

REYES

Remote Experience for Young Engineers and Scientists

Guest lecture

Symmetries and how to use them in physics

Felipe G. Ortega-Gama

PhD Physics candidate

Cosmovitral, Photo: Jesús Cabrera

July 24th 2020



WILLIAM & MARY
CHARTERED 1693

felipeortegagama@gmail.com

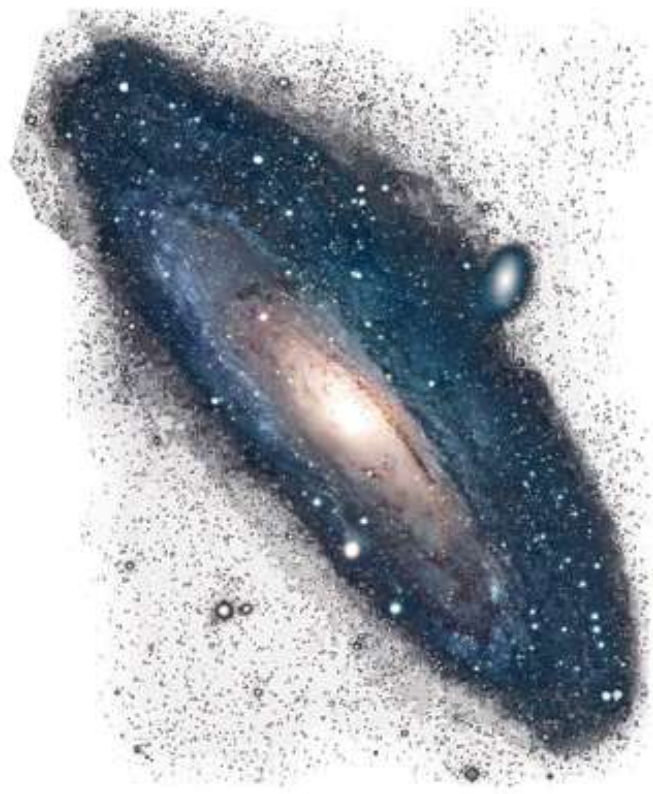


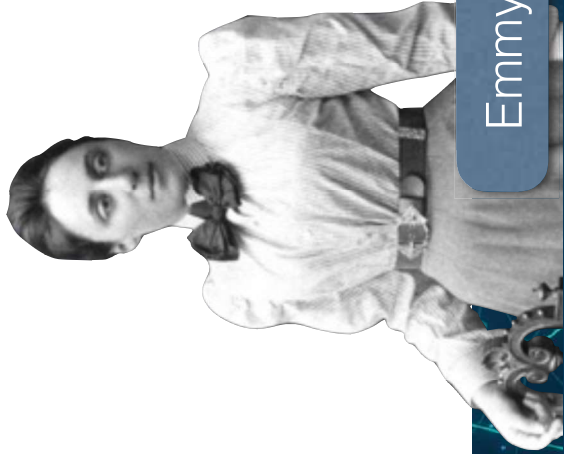
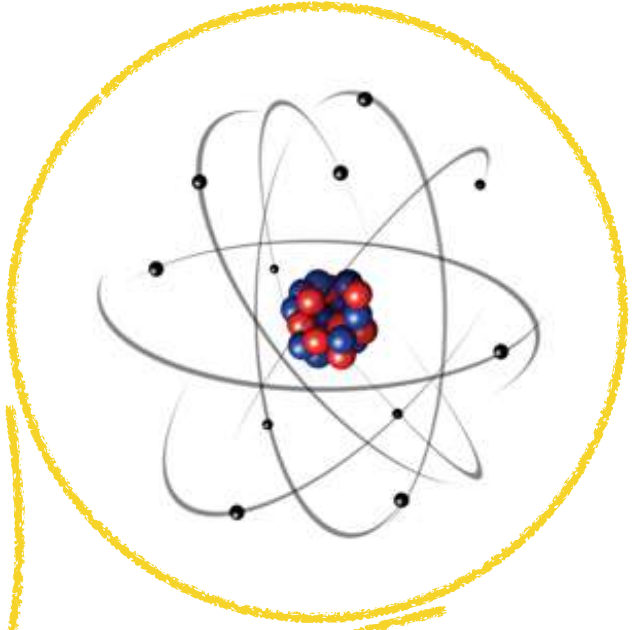
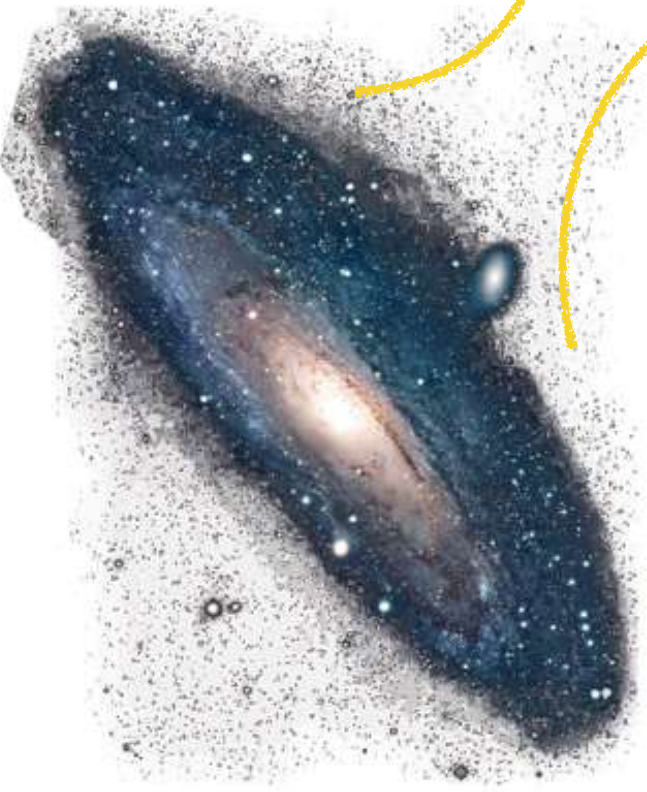
Emmy Noether





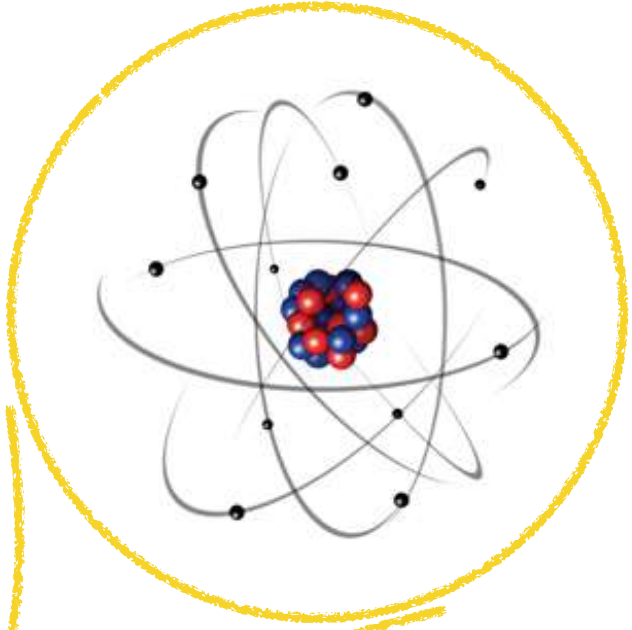
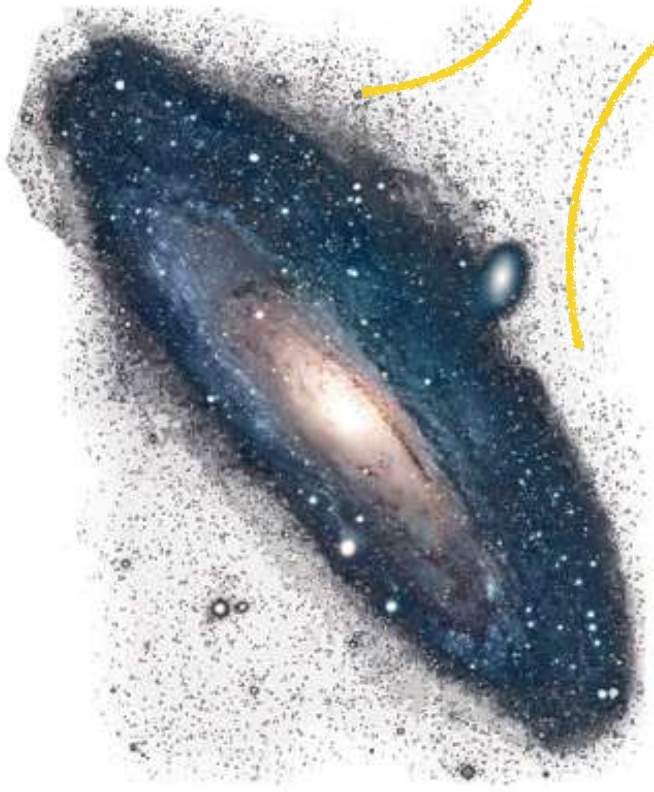
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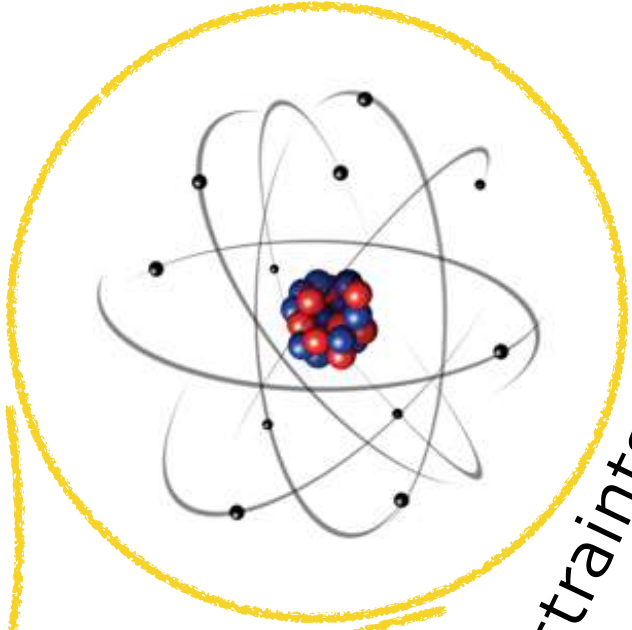
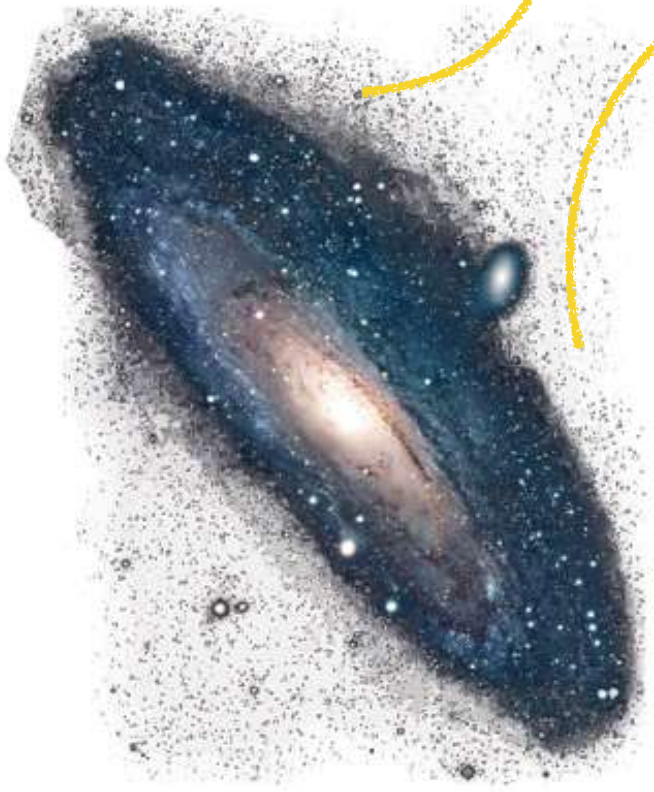
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How can we explain/
understand all of this?



Emmy Noether

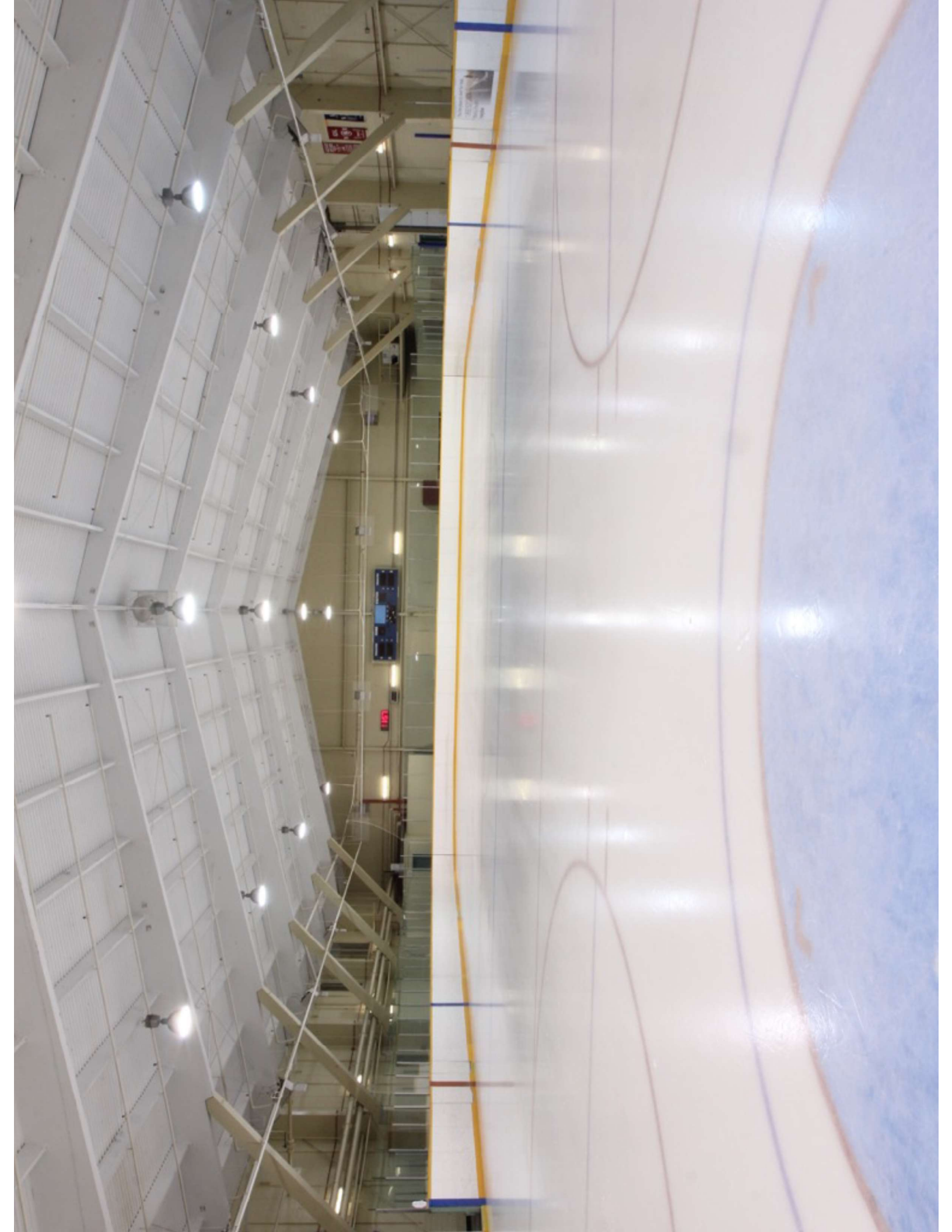
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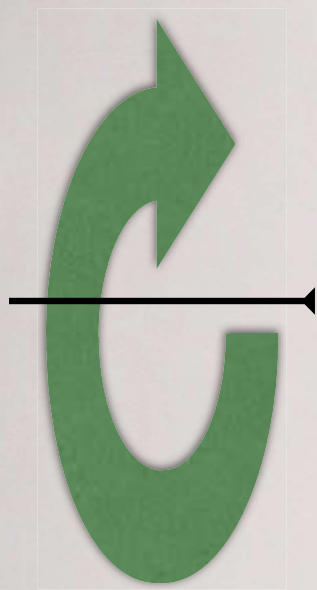
Are there any constraints
about what can happen?

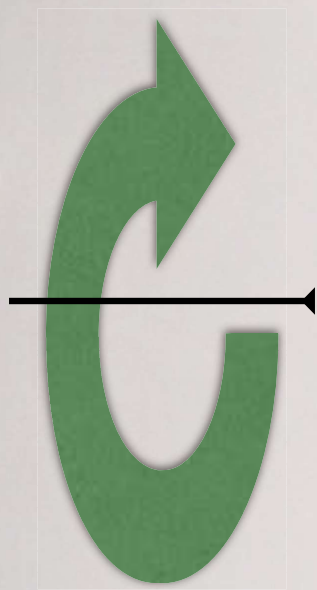


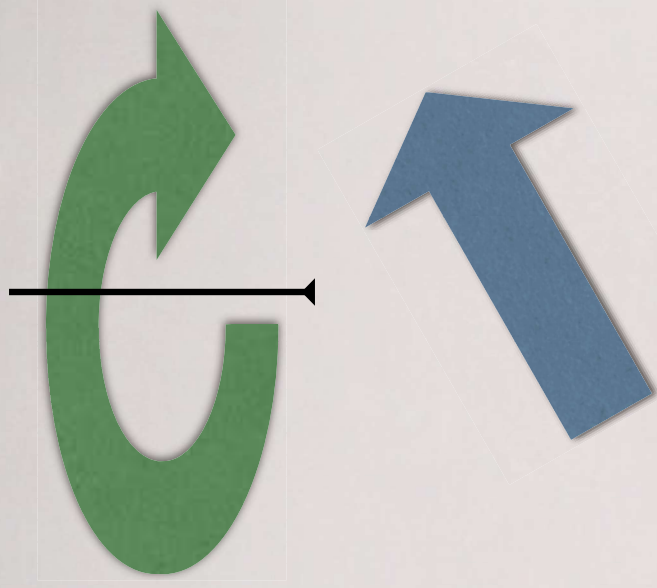
Emmy Noether











(Local) Symmetries!

Tara Lipinski - Nagano 1998



<https://www.olympic.org/videos/figure-skating/nagano-1998>

Tara Lipinski - Nagano 1998



$\frac{d\vec{L}}{dt} = 0.$ Angular momentum conservation

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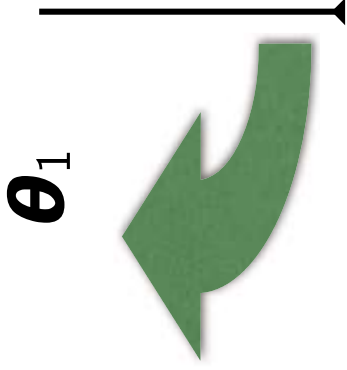
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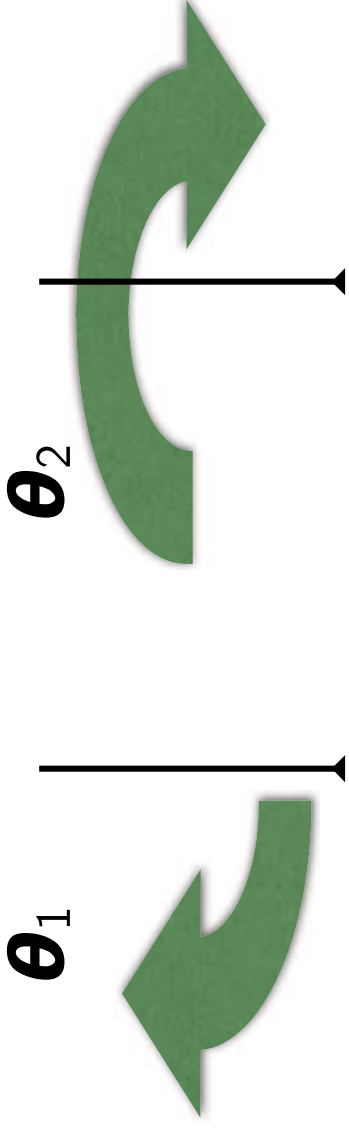
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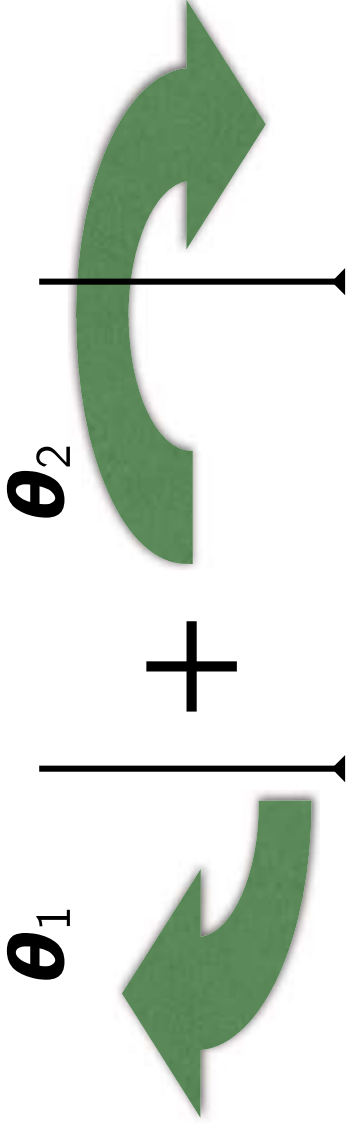
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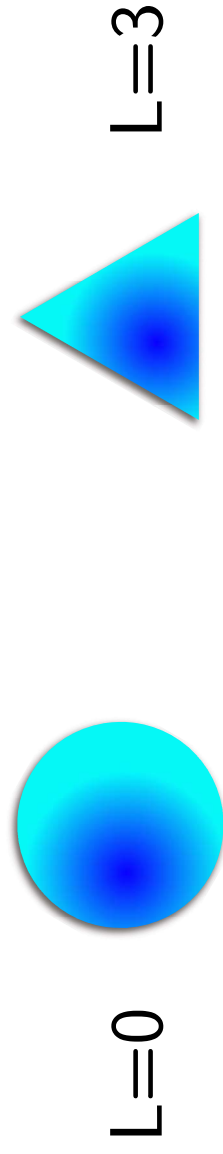
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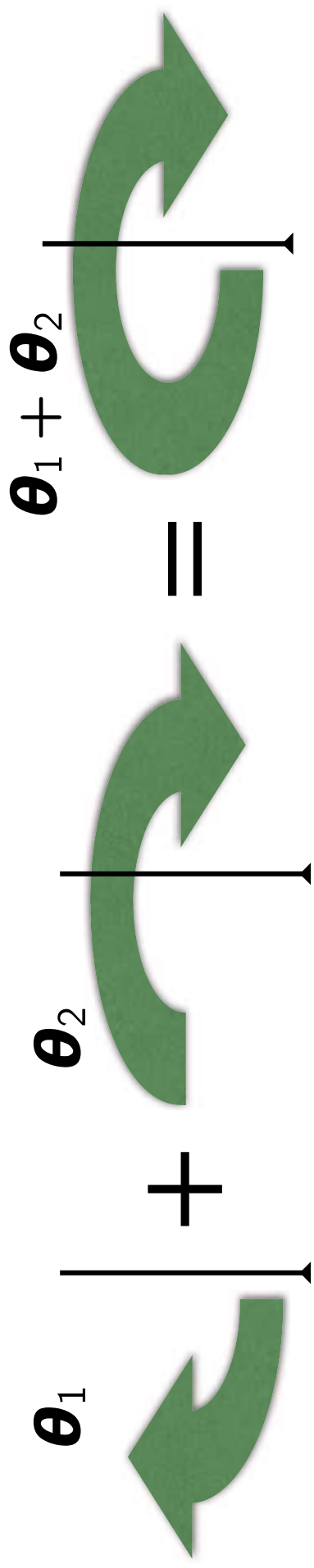


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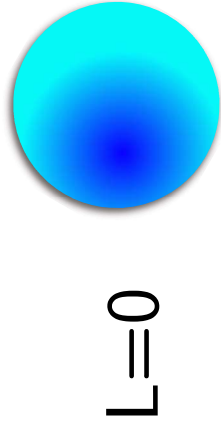
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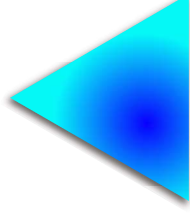
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$L=0$



$L=3$

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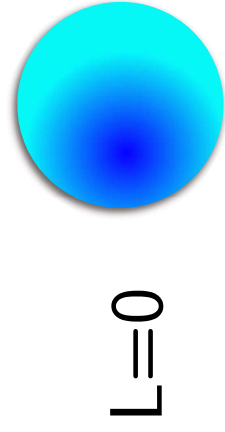
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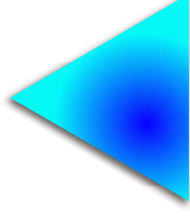
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The particles of our universe

- Our universe, at least locally, is Poincaré symmetric.



The particles of our universe

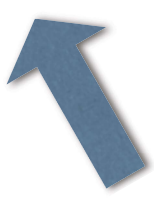


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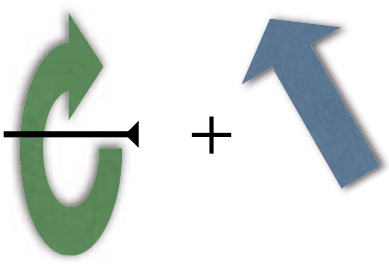
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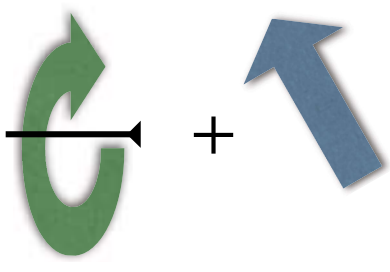
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The particles of our universe

- Our universe, at least locally, is Poincaré symmetric.
- A bunch of Quantum Mechanics and group theory.

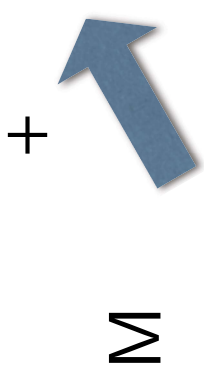


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+



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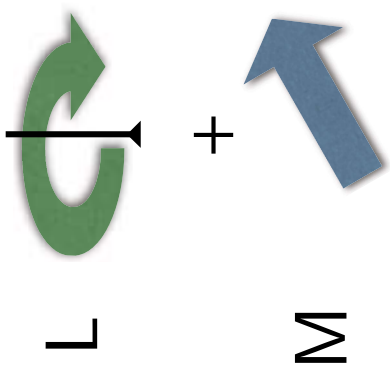


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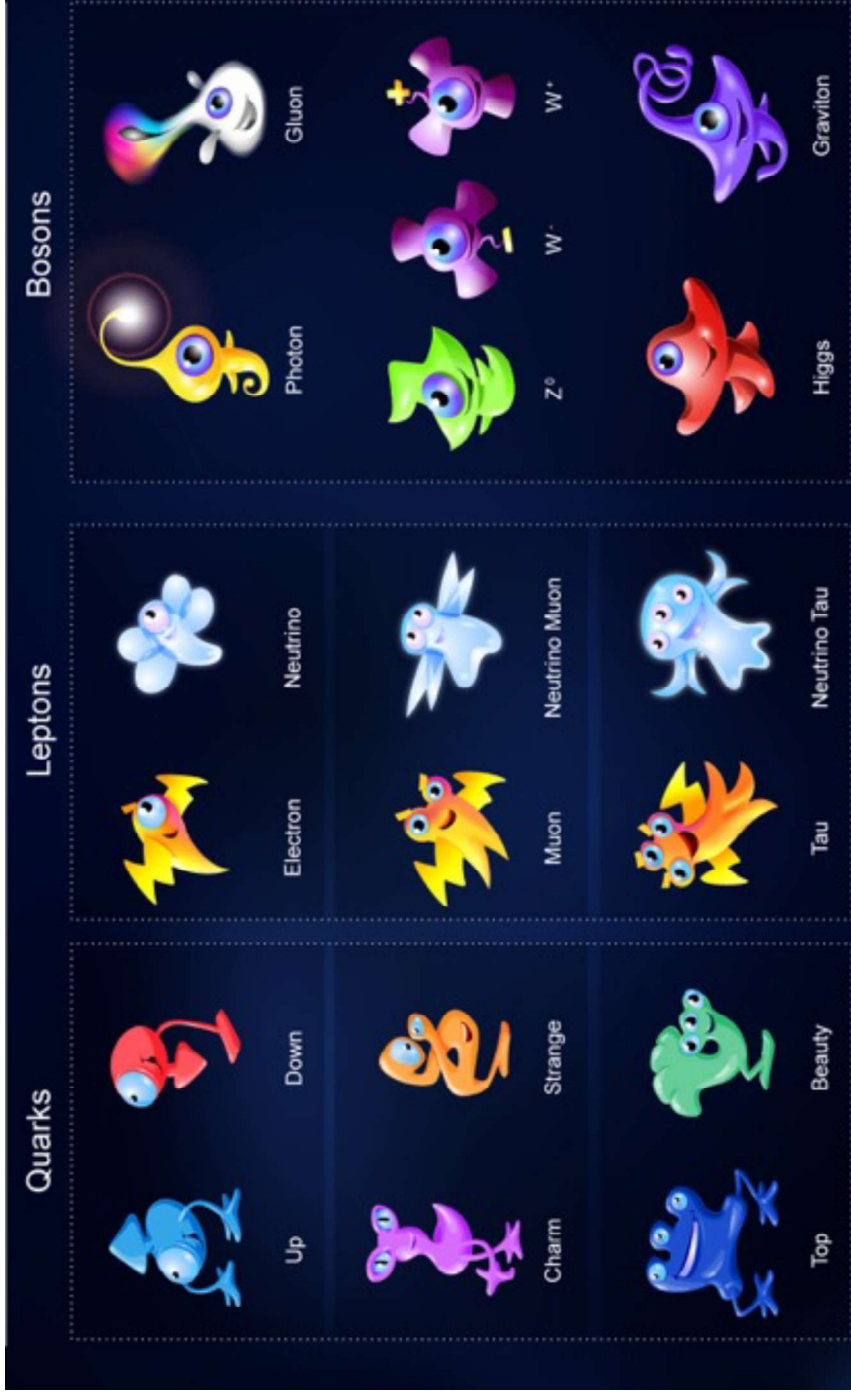
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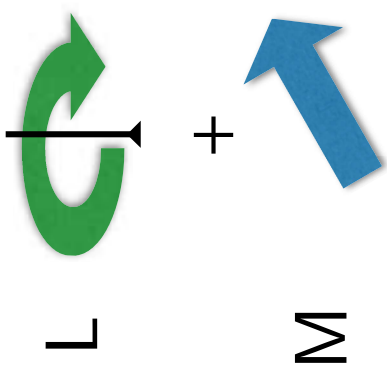
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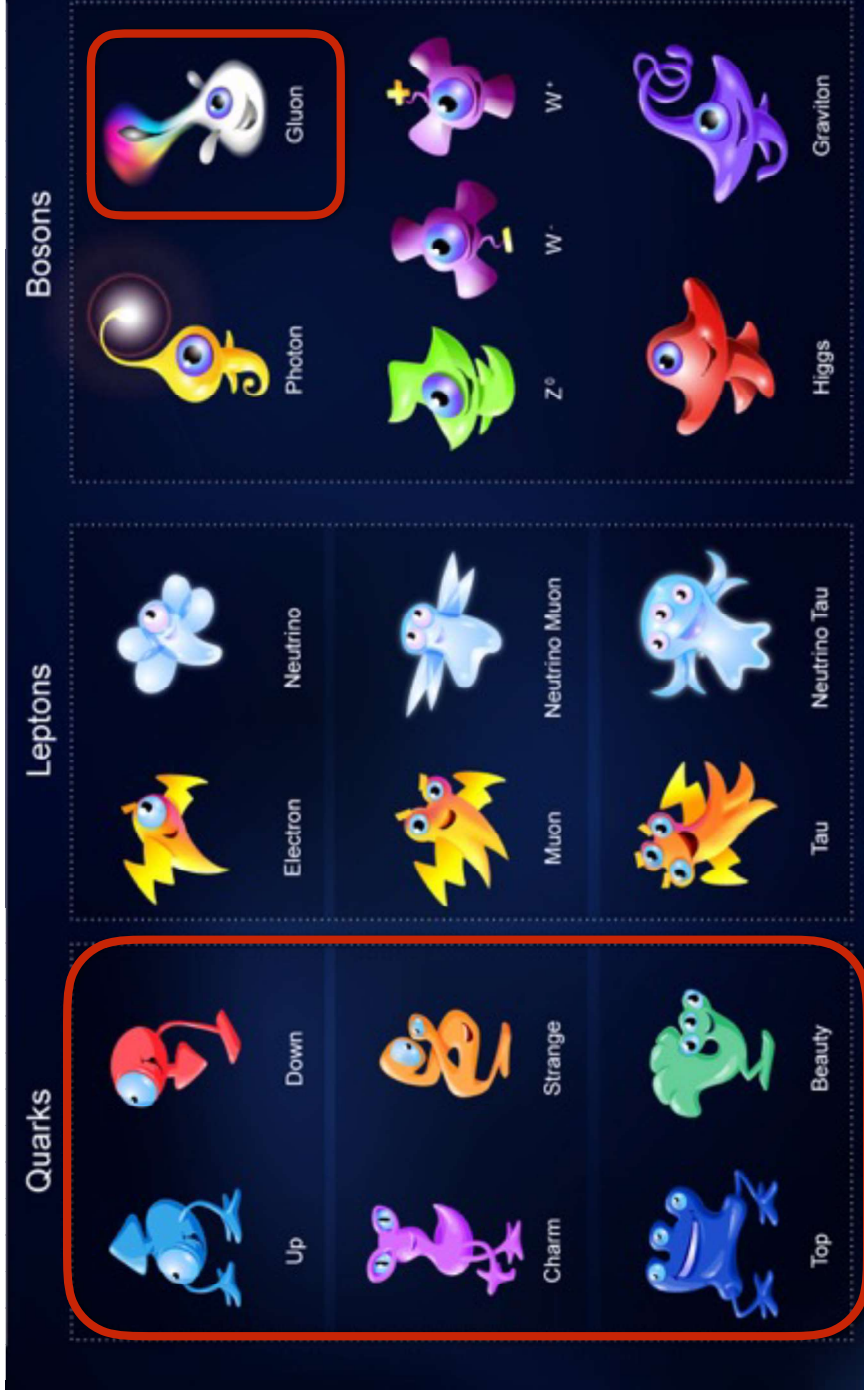


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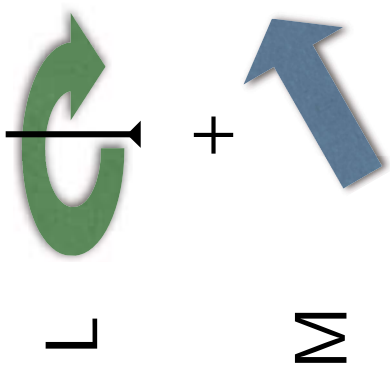


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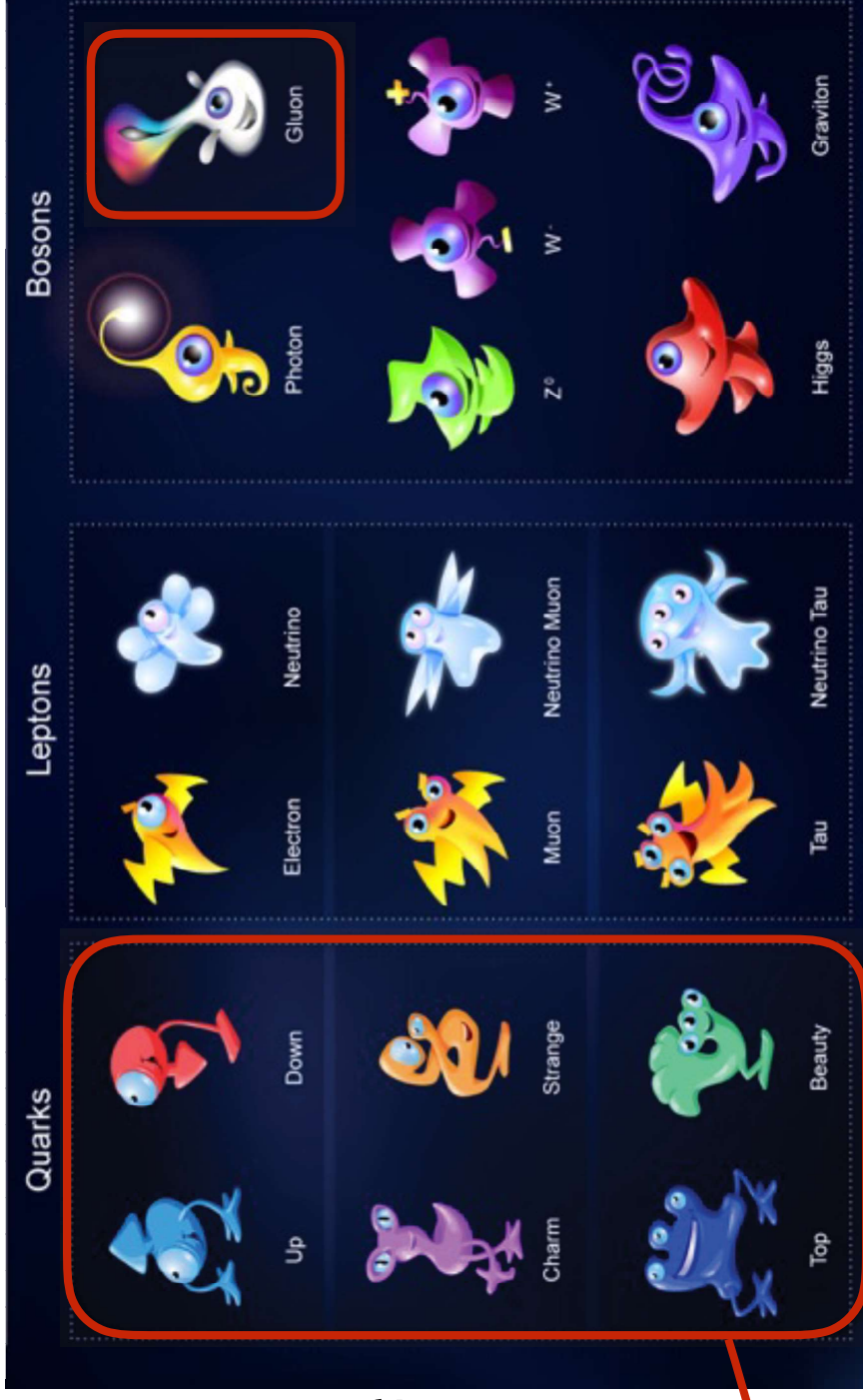


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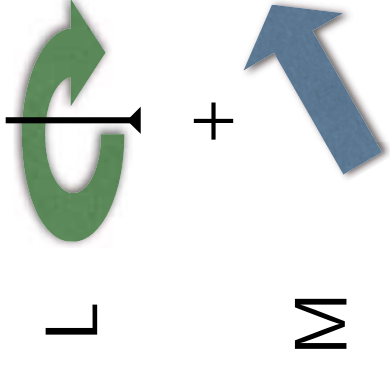


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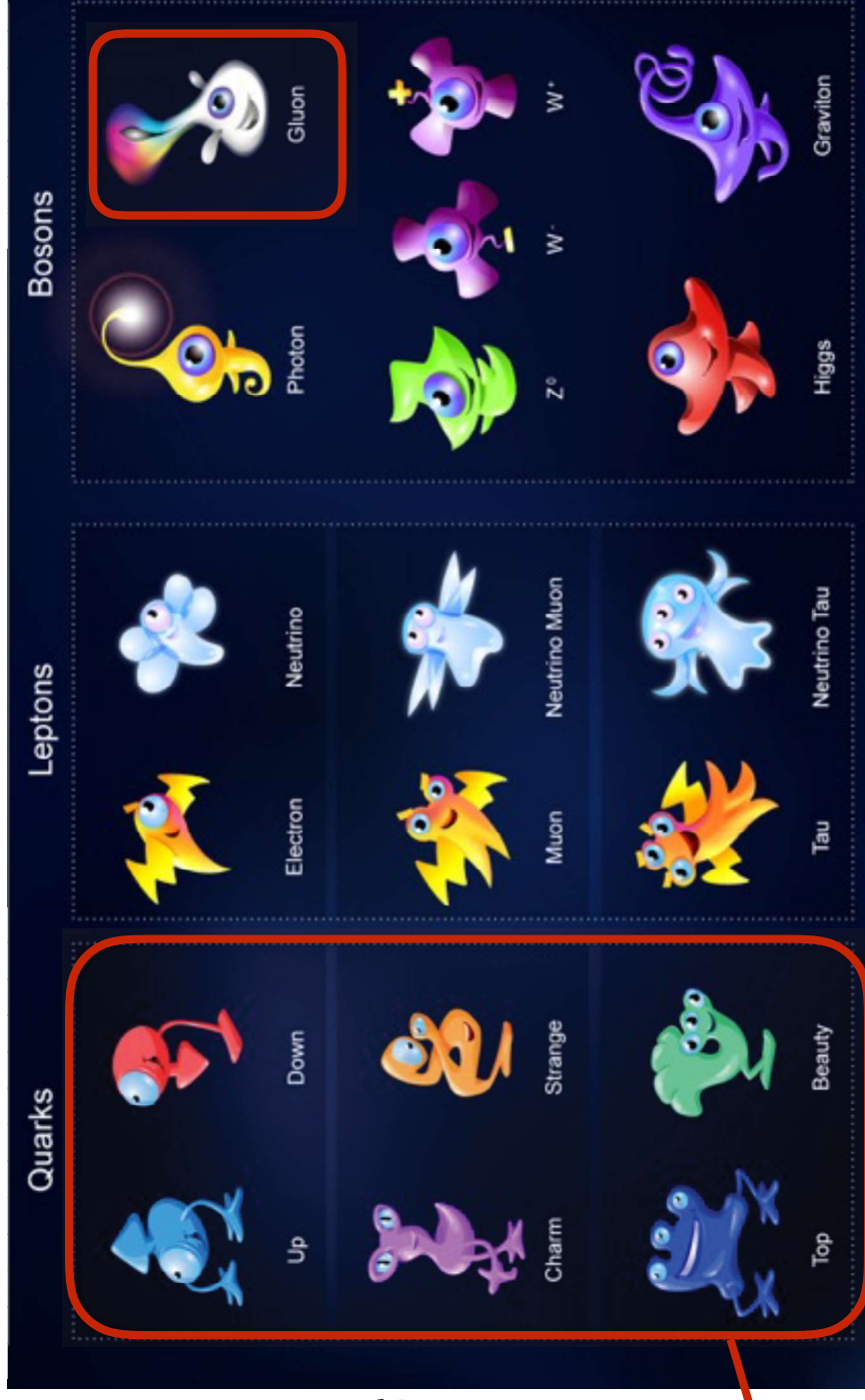
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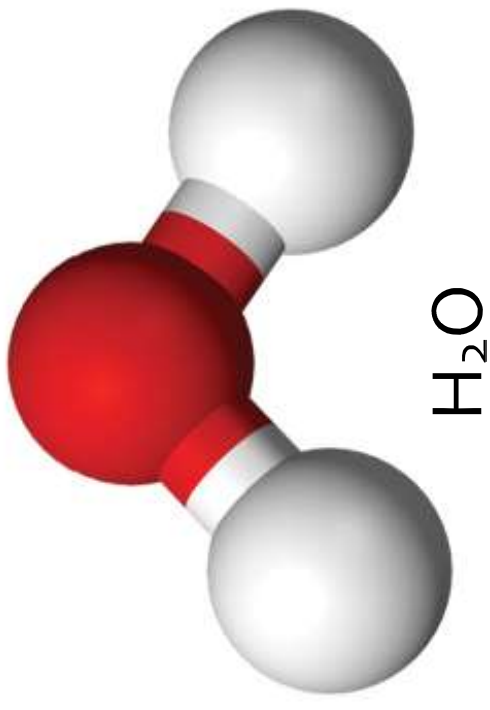
The particles of our universe:

Strong force:
Atomic Nuclei



Heavy ice (or water)

Discovered in 1931



Water

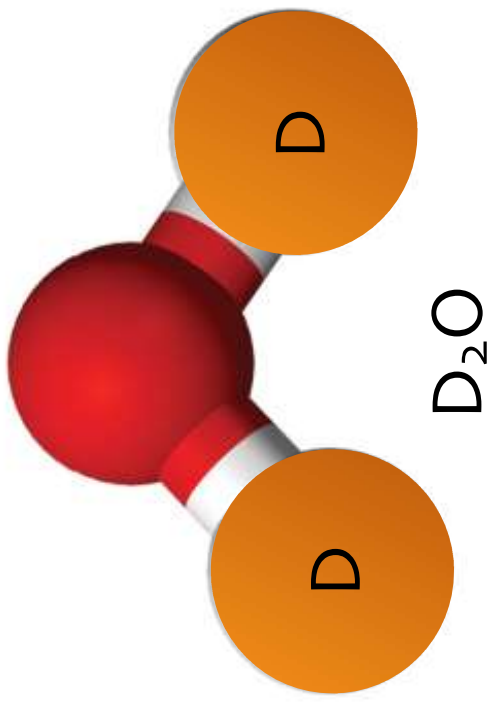
1.0 g/ml

Heavy water

1.1 g/ml

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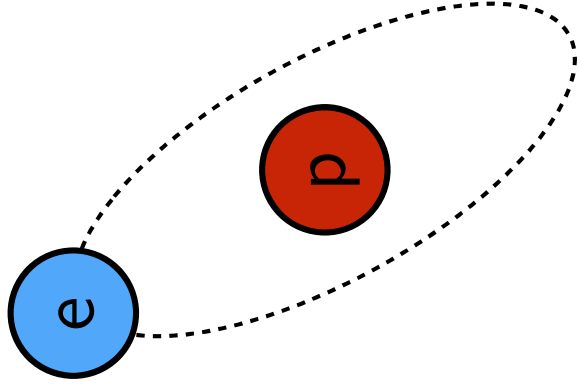
1.0 g/ml

Heavy water

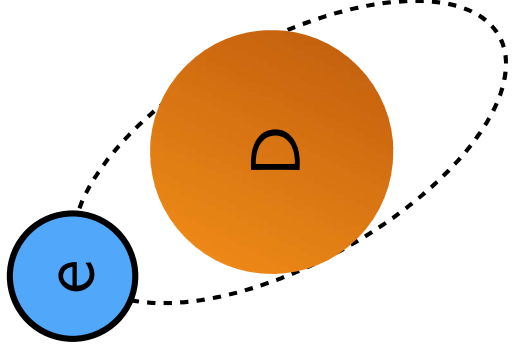
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The neutron and the proton

Discovered in 1932



Hydrogen

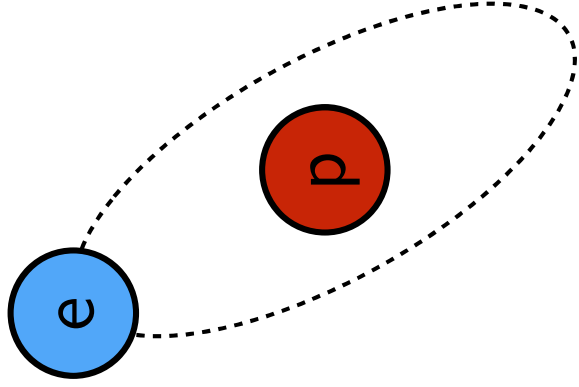


Deuterium

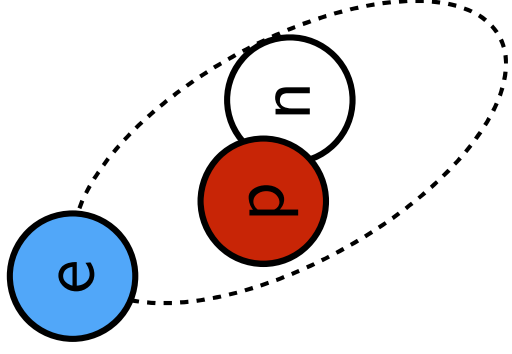
proton	neutron
1.673×10^{-27} kg	1.675×10^{-27} kg
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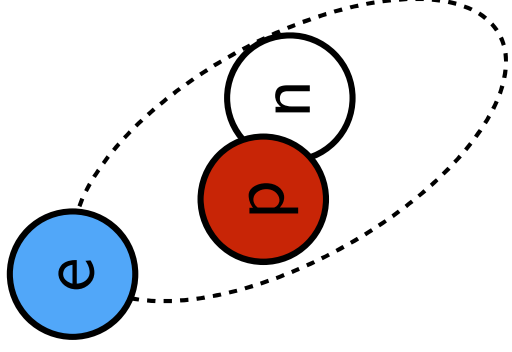
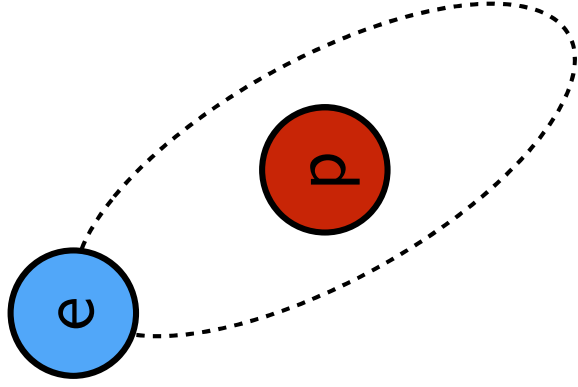


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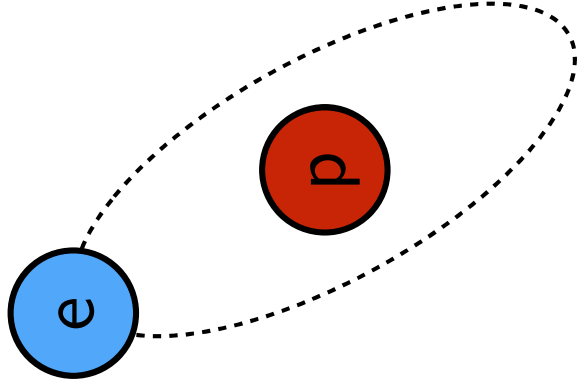
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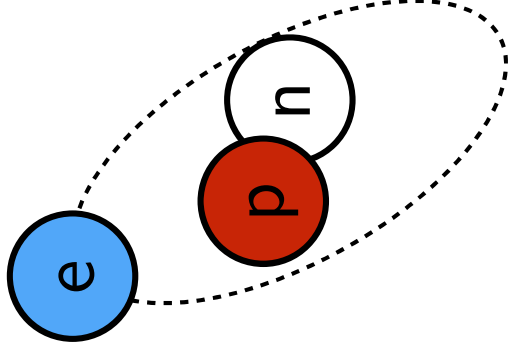


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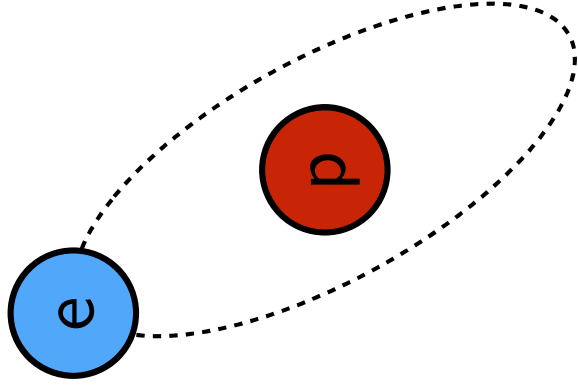


Deuterium

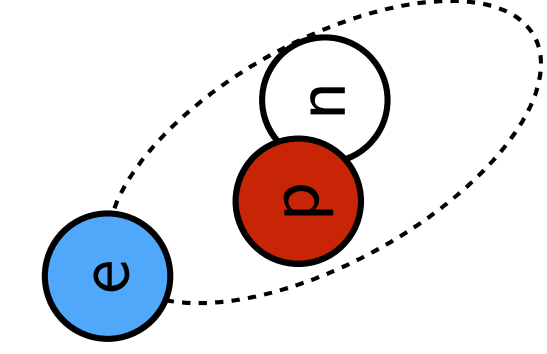
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What if there is a symmetry relating them?

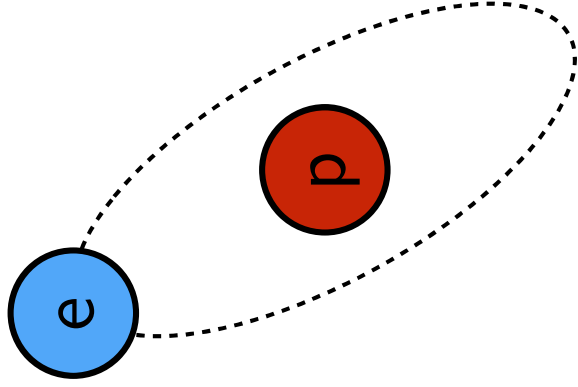


Werner Heisenberg

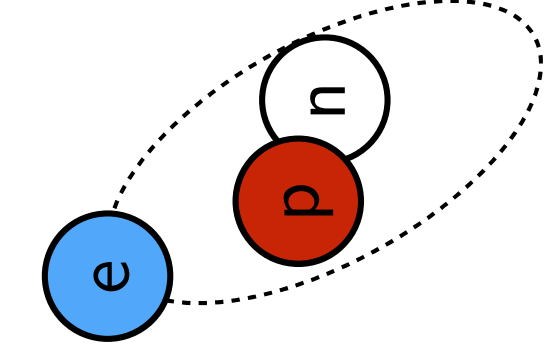
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Isospin symmetry

The pion: π

Discovered in 1947

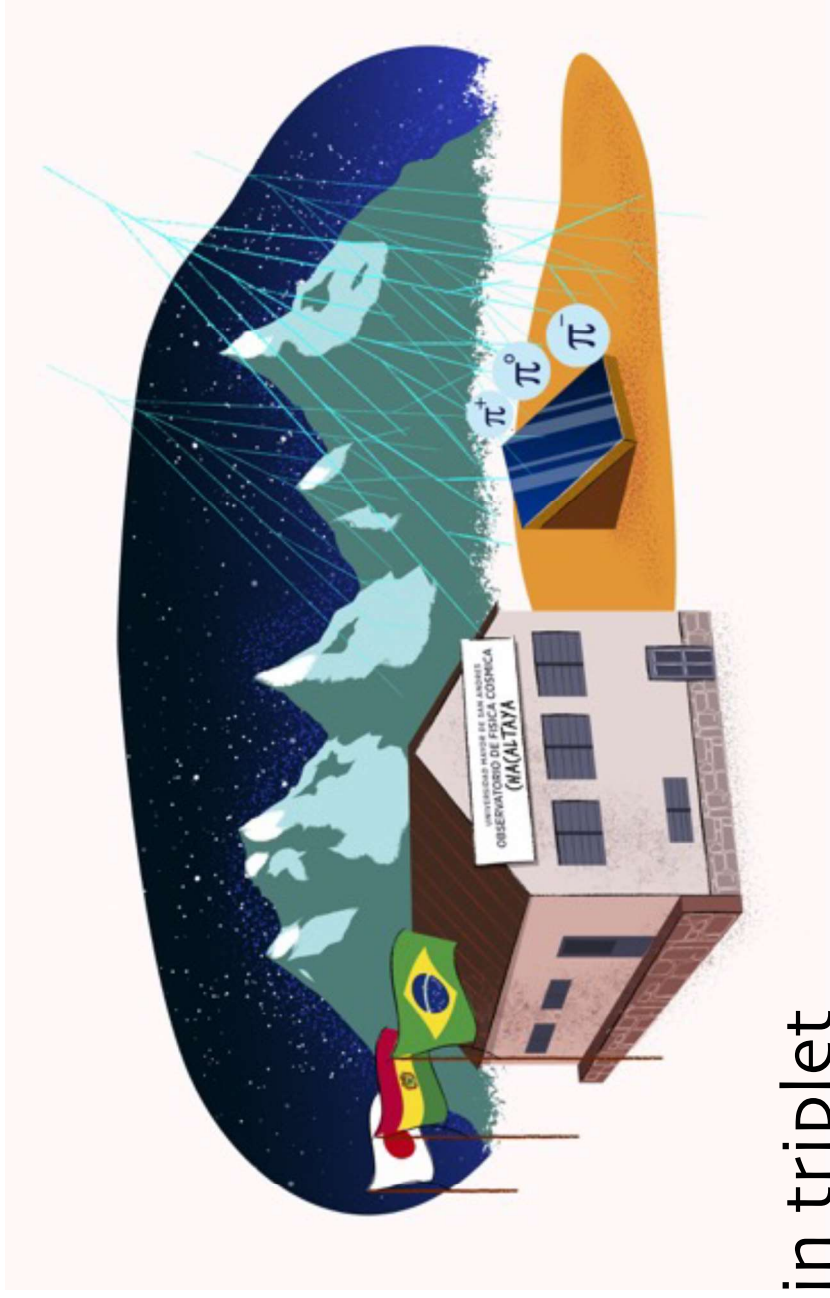


Illustration by Sandbox Studio, Chicago with Pedro Rivas

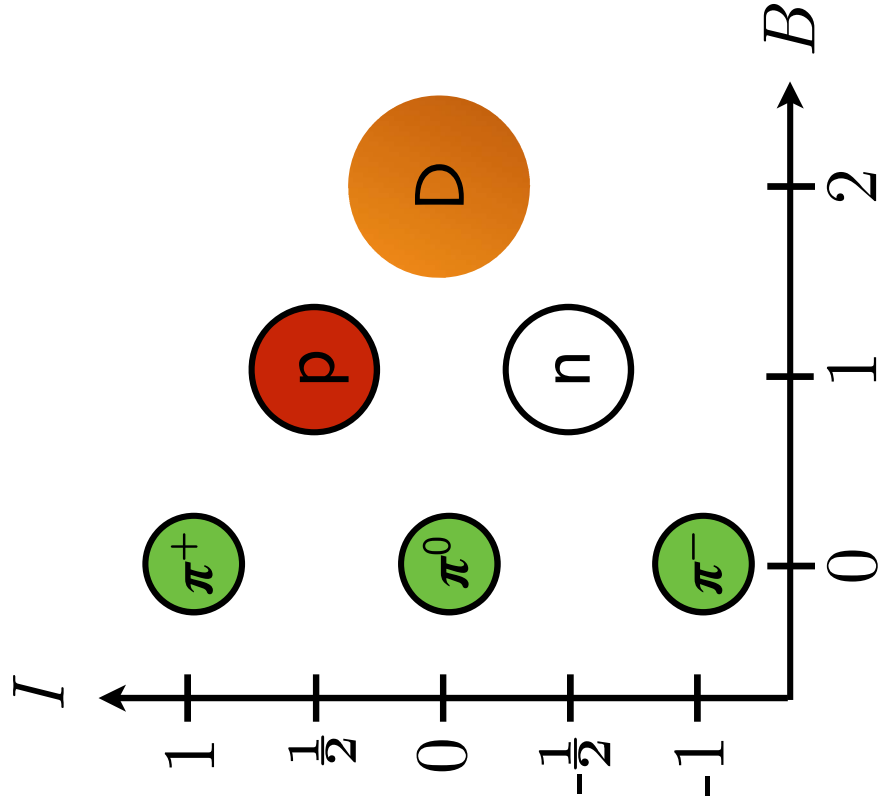
Isospin triplet

π^{\pm} π^0

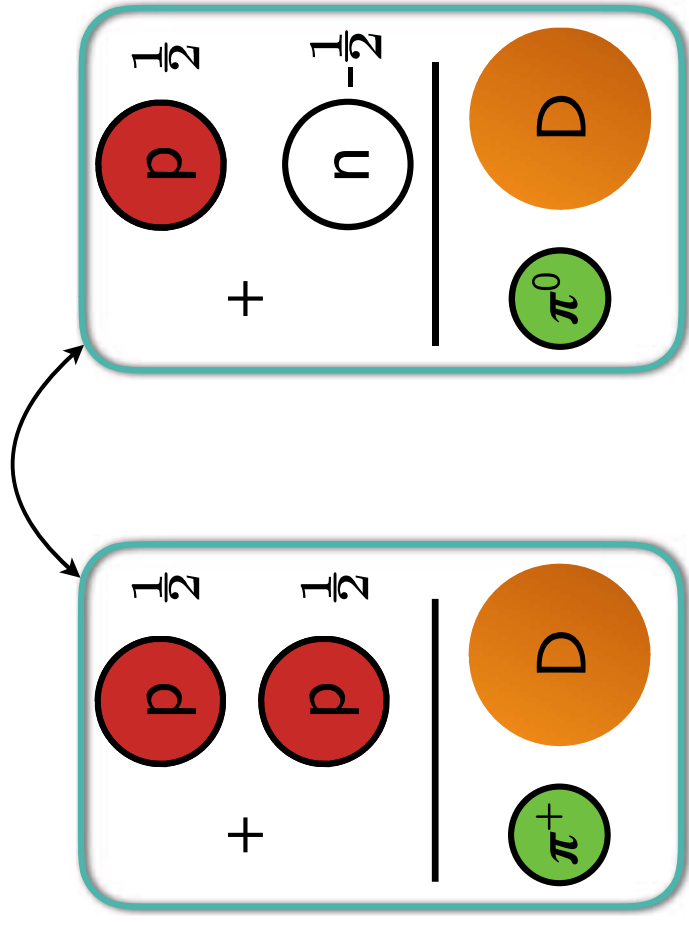
140 MeV/c²

135 MeV/c²

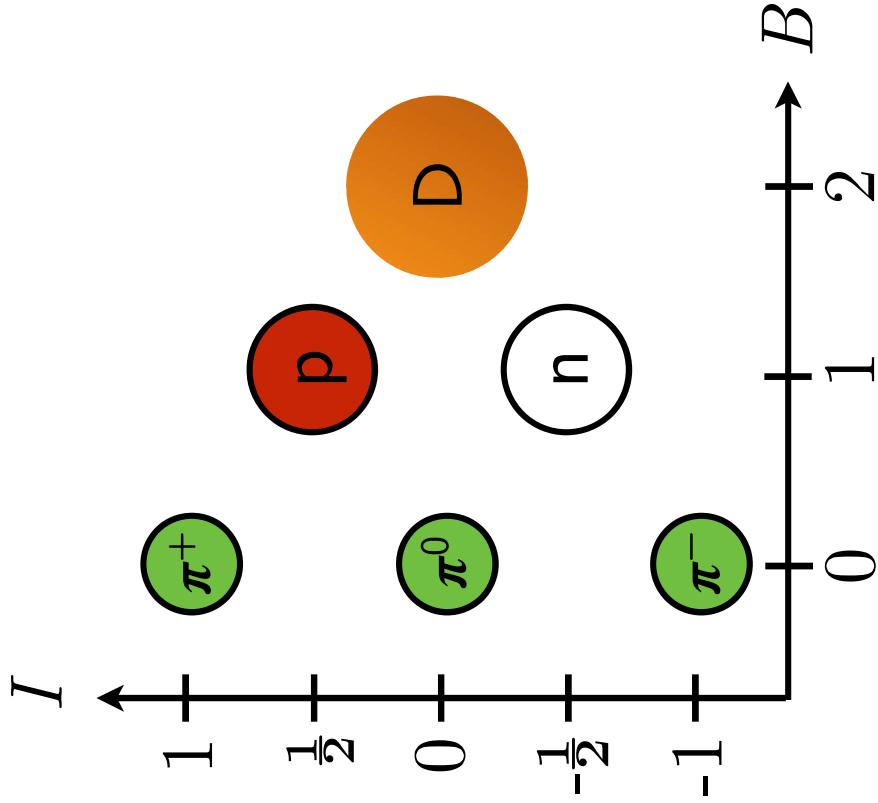
Isospin and the zoo



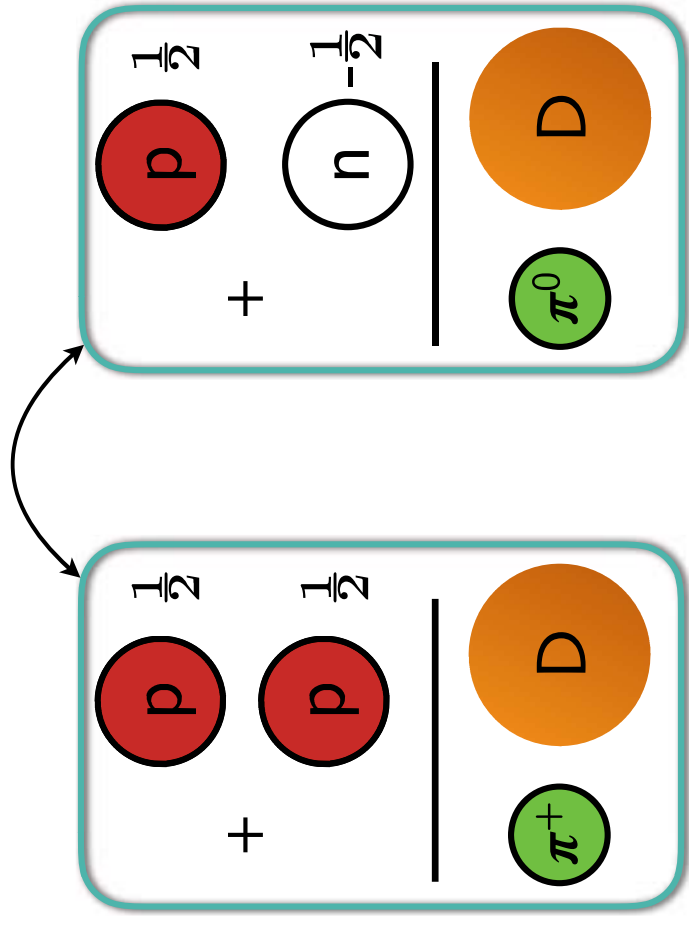
Related by isospin symmetry



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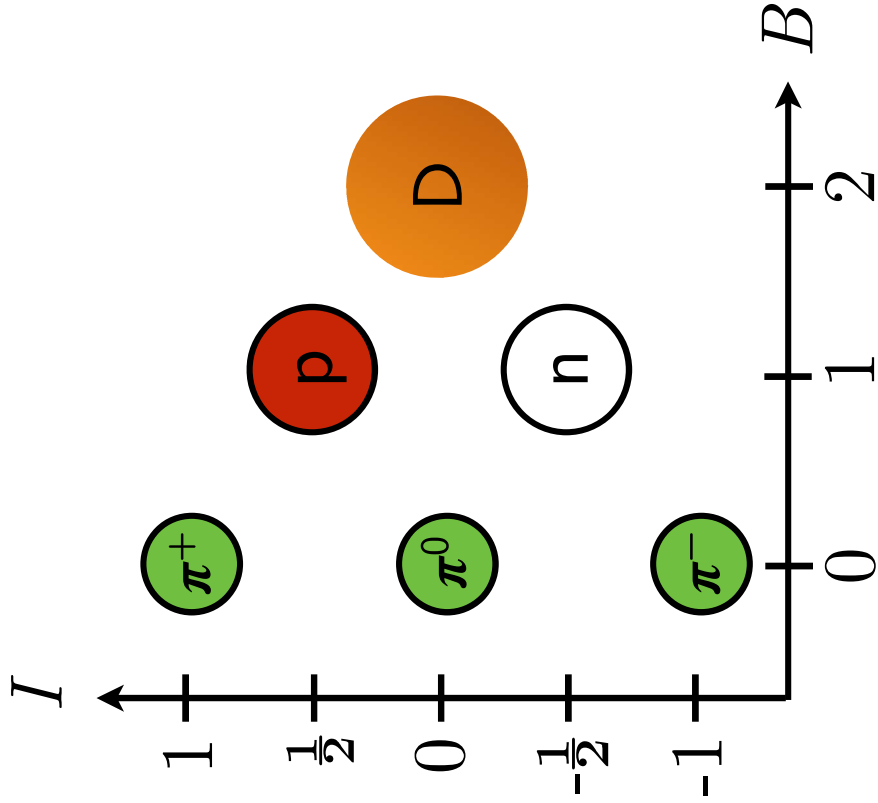


Related by isospin symmetry

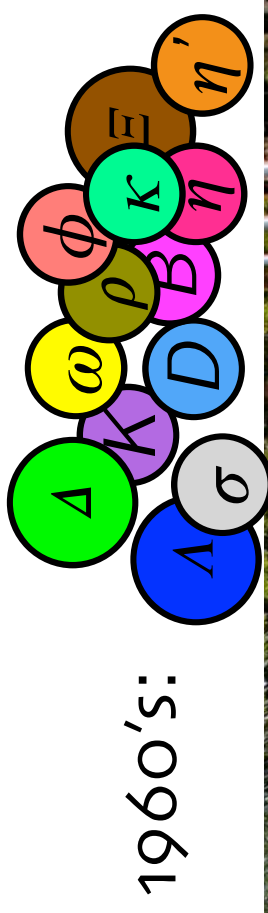
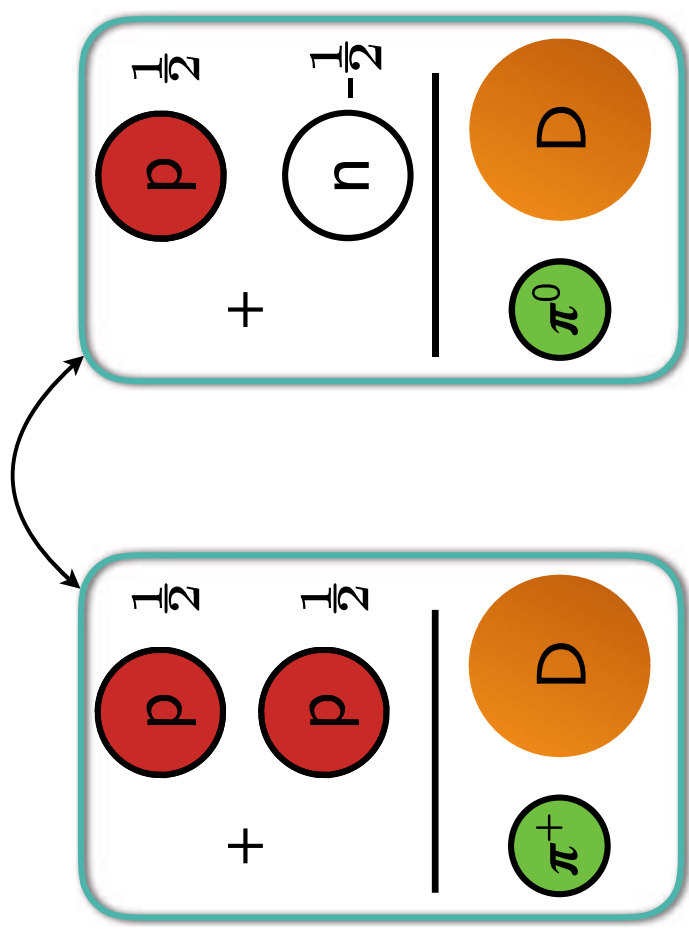


1960's:

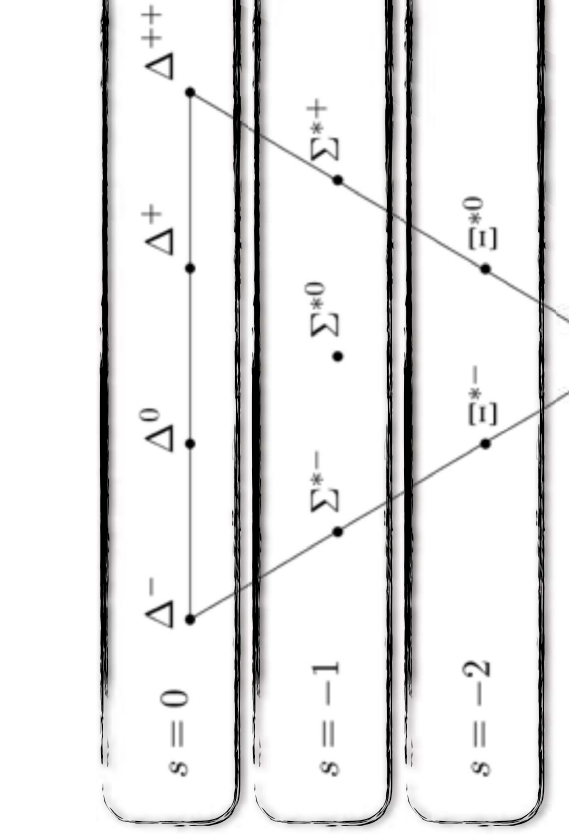
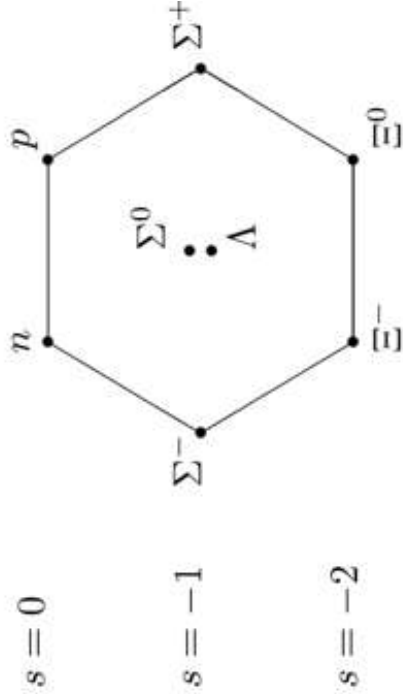
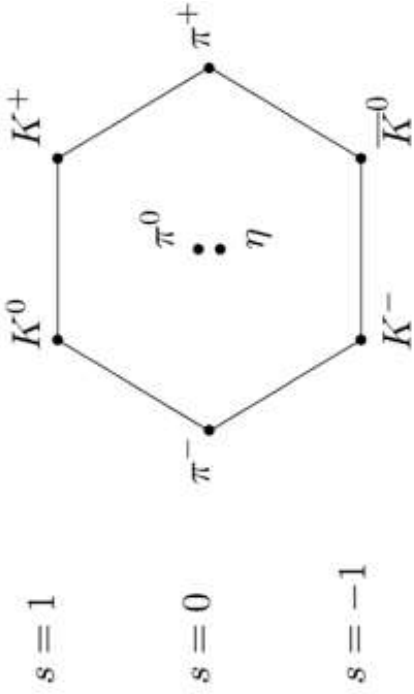
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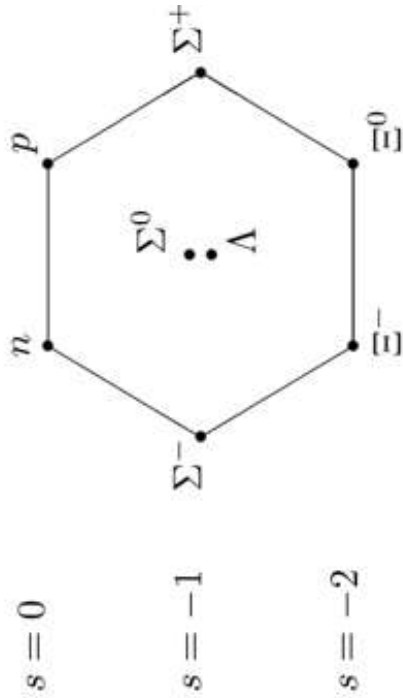
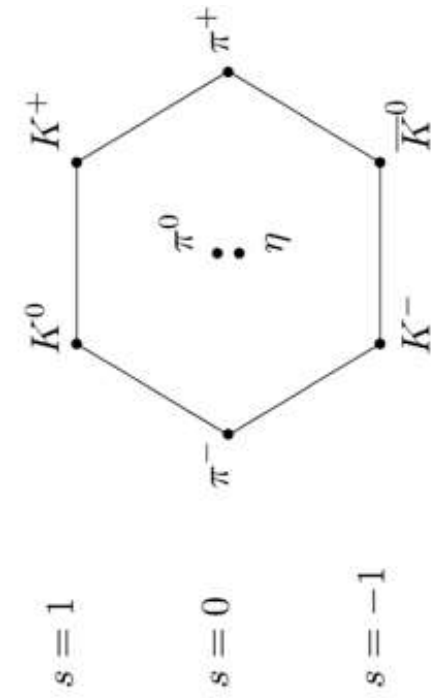
Related by isospin symmetry



The Eightfold way

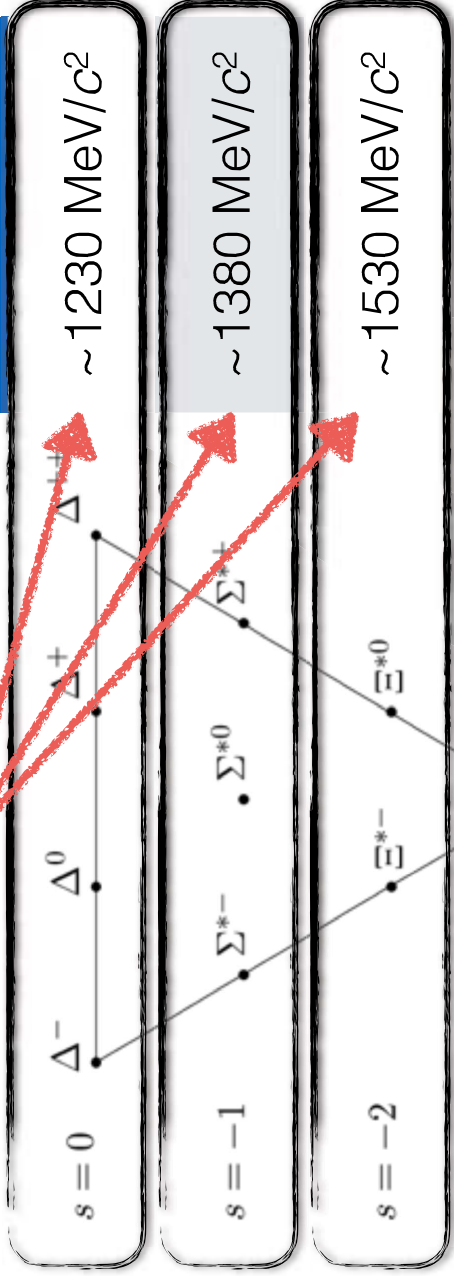


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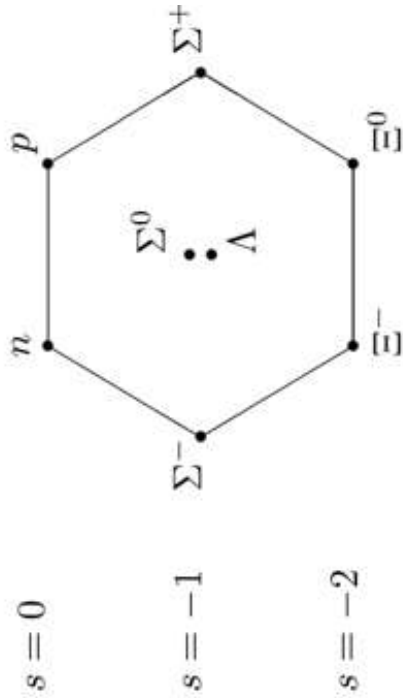
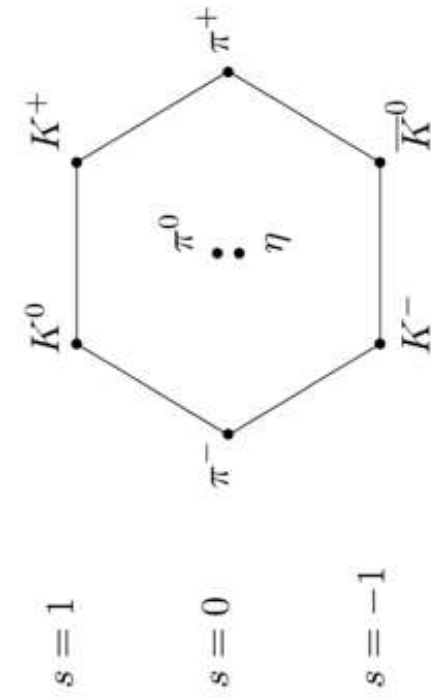


Difference: $150 \text{ MeV}/c^2$

Mass

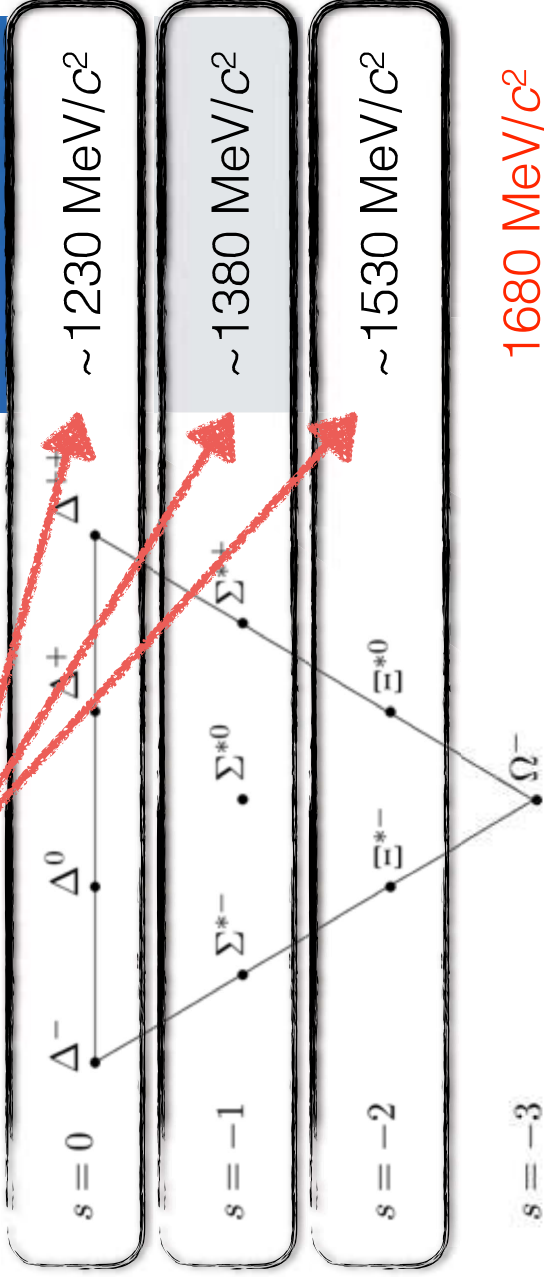


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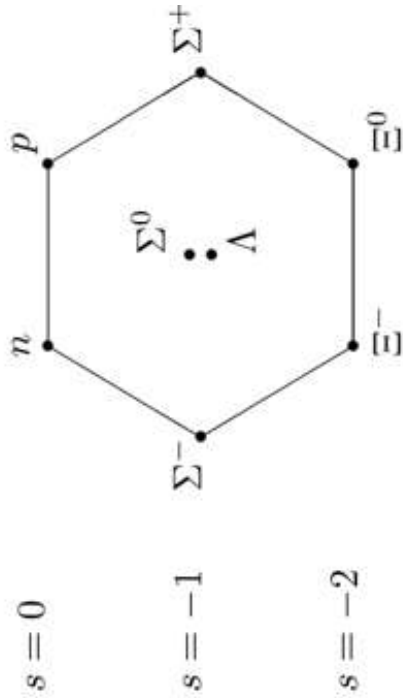
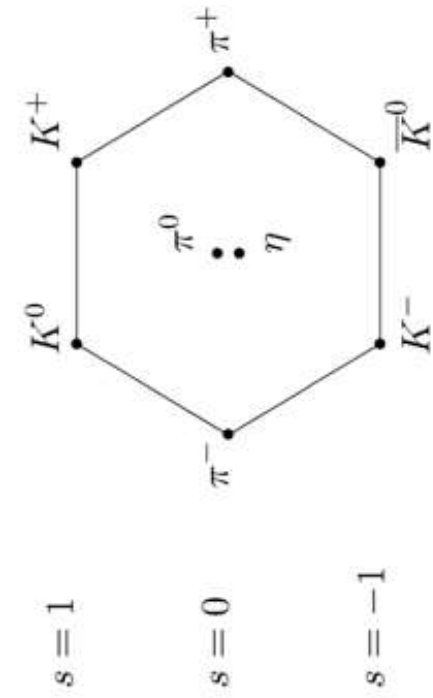


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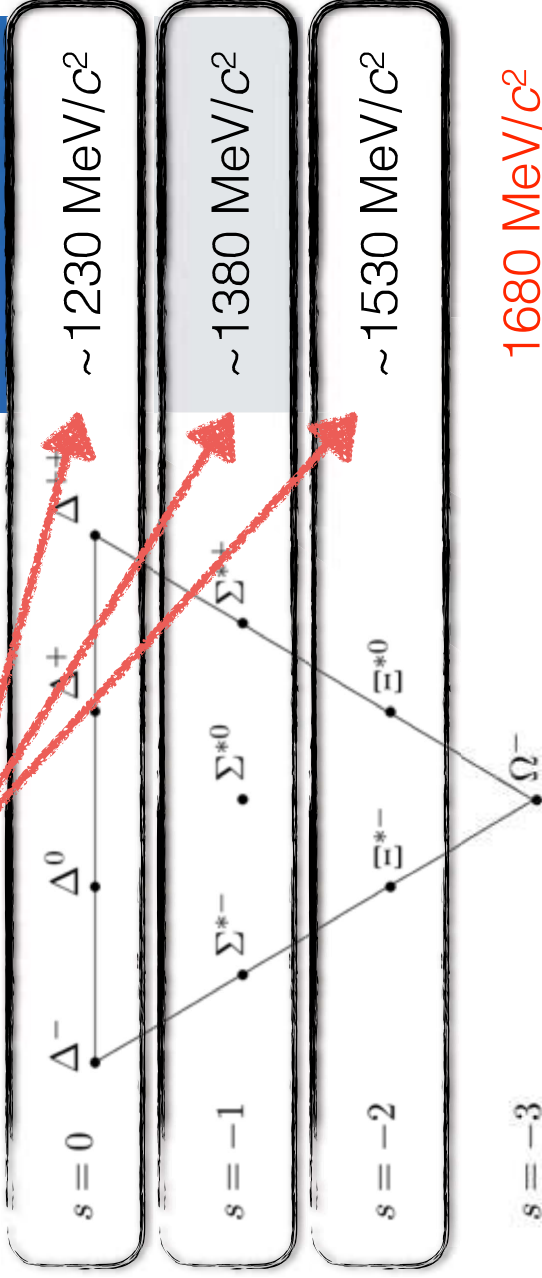


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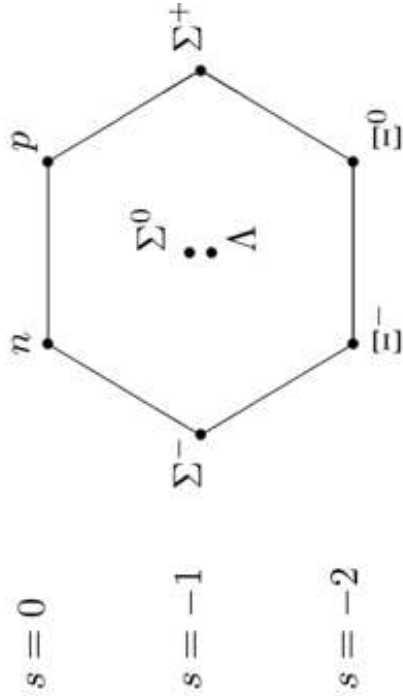
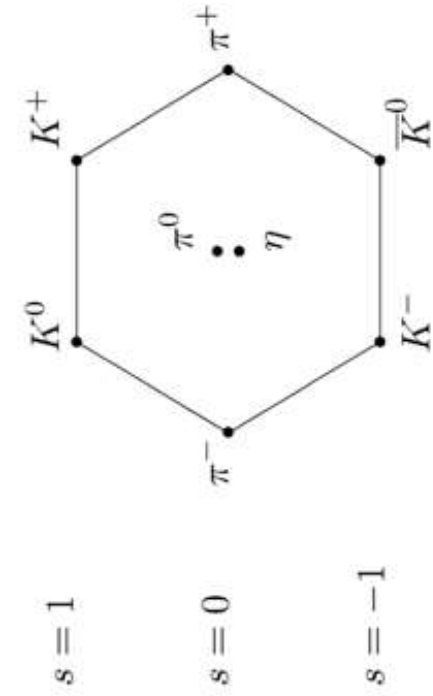


$1680 \text{ MeV}/c^2$

Experimental value: $1672 \text{ MeV}/c^2$

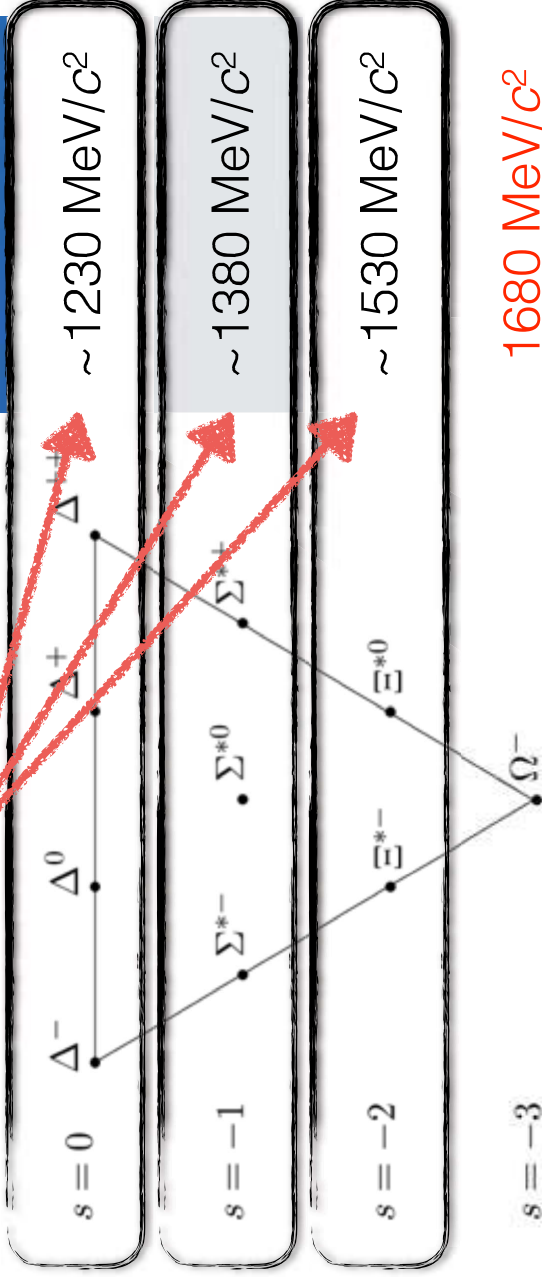


The Eightfold way

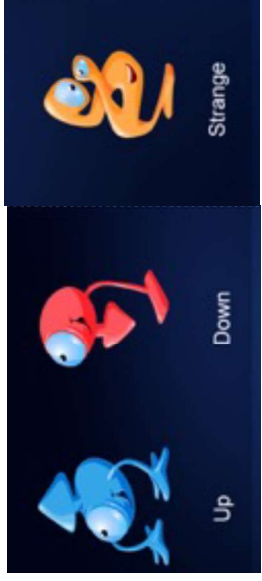


Difference: $150 \text{ MeV}/c^2$

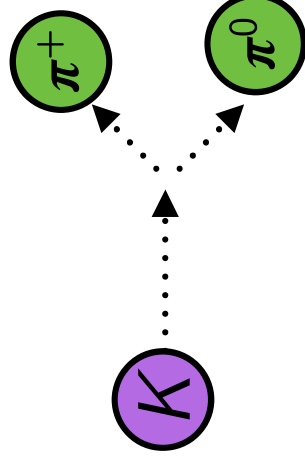
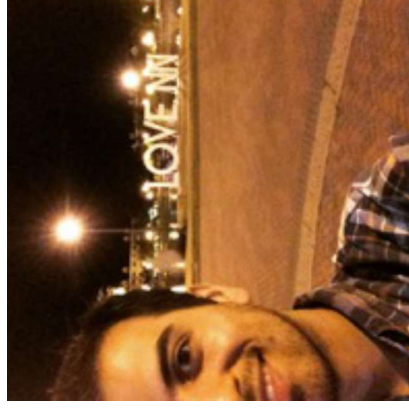
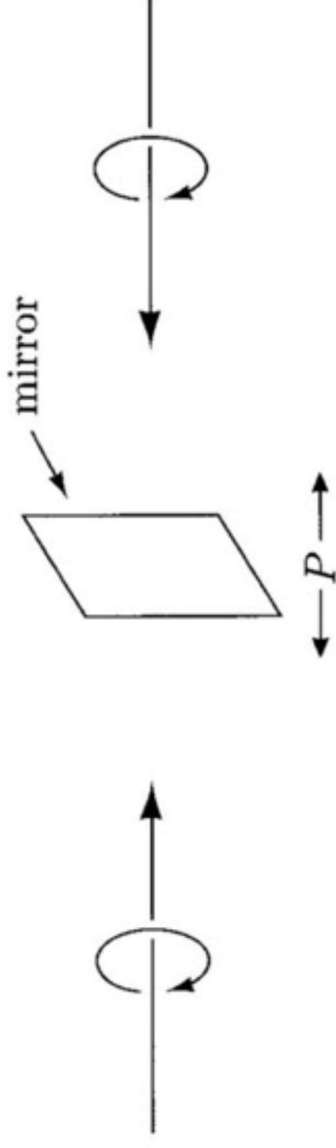
Mass



Experimental value: $1672 \text{ MeV}/c^2$

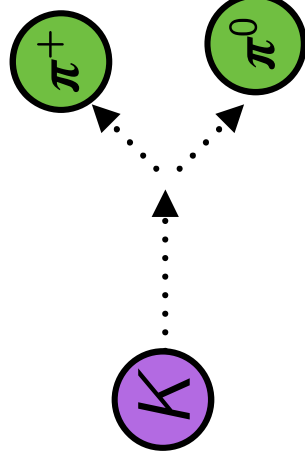
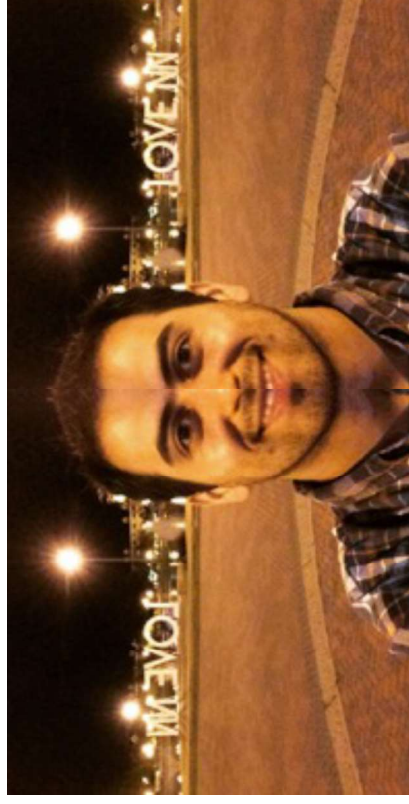
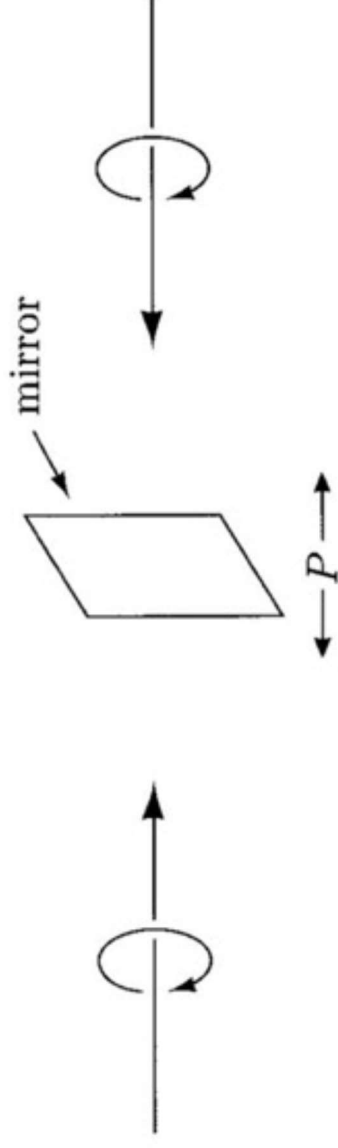


But beware: symmetry is not
always good



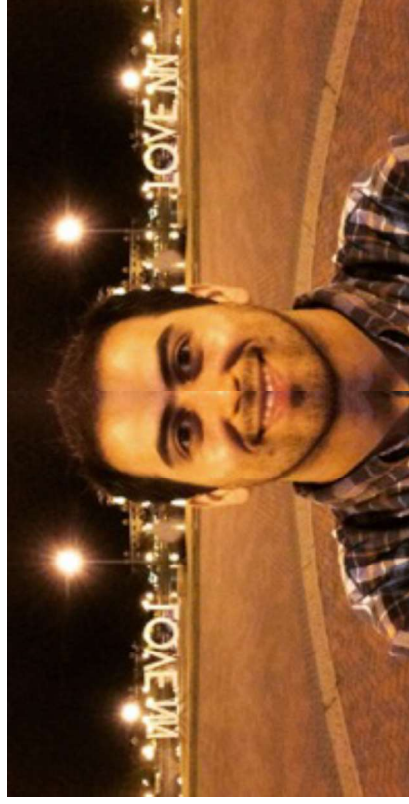
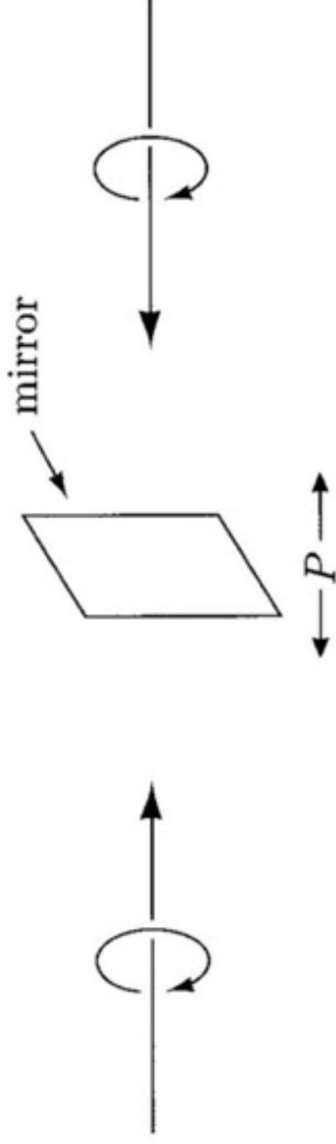
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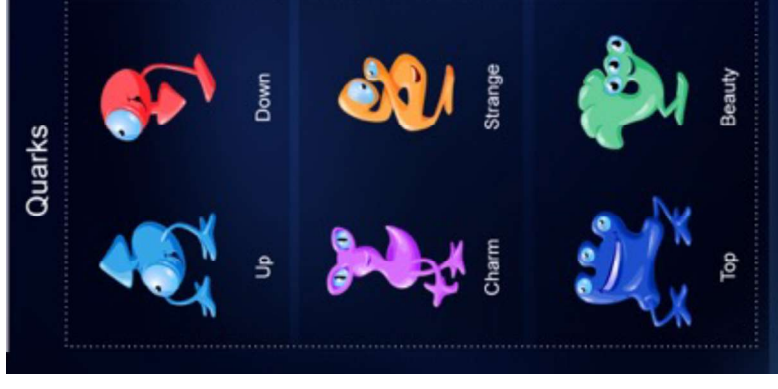
The rest is history

- Dropping parity eventually led to the proposal of the other quarks.
- Z, W and Higgs particle are also the result of a broken symmetry.
- Symmetry as a tool is here to stay, when used properly!



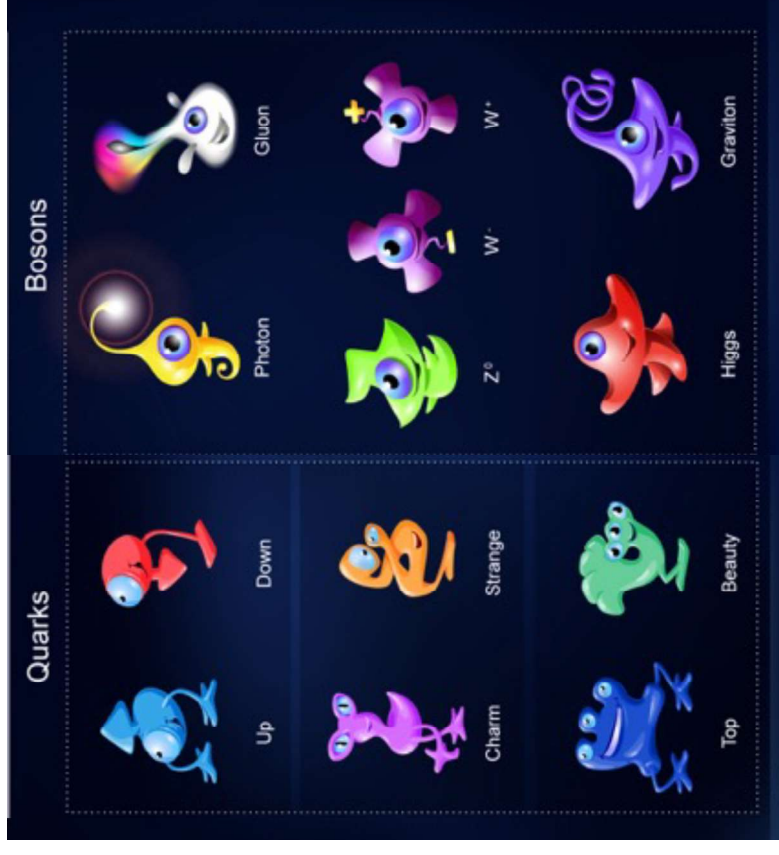
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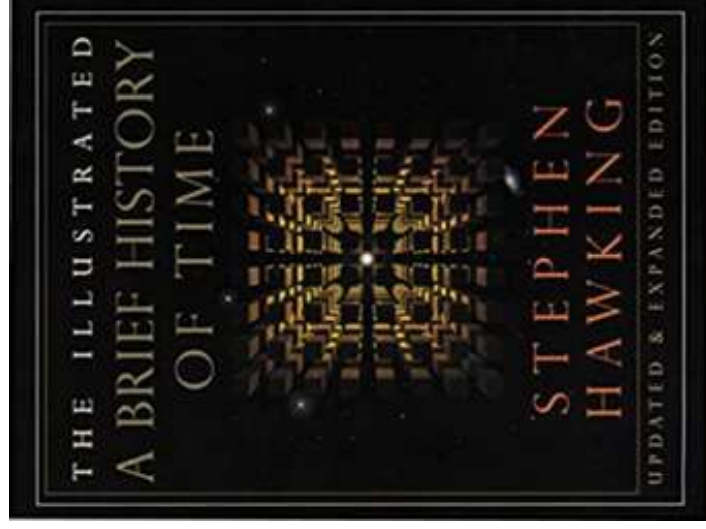
Further reading

Discoveries



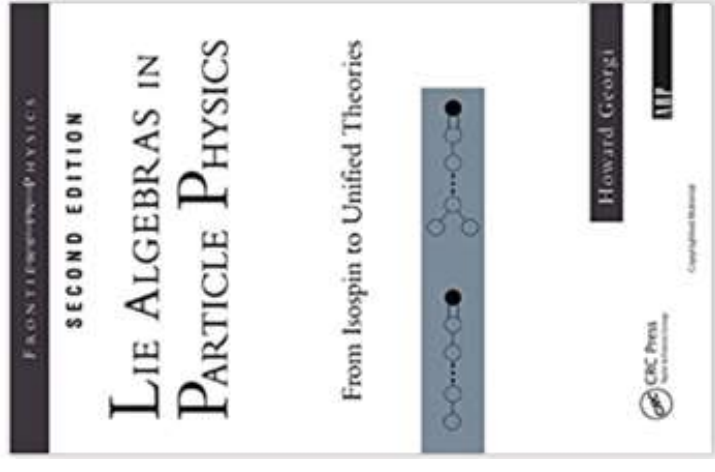
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Physics
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Mathematics
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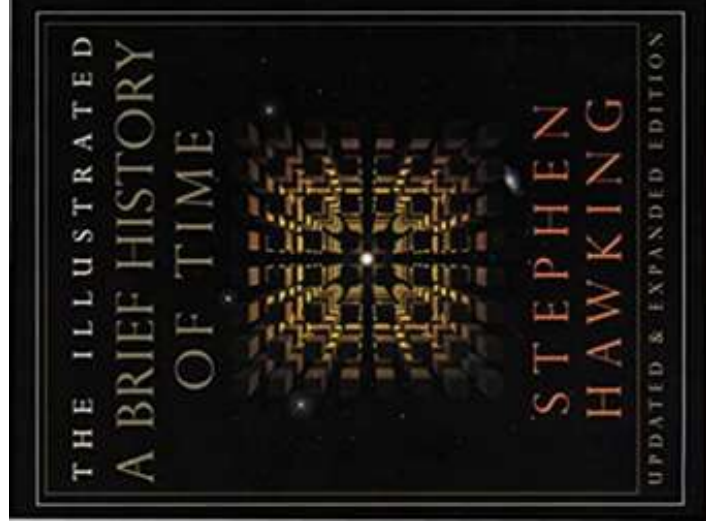
Further reading

Discoveries



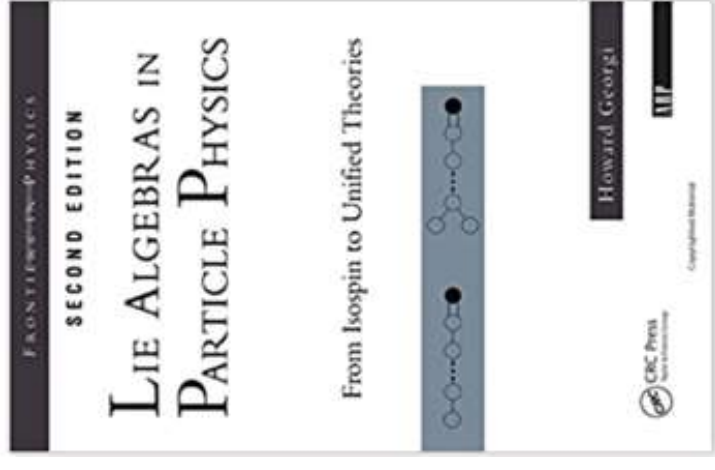
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Questions?