



Dark matter

What is it?

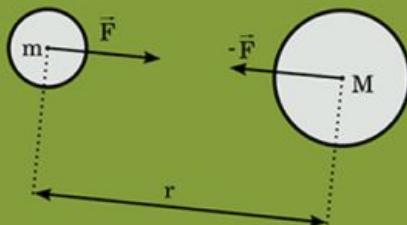


It's not cats.

The background of the image is a dark, star-filled night sky. In the lower half, the silhouettes of several tall evergreen trees are visible against the lighter sky. The text is centered over this scene.

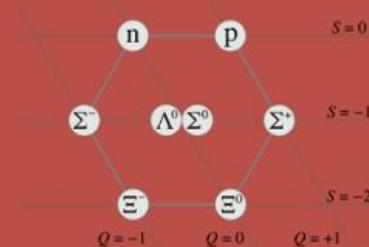
What is the nature of our universe?

$$G_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R + g_{\mu\nu}\Lambda = \frac{8\pi G}{c^4}T_{\mu\nu}$$



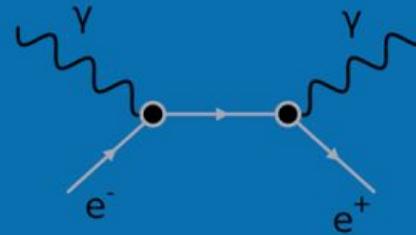
Gravity

$$\mathcal{L} = \bar{\psi}_i \left(i\gamma^\mu (D_\mu)_{ij} - m\delta_{ij} \right) \psi_j - \frac{1}{4} G_{\mu\nu}^a G_a^{\mu\nu}$$



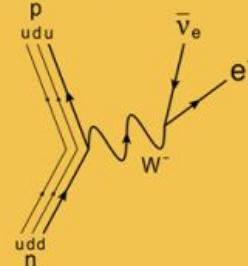
Strong

$$\mathcal{L} = \bar{\psi} (i\gamma^\mu D_\mu - m) \psi - \frac{1}{4} F_{\mu\nu} F^{\mu\nu}$$



Electromagnetism

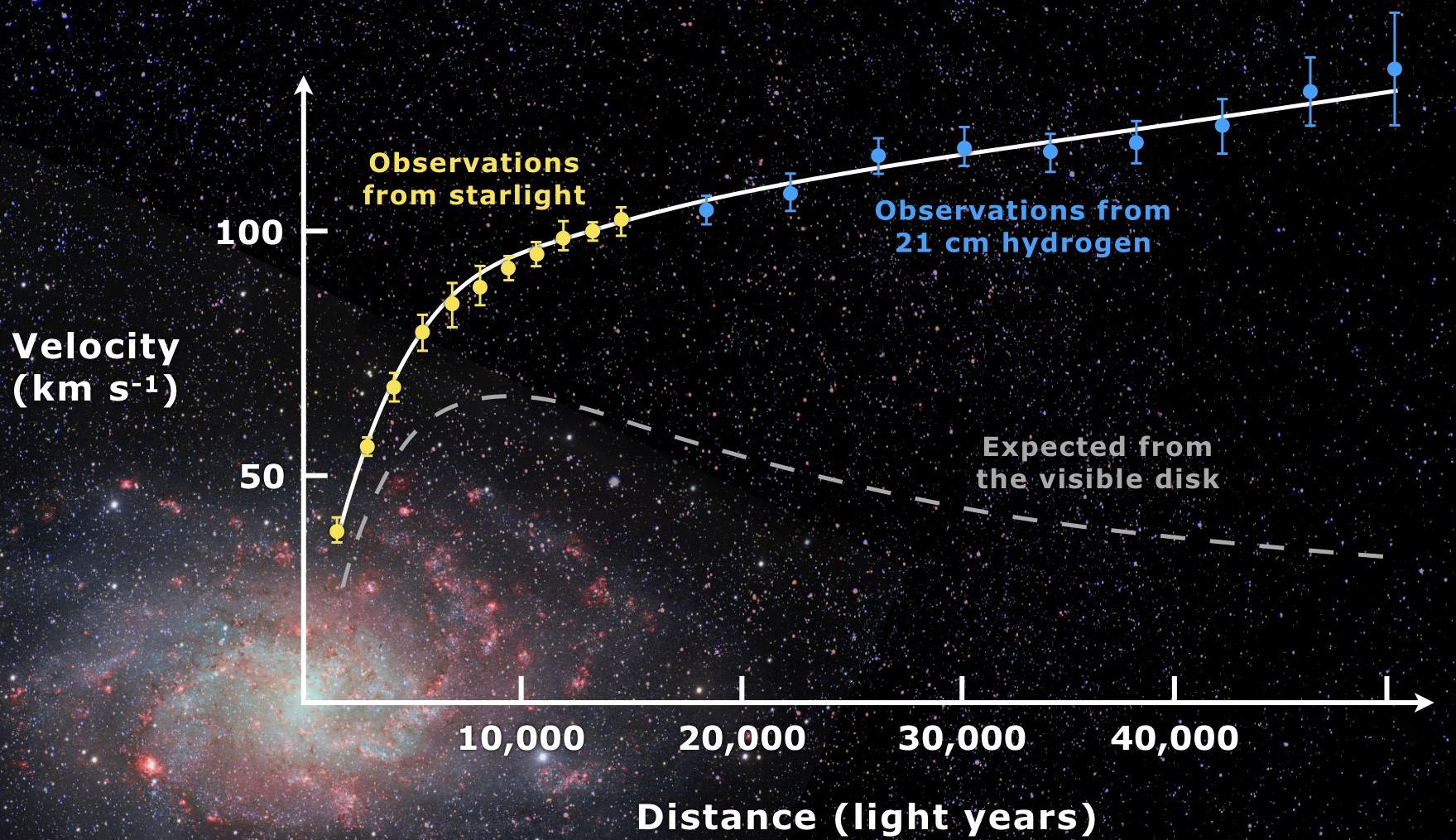
$$\mathcal{L} = g(\bar{\nu}_{eL}, \bar{e}) \gamma^\mu \left\{ \begin{pmatrix} -\sqrt{1+\xi^2} Z_\mu & 0 \\ 0 & \frac{\xi A_\mu}{\sqrt{1+\xi^2}} - \frac{\xi^2}{\sqrt{1+\xi^2}} Z_\mu \end{pmatrix} + \frac{1-\gamma^5}{4} \begin{pmatrix} -\sqrt{1+\xi^2} Z_\mu & -\sqrt{2} W_\mu^+ \\ -\sqrt{2} W_\mu^- & \sqrt{1+\xi^2} Z_\mu \end{pmatrix} \right\} \begin{pmatrix} \nu_{eL} \\ e \end{pmatrix}$$



Weak

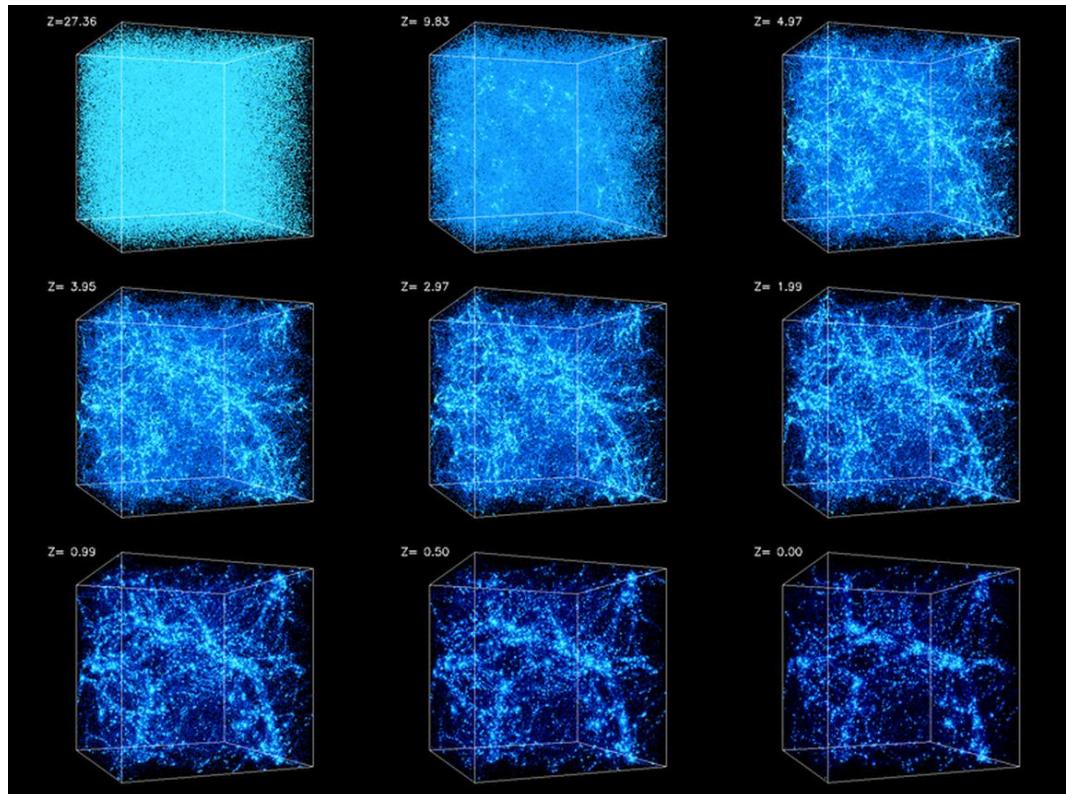
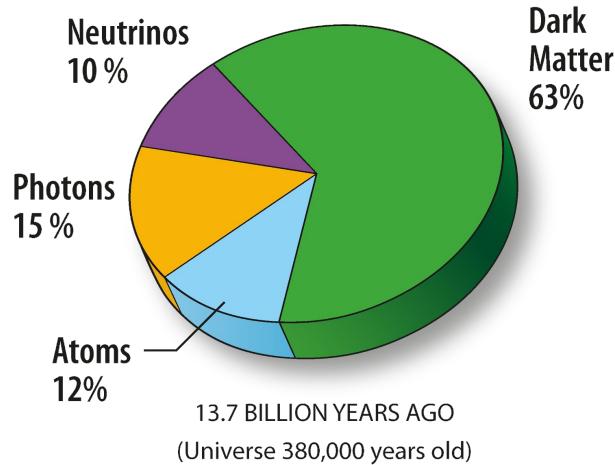
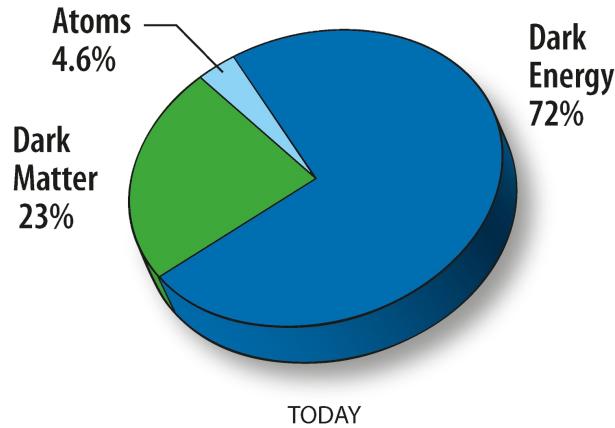
Gravity.





OK.

What does **dark matter** *do*,
What has it *done*?



Structure Formation Simulation

Why do we care?

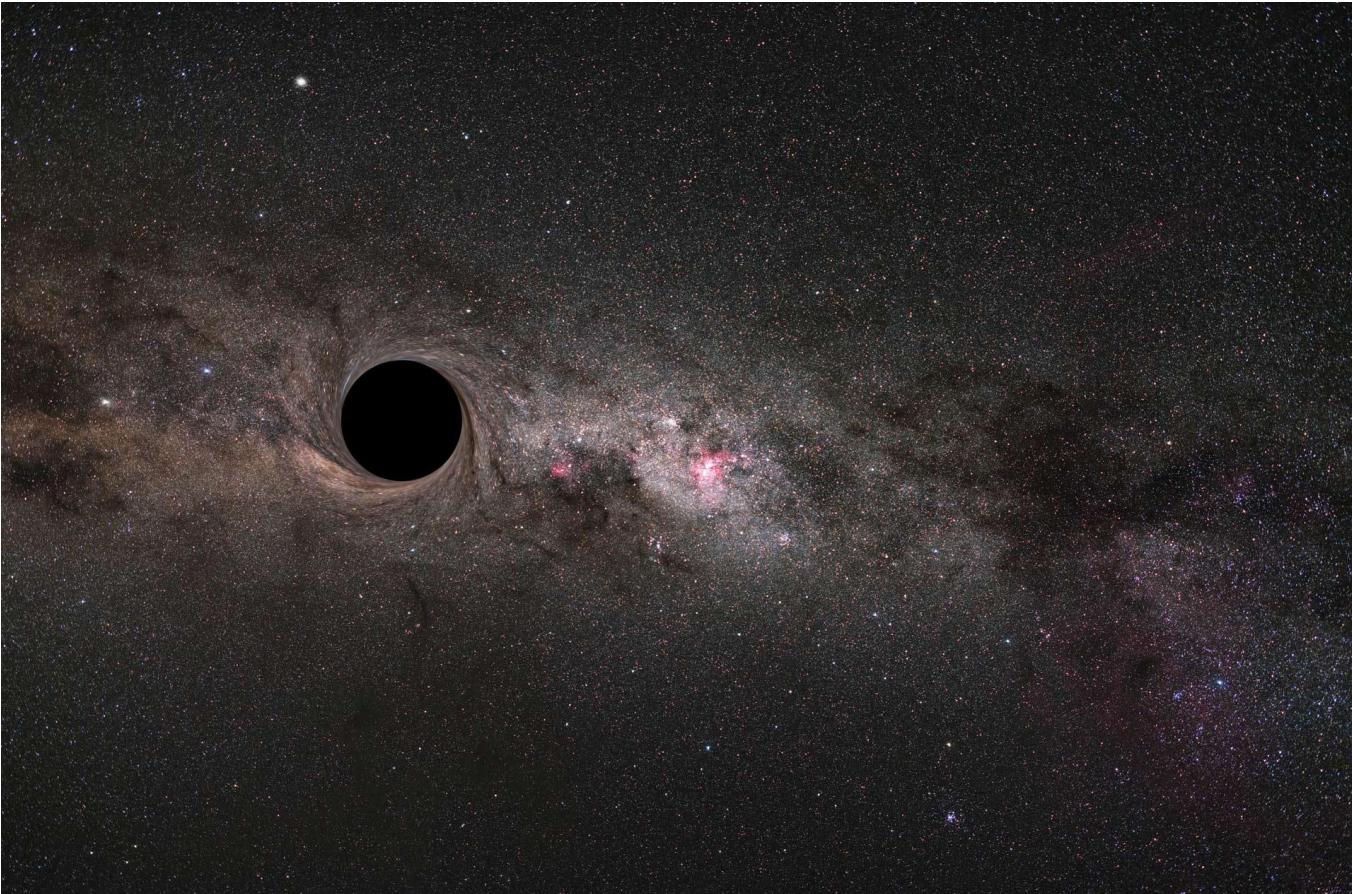


<i>Name</i>	<i>Relative strength</i>	<i>Range</i>	<i>Operates among</i>
Gravitational force	10^{-39}	Infinite	All objects in the universe
Weak nuclear force	10^{-13}	Very short, Sub-nuclear size ($\sim 10^{-16}$ m)	Some elementary particles, particularly electron and neutrino
Electromagnetic force	10^{-2}	Infinite	Charged particles
Strong nuclear force	1	Short, nuclear size ($\sim 10^{-15}$ m)	Nucleons, heavier elementary particles

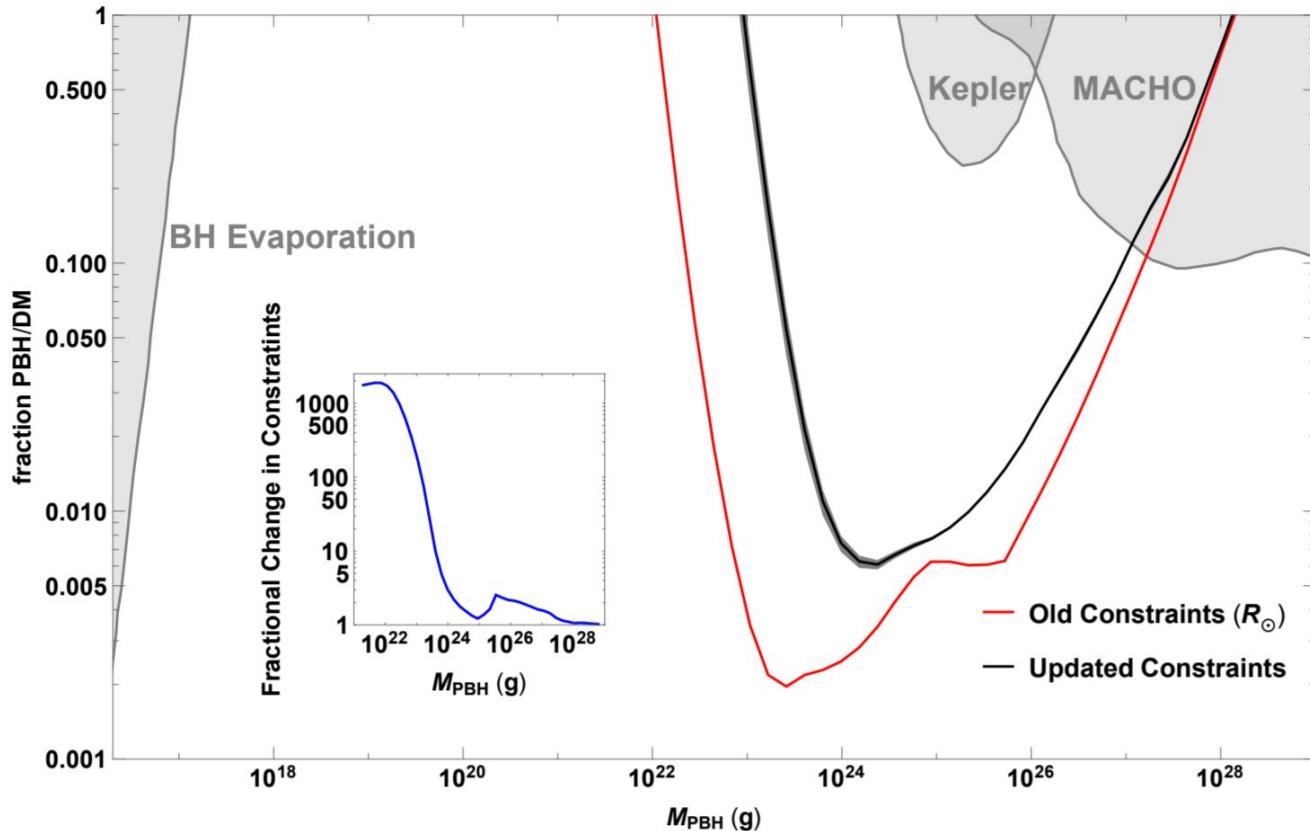
What is dark matter (again)?

A close-up photograph of a white cat's face. The cat has dark eyes and a small pink ear. It is looking directly at the camera with a neutral expression. The background is slightly blurred, showing some vertical stripes and a blue object.

Still not cats.

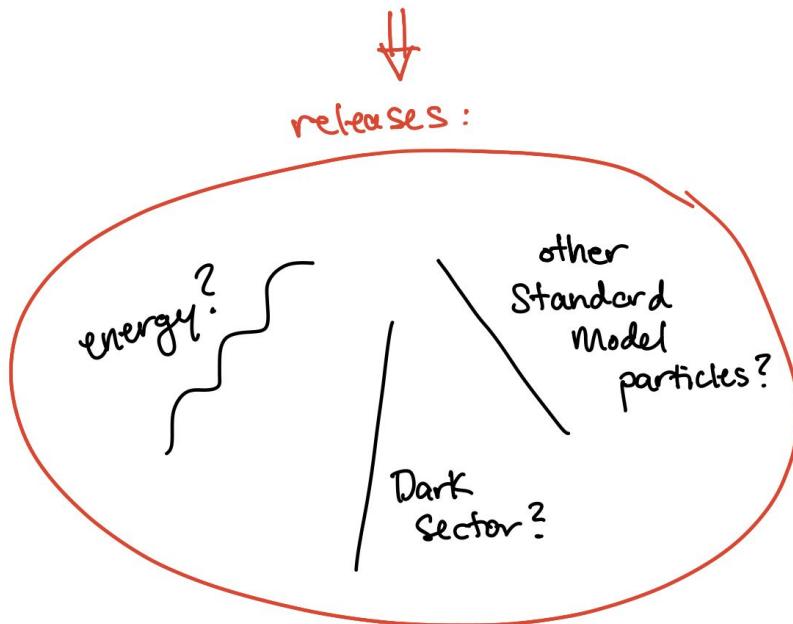
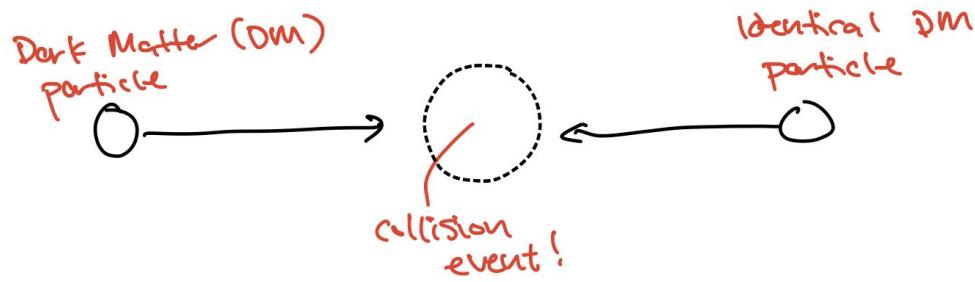


Primordial Black Holes.

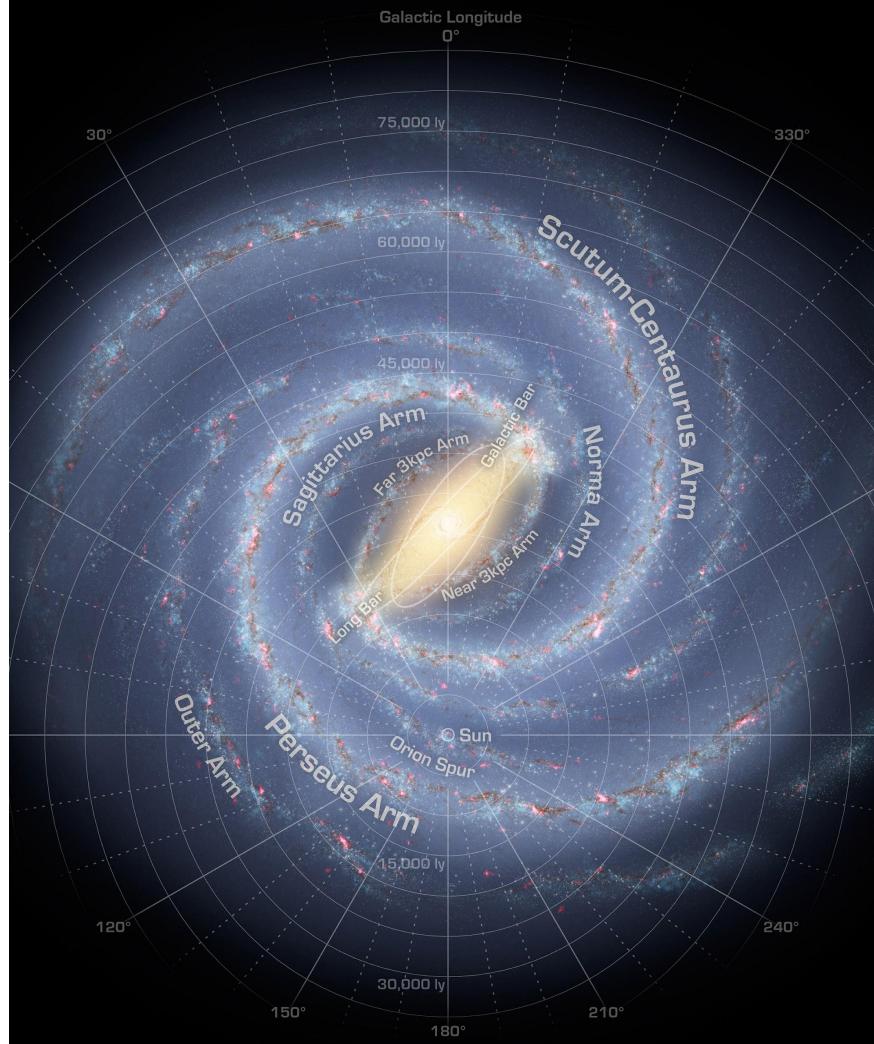


Updated Constraints on Asteroid-Mass Primordial Black Holes as Dark Matter.

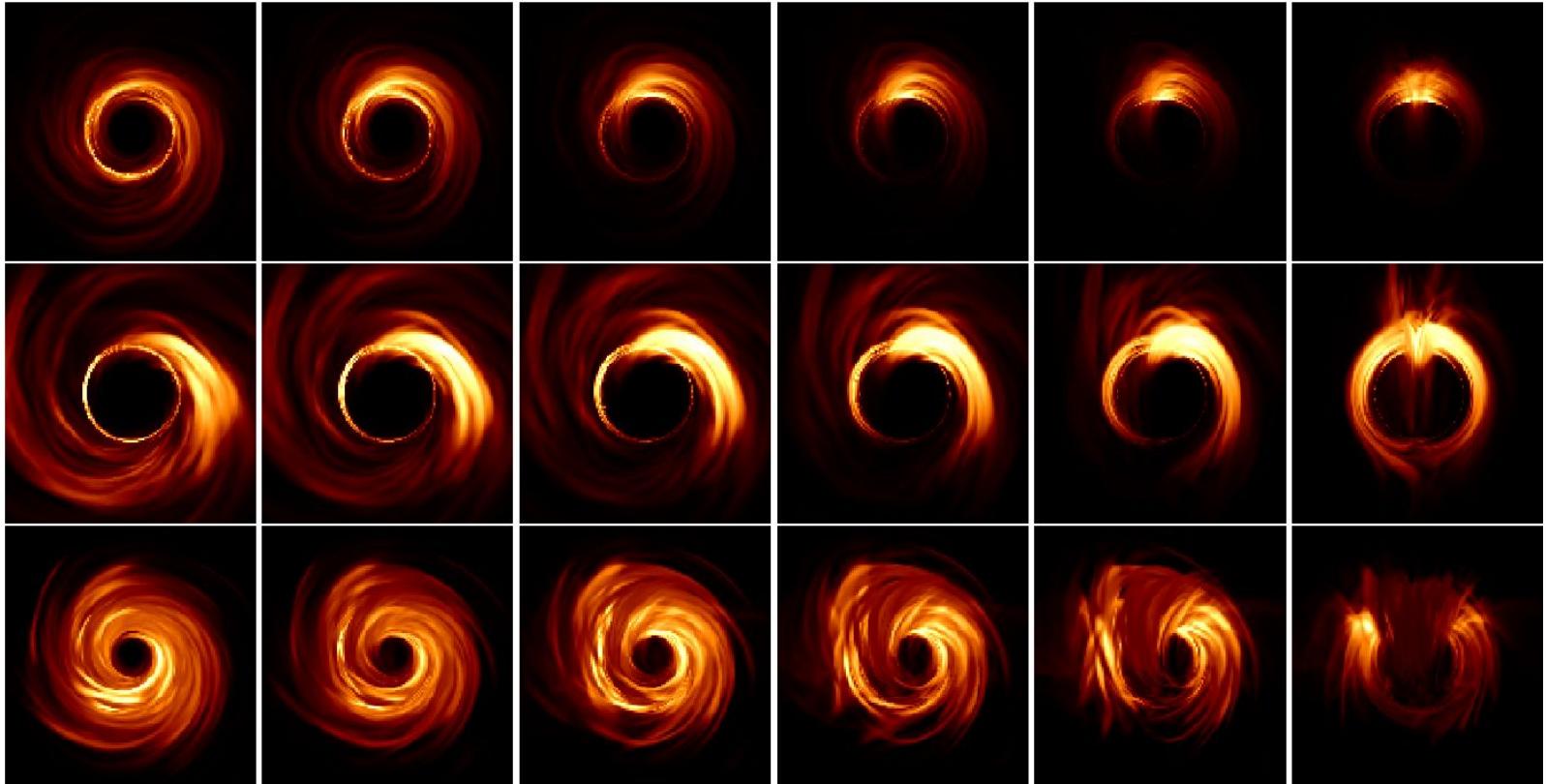
Let's consider...







Milky Way Galaxy.



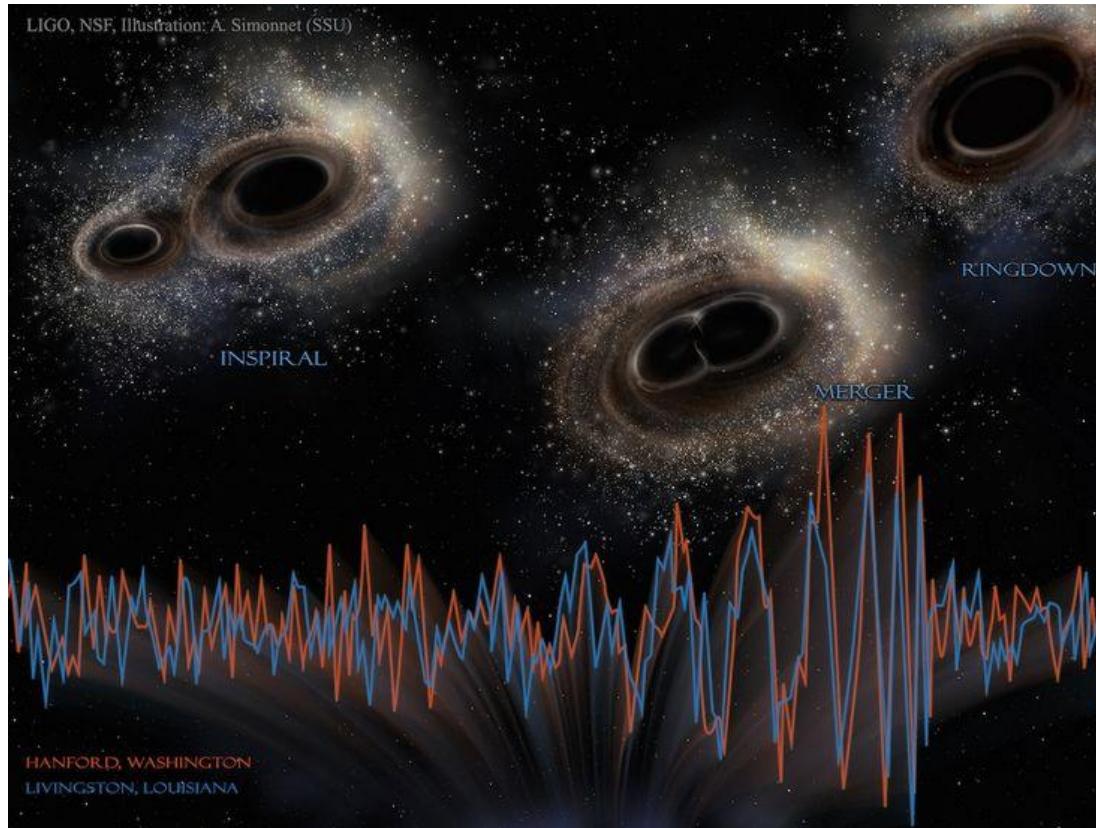
Sgr A* (simulation).



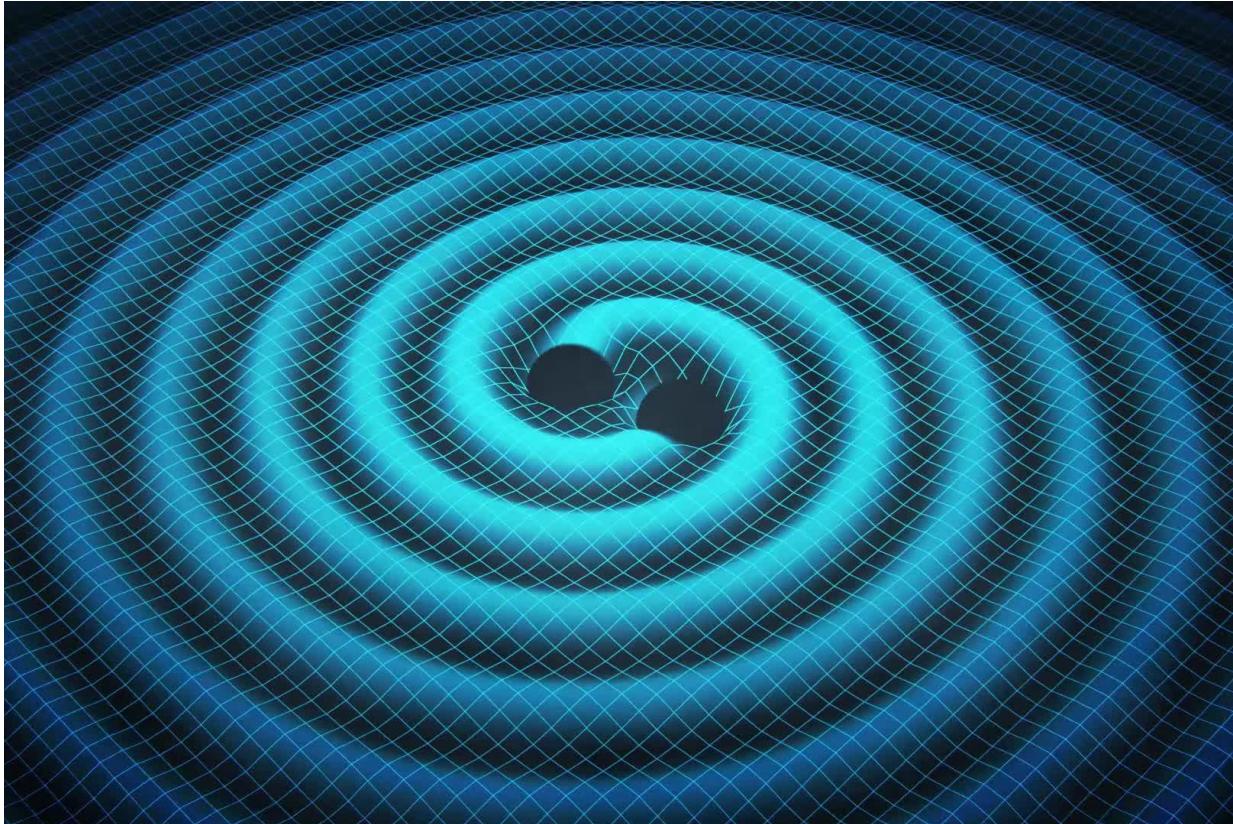
A Hidden Friend!



LIGO, NSF, Illustration: A. Simonnet (SSU)



Generic black hole binary & merging process.



Gravitational Wave Emission & “Dynamical Friction”.



