WEBCAMS UNDER THE SPOTLIGHT

MEASURING THE KEY PERFORMANCE CHARACTERISTICS
OF A WEBCAM BASED IMAGER

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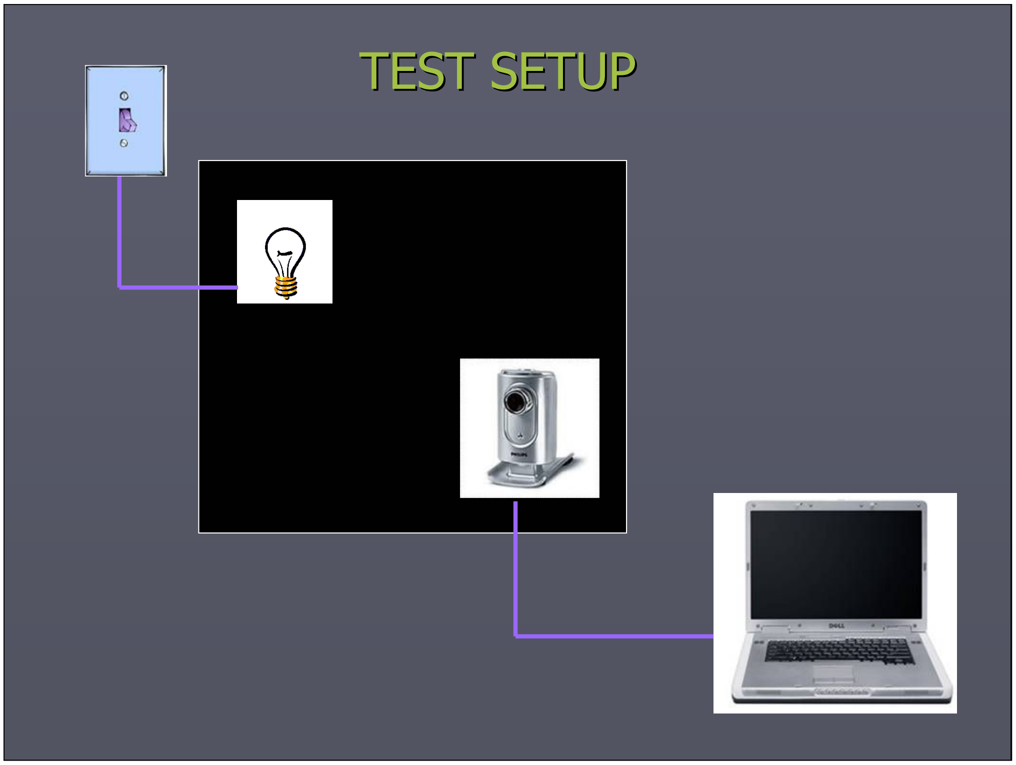
If a camera is going to be used for scientific measurements, it is important to know the linearity, gain and noise characteristics. Understanding these parameters can also help in getting the best images.

Unfortunately, while most astro-camera manufacturers publish these figures, we have little knowledge about these important values for webcam based imagers.

This presentation describes how these have been measured using simple equipment, for a B+W SC3 long exposure and RAW firmware modified Vesta webcam.

Examples are given of how these results can be applied to get the best out of the camera for both imaging and scientific applications.

The presentation finishes off with some examples of photometry, spectroscopy and spectroheligraphy using webcam based imagers

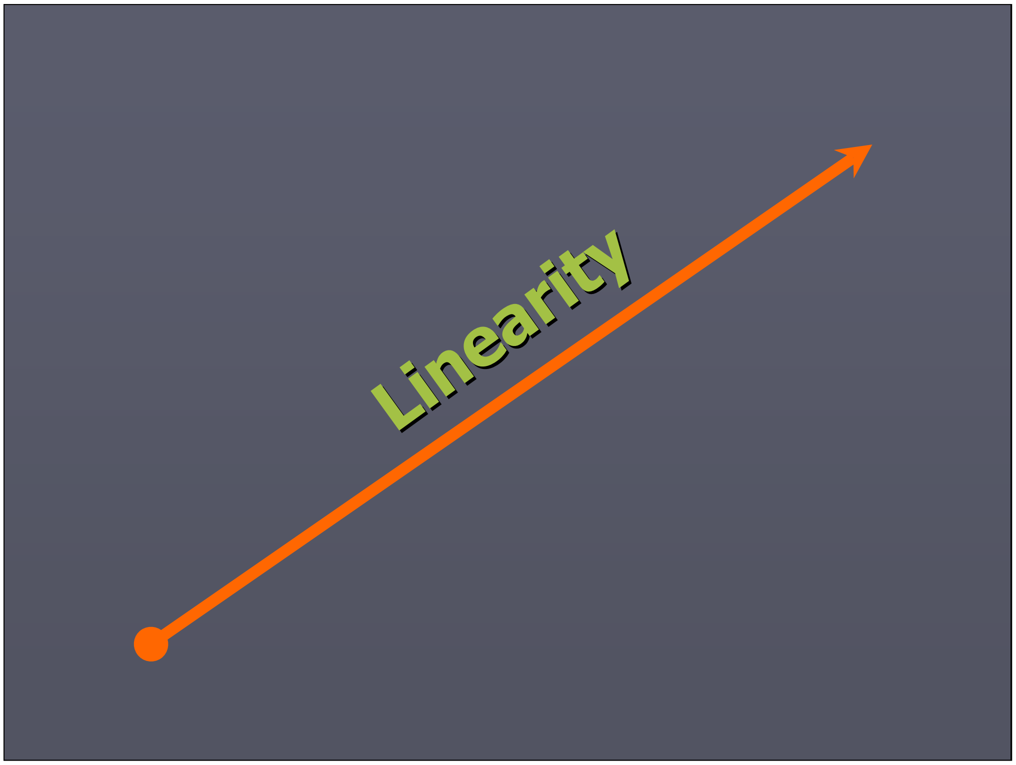


The test setup consisted of a light tight box containing the webcam and a very dim light source wit ha means of switching it on and off and varying the light output. (Long exposures of several seconds are used for the measurements)

The illumination of the CCD should be reasonably even but this is not critical. It was achieved in this case by removing the webcam lens, using translucent sheets of paper and reflecting the light off the walls and baffles placed in the box. The intensity of the light is not changed during a measurement run and so, although a rheostat type of system could be used to vary the light output, in practise the required light level was set for each run by altering the geometry of the light baffles.

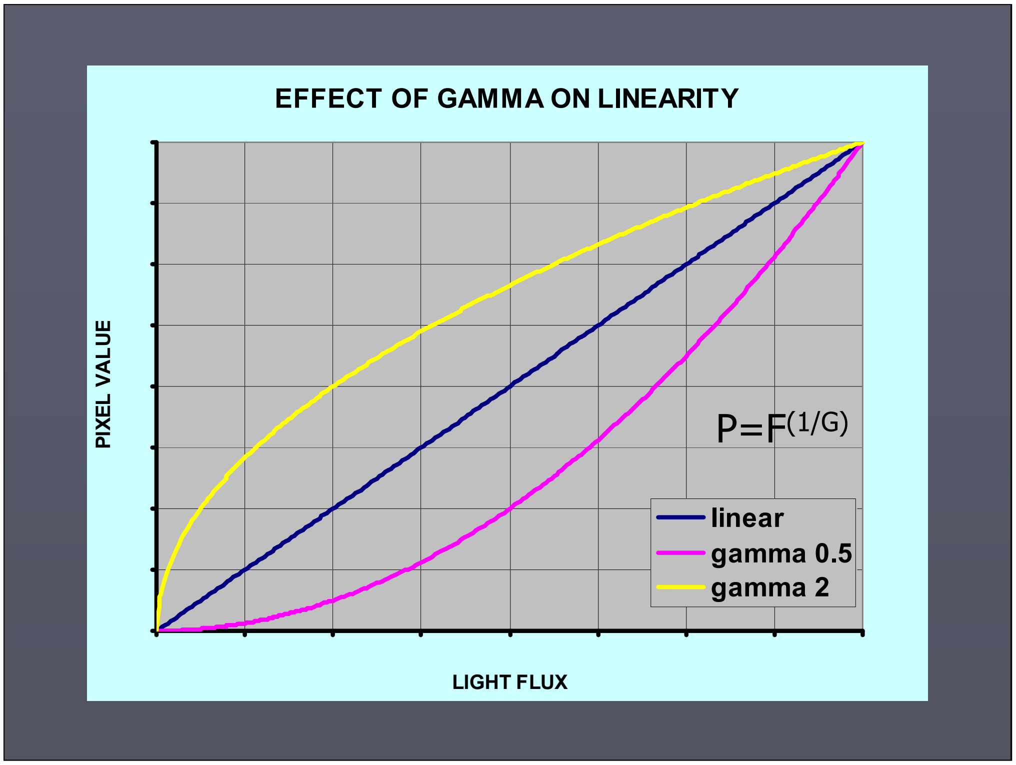
K3CCDtools software was used as the capture program and WcCtrl software was used to adjust and log the camera settings.

The images were measured using Teleauto software (A 100x100 pixel region to the bottom right of the image, free of hot pixels and away from potential amp glow problems was used)



The first parameter to be measured was linearity – the output of the camera relative to the amount of illumination.

Ideally the output should be proportional to the illumination. ie a graph of mean pixel brightness against the amount of light falling on the CCD should be a straight line and the pixel brightness should be zero when the there is no light.



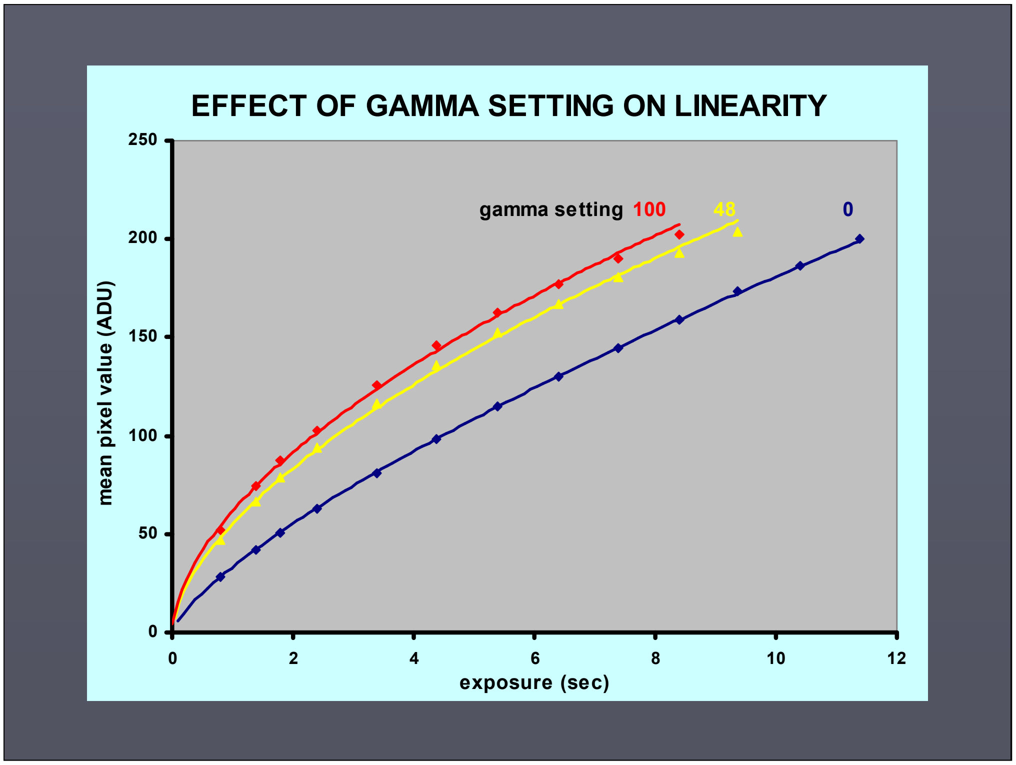
Unlike astro cameras which are normally designed to be as linear as possible, webcams have an adjustment specifically designed to make the camera non linear ie the gamma adjustment.

The gamma setting alters the relationship between the amount of light and the pixel value recorded. There are various ways of defining gamma but I have used the commonly found equation shown on the slide, with the addition of a scaling factor to keep the maximum value constant (eg 255) independent of gamma.

The effect of high gamma is to enhance the low brightnesses while compressing the higher levels. This can be of value to make the most of the limited dynamic range of 8 bit webcam based cameras when imaging faint deep sky objects where the wanted detail may be in the darker parts of the image.

The reverse is true for low gamma settings which are often used in planetary imaging to ensure that the brighter levels on the planet surface are enhanced while minimising the number of levels dedicated to recording the dark background sky.

Accurate photometric measurements and correct dark and flat compensation in imaging however depend on having a linear response.



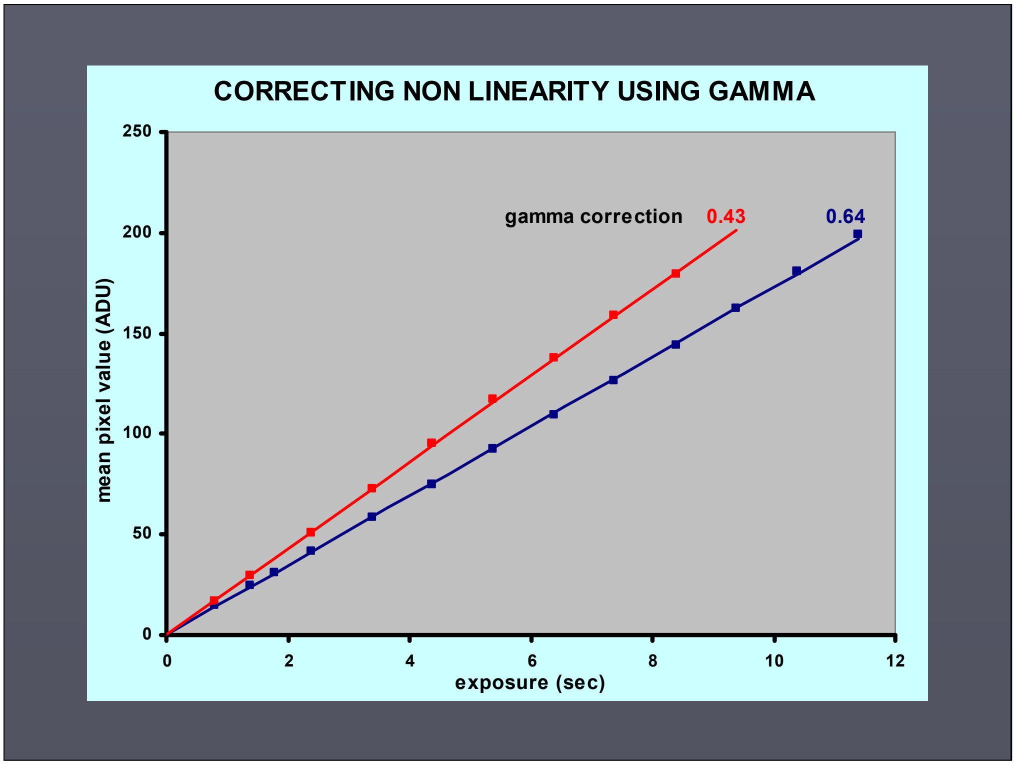
Linearity was measured by taking a series of exposures of different lengths with the light at constant brightness (light). The camera output at zero light levels (dark) was also recorded for each exposure time and subtracted from the corresponding light.

NOTE: The brightness level was carefully adjusted so that the minimum value on the individual dark frames was always just above zero as recorded by the k3CCDtools histogram bar. this was important to ensure all the camera signal was being recorded

10 repeat subframes were stacked for each exposure and the mean pixel value for the same 100x100 pixel area of the stack was measured.

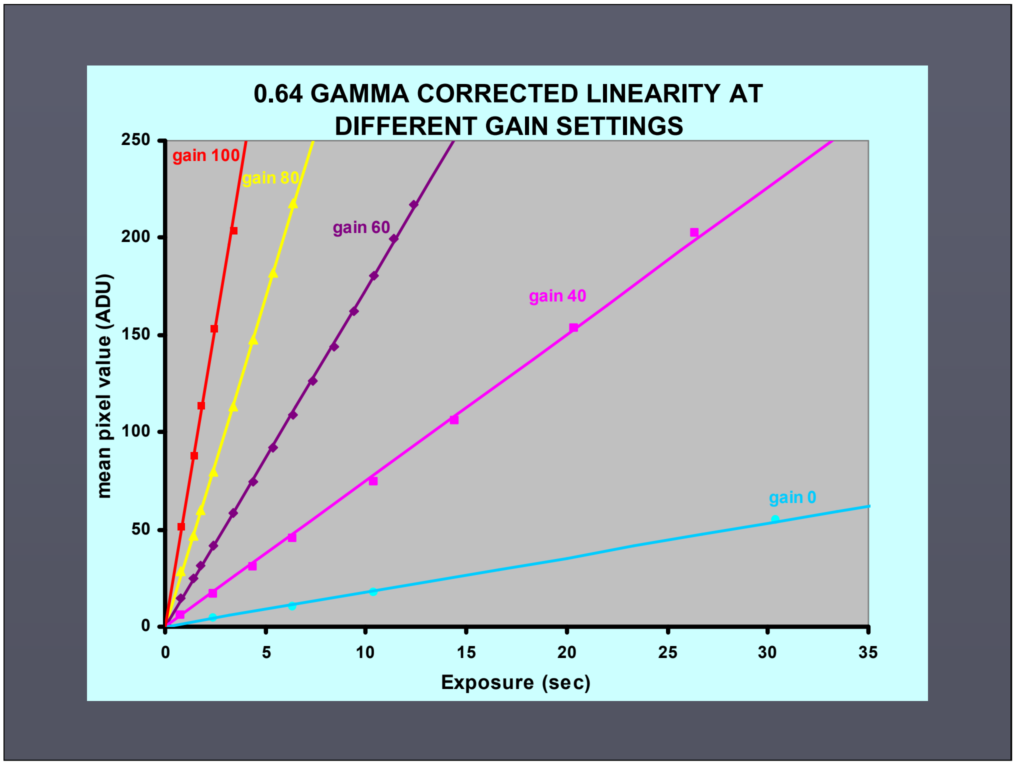
The graph shows the results for various gamma settings (gain setting 60)

It is immediately apparent that even at the lowest gamma setting, the camera response is significantly non linear, corresponding to a gamma value >1



By applying an inverse gamma correction to the images (both dark and light) it proved possible to correct the response of the camera to produce a linear result at any given gamma setting.

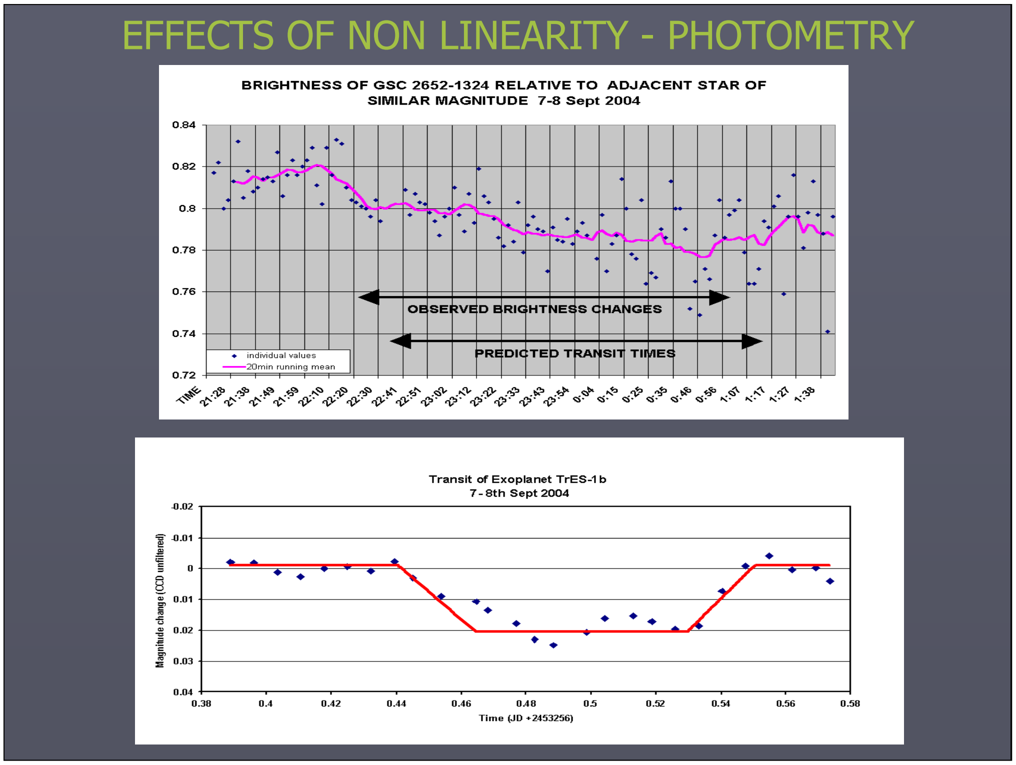
The graph shows the required correction at 0 and 100 gamma setting and reveals that, apart from the deliberate internal gamma adjustment, the camera is remarkably linear over the measured pixel range.



To test whether this result was true for all gain settings, a set of runs was made at 0 gamma and for a range of gains.

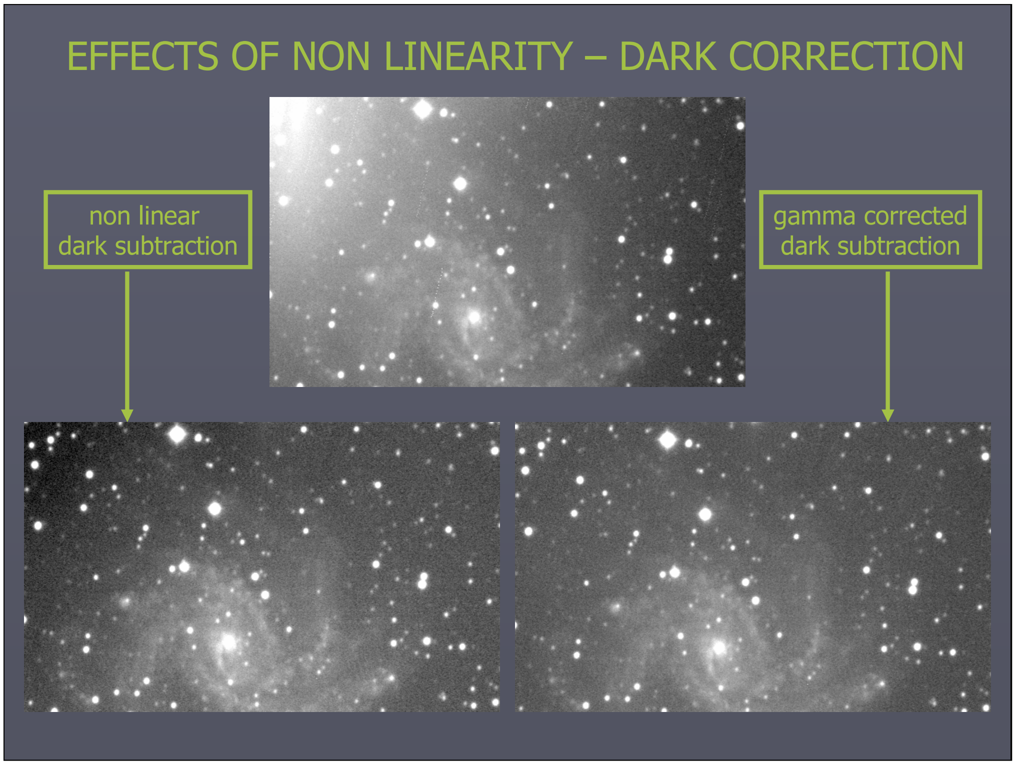
After applying the required gamma correction, the camera output proved to be linear for all gain setings.

NOTE: It would be useful if the gamma setting could be accessed and adjusted in firmware to give a linear output – a job for the TWIRG group perhaps



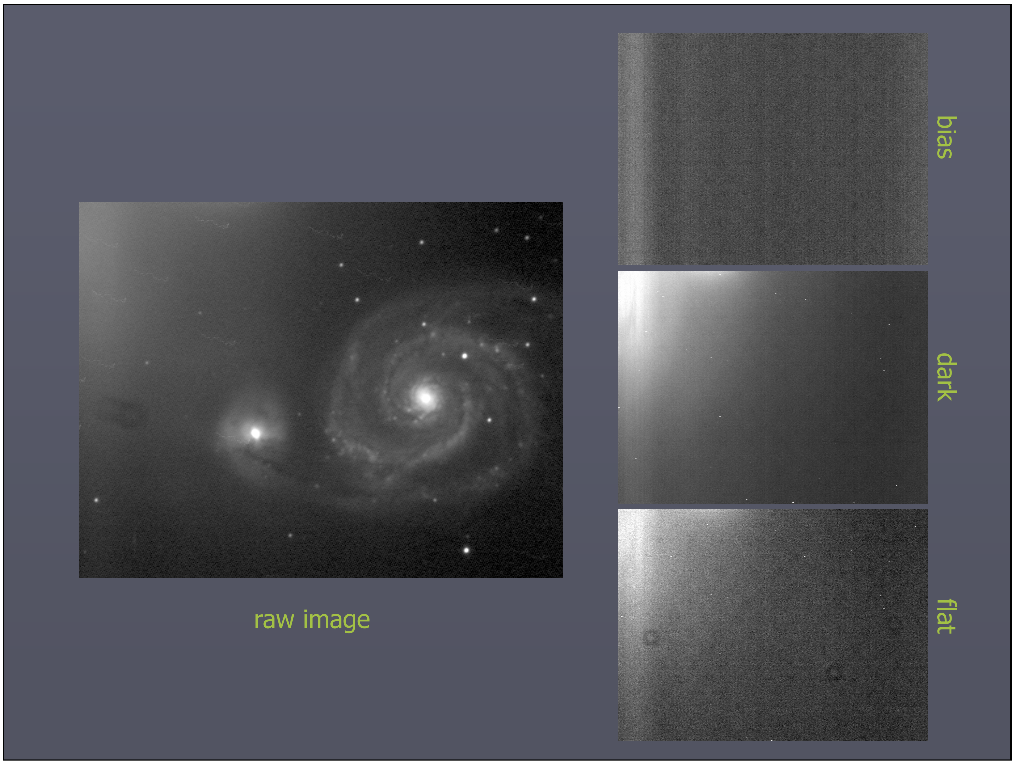
As an example of the effect of improved linearity on scientific measurements, consider a high precision photometry application such as exoplanet transits which require a precision of better than 10mmag for periods of several hours during changes in object altitude and sky conditions.

While the technique of differential photometry (comparing the target with a nearby star of known brightness) can help eliminate many errors, at this level of precision, the effect of non linearity as the star brightnesses move up and down the camera response curve can lead to significant drifts, masking the transit (upper graph) After correcting for non linearity, the drift disappears and the dip as the planet transits the star becomes clear.



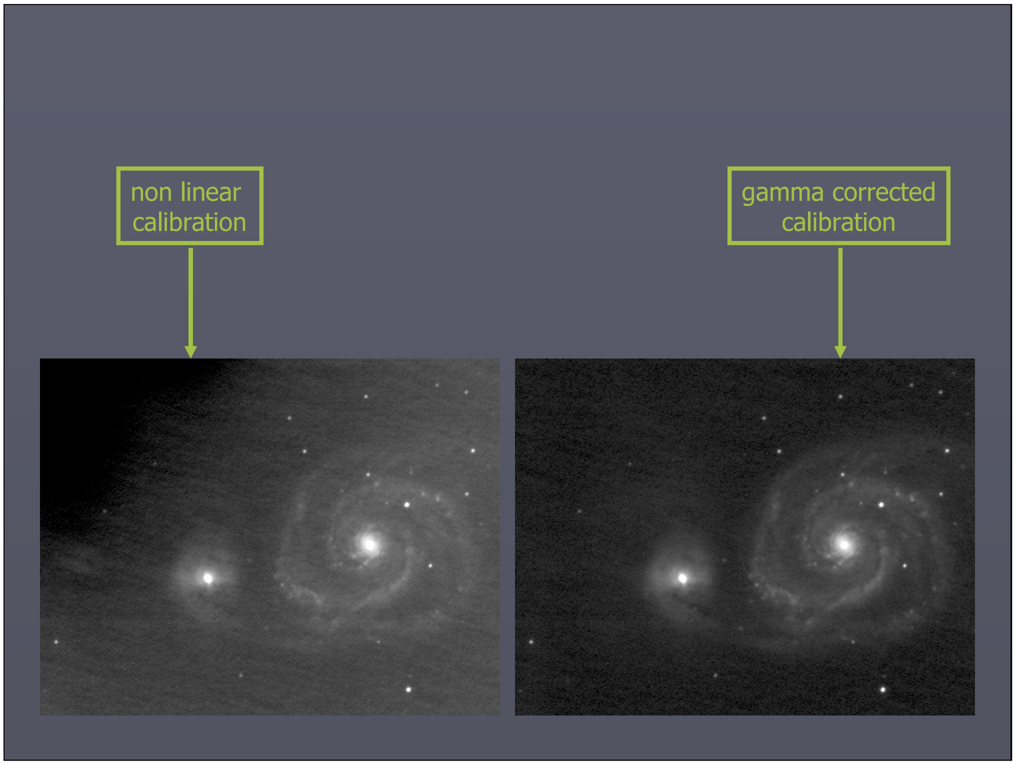
Similarly, non linearity can affect the correction of images for darks and flats.

Here in this long exposure image of NGC6946, the dark correction overcorrects the amp glow in the top left hand corner, leaving it too dark. Linearising the images before correction produces a much more even background.



This is another example (M51) where bias (short exposure dark) dark and flat fields have also been taken.

NOTE To produce a “worst case” situation, maximum gamma setting was used, the CCD was deliberately left dusty and the image was taken at twilight during a full moon!



The background is noisy in both calibrated images due to a noisy flat (taken, using the T shirt technique, too late in the fading twilight) The beneficial effects of linearity correction on the amp glow and dust donuts are still clear however.

NOTE: For the linearity correction to work, it is important that the black levels are not clipped in any of the the images. ie the minimum pixel value in the bias (or dark if bias are not taken) must be above zero