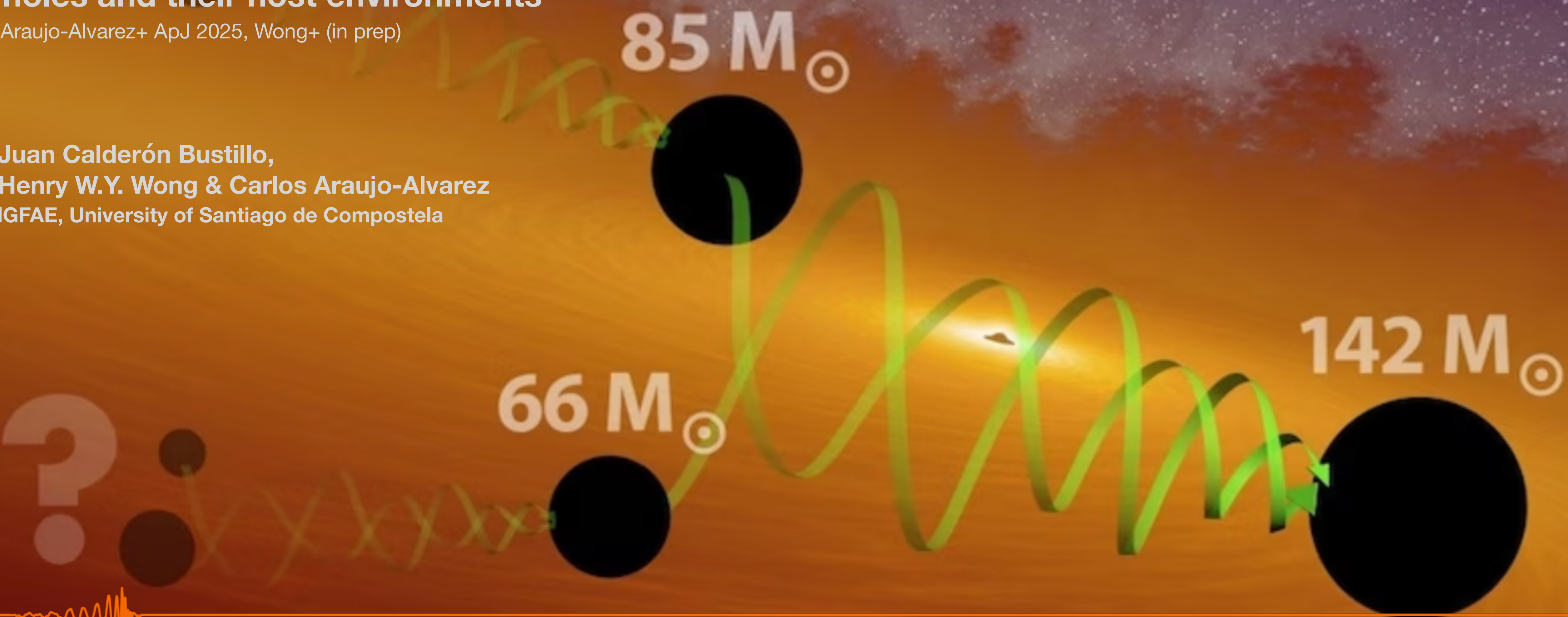


Finding the ancestors of LIGO-Virgo-KAGRA black holes and their host environments

Araujo-Alvarez+ ApJ 2025, Wong+ (in prep)

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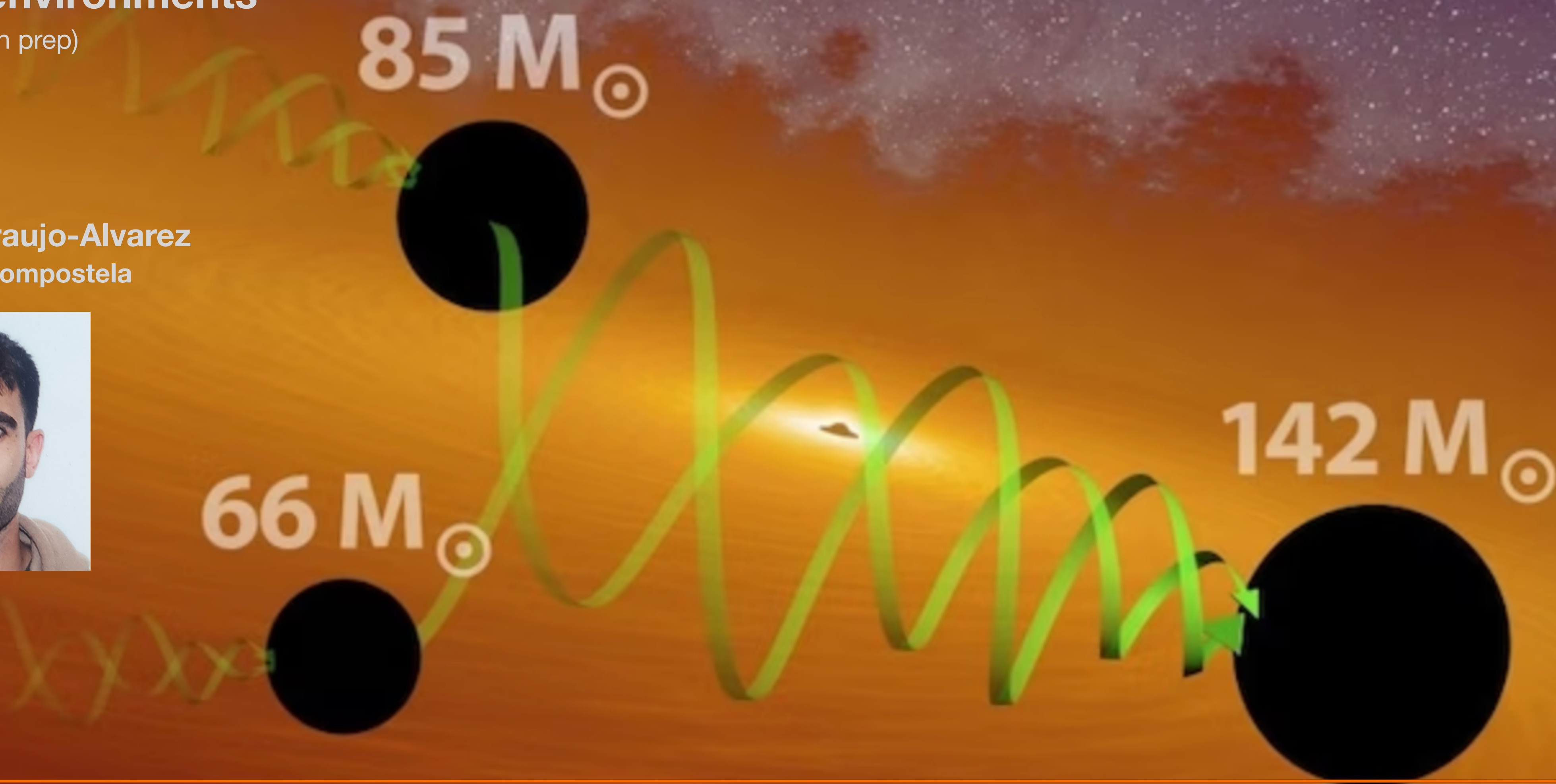
Iberian Gravitational-wave Meeting, CIEMAT, Madrid, June 2025



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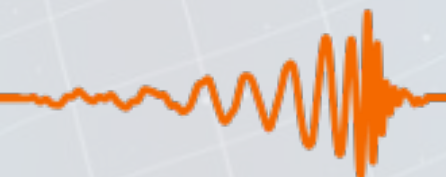


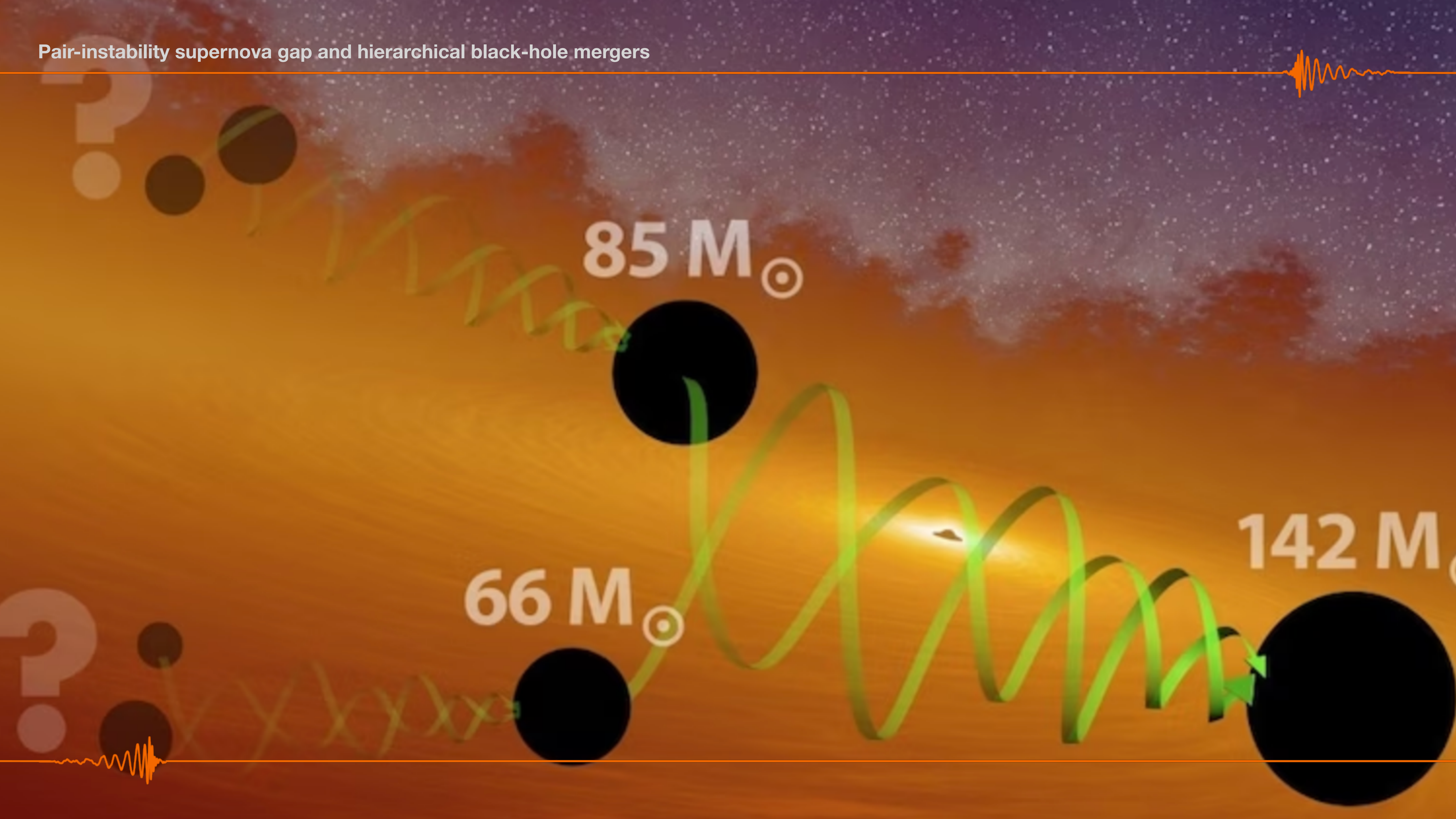
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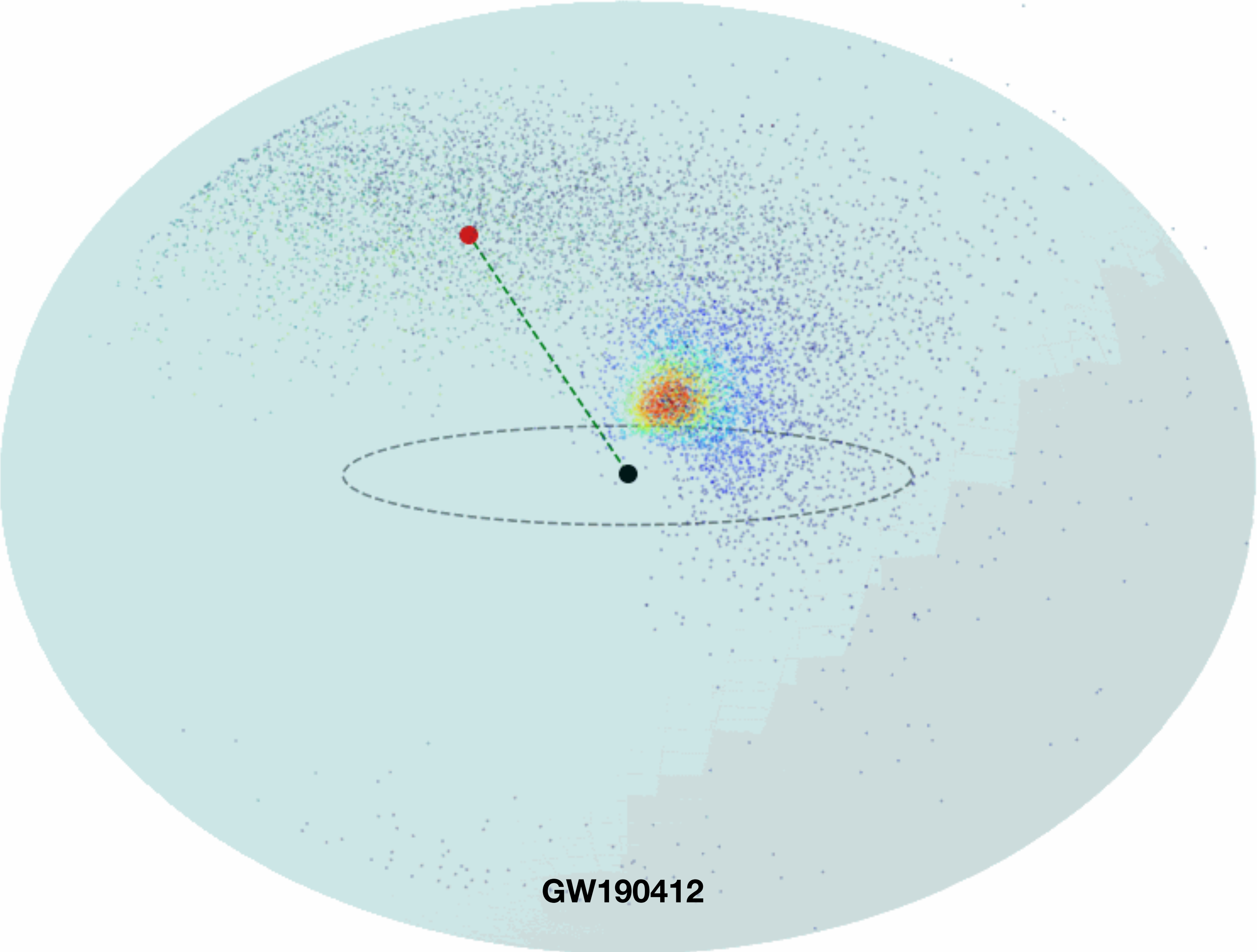


- **Black-holes in the pair-instability supernova gap & hierarchical formation channels**
- **Environments**
- **Black-hole recoil and final spin**
 - Figuring out ancestors and environments: “backward method”
 - Figuring out ancestors and environments: “forward method” and environment selection
- **Conclusions**

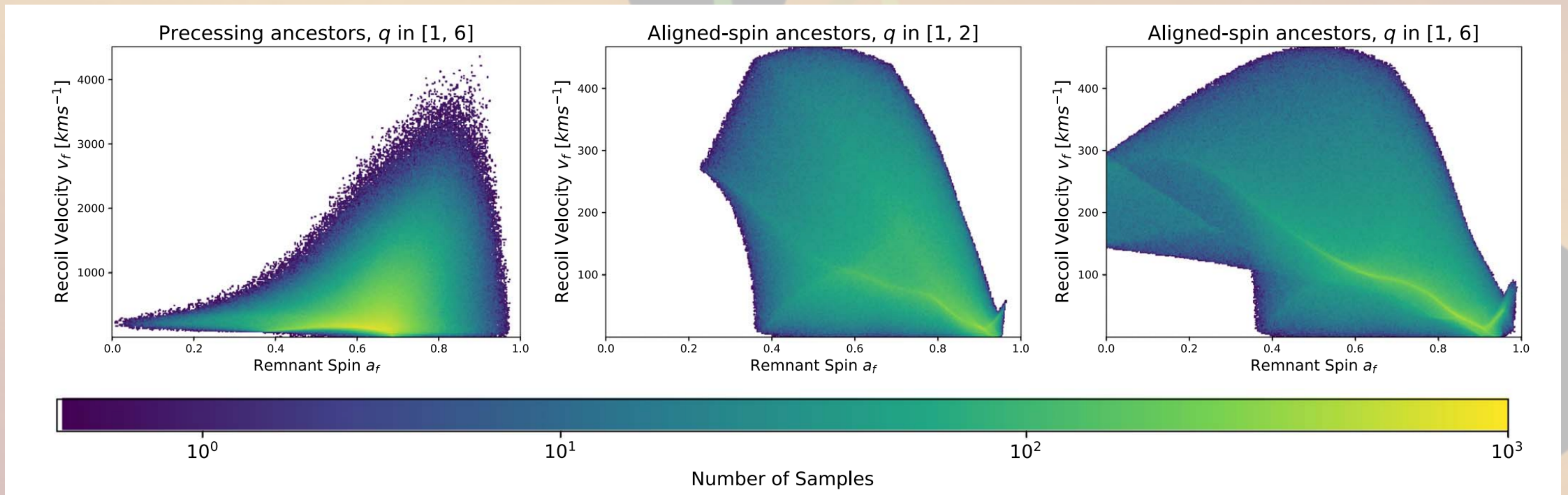








- Tight relation between final kick and final spin
 - Can “infer” birth kick from final spin
 - Environment escape velocity determines the spin distribution of 2g black holes (See also [Borchers+Fishbach '25](#))



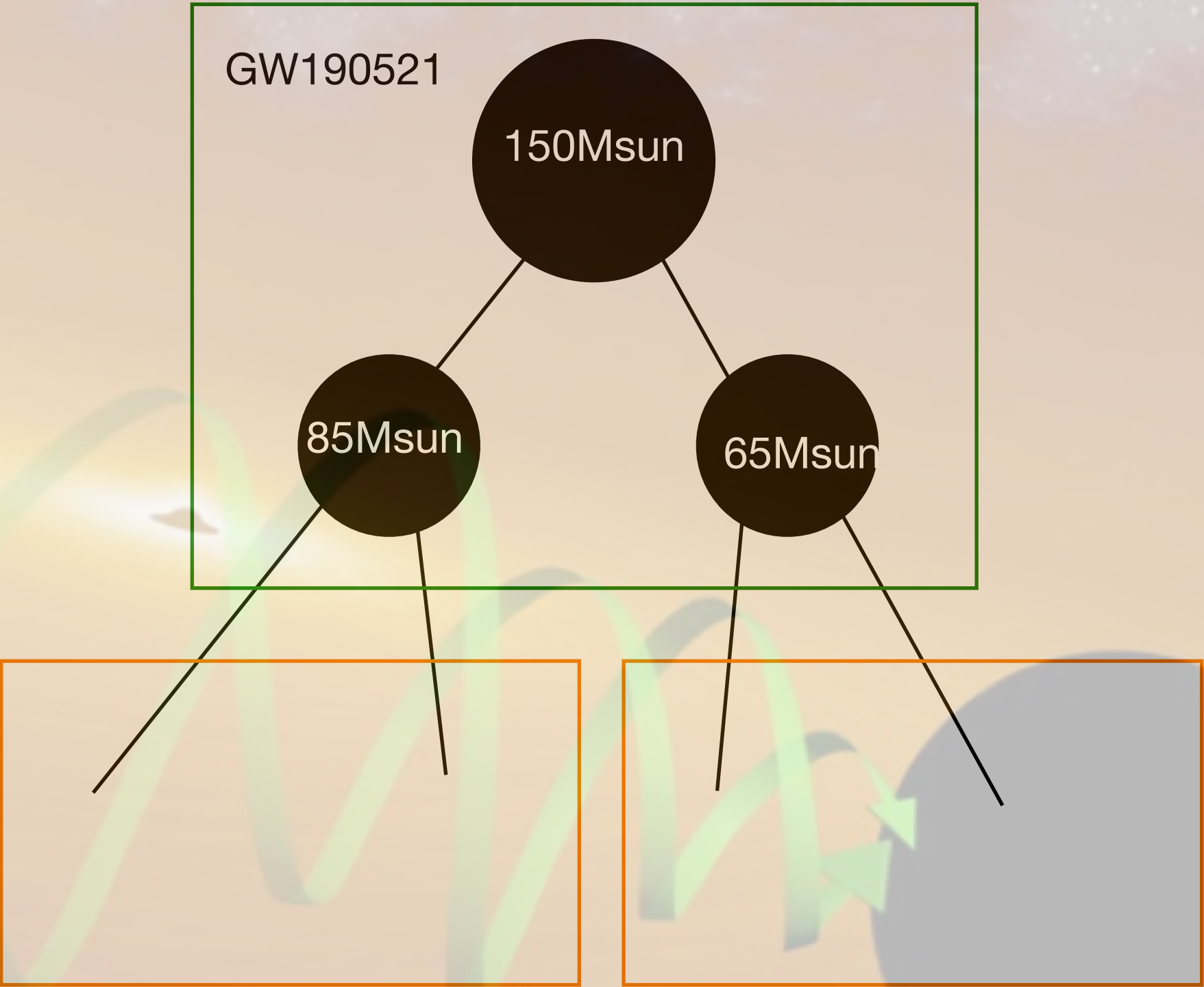


Start from estimates for the putative “children”

Key: respect the priors and posteriors for their parameter

- They have ancestors
 - They “lived” in an environment
 - Their “child” had to stay in the environment
-
- “Invert” relations between binary parameters and final mass, spin and kick
 - Find ancestor properties and birth recoil

Observed black-hole merger (LVK '20 PRL)

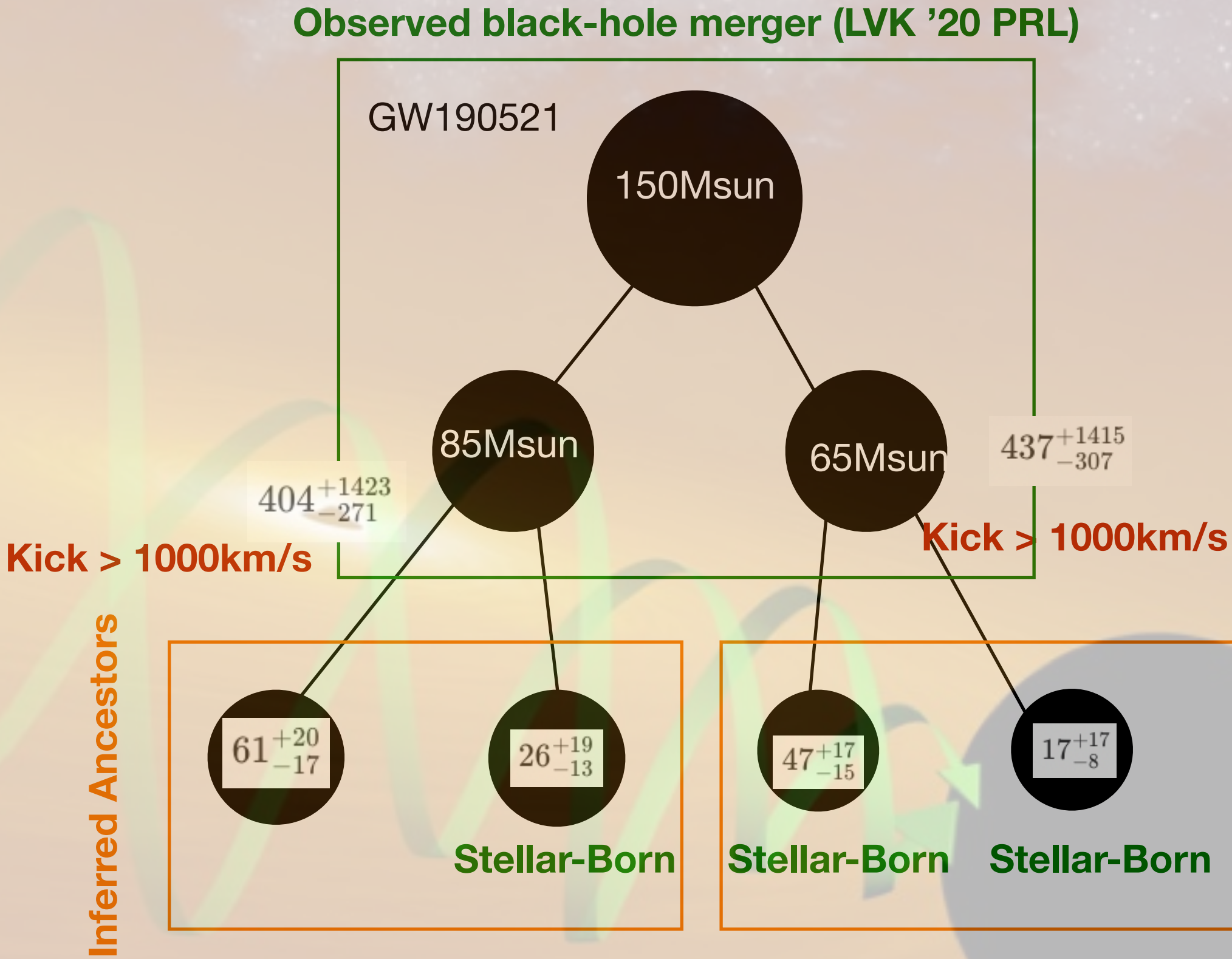


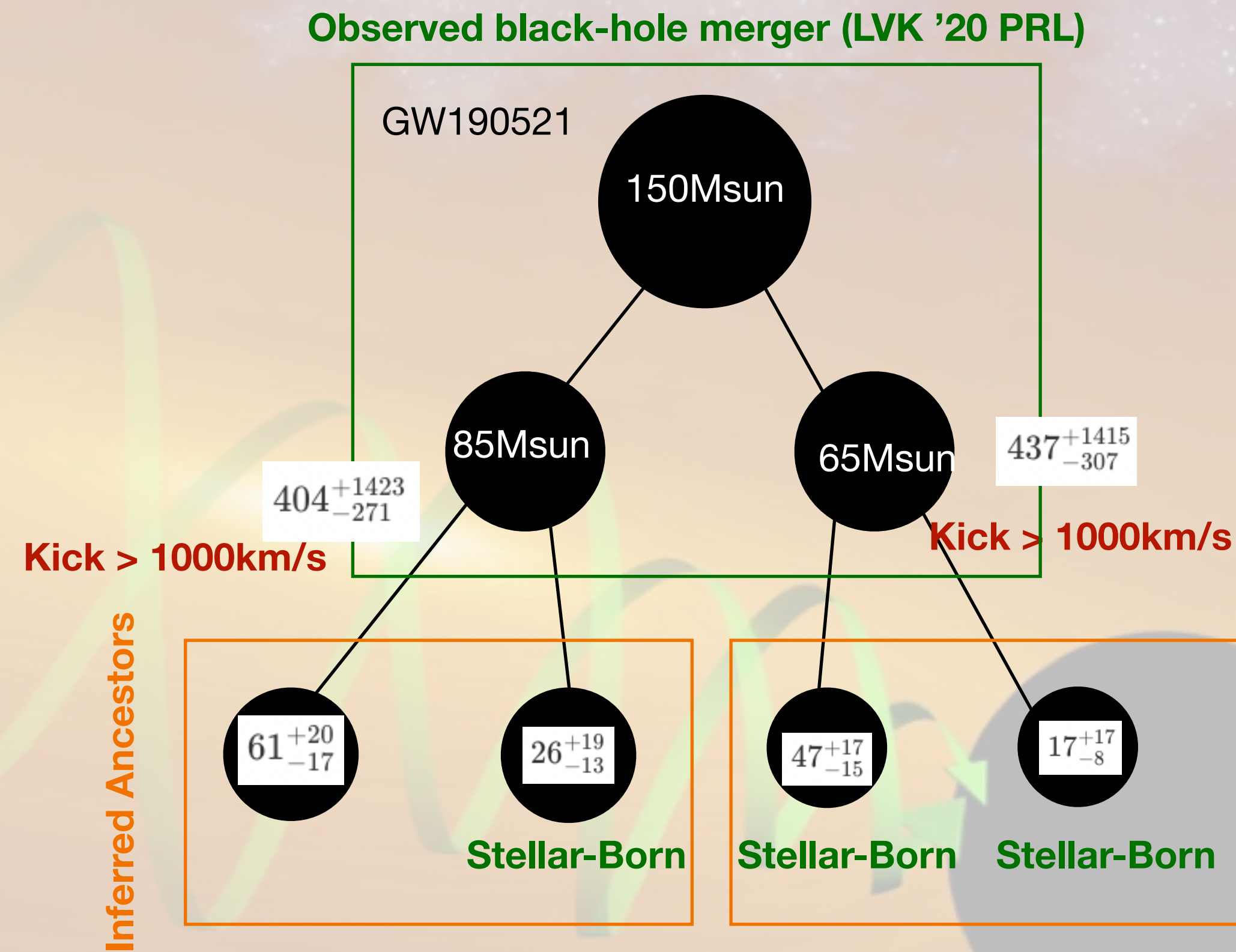
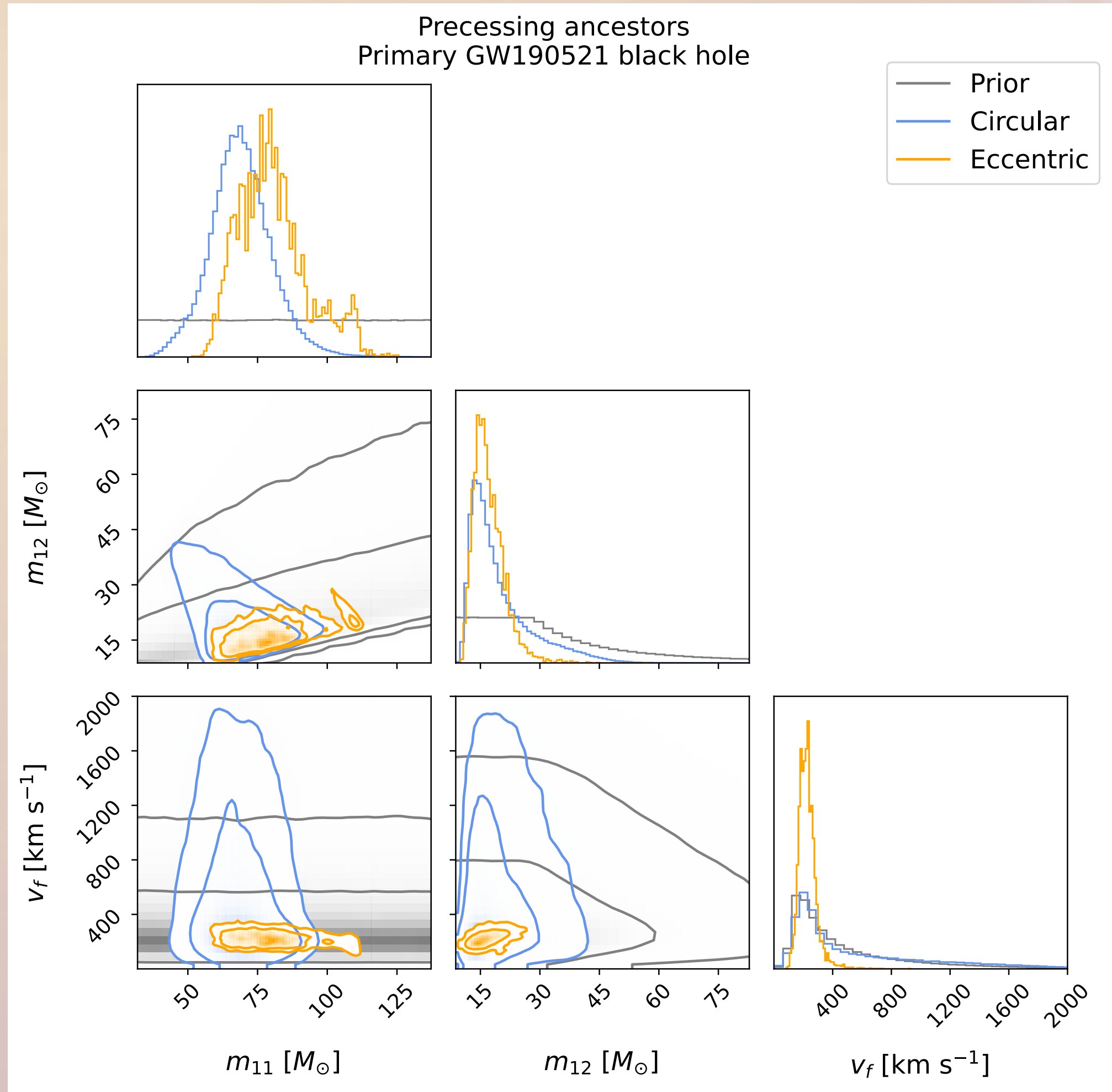


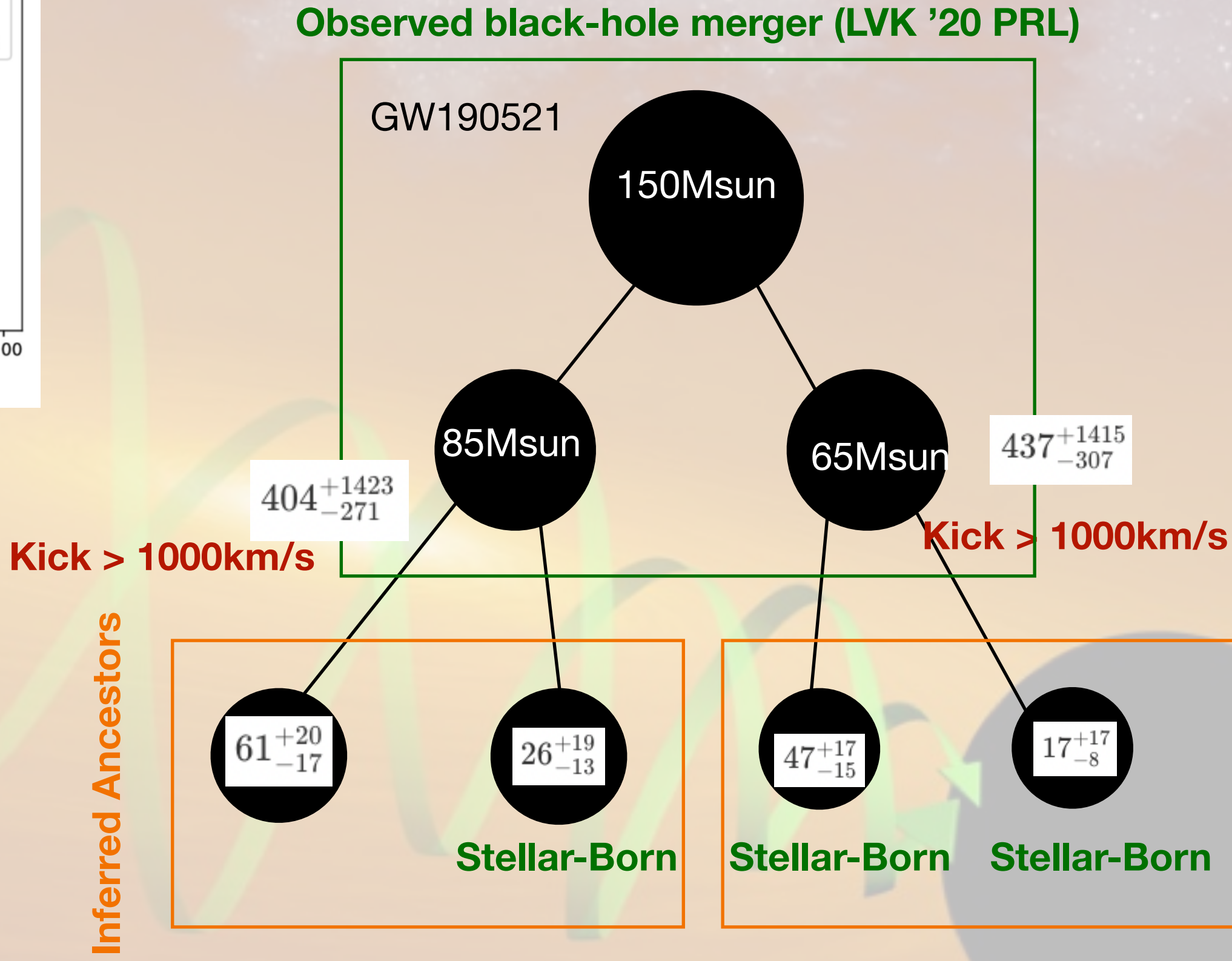
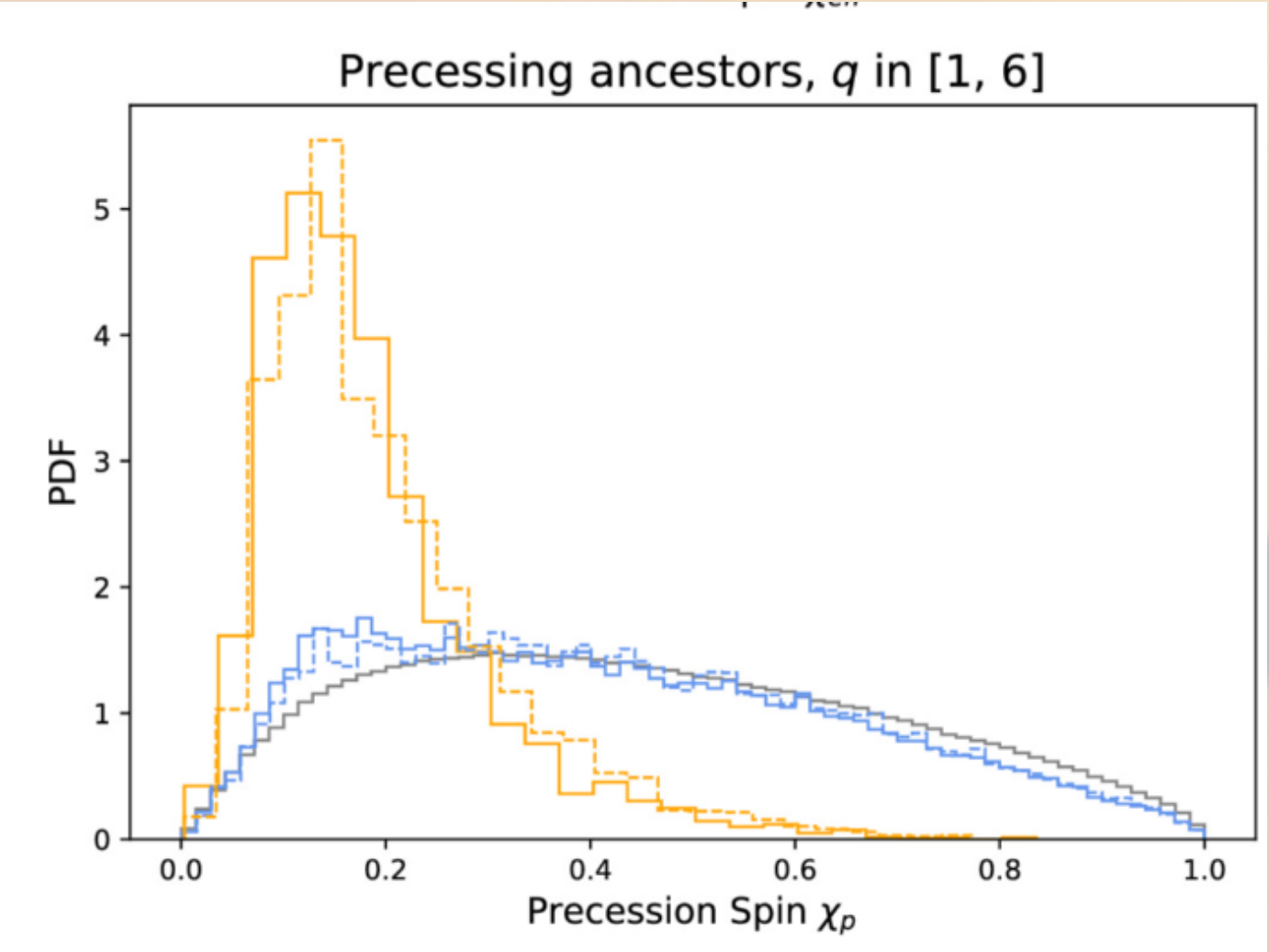
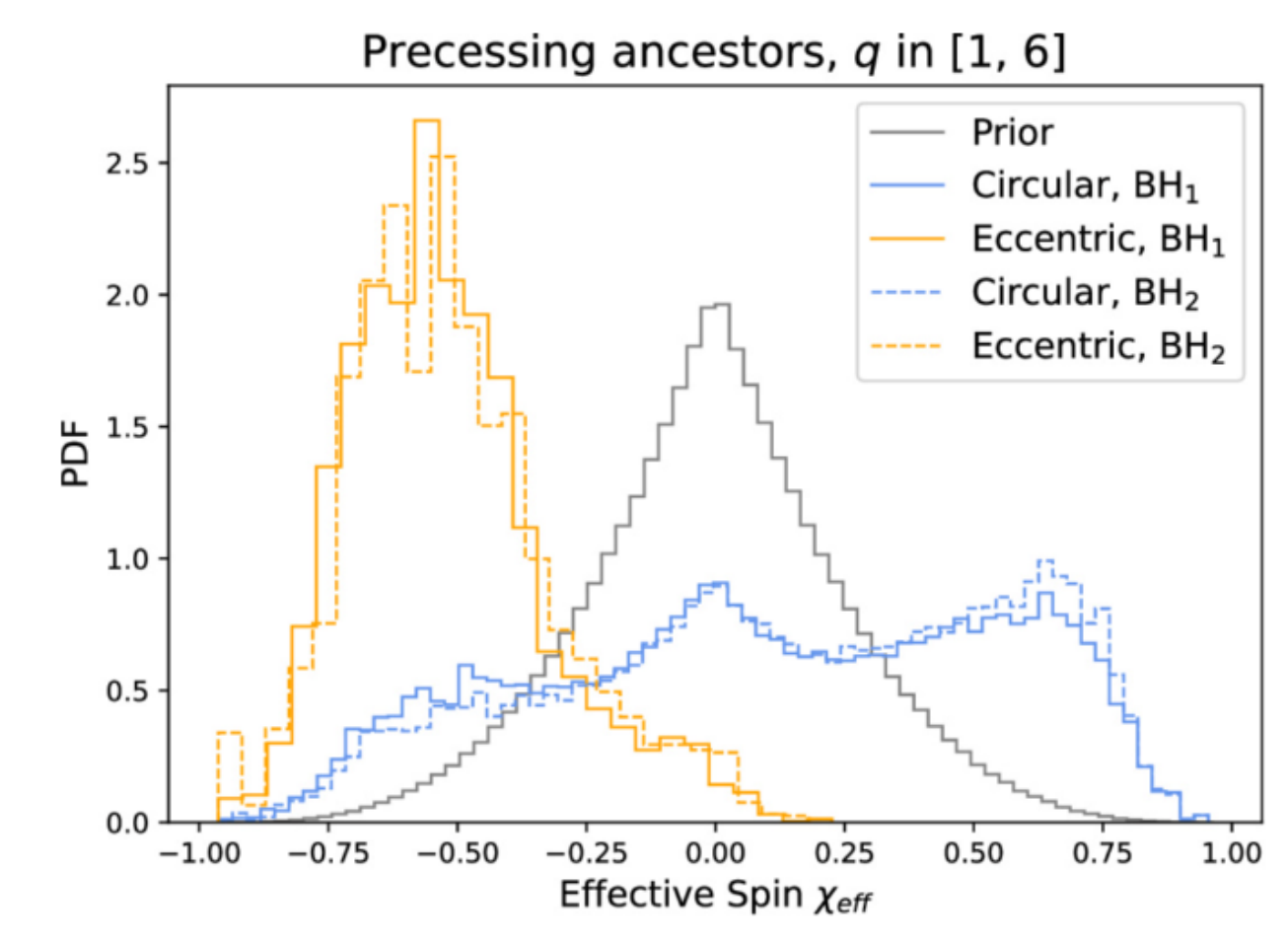
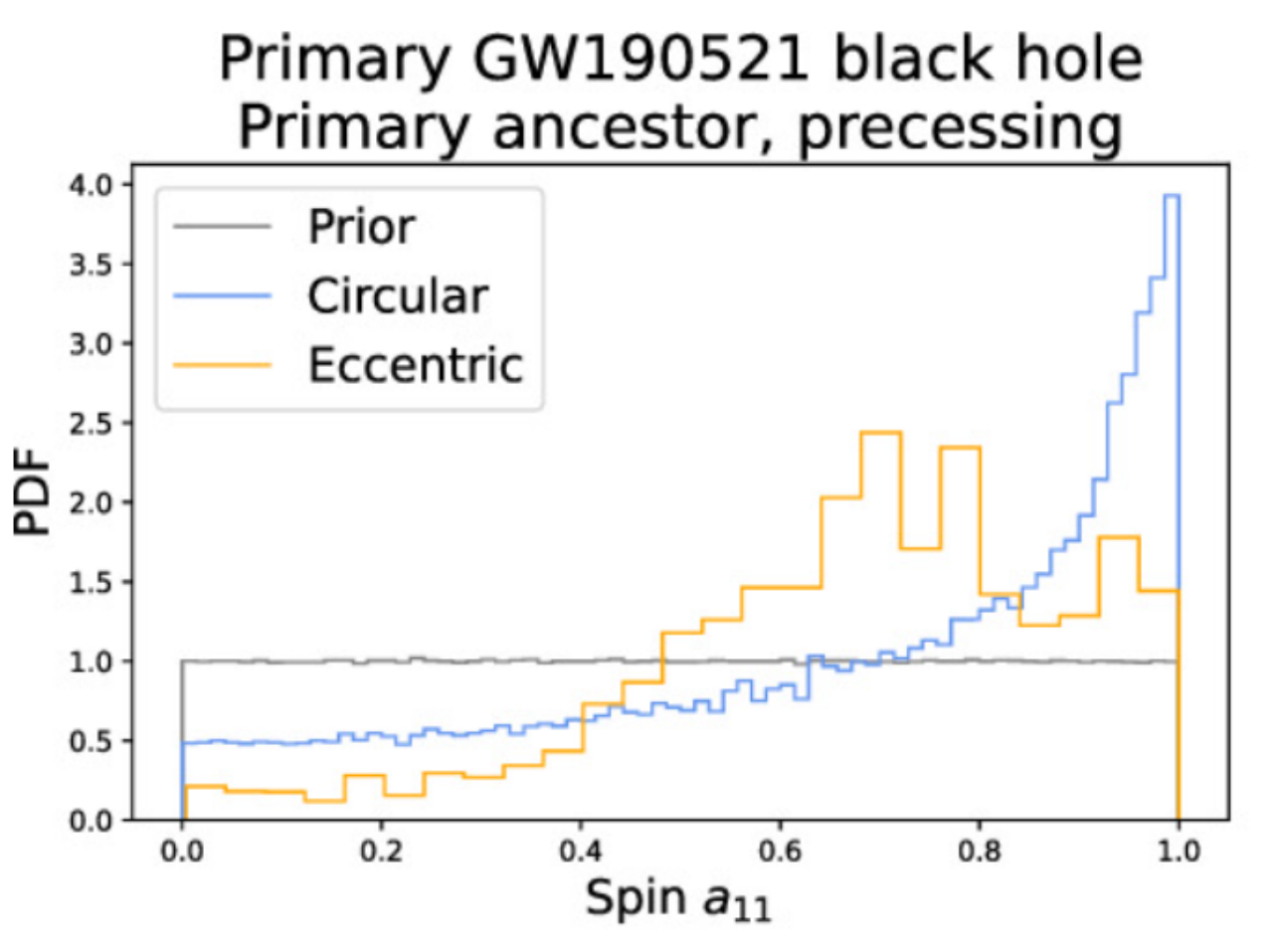
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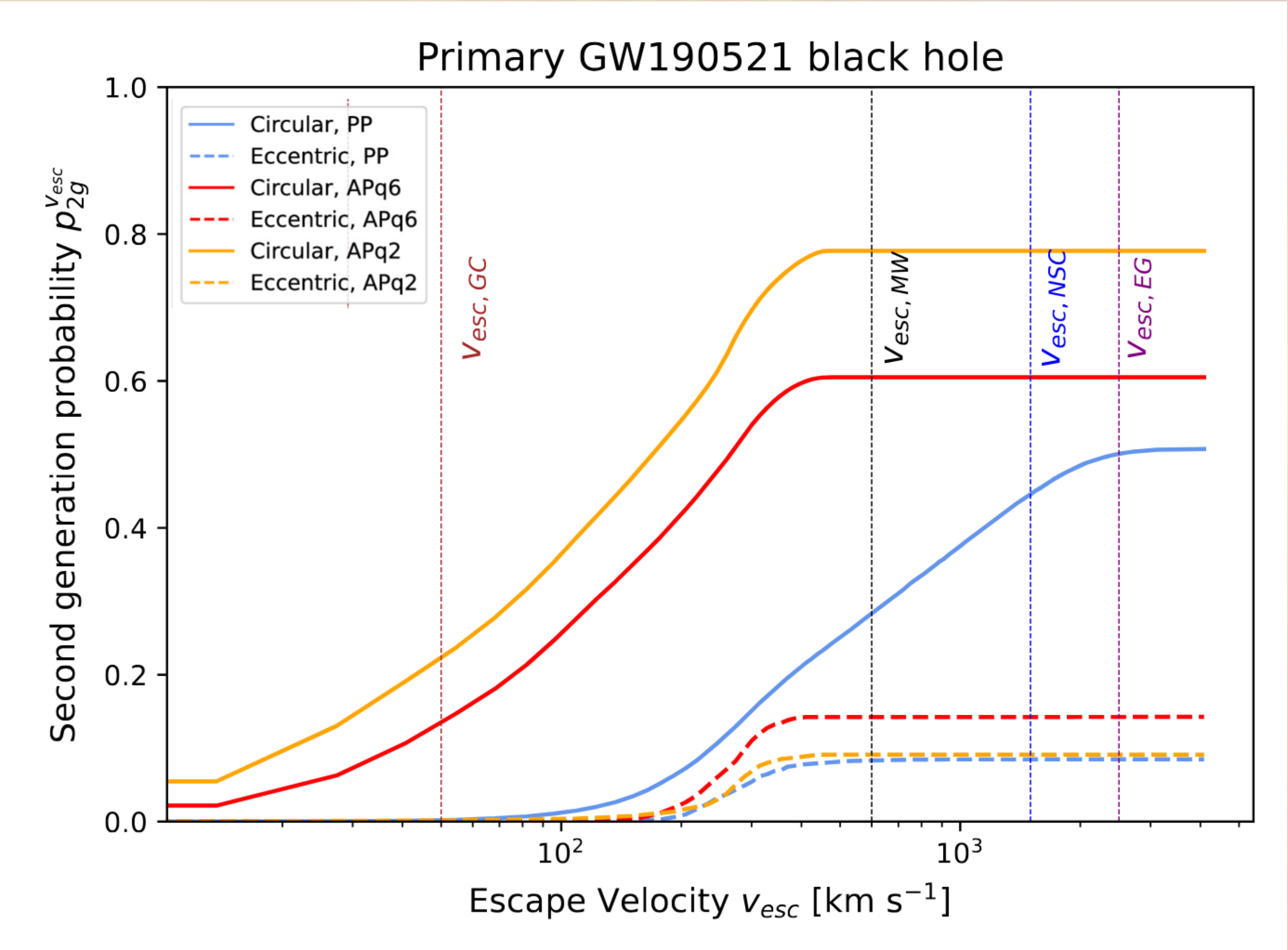






Now used for O4 detections

Probability of both parents having masses < 65Msun and birth kick below escape velocity



Very tough to form the primary BH of GW190521 to form in a Globular Cluster

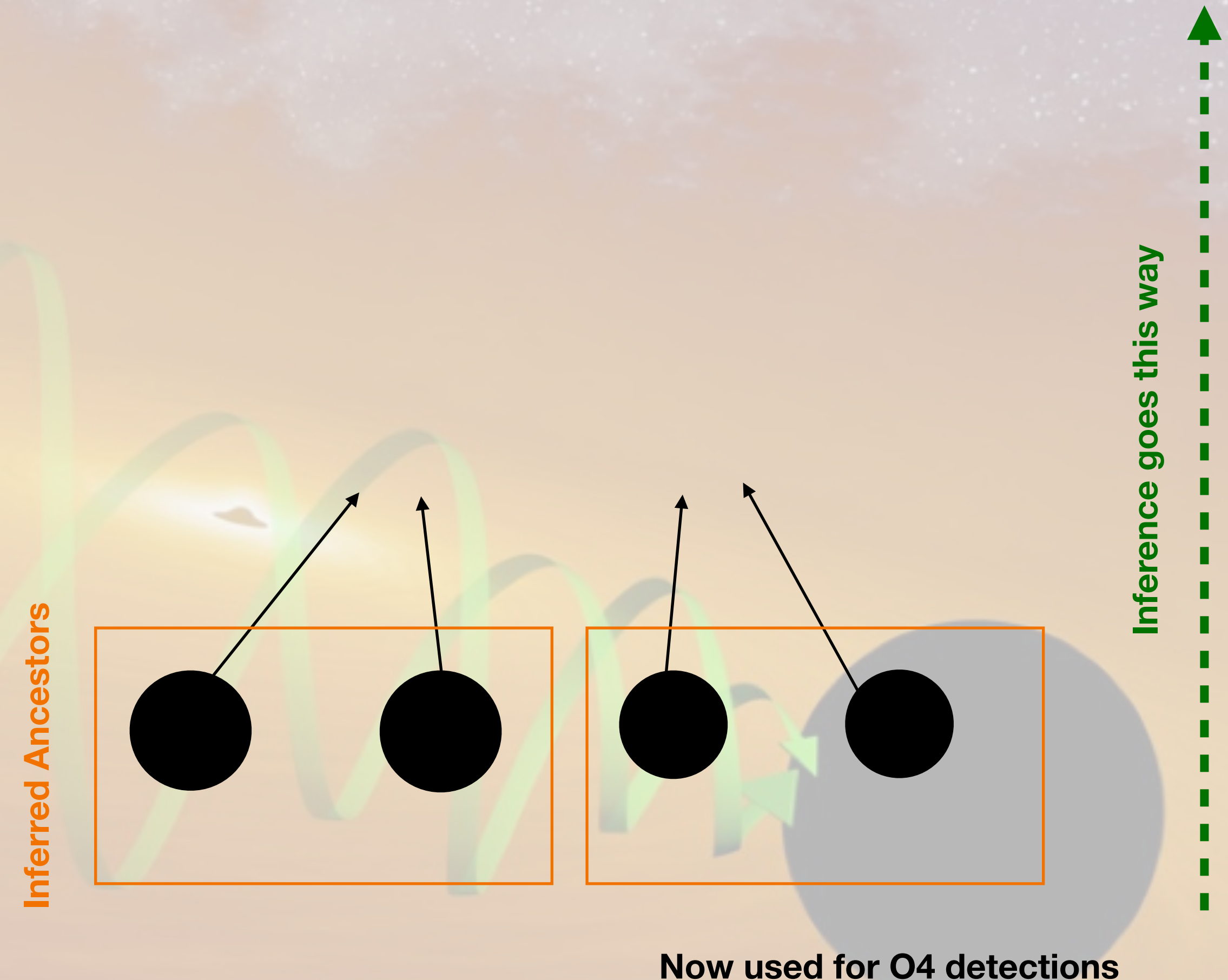
GW190521 Scenario		$p(\theta_{anc})$	$p(anc d)$	$p^{GC}(2g anc)$	$p^{MW}(2g anc)$	$p^{NSC}(2g anc)$	$p^{EG}(2g anc)$
BH ₁	Circular	PP	0.97	0.002	0.293	0.461	0.518
		APq2	0.86	0.259	0.903	0.903	0.903
		APq6	1.00	0.135	0.605	0.605	0.605
	Eccentric	PP	0.73	0.000	0.114	0.116	0.116
		APq2*	0.16	0.011	0.572	0.572	0.572
		APq6	1.00	0.000	0.143	0.143	0.143

..... but wait for the next slides

Start from priors for the ancestors (parents, grandparents....)

Compute the corresponding mass and spin priors induced on the BHs observed by LVK, for each v_{esc}

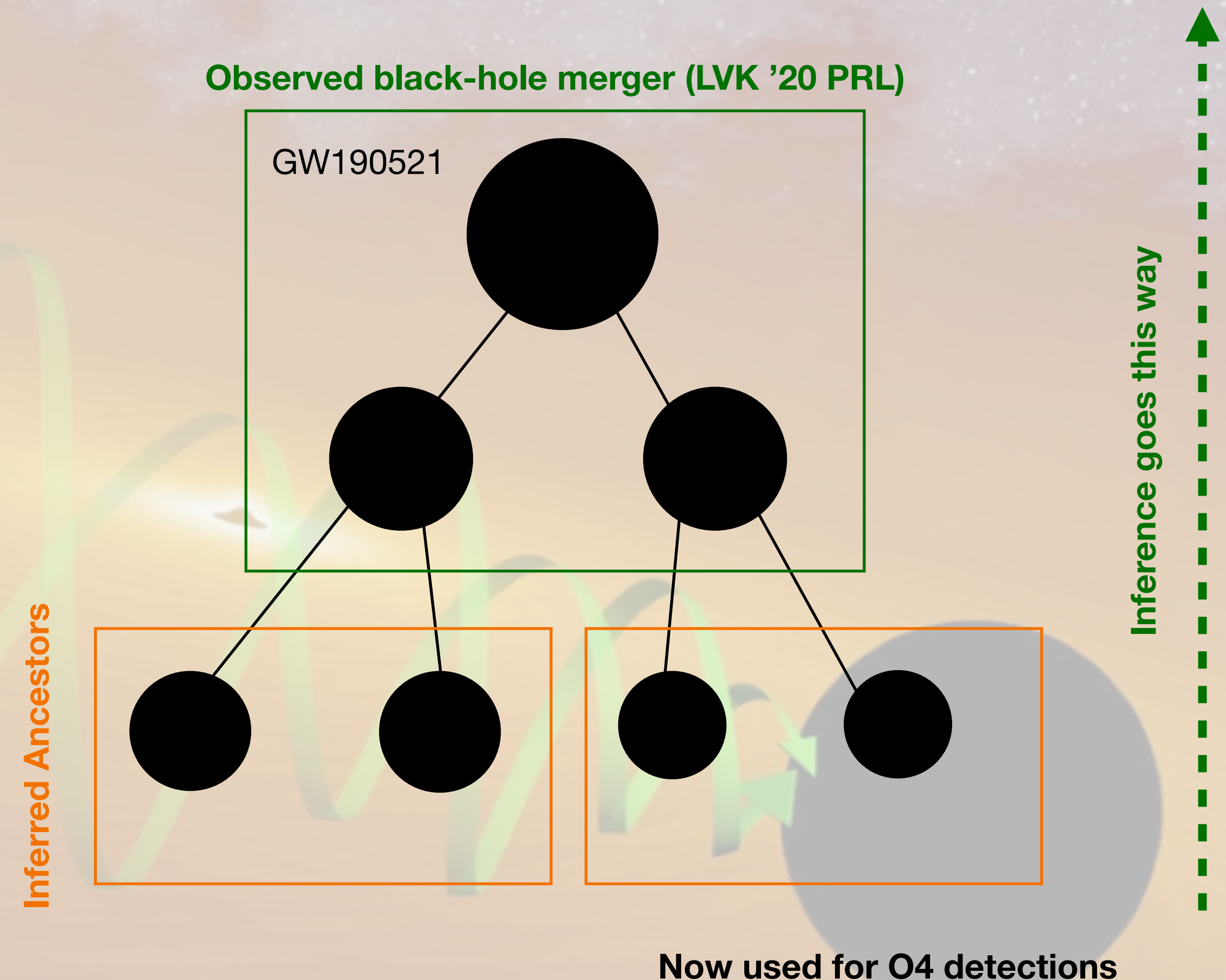
- “Obtain new” estimates for masses and spins
- Environment characterised by escape velocity
- Read estimates for ancestral generations
 - **Not new:** Mahapatra+ '24.
- FOCUS here: obtain Bayesian Evidence!!



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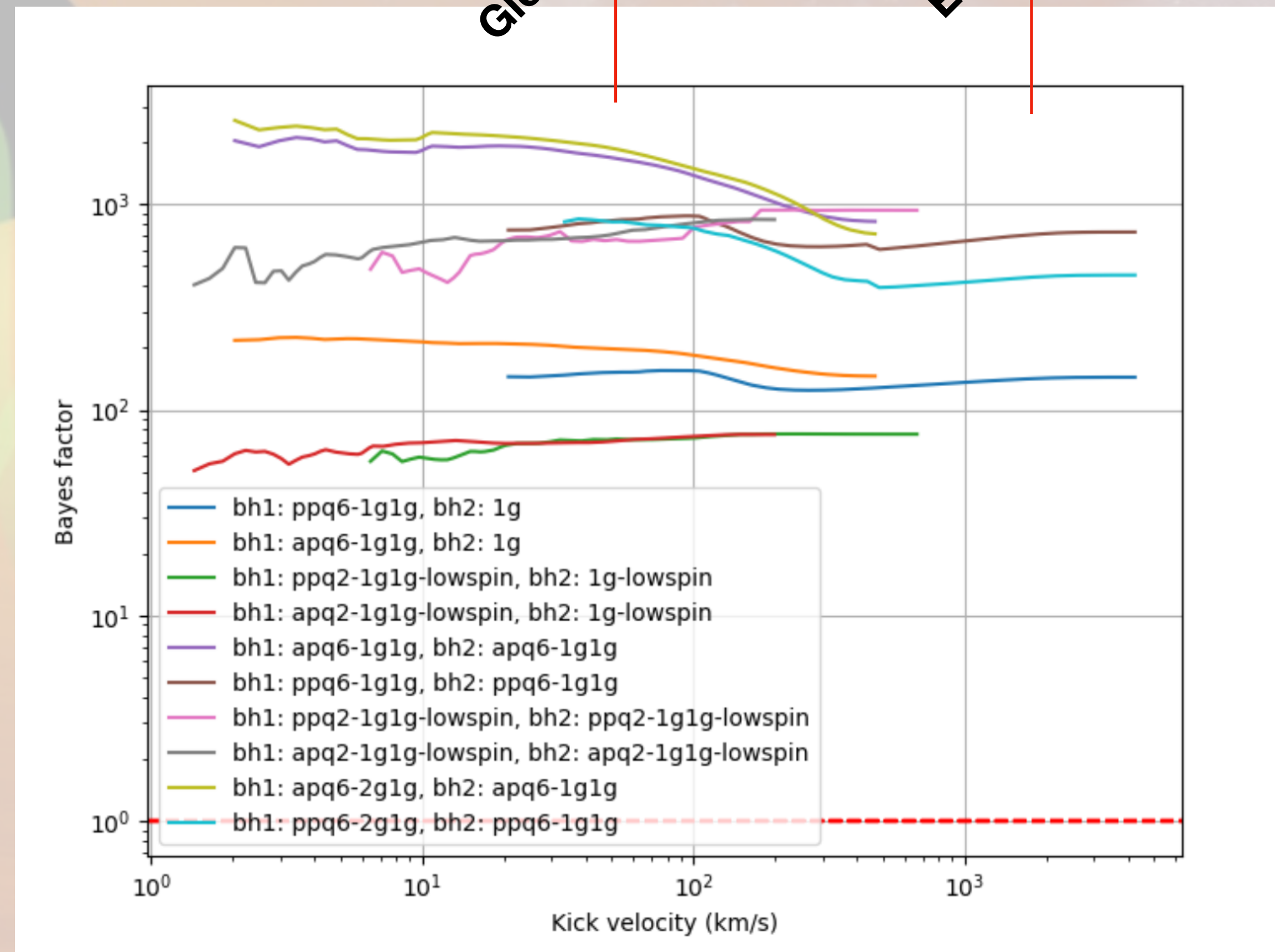


Environment characterised by escape velocity

Globular Cluster is most favoured!

Reason:

- GW190521 spins peak near 1
- Easier to form with large mass ratio ancestors
- These have low kicks
- Precisely what can be retained in a GC!



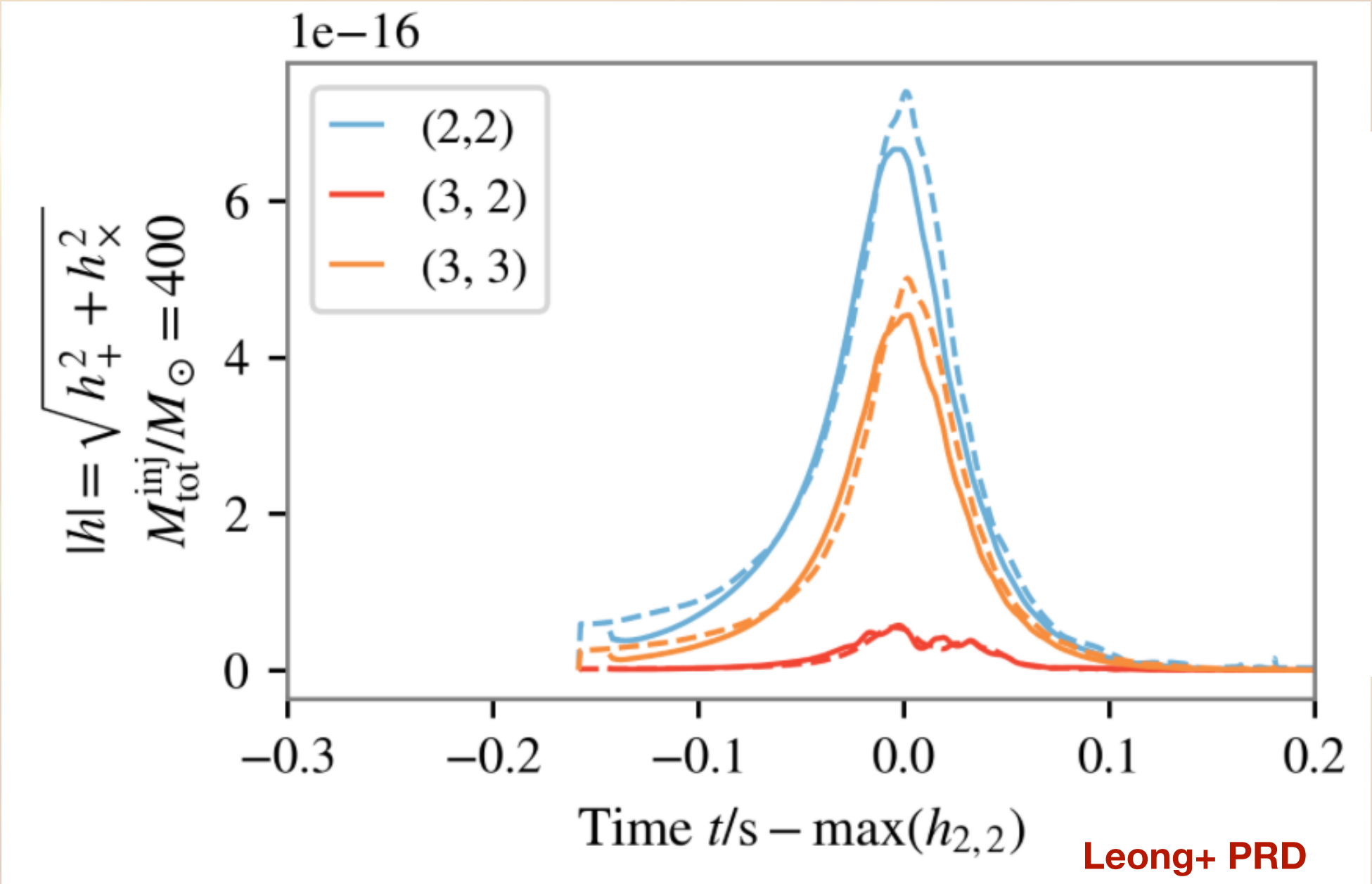
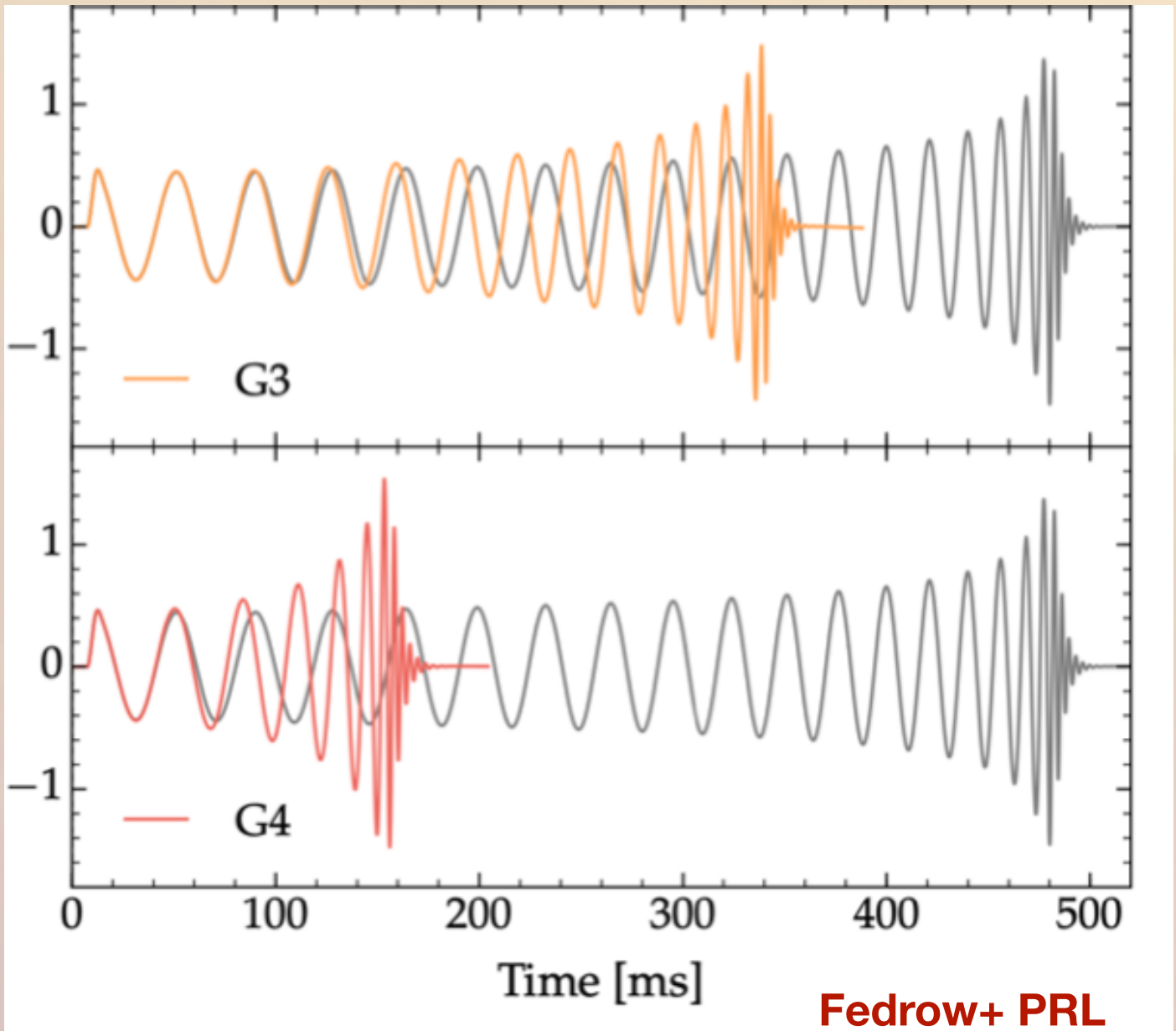
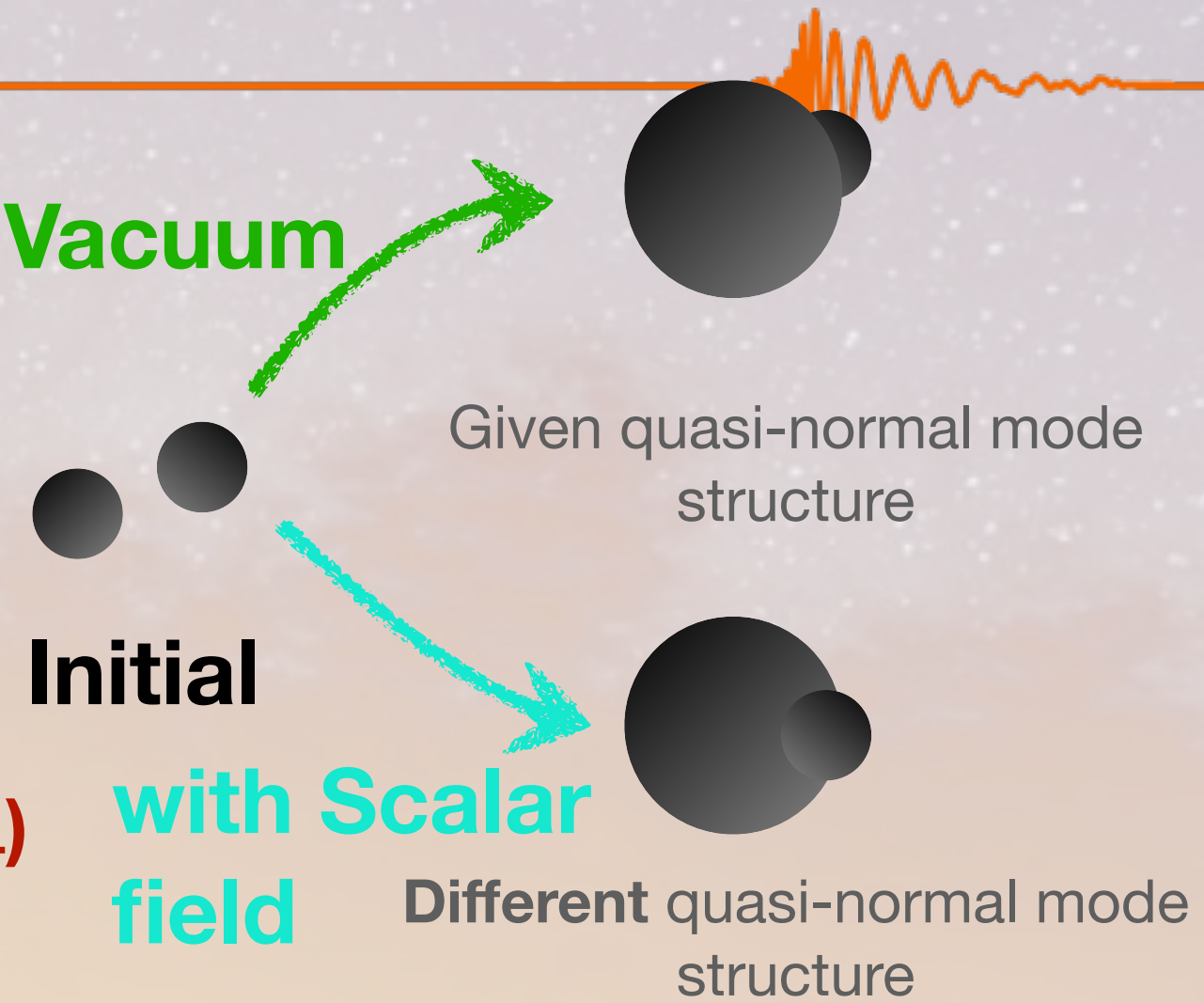
Evidence as a function of host escape velocity for different “generations”

Environment impacts waveform morphology

Mass accretion —> alter signal frequency + “increased” final mass

Altered dynamics —> Altered ringdown mode structure (Leong, JCB + '23 PRD)

First searches for these effects in LVK data: **effects too subtle to be detected** (Caneva-Santoro+ PRL)



Environment impacts waveform

Mass accretion → alter sign

Altered dynamics → Altered

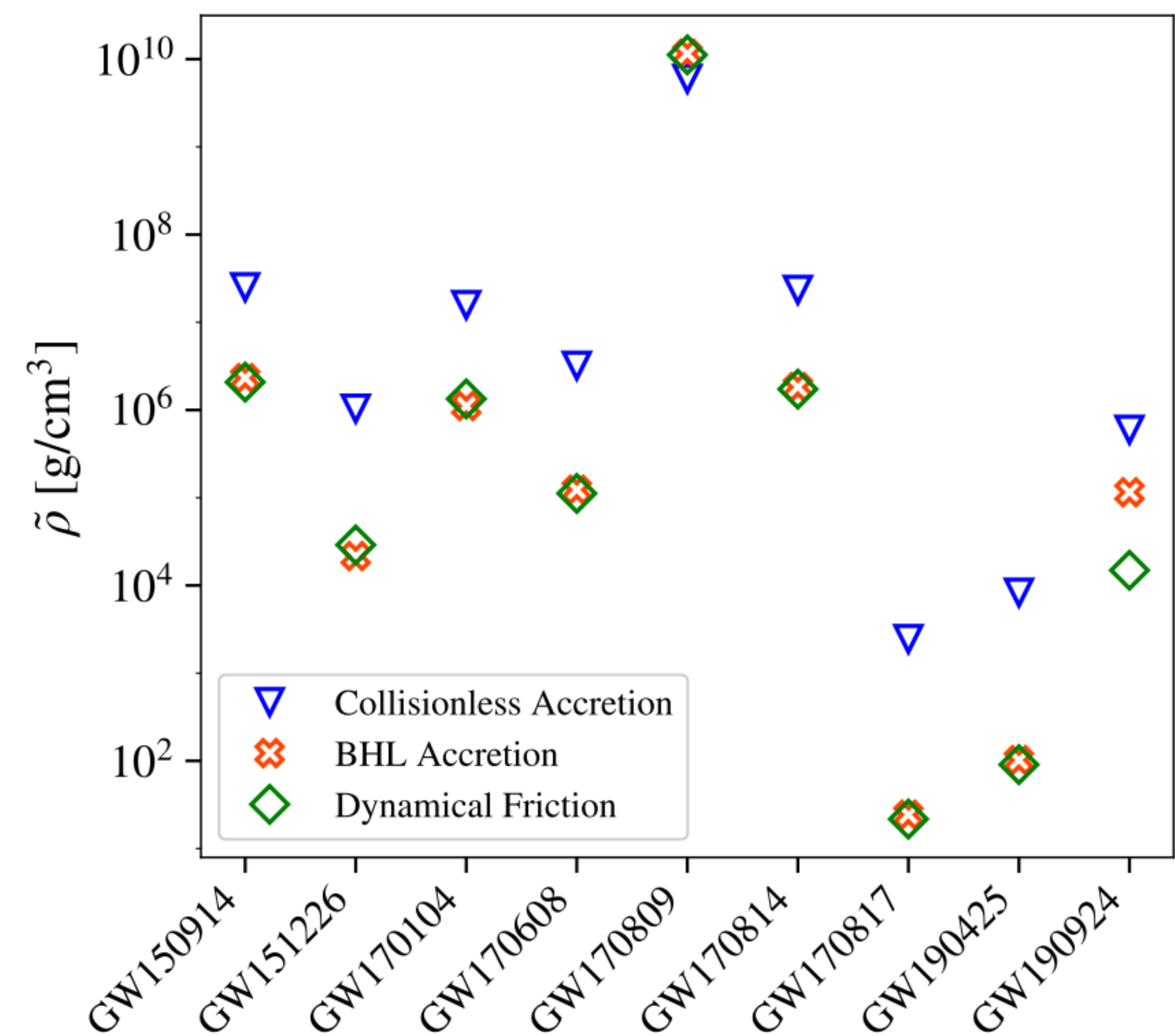
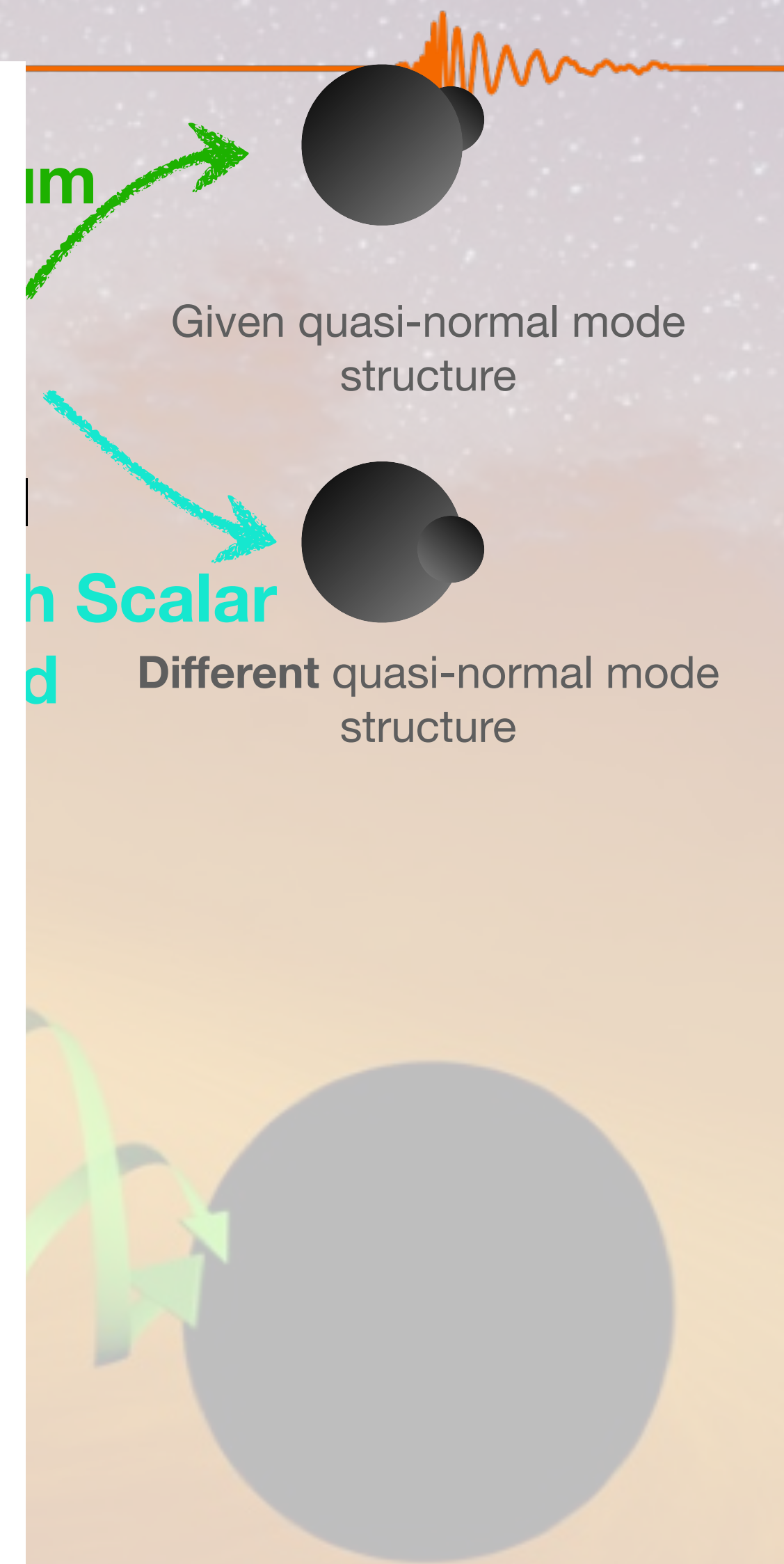


FIG. 1. 90% upper bounds on the environmental density obtained considering the effect of CA (blue triangle), BHLA (red cross), and DF (green diamond).





Hierarchical channels are likely contributors to the observed BH population

Bayesian framework to estimate putative ancestors and constrain host environments

GW190521:

Globular cluster origin **very slightly preferred**

2g + 1g black-hole merger

Combining GW190521, GW200220 and GW190426:

No clear evidence for a fraction of events coming from globular cluster

Limitations:

Final parameter fits limited to quasi-circular mergers

Very naive priors on the mass and spins of the first generation black holes

