Determining the Aesthetic Appeal of Astronomical Images

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See <www.mitpressjournals.org/toc/leon/48/1> for supplemental files associated with this issue.

Submitted: 4 December 2013

Abstract

In the context of images used for astronomy education and outreach purposes, this paper describes a set of parameters that are key in determining the aesthetic appeal, or beauty — and therefore effectiveness— of an astronomical image.

Keywords: astronomy, beauty, engagement

The importance of images in the public communication of astronomy can hardly be overstated [1]. Images are not just a means of visual communication. They can inspire awe, wonder and enthusiasm, and are a perfect way to portray the Universe as a fascinating place. Producing engaging astronomical images with aesthetic appeal or beauty is, thus, an important objective for astronomical communicators. If we can determine the parameters that influence how well an image is received by the viewer, it becomes easier to produce higher-quality images and it becomes possible for a wider range of people and observatories to produce them as well.

Based on the experience of composing almost 1000 outreach images from raw data from ESO's telescopes and the NASA/ESA Hubble Space Telescope, we propose that six parameters are key in determining the aesthetic appeal of an astronomical color image: photogenic resolution, definition (or structure or contrast), color, composition, signal-to-noise ratio, and the quality of removal of instrumental artifacts.

Photogenic Resolution

Early marketing for consumer digital cameras often concentrated on the total number of pixels in the detector, and hence in the resultant photographs. A larger number of "megapixels" is often considered to indicate a better camera, taking better photographs. However, in real life there are other limiting technical factors such as the quality of the camera's optics and the blurring of the images by the atmospheric turbulence (which also manifests itself in the twinkling of stars at night due to atmospheric scattering or the flickering of distant objects in the daytime due to heat haze).

The real factor that limits the aesthetics of an image is the photogenic resolution, r_{photo} — the number of effective resolution elements (the size of the finest feature that can be resolved) across the field of view (FOV): $r_{photo} = FOV/\theta_{effective}$ where $\theta_{effective}$ is the effective angular size of the smallest resolved detail — that is, the size of a star in the image. For an astronomical image, one can simplistically view this as the highest number of stars (considered to be point sources) that can fit side by side across the field of view.

In our experience, for an image to look impressive, the photogenic resolution should be larger than of order 1000. For instance, the MPG/ESO 2.2-metre telescope's Wide Field Imager (2.2-m/WFI) can produce individual images with $r_{photo} > 2000$, as can the Wide Field Channel of Hubble's Advanced Camera for Surveys (HST/ACS-WFC).

It is insightful to examine the photogenic resolution by plotting the field of view against the effective angular resolution (Figure 1 [2]). In this plot, lines of constant photogenic resolution form diagonal lines, and examples are shown from $r_{photo} = 10$ (lower left) to 10 000 (upper right).

Definition

Even if an image has a very high photogenic resolution, its content is still the most important factor. The frame of the image needs to be filled with an object of interesting structure, such as a galaxy or a nebula. And definition, or contrast, in the interesting parts of that object is our second key parameter in the aesthetic appeal of an astronomical image.

The definition is fixed in the representation of the dynamic range, defined as the ratio between the maximum and minimum values of a physical measurement [3]. In an astronomical image, the highest values are typically reached by bright stars, while the minimum value corresponds to the dark sky. A nice — but faint — nebula will cover a large section of the image, but at very low brightness.

The definition is adjusted during image processing where the original high dynamic range FITS data [4] are mapped to the (often more limited) range of pixel values that can be shown in the outreach image. This is done with the help of a stretch function. The choice of stretch function to reach a good contrast depends greatly on the difference in brightness between the different interesting parts of the images. Typically, a galaxy will need a highly non-linear stretch to reach a good contrast, because of the

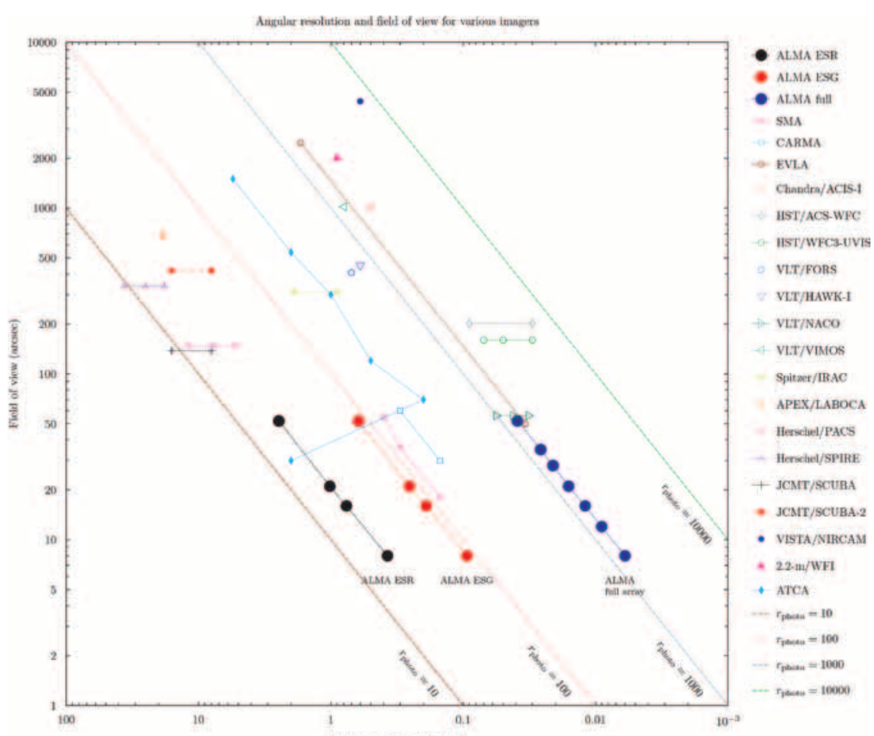

Fig. 1: Effective angular resolution plotted against the field of view for a selection of different imagers. The diagonal lines mark constant photogenic resolutions. (© Lars Lindberg Christensen)

 doi:10.1162/LEON_a_00900

high dynamic range between the bright centre and the fainter outer areas. Without adjusting the dynamic range, most astronomical images would just show some saturated highlights in a very dark image, similar to taking a portrait against a background sunset.

Color

Images of astronomical objects are usually taken with electronic detectors such as charged coupled devices (CCDs) or infrared array, somewhat similar to those found in digital cameras.

These detectors collect the light and measure its intensity in each pixel, but do not give any information on the color of the light. Color outreach images are composited by taking individual greyscale exposures through filters, colorising them and "stacking" them together. In principle, three 16-bit greyscale images obtained through red, green, and blue filters can create a color image with 281 trillion colors.

The more separated the wavelengths of the chosen filters are, the more colorful and appealing the resulting composite will be. Also, the better the filter set is at sampling the observed wavelength range, the more colorful the result will be. In the visible range, for example, the use of B (blue), V (green) and R (red) filters ensures a good coverage of the visible spectrum (blue to red), samples a typical (e.g. G dwarf) stellar blackbody well (on both sides of the peak), and produces an image with a wide separation of colors (or color gamut).

Composition

To obtain a pleasing composition and not waste photogenic resolution, the object should fill as much of the field of view as possible. In practice, the size of an astronomical object is fixed, as is the field of view of an instrument, so matching size and field of view can only be done by selecting the subject: many very nice objects are either too small or too large for a given instrument.

As a very large fraction of the astronomical data used in outreach images were originally acquired for scientific purpose, the outreach image composition is most often decided in the very last phase when the color composite is done, just before the image is ready for publication. Since most producers of outreach images at observatories produce the "raw material" for others to use — journalists, text book writers and movie directors — one can argue that the images should, in principle, be cropped wider rather than tighter, leaving the final composition to the user's preference. Speaking against this, however, many of these recipients do not have the means to process or even crop large astronomical images efficiently. Moreover, the resolution of images published today needs to be compatible with both large and very small devices. This suggests a need to deliver a final "perfect composition".

Signal-to-Noise ratio

While the overall contrast, or definition, of an image is a concept that applies globally to the entire image, the signal-to-noise ratio applies to individual regions of an image, down to the individual pixels. The noise is random variations of the light level from one pixel to the next, which occur even if the illumination of these pixels is similar. It is not an instrumental effect, and cannot be corrected for. The noise is inherent to the nature of light, and the only solution to get a good signal-to-noise ratio or "depth" of an image is to collect more light, i.e. to use a larger telescope, or to increase the duration (or the total number) of the exposures. Access to a large telescope is very restricted, so the signal-to-noise ratio of the fainter regions of an object is not always optimal. Sophisticated noise reduction algorithms such as those found in software packages like Photoshop, or in plug-ins like Topaz DeNoise, Noise Ninja or Neat Image, can be applied to mitigate the noise during the last stages of graphical processing, but noise removal can never be perfect and should not come at the price of loss of details, sharpness, and resolution, or introduction of unphysical artifacts.

Removal of Artifacts

Experience shows that one of the things that disturbs the viewing pleasure for members of the public are residual artifacts from the sensor or the telescope. The rule of thumb is simple: while scientists may be able to concentrate only on the parts of the data that are relevant to them, ignoring artifacts, members of the public will focus on anything non-cosmic! All artifacts must be removed in order to not distract the eye, disturb the aesthetic appeal, or waste the audience's finite attention on aspects of the image that are not part of the scientific outreach message. Most of the artifacts can be removed algorithmically in the level of the astronomical processing of the FITS image, but some will make their way to the final image, and must be corrected at that stage (sometimes to the order of one or two hundred hours of manual cleaning work for a large image) [5].

Conclusion

Turning raw data into aesthetic pictures takes real effort: planning, astronomical insight, technical insight, graphical insight and dedication. It is proposed here that at least six main parameters contribute to an astronomical picture's aesthetic appeal. If you know how to control these six parameters well, know your telescope and data, and are prepared to spend the necessary time on finding your image's niche within this six-parameter space and on finding workarounds and compromises for datasets that are not optimal, we claim that any telescope/imager can deliver aesthetically pleasing astronomical images.

References and Notes

* This article is based on a presentation given at the conference Images and Visualisation: Imaging Technology, Truth and Trust, held 17–21 September 2012 in Norrköping, Sweden.

1. A more detailed version of this paper is in preparation for *Communicating Astronomy with the Public Journal*.

2. Douglas Pierce-Price, Olivier R. Hainaut, and Lars Lindberg Christensen, *ALMA's potential for visually impressive outreach images* (Internal ESO/ALMA outreach report, 2011)

3. For comparison, the dynamic range of the human eye without any pupillary adjustment is 1000–10 000. In deep astronomical images the dynamic ranges can reach 10 000. Typical computer screens or printers can only show a dynamic range of 700–1000.

4. See <http://en.wikipedia.org/wiki/High_dynamic_range_imaging>, first accessed 1 July 2011.

5. Olivier R. Hainaut (2009), *Retouching of astronomical data for the production of outreach images* <http://www.eso.org/~ohainaut/images/imageProc.html>, accessed 1 January 2010.