

**update on
BLACK HOLES
Nature's
MOST EXTREME
DENSITY**

Program by

Rick Kang

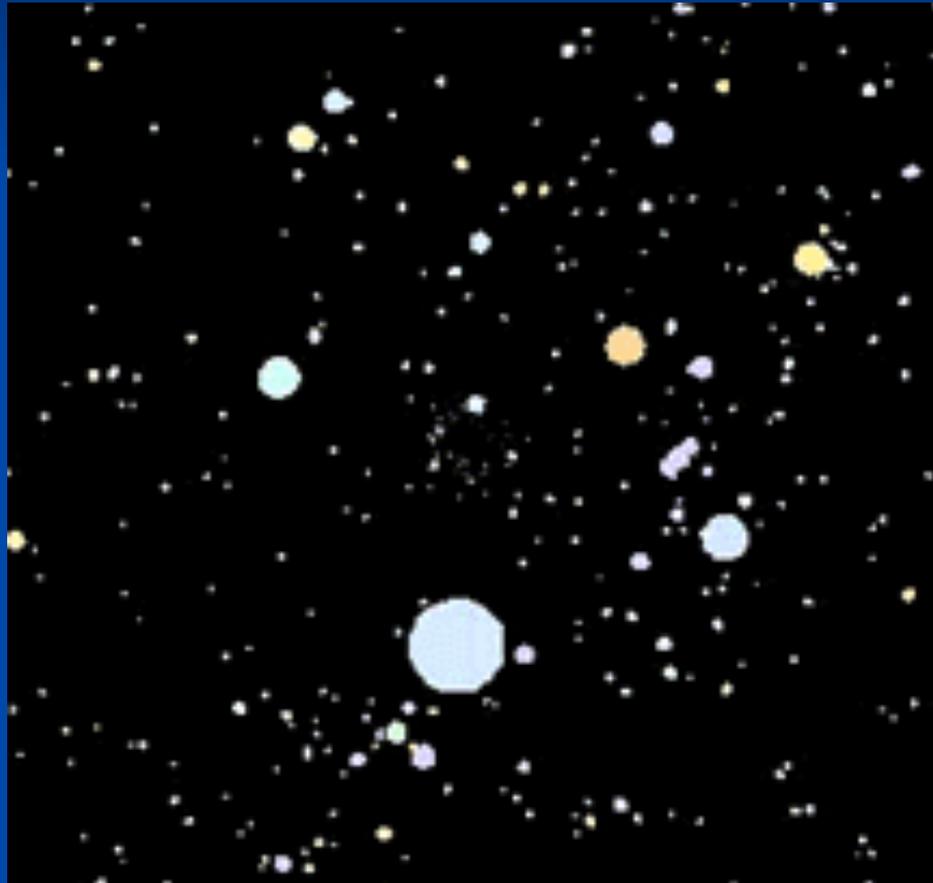
Oregon Astrophysics Outreach

Pine Mtn. Observatory

Today's program:

- Review of basics:
 - What's a Black Hole?
 - How do they form?
- What we have found so far:
 - Examples, correlations of features to data
- Several recent discoveries, plus outstanding questions/mysteries
- STEM (Sci-Tech-Engineering-Math) applications to investigate nature of INVISIBLE OBJECTS!

Artists' rendition of BLACK HOLE



Black Holes are Regions of Spacetime from which light cannot escape

- **What is Spacetime? 4D description of environment – flexible – lets us envision how Gravity works.**

Some working definitions of Black Hole

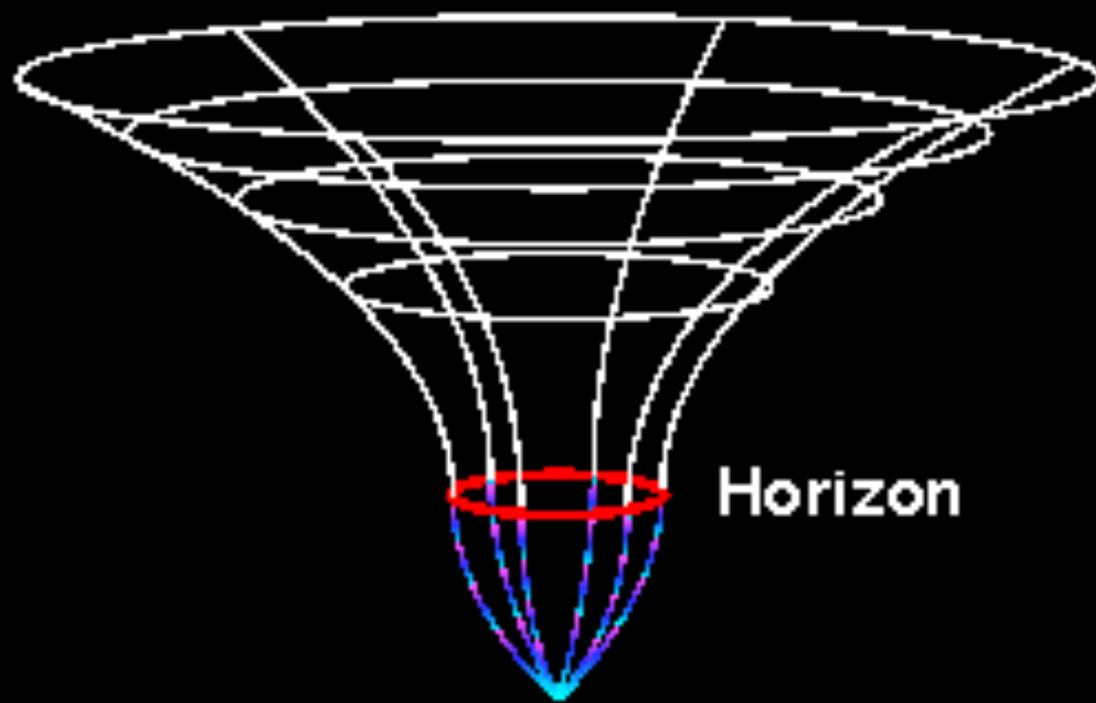
- Major curvature (distortion) of the spacetime, caused by **infinitely dense** mass (singularity).
- Infinitely steep and deep **Gravity Well**.
- A place from which there's no escape...you'd have to **EXCEED** the speed of light to get out.

No slides of Black Holes ☹️ - sorry...

- No light escapes to get to a CAMERA to create an image.
- But, let's BUILD a BLACK HOLE and show how it works within SPACETIME.

Spacetime is FLEXIBLE – it can be distorted

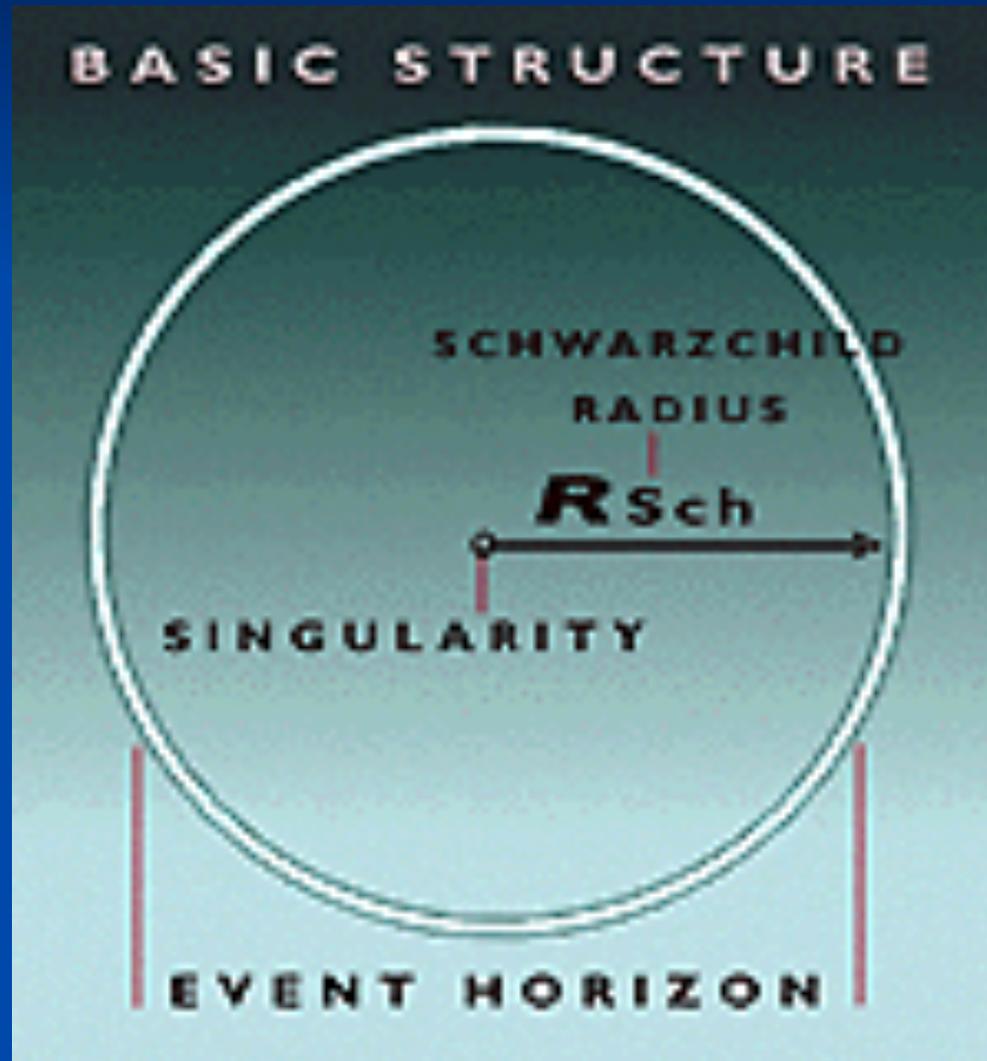
- Let's assemble several Spacetime models
- Use the *stretchy fabric* for your Spacetime
- Stretch it across the top of a black plastic pot, secure with a bungy cord.



Horizon

Singularity

A 2D map of a black hole



How wide is the Event Horizon?

(How small do you need to crush a Mass down to until it forms a Black Hole, Light cannot escape (local gravity is too strong))?

- Roughly, in miles,
 $2 \times \text{Mass of object} / \text{Mass of Sun}$
- A Solar Mass black hole has event horizon about 2 miles wide.
- An Earth Mass black hole has event horizon only a few inches wide!

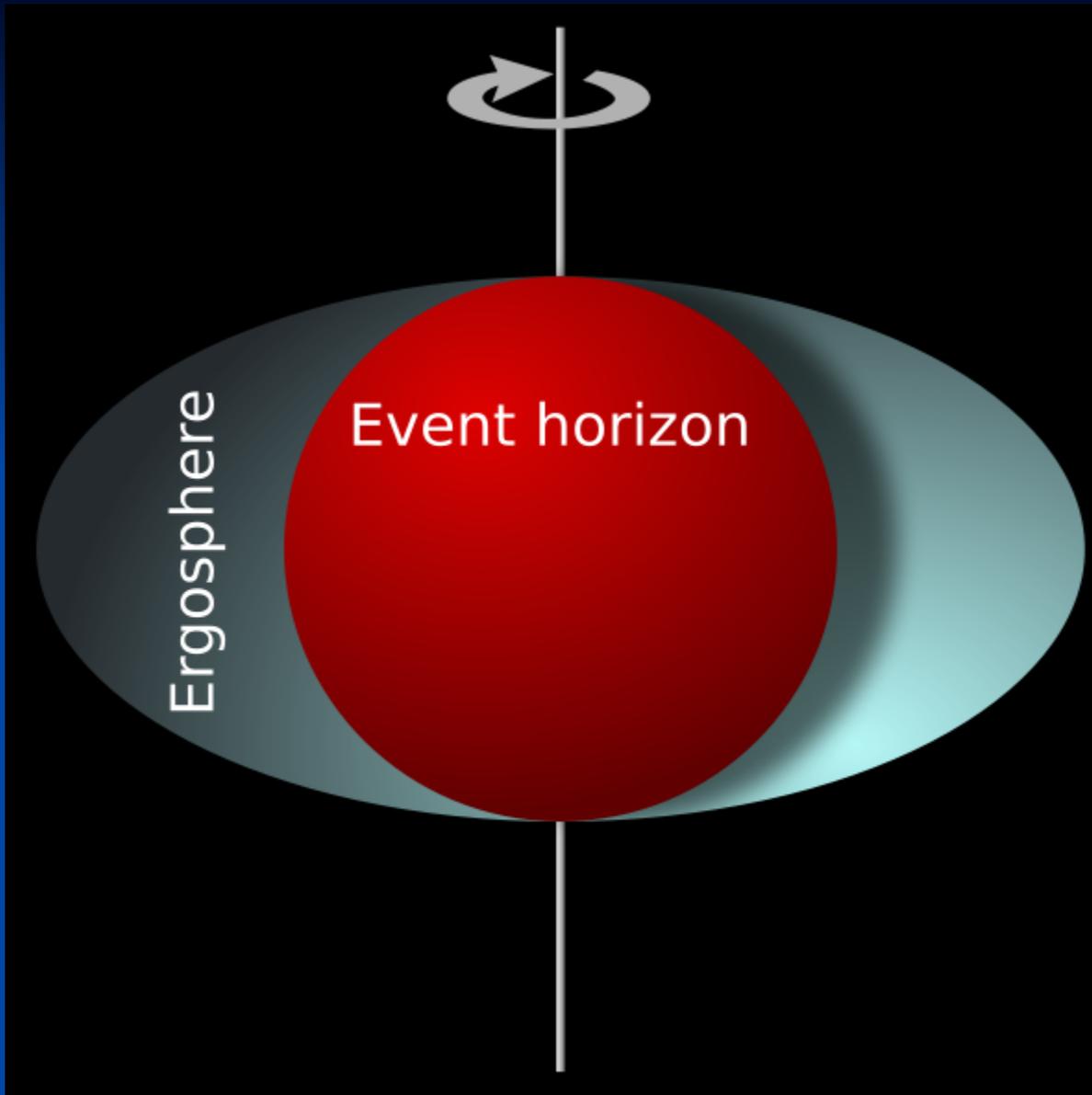
Sizes of Black Holes

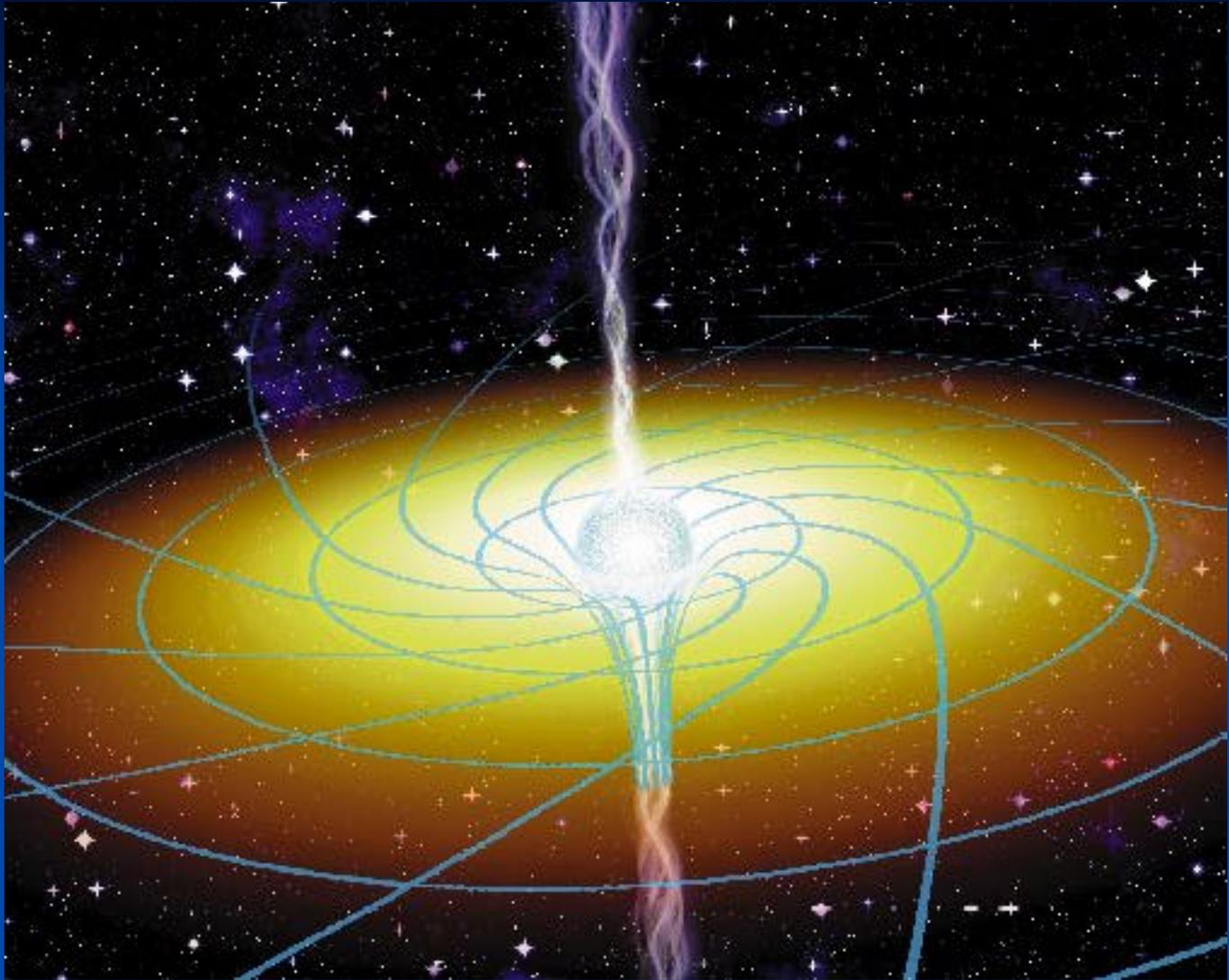
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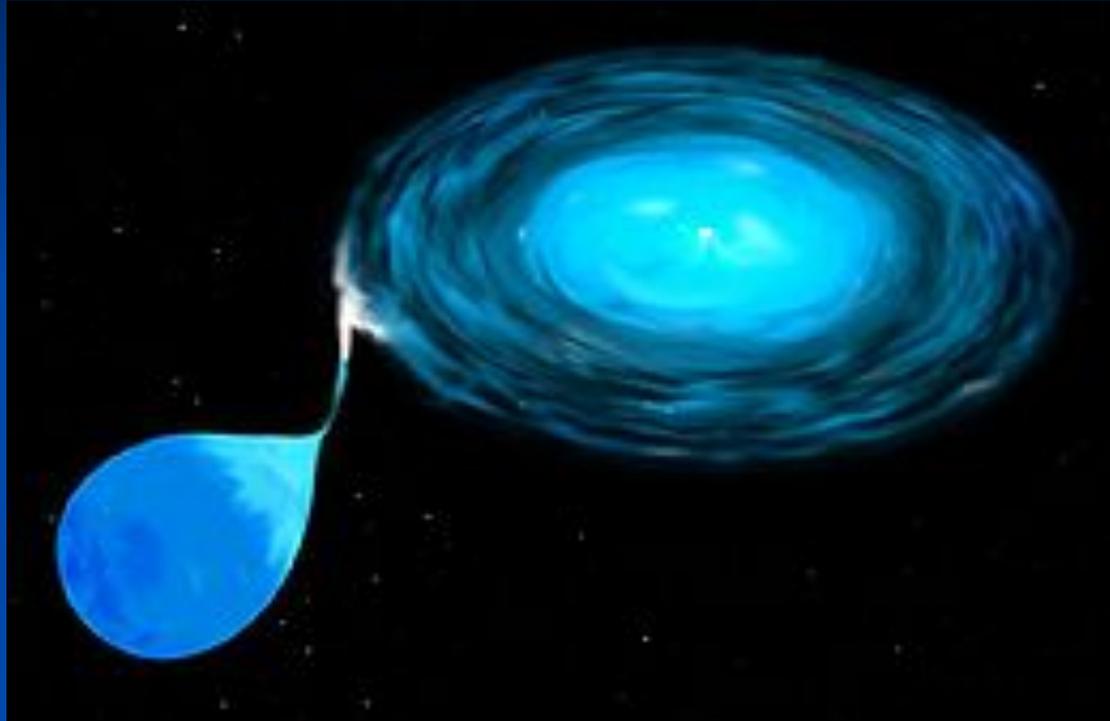
- Typically the DIAMETER of the EVENT HORIZON or
- The MASS stuffed into the SINGULARITY (which is ZERO VOLUME, ZERO DIAMETER – stays that way)

Categories of Black Holes

- Primordial (ancient) tiny Black Holes created by turbulence at origin of Universe...none detected yet...potentially dangerous due to compactness.
- Stellar Mass Black Holes – collapse of supergiant stars-probably one formed per galaxy per year, we've found quite a few.
- Medium mass...not many found, unknown why...
- Supermassive – millions to billions of Solar Mass...at center of MOST Galaxies, lots of evidence, likely affect galaxy formation.







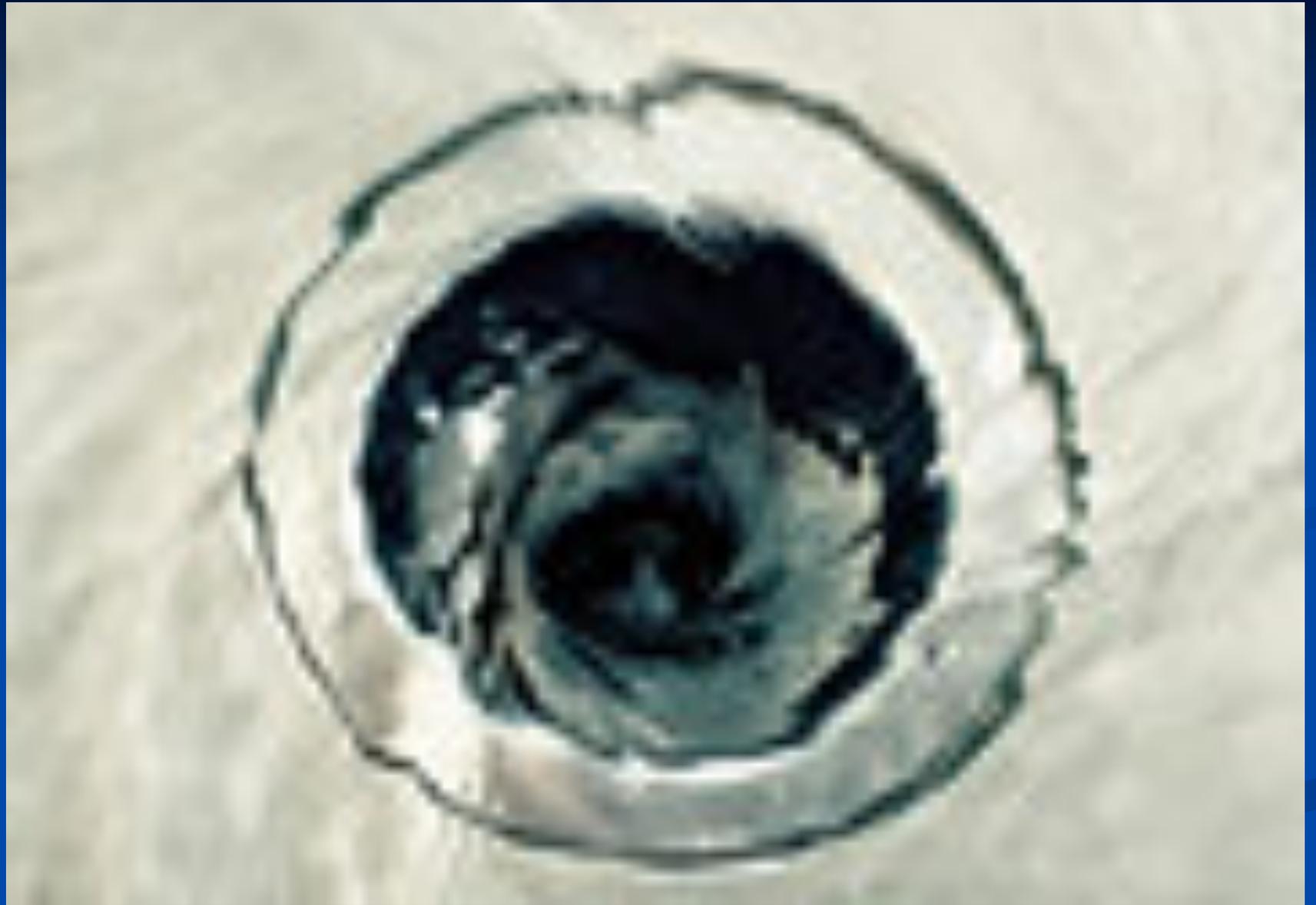
“a black hole has no hair”

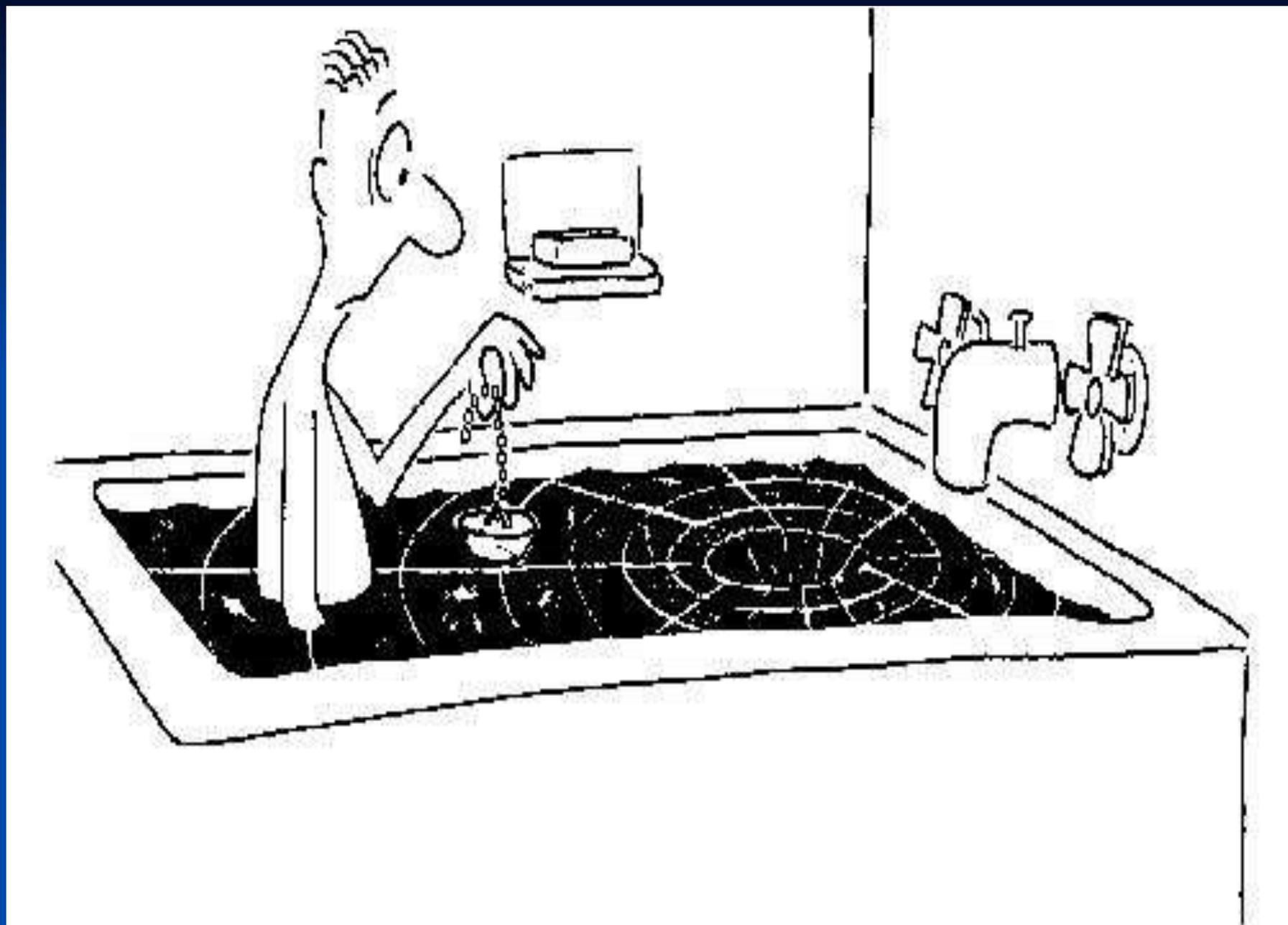
- Black holes quantitatively only have
 1. MASS (within singularity)
 2. May have CHARGE
 3. May have SPIN (rotation)

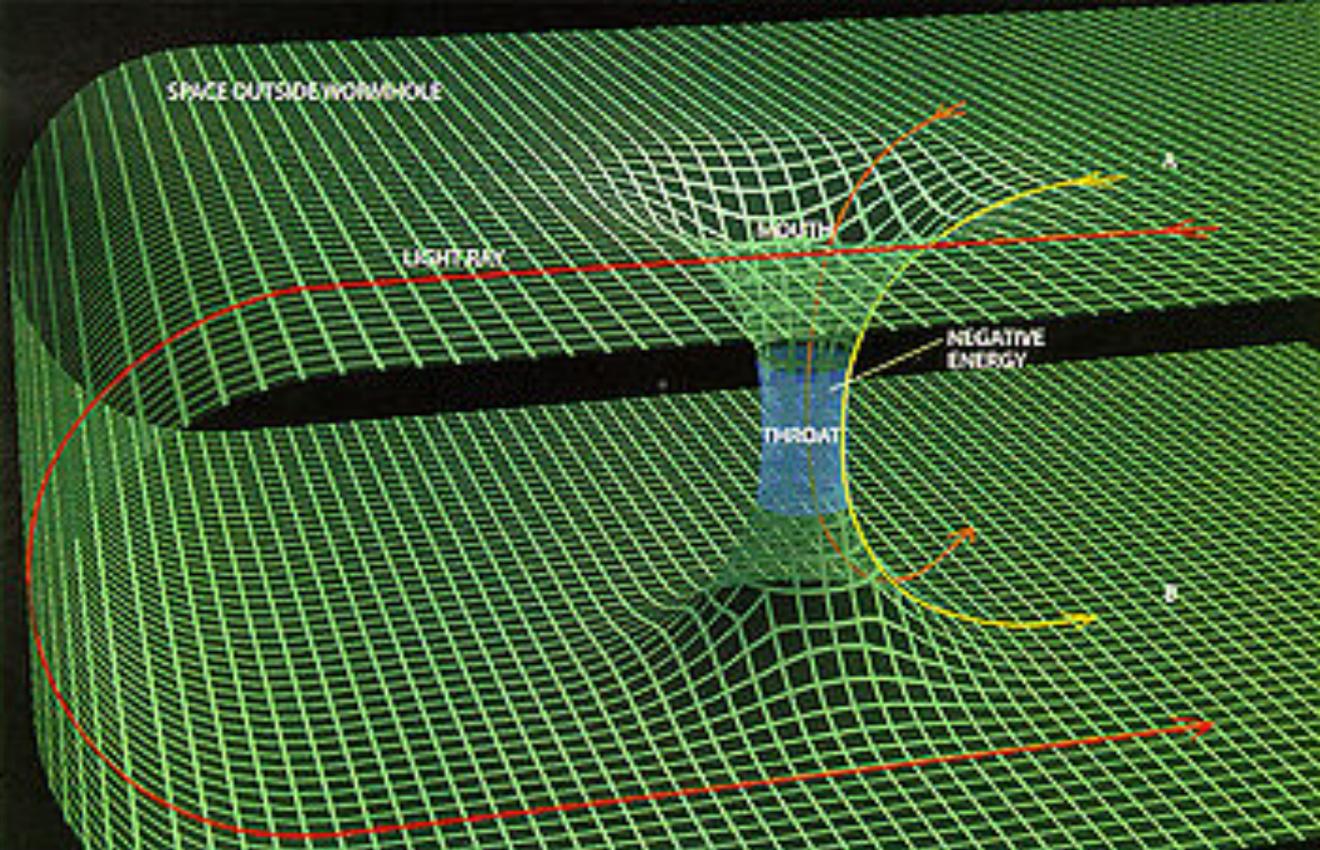
Nothing else to measure.

(diameter of event horizon depends on mass of singularity as we'll see)

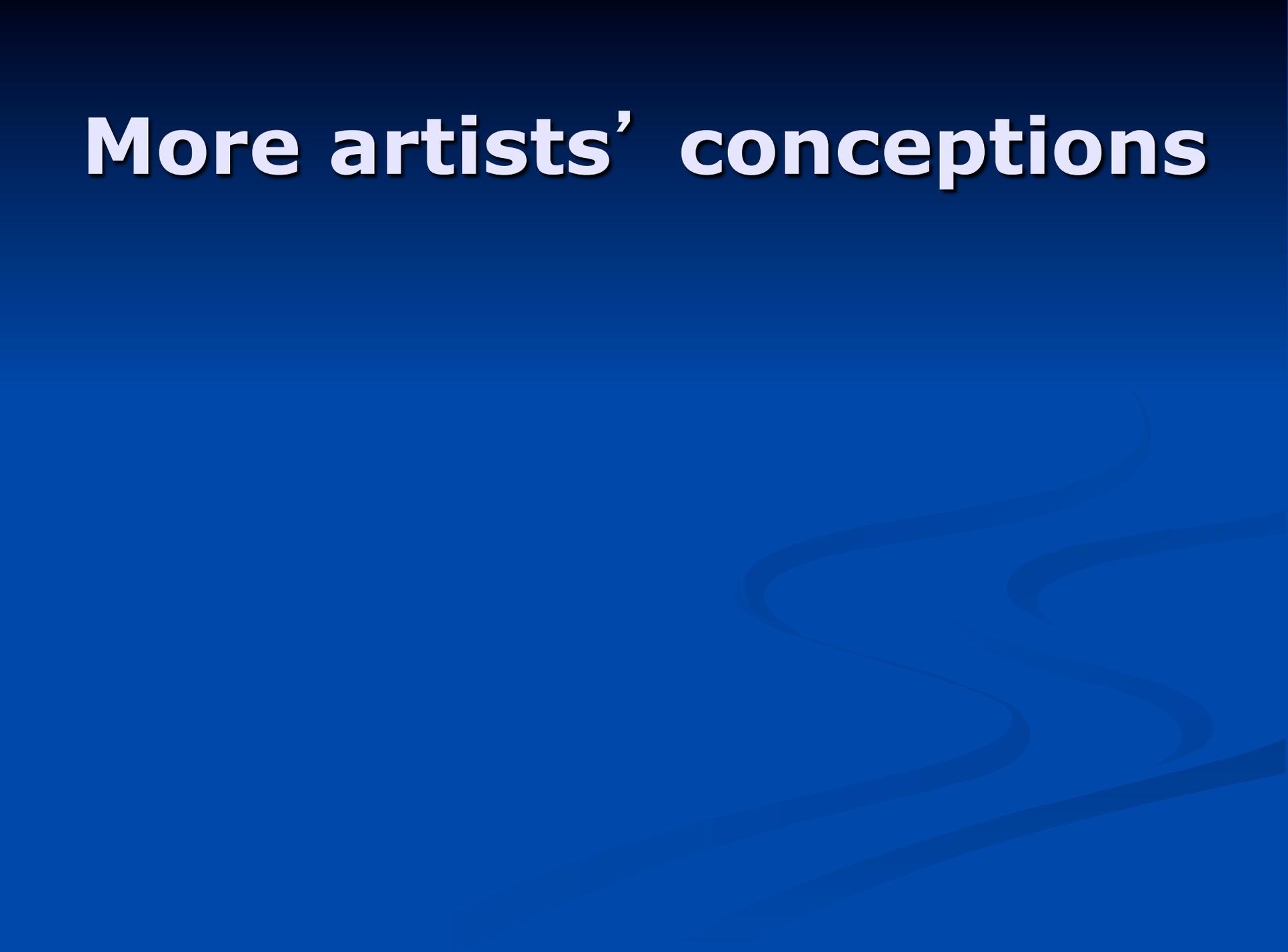
And, they're really NOT like vacuum cleaners, much more like a DRAIN.

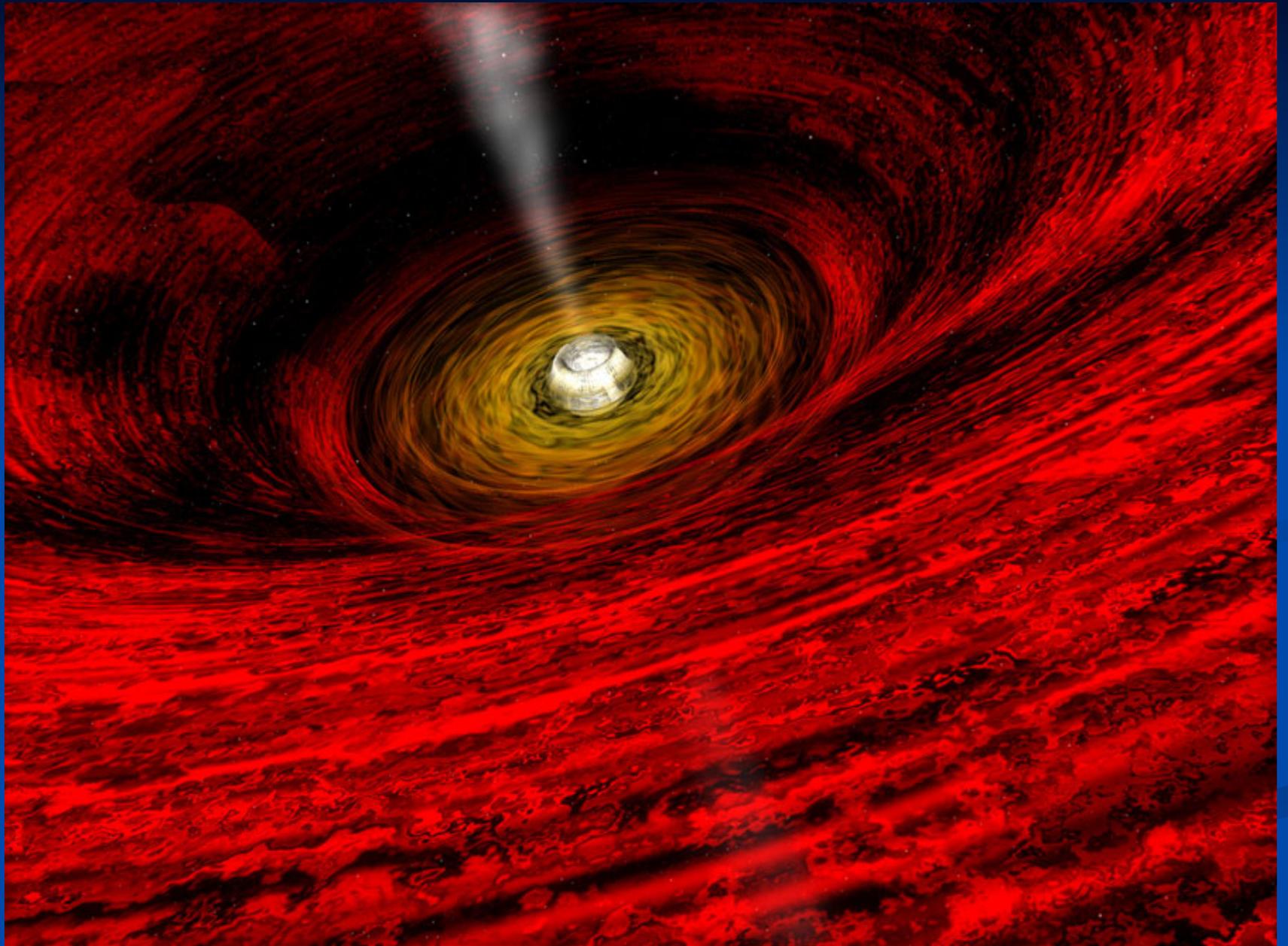






More artists' conceptions

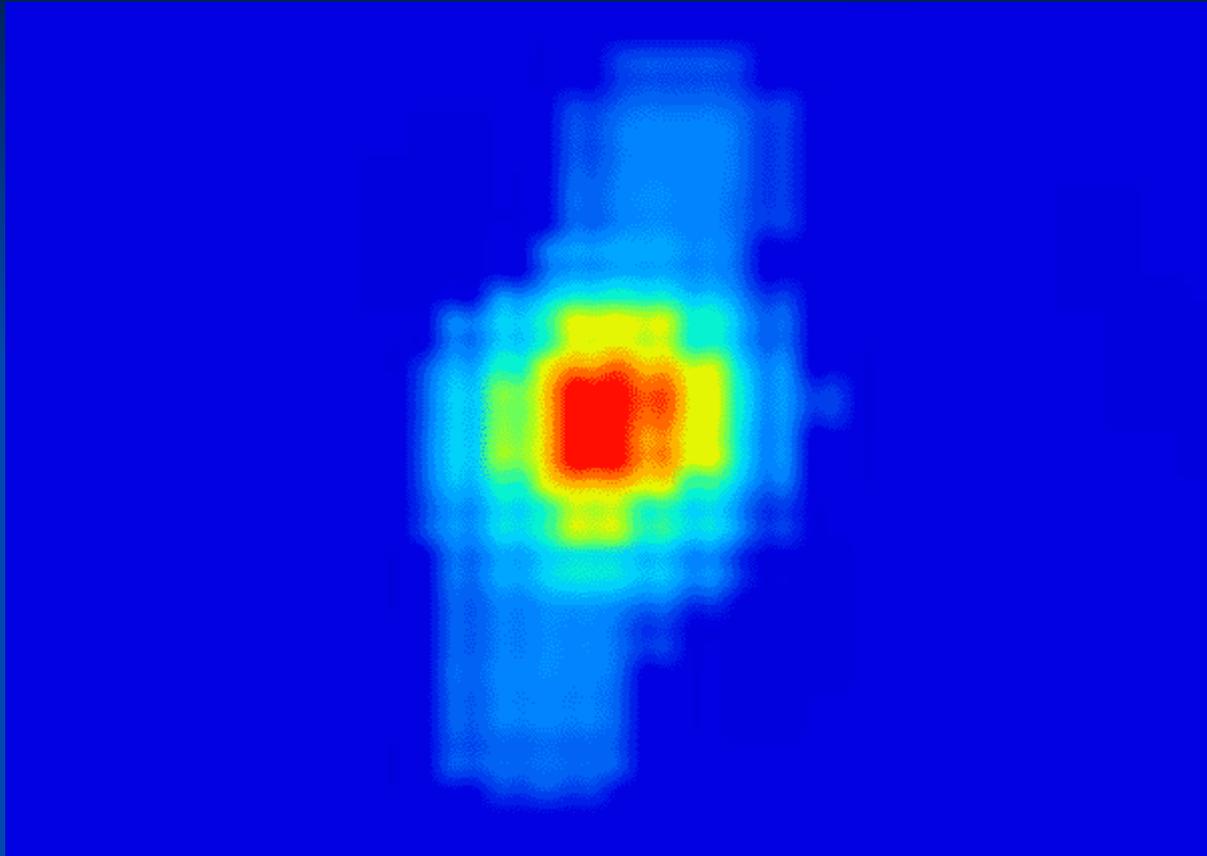
The background of the slide is a solid blue color. In the lower right quadrant, there are several overlapping, wavy white lines that create a sense of movement and depth, resembling stylized waves or abstract brushstrokes.





Good news, Bad news

- Nearest Black Hole is about 1600 light years away...too far to bother us
- At that distance, would take a spacecraft many THOUSAND years to get there, so we can't do any experiments directly.



How Black Holes initially form

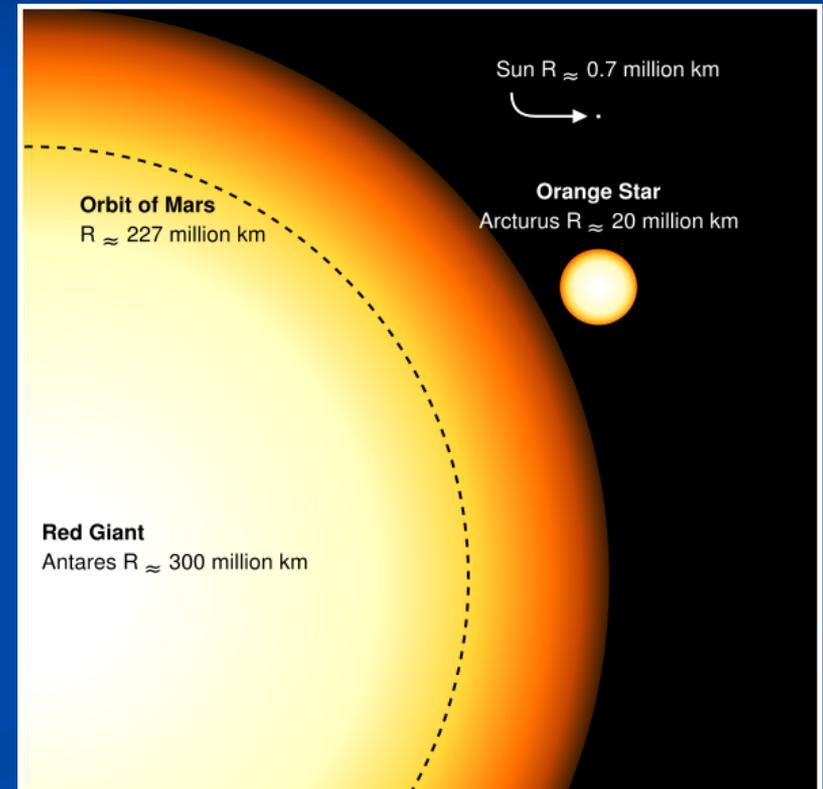


**Stars are distant large Spheres
of very hot Gasses – (distant
Suns)**

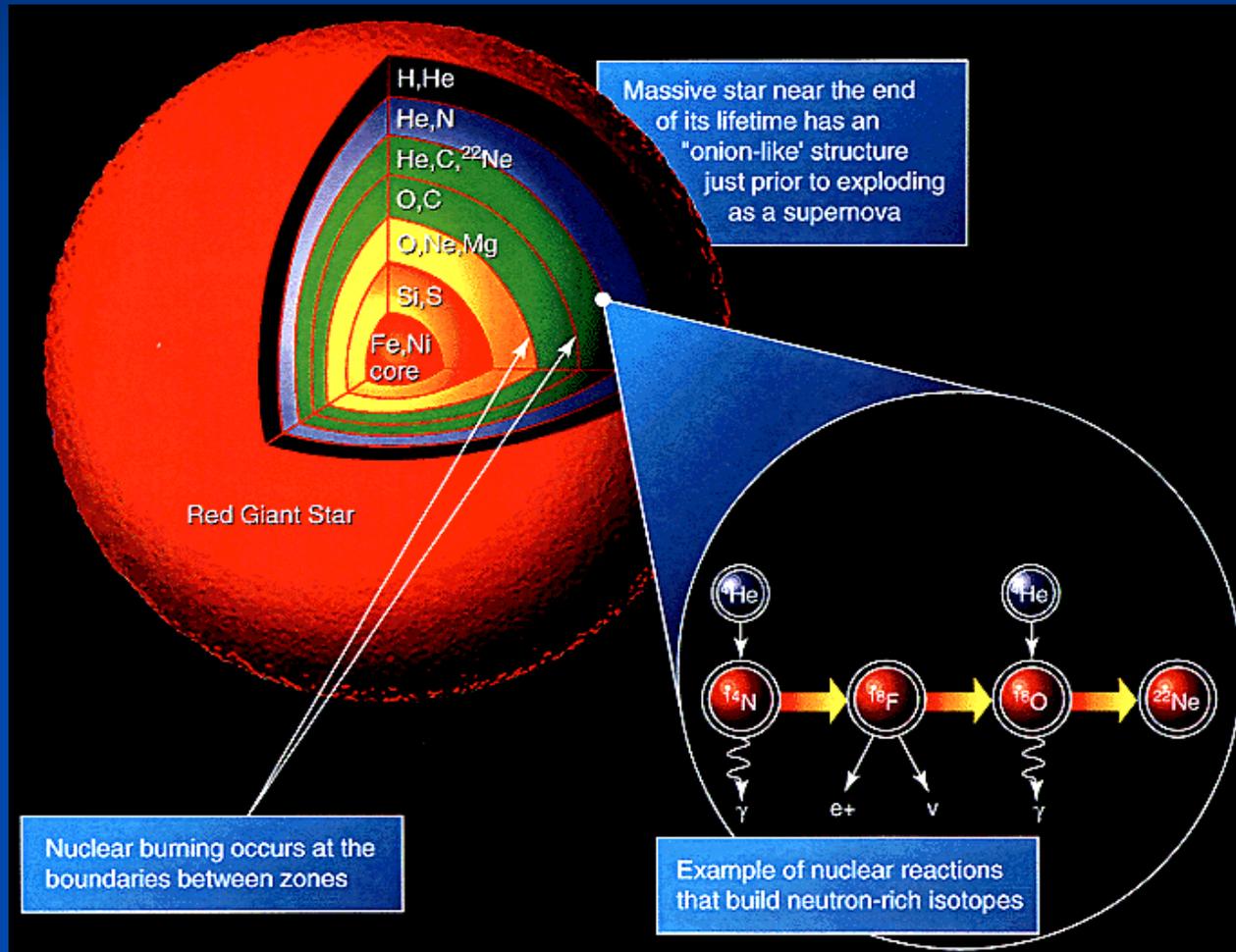


Nature lets stars form in a wide range of **MASSSES**

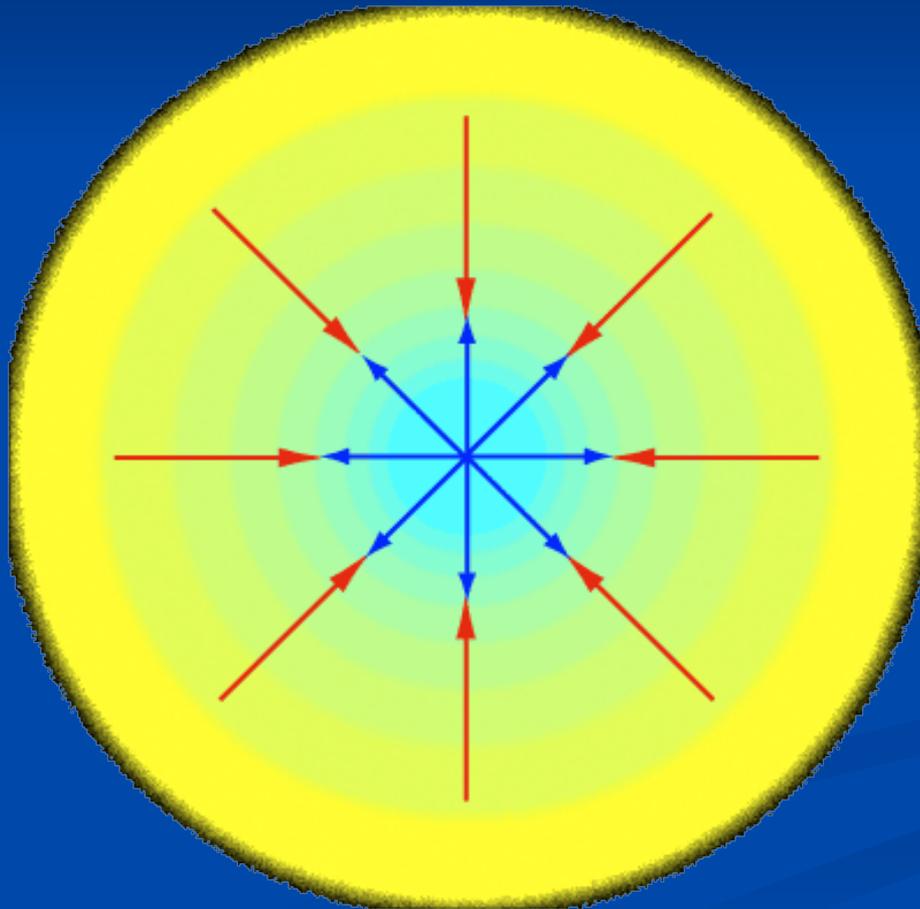
(gravity squeezes gas and dust in nebula into a star)



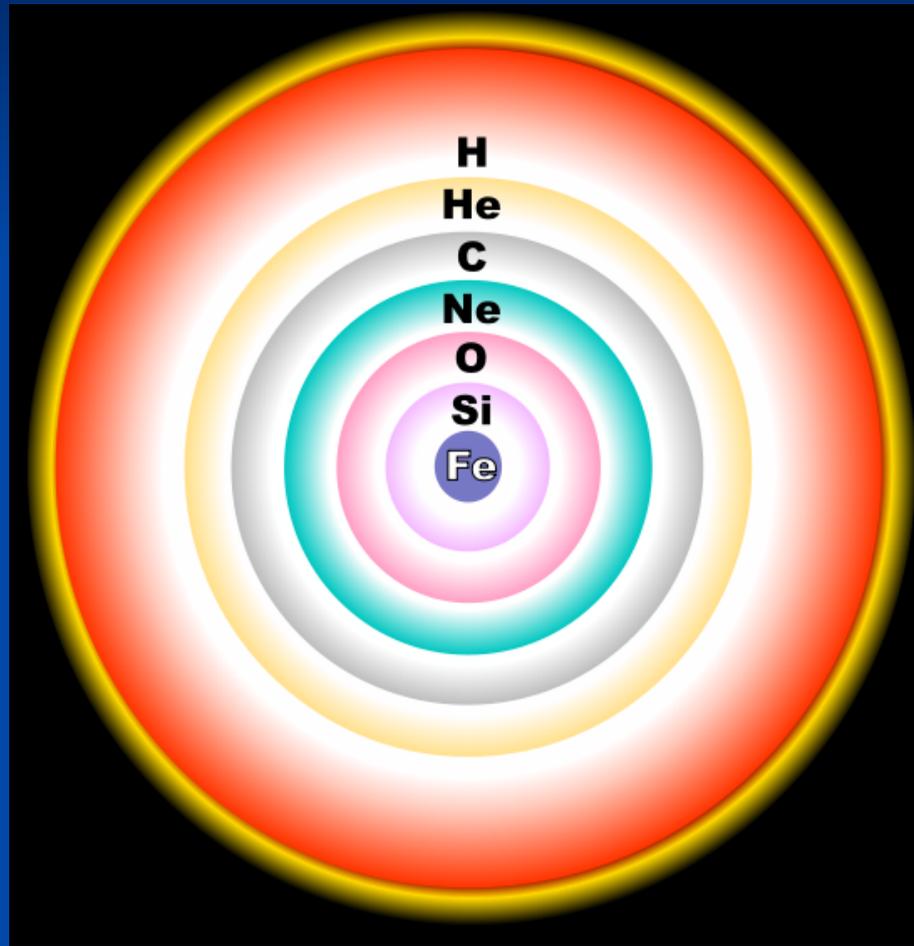
Stars fuse atomic nuclei creating new elements and lots of light.



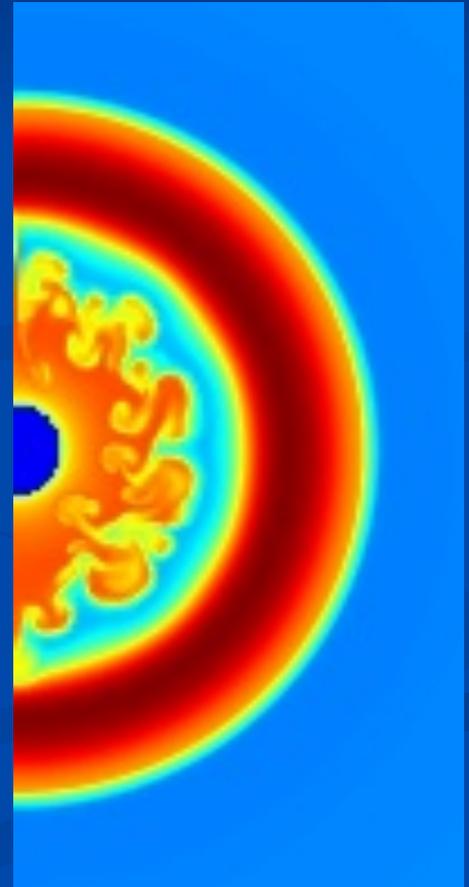
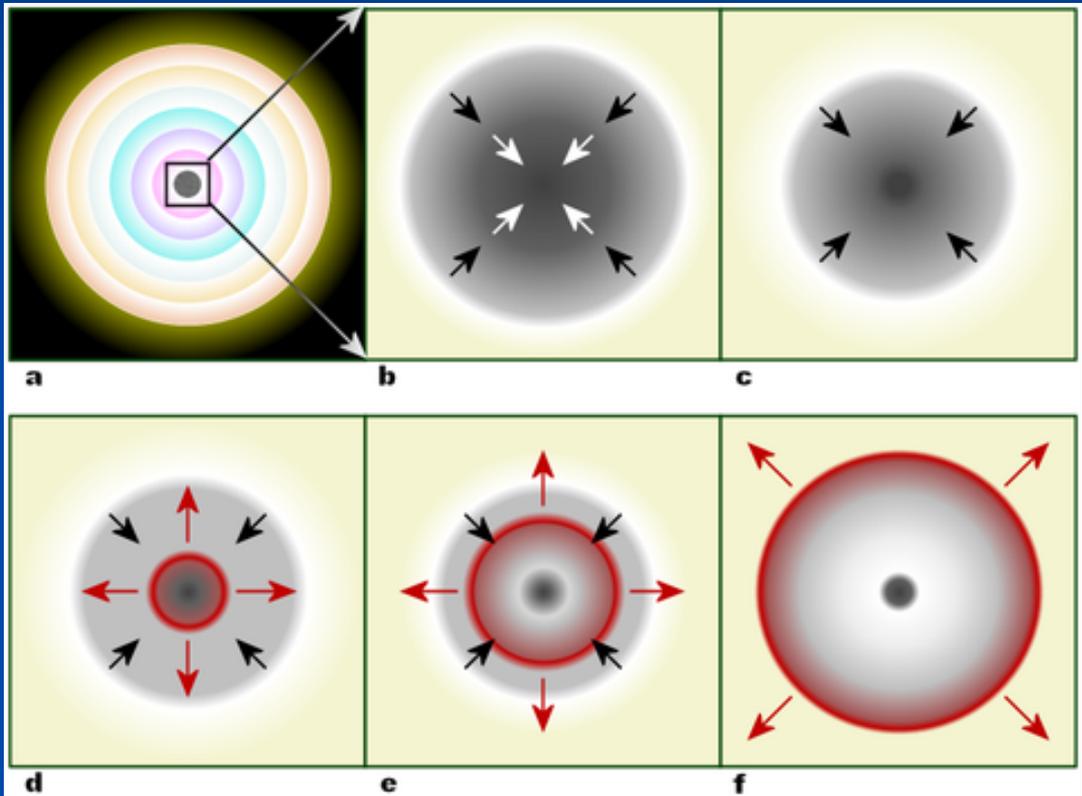
Star diameter is balancing act: outward radiation pressure vs. gravity

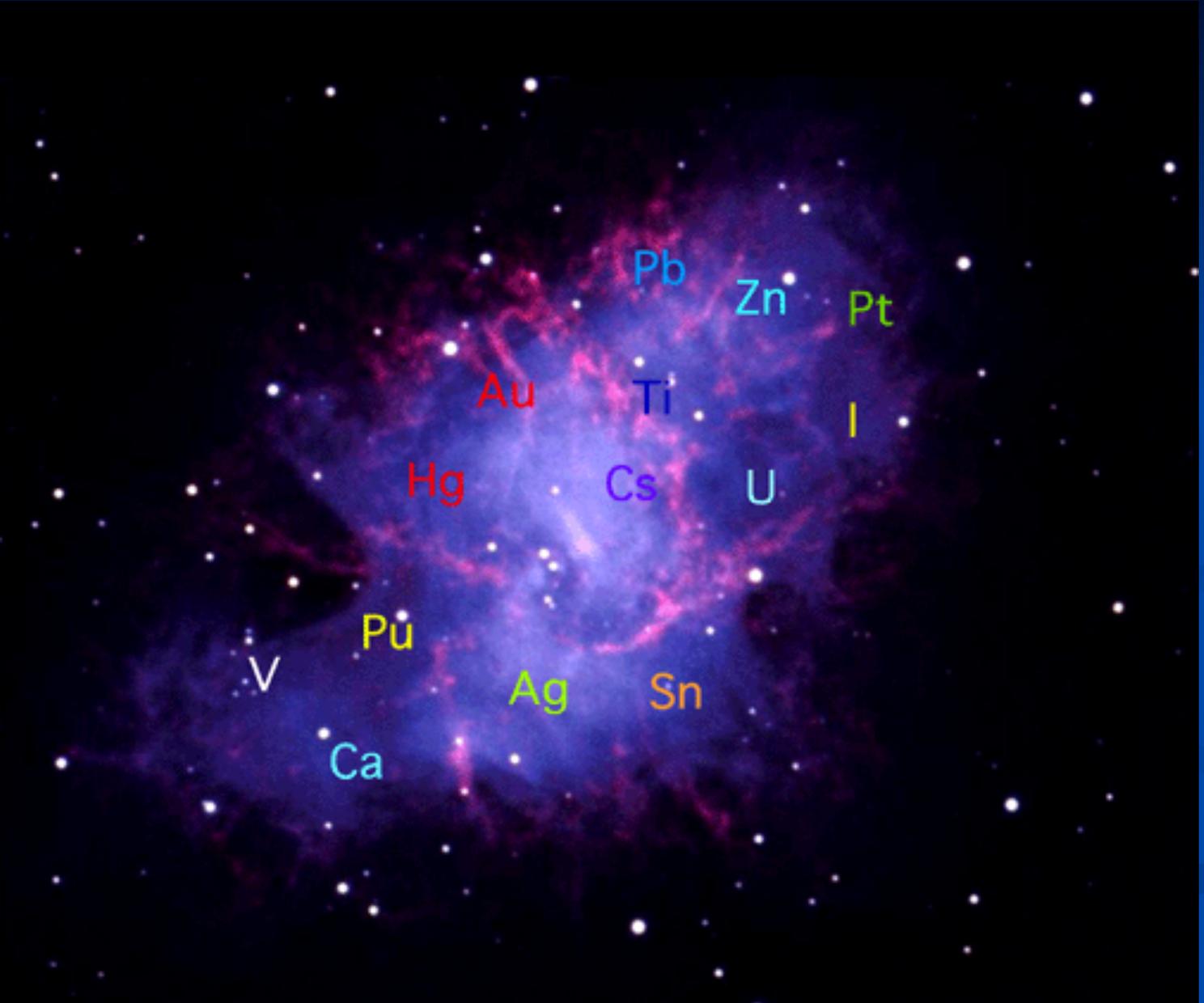


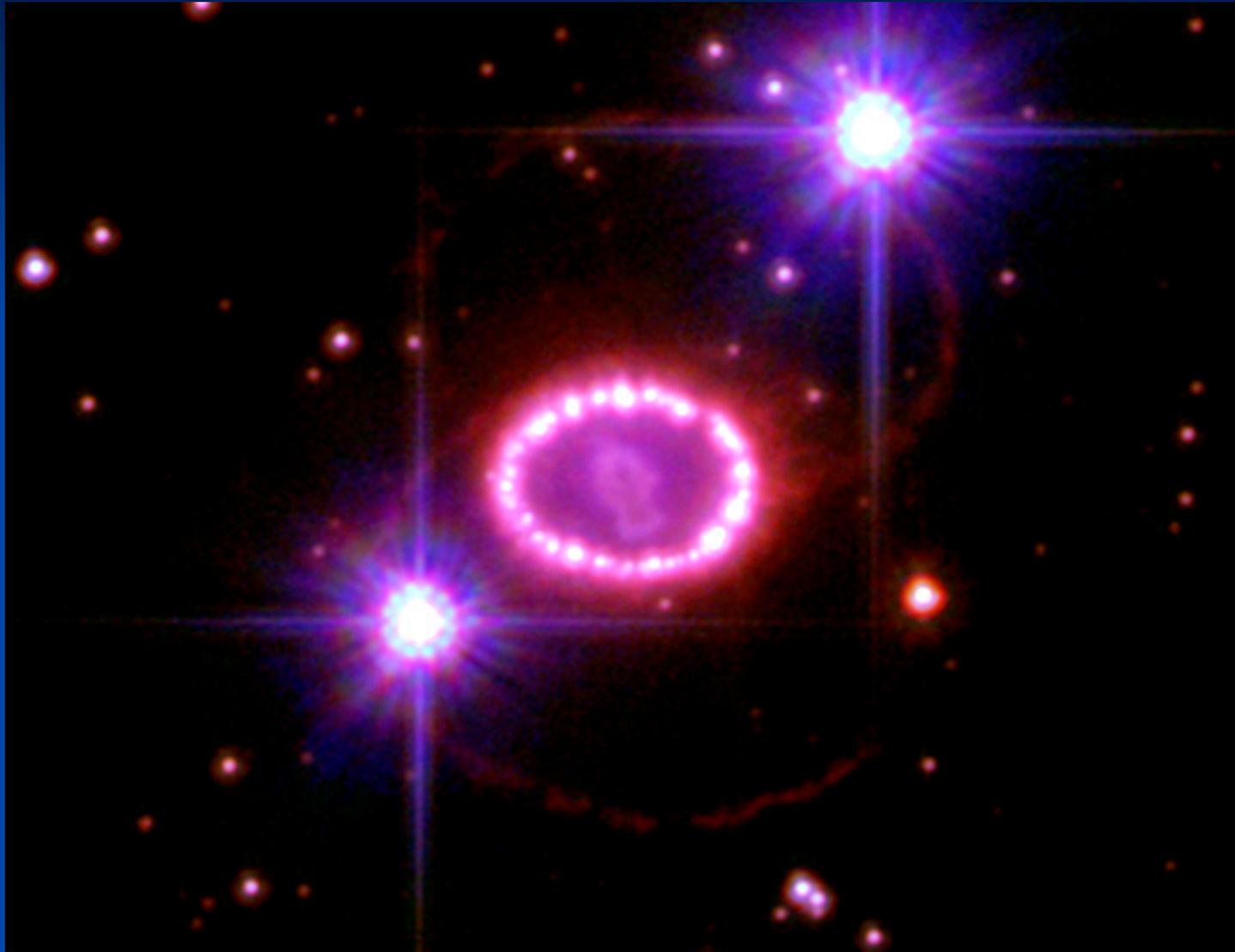
**Iron core can no longer fuse.
GRAVITY WINS!**



Catastrophic COLLAPSE and REBOUND: supernova







Core is crushed to POINT, a SINGULARITY, of INFINITE DENSITY

The fatal loop:

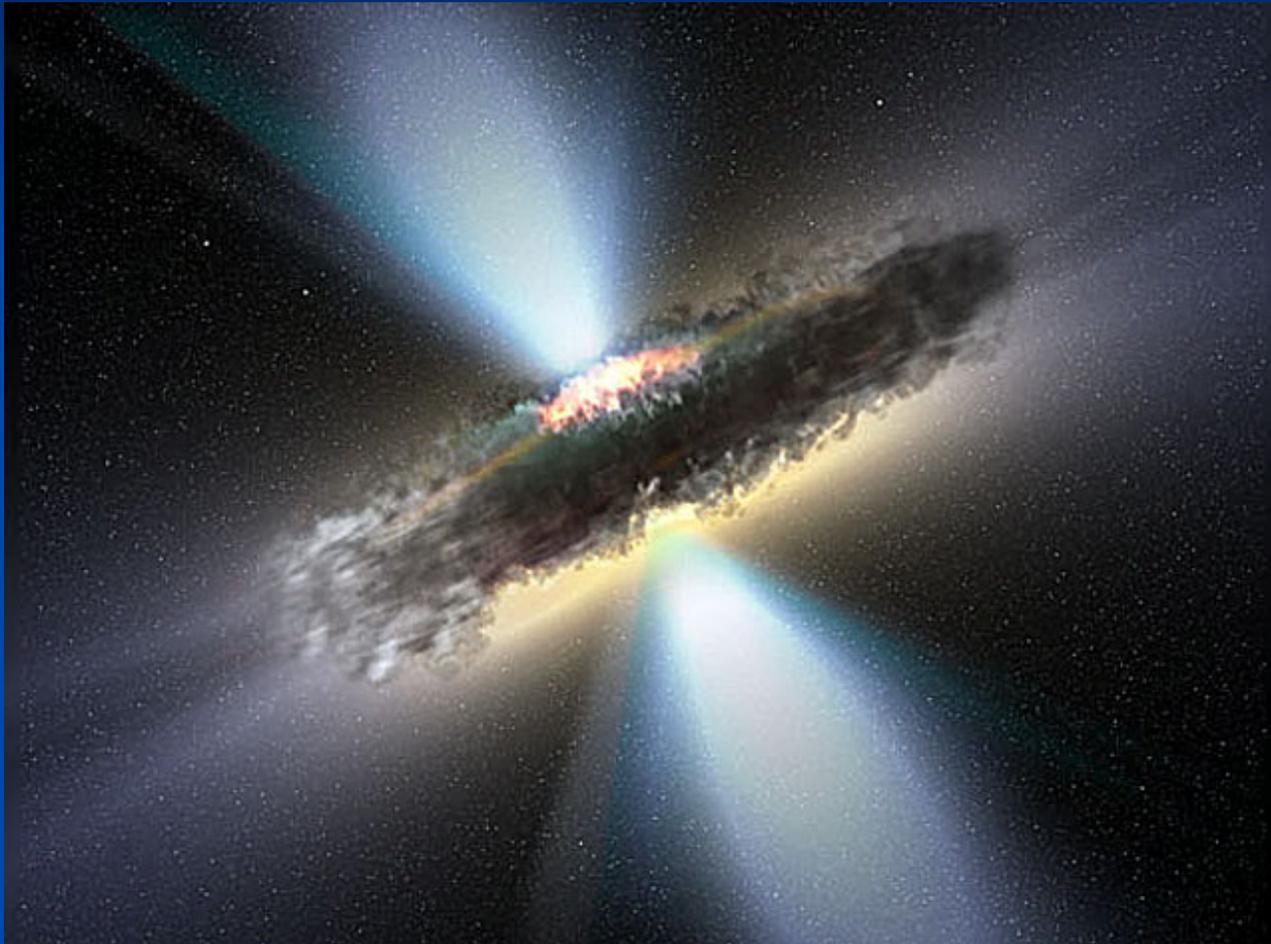
- Volume decreases
- Density *increases*
- Gravity *intensifies* – is concentrated

BLACK HOLE is FORMED!

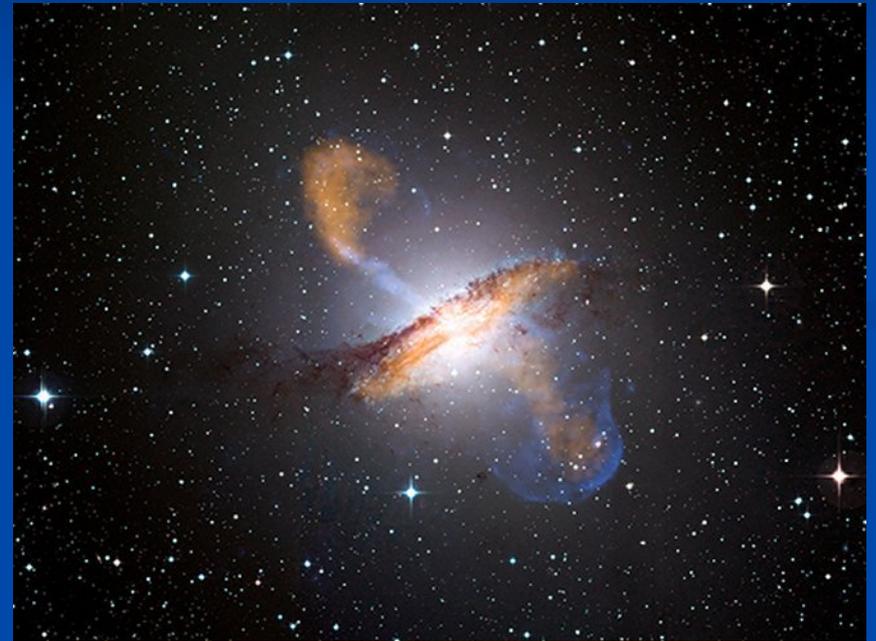
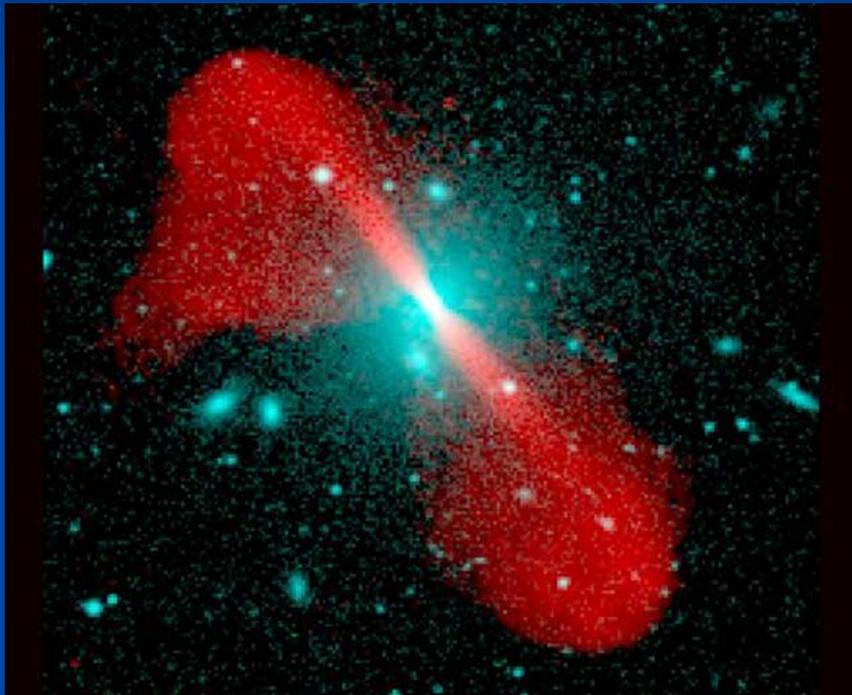
Use a piece of Aluminum Foil as a Nebula

- See if you can change the foil nebula into a BLACK HOLE
- Let's go step by step, increasing the DENSITY
- Demonstrate the effects of the BLACK HOLE on its SPACETIME (your flexible cloth)
- Compare effects of MASS and of DENSITY on your SPACETIME

Dusty torus surrounds event horizon

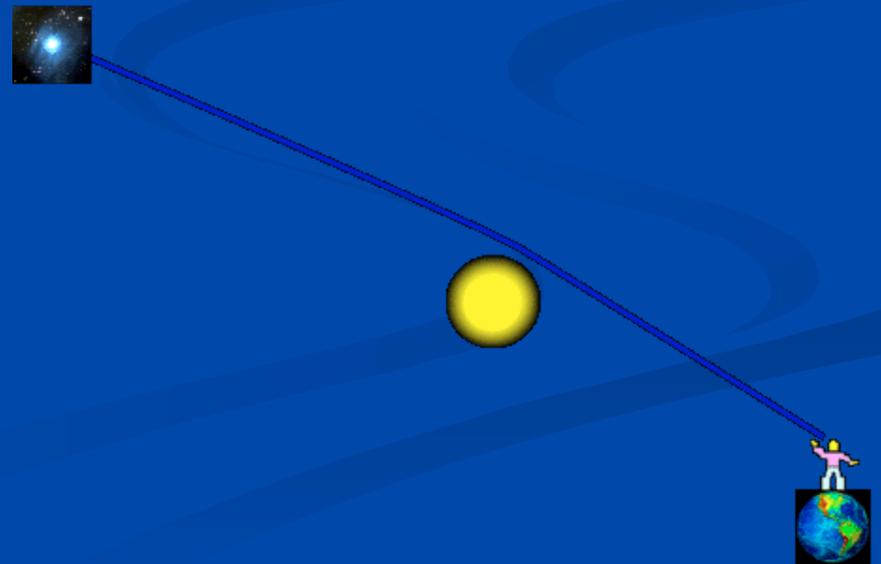
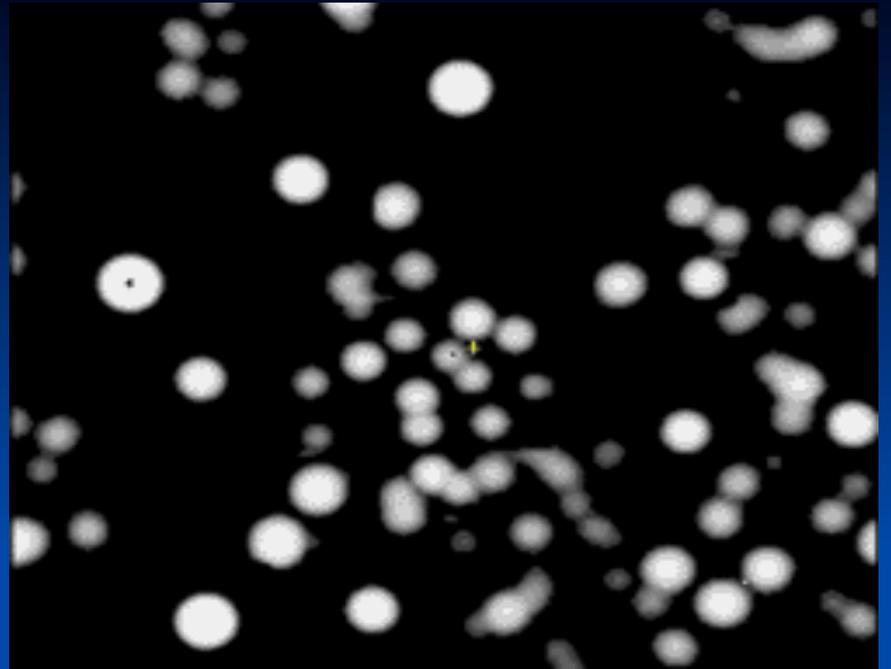
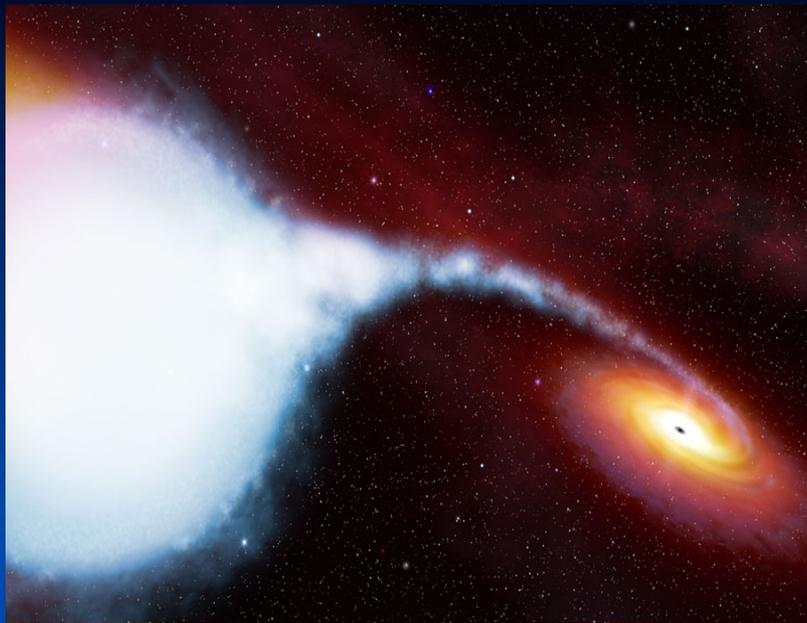


Jets are very common

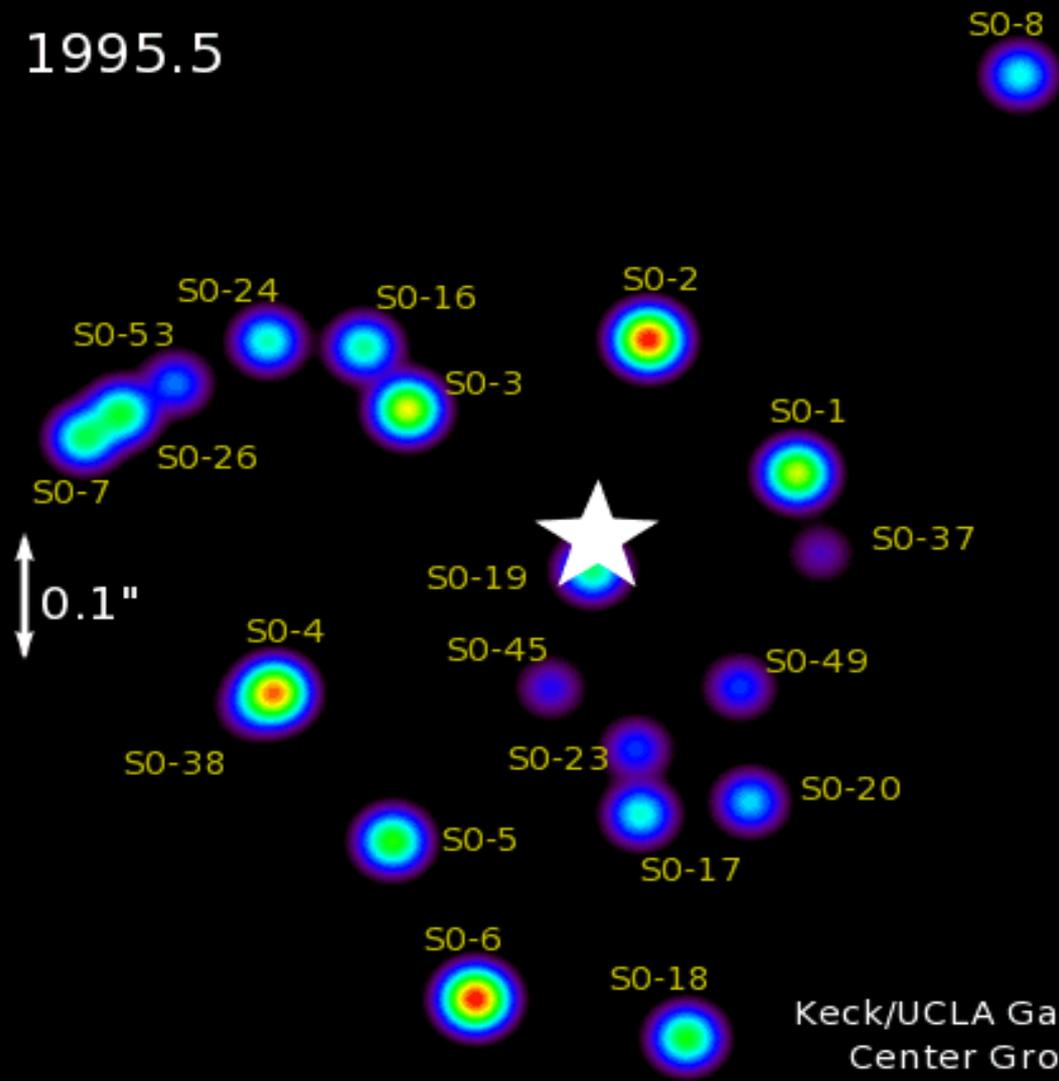


How to find Black Holes since they're invisible

- Radiation from turbulence in Accretion Disk
- Orbital motion of objects orbiting invisible object
- Jets
- Distortions of light from background objects

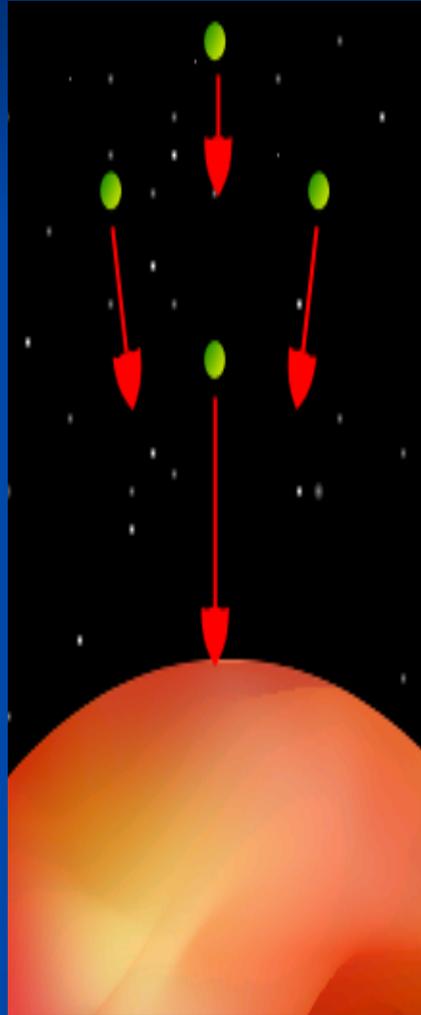


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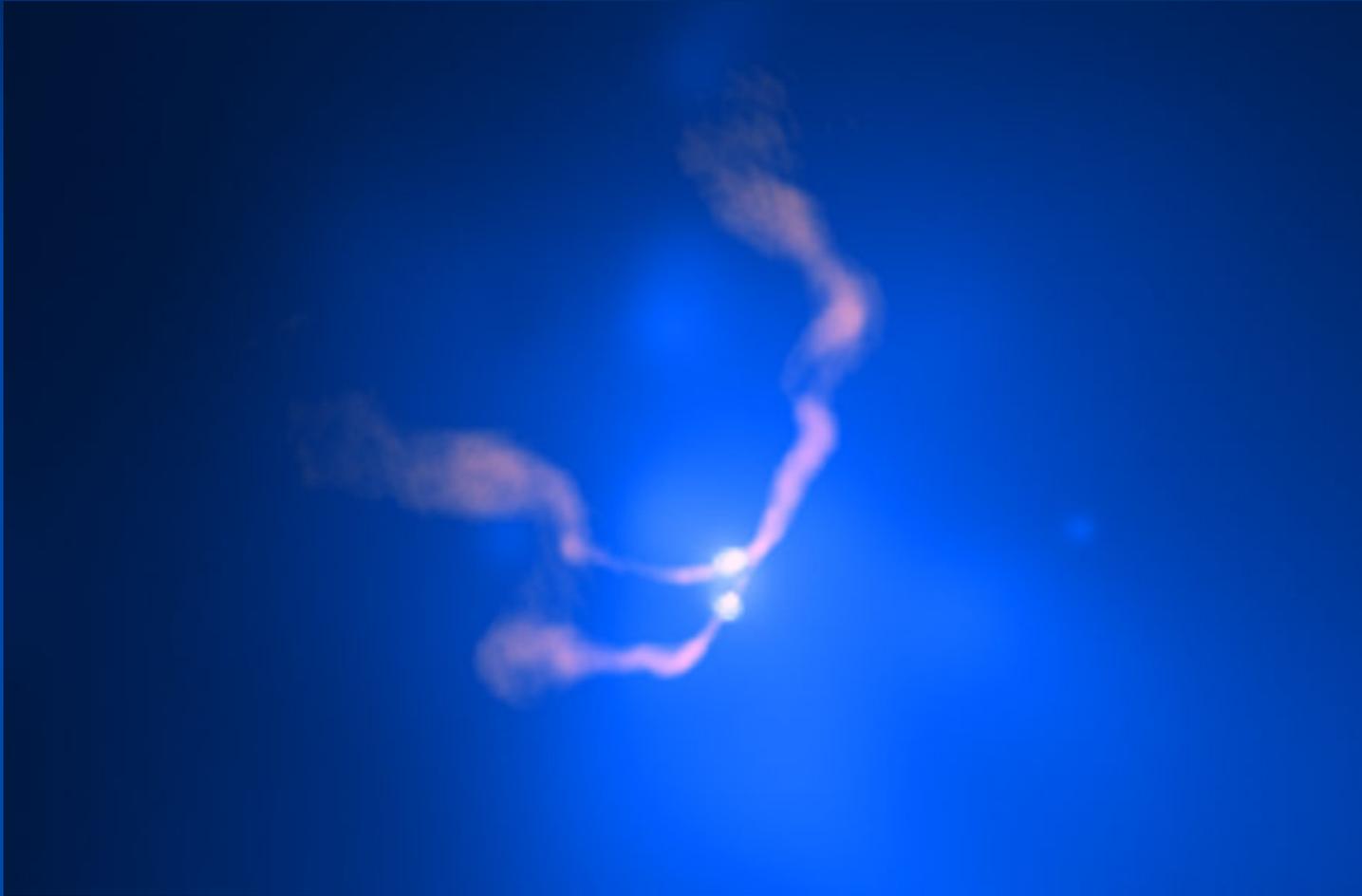
Keck/UCLA Galactic
Center Group

Don't fall in – you'd be SPAGHETTIFIED by tidal distortion

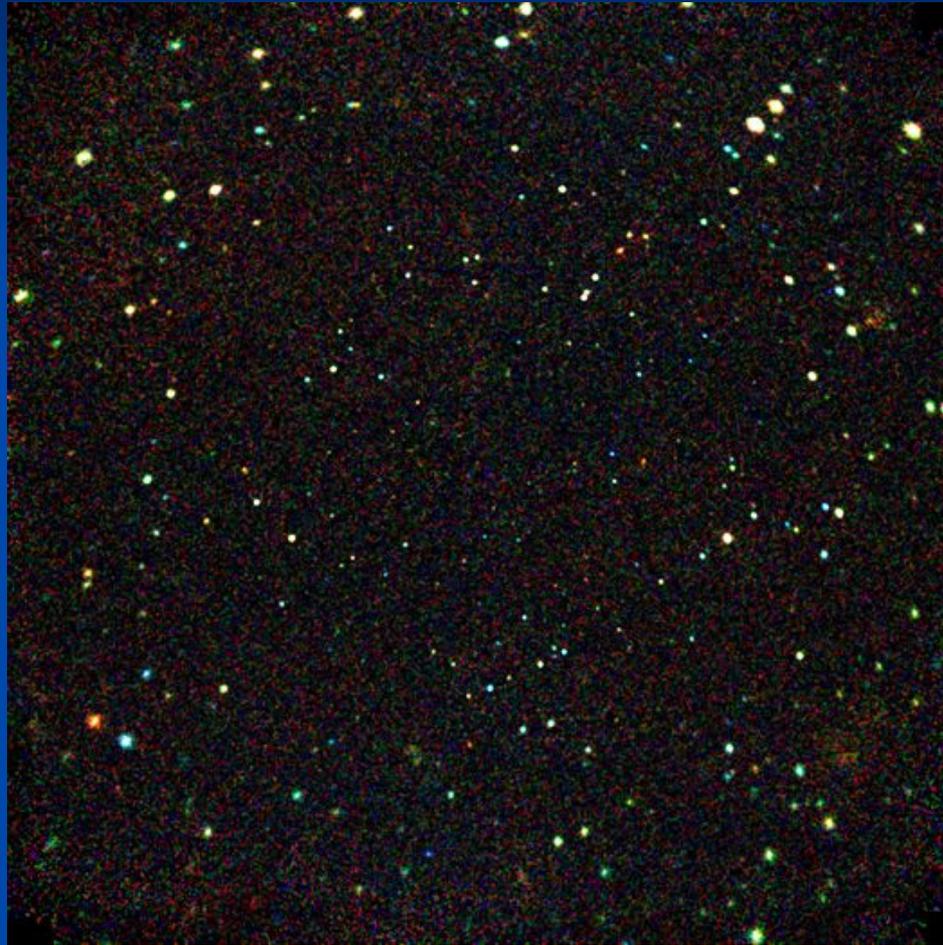


**Some recent data
references from T. Maciel,
Cambridge**

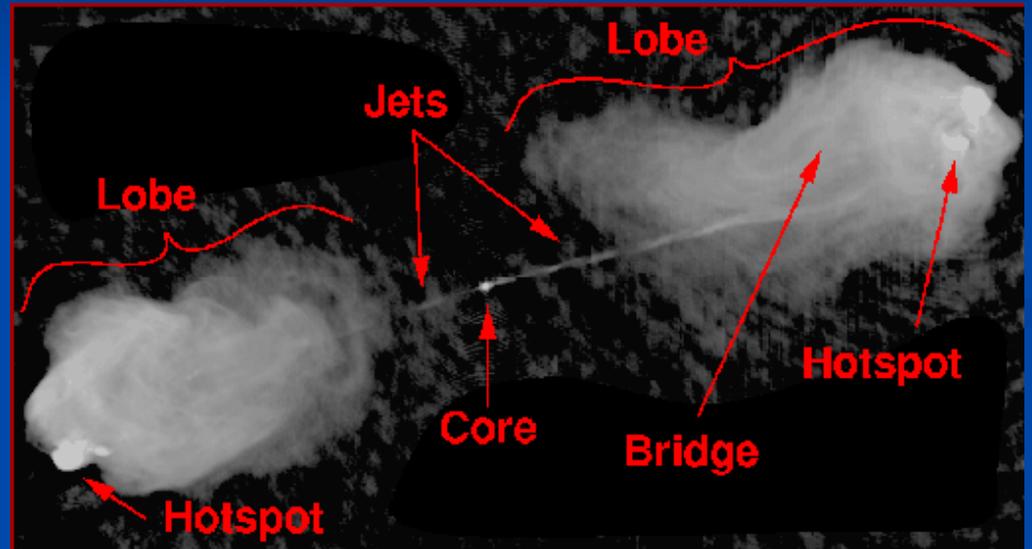
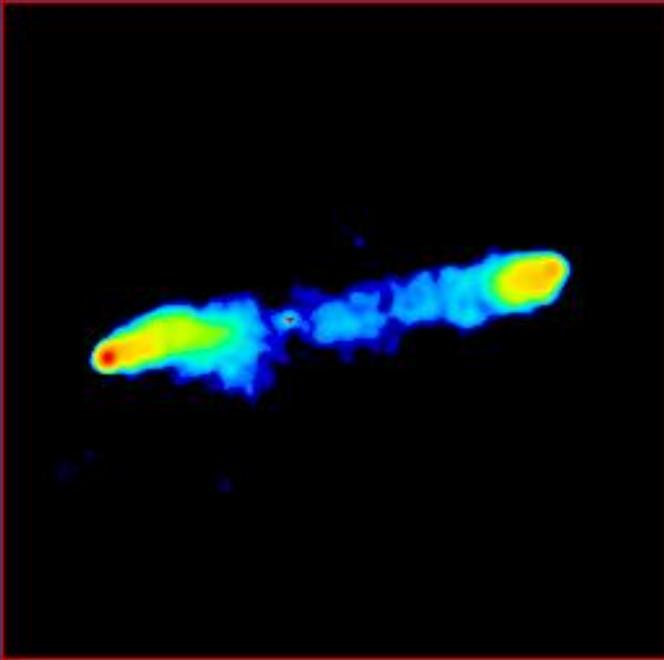
Merged galactic nuclei-pair of BHs



Chandra Deep Field



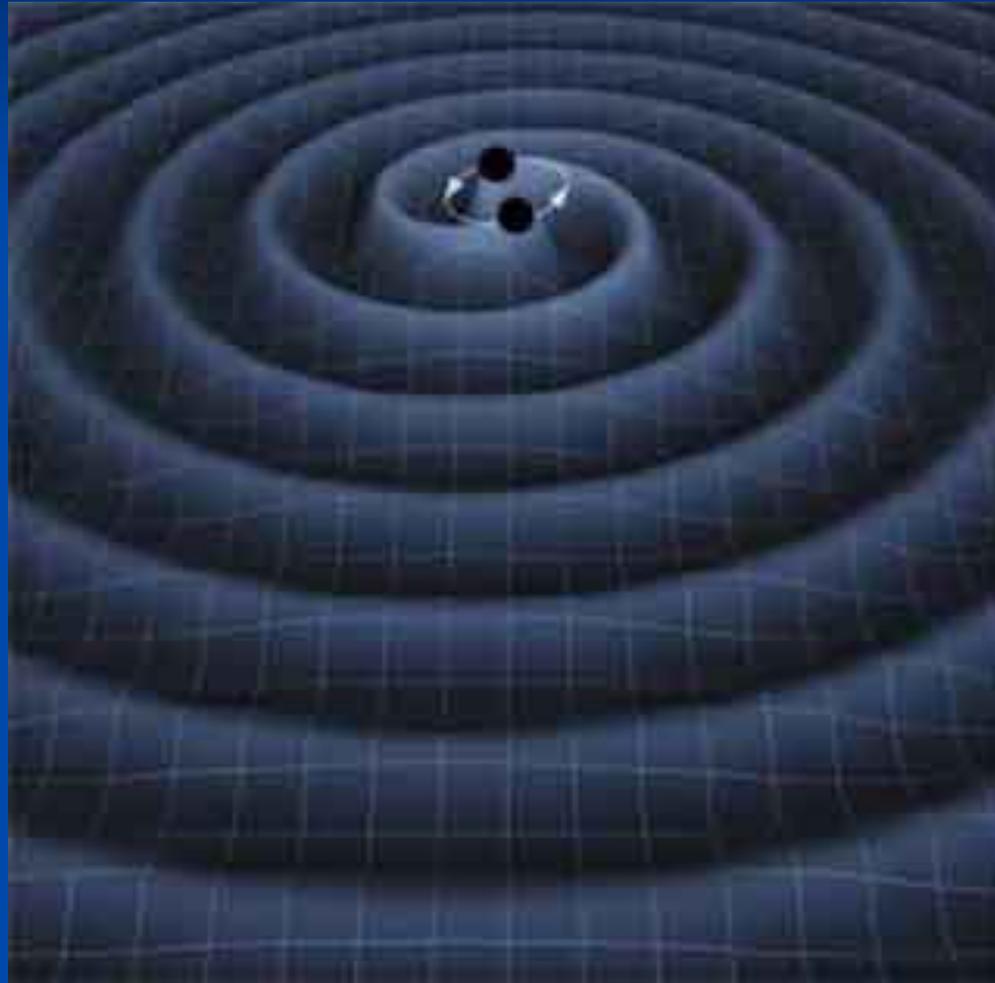
DRAGN



M81 core



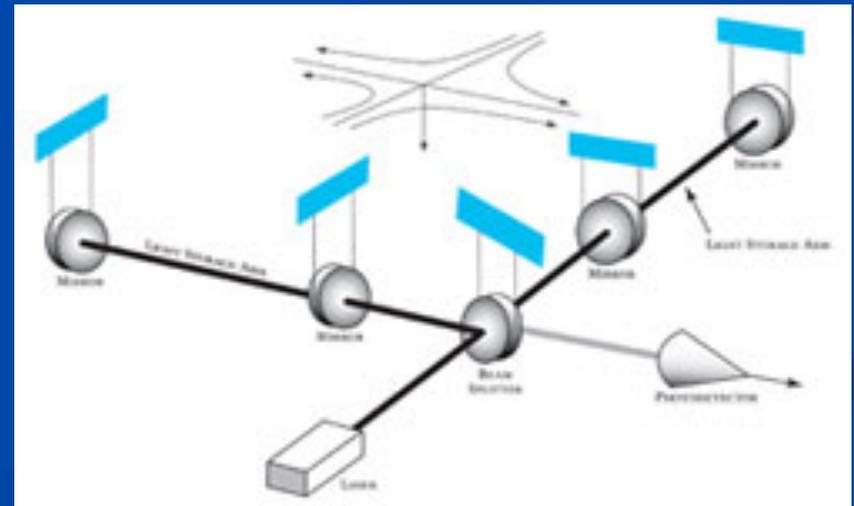
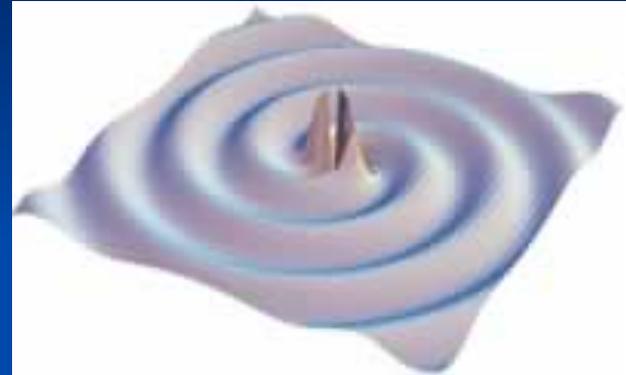
Merger of BHs may cause **GRAVITY WAVE**



LIGO Gravity Wave Tel.



How LIGO detects gravity waves



Signal of Star shredded by SMBH



XMM Newton Telescope

