Simulation of the LISA Data Stream from Galactic White Dwarf Binaries

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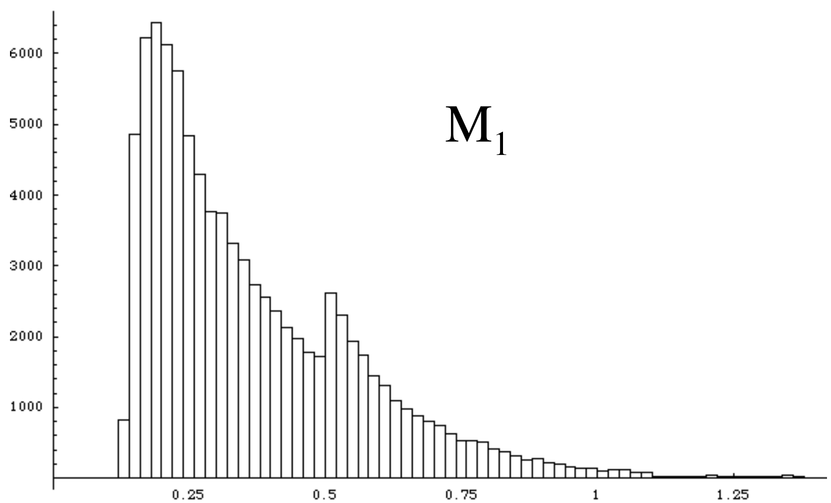
Confusion-limited Background

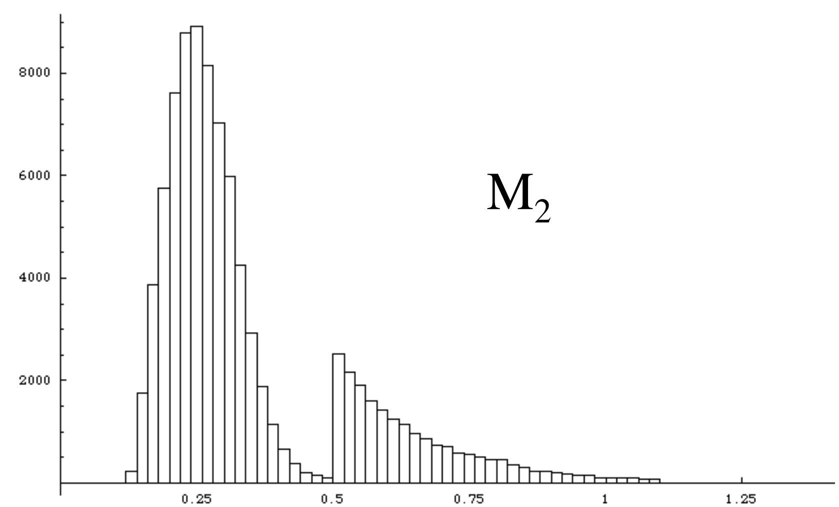
- Galactic population of close white dwarf binaries will dominate LISA signal
- Below ~ 1 mHz signal will be isotropic and effectively gaussian with > 100 sources per bin for a 1-year observation
- Above ~ 5 mHz signal will be individually resolvable sources
- Simulate the transition region with 90,000 binaries to develop a tool for testing analysis techniques

Phenomenological Population Synthesis

- Assume uniform birthrate
- Assign binary type at birth according to Nelemans et al.
- Assign component masses according to Iben & Tutukov
- Assign orbital period at birth according to mass of secondary
- Evolve each binary to present and retain if orbital period is < 2000 s and binary has not merged

Mass Distributions



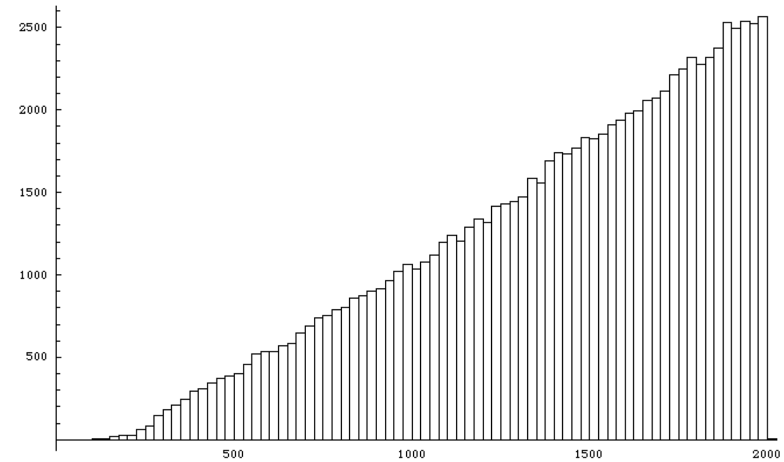


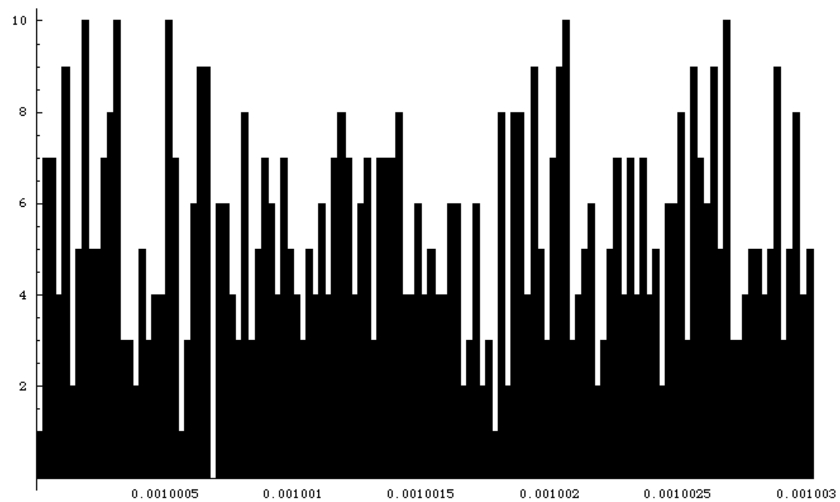
Orbital Period Distribution

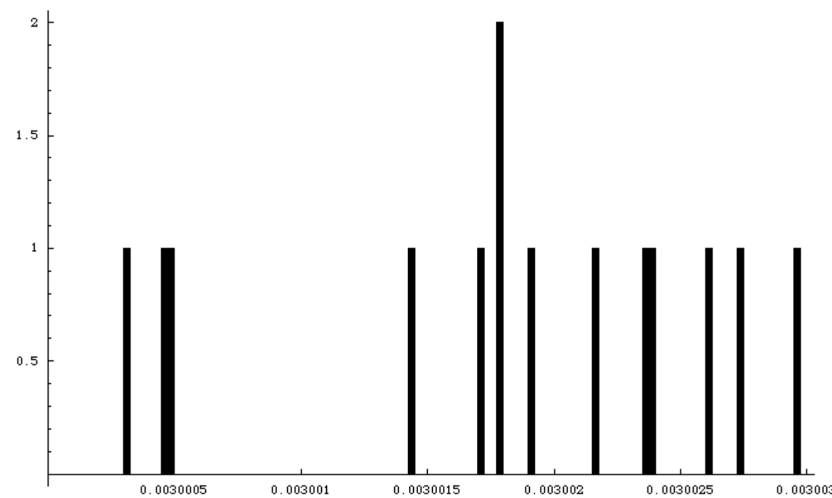
Orbital period

100 bins above 3 mHz

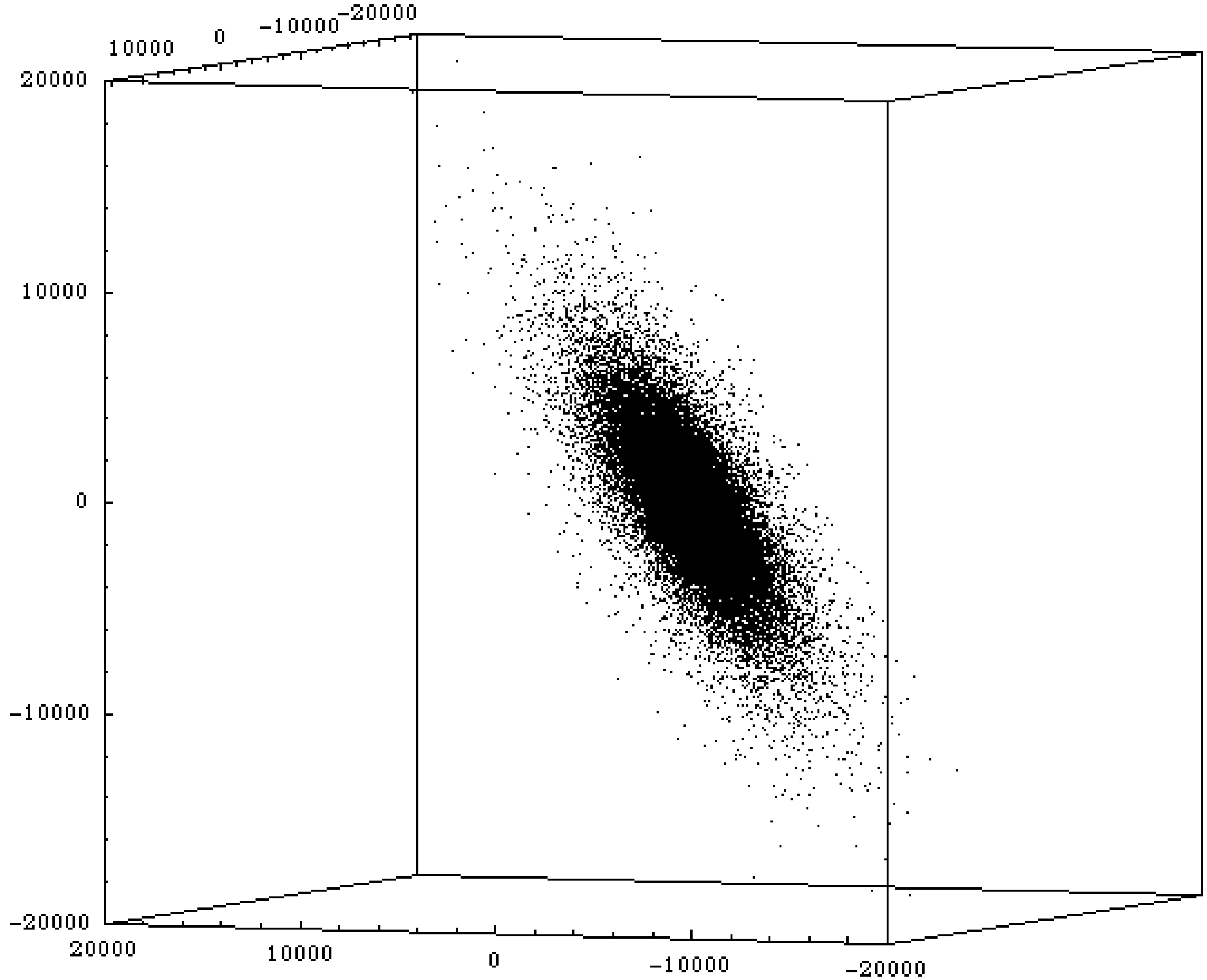
100 bins above 1 mHz







Spatial Distribution



Generating the Signal

$$h(t) = \frac{\sqrt{3}}{2} A(t) \cos\left[2\pi f_0 t + \Phi_p(t) + \Phi_D(t) + \Phi_0\right]$$

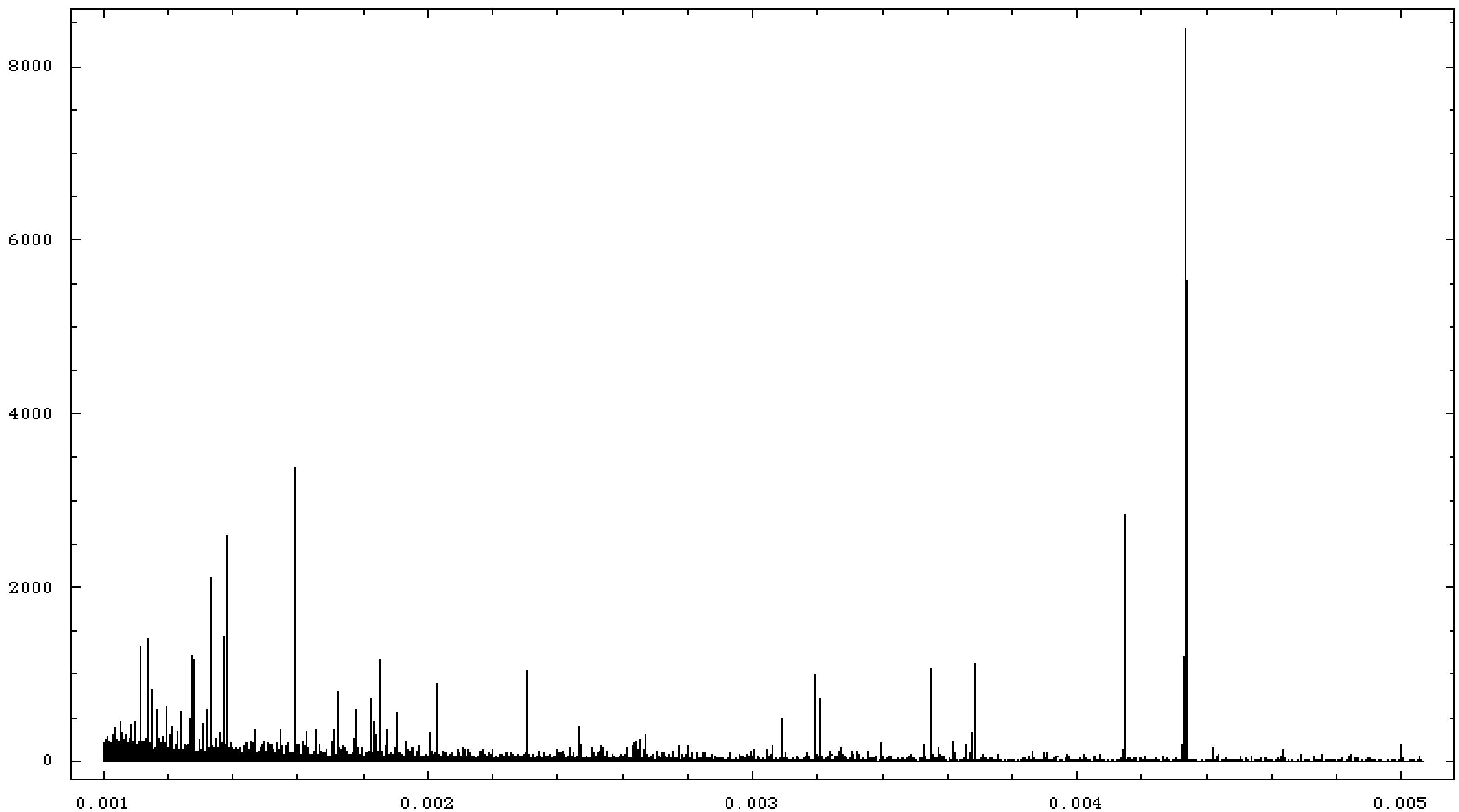
$$A(t) = \sqrt{\left(A_+ F^+(t)\right)^2 + \left(A_\times F^\times(t)\right)^2}$$

$$\Phi_p(t) = \tan^{-1}\left(\left(-A_\times F^\times(t)\right) / A_+ F^+(t)\right)$$

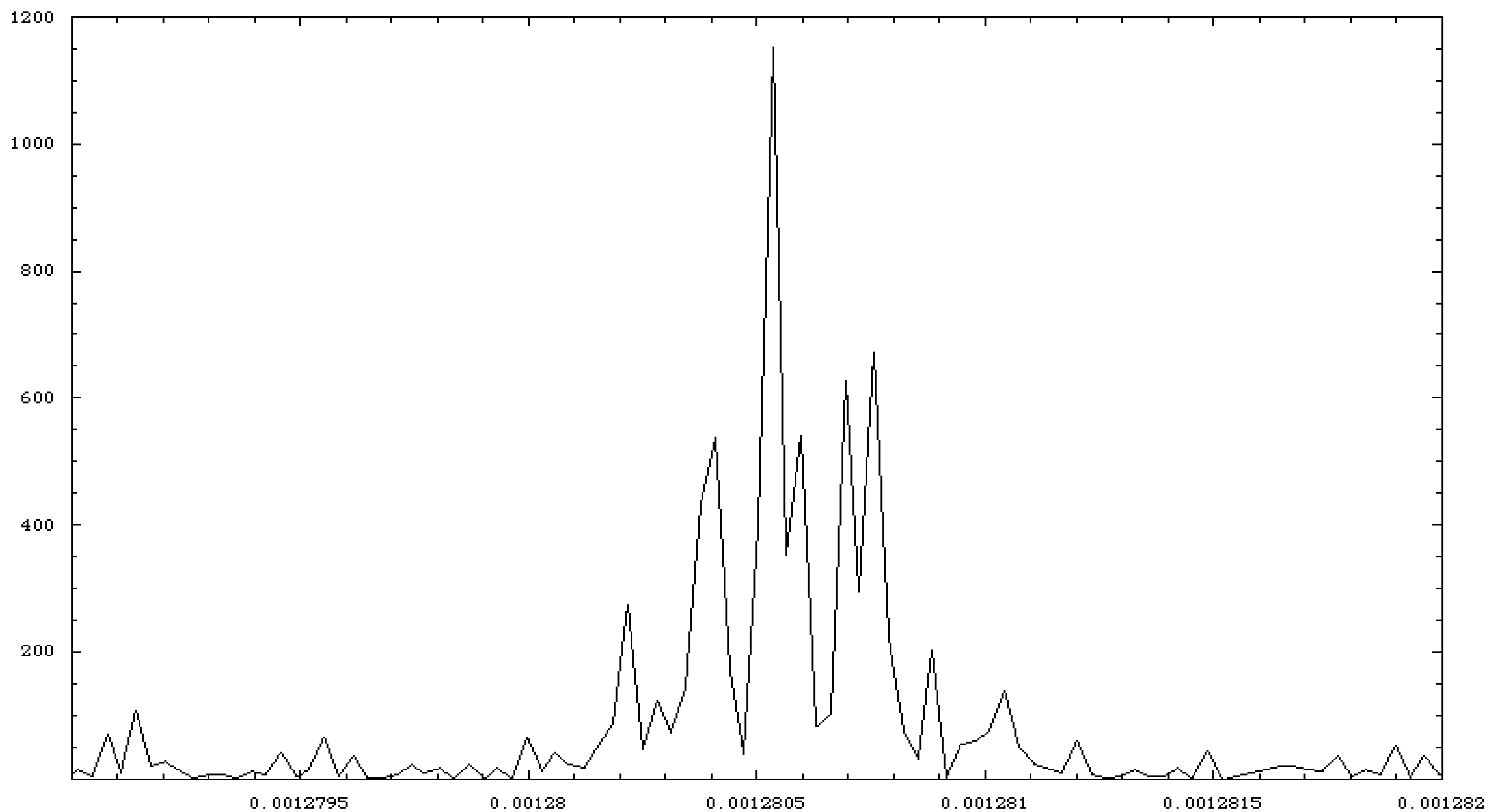
$$\Phi_D(t) = \left(2\pi R_\oplus f_0 / c\right) \sin\theta_s \cos\left[\phi_\oplus(t) - \phi_s\right]$$

Generate time series data with a sampling rate of 1 data point per second. One year of data (3.2×10^7 points).

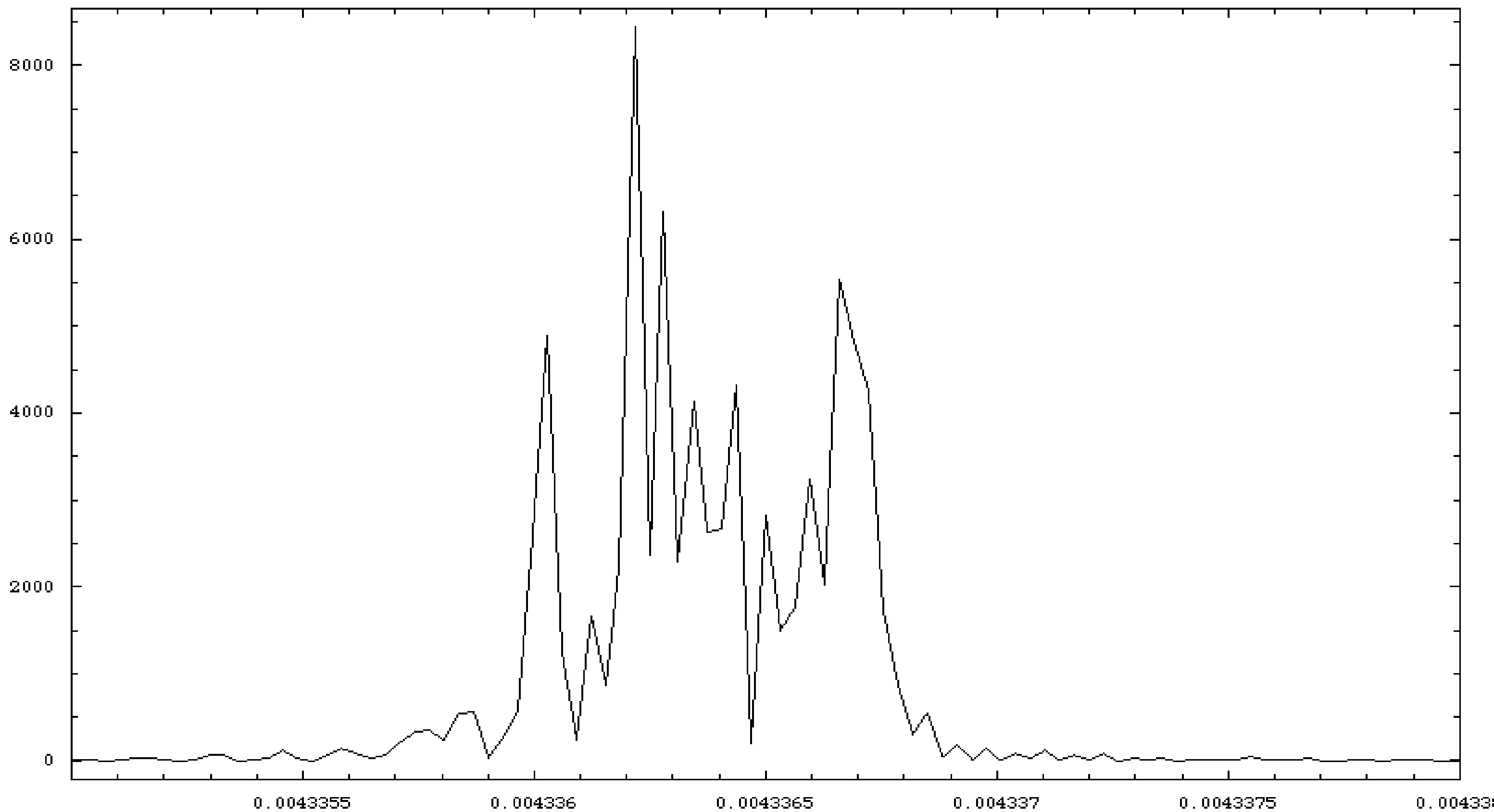
Full Spectrum



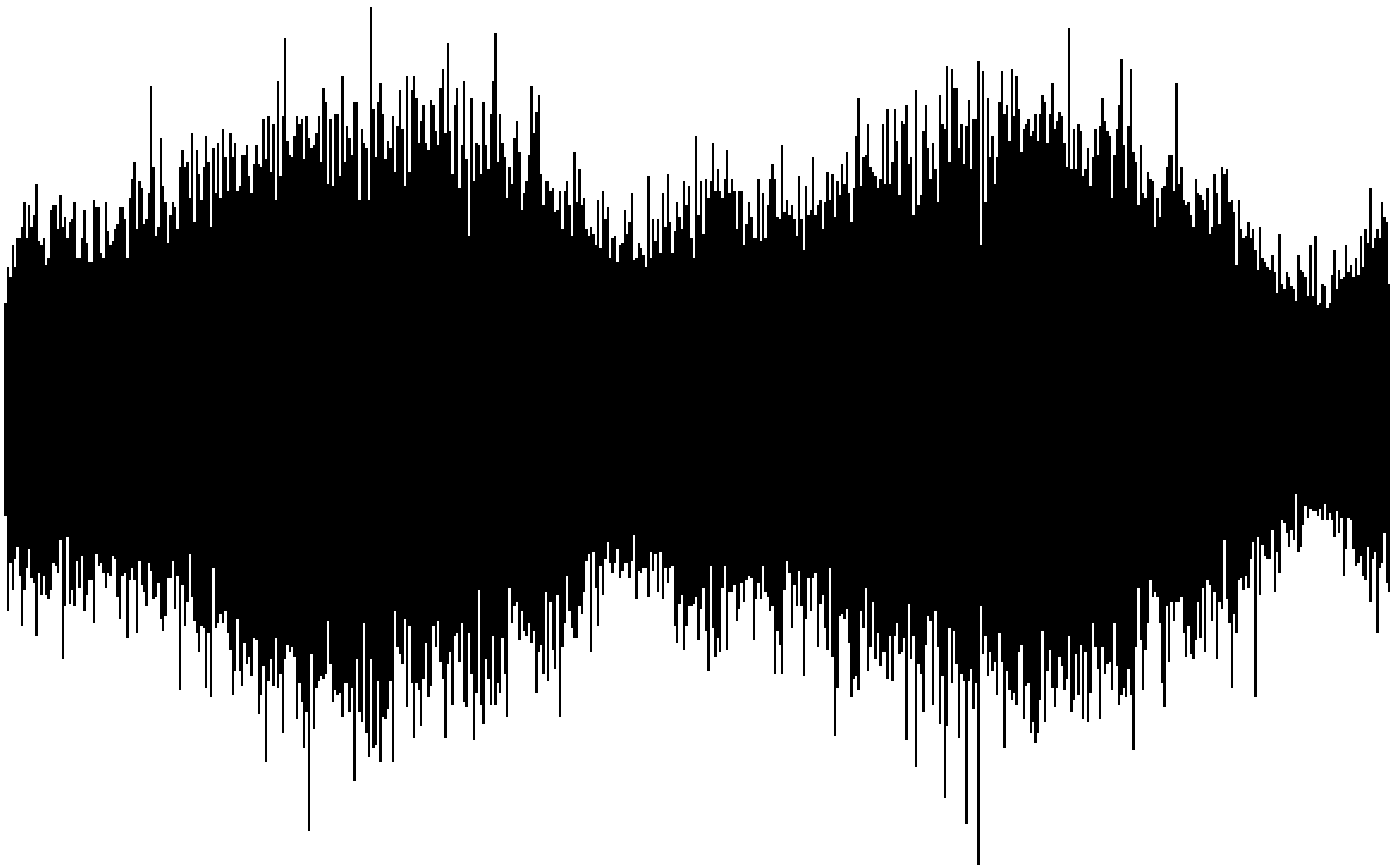
Spectrum around 1.3 mHz



Spectrum around 4.3 mHz

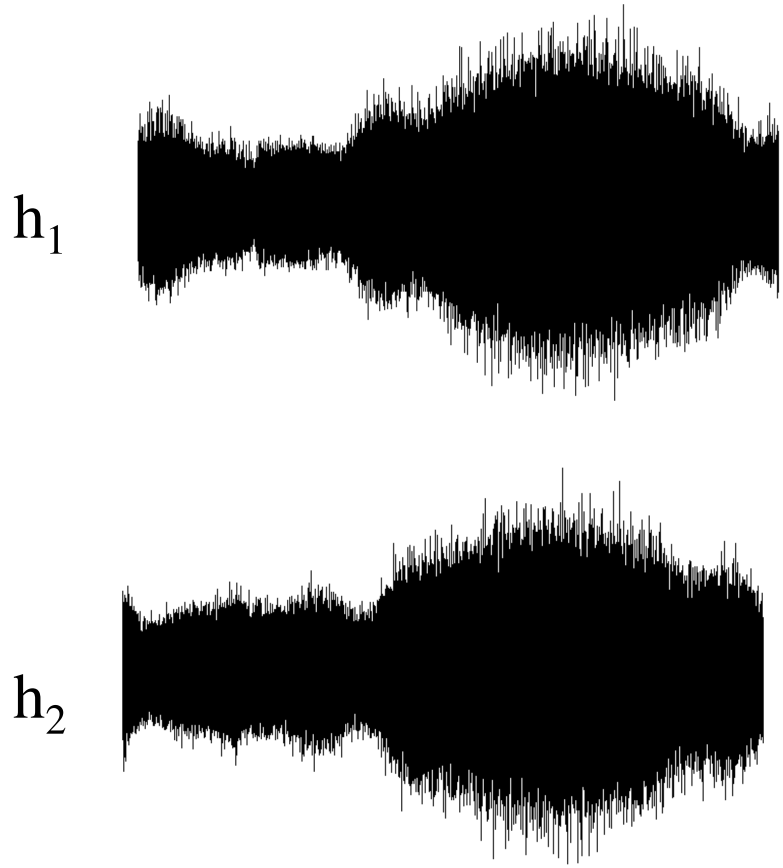


Time Series



NGC 104 (47 Tuc)

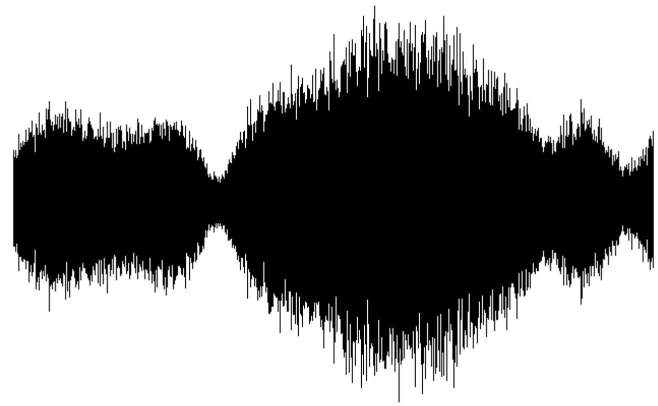
- Large, nearby globular cluster
- Dense core
- Binaries formed through dynamical encounters
- Lots of *Chandra* sources
- Large number of millisecond pulsars



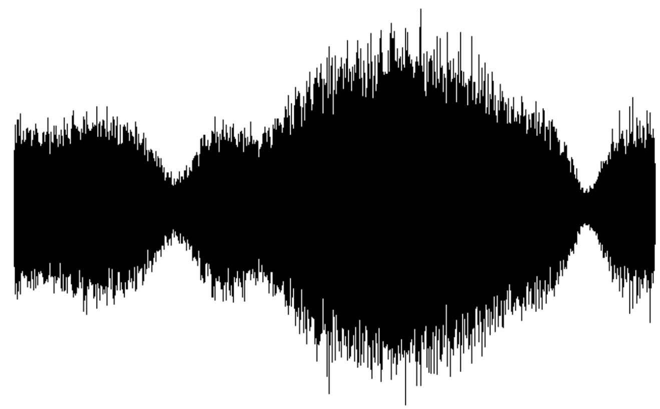
NGC 5139 (□ Cen)

- Largest galactic globular cluster
- Open core
- Binaries are primordial
- Has measurable rotation
- May be core of a dwarf spheroidal galaxy

h_1

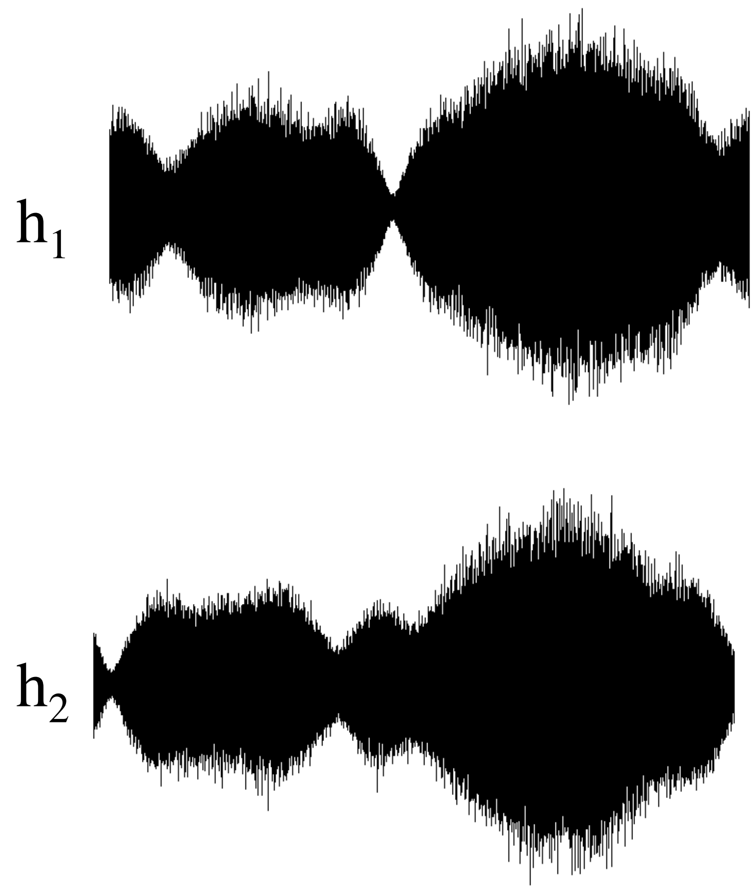


h_2



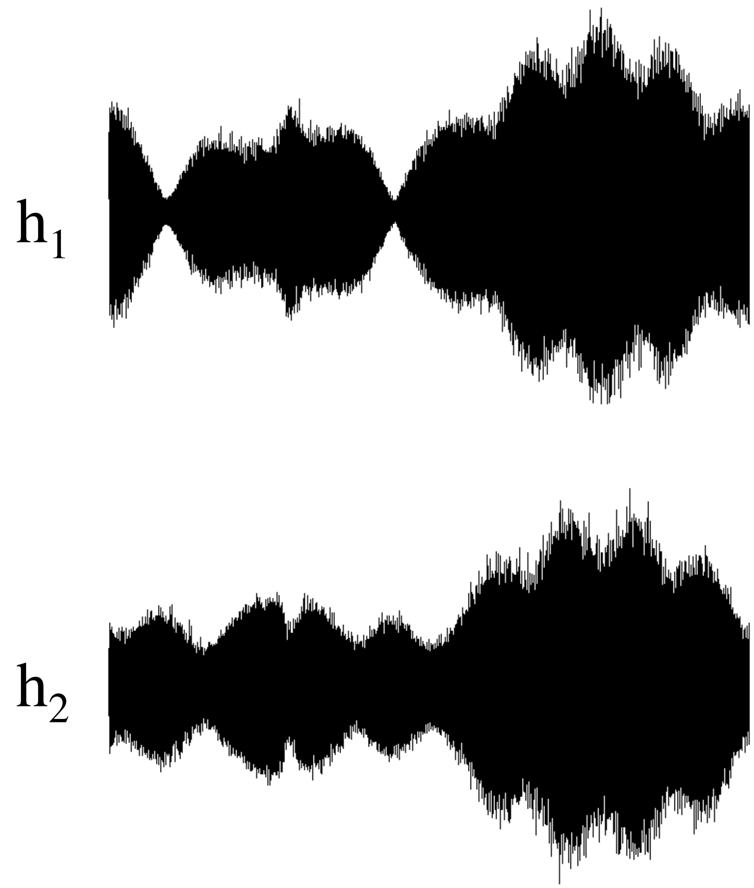
NGC 6397

- Nearest galactic globular cluster
- Probably core collapsed
- ~ 20 X-ray sources
- Evidence of mass segregation
- Binaries formed through dynamical encounters



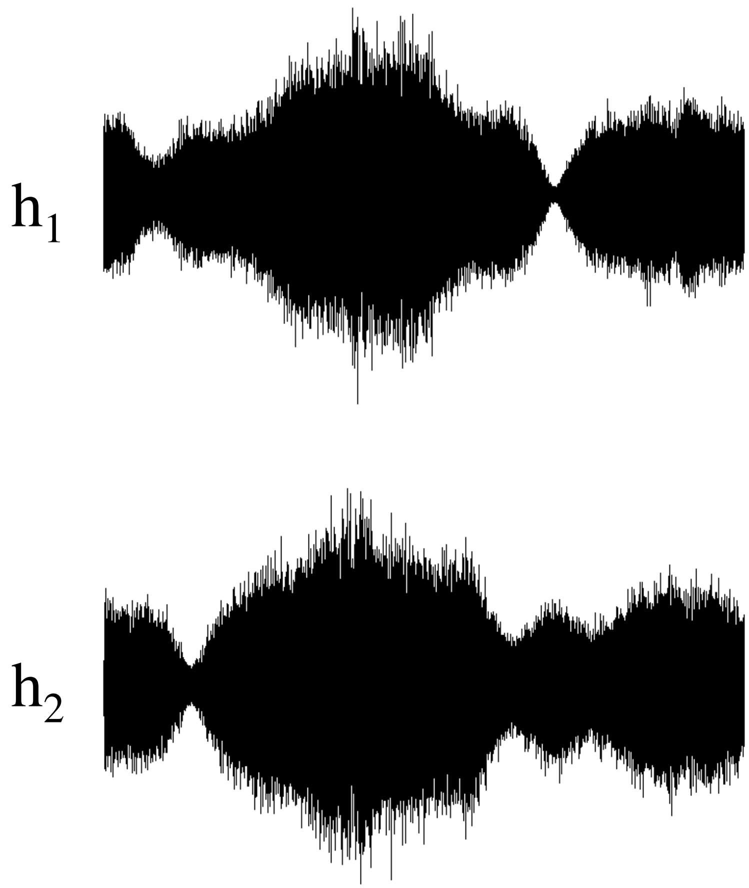
NGC 6752

- Nearby galactic globular cluster
- Core collapsed
- ~ 20 X-ray sources
- 15%-38% binary fraction in the core
- 5 millisecond pulsars
- Binaries formed through dynamical encounters

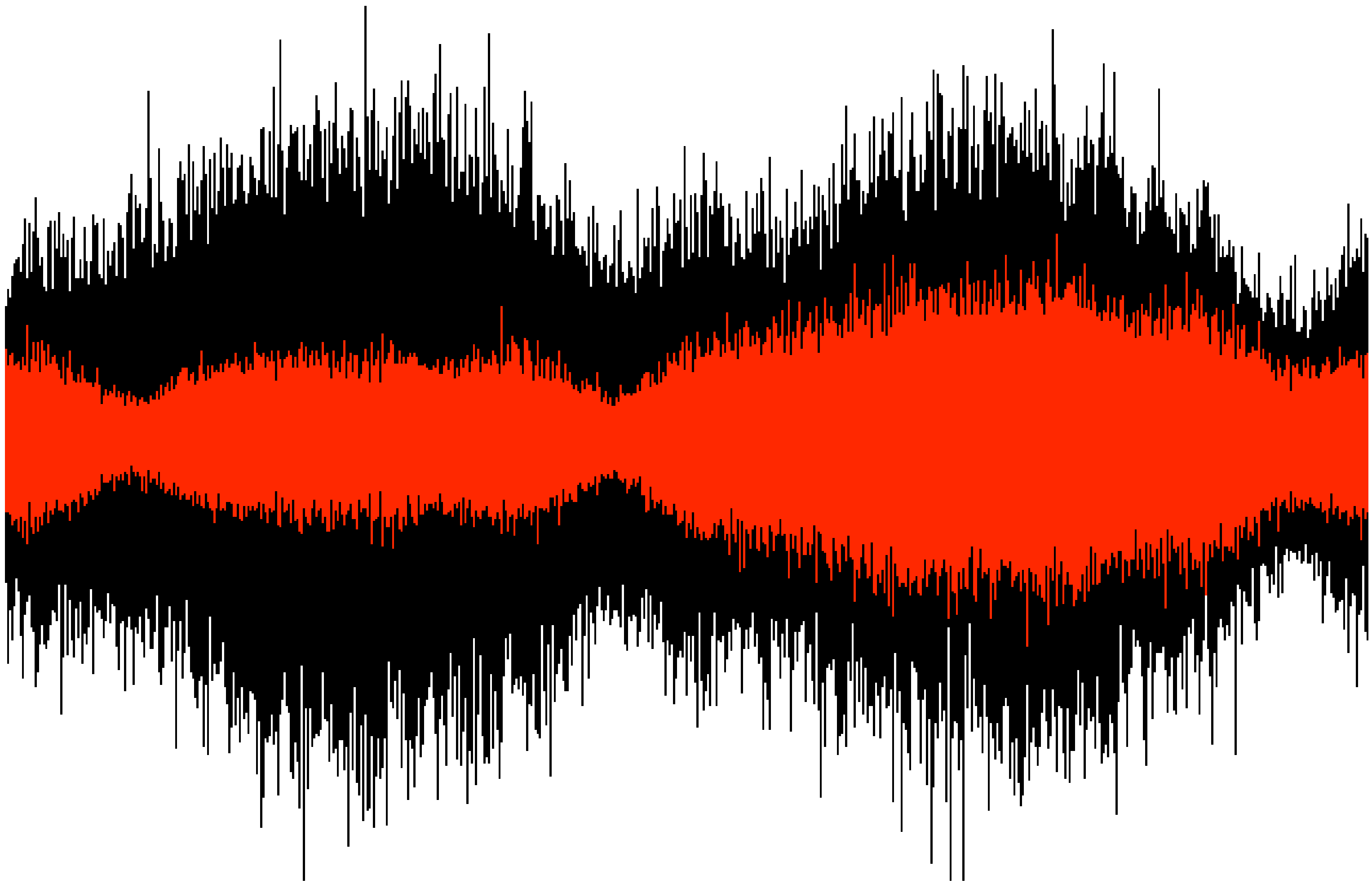


NGC 7078 (M 15)

- Distant galactic globular cluster
- May harbor an intermediate mass black hole (Gerssen et al.)
- May harbor a large number of compact objects (Baumgardt et al.)



Globular Cluster and Disk



Future Work

- Include binaries with orbital period above 2000 s
- Use the LISA Simulator (Cornish & Rubbo) to generate signal
- Develop realistic globular cluster binary populations
- Test data analysis techniques for identifying globular cluster binaries

Conclusions

- We have simulated the LISA data stream for a population of 90,000 close white dwarf binaries
- Data stream can be added to a specific choice for instrument noise to investigate data extraction for different noise levels.
- Simulation uses long wavelength approximation, so higher frequency sources may need to be modified.
- Data stream is available on CD.