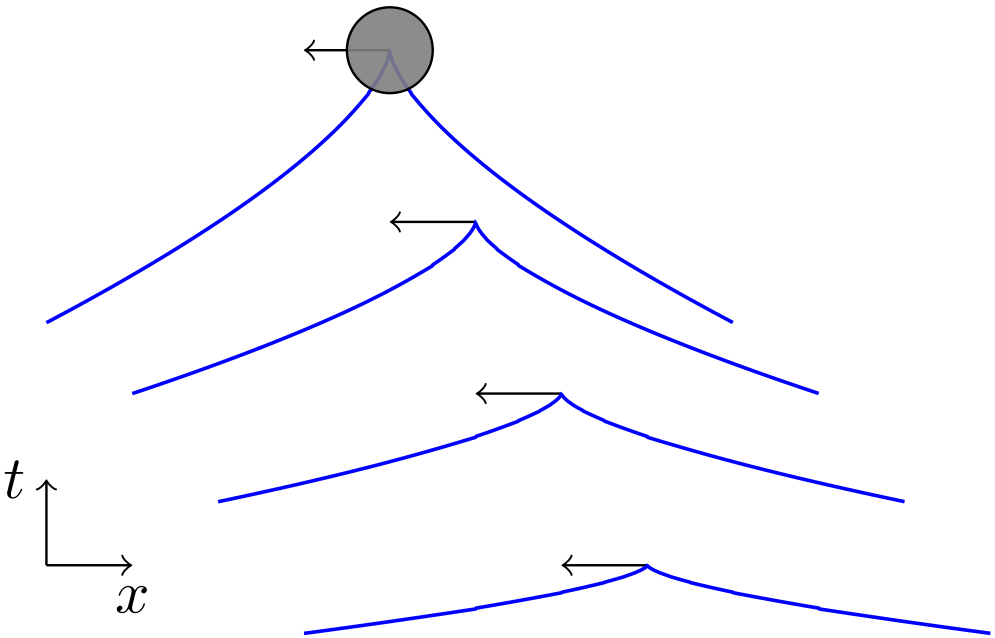
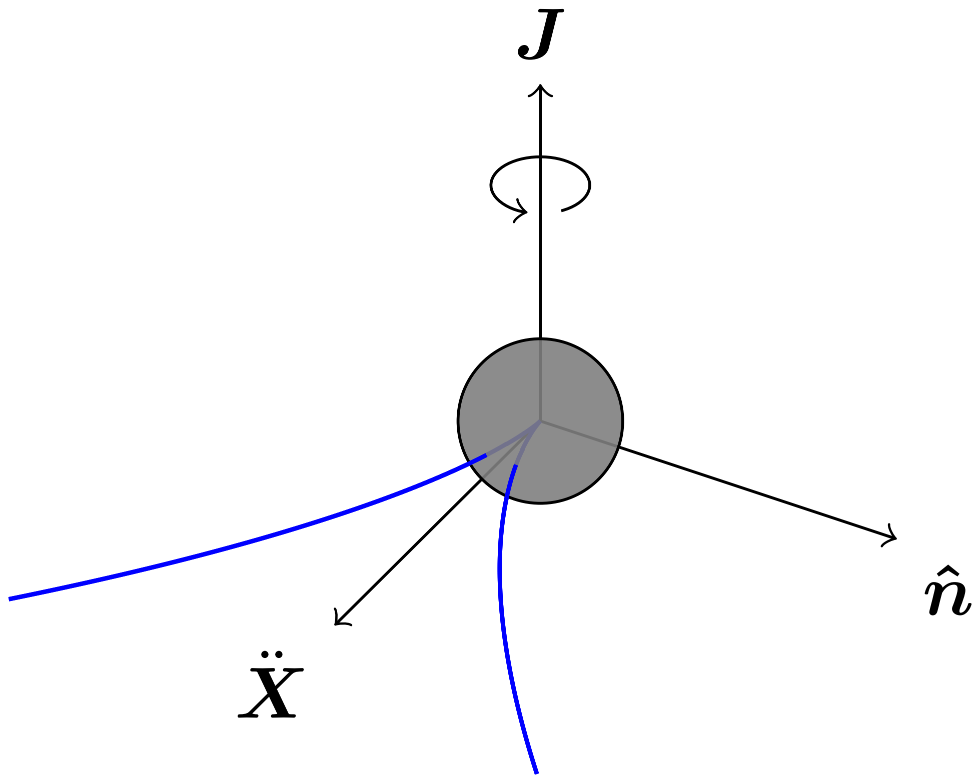
Primordial black holes from cusp collapse on cosmic strings

Alexander C. Jenkins and Mairi Sakellariadou

Our results in a nutshell

We have shown that cosmic strings create a large number of primordial black holes (PBHs) through the collapse of cusps (sharp, highly compact features which form generically on cosmic string loops).





These PBHs have some interesting properties that distinguish them from other known BH populations (primordial and astrophysical), representing an exciting new way of searching for cosmic strings.

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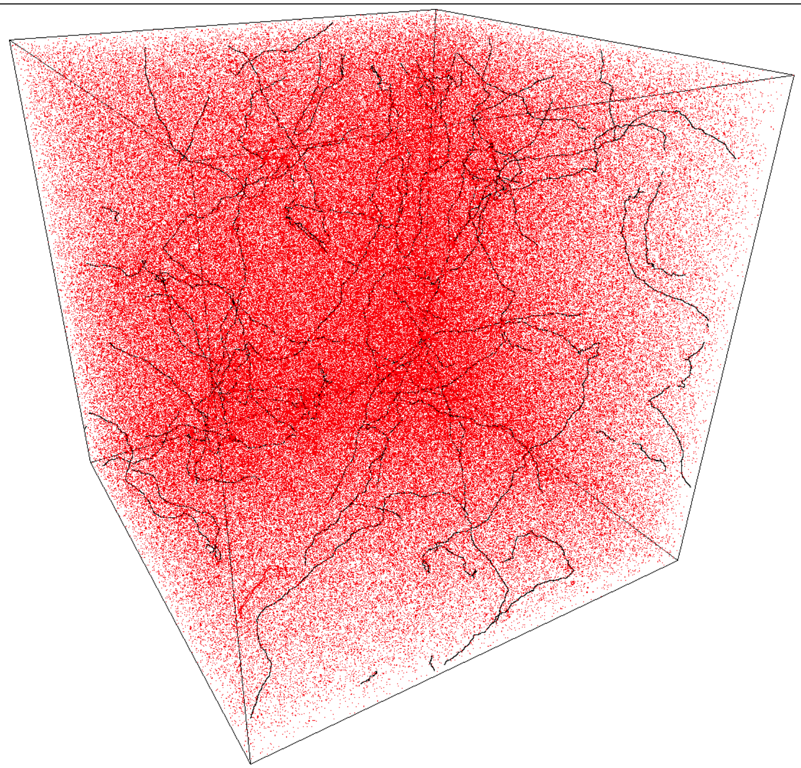
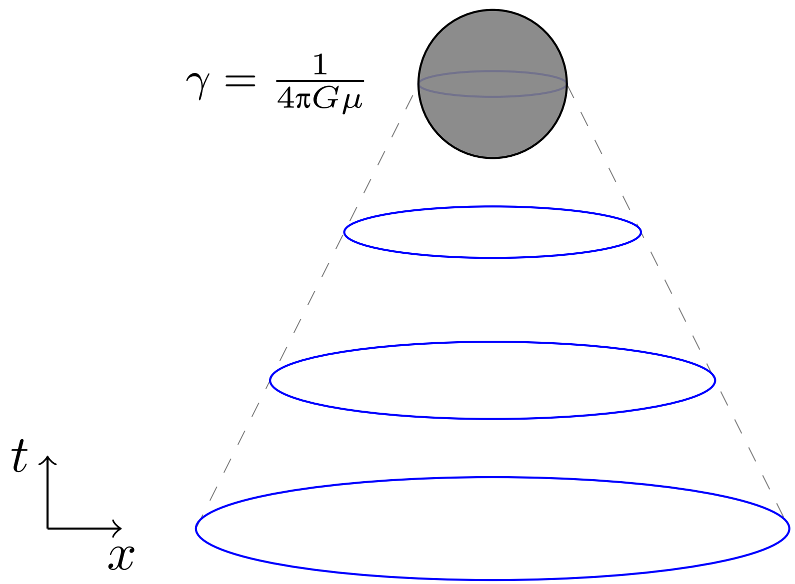


What are primordial black holes?

By "primordial", we mean any black hole which is *not* formed from stellar evolution. There are several exotic processes through which PBHs may have been formed in the early Universe, including the collapse of circular cosmic string loops (shown below). Our cusp-collapse mechanism occurs under much more generic conditions, resulting in many more PBHs than previously thought.

What are cosmic strings?

Cosmic strings are macroscopic, stable, line-like configurations of quantum fields that are predicted by many extensions to the Standard Model of particle physics. Detecting them would give us unprecedented insights into the laws of nature at extreme energies.



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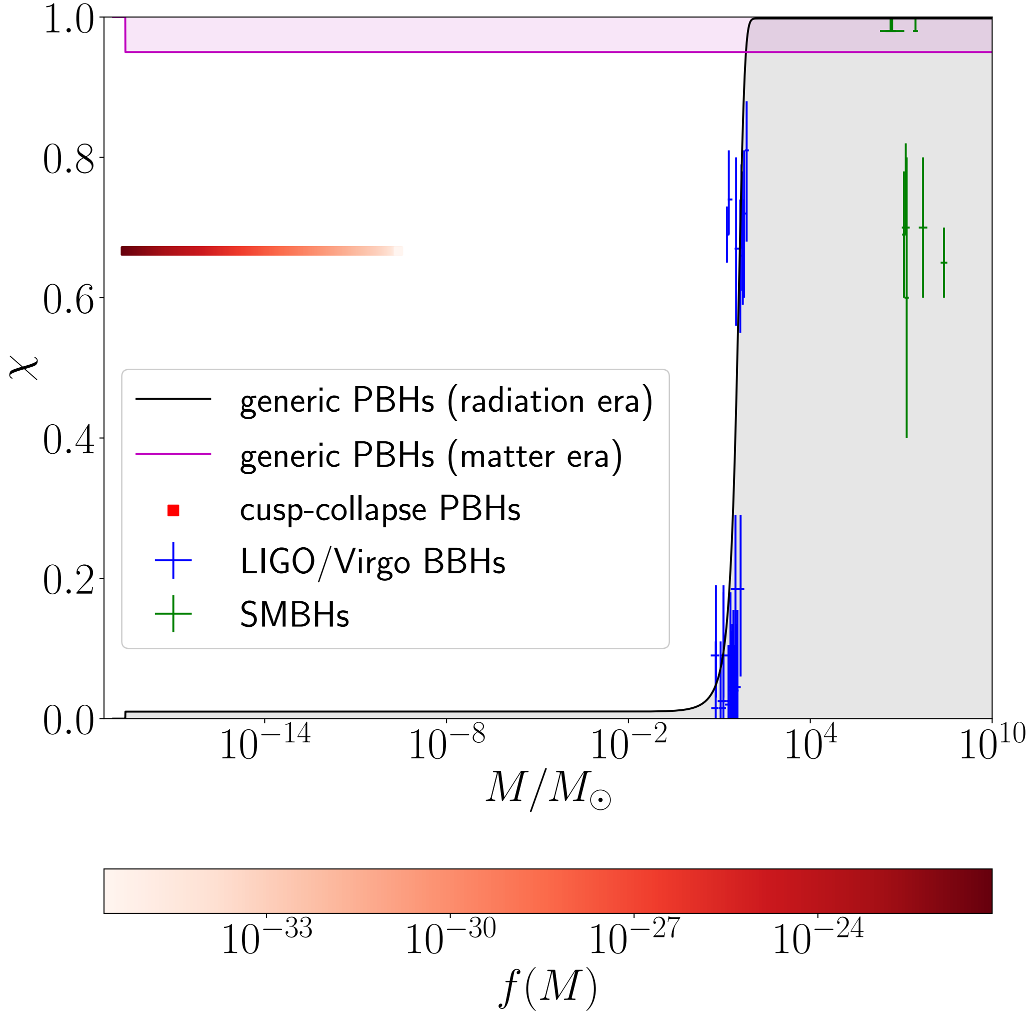
A unique black hole population



- We find that cusp-collapse PBHs have large spins $\chi = 2/3$, with $\chi = 1$ the maximum allowed by general relativity.
- This is in contrast with other PBH formation mechanisms, which lead to $\chi \approx 0$ (or in some scenarios, $\chi \approx 1$).
- Astrophysical black holes can have spins in this range, but their masses are much larger ($M_{\rm BH} \gtrsim 5 M_\odot$).
- This means cusp-collapse PBHs are a "smoking gun" signal of cosmic strings.
- Cusp-collapse PBHs are also born with velocities near the speed of light, which could lead to interesting observational consequences.

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Effects on the gravitational-wave signal

- Cusps on cosmic string loops are a promising source of gravitational waves (GWs) for observatories like LIGO/Virgo.
- Cusp collapse will leave clear imprints on the emitted GW signal, with important implications for LIGO/Virgo searches.
- Shown on the right is a heuristic model of the GW strain signal. The collapse happens just before the peak of the standard cusp signal.
- We also expect a high-frequency component from the quasi-normal ringing of the newly-formed PBH horizon.