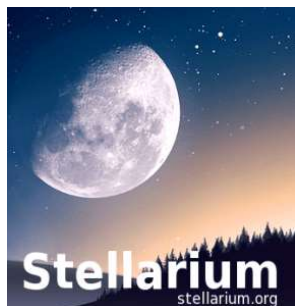<div style="border:1px solid black">

Free On-Line Lab Activities for Astro 101:
A Topical Listing
(Organized by Chapters of the Textbook *OpenStax Astronomy*)

Compiled by Andrew Fraknoi

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Here we have indexed and annotated astronomy lab activities on the web that would work with non-science majors taking the introductory astronomy course. If we have missed any labs that are available free online, please suggest additions by emailing fraknoi@fhda.edu

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Chapter 1: INTRODUCTION TO ASTRONOMY, SCIENCE, MEASUREMENT

1.1   The Nature of Astronomy
1.2   The Nature of Science
1.3   The Laws of Nature
1.4   Numbers in Astronomy
1.5   Consequences of Light Travel Time
1.6   A Tour of the Universe

Introduction to Active Learning: Exploring the Size of the Universe (students learn how to do lab groups, using a hall-way scale model of the solar system and extensions) from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/foundational-labs/introduction-to-active-3/

Fundamentals of Measurement and Error Analysis – from the GEAS Project at New Mexico State (to prepare for the semester's labs): http://astronomy.nmsu.edu/geas/labs/html/lab01.shtml

Scientific Measurement and Data (using bean bag throws) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/measurement_lab/Scientific_Measurement_Lab_05_A153.pdf

Units and Conversions (for all the different units that come up in lab) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/units_conversions/Unit_Conversion_Scaling_1_4.pdf

Is Umbrellaology a Science? (a short discussion activity to get students thinking about science) – from Weber State University: https://physics.weber.edu/johnston/astro/umbrellaology.htm

Math Toolbox (not a lab, but a great guide to basic math and units ideas for non-science students) – from Boston University: https://www.bu.edu/astronomy/files/2009/09/mathToolbox.pdf

Tools for Success in Astronomy Lab (measurement, math, calculators, graphs, etc.) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (activity 1)

Working with Numbers, Graphs and the Computer – from the Villanova University lab manual (Lab A): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

Math for Astronomy Review (long guide to algebra, trigonometry, measurement, statistics, etc.) – from William & Mary: http://physics.wm.edu/~labs/astro/ (click on lab #3)

Measurements and Experimental Uncertainty – from the Villanova University lab manual (Lab B): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

Data Collecting (evaluating data and errors) – from the University of Washington: https://drive.google.com/file/d/1JrEAGLY0fuo1suwPTBNUVPn5lmS4HxZ6/view (fill-in sheet at: https://drive.google.com/file/d/1lzqPjusSITQvoSoK9vpYM6vo-50oOU7j/view)

Astronomy Math Review (a primer and exercises for basic math and error analysis for labs) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 37): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Mathematical Review Activity (2 different files needed) – from Georgia State University: http://sites.gsu.edu/astr1020lab/astronomy-1020-lab-manual/

Cosmic Calendar Activity (scaling activity, putting the events in the history of the universe on a one-year calendar) – from the Astronomical Society of the Pacific: https://astrosociety.org/file_download/inline/209270e9-db28-455c-85cc-c4f29f1fa349

Astronomy in the Marketplace (ice-breaker activity for a first lab; students think of all the astronomically named products they can; can broaden to music and movies) – from Dennis Schatz & the Astronomical Society of the Pacific: https://mo-www.cfa.harvard.edu/OWN/pdf/mit/HandsOnActivities.pdf (see pp. 5-9)

Visual Observations (using the naked eye and a small telescope) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 1-5)

Size and Scale (calculation activities with scale models) – a minilab activity from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html

Finding Your Way to Mars, Pennsylvania: An Astronomy and Geography Activity (an extra-credit activity where students use the Web to investigate place names from astronomy): https://www-tc.pbs.org/seeinginthedark/pdfs/geography_astronomy_activity.pdf

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Chapter 2: THE SKY, HISTORICAL ASTRONOMY, ASTROLOGY

2.1   The Sky Above
2.2   Ancient Astronomy
2.3   Astrology and Astronomy
2.4   The Birth of Modern Astronomy: Copernicus & Galileo

Motions in the Sky with *Stellarium* (introduces the celestial sphere and its motions, using the free software package) – from the University of Tennessee:

http://astrolab.phys.utk.edu/Lindsay_manual/motions_in_the_sky/Motions_in_the_Sky_Lab_v01.pdf

Observing the Night Sky (get to know the sky and various tools for orientation, including star wheels, atlases, and the free *Stellarium* software) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/foundational-labs/observing-the-night-sky/ Also see their Exploring the Night Sky: http://astro.physics.uiowa.edu/ITU/labs/foundational-labs/exploring-the-night-sky/

Rotating Sky (use the *Rotating Sky Explorer* app to learn about celestial motions and coordinates) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_motion2_sg.pdf (for instructor guidelines, see: https://astro.unl.edu/nativeapps/NAAP_resources/motion2_classdemo.pdf) (download the apps themselves at https://astro.unl.edu/nativeapps/)

Sky Motions (learn to use a planisphere in a planetarium) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/motions-and-historical-astronomy/planetarium-sky-motions

Orientation to the Sky: Apparent Motions (use *Rotating Sky Explorer* and *Stellarium* to explore the sky and how we see things move in it) – from William and Mary: http://physics.wm.edu/~labs/astro/ (click on Lab #2)

Should Uncle Fred be in the Sky: Sky Heroes (ice-breaker activity: what if we renamed the constellations after heroes in your family, or in recent history – who would get a constellation?) – from Project ASTRO at the Astronomical Society of the Pacific: http://www-tc.pbs.org/seeinginthedark/pdfs/family_heros.pdf or http://www-tc.pbs.org/seeinginthedark/pdfs/Sky_Heroes.pdf

Observing the Sky (use *Stellarium* to find what is in the sky tonight) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #2)

Measuring Angular Sizes and Distances (use a paper cross-staff) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/motions-and-historical-astronomy/measuring-angular-sizes-and-distances

The Eratosthenes Experiment (measure the circumference of the Earth and a section on measurement errors) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 61-68)

Estimating the Circumference of the Earth Using the Method of Eratosthenes (uses the free *Stellarium* software) – from the *My Science Walks* website: https://www.mysciencewalks.com/circumference-of-the-earth-eratosthenes.html

Estimating the Distance to the Sun Using the Method of Aristarchus (uses the free *Stellarium* software) – from the *My Science Walks* website: https://www.mysciencewalks.com/distance-to-the-sun-aristarchus.html

Estimating the Size of the Moon Using the Method of Aristarchus (uses the free *Stellarium* software) – from the *My Science Walks* website: https://www.mysciencewalks.com/size-of-the-moon-aristarchus.html

Phases of Venus (use a model to show how Galileo's observation of the phases indicate the planet goes around the Sun) – from the York College (CCNY) lab manual (Lab 4): https://www.york.cuny.edu/earth-and-physical-sciences/physics-lab-manuals/astr140-lab-manual-4e.pdf/view

Phases of Venus (use the free *Stellarium* software to replicate Galileo's observations, calculate the synodic and sidereal periods of Venus) – from the University of Central Arkansas: https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/venus.html

Sky Patterns (observe constellations) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 3): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Night Lab: Motions in the Sky (learn how to find Polaris and observe the motion of objects during the night) – from Boston University: https://www.bu.edu/astronomy/files/2013/09/nightlab1v05.pdf

Night Lab: What's the Name of That Star (planispheres and star identification) – from Boston University: https://www.bu.edu/astronomy/files/2017/01/nightlab2v04.pdf

Knowing Constellations and Bright Stars (a self-paced lab using a planisphere) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 143-148)

Celestial Motions and Celestial Sphere (some of it uses *Starry Night,* but could be done with other such software) – from Wake Forest University: http://users.wfu.edu/cookgb/Astronomy/LabManual/in1.pdf

Motions of the Planets (use *Stellarium* to understand retrograde motion) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #4)

Solar System Models (use an app to see the differences between the Ptolemaic and Copernican models) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_ssm_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

In the Footsteps of Galileo: Observing the (Galilean) Moons of Jupiter – calculate the periods of the four large jovian moons from simulated data – from the Astronomical Society of the Pacific: https://astrosociety.org/file_download/inline/1689e781-3f4a-4178-8f7a-7bc581986242

An Introduction for Students to "Stellarium" (the free open-source planetarium software) – from the University of Indiana. Go to: https://www.astro.indiana.edu/catyp/minilabs.html and click on the last link under "Night Sky" to download the brief Word document with exercises to fill out on how the software works.

Using "Stellarium" (a good introduction to the features of the software) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download the first exercise)

The Night Sky (an introduction to the free "Stellarium" software and exercises using it) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Night_Sky

Constellations and Stellar Magnitude (finding and sketching constellations) *and* Naked Eye Constellations – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 9-14)

Identify Constellations (instructions for using *Stellarium* to identify stars and constellations; also has links to other convenient sources of sky information) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Identify_Constellations

Constellation Imaging (take photos with a CCD camera) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 71-77)

Star Wheels (using a planisphere) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 1): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Viewing the Sky (using a star chart and getting to know constellations) – a minilab activity from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html

Dark Sky Observing (requires telescope equipment) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 4): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Introduction to the Meade LX-10 and a Planisphere (hands-on-guide to using a small telescope) – from William & Mary: http://physics.wm.edu/~labs/astro/ (click on Lab #4) [also see their lab "Introduction to the Night Sky" which is #1 under *Outside Observations*]

Activities Examining Astrology Skeptically (several different activities and questions to ask) – from the Astronomical Society of the Pacific: https://astrosociety.org/file_download/inline/b93fa8d7-4dc5-4372-9270-feacd73ac56d

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Chapter 3: PLANETARY MOTION, ORBITS, GRAVITY

3.1   Kepler &the Laws of Planetary Motion
3.2   Newton's Great Synthesis
3.3   Newton's Universal Law of Gravitation
3.4   Orbits in the Solar System
3.5   Motions of Satellites and Spacecraft

Planetary Motion (model the apparent motion of planets using a shadow orrery) – from the York College (CCNY) lab manual (Lab 3): https://www.york.cuny.edu/earth-and-physical-sciences/physics-lab-manuals/astr140-lab-manual-4e.pdf/view

Kepler's First Law and the Orbit of Mars (construct and analyze the orbit from real data) – from the University of Central Arkansas: https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/kepler.html

Exploring Kepler's Laws of Planetary Motion (using a PhET simulation) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/kepler/kepler_laws_lab_v1.pdf

Planetary Orbits Simulator (use the simulator to explore Kepler's laws of planetary motion) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_pos_sg.pdf (instructor guidelines are at: https://astro.unl.edu/nativeapps/NAAP_resources/pos_classdemo.pdf) (download the app itself at https://astro.unl.edu/nativeapps/)

Orbit of Mercury Lab (understanding planetary orbits and plotting the orbit of Mercury) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/orbit_of_mercury/lab_orbit_of_mercury_v02.pdf

The Orbit of Mercury (understanding the movement of Mercury in our sky, and calculating aspects of its orbit) from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 67-78)

Kepler's Laws (experiment with computer simulations of orbits) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 47-52)

Calculating the Mass of Saturn (use Kepler's 3rd law as modified by Newton) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 69-76)

Apparent Positions of the Planets (their motions in the sky) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 6-12)

Planetary Motions: Using a Shadow Orrery – from Boston University: https://www.bu.edu/astronomy/files/2021/09/Orrery_101.pdf

Kepler's Law and the Mass of Jupiter (from the motions of its moons) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 58-61)

Kepler's Laws of Planetary Motion I (looking at the orbits of the moons of Jupiter) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 16): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Kepler's Laws of Planetary Motion II (Kepler's Third Law applied to the moons of Jupiter) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 17): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Kepler's Third Law (use *Stellarium* to measure the period and radius of planetary orbits and see if Kepler's law works) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #5)

Orbiting Earth (model and calculate orbits) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 18): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Newtonian Gravity (examine how the force changes with distance, compare the pull of Mars to that of a nearby doctor on a newborn baby, determine the mass of Earth) – from the University of Central Arkansas: https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/gravity.html

Density (learn about mass, volume, density and measure the density of different substances and worlds) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 89-101)

Chapter 4: SKY PHENOMENA, TIME, SEASONS, MOON PHASES, ECLIPSES, etc.

4.1   Earth and Sky
4.2   The Seasons
4.3   Keeping Time
4.4   The Calendar
4.5   Phases and Motions of the Moon
4.6   Ocean Tides and the Moon
4.7   Eclipses of the Sun and Moon

Observing Project with Sunset Positions and Moon Phases – Jennifer Scott (Towson U): http://most.oercommons.org/courses/sky-observing-project/view

Determining the Direction to Mecca (requires concepts of latitude and longitude; uses the free *Stellarium* software and teaches about Islamic astronomy) – from the *My Science Walks* website: https://www.mysciencewalks.com/direction-to-mecca.html

Introduction to *Stellarium,* Astronomical Coordinates, and the Sun over the Seasons – from the University of Central Arkansas:
https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/stellarium.html

Solar and Sidereal Days (continues the introduction of *Stellarium* from the above lab, with more on the position of the Sun in the course of a year) – from the University of Central Arkansas:
https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/sidereal.html

Mapping the Sky (use *Stellarium* to get familiar with coordinate systems on Earth and in the sky) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #3)

Basic Coordinates and Seasons (use apps about terrestrial & celestial coordinates, and the seasons & the ecliptic) – from the University of Nebraska Astronomy Applet Project:
https://astro.unl.edu/nativeapps/NAAP_resources/naap_motion1_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Motions of the Sun (investigate the daily and seasonal motions of the Sun with several simulator apps) – from the University of Nebraska:
https://astro.unl.edu/nativeapps/NAAP_resources/naap_motion3_sg.pdf (see guidelines for instructors at: https://astro.unl.edu/nativeapps/NAAP_resources/motion3_classdemo.pdf) (download the apps themselves at https://astro.unl.edu/nativeapps/)

The Sidereal Day of Aryabhata (use the free *Stellarium* software to teach about ancient Indian astronomy) – from the *My Science Walks* website:
https://www.mysciencewalks.com/sidereal-day-of-aryabhata.html

The Earth Rotates (use images from a Foucault Pendulum) – from the University of Louisville:
http://prancer.physics.louisville.edu/astrowiki/index.php/The_Earth_Rotates

Rotating Sky (use an app that shows the flat Earth, the celestial sphere, and a horizon view) – from the University of Nebraska Astronomy Applet Project:
https://astro.unl.edu/nativeapps/NAAP_resources/naap_motion2_sg.pdf (students sheets at: https://astro.unl.edu/nativeapps/NAAP_resources/) (download the apps themselves at https://astro.unl.edu/nativeapps/)

Celestial Sphere/Coordinates (measure the location of bright stars) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 13-17)

Coordinate Systems (on Earth and in the sky) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 2):
https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Observing the Sky (and Tracking the Moon) – from the GEAS Project at New Mexico State:
http://astronomy.nmsu.edu/geas/labs/html/lab02.shtml

Phases of the Moon with Lunar Observations – from the University of Tennessee:
http://astrolab.phys.utk.edu/Lindsay_manual/lunar_labs/Lunar_Phases_Lab_stellarium_edition.pdf

Lunar Phases (use a lunar phases simulator and diagrams to understand the geometry of the phases and how they appear in the sky) – from the University of Nebraska:
https://astro.unl.edu/nativeapps/NAAP_resources/naap_lps_sg_05.pdf (Instructor guidelines are at: https://astro.unl.edu/nativeapps/NAAP_resources/lps_classdemo.pdf) (download the apps themselves at https://astro.unl.edu/nativeapps/)

Phases of the Moon (short activity getting to know them by acting out the motions) – from the University of Washington: https://drive.google.com/file/d/1s7_GhT2fZ0UKqZYsjpR8hrF-ih4s37GM/view

Phases of the Moon (use balls and a flashlight, with exercises from different perspectives) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 35-45)

The Origin of the Seasons (use a globe, flashlight and other tools to discover why we have seasons and do calculations about seasonal effects) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 17-33)

The Seasons (use *Stellarium* to understand the reasons for the seasons) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #6)

Apparent Motions of the Sun and the Moon – from the University of Colorado Manual: https://www.colorado.edu/sbo/facultystudent-resources/aps-course-lab-manuals (pp. 33-44)

Earth-Sun-Moon System (Moon's motions & phases) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 18-21)

Lunar Eclipses and the History of Astronomy (timing an eclipse and calculating the distance to the Moon) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 55-57)

Lunar Eclipses and the Saros Cycle (uses the *Starry Night* computer program; but could be adapted to free equivalents) – from the Villanova University lab manual (Lab C): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

The Next North American Total Solar Eclipse (familiarizes students with solar eclipses and the 2024 total one; uses the *Starry Night* computer program; but could be adapted to free equivalents) – from the Villanova University lab manual (Lab D): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

Motions of the Earth (mostly calculating velocities and accelerations) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 15): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Solar Lab (measure longitude, etc. with a solar angle device) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 22): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Solar Eclipses (detailed observing lab that assumes an eclipse is happening) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 24): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Eclipses & the Moon (use *Stellarium* to understand how and when lunar and solar eclipses happen) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #7)

Lunar Eclipses (observing lab that assumes an eclipse is happening) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 27): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Measuring Longitude Differences with the (Lunar) Eclipse of Alexander the Great (uses the free *Stellarium* software and teaches about ancient eclipse observations) – from the *My Science Walks* website: https://www.mysciencewalks.com/lunar-eclipse-of-alexander-the-great.html

Babylonian Cycles (learn about lunar and sidereal months, eclipse cycles, and the work of ancient Babylonian astronomers; uses the free *Stellarium* software) – from the *My Science Walks* website: https://www.mysciencewalks.com/babylonian-cycles.html

Synodic and Sidereal Months (use free *Stellarium* software to measure the synodic & sidereal period of the Moon): https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/lunarMonth.html

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Chapter 5: RADIATION, SPECTRA, DOPPLER EFFECT

5.1 The Behavior of Light
5.2 The Electromagnetic Spectrum
5.3 Spectroscopy in Astronomy
5.4 The Structure of the Atom
5.5 Formation of Spectral Lines
5.6 The Doppler Effect

Luminosity and Brightness (use a wax photometer) – from Boston University: https://www.bu.edu/astronomy/files/2015/01/luminosity.pdf

Old Faithful in IR (Images and Pseudo-color) – a minilab activity from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html

Thermal Radiation Laws (understand Wien's Law and the Stefan-Boltzmann Law and apply them to measuring blackbody temperatures, in the Kepler 62 exoplanet system) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/thermal_radiation_laws/thermal_radiation_laws_lab_A153_online.pdf

Thermal Radiation Laws (understand Wien's Law and the Stefan-Boltzmann Law and apply them to measuring blackbody temperatures, and the spectra of stars) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/thermal_radiation_laws/thermal_radiation_laws_lab_A154_online.pdf

Blackbody Radiation (do calculations using Wien's Law and the Stefan-Boltzmann Law) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 34): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Light and Color (filters and spectroscopes) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 103-116)

Fun with the Sun (using ultra-violet sensitive beads to study what produces and what absorbs UV; an activity for younger students that could be adapted to be part of a college lab) – from the SPIE Hands-on Optics project; download from: https://spie.org/education/education-outreach-resources/hands-on-optics

Blackbody Curves and UBV Filters (use simulation apps to understand how different sources, filters, and detectors interact) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_blackbody_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Black Bodies and Astronomical Filters (short exercises using the *Blackbody Spectrum* PhET simulation) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Black_Body_and_Filters

Light and Kirchhoff's Laws (use a spectroscope and spectrum tubes, etc) – from the York College (CCNY) lab manual (Lab 6): https://www.york.cuny.edu/earth-and-physical-sciences/physics-lab-manuals/astr140-lab-manual-4e.pdf/view

The Hydrogen Atom (use apps to understand the interaction of an H atom with different photons) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_hydrogen_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Spectral Barcodes (gas tubes and analyzing spectra) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 117-125)

Spectra of Gases and Solids (observe continuous spectra, emission-line spectra, and the solar absorption-line spectrum) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 20-25)

Spectroscopy (use a handheld spectrometer and spectrum tubes; deriving the composition, temperature, and radial velocity of stars) – from the University of Central Arkansas: https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/spectroscopy.html

Spectroscopy (use spectrometer and software) – from Boston University: https://www.bu.edu/astronomy/files/2017/01/spectroscopy_2016.1.pdf

Analyzing Spectra (look at different types of spectra, pen and paper activity) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/physical-laws-and-fundamentals/analyzing-spectra

Identifying Lines in the Solar Spectrum (compare to known Fraunhofer lines) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/physical-laws-and-fundamentals/identifying-lines-in-the-solar-spectrum

Spectrum Analysis (treats different kinds of spectra, uses spectrum tubes) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/physical-laws-and-fundamentals/spectrum-analysis

Spectroscopic Identification of Gaseous Elements (use spectrum tubes) – from Wake Forest University: http://users.wfu.edu/cookgb/Astronomy/LabManual/in5.pdf

Astronomy in Color: Image Builder (use the images of astronomical objects provided at different wavelengths to build up a multi-color image; needs a write-up, but not hard to figure out) – from the University of Indiana: https://www.astro.indiana.edu/ala/3color/index.html

See also the lab "Elements and Supernovae" for Chapter 23 (which has a lot of exercises involving atoms)

Chapter 6: TELESCOPES AND DETECTORS

6.1   Telescopes
6.2   Telescopes Today
6.3   Visible-Light Detectors and Instruments
6.4   Radio Telescopes
6.5   Observations Outside the Earth's Atmosphere
6.6   The Future of Large Telescopes

Telescope optics (lenses on an optical bench and different telescope designs) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 89-101)

Optics and Telescopes (use lens kits and optical benches to compare properties of different lenses and combinations) – from Boston University: https://www.bu.edu/astronomy/files/2021/09/Optics.pdf

Geometrical Optics (use an optical bench and lenses) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 7): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

The Optics of Thin Lenses (use a ray table to discover how lenses form an image; applying the thin lens equation and the magnification equation) – from William & Mary: http://physics.wm.edu/~labs/astro/ (click on lab #6) [see also their lab #7, The Telescope, where you construct a basic telescope set up by measuring focal length of lenses]

Telescopes I (use lenses on an optical bench) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 8): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Telescopes II (requires a variety of small telescopes with different mounts and eyepieces) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 9): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Telescopes (getting to know different kinds of astronomical instruments) – from the U. of Washington: https://drive.google.com/file/d/16Cy2hZj1dBVJWBOVL2qOwTDlQ9l8-pUM/view

Introduction to Telescopes (do a finder chart using *Stellarium,* explore the optics of a *GalileoScope,* set & align a regular telescope and find things in sky) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/foundational-labs/introduction-to-telescopes-2/

The Properties of Lenses and Telescopes (uses optical bench and lenses) – from Wake Forest University: http://users.wfu.edu/cookgb/Astronomy/LabManual/in6.pdf

Light and Telescopes (requires lenses, mirror, demonstration telescope; determine how optics work and the properties of the human eye) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Light_and_Telescopes

Telescope Field of View (use *Stellarium* to compare the apparent field of view and true field of view of a telescope, and then use the drift method to measure the latter) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #9)znc

Measuring the Effects of Light Pollution (compare apparent brightnesses of stars in a dark and urban site) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 139-142)

Lights and Light Pollution (use a diffraction grating to classify campus lights) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 22-23)

Introduction to Telescopes (understanding their optics, and first observations) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 25-31)

Introduction to CCD Observing (how CCDs works and observing AV Peg) – from the New
  Mexico Institute of Mining & Technology:
  http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 32-38)
Introduction to CCD Color Imaging (continues above lab) – from the New Mexico Institute of
  Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 39-41)
Experiment with CCD Camera Images (provides links to image processing software and sample
  images; quite detailed) – from the University of Louisville:
  https://prancer.physics.louisville.edu/astrowiki/index.php/Experiment_with_CCD_Camera_I
  mages
Colors and Spectra (requires hand-held spectroscope, grating, filters, light sources, laser) – from
  the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 10):
  https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub
Introduction to Spectroscopy (requires an SBIG-SGS spectroscope or its equivalent) – from the
  New Mexico Institute of Mining & Technology:
  http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 42-46)
Atomic Spectra (examine and understand continuous versus line spectra) – from the manual by
  Huebner, Reynolds & Smith at University of N. Florida (Activity 11):
  https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub
Light and Spectra (identify elements from spectra, measuring Doppler shifts) – from Georgia
  State University: https://s3.us-west-2.amazonaws.com/us-west-
  2.files.campus.edublogs.org/sites.gsu.edu/dist/1/13260/files/2021/02/13ed-14-Light-Spectra-
  online.pdf
The Spectroscope (use a spectroscope to measure wavelengths of known and unknown gases) –
  from William & Mary: http://physics.wm.edu/~labs/astro/ (click on Lab #8)
Diffraction and Interference (requires various pieces of lab equipment) – from the manual by
  Huebner, Reynolds & Smith at University of N. Florida (Activity 14):
  https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub
Observing the Heavens with a Telescope (learn to use a commercial Schmidt-Cassegrain
  Telescope; observe the Moon and other celestial object and start a log and sketches) – from
  the labs at Wake Forest University:
  http://users.wfu.edu/cookgb/Astronomy/LabManual/out2.pdf
Funding Panel (students are given 7 simplified proposals for new telescope facilities and are
  asked to evaluate them; from 2012, so a bit dated, but a nice model for an activity that lets
  students think like astronomers) – from the University of Indiana:
  https://www.astro.indiana.edu/catyp/minilabs.html (download the 2nd lab under "Other")

Chapter 7: OVERVIEW OF SOLAR SYSTEM, DATING METHODS

Comparative Planetology (learn from planetary data, make categories of planets) – from the
  York College (CCNY) lab manual (Lab 7): https://www.york.cuny.edu/earth-and-physical-
  sciences/physics-lab-manuals/astr140-lab-manual-4e.pdf/view

Comparative Planetology (categorize craters, channels, volcanoes and rings on different planets using images) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/comparing-planets

Cratering the Lunar Surface (includes how to make a crater, and age dating) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab03.shtml

The Colorado Scale Model Solar System (calculate a scale model for a university campus) – from the University of Colorado Manual: https://www.colorado.edu/sbo/facultystudent-resources/aps-course-lab-manuals (pp. 25-32)

Scale Model of the Solar System (calculate a "football field" model) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 79-88)

Collisions, Sledgehammers, and Impact Craters (look at sizes of meteoroids/asteroids in the solar system and the size distribution of lunar craters) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 77-88)

Planet Topography: Impact Craters (simulate cratering in the lab) – from Boston University: https://www.bu.edu/astronomy/files/2021/09/Craters_101.pdf

Planetary Observing (use binoculars/telescopes; assumes there are planets in the evening sky) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 29): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Radioactivity and Time (introduces the idea of using radioactive materials for measuring time intervals; requires a cesium/barium mini-generator, Geiger tube) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 42): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Martian Craters (use crater counts to estimate the age of a region on Mars' surface) – from the York College (CCNY) lab manual (Lab 8): https://www.york.cuny.edu/earth-and-physical-sciences/physics-lab-manuals/astr140-lab-manual-4e.pdf/view

Reflectance Spectroscopy (how we know what material the surfaces of solid worlds contain) – from the University of Washington Astrobiology Lab Manual: https://depts.washington.edu/astrobio/drupal/sites/default/files/F431_UWABLabManual.pdf (p. 15)

Heating and Cooling of Planets and Daytime Observations (use soft-drink cans painted black & white and thermometer to understand planetary processes; use local telescopes to find planets in daytime sky) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 179-192)

Atmospheric Escape (examine the temperature and gravity of five worlds, calculate their ability to hold on to an atmosphere) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/atmospheric-escape (note a much-easier-to-read Word document is available for download at the bottom of the web page)

See also: Is Science (and the Exploration of the Solar System) Worth the Cost? – under Chapter 14.

And there are labs about dating in the chapters on the Moon and on Mars.

Chapter 8: EARTH AS A PLANET

Blue Marble Matches (a series of activities comparing Earth surface features to those of other planets we have explored; the high-school version is adaptable for Astro 101): https://www.nasa.gov/stem-ed-resources/blue-marble-matches.html

Estimating the Earth's Density (measure our planet's radius, volume, and mass) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 103-114)

Locating Earthquakes (use seismometer readings from several stations) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 133-144)

Hot Spot Activity (use a map of the Hawaiian islands and ruler to measure the movement of the Pacific tectonic plate and the age of each island) – from the Lunar and Planetary Institute: https://www.lpi.usra.edu/education/step2012/participant/HotSpotMotion.pdf

How High Up is Space? (short activity with calculations of where space begins) – from the Astronomical Society of the Pacific: https://astrosociety.org/file_download/inline/74e02a72-a5c6-48d3-a498-d87732a44388

Chapter 9: THE MOON AND MERCURY

Cratering the Lunar Surface (includes how to make a crater and age dating) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab03.shtml

Collisions, Sledgehammers, and Impact Craters (sizes of meteoroids/asteroids in the solar system and the size distribution of lunar craters) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 77-88)

Telescopic Observations of the Moon (use the unaided eye and then a small telescope to get to know features on the Moon) – from William & Mary: http://physics.wm.edu/~labs/astro/ (click on Outside Lab #3)

Lunar Imaging (take CCD images of the Moon and identify interesting features) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 57-70)

Lunar Topology (take CCD images of the Moon and measure the height of crater walls) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 52-54)

Surface of the Moon (use pictures of the Moon to deduce relative ages and formation processes of surface features) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 145-162)

Observing Lunar Features (simulate the formation of craters using a tray of flour, examine lunar craters with a telescope or on provided images, calculate the height of craters) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/observational-labs/studying-the-moon/

The Moon (study a lunar map, lunar photos, and use apps to understand lunar phases) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/observational-labs/the-moon/

Geological Mapping (brief; use a good close-up image of part of the Moon to classify and understand geological forms and dating) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/geological-mapping

Geologic Mapping of the Moon (use an Apollo 15 image and whole moon image to analyze the nature and age of various land-forms on the Moon) – from the Lunar & Planetary Institute: https://www.lpi.usra.edu/education/workshops/unknownMoon/Tuesday/GeologicMappingofMoon.pdf

Lunar Lab (familiarize yourself with the Moon using images, almanacs) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 25): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Lunar Observing (using binoculars and telescopes) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 26): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Planning a Mission to the Lunar South Pole (evaluate the importance of temperature, neutron flux, Earth visibility, and Sun visibility for such a mission) – from the Lunar Reconnaissance Orbiter project: https://lunar.gsfc.nasa.gov/lessonkit/Diviner-Planning%20a%20Mission%20to%20South%20Pole.pdf

Elliptical Orbit of Mercury (calculate and plot the Mercury year and day) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 19): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

See also the "Orbit of Mercury" lab under Chapter 3

Chapter 10: VENUS AND MARS

10.1   The Nearest Planets: An Overview
10.2   The Geology of Venus
10.3   The Massive Atmosphere of Venus
10.4   The Geology of Mars
10.5   Water and Life on Mars

Mars Meteorology (look at real martian weather data) – from the Lunar & Planetary Institute: https://www.lpi.usra.edu/education/workshops/mars/2014/Friday/Mars_Meteorology.pdf

Cratering and the Martian Surface (estimate ages) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab04.shtml

Motions of Mars (graphing and drawing exercise) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 20): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Terraforming Mars (a group discussion activity about how and whether we do this) – from Sam Houston State University: https://www.shsu.edu/stm009/ACL/pdffiles/terraform.pdf

Mars: Introduction (getting to know the red planet) – in the University of Washington Astrobiology Lab Manual: https://depts.washington.edu/astrobio/drupal/sites/default/files/F431_UWABLabManual.pdf (p. 28)

Crater Counting on Mars (use photos of four regions of Mars and determine relative ages using crater counts; get absolute ages using a calibrated lunar image) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/crater-counting-on-mars (download the Word file at the bottom of the web page)

Explore Mars (use images, websites, map measurements, etc; written in 2013) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Explore_Mars

Plate Tectonics on Mars? (short activity examining an image of the big volcanoes on Mars, to see if their alignment and crater counts are compatible with plate tectonics) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/plate-tectonics-on-mars

Google Earth: Mars Mode (exploring Mars terrain) – in the University of Washington Astrobiology Lab Manual: https://depts.washington.edu/astrobio/drupal/sites/default/files/F431_UWABLabManual.pdf (p. 32)

See the lab "Martian Craters" under Chapter 7

Chapter 11: JUPITER, SATURN, URANUS, NEPTUNE

11.1   Exploring the Outer Planets
11.2   The Jovian Planets
11.3   Atmospheres of the Giant Planets

So far, no labs have been identified for this chapter.

Chapter 12: RINGS, LARGE MOONS, AND PLUTO

12.1   Rings and Moons
12.2   The Galilean Moons of Jupiter
12.3   Titan and Pluto
12.4   Planetary Rings

In the Footsteps of Galileo: Observing the Moons of Jupiter (and calculating their orbital periods) – from the Astronomical Society of the Pacific: https://astrosociety.org/file_download/inline/1689e781-3f4a-4178-8f7a-7bc581986242

Roemer's Measurement of the Speed of Light (timing the motion of Jupiter's large moons; uses the *Starry Night* computer program; but could be adapted to free equivalents) – from the Villanova University lab manual (Lab I): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

See under Chapter 3 for two labs: Kepler's Laws of Planetary Motion, which look at the motions of Jupiter's moons

Chapter 13: ASTEROIDS AND COMETS

13.1   Asteroids
13.2   Asteroids and Planetary Defense
13.3   The "Long-Haired" Comets
13.4   The Origin and Fate of Comets

Observing Comets (assumes there is a comet in the sky) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 28): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Comets (look at the motions of Halley's Comet and Comet Swift-Tuttle; uses the commercial *Starry Night* software, but could be replaced with a free program) – from the Villanova University lab manual (Lab J): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

Observing Comets (use comet images and comet data to examine and measure their properties) – from University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/observational-labs/observing-comets/

Near Earth Asteroids (learn about cratering, recreate the formation of Arizona's Meteorite (Barringer) crater using on-line software, use images to estimate the diameter of an NEO) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/professional-labs/introduction-to-impact/

Impact Craters (short activity: students research and examine terrestrial impact craters and estimate frequency) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (click title under "Solar System" to download a Word file)

Building a Comet (learn about asteroids & comets; make impact craters using ball bearings and flour; make a comet out of water, ammonia, dry ice, etc.; test its durability) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 225-237)

Chapter 14: METEORS, METEORITES, ORIGIN OF SS, EXOPLANETS 1

14.1   Meteors
14.2   Meteorites: Stones from Heaven
14.3   Formation of the Solar System
14.4   Comparison with Other Planetary Systems
14.5   Planetary Evolution

Atmospheric Retention (use several apps to understand the evolution of atmospheres on planets with different temperatures and gravities) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_atmosphere_sg.pdf (instructor guidelines are at: https://astro.unl.edu/nativeapps/NAAP_resources/atmosphere_classdemo.pdf) (download the apps themselves at: https://astro.unl.edu/nativeapps/)

Classifying Meteorites (learn about different types, then classify unknown samples; requires a collection of samples for students) – from the University of Washington:

Is Science (and the Exploration of the Solar System) Worth the Cost? (a group discussion activity) from Sam Houston State University: https://www.shsu.edu/stm009/ACL/pdffiles/science.pdf

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Chapter 15: THE SUN, SOLAR ACTIVITY, SPACE WEATHER

Solar Rotation (calculate from the motion of sunspots) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 78-87)
The Rotation of the Sun (measure nine solar images to get the Sun's rotation period and learn how to estimate errors) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/rotation-of-the-sun
Introduction to the Sun and its Cycle (sunspots and sunspot cycles) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 48-51)
Solar Lab (measuring the Sun's rotational period using sunspots) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 22): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub
Solar Observing (using a small telescope with solar filter and spectrometer) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 23): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub
Properties of the Sun (use images of the Sun to calculate the Sun's rotation period and the velocity of matter leaving in a coronal mass ejection) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/properties-of-the-sun
NASA's Solar Dynamics Observatory Data in the Classroom (a 2-week sequence of lab activities for Astro 101 students) – from Scott Hildreth, et al, Chabot College: http://solar-center.stanford.edu/activities/SDO/Chabot-SDO-Data-in-the-Classroom.pdf
Activity Cycles on Other Stars (brief, elementary activity where students plot data to find the length that is equivalent to our sunspot cycle) – From Image Project at NASA Goddard: https://image.gsfc.nasa.gov/poetry//activity/a1.html

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Chapter 16: NUCLEAR FUSION AND THE SOLAR INTERIOR

Solar Energy (brief; calculate the age of the Sun from its mass and fuel consumption rate) – University of Indiana Minilab to download at: https://www.astro.indiana.edu/catyp/minilabs.html

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Chapter 17: MEASURING/DERIVING STELLAR CHARACTERISTICS

17.1   The Brightness of Stars
17.2   Colors of Stars
17.3   The Spectra of Stars and Brown Dwarves
17.4   Measuring Stellar Radius, Composition, and Motion

Intensity Versus Distance (use a photometer to see how brightness of a bulb varies with distance and then apply it to stars) – from the University of Tennessee: http://astrolab.phys.utk.edu/White-Manual/A154Lab4New.pdf

Magnitude Scale (mostly doing calculations) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 31): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Follow Proxima Centauri (measure its proper motion) – from the University of Louisville: http://prancer.physics.louisville.edu/astrowiki/index.php/Follow_Proxima_Centauri

The Proper Motion of Barnard's Star – a mini-lab activity from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html

Star Magnitudes & Distances (use *Stellarium* to understand magnitude scales, then get distances from parallax and from comparing apparent and absolute magnitudes) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #10)

Star Colors and the (B-V) Index (use information from *Stellarium* to understand star colors and color indices – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #11)

Spectral Classification of Stars (examine and classify stars using the strength of the Balmer absorption lines of H) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/spectral-classification-of-stars (comes in several versions)

See also: Luminosity and Brightness lab from Boston University under Chapter 5

Chapter 18: STAR MASSES, DIAMETERS, AND THE H-R DIAGRAM

18.1   A Stellar Census
18.2   Measuring Stellar Masses
18.3   Diameters of Stars
18.4   The H-R Diagram

Eclipsing Binary Stars (use an eclipsing binary star simulator to measure and determine the characteristics of the stars) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_ebs_sg.pdf (Guidelines for

instructors are at: https://astro.unl.edu/nativeapps/NAAP_resources/ebs_classdemo.pdf)
(download the apps themselves at https://astro.unl.edu/nativeapps/)

Binary Stars (observing and understanding visual binaries and eclipsing binary systems) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 35): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Stellar Spectral Classes and the H-R Diagram (use *Stellarium* to construct an H-R diagram and then explore the idea of spectral classes) – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/hr_diagrams1/hr_diagrams_first_lab_stellarproperties_v01online.pdf

The Nearest and Brightest Stars (construct an H-R diagram from data tables) – University of Indiana Minilab to download at: https://www.astro.indiana.edu/catyp/minilabs.html

Hertzsprung-Russell Diagram (plot nearest & brightest stars; use a temperature overlay) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 32): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

The H-R Diagram (use *Stellarium* to obtain the spectral type & absolute magnitude of nearest stars and brightest stars; construct and learn about H-R diagram) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #12)

Plotting Stars on the H-R Diagram (requires a list of nearest and brightest stars, but these can be found in the appendices of the OpenStax textbook) – from the manual for Wake Forest University: http://users.wfu.edu/cookgb/Astronomy/LabManual/in8.pdf

The H-R Diagram and the Properties of Stars (students work with graphs showing H-R diagrams and answer questions) – from Georgia State University: https://s3.us-west-2.amazonaws.com/us-west-2.files.campus.edublogs.org/sites.gsu.edu/dist/1/13260/files/2020/01/18-HR-Diagram-LAB.pdf (to get the graphs, go to: http://sites.gsu.edu/astr1020lab/hertzsprung-russell-diagram-lab/)

H-R Diagram (use an app to see what makes the diagram useful for astronomers) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_hr_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Familiar Stars (students examine a list of nearest and brightest stars and are asked to draw conclusions about them – brief) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the 12th entry under "Stars")

Chapter 19: DISTANCE METHODS, VARIABLE STARS

19.1   Fundamental Units of Distance
19.2   Surveying the Stars
19.3   Variable Stars: One Key to Cosmic Distances
19.4   The H-R Diagram and Cosmic Distances

Parallax Measurements and Determining Distances (students first measure distances to nearby objects on Earth and then learn about doing the same for stars) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab05.shtml

Estimating the Distance to the Moon Using the Method of Hipparchus (uses the free *Stellarium* software) – from the *My Science Walks* website: https://www.mysciencewalks.com/distance-to-the-moon-hipparchus.html

Transits of Venus (use *Stellarium* to calculate the diameter of the Sun from transit data for Venus and concepts of parallax; then do the same for a transit of Mercury) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #8)

Distances to Stars Using Measured Parallax (calculate parallax from angular shift)– from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/distances-to-stars-using-measured-parallax

Parallax (use a mirror and cross-staff, do calculations) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 21): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Parallax (measure shift and distance of some sample stars with provided images and grids) – from Georgia State University: https://s3.us-west-2.amazonaws.com/us-west-2.files.campus.edublogs.org/sites.gsu.edu/dist/1/13260/files/2020/01/16-Parallax-Online-LAB.pdf

Finding the Distances and Sizes of Remote Objects (learn to do terrestrial parallax measurement) – from Wake Forest University: http://users.wfu.edu/cookgb/Astronomy/LabManual/out4.pdf

Parallax and the Distance to the Stars (use two photos of the class to measure terrestrial parallax and *Stellarium* to explore the parallax of the stars) – from William & Mary: http://physics.wm.edu/~labs/astro/ (click on lab #9)

Measuring Distances Using Parallax (first using your eyes, then for stars) – from New Mexico State University: http://astronomy.nmsu.edu/feuilldk/a110/Ast110Fall2015.pdf (pp. 121-134)

Star Magnitudes & Distances (use *Stellarium* to understand magnitude scales, then get distances from parallax and from comparing apparent and absolute magnitudes) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #10)

Cluster Color-Magnitude Diagrams (use the diagrams from several clusters to calculate distances and ages) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/cluster-color-magnitude-diagrams (note there are alternate versions at the bottom downloadable as Word files)

The Cosmic Distance Ladder (uses four simulations/apps to show students different ways astronomical distances are measured) – from the University of Nebraska Astronomy Applet Project: https://astro.unl.edu/nativeapps/NAAP_resources/naap_distance_sg_08.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Variable Stars (learn about and observe various types of variables) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 36): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

RR Lyrae Distances (use light curves from variable stars in a dwarf galaxy to get its distance) – from Laura Sparks at Santa Rosa Junior College: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/rr-lyrae-distances or

Variable Star Photometry (use a blink comparator simulator and two photometry simulators to analyze data from variable stars) – from the University of Nebraska:

https://astro.unl.edu/nativeapps/NAAP_resources/naap_vsp_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Applying H-R Diagrams: Spectral Parallax and Stellar Sizes – from the University of Tennessee: http://astrolab.phys.utk.edu/Lindsay_manual/hr_diagrams2/hr_diagrams2_spectroscopic_parallax_online.pdf

The Distance to Galaxy M100 as Determined with Cepheid Variable Stars (using Hubble data) – from ESO/ESA: https://sci.esa.int/documents/34439/36575/1567254558082-4-exercise2-high.pdf

Variable Stars in Messier 3 (use image processing software to measure magnitudes, use RR Lyrae stars to measure the distance to a globular cluster) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Variable_Stars_in_Messier_3

Distance to a Star Cluster (use data from open cluster M25 to find the interstellar reddening for the cluster and then estimate its distance) – from Georgia State University: https://s3.us-west-2.amazonaws.com/us-west-2.files.campus.edublogs.org/sites.gsu.edu/dist/1/13260/files/2020/01/21-Distance-to-a-Star-Cluster-LAB.pdf

The American Association of Variable Star Observers has a series of beginner's observing activities at: https://www.aavso.org/education (scroll down to "Online Resources: Observing")

Chapter 20: INTERSTELAR MEDIUM, COSMIC RAYS

20.1   The Interstellar Medium
20.2   Interstellar Gas
20.3   Cosmic Dust
20.4   Cosmic Rays
20.5   Recycling Cosmic Material
20.6   Interstellar Matter Around the Sun

The Messier List (mapping nebulae, clusters, and galaxies) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 5): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

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Chapter 21: STAR FORMATION, STELLAR EVOLUTION, EXOPLANETS 2

21.1   Star Formation
21.2   The H-R Diagram and the Study of Stellar Evolution
21.3   Evidence That Planets Form Around Other Stars
21.4   Planets Beyond the Solar System: Search and Discovery

Finding Dust Disks with Spitzer (use Spitzer data to identify characteristics of stars whose infrared signature might hint at the presence of a proto-planetary disk) – from the University of Indiana and the Spitzer Project: https://www.astro.indiana.edu/irworkshop/dust_disks_teacher_guide.pdf (for student handouts, a Powerpoint deck and more, go to:

https://www.astro.indiana.edu/catyp/minilabs.html, look under "Stars" and find the title of this lab.)

Discovery of Extrasolar Planets (using the radial velocity method) – from the NASA SIM mission and Washington State University: http://astro.wsu.edu/labs/Discovery-of-Extrasolar-Planets.pdf

Extra-Solar Planets (use simulation apps to understand both the radial-velocity and the transit methods) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_esp_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Transiting Extrasolar Planets (using Kepler data) – from the University of Colorado Manual: https://www.colorado.edu/sbo/sites/default/files/attached-files/1010manual_s20.pdf (pp. 127-135)

Transiting Exoplanets (involves doing your own CCD observations, but much of it can be done without that) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 62-68)

Searching for Extrasolar Planets (using radial velocity and transits) – from Boston University: https://www.bu.edu/astronomy/files/2021/09/Extrasolar.pdf

Detecting Extrasolar Planets (Uses the Nebraska applets *Exoplanet Radial Velocity Simulator* and *Exoplanet Transit Simulator)* – from the Villanova University lab manual (Lab K): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

The Discovery of Exoplanet 51 Pegasi B (use actual radial velocity data to obtain the period and mass of the planet) – from the University of Central Arkansas: https://faculty.uca.edu/njaustin/PHYS1401/Laboratory/exoplanet.html

51 Peg's Planet (brief activity taking data from the first exoplanet discovered, and calculating the properties of the system) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the first activity under "Exoplanets")

Exoplanets: The Radial Velocity Method (use radial velocity curve to calculate period and mass of an orbiting planet) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/exoplanets-the-radial-velocity-method

Exoplanets: The Transit Method (use the light curve of a transiting planet to calculate the radius; also discusses getting density) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/planets-star-systems/exoplanets-the-transit-method (download the Word version at the end)

Characterizing Exoplanets (use transit light curves to find properties of exoplanets, learn about and categorize different types, calculate habitable zones; 2015 lab, but still useful) – from New Mexico State University: http://astronomy.nmsu.edu/astro/Ast105labmanual.pdf (pp. 239-257)

Habitable Zones (brief activity using a simulation to calculate the temperature on several exoplanets; note that the calculator needed has moved and is at: https://www.astro.indiana.edu/ala/PlanetTemp/index.html) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the third activity under "Exoplanets")

See the first "Thermal Radiation Laws" Lab listed under Chapter 6; it applies to exoplanets.

Chapter 22: LATER STELLAR EVOLUTION, RED GIANTS, STAR CLUSTERS

The H-R Diagram and Stellar Evolution (use star cluster data to estimate cluster ages) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab06.shtml

Red Giants (make an H-R Diagram for the brightest stars in the sky and use data from *Stellarium* to figure out which are red giants; think about characteristics and evolution of these stars) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #13)

Properties of Planetary Nebulae (use images of the Ring Nebula to calculate the size, age, mass-loss rate, and mass-return rate of the nebula) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/stars-properties-evolution-clusters/properties-of-planetary-nebulae

Colour-Magnitude Diagrams (finding the age and distance of globular clusters) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 26-31)

Star Clusters (compare and analyze the H-R diagrams of six star clusters) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the 19th entry under "Stars")

The H-R Diagram and the Ages of Globular Clusters (learn about the H-R diagram, plot data, measure the main-sequence turn-off points, and calculate ages) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/foundational-labs/exploring-hertzsprung-russe/

Chapter 23: WHITE DWARFS, SUPERNOVAE, NEUTRON STARS, PULSARS

Medieval Supernovas (use *Stellarium* software and its historical supernovae plugin; you also get to make a supernova light curve) – from the *My Science Walks* website: https://www.mysciencewalks.com/medieval-supernovas.html

Timing an X-ray Pulsar (use X-ray data to identify an object as a rotating neutron star, and determine its period of rotation) – from the NASA RXTE Mission: https://heasarc.gsfc.nasa.gov/docs/xte/learning_center/xray_pulsar.html

Measuring the Distance to Supernova 1987A (from its expansion; uses Hubble data) – from ESO/ESA: https://sci.esa.int/documents/34439/36575/1567254555538-3-exercise1-high.pdf

Cosmic Recycling (measure the expansion rate of the filaments of the Crab Nebula): – a minilab activity from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html

Elements and Supernovae (get familiar with the periodic table and radioactivity & a supernova bounce model with balls) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 33):
https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

SN Ia in M51 (very brief activity: students examine photos of a supernova, plot a light curve to determine which type it is) – from the University of Indiana:
https://www.astro.indiana.edu/catyp/minilabs.html (download 9th activity under "Galaxies")

Measure a Nearby Supernova (on provided images and data, measure characteristics of two supernovae in nearby galaxies, and establish what type they are) – from the University of Louisville:
https://prancer.physics.louisville.edu/astrowiki/index.php/Measure_a_Nearby_Supernova

Star Party (a discussion activity on stellar evolution, where students discuss various true or false statements about the life stories of the stars) – from NASA's Infiniscope project and Arizona State: https://etx.asu.edu/wp-content/uploads/2021/02/Star_Party_HS_Lesson.pdf

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Chapter 24: BLACK HOLES & GRAVITATIONAL WAVES

24.1   Introducing General Relativity
24.2   The Principle of Equivalence
24.3   Spacetime and Gravity
24.4   Tests of General Relativity
24.5   Time in General Relativity
24.6   Black Holes
24.7   Evidence for Black Holes
24.8   Gravitational Wave Astronomy

Black Holes (brief series of scale model and calculation activities, to envision black holes and their environments) – from the University of Indiana
https://www.astro.indiana.edu/catyp/minilabs.html (download the 3rd activity under "Other")

Gravitational Wave Detection in the Introductory Lab – an article with well-explained calculation exercises, requiring algebra, by Lior Burko:
https://arxiv.org/ftp/arxiv/papers/1602/1602.04666.pdf

Chapter 25: MILKY WAY GALAXY

25.1   The Architecture of the Galaxy
25.2   Spiral Structure
25.3   The Mass of the Galaxy
25.4   The Center of the Galaxy
25.5   Stellar Populations in the Galaxy
25.6   The Formation of the Galaxy

How Big is Our Galaxy? (use variable stars to estimate distance to various globular clusters and use their distribution to estimate the size of the Galaxy; plus get its mass)—from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 32-39)

Stellar Distribution Assignment (see how different stellar types are distributed in the Galaxy) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 82-87)

The Milky Way (use *Stellarium* to inspect the appearance of the Milky Way in the sky; use globular cluster information to make a map of their distribution) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #14)

The Messier List (map nebulae, clusters, and galaxies relative to the galactic disk)– from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 5): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Galactic Structure Assignment (plot objects in the Messier and Caldwell catalogs to trace features of our Galaxy) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 88-89)

Mapping the Galaxy (learn about different kinds of map projections and then mapping clusters and nebulae among the constellations to see how our Galaxy is shaped) – from New Mexico State University: http://astronomy.nmsu.edu/feuilldk/a110/Ast110Fall2015.pdf (pp. 203-217)

Distance to the Center of the Milky Way (from the location of globular clusters) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/motions-and-historical-astronomy/distance-to-the-center-of-the-milky-way

Determining Spiral Structure (short activity to use the location of HII regions to map our Galaxy) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the third activity under "Galaxies")

Milky Way Rotation Curve: Weighing the Milky Way (brief calculation and graphing using globular cluster masses, distances, and velocities, to demonstrate the existence of dark matter) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the 4th file under "Galaxies")

Chapter 26: GALAXIES, TYPES, PROPERTIES, HUBBLE LAW, EXPANSION

26.1   The Great Nebula Debate
26.2   Types of Galaxies
26.3   Properties of Galaxies
26.4   The Extragalactic Distance Scale
26.5   The Expanding Universe

Galaxy Properties (classify galaxies) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab08.shtml

Galaxies (short activity, organizing photos of galaxies into Hubble's tuning-fork diagram for galaxy shapes) – from U. of Tennessee: http://astrolab.phys.utk.edu/White-Manual/A154Lab6.pdf

Galaxies Lab (classification activity) – from the Georgia State University (note you have to click on three separate documents to get the full lab): http://sites.gsu.edu/astr1020lab/astronomy-1020-lab-manual/

Galaxy Morphology (classify galaxy images taken by students, but you could also supply images) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 73-76)

Galaxy Classification (based on shapes, dust, and star formation) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/galaxies-and-cosmology/galaxy-classification

Classifying Galaxies (on photographs and negatives of one or more galaxy clusters) – from the manual by Huebner, Reynolds & Smith at University of N. Florida (Activity 43): https://digitalcommons.unf.edu/cgi/viewcontent.cgi?article=1000&context=aphy_facpub

Classifying Galaxies (put images into Hubble's and deVaucouleurs' schemes, looking at clusters, using Galaxy Zoo) – from the University of Iowa: http://astro.physics.uiowa.edu/ITU/labs/foundational-labs/classifying-galaxies/

Galactic Rotation (analyze rotation curve for the Andromeda Galaxy) – from Georgia State University: http://sites.gsu.edu/astr1020lab/astronomy-1020-lab-manual/

Hubble's Law and the Cosmic Distance Scale (estimate distances for elliptical galaxies and deriving a Hubble Law plot) – from the GEAS Project at New Mexico State: http://astronomy.nmsu.edu/geas/labs/html/lab07.shtml

Hubble's Law lab (includes measuring spectra, comes in long and short version) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/galaxies-and-cosmology/hubbles-law

Hubble's Law: Finding the Age of the Universe (learn how to measure Doppler shift on spectra, calculating Hubble's constant, and its inverse) – from New Mexico State University: http://astronomy.nmsu.edu/feuilldk/a110/Ast110Fall2015.pdf (pp. 255-267)

Hubble's Law and the Cosmological Principle (use *Stellarium* to derive the law and to examine the distribution of galaxies) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download the 16th exercise)

The Expanding (Balloon) Universe (use an expanding balloon to understand Hubble's Law) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/galaxies-and-cosmology/the-expanding-balloon-universe

The Extragalactic Distance Scale and the Hubble Law (brief; plot galaxy distances and velocities to discover the Hubble Law, use it to estimate new distances and the age of the universe) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the 12th file under "Galaxies")

Dark Matter (work with data from NGC 2742 to measure the amount of dark matter) – from the University of Washington: https://sites.google.com/a/uw.edu/introductory-astronomy-clearinghouse/activities/galaxies-and-cosmology/dark-matter

What is Redshift (use galaxies' recession velocities to calculate redshift and lookback time, using on-line calculators that take relativistic effects into consideration) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the first activity under "Cosmology"; note that the URL of the first calculator has changed – it is now at: https://www.calctool.org/CALC/phys/relativity/redshift)

Chapter 27: QUASARS, ACTIVE GALAXIES, SUPER-MASSIVE BLACK HOLES, AND GAMMA-RAY BURSTS

27.1   The Quasars

Imagine the Universe: Active Galaxies Activities Manual (three high-school level activities, easily adapted to college labs: 1) perspectives – what AGN's look like from different directions; 2) angular size estimates; 3) light travel time): https://imagine.gsfc.nasa.gov/observatories/learning/fermi/classroom/docs/agn_guide.pdf

Supermassive Black Holes (short activity calculating and plotting properties of central super-massive black holes and the galaxies in which they live) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the 15th file under "Galaxies")

Chapter 28: EVOLUTION OF GALAXIES, FORMATION OF STRUCTURE, GALAXY CLUSTERS, DARK MATTER AND DARK ENERGY

The Hubble Tuning Fork & Galaxy Evolution (use *Stellarium* to classify galaxy shapes and then use distances to see if galaxy types have evolved over time; join the Galaxy Zoo citizen science project and classify further galaxies) – from Colorado Mountain College: https://library.coloradomtn.edu/astronomy/stellarium (download exercise #15)

Counting Galaxies (count different types of Galaxies in the Leo Cluster) – from the New Mexico Institute of Mining & Technology: http://kestrel.nmt.edu/~dmeier/P327L_labmanual.pdf (pp. 90-92)

How Many Galaxies are There in the Entire Universe (covers estimating, uncertainty, using the Hubble Deep Field image to do sample counts) – from New Mexico State University: http://astronomy.nmsu.edu/feuilldk/a110/Ast110Fall2015.pdf (pp. 241-254)

Survey Galaxies in Virgo (examine the Virgo cluster through various images and software, and measure properties of some of its galaxies) – from the University of Louisville: https://prancer.physics.louisville.edu/astrowiki/index.php/Survey_Galaxies_in_Virgo

Lab Exercises and Apps Related to the Hubble Ultra-Deep Field Image (ten different exercises with instructor guides and student manuals) – from Arizona State University: http://ahah.asu.edu/exercises.html

Large Scale Structure with the Hubble Deep Field (brief; students examine an image of the HDF with redshifts shown and draw a histogram of the number of galaxies at each redshift and look for clustering) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the third activity under "Cosmology")

Rotation Curve: Dark Matter in NGC2742 (a brief calculation and plotting activity, determining the amount of luminous matter and dark matter in a galaxy) – from the University of

Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the third to last activity under "Galaxies")

Galaxy Voids (very brief; students examine the map made from the Anglo-Australian telescope 2dF Galaxy Redshift Survey, measuring the size of filaments and voids) – from the University of Indiana: https://www.astro.indiana.edu/catyp/minilabs.html (download the fourth activity under "Cosmology")

Note that a number of the labs recommended for Chapter 26 also pertain to this chapter.

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Chapter 29: COSMOLOGY: THEORIES AND EVIDENCE

29.1   The Age of the Universe
29.2   A Model of the Universe
29.3   The Beginning of the Universe
29.4   The Cosmic Background Radiation
29.5   What is the Universe Really Made of?
29.6   The Inflationary Universe
29.7   The Anthropic Principle

Particle Soup: Nucleosynthesis (explore reactions right after the Big Bang and how helium was made) – from the University of Washington:
https://drive.google.com/file/d/1w1cTP_HEaRtEm0l7bezWaKELnVxJmmb_/view

The Curvature of Space (a brief activity exploring different geometries using prints by the artist Escher) – from the University of Washington:
https://drive.google.com/file/d/17t1j05Pu2nXjVXBkqzM7-NjWjrQJhDs6/view

What is the Age and Size of the Universe? (uses one of the CLEA computer labs; which is no longer supported) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 40-45)

Cosmic Acceleration (downloadable Word document; brief pen and paper exercise using data from Type Ia supernovae) – from the University of Indiana:
https://www.astro.indiana.edu/catyp/minilabs.html (it is entry 2 under "Cosmology")

The Magnitudes of Type Ia Supernovae (use data from nine Type Ia supernovae in galaxies with known distances to test the idea that all Type Ia have the same maximum luminosity) – from Princeton, but on line from the University of Indiana:
https://www.astro.indiana.edu/catyp/minilabs.html (download the 9th lab under "Galaxies")

The "Cosmic Times" Project (using 'newspaper' articles about major developments in cosmology, this sequence of activities allows students to explore and discuss the discoveries that led to our present picture; note that there are big files you can download with suggestions for instructors) – from NASA Goddard:
https://imagine.gsfc.nasa.gov/educators/programs/cosmictimes/educators/guide/index.html

Some of the activities under Chapter 26, dealing with the expansion of the universe, are also relevant to this chapter.

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Chapter 30: ASTROBIOLOGY AND SETI

30.1   The Cosmic Context for Life
30.2   Astrobiology

Search for Extraterrestrial Intelligence (estimate the number of technological civilizations in the Galaxy using the Drake Equation) – from the University of Victoria: http://www.astro.uvic.ca/~robb/lab (pp. 46-56)

The Drake Equation (has an analogy that uses similar estimating skills, and then asks students to consider each factor) – in the University of Washington Astrobiology Lab Manual: https://depts.washington.edu/astrobio/drupal/sites/default/files/F431_UWABLabManual.pdf (p. 43)

Extra-terrestrial Life (estimate using the Drake Equation and then discuss result) – from Sam Houston State U: https://www.shsu.edu/stm009/ACL/pdffiles/ETlife.pdf

Habitable Zones (use a Circumstellar Zone Simulator App; explore stellar and galactic habitable zones) – from the University of Nebraska: https://astro.unl.edu/nativeapps/NAAP_resources/naap_habitablezones_sg.pdf (download the apps themselves at https://astro.unl.edu/nativeapps/)

Exploring Habitable Zones (use NAAP programs to explore stellar and galactic habitable zones; see the entry directly above) – from the Villanova University lab manual (Lab L): http://aprsa.villanova.edu/files/2019_fall_MSE2150_manual.pdf

Who Speaks for Earth? (discuss what we do next after receiving a SETI message) – from the Astronomical Society of the Pacific: https://www.fraknoi.com/wp-content/uploads/2021/12/Who-Speaks-for-Earth-Activity.pdf

Movie Review Lab (do an analysis of the astronomy in a science fiction film) – from Georgia State University: https://cpb-us-w2.wpmucdn.com/sites.gsu.edu/dist/1/13260/files/2020/05/ASTR-1020-Movie-Review-Lab.pdf

See also the Habitable Zones activity under Chapter 21.

The University of Washington has a separate lab manual for its slightly more specialized Astrobiology course at: https://depts.washington.edu/astrobio/drupal/sites/default/files/F431_UWABLabManual.pdf