Holographic R-symmetric flows and the τ_U conjecture

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Crete 17/06/2013

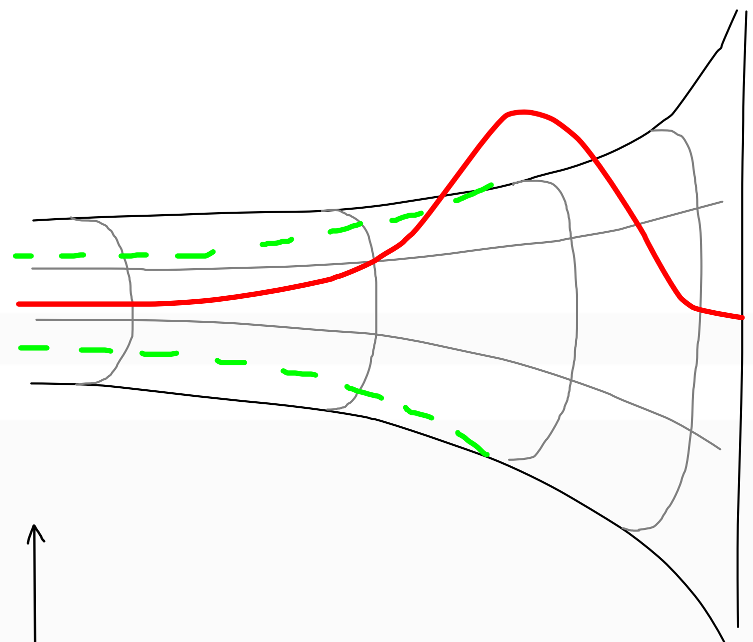
based on work with: M. Bertolini, F. Porri

Intro & Motivations

- Monotonic quantities can be a useful constraint on the dynamics of RG flows;
- Via holography, they are expected to correspond to monotonic functions of the extra dimension in domain wall geometries;
- Buican conjectured the existence of a monotonic quantity τ_U in R-symmetric RG flows, whose validity would put a bound on emergent symmetries in the IR;
- Our aim is to explore the existence of a corresponding monotonic function in supergravity, both to test the conjecture & to refine the holographic dictionary outside the conformal regime.

Holographic RG flows

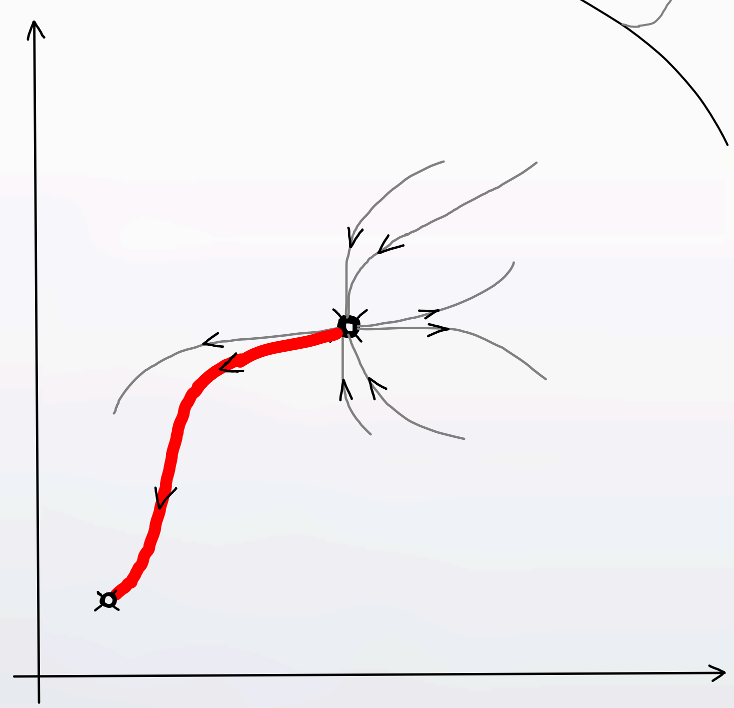
Background scalars



Domain wall
$AdS^{UV} \rightarrow AdS^{IR}$

$\updownarrow$

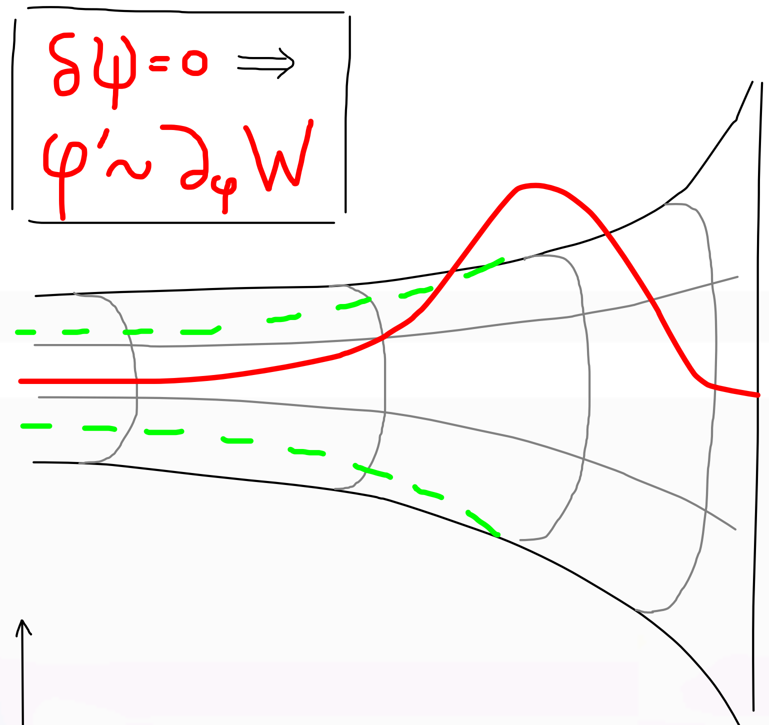
Running couplings



Renormalization group flow
$CFT^{UV} \rightarrow CFT^{IR}$

... + SUSY (d=4)

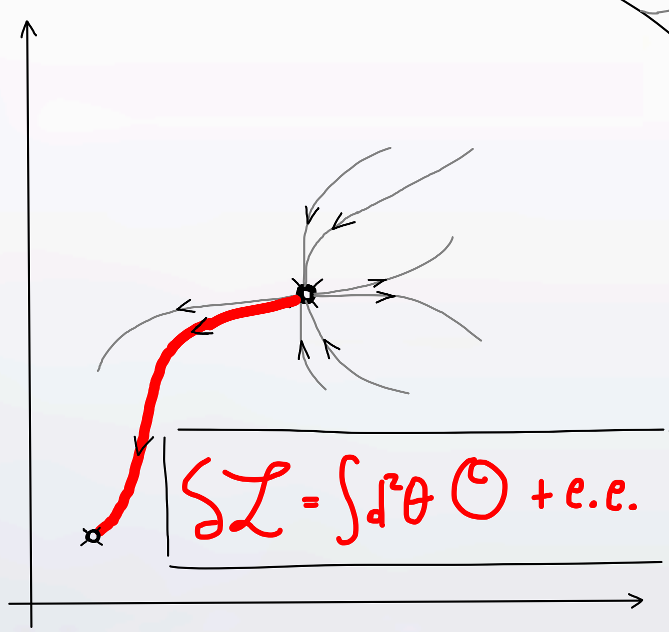
1st order
equations
for the scalars



BPS domain wall in
$\mathcal{N} = 2, 5d$ gauged SUGRA

↕

supersymmetric
defs/VEVs



Renormalization
group flow
$SCFT^{UV} \to SCFT^{IR}$

A conjecture

Buican

$\mathcal{N}=1$ 4d RG flow which **preserves a** $U(1)_R$

$$\bar{D}^{\dot{\alpha}}\mathcal{R}_{\alpha\dot{\alpha}} = \bar{D}^2 D_\alpha U \qquad \text{R-multiplet}$$

$$\mathcal{R}_{\alpha\dot{\alpha}} \supset (T_{\mu\nu}, S_{\mu\alpha}, R_\mu) \qquad \partial^\mu R_\mu = 0$$

$$U \supset U_\mu \quad + \text{ anomalies} \qquad \partial^\mu U_\mu \neq 0$$

At fixed points $\quad U_\mu \to \frac{3}{2}(R_\mu - \tilde{R}_\mu) \qquad \partial^\mu U_\mu \to 0$

$$\langle U_\mu(x) U_\nu(0)\rangle = \frac{\tau_U}{(2\pi^4)}(\partial^2\eta_{\mu\nu} - \partial_\mu\partial_\nu)\frac{1}{x^4}$$

Conjecture: $\quad \tau_U^{UV} > \tau_U^{IR}$

- works in *many* examples: SQCD with any gauge group/with extended susy, s-confining theories, Kutasov theory...

- interesting because it can be read as a bound on emergent symmetries: no emergent symmetry implies $\tau_U^{IR} = 0$

An example of monotonicity in 4d RG flows is the a-theorem:

$$\boxed{a_{UV} > a_{IR}}$$

Cardy; Komargodski-Schwimmer

In holographic RG flows, as a consequence of the NEC, one can define a monotonic function of the bulk coordinate $a(r)$ interpolating between the UV-IR

Girardello-Petrini-Porrati-Zaffaroni; Friedmann-Gubser-Pilch-Warner; Henningson-Skenderis; Myers-Sinha

Does τ_U correspond to a monotonic function in SUGRA?

Dictionary

$\mathcal{N} = 1, 4d$ **SUSY FT**		$\mathcal{N} = 2, 5d$ **SUGRA**
Chiral Operators	$\longleftrightarrow$	Hypermultiplets
Linear Operators	$\longleftrightarrow$	Vector multiplets
Space of couplings	$\longleftrightarrow$	Scalar Manifold
Symmetries	$\longleftrightarrow$	Isometries
Symmetry of the fixed point	$\longleftrightarrow$	Killing vector = 0 at critical point
Symmetry of the flow	$\longleftrightarrow$	Killing vector = 0 along the curve

Dual of an R-symmetry

R-symmetry $=$ $U(1)$ under which $S_{\mu\alpha}$ is charged

⇒ Dual gauge symmetry acts on gravitino

$A^I_\mu, I = 0, \ldots, n_V$ basis of abelian gauge bosons

$$(\mathcal{D}_\mu \psi)^i \supset A^I_\mu P^r_I (\sigma^r)^i_j \psi^j$$

P^r_I functions on the hyper-scalars

A^I_μ is dual to an R-current ⇔ $P^r_I \neq 0$

Geometric meaning of P_I^r $\longrightarrow$ $SU(2)$-triplet of moment maps on the hyper-scalar manifold

At **susy critical points** of the scalar potential

$$P_I^r|_{c.p.} = P^r h_I$$

An analogue factorization holds along **R-symmetric flows**

$$P_I^r \equiv \mathcal{P}^r H_I$$

$h_I A_\mu^I$ combination giving the superconformal R-symm

Tachikawa

$\Rightarrow$ H_I gives a natural extrapolation along the flow

Definition of $\tau_U(r)$

$v^I K_I = 0$ R-symmetry preserved along the flow

$$u^I = \frac{3}{2}(v^I - H^I) \longrightarrow \frac{3}{2}(v^I - h^I) \quad \text{that is} \quad \frac{3}{2}\left(R - \tilde{R}\right)$$

Holographic two-point function

$$< J_{I\mu} J_{J\nu} > = \frac{\tau_{IJ}}{(2\pi)^4}(\partial^2 \eta_{\mu\nu} - \partial_\mu \partial_\nu)\frac{1}{x^4}\,, \qquad \tau_{IJ} = \frac{8\pi^2 L}{\kappa_5^2} a_{IJ}$$

a_{IJ} ↓ Gauge kinetic function

$$\boxed{\tau_U(r) = \frac{8\pi^2 L(r)}{\kappa_5^2} a_{IJ}(r) u^I(r) u^J(r)}$$

Interpolates between $\tau_U^{UV} / \tau_U^{IR}$

Test of monotonicity

Concrete "minimal" model: SUGRA coupled to 1 vector + 1 hyper

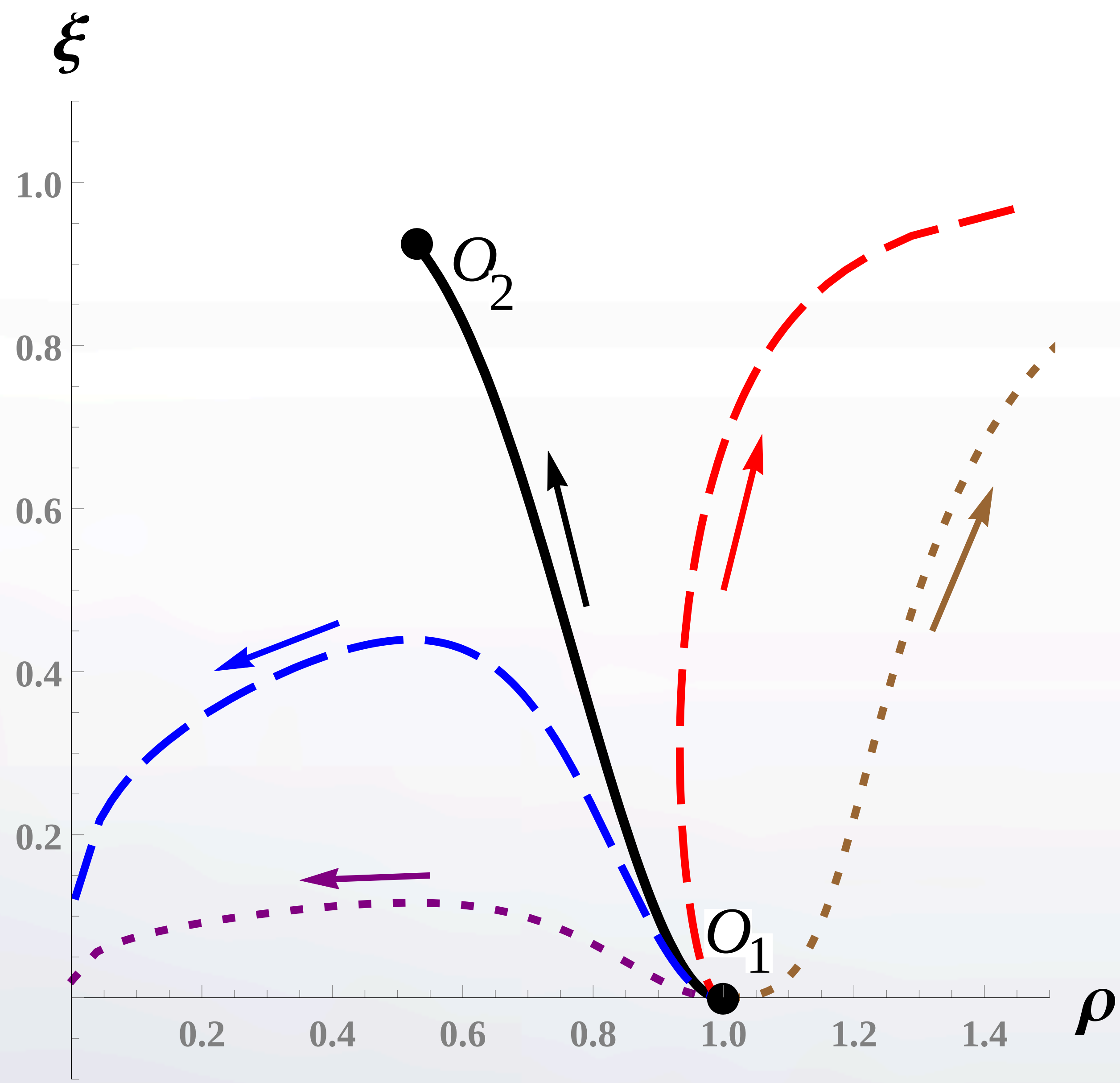
Gauging of a $U(1) \times U(1)$ Ceresole-Dall'Agata -Kallosh-Van Proeyen

1 hyper ⟶ susy deformation of the fixed point

1 vector ⟶ flavor symmetry mixing with $\tilde{R}$

Scalar manifold: $\mathcal{M}_{vec} = O(1,1)\ ,\ \mathcal{M}_{hyp} = \frac{SU(2,1)}{SU(2) \times U(1)}$

DW Solutions



$$O_1 : \quad q^X = (1,\ 0,\ 0,\ 0),$$
$$\rho = 1$$

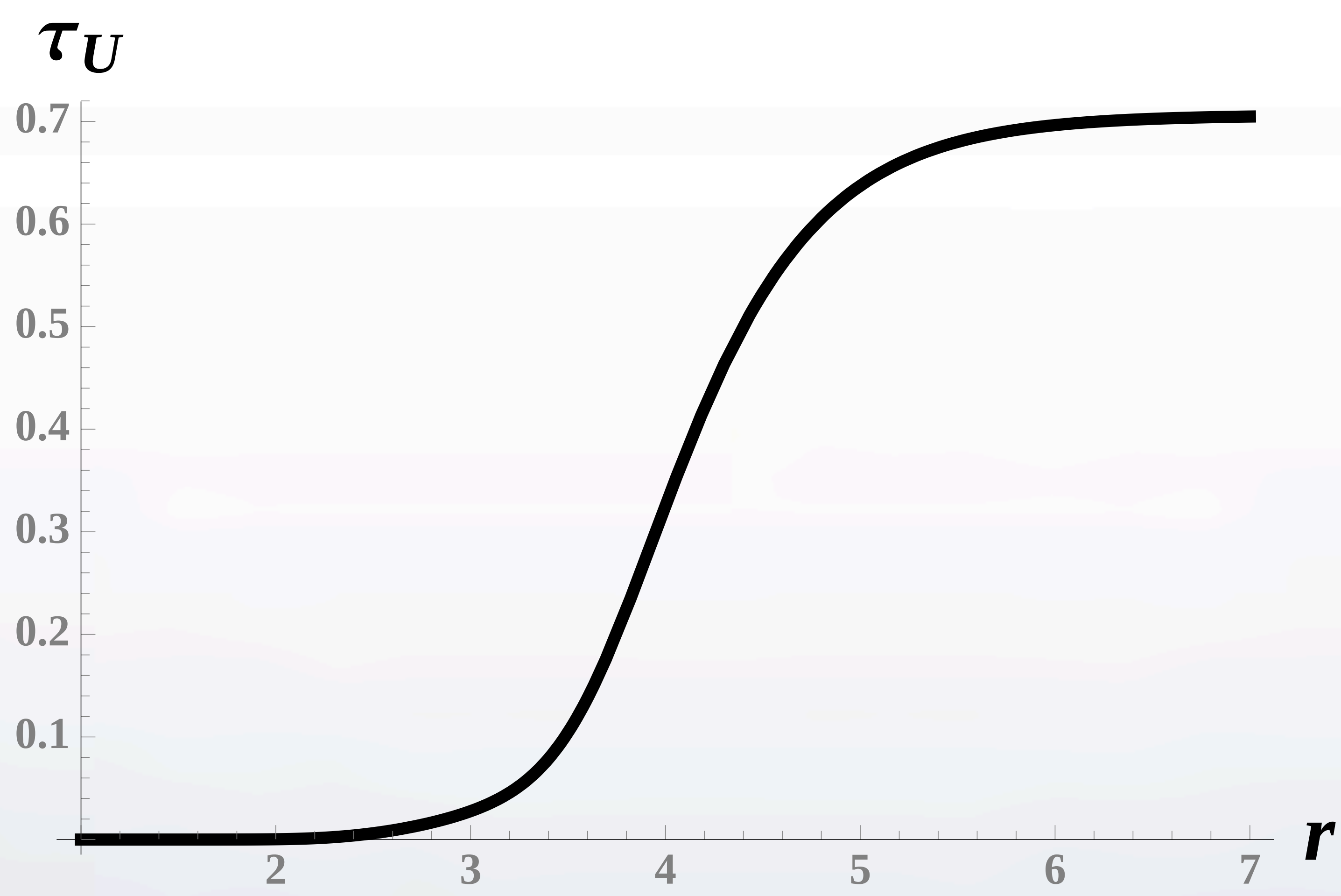
$$O_2 : \quad q^X = (1 - \bar{\xi}^2, 0, \bar{\xi}\cos(\varphi), \bar{\xi}\sin(\varphi))$$
$$\rho = \bar{\rho}$$

circle of critical points

depend on parameters of the gauging

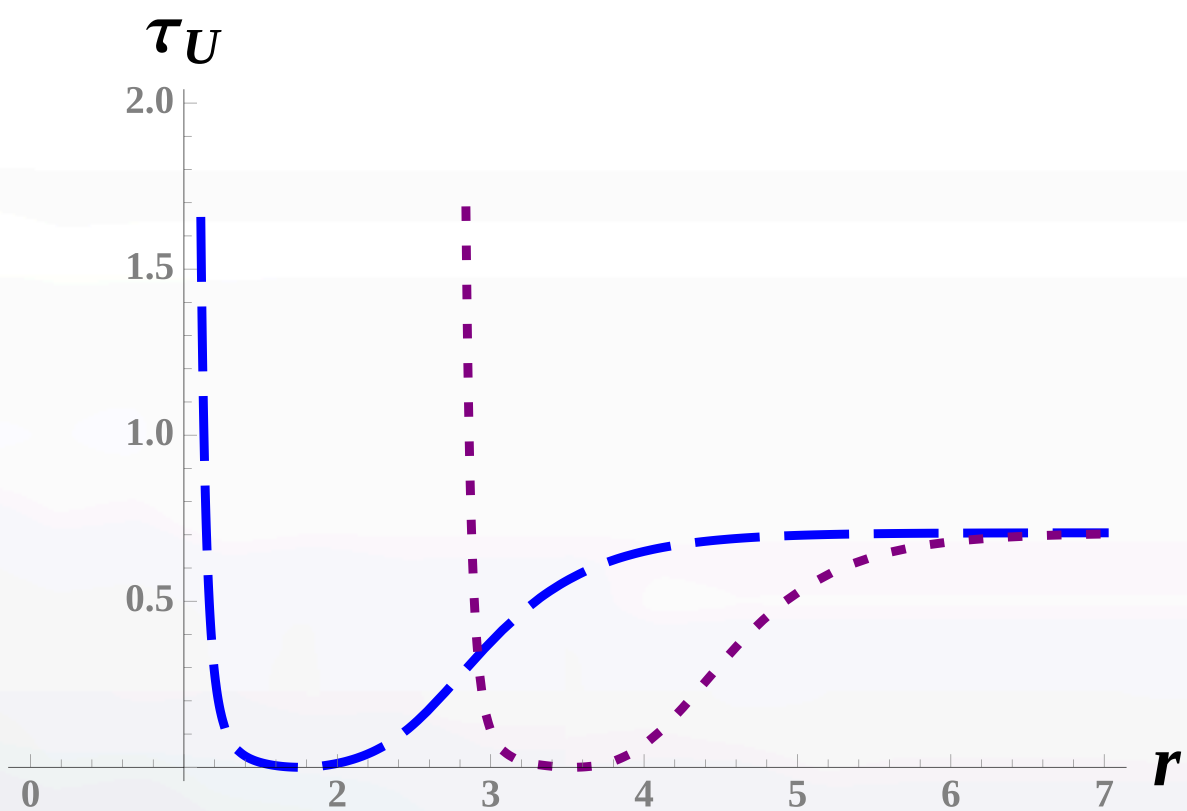
Results

2-parameters family of smooth DW solutions

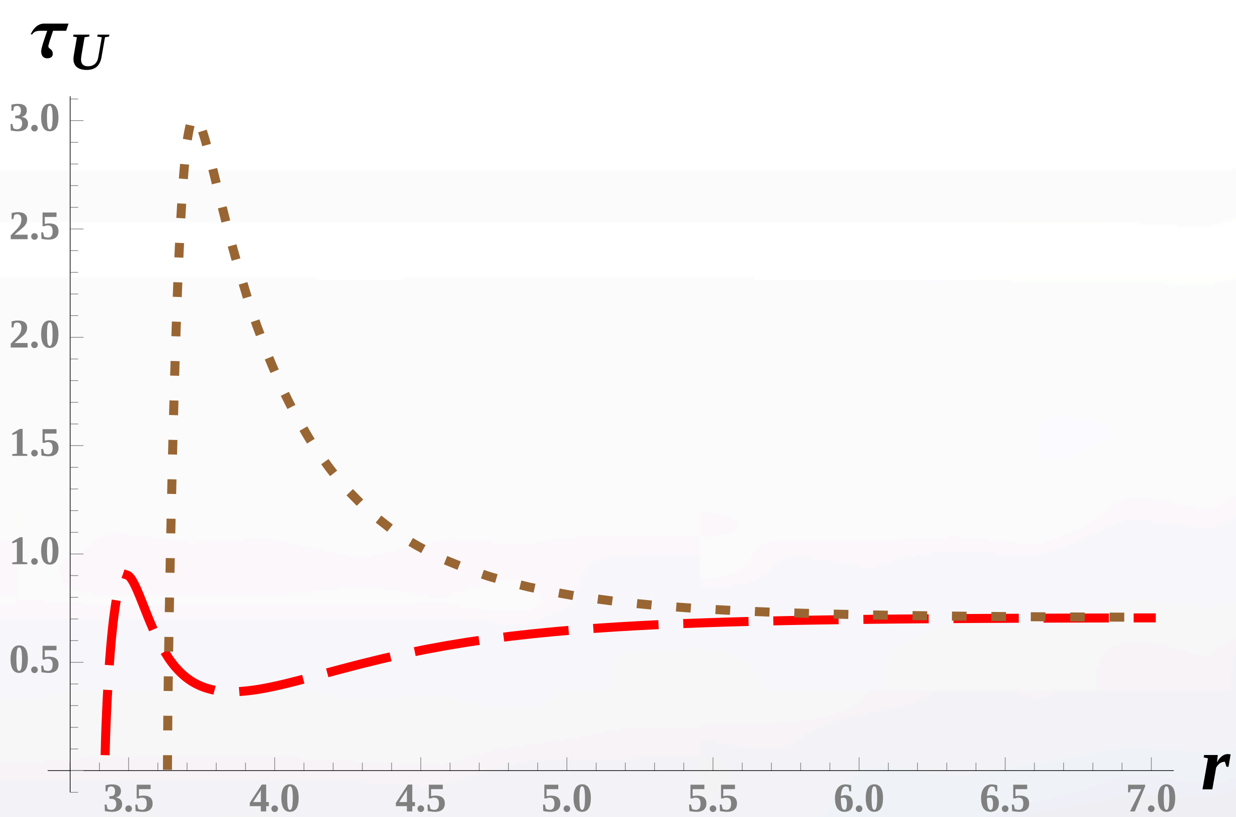


Results

Gapped phases



Good IR



Bad IR

Gubser

Conclusions

- We have explored the existence of a monotonic function in supersymmetric AdS-domain wall solutions of 5d supergravity, associated to a field theory conjecture in R-symmetric RG flows.
- We have found the general consequences of the existence of an R-symmetry along the flow for the supergravity theory; this lead to a natural definition for the interpolating function.
- We tested our proposal in a simple setup, finding a monotonic behavior in smooth solutions as well as in well-behaved gapped flows.
- Future prospects: test in other flows; analysis of the sugra dual of the R/FZ-multiplets.

Thank you!