

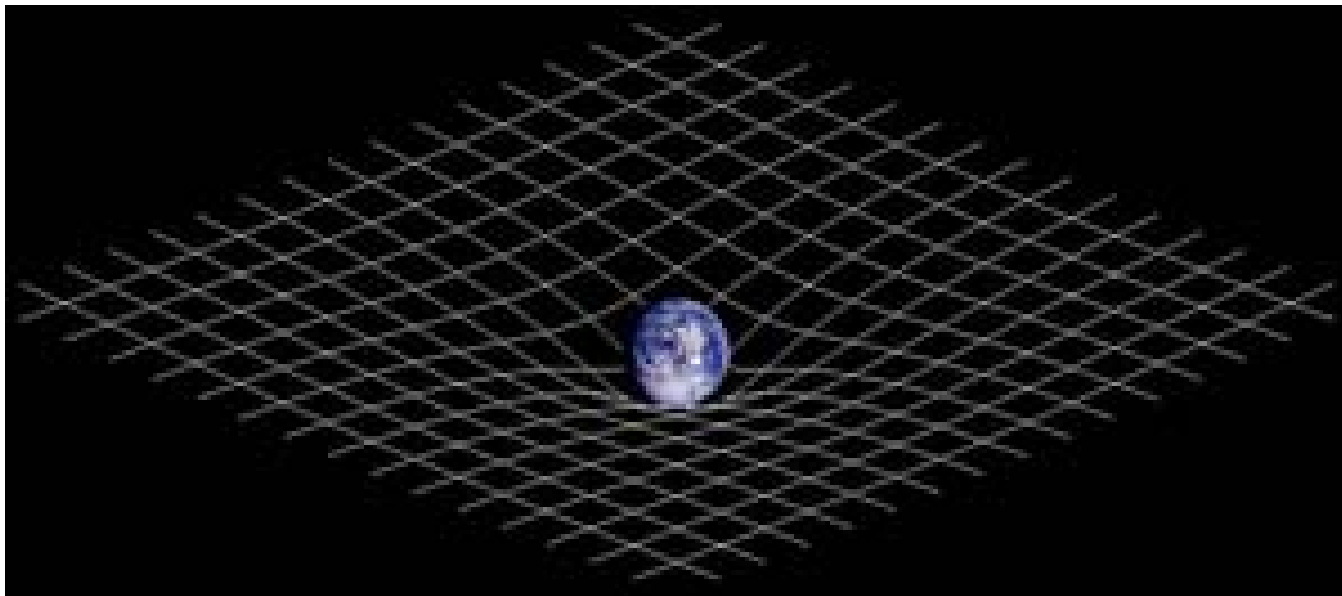
Cosmic Ripples: LIGO's Search for Gravitational Waves

Tiffany Summerscales
Andrews University



What is a Gravitational Wave?

Space tells matter how to move.
Matter tells space how to curve.
– John A. Wheeler

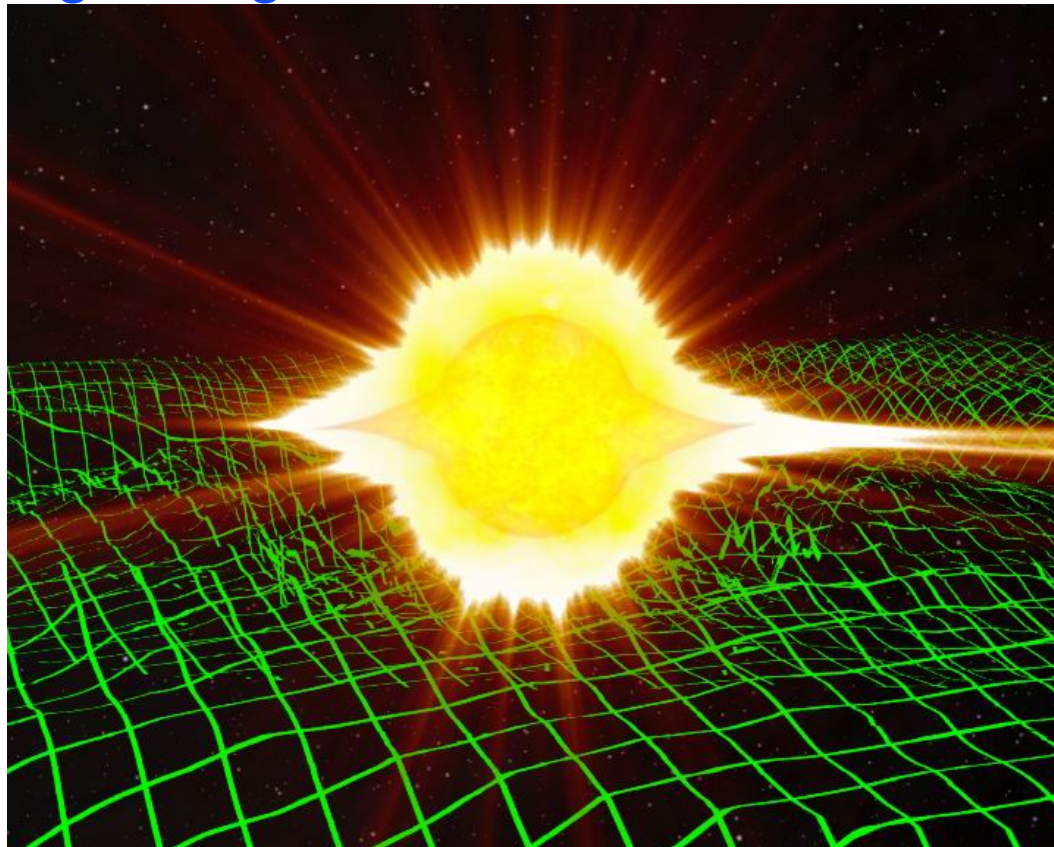


http://en.wikipedia.org/wiki/Image:Spacetime_curvature.png

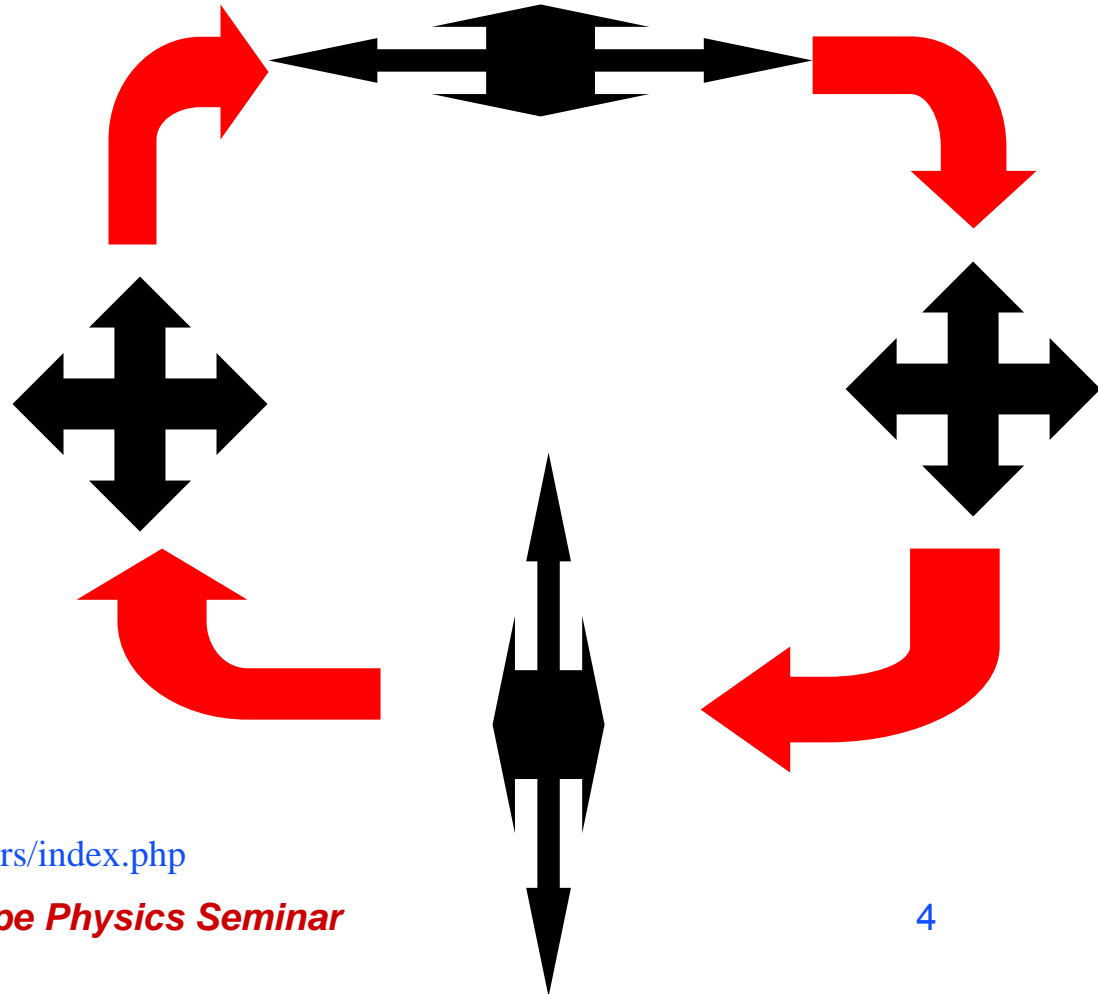
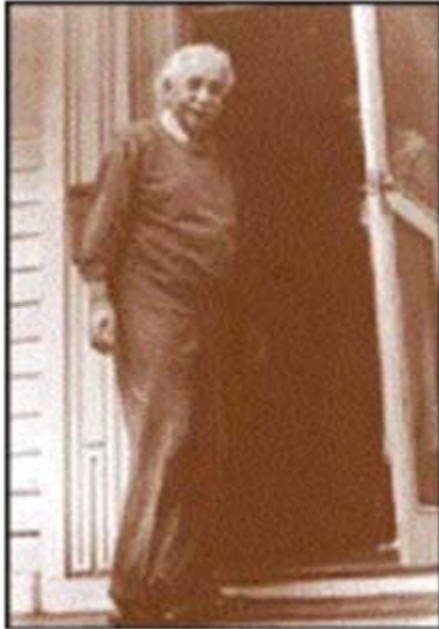


What is a Gravitational Wave?

- Change in matter distribution = Change in curvature
- Propagating change in curvature = A Gravitational Wave



What is a Gravitational Wave?



Animation from <http://www.ligo-la-caltech.edu/Posters/index.php>

April 13, 2006

G070102-00-Z

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Gravitational Waves are Small!

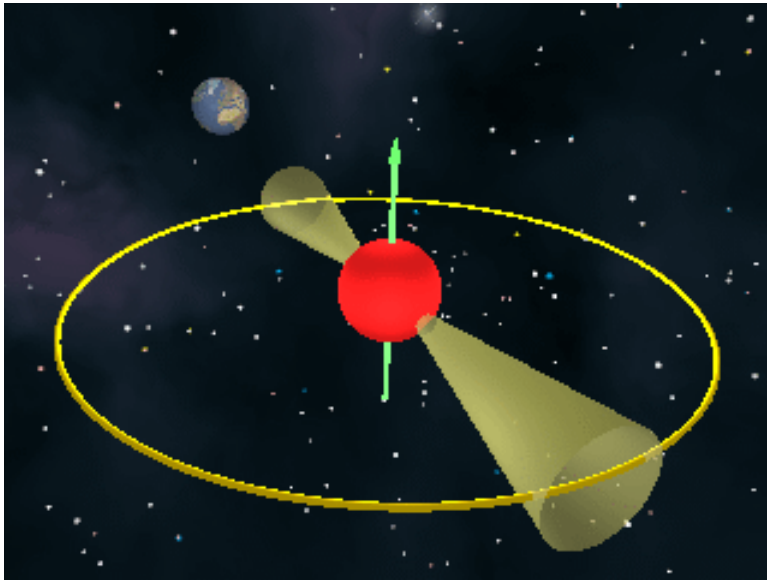
Gravitational Waves Measured in Strain

$$h = \frac{\Delta L}{2L}$$



$$h_{\max} \sim 10^{-21}$$

$$\Delta L = 2D_{\text{Earth}} (10^{-21}) \approx 1 \times 10^{-14}$$



<http://www.jb.man.ac.uk/news/neutronstar/neutronstar.gif>

http://nobelprize.org/nobel_prizes/physics/laureates/1993



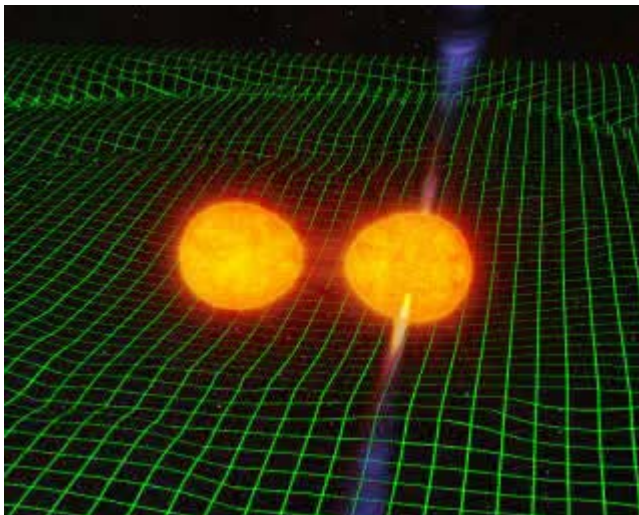
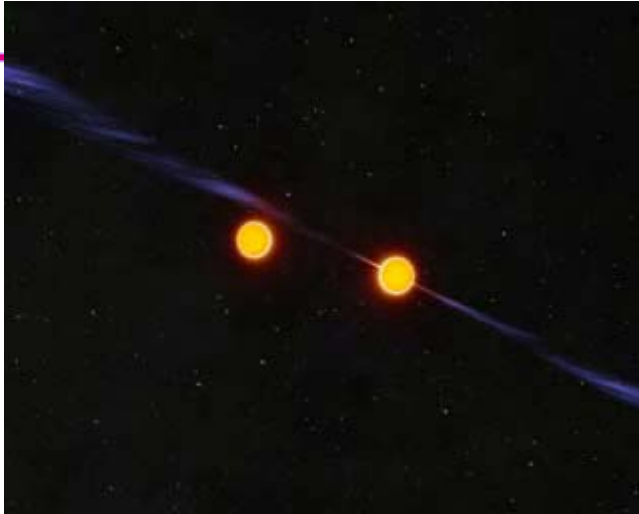
Hulse



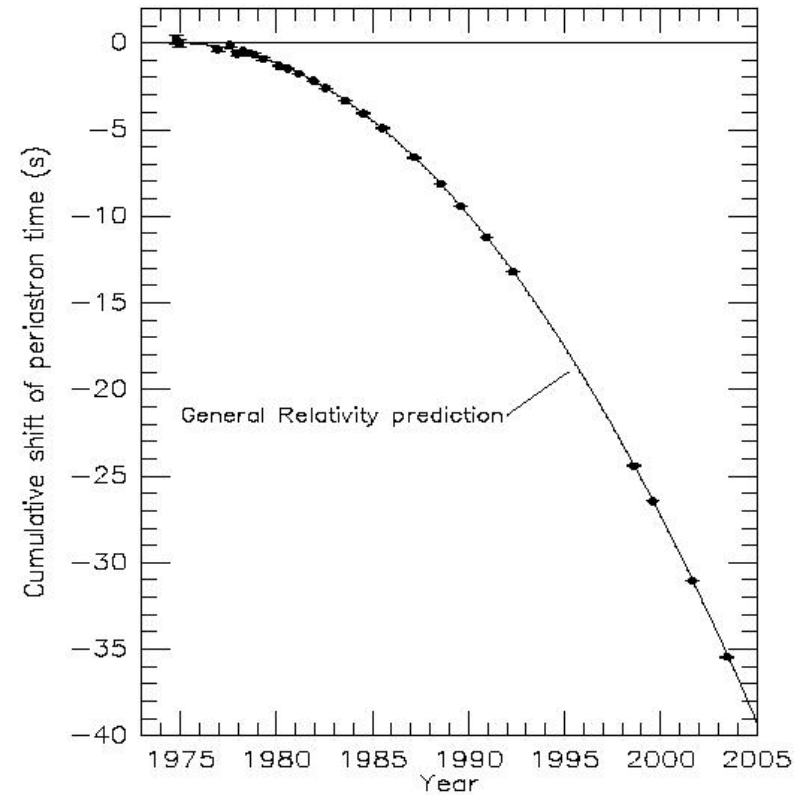
Taylor

In 1974, Russell Hulse and Joseph Taylor discover a new pulsar

The Hulse-Taylor Binary Pulsar

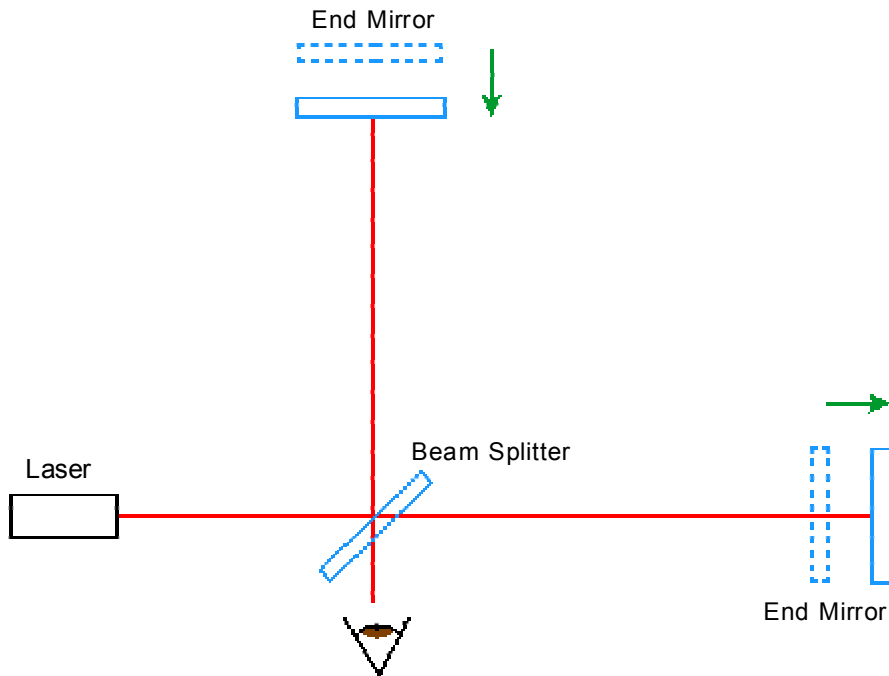


<http://arxiv.org/abs/astro-ph/0407149>

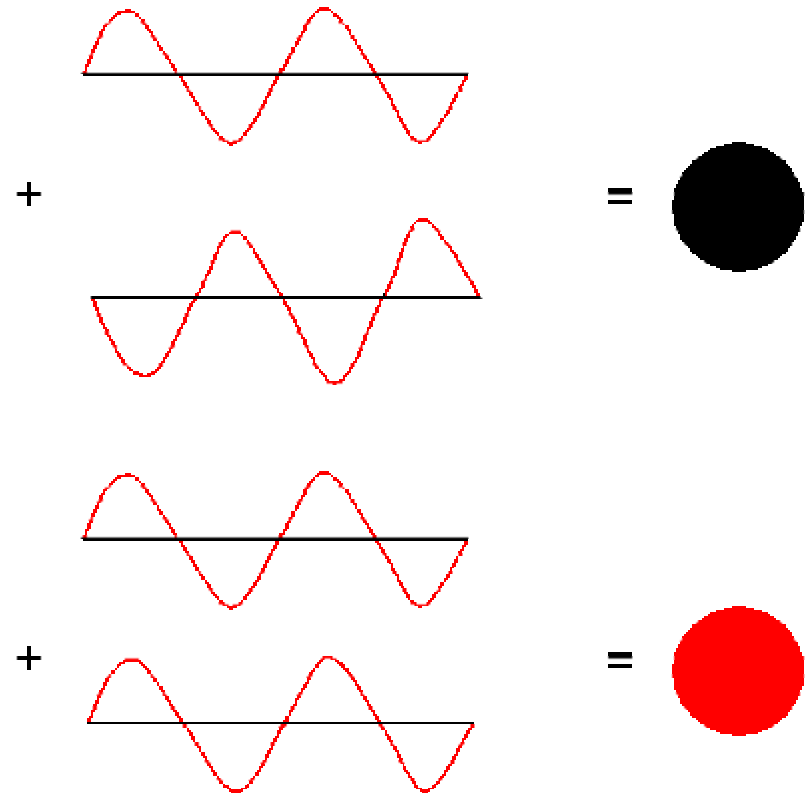


http://www.atnf.csiro.au/news/press/neutron_binary/
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Interferometry



LIGO

A Network of Gravitational Wave Detectors



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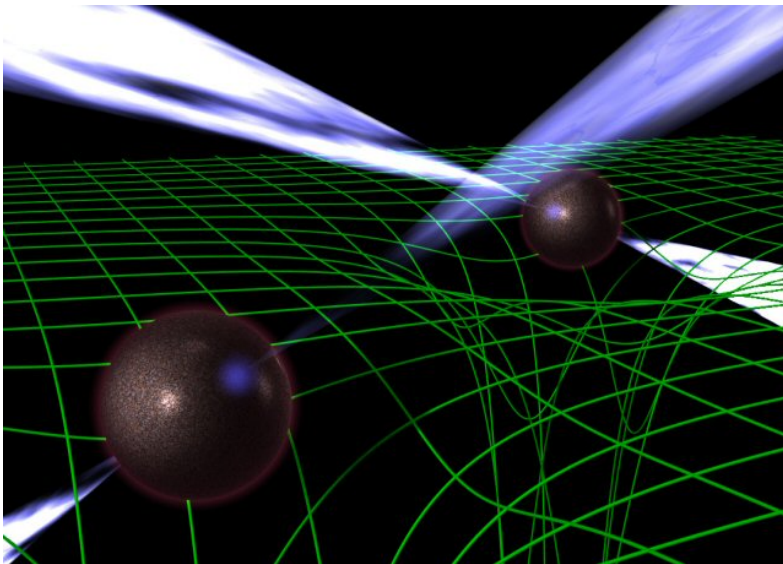
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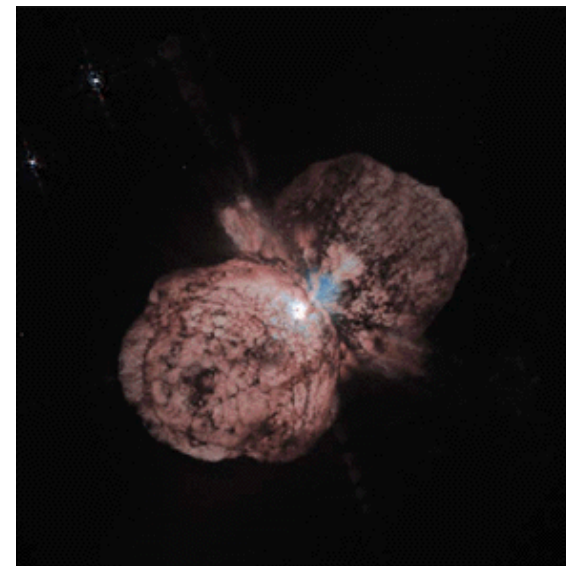
<http://www.aic.cuhk.edu/web8/world%20map.jpg>

Target Sources

- Binary neutron star inspirals and binary black hole inspirals
- Spinning neutron stars
- Bursts from supernovae etc
- Stochastic background from indistinguishable sources and/or the creation of the universe



http://hubblesite.org/gallery/album/entire_collection/pr1996023a/



<http://www.jb.man.ac.uk/research/pulsar/doublepulsarcd/>

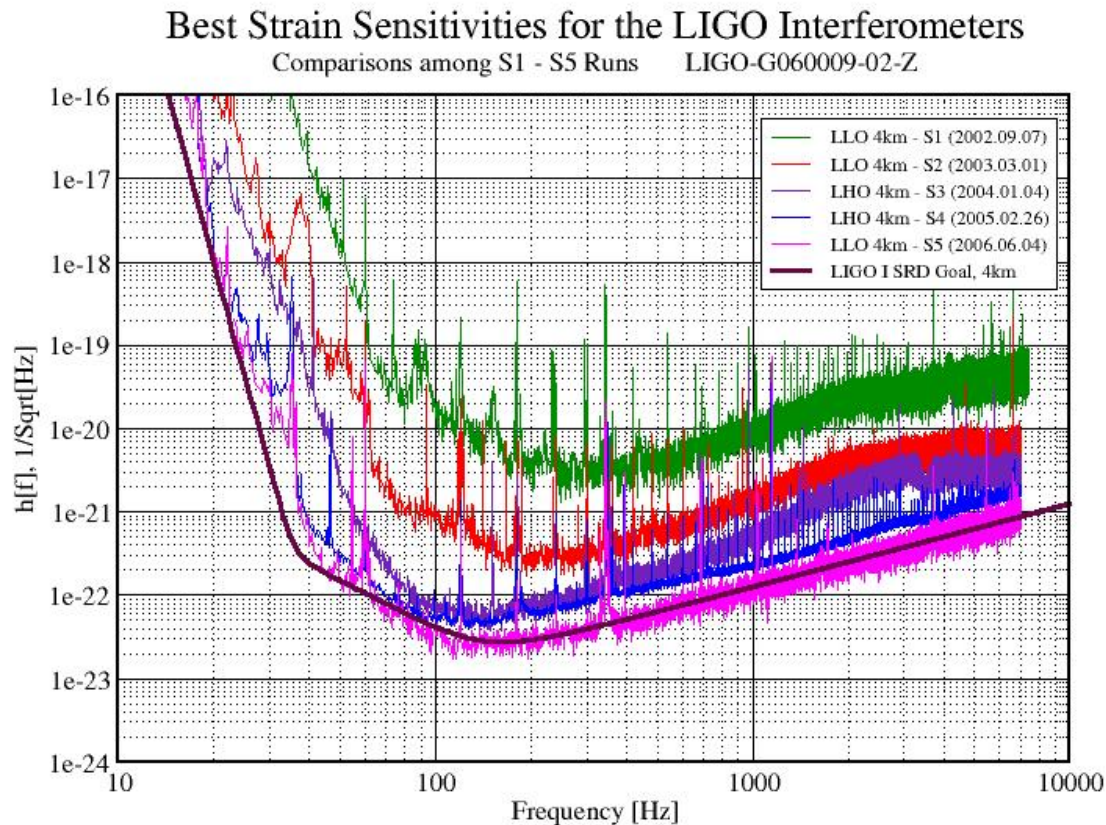
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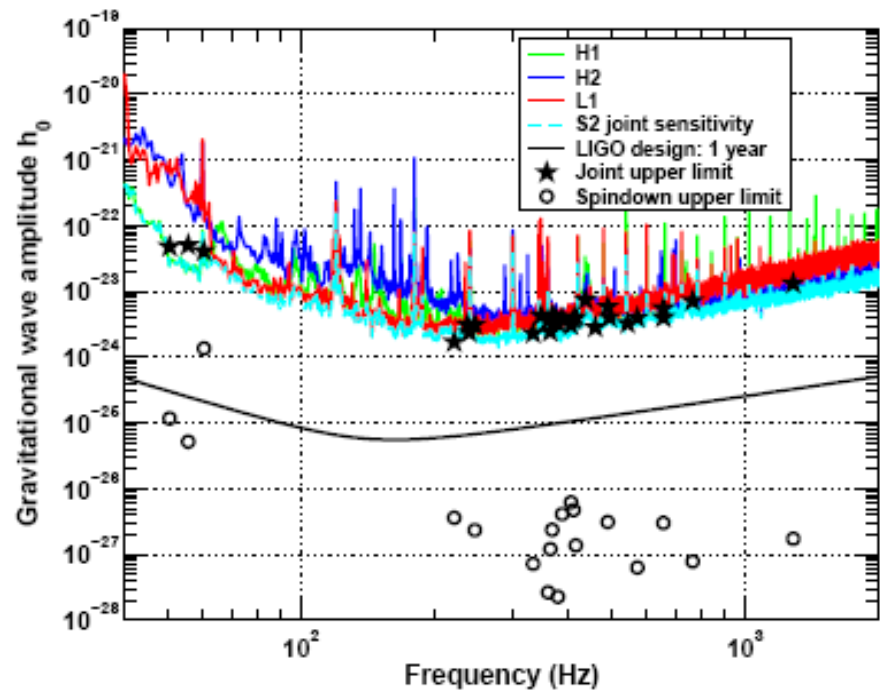
Current Status

- LIGO is taking data right now!
- Goal: One year of data at design sensitivity





- Neutron star inspirals (gr-qc/0505041)**
 LIGO Limit = $47 \text{ year}^{-1} \text{ MWEG}^{-1}$ Expected = $1.9 \times 10^{-4} \text{ year}^{-1} \text{ MWEG}^{-1}$
 (gr-qc/0608280)
- Black hole (between 3 and 20 solar masses) inspirals (gr-qc/0509129)**
 LIGO Limit = $35 \text{ year}^{-1} \text{ MWEG}^{-1}$ Expected = $10^{-4} \text{ year}^{-1} \text{ MWEG}^{-1}$
- Spinning neutron stars (gr-qc/0410007)**



LIGO @ Andrews

- Elog → Data Quality Alerts

Cumulative S5 LHO Elog Flags - Mozilla Firefox

http://www.andrews.edu/~tza/detchar/S5_LHOCum.html

Getting Started Latest Headlines

Gmail - Inbox (8) Google Cumulative S5 LHO Elog Flags

Cumulative S5 LHO Elog Flags

Seg Num	Short Description	GPS Start Time	GPS Stop Time	Local Start Time	Local Stop Time	DQ Flag Link
	H1 was misaligned	799837213	799840813	May 11, 2005 02:00:00 PST	May 11, 2005 03:00:00 PST	Link
	4k off 70 uk, MSR clock off 200us	815133613	815140813	Nov 04, 2005 02:00:00 PST	Nov 04, 2005 04:00:00 PST	Link
	EndX 60 Hz and harmonics contamination >x10 too big	815307904	815307904	Nov 06, 2005 02:24:51 PST	Nov 06, 2005 02:24:51 PST	Link
	71.88 Hz narrow peak in H2 PSL PMC error point spectrum	815312926	802551641	Nov 06, 2005 03:48:33 PST	Nov 06, 2005 03:48:33 PST	Link
	After powerup script, large downward glitch in range on the 2k	815323513	815323513	Nov 06, 2005 06:45:00 PST	Nov 06, 2005 06:45:00 PST	Link
	Hanford Patrol Call causes double dip in Sense Mon	815335213	815337253	Nov 06, 2005 10:00:00 PST	Nov 06, 2005 10:34:00 PST	Link
	2k inspiral range dip perhaps due to thermal lag	815270413	815313613	Nov 05, 2005 16:00:00 PST	Nov 06, 2005 04:00:00 PST	Link
	2k and 4k chiller, valve, and HD temps started oscillation every 30 min	815302860	815266800	Nov 06, 2005 01:00:47 PST	Nov 05, 2005 14:59:47 PST	Link
	Problem in TCS lasers	815385613	815392813	Nov 07, 2005 00:00:00 PST	Nov 07, 2005 02:00:00 PST	Link
	Resets of h1awg0, h2awg0, and frame builder reboots, to try to get back test points	815382013	815385613	Nov 06, 2005 23:00:00 PST	Nov 07, 2005 00:00:00 PST	Link
	Pulsar injections not running on H2		815418756		Nov 07, 2005 09:12:23 PST	Link
	H1-SUS-ETM?_LSC FM4 DC gain set to 1 - affects the calibration		815437283		Nov 07, 2005 14:21:10 PST	Link

Mozilla Firefox

http://ilog.ligo-wa.caltech.edu/ilog/pub/ilog.cgi?group=detector

Getting Started Latest Headlines

Gmail - Inbox (8) Google http://ilog.ligo-wa...cgi?group=d

Make Entry Latest Log Today Previous Next List Past 1 3 6 Mon

HANFORD Detector LOG: Wednesday Nov 08, 2006

08:00:03 Wed Nov 8 2006 (Local)

Topic: general, Operator Author: Vagesh Parameshwaraiah

Owl Summary

[View External Object](#)

H2 and L1 were the only ifos in Science mode tonight. H1 is down from ongoing ISCT4 float H2-1855 has been up for 9+ hours now with its range at ~6.5Mpc.

H2 SUS STAT is RED from H2 ETMY SUS OL FOM's rapid increase to more than 9.0 over the last 8 hours. H2 ETMY OL SUM trended down to less than 2.0 last two days and has been climbing up again last few hours. Plot attached.

Oscar called in to say that he would start tumbleweed bailing activity at ~9:00AM PDT from X-End and reach the CS by noon.

H1 RBS alarm beeped since RBS M1-Y is above its limits.

- [Vagesh Parameshwaraiah](#) <http://ilog.ligo-wa.caltech> (ref url)

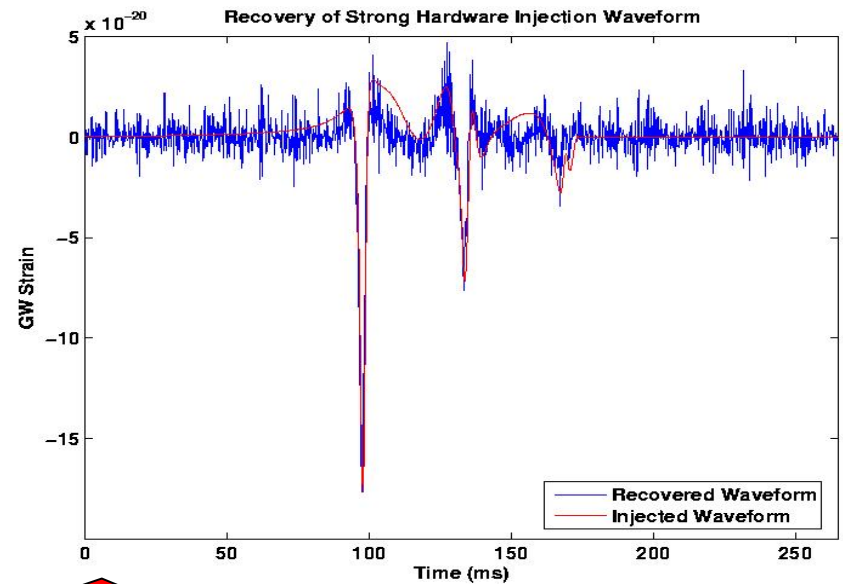
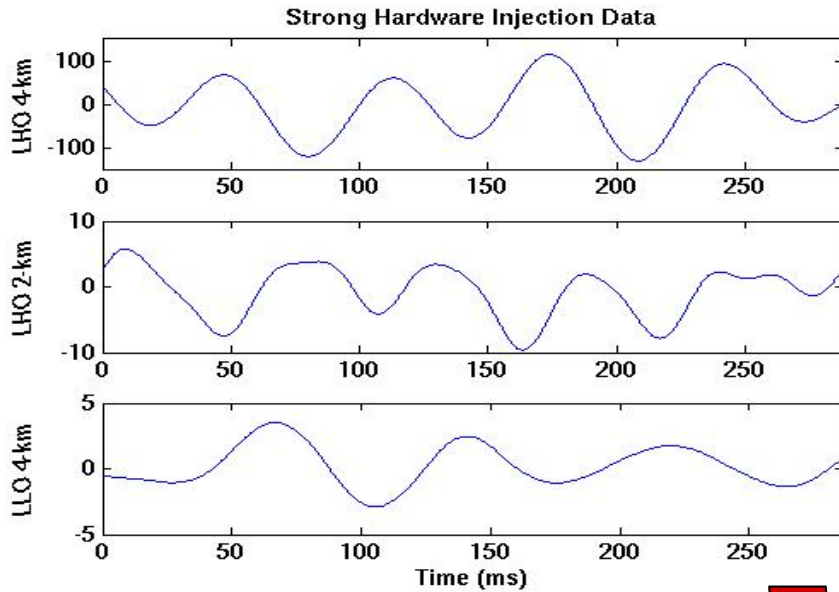
2k, 4k, ETMy

Add or Remove Keyword: NO_KEYWORD Submit

Done

LIGO @ Andrews

- Waveform Recovery



&





Other LIGO Opportunities

- Summer Research Opportunities
 - » LIGO REU http://www.ligo.caltech.edu/LIGO_web/students/undergrads.html
- Join the Search for Gravitational Waves
 - » Einstein@Home <http://einstein.phys.uwm.edu/>
- Learn More about LIGO
 - » LIGO website <http://www.ligo.caltech.edu>
 - » Einstein's Unfinished Symphony by Marcia Bartusiak