

PRIMORDIAL BLACK HOLES

in BRANE WORLDS

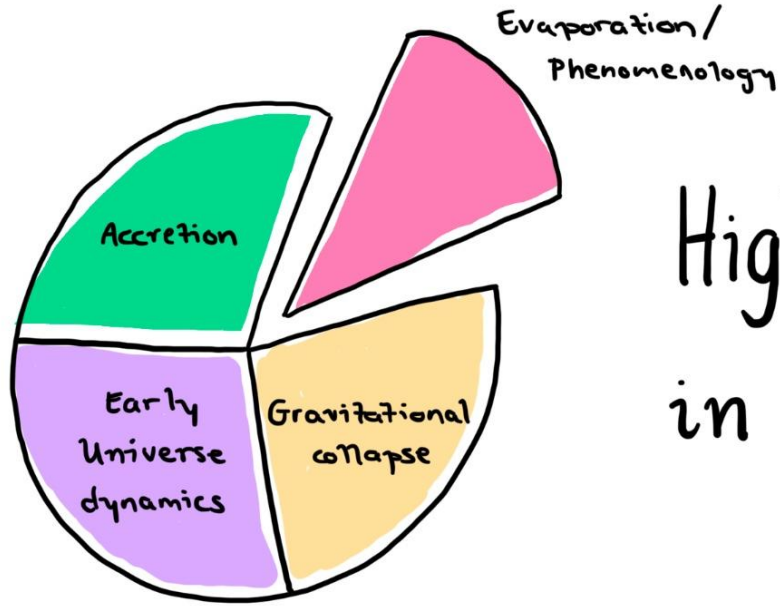
NEHOP 25

ITZI ALDECOA TAMAYO, DAVID SEERY & CHRIS BYRNES

- University of Sussex, UK

- ICCUB, Barcelona, Spain

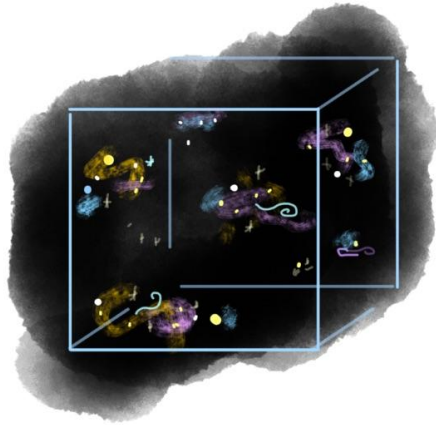
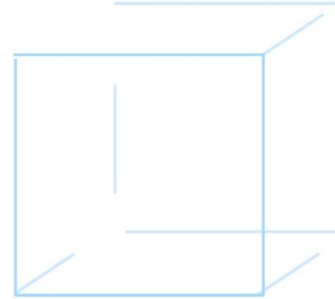
 ULB, Brussels



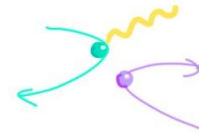
Higher dimensional BHs
in a cosmological context

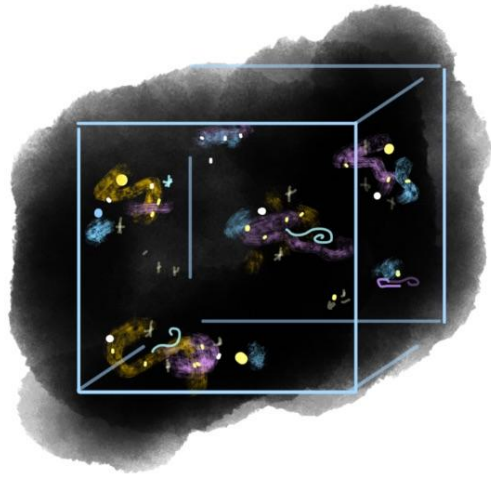
For illustrative purposes, let's imagine:

our (3+1)-dimensional
flat universe

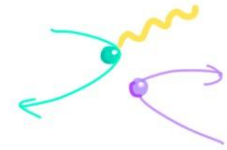


full of Standard model particles
and interactions,

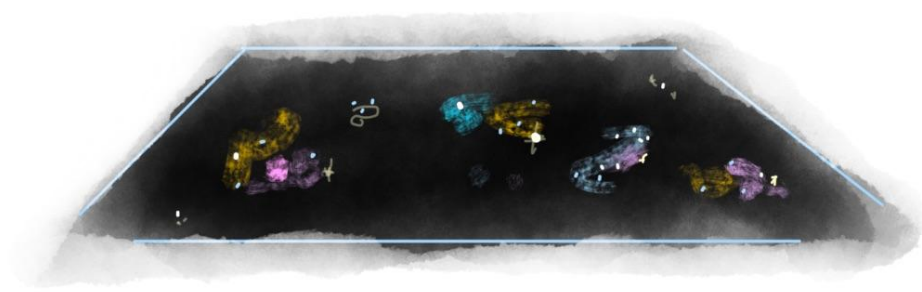




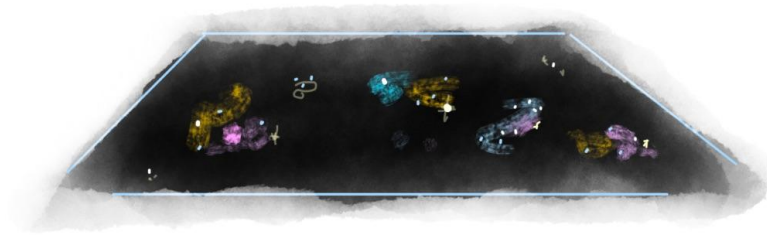
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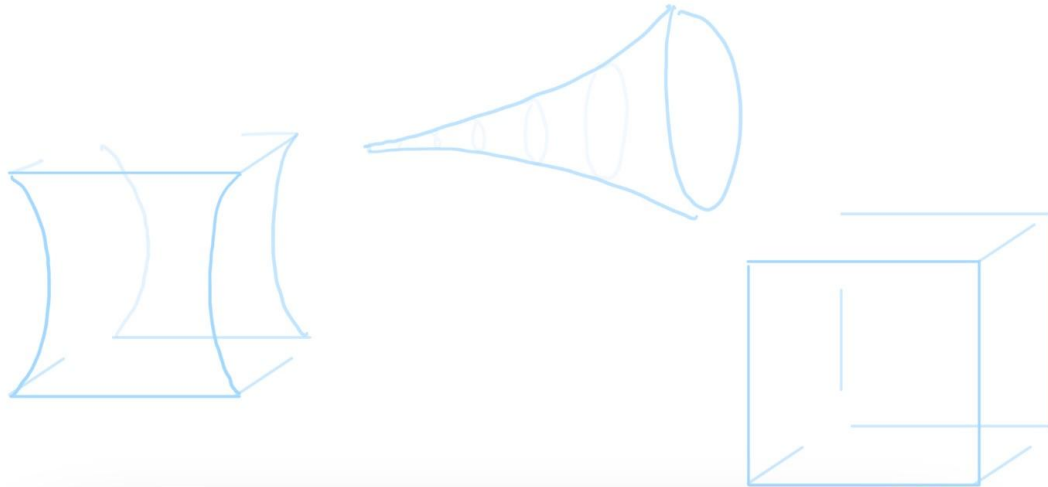
↗ (hyper)
as a surface

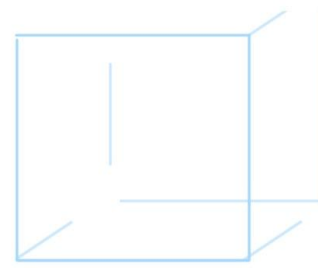


as a surface ^(Hyper)

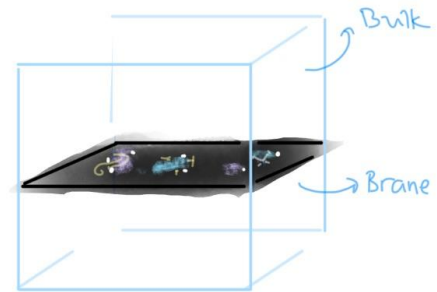
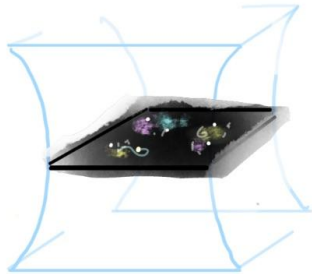
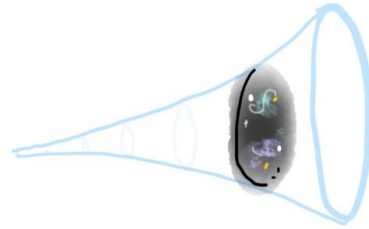


embedded in a volume with some curvature





that is otherwise empty.

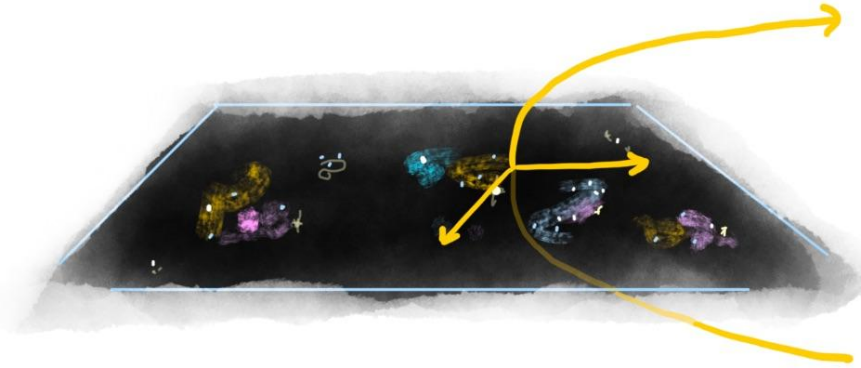


We choose an AdS_5 bulk with Z_2 symmetry about the brane

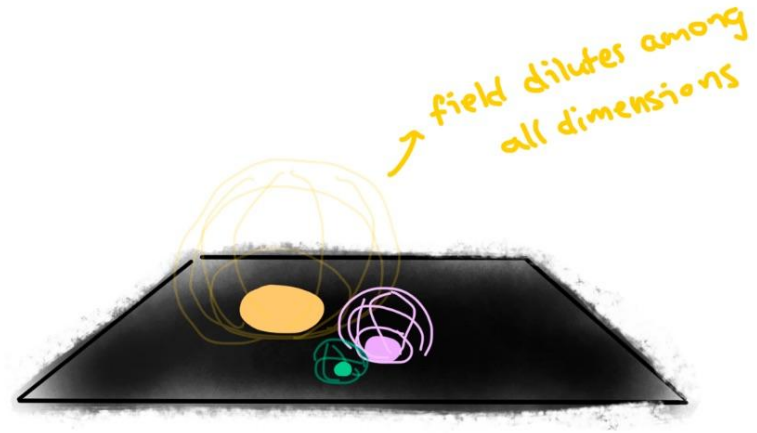
Randall-Sundrum Type II

So:

WARPED EXTRA DIMENSION
FLAT FRIEDMANN BRANE

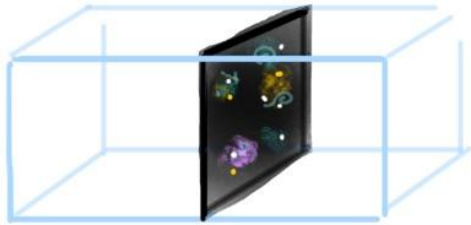


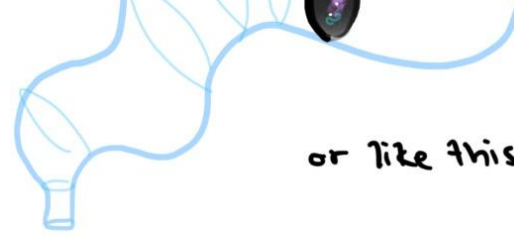
SM interactions are confined to our universe, but
gravity is a $(4+1)$ -dimensional field



This confinement results in many observables being very similar

in a framework like this



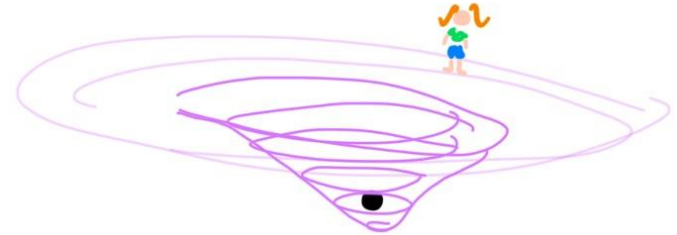


or like this.

Gravity being $(n+1)$ -dimensional can however have a significant
impact on how spacetime behaves → (very interesting!)



Early universe expansion



Vicinity of massive objects

Standard (3+1)-d \rightarrow Schwarzschild metric

$$ds^2 = -\left(1 - \frac{r_s}{r}\right) dt^2 + \left(1 - \frac{r_s}{r}\right)^{-1} dr^2 + r^2 d\Omega^2$$

\downarrow Asymptotically flat

\hookrightarrow Spherically symmetric (3D)

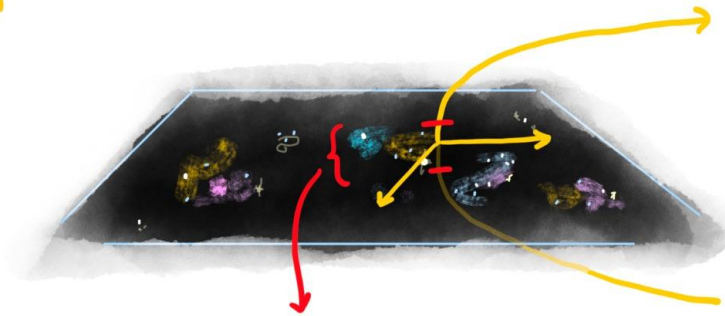
(4+1)-d generalization:

$$ds^2 = -\left(1 - \frac{r_s^2}{r^2}\right) dt^2 + \left(1 - \frac{r_s^2}{r^2}\right)^{-1} dr^2 + r^2 d\Omega^3$$

\downarrow Asymptotically flat

\hookrightarrow Spherically symmetric (4D)

FLAT FRIEDMANN BRANE
WARPED EXTRA DIMENSION



effectively flat
in this domain

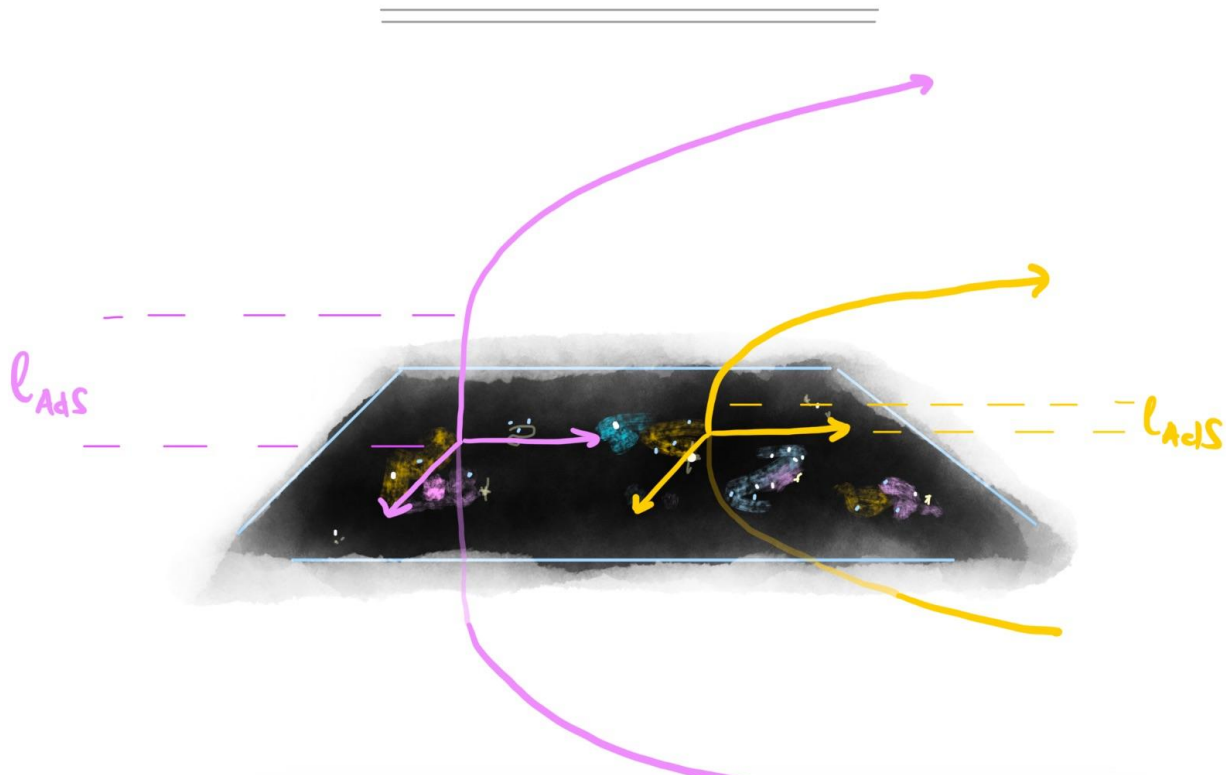
↳ 5D generalisation of Schwarzschild OK for very small objects and in the near-horizon regime

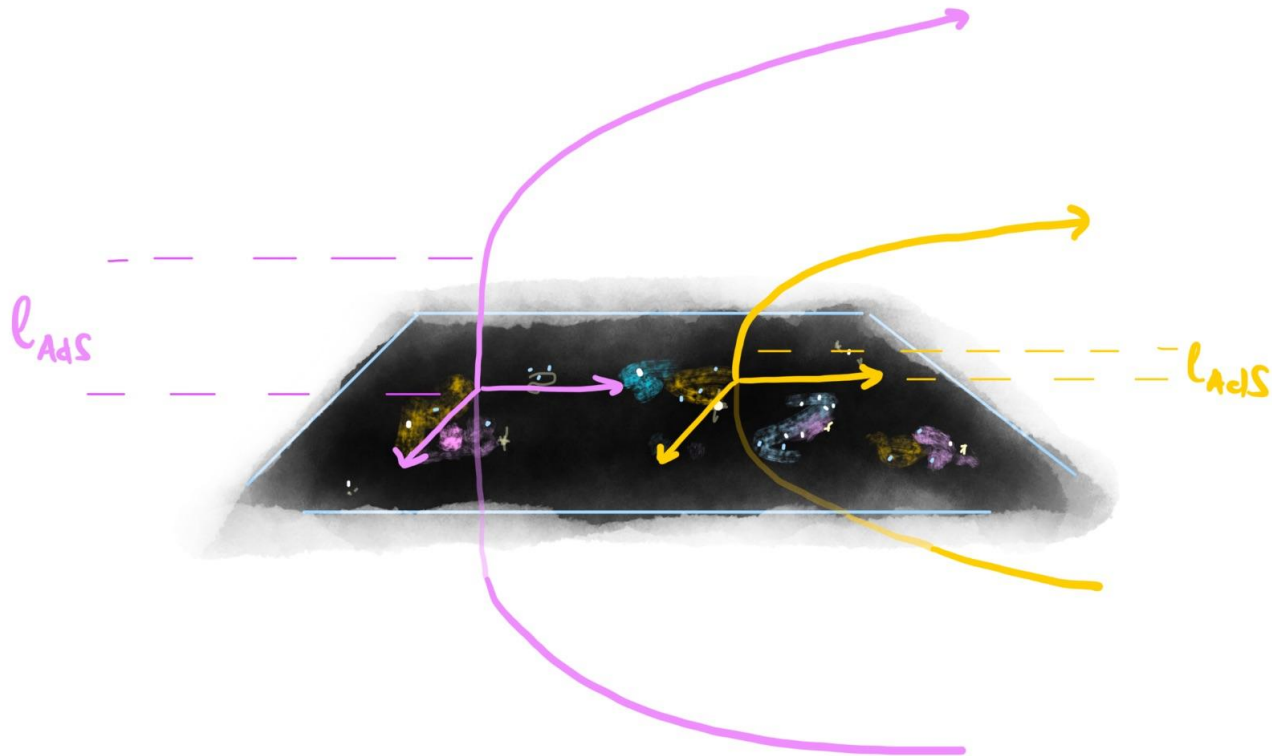
relative to what?



↪ 5D generalisation of Schwarzschild OK for very small objects and in the near-horizon regime

relative to what?

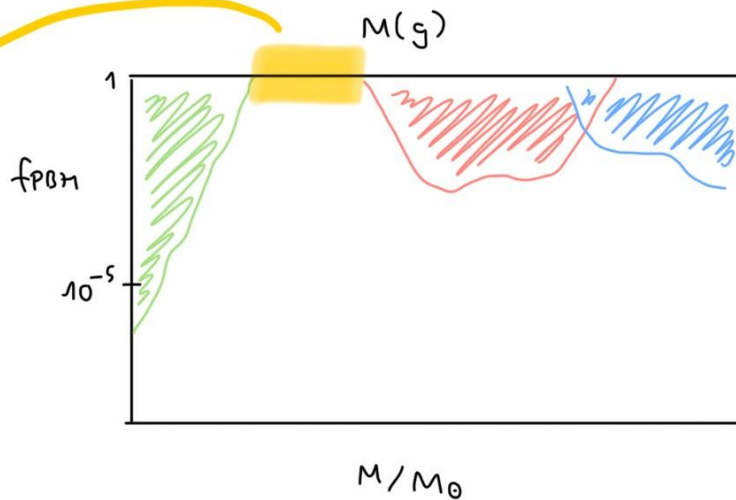




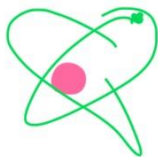
$$l_{\text{AdS}} = \text{AdS radius} < 10^{-6} \text{ m}$$

→ observations

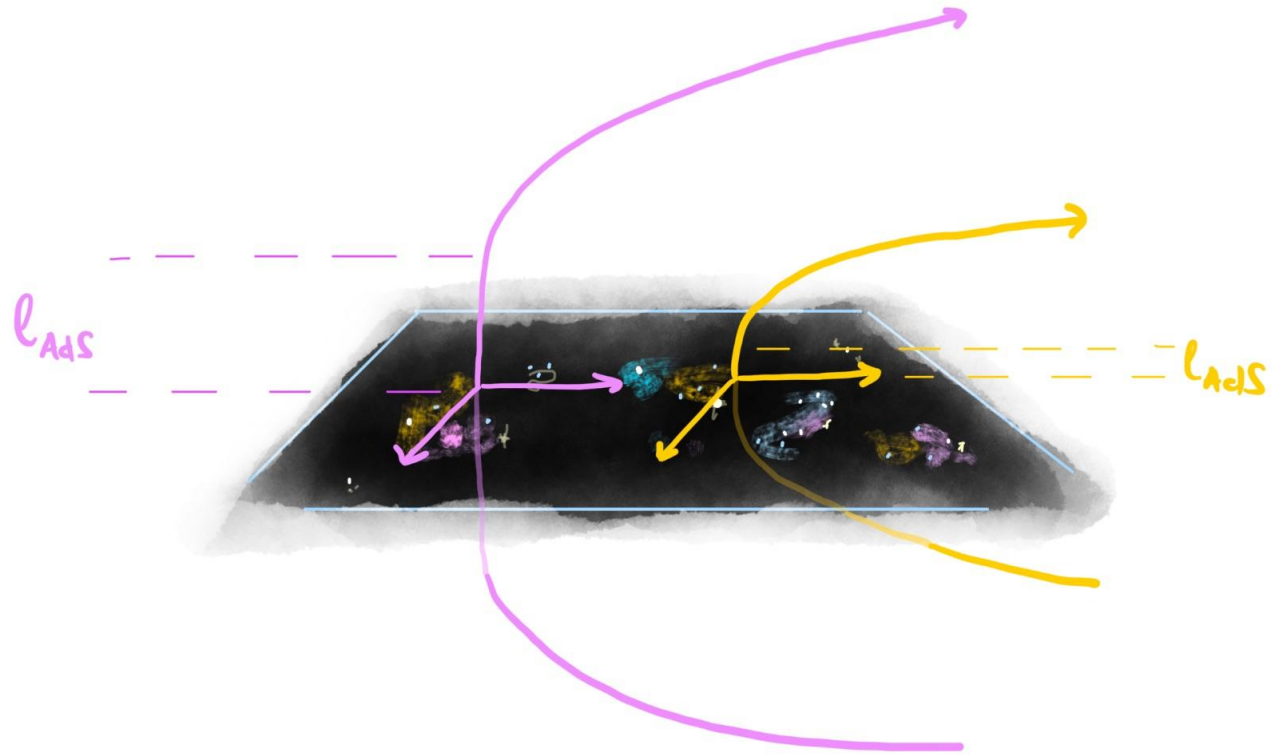
(3+1)-d standard cosmo:

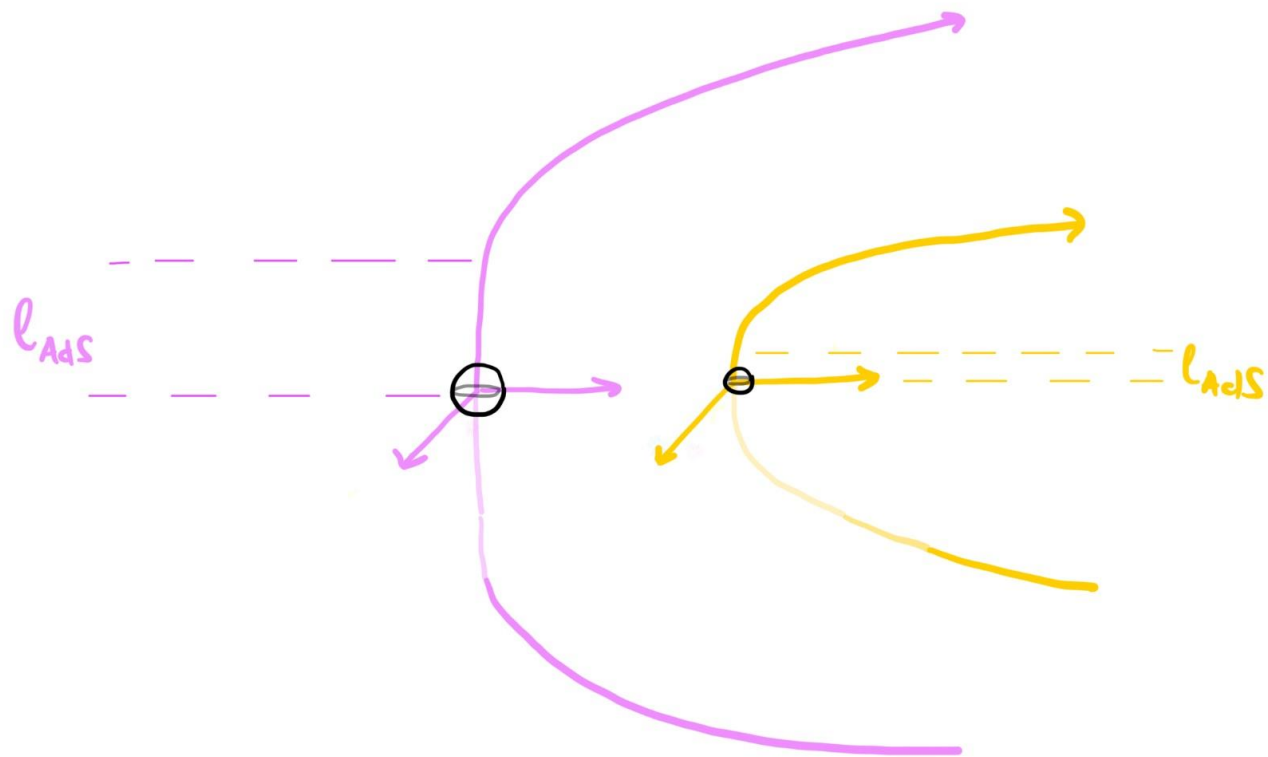


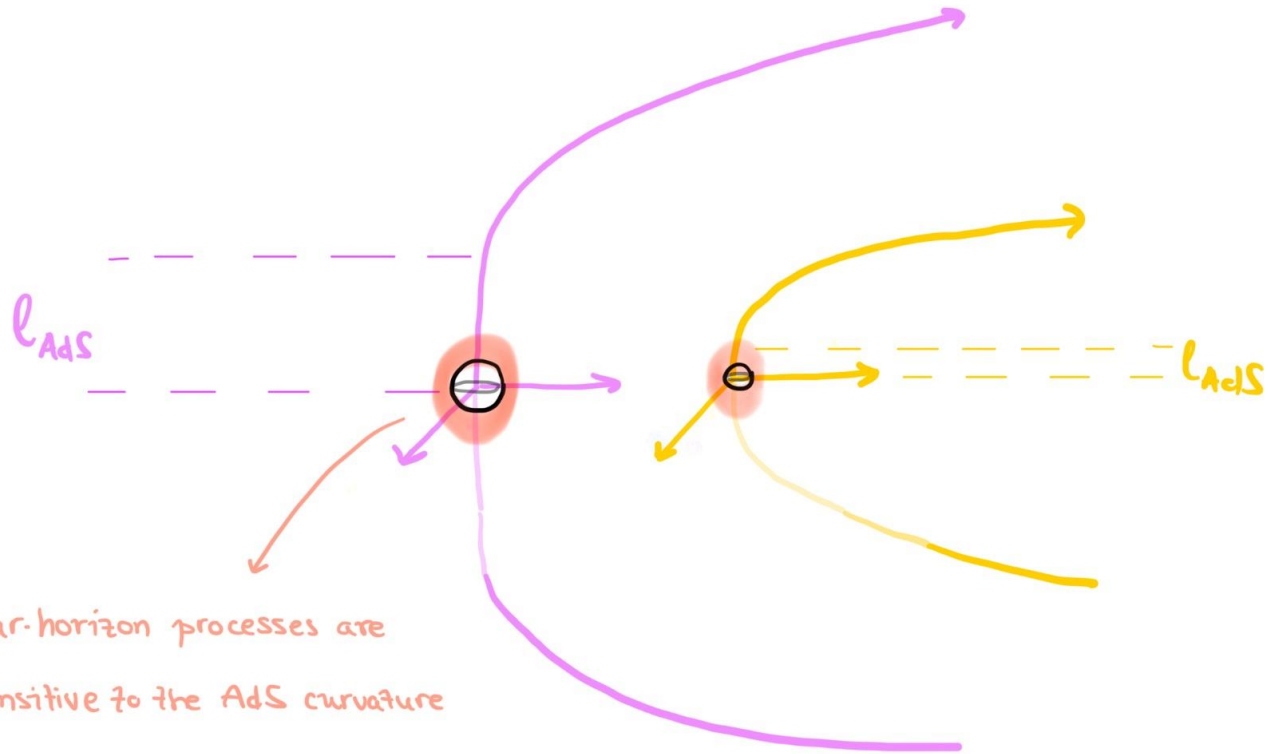
DM window BHs size
of the order of the size
of a Hydrogen atom



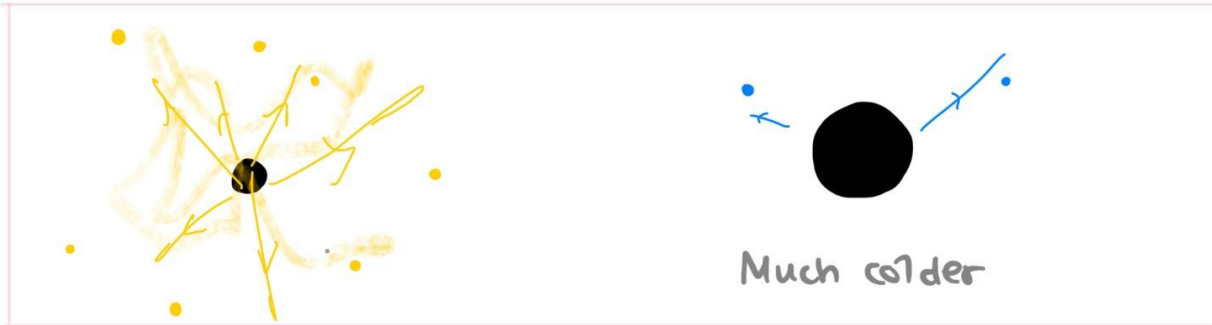
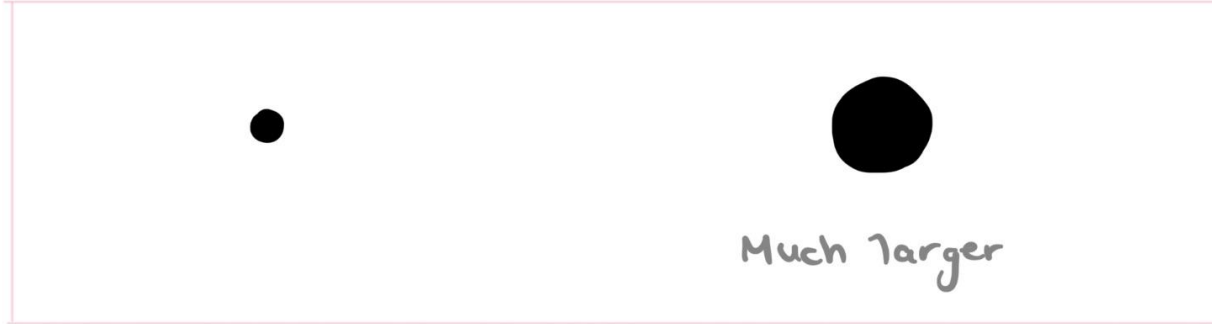
(clearly $r \ll \ell$)







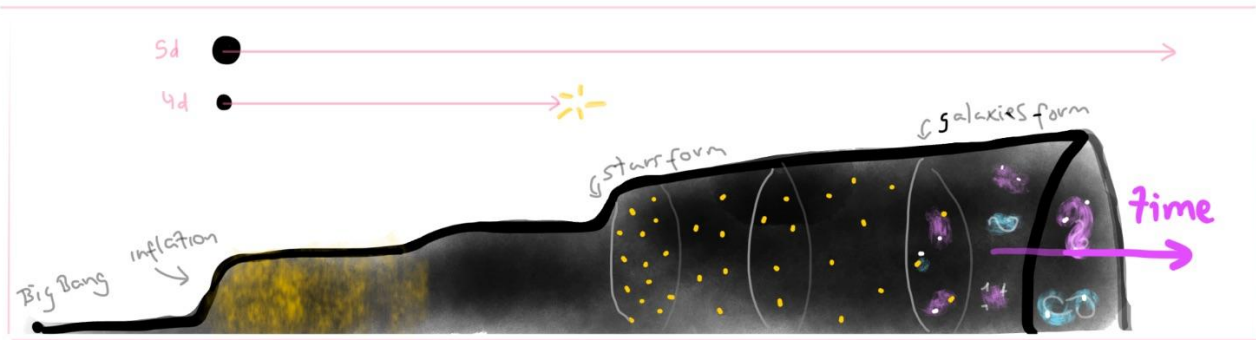
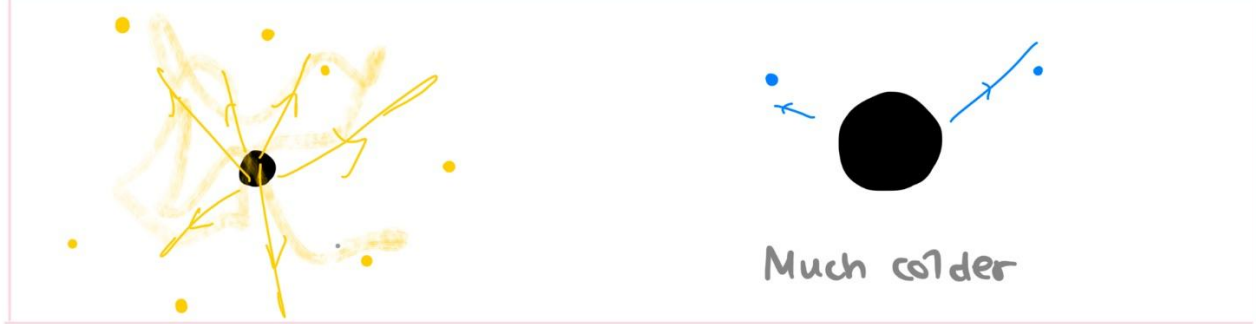
For a fixed mass, $(4+1)$ -d Schwarzschild BHs:



5d ● —————→

4d ● —————→ ✨

galaxies form

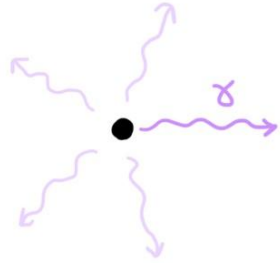


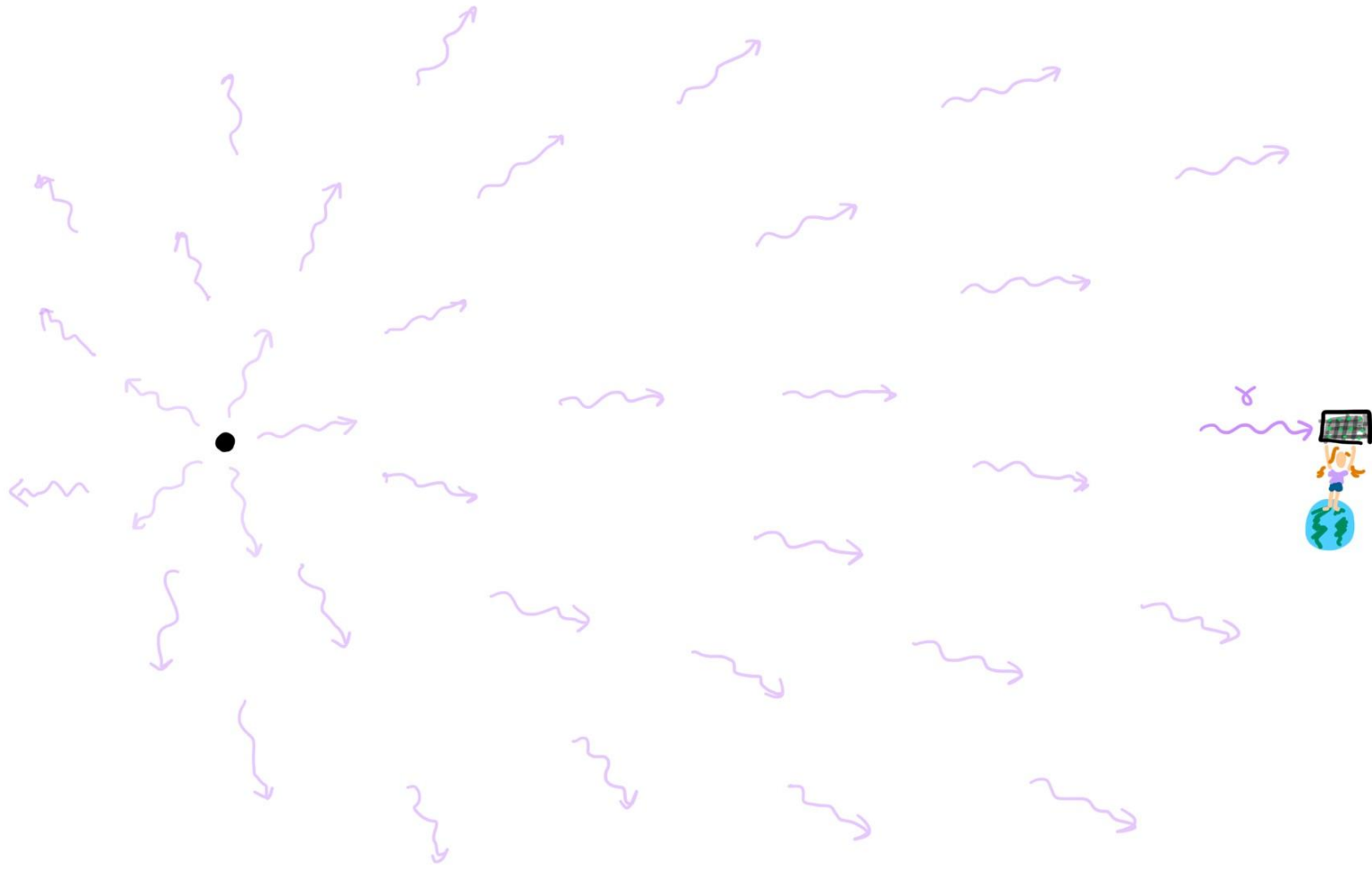
Phenomenology \rightarrow very different!

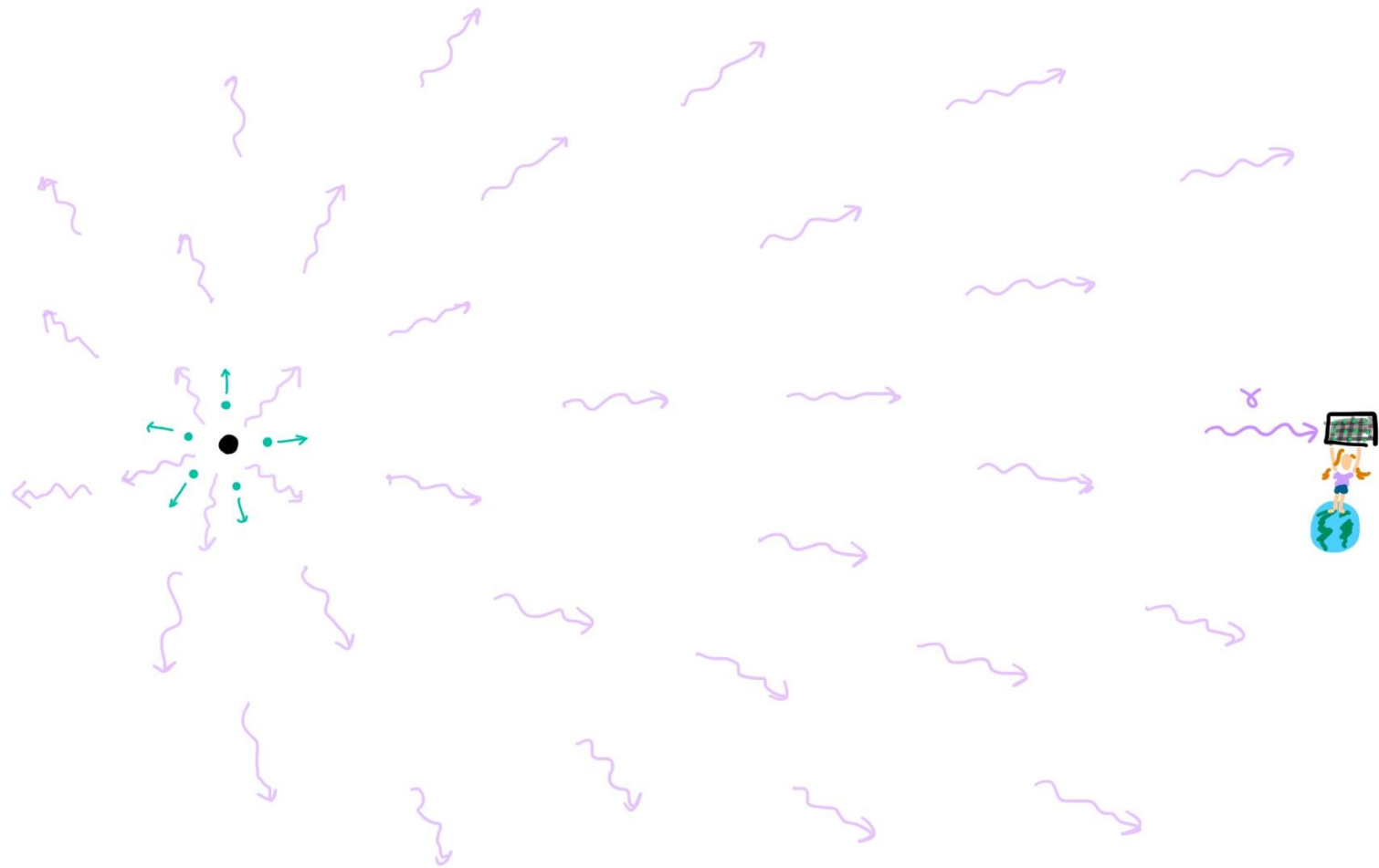
Interesting number: $M_{\text{BH}}(\tau = t_0) \sim 10^9 \text{ g}$ \rightarrow in 4D, 10^{14} g!

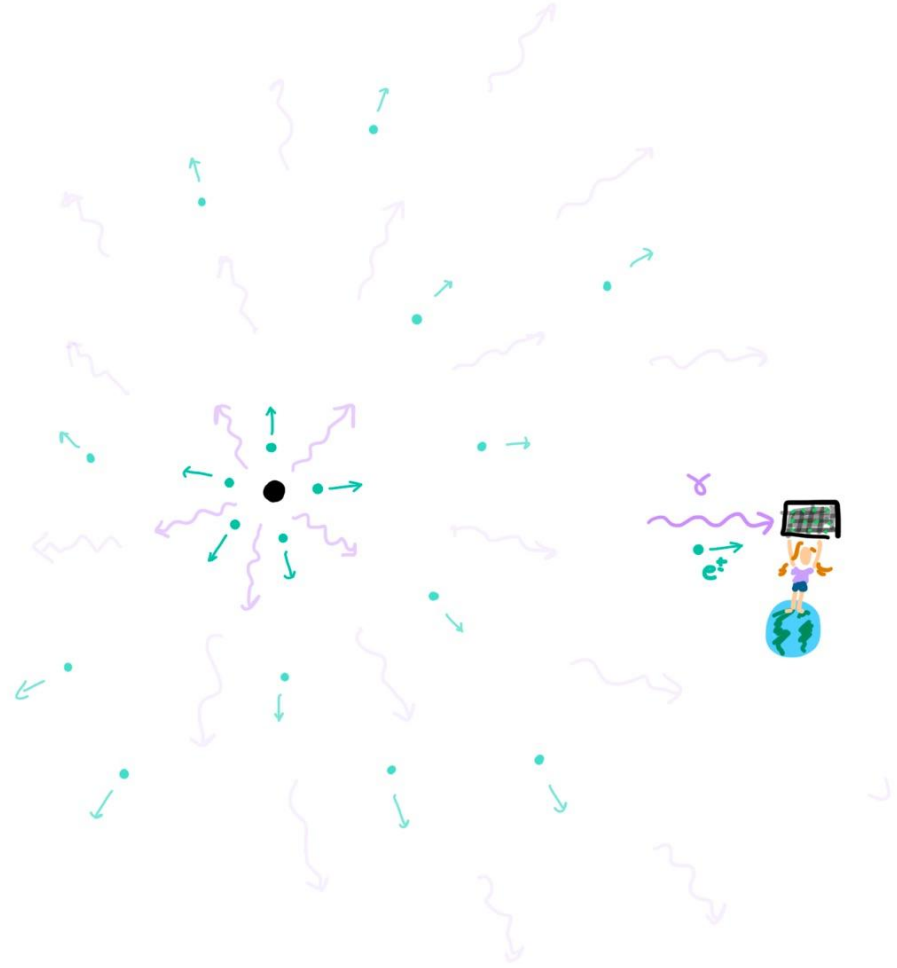
What impact does this have
on observations?



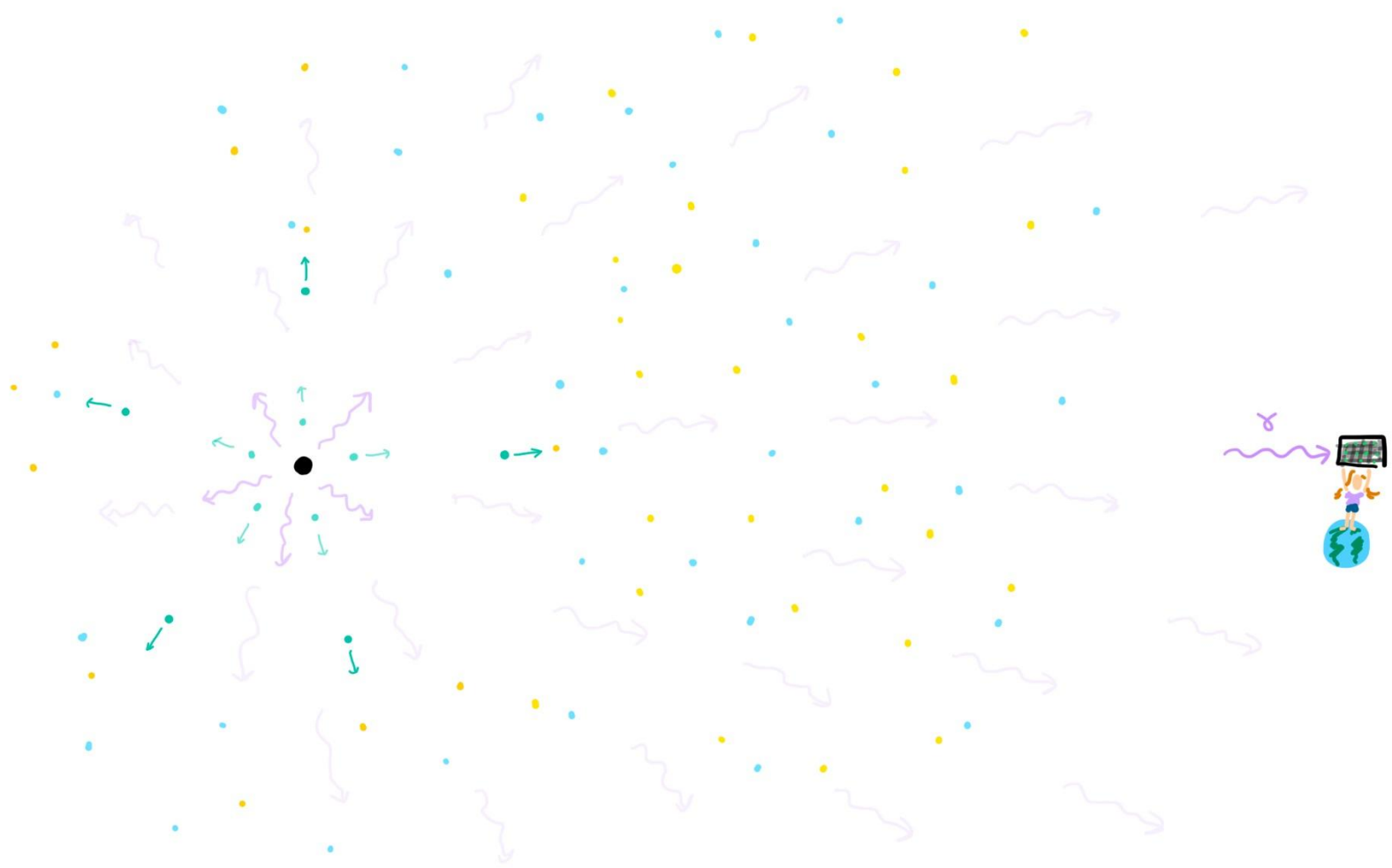


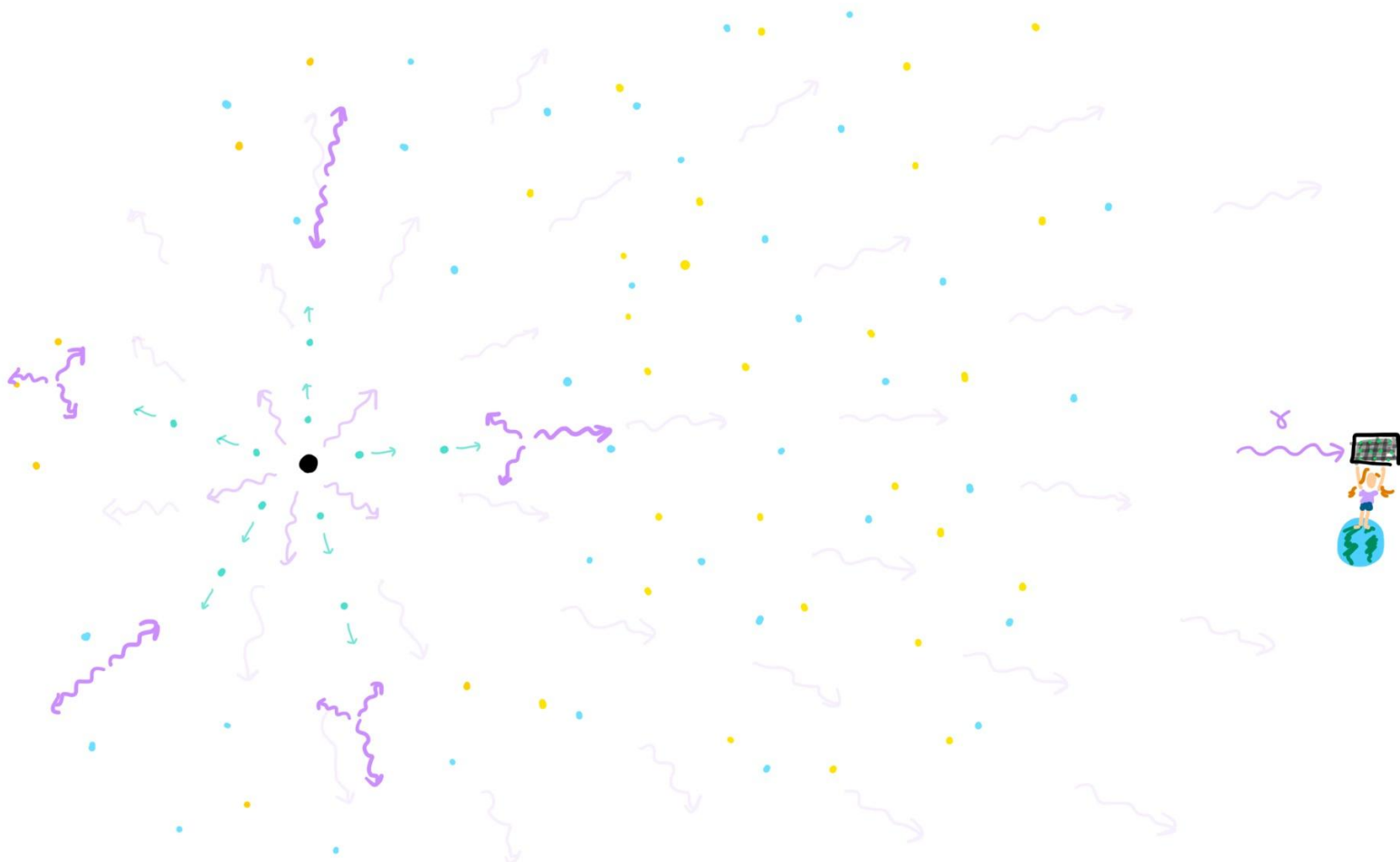






(Voyager et...)

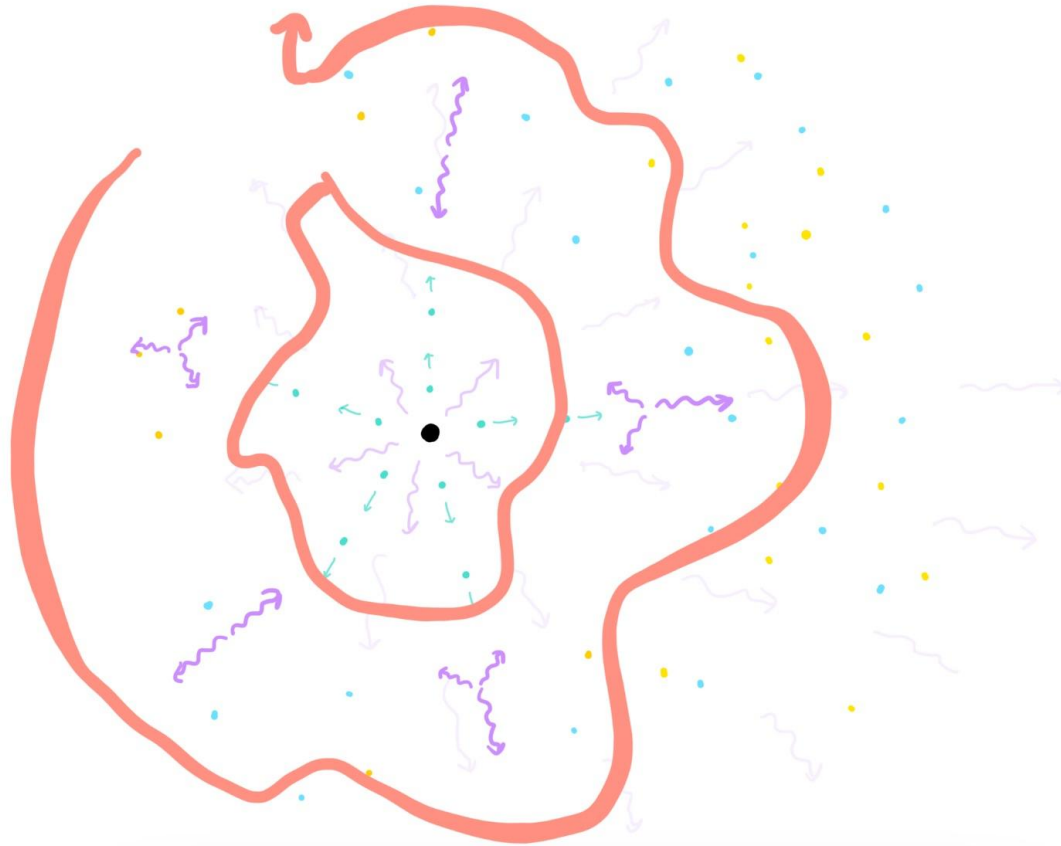


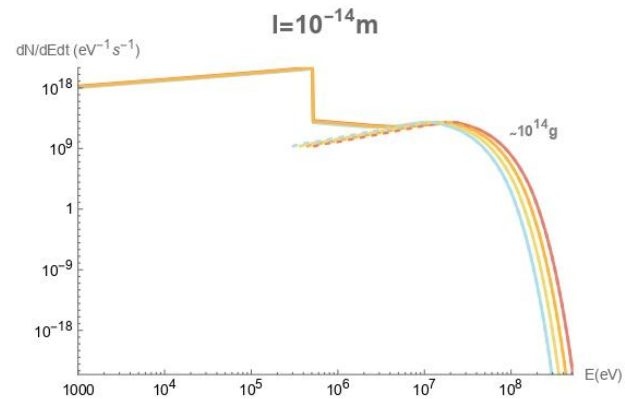
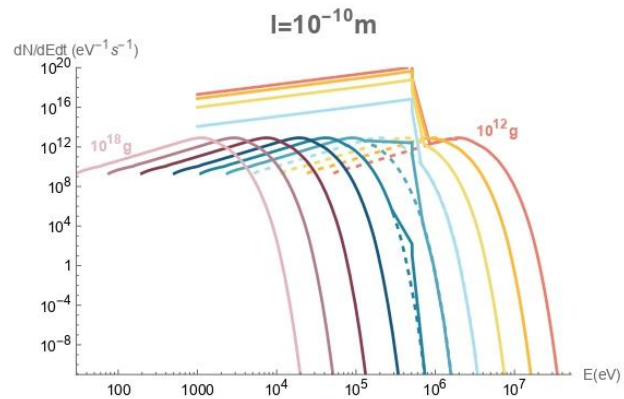
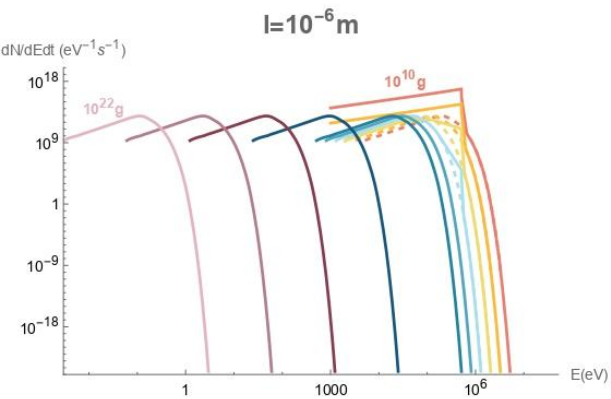


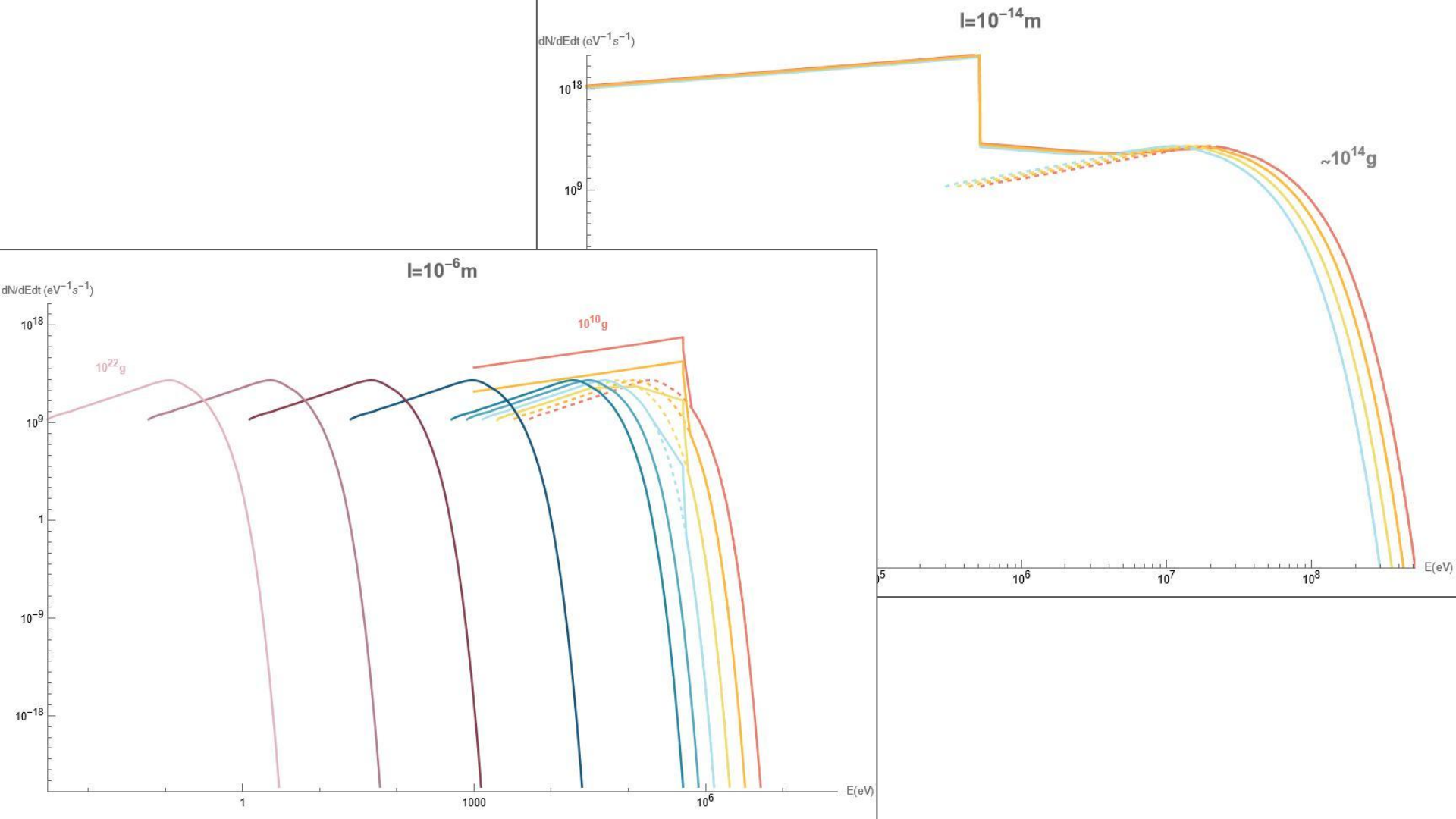
To compute direct Hawking emission we use **BLACKMAX**
with graybody factors from [Iida et al 0602.188](#) *(BlackMax for braneworlds)*



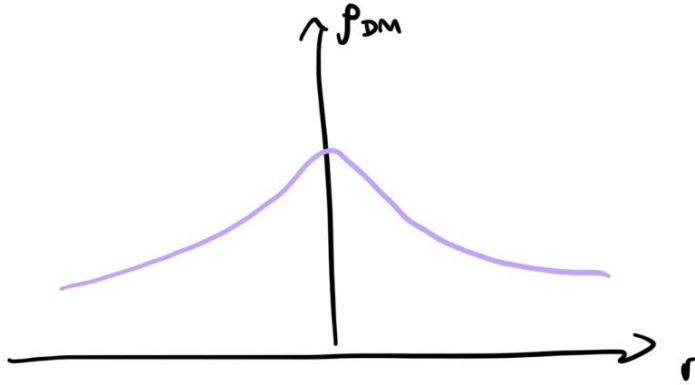
To compute final products we use Standard Model QFT
and astroparticle physics data for the interstellar medium



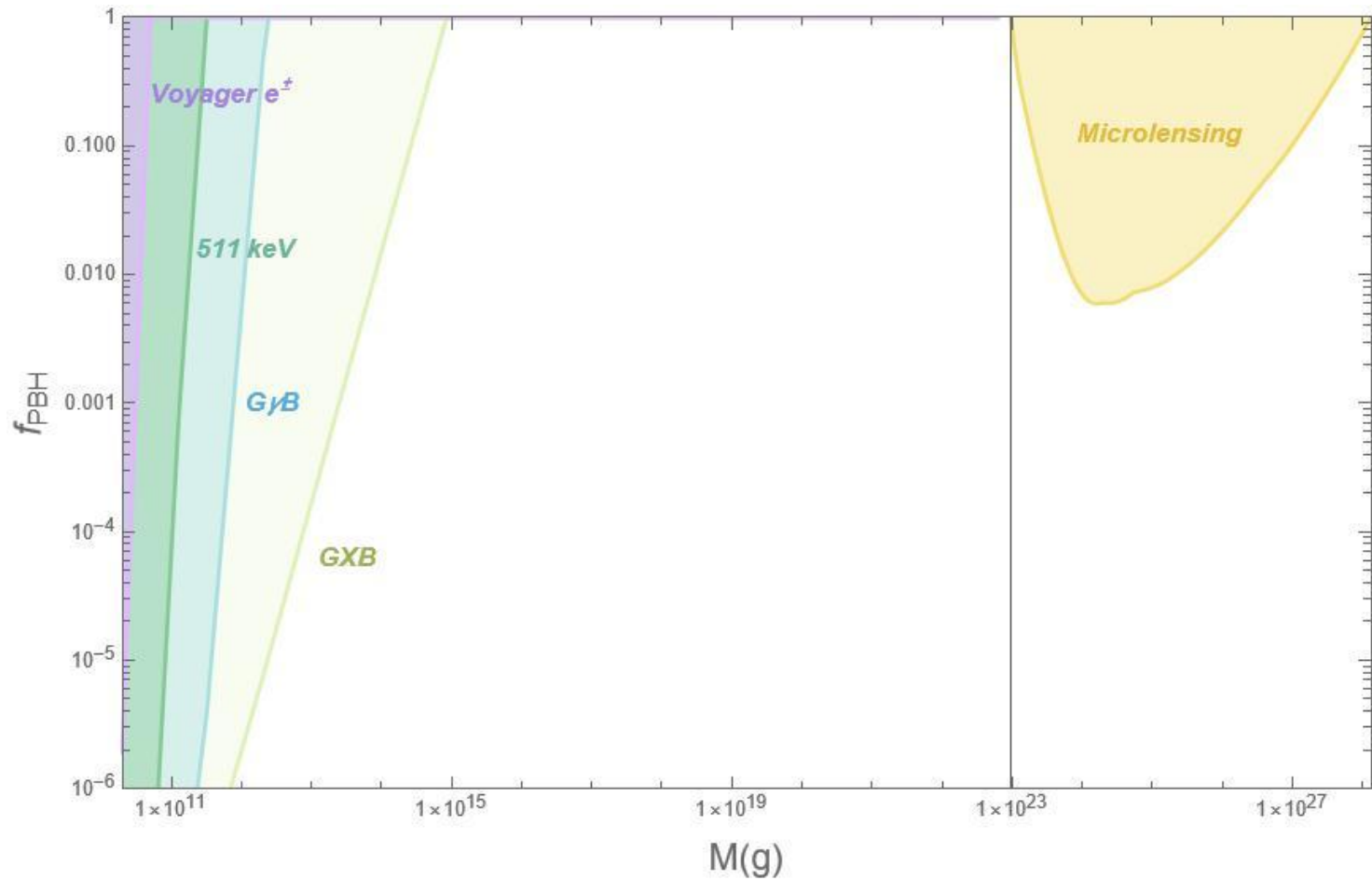


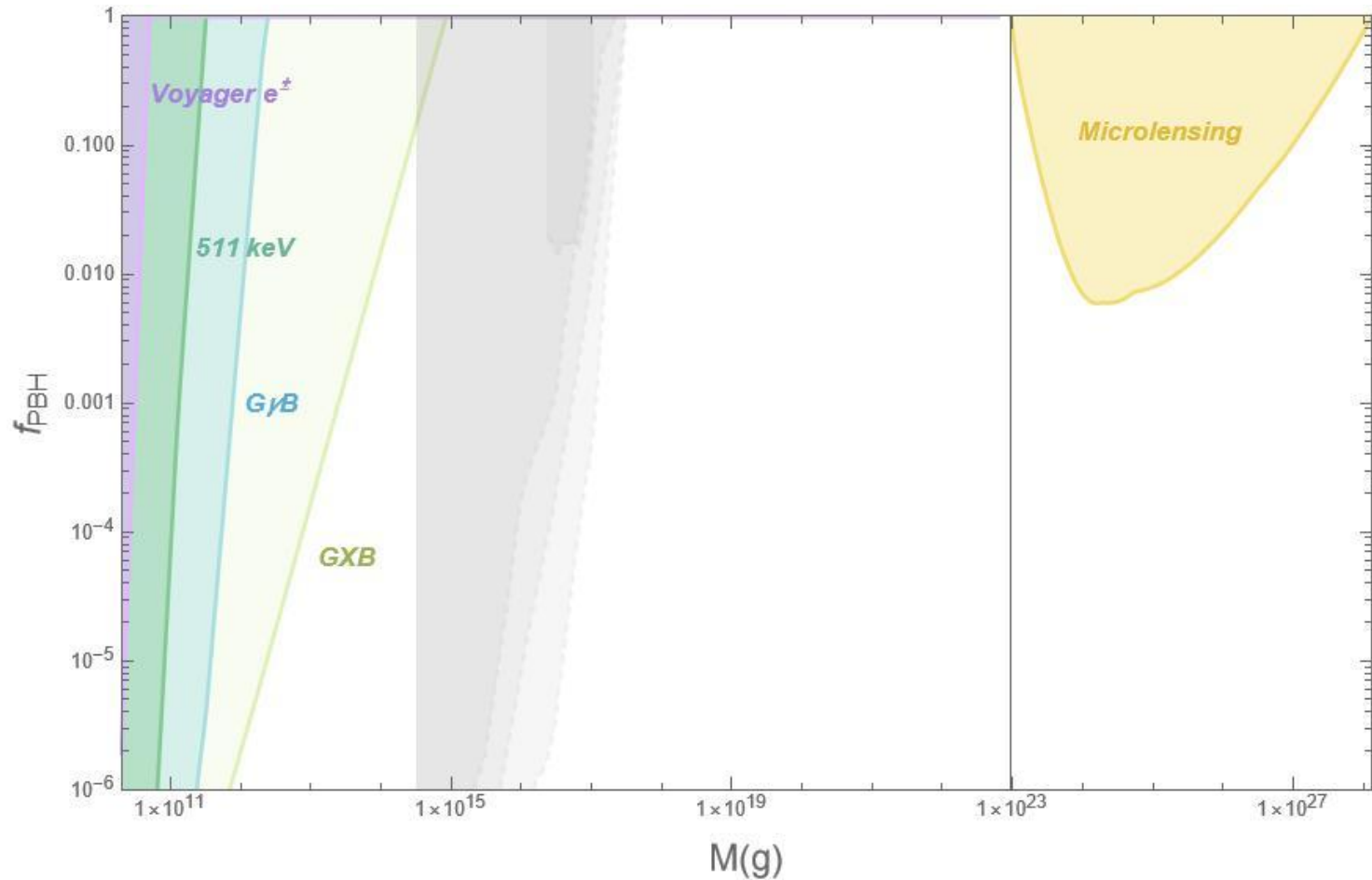


We take a Navarro - Frank - White DM profile



and calculate the net photon and e^+ flux reaching our detectors

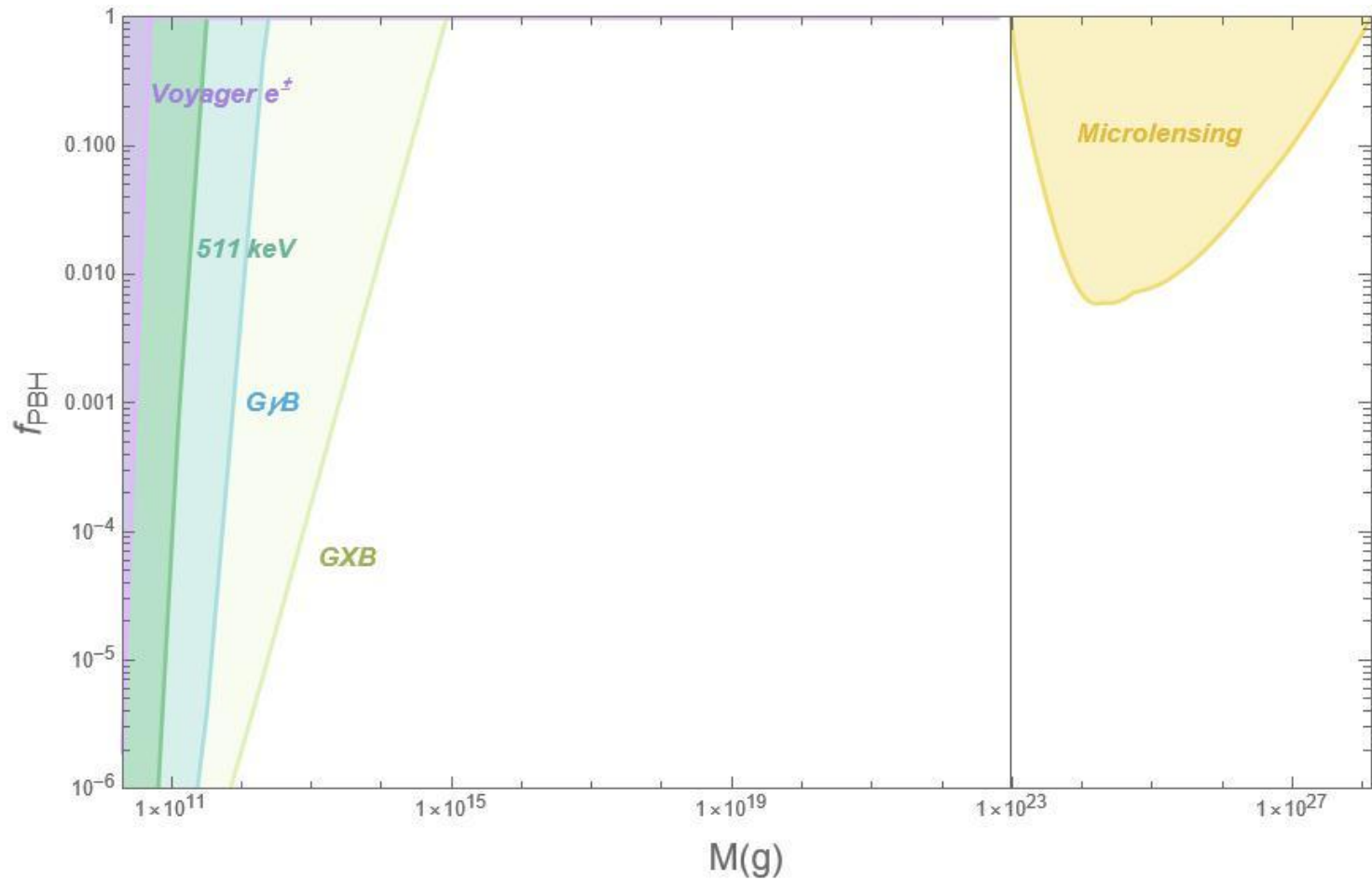


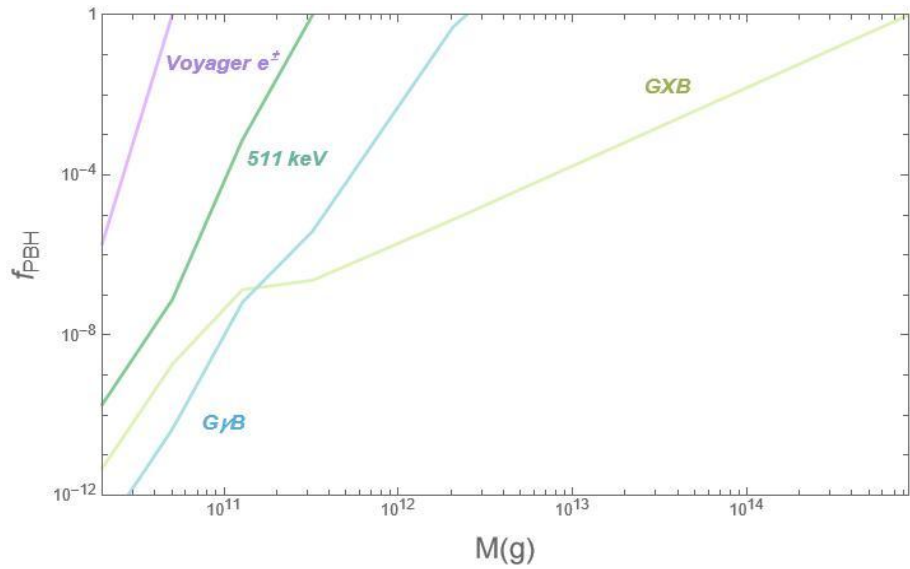


De la Torre Lugue et al 2406.11949

Latha et al 2004.00627

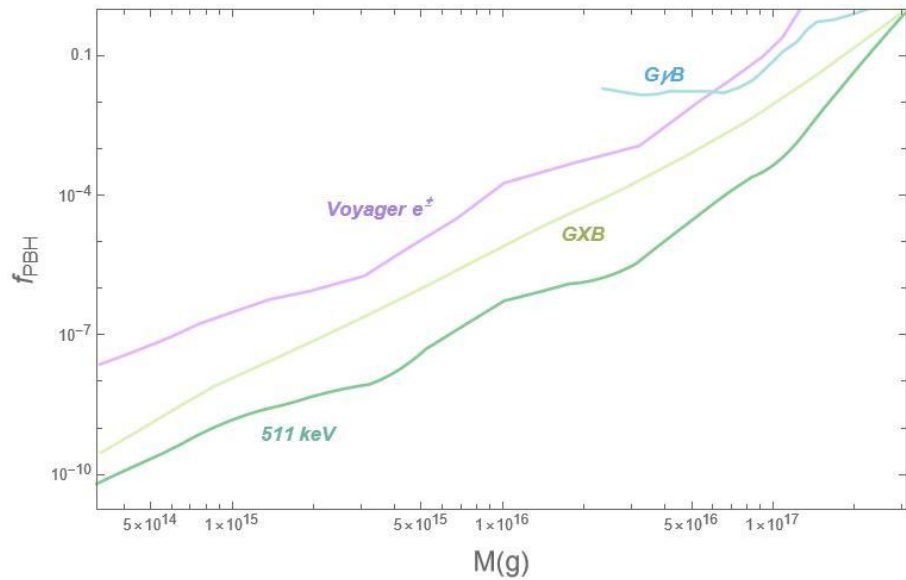
Smyth et al 1910.01285



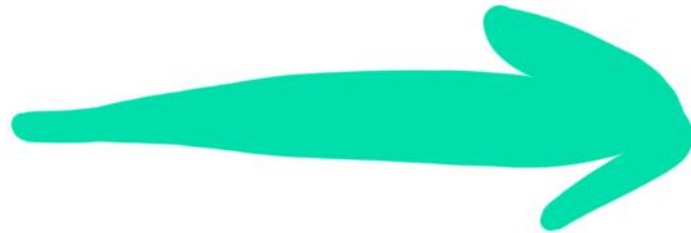


Randall-Sundrum II

Standard (3+1)d



Takeaways



Braneworlds have very interesting features
and are compatible with observations



Higher-dimensional BHs are colder and have
different properties



DM window can look very different if we embed
our Universe in a higher-d spacetime