Equipment & Techniques Section

# Understanding image defects (part 1)

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The ideal image of a star field has pin-point stars that are round and equally sharp across the entire field, with an evenly dark background, no out-of-place bright or dark pixels, and no ghosts, shadows, or unexplained illumination. There are many issues that can cause this ideal not to be achieved. In this and the following article, I will discuss how to diagnose and treat some of the common ones.

## Trailed stars

Trailed stars may result from imperfect polar alignment, drive errors, vibration from sources such as wind, or lack of rigidity in the optical train. The likelihood of errors becoming visible is dependent on focal length, pixel size (*i.e.* image scale) and exposure time. In the case of imperfect polar alignment or poor driving, you can compensate by using shorter exposures or reducing the focal length (which is done on refractors and Schmidt-Cassegrains using a focal reducer).

The route to obtaining good tracking begins with having a mount that is adequate for the telescope, which means it should be over-specified by the standards that telescope manufacturers usually recommend. With modern cameras, considerable success is possible on deep sky objects with a high surface brightness (such as planetary nebulae and globular clusters), using exposures as short as a few seconds and stacking many images. However, imaging of low surface brightness objects, such as diffuse nebulae and galaxies, requires exposures that last minutes. For this, there is still no good alternative to the German Equatorial Mount (GEM) and – if you are serious about this type of imaging – I recommend spending more on the mount than on the telescope.

The average tracking of a good GEM will exactly match sidereal rate (the rate of the Earth's rotation with respect to the 'fixed' stars), but mounts driven by the traditional worm-and-gear-wheel still have a small acceleration and deceleration with each turn of the worm, due to its being not quite circular – this is the periodic error. The best GEMs reduce this error to a few seconds of arc, which can be regarded as negligible except for focal lengths of over 2m.

Trailing can also be due to optics shifting in their cells (particularly a problem with SCTs), flexure, or loose coupling of components. Even if all these effects are eliminated, the sky itself produces an image shift: objects are increasingly refracted upwards as they approach the horizon.

The most precise tracking requires an autoguiding system, whereby an image of a guide star on a secondary detector is monitored on a short time cycle (a few seconds). Shifts in this star's position on the detector – too small to affect the main image – are used to generate a guiding signal that speeds up or slows down the mount, and nudges it in declination to keep the imaging on track. Autoguiding is not best used as a substitute for accurate polar alignment however, and periodic error correction (obtained by recording the worm error over a cycle and programming compensation into the control system) may be tried first.

## Blurred or distorted stars at the image edges

There are a number of possible effects in this category. Assuming you have achieved perfect focus at the image centre, if the stars go out of focus towards all the image edges symmetrically (yet remain round) you have field curvature. This is present in refractors (particularly faster ones: those with a focal ratio below *f*/8) and SCTs, always becoming more noticeable as the detector gets larger. It is corrected with a lens called a 'focal reducer' or 'field flattener' (the same lens normally having both effects). For optimum results, the flattener needs to be engineered to the specific telescope (though ×0.63 focal reduction is generic for those used with SCTs), and the flattener-to-detector distance needs to be correct. For most, 55mm is recommended, but error an of a few millimetres is probably not noticeably detrimental. If the flattening is not perfect, best results may be obtained with focusing that compromises between the centre and edges of the field.

An image of M31 provided by Ron Morley, where stars show different distortions in different corners. This was found to be due to use of a damaged diagonal prism unit in the imaging train.


**An imaging train for monochrome imaging with a short-focus refractor, incorporating a field flattener and tilt adjuster. All the components are threaded together, for rigidity.** ***David Arditti***

With Newtonians, particularly those faster than *f*/5, a different defect predominates: a comet-shaped distortion of stars at the edges of the field. This is coma, and again it becomes more of a problem with larger detectors, such as those in DSLRs. It is treated with a coma corrector, which again requires the appropriate lens-to-detector distance for optimum results. Coma correctors may slightly increase or decrease the effective focal ratio, and in practice there can be an issue with having enough inward travel on the Newtonian focuser. In theory, they correct perfectly only for one specific focal ratio, but in practice are quite good over a range.

It is often found, however, that star distortions are not symmetric across the image. Those in one corner of the image may be sharper than those in another corner, and stars in different parts may have distortions of different shapes. These effects (assuming the optics are well-made) are a consequence of miscollimation (misalignment) of some kind. If they are combined with slight star trailing, the situation may be confusing to diagnose.

If these errors cannot be eliminated by re-collimating the telescope, the fault will be that some other part of the imaging train is not square-on to the optical axis. The detectors in astronomical cameras can sometimes be misaligned, with resulting distortions that become visible at low focal ratios. If you wish to risk delving inside the camera (which might invalidate a warranty), the mounting of the detector is sometimes slightly adjustable with screws, You can also square the detector on using a camera tilt adjuster, which is a pair of threaded rings with push-pull adjustment screws, that is fitted into the imaging train immediately in front of the camera.