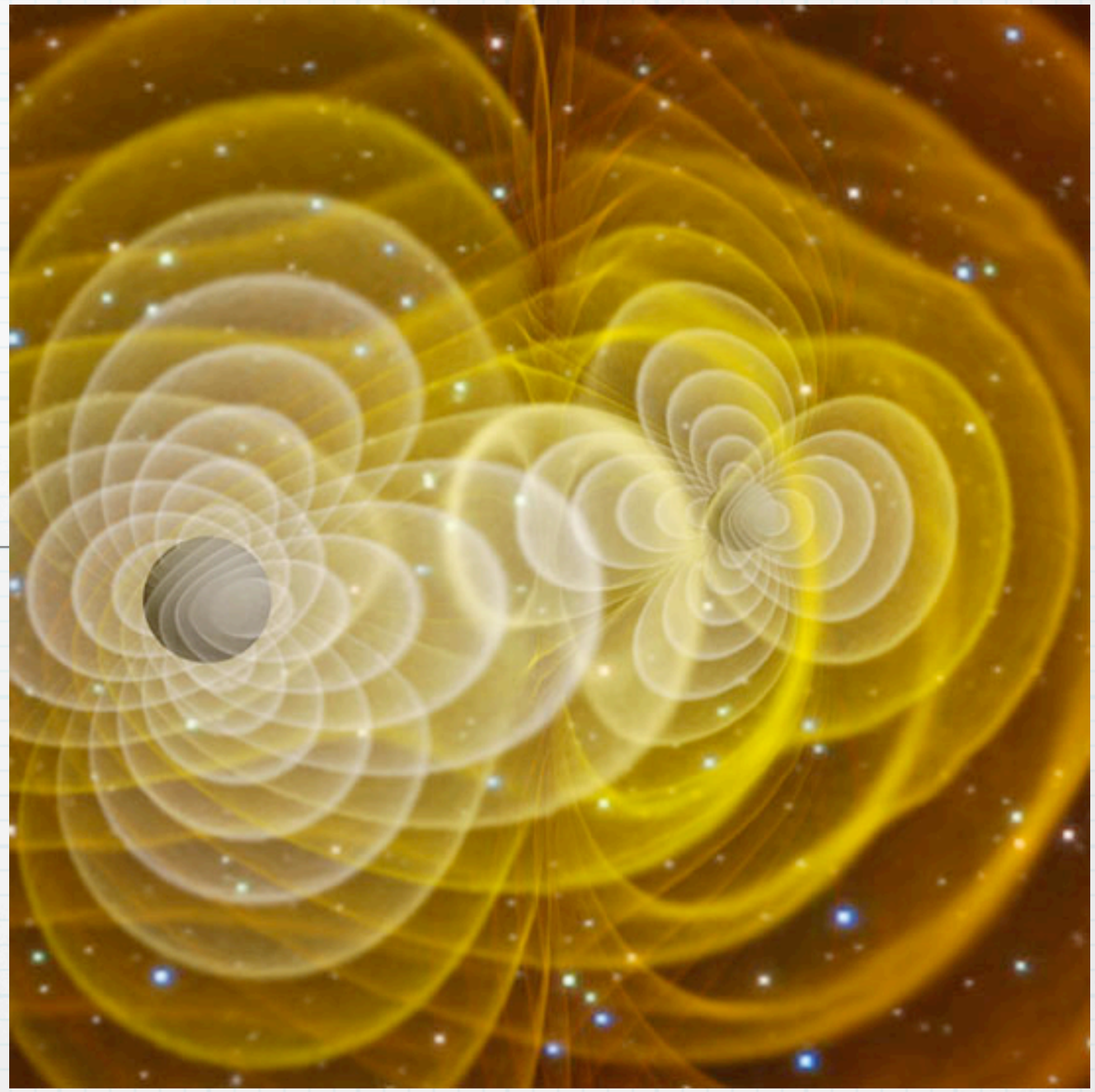
Standard Sirens

Measuring cosmic expansion with merging black holes

M. D. Klimek
May Day 2008

D. Holz & S. Hughes
ApJ 629, 15 (2005)

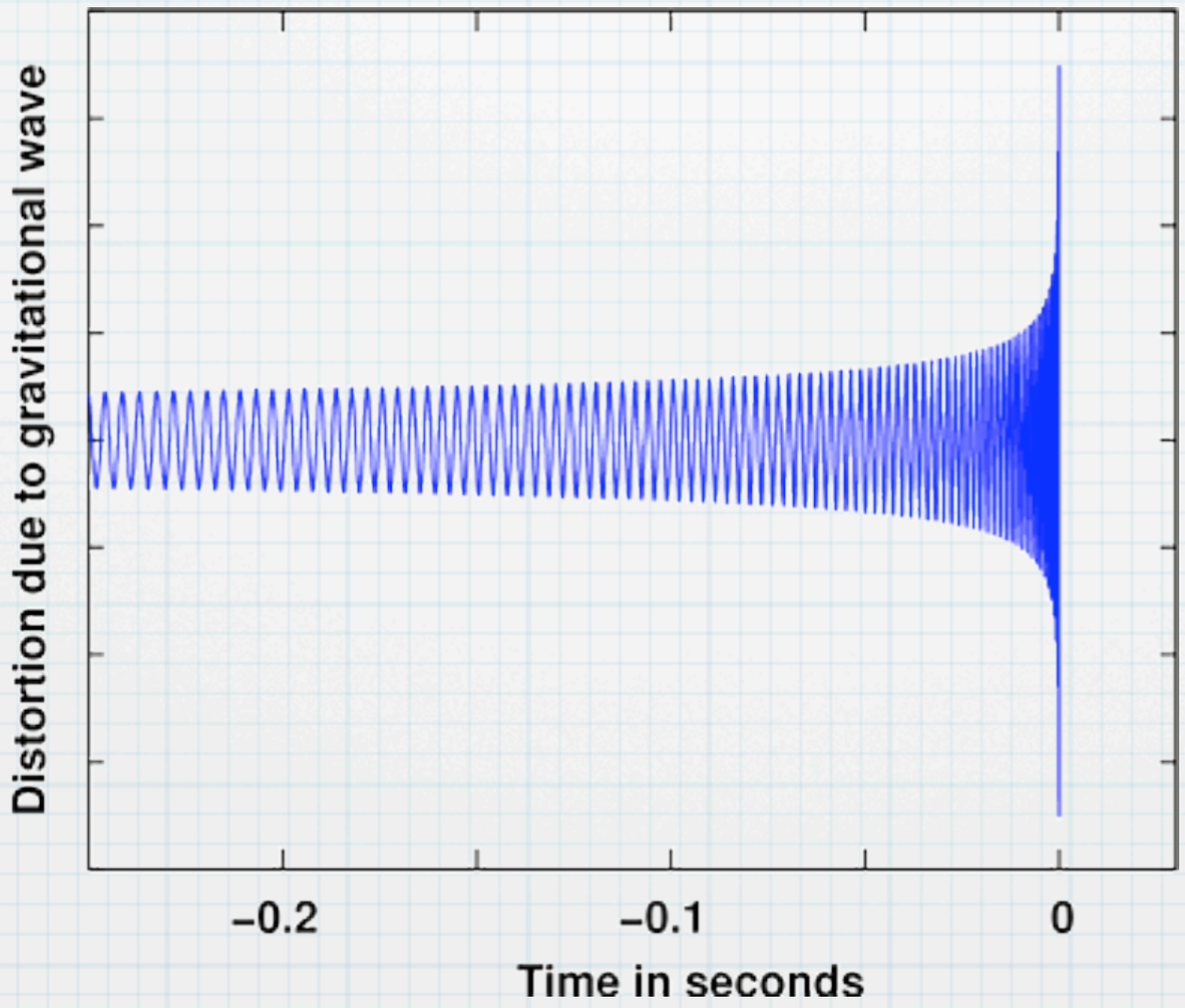


Black hole mergers

* May be the most luminous events in the Universe -- 10^{57} erg in gravity waves!
* Visible to great distances, z=10 or more!
* Expected to trace structure formation and protogalaxies
* Precise determination of luminosity distance possible

The in-spiral waveform

The in-spiral phase of the merger is of interest to us. During this time the GW has a form:



The in-spiral waveform

The in-spiral phase of the merger is of interest to us. During this time the GW has a form:

$$h_\times = \frac{4\mathcal{M}_z^{5/3}[\pi f(t)]^{2/3}(\hat{L}\cdot\hat{n})}{D_L}\sin[\Phi(t)].$$

"Chirp mass"

$$\mathcal{M}_z \equiv (1+z)(m_1 m_2)^{3/5}(m_1+m_2)^{1/5}$$

Degenerate with redshift

Orbit orientation

$$\Phi(t) = \int^t 2\pi f(t')dt'$$
$$= -2[\frac{1}{5}\mathcal{M}^{-1}(t_0 - t)]^{5/8}$$

$$\frac{df}{dt} = \frac{96}{5}\pi^{8/3}\mathcal{M}^{5/3}f^{11/3},$$

freq. and thus amplitude increase as merger progresses

Watching phase can uniquely determine M.

Amplitude alone gives curve in M-D_L plane.

The in-spiral waveform

The in-spiral phase of the merger is of interest to us. During this time the GW has a form:

$$h_\times = \frac{4\mathcal{M}_z^{5/3}[\pi f(t)]^{2/3}(\hat{L}\cdot\hat{n})}{D_L}\sin[\Phi(t)].$$

Can be determined by LISA

"Chirp mass"

$$\mathcal{M}_z \equiv (1+z)(m_1 m_2)^{3/5}(m_1+m_2)^{1/5}$$

Degenerate with redshift

Orbit orientation

$$\Phi(t) = \int^t 2\pi f(t')dt'$$

$$= -2[\frac{1}{5}\mathcal{M}^{-1}(t_0 - t)]^{5/8}$$

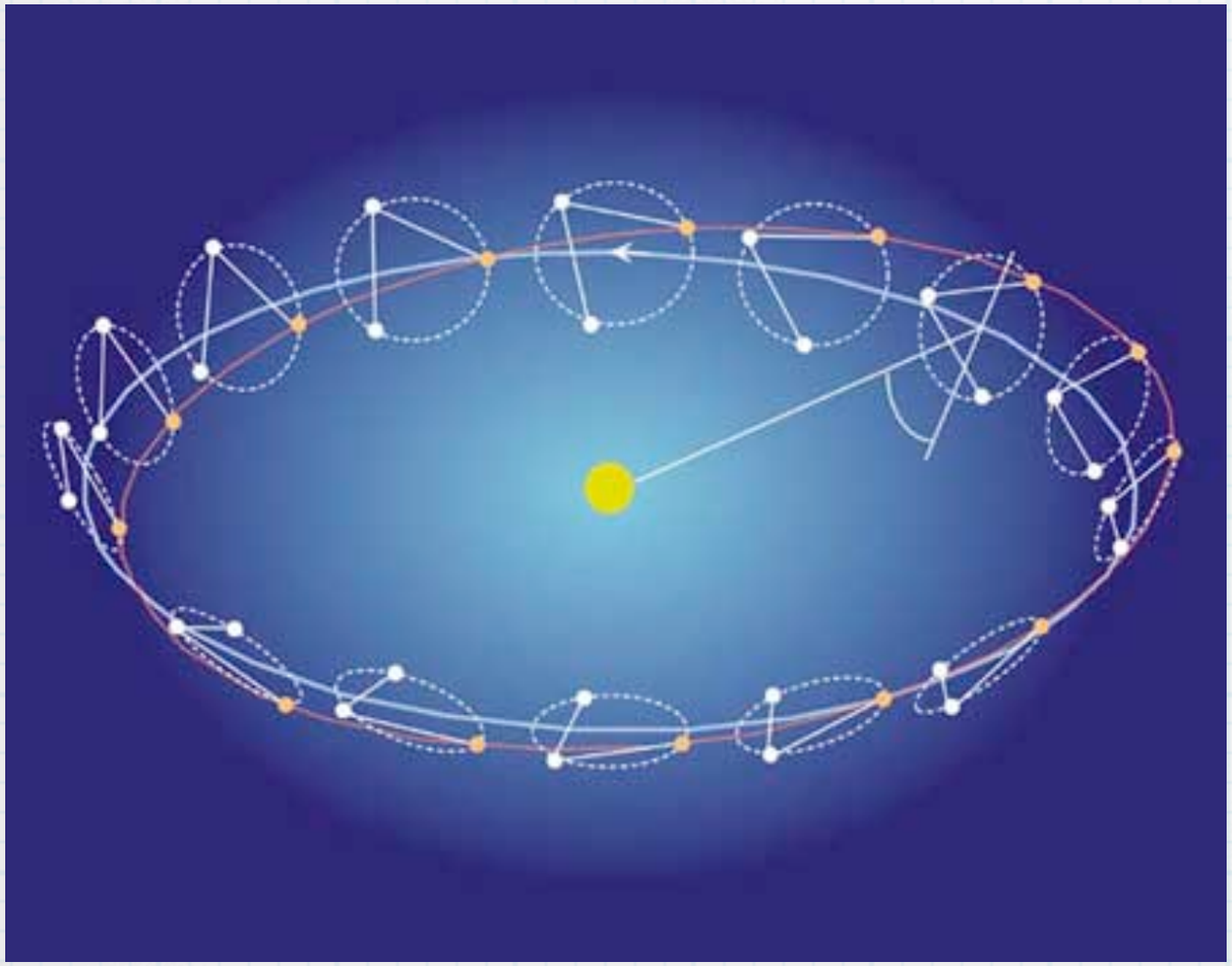
$$\frac{df}{dt} = \frac{96}{5}\pi^{8/3}\mathcal{M}^{5/3}f^{11/3},$$

freq. and thus amplitude increase as merger progresses

Watching phase can uniquely determine M.

Amplitude alone gives curve in M-D_L plane.

Laser Interferometry Space Antenna (LISA)



The LISA constellation follows the earth in a tumbling orbit. This constant change in orientation allows good determination of the GW source position and orientation, thus breaking the degeneracy and allowing a unique determination of the luminosity distance.

EM counterparts

* Although GWs allow a powerful determination of D_L, they don't provide any redshift information.
* Many theoretical models predict electromagnetic afterglows or precursors to merger events.
* How feasible will it be to find an EM counterpart?

EM counterparts

* Based on the density of galaxies seen in HDF and the expected uncertainty in the pointing measurement of LISA, the authors estimate order 10 galaxies that will require EM follow-up.
* Merger host candidates likely to have disturbed morphologies.

Selling points

* a bit less convenient, perhaps, but entirely different systematics

    * Mergers visible in GWs to very high redshift/distances

    * Potentially more precise than SNe

    * Interesting in other cosmological contexts as well