Can Thorne-Zytkow objects source GW190814 type events?

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- Mass gap between black holes and neutron stars
- Gravitational wave detection of mass gap event
- What is the mass gap object?

Mass Gap

- Neutron stars greater than about 2 solar masses cannot exist (maximum mass that can be held up by neutron degeneracy pressure)
- If the envelope is not ejected it is usually massive enough to form a black hole of at least 5 solar masses.
- Thus there is expected to be a “mass gap” between the most massive neutron stars and the least massive black hole
- This expectation is supported by observations of X-ray binaries: a black hole or neutron star in a binary system that is accreting gas from its companion

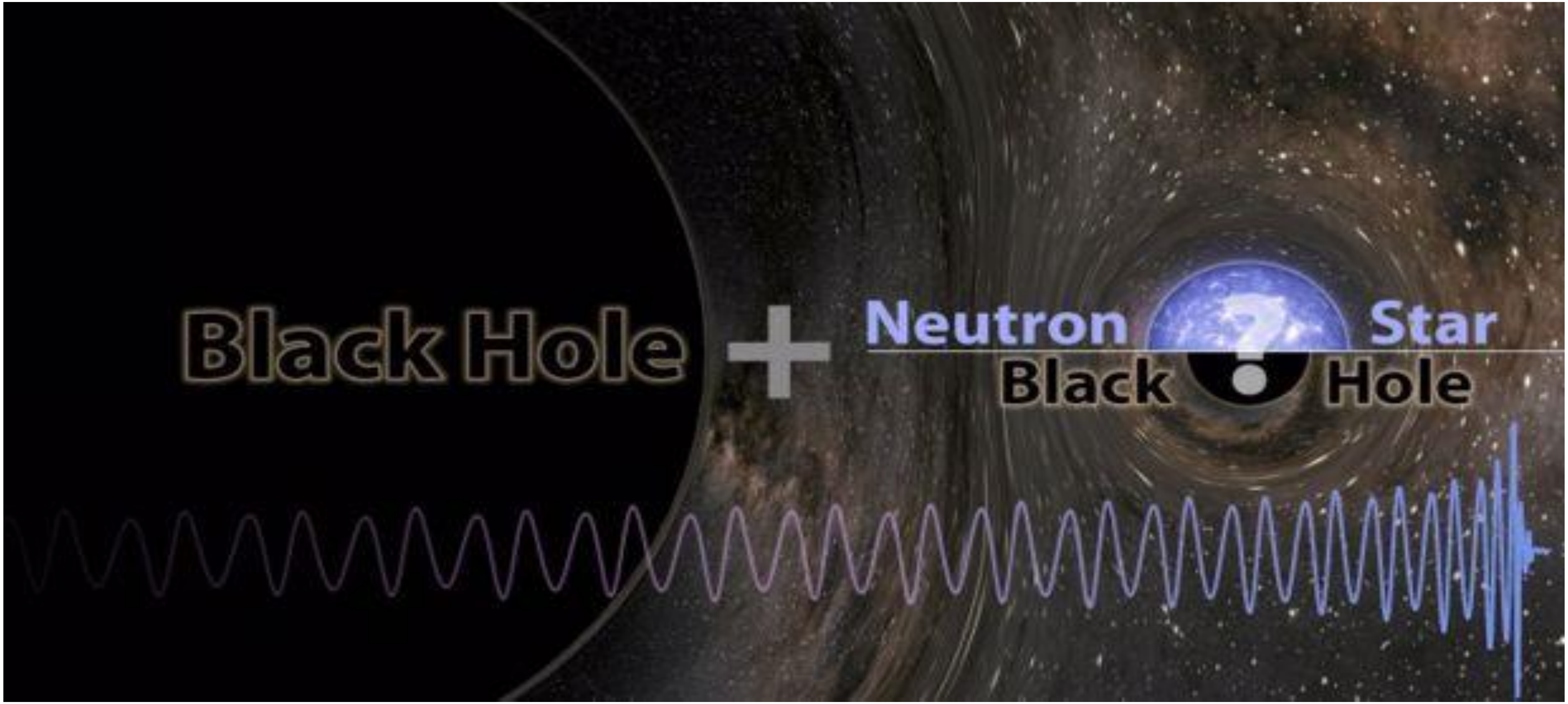
Detection of Gravitational waves

Gravitational waves from a mass gap event

- However, LIGO has detected a “mass-gap” event: the merger of a 23 solar mass black hole with a 2.6 solar mass object.

- This object is either the most massive neutron star or the least massive black hole ever observed.

GW190814



What is it?

- Almost certainly too heavy to be a neutron star, so probably a black hole.
- But we know something that makes black holes in this mass range: binary neutron star mergers.
- Yes, but LIGO-Virgo detection of a mass gap object leads to estimates of rates of merger of such objects with black holes of 1-23 per cubic Gigaparsec per year. This is much too large to be accounted for by the black holes formed from binary neutron star mergers.

Thorne-Zytkow object: a red giant star with a neutron star in its core

- K.S. Thorne and A.N. Zytkow, Astrophys. J. 212, 832 (1977)
- Estimated to form at the rate of about 1.5 X 10^{-4} per year in a Milky Way type galaxy.
- Can form mass gap black hole if the neutron star absorbs enough material to exceed the maximum neutron star mass.
- We estimate the formation rate of mass gap objects from this mechanism of around 900 per cubic Gigaparsec per year.

But do they merge with black holes at the appropriate rate?

- Cluster or field?
- Cluster: in dense stellar environments (globular clusters, nuclear clusters) a black hole can encounter and eventually merge with another black hole.
- Field: massive stars born in the same star system may eventually (sometimes through a common envelope phase) come close enough that the black holes they form may merge within the age of the universe
- For Thorne-Zytkow objects, this would require at least triples.

Clusters? No!

- Simulations of the dynamics of black holes in clusters give far too small a probability of merger between a mass gap object and a more massive black hole.
- The reason is that the dynamics of black holes in clusters leads to the formation of binaries of similar mass: even if a mass gap object were to form a binary with a more massive black hole, its place in the binary would be taken by a more massive black hole before the orbit could harden sufficiently.

Field Triples? Maybe.

- The star system would have to be at least a hierarchical triple, with the most massive star forming a black hole, then the middle star forming a neutron star and merging with the red giant phase of the least massive star.
- A reliable estimate of the rate of this process would need the sort of evolution and dynamics codes used for binaries, but generalized for triples.

Conclusion

- Thorne-Zytkow objects are a possible explanation for the mass gap event.
- The cluster version of this scenario is ruled out, but the hierarchical triple version is not.