三维超对称量子场论的几何结构

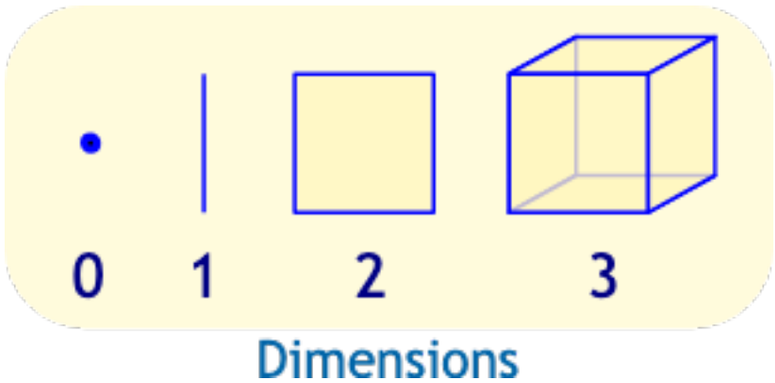
山东大学齐鲁青年论坛（物理）

程 实

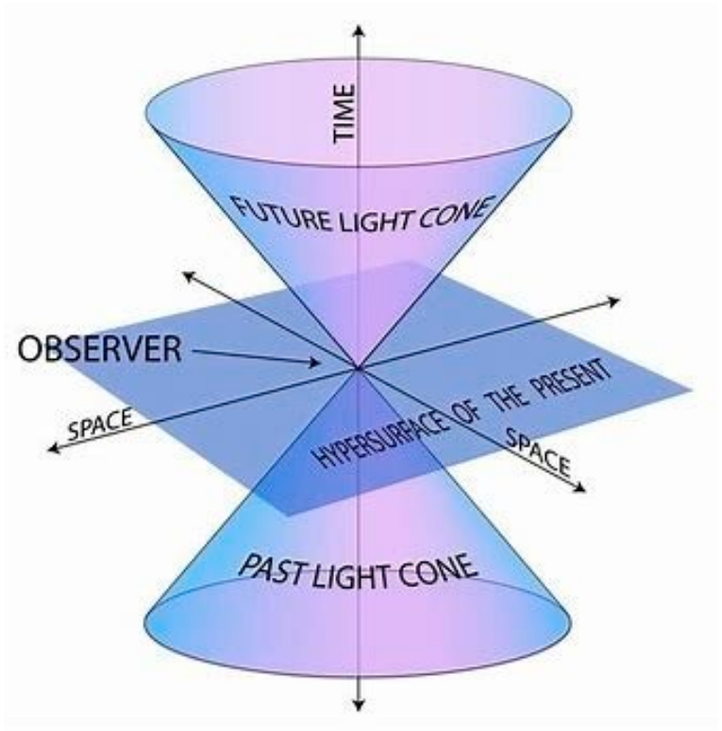
复旦大学

many figures are from google, wikipedia, and so on.

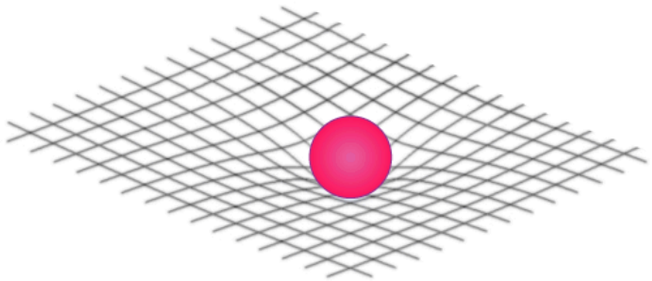
N-维时空


0
1
2
3
Dimensions

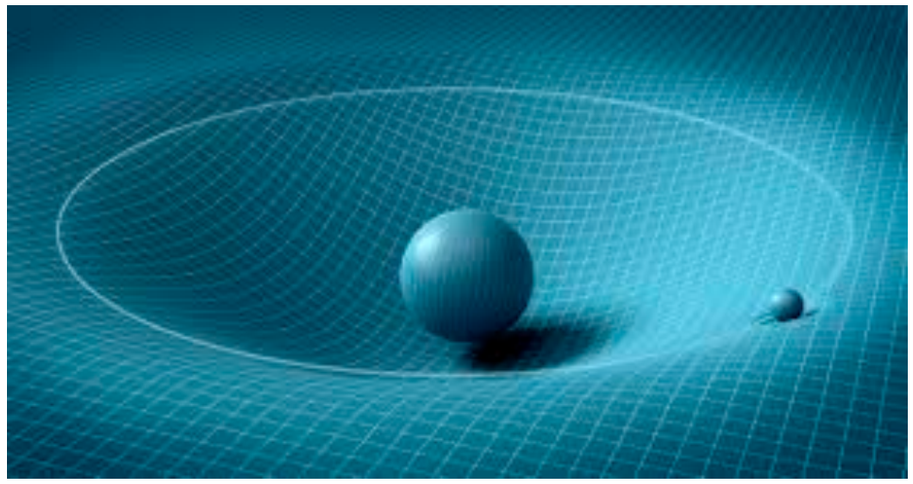
狭义相对论

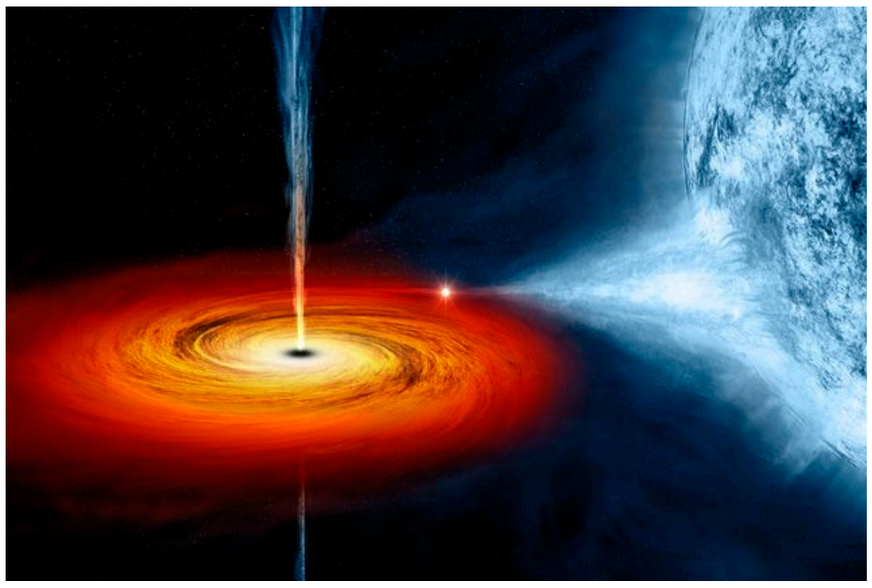

TIME
FUTURE LIGHT CONE
OBSERVER
SPACE
HYPERSURFACE OF THE PRESENT
SPACE
PAST LIGHT CONE

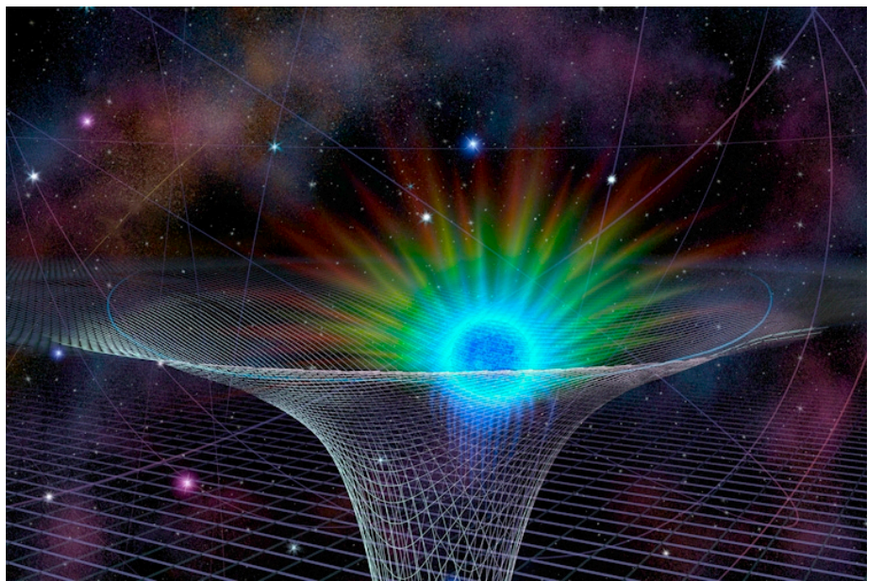
广义相对论与黎曼几何



$$G_{\mu\nu}+\Lambda g_{\mu\nu}=\frac{8\pi G}{c^4}T_{\mu\nu}$$







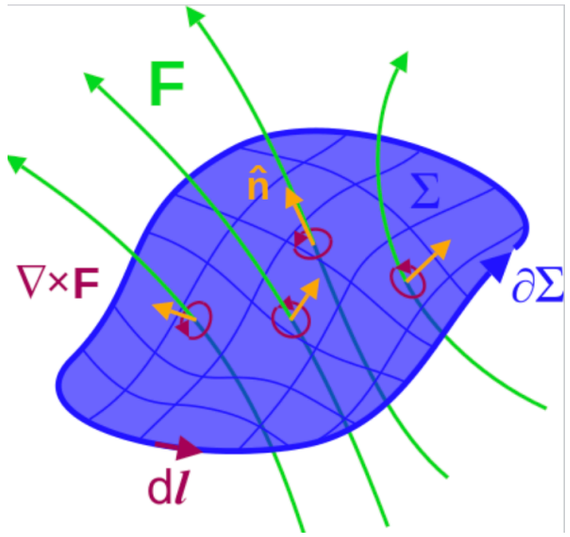
麦克斯韦理论

$$\nabla \cdot \mathbf{E} = 4\pi\rho$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t}$$

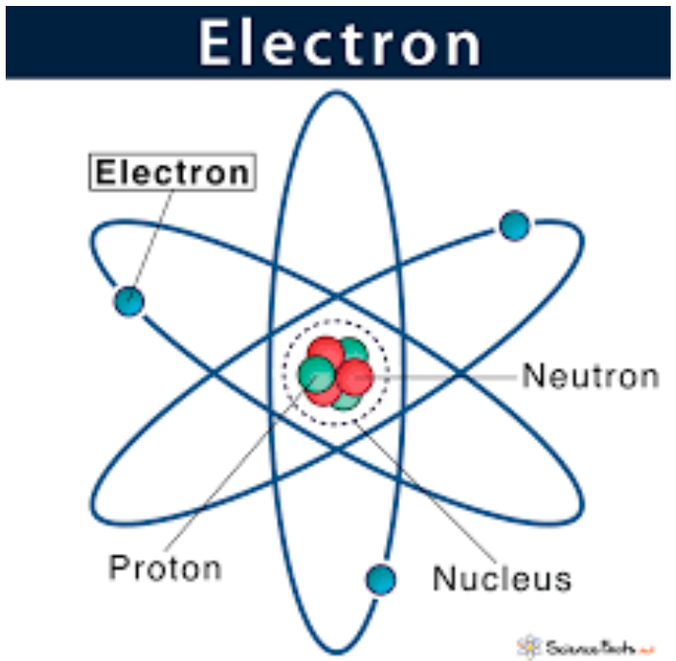
$$\nabla \times \mathbf{B} = \frac{1}{c}\left(4\pi\mathbf{J} + \frac{\partial \mathbf{E}}{\partial t}\right)$$

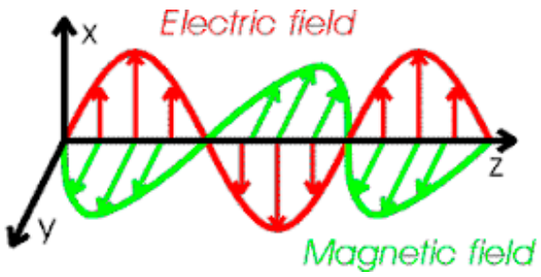


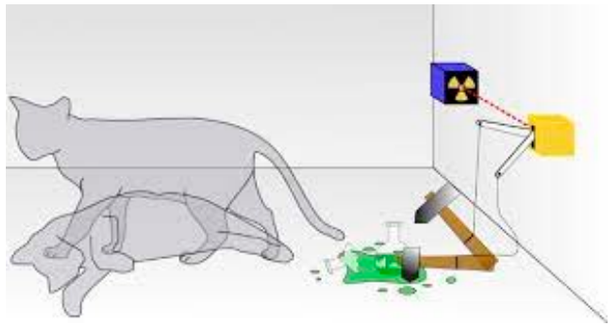
从此，物理可以用场来描述。　　电磁场 -> 光子

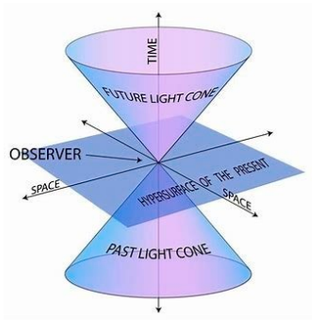
场 <-> 粒子

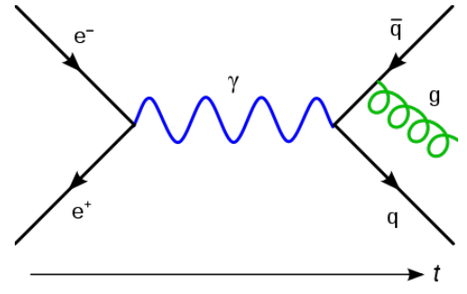
规范/光子场 + 物质场





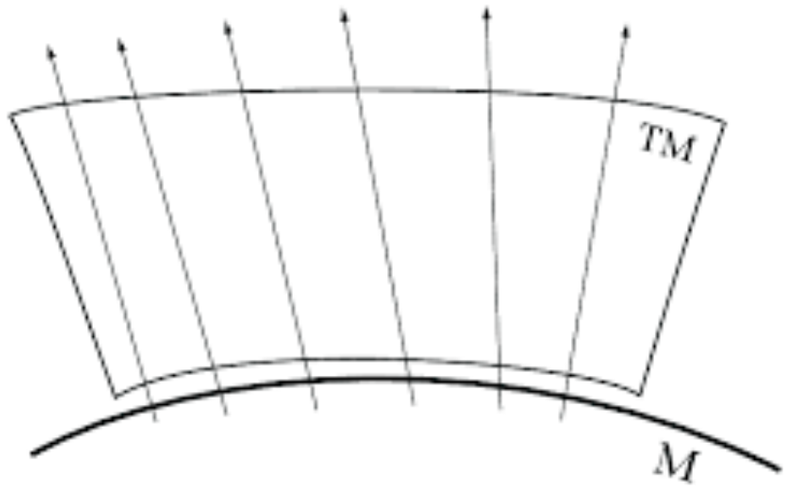


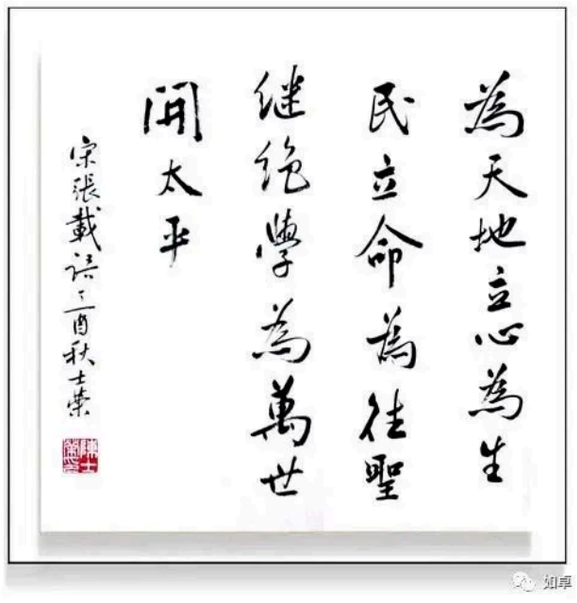


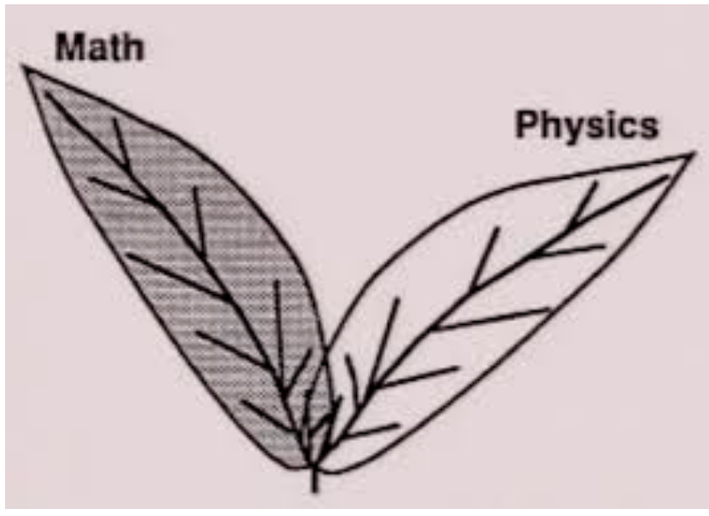


麦克斯韦理论　＋　量子力学　＋　相对论　⟶　规范场论

杨-米尔斯理论描述为纤维丛

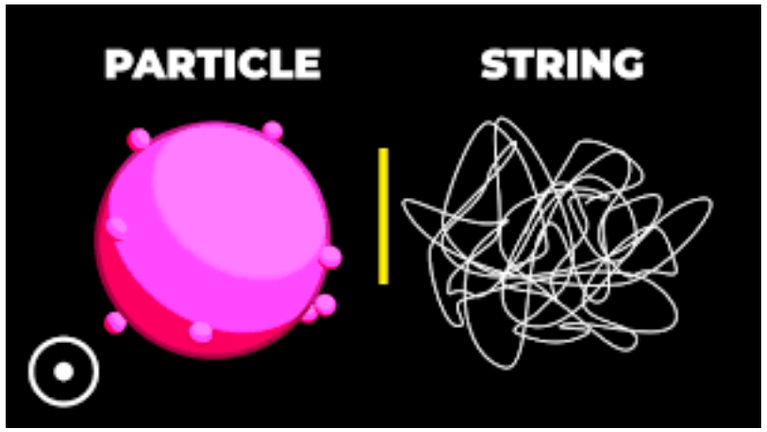


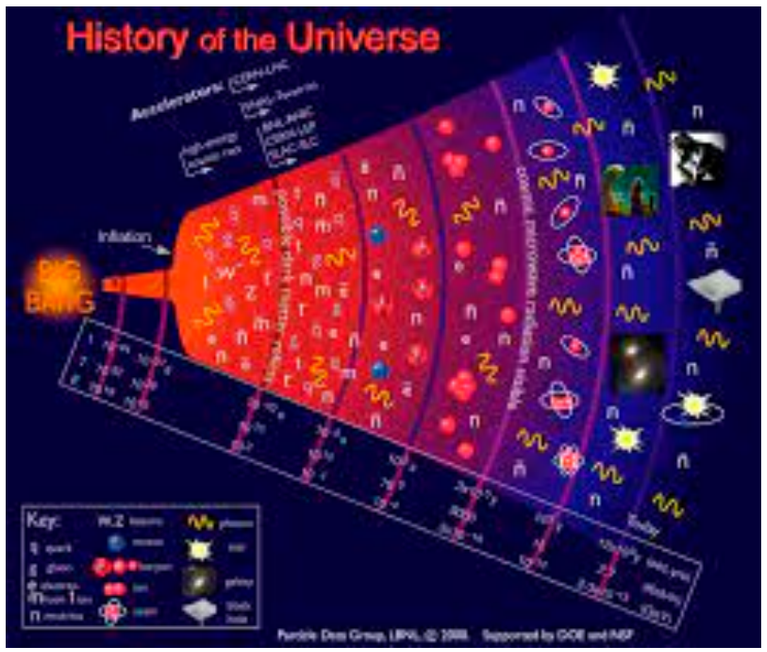


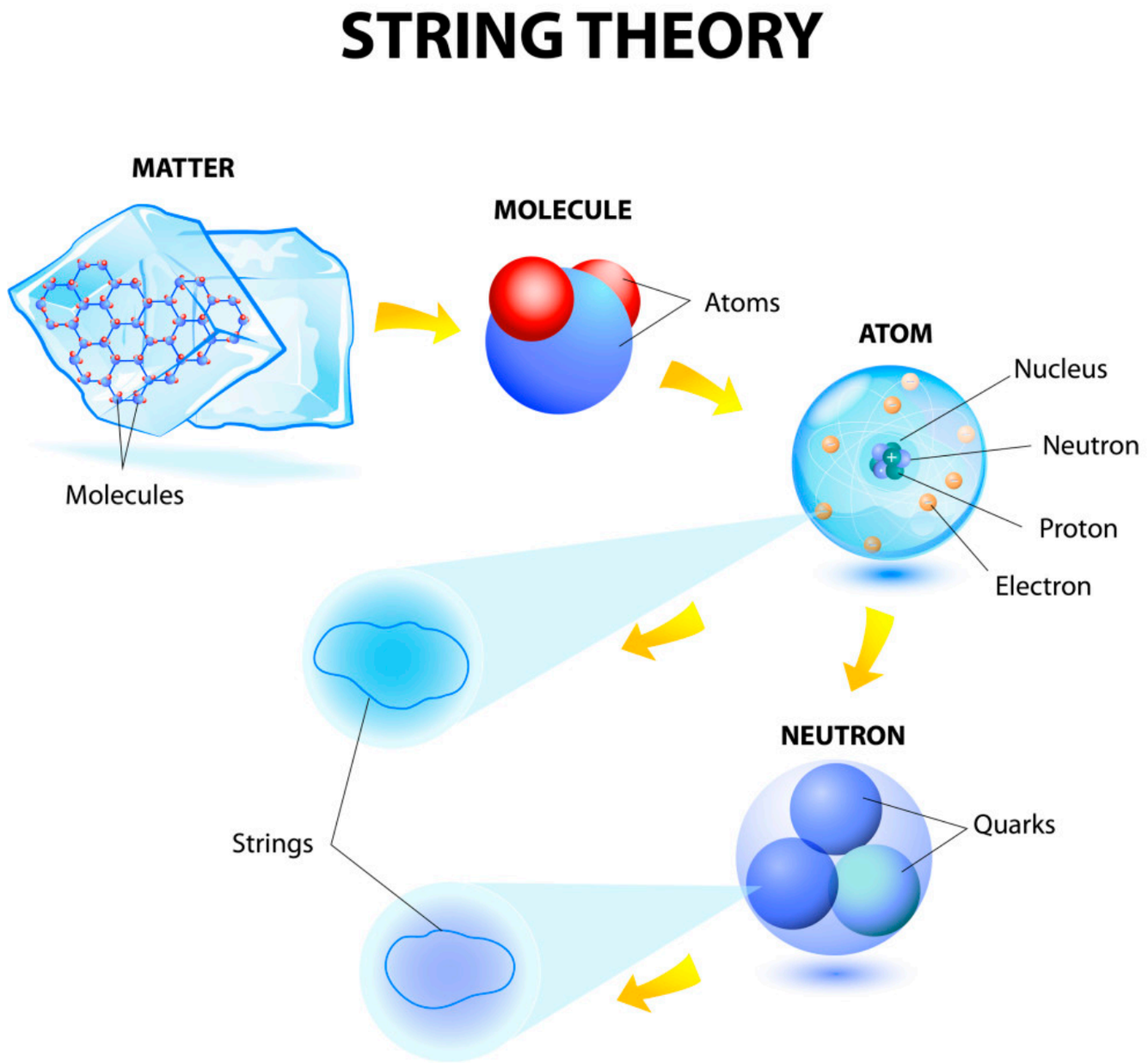


场论与几何

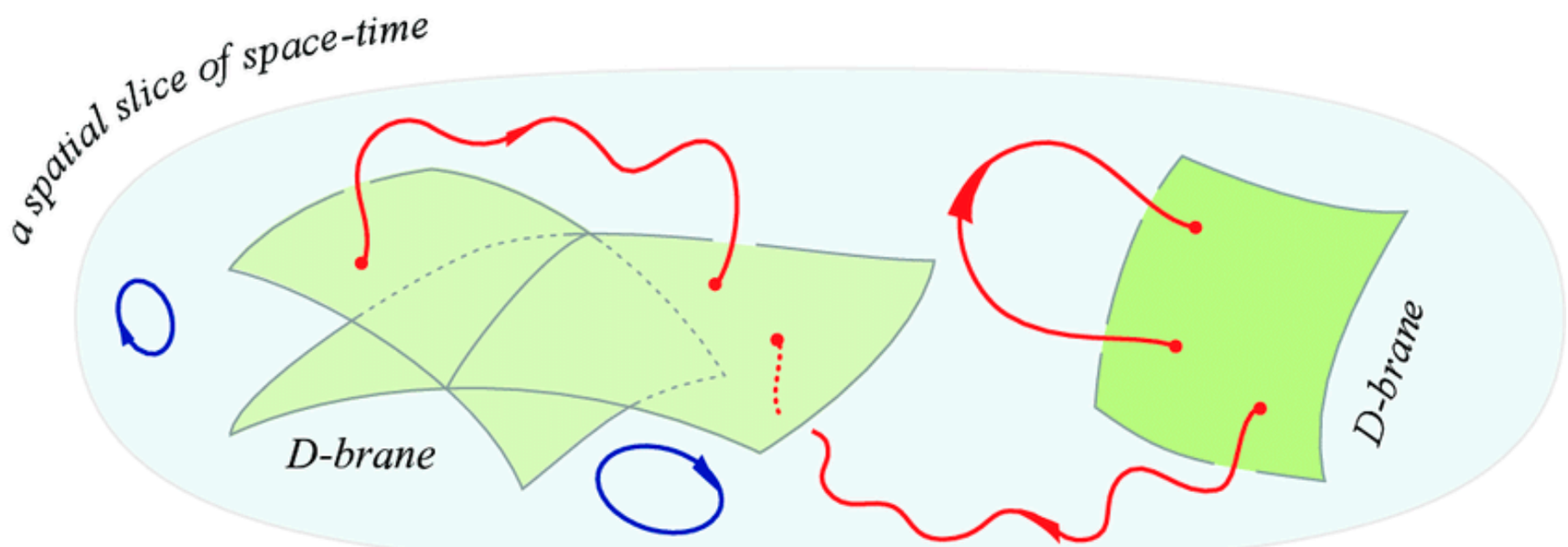
弦理论：终极理论最佳候选者







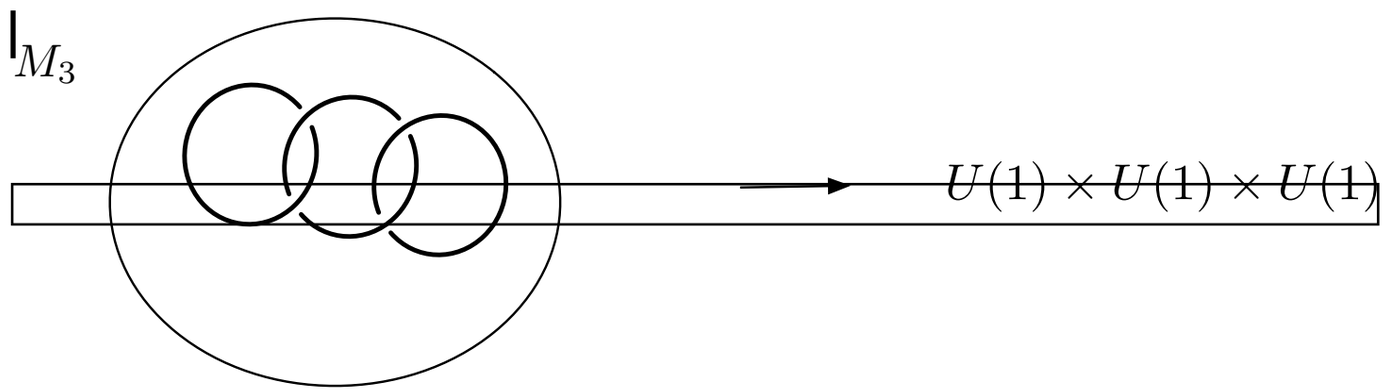
多种多样的膜和弦



物理对象天生携带几何结构

一个方向是关注三维场论，比如陈-西蒙斯理论。

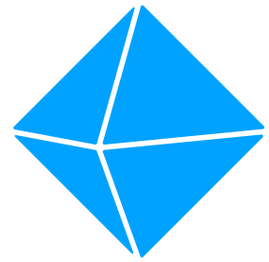
紧致化(compactification)



三维场论和三维流形的对应

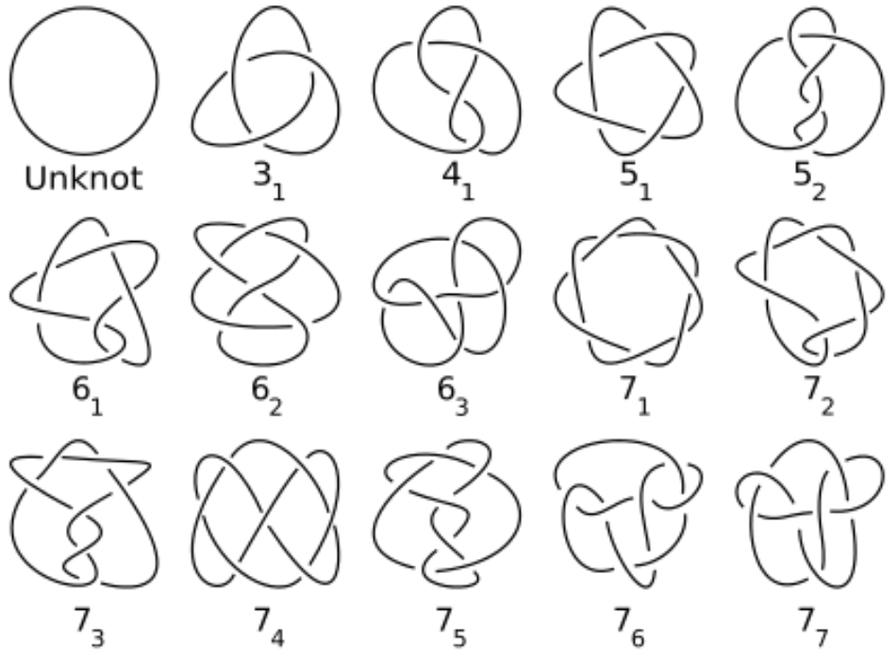
T[M3] <—> M3

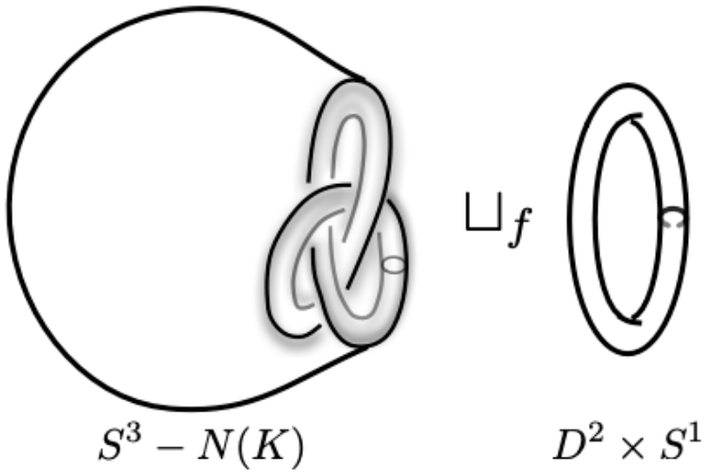
三维流形

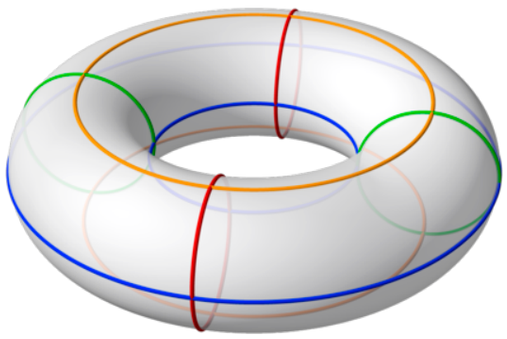


庞加莱猜想

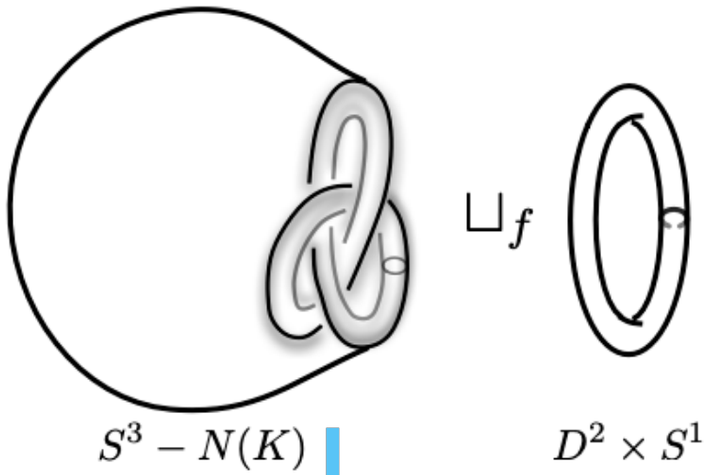

Numberphile


Unknot
3_1
4_1
5_1
5_2
6_1
6_2
6_3
7_1
7_2
7_3
7_4
7_5
7_6
7_7

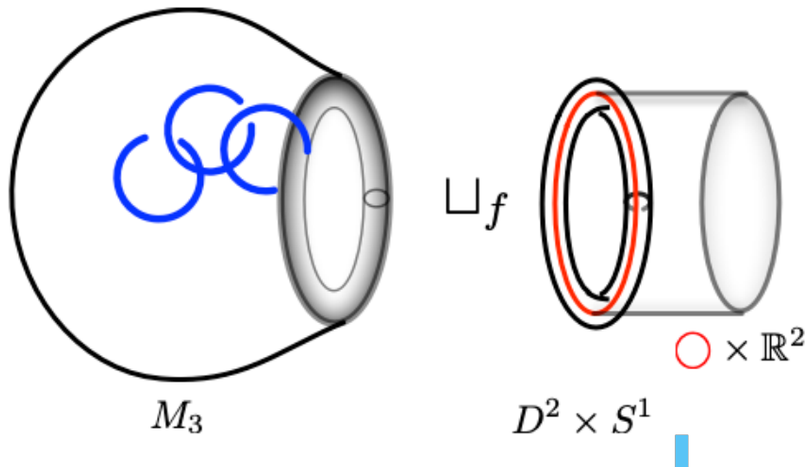

$\sqcup_f$
$S^3 - N(K)$
$D^2 \times S^1$



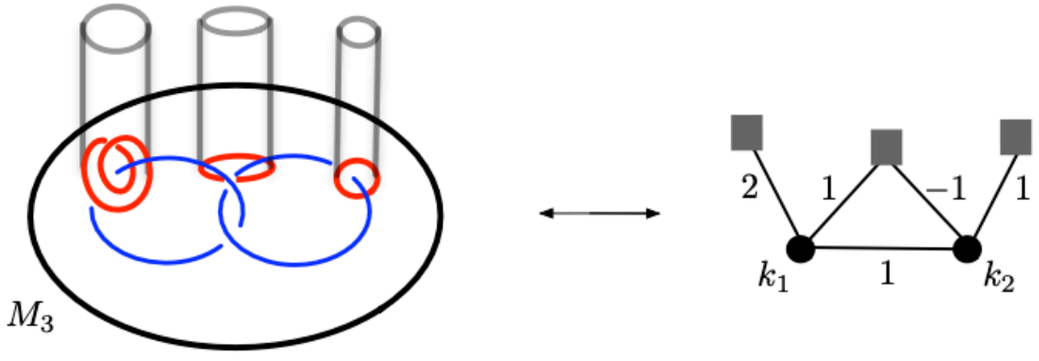
三维场论的紧致化构造



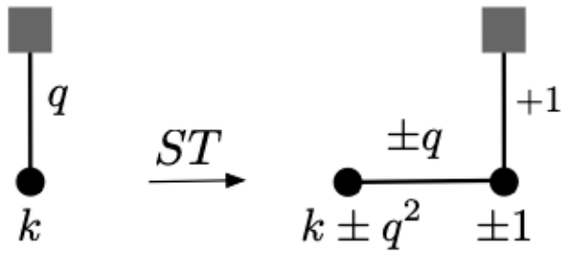
光子场

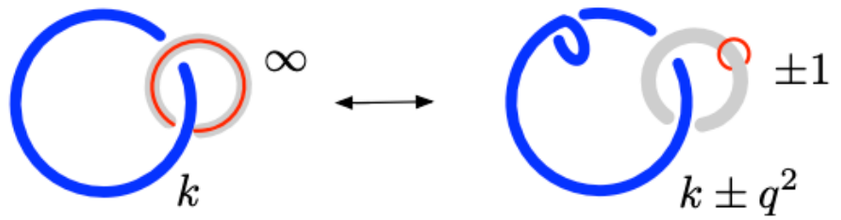


物质场



对偶性





[1] S. Cheng, *Surgery Constructions for 3d Theories, Part I: Matter Circles and Links*, [arXiv:2310.07624].

[2] S. Cheng and P. Sułkowski, *3d $\mathcal{N} = 2$ theories and plumbing graphs: adding matter, gauging, and new dualities*, *JHEP* 08 (2023) 136, [arXiv:2302.13371].

S^3

$M = S^3$

$\langle O_a O_a O_a \rangle = \cdots$

$W = \phi_1 \phi_2 \phi_3$

Stein relative

(II)

$M3 \# S^3 = M_3$

$ab \neq ba$

Conj 1 : Any circle S^1 $\pi_1(S^3 \setminus K)$ can be a meridian circle.

(V)

Knot group

$\pi_1(M_3) = \{ a, b, \ldots \mid aba = bab \}$

K_1 K_2

$\times \mathbb{R}^2/\mathbb{Z}_p$

Surgeries

M_3

S^3

K_1

$T[M_3]$

Page 30 (I)

Conj 2 Knot group relation

(V) ⟷ (V)

Superpotential

80万

2024年10月

"Thurston"

Matter F

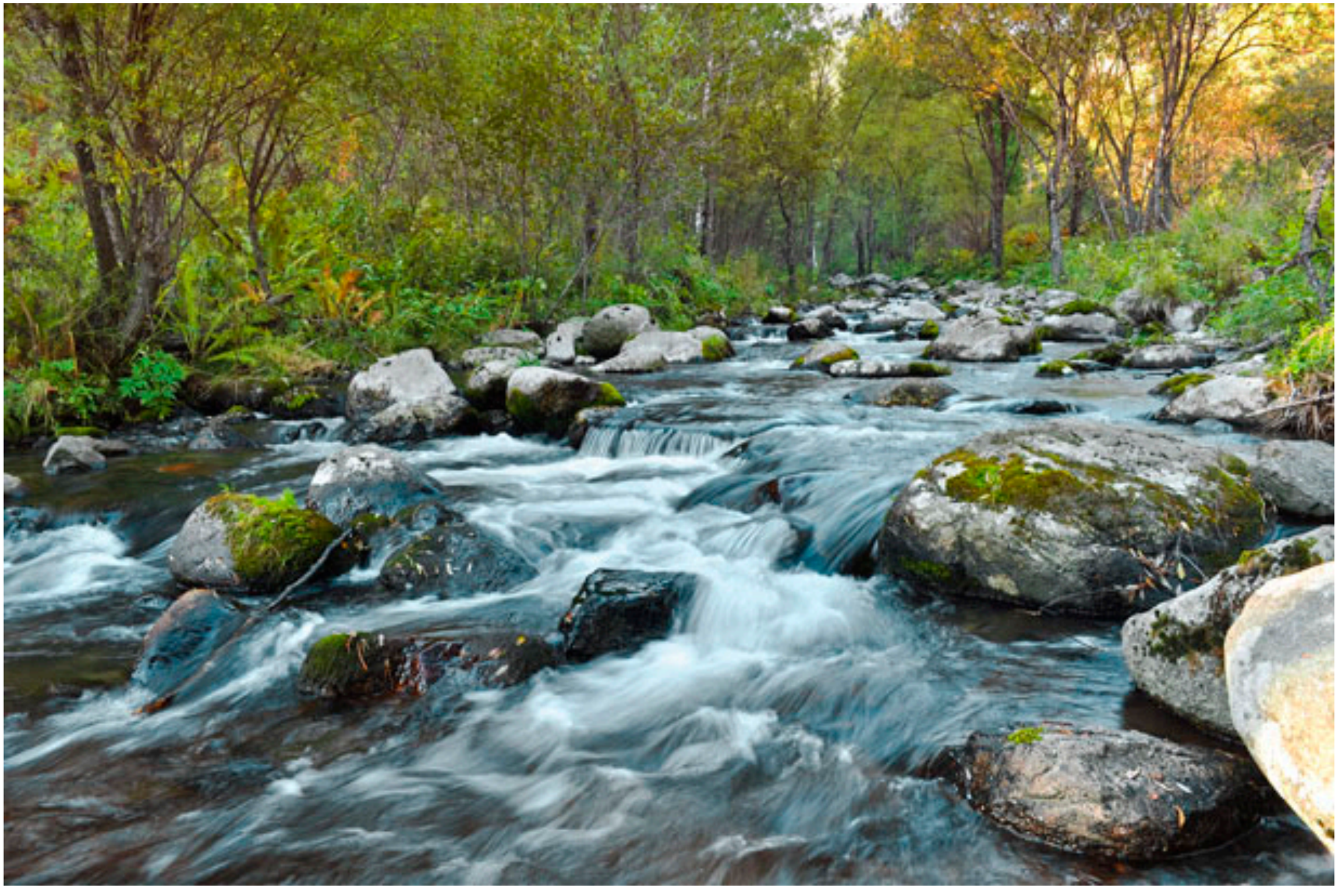
SI

Matter F

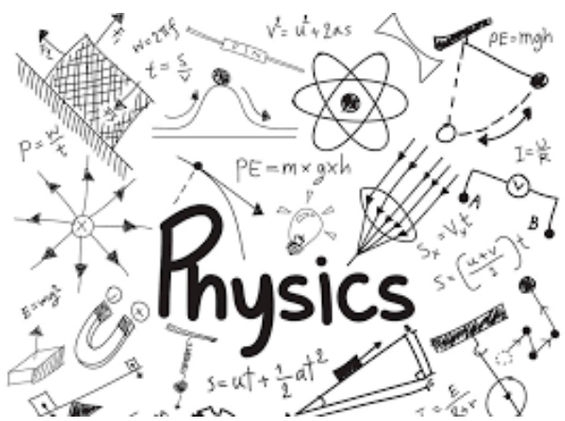
"knots & links", Rolfsen

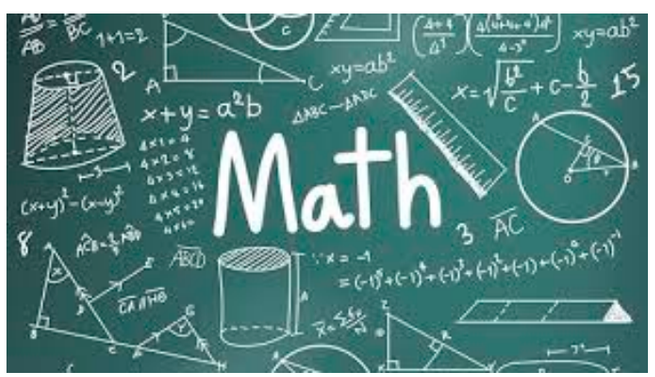
"knots & links"

科研项目： 将三维场论通过三维流形进行几何化



三维超对称场论的几何化





目标依然任重道远

非常感谢！