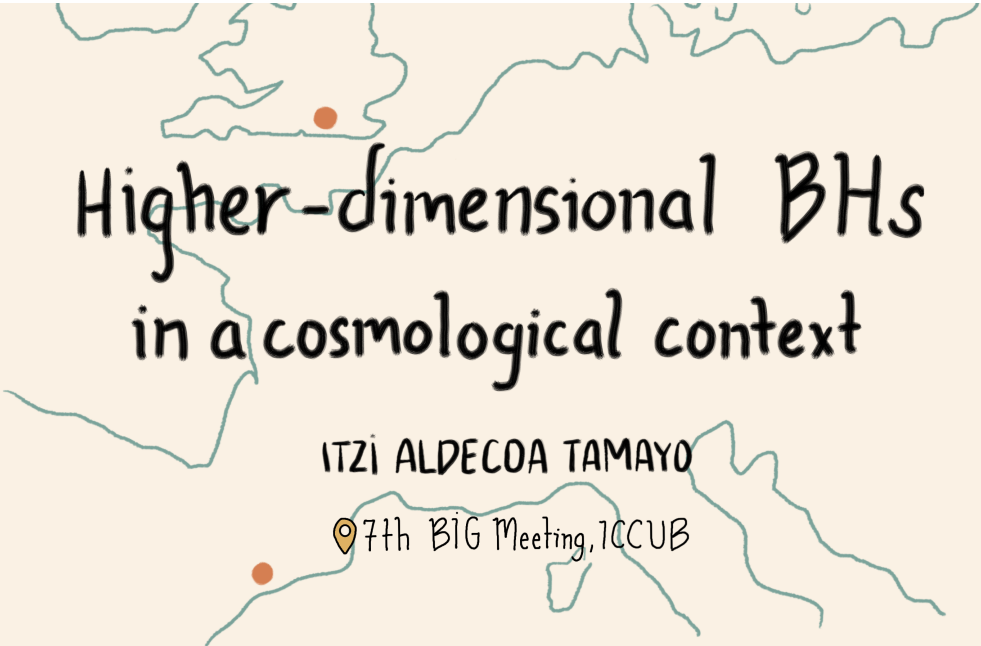


Higher-dimensional BHs in a cosmological context

ITZI ALDECOA TAMAYO

 7th BIG Meeting, ICCUB

A hand-drawn map of the Americas, including North and South America, rendered in light blue outlines on a light beige background. Two orange dots are placed on the map: one in the northern part of North America and another in the southern part of South America.

Higher-dimensional BHs in a cosmological context

ITZI ALDECOA TAMAYO

📍 7th BIG Meeting, ICCUB



A hand-drawn map of Europe in light blue lines on a tan background. Two orange dots mark specific locations. The top dot is in the British Isles, labeled 'C. Byrnes & D. Seery'. The bottom dot is in the Iberian Peninsula, labeled 'R. Emparan'. The central text is written in a large, black, handwritten font.

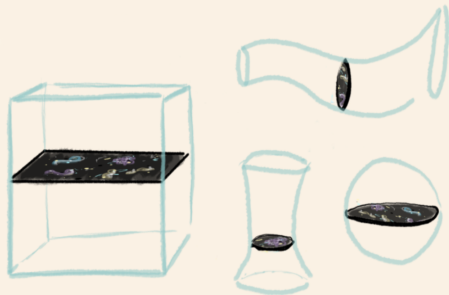
C. Byrnes & D. Seery

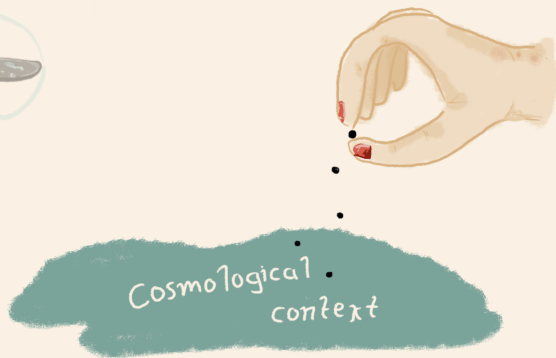
Higher-dimensional BHs in a cosmological context

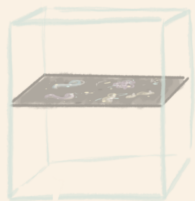
ITZI ALDECOA TAMAYO

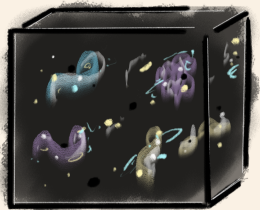
📍 7th BIG Meeting, ICCUB

R. Emparan

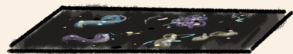


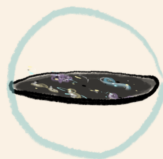
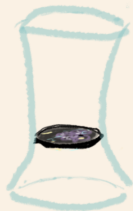
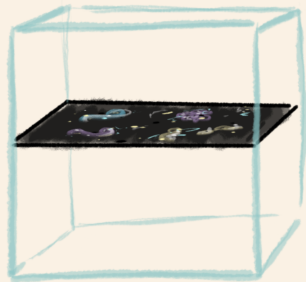


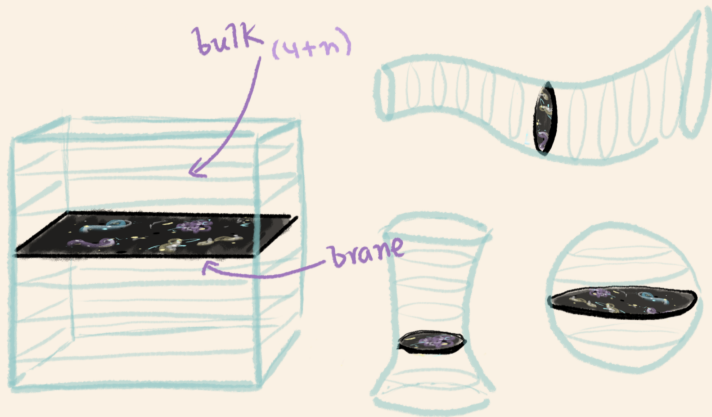




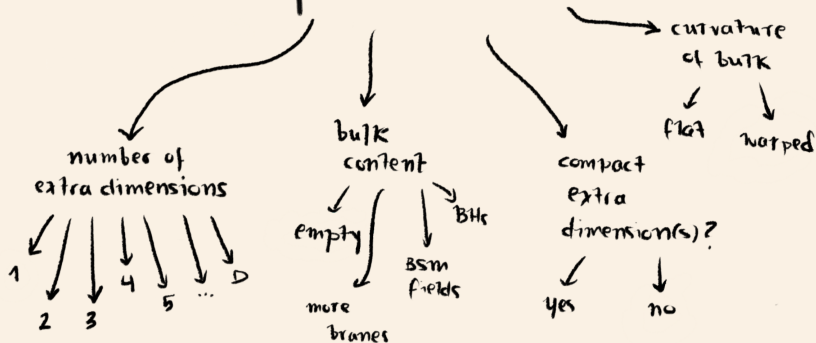






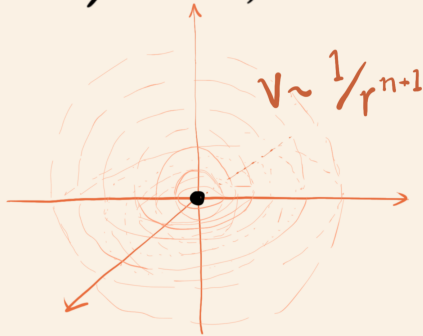


Higher-dimensional frameworks



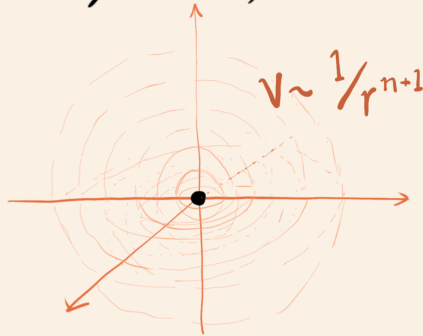
$$G_{\mu\nu}^{(4+n)} = \kappa T_{\mu\nu}^{(4+n)}$$

$$G_{\mu\nu}^{(4+n)} = \kappa T_{\mu\nu}^{(4+n)}$$



Gravity propagates
in all directions

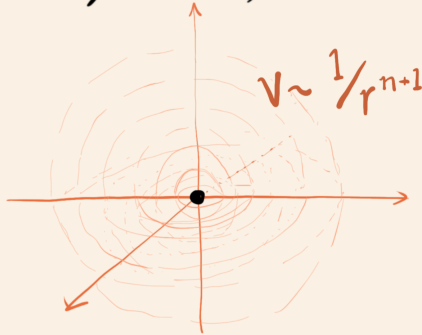
$$G_{\mu\nu}^{(4+n)} = \kappa T_{\mu\nu}^{(4+n)}$$



Gravity propagates
in all directions

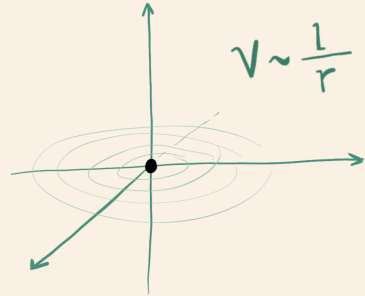
SM fields remain
(3+1)-dimensional

$$G_{\mu\nu}^{(4+n)} = \kappa T_{\mu\nu}^{(4+n)}$$



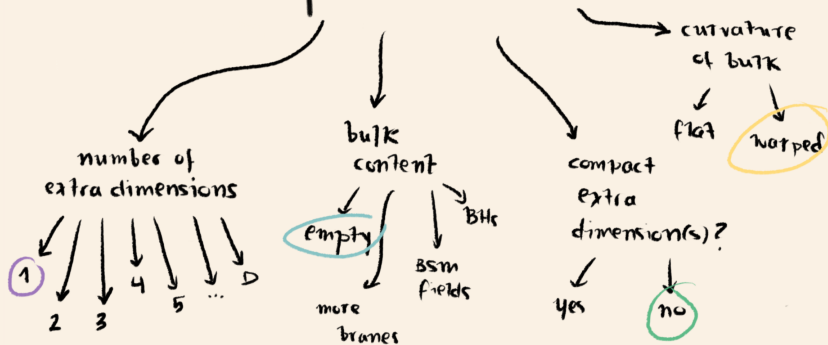
Gravity propagates
in all directions

SM fields remain
 $(3+1)$ -dimensional

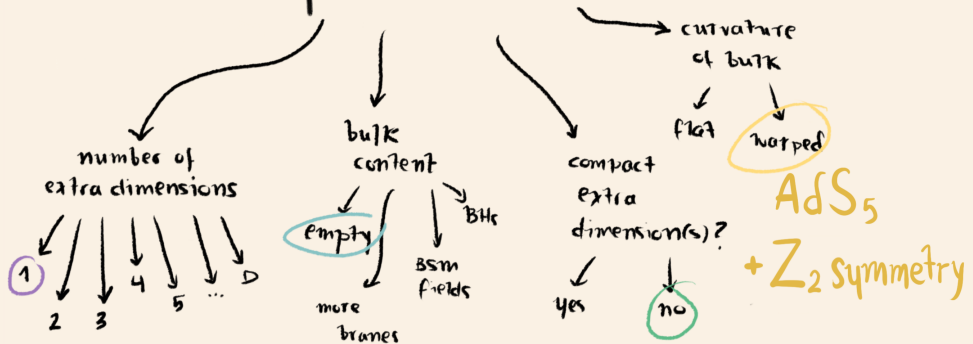


Ordinary particles are
confined to the brane

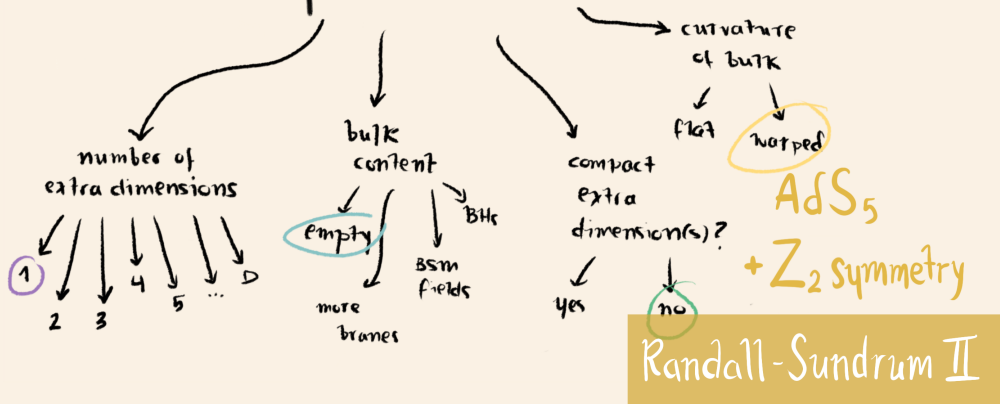
Higher-dimensional frameworks



Higher-dimensional frameworks



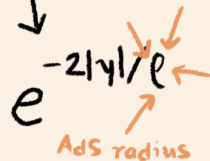
Higher-dimensional frameworks



Randall-Sundrum II

Randall-Sundrum II

$$^{(5)}ds^2 = e^{-2|y|/\ell} g_{\mu\nu} dx^\mu dx^\nu + dy^2$$

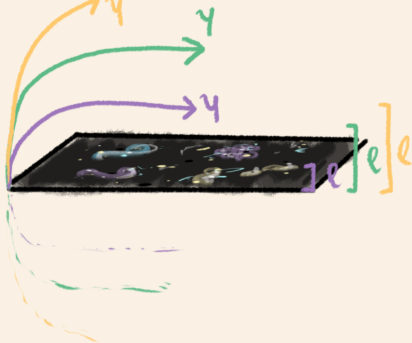


$e^{-2|y|/\ell}$
AdS radius

The diagram shows the exponential factor $e^{-2|y|/\ell}$ from the metric tensor equation. Four orange arrows point to the ℓ in the denominator, with the text "AdS radius" written below them.

Randall-Sundrum II

$$^{(5)}ds^2 = e^{-2|y|/\ell} g_{\mu\nu} dx^\mu dx^\nu + dy^2$$



$$e^{-2|y|/\ell}$$

AdS radius

Black holes in Randall-Sundrum II

Black holes in Randall-Sundrum II

Natural testing ground for alternative theories of gravity

Black holes in Randall-Sundrum II

Natural testing ground for alternative theories of gravity

Black holes in Randall-Sundrum II

Natural testing ground for alternative theories of gravity

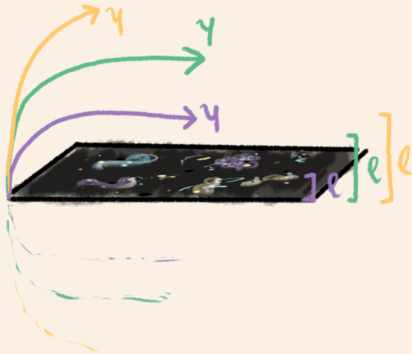
Metric (& properties) very scale-dependent

Black holes in Randall-Sundrum II

Metric (& properties):

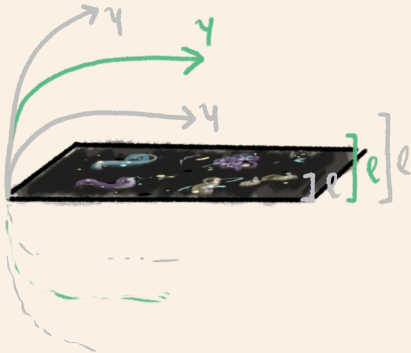
Black holes in Randall-Sundrum II

Metric (& properties):



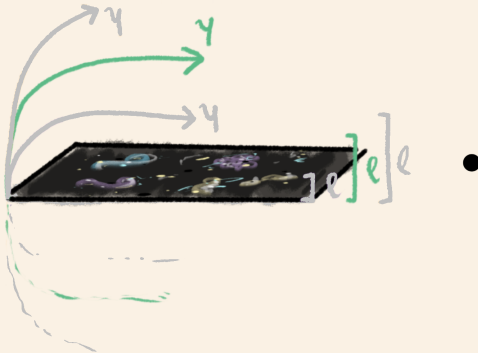
Black holes in Randall-Sundrum II

Metric (& properties):



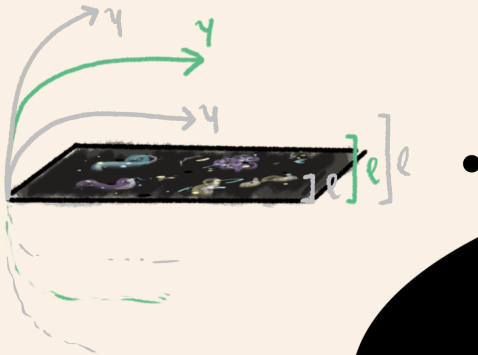
Black holes in Randall-Sundrum II

Metric (& properties):



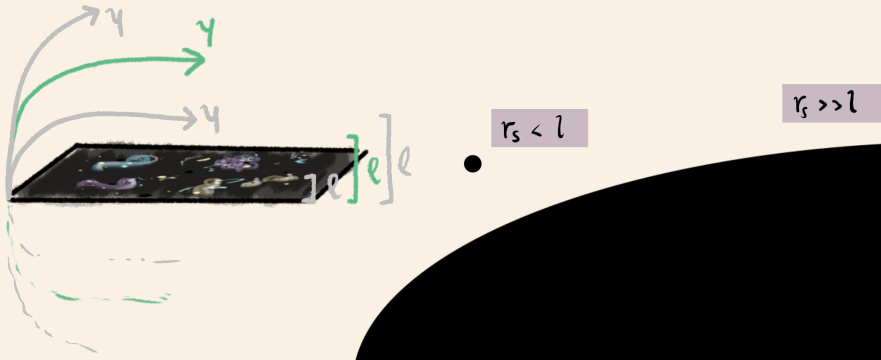
Black holes in Randall-Sundrum II

Metric (& properties):



Black holes in Randall-Sundrum II

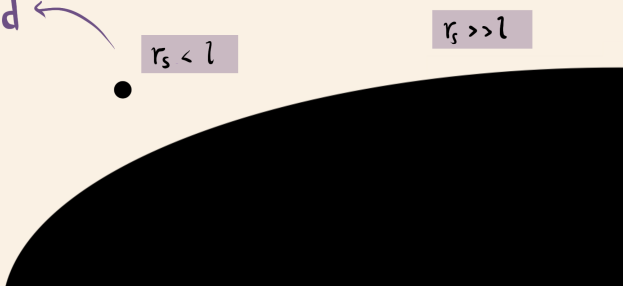
Metric (& properties):



Black holes in Randall-Sundrum II

Metric (& properties):

5-Dimensional Schwarzschild



A diagram illustrating a black hole in Randall-Sundrum II. A small black dot represents the black hole. A curved arrow points from the text '5-Dimensional Schwarzschild' to this dot. To the right of the dot is a large, solid black curved shape representing the event horizon. Two labels are present: $r_s < l$ next to the black dot and $r_s \gg l$ next to the event horizon.

$$r_s < l$$

$$r_s \gg l$$

Black holes in Randall-Sundrum II

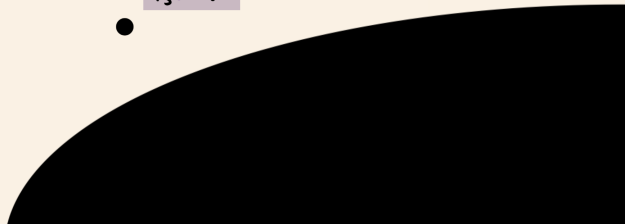
Metric (& properties):

5-dimensional Schwarzschild

$\approx$ 4-dimensional Schwarzschild

$r_s < l$

$r_s \gg l$

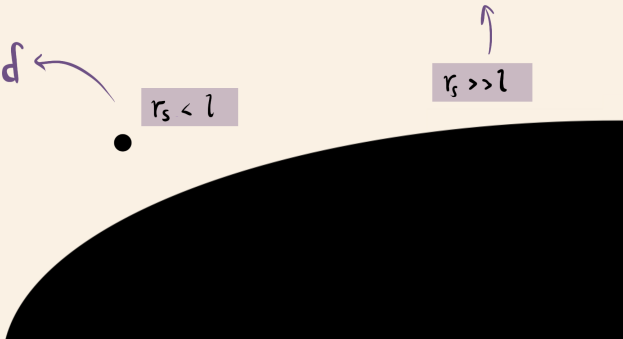


Black holes in Randall-Sundrum II

Metric (& properties):

$\approx$ 4-dimensional Schwarzschild

5-dimensional Schwarzschild $\leftarrow$


$$r_s < l$$

$$r_s \gg l$$

Black holes in Randall-Sundrum II

Metric (& properties):

5-dimensional Schwarzschild

$\approx$ 4-dimensional Schwarzschild

• $\approx$ Usual properties

$$r_s < l$$

$$r_s \gg l$$



Black holes in Randall-Sundrum II

Metric (& properties):

5-dimensional Schwarzschild

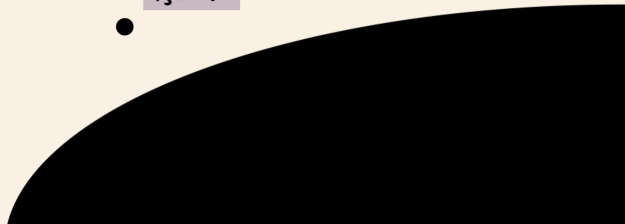
- Colder
- Much longer lifetime

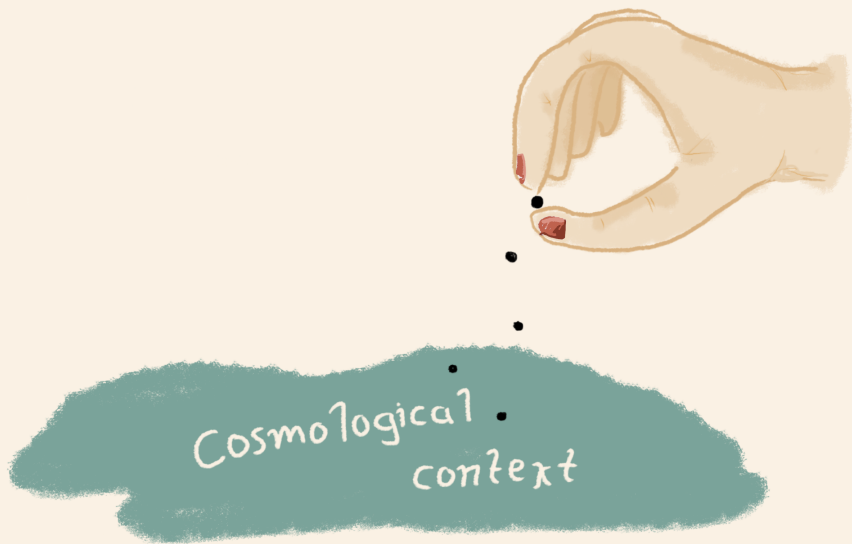
$\approx$ 4-dimensional Schwarzschild

- $\approx$ Usual properties

$$r_s \gg l$$

$$r_s < l$$



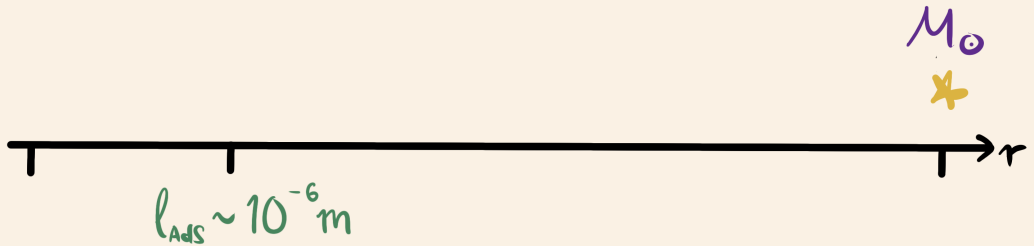


Braneworld cosmology

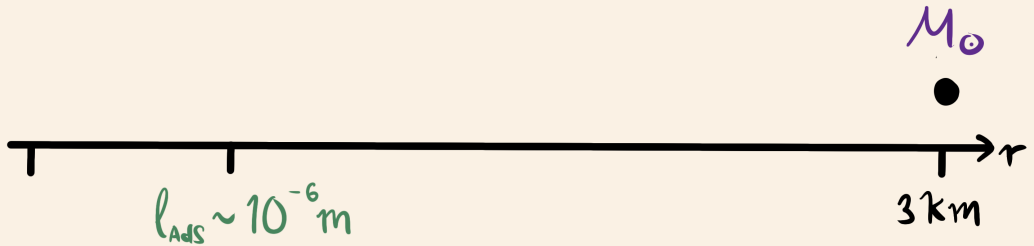
Braneworld cosmology



Braneworld cosmology



Braneworld cosmology



Braneworld cosmology

Primordial origin



Braneworld cosmology

PBHDM



$l_{\text{AdS}} \sim 10^{-6} \text{ m}$

$M_{\odot}$



3 km

$\rightarrow r$

Braneworld cosmology

PBHDM



PBH

Braneworld cosmology

5d

4d

PBHDM



$M_\odot$



PBH

Braneworld cosmology

5d

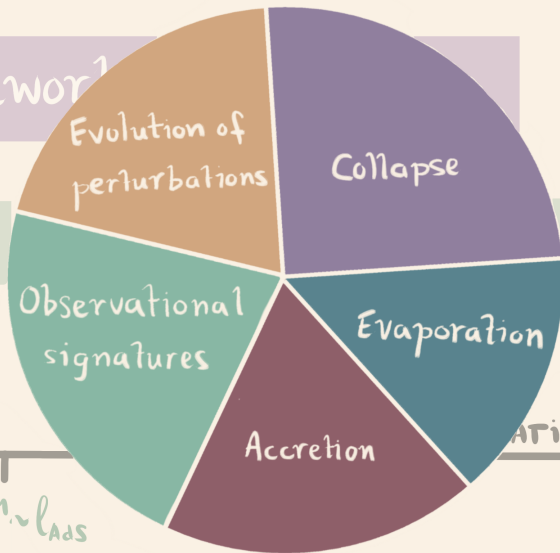
4d



PBH

Brane world

5d



end of
inflation

$H^{-1} \sim l_{\text{AdS}}$

Evaporation

t

pBH

Braneworld

5d

Evolution of
perturbations

Collapse

Observational
signatures

Evaporation

Accretion

Evaporation

end of
inflation

$H^{-1} \sim \ell_{\text{AdS}}$

t

Super interesting!

COVARIANT APPROACH TO ACCRETION IN BRANEWORLDS: THE VIEWPOINT OF A BRANE-BOUND OBSERVER

Itzi Aldecoa Tamayo[✉], Christian T. Byrnes[✉] and David Seery[✉]

Astronomy Centre, University of Sussex, Falmer, Brighton, BN1 9QH, UK

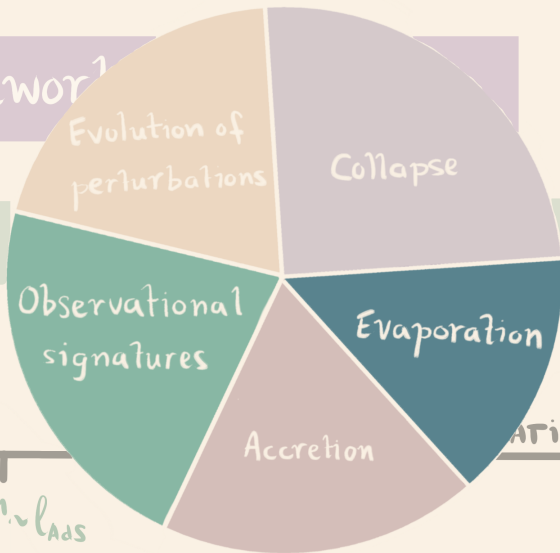
ABSTRACT

Higher-dimensional black holes have been extensively studied over the years, primarily from heuristic and fundamental perspectives or within the context of holographic applications. However, their interaction with baryonic matter confined to the brane is also of particular interest in cosmology. At the end of the day, we are four-dimensional observers bound to the brane—so how is higher-dimensional gravity perceived, from our perspective, during black hole accretion? We revisit this question using the Gauss–Codazzi and energy conservation equations within the covariant Shimizu–Maeda–Sasaki framework. We restrict our study to Randall–Sundrum type-II universes, although the idea behind our interpretation extends beyond five-dimensional scenarios. Our analysis shows that brane-world effects play a significant role in the early Universe, making them especially relevant to the evolution of primordial black holes.

PBH

Brane world

5d



end of
inflation

$H^{-1} \sim \ell_{\text{AdS}}$

Evaporation

t

PRIMORDIAL BLACK HOLES IN RANDALL–SUNDRUM: COSMOLOGICAL SIGNATURES

Itzi Aldecoa Tamayo[✉], Christian T. Byrnes[✉], and David Seery[✉]

Astronomy Centre, University of Sussex, Falmer, Brighton, BN1 9QH, UK

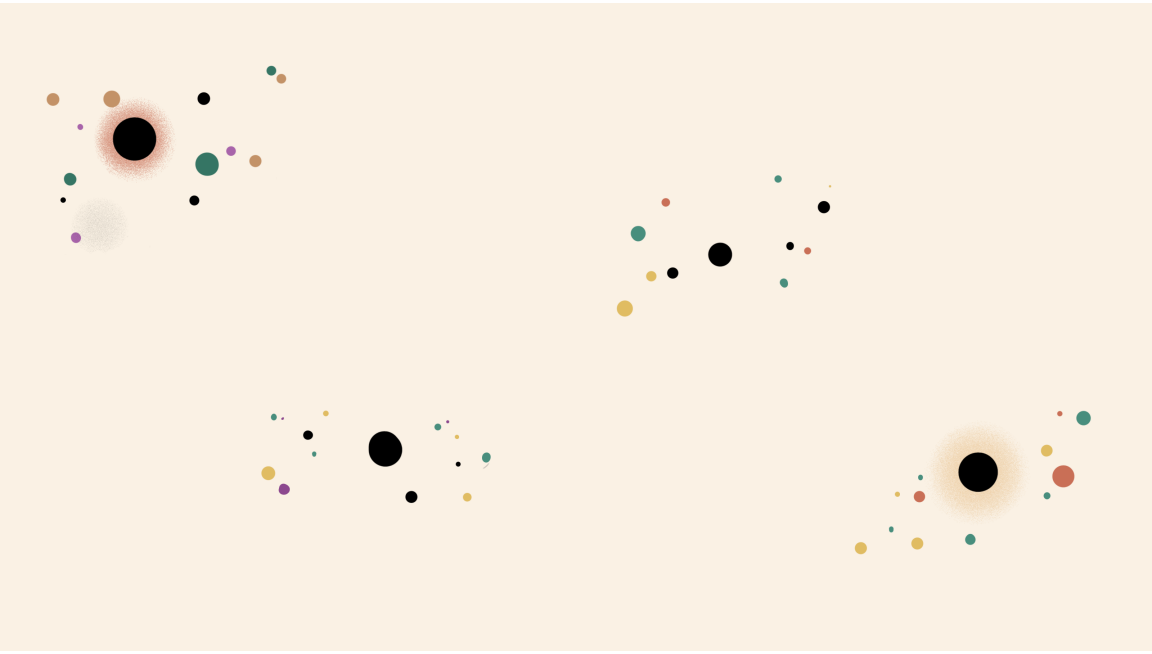
ABSTRACT

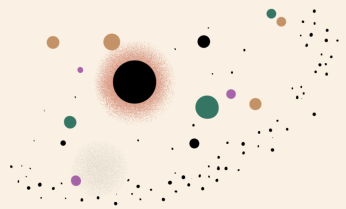
We reconsider primordial black hole physics in Randall–Sundrum Type-II universes, focusing on constraints from cosmological and astrophysical observables. We pay particular attention to scenarios that allow the entirety of dark matter to be in the form of higher-dimensional primordial black holes. This is possible for a range of AdS radii and black hole masses. Observable constraints are generally modified due to the changes in the higher-dimensional gravitational sector, and come from low-energy $e^\pm$ emission, microlensing, and possibly from contributions to unresolved radiation backgrounds. We discuss constraints from the cosmic microwave background due to injection of Hawking quanta into the intergalactic medium. Finally, we comment on recent discussions on the compatibility of higher-dimensional black holes and the KM3-230213A event.

Let's assume we have ...

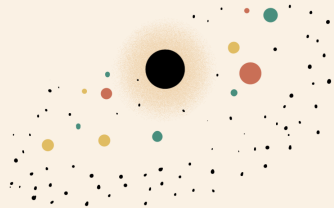
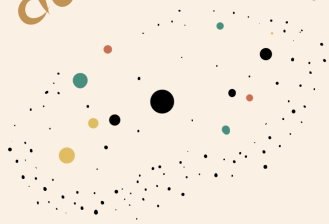
PBH formation in the early Universe

A monochromatic PBH distribution





PBHs behave as dark matter

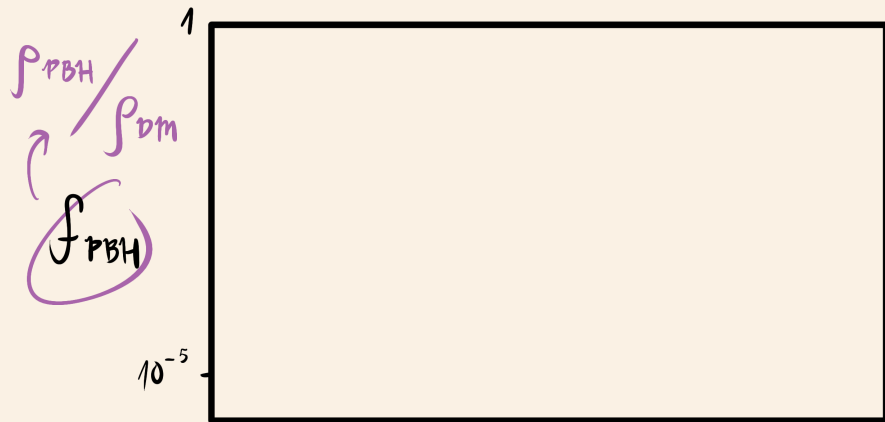


$$\mu_{\text{BH}}(g)$$

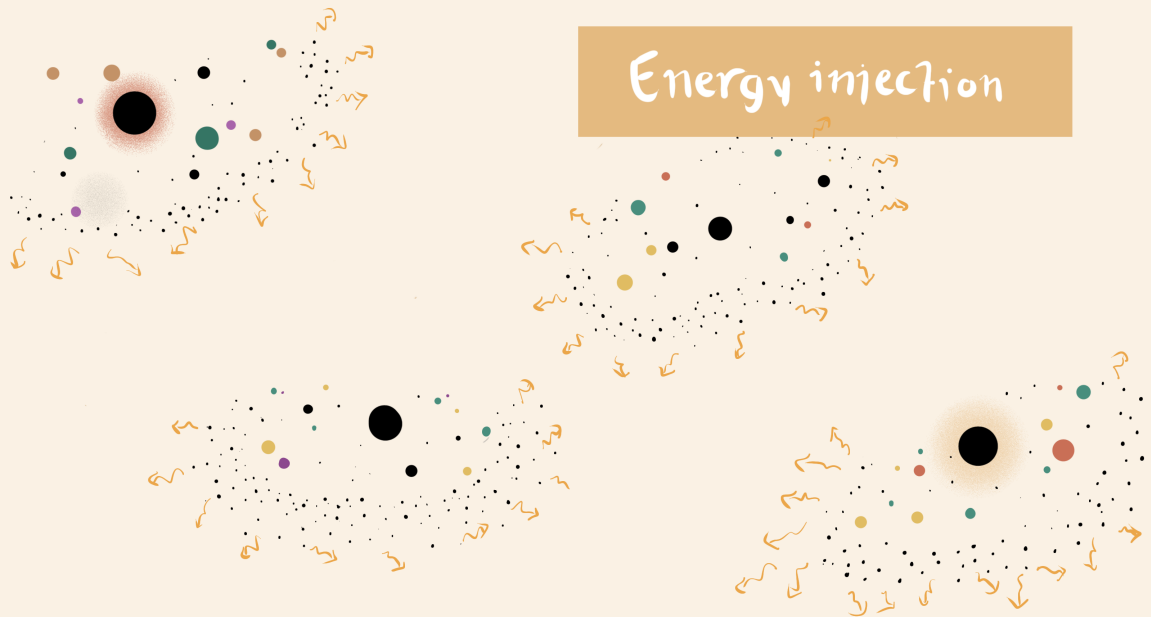
$$f_{\text{PBH}}$$

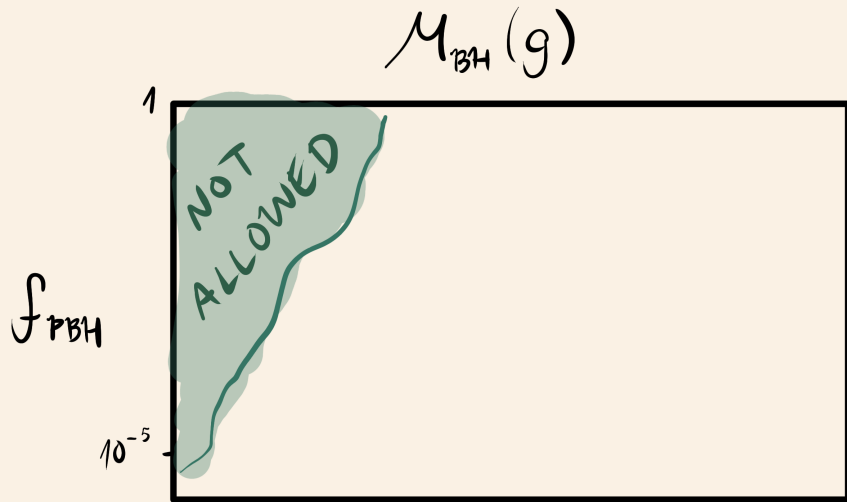


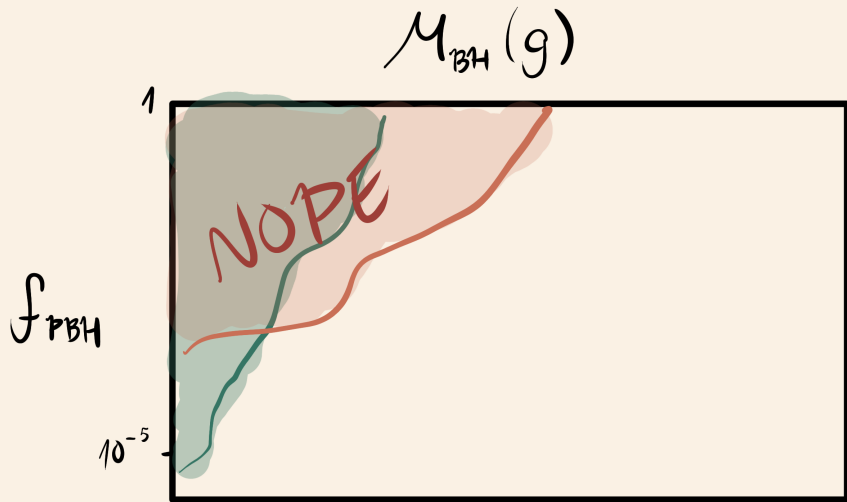
$\mu_{\text{BH}}(g)$

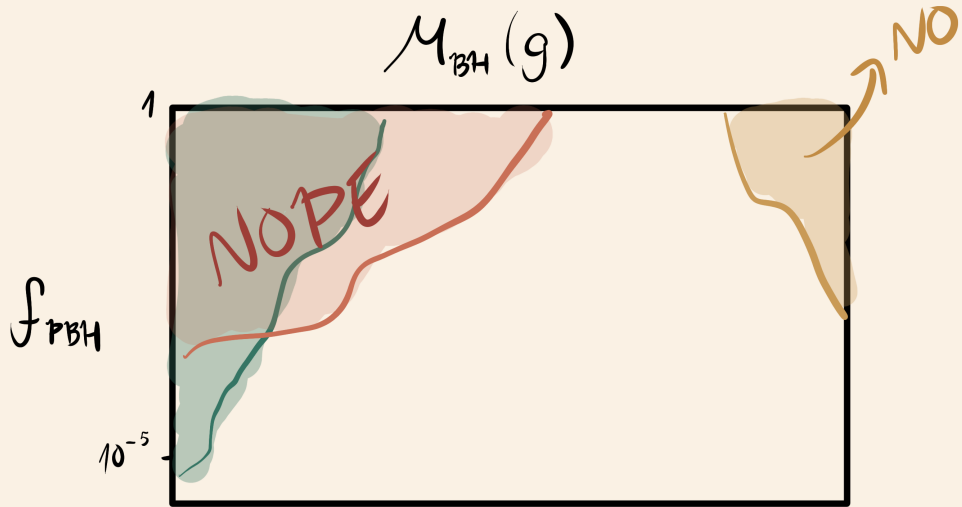


Energy injection









Black Holes Radiate Mainly on the Brane

Roberto Emparan,¹ Gary T. Horowitz,² and Robert C. Myers³

PHYSICAL REVIEW D **77**, 076007 (2008)

BlackMax: A black-hole event generator with rotation, recoil, split branes, and brane tension

De-Chang Dai,¹ Glenn Starkman,¹ Dejan Stojkovic,² Cigdem Issever,³ Eram Rizvi,⁴ and Jeff Tseng³

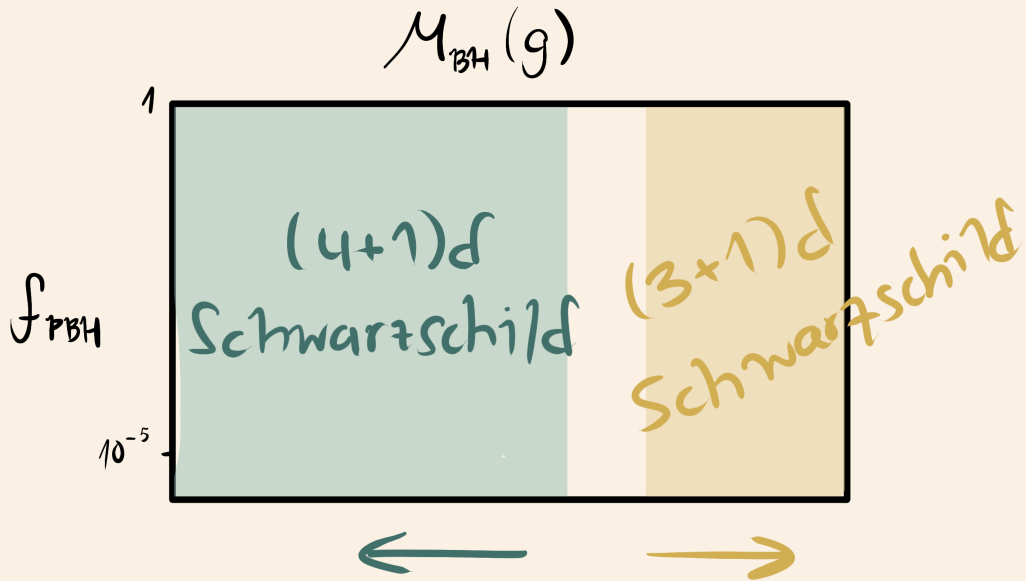
$\mu_{\text{BH}}(g)$

1

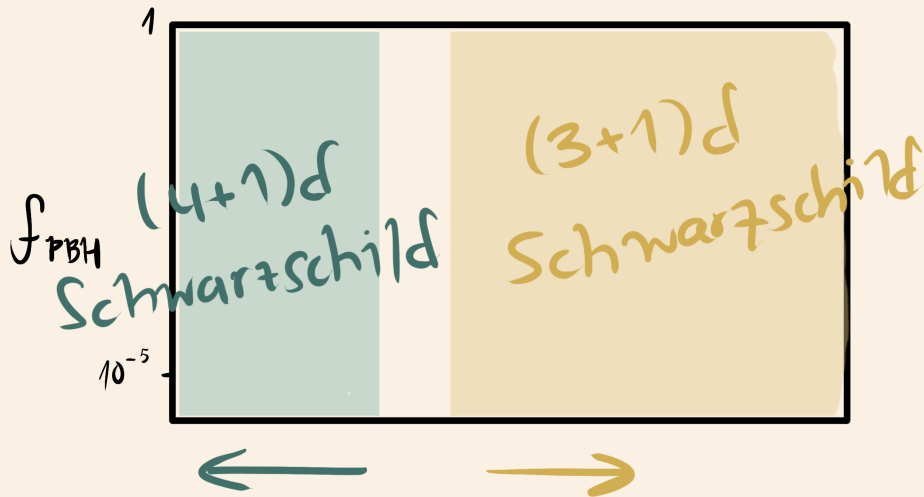
f_{PBH}

10^{-5}



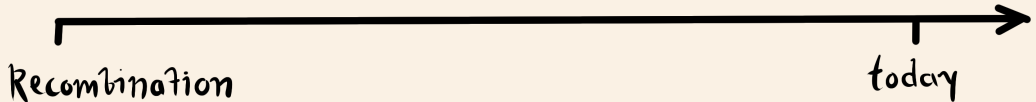


$$M_{\text{BH}}(g)$$



Time of injection

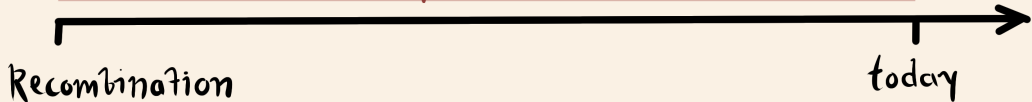
Time of injection



Time of injection

Unresolved radiation

Does it spoil the CMB?

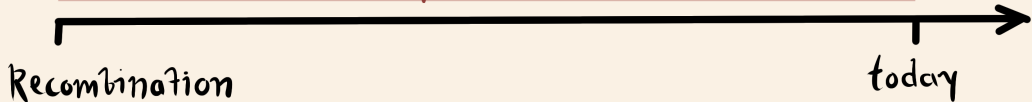


Time of injection

x-ray, γ -ray, 511 keV,
e[±] at heliopause, galactic,
extragalactic, ...

Unresolved radiation

Does it spoil the CMB?



Time of injection

Can this unresolved
radiation be attributed
to PBHs?

X-ray, γ -ray, 511 keV,
 $e^{\pm}$ at heliopause, galactic,
extragalactic, ...

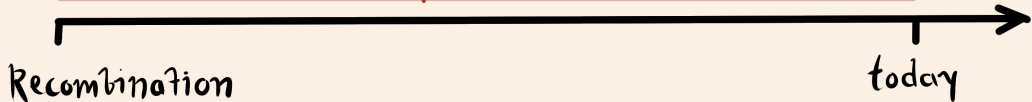
Recombination

today

Time of injection

Unresolved radiation

Does it spoil the CMB?



Time of injection

PBH environment
very important

Unresolved radiation

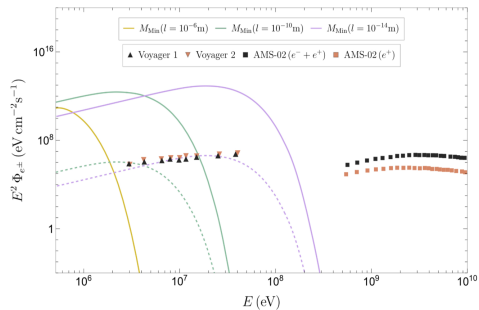
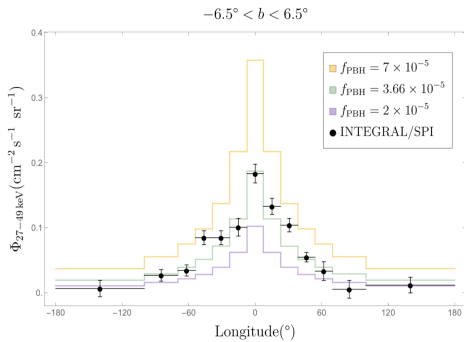
Does it spoil the CMB?

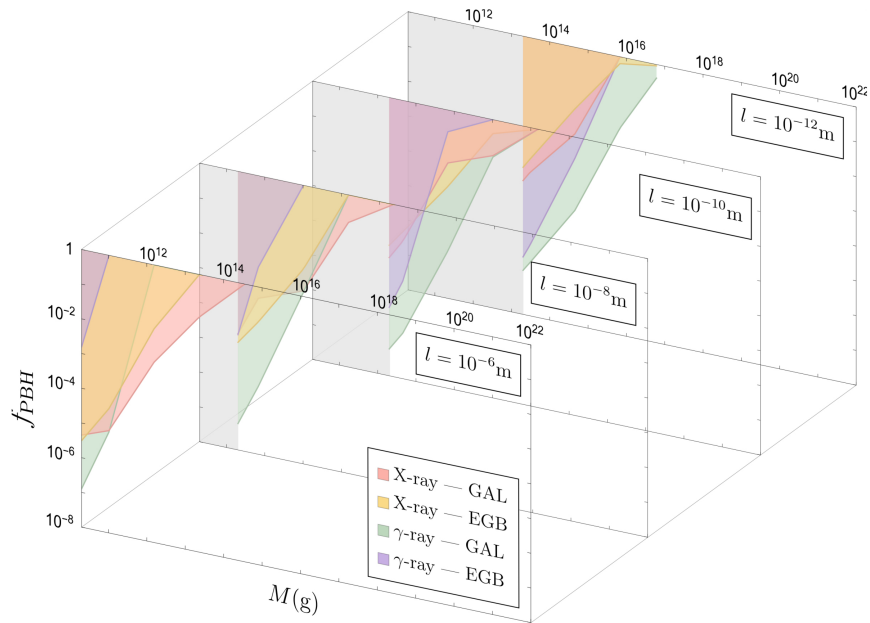
Recombination

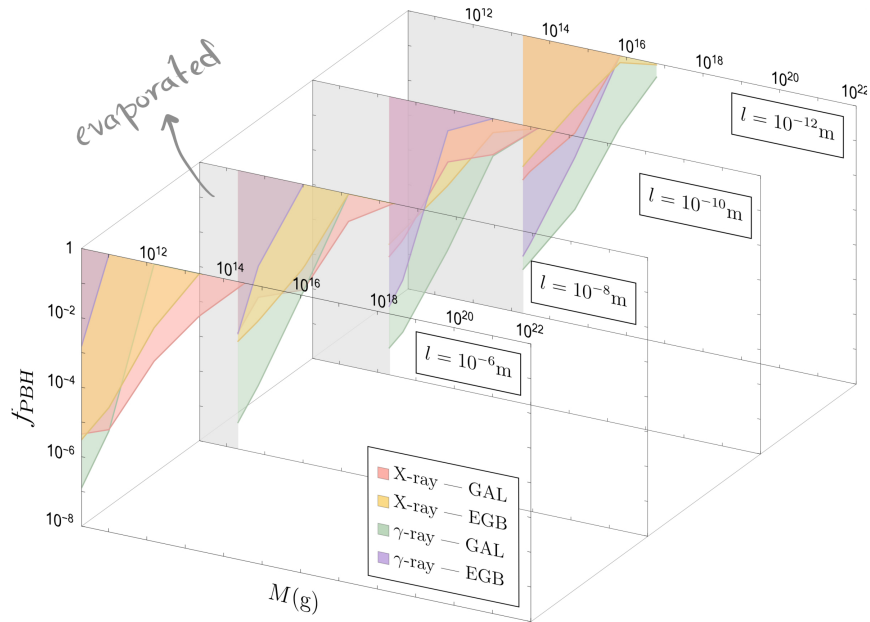
today

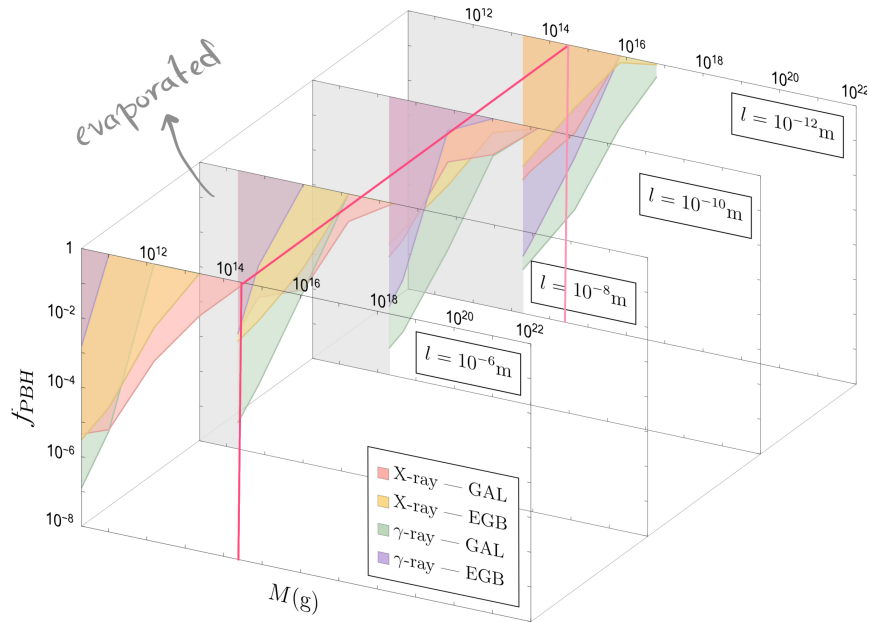


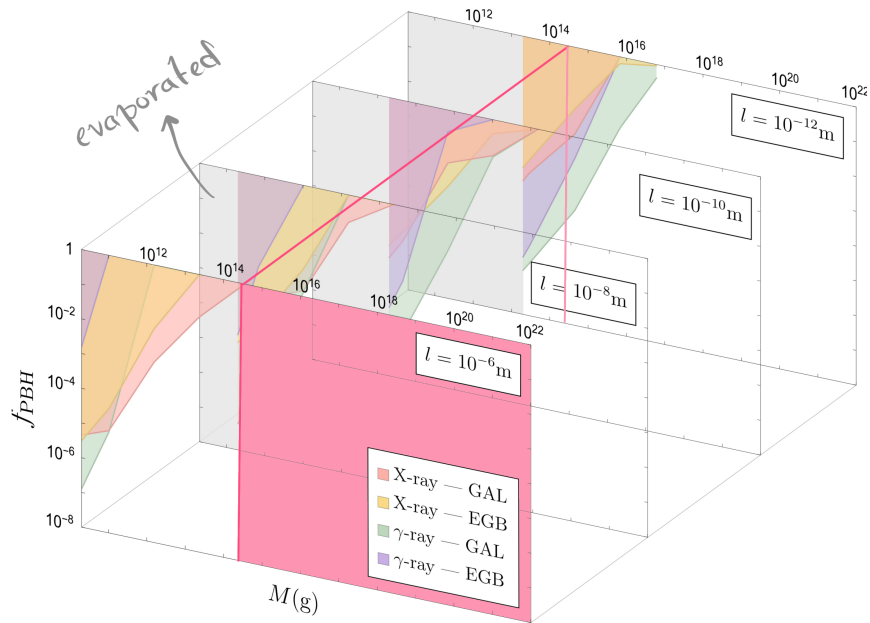
Unresolved radiation







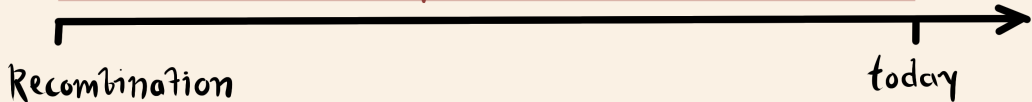




Time of injection

Unresolved radiation

Does it spoil the CMB?



Does it spoil the CMB?

The Cosmic Linear Anisotropy Solving System (CLASS) II: Approximation schemes

Diego Blas^a, Julien Lesgourgues^{a,b,c}, Thomas Tram^{d,b}

Exotic energy injection with ExoCLASS: Application to the Higgs portal model and evaporating black holes

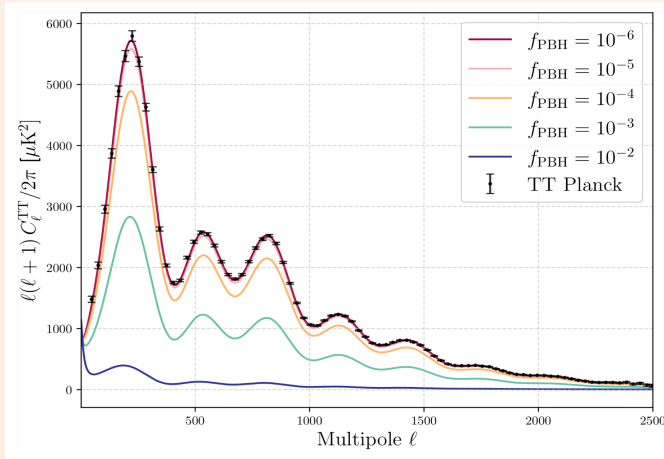
Patrick Stöcker,^a Michael Krämer,^a Julien Lesgourgues,^a Vivian Poulin^b

PHYSICAL REVIEW D **105**, 103508 (2022)

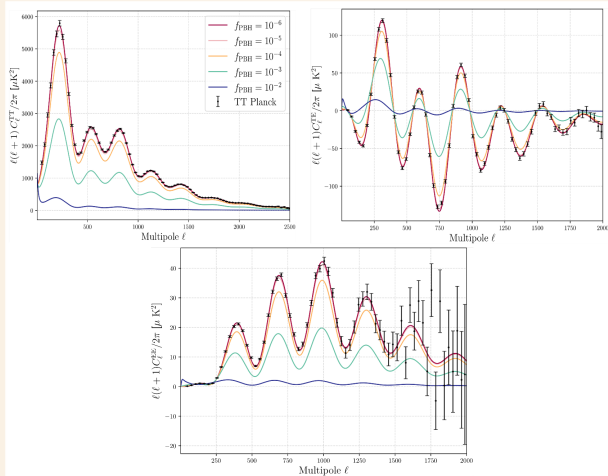
Primordial black hole dark matter in the context of extra dimensions

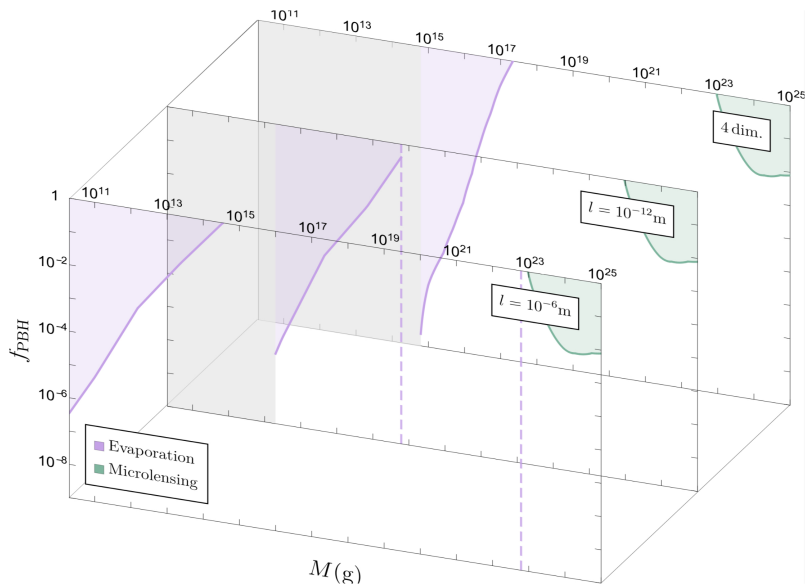
Avi Friedlander^{1,2,*}, Katherine J. Mack^{3,4,†}, Sarah Schon^{5,1,‡}, Ningqiang Song^{6,1,§} and Aaron C. Vincent^{1,2,4,||}

Does it spoil the CMB?

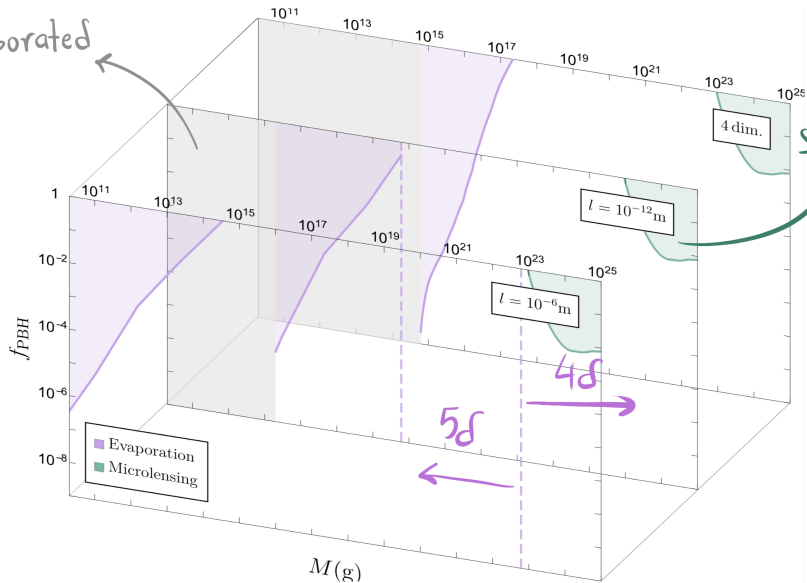


Does it spoil the CMB?

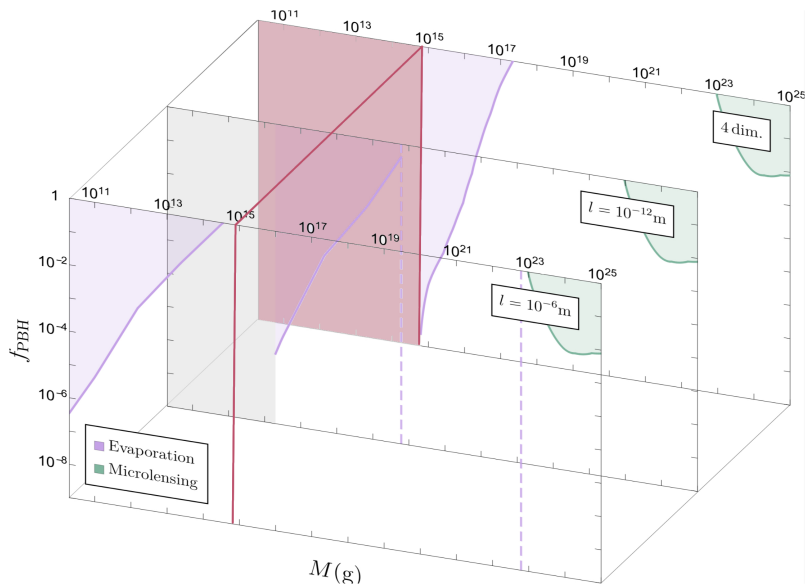


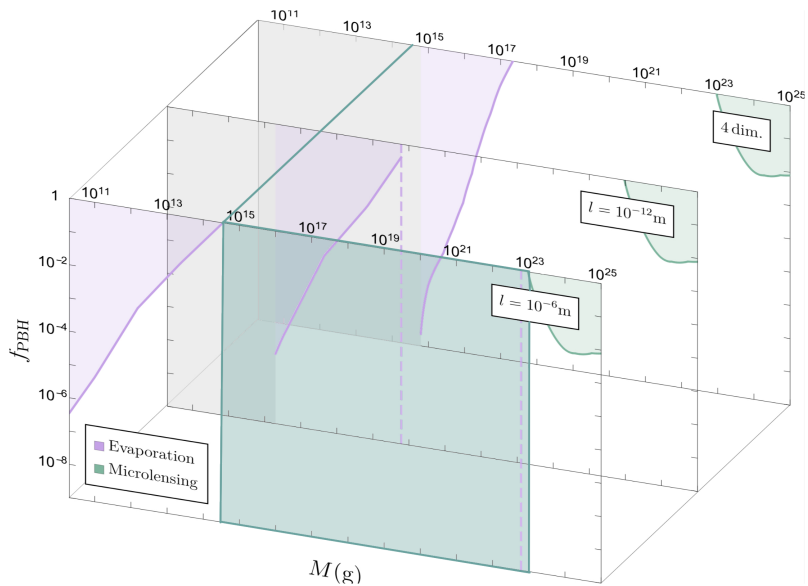


fully evaporated



Smyth et al.
(2019)





Takeaways

- Black holes → excellent testing ground

Randall-Sundrum II → PBHs

Takeaways

- Black holes → excellent testing ground

Randall-Sundrum II → PBHs

- If you like GR, ask Itzi to tell you all about accretion

Takeaways

- Black holes → excellent testing ground

Randall-Sundrum II → PBHs

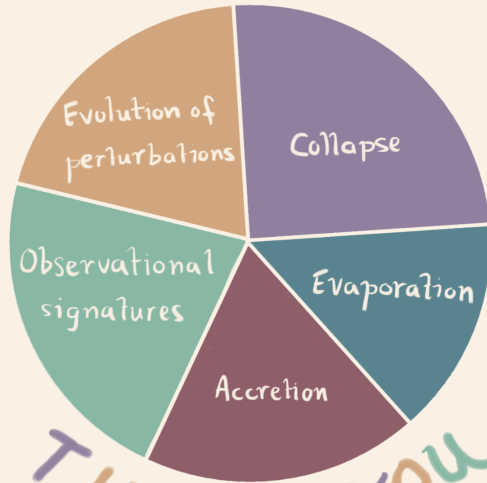
- If you like GR, ask Itzi to tell you all about accretion
- Very small & cold BHs could still be around

Takeaways

- Black holes → excellent testing ground

Randall-Sundrum II → PBHs

- If you like GR, ask Itzi to tell you all about accretion
- Very small & cold BHs could still be around
- Dark Matter could be of purely gravitational & higher-d nature
DM window → model dependent



THANK YOU

