Hyperbolic Encounters of Primordial Black Holes in Dark Matter Spikes

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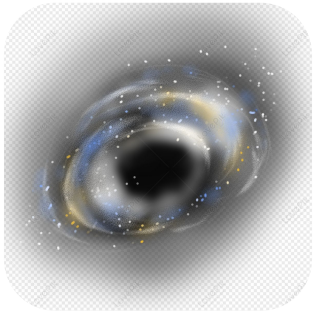
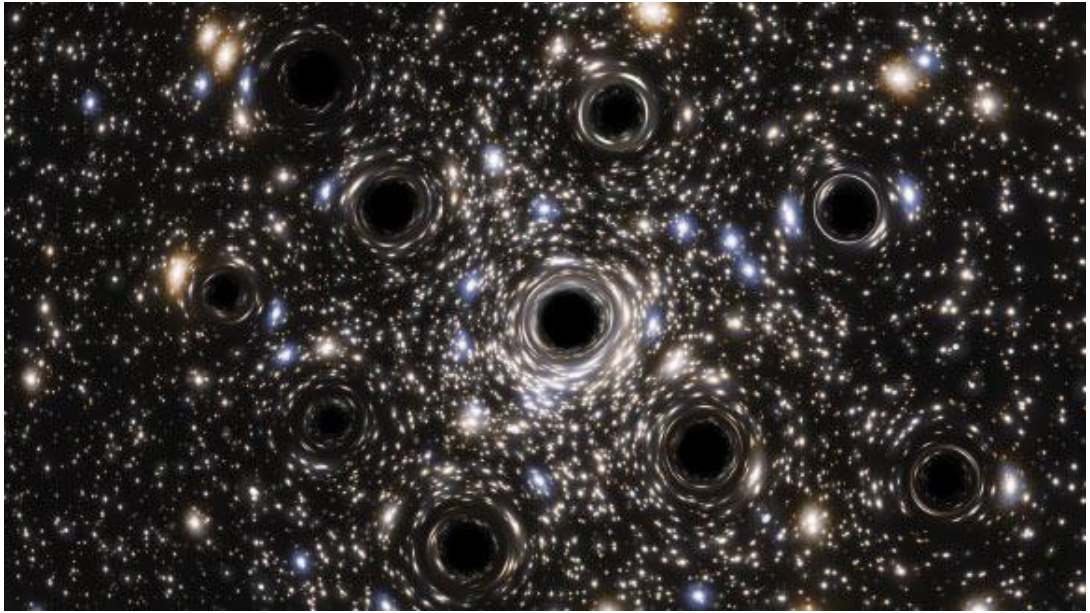


Working with Dr. Sinha, Dr. Xu, and Badal Bhalla

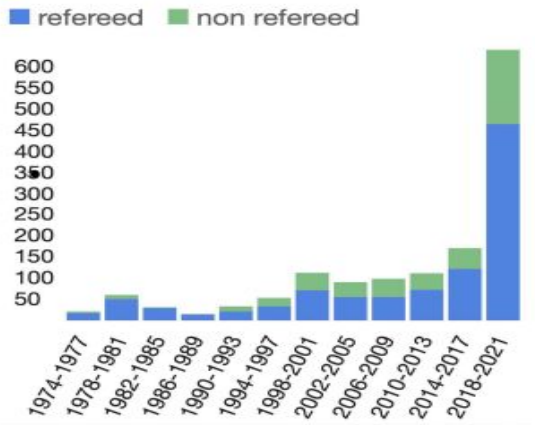
What Are Primordial Black Holes?

- Predicted by Hawking and Carr in the 1970s
- Hypothesized to be created during inflation
- Could solve some outstanding problems in physics



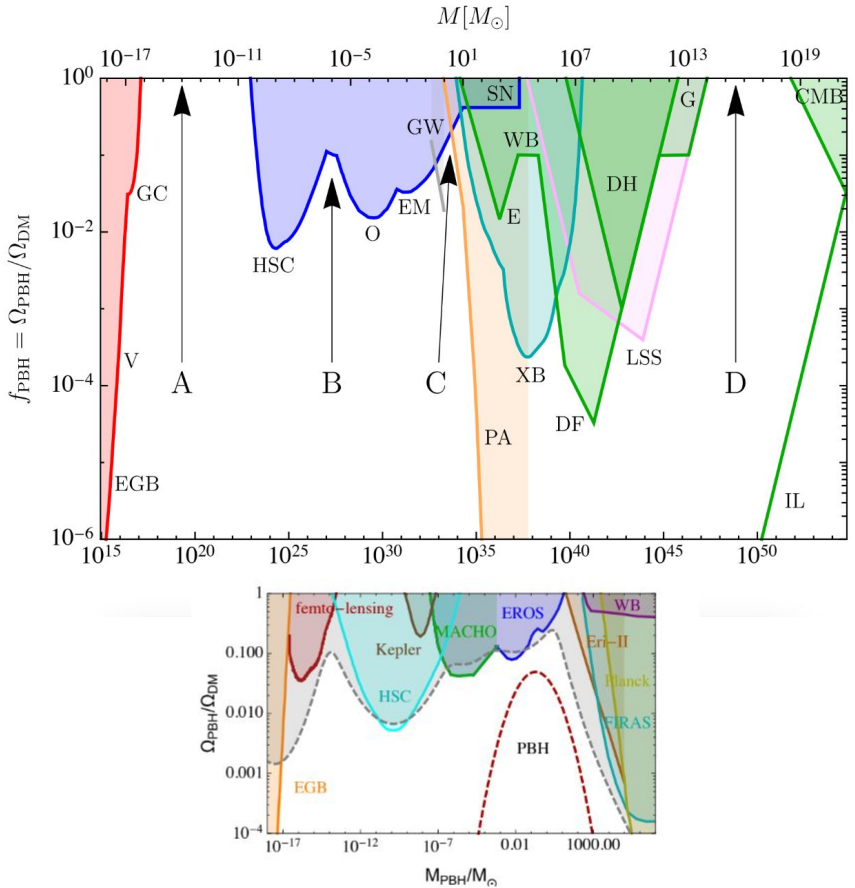
Why Primordial Black Holes?

- LIGO found gravitational waves from the merging of two 30 Solar Mass black holes
- Increased interest in Primordial Black Holes in recent years



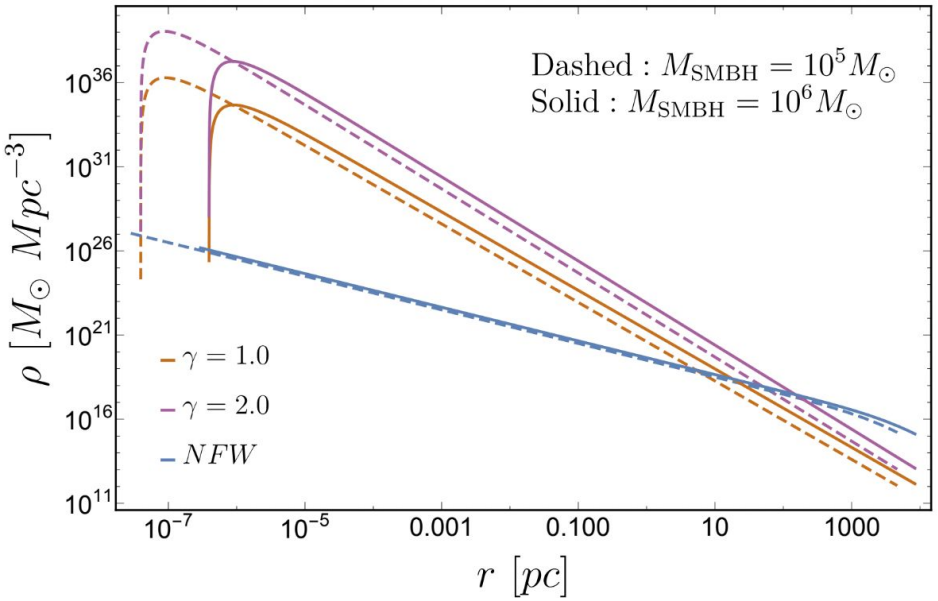
Primordial Black Holes as Dark Matter Candidates

- Primordial Black Holes have been considered as a Dark Matter candidate
- Hawking radiation constraints the lowest mass region and microlensing excludes the middle ranges
- So, we are looking at Primordial Black Holes in the asteroid/lunar mass region (A)



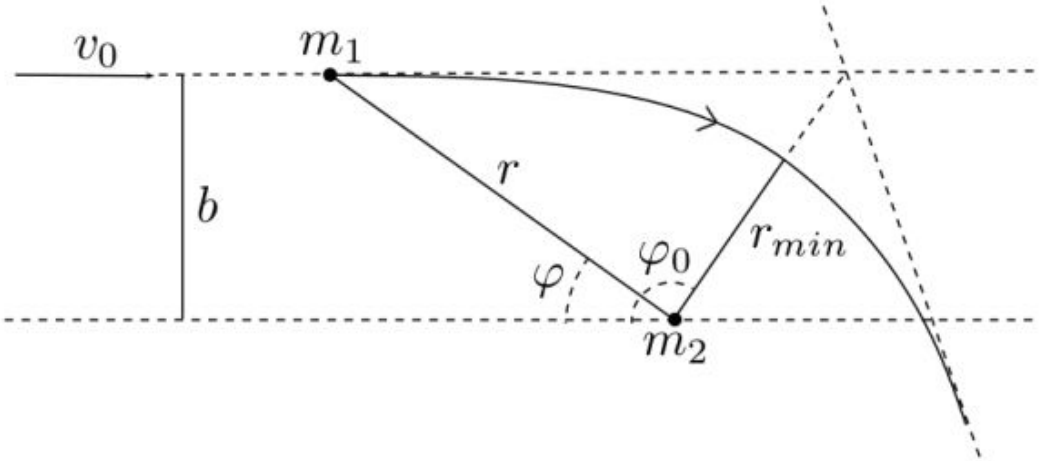
Dark Matter Spike Near Supermassive Black Holes

- Standard theory of dark matter distribution in halos is Navarro-Frenk-White profile
- We are looking at a Dark Matter spike distribution predicted by Gondolo and Silk due to N-body simulations



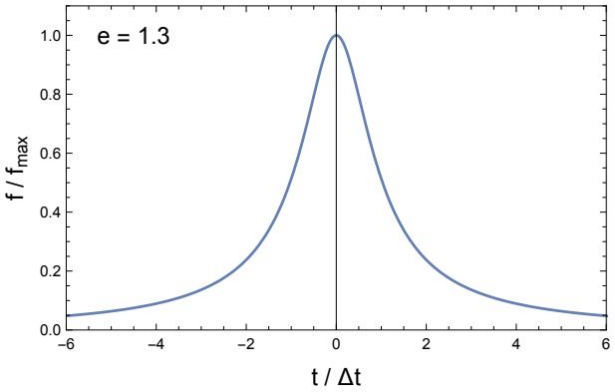
Hyperbolic Encounters of Primordial Black Holes

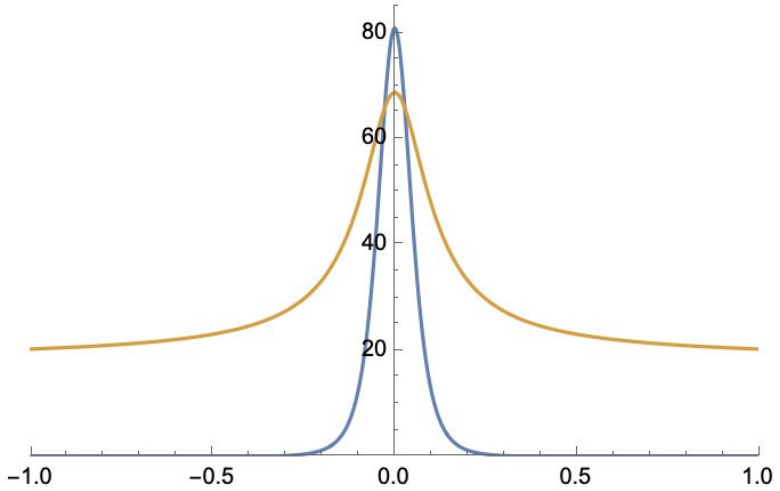
- When two black holes pass each other hyperbolically, a gravitational wave is released
- The signal of this gravitational wave depends on the mass, relative velocity, impact parameter (b), and observing distance



Hyperbolic Encounters of Primordial Black Holes

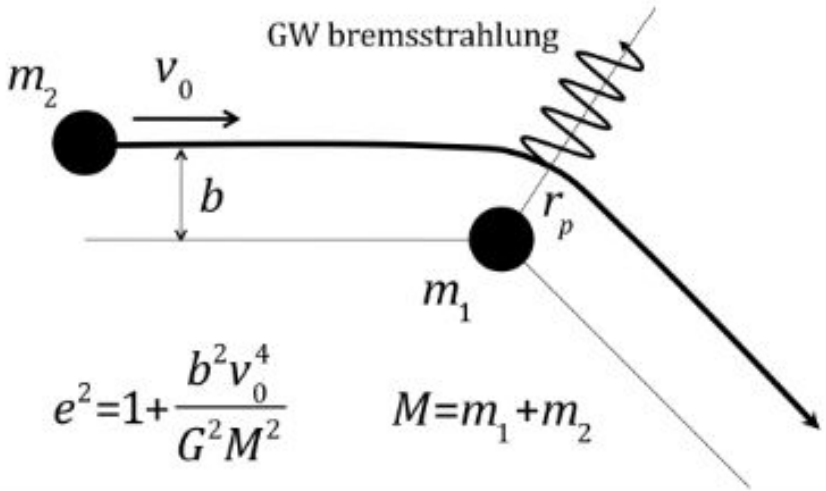
- Using the quadrupole moment of the system, I was able to reproduce calculations for the observables.
- The observables are strain, power, and frequency of the gravitational waves





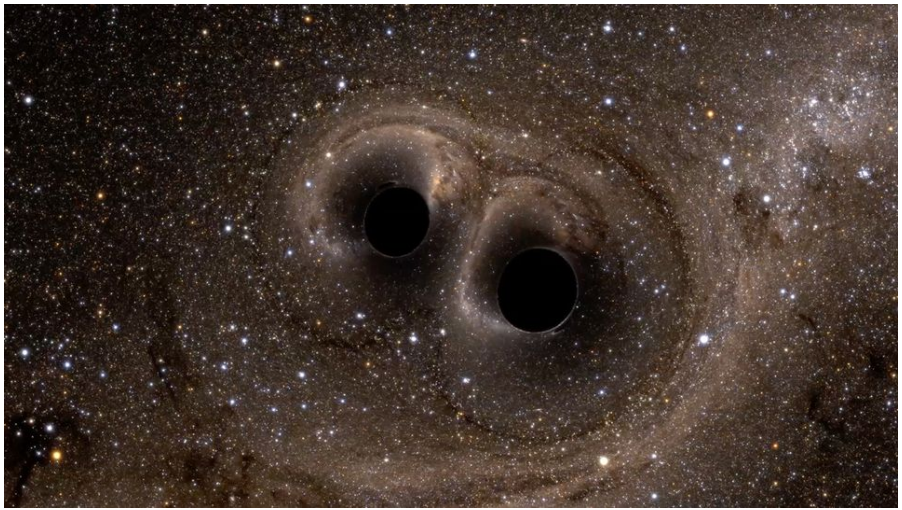
Hyperbolic Encounters of Primordial Black Holes

- Using these formulas, I was able to calculate values for what the power, strain, frequency of the events would be in the asteroid mass case
- This formulas would only depend on the five variables mentioned earlier
- These calculations have been done before, but not for the asteroid mass case



Stochastic Background from Events

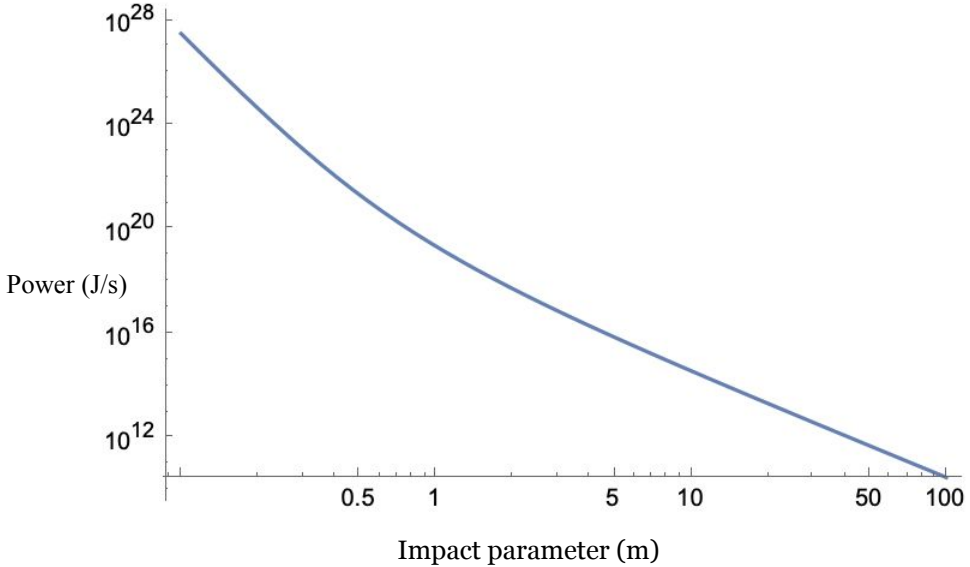
- If we know the effect of a single event, then we need to also understand how many events we expect to observe
- A previous paper has done a simplistic calculation of number of events for the merging case



Stochastic Background from Events

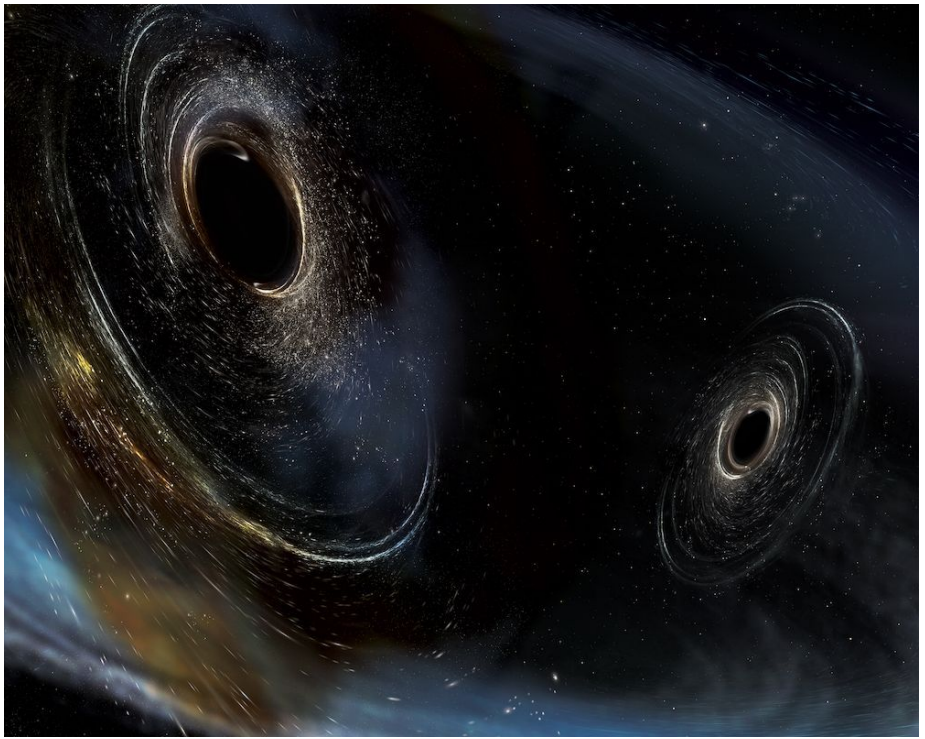
- For all variables we are concerned with the average over all events
- For velocity we can estimate the relative velocity of the two primordial black holes using the orbital velocity
- Power, strain, and frequency depend greatly on the impact parameter, so a balance between number and the strength of events is considered

$$N_{\rm sp} = \int_{4R_{\rm s}}^{R_{\rm sp}} \frac{1}{2}\left(\frac{\rho_{\rm sp}(r)}{M_{\rm PBH}}\right)^2 \sigma_m(r) v(r)\, d^3 r,$$



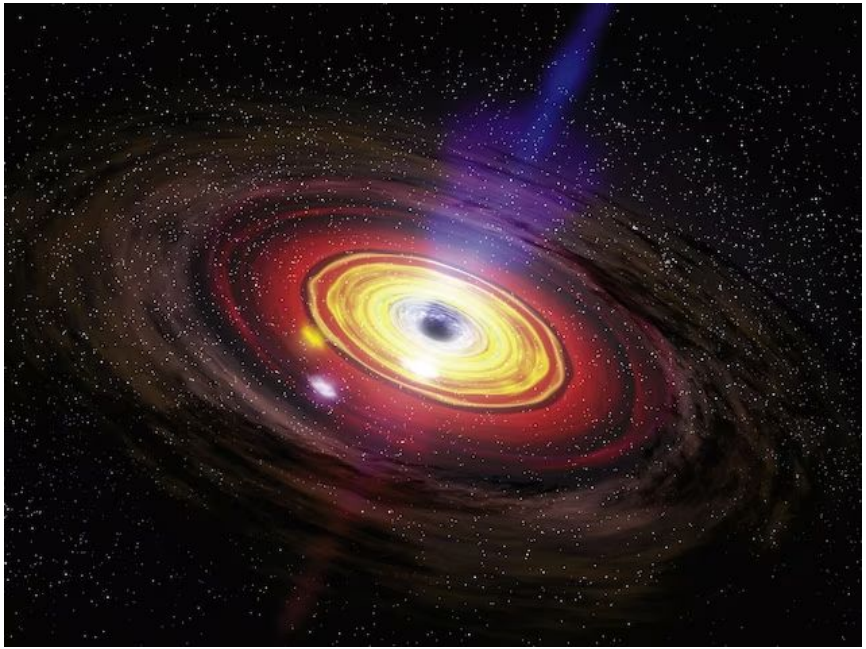
Future Factors to Consider

- Current plan is to specify a specific impact parameter and consider all events under that impact parameter and ignoring the cases which would lead to merging



Future Factors to Consider

- The particular dark matter spike distribution of matter would greatly affect the results so many must be considered
- Furthermore, the mass function of SMBHs is not well understood and this would also have a large impact



Why?

- The sum of all these hyperbolic interactions will hopefully be detectable by LISA
- LISA will launched in the 2030s to detect a new spectrum of gravitational waves
- Will reveal more about Primordial Black Holes, constraining them further or showing evidence towards their existence