

# On Predictions of 2T-Physics

It gives detailed phenomenological results relevant for cosmology and LHC physics, but no time for them in this short talk. Instead, I will discuss **some** predictions in general conceptual terms.

2T-Physics follows from a **gauge symmetry in phase space**.  
It leads to deep consequences for physics and spacetime.

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CERN, May 1, 2010

# The Fundamental Principle (1998)

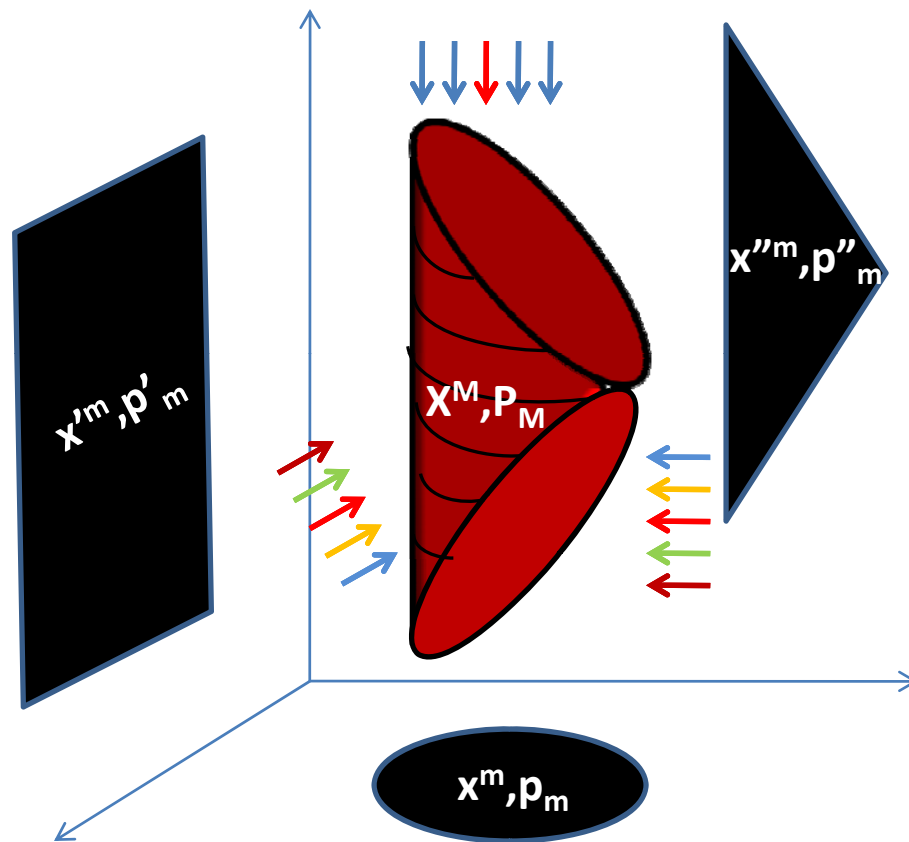
position-momentum symmetry in the formulation of fundamental physics

- General coordinate invariance removes bias of observers in  $X$ -space. Next level: local symmetry in phase space  $(X^M, P_M)$ , not just in  $X$ -space  $\rightarrow$  A **subset of canonical transformations localized on the worldline.**
- Three generators  $Q_{ij}(X,P)$ :  $\{Q_{11}, Q_{22}, Q_{12}=Q_{21}\}$  form  $Sp(2,R)$  under Poisson brackets. Example, flat spacetime:  $Q_{11}=X^2$ ,  $Q_{22}=P^2$ ,  $Q_{12}=X.P$ , any signature metric. More general  $Q_{ij}(X,P)$  generate general coordinate symmetry, gauge symmetry, and much more symmetry (hep-th/0103042).
- Gauge invariant sector  $Q_{ij}=0$ . It exists non-trivially only if spacetime has two times, no less and no more (no ghosts). So  $2T$  is not an input, it is a consequence of symmetry.

## Some consequences of the gauge symmetry

- **2T required** (not just permitted). All physics reformulated in 4+2 dims. (more generally  $d+2$ ). All observed 1T physics at all scales fits into the 4+2 formalism.
- No problems with ghosts or causality. **Gauge invariant** sector effectively 1T theory: 1+1 dimensions removable, e.g.  $A_M(X^M) \rightarrow A_\mu(x^\mu)$  **shadow**, no Kaluza-Klein modes !!
- But not the same as 1T formulation of physics. Not a zero sum game. Large number of correct predictions that the standard 1T formulation of physics misses **systematically** is obtained. This is the main content of 2T-physics.
- Includes the SM, GR, SUSY, SUGRA, as 4+2 dimensional 2T field theories consistent with their 1T counterparts in 3+1 dimensions.
- Plus **systematic new predictions** in the form of dualities and hidden symmetries  $\rightarrow$  (1T formalism misses these, it is incomplete)
- **Phenomenologically correct !  $\rightarrow$  Challenges 1T, you need 2T !!**

# 2T-Physics as a completion and unifying framework for 1T-physics<sup>4/7</sup>



- 1) 1T-physics is incomplete !!!
- 2) 2T-physics makes new testable predictions.

The relation between 2T-physics and 1T-physics described by an analogy :

Consider object in the room  $\approx$   
(phase space,  $X^M, P_M$  in 4+2 dims.)  
and its MANY shadows on walls  $\approx$   
(MANY phase spaces,  $x^m, p_m$  in 3+1)

holographic  
ONE 2T system  $\rightarrow$  MANY 1T systems  
Predict many relations among the shadows (dualities, symmetries  $d+2$ ).

Contains systematically missed information in 1T-physics approach.  
This info related to higher spacetime:  
Observers like us are stuck on the "walls" (3+1 dims.), no privilege to be in the room (4+2). Instead of interpreting the shadows as different dynamical systems (1T), must recognize they are perspectives in higher spacetime. Then, we can indirectly "see" the extra 1+1 dims.

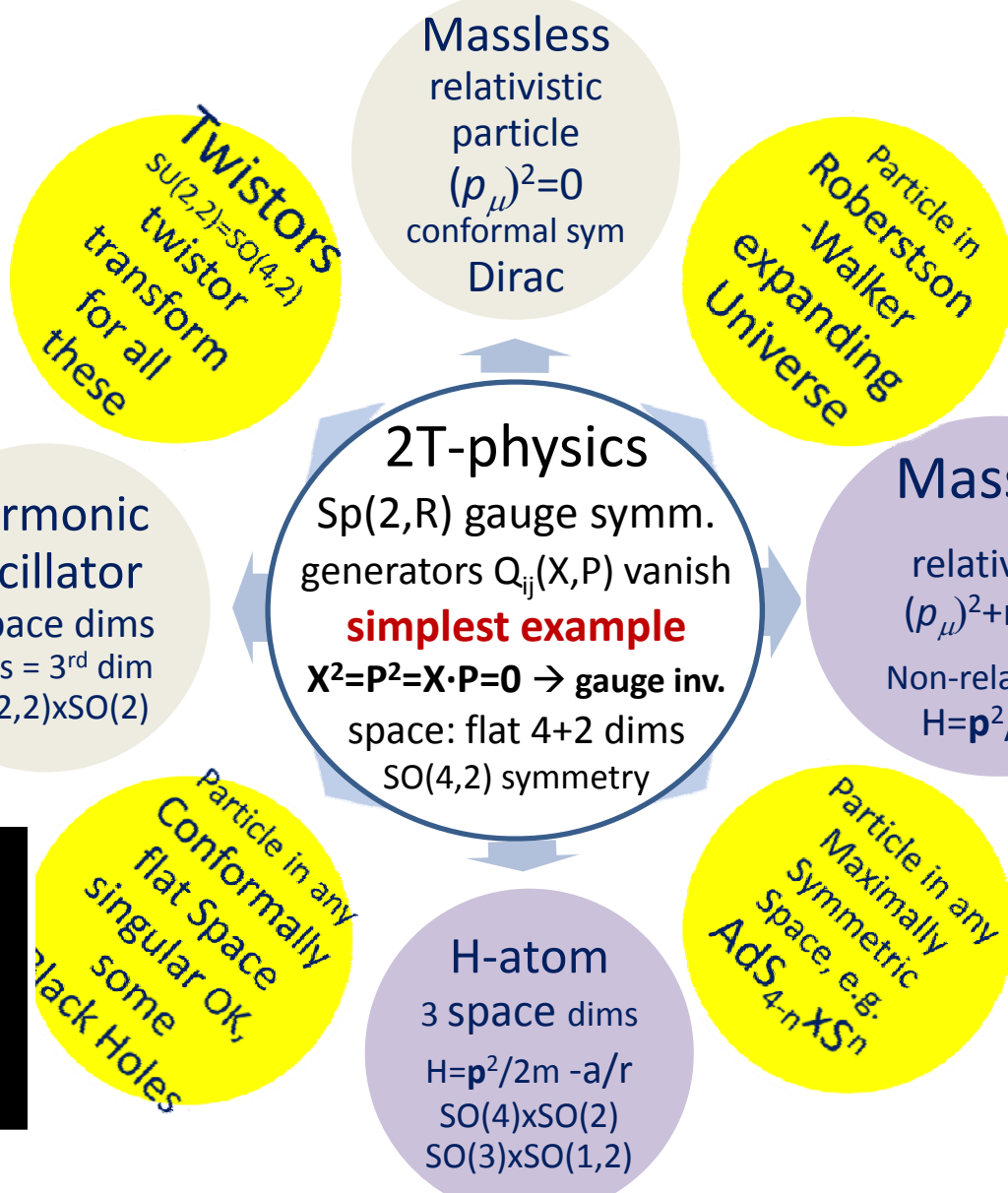
# Shadows from 2T-physics → hidden info in 1T-physics <sup>5/7</sup>

Hidden Symm.  
 $SO(d,2)$ , (d=4)  
 $C_2=1-d^2/4 = -3$   
 singleton

Emergent  
 spacetimes  
 and emergent  
 parameters:  
 mass,  
 couplings,  
 curvature, etc.

2T-physics predicts  
hidden symmetries  
 and dualities (with  
 parameters) among  
 the shadows

Shadows emerge for  $\infty$  choices of the  $Q_{ij}(X,P)$  & in **2T-field theory**



Free or interacting  
 systems with/without  
 mass in flat/curved  
 3+1 space-time

“time” &  
 Hamiltonian in  
 3+1 attributed  
 to perspectives  
 of observers in  
**4+2 phase space**

Main points  
 1) **no ghosts:**  
 2T-physics is  
 compatible  
 with 1T-physics  
 2) **Systematic new  
 info & insight  
 absent in  
 1T physics**

# Progress in 2T-physics

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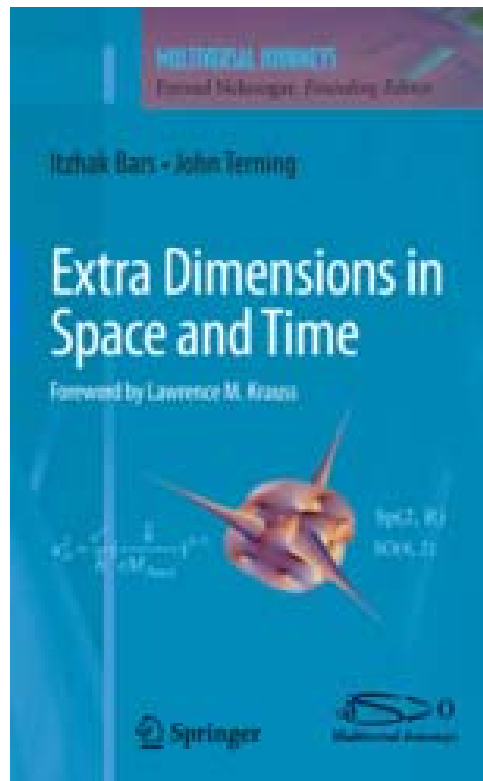
- **Local  $Sp(2,R)$ : A general principle in Class. & Quant. Mech.**  
A principle for a higher unification and deeper insight into physics & space-time  
Reveals more physics phenomena that are systematically missed in 1T-physics.
- **Principles of 2T field theory in  $d+2$  dimensions**  
The Standard Model, General Relativity, and GUTS in 2T-physics,  
IB+Y.C.Kuo 0605267, IB 0606045, 0610187, 0804.1585; IB+S.H.Chen 0811.2510  
➔ Phenomenological applications: Cosmology 1004.0752, LHC 0606045, 0610187,  
Path integral quantization in  $d+2$  field theory – in progress
- **SUSY in  $4+2$  and in Higher dimensions**  
IB+Y.C.Kuo, 0702089, 0703002, 0808.0537 (N=1,2,4 in  $4+2$  dims) Klein-Gordon, Dirac, Yang-Mills fields.  
**IB+Y.C.Kuo, N=1 SYM in  $10+2$  – (parent of N=4 SYM in  $3+1$ ; parent of M(atrix) theory).**  
SUGRA  $10+2$  and  $11+2$  (toward M-theory in 2T framework): path is clear, details in progress
- **Non-perturbative technical tools in 1T-field theory**  
Sp(2,R)-induced dualities among 1T field theories (many shadows of 2T-field theory)  
IB+Chen+Quelin 0705.2834; IB+Quelin 0802.1947 + in progress.
- **Strings, Branes, M-theory in 2T-physics (partial progress)**  
IB+Deliduman+Minic, 9906223, 9904063; IB 0407239 .  
M-theory; expect  $11+2$  dims  $\rightarrow$  OSp(1|64) global SUSY, related to S-theory (IB 9607112)
- **A more fundamental approach – field theory in phase space (full Q,P symm)**  
IB + Deliduman 0103042, IB + S.J.Rey 0104135, IB 0106013, + under development

Constraints on  
1T scalar fields.  
Reminiscent of  
a **subset** of “no  
scale models”.  
New concepts...

# Where to find more information on 2T-physics

For concepts and technical guidance on over 50 papers  
My recent talk: **arXiv:1004.0688**

A book at an elementary level for science enthusiasts (Springer 2009):



By  
Itzhak Bars  
and  
John Terning

It can be downloaded at your  
university if your library has a  
contract with Springer  
(or here at CERN)  
DOI: 10.1007/978-0-387-77638-5