Peering into the Underworld

Predicting compact remnant microlensing events in a Gaia + GaiaNIR future

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With:
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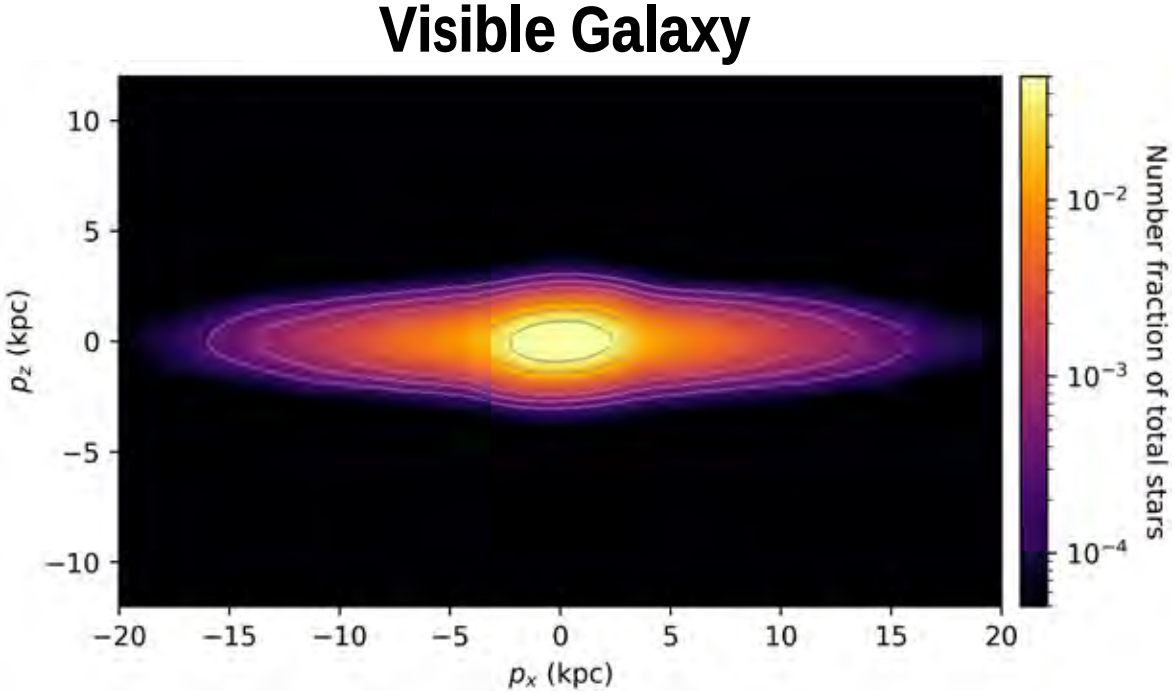
What's in this talk?

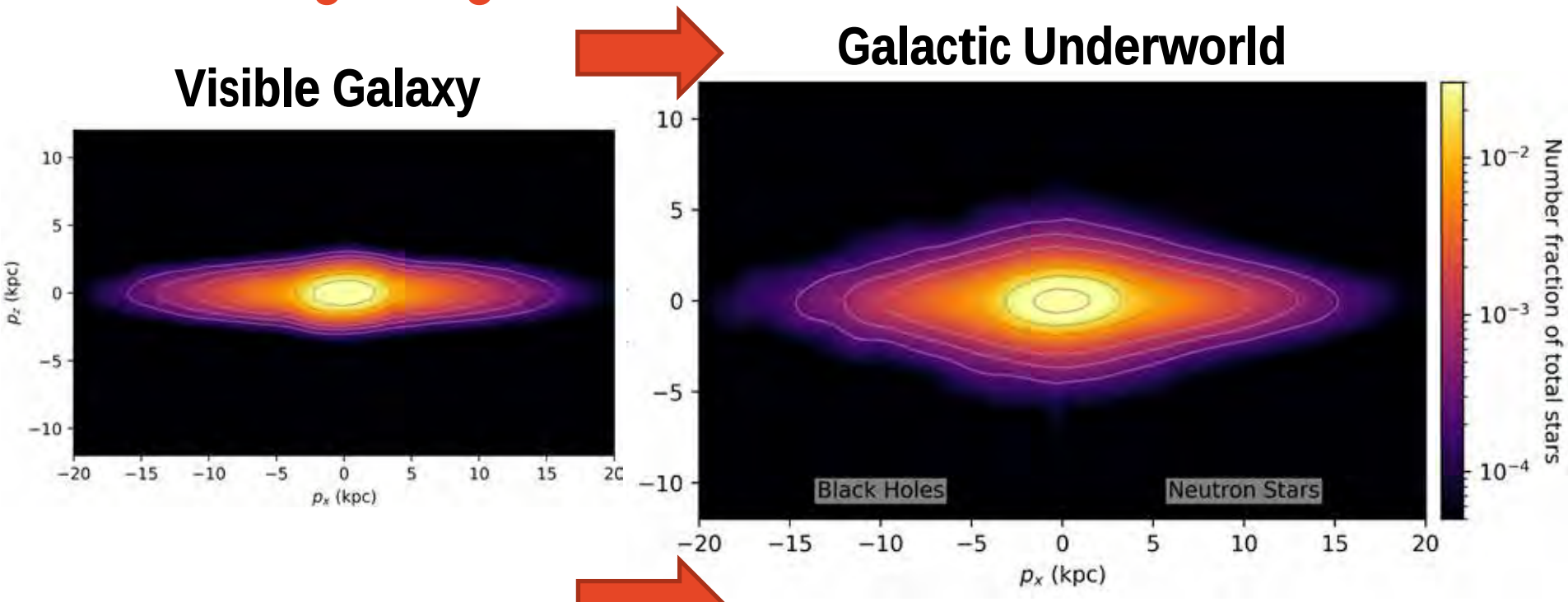
- How do you simulate the galactic underworld?
- What does the galactic underworld look like?
- How do you simulate microlensing events?
- What do they look like?
- How do they compare to observations?
- Conclusion
- Questions?

Simulating the galactic underworld



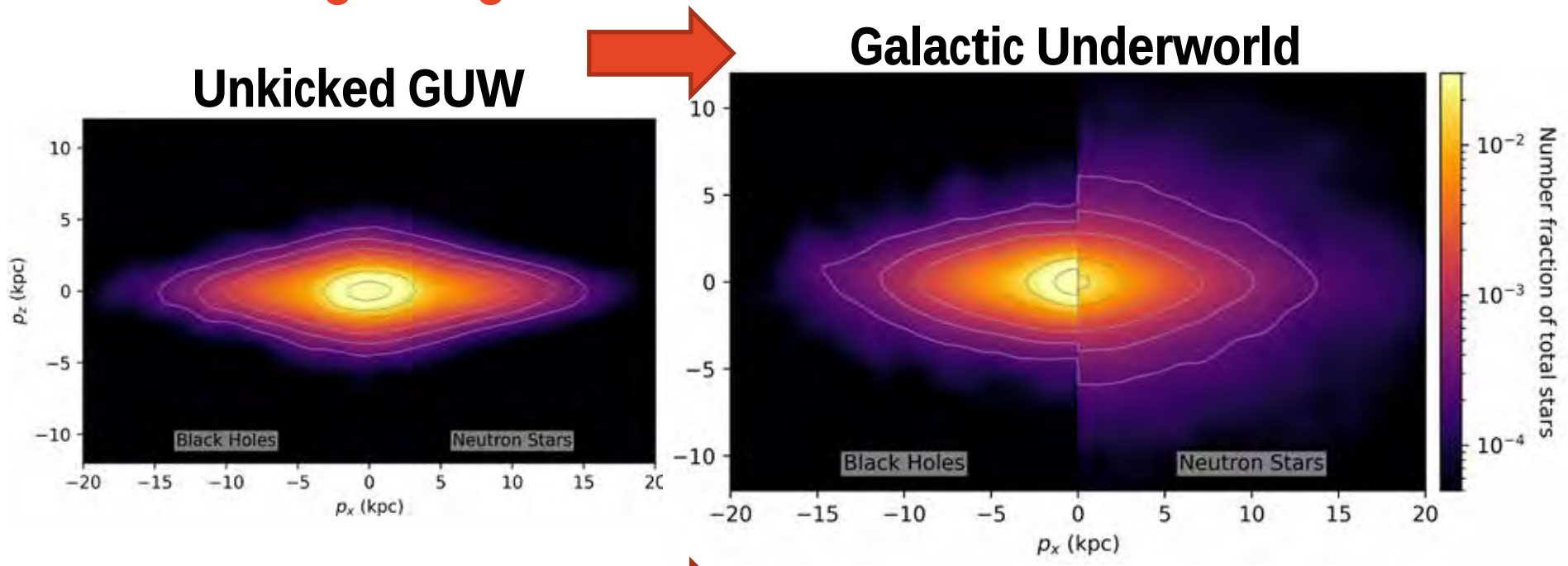
- **What you need:**
  - Formation locations
  - **Different galactic shape**
  - **Changing star formation rate**
  - **Evolution through time**

Simulating the galactic underworld



- **What you need:**
  - Formation locations
  - Natal kicks
  - Time evolution
- **Neutron stars get kicks ~300km/s**
- **Disrupt binaries**
- **Black holes are heavier**

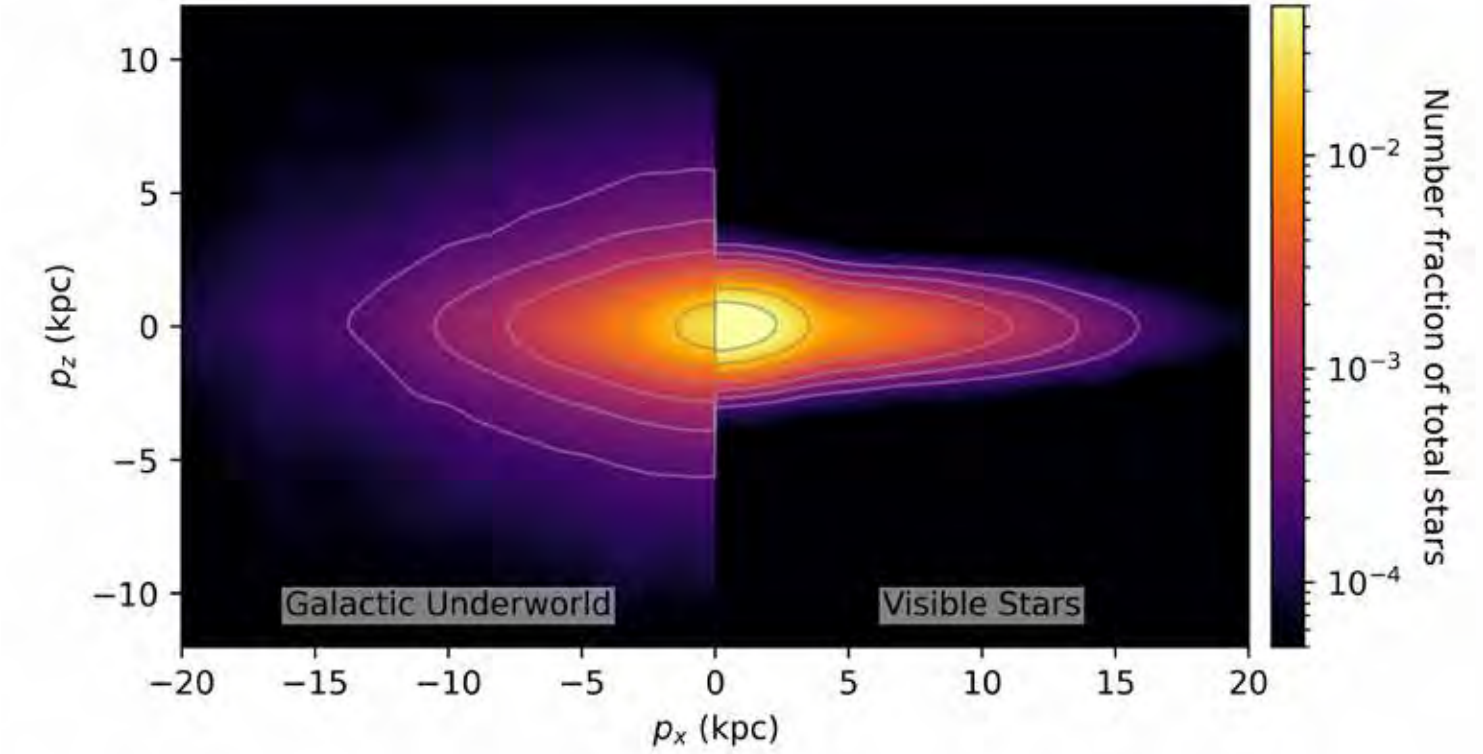
Simulating the galactic underworld



- **What you need:**
  - Formation locations
  - Natal kicks
  - Time evolution

The difference

(arXiv:2210.04241)



Scale height: $334 \pm 8 \rightarrow 1260 \pm 30$ pc

Nearest neutron star/black hole: $\sim 19/21$ pc

$\sim 40\%$ of neutron stars have galactic escape velocity

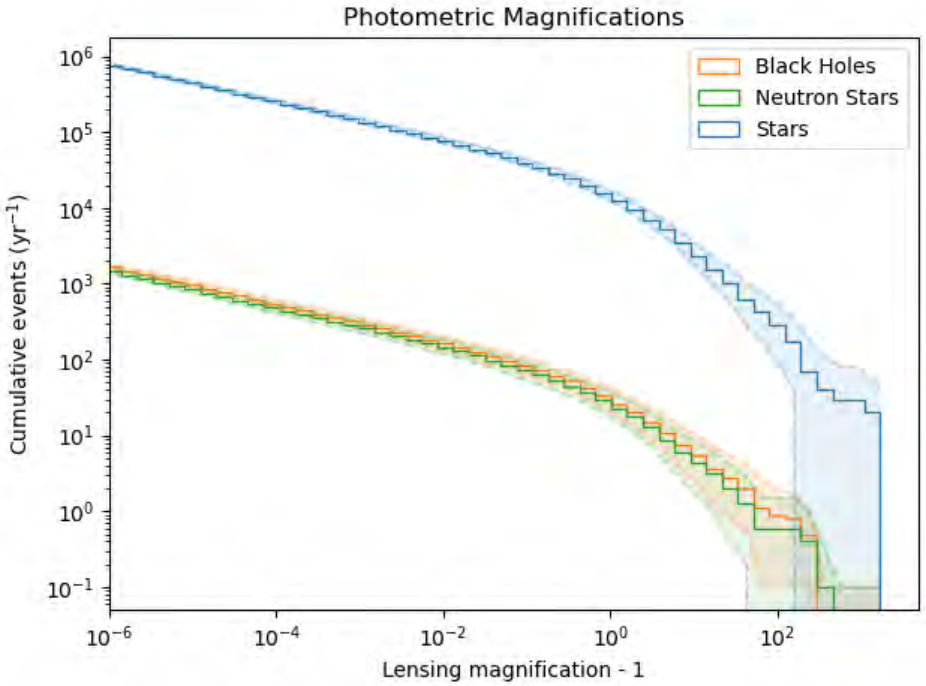
Mass loss $= 2.1 \times 10^8 M_\odot = 0.4\%$ galactic stellar mass

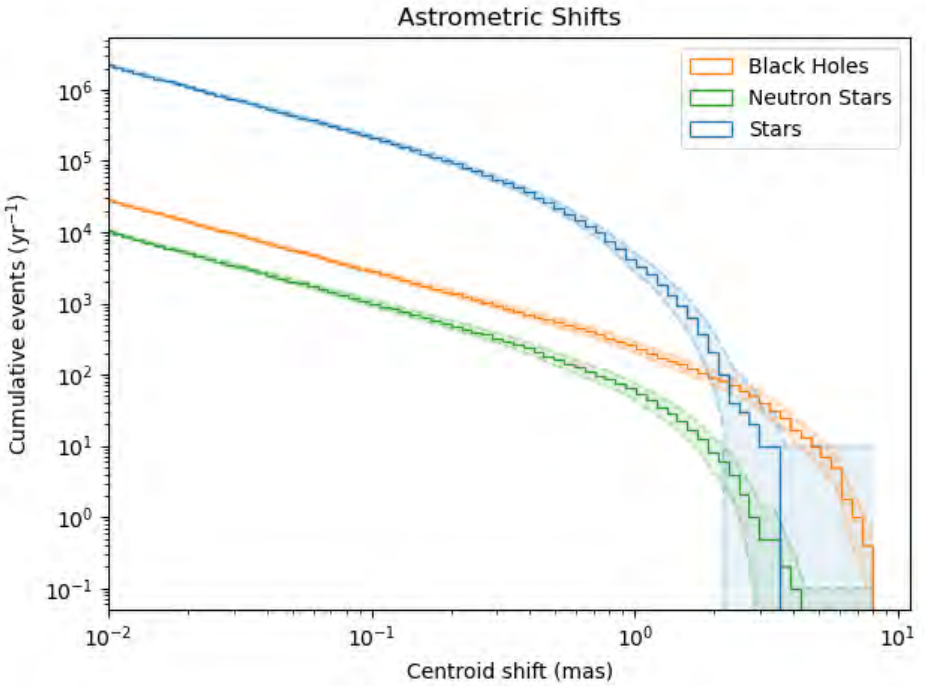
Microlensing simulations

- **Take a black hole**
  - Work out on-sky path over 10/32/10,000 years
  - Query Gaia catalogue for stars nearby to this path
  - Evolve the black hole to find its closest approach
  - Calculate microlensing effect for each star
- **Repeat for every black hole ($\sim 10^8$), neutron star ($\sim 10^9$) and star ($\sim 10^{11}$)**

Look at the results!

How many detections do we get?





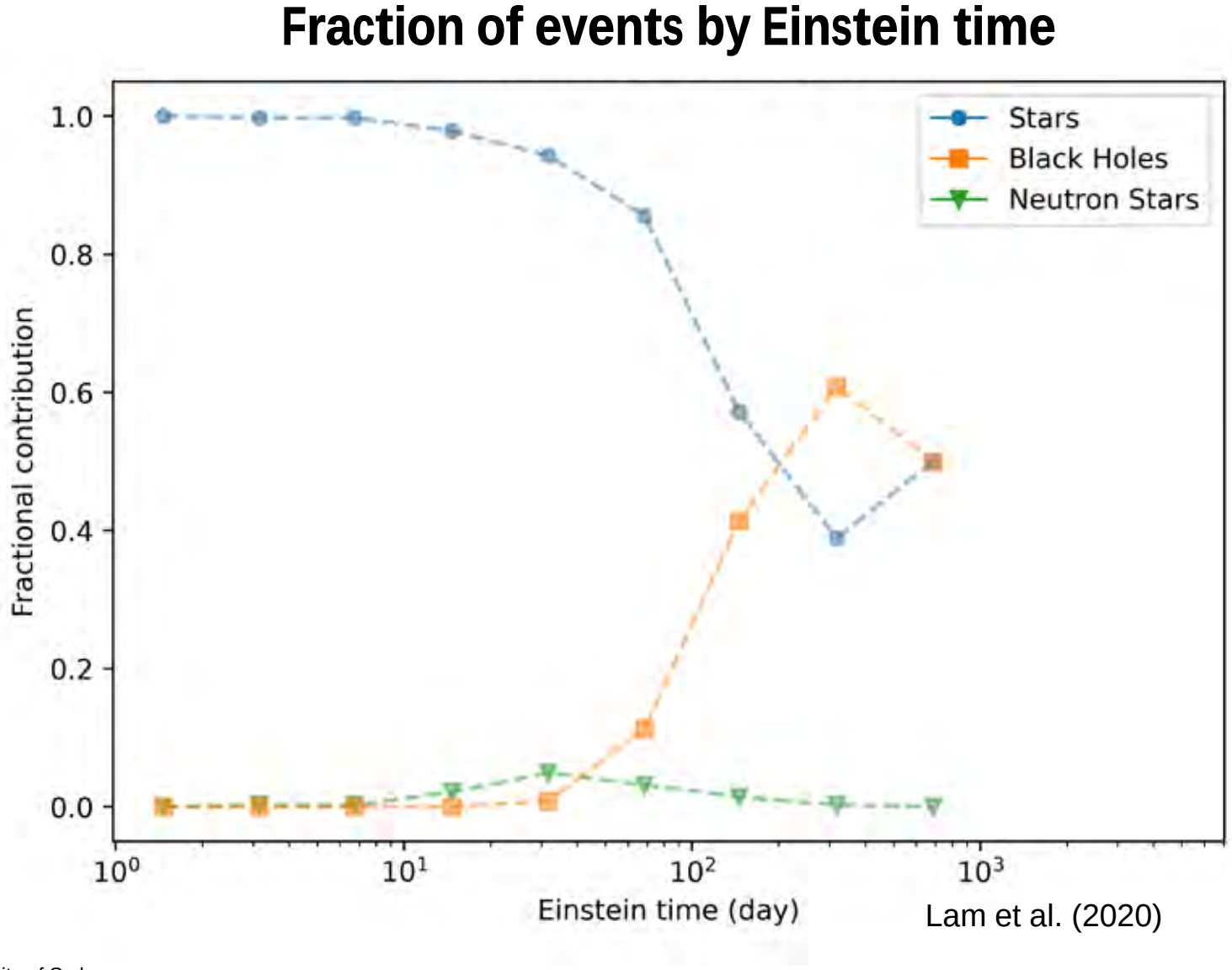
> 2 magnification

BH: 26^{+3}_{-3},
NS: 23^{+3}_{-3},
Star: 12800^{+700}_{-700}

> 1 mas shift

BH: 231^{+9}_{-9},
NS: 55^{+5}_{-5},
Star: 3400^{+400}_{-400}

What does a detection look like?



Lam et al. (2020)

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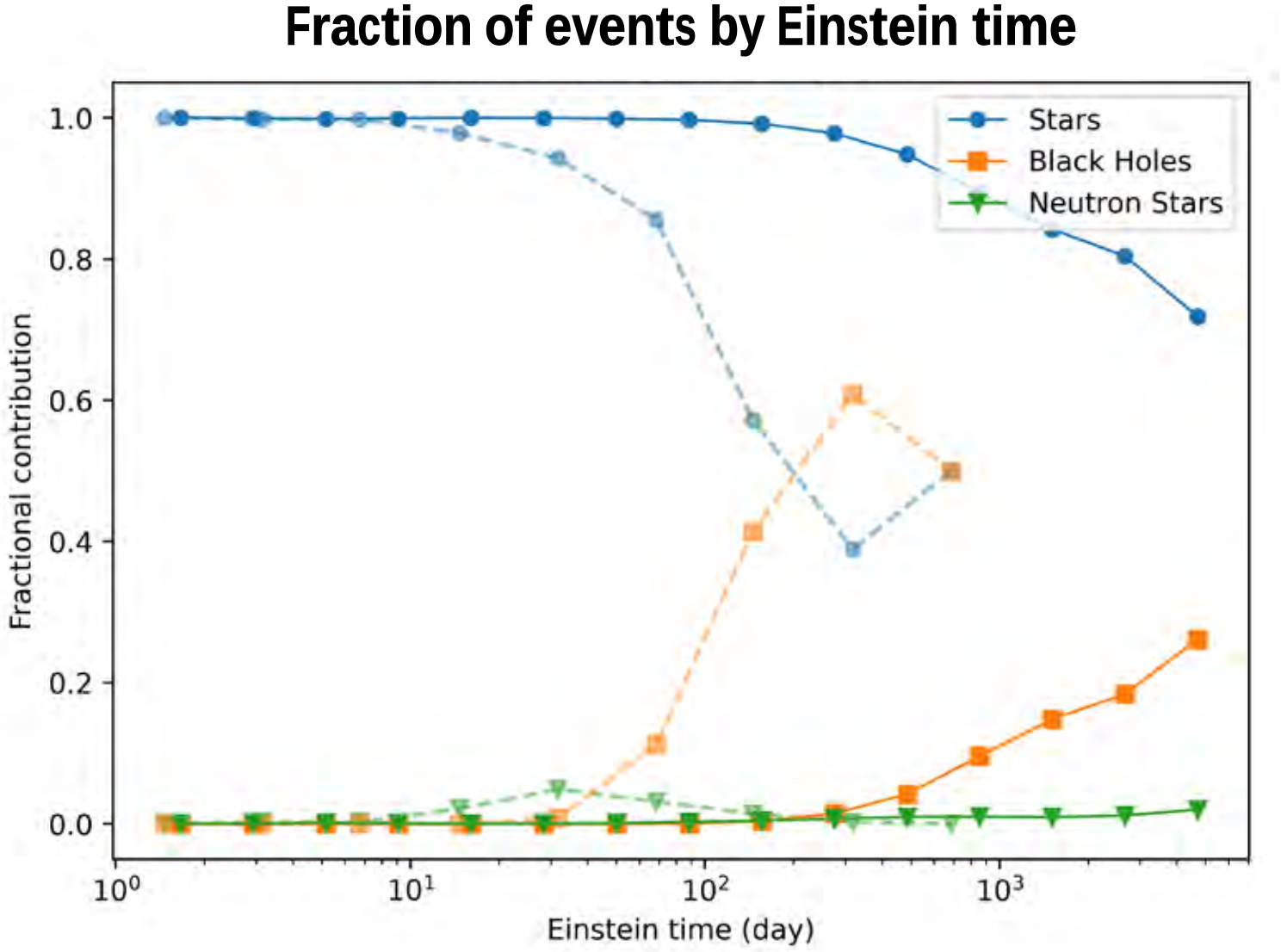

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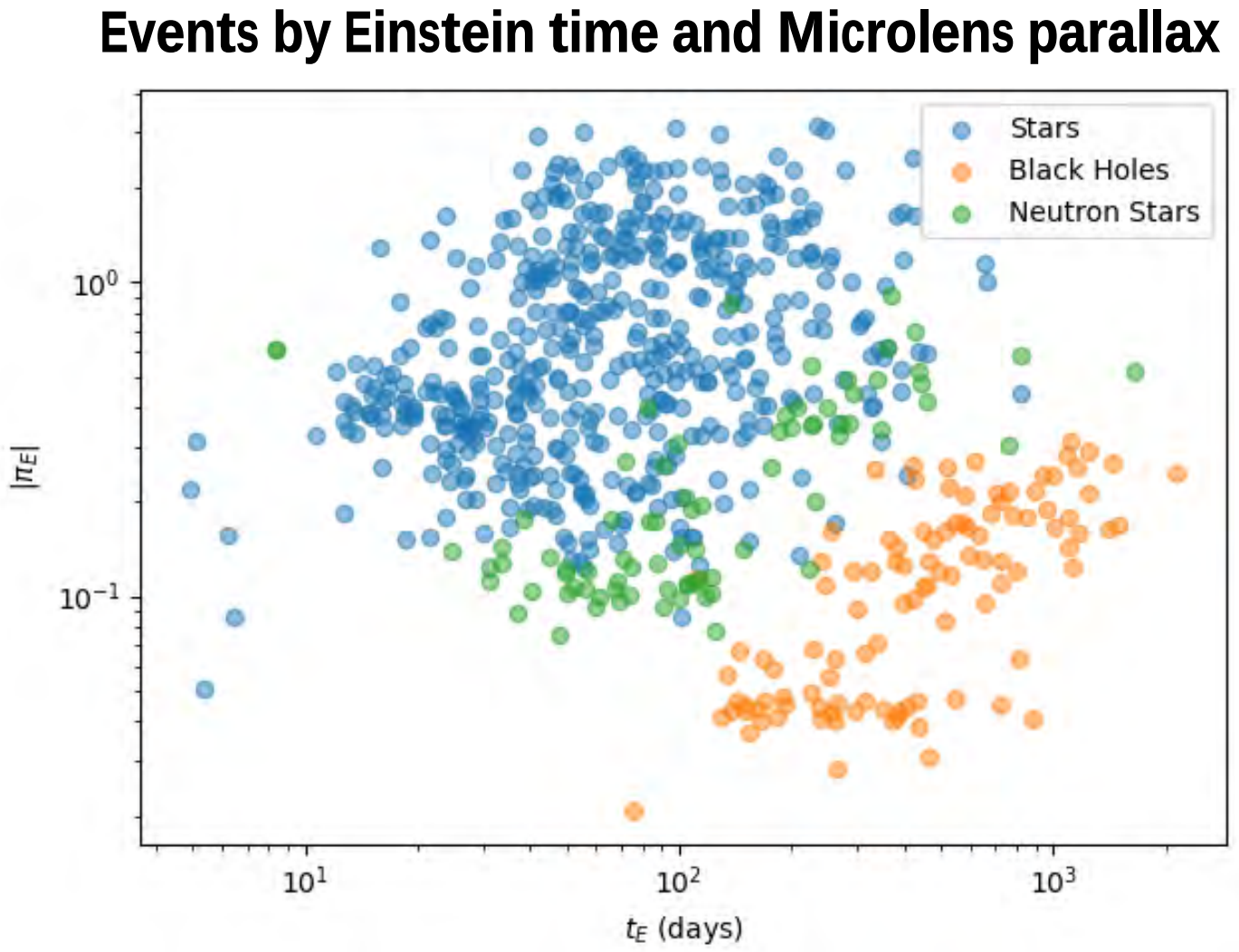
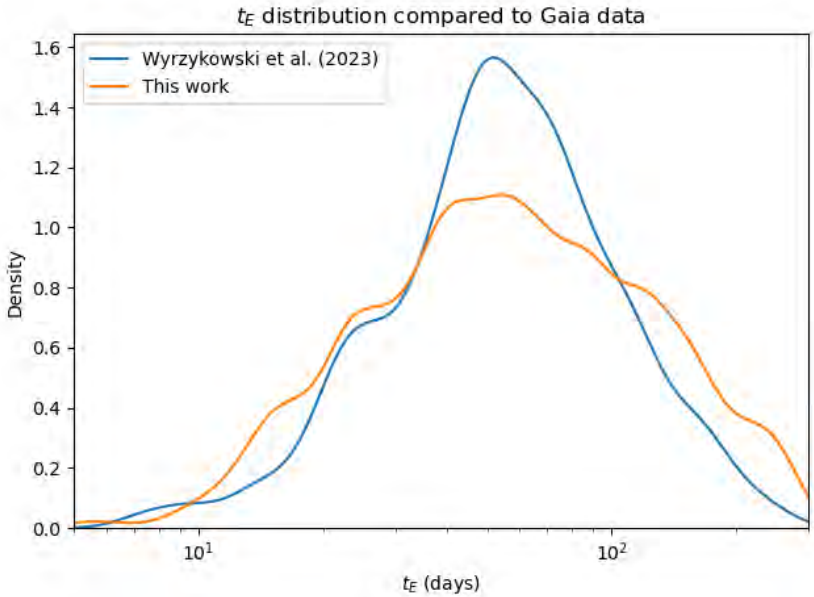
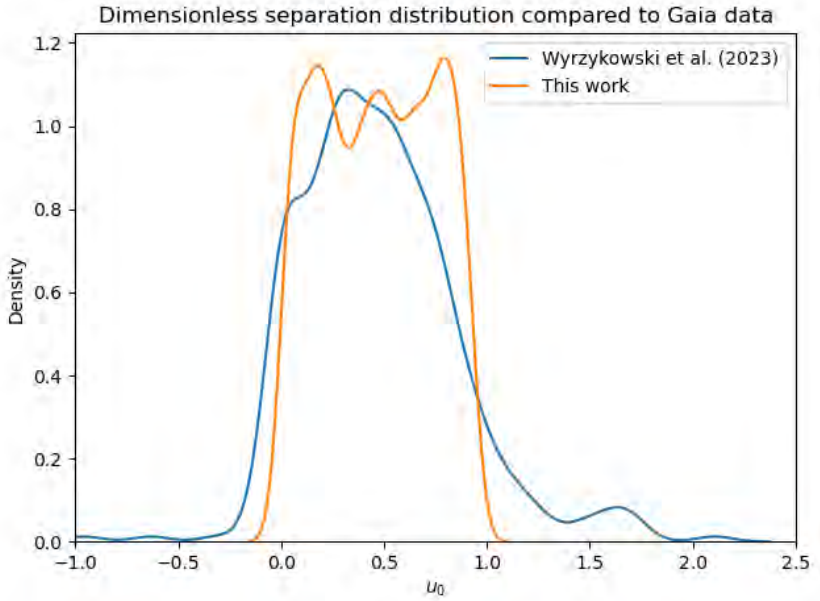
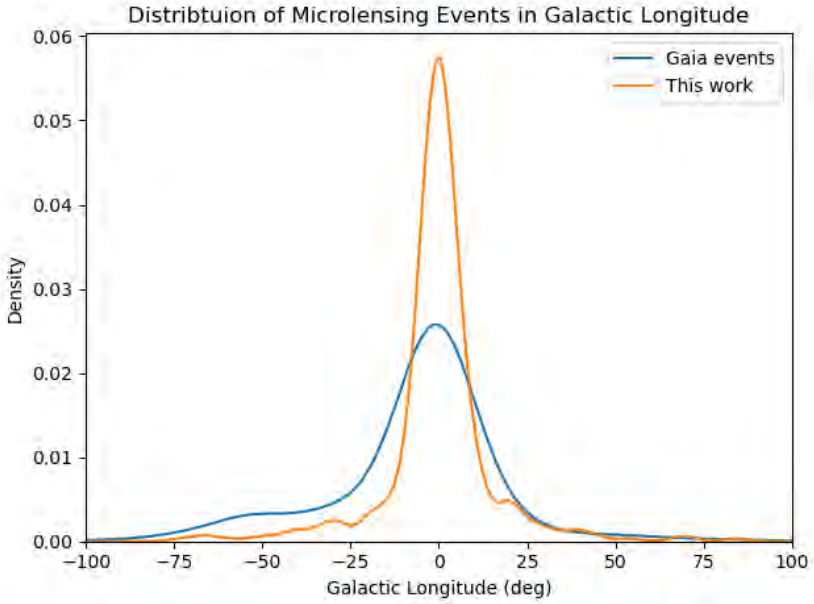
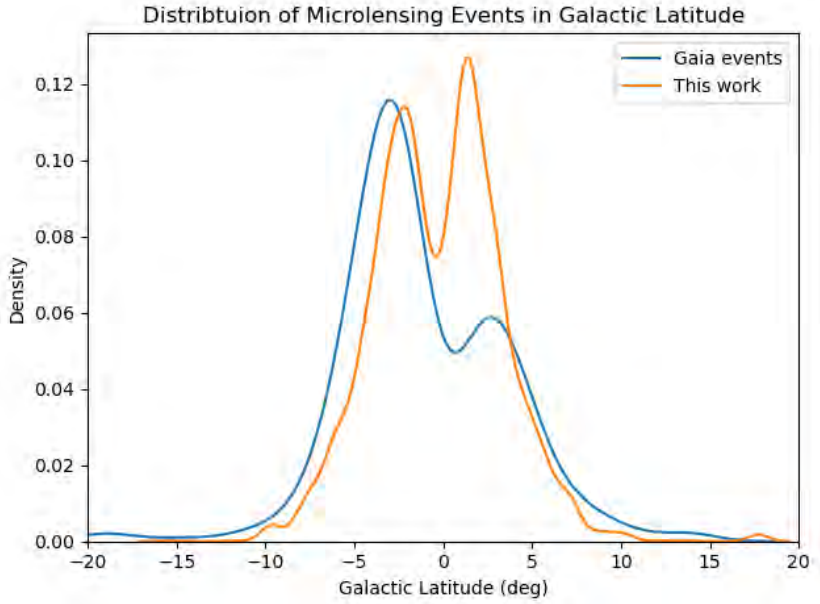


Does this match observations? ... Yes!









Conclusions

- We simulate the black hole and neutron star population (arXiv:2210.04241)
- It looks significantly different to the visible Galaxy
- We predict black hole microlensing events (Submitted)
- Black holes are distinct in $t_E - \pi_E$ space
- Our simulations are a good match to Gaia data

Questions?