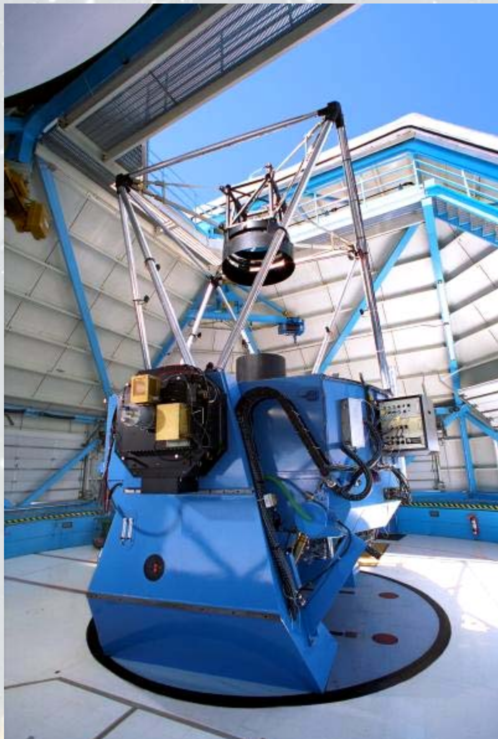
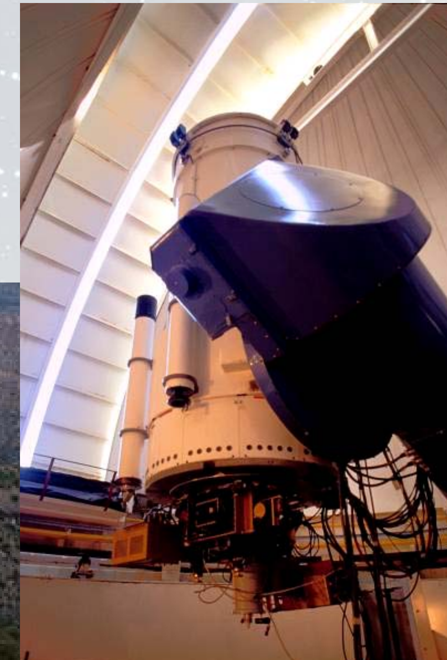
WIYN's Role in the US System of Telescopes



WIYN 3.5-m



0.9-m (36-inch)

The WIYN 3.5-m Telescope

- Alt-Az telescope mount
- Active optics corrects for mirror flexure (15-30s updates)
- Wide Field capability (1º unvignetted) at two Nasmyth ports
- Native seeing ~0.7” in R-band
- Slow f-ratio (6.3), well-suited to narrowband science
- Three available ports: 2 Nasmyth & one Cass port → can have four instruments “hot” (usually 3 are available)

W	–	University of Wisconsin (26%)
I	–	Indiana University (17%)
Y	–	Yale University (17%)
N	–	NOAO (40%)

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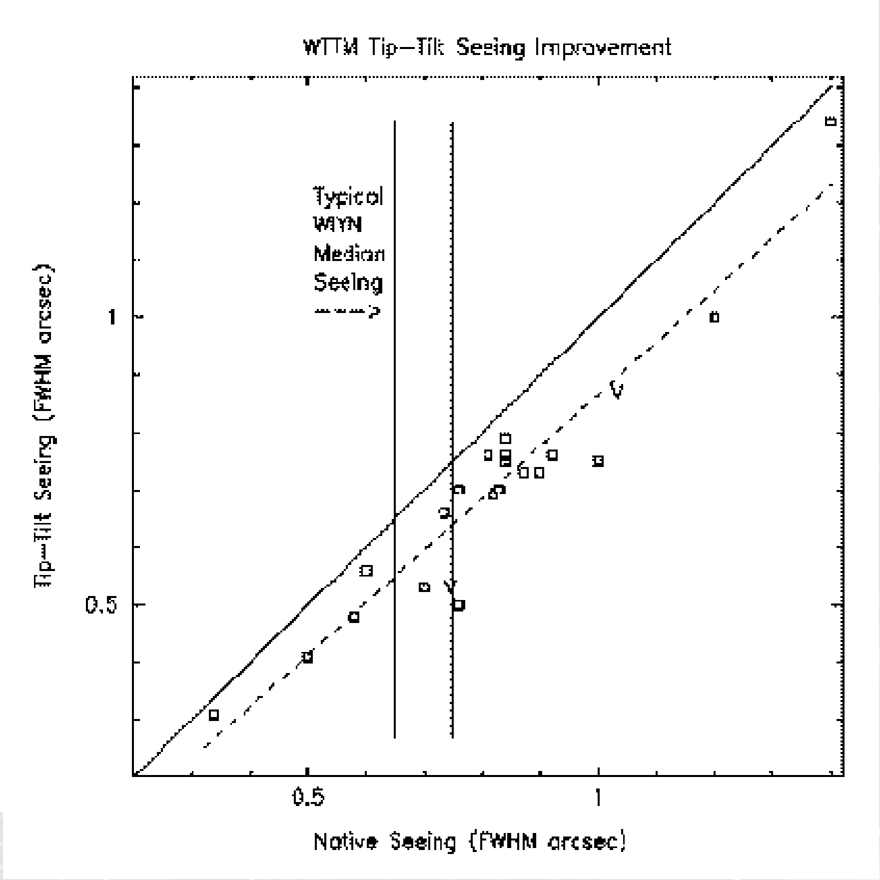
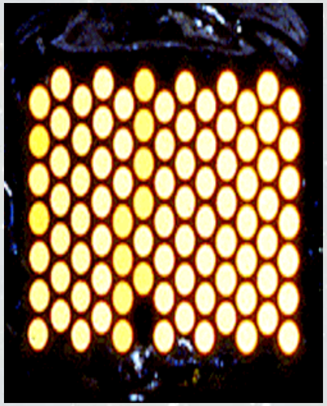
WIYN's Capabilities – Well Suited For Programs Needing …

- Good image quality
- 1º field of view
- Remote observing
  - Broad student participation
  - Short runs, split nights
  - Multiple observers per night
  - Rapid schedule changes
- Multiple instruments
  - To change program with conditions
  - Various observing modes possible, but not currently supported
    - Queue
    - Target of Opportunity
    - Synoptic

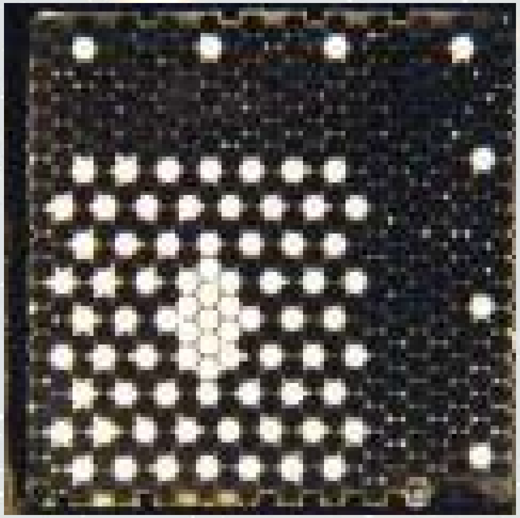


Current Instruments

- MiniMosaic (4Kx4K) imager (10’ field)
- OPTIC (4Kx4K) imager with OT CCDs [50% loan from J. Tonry]
- WTTM (2Kx2K) tip/tilt corrected imager [always on]
- Hydra fiber positioner (~85 fibers, 2” and 3” sets)[dedicated port]
- Densepak – 7x13 fiber bundle (3” fibers; closely spaced)
- Sparsepak – 82 fibers (5” fibers; great for LSB objects)



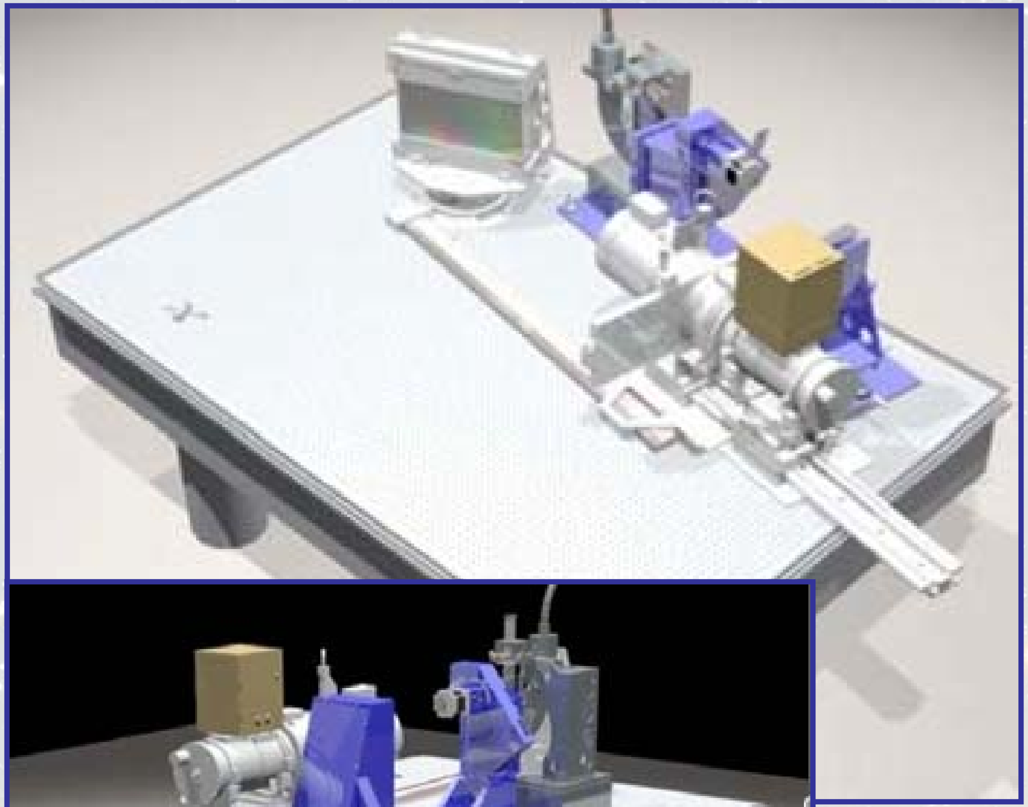
Densepak

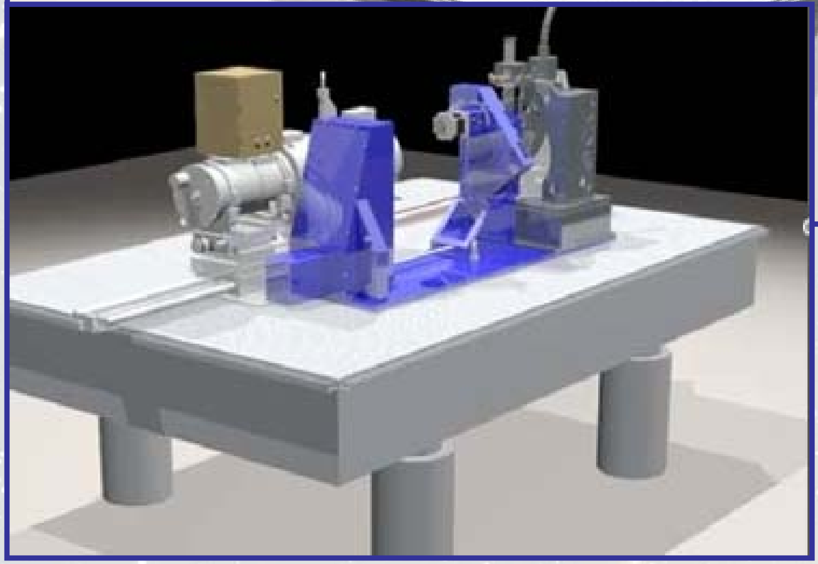


Sparsepak

Bench Spectrograph

- Provides stability for accurate velocities
- Resolution: 1,000 - 18,000
- Fed by 4 fiber bundles
- Upgrade in progress for efficiency gains of 2-4X
  - ♦ VPH gratings
    - 740 line/mm now
    - 3300 line/mm in Spring
  - ♦ New f/4 off-axis collimator (Fall 2007)
  - ♦ New CCD (Fall 2007)

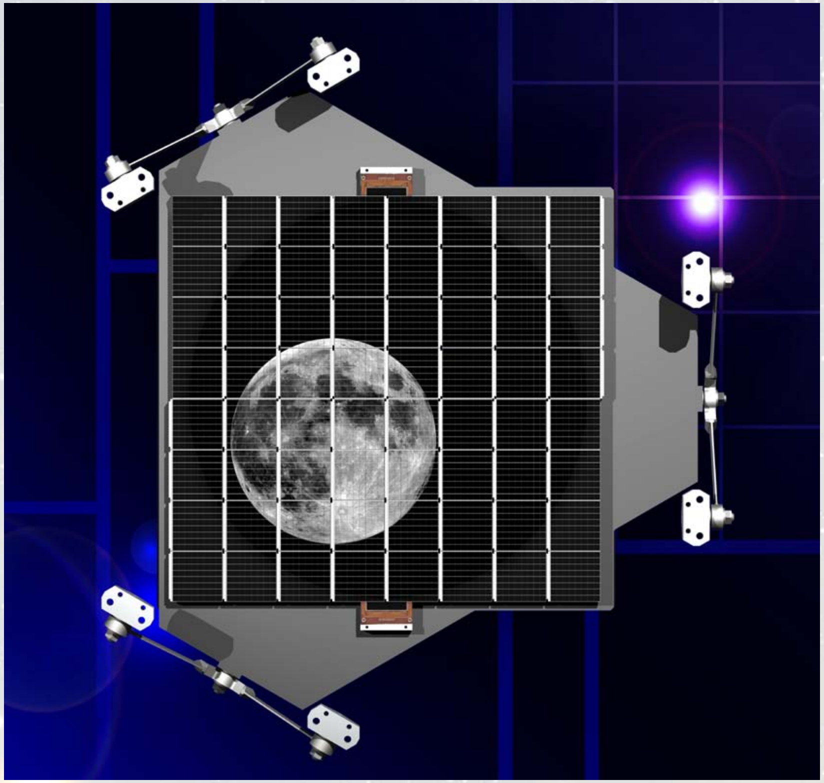




Under Development

- QUOTA – NSF/ATI and WIYN funded (about 50% - 50%)
  - 8K x 8K imager with 4 OT sensors ("OTAs", more later)
  - 0.11" pixels
  - 16 arcmin FOV
  - Commissioning began October 2006
- WHIRC – WIYN HIgh Resolution infraRed Camera
  Funded by STScI, NSF/ATI (led by Margaret Meixner, STScI), & WIYN
  - 2K x 2K Near-infrared imager for WIYN Tip/Tilt adapter
  - 0.1" pixels for near-diffraction limited imaging (3' FOV)
  - 13 Filters, including narrow-band, 3 redshifted
  - Expected delivery – mid 2007
- One Degree Imager – Funding from WIYN (75%) & NSF/TSIP (25%)
  - 32K x 32K imager with OTAs
  - ODI Details to follow
  - Expected delivery – mid 2009

One Degree Imager Overview



Sample Science Drivers for ODI

- Galaxy Evolution: Galaxies resolve if seeing better than 0.4’’
- Resolved Stellar Populations: Deep photometry under excellent seeing condition (RR Lyr in Local Group Galaxies)
- Astrometry: Proper motion of stars, Kuiper Belt Objects, parallaxes to 1 kpc
- Large field of view for surveys: from Galactic structure to galaxy evolution at high z
- Good image quality improves weak lensing detection
- Fast readout (8s) to study the variable sky
- High-Speed Photometry (to 40 Hz): Flickering stars; accretion disks in Galactic & AGN sources to 50 millisecond timescale; planet transits

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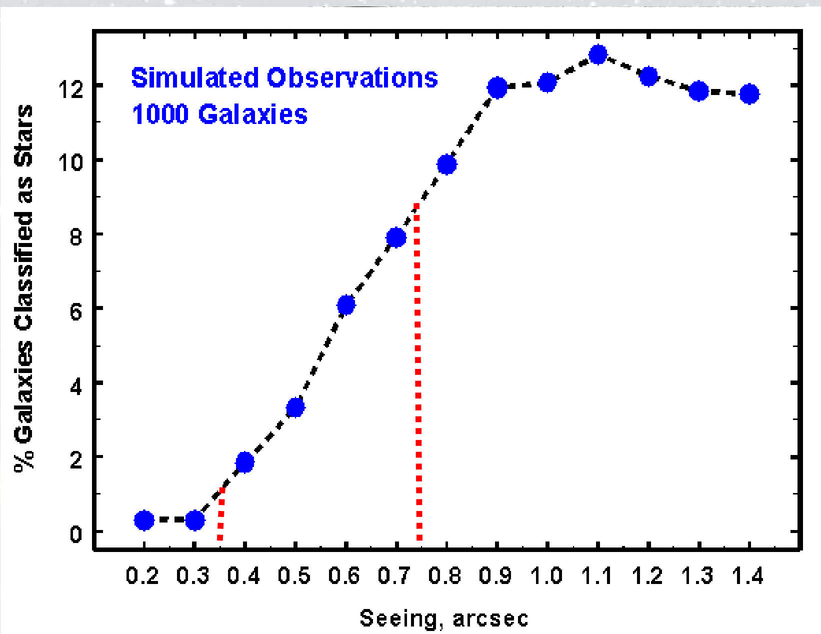
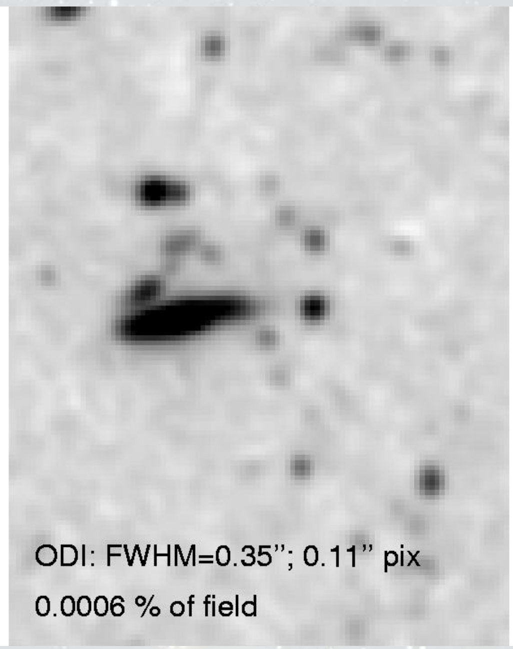
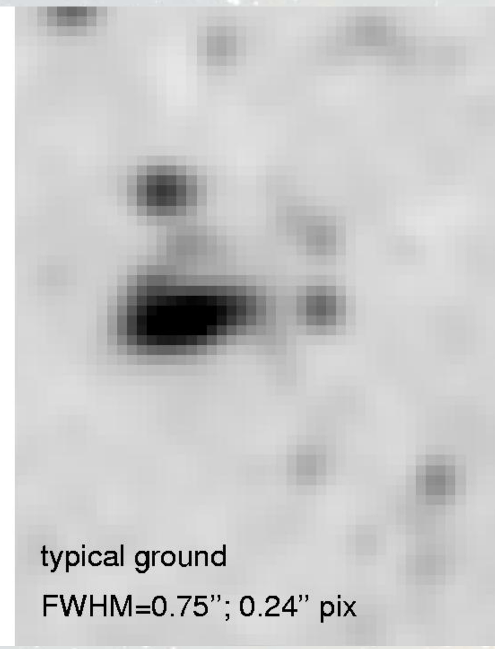
Sample Scientific Motivation: High-Z Study

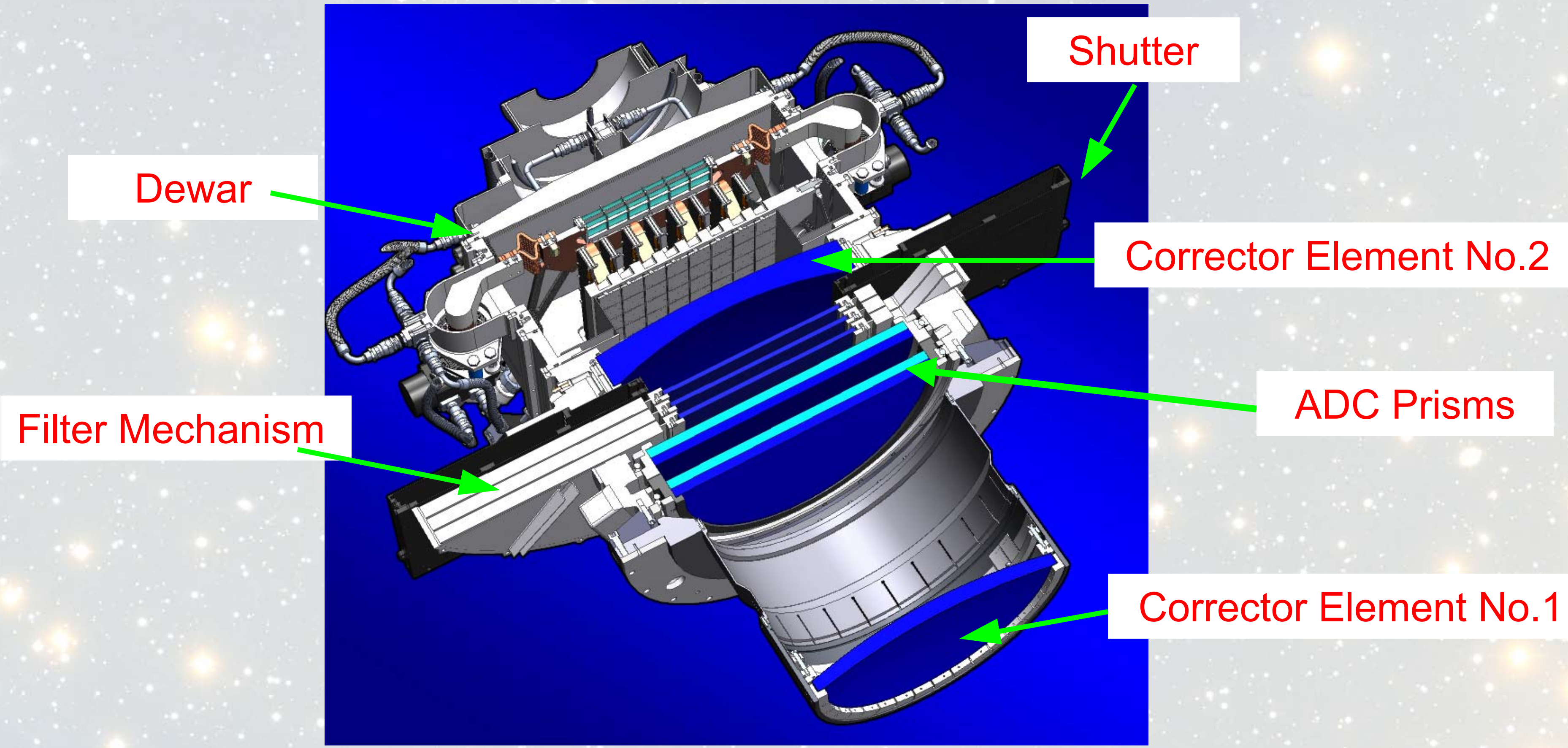
- *z*-band dropouts
  - Deep imaging of galaxies – confusion limited with imagers having 0.75” FWHM, 0.25” pixels
  - Simulation of ODI image of Hubble UDF by Pieter von Dokkum (Yale)







Inside ODI



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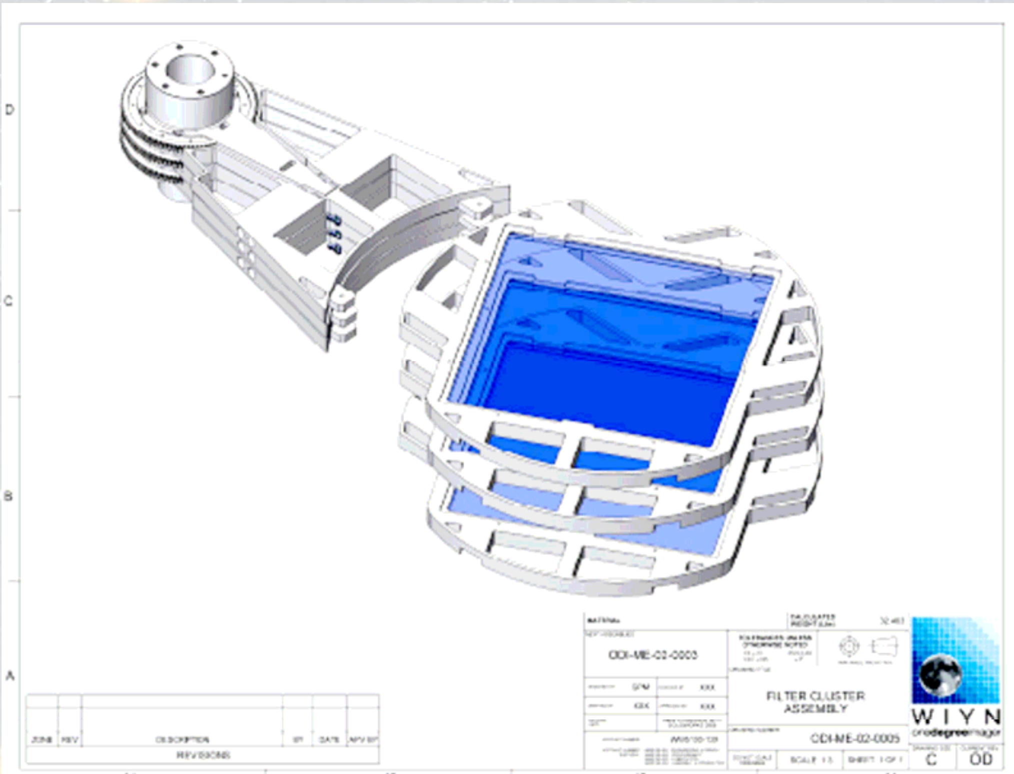
ODI Filter Mechanism



- Three banks of 3 “swing” arms
- Fast, light, relatively simple
- Filter carriers removable
- Multiple filters at once
  - Polarimetry ?
  - Grism ?
- Sloan griz
- Plus
  - Johnson U
  - Near-IR Y
  - Usual narrow band

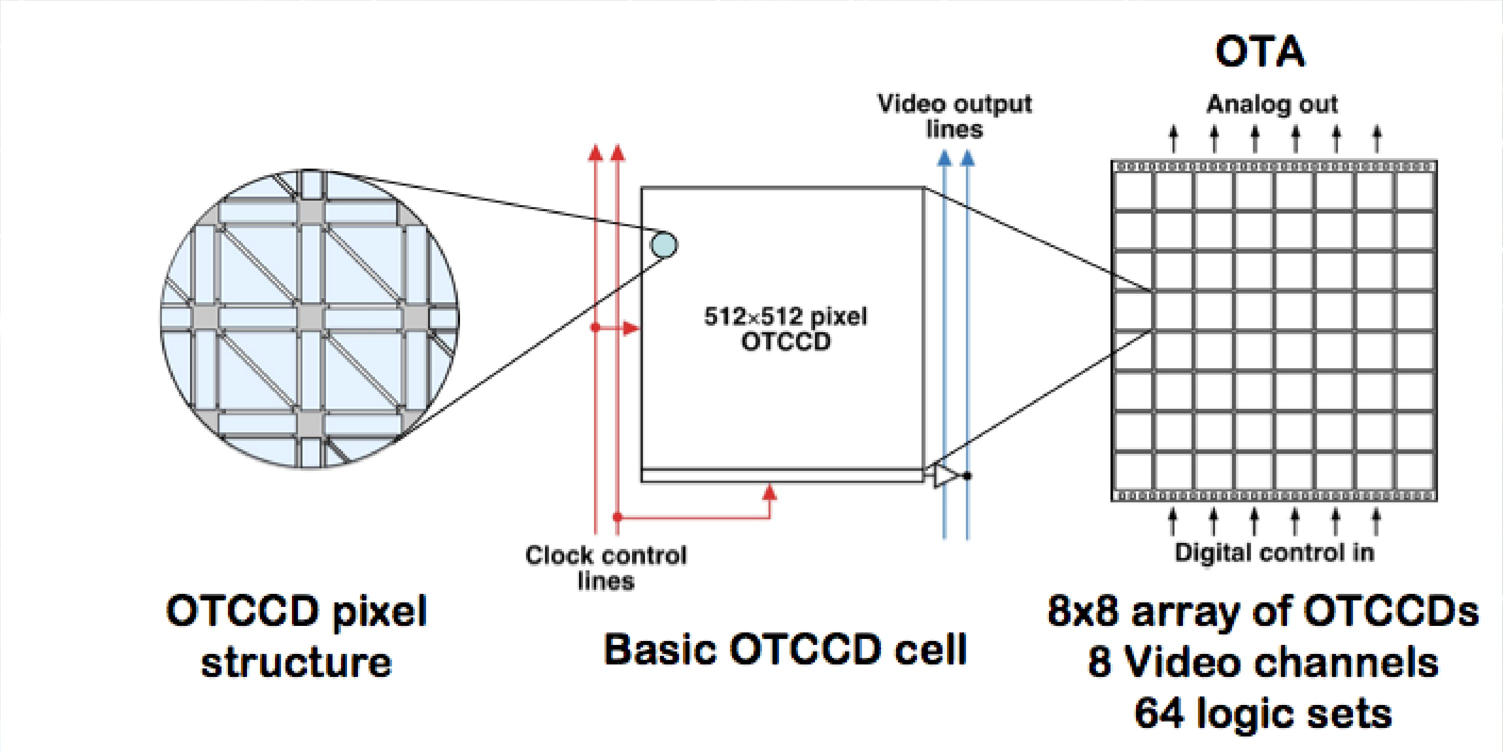
ODI’s place in the Astronomical Landscape

ODI will differ from other wide-field imagers in these areas:

- Image quality – median seeing ~0.54”, corrected R-band
  - fine sampling – 0.11”/pixel
  - OT correction (atmospheric tip/tilt, shake, guide errors)
- Time resolution
  - Fast readout of entire array (<20s)
  - Very fast readout of ~300 small regions (20-40 Hz)
- 9 filter slots (2 or 3 can be used in series)
- Good for narrow-band filters – slow f/ratio (6.3)
- OT CCD structure improves astrometry (0.002” relative precision per exposure)
- Access – generally-use instrument available to community

The Orthogonal Transfer CCD and Array

- Pixel is broken into 2 triangles with extra gate
- Allows charge to clock up/down or left/right



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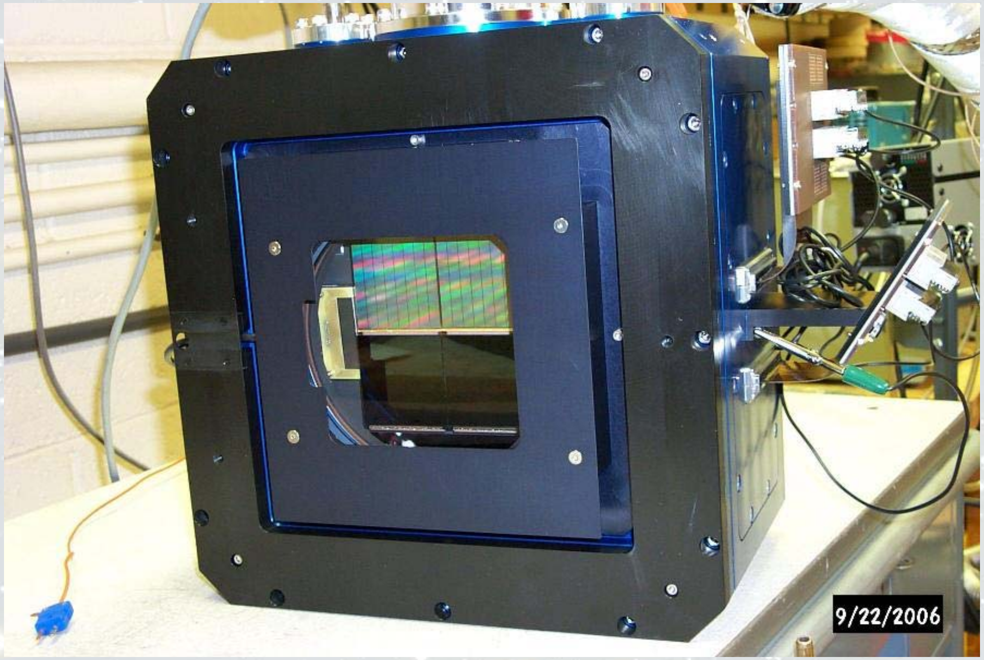
QUOTA - the ODI Demo Camera

- QUOTA → "Quad Orthogonal Transfer Array"
- 8K x 8K prototype to test OTAs, controllers, filters, shutter, software
- Uses 4 OTAs (4K x 4K)
- Uses one 32-channel MONSOON controller



QUOTA shown with 2 thin and 2 (disconnected) thick OTAs

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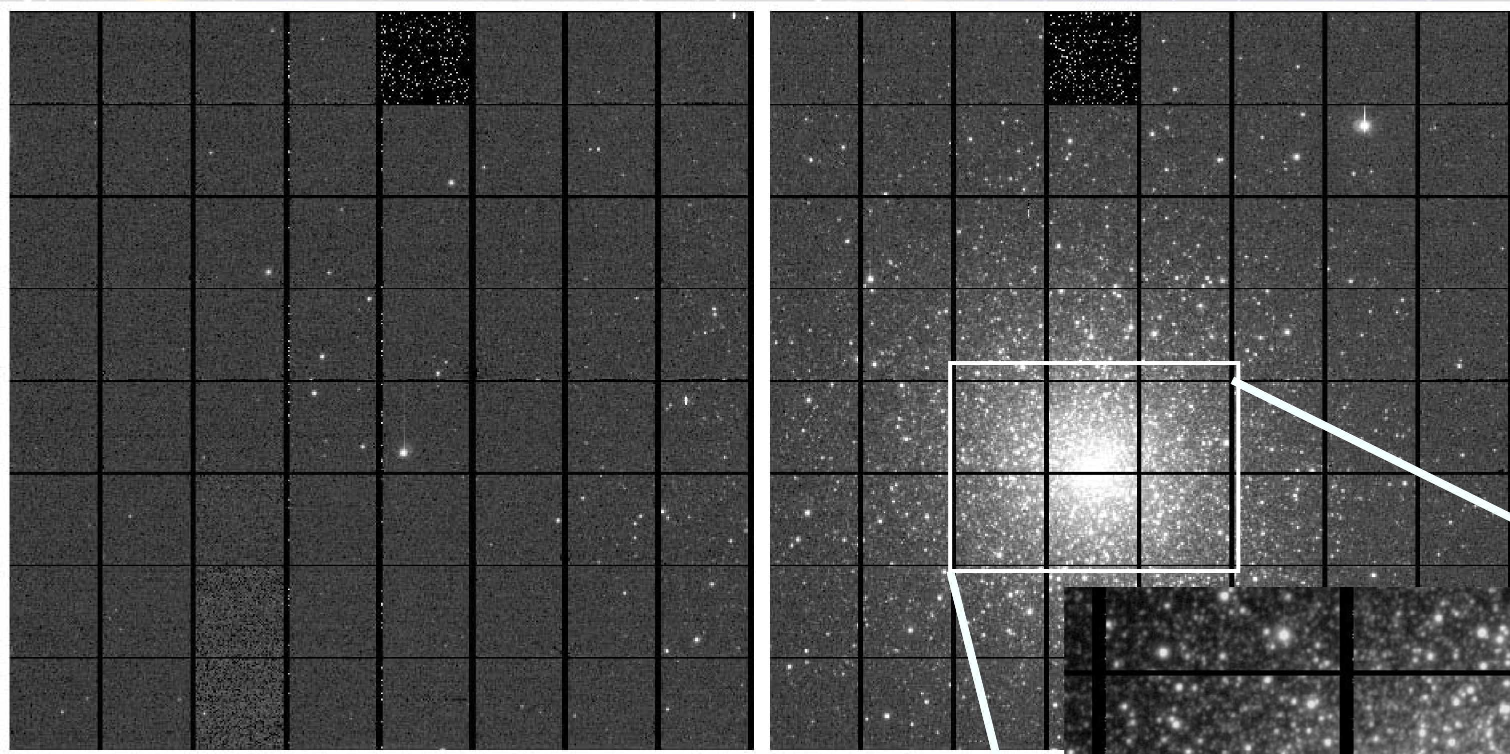
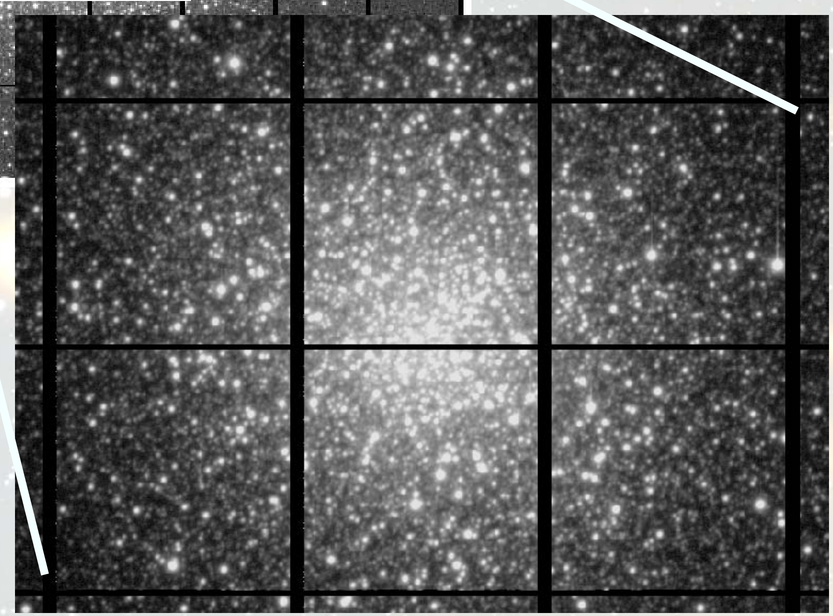
Globular Cluster M2





FWHM 0.54” (r’) across field

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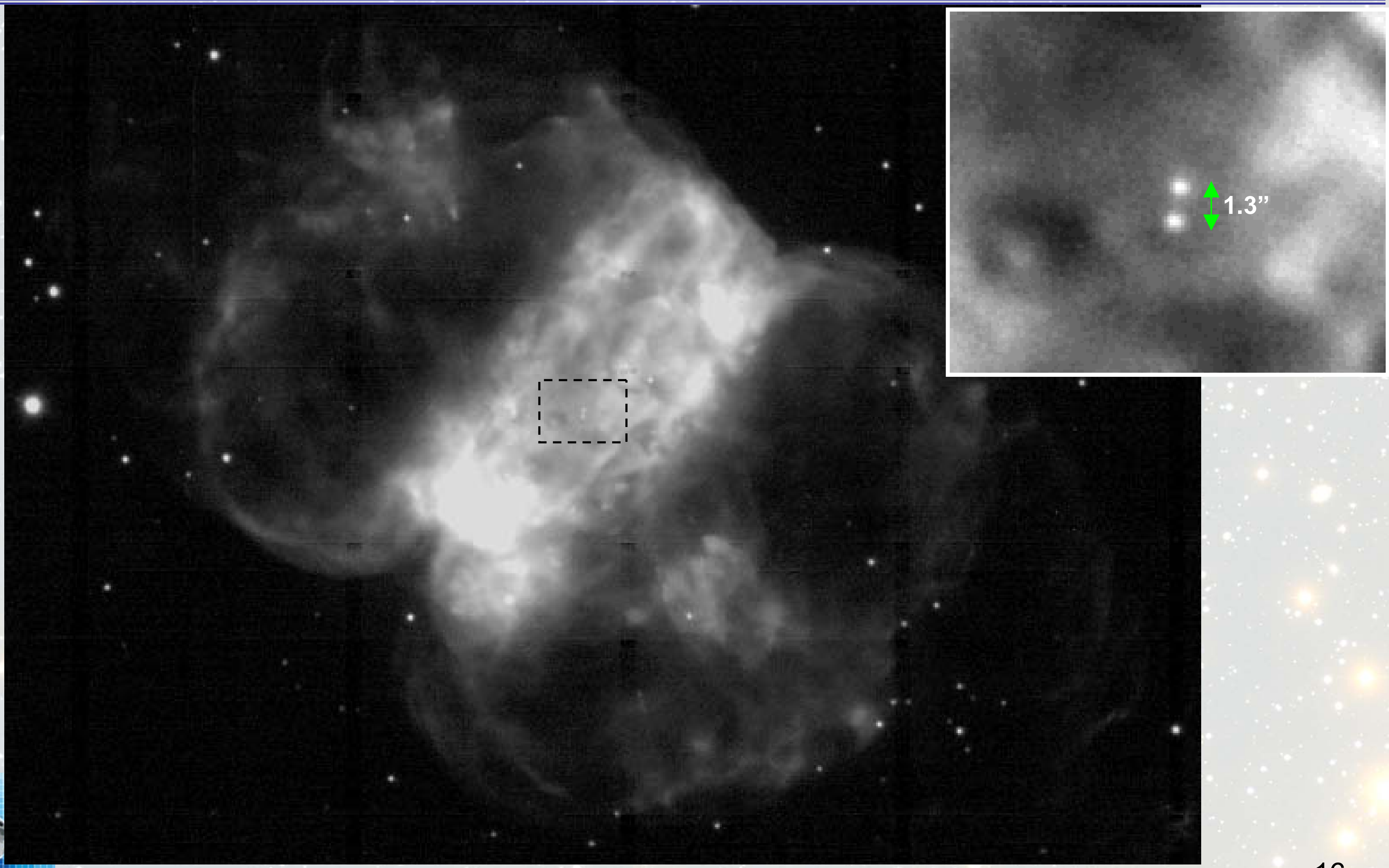
M76 in Hα (0.6” FWHM)



TSIP Return to Community

- ODI is funded at ~25% through TSIP
- WIYN will provide:
  - 40 nights from the non-NOAO 60% share (7 nts per semester starting Fall 2009)
  - Invitation to participate in a 90-night survey carried out by Yale
  - All ODI data will be made public after 18 month proprietary period

- Yale 3-year survey strawman strategy
  - Targeting stellar parallaxes, high redshift galaxies, SNe, variables
  - 3^h every 4^{th} night using z' and Y filters in groups of 4 months
  - 3 deep field and 90 shallow fields (over a year) to:
    - z' ~ 27.5 (deep); z' ~ 26.0 (wide)
    - Y depends on detector performance
  - Opportunity for community to refine plan, add time

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ODI Team

- John Cavin, Project Manager
- Charles Corson, Telescope Engineer
- Daniel Harbeck, Project Scientist
- Charles Harmer, Optical Designer
- Steve Howell, Telescope Scientist
- George Jacoby, ODI optics, QUOTA
- Joe Keyes, Mechanical Engineer
- Pat Knezek, Design Review Coordinator
- Gene McDougall, Electronics Engineer
- Gary Muller, Mechanical Engineer
- Dave Sawyer, Project Engineer
- Andrey Yeatts, Software Engineer
- NOAO engineering, Monsoon

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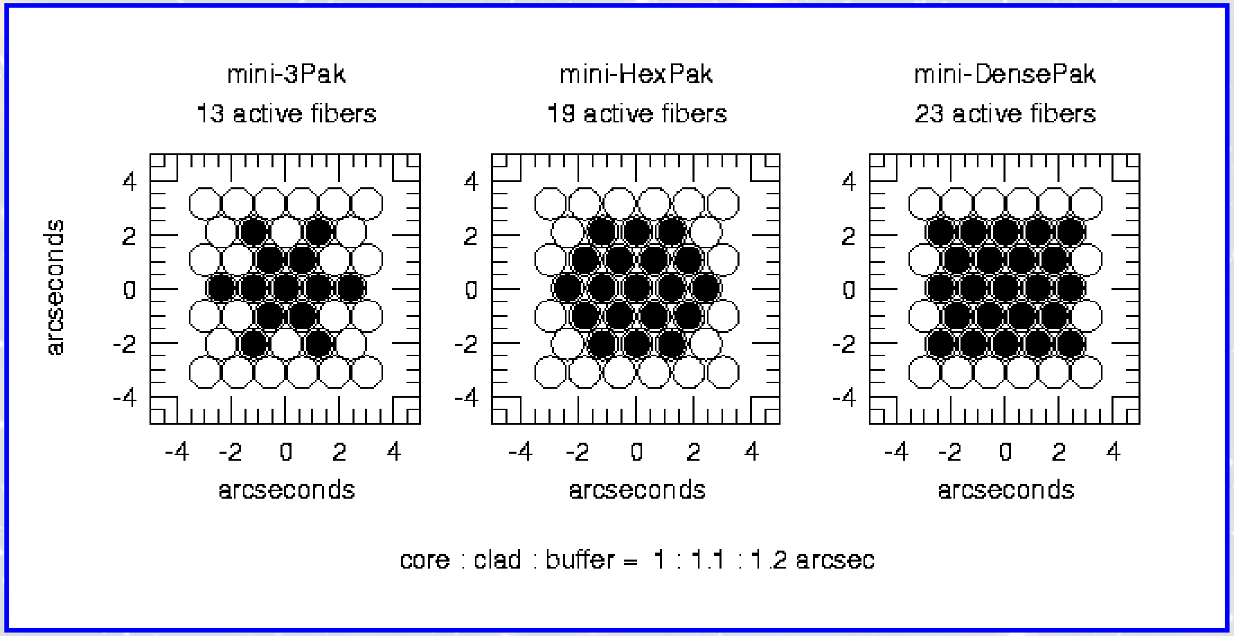
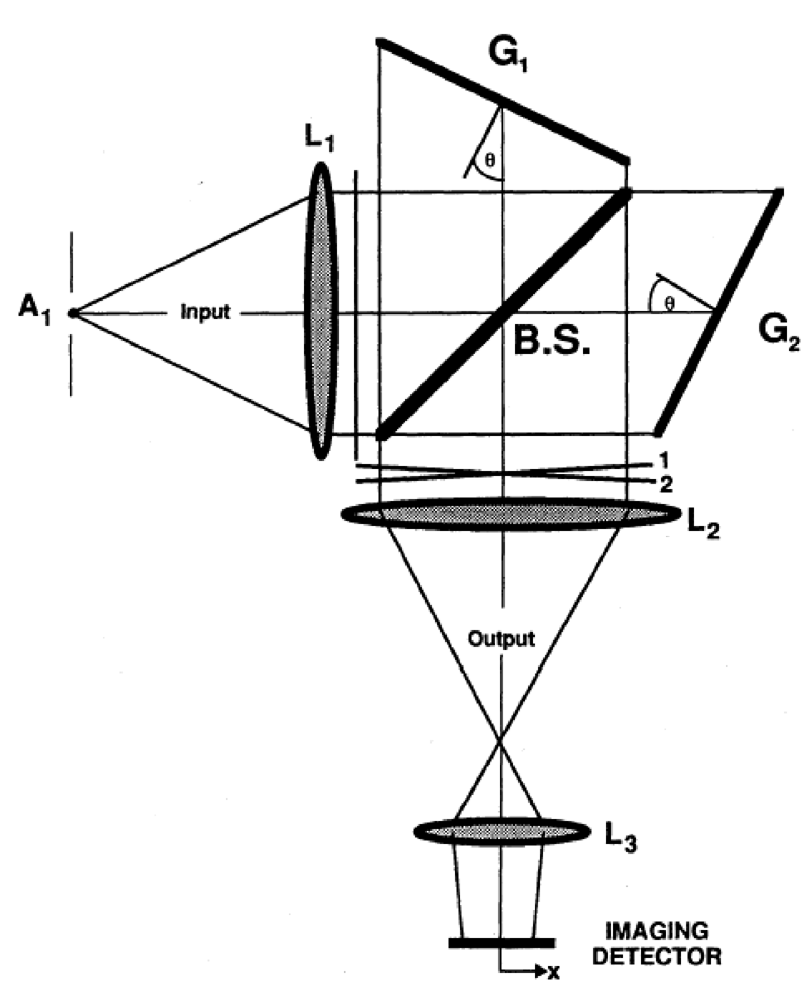
Future Instruments ?

- WIYN is now planning the next major instrument after ODI
- Strong interest in multiple deployable IFU spectroscopy
  - Leverages existing re-built Hydra robotics
  - Leverages investment in Bench spectrograph upgrades (VPH gratings, new collimator, new CCD)
  - Fiber configuration TBD, number of IFUs can be 5-30



For details, see Matt Bershady!

Spatial Heterodyne Spectroscopy (SHS)



- Compact spectrometer for ELTs – concept to be tested at WIYN.
- Wavelength dependent Fizeau fringes which result from crossed wavefronts 1 and 2 at the exit of the interferometer are recorded along the x-direction by a detector array.
- The Fourier transform of the fringe pattern returns the spectrum.
- See Andy Sheinis!

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WIYN 0.9-m Telescope

- Formerly, operated by KPNO
- WIYN renovated in 2001
- Heavily used for students, outreach
- ~20% of time is available through NOAO
- Instruments
  - Kitt Peak Mosaic (8K x 8K) – One Degree FOV (0.4” pixels)
  - 2K x 2K SITe CCD (21 arcmin FOV, 0.68” pixels)
- Future – “Half Degree Imager”
  - 4K x 4K Monolithic imager (0.4” pixels)
  - Funded by PREST

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PREST Return to Community (5 years)

- 20% access to HDI
- Access to all HDI data after proprietary period
- Access to 0.9m queue opportunities
  - 1-2 hours per night for synoptic targets
  - "Opportunity" queue ("Let's make a deal" with whoever is observing) – See: http://www.noao.edu/0.9m/oq/
    - **Web posting of desired observation and proposed reward!**
    - Rewards like co-authorship are more attractive than acknowledgements
    - Short blocks of time are more likely to be chosen than large blocks
    - Standard (UBVRI) filters impact calibration plans less than special filters
    - Moonlit conditions are more attractive than dark conditions
    - Interesting and complete descriptions of the science may be more inspiring
    - Friendly, prompt and helpful correspondence with observers fosters better observations.

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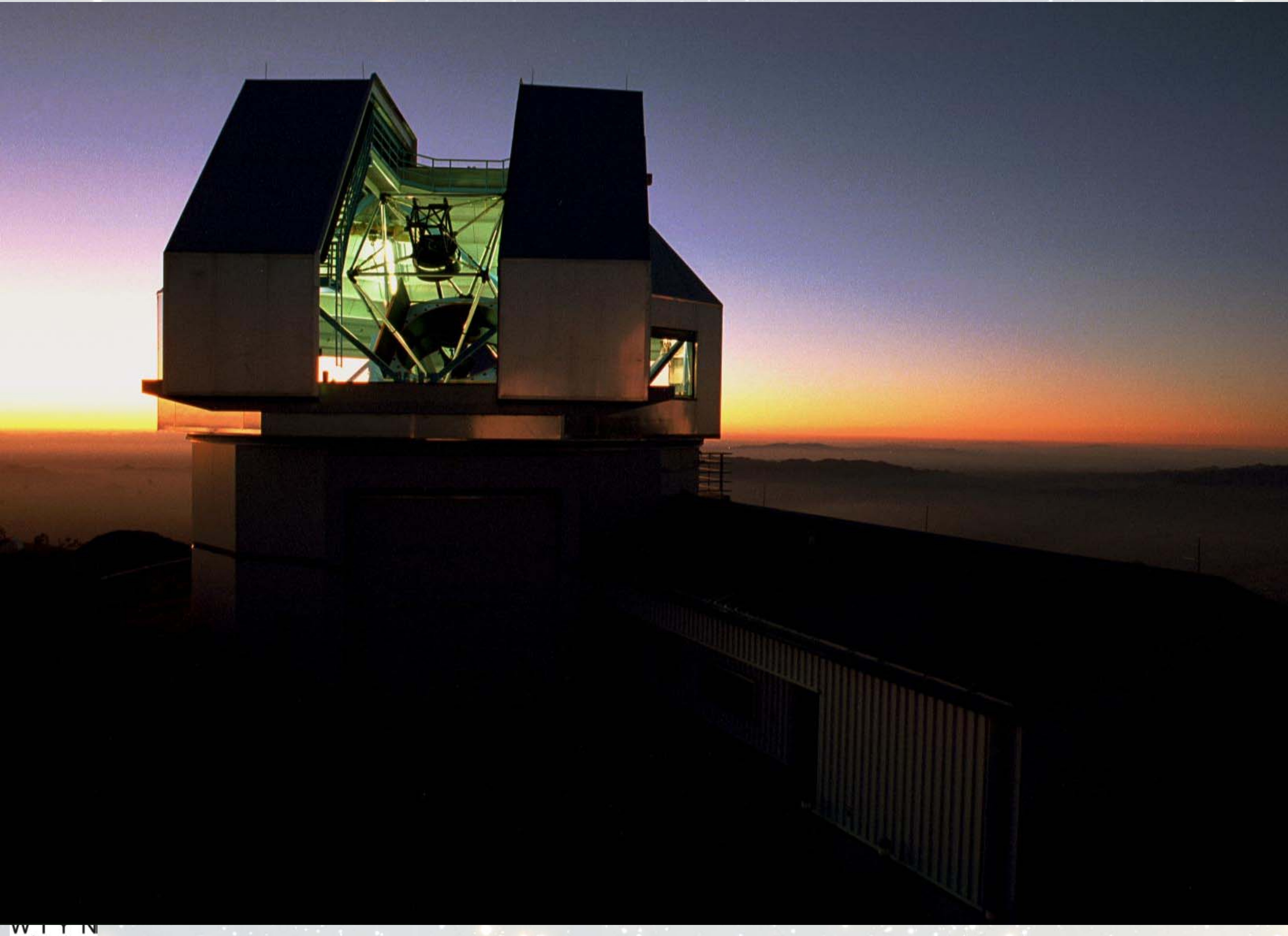

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WHIRC Details

Selected IR array	Raytheon Virgo/Vista science grade array
Wavelength range	0.8 – 2.5 μm
Plate scale	0.1"/pixel
Field of view	~3.4'x3.4'
Focal plane	Raytheon ($2K^2$ with 20 μm pixels)
Array cost	$200K (includes MUX for testing)
Estimated QE (JHK_s)	80%,91%,90%
Filters	13 filters (J, H, K_s, numerous narrowband, eg. Brγ, HeI, H_2, CO, some redshifted)

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WHIRC Filter Set (13)

Filter	Wavelength
	μm
J	1.25
H	1.635
Ks	2.15
He I	1.083
Pa β	1.2840
[Fe II]	1.6463
Br γ	2.16
CO	2.295
Pa β +4500 km/s	1.3032
[Fe II] +4500 km/s	1.6710
Br γ +4500 km/s	2.1924
Low airglow	1.061
H_2	2.12

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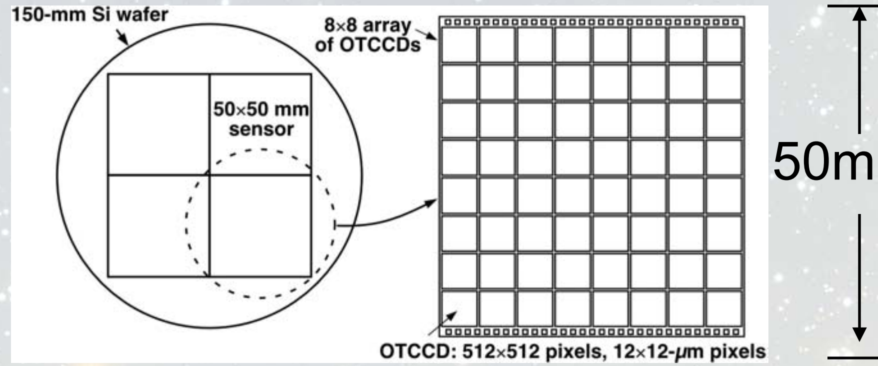
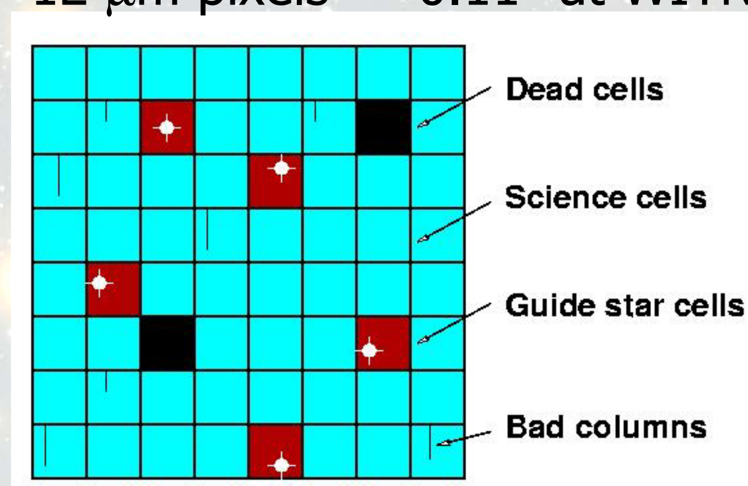
OTAs: Orthogonal Transfer Arrays

- 64 independent 480x494 CCDs
  - Individual addressing of CCDs
  - 1 arcmin field of view at WIYN
  - Bad columns confined to cells
  - Point defects are tolerated
- Cells with bright stars → guide stars, or read fast, up to 40 Hz, to avoid blooming, or for time studies
- 8 video channels – 8s readout
- Intercell gaps (0.1-0.3 mm; 1-3”);
- Inter-OTA spacings: ~1 mm (10”)



12 μm pixels = 0.11″ at WIYN



Compare to Some Large Imagers

Telescope /Imager	Aperture, m /f-ratio	Field, Deg^2	Nr. Pixels	Pixel Size, arcsec	Readout Time, sec	Seeing, R-band	Metric, M
CFHT/Megacam	3.6/4.1	1.00	20K x 18K	0.18	20	~0.7"	1.9
MMT/Megacam	6.5/5.0	0.16	16K x 16K	0.09	30	~0.65"?	1.0
LSST/DMT (~2013)	(6.9)/1.2	9.00	47K x 47K	0.20?	4?	~0.6"?	100
Subaru/Suprime	8.2/1.8	0.25	10K x 8K	0.20	60	~0.6"	2.0
WIYN/ODI (2009)	3.5/6.3	1.00	32K x 32K	0.11	4	~0.5"	4.1

$$\text{Metric, M} = \frac{A\,\Omega\,\varepsilon}{d\theta^2}$$

A = aperture

Ω = Solid angle on sky

ε = Efficiency of the system (e.g., readout time)

$d\theta$ = Seeing (e.g., FWHM)

$M_{MiniMo} = 0.04$

$M_{Mosaic} = 0.29$

$M_{QUOTA} = 0.33$

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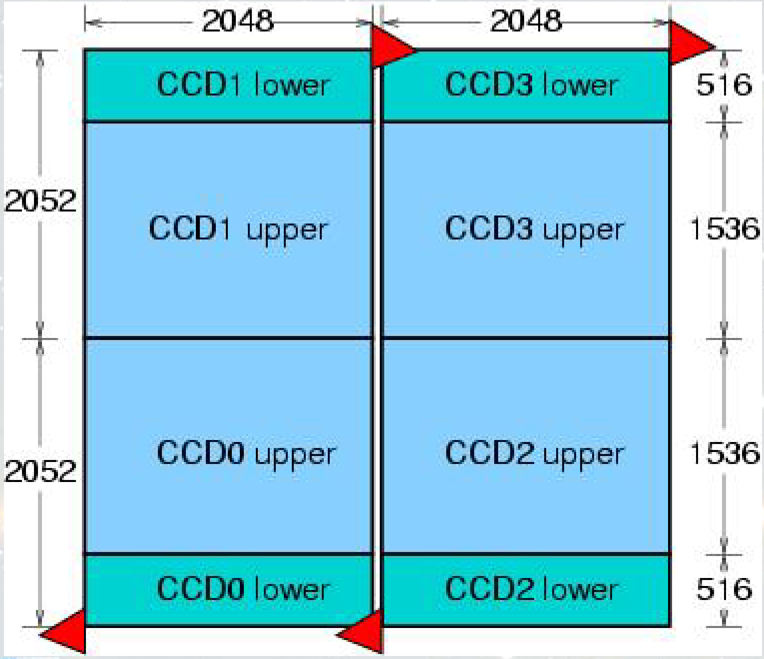
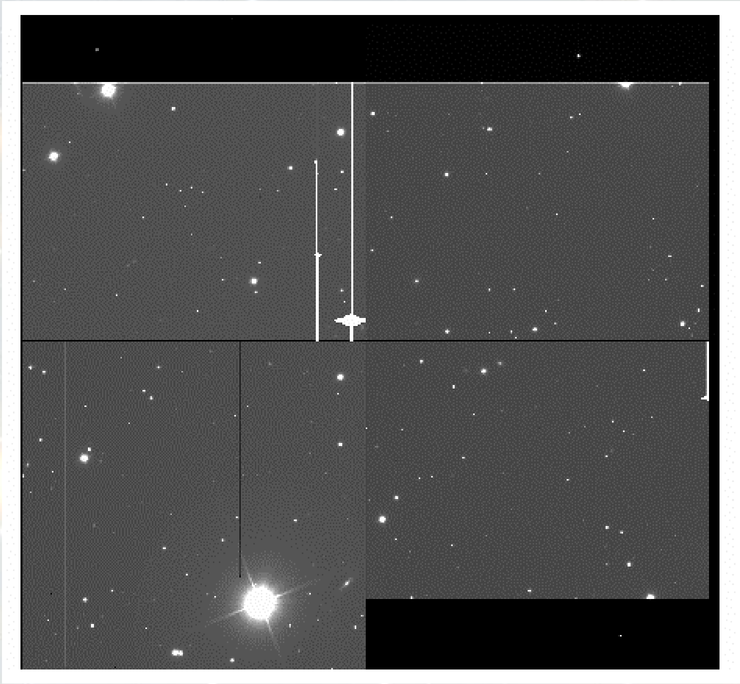
OPTIC – ODI's Ancestor

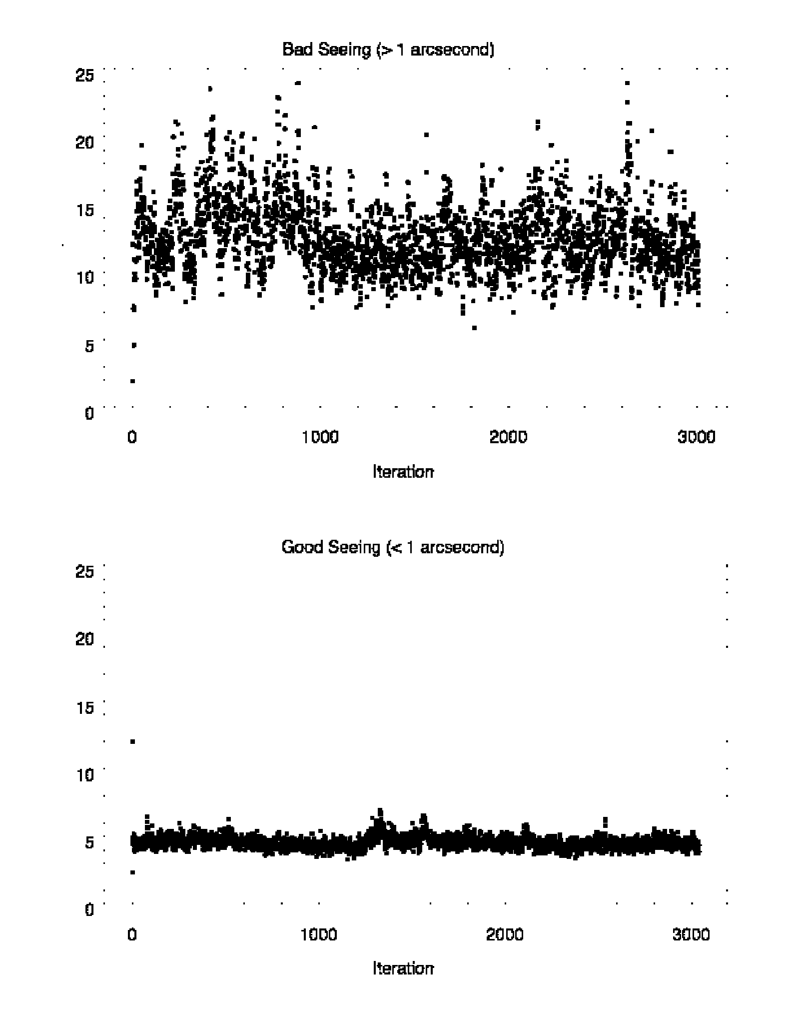
- CCD Format
  - 2 – 2Kx4K OT CCDs
  - 4 high-speed read zones
  - 4 science zones

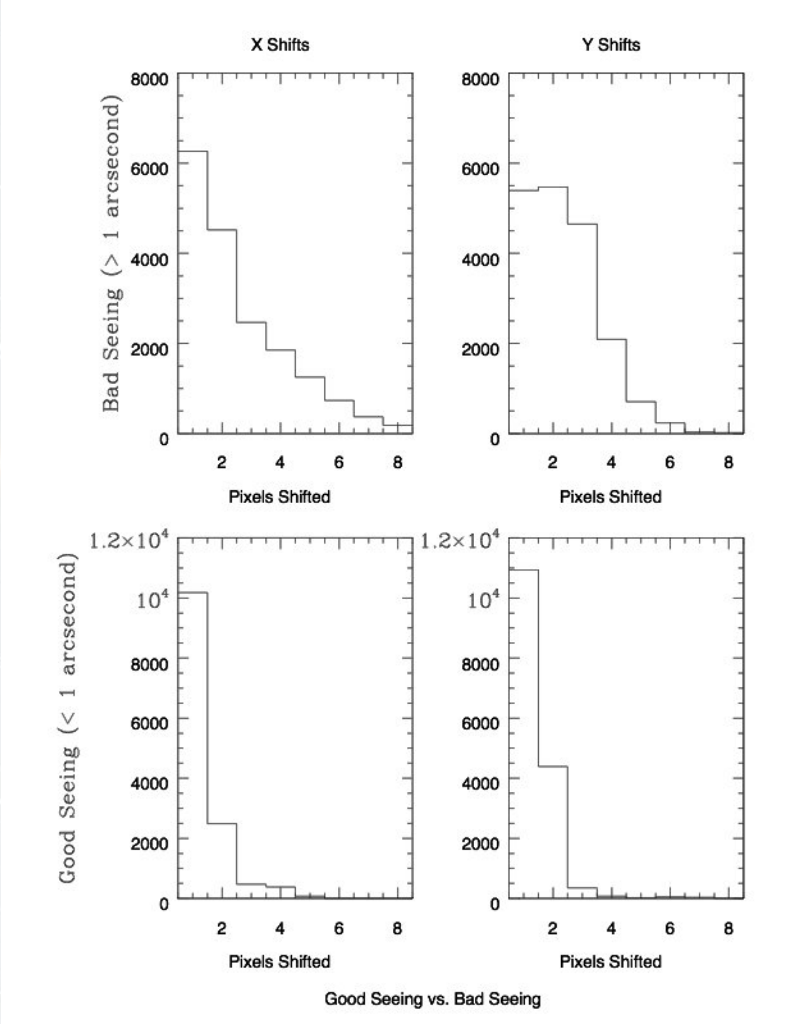


- Example – 300s R-band image
  - 3 of 4 guide regions selected
  - Read at 10-50 Hz
  - Tip/tilt correct remaining pixels

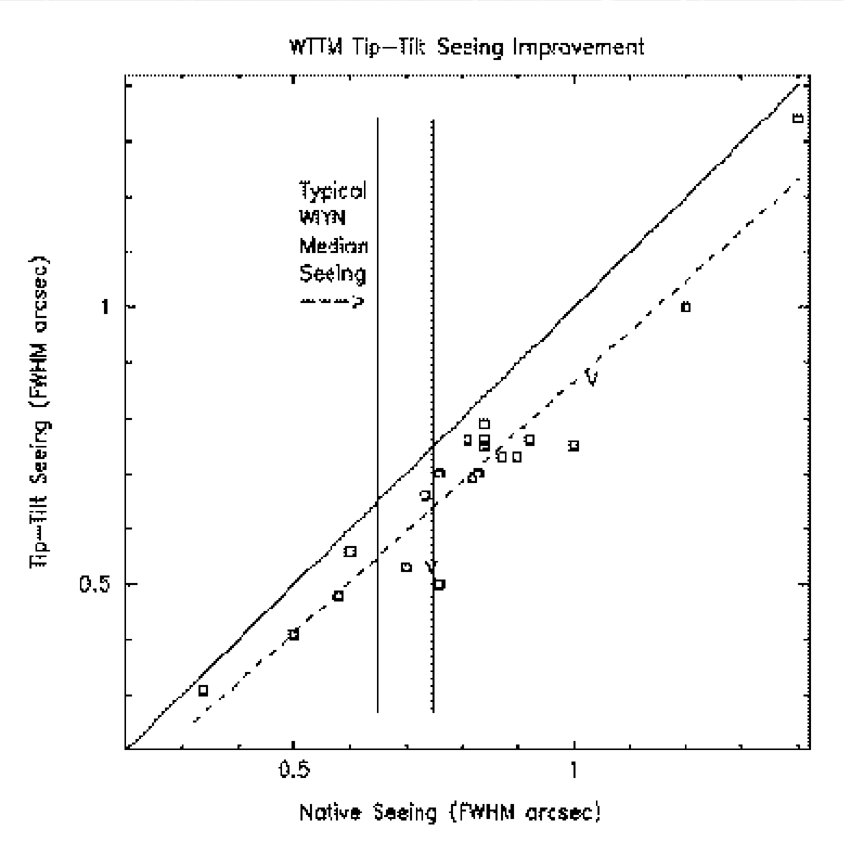


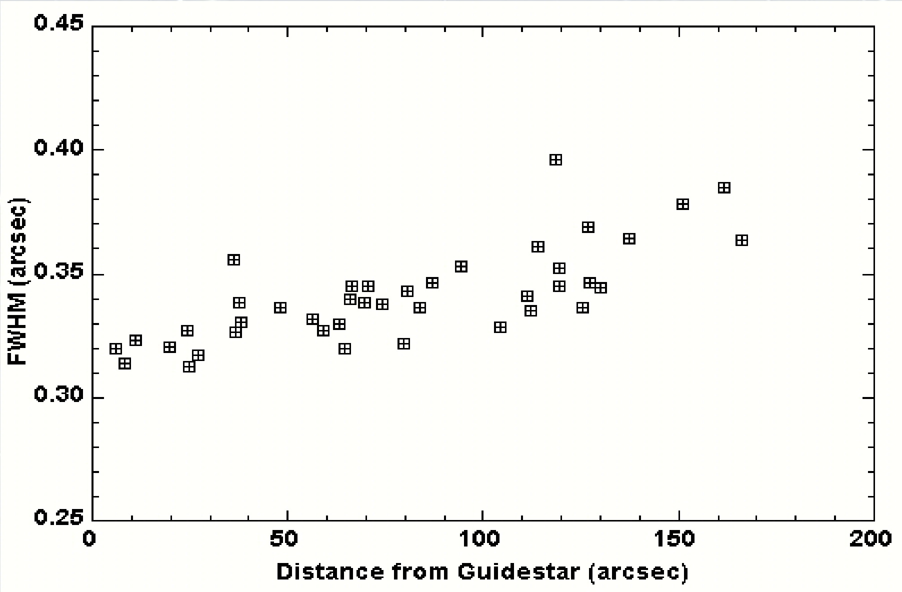
Example of Guide Histories





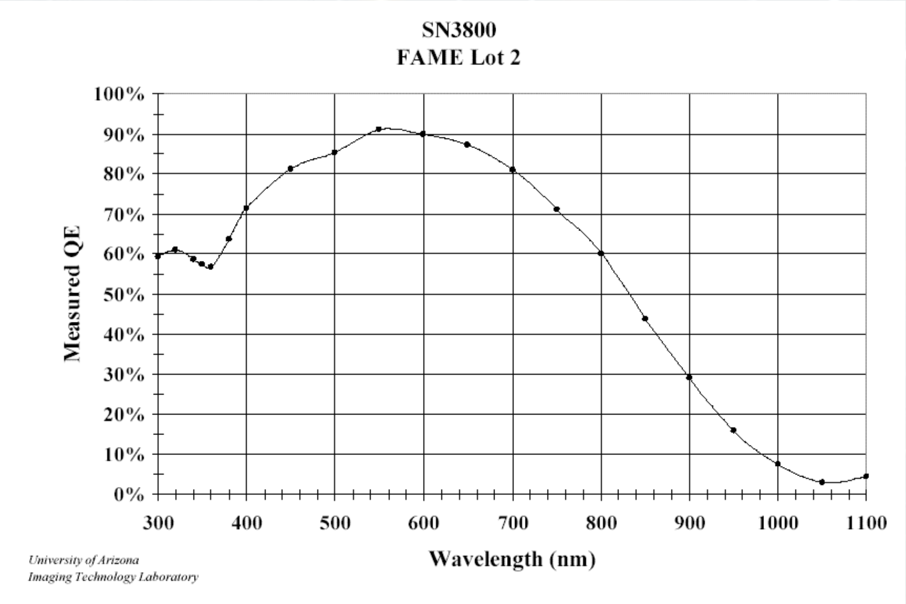
Tip/Tilt Improvements



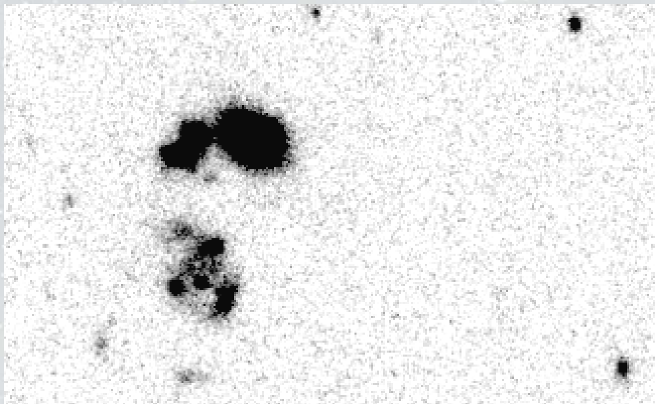


Quantum Efficiency

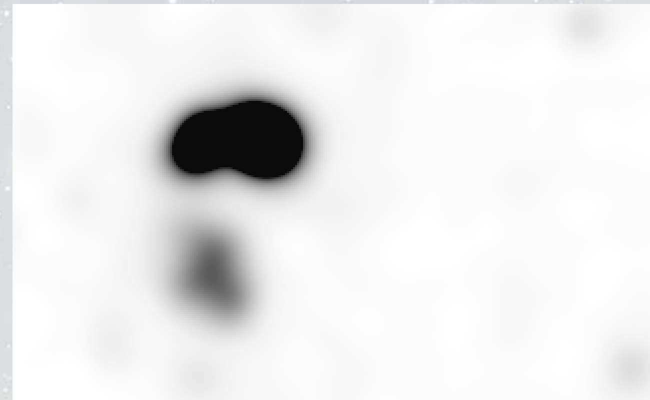
- Quantum Efficiency (QE) has not been evaluated yet. The backside processing for OTAs is no different than conventional CCDs, so it is expected to be similar to other thinned devices such as FAME (plot below).
- The QE will be evaluated with one of the thinned devices expected this week (August 24).



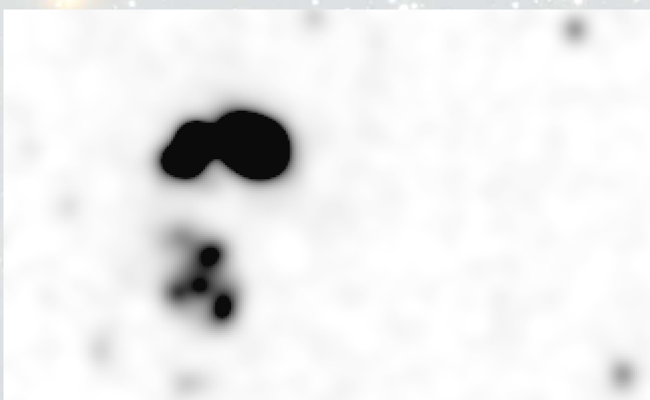
Need for Atmospheric Dispersion Compensator



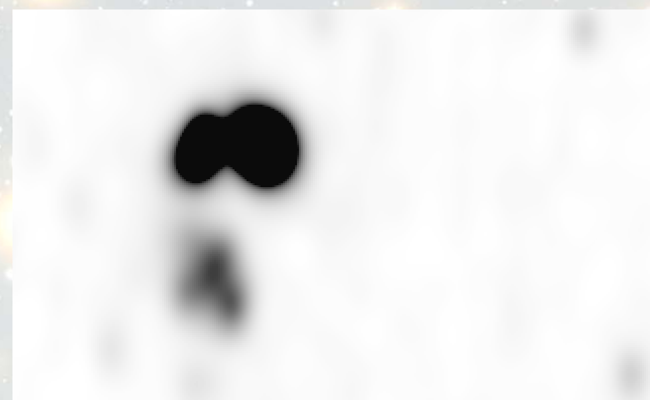
HDF South



0.8” simulated seeing



0.4” simulated seeing
ODI goal



0.4” simulated seeing
w/o ADC at X=1.3, g’ band