NORTON'S STAR ATLAS

NORTON'S STAR ATLAS

AND REFERENCE HANDBOOK

(Epoch 1950·0) *Sixteenth Edition*

by Arthur P. Norton

THE REFERENCE HANDBOOK AND LISTS OF INTERESTING OBJECTS
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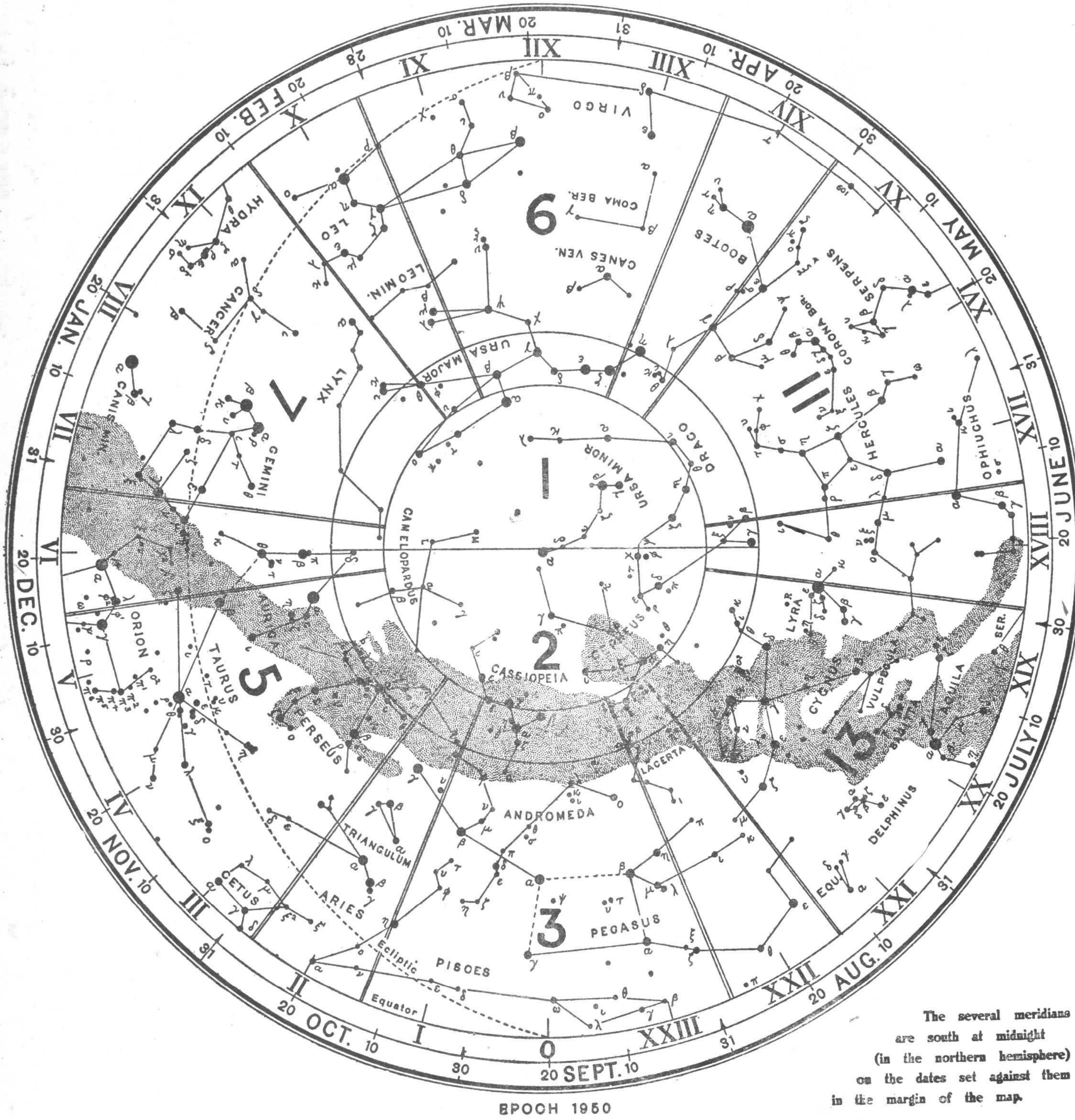
NORTHERN INDEX MAP



The several meridians are south at midnight (in the northern hemisphere) on the dates set against them in the margin of the map.

PREFACE

The First Edition of *Norton's Star Atlas* was published in 1910. It was primarily designed for those amateur observers whose telescopes were mounted on altazimuth stands or as equatorials without graduated setting circles. It was also intended to be used as a companion to Webb's *Celestial Objects for Common Telescopes* (recently reprinted in the U.S.A. as a paperback) and Smyth's *Cycle of Celestial Objects*, now out of print and unobtainable except in astronomical libraries. Almost all the objects listed in the latest editions of both works, down to and including stars of the seventh magnitude, are shown in the maps, also several fainter objects of particular interest.

The plan and arrangement of the maps, with large overlaps, enable an area of about one-fifth of the entire heavens to be seen at a single opening, and no constellation is inconveniently broken up. The distortion is slight considering the large area represented. Altogether the maps indicate the positions of over 8,400 stars and 600 nebulæ. Bright variable and red stars are indicated by 'v' and 'R' respectively. For particulars of double stars reference should be made to the lists on the backs of the maps, and to 'Webb' and 'Smyth'.

The constellation boundaries used are those prepared by Monsieur E. Delporte and adopted by the International Astronomical Union in 1930. The epoch of Delporte's boundaries was 1875, and by 1950 the change of their positions in Right Ascension and Declination, due mainly to 75 years of precession, was appreciable. With respect to the stars themselves, however, the positions of the boundaries remain unaltered. The ninth and subsequent editions of 'Norton' contain charts completely redrawn for the standard epoch 1950·0.

The Galactic Charts introduced in the fifteenth and reprinted in this edition were completely redrawn using the new system of galactic co-ordinates adopted at the Moscow general assembly of the I.A.U. in 1958. The galactic equator and poles, where they appear on the star maps, have also been plotted on the new basis. This work was undertaken by Norman G. Matthew, Director of the Observatory, Calton Hill, Edinburgh.

All the features of the original maps are retained, with certain alterations:

(*a*) Stars down to magnitude 6·35 from the *Revised Harvard Photometry* have been charted. In the original edition the star places were taken mainly from Houzeau's *Uranométrie Générale.* A careful comparison of the magnitudes of Houzeau's fainter naked-eye stars with those given in the *Harvard Photometry* and its Supplement showed that many of his stars were placed at a lower, sometimes much lower, magnitude than 6·35; such stars have generally been omitted. On the other hand, many Harvard stars not in Houzeau have been inserted, as well as several additional double stars from various sources.

(*b*) All nebulæ, except those in the Messier Catalogue and those listed in the Herschel catalogues, are designated by their N.G.C. number.

(*c*) Variable stars having a maximum brightness of magnitude 6 or 7 have been indicated on the maps by small circles.

(*d*) The Milky Way is in many places very complex in structure, with star clouds, dark spaces and dark winding lanes. No single-tone representation, as used in this work, can satisfactorily represent its real structure. The outline of R. A. Proctor is again used here, for it does at least represent the position and boundaries of the Milky Way, and gives some impression of its complexity.

(*e*) A map of the Moon, with the selenographic co-ordinates of 300 named features, is again included for the benefit of visual observers.

(*f*) For the first time a map of Mars is provided in this edition. The map reproduced is the one adopted by the I.A.U. to show the recommended nomenclature for the 128 features listed. The Editors consider this more useful to the visual observer than a detailed map of the terrain visible only on photographs obtained by space-probes.

Arthur P. Norton and James Gall Inglis, who had collaborated since 1919 in revisions of the text of the Reference Handbook, died in 1955 and 1939 respectively; later revisions were undertaken by the present proprietor, Robert M. Gall Inglis. The text of this sixteenth edition of the Reference Handbook has been completely rewritten and brought up to date, and the lists of telescopic objects revised and enlarged. The proprietor cannot express sufficient thanks to Patrick Moore, Gilbert Satterthwaite, Howard Miles, Iain Nicolson, Julian Marsh and Christopher Kitchin for so willingly undertaking this onerous task.

The intention of the original edition has been maintained—to provide both the amateur observer and the general reader with a reference book to which he can turn for an explanation of unfamiliar terms—especially the terminology of observational astronomy which is inadequately dealt with in many text-books. The explanations are necessarily compressed, but it is hoped that they are sufficiently complete for the purpose.

The new text has been arranged in an order differing from that of the earlier editions, in order to present the data in a coherent and logical sequence, and to avoid unnecessary duplication. In accordance with current recommendations for all scientific publications, all data have been presented in metric units in this edition; as far as possible the recommendations of the I.A.U. for astronomical publications have also been followed.

This being the first occasion on which the text of the Reference Handbook has been entirely reset, we have seized the opportunity to give it a new typographical style. Our intention has been to present the text in a more modern and spacious manner, whilst endeavouring to retain the spirit of the earlier editions. In particular we hope that the many tables retained from the previous editions will be found even more useful in their redesigned layout. The revised lists of interesting objects have also been printed in a new format.

The Editors hope that the revised edition will be found a valuable source of helpful information, especially by the observer, and that it will provide him with sufficient detail for his immediate needs. This should be amplified by consulting the many books available on most aspects of astronomy. After careful consideration the Editors decided not to include an annotated bibliography here, in view of the rate at which lists of available astronomical works go out of date, compared with the longevity enjoyed by previous editions of 'Norton' and which they hope this edition will be found useful enough to maintain.

The Editors wish to express their thanks to Peter Bate for redesigning the title page, case and jacket; to Peter Gill, for much help with the sections relating to the Sun; to Oxford Illustrators Limited for their excellent draughtsmanship; to the Comptroller of Her Majesty's Stationery Office for permission to reproduce Crown Copyright material; to the Council of the British Astronomical Association for permission to reproduce data taken from its *Handbook*, *Memoirs* and *Journal*; and to the Sky Publishing Corporation of Cambridge, Massachusetts, for permission to reproduce material from *Sky & Telescope*, and the map of the Moon.

The Editors also wish to express their indebtedness to the printers, Messrs Robert MacLehose & Co. Ltd, for their patience, skill and efficiency, and especially to Mr William Bryson whose expertise and personal interest in the preparation of this edition have considerably lightened the editorial burden.

Edinburgh — ROBERT M. GALL INGLIS
Selsey — PATRICK MOORE
Orpington — GILBERT E. SATTERTHWAITE
November 1973

CONTENTS

I. GENERAL

SOME ASTRONOMICAL TERMS

The following selection is not intended to be comprehensive, but comprises terms which have not been defined later in the text. Many similar terms are defined within the specialized sections. Reference to the Index will permit the location of any term to be readily ascertained.

Angular Diameter. Although they are at very different distances, all astronomical bodies appear to be at the same distance—hence the concept of a celestial sphere. Measurements of their relative positions are therefore made in angular measure, which is independent of their actual distances. In the same way the diameters of those bodies close enough to have them measured can be directly compared if they are expressed in angular measure, rather than actual units of length. Thus the apparent diameter of a planet at a given instant is expressed in seconds of arc; the actual diameter can be calculated from the angular diameter and the distance of the planet at the time using simple trigonometry.

Apparent/True. In astronomy the term *apparent* is used to indicate that which is seen by the observer, e.g. the apparent place of a star is its observed position at the instant of observation. Apparent is also used where an observed function is affected by other factors for which corrections must be applied to arrive at the true function: thus observed positions and movements of heavenly bodies are affected by refraction, aberration, annual parallax, light-time, diminution of brightness with distance, etc., all of which must be corrected for in order to obtain the true position or movement. In some instances 'true' = 'apparent', as in, e.g., True Time, True Equinox.

Appulse. The apparent close approach of one celestial object to another, although they may be far apart in actual distance. Thus a planet and the Moon may lie in almost the same direction in space, although at very different distances; they are said to be in appulse when closest together as seen in the sky.

Clock Star. A bright star whose position and proper motion are very accurately known and can therefore be assumed; used for the determination of the error of observatory clocks, to be applied in reducing positional observations of other stars, and for the provision of a time service.

Cusp. One of the 'horns' of the crescent phase of the Moon or an inferior planet.

Dichotomy. The instant of exact half-phase of the Moon or an inferior planet.

Earth Sciences. General term embracing all the scientific studies of the planet Earth, including geology and all its related subjects, geophysics, geodesy, physical geography, etc.

Ephemeris. A table showing the calculated positions, at regular intervals, of a celestial object. Plural *ephemerides*.

Equation. Often used in the sense of a correction to observed data to eliminate instrumental, ocular and other imperfections. These are sometimes grouped together as *systematic errors* when they recur if observations are repeated with the same instruments and under the same conditions, and as *accidental errors* when they do not repeat. The term is also used for a correction to take account of an orbital irregularity, as in *Equation of Time*, *Equation of Equinoxes*, etc.

The *Personal Equation* is a small error involuntarily introduced into his observations by a particular observer; its effect is usually consistent for repeated similar observations by an experienced observer, but varies quite randomly between different observers.

Exosphere. The outermost layer of the Earth's atmosphere, above the ionosphere.

Extinction. An effect of the atmosphere, which dims the light reaching us from distant objects by absorbing and dispersing it. Its effect varies with the altitude of the object above the horizon, since the closer to the horizon it appears the greater the thickness of the atmosphere its light rays will have traversed. The brightness of a star in the zenith will be reduced by only about 0·3 magnitudes, whereas the extinction at 20° altitude is about 0·9 magnitudes and at 10° altitude about 1·6 magnitudes.

Fundamental Stars. Stars whose position and proper motion are so well known that they have been adopted for use as a frame of reference for positional observations of other objects.

Geodesy. The study of the dimensions and figure of the Earth.

Geoid. The hypothetical shape of the globe of the Earth, used in geodetic calculations; the surface of the geoid is approximately the same as 'mean sea level' envisaged as extending over the entire surface of the globe.

Geology. The study of the structure, composition and history of the Earth as a planet; its techniques are now being widely applied in the study of the Moon and other planets.

Geophysics. The study of the Earth's physical state and of physical phenomena within it, such as seismology, terrestrial magnetism, etc. Its techniques are also being applied in the study of the Moon and other planets by space probes, etc.

Great Circle. A circle formed on the surface of a sphere by a plane passing through the centre of the sphere; thus the diameter of a great circle is equal to that of the sphere. The term is used in calculations based upon the concept of the celestial sphere.

Green Flash. This phenomenon, caused by the Earth's atmosphere, is seen for one or two seconds either as the last remnant of the setting Sun vanishes or just at the moment of sunrise. The general conditions required are a distant sharply defined low horizon (preferably sea). Cool weather and absence of red tints seem to favour visibility. During the last seconds of visibility, the strong red colour of the Sun suddenly changes to a vivid green. The period of visibility tends to increase in summer months with increasing latitude, i.e. as the angle of descent of the Sun decreases. In the Antarctic, it has been observed for 30 minutes. Occasionally it takes the form of a white flash followed by a deep blue one. A similar type of phenomenon, the red flash, is sometimes seen as the lower edge of the Sun is seen to emerge from a dark cloud near the horizon.

Ionosphere. Part of the Earth's atmosphere where the constituent atoms are partly ionized by ultra-violet radiation from the Sun. Its height varies, but is approximately between 80 and 400 km above the surface of the Earth.

Light Curve. A graph of the apparent magnitude of a variable star (or other variable object) plotted against an appropriate time-scale.

Light-time. The time taken for light, travelling at a velocity of 299,793 km/s, to reach the Earth from a distant object. A correction for the effect of light-time is necessary when calculating rotation periods of planets, etc. The observed times of maxima and minima of variable stars require a light-time correction depending upon the position of the Earth in its orbit at the time of observation, as periods of variation are stated for the Earth at mean distance from the star.

Limb. The apparent edge of the Sun, Moon, a planet or any body having a detectable disk. Regions adjoining a limb are termed limb regions (especially used for the Moon). The leading limb of an object as it moves due to the diurnal rotation of the Earth is termed the *preceding limb,* and the 'trailing' limb is termed the *following limb.* The other extremities are termed the north and south limbs, as appropriate.

Lunation. Term used to denote one complete cycle of phases of the Moon, occupying 29½ days on average. It is the Moon's synodic period, also known as a *synodic month.*

Mesosphere. The upper part of the stratosphere, between about 50 and 80 km above the Earth's surface.

Metagalaxy. Term used to describe the entire cosmos, embodying all known and imagined celestial objects and the space lying between them.

Metonic Cycle. A period of 19 years, after which the phases of the Moon will recur on the same calendar date and within two hours of the same time, discovered by Meton of Athens in 432 B.C. It arises from the fact that 235 lunations equal 19 tropical years almost exactly, about 6939½ days.

Mock Sun. Another name for *parhelion,* q.v.

North Point. The point on the celestial sphere due north of the observer, where the meridian plane intersects the horizon. The term is also used to denote the point on the hour circle through an observed object nearest to the north celestial pole, used as a zero reference for observations of position angle.

Parhelion. Sometimes termed a mock sun, this is an image of the Sun formed by refraction through ice crystals in the Earth's atmosphere; usually diffuse, and situated 22° from the real Sun. Common in polar regions, but often seen elsewhere.

Parselene. A diffuse image of the Moon formed by ice crystals in the upper atmosphere, usually seen 22° from the true Moon. Usually seen only in the polar regions.

Penumbra. The outer parts of the shadow cast by an object in a light beam from an extended source, e.g. the outer part of the Moon's shadow during a solar eclipse, falling upon part of the Earth's surface which is illuminated by only part of the Sun's disk. Also used for the outer, greyish region of a sunspot.

Planisphere. A device which can be set for the date and used to show the constellations visible from a given latitude at a given time of night. A useful aid to star recognition.

Planetology. The study of the physical nature of the planets; embraces not only their study as astronomical objects, but also the application of earth science techniques to their study, as with modern space-probe observations using geophysical techniques, the geological study of the Moon's surface, the petrological and mineralogical study of lunar rock samples, etc.

Position Angle. The position angle of a planet's axis, or of any such 'line' on the disk of a celestial object, is its inclination to the hour circle passing through the centre of the object. It is measured from the north point eastwards, from 0° to 360°.

Radius Vector. A hypothetical straight line joining an orbiting body and the focus of the orbit, e.g. the line joining a planet and the Sun. Used in dynamical calculations.

Refraction. As the Earth's atmosphere decreases in density with height above the surface, so too does its refractive index; in consequence, light from a distant object follows a curved path through the atmosphere, although the observer will believe it to have come from the direction along which it arrives at the Earth's surface. The effect of this is to cause objects to appear to have a greater altitude than they have in fact. The effect is maximal at the horizon, more than ½°, and decreases to nil at the zenith.

Saros. A period of 18 y 11 d, after which the Sun, the Moon and the nodes of the Moon's orbit return to virtually the same relative positions. It was long believed to have been discovered by the Chaldæans more than 2500 years ago, but may date from the seventeenth century. It enables eclipses to be predicted with considerable accuracy.

Scintillation. The 'twinkling' of the stars, due to local minor variations in the refractive index of the Earth's atmosphere due to inhomogeneities and disturbances. These cause not only small variations in the brightness of a star, but also variations in its colour and small 'wanderings' about its mean observed position.

Small Circle. A circle formed on the celestial sphere by any plane through the sphere which does not pass through the centre of the sphere. The diameter of a small circle is thus less than the diameter of the sphere containing it.

Stratosphere. That part of the Earth's atmosphere at an altitude of about 11 to 80 km.

Troposphere. The lowest layer of the Earth's atmosphere, up to a height of about 11 km.

Twilight. From ancient times this has been reckoned as ending (in the evening, commencing in the morning) when 6th magnitude stars are just visible in the zenith. This coincides with the modern definition of *astronomical twilight*—when the Sun's centre is 18° below the horizon. *Nautical twilight* is defined by the instant when the Sun is 12° below the horizon, and *Civil Twilight* when it is 6° below the horizon.

Twilight lengthens with distance of the observer from the Equator, and is shortest as seen from anywhere on Earth at the equinoxes.

Twinkling. *Scintillation*, q.v.

Umbra. The dark part of the shadow cast by an object illuminated by an extended source, e.g. the shadow cone of the Moon within which the Sun is seen to be totally eclipsed. Also used for the dark inner portion of a sunspot.

Vertex. The point on the limb of an object farthest from the observer's horizon. The Moon's vertex is used in observations of lunar occultations. Distances from the vertex are counted eastwards from 0° to 360°.

Vertical Circle. A circle on the celestial sphere which passes through both the zenith and nadir, and is thus perpendicular to the horizon.

Some Terms Occurring in Astronomical Papers

Errors of Observation. These are of two kinds—Systematic Errors and Accidental Errors. *Systematic errors* are those which repeat (and can therefore be readily determined) when observations are repeated under similar conditions. They are often inherent in the instrument used, in which case they can be detected by the use of a different instrument. Other systematic errors may depend upon climatic conditions, and many other parameters.

Accidental errors are erratic, but can be estimated by analysis of the small discrepancies between the individual observations of a series, or between observed and calculated values; these discrepancies are known as *residuals*.

Probable Error. The probable error of a series of observations is a value derived mathematically from the residuals; it is an indication of the reliability of the figures given. It is often abbreviated to p.e., and is usually prefixed by the sign ±, indicating that it is an even chance whether a given value will be greater or smaller by the amount of the probable error. The smaller the probable error, the greater the reliability.

Mean. The mean value of a set of observations is a straight arithmetic mean or average, i.e. the sum of the individual values divided by the number of values used. If the observations are *weighted* according to their relative reliability, the individual values are first multiplied by weighting factors before they are summed and the mean taken; this is then termed a *weighted mean.*

Method of Least Squares. A method used to determine the most likely mean value derivable from a series of different observed values. It is based upon the principle that the weights of a series of observations with differing probable errors are inversely proportional to the squares of their probable errors.

Correlation. When two varying quantities are compared, the extent to which their variations appear to be inter-related is termed their correlation. It is measured by statistical methods and is usually expressed in the form of a *correlation coefficient*. This is expressed as a decimal fraction, i.e. a coefficient of 1·00 would imply perfect correlation.

Interpolation, Extrapolation. *Interpolation* is the process of finding values for dates, hours, quantities, etc., intermediate to those given in a table. For ordinary purposes, the proportional amount of the difference between the figures for the two nearest dates, quantities, etc., usually suffices, it being assumed for simplicity that the change in the interval is uniform; a more accurate result, useful when maximum or minimum occurs between the dates, is obtained by plotting on squared paper several successive dates, or figures, on each side of the one required and drawing a curve through these points.

For really accurate interpolation between the tabulated values of a complexly varying function it is necessary to apply a special formula; the one most commonly used is due to the early nineteenth-century German astronomer F. W. Bessel. Special tables of coefficients are used to facilitate the calculations.

Extrapolation, a similar process, extends a series of figures beyond the limit of the last figure actually known; there being only one limiting figure, however, it is less simple than interpolation and less accurate.

FUNDAMENTAL CONCEPTS

Celestial Sphere

A convenient means of studying the relative positions of the heavenly bodies, based upon their appearance to the observer. He seems to be at the centre of a vast hollow sphere—half of it unseen, beneath his feet—which revolves around the Earth once a day. The stars appear to be fixed on the inside surface of this sphere—i.e. at a uniform distance from the Earth—although in fact they are at vastly differing distances.

The celestial sphere may be regarded as of infinite radius, and therefore concentric with the Earth, the distance of the observers on the Earth's surface from its centre being negligible.

Positional astronomy is concerned with the relative *directions* of the heavenly bodies, and their apparent distances apart are expressed in angular measure. Most problems in positional astronomy can therefore be solved by the use of spherical trigonometry. The hypothetical concept of a celestial sphere is invaluable as the foundation upon which all fundamental considerations of the positions and motions of heavenly bodies are based.

The Geometry of the Celestial Sphere

The basic features of the celestial sphere are depicted in Figs. 1 and 2. In Fig. 1 the observer is located at O, the centre of the sphere. $NESW$ is his horizon, N, E, S and W being the north, east, south and west points. His zenith is at Z, his nadir at Z'. His meridian plane is the vertical circle $ZNZ'S$.

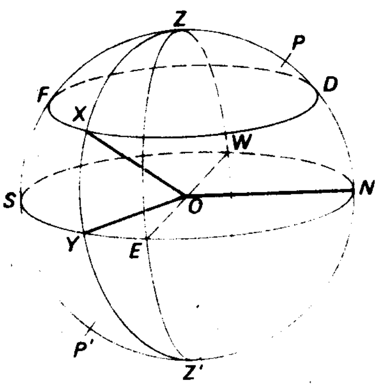


FIGURE 1.

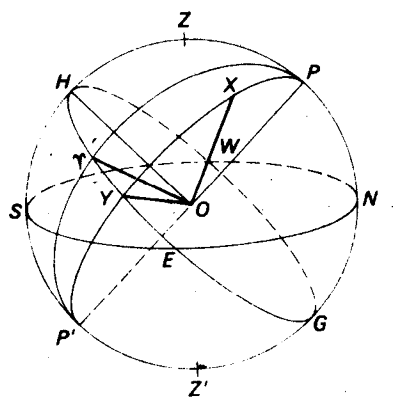


FIGURE 2.

If X represents the position of a star, its vertical is $ZXYZ'$; the small circle through the star parallel to the plane of the horizon, DXF, is termed the *almucantar* of the star.

The horizontal co-ordinates of the star are also shown in Fig. 1—the *altitude* being the angle YOX and the *azimuth* angle NOY. (Azimuth may be expressed in other ways when used by surveyors and navigators, but in modern astronomical usage is always measured eastward from the north point.)

In Fig. 2 P, P' represent the north and south celestial poles, and $NESW$ the horizon as before. PP' is thus the axis of rotation of the celestial sphere. The great circle $GEHW$ is the *celestial equator*. The *meridian* $NPZS$ is the hour circle through the zenith, and is perpendicular to both the equator and the horizon.

X again denotes the position of a star, $PXYP'$ being the *hour circle* through the star. The angle between the hour circle through the star and the meridian, $\angle HOY$, is the *hour angle* of the star. (It is usually measured westwards from the meridian, i.e. the arc $HWGEY$ or $360^\circ - \angle HOY$.)

♈ is the *First Point of Aries*, or *Vernal Equinox*. The hour circle through ♈ (P♈P') is the *equinoctial colure*. The star's Right Ascension is the angle between the equinoctial colure and the hour circle through the star, i.e. $\angle$ ♈OY. The Declination of the star is $\angle XOY$, its North Polar Distance is $\angle POX$.

The Celestial Poles. These are the poles of rotation of the celestial sphere; they are directly overhead at the terrestrial poles.

The Celestial Equator (sometimes termed the *Equinoctial*) is the great circle having as its poles the celestial poles—i.e. the circle that is at all points equidistant from both of them. Every point on the celestial equator passes directly over every point on the terrestrial equator every day.

Zenith, Nadir. The *zenith* is the point immediately overhead; the *nadir* is the diametrically opposite point, i.e. immediately beneath the observer's feet. It is therefore an unobservable position, used only in a hypothetical sense.

Hour Circles. These are great circles passing through a celestial object and the celestial poles; they are therefore perpendicular to the celestial equator. They are occasionally termed declination circles, but this term is not preferred owing to the possibility of its being confused with parallels of Declination which are not necessarily great circles and are *parallel* to the equator.

It should be noted that the same terms are used, perhaps confusingly, to describe the setting circles of an equatorially mounted telescope; the circle on the polar axis is termed the 'hour circle' and is graduated in h, m and s of time; that on the declination axis is known as the 'declination circle' and is graduated in °, ′ and ″ of arc.

The Ecliptic

This is another important great circle on the star sphere, which intersects the celestial equator at an angle of 23½° and lies in a plane which passes through the centres of the Sun and the Earth: it represents the yearly path of the Sun's centre on the celestial sphere, as seen from the Earth, or the Earth's as seen from the Sun: it is shown in Maps 3–14. *The Ecliptic Poles*, the points on the star sphere 90° from the Ecliptic (about 23½° from the Terrestrial poles), are at R.A. 18 h and 6 h, and Dec. 66½° N and S, respectively.

The Ecliptic and its poles are 'sensibly' (i.e. for ordinary purposes) fixed on the celestial sphere, but change slightly in centuries. The former also represents (*a*) the central line of the Zodiac; (*b*) the average path of the Moon, Mercury and Venus, on the celestial sphere, but not those of the other major planets—though these are always *near* the Ecliptic, except Pluto.

Obliquity of the Ecliptic. The inclination of the Ecliptic to the celestial equator—approximately 23° 27′—which represents the maximum angular distance of the Sun north or south of the celestial equator at the solstices. The obliquity may vary from the mean value by up to 9″; the mean value was 23° 26′ 45″ on 1950 January 1 and decreases annually by 0″·47.

The Zodiac (literally 'circle of the animals'—most of the signs represent living creatures) is the belt of the sky 8–9° on each side of the Ecliptic, within which the Sun, Moon and all the planets known to the ancients are found.

Starting yearly at the First Point of Aries, it is divided into the twelve 'Signs of the Zodiac' (see symbols, p. 30)—each 30° of longitude on the Ecliptic—which, however, do *not* coincide with the constellations of the same name, although they did so some 2100 years ago when the First Point was named, precession having carried them westwards some 30°, or a whole sign.

The Equinoxes

These are the two days of the year on which, everywhere on Earth, day and night are of equal duration—hence the name. The instant when the Sun reaches its ascending node—i.e. when it crosses the celestial equator moving northwards on about March 21—is the *Vernal Equinox*. The *Autumnal Equinox* is the corresponding moment, around September 23, when the Sun reaches descending node and passes into the southern celestial hemisphere.

The Vernal Equinox, or **First Point of Aries.** This is the zero for the celestial measurements corresponding to terrestrial longitude; it is the point of intersection on the star sphere, at any moment, of the celestial equator and the ecliptic, at or near the point where the Sun crosses the former from south to north on about March 21.

This point—the *True* or *Apparent Equinox*, or *The Equinox* of any date—moves westward on the ecliptic 1/7th second of arc every day, but is nevertheless the most convenient point for the purpose, as the Sun's position in the sky, measured from it, remains practically the same on a given day of the year for thousands of years, by the leap year arrangements of the calendar, though those of the stars slowly change. 'Vernal Equinox', *when used in connection with measurements*, always means this moving True Equinox, but the *literal* Vernal Equinox is the instant when the Sun's centre actually crosses the celestial equator.

The Mean Equinox is the True Equinox corrected for the irregularity [max. ± 1¼ s] called *Nutation in Right Ascension*. Positions in star charts and catalogues are measured from it, at the time when the Sun's mean longitude is 280°, about Jan. 1: thus for 1950, the star positions are called 'mean places for 1950·0'. '·0' after a year always indicates the 280° start.

The position of the First Point of Aries is about nine moon-breadths west of the end of a line drawn first from α Andromedæ to γ Pegasi (which form one side of the 'Square of Pegasus'), then extended downwards for the same length.

The name originates from the time of Hipparchus, about 2100 years ago, when the vernal equinox was in the constellation Aries; due to precession it is now actually in Pisces.

The First Point of Libra. The descending node of the Sun's apparent path, or *autumnal equinox*. Due to precession the First Point of Libra is no longer situated in that constellation; at the present time it is in Virgo.

Colures. The *equinoctial colure* is the hour circle of the First Point of Aries, or vernal equinox. It also passes through the autumnal equinox, and is therefore the hour circle of R.A. 0 h and 12 h. The *solstitial colure* is the great circle which passes through the summer and winter solstices, i.e. the hour circle of R.A. 6 h and 18 h.

The Solstices

These are the two days in the year when the Sun is at its greatest angular distance from the equator, i.e. the occasion of the longest day and shortest night in one hemisphere of the Earth, and vice versa in the other. The longest day in the northern hemisphere occurs on about June 21—the *summer solstice*—and the shortest on about December 22, the *winter solstice*. These dates mark the winter solstice and summer solstice respectively in the southern hemisphere. The Sun's positions when it is momentarily stationary on these occasions are termed the *solstitial points*.

Diurnal Rotation

The apparent rotation of the celestial sphere, due to the axial rotation of the Earth. It is the motion which gives rise to the daily rising and setting of the Sun, the stars and all other heavenly bodies.

Culmination, or *Southing*. A celestial object *culminates* when it reaches its highest point above the observer's horizon. In the northern terrestrial hemisphere, *souths* is used in the same sense, as culmination is always at the instant when the object is due south of the observer; in the southern hemisphere, objects culminate when due north of the south pole.

Rising and Setting of Stars. At the terrestrial equator, the celestial poles lie on the horizon; all the stars remain above the horizon for half a day, and their rising and setting are at right angles to the horizon. At the terrestrial poles, on the other hand, the celestial equator coincides with the horizon, parallel with which the stars move in circles, neither rising nor setting, the other half of the star sphere being never seen.

In intermediate latitudes there is every variety between these extremes, but always some stars never set (and a corresponding area round the opposite pole, never rise); also the paths in the sky cut the horizon obliquely—all in proportion to the observer's distance from the terrestrial pole or equator.

The stars which rise and set always do so at the same points on the horizon—unlike the Sun, Moon and planets, which rise and set at different points on successive days. In temperate latitudes, especially, those nearest the celestial pole rise far north (in the southern hemisphere, *south*), and are above the horizon most of the twenty-four hours; at increasing distances from the celestial pole they rise further and further south (or *north*) and their time above the horizon diminishes until, for the stars furthest south (or *north*), they set again a very short time after rising. Stars on the celestial equator rise due east and set due west, and are above the horizon for twelve hours as seen from all over the Earth—except at the poles.

Stars rise, 'south' or 'north', and set, at a given hour *only once a year*, always on or about the same date, for they culminate nearly four minutes earlier each day, and make 366¼ revolutions in 365¼ solar days.

On one day in the year 'southing', etc., occurs *twice*, for when a star souths at 12.01 a.m. it will south again at 11.57 p.m. the same day. This occurs with the superior planets also—Mars, and the asteroids in general, about each second year—their mean daily motions being less than the Earth's. Mars and Venus, however, may not south at all on one day in the year.

Circumpolar Stars (stars that never set or rise). Stars never set when their distance from the celestial pole is less than the observer's latitude on Earth; i.e. stars with Declinations greater than the observer's co-latitude never set—those in the corresponding area around the opposite celestial pole never rise.

The Meridian

An observer's meridian is the great circle of the celestial sphere which passes through both celestial poles and the zenith; it always meets the horizon in the north and south points. The term *meridian plane* is also used. 'On the meridian', 'meridian passage', etc., have the same meaning as *culmination*, or *transit*, q.v.

Prime Meridian. The meridian adopted as the zero of longitude measurement on the surface of a planet. In the case of the Earth, the Prime Meridian adopted by international agreement in 1894 is that of the Airy Transit Circle at the Royal Observatory, Greenwich, England.

Transit. A celestial object *transits* when it crosses a particular meridian. The term is also used for a meridian or surface marking crossing the *central meridian* of the disk of a rotating planet.

Upper Transit, or *Upper Culmination*, is used to describe the meridian passage from east to west of an object 'above the pole'—i.e. between the north pole and the south point on the horizon for an observer in the northern hemisphere.

Lower Transit, or *Lower Culmination*, of a circumpolar star is the meridian passage from west to east—'below pole'—which takes place twelve sidereal hours after upper transit. For an observer in the northern hemisphere this is when the star is between the north pole and the north point on the horizon, and is the instant of closest approach of the star to the horizon.

The term transit is also used to denote the passage of an inferior planet across the Sun's disk, or the passage of a planet's satellite or its shadow across the disk of the primary.

Epoch

A fixed point in time. Thus the instant at which a particular observation is made is known as the *epoch of observation*. Observations of the same object made at various times are usually referred to a single epoch—either the beginning of the year (e.g. the epoch 1972·0) or to the *standard* or *fundamental epoch*.

Standard Epoch. This is an epoch used as the basis for comparison of observations, especially positional observations, over a long period of time—half a century or so. The fundamental epoch at present used is 1950·0; it will remain in use until the new epoch 2000·0 is adopted by international agreement.

POSITION

Celestial Co-ordinate Systems

Astronomical positions are normally measured on the celestial sphere, using one of three systems of spherical co-ordinates, each of which has a different reference plane.

Horizontal Co-ordinates. These are referred to the plane of the observer's horizon. The co-ordinates used are the *altitude* (the angular distance of the body above the horizon) and the *azimuth* (the angle between the vertical plane through the object and the observer's meridian plane). Altitude is measured as the object's vertical angular distance above the horizon, azimuth as the angular distance eastwards around the horizon from the north point.

Equatorial Co-ordinates. These are referred to the plane of the celestial equator. The co-ordinates used are the Right Ascension or Hour Angle, and the Declination or Polar Distance.

Right Ascension is the angle between the hour circle through the object and the First Point of Aries;

it is usually abbreviated to R.A. or α. It is measured eastwards along the celestial equator from the True Equinox, sometimes in arc (0° to 360°) but usually in sidereal time (h, m, s). One hour is equivalent to 15°, one degree to 4 m. The R.A. is the interval in sidereal time between the transit of the True Equinox and that of the body concerned. An alternative sometimes used is the *Hour Angle*—the angle between the hour circle through the object and the observer's meridian. It is the difference between the R.A. of the object and the R.A. circle on the meridian at the time of observation, and is measured westwards from the meridian.

The *Declination* is the angular distance of the object north or south of the celestial equator, reckoned positive when north and negative when south of the equator. It is usually abbreviated to Dec. or δ. In some calculations where it is desirable to avoid the use of negative values, the polar distance is used, i.e. the angular distance from the north celestial pole—the North Polar Distance (N.P.D.) or from the south celestial pole—the South Polar Distance (S.P.D.). The polar distance is, of course, equivalent to 90° – Dec.

Ecliptic Co-ordinates. These are referred to the plane of the ecliptic. The co-ordinates used are *celestial latitude* (the perpendicular distance of the object from the ecliptic in angular measure) and *celestial longitude* (the angular distance along the ecliptic between the plane through the object and the First Point of Aries). These co-ordinates are strictly *geocentric* latitude and longitude—i.e. as observed from the Earth's centre. Observations are of course *topocentric*—observed from a point on the surface of the Earth—but geocentric co-ordinates are usually tabulated as they are universally applicable, whereas the slight corrections required to convert them to topocentric values for a given location can be simply made.

Heliocentric Co-ordinates are also used—these too are referred to the plane of the ecliptic but indicate the position of an object as seen from the centre of the Sun. They are particularly used in calculations of the relative positions of the planets and other bodies of the solar system. The Earth's heliocentric longitude at a given instant is equal to the Sun's geocentric longitude plus 180°.

Alternative Planes of Reference

The celestial equator, though most convenient for finding or recording positions on the celestial sphere, by means of the R.A. and Dec., is a less suitable plane of reference for many purposes and other planes and great circles are used instead. Briefly, the position of an object is indicated, with respect to the:

Celestial Equator . . .	. by its Declination, and Right Ascension, from the Vernal Equinox.
Ecliptic,	
(*a*) from the Earth's centre	. by its Geocentric Latitude, and Longitude, from the Vernal Equinox.
(*b*) from the Sun's centre .	. by its Heliocentric Latitude, and Longitude, from the Vernal Equinox.
Horizon of the observer .	. by its Altitude, and Azimuth, from the North Point.
Meridian	. by its Hour Angle from the meridian, and Declination from the Celestial Equator.
Hour Circle or Declination Circle	by its Position Angle, from the North Point.
Galactic Plane, or Milky Way	. by its Galactic Latitude, and Longitude, from the direction of the presumed centre of the Galaxy.
Sun's Equator	. by its Heliographic Latititude, and Longitude, from arbitrary zero.
Planet's or Moon's Equator	. by its Planetographic Latitude, and Longitude.
Limb of the Sun, Moon, or Planet	by its Distance (*a*) from the North Point; (*b*) from the Vertex.

The Invariable Plane of the Solar System, passing through the System's centre of gravity, forms an unvarying reference plane, since it does not change its position in space due to planetary perturbations, as the ecliptic does. Inclined 1° 35′ to the ecliptic plane, 7° to Sun's equator; longitude of ascending node 106° 35′ (epoch 1850).

The Fundamental Plane, used in occultations and eclipses, is the plane passing through the centre of the Earth perpendicular to a line drawn from the star, or the centre of the Sun, through the centre of the Moon.

Galactic Co-ordinates

Studies of the distribution of stars, nebulæ and clusters within the Galaxy require their positions to be measured in a special co-ordinate system referred to the plane of the Galaxy. The co-ordinates used are Galactic Latitude and Longitude. The poles of the Galactic Plane and the zero of Galactic Longitude were redefined by the International Astronomical Union in 1959. The north galactic pole is at R.A. 12 h 49 m, Dec. $+27° 24'$ (epoch 1950·0). The zero of galactic longitude is the direction of the presumed centre of the Galaxy, R.A. 17 h 42·4 m, Dec. $-28° 55'$ (epoch 1950·0).

Galactic Latitude is the angular distance of the object perpendicularly from the Galactic Plane. *Galactic Longitude* is measured in arc around the galactic equator from the defined zero point, from 0° to 360°.

Star Places

The positions of the 'fixed' stars are usually given in Right Ascension and Declination, i.e. referred to the equator and equinox. Due to precession, the positions of the equator and equinox on the celestial sphere are constantly changing, and it is therefore necessary for accurate star positions to be referred to the equator and equinox at a given date or epoch.

Three forms of star place are used, the true place, apparent place and mean place.

The True Place is given by the heliocentric co-ordinates of the star on the celestial sphere at the instant of observation, i.e. referred to the true equator and equinox of that instant.

The Apparent Place is the geocentric position of the star on the celestial sphere as observed from the Earth. It differs from the True Place by small quantities due to annual parallax and aberration.

The Mean Place is the heliocentric position of the star on the celestial sphere, reduced to the mean equator and equinox for the beginning of the year of the observation (see below).

Reduction of Star Places

In order to facilitate the analysis and comparison of observations made during a given year it is usual to reduce the observed place of the star to a mean place—i.e. to the mean equator and equinox for the beginning of the year. This requires corrections to the observed co-ordinates for the effects of precession, nutation, aberration, annual parallax and proper motion during the interval elapsed between the beginning of the year and the moment of observation.

Fundamental Epoch. When observations made over a period of some years are to be compared it is necessary for them all to be reduced to a common epoch; to facilitate intercomparison of observations a fundamental epoch is adopted to which all appropriate observations are reduced. Star places are also listed in catalogues reduced to the fundamental epoch. It is usual for a fundamental epoch to be used for half a century or so; thus the fundamental epoch currently in use is 1950·0, which is unlikely to be superseded until 2000·0 is universally adopted.

Precession. The precession of the equinoxes is a westward movement of the nodes of the ecliptic (the equinoxes), relative to the background stars, of $50''\cdot2$ per annum. It is caused by the gravitational attraction of the Sun and Moon on the Earth's equatorial bulge. The Earth's axis (inclined at $23\frac{1}{2}°$ to the plane of its orbit) completes a whole rotation in 25,800 years. The pole of the heavens therefore traces out a circle $23\frac{1}{2}°$ in radius in that period. As a result of this *Polaris* is only temporarily the closest bright star to the north celestial pole. About 4500 years ago it was *Thuban* (α Draconis); 8000 years hence it will be *Deneb* (α Cygni) and in 12,000 years time *Vega* (α Lyræ).

The apparent movement of the pole is undetectable to the naked eye in a lifetime; its effects on the accurate measurement of star positions are however considerable. All positional observations are made relative to the celestial poles at the time of observation, but are usually reduced to a standard epoch (see *Mean Place*, above); corrections for the effects of precession have therefore to be made when reducing the star's observed R.A. and Dec. to the standard epoch.

Due to precession every star—except those less than $23\frac{1}{2}°$ from the ecliptic poles—passes through every hour of Right Ascension from 0 h to 24 h once every 25,800 years; also the Declinations swing through 47° ($23\frac{1}{2}° \times 2$) every 12,900 years; as a result the stars visible from a given place or at a given season are greatly changed during that time.