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BLACK HOLES: MYTHS, LEGENDS & TRUTHS

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RMSGC Workshop USU – Uintah Basin 24 June 2010

- Modern gravity
- Black holes we have known
- Seeing black holes
- Listening to the songs of gravity



Albert Einstein

- 1905:Working as a patent clerk in Bern, Switzerland
- In this "Miracle Year", he published 3 papers that transformed physics

- Brownian motion
- Photoelectric effect & the revival of photon theory
- Special relativity: the ultimate speed limit



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Gravity: Isaac Newton

- Isaac Newton (1642-1726)
- Lucasian Professor at Cambridge
 - I687 Principia
 - I704 Optiks
- Knewtonian gravity was the first great physical law
- Attractive force between masses, falls off with distance
- Einstein knew this was *incompatible with Special Relativity*, and in 1915 introduced General Relativity



General Relativity: Flat Spacetime

When there is no gravity, particles travel in straight lines

General Relativity: Curved Spacetime

When there is gravity, particles travel on curved lines

General Relativity: Orbits

General relativity correctly gives everything Newtonian gravity does, like orbits!

General Relativity: One page mantra...

- Matter tells space how to curve
- Space tells matter how to move

G_g = 8TT_d Marran Start Devenuer Team of New Yorks

100

Consequences of General Relativity

What is a Black Hole?

- Compact object, with HIGH ESCAPE VELOCITY
- Sun: radius = 1.4 million km
 - v = 618 km/s
- Earth: radius = 6400 km
 - v = I km/s
- white dwarf: radius = 6400 km

v = 6450 km/s

black hole: radius = 3 km

v = c = 300,000 km/s

Not a new idea!

Einstein did not invent black holes!

- Black holes are a *natural consequence* of gravity!
- Black holes were discovered in Newtonian gravity by Rev. John Michell in 1783 (!)
- What did Einstein add to the idea of black holes?
 - You cannot escape from a black hole
 - The speed of light is a maximum speed limit (special relativity)

[35]

VII. On the Means of differentiating the Diffance, Magnitude, &c. of the Fixed Stars, in confequence of the Diminution of the Velocity of their Light, in cafe fuch a Diminution should be found to take place in any of them, and fuch other Data should be procured from Observations, as would be farther necessary for that Purpose. By the Rev. John Michell, B. D. F. R. S. In a Letter to Henry Cavendish, Esq. F. R. S. and A. S.

Read November 27, 1783.

29. If there fhould really exift in nature any bodies, whole denfity is not lefs than that of the fun, and whole diameters are more than 500 times the diameter of the fun, fince their light could not arrive at us; or if there fhould exift any other bodies of a fomewhat fmaller fize, which are not naturally luminous; of the exiftence of bodies under either of these circumftances, we could have no information from fight ; yet, if any other luminous bodies fhould happen to revolve about them we might ftill perhaps from the motions of thefe revolving bodies infer the exiftence of the central ones with fome degree of probability, as this might afford a clue to fome of the apparent irregularities of the revolving bodies, which would not be easily explicable on any other hypothesis; but as the confequences of fuch a fuppolition are very obvious, and the confideration of them fornewhat belide my prefent purpole, I fhall not profecute them any farther.

Black hole observer's report...

Image credit: M. Larson

Candidate: Cygnus X-1

Candidate: Cygnus X-1

Invisible companion of a blue supergiant star is a suspected 10 solar mass black hole – the closest black hole to Earth (~5900 lyr)!

Center of the Milky Way

Stars in Motion...

Why do we think this is a black hole?

- To explain the motion we see in the stars, you need 35 billion stars per cubic lightyear
- If this were caused by stars and not a black hole, there should be 90 million stars in this picture!

Exploring black holes

Intrepid explorers (or infalling matter -- stars, hydrogen gas, etc.) are needed to explore close to a black hole.

Near the black hole

- Far away, you can't tell its a black hole
- As you get closer, the black hole stretches space and time
- Starship clocks run slow near the black hole
- Your friends you left behind measure different distances than the crew

Tidal forces...

- As you approach a black hole, it pulls harder on the parts close to it -- tidal forces
- Eventually, tidal forces pull you apart
 - Spaghettification

 Black holes can destroy stars this way

Black holes eating stars...

Tidal forces in Nature...

- Tidal forces are not unique to black holes
- I992:Tidal forces rip apart Shoemaker-Levy 9
- I994: Remnants of SL9 impact Jupiter

LISA

Binary Black Holes

- Half of all stars we see in the sky are binaries
- If stars evolve into black holes, then binary star systems can evolve into binary black holes!

Waveform Zoology

- Gravitational waves encode astrophysical information!
- They aren't good for making pretty pictures! :-(

10 Msun BH + 10,000 Msun BH circular orbits

10 Msun BH + 10,000 Msun BH eccentric orbits

More information, reading

- ALBERT EINSTEIN: www.aip.org/history/einstein/
- LISA: lisa.nasa.gov

BLACK HOLES AND TIME WARPS (Kip S. Thorne)

- EINSTEIN'S UNFINISHED SYMPHONY (Marcia Bartusiak)
- EXPLORING BLACK HOLES (Ed Taylor/John Wheeler)

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