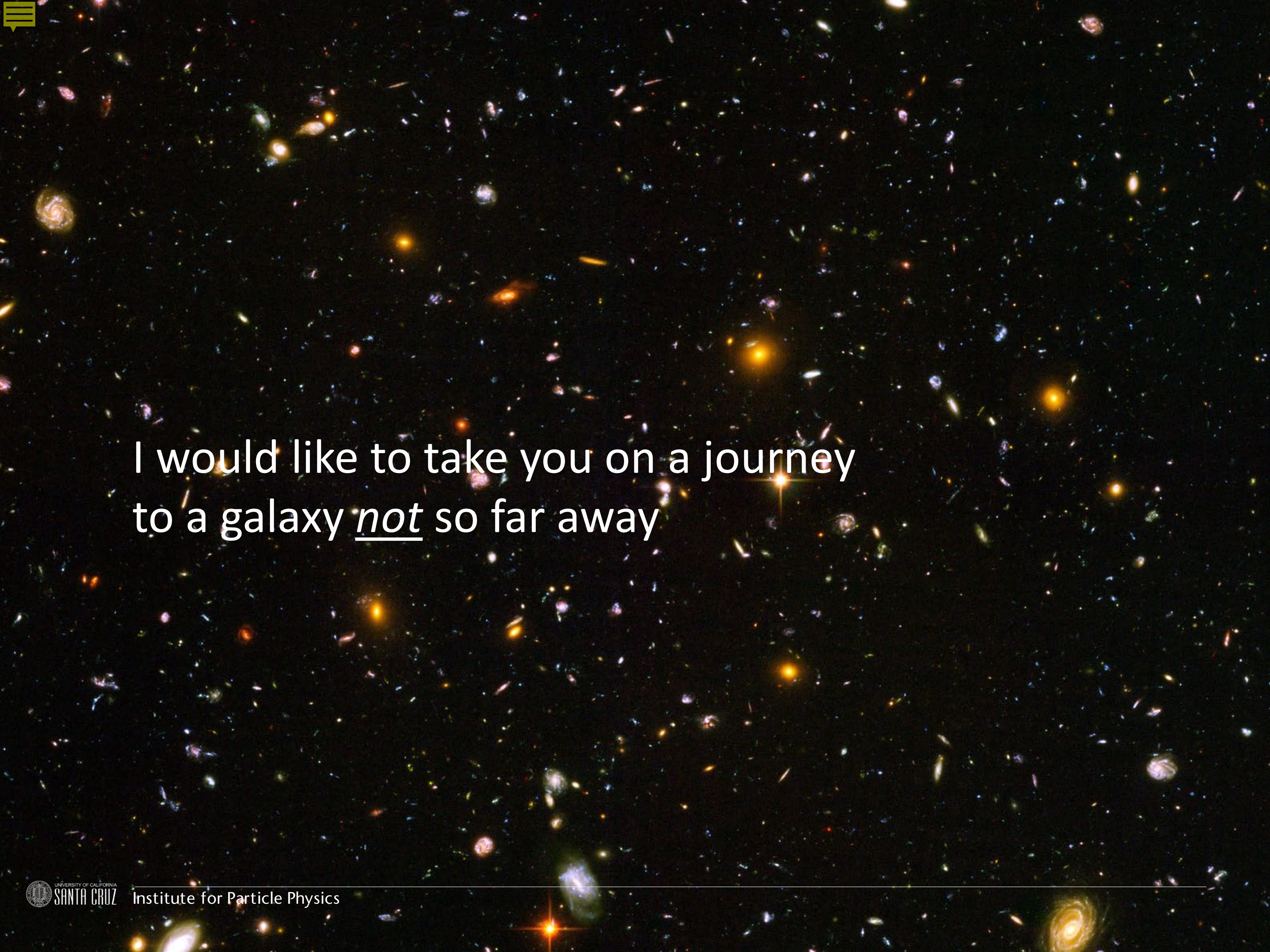


I would like to take you on a journey
to a galaxy *not* so far away

Our Milky Way

. Central black hole, **Sagittarius A*** (Sgr A*)

. Particulate **Dark Matter** agglomerates towards center

. Dark matter density spikes → annihilation signatures

. Spike sensitive to perturbations (e.g., binary companion)

. **Sgr A* not alone**

Galaxy Formation

. Galaxies **coalesce** during collisions

. Galaxy centers contain **seedling black holes**

. **Sgr A* merging with companion black hole** (constrained by observation)

. New scientific instruments & data (EHT, orbital stability constraints, etc.)

What *if* a companion black hole to Sgr A* exists in our Milky Way?

→ **Dark matter distribution**

→ **Dark matter self-annihilation luminosity**

How does a companion black hole affect the density spike in our own galaxy?

Single Black Hole Case

Gondolo, P., Silk, J. (1999). Dark Matter Annihilation at the Galactic Center.

$$\rho(r) = \rho_0 \left(\frac{r}{r_0}\right)^{-\gamma}, \quad 0 < \gamma < 2 \quad \xrightarrow[\text{adiabatic}]{} \quad \rho'(r) \approx \rho_R \left(\frac{R_{sp}}{r}\right)^{\gamma_{sp}}, \quad 2.25 \leq \gamma_{sp} \leq 2.5$$

. Modified power law $\boldsymbol{\rho'(r)}$ with evolved parameters

. New slope parameter γ_{sp} is **strictly steeper** than γ

Single Black Hole Case

Gondolo, P., Silk, J. (1999). Dark Matter Annihilation at the Galactic Center.

. Dark matter **self-annihilation** depletes inner halo

. Maximal density set by annihilation: $\rho_{core} = \dfrac{m}{\sigma v \cdot t_{bh}}$

→ m mass of dark matter

→ σv cross-section · velocity

→ t_{BH} age of black hole (Sgr A* $\sim 10^{10}$ yrs)

. Associated cutoff radius, $R_{core} = R_{sp} \left(\dfrac{\rho_R}{\rho_{core}} \right)^{\frac{1}{\gamma_{sp}}}$

Single Black Hole Case

Gondolo, P., Silk, J. (1999). Dark Matter Annihilation at the Galactic Center.

. Final dark matter density profile: $\rho_{sp}(r) = \dfrac{\rho'(r)\rho_{core}}{\rho'(r) + \rho_{core}}$

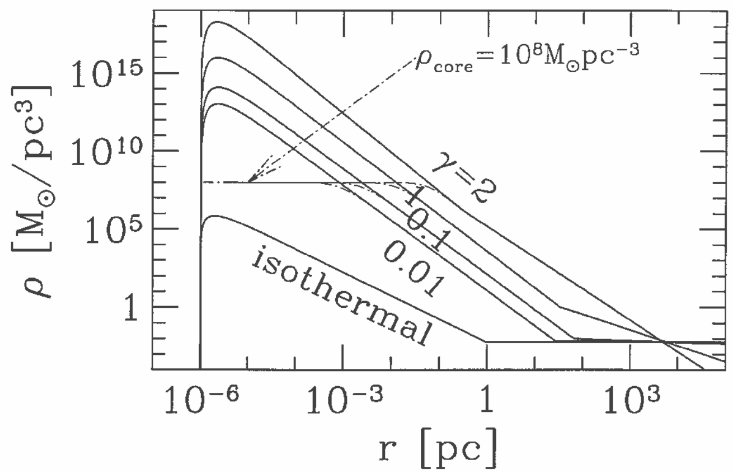


FIG. 1. Examples of spike density profiles.

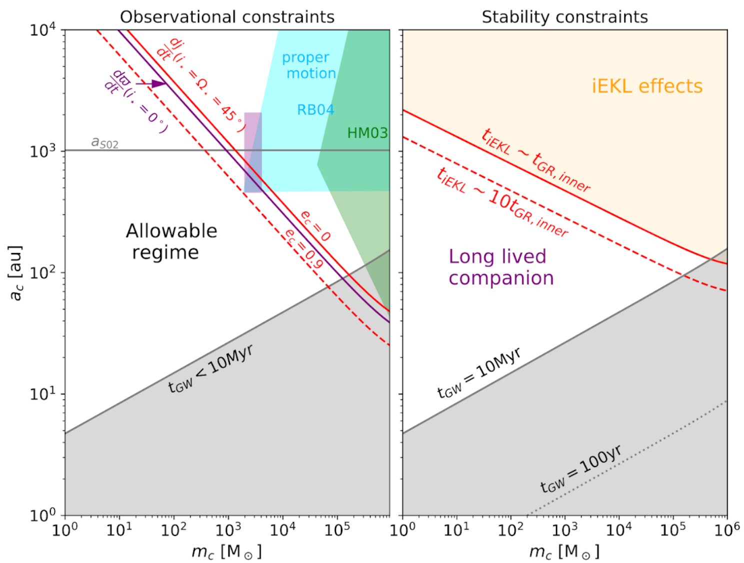
Sgr A* Hidden Friend

Justification for inquiry:

. **Galaxy formation** hierarchy

. Further **orbital configuration** constraints

Naoz, S., et al. (2019). A Hidden Friend for the Galactic Center Black Hole, Sgr A.*



Binary Black Hole System

Kavanagh, B., et al. (2020). Detecting dark matter around black holes with gravitational waves: Effects of dark-matter dynamics on the gravitational waveform

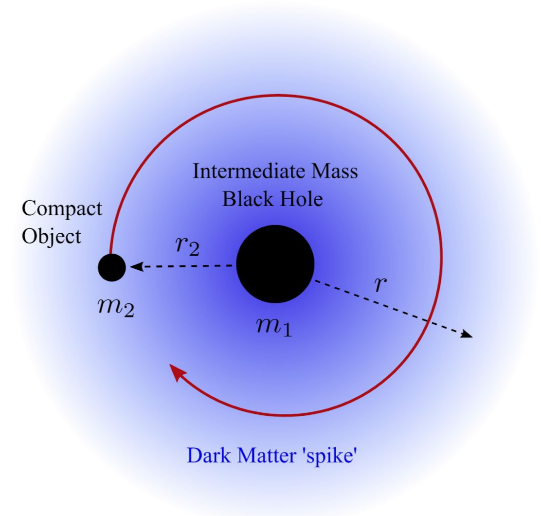
. Dark matter exerts **dynamical friction** force

. Energy conservation:

$$\frac{dE_{orb}}{dt} = -\frac{dE_{GW}}{dt} - \frac{dE_{DF}}{dt}$$

$$\frac{dE_{GW}}{dt} = \frac{32G^4M(m_1m_2)^2}{5(cr_2)^5}$$

$$\frac{dE_{DF}}{dt} = 4\pi(Gm_2)^2\rho_{DM}(r_2)\xi(v)v^{-1}\log\Lambda$$



. Orbital energy → dark matter halo → **density coring** effect

Hidden Friend's Effects

. Simplifying assumptions:

→ **static** r_2, binary separation (further research necessary)

→ **Hollowed halo** in response to energy injection

. **Scouring radius** set by dynamical friction:

$$r_{sc} \rightarrow E_{BE}(r^*) = \Delta E(r^*)$$

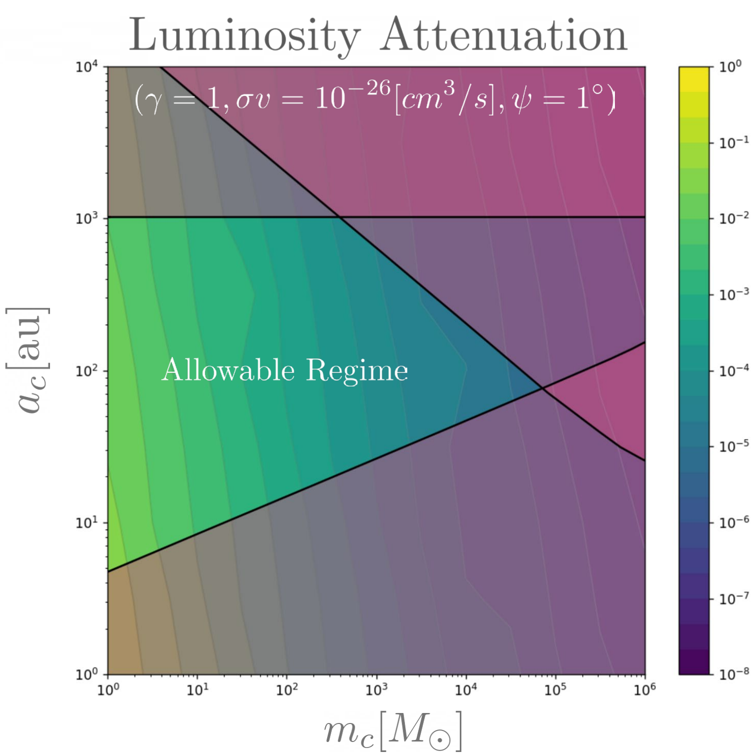
. Final, **modified** dark matter density profile:

$$\rho_{mod}(r) = \begin{cases} 0 & r < r_{sc} \\ \rho_{sp}(r) & r > r_{sc} \end{cases}$$

Hidden Friend’s Effects

. Annihilation luminosity, **J-factor** ratio $\sim \frac{J(\rho_{mod})}{J(\rho_{sp})}$

$$J(\Delta\Omega, \psi) \approx \int dl(\psi)(\rho_{DM})^2$$



$\frac{J(\rho_{mod})}{J(\rho_{sp})}$

Hidden Friend's Wake:
Dark Matter and a Binary at the Galactic Center*

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