Constraining higher dimensions with MBHB merger events

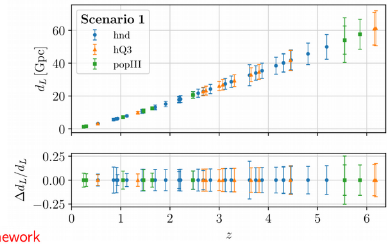
arXiv:2004.04009 (M.Corman,C.Escamilla-Rivera, M.A.Hendry)

(K.Pardo et al.,B.P.Abbot et al.)

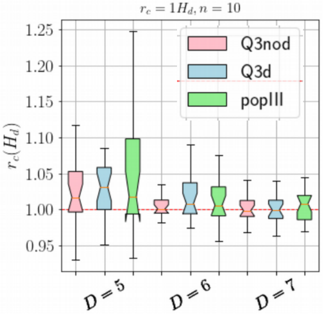
$$h_\times(t_o) = \frac{4}{d_L^{GW}} (G\mathcal{M}_{cz})^{5/3} (\pi f_o)^{2/3} \cos\theta \sin\Phi(t_o)$$

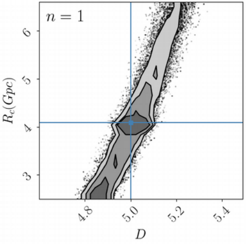
$$d_L^{GW} = d_L^{EM} \left[1 + \left(\frac{d_L^{EM}}{R_c(1+z)}\right)^2\right]^{(D-4)/2n}$$

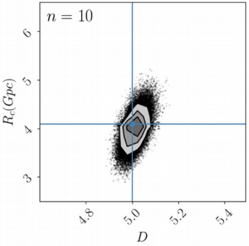
(Belgacem et al.)

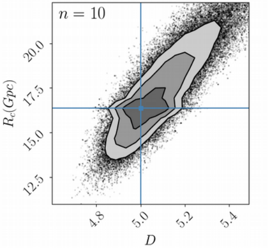


Bayesian framework









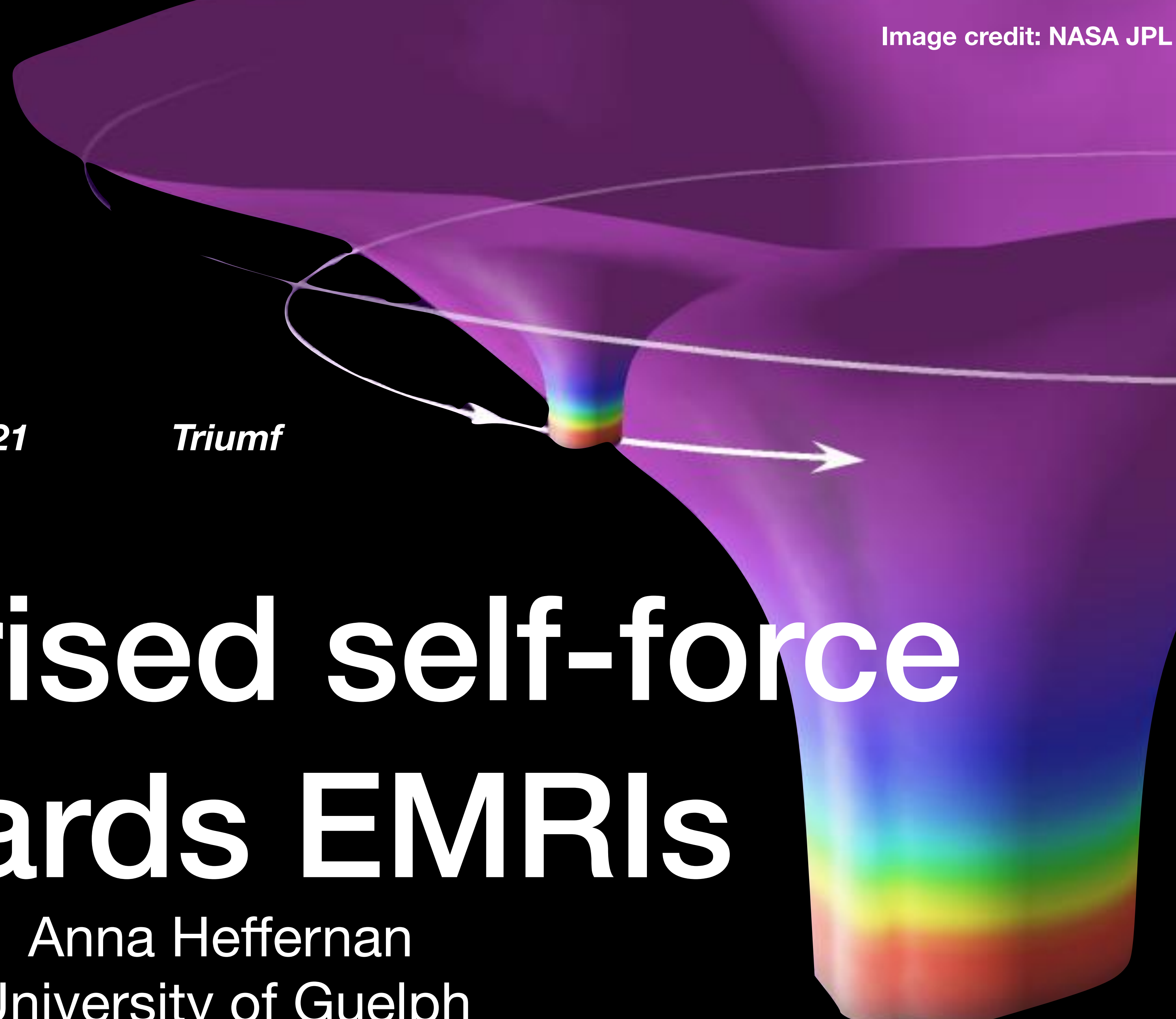


Image credit: NASA JPL

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LISA Canada Workshop, April 2021 *Triumf*

Regularised self-force towards EMRIs

Anna Heffernan
University of Guelph
Perimeter Institute of Theoretical Physics

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EMRIs

Extreme Mass Ratio Inspirals

- Precision astronomical probes
  - Parameters measured with variance that scales $N_{cycles}^{-1} \approx 10^{-4} - 10^{-5}$
  - Spin ($10^{-6} - 10^{-3}$), redshifted mass ($10^{-6} - 10^{-4}$), distance and source masses (~0.03 - 0.3)
  - Environmental information (accretion disc)
  - Sky location $\leq 10 \text{ deg}^2$
- Galaxy and Massive Black Hole Evolution
- EMRIs as sirens - constraining the Hubble constant
- Mapping spacetime geometry
  - Deviations from GR - more orbits => tighter constraints on alternative theories of gravity

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What is the self-force?

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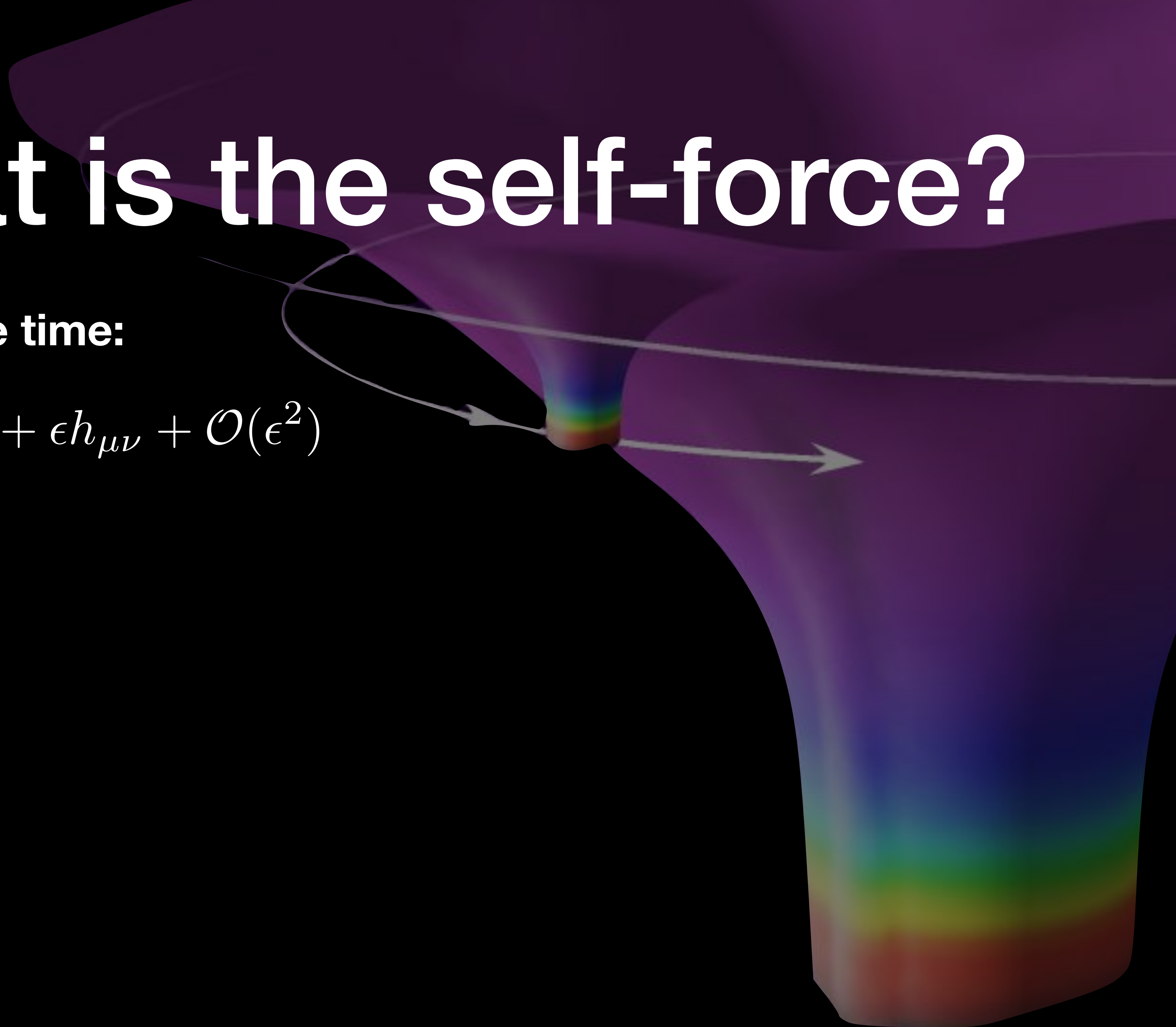
Far zone: $\mathrm{g}_{\mu\nu} = g^{(M)}_{\mu\nu} + \epsilon h_{\mu\nu} + \mathcal{O}(\epsilon^2)$



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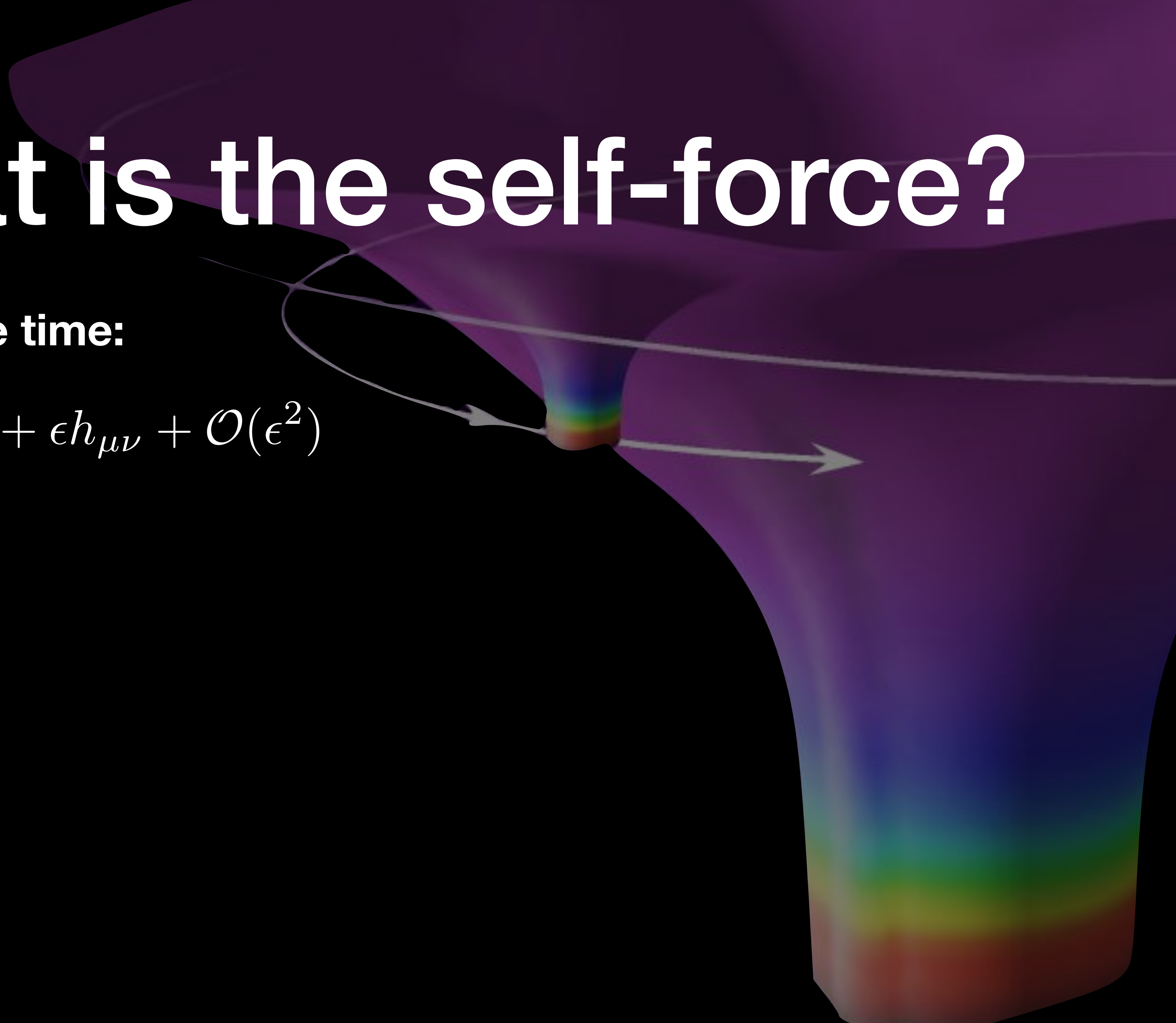

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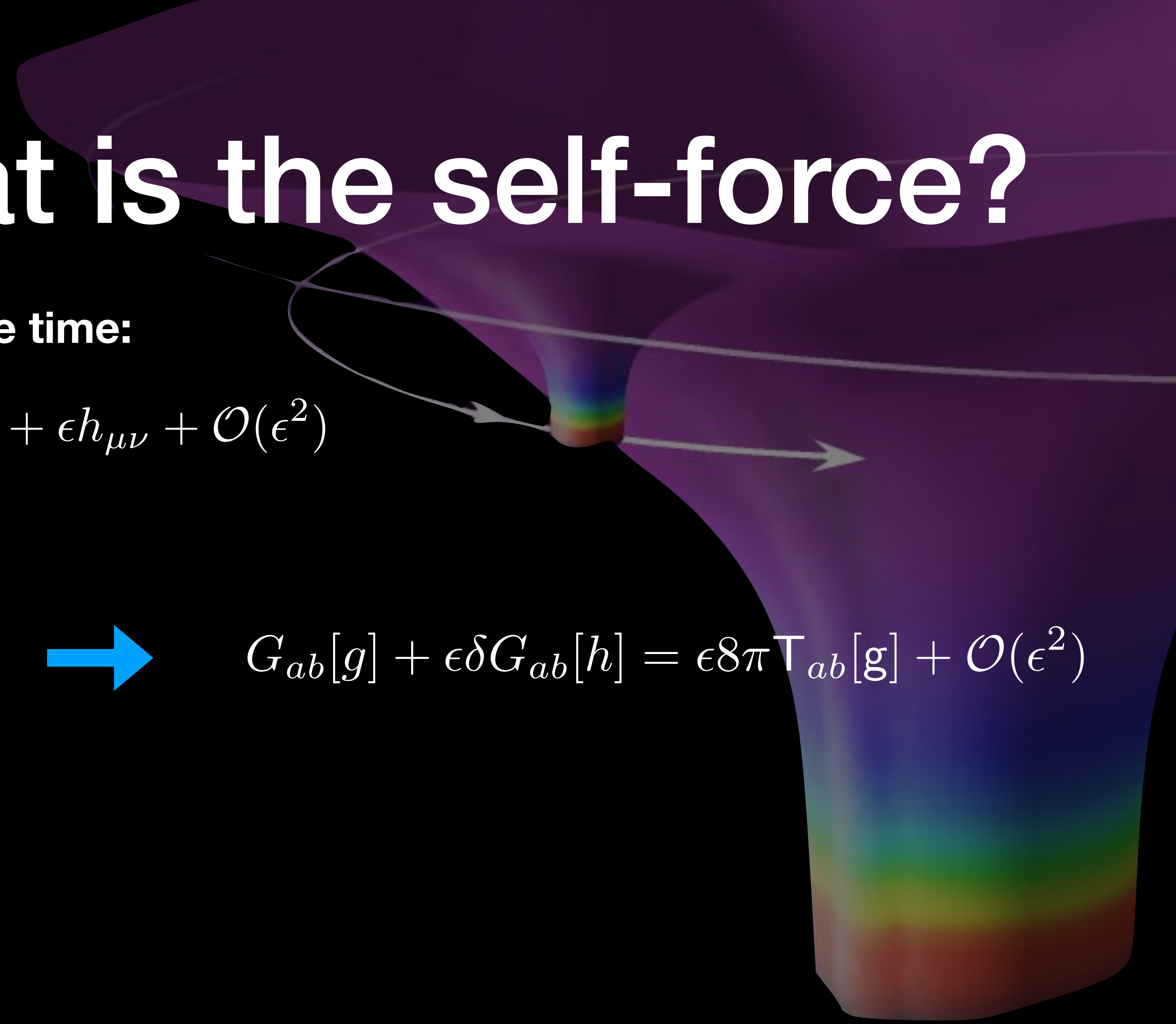

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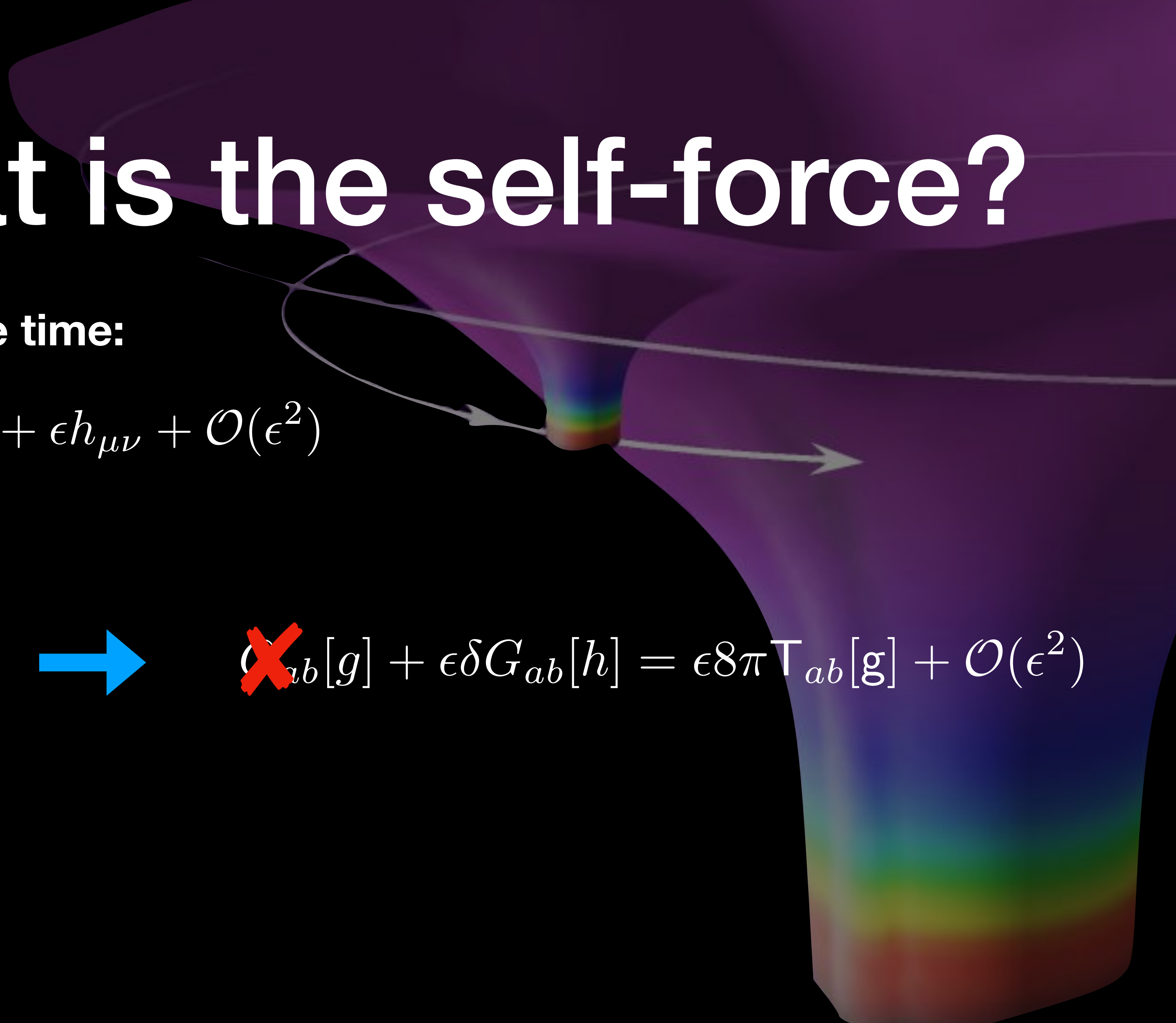

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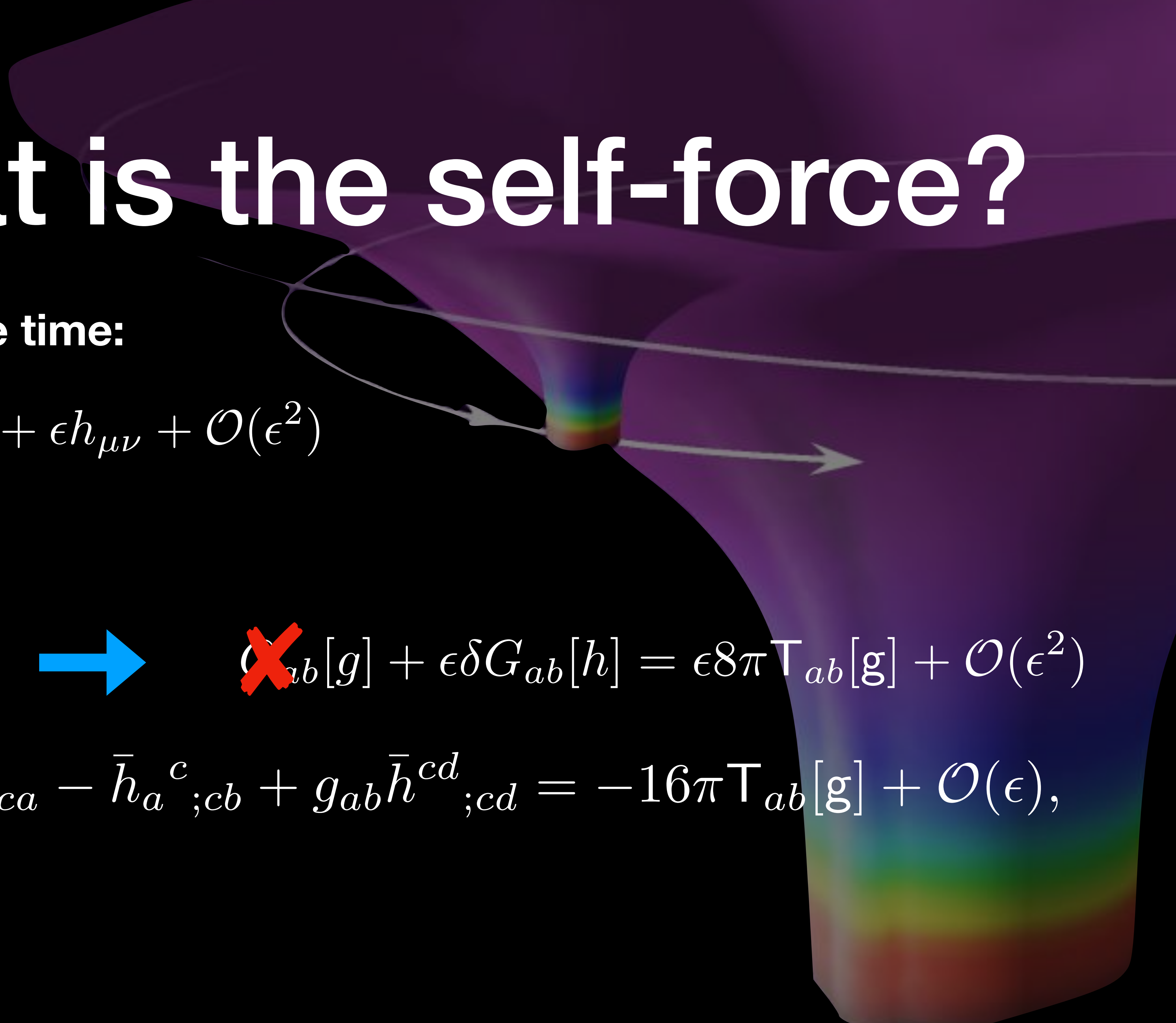

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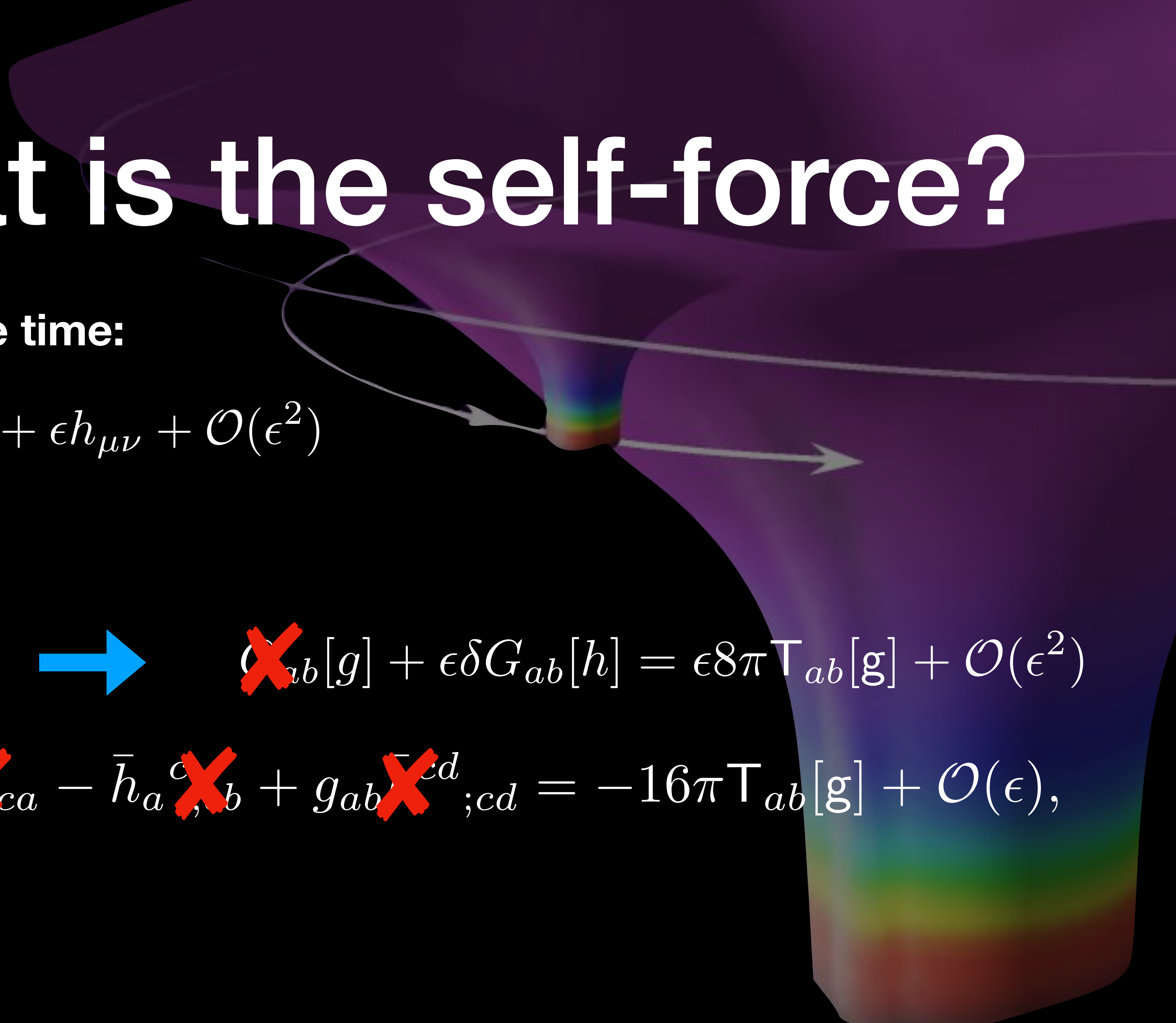

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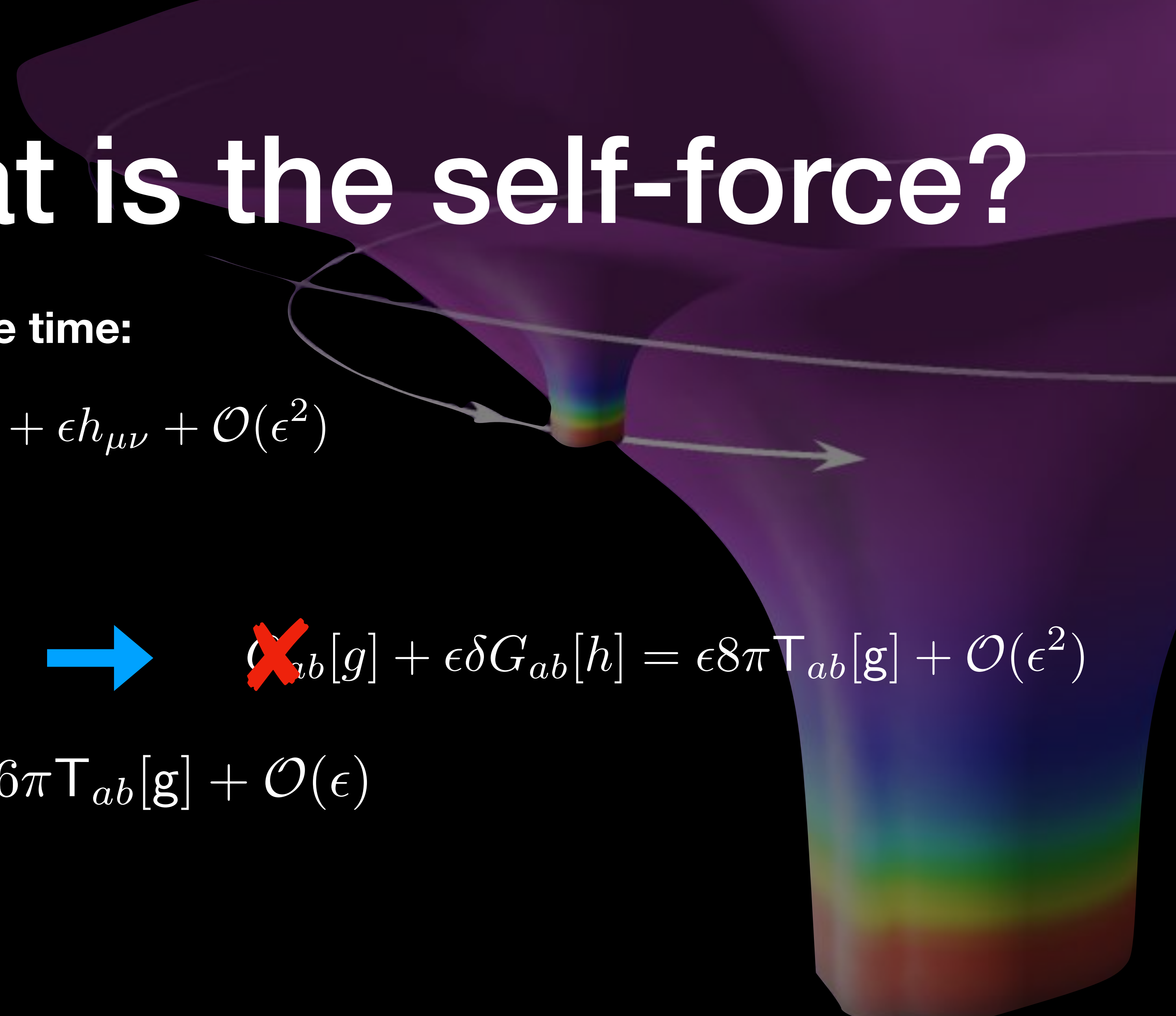

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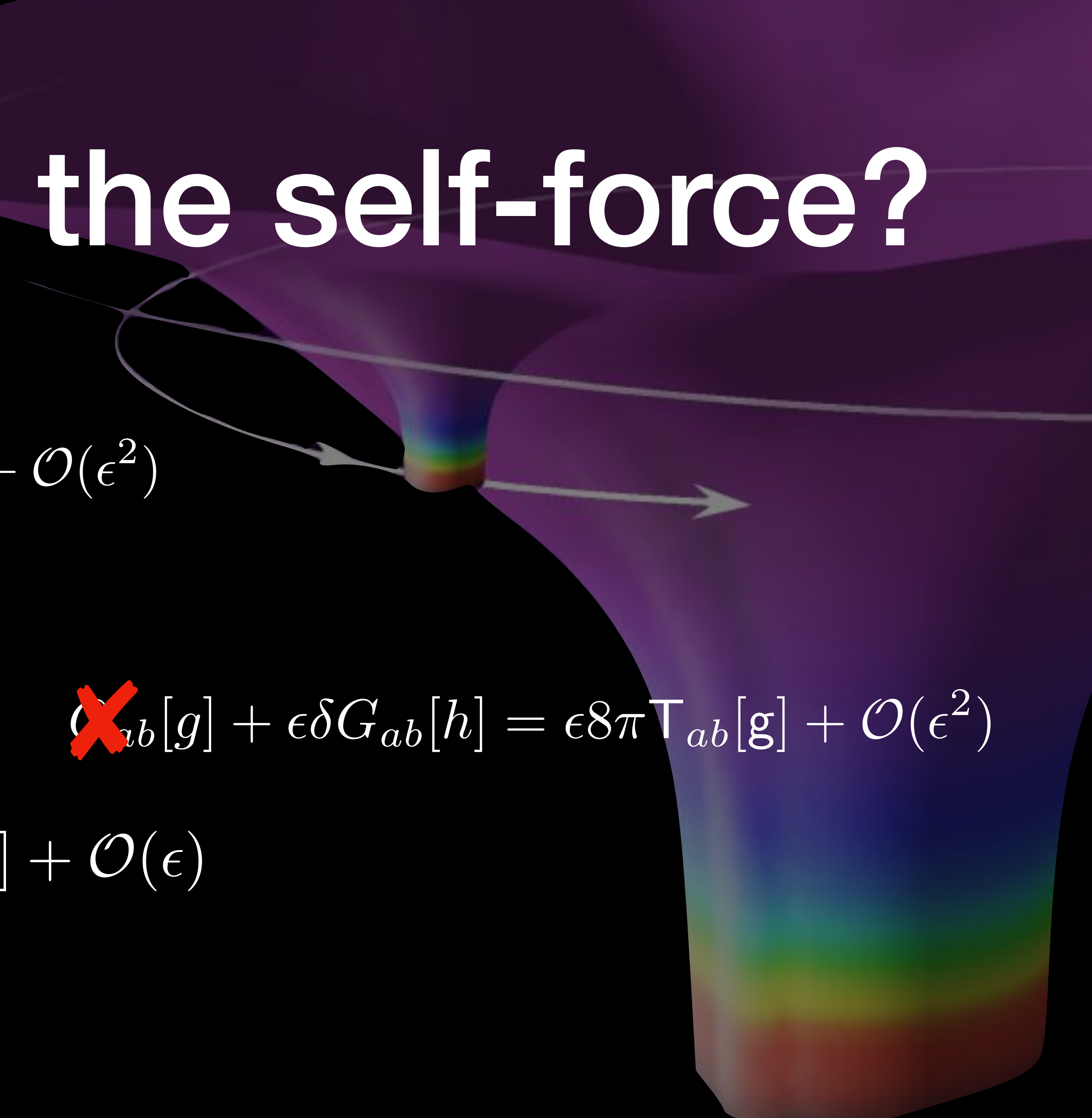

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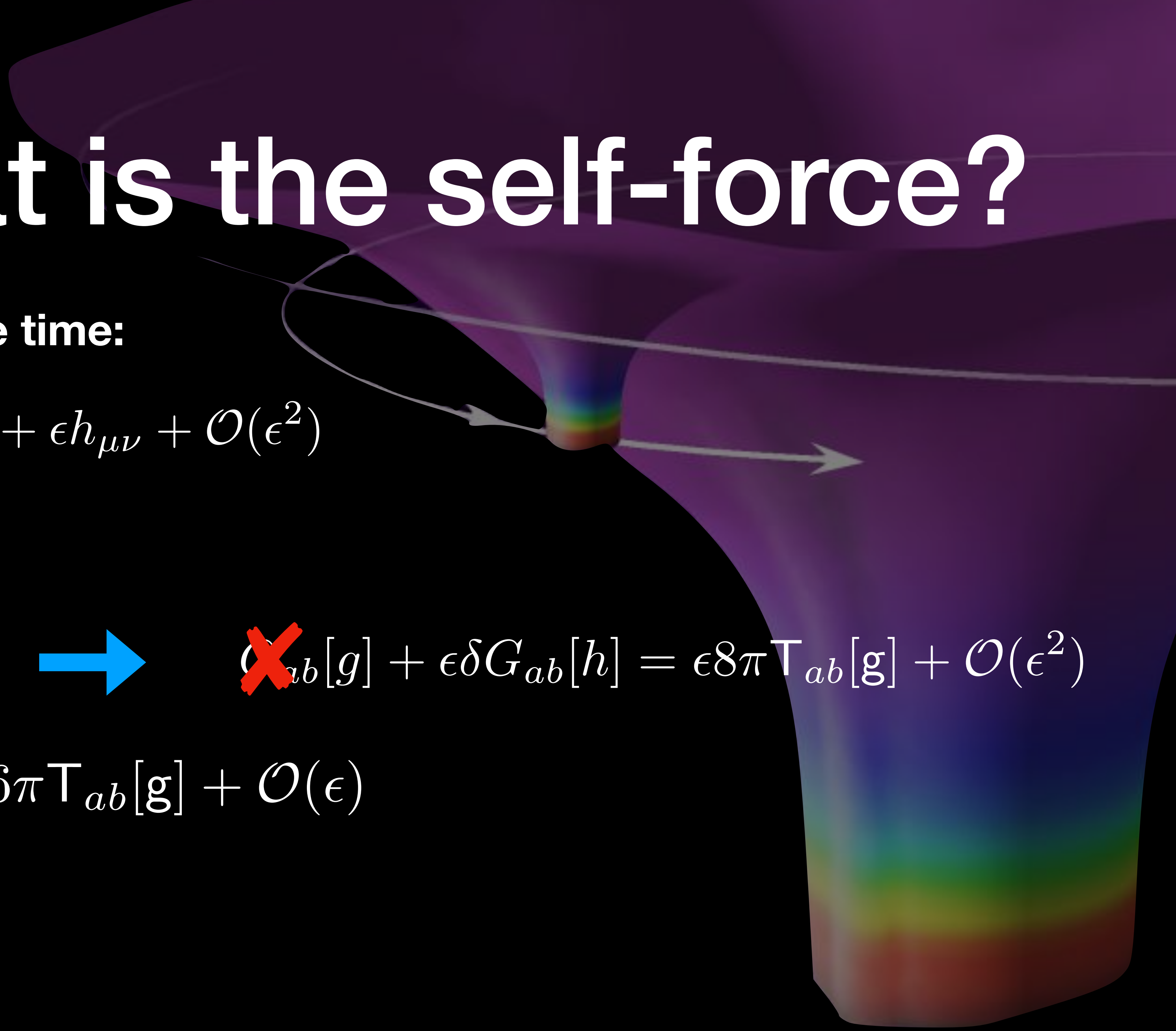

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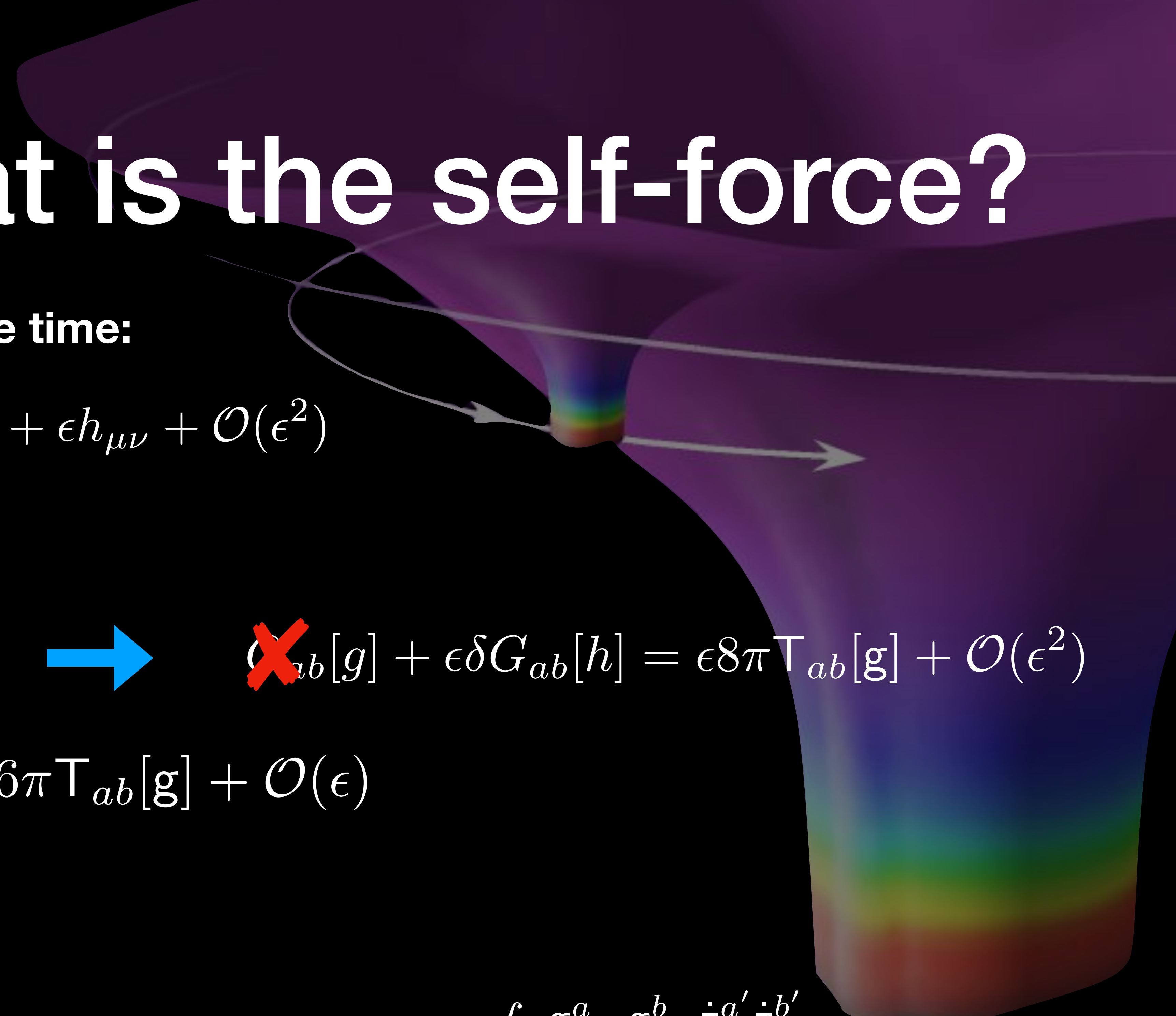

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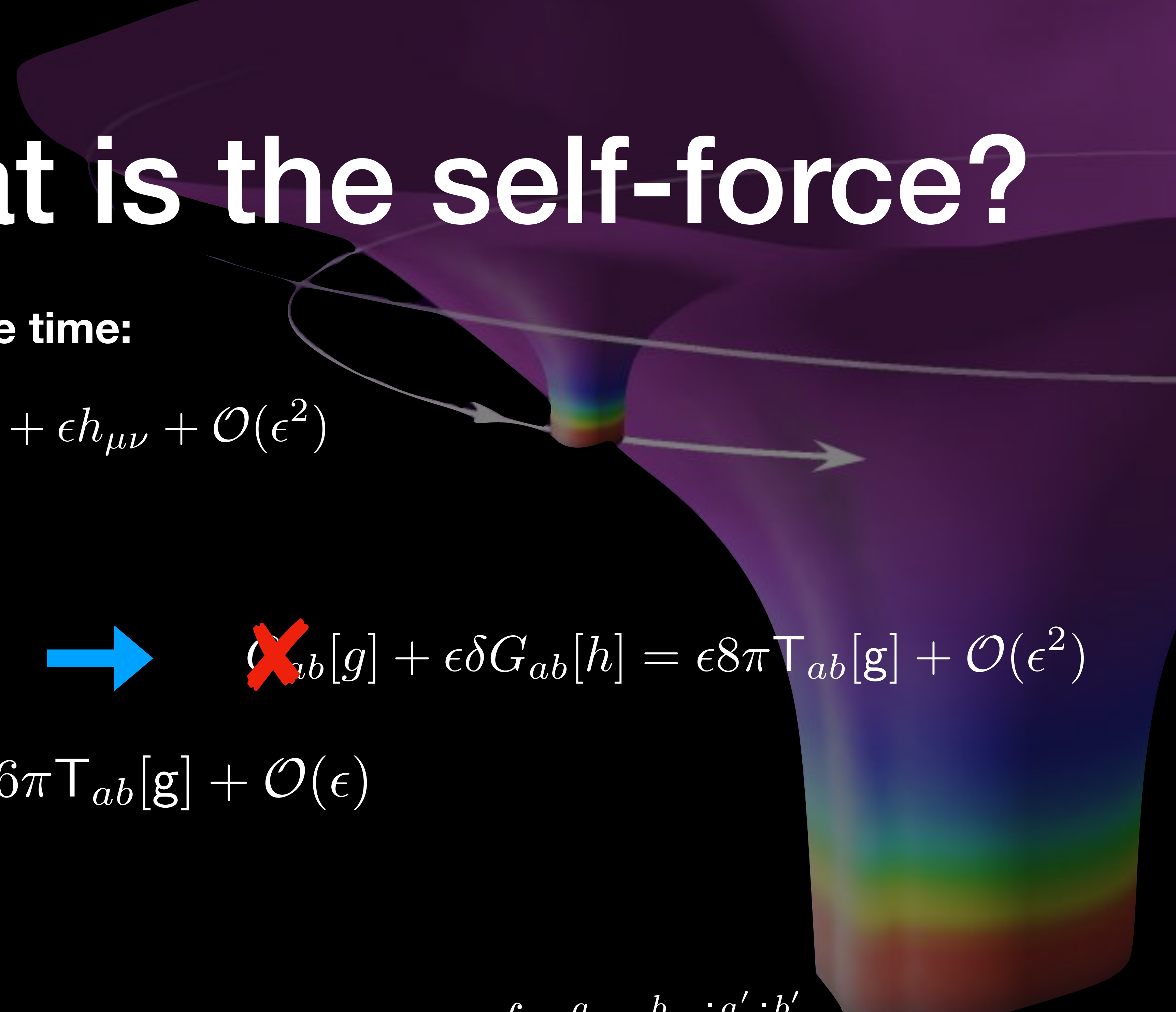

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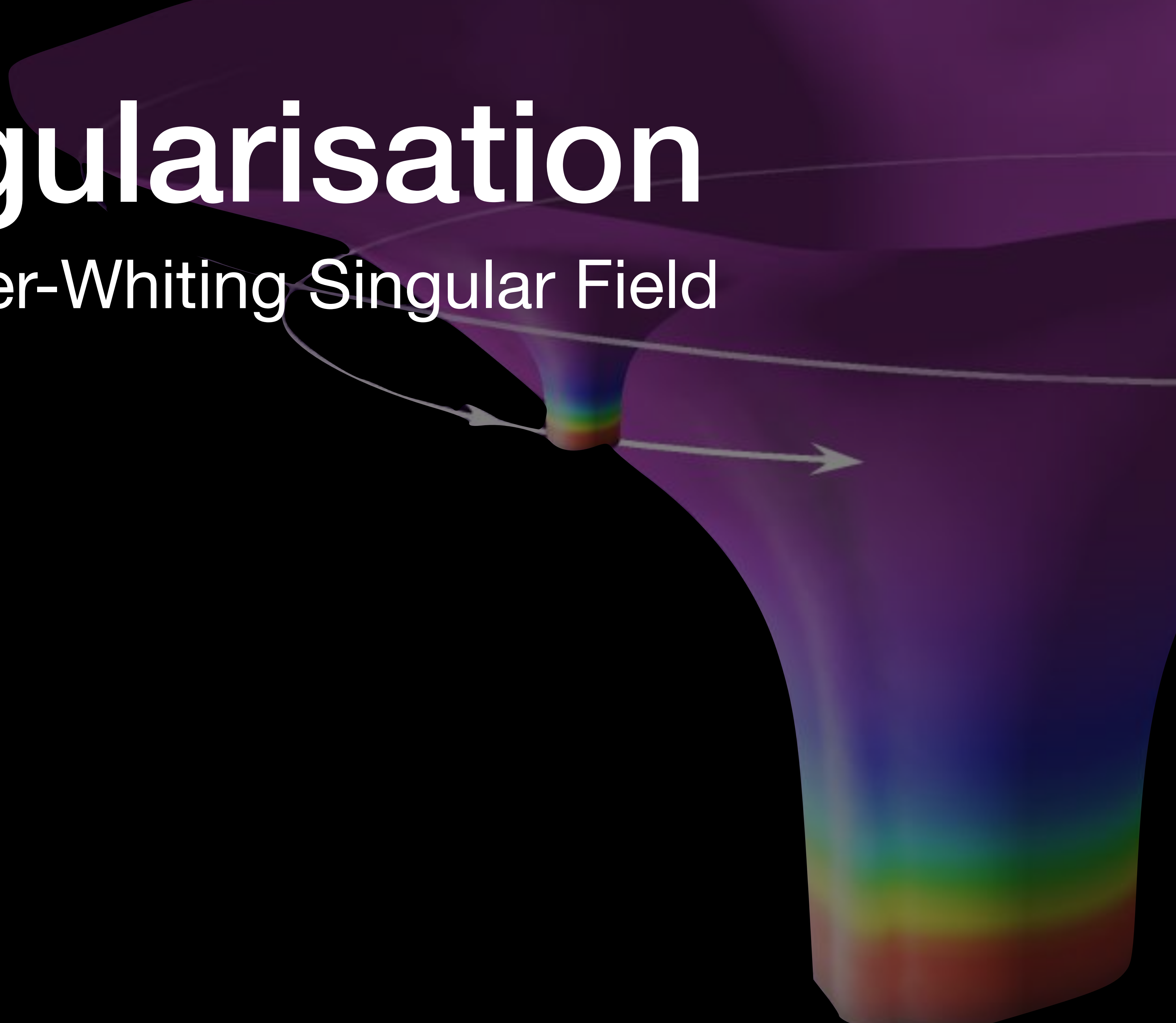
Regularisation

Detweiler-Whiting Singular Field



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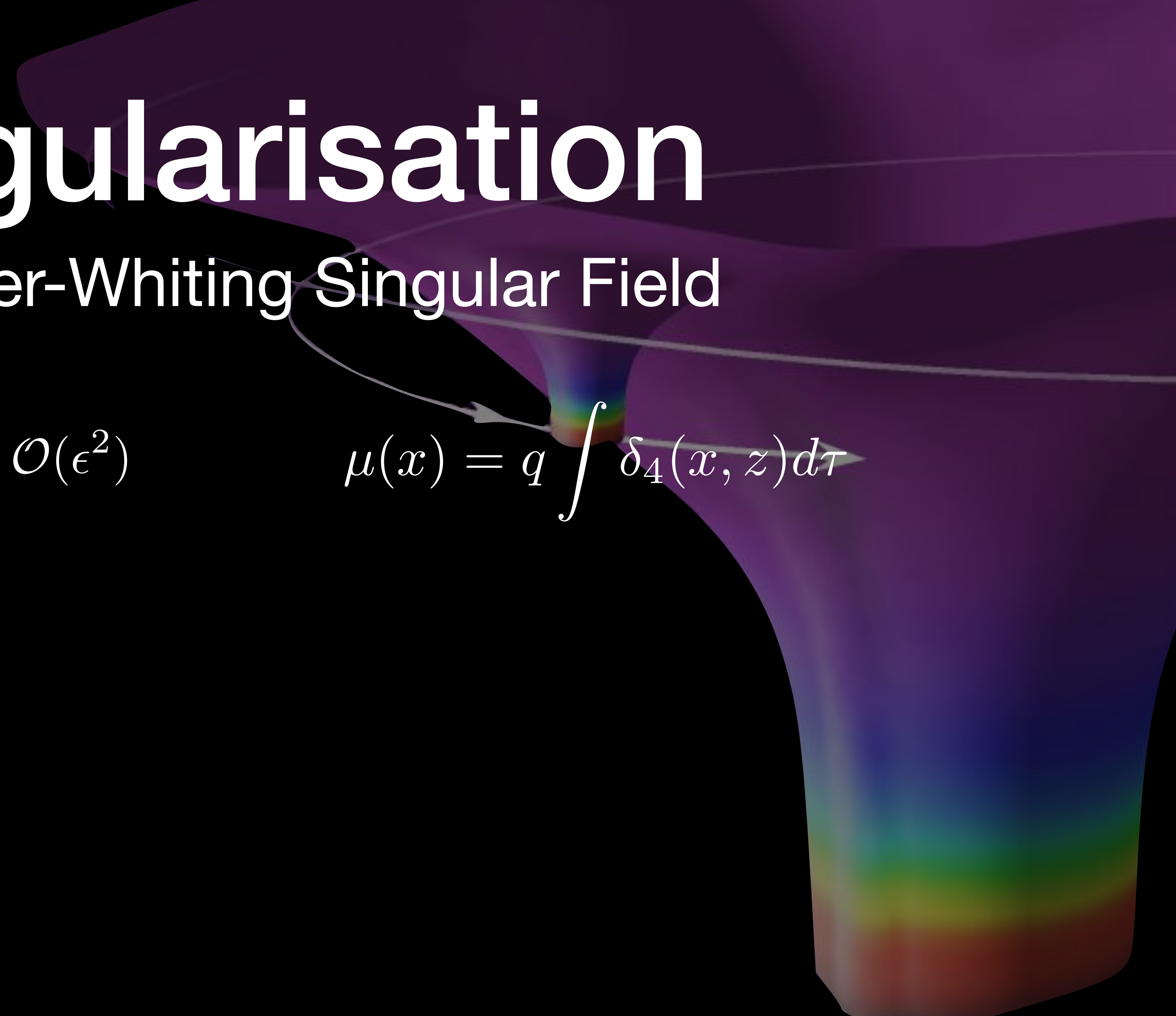

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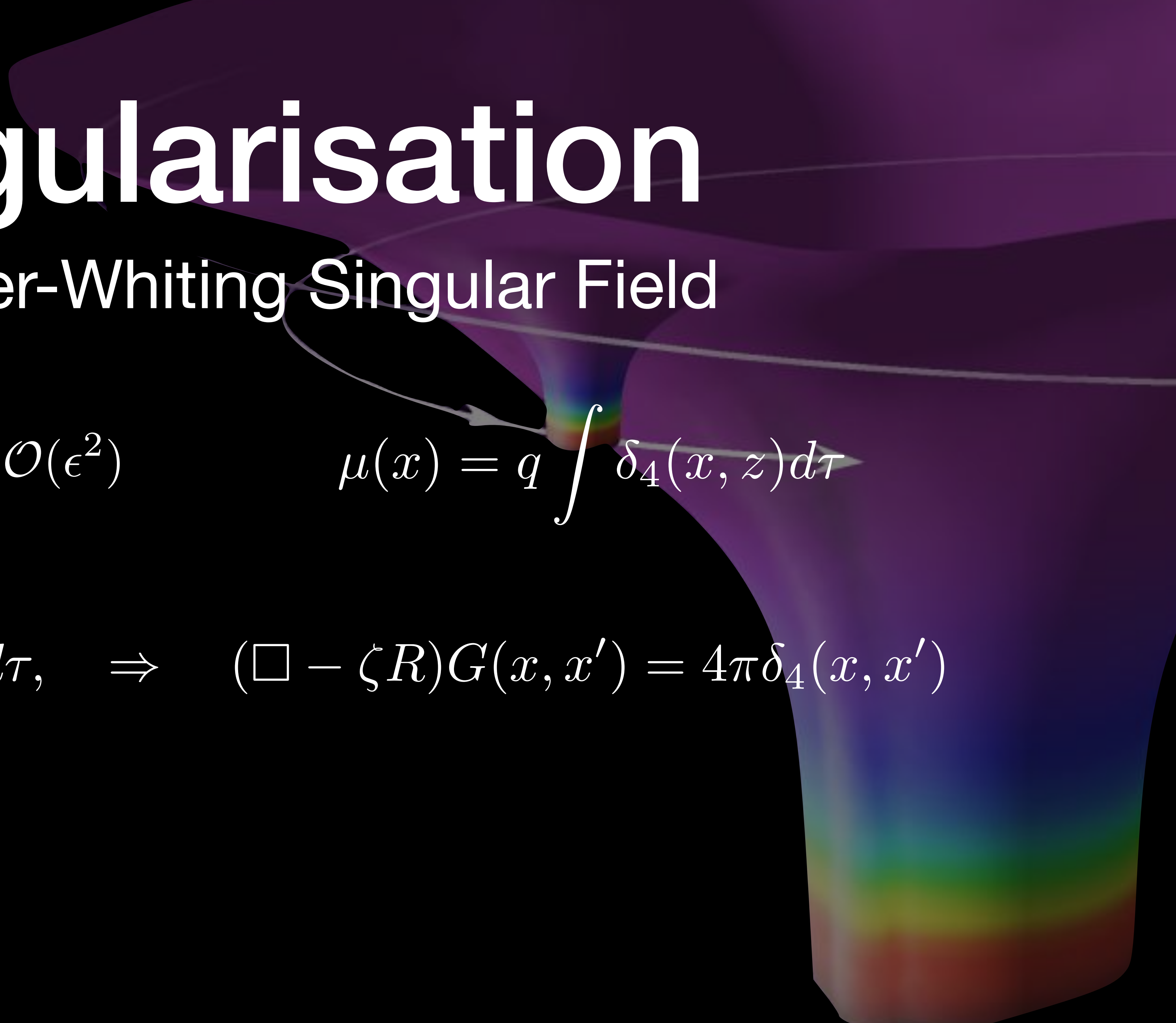

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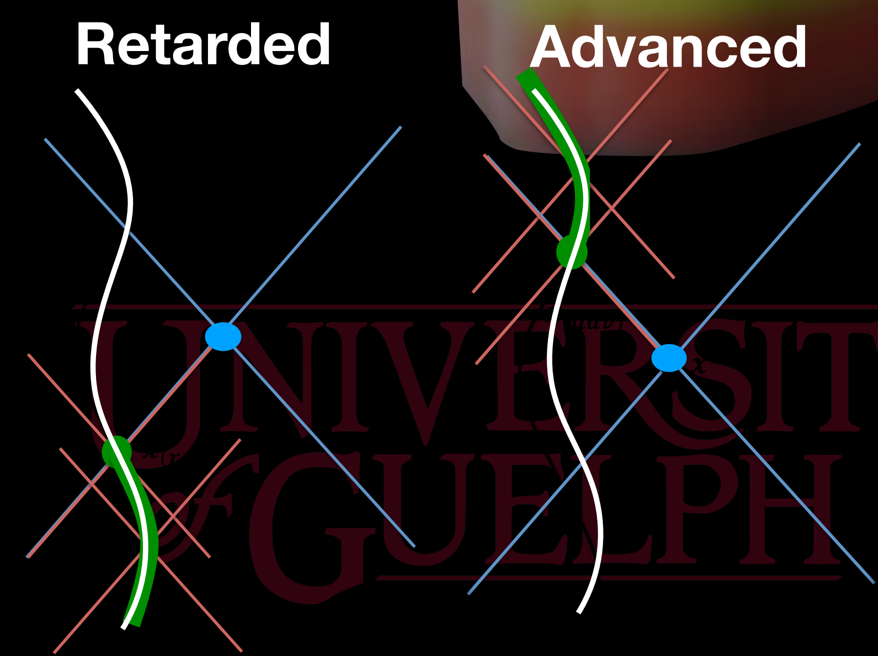

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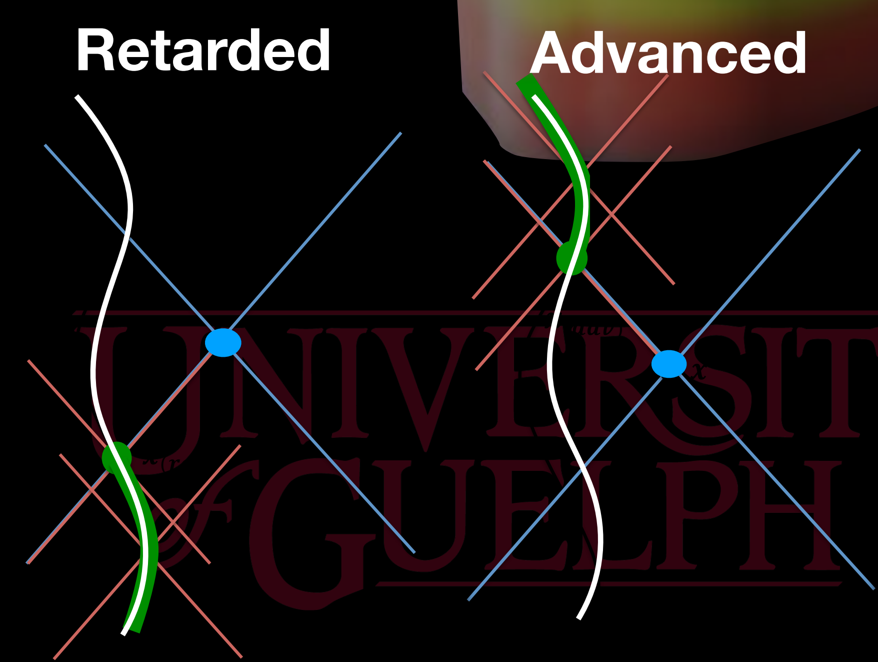

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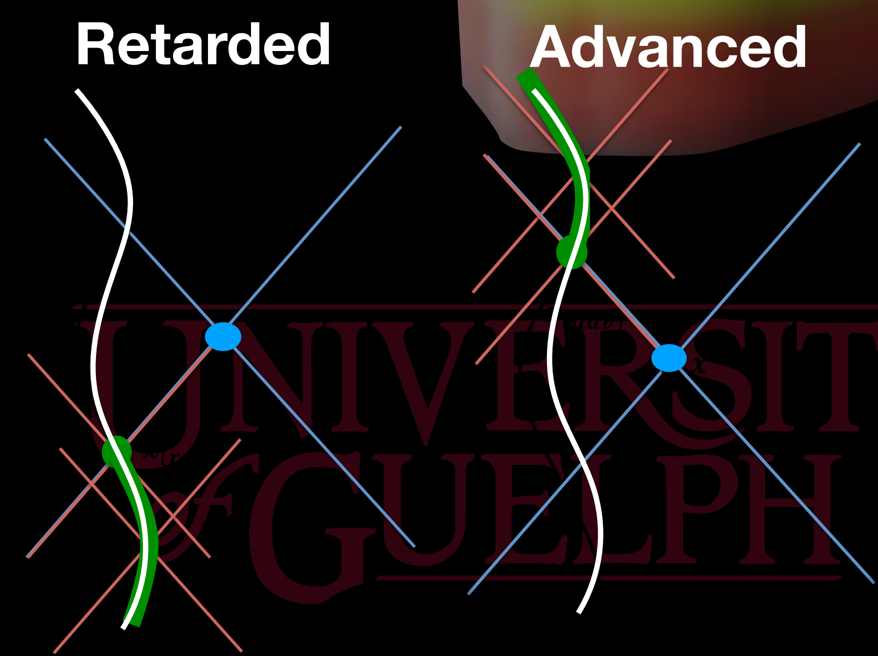

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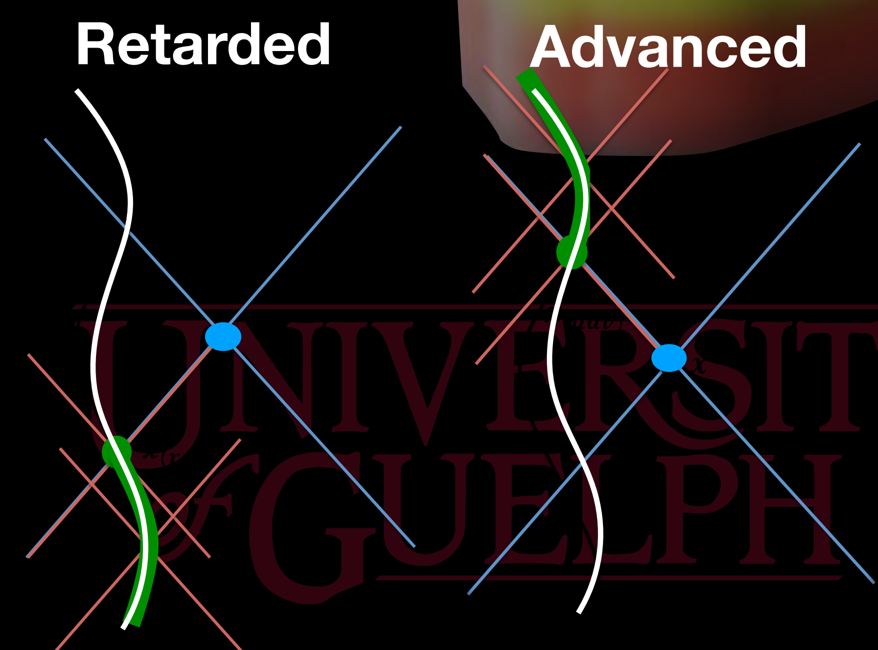

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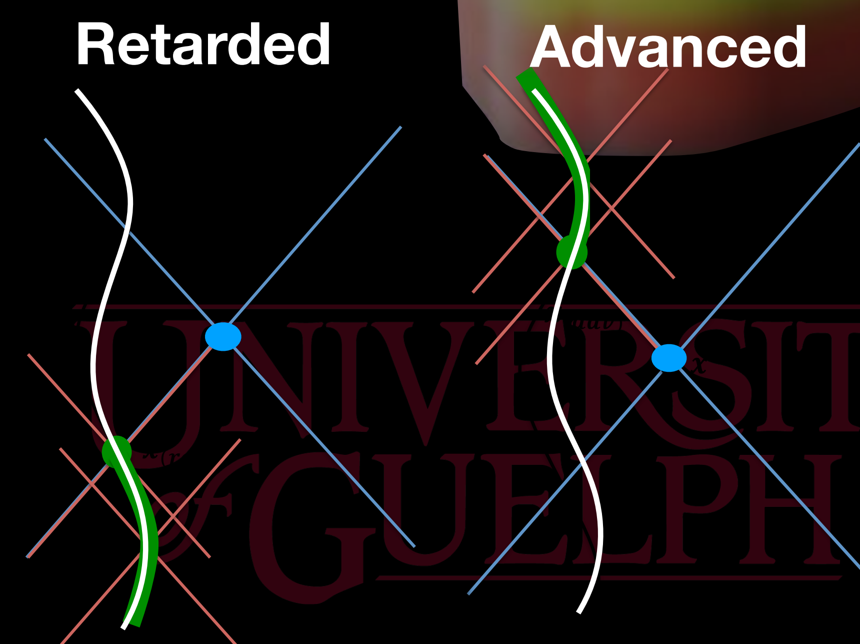

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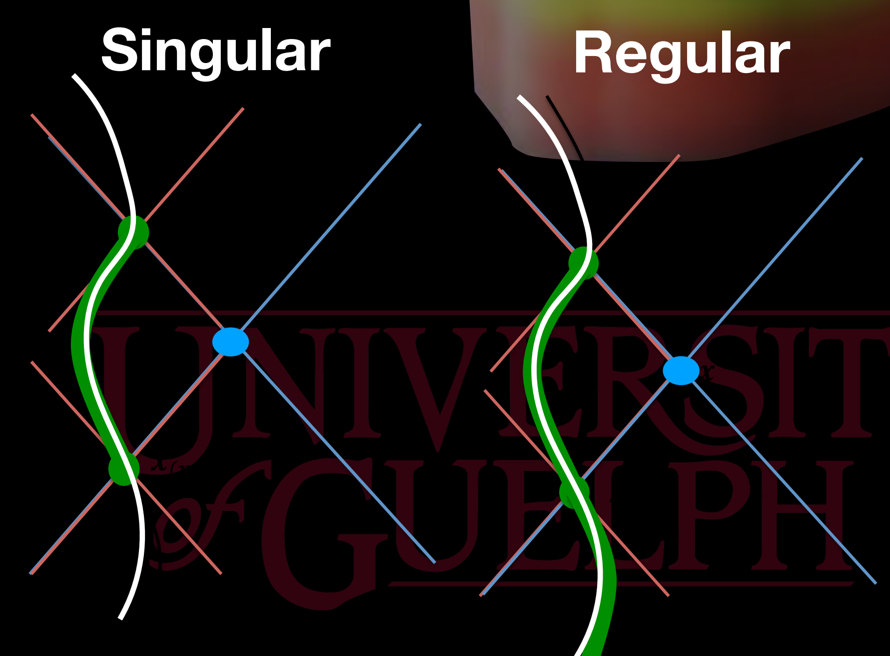

Increased Efficiency

Mode-Sum Regularisation: Scalar Case

- Mode-sum regularisation
  - Barrack, Ori (2001)

$$F_a(\bar{x}) = \sum_{\ell}^{\infty}\left(F_a^{\ell(ret)}(\bar{x}) - F_a^{\ell(S)}(\bar{x})\right),$$

  - Expansions of the form,

$$F_a^{\ell(S)}(\bar{x}) = \tilde{F}_a^{\ell/(S)}(\bar{x}) + \mathcal{O}(\epsilon^{n+1})$$

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Increased Efficiency

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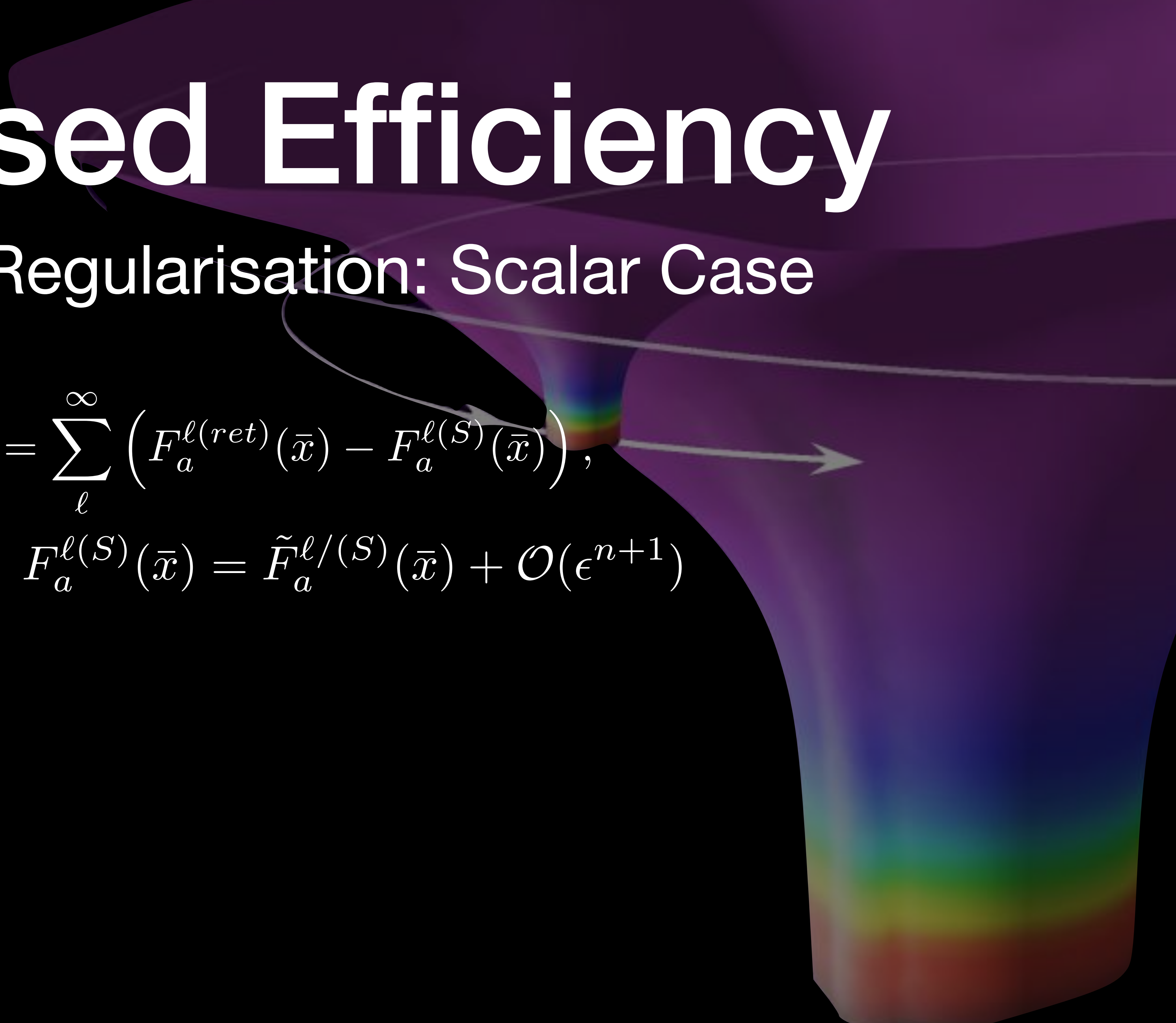

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→ ℓ^{-n-2} convergence

→ higher order parameters increase efficiency

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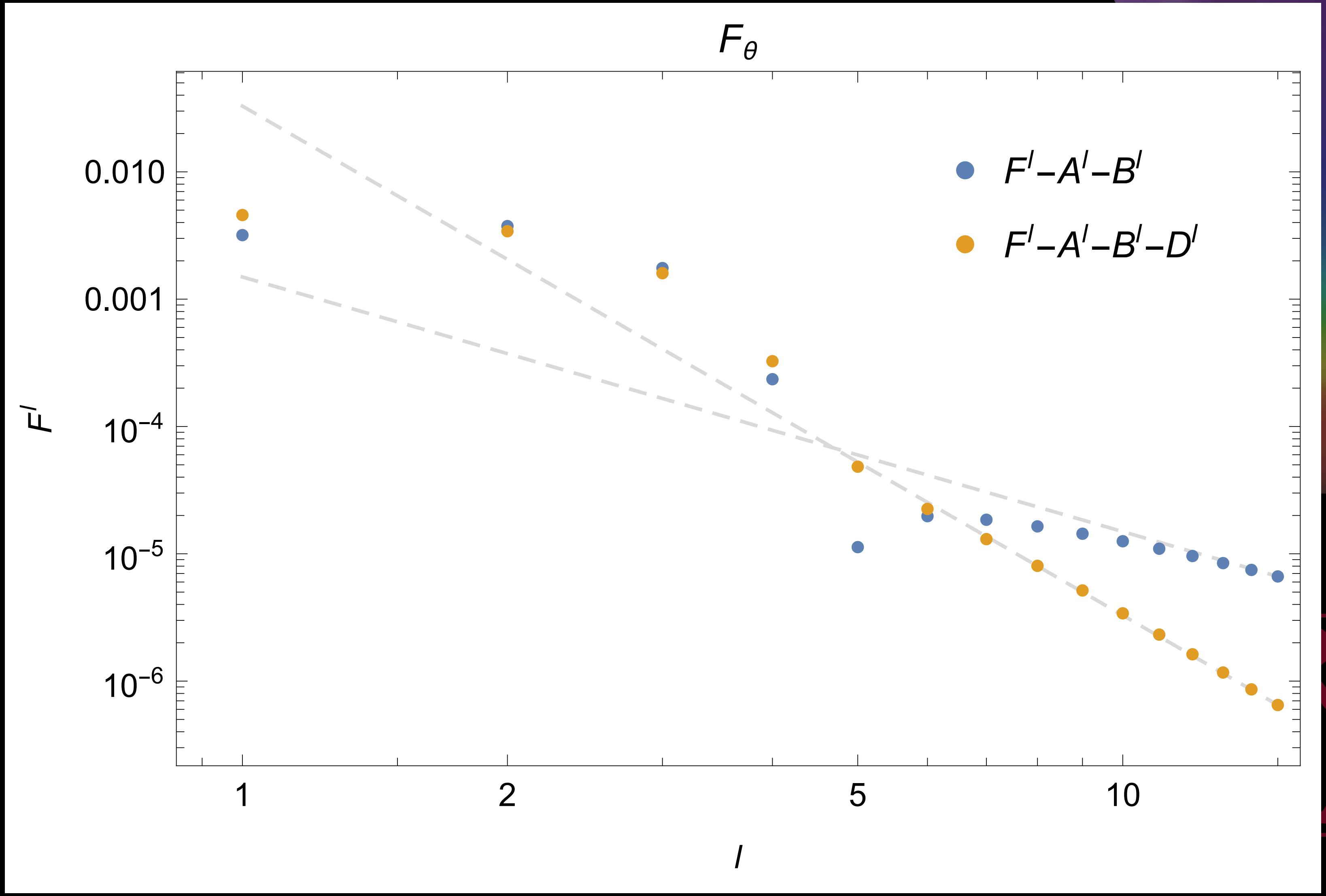

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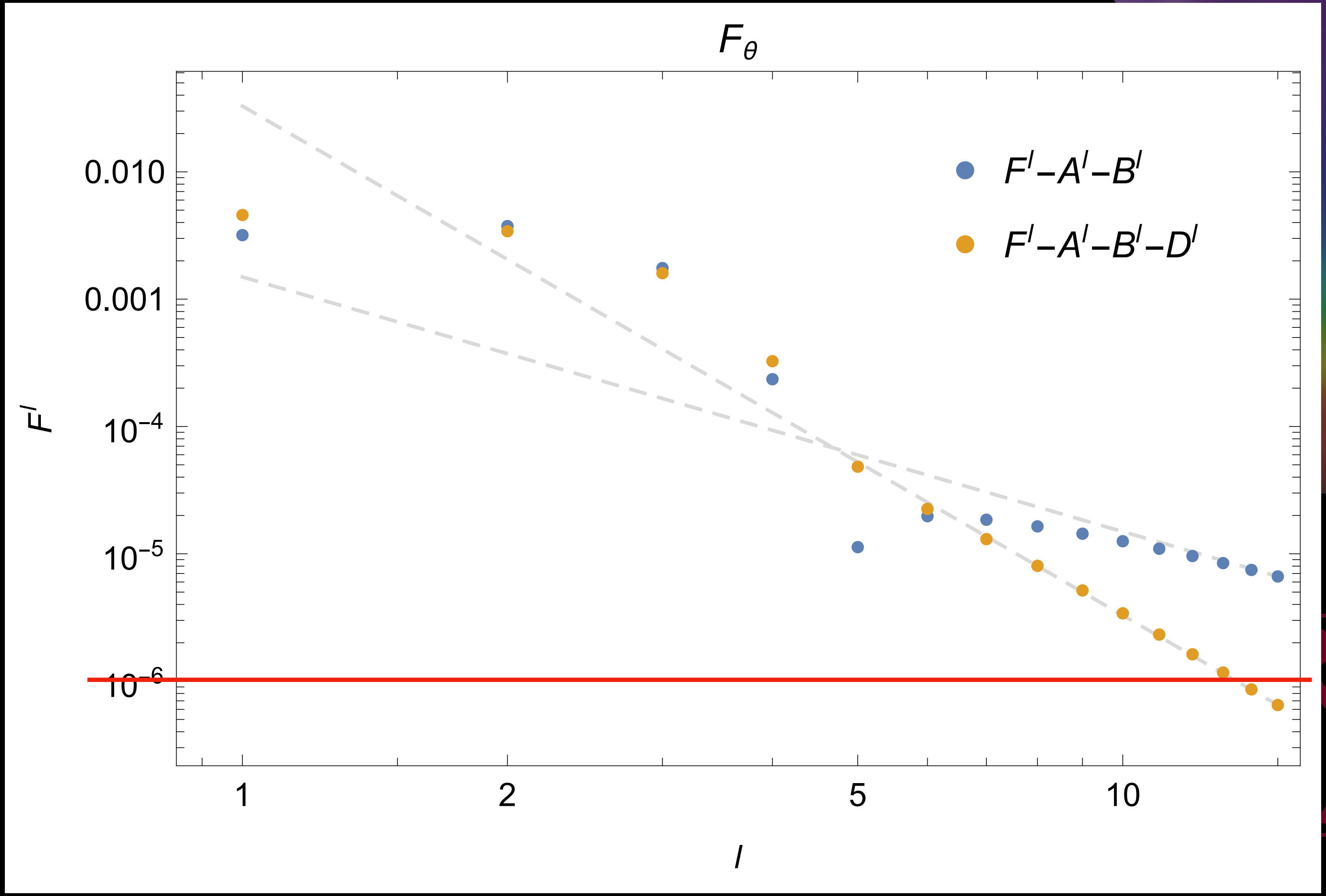

Data by Zach Nasipak

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Image credit: NASA JPL

Thank you!

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Wet EMRIs may be more common for space-borne gravitational wave detection

Zhen Pan, Perimeter Institute

arXiv: 2101.09146, 2104.01208

Apr 28, 2021

Dry EMRIs v.s. Wet EMRIs: pictures

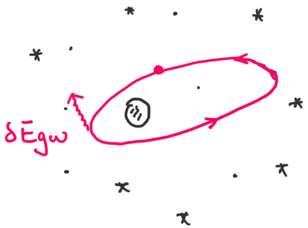


Figure: Dry EMRIs via loss cone

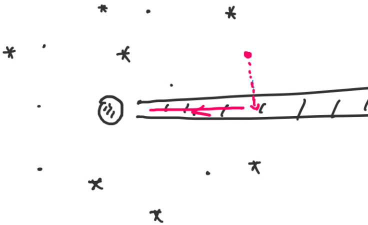


Figure: Wet EMRIs in AGN disks

Dry EMRIs v.s. Wet EMRIs: rates

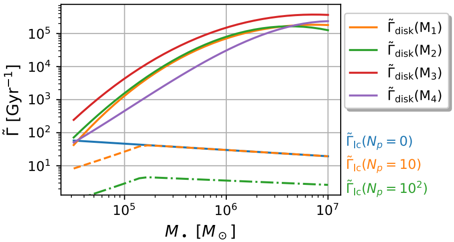
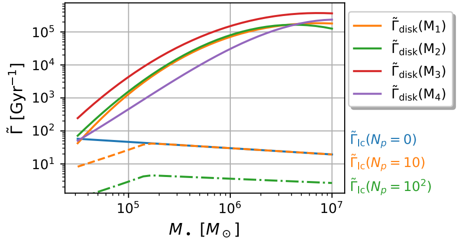


Figure: Wet EMRI rate per AGN vs Dry per MBH: $\tilde{\Gamma}_{\rm wet}/\tilde{\Gamma}_{\rm dry} = \mathcal{O}(10 - 10^3)$.

Dry EMRIs v.s. Wet EMRIs: rates

AGN fraction: $f_{\rm AGN} \sim 1\%$



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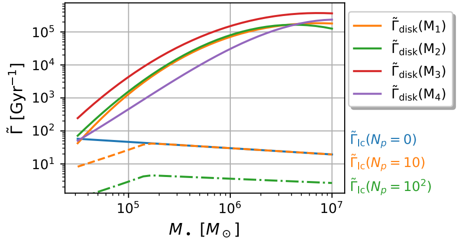
Wet vs Dry EMRI rates [yr^{-1}Gpc^{-3}]

$$\frac{\mathcal{R}_{\rm wet}}{\mathcal{R}_{\rm dry}} = \mathcal{O}(10)$$



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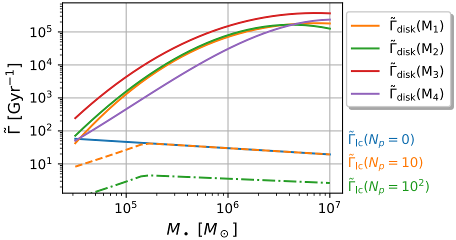
Distinguishable source properties:

eccentricity e, inclination ι, environmental imprints on the waveform $\delta\phi$



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Thank you !

LISA CANADA WORKSHOP

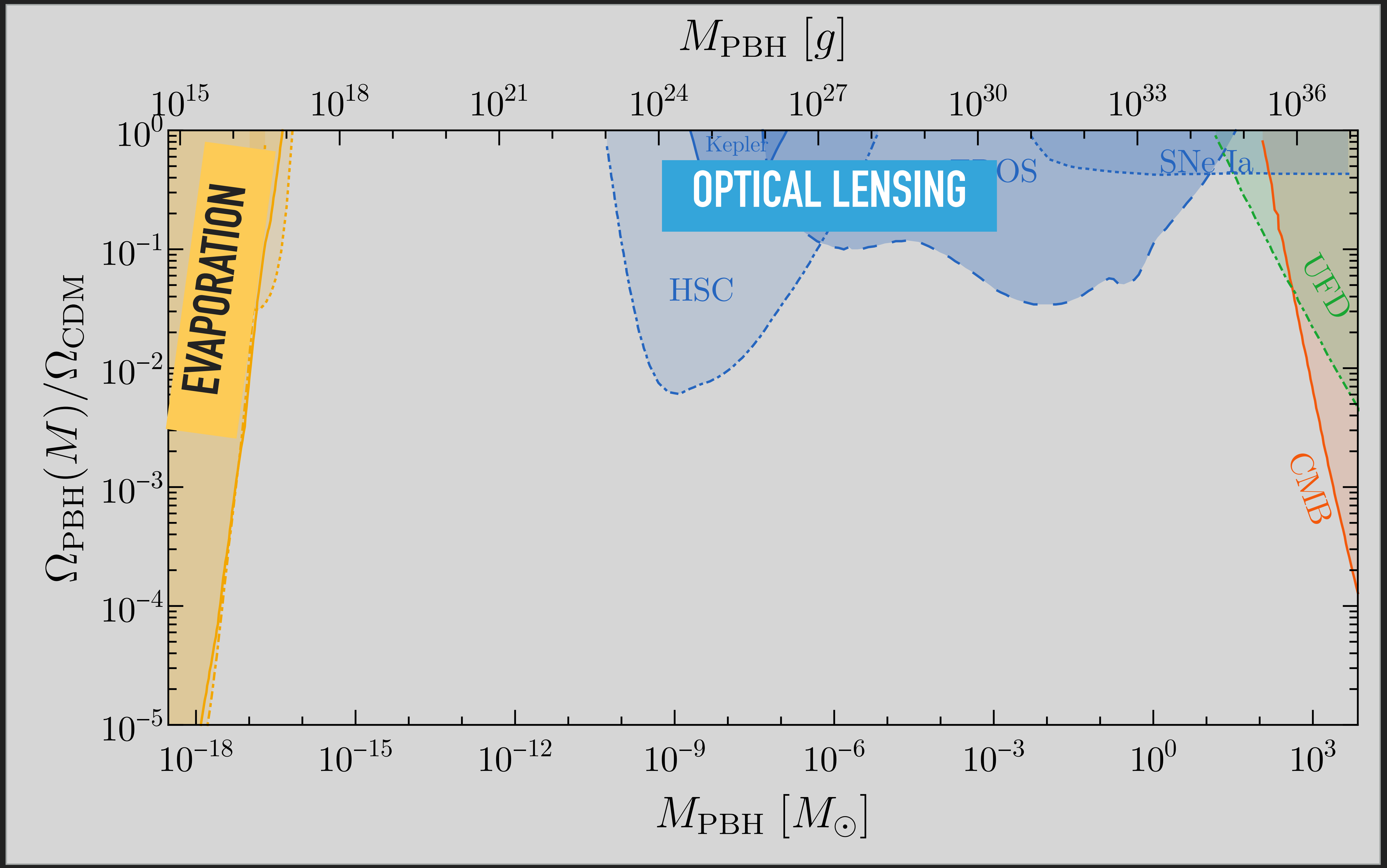
28 APRIL 2021

DAVIDE RACCO

PERIMETER INSTITUTE

COSMOLOGICAL GW BACKGROUNDS: FROM PBHS TO PHASE TRANSITIONS

LISA CAN PROBE THE REMAINING WINDOW



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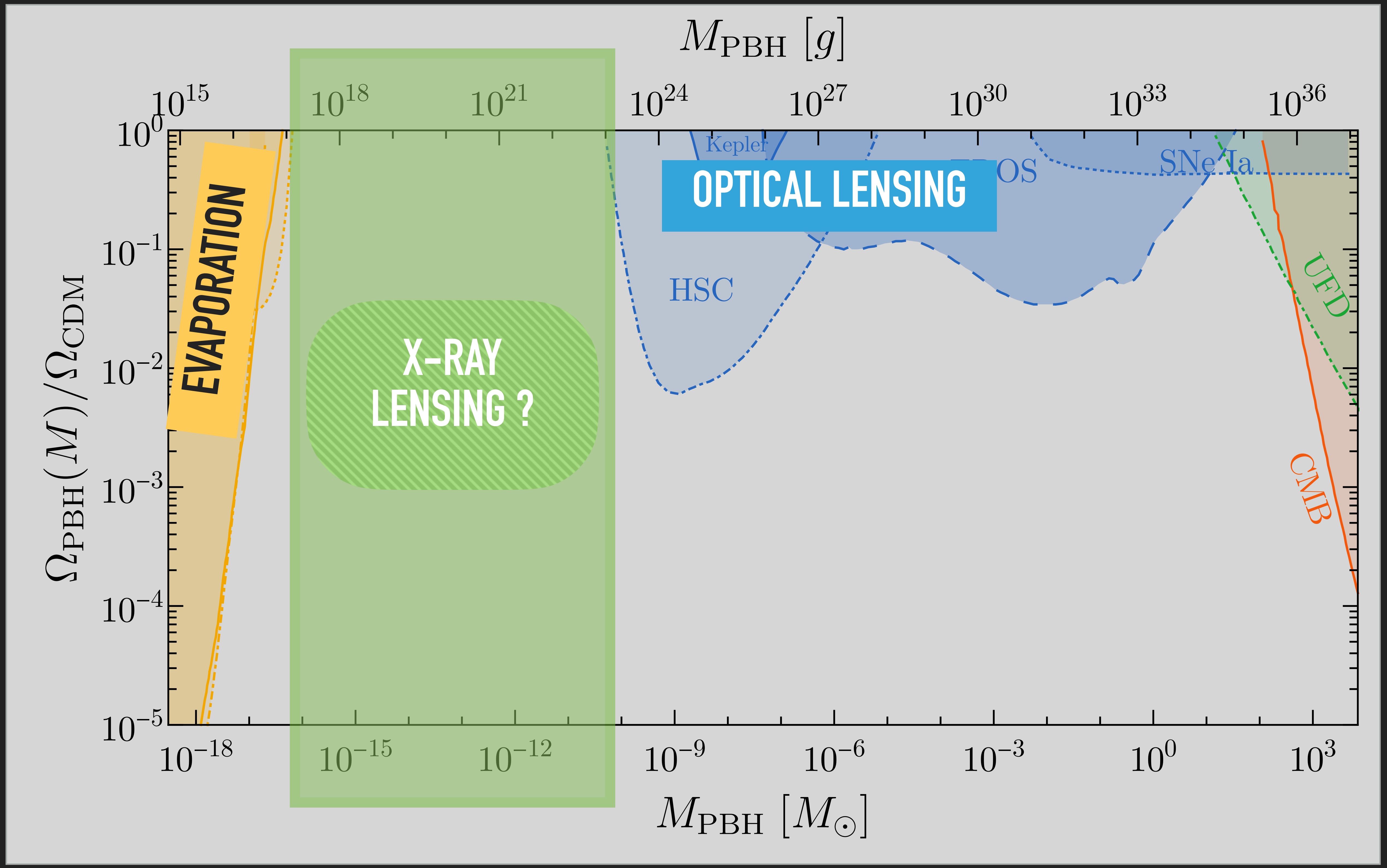
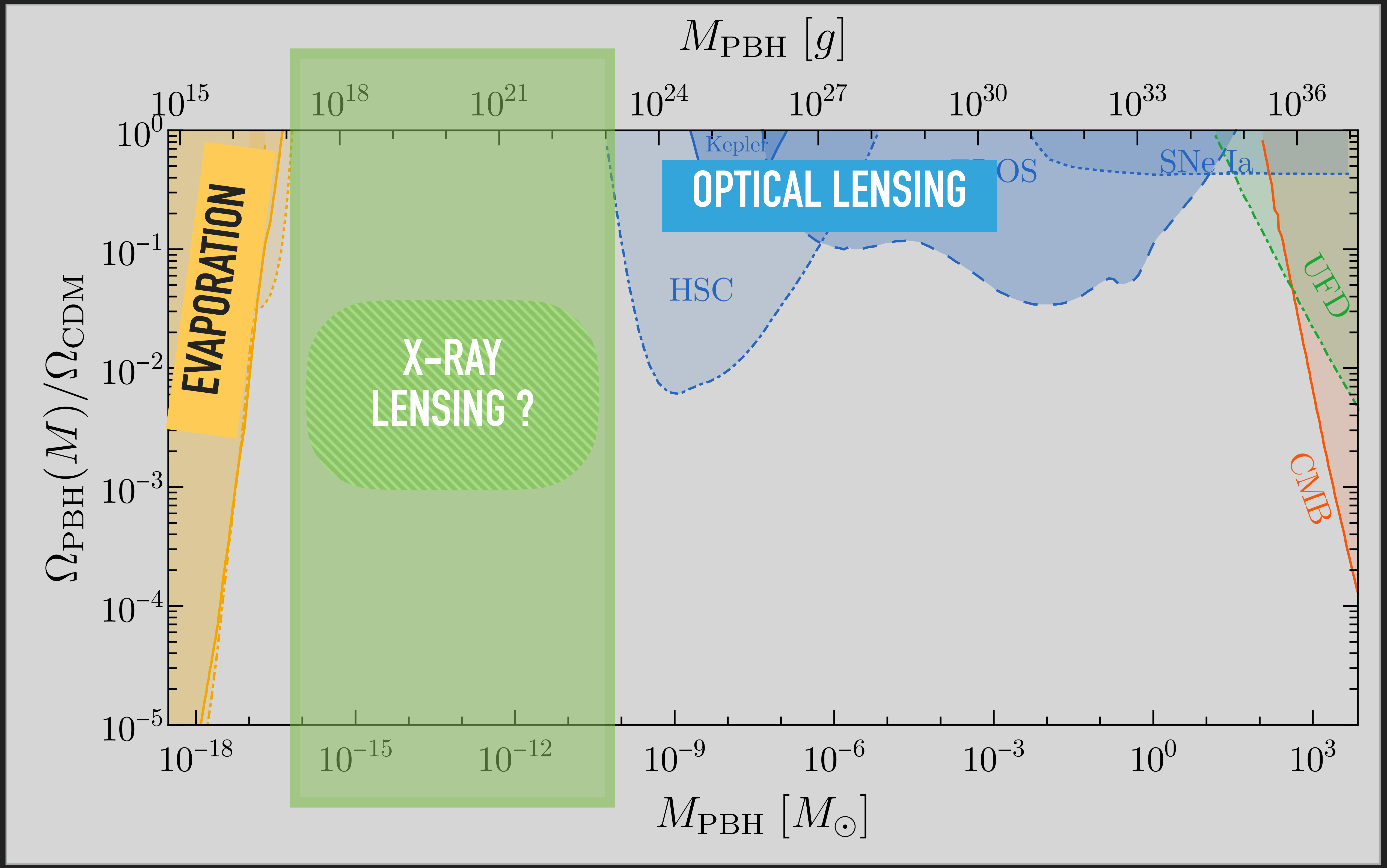


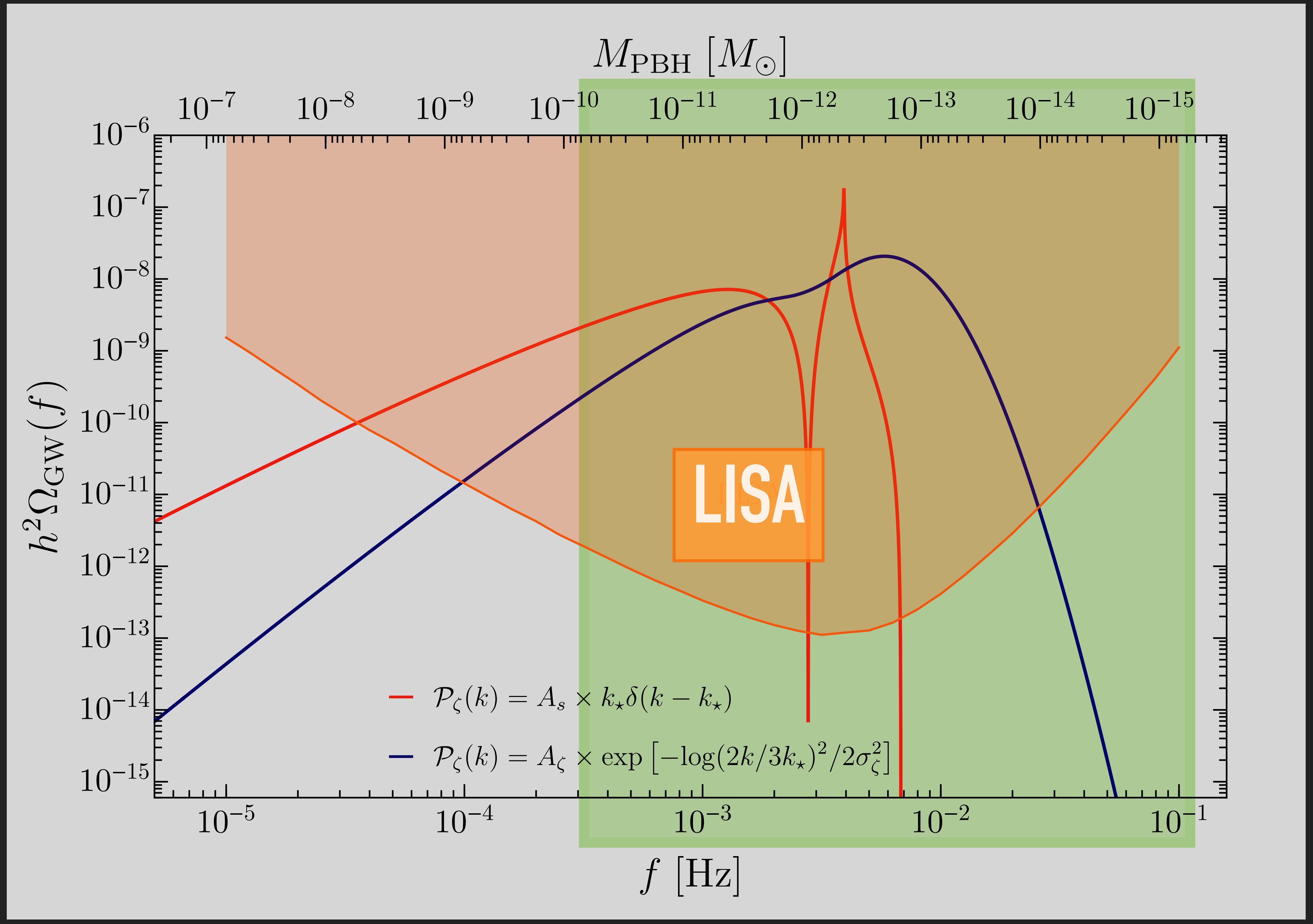
LISA CAN PROBE THE REMAINING WINDOW

Collapse from large overdensities

PRIMORDIAL BLACK HOLES

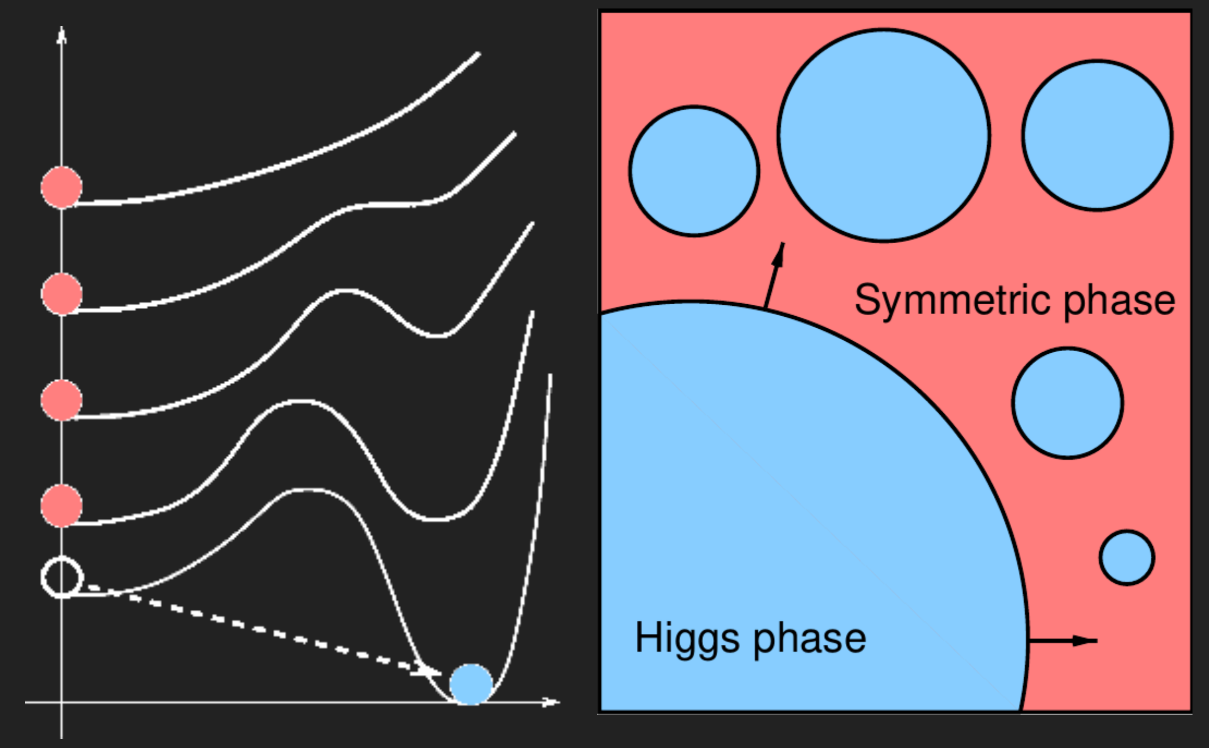
GRAVITATIONAL WAVES

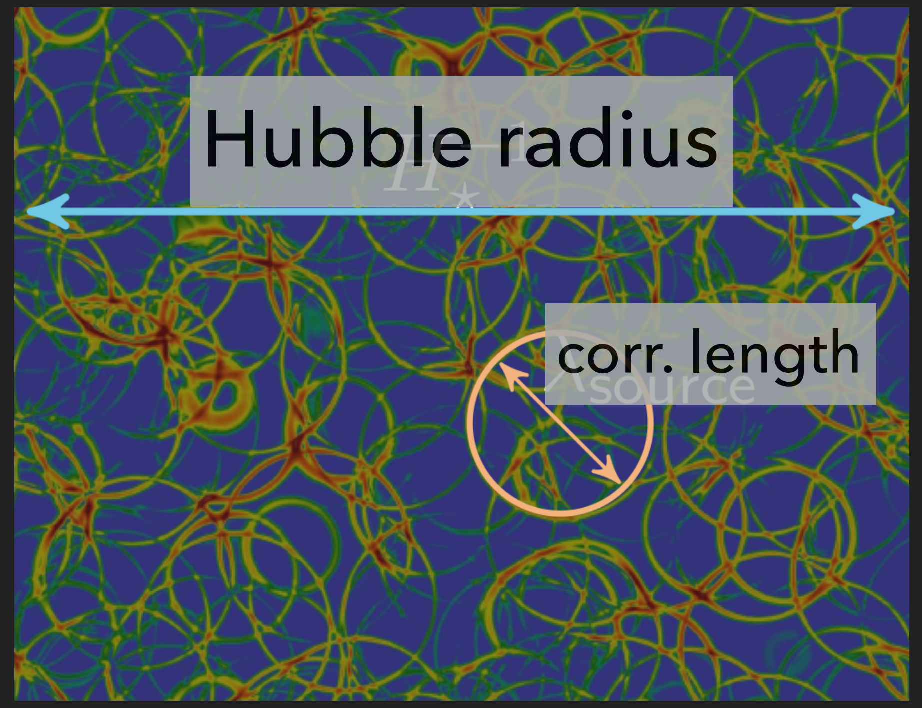


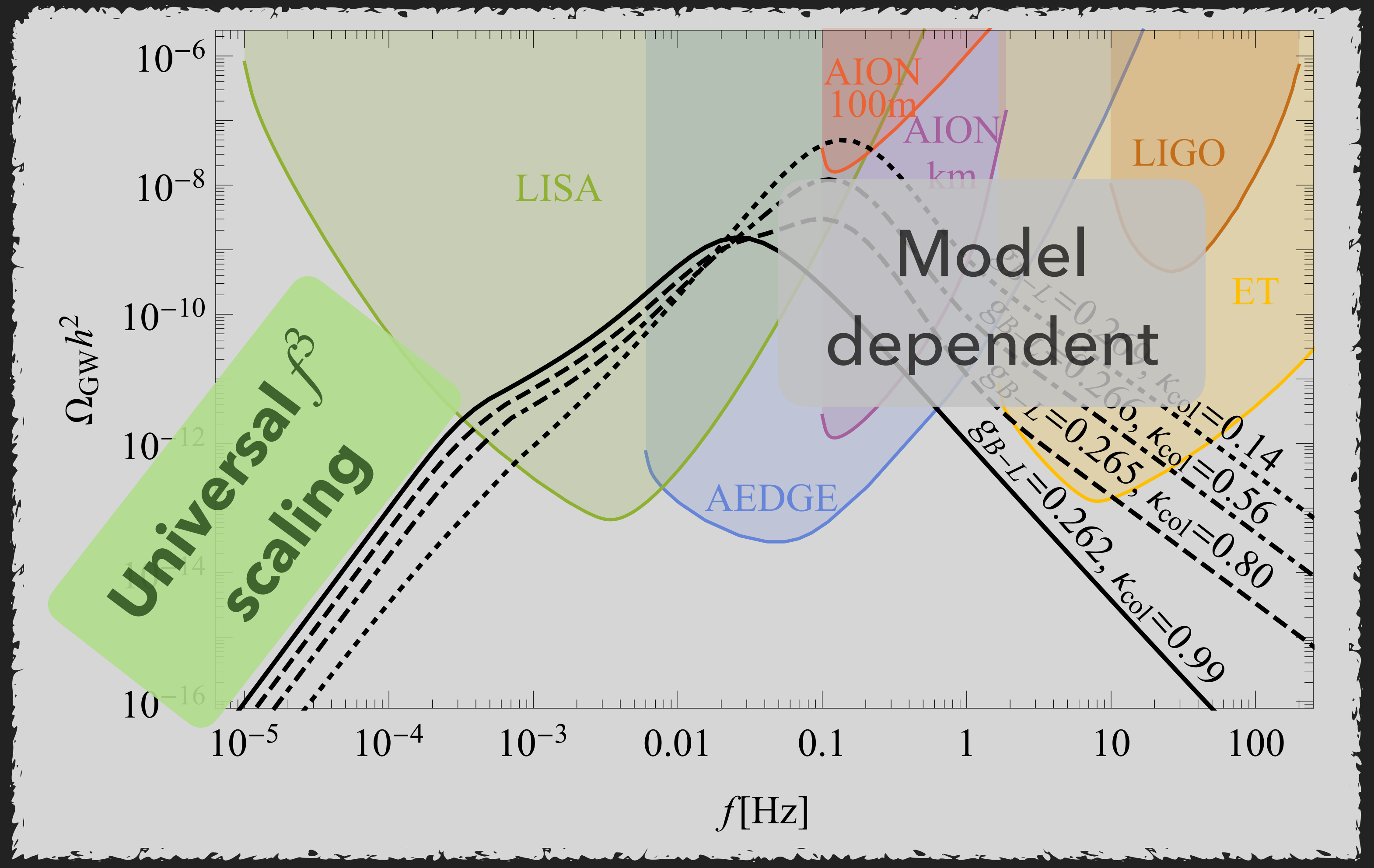


[Bartolo, De Luca, Franciolini, Peloso, **Racco**, Riotto 1810.12224]

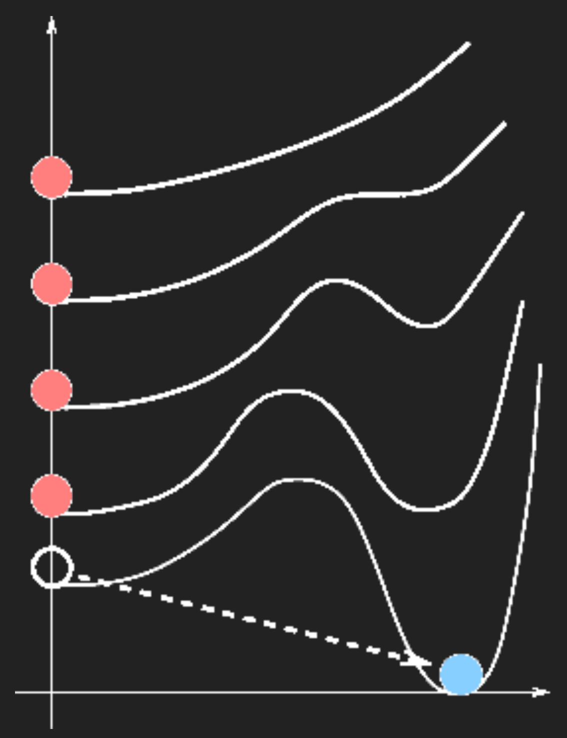
PHASE TRANSITIONS AND CAUSALITY

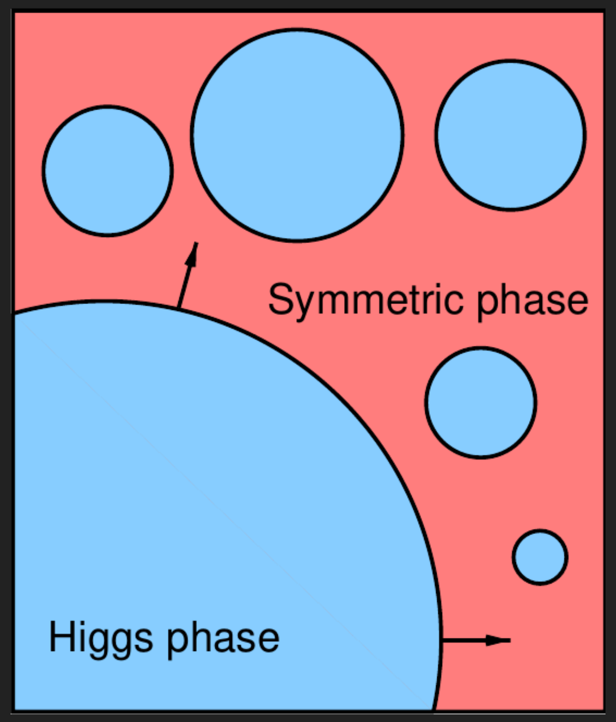


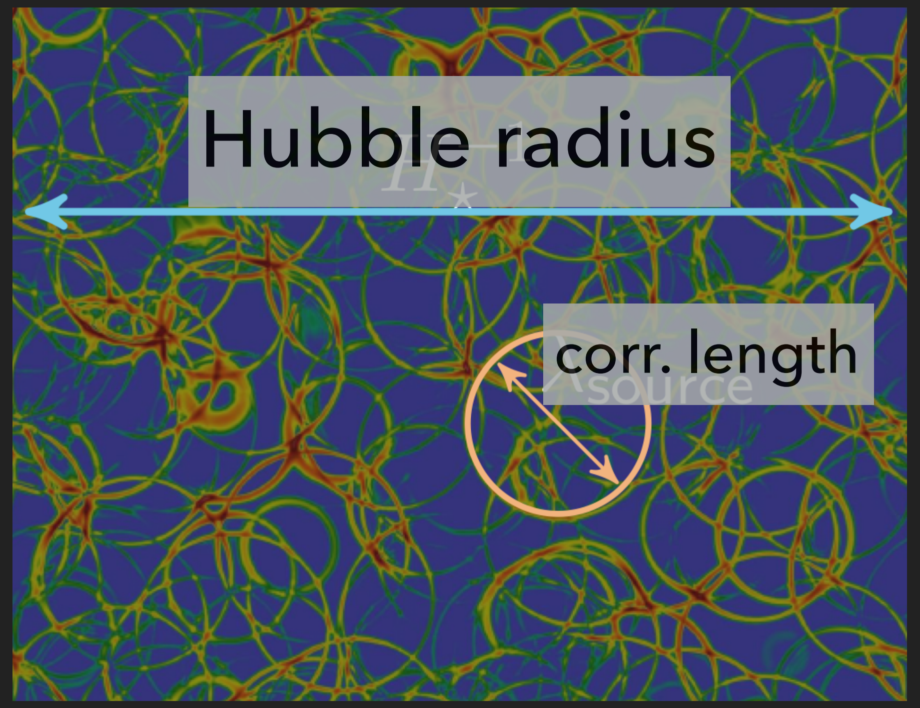


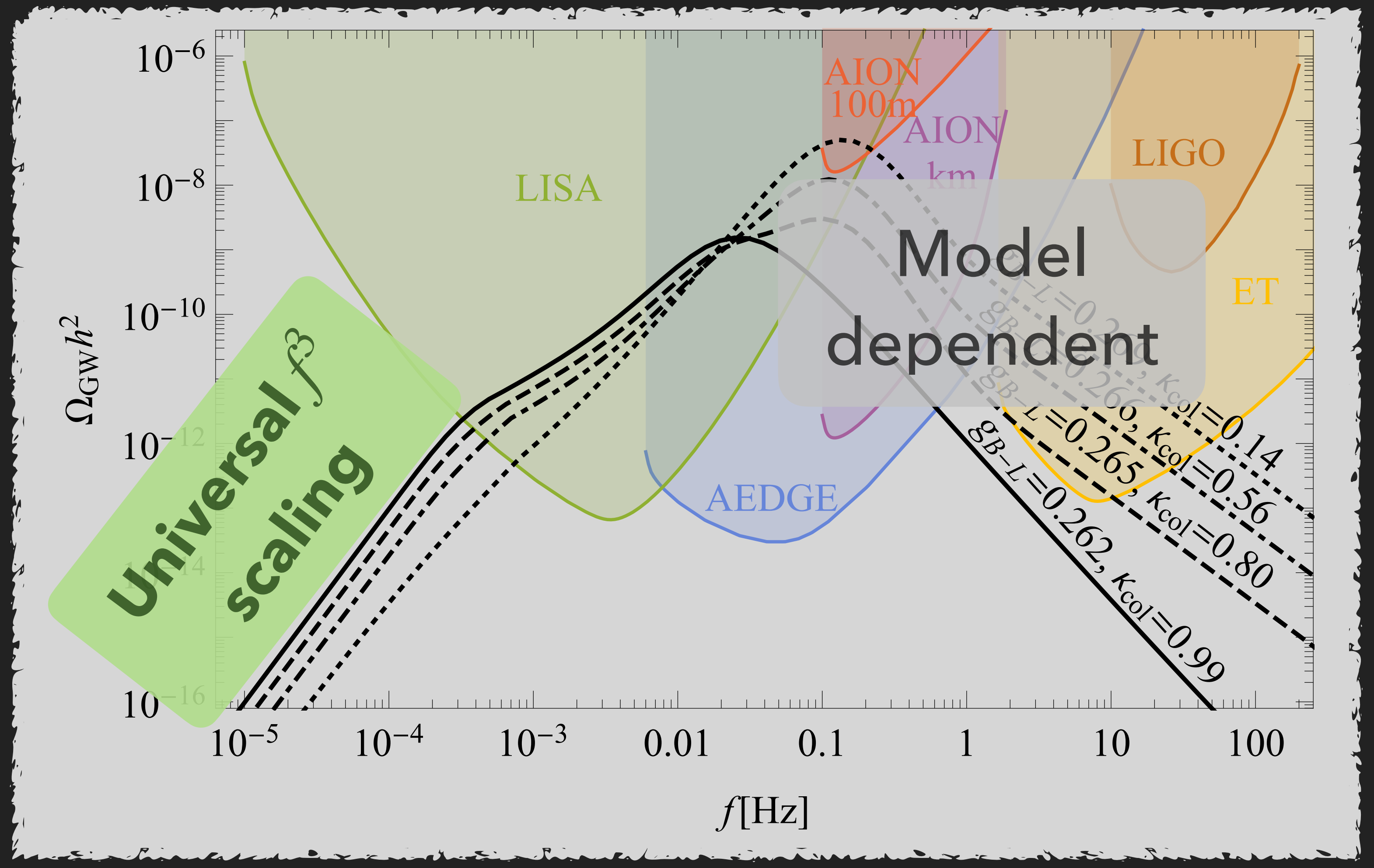


PHASE TRANSITIONS AND CAUSALITY

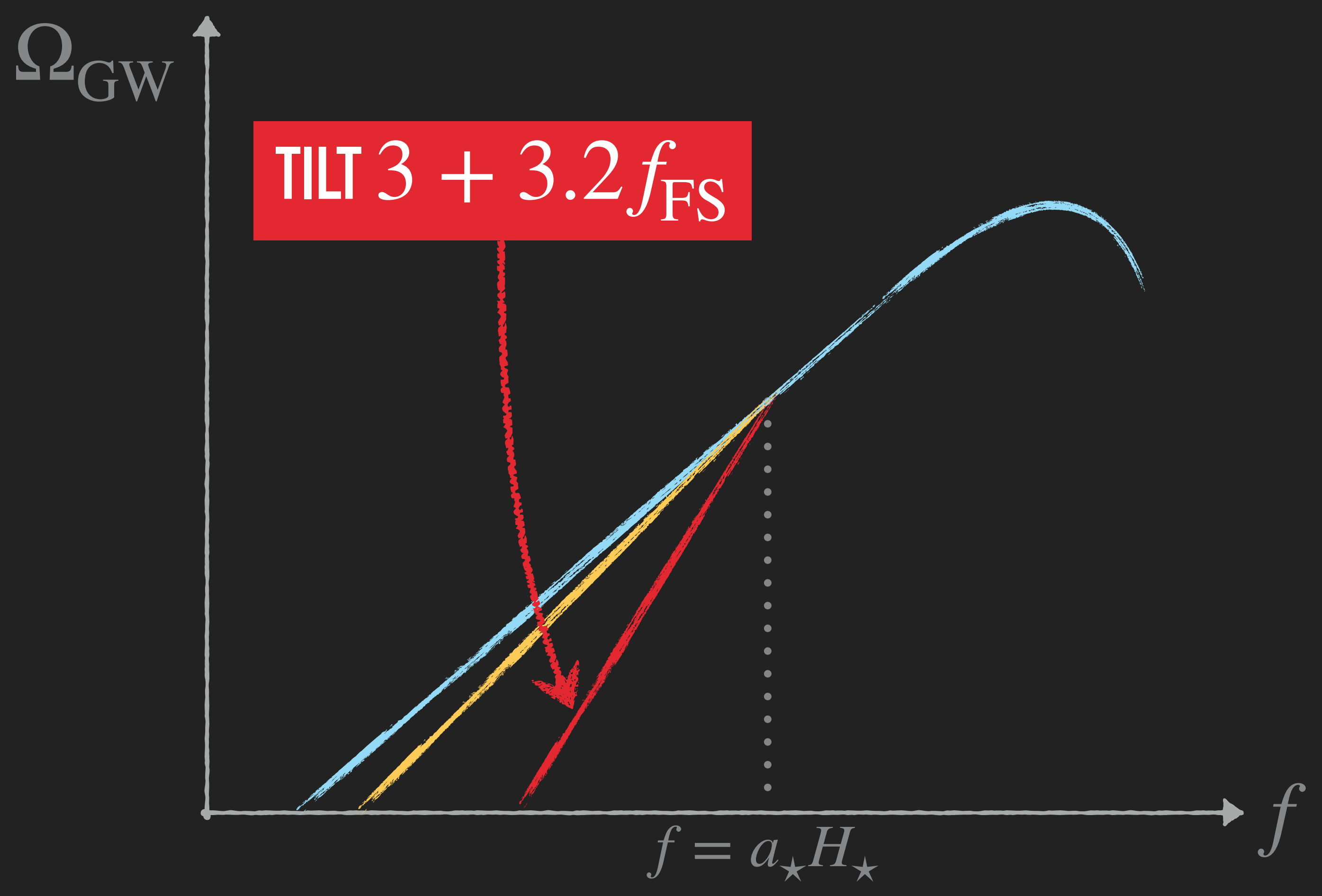




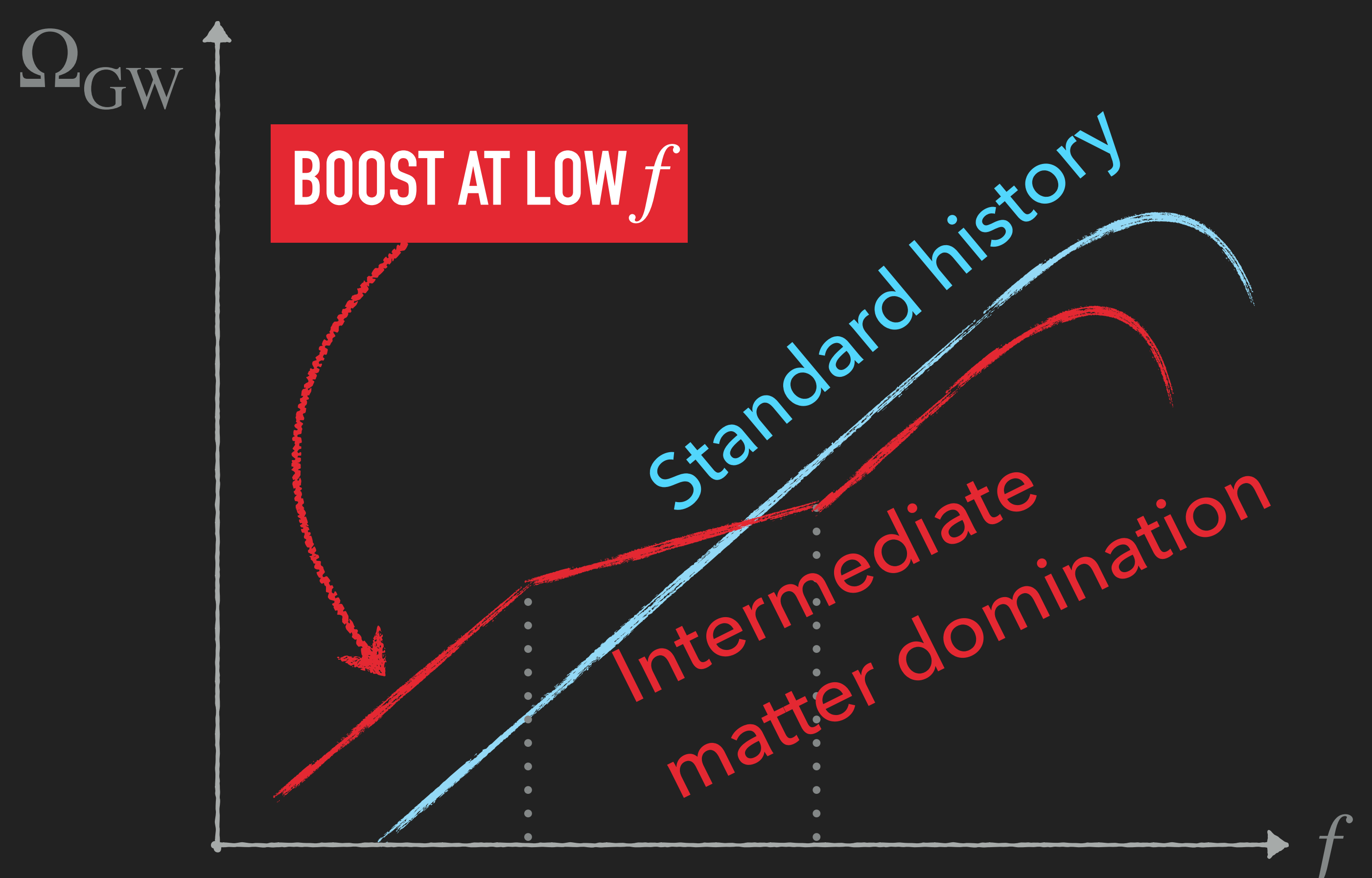




IMPACT OF FREE-STREAMING PARTICLES



EFFECT OF MATTER-DOMINATED PHASE



[Hook, Marques-Tavares, **Racco** 2010.03568]

Quantum Gravity effects on Gravity Wave detection

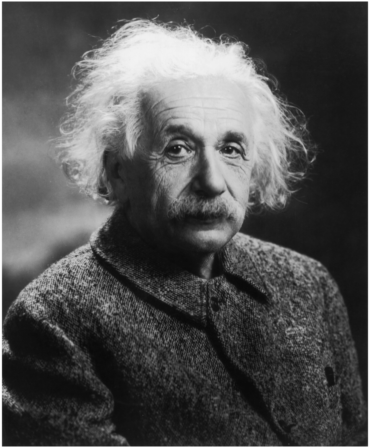
Vasil Todorinov

Dept. of Physics and Astronomy
University of Lethbridge

April 28, 2021

Quantum Gravity

General Relativity



Quantum Mechanics

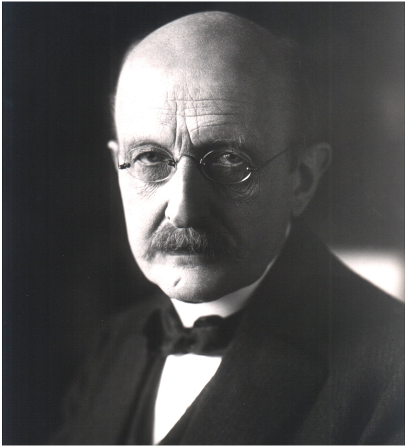


Image Credit: Time Magazine Image Archive

Image Credit: Transocean Berlin https://library.si.edu/image-gallery/73553

Theories of Quantum Gravity

- String Theory: *Strings replace point particles*
- Loop Quantum Gravity: Gives quatization of *time, length, area, and volume*
- Phenomenological Models
  - Doubly Special Relativity:
    Dynamics with postulated Lorentz invariant length scale.
  - Generalized Uncertainty Principle:
    Deformation of the position-momentum commutator to accumulate minimal uncertainty in position

A new window to the universe

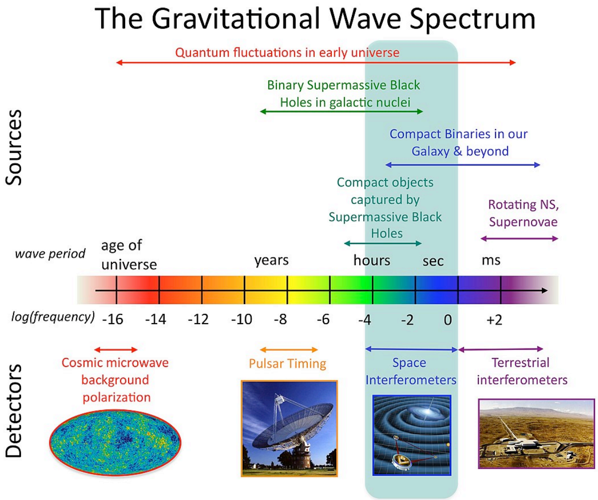


Image Credit: NASA Goddard Space Flight Center

LISA as a Quantum Gravity measurement (1)

- Noise in the detectors
  P. Bosso, S. Das, R. Mann Phys. Lett. B **785** 498, (2018) arXiv:1804.03620

$$(\Delta z)^2 \propto \Xi_{(0)} + \underbrace{\sqrt{\gamma}\Xi_{(1)} + \gamma\Xi_{(2)}}_{GUP\ contribution}$$

where $\gamma = \gamma_0/(M_{Pl}c)^2$ and $\gamma_0 \in \mathbb{R}$

- Quasi-Normal Modes in alternative theories of Gravity
  J. L. Blázquez-Salcedo et. al. Phys. J. Plus **134** (2019) 1, 46

$$\tilde{G}^{\rho}_{\mu} = G^{\rho}_{\mu} + 2\gamma\hbar^2 \left[\nabla^{\sigma}\nabla_{\sigma}R^{\rho}_{\mu} + \delta^{\rho}_{\mu}\left(\frac{1}{2}\left(-R^{\sigma\lambda}\right)R_{\sigma\lambda} + \frac{R^2}{4} - \frac{1}{2}\nabla^{\sigma}\nabla_{\sigma}R\right) + 2R^{\lambda\sigma}R^{\rho}_{\lambda\mu\sigma} - RR^{\rho}_{\mu}\right]$$

LISA as a Quantum Gravity measurement (2)

- Gravitational Wave luminosity distance: QG modifies the propagator of GW
  E. Belgacem, Y. Dirian, S. Foffa, M. Maggiore Phys. Rev. D **97** (2018) 10, 104066

$$P_{\mu\nu\rho\sigma} = \frac{\eta_{\mu\rho}\eta_{\nu\sigma} + \eta_{\mu\sigma}\eta_{\nu\rho} - \eta_{\mu\nu}\eta_{\rho\sigma}}{k^2(1 + \underbrace{2\gamma k^2}_{GUP})}$$

$$\frac{d_L^{GW}}{d_L^{EM}} = \exp\left[-\int_0^z \frac{dz'}{1+z'}\delta(z')\right]$$

- Quantum Gravity relics in the Primordial Gravitational Wave power spectrum
  C.s Kiefer, M. Kraemer Int. J. Mod.Phys. D **21** (2012), 1241001
  H. Noh, and J. Hwang Phys. Rev. D **59** (1999), 047501

Thank you for your attention!