

1. Einführung

- 1.1. Was ist Physik?
- 1.2. Physikalische Größen und Einheiten
- 1.3. Messungen, Datenauswertung, Fehler

2. Klassische Mechanik

- 2.1. Kinematik der Massenpunkte
- 2.2. Dynamik der Massenpunkte
- 2.3. Systeme von Massenpunkten
- 2.4. Rotation

3. Gravitation

- 3.1. Gravitationsgesetz
- 3.2. Feld und Potential

3.3. Planetenbahnen: Kepler

3.4. Massenverteilungen

3.5. Dunkle Materie

4. Relativistische Mechanik

4.1. Bezugssysteme und Transformationen

4.2. Spezielle Relativitätstheorie

4.3. Relativistische Kinematik

5. Feste Körper und Flüssigkeiten

5.1. Feste Körper

5.2. Hydrostatik und Hydrodynamik

6. Schwingungen und Wellen

6.1. Schwingungen

6.2. Wellen

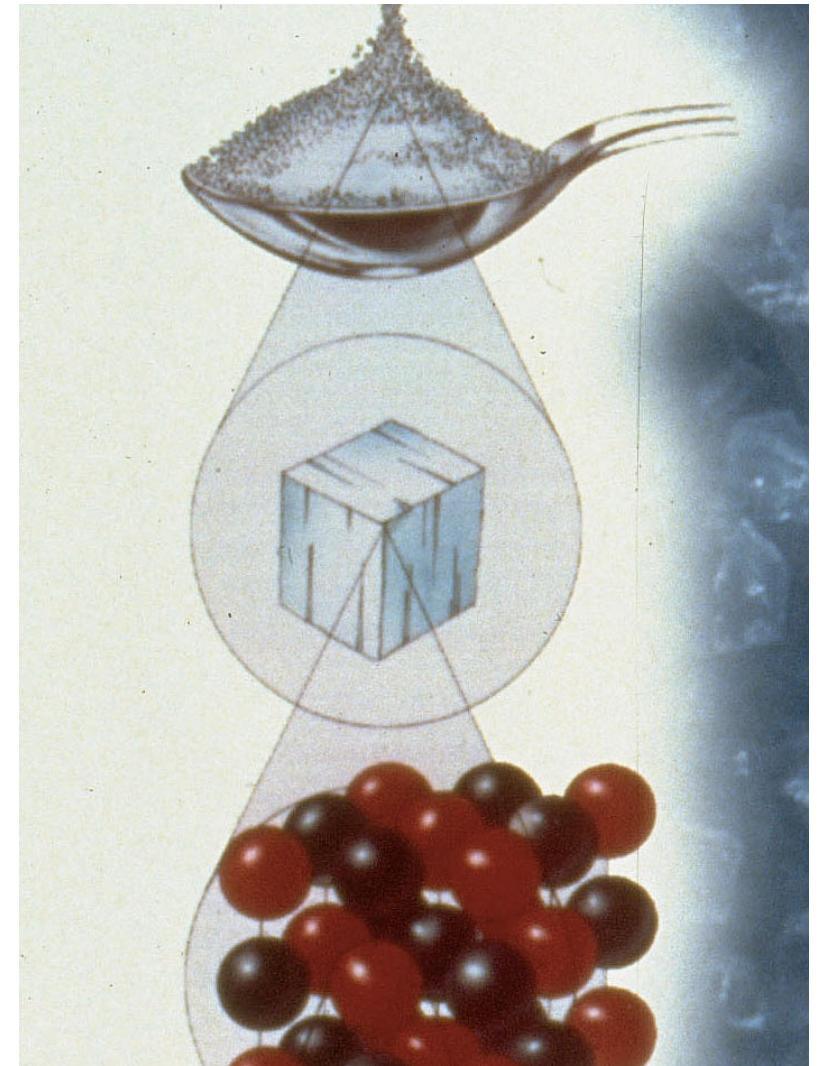
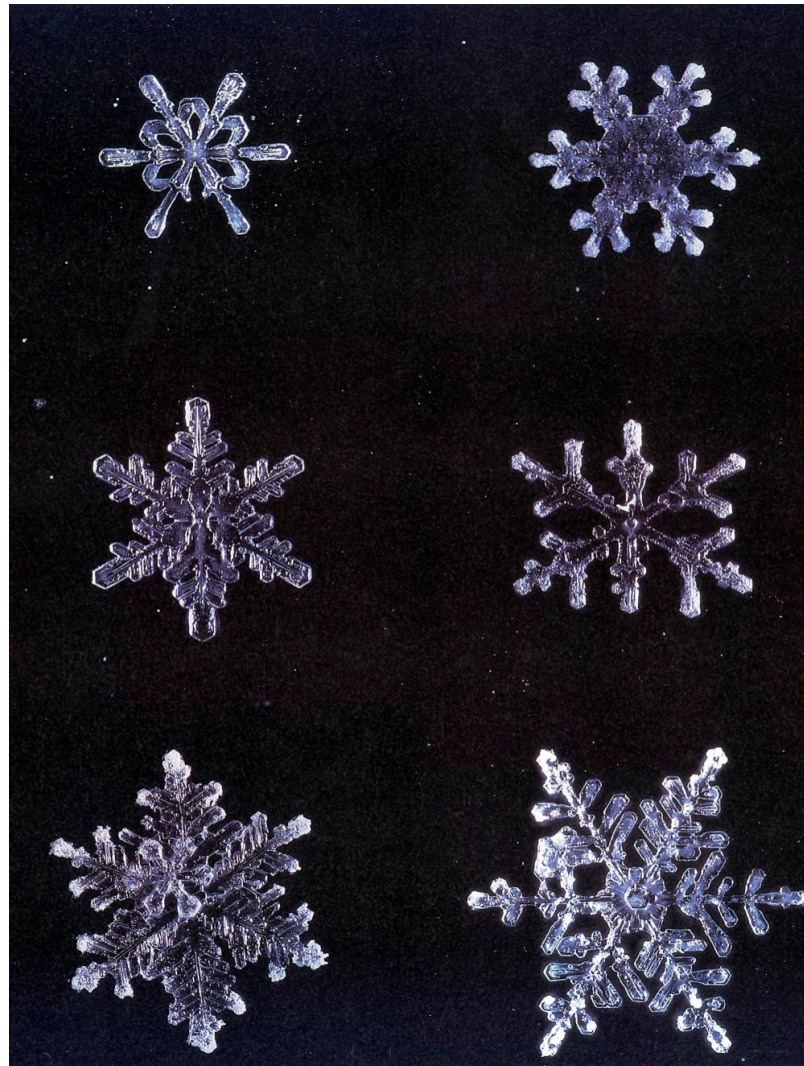
I. I Was ist Physik?

Was ist Physik nicht?

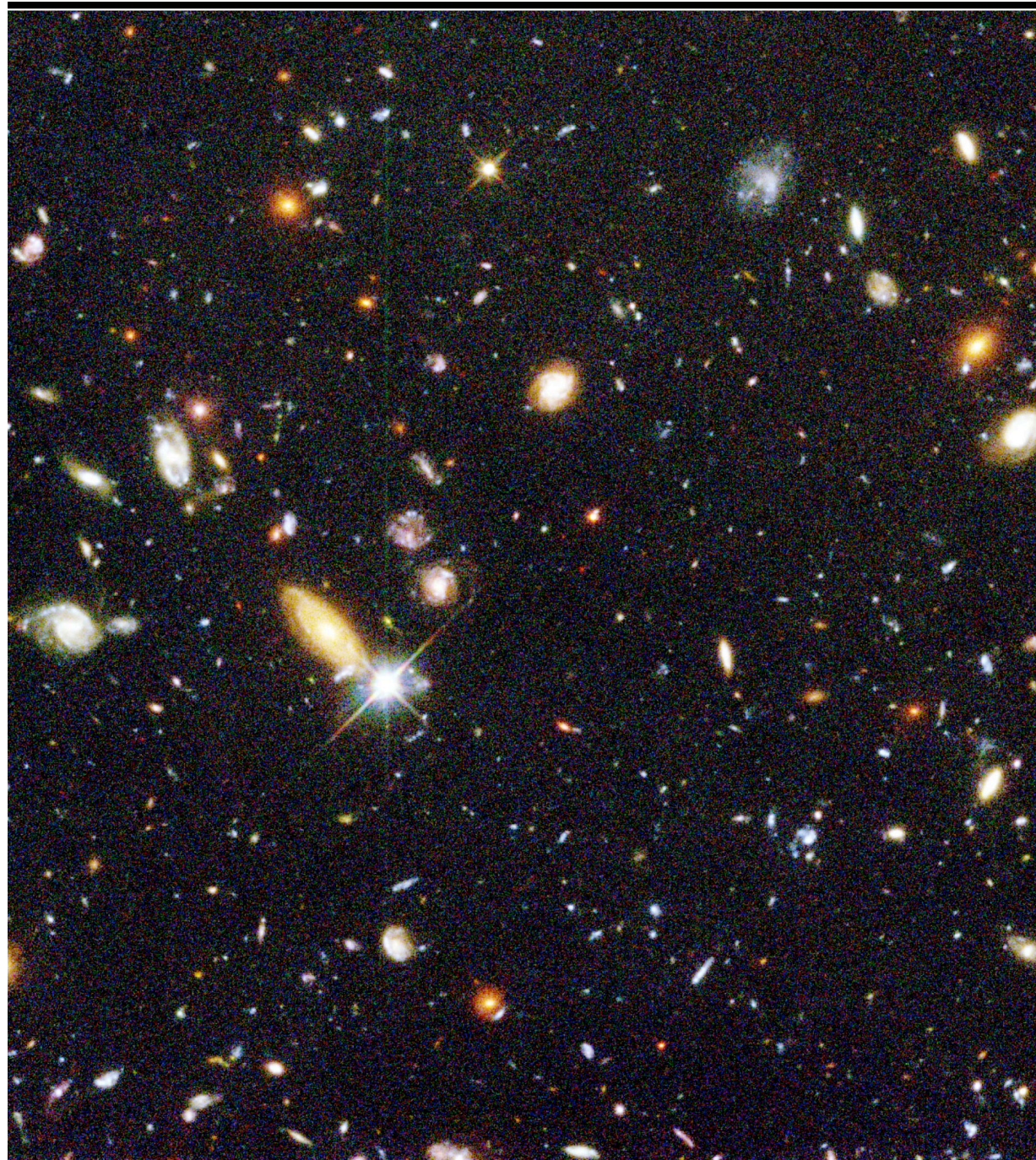
Atlas trägt die Welt

- DIMITRI: “Wenn Atlas die Welt auf seinem Rücken trägt, auf wem steht dann Atlas?”
- TASSO: “Atlas steht auf dem Rücken einer Schildkröte.”
- DIMITRI: “Aber worauf steht diese Schildkröte?”
- TASSO: “Auf einer zweiten Schildkröte.”
- DIMITRI: “Und worauf steht dann diese Schildkröte?”
- TASSO: “Mein lieber Dimitri, es sind lauter Schildkröten, bis ganz nach unten!”





WAS ist das?

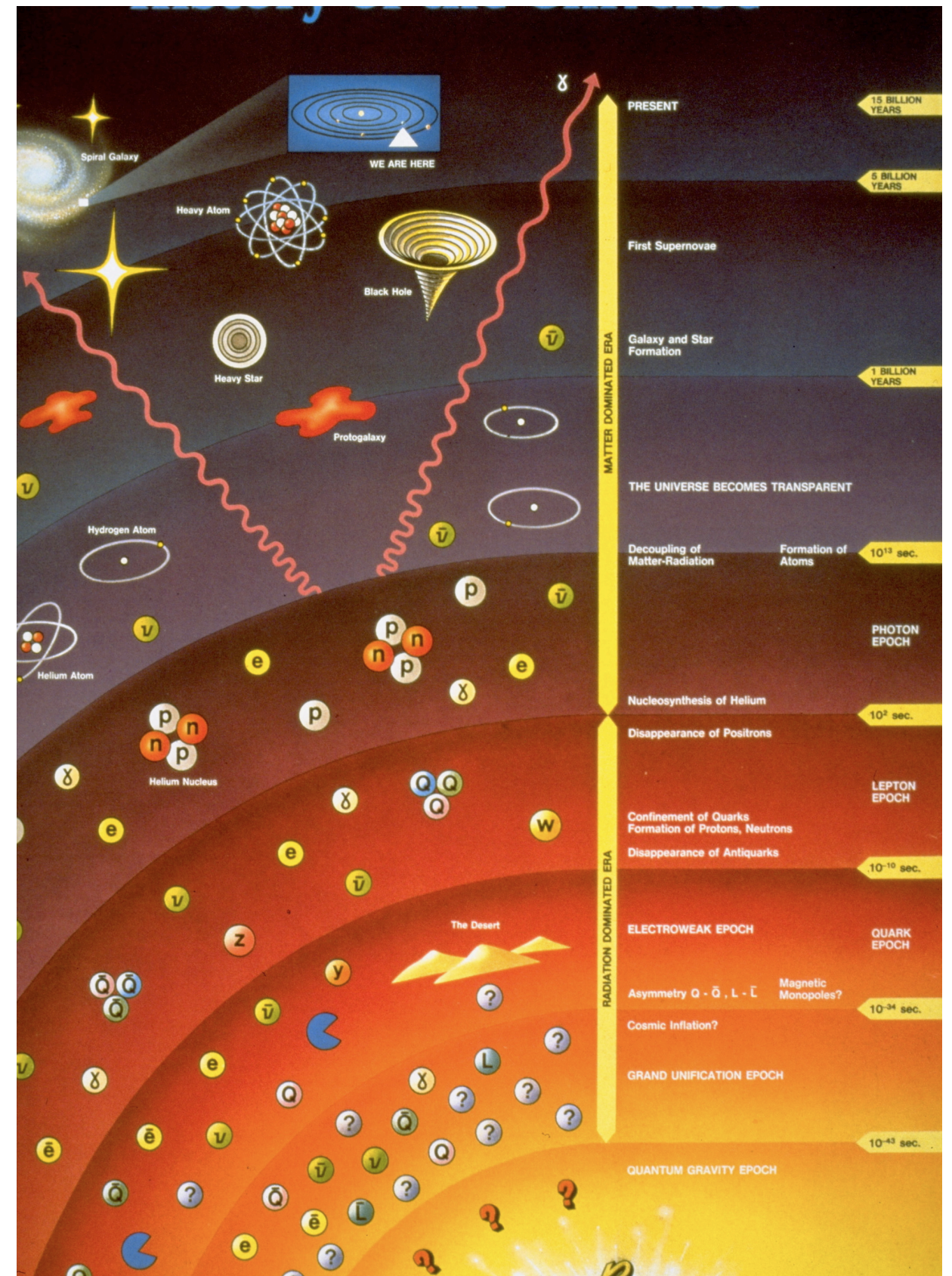


Hubble Deep Field
Hubble Space Telescope • WFPC2

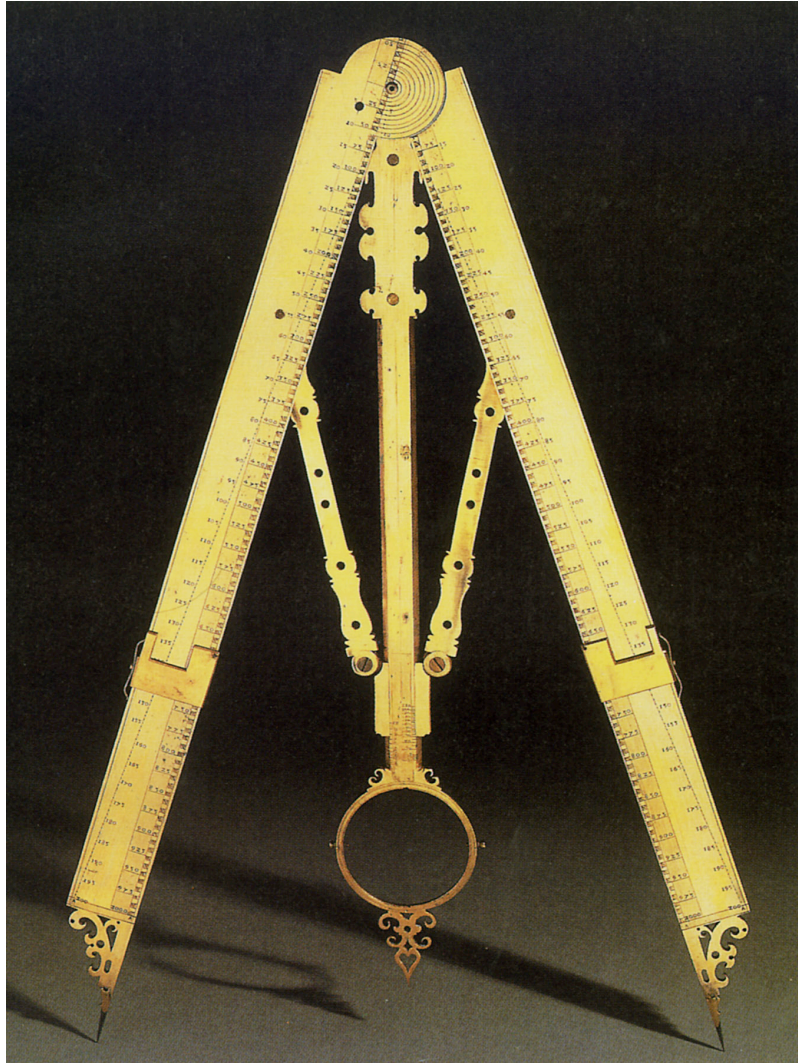
96-01a • ST ScI OPO • January 15, 1995 • R. Williams (ST ScI), NASA



Wievie?



WIE kann man Vorgänge beschreiben?



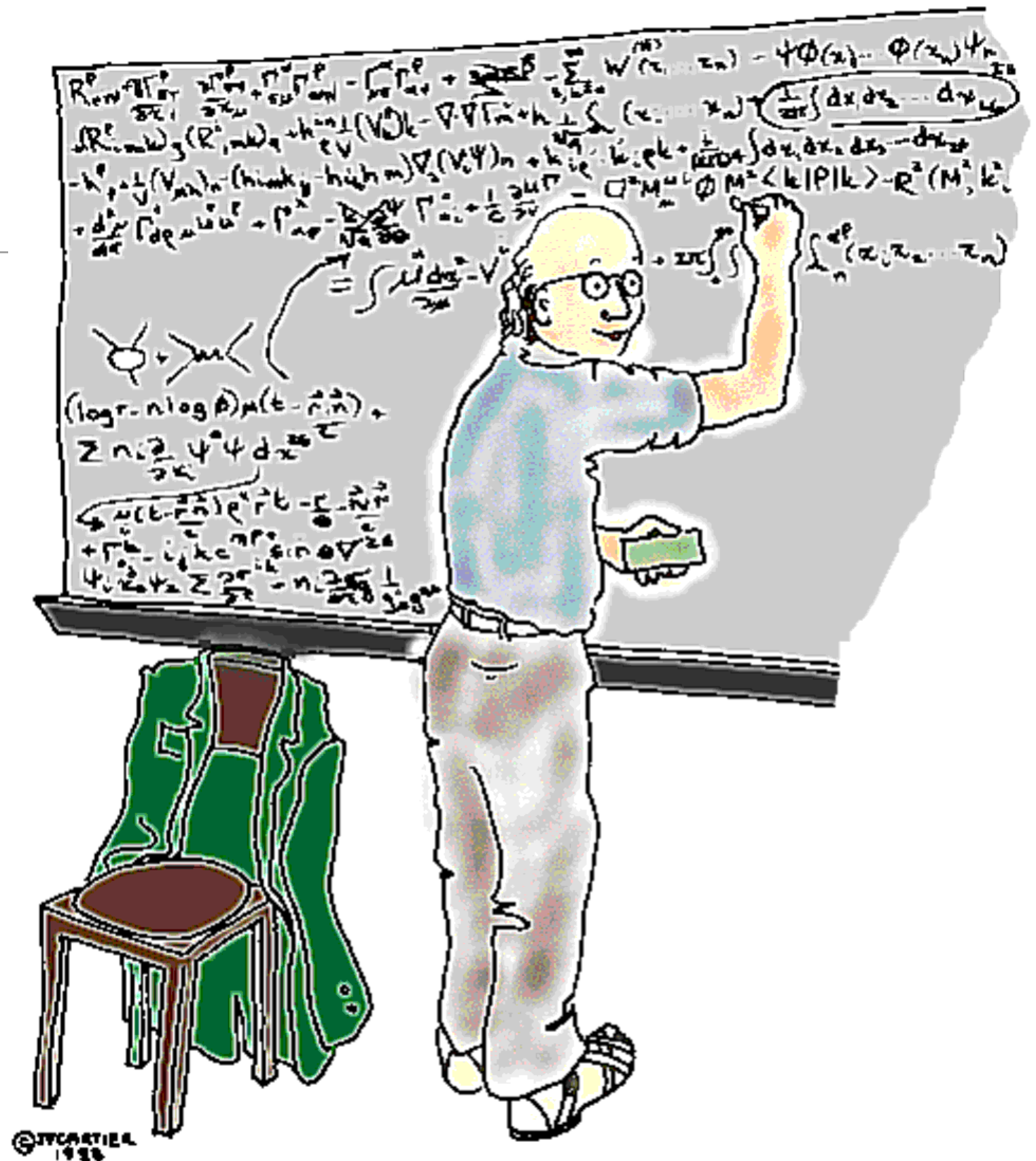
Wo?

Wann?

Wie oft?

Was ist...

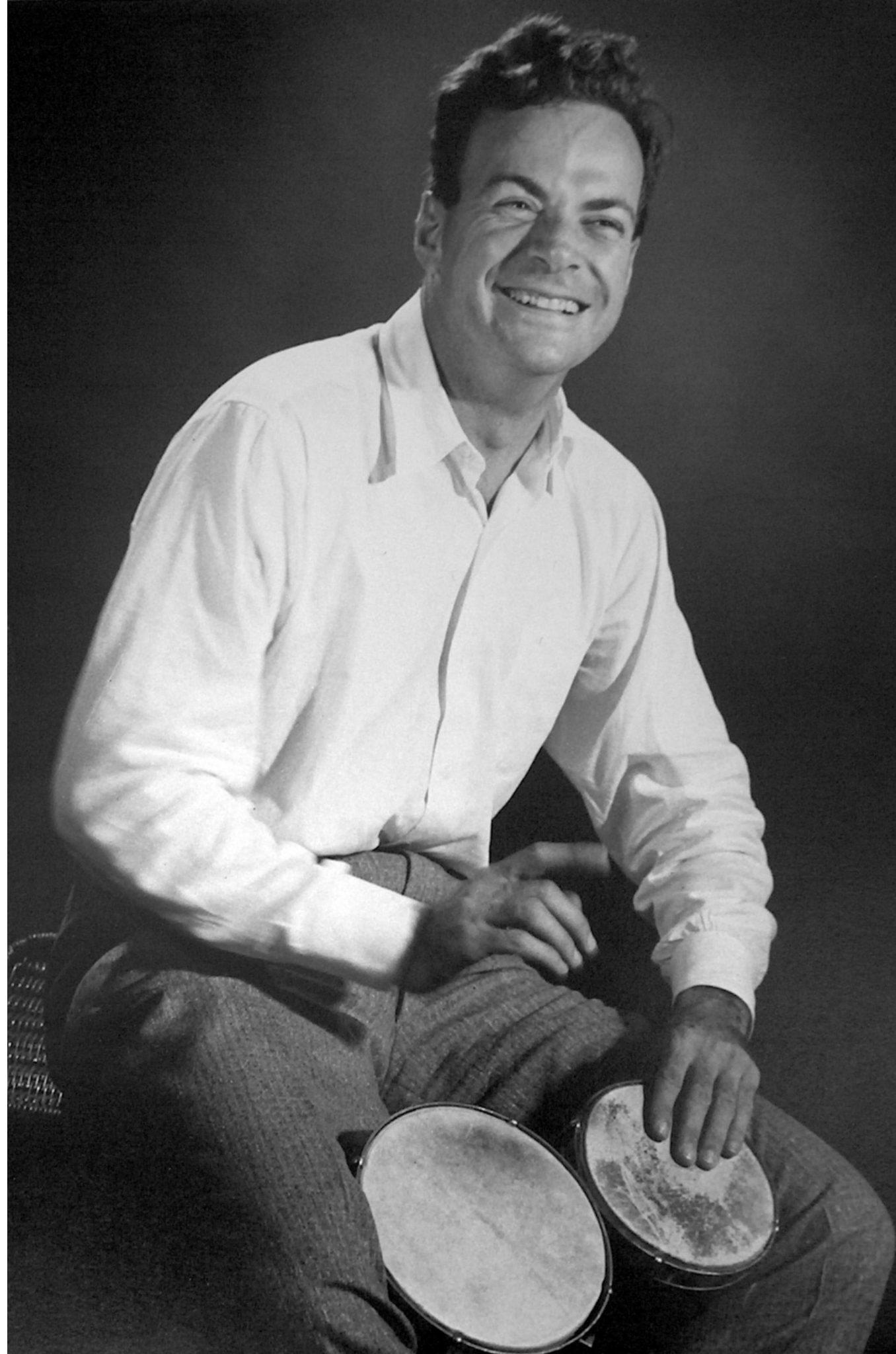
- wesentlich?
- nebensächlich?
- störend?



"At this point we notice that this equation is beautifully simplified if we assume that space-time has 92 dimensions."

Richard P. Feynman

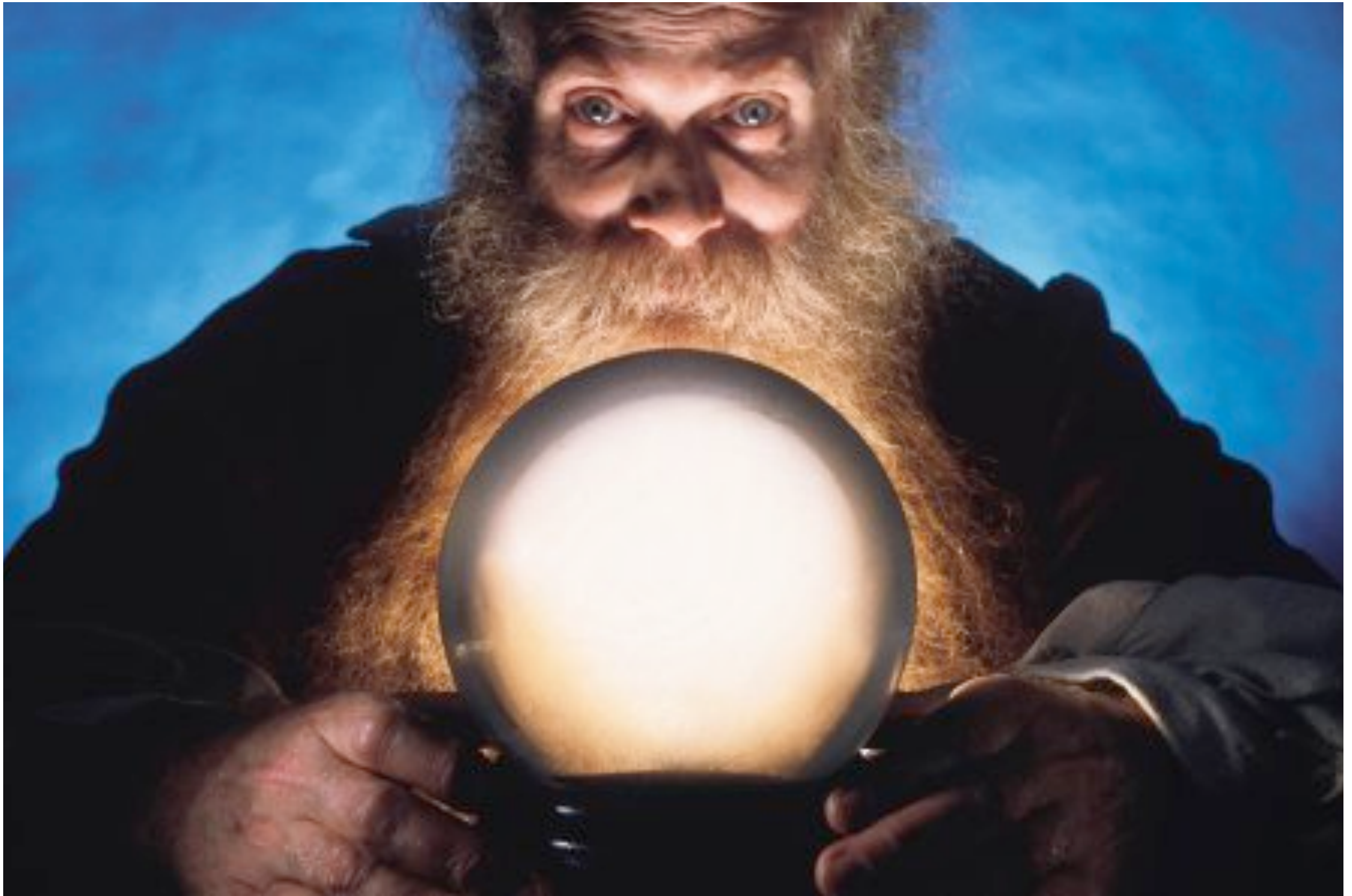
- “Physics is a number”





Danke, Teilchenforschungszentrum CERN. Deutschland ist aus dem Häuschen

Das Higgs-Boson

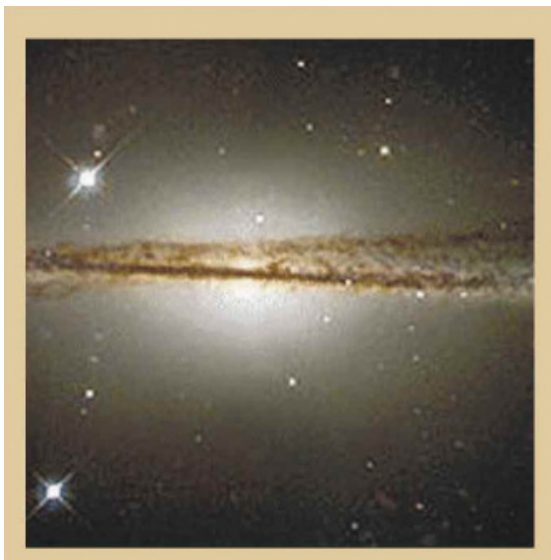


WAS WIRD geschehen, wenn ...?
Vorhersagekraft einer Theorie!

Kurze Rundschau

über 14 Milliarden Jahre – von Quarks zum Kosmos

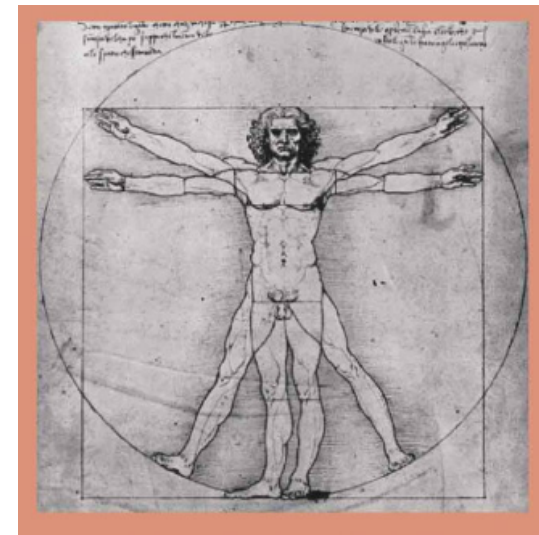




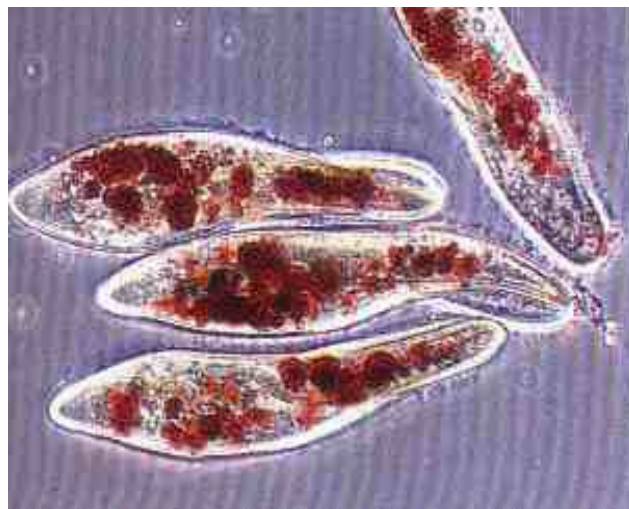
10^{26} m



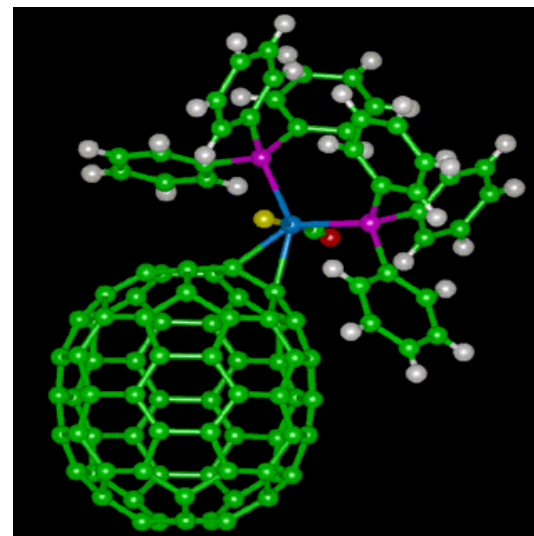
10^7 m



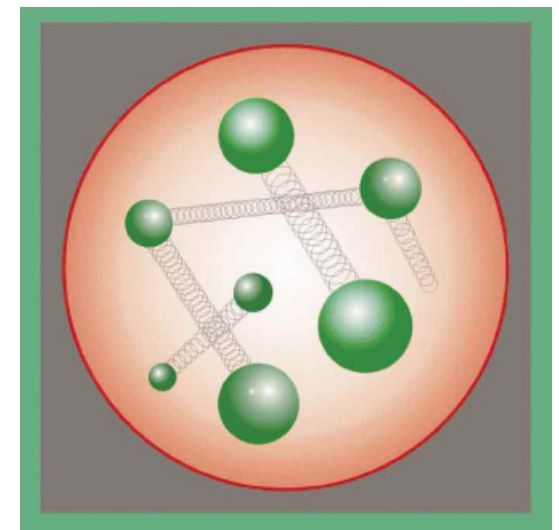
10^1 m



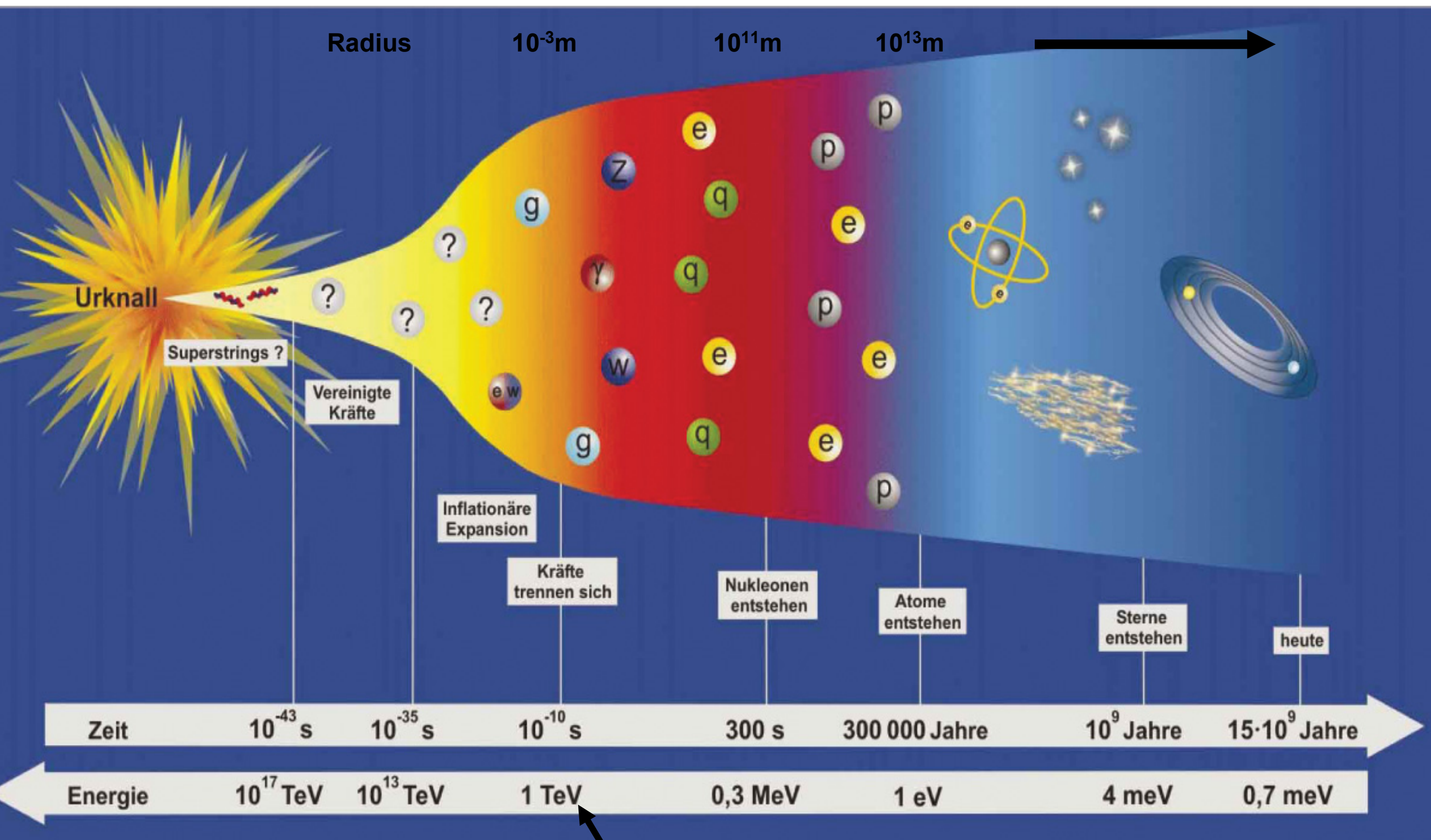
10^{-4} m



10^{-8} m



10^{-15} m



Teilchenbeschleuniger

Dalton 1803-1808

**Lehre von den Atomen als
Grundbausteinen der Stoffe**

Meyer/Mendelejev 1869-1871

Periodensystem der Elemente

10^7 Chemische Verbindungen $\rightarrow$ 112 Atome

Rutherford (1871-1937)

Atome: kompakter Kern mit Elektronenhülle

Bothe, Chadwick, Joliot (um 1932)

Neutronen und Protonen im Kern

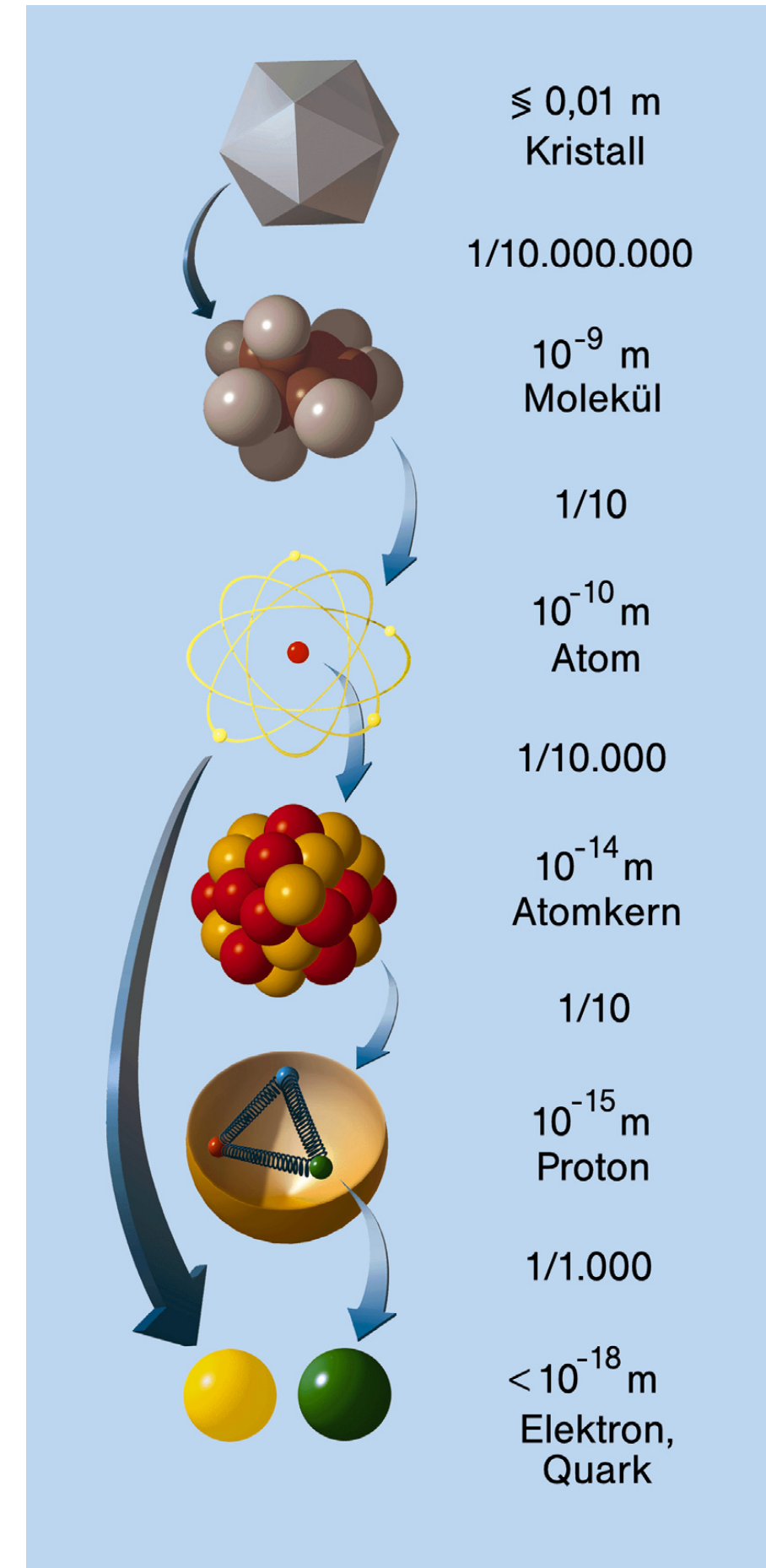
112 Atome $\longrightarrow$ 3 Bausteine

Gell-Mann, Zweig (1964)

Protonen, Neutronen, andere Hadronen

Bestehen aus Quarks

>100 Elementarteilchen $\longrightarrow$ 6 Quarks



GRAVITATION:

NEWTON (1642-1727):

GRAVITATIONSGESETZ



ELEKTRIZITÄT, MAGNETISMUS:

MAXWELL (1831-1879):

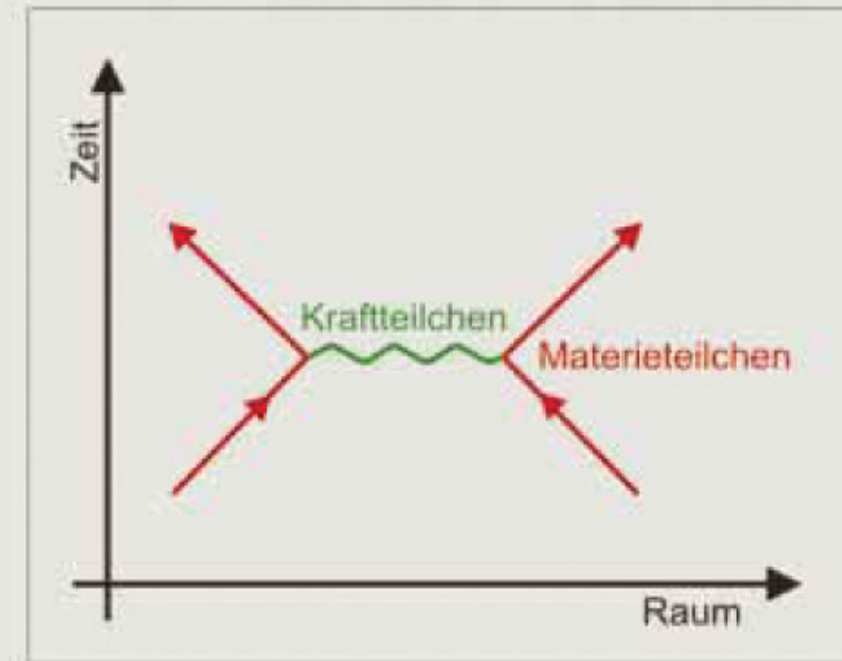
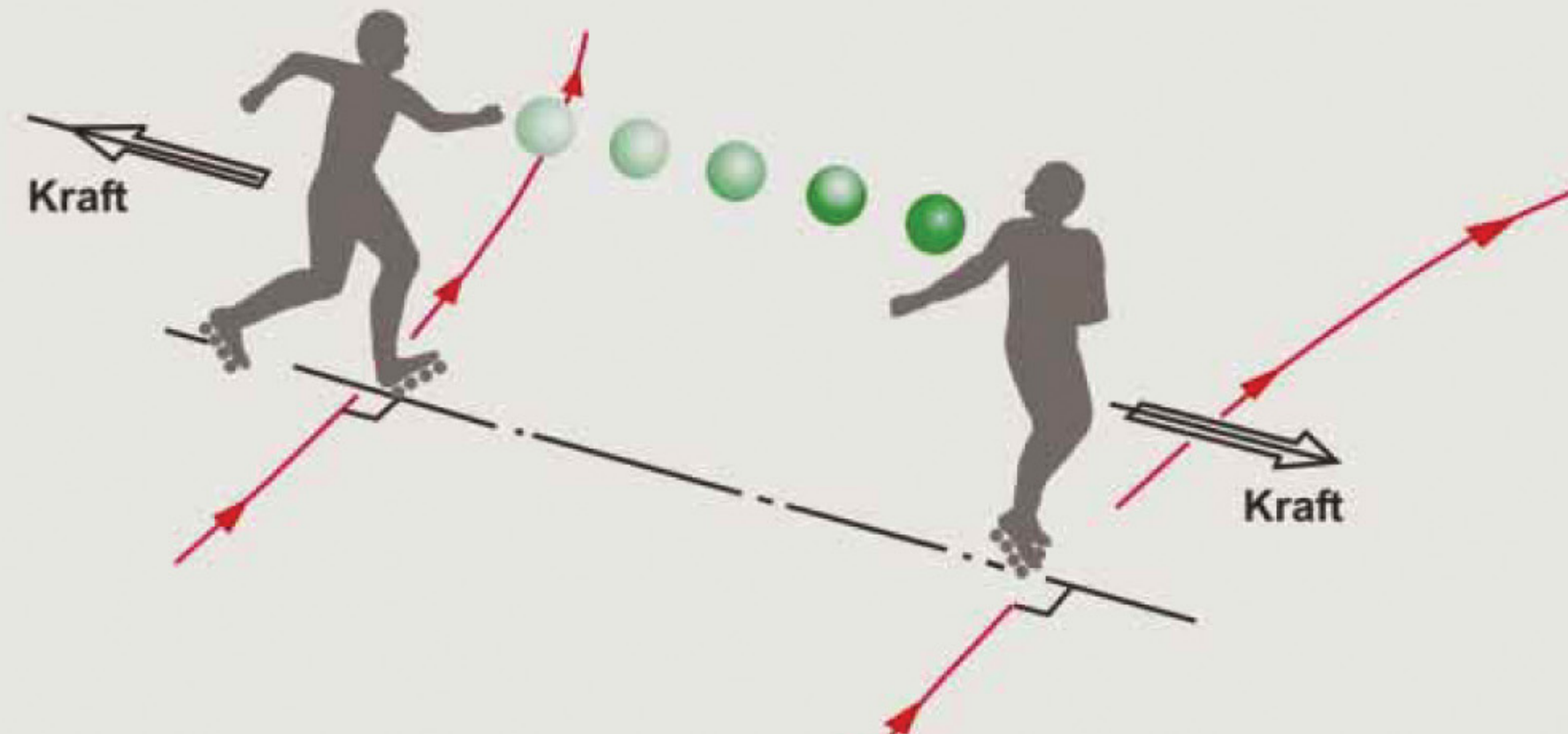
**VEREINIGUNG ELEKTROSTATIK
UND MAGNETISMUS**



**HEINRICH HERTZ (1857-94): ENTDECKUNG DER ELEKTRO-
MAGNETISCHEN WELLEN IN KARLSRUHE**

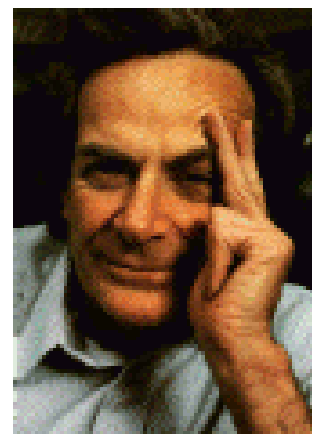


Heinrich Hertz (1857-1894). He taught and carried out research from 1885 to 1889 at the University of Karlsruhe.



ALLGEMEIN:

- KRÄFTE ENTSTEHEN DURCH AUSTAUSCH VON BOSONEN
- SCHEMATISCHE BESCHREIBUNG DURCH FEYNMANDIAGRAMME



Standard Model of FUNDAMENTAL PARTICLES AND INTERACTIONS

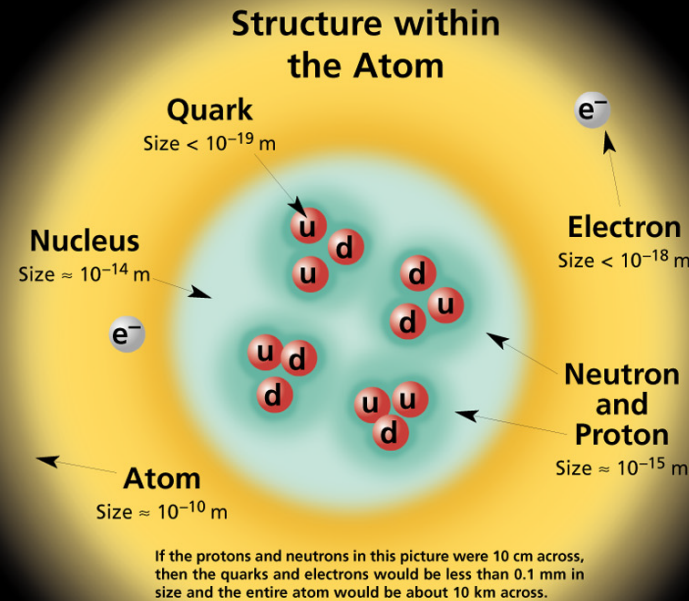
The Standard Model summarizes the current knowledge in Particle Physics. It is the quantum theory that includes the theory of strong interactions (quantum chromodynamics or QCD) and the unified theory of weak and electromagnetic interactions (electroweak). Gravity is included on this chart because it is one of the fundamental interactions even though not part of the "Standard Model."

FERMIONS

matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin = 1/2		
Flavor	Mass GeV/c ²	Electric charge
ν_e electron neutrino	$<1 \times 10^{-8}$	0
e^- electron	0.000511	-1
ν_μ muon neutrino	<0.0002	0
μ^- muon	0.106	-1
ν_τ tau neutrino	<0.02	0
τ^- tau	1.7771	-1

Quarks spin = 1/2		
Flavor	Approx. Mass GeV/c ²	Electric charge
U up	0.003	2/3
d down	0.006	-1/3
C charm	1.3	2/3
S strange	0.1	-1/3
t top	175	2/3
b bottom	4.3	-1/3



BOSONS

force carriers
spin = 0, 1, 2, ...

Unified Electroweak spin = 1		
Name	Mass GeV/c ²	Electric charge
γ photon	0	0
W^-	80.4	-1
W^+	80.4	+1
Z^0	91.187	0

Strong (color) spin = 1		
Name	Mass GeV/c ²	Electric charge
g gluon	0	0

Color Charge
Each quark carries one of three types of "strong charge," also called "color charge." These charges have nothing to do with the colors of visible light. There are eight possible types of color charge for gluons. Just as electrically-charged particles interact by exchanging photons, in strong interactions color-charged particles interact by exchanging gluons. Leptons, photons, and W and Z bosons have no strong interactions and hence no color charge.

Quarks Confined in Mesons and Baryons

One cannot isolate quarks and gluons; they are confined in color-neutral particles called **hadrons**. This confinement (binding) results from multiple exchanges of gluons among the color-charged constituents. As color-charged particles (quarks and gluons) move apart, the energy in the color-force field between them increases. This energy eventually is converted into additional quark-antiquark pairs (see figure below). The quarks and antiquarks then combine into hadrons; these are the particles seen to emerge. Two types of hadrons have been observed in nature: **mesons** $q\bar{q}$ and **baryons** qqq .

Residual Strong Interaction

The strong binding of color-neutral protons and neutrons to form nuclei is due to residual strong interactions between their color-charged constituents. It is similar to the residual electrical interaction that binds electrically neutral atoms to form molecules. It can also be viewed as the exchange of mesons between the hadrons.

PROPERTIES OF THE INTERACTIONS

Baryons qqq and Antibaryons $\bar{q}\bar{q}\bar{q}$					
Baryons are fermionic hadrons. There are about 120 types of baryons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c ²	Spin
p	proton	uud	1	0.938	1/2
$\bar{p}$	anti-proton	$\bar{u}\bar{u}\bar{d}$	-1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	-1	1.672	3/2

Property \ Interaction	Gravitational	Weak	Electromagnetic	Strong	
		(Electroweak)		Fundamental	Residual
Acts on:	Mass – Energy	Flavor	Electric Charge	Color Charge	See Residual Strong Interaction Note
Particles experiencing:	All	Quarks, Leptons	Electrically charged	Quarks, Gluons	Hadrons
Particles mediating:	Graviton (not yet observed)	W^+ W^- Z^0	γ	Gluons	Mesons
Strength relative to electromag for two u quarks at:	10^{-41}	0.8	1	25	Not applicable to quarks
	10^{-41}	10^{-4}	1	60	
	10^{-36}	10^{-7}	1	Not applicable to hadrons	

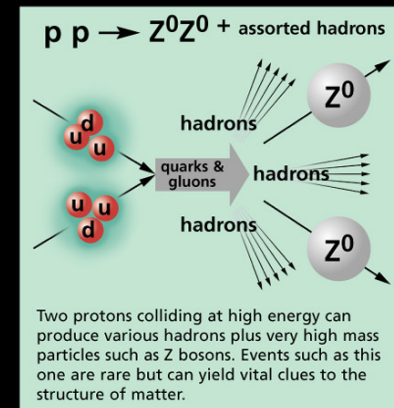
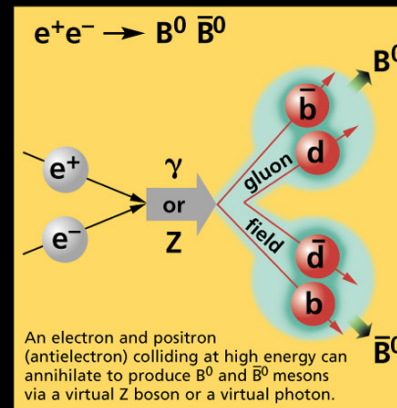
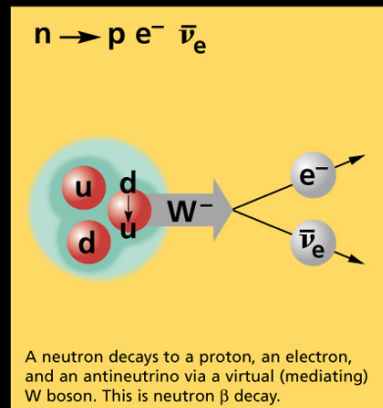
Mesons $q\bar{q}$					
Mesons are bosonic hadrons. There are about 140 types of mesons.					
Symbol	Name	Quark content	Electric charge	Mass GeV/c ²	Spin
π^+	pion	$u\bar{d}$	+1	0.140	0
K^-	kaon	$s\bar{u}$	-1	0.494	0
ρ^+	rho	$u\bar{d}$	+1	0.770	1
B^0	B-zero	$d\bar{b}$	0	5.279	0
η_c	eta-c	$c\bar{c}$	0	2.980	0

Matter and Antimatter

For every particle type there is a corresponding antiparticle type, denoted by a bar over the particle symbol (unless + or - charge is shown). Particle and antiparticle have identical mass and spin but opposite charges. Some electrically neutral bosons (e.g., Z^0 , γ , and $\eta_c = c\bar{c}$, but not $K^0 = d\bar{s}$) are their own antiparticles.

Figures

These diagrams are an artist's conception of physical processes. They are **not** exact and have **no** meaningful scale. Green shaded areas represent the cloud of gluons or the gluon field, and red lines the quark paths.



The Particle Adventure

Visit the award-winning web feature *The Particle Adventure* at <http://ParticleAdventure.org>

This chart has been made possible by the generous support of:

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U.S. National Science Foundation
Lawrence Berkeley National Laboratory
Stanford Linear Accelerator Center
American Physical Society, Division of Particles and Fields
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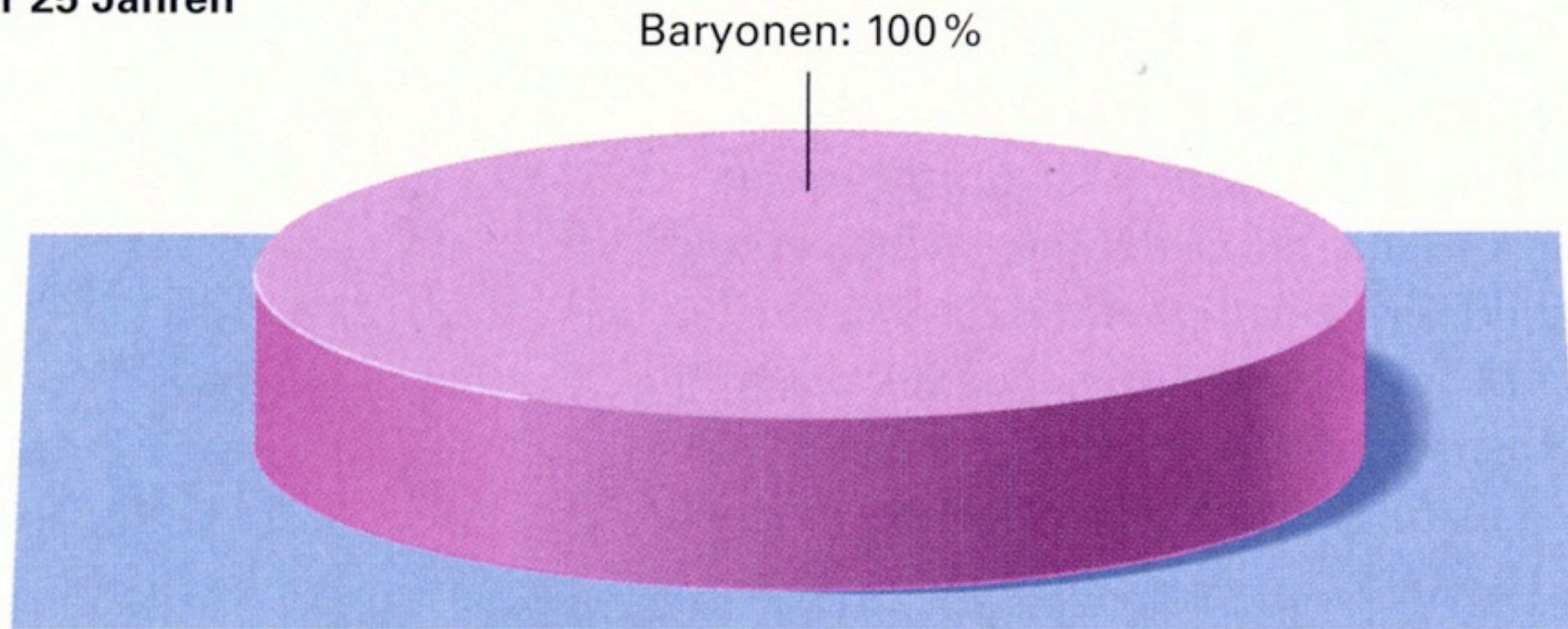


Fritz Zwicky
(1898-1974)

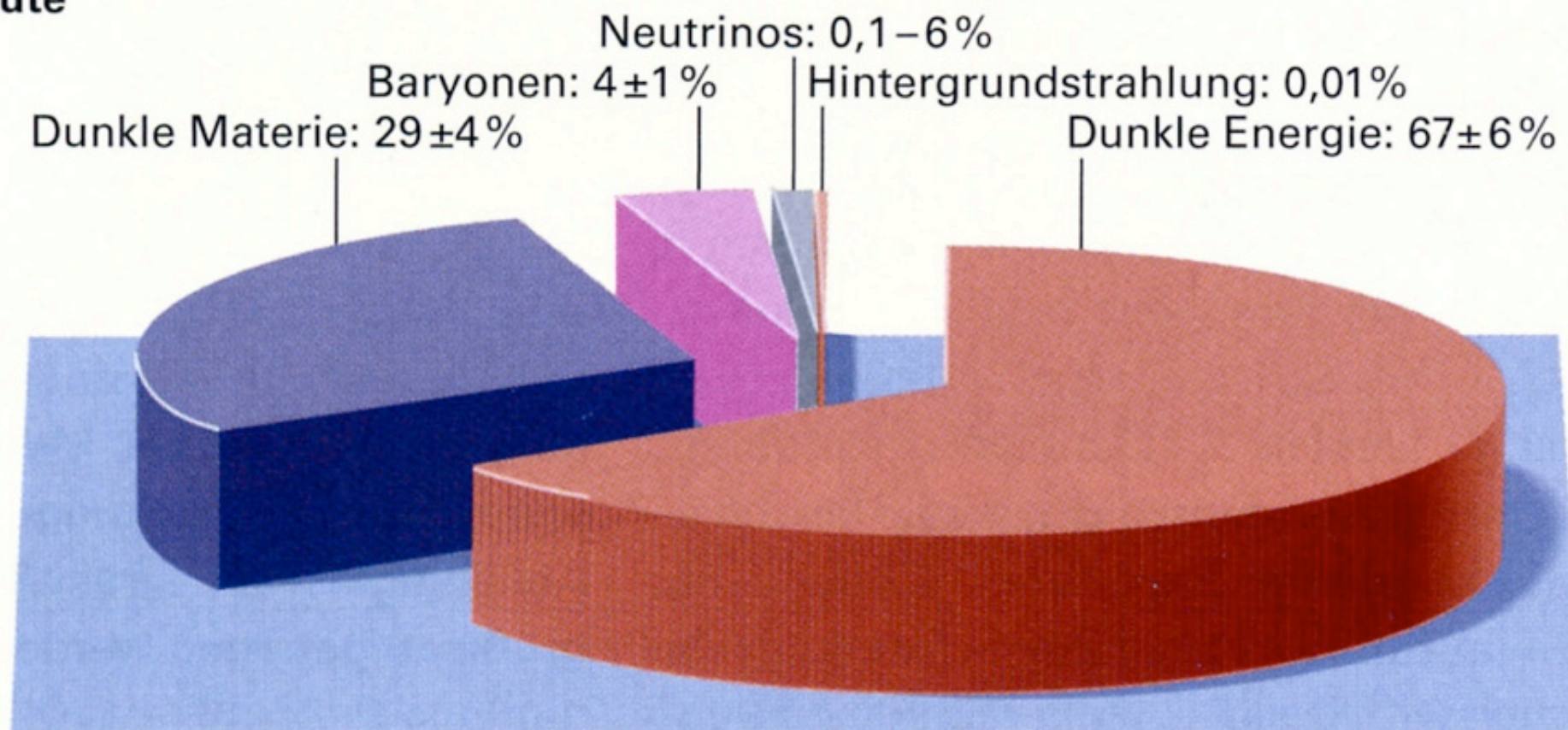
Coma-Haufen: Dunkle Materie?!

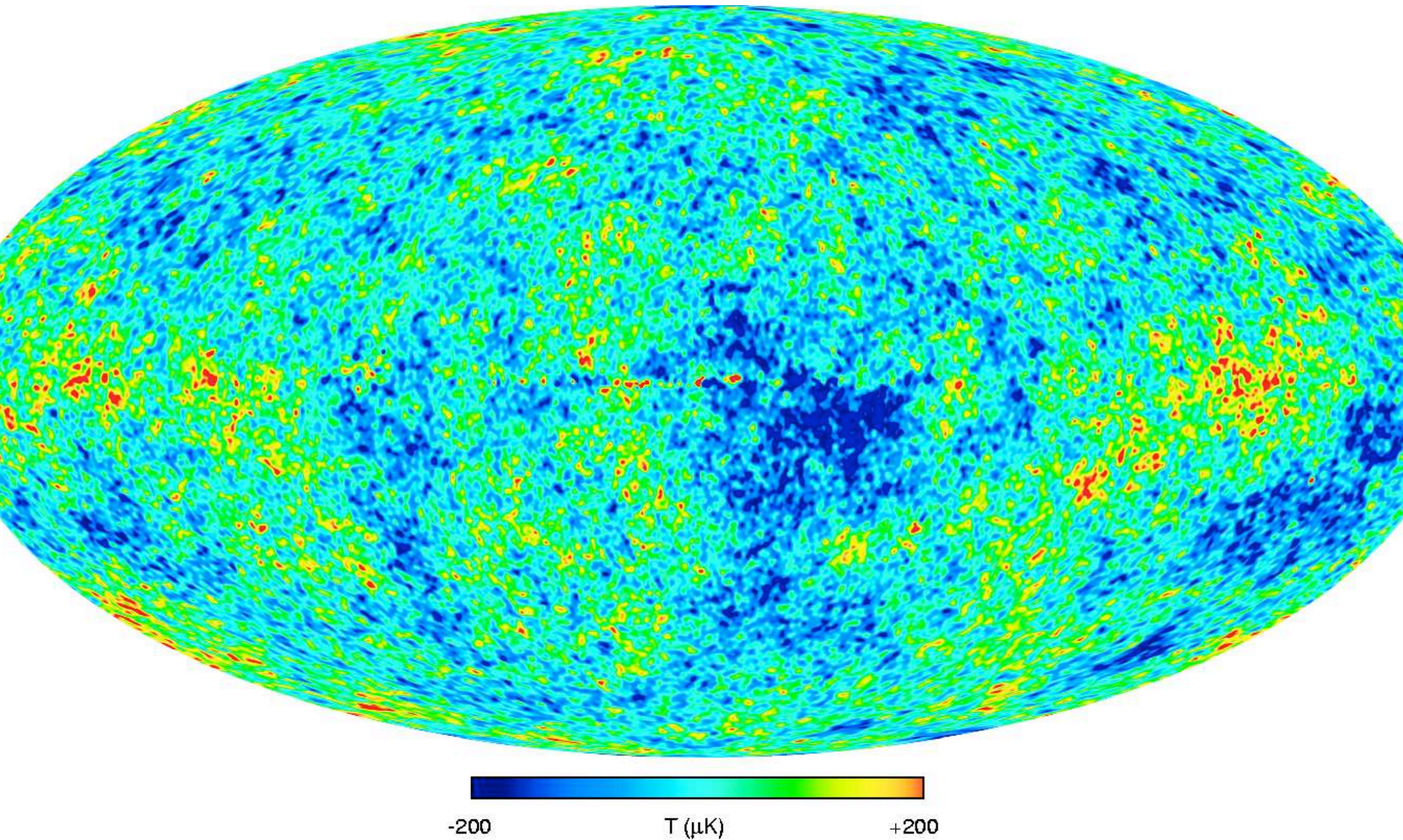


vor 25 Jahren

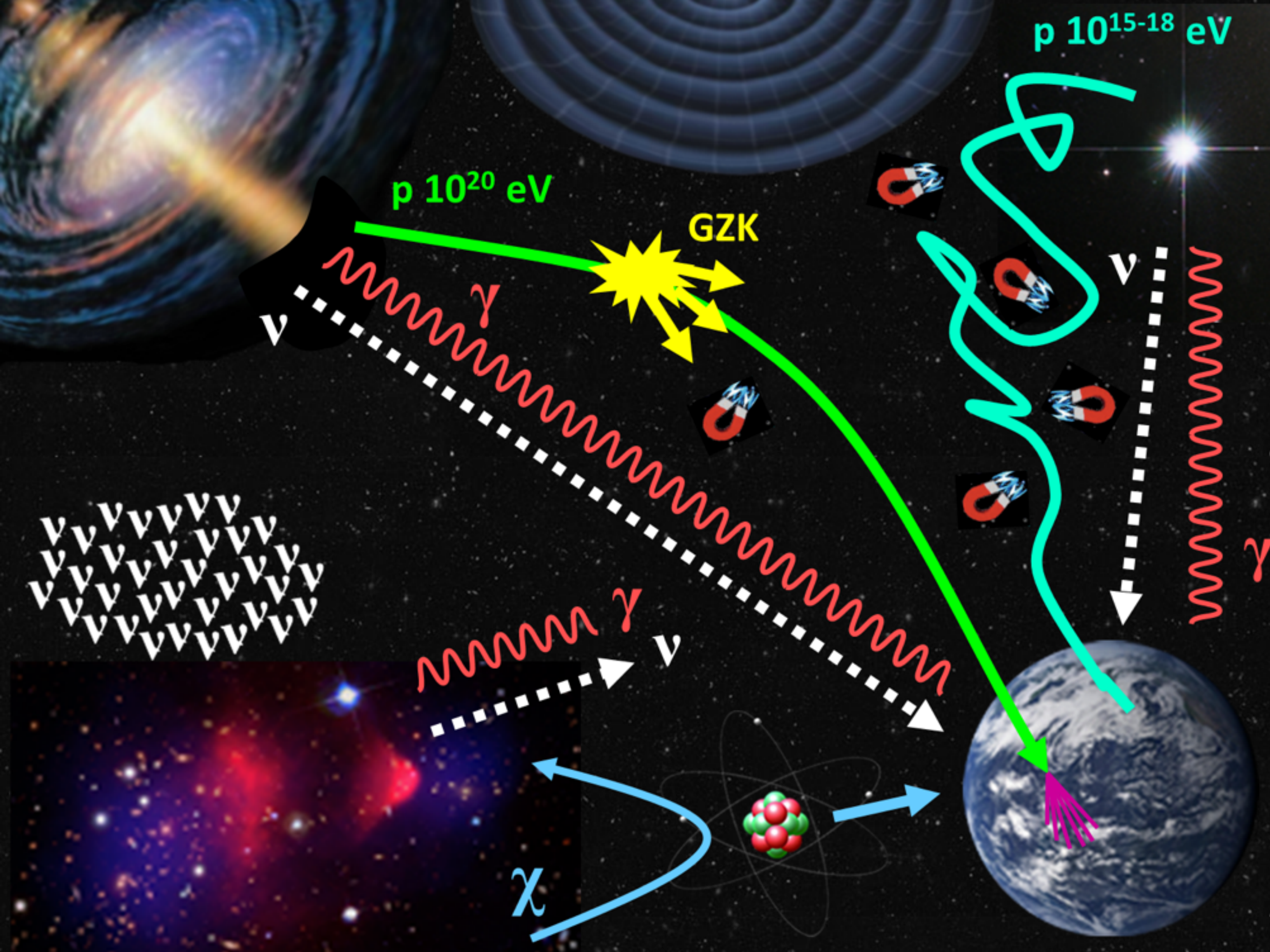


heute





WMAP: Temperaturkarte des Universums





UND WEIL SICH DAS UNIVERSUM IMMER
WEITER AUSDEHNT, BRAUCHEN WIR EBEN
EIN GRÖßERES TELESKOP !

1.2 Physikalische Größen und Einheiten

nur drei Basisgrößen: Länge, Zeit, Masse

Einige typische Längenabstände (Größenordnung)

Körper	Länge (oder Abstand)
Neutron oder Proton (Radius)	10^{-15} m
Atom	10^{-10} m
Virus (► Abbildung 1.3)	10^{-7} m
Papierbogen (Dicke)	10^{-4} m
Fingerdicke	10^{-2} m
Fußballfeldlänge	10^2 m
Höhe des Mount Everest (► Abbildung 1.3)	10^4 m
Erddurchmesser	10^7 m
Erde – Sonne	10^{11} m
Nächster Fixstern	10^{16} m
Nächste Galaxie	10^{22} m
Fernste sichtbare Galaxie	10^{26} m

Tabelle 1.2

Einige Massen

Körper	Masse (Näherungswerte)
Elektron	10^{-30} kg
Proton, Neutron	10^{-27} kg
DNA-Molekül	10^{-17} kg
Bakterium	10^{-15} kg
Mücke	10^{-5} kg
Pflaume	10^{-1} kg
Person	10^2 kg
Schiff	10^8 kg
Erde	$6 \cdot 10^{24}$ kg
Sonne	$2 \cdot 10^{30}$ kg
Galaxis	10^{41} kg

Einige typische Zeitintervalle

Zeitintervall	Sekunden (Näherungswerte)
Lebensdauer extrem instabiler subatomarer Teilchen	10^{-23} s
Lebensdauer radioaktiver Elemente	$10^{-22} \text{ bis } 10^{28} \text{ s}$
Lebensdauer eines Muon	10^{-6} s
Zeit zwischen Herzschlägen beim Menschen	10^0 s (= 1 s)
Ein Tag	10^5 s
Ein Jahr	$3 \cdot 10^7 \text{ s}$
Menschliche Lebensspanne	$2 \cdot 10^9 \text{ s}$
Aufgezeichnete Geschichte	10^{11} s
Menschen auf Erden	10^{14} s
Alter der Erde	10^{17} s
Alter des Universums	10^{18} s

Tabelle 1.4

Metrische Vorsilben

Vorsilbe	Abkürzung	Wert
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
mikro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Tabelle 1.5

Basisgrößen

Größe	Einheit	Abkürzung der Einheit
Länge	Meter	m
Zeit	Sekunde	s
Masse	Kilogramm	kg
Elektrischer Strom	Ampere	A
Temperatur	Kelvin	K
Stoffmenge	Mol	mol
Lichtstärke	Candela	cd