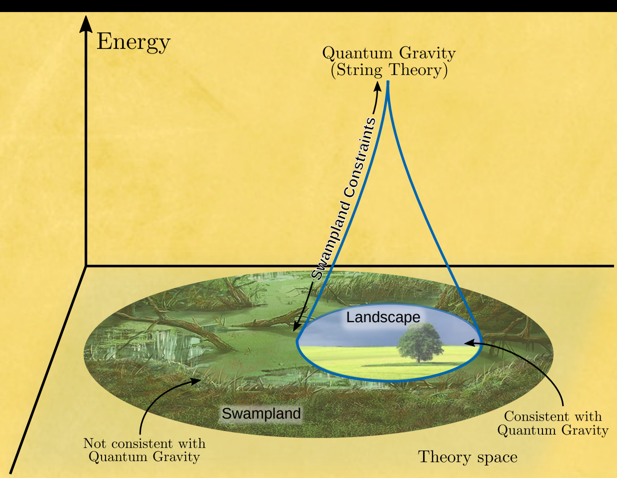
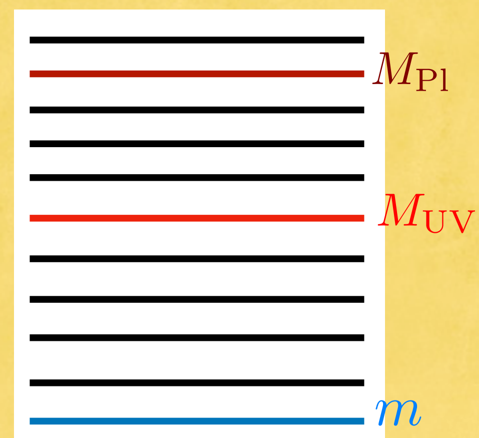
GCOS, SHDM, and UV physics

Dark Matter

- Nuclear Matter quarks, gluons
- Leptons electrons, muons, taus, neutrinos
- Photons, W, Z, h bosons
- Other dark particles

- Direct Detection (DM DM → SM SM)
- Indirect Detection (DM DM → SM SM)
- Particle Colliders (SM SM → DM DM)
- Astrophysical Probes (DM DM → DM DM)

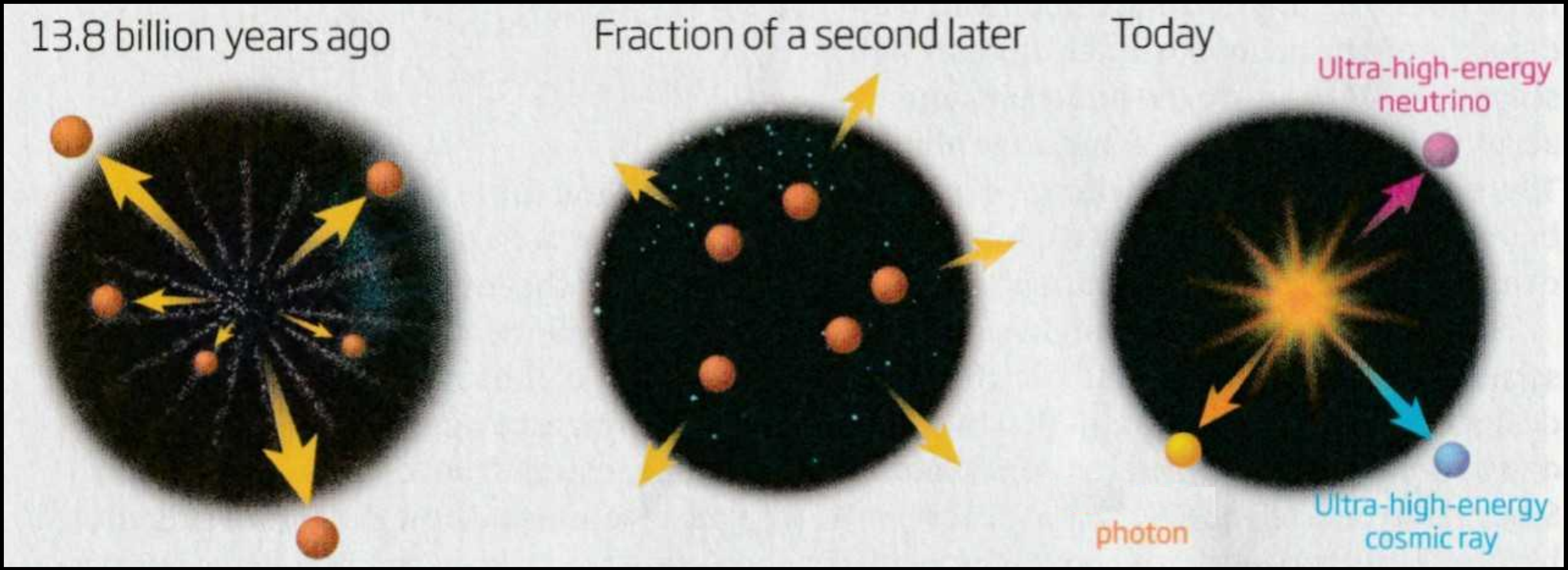




Luis Anchordoqui

CUNY

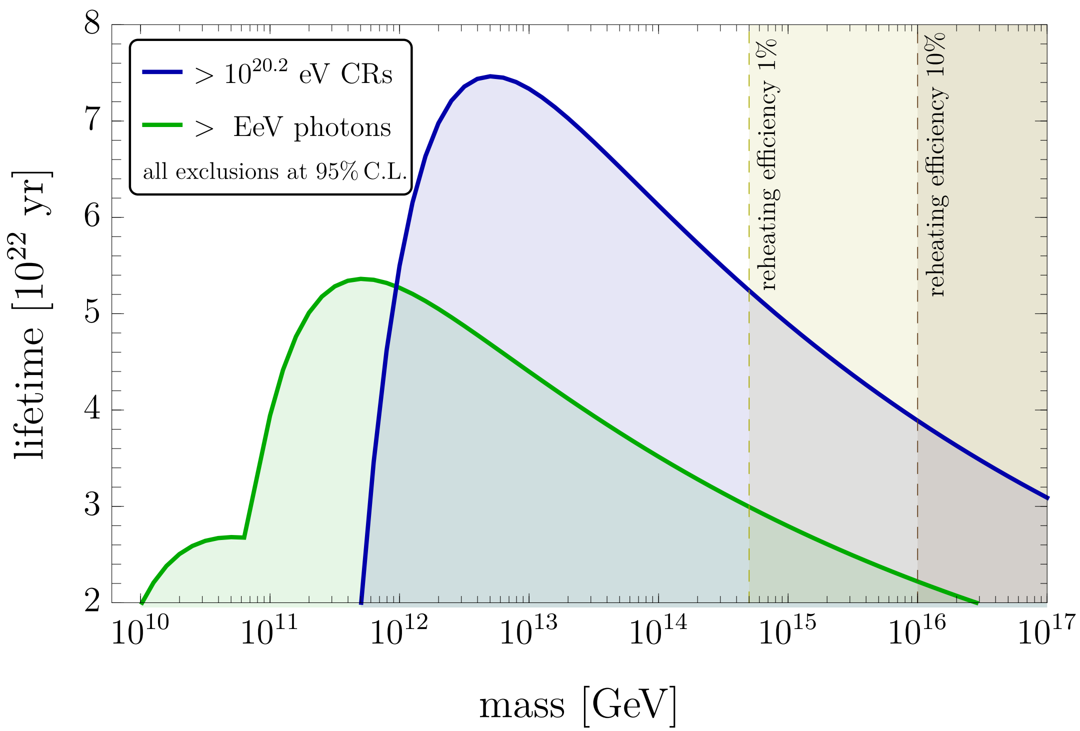
Birth and death of superheavy X-particles



- Intense fluctuating gravitational fields gave birth to superheavy X-particles just after the big bang
- The expansion of space during inflation distributed the X-particles through the cosmos
- After billions of years the X-particles decay producing a range of detectable particles
- To estimate the flux of detectable particles we need to evaluate: particle physics factor; astrophysical factor

What will GCOS data tell us about SHDM?

➢ Null search results ☛ limits on X-lifetime



LAA et al. [arXiv:2105.12895]

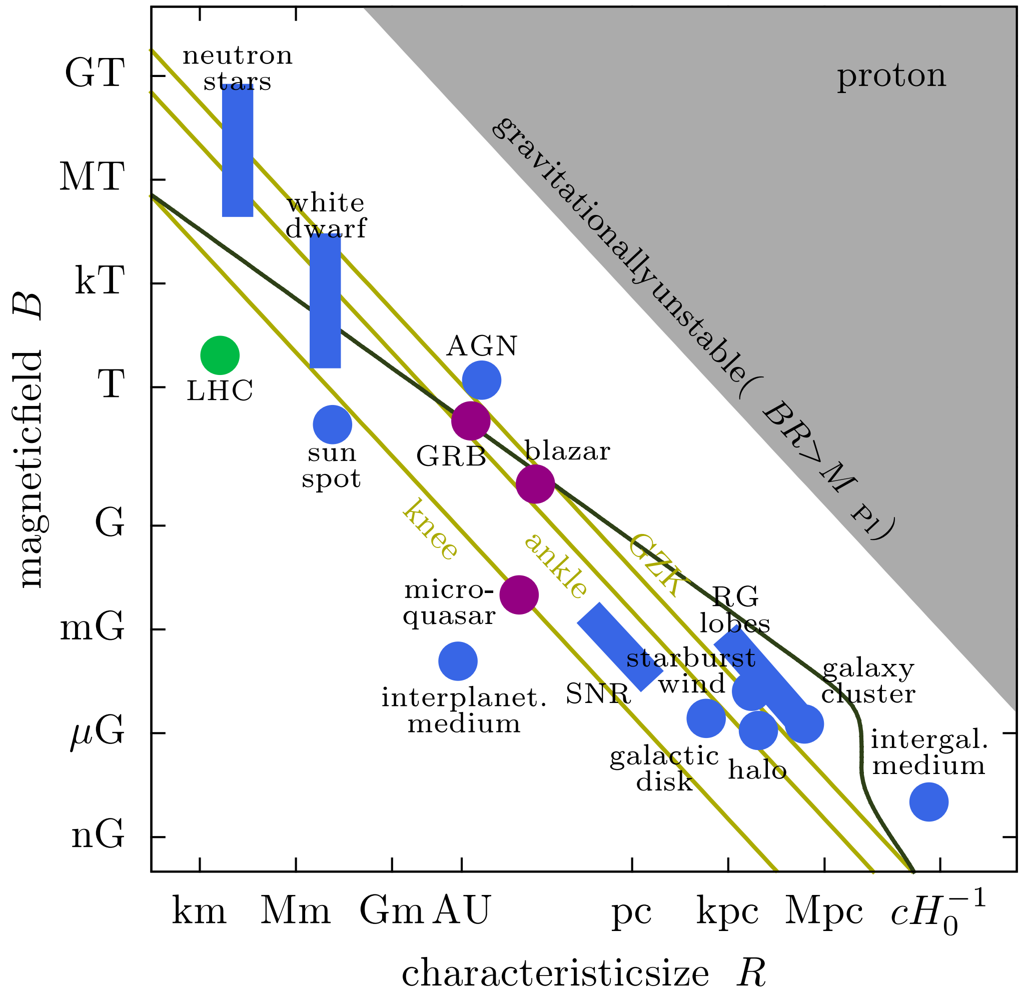
➢ Advances in constraint-based modeling of Grand Unified Theories

Pierre Auger Collaboration [arXiv:2203.08854]

Coleman et al. [arXiv:2205.05845]

➢ See Markus' talk ☛ "Chasing UHE Photons with GCOS"

Excluded region of the Hillas plot



LAA [arXiv:1807.09645]

- Total energy stored in E and B fields ☛ $\frac{1}{2}\int (E^2 + B^2) dV \sim (E^2 + B^2) R^3 \leq R M_{\rm Pl}^2$

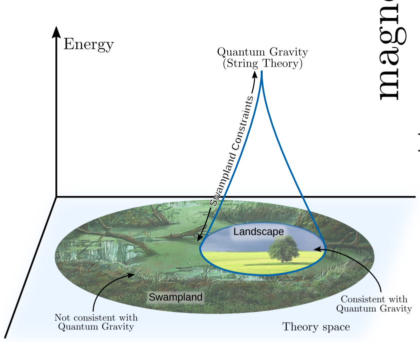
  or entire system collapses in black hole of radius R
- This implies ☛ $ER \leq M_{\rm Pl}$ or $BR \leq M_{\rm Pl}$
- Since $e = \sqrt{4\pi\alpha} \leq 1$ ☛ $E_{\rm CR,max} \sim eER \leq M_{\rm Pl}$ or $E_{\rm CR,max} \sim eBR \leq M_{\rm Pl}$

Casher and Nussinov [hep-th/9709127]

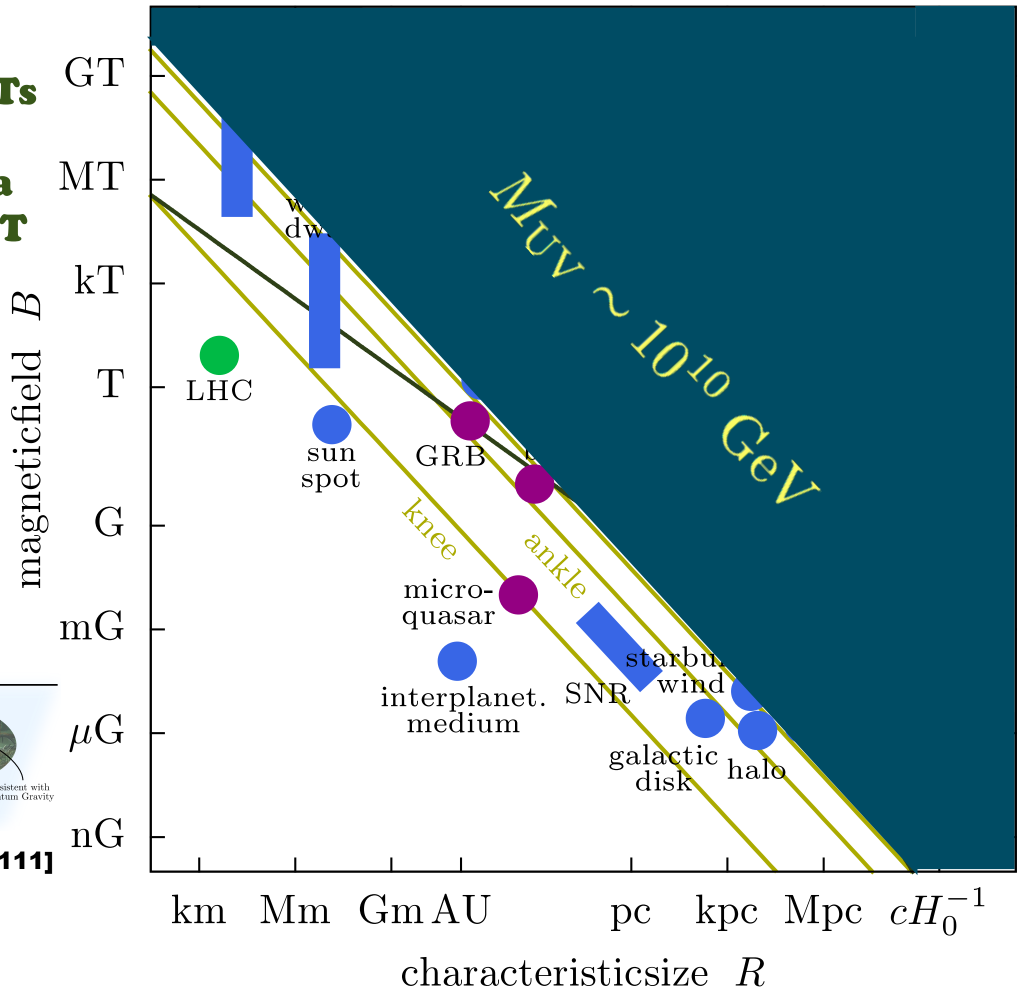
The Dark Dimension

Swampland:
IR consistent QFTs that cannot be embedded into a UV complete QGT

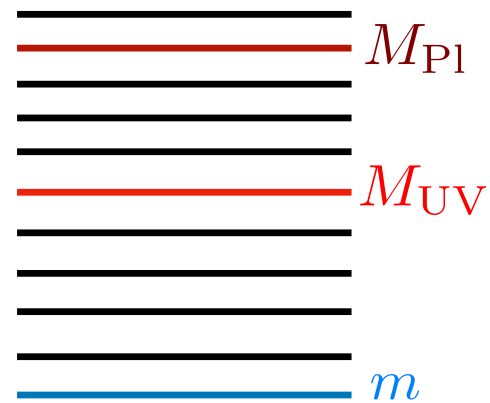
Vafa [hep-th/0509212]



Beest et al., [arXiv:2102.01111]



QFTs typically break down above certain cutoff where gravity becomes strong



KK tower with masses

$$m_n \sim \frac{n}{R_\perp}$$

- Cosmological hierarchy problem: $\Lambda \sim 10^{-122}\ M_{\rm Pl}^4$ ☛ $\Lambda^{1/4} = 2.31$ meV (or $\Lambda^{-1/4} \sim 88\ \mu$m)
- Solution: add a compact dimension with length-scale in micron range ☛ the dark dimension
- For compact circle of radius $R_\perp$ ☛ relevant mass scale is $m \sim \dfrac{1}{R_\perp} \sim \Lambda^{1/4}/\lambda$
- $M_{\rm UV} \sim \lambda^{-1/3}\ \Lambda^{1/12} M_{\rm Pl}^{2/3}$

Montero, Vafa, and Valenzuela [arXiv:2205.12293]

- Cutoff observed in cosmic ray spectrum ☛ $\lambda \sim 10^{-3} \Leftrightarrow M_{\rm UV} \sim 10^{10}$ GeV **LAA [arXiv:2205.13931]**

What will GCOS data tell us about UV physics?

➢ Does the spectrum cutoff features a source cutoff but without universal UV cutoff?

High variance in source spectra characterized by properties inherent to acceleration environment

➢ Do nuclear species in source spectra scale with Z beyond the ankle?

$E_{\rm CR}^{-\gamma} \exp[-E_{\rm CR}/E_{p,\rm max}]$ with $E_{\rm CR,max} = Z E_{p,\rm max}$ versus $E_{\rm CR}^{-\gamma} \exp[-E_{\rm CR}/E_{\rm UV}]$

NEED HIGH-STATISTICS DATA SAMPLE WITH SENSITIVITY TO BARYONIC COMPOSITION

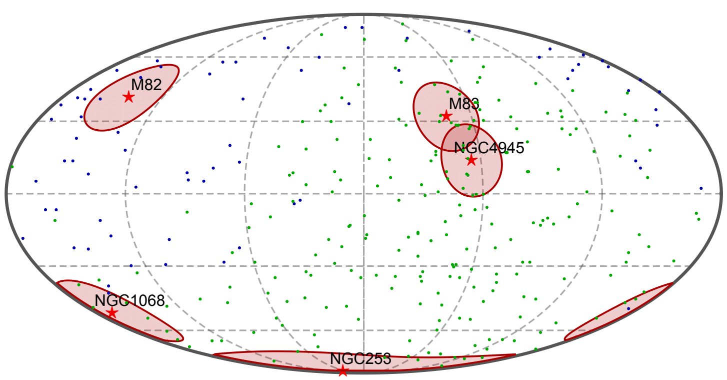
➢ How can we distinguish universal GZK cutoff from universal UV cutoff @ sources?

Study individual spectra of nearby sources

Proof of Concept ☛ Starburst Galaxies

Assume unbroken power-law spectrum $\propto E_{\rm CR}^{-\gamma}$

Auger + TA data: 231 + 72



Likelihood fit results ☛ 68% CL

Starburst	Experiment	Events	γ	$\gamma_{\rm min}$	$\gamma_{\rm max}$
NGC 4945	Auger	14	6.8	5.4	8.5
M83	Auger	13	4.6	3.7	5.7
NGC 253	Auger	8	4.8	3.6	6.4
NGC 1068	Auger	8	4.9	3.7	6.4
NGC 1068	TA	2	3.9	2.3	6.5
M82	TA	3	5.3	3.3	8.3

All spectra consistent with $\gamma = 5 \,@ 1\sigma$

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NEED HIGH-STATISTICS DATA SAMPLE WITH SENSITIVITY TO BARYONIC COMPOSITION

A "MUST" REQUIREMENT FOR GCOS DESIGN CONSIDERATIONS

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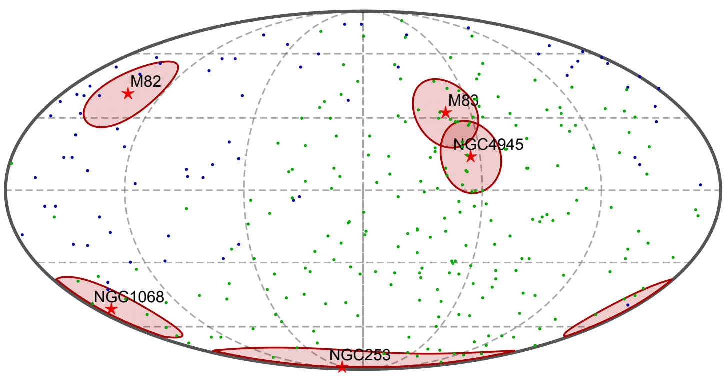

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