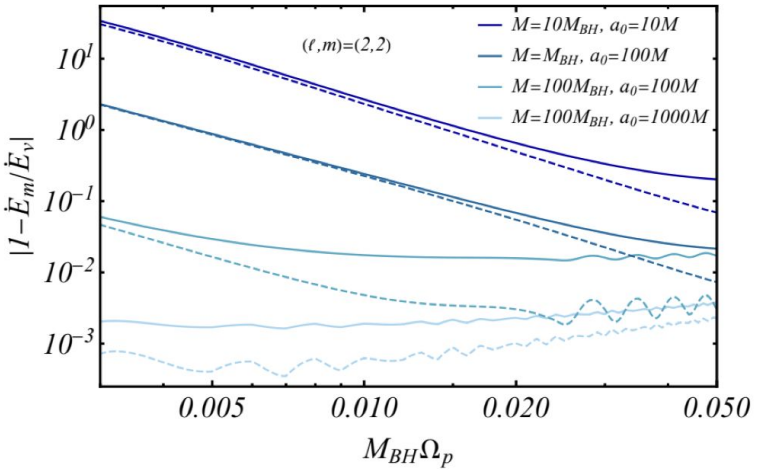
Discussion session: "Dark matter and PBHs"

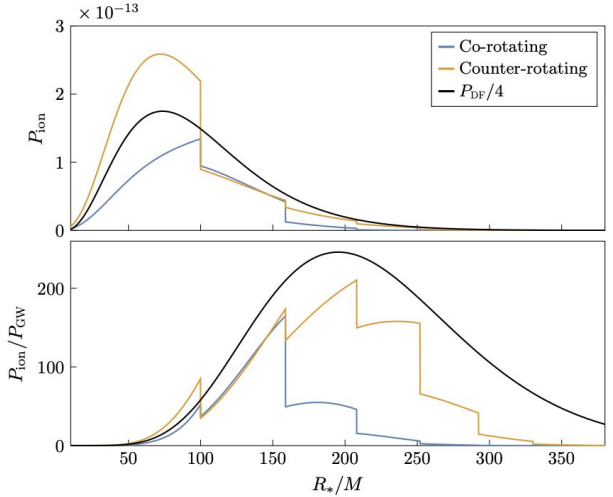
Chairs:
David Nichols & Richard Brito

Modelling

- Is it enough to consider (post-)Newtonian calculations when considering dark matter effects on IMRIs (effects typically only important at low-freqs)?
- Can we add PN calculations on top of self-force calculations for vacuum BH?
- How accurately do we need to model effects of DM in waveforms?
- Degeneracy with other astrophysical environments?



Cardoso+, PRL129, 241103 (2022)



Tomaselli+, arXiv:2305.15460

Particle Dark Matter

[w/ input from D. Blas]

- Are there more concrete models for the spikes, especially when feedback & other astrophysics can modify the DM density?
- Would this bring new phenomenology into waveforms that needs to be modeled & if so, how?
- Can we distinguish different DM models of similar types (i.e., not just ALPs or WIMPs or PBHs, but different types of ALPs, WIMPs, etc.)?
- If we detect DM spikes, what do we learn (e.g., mass, cross section, etc.)?
- If we don't detect DM spikes, what do we learn (i.e., is it only astrophysics preventing spike formation, or something more fundamental)?

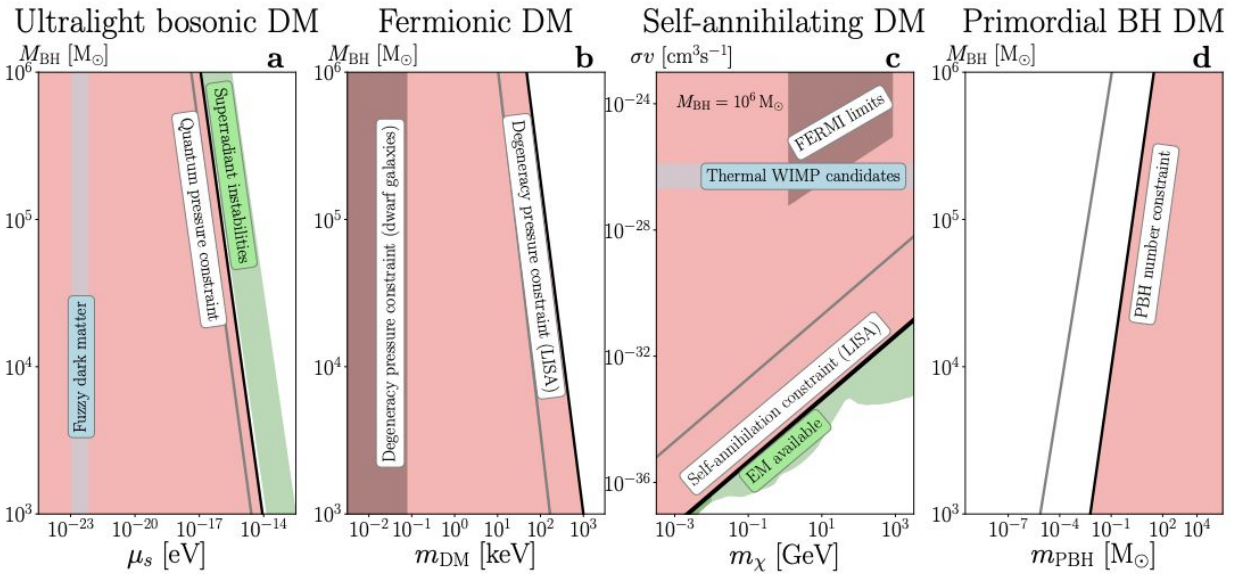


FIG. 2. New constraints (red shaded regions) on DM models if a DM spike is detected with an EMRI. For ultralight bosons (panel **a**), fermionic DM (panel **b**), and PBH DM (panel **d**), we exclude a region of the DM particle/PBH mass. The constraints depend on the mass of the detected central black hole, $M_{\rm BH}$ (the DM spike profile is uniquely predicted for given $M_{\rm BH}$ using the M–σ relation). For self-annihilating DM (panel **c**), the constraint is on the cross section-DM mass plane, assuming $M_{\rm BH} = 10^6\,{\rm M}_\odot$. If ultralight bosons exist in the $m_{\rm DM} \in [10^{-17}, 10^{-14}]$ eV range, they could be identified through superradiant-induced clouds (see Ref. [32]; panel **a**, green region). If the EMRI event is sufficiently nearby ($\simeq$ 90 Mpc), as expected of the closest EMRIs [59], electromagnetic counterparts from DM annihilation may be possible in some optimistic cases (panel **c**, green region). Previous lower limits (gray regions) on fermionic DM and upper limits on DM annihilation cross section are from Refs. [60, 61]. For all panels, the thick solid lines and thin gray lines correspond to $\gamma = 2$ and $\gamma = 1$ initial DM halo slopes, respectively. See text and Appendix for details.

From: O. Hannuksela, K. C. Y. Ng, T.G.F. Li, arXiv:1906.11845

Wave Dark Matter

[w/ input from D. Blas]

- Importance of taking all the dynamical effects from the halo/soliton/SR cloud into account in the dynamics?
- For boson clouds, it would be nice to have a pipeline that cross-correlates all signatures (BH spin measurements, monochromatic GWs, stochastic background, effects on binaries)
- Are our models too simplistic? Self-interactions, couplings to matter?
- What else should we be focusing on? E.g. Direct coupling of dark matter to detectors?

PBHs

- Are there “smoking gun” signatures of PBHs with LISA?
- E.g., if a scalar-induced SGWB is detected, how can we be confident that there also are accompanying PBHs?
- If a very high-z SMBBH merger is measured, could it also be explained through other astrophysics (e.g., is there a cut in z)?
- Any potential for multiband sources with sub-solar-mass PBHs?
- Other GW signatures for LISA not mentioned?