Software for producing trichromatic images in astronomy

Sébastien Morel¹,² and Emmanuel Davoust¹

¹: UA 285, Observatoire Midi-Pyrénées, 14 Avenue Belin, F-31400 Toulouse, France
²: Ecole Supérieure d'Electricité, 2 rue Belin, F-57078 Metz Cedex 3, France

(Received 22 August 1994; accepted 6 June 1995)

Abstract. We present a software package for combining three monochromatic images of an astronomical object into a trichromatic color image. We first discuss the meaning of “true” colors in astronomical images. We then describe the different steps of our method; choosing the relevant dynamic intensity range in each filter, inventorying the different colors, optimizing the color map, modifying the balance of colors, and enhancing contrasts at low intensity levels. While the first steps are automatic, the last two are interactive.

1. Introduction

False-color images of astronomical objects, where different colors represent only different intensity levels in the image, are extremely common in the literature. They allow a much larger dynamic range in intensity to be displayed than, for example, grey-scale images. These images, of course, do not tell us anything about the colors of the objects.

On the contrary, “true” color images of astronomical objects, as they would be seen through the telescope, were the eye sensitive enough, are still quite rare. Astronomers have shown very little interest in producing such images; they prefer quantitative measures, such as (B - V) color index maps, for example. The main reason probably is that the true colors of a planetary nebula or of a galaxy do not really mean anything, as they cannot be related to anything comparable on Earth. Another reason is that large telescopes no longer have eye-pieces through which one can gaze at the sky; they have conveniently been replaced by highly sensitive video or CCD cameras that allow astronomers to view the sky from their armchair, but in black-and-white, and they no longer know what the colors are.

One major exception is the solar system, as colors of planets can often be discerned at the telescope; these colors can also be related to the colors of the ground on Earth. The Voyager images of the solar system are in colors that match what we would see from close up. Another remarkable exception is Jim Wray’s Color Atlas of galaxies (1988), which provides color images of over 900 galaxies, based on photographs taken in the (U, B, V) system. This atlas could very well be a reference for what galaxies should look like in colors, if the advent of CCD cameras had not shifted the standard filters toward the red, where these receivers are most sensitive. Finally, we should mention the growing interest of amateur astronomers; popular astronomy journals often display their successful attempts at taking color photographs of heavenly bodies.

Since color images of the sky by professional astronomers are now beginning to appear in the media, for example HST’s first “corrected” view of M 100, computer programs for producing these color images must exist. But, surprisingly, very little information on the subject has appeared in the literature.
astronomical literature. The present paper is meant to fill this gap, and provides a general view of the subject, together with a detailed description of our method. We recommend that experts in image treatment go directly to Sections 6, 7, and 9, which contain the most original work.

2. The meaning of “true” colors

There are several methods for producing color images. In one method, HSI, the color of each image pixel is defined by its Hue (the color’s peak wavelength), Saturation (the hue’s purity) and Intensity. In another, RGB, the image is decomposed into three primary colors, Red, Green and Blue. The colors perceived by the human eye can largely be reproduced by the combination of three primary colors (for a non-technical presentation of color perception of the eye, see Robertson, 1992), and, for this reason, this method is used in computer and television color screens. This is also the method adopted here.

A first problem, when aiming at obtaining “true” color images by this method, is that the combination of filter transmission and camera spectral response used in astronomy does not necessarily match those used, say, by camcorders to successfully reproduce scenes in colors. One could, of course, imagine some kind of color equations to go from one system of filters to the other, but these equations would obviously depend on the nature of the object.

Another problem arises for emission-line objects. Because there is overlap in the domains of sensitivity of the three kinds of cones in the human eye, it is capable of perceiving the color of monochromatic objects to a certain extent. This is not the case for the set of wide-band filters commonly used in astronomy; one has to use images taken with narrow-band filters to reproduce the colors of monochromatic objects properly. This is why diffuse emission nebulae and planetary nebulae are tricky objects to reproduce in colors. Any amateur (or old professional) astronomer will tell you that the Orion nebula is greenish; but how many times have you seen it displayed in different shades of pink or red, simply because the [OIII] emission at 5007Å falls in between two wide-band filters!

In short, it is probably illusory to try and reproduce the true colors of astronomical objects for the time being.

Incidentally, in this paper a monochromatic image is an image obtained using a filter of any width, as opposed to a trichromatic image, while a monochromatic object is one that mainly emits one or several emission lines.

The next best thing that one can do is to produce the colors of the objects as they would be seen if our eyes had the same spectral response as the combination of camera and filter set used. This amounts to calibrating the relative intensities in the three monochromatic images, for example by measuring the response of the receiver to a source of given uniform (white) intensity seen through each of the three filters, and then correcting two of the three monochromatic images accordingly.

But this method, which is still realistic, will lead to disappointing results, because the colors of astronomical objects are mostly unsaturated, and their color images tend to be very pale; this is also true for many emission-line objects, as they tend to be immersed in white stellar light. For the whole truth about stellar colors, we refer to Steffey (1992). This is what we experienced with galaxies; calibrating monochromatic images with published aperture photometry of the object does not give aesthetically pleasing results. Furthermore, galaxies have such a large dynamic range that the outer parts of disks of spiral galaxies are barely perceptible, or else the central regions are completely overexposed and white.