C01: "Ultimate Theory"

Quantum Gravity / String Theory

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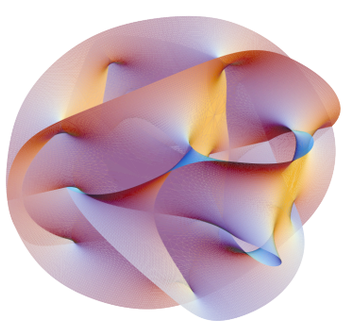
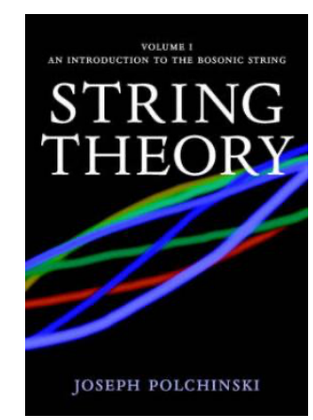
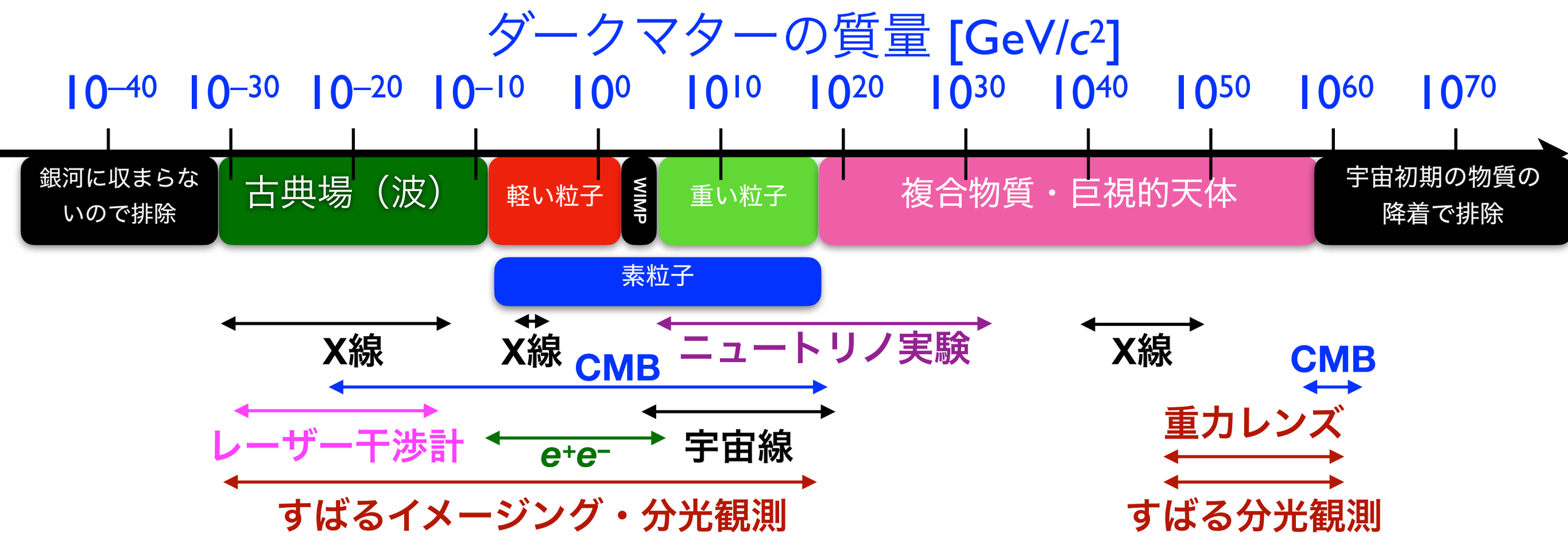
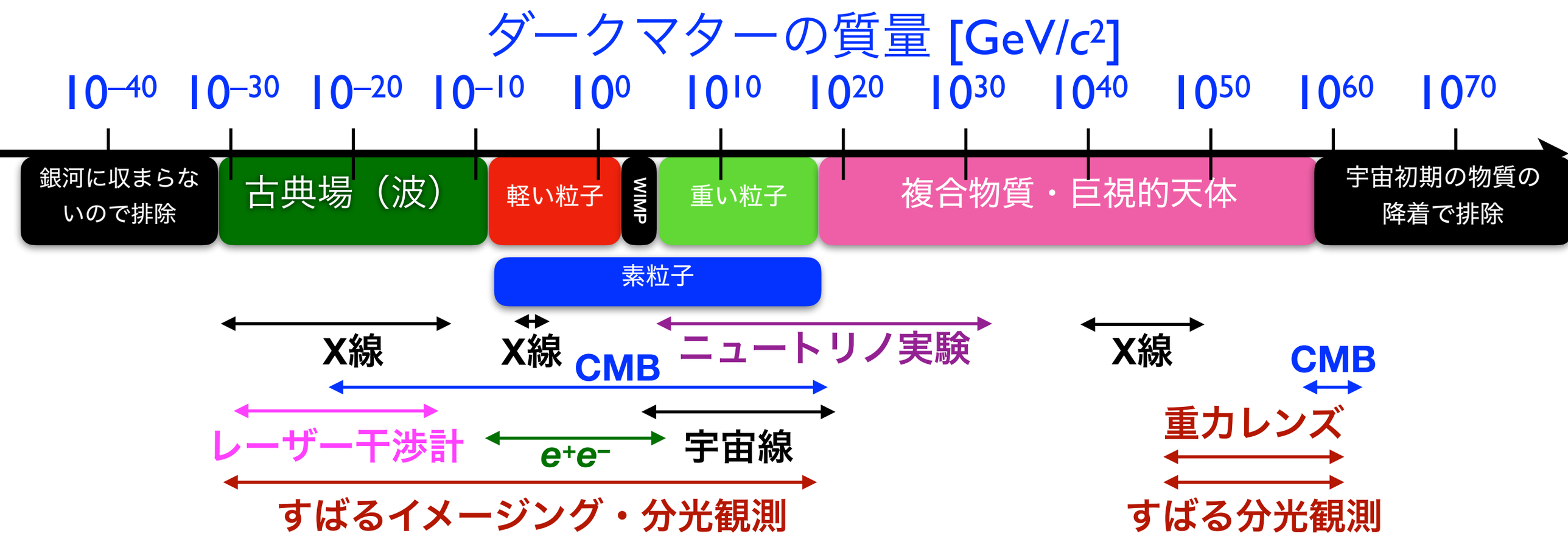
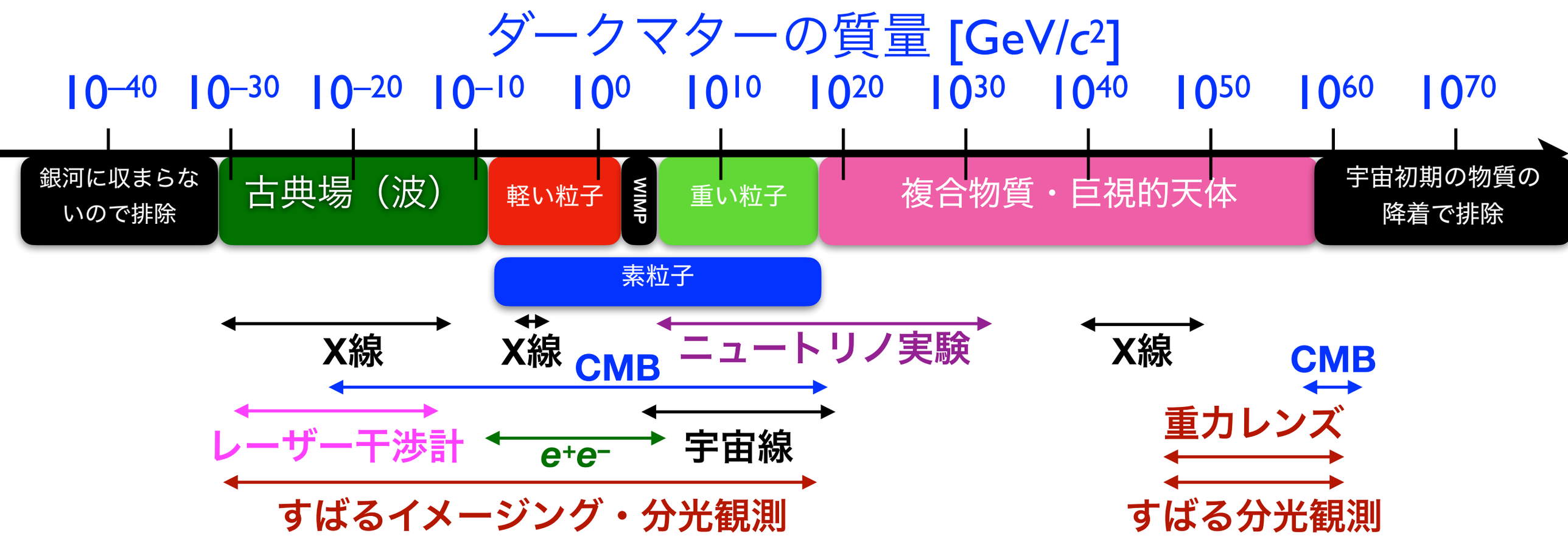





ダークマターの質量 [GeV/c²]
10⁻⁴⁰
10⁻³⁰
10⁻²⁰
10⁻¹⁰
10⁰
10¹⁰
10²⁰
10³⁰
10⁴⁰
10⁵⁰
10⁶⁰
10⁷⁰
銀河に収まらないので排除
古典場（波）
軽い粒子
WIMP
重い粒子
複合物質・巨視的天体
宇宙初期の物質の降着で排除
素粒子
X線
X線
CMB
ニュートリノ実験
X線
CMB
レーザー干渉計
e⁺e⁻
宇宙線
重力レンズ
すばるイメージング・分光観測
すばる分光観測



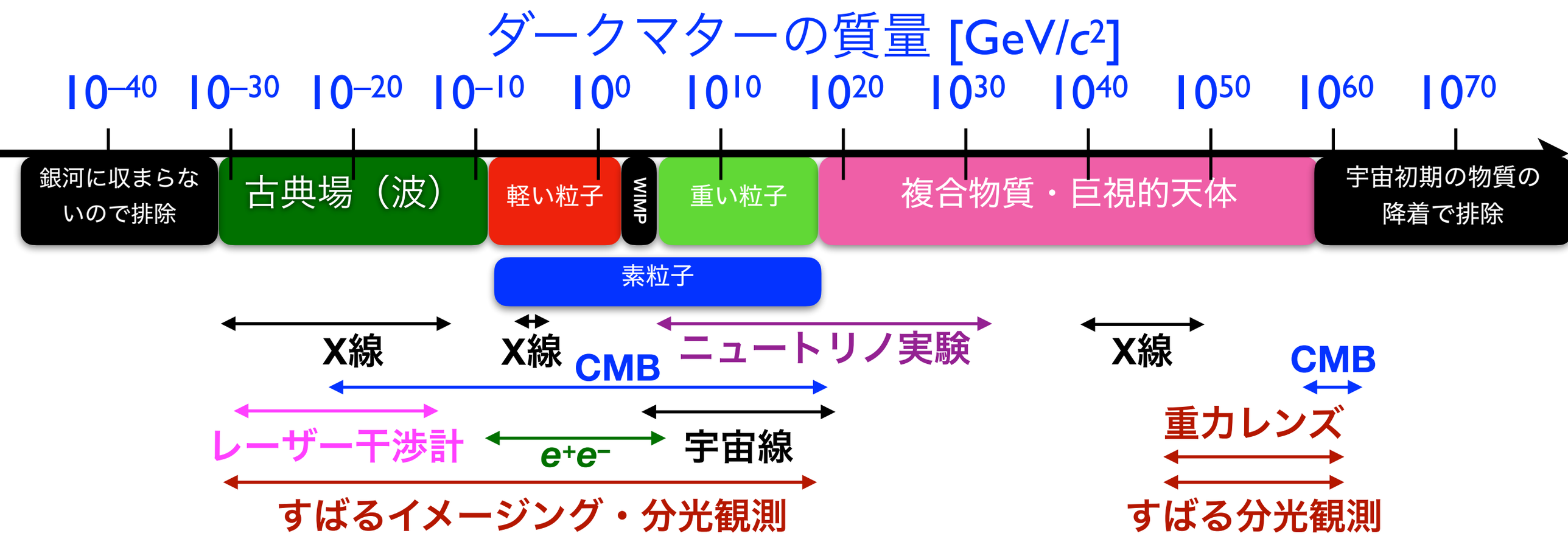
huge discovery space!



huge discovery space!

"string theorist"

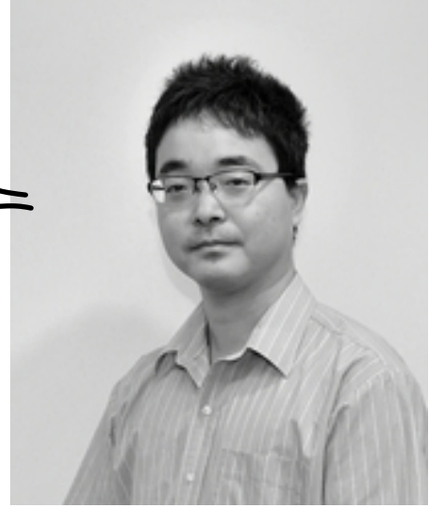
where should I look at?

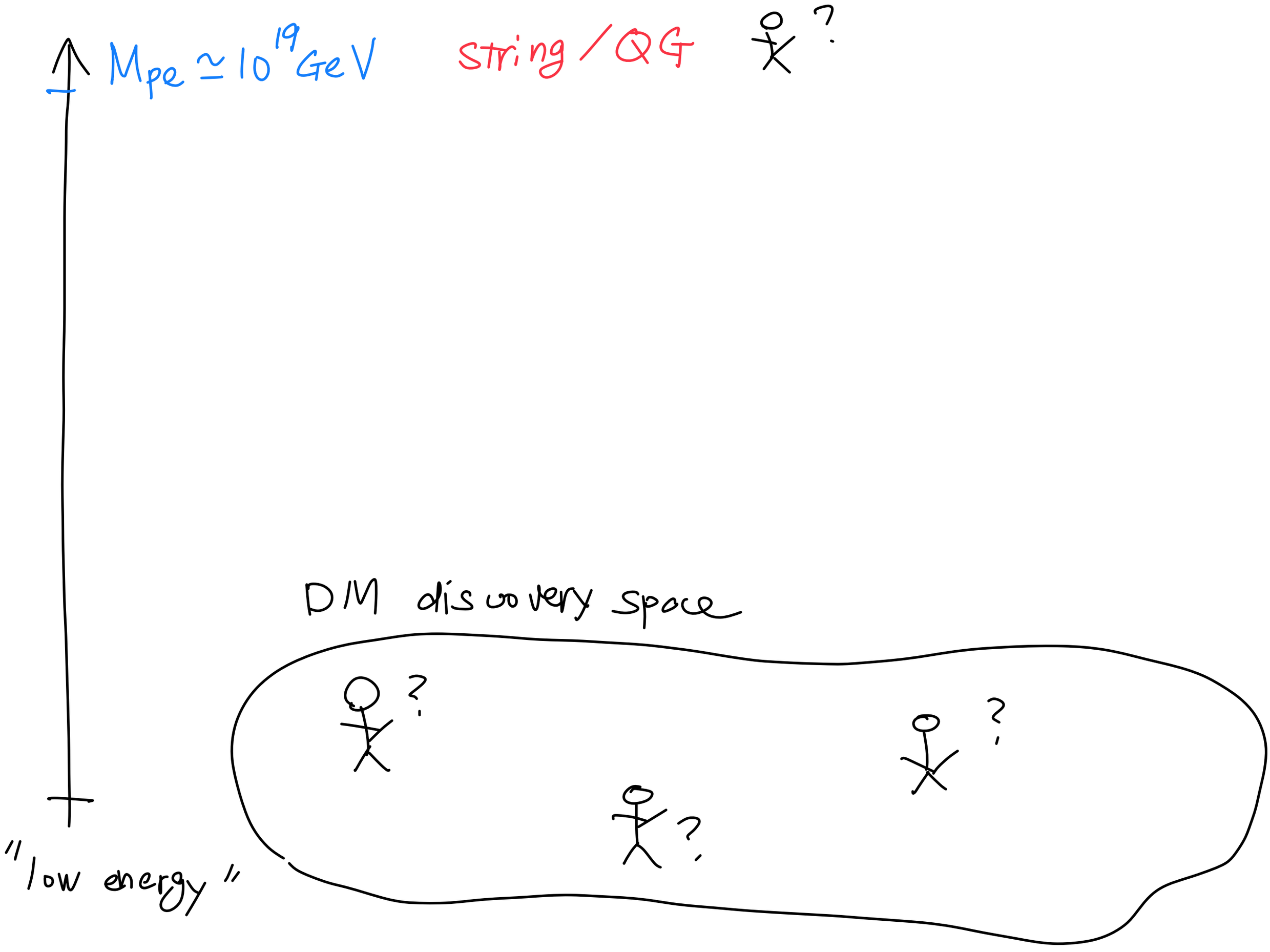


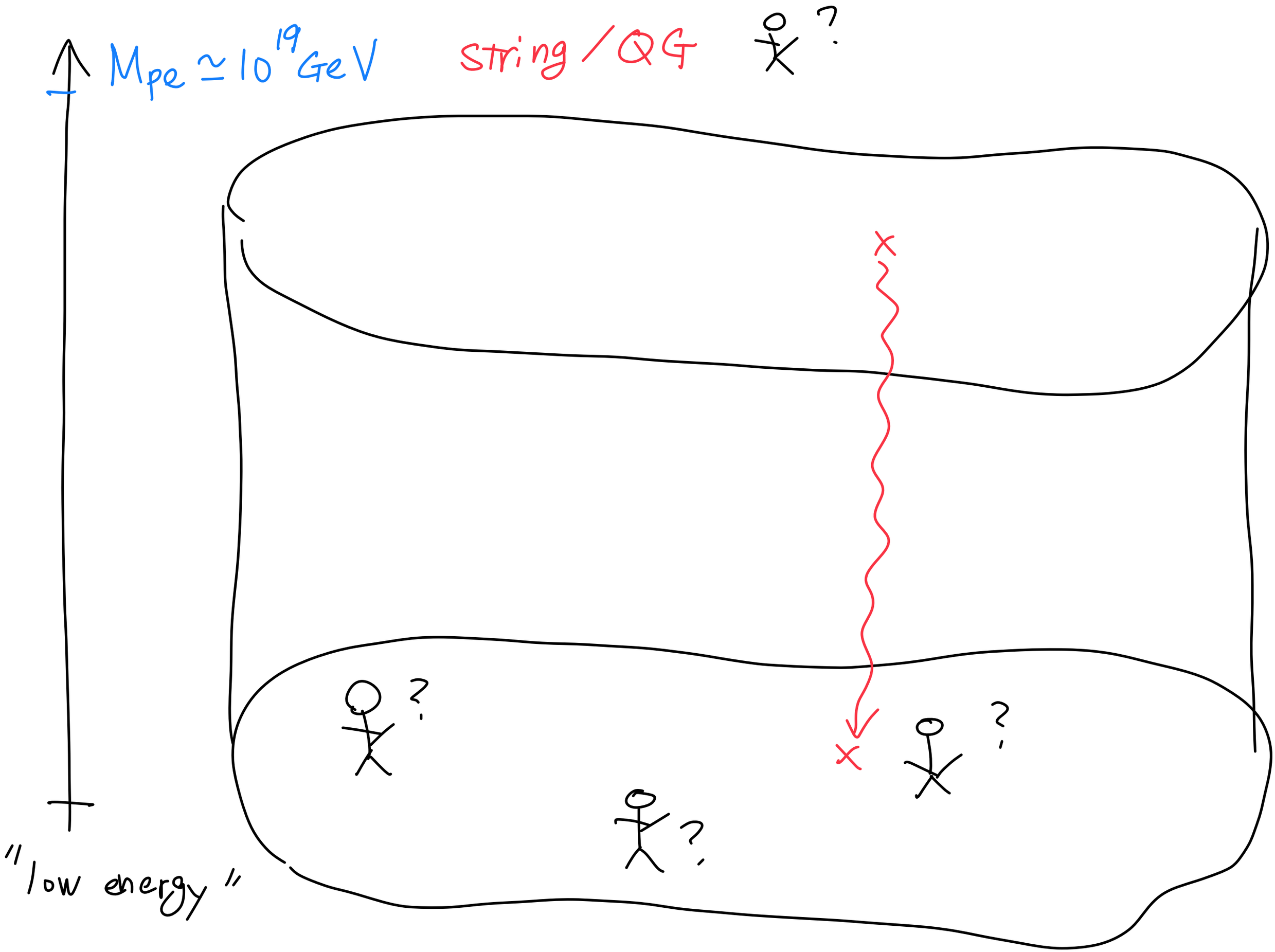
huge discovery space!

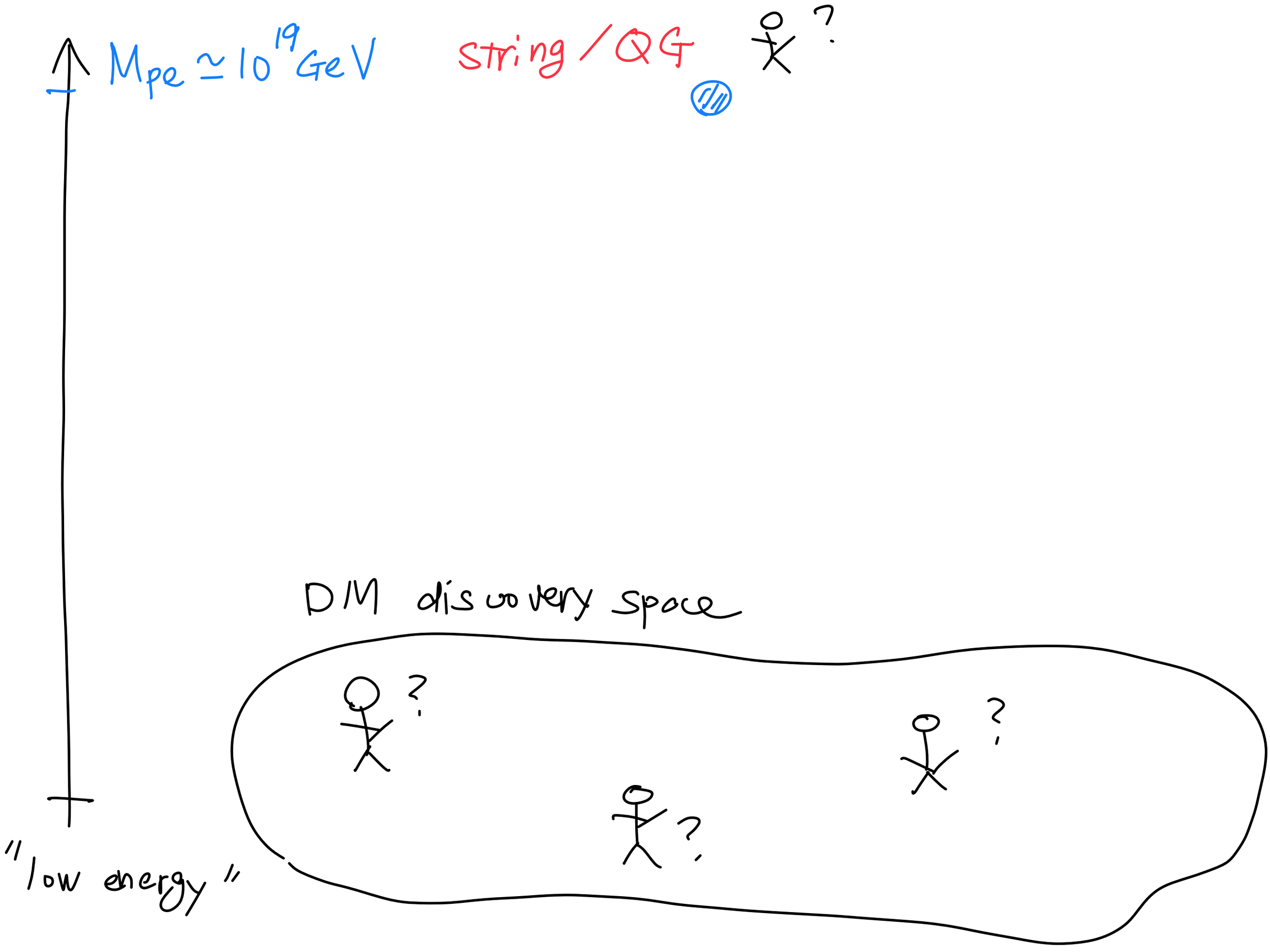
"string theorist"

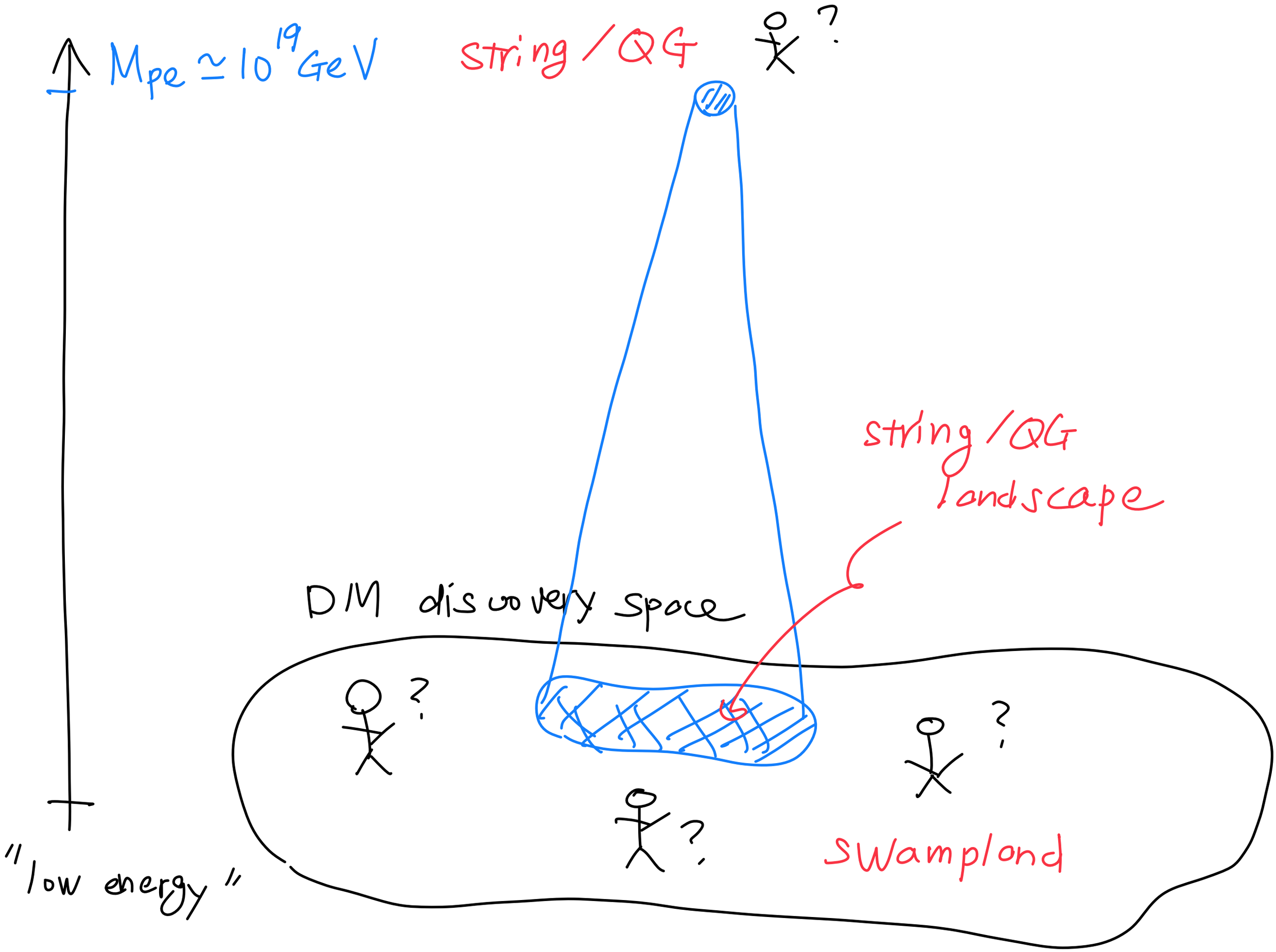
Is discovery space really huge?

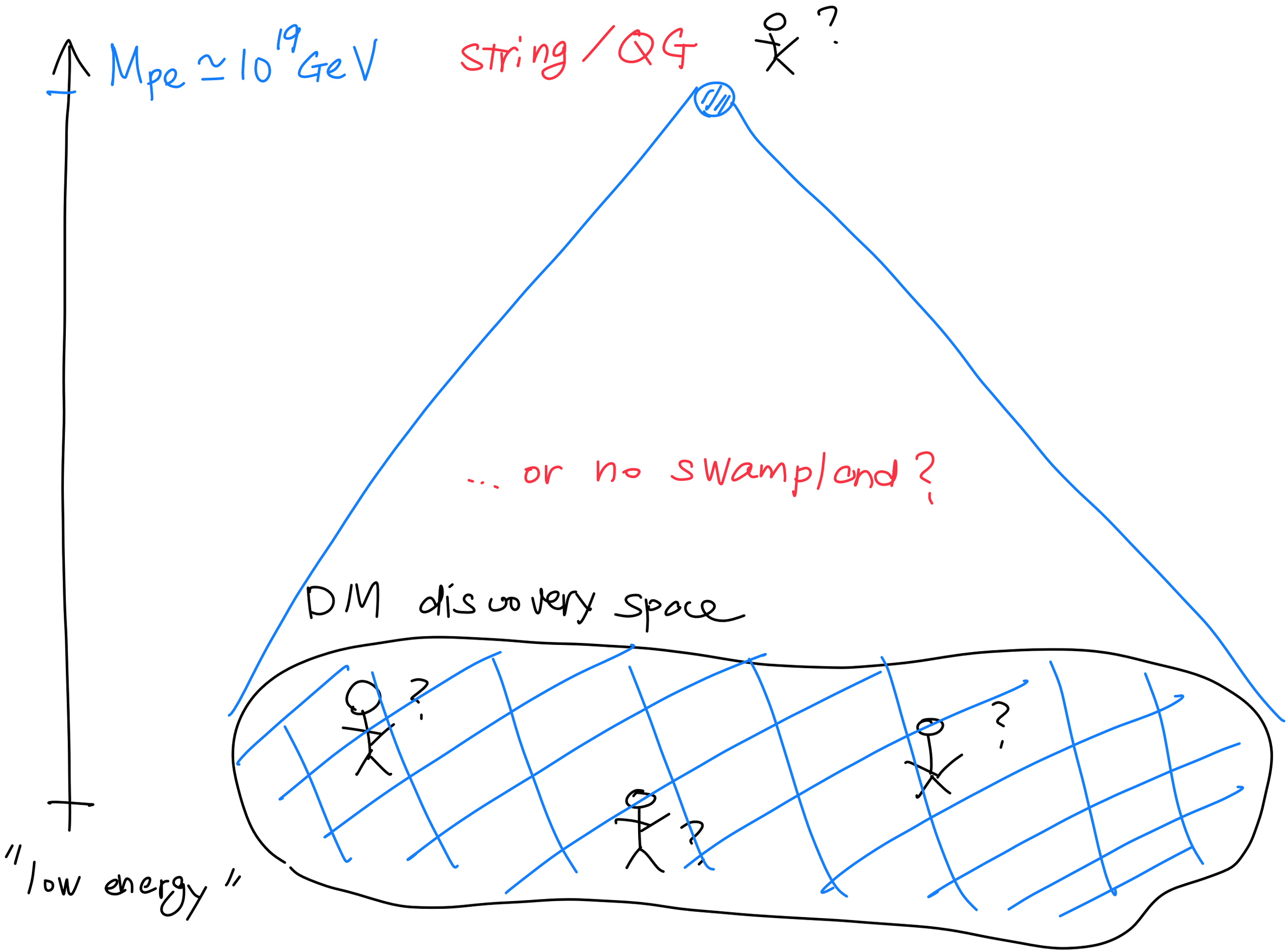


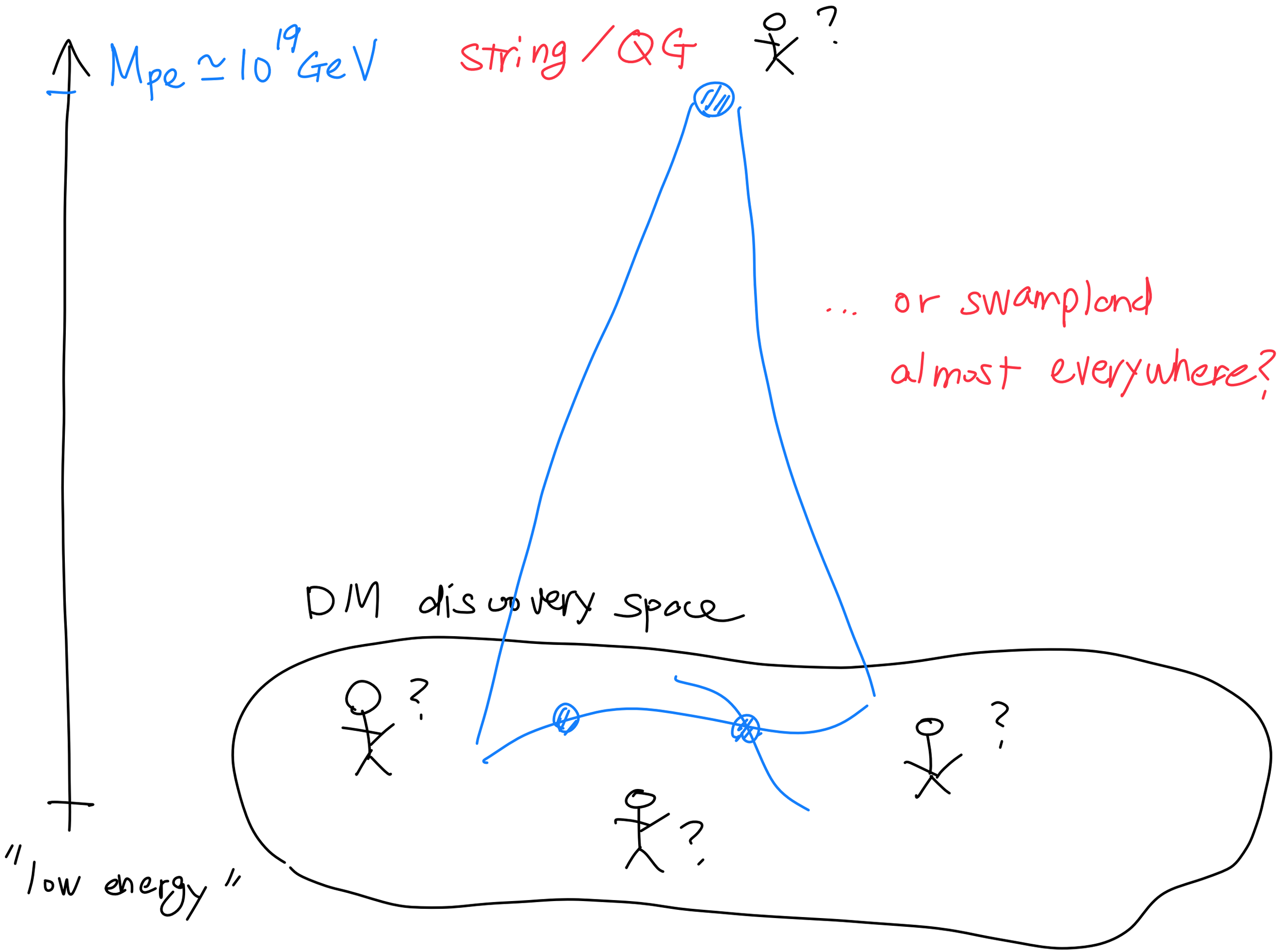

$M_{pl} \simeq 10^{19}$ GeV
string / QG
DM discovery space
"low energy"


$M_{pe} \simeq 10^{19}$ GeV
string / QG
"low energy"


$M_{pl} \simeq 10^{19}$ GeV
string / QG
?
DM discovery space
?
?
?
"low energy"

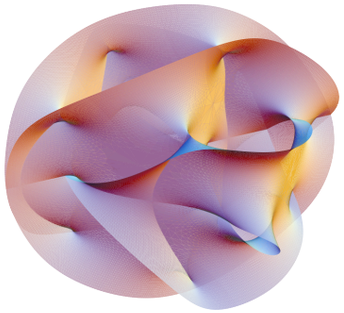

$M_{pl} \simeq 10^{19}$ GeV
string / QG
?
string / QG landscape
DM discovery space
?
?
?
swampland
"low energy"

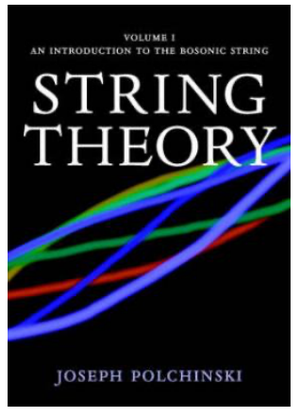

$M_{pl} \simeq 10^{19}$ GeV
string / QG
?
... or no swampland ?
DM discovery space
?
?
?
"low energy"


$M_{pl} \simeq 10^{19}$ GeV
string / QG
?
... or swampland
almost everywhere?
DM discovery space
?
?
?
"low energy"

C01班

量子重力としての超弦理論：究極の統一理論





どんな宇宙が実現されるか？

どんな力？

どんなポテンシャル？

どんな物質？

どんな対称性？

アクシオン
(A01, B01)

宇宙背景輻射
(B06)

重い粒子
(A02)

軽い粒子
(B04, B05)

原始ブラックホール
(A03, B02, B03)

The Team

Yasunori Nomura	Ryo Saito	Satoshi Shirai	Syuhei Iguro
(UC Berkeley)	(Yamaguchi)	(IPMU)	(Nagoya ↓ IPMU)
hep-th	astro-ph	hep-ph	hep-ph
hep-ph	gr-qc	hep-th	
⋮	⋮	⋮	

new collaboration welcome!

Example : Axion — DM (e.g. QCD axion, Fuzzy DM, ...)

— DE (quintessence axion)

— inflation (natural inflation, ...)

— CMB (birefringence)

$$\mathcal{L} \supset \frac{a}{f_a} \mathbb{E} \cdot \mathbb{B}$$

global sym. $a \to a + \text{const.}$ broken by

non-perturbative instanton effects ☺

* Axion Quality Problem

global sym broken also by

string / membrane instanton, wormhole, ...

* Weak gravity conjecture

"$f_a \lesssim M_{pl}$"

implications?

loophole?

* string axiverse

many axions from string theory

(many moduli)

* non-cosine potential

large N

holography

lattice

chiral Lag.

Synergy : Example

Nomura

multiverse

Saito

PBH

Shirai

WIMP

Yamazaki

!!

Synergy: Example

Nomura

Saito

cosmology

Shirai

particle physics

Yamazaki

string theory

implications of

de Sitter swampland conj.

Synergy : Example

Nomura Saito Shirai Yamazaki

new axion inflation model

(w/ T. Watari)

Synergy: Example

Yoo (A03)

Saito

Sasaki

(A03)

Yamazaki

Kusenko (A03)

Yamada

Summary

* String/QG IS relevant for DM

New Possibilities

New Impossibilities

Highlight New Parameter Regions

critical look at DM discovery space

* Synergies between different ideas/theories/experiments