

# Galaxy



A galaxy is a large, massive system consisting of stars, an interstellar medium of gas and dust, stellar remnants, and dark matter, all bound together by gravity.

- There are probably **about 2 trillion galaxies** in the observable Universe!
- Tens of thousands of galaxies have now been catalogued, but **only a few given a well-established name** (example: Andromeda Galaxy, Magellanic Clouds, etc.)
- Sizes of galaxies range from **dwarfs** with as few as ten million stars to **giants** with one hundred trillion stars; most galaxies in the Universe appear to contain only a few billion stars.

# (Hubble) Galaxy Types

Have *black holes* at their centers!

EVOLUTION?

Spiral

May have  
“wandering”  
black holes...

Irregular

Elliptical



Elliptical galaxies have smooth, featureless light distributions and appear as *ellipses* in images; they consist mostly of **old stars**.



Spiral galaxies consist of a flat, rotating disc of two or more *spiral arms* containing mostly **young stars**, gas and dust, and a central *bulge* of older stars.



Irregular galaxies do not have any distinct regular shape.

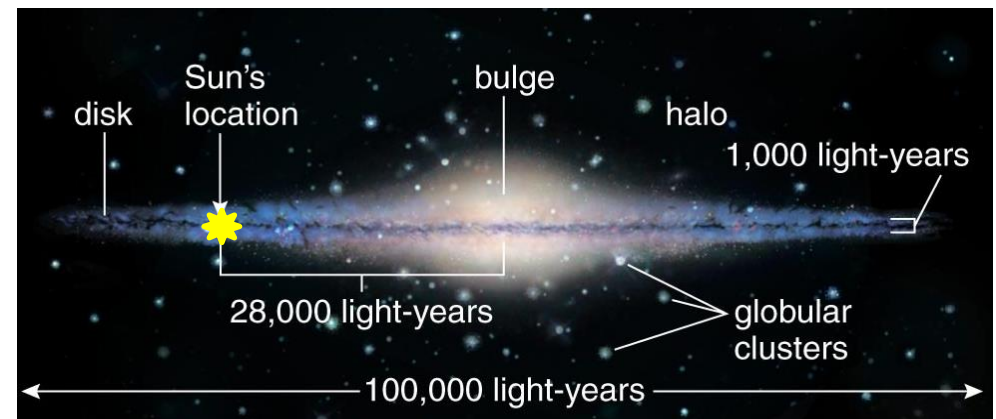
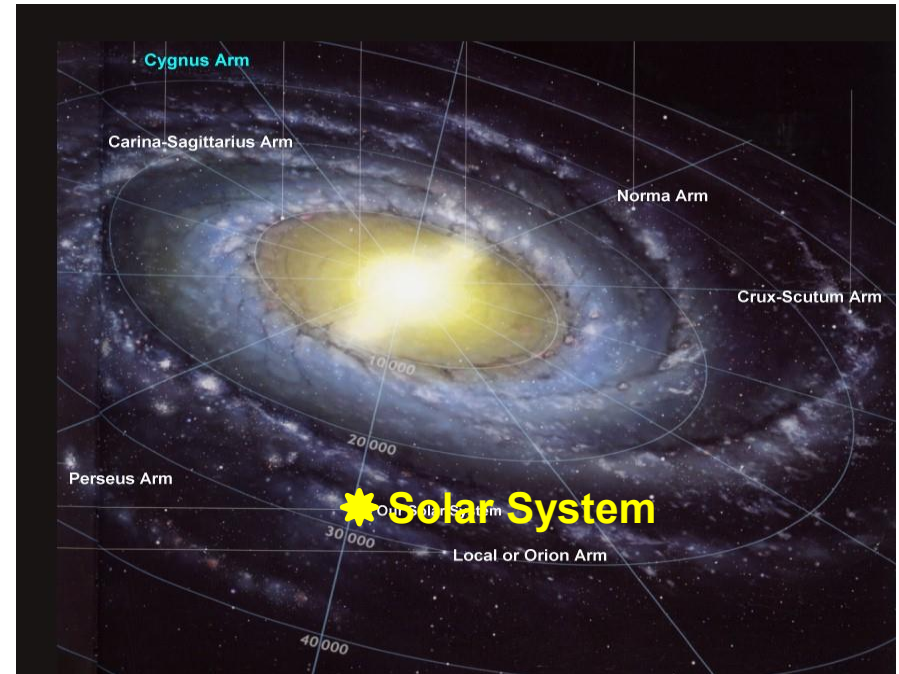
Together they make **~60%** of all galaxies in the observable Universe.

# Our Galaxy: the Milky Way

The Milky Way is a large **barred spiral galaxy** (we think!) some **~100,000 light-years** in diameter, which contains **100–400 billion stars**. It may contain at least as many planets as well.



Every star we see in the night sky is in our own galaxy. We cannot see stars in other galaxies because they are too far away.



# Our Local Group of Galaxies

The total size of the Local Group is **10 million light-years across.**



It contains **more than 50** (mostly *dwarf*) **galaxies.**



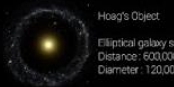
UGC 10214 - "The Tadpole"  
Disturbed spiral galaxy with a very long tail  
Distance: 420,000,000 LY  
Total length: 390,000 LY



NGC 1316 - "Fornax A"  
Dusty elliptical galaxy  
Distance: 62,000,000 LY  
Diameter: 220,000 LY



NGC 908  
Starbursting galaxy with disturbed spiral arms  
Distance: 55,000,000 LY  
Diameter: 75,000 LY



Hoag's Object  
Elliptical galaxy surrounded by a ring of blue stars  
Distance: 600,000,000 LY  
Diameter: 120,000 LY (of outer ring)



Hercules A  
Giant elliptical galaxy with powerful radio jets (shown in pink) powered by a supermassive black hole at the galaxy's center  
Distance: 2,100,000,000 LY  
Diameter: 1,500,000 LY (jets)



M100  
Spiral galaxy in the Virgo Cluster  
Distance: 55,000,000 LY  
Diameter: 160,000 LY



NGC 6670  
Two interacting galaxies seen edge-on  
Distance: 400,000,000 LY  
Diameter: 120,000 LY



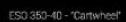
The Milky Way  
It's us!  
Diameter about 100,000 LY  
Artist's impression (Nick Rafter)



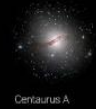
M31 - "Andromeda"  
Nearby spiral in our Local Group  
About as massive as the Milky Way  
It's headed straight for us! Collision in about 4 billion years  
Distance: 2,500,000 LY  
The main stellar disc is about the same size as the Milky Way but an extended, fainter disc spans about 220,000 LY



M104 - "Sombrero"  
Spiral galaxy with a prominent bulge and dust ring  
Distance: 28,000,000 LY  
Diameter: 50,000 LY



ESO 350-40 - "Cinwheel"  
Everyone's favourite ring galaxy (well, probably)  
Distance: 500,000,000 LY  
Diameter: 180,000 LY



Centaurus A  
Elliptical galaxy with a prominent dust lane. It also possesses radio jets (not shown) of a similar size to those of Hercules A  
Distance: 130,000,000 LY  
Diameter: 97,000 LY



M87  
A giant elliptical at the center of the Virgo Cluster. At its center, material falling onto a supermassive black hole is emitting powerful jets  
Distance: 53,000,000 LY  
Diameter: 980,000 LY



NGC 4921  
A spiral galaxy in the Coma Cluster, it has lost much of its gas and can longer form many new, blue stars, giving it an unusually pale appearance  
Distance: 320,000,000 LY  
Diameter: 230,000 LY



Arp 81  
Two merging galaxies  
Distance: 280,000,000 LY  
Diameter: 200,000 LY



NGC 1365  
Barred spiral galaxy in the Fornax Cluster  
Distance: 81,000,000 LY  
Diameter: 200,000 LY



M81  
Arguably the largest spiral  
Normal stellar disc embedded in a huge, very faint halo  
Distance: 1,400,000,000 LY  
Diameter: 30,000 LY (inner disc)  
Diameter: 650,000 LY (outer disc)  
(image is an original artist's impression, not a real observation of M81)



NGC 7049  
Elliptical galaxy with an unusual dust ring  
Distance: 90,000,000 LY  
Diameter: 150,000 LY

# Galaxy sizes comparison

**The largest  
known galaxy**

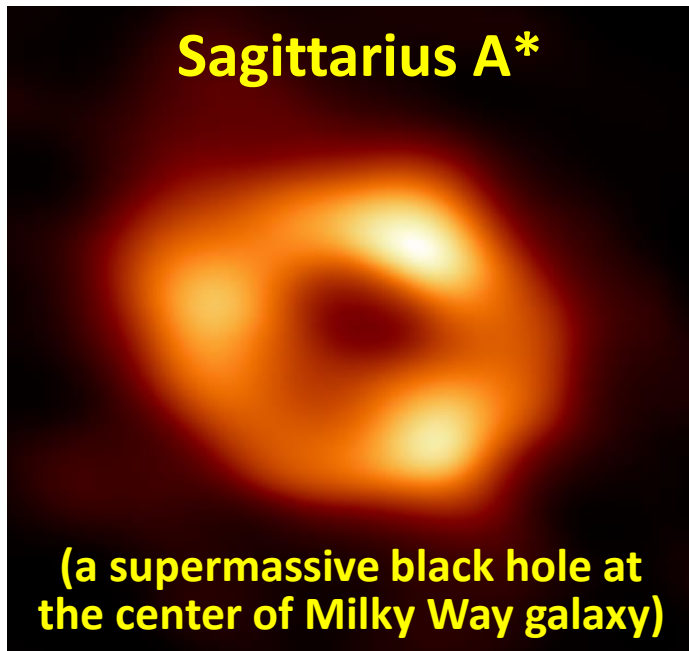


**IC 1101**

**would fit over 50 Milky Ways!**

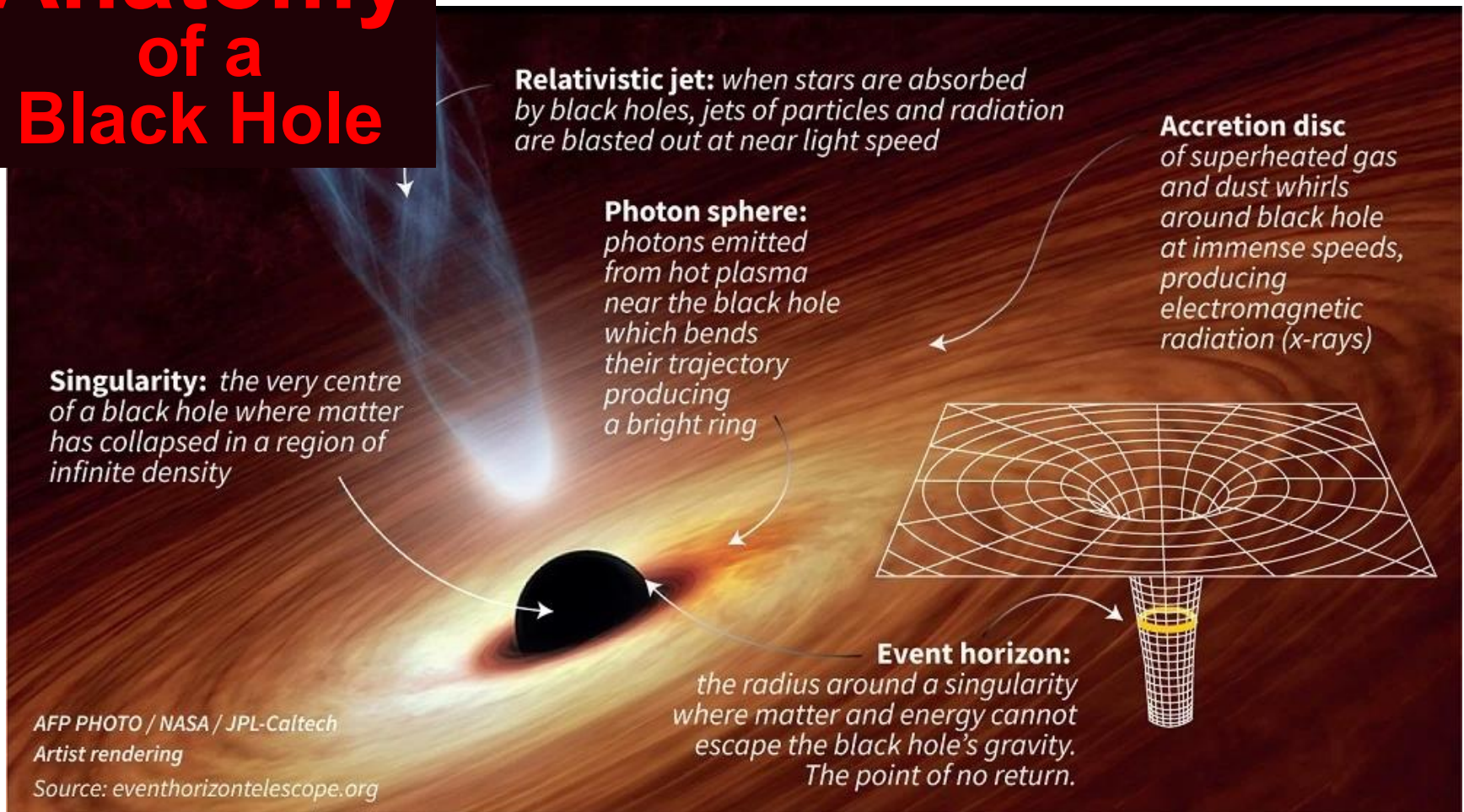
# Black Holes

Black holes are volumes of space where gravity is extreme enough to prevent the escape of even the fastest moving particles – light photons!



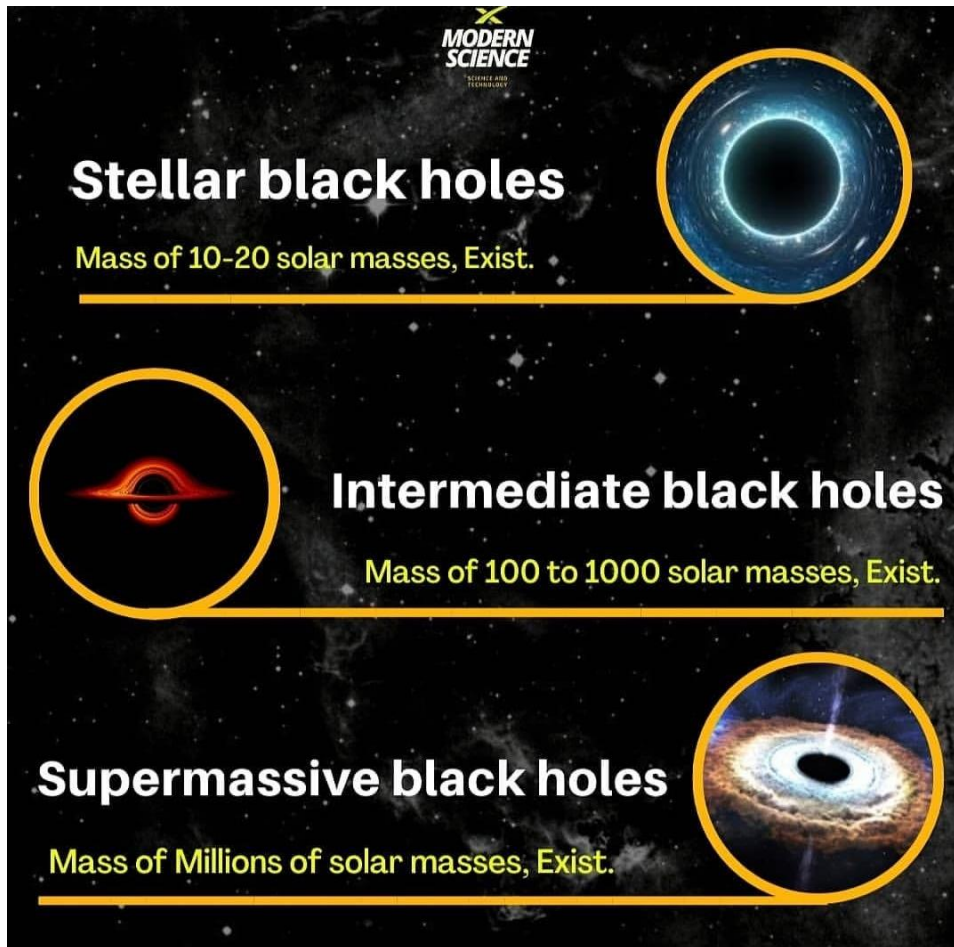
- The first black holes are thought to have begun to emerge ~13.5 billion years ago resulting from deaths of short-lived massive stars.
- After a black hole has formed, it can continue to slowly grow by absorbing mass (like gas or other stars) from its surroundings and merging with other black holes.

# Anatomy of a Black Hole



- Black holes have **infinitely dense core** (“singularity”).
- Their “**size**” is defined by the **event horizon** - the boundary of the region from which no escape is possible.

# Black Hole Types



## ← STELLAR

formed by the gravitational collapse of a star following a supernova explosion

## ← INTERMEDIATE

**poorly understood**; may be found at the centers of globular clusters or within low-luminosity galaxies

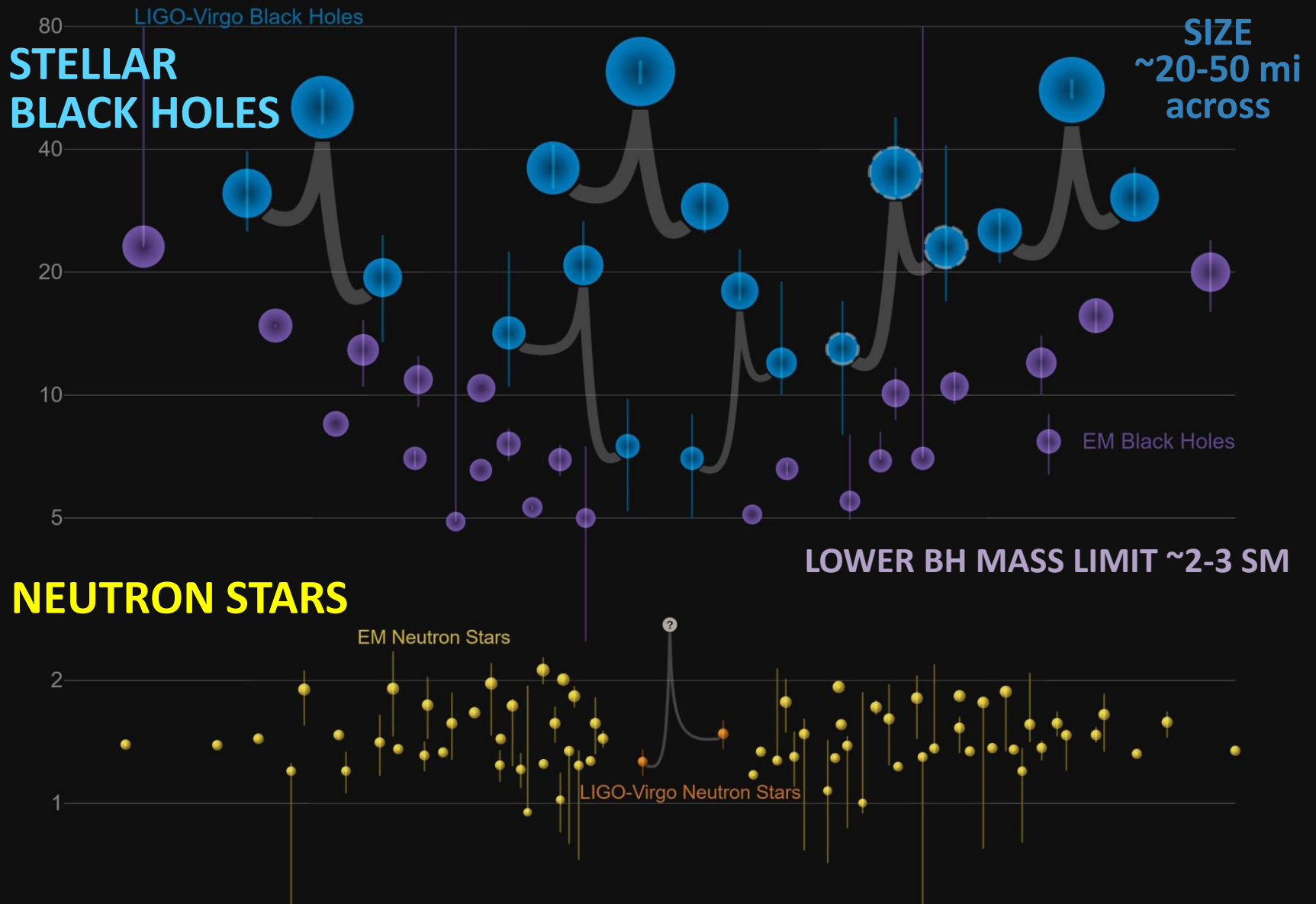
## ← SUPERMASSIVE

found at the centers of all large galaxies; **formation?**

+ **Theoretical Primordial Black Holes**, formed soon after the Big Bang by gravitational collapse of extremely dense pockets of subatomic matter – can be ANY mass! – **is THIS “dark matter”?**

# Masses in the Stellar Graveyard

*in Solar Masses*



# Largest SMBH Detected

↓ PHOENIX A\*

about 100 billion SM  
over 2000 AU across

Phoenix A

TON 618

SAGITTARIUS A\* (Milky Way)  
~4 million SM, ~0.1 AU

~40 billion SM,  
~1000 AU across

TON 618

OJ 287

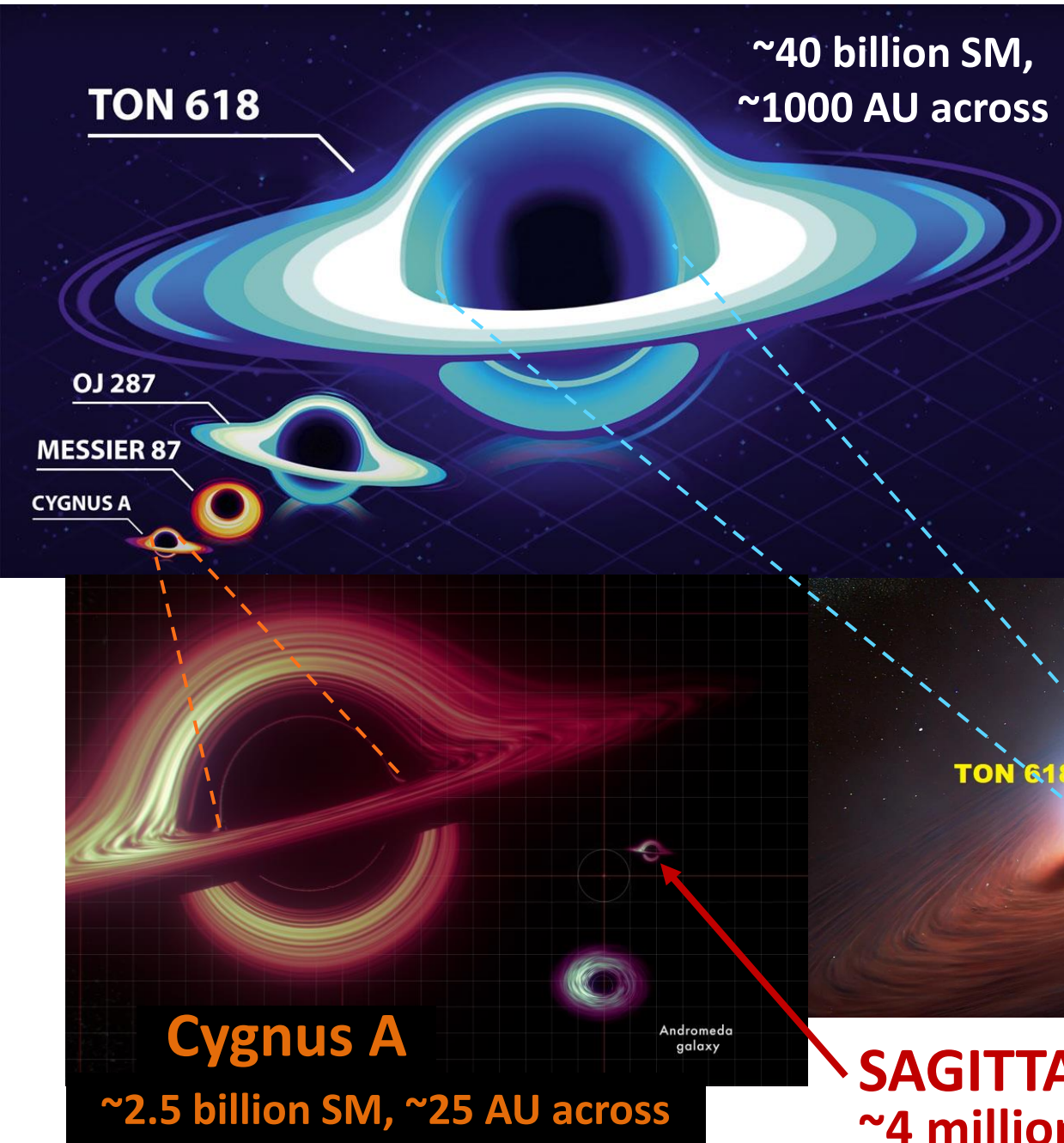
MESSIER 87

CYGNUS A

Cygnus A

~2.5 billion SM, ~25 AU across

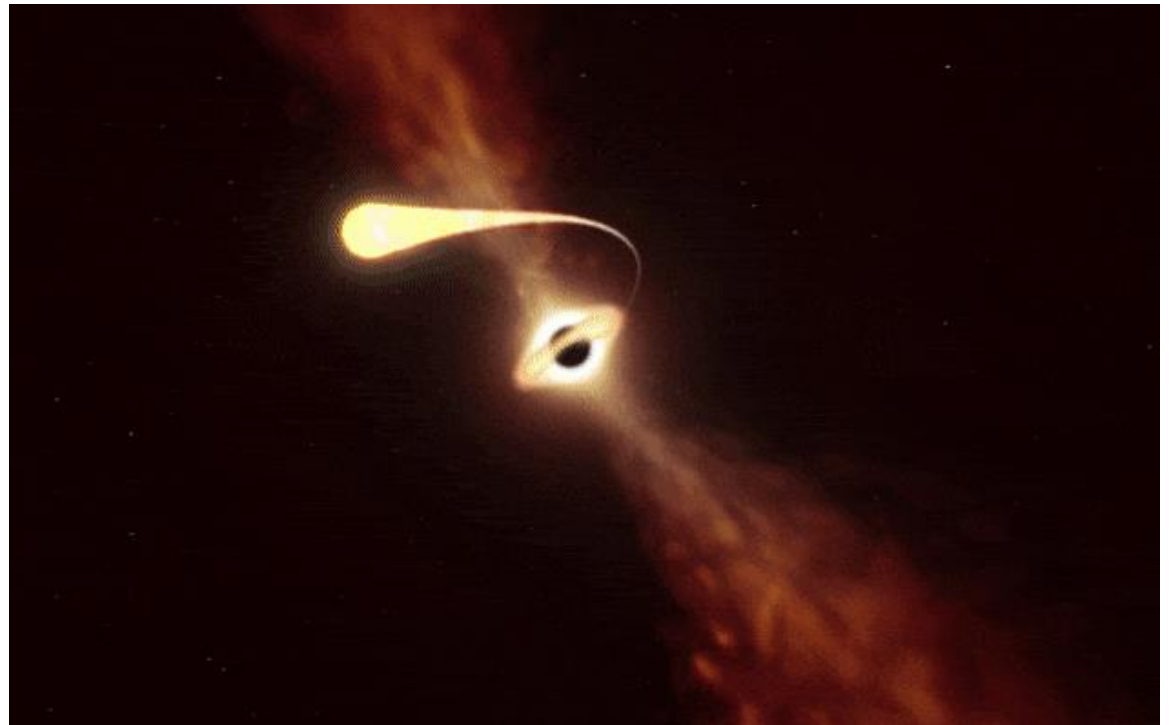
Andromeda galaxy



What happens when matter gets too close to a black hole?

# Spaghettification-

- the **tidal effect** (*tidal disruption*) caused by strong gravitational fields.



- When falling towards a black hole, an object is **stretched in the direction of the black hole** and simultaneously **compressed perpendicular to it** as it falls, which can result in it breaking out into a line of debris.