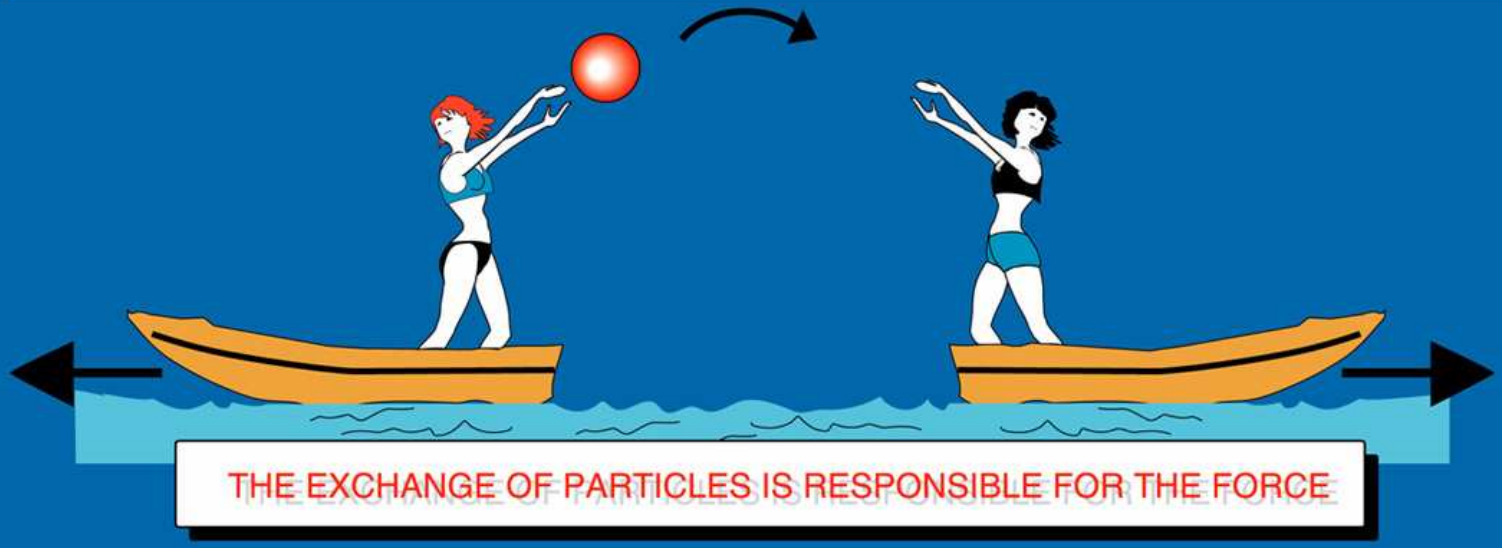
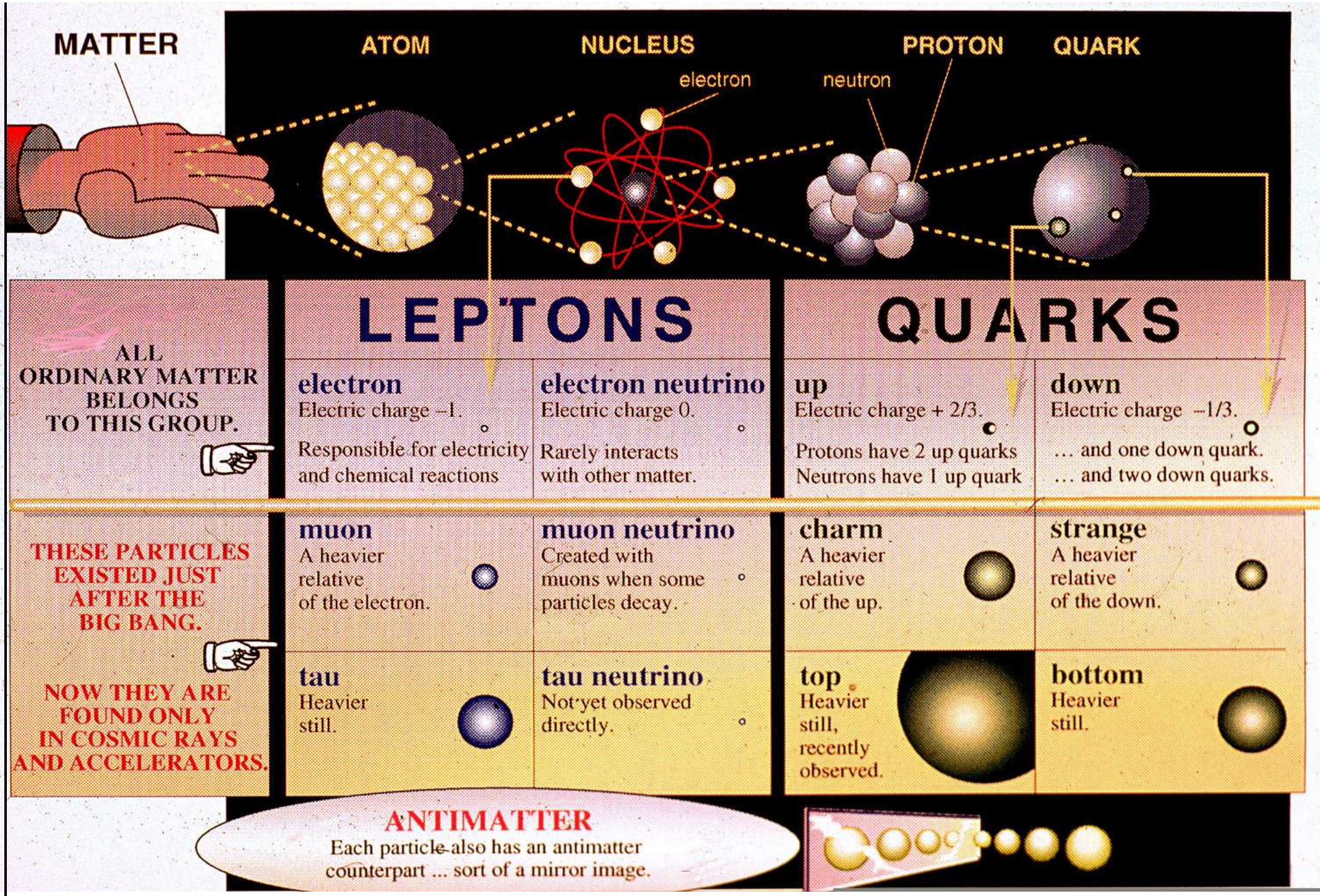
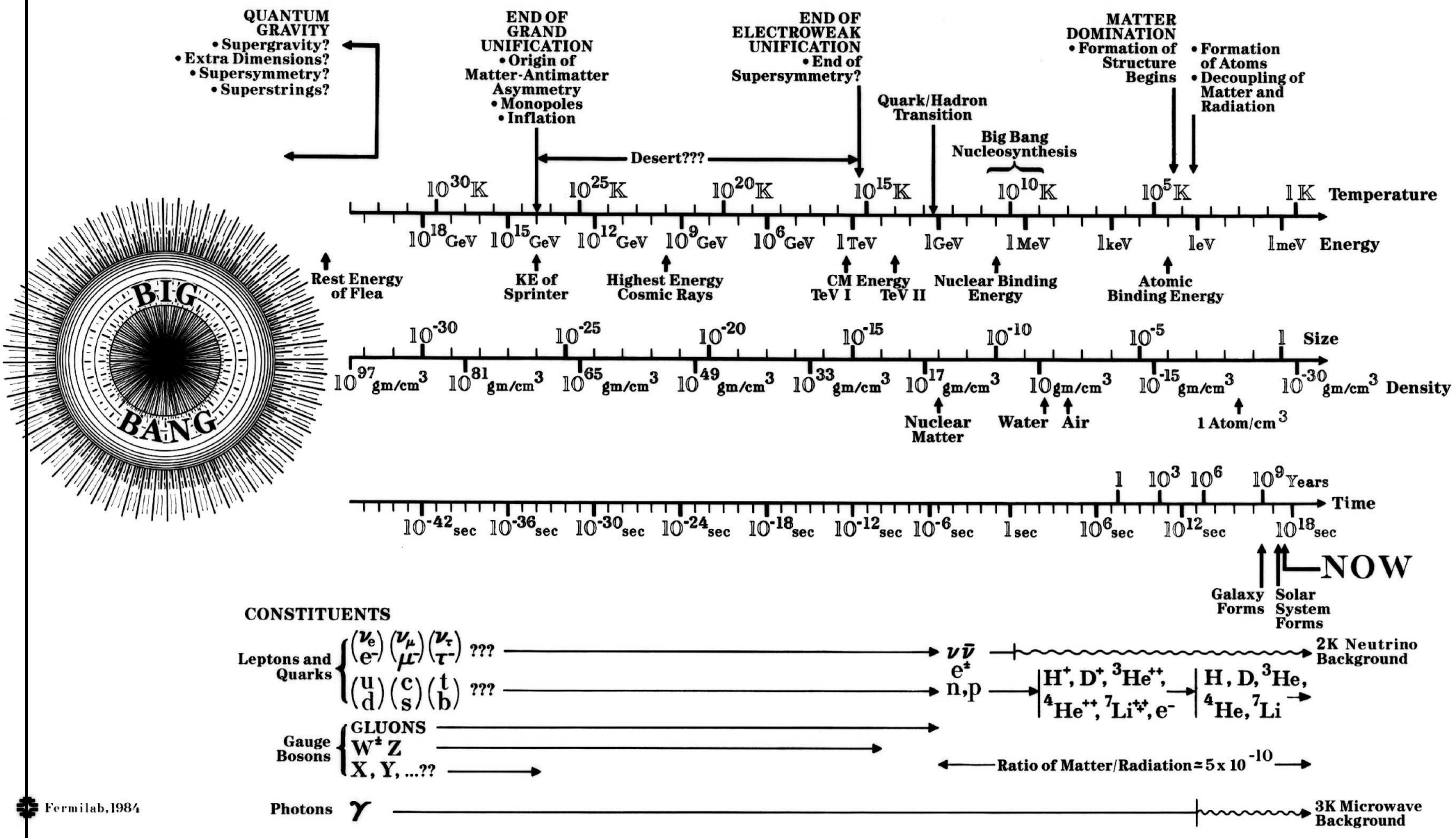
The forces in Nature

TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	~ 10^{-3}	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	~ 10^{-5}	BOSONS Z^0 , W+ , W- (HEAVY)	RADIOACTIVE BETA DESINTEGRATION
GRAVITATION	~ 10^{-38}	GRAVITONS (?)	HEAVENLY BODIES



PD Dr. H. Kroha: Einführung in die moderne Teilchenphysik, ET2, WS 2001/02




QUANTUM GRAVITY
• Supergravity?
• Extra Dimensions?
• Supersymmetry?
• Superstrings?
END OF GRAND UNIFICATION
• Origin of Matter-Antimatter Asymmetry
• Monopoles
• Inflation
END OF ELECTROWEAK UNIFICATION
• End of Supersymmetry?
Quark/Hadron Transition
Big Bang Nucleosynthesis
MATTER DOMINATION
• Formation of Structure Begins
• Formation of Atoms
• Decoupling of Matter and Radiation
Desert???
10^{30}K 10^{25}K 10^{20}K 10^{15}K 10^{10}K 10^{5}K 1K Temperature
10^{18}GeV 10^{15}GeV 10^{12}GeV 10^{9}GeV 10^{6}GeV 1TeV 1GeV 1MeV 1keV 1eV 1meV Energy
Rest Energy of Flea
KE of Sprinter
Highest Energy Cosmic Rays
CM Energy TeV I
TeV II
Nuclear Binding Energy
Atomic Binding Energy
BIG BANG
10^{-30} 10^{-25} 10^{-20} 10^{-15} 10^{-10} 10^{-5} 1 Size
10^{97} gm/cm^3 10^{81} gm/cm^3 10^{65} gm/cm^3 10^{49} gm/cm^3 10^{33} gm/cm^3 10^{17} gm/cm^3 10 gm/cm^3 10^{-15} gm/cm^3 10^{-30} gm/cm^3 Density
Nuclear Matter
Water
Air
1 Atom/cm^3
1 10^3 10^6 10^9 Years Time
10^{-42}sec 10^{-36}sec 10^{-30}sec 10^{-24}sec 10^{-18}sec 10^{-12}sec 10^{-6}sec 1sec 10^{6}sec 10^{12}sec 10^{18}sec
NOW
Galaxy Forms
Solar System Forms
CONSTITUENTS
Leptons and Quarks
$\begin{pmatrix}\nu_e\\e^-\end{pmatrix}\begin{pmatrix}\nu_\mu\\\mu^-\end{pmatrix}\begin{pmatrix}\nu_\tau\\\tau^-\end{pmatrix}$???
$\begin{pmatrix}u\\d\end{pmatrix}\begin{pmatrix}c\\s\end{pmatrix}\begin{pmatrix}t\\b\end{pmatrix}$???
$\nu\bar{\nu}$
$e^{\pm}$
n,p
$H^+, D^+, {}^3He^{++}, {}^4He^{++}, {}^7Li^{+++}, e^-$
H, D, ^{3}He, ^{4}He, ^{7}Li
2K Neutrino Background
Gauge Bosons
GLUONS
$W^{\pm}$ Z
X, Y, ...??
Ratio of Matter/Radiation = 5 x 10^{-10}
Photons γ
3K Microwave Background
Fermilab, 1984