Draft version November 3, 2009
Preprint typeset using LaTeX style emulateapj v. 08/13/06

ORIENTING YOURSELF ON THE SKY

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ABSTRACT

We provide a brief introduction to the celestial sphere and some of its notable features (celestial equator, ecliptic, equinoxes, zodiac). We also touch on the definition of astronomical time and the consequences of the precession of the equinoxes. We then discuss its use as a tool for defining the position of astronomical objects, and define right ascension and declination. We move on to describe the activities for our second session, designed to allow you to explore the properties of the celestial sphere, to begin setting up your laptop for observations, and to practice assembling, balancing, and aligning your 6" Schmidt–Cassegrain.

Subject headings: tools: celestial sphere — telescopes: Schmidt–Cassegrain

1. THE CELESTIAL SPHERE (THANK YOU WIKIPEDIA!)

The celestial sphere is an imaginary rotating sphere of infinite radius, concentric and coaxial with the Earth. All objects in the sky can be thought of as lying upon the sphere, and their positions can be described by constructing a coordinate system using the sphere.

Before we get to that, a quick aside on clocks and stellar motions: as the Earth rotates from west to east around its axis once every 23 hours 56 minutes, the celestial sphere and all objects on it appear to rotate from east to west around the celestial poles in the same time. This is the diurnal motion. Stars will rise in the east, reach their maximum altitude on the north–south line (the local meridian) and set in the west (unless they are circumpolar). On the next night a particular star will rise again, but with our normal clocks running a 24 hour cycle, it will do so 4 minutes earlier. By the following night the difference will be 8 minutes, and so forth with every following night.

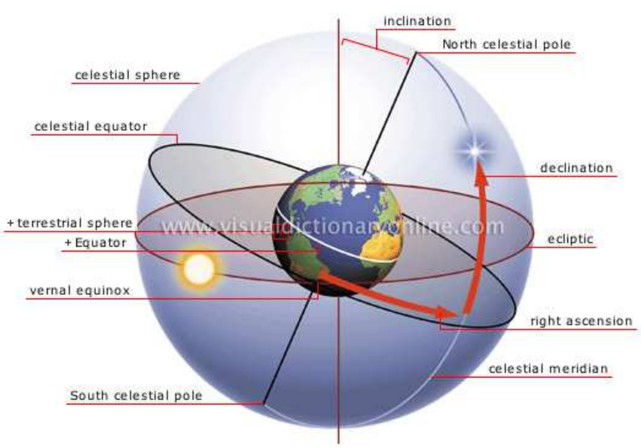

Fig. 1.— The celestial sphere. From the Merriam–Webster Visual Dictionary online.

The reason for the apparent inaccuracy of our clocks is that the Sun is not standing still on the celestial sphere, as the stars do, but moves about 1° per day eastwards over a great circle known as the ecliptic (which traces the annual motion of the Sun). As an angle of 1° corresponds to 4 minutes in time, we need 4 extra minutes of diurnal motion to see the Sun back on (for example) the meridian again, making the duration of one rotation 24 hours (on average, ignoring small seasonal variations).

As you have probably noted, this discussion (and what follows) essentially assumes a Ptolemaic universe, in which everything revolves around the Earth!

1.1. *Some notable features of the celestial sphere*

1.1.1. *The ecliptic*

The ecliptic is the apparent path the Sun traces out in the sky during the year. The name ecliptic is derived from being the place where eclipses occur.

As the rotation axis of the Earth is not perpendicular to its orbital plane, the equatorial plane is not parallel to the ecliptic plane, but makes an angle of about 23° 26′.

1.1.2. *The equinoxes*

Equinoxes occur twice a year, when the tilt of the Earth's axis is oriented neither away from nor toward the Sun, so that the Sun is over the equator. The name is derived from the Latin "aequus" (equal) and "nox" (night), because at the equinox the night and day are equally long. In the context of the celestial sphere, the equinox refers to the intersection of the celestial equator and of the ecliptic.

1.1.3. *The zodiac*

The apparent path of the Sun across the sky takes it through twelve constellations that together constitute the zodiac. Babylonian astronomers are believed to have developed the zodiac of twelve signs, making this the first known celestial coordinate system.

The boundaries of all the constellations in the sky were set by the International Astronomical Union in 1930. This was essentially a mapping exercise to make the work of astronomers more efficient, and the boundaries of the constellations are not therefore in any meaningful sense equivalent to the zodiac signs. Along with the twelve original constellations, the boundaries of a thirteenth constellation, Ophiuchus (the serpent bearer), were set within the bounds of the zodiac.

The signs of the zodiac do not necessarily coincide with the actual constellations for which they are named. While the mapping exercise described above is partially to blame, the main reason for this discrepancy is the precession of the equinoxes. The axis of rotation of the Earth slowly changes direction, making one complete turn in approximately 26,000 years (see Figure 2). Originally, the summer equinox in the Northern hemisphere occurred while the Sun was in Aries, but after about one–twelfth of a cycle since the invention of the zodiac, the Sun is in Aries roughly a month later in the year, in May. This obviously holds for the other constellations as well, and as a result, in Western astrology the link between sign and constellation has been broken.

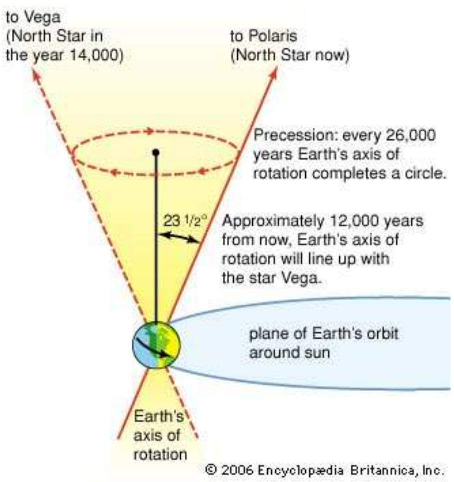

Fig. 2.— The precession of the equinoxes. Its discovery is generally attributed to the ancient Greek astronomer Hipparchus (ca. 150 B.C.), one of the great observational astronomers of any era.

The zodiac also means a region of the celestial sphere that includes a band of 8° above and below the ecliptic, and therefore encompasses the paths of the Moon and the naked eye planets (Mercury, Venus, Mars, Jupiter, and Saturn). The classical astronomers called these planets wandering stars to differentiate them from the fixed stars of the celestial sphere.

1.2. *Navigating the celestial sphere*

The equatorial coordinate system is probably the most widely used celestial coordinate system. It uses right ascension and declination to describe the position of an object on the celestial sphere.

1.2.1. *Right ascension and declination*

RA (or α) is the celestial equivalent of terrestrial longitude. Both RA and longitude measure an east–west angle along the equator; and both measure from a zero point on the equator. For longitude, the zero point is the Prime Meridian; for RA, the zero point is known as the First Point of Aries, which is the place in the sky where the Sun crosses the celestial equator in March.

DEC (or δ) is the celestial equivalent of terrestrial latitude, and is measured in degrees north and south of the celestial equator.

1.2.2. *Wait—what about precession?*

As discussed earlier, the position of the equinoxes changes over time, so that the RA zero point is shifting and that the RA and DEC of stars are constantly changing. In practice, to specify coordinates properly you need not only an (RA, DEC) combination but also the date applying to the coordinate system, sometimes known as the "equinox." The currently used standard epoch is J2000.0, which is January 1, 2000 at 12:00 Terrestrial Time (TT)[1]. Until a few years ago measurements using B1950 were common; the B stands for the Besselian epoch and refers to a Besselian year as opposed to the currently used Julian epoch/year (Google the definitions if you really want them).

1.2.3. *Sexagesimal coordinates*

In defining celestial coordinates, astronomers often use of sexagesimal notation, i.e., base 60 (another system we have inherited from the Babylonians). A declination of 12.3456° is expressed as $+12° \; 20' \; 44''$, or 12 degrees, 20 arcminutes, and 44 arcseconds[2]. (DEC values generally have a leading sign, even if positive, as it helps to distinguish them from RAs, which never need a sign.)

What is even more confusing is that when expressing RA astronomers still use time as opposed to angles. This is because before computers the way to measure the coordinates of some object passing through your field of view was to measure the time difference between its passage and that of the First Point of Aries. As a result, RAs are commonly expressed as hours, minutes, and seconds, and have a range from 0 to 24 hours. Fortunately, because the Earth rotates at an approximately constant rate, the conversion to degrees is fairly easy. Since a complete circle has 360 degrees, an hour of RA is equal to 1/24 of this, or 15°, a minute of RA is $15'$, and a second of RA is $15''$.

For both RA and DEC it is common to express the sexagesimal values as a string with colons (or sometimes just spaces) between components. $12° \; 20' \; 44''$ might appear as 12:20:44 or 12 20 44.

[1] This the modern astronomical standard for the passage of time on the surface of the Earth (for civil purposes, Coordinated Universal Time (UTC) is standard). Since time moves at different rates for observers in different locations (due to relativity), and "the surface of the Earth" is not a single point in space, TT is a theoretical ideal; its measurement is approximated by the International Atomic Time (TAI) +32.184 seconds.

[2] Thanks to Clive Page's notes on AstroGrid for providing the basis for much of this discussion.