DOWNLOAD PDF SCIENCE WITH ADAPTIVE OPTICS

Chapter 1 : Center for Adaptive Optics | Home

Adaptive optics is a relatively new field, yet it is spreading rapidly and allows new questions to be asked about how the visual system is organized.

Retinal ganglion cells and axons at the macular edge of a healthy subject. Barry Cense and co-authors publish their findings in Journal of Biophotonics. Omer will be greatly missed! Congratulations to Barry Cense! This honor reflects the hard work of so many from the lab! Congratulations to Ravi Jonnal and our other collaborating colleagues at UC-Davis on publication of "The cellular origins of the outer retinal bands in optical coherence tomography images" in Invest. Ayoub Lassoued and Furu Zhang joined our lab as new graduate students. Welcome Ayoub and Furu! Congratulations to Omer Kocaoglu on publication of "Adaptive optics optical coherence tomography with dynamic retinal tracking" in Biomedical Optics Express! Congratulations to Zhuolin Liu on acceptance of "In-the-plane design of an off-axis ophthalmic adaptive optics system using toroidal mirrors" in Biomedical Optics Express! Don Miller has been elected a Fellow of the Optical Society of America "for pioneering research in high resolution imaging and adaptive optics in the eye. Congratulations to former lab member Barry Cense and our other collaborators on acceptance of "Henle fiber layer phase retardation measured with polarization-sensitive optical coherence tomography" in Biomedical Optics Express! The meeting was co-chaired by Prof Miller. We wish him the very best! Tim Turner joined our lab as new scientific programmer. Welcome to The Miller Lab! We are a group of passionate scientists and engineers with a common goal to advance the field of biomedical optics in eye research We develop and apply powerful optical imaging systems to study structures and processes in the living eye that was previously not possible. These instruments open up exciting new directions to study both normal and pathological vision. The long term goal is to translate our findings to the clinic to facilitate earlier detection and improved treatment of diseases that lead to blindness. The lab is part of a highly active and well funded community at IU working in the broad area of optics and imaging for vision research.

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Chapter 2 : CfAO Fall Science Retreat

The Center for Adaptive Optics Fall Science Retreat provides a forum for researchers in the adaptive optics field to share current results and plan future collaborations. The CfAO Fall Retreat this year will center around four workshops, with overlapping themes in adaptive optics.

The Shack-Hartmann sensor is one type of wavefront sensor used for adaptive optics. Negative images of a star through a telescope. The left-hand panel shows the slow-motion movie of a star when the adaptive optics system is switched off. The right-hand panel shows the slow motion movie of the same star when the AO system is switched on. Visual images produced by any telescope larger than approximately 20 centimeters are blurred by these distortions. Wavefront sensing and correction[edit] An adaptive optics system tries to correct these distortions , using a wavefront sensor which takes some of the astronomical light, a deformable mirror that lies in the optical path, and a computer that receives input from the detector. The wavefront sensor measures the distortions the atmosphere has introduced on the timescale of a few milliseconds ; the computer calculates the optimal mirror shape to correct the distortions and the surface of the deformable mirror is reshaped accordingly. For example, an 8â€"10 m telescope like the VLT or Keck can produce AO-corrected images with an angular resolution of 30â€"60 milliarcsecond mas resolution at infrared wavelengths, while the resolution without correction is of the order of 1 arcsecond. In order to perform adaptive optics correction, the shape of the incoming wavefronts must be measured as a function of position in the telescope aperture plane. Typically the circular telescope aperture is split up into an array of pixels in a wavefront sensor, either using an array of small lenslets a Shackâ€"Hartmann sensor , or using a curvature or pyramid sensor which operates on images of the telescope aperture. The mean wavefront perturbation in each pixel is calculated. This pixelated map of the wavefronts is fed into the deformable mirror and used to correct the wavefront errors introduced by the atmosphere. The deformable mirror corrects incoming light so that the images appear sharp. Using guide stars[edit] Natural guide stars[edit] Because a science target is often too faint to be used as a reference star for measuring the shape of the optical wavefronts, a nearby brighter guide star can be used instead. A laser beam directed toward the centre of the Milky Way. This laser beam can then be used as a guide star for the AO. The necessity of a reference star means that an adaptive optics system cannot work everywhere on the sky, but only where a guide star of sufficient luminosity for current systems, about magnitude 12â€"15 can be found very near to the object of the observation. This severely limits the application of the technique for astronomical observations. Another major limitation is the small field of view over which the adaptive optics correction is good. As the angular distance from the guide star increases, the image quality degrades. A technique known as "multiconjugate adaptive optics" uses several deformable mirrors to achieve a greater field of view. Artificial guide stars[edit] An alternative is the use of a laser beam to generate a reference light source a laser guide star , LGS in the atmosphere. LGSs come in two flavors: Rayleigh guide stars and sodium guide stars. Sodium guide stars use laser light at nm to excite sodium atoms higher in the mesosphere and thermosphere , which then appear to "glow". The lasers are often pulsed, with measurement of the atmosphere being limited to a window occurring a few microseconds after the pulse has been launched. This allows the system to ignore most scattered light at ground level; only light which has travelled for several microseconds high up into the atmosphere and back is actually detected. These optical aberrations diminish the quality of the image formed on the retina, sometimes necessitating the wearing of spectacles or contact lenses. In the case of retinal imaging, light passing out of the eye carries similar wavefront distortions, leading to an inability to resolve the microscopic structure cells and capillaries of the retina. Spectacles and contact lenses correct "low-order aberrations", such as defocus and astigmatism, which tend to be stable in humans for long periods of time months or years. While correction of these is sufficient for normal visual functioning, it is generally insufficient to achieve microscopic resolution. Additionally, "high-order aberrations", such as coma, spherical aberration , and trefoil, must also be corrected in order to achieve microscopic resolution. High-order aberrations, unlike low-order, are not stable over time, and may change over time scales of 0. The correction of these aberrations requires continuous, high-frequency measurement and compensation. Measurement of ocular aberrations[edit] Ocular aberrations are generally measured using a wavefront sensor , and the most commonly used type of wavefront sensor is the Shack-Hartmann. Ocular aberrations are caused by spatial phase nonuniformities in the wavefront exiting the eye. The lenslets cause spots to be focused onto the CCD chip, and the positions of these spots are calculated using a centroiding algorithm. The positions of these spots are compared with the positions of reference spots, and the displacements between the two are used to determine the local curvature of the wavefront allowing one to numerically reconstruct the wavefront informationâ€”an estimate of the phase nonuniformities causing aberration. The phase errors can be used to reconstruct the wavefront, which can then be used to control the deformable mirror. Alternatively, the local phase errors can be used directly to calculate the deformable mirror instructions. If the wavefront error is measured after it has been corrected by the wavefront corrector, then operation is said to be "closed loop". In the latter case then the wavefront errors measured will be small, and errors in the measurement and correction are more likely to be removed. Closed loop correction is the norm. Applications[edit] Adaptive optics was first applied to flood-illumination retinal imaging to produce images of single cones in the living human eye. It has also been used in conjunction with scanning laser ophthalmoscopy to produce also in living human eyes the first images of retinal microvasculature and associated blood flow and retinal pigment epithelium cells in addition to single cones. Combined with optical coherence tomography , adaptive optics has allowed the first three-dimensional images of living cone photoreceptors to be collected. The required wavefront correction is either measured directly using wavefront sensor or estimated by using sensorless AO techniques. It is also expected to play a military role by allowing ground-based and airborne laser weapons to reach and destroy targets at a distance including satellites in orbit. Adaptive optics has been used to enhance the performance of free space optical communication systems [14] [15] and to control the spatial output of optical fibers. Propagation of a curved wavefront always leads to amplitude variation. This needs to be considered if a good beam profile is to be achieved in laser applications. Adaptive optics, especially wavefront-coding spatial light modulators, are frequently used in optical trapping applications to multiplex and dynamically reconfigure laser foci that are used to micro-manipulate biological specimens. Beam stabilization[edit] A rather simple example is the stabilization of the position and direction of laser beam between modules in a large free space optical communication system. Fourier optics is used to control both direction and position. The actual beam is measured by photo diodes. This signal is fed into some Analog-to-digital converters and a microcontroller runs a PID controller algorithm. The controller drives some digital-to-analog converters which drive stepper motors attached to mirror mounts. If the beam is to be centered onto 4-quadrant diodes, no Analog-to-digital converter is needed. Operational amplifiers are sufficient.

Chapter 3 : ESO - What is Active and Adaptive Optics?

Adaptive optics is a technique to compensate for the blurring effect of the Earth's atmosphere, also known as astronomical seeing, which is a big problem faced by all ground-based telescopes.

Adaptive optics AO measures and then corrects the atmospheric turbulence using a deformable mirror that changes shape 1, times per second. Initially, AO relied on the light of a star Keck Observatory is once again pushing the boundaries in the field of adaptive optics AO after receiving a powerful boost of support. As such, the KAPA team is also placing a priority on the broader impact goals of education and workforce development. The project will engage: The KAPA team will also launch a new summer school focused on astronomy technology and instrumentation for about 25 undergraduate and graduate students every summer over the course of the five-year project. This is done using lasers to create an artificial star anywhere in the sky, fast sensors to measure the atmospheric blurring, and a deformable mirror to correct for it - all done about times per second. The goal is to study the finest detail possible by largely removing the blurring effect of the atmosphere. It allows ground-based telescopes to match and even exceed the performance of space-based telescopes at much more modest costs. To further improve the clarity of these images, the KAPA project will upgrade the current system by replacing key components: The laser beam will be divided into three laser guide stars to fully sample the atmosphere above the telescope using a technique called laser tomography. The project also includes upgrades to a near-infrared tip-tilt sensor to improve sky coverage and a technique called point spread function reconstruction that will optimize the value of the science data obtained with the accompanying science instrument an integral field spectrograph and imager called OSIRIS. Keck Observatory pioneered the astronomical use of both natural guide star NGS and laser guide star adaptive optics LGS AO on large telescopes and current systems now deliver images three to four times sharper than the Hubble Space Telescope. Keck AO has imaged the four massive planets orbiting the star HR, measured the mass of the giant black hole at the center of our Milky Way Galaxy, discovered new supernovae in distant galaxies, and identified the specific stars that were their progenitors. Keck Observatory telescopes are the most scientifically productive on Earth. Keck Observatory is a private c 3 non-profit organization operated as a scientific partnership among the California Institute of Technology, the University of California, and the National Aeronautics and Space Administration. The Observatory was made possible by the generous financial support of the W. We wish to recognize and acknowledge the very significant cultural role and reverence that the summit of Maunakea has always had within the Native Hawaiian community. We are most fortunate to have the opportunity to conduct observations from this mountain. For more information, visit: NSF funds reach all 50 states through grants to nearly 2, colleges, universities and other institutions. Each year, NSF receives more than 50, competitive proposals for funding and makes about 12, new funding awards.

Chapter 4 : Move over, Hubble. This sharp pic of Neptune was taken from Earth | Science News

Adaptive optics (AO) is a technology used to improve the performance of optical systems by reducing the effect of incoming wavefront distortions by deforming a mirror in order to compensate for the distortion.

Vacancies What is Active and Adaptive Optics? Active Optics is used to overcome the first limitation and Adaptive Optics the latter, giving ultimately images near the diffraction limit of the primary mirror. There are a number of physical limitations to adaptive optics performance, leading to successive generations of more and more sophisticated techniques detailed below. The Quest for Image Quality Since its invention years ago, the astronomical telescope has evolved from a small, manually pointed device for visual observations to a large and sophisticated computer-controlled instrument with full digital output. Throughout this development, two parameters have been particularly important: For a perfect telescope used in a vacuum, resolution is directly proportional to the inverse of the telescope diameter. A plane wavefront from distant star effectively at infinity would be converted by the telescope into a perfectly spherical wavefront, forming the image,with an angular resolution only limited by light diffraction - aptly called the diffraction limit. In practice, however, both atmospheric and telescope errors Fig. Even at the best sites, ground-based telescopes observing at visible wavelengths cannot, because of atmospheric turbulence alone, achieve an angular resolution better than telescopes of to cm diameter. For a 4-m telescope, atmospheric distortion degrades the spatial resolution by more than one order of magnitude compared with the diffraction limit, and the intensity at the center of the star image is lowered by a factor of or more. The cause is random spatial and temporal wavefront perturbations inducedby turbulence in various layers of the atmosphere; one of the principal reasons for flying the Hubble Space Telescope was to avoid this image smearing. In addition, image quality is affected by permanent manufacturing errors and by long time scale-wavefront aberrations introduced by mechanical,thermal, and optical effects in the telescope, such as defocusing, decentering, or mirror deformations generated by their supporting devices. Passive Optics Until recently, the astronomical telescope has remained a "passive" instrument. Without any in-built corrective devices to improve the quality of star images during observations, the only possible adjustments were those performed during daytime or at the beginning of the night. Although it was thought that atmospheric distortions could not be avoided, mechanical improvements have been made to minimize telescope errors. Mirror figuring and polishing were improved, and stiffer structures and mirrors used to minimize gravitationally-induced deformations. Low-expansion glass was introduced to avoid mirror distortions as temperature varies. To reduce local temperature effects, heat dissipation from motors and electronic equipment was minimized during the night, and the dome, which in addition shields the telescope from the effects of wind buffeting,cooled during the day. In such properly designed and well-manufactured medium size telescopes, image quality is limited mainly by atmospheric distortions. Active Optics However, as plans were developed in the 80s to enhance light-collecting power by building telescopes with primary mirrors well above 4 m in diameter, it became clear that conventional methods of maintaining image quality were ruled out by cost and structure weight limitations. The first fully active telescope,the ESO 3. Active optics is very much at the heart of the segmented m Keck primary mirror , in operation since on Mauna Kea, Hawaii and of e. Another complication is that,for short integration times, the field of view over which the atmospheric wavefront distortions and hence the images are correlated, the isoplanatic angle, is very small only a few arc second for visible wavelengths. Because of the high bandwidth and the small field to which correction can generally be applied, adaptive optics uses a small deformable mirror with a diameter of 8 to 20 cm located behind the focus of the telescope at or near an image of the pupil. In some current projects, the possibility of using a large deformable secondary mirror is being developed. The choice of the number of usually piezoelectric actuators is a trade off between degree of correction, use of faint reference sources see below and available budget. For instance, a near-perfect correction for an observation done in visible light 0. However, some military systems for satellite observations in the USA do provide full correction in the visible on at least 1-m class telescopes. Two main methods are used to measure the degraded wavefront, the Shack-Hartmann device, which measured the slope of the wavefront from the positions of the images of the reference star given by each subpupil, and curvature sensing, where the intensities measured in strongly defocused images provided directly give the local curvatures of the wavefront. Correction in the Shack-Hartmann device is made with individual piezoelectric actuators. Correction in a curvature sensing system is accomplished with a bimorph adaptive mirror, made of two bonded piezoelectric plates. With both methods, wavefront sensing is done on a reference star, or even on the observed object itself if it is bright enough and has sufficiently sharp light gradients. The control system is generally a specialized computer that calculates from the wavefront-sensor measurements the commands sent to the actuators of the deformable mirror. The calculation must be done fast within 0. The required computing power needed can exceed several hundred million operations for each set of commands sent to a actuator deformable mirror. As in active optics systems, zonal or modal control methods are used. In zonal control, each zone or segment of the mirror is controlled independently by wavefront signals that are measured for the subaperture corresponding to that zone. In modal control, the wavefront is expressed as the linear combination of modes that best fit the atmospheric perturbations. It is generally NOT possible to find a sufficiently bright reference star close enough to an arbitrary astronomical object. Conditions are much better in the infrared than in the visible since atmospheric turbulence and especially its high spatial frequencies has, for a given AO correction, a weaker effect on longer wavelengths. The spatial and temporal sampling of the disturbed wavefront can therefore be reduced, which in turn permits the use of fainter reference stars. Coupled with the larger isoplanetic angle in the IR, this gives a much better outlook for AO correction than in the visible. Nevertheless, even for observations at 2. It is therefore quite normal that most scientific applications of AO so far have been on objects which naturally provide their reference object like solar system small bodies, stellar environments,stellar clusters and a few very bright Seyfert nuclei. At this time, a number of team or general purposes astronomical AO systems are routinely working on 4-m class or larger telescopes: Advanced Adaptive Optics I: Laser Guide Stars The most promising way to overcome the isoplanatic angle limitation is the use of artificial reference stars, also referred to as laser guide stars LGS Fig. These are patches of light created by the back-scattering of pulsed laser light by sodium atoms in the high mesosphere or by molecules and particles located in the low stratosphere. The laser beam is focused at an altitude of about 90 km in the first case Sodium resonance and 10 to 20 km in the second case Rayleigh diffusion. Such an artificial reference star can be created as close to the astronomical target as desired, and a wavefront sensor measuring the scattered laser light is used to correct the wavefront aberrations on the target object. Air Force Starfire Optical Range. Navy reported an improved resolution by almost a factor of 10 ona 1-m telescope in San Diego, California. Some systems for astronomical. On the "Civilian" side, the first astronomical observation was done Nevertheless, there are still a number of physical limitations with an LGS. A first problem, focus anisoplanatism, also called the cone effect, became evident very early on. Because the artificial star is created at a relatively low altitude, back-scattered light collected by the telescope forms a conical beam, which does not cross exactly the same turbulence-layer areas as the light coming from the distant astronomical source. This leads to a phase estimation error, which in principle may be solved by the simultaneous use of several laser guide stars around the observed object. The effect is minimized with the sodium resonance technique and roughly equivalent on an 8-m telescope to the phase error experienced with an NGS 10" away from the astronomical target. Even more severe is the image motion or tilt determination problem. A more performant and complex solution would be to use two different AO systems with two laser beacons, one, for the astronomical object and one for the reference star. An obvious implication is that the larger the telescope, the greater the sky coverage because the gain in resolution brought about by the increase of the diameter of the optics is fully exploited. On the other hand, it has severe technological implications,as it requires the duplication of all components deformable mirror, wavefront sensor, and laser guide star. Adaptive optics with a multicolour laser probe is another concept investigated to solve the tilt determination problem of laser beacon based AO. Only applicable to sodium resonant scattering at 90 km, it excites different states of the sodium atoms and makes use of the slight variation in the refraction index of air with wavelength. Its main drawback is the limited returned flux, owing to the saturation of mesospheric sodium layer. Advanced Adaptive Optics II: All AO systems provide this basic mode, often supplemented with a scanning filter circular variable filter or scanning Fabry-Perot to get full data cubes with both the 2D spatial and 1D spectral information on the astronomical targets. Getting these data cubes in a single exposure is very attractive, given the time variable nature of turbulence, even after AO correction. Conclusion There are many substantial technological challenges in AO. The latter are especially interesting at thermal wavelengths, where any additional mirror raises the already huge thermal background seen by the instruments. NGS-based AO in the Infrared is routinely achieving near diffraction-limited images and spectroscopic data cubes on large telescopes up to the present generation of m diameter. Significant corrections have been obtained in the visible in exceptionally good seeing conditions, but diffraction-limited performance has up to now Single LGS systems are now or soon operating at a number of Observatories, but routine demonstration of their potential for getting very high sky coverage has not yet been achieved. MCAO techniques are still in their infancy. Many recent astronomical discoveries can be directly attributed to new optical observation capabilities. With the new generation of Very Large Telescopes entering into operation, the role of AO systems and for even better resolution, interferometry is extremely important. With this capability, their huge light-gathering along with the ability to resolve small details, both spatially and spectrally, has the potential to bring major advances in ground-based astronomy in the new decade.

Chapter 5 : Vision science and adaptive optics, the state of the field. â€” PSY

The field of Adaptive Optics (AO) for astronomy has matured in recent years, and diffraction-limited image resolution in the near-infrared is now routinely achieved by ground-based 8 to 10m class tele.

Chapter 6 : A review of astronomical science with visible light adaptive optics â€" University of Arizona

Leading experts present the latest technology and applicationsin adaptive optics for vision science. Featuring contributions from the foremost researchers in thefield, Adaptive Optics for Vision Science is the first book devotedentirely to providing the fundamentals of adaptive optics alongwith its practical applications in vision science.

Chapter 7 : Adaptive optics (astronomy) - AccessScience from McGraw-Hill Education

Adaptive optics is a relatively new ï¬•eld, yet it is spreading rapidly and allows new questions to be asked about how the visual system is organized. The editors of this feature issue have posed a series of question.

Chapter 8 : Adaptive Optics [image] | EurekAlert! Science News

We review astronomical results in the visible (Î»adaptive optics. Other than a brief period in the early s, there has been little (science published with AO in the visible from (outside of the solar or Space Surveillance Astronomy communities where visible AO is the norm, but not the topic of this invited review).

Chapter 9 : Supersharp images from new VLT adaptive optics

Adaptive optics is a new technique to greatly enhance the resolution of an image. Imaging with adaptive optics systems is becoming common at large astronomical and military telescopes. A modern telescope is the most powerful tool for imaging distant objects at high resolution.