

## Appendix A

### Glossary

Absolute magnitude	Apparent magnitude a star would have at a distance of 10 parsecs (32.6 LY).
Absorption lines	Dark lines superimposed on a continuous electromagnetic spectrum due to absorption of certain frequencies by the medium through which the radiation has passed.
AM	Amplitude modulation. Imposing a signal on transmitted energy by varying the intensity of the wave.
Amplitude	The maximum variation in strength of an electromagnetic wave in one wavelength.
Ångstrom	Unit of length equal to $10^{-10}$ m. Sometimes used to measure wavelengths of visible light. Now largely superseded by the nanometer ( $10^{-9}$ m).
Aphelion	The point in a body's orbit (Earth's, for example) around the sun where the orbiting body is farthest from the sun.
Apogee	The point in a body's orbit (the moon's, for example) around Earth where the orbiting body is farthest from Earth.
Apparent magnitude	Measure of the observed brightness received from a source.
Astrometry	Technique of precisely measuring any wobble in a star's position that might be caused by planets orbiting the star and thus exerting a slight gravitational tug on it.
Astronomical horizon	The hypothetical interface between Earth and sky, as would be seen by the observer if the surrounding terrain were perfectly flat.
Astronomical unit	Mean Earth-to-sun distance, approximately 150,000,000 km.
Atmospheric window	Property of Earth's atmosphere that allows only certain wavelengths of electromagnetic energy to pass through, absorbing all other wavelengths.
AU	Abbreviation for astronomical unit.
Azimuth	In the horizon coordinate system, the horizontal angle from some arbitrary reference direction (north, usually) clockwise to the object circle.

Background radiation	Electromagnetic radiation originating from no specific location.
Beam width	The angle within which an antenna receives radio waves.
Binary stars	Two stars that are so close as to orbit around a common center of gravity.
Black dwarf	One possible final stage in the evolution of a star, in which all the energy is exhausted and it no longer emits radiation.
Black hole	A region of space surrounding a very massive collapsed star. Gravity is so intense in a black hole that the escape velocity is equal to or greater than the speed of light, thus no radiation can escape.
Blackbody	A hypothetical object that is a perfect radiator, absorbing and re-emitting all radiation that impinges upon it.
Blazar	Short for BL Lacertae object: a class of galaxies whose light is polarized and has a non-thermal spectrum, and whose brightness fluctuates dramatically.
Blue shift	Apparent shortening of the wavelength, due to Doppler effect, of radiation received from a source in motion toward the observer.
Bowshock	The upstream (closest to the sun) boundary of a planet's magnetosphere, interfacing with the solar wind.
Brightness spectrum	Variation of radiation brightness with frequency.
Brightness	Also referred to as surface brightness. Power of radiation received per unit area per unit solid angle per unit frequency interval. Note that this is not the common usage of "brightness." What is commonly referred to as brightness is a characteristic of the source of the radiation (rather than the radiation received) and is what astronomers call <i>luminosity</i> .
Celestial equator	A great circle on the celestial sphere, concentric with Earth's equator.
Celestial latitude	In the ecliptic coordinate system, the angle of an object in the sky north or south ( $\pm 90^\circ$ ) of the ecliptic plane.
Celestial longitude	In the ecliptic coordinate system, the angle of an object in the sky eastward along the ecliptic from the vernal equinox (0-360°).
Celestial poles	Points about which the celestial sphere appears to rotate; intersections of the celestial sphere with Earth's axis.
Celestial sphere	Apparent sphere of the sky, whose diameter is the distance from Earth to the farthest observable object.
Cepheid	A type of regular variable star that has a short period of a few days to a few weeks. It has been found that in these stars, the longer the period, the more luminous the star.
Chromosphere	The part of the sun's atmosphere lying above the photosphere and below the outer corona.

Corona	The outer atmosphere of the sun. Visible to the naked eye only during a total solar eclipse.
Cyclotron radiation	Electromagnetic radiation emitted when charged particles are moved within a magnetic field at non-relativistic speeds (that is, not close to the speed of light).
Declination	Angular distance north or south of the equator of some object in the sky, measuring along an hour circle passing through that object.
Diffraction	Slight bending of electromagnetic waves as they pass by obstacles.
Discrete source	A sources of radiation whose direction can be identified. Discrete sources may be further classified as point sources, localized sources, and extended sources.
Doppler effect	Apparent change in wavelength of the radiation from a source due to its motion relative to the observer.
Ecliptic coordinate system	Coordinate system using the plane of the ecliptic as the reference.
Electromagnetic spectrum	The full range of wavelengths or frequencies of electromagnetic radiation.
Electromagnetic radiation	Radiation consisting of waves propagated through the building up and breaking down of electric and magnetic fields; include radio, infrared, light, ultraviolet, x-rays, and gamma rays.
Elevation	In the horizon coordinate system, the angle upward from the horizon to an object in the sky.
Emission lines	Discrete, bright lines in the spectrum.
Epoch	A date chosen for reference purposes in quoting astronomical coordinates, to account for the slight changes in the apparent positions of objects in the sky due to Earth's precession.
Equator	A great circle on Earth $90^\circ$ from its poles.
Equatorial coordinate system	A coordinate system using Earth's equator as the plane of reference.
Extended source	Discrete emitter of radiation that covers a relatively large part of the sky, for example, the Milky Way galaxy. The terms localized and extended are relative and depend on the angular resolution of the telescope observing them.
Faraday rotation	Rotation of an electromagnetic wave's polarization as it passes through a magnetic field parallel to the propagation of the wave in a medium.
Field	The effect of forces, such as gravity and magnetism, that act on distant objects.

Flare star	Faint red dwarf stars that may brighten up by several magnitudes over a few minutes, and fade back to their usual brightness within an hour.
FM	Frequency modulation. Imposing a signal on transmitted energy by varying the frequency of the wave.
Galactic coordinate system	A coordinate system using the plane of the Milky Way galaxy as the reference.
Gravitational lens	An effect produced by the bending of radiation as it passes within the gravitational field of another object. May appear to an observer on Earth as one or more duplicate images of the same source.
Horizon coordinate system	A coordinate system using a plane through the observing point parallel to the horizon as the reference.
Horizon mask	A diagram that maps in silhouette the horizon in $360^\circ$ as actually seen by the observer.
Hour angle	The elapsed time since an object in the sky crossed the meridian point of the observer.
Hour circle (object's)	A great circle on the celestial sphere that passes through both poles and the object being observed in the sky.
Index of refraction	Ratio of the speed of electromagnetic radiation in a vacuum to the speed of electromagnetic radiation in a given medium.
Intensity	Power of electromagnetic radiation received per unit area.
Interference	The additive combination of two electromagnetic waves of the same frequency and travelling in the same directive. If the waves are in phase, it is called constructive interference, with the resulting wave twice the amplitude of the original waves. If the waves are $180^\circ$
Interferometry	In radio astronomy, use of more than one radio telescope to enhance the resolution of the radio image from a source.
Inverse-square law	The amount of electromagnetic energy reaching a given point in a given unit of time decreases in proportion to the square of the distance from the source of the energy.
ISM	Interstellar medium.
Kelvin	A unit of absolute temperature. In the Kelvin temperature scale, 0 is absolute zero, the temperature where molecular motion ceases and the material has no kinetic energy. Water freezes at 273 K.
Light year	Distance light (electromagnetic energy) travels in a vacuum during one year, or $9.46 \times 10^{12}$ km.

Localized source	A discrete radiation source of very small extent. A single star is normally considered a localized source.
LY	Abbreviation for light year.
Magnetosphere	Region around a planet in which its magnetic field dominates the interplanetary field carried by the solar wind.
Maser (astronomical)	For Microwave-amplified Stimulated Emission of Radiation. An ultracompact site in molecular clouds (usually of water vapor, hydroxyl radicals, silicon monoxide, or methanol) in the interstellar medium or very near long-period variable stars, in which certain molecular emissions lines are enormously amplified.
Meridian	A great circle on the celestial sphere that passes through both poles and the zenith.
Nadir	The point on the celestial sphere immediately below the observer. Directly opposite the overhead point, or zenith.
Nanometer	One thousand-millionth of a meter, $10^{-9}$ m. Commonly used to measure wavelengths in the visible light and UV ranges.
Nebula	Cloud of interstellar gas or dust.
Neutron star	A star of extremely high density but low luminosity, composed almost entirely of neutrons.
Non-thermal emissions	Electromagnetic radiation produced by synchrotron radiation, maser line emissions from atoms and molecules, or other mechanisms not related to temperature.
Nutation (Earth's)	A slight, slow nodding of Earth's axis (about 9 arcsecs to either side of its mean position in about 18 years 220 days). This motion is apart from precession of the axis and is caused by the gravitational pull of the moon on Earth's equatorial bulge as the moon moves slightly above and slightly below the ecliptic in its orbit.
Object circle	In the horizon coordinate system, the vertical circle through a celestial object and the zenith.
Oblateness	The flattening of a sphere. Earth is oblate such that its diameter from pole to pole is 43 km less than its equatorial diameter.
Occultation	Passing of one celestial body in front of another as observed from Earth.
Optical astronomy	Study of the extraterrestrial universe using primarily visible light observations.
Optical window	The characteristic of Earth's atmosphere that allows visible light to pass through.
Parsec	The distance of an object at which 1 AU would subtend one arcsec; 1 parsec = 3.26 light years.

Perigee	The point in a body's orbit (the moon's, for example) around Earth when the orbiting body is closest to Earth.
Perihelion	The point in a body's orbit (Earth's, for example) around the sun when the orbiting body is closest to the sun.
Phase	Angular distance between peaks or troughs of two wave forms of similar frequency.
Photon astronomy	Study of the extraterrestrial universe using observations of the entire electromagnetic spectrum.
Photosphere	The region of the sun (or any star) from which continuous spectrum radiation escapes into space; the visible disk of the sun.
Plasma	A hot, ionized gas.
Point source	An idealized discrete source of radiation that subtends an infinitesimally small angle.
Polarization	The direction of the electric vector of an electromagnetic wave. Polarization may be linear, circular, random, elliptical, or any combination.
Precession (Earth's)	A slow, conical motion of Earth's axis of rotation, similar to the wobble of a spinning top.
Prime vertical	In the horizon coordinate system, the great circle through the east and west points and the zenith.
Pulsar	A neutron star radio source that emits in rapid, regular pulses.
Quasar	A very distant, very luminous source of visible and radio energy. May be the oldest and most distant objects in the universe.
Radio astronomy	Study of the extraterrestrial universe using observations of radio frequency radiation, rather than visible light.
Radio galaxy	Galaxy that is a strong emitter of radio energy, perhaps emitting $10^5$ - $10^6$ times more radio energy than a "normal" galaxy.
Radio star	A star that is a strong emitter of radio frequency radiation.
Radio window	The property of Earth's atmosphere that allows certain wavelengths of electromagnetic radiation in the radio range to pass through.
Recombination lines	Emission and absorption lines seen when oppositely charged ions recombine to an electrically neutral state, producing a highly excited neutral atom, with electrons transitioning between states, emitting and absorbing photons.
Red shift	Apparent lengthening of the wavelength of radiation received from a source. May be caused by Doppler effect, the expansion of space, or gravitational effects of very massive objects.
Right ascension	In the equatorial coordinate system, the angle (usually in hours, minutes, seconds) measured eastward along the celestial equator

	from the vernal equinox to the hour circle passing through an object in the sky.
$R_j$	Abbreviation for one Jupiter radius (about 5 million km). Used to describe distances in the Jupiter system.
RR Lyrae variable	Regular variable stars whose periods are very short (between about 1.25 and 30 hours).
S-band	Range of radio frequencies of about 2-4 GHz, or wavelengths of 15 - 7.5 cm.
Scintillation	Effect produced by phase shifting of electromagnetic waves from a discrete source as they pass through Earth's atmosphere. In the visible light range, perceived as twinkling of stars.
SETI	Search for extraterrestrial intelligence. Using radio telescopes, astronomers "listen" for artificially modulated radio frequency signals from parts of the universe most "likely" to spawn life as we know it.
Sidereal day	The time required for Earth to revolve $360^\circ$ with respect to a celestial object outside the solar system. About 23 hours 56 minutes duration in terms of solar time.
Solar day	The time required for Earth to revolve $360^\circ$ with respect to the sun.
Solar flare	Brilliant outbreak in the sun's outer atmosphere, usually associated with active groups of sunspots.
Spectral power	Power of electromagnetic radiation per unit of frequency bandwidth.
Stellar wind	The outflow of gas from a star, sometimes at speeds as high as hundreds of kilometers per second.
Sunspot	A temporary cool region in the solar photosphere that appears dark by contrast against the surrounding hotter photosphere.
Superluminal velocity	Apparent motion of an object at greater than light speed; apparency is caused by a projection effect due to the motion's vector component toward Earth.
Supernova	A star that experiences a cataclysmic explosion, sending much of its material into space.
Superposition	The ability of electromagnetic (and other types of) waves to traverse the same space independently of each other.
Surface brightness	See <i>brightness</i> .
Synchrotron radiation	Radiation emitted by charged particles being accelerated in magnetic fields and moving at near the speed of light.
Thermal emissions	Radiation emitted due to an object's temperature (for example, blackbody radiation) or by an ionized gas.

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Vernal equinox

The point on the celestial sphere where the sun crosses the celestial equator from south to north. The date of this crossing (about March 21) is also called the vernal equinox.

X-band

Range of radio frequencies of about 8-12 GHz, or wavelengths of 3.75 - 2.4 cm.

Zenith

The point on the celestial sphere directly overhead the observer.

## Appendix B

### References and Further Reading

#### Books:

- \*California Department of Education, 1990. *Science Framework for California Public Schools, Kindergarten Through Grade Twelve*.
- Chen, F.F., 1984. *Introduction to Plasma Physics and Controlled Fusion: Volume 1: Plasma Physics (Second Edition)*. Plenum Press, New York.
- \*Doody, D.F., and G.R. Stephan, 1995. *Basics of Space Flight Learner's Workbook*. Jet Propulsion Laboratory, JPL D-9774.
- Eisberg, R., and R. Resnick, 1985. *Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles*. Second edition. John Wiley & Sons, New York.
- \*Ferris, T., 1987. *Galaxies*. Harrison House, New York.
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- Harrison, E.R., 1981. *Cosmology: The Science of the Universe*. Cambridge University Press.
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- Kraus, J.D., 1986. *Radio Astronomy, 2nd edition*. Cygnus-Quasar Books, Powell, OH.
- \*Moore, P., 1988. *The New Atlas of the Universe*. Arch Cape Press, New York. (A bit dated, but very readable and beautifully illustrated "coffee table" book.)
- \*Morrison, D., S. Wolff, and A. Fraknoi, 1995. *Abell's Exploration of the Universe*. Seventh Edition. Saunders College Publishing, division of Holt, Rinehart and Winston, Inc.
- Shields, J.P., 1986. *The Amateur Radio Astronomer's Handbook*. Crown Publishers, Inc., New York.
- Verschuur, G.L., and K.I. Kellermann (Eds.), 1988. *Galactic and Extragalactic Radio Astronomy, 2nd Edition*. Springer-Verlag, New York.
- Weidner, R.T., and R.L. Sells, 1973. *Elementary Modern Physics (alternate second edition)*. Allyn and Bacon, Inc., Boston.
- \*Wynn-Williams, G., 1992. *The Fullness of Space*. Cambridge University Press.

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\* Recommended reading (i.e., technical level approximately the same as this workbook).

## **World-Wide Web Pages:**

National Radio Astronomy Observatory Home Page, <http://www.nrao.edu>.

Water Masers in the Direction of the Galactic Center,

<http://www.cv.nrao.edu/~eschulma/h2o.html>.

What is the VLA?

<http://www.nrao.edu/doc/vla/html.VLAintro.shtml>

JPL Molecular Spectroscopy Home Page,

<http://spec.jpl.nasa.gov>

JPL Deep space Network Home Page,

<http://deepspace.jpl.nasa.gov/dsn>

Basics of Space Flight Learner's Workbook,

<http://www.jpl.nasa.gov/basics>

SETI (Search for Extraterrestrial Intelligence) Institute Home Page,

<http://www.seti-inst.edu>

Multiwavelength Atlas of Galaxies,

[http://hea-www.harvard.edu/~mackie/atlas/atlas\\_edu.html](http://hea-www.harvard.edu/~mackie/atlas/atlas_edu.html)

Spectroscopy,

<http://www-wilson.ucsd.edu/education/spectroscopy/spectroscopy.html>

An Introduction to Astrophysical Masers,

<http://spacsun.rice.edu/~parviz/masers.html>.

University of Bradford. From CD ROM "Earth and Universe," BTL Publishing Ltd., 1993,

<http://WWW.eia.brad.ac.uk/btl/>

## **Video:**

*Powers of Ten*. Copy available at AVSTC.

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