Astronomy's much more fun when you're not an astronomer.
Brian May

Twinkle, Twinkle

Hi AST 111. In this module we're going to talk about how Earth's atmosphere affects ground-based observations and why we put telescopes in space.

So how does Earth's atmosphere affect observing? Well, the curt answer is that Earth's atmosphere limits observing at visible light wavelength to nighttime — stars come out at night — and clear weather. Light pollution can also lessen the quality of observations.

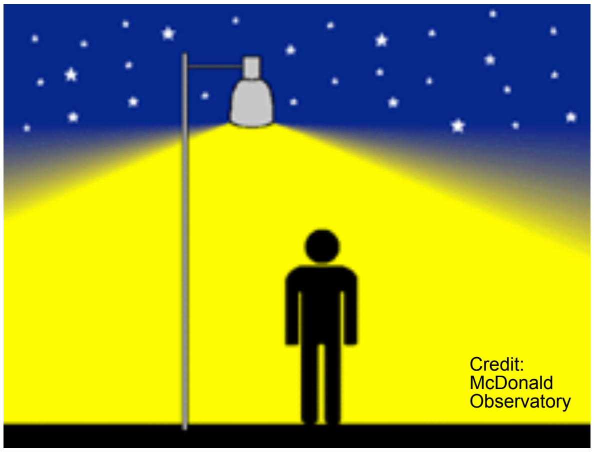
Los Angeles 1932 Credit: Mt. Wilson Observatory

Los Angeles 2008 Credit: Mt. Wilson Observatory

The images above are Los Angeles, California, circa 1932, when the Mt. Wilson Observatory was built above the hills of Los Angeles, and in 2008. The light pollution hasn't reduced any in the last 20 years. The visible wavelength night skies have largely been obliterated from Los Angeles. The Observatory found itself unable to compete in visible wavelengths because this background noise was so large. Rather than mothball the Observatory and move it, there was an aggressive shift to observe in the infrared where they're not as affected from the glittering lights around Hollywood.

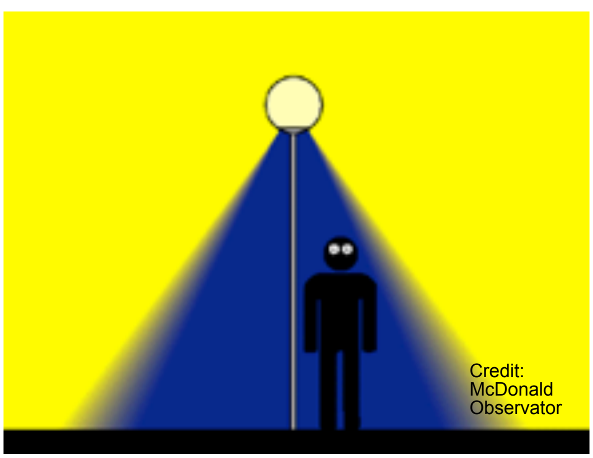
The image above is a pretty cool shot of the world at night. It was made from multiple images from the Space Shuttle stitched together. You can clearly see the United States there. You can actually make out the highways that crisscross the country from all of the vehicles on it. The East Coast is highly lit up. Most of the West Coast -- you can pick out San Diego, LA, San Francisco. There are not many places left in the US where you have a sky dark enough to see, for example, the Milky Way - which is quite a stunning sight. There are still places in Arizona, New Mexico, and Hawaii though.

So let's talk a little about light pollution - the good, the bad, and the ugly. Sounds like a movie you may have seen.



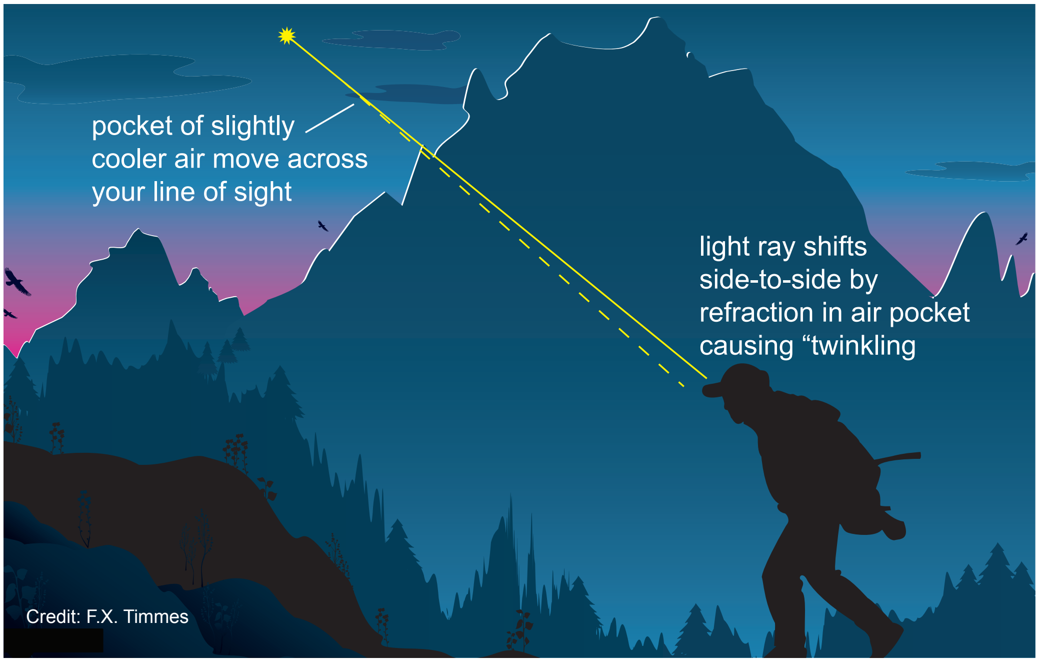
The good. You've got an enclosure which blocks the light from going up and focuses all the light down. It directs the light where you need it downward and to the sides. It's more cost effective. And it helps preserve the night sky for us and future generations.

The bad. You don't have that light enclosure. You've got a lot of light going up into the sky. This kind of lighting also produces glare, light trespassing onto your neighbors, and provides a very harsh illumination hence very sharp reliefs on shadows.



The ugly. Those glass globes with a base at the bottom as a foundation. All the light is going up, so it's illuminating the bellies of bats. The exact place where you want the light, which is down, is blocked out because you've got your support structure in the way.

There's a lot of activity to help educate people on the good, the bad, and the ugly. It's getting some traction these green days as more and more cities are replacing their bad or ugly lighting with the good kind of lighting.



Stars don't actually twinkle. The twinkling is due to turbulence in the Earth's atmosphere. Twinkling causes an image to dance around in the focal plane of a telescope.

It's very much like being at the bottom of a pool. Have you been at the bottom of a pool and looked up? It's pretty hard to focus on an object, right? Because the light is coming through the water and the water's moving around, and so it's hard to get a crisp image. It’s like that on the surface of the Earth, but instead of water, we have a pool of air above us.

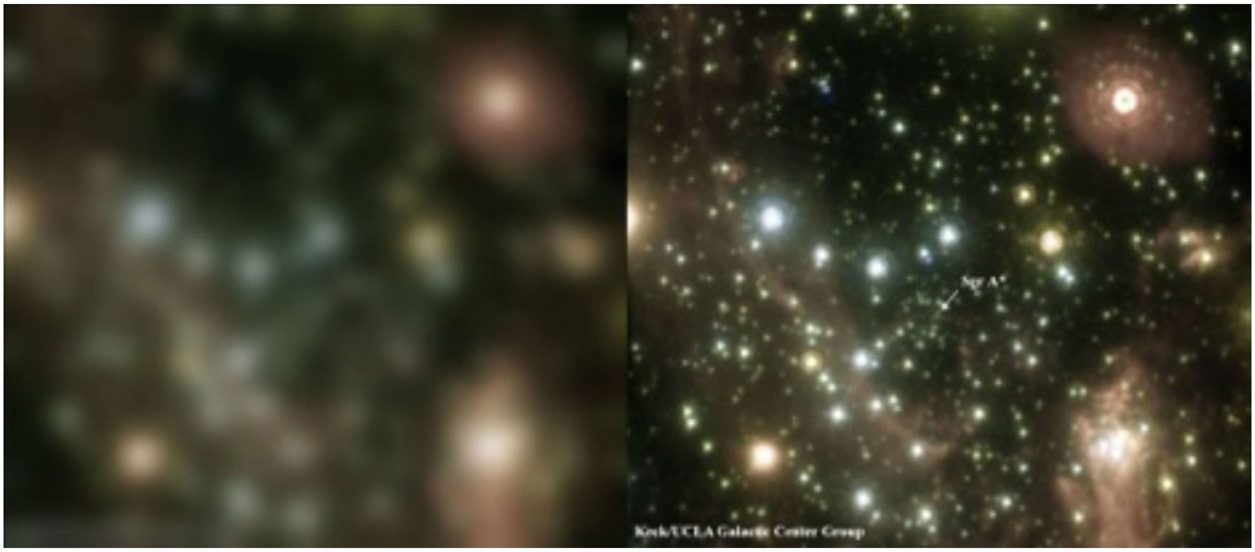
Light arriving from the planets and the stars and the galaxies has to get through that pool of air, through our atmosphere. But there's motion of air parcels in the atmosphere. And that motion causes the light to not be focused at a single point, to dance around and twinkle.

Twinkling might be good for poems -- Twinkle, Twinkle, Little Star -- but it's not so great for astronomy when you've spent a lot of time and energy and money gathering that light and focusing that light to see what's out there.

One way to get around the turbulence in the atmosphere is something known as adaptive optics. The essential idea is you make the deformable telescope mirror do the anti-dance of whatever the atmosphere is doing. The anti-dance!

In order to know what kind of dance the atmosphere is doing, typically you shoot a laser beam up into the sky. The image above shows an example. You know the wavelength of the laser beam going out. That laser light is going to reflect off different layers of the atmosphere. With a special high-speed camera you take pictures of the star dancing. These pictures tell you what the atmosphere's is doing up there, and how to correct for the dance.

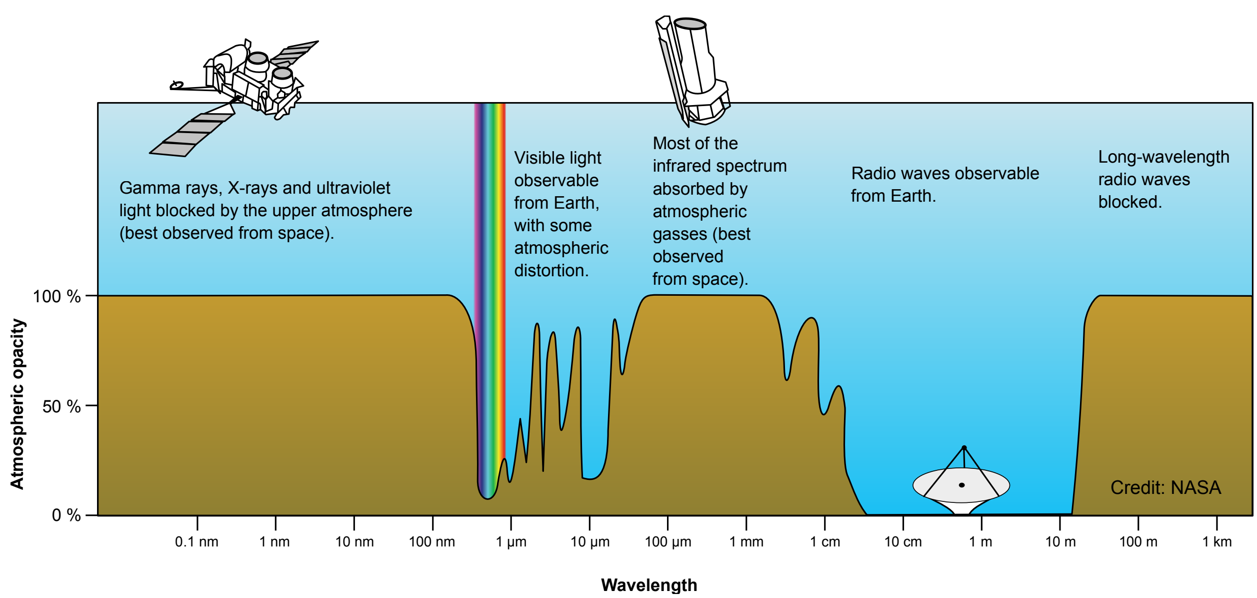
Then you program your computers to control the servos on the back of your telescope mirror to do the anti-dance to cancel out the motion of the atmosphere. It's quite a nifty technological trick. It's called adaptive optics.



Without adaptive optics With adaptive optics

Above is an example of how effective adaptive optics can be. The left image shows the central regions of our Milky Way galaxy without adaptive optics. Looks blobby and blurry to me. The right image shows the same region with adaptive optics. Wow! Quite the difference from being able to the anti-dance. The arrow and label marked “Sgr A*” marks the center location of where our billion solar mass central black hole resides.

All major observatories these days have adaptive optics packages on their telescopes. It's not quite as good as going into space. Space is still better. But space is a lot more costly. With adaptive optics you get like 90% of the benefit for about 2% of the cost.



Why do we put telescopes in space anyway? Well, for one you go up in space to get above the atmosphere and the problems of the atmosphere, as we just talked about. But the major reason why you put telescopes in space is to observe at all kinds of wavelengths that you cannot get at the surface of Earth because Earth's atmosphere blocks it. This blocking is good for us and other life forms because it's a protective blanket. But it's bad for astronomy because most wavelengths never make it to the ground.

The image above shows the different types of radiation and how far they penetrate our atmosphere.Visible light, of course, penetrates all the way down to the surface. That's why our eyes see in visible light. But stuff like the ultraviolet is blocked high up in the atmosphere by our ozone. Again, that's good for us life forms, because it blocks harmful ultraviolet radiation.
So if you want to see what the universe looks like in the ultraviolet, the only way to do it is to get above the atmosphere. Ditto other wavelengths as shown in the figure. So the primary reason why you put telescopes in space is to get above the blocking effects of the Earth's atmosphere. Space is, of course, a lot more expensive. But there are things you can observe in space that you just can't see from the ground.

Thanks! Bye Bye.