Science Capabilities of ODI on WIYN

What can ODI do for you?

AAS Meeting #214 Session 220.03
Meeting within a Meeting: "Science with the WIYN One Degree Imager"

6/9/2009

ODI will be a facility instrument at WIYN

Roughly 40% of the time is NOAO time, open to the whole astronomical community.

Going forward, it will likely be the primary wide-field optical imager available to the community in the Northern Hemisphere.

But – not just "another" 1 degree imager…

ODI features

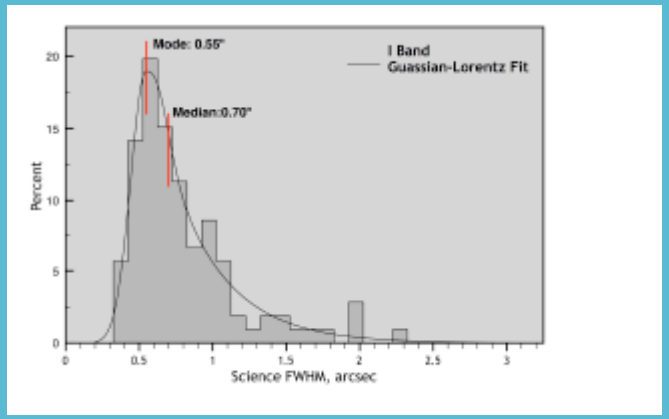
- Optimized for image quality over a wide field.
- Orthogonal Transfer Array technology allow multiple observing modes.
- Fast readout time and focus sensors for efficient observing.
- Optimized for “good” response over a very wide range of wavelengths (3500-10000A).
- Designed to work with narrow-band filters.

Image Quality—Seeing matters!

The WIYN telescope already delivers good image quality with the current optical imagers such as Mini-MOSAIC.

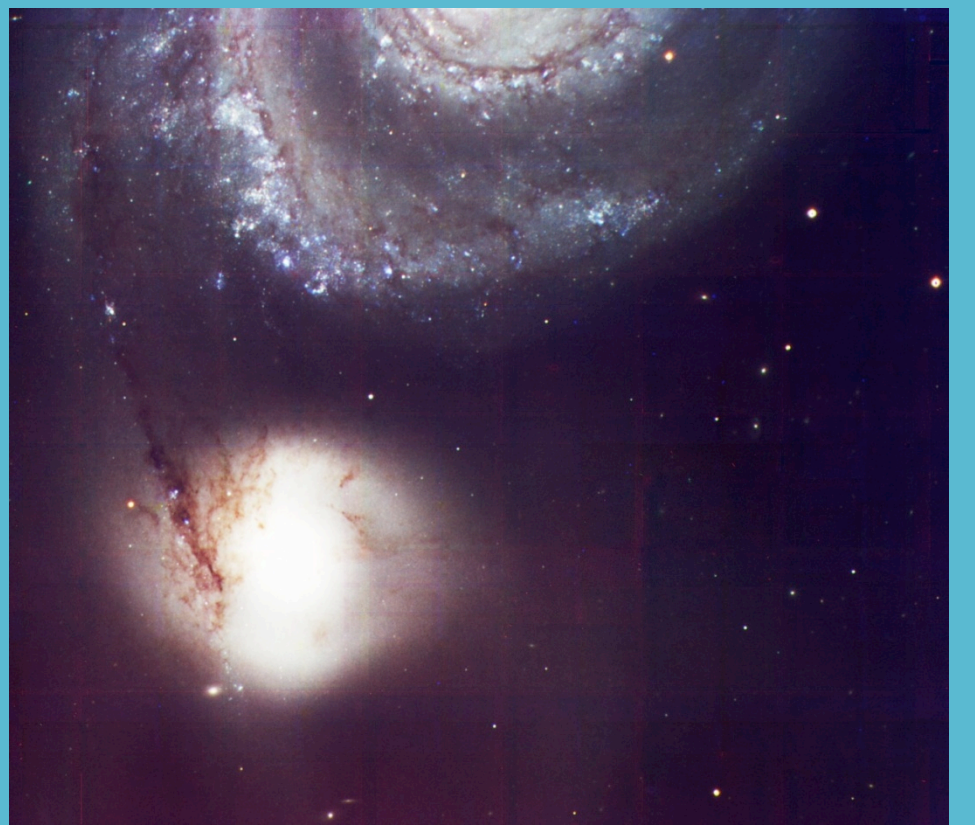
The experience of the past years with the OPTIC and QUOTA OT cameras on WIYN suggests that ~0.1” improvement in median seeing conditions can be obtained via OT guiding. (more improvement in worse seeing)

ODI will “routinely” (~30-40% of the time) deliver images with <0.5” FWHM in the redder bands (i’ and z’).



FWHM distribution of 106 OPTIC I exposures (from WIYN DIQ report)

U=band exposure from WIYN — FWHM is 0.45”!



Effects of seeing—just a few examples

More examples in the next two sessions…think of your own projects!

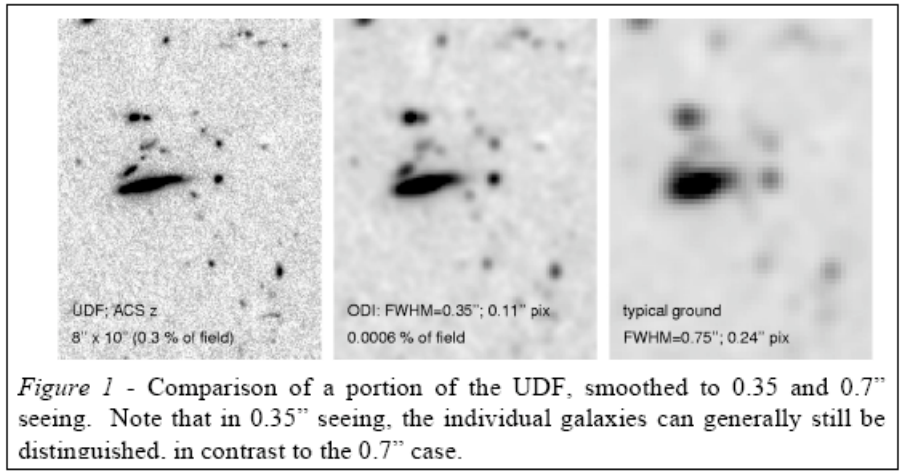
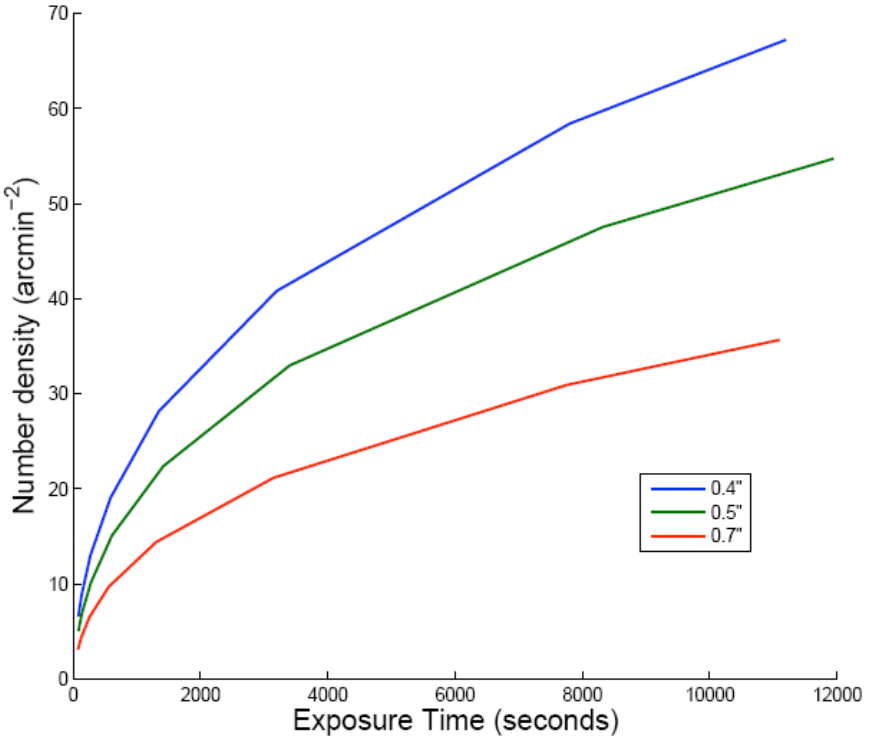


Figure 1 - Comparison of a portion of the UDF, smoothed to 0.35 and 0.7" seeing. Note that in 0.35" seeing, the individual galaxies can generally still be distinguished, in contrast to the 0.7" case.

Number of resolved galaxies per unit exposure time as a function of seeing (based on COSMOS ACS size distribution and ODI sensitivity)

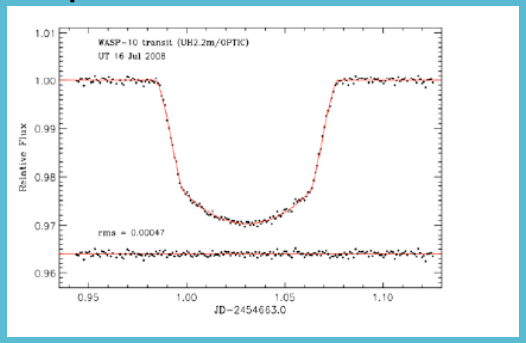


Galaxy morphology studies possible out to z>>1

Star-galaxy separation at I~23 allows all the hydrogen-burning stars within 100pc to be identified.

Multiple image Modes

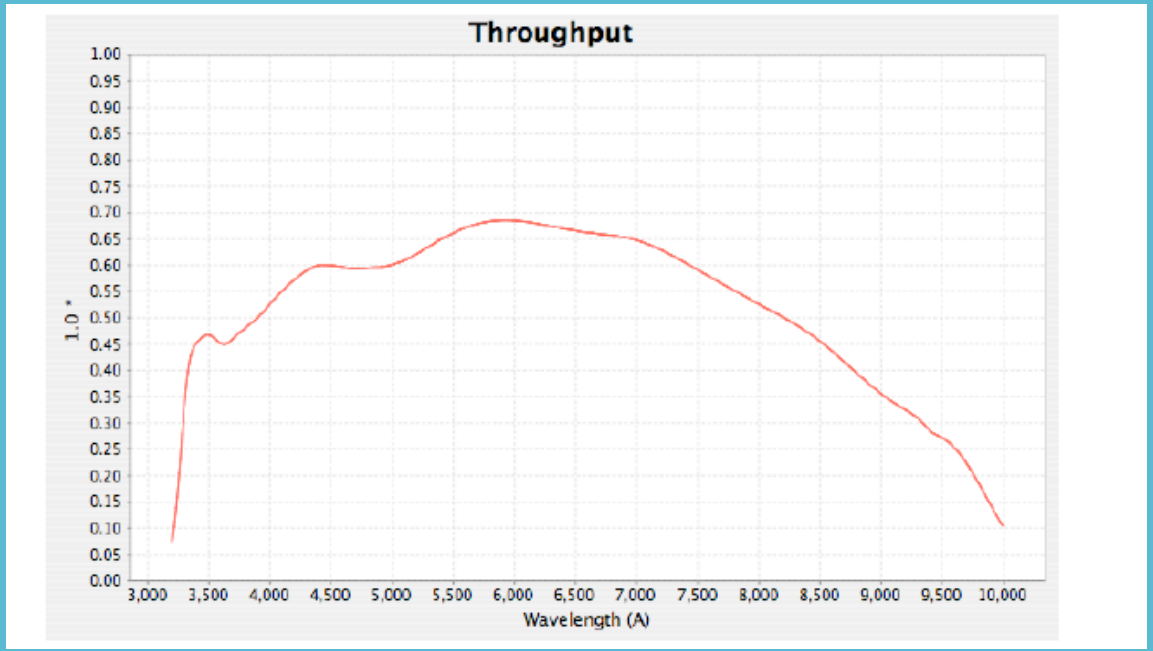
- Static imager –like a (much larger) version of Mosaic. Simplest mode. Good for projects that do not need image quality and want complete area coverage
- Coherent guiding--common OT correction derived from stars at edges/corners of the array, applied to all data. Moderate image correction (basically guiding and windshake), but coherent PSF shapes. Efficient way to get part of the OT benefits, but still simple operation.
- Local Guiding—OT correction derived from stars in local cell. Most effective OT correction. Depends on the stellar density (better away from the galactic poles). Default operation, but more tricky reductions.
- Stellar stream photometry—the OT stars can be used as a high-speed photometer with good relative photometric precision—a 20Hz monitor of the brightness! (image courtesy of S. Howell)



- Non-sidereal tracking?--the array can track to follow faint KBOs and NEOs—deeper sensitivity is possible than with a conventional imager.

Throughput of telescope, optics and detector u-z

(Minimum throughput requirements from Science Requirements Document)



Excellent response u-i, good response at z' (though not as good as DECam).

Science enabled by spectral sensitivity

- Photometric redshifts
- Stellar populations in nearby galaxies in few shots.
- Distant galaxy searches
- Wide-field u’ surveys.
- Supernova lightcurves to moderate redshift

Narrow-band capability

- ODI will be the widest field narrow-band capable facility on a >3m telescope when it is commissioned.

1 Narrow-band filter is expected at commissioning—Hα.

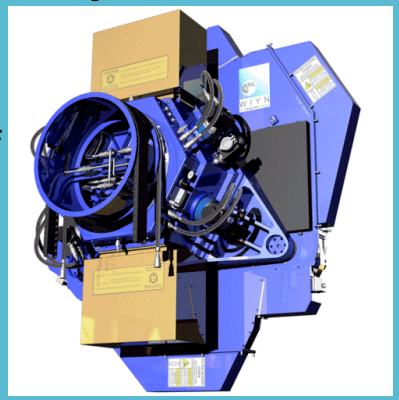
ODI is capable of multiple narrow-band filters over the entire spectral range. This will allow us to study:

Search for high-z galaxies

Star formation at different redshifts

Intergalactic Planetary Nebulae

SNR in the Milky Way and Andromeda.



ODI assembly with one of the filter wheel arms visible.

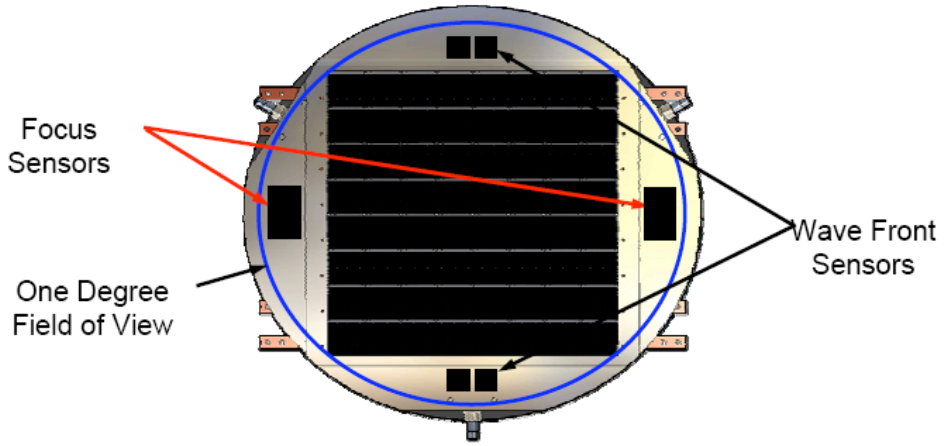
But the filters will be expensive—start saving up now!

Basic ODI design

64 OTA detectors, each with 0.11” pixels, spanning one degree (1 gigapixel camera)

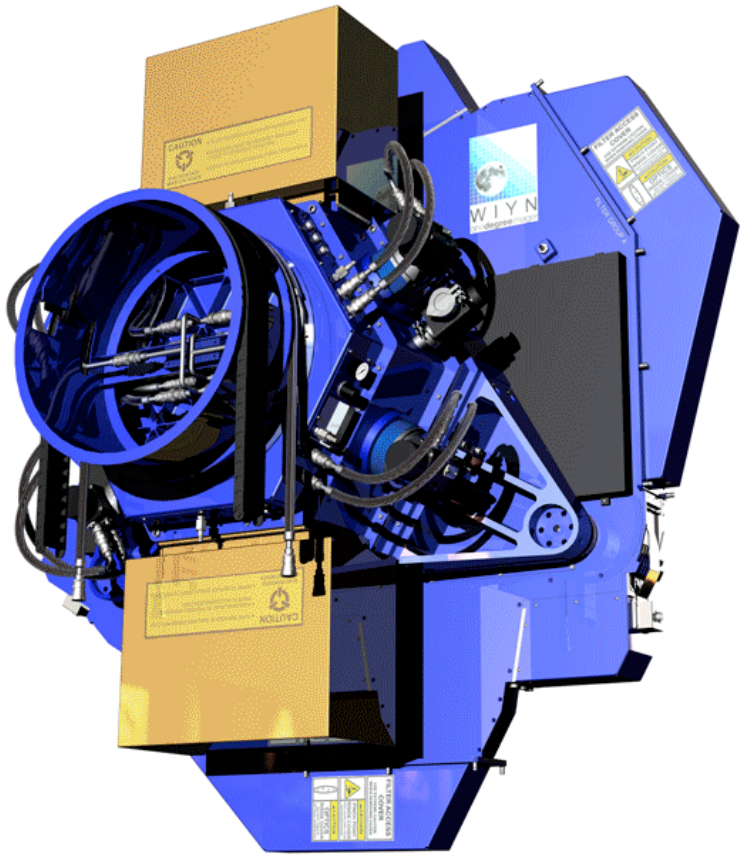
Built by the WIYN consortium, but will be the Primary WF imager for NOAO starting in 2011(ish).

First light in January 2010.



ODI (2009) → 32K x 32K Array -- Uses 64 OTAs

Diagonal ~22.5 inches; Corrector ~26 inches diameter

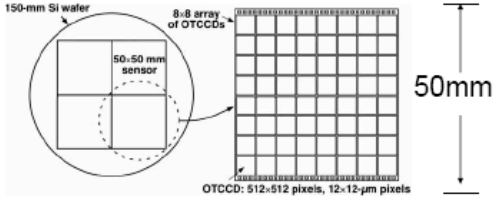


The camera –an array of arrays.

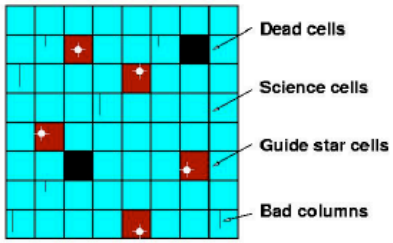
(slide lifted from CoDR presentation by Pat Knezek)

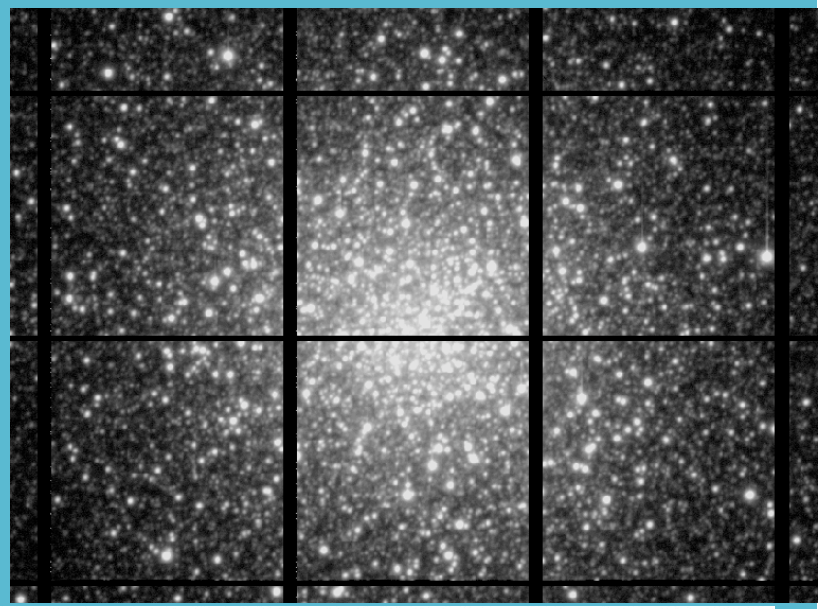
Summary of OTA Properties

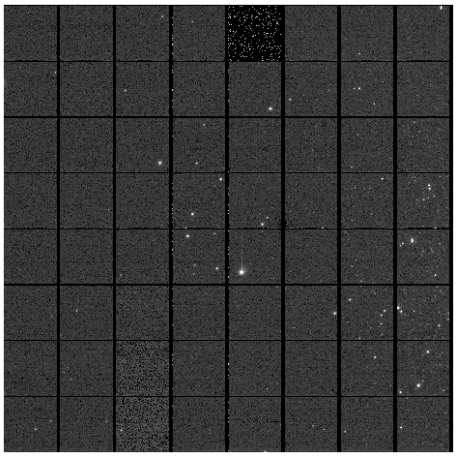
- 64 independent 480x494 CCDs
  - Individual addressing of CCDs
  - 1 arcmin field of view at WIYN
  - Bad columns confined to cells
  - Point defects are tolerated
- Cells with bright stars → guide stars, or read fast, up to 50 Hz, to avoid blooming, or for time studies
- 8 video channels – 2s readout
- Intercell gaps (0.1-0.3 mm; 1-3"); dithering required
- Inter-OTA spacings: ~2 mm (20")

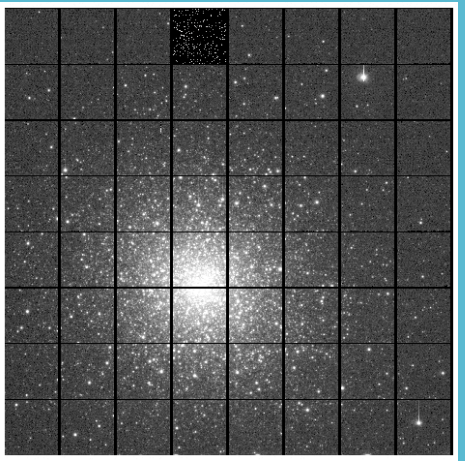


12 μm pixels = 0.11″ at WIYN









Actual images from QUOTA, the prototype (4 of 64 CCDS)

Examples of driving science projects

- Galaxy populations—morphology and redshift evolution
- Stellar populations—within the galaxy and MW satellites.
- Astrometry—parallax and proper motions
- Weak Gravitational lensing
- Halo populations of nearby galaxies
- Strong gravitational lensing—resolving arcs and arclets.
- Tidal streams and disrupted satellites.

IV. Summary of Key Requirements

Subject	Requirement
Field of view & filling factor	1° circular unvignetted field of view. 80% filling factor. One fixed orientation of the field of view on sky.
Availability	Whenever WIYN is scheduled. Allow for a one month servicing shutdown in the summer. Avaialble for observer 4 hours before sunset to 1 hour after sunrise. 1 hour recovery time after a <24 hour long shutdown.
Operational mode	ODI will be operated at the WIYN facility.
Lifetime and port	10 years, at the sole instrument at the WIYN port.
Image Quality	Deliver 0.3" in z-band at zenith, deliver 0.5" in g' and U band.
Tip/Tilt on-chip guiding	Must not degrade image quality.
Throughput	Defined as goal based on simulations including telescope, corrector, and detectors
Noise	Total instrument noise <10e⁻ in 30 minute long exposures.
Data Acquisition mode	• Static imaging • Static imaging with common mode tip/tilt correction @20Hz loop rate, optional non-sidereal tracking • Static imaging with local tip/tilt correction on 4'x4' cells @20Hz loop rate • Targeted shutterless photometry at 0.5Hz to 20Hz.
Shutter-close time	<20sec in repeated imaging mode. Requirement on observing cadences otherwise.
Filter loaded in the instrument	at least 8
Photometry	< 1% absolute photometry for point sources in 90% of field of view, flat-fielding of instrument <0.75%.
Astrometry:	<0.1" globally, <0.001" on 2' scale
Shutterless Photometry	< 0.01mag relative photometry
Telescope requirements	WIYN performs according to WODC 00-01-03.
Calibration	Standard calibration scripts will be available

An example—astrometric measurements of nearby stars.

Centroid measurements depend on the seeing—the better the image quality is, the smaller the positional uncertainty. With 0.35-0.4” seeing and repeated observations, ODI is expected to have a relative positional uncertainty of ~0.002” for moderate magnitude stars.

Because the volume probed scales as the cube of the parallax, ODI will allow probes 3x further in parallax and proper motion space for constant exposure time with the same distance and velocity precision. ODI will be able to obtain ten-sigma parallax measurements out to 150 pc, down to a magnitude of z=22, or an absolute magnitude of around 16. Thus, we will be able to reach all stars on the hydrogen burning main sequence, as well as significant numbers of brown and white dwarfs.

(Thanks to Bill Van Altena for the information)

Another example—Variable stars in open clusters

Using the fast readout mode on OT cells containing open cluster stars, time series photometry can be obtained for up to ~500 stars at once (in the ideal case).

Combined with the wide field of view, large portions of Open clusters can be efficiently mapped.

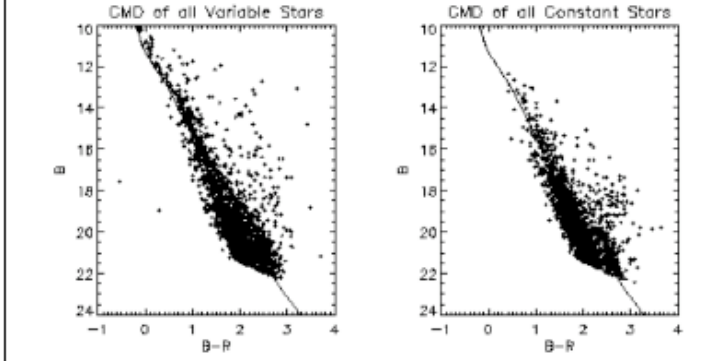


Figure 2 - Color magnitude diagrams for the young open cluster NGC 2301 separated into variable and non-variable stars. Note the upper main sequence stars are all variable and the lowest mass stars (M6V here) are not yet fully on the ZAMS. The precision obtained for the brightest 4.5 magnitudes was 1-2 mmags (Howell et al. 2005b).

Searches for rare, faint, or barely resolved objects can benefit greatly from ODI

Yale Survey

- >=90 nights to be allocated
- Open to participation by the community
- Multiple science goals

For more, come to Charles Bailyn's talk in the afternoon session!

Your science here…

(Come to the discussion tomorrow on community science with ODI…)

A QUICK SHOPPER'S GUIDE--ODI and DECam

The two workhorse public imagers, ca. 2011

Property	ODI	DECam
Detectors	64	62
Pixel Scale	0.11"	0.27"
Aperture	3.5m	3.9m
Readout time	10 seconds	17 seconds
FOV	1 square degree	3 square degrees
Sensitivity at 950nm	~45%	~65%
Sensitivity at 380nm	~50%	~20%

Other considerations apply (for example ODI will support narrowband filters, which will be hard to deliver w/DECam)