ENERGY OF GRAVITY WAVES

Units 10 & !!

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& New York Times, February 11, 2016 & January 1, 2017 by Dennis Overbye

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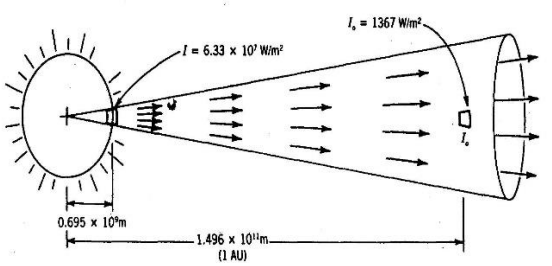
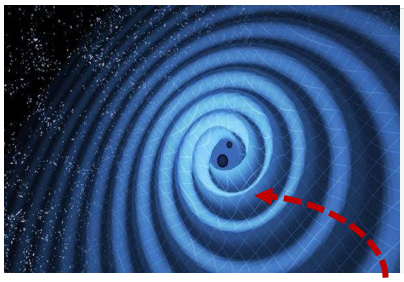
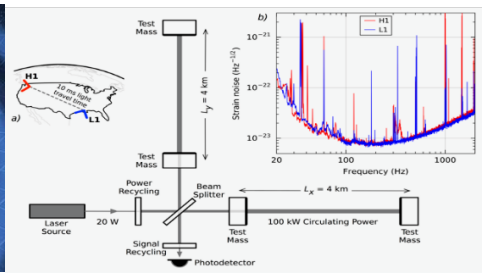
Gravitational Waves Detected, Confirming Einstein's Theory







A team of scientists announced on Thursday that **they had heard and recorded the sound of two black holes colliding a billion light-years away,** a fleeting chirp that fulfilled the last prediction of Einstein's general theory of relativity. That faint rising tone, physicists say, is the first direct evidence of gravitational waves, the **ripples in the fabric of space-time that Einstein predicted a century ago.** (Listen to it here.) It completes his vision of a universe in which space and time are interwoven and dynamic, able to stretch, shrink and jiggle. A pair of L-shaped antennas, known as LIGO, in Hanford, Wash., left, and Livingston, La., detected the gravitational waves on Sept. 14.

On Sept. 14, the system had barely finished being calibrated and was in what is called an engineering run at 4 a.m. when a loud signal came through at the Livingston site. "Data was streaming, and then 'bam,' " recalled David Reitze, a Caltech professor who is the director of the LIGO Laboratory, the group that built and runs the detectors. Ten milliseconds later, the signal hit the Hanford site. LIGO scientists later determined that the likelihood of such signals landing simultaneously by pure chance was vanishingly small. Nobody was awake in the United States, but computers tagged the event, and European colleagues noticed. "It was waving hello," he said. "It was amazing. The signal was so big, I didn't believe it." The frequency of the chirp was too low for neutron stars, the physicists knew. Detailed analysis of its form told a tale of Brobdingnagian activities in a far corner of the universe: the last waltz of a Pair of black holes. **One of them was 36 times as massive as the sun the other 29. As they approached the end, at half the speed of light, they were circling each other 250 times a second. And then the ringing stopped as the two holes coalesced into a single black hole, a trapdoor in space with the equivalent mass of 62 suns. All in a fifth of a second, Earth time. (((Lost in the transformation was about *three* solar masses' worth of energy, vaporized into gravitational waves)))))) in an unseen and barely felt. (((As visible light, that energy would be equivalent to the brightness of a billion trillion suns)))))).** And yet it moved the LIGO mirrors only four one-thousandths of the diameter of a proton. The signal conformed precisely to the predictions of general relativity for black holes as calculated in computer simulations.

INTRODUCTION: The goal of this application is to verify the statement above. The two black holes of 29 and 36 solar masses spiral together and form a single black hole of 62 solar masses. The 3-solar mass energy loss/s. forms gravitational waves equivalent to the light of billion trillion (10^9 X 10^{12}= 10^{21}) suns.

QUESTIONS: (a) In graphic in upper left it is seen sun surface emits 6.3 X 10^7 W./m^2 of light. The sun's radius is seen to be 700,000 km. Find the area of the sun's surface ? , (b) Find total light energy emitted from sun's surface ?, (c) Find total light energy/s. emitted from billion trillion (10^{21}) suns?, (d) Find the rest mass energy of 3 solar masses/s. using E = m c^2 ?, (e) Why would mass energy of three solar masses be more than actual gravitational waves?

HINTS: Area of sphere = 4πr^2 , [___W/m.^{2}][____ m.^{2}] = ____W , solar mass = 2 X 10^{30} kg. , c = 3 X 10^8 m./s. , E = m c^2

ANSWERS: (a) 6.15 X 10^{18} m.^{2} , (b) ~ 3.8 X 10^{26} Watts , (c) ~ 3.8 X 10^{47} W, (d) ~ 5.4 X 10^{47} Watts, (e) All the data mentioned here are approximations. Thus, in the process of squaring and calculating some approximation error should be expected. In any event, the ~ 70% of the rest mass energy of 3 solar masses has converted into the gravitational wave. Not far off! Dr. JC.