LIGO-T2100196

Optimal Settings for Fast Low-Latency Skymaps of Neutron Star Binaries

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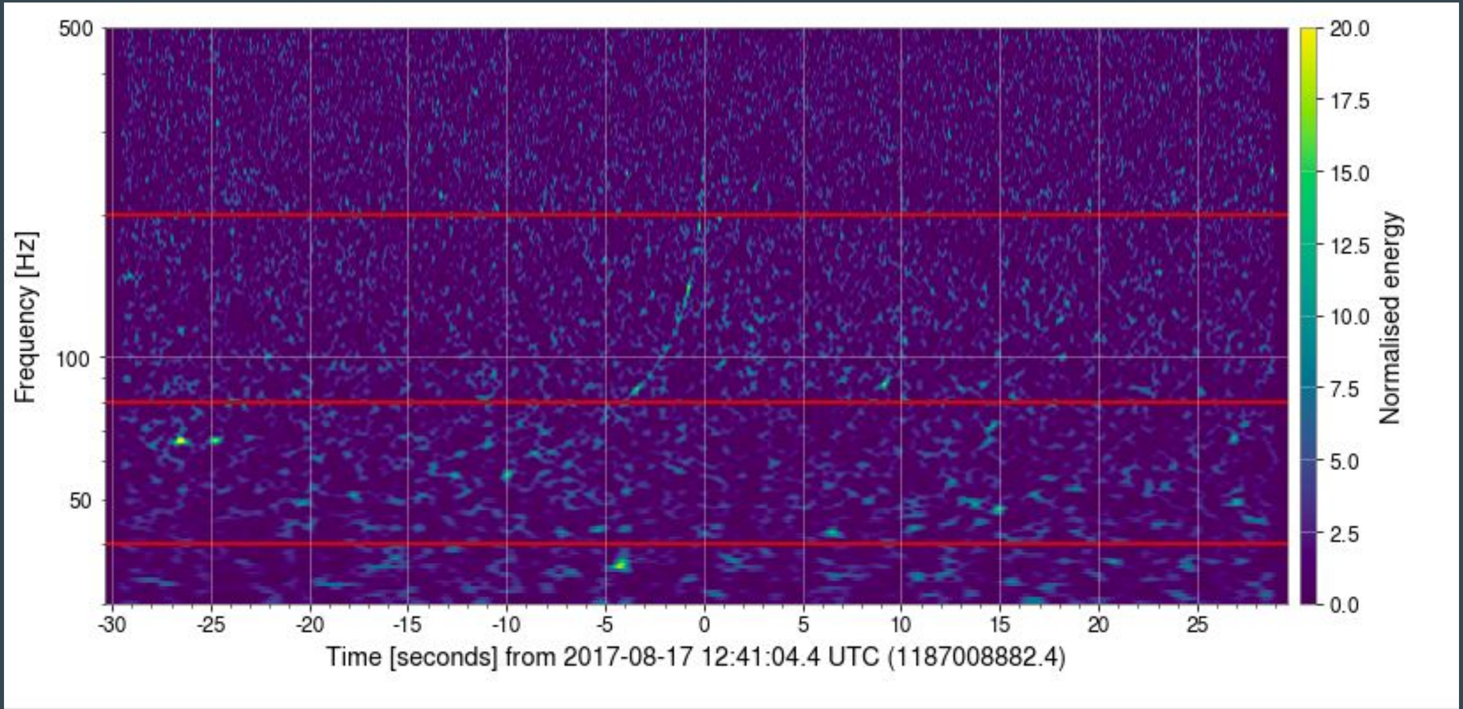
Motivations and Methods

What? Determine the best settings for prompt and reliable skymap estimation

Why? Improve localization of signal sources by returning information ASAP

How? Parameter estimation, Bayesian inference, sampling, BILBY

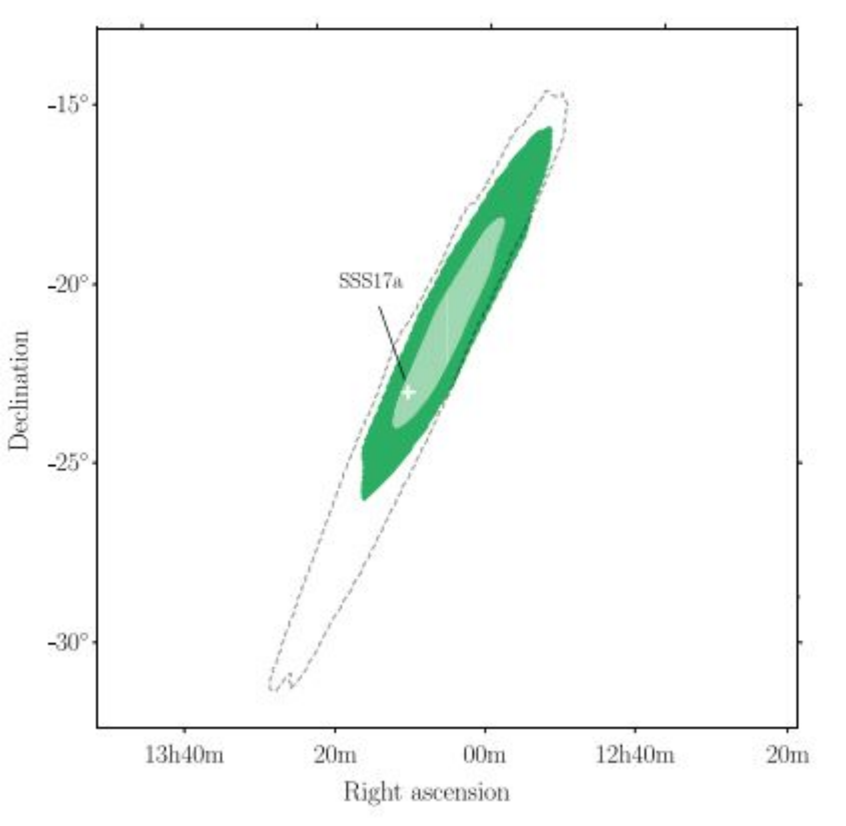
Signal track of GW170817



Settings:

1. Segment length
2. Sampling rate

Localization of GW170817



B. Abbott et al., Properties of the binary neutron star merger GW170817, (2019), arXiv:1805.11579

Parameters

Intrinsic:

- Mass
  - Chirp mass: $$\mathcal{M} = \frac{(m_1 m_2)^{3/5}}{(m_1 + m_2)^{1/5}}.$$
  - Mass ratio: $q = m_2/m_1 \leqslant 1$
- Spin (magnitudes and angles)
- Tidal deformability (BNS)

Extrinsic:

- Inclination and polarization angles
- Phase
- Time
- Distance
- Right ascension (longitude)
- Declination (latitude)

BILBY

Bayesian inference

Given the **likelihood**, **prior**, and **evidence**, we want to find the **posterior probability distribution**.

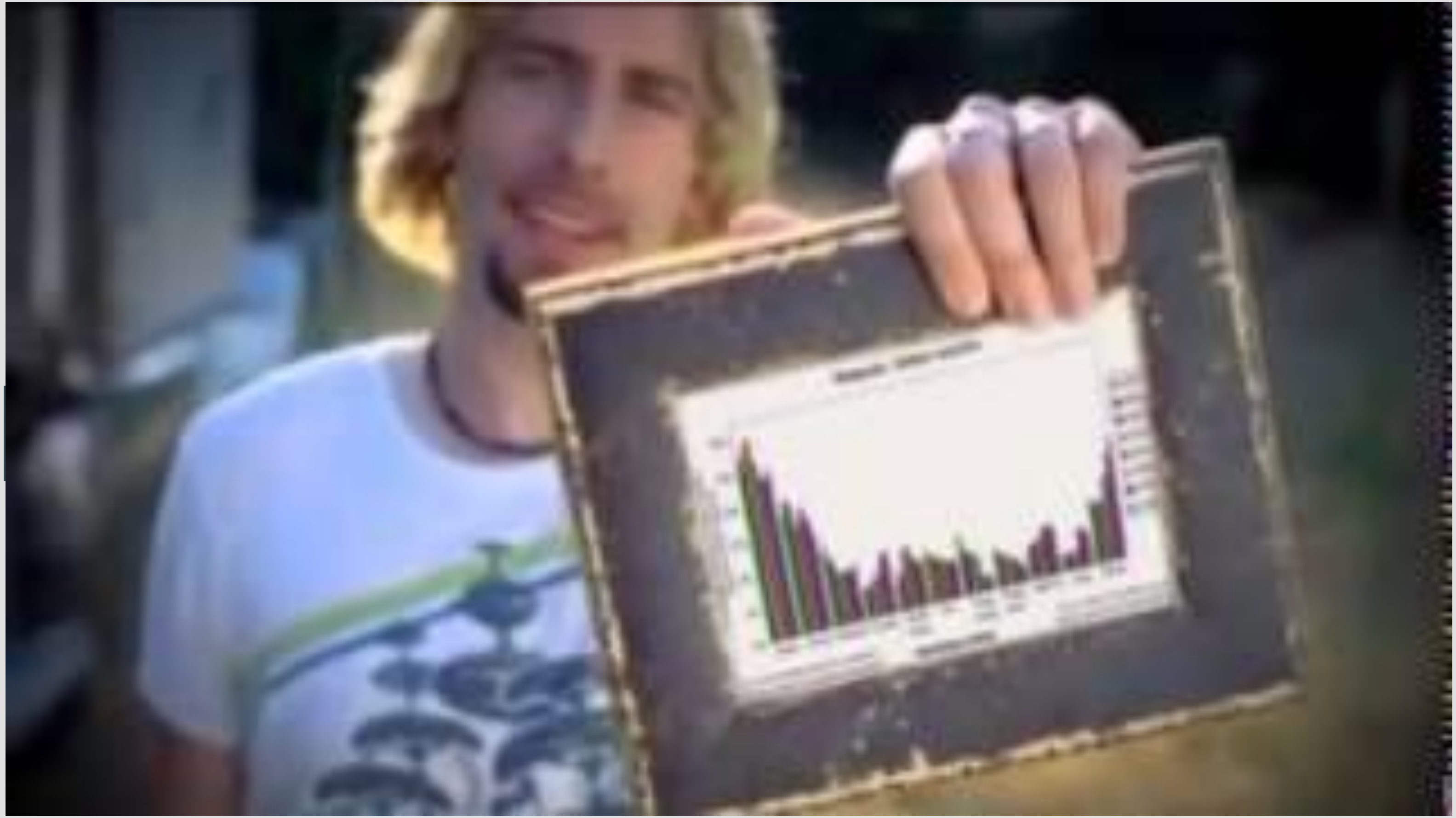
$$p(\theta|d) = \frac{\mathcal{L}(d|\theta)\pi(\theta)}{\mathcal{Z}}$$

likelihood, prior, posterior, evidence

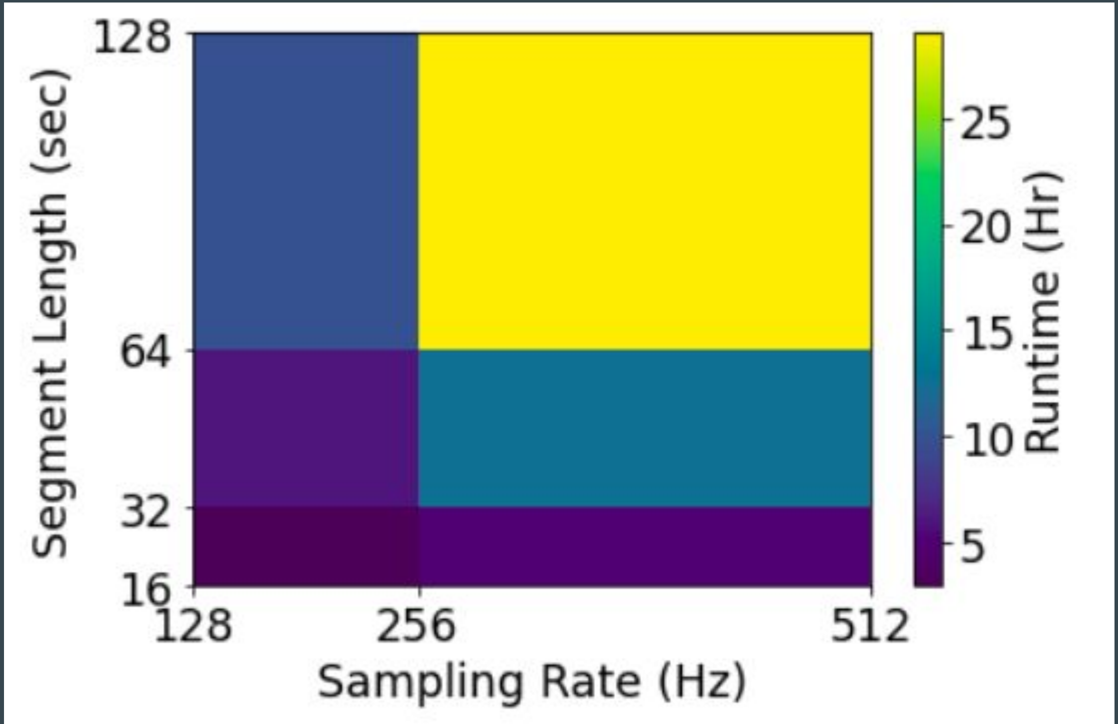
where θ=parameters, d=data

Stochastic Sampling

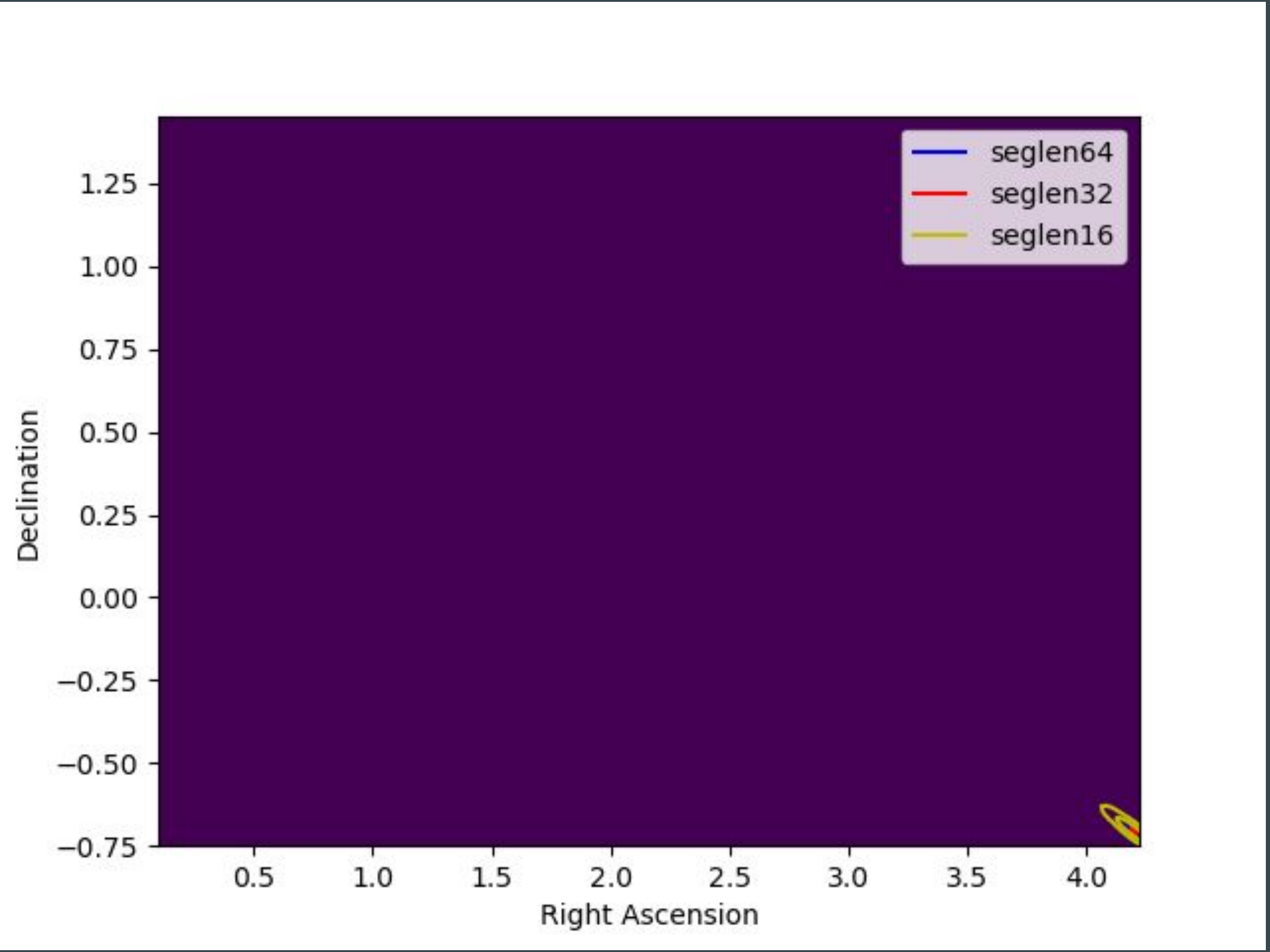
- Two types: Monte Carlo Markov Chain (MCMC) and nested sampling
- MCMC
  - Random walk along posterior distribution
- Nested sampling
  - Live points drawn from prior distribution, lowest likelihood point removed each iteration
- Bilby’s default sampler, Dynesty, uses both of these



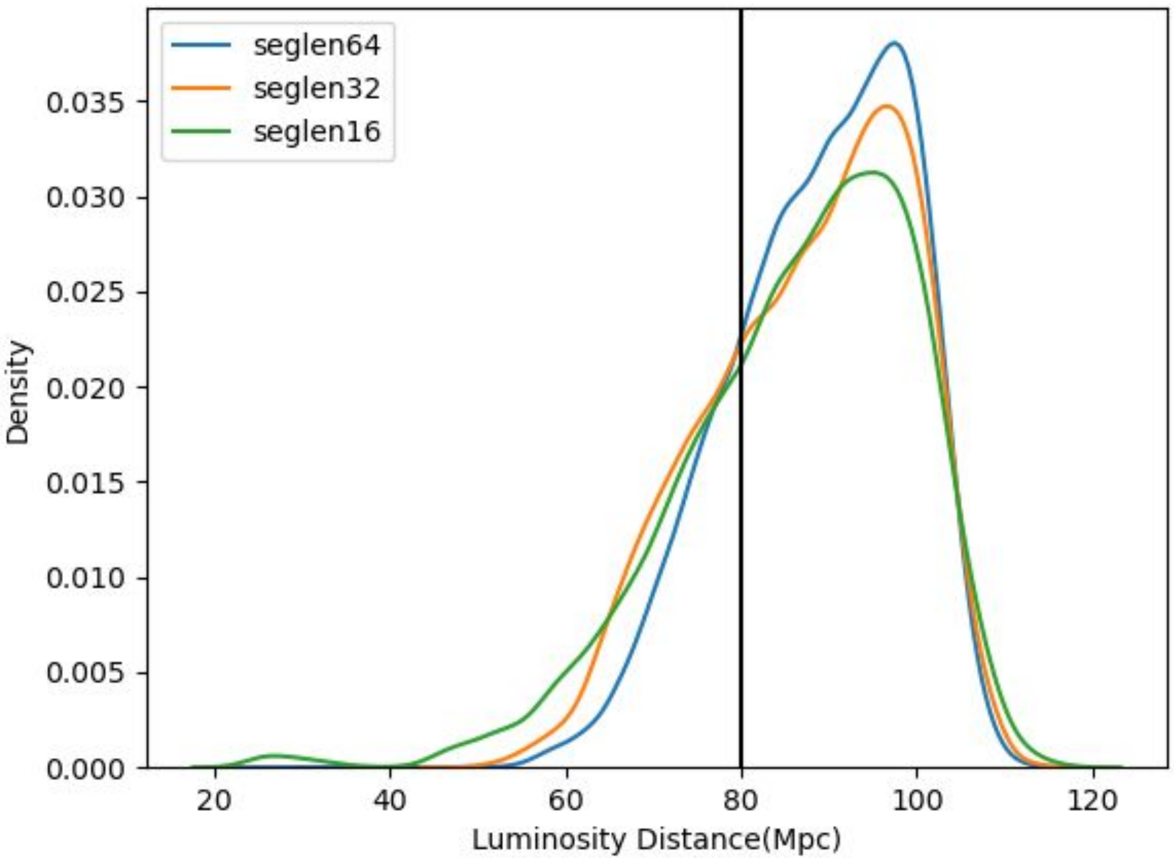
Optimal Settings for Runtime

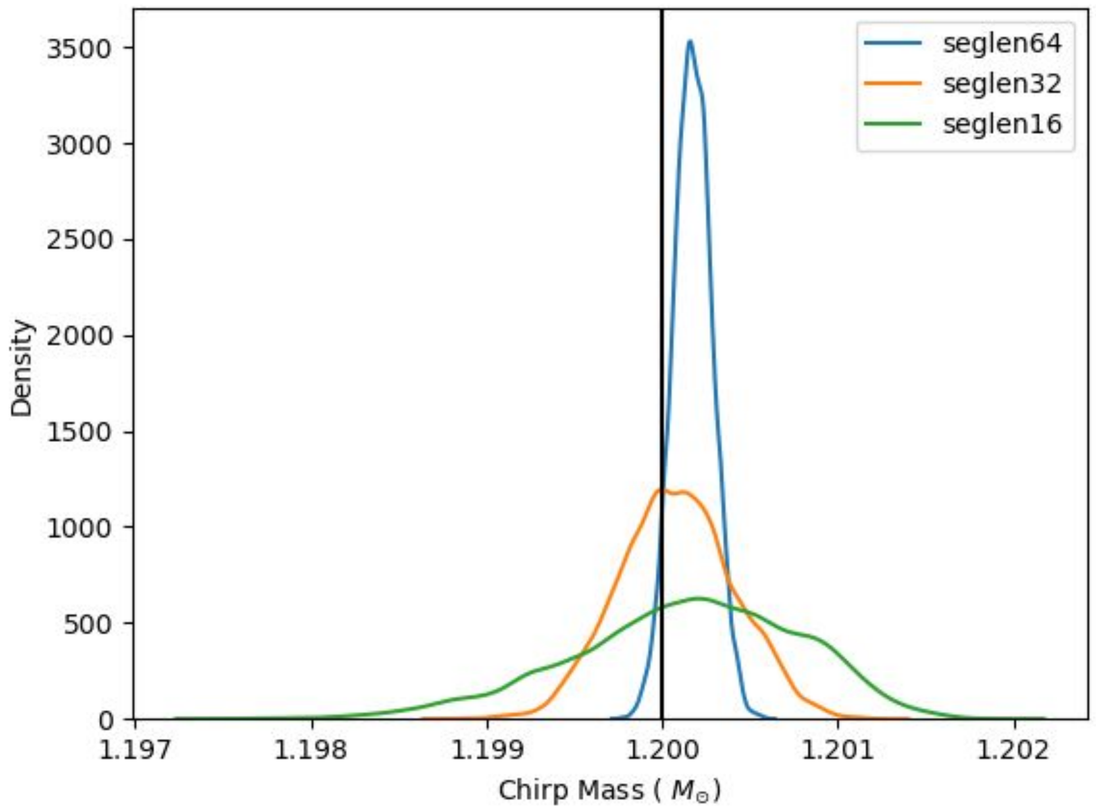


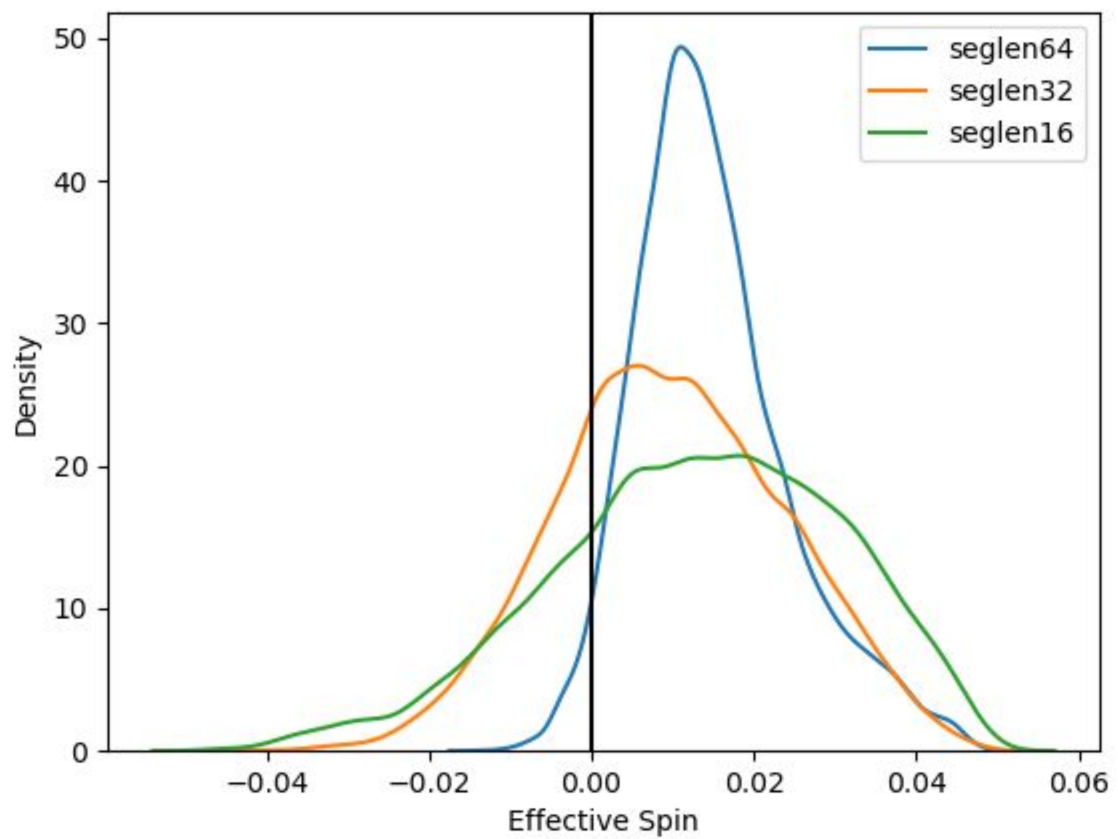
Srate=512 Hz



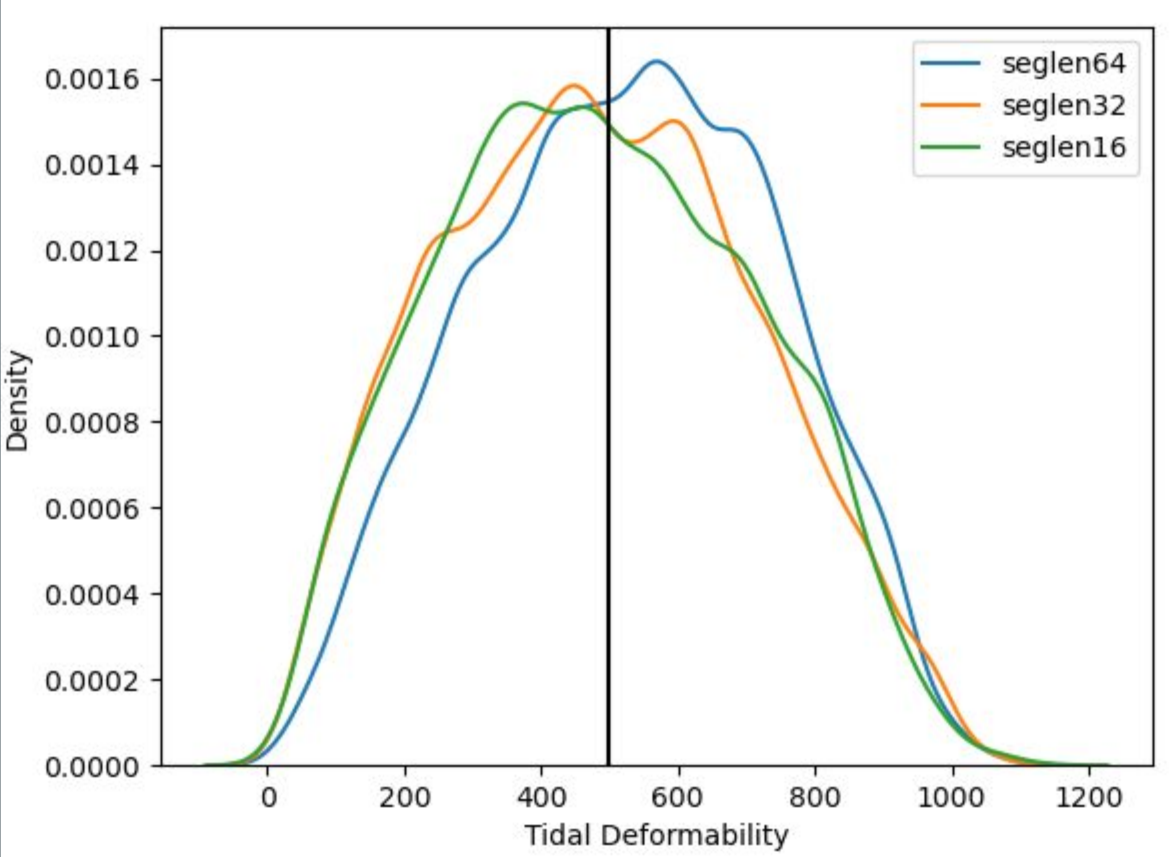
seglen64
seglen32
seglen16
1.25
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
Declination
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Right Ascension


seglen64
seglen32
seglen16
Density
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0.035
20
40
60
80
100
120
Luminosity Distance(Mpc)

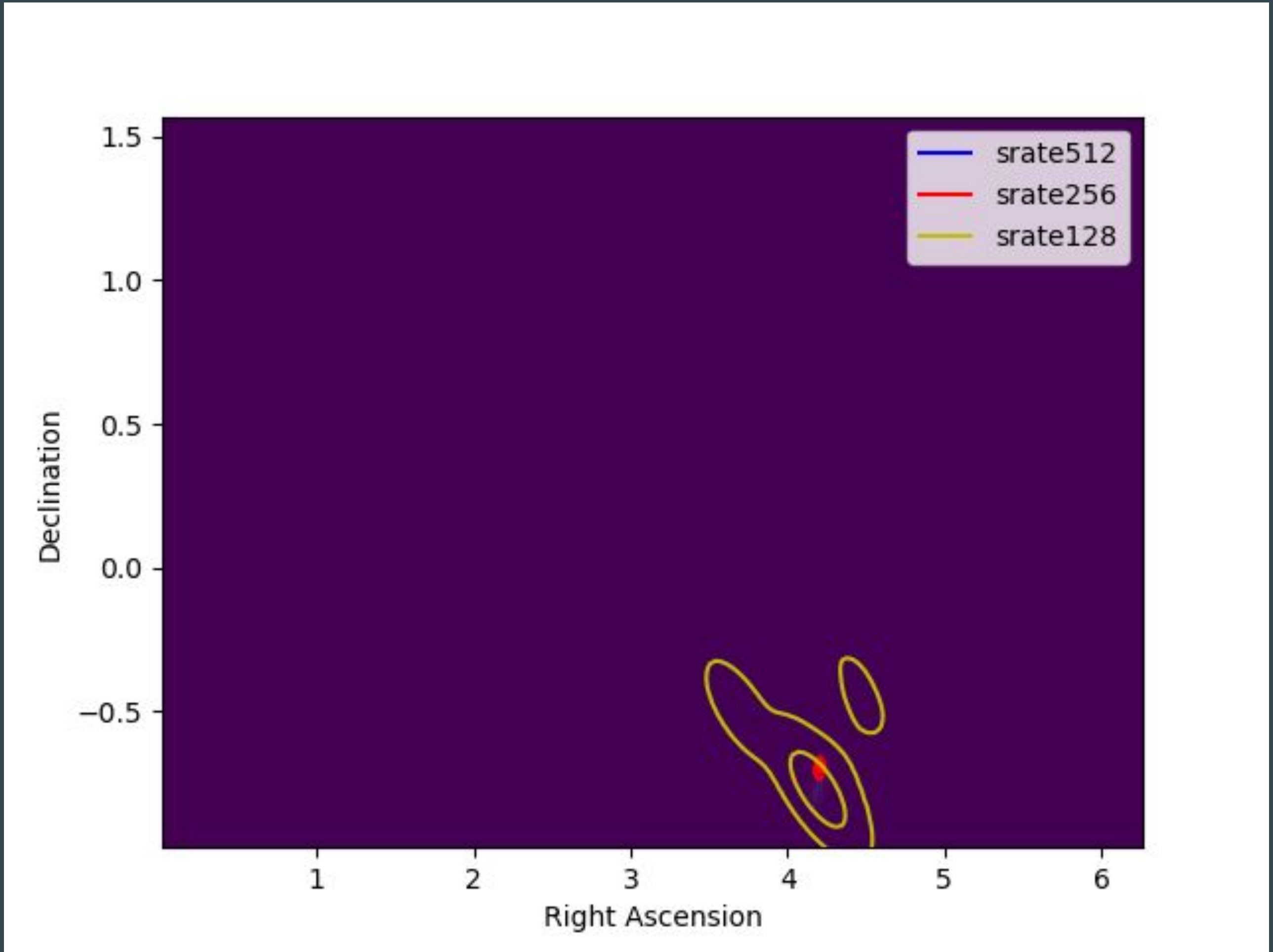

seglen64
seglen32
seglen16
Density
Chirp Mass ($M_\odot$)
0
500
1000
1500
2000
2500
3000
3500
1.197
1.198
1.199
1.200
1.201
1.202

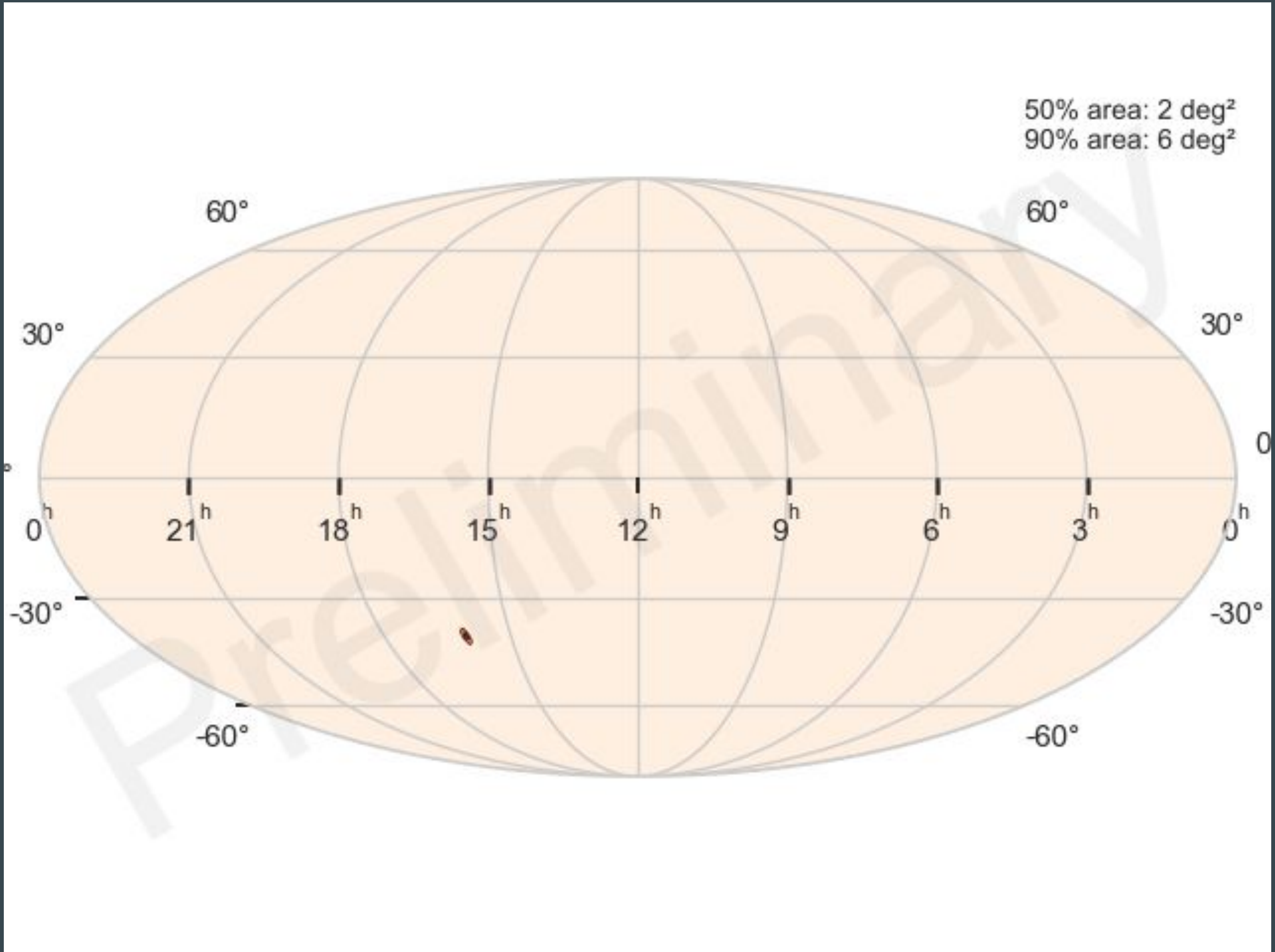


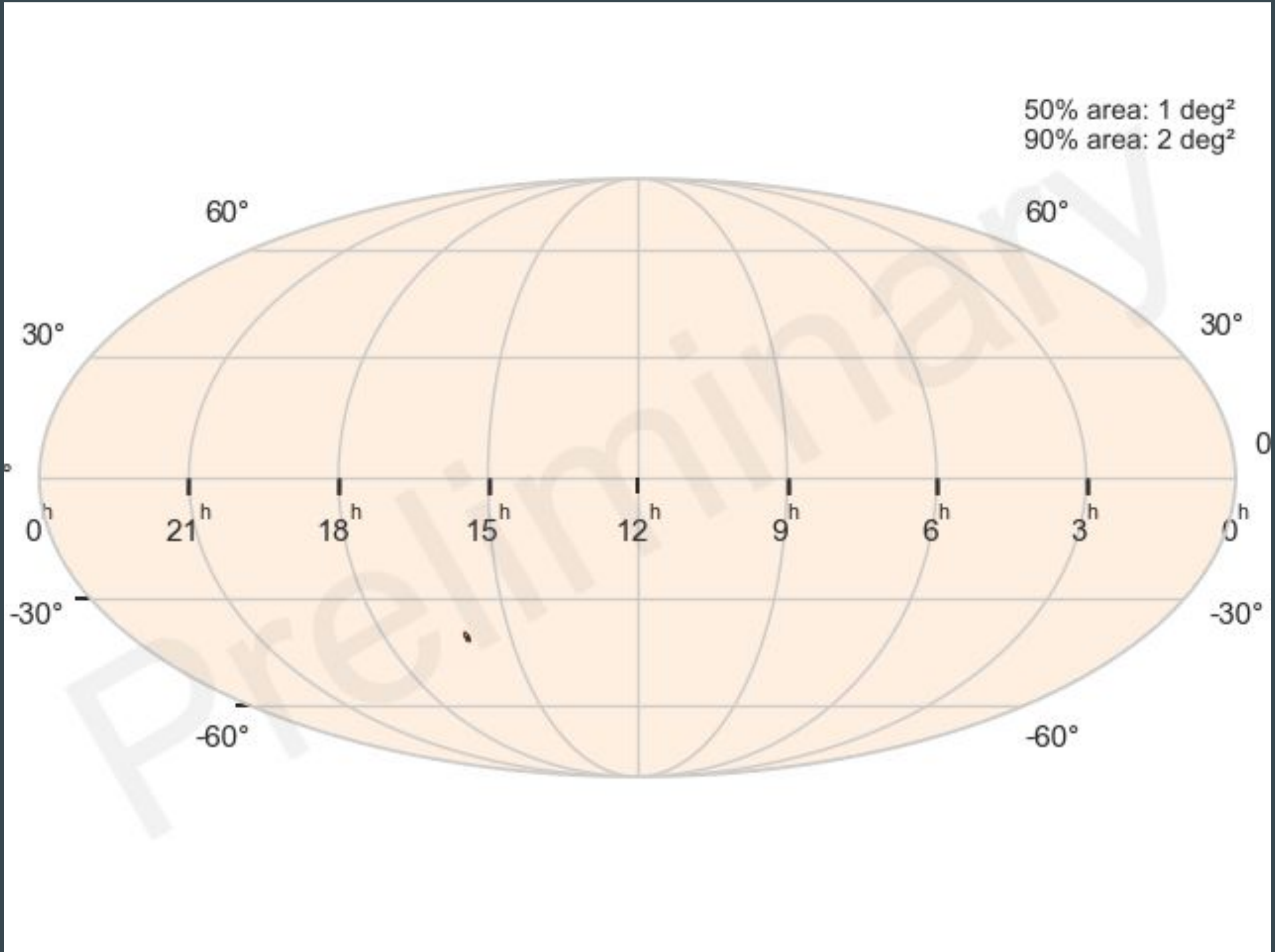
seglen64
seglen32
seglen16
Density
Effective Spin
0
10
20
30
40
50
−0.04
−0.02
0.00
0.02
0.04
0.06


seglen64
seglen32
seglen16
Density
0.0000
0.0002
0.0004
0.0006
0.0008
0.0010
0.0012
0.0014
0.0016
0
200
400
600
800
1000
1200
Tidal Deformability

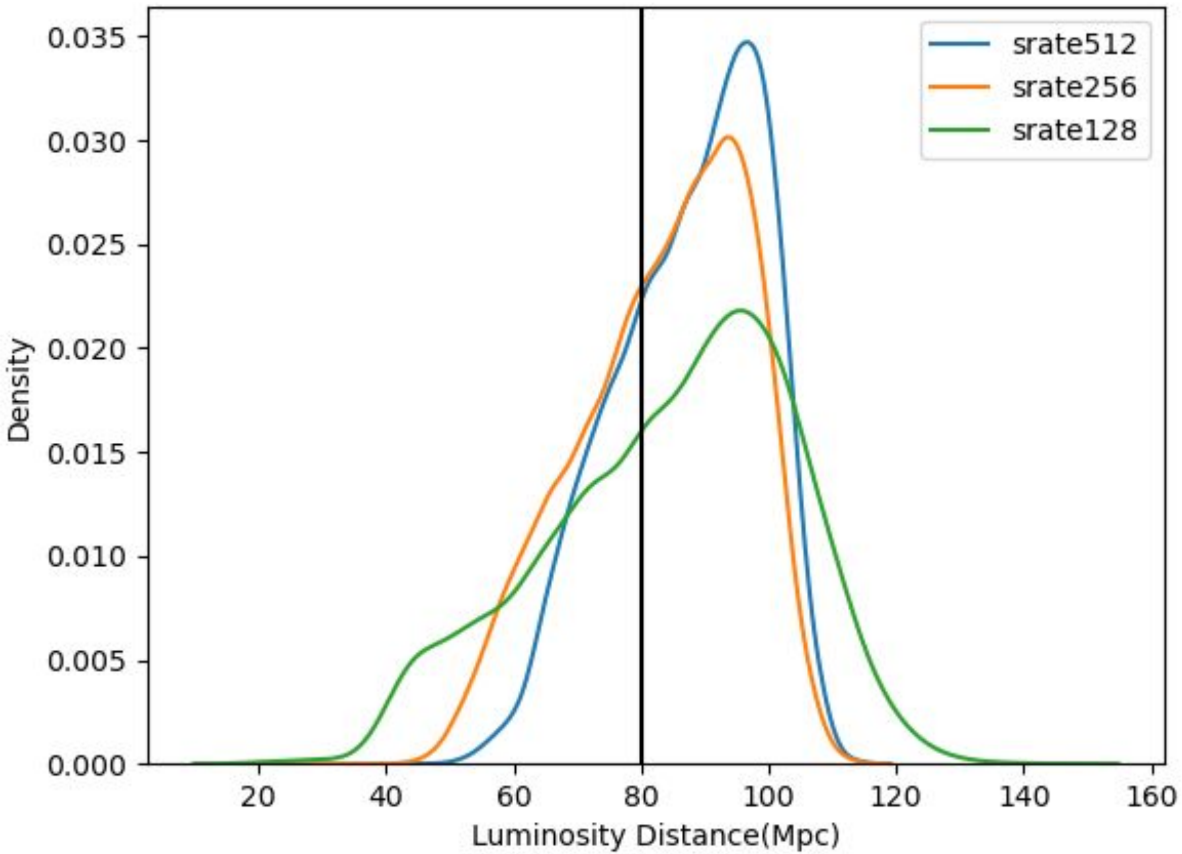
Seglen=32 sec



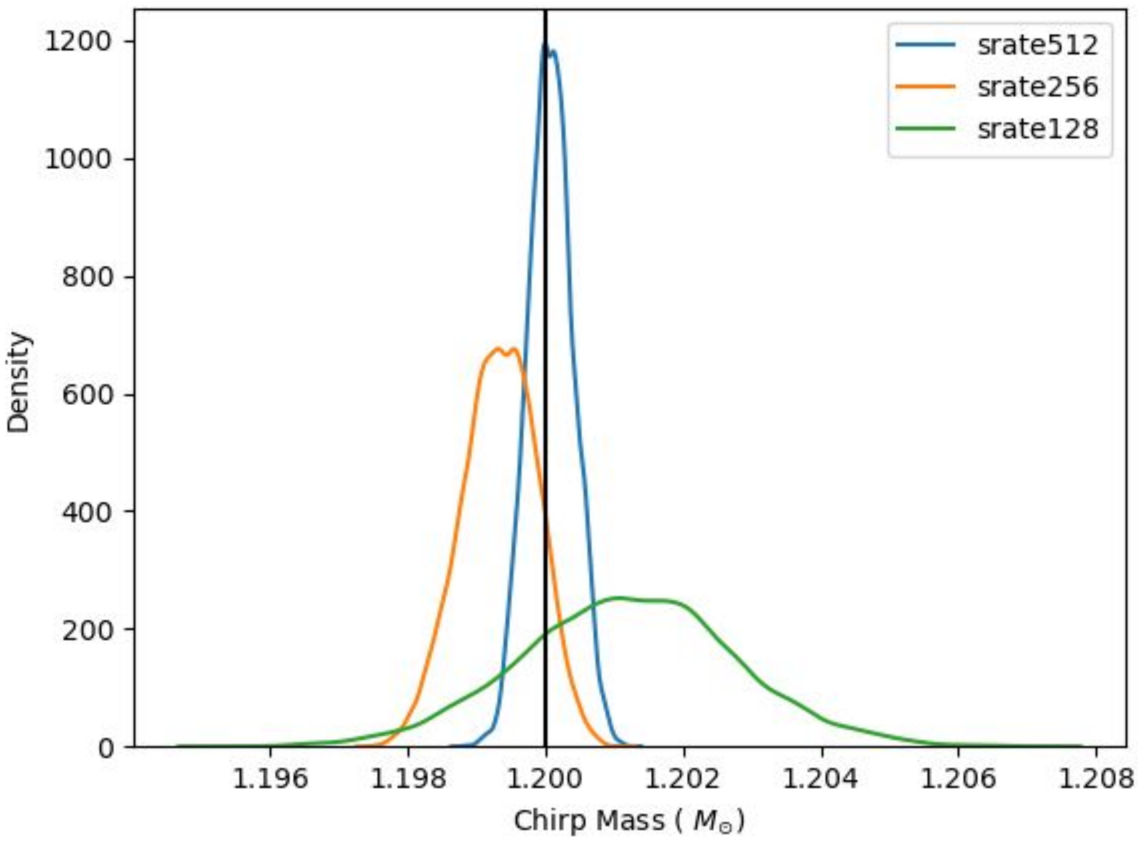

50% area: 2 deg²
90% area: 6 deg²
60°
60°
30°
30°
0h
21h
18h
15h
12h
9h
6h
3h
0h
-30°
-30°
-60°
-60°
Preliminary



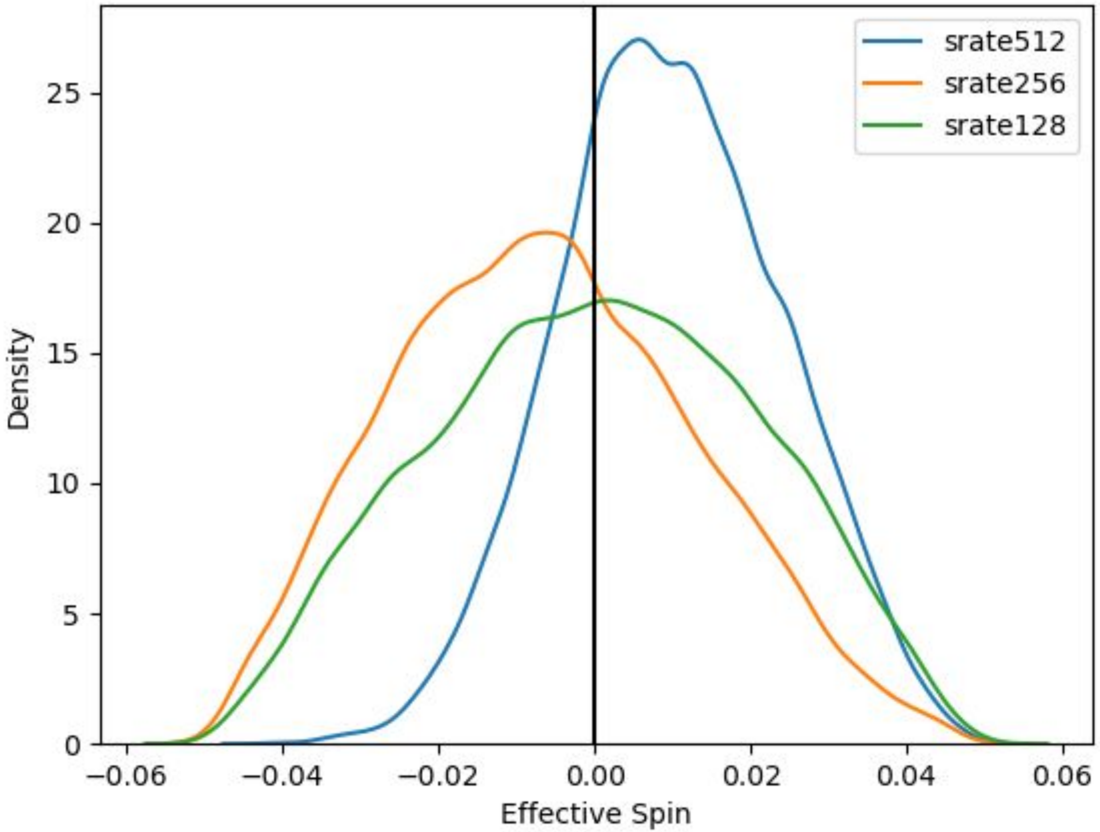
50% area: 1 deg²
90% area: 2 deg²
Preliminary
60°
30°
0°
-30°
-60°
0h
21h
18h
15h
12h
9h
6h
3h
0h



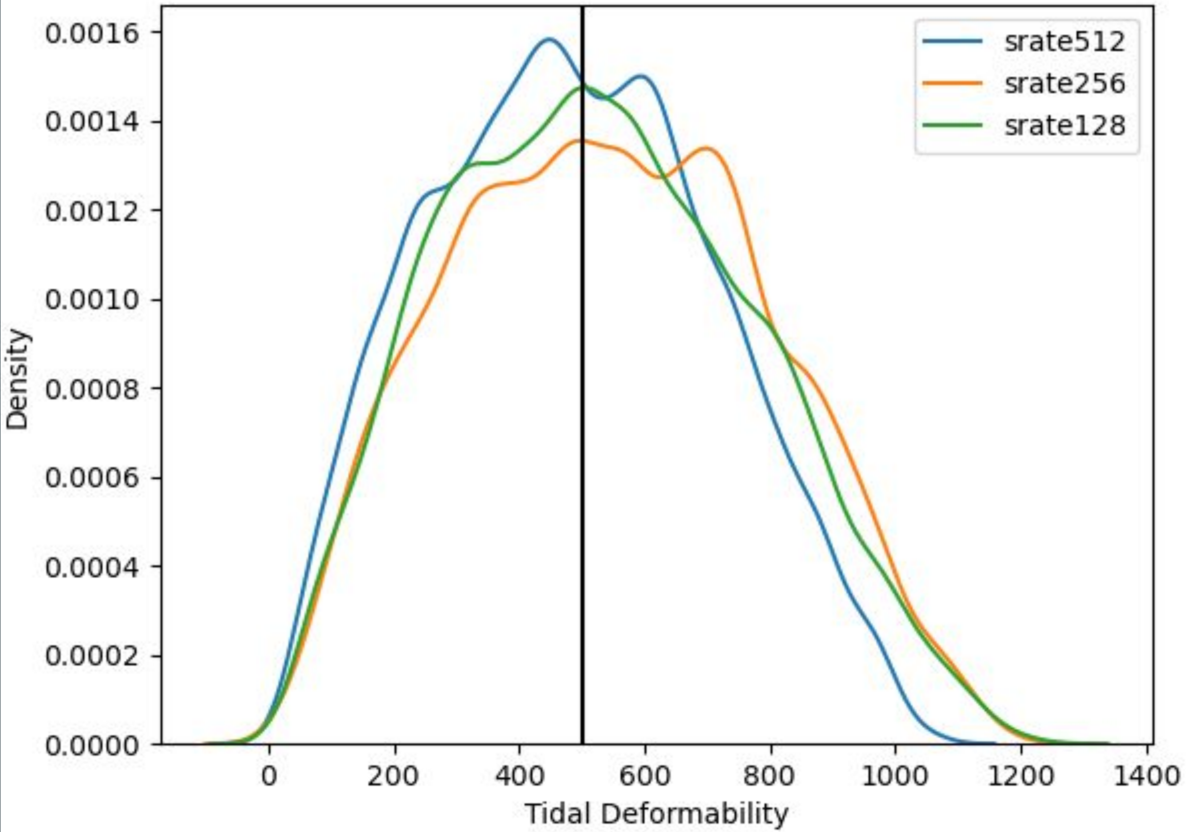
srate512
srate256
srate128
Density
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
20
40
60
80
100
120
140
160
Luminosity Distance(Mpc)



srate512
srate256
srate128
Density
Chirp Mass ($M_\odot$)
1200
1000
800
600
400
200
0
1.196
1.198
1.200
1.202
1.204
1.206
1.208



srate512
srate256
srate128
Density
25
20
15
10
5
0
−0.06
−0.04
−0.02
0.00
0.02
0.04
0.06
Effective Spin



0.0016
0.0014
0.0012
0.0010
0.0008
0.0006
0.0004
0.0002
0.0000
Density
0
200
400
600
800
1000
1200
1400
Tidal Deformability
srate512
srate256
srate128

Conclusions

- Smaller sampling rate and segment length lead to a shorter runtime.
- As we remove certain frequency data (eg. decrease segment length/sampling rate), we end up with worse posterior results for certain parameters like mass and spin.
- Assuming O3 design sensitivity and setup, we are able to localize a BNS source up to 80 Mpc away very well, with a reasonable runtime.

Acknowledgements

I would like to thank the NSF and Caltech for providing me this research opportunity. I would like to thank my mentors, Katerina and Isaac, for guiding and supporting me throughout this project.

Thank you! Questions?