Wednesday, April 19, 2017

Exam 4, Skywatch 4, Friday, April 21.

***Review Session Tomorrow, 5 – 6 PM, Welch* 2.308.**

Lectures 21 to 30

Reading for Exam 4:

Chapter 8 Neutron Stars - Sections 8.1, 8.2, 8.5, 8.6, 8.10;
Chapter 9 Theory of Black Holes: 9.1 to 9.5, 9.8

Astronomy in the news?

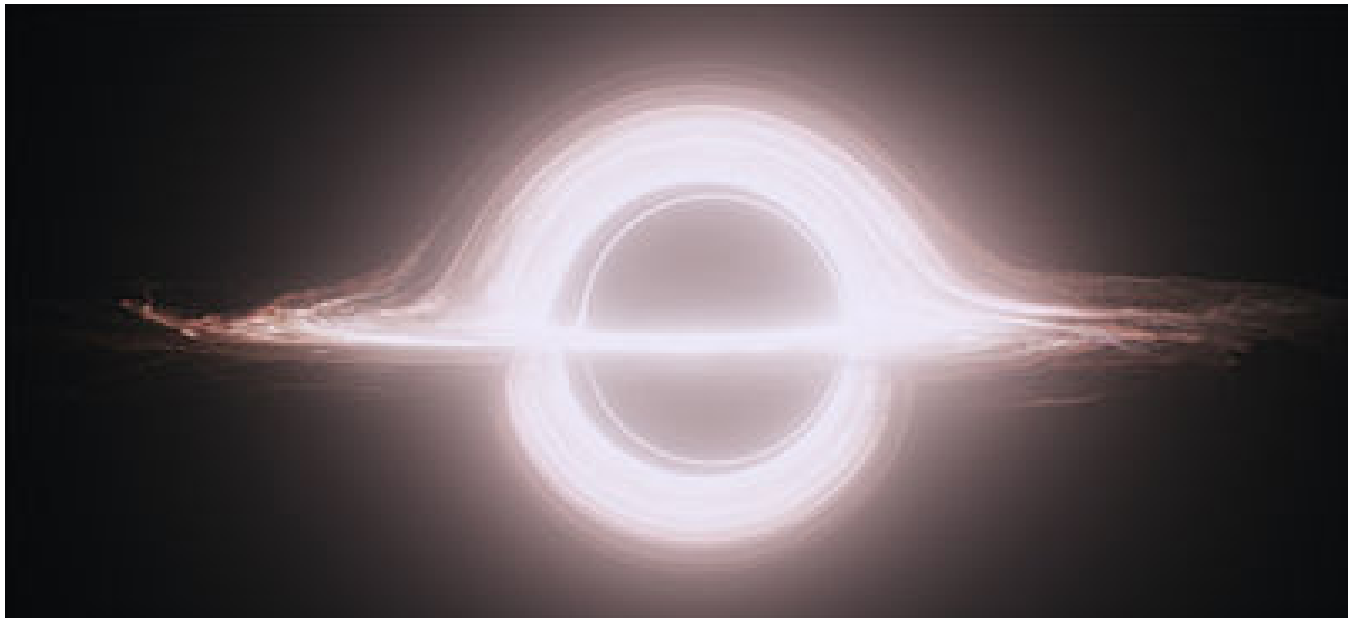
Asteroid passed by Earth only 4 times further than the Moon.

National Geographic Channel will do a 10 part series on the life of Einstein, “Genius,” beginning April 25 (Monday).

Goal:

To understand how we have discovered supermassive black holes and how they affect galaxy formation and evolution.

Gargantua: the giant black hole from the movie *Interstellar*



Supermassive Black Holes

Long suspected in quasars, active galactic nuclei: huge power from small volume, billion solar mass black hole could do it.

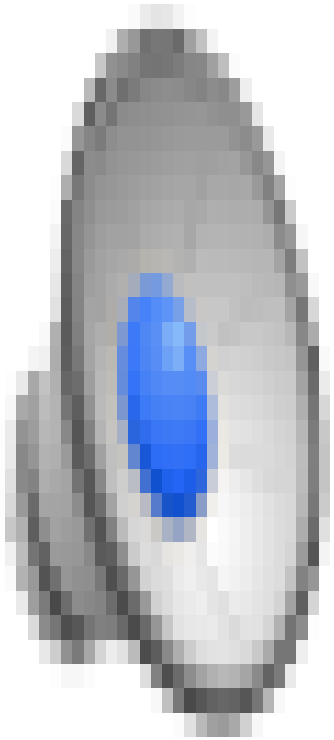
Proof that many (even most! John Kormendy, Karl Gebrhardt UT) ordinary galaxies also have a supermassive black hole in their centers (dead quasar).

Again, do not yet see a "dark spot," but use Kepler's Laws, motion of many stars, gas $\Rightarrow$ orbital period, separation

3.7 million $M_{\odot}$ black hole in our Galaxy [UCLA link – movie; next slide]

Center of Milky Way Galaxy in direction of constellation Sagittarius – (find Sagittarius for sky watch)

Stars orbiting the supermassive black hole in the center of the Milky Way



Supermassive Black Holes

Up to billion $M_\odot$ black holes in quasars.

Jet from billion $M_\odot$ black hole in center of M87, large elliptical galaxy in the Virgo cluster (find Virgo!)

Surprising discovery:

It was long thought that supermassive black holes were somewhat incidental to galaxies.

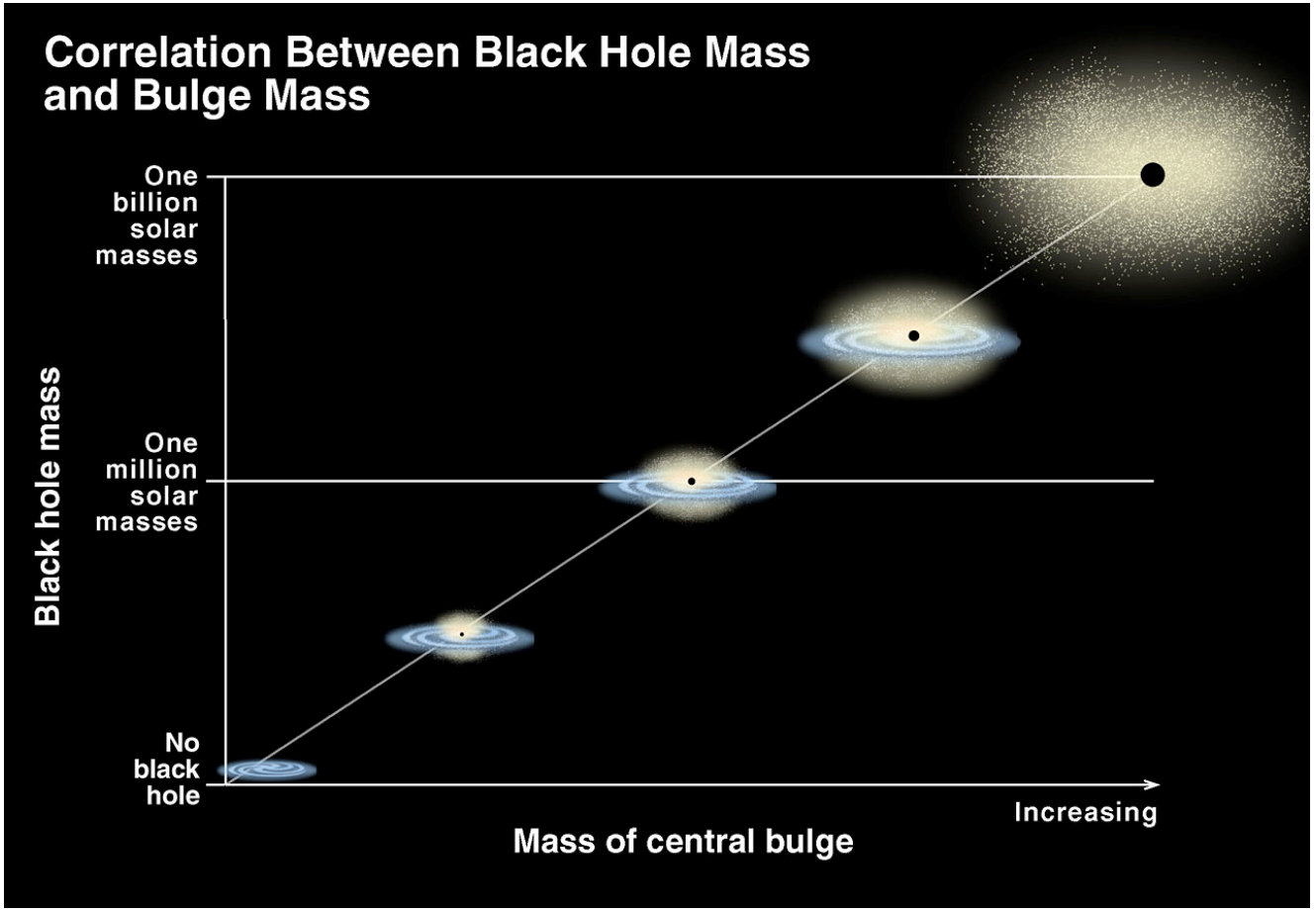
Formed of matter that somehow drained into the center of the galaxy, so galaxy could have large mass or small mass black hole depending on circumstances.

Recent work by John Kormandy and Karl Gebhardt (UT) and others has shown that even stars so far from the center that they cannot possibly feel the gravity of the black hole *now* are moving in such a way that ***the larger the mass black hole, the higher the speed of the stars!***

Andromeda
M31

Correlation Between Black Hole Mass and Galaxy Bulge Mass

Mass of Black Hole



Mass of Central Bulge of Galaxy

The implication is that the mass of the galaxy (at least the inner portions, the Bulge) is always close to 800 times the mass of the black hole.

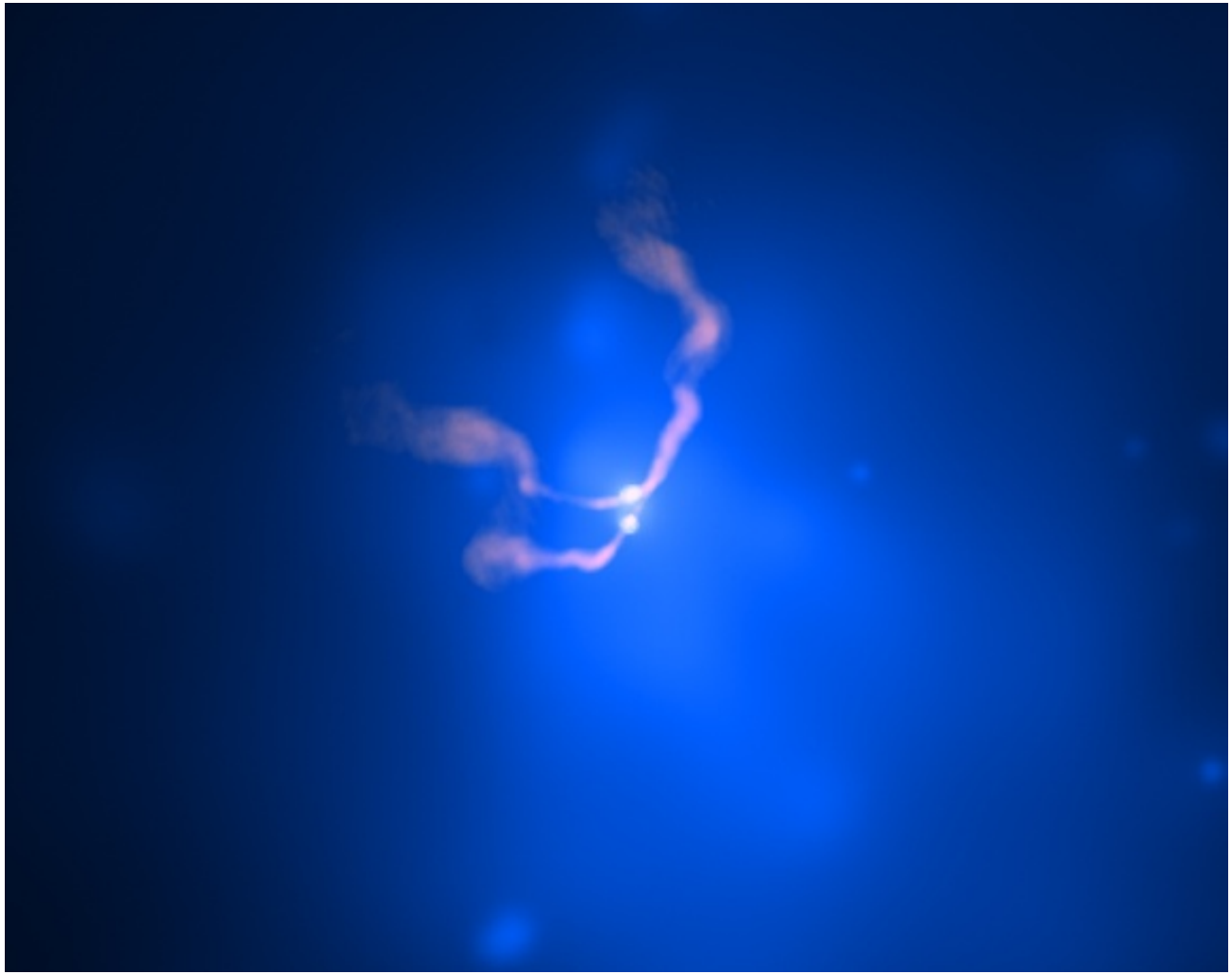
This means that ***the formation of the black hole is somehow intimately connected with the formation and structure of the whole galaxy.***

Galaxies “know” how big a black hole to make.

Mechanism uncertain: Does the galaxy control the black hole or the black hole somehow control the galaxy?

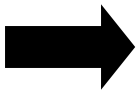
Most popular current idea: energy from accretion of matter into disk around black hole feeds back to the surrounding galaxy, blowing excess galaxy gas away when galaxies are young and growing.

Colliding black holes in galaxy 3C75, feed energy back into the stars and gas of the colliding galaxies.

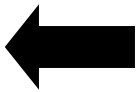


One Minute Exam

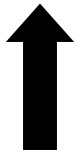
What is the relation between the mass of a supermassive black hole and the galaxy in which it resides?



There is none, the black hole can be big or small, depending on how it grew and for how long



The larger the mass of the galactic bulge, the smaller the mass of the black hole

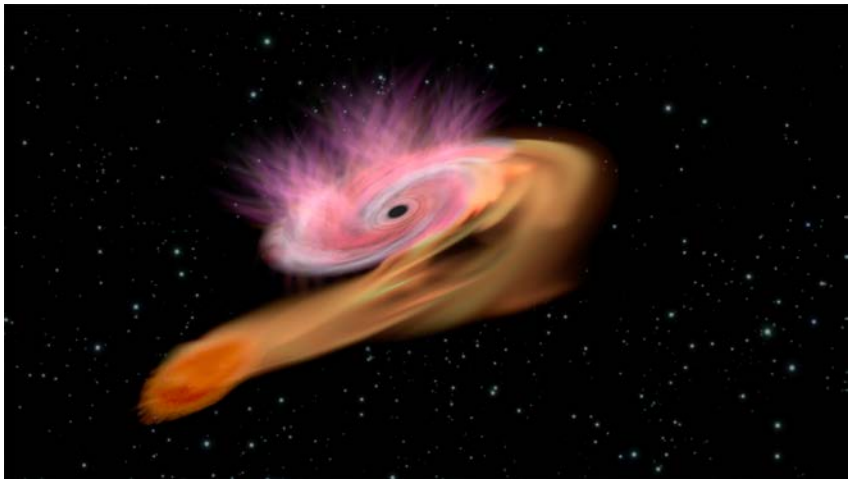


The larger the mass of the galactic bulge, the larger the mass of the black hole

The larger the radius of the galactic bulge, the larger the mass of the black hole

Tidal Disruption Events (TDE)

Another way to discover supermassive black holes. When a star passes near a supermassive black hole the tidal forces can rip the star apart. The torn matter temporarily forms an accretion disk around the black hole and sometime magnetic jets. About 70 candidates discovered, one at Texas.



Now, a whole new way to discover black holes!

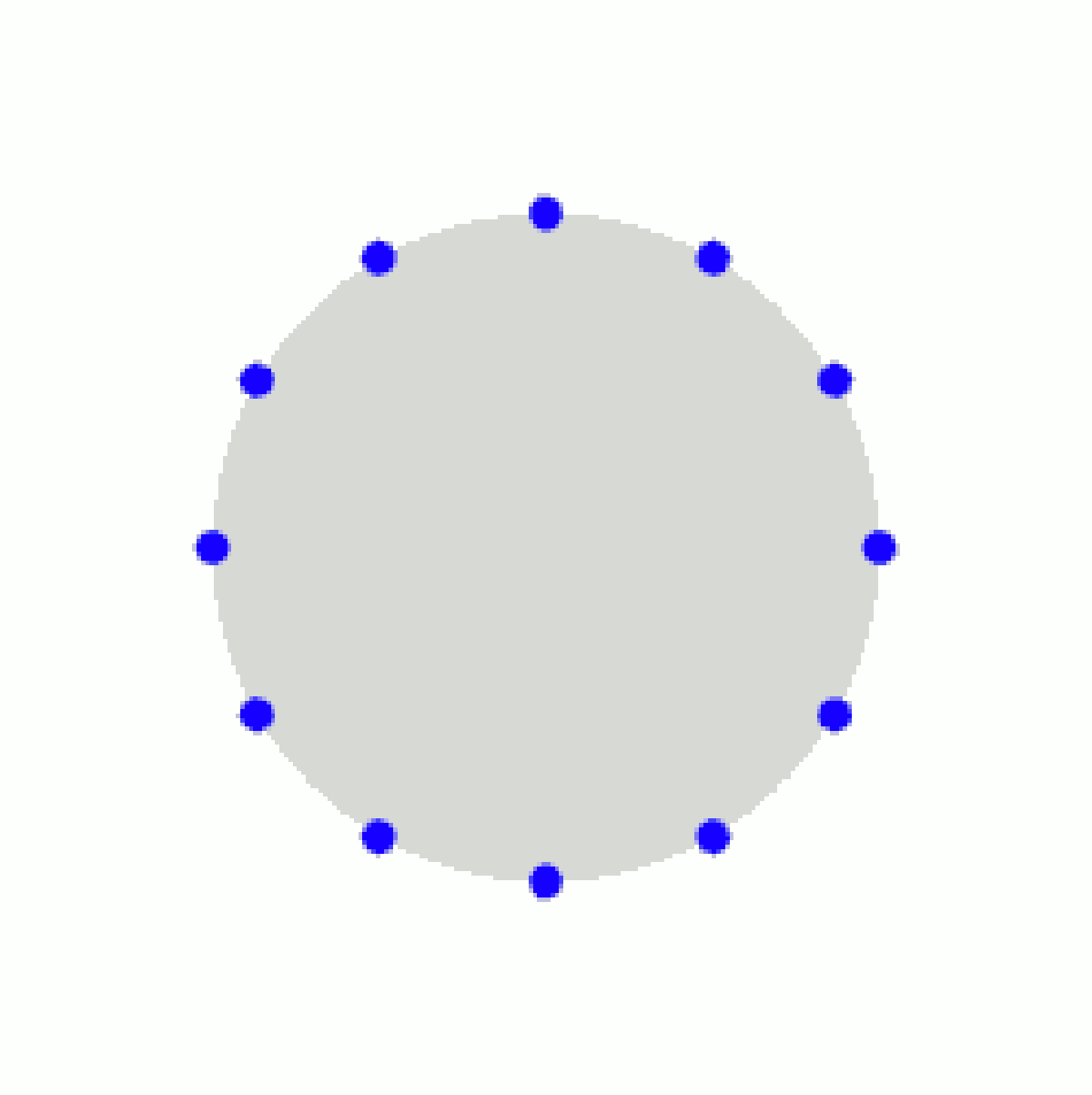
The LIGO revolution
(**Laser Interferometer Gravitational-Wave Observatory)**

Livingston, La

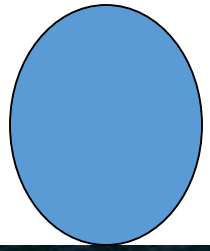
Hanford, WA

Gravitational waves from two inspiralling, merging black holes a billion light years away. Seen twice in the last year, maybe a third time.

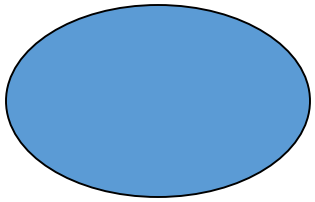
Affect of gravitational waves on a ring of particles

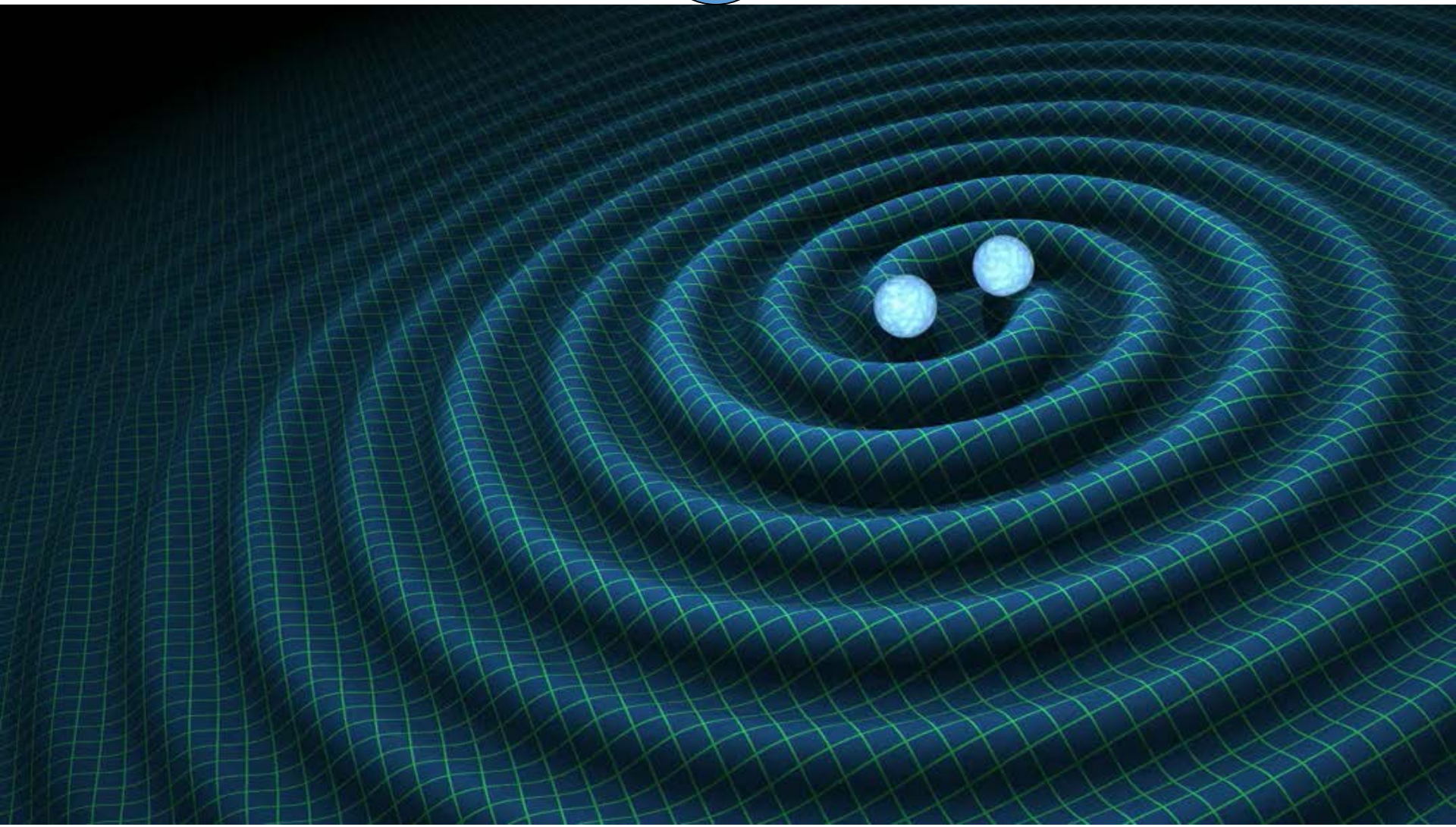


Peaks squish space like this

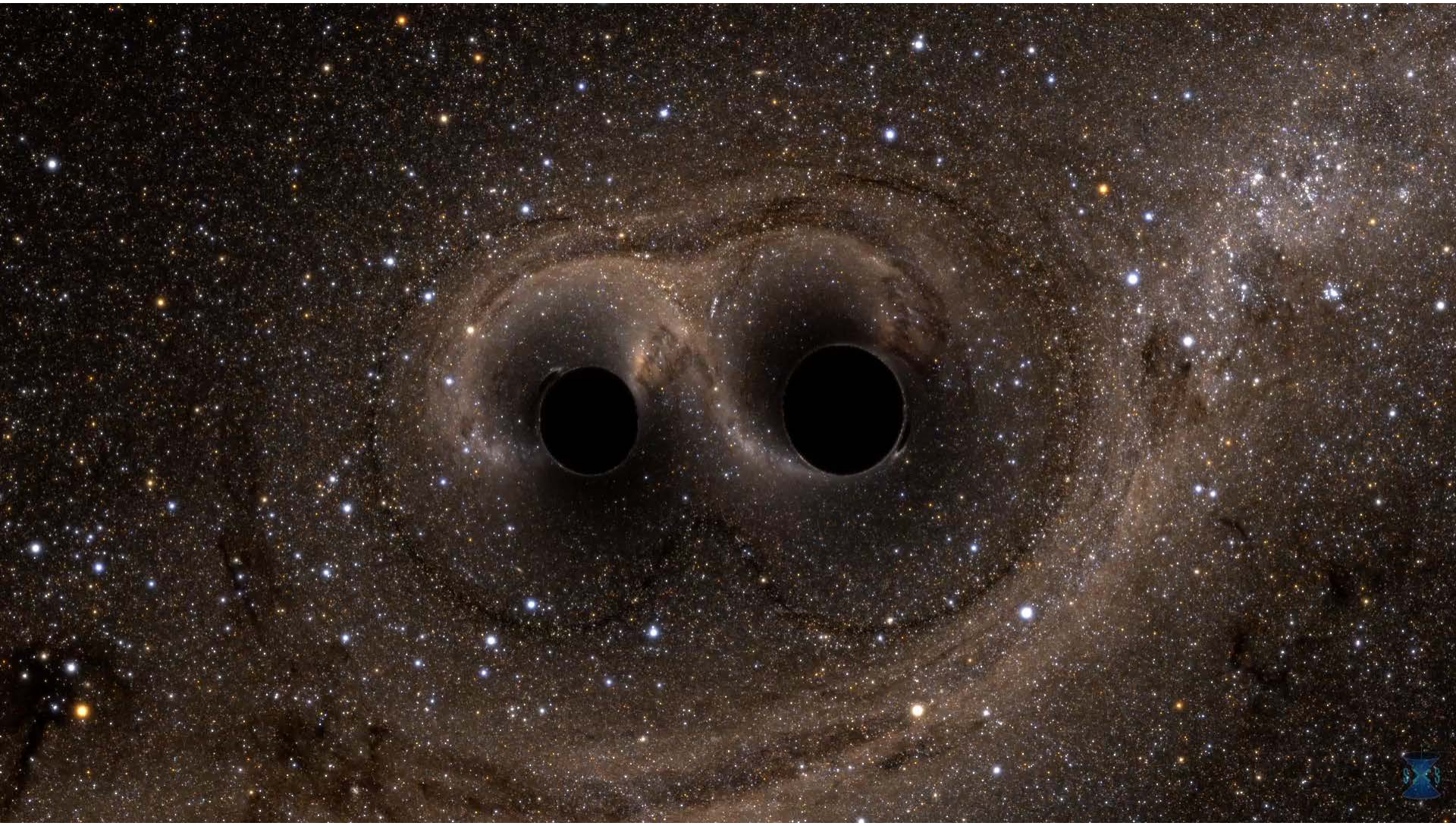


troughs like this





Merging and ringdown of two black holes and their gravitational lens distortion of the star field behind them.



Inspiral and merging of two black holes and the corresponding behavior in an embedding diagram to show how the surrounding space itself is warped. Sound track of “chirp” is across the bottom.