



Explorations: Introduction to Astronomy, 9th edition

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NEW IN THE NINETH EDITION

In this ninth edition of *Explorations*, we continue to update the art and text throughout the book in response to readers' comments and suggestions. One of the best aspects of McGraw-Hill's electronic resources for students is that we can find the links back to text and figures related to questions that students are having difficulty answering. We have closely examined these materials and worked on making sure the wording and imagery is as clear as possible. In addition to changes for clarity, there are several places where we have made more extensive revisions in response to recent research and requests for extra detail. These include the following:

- The latest results and analysis of exoplanets based on *Kepler* and other observations continue to change our views about planets and planetary systems. This is a rapidly expanding subject with exciting new results that we have attempted to distill to the most important and solid results in Chapter 8. The growing understanding of planetary systems has touched many aspects of the Solar System chapters as well.
- Fascinating new discoveries such as the interstellar asteroid 'Oumuamua and gravitational waves from merging black holes and neutron stars by LIGO have each received new coverage.
- The demonstration that merging neutron stars are the likely source for the rapid-process

chemical elements has led us to revisit the discussion of the origins of the elements. This appears in multiple places throughout the text (red giants, planetary nebula phase, supernova explosions), and we have expanded the “Cosmic Periodic Table,” to indicate the latest thinking about how the elements each formed.

- We have compiled many “Projects” that can be carried out by students on their own, or used in class to illustrate ideas in lecture. Most of these use the planetarium program *Stellarium* to link a topic to what is actually visible in the sky. Some are based on activities we have used with our own students. The Projects are indicated by a new icon in the text, and details of each are described online.
- The foldout star chart has been updated to show the positions of Messier objects and a selection of brighter southern objects suitable for binoculars or a small telescope. The Moon and planet finder tables now show dates of partial eclipses in addition to total eclipses.

DETAILED REVISIONS

Some of the changes may be of particular interest for the instructor who previously used the eighth edition. The following list calls attention to new figures and revised text that may be useful in updating lecture presentations and class notes:

chapter 1: Better image of annular eclipse. Modifications to illustration of lunar orbit precession for clarity. Updated table of upcoming eclipses.

essay 1: New examples of star charts based on the new foldout star-chart and *Stellarium*. New image of 2016 transit of Mercury.

essay 2: Added new section on gravitational waves along with a figure illustrating the LIGO detection.

chapter 5: Added mention of neutron-star mergers as possible source of gamma ray bursts to “Extending Our Reach” box. Reorganized discussion of atmospheric refraction.

chapter 6: Revised discussions of the greenhouse effect and the origin of the atmosphere.

chapter 7: Revised discussion of tides.

chapter 8: Haumea and Makemake included in figures and text when discussing dwarf planets. Mentions of Bode’s rule are now further de-emphasized since findings that it does not appear to apply to other planetary systems. Extensive revisions to section on other planetary systems, including several new figures illustrating exoplanets. Updated figure showing all exoplanetary systems with at least five planets now also shows where heating from star is similar to Earth’s. Added ALMA image of dust disk around HL Tau.

chapter 9: Added *Messenger* images and discussion of Mercury’s spider troughs, volcanic vents, and “hollows.” Noted recent hypotheses about major collisions contributing to planetary magnetic fields and importance of magnetic fields for retaining an atmosphere. Revised diagrams of the orbits of Mercury and Venus and expanded discussion of resonances in their orbits. Updated discussion of Mars’s polar caps and complex climate history. Added images of Victoria Crater and comparison of the three types of Martian rovers to date. Updated images and discussion of *Curiosity*’s mission. Added consideration of exo-planet properties to section comparing terrestrial planets.

chapter 10: Added *Juno* image of Jupiter’s polar region. Expanded discussion of tidal heating of Io.

chapter 11: Added *Dawn* image of Vesta's south pole. New "Extending our reach" box on the interstellar asteroid 'Oumuamua. Added new figure and discussion of the possibility of a planet orbiting in the outer Solar System.

chapter 12: Revised description of modeling of Sun's internal structure. New image of Super-Kamiokande, and expanded discussion of solar neutrinos and the new physics they revealed. Updates to graphics on magnetic field interaction with charged particles, solar wind termination, and solar cycle. Revised discussion of links of solar cycle with Earth's climate and added information about Annie Maunder's contribution.

chapter 13: Revised explanation of absolute magnitudes. Reorganized section on stellar spectra to clarify how temperature affects which elements' lines are seen, and trimmed some of the early history of spectral classification.

chapter 14: Added diagram showing convection regions for different mass stars and added to discussion of causes of convection and effects on stellar evolution. Added discussion of "dredge up" in red giants and the importance for enriching interstellar clouds with carbon and other elements. Revised figure and discussion of shell burning in high-mass stars and updated discussion of contributions of type II supernova explosions to heavy element production.

chapter 15: Expanded discussion of type Ia supernova explosions and the elements they produce. Abbreviated discussion of early models of pulsars and clarified discussion of effects of angular momentum conservation and generation of electromagnetic beaming. Added "Science at Work" box about observation of merging neutron stars and the detection of heavy elements it produced.

chapter 16: Revised discussion of effects of interstellar clouds on starlight, emphasizing complementarity of scattering, dimming, and reddening. Updated figure showing stellar orbits at Galactic center.

chapter 17: Expanded discussion of causes of spiral structure. Added side-by-side comparison of optical and radio neutral hydrogen images of M81. Revised discussion of determining galaxy distances to explain some of the observational challenges. Updated discussion and illustration of evolutionary effects of galaxy mergers.

chapter 18: Revised discussion and figure explaining the cosmic horizon. Expanded discussion of CMB fluctuations and their connection to the amount of dark and normal matter present in the Universe.

essay 4: Added genetic "family tree" and discussion of archaea's central role in the evolution of life on Earth.