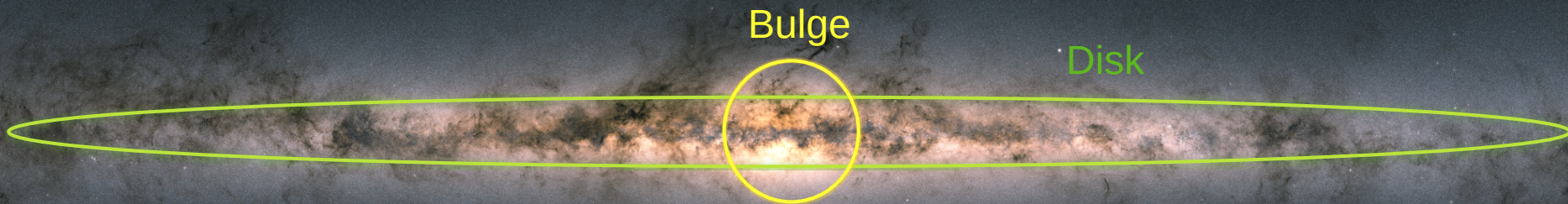


Separation of Milky Way bulge and disk in LISA residual data



Solano Felicio
Astrid Lamberts
Alexander Criswell
Alice Perego
Nelson Christensen

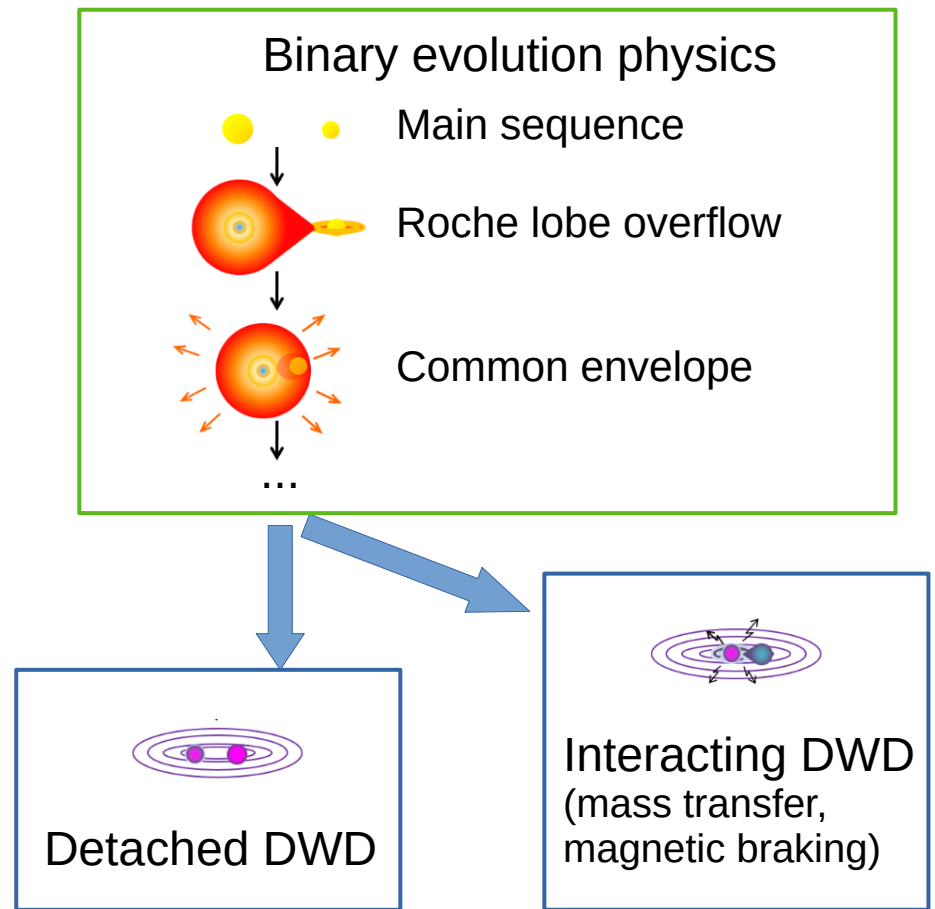


2026-05-04

Solano Felicio | Journées LISA France 2026

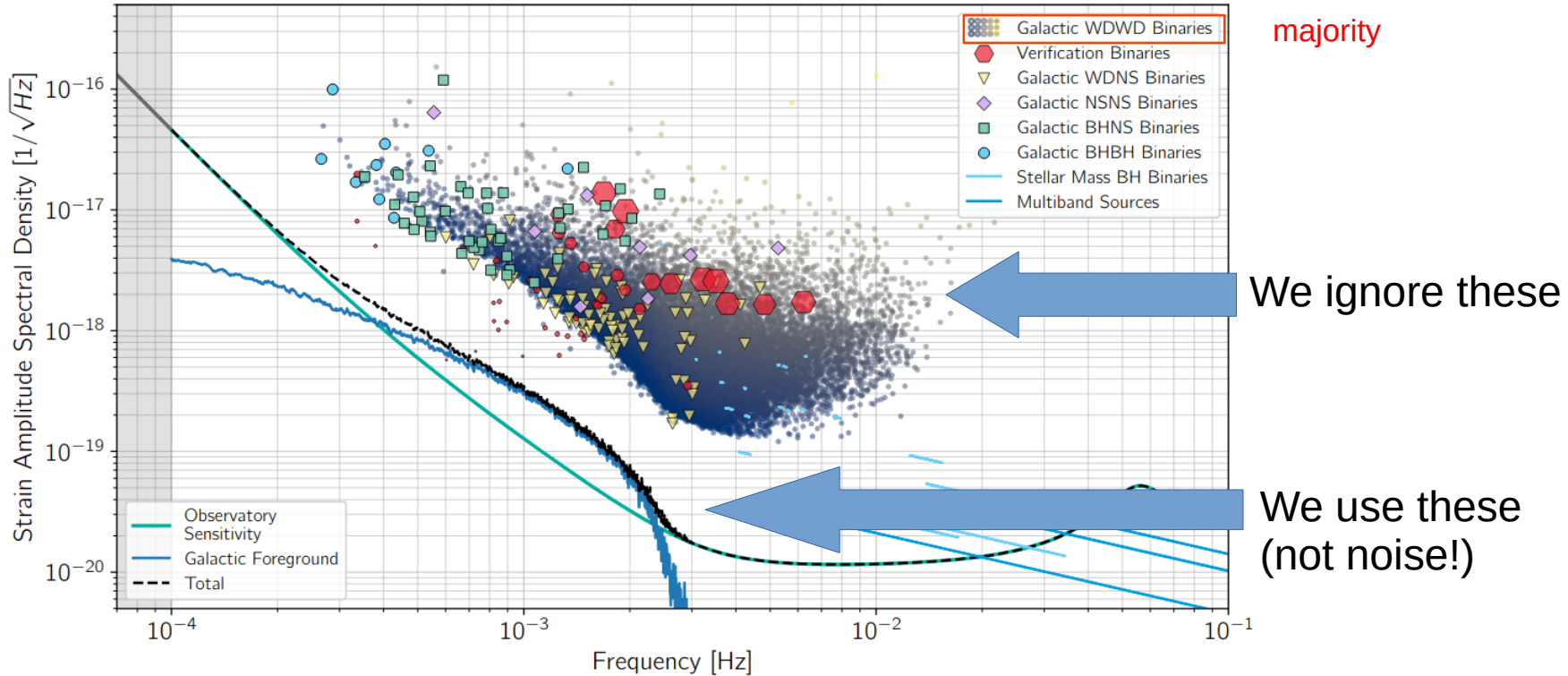
Image: ESA/Gaia/DPAC

- 97% of stars end their lives as white dwarfs ($\lesssim 10 M_{\odot}$)
- $\sim 1/3$ are binaries
- Conclusion: there are many binary white dwarfs
- Milky Way, LISA band only: $\sim 10^7$



Adapted from Tauris and van den Heuvel (2022)

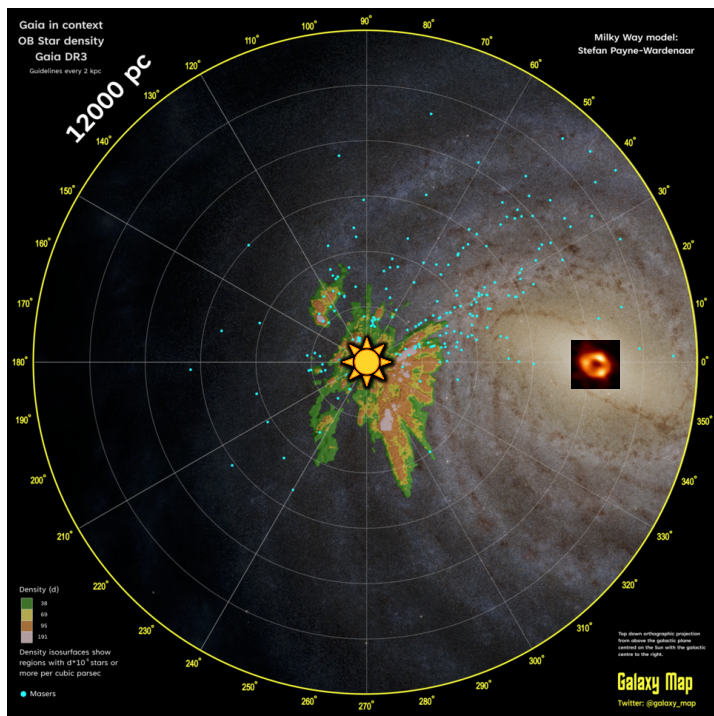
LISA Galactic Binaries



Source: LISA Definition Study Report (2024)

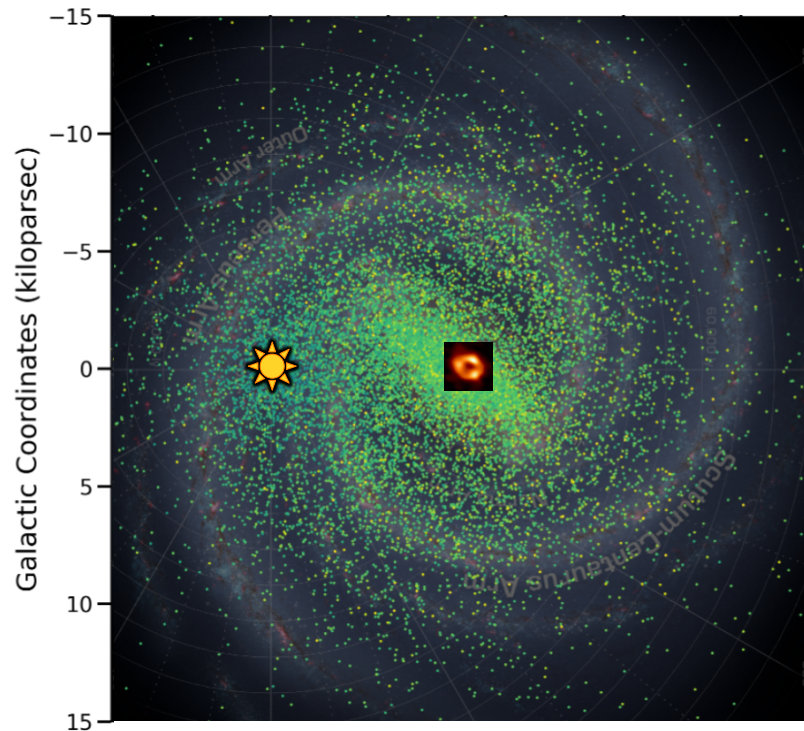
Q: What can LISA tell us about the Milky Way that telescopes can't?

Gaia star density: affected by dust



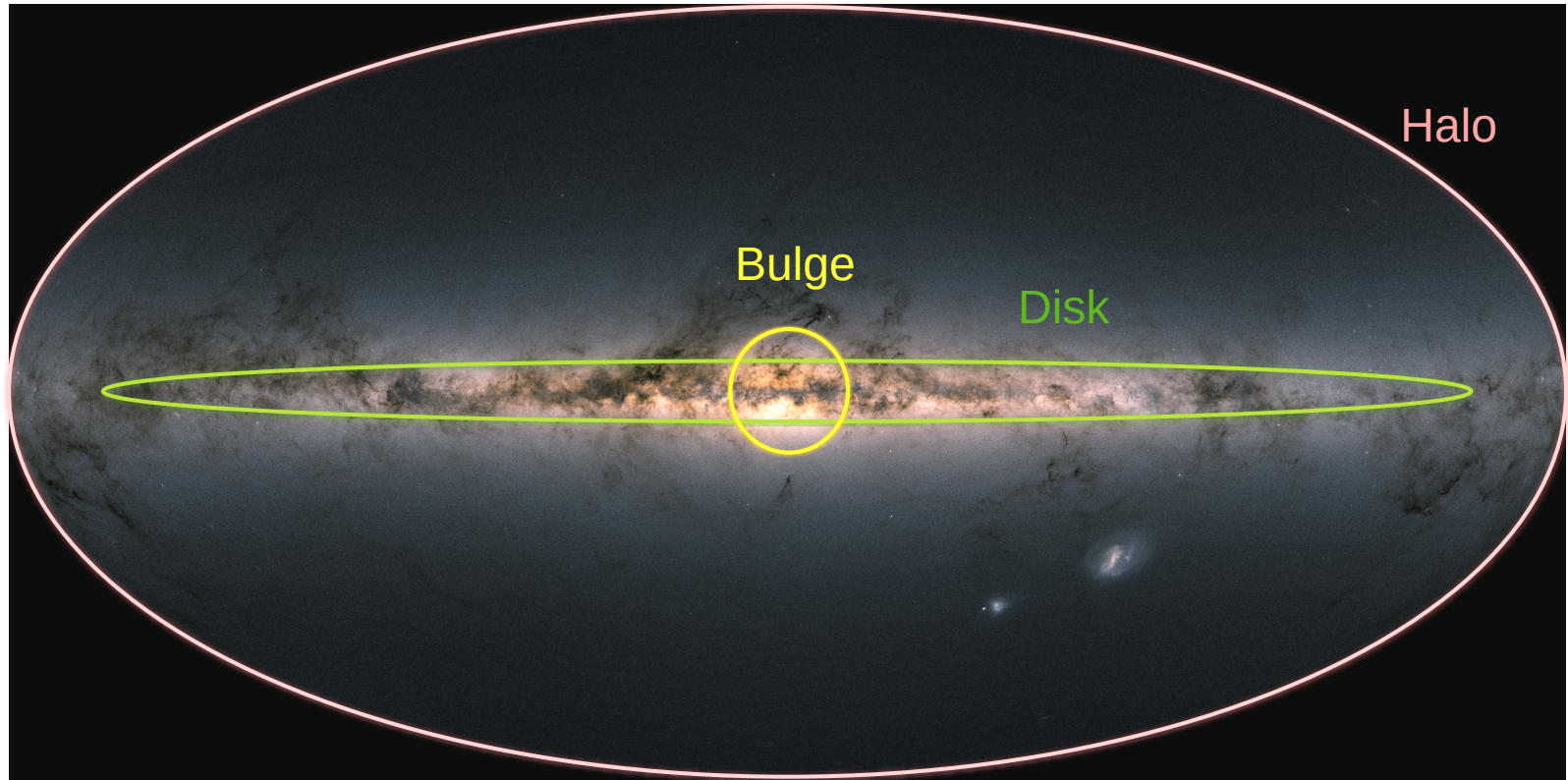
Credit: Kevin Jardine at galaxymap.org
From Gaia DR3

LISA Galactic Binaries: unaffected



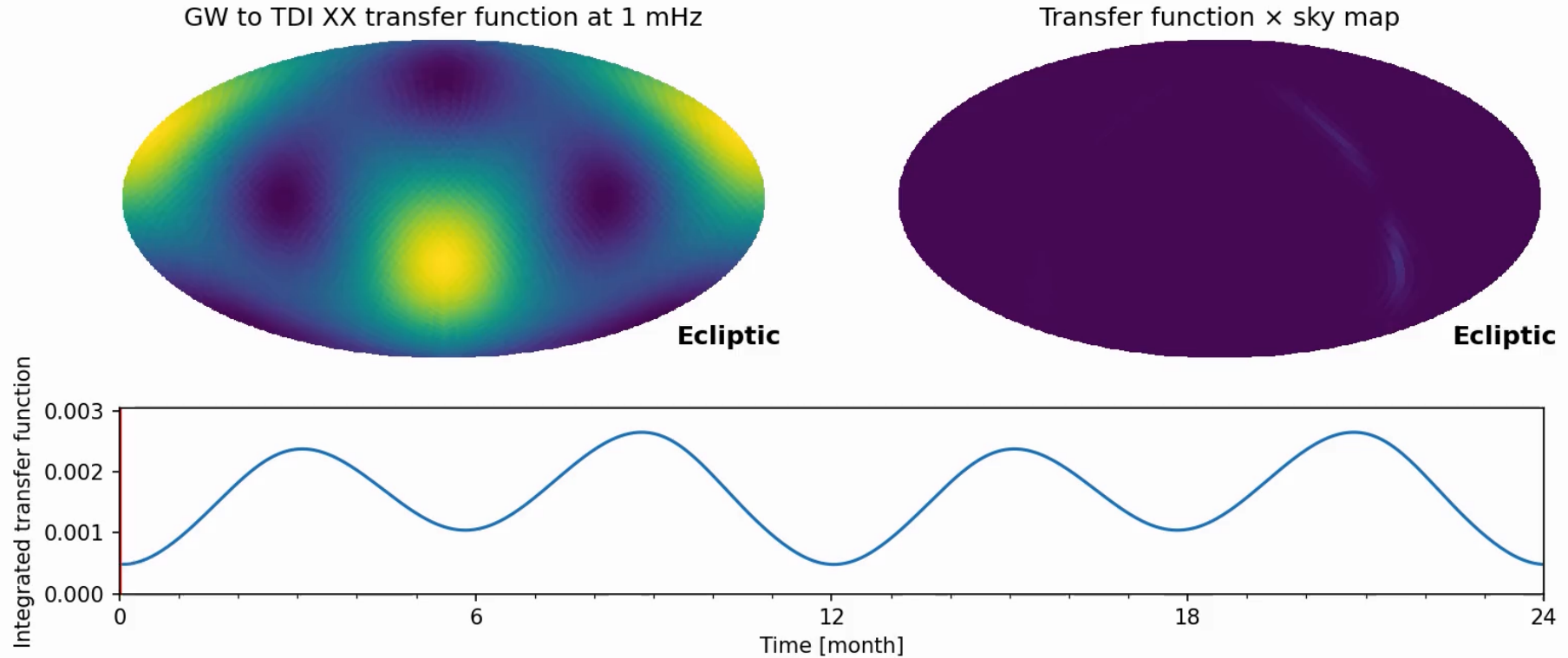
Adapted from LISA Definition Study Report (2024)

Milky Way structure (extremely simplified)



ESA/Gaia/DPAC; CC BY-SA 3.0 IGO. Acknowledgement: A. Moitinho.

Anisotropy-induced time modulation in LISA data



Building mock catalogues the easy way

(1) Take existing catalogues

FIRE / Lamberts et al. 2019
Cosmological simulation,
realistic spatial distribution
coupled to star formation

Perego et al. 2025
Homogeneous intrinsic
parameter distribution,
parametric spatial templates

(2) Resample

Heterogeneous
catalogue 
Bulge \neq Disk

Homogeneous
catalogue 
Bulge \sim Disk

McMillan (2011) shape templates

$$\rho_{\text{disk}} \propto \exp(-r/r_h) \exp(-|z|/z_h)$$

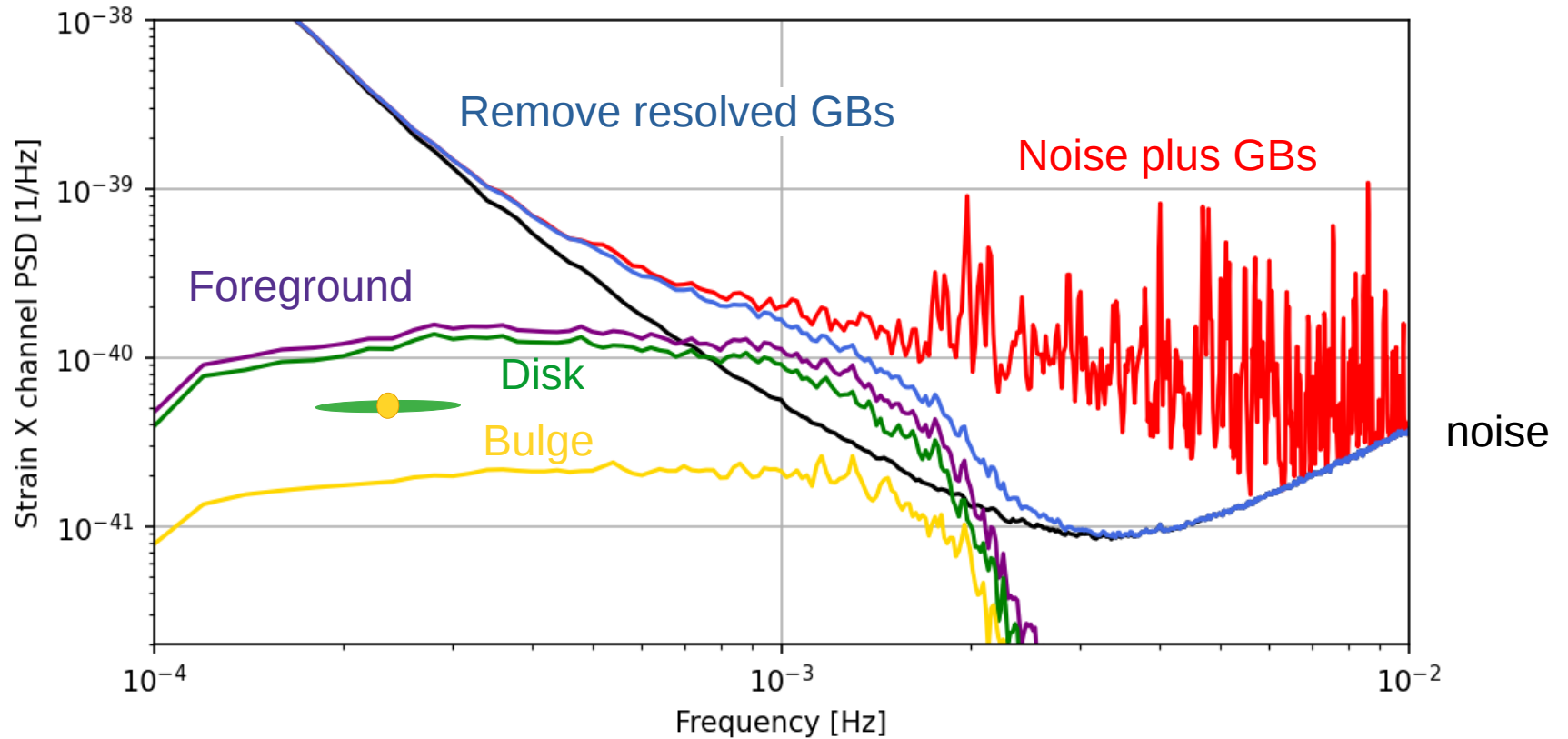
$$\rho_{\text{bulge}} \propto \frac{\exp[-(r'/r_{\text{cut}})^2]}{(1 + r'/r_0)^\alpha}$$

$$r' \equiv \sqrt{r^2 + (z/q)^2}$$

Chosen parameters:

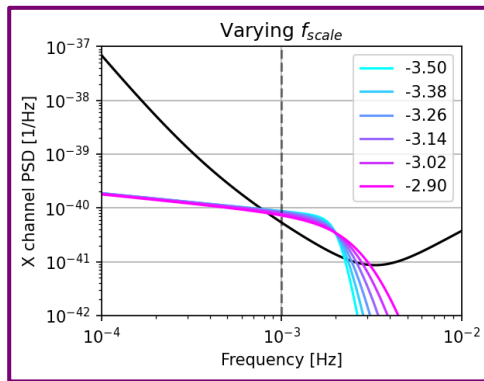
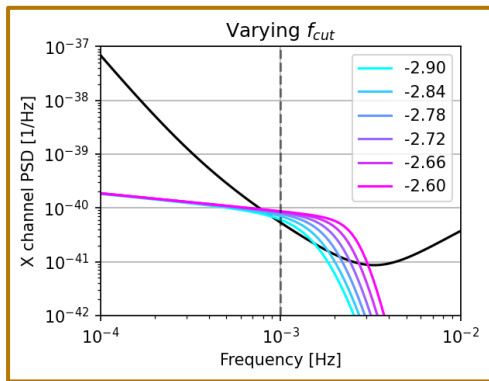
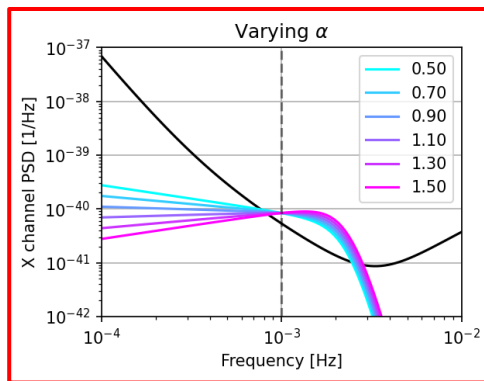
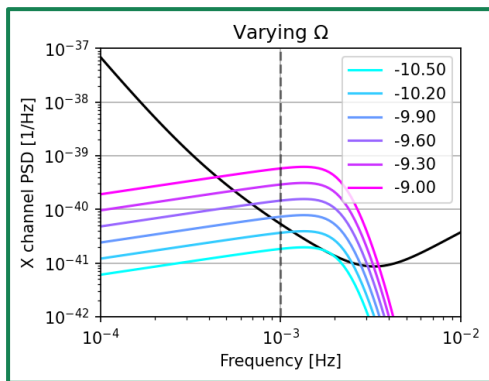
- Total mass
- Bulge/disk ratio

Simulating LISA data



Spectral model

$$\Omega_{\text{gw}}(f) = \Omega_0 \left(\frac{f}{1 \text{ mHz}} \right)^\alpha \frac{1}{2} \left[1 + \tanh \left(\frac{-(f - f_{\text{cut}})}{f_{\text{scale}}} \right) \right]$$



7 parameters:

Instrument

- N_a test mass noise
- N_p OMS noise

Foreground amplitudes

- Ω_{bulge}
- Ω_{disk}

Foreground shape

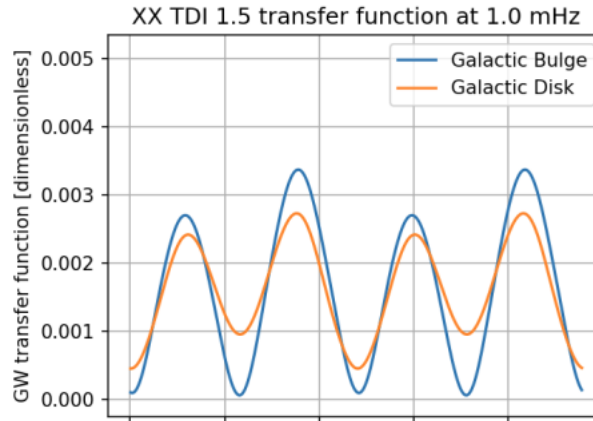
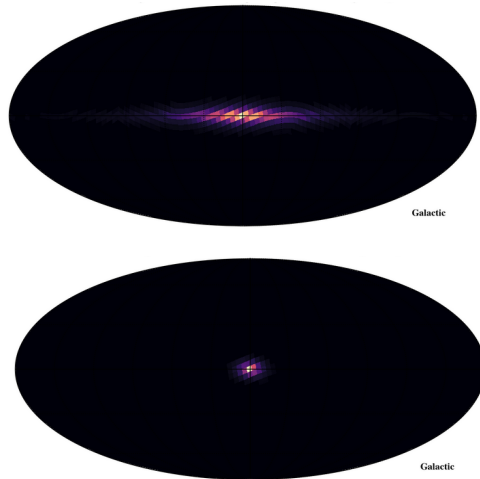
- α
- f_{scale}
- f_{cut}

Envelope model

Known SGWB transfer functions

$$R_{IJ}(t, f) = \frac{1}{2} \int d^2\mathbf{n} \mathcal{P}(\mathbf{n}) \left(\sum_{A=+, \times} F_I^A(t, f, \mathbf{n})^* F_J^A(t, f, \mathbf{n}) \right)$$

Sky map: line of sight integral (density/ r^2) d^3x
(arbitrary lower bound 2 kpc)



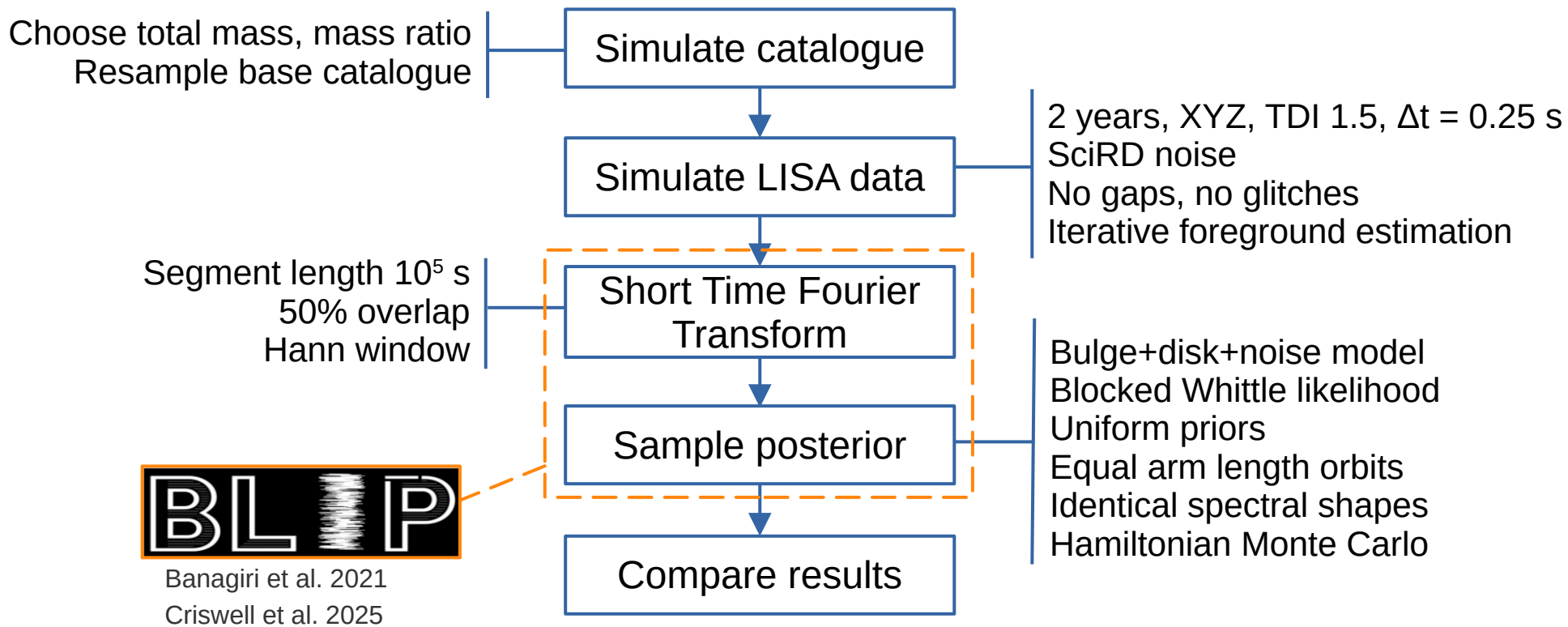
LISA antenna patterns:
Assume quasi-static,
equal arm length constellation



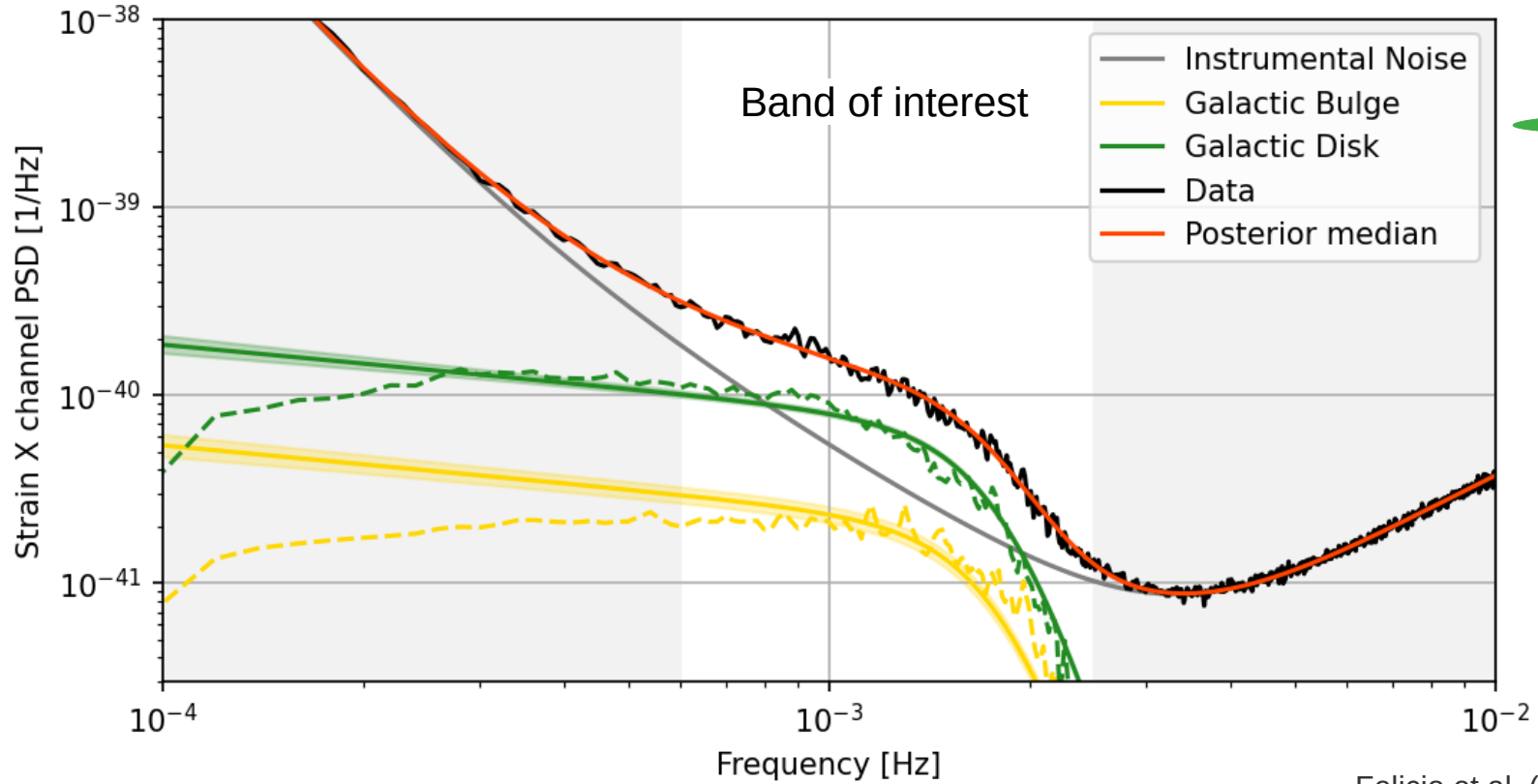
Multiply by PSDs to
get time-frequency
covariance

Felicio et al. (in prep.)

Methods

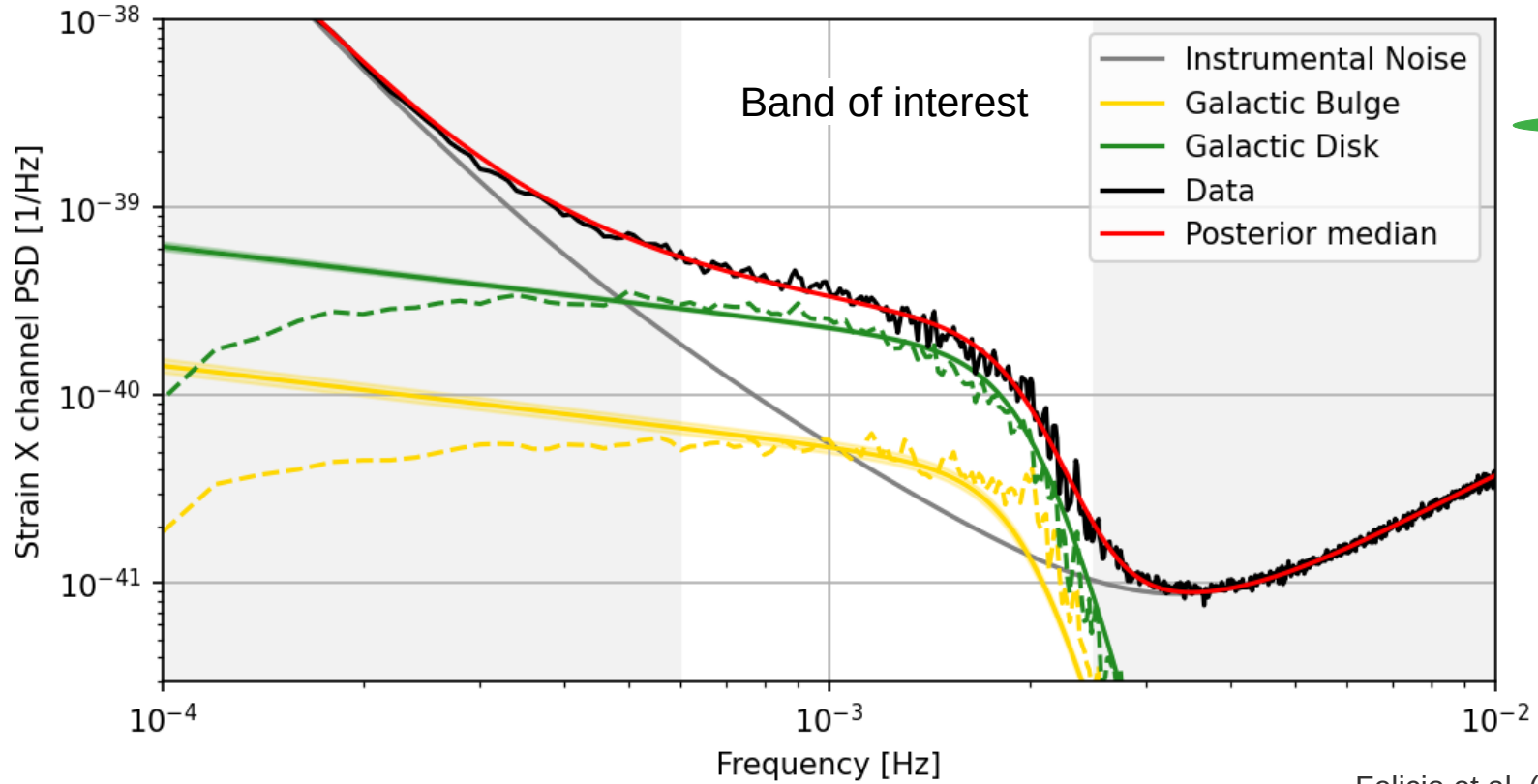


Example result: 40% reference mass

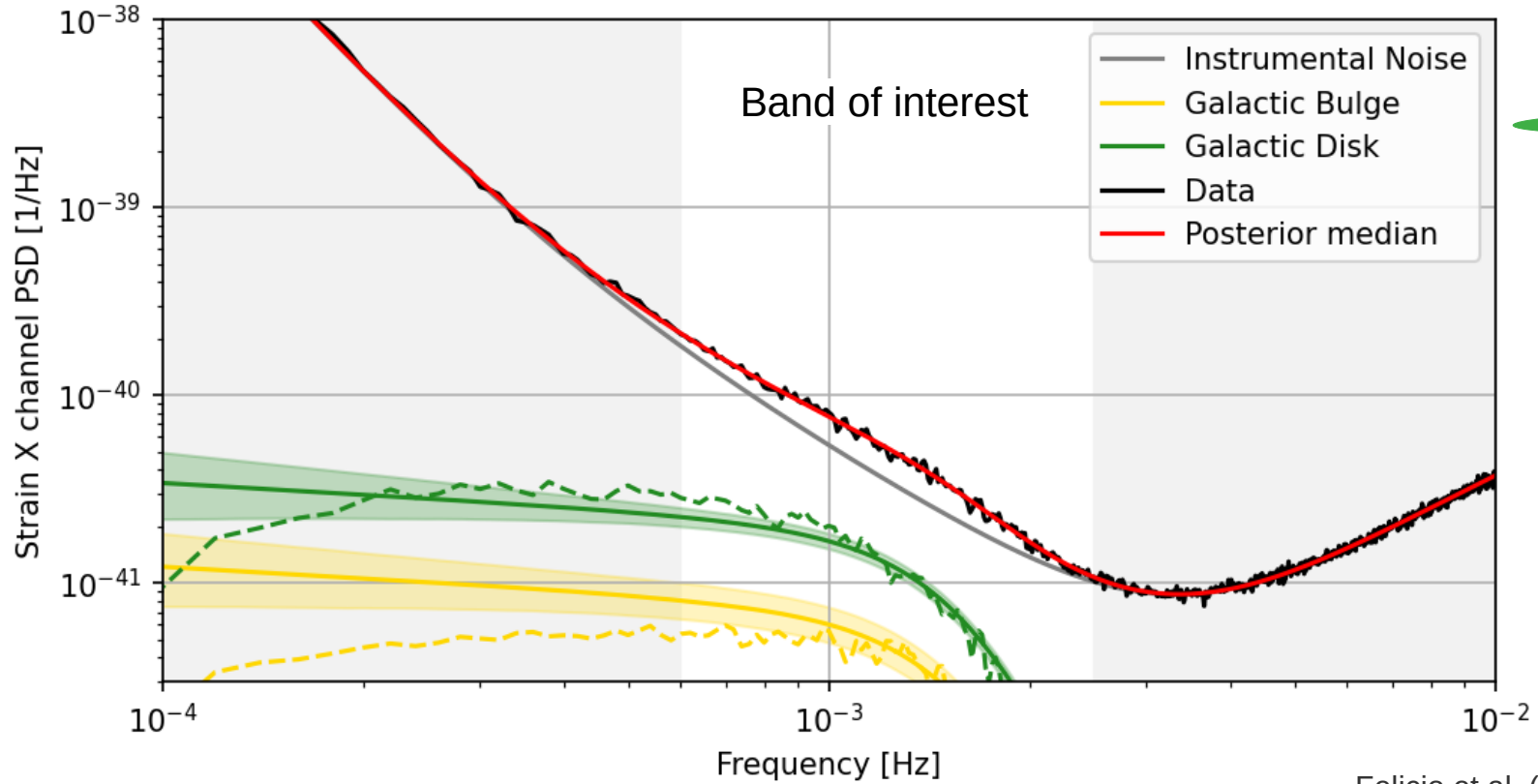


Felicio et al. (in prep.)

Example result: 100% reference mass



Example result: 10% reference mass





Conclusion: *we can* separate the bulge
and disk foreground components.

Application: measuring the Milky Way* stellar mass

Total mass: $0.1, 0.4, 0.7, 1.0 \times M_{\text{ref}}$
Bulge to disk ratio: $0.3, 0.5, 0.8$

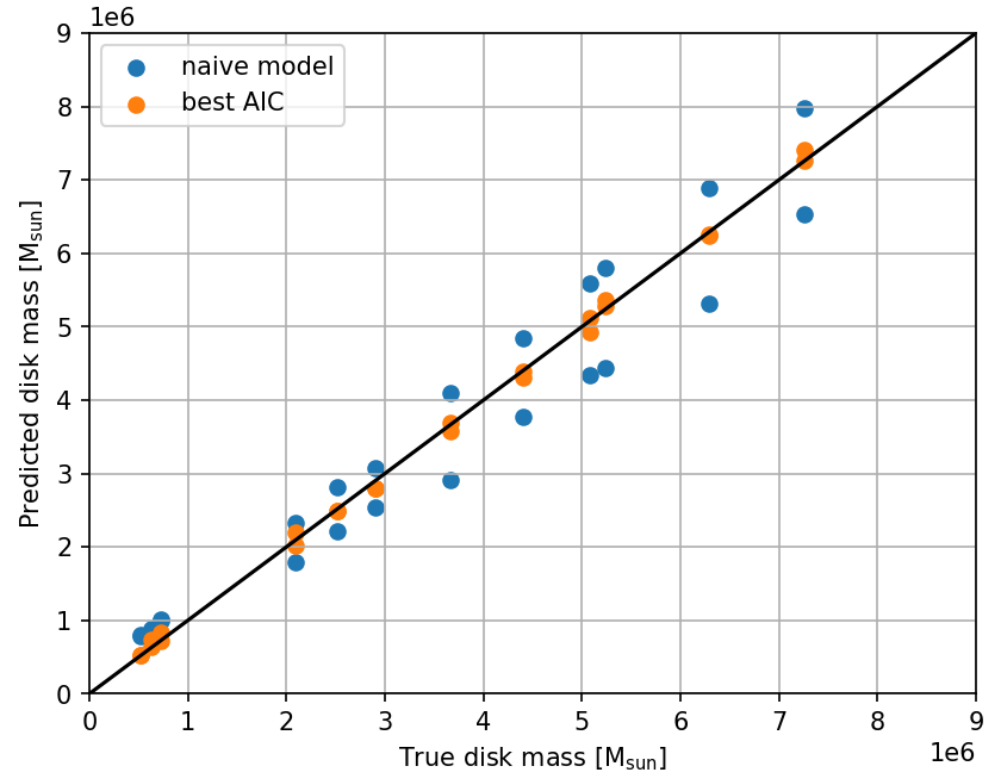
Two kinds of catalogues:

- homogeneous, COSMIC 
- heterogeneous, BPS 

Linear fit to the 24 posteriors:

- prediction of bulge/disk ratio within 8%
- prediction of total mass within 2%
- statistical errors only; systematics TBD.

*only the LISA-band DWD subpopulation



We can separate the bulge and disk foreground components. What next?

easier

Flexible spectral model: different shapes

Put this in a global fit



Refine Milky Way structure (e.g. spiral arms)

Use resolved sources

Joint EM/GW inference: “multi-messenger Milky Way astrophysics”

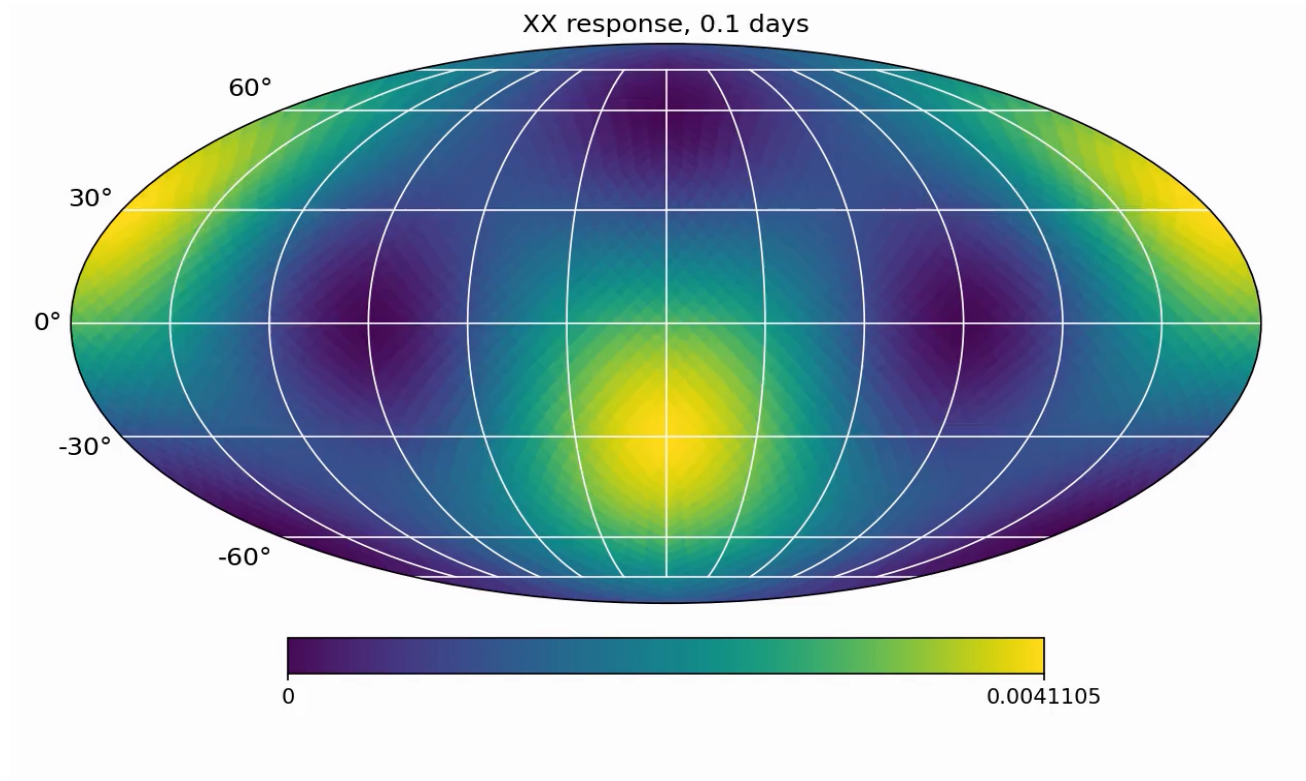
Upgrade to dynamical model, constrain DM halo

harder

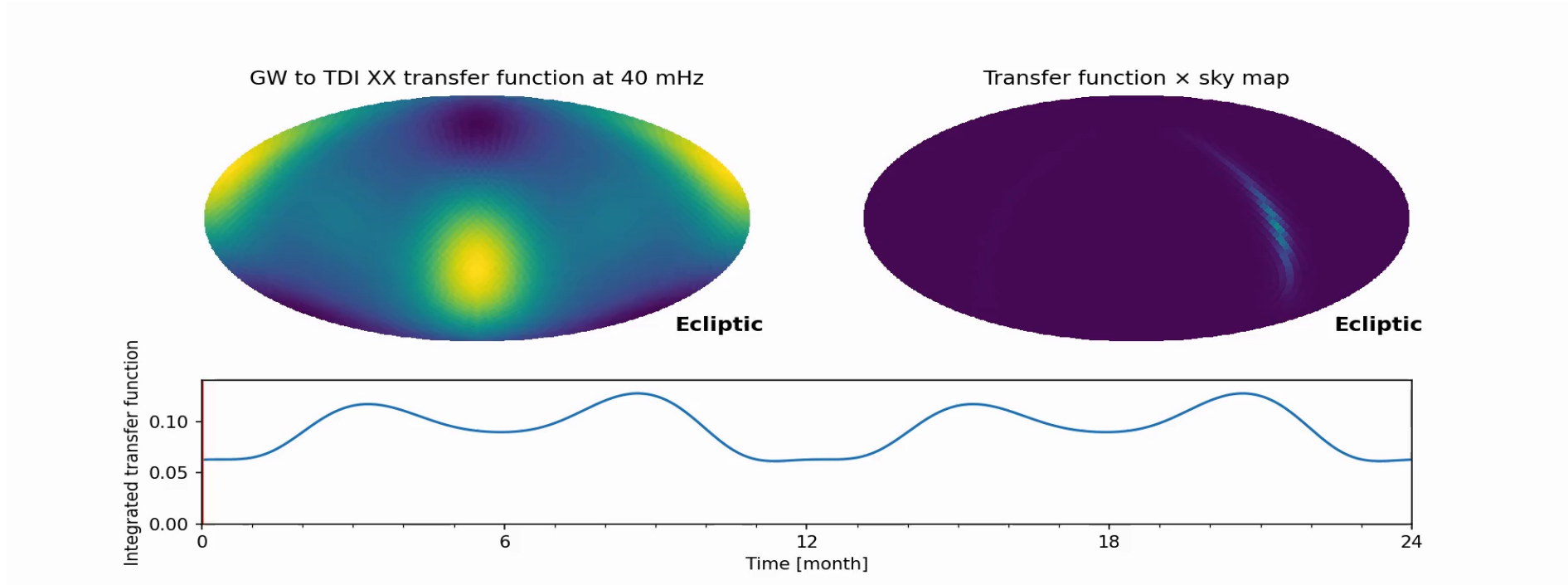
Thanks for
your attention

Backup slides

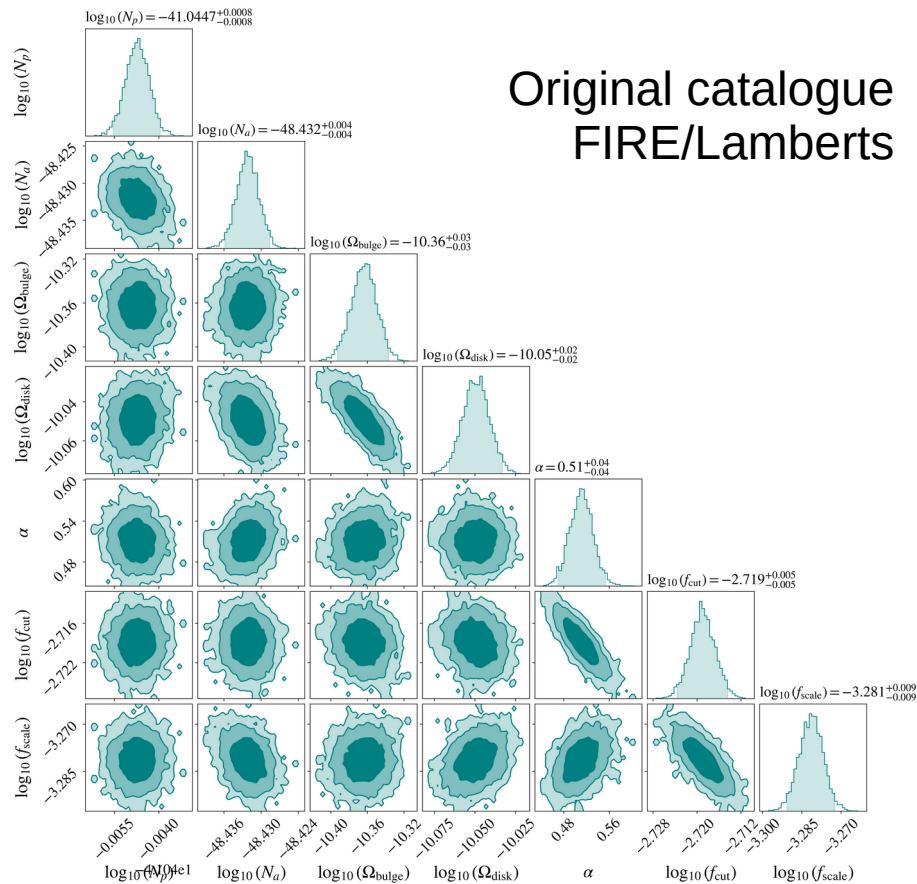
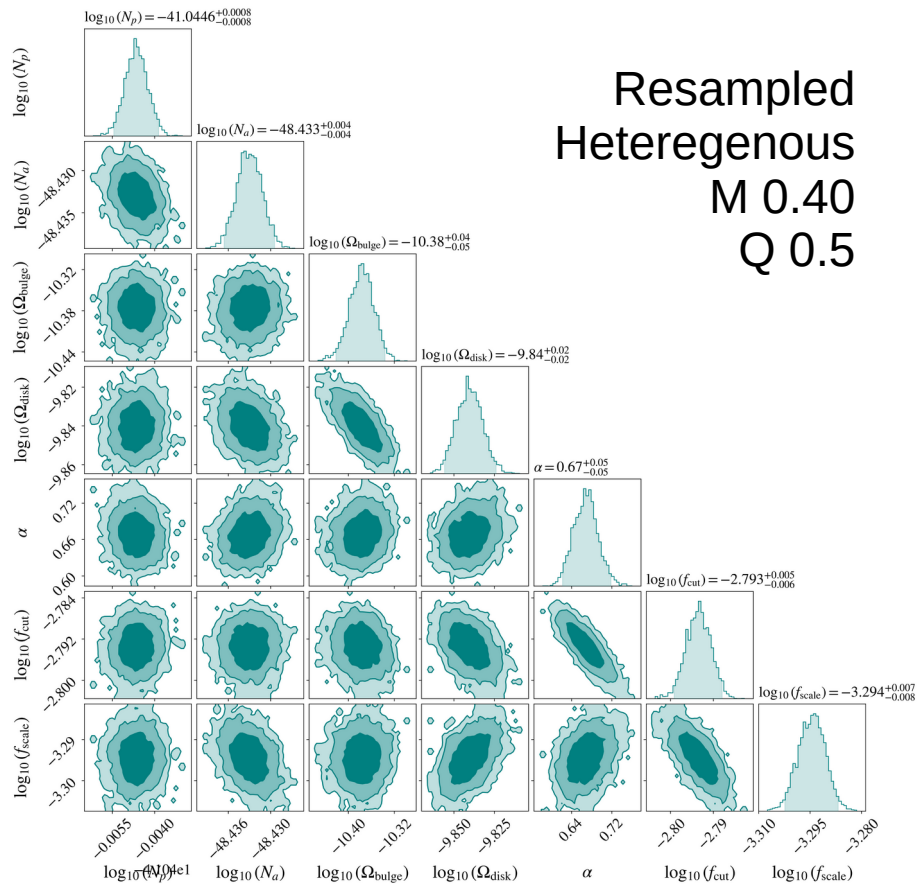
Antenna pattern hot spots at $\pm 30^\circ$ ecliptic latitude



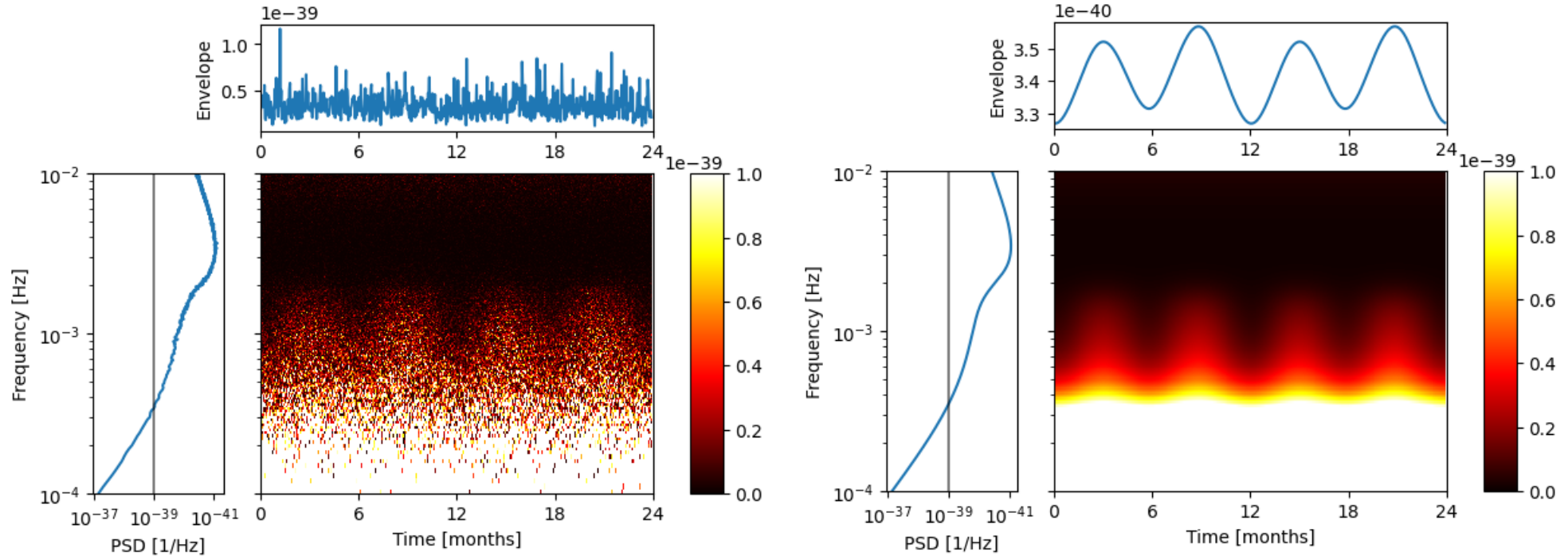
Antenna pattern at high frequencies



Typical posteriors



Data vs model in time-frequency



Bulge vs disk envelopes

