On black hole spectroscopy using Binary black hole ringdown

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This is a work done in collaboration with Xisco Jimenez Forteza,
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On the Ringdown overtones, black hole spectroscopy, no-hair theorem tests

Ringdown Waveform

$$h = \Sigma_{lmn} A_{lmn} e^{-\iota \omega_{lmn} t} e^{-t/\tau_{lmn}} \mathcal{Y}_{lm}$$

Overtones

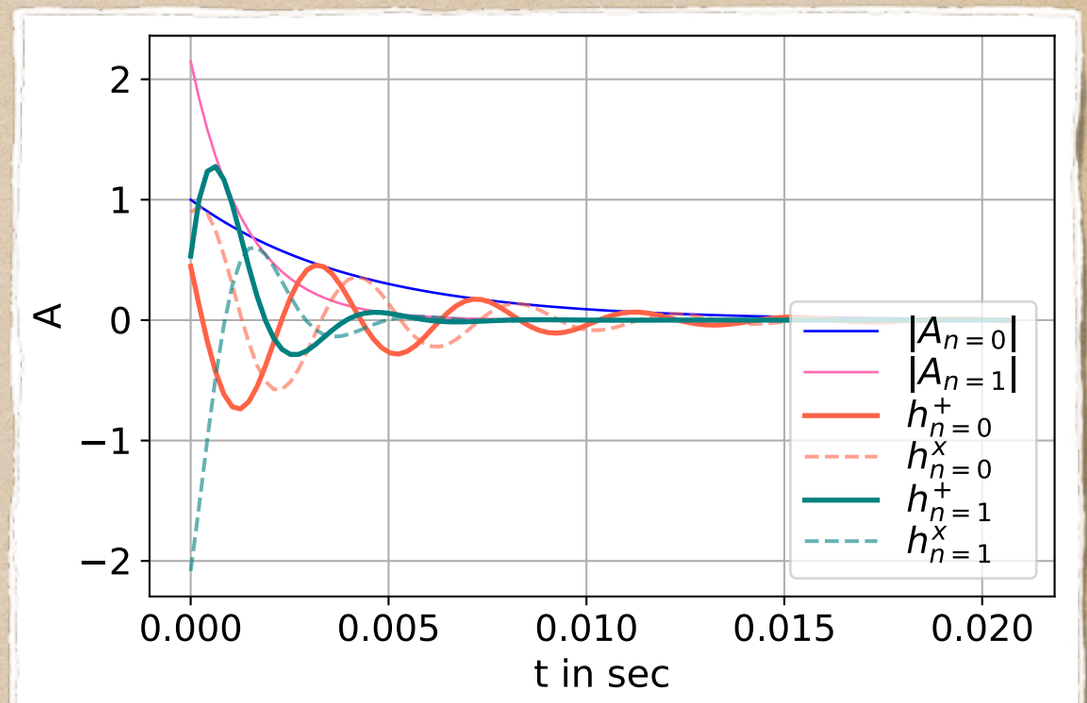
Angular modes

The Quasi-normal-mode spectrum:
unique to the mass and spin of the BH

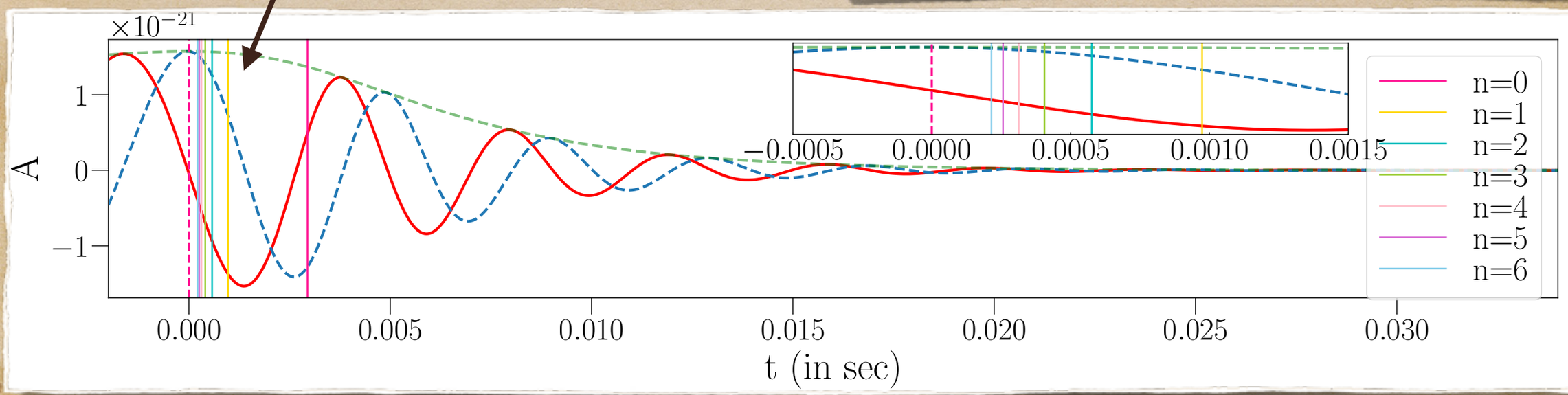
Overtones have been know to be important in RD modeling for a long time but they have only recently been considered for BH spectroscopy

The troubles with modeling RD with overtones

1. Do the overtones really start simultaneously?
2. Are we sure that we can calibrate the amplitudes?



Half life of overtones are very short



Amplitude for overtones

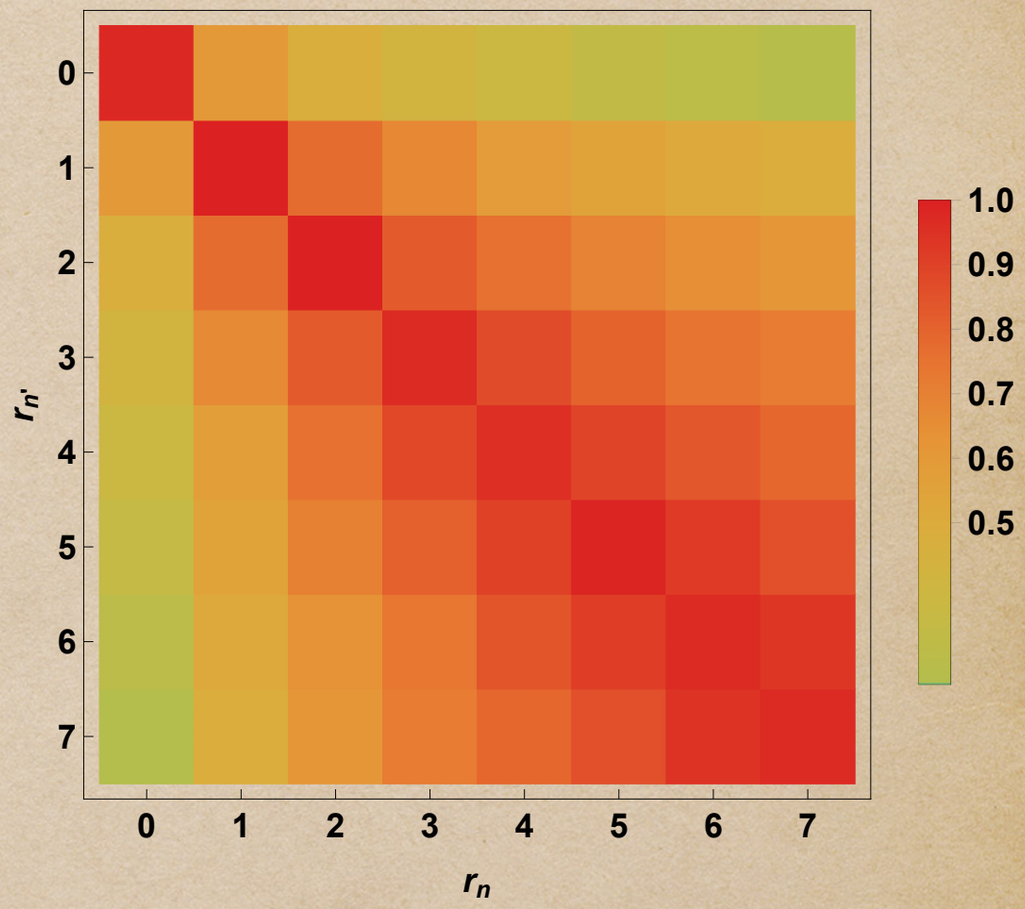
Amplitude ratio between n=0 and n=1 tone as a function of mass ratio q when fit from the peak of the waveform

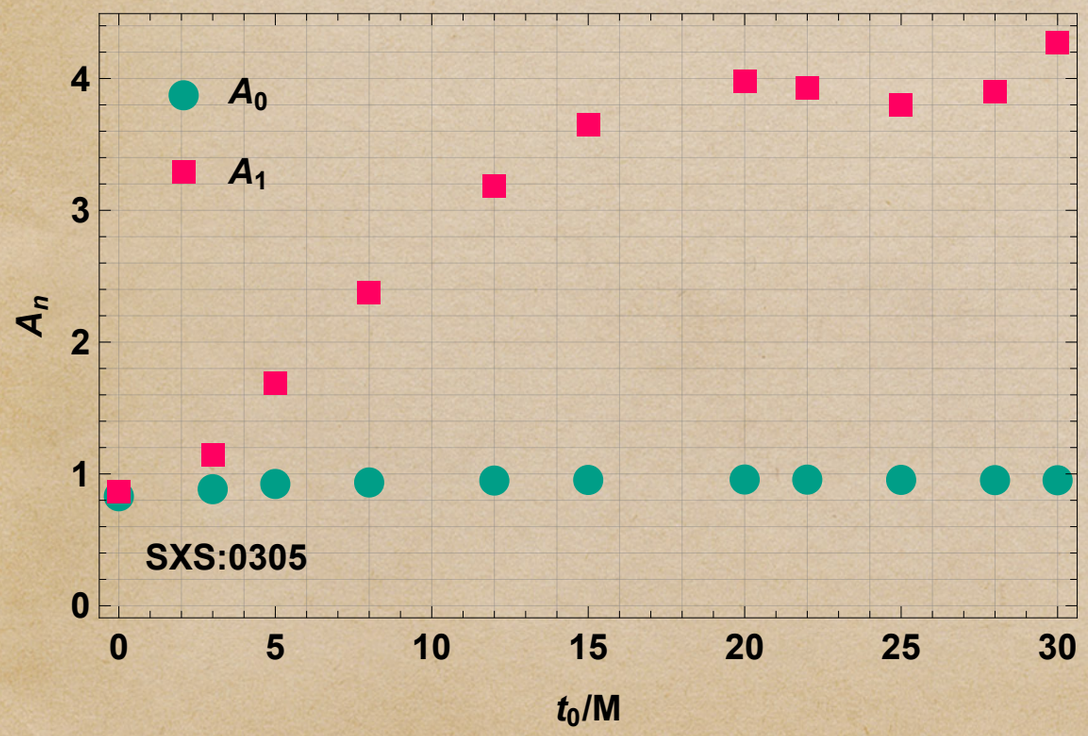
Our fit values matches that presented in Matt et al. for a q=1.2 system (for first 7 tones)

	SXS:0305	
n	A_n	ϕ_n
0	0.978518	-2.11289
1	4.29435	1.38519
2	11.6503	0.128732
3	23.6475	2.24624
4	34.0133	-0.0202084
5	30.4153	0.963395
6	14.8093	-0.797055
7	3.03776	-2.64276

Although reproducible the amplitudes don't look stable!

Fit amplitude correlation for 7-tone RD

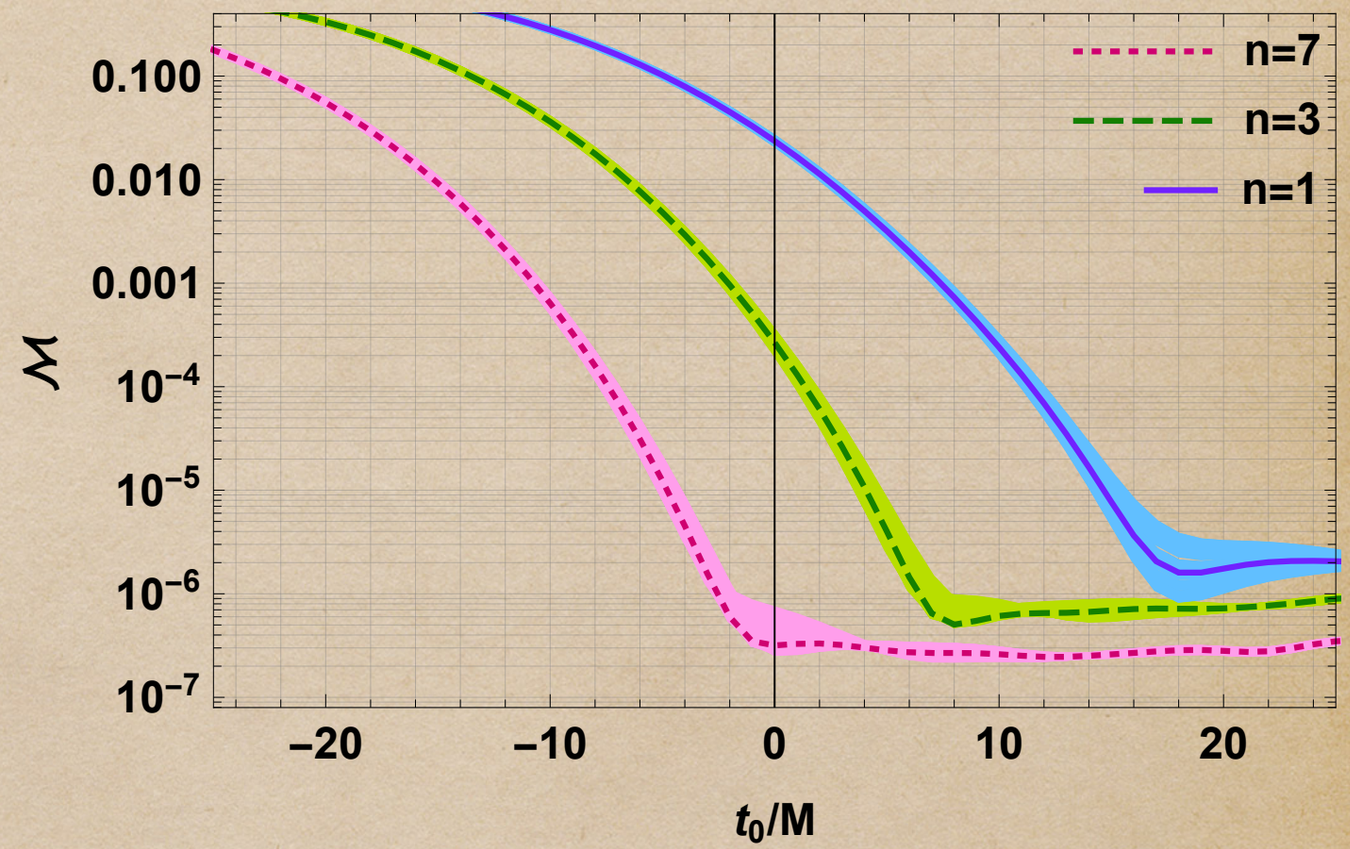




Instability with respect to start time of the fit for a 2-tone RD

Do we really need QNMs to reproduce these fits?

No, so long as we have the frequency of n=0 mode, we can model RD accurately with up to 2% error in the tone's frequency

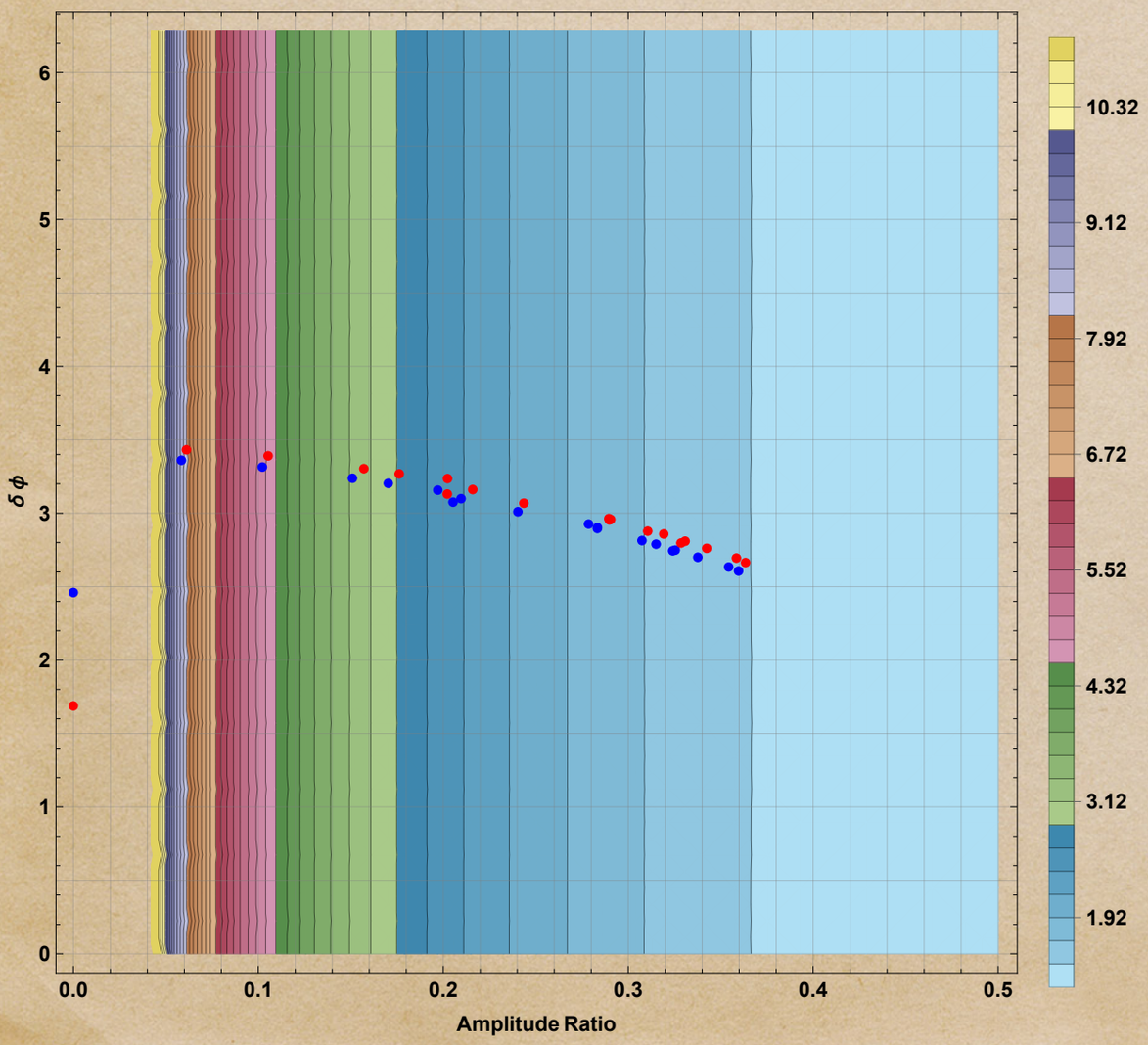


2% error in frequencies is comparable to the frequency separation between the frequency of the subdominant tone and the dominant mode

Modes versus tones for resolvability

Using Rayleigh resolvability condition

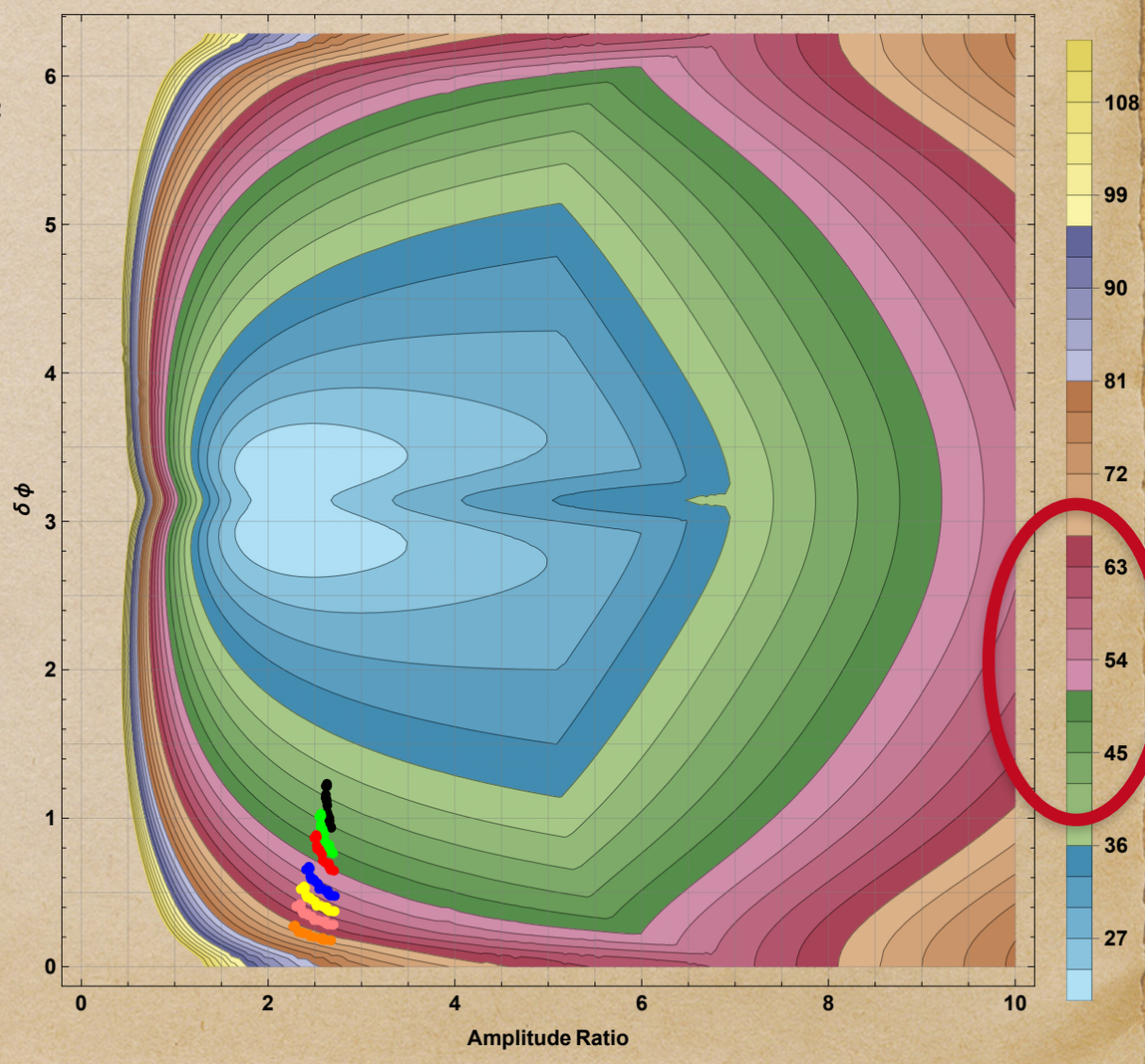
Modes for start time of 10 M and 15 M



Tones for start time of

{ 0, 3, 5, 8, 10,12 ,15}M -

(black to orange)



Conclusion

- Overtones are valuable to perform spectroscopy especially for near equal mass BBH systems.
- However, both the analysis and interpretation of BBH RD spectroscopy using overtones should be done very carefully.
- Overtones need about an order of magnitude higher SNR to allow for resolvability of frequencies compared to angular modes.
- We are currently investigating a detailed comparison on modes versus overtones for different parameter space of BBH systems.