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Adaptive Optics: Taking the Twinkle Out of the Star

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Special points of interest:

- Twinkling stars..
- Triton Fun stuff
- Superfluous questions

When we gaze up at the stars at night, they usually appear to twinkle. This twinkling can be quite beautiful and has inspired poets and lovers alike. However, as an astronomer, the twinkling of the stars is a problem.

The stars twinkle because as the light travels through the Earth's atmosphere, it encounters turbulent pockets of air with slightly different temperatures. These turbulent pockets act as little prisms bending the path of the light, this way and that. Thus when we look at a star it appears to make small little jumps from one location to the next. When astronomers take long exposures of the sky, the jumping causes the image of the star to blur out. Ultimately the turbulence in the Earth's atmosphere limits the resolution of our telescopes. Therefore, if two stars are very close together, we might see them as one object instead of two, or if a distant galaxy has some structure in it, we might not be able to tell because the image gets smeared out by the atmosphere. In astronomy, a measure of this blurring of the image by the atmosphere is called "seeing".

Astronomers have tried various techniques to reduce the seeing and thus generate higher resolution data. The first technique that was used was to put telescopes on mountain tops, especially at sites where the atmosphere has little turbulence. Mauna Kea is a 14,000 ft mountain in Hawaii and it has some of the best seeing in the world. Therefore it is a great place to do astronomy and the largest optical telescope in the world is on top of Mauna Kea: the Keck Telescope.

However, even telescopes on top of mountains have to look through some atmosphere. Therefore astronomers have realized the best way to overcome this limitation is to put telescopes into space! The Hubble Space Telescope is one of NASA's most famous and successful missions, its resolution is so exquisite that it has resolved planets around other stars and observed the structures of galaxies 12 billion light-years away.

Unfortunately, it is very expensive to put a telescope into space, especially a large telescope. The primary mirror on the Hubble Space Telescope is only 2.4 meters in diameter; in contrast the Keck Telescope primary mirror is 10 meters across. While the Hubble has much better resolution than a ground based telescope, its resolution is actually limited by its small size. If we could put Keck into space, the resolution of Keck would be 4 times better than Hubble! Unfortunately there is no rocket capable of carrying Keck into space, it's just too heavy.

Hubble space telescope

Majestic in the sky

However, astronomers are very clever and have recently developed technology to correct their data for seeing. The new technology is called *adaptive optics* and it is basically designed to take the twinkle out of the star. Adaptive optics produces excellent images for science.

The way that this technology works is that it uses a reference source to track the effect of turbulence on the images. It then makes real time corrections to the light using a deformable mirror that reverses the action of the atmosphere. Thus the light hitting the science camera acts as if it didn't pass through the atmosphere at all; it's as if we put Keck into space (without using a rocket).

The key to this technology is having a good reference source that we can image on very short time-scales (100s of updates a second).

continued, pg 2 —>

We are always looking for **contributors** to the Science Newsletter. If you would like to write an article about a science subject you are excited about, or contribute a superfluous question, or if you would like to be on our **mailing list** for future newsletters, please e-mail us at:

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Twinkling away: *continued*

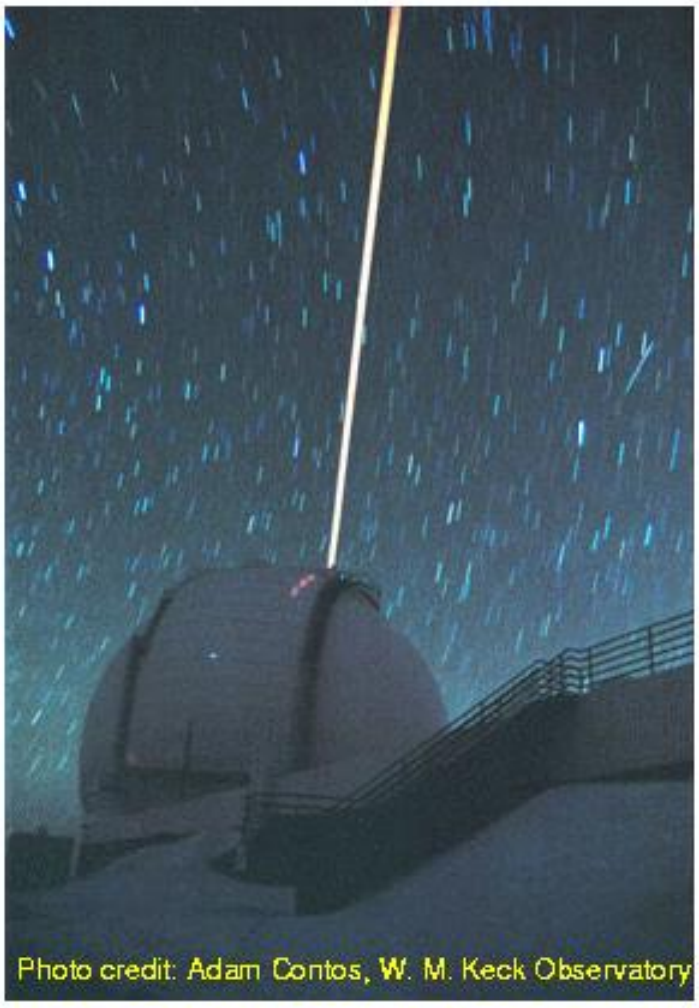
Photos/Info: NASA /Keck Observatory/A. Contos/STScI

The best sources are bright stars near to our science targets. The starlight is sent to a camera that tracks the way the image is jumping around. This data is fed to a computer which tells the deformable mirror how to move to correct the image. While this is going on, the science data is going to a separate camera that can take deep images that astronomers will analyze later.

This all works quite well producing very high resolution imaging. However, there is often not a bright star near the science target an astronomer is interested in. This really limits the usefulness of adaptive optics. Fortunately, astronomers have developed another technology to overcome this limitation. They create their own stars by shooting lasers into the sky.

The earth's atmosphere contains a thin layer of sodium atoms about 90 km up. This sodium layer is actually deposited by small meteorites that hit the atmosphere continually over the course of a year. Astronomers are now using lasers whose light is tuned to excite sodium atoms, causing them to *fluoresce*. Thus, astronomers create artificial stars with sodium lasers and they make these stars right on top of their favorite science targets. They then use these artificial stars to track and correct for the turbulence in the atmosphere.

Right now, adaptive optics works best in the near-infrared wavelengths. Optical data is much harder to correct than that in the infrared. However, the sodium laser is optical light, so the astronomers use the optical light to track the atmosphere and use the near-infrared light to take their science data. Keck has the most successful laser guide star adaptive optics system in the world. It has observed planets around nearby stars.



The Keck Telescope in Hawaii

Firing a laser into the sky to create an artificial star

It has resolved individual stars in nearby galaxies, and it has observed the structure of the earliest galaxies. Its resolution in the near-infrared is 4 times higher than the resolution of Hubble at those wavelengths. While adaptive optics may have taken the twinkle out of the stars, it has opened a whole new window on the universe and will be an important technology for many years to come.

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References

1) http://www.keckobservatory.org/

Great photos and information

2) http://hubblesite.org/

Space Telescope Science Institute site

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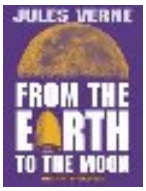

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** Send us your superfluous questions for a future issue ! They can be on any subject. The funnier, the better. M.D., our editor, appreciates the help and will send you a free Triton Fun coffee mug as compensation for your question. Or write an article for us and be read by professional and amateur astronomers and scientists in the U.S. and Canada ! **

Superfluous Questions:

1) In the TV show *Star Trek*, Capt Kirk outwits the gangsters with a card game called *what*?

a) Krako b) Fizzbin c) Kalo d) Oxmix

2) The Cy Young award is given to players in *what* sport ?

a) cricket b) rugby c) baseball d) hockey

3 The big toe is also called *what*?

a) hallux b) phalanges c) plantigrade d) metatarsal

4) In the TV show *All Creatures Great and Small*, Mrs Pumphrey's dog is a *what*?

a) Poodle b) Pekingese c) Chow d) Terrier

—> ANSWERS in next months issue of the Science Newsletter ! <——-

** ANSWERS to May's Superfluous Questions: 1. c) Jackson Roykirk 2. d) Pluto 3. d) Chris Hamill 4. d) ear