ADAPTIVE OPTICS


INTRODUCTION

Turbulence in the Earth’s atmosphere (e.g. due to temperature fluctuations) produces inhomogeneities in the refractive index. These affect the image quality (performance) of ground-based astronomical telescopes. In addition to the twinkling of the star the radiation is smeared out by the turbulence. This blurring effect is so large that even the largest telescopes like VLT or Keck have no better resolution than a 20cm “backyard” telescope. This setback motivated the launch of large telescopes like the Hubble Space Telescope, which is more extremely costly to build and operate.

Figure 1. Comparison image using AO (left) and without. Image by Benoit Schilling

Figure 2. Air refractive index fluctuations and corresponding image with natural seeing and with AO

ADAPTIVE OPTICS (AO)

Adaptive Optics refers to optical systems which adapt to compensate for optical effect introduced by the medium between the object and the image. AO was first introduced by Babcock (1953). It consists of using an active optical element, such as deformable mirror to correct the instantaneous wavefront distortion. They are measured by a wave-front sensor which delivers the signals necessary to drive the corrective element.

When one wants to observe a faint galaxy, there are several steps carried out to obtain a nearly diffraction limited image. The first one is to find a relatively bright reference star called guide star. One needs this bright star to measure the atmospheric distortions:

1. Light from the guide star as well as the faint galaxy passes through the telescope’s optics. The light of the star is sent to a wave-front sensor (which actually is a high speed camera) that can measure how the star light is distorted at a rate of 200 Hz.
2. This information is processed by a fast computer in order to calculate the shape of the active optical element deformable mirror, which will cancel out the phase distortion due to turbulence.
3. Light from both the guide star and target object is reflected from deformable mirror and is in phase because the distortions have been removed. And with sharper images comes an additional gain in contrast which means that faint objects can be detected and studied more easily.

ADAPTIVE OPTICS COMPONENT

1. Wave-front sensor: This sensor must probe the turbulent atmosphere hundreds to thousands of times a second. Commonly it is a CCD, Shack-Hartmann wave-sensor or curvature sensing.
2. Deformable mirror: Deformable mirror are made of thin sheet of glass which is attached to their back are actuators. These device responds to an external force by changing the shape of the active optical element deformable mirror, which will correct the instantaneous wavefront distortion. They are measured by a wave-front sensor which delivers the signals necessary to drive the corrective element.
3. Control system (real-time computer).

DATA ANALYSIS & RESULT

OBJECTIVE

AO is a technology to improve the astronomical image by reducing the effect of atmospheric distortion or twinkling. Atmospheric distortion or seeing for astronomer also known by FWHM value. FWHM or Full Width at Half Maximum is the width of the star image at half its peak brightness. The smaller the FWHM value, the better the image which will make it easier to resolve two very close object.

THE EXPERIMENT

The aim of the experiment was to compare the average of FWHM (seeing value) of each stars which is in same field of view and same exposure time using AO-on and AO-off. After that, determined the FWHM and get their average. Make a bar graph of the data and do a detail analysis. Naked eyes can’t see clearly the different both of the image, but the analysis does. The Running Chicken Nebula IC 2944 was first complete image taken by using AO in front of parking lot of Block C, Jabatan Fizik-Fakulti Sains, Universiti Malaya.

CONCLUSION

Theoretically using Adaptive Optics, the turbulence effect on the image taken will be reduce up to 30%. However, preliminary analysis shows that Seeing (FWHM) for IC 2944 AO-off image is 0.65 arcsec. Using Adaptive Optics, the improvement of the image Seeing (FWHM) is 6.15%, that is 0.61 arcsec. In future, work will be carried out to improve on the image so as to achieve theoretical value.