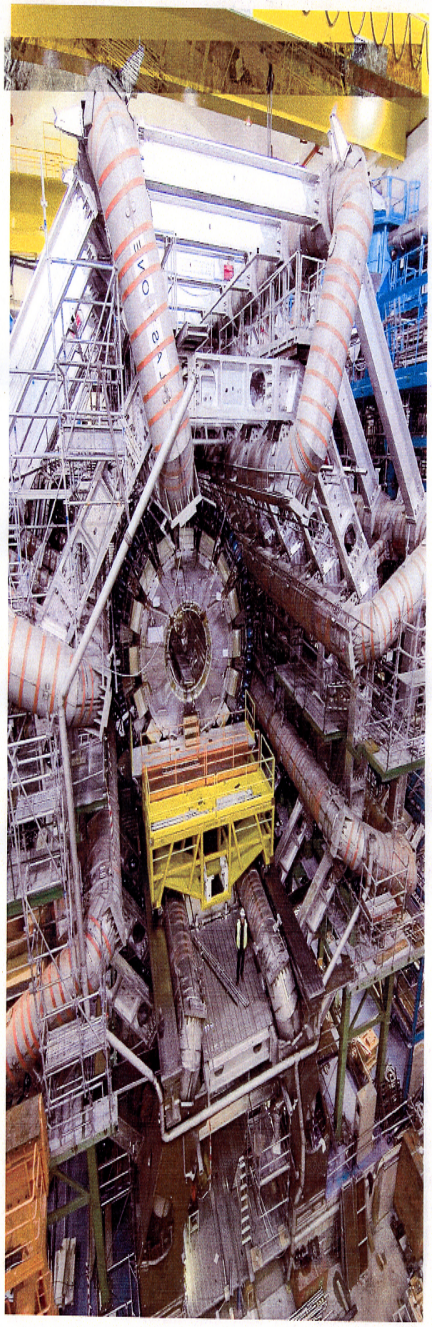
$\neq$

NO



AU DELÀ
DES
FRONTIÈRES
DE LA
SCIENCE
GUROUS
PHILOSOPHES
PROPHÈTES...
CINGLÉS





9

La VRAI

DIFFICULTÉ à

Comprendre les

PARTICULES ELÉMENTAIRES:

Elles sont

TROP

SIMPLES

PARTICULE ÉLÉMENTAIRE

LE CONTRAIRE

(TRÉS PEU DE PROPRIÉTÉS)

MASSE (0.5 MeV/c^2)

CHARGE (-1)

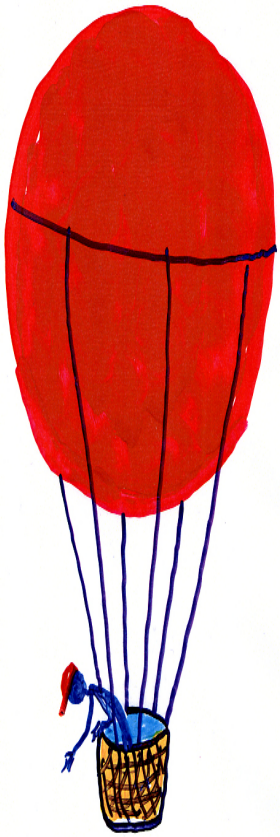
⇩

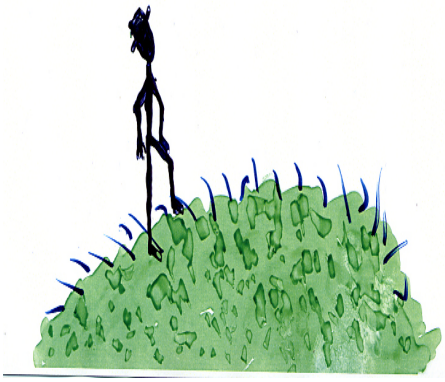
ELECTRON !!

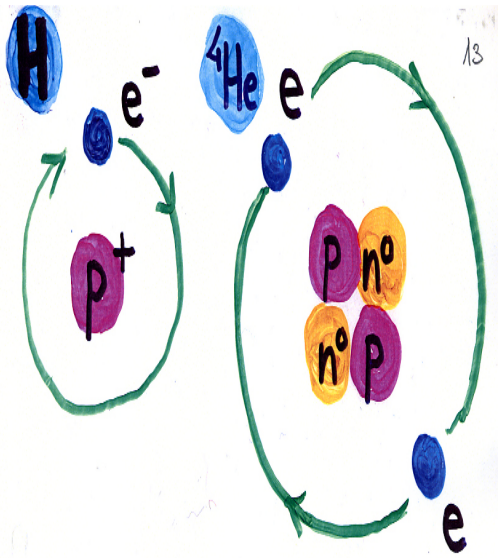
QUE D'AUTRE ?

SPIN 1/2

COUSIN : NEUTRINO

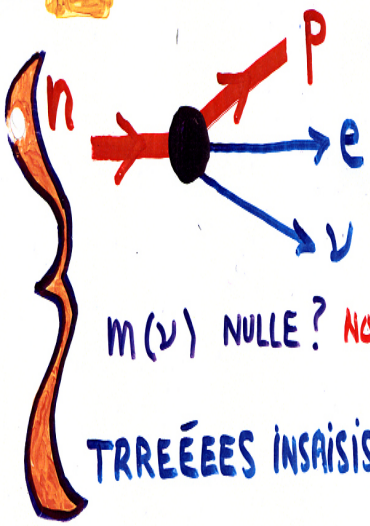






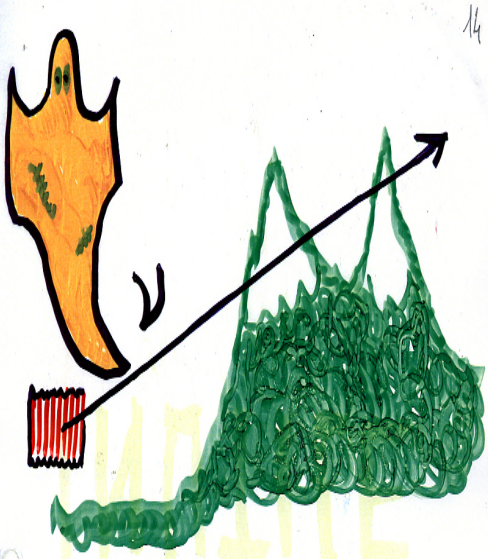
$n^0 \approx p^+$ SANS CHARGE ÉLECTRIQUE

$\nu^0 \approx e^-$ SANS CHARGE ÉLECTRIQUE

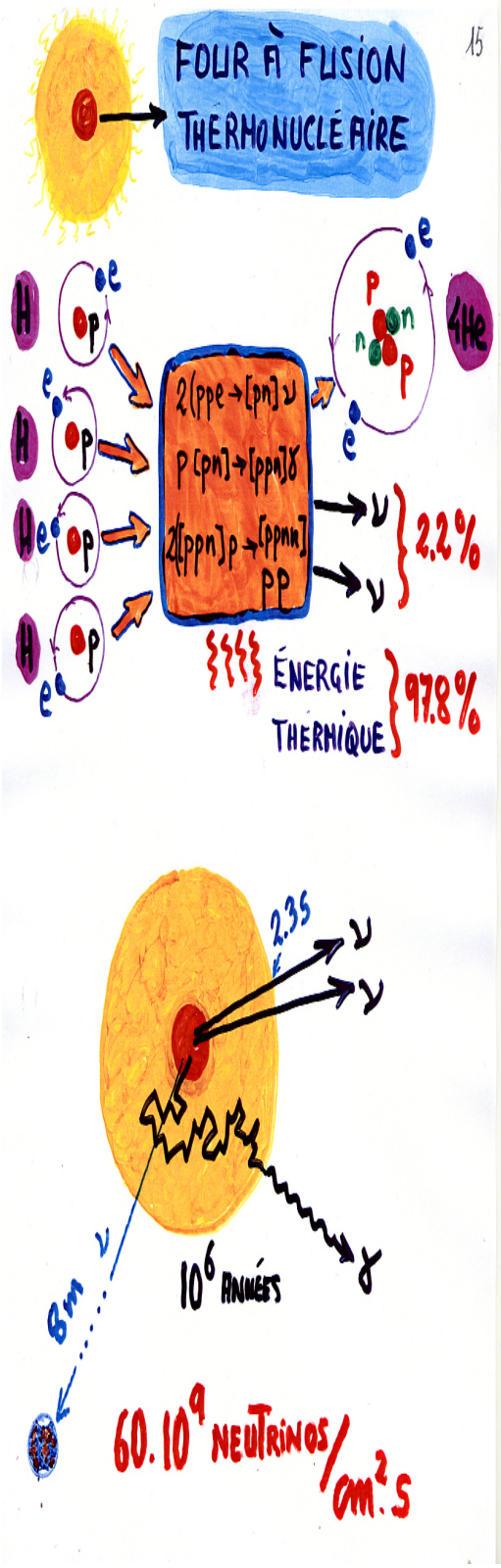


$m(\nu)$ NULLE ? NON !

TRREÉEES INSAISISABLES



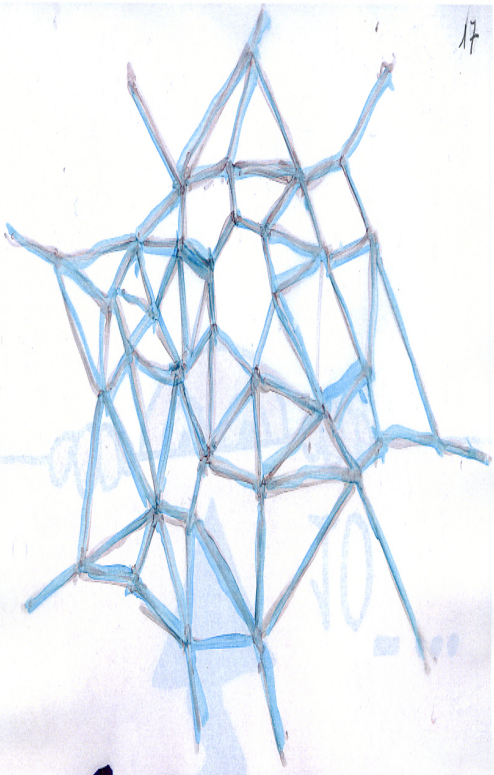
À QUOI "SERT" D'ÉTUDIER DES PARTICULES QUI NE "FONT" PAS GRAND'CHOSE ¿?


FOUR À FUSION THERMONUCLÉAIRE
H
e
p
2(ppe→[pn]ν
p[pn]→[ppn]γ
2([ppn]p→[ppnn]pp
ν
ν
2.2%
ÉNERGIE THERMIQUE
97.8%
4He
2.3s
ν
ν
γ
8m ν
10^6 ANNÉES
60.10^9 NEUTRINOS/cm².s

June 5, 1998

Neutrinos in the Sun

Credit: R. Svoboda and K. Gordan (LSU)



WWW

UN'ALTRO MODO DI COMUNICARE

u	c	t
d	s	b
e	μ	τ
ν_1	ν_2	ν_3

γ, g, $W^{\pm}$, Z^0

G

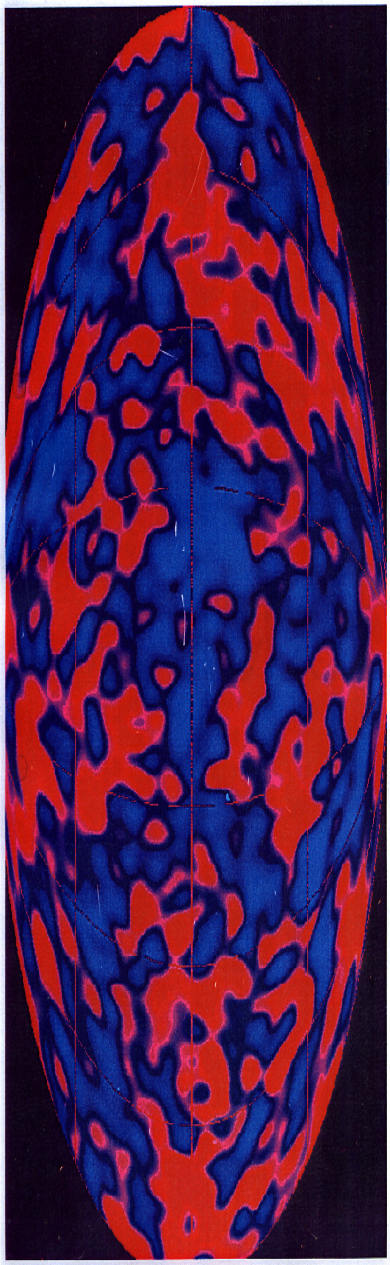
$e \approx \mu \approx \tau$

$$\mu \rightarrow e\, \bar{\nu}_e\, \nu_\mu$$

$\sim 2.2\,\mu s$

Trasferenza da combaciare con la N°19
FORCE =
PARTICULE
(ÉCHANGÉE)
UNIFICATION

UNE VISITE à L'UNI-VERS

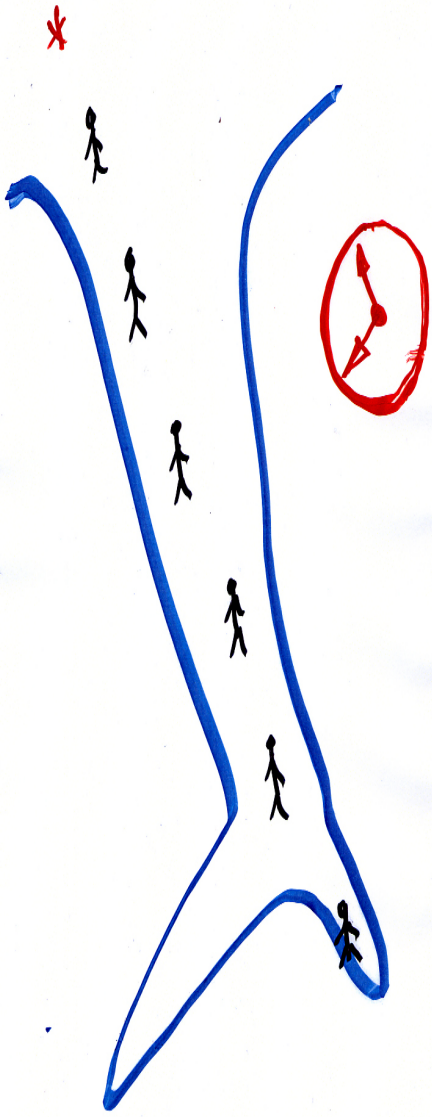


LA RADIAZIONE DI FONDO VIENE DA MOLTO LONTANO (CIRCA 13,7 MILLIARDI DI ANNI LUCE)

FU EMESSA MOLTO TEMPO FÀ (CIRCA 13 MILLIARDI DI ANNI FÀ)

QUANDO L'UNIVERSO ERA UN BIMBO:

ETÀ: 100.000 ANNI



da combaciare con
la 24

CIAO

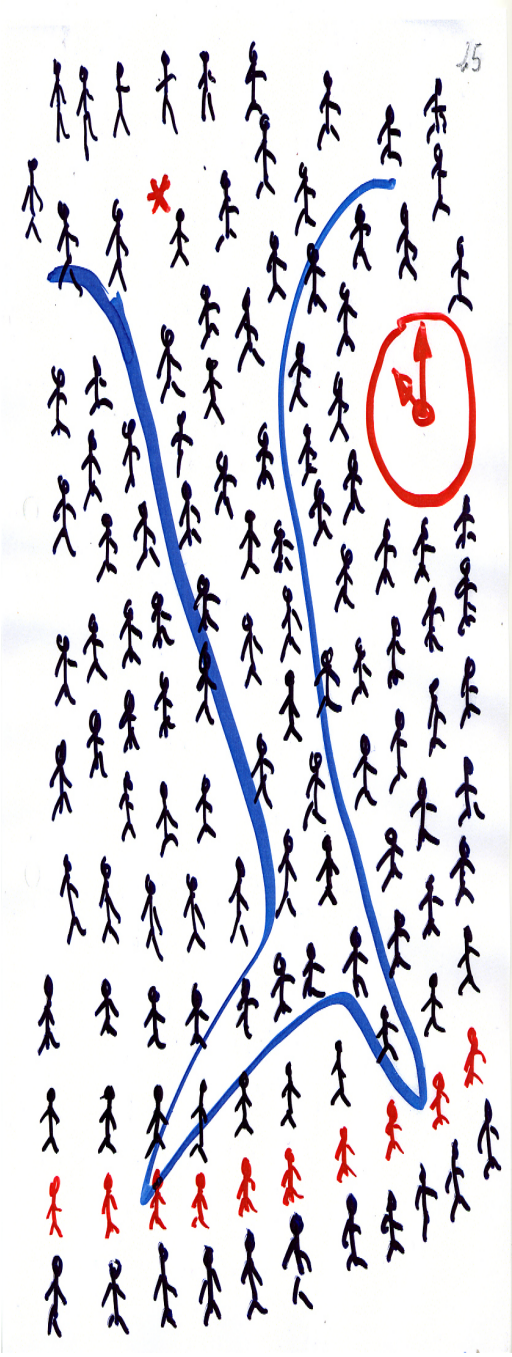
CIAO

CIAO

CIAO

CIAO

CIAO



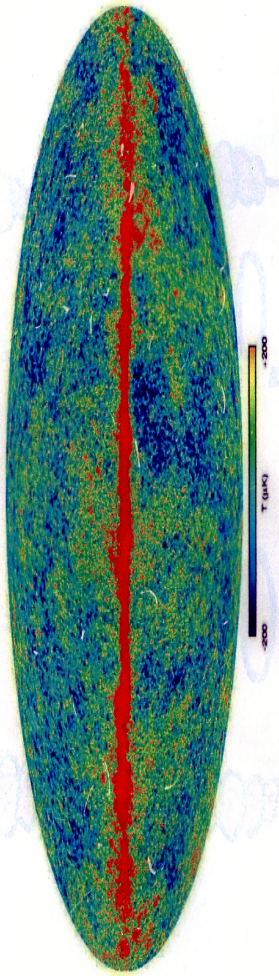
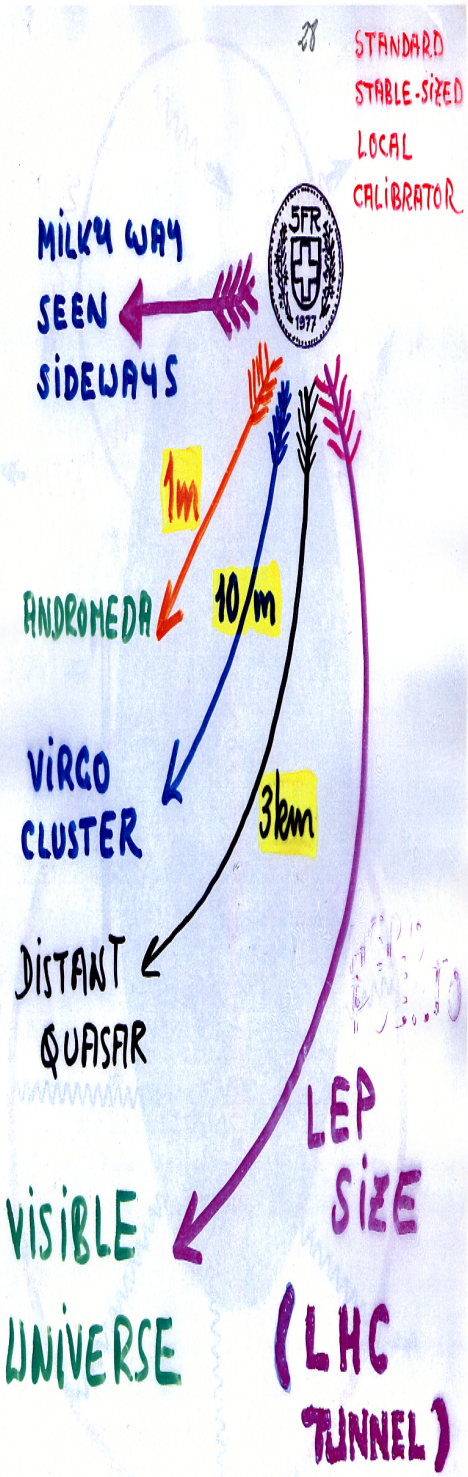


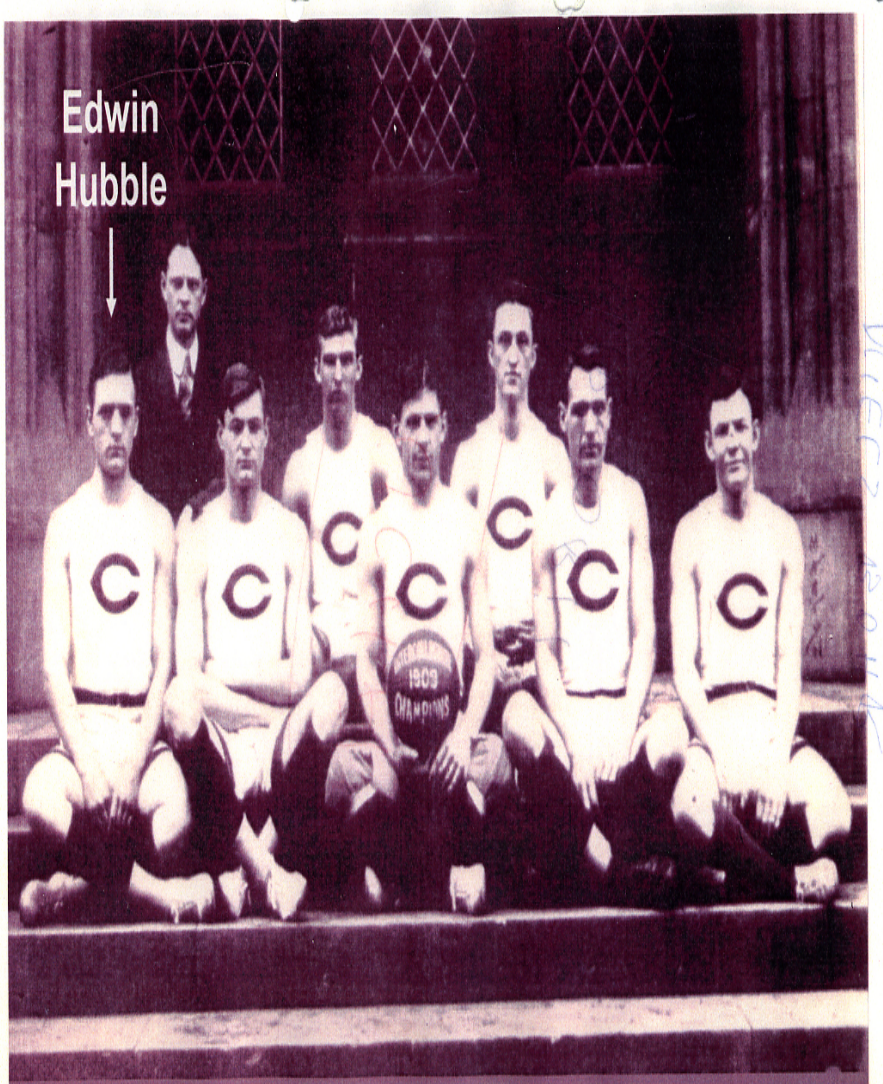
Fig. 2c.— W-band


STANDARD
STABLE-SIZED
LOCAL
CALIBRATOR
MILKY WAY
SEEN
SIDEWAYS
1m
ANDROMEDA
10 m
VIRGO
CLUSTER
3km
DISTANT
QUASAR
LEP
SIZE
VISIBLE
UNIVERSE
(LHC
TUNNEL)

DESCRIPTION

EDWIN HUBBLE
(1927)
BEGAT
COSMOLOGY
AS A SCIENCE

REDSHIFT (RECESSIVE
VELOCITY) VS. DISTANCE
RELATION



University of Chicago 1909 National Champions

E.P. HUBBLE Proc. Nat. Ac. Sc. 15 168 (1927)

(EL REINO DE LAS NEBULOSAS)

that the velocity-distance relation (Fig. 9) emerged from the data in essentially its present form.

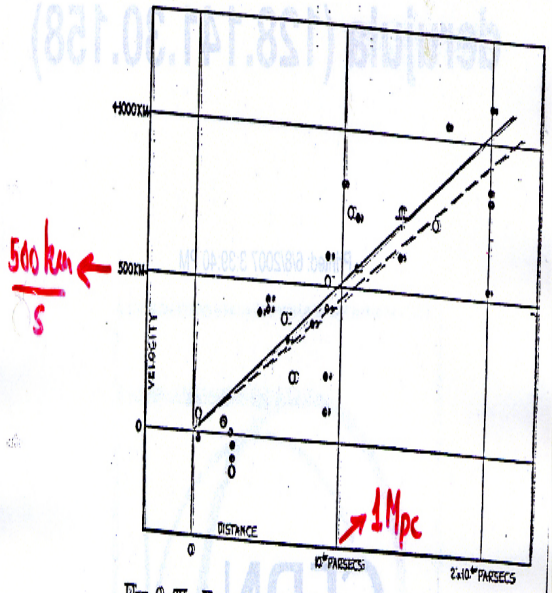


FIG. 9. *The Formulation of the Velocity-Distance Relation.*

The radial velocities (in km/sec.), corrected for solar motion, are plotted against distances (in parsecs) estimated from involved stars and, in the case of the Virgo cluster (represented by the four most distant nebulæ), from the mean luminosity of all nebulæ in the cluster. The black disks and full line represent a solution for the solar motion using the nebulæ individually; the circles and dashed line, a solution combining the nebulæ into groups.

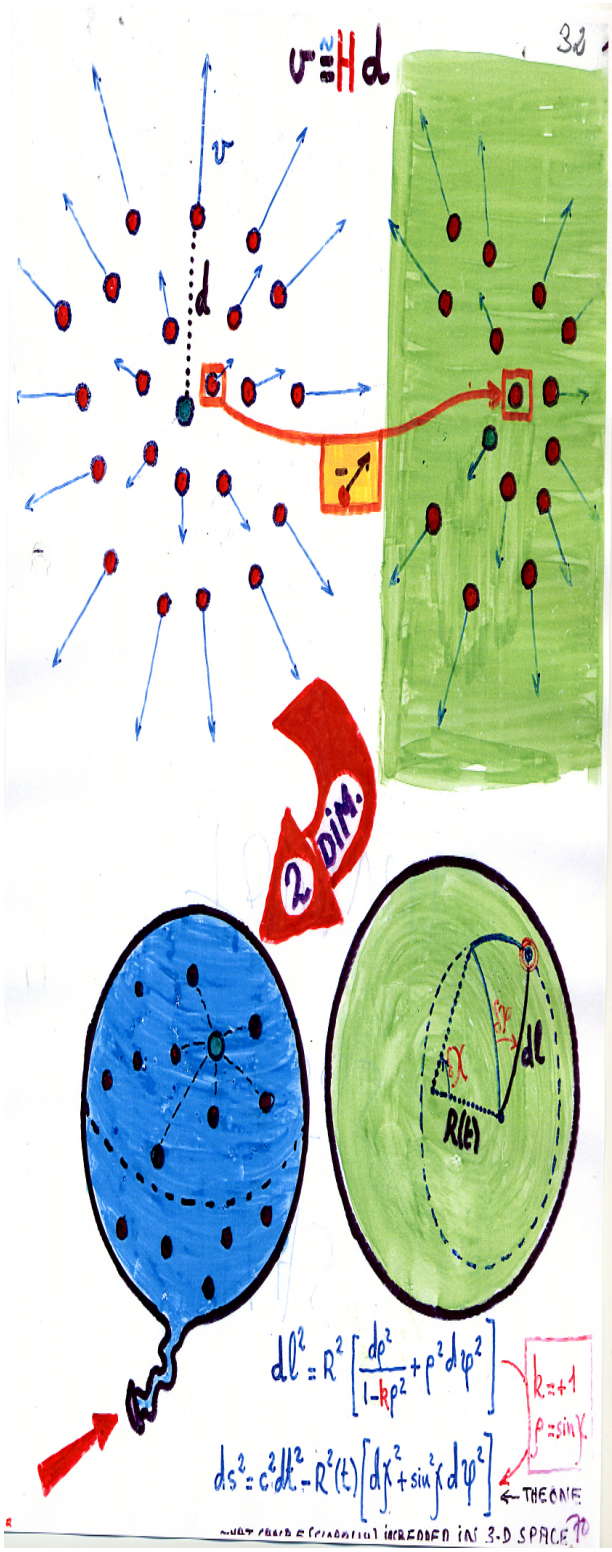
$v \sim H d$

$H \sim 500$ km/(s. Mpc) $\left[\frac{1}{T}\right]$

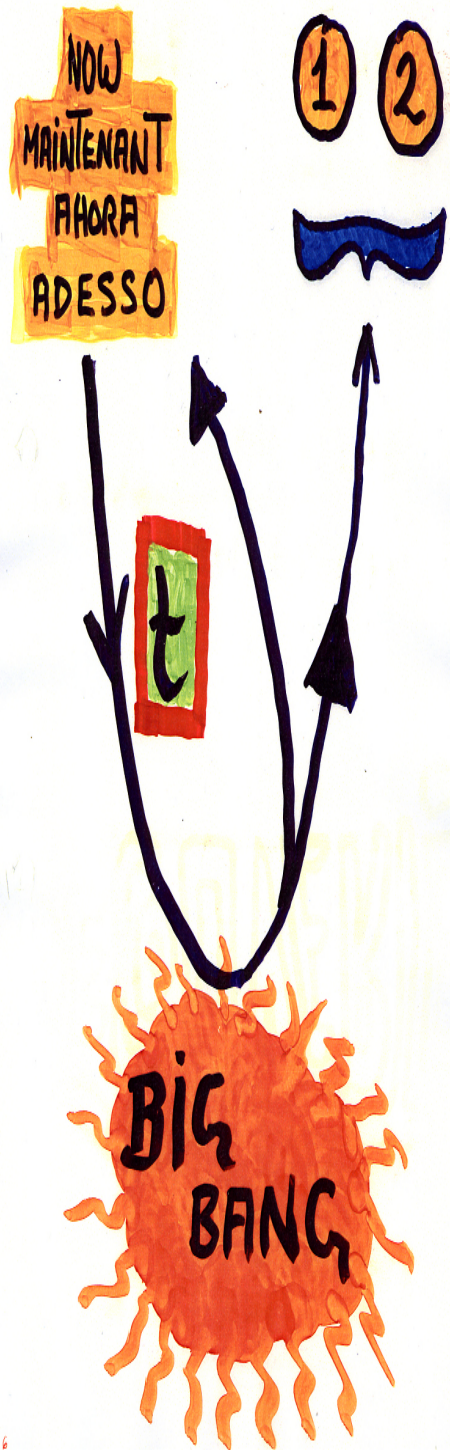
SOME 60 YEARS LATER

TREND UNDISPUTED

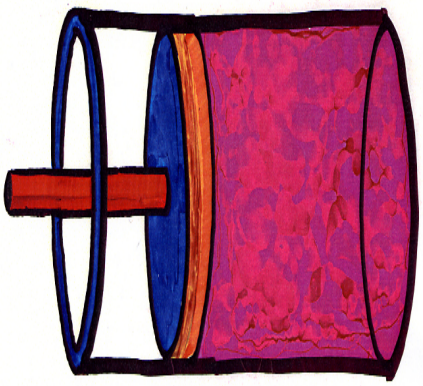
SLOPE DEBATED



32
v ≅ H d
v
d
2 DIM.
dl
R(t)
$dl^2 = R^2\left[\frac{d\rho^2}{1-k\rho^2} + \rho^2 d\varphi^2\right]$
k = +1
ρ = sin χ
$ds^2 = c^2dt^2 - R^2(t)\left[d\chi^2 + \sin^2\chi\, d\varphi^2\right]$
← THEONE
INCREDDED IN 3-D SPACE


NOW
MAINTENANT
AHORA
ADESSO
1
2
t
BIG
BANG

UN CYLINDRE...



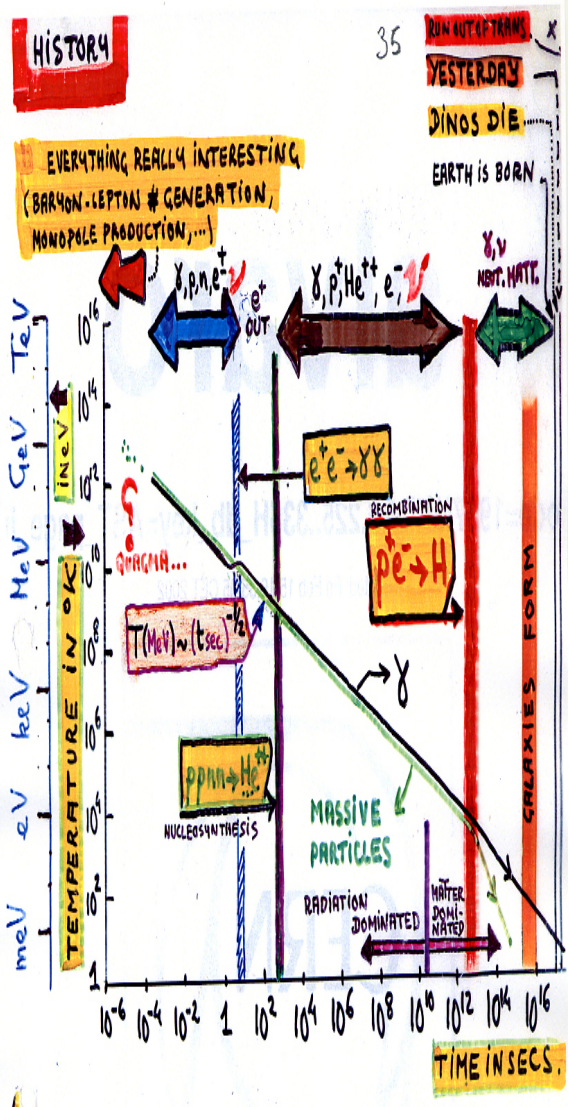
... OU L'UNIVERS

PASSÉ { PLUS CONCENTRÉ
PLUS CHAUD

T = E moyenne

HAUTE T = HAUTE E

HISTORY



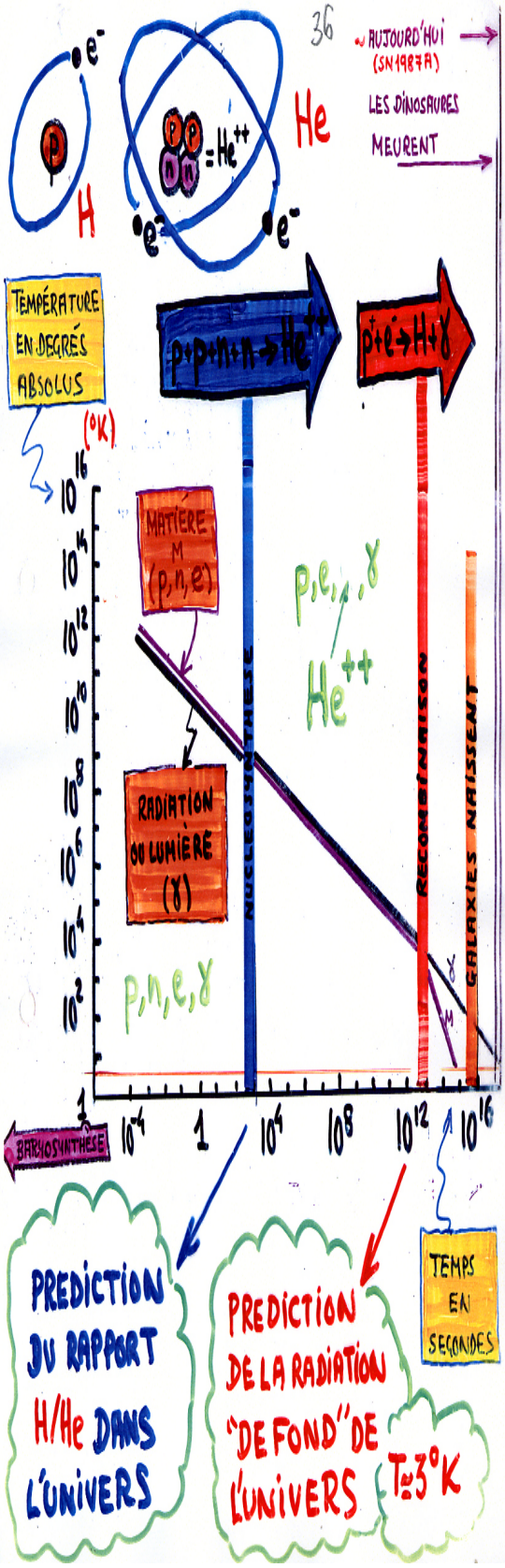
BACK.

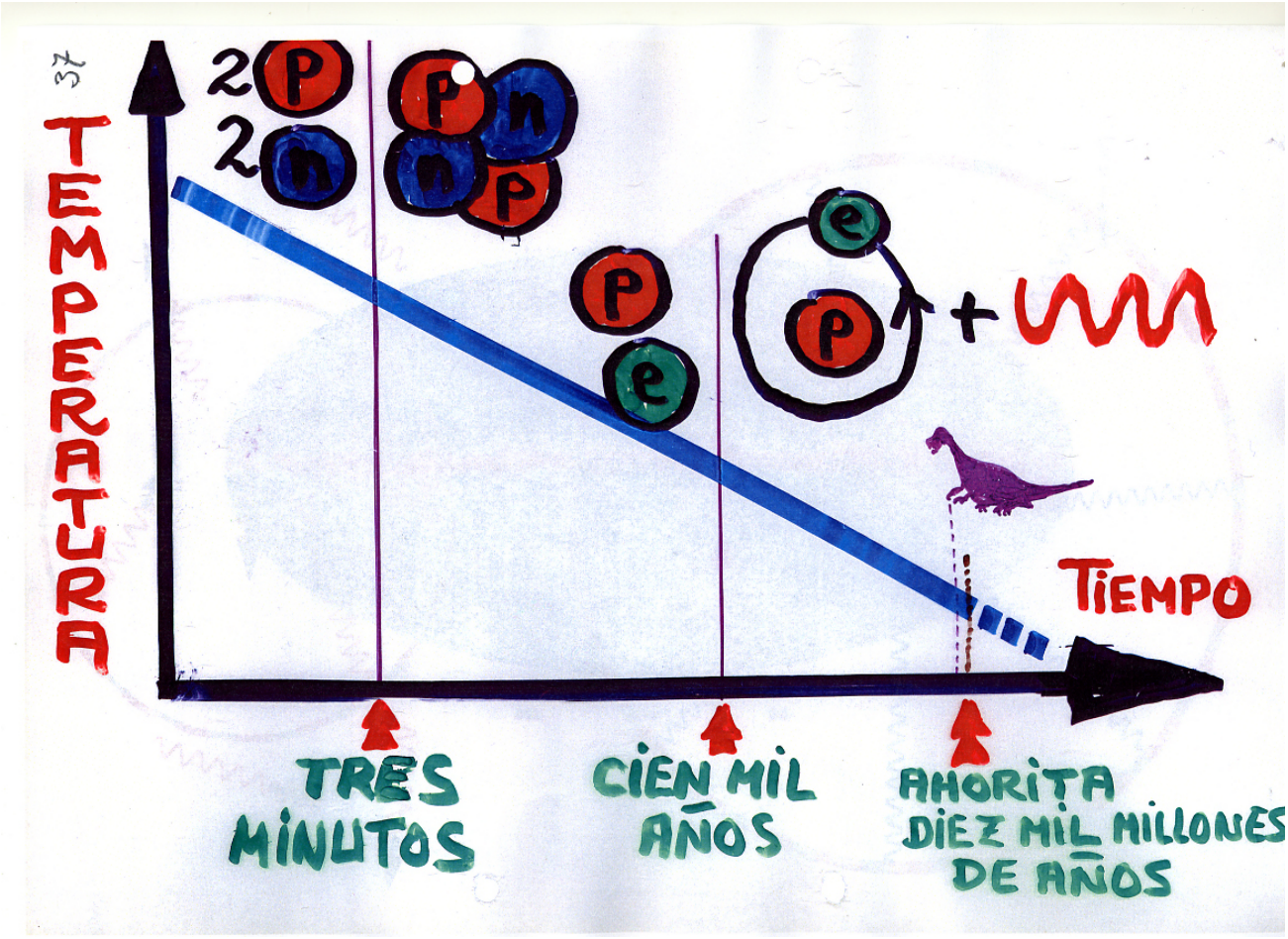
- MATTER IS NEUTRAL, UNIVERSE TRANSPARENT
- $H \to p^+ e^-$, γ INTERACTS LARGE, γ-MASSIVE PARTS. EQUILIBR
- TEMPERATURE SO HIGH $e^+e^- \rightleftarrows \gamma\gamma$

FORWARDS

- $2p2n \to He^{++}$ CORRECT PREDICT PRIMORD. ABUNDANCE 25-30%
- $e^+e^- \to \gamma\gamma$ PHOTONS HEAT UP A LITTLE BIT
- γ DECOUPLE, COOL AS UNIVERSE EXPANDS

CORRECT PREDICTION OF 2.7°K BACKGROUND RADIATION


AUJOURD'HUI
(SN1987A)
LES DINOSAURES MEURENT
H
He
$=He^{++}$
TEMPÉRATURE EN DEGRÉS ABSOLUS
(°K)
$p+p+n+n \rightarrow He^{++}$
$p^+ + e^- \rightarrow H + \gamma$
MATIÈRE M (p,n,e)
RADIATION OU LUMIÈRE (γ)
p,n,e,γ
p,e,γ
He^{++}
NUCLEOSYNTHESE
RECOMBINAISON
GALAXIES NAISSENT
BARYOSYNTHESE
TEMPS EN SECONDES
PREDICTION DU RAPPORT H/He DANS L'UNIVERS
PREDICTION DE LA RADIATION "DE FOND" DE L'UNIVERS
T≈3°K


37
TEMPERATURA
2 P
2 n
P
n
n
P
P
e
e
P
+
TIEMPO
TRES MINUTOS
CIEN MIL AÑOS
AHORITA DIEZ MIL MILLONES DE AÑOS

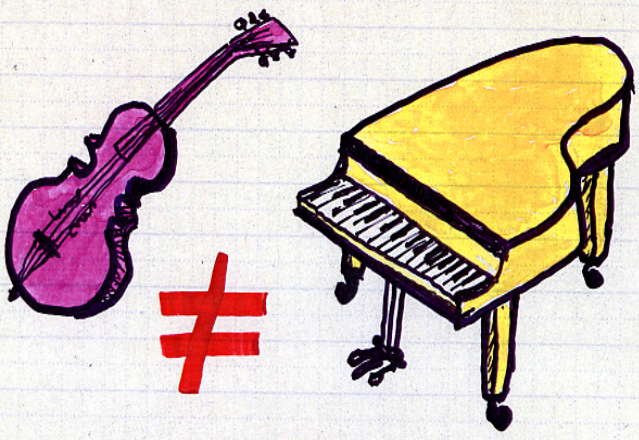
ACCÉLÉRATEUR
10 * E
ET ON
COMPRENDS
LOIS DE LA
NATURE
10 * "intime"
HISTOIRE DE
L'UNIVERS
100 * "Jeune"

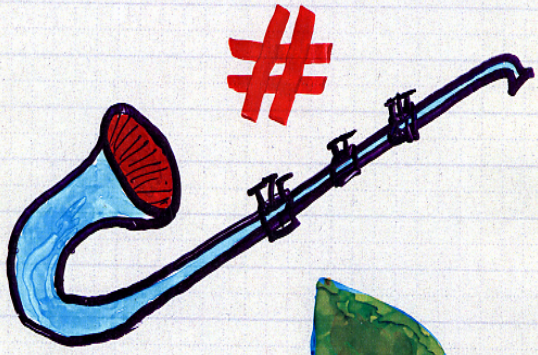
Recette pour faire (notre) UNIVERS

Ingrèdients (en pourcentage)

- **Lumière et Neutrinos** << 1 %
- **Matière "normale"** ~~~ 1 %~~ 4%
  (tout juste une pincée !)
- **Matière "sombre"** ~~~ 30 %~~ 22%
  (inconnue !!)
- **Énergie du vide** ~~~ 70 %~~ 74%
  (Totalement mystèrieuse !!!)

Bien Mélanger et .....
Servir TRÈS chaud





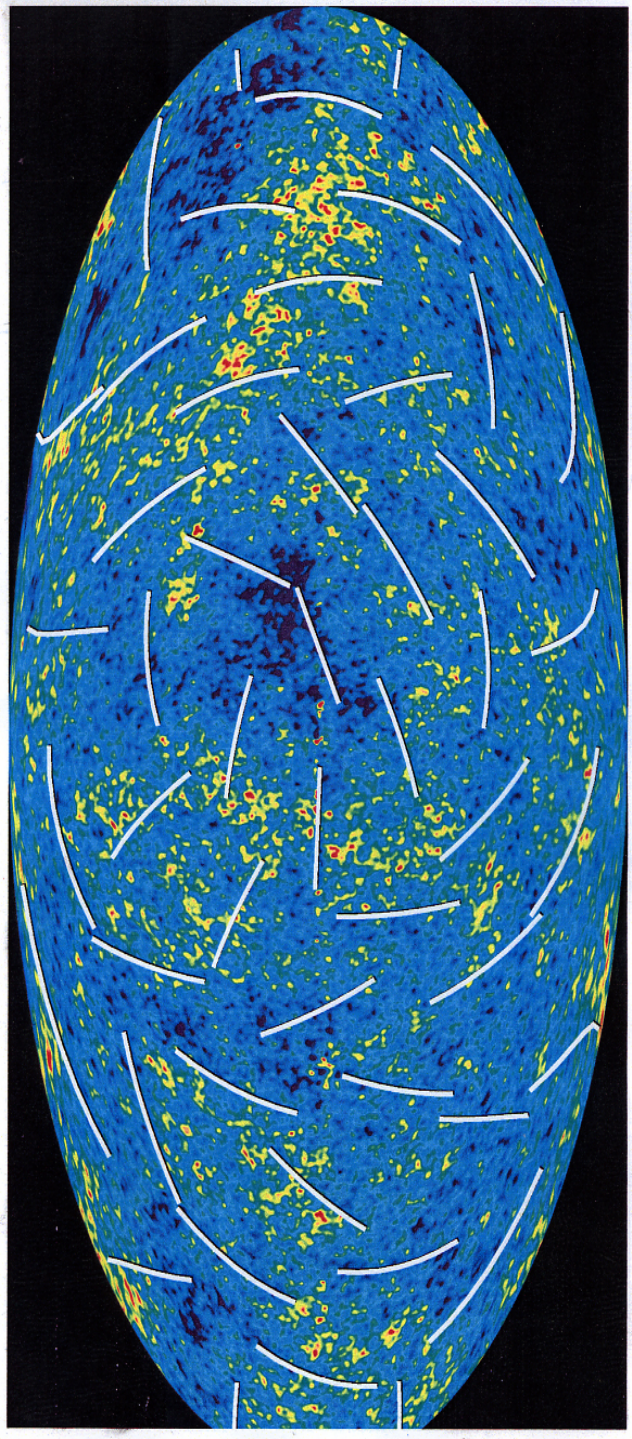
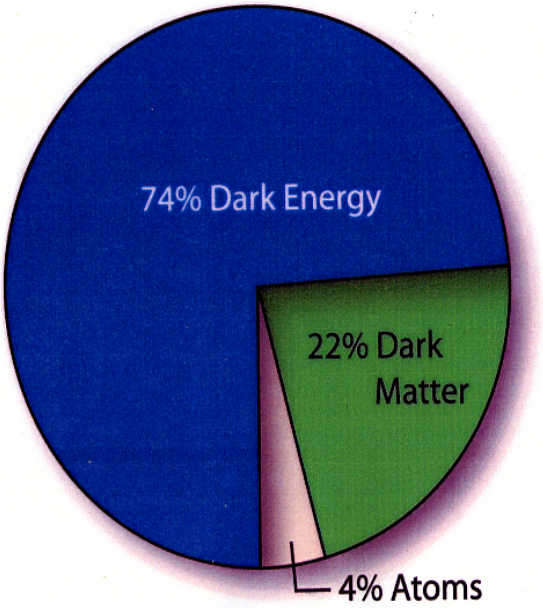
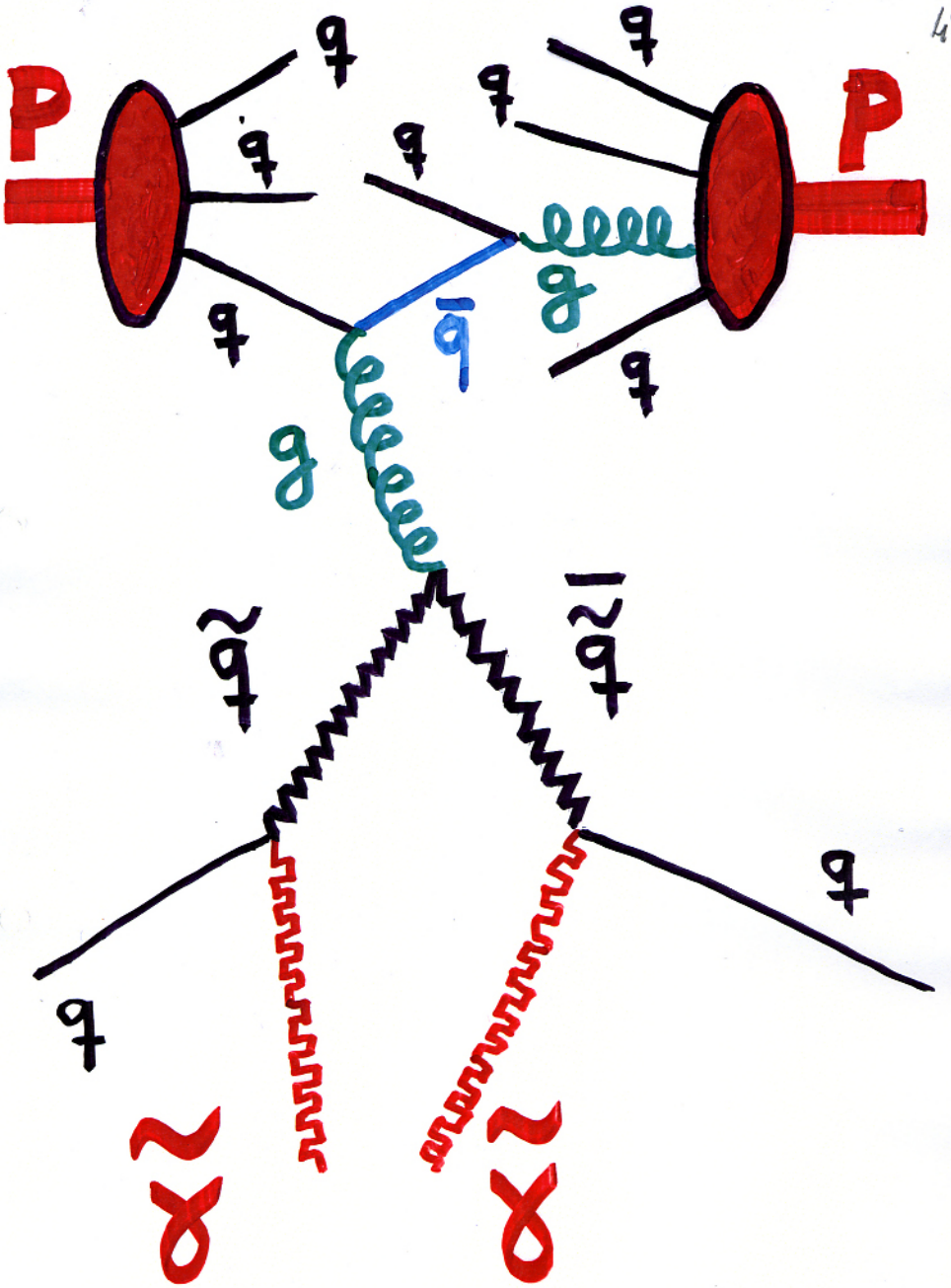
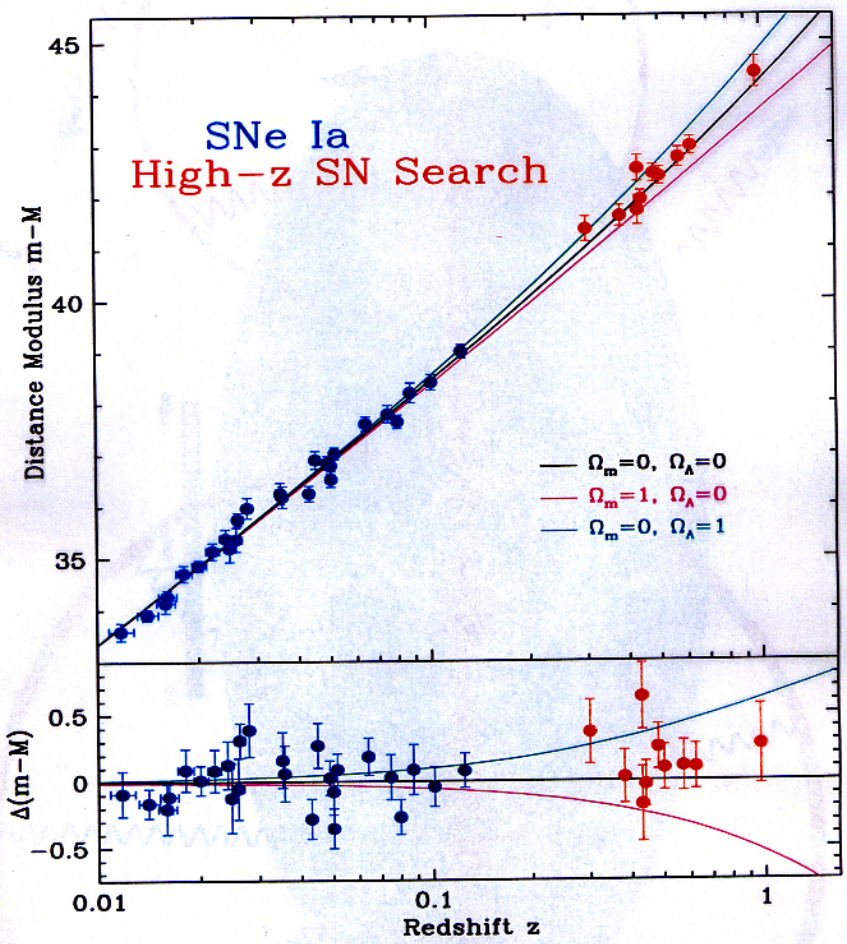


Fig. 12.— The WMAP angular power spectrum. (top:) The WMAP temperature (TT) results are consistent with the ACBAR and CBI measurements, as shown. The TT angular power spectrum is now highly constrained. Our best fit running index ΛCDM model is shown. The grey band represents the cosmic variance expected for that model. The quadrupole has a surprisingly low amplitude. Also, there are excursions from a smooth spectrum (e.g., at $\ell \approx 40$ and $\ell \approx 210$) that are only slightly larger than expected statistically. While intriguing, they may result from a combination of cosmic variance, subdominant astrophysical processes, and small effects from approximations made for this first year data analysis (Hinshaw et al. 2003b). We do not attach cosmological significance to them at present. More integration time and more detailed analyses are needed. (bottom:) The temperature-polarization (TE) cross-power spectrum, $(l+1)C_l/2\pi$. (Note that this is not multiplied by the additional factor of l.) The peak in the TE spectrum near $l \sim 300$ is out of phase with the TT power spectrum, as predicted for adiabatic initial conditions. The antipeak in the TE spectrum near $l \sim 150$ is evidence for superhorizon modes at decoupling, as predicted by inflationary models.


74% Dark Energy
22% Dark Matter
4% Atoms


P
P
q
q
q
q
q
q
q
q
g
g
$\bar{q}$
$\tilde{q}$
$\bar{\tilde{q}}$
q
q
$\tilde{\gamma}$
$\tilde{\gamma}$


SNe Ia
High−z SN Search
Distance Modulus m−M
45
40
35
Ω_m=0, Ω_Λ=0
Ω_m=1, Ω_Λ=0
Ω_m=0, Ω_Λ=1
Δ(m−M)
0.5
0
−0.5
0.01
0.1
1
Redshift z

Riess et al.

La

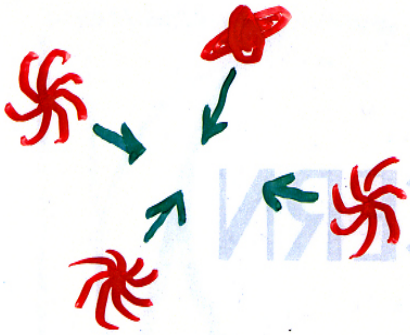
"CONSTANTE COSMOLOGIQUE"

Λ

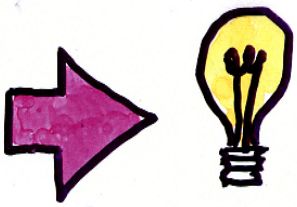
© A. EINSTEIN
DROITS D'AUTEUR

POURQUOI EINSTEIN INVENTA Λ ?

UNIVERS STATIQUE

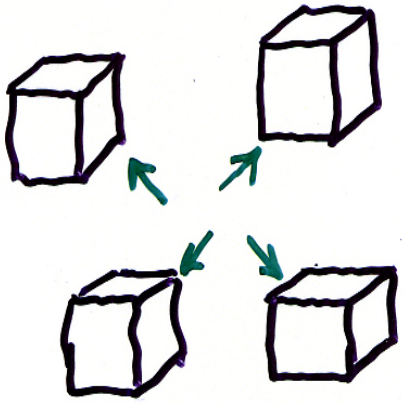


... COLLAPSERAIT !!



INTRODUIRE

UNE FORCE ÉGALE
ET OPPOSÉE



IDÉE OSÉE : LA FORCE EST
EXCERBÉE PAR
LE VIDE SUR LE VIDE

HUBBLE ➡ "LA PLUS GRANDE ERREUR
DE MA CARRIÈRE" (A.E.)

Le VIDE ≠ Le NÉANT

=

ÉNÉRGIE du VIDE

$$\Lambda = 0$$

THE GREATEST OF ALL NATURAL DISASTERS

EINSTEIN

vs

E

KN

HIGGS

A B L W

G B E R

E L R A

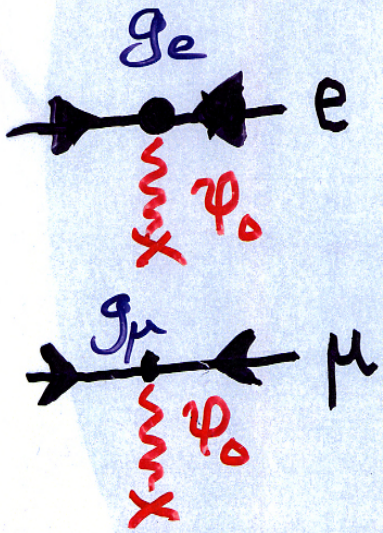
N E T L

Nik and BROUT

STANDARD MODEL

$\exists\ \varphi(x)$ SCALAR FIELD

$$\langle 0|\varphi(x)|0\rangle = \varphi_0 \neq 0$$



HANDEDNESS FLIPPER

$$m_e = g_e \varphi_0$$

$$m_\mu = g_\mu \varphi_0$$

$$\ldots$$

Λ IS THE 'VACUUM' E-DENSITY

$|0\rangle$ = WHAT REMAINS AFTER YOU TAKE OUT EVERYTHING THAT IS TAKABLE-OUTABLE

$$\langle 0|T_{\mu\nu}|0\rangle = \rho_0 \, g_{\mu\nu}$$

$$E_{\mu\nu} = 8\pi T_{\mu\nu} G_N$$

$$\rightarrow \underbrace{8\pi G_N \rho_0}_{\Lambda} \, g_{\mu\nu}$$

GRAVITY COUPLES TO ENERGY-DENSITY OF EVERYTHING

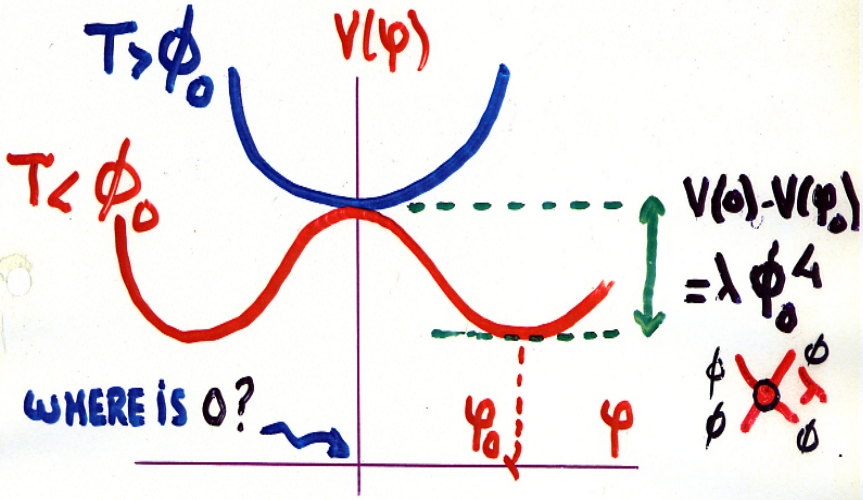
ENERGY (NOT DIFFERENCES) IS WHAT MATTERS

$\Lambda = 0$ THE VACUUM IS VOID [OK. ENGL.] ~~B~~ ~~Pk~~

WEAK PHASE TRANSITION

$T > \phi_0$ (246 GeV)

$\hookrightarrow T < \phi_0$



$$\Lambda_{EMPIR} \lesssim 9\frac{H_0^2}{c^2} \sim 3.\,10^{-83}\,\mathrm{GeV}^2$$

$$\Delta\Lambda\left[\begin{matrix}\text{WEAK}\\ \text{TRANS.}\end{matrix}\right] = 2\pi\lambda G_N \phi_0^4 = 2\pi\lambda\, \underbrace{3.10^{-29}\,\mathrm{GeV}^2}$$

OBSERVABLE SPACE CURVATURE OVER ~20 cm

$$\Delta\Lambda_{WEAK} \sim 10^{54}\,\Lambda_{EMPIR.}$$

Si le **VIDE**

a une "Substance"

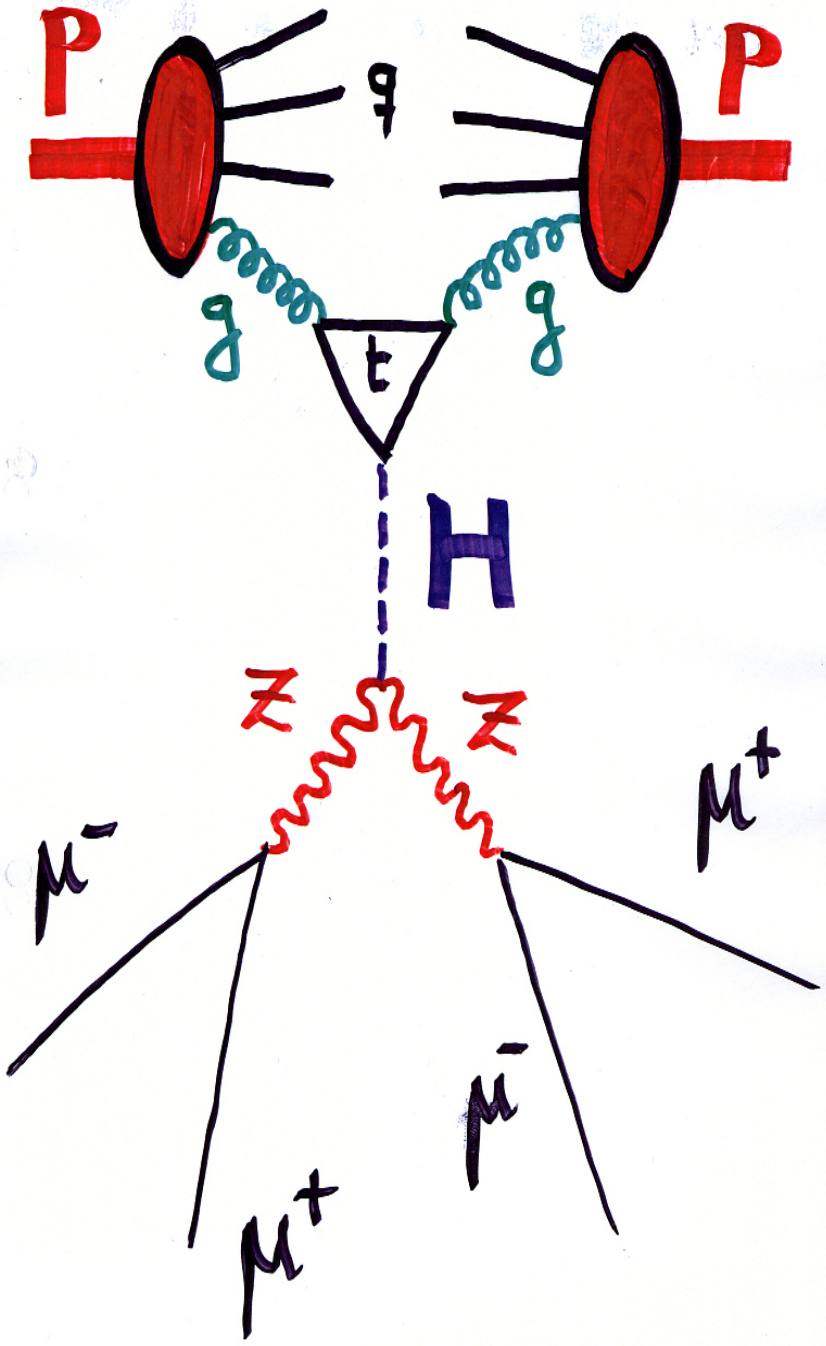
on peut le faire VIBRER !!

VIBRATIONS =

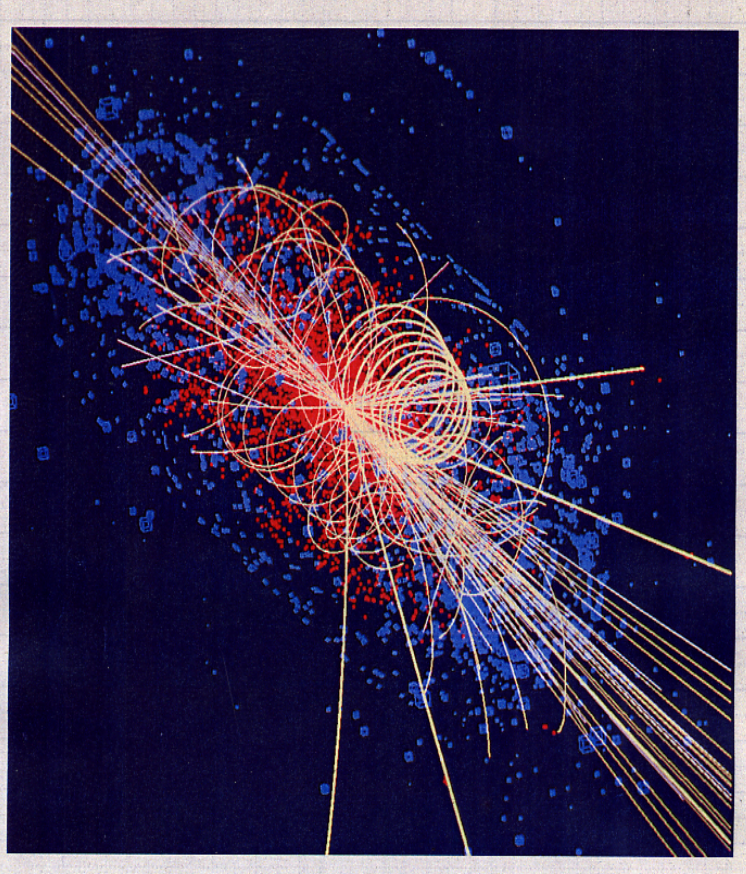
particules de

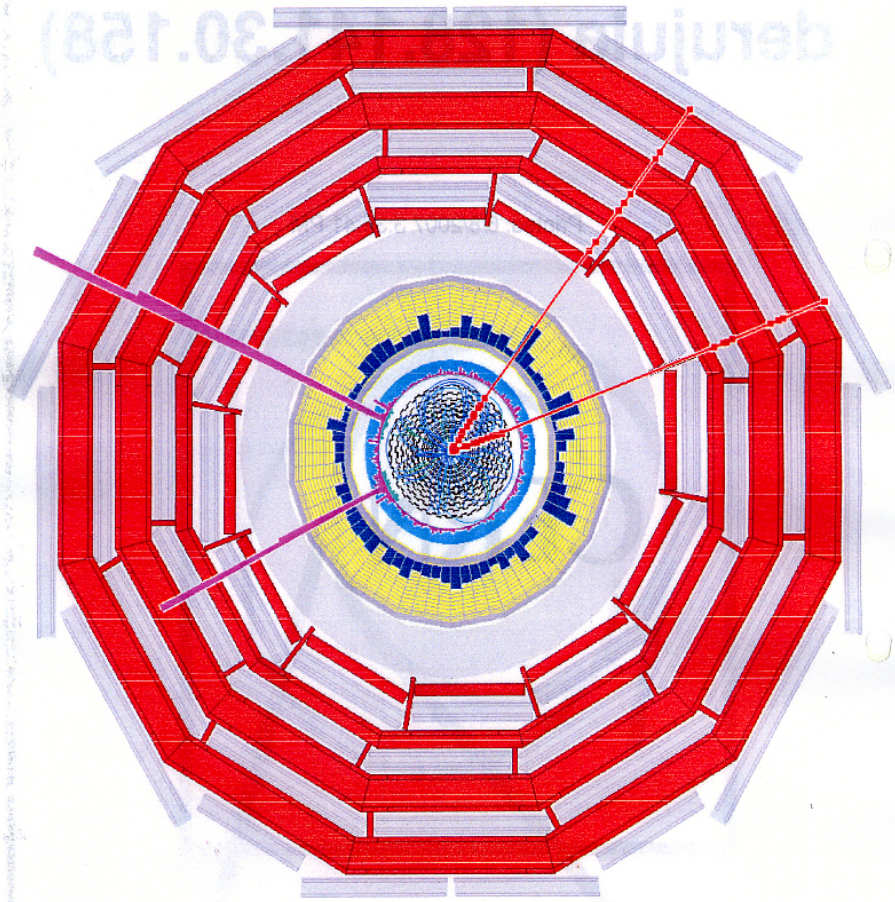
HIGGS

LHC


P
q
P
g
g
t
H
Z
Z
μ⁻
μ⁺
μ⁻
μ⁺

60





- WE HAVE NOT UNDERSTOOD THE ORIGIN OF MASS

- WE HAVE NOT UNDERSTOOD WHAT THE MASS OF THE UNIVERSE CONSISTS OF

- ANYBODY NOT WORRYING ABOUT Λ $\geq$ 1 HOUR/DAY SHOULD BE ARRESTED AND THROWN IN JAIL

63
53

STOP