Deep Wide-Field Optical/IR Surveys
Present and Future

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NOAO

Building the Foundation for U.S. Astronomy at m/cm Wavelengths in 2010 and Beyond
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Outline

• The power of wide-field surveys
  (with illustrations from NDWFS++, focusing on the origin and evolution of the most massive galaxies)

• OIR Survey capabilities in 2010+
  (focus on WFMOS)
The Age of Deep OIR Surveys

Large wide-field imaging/spectroscopic surveys:
- SDSS/2DF/2MASS (see M. Strauss talk)

Many small-field, deep surveys*:
- HDF/CDF/UDF ~10 '/10-100nJy
- GEMS 800 '/15nJy
- GOODS 300 '/30nJy
- COSMOS 2 °/ 60nJy
- FIRES 5-25 '/ 0.1-0.2μJy
- Combo-17 ~1 °/ 0.4 μJy
- DEEP2 4 °/ 0.8μJy
- COSMOS 2 °/ 0.06 μJy
- NDWFS++ 18 °/ 0.15μJy
- UKIDSS 0.8 °/ 2μJy; 2.4°/ 3.7μJy; 27°/ 37μJy
- CFHT-LS 4 °/14nJy ; 170 °/0.16μJy ; 410 °/0.36μJy
- SWIRE 65 °/ 0.3mJy (@24μm)

*incomplete list
Motivation
(an extragalactic perspective)
Most modern surveys are multiwavelength endeavours - e.g., The NOAO Deep Wide-Field Survey
Depth inequities of current deep multiwavelength surveys

NDWFS/Bootes (9 sq deg):

~2 million optical sources
~370,000 3.6 $\mu$m sources
~25,000 24 $\mu$m sources
~3,200 radio sources
~3,200 X-ray sources

i.e., X/IR/Radio surveys are currently only deep enough to pick out mostly extreme populations

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Radio Identification Rates of 24$\mu$m Sources

From M. Dickinson
The Power of Wide-Field Surveys

Statistical approach to complex problems

Large samples
- define population trends
- statistically precise measurements
- rare populations

Wide area
- large scale clustering
- less sensitive to cosmic variance
The Power of Wide-Field Surveys

*Statistical approach to complex problems*

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Global trends in the galaxy color-color diagram...

\[ \tau = 1 \text{Gyr BC03/Salpeter} \]

Red envelope population

\(~600,000\) galaxies

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trace the evolution of the red galaxy population

Red sequence ‘bluens’ with increasing redshift
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Statistical approach to complex problems

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Red Galaxy Luminosity Functions

Brown et al. 2006
Number density evolution as $f(\Phi_{\text{mass}})$

Comoving space density of massive galaxies is constant with redshift!
The Power of Wide-Field Surveys

Statistical approach to complex problems

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- define population trends
- statistically precise measurements
- rare populations

Wide area
- large scale clustering
- less sensitive to cosmic variance
A Rare \( z \approx 2 \) Population of IR-Luminous, optically faint Galaxies

Brand et al. (2006)
Large Lyα Nebulae: The Formation Sites of the Most Massive Galaxies

First Radio-Loud z>6 Quasar

McGreer, Helfand, Becker 2006
Stern et al. 2006
Future OIR Surveys / Capabilities

UKIDSS (now)
CFHT-LS (now)
VISTA (2007) (1.65° FoV; Z-Ks; 0.34″/pix; 67 Megapix)
DES (2009) (2° FoV)
PanSTARRS (2010) (3° FoV; 0.3″/pix; 1.4 Gigapix)
LSST (2013+) (3° FoV)

Herschel/Planck (2008)
WISE (2009)
JWST (2013+)

WFMOS/HyperSCam (2012/2010?)
WFMOS on the Subaru Telescope

Next-generation instrument from Gemini/Aspen

Located at prime-focus of Subaru 8m telescope

Baseline design:
- $1.5^\circ$ FoV
- 4800 fibers
- $\lambda\lambda 4000\text{A}-1\mu\text{m}$
- $R \sim 3000$ and 30000

Key projects:
- $w(z)$ through BAO
- Galactic archaeology
- Galaxy formation/evolution
Formation of the acoustic peak

Simulation by D. Eisenstein (http://cmb.as.arizona.edu/~eisenste/acousticpeak/)
The Scale of Acoustic Oscillations are a Standard Ruler

Eisenstein et al. 2005

Hinshaw et al. 2006
Two Baseline Surveys for WFMOS

$0.5 < z < 1.3$ : $2 \times 10^6$ emission line galaxies over $2000 \text{ deg}^2$ (900 hrs)

$2.3 < z < 3.3$ : $600,000$ LBGs over $300 \text{ deg}^2$ (800 hrs)

Distance Errors versus Redshift
Predicted results for $\Lambda$CDM

- WFMOS + SDSS + Planck provides $\sigma(w)= 0.08$ at $z=0.7$
- Adding ground-based SNe can provide $\sigma(w)= 0.05$
  - Complementary to space!

(Assumes SNe in 2012 : 1% in $\Delta z=0.1$ bins to $z=1$ for ground, 1.7 for space)

Dark Energy Constraints in $\Lambda$CDM
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Fin
NOAO Deep Wide-Field Survey Team

Arjun Dey and Buell Jannuzi, PIs

Taft Armandroff, Ed Ajhar (Miami), Bob Blum, Todd Boroson, **Kate Brand**, **Michael Brown**, Chuck Claver, **Lindsey Davis** (NRAO), Ian Dell'Antonio (Brown), Mark Dickinson, Richard Elston, Richard Green, Pat Hall (Princeton), Dan Hoard, George Jacoby (WIYN), Dick Joyce, Tod Lauer, Roger Lynds, Sangeeta Malhotra (ASU), Mike Merrill, Joan Najita, Earl O'Neil (Steward), Marc Postman (STScI), Ron Probst, Travis Rector, James Rhoads (ASU), Robert Schommer, Nigel Sharp (NSF), Malcolm Smith, Paul S. Smith (Steward), **Glenn Tiede**, **Frank Valdes**, Jeff Valenti (STScI), Ted von Hippel (UofTexas), Alistair Walker, and Sidney Wolff.

Erin Ryan, Emma Hogan, Lissa Miller, Alyson Ford

+ *Xbootes*
+ *Spitzer/GTO*
+ *GALEX/GTO*
+ *AGES*
+ *FLAMEX*
+ ...
Breaking the $w$-Curvature Degeneracy

- To prove $w \neq -1$, we should exclude the possibility of a small spatial curvature.
- SNe alone, even from space, do not do this well.
- SNe plus acoustic oscillations do very well, because the acoustic oscillations connect the distance scale to $z=1000$. 

![Graph showing the relationship between $w$ and $\Omega_k$]