MEASURING THE HUBBLE CONSTANT WITH DYNAMICAL TIDES IN INSPIRALING NEUTRON STAR BINARIES

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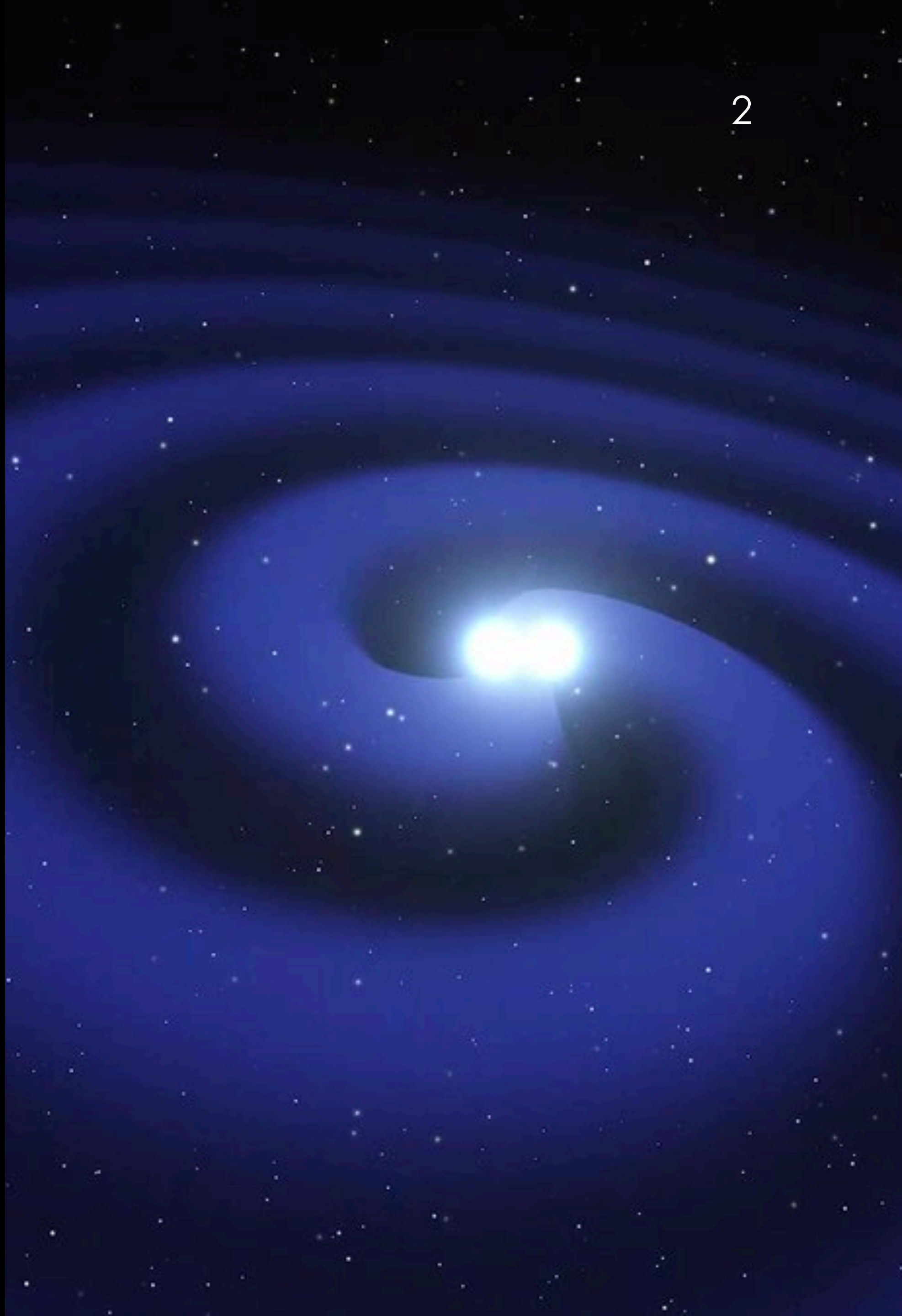
INTRODUCTION

- goal of cosmology is to understand how the universe came to be and what it will be in the distant future
- Gravitational waves were theorized by Albert Einstein and only recently has it been possible to use them for cosmology
- This was done with the famous discovery of GW170817 and the use of multi-messenger astronomy
- We try to expand and refine a preexisting theoretical method proposed by (Messenger & Read 12) to do cosmology without light



THE PROBLEM

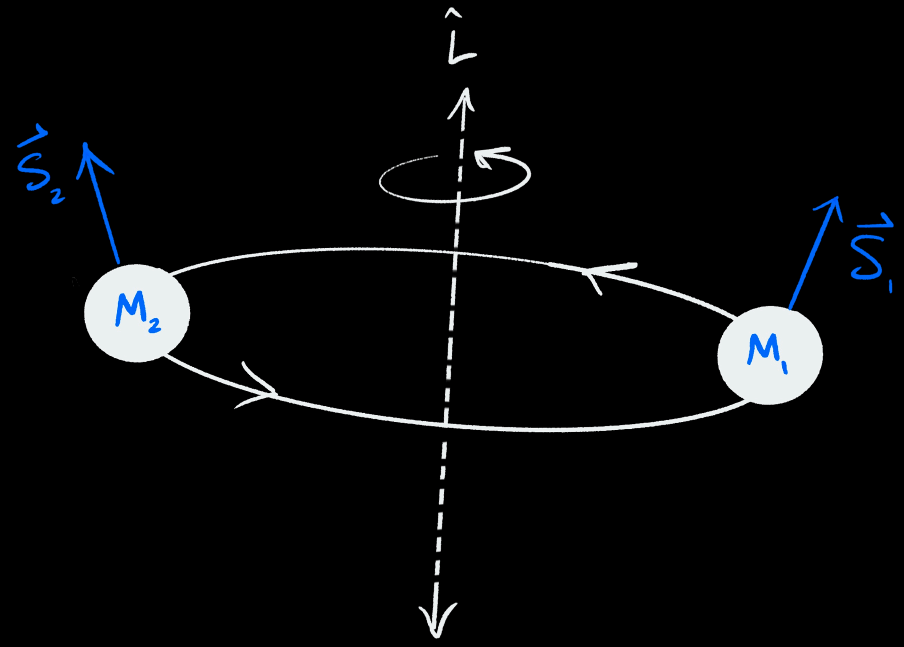
- There is a growing problem in the astronomy community known as the "Hubble Tension" with cosmological consequences
- To understand this problem we need to review some basic cosmology:
- Hubble - Lemaître Law: $v = cz = H_0 d$
- This is the observation that objects are moving away from Earth with velocities proportional to their distance
- Type Ia Supernovae Standard Candle Results: $H_0 \approx 74.03 \pm 1.42 \text{ km s}^{-1}\text{Mpc}^{-1}$
  (Riess et. al '19)
- The Cosmic Microwave Background Results: $H_0 \approx 67.4 \pm 0.5 \text{ km s}^{-1}\text{Mpc}^{-1}$
  (Plank Collaboration et. al '18)
- This disagreement has been creating a problem for astronomers and needs addressing

BINARY NEUTRON STAR MERGER

- Our work is done in the frequency domain
  $\tilde{h}(f) = A(f)e^{i\,\Phi(f)}$

  Contains Redshift

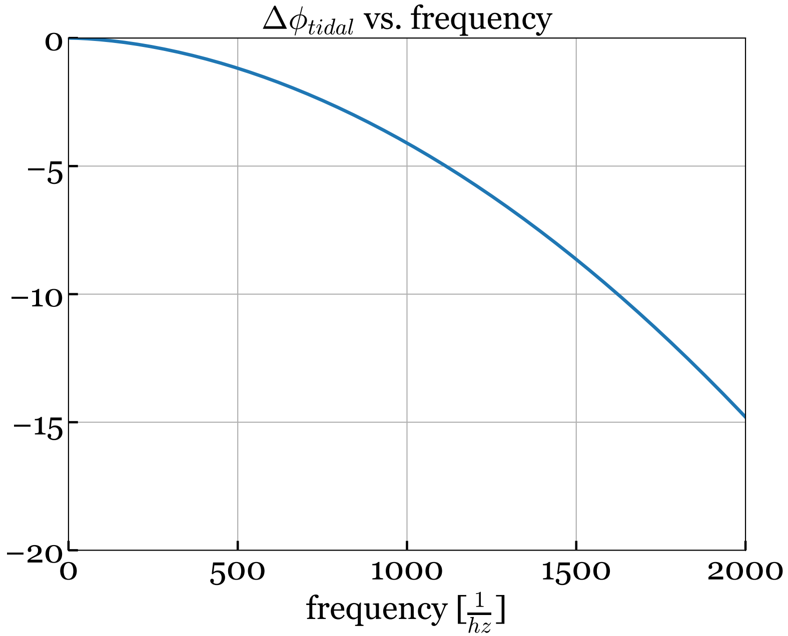
  Contains Luminosity Distance
- $\Phi(f) = \phi_{\text{tidal}}(f) + \phi_{\text{point particle}}(f)$
- Point Particle Phase is PN effect so $M \rightarrow M(1+z)$ to compensate for $f \rightarrow \frac{f}{1+z}$ to preserve the phase (Redshifted Parameters)
- Tidal Phase is not PN effect, it is internal NS physics. The mass does not follow the same redshift effect. (Not Redshifted Parameters)

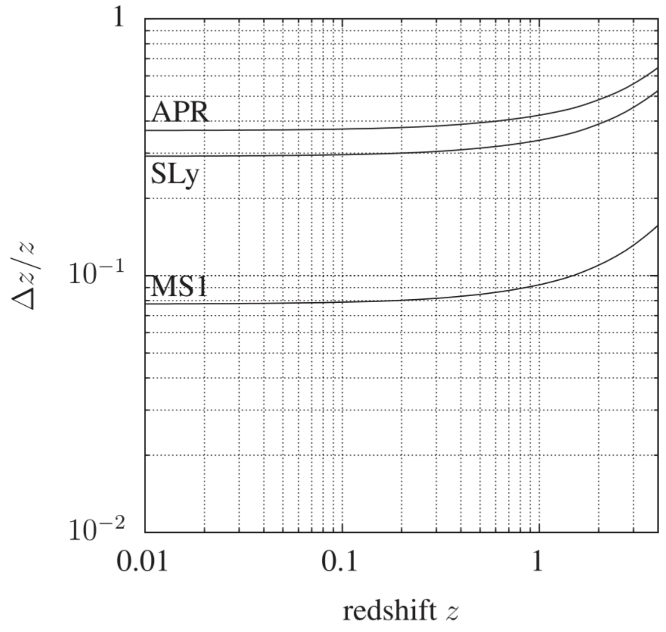


TIDAL MODES

- What is a f-mode?
- Previous work done by (Messenger & Read ‘12) makes use of the f-mode phase contributions within a neutron star to “break a degeneracy between the system’s mass parameters and redshift” assuming EOS is well known
- This allows for a measurement of both luminosity distance and redshift simultaneously

TIDAL MODES





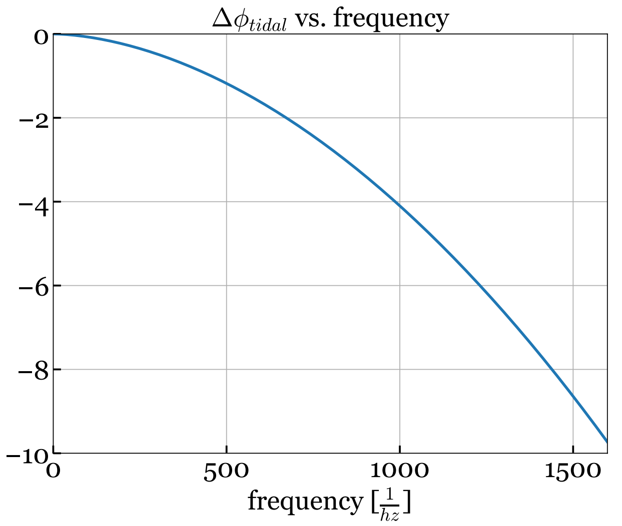
(Messenger & Read '12)

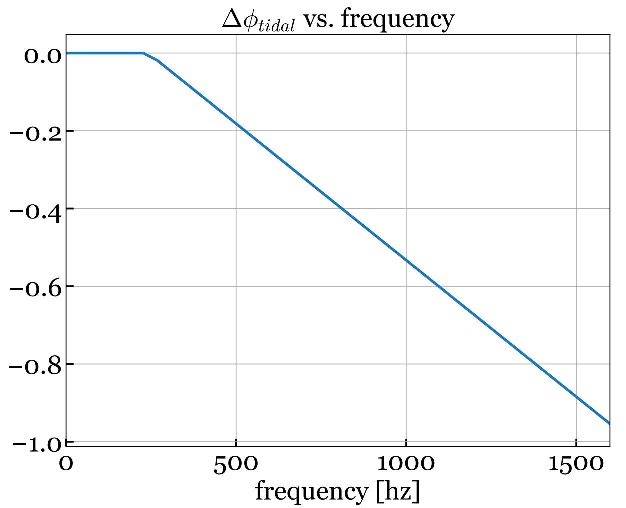
- The top figure is a plot of the phase shift due to tidal effects from the f-mode alone
- The bottom is Figure 1 of (Messenger & Read '12) which shows how accurately one could measure z with respect to z

TIDAL MODES

- The biggest problem with f-modes is that their resonance occurs at a frequency that is too large (beyond what the detectors are capable of detecting)
- g-modes have too small of an effect to be detectable but achieve resonance within frequency band
- r-modes are not as strong as f-modes but they achieve resonances within the LIGO/Virgo frequency band.

TIDAL MODES

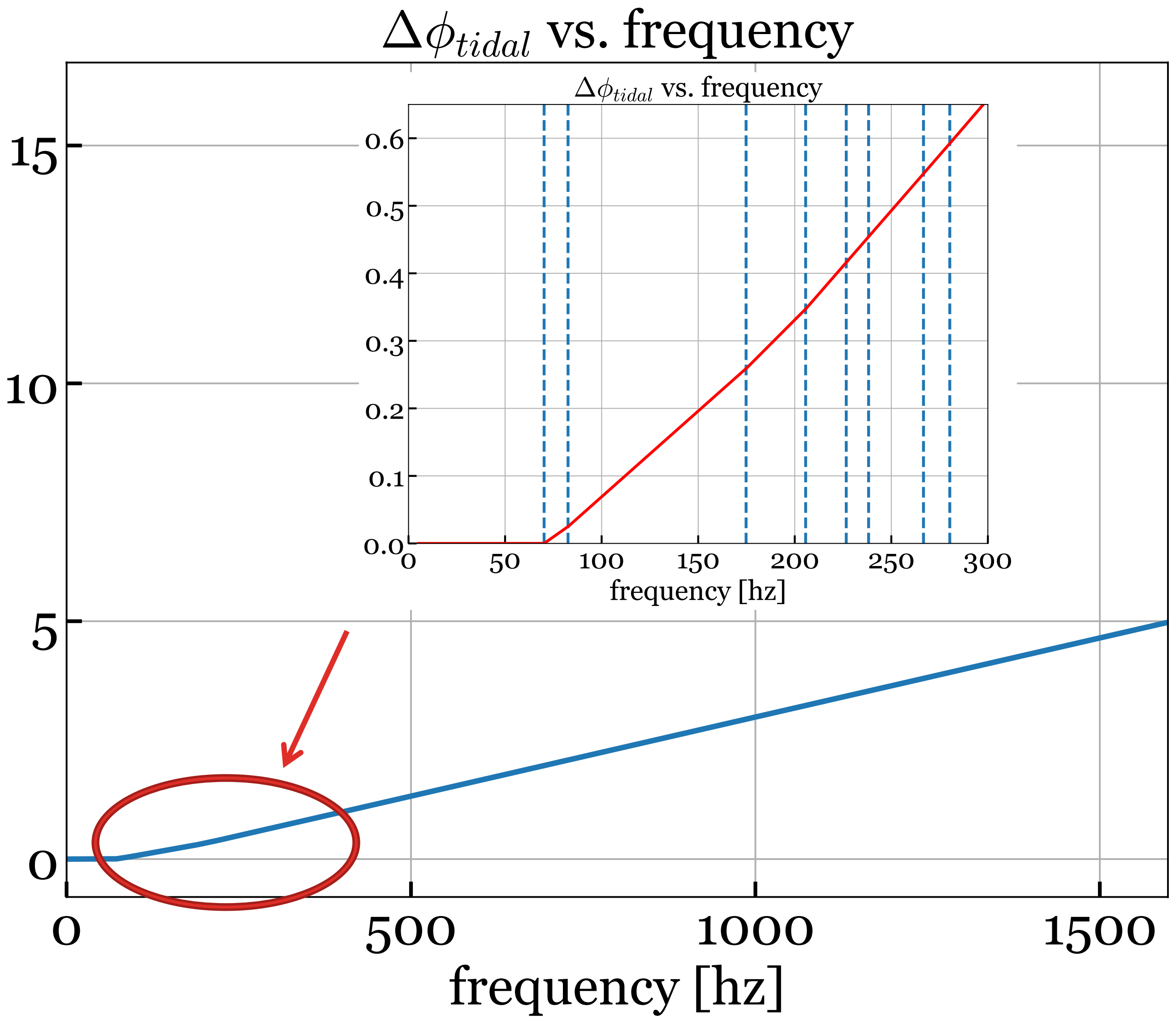




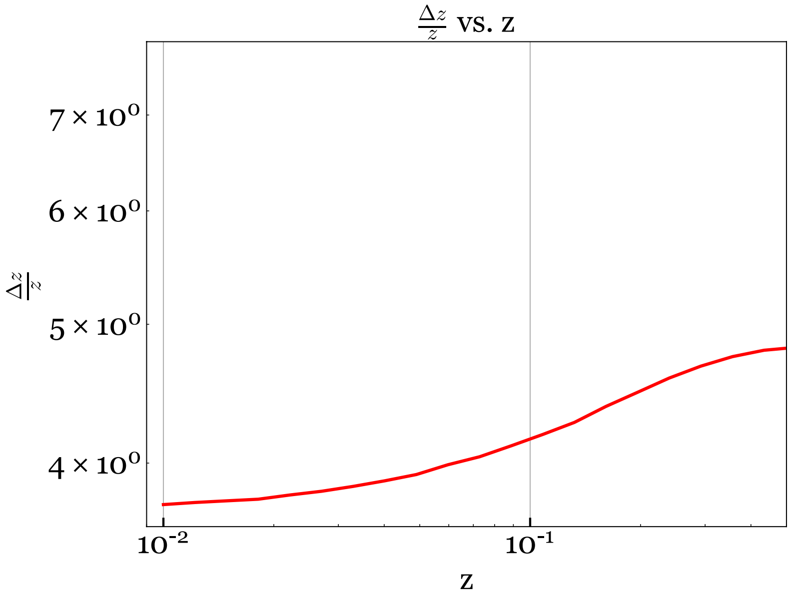
- Above is the f-mode tidal phase contribution
- Below is the r-mode tidal phase contribution discussed in (Flanagan & Racine ‘07)
- Now we compare spin parameter χ, for Point particle it is not redshifted, for tidal it is redshifted

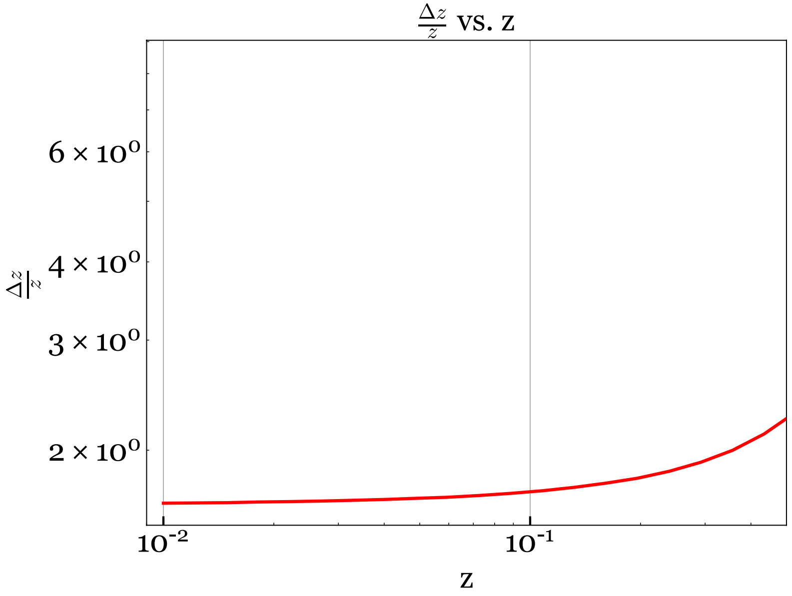
MORE INERTIAL MODES

- We looked a new paper written by (Poisson '20), in which he utilizes 4 inertial modes
- All together the total tidal phase contribution becomes significantly larger than only one r-mode



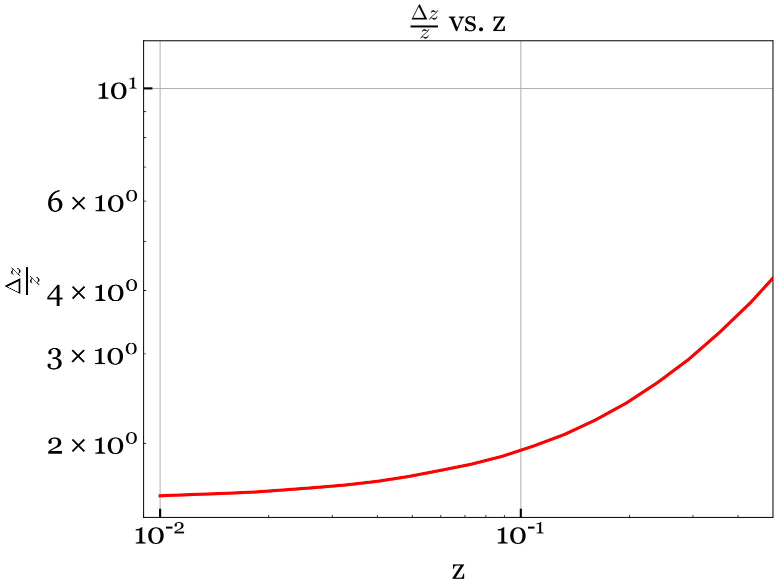
RESULTS

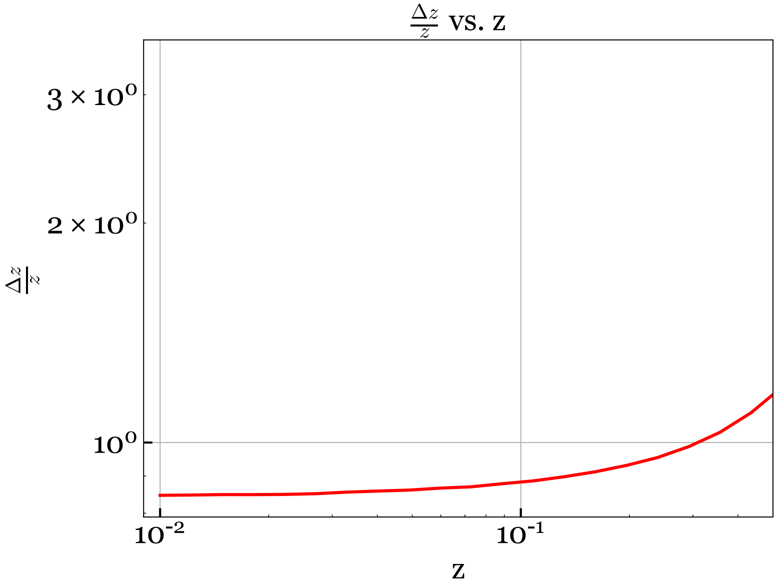




- Top: $\psi_1, \psi_2 = \frac{\pi}{3}, \frac{\pi}{6}$, $\Omega_1, \Omega_2 = 30 \ * 2\pi, 50 \ * 2\pi$

- Bottom: $\psi_1, \psi_2 = \frac{\pi}{3}, \frac{\pi}{6}$, $\Omega_1, \Omega_2 = 80 \ * 2\pi, 100 \ * 2\pi$





RESULTS

- Top: $\psi_1, \psi_2 = \frac{3\pi}{4}, \frac{5\pi}{6}$, $\Omega_1, \Omega_2 = 50 * 2\pi, 30 * 2\pi$

- Bottom: $\psi_1, \psi_2 = \frac{3\pi}{4}, \frac{5\pi}{6}$, $\Omega_1, \Omega_2 = 100 * 2\pi, 80 * 2\pi$

SUMMARY

- This is important because a successful measurement of redshift without light has large implications on the "Hubble Tension"
- Multi-Messenger astronomy is not always reliable, having a "backup" method incase it is not possible to observe a BNS is extremely valuable
- Tidal modes allow for us to measure a redshift in the waveform which is inherently difficult to do with GWs

FUTURE WORK

- Our goals in the future will be to accurately incorporate the 4 inertial modes of (Poisson ‘20) with the original f-modes used in (Messenger & Read ‘12)
- This will hopefully make a significantly large phase shift which will correspond to a more precise measurement of redshift
- explore how much more relaxed our assumptions can become about the EOS of the NS

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QUESTIONS

- Thank you for listening