Exploring the dark side with the Nancy Grace Roman Space Telescope

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Summary and main results

- We may have already seen evidence of macroscopic dark matter in OGLE observations (Niikura et al. 2019).
- However, it is at present difficult to disentangle from the distribution of Earth-mass free-floating planets.
- Roman's Galactic Bulge Time Domain Survey will allow *statistical* discrimination of these two populations.
- **Roman will be able to unambiguously determine the nature of this population.**

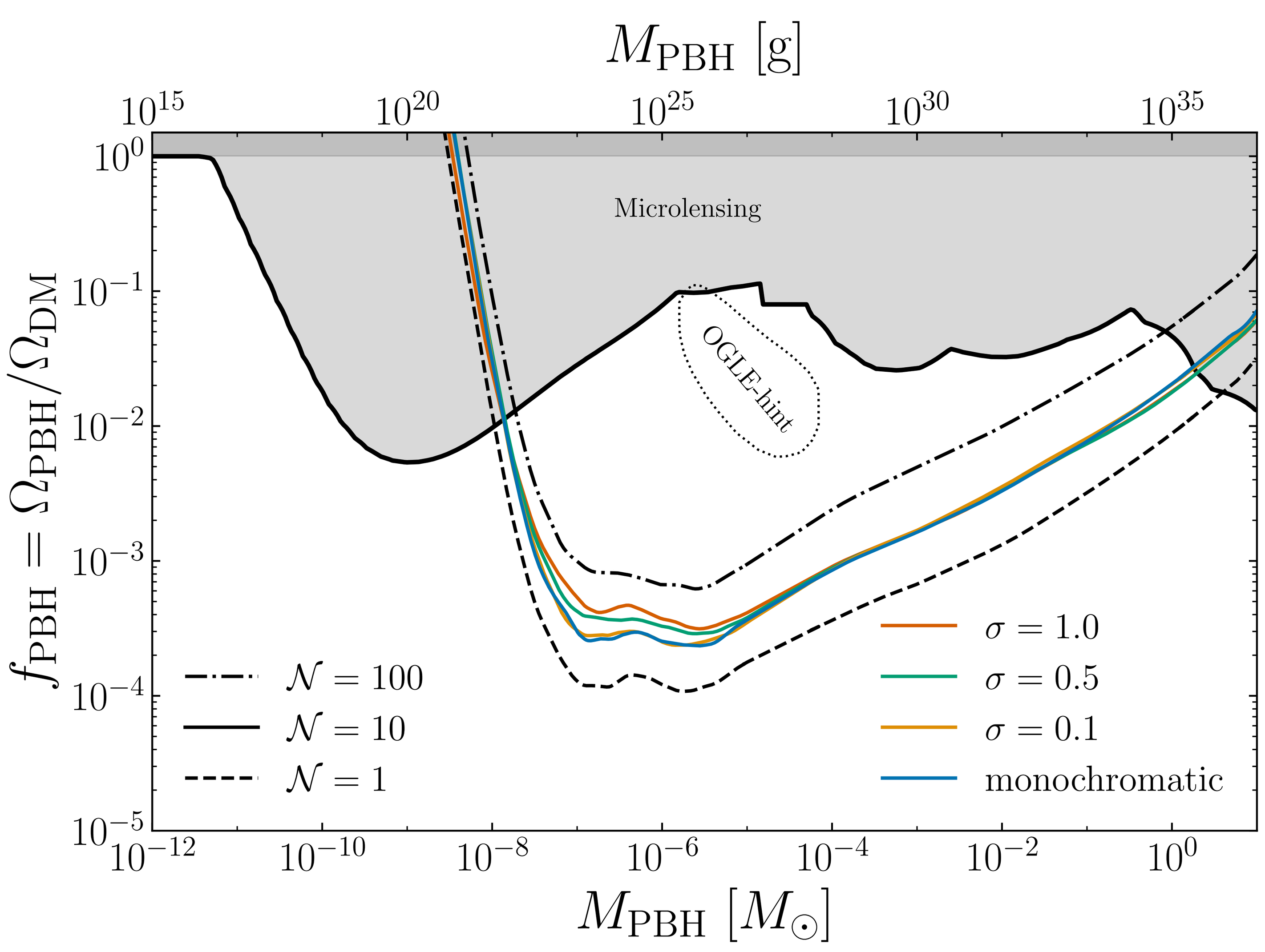

Figure 1: Dark matter parameter space in which the Roman GBTDS will yield sufficient statistics to identify a subpopulation of macroscopic dark matter within a background of free-floating planets.

1. Primordial black holes

- *Primordial black holes (PBHs)*: black holes formed in the early universe by new physics.
- Well-motivated candidate for dark matter (or sub-fraction $f_{\rm PBH}$).
- **We may have already seen a first hint of this population in OGLE observations.** (Niikura et al. 2019)

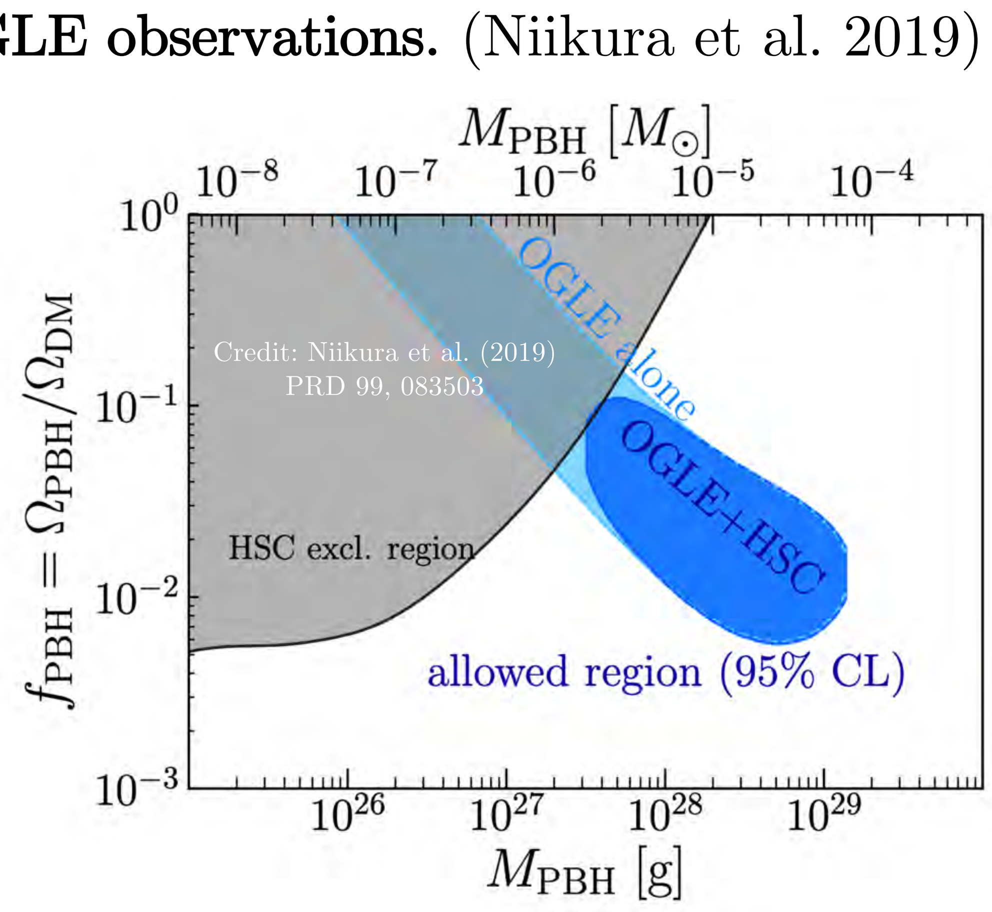

Figure 2: Blue region indicates mass range and abundance of PBHs that could explain the 6 ultrashort-timescale OGLE events.

2. Free-floating planets

- *Free-floating planets (FFPs):* planets and planetesimals that were ejected from their birth system during planet formation.
- Theory and observation indicate a large population of such objects, with **$\gtrsim 1 - 10$ Earth-mass FFPs per star**.

3. Galactic Bulge Time Domain Survey

- Nancy Grace Roman Space Telescope: NASA's next flagship mission, launches in 2027.
- *Galactic Bulge Time Domain Survey (GBTDS)*: 6 x 72-day microlensing observation of Galactic Bulge.
- Expected to detect **$\sim 100 - 1000$ FFPs** and may detect up to **$\sim$ 10,000 PBHs** if PBHs saturate current limits.

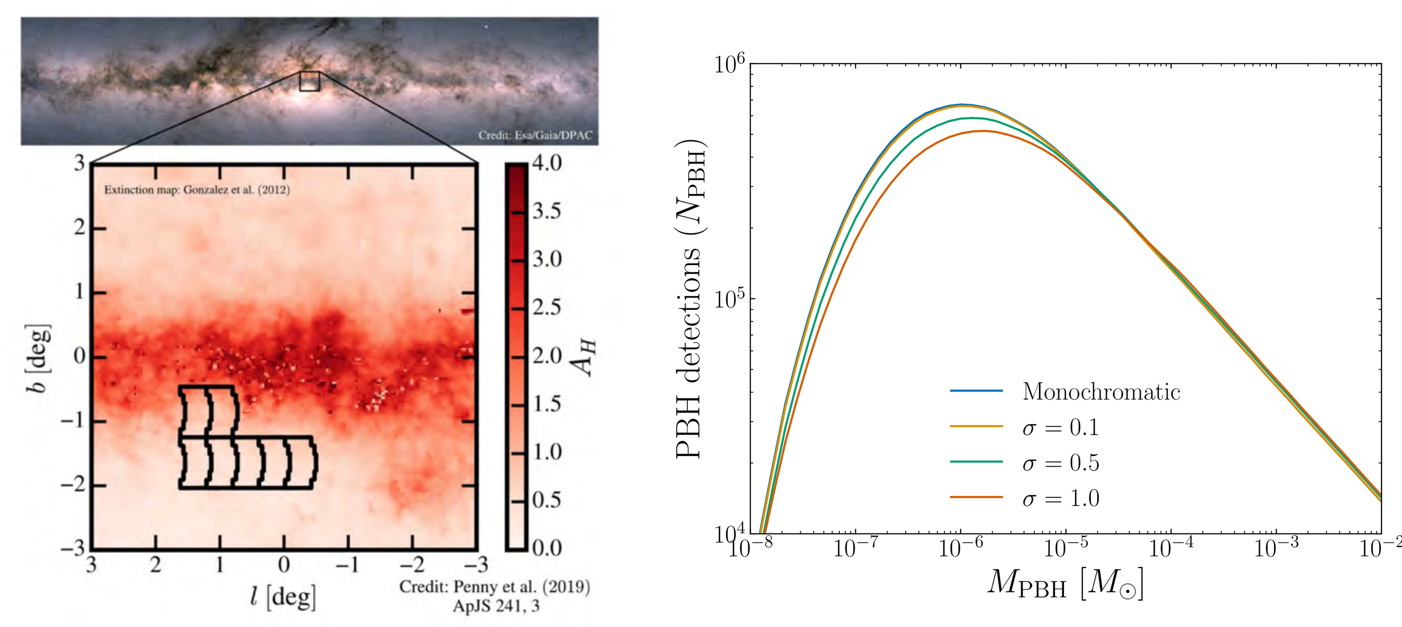

Figure 3: *Left:* Observation fields of Galactic Bulge Time Domain Survey. *Right:* Number of PBHs detected given log-normal mass distributions of various widths σ and $f_{\rm PBH} = 1$.

4. Discriminating PBHs from FFPs

- Nature of lens cannot be discerned from single events, *however* **PBHs and FFPs have different mass functions.**

PBH: *log-normal*
$$\frac{dN_{\rm PBH}}{d\log M} = \frac{\mathcal{N}_{\rm PBH}}{\sqrt{2\pi}\sigma}\exp\left[-\left(\frac{\log(M/M_c)}{\sqrt{2}\sigma}\right)^2\right]$$

FFP: *power-law*
$$\frac{dN_{\rm FFP}}{d\log M} = \mathcal{N}_{\rm FFP}\left(\frac{M}{M_\oplus}\right)^{-p}$$

- The GBTDS will yield sufficient detections to *statistically discriminate* these two populations.

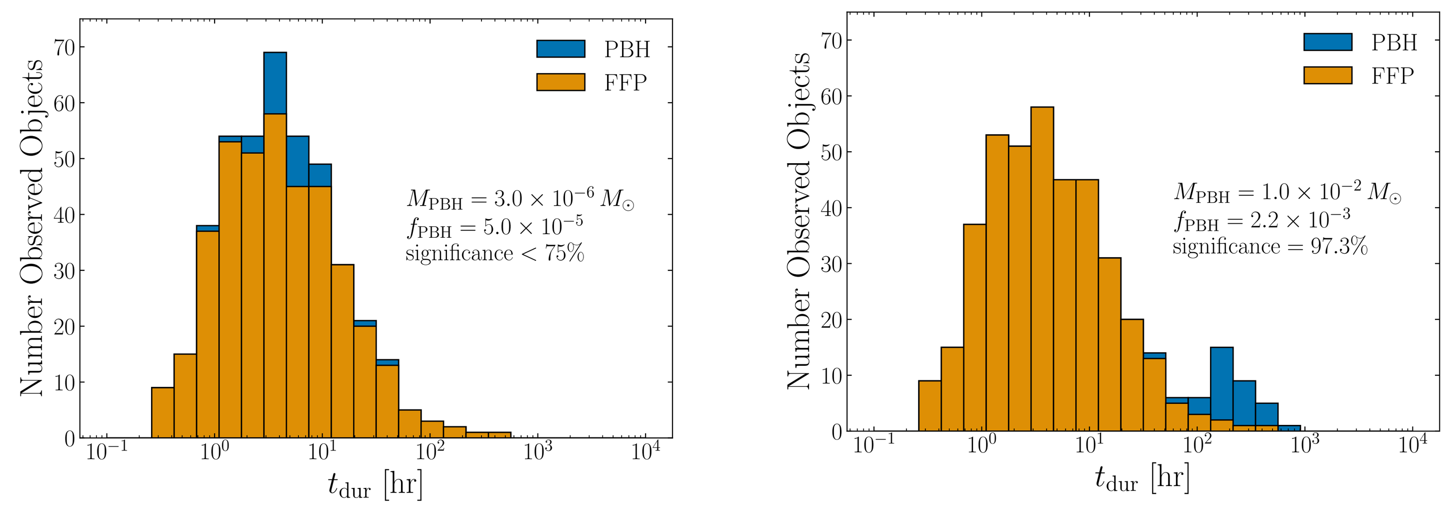

Figure 4: Distributions of observation times for FFP (orange) and PBH (blue) populations. *Left:* The two populations **cannot** be statistically separated. *Right:* The two populations **can.**

Bonus: extended DM lenses

- Dark matter may be composed of macroscopic objects with extension comparable to the Einstein radius (e.g. boson stars, axion minihalos, etc.)
- Roman will be sensitive not only to detecting such candidates, but also to **unique caustic features that reveal DM microphysics.**

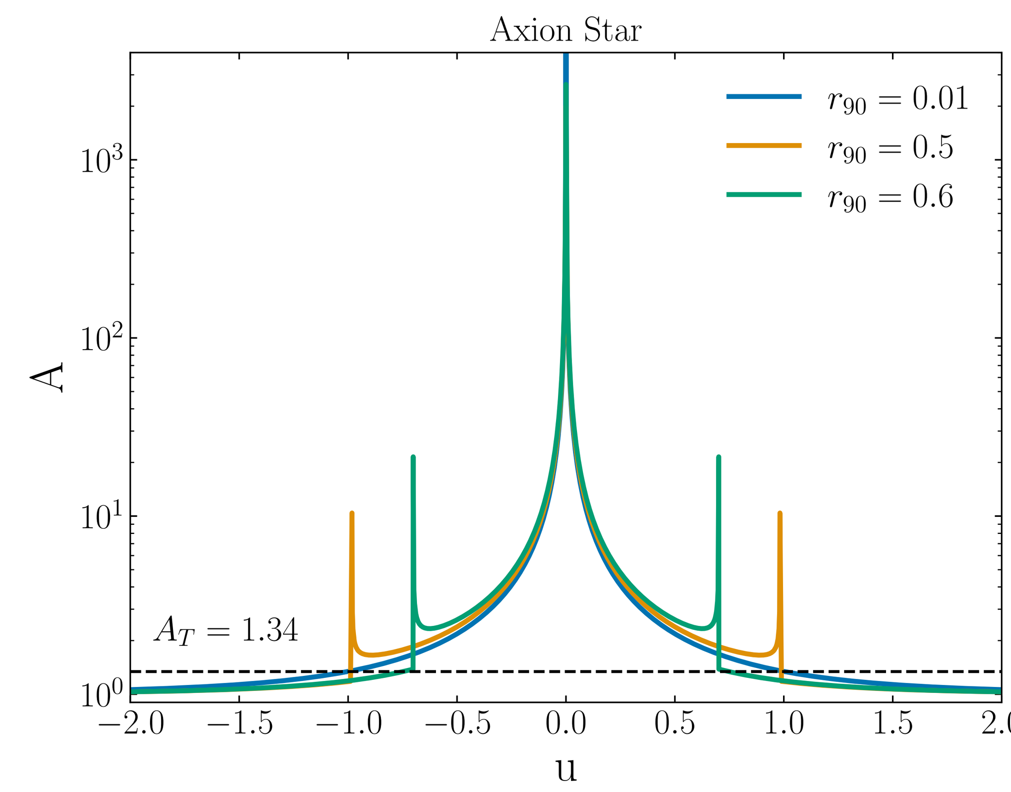

Figure 5: Magnification curve for fiducial axion star. The position of the symmetric caustic features is sensitive to underlying axion couplings.