



Equipment & Techniques Section

Understanding image defects (part II)



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Hot, black & stuck pixels

Close examination of the image of M31 included in my last article shows, in addition to the distorted stars, some bright streaks only 1–2 pixels wide (2019 April, 71(2), p.71). These are due to ‘hot pixels’ in the camera detector: pixels that always give a high output even when little light falls on them.

Hot pixels are a fact of life in semiconductor arrays, with always a few even in the best and newest cameras. They have turned into streaks in this example because a number of sub-exposures (‘subs’) have been stacked and the stars have drifted slightly in the field, causing the hot pixels to move in the stacked image.

The reverse of a hot pixel is a ‘black’ or ‘dead’ one, giving very low or zero output. These tend not to be so noticeable in deep sky imaging, but they can occur. There are also ‘stuck’ or saturated pixels, which often result in coloured spots in DSLR images.

The effects of hot pixels can be minimised by subtracting from each of the subs (before stacking) the signal from every pixel, measured for the same exposure and temperature; with no light falling on the detector. This is known as dark frame (or dark field) subtraction. The dark frame used for the subtraction is, ideally, an average of many dark frames taken under the same conditions. Dark frames are taken with the telescope or lens aperture covered, or with the camera shutter closed. The optical system does not matter, as there is no light entering it; the process is merely a characterisation of the camera. Subtraction is done by specialist astro-imaging software – a free package that does this is *DeepSkyStacker* (for Windows).

Dark subtraction deals with hot pixels – and the amplifier glow that is visible on the detectors of DSLRs in long exposures – but black pixels will remain black. Additionally, if a stuck pixel

value is subtracted from itself, a dark hole or a coloured spot in the image will result; similar effects may also result from over-subtraction if the detector temperature changes. Temperature should not be an issue with most modern astro-cameras with fixed-point cooling, but it does affect DSLRs, which get hotter the longer they are used. Fortunately, slightly imperfect tracking reduces the visibility of these pixel irregularities, after the subs are stacked on the stars.

Once taken, dark frames for a particular exposure and temperature may be re-used, until the characteristics of the detector change with age.

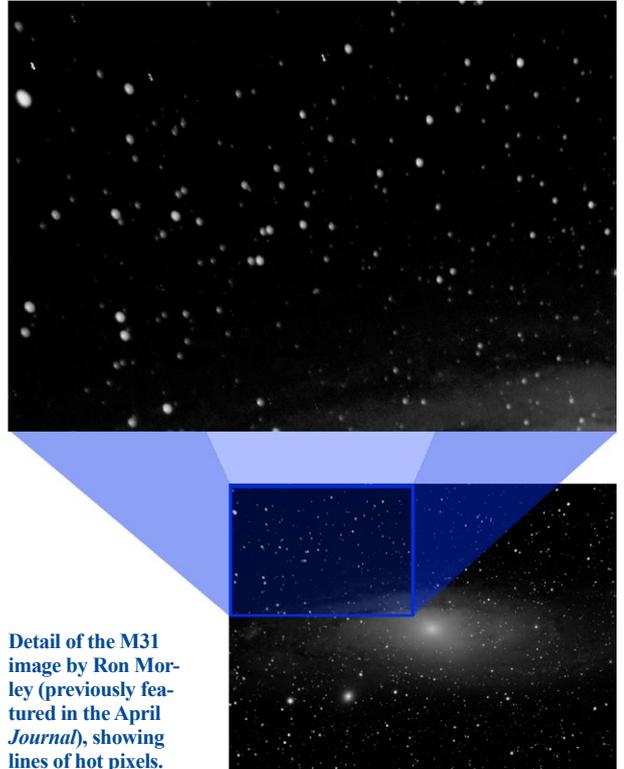
Gradients, vignetting & dust

The result of stacking long-exposure subs is an average image, with less noise than contained by the subs individually. The difference between the dimmest and brightest pixel values can be mapped, using image-processing software, to a far wider range of brightnesses in the final image.

There will be a floor level of brightness of the stacked image that is far above zero, due to skyglow and light pollution; this must be rendered close to zero in the final image. In fact, the statistical profile of images taken in a light-polluted location can often show only a small signal on a high base of pollution noise. Nevertheless, even these images can process well, provided the base to be removed is uniform. If parts of it are brighter than others, then gradients of sky brightness will remain in the final image.

Non-uniformity of illumination is due to parts of the detector toward the edges not having a light path from the whole aperture – this is known as ‘vignetting’. Dirt on the detector and other factors also reduce sensitivity in places. More complicated optical designs (such as Schmidt-Cassegrains) suffer more vignetting than simple lenses and refractors. Dust close to the detector (e.g. on filters) shows up on the image as a dark circle or – in telescopes with a secondary mirror – a ring/doughnut (a shadow of the aperture).

Vignetting, and all but the worst effects of contamination, can be dealt with by taking a flat field or frame. This is a very short exposure (a fraction of a sec-

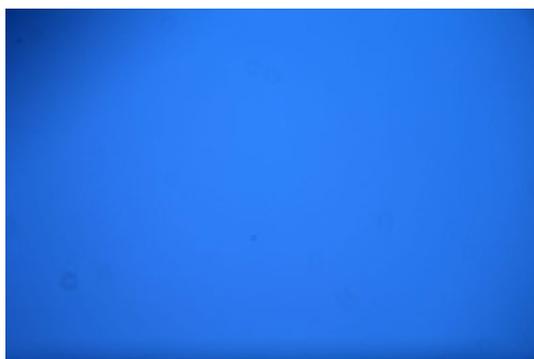


Detail of the M31 image by Ron Morley (previously featured in the April Journal), showing lines of hot pixels.

ond) with the aperture exposed to uniform illumination. Flat fields can be taken by imaging a cloudless twilight sky; covering the aperture with an illuminated diffusing cloth, or by using a specially constructed luminescent screen. As with dark frames, a good number needs to be taken (more than 10), to average out the response. The exposure needs to be chosen so the signal is high, but no pixels are saturated (over-exposed). Temperature is unimportant as exposure is short, but the optical system needs to be exactly the same as for the light frames: in focus, with the same filter.

Imaging software (*DeepSkyStacker*, *Astro-ImageJ*, *Nebulosity*, *Astroart*, *Maxim DL*, *Pix-Insight*, etc.) is used to divide the pixel values in each of the subs by the values in the average flat. This division by the arbitrary values in the flat evens out the response. The combined process of dark subtraction and flat division is known as ‘calibration’.

Flat-fielding also reduces the effects of black and stuck pixels. With colour cameras, it can additionally correct for a gradient of colour that may arise when light passes through a fast (low *f*/ratio) optical system and an interference filter (e.g. one made to suppress light pollution). It cannot, however, correct for gradients of illumination or colour that are due to the sky, such as light pollution approaching the horizon or moonlight. Processing software can help with this, notably Russell Croman’s *Photoshop* plugin *GradientXterminator*. 



Flat field (average of 32 frames) taken on a twilight sky by a DSLR on a 254mm Newtonian, showing typical vignetting and dust effects.