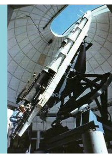
Instruments and Imaging Section
Technical Tips No. 16
20 January 2016



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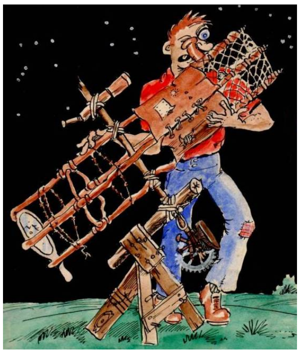


Not quite there ...

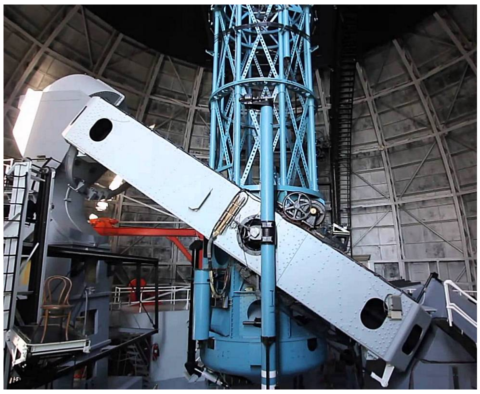
The photograph in the previous *Technical Tips* shows George Elwood Smith (*b*.1930) and Willard Sterling Boyle (1924–2011), co-inventors, in 1969, of an imaging semiconductor circuit: the charge-coupled device (CCD). For this they were awarded the Franklin Institute's Stuart Ballantine Medal in 1973, the IEEE Morris N. Liebmann Memorial Award in 1974, the Charles Stark Draper Prize in 2006, and the Nobel Prize in Physics in 2009. In 2015, Smith was also awarded the Progress Medal and Honorary Fellowship of the Royal Photographic Society. They were identified by Jeremy Shears. The other photograph (though not part of the challenge) was identified by Brian Ingram. It shows (I quote) 'Mr George R. Lawrence using what was then the "World's Largest Camera" to take a photograph of the Chicago and Alton Railroad's new train, known as "The Handsomest Train In The World", in 1900. The train was necessarily stationary. The camera used photographic plates of 8 x 4 feet, and the exposure time was 2½ minutes. Apparently, two lenses were made for the instrument, both of Zeiss patent and produced by Bausch and Lomb, but I am not aware of the aperture.' The current challenge is simply to identify the instrument above.

Equatorial mounts and polar alignment

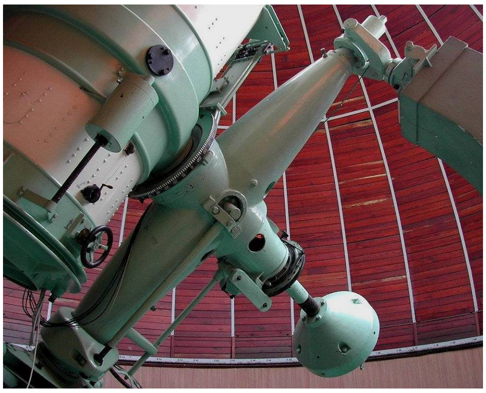
Bob Marriott

The German equatorial mount was invented by Joseph von Fraunhofer – the first of them for the 9.5-inch f/18 refractor manufactured for Dorpat Observatory, Estonia, and installed in 1824. With this instrument, F. G. W. Struve embarked on a programme of micrometrical measures of double stars. The first catalogue of results was published in 1827, and in 1837 Struve published his *Stellarum Duplicium et Multiplicium Mensurae Micrometricae*, containing measures, magnitudes, and colours of almost 3,000 binary stars. Over subsequent decades, various other types of equatorial mount were invented and developed to suit different types of instrument and different observational requirements. Some examples are shown here, but there are numerous variants and modifications, such as the Coudé mount, the polar telescope, and equatorial platforms such as the Poncet mount. In addition, coelostats and siderostats consist of plane mirrors driven at different rates and directing light to a fixed instrument. Essentially, equatorial mounts are designed to compensate for the tilt of the Earth's axis, to provide maximum access to the sky – though with some designs this is limited – and to be as convenient as possible for the observer.

German equatorial (Cooke)

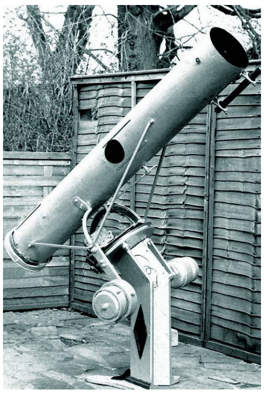


English (yoke)

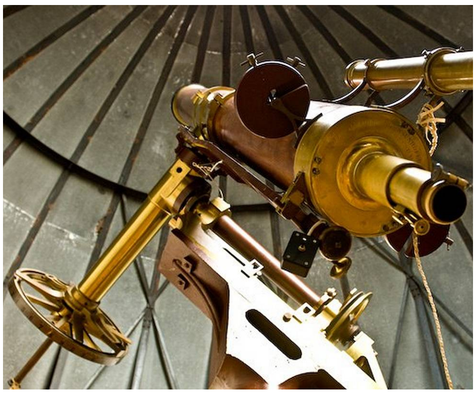


Cross-axis

Fork



Equestrian



German equatorial (Merz)

Springfield

Horseshoe

RA / α	Right Acension	N	north
Dec / δ	Declination	S	south
φ	latitude	E	east
Δ	difference	W	west
T / t	Time / time	LMT	Local Mean Time
p	preceding	LST	Local Sidereal Time
f	following	NCP	North Celestial Pole

The following stages in setting up an equatorial mount ensure that the polar axis is parallel to the Earth's axis, and that the Dec axis is perpendicular to the polar axis and to the plane containing the optical axis. (Abbreviations and symbols are shown at right.)

1 Orientation of the polar axis in azimuth and altitude.
2 Zero setting of the Dec circle index or vernier.
3 Adjustment of the polar axis in altitude.
4 Adjustment of the polar axis in azimuth.
5 Zero setting of the RA circle index or vernier.
6 Perpendicularity of the Dec and optical axes.
7 Perpendicularity of the Dec and polar axes.

The order in which these stages are carried out is important, and the several methods available at each stage vary in accuracy, convenience, and type of mount. All of them can be used for setting up a German equatorial mount, reversible on the E and W sides of the pier, but some of them cannot be used for setting up the type of fork mount often used with Schmidt–Cassegrain telescopes. (In the latter case the fork can be rotated, but the lower end of the telescope is sometimes prevented from moving through the fork.) Acceptable limits of accuracy are dependent on the intended methods of observation. For most visual observing, meticulous accuracy is not a necessity, but for micrometrical work and imaging, adjustments are far more critical. The mount must be equipped with appropriate facilities for adjustment, otherwise difficulties will be encountered. These methods also assume the absence of GPS, drive correctors, autoguiders, 'go to', and other technology, but even if these are used, inaccurate alignment can result in field rotation, degraded images, and incorrect positional measurements.

A low-power eyepiece and a high-power eyepiece with cross-webs or a reticule are required, and there must be a clear view of the NCP and preferably of the intersection point of the meridian and the equator. Coarse setting circles are of little use in most circumstances, so if circles are to be used they must be finely divided and accurate. (The author's Zeiss refractor has engraved silver circles, each with two double verniers reading to 2s in RA and 30 arcsec in Dec.) The index errors of circles must be determined if they are to be used in determining a particular error, but if the mount is not fitted with circles, stages 2 and 5 can be omitted, while stages 3 and 4 can be carried out either with or without circles. In stages 6 and 7 only the RA circle need be used, though it can be assumed that for instruments obtained commercially, adjustment of the optical axis relative to the Dec axis, and of the Dec axis relative to the polar axis, are ensured by the maker, in which case, stages 6 and 7 can be omitted.

If any particular stage involves a large shift in the position of the head, it is probable that previous adjustments will have been affected, so these must be repeated. For example, a large change in the azimuth of the head in stage 4 will also affect the adjustment in stage 3, and stages 3 and 4 must therefore be repeated as fine adjustments after the first coarse adjustment in stage 4.

1 Orientation of the polar axis in azimuth and altitude

Approximate orientation, subject to adjustment in stages 3 and 4.

Azimuth

1.1

The equatorial head aligned N–S on a meridian mark on the ground with the aid of a prismatic compass (distanced from metal components). There are three types of 'north':

- True north is the direction of a meridian of longitude which converges on the north pole.
- Magnetic north is the direction indicated by a magnetic compass. It moves slowly with a variable rate, and currently, in Great Britain, is west of grid north.
- Grid north is the direction of a grid line which is parallel to the central meridian on the National Grid.

The horizontal angular difference between true north and magnetic north is called the magnetic variation or declination. The horizontal angular difference between grid north and magnetic north is called the grid magnetic angle, which needs to be applied when converting between magnetic and grid bearings. The current magnetic variation is obtainable from the website of the British Geological Survey:

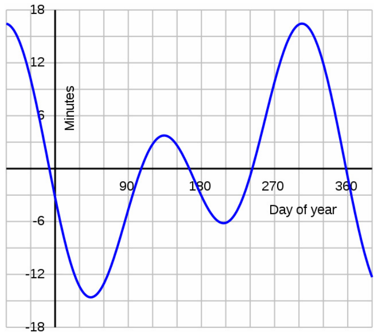
http://www.geomag.bgs.ac.uk/data_service/models_compass/gma_calc.html

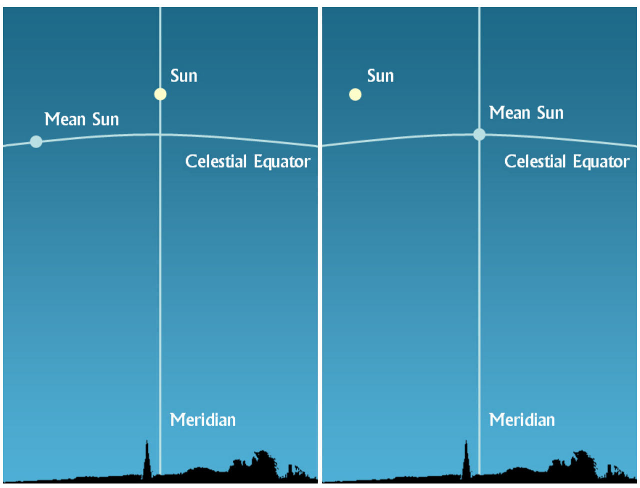
The latitude and longitude of the observing site can be obtained from Google Earth or from

http://www.latlong.net/

1.2

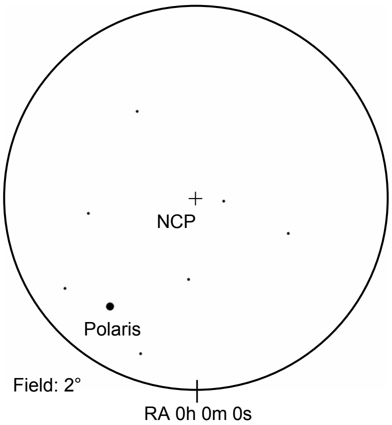
The meridian marked by the shadow of a plummet at true noon: equation of time applied to LMT. The equation of time is the difference between apparent solar time, which tracks the motion of the Sun, and mean solar time, which tracks a theoretical mean Sun. During a year this varies as shown by the graph. Apparent time can be fast by as much as 16m 33s, around 3 November, or slow by as much as 14m 6s, around 12 February, and is zero around 15 April, 13 June, 1 September, and 25 December.





1.3

The meridian defined by two plummets aligned on Polaris at upper or lower culmination (above or below the NCP). The current declination of Polaris is 89° 15' 51", and it therefore lies about three quarters of a degree from the NCP. (Many websites provide instructions for centring Polaris in the eyepiece field in order to adjust the mount in altitude and azimuth. While this is of acceptable tolerance for visual observing, it does not result in accurate polar alignment. For comparison, the full Moon could easily be placed between Polaris and the NCP.)



1.4

With the Dec axis made horizontal with a striding level, or with the RA circle reading 0h 0m 0s, bring a star of known RA (α) to the centre of a low-power field when LST = α, by rotating the entire head in azimuth.

Altitude

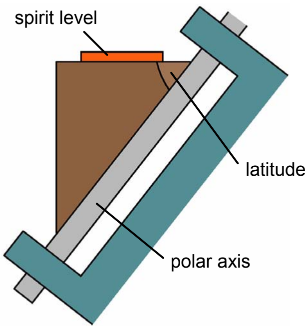
Before adjusting the head, the base supporting it must be made horizontal by levels placed in line with, and at right angles to, the meridian.

1.5

The latitude of the observing site (see stage 1.1) should be correct to the smallest fraction of a degree to which the latitude scale on the mounting can be read. With the base of the head levelled, this angle is then set on the latitude scale.

1.6

If the mount is without a latitude scale, a home-made clinometer can be used.



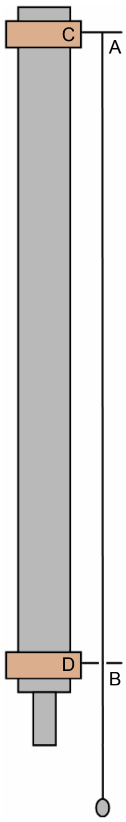
2 Zero setting of the Dec circle index or vernier

2.1

Select a fairly bright star near the meridian (the altitude of which will vary by a negligible amount during a few minutes). With the telescope E of the pier, bring the star to the intersection of the webs of the high-power eyepiece, clamp, and read the Dec circle, δ'. Reverse the telescope, return the star to the webs, and reread the Dec circle, δ''. Assuming that $\delta' \neq \delta''$, adjust the index or vernier to read $(\delta' + \delta'')/2$ when the star is at the intersection of the webs, or is bisected by the horizontal web if the webs have been oriented N–S and E–W. Repeat until the readings E and W of the pier agree, and preferably repeat the entire procedure with a star of widely different Dec. If the readings will not agree, treat any residual error as a correction to be applied, with a change of sign, to all Dec circle readings.

2.2

The base supporting the head having been levelled N–S and E–W, mark the head's position in azimuth. Then turn it through 180° so that the upper end of the polar axis is lying due S of the lower end. Bring Polaris, at its upper or lower culmination, to the intersection of the webs, clamp, and read the Dec vernier. Reverse the telescope and repeat. As in stage 2.1, if the two readings do not agree, set the verniers to their mean value when Polaris is at the centre of the field, and repeat.



2.3

A method that can be used by day, but is not otherwise convenient and applies only to refractors, involves the removal of the eyepiece and the object glass in its cell. First attach a plummet to the intersection of a wooden crossbar laid symmetrically over the top of the telescope. With the tube positioned so that the plummet falls centrally through the drawtube opening, the tube will be directed at the zenith. Set the Dec vernier to read the latitude of the observing site, reverse the telescope, readjust its position relative to the plummet, and reread the vernier. If the two readings are different, set the verniers to their mean. Repeat until the circle reading is the same on either side of the pier. Note the index error, if any, and apply it as a correction to all subsequent Dec circle readings. Alternatively (at left), two brackets can be fixed to the tube with collars. With CD parallel to the optical axis, a plummet suspended from point A on one bracket will pass centrally through the hole B in the other, provided the telescope is vertical and that CA = DB. Otherwise, the telescope can be pointed to the zenith by placing a spirit level across the cell of the objective and centring the bubble in both E–W and N–S directions.

3 Adjustment of the polar axis in altitude

Without circles

3.1

The NCP lies within about 3m of RA of the line joining Polaris and η UMa, so that at ±6h ST of the culmination of η, the altitudes of Polaris and the NCP are very nearly equal. Using a plummet, set the Dec axis in the vertical plane through the polar axis, and clamp the polar axis. Adjust the elevation of the polar axis until Polaris can be brought to the intersection of the webs by rotating the Dec axis only. The inaccuracy in the derived altitude resulting from assuming that the two stars and the NCP lie on the same RA circle is of the order of 50 arcsec. The elevation is too small if η UMa is W of the NCP, or too great if it is E of the NCP.

3.2

To correct the elevation and azimuth of the polar axis in a single operation, centre Polaris in the low-power field and clamp the Dec axis. Rotate the polar axis through a wide angle, and note whether the image has moved relative to the webs. Reduce any such movement to a minimum by adjustment of the telescope in Dec, and carry out fine adjustment with the high-power eyepiece. The tube and the polar axis will then be virtually parallel. Clamp both axes and adjust the head bodily (elevation and azimuth of the polar axis) so as to bring the NCP to the centre of the field. The NCP lies at a distance of about 44 arcmin from Polaris in the direction of η UMa. The adjustment can be made by eye estimation (the field diameter being known), with a map of the polar field, or, if available, with a micrometer.

3.3

Orient the webs of the low-power eyepiece N–S, E–W by trailing an equatorial star near the meridian (star over web, or web over star with Dec axis clamped). Select a pair of stars in the NE or NW sky, differing in RA by several hours and in Dec by at most a few arcminutes. Set the *f* member of the pair at the intersection of the webs and clamp the Dec axis. Rotate the polar axis to bring the *p* star to the N–S web. Knowing the difference in Dec of the two stars, estimate whether it is too far N or S in the field. Then:

If *p* star is too far N and both stars are E of the meridian
the elevation of the polar axis is too great

If *p* star is too far S and both stars are E of the meridian
the elevation of the polar axis is too small

If *p* star is too far N and both stars are W of the meridian
the elevation of the polar axis is too small

If *p* star is too far S and both stars are W of the meridian
the elevation of the polar axis is too great

Adjust the elevation of the axis by half the amount required to bring the star to its estimated correct position on the N–S web. If necessary, correct the orientation of the webs and repeat the procedure first with the low-power eyepiece and finally with the high-power eyepiece. In the latter case it may be necesssary to use another pair of stars, of smaller difference in Dec. The practical inconvenience of this method lies in the necessity of selecting pairs of stars of closely similar Dec.

3.4

Observe a near-equatorial star when on the meridian and when at equal distances E and W. At the first (E) observation, bring the star to the intersection of the webs, oriented N–S and E–W, and clamp the Dec axis. With the second and third observations, note whether the star has shifted N or S from the E–W web, and, if so, estimate by how much. If the position of the star at the meridian is:

midway between its positions when E and W of the meridian
elevation of polar axis is correct

N of the mean of its positions when E and W of the meridian
elevation of polar axis is too great.

S of the mean of its positions when E and W of the meridian
elevation of the polar axis is too small

Having reduced the error, and if necessary reoriented the E–W web, repeat the observations at increased intervals before and after culmination.

3.5

The most satisfactory method capable of revealing very small errors in the elevation of the polar axis is as follows. Select two stars about 6h E and W of the meridian respectively, and in about 45° N Dec. Orient the high-power eyepiece with its webs N–S and E–W by trailing an equatorial star on the meridian. Bring the E star to the intersection of the webs, and clamp the Dec axis. Follow the star with the drive or RA slow motion, and note whether it tends to drift N or S from the E–W web. If the elevation of the axis is nearly correct this drift will be slow, and some time will pass before it becomes perceptible. Repeat the observation with the W star. Then:

If E star drifts too far N
elevation of the polar axis is too great

If W star drifts too far S
elevation of the polar axis is too great

If E star drifts too far S
elevation of the polar axis is too small

If W star drifts too far N
elevation of the polar axis is too small

Correction of the elevation of the axis must be carried out by trial and error.

With circles

3.6

Select a star of known Dec, and, to minimise the effects of refraction and of the still approximate azimuth adjustment, small zenith distance. Set the Dec on the circle, the index error having been eliminated or allowed for, and clamp the Dec axis. Adjust the elevation of the polar axis so that the star, when on or very close to the meridian, can be brought to the intersection of the webs of the high-power eyepiece by sweeping in RA only. Reverse the telescope and repeat, and finally, check with another star.

3.7

With the set-up described in stage 2.3, set the Dec axis horizontal by means of a striding level, and clamp the polar axis. Rotate the telescope about the Dec axis so that the plummet falls centrally through the hole in the lower bracket. The Dec circle reading should now be the latitude of the observing site. If it is not, set this reading on the Dec circle and bring the plummet back to the centre of the lower bracket hole by adjusting the elevation of the polar axis. Alternatively, a spirit level can be used, as described previously.

4 Adjustment of the polar axis in azimuth

Without circles

4.1

Assume that Polaris, η UMa, and the NCP lie on the same RA circle (as in stage 3.1). Set the Dec axis horizontal with a striding level, and clamp the polar axis. At the upper or lower culmination of η UMa, the azimuth of the head is adjusted so that Polaris can be brought to the intersection of the webs by the Dec slow motion. If the observation is made at upper culmination the N end of the axis will lie about 50 arcsec too far W, and if at lower culmination the axis will lie 50 arcsec too far E.

4.2

To correct the elevation and azimuth of the polar axis in a single operation, see stage 3.2.

4.3

Orient the webs N–S, E–W on an equatorial star at the meridian. Select two near-equatorial stars of known RA and Dec, situated at equal distances (about 30m) E and W of the meridian, and differing in Dec by not more than a few arcmin. Bring the E star to the intersection of the webs and clamp the Dec axis. Swing the telescope westward in RA to bring the second star into the field. Knowing the difference in Dec, estimate whether it lies too far N or S in the field. Then:

If W star is too far S
polar axis is lying NE–SW

If W star is too far N
polar axis is lying NW–SE

Reduce the error by half by adjusting the polar axis in azimuth. Repeat with a second pair of stars with Dec different from the first two. Finally, repeat with pairs of stars of increasing difference in Dec until no error is detectable over arcs of 6h–8h. As with the procedure in stage 3.3, the inconvenience of this method is the necessity of selecting pairs of stars of closely similar Dec. Instead of a pair of stars, a single star could be observed when E and again when W of the meridian, but this procedure takes longer.

4.4

Employs the same principle as in stage 3.3, but the first setting of the telescope in Dec is made on a star at the meridian, and the comparisons are made with stars at equal distances E and W of the meridian. Then:

If E star is too far N
polar axis is lying NE–SW

If W star is too far S
polar axis is lying NE–SW

If E star is too far S
polar axis is lying NW–SE

If W star is too far N
polar axis is lying NW–SW

4.5

Orient the webs N–S, E–W on an equatorial star at the meridian. Select two stars of known RA and Dec, with a difference in RA of a few minutes, situated respectively in S Dec and high N Dec. When they are close to the meridian, clamp the telescope in RA slightly ahead of the *p* star, and time its transit at the N–S web. Rotate the telescope about the Dec axis to pick up the *f* star, and time its transit. Then:

If transit of *f* star occurs too early
polar axis is lying NE–SW

If transit of *f* star occurs too late
polar axis is lying NW–SE

With circles

4.6

Select a star of known RA and Dec, situated approximately midway between the meridian and the E or W horizon, and between the zenith and the horizon. Set the Dec circle to the Dec of the star, and clamp. Adjust the azimuth of the polar axis so that the star can be brought to the intersection of the webs by motion in RA only. Repeat with a second star, situated in approximately the same position across the meridian, and make the final adjustments with the high-power eyepiece.

4.7

A method of great precision, using finely divided and accurate circles, involves the prior elimination or determination of the RA circle index error (see stage 5) and the observation of a circumpolar star of known RA and Dec. A few minutes before upper or lower culmination, note the time of its transit at the N–S web of the high-power eyepiece, T_1, and the RA circle reading, t_1. Reverse the telescope and note T_1, t_1. Then:

$$a = \frac{1}{15}\left(\alpha - \frac{T_1 + T_2}{2} - \Delta T + \frac{t'_1 + t'_2}{2}\right)\frac{\cos\delta}{\sin\varphi \pm \delta}$$

where

a = required azimuth correction in arcsec
t'_1, t'_2 = values of t_1, t_2 corrected for index error
ΔT = drive correction
φ = latitude of the observing site

The sign of δ in the denominator of the last term is + for lower culmination and – for upper culmination. If the derived value of a is +, the polar axis is oriented NW–SE, and if the value is –, it is oriented NE–SW.

5 Zero setting of the RA circle index or vernier

5.1

Set the Dec axis horizontal with a spirit level and clamp the polar axis. Set the RA circle index or vernier to zero. If two verniers are fitted, one reading LST and the other RA, their zero readings must coincide.

5.2

Calculate the exact time of culmination of a star of known RA. Just before culmination, bring it to the intersection of the webs in a high-power eyepiece, clamp both axes, and follow it with slow motion in RA. At the calculated instant of meridian transit, stop following the star. Then set the RA circle vernier to zero, and the RA vernier, if present, to the RA of the star.

5.3

With the set-up as in stage 2.1, note the RA circle reading, t, then reverse the telescope and reread the RA circle, t'. If t ≠ t', the zero setting of the RA circle index or vernier (stage 5), the perpendicularity of the Dec and optical axes (stage 6), or the perpendicularity of the Dec and polar axes (stage 7) may need correction. Assuming that the two latter are correct, the index error is

$$\frac{(t + t')}{2} - 24\text{h } 0\text{m } 0\text{s}$$

which can be removed either by setting the circle to the reading $\frac{t + t'}{2}$ and adjusting the vernier to read 24h 0m 0s, or applied with a change of sign as a constant correction to all RA circle readings.

6 Perpendicularity of the Dec and optical axes

With circles

6.1

Select an equatorial star near the meridian; clamp the telescope ahead of it, and time its transit at the N–S web, T_1. Read the RA circle, t_1. Reverse the telescope; again clamp it ahead of the star, time its transit at the N–S web, T_2, and read the RA circle, t_2. Then, if the collimation error is zero,

$$T_2 - T_1 = t_2 - t_2$$

If $T_2 - T_1$ is greater or less than $t_2 - t_1$, the angle between the object-glass end of the tube and the Dec axis is more than or less than a right angle. The collimation error

$$\frac{(T_2 - T_1) - (t_2 - t_1)}{2}$$

can be applied as a correction, or can be removed if the requisite adjustment is provided. If the difference between $(T_2 - T_1)$ and $(t_2 - t_1)$ is expressed in seconds of time, and b = the length of the cradle in inches, the distance that the end of the cradle must be displaced from its existing position is, in inches,

$$15b \left[\frac{(T_2 - T_1) - (t_2 - t_1)}{206265}\right]$$

7 Perpendicularity of the Dec and polar axes

With circles

7.1

Set the Dec axis horizontal with a striding level, and read the RA circle, t_1. Reverse the telescope, level the axis, and reread the RA circle, t_2. Then, it should be that

$$t_1 = t_2 \qquad \text{(12h graduation)}$$

or

$$t_1 = t_2 \pm 12\text{h} \quad \text{(24h graduation)}$$

Most small mountings make no provision for the correction of this error, so if the mounting is faulty it should be returned to the maker.

7.2

This error can be distinguished from collimation error by utilising observations described in stage 6. Both errors have the effect of introducing inequality between $(T_2 - T_1)$ and $(t_2 - t_1)$, but if the cause of the discrepancy is lack of perpendicularity between the instrument's axes, the error will be a function of δ, or more precisely, of $\tan \delta$. Therefore, the observations should be repeated with a star not less than 45° from the equator. The magnitude of the error is

$$\frac{(T_2 - T_1) - (t_2 - t_1)}{2 \tan \delta}$$

Other considerations

These methods apply to setting up an instrument in the northern hemisphere, but in the southern hemisphere they can be adapted by using σ Oct. At mag. 5.6 it is a naked-eye object (in darker skies) and is easily visible telescopically, and lies at Dec –88° 57' 23". An alternative is to use BQ Oct, which, although of mag. 6.8, lies only 14 arcmin from the South Celestial Pole. However, not all the methods involve observation of Polaris, and in the southern hemisphere will not involve observation of a southern pole star.

The more accurate of these methods are capable of reducing the angle between the polar axis and the parallel to the Earth's axis passing through the mount to less than 1 arcmin. Providing that this angle does not exceed 2 or 3 arcmin, the setting will be good enough for ordinary visual observation in most circumstances. Consequently, portable equatorials can be set up by using one or more of these methods, as convenient, and the head adjusted with sufficient accuracy to within about 10 arcmin so that the drive or slow-motion operation in RA will maintain an object near the centre of the field for considerable periods without any requirement for readjustment in Dec.

Some instruments are equipped with a small optical pole-finder, which can also be obtained separately. Such a device is adequate for visual work or for wide-field or short-exposure imaging, but more accurate alignment is necessary for long-exposure imaging, where divergence of the polar and terrestrial axes makes the camera rotate slowly about the image of the guide star, so that the images of all other stars in the field will be arcs rather than points. The lengths of these arcs are a function of their distance from the guide star and of the guide star from the NCP.

In addition, the effect of atmospheric refraction must be taken into account. This effect is virtually nil over an area of sky centred on the meridian in (for mid-northerly latitudes) Dec about 20° N, with a radius of about 30°, but otherwise it increases the observed zenith distance of a star as it approaches its culmination, and decreases it as it passes from culmination towards setting. Therefore, with a precisely adjusted polar axis, southward adjustment in Dec while following a star E of the meridian is necessary, and northward adjustment when the star is W of the meridian. At the same time, the drive rate is falsified, since refraction keeps the star apparently above the horizon for a slightly longer period than in actuality. For visual observation and for imaging it is convenient to partially compensate for this by increasing the elevation of the polar axis slightly so as to direct it at a fictitious pole as affected by refraction, which, however, varies with atmospheric pressure and can be deduced from barometric measurements.

Conversely, critical positional work such as double-star micrometry demands the greatest possible precision in the adjustment of the polar axis, which must be directed at the true pole. As with imaging, the tolerance for the orientation of the polar axis decreases rapidly with decreasing polar distance, resulting in field rotation, which affects measurements of position angles. Moreover, if a double star is measured when it is at low altitude, refraction can also affect the position angle. Therefore, measures should be carried out when the object reaches its highest altitude, approaching, or at, upper culmination, as potential errors are thereby reduced to a minimum.

The methods described here generally account for all requirements and eventualities involved in the setting-up of an instrument. Even approximate polar alignment can prove beneficial, but the finest and most critical adjustments are dependent on the types of object and methods of observation intended. Whether the instrument be a portable 6-inch Newtonian reflector or an exceedingly expensive telescope in a fully equipped observatory bristling with all manner of technology, a poor set-up and inefficient use will detract from any advantages of whatever system might be utilised. Assuming that the instrument is not inadequate in itself, other necessities include a solid and stable ground-base, accurately collimated optics, and familiarity with the operation and capabilities of the equipment. All these factors combine to increase the probability of obtaining superior results.

Nevertheless, having an instrument properly set up fulfils only part of the potential of the telescope and its user. Observational work is often impeded by poor seeing, inadequate transparency, bad weather, light pollution, and other unwelcome factors, but it is the fortune of the astronomer to bear such adversities with fortitude and to adapt accordingly. Never let it be said that astronomy is 'easy'. Ultimately, the production of high-quality, accurate, and reliable observations is dependent on the experience, skill, patience, and integrity of the observer.