Gravitational solutions in supergravity: from inflation to black holes

Masato Nozawa

University of Milan

JSPS visiting researcher
string theory group of INFN Milan

My recent works

Cosmology:

H.Kodama, M.N, `Inflation in maximal gauged supergravity'
JCAP 1505 028 (2015) [arXiv:1502.01378]

General Relativity:

M.N, T.Shiromizu `Positive mass theorem in extended supergravities'
Nucl.Phys. B 887 380 (2014) [arXiv:1407.3355]

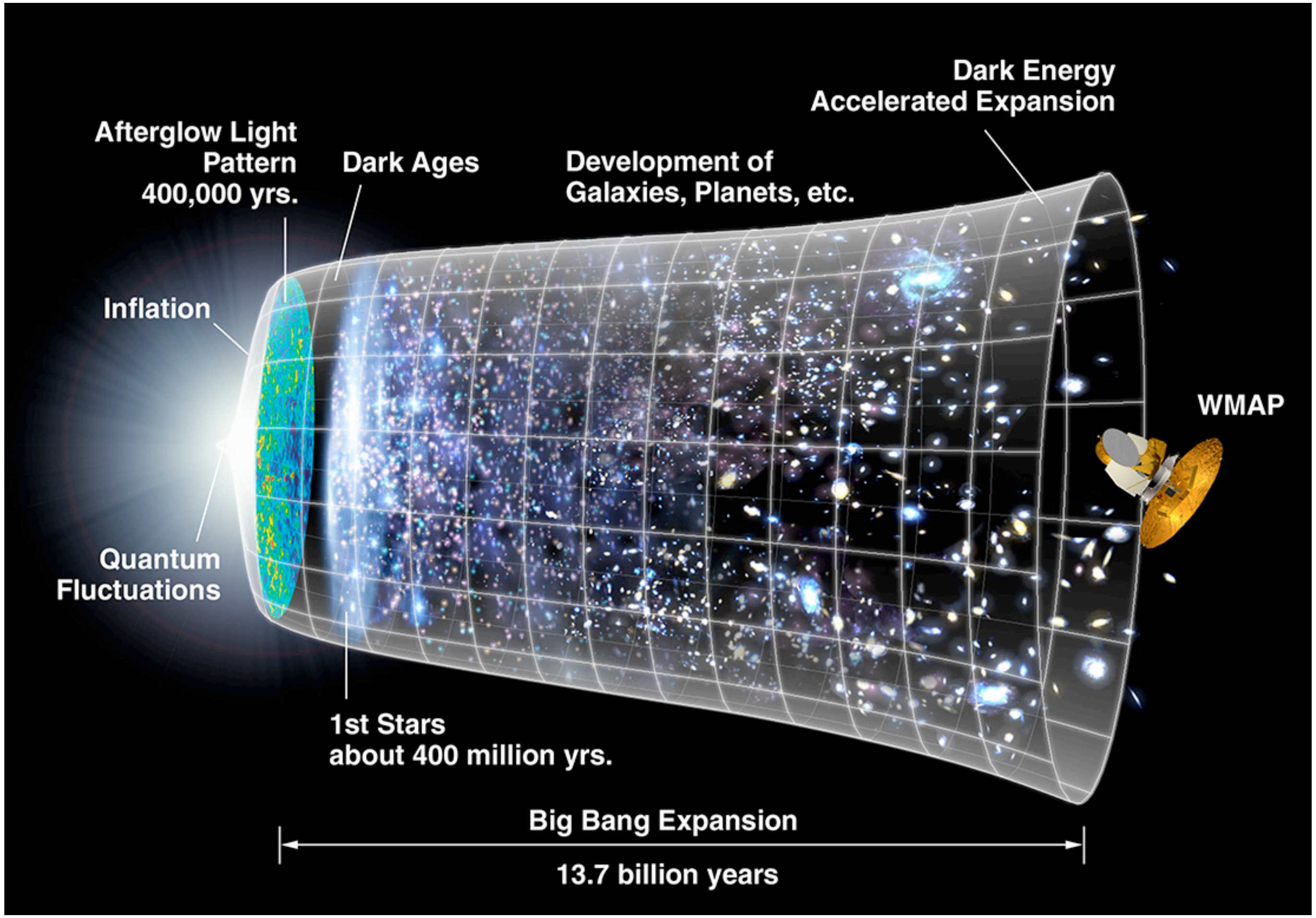
D.Klemm, M.N, M.Rabiosi, `On the integrability of Einstein-Maxwell-(A)dS gravity in presence of Killing vectors [arXiv:1506.09017]

Supergravity:

D.Klemm, M.N, `Geometry of Killing spinors in neutral signature'
[arXiv:1504.02710], to appear in CQG

F.Faedo, D.Klemm, M.N, `Hairy black holes in N=2 gauged supergravity' [arXiv:1505.02986]

Evolutionary scenario of universe



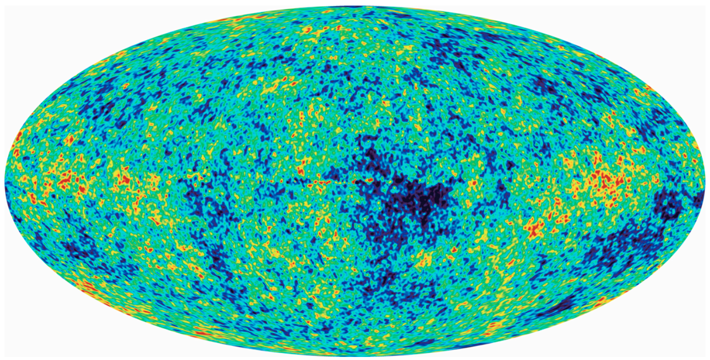
WMAP

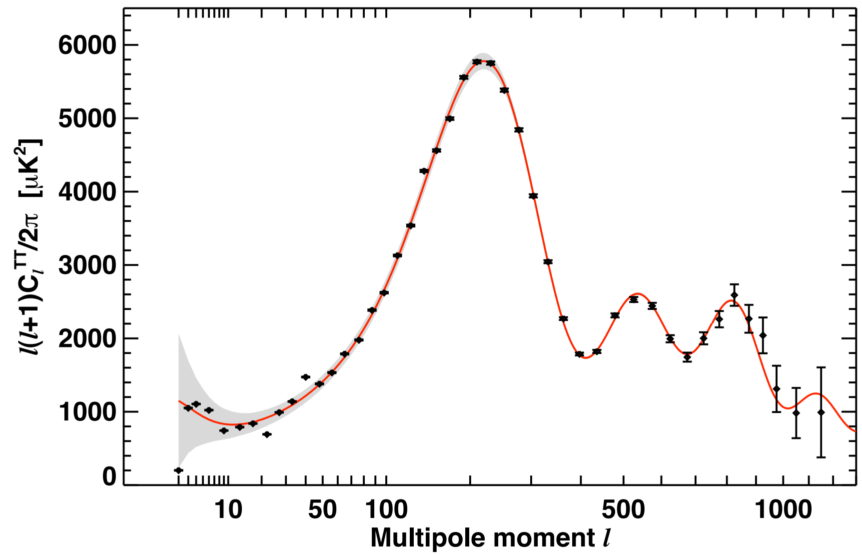
- universe began with a big bang 13.8 billion years ago
- composite of the universe (dark matter, dark energy)

Observational cosmology

Cosmic microwave background observations

Planck 2015

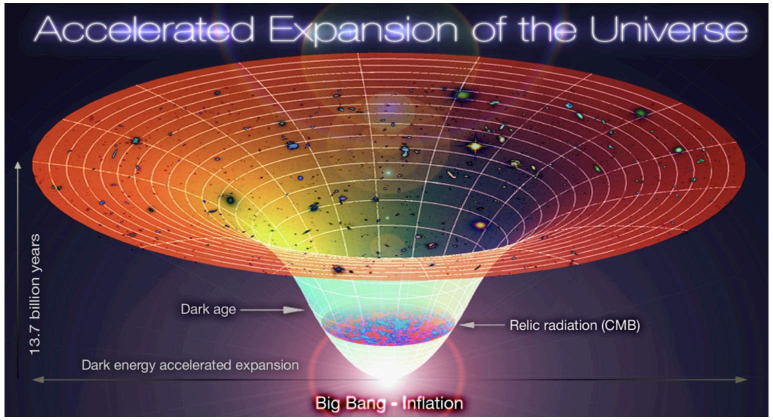




✓amplitude $\delta T/T \sim 10^{-5}$
✓adiabatic
✓scale invariant spectrum
✓gaussian distribution

$$\delta T/T = \sum_{lm} a_{lm} Y_{lm} \qquad \langle a^*_{lm} a_{l'm'} \rangle = C_l \delta_{ll'} \delta_{mm'}$$

Universe underwent an accelerated expansion `inflation'



Inflation

Inflation:

- resolves open issues of big bang universe
  horizon, flatness, monopole,
  initial singularity problems...



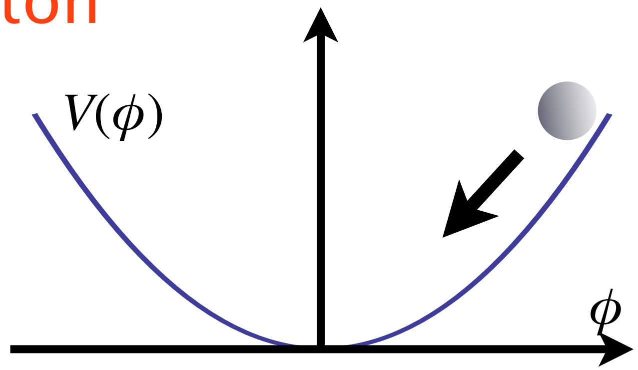
Starobinsky, Sato, Guth

- is driven by an effective scalar field \`inflaton'

$$ds^2 = -dt^2 + a^2(t)d\mathbf{x}^2 \qquad H \equiv \frac{\dot{a}}{a}\,,$$

$$\dot{H} = -\frac{1}{2}\dot{\phi}^2 \ll 1 \longrightarrow a(t) \simeq e^{Ht}$$

slow-roll quasi deSitter phase



- generates a curvature perturbations for seed of structure formation scale-invariant, adiabatic, Gaussian

Open issue: particle physics interpretation is still lacking

Motivation: construction of consistent inflationary universe model from fundamental theory (string theory)

N=1 vs N=8 supergravity

Supergravity: low-energy limit of string theory

SUSY	N=1		N=8
phenomenology	chiral theory		?
variety	rich		restrictive
SUSY breaking	many		spontaneous
scalar	Hodge-Kahler		$E_{7(7)}/SU(8)$
# of scalars	arbitrary		70
Potential	Kahler potential & superpotential		gaugings

Objection:

(slow-roll) inflation consistent with observations occurs in N=8 supergravity?

N=8 gauged supergravity

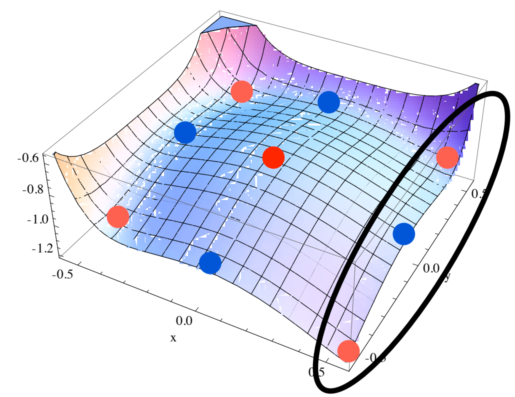
In addition to the deWit-Nicolai theory (c=0), a new deformation of N=8 gauged SUGRA was recently found

Dall'Agata-Inverso-Trigiante 2012

- theory contains controllable parameter c

$$\theta\xi = c\,,$$

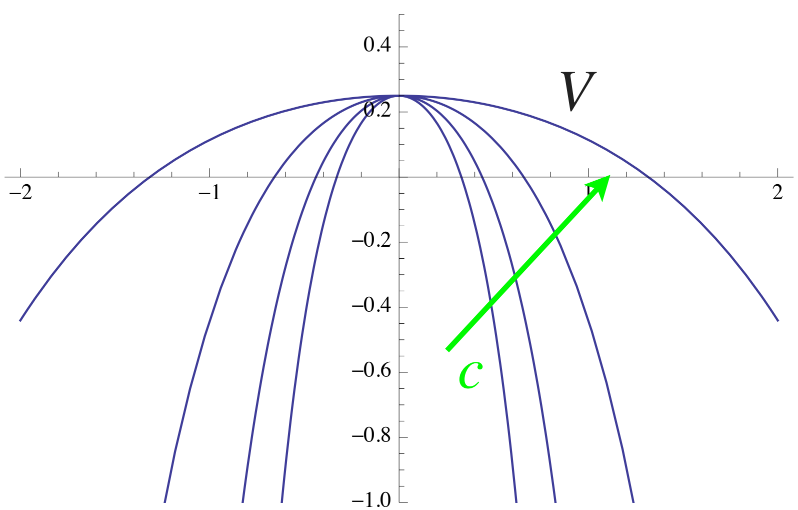
different symplectic embedding



- first example of `slow-roll' de Sitter vacua

Dall'Agata-Inverso 2012

$SO(4)=SO(3)xSO(3)/Z_2$ sector of SO(4,4) gauging



potential can be flattened by choosing the deformation parameter c

Inflation in N=8 supergravity

focus on SO(3)xSO(3) invariant sector of SO(4,4) gaugings

Kodama-MN 2015

Einstein-Scalar system:

$$\mathcal{L} = (R - 2V(\phi)) \star 1 - K_{\alpha\beta} \mathrm{d}\phi^\alpha \wedge \star \mathrm{d}\phi^\beta$$

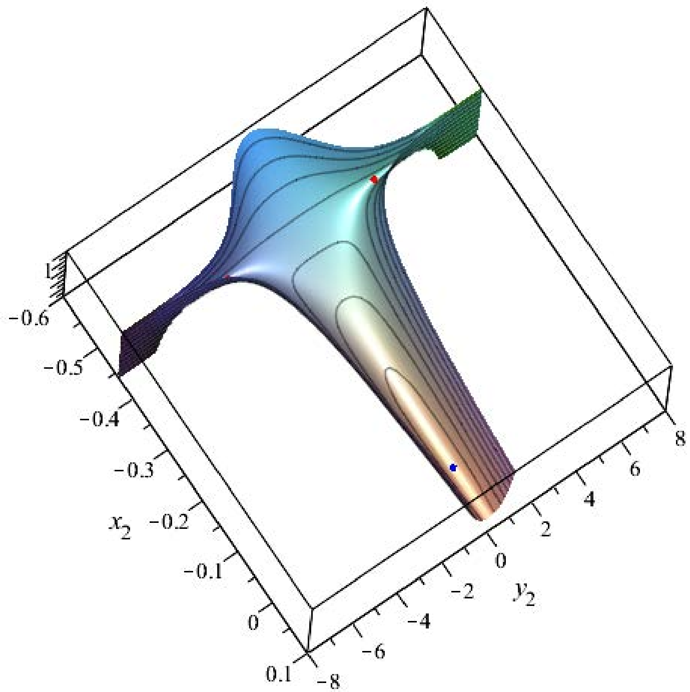
$$ds_T^2 = 3dx_-^2 + \frac{1}{2}\sum_i d\mu_i^2 + \sinh^2(\mu_2-\mu_3)\chi_1^2 + \sinh^2(\mu_3-\mu_1)\chi_2^2 + \sinh^2(\mu_1-\mu_2)\chi_3^2 \, .$$

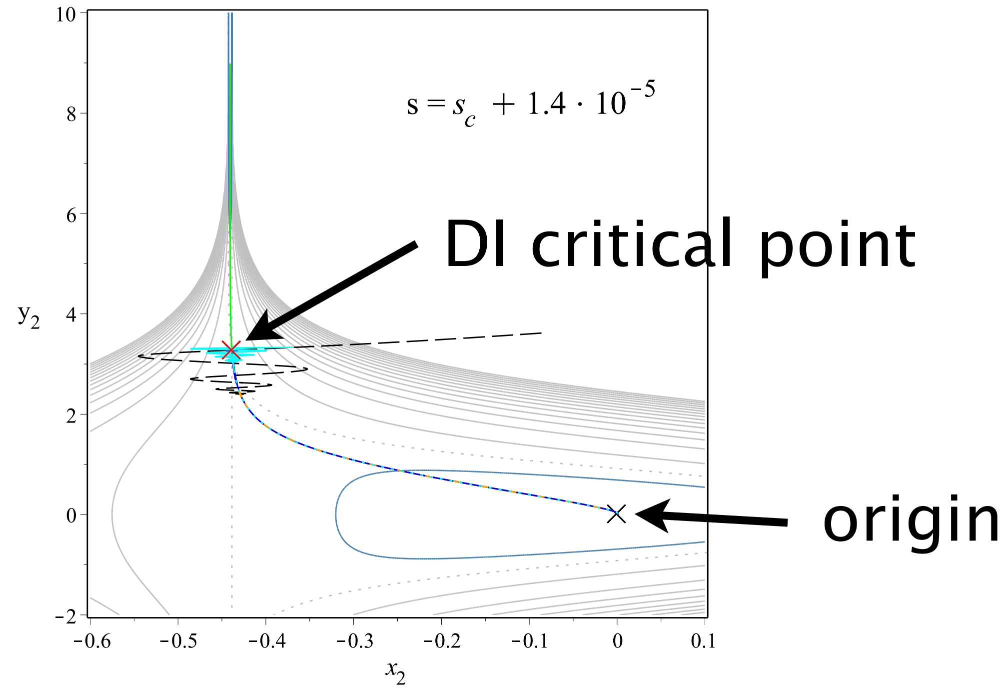
$$\begin{aligned} g^{-2}V = \; & \left(e^{6x_2} + c^2 e^{-6x_2}\right)\left[2C_{321}\cosh(2\mu_1 - 2\mu_2) + 2C_{312}\cosh(2\mu_3 - 2\mu_1) \right. \\ & \qquad \left. + 2C_{31-1}\cosh(2\mu_2 - 2\mu_3) + C_{300}\right] \\ & + \left(e^{-2x_2} + c^2 e^{2x_2}\right)\left[2C_{111}\cosh(2\mu_1) + 2C_{110}\cosh(2\mu_2) + 2C_{101}\cosh(2\mu_3) + C_{100}\right] \\ & + 2\left(e^{2x_2} + c^2 e^{-2x_2}\right)\left[C'_{111}\cosh(2\mu_1) + C'_{110}\cosh(2\mu_2) + C'_{101}\cosh(2\mu_3)\right] , \end{aligned}$$

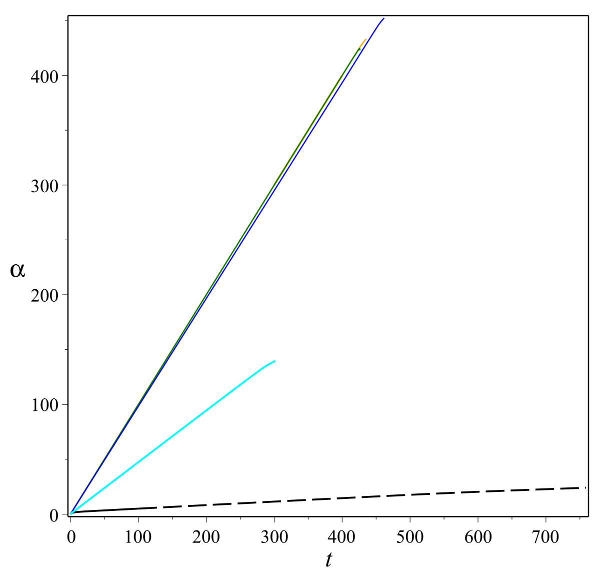
$$C_{110} = -\frac{3}{64}\sin^2\theta_1\cos^2\theta_3 \, ,$$ etc

- first example of analytic expressions for 6 dim scalars
- numerically traced the trajectory of inflaton

Inflation in N=8 supergravity



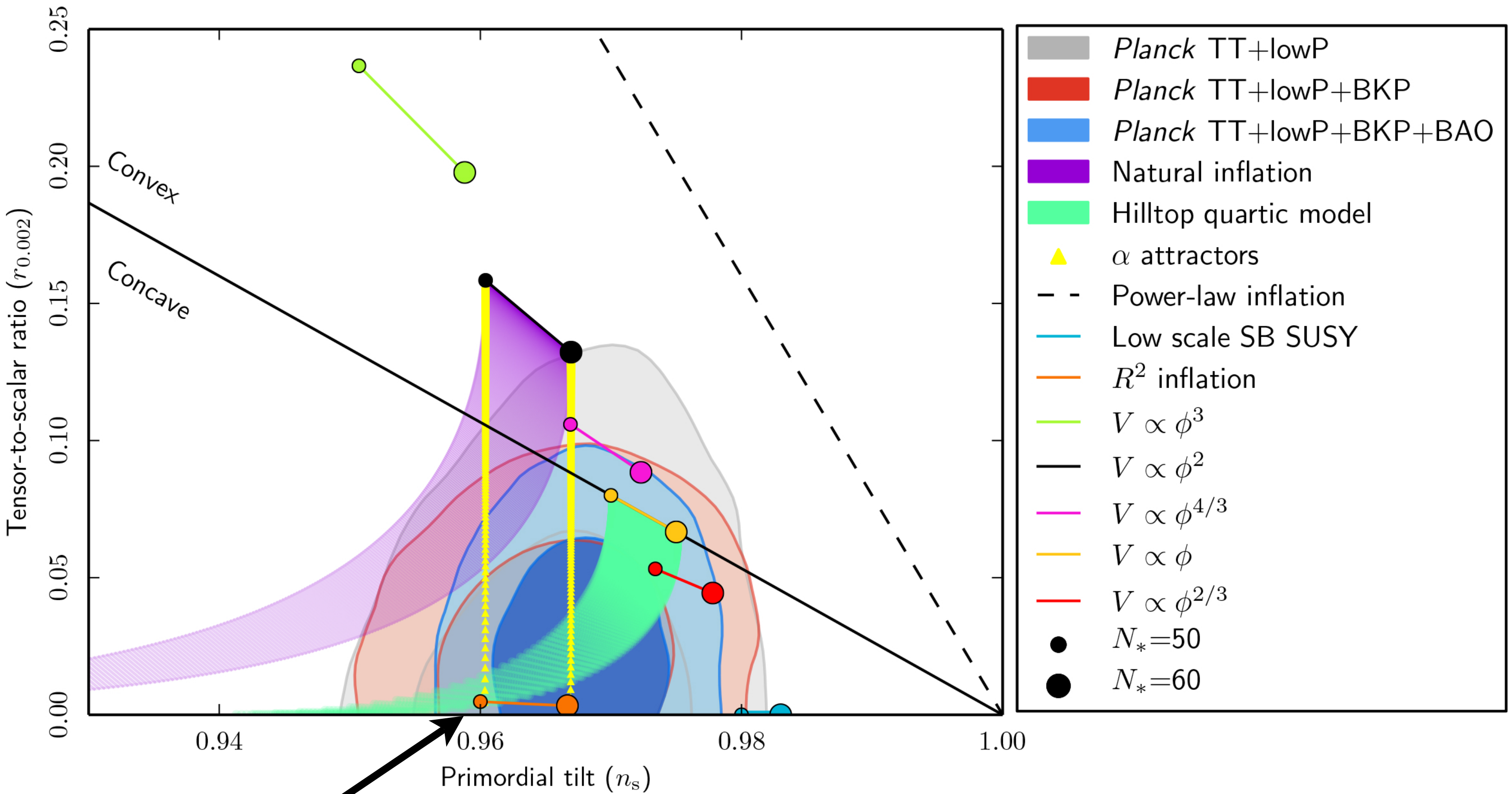




By controlling the deformation parameter, sufficient duration of inflation (N=60 e-folding) can be achieved!

does not require the fine-tuning of initial condition for scalars

Inflation in N=8 supergravity



Our model:

$n_s \sim 0.96$:(slightly) red-tilted

$r \sim 10^{-3}$:small amount of gravitational waves

would be tested in future observations (LiteBIRD)

Summary

Compared to N=1 supergravity, N=8 theory is more predictable to inflation

- proposed a method for deriving the potential in analytic manner

- were able to evaluate the mass spectrum group-theoretically

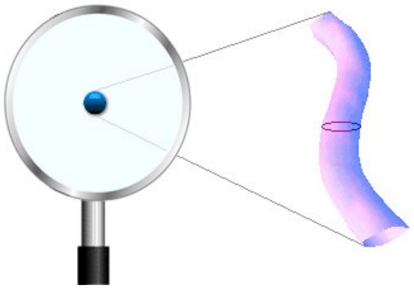
- constructed cosmic inflationary model

  without fine-tuning of initial conditions

  compatible with Planck data

String cosmology

String theory:



- likely candidate of particle unifications
- predicts higher dimensions (10/11)
- reduces in low energy to supergravity

Difficulties (in N=1 supergravity framework):

- how to obtain/stabilize 4 dimensional world

- string landscape problem

  10^{500} false vacua   Susskind 2003

- `predictability' problem

  arbitrary # of scalars & shape of V are allowed

$$V = e^K (G^{a\bar{b}} D_a W \overline{D_b W} - 3|W|^2)\,,$$

K=$K(\phi, \phi^*)$: Kahler potential
W=$W(\phi)$: superpotential

- how to obtain accelerated expansion

  c.f `No-go theorem' in higher dim SUGRA   Maldacena-Nunez 2003

Our approach