

Towards a “Kicked” Frequency-Domain Waveform Approximant

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eXtreme Gravity Institute
Montana State University

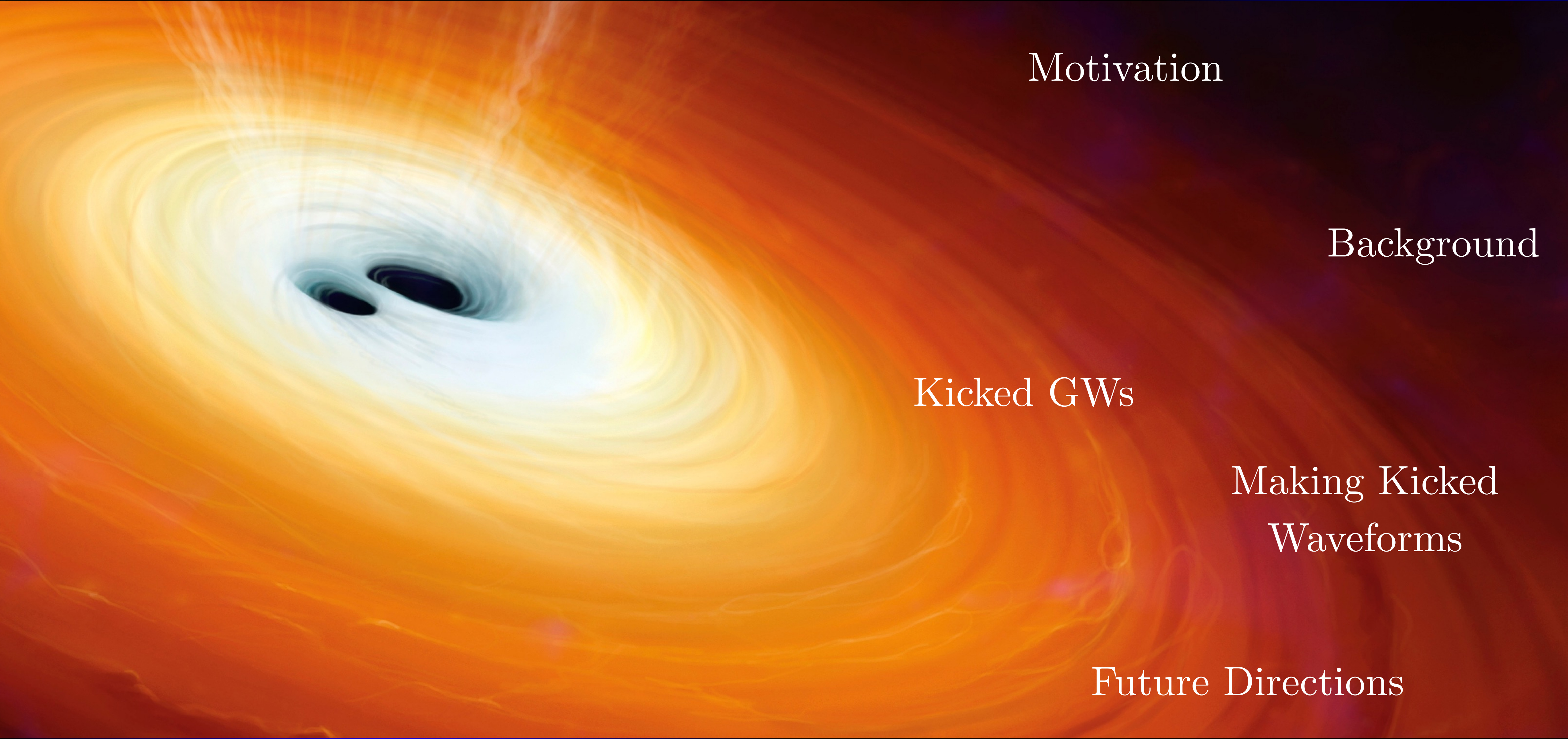
TAPIR- California Institute
of Technology



SURF - Final Project
25th August 2017



Road Map



Motivation

Background

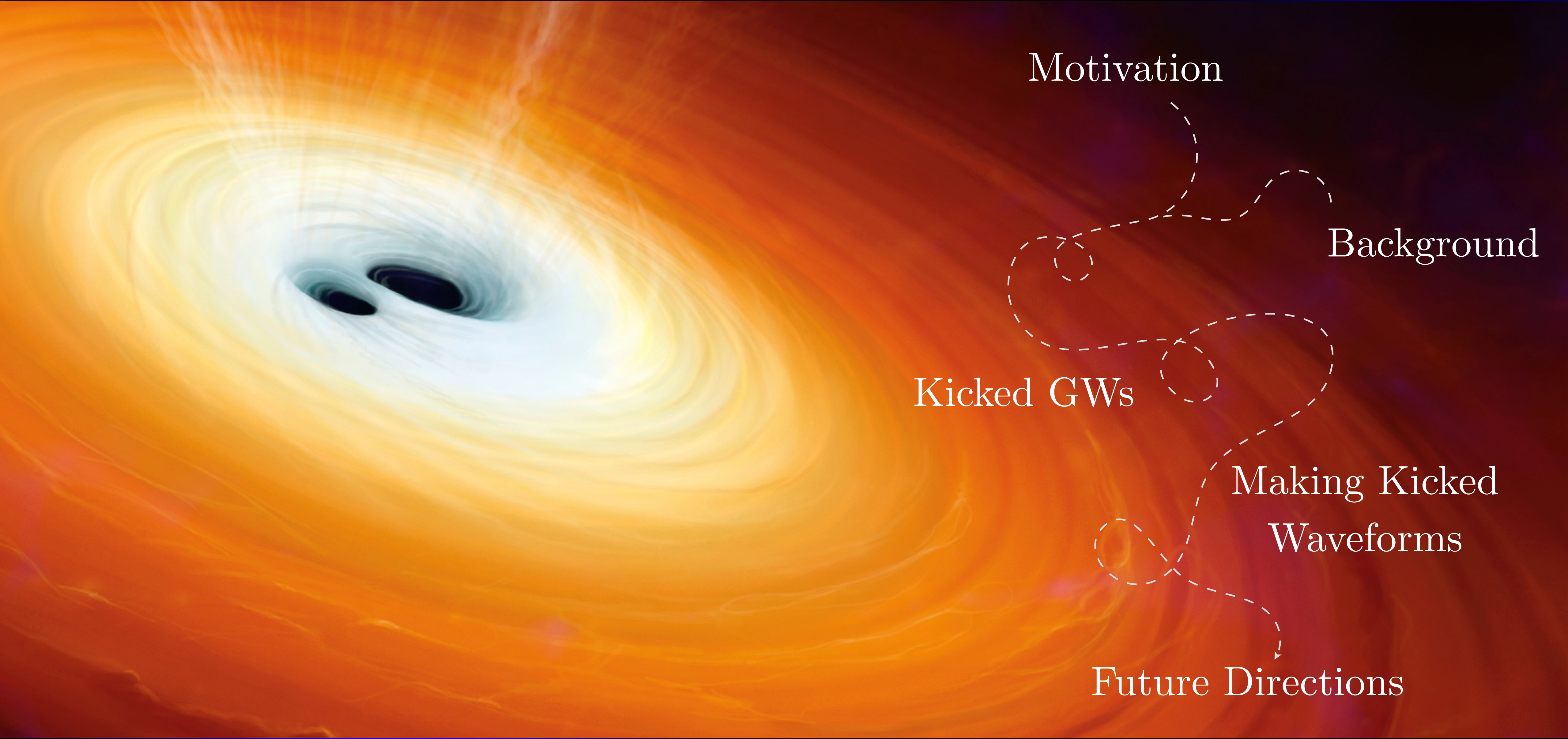
Kicked GWs

Making Kicked
Waveforms

Future Directions



Road Map



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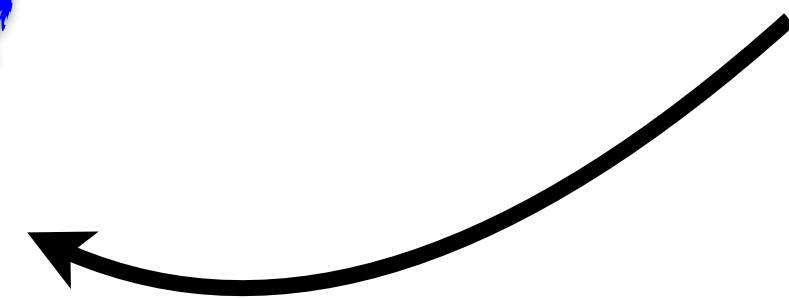
Kicked GWs

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Future Directions

Currently have
EM candidates
for kicks

GWs will provide the first direct detection
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Merger rates for LISA

Black hole kicks can
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 $v \sim 0.01c$

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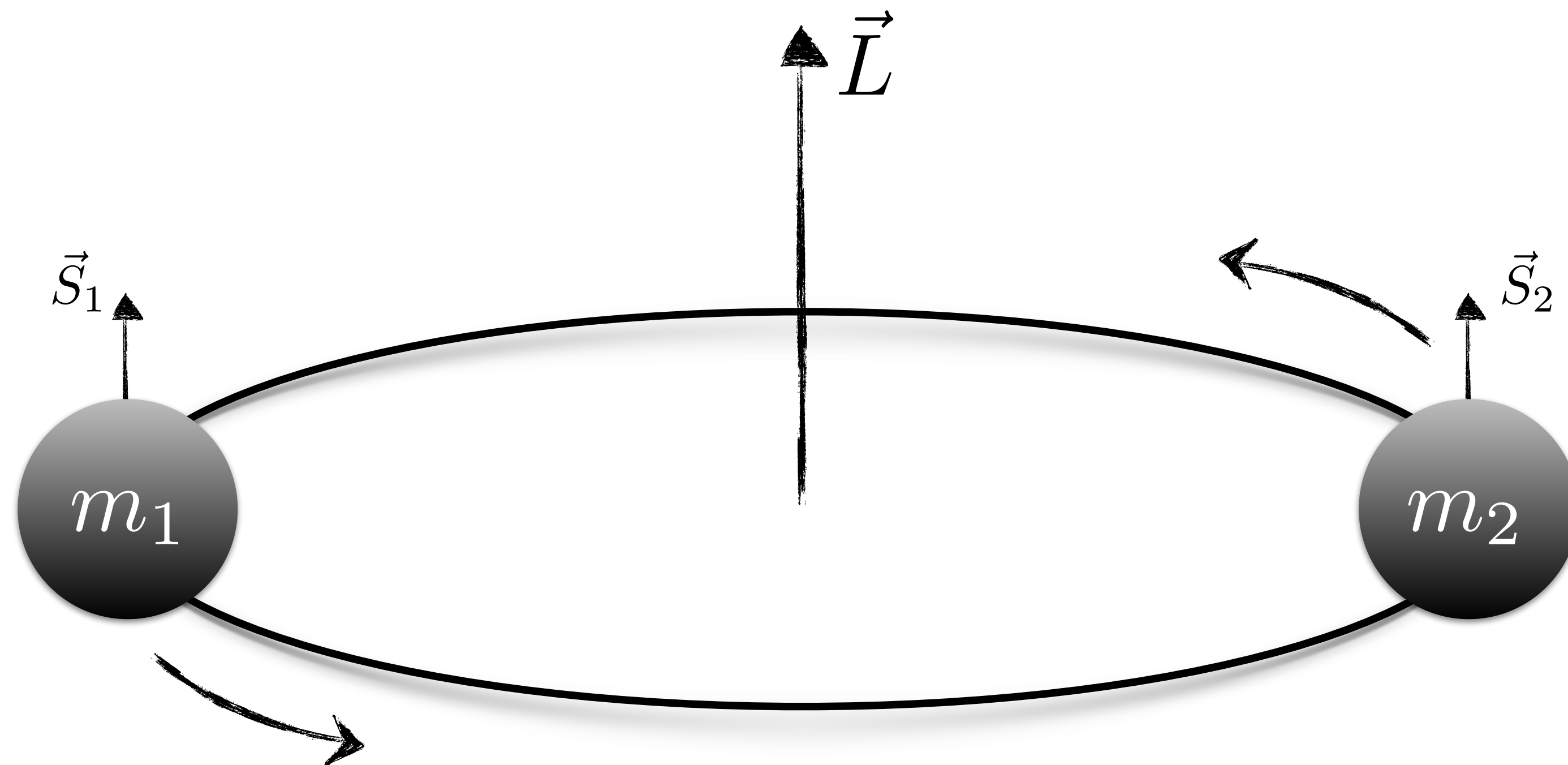
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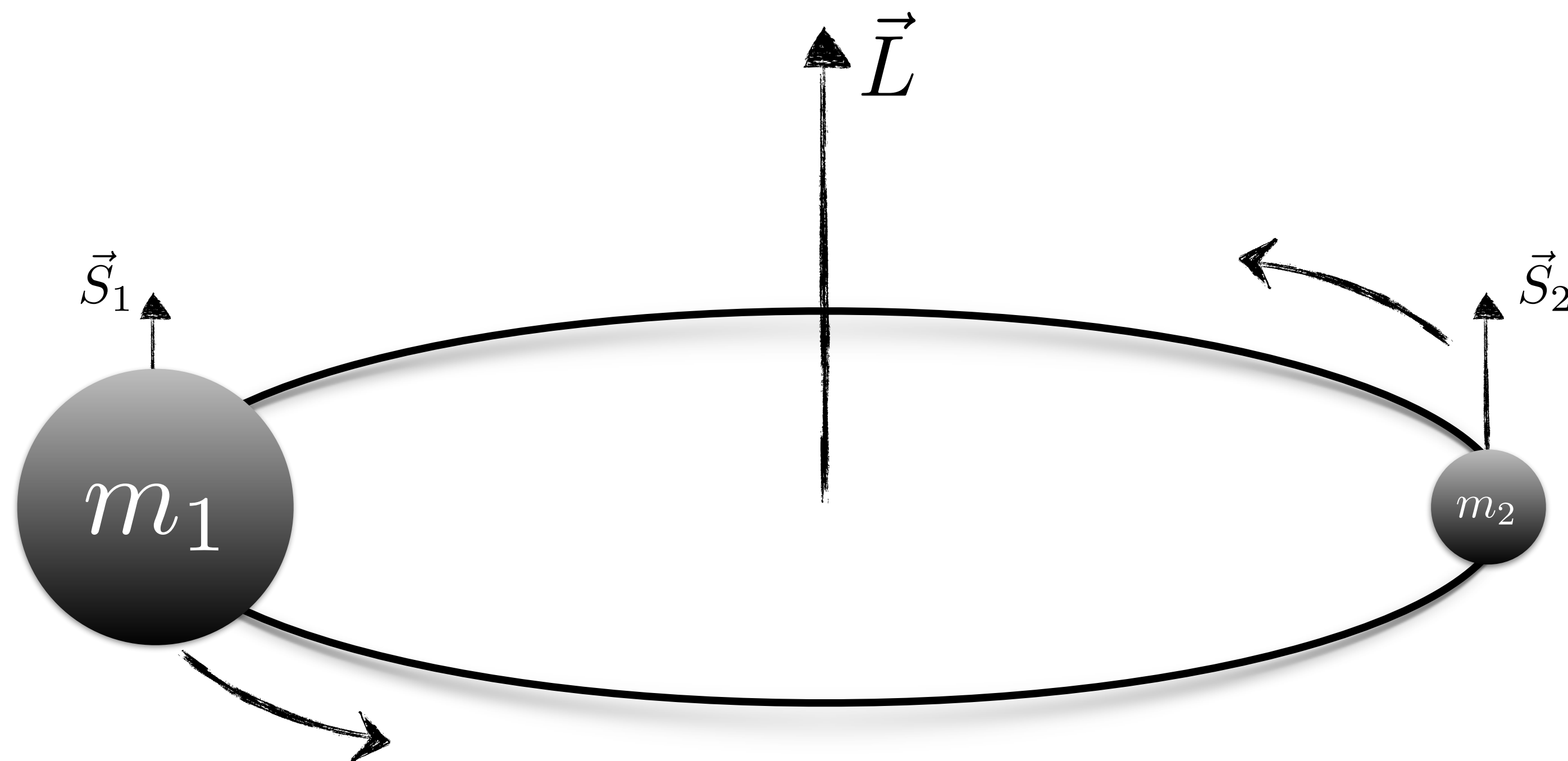
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Direct confirmation
that GWs carry
linear momentum

Tests of GR!

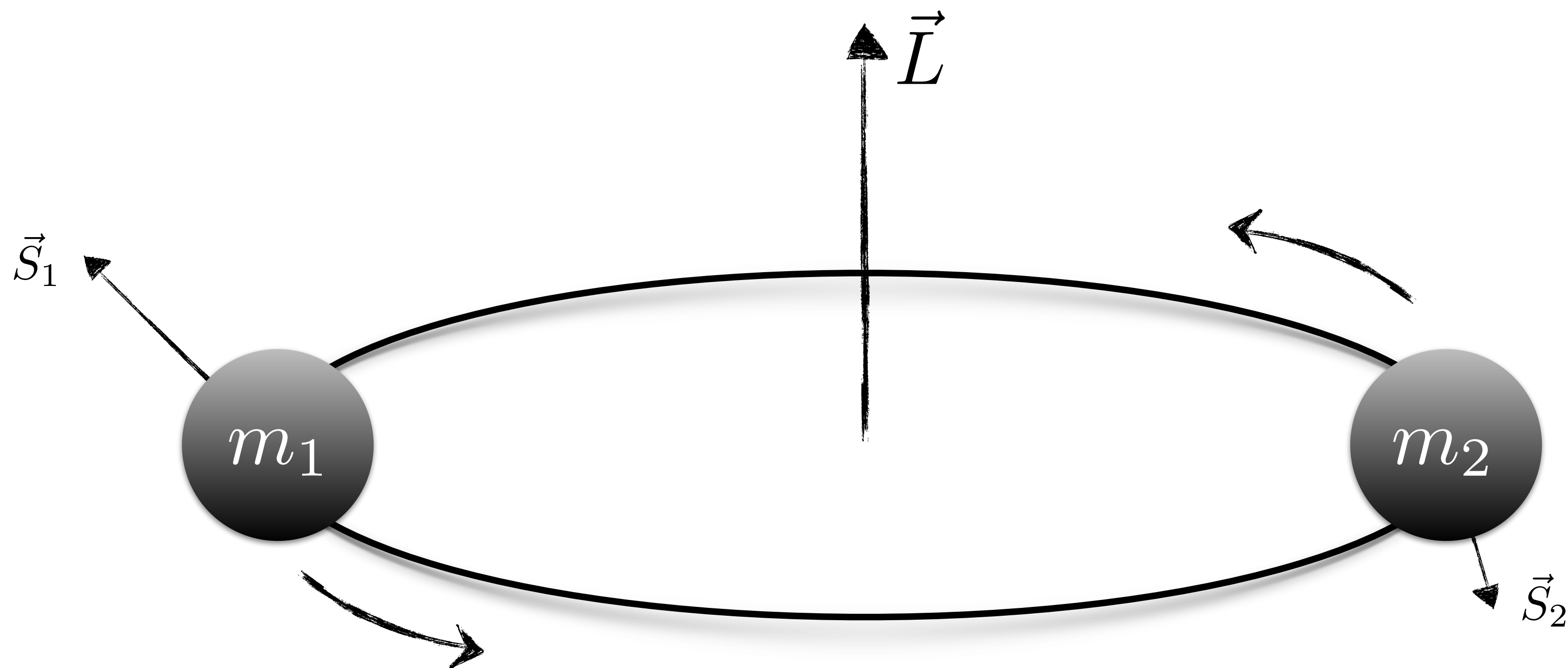


Two Kinds of Asymmetry:



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- mass



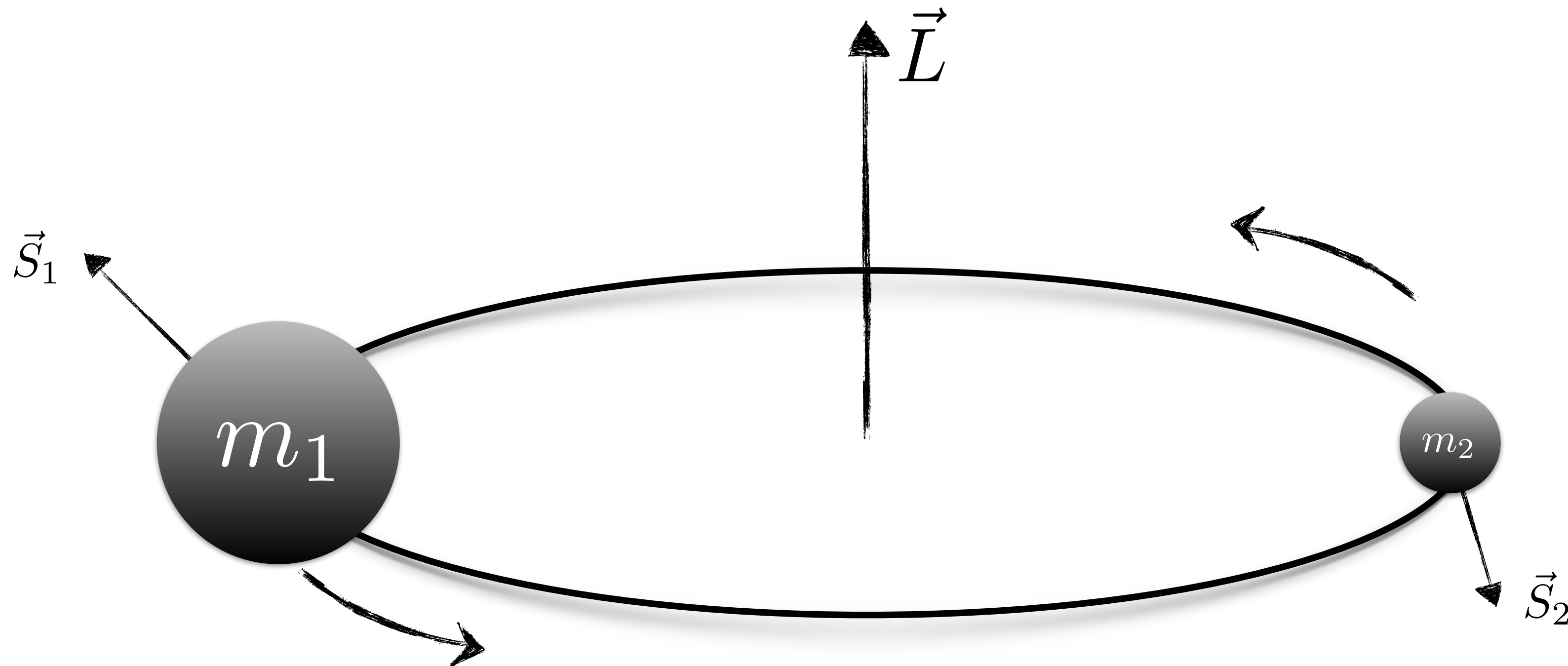
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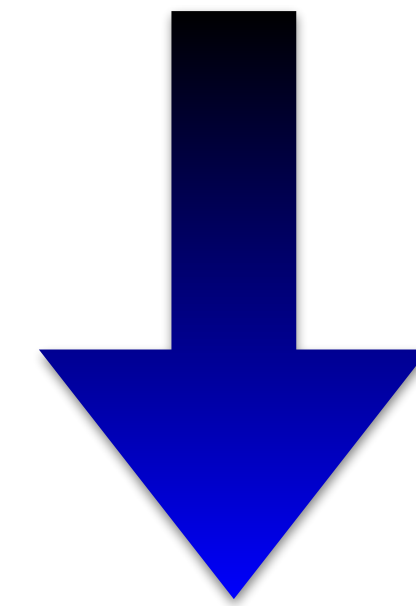
What *are* Black Hole Recoils?

This is a generic black hole binary!



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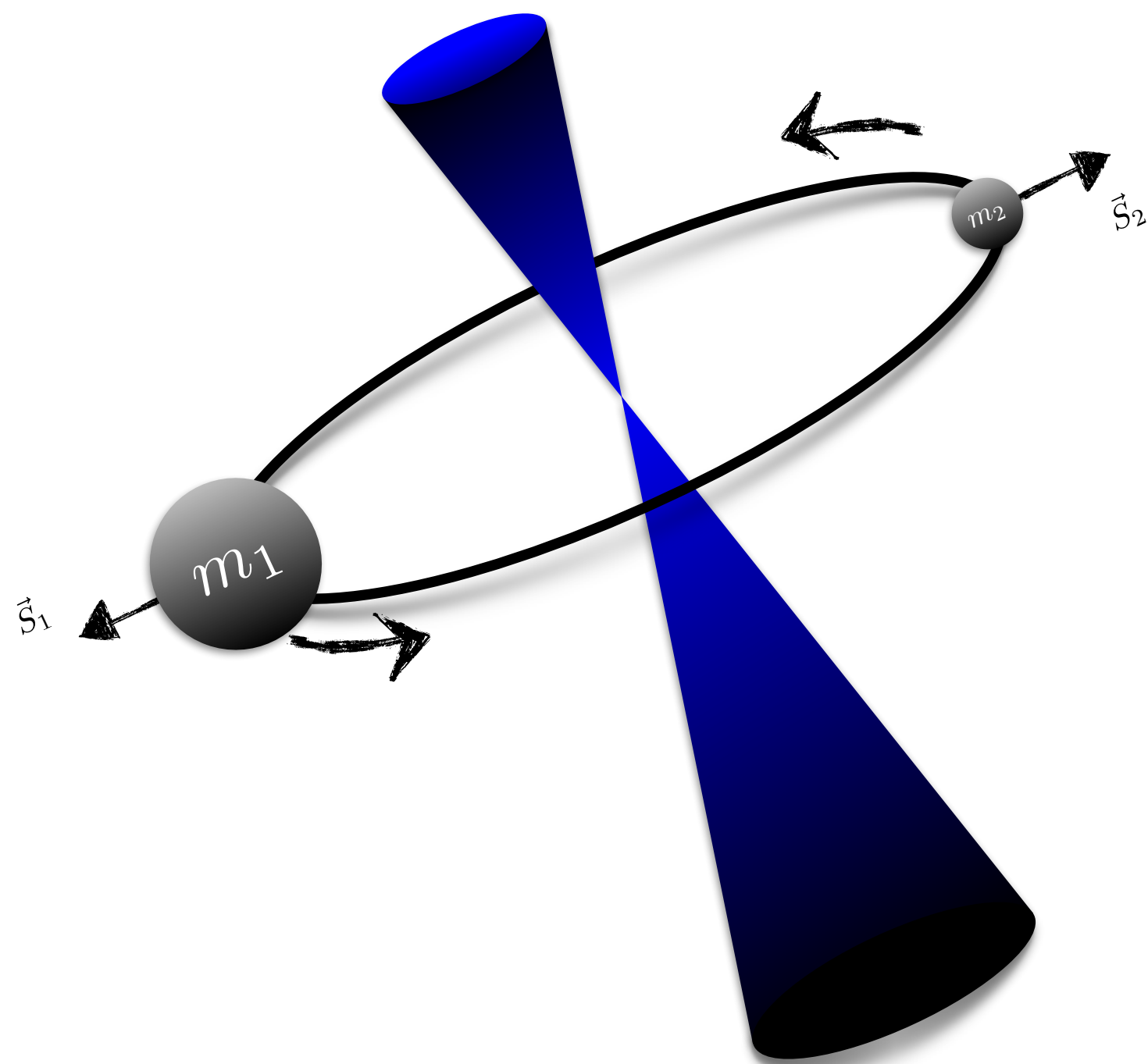


Anisotropic GW Emission

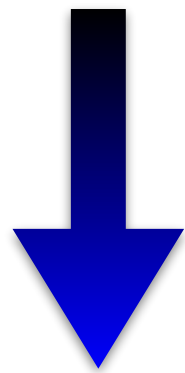
Anisotropic emission



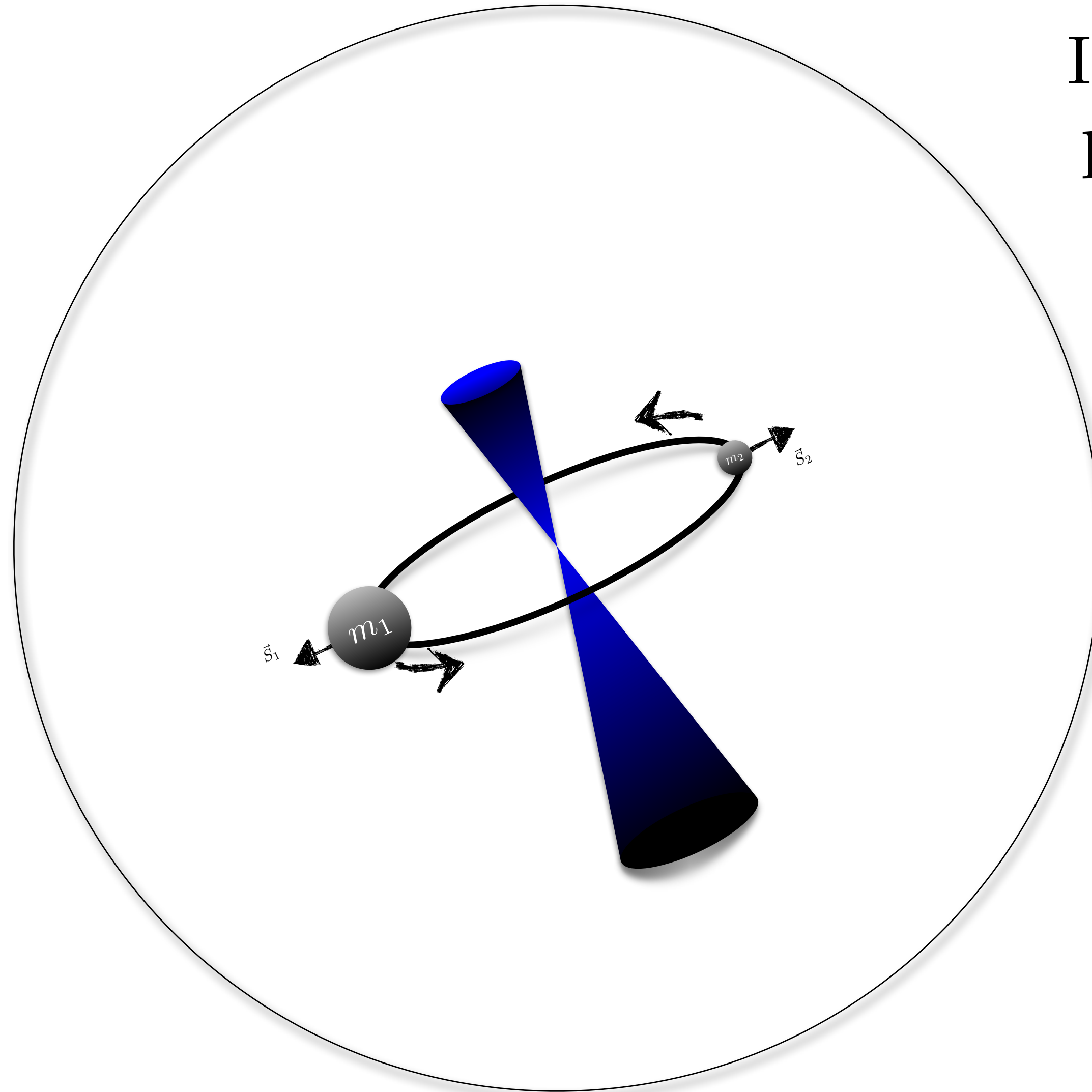
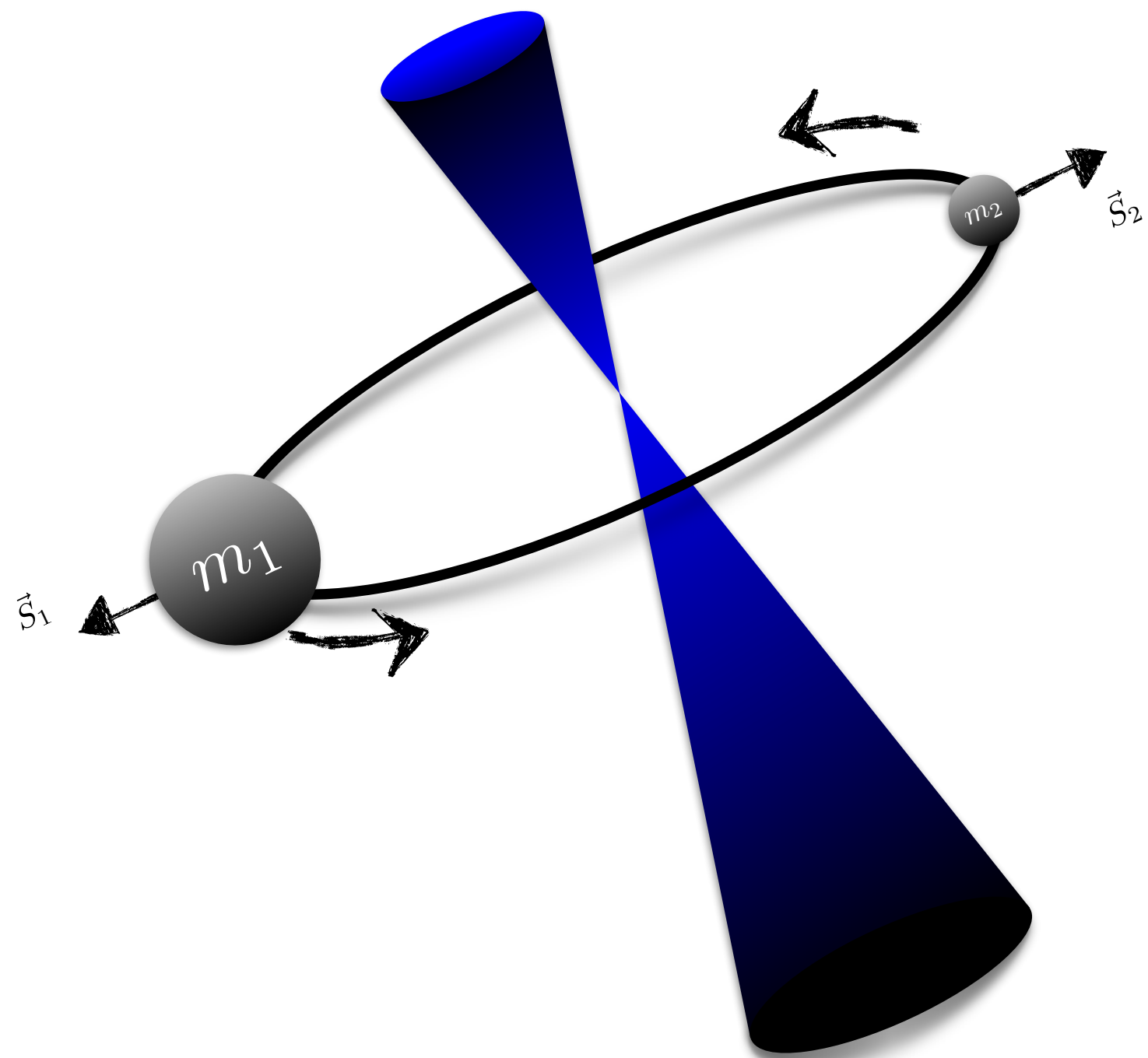
GW beaming



Anisotropic emission



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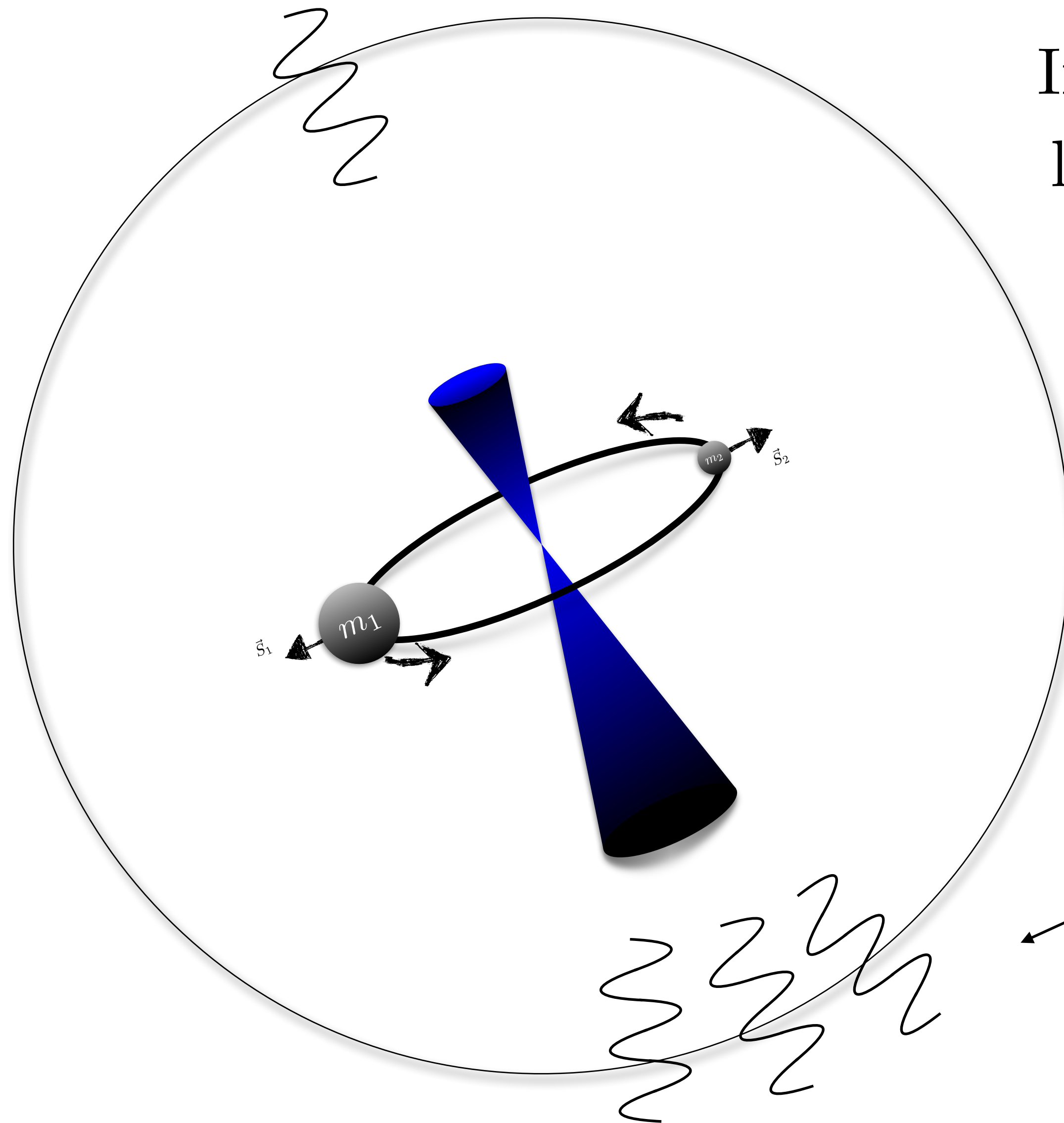
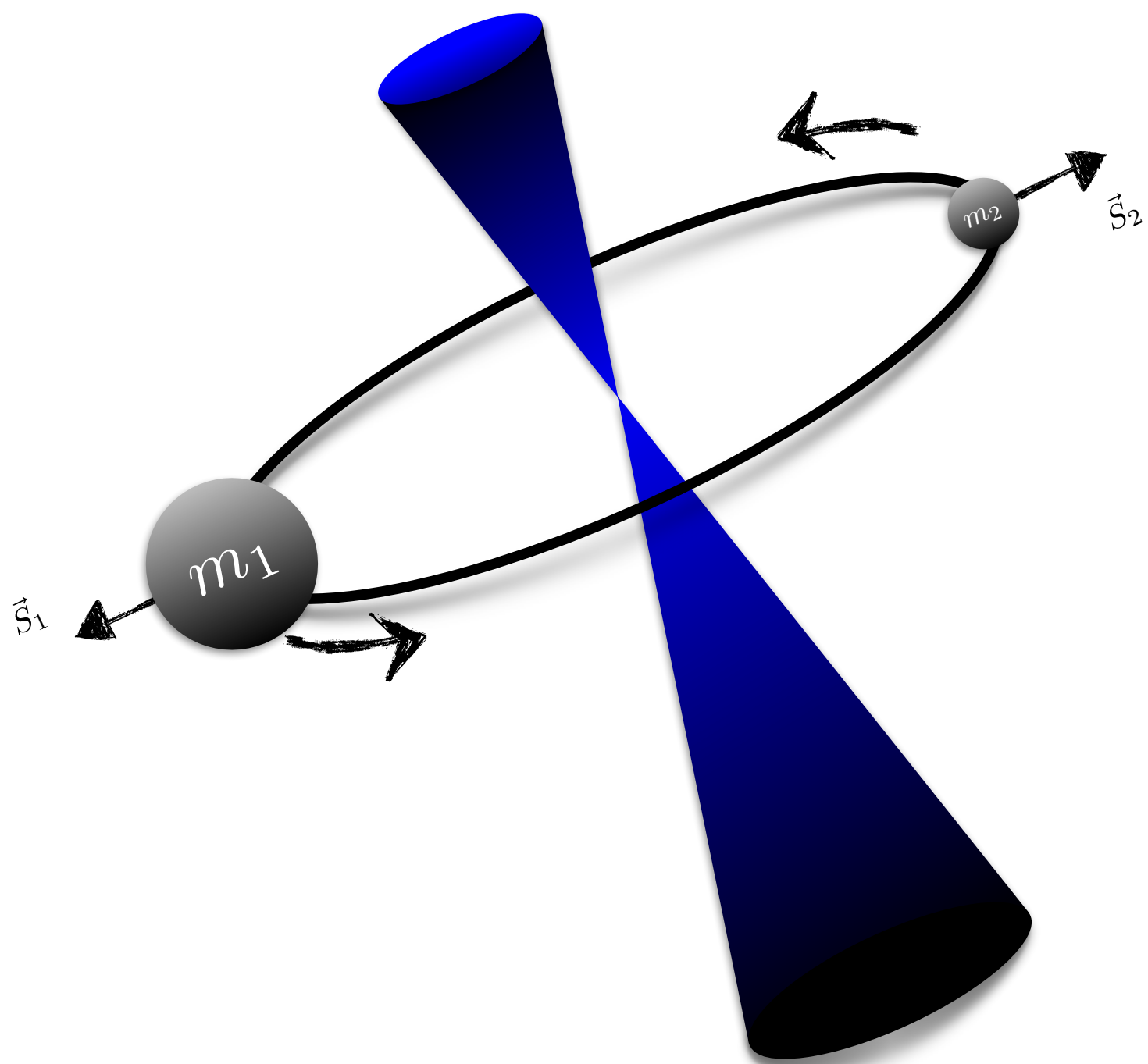


In GR, GWs carry linear momentum

Anisotropic emission



GW beaming



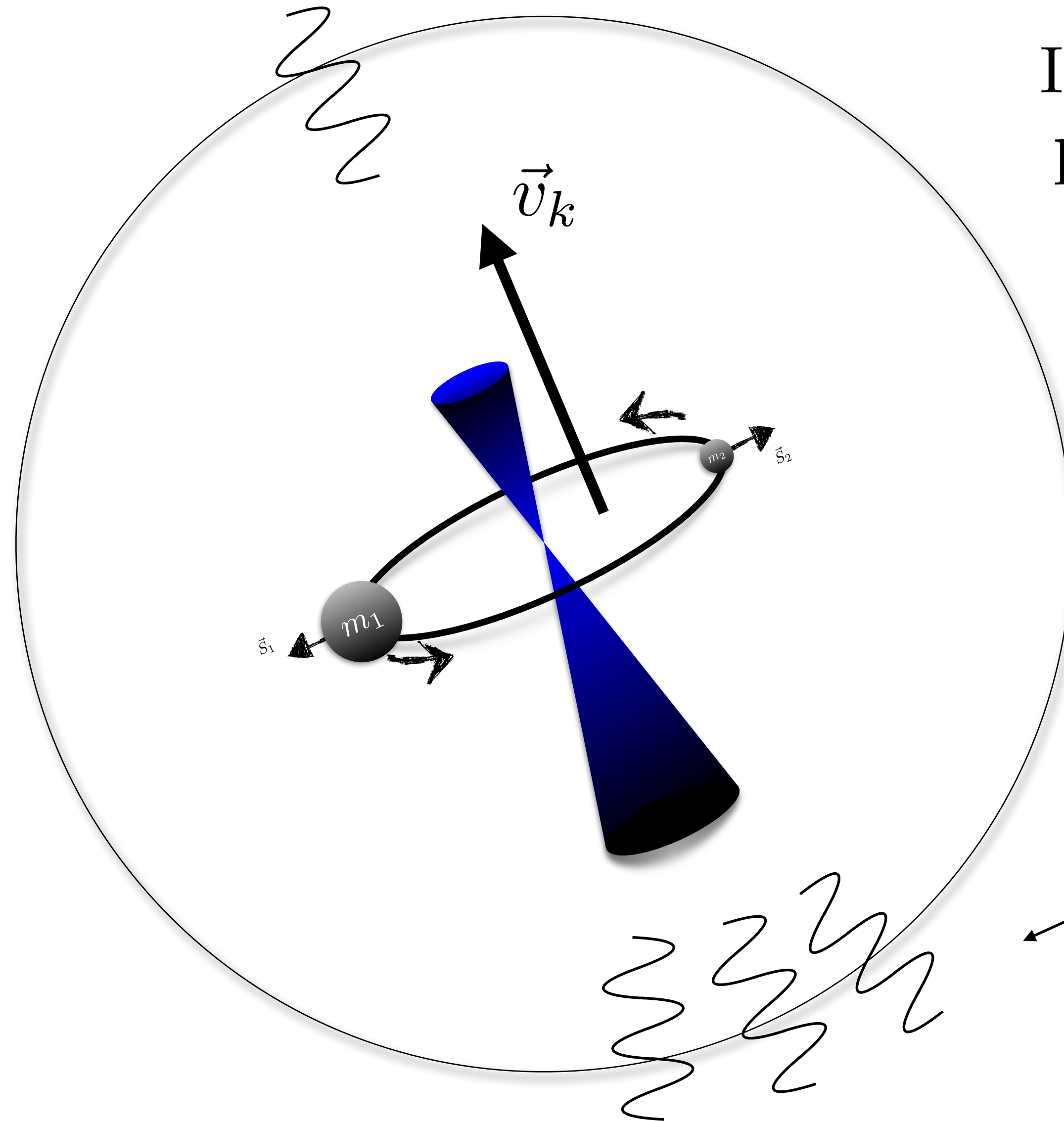
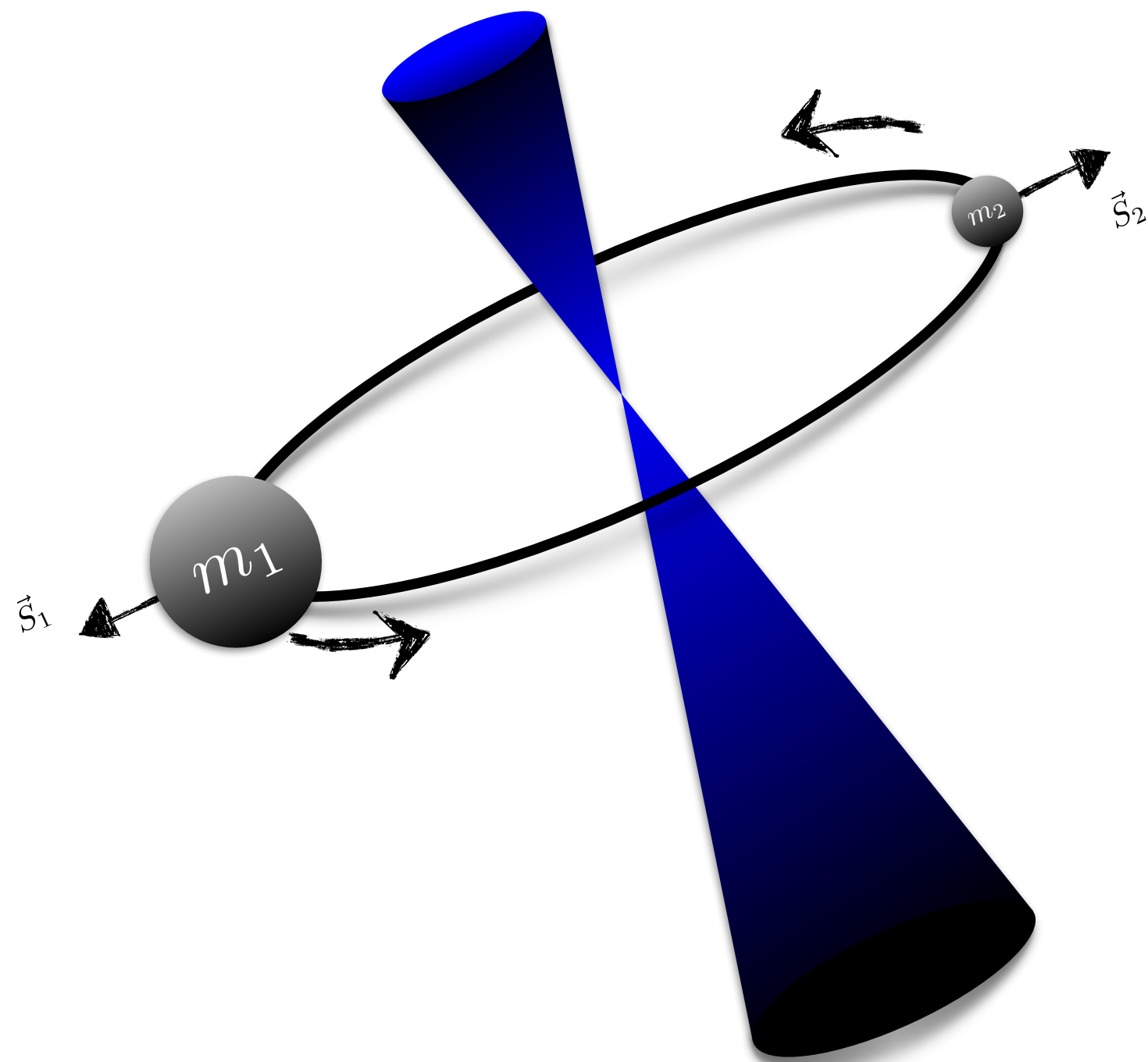
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Net linear momentum flux at infinity

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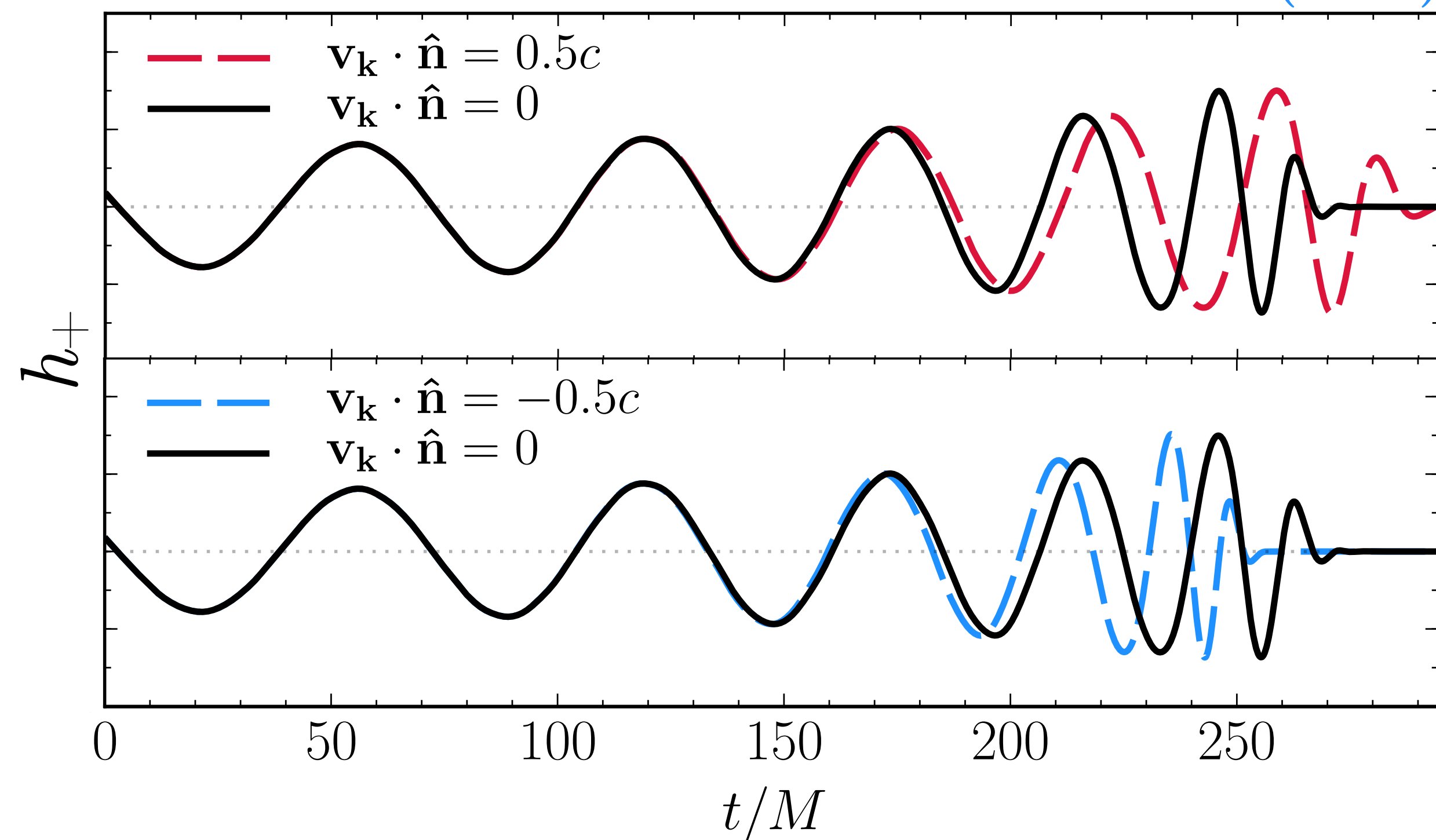
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Gerosa and Moore (2016)



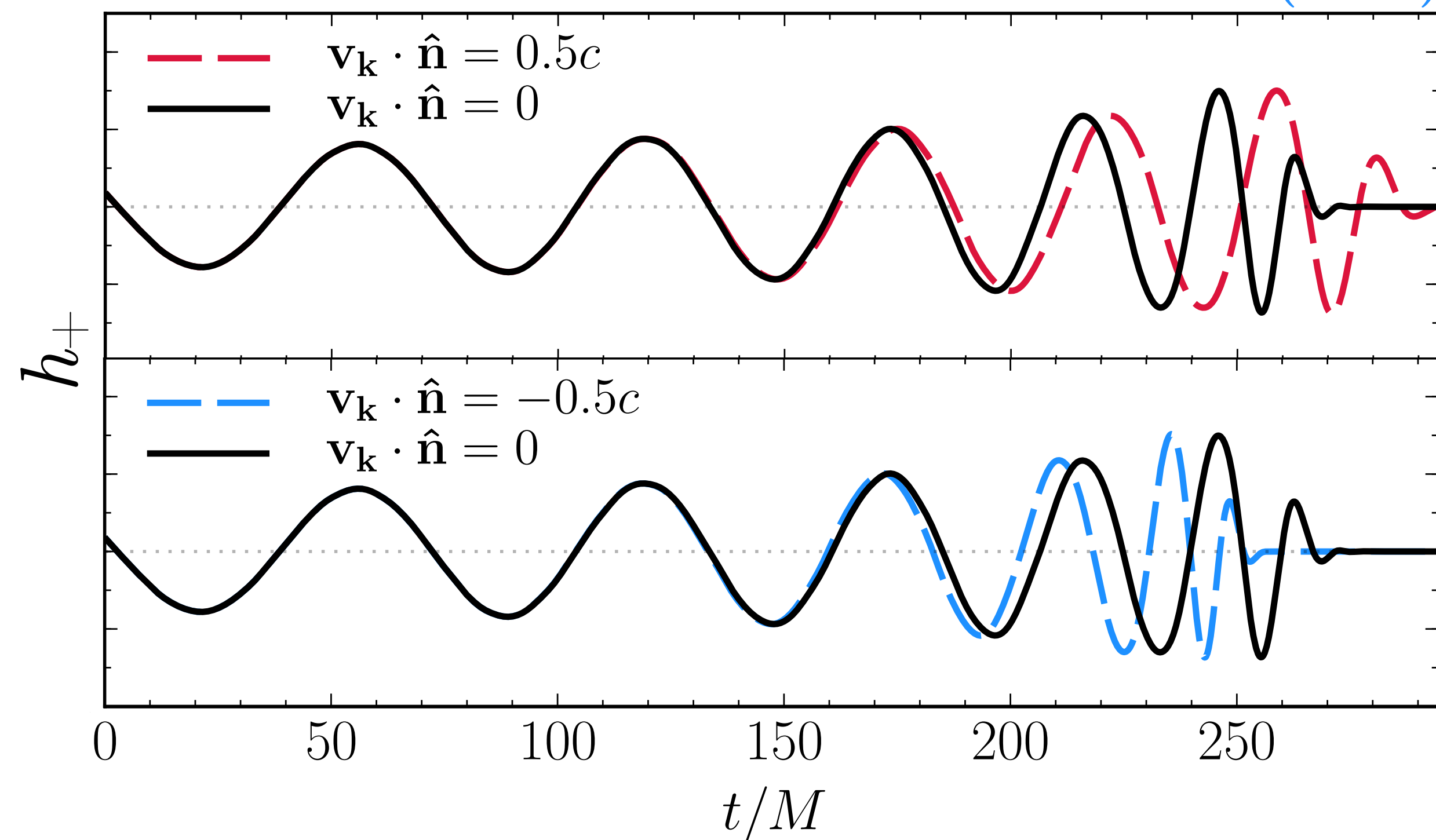
moving away from earth
red-shifted waveform

moving toward earth
blue-shifted waveform

Warning:
unphysical kick

NR simulations imply:
kicks imparted
over $\sigma \sim 10M$
and gaussian!

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moving away from earth
red-shifted waveform

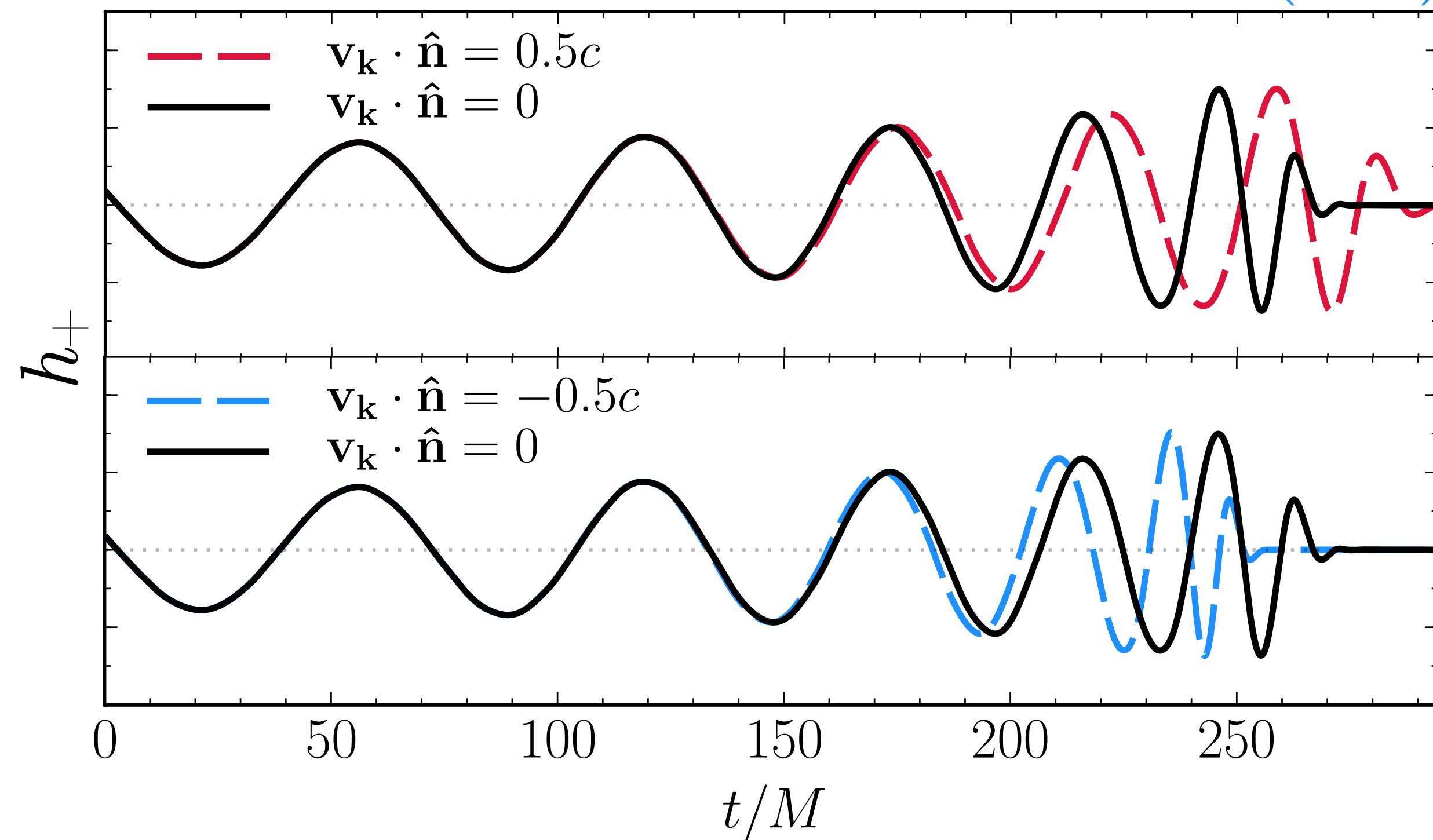
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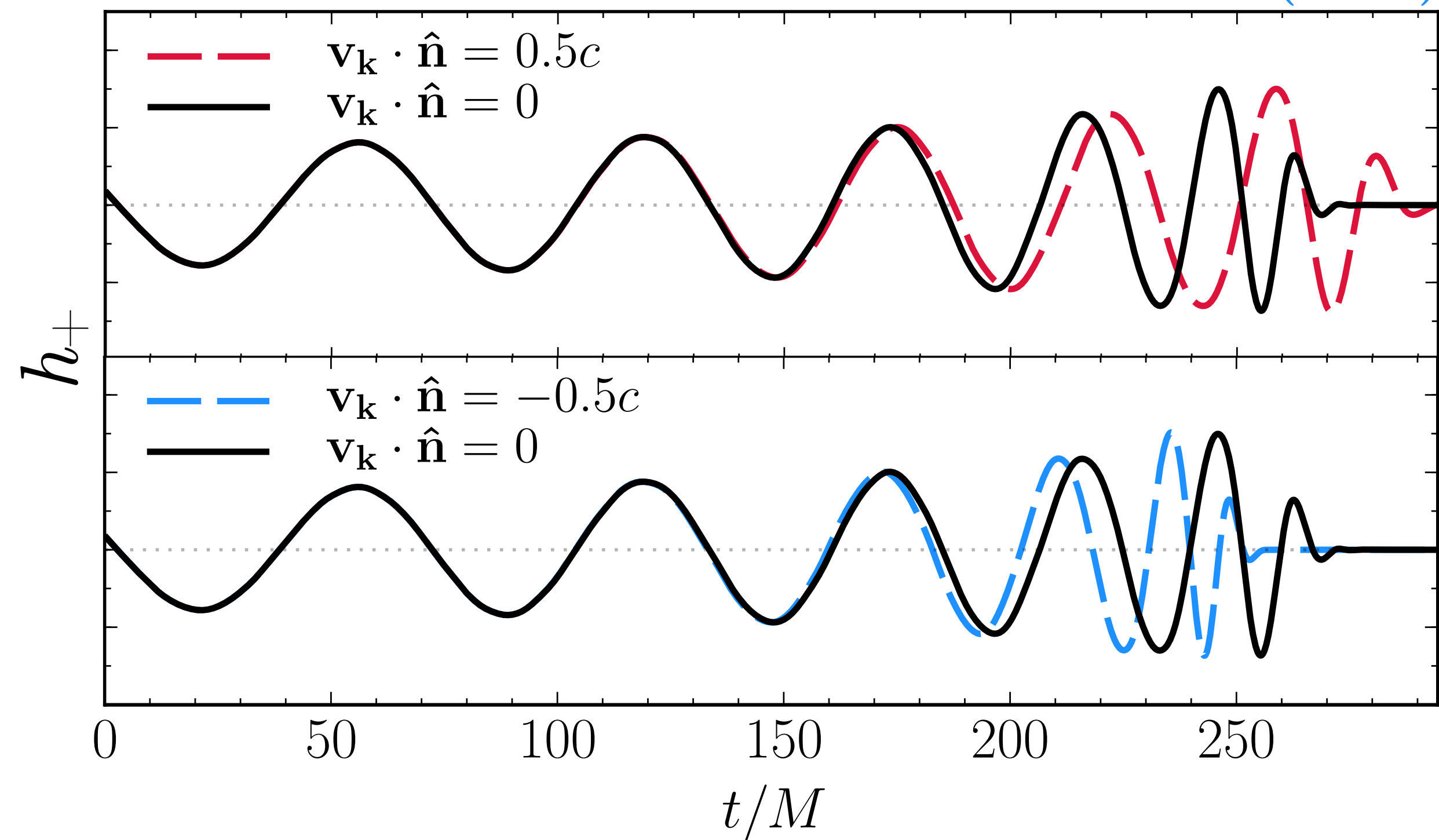
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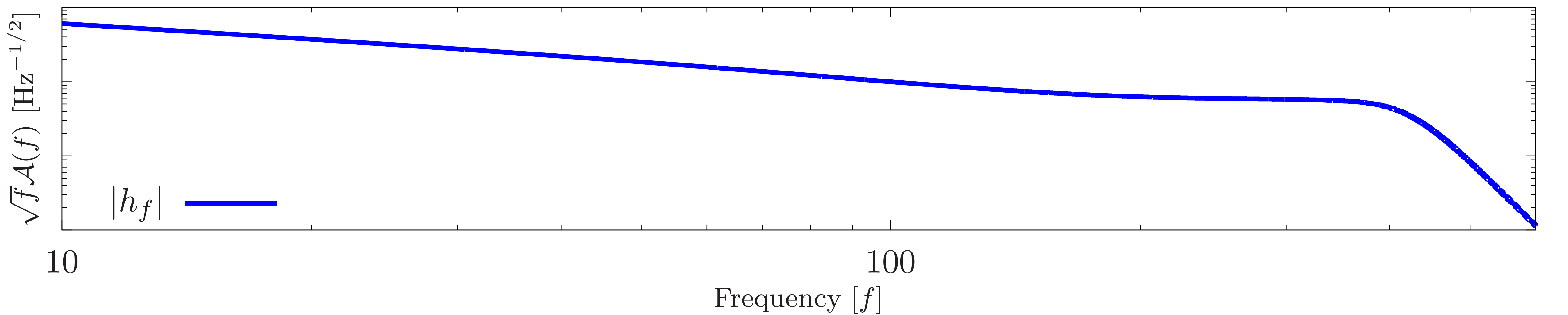
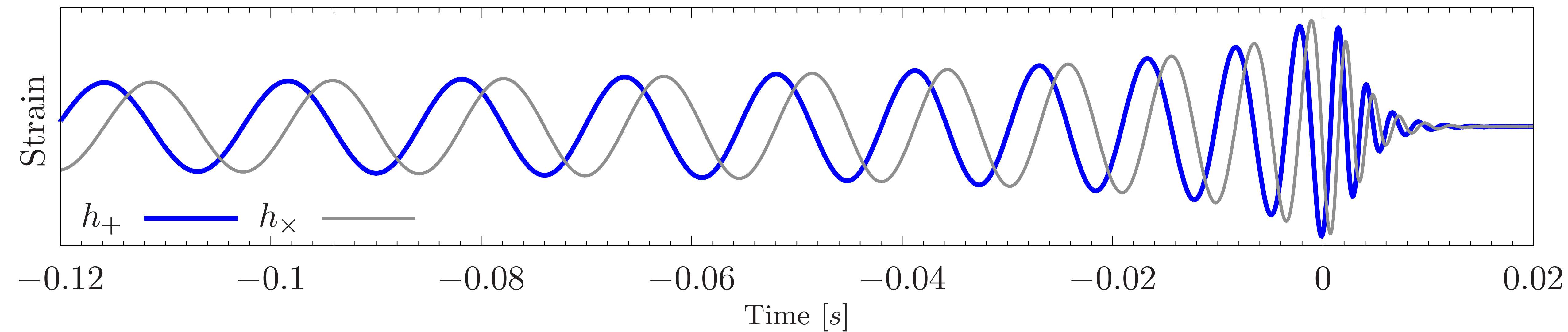
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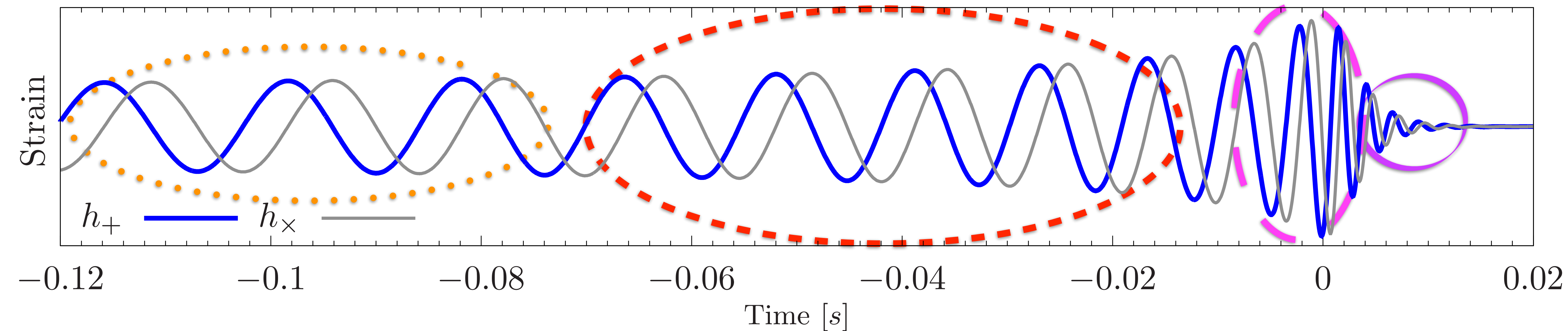
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$$m \rightarrow m' \equiv m(1 + v(f))$$

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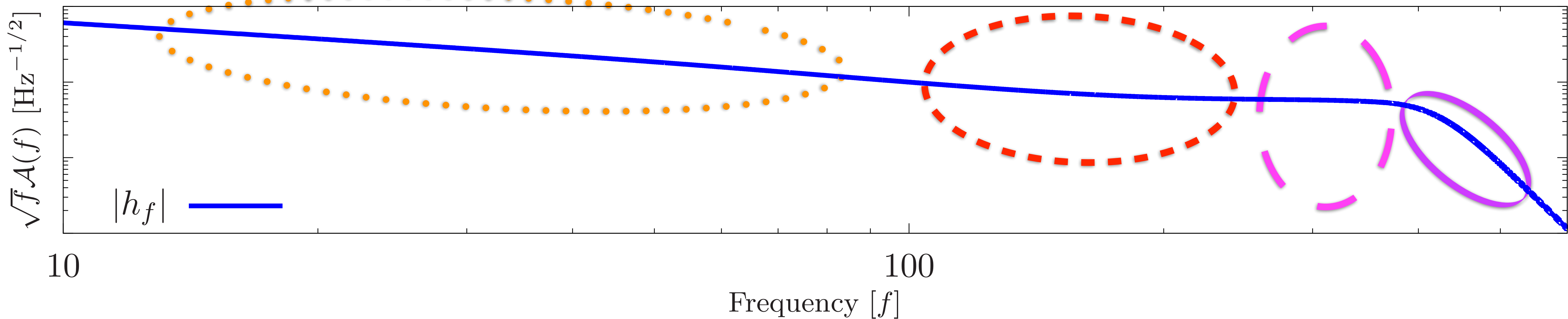


Inspiral

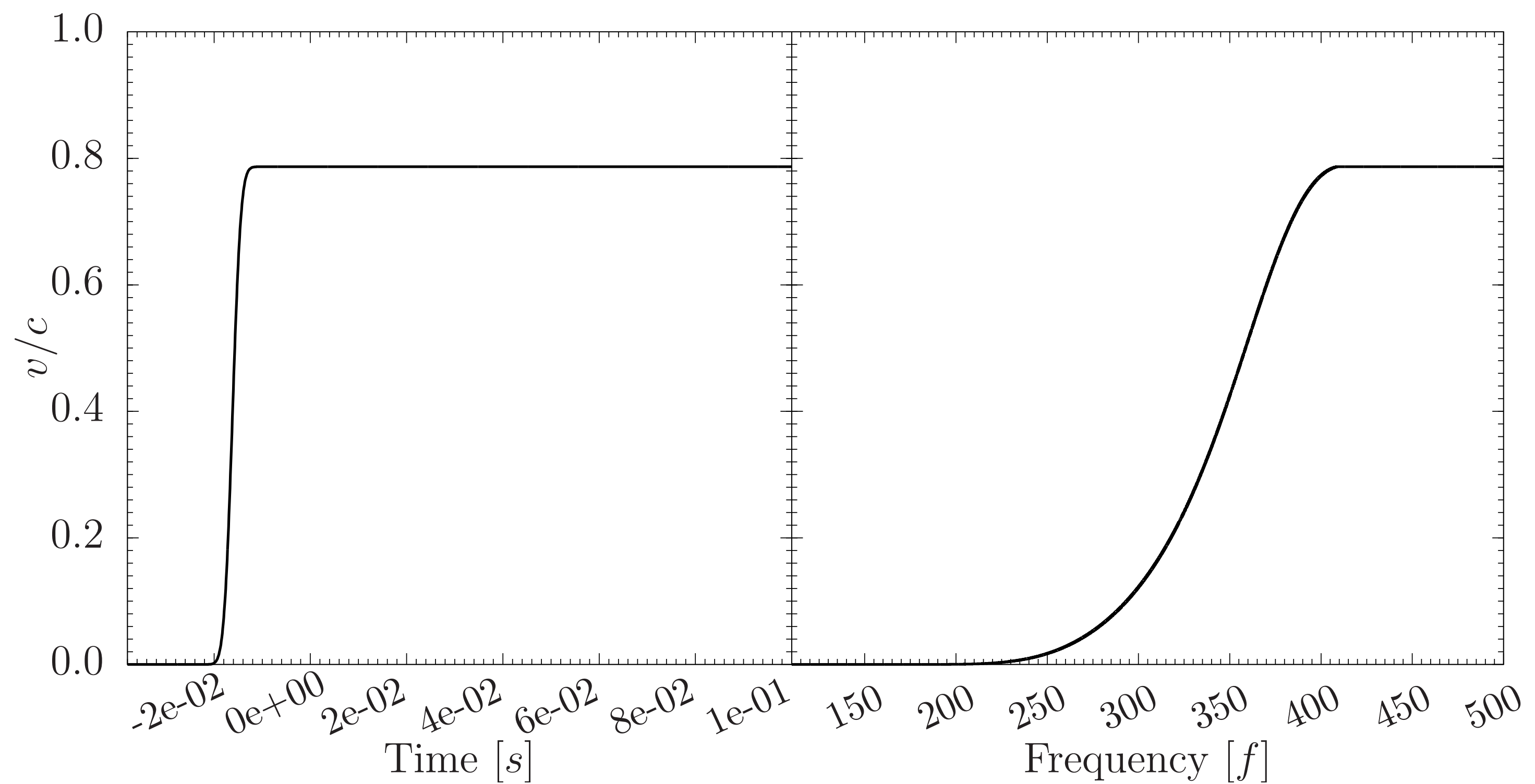
Intermediate

Merger

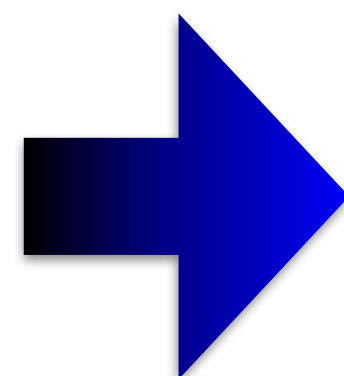
Ringdown



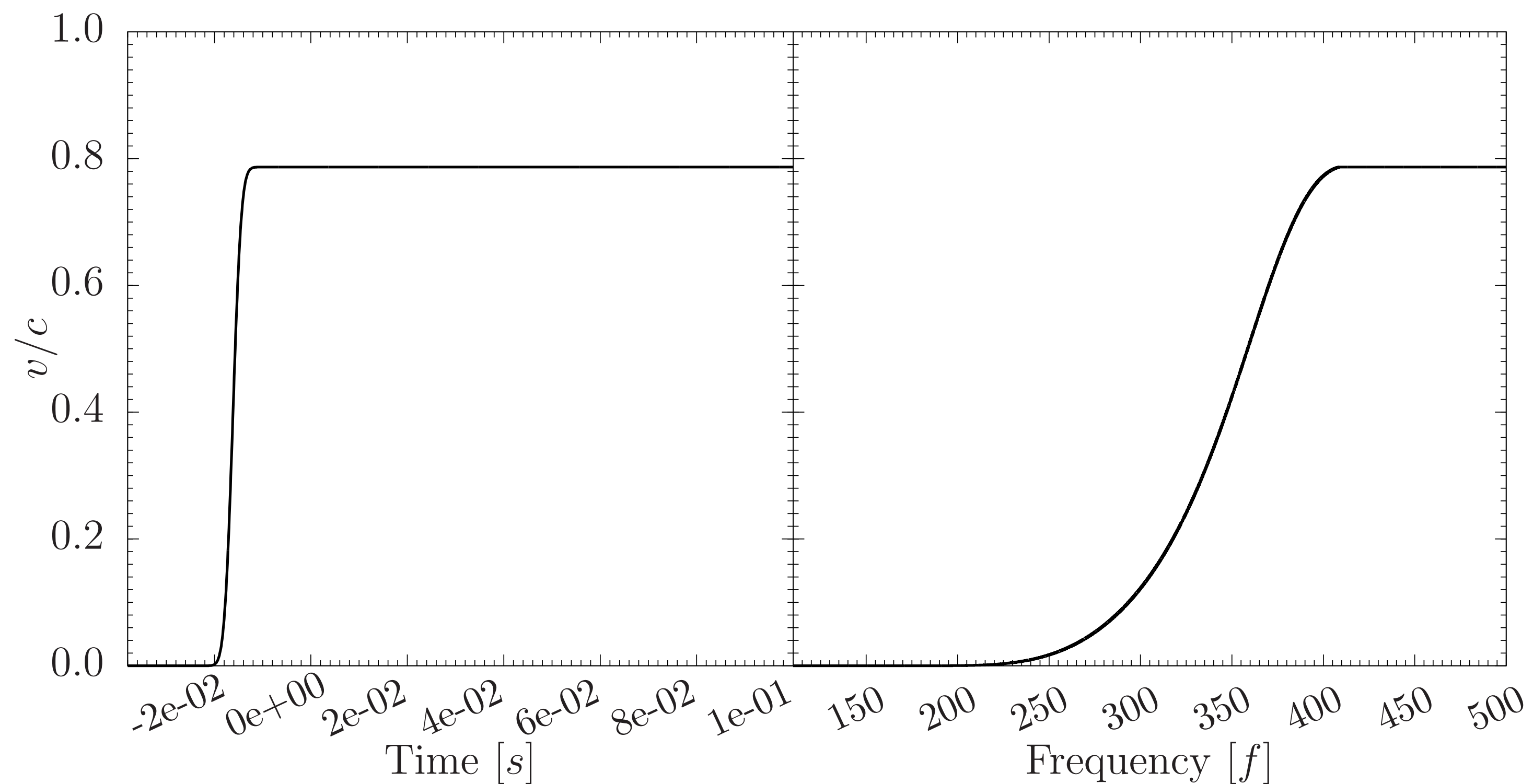
Calculate
 $v(t)$



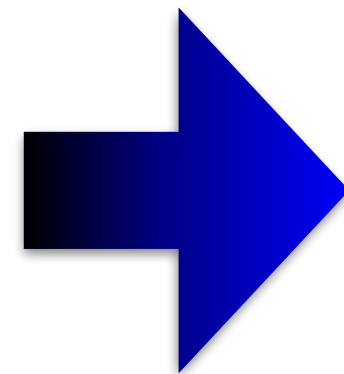
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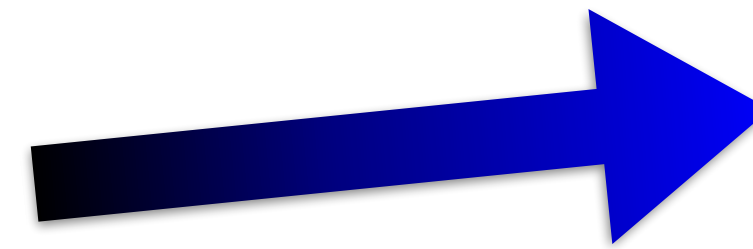
Find
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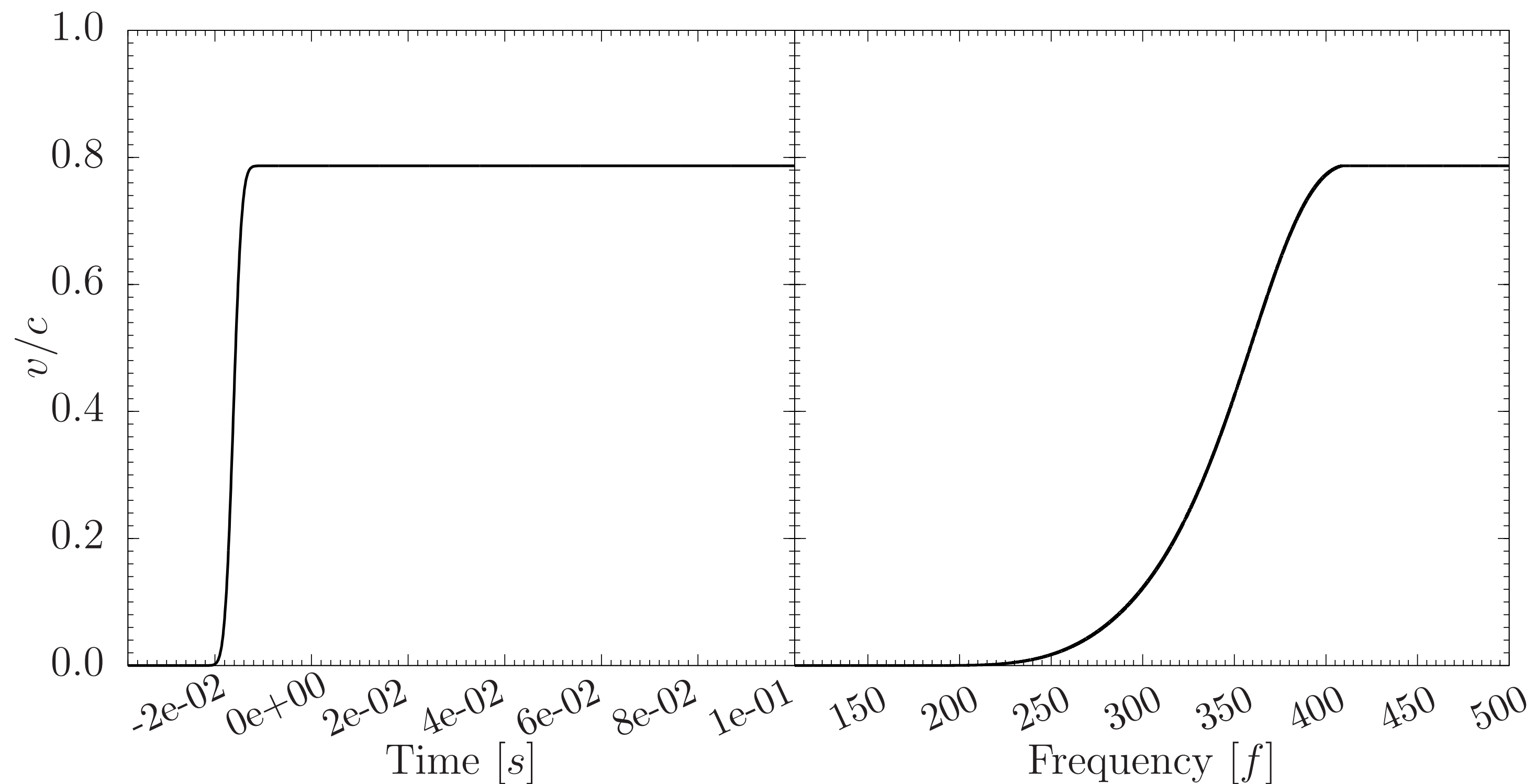
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In Time Domain:

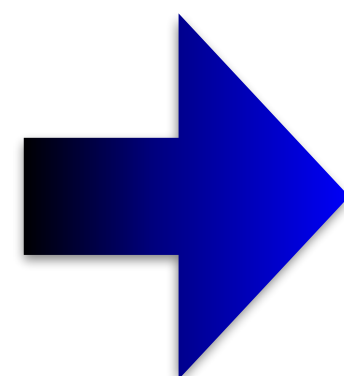
given $h(t) = A(t)e^{i\phi(t)}$

$$f(t) = \frac{1}{2\pi} \frac{d\phi(t)}{dt}$$

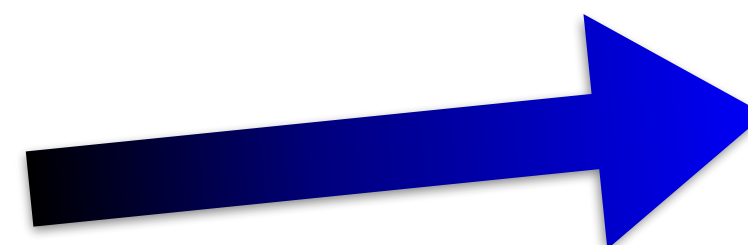


How Do We Find $v(f)$?

Calculate
 $v(t)$



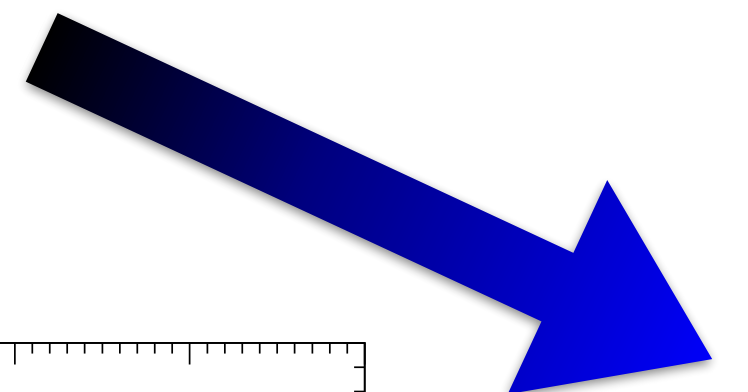
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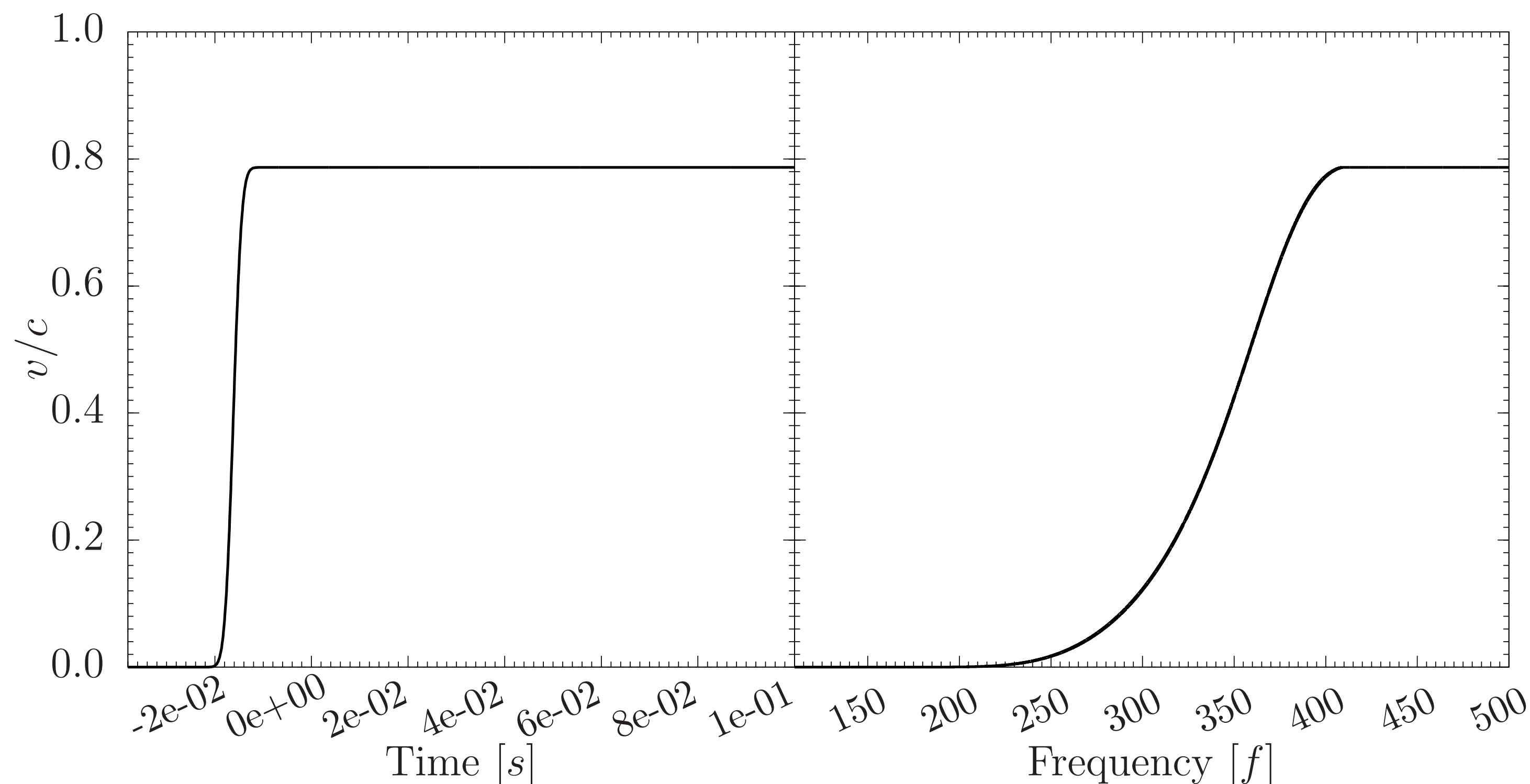


In Frequency Domain:

given $\tilde{h}(f) = \mathcal{A}(f)e^{i\psi(f)}$

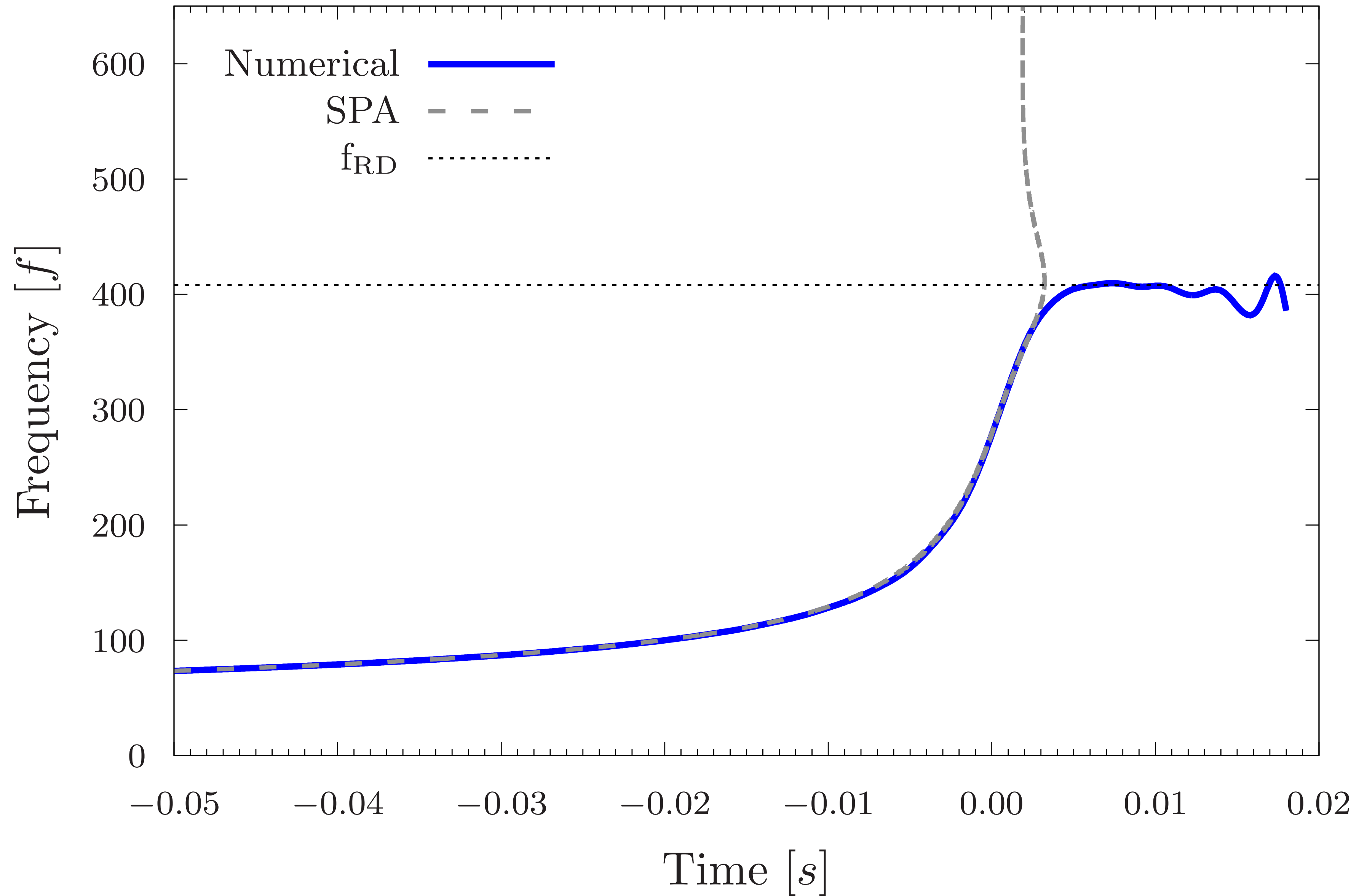
use SPA

$$t(f) = \frac{1}{2\pi} \frac{d\psi(f)}{df}$$





Comparing Numerics and Phenomenology





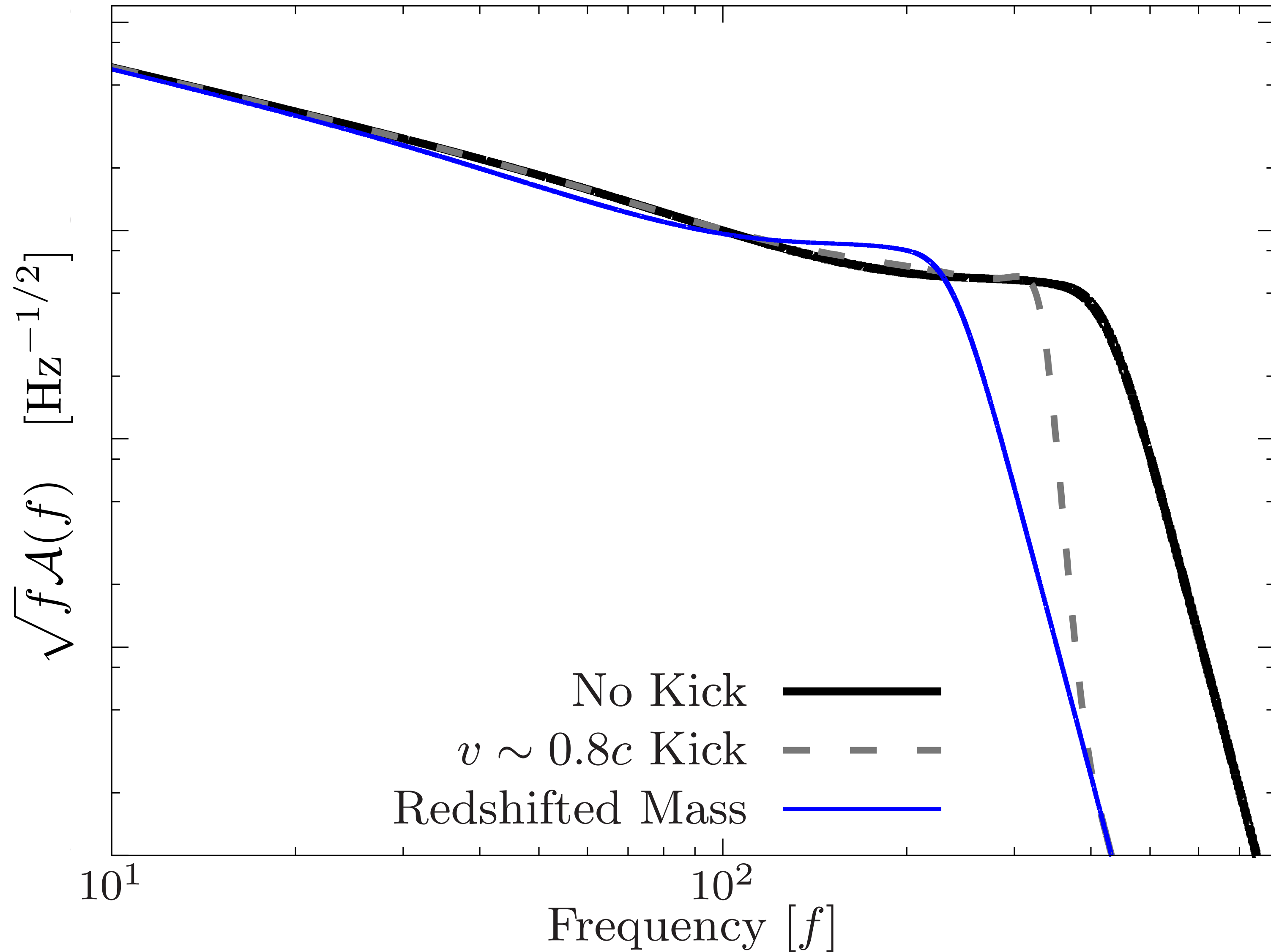
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- Determine how we can address degeneracies that arise from the presence of kicks in the waveform
- Use our kicked waveform approximant to determine constraints that can be placed on kick velocities
- Understand how 3rd generation detectors can aid in black hole kick detection
- Modify IMRPhenomP to include black hole kicks