Astro 121, Fall 2005
Week 13 (November 30)

Topic: Adaptive optics and telescopes of the future

Break: Michael and Victoria

Reading for next week:

- Bradt, *Astronomy Methods*, pp. 119–128. The basic ideas of adaptive optics, but without a lot of detail. Some good diagrams illustrating out-of-phase wavefronts.
- McLean, *Electronic Imaging in Astronomy,* Chapter 14. This will give you the basic terms and ideas of adaptive optics in somewhat more detail (but less graphically) than Bradt.
- *Very High Angular Resolution Imaging* See the first article, by Colin Masson. Much of the article is redundant with other material, so don't read it, but do look at Figure 1 to get a more physical idea what r_0 means.
- *Adaptive Optics in Astronomy*, edited by F. Roddier. Read pp. 9–19 for a somewhat more detailed explanation of the various equations than McLean gives. Also see Chapter 14 for a discussion of the practicalities of actually observing with an AO system. (This book is on its way over from Haverford – should be here sometime on Monday.)
- Also go to the adaptive optics links at http://astro.swarthmore.edu/astro121/. Definitely check out the images and movies to get a visceral feel of what AO can do for you; the *Science* magazine article is also good reading.

Important concepts and problems:

0. Check your schedules and see when a good time for seminar dinner would be.

1. Explain the basic idea of adaptive optics. What are we trying to accomplish, and how do we go about it? To do this well, you'll want to define the following terms:

   a. Strehl ratio.

   b. Coherence length or Fried parameter r_0.

   c. Coherence time.

   d. Isoplanatic patch.

2. Why is AO being used primarily at near-infrared wavelengths? What is it about IR that makes AO inherently easier than doing it at optical wavelengths?

3. Draw a picture of distorted wavefronts (similar to the diagrams in Bradt) and use it to explain the idea of tip/tilt correction. What part of the wavefront distortion is taken out by a tip/tilt system?

4. The number of actuators needed for AO control of a mirror of diameter D is roughly $(D/r_0)^2$. Give a physical explanation for why this is so.

5. Derive an expression giving the approximate physical distance that AO mirror actuators must be able to travel in order to properly correct the wavefront. Evaluate your expression for $\lambda = 2.2$ μm.

6. If the turbulent layer in the atmosphere blows across the telescope at an average velocity <v> = 10 m/s, and the coherence length is given by $r_0(\lambda) = (10\text{ cm})\left(\frac{\lambda}{0.5\ \mu\text{m}}\right)^{6/5}$, what response time is needed for the AO system?

7. Why must AO guide stars be bright?

8. What are the strengths and weaknesses of using natural guide stars vs. laser guide stars?

9. Future telescopes. Where is astronomy headed in the next 10—20 years? Get on the web and find some information about the following telescopes that are either proposed or under construction. You should gather at least the basic technical specs of the telescope(s) and the basic science goals. While you're looking into this, think about what (if anything) these projects have in common. Can you identify any trends?

   a. ALMA

   b. Space Interferometer Mission (SIM)

   c. Next Generation Space Telescope (NGST) [Now also called the James Webb Space Telescope.]

   d. Large Binocular Telescope (LBT)

   e. The DIVA satellite

   f. Find one other future telescope/mission that I haven't mentioned here.

10. The farther future. Except for NGST, the projects listed above are fairly well underway. The best crystal-ball look into astronomy's future may be the McKee-Taylor report, *Astronomy and Astrophysics in the New Millennium*. Each decade, astronomers in the U.S. put together a review commission and issue a report on their priorities for the next 10 years. This has proven useful in setting priorities for national astronomy spending. Take a look at the current report, linked from the course web page. Just reading the last four pages of the Executive Summary will give you a taste for the kinds of new missions under development.