SCALAR CLOUDS AROUND BLACK HOLES

KATY CLOUGH
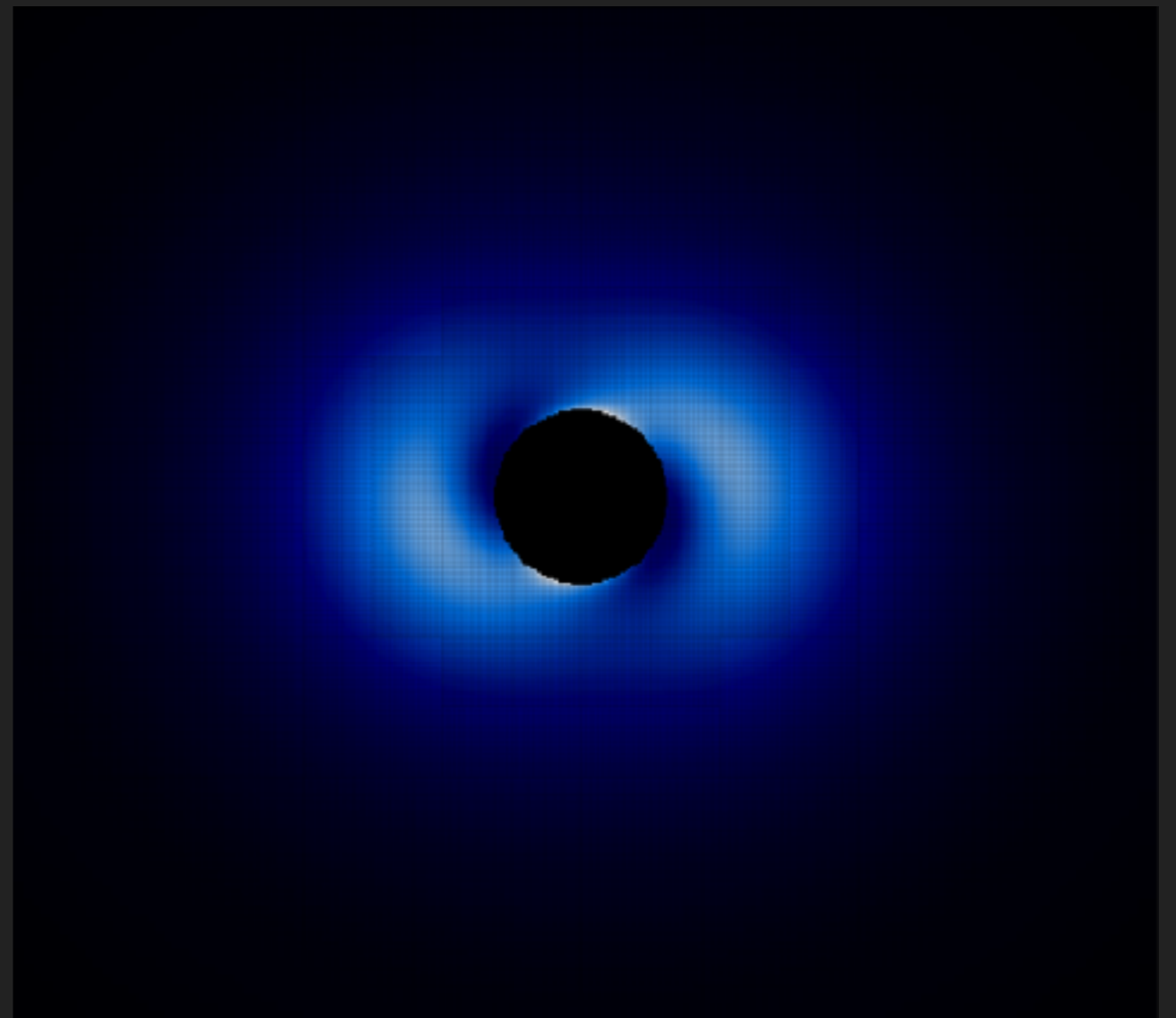
BLACK HOLES ARE BECOMING MORE ACCESSIBLE

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)
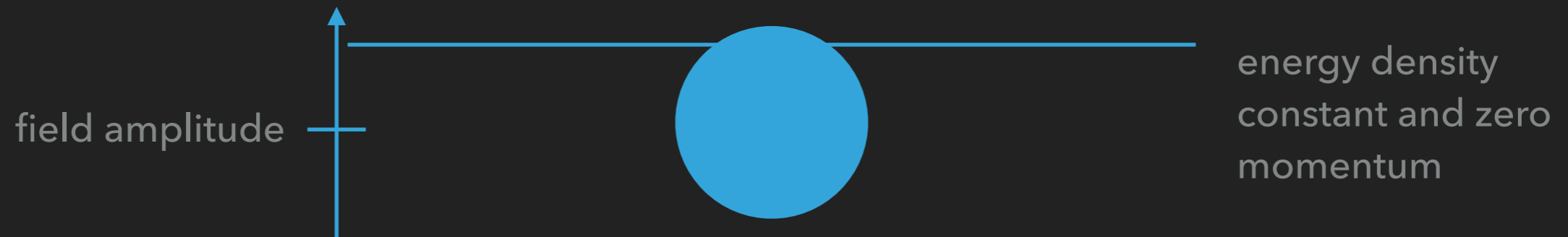
SCALAR DARK MATTER

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

▸ Expectation value of coherent state $$\nabla_\mu \nabla^\mu \phi = -m^2 \phi$$
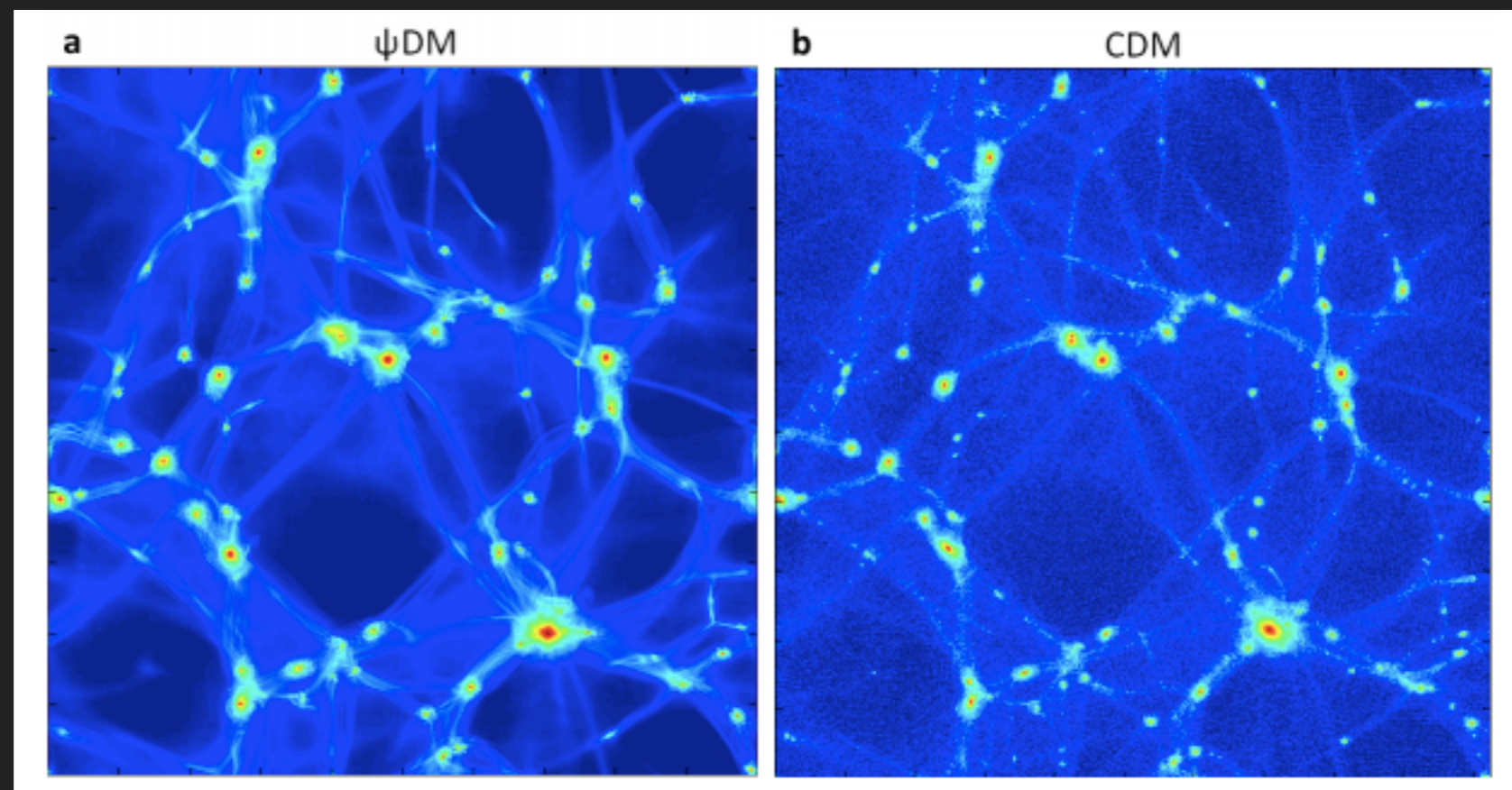
SCALAR DARK MATTER

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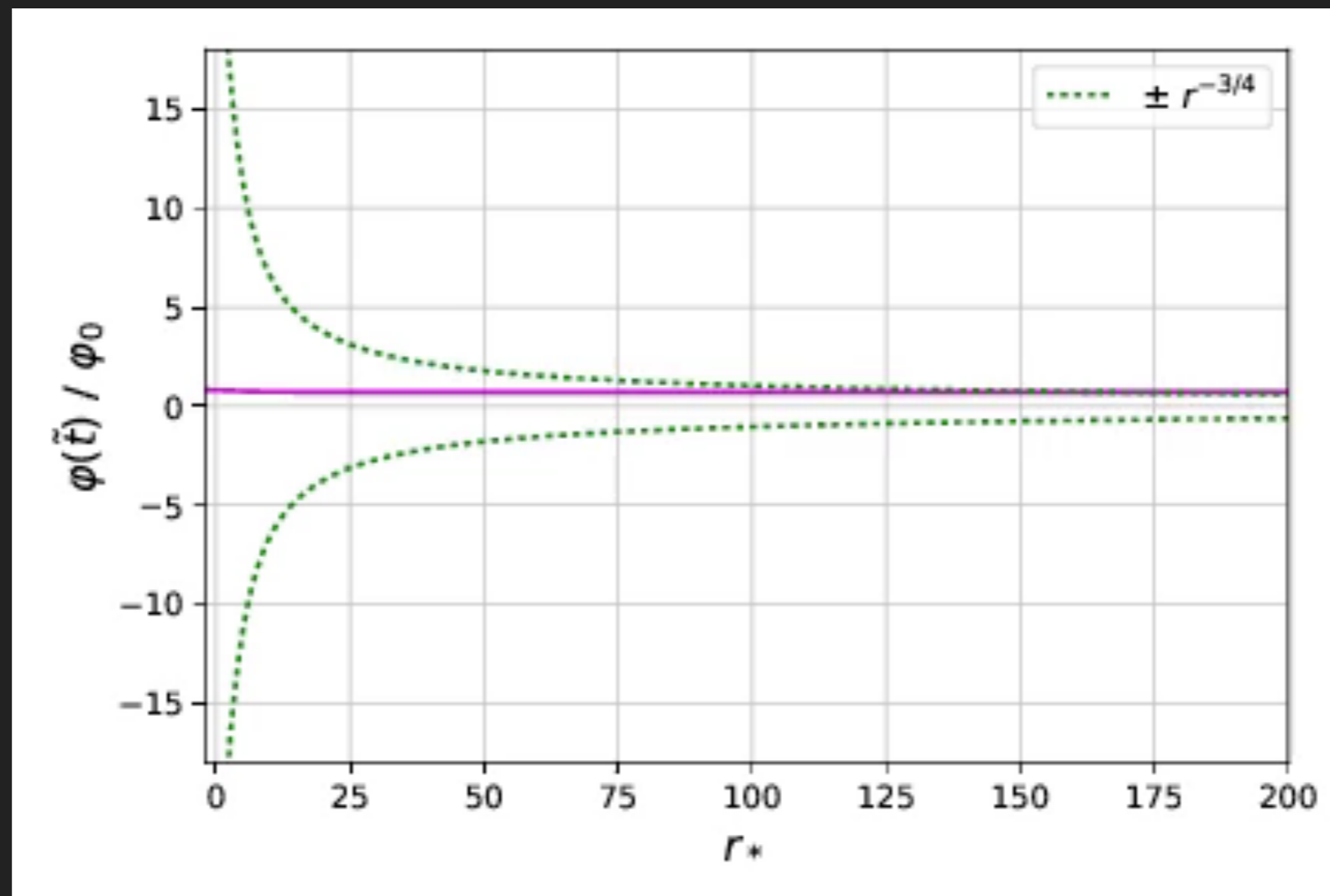
field amplitude

energy density constant and zero momentum

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

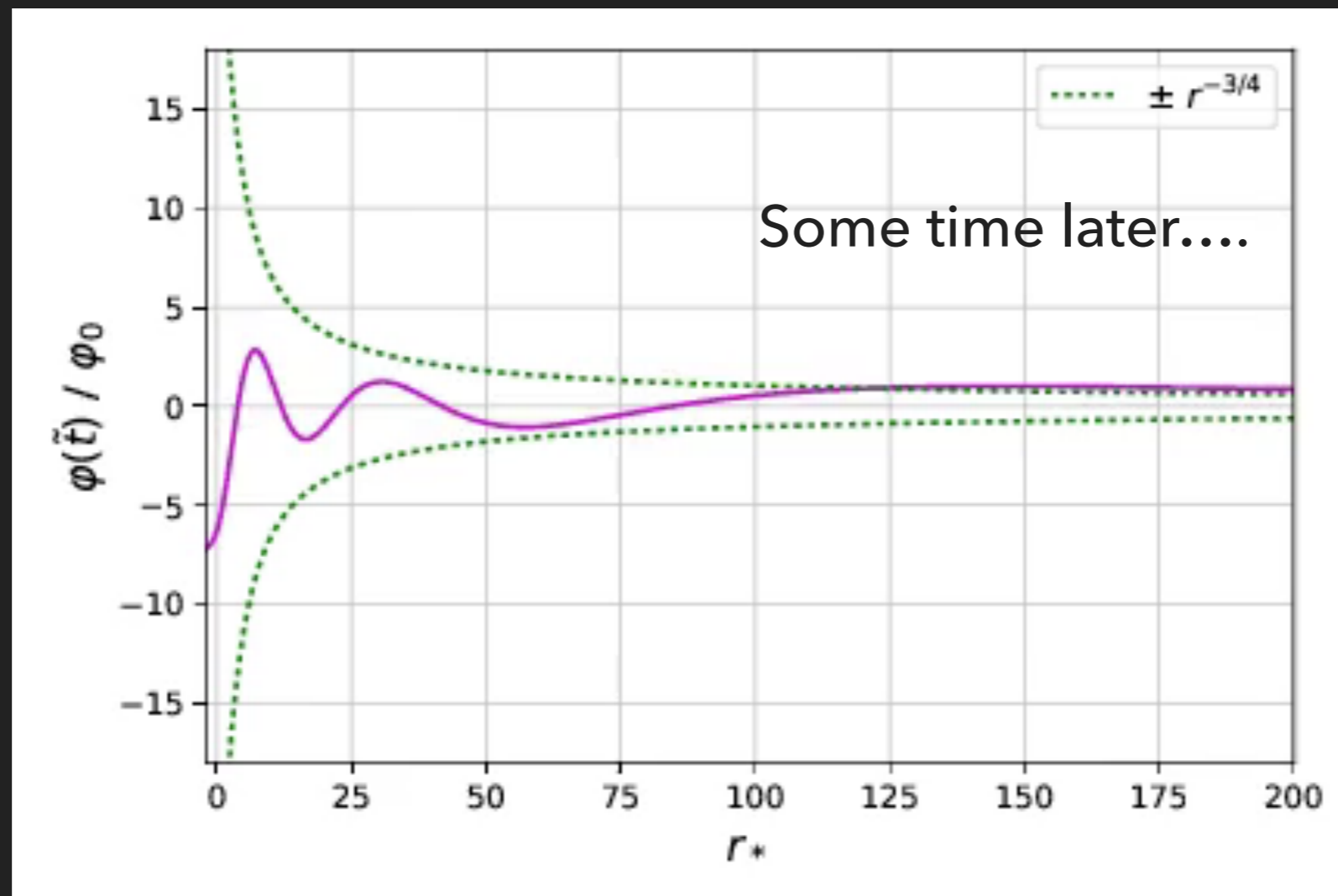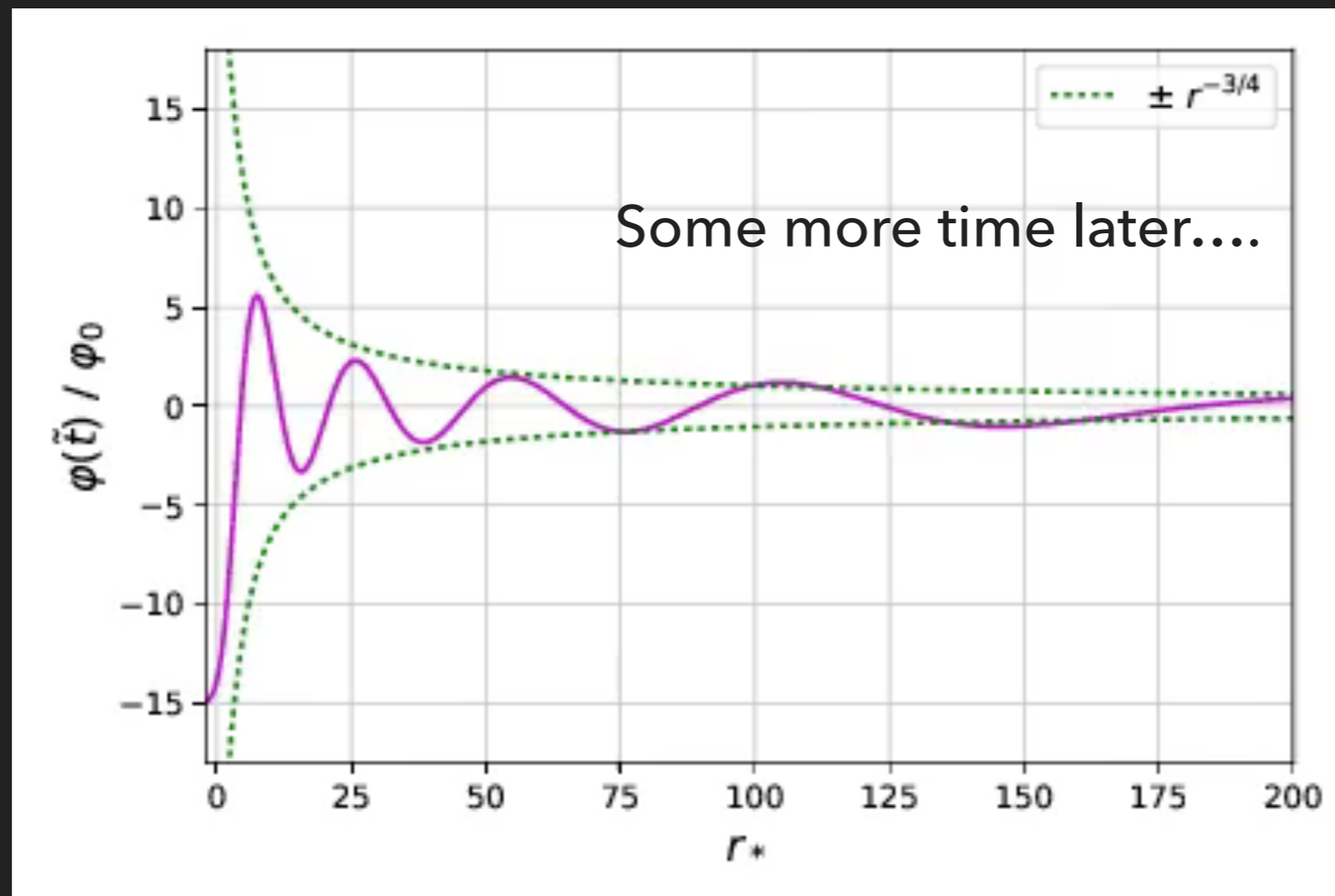# SCALAR DARK MATTER CLOUDS

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

WHY R^{-3/4}

Assume a uniform flux (independent of r)
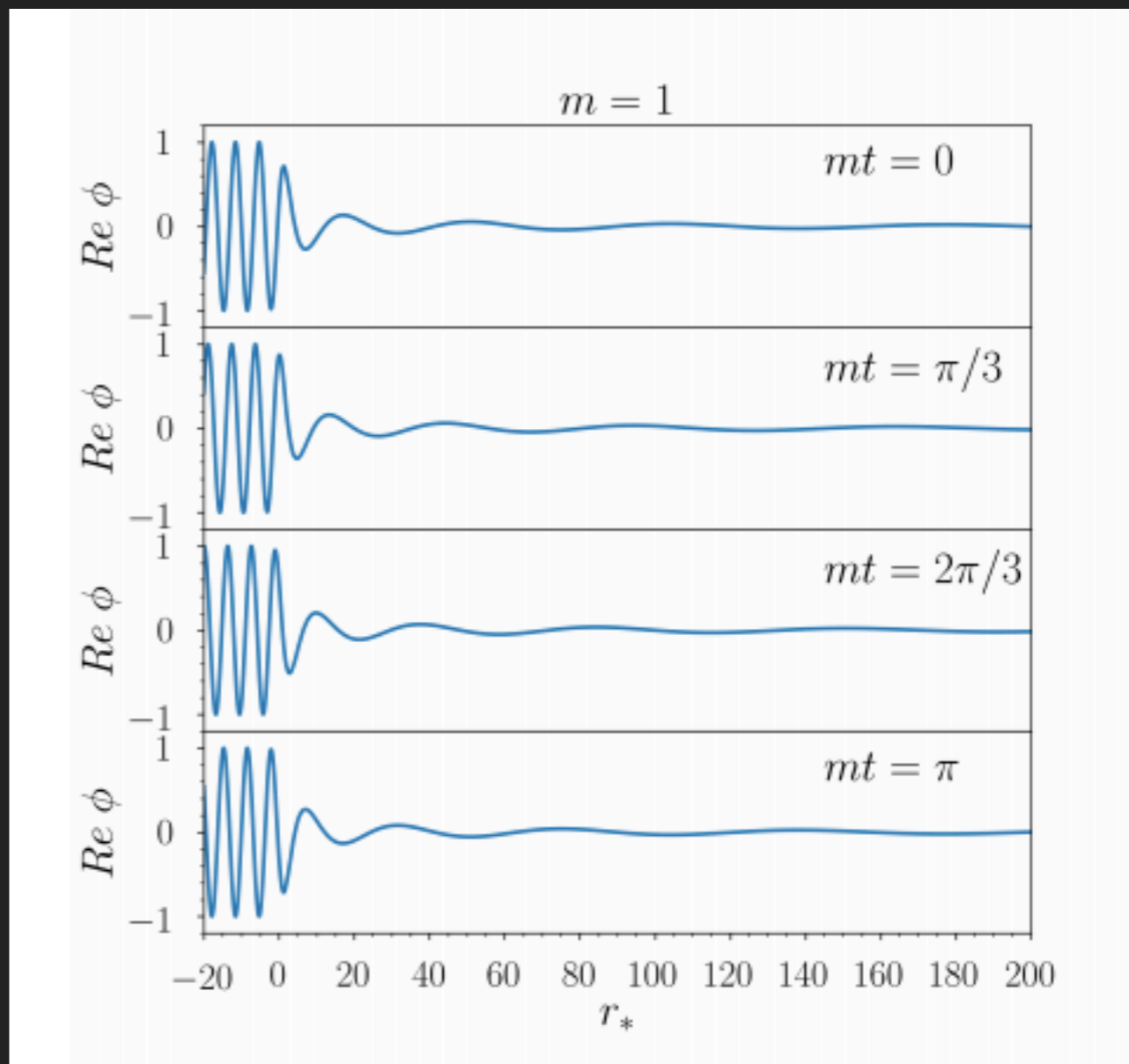
$$S_r = 4\pi r^2 \rho v$$

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

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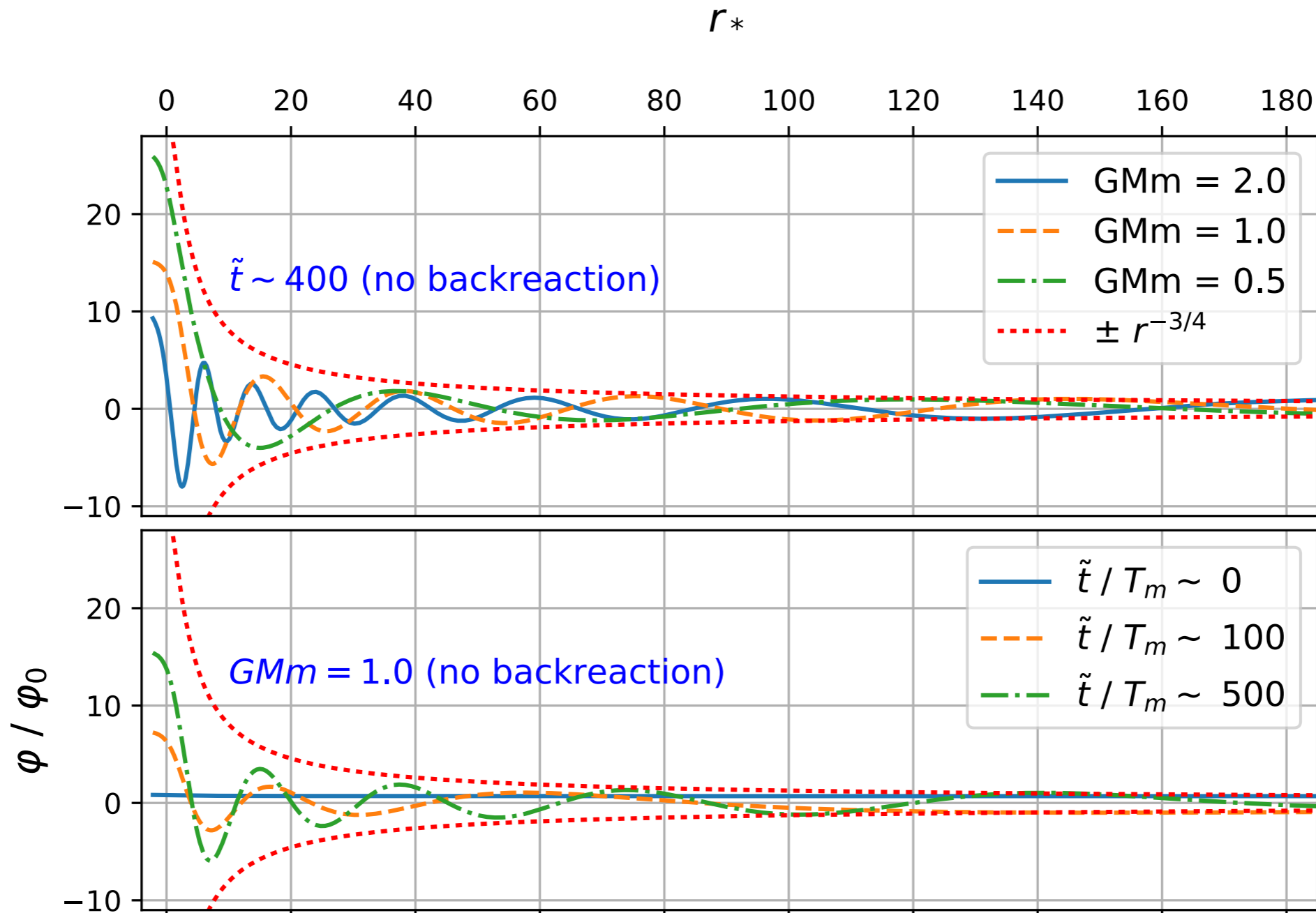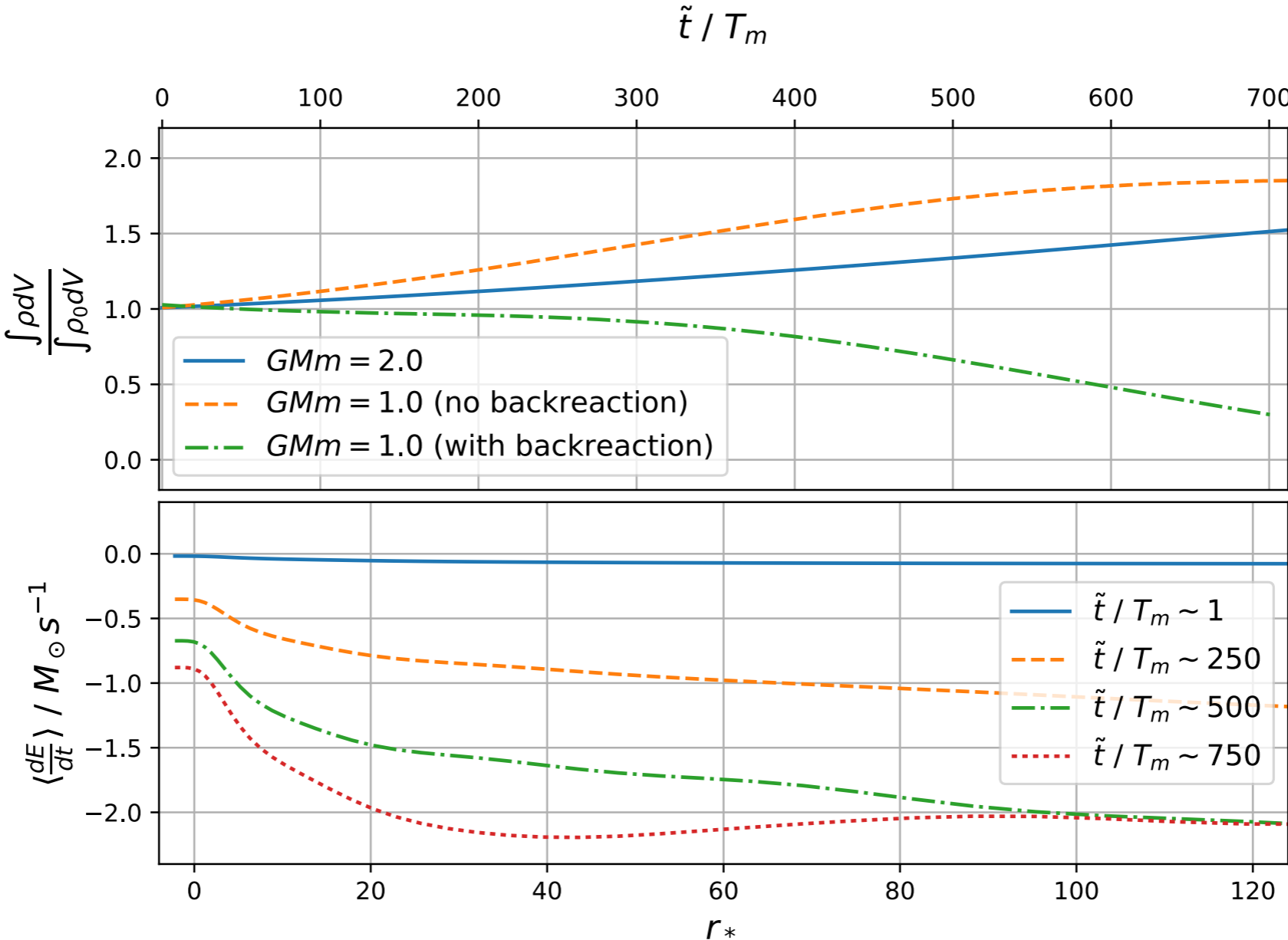
$$\rho \sim \phi^2 \sim (r^{-3/4})^2$$

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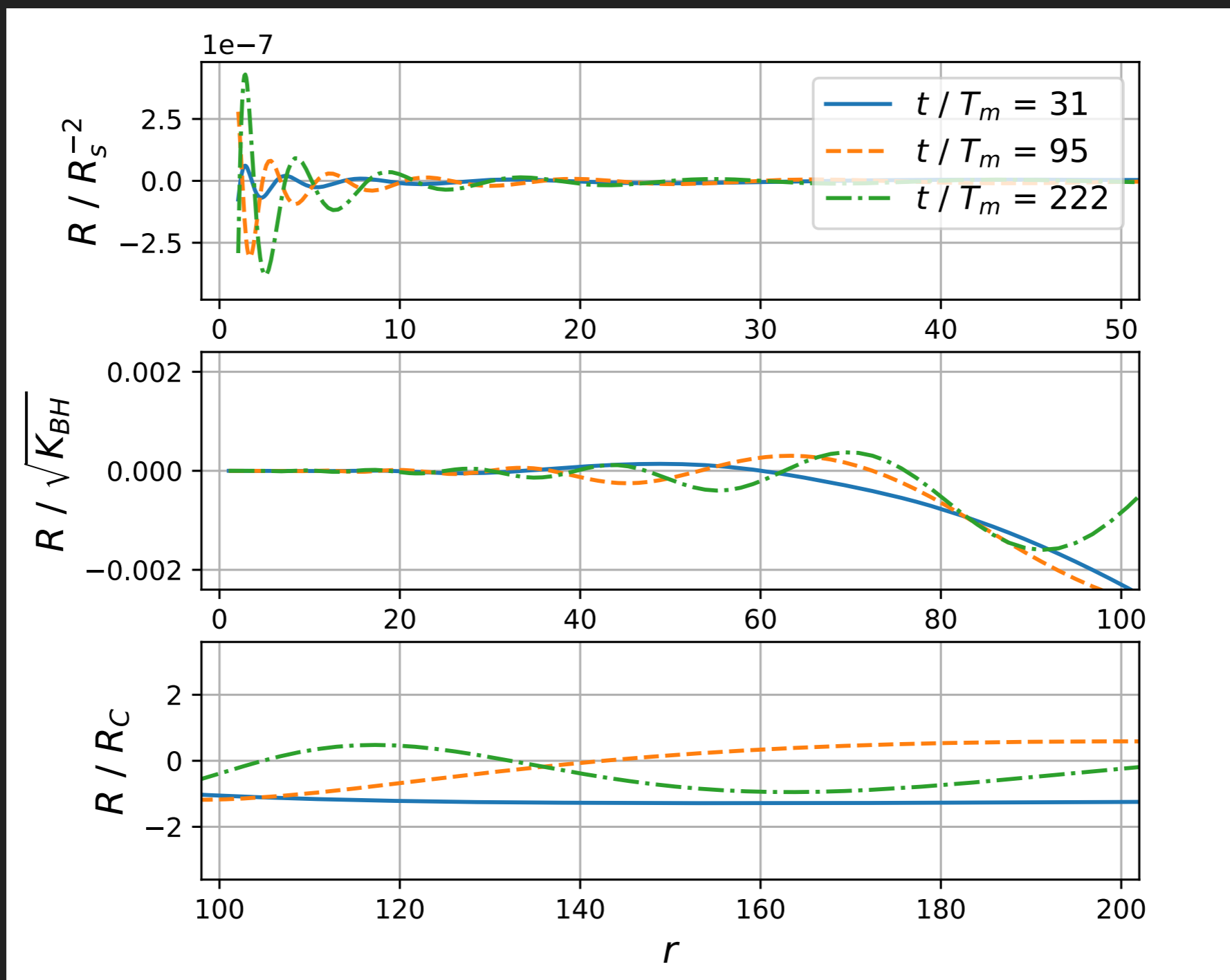JCAP 1906 (2019) no.06, 038

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

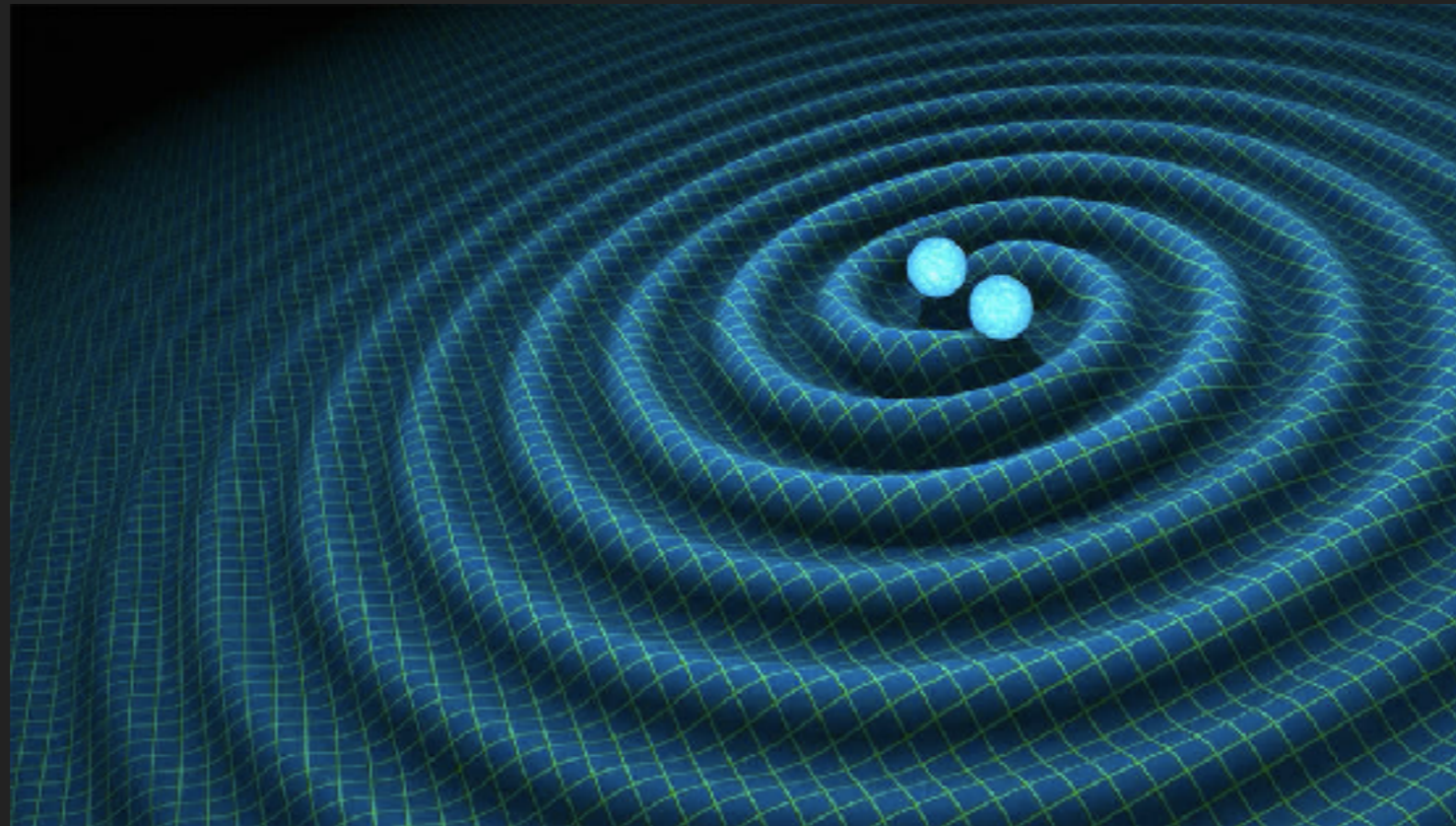Ultralight Dark Matter Resonates with Binary Pulsars
Diego Blas, Diana López Nacir, and Sergey Sibiryakov
Phys. Rev. Lett. 118, 261102 2017

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
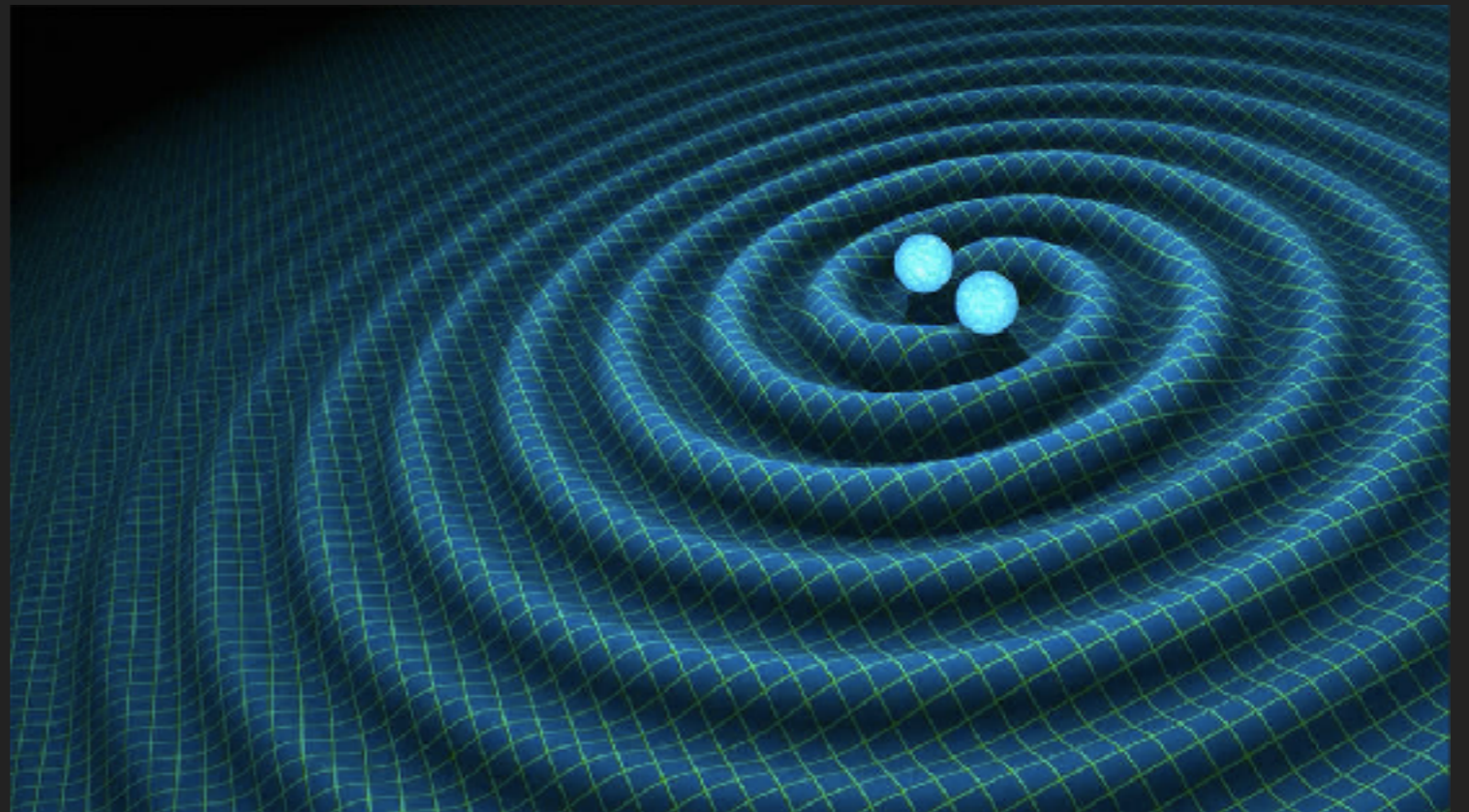
IMPACT ON THE MERGER SIGNAL

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