

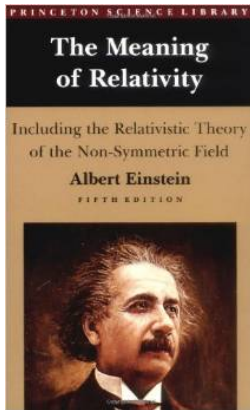


Credits and Research

Here’s the list of sources I used to put together the “How fast is it” video book. These books, videos and websites also represent resources you can use to do further research.

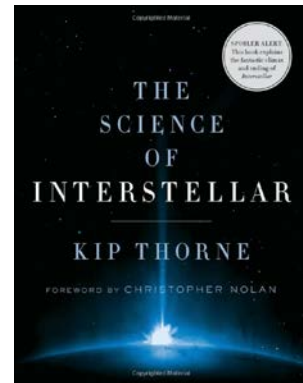
[**Music:** *Stravinsky - Apollon Musagete, Scene 2 Apotheose - Apollo, Leader of the Muses*) is a ballet composed between 1927 and 1928.]

Books

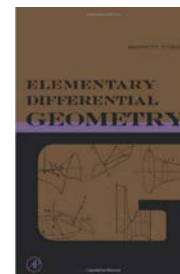


“The Meaning of Relativity” is Einstein’s own book on the subject. It’s a worthwhile read even if you don’t do the math.

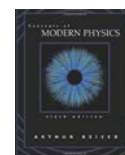
Kip Thorne’s book “The Science of Interstellar” covers the science behind the movie. It’s a great resource for understanding Black Holes.



“Elementary Differential Geometry” by Barrett O’Neill was the textbook I used at San Diego State University. It is well written and covers the foundations in geometry needed for a deeper understanding of General Relativity.



Another good college textbook is “Concepts of Modern Physics” by Arthur Beiser.





Special Places

Here are two sources that are particularly useful for learning about Relativity Theory.



One of them is the Stanford University YouTube series on the subject presented by Leonard Susskind. I used it extensively. But it assumes a deep understanding of the math.

<https://www.youtube.com/watch?v=toGH5BdgRZ4>

Better yet, for those who are not familiar with differential equations, Dr. John D. Norton's website is outstanding. Norton has a deep understanding of the subject matter and discusses it in non-mathematical terms. I used his examples extensively.

Einstein for Everyone

JOHN D. NORTON



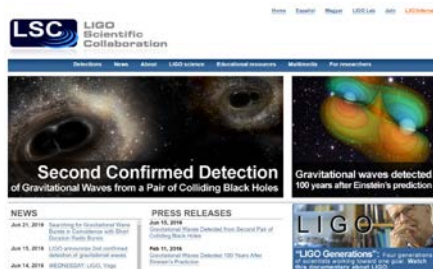
Nallabor Press

2007

revisions 2008, 2010, 2011, 2012, 2013

http://www.pitt.edu/~jdnorton/teaching/HPS_0410/index.html

For Gravitational waves, there is no better source than the LIGO site itself as well as the associated Caltech/MIT site. They have created resource usable by everyone from middle school to post-doctoral students. It also has an outreach facility for teachers.



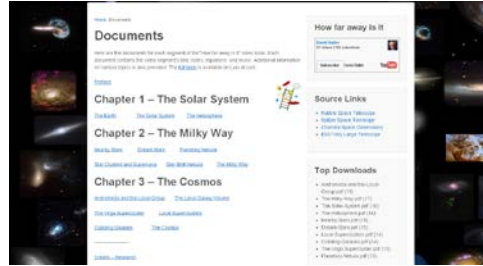
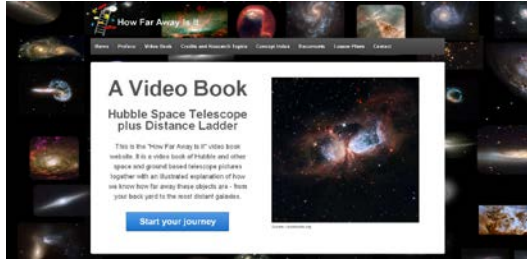
www.ligo.org



www.ligo.caltech.edu



And don't forget, every How Far Away Is It video segment, including these have a document with the text, links, music, pictures and notes located on howfarawayisit.com/documents



The following identifies all my sources. Thanks for watching.

Websites

Animal speed records

http://www.pbrc.hawaii.edu/~petra/animal_olympians.html

List of vehicle speed records

http://en.wikipedia.org/wiki/List_of_vehicle_speed_records

http://content.time.com/time/photogallery/0,29307,1853267_1785046,00.html

Time dilation

<http://arstechnica.com/science/2014/09/time-dilation-measured-at-40-percent-of-the-speed-of-light-in-the-lab/>

Time Dilation and Spacecraft

<http://blogs.esa.int/rocketscience/2014/02/14/time-dilation-and-spacecraft/>

An atomic clock is used for precise time-stamping, which in fact allows controllers to see the time dilation effects from Einstein's Theory of General Relativity.

http://en.wikipedia.org/wiki/Error_analysis_for_the_Global_Positioning_System

Cosmic ray muons and relativistic time dilation

<https://teachers.web.cern.ch/teachers/archiv/hst2000/teaching/expt/muoncalc/lifecalc.htm>

Water waves - Dan Russell 2011

<http://www.acs.psu.edu/drussell/Demos/waves/Lwave-v8.gif>

Aircraft – and the sound barrier

http://www.newworldencyclopedia.org/entry/Sound_barrier#Early_problemsOf

Waves and Light

<http://www.mrsciguy.com/Physics/Waves.html>

How did we find out about the Speed of Light-Isaac Asimov

https://docs.google.com/document/d/1ha9_i8JaSG2ucmvd1uQh1utsj2x7S-FKpYh1QZEwYEQ/edit#heading=h.wmmlc9x44g1m



The Technical Services Group at MIT's Department of Physics

<http://tsgphysics.mit.edu/front/>

Cesium Atoms at Work

<http://tycho.usno.navy.mil/cesium.html>

This is called space contraction.

<http://www.nasa.gov/exploration/systems/orion/index.html>

L-Space Excursions Spaceship

<http://slybrarian.livejournal.com/25136.html>

Abell 1689

<http://hubblesite.org/newscenter/archive/releases/2003/01/>

Einstein Rings

<http://hubblesite.org/newscenter/archive/releases/2003/01/video/c/>

SDSS J162746.44-005357.5

<http://hubblesite.org/newscenter/archive/releases/2005/32/image/g/>

Hubble spies Big Bang frontiers

<http://www.spacetelescope.org/news/heic1523/?lang>

The Mossbauer Effect

<http://www.ajaja.paradoxinc.org/Physics/The-Effects/Mossbauer/Mossbauer.html>

Harvard Tower Experiment

<http://hyperphysics.phy-astr.gsu.edu/hbase/relativ/gratim.html>

The Experiment of Rebka and Pound (an excellent online book on physics)

http://www.relativity.li/en/epstein2/read/i0_en/i4_en/

On The Science of Interstellar – an excellent article on Kerr metric and Gargantua

<http://relativitydigest.com/2014/11/07/on-the-science-of-interstellar/>

Thomas A Moore – A General Relativity Workbook (a very well put together written coverage of General Relativity)

<http://www.physicspages.com/index-physics-relativity/thomas-a-moore-a-general-relativity-workbook/>

Parsing the Science of Interstellar with Physicist Kip Thorne

<http://blogs.scientificamerican.com/observations/parsing-the-science-of-interstellar-with-physicist-kip-thorne/>

An article detailing the science of Interstellar:

<http://www.space.com/27692-science-of-interstellar-infographic.html>

Gravitational waves

<http://news.nationalgeographic.com/2015/04/150422-black-holes-cosmos-gravity-collision-quasar-space-science/>



Pulsars

<http://spiff.rit.edu/classes/phys230/lectures/ns/ns.html>

<http://chandra.harvard.edu/photo/2011/crab/>

<http://www.jb.man.ac.uk/~pulsar/Education/Sounds/sounds.html>

<http://www.cv.nrao.edu/course/astr534/Pulsars.html>

<http://astronomy.swin.edu.au/cms/astro/cosmos/p/Pulsar+Dispersion+Measure>

<http://www.jb.man.ac.uk/distance/frontiers/pulsars/section5.html>

<http://hubblesite.org/newscenter/archive/releases/2000/35/image/a/>

<http://www.daviddarling.info/encyclopedia/H/HulseTaylor.html>

<https://astr109.wordpress.com/what-is-it/>

The Binary Pulsar PSR 1913+16

<http://www.astro.cornell.edu/academics/courses/astro201/psr1913.htm>

View of PSR B1913+16

<http://aladin.u-strasbg.fr/AladinLite/?target=PSR%20B1913%2b16.7&fov=0.033334&survey=P%2fDSS2%2fcolor>

Gravitational Waves Websites

<http://www.tapir.caltech.edu/~teviet/Waves/gwave.html>

<http://hyperphysics.phy-astr.gsu.edu/hbase/forces/gravwav.html>

https://en.wikipedia.org/wiki/Gravitational_wave

Latest on the Hubble Constant

<http://hubblesite.org/newscenter/archive/releases/2016/17/>

Waveform Catalogs

<http://astrogravs.gsfc.nasa.gov/docs/catalog.html>

Gravoscope allows you to overlay the projected possible locations of gravitational waves detected by Advanced LIGO

<http://astrog80.astro.cf.ac.uk/Gravoscope>



Source galaxy count (up to 7×10^4)

<http://physics.stackexchange.com/questions/235593/how-many-galaxies-could-be-the-source-of-the-recent-ligo-detection>

How to find source direction from receiver timing

<http://www.wired.com/2016/02/ligo-aint-gravitational-wave-detector-observatory>

Strain Gauges

<http://blog.prosig.com/2008/09/08/strain-gauges-explained/>

University of Cambridge, Institute of Astronomy

<http://www.ast.cam.ac.uk/research/cosmology.and.fundamental.physics/gravitational.waves>

Christopher Berry – Gravitational Wave Astronomer

<https://cplberry.com/category/equation-free/>

Joe Webber blog

<https://writescience.wordpress.com/tag/joe-weber/>

Australian astrophysicist Katie Mack will answer your – and our – questions

<https://www.theguardian.com/science/live/2016/feb/12/gravitational-waves-an-astrophysicist-answers-your-questions-live>

LIGO Website

GW150914: Factsheet

<http://ligo.elte.hu/detections/GW150914-FactSheet.pdf>

Ligo Vibration Isolation

<https://www.ligo.caltech.edu/page/vibration-isolation>

Caltech and MIT on Ligo detection

<http://www.caltech.edu/gwave>



LIGO Interferometer Sensitivity

<http://www.ligo.org/science/Publication-O1Noise/index.php#sthash.M3pNrLJA.dpuf>

Data release for event GW150914

<https://losc.ligo.org/events/GW150914>

Inspirational gravitational waves

<http://www.ligo.org/science/GW-Inspiral.php#sthash.tlfc5805.dpuf>

Burst gravitational

<http://www.ligo.org/science/GW-Burst.php#sthash.TOE6cNl1.dpuf>

LIGO Flyer

https://dcc.ligo.org/public/0122/T1500543/001/aLIGO_flyer_2015.pdf

Source sky location picture

[Image Credit: LIGO/Axel Mellinger](#)

More LIGO links

<http://www.ligo.org/science/GW-Detecting.php#sthash.Pa736a40.dpuf>

<http://www.ligo.org/science/GW-Multiple.php#sthash.8m5FfeNm.dpuf>

<http://www.ligo.org/science/GW-IFO.php#sthash.gDjUcobu.dpuf>

<http://www.ligo.org/science/GW-Enhance.php#sthash.Jz0hAO46.dpuf>

<http://www.ligo.org/science/Publication-GW150914/index.php>

Videos

A wild tiger angelfish filmed at Aliwal Shoal, South Africa

<https://www.youtube.com/watch?v=vTQl4r3cYO0>

Special relativity

<https://www.youtube.com/watch?v=toGH5BdgRZ4>

Usain Bolt – Fast as Lightning – 2012

<https://www.youtube.com/watch?v=OetgMcfZQg>

Smithsonian's This Is Why You Can't Outrun a Cheetah

<https://www.youtube.com/watch?v=V8vejVgIHg>

National Geographic's World's Deadliest - Fastest Animal Makes a Kill

<https://www.youtube.com/watch?v=r7glchYNew>



Mike Theiss UltimateChase.com YouTube video

<https://www.youtube.com/watch?v=RIRodRRFu4s>

Thrust SSC Supersonic Boom

<https://www.youtube.com/watch?v=TYEtQGLzvkJ>

Air is an elastic medium and sound is a disturbance that moves through it.

<https://www.youtube.com/watch?v=jXSaEnM3wWg>

The X-1 Program: Chuck Yeager Exceeding the Speed of Sound; 1947 USAF Archive Films

<https://www.youtube.com/watch?v=KNcIkTQEadE>

SR-71 Blackbird - Speed: Mach 3+

<https://www.youtube.com/watch?v=ZUNPUIzrKqs>

Fastest Aircraft in the World - X-15 Rocket Jet Flight - 4,500 MPH Space Plane

<https://www.youtube.com/watch?v=TR5SYp948kw>

APOLLO 10 launch: "Relive this fantastic launch on TV", ABC News coverage, May 18, 1969

<https://www.youtube.com/watch?v=aosZbAStq7Y>

SpaceX Rocket Launch

<https://www.youtube.com/watch?v=rFDh3E6wxx8>

Fizeau experiment

<https://www.youtube.com/watch?v=ScN-btW8ST8>

Fizeau Apparatus

<https://www.youtube.com/watch?v=tyHR8upvg9U>

Michelson Interferometer

<https://www.youtube.com/watch?v=j-u3IEgcTiQ>

3D HD Star Wars Jump to light speed

<https://www.youtube.com/watch?v=uvnk9dcqVbA>

Traveling Speed of Light Backwards

https://www.youtube.com/watch?v=rjfvjD_hRG4

NASA Mars Science Laboratory (Curiosity Rover) Mission Animation

https://www.youtube.com/watch?v=gwinFP8_qIM

What's a Tensor?

<https://www.youtube.com/watch?v=f5liqUk0ZTw>

Tensor Calculus 0: Introduction

<https://www.youtube.com/watch?v=e0eJXttPRZI>

GPS & Relativity

<https://www.youtube.com/watch?v=zQdIjwoi-u4>



Precession by gyro top

<https://www.youtube.com/watch?v=sHnDzGWcqIQ>

Interstellar – Building a Black Hole – Official Warner Bros.

https://www.youtube.com/watch?v=MfGfZwQ_qaY

Interstellar black hole

<https://www.youtube.com/watch?v=vkH-azOydXM>

Interstellar gravitational lensing

<https://www.youtube.com/watch?v=u1kaaR4DOSg>

The Quantum Guide - Pulsars

<https://www.youtube.com/watch?v=YzbTfC0tyxg>

Neutron Star Merge

<http://svs.gsfc.nasa.gov/10543>

Leonard Susskind's Stanford General Relativity Lecture 10

<https://www.youtube.com/watch?v=SwhOffh0kEE>

NASA | Magnificent Eruption in Full HD

<https://www.youtube.com/watch?v=GrnGi-q6iWc>

Laser Interferometer Space Antenna (LISA) Mission

<https://www.youtube.com/watch?v=MUHE8x8nq7U>

Gravitational wave detection a step closer with Advanced LIGO

<https://www.youtube.com/watch?v=FXlg3cr-q44>

LIGO Journey of a G-Wave

<https://www.youtube.com/watch?v=-LPsEV-I4js>

LIGO Gravitational Wave Chirp

<https://www.youtube.com/watch?v=TWqhUANNFXw>



Papers

The Kerr-Metric: describing Rotating Black Holes and Geodesics, P.C. van der Wijk, Rijksuniversiteit Groningen, September 2007

Pound-Rebka Experiment

http://www.rorabeck.com/pound_rebka.pdf

Physical and Geometric Interpretations of the Riemann Tensor, Ricci Tensor, and Scalar Curvature

Lee C. Loveridge, February 4, 2008

<http://arxiv.org/pdf/gr-qc/0401099v1.pdf>

Orbit of Mercury

http://www.math.toronto.edu/~colliand/426_03/Papers03/C_Pollock.pdf

Coalescence of Spinning Binary Neutron Stars of Equal Mass

<http://ptp.oxfordjournals.org/content/88/6/1079.full.pdf>

“Observation of Gravitational Waves from a Binary Black Hole Merger” B. P. Abbott et al.* (LIGO Scientific Collaboration and Virgo Collaboration) (Received 21 January 2016; published 11 February 2016)

<http://authors.library.caltech.edu/64405/1/PhysRevLett.116.061102.pdf>

Books

Albert Einstein, “The Meaning of Relativity” Princeton University Press 1956

Barrett O’Neil, “Elementary Differential Geometry” Wiley-Interscience 1970

Kip Thorne, “The Science of Interstellar”, W.W. Norton 2014

Rodney A. Brooks, “Fields of Color: The theory that escaped Einstein” Epic Publications 2010

Stephen Hawking, “The Universe in a Nutshell” Bantam 2001

Arthur Beiser, “Perspectives of Modern Physics” McGraw-Hill 1969

Jerry B. Marion, “Classical Dynamics of Particles and Systems” Academic Press 1970

Richard T. Weidner & Robert L. Sells, “Elementary Modern Physics” Allyn and Bacon, Inc. 1969



Music

The Speed of Light

Giachino Rossini - William Tell Overture
Beethoven – Symphony No 7 Allegretto
Mozart – Violin Concerto No 5 Turkish II
Joseph Haydn – Symphony No 98
Chopin – Raindrop
Puccini – Tosca Vissi d'arte

Special Relativity

Felix Mendelssohn - Concerto for Piano, Violin and String Orchestra
Antonin Dvorák- Serenade for Strings, tempo di valse
Edward Elgar - Cello Concerto
Mozart - Eine Kleine Nachtmusik Romanze
Beethoven - Fur Elise

General Relativity I - Geometry

Stravinsky - Apollon Musagete
Dvorak - Songs My Mother Taught Me
Puccini - O mio Babbino caro
Debussy - Prelude to the Afternoon of a Faun
Schumann - Traumerai (From a Song of Love)
John Williams - Across the Stars (Episode II)

General Relativity II - Effects

Mozart - Flute Concerto No 2
David Arkenstone - Rob Roy - Rob and Mary
Grieg - Holberg Suite, Sarabande (Andante)
Korsakov - Capriccio Espagnol
Heuberger - Midnight Bells
Liszt - Les Préludes - Symphonic Poem No3
Hans Zimmer - STAY



General Relativity III – Gravitational Waves

Puccini - Madame Butterfly Humming Chorus

Handel - Concerto Grosso – Larghetto

Debussy – Reverie

Beethoven - The Creatures of Prometheus

Offenbach - Barcarolle - The Tales of Hoffman

Mozart - Symphony No 40 First Movement

Puccini - Madame Butterfly un Bel Di Vedremo