



Dark Matter and Quantum Gravity

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Model for Dark Matter

Dark Matter Physics

Axion-DM
WIMP
PBH
...



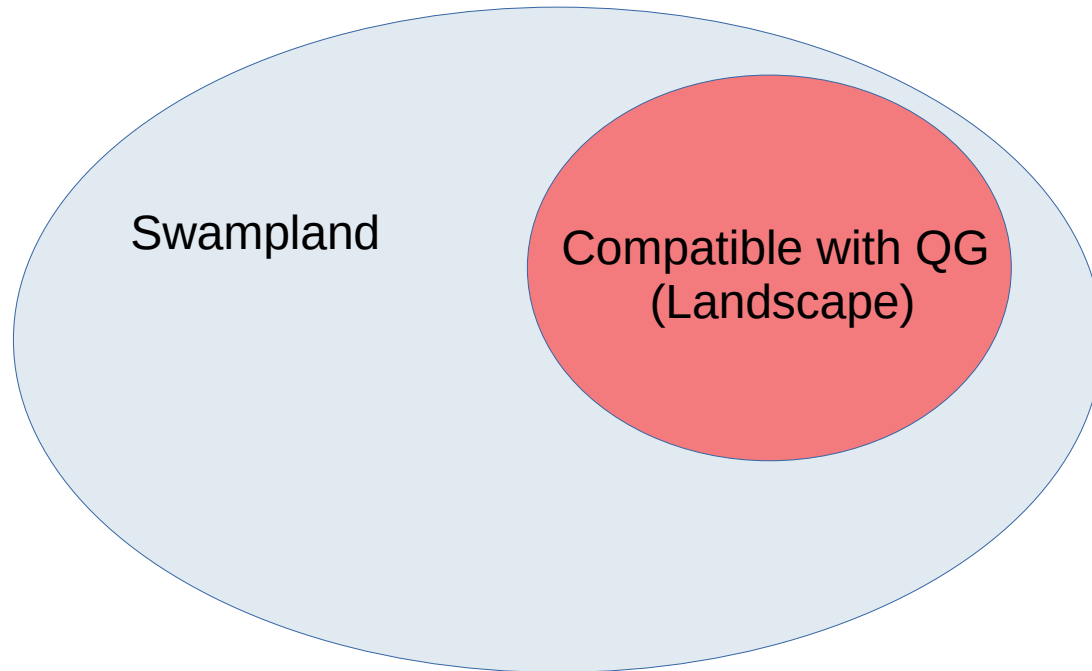
Quantum Field Theory (QFT)



Quantum Gravity (QG)

QFT and QG

Consistent QFT



Example of Swampland

- **No global symmetry** Banks & Dixon 88
- **Weak gravity conjecture** Arkani-Hamed et.al. 2006
 - Gravity should be weakest force.
- **Distance conjecture** Ooguri & Vafa 2006
 - Derivation of field VEV is less than M_{pl} .
- **de Sitter conjecture** Obied et.al, 2018
 - Forbidding flat potential with $V > 0$.


QG Challenge for DM

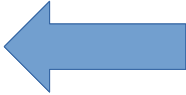
Requirement of Dark Matter

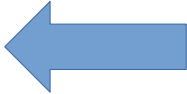
- **Stability**
 - Some symmetry
 - Light DM mass
 - ...
- **Weakly Interacting**
- **Proper Production Mechanism**
 - Inflaton dynamics
 - Production from Plasma
 - ...

QG Challenge for DM

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- **Stability**
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Weak gravity conj.
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de Sitter conj.
Weak gravity conj.

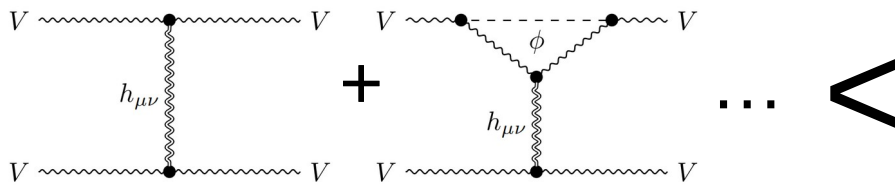
DM and Quantum Gravity

- Model building avoiding swampland conditions.
 - e.g., Based on accidental symmetry of gauge theory.
[YN, SS & MY]
- Improving swampland condition in quantitative way.
 - Gravitational Positivity Bound on Dark Matter Model.
[K.Aoki, T.Noumi, RS, S.Sato, SS, J.Tokuda & MY]

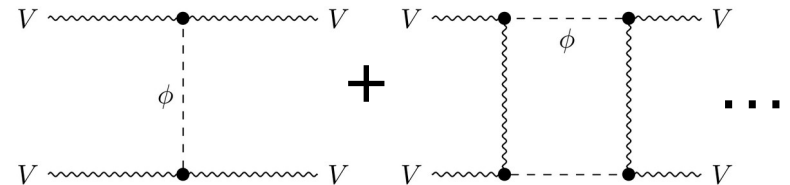
Positivity Bound

Condition of EFT has “good” high energy theory including gravity.

Gravitational Process



Non-Gravitational Process



Dark Matter cannot be “completely dark.”

Phenomenological Implication

- **Applying concrete models:**
 - **Dark Gauge Boson**
 - Lower-bound on mass and interaction strength
 - **Minimal Higgs-portal Dark Matter Model**
 - Lower-bound on Higgs-DM interaction
 - Tension with Freeze-in scenario?
 - ...
- **Uncertainty of constraint.**
 - Constraint also depends on details of QG.
 - Discovery of DM may probe QG.

Two Exciting Talks

- Toshifumi Noumi
 - Overview of gravitational positivity bound.
 - Application to SM and new physics.
- Katsuki Aoki
 - Positivity bound on massive and unstable particles.