Measuring the dark matter environments of black hole binaries with gravitational waves

Adam Coogan (GRAPPA)

With Gianfranco Bertone, Daniele Gaggero, Bradley J. Kavanagh, and David A. Nichols

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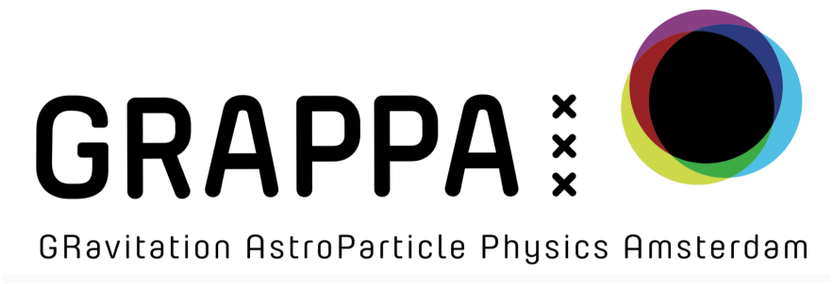
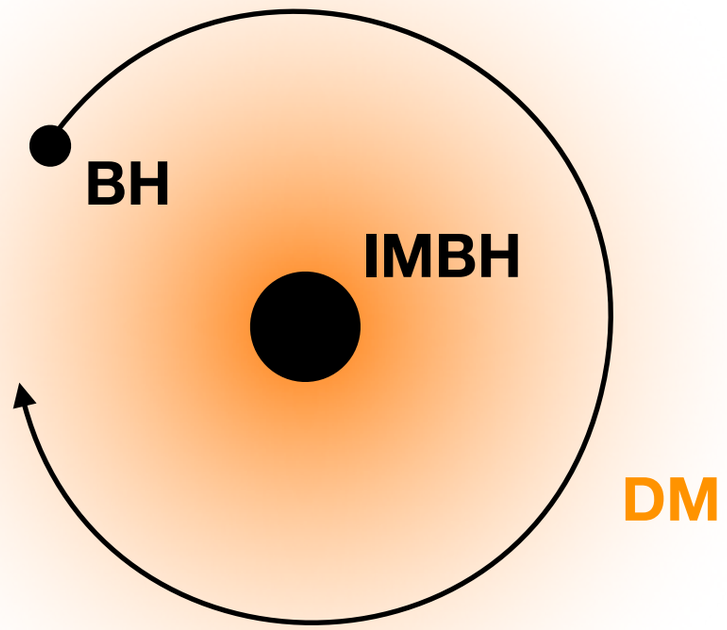
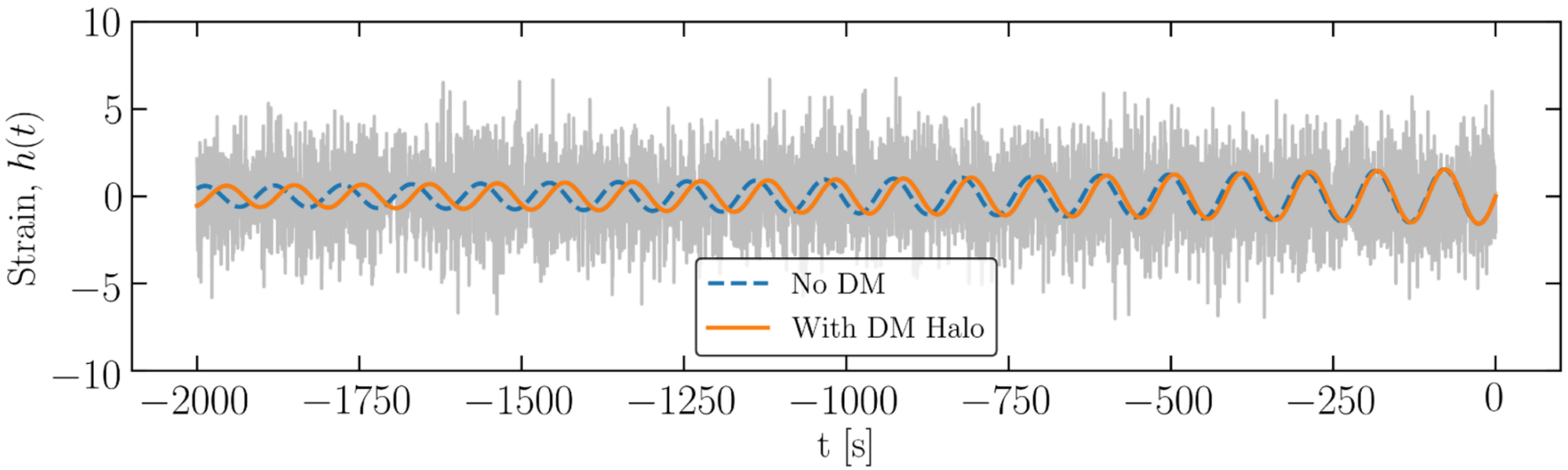


Dark dresses

- **Intermediate-mass black holes** could grow dense dark matter halos
- Gravitational waves signal **dephased** by halo's dynamical friction





Eg: Gondolo & Silk 9906391

Dephasing: Bradley Kavanagh

Observational questions

🔭 **Detectability:** which dark dresses could LISA see?

🔍 **Discoverability:** can we distinguish from GR-in-vacuum?

📏 **Measurability:** how well can parameters be measured?

Dark dress evolution

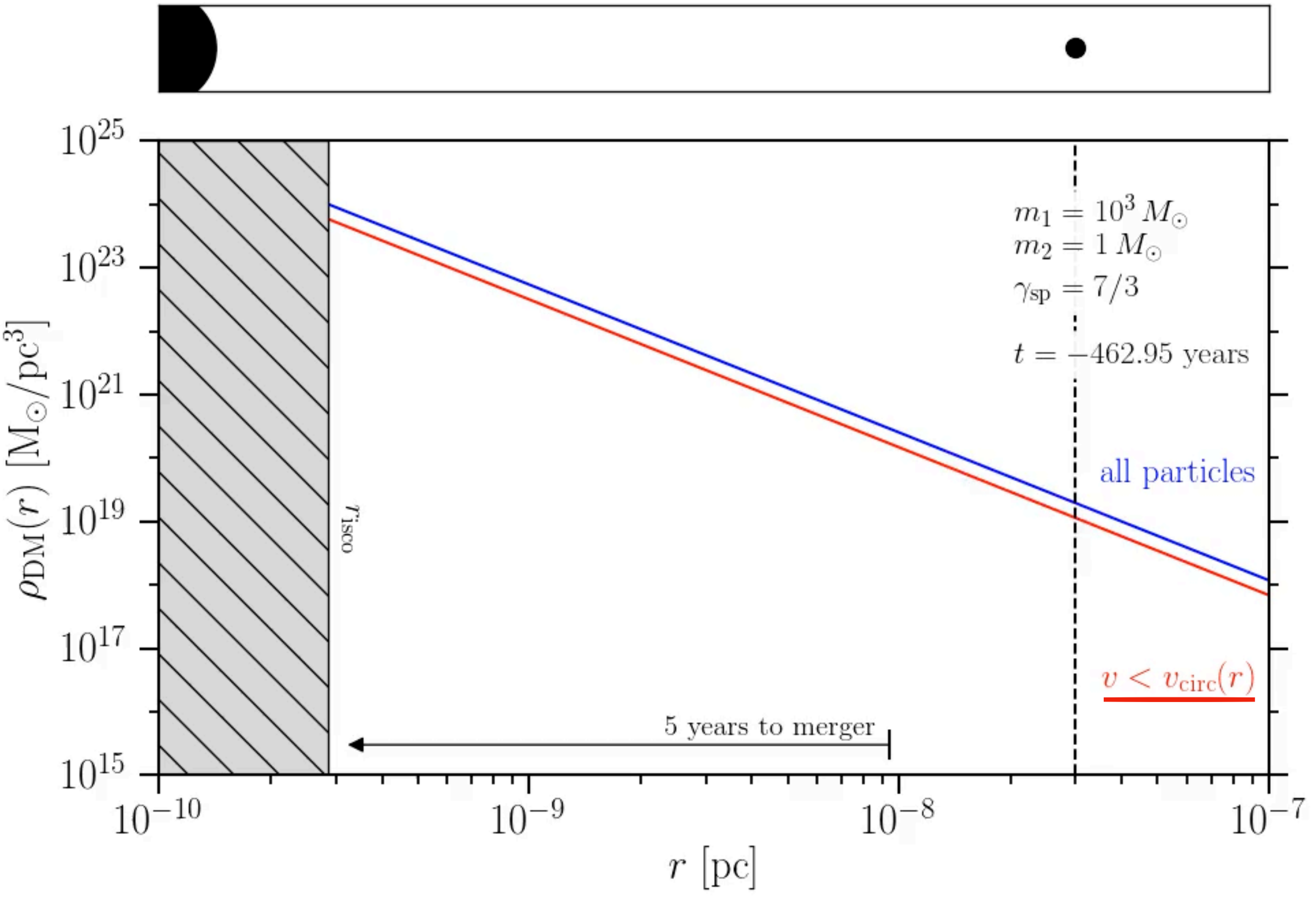
- Eda et al 1408.3534: non-evolving DM halo
- Kavanagh et al 2002.12811: **cannot ignore** halo evolution
- Numerical model: co-evolves DM phase-space distribution* with binary separation at Newtonian order

~~**Model runtime: ~days / system**~~

Instead: develop fast waveform model

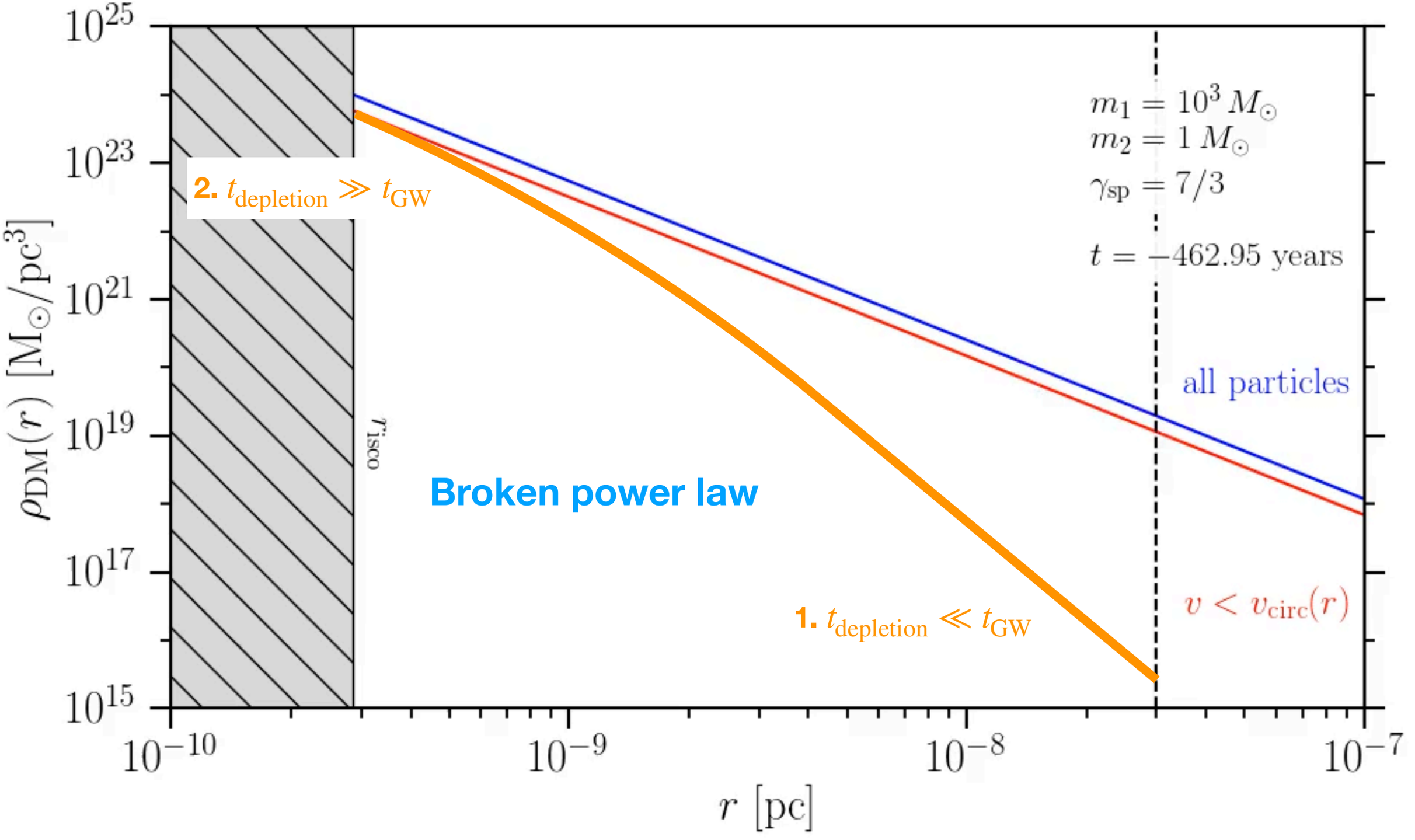
https://github.com/bradkav/HaloFeedback

* Spherically-symmetric, isotropic



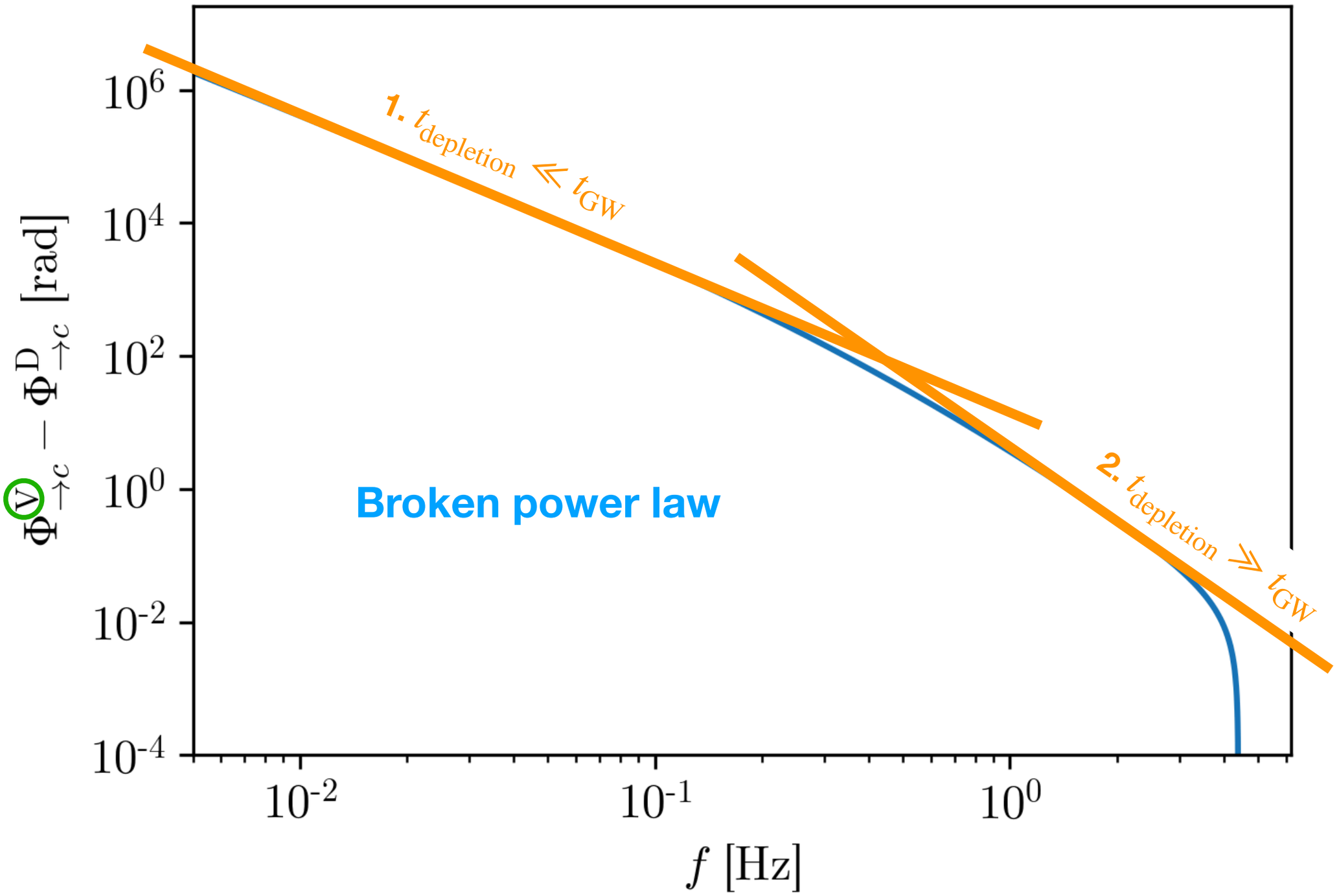
Animation: Bradley Kavanagh

Effective density profile



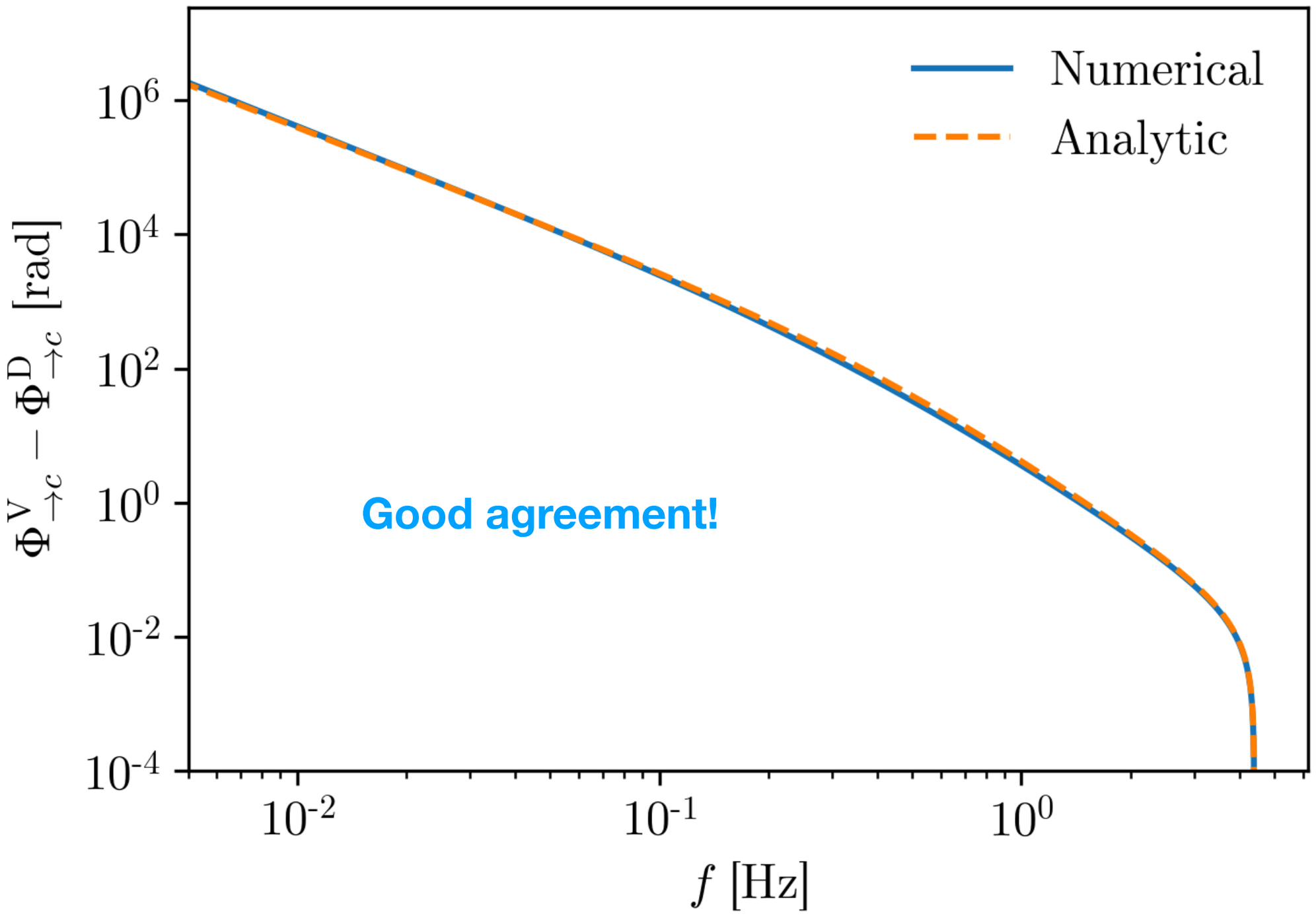
Animation: Bradley Kavanagh

Dephasing features



System w/o DM

Waveform model



Analysis

🔭 **Detectability:** which dark dresses could LISA see?

- Signal-to-noise ratio

🔎 **Discoverability:** can we distinguish from GR-in-vacuum?

- Bayes factor

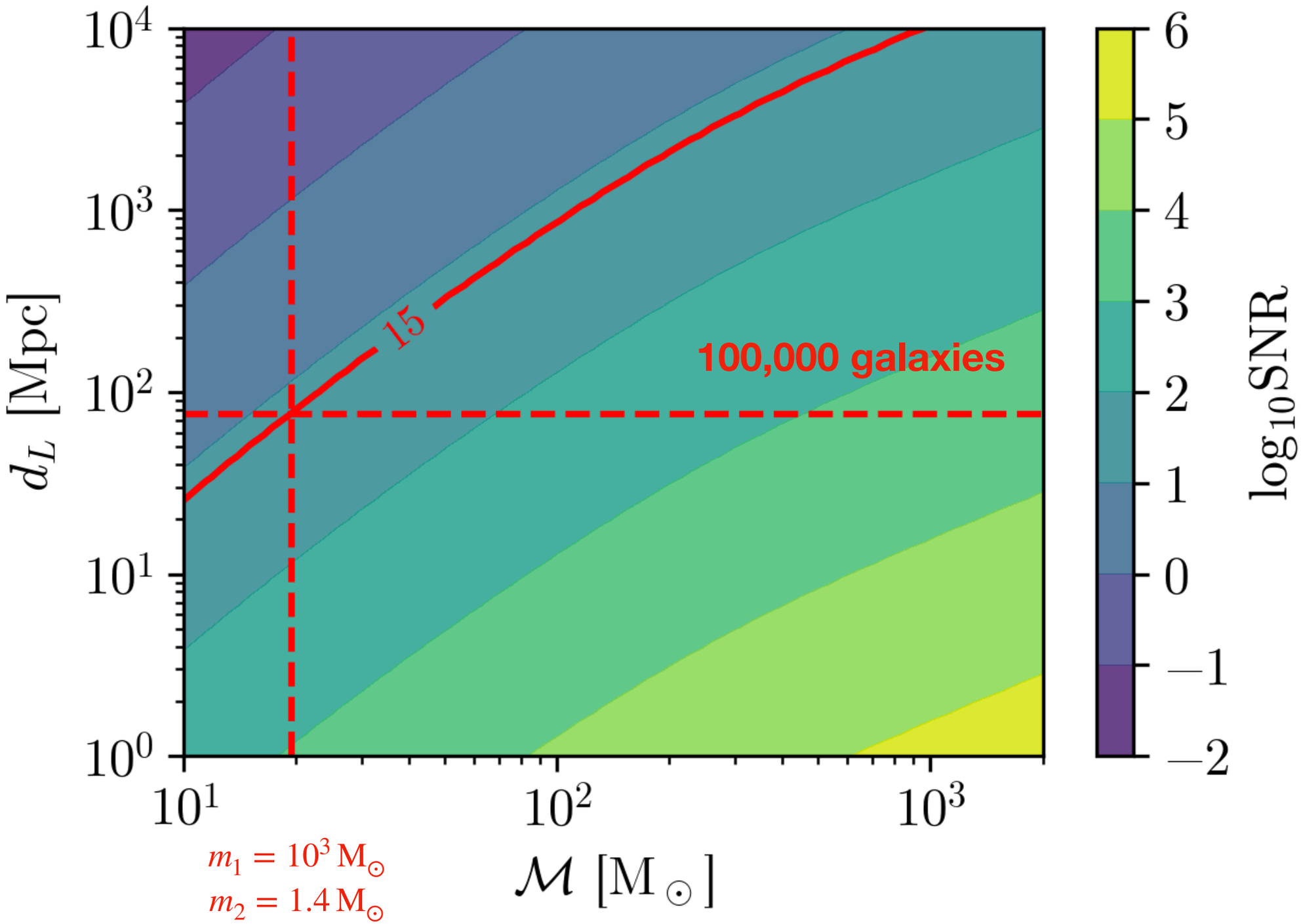
📏 **Measurability:** how well can parameters be measured?

- Posterior over $(\underbrace{\gamma_s,\ \rho_6,}\ \mathscr{M},\ \log_{10} q)$

Initial halo slope & normalization

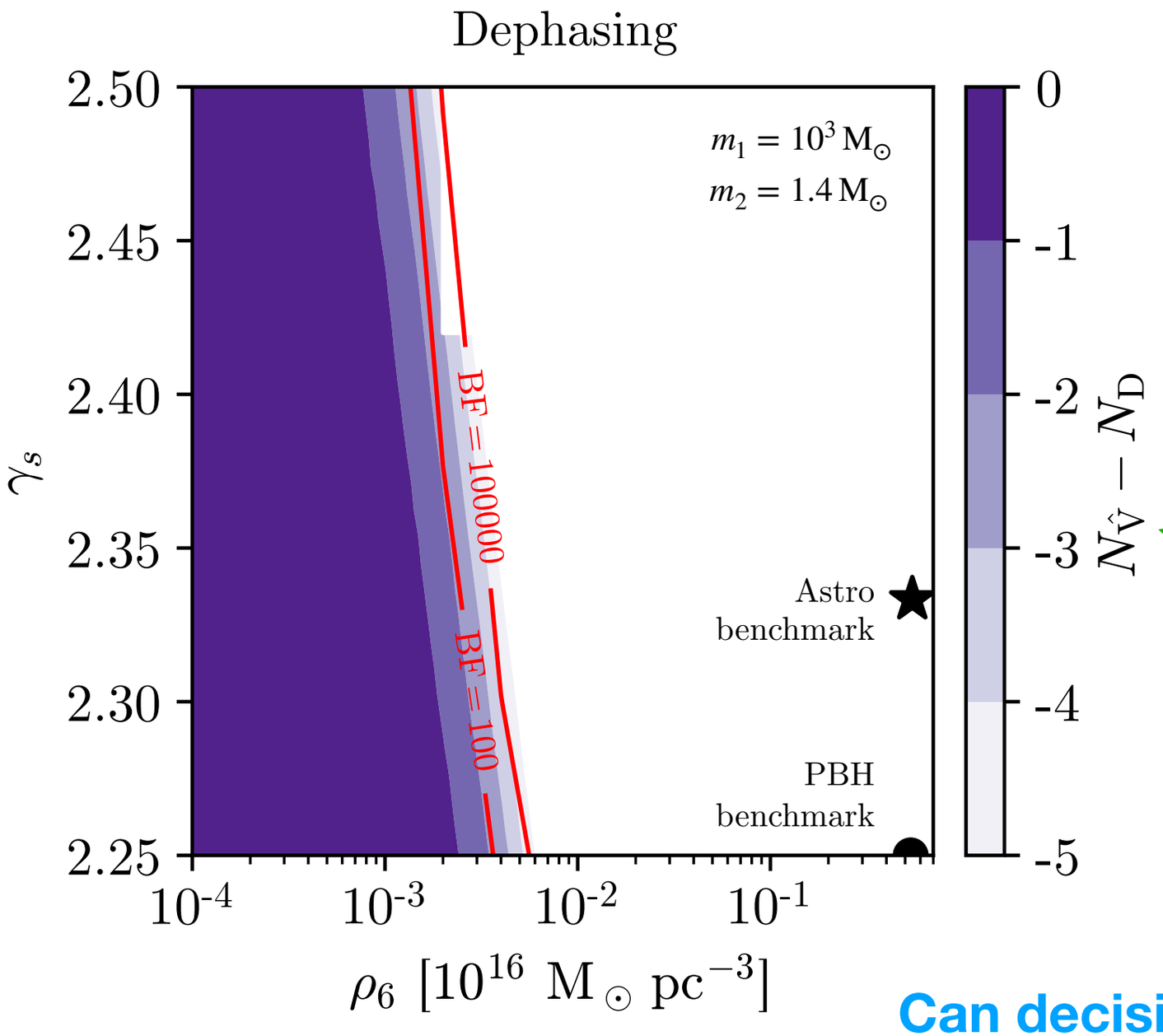
* Likelihood maximized over extrinsic parameters

🔭 Detectability



Eg: Moore et al 1905.11998

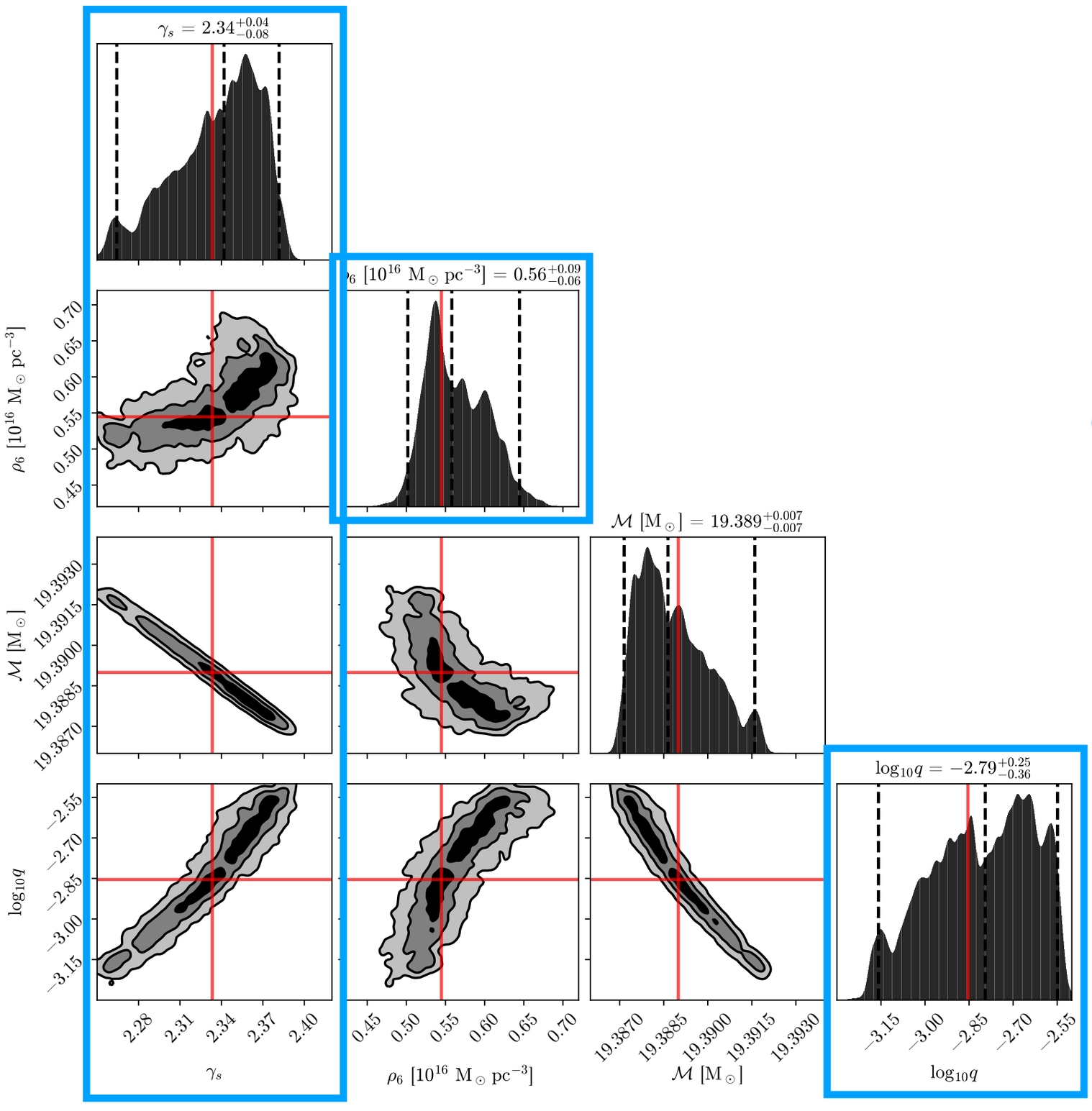
🔍 Discoverability



Can decisively distinguish benchmarks from GR-in-vacuum binaries

Astro: Eda et al 1408.3534
PBH: Adamek et al 1901.08528

Measurability



Can measure halo slope

Clearly measure density normalization

Mass ratio measurement at Newtonian order

Astro: Eda et al 1408.3534

Conclusions

- Developed **effective model** to study detection questions:
  - Dark dresses within ~100 Mpc are ***detectable***
  - Can ***discover*** that fiducial systems are not GR-in-vacuum
  - Can ***measure*** DM density profile normalization, slope and even mass ratio
- First step: motivation to refine modeling and analysis

Thanks!