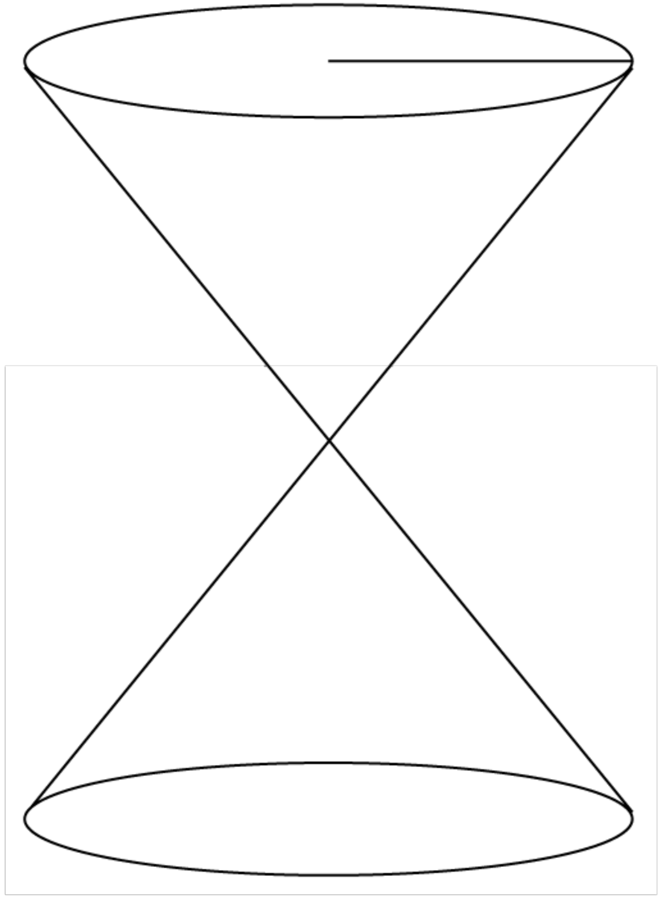


CPT Symmetric Universe

Latham Boyle, Kieran Finn and Neil Turok

based on

arXiv:1803.08928

arXiv:1803.08930

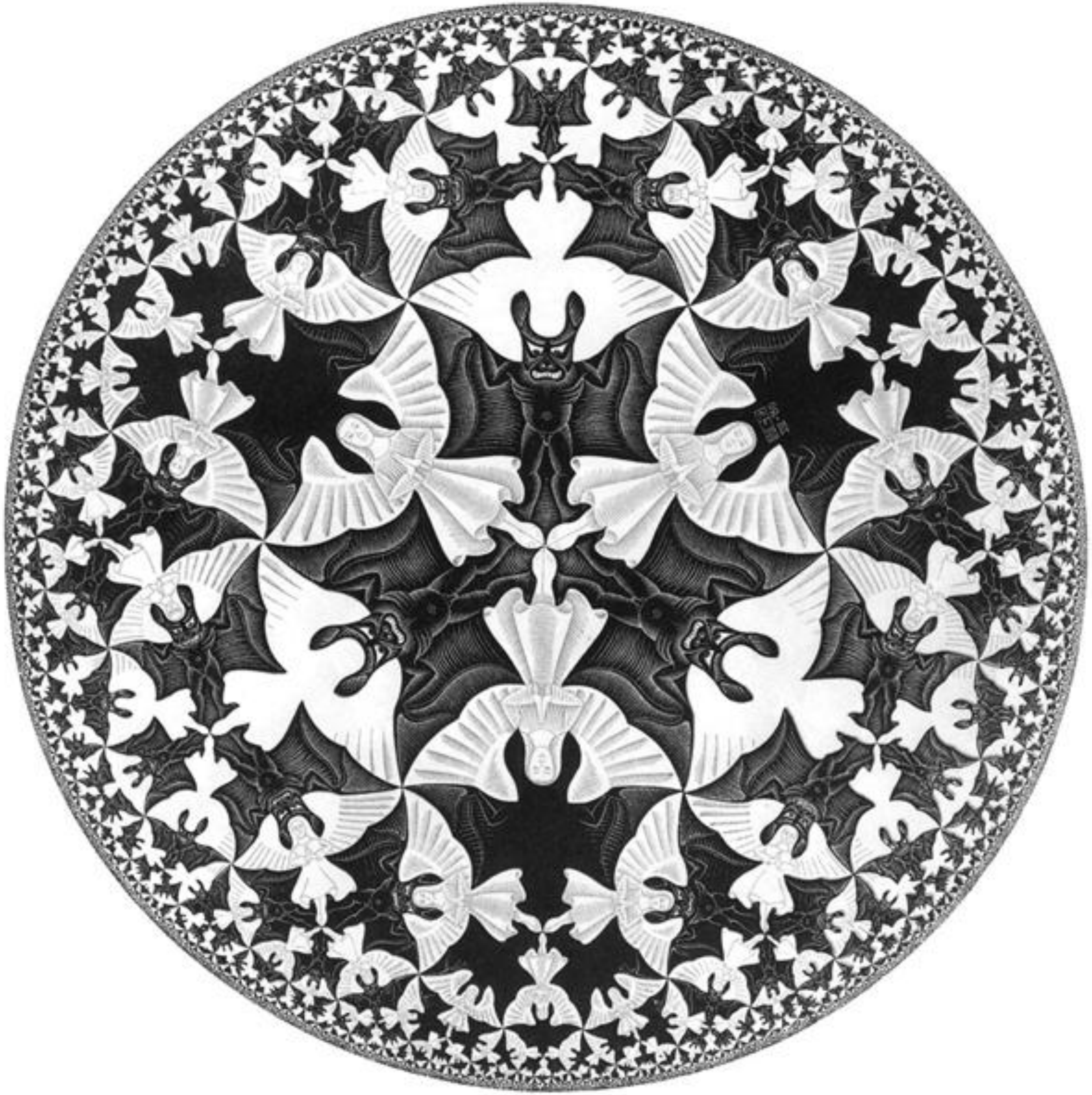
(arXiv:1803.11554)

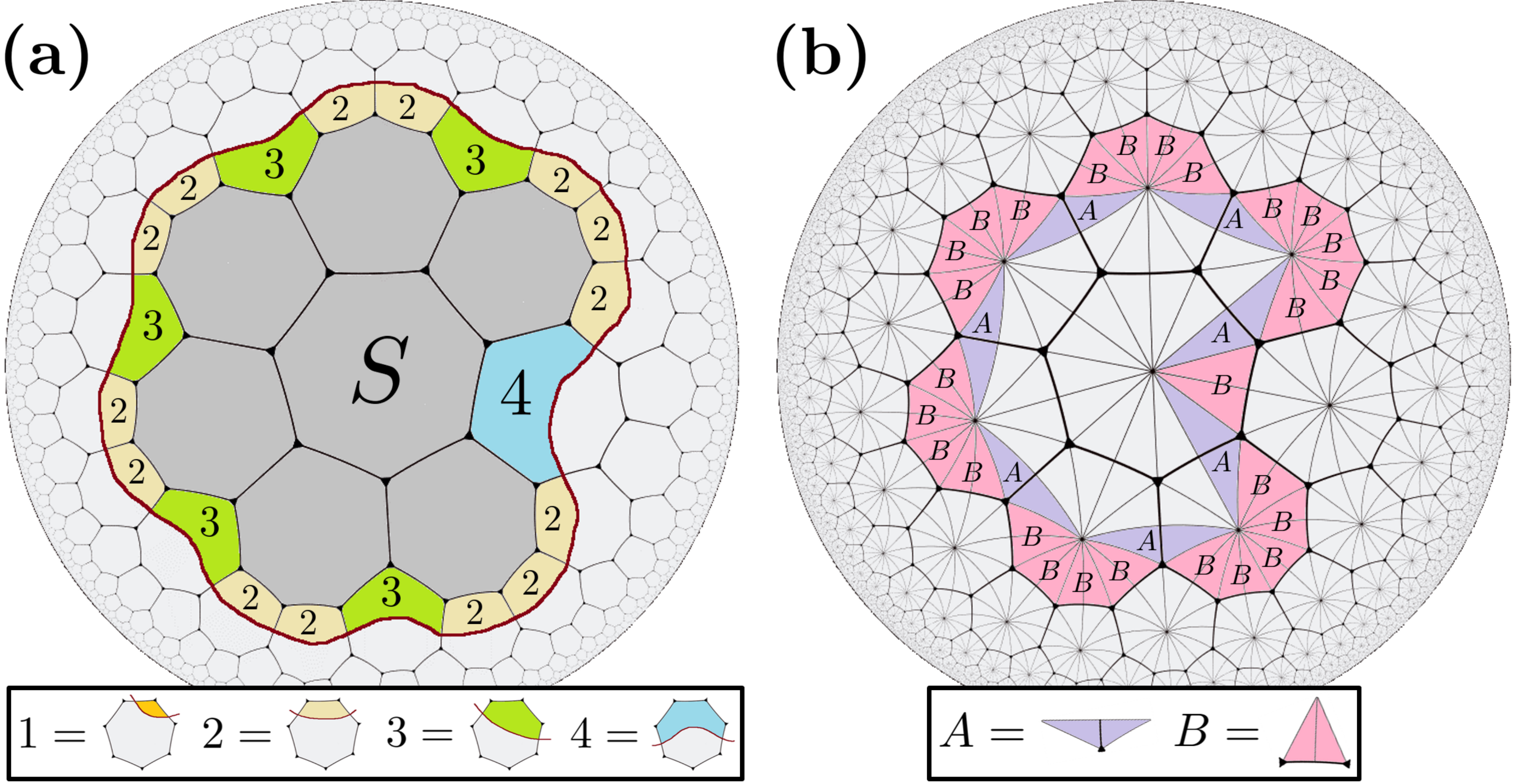
But first a brief digression!

Conformal Quasicrystals and Holography

Latham Boyle[1], Ben Dickens[2] and Felix Flicker[2,3]
[1] *Perimeter Institute for Theoretical Physics, Waterloo, Ontario N2L 2Y5, Canada, N2L 2Y5*
[2] *Department of Physics, University of California, Berkeley, California 94720, USA*
[3] *Rudolf Peierls Centre for Theoretical Physics, University of Oxford, Department of Physics, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, United Kingdom*

Recent studies of holographic tensor network models defined on regular tesselations of hyperbolic space have not yet addressed the underlying discrete geometry of the boundary. We show that the boundary degrees of freedom naturally live on a novel structure, a *conformal quasicrystal*, that provides a discrete model of conformal geometry. We introduce and construct a class of one-dimensional conformal quasicrystals, and discuss a higher-dimensional example (related to the Penrose tiling). Our construction permits discretizations of conformal field theories that preserve an infinite discrete subgroup of the global conformal group at the cost of lattice periodicity.





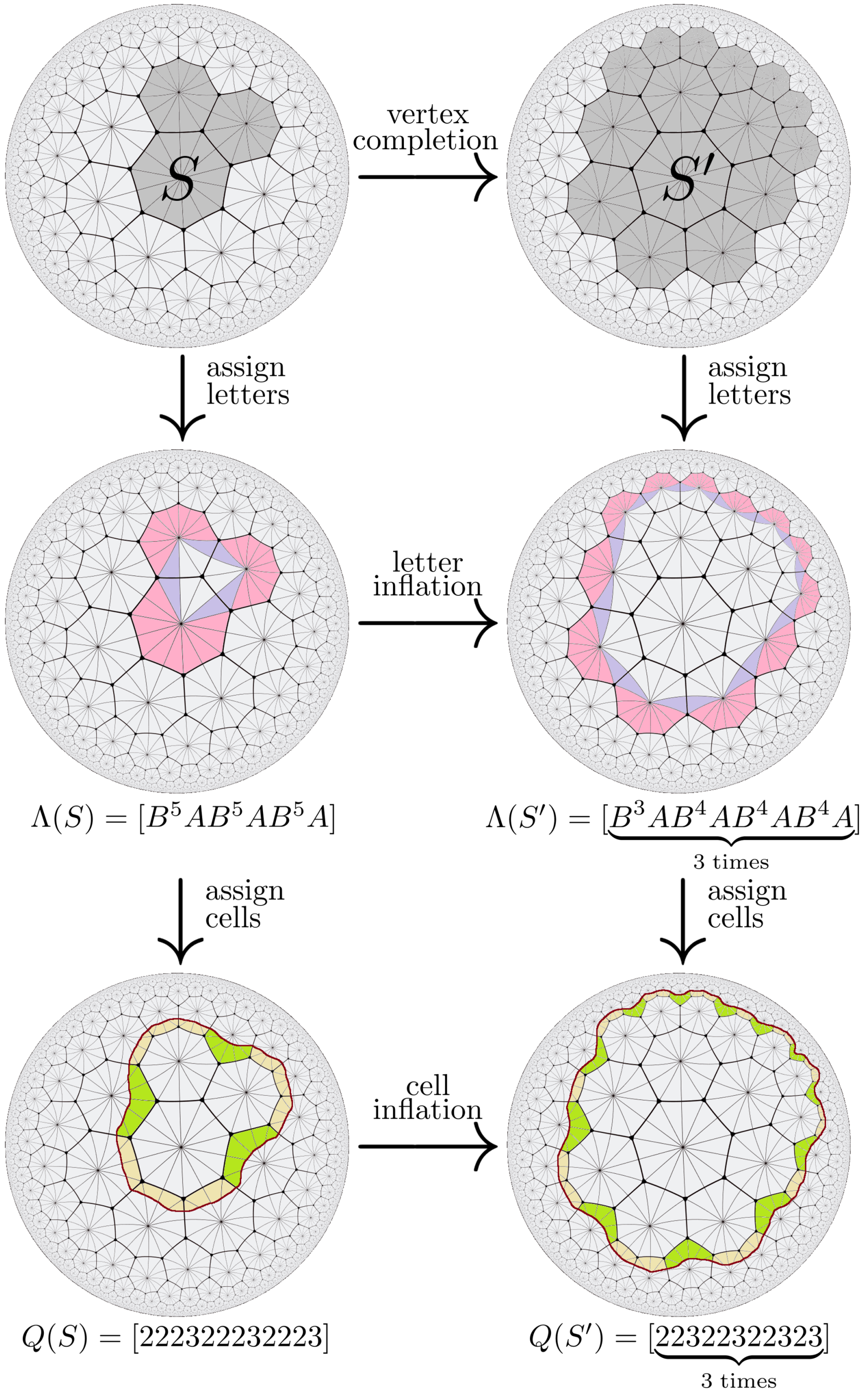
(c)

$$Q(S) = [42223223223223223222]$$

$$\Lambda(S) = [BABABBBBBABBBBABBBBABBBBABBBBABBBB]$$

(d)

$$2 \leftrightarrow B \quad 3 \leftrightarrow BAB \quad 4 \leftrightarrow BABAB \quad \cdots \quad n \leftrightarrow B\,\underbrace{AB\ldots AB}_{n-2\text{ times}}$$

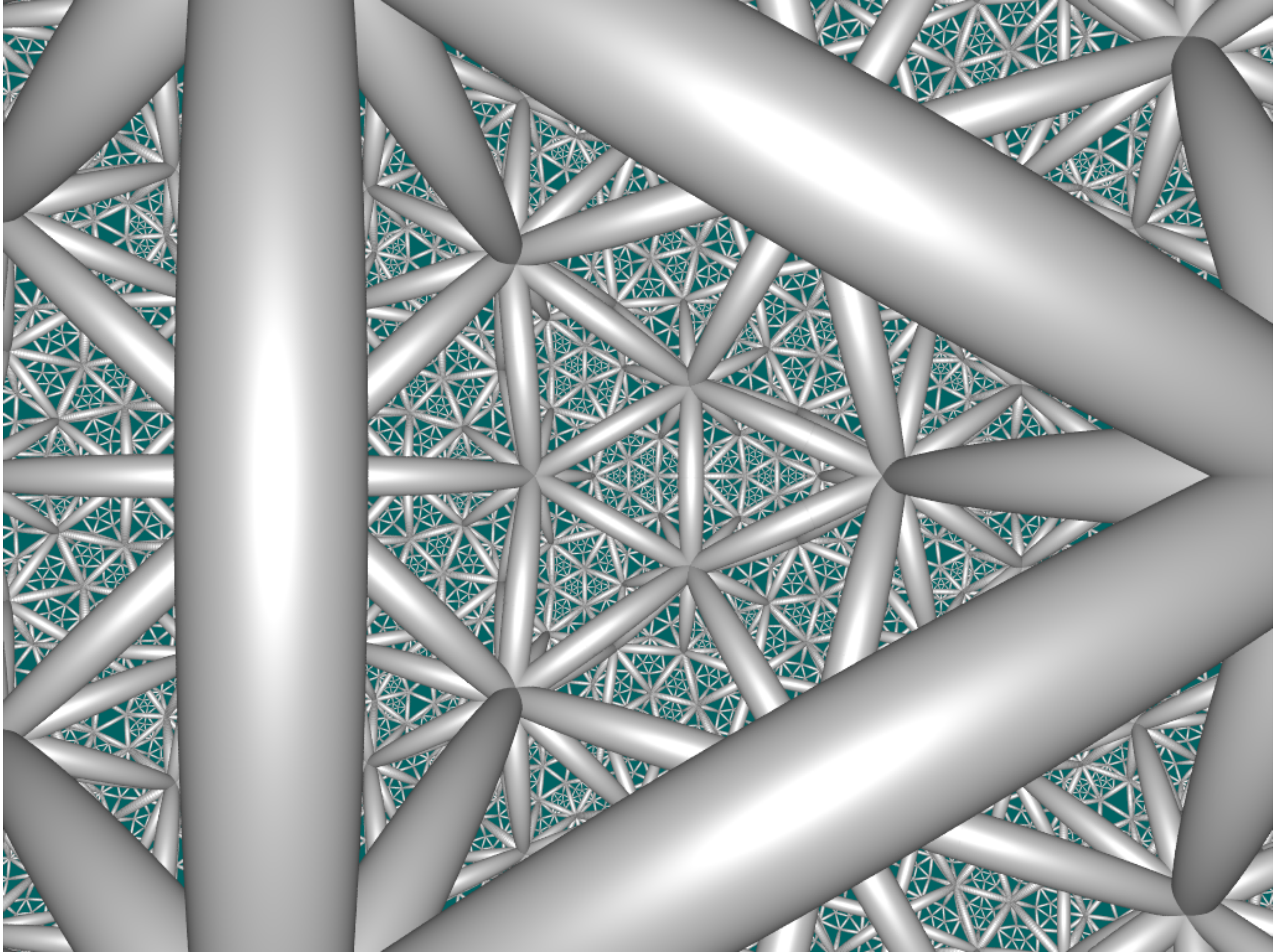


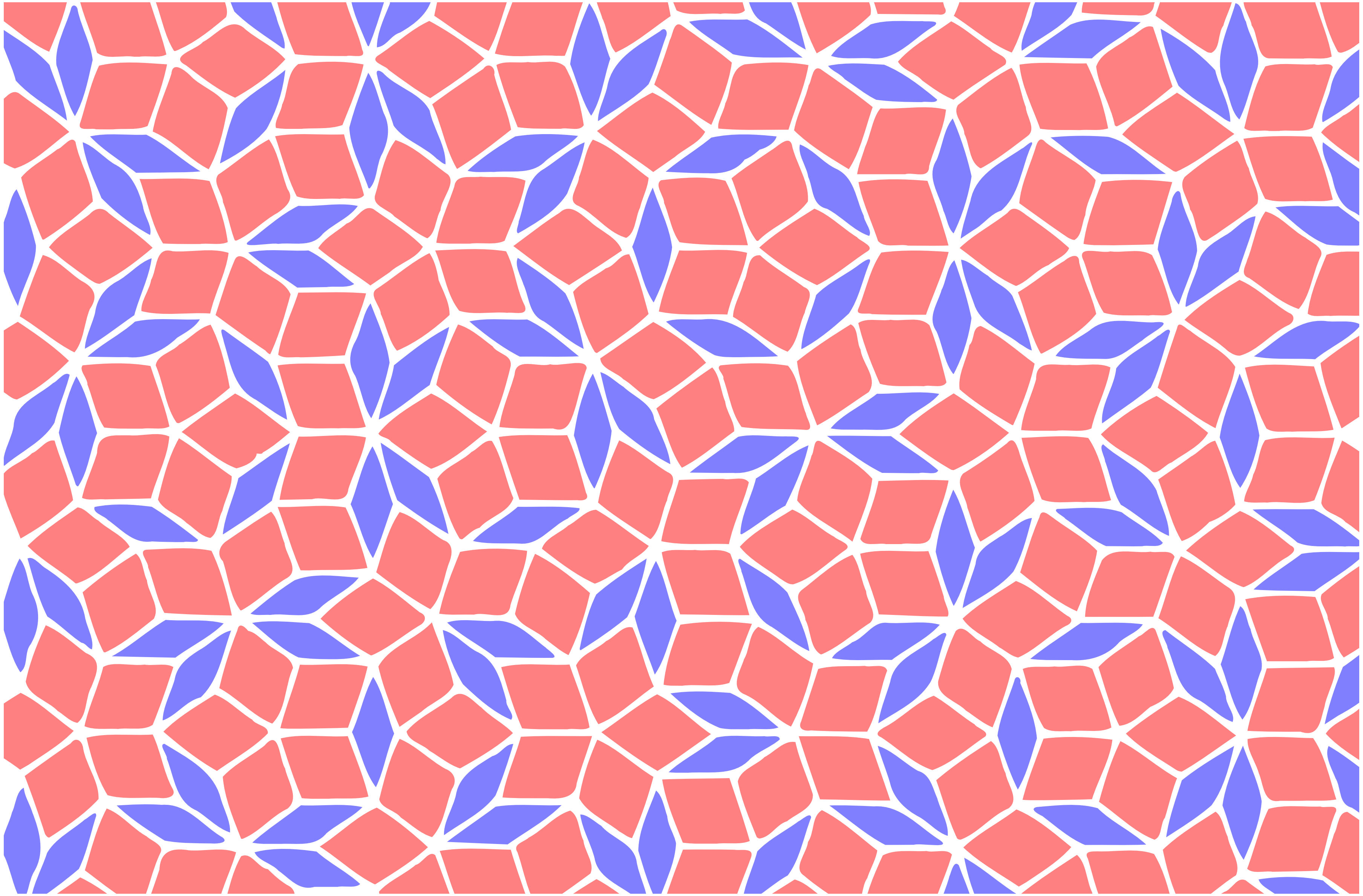
$$A \to A^{-1}B^{-5}$$

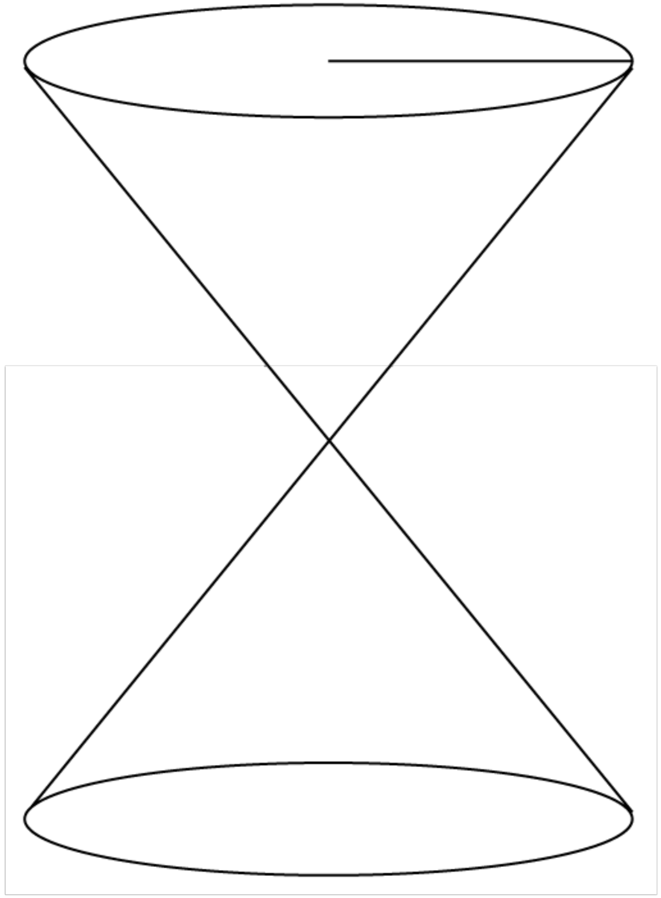
$$B \to B^4 A$$

$$2 \to 223$$

$$2 \to 23$$







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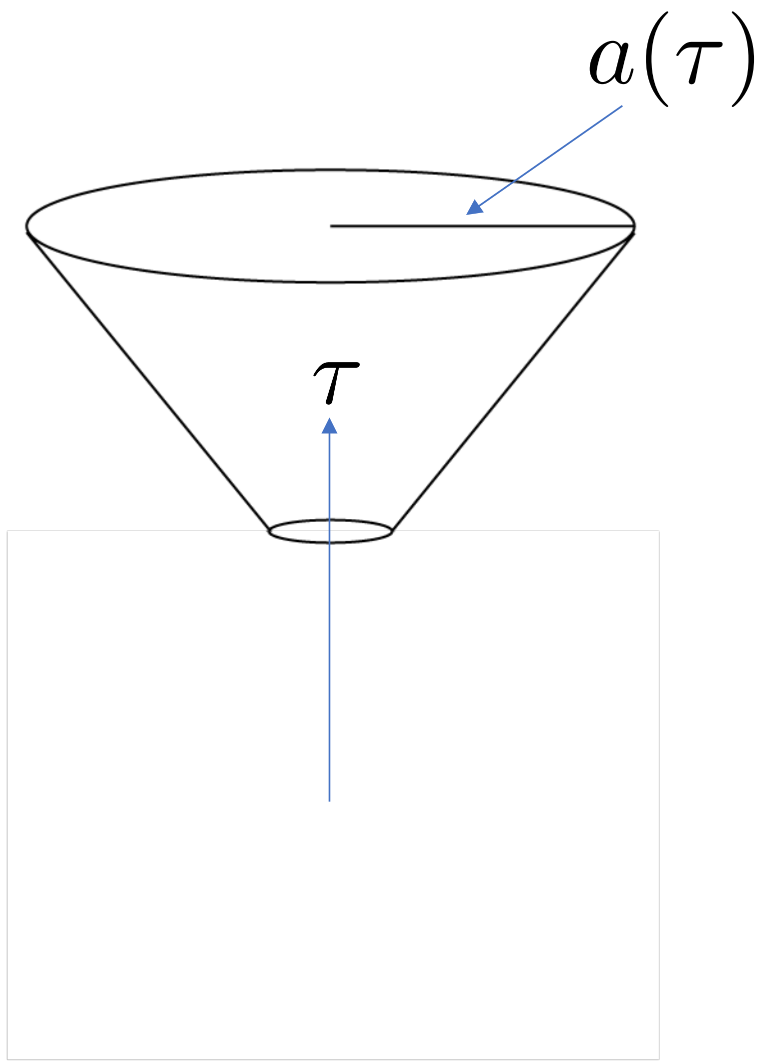
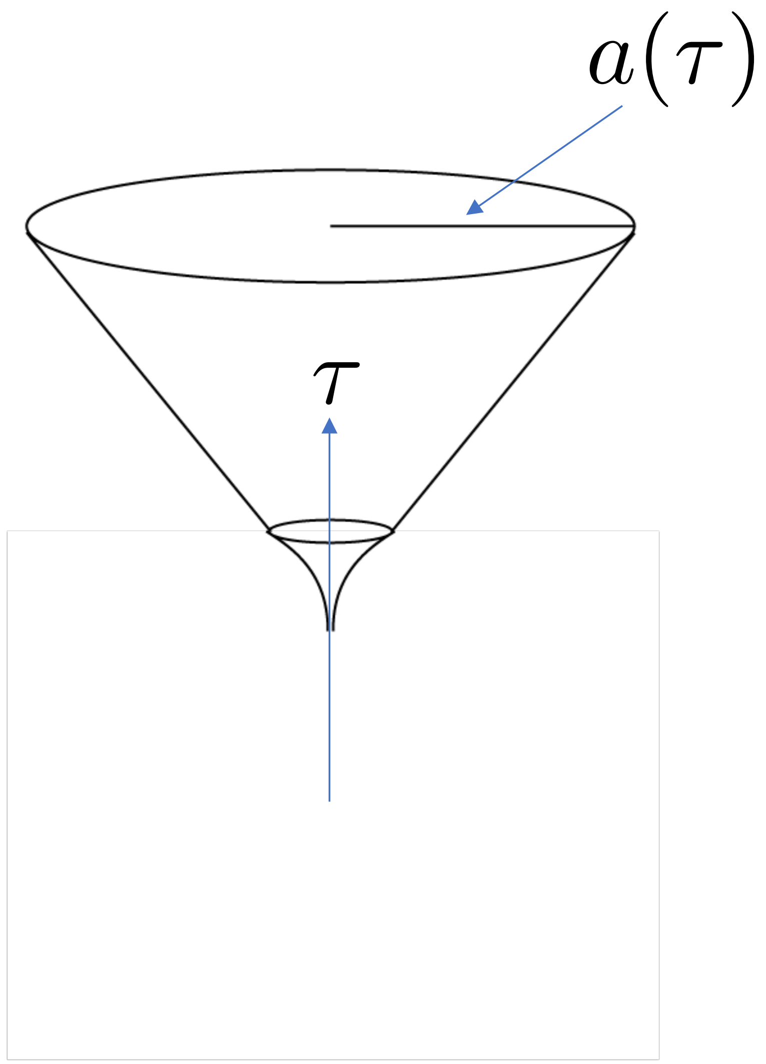

$a(\tau)$
τ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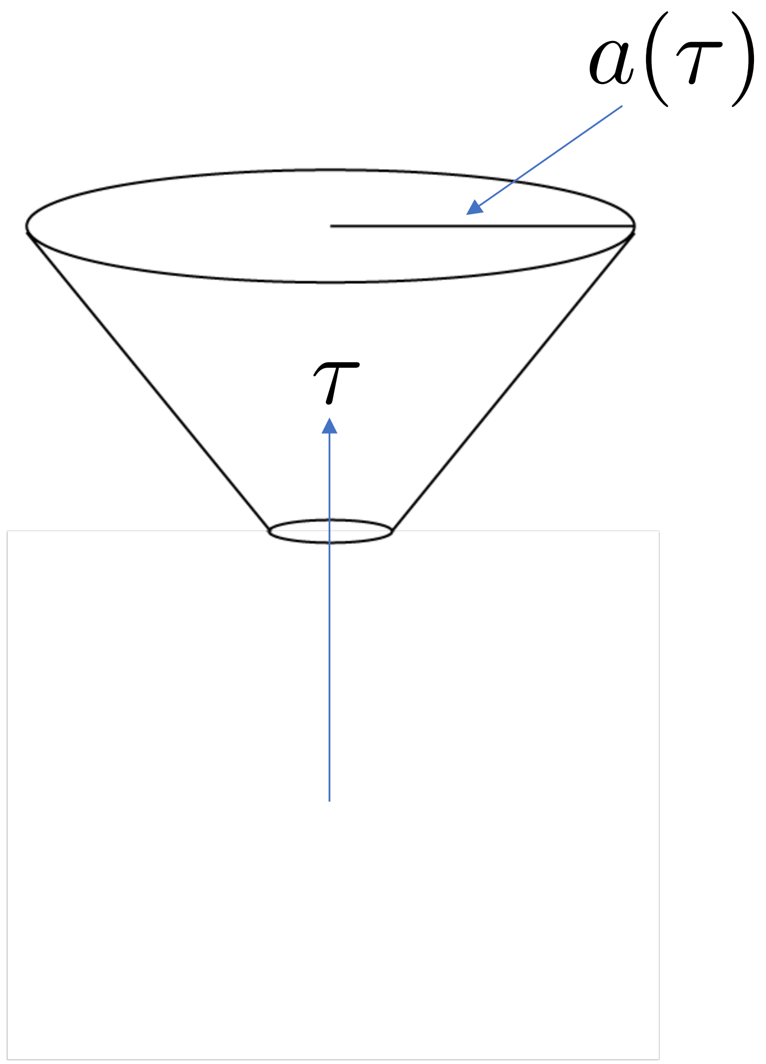
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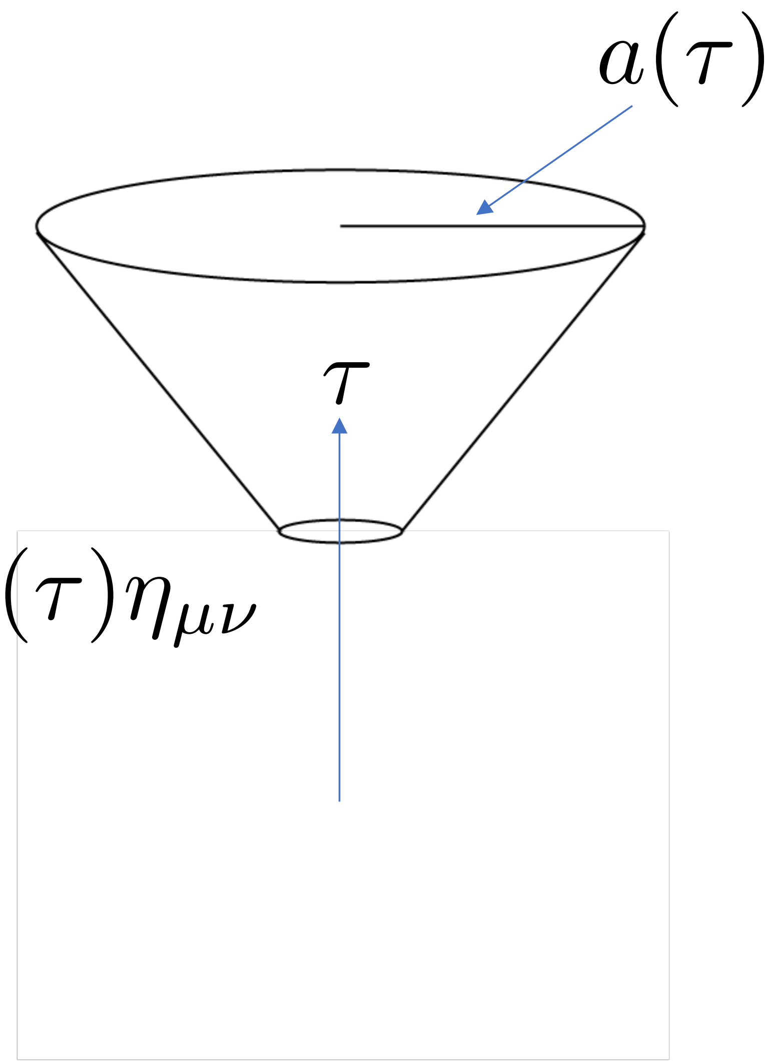
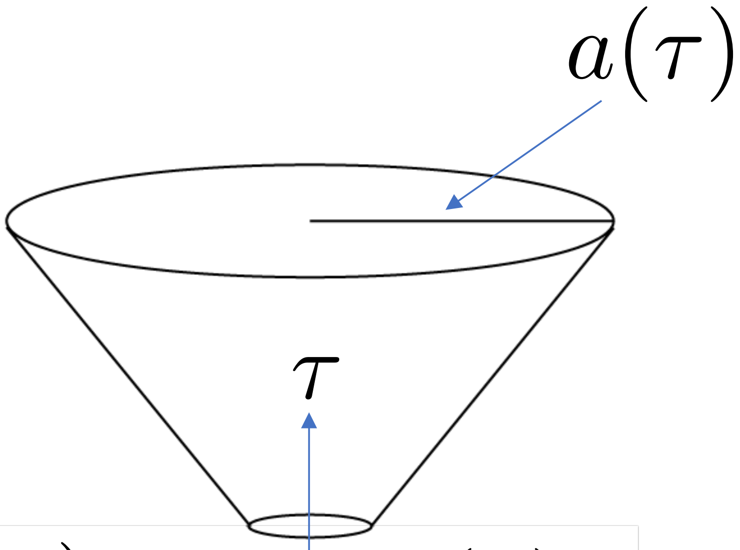
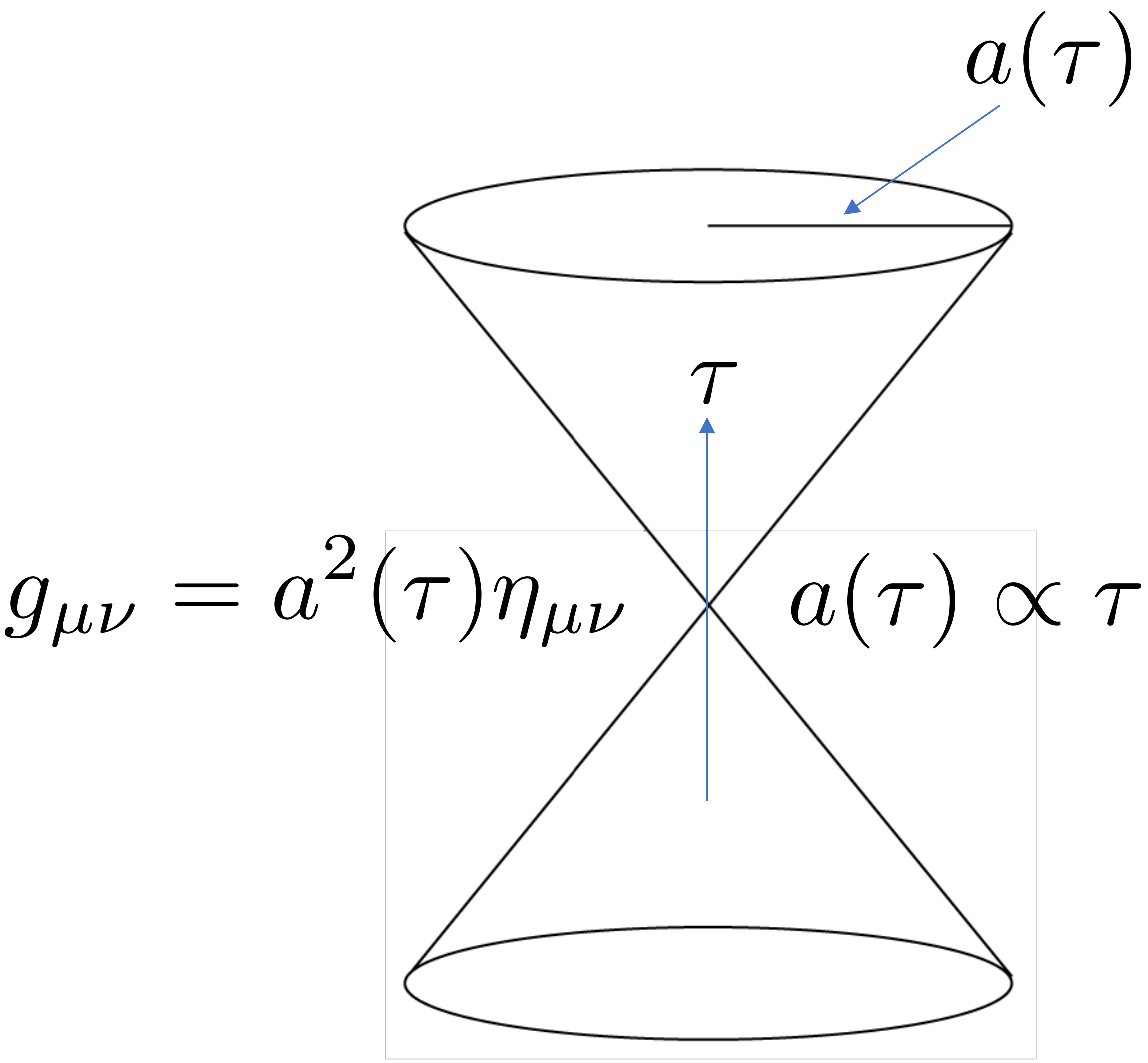


$$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu}$$



$$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu} \qquad a(\tau) \propto \tau$$



$a(\tau)$
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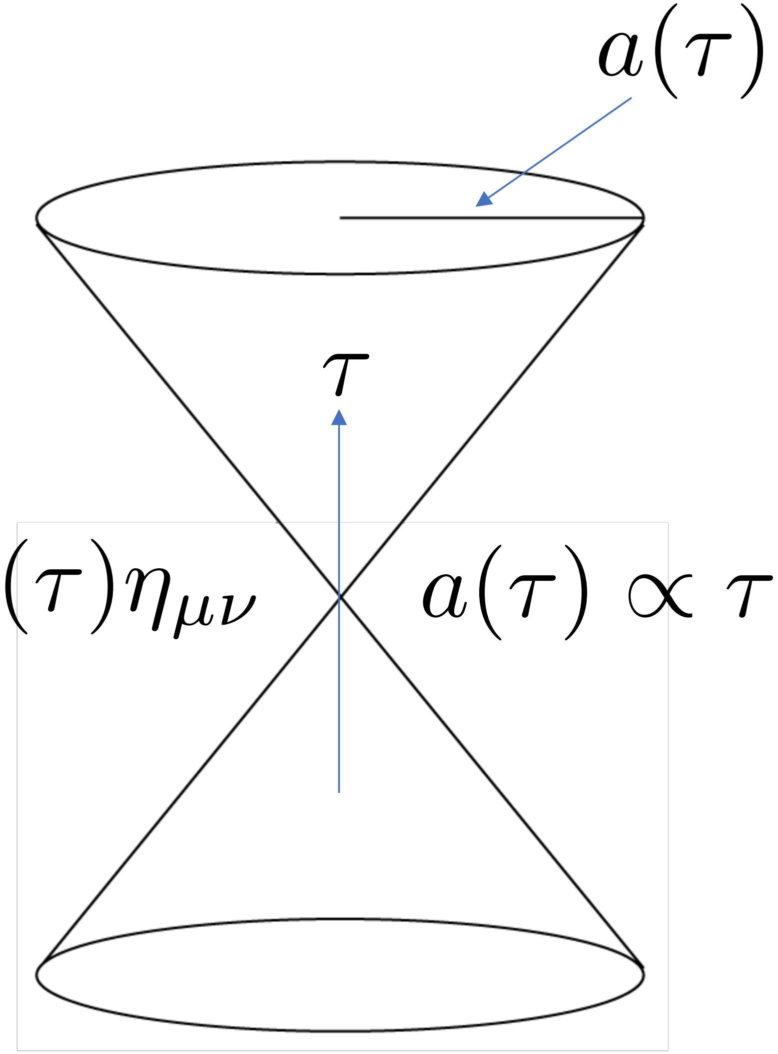
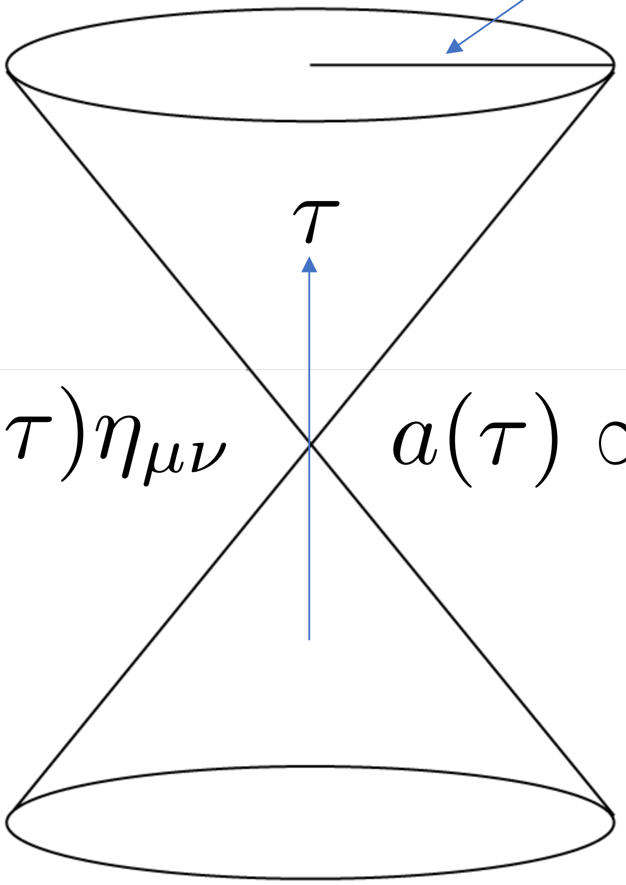
$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu}$
$a(\tau) \propto \tau$



$$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu} \qquad a(\tau) \propto \tau$$

new isometry:

$$\tau \to -\tau$$



$$g_{\mu\nu} = a^2(\tau)\eta_{\mu\nu}$$

$$a(\tau) \propto \tau$$

new isometry:

$$\tau \to -\tau$$

preferred vacuum:

$$|0_{CPT}\rangle$$

The standard model

The standard model

	$SU(3)$	$SU(2)$	$U(1)$

The standard model

	$SU(3)$	$SU(2)$	$U(1)$
q_L^i			

$$q_L^i = \begin{pmatrix} u_L^i \\ d_L^i \end{pmatrix}$$

The standard model

	$SU(3)$	$SU(2)$	$U(1)$
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u_R^i			

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The standard model

	$SU(3)$	$SU(2)$	$U(1)$
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u_R^i	$\mathbf{3}$		
d_R^i	$\mathbf{3}$		
l_L^i			
ν_R^i			
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q_L^i	3	2	
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d_R^i	3		
l_L^i	1	2	
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e_R^i	1		

$$q_L^i = \begin{pmatrix} u_L^i \\ d_L^i \end{pmatrix}$$

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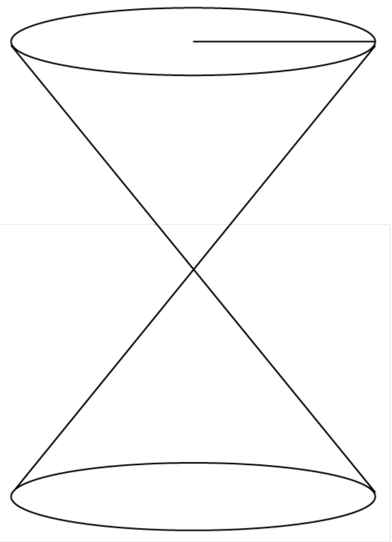
$$\psi(x) = \sum_h \int \frac{d^3\mathbf{p}}{(2\pi)^{3/2}} \left[a(\mathbf{p}, h)\psi(\mathbf{p}, h, x) + b^\dagger(\mathbf{p}, h)\psi^c(\mathbf{p}, h, x)\right]$$

$$\psi(x) = \sum_h \int \frac{d^3\mathbf{p}}{(2\pi)^{3/2}} [a(\mathbf{p},h)\psi(\mathbf{p},h,x) + b^\dagger(\mathbf{p},h)\psi^c(\mathbf{p},h,x)]$$



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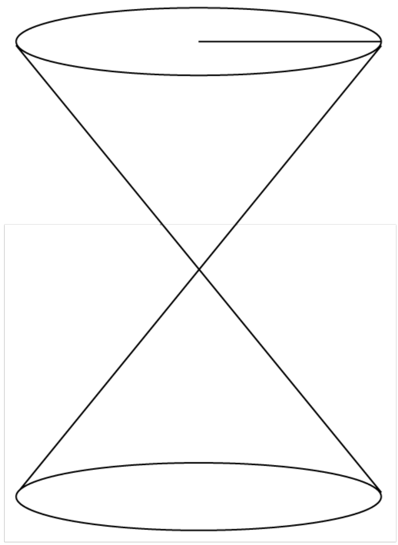
$\psi_+(\mathbf{p},h,x)$



$a_+, b_+ \quad \Rightarrow \quad |0_+\rangle$

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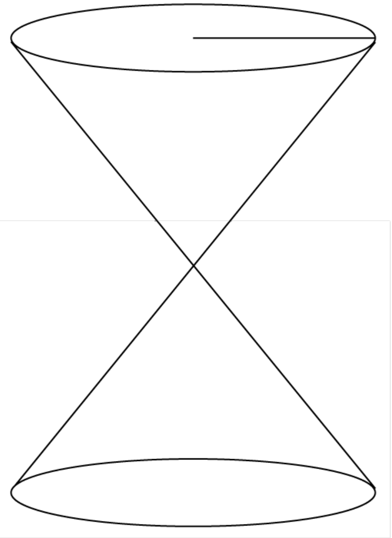

$\psi_-(\mathbf{p},h,x)$ $\qquad a_-, b_- \quad \Rightarrow \quad |0_-\rangle$

$$\psi(x) = \sum_h \int \frac{d^3\mathbf{p}}{(2\pi)^{3/2}} \left[a(\mathbf{p},h)\psi(\mathbf{p},h,x) + b^\dagger(\mathbf{p},h)\psi^c(\mathbf{p},h,x)\right]$$

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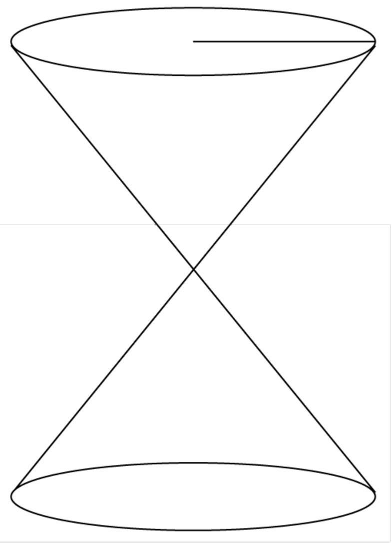


$\psi_0(\mathbf{p},h,x)$ $\quad a_0, b_0 \;\Rightarrow\; |0_0\rangle$

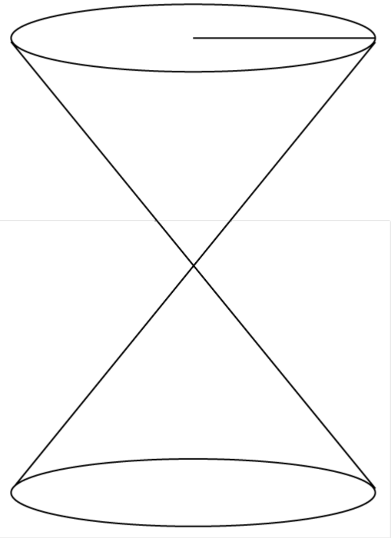
$\psi_-(\mathbf{p},h,x)$ $\quad a_-, b_- \;\Rightarrow\; |0_-\rangle$

$$\psi(x) = \sum_h \int \frac{d^3\mathbf{p}}{(2\pi)^{3/2}} [a(\mathbf{p},h)\psi(\mathbf{p},h,x) + b^\dagger(\mathbf{p},h)\psi^c(\mathbf{p},h,x)]$$

$$\psi_+(\mathbf{p},h,x)$$

$$\psi_0(\mathbf{p},h,x)$$

$$\psi_-(\mathbf{p},h,x)$$



$$a_+, b_+ \quad \Rightarrow \quad |0_+\rangle$$

$$a_0, b_0 \quad \Rightarrow \quad |0_0\rangle$$

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$$\psi_0(\mathbf{p},h,x) = \alpha(\mathbf{p})\psi_+(\mathbf{p},h,x) + \beta(\mathbf{p})\psi^c_+(-\mathbf{p},h,x)$$

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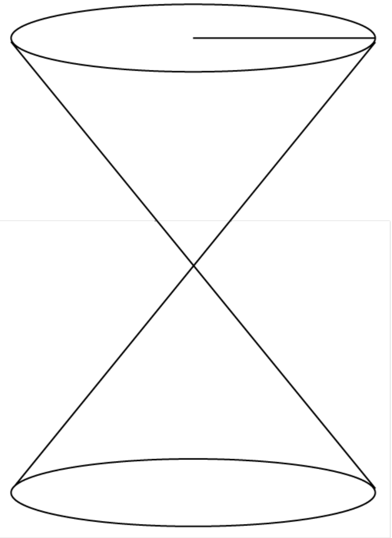

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$$\langle 0_0|a_+^\dagger(\mathbf{p},h)a_+(\mathbf{p},h)|0_0\rangle = |\beta(\mathbf{p})|^2 = \exp\left[-\pi p^2 \frac{M_{pl}}{M}\left(\frac{3}{\rho_1}\right)^{\frac{1}{2}}\right]$$

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one stable neutrino: ν_R^1

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$$\frac{n_{\rm dm}}{s_{\rm rad}} = C\left(\frac{m_{dm}}{m_{pl}}\right)^{3/2} \qquad (C = 0.003476\ldots)$$

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3 light ν's are majorana ($0\nu\beta\beta$ decay)

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lightest ν is massless ($m_{\rm tot} = 0.05$eV, 0.1eV)

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lightest ν is massless ($m_{\rm tot} = 0.05$eV, 0.1eV)

other 2 heavy $\nu's$: leptogenesis

[hep-ph] 30 Mar 2018

Upgoing ANITA events as evidence of the CPT symmetric universe

Luis A. Anchordoqui,[1,2,3] Vernon Barger,[4] John G. Learned,[5] Danny Marfatia,[5] and Thomas J. Weiler[6]

[1] *Department of Physics & Astronomy, Lehman College, City University of New York, NY 10468, USA*
[2] *Department of Physics, Graduate Center, City University of New York, NY 10016, USA*
[3] *Department of Astrophysics, American Museum of Natural History, NY 10024, USA*
[4] *Department of Physics, University of Wisconsin, Madison, WI 53706, USA*
[5] *Department of Physics & Astronomy, University of Hawaii at Manoa, Honolulu, HI 96822, USA*
[6] *Department of Physics & Astronomy, Vanderbilt University, Nashville TN 37235, USA*

(Dated: April 1, 2018)

We explain the two upgoing ultra-high energy shower events observed by ANITA as arising from the decay in the Earth's core of the quasi-stable dark matter candidate in the CPT symmetric universe. The dark matter particle is a 480 PeV right-handed neutrino that decays into a Higgs and a light Majorana neutrino. The latter interacts in the Earth's crust to produce a τ lepton that in turn initiate an atmospheric upgoing shower.

The three balloon flights of the ANITA experiment have resulted in the observation of two unusual upgoing showers with energies of (600 ± 400) PeV [1] and (560^{+300}_{-200}) PeV [2]. The energy estimates are made un-

with the non-observation of similar events at cosmic ray facilities and IceCube.

Cosmic ray facilities have seen downgoing shower events with energies up to $\sim 10^5$ PeV, but have not

- No primordial tensor perturbations (GWs)

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- No primordial vector perturbations (vorticity)

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- Correct boundary condition for primordial scalar perturbations (CMB oscillations)

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- CPT hypothesis “protects” Weyl character of Big Bang singularity, and predicts thermodynamic arrow of time flows away from the bang in “either direction” (w.r.t. the conformal time tau)

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- Earlier through-the-bang references:
  - Bars, Chen, Steinhardt, Turok: arXiv:1105.3606, 1112.2470, 1207.1940, 1307.1848
  - Gielen, Turok: arXiv:1510.00699, 1612.02792
  - Barbour, Koslowski, Mercati, Sloan: arXiv:1409.0917, 1507.06498, 1604.03956, 1607.02460

Thank you!