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The WIYN One Degree Imager

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Abstract. The WIYN consortium is building a next generation wide-field imager for its 3.5m telescope. This instrument is designed to deliver excellent image quality limited by the site (0.3”-0.4”) over a one degree field of view and uses active image motion stabilisation. We outline the concept of the instrument and describe its position in the ecosystem of upcoming wide field imagers.

1. Overview

The WIYN Consortium (University of **W**isconsin, Madison; **I**ndiana University, Bloomington; **Y**ale University, and the **N**ational Astromical Optical Observatory, Tucson) owns and operates its 3.5m telescope at Kitt Peak, Arizona. This modern, lightweight telescope is capable of delivering site-limited image quality, which has a mode of 0.6” in the R band; frequently the delivered image quality (DIQ) is $\leq$ 0.4” throughout all optical bandpasses. However, WIYN’s built-in one degree field of view and image quality are not simultaneously utilized, and the WIYN consortium committed to build a One Degree Imager (ODI) to ensure the facility’s scientific competitiveness in the future. The scheduled first light is in early 2010.

ODI is designed to deliver images at less than 0.3” seeing when the site provides it over the entire field of view. A two-element field corrector and an atmospheric dispersion compensator are required. The relatively slow telescope beam (f/6.3) of WIYN relaxed the demands for the flatness of the focal surface to achieve this image quality. At the same time, the design of narrow-band filters will be relatively easy compared to other upcoming wide field imaging capabilities with fast beam speeds (e.g., LSST with f/1.25; Subaru with f/1.8).

Image quality is a strong driver for ODI, and *image motion* will be actively compensated for throughout the one degree field of view. Such image motion is introduced by RA/DEC guide errors and wind shake (motion is correlated over the entire field of view), and by atmospheric turbulence (motion is correlated only within $\sim$ 4’). Two precursor instruments at WIYN have already demonstrated the benefits of active image motion compensation: the WIYN Tip/Tilt Mirror system, and the Orthogonal Parallel Transfer Imaging Camera. The typical improvement achieved is 0.1” to 0.15” in the R-band at median seeing condition. An early design of ODI was presented in Jacoby et al. 2002, SPIE, 4836, 217.

1.1. Tip/tilt image motion correction over a 1° field of view

Image motion caused by atmospheric turbulence is correlated only within patches of $\sim$ 4’ size, and needs to be locally sensed by bright guide stars for which the motion is corrected. The approach in ODI to achieve such motion correction over the entire 1° field of view is to use Orthogonal Transfer Array (OTA) CCD detectors (Tonry at el. 2002) . The pixel structure of Orthogonal Transfer CCD’s allows the charge in a detector to be moved both up/down and to the left/right during an integration. Each detector is divided into an 8x8 array of independent CCD cells that image $\approx$ 1’x1’ on the sky. Cells containing bright stars are operated in fast video mode and sense local image motion. The surrounding CCD cells will integrate the light while the charge is moved according to the movement of the nearby guide star. In this sense ODI will have a multi-conjugate, lowest order adaptive optics system.

2. Science with ODI & Future Imaging Capabilities

ODI is different from many other current wide field imaging projects as it is being built as a general facility instrument at WIYN . As such it is not driven by a single science case. Nevertheless, a few motivating science cases are summarised:
• The Local Universe: Wide field surveys of Galactic structure and stellar populations in the nearby Universe benefit from the area coverage and expected image quality of ODI. Image quality is as important as is aperture size for achieving deep photometry.
• The Distant Universe: ODI will have a high blue sensitivity, supplementing surveys for photo-z and star formation rates from redshifted UV emission in the low to intermediate redshift range. On the red end, e.g., wide-field narrow-band searches for L_α emitter's at z=5.7 and z=6.5 will be feasible.
• The Variable Universe: ODI will be permanently mounted at WIYN, enabling synoptic programs. The video mode of OTA detectors offers an interesting niche for variability studies: fast real-time photometry at a rate of up to 20Hz can be obtained simultaneously for 512 stars, or for 4096 stars at a slower rate.

A reasonable metric to compare imagers is $\frac{\text{Collecting Area}\cdot\text{Field of View}}{(\text{Seeing})^2}$. In this metric, ODI will be on-par with PanSTARRS PS1, the Dark Energy Camera, and Subaru's Suprime-Cam. The next class of wide field imaging projects (PanSTARRS PS4, Large Synaptic Survey Telescope, and Subaru's Hyper Subprime-Cam) will boost the throughput by almost a factor of 10 compared to what is currently achieved. In this new environment ODI will still have its niches: ODI will always be mounted enabling long-term synoptic surveys. ODI will be a general facility instrument, not a dedicated survey. And, ODI will excel in image quality.

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References

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