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Imaging planets from imaginary worlds

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The planets in our solar system are remarkable and captivating objects for beginning astronomers to study. While merely observing the planets is fairly easy, it can be difficult to capture the high-quality images beginners hope for. The methods used for deep-sky astrophotography are optimized for dim, fairly large objects using large apertures and long exposure times. These tools do not work nearly as well for the planets, which have the reverse properties: they are bright and very small. As such, the planets can serve as great teaching tools for capturing astronomical images, using software processing tools, and understanding the role of angular size in a flat image. In this paper, we will explain how to implement "Lucky Imaging,"[1] a simple but powerful process for photographing the planets. World-class facilities use Lucky Imaging in conjunction with adaptive optics,[2] but we will show how you can achieve striking telescopic images with only a commonly available smartphone. We will show an example of how this tool can be combined with an image processing tool like PhotoShop to create imaginative images of what the planets might look like if Earth were in a different place. These tasks also enable the students to grapple with the implications of the fact that we perceive angular size rather than linear size.

The small angular size of the planets poses unique challenges for the student astrophotographer. Saturn's rings, at their widest, span only about 40 arcseconds. Jupiter at its widest only spans about 50 arcseconds. Turbulence in Earth's atmosphere can effectively hide the details of these planets, making images look blurry, unsatisfying, and discouraging to beginning astronomers. Although an 8-in (200-mm) reflecting telescope would be expected to have a limiting resolution at the Rayleigh criterion of half an arcsecond, poor atmospheric seeing effectively limits the resolving power of the telescope to more than five times that.

The Lucky Imaging technique is a clever means of using the speed of modern cameras to reduce the effects of atmospheric turbulence. It is based on a simple premise: the atmospheric distortion in images will be statistically random. This means that each time an image is taken, there is a small chance that it will hardly be distorted at all. You can take advantage of this fact by capturing hundreds or thousands of images of the same target, knowing that a small percentage of them will be much less distorted than the rest. Once you have many images, you can select and average the best of them into a single image, discarding the more heavily distorted shots. This technique has been used to study exoplanets,[3] for solar imaging,[4] and even to improve spectrographic images.[5-6]

Students may expect it to be tedious and excessive to capture thousands of images and select only the best ones. However, almost every modern smartphone has a camera suitable for this purpose, and there are free software packages for Windows that automate the processing. Every iPhone released since 2014 is capable of capturing high-speed video at 240 frames per second.[7] Although it can be quite challenging to align a small smartphone camera lens with a telescope eyepiece and hold it in place, the high-speed video feature makes it possible to capture thousands of frames in just a few seconds, and since the frames that survive the selection process will be aligned and combined in a computer, it is not necessary to hold the device steady. It should be noted that the autofocus feature of the phone camera will not, in general, be helpful.[8]

Figure 1 shows a single frame of Saturn captured with high-speed video from an iPhone 8 Plus through an 8-in reflecting telescope with a 2x Barlow lens and a 12-mm eyepiece. The phone was set to capture 240 fps video at 720p resolution. We include this image primarily to contrast with the final image that Lucky Imaging will produce.

A free Windows-based program called Planetary Imaging PreProcessor (PIPP)[9] can be used to roughly center Saturn in the frames of the video, reducing the impact of camera shake and drift. PIPP also crops most of the black background out

Fig. 1. Single-frame 4-ms image of Saturn, imaged from Greensboro, NC, on April 5, 2018, 10:28 UTC. Image taken with an iPhone 8 Plus and the Procam App through an 8-in f/10 Meade LX200 telescope with a 2x Barlow and a 12-mm eyepiece. Although the planet and its rings are clearly distinguished, the image is blurry and lacks detail.

Fig. 2. Result of Lucky Imaging technique when applied to 500 frames similar to the image shown in Fig. 1, rejecting 1900 other frames in the 10-s movie file. Gaps in the rings become visible, as well as the shadow of the planet on the rings behind it.

of the image and performs various image quality corrections. The next steps are to more precisely align the frames, select the "best frames," and stack them into a single image. A commonly used tool for these steps is a Windows-based program called RegiStax.[10-11] RegiStax allows the user to select a method for assessing the quality of the images and choosing only the best frames to process.[12] The user then selects up to 500 points around the features of the planet, and RegiStax will identify these features in each image, align the images, and average them to create a single, final image. Figure 2 shows the result of stacking 500 images culled from roughly 2400 frames of the high-speed iPhone movie. In comparison to Fig. 1, the image is far crisper, and details such as the gaps in the rings and the shadow of the planet on the back side of the rings are clearly evident.

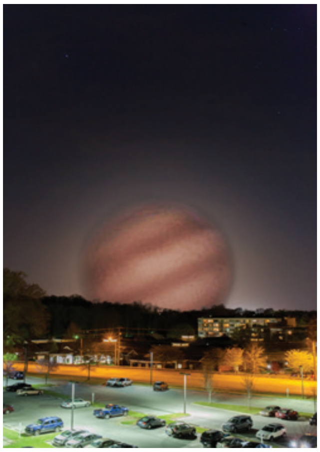

Fig. 3. A setting Jupiter, as seen from a hypothetical Earth at the location of the moon Io. The image of the planet was created using the Lucky Imaging technique and composited into the parking lot landscape using Adobe Photoshop. Shining haze around the planet was added for aesthetic effect.

Lucky Imaging allows a beginner to capture beautiful images of the planets without the need for an expensive camera or even a very large telescope: an ideal situation for beginners and students. The ability to create high-quality images of planets can encourage students to dive deeper into astronomy and astrophotography. In particular, once you have a high-quality image like that shown in Fig. 2, you could combine this image with others to help students understand the nature of angular size and expand their imagination for how the skies on other worlds might look.

Students often struggle to understand that perceived sizes are angular, even when looking at a flat photograph. Since the distances from the camera to the objects displayed in the photo are often unknown, particularly in astrophotography, beginners don't realize how much they intuit sizes from comparison between objects in the field. Many optical illusions, including the famous Moon illusion,[13] rely on our brains' propensity for inferring linear size from perceived angular size.[14-15] Once students have used Lucky Imaging to construct a striking image of a solar system planet, they can explore angular size (and the implications of geometric optics in cameras) by compositing this image onto a familiar background landscape to represent how the planet would look if Earth were in a different location.

Fig. 4. The Lucky Imaging version of Saturn (same as in Fig. 2), as it might be seen in an observing session on Rhea. The dome of Guilford College's Cline Observatory is shown in the foreground.

Figures 3 and 4 show such imaginary alterna-terrestrial landscapes for Lucky Images of Jupiter and Saturn, respectively (the image of Saturn in Fig. 4 is the same image shown in Fig. 2). Figure 3 demonstrates how Jupiter would look, setting beyond a Guilford College parking lot, if Earth were orbiting Jupiter at the distance of Io. Jupiter would take up roughly 19° in the sky if seen from Io, and since the parking lot image was recorded through a full-frame Canon DSLR with a 40-mm camera lens, the angular size of the horizontal image length is about 33°.[16] Jupiter's diameter should therefore fill 63% of the width of the image, and this width is shown in Fig. 3, as the planet looms over the foreground cars. Similarly, Fig. 4 shows Saturn composited at an angular size of 29°, floating above the Cline Observatory dome, as it would if Earth were orbiting Saturn at the distance of the moon Rhea. Creating a fanciful, yet geometrically accurate, landscape can be a wonderful gateway into the world of astrophotography for beginners and students alike.

References

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