The WIYN One Degree Imager: An Overview

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Finding Answers to Some Key Questions in Astronomy

- Large Scale structure in the Universe (many degrees).
- Structure of Galaxy Clusters (a few degrees)
- Weak and strong lensing (a few degrees)
- Structure of galaxies (sub-arcsecond for large z, but large samples)
- Structure of the Galactic halo (entire sky)
- Very rare objects (Extremely metal-poor stars, interacting binaries, ...)

- The astronomical community is building a plethora of new wide field imagers:
  - Skymapper, VST, VISTA, DECam, ODI, PanSTARRS, LSST, Hyper-SuprimeCam, ...
A One Degree Imager for WIYN

• Use WIYN's 1° field of view.
• Utilize the excellent seeing of site & telescope.

Further enhance image quality by active tip/tilt image motion compensation.
• 20 Hz guide loop speed required, 50Hz goal.
• Shown to improve median seeing in R by 0.15”.

Median DIQ of ~0.55” in r’, capability of DIQ < 0.3” design goals.

• Sample the focal plane with 0.11” pixels -> 1GPixel camera.

High observing efficiency, automated cadences:
• shutter close to open <<20 sec in snapshot mode

Provide on-site basic data reduction
• Instrumental detrending, meta data, WCS...
Effect of Tip/Tilt motion on image quality

• Atmospheric turbulence, wind-shake cause image motion.

• Some image motion is correlated, e.g., due to telescope shake

• Uncorrelated image motion due to atmospheric turbulence

• (Not too new) Idea: sense motion from a bright guide star and compensate for it
  • Active secondary mirror (common in AO systems)
  • Move detector (consumer digital cameras)
  • Move electrons in detector (Orthogonal Transfer CCD)

• New Idea: do it over 1º FoV
Orthogonal Transfer Array CCD

Each cell is an independent CCD ~1’ on sky.

Each cell can be read out in video mode.

Each cell is either imaging or obtaining guiding information at up to 30Hz.

Tip/tilt correction can be applied to each individual cell.
OTA Detector Development

- OT(A) concept invented by John Tonry (IfA)
- Collaborative development of OTAs w/ PanSTARRS project

- ODI works with STA/DALSA
- Wafer production complete.

- Processing of wafers done by ITL (University of Arizona)
  - Thinning, packaging, and testing.
  - Mounting detectors on SiC focal plane.

- Delivery of 64 detectors in May 2010.
OTA Imaging w/ QUOTA

- 4 Detectors
- M 15
- SDSS r'
- 120 sec

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M51 seen by QUOTA:
- 50 min in U, 0.4" seeing
- 15 min in Y (red end of z')
- demonstration of sensitivity and image quality
- also demonstration of fringe behaviour
... on a 1° Field of View
Think about dithering!

- No dither - live with incompleteness.
- Small dither - cover the gaps between OTA cells.
- Large dither - cover gaps between OTA cells AND detectors
- Huge dither - potentially best flat fielding.
OTA Operational Modes

- **Static Imaging**
  - Use focal plane as conventional imager.
  - *Snapshot programs, photometric standards*

- **Coherent Correction**
  - Sample only a few guide stars (e.g., one in each corner).
  - Correct 1° field for common-mode image motion.
  - Removes guide error, wind shake.

- **Local Correction (default mode)**
  - One guide star every 4 arcminutes; ~200 over 1°!!
  - Correct for atmospheric turbulence (tip/tilt only).
  - Correct in ~4’x4’ cells only.
  - Not fully possible everywhere on sky.

- **Targeted Photometry**
  - Use guide star for shutterless photometry.
  - Select guide star for science goals (vs. to optimise guiding).
  - up to 512 guide stars.

*First commissioning phase*

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Filter Mechanism

- Design challenge: filter size (42cm)
- **Filter cost** ($65k-$100k est.)
- Filter weight
- Safe handling
- Minimum of 8 live filters as requirements

- ~30 seconds filter change time
• 3 Filters delivered to WIYN:
  • SDSS g’ r’ i’
• Additional filters to be acquired:
  • SDSS u’ i’
  • Narrow-band filter?
ODI Filter Performance

AURA-WIYN, ODI-OP-04-0006 RevA "r" band filter Lot 3009 (ED842) In-band T% Uniformity
Pk T% variation: 96.96%-98.31%
Blue HP variation: 551.23-554.28nm; Red HP variation: 690.12-692.96nm

AURA-WIYN, ODI-OP-04-0006 RevA "t" band filter Lot 3009 (ED842) In-band T% Uniformity
Pk T% variation: 97.66%-98.43%
Blue HP variation: 690.64-694.83nm; Red HP variation: 819.72-823.17nm
• 3x mirror reflections (Al coating)
• 8x reflection losses at optical surfaces (coatings, as built)
• PBL6Y, Fuse Silica
• CCD sensitivity
Corrector Optics Design...

• Atmospheric Dispersion Compensator (ADC)
  • less than 2% distortion over 1° FoV

• 2-element Design
• One aspheric surface

All optics received
Lenses coated or at coating.
Prisms under evaluation for quality.
Shutter

- 2-blade design for accurate timing & short exposure times
- Designed and fabricated by the University of Bonn (Germany)
- Delivered and accepted.
Focal Plane Module
Stargrasp CCD Controller
Resources

- ODI Web Page
  http://www.wiyn.org/ODI

- Guide Star Prediction Tool
  Experimental tool for guide star prediction.
  Not linked in ODI web page yet, preview at:

  http://www.wiyn.org/quotas/Software/odip2/

- Exposure Time Calculator
  In the Observing section, follow the link to Exposure Time Calculator
User Interface

• Queue-like user interface
  • Define observing sequence (e.g., 9x 100 sec in $g'$; 1200s Ha + 300s $r'$).
  • Define pointing (coordinates).
  • Define boundary conditions.
  • Combine pointing & sequence to define visits.

• Designed to enable book keeping for extended programs.
• Designed to be expandable into a queue system.

• Baseline for observations: visitor mode. See Pierre's talk for broader vision.

• Data handling:
  • 0.5-4TB / night
  • Data archive & calibration pipeline to be offered by WIYN.
  • Integrated calibration process, standard calibration plan.
• Project seeded; more details in Pierre's talk.
**ODI Time Line**

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<thead>
<tr>
<th>2010</th>
<th>2011</th>
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<td>Aug</td>
<td>Sep</td>
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**Semester 2010B**
- Schedule IAS ONLY
- ODI Installation & Engineering Commissioning

**Semester 2011A**
- Allocate Hydra port independently from ODI
- Scientific Commissioning Static & Coherent mode
- Scientific Commissioning Advanced Modes

- 100% telescope access for ODI
- 60% telescope access for ODI

**Notes:**
- Reserve
- ODI offered in shared risk; Static & Coherent correction mode

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Daniel Harbeck
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Implications for Yale Survey

• Expect start of data acquisition earliest in Spring 2011. For **first semester**:
  
  • Only Static and coherently corrected imaging (everywhere on sky!).
  • Expect inefficiencies, larger overhead.
  • Automatic dithering not working perfectly yet.
  • Remote scripting (“Phase II”) used for the first time for production.
  • **Keep first semester observations simple!**

• Data pipeline ramping up
  
  • Calibration not perfect yet - need to gain experience in Tier I.
  • Limited “Tier II” support only (e.g., stacking of dithered exposures).

• Advanced (“Standard”) modes to be enabled Fall 2011
  
  • Local image motion correction
  • **Check availability of guide stars!**
  • Data pipeline should be functional.
Bonus Tracks
Availability of guide stars

- At least one guide star available per chip on whole sky.

- Pointing needs optimization!

- If very few guide stars are available, correct for correlated image motion only.