Potential of *Gaia* to constrain Primordial Black Holes using Astrometric Microlensing

[Based on my work: ArXiv 2208.14460]

Himanshu Verma
IIT Bombay, India
Ph.D. Supervisor: Prof. Vikram Rentala

25th Microlensing Conference

PC: Gaia Collaboration

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Introducing The Research Problem

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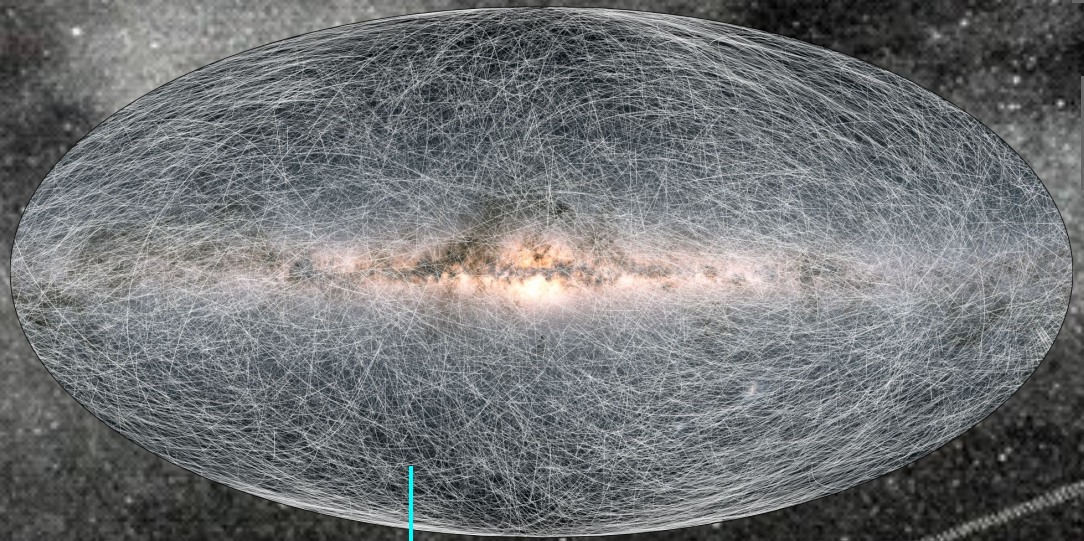
Dark Matter

Primordial Black Holes?

How many trajectories out of a billion are going to have **Astrometric Microlensing signatures** due to PBHs?



Time Series data of more than **a billion** stars

PC: Gaia Collaboration

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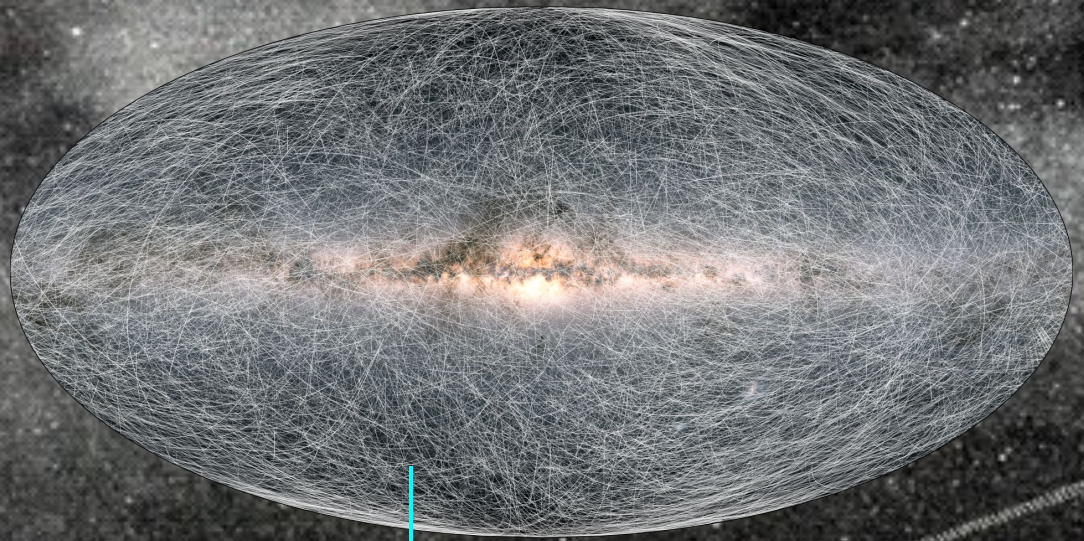

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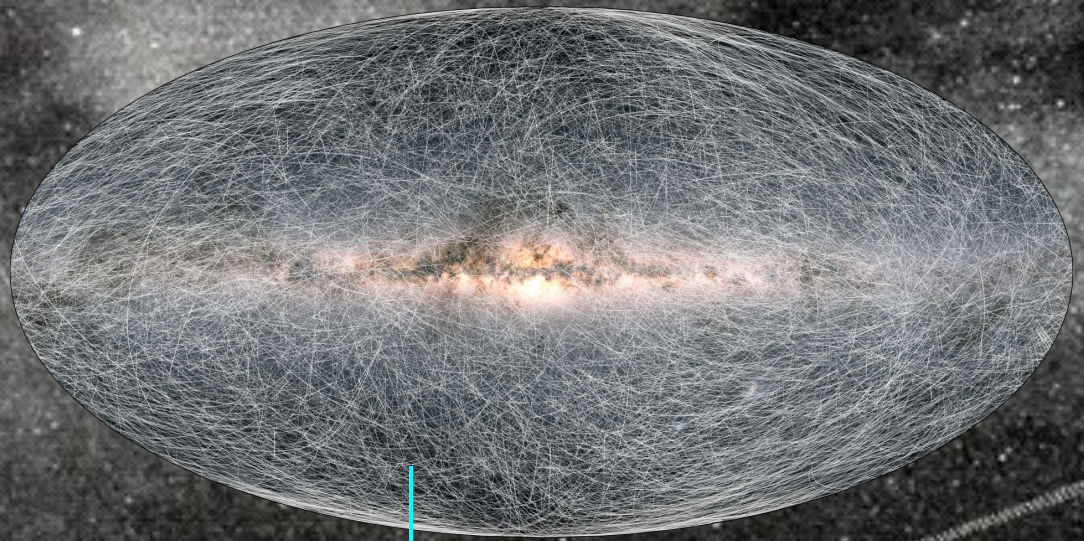

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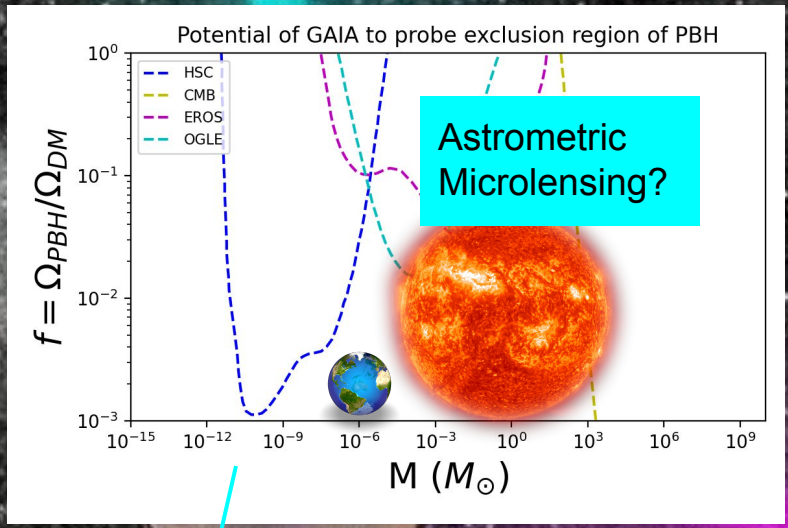
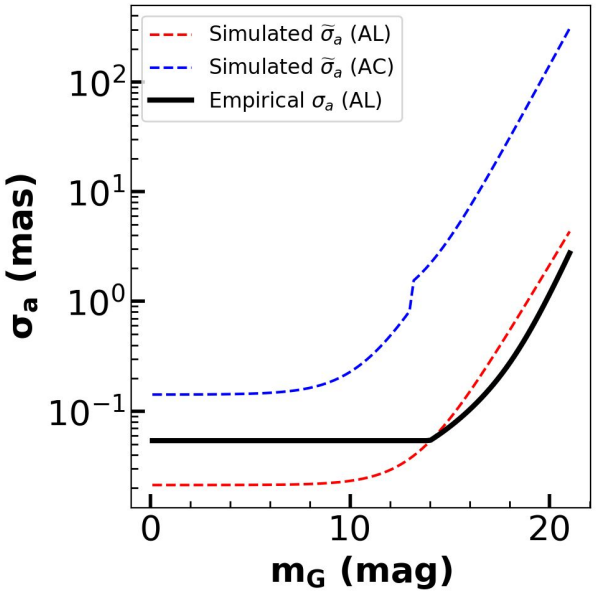


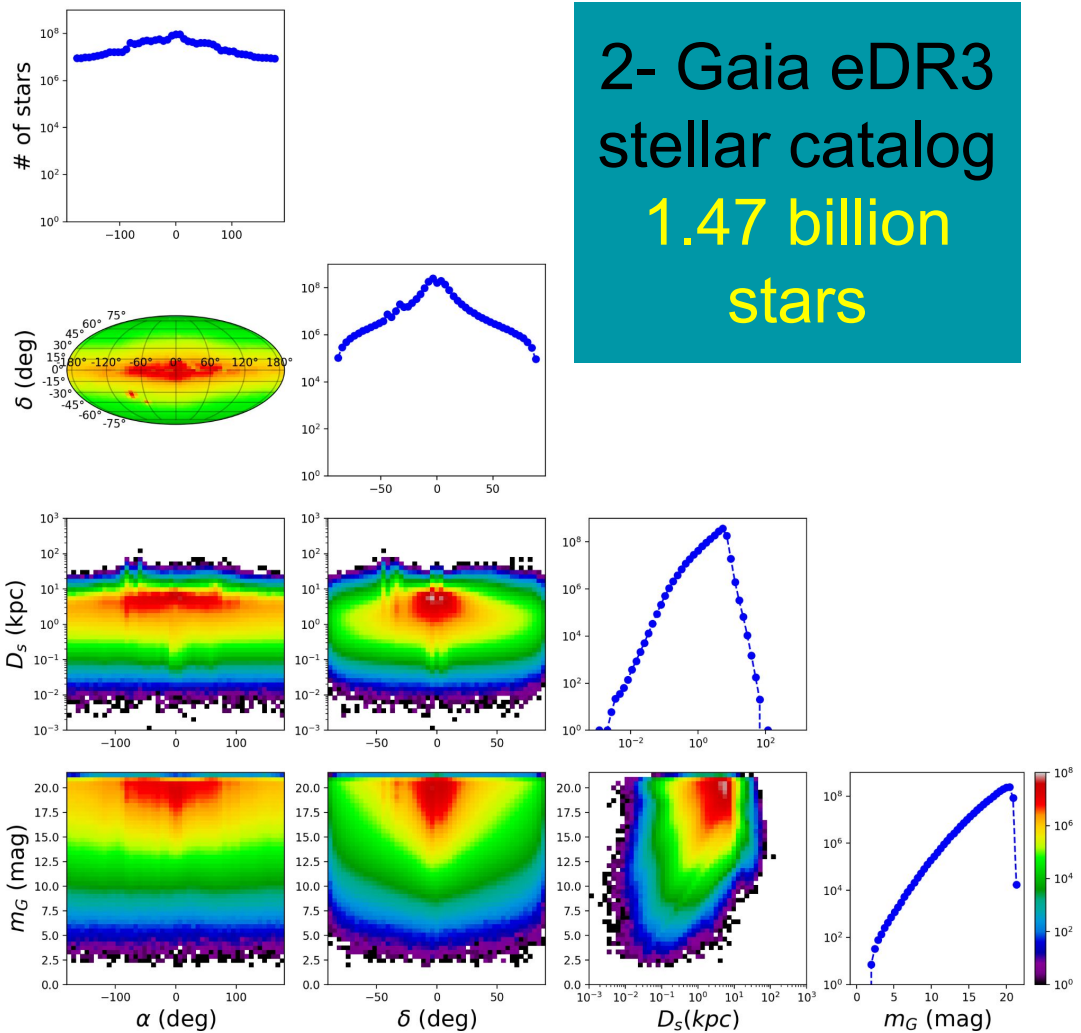
Monochromatic mass function of PBHs

1- Gaia Uncertainty Model

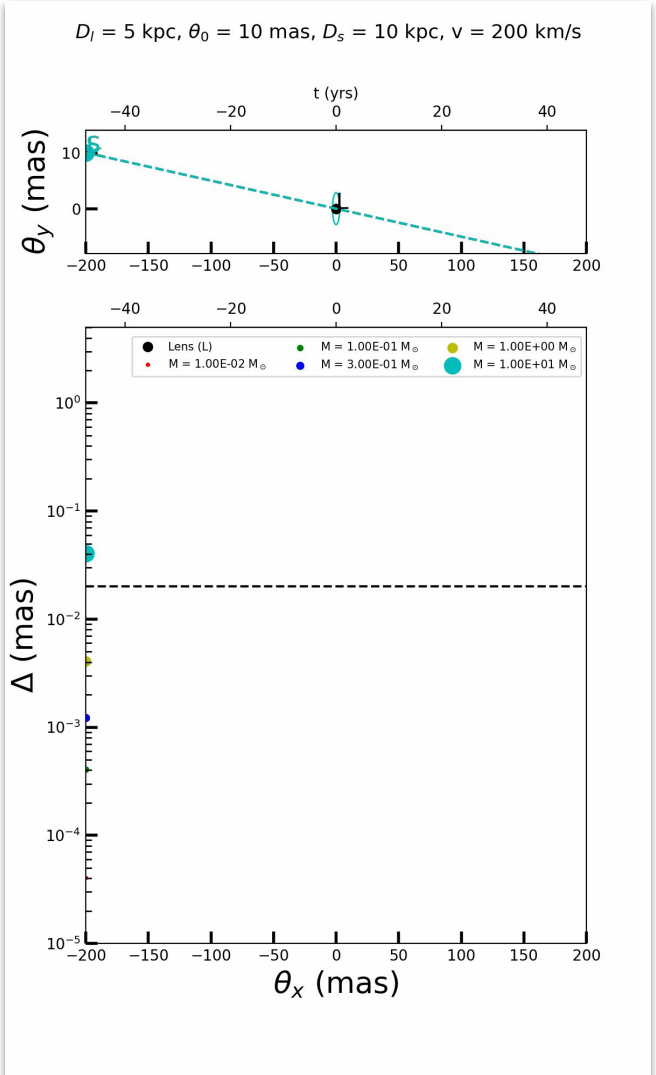
$t_s = 5 \text{ years} / 35 = 52.2 \text{ days}$



2- Gaia eDR3 stellar catalog 1.47 billion stars



Astrometric Microlensing due to PBHs



Short Duration Lensing Event

$$\langle t_e \rangle < t_s = 52.2 \text{ days}$$

No observable lensing signal for SDLE

Intermediate Duration Lensing Event

$$t_s < \langle t_e \rangle < t_{\text{obs}} = 5 \text{ years}$$

IDLE observable: $\langle (\delta\theta)_{\text{max}} \rangle = \langle \Delta_{\text{max}} \rangle$

Long Duration Lensing Event

$$t_{\text{obs}} < \langle t_e \rangle$$

LDLE observable: $\langle \Delta_{\text{LDLE}} \rangle = \langle \Delta_{\text{out}} - \Delta_{\text{in}} \rangle$

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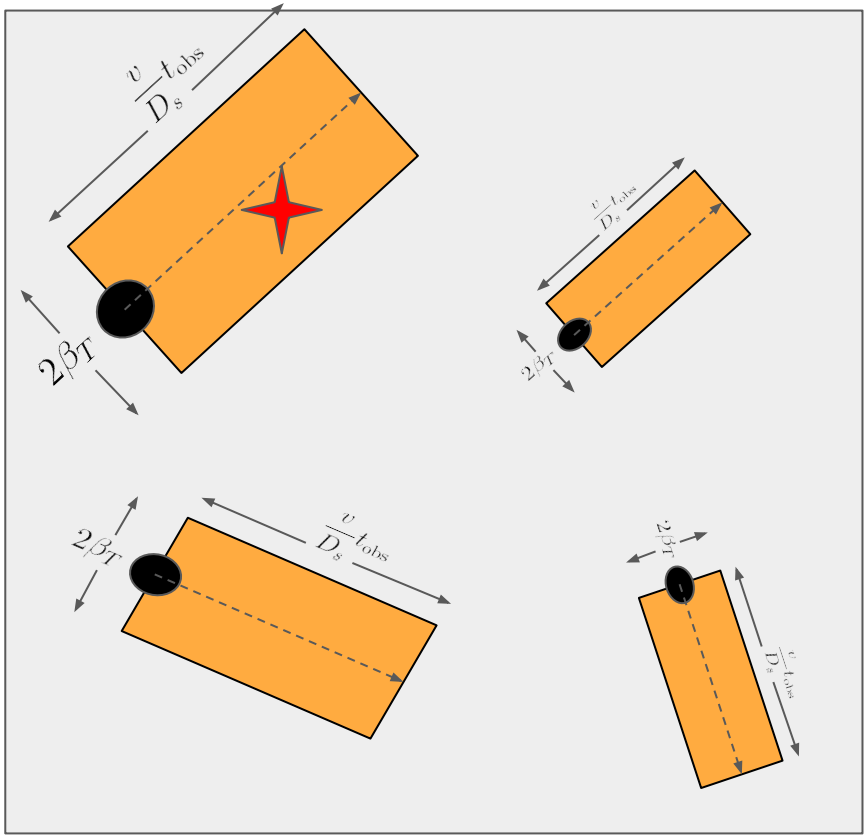
Probability of Gaia detecting lensing signal from a given star



$$P_{\rm star} = \int_0^{D_s} D_l^2 dD_l \Delta\Omega \frac{f}{M} \rho_{\rm DM}(D_l, \alpha, \delta) p^c_{\rm lensing}$$

$$p^c_{\rm lensing} = \begin{cases} 0 & ; \langle t_e \rangle < t_s, \\ \frac{2}{\Delta\Omega}\left(\frac{\theta_E}{\sigma_a(m_G)} + \sqrt{\frac{\theta_E^2}{\sigma_a(m_G)^2} - 8}\right)\theta_E \mu t_{\rm obs} & ; t_s < \langle t_e \rangle < t_{\rm obs}, \\ \frac{2}{\Delta\Omega}\sqrt{\frac{t_{\rm obs} v}{D_l}\frac{1}{\sigma_a(m_G)}}\theta_E \mu t_{\rm obs} & ; t_{\rm obs} < \langle t_e \rangle. \end{cases}$$

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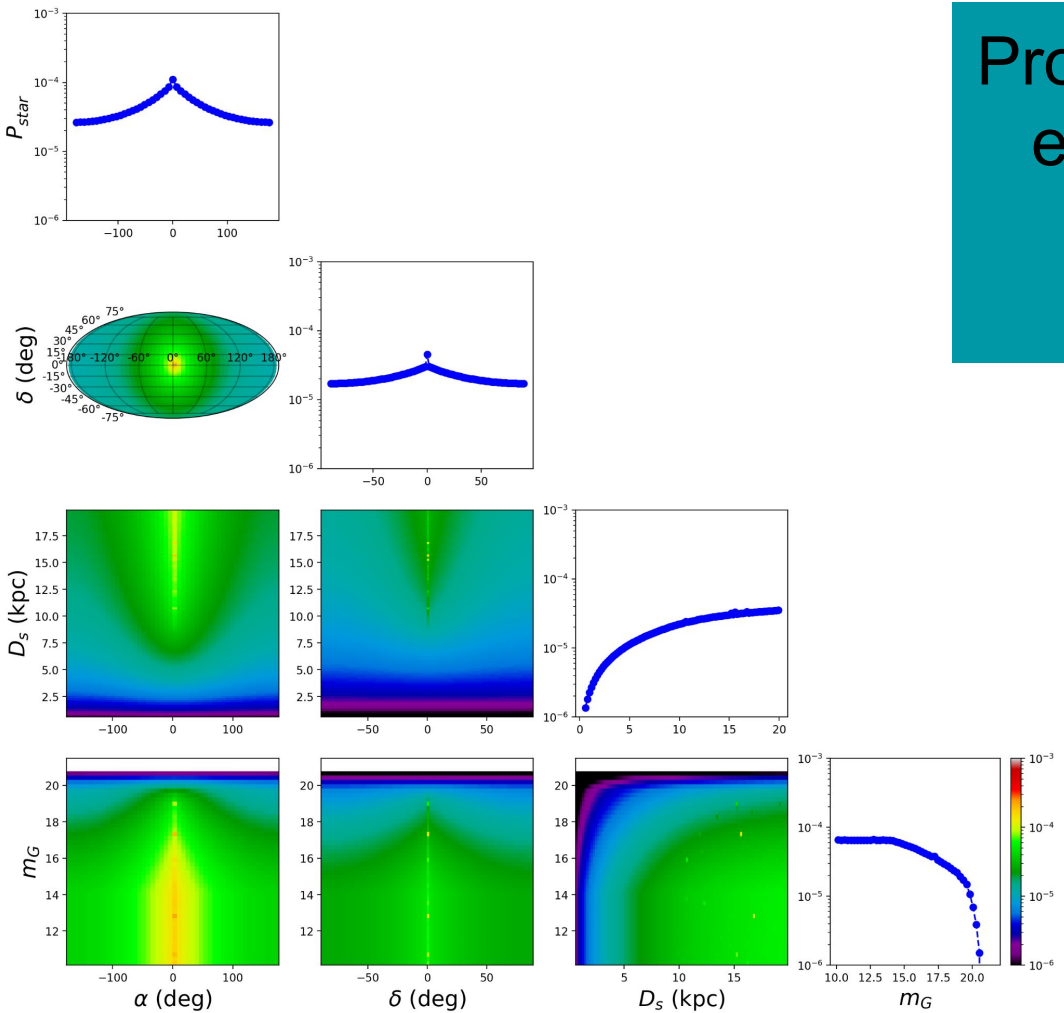

Probability of the AML signal expected to be observed by Gaia (f=1, M=14 Msun)

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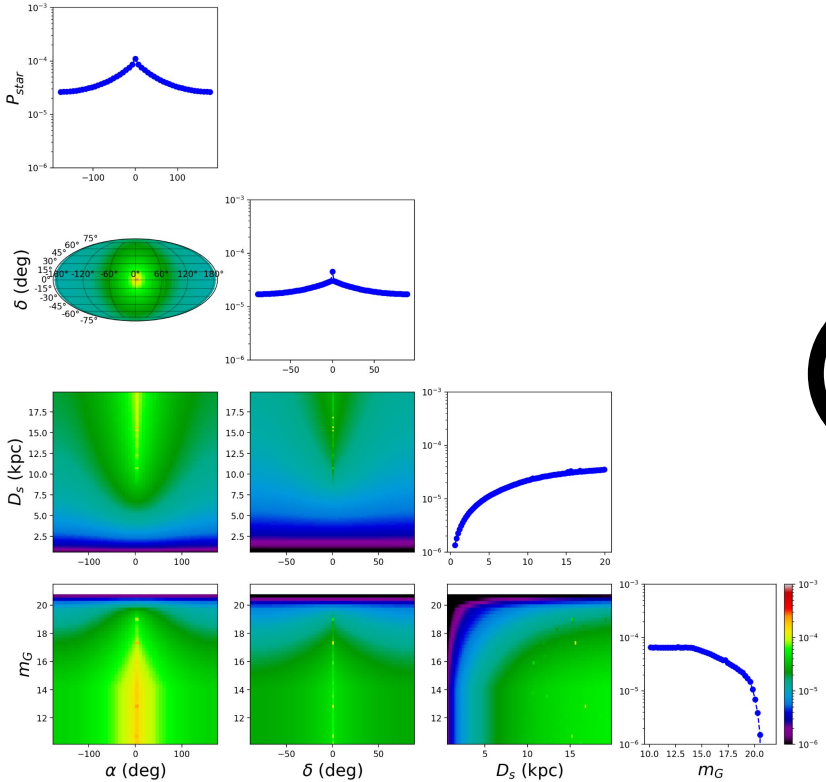

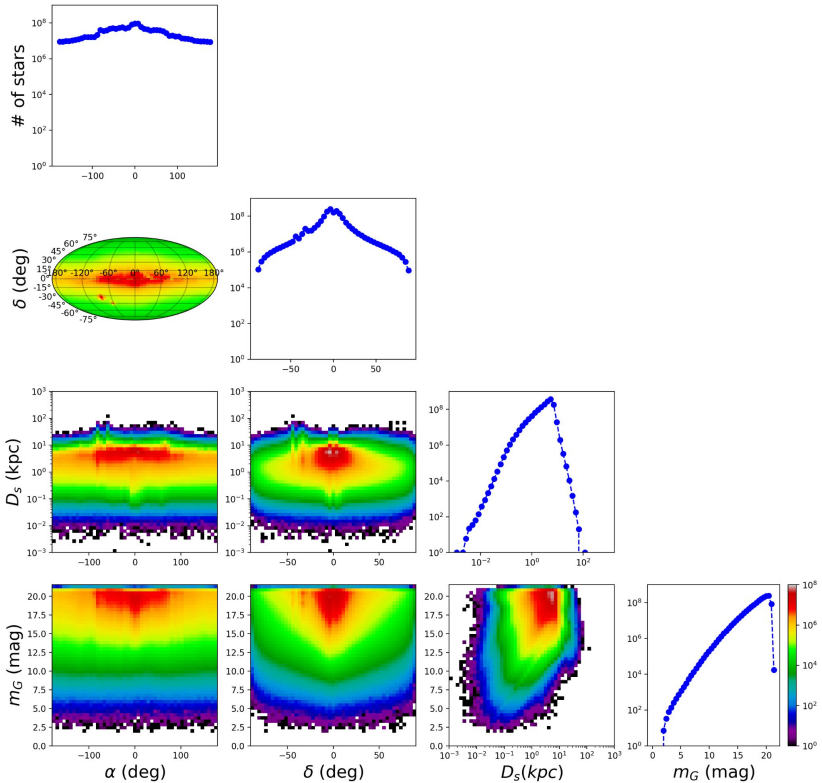

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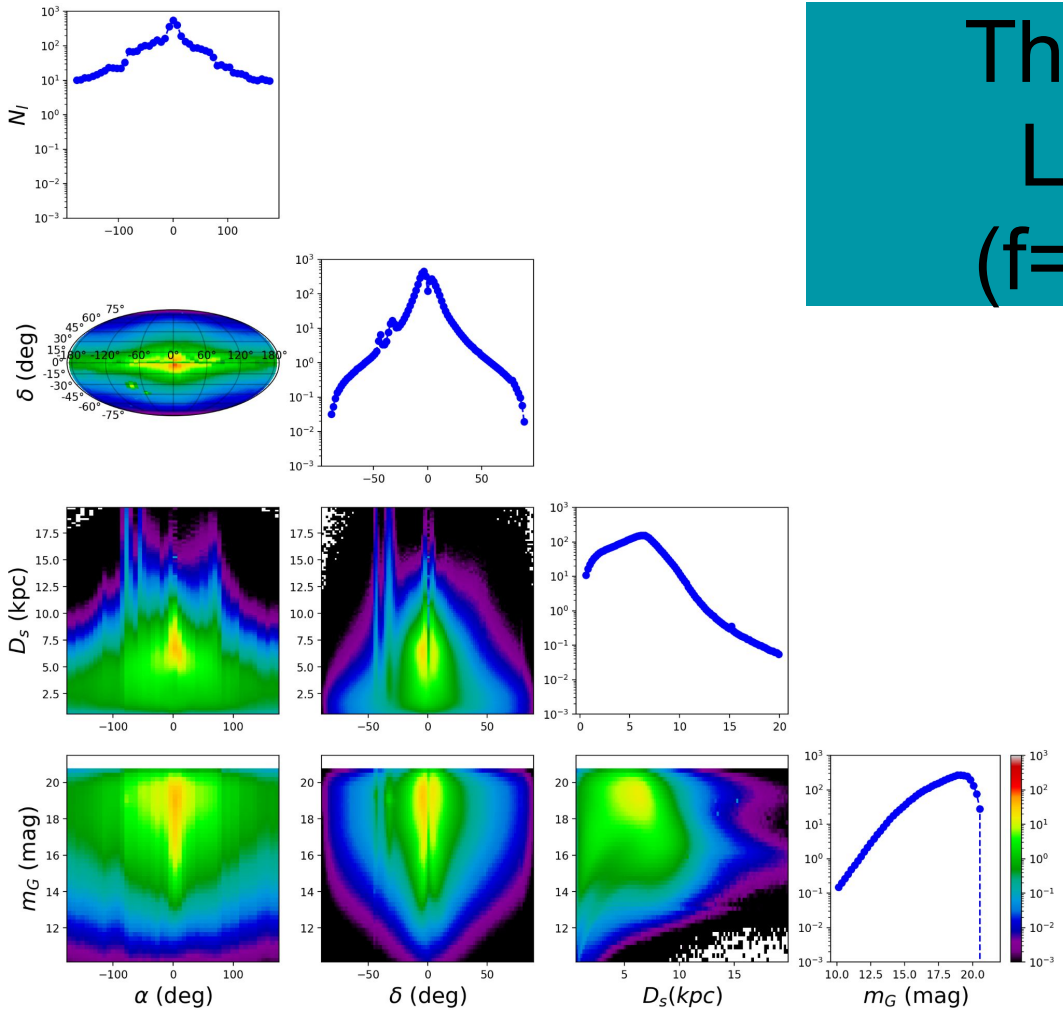
The Distribution of Lensing Events (f=1, M=14 Msun)



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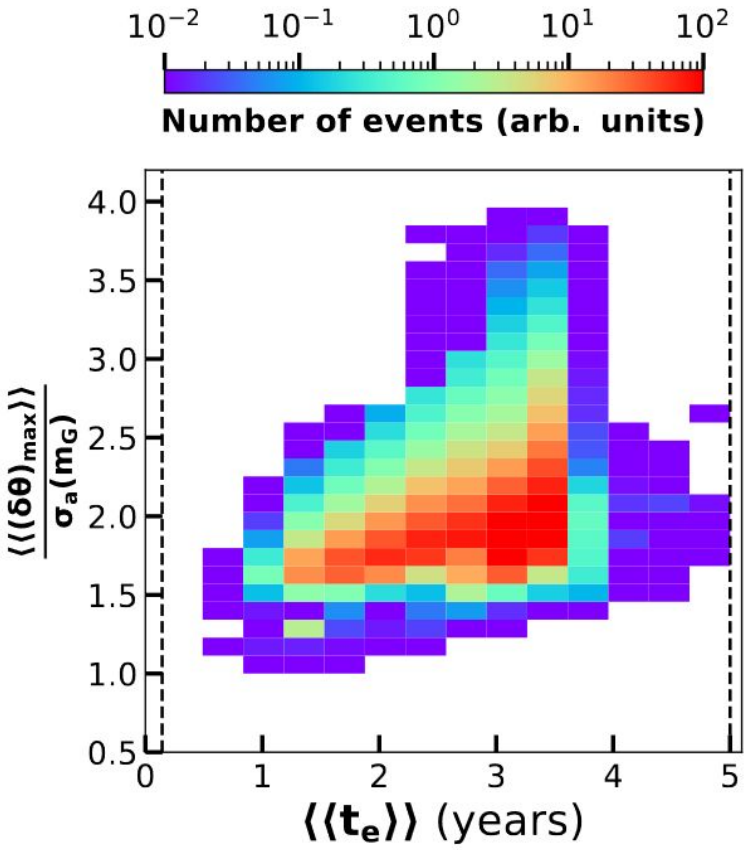
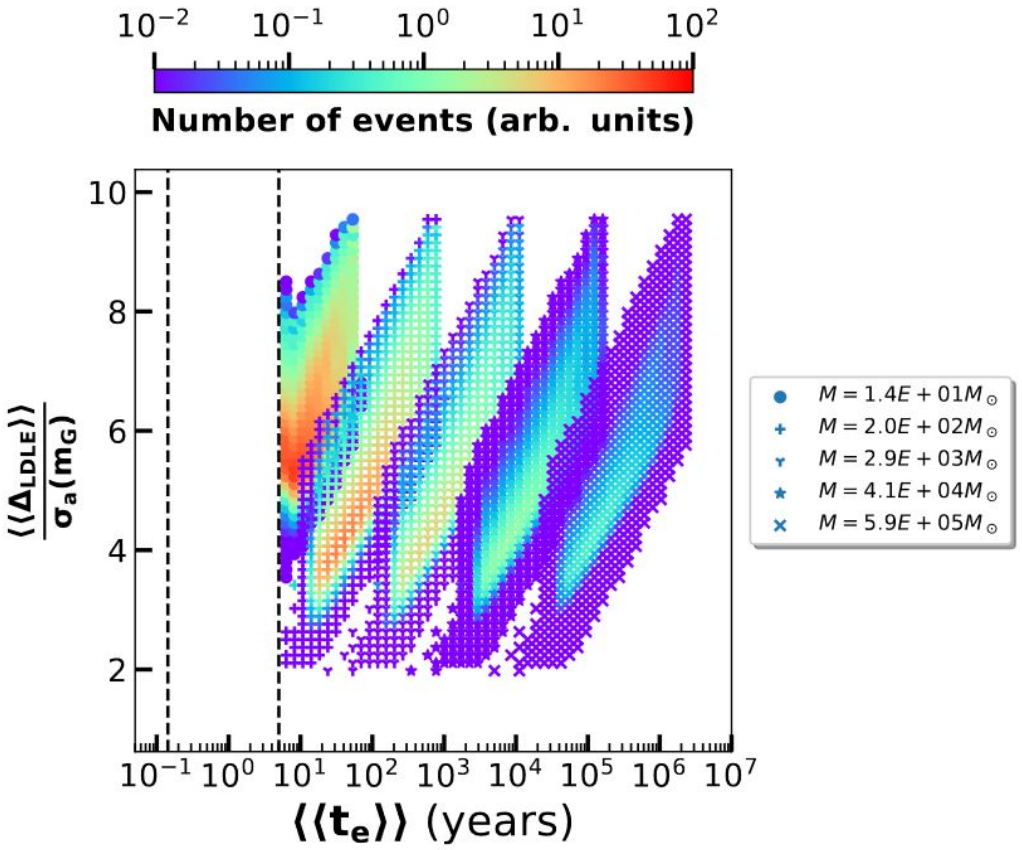


(a) IDLE observables



(b) LDLE observables

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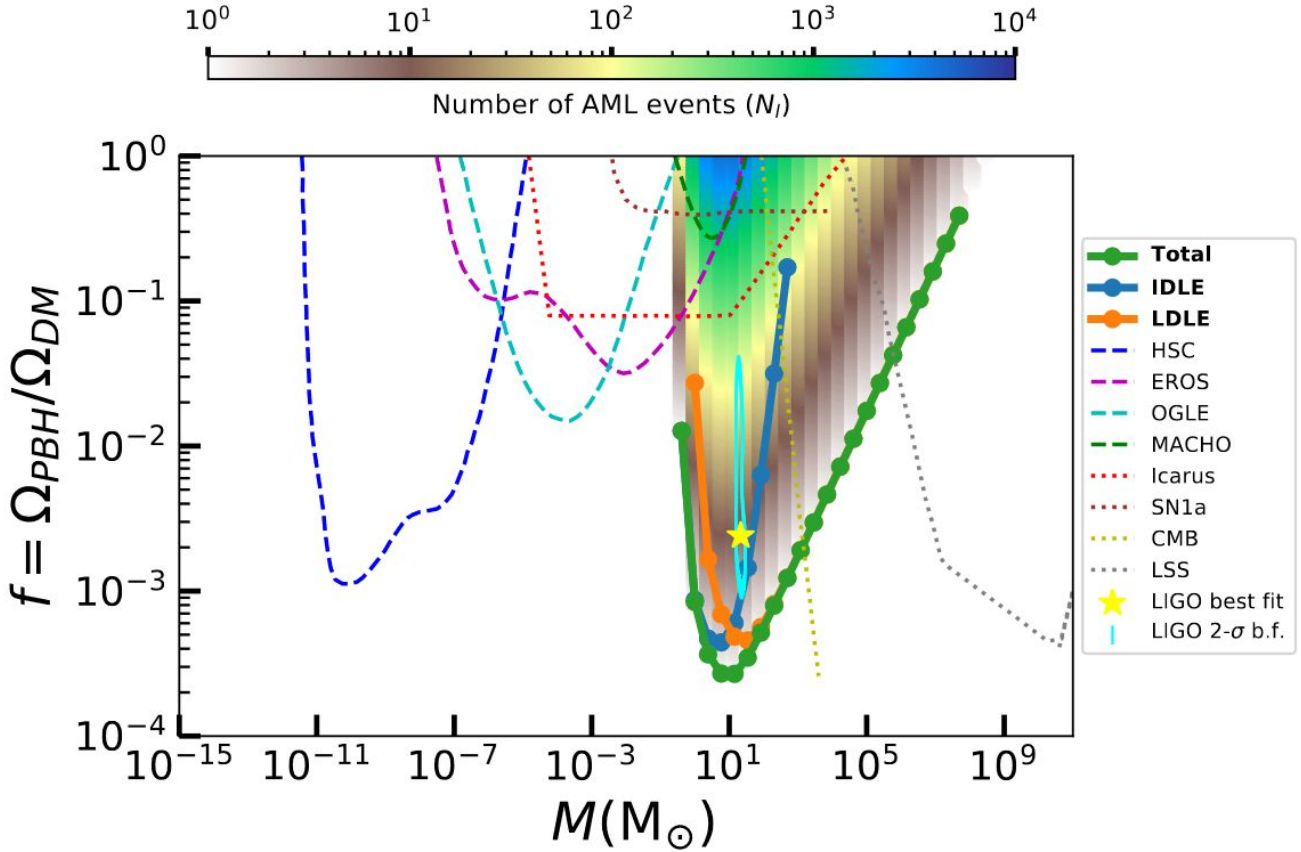
The Expected Exclusion by *Gaia*



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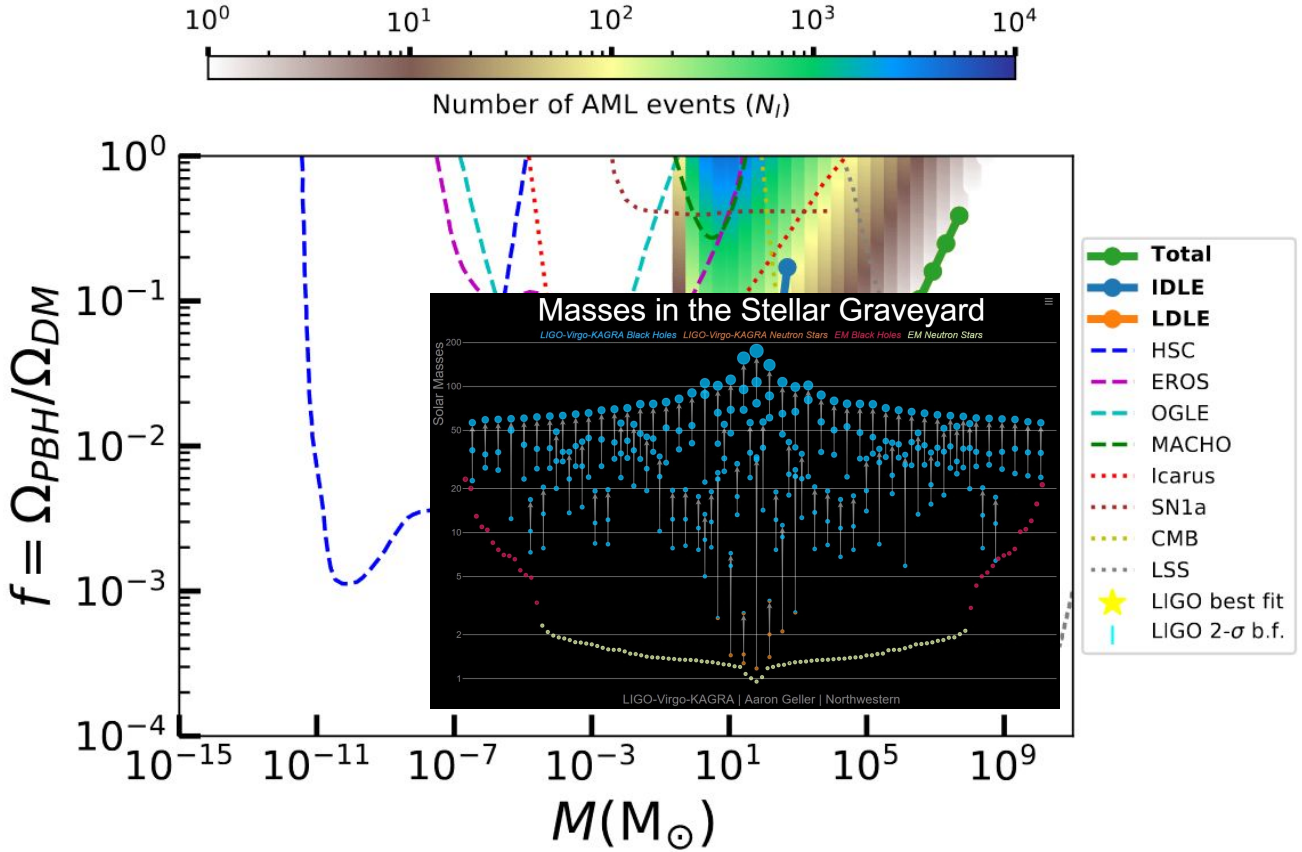

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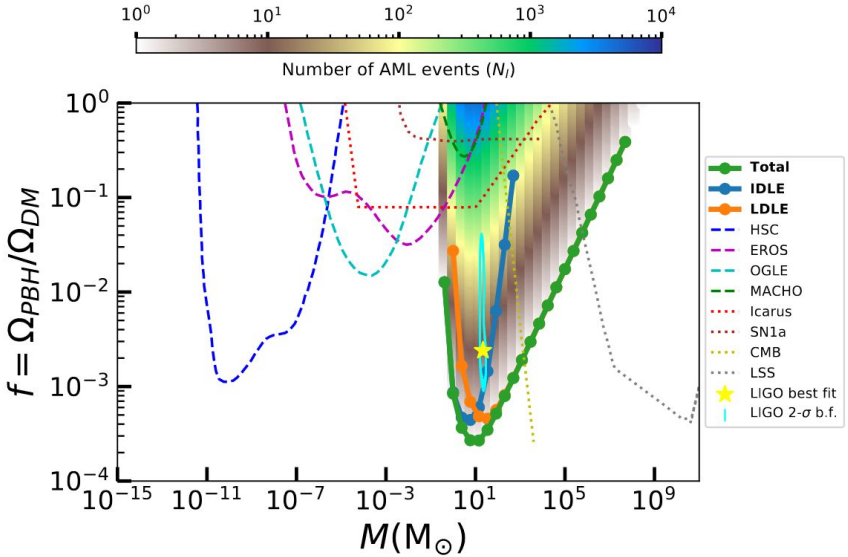
Summary

- Prediction for the expected sensitivity of Gaia to the PBH parameter space (f, M)
- Two different classes of detectable lensing events, IDLEs and LDLEs.
- Expected AML event observable distributions from PBH induced astrometric microlensing.
- Gaia is sensitive to PBHs with mass between 0.4 $M_\odot$ to $5 \times 10^7\, M_\odot$ with peak sensitivity to PBH masses of 10 $M_\odot$ with fraction f = 3×10^{-4}



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Future Prospects

1) **We are actually simulating trajectory of each star in the Gaia catalog and add PBH Dark Matter in the Galaxy with certain velocity distribution.**
2) Once time-series data is publicly available we can search for the PBHs by fitting the actual trajectory data provided by Gaia.
3) Using the distribution of the lensing observables we can detect the presence of PBHs statistically.
4) The same analysis can be done for extended lenses eg. axion miniclusters and the substructures of the DM in our Milky Way.

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Thank You

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