

SCALAR CLOUDS AROUND BLACK HOLES

KATY CLOUGH

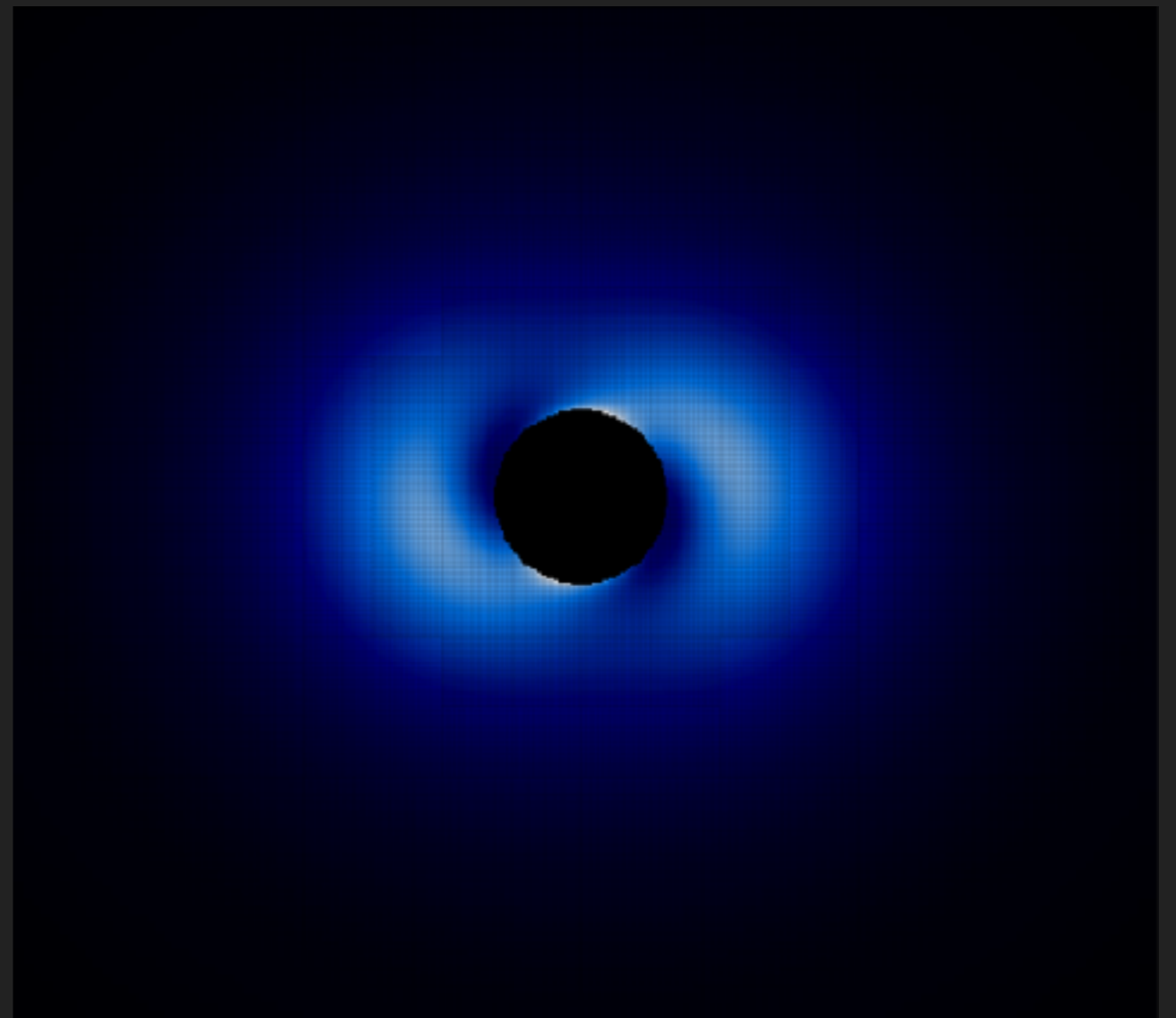


BLACK HOLES ARE BECOMING MORE ACCESSIBLE

The image is a screenshot of a BBC News article. At the top, the BBC logo is on the left, followed by a 'Sign in' button and navigation links for News, Sport, Weather, Shop, Reel, Travel, and More. A search bar is on the right. Below this is a red banner with the word 'NEWS' in white. Underneath the banner is a navigation menu with links for Home, Video, World, Asia, UK, Business, Tech, Science, Stories, Entertainment & Arts, Health, World News TV, and More. The article is in the 'Science & Environment' section. The main headline is 'First ever black hole image released' in a large, bold, black font. Below the headline, it says 'By Pallab Ghosh' and 'Science correspondent, BBC News'. There is a timestamp '6 hours ago' and social media sharing icons for Facebook, Messenger, Twitter, Email, and a general 'Share' button. The main content area features a large, circular image of a black hole, showing a dark center surrounded by a bright, glowing ring of light. Below the image is a white waveform graphic on a black background, representing gravitational waves.

BLACK HOLES HAVE NO (SCALAR) HAIR

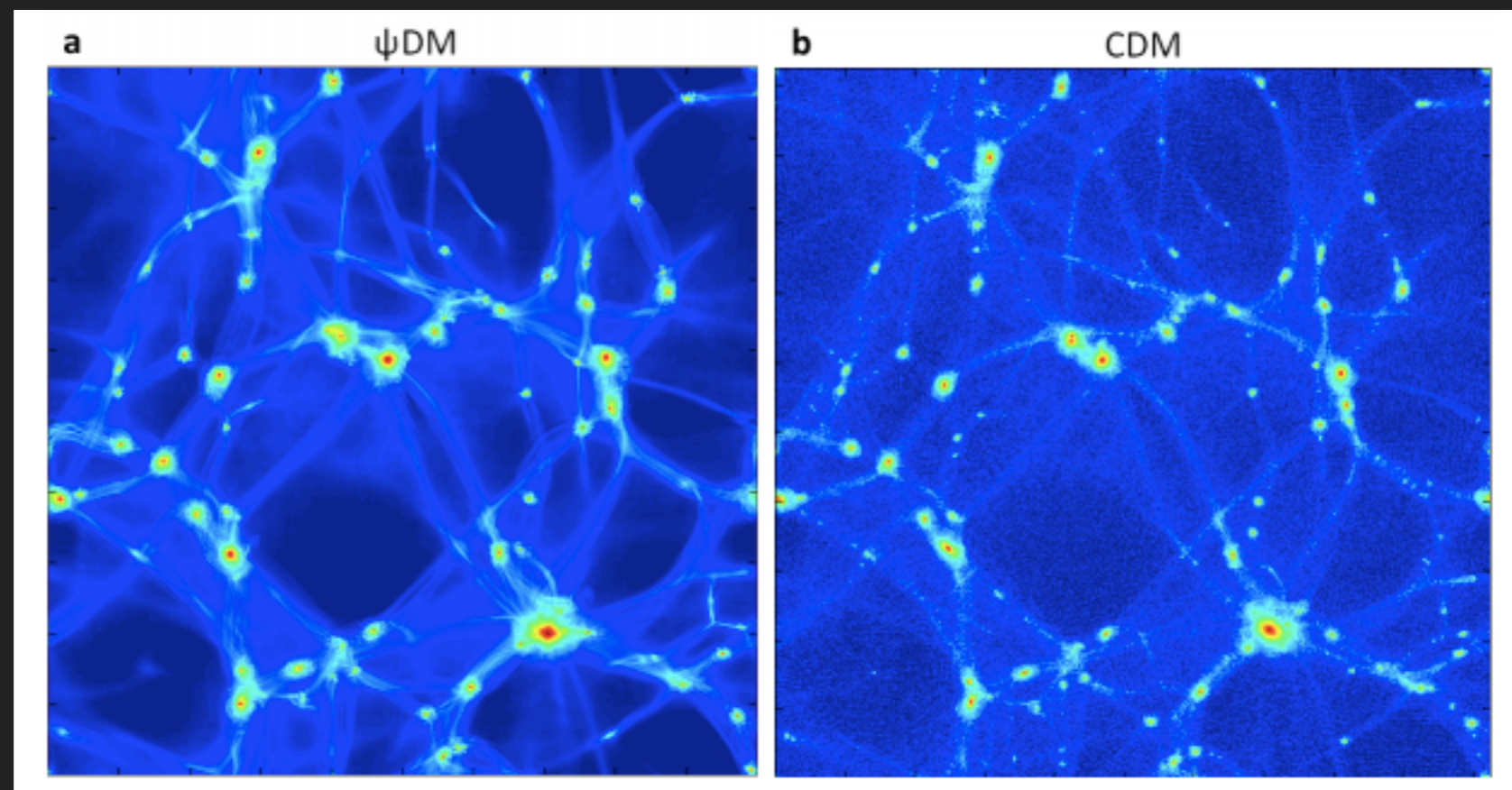
- ▶ Assumptions:
Metric and (minimally coupled) field are stationary, embedded in an asymptotically flat spacetime, hair is regular at the horizon.
- ▶ Counterexample:
Superradiance in a complex scalar, with spinning BH
(Herdeiro & Radu PRL 112 2014)



SCALAR DARK MATTER

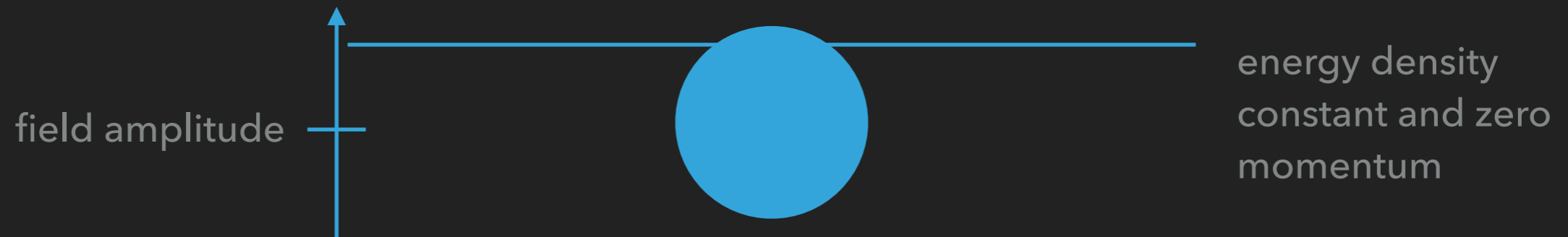
- ▶ If DM is light (sub eV) it should be a bosonic particle with a high occupation number

- ▶ Expectation value of coherent state $\nabla_{\mu} \nabla^{\mu} \phi = -m^2 \phi$

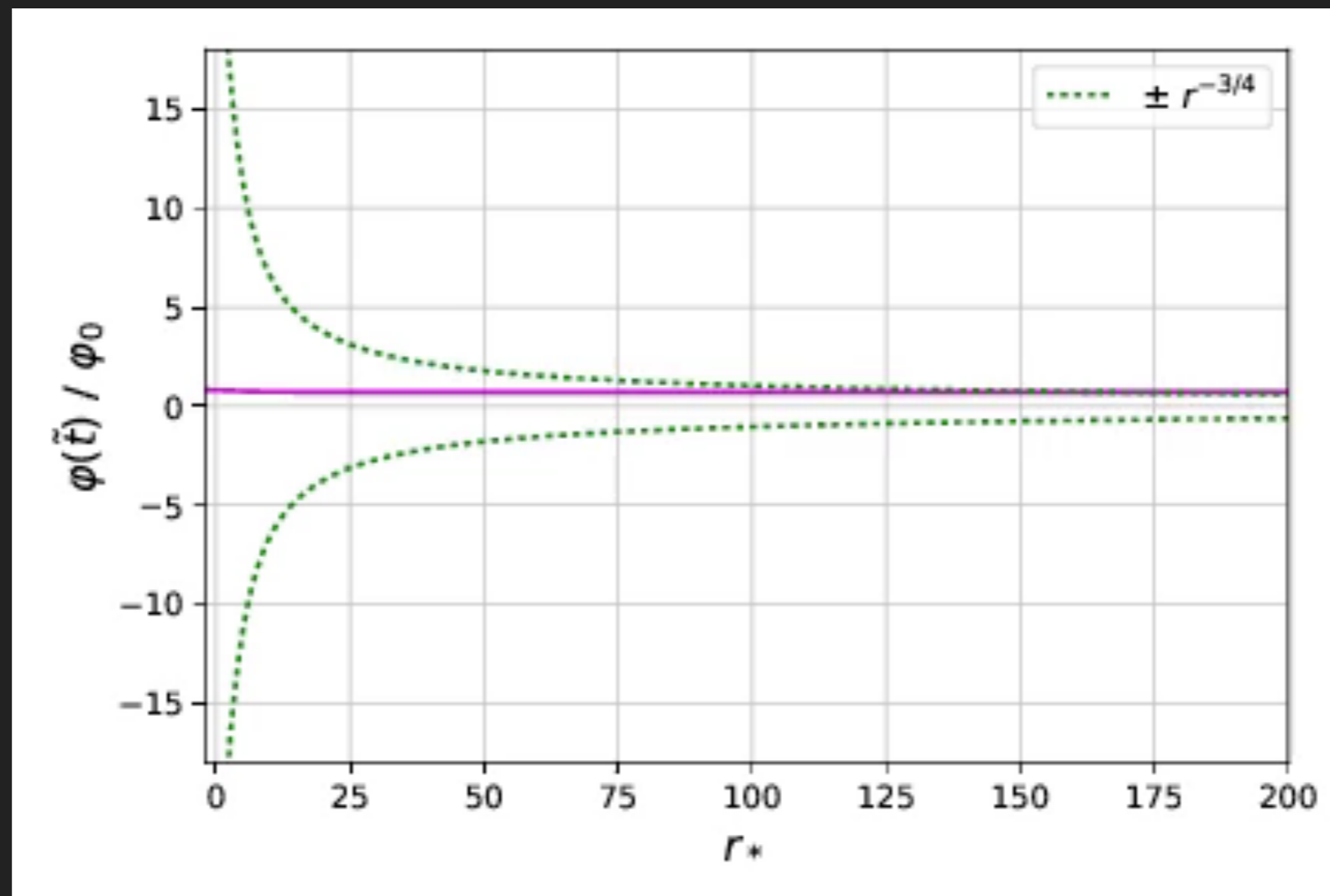


SCALAR DARK MATTER

What happens to the field around a BH in a homogeneously oscillating region?



SCALAR DARK MATTER CLOUDS



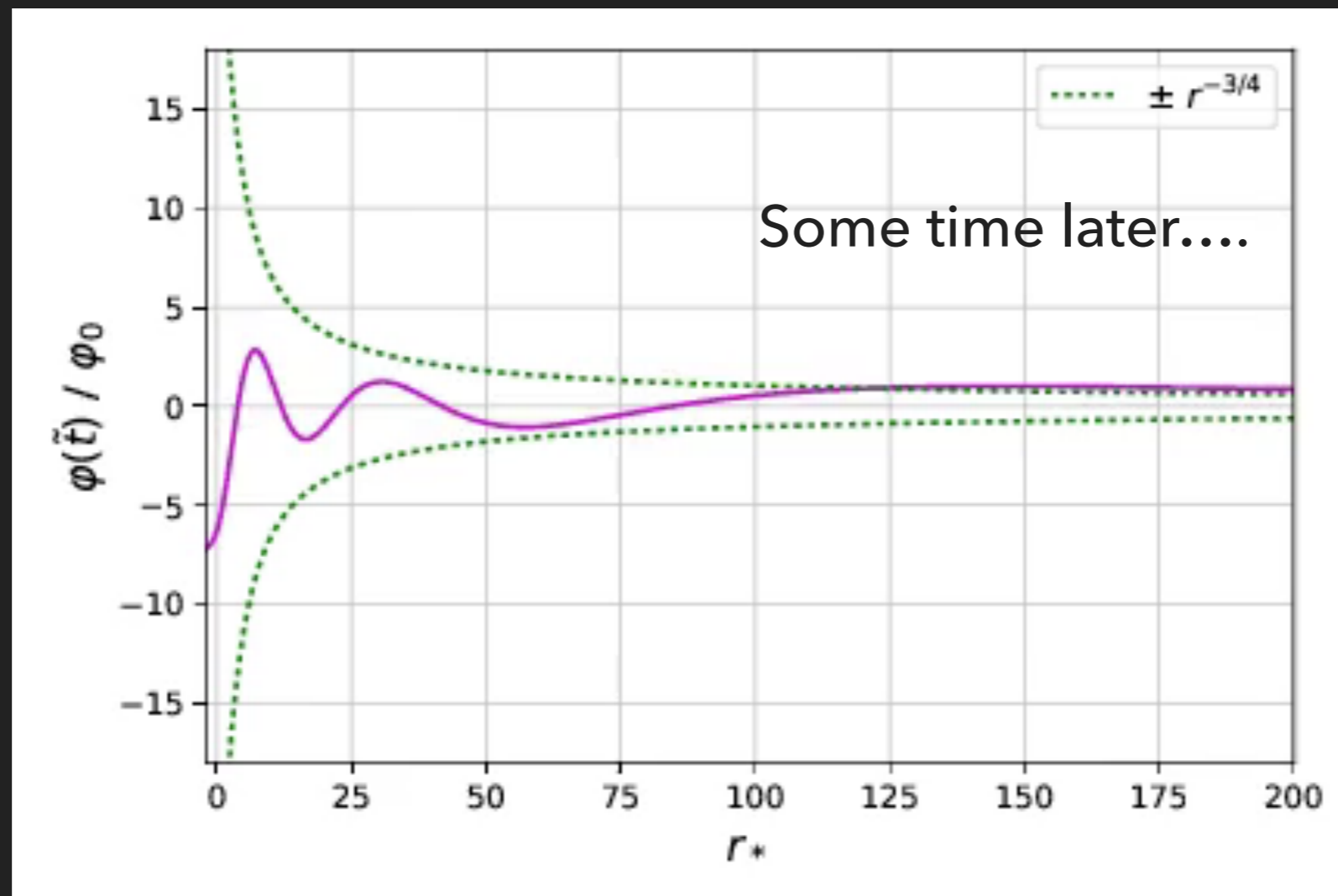
On the growth of massive scalar hair around a Schwarzschild black hole

Katy Clough, Pedro G. Ferreira, Macarena Lagos

arXiv:1904.12783



SCALAR DARK MATTER CLOUDS



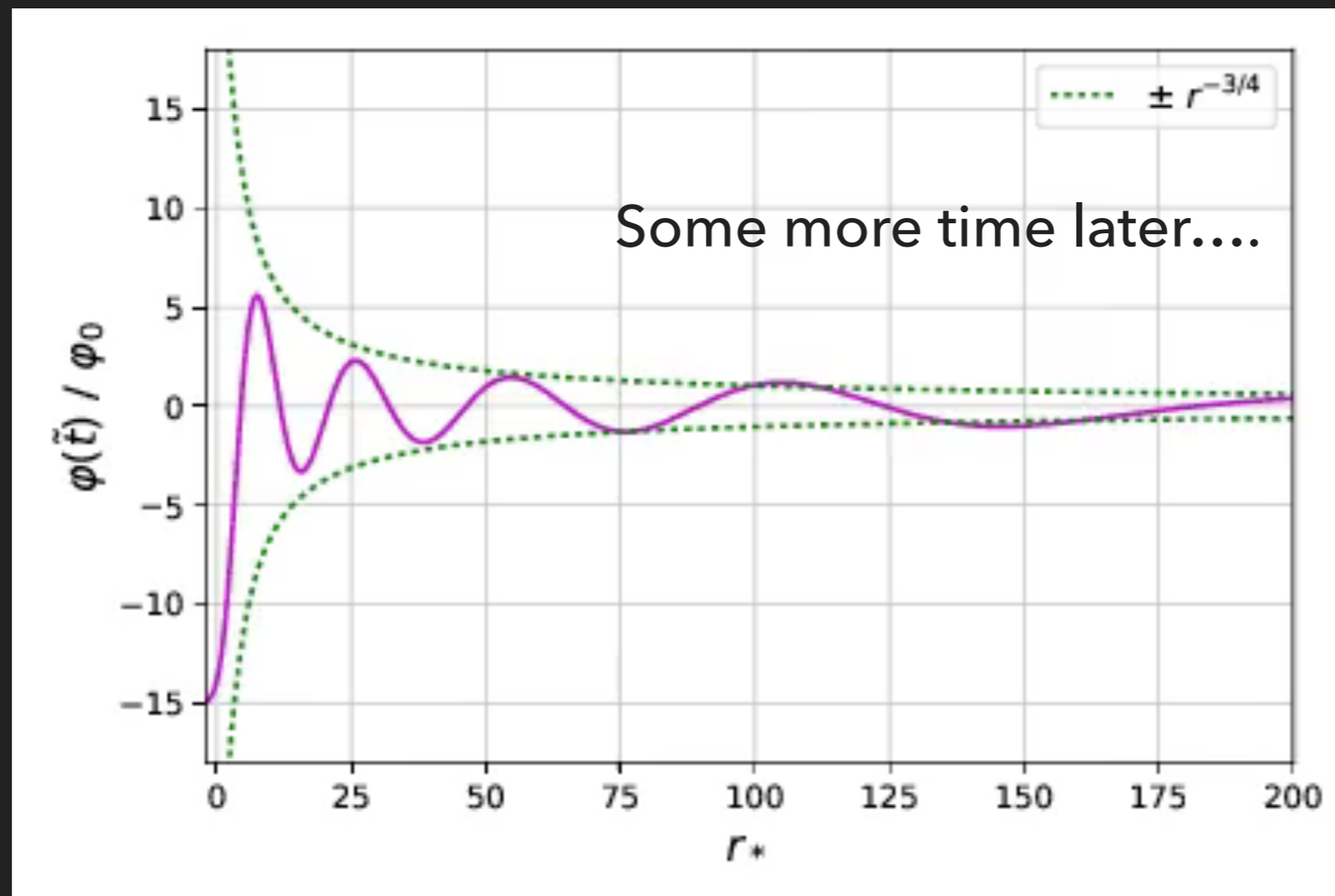
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WHY $r^{-3/4}$

Assume a uniform flux
(independent of r)

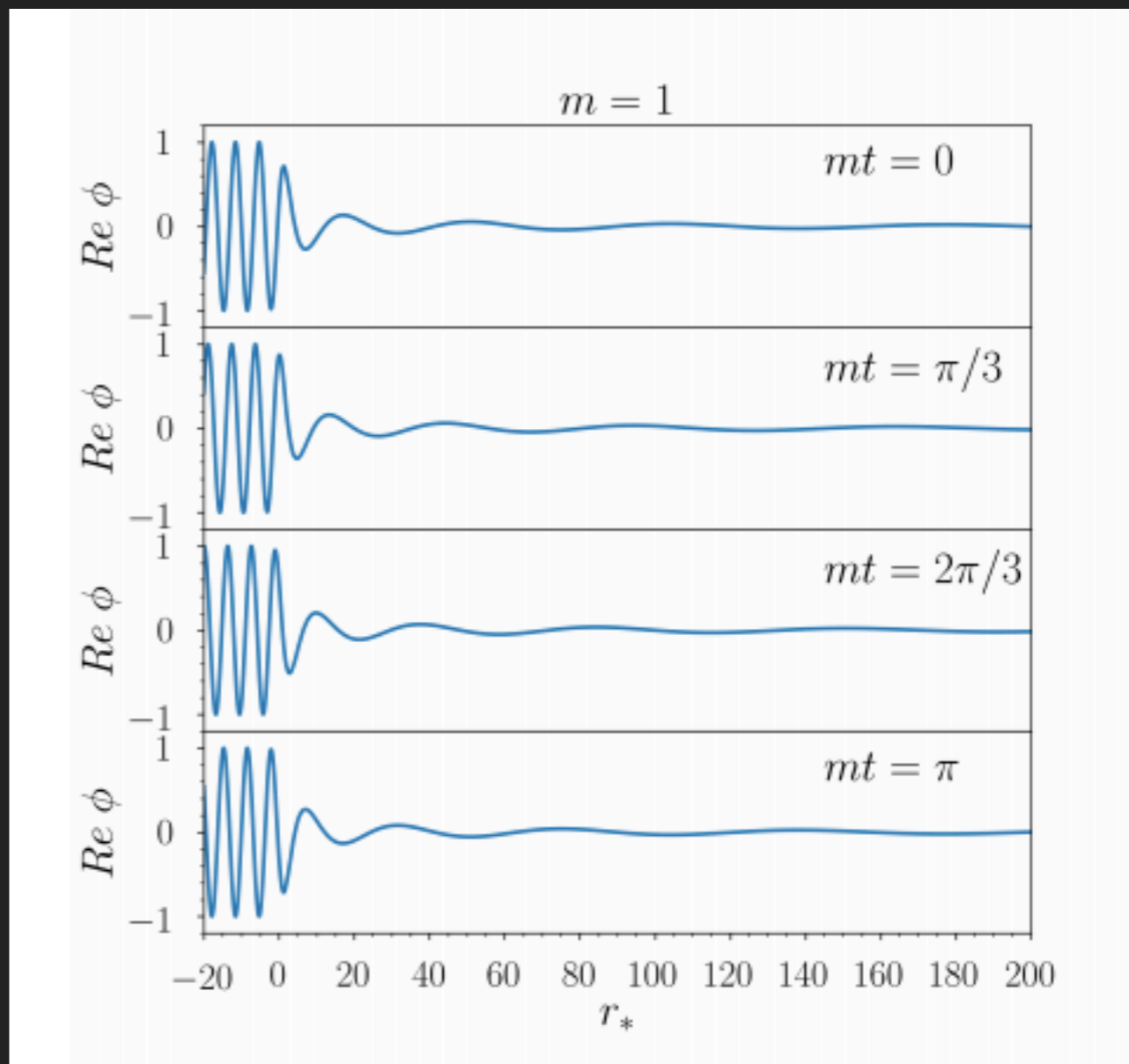
$$S_r = 4\pi r^2 \rho v$$

$$v \sim r^{-1/2}$$

$$\rho \sim r^{-3/2}$$

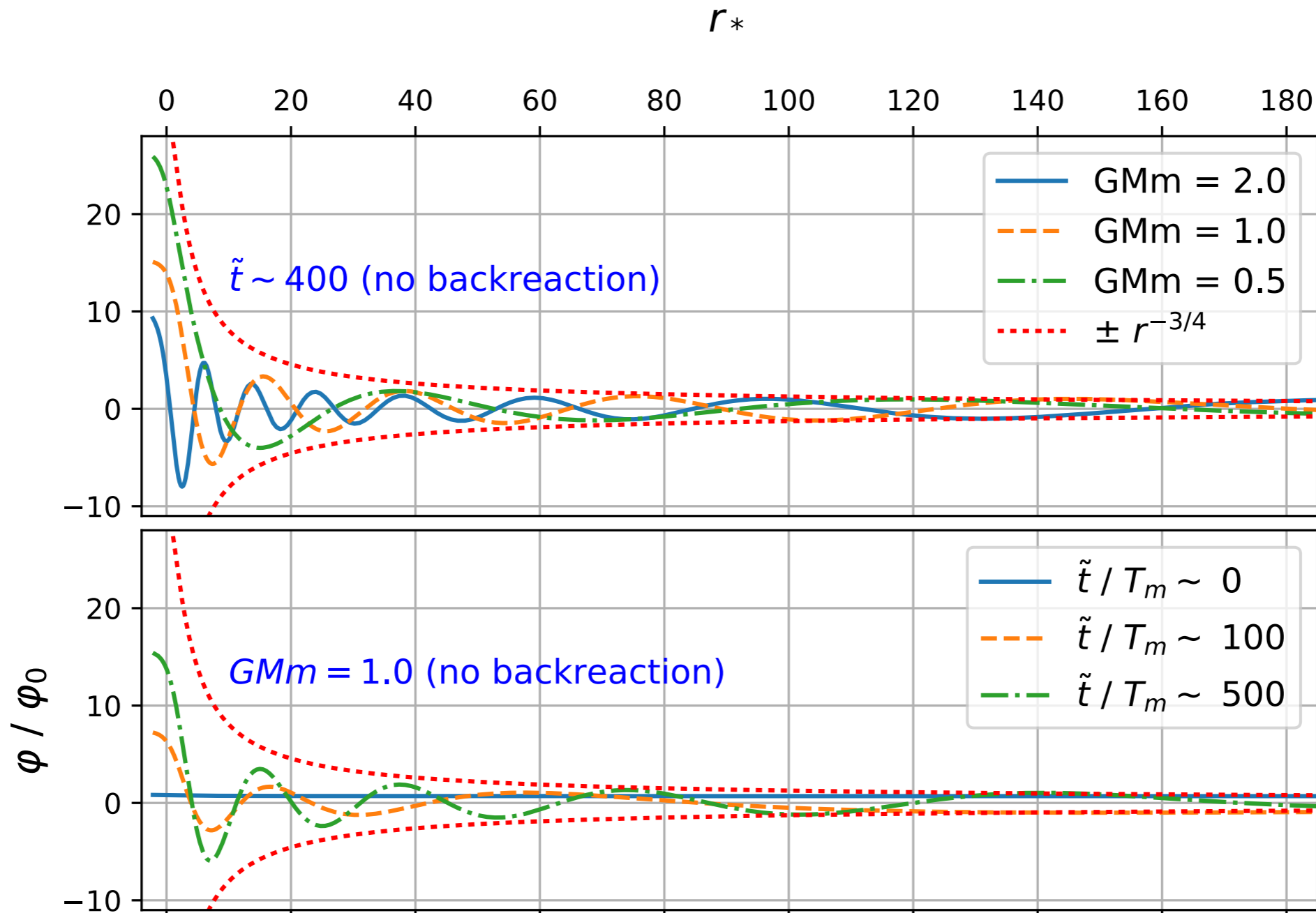
$$\rho \sim \phi^2 \sim (r^{-3/4})^2$$

Confluent Huen function

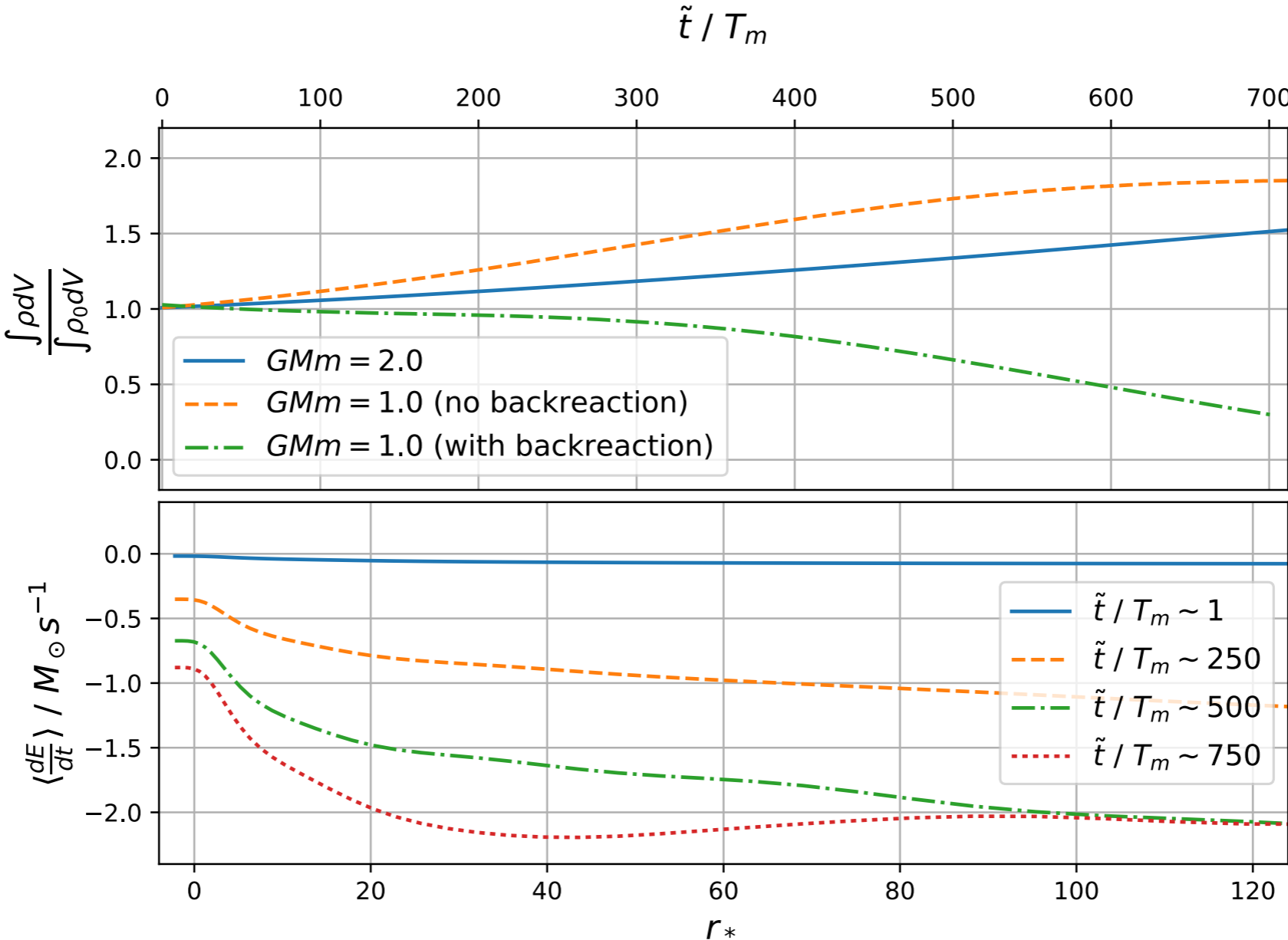


Black Hole Hair from Scalar Dark Matter
Lam Hui, Daniel Kabat, Xinyu Li, Luca Santoni,
Sam S. C. Wong
JCAP 1906 (2019) no.06, 038

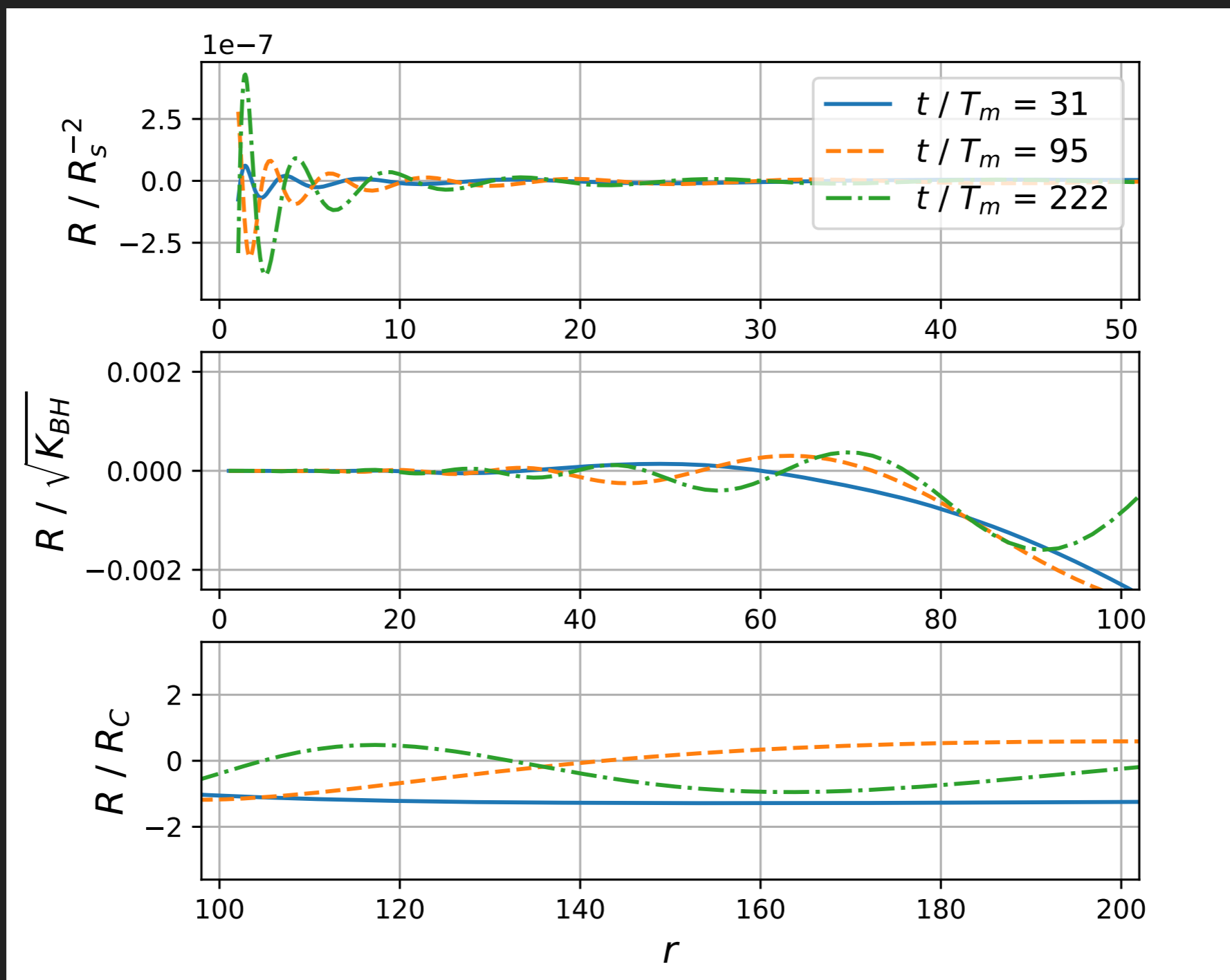
RADIAL PROFILES VARY DEPENDING ON SCALAR MASS



DOES THE GROWTH END?



IMPRINTS ON THE METRIC



SIZE OF THE EFFECT FOR TYPICAL ASYMPTOTIC DM DENSITY

- ▶ Maximum energy density at horizon

$$\rho \sim \rho_0 \left(\frac{r_0}{r_s} \right)^{3/2} \sim 10^9 \rho_0 \left(\frac{r_0/r_s}{10^6} \right)^{3/2}$$

- ▶ Comparison to curvature of BH

$$\frac{16\pi G\rho}{1/r_s^2} \sim 10^{-12} \left(\frac{M_{BH}}{10^9 M_\odot} \right)^2 \left(\frac{\rho_0}{1 \text{ GeV/cm}^3} \right) \left(\frac{r_0/r_s}{10^6} \right)^{3/2}$$

WILL A COMPANION ENHANCE OR DESTROY THESE CLOUDS?

Effective field theory for black holes
with induced scalar charges

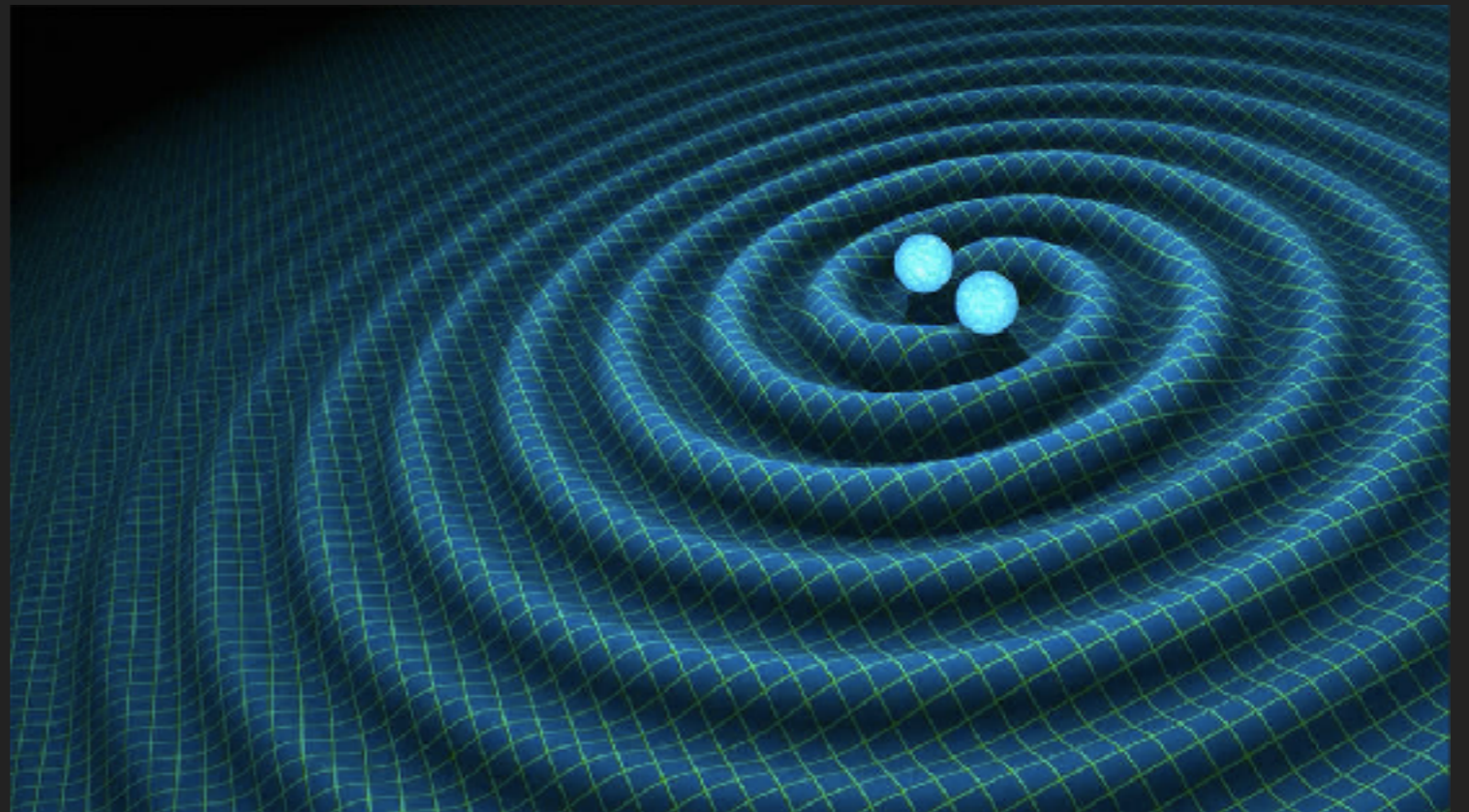
Leong Khim Wong, Anne-Christine
Davis, Ruth Gregory
arXiv:1903.07080

Ultralight Dark Matter Resonates with
Binary Pulsars

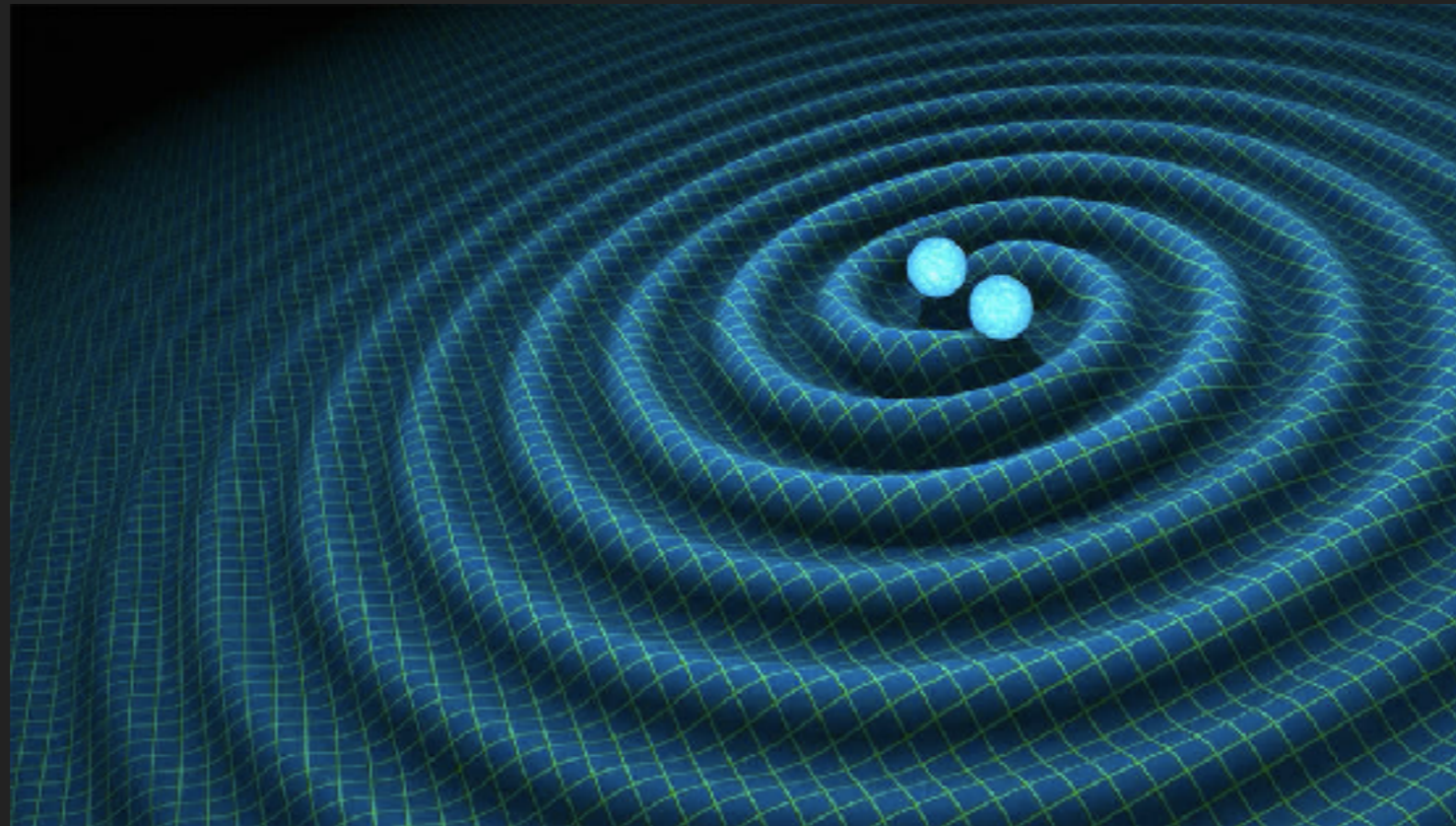
Diego Blas, Diana López Nacir, and
Sergey Sibiryakov
Phys. Rev. Lett. 118, 261102 2017

Orbital fingerprints of ultralight
scalar fields around black holes

Miguel C. Ferreira, Caio F. B.
Macedo, Vitor Cardoso
Phys.Rev. D96 (2017) no.8, 083017



IMPACT ON THE MERGER SIGNAL



IN SUMMARY

- ▶ New opportunities to study physics in untested regimes around BHs
- ▶ BHs can have long lived non trivial scalar configurations, and will do if DM is bosonic
- ▶ Need numerics to study more realistic dynamical cases

