ΔT: the difference between **Terrestrial Time (TT)** and **Universal Time (UT)**: $\Delta T = \mathrm{TT} - \mathrm{UT1}$.

ΔUT1 (or ΔUT): the value of the difference between **Universal Time (UT)** and **Coordinated Universal Time (UTC)**: $\Delta\mathrm{UT1} = \mathrm{UT1} - \mathrm{UTC}$.

aberration (of light): the apparent shift in the position of a body from its geometric position, caused by the finite velocity of light in combination with the motion of the observer with respect to the body.

aberration, annual: the component of stellar **aberration** resulting from the motion of the Earth about the Sun. (See **aberration, stellar**.)

aberration, diurnal: the component of stellar **aberration** resulting from the observer's diurnal motion about the center of the Earth due to Earth's rotation. (See **aberration, stellar**.)

aberration, E-terms of: terms of the annual **aberration** that depend on the **eccentricity** and longitude of **perihelion** of the Earth. (See **perihelion**; **aberration, annual**.)

aberration, elliptic: see **aberration, E-terms of**.

aberration, planetary: the total angular displacement of the observed position of a solar system body from its instantaneous geometric direction as would be seen by an observer at the geocenter. This displacement is produced by the combination of **aberration of light** and **light-time displacement**.

aberration, secular: the component of stellar aberration resulting from the essentially uniform and almost rectilinear motion of the entire solar system in space. Secular aberration is usually disregarded. (See **aberration, stellar**.)

aberration, stellar: the apparent angular displacement of the observed position of a celestial body resulting from the motion of the observer. Stellar aberration is divided into the diurnal, annual, and secular components. (See **aberration, diurnal**; **aberration, annual**; **aberration, secular**.)

altitude: the angular distance of a celestial body above or below the **horizon**, measured along the great circle passing through the body and the **zenith**. Altitude is 90° minus the **zenith distance**.

anomaly: angular separation of a body in its orbit from its **pericenter**.

anomaly, eccentric: in undisturbed elliptic motion, the angle measured at the center of the **orbit** ellipse from **pericenter** to the point on the circumscribing auxiliary circle from which a perpendicular to the major axis would intersect the orbiting body. (See **anomaly, mean**; **anomaly, true**.

anomaly, mean: the product of the **mean motion** of an orbiting body and the interval of time since the body passed the **pericenter**. Thus, the mean anomaly is the angle from the pericenter of a hypothetical body moving with a constant angular speed that is equal to the mean motion. In realistic computations, with disturbances taken into account, the mean anomaly is equal to its initial value at an **epoch** plus an integral of the mean motion over the time elapsed since the epoch. (See **anomaly, true**; **anomaly, eccentric**; **mean anomaly at epoch**.)

anomaly, mean at epoch: the value of the **mean anomaly** at a specific **epoch**, i.e., at some fiducial moment of time. It is one of the six **Keplerian elements** that specify an **orbit**. (See **Keplerian elements**; **orbital elements**; **instantaneous orbit**.)

anomaly, true: the angle, measured at the focus nearest the **pericenter** of an elliptical **orbit**, between the pericenter and the radius vector from the focus to the orbiting body; one of the standard orbital elements. (See **orbital elements**; **anomaly, eccentric**; **anomaly, mean**.)

aphelion: the most distant point from the Sun in a **heliocentric orbit**.

apogee: the point at which a body in **orbit** around the Earth reaches its farthest distance from the Earth. Apogee is sometimes used in reference to the apparent orbit of the Sun around the Earth.

apparent place: coordinates of a celestial object, referred to the **true equator and equinox** at a specific date, obtained by removing from the directly observed position of the object the effects that depend on the **topocentric** location of the observer, i.e., **refraction**, diurnal **aberration**, and geocentric (diurnal) **parallax**. Thus, the position at which the object would actually be seen from the center of the Earth — if the Earth were transparent, non-refracting, and massless — referred to the **true equator and equinox**. (See **aberration, diurnal**.)

apparent solar time: the measure of time based on the diurnal motion of the true Sun. The rate of diurnal motion undergoes seasonal variation caused by the **obliquity** of the **ecliptic** and by the **eccentricity** of the Earth's **orbit**. Additional small variations result from irregularities in the rotation of the Earth on its axis.

Aries, First point of: another name for the **vernal equinox**.

aspect: the position of any of the planets or the Moon relative to the Sun, as seen from the Earth.

astrometric ephemeris: an **ephemeris** of a solar system body in which the tabulated positions are **astrometric places**. Values in an astrometric ephemeris are essentially comparable to catalog **mean places** of stars after the star positions have been updated for **proper motion** and **parallax**.

astrometric place: direction of a solar system body formed by applying the correction for **light-time displacement** to the **geometric position**. Such a position is directly comparable with the astrometric positions of stars after the star positions have been updated for **proper motion** and **parallax**.

astronomical coordinates: the longitude and latitude of the point on Earth relative to the **geoid**. These coordinates are influenced by local gravity anomalies. (See **zenith**; **longitude, terrestrial**; **latitude, terrestrial**.)

astronomical unit (AU): the radius of a circular **orbit** in which a body of negligible mass, and free of **perturbations**, would revolve around the Sun in $2\pi/k$ days, k being the **Gaussian gravitational constant**. This is slightly less than the mean **semimajor axis** of the Earth's orbit.

astronomical zenith: see **zenith, astronomical**.

atomic second: see **second, Système International**.

augmentation: the amount by which the apparent **semidiameter** of a celestial body, as observed from the surface of the Earth, is greater than the semidiameter that would be observed from the center of the Earth.

azimuth: the angular distance measured eastward along the **horizon** from a specified reference point (usually north). Azimuth is measured to the point where the great circle determining the **altitude** of an object meets the horizon.

barycenter: the center of mass of a system of bodies; e.g., the center of mass of the solar system, or that of the Earth-Moon system.

barycentric: with reference to, or pertaining to, the **barycenter** (usually of the solar system).

Barycentric Celestial Reference System (BCRS): a system of **barycentric** space-time coordinates for the solar system within the framework of General Relativity. The metric tensor to be used in the system is specified by the IAU 2000 resolution B1.3. For all practical applications, unless otherwise stated, the BCRS is assumed to be oriented according to the ICRS axes. (See **Barycentric Coordinate Time (TCB)**.)

Barycentric Coordinate Time (TCB): the coordinate time of the **Barycentric Celestial Reference System (BCRS)**, which advances by SI seconds within that system. TCB is related to **Geocentric Coordinate Time (TCG)** and **Terrestrial Time (TT)** by relativistic transformations that include a secular term. (See **second, Système International**.)

Barycentric Dynamical Time (TDB): A time scale defined by an IAU 1976 resolution for use as an independent argument of **barycentric** ephemerides and equations of motion.

TDB was defined to have only periodic variations with respect to what is now called **Terrestrial Time (TT)**. (The definition is problematic in practice.) In the **Barycentric Celestial Reference System (BCRS)**, TDB does not advance by SI seconds but has a secular drift with respect to **Barycentric Coordinate Time (TCB)**. TDB seconds are fractionally longer than TCB seconds by a factor of about 1.55×10^{-8}. (See **second, Système International**.)

calendar: a system of reckoning time in units of solar days. The days are enumerated according to their position in cyclic patterns usually involving the motions of the Sun and/or the Moon.

catalog equinox: see **equinox, catalog**.

Celestial Ephemeris Origin (CEO): the original name for the **Celestial Intermediate Origin (CIO)** given in the IAU 2000 resolutions. Obsolete.

celestial equator: the plane perpendicular to the **Celestial Intermediate Pole (CIP)**. Colloquially, the projection onto the **celestial sphere** of the Earth's **equator**. (See **mean equator and equinox**; **true equator and equinox**.)

Celestial Intermediate Origin (CIO): the non-rotating origin of the **Celestial Intermediate Reference System**. Formerly referred to as the **Celestial Ephemeris Origin (CEO)**.

Celestial Intermediate Origin Locator (CIO Locator): denoted by s, is the difference between the **Geocentric Celestial Reference System (GCRS) right ascension** and the intermediate right ascension of the intersection of the GCRS and intermediate equators.

Celestial Intermediate Pole (CIP): the reference pole of the IAU 2000A precession–nutation model. The motions of the CIP are those of the Tisserand mean axis of the Earth with periods greater than two days. (See **precession**; **nutation**.)

Celestial Intermediate Reference System: a geocentric reference system related to the **Geocentric Celestial Reference System (GCRS)** by a time-dependent rotation taking into account **precession-nutation**. It is defined by the intermediate **equator** of the **Celestial Intermediate Pole (CIP)** and the **Celestial Intermediate Origin (CIO)** on a specific date.

celestial pole: see **pole, celestial**.

celestial sphere: an imaginary sphere of arbitrary radius upon which celestial bodies may be considered to be located. As circumstances require, the celestial sphere may be centered at the observer, at the Earth's center, or at any other location.

center of figure: that point so situated relative to the apparent figure of a body that any line drawn through it divides the figure into two parts having equal apparent areas. If the body is oddly shaped, the center of figure may lie outside the figure itself.

center of light: same as **center of figure** except referring only to the illuminated portion.

conjunction: the phenomenon in which two bodies have the same apparent **ecliptic longitude** or **right ascension** as viewed from a third body. Conjunctions are usually tabulated as **geocentric** phenomena. For Mercury and Venus, geocentric inferior conjunctions occur when the planet is between the Earth and Sun, and superior conjunctions occur when the Sun is between the planet and the Earth. (See **longitude, ecliptic**.)

constellation: 1. A grouping of stars, usually with pictorial or mythical associations, that serves to identify an area of the **celestial sphere**. **2.** One of the precisely defined areas of the celestial sphere, associated with a grouping of stars, that the **International Astronomical Union (IAU)** has designated as a constellation.

Coordinated Universal Time (UTC): the time scale available from broadcast time signals. UTC differs from **International Atomic Time (TAI)** by an integral number of seconds; it is maintained to within $\pm 0^{s}.9$ of **UT1** by the introduction of **leap seconds**. (See **International Atomic Time (TAI)**; **Universal Time**; **leap second**.)

culmination: the passage of a celestial object across the observer's **meridian**; also called "meridian passage."

culmination, lower: (also called "culmination below pole" for circumpolar stars and

the Moon) is the crossing farther from the observer's **zenith**.

culmination, upper: (also called "culmination above pole" for circumpolar stars and the Moon) or **transit** is the crossing closer to the observer's **zenith**.

day: an interval of 86 400 SI seconds, unless otherwise indicated. (See **second, Système International**.)

declination: angular distance on the **celestial sphere** north or south of the **celestial equator**. It is measured along the **hour circle** passing through the celestial object. Declination is usually given in combination with **right ascension** or **hour angle**.

defect of illumination: the angular amount of the observed lunar or planetary disk that is not illuminated to an observer on the Earth.

deflection of light: the angle by which the direction of a light ray is altered from a straight line by the gravitational field of the Sun or other massive object. As seen from the Earth, objects appear to be deflected radially away from the Sun by up to $1''.75$ at the Sun's limb. Correction for this effect, which is independent of wavelength, is included in the transformation from **mean place** to **apparent place**.

deflection of the vertical: the angle between the astronomical vertical and the geodetic vertical. (See **zenith**; **astronomical coordinates**; **geodetic coordinates**.)

delta *T*: see ΔT.

delta UT1: see Δ**UT1**.

direct motion: for orbital motion in the solar system, motion that is counterclockwise in the **orbit** as seen from the north pole of the **ecliptic**; for an object observed on the **celestial sphere**, motion that is from west to east, resulting from the relative motion of the object and the Earth.

diurnal motion: the apparent daily motion, caused by the Earth's rotation, of celestial bodies across the sky from east to west.

dynamical equinox: the ascending **node** of the Earth's mean **orbit** on the Earth's true **equator**; i.e., the intersection of the **ecliptic** with the **celestial equator** at which the Sun's **declination** changes from south to north. (See **catalog equinox**; **equinox**; **true equator and equinox**.)

dynamical time: the family of time scales introduced in 1984 to replace **ephemeris time (ET)** as the independent argument of dynamical theories and ephemerides. (See **Barycentric Dynamical Time (TDB)**; **Terrestrial Time (TT)**.)

Earth Rotation Angle (ERA): the angle, θ, measured along the **equator** of the **Celestial Intermediate Pole (CIP)** between the direction of the **Celestial Intermediate Origin (CIO)** and the **Terrestrial Intermediate Origin (TIO)**. It is a linear function of **UT1**; its time derivative is the Earth's angular velocity.

eccentricity: 1. A parameter that specifies the shape of a conic section. **2.** One of the standard elements used to describe an elliptic or hyperbolic **orbit**. For an elliptical orbit, the quantity $e = \sqrt{1 - (b^2/a^2)}$, where a and b are the lengths of the semimajor and semiminor axes, respectively. (See **orbital elements**.)

eclipse: the obscuration of a celestial body caused by its passage through the shadow cast by another body.

eclipse, annular: a solar **eclipse** in which the solar disk is not completely covered but is seen as an annulus or ring at maximum eclipse. An annular eclipse occurs when the apparent disk of the Moon is smaller than that of the Sun. (See **eclipse, solar**.)

eclipse, lunar: an **eclipse** in which the Moon passes through the shadow cast by the Earth. The eclipse may be total (the Moon passing completely through the Earth's **umbra**), partial (the Moon passing partially through the Earth's umbra at maximum eclipse), or penumbral (the Moon passing only through the Earth's **penumbra**).

eclipse, solar: an **eclipse** in which the Earth passes through the shadow cast by the Moon. It may be total (observer in the Moon's **umbra**), partial (observer in the Moon's **penumbra**), annular, or annular-total. (See **eclipse, annular**.)

ecliptic: the mean plane of the Earth's **orbit** around the Sun.

ecliptic longitude: see **longitude, ecliptic**.

elements, Besselian: quantities tabulated for the calculation of accurate predictions of an **eclipse** or **occultation** for any point on or above the surface of the Earth.

elements, Keplerian: see **Keplerian elements**.

elements, mean: see **mean elements**.

elements, orbital: see **orbital elements**.

elements, osculating: see **osculating elements**.

elongation, greatest: the instant when the **geocentric** angular distance of Mercury or Venus from the Sun is at a maximum.

elongation, planetary: the **geocentric** angle between a planet and the Sun. Planetary elongations are measured from $0°$ to $180°$, east or west of the Sun.

elongation, satellite: the **geocentric** angle between a satellite and its primary. Satellite elongations are measured from $0°$ east or west of the planet.

epact: 1. The age of the Moon. **2.** The number of days since new moon, diminished by one day, on January 1 in the Gregorian ecclesiastical lunar cycle. (See **Gregorian calendar**; **lunar phases**.)

ephemeris: a tabulation of the positions of a celestial object in an orderly sequence for a number of dates.

ephemeris hour angle: an **hour angle** referred to the **ephemeris meridian**.

ephemeris longitude: longitude measured eastward from the **ephemeris meridian**. (See **longitude, terrestrial**.)

ephemeris meridian: a fictitious **meridian** that rotates independently of the Earth at the uniform rate implicitly defined by **Terrestrial Time (TT)**. The ephemeris meridian is $1.002\,738\,\Delta T$ east of the Greenwich meridian, where $\Delta T = \mathrm{TT} - \mathrm{UT1}$.

ephemeris time (ET): the time scale used prior to 1984 as the independent variable in gravitational theories of the solar system. In 1984, ET was replaced by **dynamical time**.

ephemeris transit: the passage of a celestial body or point across the **ephemeris meridian**.

epoch: an arbitrary fixed instant of time or date used as a chronological reference datum for calendars, celestial reference systems, star catalogs, or orbital motions. (See **calendar**; **orbit**).

equation of the equinoxes: the difference apparent sidereal time minus mean sidereal time, due to the effect of **nutation** in longitude on the location of the **equinox**. Equivalently, the difference between the right ascensions of the true and mean equinoxes, expressed in time units. (See **sidereal time**).

equation of the origins: the arc length, measured positively eastward, from the **Celestial Intermediate Origin (CIO)** to the **equinox** along the intermediate **equator**; alternatively the difference between the **Earth Rotation Angle (ERA)** and **Greenwich Apparent Sidereal Time** (ERA − GAST).

equation of time: the difference **apparent solar time** minus **mean solar time**.

equator: the great circle on the surface of a body formed by the intersection of the surface with the plane passing through the center of the body perpendicular to the axis of rotation. (See **celestial equator**.)

equinox: 1. Either of the two points on the **celestial sphere** at which the **ecliptic** intersects the **celestial equator**. **2.** The time at which the Sun passes through either of these intersection points; i.e., when the apparent **ecliptic longitude** of the Sun is $0°$ or $180°$. **3.** The **vernal equinox**. (See **mean equator and equinox**; **true equator and equinox**.)

equinox, autumnal: 1. The descending **node** of the **ecliptic** on the **celestial sphere**. **2.** The time at which the apparent **ecliptic longitude** of the Sun is $180°$.

equinox, catalog: the intersection of the **hour angle** of zero **right ascension** of a star catalog with the **celestial equator**. Obsolete.

equinox, dynamical: the ascending **node** of the **ecliptic** on the Earth's **true equator**.

equinox, vernal: 1. The ascending **node** of the **ecliptic** on the **celestial equator**. **2.** The time at which the apparent **ecliptic longitude** of the Sun is 0°.

ERA: see **Earth Rotation Angle**.

era: a system of chronological notation reckoned from a specific event.

flattening: a parameter that specifies the degree by which a planet's figure differs from that of a sphere; the ratio $f = (a - b)/a$, where a is the equatorial radius and b is the polar radius.

frame bias: the orientation of the **mean equator and equinox** of J2000.0 with respect to the **Geocentric Celestial Reference System (GCRS)**. It is defined by three small and constant angles, two of which describe the offset of the mean pole at J2000.0 and the other is the GCRS **right ascension** of the mean inertial equinox of J2000.0.

frequency: the number of periods of a regular, cyclic phenomenon in a given measure of time, such as a **second** or a **year** (see **period**; **second**; **year**).

frequency standard: a generator whose output is used as a precise frequency reference; a primary frequency standard is one whose frequency corresponds to the adopted definition of the second, with its specified accuracy achieved without calibration of the device. (See **second, Système International**.)

GAST: see **Greenwich Apparent Sidereal Time**.

Gaussian gravitational constant: $(k = 0.017\ 202\ 098\ 95)$: the constant defining the astronomical system of units of length (**astronomical unit**), mass (solar mass) and time (day), by means of Kepler's third law. The dimensions of k^2 are equal to those of Newton's constant of gravitation: $L^3M^{-1}T^{-2}$.

geocentric: with reference to, or pertaining to, the center of the Earth.

Geocentric Celestial Reference System (GCRS): a system of **geocentric** space-time coordinates within the framework of General Relativity. The metric tensor used in the system is specified by the IAU 2000 resolutions. The GCRS is defined such that its spatial coordinates are kinematically non-rotating with respect to those of the **Barycentric Celestial Reference System (BCRS)**. (See **Geocentric Coordinate Time (TCG)**.)

geocentric coordinates: 1. The latitude and longitude of a point on the Earth's surface relative to the center of the Earth. **2.** Celestial coordinates given with respect to the center of the Earth. (See **zenith**; **latitude, terrestrial**; **longitude, terrestrial**.)

Geocentric Coordinate Time (TCG): the coordinate time of the **Geocentric Celestial Reference System (GCRS)**, which advances by SI seconds within that system. TCG is related to **Barycentric Coordinate Time (TCB)** and **Terrestrial Time (TT)**, by relativistic transformations that include a secular term. (See **second, Système International**).

geocentric zenith: see **zenith, geocentric**.

geodetic coordinates: the latitude and longitude of a point on the Earth's surface determined from the geodetic vertical (normal to the reference ellipsoid). (See **zenith**; **latitude, terrestrial**; **longitude, terrestrial**.)

geodetic zenith: see **zenith, geodetic**.

geoid: an equipotential surface that coincides with mean sea level in the open ocean. On land it is the level surface that would be assumed by water in an imaginary network of frictionless channels connected to the ocean.

geometric position: the position of an object defined by a straight line (vector) between the center of the Earth (or the observer) and the object at a given time, without any corrections for **light-time**, **aberration**, etc.

GMST: see **Greenwich Mean Sidereal Time**.

Greenwich Apparent Sidereal Time (GAST): the Greenwich **hour angle** of the true **equinox** of date.

Greenwich Mean Sidereal Time (GMST): the Greenwich **hour angle** of the mean **equinox** of date.

Greenwich sidereal date (GSD): the number of **sidereal days** elapsed at Greenwich since the beginning of the Greenwich sidereal day that was in progress at the **Julian date (JD)** 0.0.

Greenwich sidereal day number: the integral part of the **Greenwich sidereal date (GSD)**.

Gregorian calendar: The calendar introduced by Pope Gregory XIII in 1582 to replace the **Julian calendar**. This calendar is now used as the civil calendar in most countries. In the Gregorian calendar, every year that is exactly divisible by four is a leap year, except for centurial years, which must be exactly divisible by 400 to be leap years. Thus, 2000 is a leap year, but 1900 and 2100 are not leap years.

height: the distance above or below a reference surface such as mean sea level on the Earth or a **planetographic** reference surface on another solar system planet.

heliocentric: with reference to, or pertaining to, the center of the Sun.

horizon: 1. A plane perpendicular to the line from an observer through the **zenith**. **2.** The observed border between Earth and the sky.

horizon, astronomical: the plane perpendicular to the line from an observer to the **astronomical zenith** that passes through the point of observation.

horizon, geocentric: the plane perpendicular to the line from an observer to the **geocentric zenith** that passes through the center of the Earth.

horizon, natural: the border between the sky and the Earth as seen from an observation point.

horizontal parallax: the difference between the **topocentric** and **geocentric** positions of an object, when the object is on the astronomical **horizon**.

hour angle: angular distance on the **celestial sphere** measured westward along the **celestial equator** from the **meridian** to the **hour circle** that passes through a celestial object.

hour circle: a great circle on the **celestial sphere** that passes through the **celestial poles** and is therefore perpendicular to the **celestial equator**.

IAU: see **International Astronomical Union (IAU)**.

illuminated extent: the illuminated area of an apparent planetary disk, expressed as a solid angle.

inclination: 1. The angle between two planes or their poles. **2.** Usually, the angle between an orbital plane and a reference plane. **3.** One of the standard orbital elements that specifies the orientation of the **orbit**. (See **orbital elements**.)

instantaneous orbit: the unperturbed two-body **orbit** that a body would follow if **perturbations** were to cease instantaneously. Each orbit in the solar system (and, more generally, in the many-body setting) can be represented as a sequence of instantaneous ellipses or hyperbolae whose parameters are called **orbital elements**. If these elements are chosen to be osculating, each instantaneous orbit is tangential to the physical orbit. (See **orbital elements**; **osculating elements**.)

International Astronomical Union (IAU): an international non-governmental organization that promotes the science of astronomy in all its aspects. The IAU is composed of both national and individual members. In the field of positional astronomy, the IAU, among other activities, recommends standards for data analysis and modeling, usually in the form of resolutions passed at General Assemblies held every three years.

International Atomic Time (TAI): the continuous time scale resulting from analysis by the Bureau International des Poids et Mesures of atomic time standards in many countries. The fundamental unit of TAI is the SI second on the **geoid**, and the **epoch** is 1958 January 1. (See **second, Système International**.)

International Celestial Reference Frame (ICRF): 1. A set of extragalactic objects whose adopted positions and uncertainties realize the **International Celestial Reference System (ICRS)** axes and give the uncertainties of those axes. **2.** The name of the radio catalog whose 212 defining sources serve as fiducial points to fix the axes of the ICRS, recommended by the **International Astronomical Union (IAU)** in 1997.

International Celestial Reference System (ICRS): a time-independent, kinematically non-rotating barycentric reference system recommended by the **International Astronomical Union (IAU)** in 1997. Its axes are those of the **International Celestial Reference Frame (ICRF)**.

International Terrestrial Reference Frame (ITRF): a set of reference points on the surface of the Earth whose adopted positions and velocities fix the (rotating) axes of the **International Terrestrial Reference System (ITRS)**.

International Terrestrial Reference System (ITRS): a time-dependent, non-inertial reference system co-moving with the geocenter and rotating with the Earth. The ITRS is the recommended system in which to express positions on the Earth.

invariable plane: the plane through the center of mass of the solar system perpendicular to the angular momentum vector of the solar system.

irradiation: an optical effect of contrast that makes bright objects viewed against a dark background appear to be larger than they really are.

Julian calendar: the **calendar** introduced by Julius Caesar in 46 B.C. to replace the Roman calendar. In the Julian calendar a common **year** is defined to comprise 365 days, and every fourth year is a leap year comprising 366 days. The Julian calendar was superseded by the **Gregorian calendar**.

Julian century: a period of 100 **Julian years**, 36525 days. In precise work the timescale should be specified.

Julian date (JD): the interval of time, in days and fractions of a **day**, since 4713 B.C. January 1, Greenwich noon, **Julian proleptic calendar**. In precise work, the time scale, e.g., **Terrestrial Time (TT)** or **Universal Time (UT)**, should be specified.

Julian date, modified (MJD): the **Julian date (JD)** minus 2400000.5.

Julian day number: the integral part of the **Julian date (JD)**.

Julian proleptic calendar: the calendric system employing the rules of the **Julian calendar**, but extended and applied to dates preceding its introduction.

Julian year: a period of 365.25 days. It served as the basis for the **Julian calendar**.

Keplerian Elements: a certain set of six **orbital elements**, sometimes referred to as the Keplerian set. Historically, this set included the **mean anomaly at epoch**, the **semimajor axis**, the **eccentricity** and three Euler angles: the **longitude of the ascending node**, the **inclination**, and the **argument of the pericenter**. The time of **pericenter** passage is often used as a part of the Keplerian set instead of the mean anomaly at epoch. Sometimes the longitude of pericenter (which is the sum of the longitude of the ascending node and the argument of the pericenter) is used instead of either the longitude of the ascending node or the argument of the pericenter.

Laplacian plane: 1. For planets see **invariable plane**. **2.** For a system of satellites, the fixed plane relative to which the vector sum of the disturbing forces has no orthogonal component.

latitude, celestial: see **latitude, ecliptic**.

latitude, ecliptic: angular distance on the **celestial sphere** measured north or south of the **ecliptic** along the great circle passing through the poles of the ecliptic and the celestial object. Also referred to as **celestial latitude**.

latitude, terrestrial: angular distance on the Earth measured north or south of the **equator** along the **meridian** of a geographic location.

leap second: a second inserted as the 61^{st} second of a minute at announced times to keep **UTC** within $0^s.9$ of **UT1**. Generally, leap seconds are added at the end of June or December. (See **second, Système International**; **Universal Time (UT)**; **Coordinated Universal Time (UTC)**.)

librations: variations in the orientation of the Moon's surface with respect to an observer on the Earth. Physical librations are due to variations in the orientation of the Moon's rotational axis in inertial space. The much larger optical librations are due to variations in

the rate of the Moon's orbital motion, the **obliquity** of the Moon's **equator** to its orbital plane, and the diurnal changes of geometric perspective of an observer on the Earth's surface.

light, deflection of: see **deflection of light**.

light-time: the interval of time required for light to travel from a celestial body to the Earth.

light-time displacement: the difference between the geometric and astrometric place of a solar system body. It is caused by the motion of the body during the interval it takes light to travel from the body to Earth.

light-year: the distance that light traverses in a vacuum during one **year**.

limb: the apparent edge of the Sun, Moon, or a planet or any other celestial body with a detectable disk.

limb correction: correction that must be made to the distance between the center of mass of the Moon and its **limb**. These corrections are due to the irregular surface of the Moon and are a function of the **librations** in longitude and latitude and the position angle from the central **meridian**.

local sidereal time: the local **hour angle** of a **catalog equinox**.

longitude, celestial: see **longitude, ecliptic**.

longitude, ecliptic: angular distance on the **celestial sphere** measured eastward along the **ecliptic** from the **dynamical equinox** to the great circle passing through the poles of the ecliptic and the celestial object. Also referred to as **celestial longitude**.

longitude, terrestrial: angular distance measured along the Earth's **equator** from the Greenwich **meridian** to the meridian of a geographic location.

longitude of the ascending node: given an **orbit** and a reference plane through the primary body (or center of mass): the angle, Ω, at the primary, between a fiducial direction in the reference plane and the point at which the orbit crosses the reference plane from south to north. Equivalently, Ω is one of the angles in the reference plane between the fiducial direction and the line of nodes. It is one of the six **Keplerian elements** that specify an orbit. For planetary orbits, the primary is the Sun, the reference plane is usually the **ecliptic**, and the fiducial direction is usually toward the **equinox**. (See **node**; **orbital elements**; **instantaneous orbit**.)

luminosity class: distinctions in intrinsic brightness among stars of the same spectral class. (See **spectral types or classes**.)

lunar phases: cyclically recurring apparent forms of the Moon. New moon, first quarter, full moon and last quarter are defined as the times at which the excess of the apparent **ecliptic longitude** of the Moon over that of the Sun is $0°$, $90°$, $180°$ and $270°$, respectively. (See **longitude, ecliptic**.)

lunation: the period of time between two consecutive new moons.

magnitude, stellar: a measure on a logarithmic scale of the brightness of a celestial object considered as a point source.

magnitude of a lunar eclipse: the fraction of the lunar diameter obscured by the shadow of the Earth at the greatest phase of a lunar **eclipse**, measured along the common diameter. (See **eclipse, lunar**.)

magnitude of a solar eclipse: the fraction of the solar diameter obscured by the Moon at the greatest phase of a solar **eclipse**, measured along the common diameter. (See **eclipse, solar**.)

mean distance: an average distance between the primary and the secondary gravitating body. The meaning of the mean distance depends upon the chosen method of averaging (i.e., averaging over the time, or over the **true anomaly**, or the **mean anomaly**. It is also important what power of the distance is subject to averaging.) In this volume the mean distance is defined as the inverse of the time-averaged reciprocal distance: $(\int r^{-1} dt)^{-1}$. In the two-body setting, when the disturbances are neglected and the orbit is elliptic, this

formula yields the **semimajor axis**, a, which plays the role of mean distance.

mean elements: average values of the **orbital elements** over some section of the **orbit** or over some interval of time. They are interpreted as the elements of some reference (mean) orbit that approximates the actual one and, thus, may serve as the basis for calculating orbit **perturbations**. The values of mean elements depend upon the chosen method of averaging and upon the length of time over which the averaging is made.

mean equator and equinox: the celestial reference system defined by the orientation of the Earth's equatorial plane on some specified date together with the direction of the **dynamical equinox** on that date, neglecting **nutation**. Thus, the mean equator and equinox are affected only by **precession**. Positions in a star catalog have traditionally been referred to a catalog equator and equinox that approximate the mean equator and equinox of a **standard epoch**. (See **catalog equinox**; **true equator and equinox**.)

mean motion: in undisturbed elliptic motion, the constant angular speed required for a body to complete one revolution in an **orbit** of a specified **semimajor axis**.

mean place: coordinates of a star or other celestial object (outside the solar system) at a specific date, in the **Barycentric Celestial Reference System (BCRS)**. Conceptually, the coordinates represent the direction of the object as it would hypothetically be observed from the solar system barycenter at the specified date, with respect to a fixed coordinate system (e.g., the axes of the **International Celestial Reference Frame (ICRF)**), if the masses of the Sun and other solar system bodies were negligible.

mean solar time: a measure of time based conceptually on the **diurnal motion** of a fiducial point, called the fictitious mean Sun, with uniform motion along the **celestial equator**. Obsolete.

meridian: a great circle passing through the **celestial poles** and through the **zenith** of any location on Earth. For planetary observations a meridian is half the great circle passing through the planet's poles and through any location on the planet.

month: the period of one complete synodic or sidereal revolution of the Moon around the Earth; also, a calendrical unit that approximates the period of revolution.

moonrise, moonset: the times at which the apparent upper **limb** of the Moon is on the astronomical **horizon**. In *The Astronomical Almanac*, they are computed as the times when the true **zenith distance**, referred to the center of the Earth, of the central point of the Moon's disk is $90°34' + s - \pi$, where s is the Moon's **semidiameter**, π is the **horizontal parallax**, and $34'$ is the adopted value of horizontal **refraction**.

nadir: the point on the **celestial sphere** diametrically opposite to the **zenith**.

node: either of the points on the **celestial sphere** at which the plane of an **orbit** intersects a reference plane. The position of one of the nodes (the **longitude of the ascending node**) is traditionally used as one of the standard **orbital elements**.

nutation: oscillations in the motion of the rotation pole of a freely rotating body that is undergoing torque from external gravitational forces. Nutation of the Earth's pole is specified in terms of components in **obliquity** and longitude. (See **longitude, ecliptic**.)

obliquity: in general, the angle between the equatorial and orbital planes of a body or, equivalently, between the rotational and orbital poles. For the Earth the obliquity of the **ecliptic** is the angle between the planes of the **equator** and the ecliptic.

occultation: the obscuration of one celestial body by another of greater apparent diameter; especially the passage of the Moon in front of a star or planet, or the disappearance of a satellite behind the disk of its primary. If the primary source of illumination of a reflecting body is cut off by the occultation, the phenomenon is also called an **eclipse**. The occultation of the Sun by the Moon is a solar eclipse. (See **eclipse, solar**.)

opposition: the phenomenon whereby two bodies have apparent **ecliptic longitudes** or **right ascensions** that differ by $180°$ as viewed by a third body. Oppositions are usually tabulated as **geocentric** phenomena.

orbit: the path in space followed by a celestial body as a function of time. (See **orbital**

elements.)

orbit, instantaneous: see **instantaneous orbit**.

orbital elements: a set of six independent parameters that specifies an **instantaneous orbit**. Every real **orbit** can be represented as a sequence of instantaneous ellipses or hyperbolae sharing one of their foci. At each instant of time, the position and velocity of the body is characterized by its place on one such instantaneous curve. The evolution of this representation is mathematically described by evolution of the values of orbital elements. Different sets of geometric parameters may be chosen to play the role of orbital elements. The set of **Keplerian elements** is one of many such sets. When the Lagrange constraint (the requirement that the instantaneous orbit is tangential to the actual orbit) is imposed upon the orbital elements, they are called **osculating elements**.

osculating elements: a set of parameters that specifies the instantaneous position and velocity of a celestial body in its perturbed **orbit**. Osculating elements describe the unperturbed (two-body) orbit that the body would follow if **perturbations** were to cease instantaneously. (See **orbital elements**; **instantaneous orbit**.)

parallax: the difference in apparent direction of an object as seen from two different locations; conversely, the angle at the object that is subtended by the line joining two designated points. Geocentric (diurnal) parallax is the difference in direction between a **topocentric** observation and a hypothetical **geocentric** observation. Heliocentric or annual parallax is the difference between hypothetical geocentric and **heliocentric** observations; it is the angle subtended at the observed object by the **semimajor axis** of the Earth's **orbit**. (See also **horizontal parallax**.)

parsec: the distance at which one **astronomical unit (AU)** subtends an angle of one second of arc; equivalently, the distance to an object having an annual **parallax** of one second of arc. One parsec is $1/\sin(1'') = 206264.806$ AU, or about 3.26 **light-years**.

penumbra: 1. The portion of a shadow in which light from an extended source is partially but not completely cut off by an intervening body. **2.** The area of partial shadow surrounding the **umbra**.

pericenter: the point in an **orbit** that is nearest to the center of force. (See **perigee**; **perihelion**.)

pericenter, argument of: one of the **Keplerian elements**. It is the angle measured in the **orbit** plane from the ascending node of a reference plane (usually the **ecliptic**) to the **pericenter**.

perigee: the point at which a body in **orbit** around the Earth is closest to the Earth. Perigee is sometimes used with reference to the apparent orbit of the Sun around the Earth.

perihelion: the point at which a body in **orbit** around the Sun is closest to the Sun.

period: the interval of time required to complete one revolution in an **orbit** or one cycle of a periodic phenomenon, such as a cycle of phases. (See **phase**.)

perturbations: 1. Deviations between the actual **orbit** of a celestial body and an assumed reference orbit. **2.** The forces that cause deviations between the actual and reference orbits. Perturbations, according to the first meaning, are usually calculated as quantities to be added to the coordinates of the reference orbit to obtain the precise coordinates.

phase: 1. The name applied to the apparent degree of illumination of the disk of the Moon or a planet as seen from Earth (crescent, gibbous, full, etc.). **2.** The ratio of the illuminated area of the apparent disk of a celestial body to the entire area of the apparent disk; i.e., the fraction illuminated. **3.** Used loosely to refer to one aspect of an **eclipse** (partial phase, annular phase, etc.). (Also see **lunar phases**.)

phase angle: the angle measured at the center of an illuminated body between the light source and the observer.

photometry: a measurement of the intensity of light, usually specified for a specific wavelength range.

planetocentric coordinates: coordinates for general use, where the z-axis is the mean axis

of rotation, the x-axis is the intersection of the planetary **equator** (normal to the z-axis through the center of mass) and an arbitrary prime **meridian**, and the y-axis completes a right-hand coordinate system. Longitude of a point is measured positive to the prime meridian as defined by rotational elements. Latitude of a point is the angle between the planetary equator and a line to the center of mass. The radius is measured from the center of mass to the surface point.

planetographic coordinates: coordinates for cartographic purposes dependent on an equipotential surface as a reference surface. Longitude of a point is measured in the direction opposite to the rotation (positive to the west for direct rotation) from the cartographic position of the prime **meridian** defined by a clearly observable surface feature. Latitude of a point is the angle between the planetary **equator** (normal to the z-axis and through the center of mass) and the normal to the reference surface at the point. The **height** of a point is specified as the distance above a point with the same longitude and latitude on the reference surface.

polar motion: the irregularly varying motion of the Earth's pole of rotation with respect to the Earth's crust. (See **Celestial Intermediate Pole (CIP)**.)

pole, celestial: either of the two points projected onto the **celestial sphere** by the Earth's axis. Usually, this is the axis of the **Celestial Intermediate Pole (CIP)**, but it may also refer to the instantaneous axis of rotation, or the angular momentum vector. All of these axes are within $0''.1$ of each other. If greater accuracy is desired, the specific axis should be designated.

pole, Tisserand mean: the angular momentum pole for the Earth about which the total internal angular momentum of the Earth is zero. The motions of the **Celestial Intermediate Pole (CIP)** (described by the conventional theories of **precession** and **nutation**) are those of the Tisserand mean pole with periods greater than two days in a celestial reference system (specifically, the **Geocentric Celestial Reference System (GCRS)**).

precession: the smoothly changing orientation of an orbital plane or the **equator** of a rotating body. Applied to rotational dynamics, precession may be excited by a singular event, such as a collision, a progenitor's disruption, or a tidal interaction at a close approach (free precession); or caused by continuous torques from other solar system bodies, or jetting, in the case of comets (forced precession). For the Earth's rotation, the main sources of forced precession are the torques caused by the attraction of the Sun and Moon on the Earth's equatorial bulge, called precession of the equator (formerly known as lunisolar precession). The slow change in the orientation of the Earth's orbital plane is called precession of the ecliptic (formerly known as planetary precession). The combination of both motions – that is, the motion of the equator with respect to the ecliptic – is called general precession. (see **nutation**).

proper motion: the projection onto the **celestial sphere** of the space motion of a star relative to the solar system; thus, the transverse component of the space motion of a star with respect to the solar system. Proper motion is usually tabulated in star catalogs as changes in **right ascension** and **declination** per year or century.

quadrature: a configuration in which two celestial bodies have apparent longitudes that differ by $90°$ as viewed from a third body. Quadratures are usually tabulated with respect to the Sun as viewed from the center of the Earth. (See **longitude, ecliptic**.)

radial velocity: the rate of change of the distance, usually corrected for the Earth's motion with respect to the solar system **barycenter**.

refraction: the change in direction of travel (bending) of a light ray as it passes obliquely from a medium of lesser/greater density to a medium of greater/lesser density.

refraction, astronomical: the change in direction of travel (bending) of a light ray as it passes obliquely through the atmosphere. As a result of refraction the observed **altitude** of a celestial object is greater than its geometric altitude. The amount of refraction depends on the altitude of the object and on atmospheric conditions.

retrograde motion: for orbital motion in the solar system, motion that is clockwise in the **orbit** as seen from the north pole of the **ecliptic**; for an object observed on the **celestial sphere**, motion that is from east to west, resulting from the relative motion of the object and the Earth. (See **direct motion**.)

right ascension: angular distance on the **celestial sphere** measured eastward along the **celestial equator** from the **equinox** to the **hour circle** passing through the celestial object. Right ascension is usually given in combination with **declination**.

second, Système International (SI second): the duration of 9 192 631 770 cycles of radiation corresponding to the transition between two hyperfine levels of the ground state of cesium 133.

selenocentric: with reference to, or pertaining to, the center of the Moon.

semidiameter: the angle at the observer subtended by the equatorial radius of the Sun, Moon or a planet.

semimajor axis: 1. Half the length of the major axis of an ellipse. **2.** A standard element used to describe an elliptical **orbit**. (See **orbital elements**.)

SI second: see **second, Système International**.

sidereal day: the interval of time between two consecutive **transits** of the **catalog equinox**. (See **sidereal time**.)

sidereal hour angle: angular distance on the **celestial sphere** measured westward along the **celestial equator** from the **catalog equinox** to the **hour circle** passing through the celestial object. It is equal to 360° minus **right ascension** in degrees.

sidereal time: the measure of time defined by the apparent **diurnal motion** of the **catalog equinox**; hence, a measure of the rotation of the Earth with respect to the stars rather than the Sun.

solstice: either of the two points on the **ecliptic** at which the apparent longitude of the Sun is 90° or 270°; also, the time at which the Sun is at either point. (See **longitude, ecliptic**.)

spectral types or classes: categorization of stars according to their spectra, primarily due to differing temperatures of the stellar atmosphere. From hottest to coolest, the spectral types are O, B, A, F, G, K and M.

standard epoch: a date and time that specifies the reference system to which celestial coordinates are referred. (See **mean equator and equinox**.)

stationary point: the time or position at which the rate of change of the apparent **right ascension** of a planet is momentarily zero. (See **apparent place**.)

sunrise, sunset: the times at which the apparent upper **limb** of the Sun is on the astronomical **horizon**. In *The Astronomical Almanac* they are computed as the times when the true **zenith distance**, referred to the center of the Earth, of the central point of the Sun's disk is 90°50′, based on adopted values of 34′ for horizontal **refraction** and 16′ for the Sun's **semidiameter**.

surface brightness: the visual magnitude of an average square arcsecond area of the illuminated portion of the apparent disk of the Moon or a planet.

synodic period: the mean interval of time between successive **conjunctions** of a pair of planets, as observed from the Sun; or the mean interval between successive conjunctions of a satellite with the Sun, as observed from the satellite's primary.

synodic time: pertaining to successive conjunctions; successive returns of a planet to the same **aspect** as determined by Earth.

TAI: see **International Atomic Time (TAI)**.

TCB: see **Barycentric Coordinate Time (TCB)**.

TCG: see **Geocentric Coordinate Time (TCG)**.

TDB: see **Barycentric Coordinate Time (TCB)**.

T_{eph}: the independent argument of the JPL planetary and lunar ephemerides DE405/LE405; in the terminology of General Relativity, a **barycentric** coordinate time scale. T_{eph}

is a linear function of **Barycentric Coordinate Time (TCB)** and has the same rate as **Terrestrial Time (TT)** over the time span of the ephemeris. In this volume, T_{eph} is regarded as functionally equivalent to **Barycentric Dynamical Time (TDB)**. (See **Barycentric Coordinate Time (TCB)**; **Terrestrial Time (TT)**; **Barycentric Dynamical Time (TDB)**).

terminator: the boundary between the illuminated and dark areas of a celestial body.

Terrestrial Ephemeris Origin (TEO): the original name for the **Terrestrial Intermediate Origin (TIO)**. Obsolete.

Terrestrial Intermediate Origin (TIO): the non-rotating origin of the **Terrestrial Intermediate Reference System (TIRS)**, established by the **International Astronomical Union (IAU)** in 2000. The TIO was originally set at the **International Terrestrial Reference Frame (ITRF)** origin of longitude and throughout 1900-2100 stays within 0.1 mas of the ITRF zero-meridian. Formerly referred to as the **Terrestrial Ephemeris Origin (TEO)**.

Terrestrial Intermediate Reference System (TIRS): a geocentric reference system defined by the intermediate **equator** of the **Celestial Intermediate Pole (CIP)** and the **Terrestrial Intermediate Origin (TIO)** on a specific date. It is related to the **Celestial Intermediate Reference System** by a rotation of the **Earth Rotation Angle**, θ, around the Celestial Intermediate Pole.

Terrestrial Time (TT): an idealized form of **International Atomic Time (TAI)** with an **epoch** offset; in practice, TT = TAI + $32^{s}.184$. TT thus advances by **SI seconds** on the **geoid**. Used as the independent argument for apparent **geocentric** ephemerides. (See **second, Système International**.)

TT: see **Terrestrial Time (TT)**.

topocentric: with reference to, or pertaining to, a point on the surface of the Earth.

transit: 1. The passage of the apparent center of the disk of a celestial object across a **meridian**. **2.** The passage of one celestial body in front of another of greater apparent diameter (e.g., the passage of Mercury or Venus across the Sun or Jupiter's satellites across its disk); however, the passage of the Moon in front of the larger apparent Sun is called an annular **eclipse**. (See **eclipse, annular**; **eclipse, solar**).

transit, shadow: The passage of a body's shadow across another body; however, the passage of the Moon's shadow across the Earth is called a solar eclipse.

true equator and equinox: the celestial coordinate system determined by the instantaneous positions of the **celestial equator** and **ecliptic**. The motion of this system is due to the progressive effect of **precession** and the short-term, periodic variations of **nutation**. (See **mean equator and equinox**.)

twilight: the interval of time preceding sunrise and following sunset during which the sky is partially illuminated. Civil twilight comprises the interval when the **zenith distance**, referred to the center of the Earth, of the central point of the Sun's disk is between $90°\ 50'$ and $96°$, nautical twilight comprises the interval from $96°$ to $102°$, astronomical twilight comprises the interval from $102°$ to $108°$. (See **sunrise**, **sunset**.)

umbra: the portion of a shadow cone in which none of the light from an extended light source (ignoring **refraction**) can be observed.

Universal Time (UT): a generic reference to one of several time scales that approximate the mean **diurnal motion** of the Sun; loosely, **mean solar time** on the Greenwich meridian (previously referred to as Greenwich Mean Time). In current usage, UT refers either to a time scale called UT1 or to **Coordinated Universal Time (UTC)**; in this volume, UT always refers to UT1. UT1 is formally defined by a mathematical expression that relates it to **sidereal time**. Thus, UT1 is observationally determined by the apparent diurnal motions of celestial bodies, and is affected by irregularities in the Earth's rate of rotation. UTC is an atomic time scale but is maintained within $0^{s}.9$ of UT1 by the introduction of 1-second steps when necessary. (See **leap second**.)

UT1: see **Universal Time**.

UTC: see **Coordinated Universal Time (UTC)**.

vernal equinox: see **equinox, vernal**.

vertical: the apparent direction of gravity at the point of observation (normal to the plane of a free level surface).

week: an arbitrary period of days, usually seven days; approximately equal to the number of days counted between the four phases of the Moon. (See **lunar phases**.)

year: a period of time based on the revolution of the Earth around the Sun. The calendar year is an approximation to the tropical year. The anomalistic year is the mean interval between successive passages of the Earth through **perihelion**. The sidereal year is the mean period of revolution with respect to the background stars. (See **Gregorian calendar**; **year, tropical**; **Julian year**.)

year, Besselian: the period of one complete revolution in **right ascension** of the fictitious mean Sun, as defined by Newcomb. Its length is shorter than a tropical year by $0.148 \times T$ seconds, where T is centuries since 1900.0. The beginning of the Besselian year occurs when the fictitious mean Sun is at **ecliptic longitude** 280° and was traditionally used as a standard **epoch**. Since 1984, standard epochs have been defined by the **Julian year** rather than the Besselian year. In current usage, Besselian epochs are prefaced with a "B" (e.g. B1950.0) while Julian epochs are prefaced with a "J" (e.g. J2000.0)

year, Julian: see **Julian year**.

year, tropical: the period of one complete revolution of the mean longitude of the Sun with respect to the **dynamical equinox**. The tropical year comprises a complete cycle of seasons, and its length is approximated in the long term by the civil (Gregorian) calendar.

zenith: in general, the point directly overhead on the **celestial sphere**.

zenith, astronomical: the extension to infinity of a plumb line from an observer's location.

zenith, geocentric: the point projected onto the **celestial sphere** by a line that passes through the **geocenter** and an observer.

zenith, geodetic: the point projected onto the **celestial sphere** by the line normal to the Earth's geodetic ellipsoid at an observer's location.

zenith distance: angular distance on the **celestial sphere** measured along the great circle from the **zenith** to the celestial object. Zenith distance is 90° minus **altitude**.