Review on Swampland

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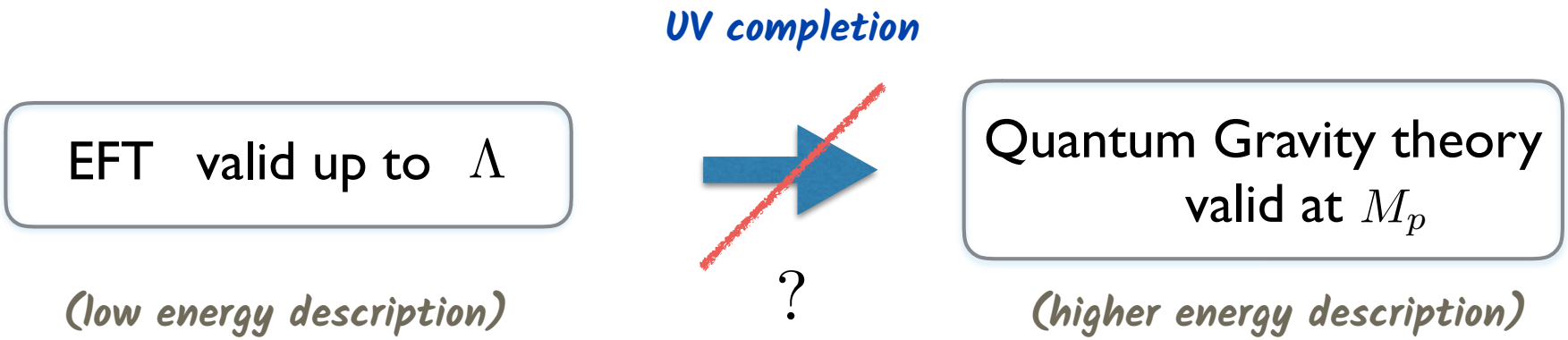
I am going to focus on the progress made in the past two years since Reece's review talk at Strings 2019…

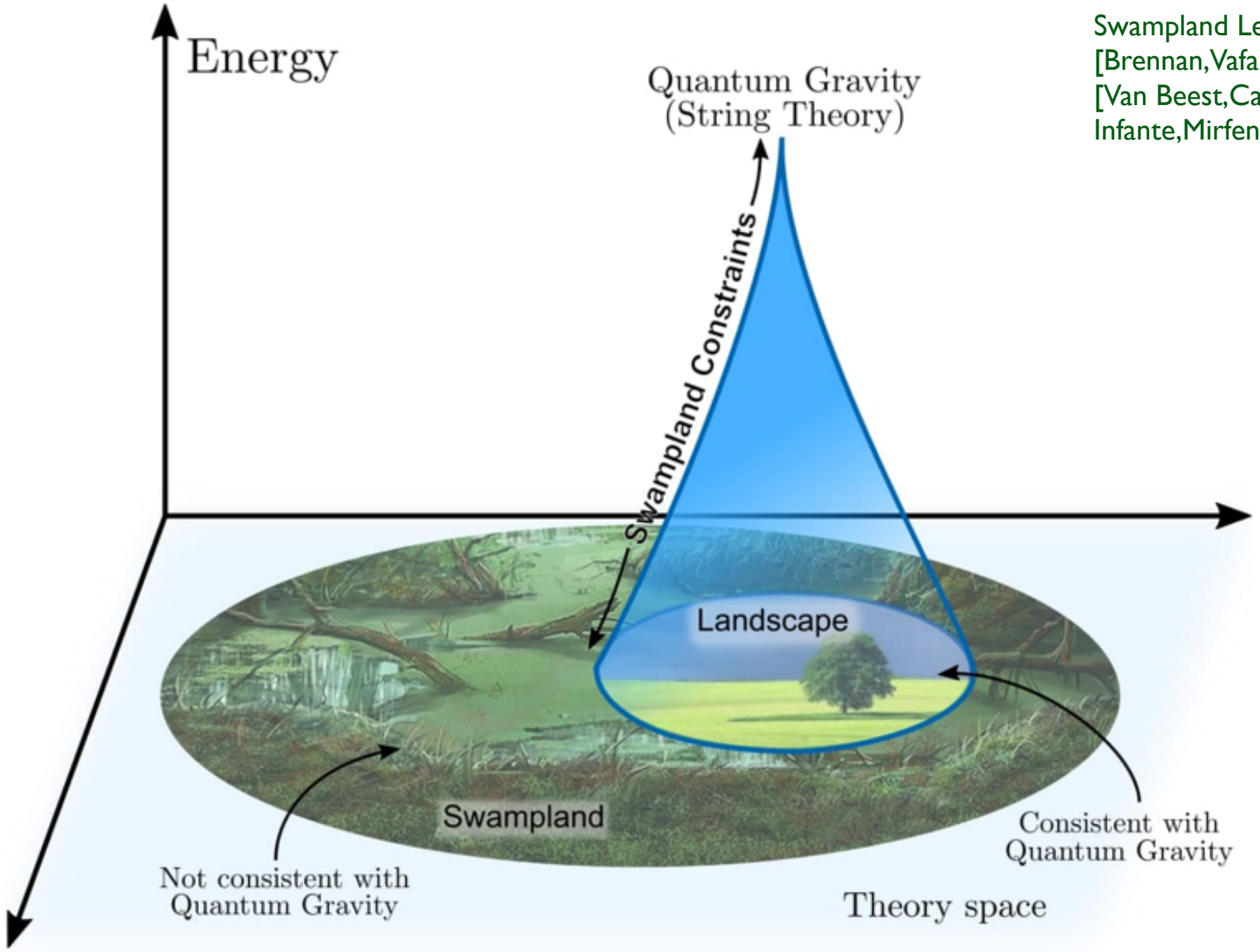
The Big Question

What Effective Field Theories (EFTs) weakly coupled to Einstein gravity can be UV completed in quantum gravity?



Not every EFT can be UV completed in a Quantum Gravity theory unless it satisfies additional constraints (beyond anomaly cancellation)

Swampland Lectures/Reviews:
[Brennan,Vafa'17] [Palti'19]
[Van Beest,Calderon-Infante,Mirfendereski,IV'21]



Swampland: Apparently consistent (anomaly-free) EFTs that cannot be UV completed in quantum gravity

[Vafa'05]

(they cannot arise as low energy limits of string theory)

Goal of the Swampland program:

What are the constraints that a low energy EFT must satisfy to be consistent with quantum gravity?

What distinguishes the landscape from the swampland?

→ UV imprint of quantum gravity at low energies

Proposals: **Swampland Conjectures**

Motivated by String Theory as well as Black Hole physics

Two years ago…

Completeness hypothesis

No global symmetries

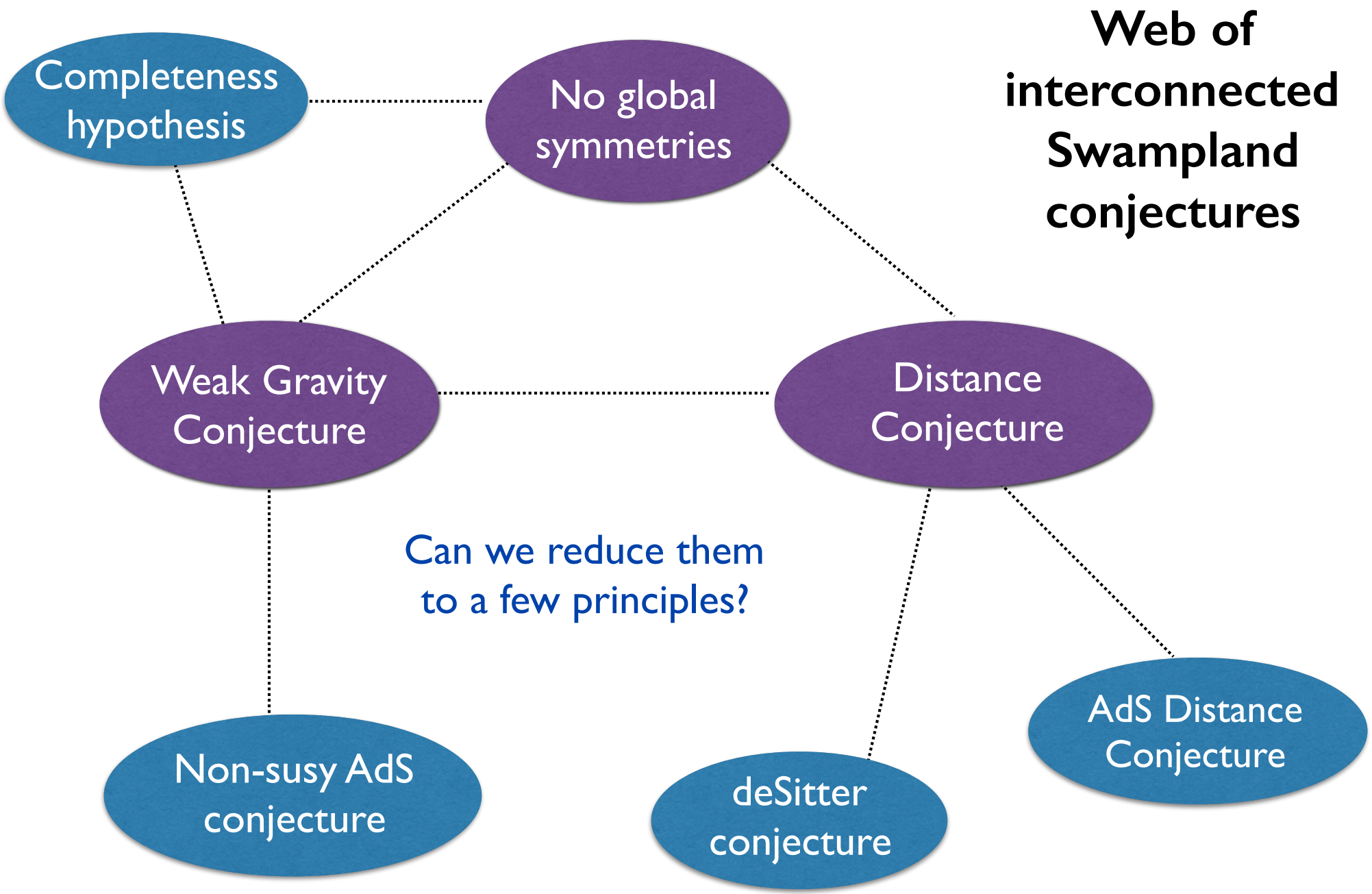
Weak Gravity Conjecture

Distance Conjecture

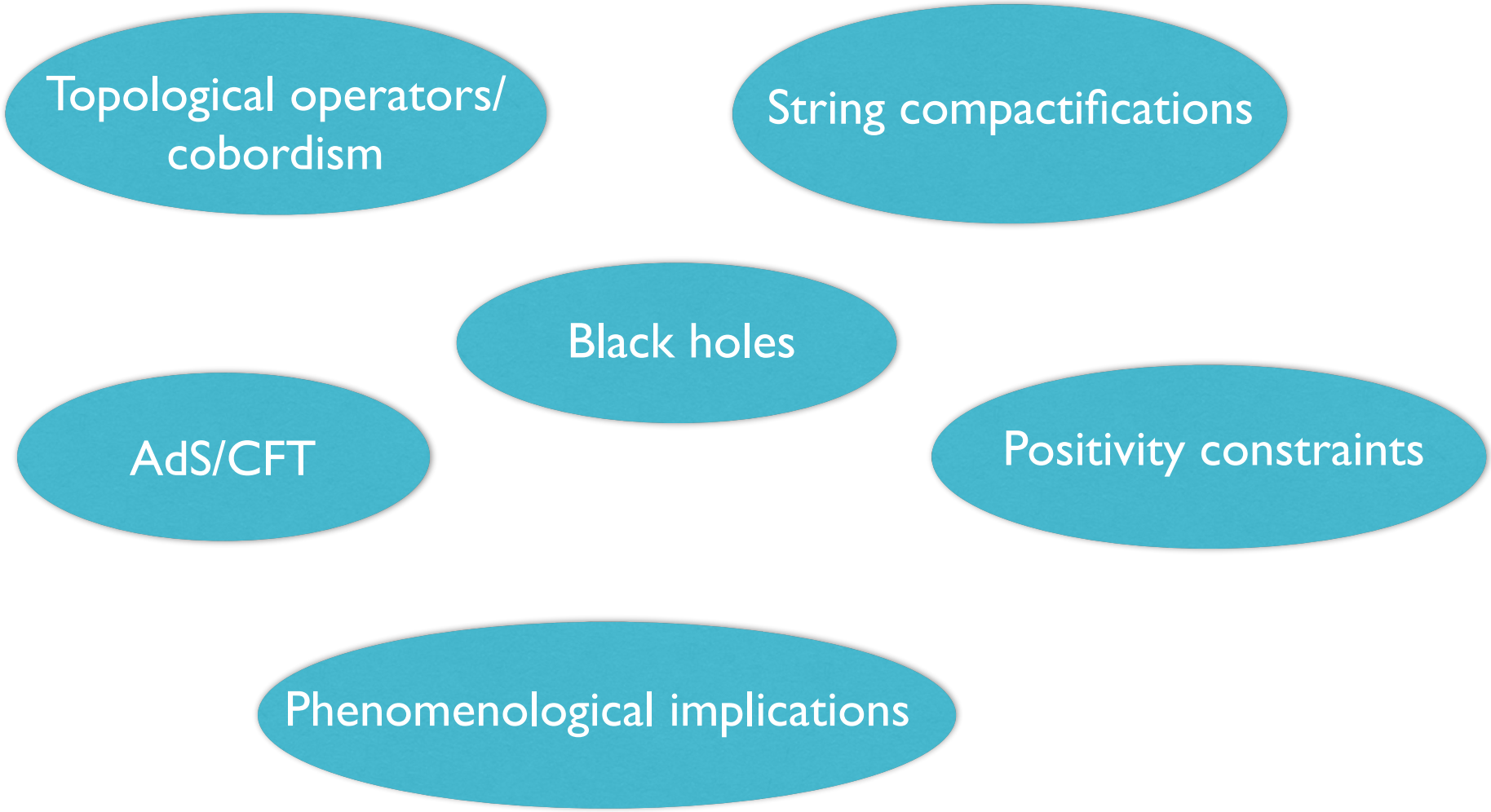
AdS Distance Conjecture

Non-susy AdS conjecture

deSitter conjecture


Web of interconnected Swampland conjectures
Completeness hypothesis
No global symmetries
Weak Gravity Conjecture
Distance Conjecture
Can we reduce them to a few principles?
Non-susy AdS conjecture
deSitter conjecture
AdS Distance Conjecture

Approaches


Topological operators/ cobordism
String compactifications
Black holes
AdS/CFT
Positivity constraints
Phenomenological implications

Approaches

Topological operators/
cobordism

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Outline

1) Topological operators/ cobordism

2) String compactifications

3) AdS/CFT

4) Positivity constraints

5) Black holes

6) Phenomenological implications

Outline

1) **Topological operators/ cobordism**
2) String compactifications
3) AdS/CFT
4) Positivity constraints
5) Black holes
6) Phenomenological implications

No global symmetries

Any global symmetry must be broken or gauged in quantum gravity

[Banks-Dixon'88] [Horowitz,Strominger,…] [Susskind] [Banks,Seiberg'11]

New zoo of generalised global symmetries to explore! See Shao's review talk

We can learn a lot not only from the presence but the absence of these symmetries

Goal: understand mechanisms by which QG avoids all these symmetries

Example: [Heidenreich,McNamara,Montero,Reece,Rudelius,IV'20]

- existence of axions and Chern-Simons terms
- localised degrees of freedom in monopole worldvolume
- branes dissolving or ending on branes

→ *consequences of avoiding Chern-Weil symmetries*

$$J = F \qquad J = F_p \wedge H_q \qquad J = tr(F \wedge F \wedge F \ldots) \qquad J = F \wedge d\phi$$

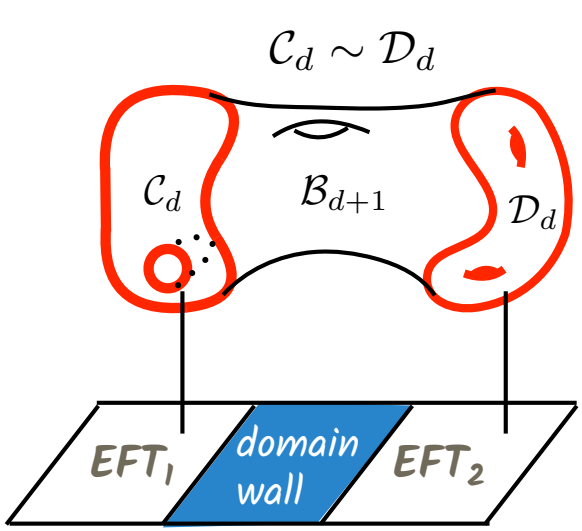
Cobordism conjecture

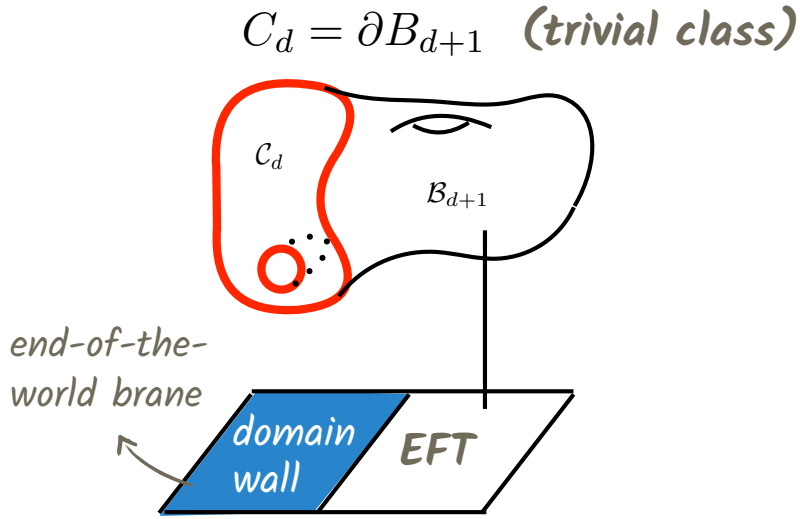
The cobordism group of a quantum gravity theory must be trivial:

$$\Omega_k^{QG} = 0$$ [McNamara,Vafa'19]

k : internal dimension
D : total dimension

to avoid a (D-k-1)-form global symmetry with charges $[M] \in \Omega_k^{QG}$





It implies all theories of same dimension are connected by finite energy domain walls, and predicts the existence of new defects in string theory!

String universality / String lamppost principle

Goal: Show that any EFT consistent with quantum gravity arises from string theory

Approach: Use swampland constraints (+ anomaly cancellation, supersymmetry…) to classify the possible EFTs and check against string theory

N=1 d>6 (16 supercharges) [Hamada,Vafa'21] [Font et al'20-21] [Cvetic et al'20] [Dierigl,Heckman'20] [Montero,Vafa'20] [Kim,Shiu,Vafa'19] …[Adams et al'10….]

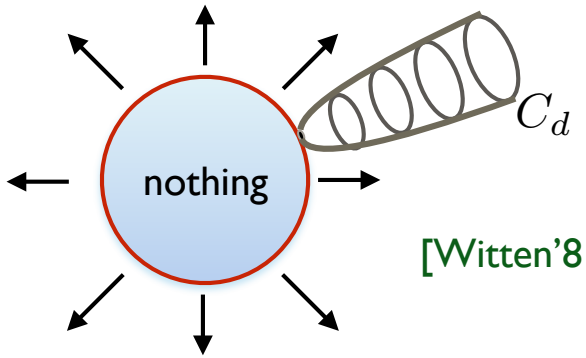
N=1 d=5,6 (8 supercharges) [Katz,Kim,Tarazi,Vafa'20] [Kim,Tarazi,Vafa'19] [Lee,Weigand'19]

See Vafa's and Graña's talk

and discussion by Cvetic and Shiu

Bubbles of nothing

Non-perturbative instability
from the vacuum to nothing:



[Witten'81]

It is topologically allowed if:

The compact space C_d shrinks to a point

i.e. $C_d = \partial B_{d+1}$

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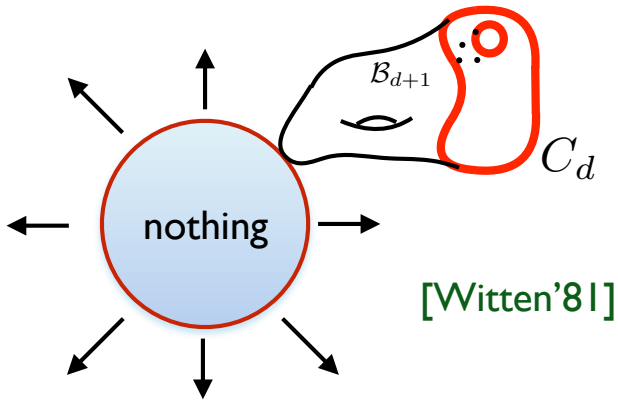


[Witten'81]

It is topologically allowed if:

The compact space C_d shrinks to a point $\Leftrightarrow$ C_d belongs to trivial class of Ω_d

i.e. $C_d = \partial B_{d+1}$

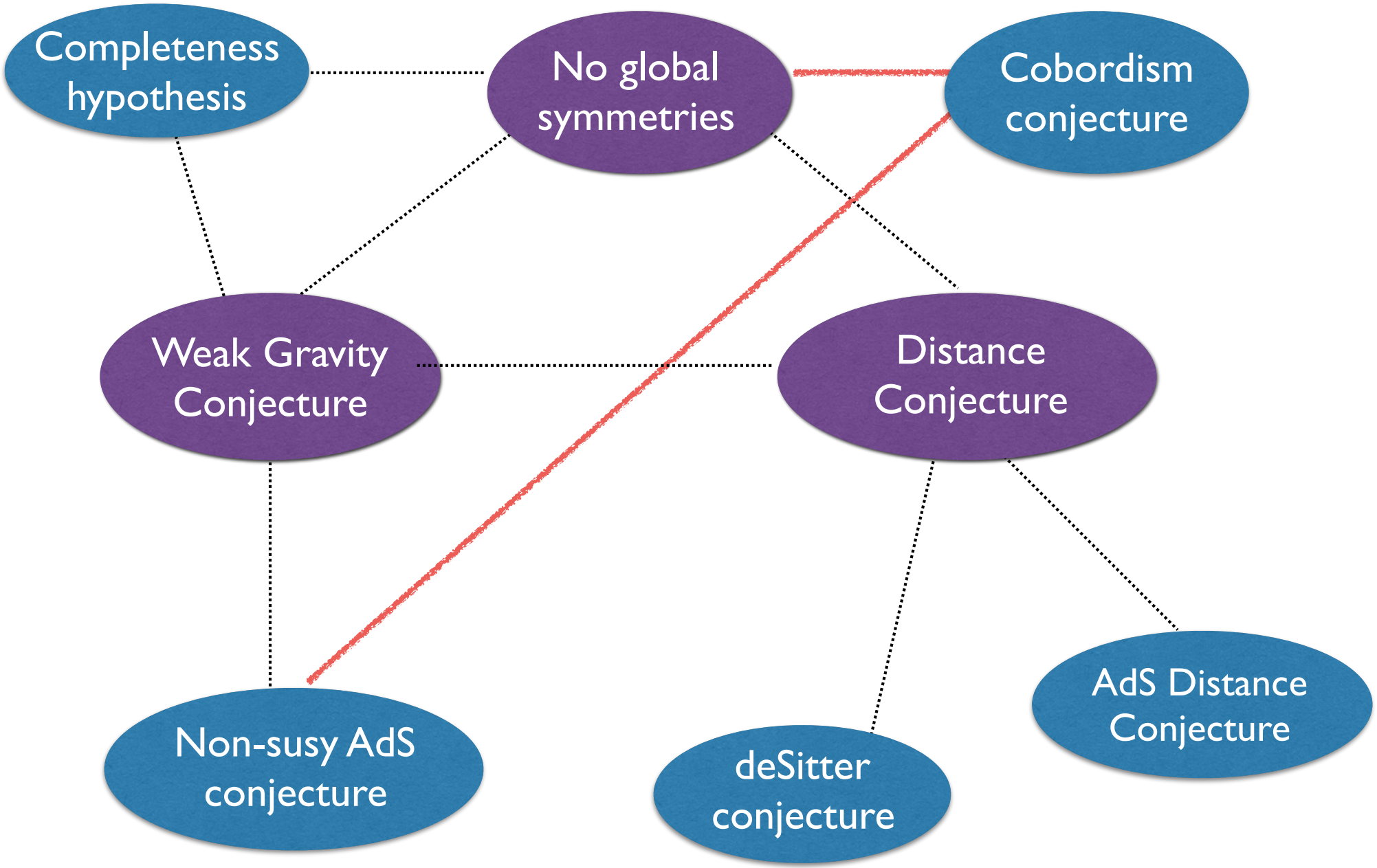
Cobordism conjecture:
$\Omega_k^{QG} = 0$ → No topological obstruction to have bubbles of nothing !!

[Garcia-Etxebarria,Montero,Sousa,IV'20]

They will expand and describe a vacuum instability if a certain energy condition (DEC) is violated semiclassically

(which can happen when supersymmetry is broken)

(see [Draper et al'21] for more BON and [Buratti et al'21] for relation between them and dynamical tadpoles)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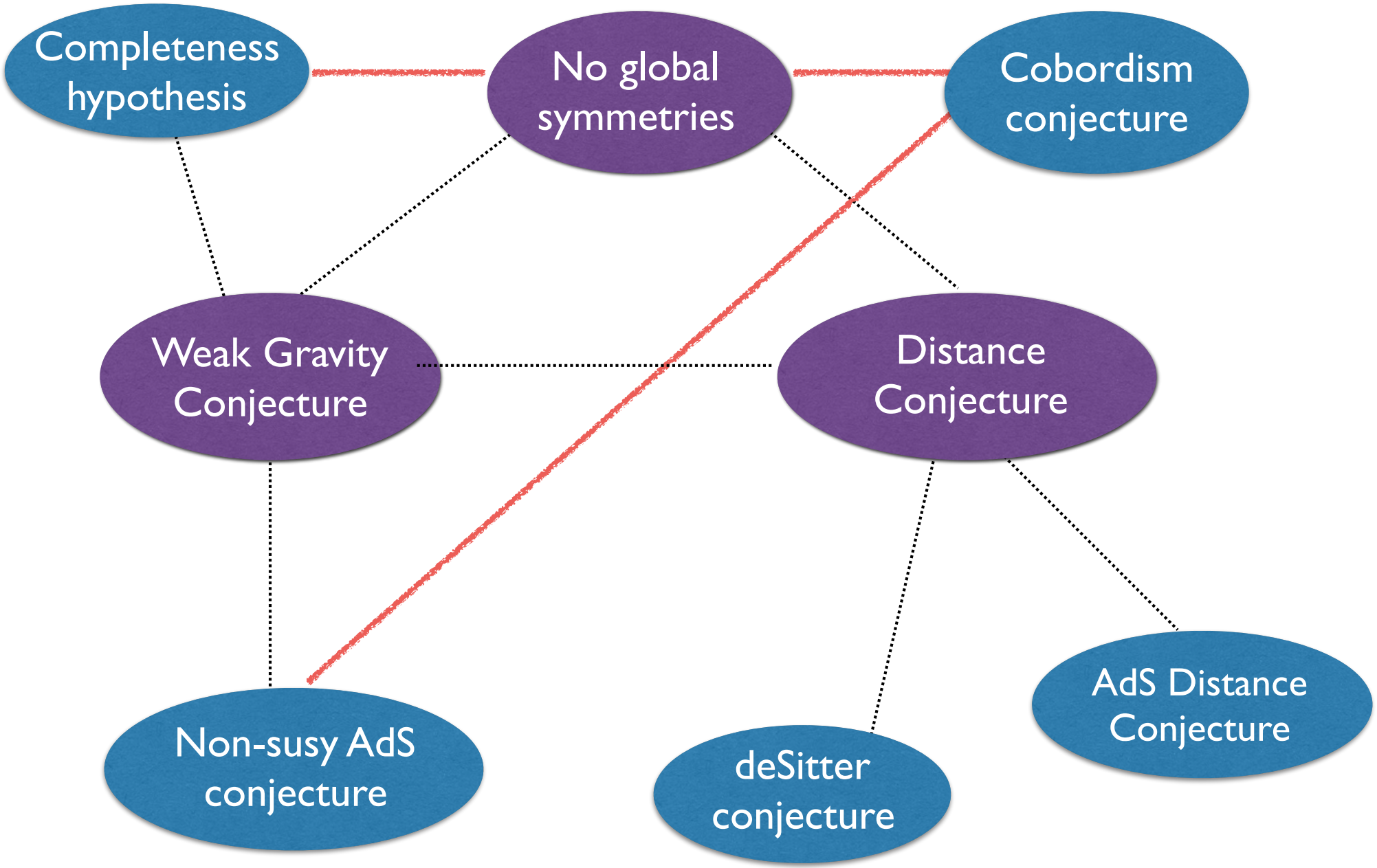
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Completeness Hypothesis

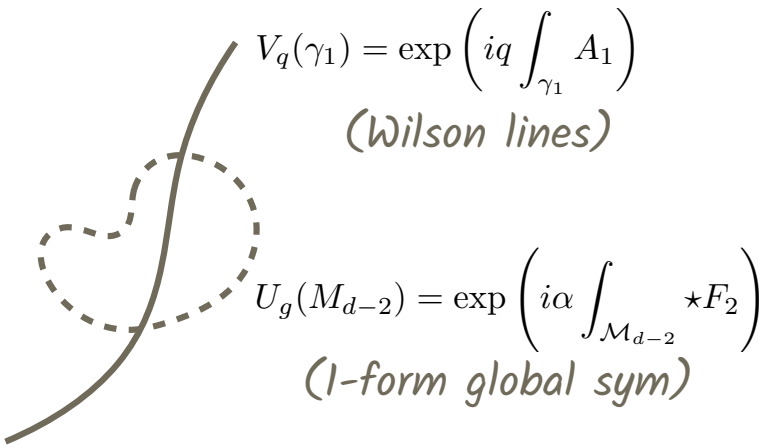
There are physical charged states in all representations of gauge group consistent with Dirac quantisation [Polchinski, Dirac…]

Does it follow from the absence of global symmetries?

No global symmetries = *No topological operators*

Complete spectrum = *All charged operators can end*

example: Maxwell theory



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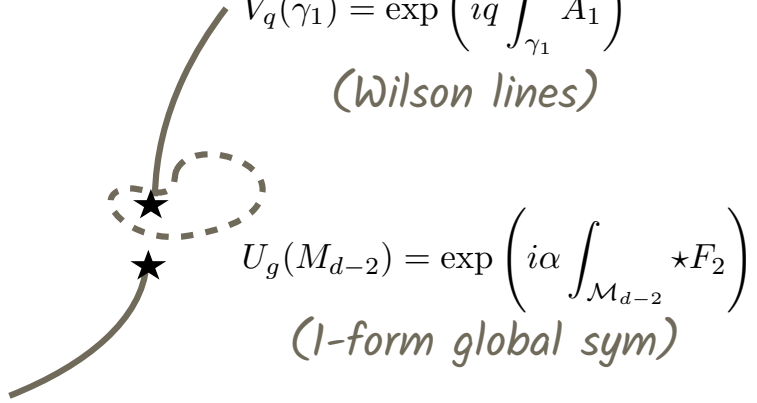
$$V_q(\gamma_1) = \exp\left(iq\int_{\gamma_1} A_1\right)$$

(Wilson lines)

$$U_g(M_{d-2}) = \exp\left(i\alpha\int_{\mathcal{M}_{d-2}} \star F_2\right)$$

(1-form global sym)



[Gaiotto, Kapustin, Seiberg, Willett'14]

The symmetry operator U_g is not topological if links non-trivially with an endable charged Wilson line

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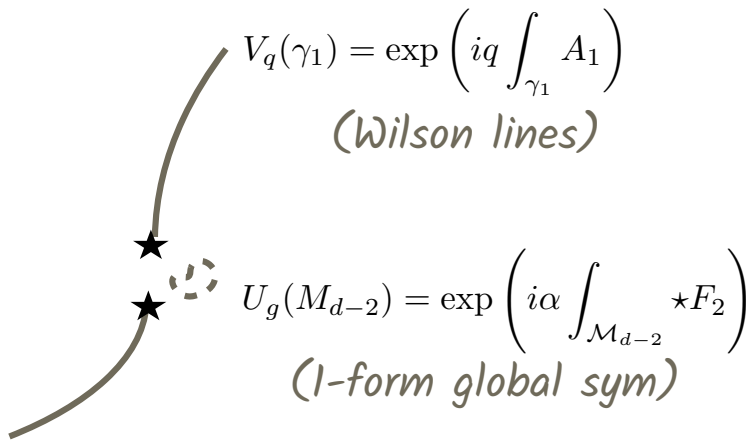

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(1-form global symmetry gets fully broken in the presence of a complete spectrum of charged particles)

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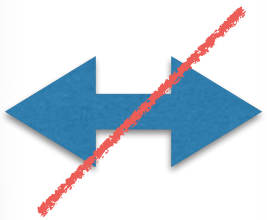
Does it follow from the absence of global symmetries?

No topological operators
(no global symmetries)



All extended charged operators can end
(complete spectrum)

not for discrete or disconnected groups

Completeness Hypothesis

There are physical charged states in all representations of gauge group consistent with Dirac quantisation [Polchinski, Dirac…]

Does it follow from the absence of global symmetries?

No topological (possibly non-invertible) operators

(no non-invertible global symmetries)

All extended charged operators can end

(complete spectrum)

Proven for:

See Shao's review talk

- *Discrete gauge symmetries in 3d TQFT* [Rudelius,Shao'20]
- *Electric symmetries for general compact gauge groups only coupled to matter* [Heidenreich,McNamara,Montero,Reece,Rudelius,IV'21]
- *(d-2)-form symmetries for general compact gauge groups only coupled to twist vortices*

No topological operators

Maybe *No global symmetries conjecture* should be replaced by

No topological operators in quantum gravity

(or more generally, no cobordism classes…)

Why?

Topology itself is dynamical in quantum gravity

It connects with recent developments to prove the absence of global symmetries

based on unitary black hole evaporation

➡ Recent derivation of unitary Page curve forbids global symmetries

[Harlow,Shaghoulian '20] (similar argument than in AdS/CFT [Harlow,Ooguri'18])

They are violated by replica wormholes (non-perturbative effects)

[Hsin et al '20] [Chen,Lin '20]

and more generally, by topology changing processes [Yonekura '20]

Outline

1) Topological operators/ cobordism

Approximate global symmetries

2) String compactifications

3) AdS/CFT

4) Positivity constraints

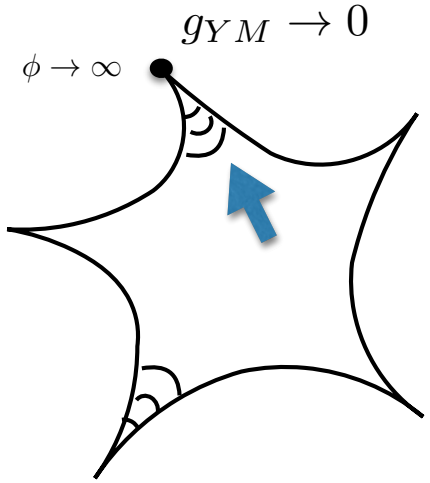
5) Black holes

6) Phenomenological implications

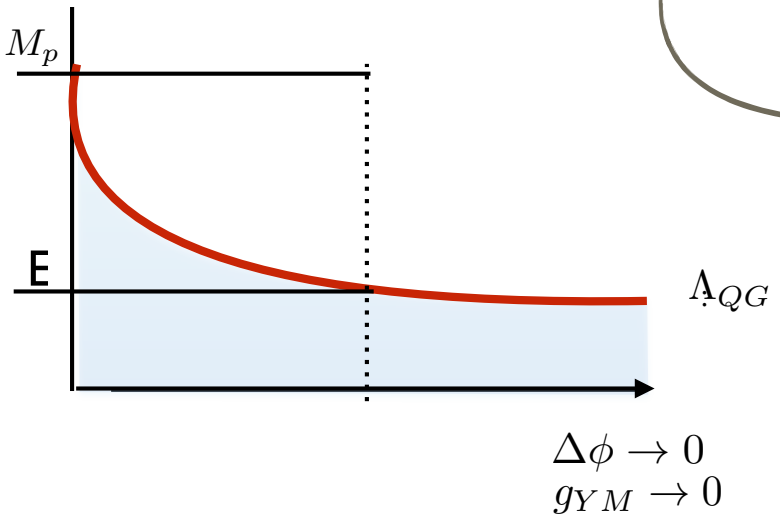
Approximate global symmetries

Can we quantify how close we can get to restoring a global symmetry?

Global symmetries get restored at infinite field distance



The EFT breaks down when approaching an infinite distance boundary of the field space



UV cut-off should go to zero

How? *Distance Conjecture*
Weak Gravity Conjecture

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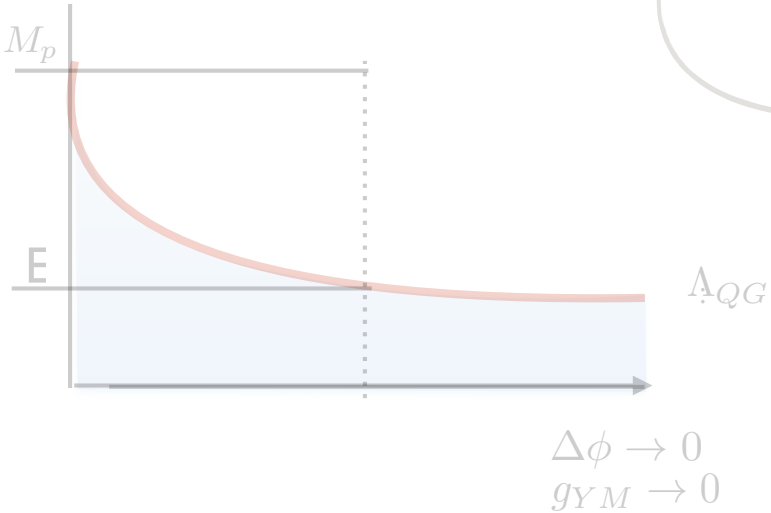

UV cut-off should go to zero

(Swampland) Distance Conjecture:

There is an infinite tower of states becoming exponentially light at every infinite field distance limit of the moduli space

$$m(P) \sim m(Q)e^{-\alpha\Delta\phi} \quad \text{when} \quad \Delta\phi \to \infty$$

(geodesic distance)

[Ooguri-Vafa'06]

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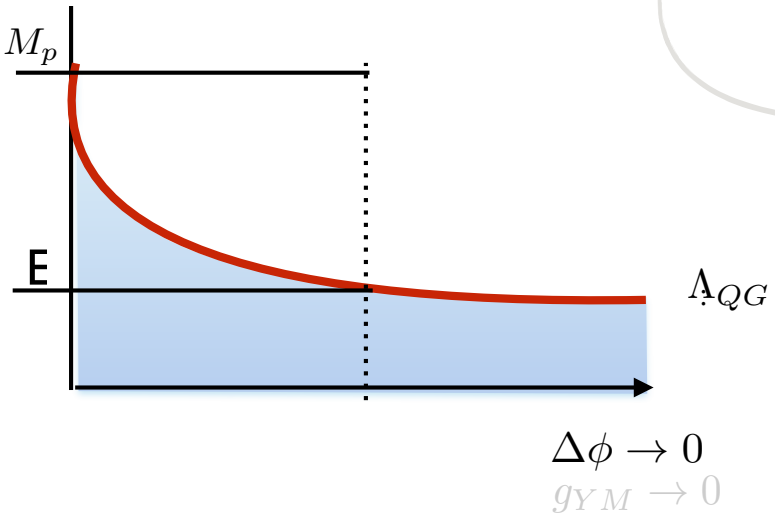

$$\Lambda_{QG} \sim M_p \exp(-\alpha \Delta\phi)$$

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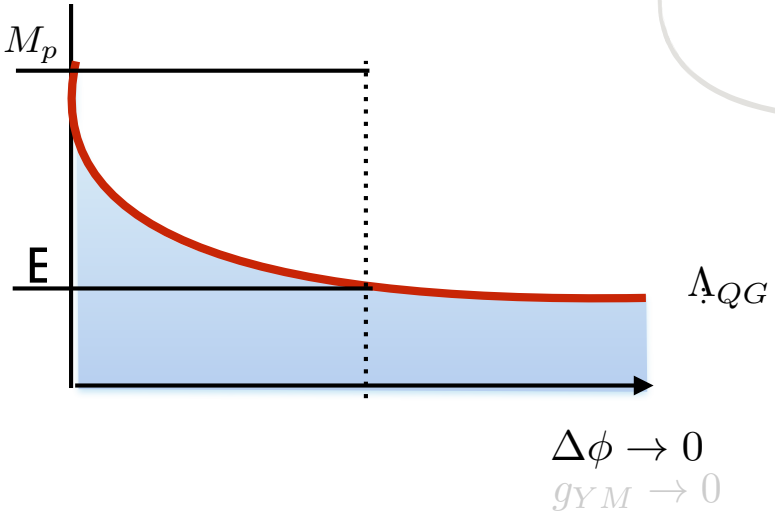
Upper bound on field range:

$$\Delta\phi \lesssim \frac{1}{\alpha} \log\left(\frac{M_p}{\Lambda}\right)$$

$$\alpha \sim \mathcal{O}(1) \quad ??$$



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(geodesic distance)

[Arkani-Hamed et al.'06]

Weak Gravity Conjecture (WGC):

Given a gauge theory, there must exist an electrically charged state with

$$\frac{Q}{M} \geq \left(\frac{Q}{M}\right)_{\text{extremal}} = \mathcal{O}(1)$$

Q=q g : charge
m : mass in Planck units

Strong version: *there is a sublattice/tower of superextremal states*

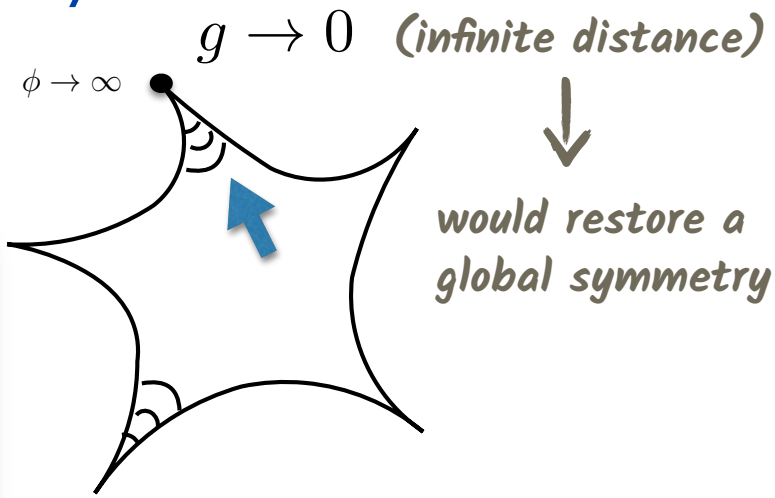
[Montero et al.'16][Heidenreich et al.'15-16][Andriolo et al'18]

UV cut-off should go to zero

How? Distance Conjecture
Weak Gravity Conjecture

Approximate global symmetries

Can we quantify how close we can get to the situation of restoring a global symmetry?



Global symmetries get restored at

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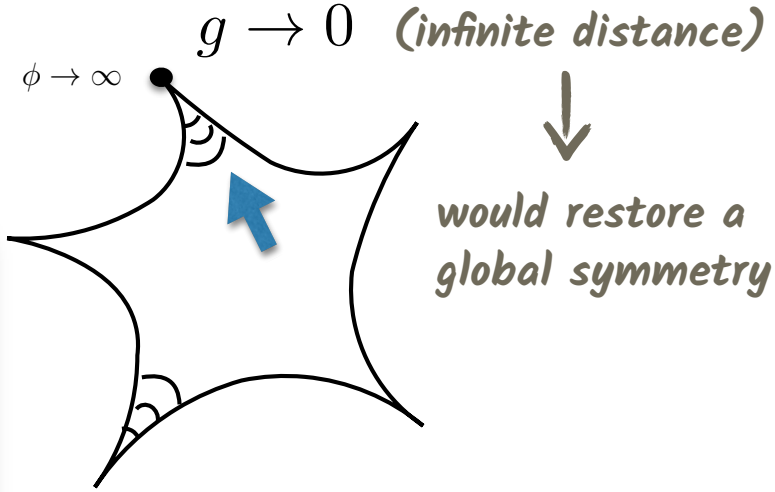

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UV cut-off should go to zero

How? *Distance Conjecture*
Weak Gravity Conjecture

Approximate global symmetries,
Weakly coupled gauge theories,
Large field ranges…

…come at a price.

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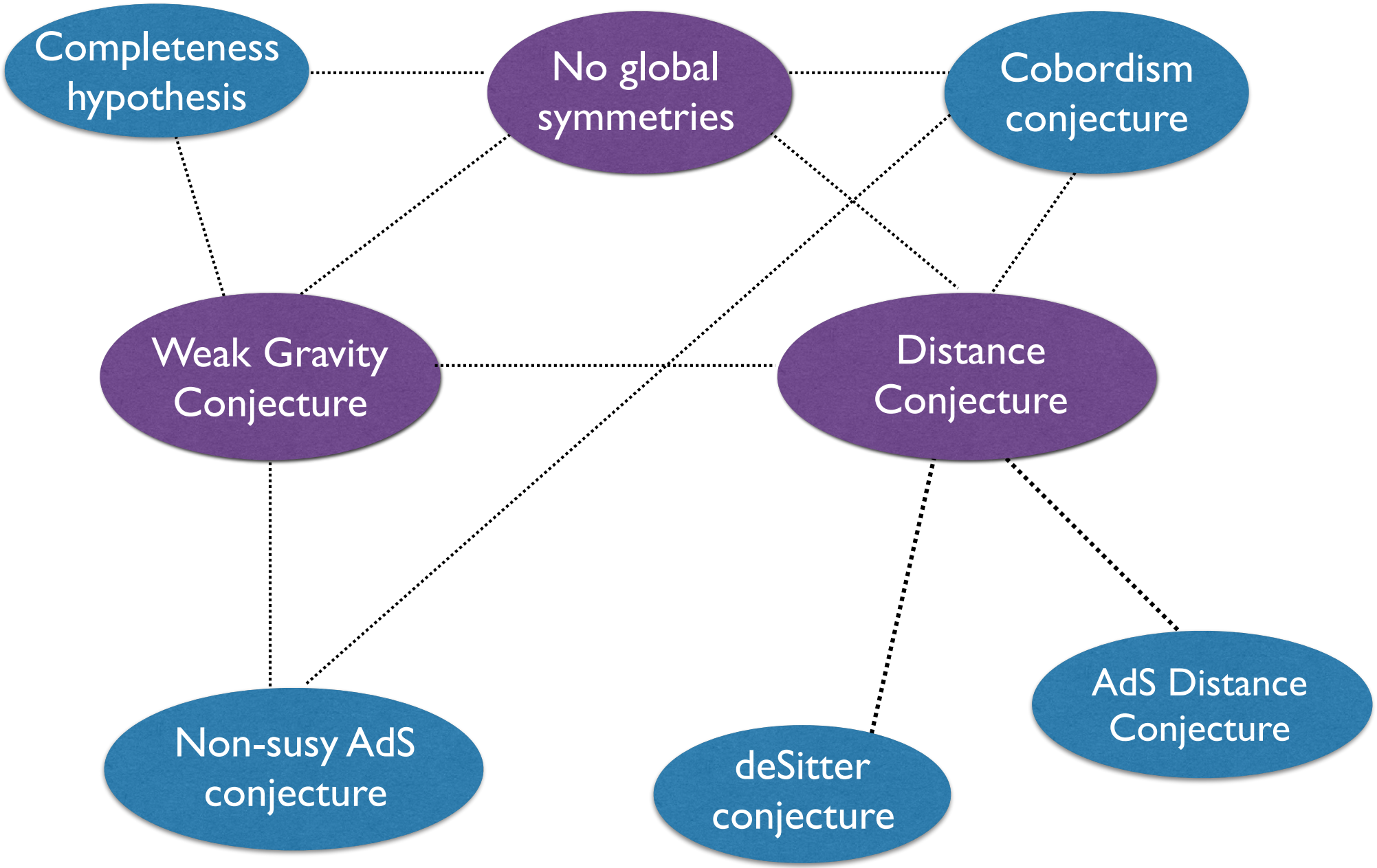
new light states imply

UV cut-off should go to zero

Universal patterns on the EFT at ***every*** *asymptotic limit*

(not just small string coupling!)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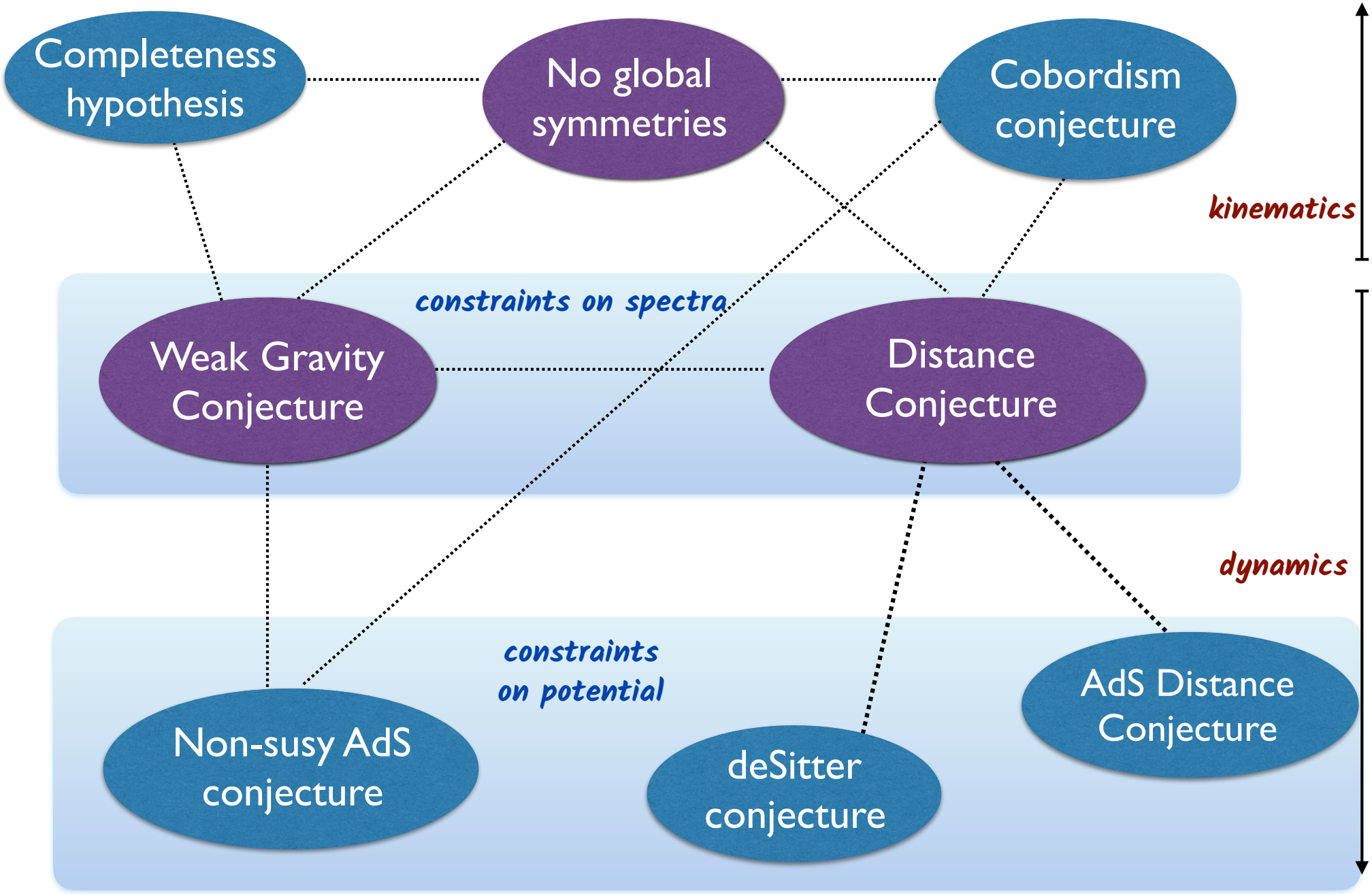
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Cobordism conjecture
kinematics
constraints on spectra
Weak Gravity Conjecture
Distance Conjecture
dynamics
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AdS Distance Conjecture

Outline

1) Topological operators/ cobordism

2) String compactifications

3) AdS/CFT

4) Positivity constraints

5) Black holes

6) Phenomenological implications

String compactifications

Rigorous tests in string compactifications:

- To sharpen the conjectures and fix "order one factors"

  e.g. concrete lower bounds for exponential rate of the tower

  $$\alpha \geq \frac{1}{\sqrt{6}} \text{ for } \mathrm{CY}_3$$ (fixed by discrete monodromy symmetries) [Grimm, Palti, IV'18] [Gendler,IV'20] [Bastian et al'20]

- It unveils universal geometric properties of compactification manifolds and interesting connections with mathematics

  - *Systematic classification of infinite distance singularities in Calabi-Yau manifolds using Mixed Hodge Structures* [Grimm, Palti, IV'18] [Grimm,Palti,Li'18] [Grimm et al'19] [Bastian et al'20]
  - *Moduli space holography?* [Cecotti,'20-21] [Grimm'20-21]
  - *Connections between algebraic geometry of CY's and modular properties of quasi-Jacobi forms* [Lee,Lerche,Weigand'18-20] [Brodie et al'21]
  - *Infinite flop chains in M-theory on CY3 (SDC -> Kawamata-Morrison conjecture)*

String compactifications

Identification of towers of states at infinite distance limits:

(Confirmation of both SDC and WGC)

☑ More than 8 supercharges: $\mathcal{M} = G/H$ [Cecotti'15]

☑ Theories with 8 supercharges:

- *4d N=2 theories: Calabi-Yau compactifications of Type II* [Grimm, Palti, IV'18] [Grimm,Palti,Li'18] [Baume et al'19] [Corvilain, Grimm, IV'18] [Lee,Lerche,Weigand'18-'19]
- *5d/6d N=1 theories: F-theory CY compactifications* [Gendler,IV'20] [Heidenreich,Rudelius'20] [Fierro Cota et al'20] [Ashmore,Ruehle'21]

☐ 4 supercharges: 4d N=1 EFTs *recent progress!*

[Klaewer et al'20] [Lanza,Marchesano,Martucci,IV'20-21] [Enriquez-Rojo et al'20]

(see [Basile et al'20][Angelantonj et al'20][Argurio et al'20] for checks of the swampland conjectures in non-supersymmetric setups)

String compactifications

4d N=1 EFTs: All examples point to the universal presence of a weakly coupled BPS axionic string becoming tensionless at infinite distance

(i.e. there is an axionic shift symmetry restored asymptotically)

➡ Bottom-up derivation of SDC if string satisfies WGC

(from mapping infinite distance limits to RG flow endpoints triggered by strings)

[Lanza,Marchesano,Martucci,IV'20-21]

➡ Leading tower: $m_{KK}^2 \simeq M_p (T_s/M_p)^w$ $w = 1, 2, 3$ in examples

very constrained SDC exponential rate! *why?*

possible dualities?

Consistent with Emergent string conjecture: [Lee,Lerche,Weigand'19]

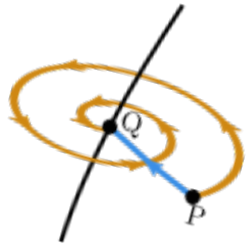
every infinite distance limit is either decompactification or string perturbative limit

Checked in [Klaewer et al'20] [Xu'20] [Lee et al'20] [Baume et al'19] ….

String compactifications

What if there is a scalar potential?

Do the valleys of the potential still satisfy SDC?



(notice they are not geodesics from UV perspective but axion monodromy trajectories)

- they should by consistency of SDC at any energy scale, which puts constraints on potentials consistent with quantum gravity

[Ooguri-Vafa'06] [Klaewer,Palti'16] [Calderon-Infante, Uranga, IV '20]

- they do in Calabi-Yau flux compactifications

(they exhibit the maximum level of non-geodesicity still compatible with SDC)

[Baume,Palti'16] [I.V.,'16] … [Grimm,Li,IV'19] [Calderon-Infante, Uranga, IV '20] [Grimm,Li'20]

String compactifications

Other swampland-related questions: *(all these issues are not settled yet)*

- **Scale separation in AdS**

- **de Sitter**

String compactifications

Other swampland-related questions: *(all these issues are not settled yet)*

- **Scale separation in AdS**

[Luest,Palti,Vafa'19]

AdS Distance conjecture: Flat space limit is at infinite distance, so there should be at infinite tower of states scaling as $m \sim \Lambda^{\alpha}$

$AdS_d \times X_p$ *Strong version:* $\alpha \geq 1/2$ *(no scale separation)*

This has triggered research in string constructions:

[De Luca et al,Tomasiello'21][Bernardo et al'21][Lavdas et al'20][Luest et al'20][Font et al'19]…

Potential counterexamples to strong version (but that satisfy mild version):

[Farakos et al'20] AdS_3 from massive Type IIA on G2 *with smeared orientifolds*

[De Wolfe et al'05] AdS_4 from massive Type IIA on CY3

New developments on the 10d uplift [Marchesano et al'20] [Junghans'20]

String compactifications

Other swampland-related questions: *(all these issues are not settled yet)*

- **de Sitter**

[Farakos et al'20][Andriot'21][Ishiguro et al'21][Shukla'21]

1) Search for dS at parametric control at asymptotic limits *(not excluded!)*

Because sometimes the best way to find something is to find out where it is not...

String compactifications

Other swampland-related questions: *(all these issues are not settled yet)*

de Sitter

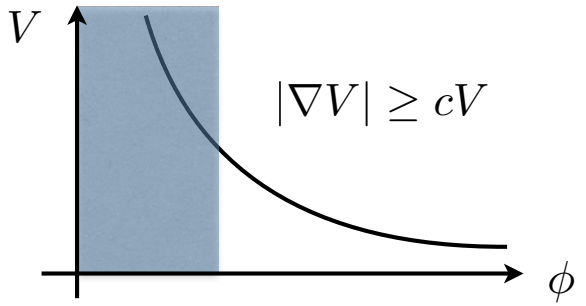
[Farakos et al'20][Andriot'21][Ishiguro et al'21][Shukla'21]

1) Search for dS at parametric control at asymptotic limits *(not excluded!)*

So far, there is a universal pattern:

➡ Runaway behaviour near every infinite distance boundary consistent with

Asymptotic de Sitter conjecture [Obied et al'18] [Ooguri et al'18]



- ✦ New no-go's for dS [Wrase,Junghans,Andriot… '18-19][Grimm et al'19] ⟶ *classification of V*
- ✦ Determine $c \sim \mathcal{O}(1)$ of dS conjecture [Andriot et al'20] [Bastian et al'20]
- ✦ Why is there a runaway?
  - triggered by the SDC tower [Ooguri,Palti,Shiu,Vafa'18]
  - consequence of membranes saturating WGC in 4d N=1 [Lanza et al'20] (also [Herraez'20])

(fluxes=membrane charges)

(see [Cribiori et al'20] for N=2 sugra)

String compactifications

Other swampland-related questions: *(all these issues are not settled yet)*

- **de Sitter**

  2) Beyond parametric control:

  KKLT and LVS *recent progress* [Gao et al'20] [Crino et al'20] [Demirtas et al'20] [Carta et al'21] [Hamada et al'21]

  not fully controlled global description yet, but not ruled out either...

  other recent proposed avenues: [De Luca,Silverstein,Torroba'21] [Bernardo et al'20]

  see discussions by Cvetic/Shiu and by Kachru/Quevedo

It might be that dS is forbidden asymptotically but allowed deeper in the bulk. How metastable can it be?

Proposal: Transplanckian Censorship Conjecture [Bedroya,Vafa'19]

dS lifetime: $\tau \leq \frac{1}{H} \log \frac{M_p}{H}$ *(short lived)*

see Bedroya's gong show talk

Outline

1) Topological operators/ cobordism

2) String compactifications

3) AdS/CFT

4) Positivity constraints

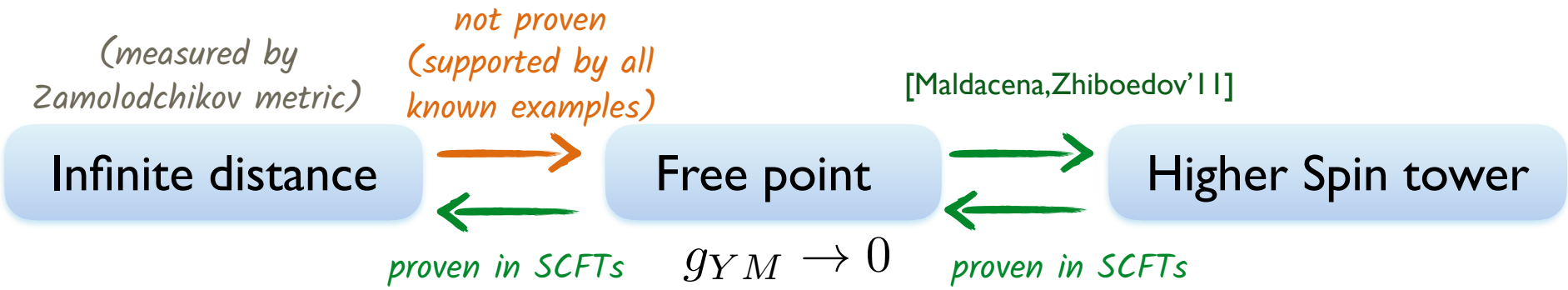
5) Black holes

6) Phenomenological implications

AdS/CFT

CFT Distance conjecture (for d>2 unitary CFTs with marginal operators)

[Perlmutter,Rastelli,Vafa,IV'20] (see also [Baume,Calderon-Infante'20])



$\exists$ tower of HS with $\gamma_J \sim e^{-\alpha d(\tau,\tau')}$ as $d(\tau,\tau') \to \infty$ in the conformal manifold

(implication: 3d conformal manifolds should be compact)

If there is a weakly coupled AdS dual, it implies a stronger version of SDC:

Infinite distance limits at fixed AdS_5 radius

$\Leftrightarrow$

Tower of higher spin fields with an exponential rate

$$\alpha = \sqrt{\frac{2c}{\dim G}}$$

gauge group getting free

Lower bound for α !

AdS/CFT

- CFT Distance conjecture: valid beyond Einstein gravity

To what extent swampland conjectures are valid beyond Einstein gravity?

Sometimes, they might hint deeper principles of quantum gravity

- Tests of WGC in non-holographic CFTs [Agarwal,Song'19] [Nakayama'20]

Outline

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Positivity constraints

Bounds on higher derivative terms of EFTs weakly coupled to gravity

from S-matrix bootstrap in 10d [Guerrieri et al'21]

from analiticity and Regge growth of S-matrix in 4d [Caron-Hout et al'21]

from unitarity and crossing in 4d [Bern et al'21]

(see also [Alberte et al'20] [Kundu'21][Noumi,Tokuda'21])

see Rastelli's review

WGC from positivity constraints on higher derivative corrections to BHs

- For Einstein-Maxwell: [Cheung et al'18][Hamada et al'18] … [Cremonini et al'19][Cano et al'19]

$$\frac{Q}{M} = 1 + \#(2\alpha_1 - \alpha_3) \overset{?}{>} 0$$

$\alpha_1 (F_{\mu\nu}F^{\mu\nu})^2$ $\qquad$ $\alpha_3 F_{\mu\nu}F_{\rho\sigma}W^{\mu\nu\rho\sigma}$

small BHs themselves satisfy WGC

(mild WGC)

- For Einstein-Maxwell-dilaton: [Loges,Noumi,Shiu'19-20]
- For Einstein-Maxwell-dilaton-axion: [Andriolo et al'20]

Unitarity + causality is not enough to show WGC unless additional UV structure is imposed (e.g. SL(2,Z) symmetry)

Black holes

Test WGC in Black hole solutions

Non-trivial checks adding higher derivative corrections or scalar fields

[Benakli et al'21,Li'21,Cvetic et al'21,Sadeghi et al'21,Cremonini et al'20,Mcinnes'21,Song et al'20,Melo et al'20,Aalsma et al'21…]

With scalars: superextremality $\neq$ repulsive force condition [Palti'17]

(gravity acts weaker) [Heidenreich et al'19]

Two different criteria for WGC?

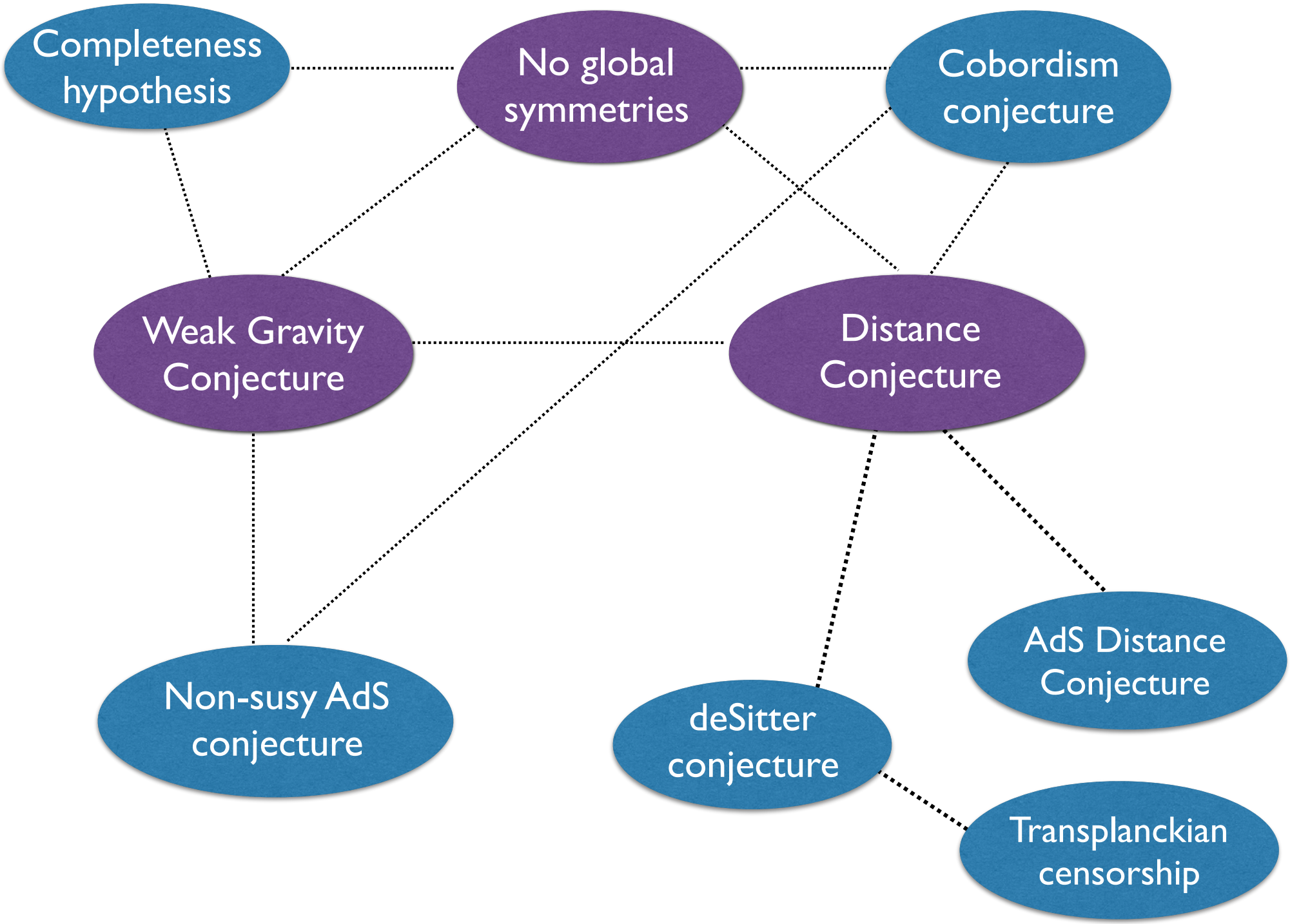
But the difference disappears for:

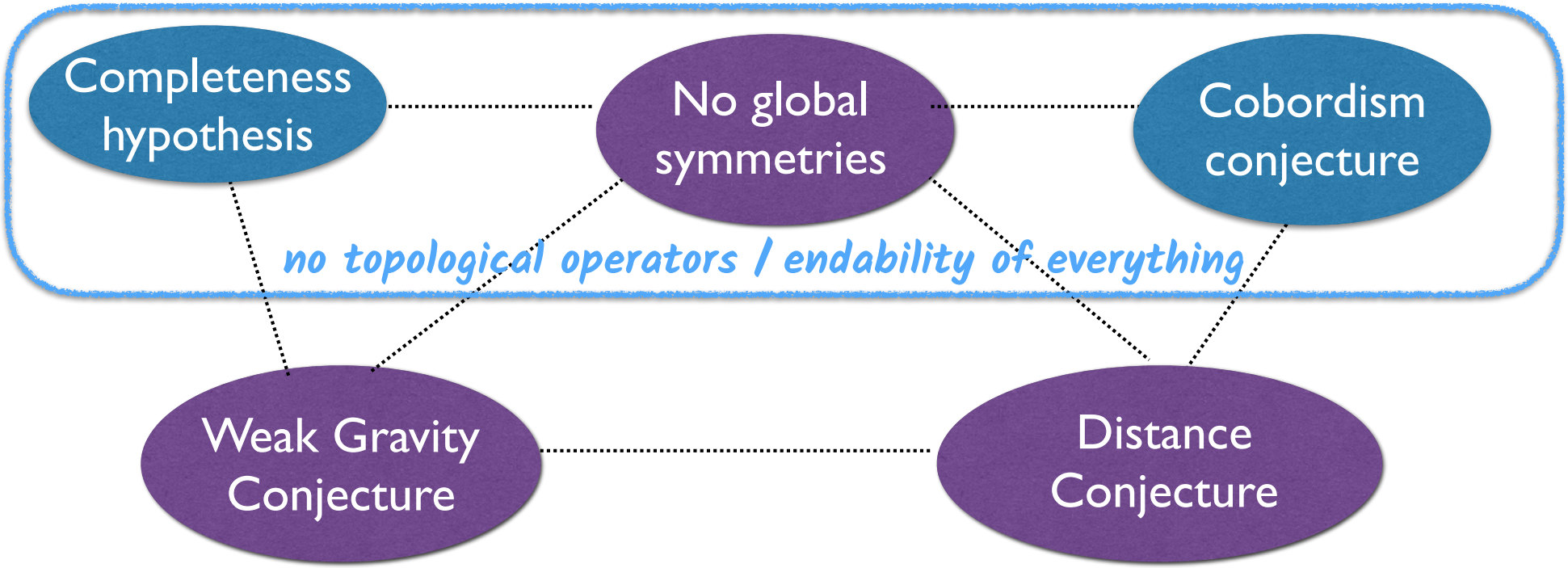
- Extremal black holes [Heidenreich'20][Van Riet'20]
- Tower of asymptotically massless states at the weak coupling limits [Lee et al'18][Gendler,IV'20]

Interplay with Distance conjecture:

Lower bound for exponential rate fixed in terms of black hole extremality bound! [Gendler,IV'20]

(whenever there is a vanishing p-form gauge coupling at infinite distance)


Completeness hypothesis
No global symmetries
Cobordism conjecture
Weak Gravity Conjecture
Distance Conjecture
Non-susy AdS conjecture
deSitter conjecture
AdS Distance Conjecture
Transplanckian censorship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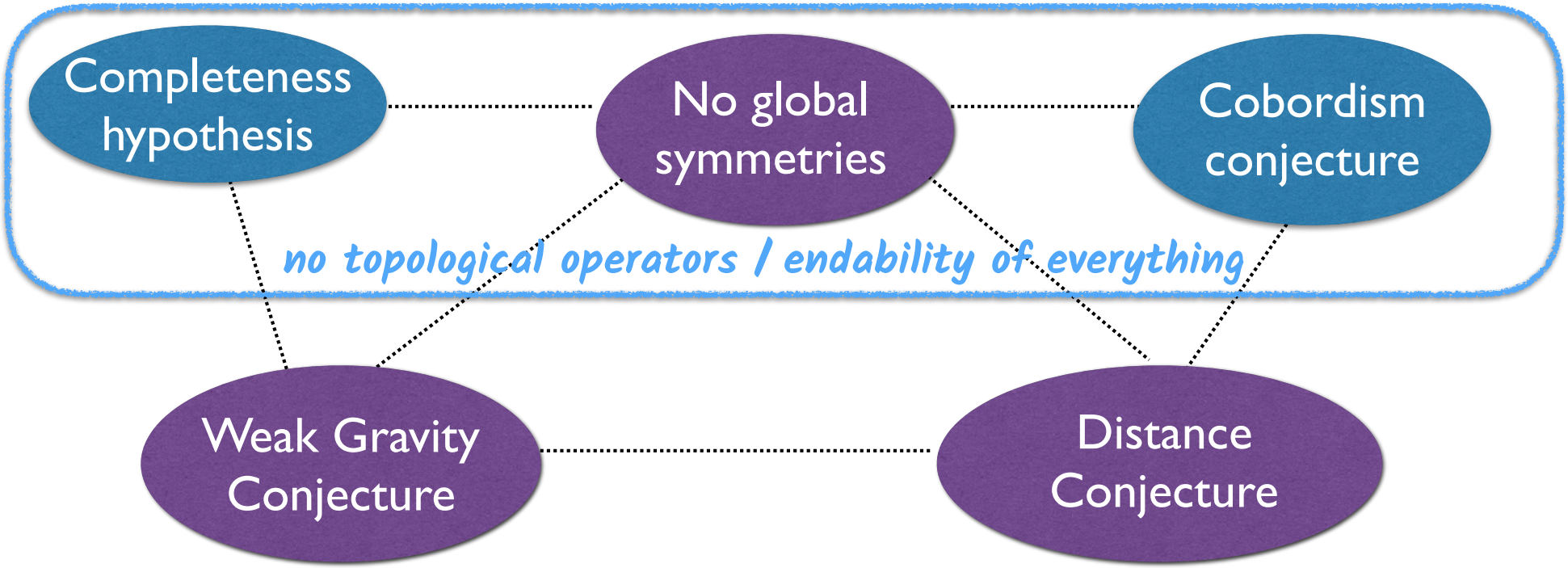
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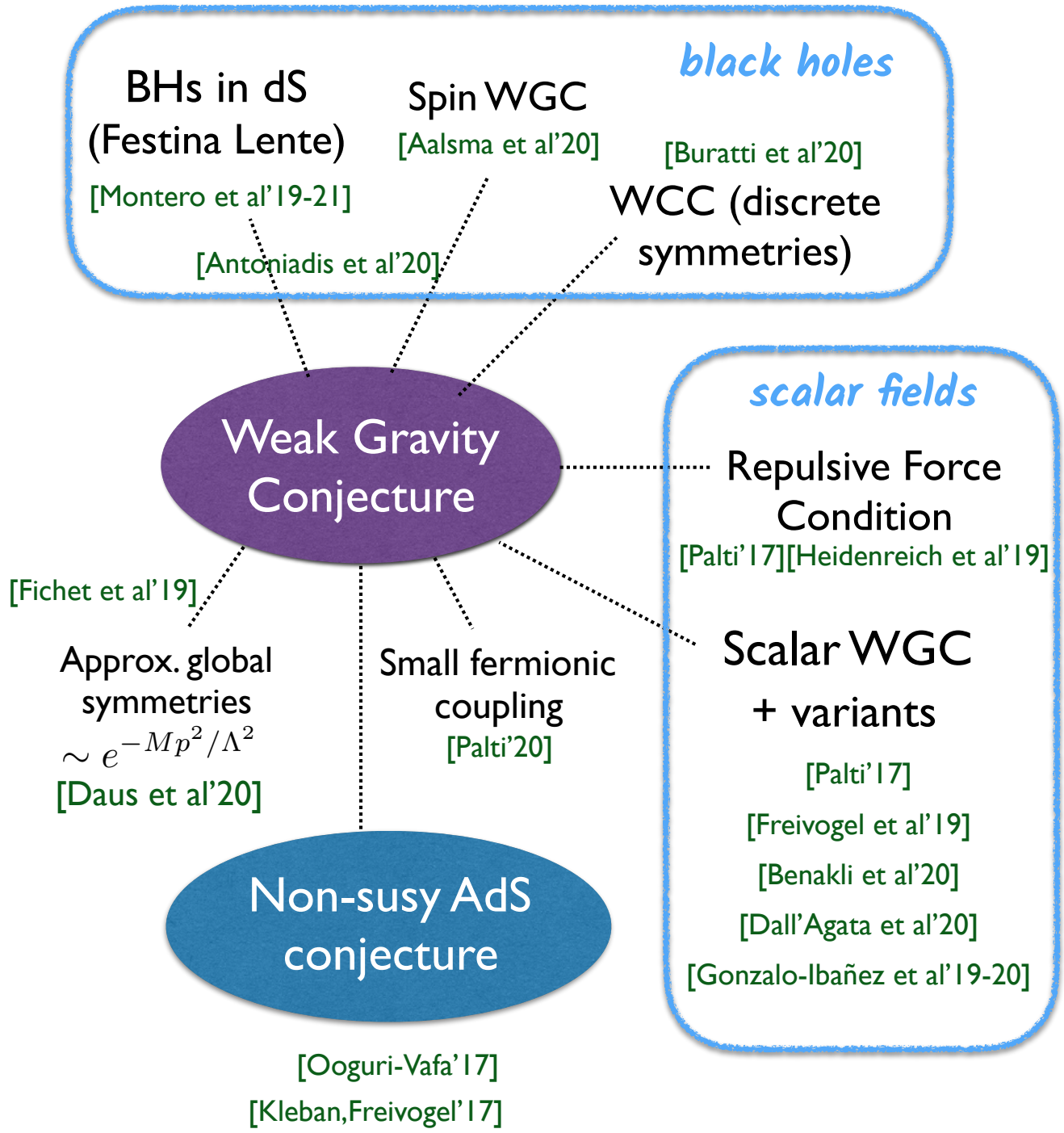
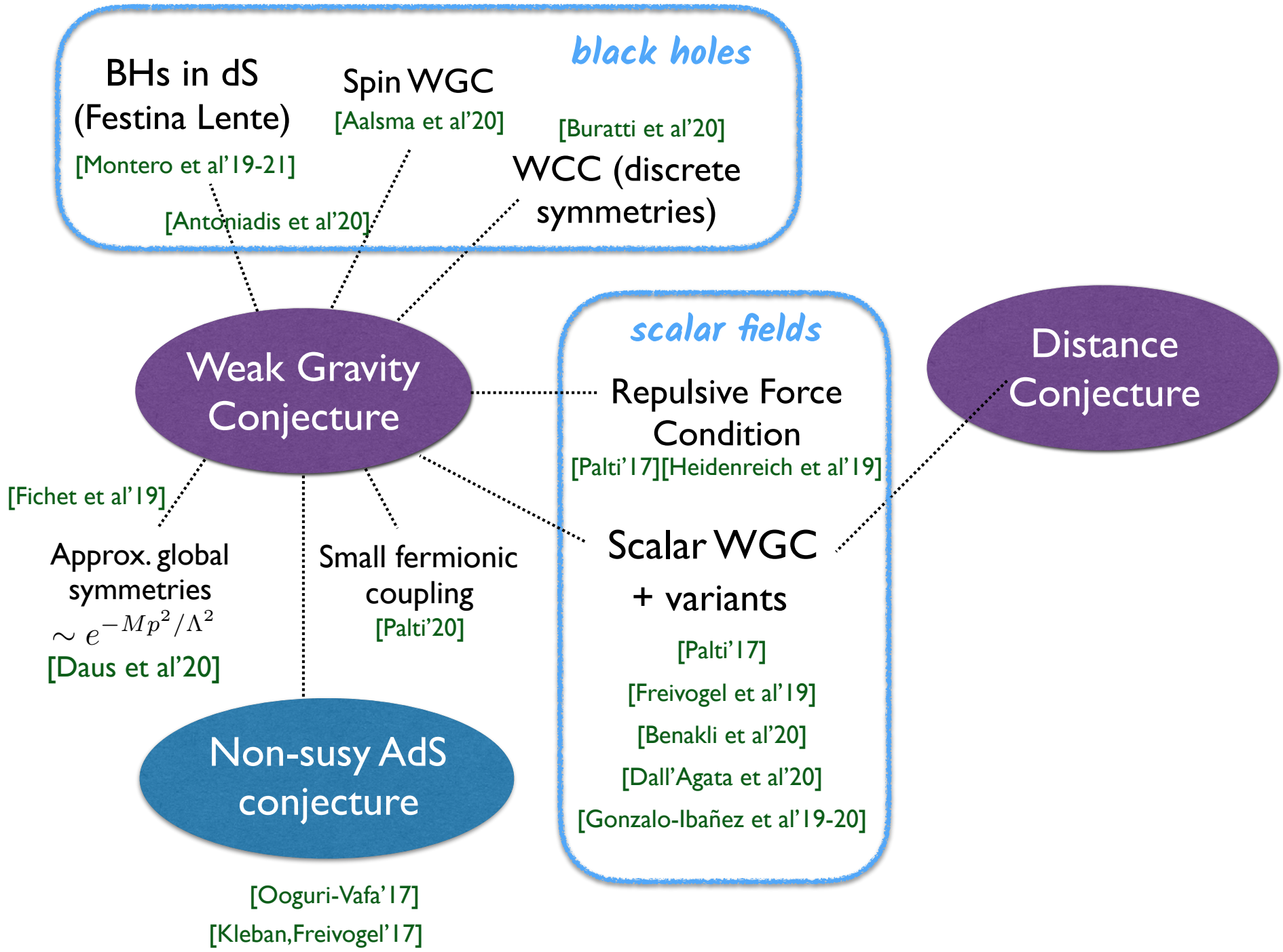

black holes
BHs in dS
(Festina Lente)
[Montero et al'19-21]
Spin WGC
[Aalsma et al'20]
[Buratti et al'20]
WCC (discrete
symmetries)
[Antoniadis et al'20]
Weak Gravity
Conjecture
scalar fields
Repulsive Force
Condition
[Palti'17][Heidenreich et al'19]
[Fichet et al'19]
Approx. global
symmetries
$\sim e^{-Mp^2/\Lambda^2}$
[Daus et al'20]
Small fermionic
coupling
[Palti'20]
Scalar WGC
+ variants
[Palti'17]
[Freivogel et al'19]
[Benakli et al'20]
[Dall'Agata et al'20]
[Gonzalo-Ibañez et al'19-20]
Non-susy AdS
conjecture
[Ooguri-Vafa'17]
[Kleban,Freivogel'17]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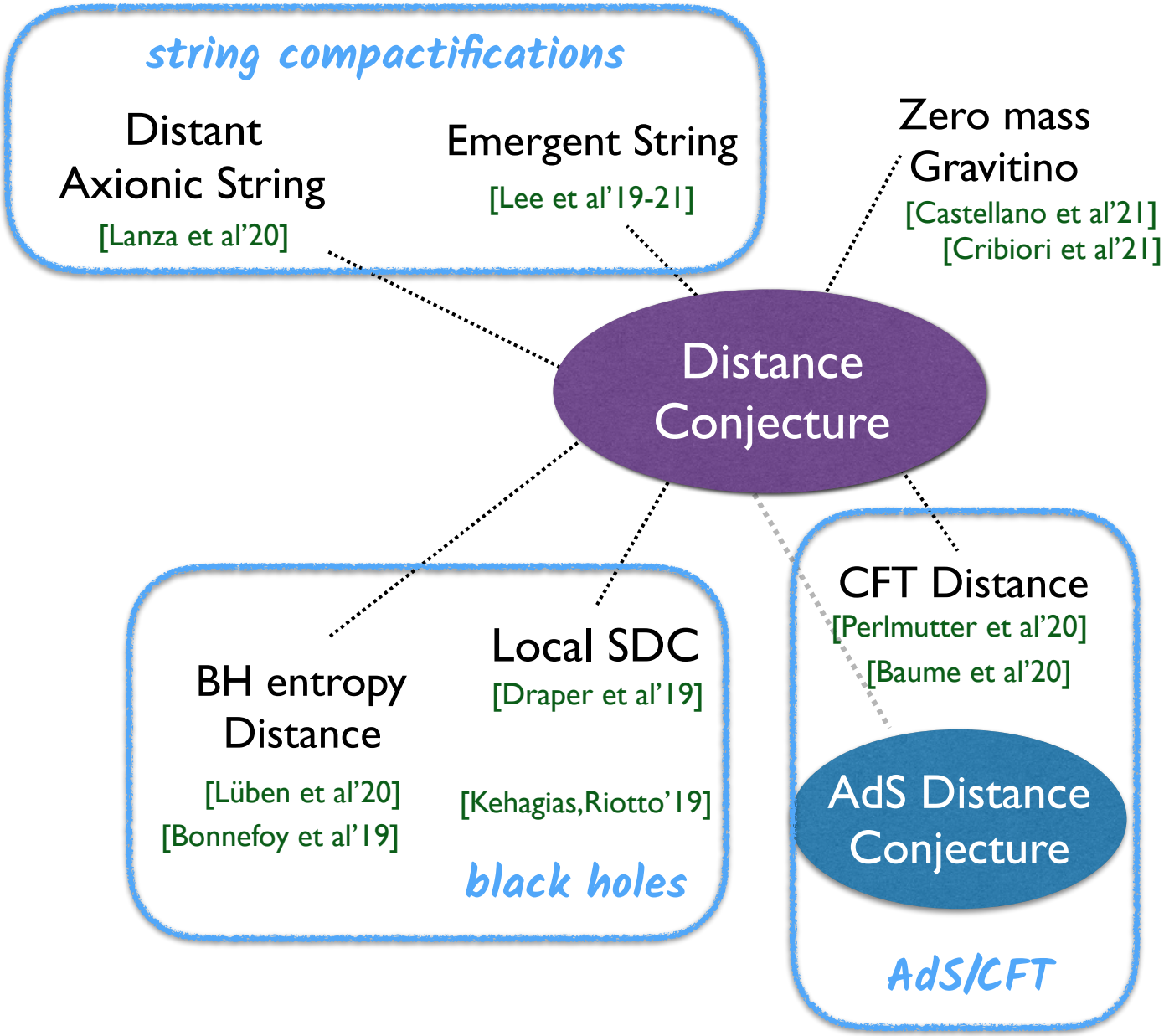
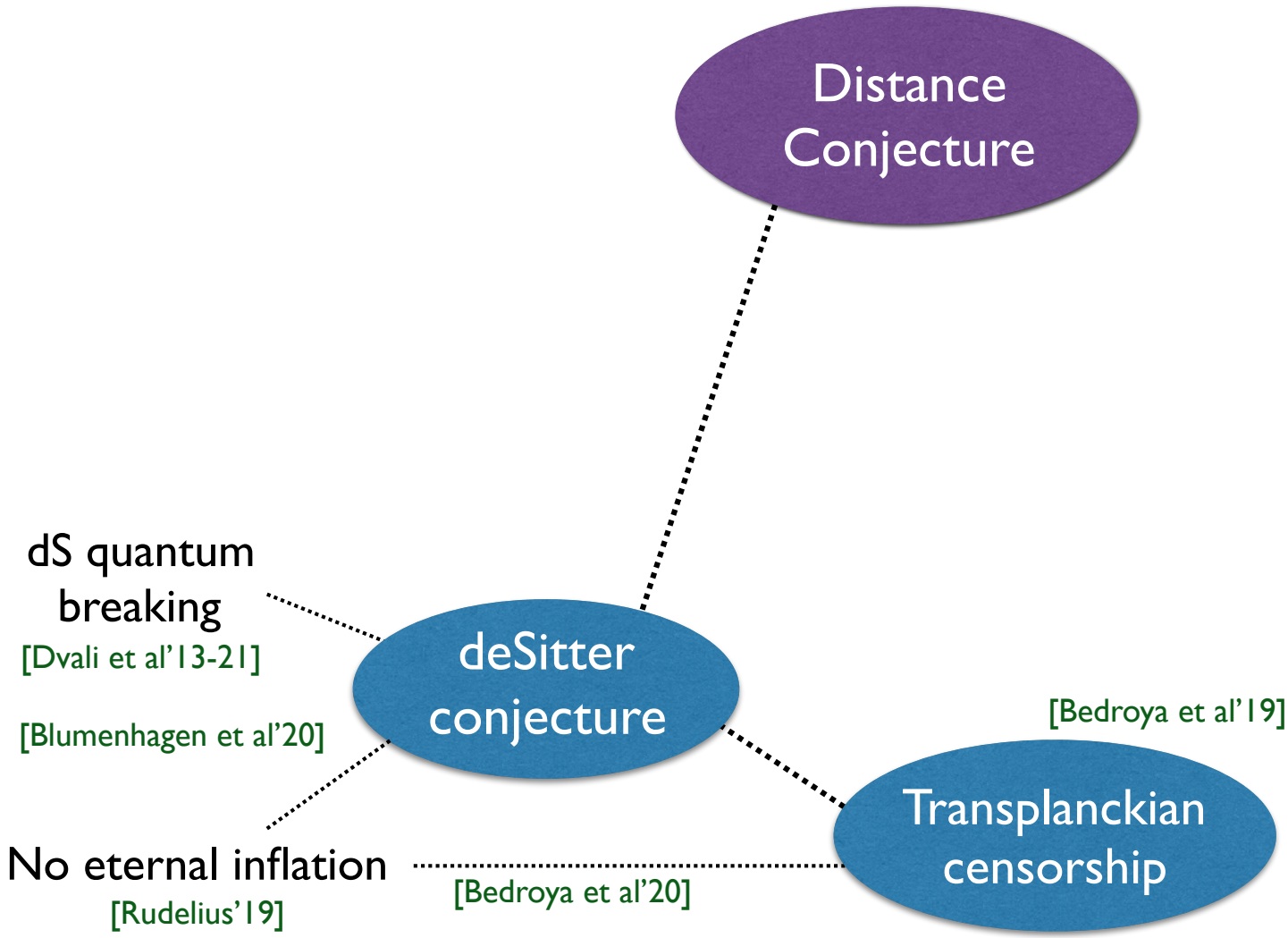

string compactifications
Distant
Axionic String
[Lanza et al'20]
Emergent String
[Lee et al'19-21]
Zero mass
Gravitino
[Castellano et al'21]
[Cribiori et al'21]
Distance
Conjecture
BH entropy
Distance
[Lüben et al'20]
[Bonnefoy et al'19]
Local SDC
[Draper et al'19]
[Kehagias,Riotto'19]
black holes
CFT Distance
[Perlmutter et al'20]
[Baume et al'20]
AdS Distance
Conjecture
AdS/CFT


Distance Conjecture
dS quantum breaking
[Dvali et al'13-21]
[Blumenhagen et al'20]
deSitter conjecture
[Bedroya et al'19]
Transplanckian censorship
No eternal inflation
[Rudelius'19]
[Bedroya et al'20]

Outline

1) Topological operators/ cobordism

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Phenomenological implications

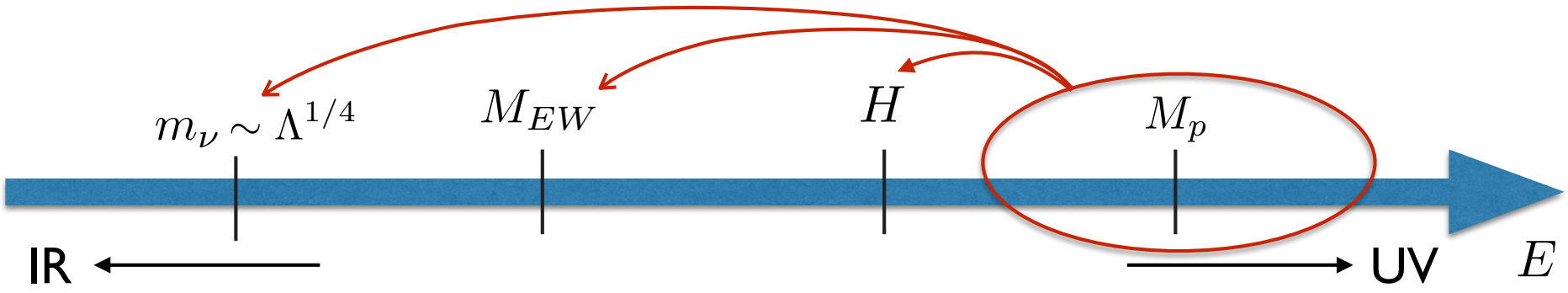
The Swampland conjectures provide constraints that any EFT must satisfy to be consistent with quantum gravity

UV imprint of quantum gravity at low energies

Potential phenomenological implications!

- Guiding principles to construct BSM models
- New insights to solve naturalness issues in our universe

(not the entire parameter space is consistent with quantum gravity!)



Phenomenological implications

Recent works of the past two years:

- Inflation/Early Universe

  [Oikonomou et al, Sadeghi et al, Brahma, Anchordoqui et al, Chakraborty et al, Osses et al, Lin et al, Jin et al, Trivedi, Mavromatos et al, Das et al, Agrawal et al, Winkler et al, Heidenreich et al, Schmitz et al, Bravo et al…]

- Dark energy

  [Seo, Cunillera et al, Bernardo et al, Banerjee et al, Berrau et al, Blumenhagen et al, Bedroya et al, Storm et al, Yang, Banerjee et al, Anchordoqui et al…]

- Eternal inflation

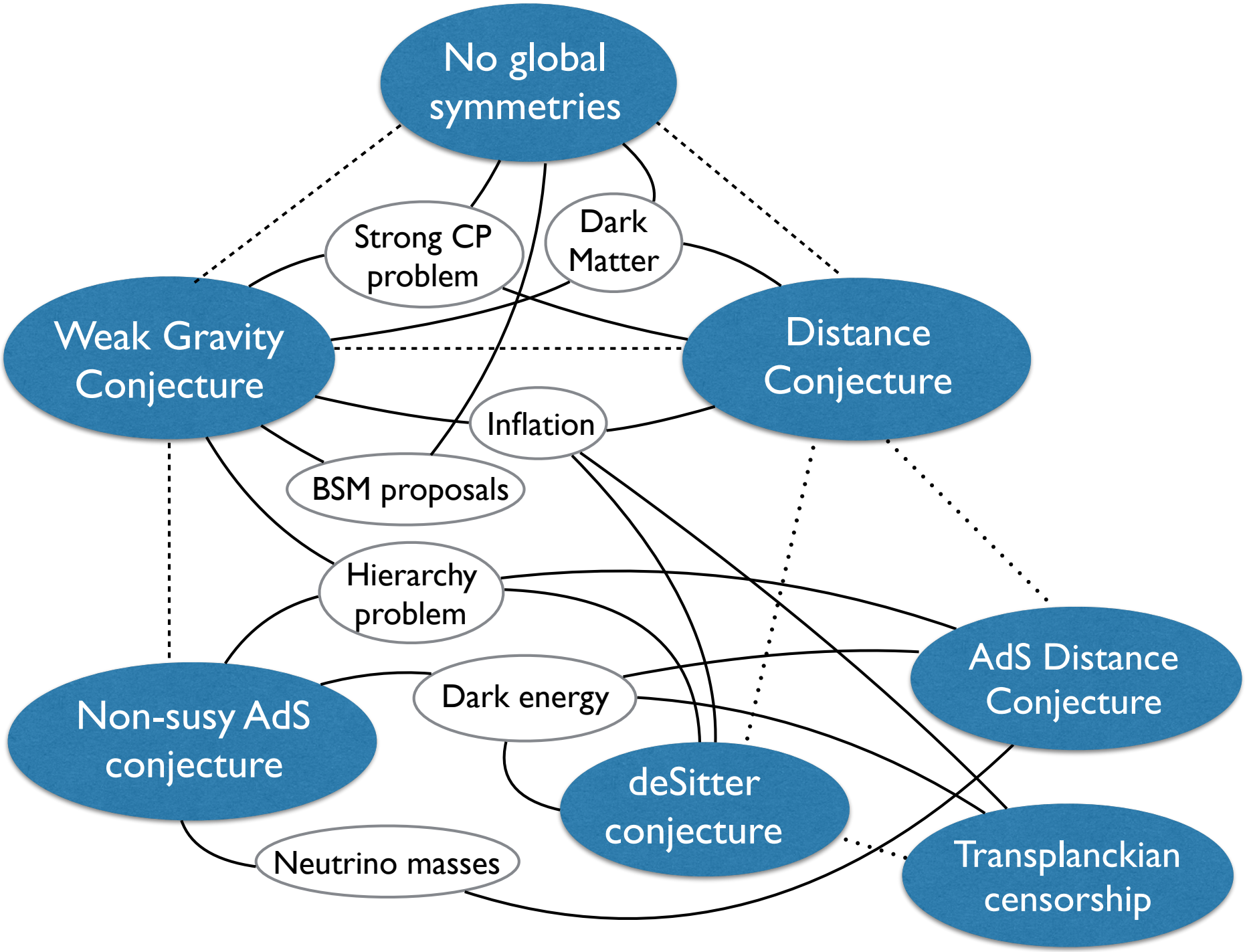
  [Chojnecki et al, Matsui et al, Rudelius…]

- Beyond Standard Model and Dark matter

  [Benakli et al, Alvey et al, Aoki et al, March-Russell et al, Yin, Das et al, Abe et al, Criag et al…]

- Naturalness issues

  [March-Russel et al, Gonzalo et al, Montero et al…]


No global symmetries
Strong CP problem
Dark Matter
Weak Gravity Conjecture
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BSM proposals
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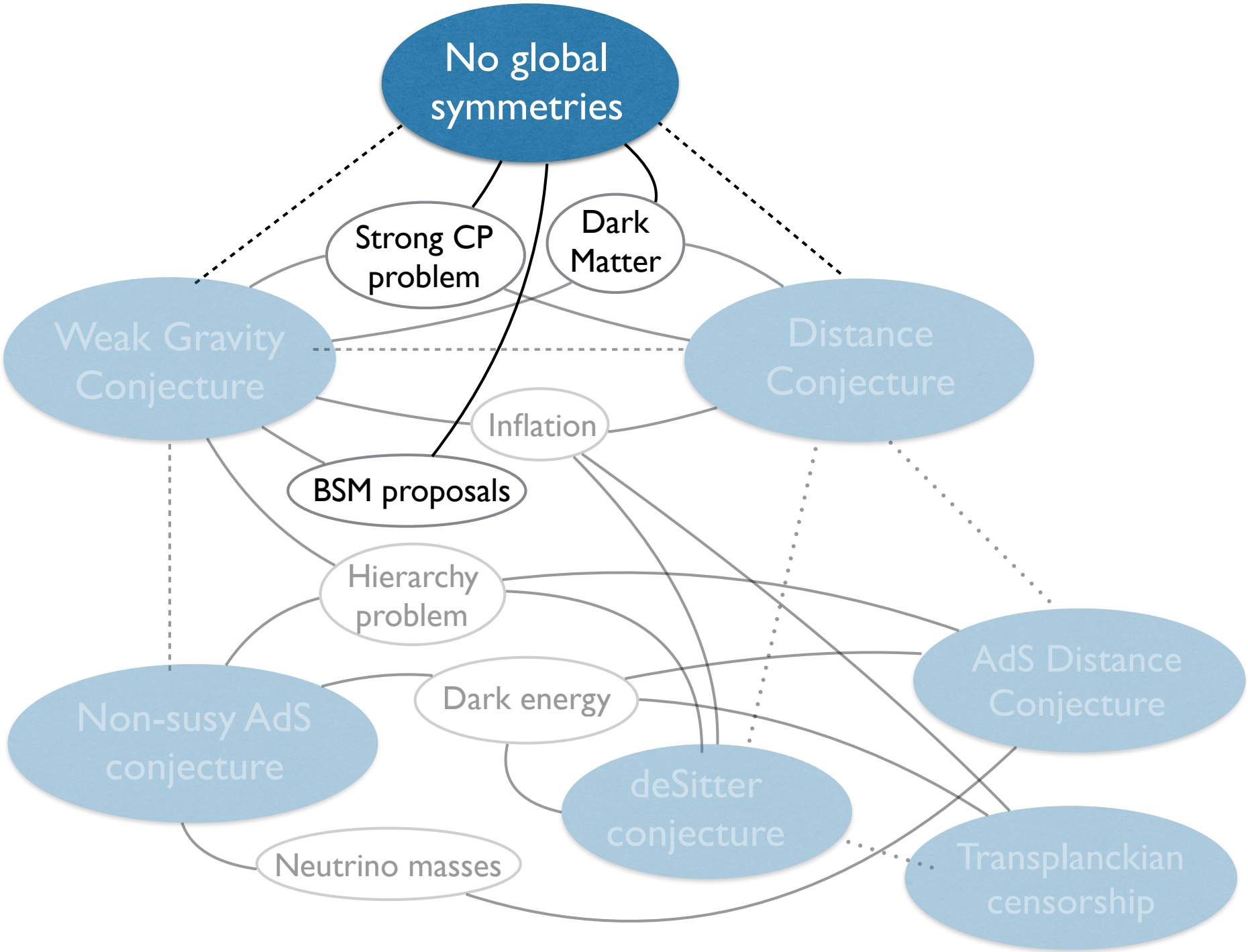
Neutrino masses
Transplanckian censorship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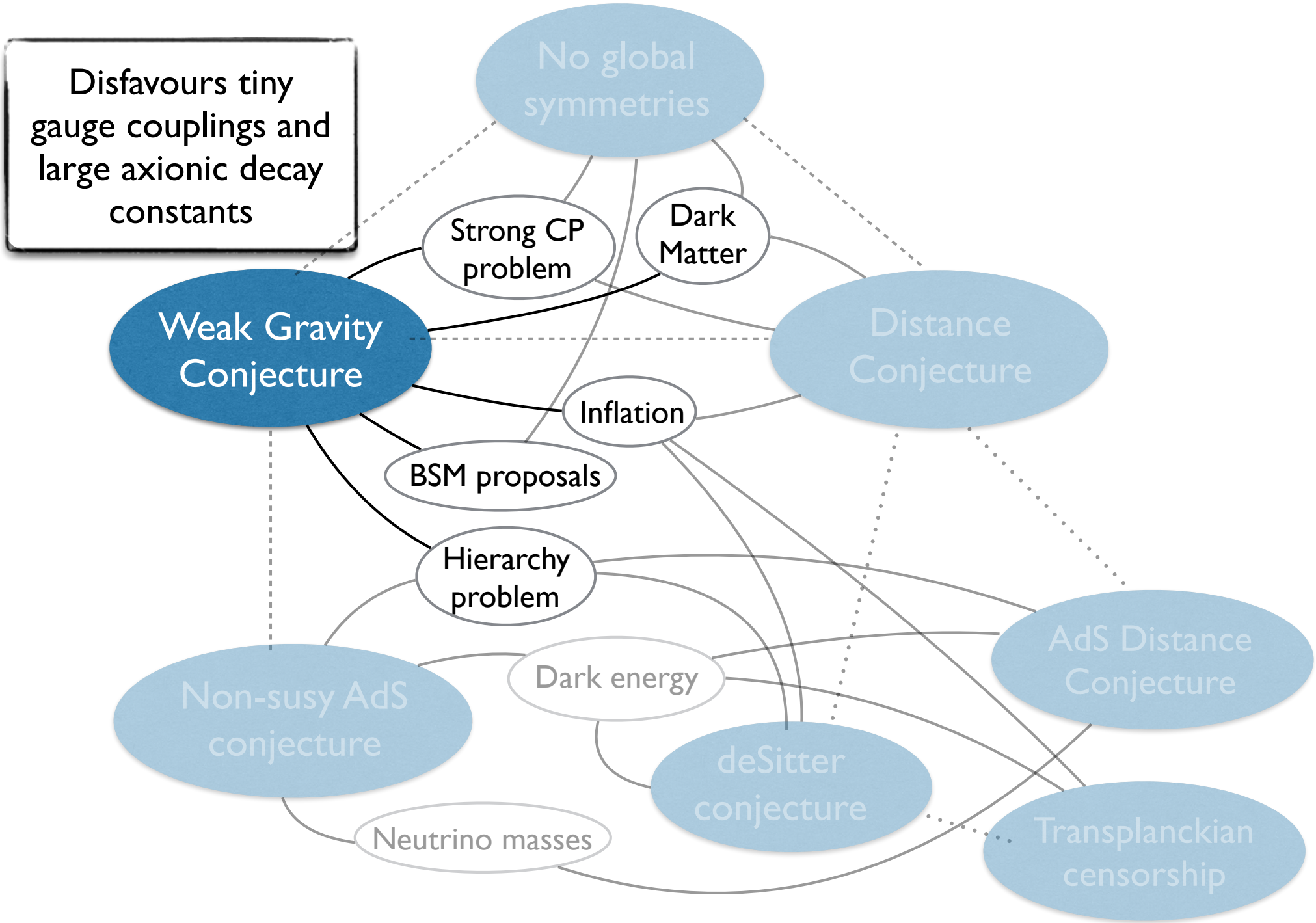
Disfavours tiny gauge couplings and large axionic decay constants
No global symmetries
Strong CP problem
Dark Matter
Weak Gravity Conjecture
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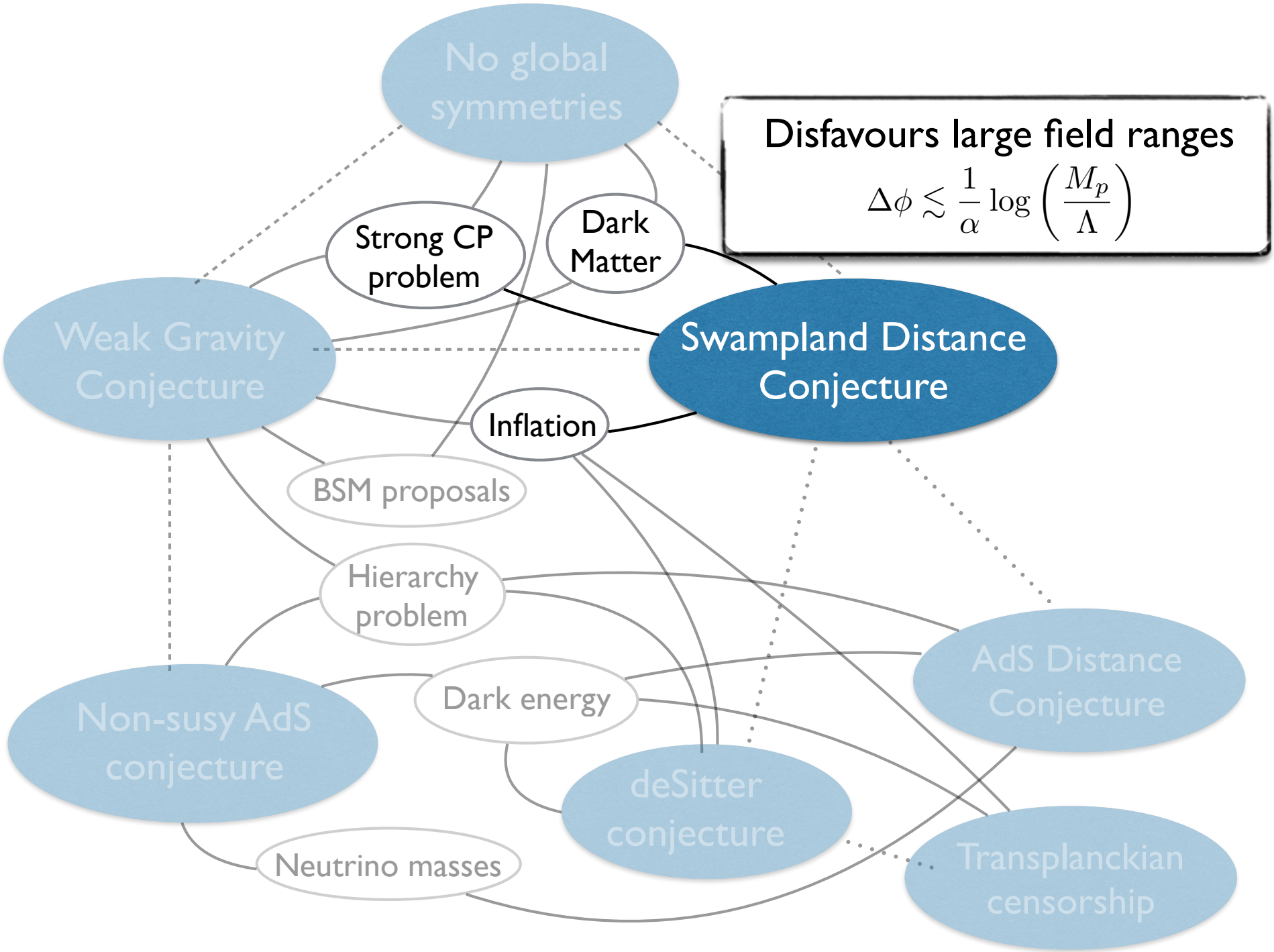
No global symmetries
Disfavours large field ranges
$\Delta\phi \lesssim \frac{1}{\alpha}\log\left(\frac{M_p}{\Lambda}\right)$
Strong CP problem
Dark Matter
Weak Gravity Conjecture
Swampland Distance Conjecture
Inflation
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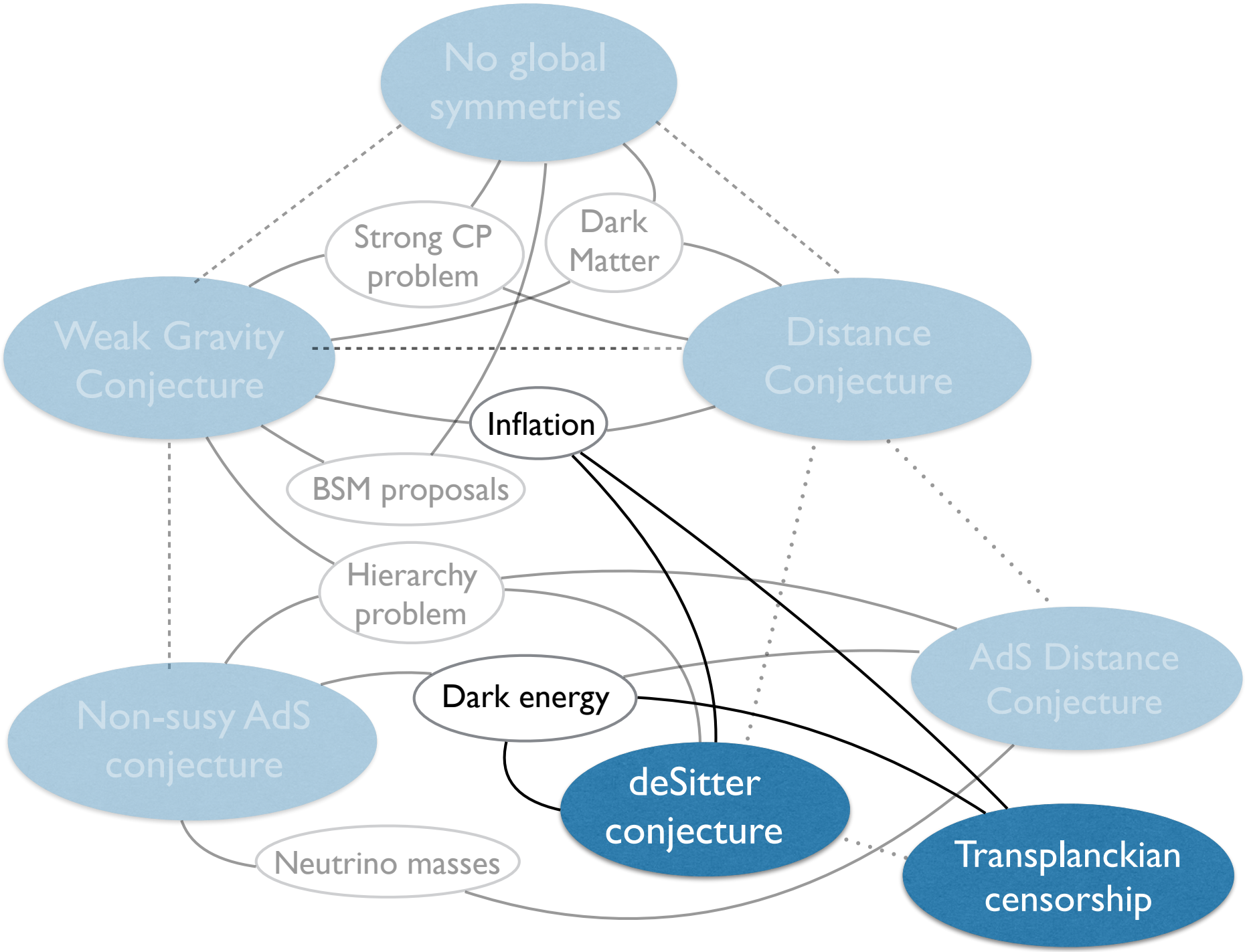
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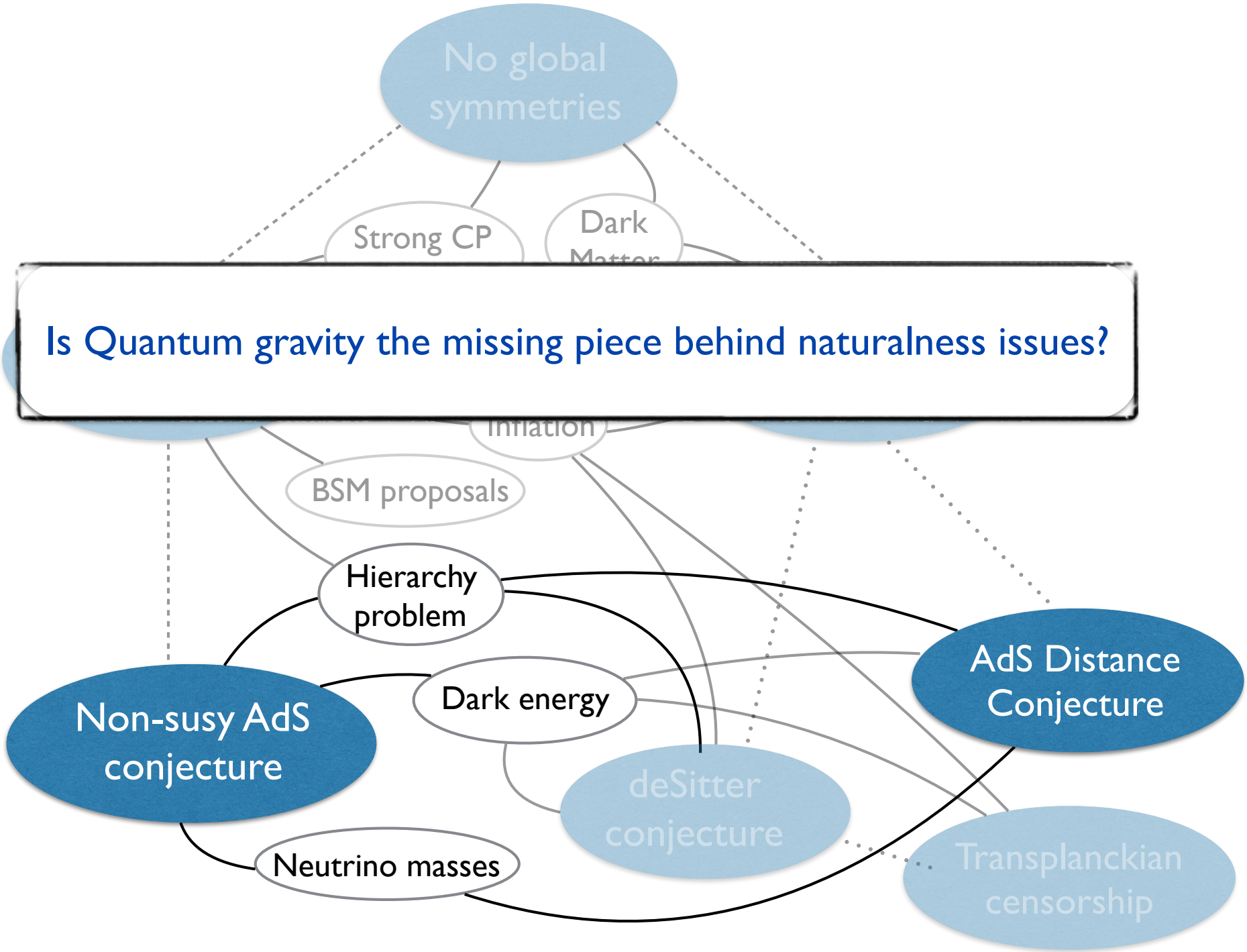
No global symmetries
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Is Quantum gravity the missing piece behind naturalness issues?
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see Cvetic/Shiu's discussion

What can we say about naturalness issues?

Recent works: (notice: they all have additional assumptions!)

- Constraints on quark masses and theta-angle from applying deSitter conjecture to QCD sector → $v_{EW} \lesssim 50\ \mathrm{TeV}$ [March-Russel et al'20]

- Requiring circle compactifications of an EFT satisfy the AdS swampland conjectures [Gonzalo,Ibañez,IV'21] see Gonzalo's gong show talk

  In a SUSY broken EFT with $\Lambda_D \geq 0$ ***and*** $(-1)^{k+1}\mathrm{Str}\,(M^{2k}) > 0$

  there must exist a surplus of light fermions with masses $m \lesssim \Lambda_D^{1/D}$

  → Applied to SM: Dirac neutrinos $m_\nu \lesssim \Lambda^{1/4}$ (or light fermonic DM)

- Festina Lente (to avoid large black holes in dS to become superextremal while evaporating)

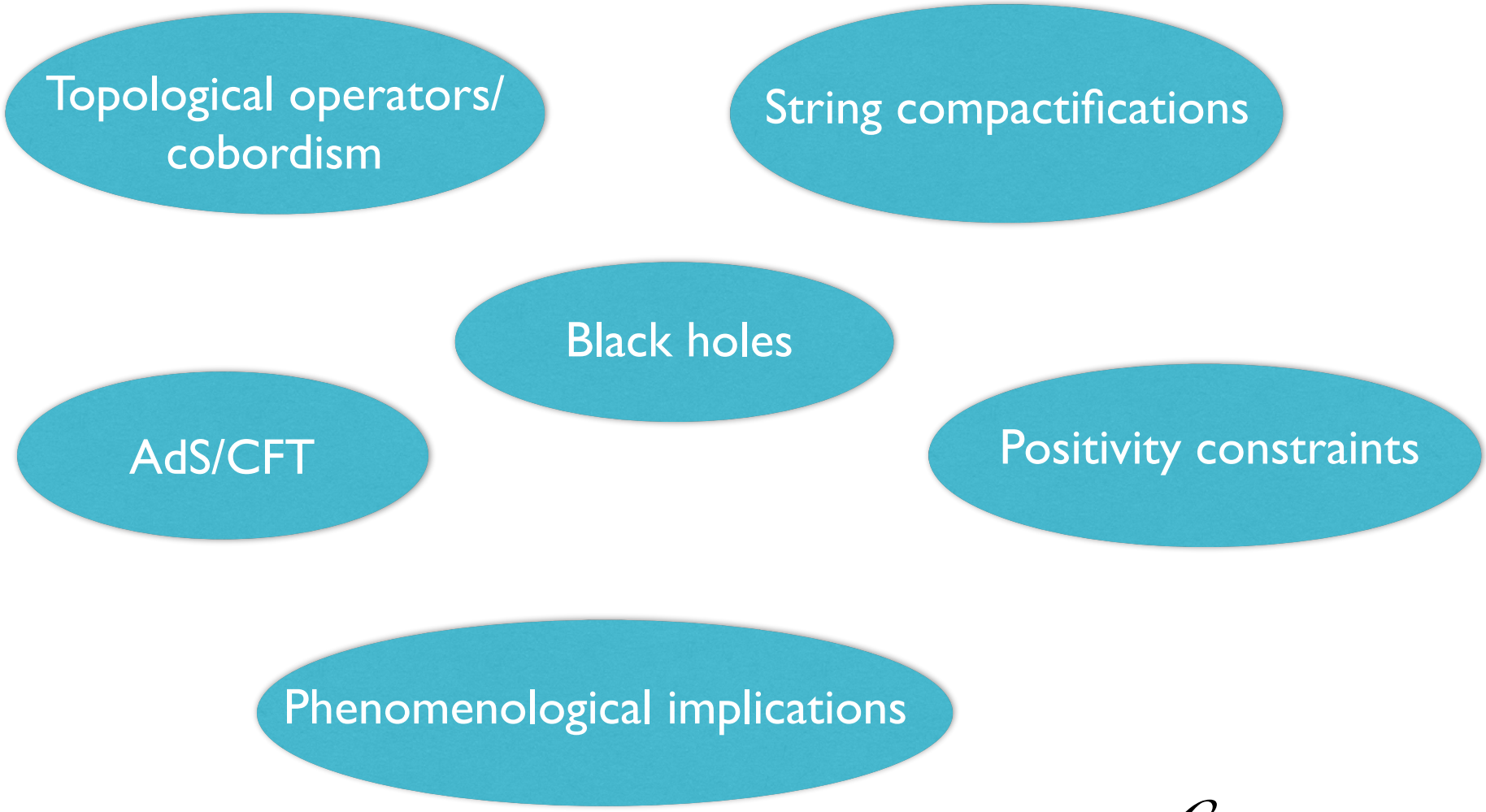
  all charged particles: $m^2 \geq \sqrt{6} g M_p H$ ***in terms of Hubble*** [Montero et al'19-21]

  (explains why EW symmetry must be spont. broken)

They relate EW hierarchy problem and cosmological constant problem!

Conclusions

Think big, act small



Thank you!