A New Adaptive Optics Education Module

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Introduction

Adaptive optics (AO) is becoming increasingly important in modern astronomy. However, few hands-on educational activities have been developed for pre-college students involving adaptive optics.

Adaptive optics is a collection of technologies that overcome limits in telescopic resolution due to distortions introduced by Earth's turbulent atmosphere. One way to overcome this limitation is with space-based telescopes. Space-based telescopes are expensive to launch and difficult to maintain. Using adaptive optics to measure and remove distortions caused by Earth's atmosphere, we can achieve nearly the same resolution from the ground as we can from space based telescopes.

Building on the success of our Hands-On Optics program, we have developed a module of Adaptive Optics activities. The hands-on activities take the students through concepts of image formation by lenses and mirrors, sources of atmospheric distortion, tip-tilt corrections, the functioning of a Shack-Hartmann sensor and using a flexible mirror to remove atmospheric distortion from an image. The accompanying teacher's guide contains step by step directions for use with students, copies of student worksheets, educational standards addressed by the activities, and extensive background materials for the teacher.

Using lasers to find the focal length of a lens (left) and spherical mirror (right).

The Activities

We have developed six key activities for the adaptive optics modules. Each individual activity is briefly described below.

Image Formation: Students learn how images are formed by converging lenses. They measure the focal lengths of lenses by focusing the images of distant objects on velum screens find the focal points of the lenses. Students also learn about the relationship between the shape of the lens and its focal length.

It's Done With Mirrors: This activity expands the concepts of image formation to include curved mirrors. Students observe the focal point of a curved mirror using lasers and measure the focal length of mirrors similar to the previous activity. The use of double sided spherical mirrors allows students to explore both convex and concave mirrors.

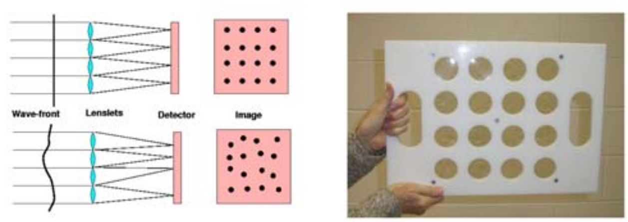
Bubbles in the Air: This activity introduces the students to the concept of atmospheric distortion. Students explore image distortion using mineral oil to simulate Earth's atmosphere. The mineral oil "atmosphere" introduces distortions into the atmosphere. Other object besides mineral oil can be used to illustrate atmospheric distortion including bubble wrap and clear gelatine. The distortions are visible with the naked eye and can be magnified using lenses from the previous activities to illustrate how a telescope magnifies distortions.

Activities (Continued)

Tip and Tilt: The first attempt at adaptive optics used tip-tilt mirrors to keep stars at a fixed point on a CCD chip. This activity gives students a template of a CCD chip, a mirror they can tip and tilt and a laser "star". Their goal is to keep the "star" at a fixed point on the CCD chip as different atmospheric distortions are introduced.

The Shack-Hartmann Sensor: This unique demonstration uses a large scale model of a Shack-Hartmann sensor. We have designed a lens array that can be used to focus the image of a distant object. When atmospheric distortions are introduced by inserting a pan of mineral oil in the optical path, students can observe the images moving from their normal positions. This illustrates the functioning of a Shack-Hartmann wavefront sensor.

Closing the Loop: Flexing the Mirror: The culminating activity has students make a cross section of a spherical mirror using a Play-Doh backing. Lasers are shined at the mirror and students find the focal point. Atmospheric distortions are introduced into the system and students attempt to get the lasers to converge at the focal point by changing the shape of the mirror.

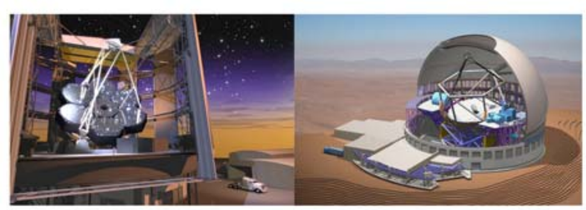


A Shack-Hartmann sensor shows the ideal pattern produced by a star (top left) and the pattern produced by a star after atmospheric distortion (bottom left). On the right is an image of our Shack-Hartmann sensor model. It uses and array of 16 lenses to illustrate how a Shack-Hartmann sensor measures wavefront distortion.

The Adaptive Optics Kit

We are in the final stages of producing the first 10 Adaptive Optics Education Kits at NOAO. The kits contain all the materials needed to do the activities and demonstrations with a classroom of students.

These kits will be made available to partners in the GSMT institutions to use in their educational programs. Further kits maybe produced if the demand warrants.



Two proposals for the GSMT are the Giant Magellan Telescope (left) and the Thirty Meter Telescope (right).

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