Tbilisi, 14-19 Oct., 2013


A.Kvinikhidze

A. Razmadze Math. Institute,

Tbilisi State University


# Gauge invariance - Dynamics of physical processes

# Non-perturbative phenomena in QFT: bound states, confinement, spontaneous symmetry breaking, mass genration, phase transitions, etc.

*Lattice calculation*

$$Z\left[j(x)\right]=\int D\psi(x)\,e^{iS\left[\psi(x),j(x)\right]}$$

$$=\int\prod_i d\psi_i\, e^{iS(\psi_i,j_i)} \qquad \textit{Lattice}$$

$$=\sum_n g^n\int D\psi(x)\,e^{iS_0\left[\psi(x),j(x)\right]}\left(\int\psi^N(x)\,dx\right)^n$$

Continuum QCD უწყვეტი QCD

Dynamical equations

Infinite series → equation

Continuum QFT:

Argon National Lab.

University of Graz,

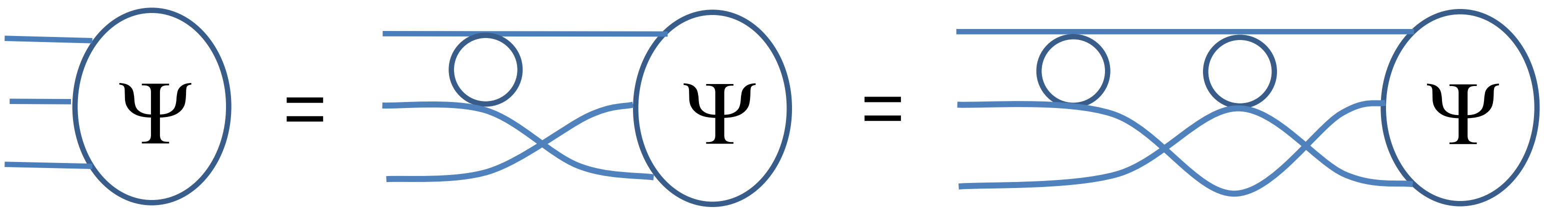
Giessen Uni

Darmstadt, Institute of Nuclear Physics

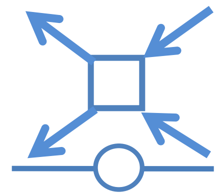
# Three relativistic particles

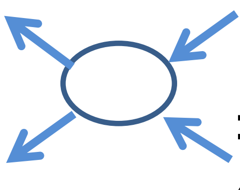
$$\psi = G_0(V_{12}+V_{23}+V_{31})\psi \Rightarrow \psi = -G_0 T_1 P_{12}\psi$$

where $$T_{12} = V_{12} + V_{12} G T_{12}$$




compact kernel

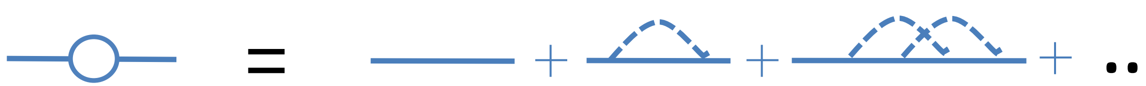
**In QFT** $V_{12} =$  $= ?$




$$= \quad T^{(2)}(E-E_3) \rightarrow \int T^{(2)}(E-z)g(z)dz$$

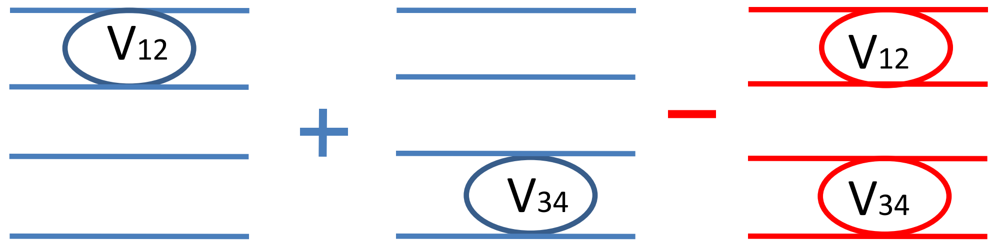


$$= g(z) = \frac{1}{z-\sqrt{\vec{p}^2+m^2}+i\varepsilon}$$

$\Rightarrow$ 

# Relativistic four-body problem:

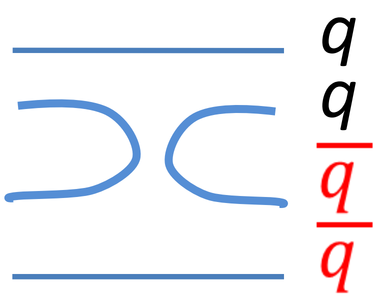
$$V = \sum$$



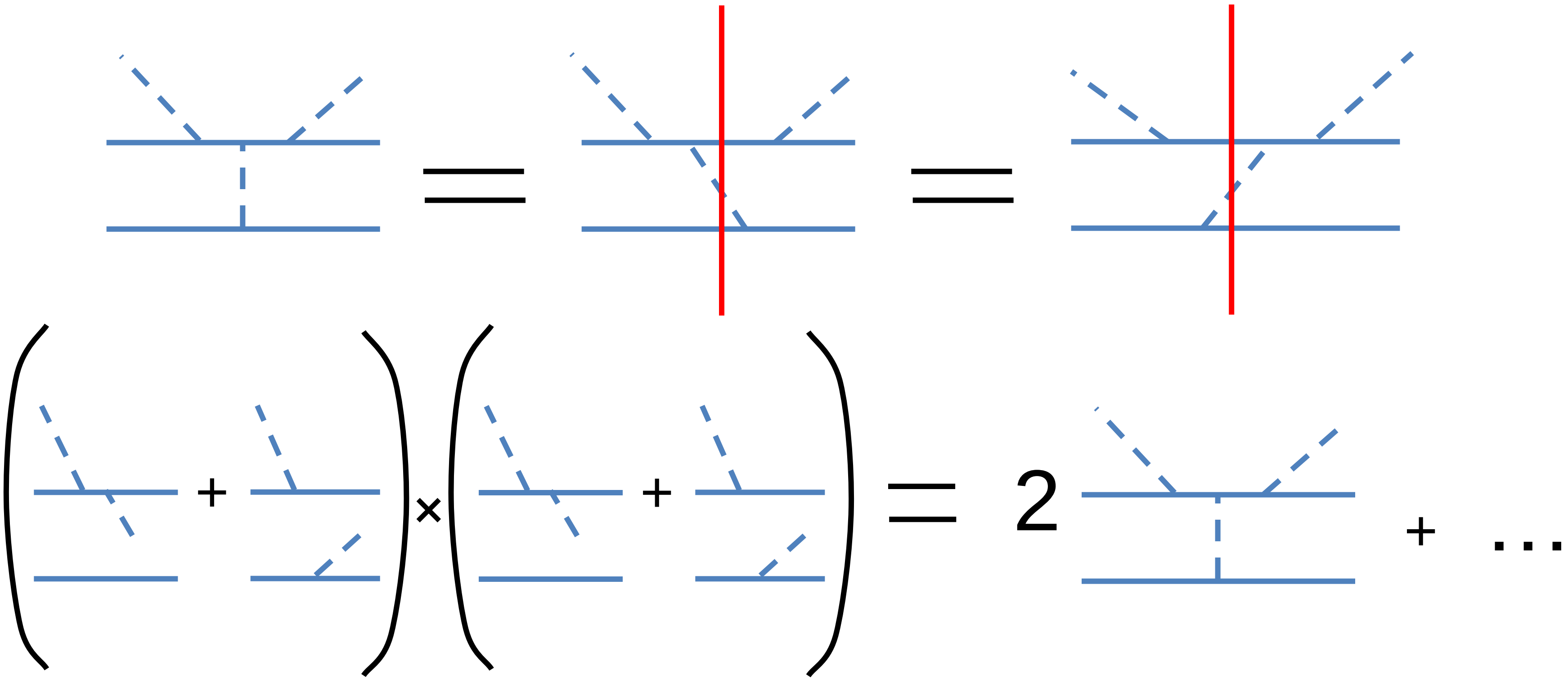

**New rerrangement**

**Recent development: exotic systems** $(q\bar{q})(q\bar{q})$

W. Heupel, G. Eichmann, C. S. Fischer, Phys. Lett. B718,545 (2012)



“famous double counting problem“)

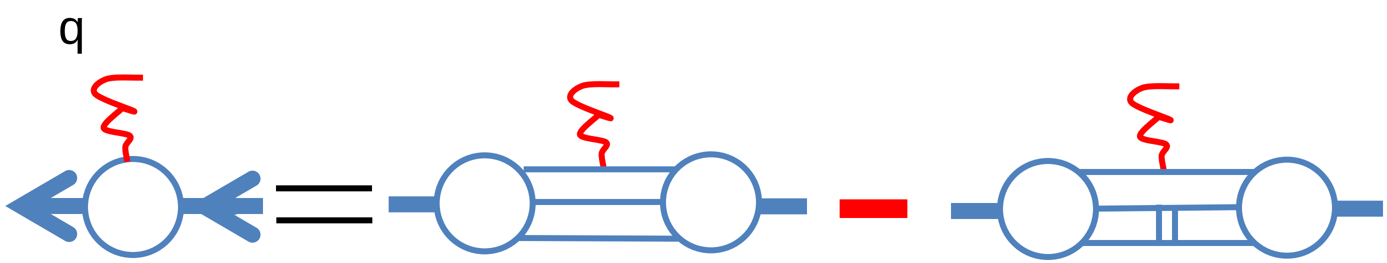


# Gauge invariant currents; working out complicated combinatorics at the same time:

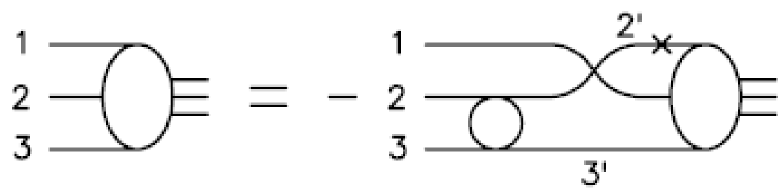
$$(G=G_0+G_0VG)_\mu$$

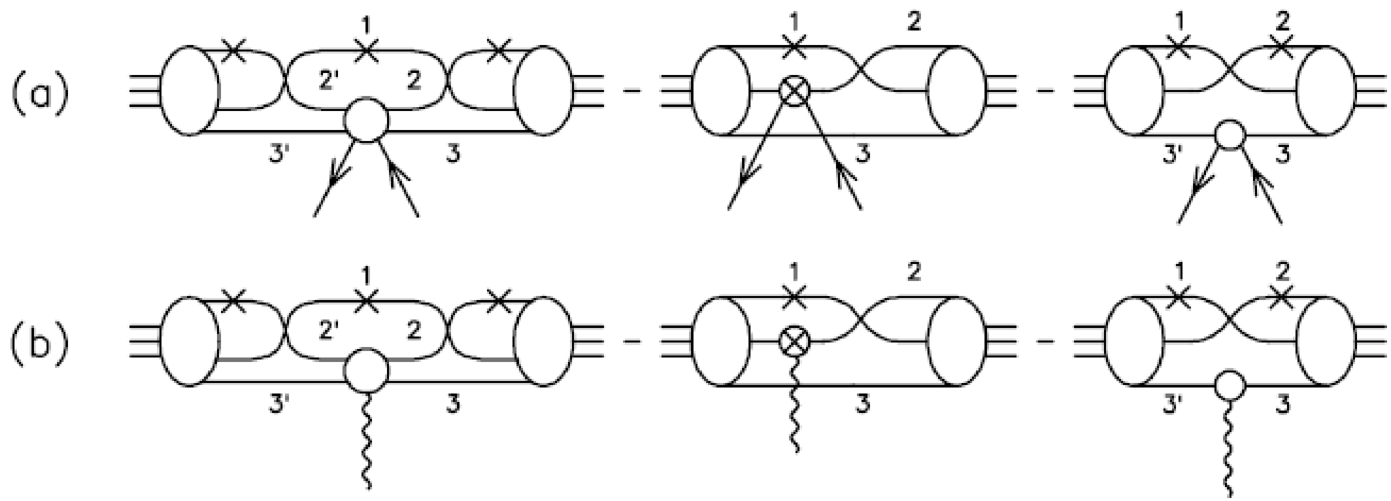
$$G_\mu=G_0+G_{0\mu}VG+G_0V_\mu G+G_0VG_\mu$$

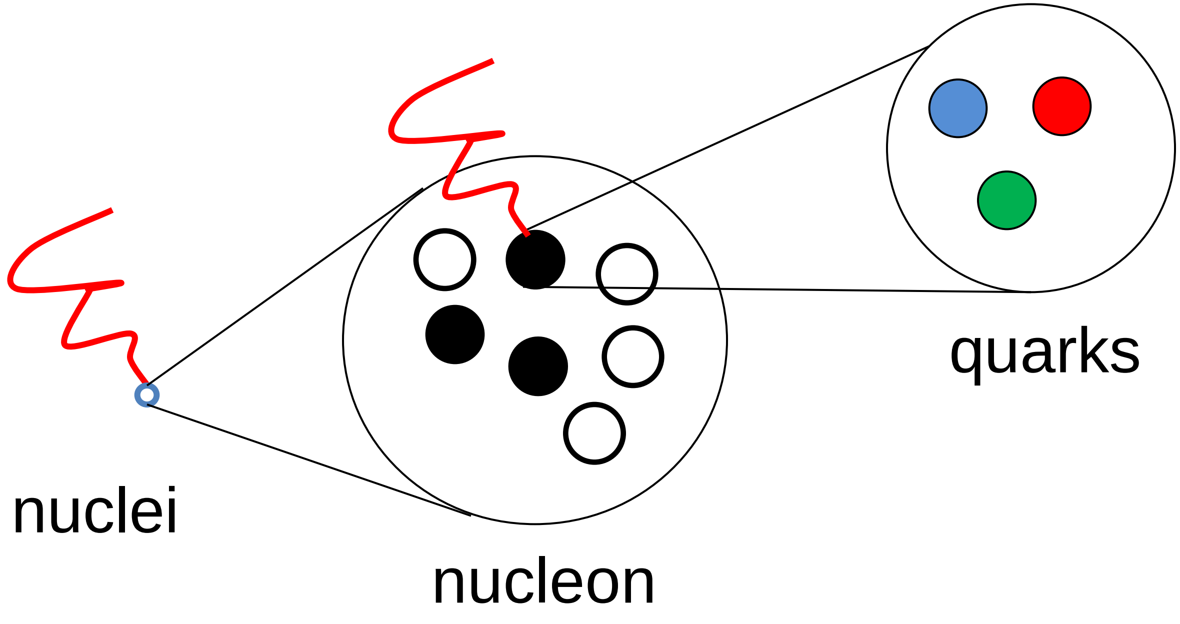
$$J_\mu(q)=$$



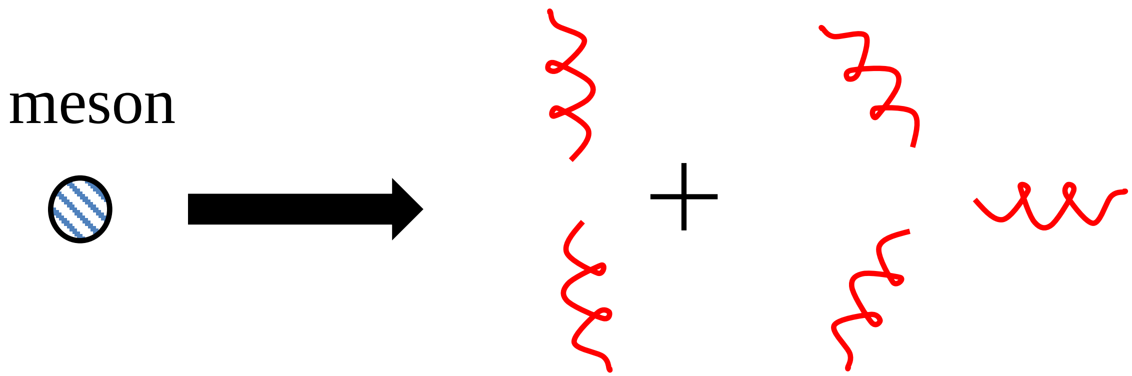
$$\Phi_1 = -t_1 d_2 d_3 P_{12} \Phi_1 \qquad \rightarrow \qquad \Phi_1 = -t_1 \delta_2 d_3 P_{12} \Phi_1$$



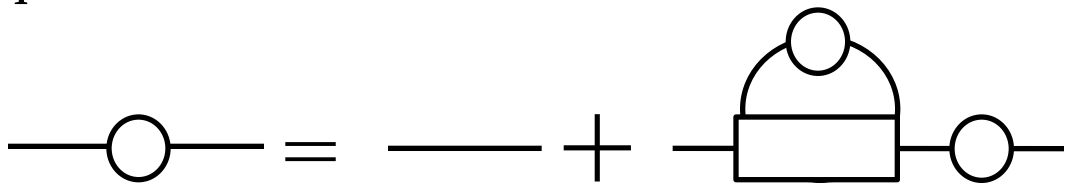

nuclei
nucleon
quarks

# ”Gauging equations” n-photon decay dynamics from gauge invariance
# Gauge Dyson-Schwinger equation few times photons

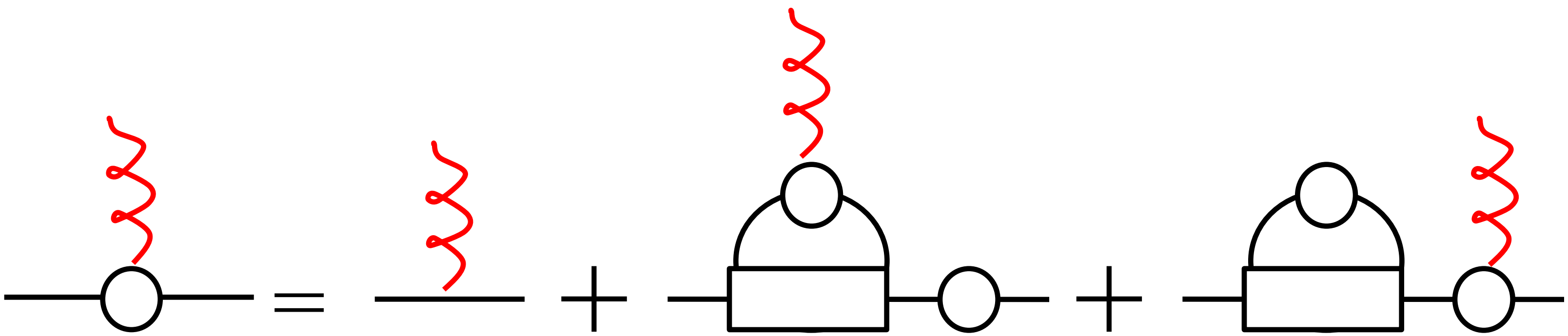



orthopositronium 3-photon decay - laboratory for precision QED tests
3-photon decays of vector quarkonia provide valuable information about underlying QCD

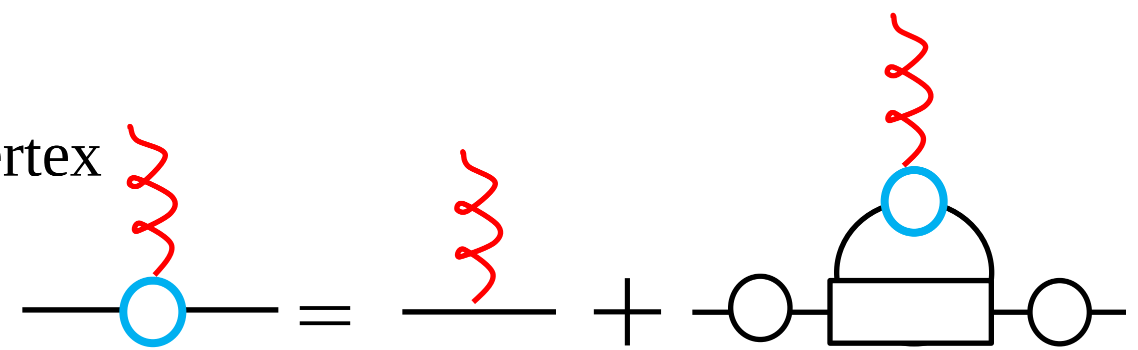
DS equation



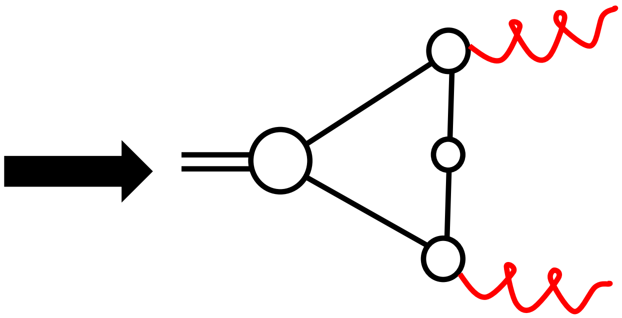
Single gauging of DS equation



Equation for **γqq** vertex

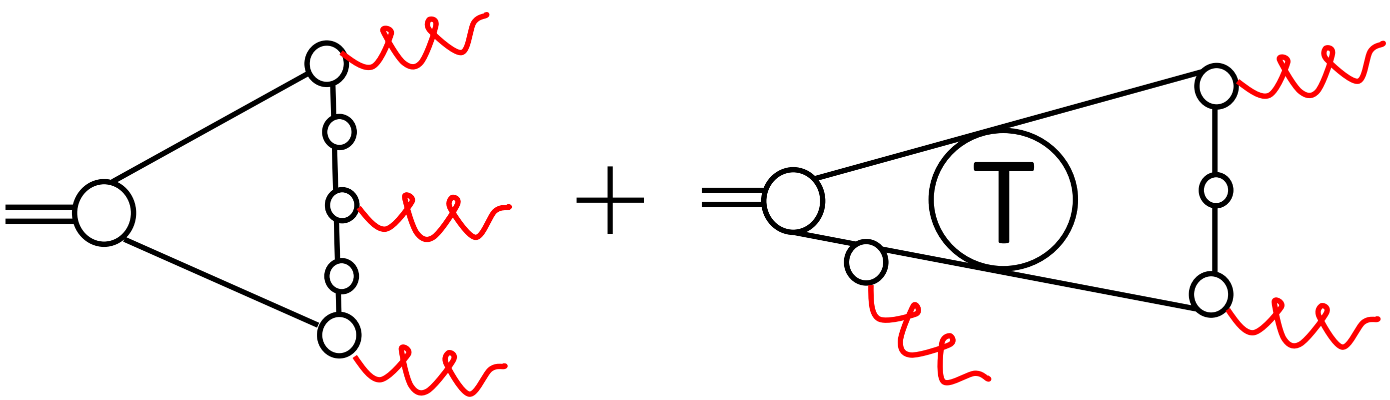


Double gauging of DS equation



**2**-photon decay amplitude

Triple gauging of DS equation

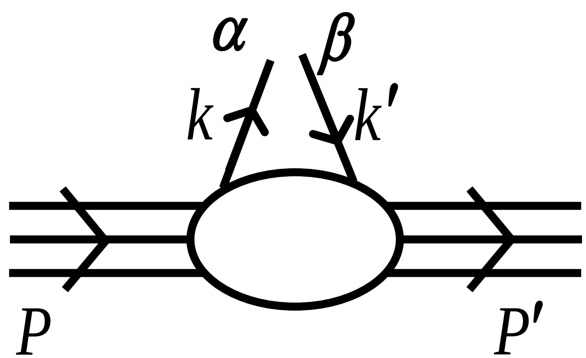



**3**-photon decay amplitude

# Generalized Parton Distribution

(GPD)

$$\rho_{\alpha\beta}\left(P',P,k\right)=\int d^4 y e^{iky}\left\langle P'\left|T\overline{q}_\beta\left(\mathbf{0}\right)q_a\left(y\right)\right|P\right\rangle$$



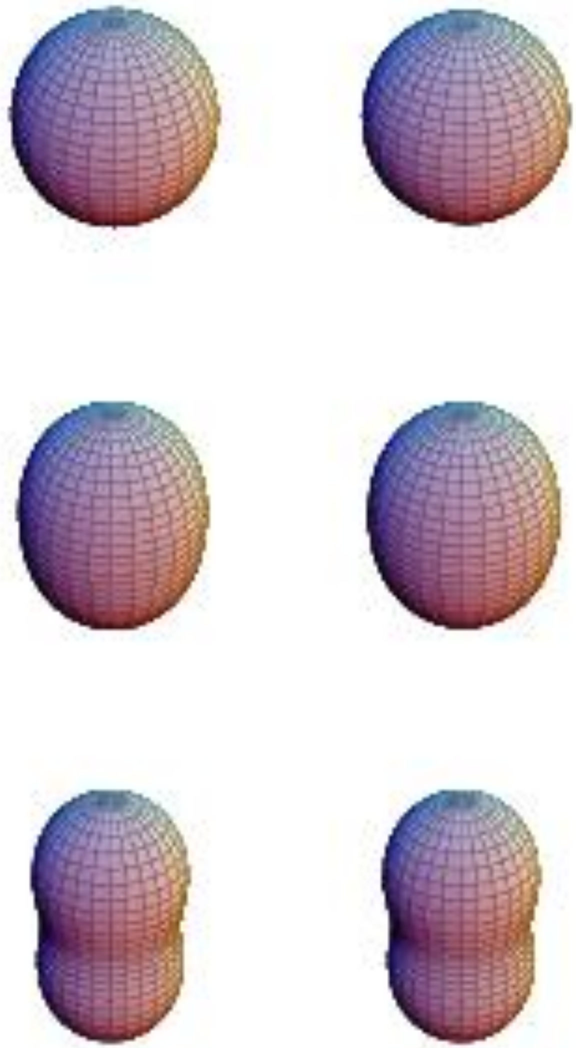


FIG. 1: Matter distributions. The spin direction s is taken as vertical, $\hat{z}$, with $n = \hat{s}$. Right column model of [7] , left column model of [10]. First row $K = 250$ MeV/c, second row $K$=1 GeV/c, third row $K \to \infty$.

On the Lagrangian level:

Gauge invariance

+finiteness of observables
    (Renormalizability)

=Determines full dynamics