Hiroko Niikura

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Earth-mass BH?
PBH constraints with OGLE

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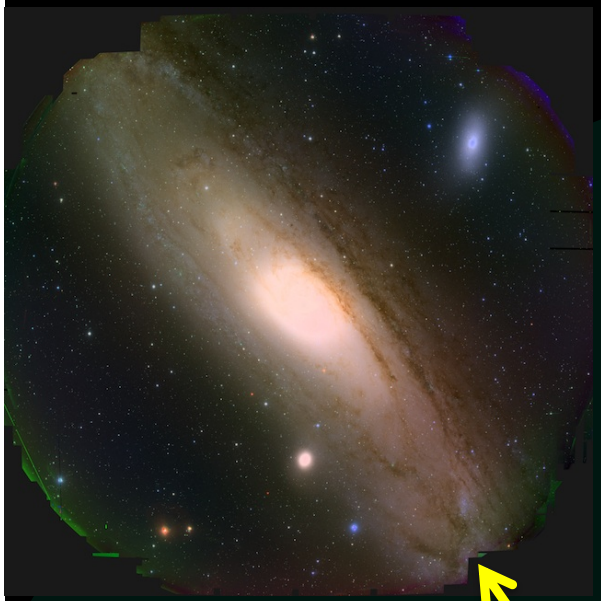
(arXiv:1901107120, PRD in press)

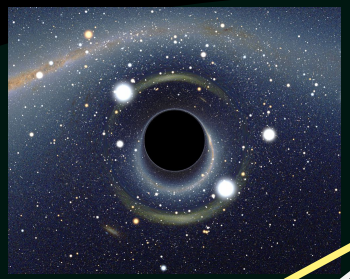
KAVLI IPMU INSTITUTE FOR THE PHYSICS AND MATHEMATICS OF THE UNIVERSE

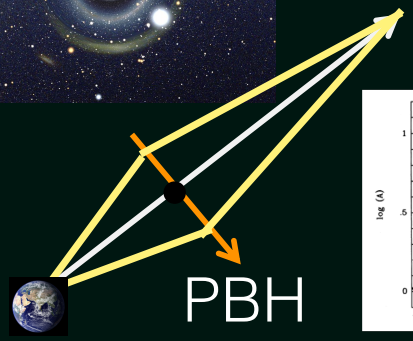
東京大学 THE UNIVERSITY OF TOKYO

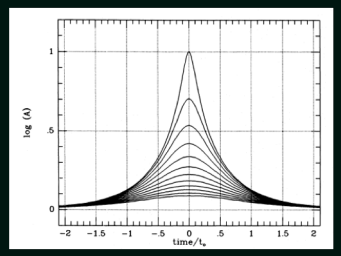
wpi

Constraining PBH with microlensing









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HSC M31
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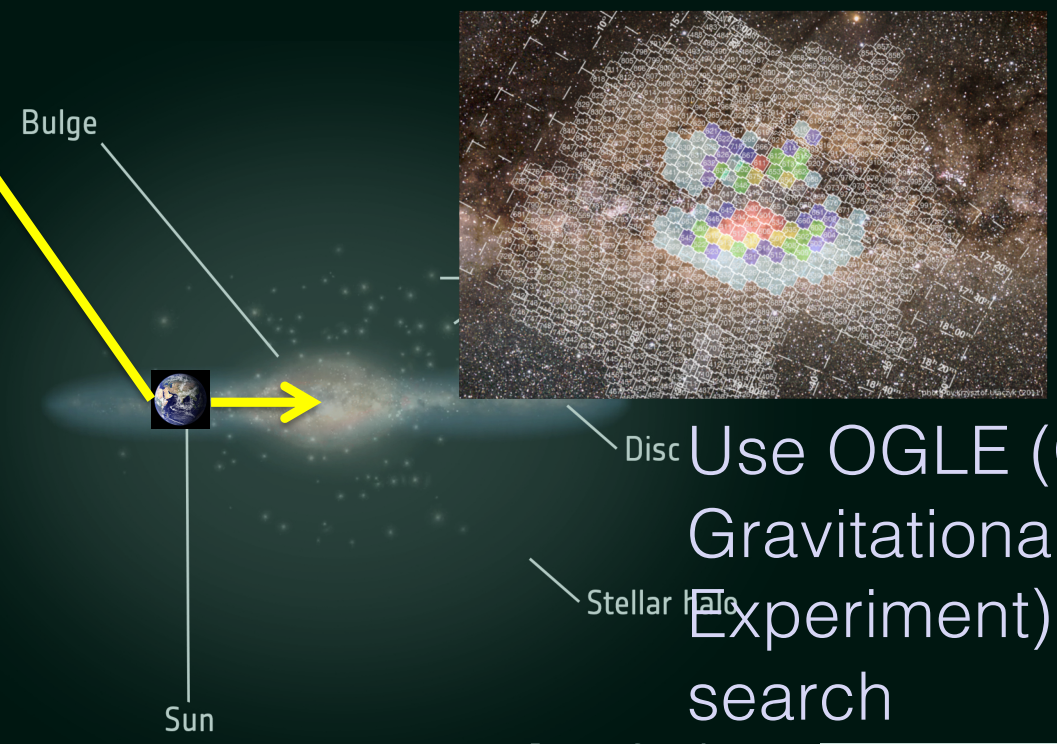
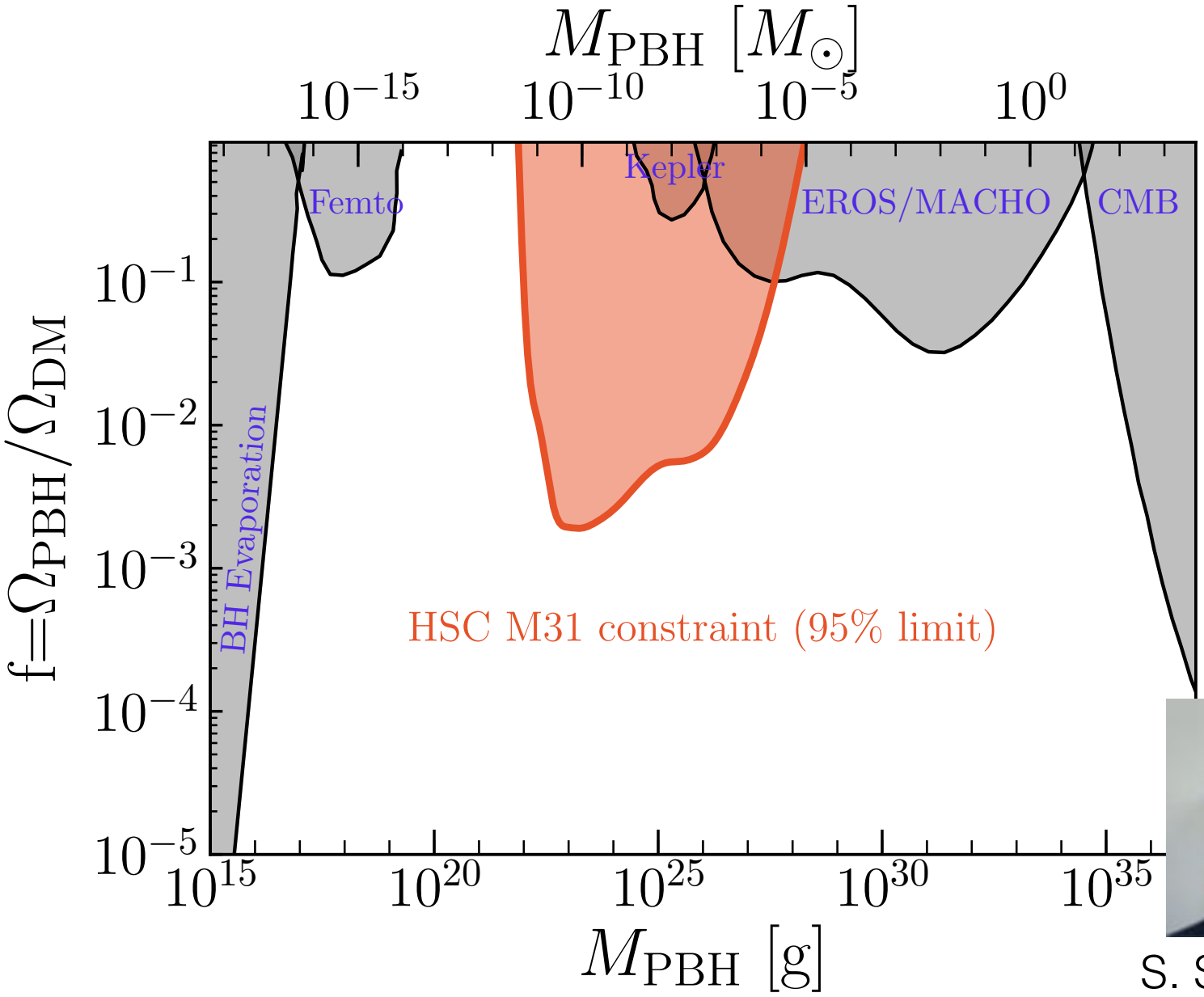
microlensing
search

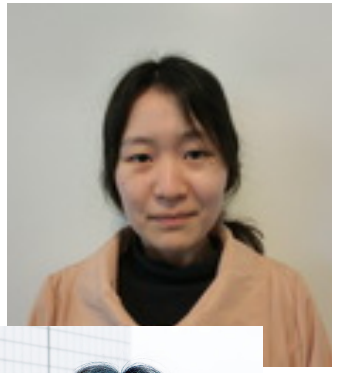


Use OGLE (Optical Gravitational Lensing Experiment) for PBH search

PBH constraints with HSC M31 ML search

Nature Astronomy in press (Niikura et al. 2019)

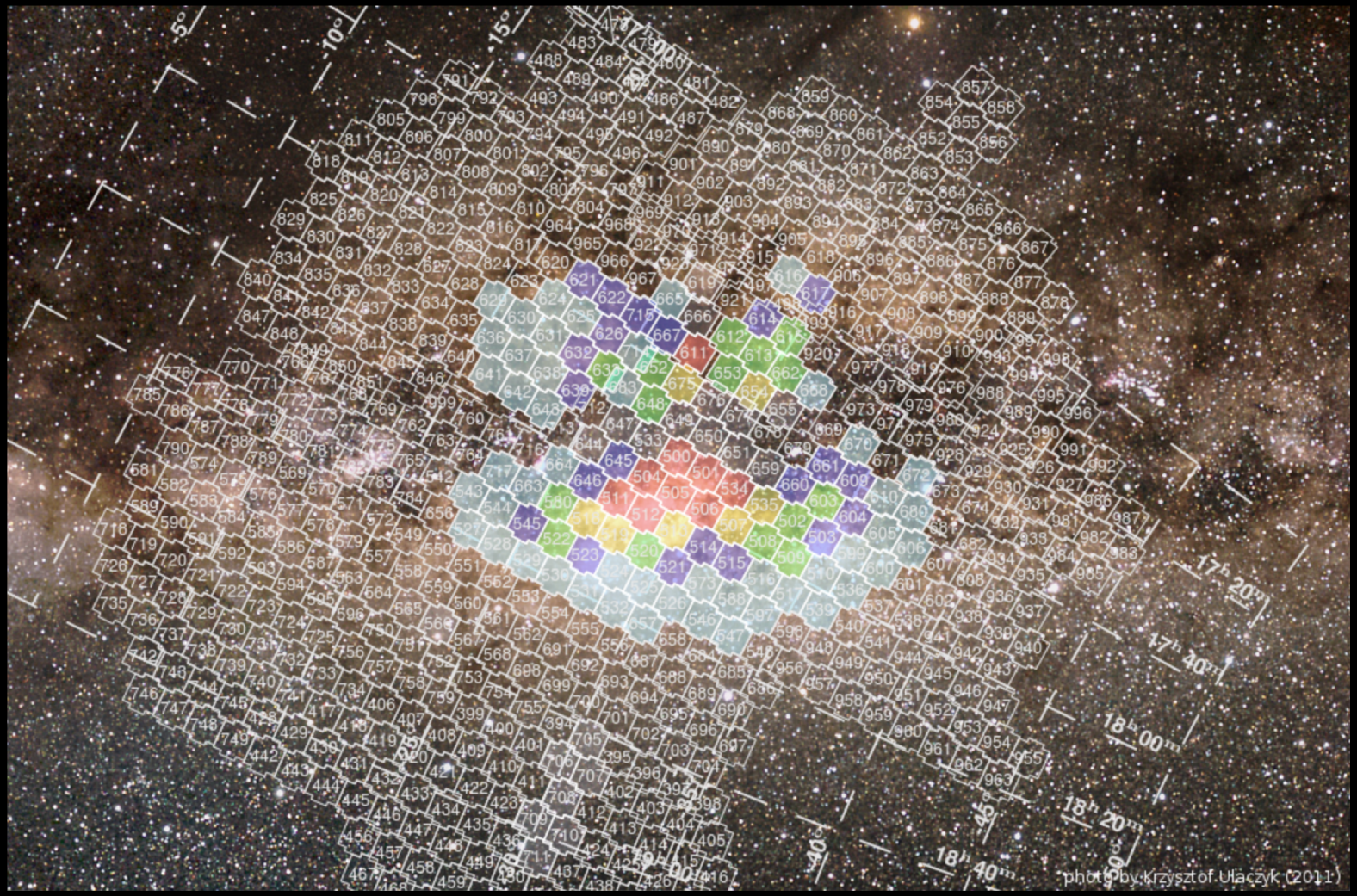




S. Sugiyama T. Kurita

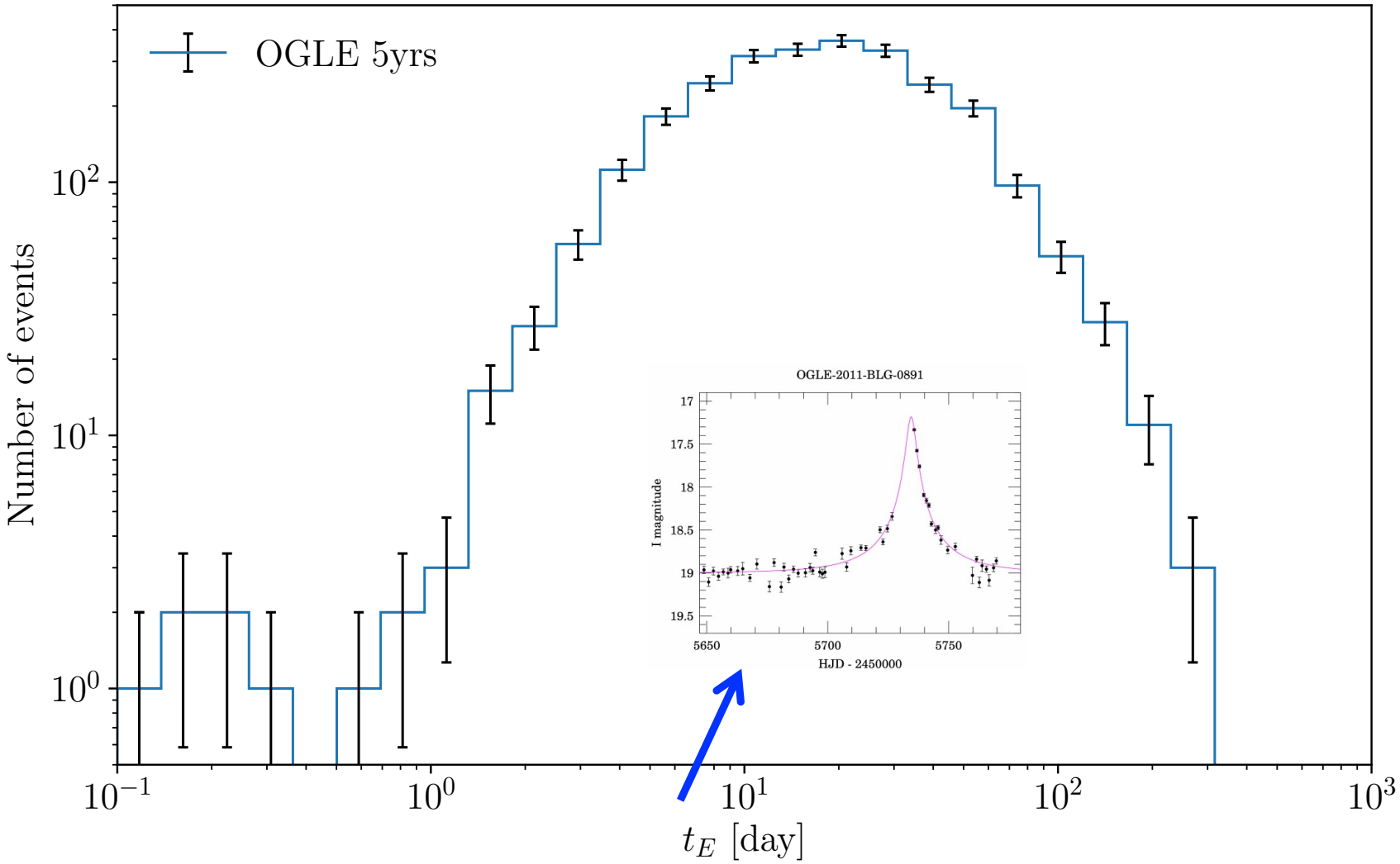
Optical Gravitational Lensing Experiment (OGLE)

- A long-term monitoring observation of Galactic bulge (1992-). PI Prof. Udalski (Warsaw)
- 1.3m Warsaw U. Telescope at Las Campanas, Chile



5-years OGLE data: Mroz et al. 2017

- 2622 ML events: the ML timescale distribution is provided (now >5000 events)



Microlensing of Galactic bulge

- Microlensing light curve timescale

$$t_{\rm E} = \frac{R_{\rm E}}{v_{\rm t}} \simeq 44\ {\rm days} \left(\frac{M}{M_\odot}\right)^{1/2} \left(\frac{d_{\rm l} d_{\rm ls}/d_{\rm s}}{4\ {\rm kpc}}\right)^{1/2} \left(\frac{v_{\rm t}}{220\ {\rm km/s}}\right)^{-1}$$

$$\mathbf{v}_t = \mathbf{v}_{\rm l} - \left(\frac{d_{\rm l}}{d_{\rm s}}\mathbf{v}_{\rm s} + \frac{d_{\rm l}}{d_{\rm s}}\mathbf{v}_{\rm o}\right)$$

- Event rate of ML for a given timescale per a source star

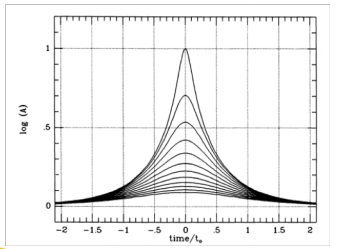
$$\frac{{\rm d}\Gamma_{\rm b}}{{\rm d}t_{\rm E}} = \frac{2\pi}{N_{\rm s}} \int_{d_{\rm s,min}}^{d_{\rm s,max}} {\rm d}d_{\rm s}\ n_{\rm s}(d_{\rm s}) \sum_i \int_{d_{\rm s,min}}^{d_{\rm s}} {\rm d}d_{\rm l} \frac{\rho_{{\rm b},i}(d_{\rm l})}{M_i} R_{\rm E}(d_{\rm s}, d_{\rm l})$$

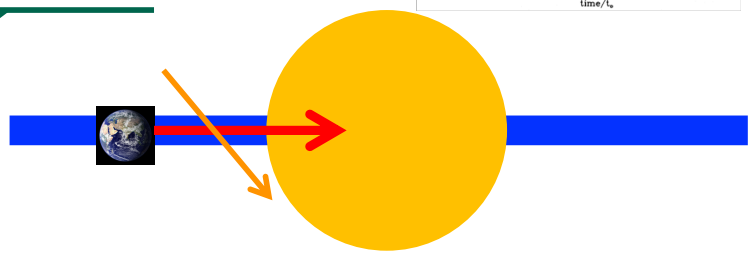
source star dist. lens dist.

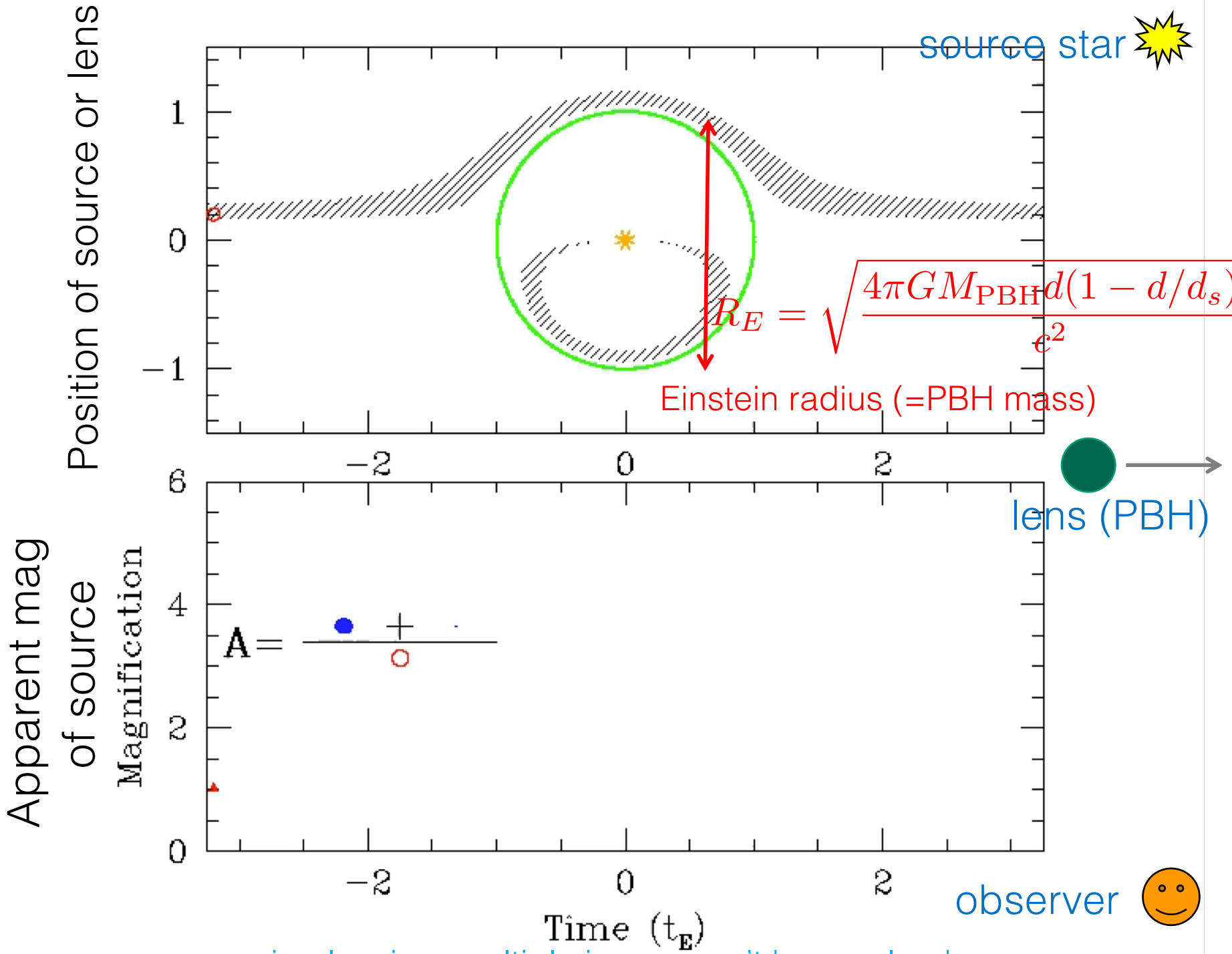
$$\times \int_0^\infty {\rm d}v_\perp \int_{-\pi/2}^{\pi/2} {\rm d}\theta\ v_\perp^2 \cos\theta f_{{\rm b},i}(v_\perp, \theta)$$

$$\times \delta_D\left(t_{\rm E} - \frac{2R_{\rm E}\cos\theta}{v_\perp}\right)$$

velocity distribution

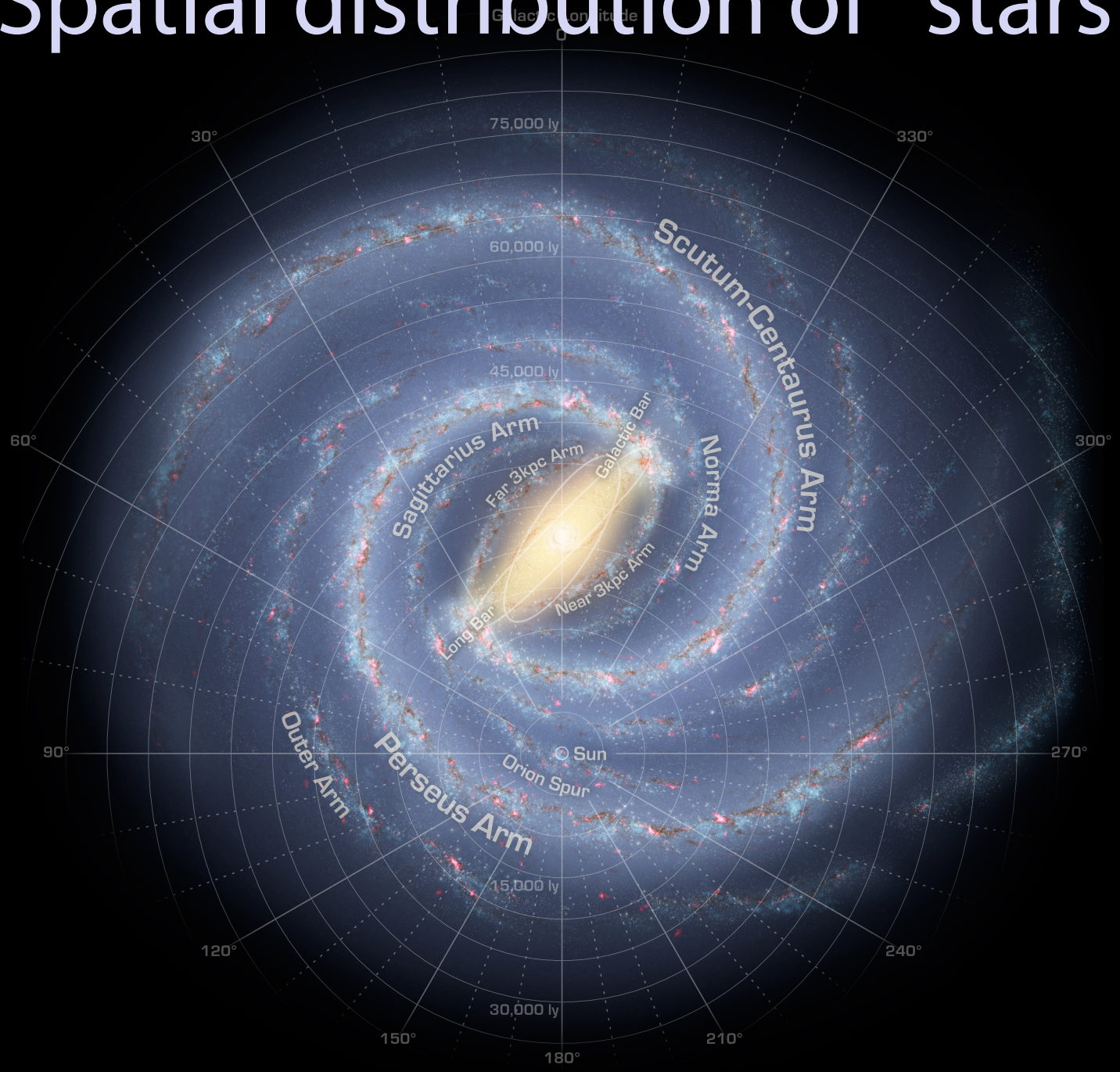






microlensing: multiple image can't be resolved

Spatial distribution of “stars”



Gould & Han 1995

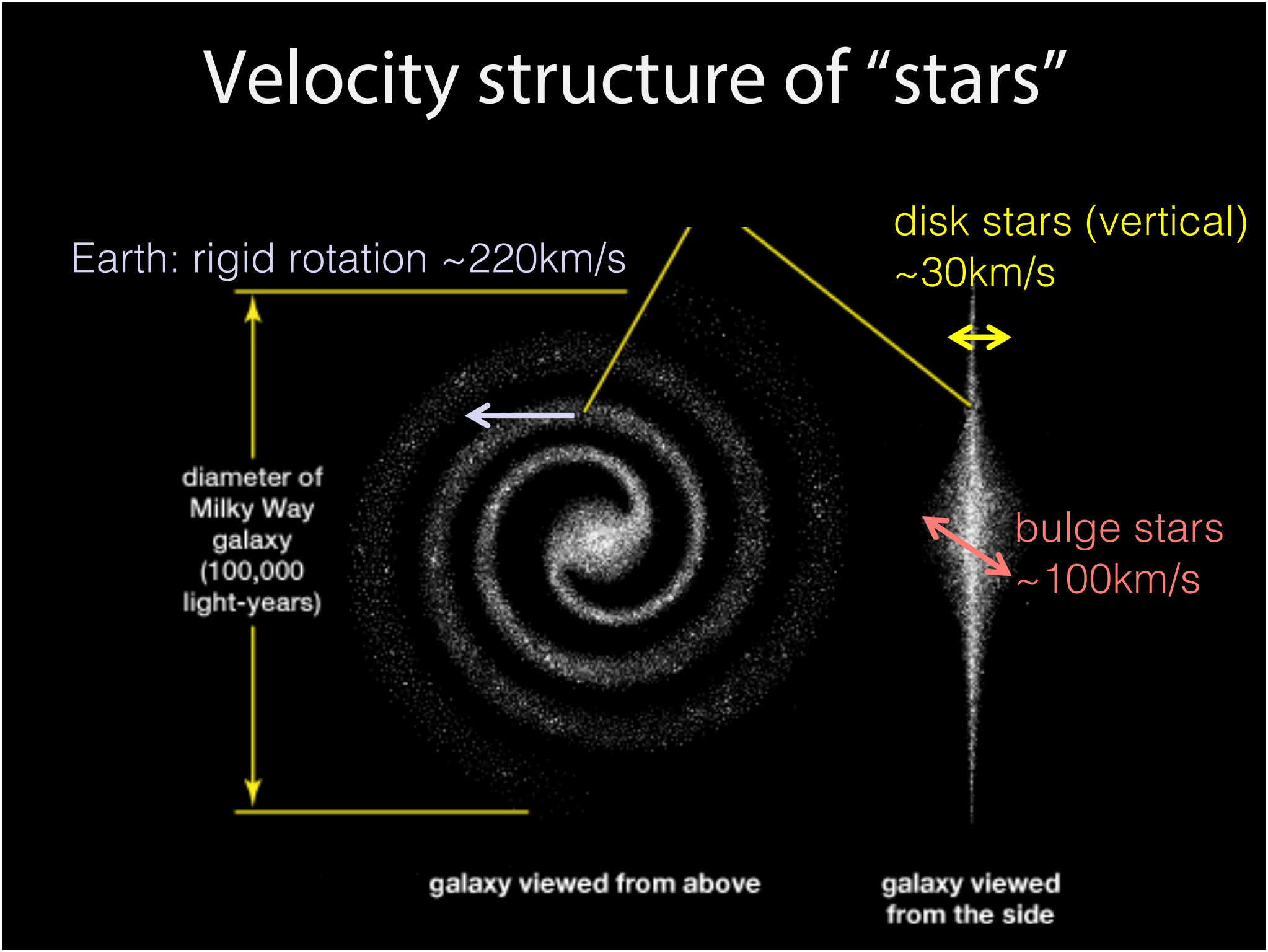
TABLE 2

BULGE AND DISK DENSITY MODELS

Location	Model	Distribution
Bulge.....	isothermal	$\rho(r) = \sigma^2_{\rm bulge}/2\pi G r^2 = 36.7(\sigma_{\rm bulge}/r)^2\ M_\odot\ {\rm pc}^{-3}$
	Kent	$\rho(s) = 1.04 \times 10^6 (s/0.482)^{-1.85}\ M_\odot\ {\rm pc}^{-3}\quad (s < 938\ {\rm pc})$
		$\rho(s) = 3.53 K_0(s/667)\ M_\odot\ {\rm pc}^{-3}\quad (s \geq 938\ {\rm pc})$
	bar	$\nu(r_s) = \nu_0 \exp(-0.5 r_s^2) \times 10^9\ L_\odot\ {\rm pc}^{-3}$
Disk.....	Bahcall	$n(R, z) = n(0, 0) \exp\{-[(R - 8000)/3500 + z/325]\}$
	Kent	$\nu(R, z) = 3.0 \exp[-(R/3001 + z/h_1)]\ L_\odot\ {\rm pc}^{-3}\quad (R < 5\ {\rm kpc})$
		$\nu(R, z) = 3.0(h_1/h_2) \exp[-(R/3001 + z/h_2)]\ L_\odot\ {\rm pc}^{-3}\quad (R \geq 5\ {\rm kpc})$
	KP	$\rho = 0.1\ M_\odot\ {\rm pc}^{-3}\quad (d < d_{\rm max})$
		$\rho = 0\ M_\odot\ {\rm pc}^{-3}\quad (d \geq d_{\rm max})$

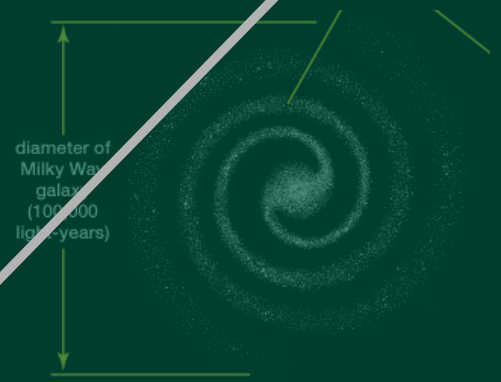
The density distribution models adopted for stellar populations. The values $r = (x^2 + y^2 + z^2)^{1/2}$, $R = (x^2 + y^2)^{1/2}$, $s^4 = R^4 + (z/0.61)^4$ are measured in pc. K_0 is a modified Bessel function and $n(0, 0) = 0.097\ {\rm pc}^{-3}$. We adopted $d_{\rm max} \sim 4$ kpc for the KP model. The Bahcall and Kent disk models and the barred bulge model are expressed in number density, $n(R, z)$, and luminosity functions, $\nu(R, z)$ and $\nu(r_s)$, respectively. For the Kent disk model two different scale heights are adopted for the inner (h_1 for $R < 5$ kpc) and outer (h_2 for $R \geq 5$ kpc) parts of the disk. The respective scale heights are $h_1 = 165$ pc and $h_2 = (0.027R + 28.3)$ pc. For the barred (anisotropic) bulge model, $\nu_0 = 3.66 \times 10^7\ L_\odot\ {\rm kpc}^{-3}$, and $r_s = \{[(x'/x_0)^2 + (y'/y_0)^2]^2 + (z'/z_0)^4\}^{1/4}$. Here the coordinates (x', y', z') have their center at the Galactic center, the longest axis is the x' axis, and the shortest axis is the z' axis. The values of the scale lengths are $x_0 = 1.58$ kpc, $y_0 = 0.62$ kpc, and $z_0 = 0.43$ kpc, respectively.

Velocity structure of "stars"

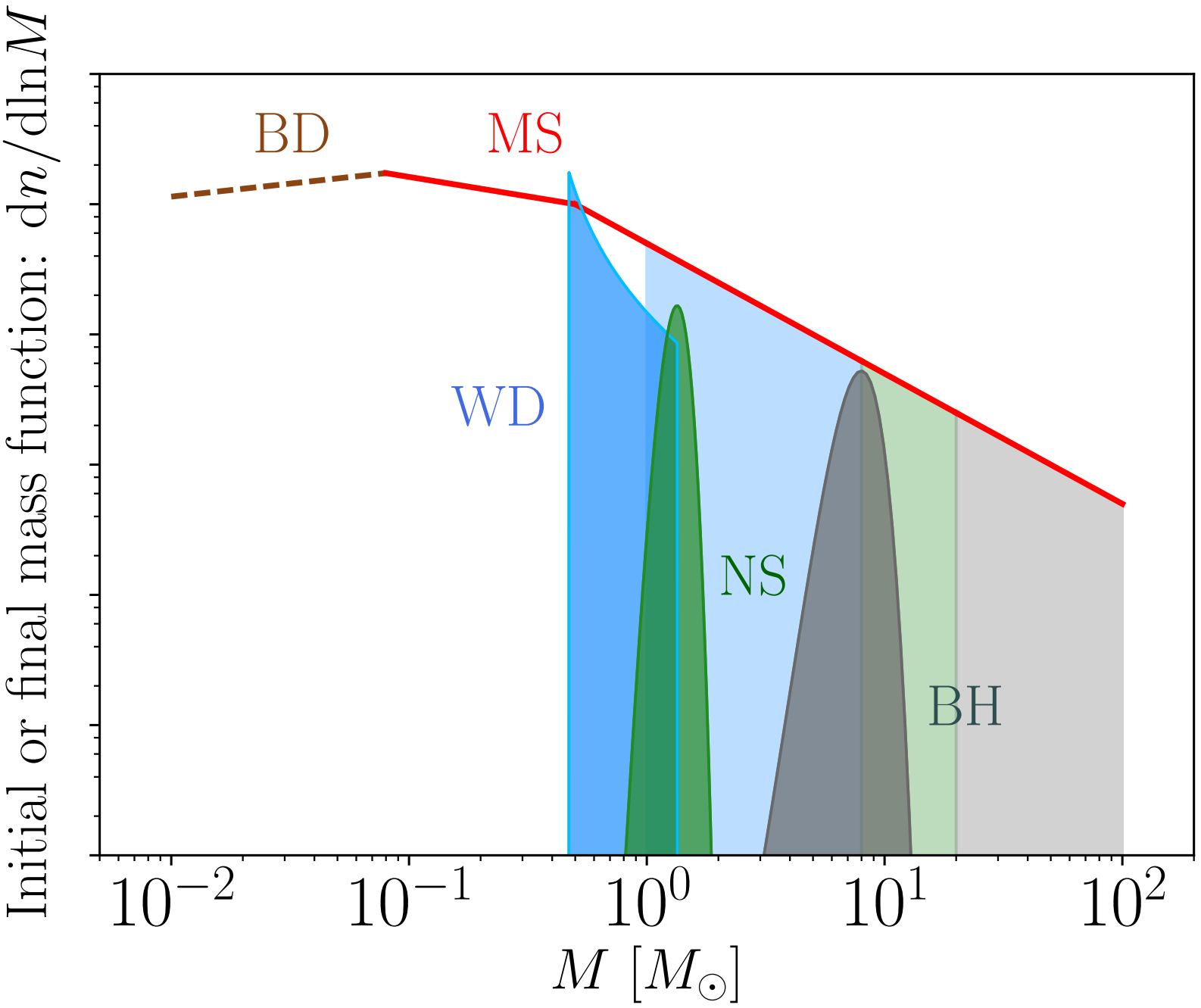


MW dark matter halo

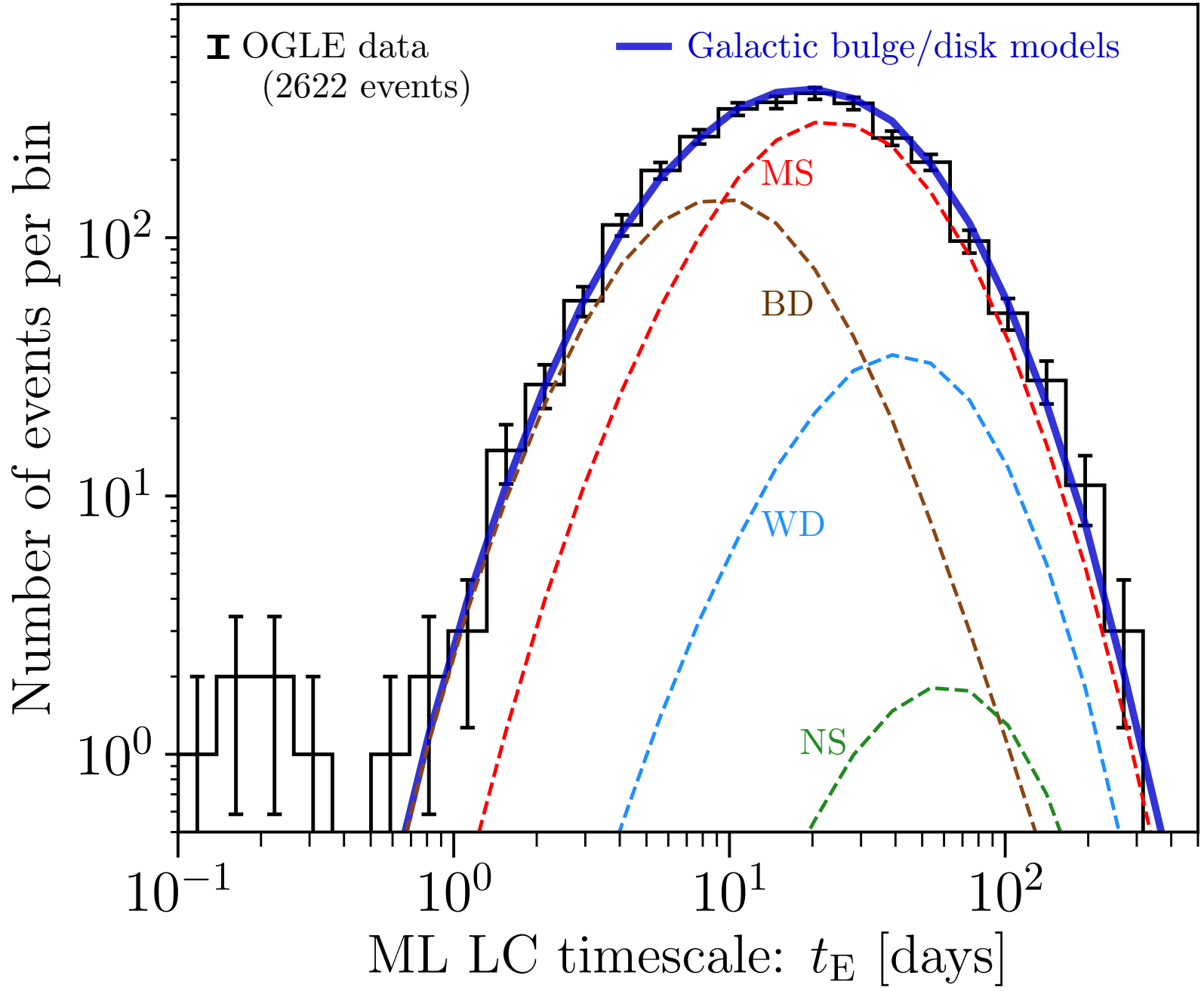
Dark matter
(WIMP),
PBH,….
~220km/s



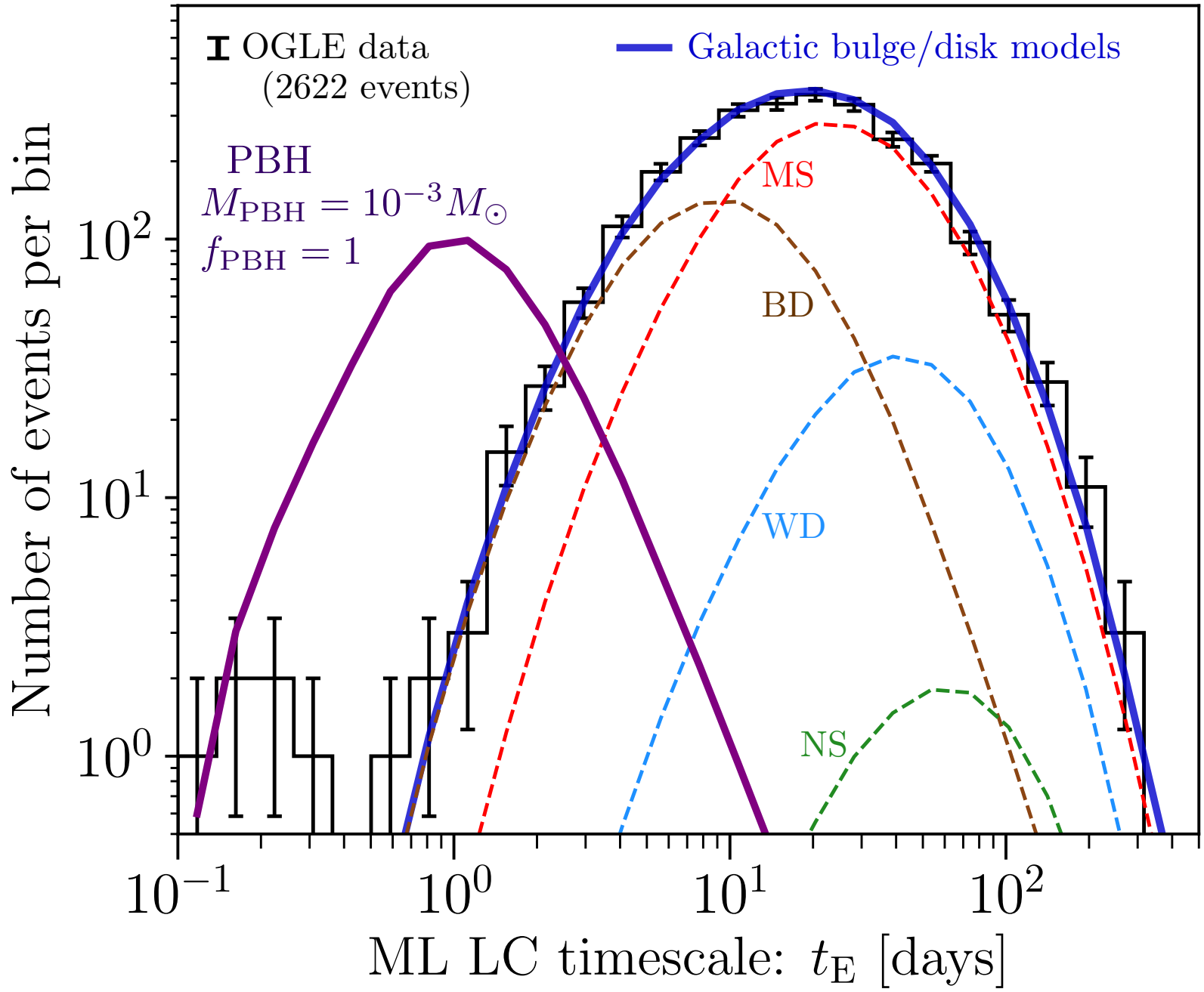
Astrophysical lenses: stars and stellar remnants



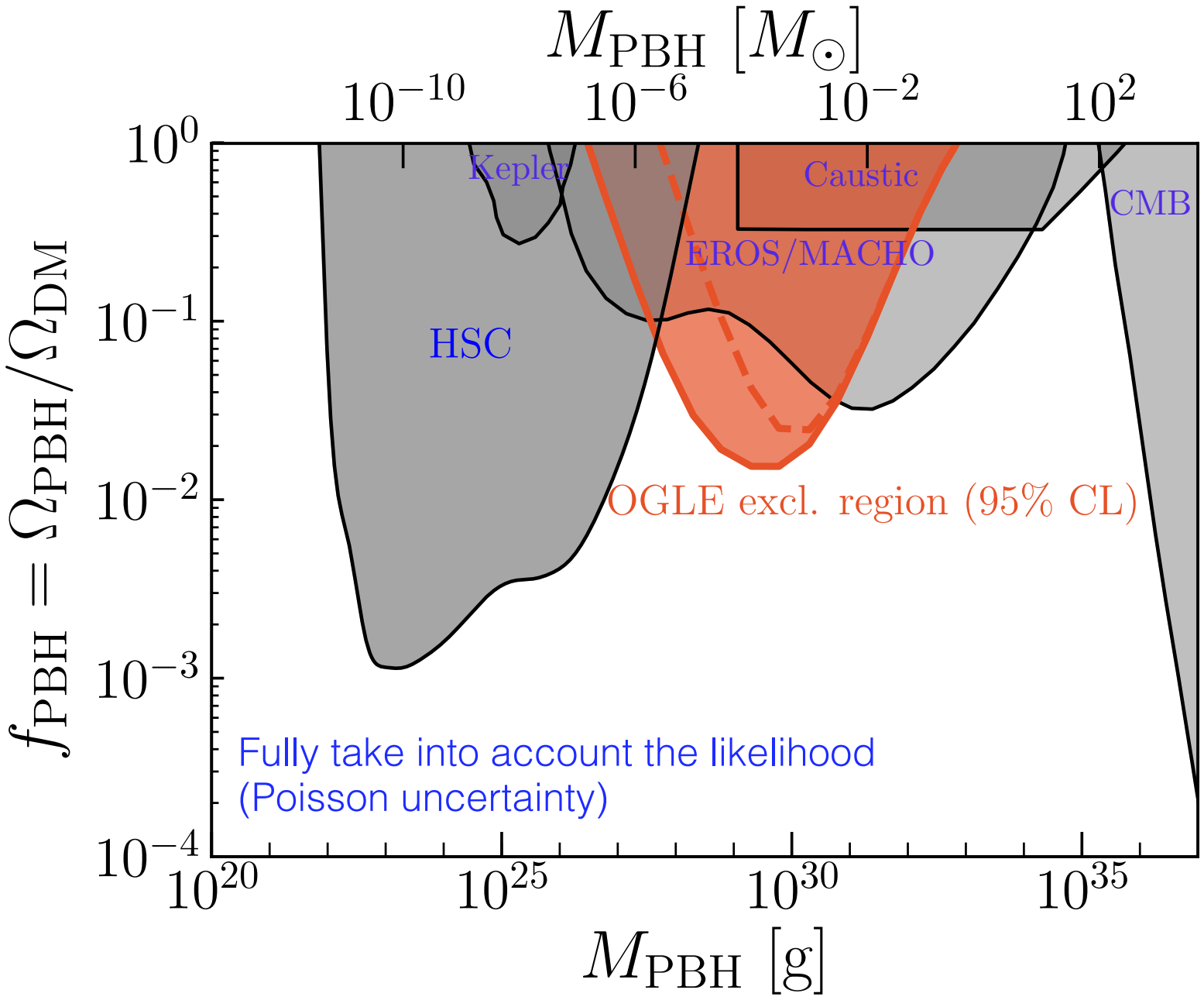
(old-days) Astronomers clever!



PBH lenses needed?



Null test: PBH upper bounds



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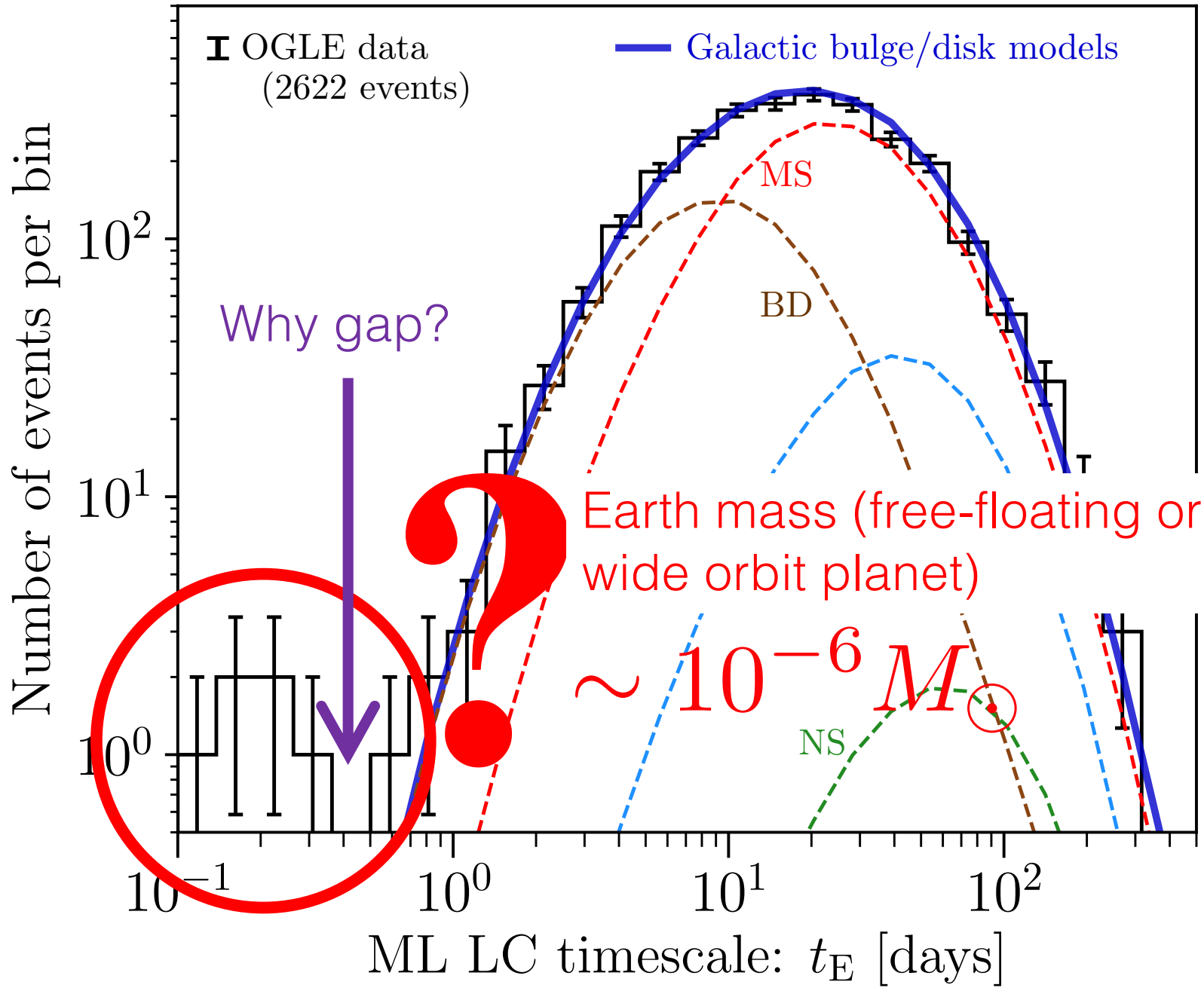
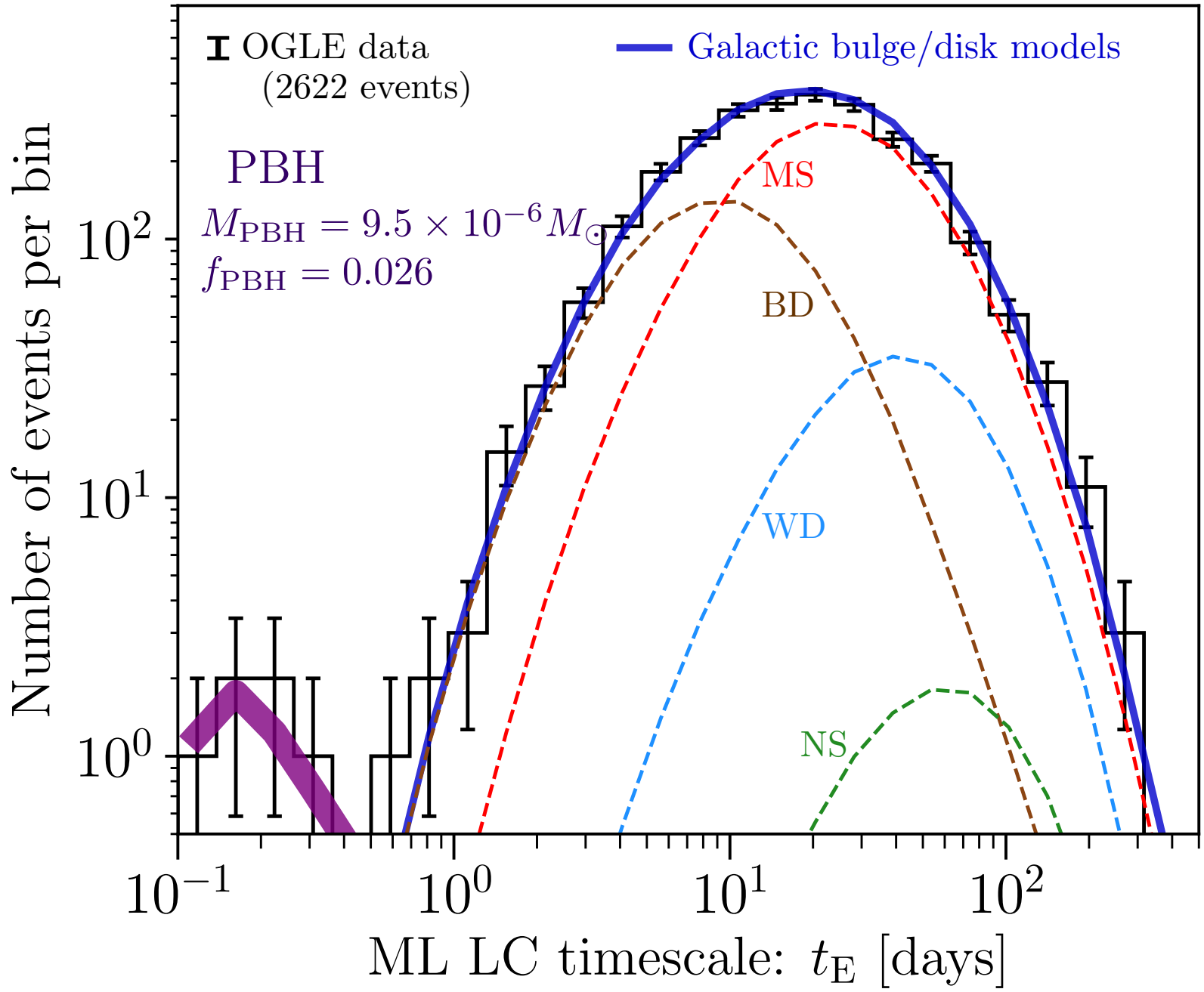


Earth-mass scale PBH?



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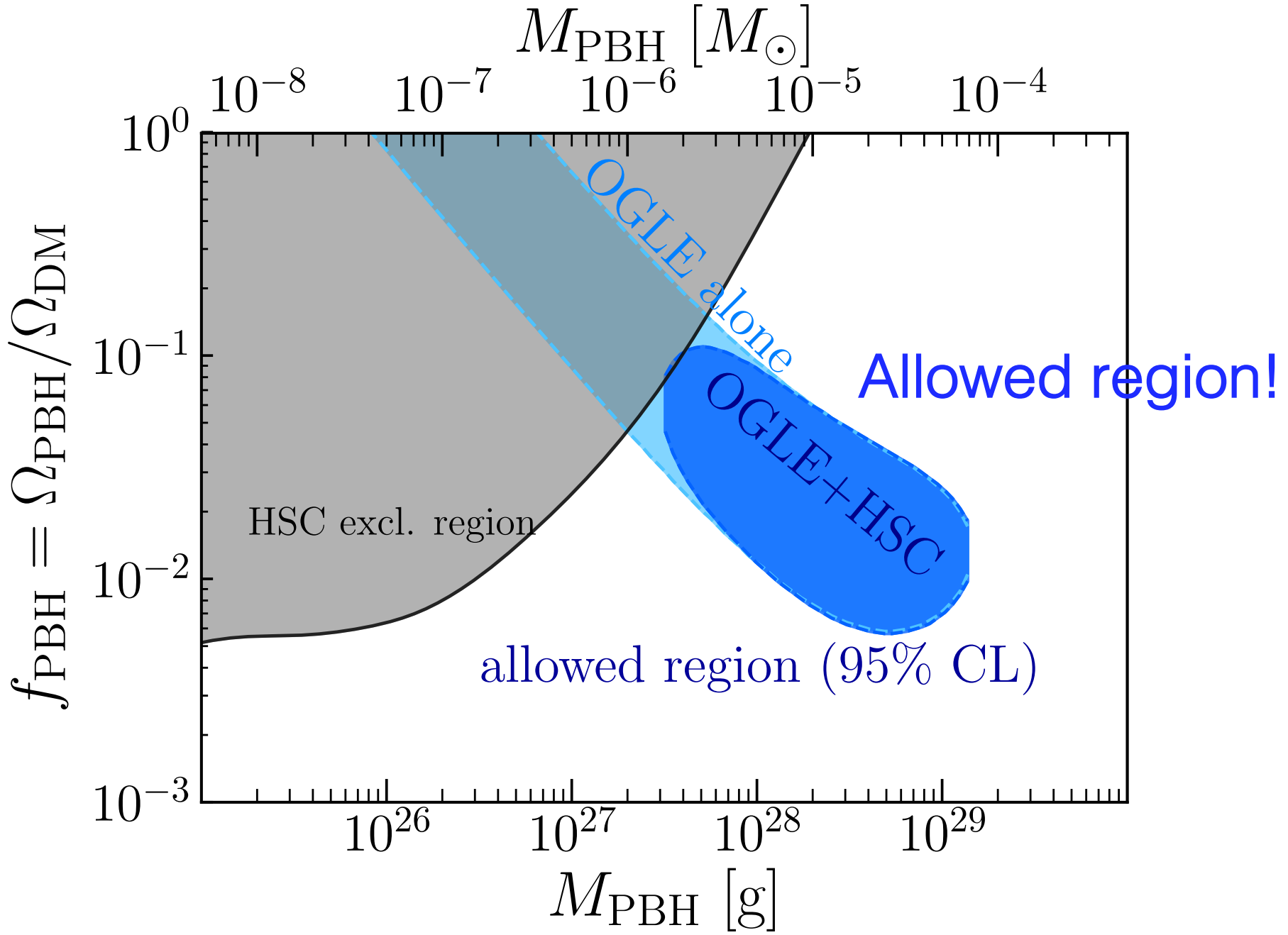

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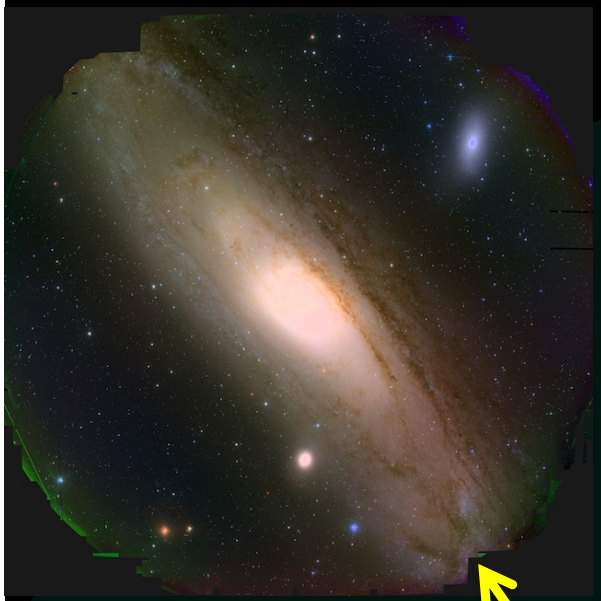

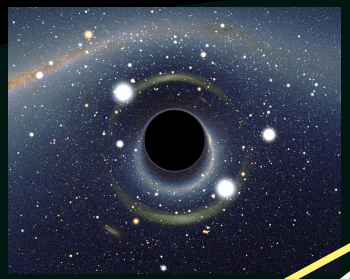

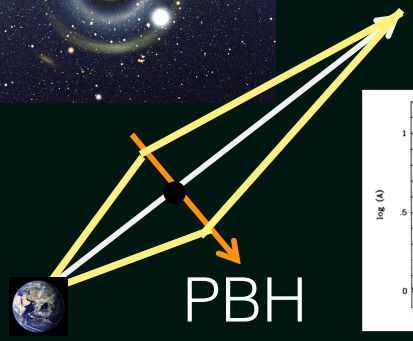

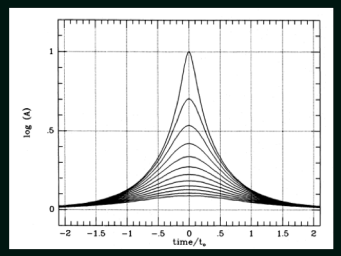

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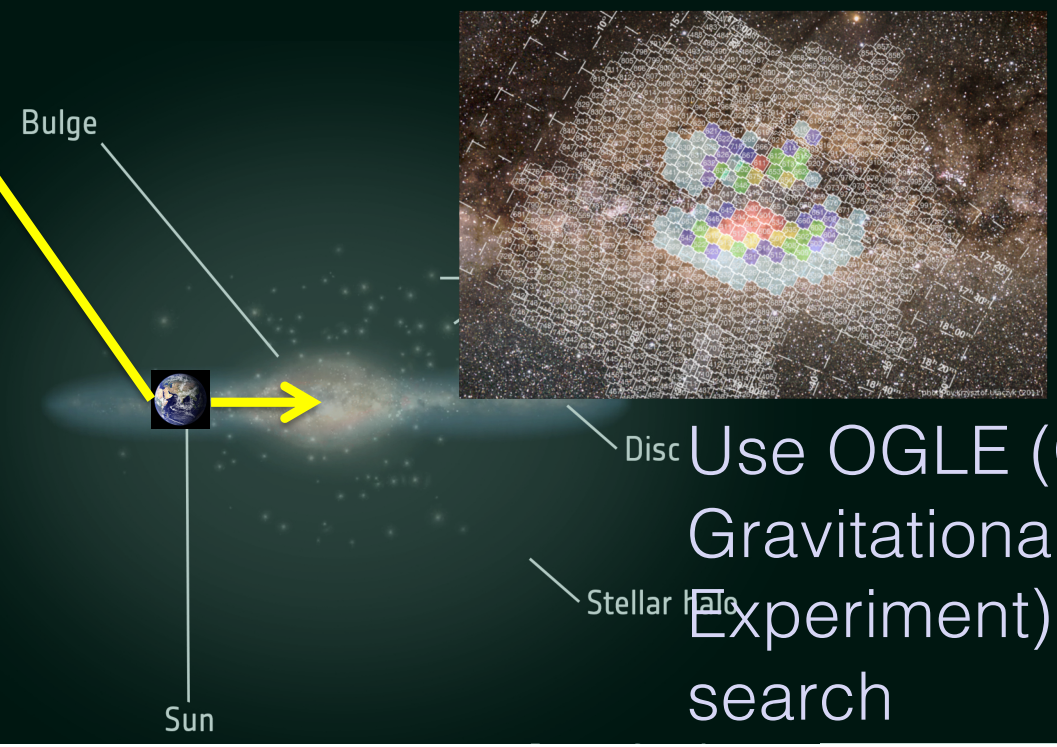

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