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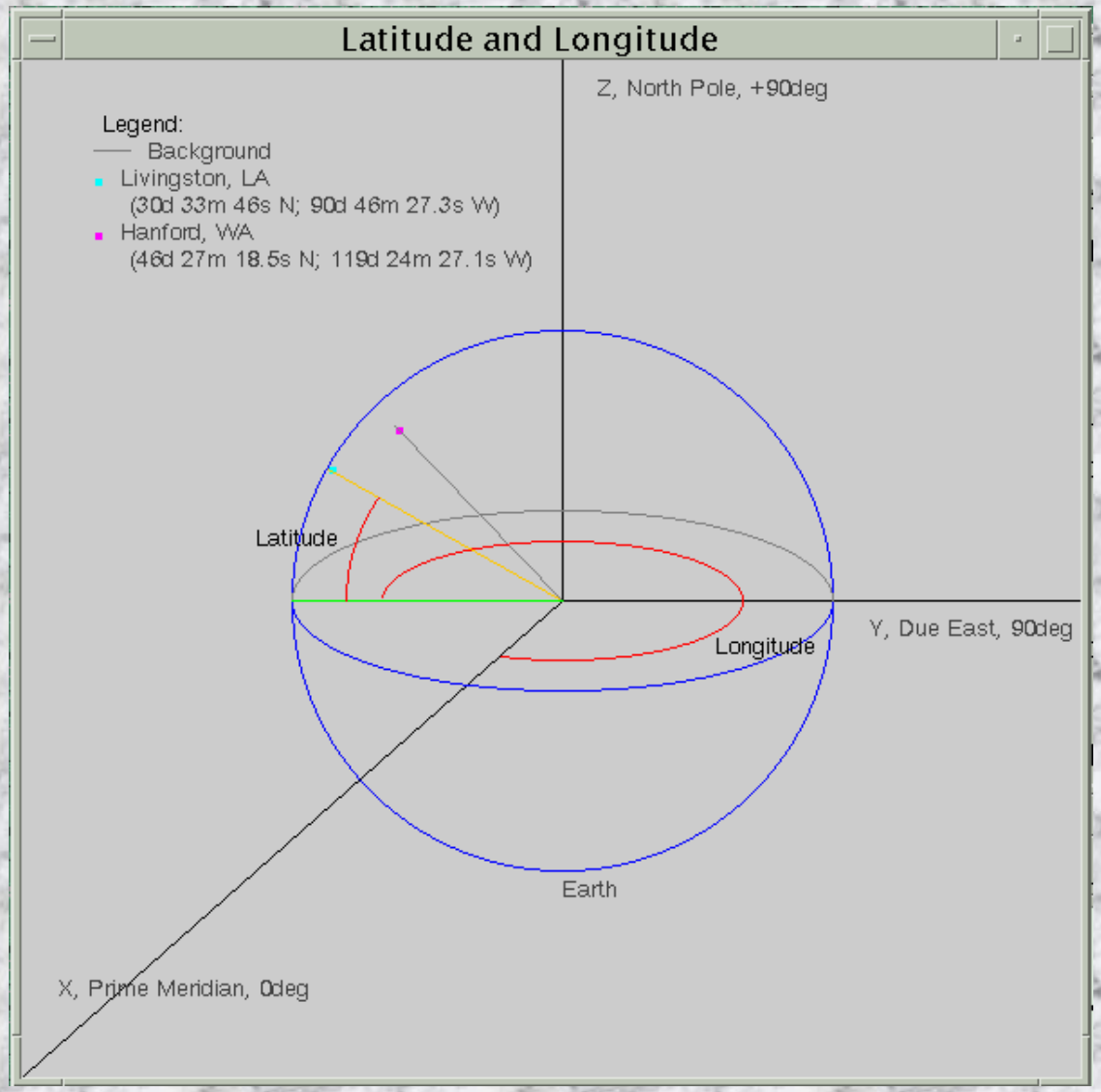
Purpose:

- LIGO End-to-End simulation program (E2E)
  - LIGO detector simulation
  - Laser field, mechanical motions and control
  - Simulate various noises
- Where's the gravitational-wave?
  - Signal simulation
    - Time series of strain, $h = r\ L/L$
    - Observes difference of two arm-lengths
    - Visualization

Program Features

- Detector
  - Location and orientation
- Source location
- Detector correlation
  - Time Delay
  - Strain strength
- Signal source
- Output
- Waveform

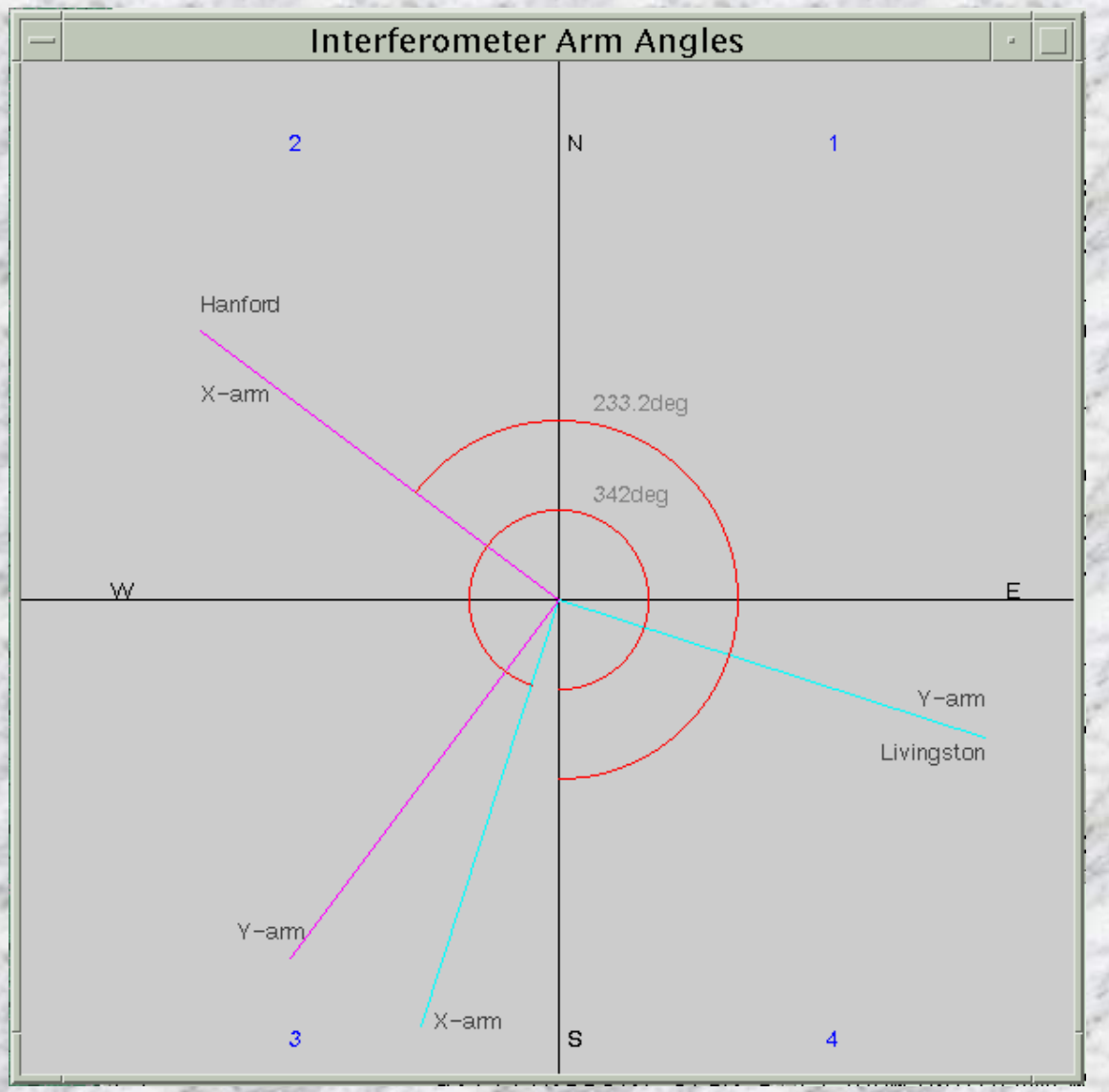
Detector



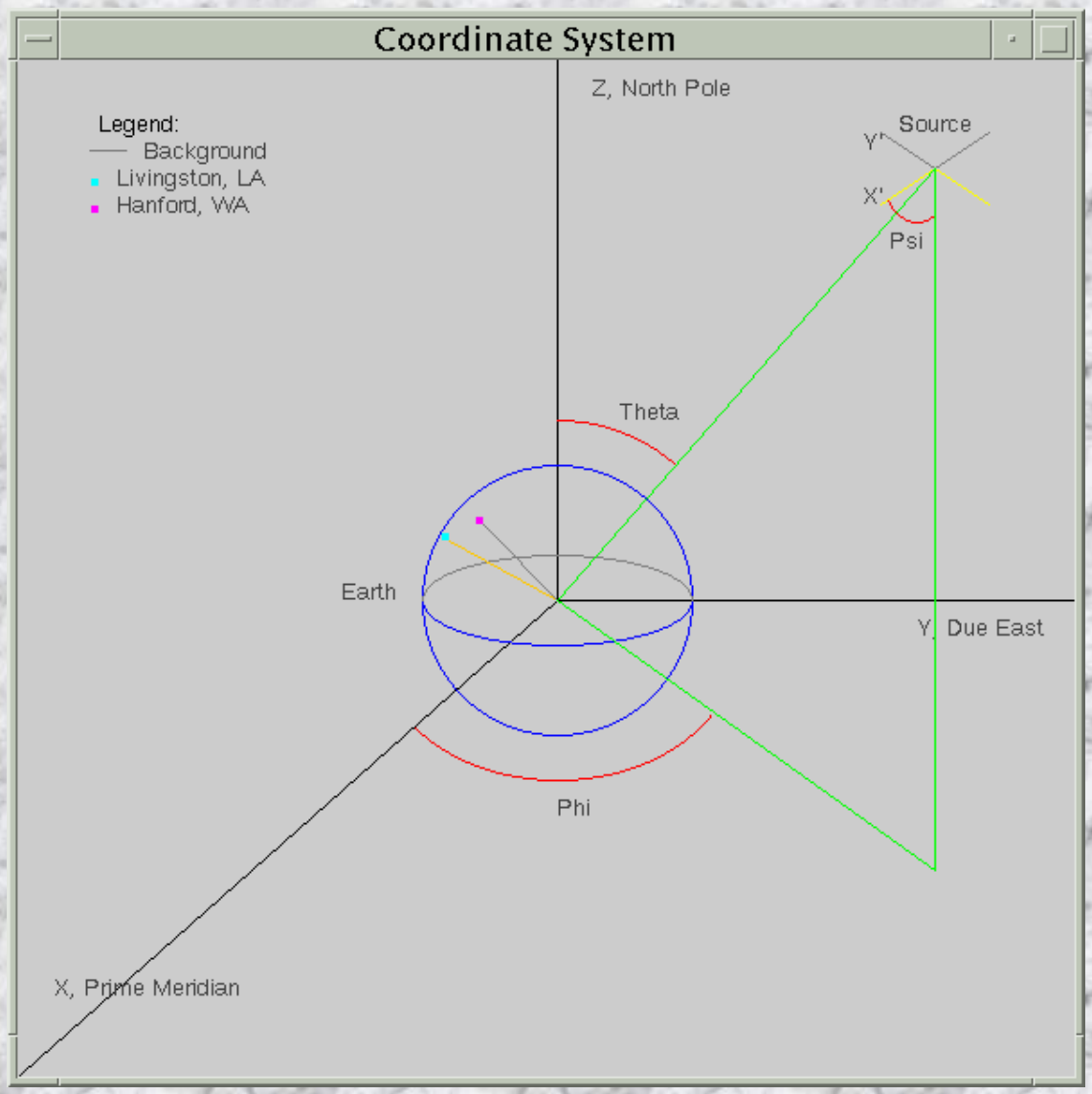
- Choose:
  - GEO
  - CIT
  - Hanford
  - Livingston
  - TAMA
  - VIRGO
- Other
  - Latitude, longitude

Detector Orientation

- Easy quadrant prompts
  - Coordinate transformation



Source Location



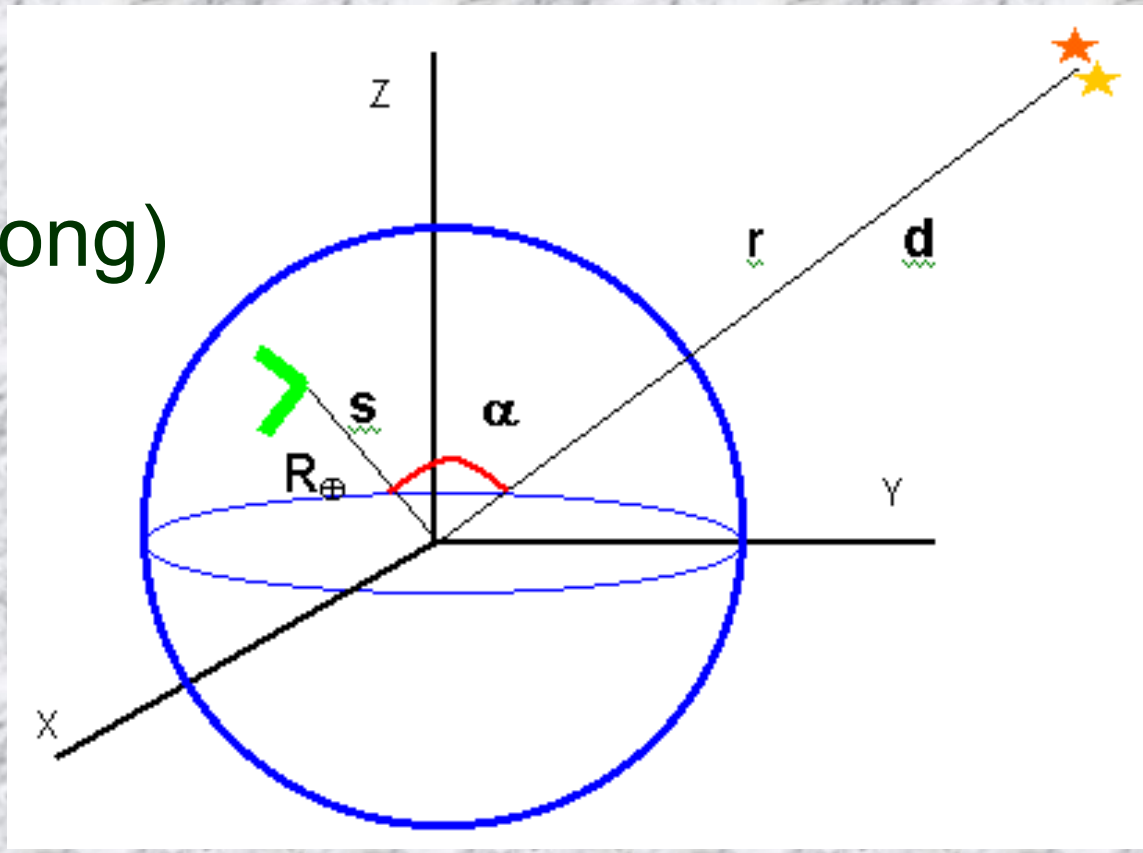
- Earth coordinate system
  - Coordinate transformation

Time Delay

- Source (r, r , a) → (x_s, y_s, z_s)
- Detector (R_r, lat, long) → (x_d, y_d, z_d)

$$t \quad \frac{R \cos}{c}$$

$$\cos \quad \frac{\mathbf{s} \quad \mathbf{d}}{|\mathbf{s}||\mathbf{d}|}$$



Signal Source

- Compact binary
  - Black holes and/or neutron stars
- Supernova
  - Hung-up core-collapse
- User specifies parameters
    - Masses, distance, orientation, *et cetera*
    - Time step
    - Frequency range

Output

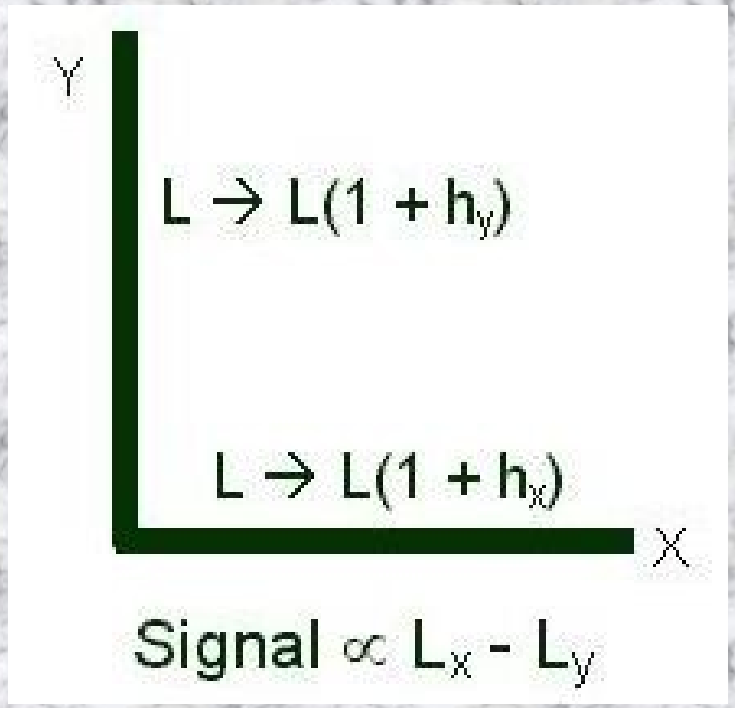
$$h_x \; e \; F_e^x h_e \; e \; F_e^x h_e$$

$$h_y \; e \; F_e^y h_e \; e \; F_e^y h_e$$

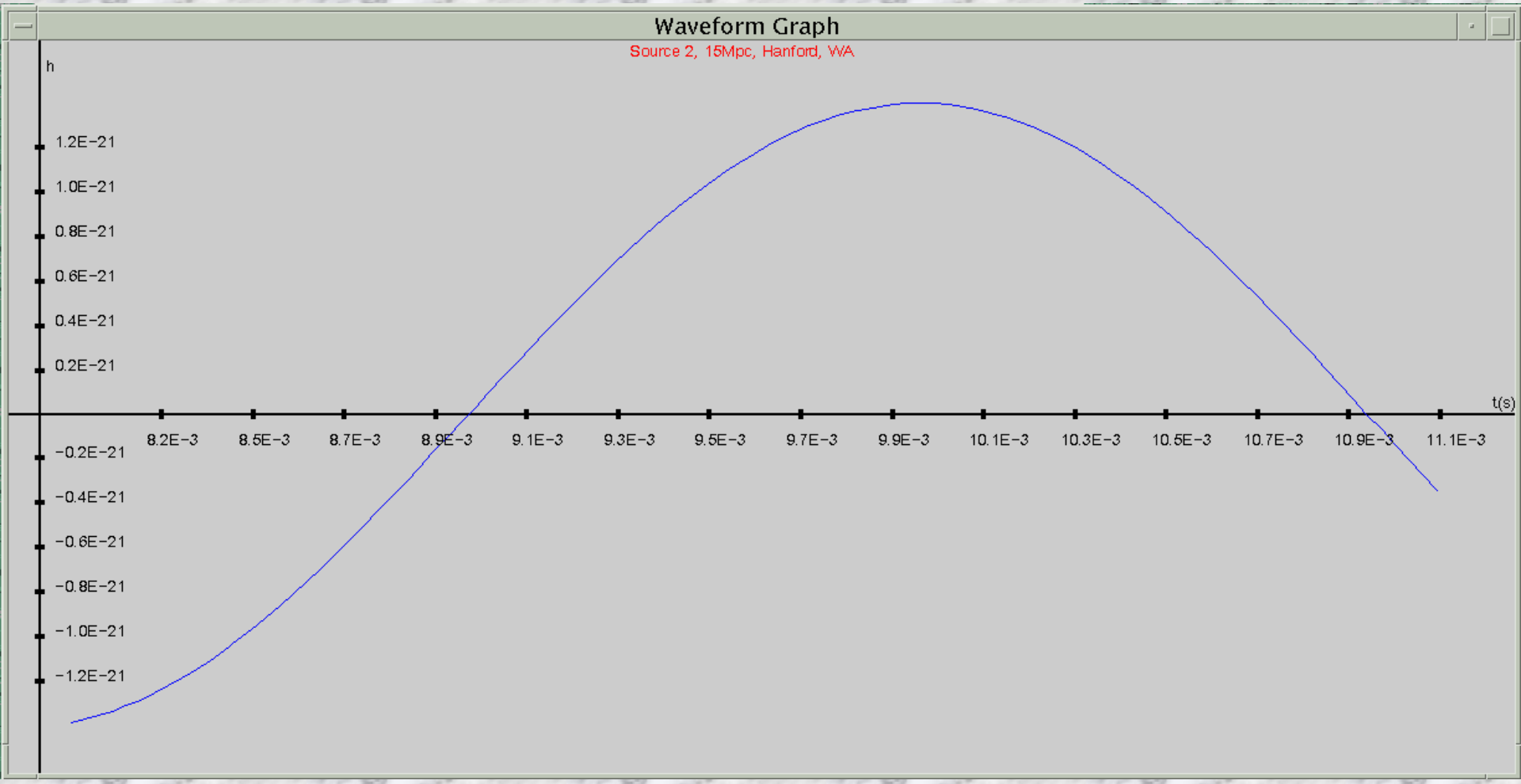
$$h \; e \; \frac{h_x \; e \; h_y}{2}$$

- Time
- Strain for each arm
  - Most useful for E2E

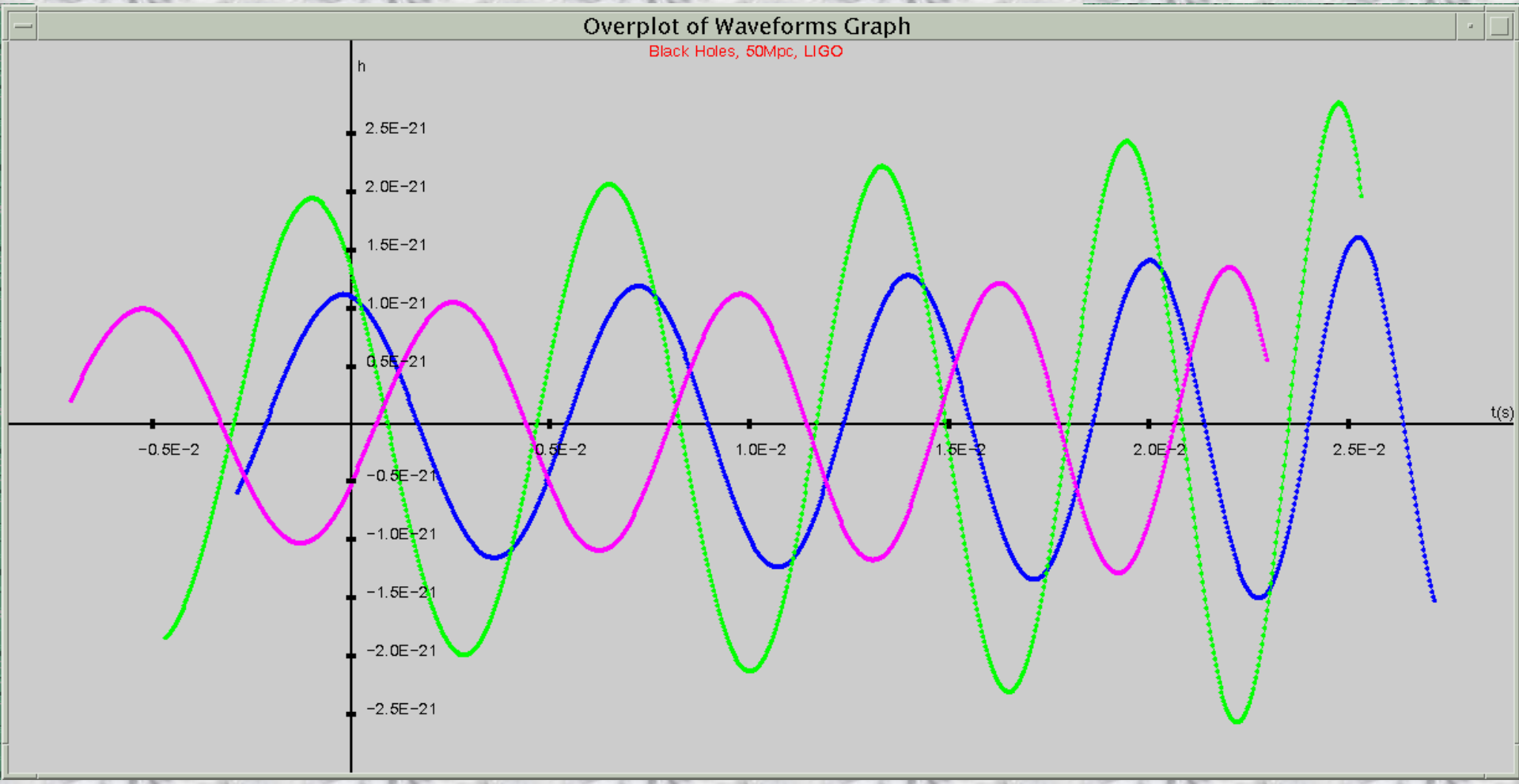
t_1	$h_+(t_1)$	$h_\times(t_1)$
t_2	$h_+(t_2)$	$h_\times(t_2)$



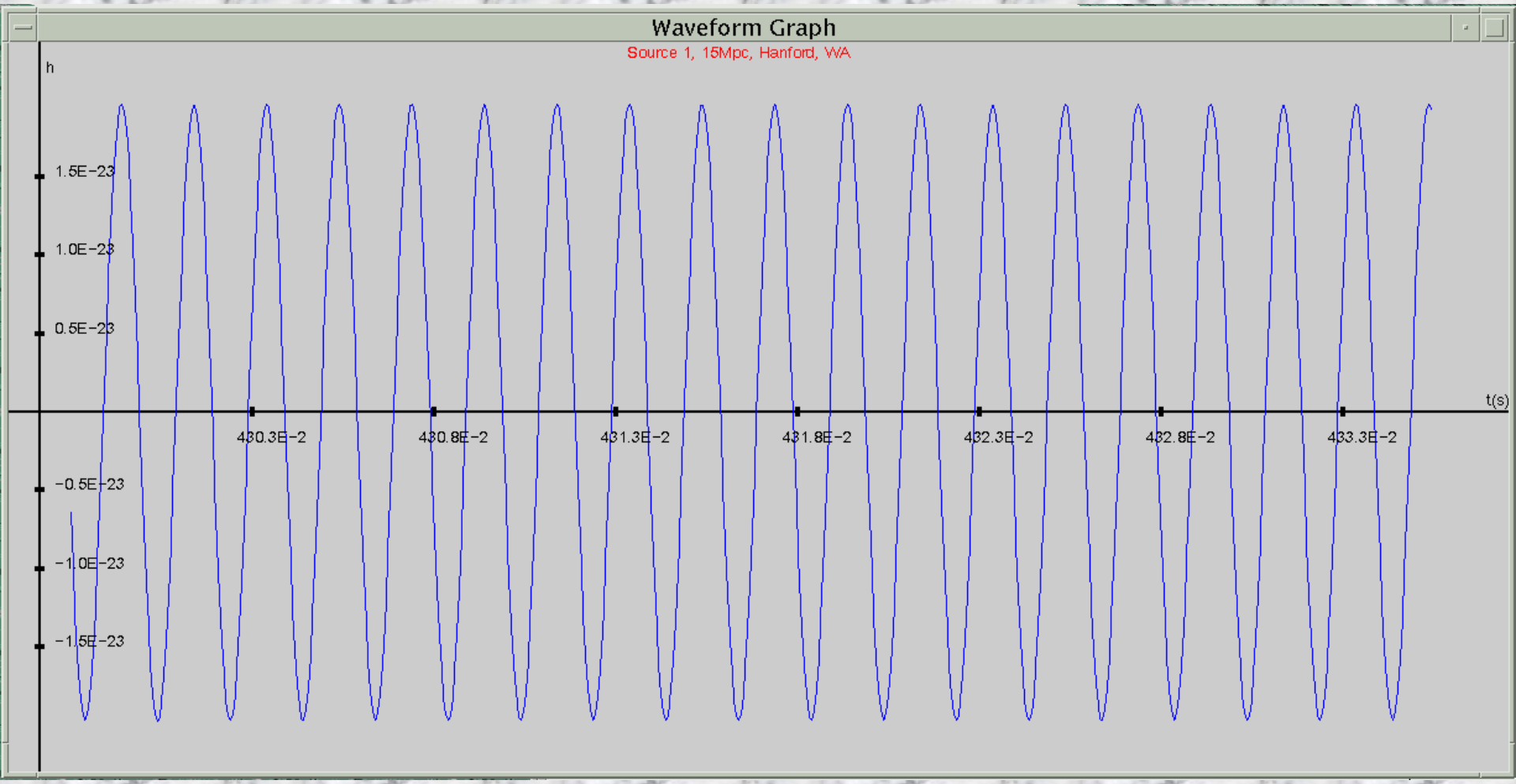
Single Waveform Graph



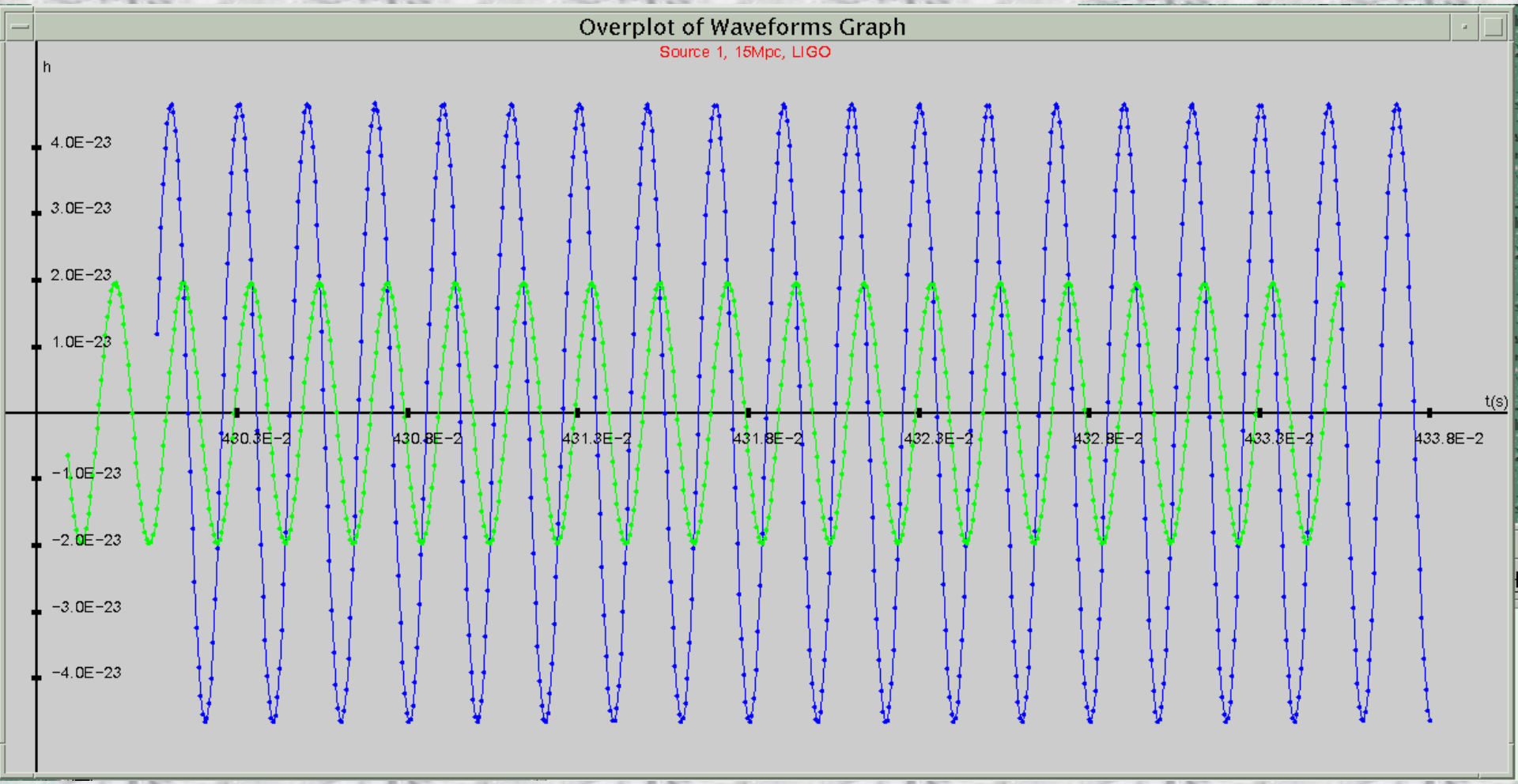
Multiple Waveform Graph



Supernova Single Waveform



Supernova Multiple Waveform



Summary

- Aide E2E
  - Simulate gravitational-wave source
- Program flexibility
  - Detector
  - Source
    - Type, location
- Visualization
  - Comparison graphs
- Documentation
  - http://www.ligo.caltech.edu/~kcooksey/