update on BLACK HOLES
Nature’s MOST EXTREME DENSITY

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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.

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.
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,
  
  \[2 \times \frac{\text{Mass of object}}{\text{Mass of Sun}}\]

- 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

Specified as:

- 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.
Ergosphere Event horizon
“a black hole has no hair”

- Black holes quantitatively only have 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
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 MASSES
(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
Don’t fall in – you’d be SPAGHETTIIFIED 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