Understanding Astro-Photos

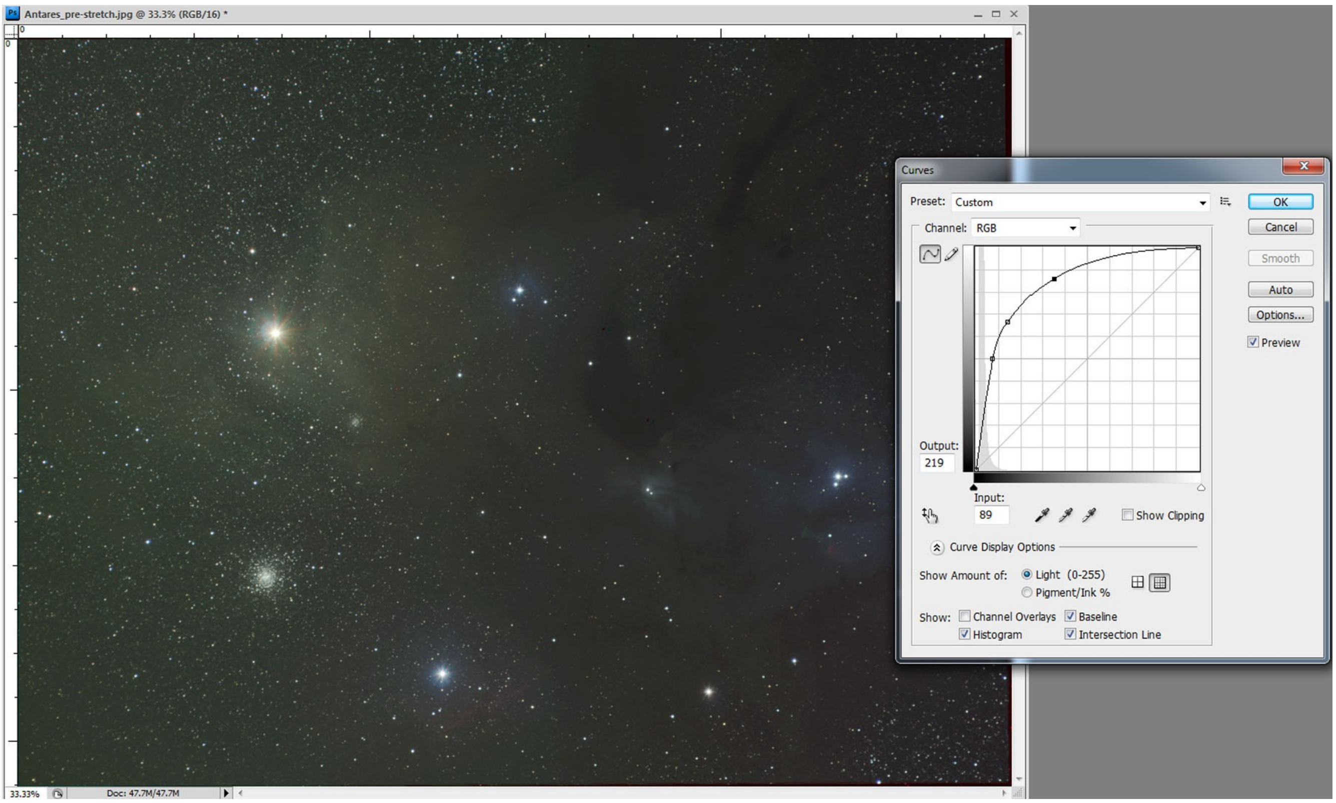
Part 1: Deep-Space Objects (DSOs)

Greg Marshall, Wa-chur-ed Observatory

The most common misconception about astro-photography is that it requires a "powerful" telescope. That is, something that provides lots of magnification, on the assumption that these objects are not visible to the naked eye because they are so distant and small. While all objects in space can be considered distant (in Earthly terms) and some are indeed quite small, the main reason that we cannot see most of the objects seen in astro-photos is that they are so dim. Therefore, all that is required to "see" them is a long exposure, provided that the sky itself is darker than the object, which is often a challenge because of worsening light pollution. We can't make our eyes do long exposures, but we can easily do so with a camera. As for magnification, my images are mostly captured with a telescope that provides only slightly more magnification than a long telephoto camera lens (640mm focal length). Some are, in fact, done with short focal length camera lenses and some with longer focal length telescopes – up to 2000mm focal length. Most of the objects in these images have angular sizes (the apparent size) greater than that of the Moon, but most are too dim to be seen, except for the brighter stars in the area.

Barnard's Loop in Orion

Although the most interesting targets are often quite dim, they are usually surrounded by relatively bright stars. As they are originally captured, most astro-photos show very little, if any, of the dim objects. By "stretching" the digital image the dynamic range can be severely compressed so that subtle details of contrast in the dim objects are visible, but the stars are kept at a reasonable brightness. A very similar concept is popular nowadays in traditional photography, where it is called HDR (high dynamic range) photography. The dynamic range in an astro-photo is usually compressed using a logarithmic transform, which maintains a monotonic variation in brightness over the entire range, but uses most of the output range for the dimmest portions of the original image.



Astro-Photo "stretched" with logarithmic curve

Most of my images are of "nebula" objects. There are 3 type of nebula: Emission nebulae generate light at specific wavelengths due to the ionization of gases. Reflection nebulae are simply clouds of dust that reflect light from nearby stars. Dark nebulae are also clouds of dust, but they form visible shapes as silhouettes by blocking light from behind them, which might be simply a star field or one of the other types of nebula.

Emission Nebula (Eastern Veil)

Reflection Nebula (Iris)

Dark Nebula (LDN673)

Many of my images are of emission nebulae because the narrow band of wavelengths emitted allows these to be captured using "narrowband filters", which block all other wavelengths, including most forms of light pollution, thus allowing these images to be captured from my suburban home observatory. Hydrogen is the most common element in the universe and the hydrogen-alpha spectral line (a deep red) dominates in many regions. The other most commonly imaged spectral lines are Oxygen-III (blue-green) and Sulfur-II (also a deep red). Because H-alpha and S-II are both red it is necessary to use some form of false color to represent the different regions when both elements are present.

Reflection and dark nebula images are captured in conventional red, green, and blue bands, thus producing natural color images (although the color is often exaggerated). These images can only be captured in places where the night sky is very dark - usually 100 miles or more from any major population area.

All types of nebulae require very long exposures, typically at least 2 hours and often much more. Narrowband images in particular usually require very long exposures, averaging 8 to 10 hours in my case.

These nebulae are all within the Milky Way galaxy. There are nebulae in other galaxies, but even though they are huge regions compared to Earth, they are relatively small regions within a galaxy, so only the nearby ones in our own galaxy show the level of detail you see here. The nebulae in this collection are all between 1,000 and 10,000 light years from Earth. Only the galaxy photos show objects far beyond the Milky Way.

In addition to the nebulae images, I have some images of “star clusters” and distant galaxies. Star clusters are, as the name suggests, simply a group of stars in a relatively dense formation. For example, The Pleiades (M45) is an "open cluster", in which the formation is relatively loose, and of low density. The other type of star cluster is the "globular cluster", in which a large number of stars form a dense ball, such as M13. In both cases the stars are gravitationally bound to each other, but the binding is much stronger in a globular cluster. Open clusters, like nebulae, are usually found within the disk of a typical galaxy such as the Milky Way, while globular clusters are usually found in the area around a galaxy, but not within the disk. The Pleiades cluster and other commonly photographed clusters of both types are all within the Milky Way galaxy. Although they are very large compared to our solar system, star clusters are quite small parts of a galaxy and are usually not distinguishable in images of other galaxies, although many are detectable in Andromeda, the nearest major galaxy.

Open Cluster (M45 – Pleiades/Subaru)

Globular Cluster (M13 – Hercules Cluster)

A galaxy is a massive collection of stars, dust, and gases that are gravitationally bound into one of several forms. The most common form is a disk with spiral arms, and this is the form we see in our own Milky Way. Except for some small satellite galaxies near the Milky Way, all of them are quite distant, with Andromeda being the nearest at about 2.5 million light years. But we are able to see many galaxies because they are so large. Some of the most distant objects we can detect are actually clusters of galaxies.

Galaxy (M31 - Andromeda)

Another category of astro-photography is "Solar System" images. This includes images of the Sun, Moon, other planets, comets/meteors, and anything else that is within our solar system. Generally speaking, these objects require greater magnification because even though they are much closer than nebulae, star clusters, and galaxies, they are also much smaller. On the other hand, most such objects are very bright, so relatively short exposures can be used.

Solar System: Moon

Part 2: Solar Images

Bob Yoesle, MAD Observatory

There are two layers of the sun that can be observed outside of a total solar eclipse; the photosphere (sphere of light) and chromosphere (sphere of color). The photosphere is 100,000 times brighter than the chromosphere. The blindingly bright photosphere can made safe to observe or image with relatively simple (hence inexpensive) broad-band "continuum" reflective and/or absorptive filters. This allows one to observe sun spots, granulation, and faculae.

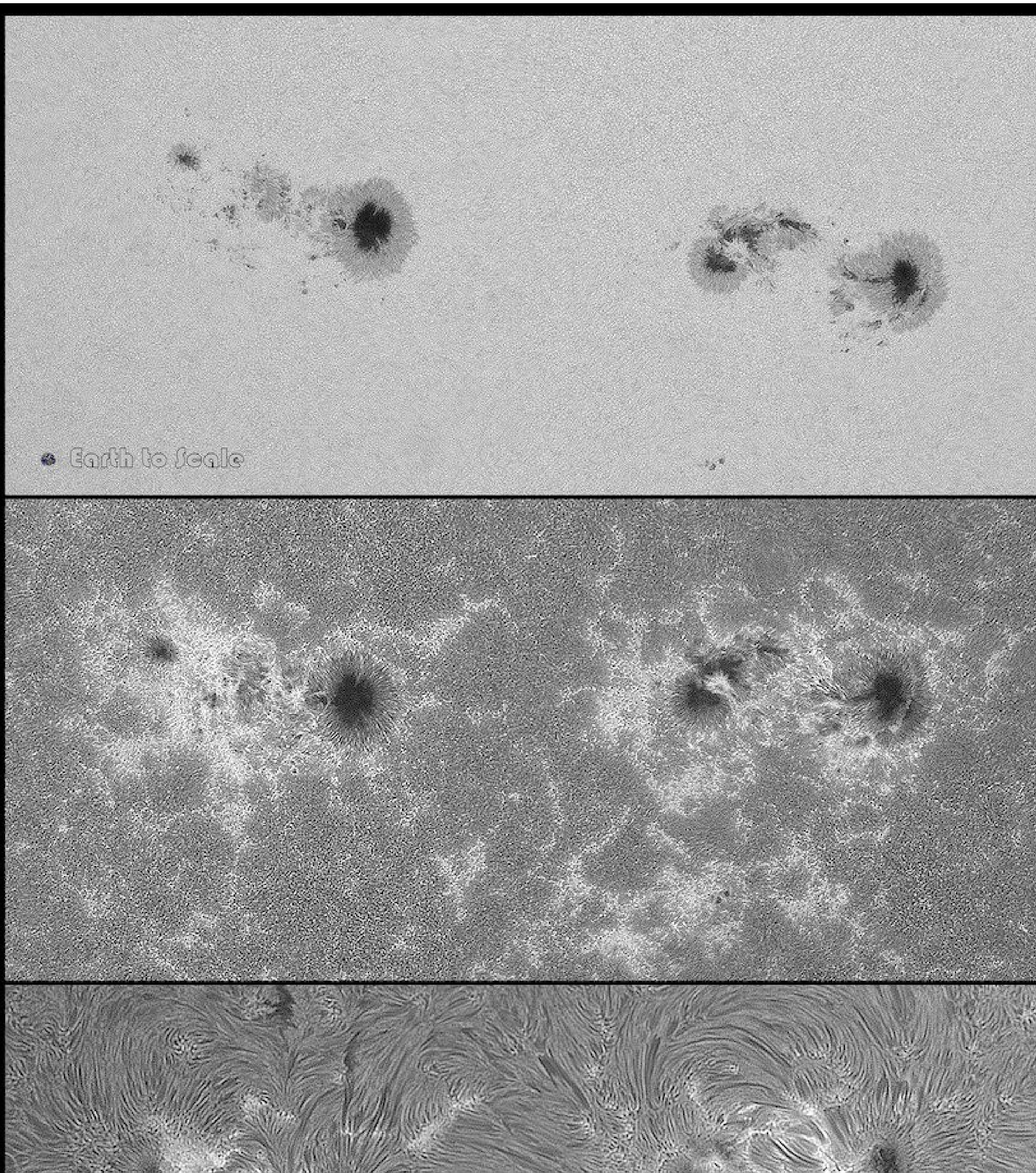
Within the bright continuous spectrum of the photosphere there are specific *absorption* lines from various elements. Identical wavelength but narrower *emission* lines originate higher above the photosphere in the chromosphere. Therefore, observation of the much dimmer chomosphere requires the use of very narrow-band filters in order to look at specific emission spectra lines contained within the underlying photosphere absorption line, while at the same time not allowing any adjoining continuum from the photosphere through.

The most common and interesting emission lines of the solar chromosphere are the Hydrogen alpha (H-alpha) emission and the Calcium K-line (CaK) emission. These filter systems allow one to observe and image prominences, flares, filaments, plage, and other dynamic features. These filters are made of a complex "stew" of interference filters and absorption filters, and hence are much more expensive compared to simple continuum filters.

Both continuum and chromosphere filters need to have very good blocking (OD5+) of ultraviolet and infrared wavelengths to be safe for visual use.

Below a large sunspot group is seen in multiple wavelengths in the photosphere and chromosphere:

Top - photosphere continuum (540 nm), Middle - chromosphere CaK (394 nm), Bottom - H-alpha chromosphere (656 nm).


Earth to Scale

Like planetary and lunar imaging, video cameras are used in order to obtain many images which are then aligned, stacked, and wavelet sharpened. Under good seeing conditions the theoretical resolution of the telescope can be realized. All images were acquired using a Point Grey Research (FLIR) Chameleon USB 2.0 camera with an Orion ED100/900 telescope at 900 or 1800 mm EFL. The continuum filter was an APM Herschel wedge with ND and Baader Continuum filters, CaK is a DIY module using double-stacked CaK Coronado filters, and H alpha used double-stacked Coronado SM90 filters. Full disc images are a 6 pane mosaic. Image acquisition with FireCapture; align, stacked, and wavelet processed in RegiStax 6; mosaics done with iMerge; and final processing in PaintShop Pro.

Part 3: Solar Eclipse Images

Kay Wyatt and Greg Marshall

On August 21, 2017, millions of people from the Oregon Coast to the South Carolina coast were held spellbound at perhaps the most amazing natural phenomena that they ever saw --- a total solar eclipse. This type of eclipse occurs when the Moon passes directly in front of the Sun, covering its luminous face and casting its darkest shadow (the ***umbra***) onto a tiny section of the Earth. A Total Solar Eclipse (TSE) also only happens when the distances between Earth, Sun, and Moon are such that the Moon's angular size is larger than that of the Sun. That is, when the Moon is relatively close to Earth and the Sun is relatively far away. If these conditions are reversed, we get an "annular eclipse" - most of the Sun is covered by the Moon, but not all of it. And, of course, if you are located outside of the narrow path of the umbra, but within the much broader ***penumbra*** the Sun is also never completely covered. This is called a partial solar eclipse.

In the August 21, 2017 eclipse, as the Moon orbited the Earth, and the Earth rotated on its axis, the Moon's shadow traveled from West to East across the continental US. With clear skies, anyone in this path saw daylight turn to near darkness and the Moon's silhouette surrounded by a pearly white ***Corona*** – the Sun's ethereal outer atmosphere.

By taking multiple exposures at different shutter speeds and combining them with complex processing techniques, the photo below shows many features of the TSE at once:

* The background sky (far enough away from the Sun) appeared as dark blue to observers – generally darker than it appears here, but not quite as dark as it is at night.

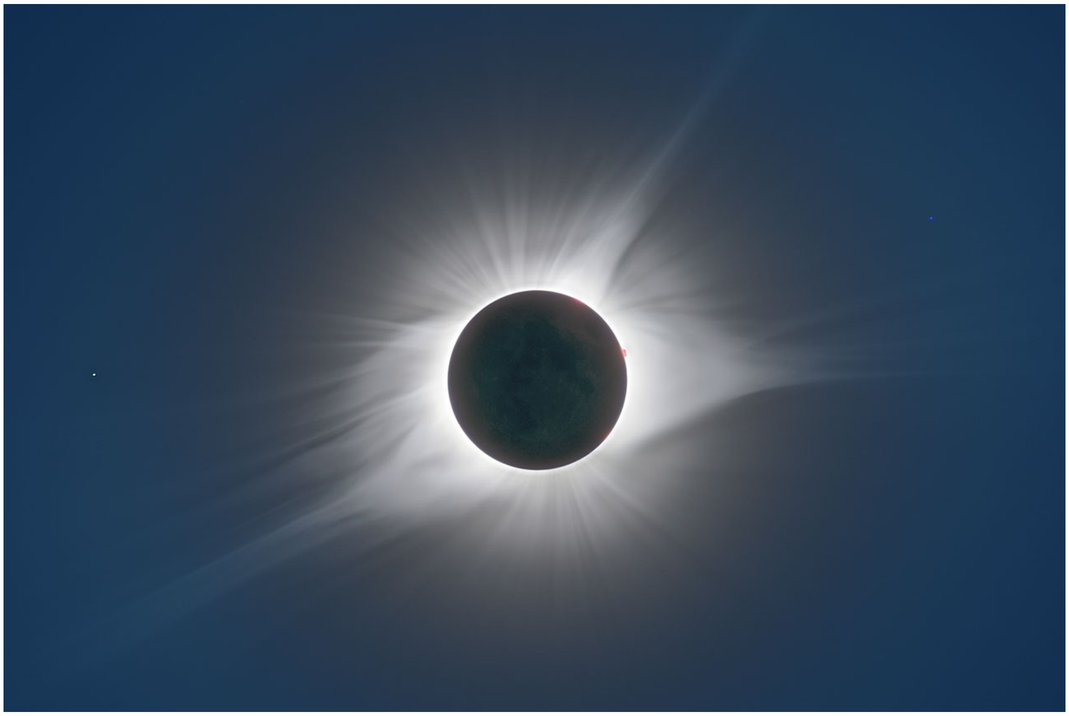
* The sky *was* dark enough that you could see bright stars. The one on the left side in this photo is Regulus, which was just 1.3 degrees away from the Sun. A dimmer star can also be found in the upper right.

* The wispy extended corona reaches out many times greater than the diameter of the Sun, like a delicate white lace. In this case, there were 3 long branches of the corona, but even much closer regions are considered part of the outer or extended corona.

* The inner corona is much brighter and closer to the Sun's disk. The range of brightness is very much compressed in this photo, which makes it harder to distinguish these regions, but the inner corona can be seen clearly in the second photo.

* Prominences were visible because they protruded from the Sun's surface far beyond the disk of the Moon. In this case, there were several such prominences, but only one is clearly visible in this photo because the others were too similar in brightness to the inner corona.

* Features of the Moon's surface (craters, etc.) were illuminated by light reflected by Earth ("Earthshine"). This seems contradictory, since the TSE observer is in a very dark place on Earth, but remember that most of our planet was not even within the partially darkened penumbra, so there was plenty of sunlight to bounce back toward the Moon.



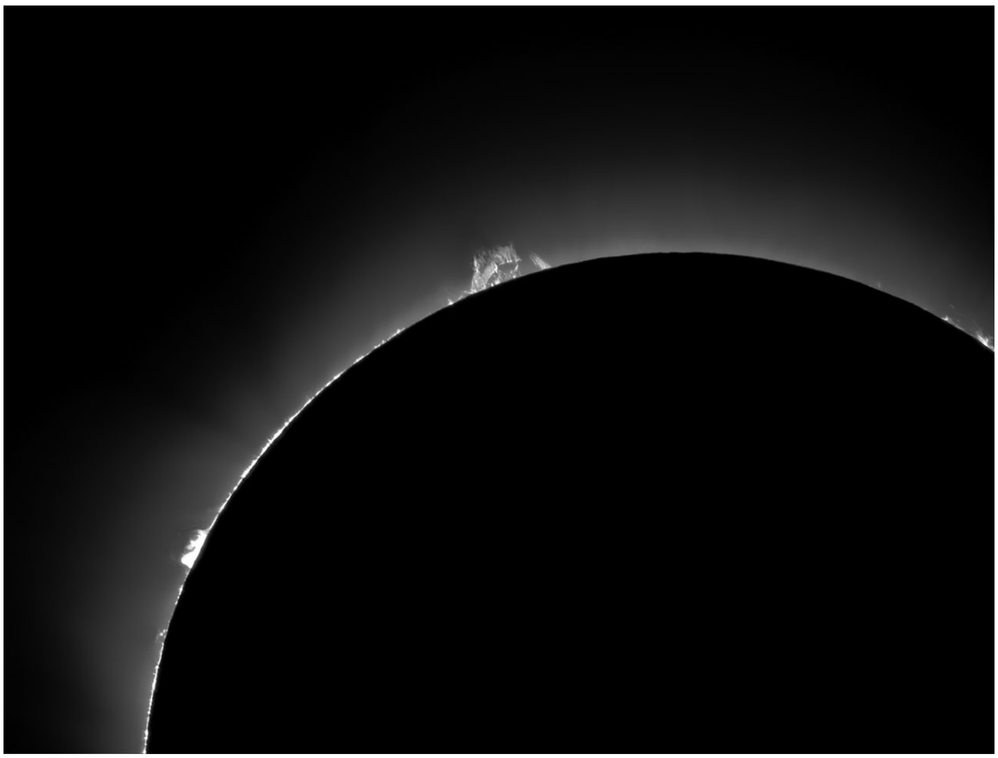
August 21, 2017 Total Solar Eclipse, Wide Field

A shorter exposure at higher magnification reveals other details:

* The inner corona glows around the entire disk of the Moon.

* Several large prominences extend far beyond the disk of the Moon. Each of them is also larger than all of Earth.

* This image was captured near the very end of totality. The ***photosphere*** is still hidden by the Moon, but a bit of the ***chromosphere***, the Sun's innermost atmosphere, is visible along the upper left edge of the Moon.



August 21, 2017 Total Solar Eclipse, Close Up

The ***photosphere*** of the Sun (which we see on a normal day) is a million times brighter than the Sun's Corona. Only when the moon covers the face of the Sun can we see this pearly white beauty with our eyes. Yet the Sun's Corona is 150 to 450 times hotter than the Sun's photosphere, making this fact one of nature's great mysteries yet to be answered.

The breathtaking beauty that a total solar eclipse offers is one that everybody should have on their bucket list.