Hunting for isolated black holes with gravitational microlensing

Casey Lam (UC Berkeley)

with Jessica Lu, Andrzej Udalski, Ian Bond, David Bennett, Jan Skowron, Przemek Mroz, Radek Poleski, OGLE collaboration, MOA collaboration, Matt Hosek, Natasha Abrams, Shrihan Agarwal, Sam Rose, and Sean Terry

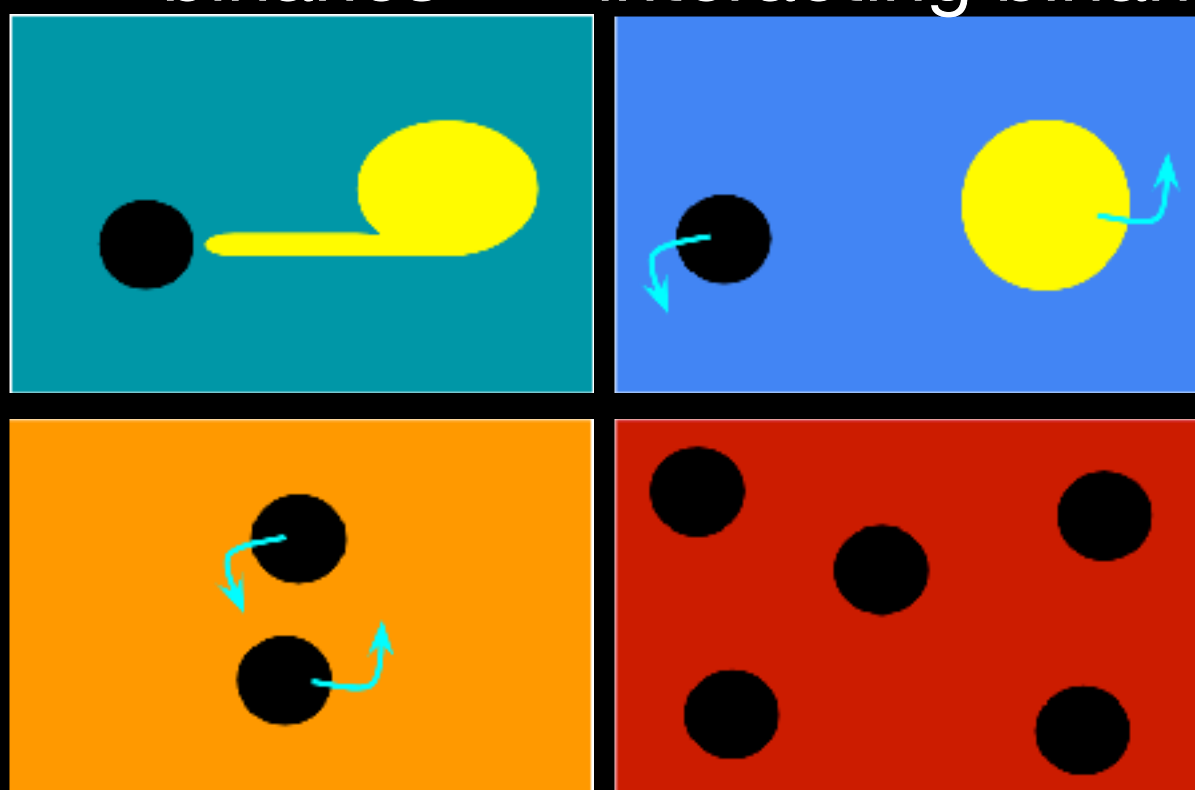
Funding support from:

Submitted to AAS journals
Preprint: arXiv 2202.01903

How many black holes are there in the Milky Way?

X-ray/accreting binaries

Wide/non-interacting binaries



Compact object binaries

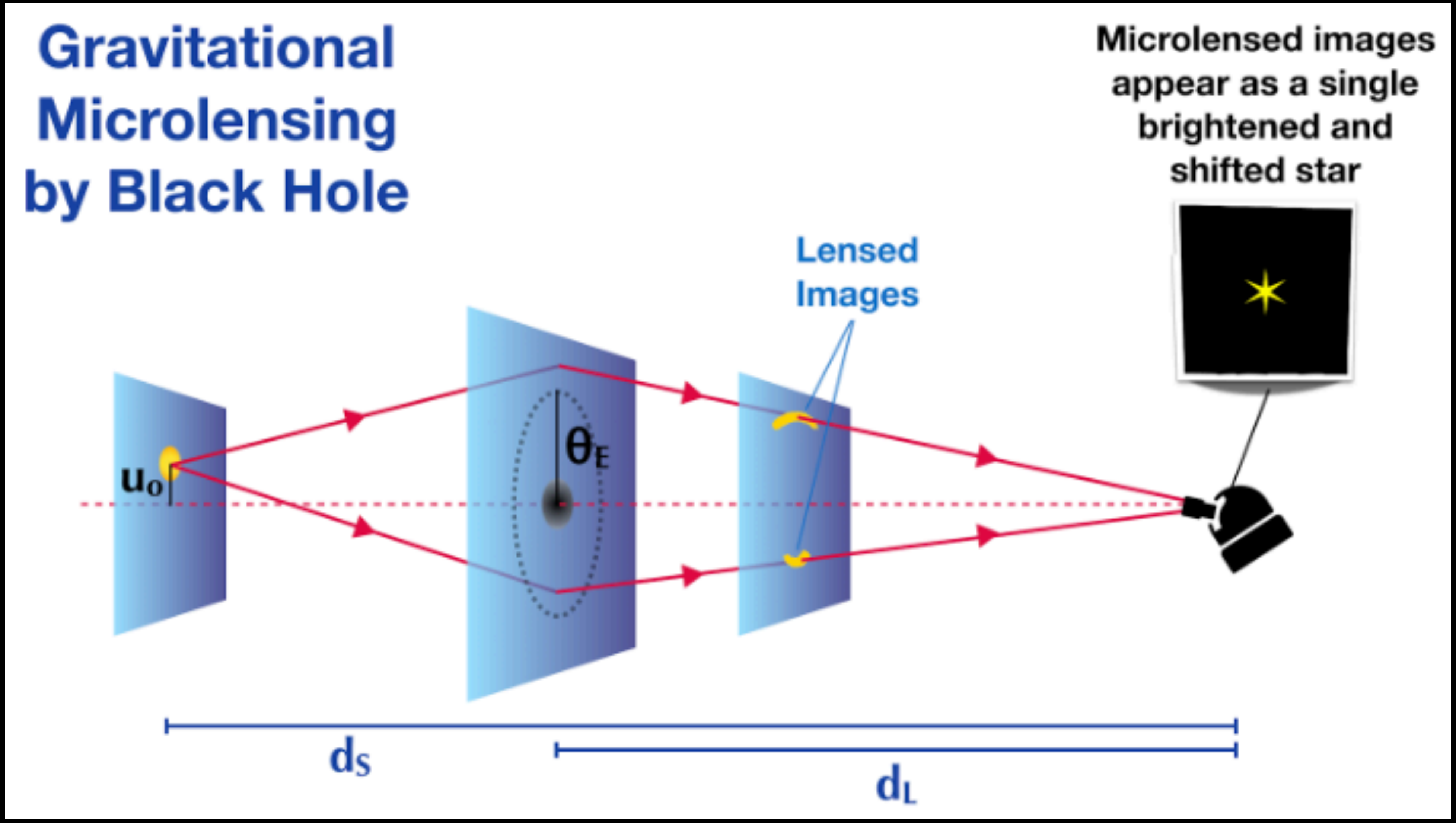
Isolated BHs

- Predicted: ~10^8 BHs in the Milky Way
- Known: ~2 dozen in binaries

- What is the BH mass function?
- What is/are the BH formation channel(s)?
- Do BHs get kicks? (If yes how big?)

Need to find the isolated black holes!

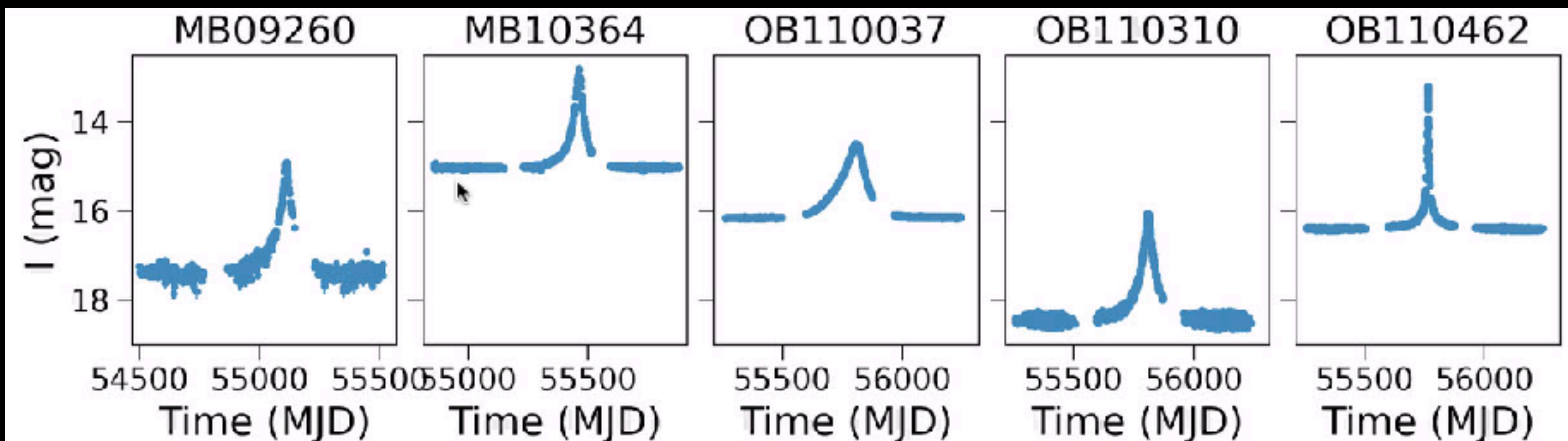
Use microlensing to find isolated BHs



Gravitational lensing depends on mass (not luminosity) of lens
--> Good for finding dark isolated objects (i.e. black holes)

A sample of 5 BH candidates

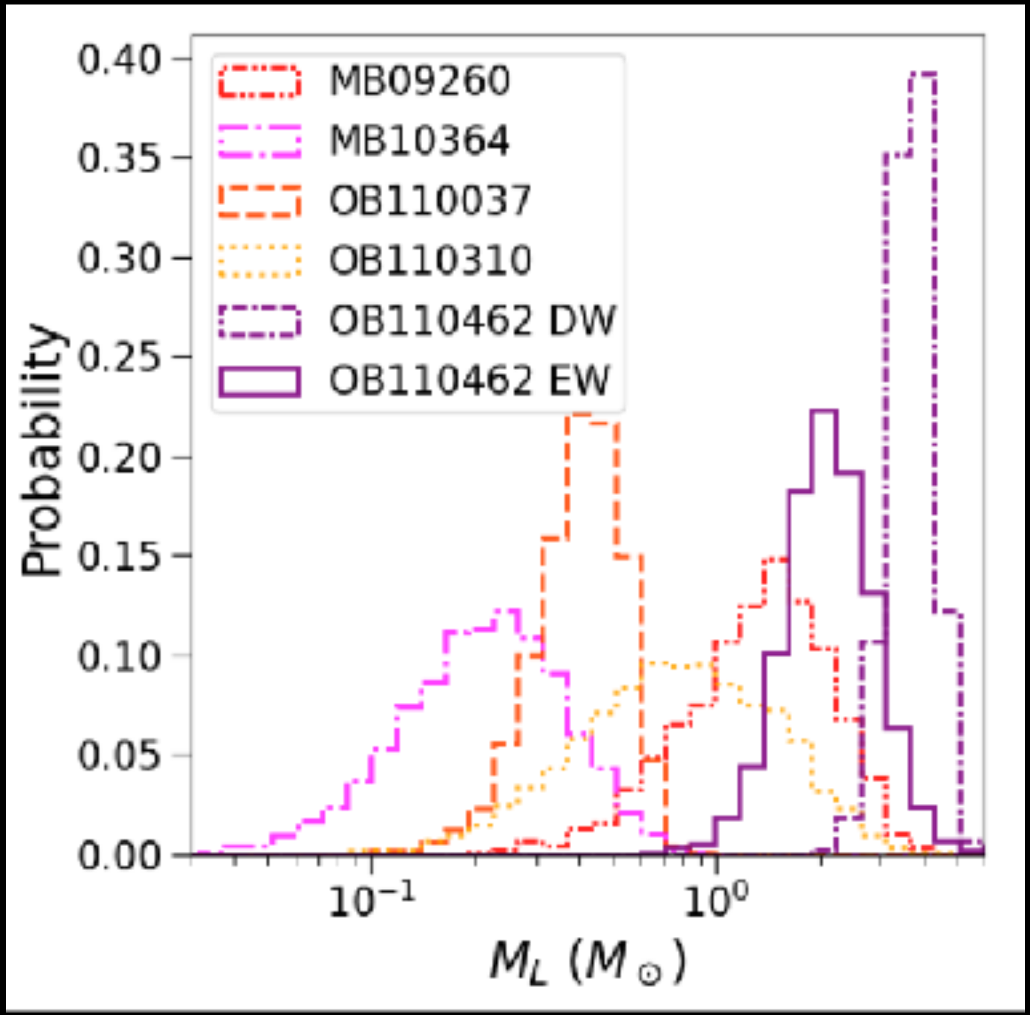
Candidates selected 2009-2011 from photometric microlensing alerts, followed up astrometrically 2009-2017 with HST WFC3-UVIS (PI: K. Sahu)



Densely sampled (~10x/night) lightcurves from surveys (OGLE, MOA)

Sparse (~8 obs/target) photometry + astrometry from HST archives

Masses and lens types (OB110462: mass gap BH or NS?!)



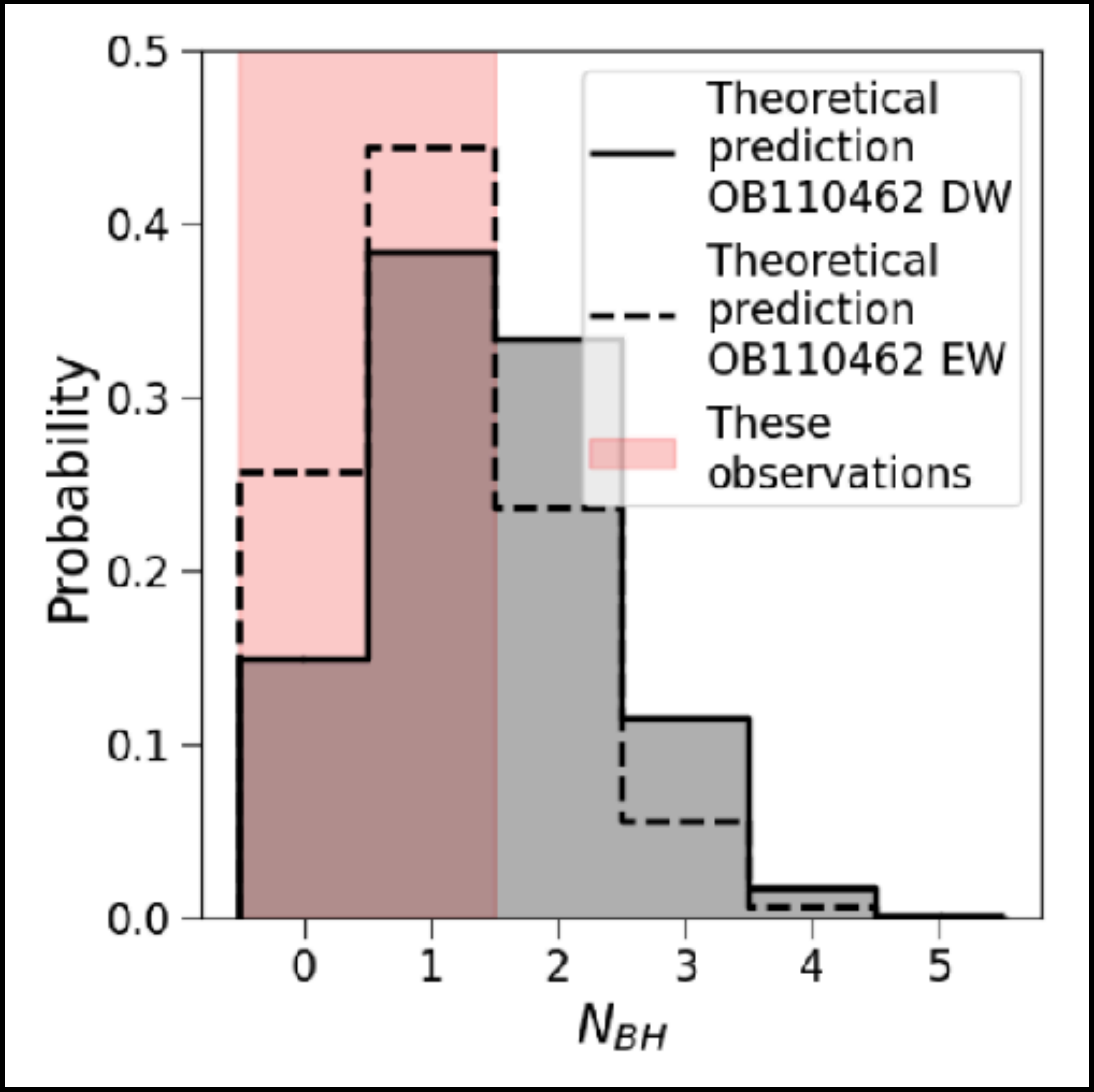
"DW" and "EW" are two different approaches to modeling OB110462

Table 9. Lens type probabilities (%)

Target	Star	BD	WD	NS	BH
MB09260	4	0	38	44	14
MB10364	36	29	36	0	0
OB110037	74	0	26	0	0
OB110310	5	3	65	22	5
OB110462 DW	0	0	0	1	99
OB110462 EW	0	0	10	51	39

Dark lens classifications by mass:
BD: $M < 0.2\ M_\odot$
WD: $0.2\ M_\odot < M < 1.2\ M_\odot$
NS: $1.2\ M_\odot < M < 2.2\ M_\odot$
BH: $M > 2.2\ M_\odot$

0-1 BH detections consistent with Galactic microlensing model prediction

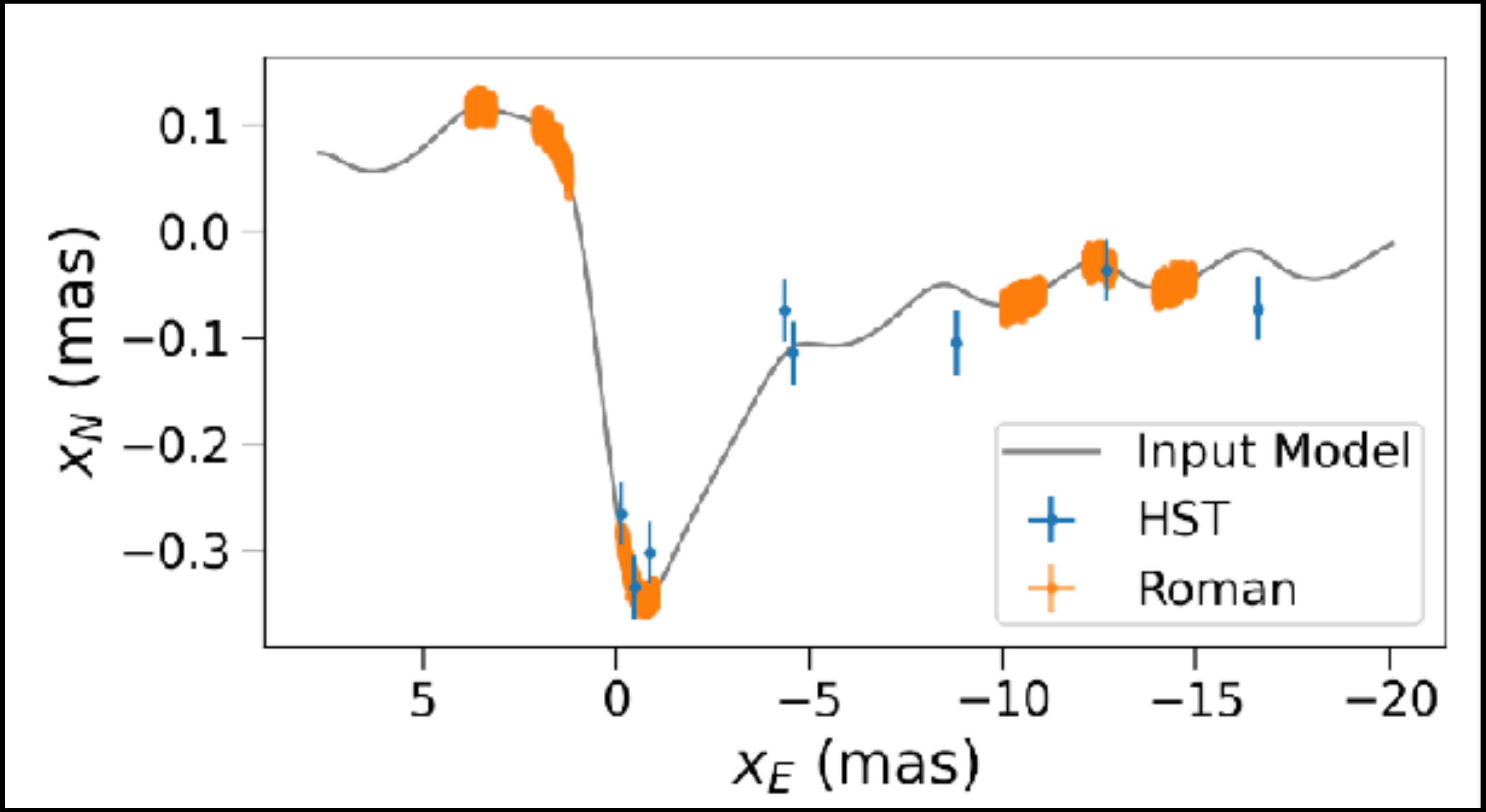


- 2 x 10^8 BHs in Milky Way model
- Longer events are more likely to have BH lenses
- Events in sample had relatively low probability of being BH lenses based on timescale (average ~25%)

Roman: simultaneous precision photometry and astrometry

Big FOV + IR + Bulge = lots of stars --> awesome astrometric precision

Roman will improve IR astrometric precision by x4 current best achievable with Keck, HST (anticipated: ~0.05 mas)

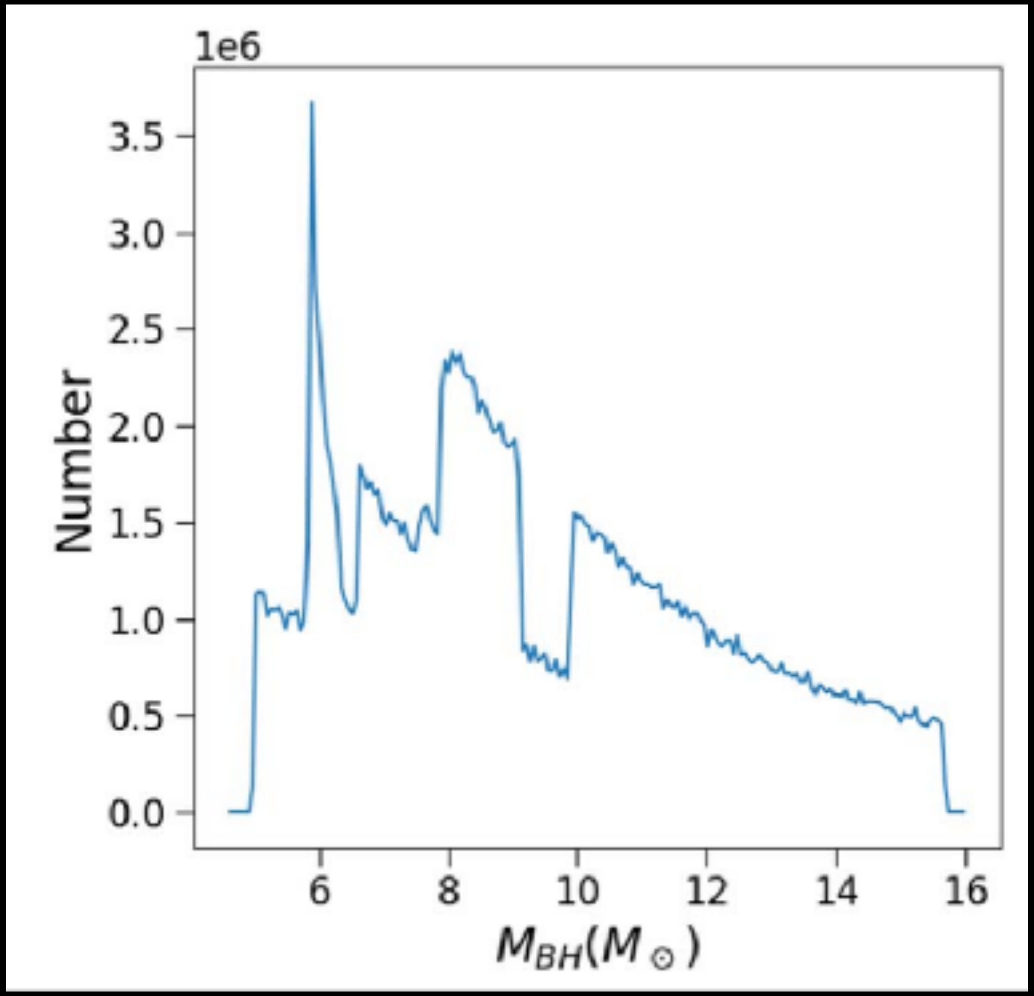


Astrometry: both densely sampled and precise!

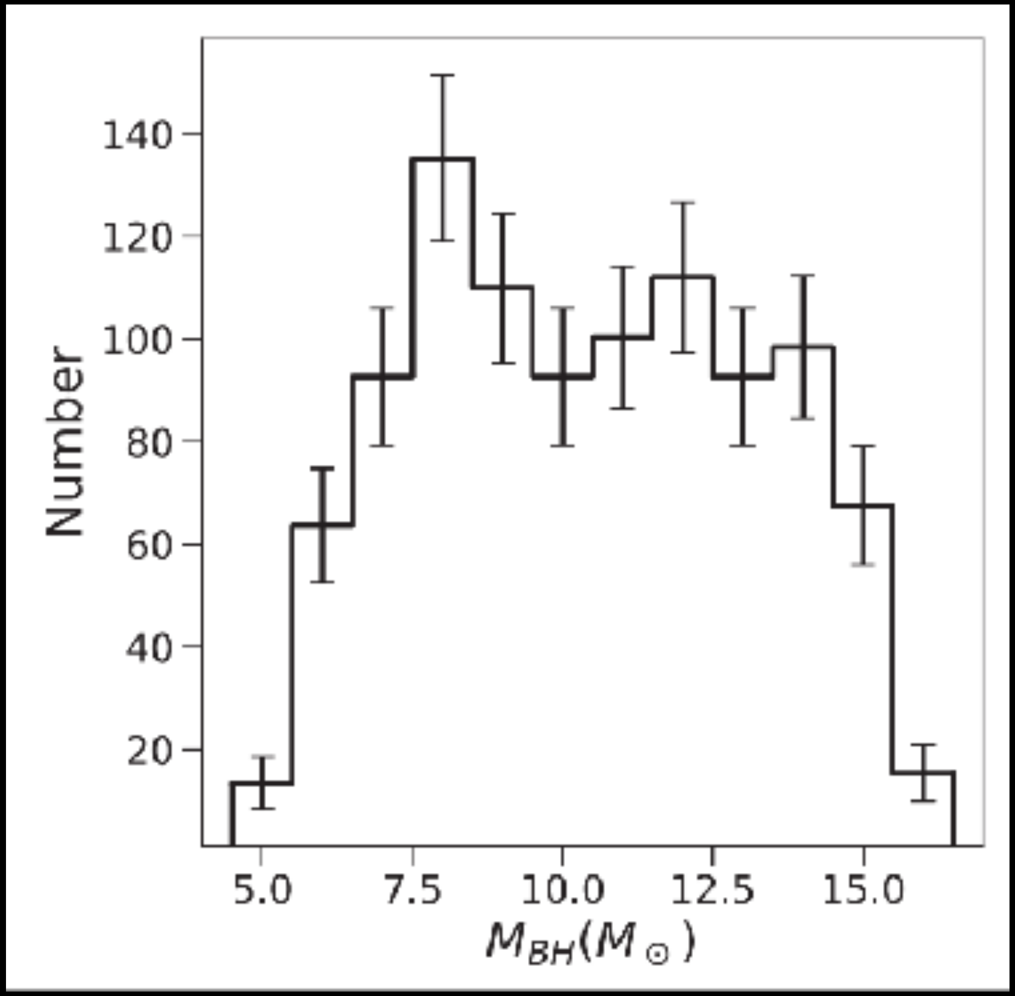
Avoid selection issues and much bigger sample than individual follow-up

Roman can measure the Milky Way BH mass function

Underlying BH distribution (SFH + IFMR + IMF)



As detected by Roman microlensing



Lam et al. 2020

O(100-1000) BH masses with Roman!

Look forward to lots of BH mass measurements with Roman!

- 0-1 BH detections in sample of 5 candidates consistent with predicted ~10^8 Galactic BHs

- Microlensing with Roman Galactic Bulge TDS should yield O(100 - 1000) BH mass measurements

- Enabled by simultaneous photometry and astrometry

The present...

...the future!

NASA