# Fast EMRI Waveforms

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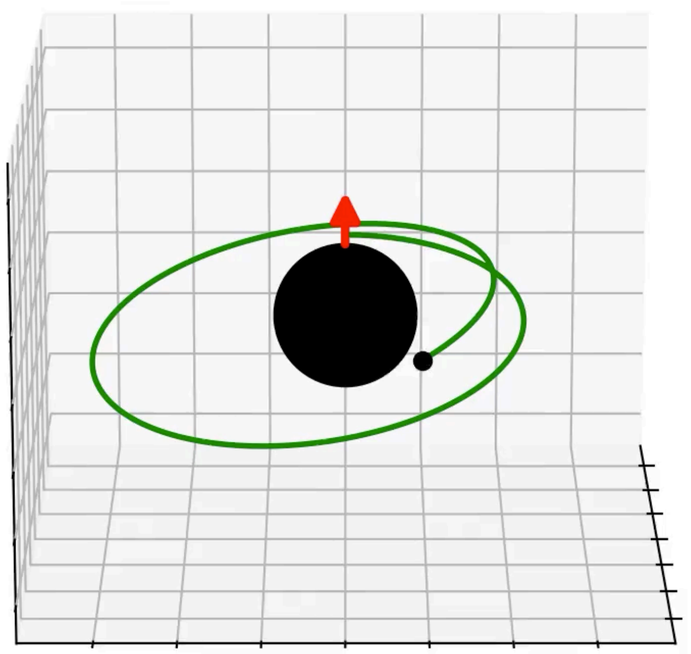
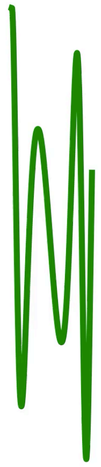
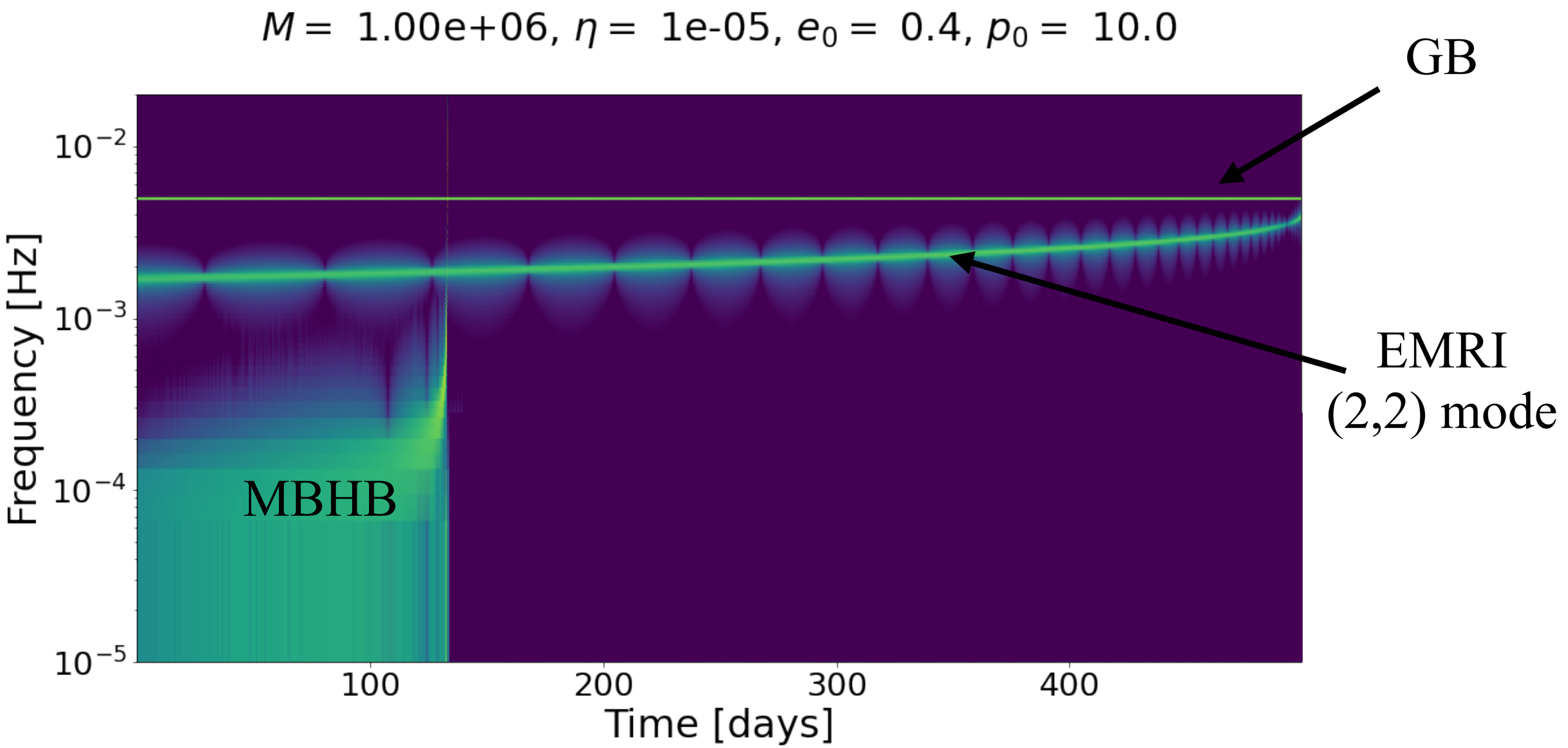
arXiv:2008.06071 - Chua, et al. 2020
arXiv:2104.04582 - Katz, LS, et al. 2021

Contributors: Michael Katz, Alvin Chua, Niels Warburton, Scott Hughes, Christian Chapman-Bird, Monica Rizzo, Soichiro Isoyama, Ryuichi Fujita



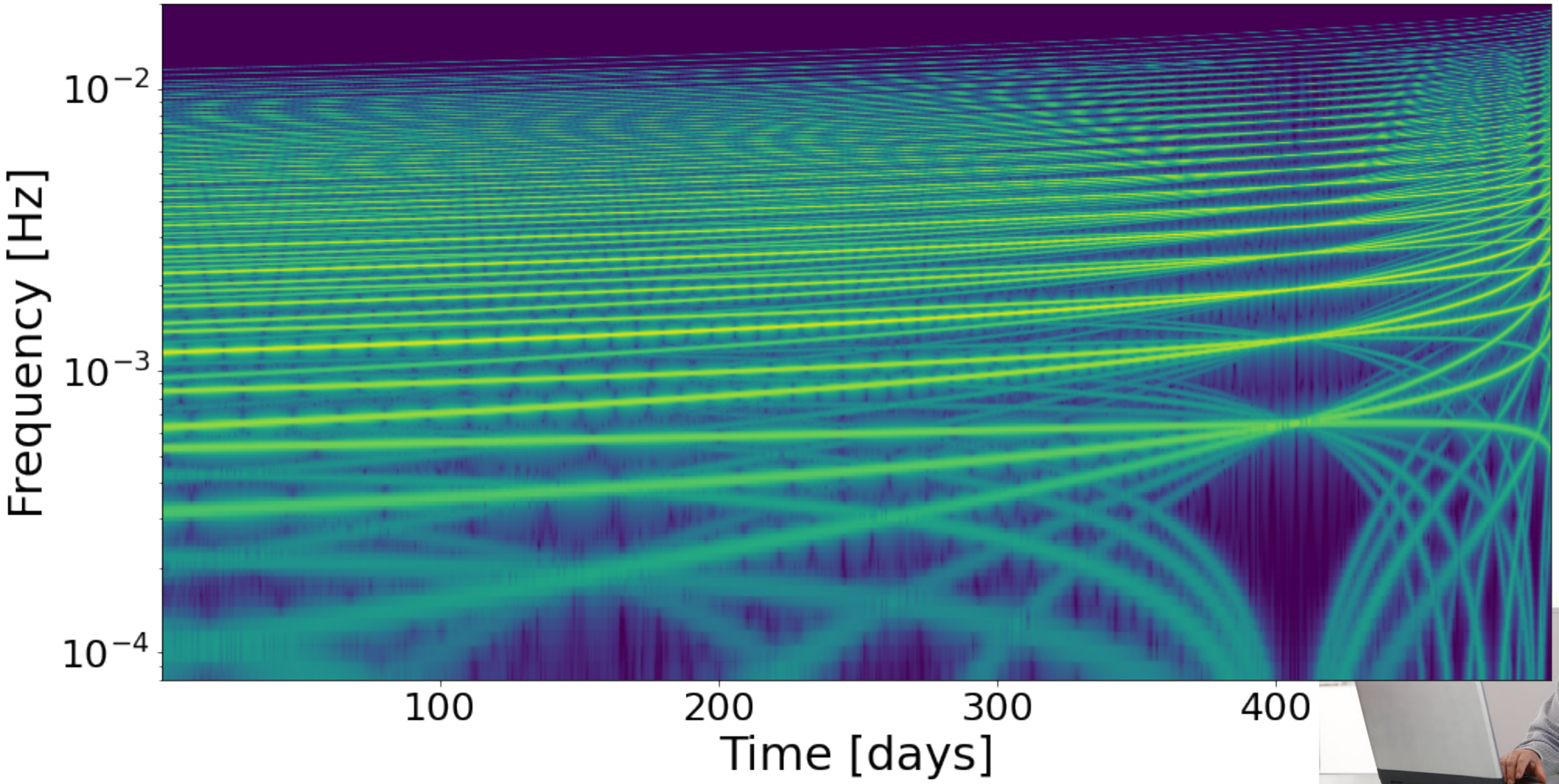


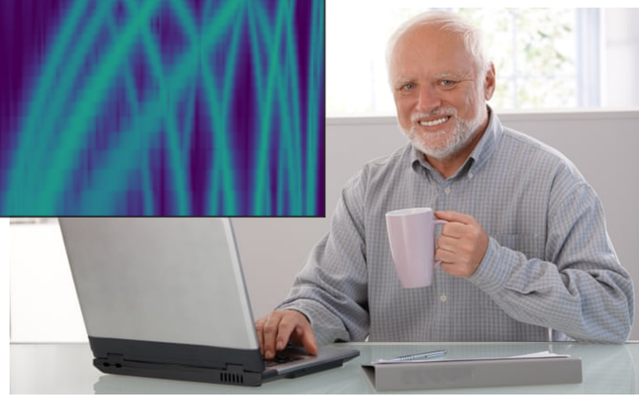
# EMRI Waveform



# EMRI Waveforms

$M = 1.00\text{e+}06$, $\eta = 1\text{e-}05$, $e_0 = 0.4$, $p_0 = 10.0$



# EMRI Waveforms

$$h = \sum_{lmnk} A_{lmnk}(t)\, S_{lmnk}(\theta_S, \phi_S)\, \exp\Big[ - i\Phi_{mnk}(t)\Big]$$

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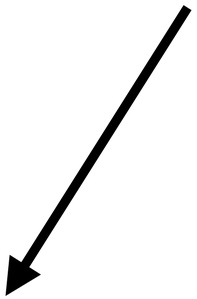
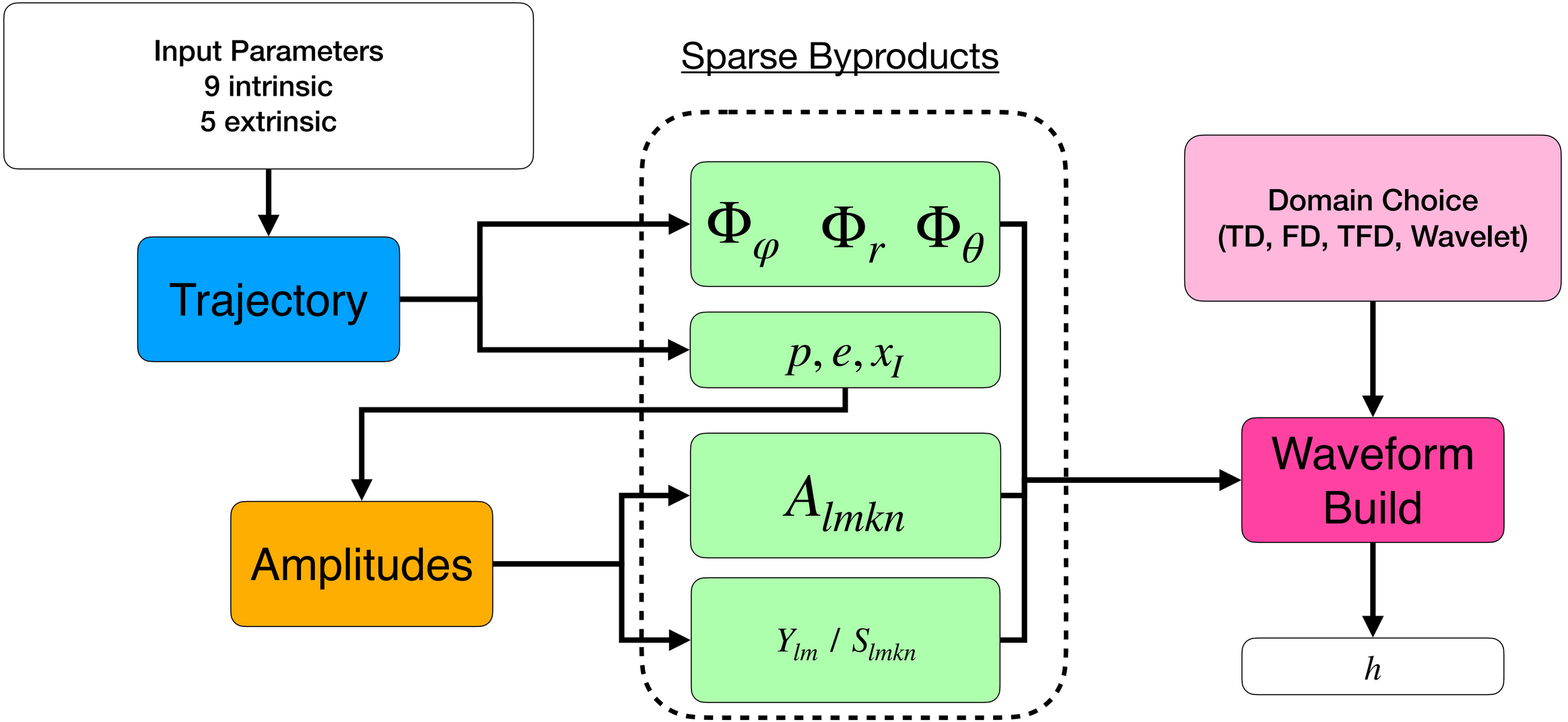


Amplitudes

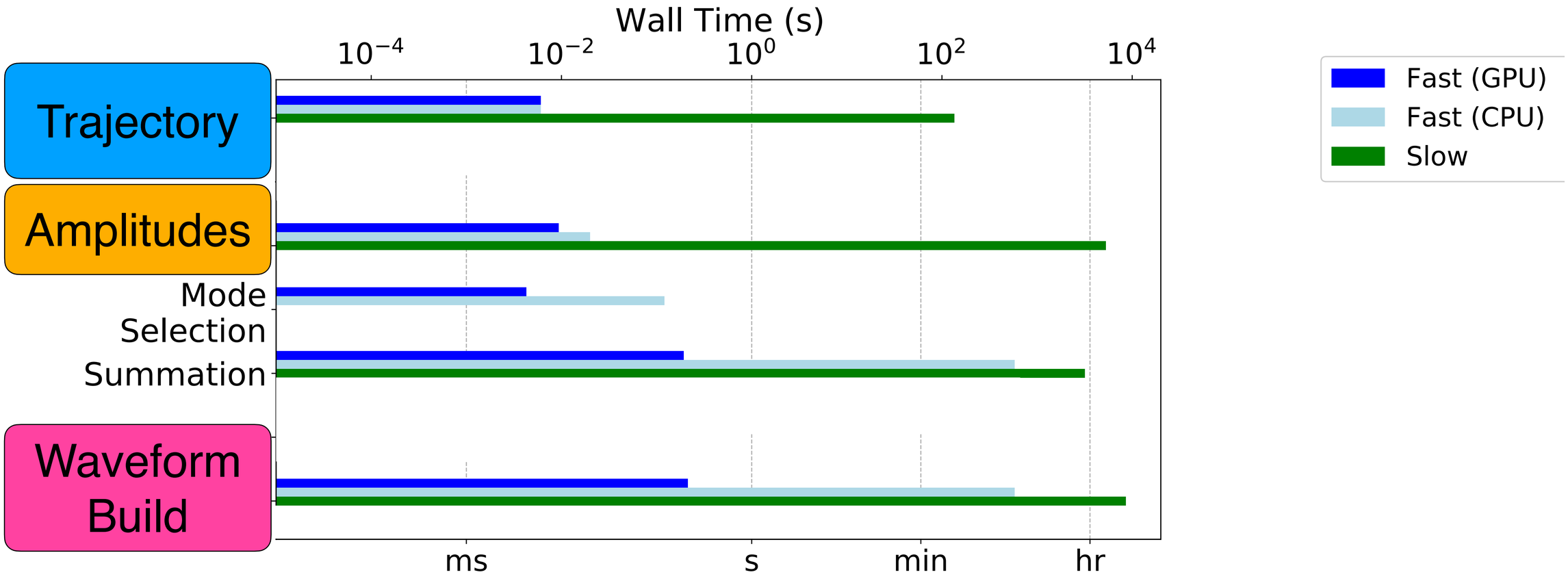
Trajectory

$$\Phi_{mnk} = m\,\Phi_{\varphi} + n\,\Phi_{r} + k\,\Phi_{\theta}$$

# FastEMRI Waveform Architecture

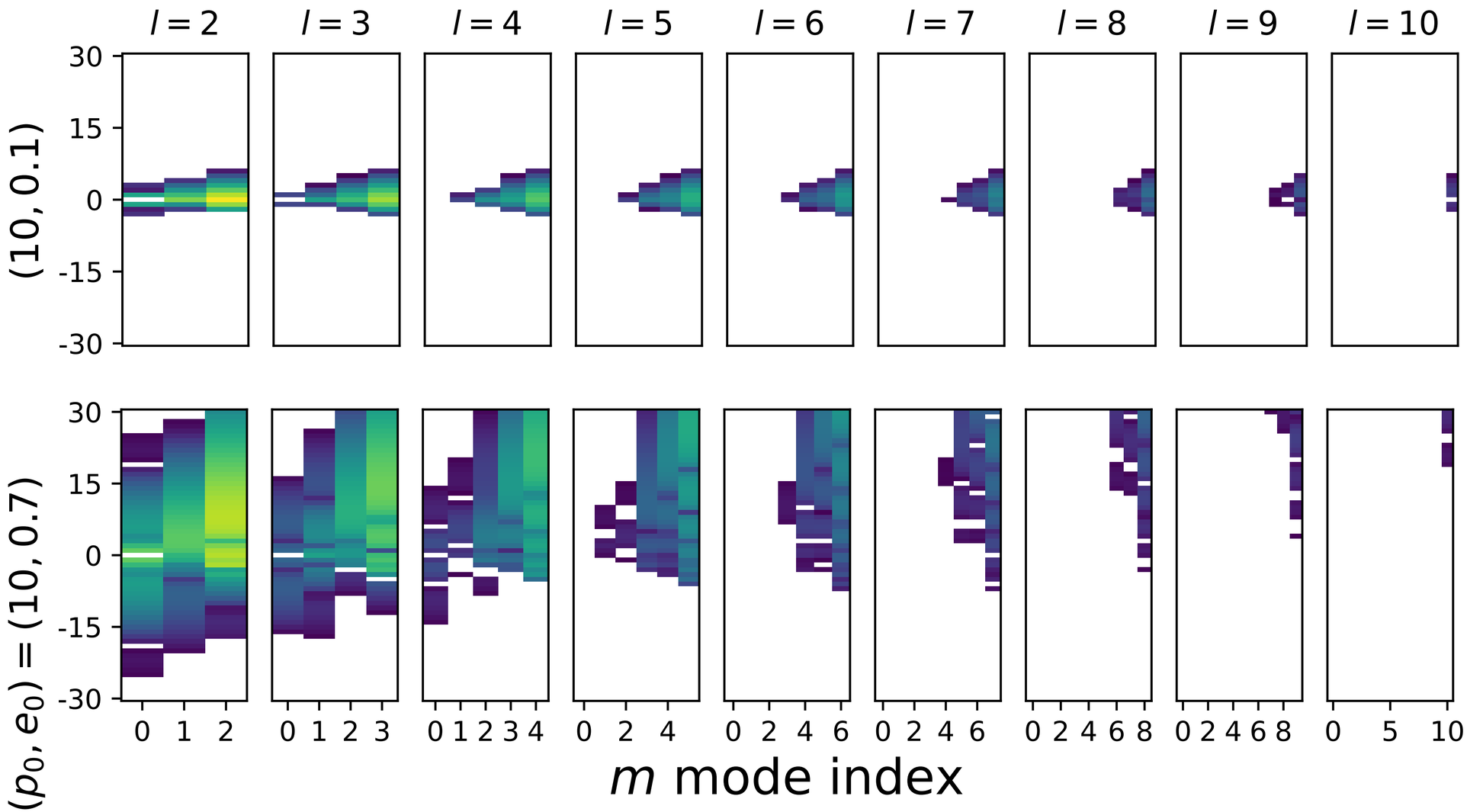


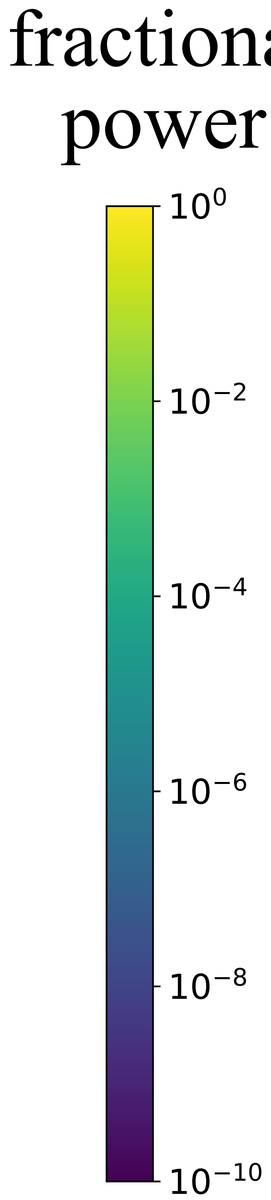
# Waveform Speed



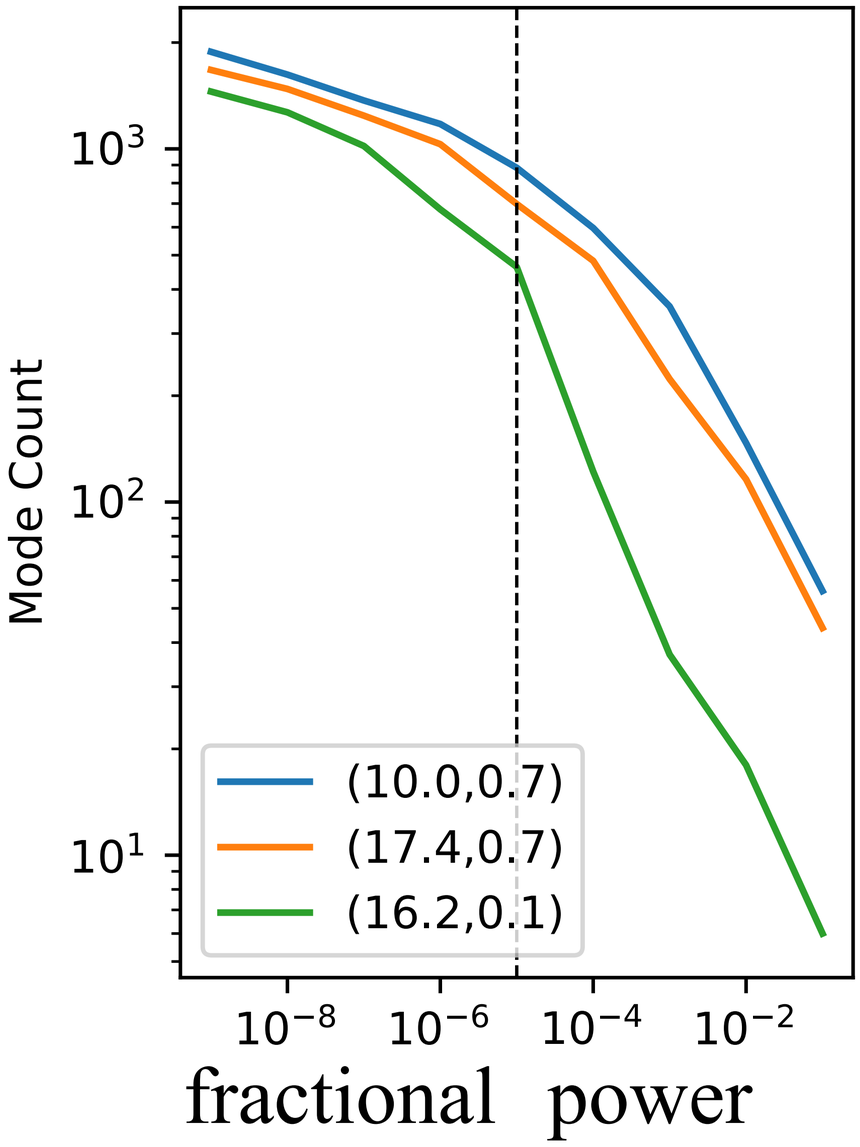

Slowest point
$(p_0, e_0) = (10, 0.7)$
Number of modes $\sim 10^3$

# Mode content

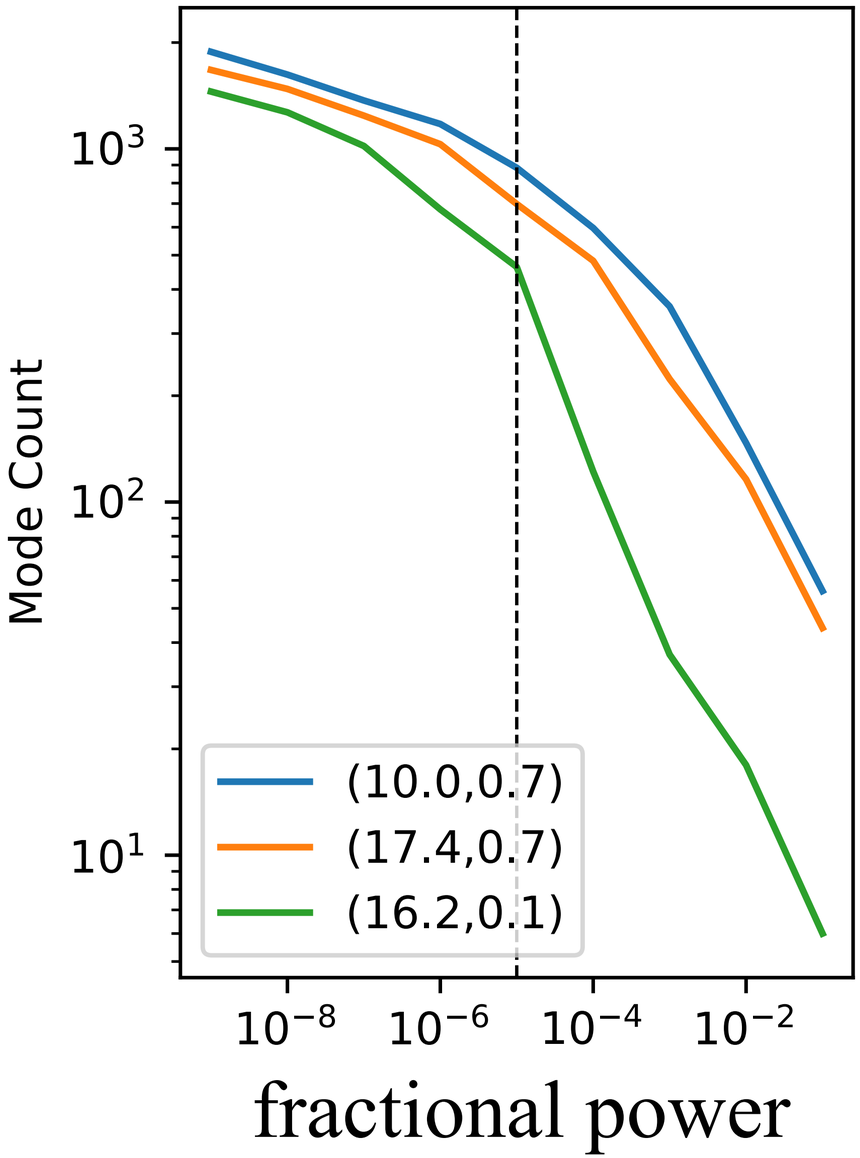


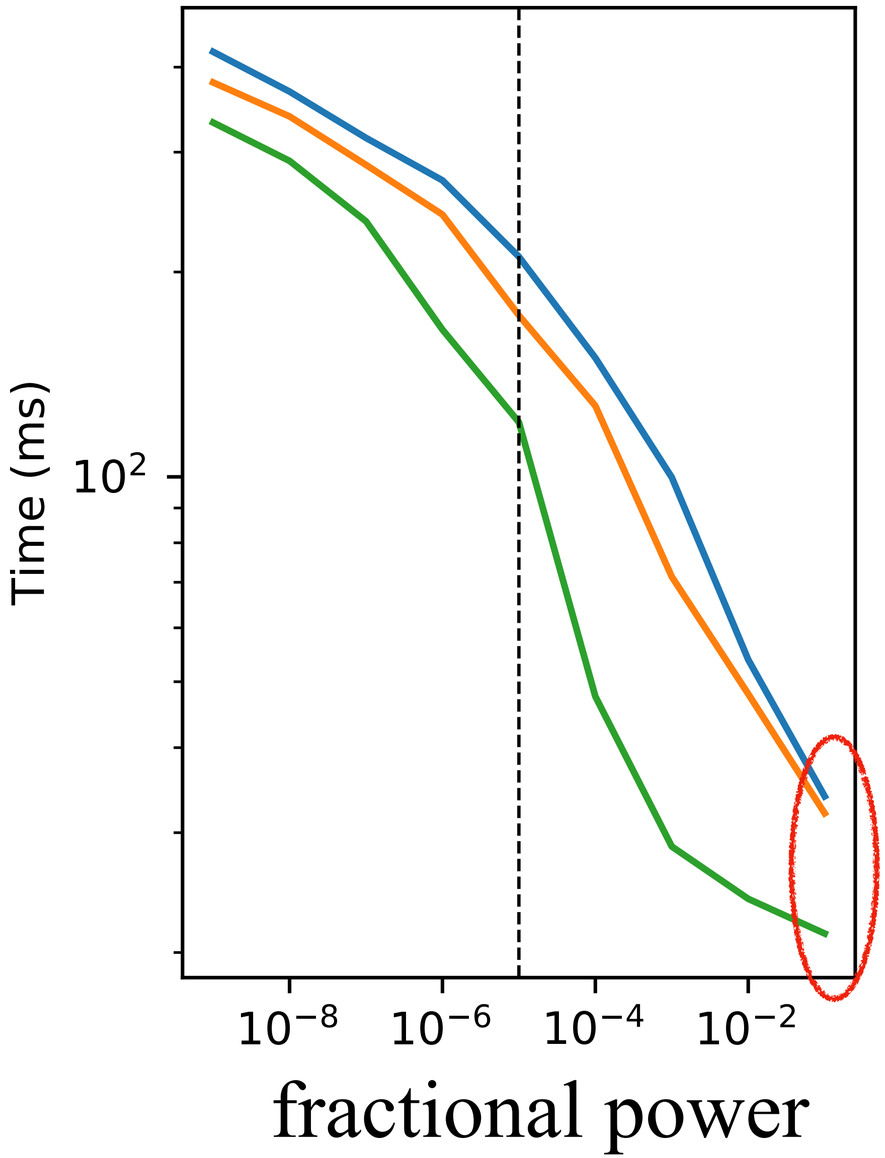



# Mode selection



# Mode selection




Mismatch
0.01

# Conclusions

Available Waveforms:

Schwarzchild Eccentric
(Fully relativistic)

Generic Kerr
(PN5+AAK)

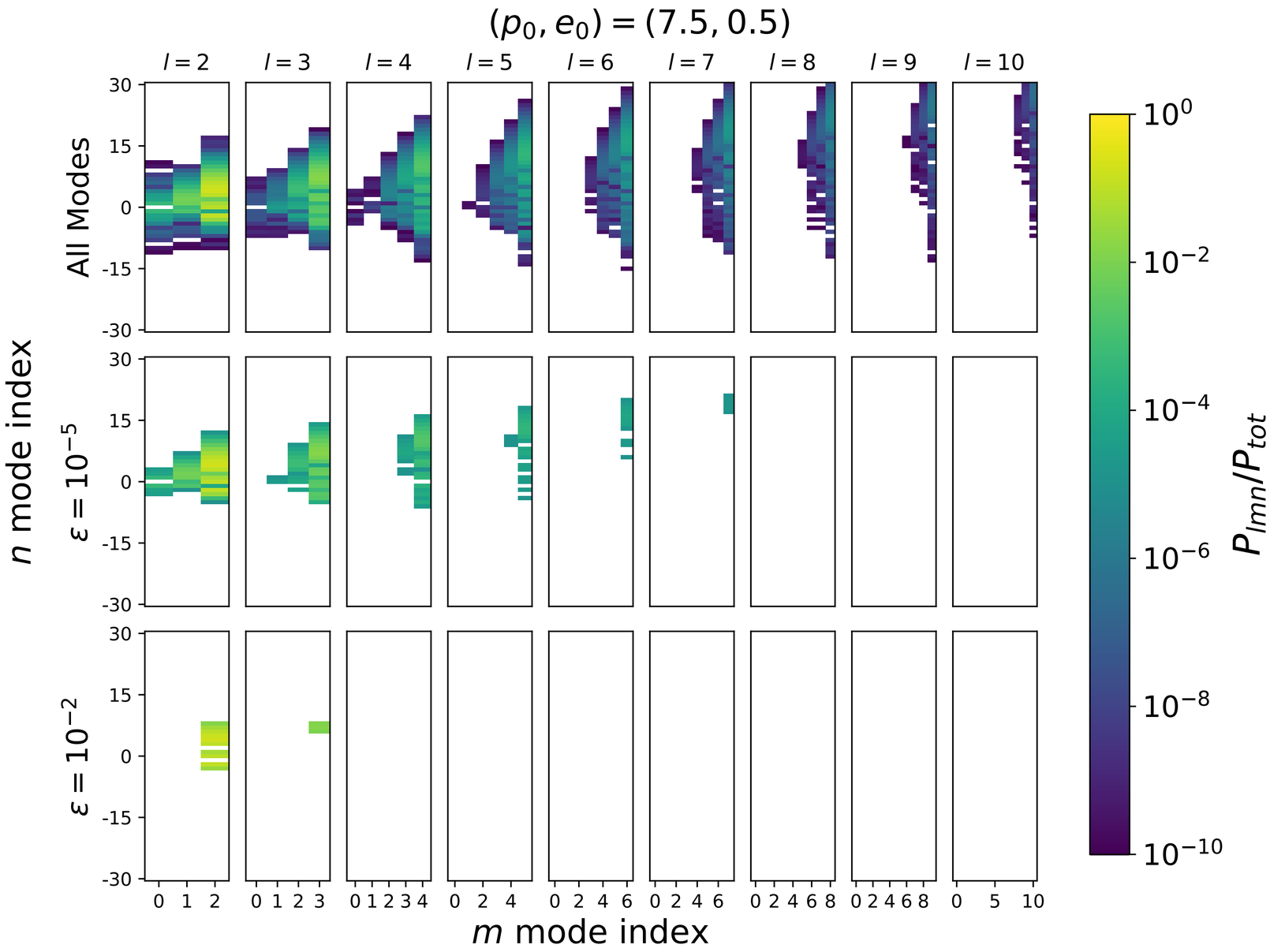
Kerr Circular (AAK)
+ Accretion effects

- EMRIs have many harmonics but we can decide how many to include!
- Flexible to include new trajectories/physics
- Fast generation due to GPU acceleration

**Reach out if you want to develop EMRI waveforms!**

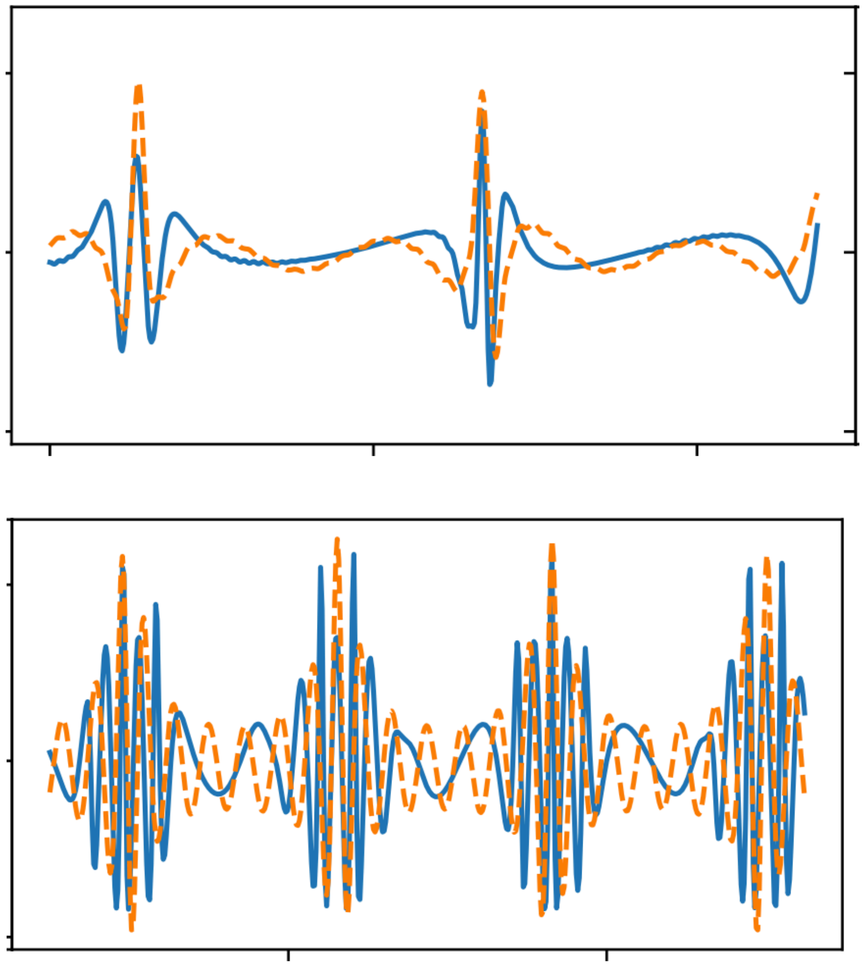
bhptoolkit.org/FastEMRIWaveforms →

# Mode Selection



# The importance of relativistic Waveforms

Relativistic Amplitudes (Injection & Template)
AAK Amplitudes (Template)



Relativistic Amplitudes (Injection & Template)
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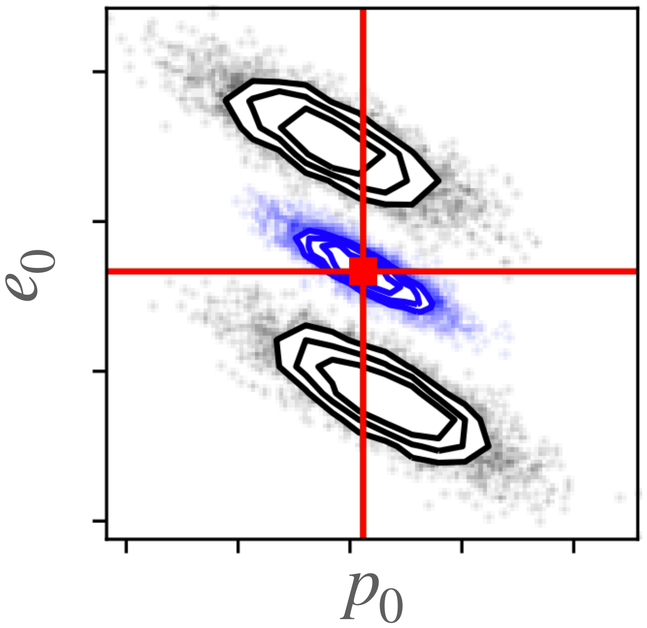
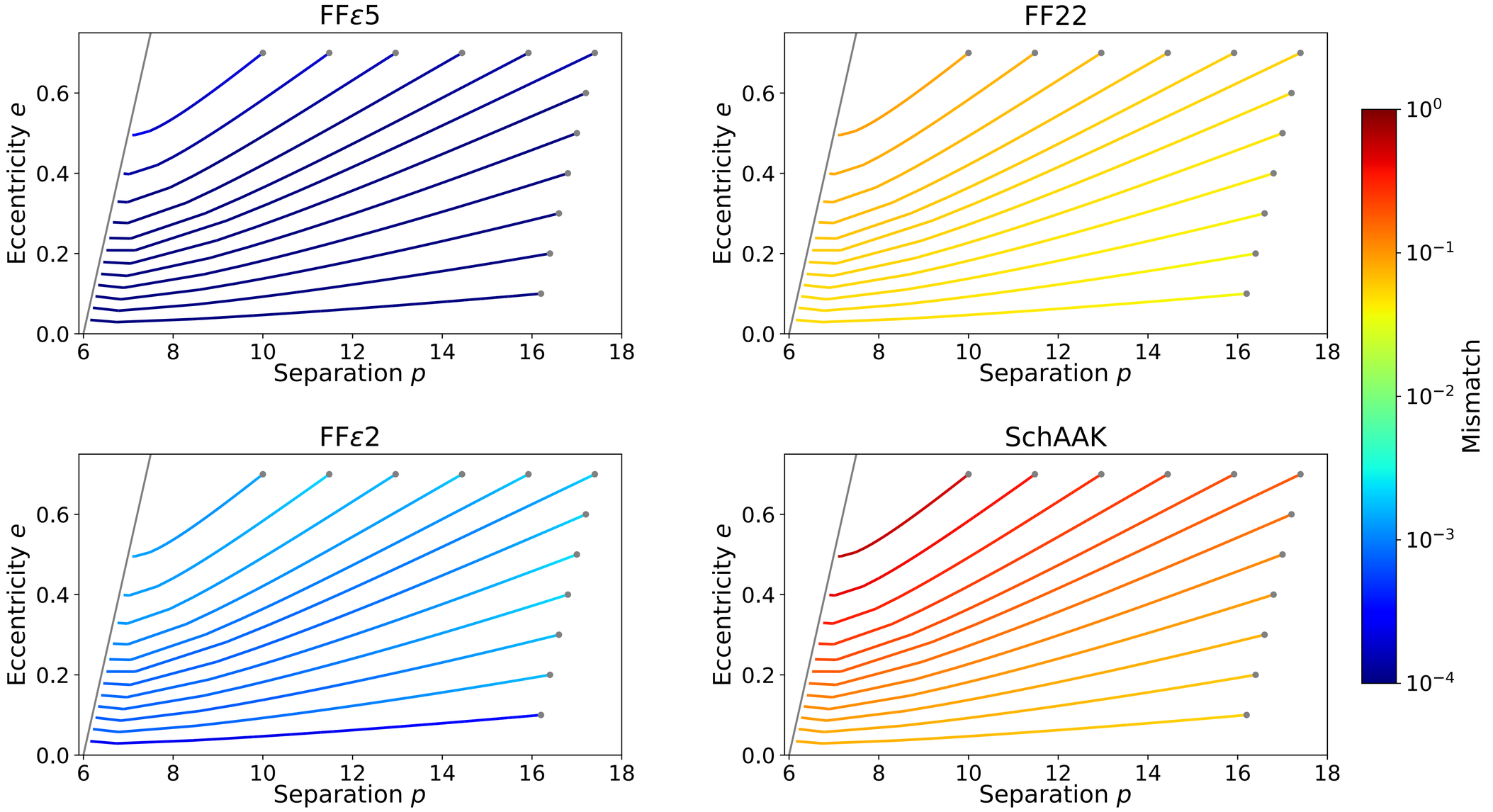
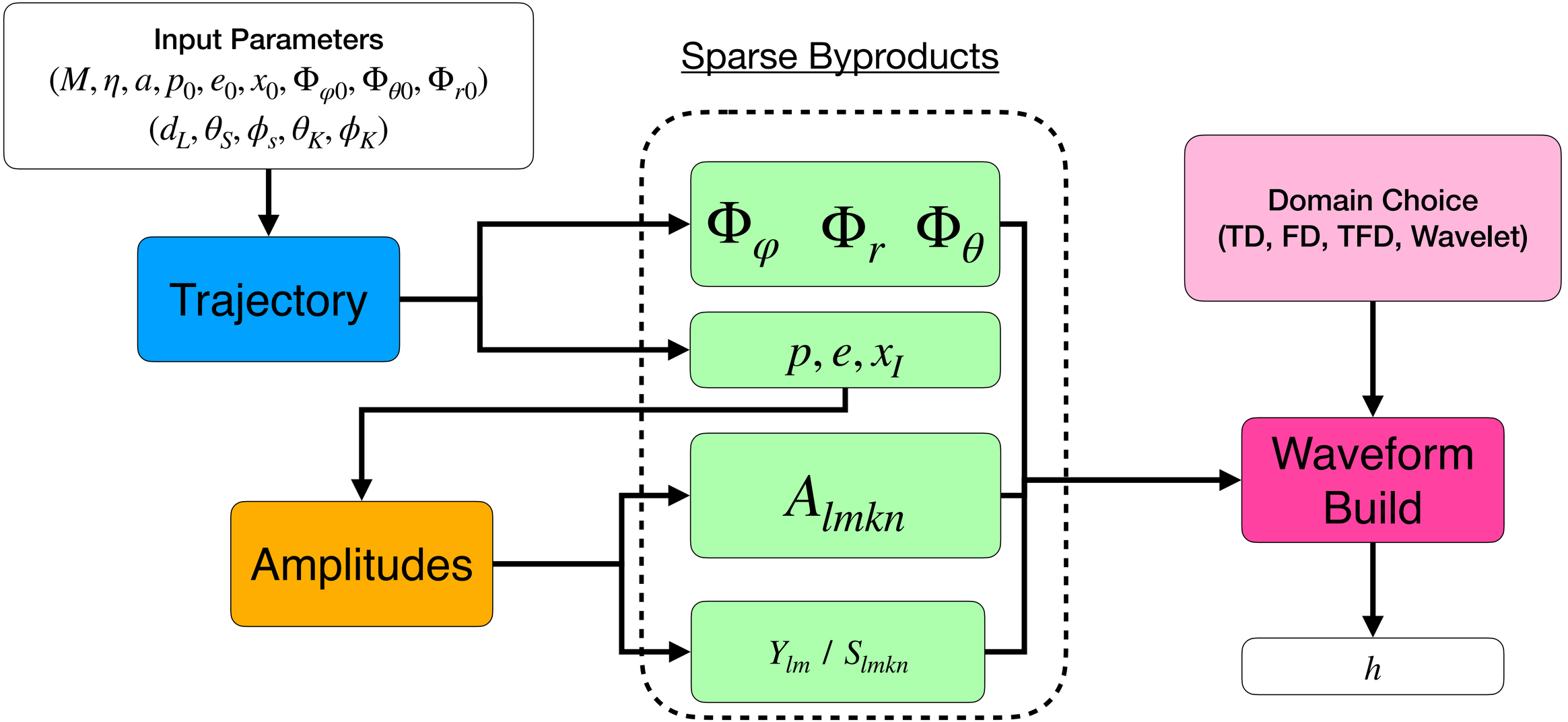


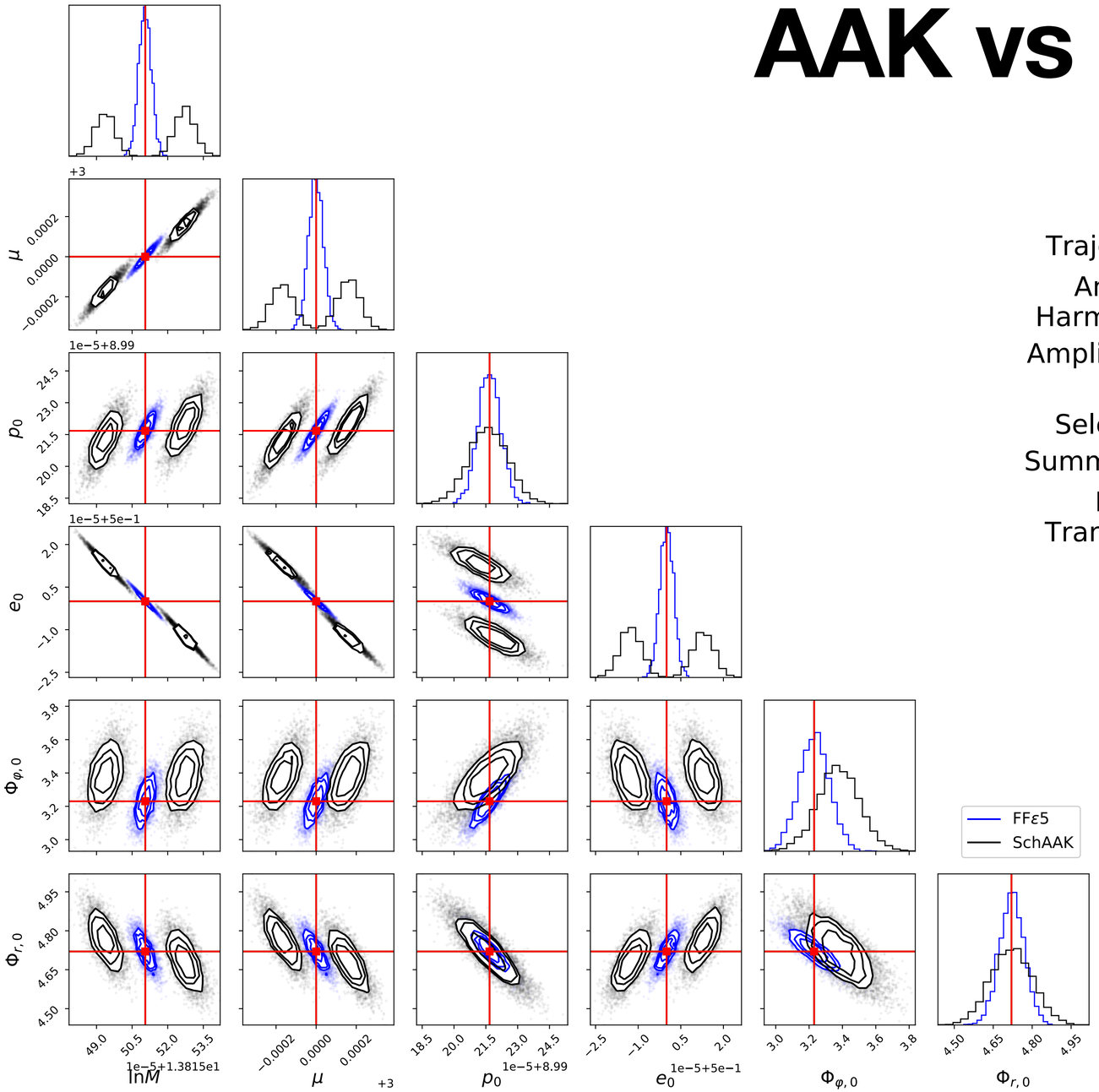
# Mismatch Models

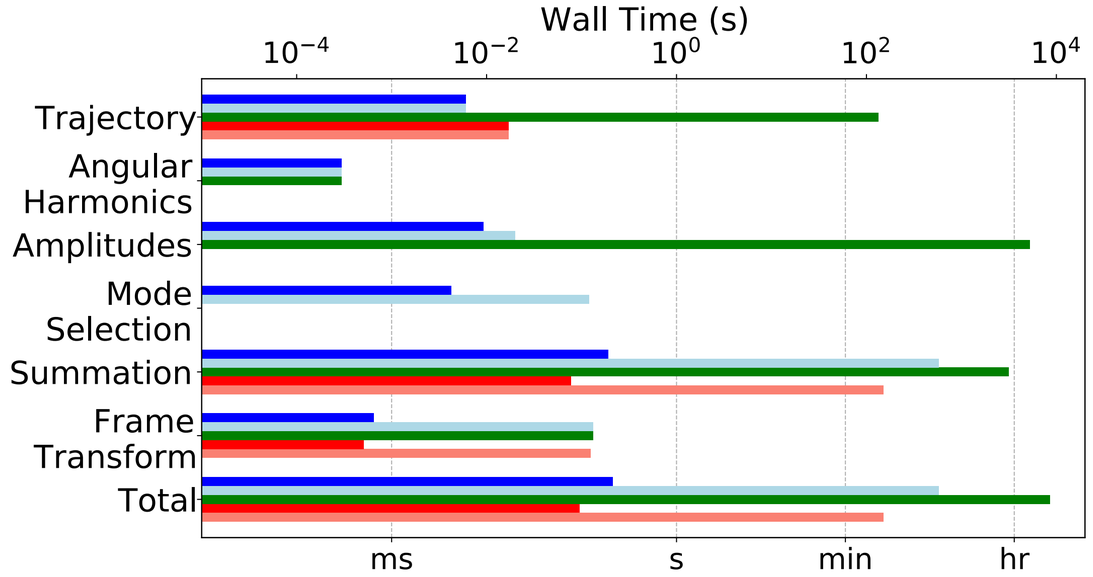


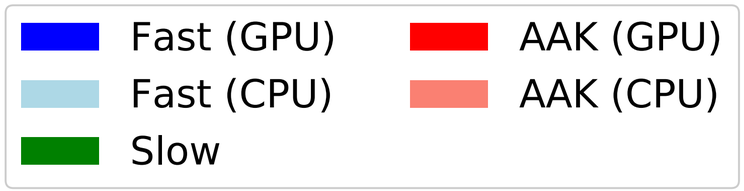
# FastEMRI Waveform Architecture



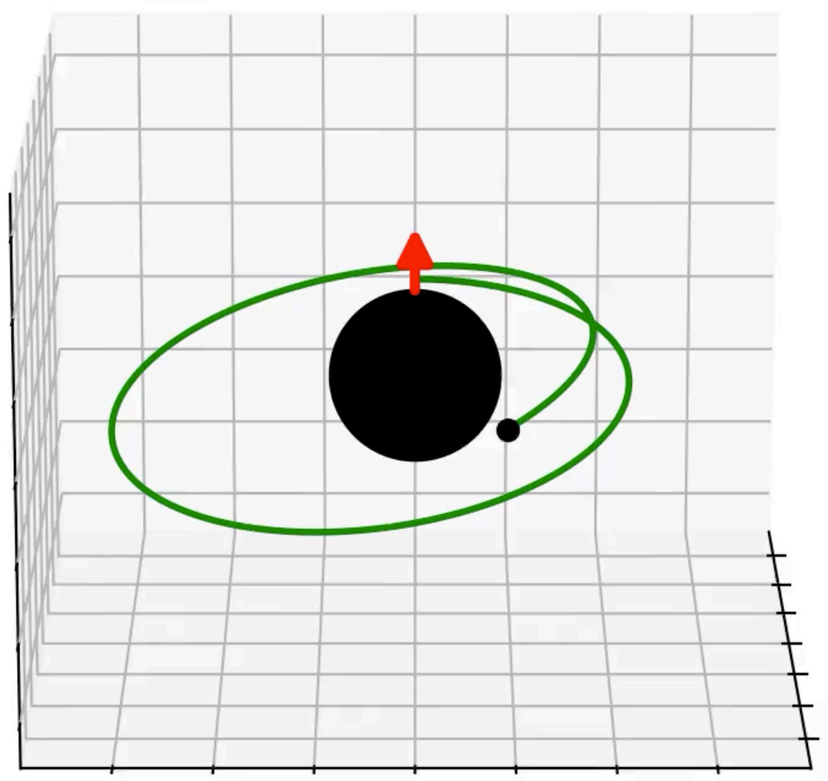
# AAK vs FEW


FFε5
SchAAK
ln$\mathcal{M}$
$\mu$
$p_0$
$e_0$
$\Phi_{\varphi,0}$
$\Phi_{r,0}$
1e−5+1.3815e1
+3
1e−5+8.99
1e−5+5e−1


Wall Time (s)
$10^{-4}$
$10^{-2}$
$10^{0}$
$10^{2}$
$10^{4}$
Trajectory
Angular Harmonics
Amplitudes
Mode Selection
Summation
Frame Transform
Total
ms
s
min
hr


Fast (GPU)
Fast (CPU)
Slow
AAK (GPU)
AAK (CPU)

# Extreme Mass Ratio Inspirals



Mass of the Black Hole

$M \sim 10^5 - 10^7 M_\odot$

Mass Compact Object

$\mu \approx 1 - 10\, M_\odot$

Mass Ratio

$\eta \approx 10^{-6} - 10^{-4}$

Signal duration $\sim 1 - 4$ years

# Mode selection