Teaching physics based on particle physics

Introducing quarks to 12-year-olds

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Short bio

Motivation

Particulate model of matter

& fundamental interactions

Optics

Mechanics

Electricity

Cosmology

Radioactivity

Thermodynamics

Modern physics

Magnetism

Overview

1. Theoretical framework
2. Model conception
3. Example

1. Theoretical framework

Rapid development of particle physics in the last 100+ years

Throughout Europe: problematic integration of particle physics in curricula

Opportunity to embed fundamental principles within the curriculum

1. Theoretical framework

concept development

Constructivist approach

Exploration of the student perspective

STCSE - Students´and Teachers´ Conceptions and Science Education
☞http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html

#	Entryty... ▲	Author	Title	Year	Journal
1	Article	Andersson	Pupils' Conceptions of Matter and its Transformations (age...	1990	Studies in Sci...
2	Article	Boz	Turkish Pupils' Conceptions of the Particulate Nature of Ma...	2006	Journal of Sci...
3	Article	Fischer and Breuer	Misconceptions as indispensable steps toward an adequat...	1993	Third Miscon...
4	Article	Gomez et al.	Students' ideas on conservation of matter: Effects of expert...	1995	Science Educ...
5	Article	Harrison and Treagust	Secondary students' mental models of atoms and molecule...	1996	Science Educ...
6	Article	Kalkanis et al.	An instructional model for a radical conceptual change tow...	2003	Science Educ...
7	Article	Meheut et al.	Pupils' (11 – 12 year olds) conceptions of combustion	1985	European Jo...
8	Article	Novick and Nussbaum	Pupils' understanding of the particulate nature of matter: A...	1981	Science Educ...
9	Article	Ozmen	Turkish primary students' conceptions about the particulat...	2011	International...
10	Article	Renstroem	Pupils conceptions of matter. A phenomenographic approa...	1987	Proceedings...
11	Article	Snir et al.	Linking phenomena with competing underlying models: A s...	2003	Science Educ...
12	Article	Stavy	Children's Ideas About Matter	1991	School Scienc...
13	Article	de Vos and Verdonk	The particulate nature of matter in science education and i...	1996	Journal of Re...
14	Article	Windschitl et al.	Beyond the scientific method: Model-based inquiry as a ne...	2008	Science Educ...
15	Article	Yair and Yair	"Everything comes to an end": An intuitive rule in physics an...	2004	Science Educ...
16	Techreport	Dow et al.	Pupils' Concepts of Gases, Liquids and Solids	1978	
17	Unpublis...	Duit	Bibliography – STCSE		
18	Unpublis...	Johnson	Symposium: Teaching and Learning the Particle Model		
19	Article	diSessa	A bird's-eye view of the "pieces" vs. "coherence" controvers...	2008	S. Vosniadou...
20	Article	Arzi and White	Change in Teachers' Knowledge of Subject Matter: A 17-Y...	2007	Science Educ...
21	Article	Baalmann et al.	Schülervorstellungen zu Prozessen der Anpassung – Ergeb...	2004	Zeitschrift für...
22	Article	Christensen and Fensham	Risk, Uncertainty and Complexity in Science Education	2012	Second Inter...
23	Article	Deng	The distinction between key ideas in teaching school physic...	2001	Science Educ...
24	Article	Dickinson	The development of a concept of material kind	1987	Science Educ...
25	Article	Duit	Schülervorstellungen und Lernen von Physik	2004	PIKO-Brief
26	Article	Duit	The constructivist view in science education – what it has to...	1996	Investigações...
27	Article	Duit and Treagust	Conceptual change: A powerful framework for improving sc...	2003	International...
28	Article	Fischer et al.	Fachdidaktische Unterrichtsforschung – Unterrichtsmodelle...	2010	Zeitschrift für...
29	Article	Flick	Where concepts meet percepts: Stimulating analogical thou...	1991	Science Educ...
30	Article	Geddis et al.	Transforming content knowledge: Learning to teach about i...	1993	Science Educ...
31	Article	Haagen-Schützenhöfer et al.	Fremdsprachiger Physikunterricht: Fremdsprachlicher Mehr...	2011	Zeitschrift für...
32	Article	Haagen-Schützenhöfer et al.	Akzeptanzbefragung zu Optikunterrichtsmaterialien	2012	Gesellschaft...
33	Article	Harrison and Treagust	Learning about atoms, molecules, and chemical bonds: A c...	2000	Science Educ...
34	Article	Härtig et al.	Sind Fachsprache und Fachwissen bezogen auf Physik unte...	2012	Zeitschrift für...
35	Article	Hobson	There are no particles, there are only fields	2013	American Jou...
36	Article	Jung	Probing Acceptance, A Technique for Investigating Learning...	1992	R. Duit, F. G...
37	Article	Karsten et al.	Planeten, Wolken oder schwarze Kisten? Wie können wir At...	2011	Physik Journ...

1. Theoretical framework

concept development

„Framework Theory Model“
Vosniadou, Vamvakoussi, & Skopeliti (2008)

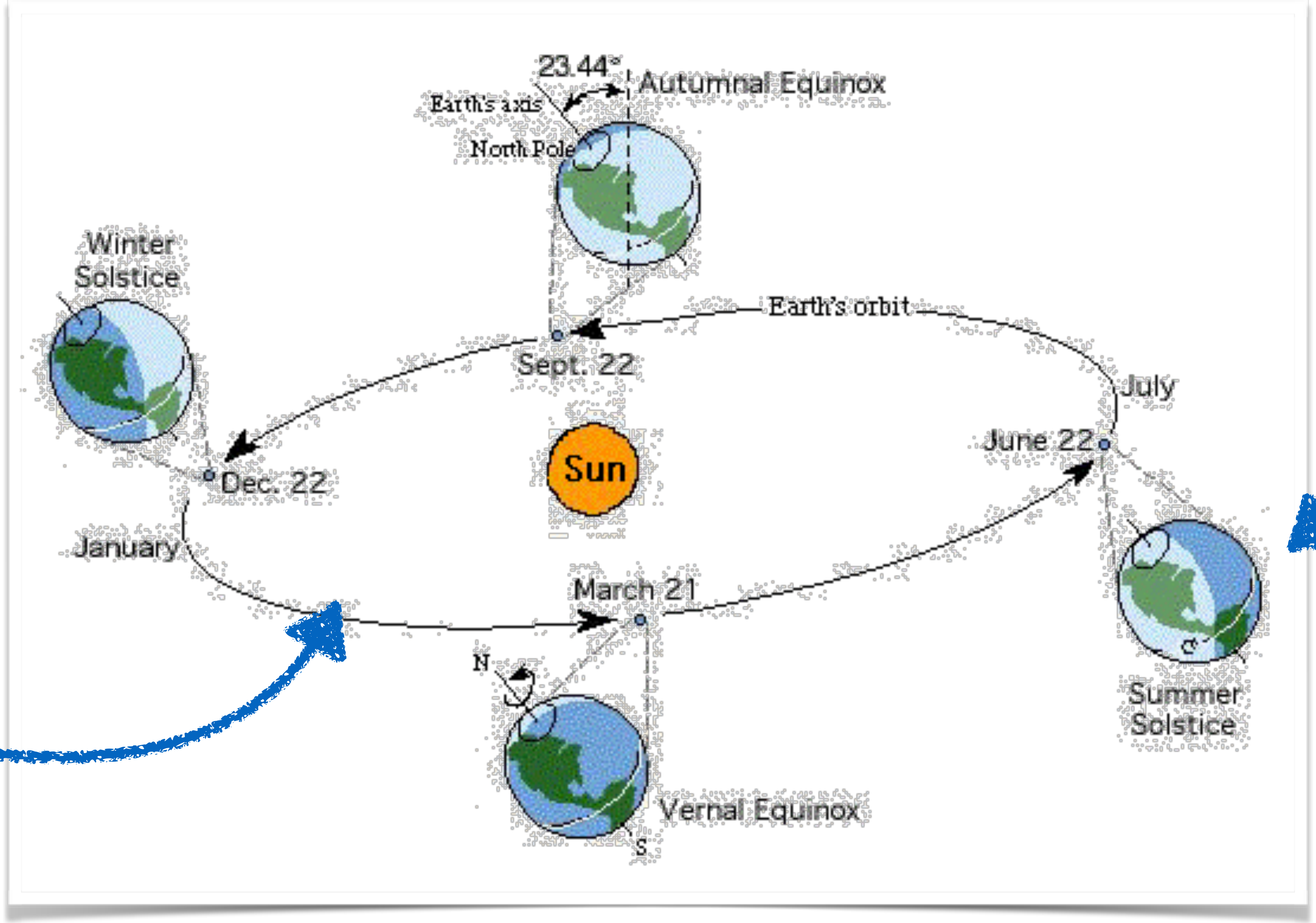
vs.

„Knowledge in Pieces“
di Sessa (2008)

For example

1. Theoretical framework

concept development



distance

inclination

1. Theoretical framework

students' conceptions

Early beginnings through chemistry education research

Particle model for chemical reactions and phase transformation

1. Theoretical framework
students' conceptions

Particle model is used to explain phenomena of gases

Rarely aids to explain everyday phenomena

However, when offered as a possible explanation, broad acceptance

1. Theoretical framework

students' conceptions

2

Significant age-dependent with respect to the acceptance of the particle model

but

age-independent misconceptions of the atomic structure of matter

1. Theoretical framework

students' conceptions

3

Everyday experiences favour continuum perception

Mixing of continuum and discontinuum conceptions

Supported by erroneous illustrations in textbooks

1. Theoretical framework

students' conceptions

4

Even with acceptance two big misconception prevail!

No reproduction of the permanent motion of particles
Negation of the existence of empty space

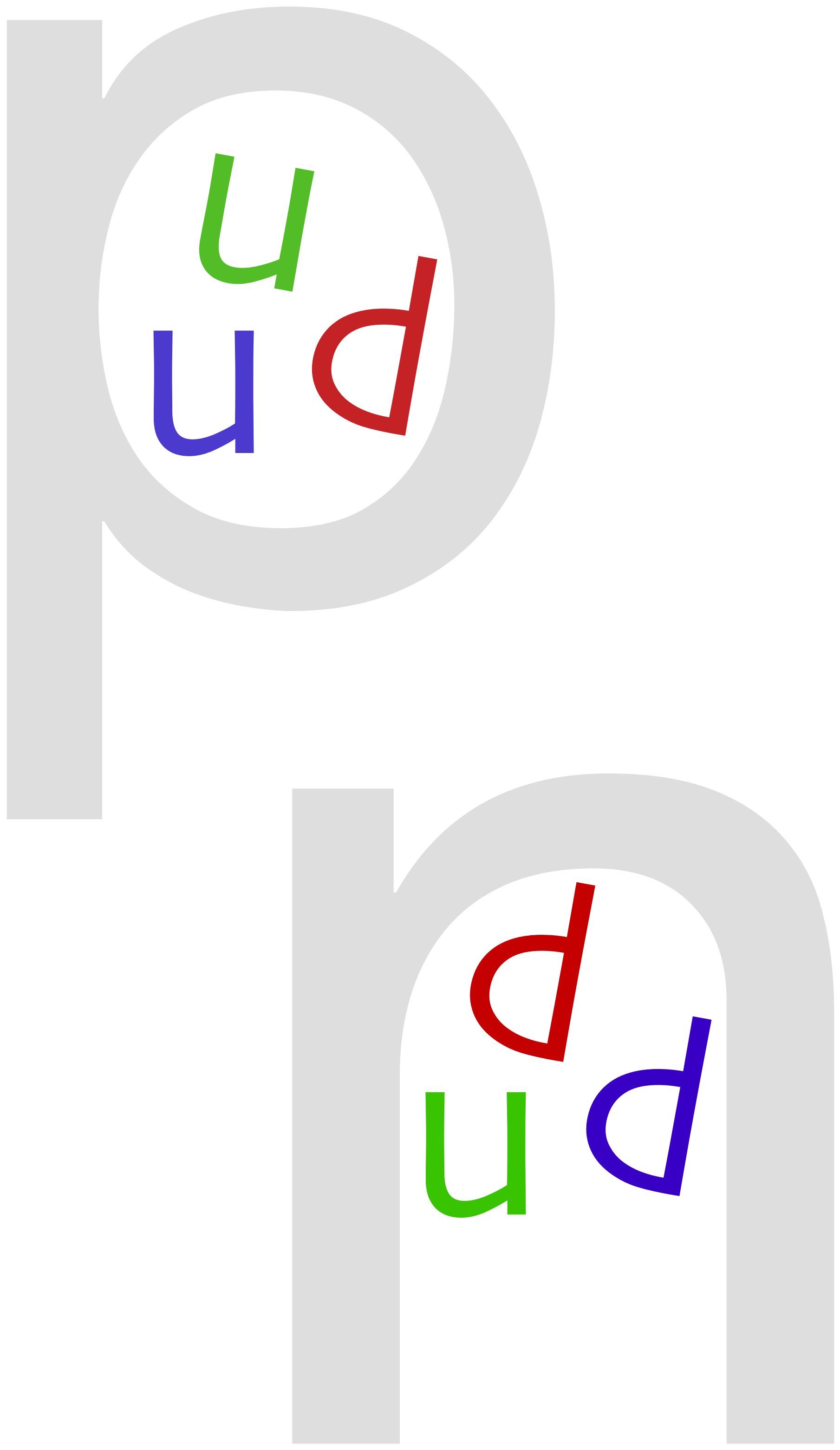
1. Theoretical framework

students' conceptions

5

Automatic transfer of macroscopic aspects and daily-life experiences into the world of particles

2. Model conception



Avoiding known misconceptions

- Permanent model character
- Linguistic accuracy
- Pure typography

2. Model conception

Permanent model character

Abstractness

Visualization problems

Ability of modelling

“With this model we describe…”

2. Model conception

Linguistic accuracy

Technical terminology vs. everyday language

Anachronistic phrasings

Rephrasing of ambiguous expressions

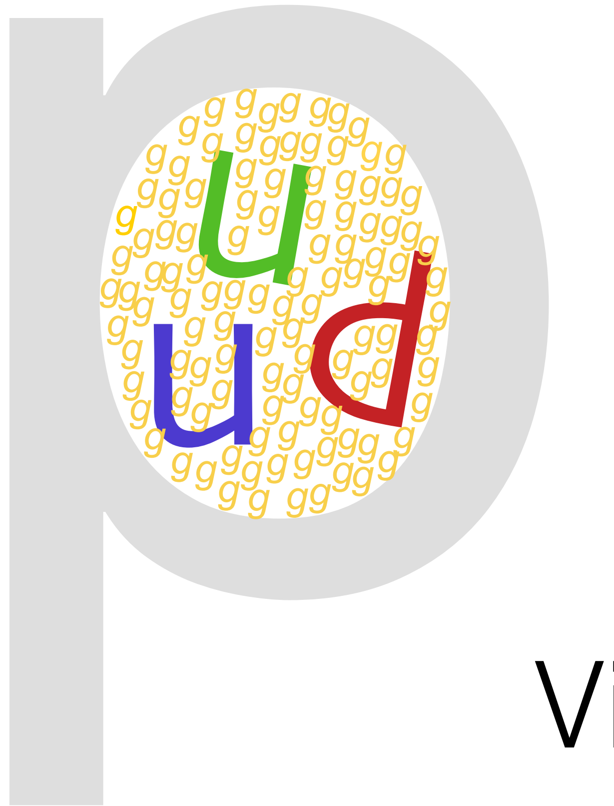
nucleus-space, orbital-space & particle-system

2. Model conception

Pure typography

“Visual representations are essential for communicating ideas in the science classroom; however, the design of such representations is not always beneficial for learners.” **Cook (2006)**

2. Model conception



Visualisation is essential

Illustrations act as source for misconceptions

Pure typography

3. Example

According to the Standard Model of particle physics, with the exception of gravitation every fundamental interaction is associated with a fundamental charge:

Electromagnetic interaction	Electric charge
Weak interaction	Weak charge
Strong interaction	Colour charge

3. Example

Within the current model we distinguish six different colour-charged states as follows:

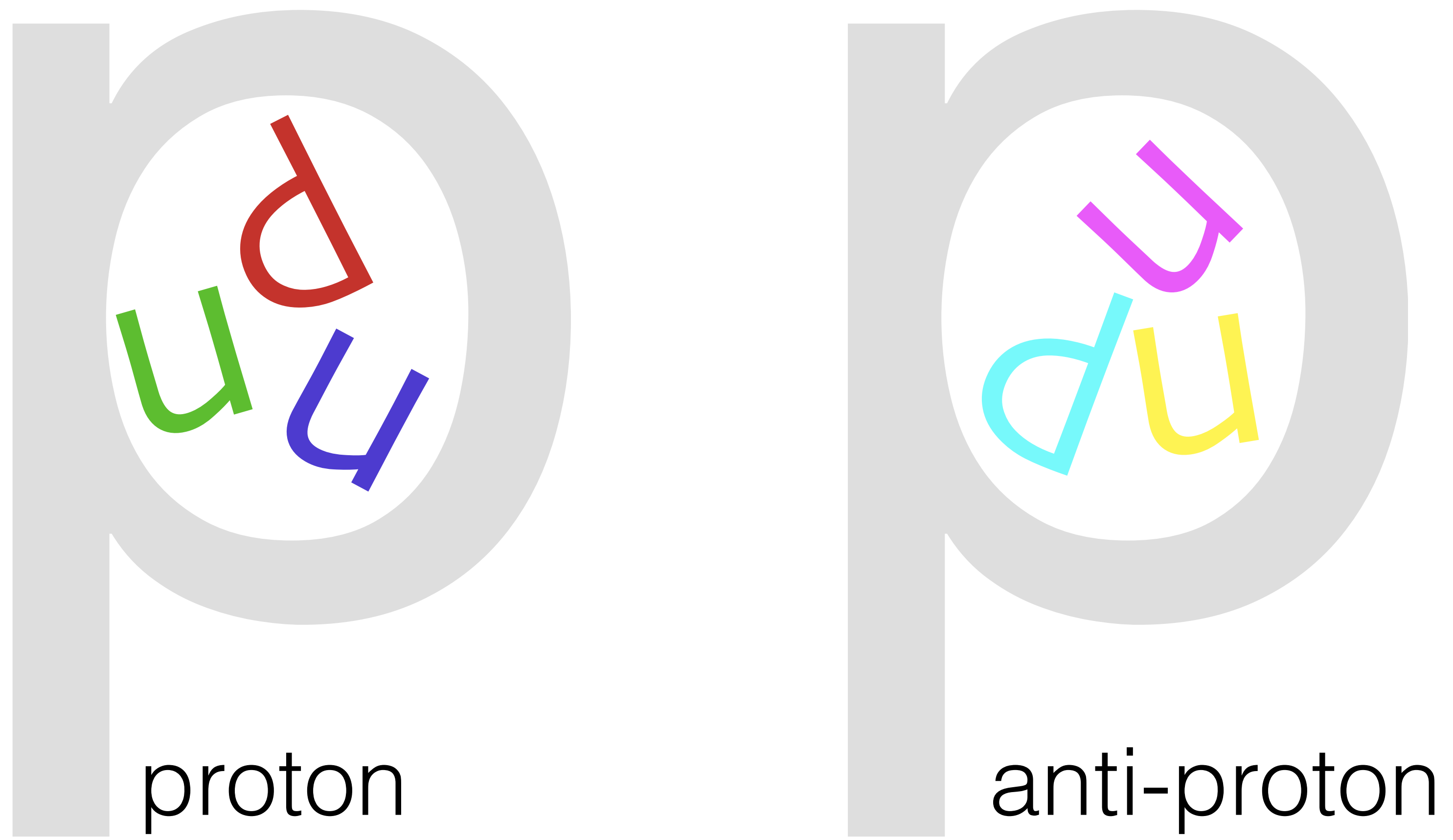
particles		anti-particles
	red	anti-red
	green	anti-green
	blue	anti-blue

Greenberg bzw. Han & Nambu (1964/65)

3. Example

Graphical implementation of color charges, particularly the visualization of anti-colours, is difficult.

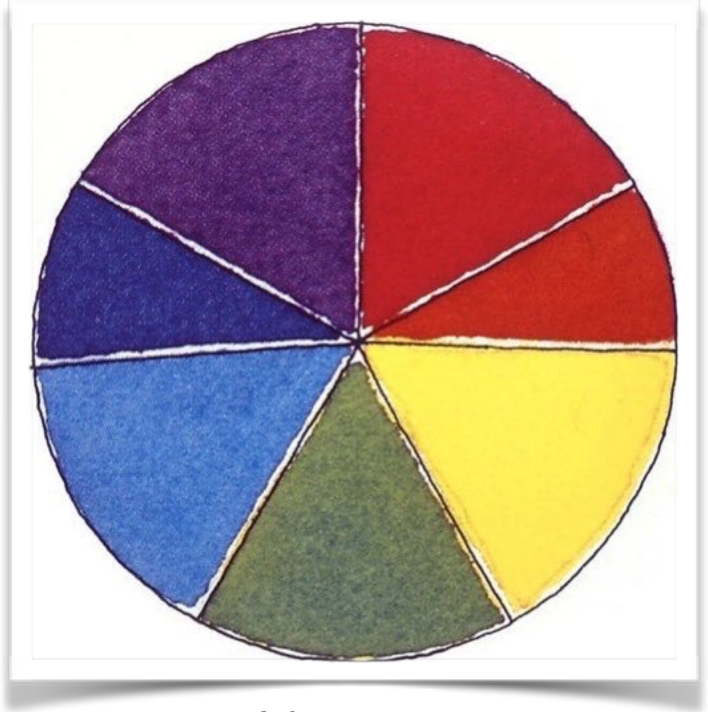
Illustrating anti-colours through the respective complementary colours of red, green, and blue is widely used.



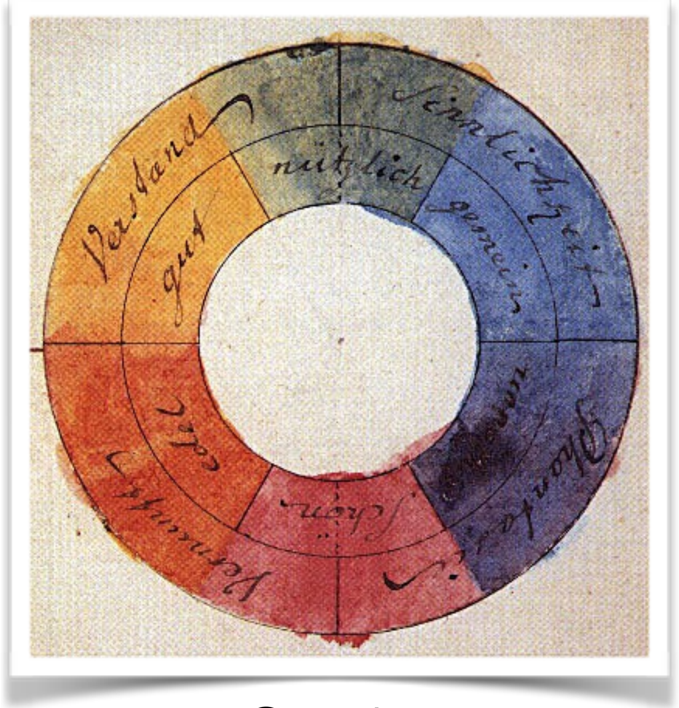
3. Example

Criticisms of the illustration through complementary colours:

- Overlay with existing knowledge from optics
- Ambiguity by different color models and colour circles



Newton



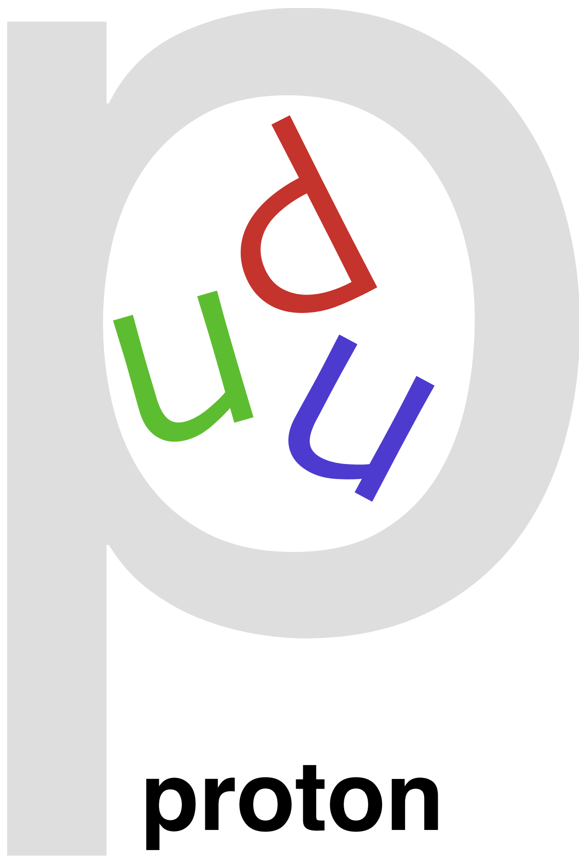
Goethe

CMYK

"Isn't the complementary colour of blue orange, of green red, and of yellow purple?" [Student, 17]

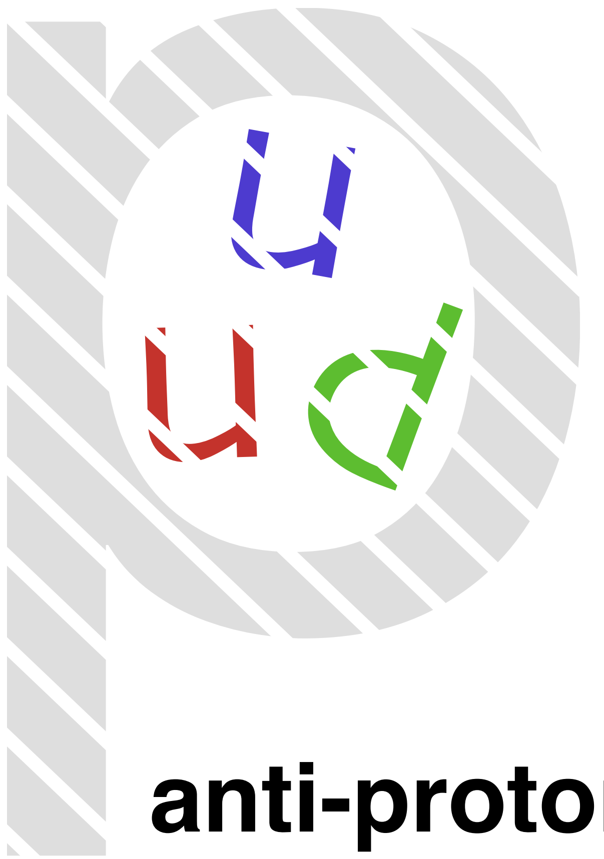
3. Example

An alternative proposal for the graphical representation of anti-colour charge:



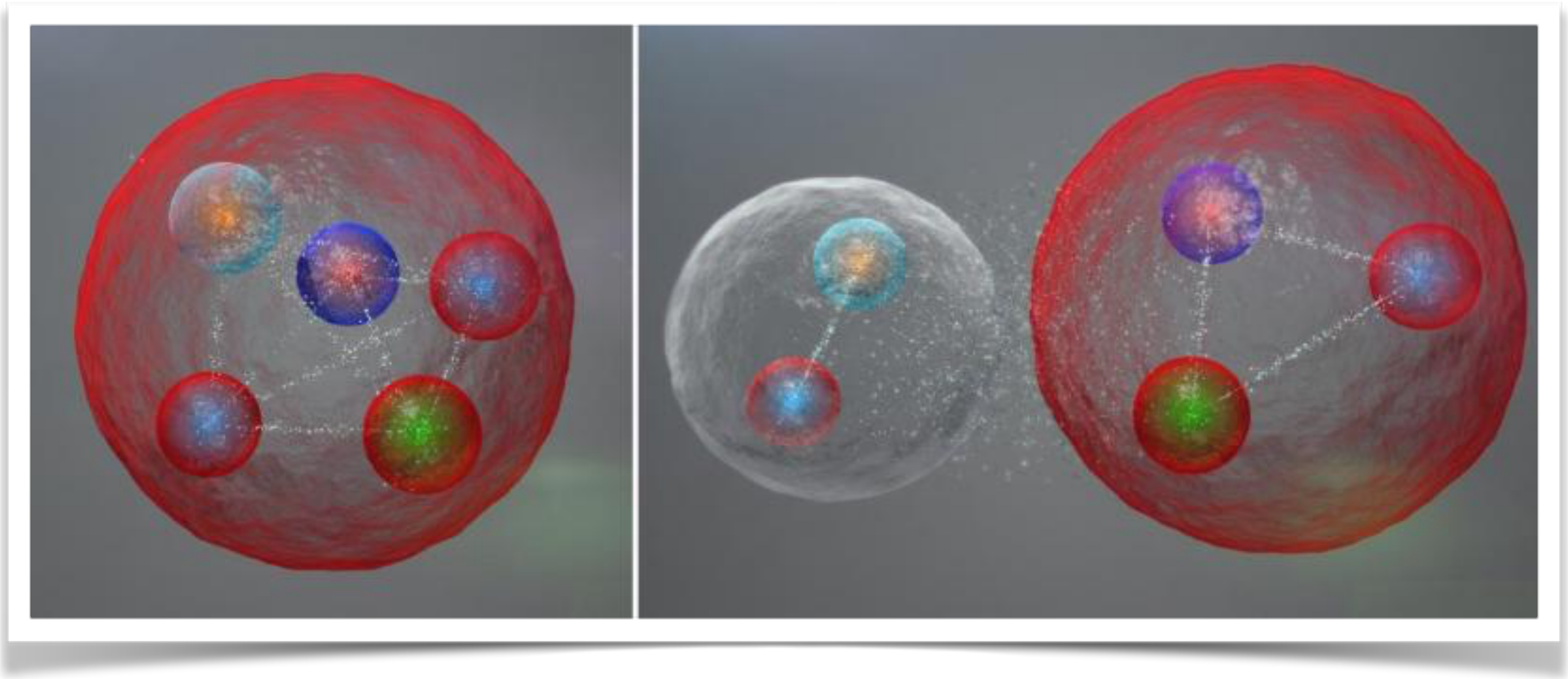
proton

anti-proton
Illustration through complementary colours



anti-proton
Illustration through striped pattern

3. Example



Merci!
Let’s talk!