Whispers from the Cosmos: The dawn of gravitational wave astronomy

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Table Mountain Star Party
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Gravity and waves
Gravitational observatories
Sources of gravitational waves
Amateur astronomy
Songs of gravity
The Cosmos as we Know it

- **Light** has been our messenger from the Cosmos
• A myriad of instruments exist to detect photons, but photons are limited by the fact that they interact readily with matter.
• Don’t look with light, look with gravity.

• Detect ripples in the fabric of spacetime generated by the dynamic motion of matter and energy in the Cosmos

• Gravitational waves travel unimpeded from source to observer
Albert Einstein (1879-1955)

- 1905, Patent clerk in Bern
- Special Relativity

There is an ultimate speed limit in the Universe!

- Newtonian gravity violates the ultimate speed limit
- General Relativity (1915)
- Gravitational waves (1922)
General Relativity

- Flat spacetime
• Flat spacetime
• Curved spacetime
• Curved spacetime
• Spacetime gives ordinary orbits!
• Spacetime gives ordinary orbits!
• Matter tells space how to curve
• Space tells matter how to move
Consequences of GR
Consequences of GR

Event Horizon

Black holes
(infinite wells)
Consequences of GR

- Event Horizon
- Black holes (infinite wells)
- Gravitational waves (propagating gravity) (ripples in spacetime)
- Gravitational waves change the distances between different points in spacetime
• Gravitational waves change the distances between different points in spacetime
Changes in Spacetime

- Gravitational waves change the distances between different points in spacetime
• Gravitational wave detectors measure the change in distances between different points in spacetime
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Measuring Spacetime

- Gravitational wave detectors measure the change in distances between different points in spacetime.
• Measure the change in distances by **timing laser light** between two points.
• Two 4 kilometer long laser interferometers
Danger!  Danger!

- Unforseen dangers of being a gravitational wave astronomer
LISA

- 5 million kilometer laser interferometer in space
Black Holes Colliding

• Simulation by John Baker (Goddard)
Black Holes Eating Stars

• Stars around black holes can have crazy orbits ("zoom-whirl")

• Eventually the black hole will eat them
Stars around black holes can have crazy orbits ("zoom-whirl")

Eventually the black hole will eat them
• 10 million compact binary stars in the Milky Way
• 5000 individually resolvable to LISA
• about 6 are well studied
Much of what we know about LISA binaries has been due to amateurs.

AM CVn should be visible to LISA within several minutes:
- RA 12 34 54.8
- DEC +37 37 43.4

Many other binaries like AM CVn we need to know more about.
• Gravitational waves encode astrophysical information!
• They aren’t good for making pretty pictures! :-(
The Songs of Gravity

10 Msun BH + 10,000 Msun BH
circular orbits

10 Msun BH + 10,000 Msun BH
eccentric orbits
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Last Thoughts

- Gravitational waves will be a new tool for probing the Cosmos that complements other astronomical tools and enhances our science capabilities.

- It challenges our ingenuity and creativity, and inspires us to explore and understand, not just gravity, but ourselves and our place in the Cosmos.
Further Reading

Black Holes & Time Warps
Kip S. Thorne

Einstein’s Unfinished Symphony
Marcia Bartusiak

Exploring Black Holes
Ed Taylor & John Wheeler
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THANKS! ENJOY OBSERVING!