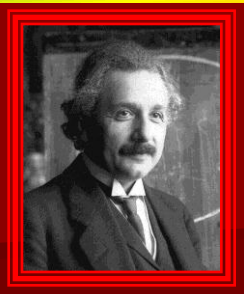
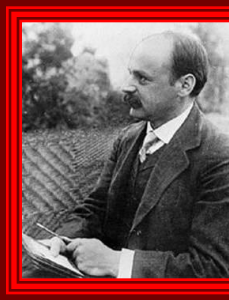
General Relativity and Black Holes

Shipov Gennady,
UVITOR, Bangkok,
Thailand
July 10, 2009

Schwarzschild Solution (1916)



$$R_{ik} = 0$$



$$ds^2 = (1 - \frac{r_g}{r})c^2 dt^2 - (1 - \frac{r_g}{r})^{-1} dr^2 - r^2 (d\theta^2 + \sin^2 \theta d\varphi^2)$$

Karl Schwarzschild (1873-1916)

$$r_g = \frac{2MG}{c^2}$$

Gravitational radius

Satang

9mm

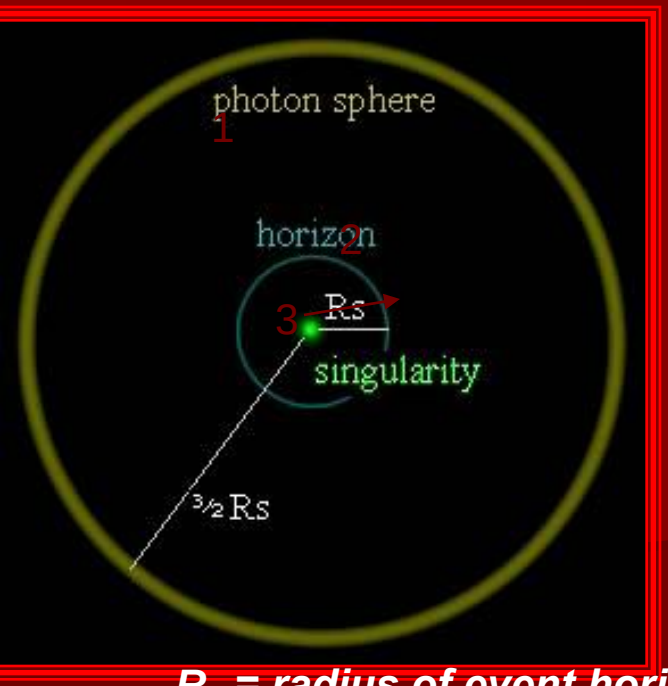
Gravitational radius of the Earth

Black Hole

When the a large mass is confined to a small size, the funnel becomes infinitely deep! The density is so high (greater than 100 trillion times water) that …
no form of matter can support itself against the crush of its own space time warp!

$$R_s = \frac{2GM}{c^2}$$

The "size" of a black hole!



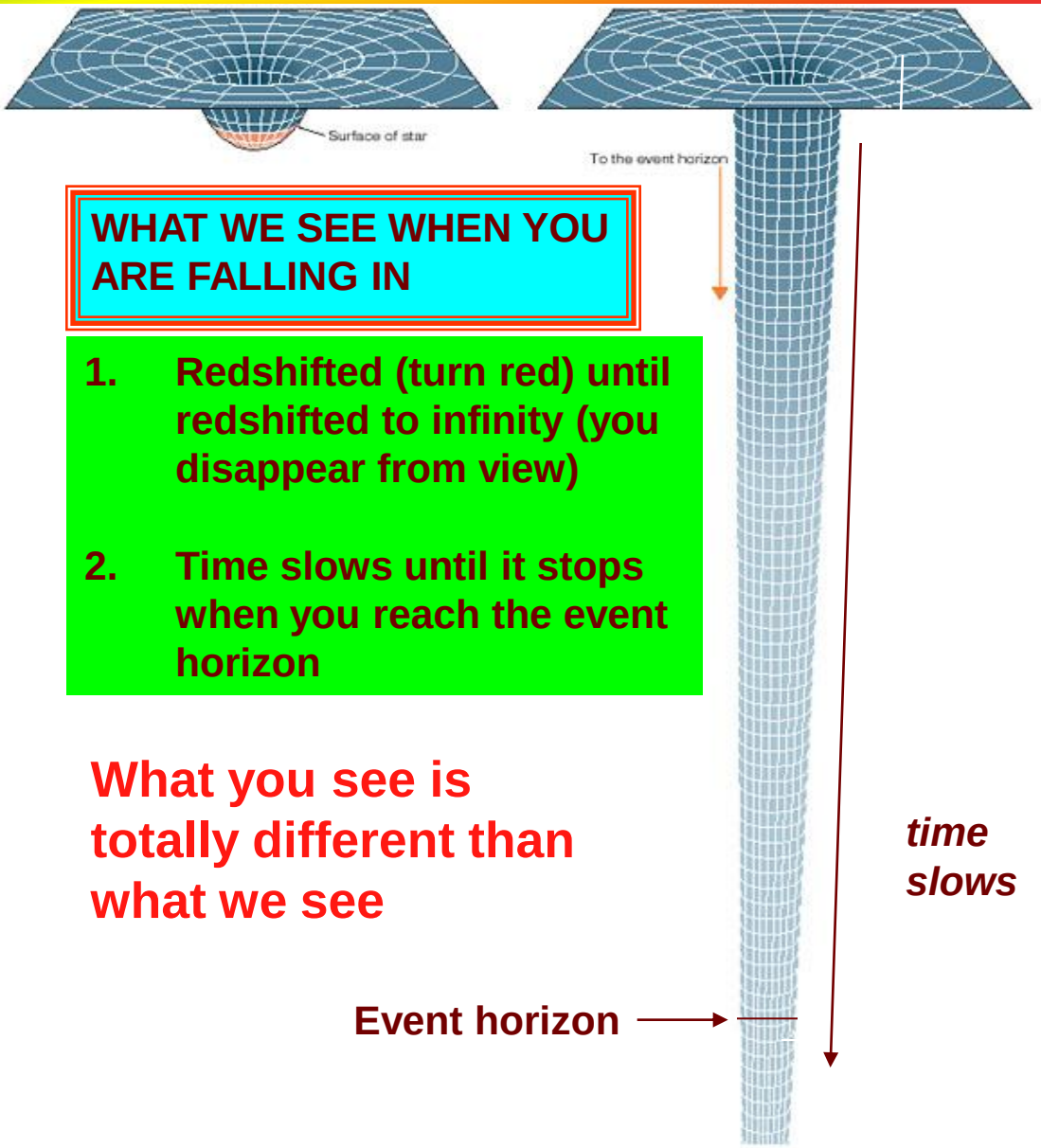
1. Photon Sphere: ***1.5R_s***
distance where light can go into circular orbit!

2. Event Horizon: ***R_s***
distance where escape speed equals speed of light!

3. Singularity: ?
Mathematical point at center… we don't know what it is, but it is where the point of the funnel comes to a head… if it does?

R_s = radius of event horizon is the "size of black hole.
Depends upon mass and the speed of light.

Physical properties of Black Hole



WHAT WE SEE WHEN YOU ARE FALLING IN

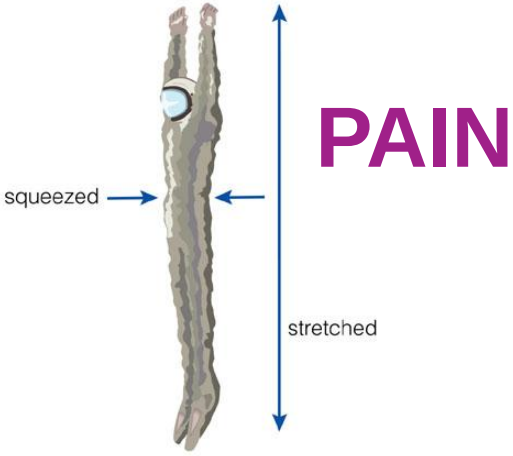
1. **Redshifted (turn red) until redshifted to infinity (you disappear from view)**
2. **Time slows until it stops when you reach the event horizon**

What you see is totally different than what we see

The space time around a star is identical to the space time around a black hole, until you get close to the event horizon.

WHAT YOU SEE FALLING IN

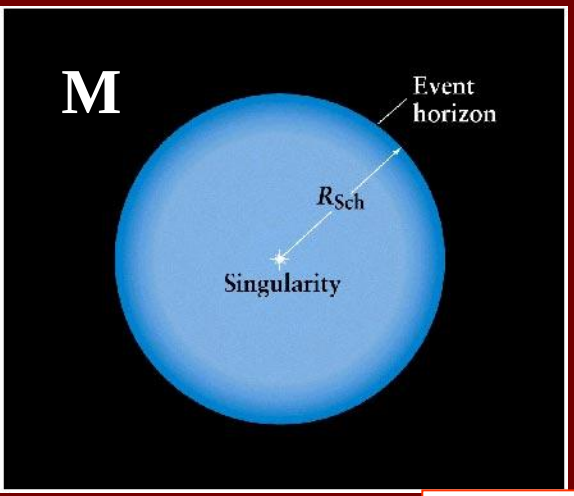
1. **Squeezed and stretched**
2. **Looking back out to the universe and all time passes by in an instant!**

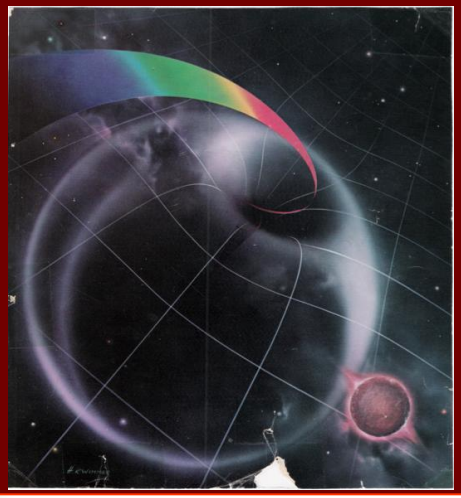


PAIN

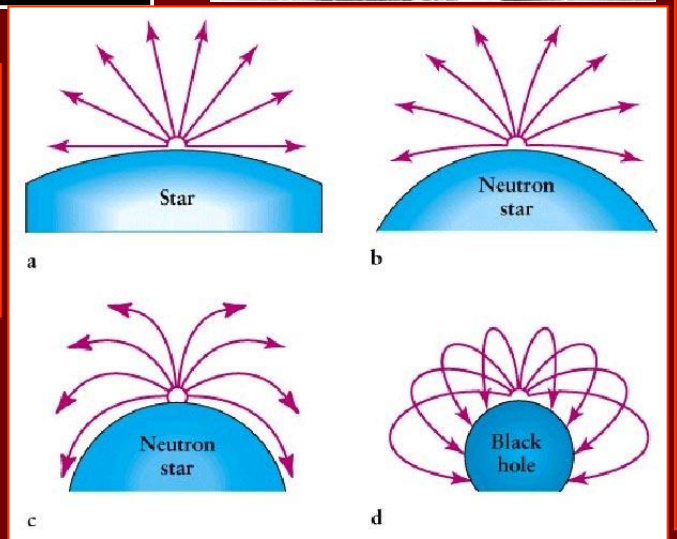
Prediction of 1915 GR - Black Holes

A nonrotating black hole has only a "center" and a "surface"





Gravity bends the path of light

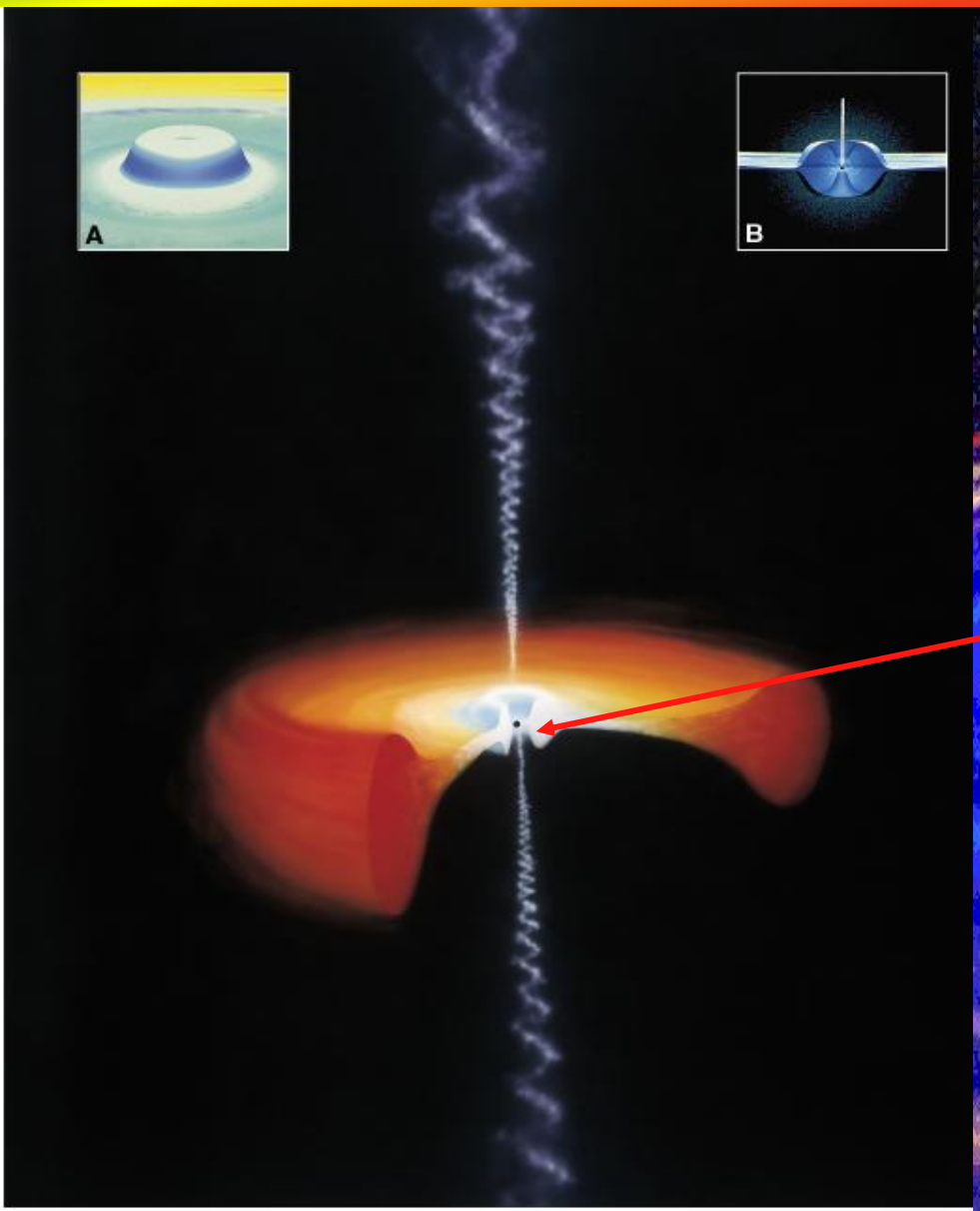


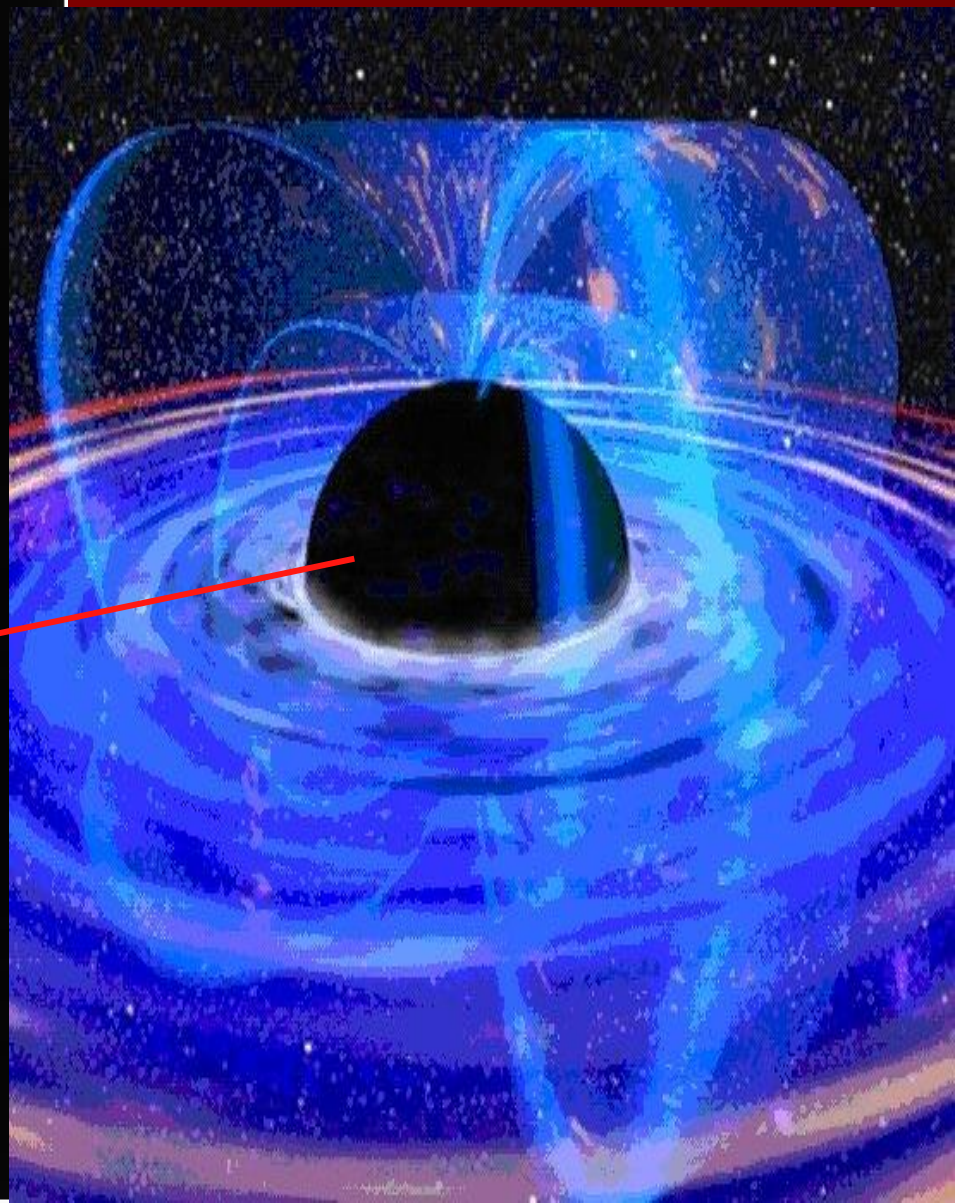
- The black hole is surrounded by an *event horizon* which is the sphere from which light cannot escape

- The distance between the center of black hole and its event horizon is the *Schwarzschild radius* ($R_{Sch} = 2GM/c^2$)

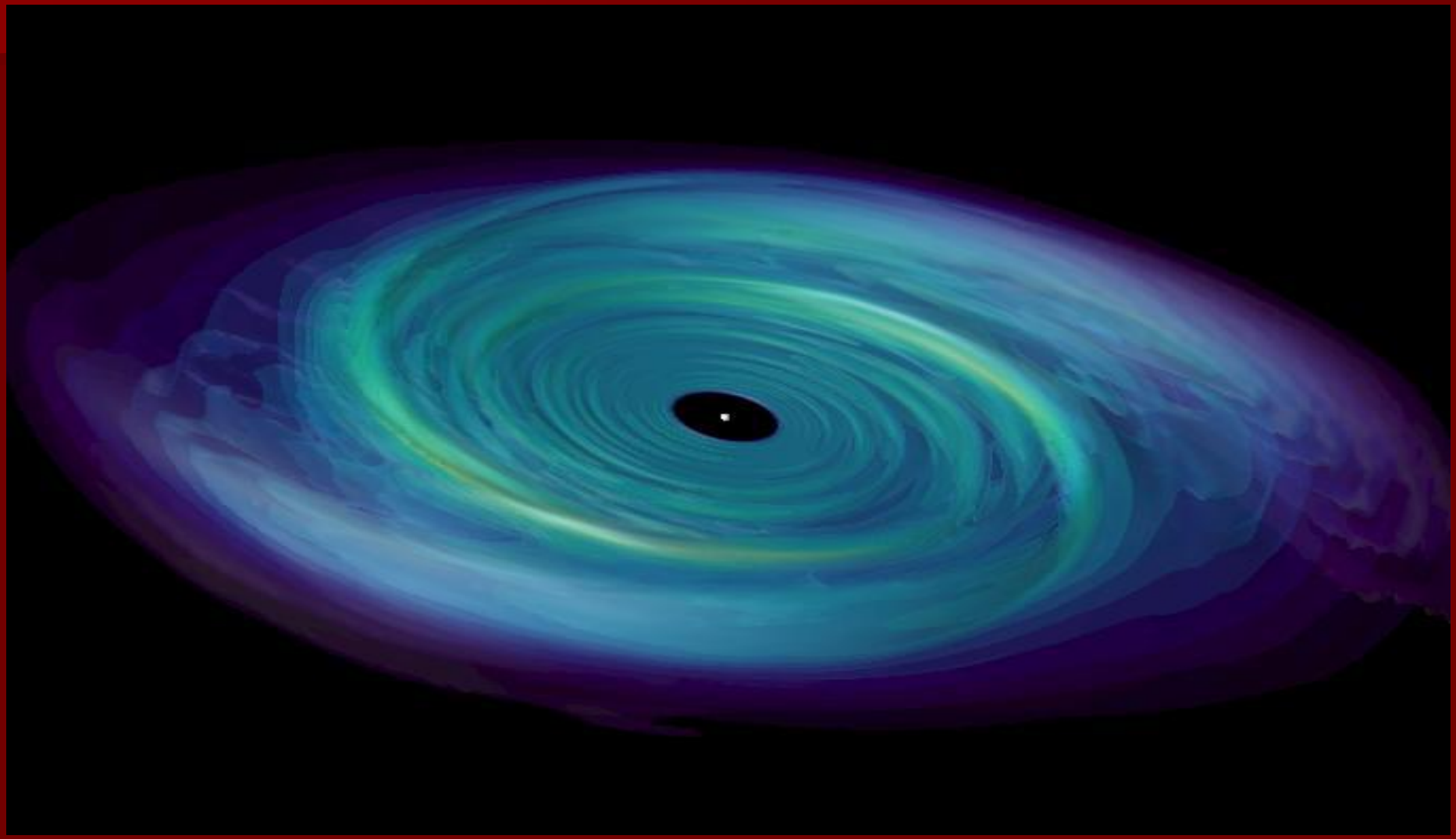
- The center of the black hole is a point of infinite density and zero volume, called a *singularity*

Simulation of Black Hole 1.



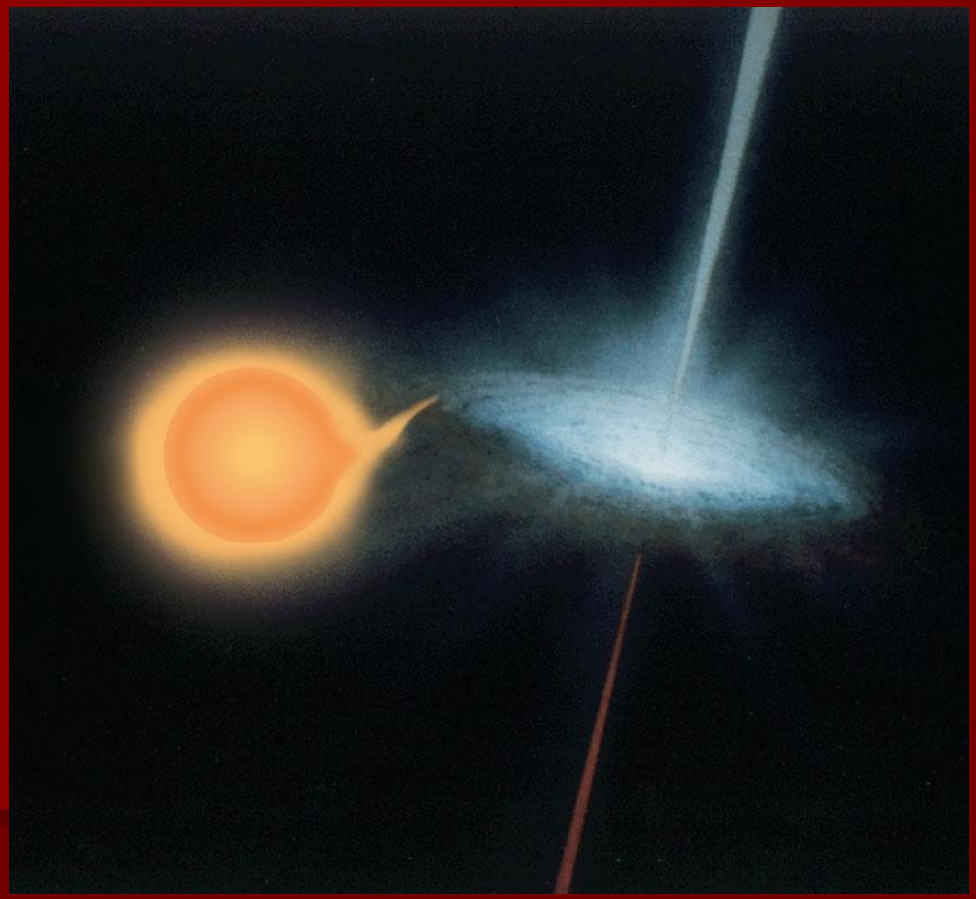


Simulation of Black Hole 2.



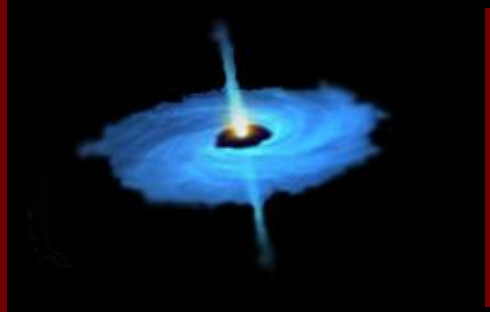
Simulation of Black Hole 3.

Most black holes are found because they are eating their companion stars!
Like Neutron Stars, there are intense magnetic fields that channels some of the matter into jets.



A Brief Summary of Black Holes

Stellar-mass black holes
The most massive stars end their lives in titanic explosions, leaving nothing behind but their ultra-dense collapsed cores.



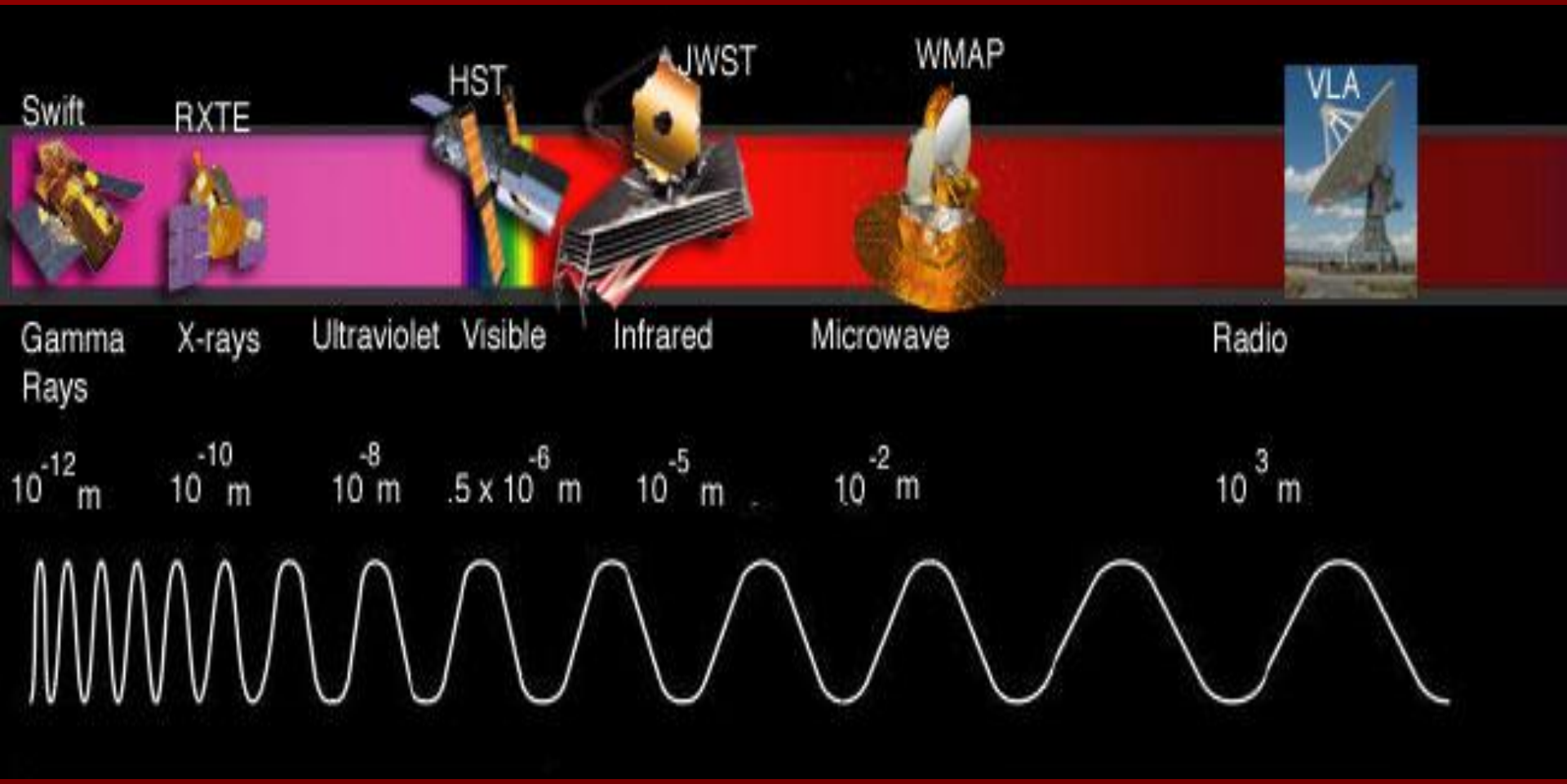
Mid-mass black holes
A new class of recently-discovered black holes have masses on the order of hundreds or thousands of stars.

Supermassive black holes
The centers of galaxies contain giant black holes, with the masses of millions, even billions, of stars.

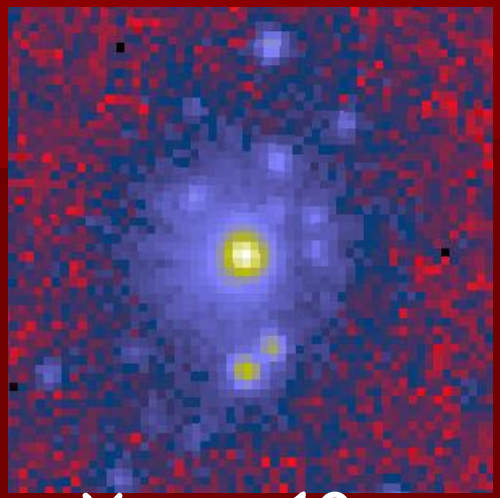
We cannot see black holes directly, but their influence on the matter around them reveals their presence.

Representations above are artists' impressions, and not to scale.

Tools for observation



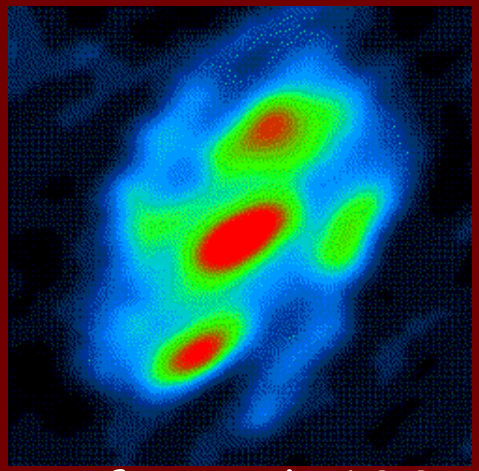
M81 galaxy (*Real Images*)



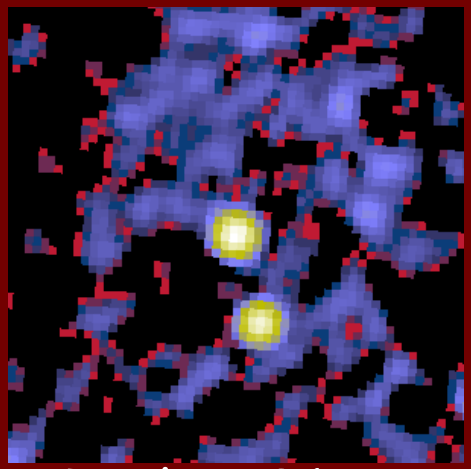
X-ray: 10 nm

UV: 200 nm

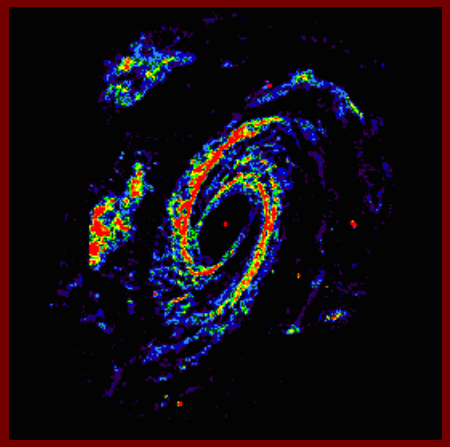
Visible: 600 nm



Infrared: 100 mm



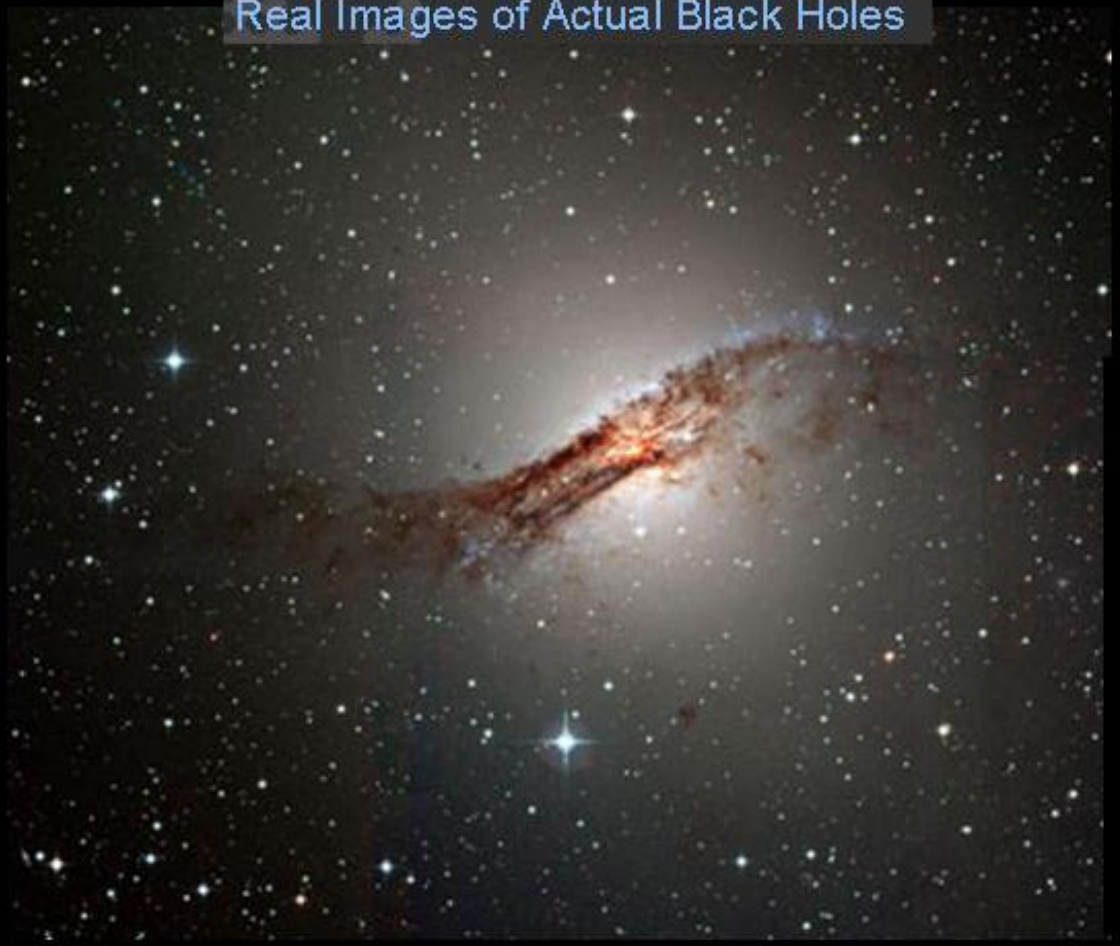
Radio: 21cm



Radio – HI filter

Real Images 1.

Centaurus A: Visible Light View



Centaurus A is a nearby galaxy that is thought to be the result of a merger of two smaller galaxies. What's behind the dust?

Real Images 2.

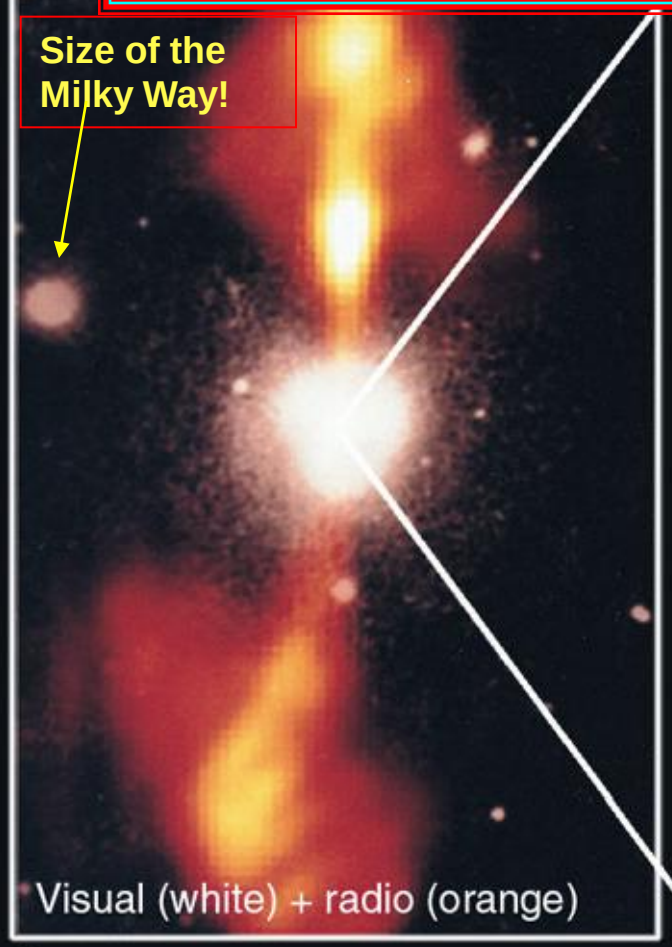
Centaurus A: X-ray Light View

A telltale sign of a black hole is a high-energy jet blasting into space. This galaxy has a supermassive black hole in its center!

Examples of observations 1.

Observable Supermassive Black Holes

In some galaxies, black holes lurk in their centers. These BHs have devoured so much matter, which makes them grow! Some BHs have masses of several million M of Sun! And the jets these babies make…. Astronomical Maniacs!!!!! More later.

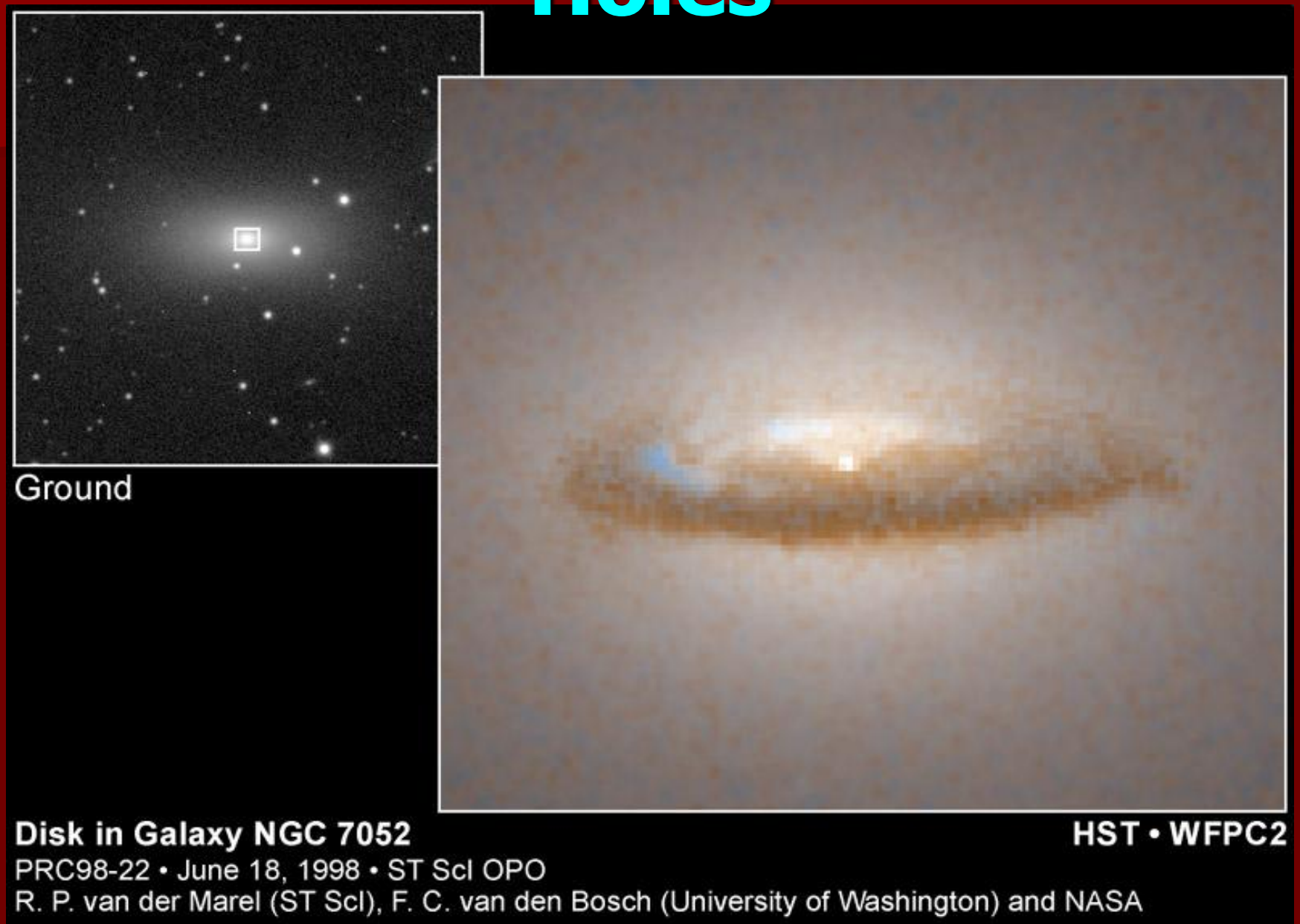


a

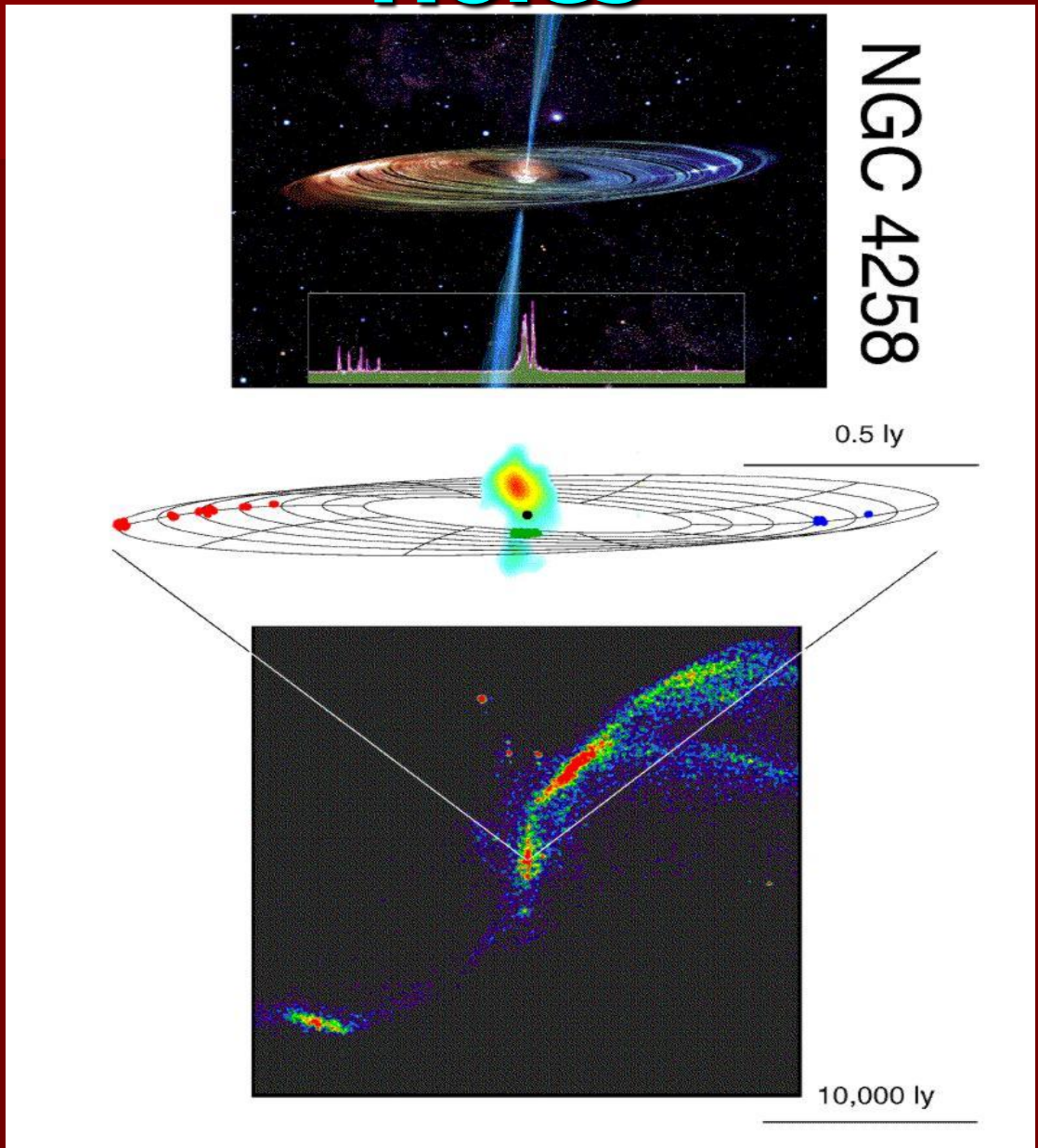
This image (and a spectrum) is smoking gun evidence, the material is orbiting very very fast and computations show that the radius is less than Event Horizon size for this object!

b

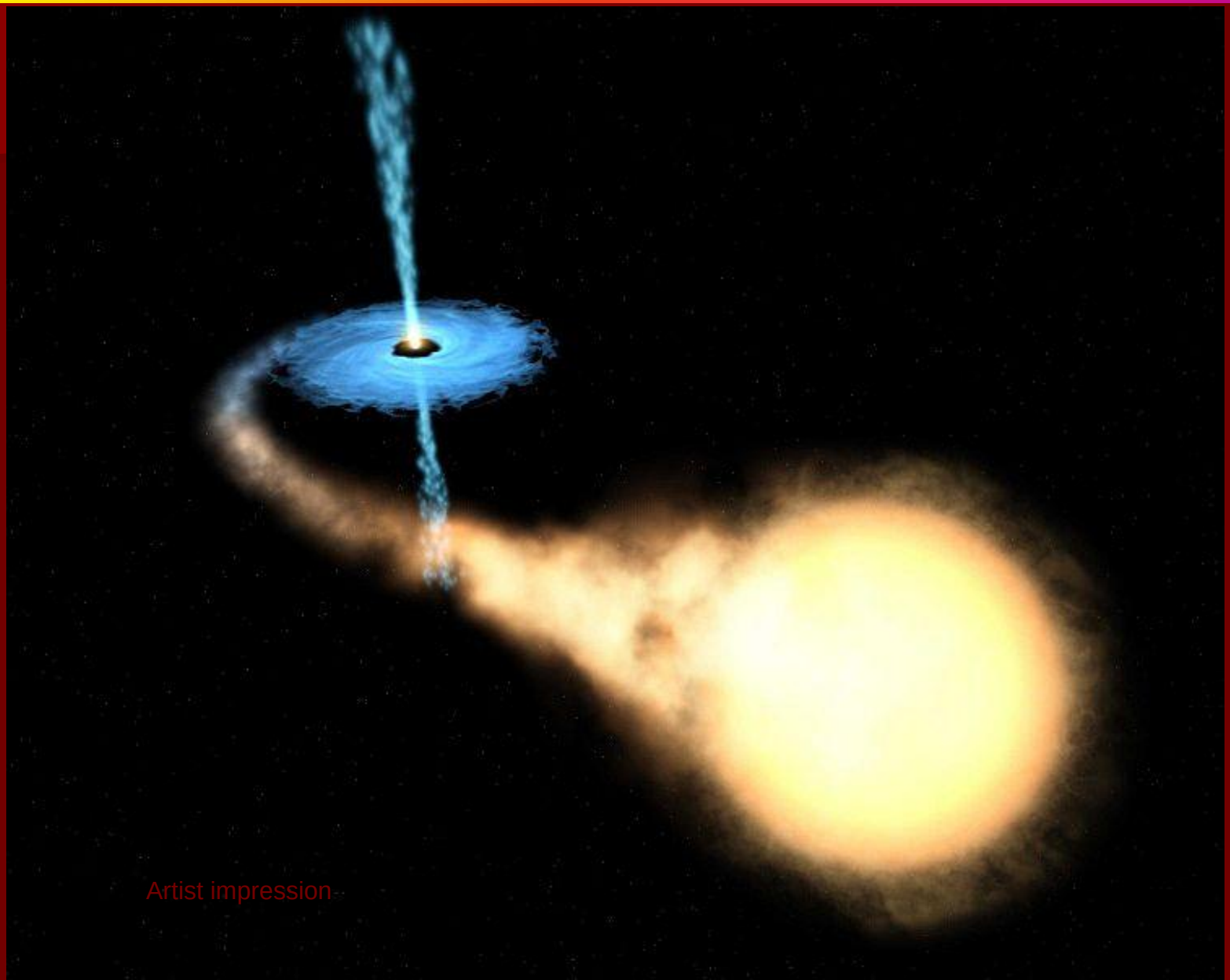
Observable Supermassive Black Holes



Observable Supermassive Black Holes

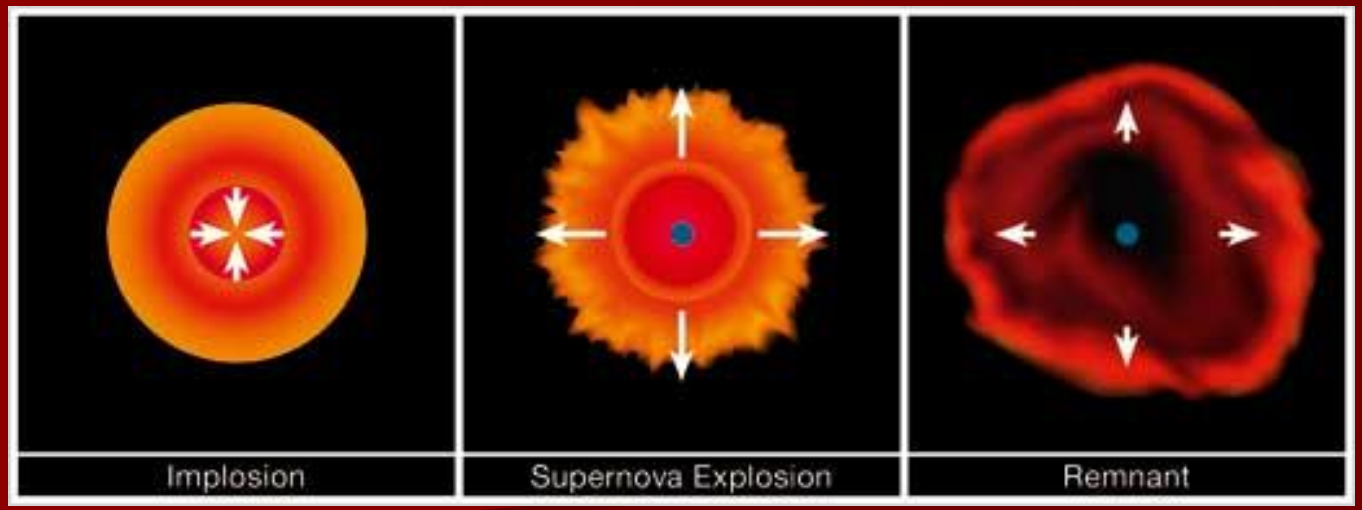


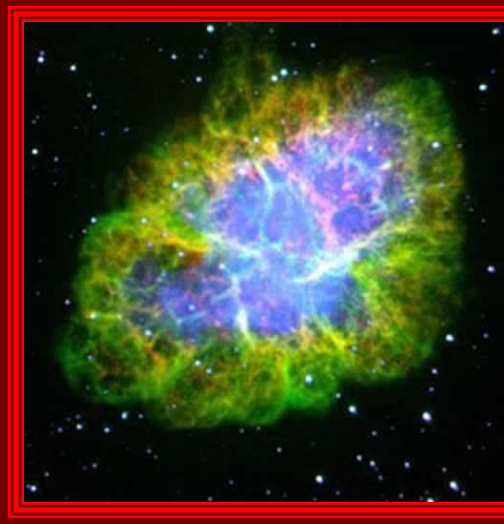
X-ray Binaries



Supernovae Type II and Hypernovae!

- Collapse..250000000 km/h!
- More energy released than our Sun in billions of years!





What is left?

To be continued by General Relativity 3

Kob Khun Krab!

Thank You for Your Attention !