Old Wine in a New Bottle

(or, is it a new wine?)

C.S. Lam

McGill & UBC, Canada

Château Mouton-Rothschild
1945 – Jeroboam

US$ 114,614 (1997)

Penfolds Grange **1951**

US$ 43,700 (2004)

Need a new bottle??

Old tales and a New direction

Local QFT, S-Matrix

(CHY scattering amplitude)

Dyson's story

PHYSIKALISCHES INSTITUT
der Eidg.Techn.Hochschule
Z ü r i c h

Prof.Dr. W. Pauli

Zurich, 8th January
1949

Dr. F. J. D y s o n
Institute for Advanced Study
P r i n c e t o n N.Y.
USA

Dear Dr. Dyson,

I thank you very much for sending your paper. It was not easy to read for us because the "Feynmann-theory", which you compare with the Schwinger-Tomonaga formalism was entirely unknown here and we had to reconstruct it from your paper.

Battle of the Sexes

Battle of the Sixties

Local quantum field theory vs S-matrix theory

UV divergence

Discovery of many hadrons

Local
QFT

Symmetry

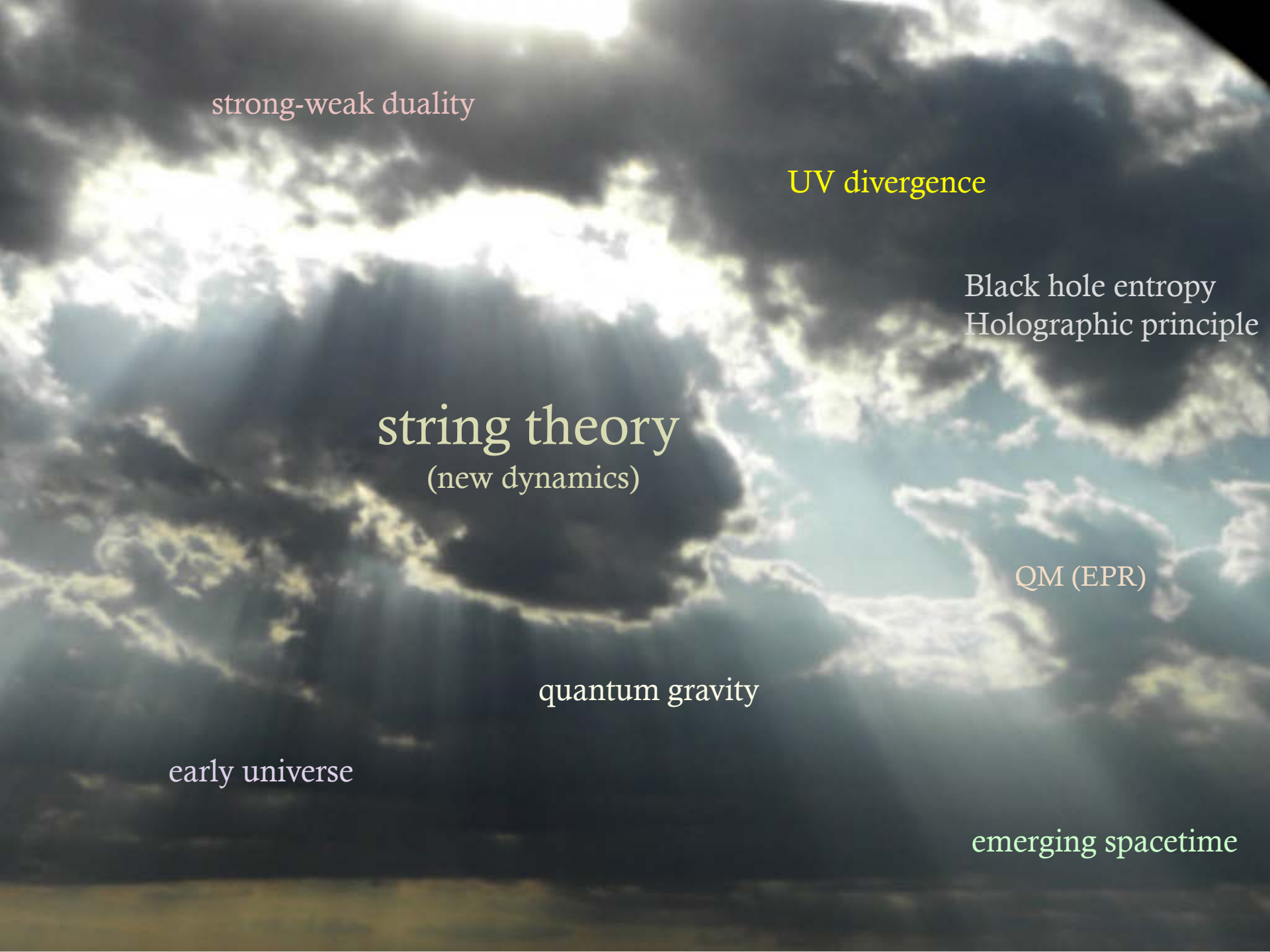
Scattering amplitudes are
experimentally more directly relevant

Analyticity of Scattering amplitudes

QFT

where is the dynamics in S-matrix ?


Local QFT fundamental?

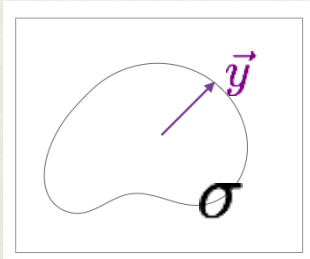

strong-weak duality
UV divergence
Black hole entropy
Holographic principle
string theory
(new dynamics)
QM (EPR)
quantum gravity
early universe
emerging spacetime

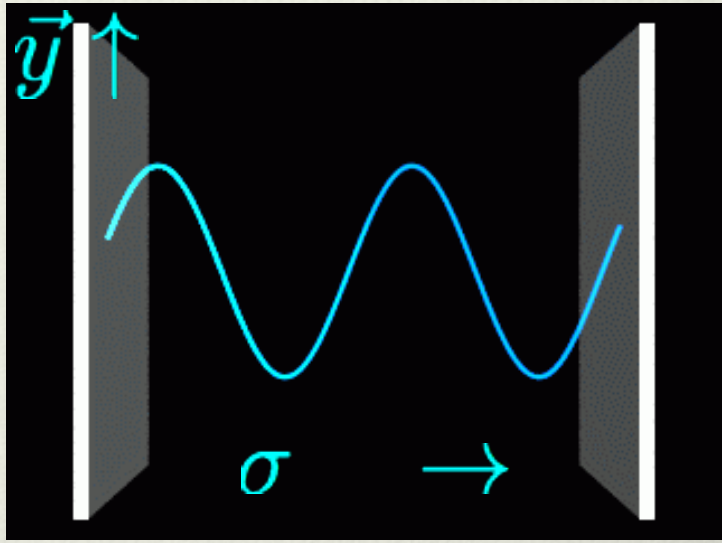
Magic of two dimensions

(arbitrary shape)

$$\frac{\partial^2 \vec{y}}{\partial \sigma^2} - \frac{\partial^2 \vec{y}}{\partial \tau^2} = 0 \Rightarrow$$

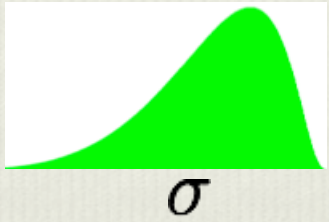
$$\vec{y} = \vec{v}\tau + \vec{a}(\sigma - \tau) + \vec{b}(\sigma + \tau)$$





ARBITRARY PULSE SHAPE

PULSE SHAPE MAINTAINED



INFINITE NUMBER OF CONSERVATION LAWS (HUGE SYMMETRY)

$$z = \sigma + i\tau$$

$$\frac{\partial^2 \vec{y}}{\partial z \partial z^*} = 0 \Rightarrow \vec{y} = \vec{a}(z^*) + \vec{b}(z)$$

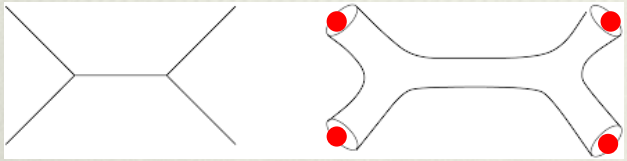
$$z \to z' = f(z) \Rightarrow$$

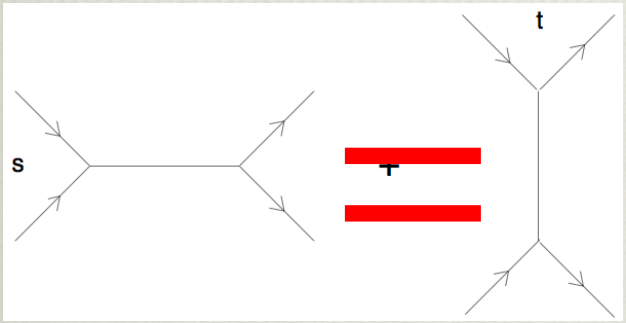
$$\vec{b}(z) \to \vec{b}(f(z)) = \vec{c}(z)$$

symmetry in the hidden complex space gives rise to string dynamics

2-DIM CONFORMAL GROUP IS INFINITE DIMENSIONAL

String Theory



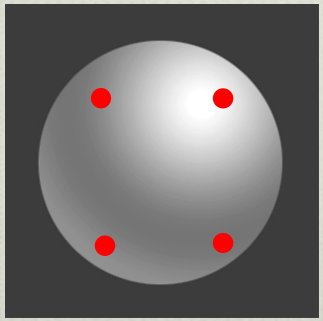


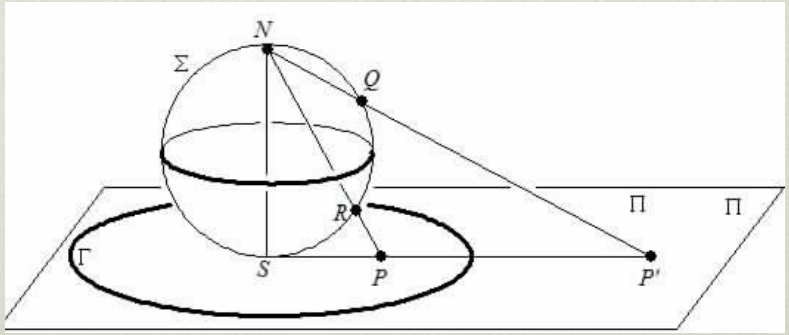
STRING SHAPE ARBITRARY

STRING MERGE & REPLICATE SMOOTHLY

ABSENCE OF SHARP VERTEX

(GAUGE AND GRAVITATIONAL) DYNAMICS SUPPLIED BY INFINITE DIMENSIONAL CONFORMAL INVARIANCE IN THE HIDDEN SPACE





The CHY Scattering Formula

Freddy Cachazo, Song He, Ellis Ye Yuan (2013)

Penfolds Grange **1951**

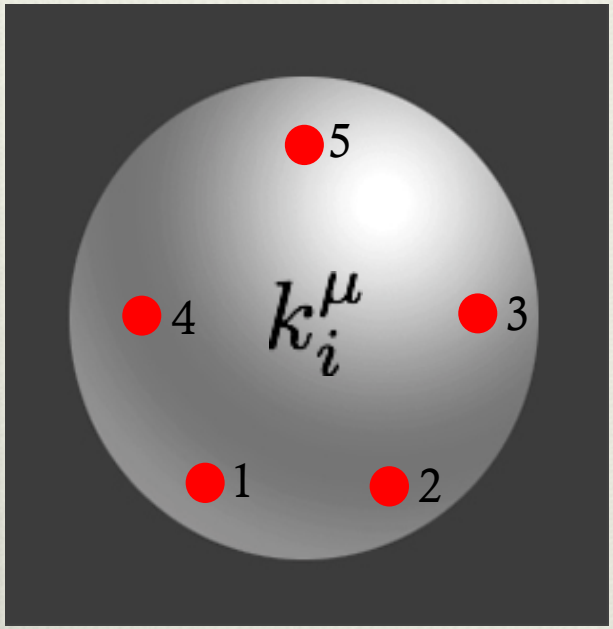
Underlying complex space

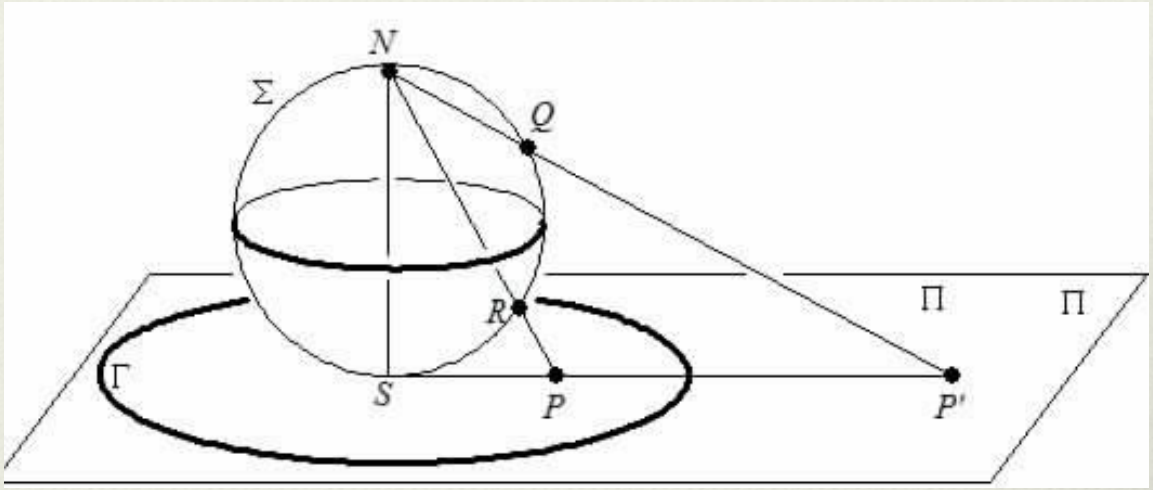
2013

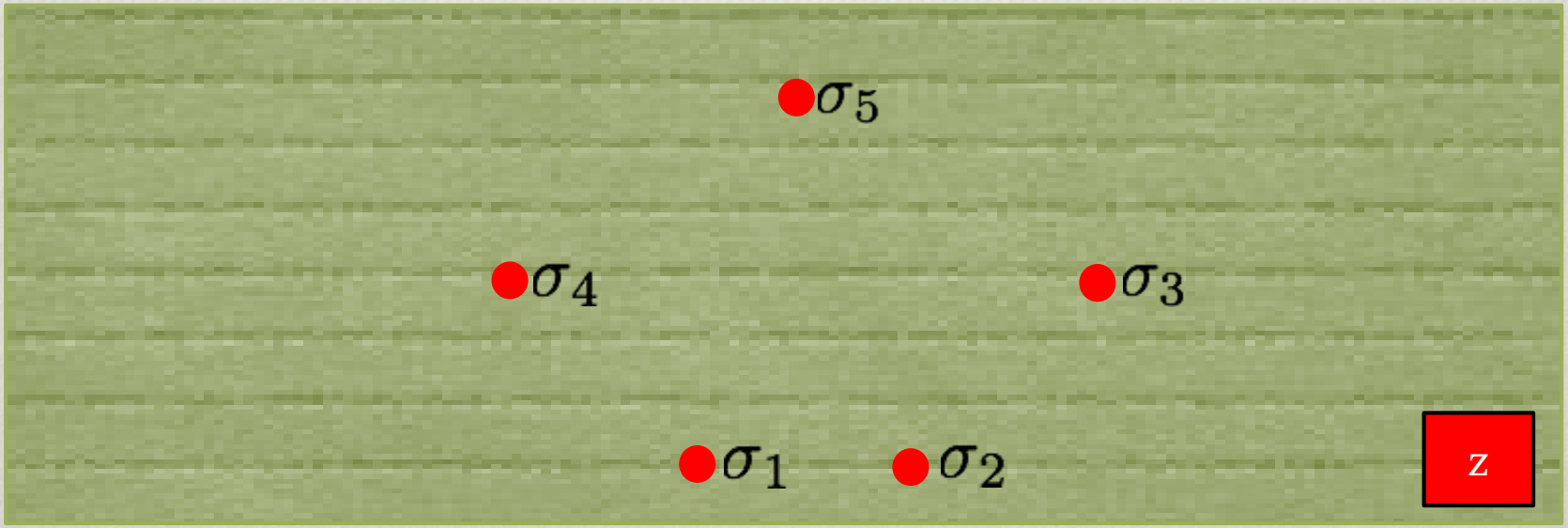
- Formulas for n-body scalar, gauge, gravity scattering amplitudes (tree)

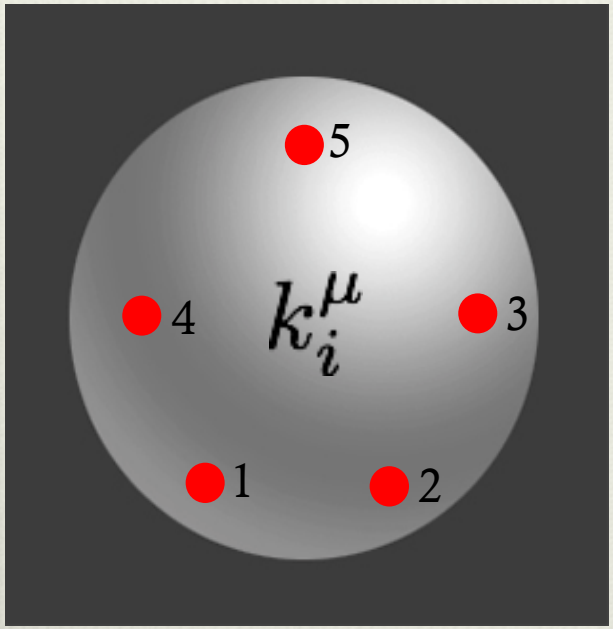
- Dynamics is provided by a (Mobius) symmetry in a hidden underlying complex space

- Spacetime locality, gauge invariance, and quantum uncertainties are emerging properties


5
4
k_i^μ
3
1
2


N
Σ
Q
R
Γ
S
P
P'
Π
Π

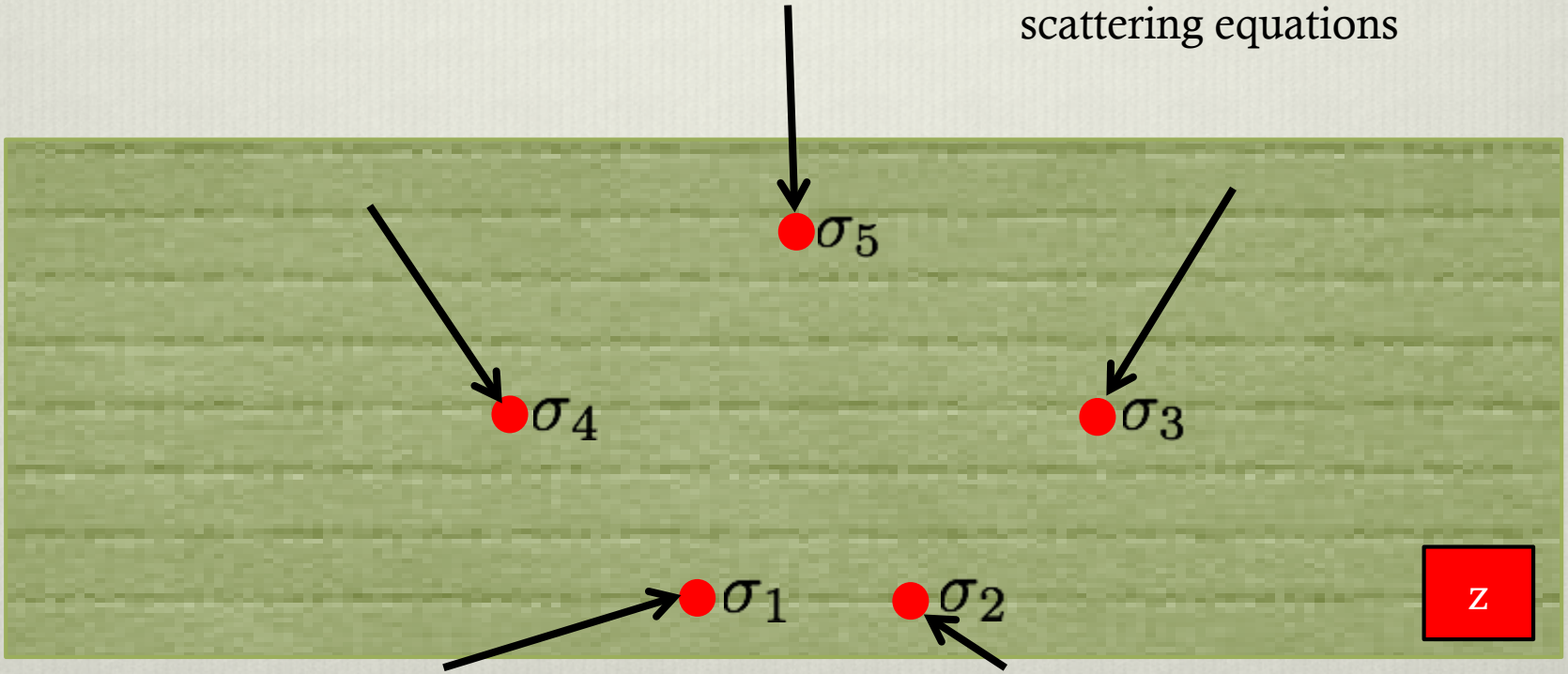

σ_5
σ_4
σ_3
σ_1
σ_2
z



$$f_i = \sum_{j \neq i}^{n} \frac{k_i . k_j}{\sigma_i - \sigma_j} = 0$$

$$(1 \leq i \leq n)$$

scattering equations



Möbius transformation

$$\sigma_i \to \frac{\alpha\sigma_i + \beta}{\gamma\sigma_i + \delta}, \ (\alpha\delta - \beta\gamma = 1)$$

translation, scaling, inversion

$$f_i = \sum_{j\neq i}^{n} \frac{k_i.k_j}{\sigma_i - \sigma_j} = 0$$

$$(1 \leq i \leq n)$$

$$f_i \to f_i(\gamma\sigma_i + \delta)^2$$

$$n \to n-3; \ \sigma_p, \sigma_q, \sigma_r$$

CHY $$M_n = \left(\frac{1}{2\pi i}\right)^{n-3} \oint_C \left(\sigma_{pqr}^2 \prod_{a\neq p,q,r}^{n} \frac{d\sigma_a}{f_a}\right) T_n$$

Mobius invariant

$$f_i = \sum_{j \neq i}^{n} \frac{k_i . k_j}{\sigma_i - \sigma_j} = 0$$

$$T_n = \begin{cases} e_n(\sigma)^2 & \text{scalar} \\ e_n(\sigma) E_n(\epsilon, k, \sigma) & \text{gluon} \\ E_n(\epsilon, k, \sigma)^2 & \text{graviton} \end{cases}$$

$$(1 \leq i \leq n)$$

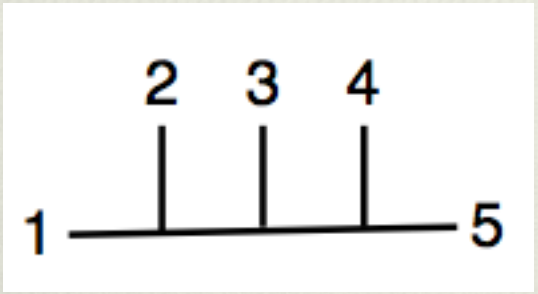
$$n \to n-3; \ \sigma_p, \sigma_q, \sigma_r$$

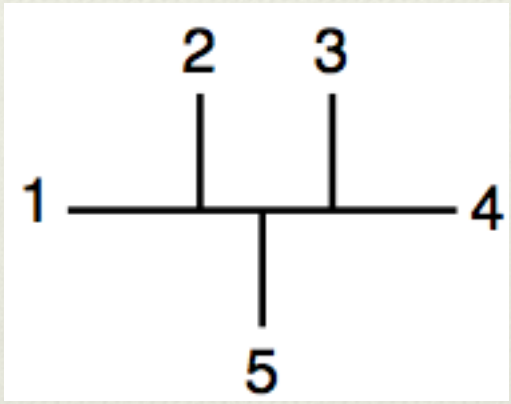
CHY $$M_n = \left(\frac{1}{2\pi i}\right)^{n-3} \oint_C \left(\sigma_{pqr}^2 \prod_{a \neq p,q,r}^{n} \frac{d\sigma_a}{f_a} \right) T_n$$

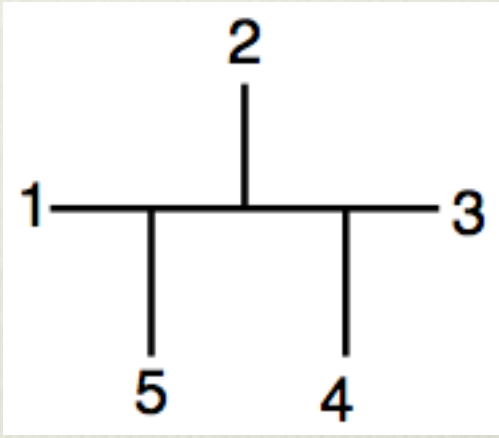
Mobius invariant

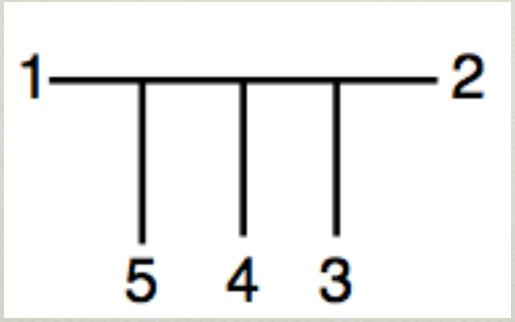
Emergence

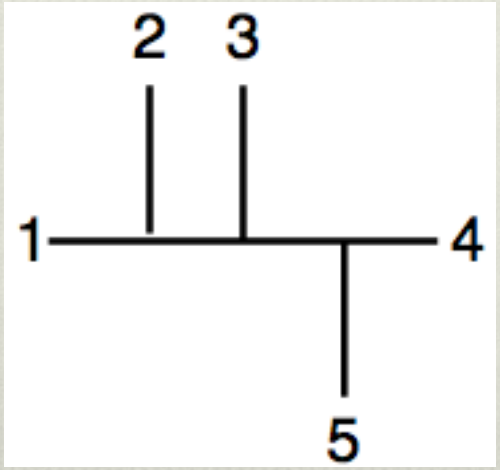
(semi-)local interaction, quantum uncertainty











Emergence

local interaction and quantum uncertainty

Wed, May 20 Academia Sinica

Thur, May 21 Tsinghua University

(with Y.-P. Yao)

U. Michigan

Conclusion

- CHY scattering amplitudes are obtained from an SL(2,C) invariance in an underlying complex space
- They lead to usual Feynman diagrams, hence emergence of local interaction and the quantum uncertainty principle
- Also local non-abelian gauge invariance and probably diffeomorphism invariance
- Can this new formulation lead to a new theory beyond the Standard Model?


Happy Retirement!