



Credits and Research

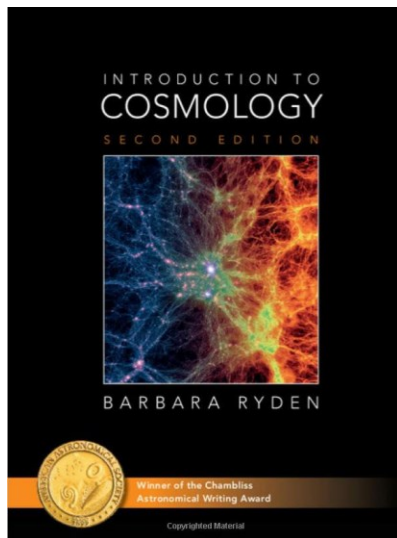
Here's the list of sources I used to put together the "How old is it" video book. These books, videos, and websites also represent resources you can use to do additional research into areas touched on in this video book.

[Music: Puccini - Tosca - E lucevan le stelle]

I used the YouTube Stanford University Cosmology Lectures 1 through 10 (January 14, 2013) by Leonard Susskind extensively. He introduces the study of Cosmology and derives the classical physics formulas that describe our expanding universe. It's the best out there.



<https://www.youtube.com/watch?v=P-medYaqVak>



Here is the book I used extensively. The author puts it all together in a very logical order that is easy to follow. But it does have a lot of calculus level math.

Ned Wright's Cosmology Tutorial

And don't miss Ned Wright's cosmological tutorial site. It is the best site for basic information presented in a straight forward way. His FAQ page is absolutely outstanding.

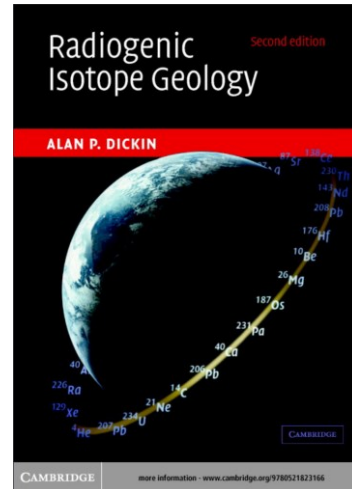


<http://www.astro.ucla.edu/~wright/cosmolog.htm>



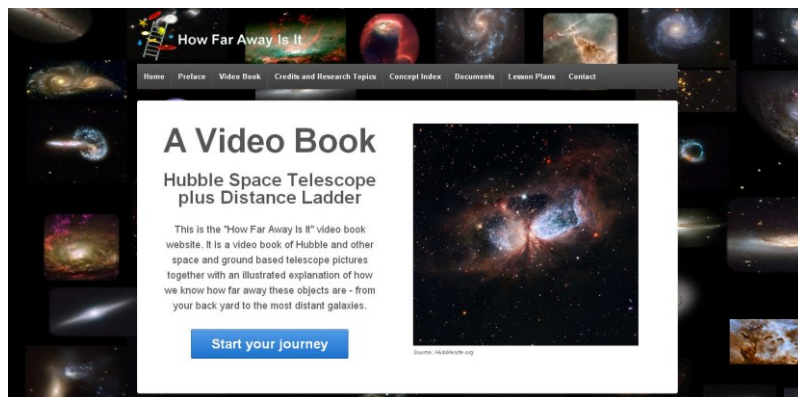
And here's another fantastic resource. It's a free book on Isotope Geology. It goes deep, but it is clear and well organized.

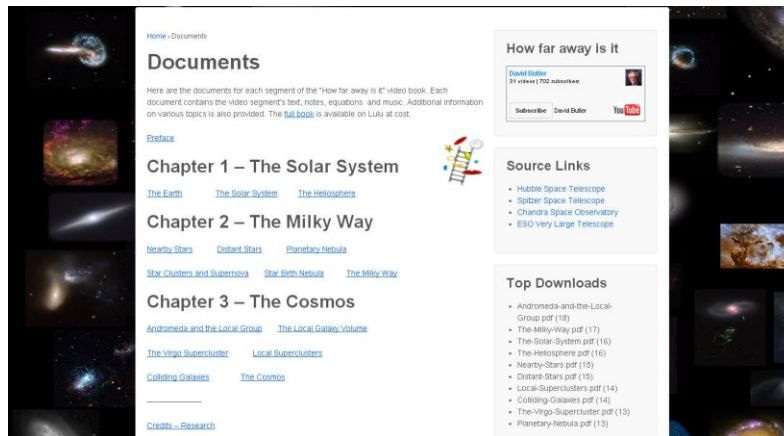
Radiogenic Isotope Geology, Alan P. Dickin;
Second Edition, 2005; School of Geography
and Earth Sciences McMaster University,
Hamilton, Ontario; Cambridge University
Press



http://www.doganaydal.com/nesneler/kutuphanekitaplar/RADIOGENIC_ISOTOPE_GEOLOGY.PDF

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





The following identifies all my sources.

Thanks for watching.

How Old is the Universe

Videos

Stanford University Cosmology Lectures 1 through 10 (January 14, 2013) by Leonard Susskind

<https://www.youtube.com/watch?v=P-medYaqVak>

4K explosion

<https://www.youtube.com/watch?v=VqBjsaKQU60>

Hubble: Galaxies Across Space and Time

<https://www.youtube.com/watch?v=q0P2-qcos90>

GN-Z11 video

<https://www.nasa.gov/feature/goddard/2016/hubble-team-breaks-cosmic-distance-record>

Casimir Effects - Peter Milonni

<https://www.youtube.com/watch?v=12yibyunRdM>

CLUES - Constrained Local Universe Evolution Simulation

https://www.youtube.com/watch?v=ulfX_47ovPU

NASA's WFIRST Mission

https://www.youtube.com/watch?v=cxmg-X7Dxug&feature=em-subscriptions_digest

The BaBar Detector



<https://www.youtube.com/watch?v=KusaugMR5IU>

How Does Fusion Power the Sun?

<https://www.youtube.com/watch?v=W1ZQ4JBv3-Y>

Hypnotic Solar Explosions 4K

<https://www.youtube.com/watch?v=lpzCSZ7Eerc>

4K | Universe's Evolution in 8K Fulldome - Illustris Simulation

<https://www.youtube.com/watch?v=C1zXumtY6x0>

Books & Papers

Introduction to Cosmology by Barbara Ryden, 2017

Cosmology and Controversy by Helge Kragh, 1996

Baryogenesis whitepaper

https://www.astro.umd.edu/~ricotti/NEWWEB/teaching/ASTR688s08/bhupal_termpaper.pdf

Paper-and-pencil cosmological calculator

<https://arxiv.org/abs/1303.5961>

Friedmann equations

http://zuserver2.star.ucl.ac.uk/~hiranya/PHAS3136/PHAS3136/PHAS3136_files/Cosmo2_34_fried.pdf

Professor Komissarov S.S.Komissarov@leeds.ac.uk lecture on cosmology with equations.

<https://www1.maths.leeds.ac.uk/~serguei/teaching/cosmology.pdf>

Ohio State course notes

<http://www.astronomy.ohio-state.edu/~dhw/A5682/notes4.pdf>

A Dynamical Study of the Friedmann Equations

<http://cds.cern.ch/record/515592/files/0108066.pdf>

Big-Bang Cosmology

<http://pdg.lbl.gov/2009/reviews/rpp2009-rev-bbang-cosmology.pdf>

Lecture 19 Big Bang Cosmology slides



http://www.pas.rochester.edu/~aran/class/PHY100_10S/lectures/P100_19_BigBang_Cosmology.pdf

Big Bang Cosmology and the Microwave Background

<http://permalink.lanl.gov/object/tr?what=info:lanl-repo/lareport/LA-UR-94-2608-08>

Big Bang Cosmology slides

<http://www.astro.uwo.ca/~basu/teach/ast020/notes/cosmology.pdf>

Planck spacecraft measures of CMB

[https://en.wikipedia.org/wiki/Planck_\(spacecraft\)#Results](https://en.wikipedia.org/wiki/Planck_(spacecraft)#Results)

How inhomogeneous is it graph?

<https://ned.ipac.caltech.edu/level5/March03/Freedman/Figures/figure11.jpg>

Evidence from Type Ia Supernovae for an Accelerating Universe and Dark Energy

<https://arxiv.org/pdf/astro-ph/0307139.pdf>

Measuring energy density

http://www-9.ijs.si/~margan/Articles/vacuum_energy_density.pdf

What's the Energy Density of the Vacuum?

http://www.nicadd.niu.edu/~bterzic/PHYS652/Lecture_10.pdf

Statistics of Caustics in Large-Scale Structure Formation

<https://arxiv.org/pdf/1412.5121.pdf>

Improved cosmological constraints from a joint analysis of the SDSS-II and SNLS supernova samples

<https://arxiv.org/pdf/1401.4064.pdf>

Measuring Cosmological Parameters via Expansion

<http://www.astronomy.ohio-state.edu/~dhw/A5682/notes9.pdf>

Nucleosynthesis Predictions and High-Precision Deuterium Measurements

<https://arxiv.org/pdf/1705.03653.pdf>

Measurements of the deuterium abundance in quasar absorption systems

<https://arxiv.org/abs/astro-ph/9803071>

History of CP Violation

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3422684/>

Good PowerPoint on inflation

http://www.phys.unm.edu/~gbtaylor/astr422/lectures/22_A422_EarlyUniverse_I.pdf



Websites

Ned Wright's Cosmology Tutorial with a great FAQ section

<http://www.astro.ucla.edu/~wright/cosmolog.htm>

HyperPhysics

<http://hyperphysics.phy-astr.gsu.edu>

Gamma Ray Bursts

<http://cseligman.com/text/galaxies/lighttravel.htm>

https://www.nasa.gov/mission_pages/swift/bursts/cosmic_record.html

<http://science.psu.edu/news-and-events/2011-news/Fox5-2011>

Cosmology lecture PowerPoint from University College London

http://zuserver2.star.ucl.ac.uk/~hiranya/PHAS3136/PHAS3136/PHAS3136_files/Cosmo2_34_fried.pdf

Wilkinson Microwave Anisotropy Probe

<https://map.gsfc.nasa.gov/>

GTR version of Friedmann Equations

<https://astrobites.org/2011/10/09/general-relativity-friedmann-equations-and-accelerating-expansion-a-quick-overview/>

<http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/fried.html>

The Hubble constant value

<https://www.cfa.harvard.edu/~dfabricant/huchra/hubble/>

Bound and unbound escape velocity

http://staff.on.br/jlkm/astron2e/AT_MEDIA/CH26/CHAP26AT.HTM

University of Oregon lecture

<http://abyss.uoregon.edu/~js/cosmo/lectures/lec05.html>

Energy Density of the Vacuum

<http://math.ucr.edu/home/baez/vacuum.html>

SDSS web layout of the galaxies

<http://ircamera.as.arizona.edu/NatSci102/NatSci102/lectures/galaxydist.htm>

Dark Energy, Dark Matter



<https://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy>

Distance vs Redshift

<https://www.eso.org/~bleibund/papers/EPN/epn.html>

http://hubblesite.org/image/2014/news_release/2006-52

Host Galaxies of Distant Supernovae

<http://supernova.lbl.gov/video.html>

Supernova profile

<http://www2.lbl.gov/Science-Articles/Archive/sabl/2005/October/04-supernovae.html>

Supernovae: The Stellar Route to Understanding Dark Energy

<http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/inflat.html#c1>

Inflationary Period in Big Bang

<https://www.cfa.harvard.edu/news/2011-04>

The Best Way to Measure Dark Energy Just Got Better

<http://math.ucr.edu/home/baez/vacuum.html>

Cosmic Inventory II: Baryonic and Dark Matter

<http://hubblesite.org/video/798/news/91-astronomical>

The Cosmic Microwave Background

<http://planck.cf.ac.uk/science/cmb>

<http://astronomy.swin.edu.au/cosmos/C/Critical+Density>

Critical density calculations.

<http://www.astro.ucla.edu/~wright/density.html>

Abell 370

<http://www.spacetelescope.org/images/heic1711a/>

Estimating the Vacuum Energy Density - an Overview of Possible Scenarios Erik Margan

https://en.wikipedia.org/wiki/Observable_universe#/media/File:Observable_universe_logarithmic_illustration.png

2MASS Redshift Survey

<https://www.cfa.harvard.edu/~dfabricant/huchra/2mass/>



THE COSMIC MICROWAVE BACKGROUND

<https://ned.ipac.caltech.edu/level5/Sept02/Kinney/Kinney3.html>

High Red Shift Supernovae 1a and Cosmic Acceleration

<http://web.physics.ucsb.edu/~jatila/LambdaLabs/>

Fractal Structure of Isothermal Lines and Loops on the Cosmic Microwave Background

<http://inspirehep.net/record/880036>

Ionization of Hydrogen

http://csep10.phys.utk.edu/OJTA2dev/ojta/c2c/ordinary_stars/harvard/ionization_tl.html

Cosmic Inflation

https://ned.ipac.caltech.edu/level5/Glossary/Essay_1ss.html

Formation of a group of galaxies

<http://cosmicweb.uchicago.edu/group.html>

South America Galaxy

<https://www.spacetelescope.org/images/potw1323a/>

Casimir effect

<https://briankoberlein.com/2015/03/06/nothing-but-net/>

Evolving the Universe, from the Cosmic Microwave Background to now

<https://map.gsfc.nasa.gov/resources/animconcepts.html>

CASIMIR EFFECT LINKS

<http://www.mit.edu/~kardar/research/seminars/Casimir2010/talks/Konstanz/Casimir.html>

iPTF16geu $z = 0.4 - 4.3$ bly

<https://www.spacetelescope.org/news/heic1710/>

SN UDS10Wil

https://www.nasa.gov/mission_pages/hubble/science/sn-wilson.html

SN CL012Car $z = 1.28$

<http://www.spacefellowship.com/news/art38400/hubble-astronomers-use-supernovae-to-gauge-power-of-cosmic-lenses.html>

Expansion history graph creator

<http://csep10.phys.utk.edu/guidry/darkEnergy/universeEvolRK.html>

Hot quark soup that existed at the dawn of the universe

<http://www.sciencedaily.com/releases/2015/04/150414125710.htm>



Theory provides roadmap in quest for quark soup 'critical point'

<https://phys.org/news/2017-01-theory-roadmap-quest-quark-soup.html>

BaBar has now discovered *direct* CP violation for B mesons.

<http://www2.slac.stanford.edu/tip/special/cp.htm>

Scientists Search for Quasar's "Missing" Galaxy

<https://scitechdaily.com/scientists-search-for-quasars-missing-galaxy/>

pks 1937-101 (qso B1937-1009)

<http://simbad.u-strasbg.fr/simbad/sim-id?Ident=%20PKS%201937-101%20>

Cosmic Microwave Background

<http://astronomy.swin.edu.au/cosmos/C/Cosmic+Microwave+Background>

CP Violation in Kaon Decay

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

NASA's WFIRST Mission

https://www.youtube.com/watch?v=cxmg-X7Dxug&feature=em-subsub_digest

Daya Bay Reactor Neutrino Experiment

<https://www.bnl.gov/newsroom/news.php?a=111395>

Hot quark soup that existed at the dawn of the universe

<https://www.sciencedaily.com/releases/2015/04/150414125710.htm>

ALAS hunt for dark matter

<http://atlas.cern/updates/physics-briefing/chasing-invisible>

LISA

<https://lisa.nasa.gov/>

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

Supernovae Cosmology Project

<http://supernova.lbl.gov/>

The High Z SN Search

<https://www.cfa.harvard.edu/supernova/home.html>

ARP 299 4k photo

http://chandra.harvard.edu/photo/4k_images.html



The Era of Reionization Credits

01 – Reionization Introduction

<https://www.quantum-inspire.com/kbase/superposition-and-entanglement/>
<https://www.quantum-inspire.com/kbase/full-adder>

02 - Discovering the 1st Quasar

<https://astronomynow.com/2019/03/07/seek-out-3c-273-the-brightest-optical-quasar-in-the-spring-sky/>
<https://www.parkes.atnf.csiro.au/people/sar049/3C273/>
<https://www.parkes.atnf.csiro.au/people/sar049/3C273/>
<https://www.youtube.com/watch?v=t3QoMazg94M>
<http://spiff.rit.edu/richmond/occult/bessel/bessel.html#:~:text=across%20the%20ground.-,The%20diffraction%20pattern%20of%20a%20monochromatic%20point%20source%20covered%20by,ando%20onto%20a%20distant%20screen.>
<https://www.youtube.com/watch?v=a2Dkv1OMUmg> Occultation of Kappa Geminorum.
 Chrome-extension://efaidnbmnnnibpcajpcgclefindmkaj/https://arxiv.org/pdf/1811.12714
<https://adsabs.harvard.edu/full/1962MNRAS.124..343H>
[https://ned.ipac.caltech.edu/level5/Glossary/Essay_fanaroff.html#:~:text=Sources%20with%20RFR%20%3C%200.5,\(9.2\)](https://ned.ipac.caltech.edu/level5/Glossary/Essay_fanaroff.html#:~:text=Sources%20with%20RFR%20%3C%200.5,(9.2))
<https://www.parkes.atnf.csiro.au/people/sar049/3C273/>
<https://www.youtube.com/watch?v=SZqI5SeD0ZI>
https://www.aavso.org/vsots_3c273
<https://esahubble.org/images/potw1346a/>

03 - Reionization Discovery

<https://skyserver.sdss.org/dr1/en/sdss/discoveries/discoveries.asp#gunn>
<https://ui.adsabs.harvard.edu/abs/2023ApJ...950...68E/abstract>

05 –Reionization Growth

<https://esawebb.org/news/weic2405/?lang>
<https://www.nature.com/articles/s41586-024-07043-6>
<https://www.omnicalculator.com/physics/luminosity#absolute-and-apparent-magnitude>
<https://esawebb.org/images/weic2220a/>
<https://esawebb.org/images/protocluster-2/>
<https://esawebb.org/images/weic2220c/>
<https://www.britannica.com/science/quasar#/media/1/486494/17804>



<https://www.eso.org/public/images/eso1118a/>
<https://esawebb.org/news/weic2402/?lang>
<https://www.nature.com/articles/s41550-023-02179-3>
<https://www.space.com/30170-most-distant-galaxy-discovered.html>
[Deciphering Lyman- \$\alpha\$ emission deep into the epoch of reionization](#)
https://cosmicdawn.astro.ucla.edu/epoch_of_reionization.html
<https://ned.ipac.caltech.edu/level5/March19/Wise/Wise4.html>
<https://ned.ipac.caltech.edu/level5/March19/Wise/Wise3.html>
<https://en.wikipedia.org/wiki/Reionization>

06 – Cosmic Dawn

https://cosmicdawn.astro.ucla.edu/epoch_of_reionization.html
<https://news.ucsc.edu/2021/06/cosmic-dawn.html>
https://cosmicdawn.astro.ucla.edu/epoch_of_reionization.html
<https://arxiv.org/abs/2303.07594>
<https://webbtelescope.org/contents/early-highlights/nasas-james-webb-space-telescope-finds-most-distant-known-galaxy>
<chrome-extension://efaidnbmnnnibpcajpcgclefindmkaj/https://arxiv.org/pdf/2405.18485>
<https://arxiv.org/abs/2405.18485>
<https://www.jameswebbdiscovery.com/discoveries/journey-to-cosmic-dawn-james-webb-space-telescope-finds-oldest-galaxy-ever>

Webb Telescope Page

<https://webbtelescope.org/contents/news-releases/2023/news-2023-122>

Kavli Institute for Cosmology, Cambridge - Evolution of the Intergalactic Medium

<https://www.kicc.cam.ac.uk/research/RTigm>

EIGER Whitepaper

<https://iopscience.iop.org/article/10.3847/1538-4357/acc588>

The Era of Reionization (Simulation)

<https://www.youtube.com/watch?v=OIHPQZhGiZY&t=6s>

“Nature” article on Quasar

<https://www.nature.com/articles/nature14241>

Good Laymen-Alpha Forest video

<https://www.youtube.com/watch?v=nrHcKF8kay8&t=1120s>



How Old Are Stars

Molecular Cloud Collapse

<https://www.astronomynotes.com/evolutn/s3.htm>

<http://www.astronomy.ohio-state.edu/~jaj/Ast162/lectures/notesWL14.pdf>

https://www.researchgate.net/publication/51989536_The_clustered_nature_of_star_formation_P_re--main-sequence_clusters_inthe_star-forming_region_NGC_602N90_in_the_Small_Magellanic_Cloud

<https://arxiv.org/pdf/1307.8445.pdf> T-Tauri stars in NGC 602

Protostar Formation

<https://pages.uoregon.edu/jimbrau/ast122-2015/Notes/Chapter19.html>

<https://www.spacetelescope.org/images/potw1607a/>

<https://www.spacetelescope.org/images/heic1303a/> HBC 1 - 2700 ly

<https://www.spacetelescope.org/videos/heic1303a/> Protostar LRL 54361 – 950 ly

<https://apod.nasa.gov/apod/ap090803.html>

<https://www.spacetelescope.org/images/heic1424a/> XZ Tauri – 450 ly

http://www.astronomy.ohio-state.edu/~ryden/ast162_4/notes14.html

<https://www.astro.princeton.edu/~gk/A403/fusion.pdf>

https://www.atnf.csiro.au/outreach/education/senior/astrophysics/stellarevolution_mainsequence.html

Becoming a Main Sequence Star

http://www.daviddarling.info/encyclopedia/M/mass-radius_relation.html

http://astro.osu.edu/~ryden/ast162_4/notes14.html mass luminosity relationship

<http://www.astro.caltech.edu/~george/ay20/Ay20-Lec7x.pdf>

<http://hyperphysics.phy-astr.gsu.edu/hbase/Astro/startime.html> stellar lifetime calculator



Solar Fusion Rates

<http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/kintem.html> thermal energy

<http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/Scheq.html> free particle wave function

<http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/barr.html#c1> barrier penetration energy

<http://hyperphysics.phy-astr.gsu.edu/hbase/NucEne/coubar.html> coulomb barrier

<https://physics.stackexchange.com/questions/73970/with-what-probability-does-nuclear-fusion-occur-at-energies-far-below-the-coulom>

http://www.physics.smu.edu/cooley/phy3368/lectures/150225_lecture.pdf Gamow factor

https://wikivisually.com/wiki/Gamow_factor

<https://web.njit.edu/~gary/202/Lecture17.html>

When Stars Run Out of Hydrogen

<http://www.sci-news.com/astronomy/hubble-open-star-cluster-messier-11-07025.html>

https://www.e-education.psu.edu/astro801/content/17_p6.html

<http://jthommes.com/Astro/OpenClusters.htm>

<http://www.astroimages.org/ccd/m67.html> M67 HR diagram

<https://courses.lumenlearning.com/astronomy/chapter/evolution-from-the-main-sequence-to-red-giants/>

<https://www.aanda.org/articles/aa/pdf/2018/08/aa32843-18.pdf> Gaia DR2 – Observational

<http://www.astronomy.com/news/2007/04/how-old-are-stars>

http://ftp.lowell.edu/media/content/release_supplements/gyro_background.pdf

<http://curious.astro.cornell.edu/our-solar-system/51-our-solar-system/the-sun/birth-death-and-evolution-of-the-sun/167-how-do-you-calculate-the-lifetime-of-the-sun-advanced>



How Old is the Earth and Solar System

Videos

<https://www.youtube.com/watch?v=CX8DSLWv0C8>

Beautiful lava flows created by Charles Wood

<https://www.youtube.com/watch?v=N62RWnSruQQ> Kilauea Lava Flow

<https://www.youtube.com/watch?v=ryrXAGY1dmE> plate tectonics

<https://oyc.yale.edu/astronomy/astr-160> Hot Jupiters - Professor Charles Bailyn

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

<https://www.youtube.com/watch?v=x1QTc5YeO6w> Benu

<https://www.youtube.com/watch?v=o2lRpiediP8> collision that formed the moon.

https://www.youtube.com/watch?v=RyfGXg7HY_k Half-Life

https://www.youtube.com/watch?v=J-wao0O0_qM Mass Spectrometer

<https://www.youtube.com/watch?v=fCJF2SaBEec> Adding a Spike – Isotope Dilution

<https://www.youtube.com/watch?v=AwFoD2RJl1w> Memorial University of Newfoundland

<https://www.youtube.com/watch?v=Z6DpPQ8QdLg> Earth from the Moon

<https://www.youtube.com/watch?v=d4KyImpOdvs> Meteor Shower

<https://www.youtube.com/watch?v=oWK0Jep1Lqc> Allende

Books & Papers

Radiogenic Isotope Geology, Alan P. Dickin; Second Edition, 2005; School of Geography and Earth Sciences McMaster University, Hamilton, Ontario; Cambridge University Press

http://www.doganaydal.com/nesneler/kutuphanekitaplar/RADIOGENIC_ISOTOPE_GEOLOGY.PDF

<https://www.aanda.org/articles/aa/pdf/2015/11/aa26093-15.pdf> Comet 67P

<https://www.lpi.usra.edu/books/PPV/8057.pdf> Oxygen Isotopic

http://www.geo.cornell.edu/geology/classes/Geo656/656notes07/656_07Lecture27.pdf Cornell Geochemistry class lecture notes on Oxygen Fractionation

<https://www.hou.usra.edu/meetings/lpsc2014/pdf/2654.pdf> Zircon Dating

<http://nora.nerc.ac.uk/id/eprint/510788/1/Schaltegger%20et%20al%20resubmission%20%28last%20version%29.pdf> U-Th-Pb zircon geochronology

https://www.whoi.edu/cms/files/dfino/2005/6/Notes03_3264.pdf good whitepaper on age of elements



<http://www.geology.wisc.edu/~valley/zircons/Wilde2001Nature.pdf> Evidence from detrital zircons for the existence of continental crust and oceans on the Earth 4.4 Gyr ago

<https://curator.jsc.nasa.gov/lunar/lsc/14163.pdf> moon rock analysis

<https://advances.sciencemag.org/content/advances/3/1/e1602365.full.pdf> moon rocks

Website Links

Circumstellar Disk Contents

<https://www.britannica.com/science/nebula/Chemical-composition-and-physical-processes>

<https://www.forbes.com/sites/startswithabang/2019/02/13/what-was-it-like-when-the-universe-made-its-heaviest-elements/#90c7e30735b2>

Circumstellar Disk Dust

http://coolcosmos.ipac.caltech.edu/cosmic_classroom/cosmic_reference/dust.html

<http://www.astronoo.com/en/articles/interstellar-dust.html>

<https://www.sciencedirect.com/science/article/pii/S0273117703008548>

https://ned.ipac.caltech.edu/level5/March02/Li/Li3_1_2.html

<https://www.soest.hawaii.edu/soestwp/announce/news/experiments-trace-interstellar-dust-back-to-solar-systems-formation/>

Planetesimals

<https://ui.adsabs.harvard.edu/abs/2017DPS....4910009F/abstract>

Giant Impact Hypothesis

<https://www.extremetech.com/extreme/285173-new-nasa-study-suggests-moon-is-made-of-material-from-earth-not-theia>

<https://science.sciencemag.org/content/351/6272/493>

<https://www.nature.com/articles/s41561-020-0550-0> moon rock ratios

<https://lsintspl3.wgbh.org/en-us/lesson/buac19-il-moonformearth/8>

<https://www.lpi.usra.edu/lunar/samples/atlas/> Lunar sample atlas

<https://science.sciencemag.org/content/294/5541/345/tab-figures-data>

<https://www.nature.com/articles/ncomms5040>

<https://www.semanticscholar.org/paper/Oxygen-isotope-measurements-of-terrestrial-using-a-Ahn-Lee/86cf7c5633e8ca27998dee9bc25026e1f8f31e66>

<http://plate-tectonic.narod.ru/juandefuca2photoalbum.html>



<https://pubs.geoscienceworld.org/msa/rimg/article/141067/highly-siderophile-elements-in-earth-mars-the-moon>

<https://science.sciencemag.org/content/351/6272/493> earth moon oxygen isotopic ratios

<https://astronomy.com/news/2019/05/giant-impact-hypothesis-an-evolving-legacy-of-apollo>

<https://advances.sciencemag.org/content/4/3/eaao5928.full>

<https://www.sciencedirect.com/topics/earth-and-planetary-sciences/isotopic-fractionation>

<https://science.sciencemag.org/content/351/6272/493>

<https://ui.adsabs.harvard.edu/abs/2004AGUFM.V41D..08R/abstract>

https://www.researchgate.net/figure/Oxygen-isotopic-composition-of-NEA-003-A-plots-along-the-terrestrial-fractionation-line_fig2_252674070

Mass Spectrometer

http://labman.phys.utk.edu/phys136core/modules/m7/mass_spectrometer.html

Zircon Dating

<https://uwaterloo.ca/earth-sciences-museum/resources/detailed-rocks-and-minerals-articles/uranium>

<https://www.thoughtco.com/uranium-lead-dating-1440810>

<http://metadata.berkeley.edu/nuclear-forensics/Decay%20Chains.html>

<https://www.futurity.org/zircon-crystals-geology-earth-1895292/>

<https://www.sandatlas.org/zircon/>

Oldest Earth and Moon Rocks

<https://www.livescience.com/2896-oldest-rocks-earth.html>

https://www.nationalgeographic.com/science/2019/01/earths-oldest-rock-found-on-moon-get-facts-apollo-14-zircons/#/kring_modified-version-of-nasa-photo-s71-29091_illust-3.jpg

<https://www.catawiki.com/stories/5329-5-of-the-oldest-meteorites-found-on-earth>

http://earthguide.ucsd.edu/virtualmuseum/ita/05_2.shtml

http://earthguide.ucsd.edu/virtualmuseum/ita/05_3.shtml meteors

<http://www.geologyin.com/2015/12/the-oldest-known-rock-on-planet-earth.html>

<https://pubs.usgs.gov/gip/geotime/age.html>

<https://pubs.usgs.gov/gip/geotime/contents.html>

<http://chemistry.bd.psu.edu/jircitano/mole.html>

<https://medium.com/starts-with-a-bang/ask-ethan-how-do-we-know-the-age-of-the-solar-system-5377775c9f7>



<https://hps.org/publicinformation/ate/q8270.html>

<https://www.universetoday.com/75805/how-old-is-the-earth/>

<https://onlinelibrary.wiley.com/doi/full/10.1111/maps.13184>

Dating Meteorites

<https://www.airspacemag.com/videos/category/new-label/arizonas-jaw-dropping-mile-long-meteor-crater/>

<https://www.britannica.com/science/meteorite>

https://en.wikipedia.org/wiki/Lead%E2%80%93lead_dating#Precise_Pb%E2%80%93Pb_dating_of_meteorites

<http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/hhpb.html#c1>

<https://www.sciencedirect.com/science/article/abs/pii/0016703776901095> **Allende results**

<https://www.sciencedirect.com/science/article/abs/pii/0016703770901511>

https://www.tulane.edu/~sanelson/eens212/radiometric_dating.htm

<http://hyperphysics.phy-astr.gsu.edu/hbase/Nuclear/PbPb.html>

<https://www.phy.olemiss.edu/~luca/astr/Topics-Solar/Formation-N.html>



Music

Big Bang Cosmological Fundamentals

@00:00 Puccini, Giacomo: Che gelida manina - what a cold little hand La Boheme Act I: Rodolfo's Aria - "Che gelida manina" (Instrumental Version), Sofia Philharmonic Orchestra; from the album "100 Must-Have Opera Karaoke" 2015

@04:34 Beethoven, Ludwig van: Piano Concerto No. 2 in B-Flat Major, Op. 19: II. Adagio; Anton Dikov, Sofia Philharmonic Orchestra; from the album "50 Must-Have Adagio Masterpieces" 2013

@09:41 Borodin, Alexander: Polovetsian Dances from Prince Igor; London Philharmonic Orchestra; from the album "The Greatest Classical Masterpieces! (Digitally Remastered)" 2008

@13:26 Tchaikovsky, Pyotr Ilyich: Waltz from Sleeping Beauty from the album Tchaikovsky Peter Ilyich 2009

@16:37 Schubert, Franz: Music to Rosamunde, D. 797_ Ballet Music No. 1_ II. Andante un poco assai; Hermitage Museum Orchestra and Alexander Titov; from the album "Schubert - 100 Supreme Classical Masterpieces: Rise of the Masters" 2011

@22:24 Offenbach, Jacques: Barcarolle (from Tales of Hoffman); from the album "A Calendar of Classics - July" 2007

@25:40 Bach, Johann Sebastian: Double Violin Concerto; Anne-Sophie Mutter, English Chamber Orchestra, Salvatore Accardo; from the album "Essential Adagios" 2010

@33:00 Rimsky-Korsakov: Scheherazade, II, Lento; Berliner Philharmoniker, from the album "Rimsky-Korsakov Greatest Hits" 2005



Big Bang Λ CDM Cosmology

@00:00 Bach, Johann Sebastian: Wachet auf, ruft uns die Stimme, BWV 645 ('Sleepers, awake'); Raymond Agoult and The New Symphony Orchestra of London – from the album “Essential Bach (2CDs)” 2000

@04:46 Offenbach, Jacques: Barcarolle (from Tales Of Hoffman); from the album “A Calendar of Classics - July” 2007

@09:00 Strauss II, Johann: Waltz on the Beautiful Blue Danube, Op. 314; Peter Guth & Royal Philharmonic Orchestra, from the album “Strauss: Emperor Waltz, Waltz on the Beautiful Blue Danube, Overture to Die Fleidermaus” 1998

@15:05 Bach, Johann Sebastian: Concerto for Violin, Strings and Continuo in E Major, BWV 1042: II. Adagio; Christian Altenburger, German Bach Soloists, from the album “50 Must-Have Adagio Masterpieces” 2013

@21:22 Beethoven, Ludwig van: “The Emperor” Adagio from Piano Concerto No.5 in E Flat Major. Op.73 “The Emperor”; Julia Thornton, from the album “Essential Adagios” 2010

@27:56 Mozart, Wolfgang Amadeus: Symphony No.8 in D, K.48 - 2. Andante; Academy of St. Martin in the Fields and Sir Neville Marriner; from the album “Mozart: The Symphonies, Vol.1 (Complete Mozart Edition)”

@36:21 Puccini, Giacomo: Turandot, Act III: Calaf's Aria - "Nessun dorma" - none shall sleep; (Instrumental Version); Sofia Philharmonic Orchestra; from the album “100 Must-Have Opera Karaoke” 2015

@39:52 Nicolai, Otto: Moon Choir (from The Merry Widows Of Windsor); Otto Nicolai & Bulgarian National Choir, Sofia Philharmonic Orchestra, from the album “66 Must-Have Sensual Classics” 2011

@36:21 Puccini, Giacomo: Turandot, Act III: Calaf's Aria - "Nessun dorma" - none shall sleep; (Instrumental Version); Sofia Philharmonic Orchestra; from the album “100 Must-Have Opera Karaoke” 2015



Reionization

@00:00:00 Haffner - Symphony No. 35: from the album “Meditation: Classical Relaxation” 2010

@00:07:55 Svendsen - Romance in G, Op. 26: Miklos Szenthelyi; from the album “Meditation: Classical Relaxation” 2010

How Old Are Stars

@00:00 Giordani, Giuseppe: “Caro Mio Ben” - from the album “Meditation: Classical Relaxation” 2010

@06:56 Chopin, Fryderyk: “Prelude in E Minor, Op. 28, No. 4” – from the album “Chopin: The Romantic World Of Chopin's Piano, Vol. 3” 2000

@10:39 Puccini, Giacomo: La rondine: “La rondine, Act I: Doretta's Aria (arr. for flugelhorn and brass band)” - Grimethorpe Colliery RJB Band with Peter Parkes from the album Grimethorpe Colliery Band: Melody Shop (The) 1998

@14:09 Gluck, Christoph Willibald: “Dance Of The Blessed Spirits (from Orpheus and Eurydice)” conductor Herbert Kegel from the album “Meditation: Classical Relaxation” 2010

@24:33 Schubert, Franz: “Andante con moto (from Symphony No. 8)” – Conductor Janos Kovacs; from the album “Meditation: Classical Relaxation” 2010

How Old is the Earth-Moon System

@00:00 Beethoven: Piano Concerto in A Minor, Adagio: Danial Gerard from the album “Meditation: Classical Relaxation” 2010

@07:36 Verdi: La Traviata - Prelude to Act 1: from the album “Meditation: Classical Relaxation” 2010

@14:33 Mozart - Symphony No. 36 - Linz, Poco adagio: from the album “Meditation: Classical Relaxation” 2010



How Old is the Solar System

@00:00 Beethoven: Symphony No. 6 in F Major, Op. 68 Pastoral I. Allegro ma non troppo; London Symphony Orchestra; Josef Krips, Conductor; from the album Ludwig van Beethoven: Symphony No. 6 (Pastorale), Egmont Overture - Incidental Music, Op. 84, Fidelio Overture/March, Op. 72, Coriolan Overture, Op. 62, 2009

@12:47 Puccini, Giacomo: Edgar Act 1 – Prelude; Radio-Symphonic-Orchester Berlin and Riccardo Chailly; from the album Puccini Without Words 2006

@23:45 Schubert: Symphony No. 5, Andante; from the album “Meditation: Classical Relaxation” 2010

How old is it - Credits

@00:00 Puccini, Giacomo: Tosca, Act III: Cavaradossi's Aria - "E lucevan le stelle" - and the stars were shining (Instrumental Version); Sofia Philharmonic Orchestra, from the album “100 Must-Have Opera Karaoke” 2015