Astrophysics of gravitational wave sources

Lecture 11: Merger & subsequent evolution of the remnant

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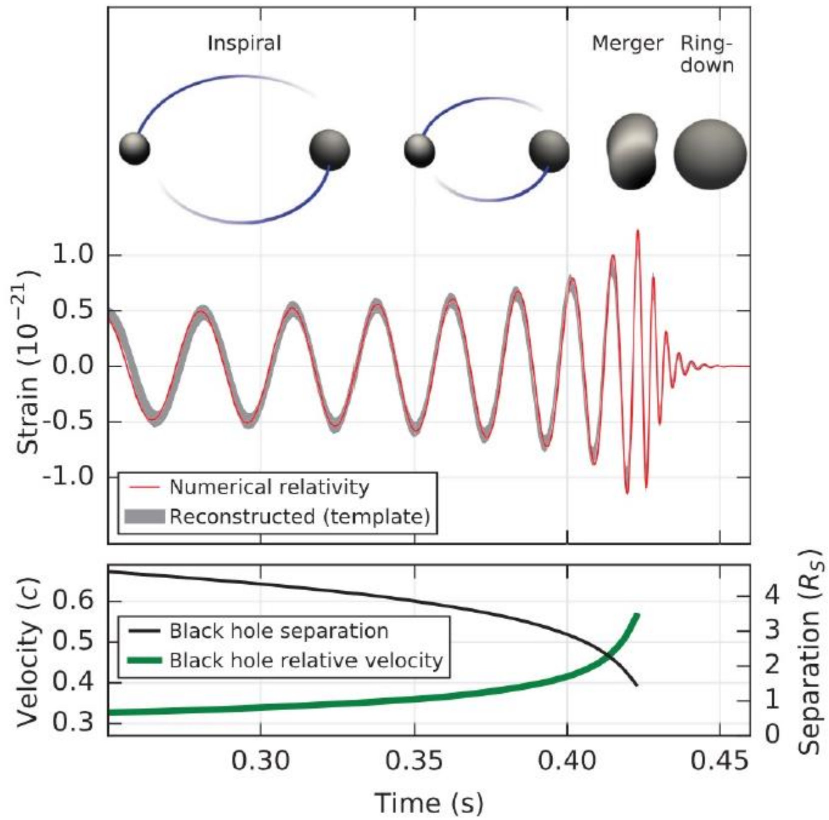
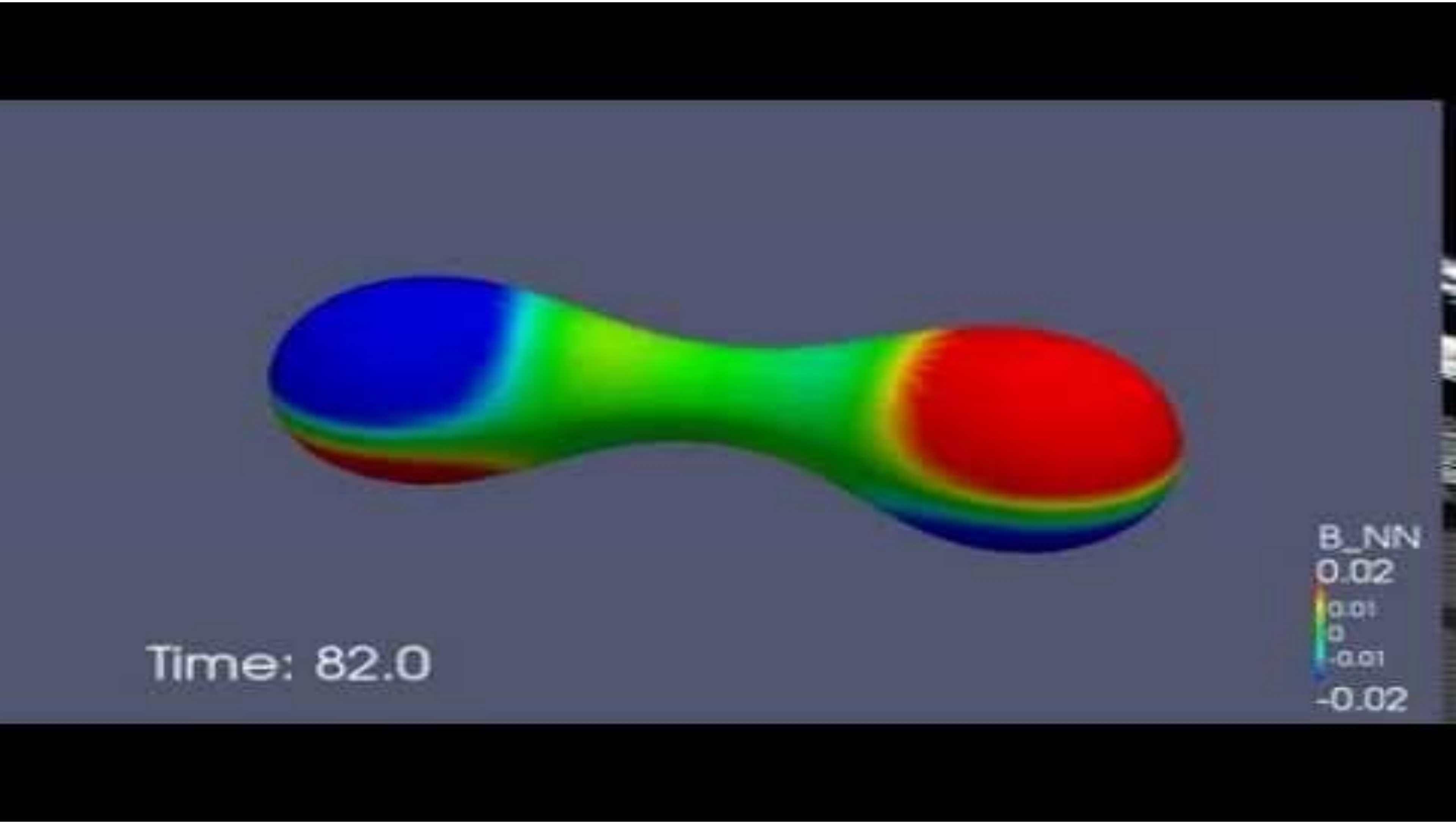
Binary black hole mergers

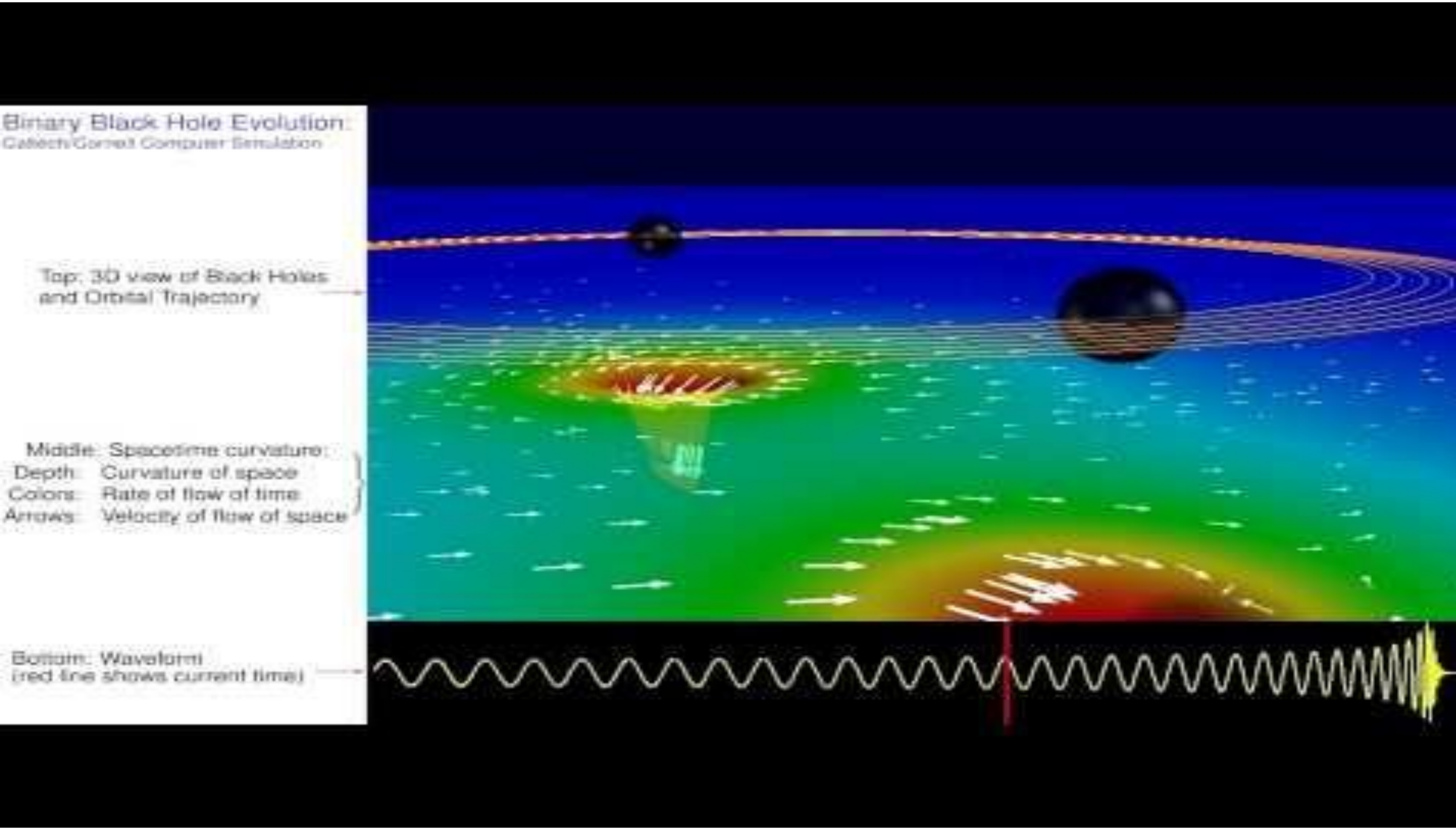


Abbott et al. (2016)

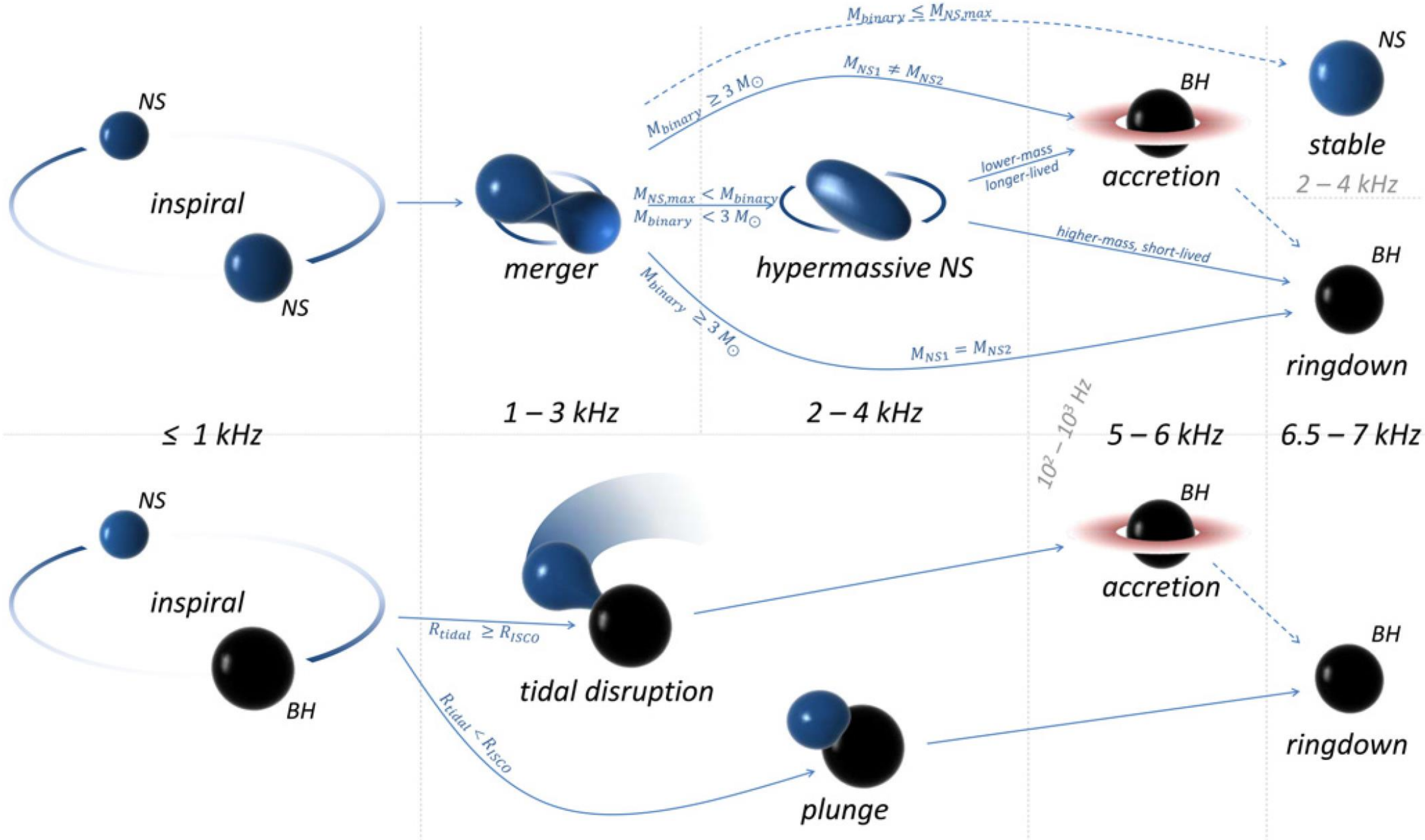
Black hole collision



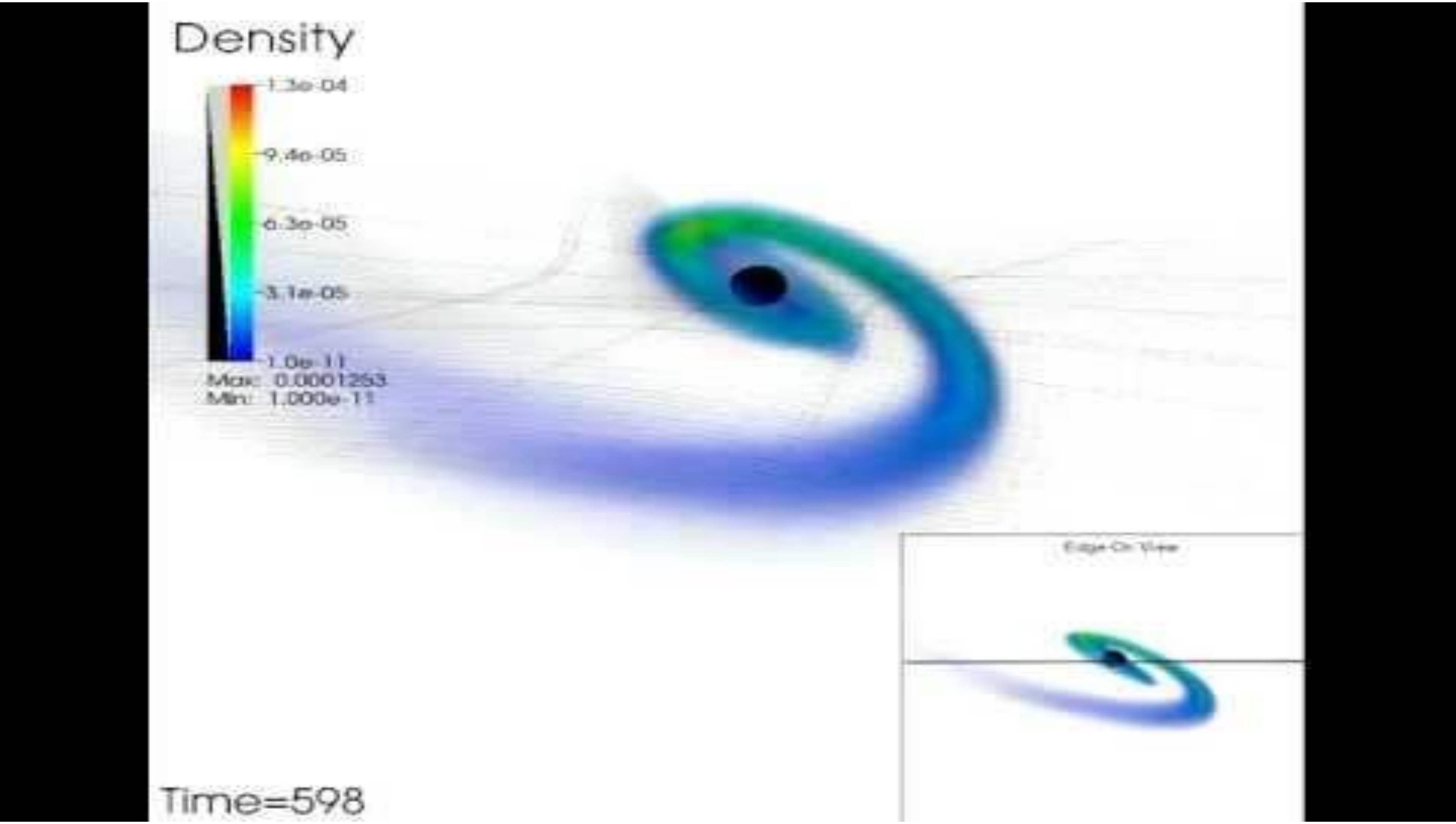
https://www.black-holes.org/



https://www.black-holes.org/

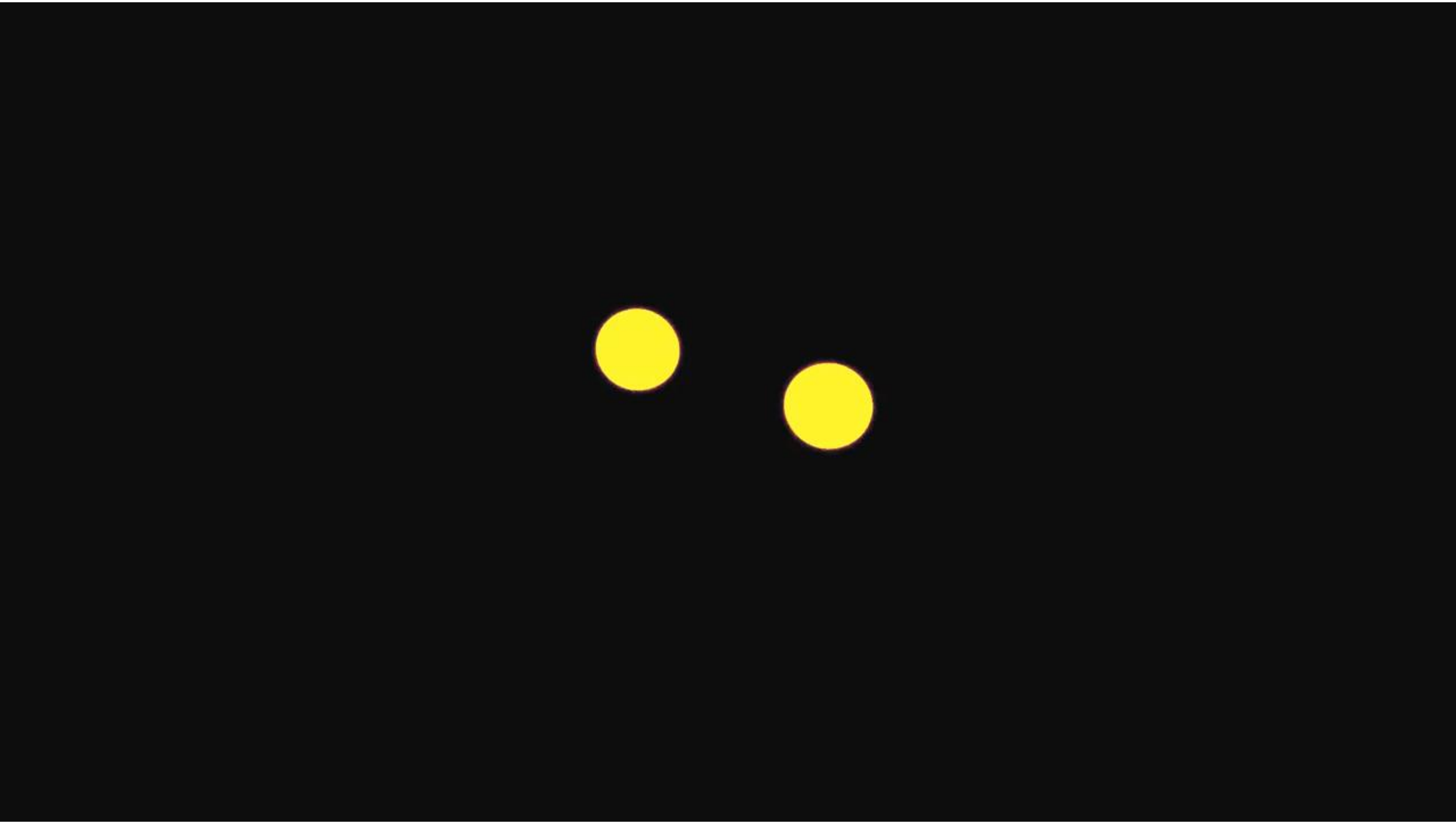


Bartos et al. (2013)



https://www.black-holes.org/

Binary neutron star merger



Radice et al.

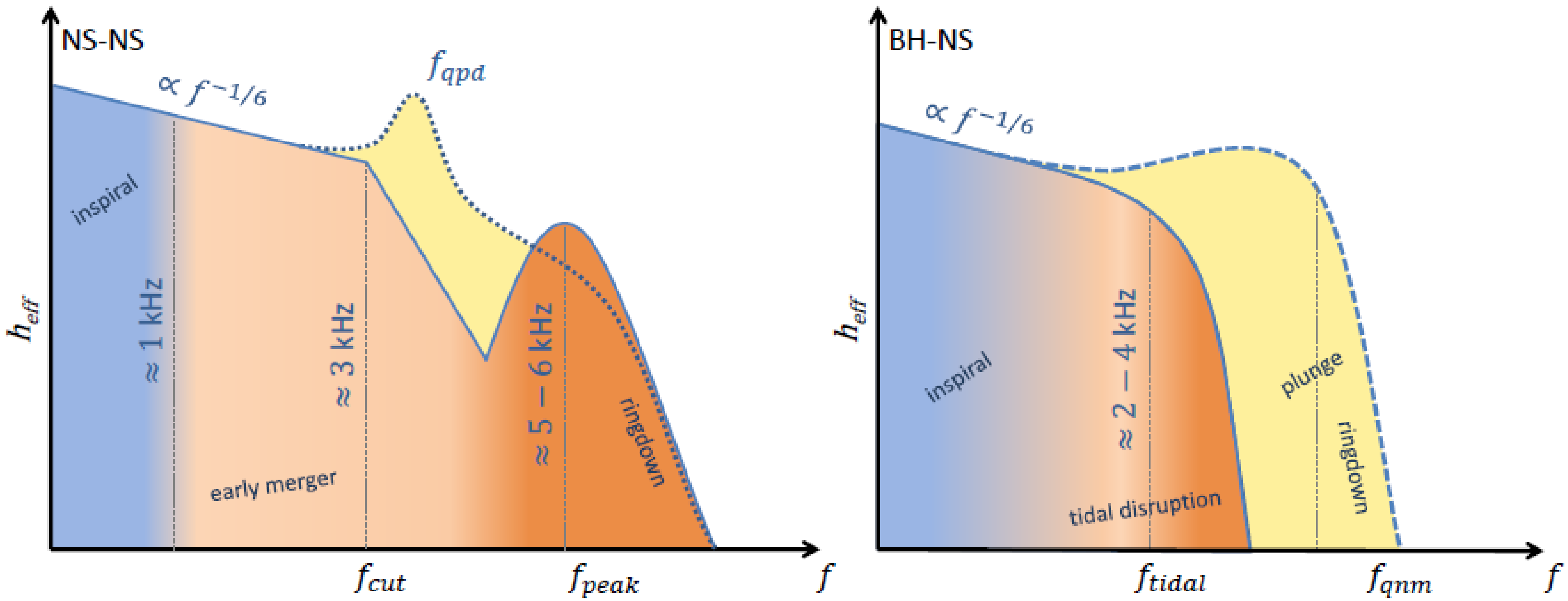


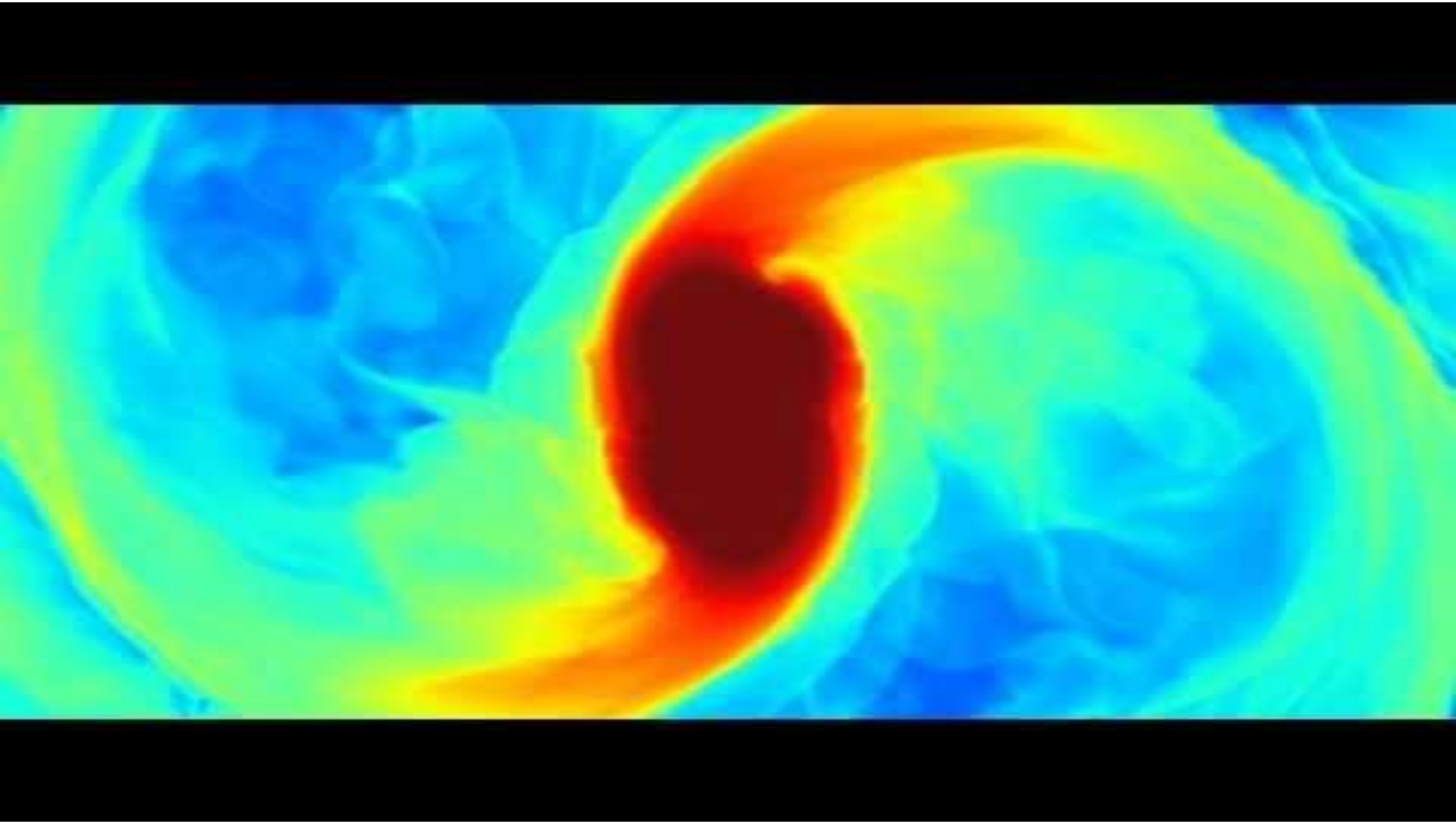
Figure 2. Schematic spectrum of effective amplitude h_{eff} for compact binary coalescences. **(left)** NS-NS binaries. During the inspiral phase up to $\approx 1\,\text{kHz}$ and the early-merger phase up to $f_{\text{cut}} \sim 3\,\text{kHz}$, the system retains its binary-like structure and h_{eff} scales as $f^{-1/6}$. If a BH is promptly formed, matter quickly falls in the BH, losing angular momentum through emitting GWs around a peak frequency $f_{\text{peak}} \sim 5-6\,\text{kHz}$. If a protoneutron star is formed from a NS-NS binary, it will radiate GWs through its quasiperiodic rotation at $f_{\text{qpd}} \sim 2-4\,\text{kHz}$. After matter falls into the BH, the BH rings down, emitting GWs at $\approx 6.5-7\,\text{kHz}$ with exponentially decaying amplitude. **(right)** BH-NS binaries. During the inspiral phase, h_{eff} scales as $f^{-1/6}$. If the NS is tidally disrupted before reaching the ISCO, GW emission will cut off at $f_{\text{tidal}} \sim 2-4\,\text{kHz}$, i.e. the GW frequency at tidal disruption [66, 67]. If the NS plunges into the BH without being tidally disrupted, the plunge cuts off GW emission from the binary and excites the quasinormal mode of the remaining BH, which rings down emitting GWs at frequency f_{qnm} (NS-NS representation was partially inspired by Kiuchi et al. [61]; BH-NS representation is based on Kyutoku et al. [66]).

Bartos et al. (2013)

Subsequent evolution of the (rotating) remnant

$$\beta \equiv T_{\rm rot}/|W|$$

- Dynamical instability (non-axisymmetric shape with same angular momentum is energetically favorable
  - Uniformly rotating body $\beta \gtrsim 0.27$
  - Differentially rotating body $\beta \lesssim 0.09$
- Secular instability (redistribution of angular momentum)
  - Dissipation due to GW or viscosity $\beta \gtrsim 0.14$
- What about magnetic fields?



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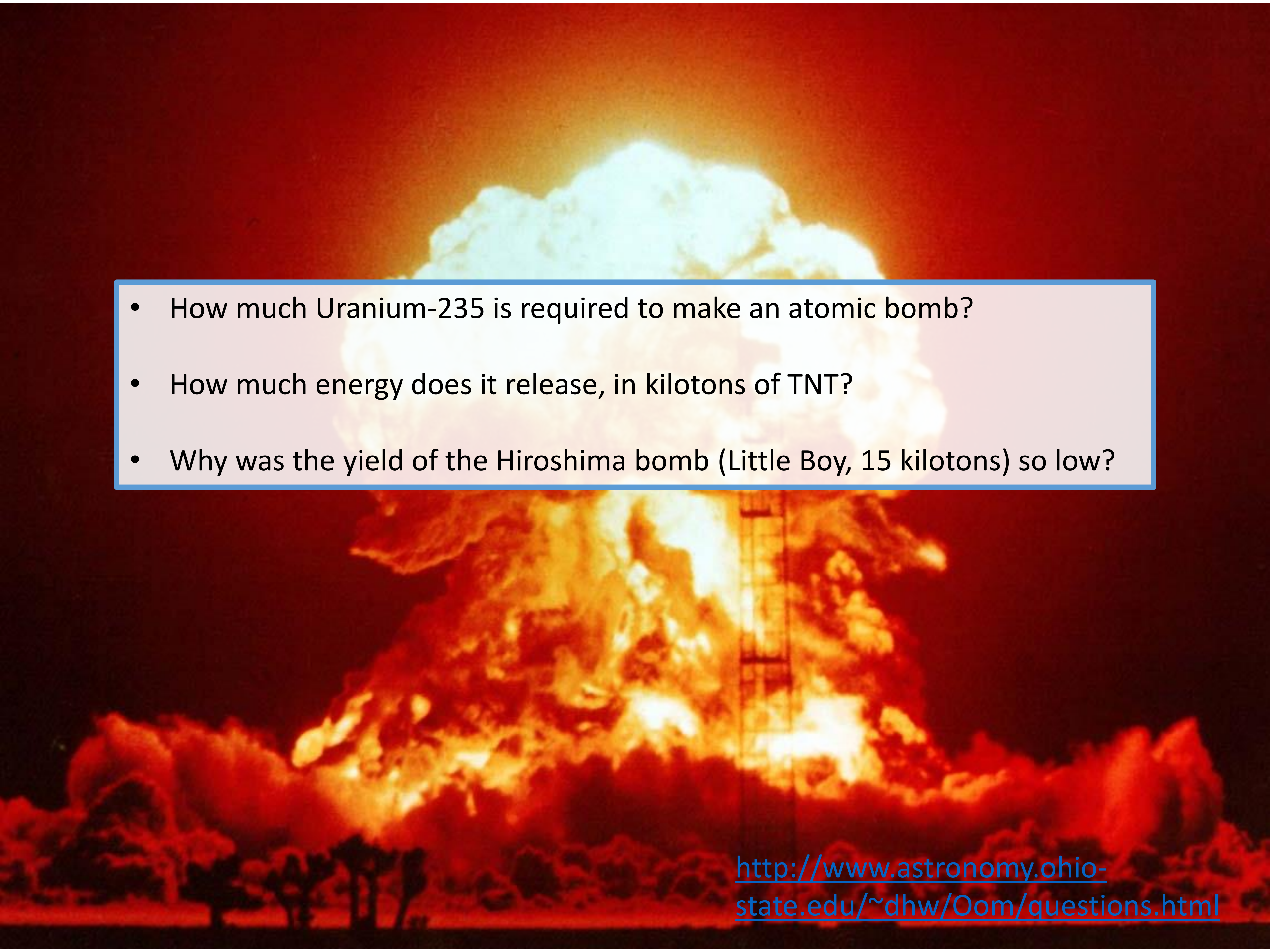

- How much Uranium-235 is required to make an atomic bomb?
- How much energy does it release, in kilotons of TNT?
- Why was the yield of the Hiroshima bomb (Little Boy, 15 kilotons) so low?

http://www.astronomy.ohio-state.edu/~dhw/Oom/questions.html