An Overview of the BigBOSS Project

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NOAO

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Outline

- Brief history
- Overview of instrument
- Overview of project
- Community science and NOAO role
- Optimistic timeline and Challenges

see http://bigboss.lbl.gov/ and http://www.noao.edu/meetings/bigboss/ for details

National Optical Astronomy Observatory

Mission:

- provide the best ground-based astronomical capabilities to *ALL* astronomers
- promote public understanding and support of US ground-based OIR astronomy

Peer-review access to current OIR facilities:

- KPNO, CTIO, Gemini Observatory
- Keck, Magellan, MMT, Palomar, Subaru

New Initiatives:

- Dark Energy Camera on CTIO Blanco
- BigBOSS on KPNO Mayall
- Large Synoptic Survey Telescope

Brief History of BigBOSS

- NOAO has
  - long sought a highly multiplexed spectroscopic capability for US astronomy (cf. NGOS, SWIFT, KAOS, WFMOS)
  - been seeking ways of repurposing the midscale aperture telescopes => Blanco + DECam and Mayall + ?
- 2009: BigBOSS white paper submitted to Astro2010 Decadal Survey
- 2009: NOAO solicits Large Scale Programs for Mayall
- 2010: BigBOSS proposed by LBNL-led, international consortium. Critically (and positively!) reviewed by committee chaired by Laureate Brian Schmidt.
- 2011: NOAO engages with BigBOSS team to retire risk and address issues raised by Schmidt committee. First BigBOSS community workshop held.
- 2011 Dec: DOE review of BigBOSS – very positive!
- 2012: BigBOSS in R&D phase

BigBOSS Collaboration

... and still growing!

US Members:

Brookhaven National Laboratory, Carnegie Mellon University, Fermi National Accelerator Laboratory, Johns Hopkins University, Lawrence Berkeley National Laboratory, National Optical Astronomy Observatory, New York University, The Ohio State University, SLAC National Accelerator Laboratory, University of California, Berkeley, University of Kansas, University of Michigan, University of Pittsburgh, University of Utah, Yale University.

International Institutions:

Ewha Womans University, Korea; French Participation Group (APC, IAP- Paris; CPP, CPT, LAP Marseille; CEA, IRFU – Saclay); Spanish Participation Group (IAA, Granada; IAC, Tenerife; ICC, Barcelona; IFT, Madrid; U. Valencia); Shanghai Astronomical Observatory, UK Participation Group (Durham, Edinburgh, UC London, Portsmouth); University of Science and Technology of China.

Science Focus of Key Project

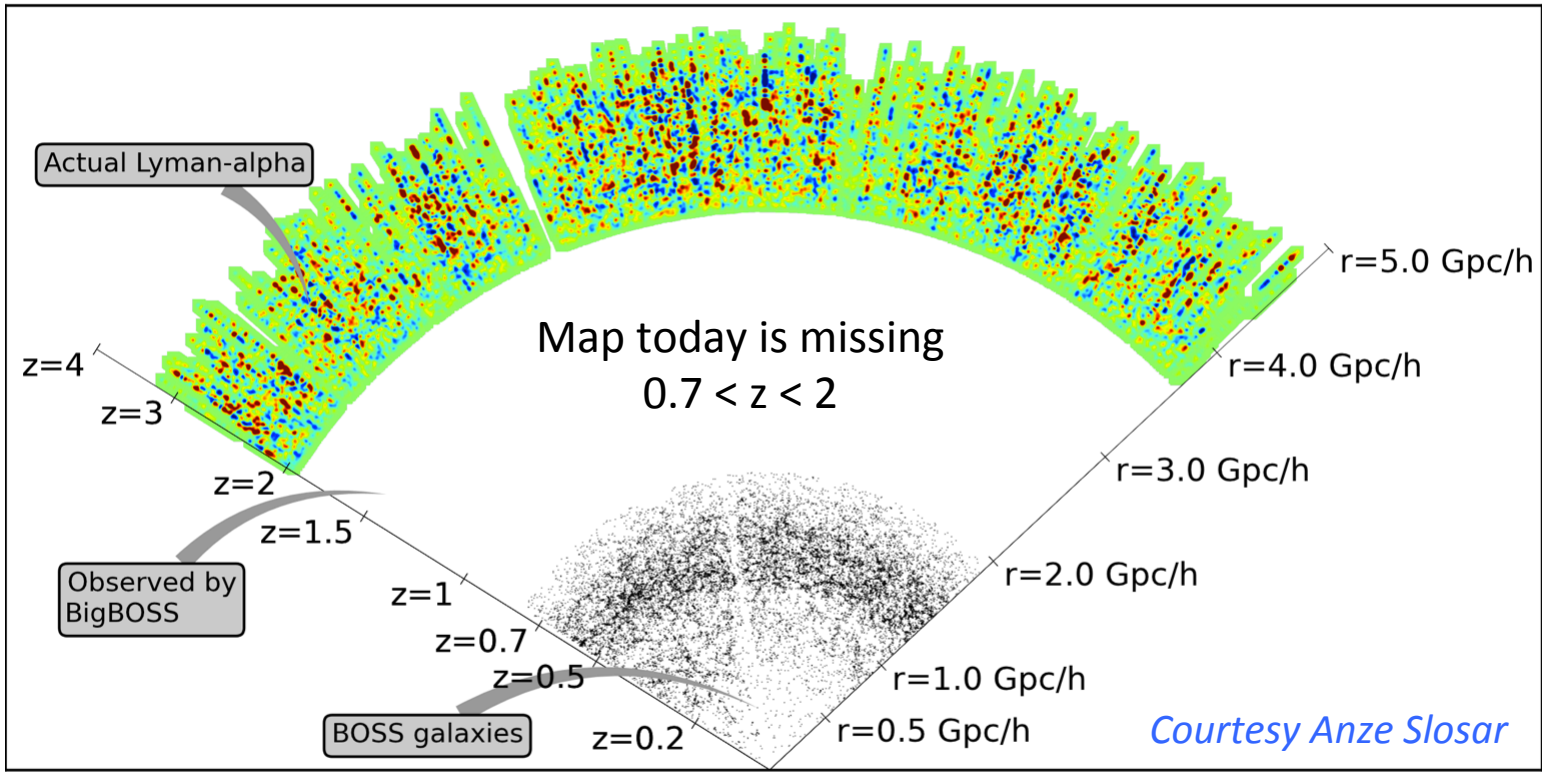
- Measure the expansion history of the universe using galaxies & Lyα absorbers as tracers, and thereby constrain:
  - Dark energy parameters
    - BAO + RSD; Stage IV Dark Energy Experiment
  - Neutrino masses
    - Summed mass over all flavors
  - Inflation
    - Slope and non-gaussianity of primordial spectrum

See Nikhil Padmanabhan's talk!

BigBOSS is Revolutionary!

BigBOSS requires spectroscopic redshifts:

- >20 million objects spanning z=0→2
- ~1/3 of full sky, or ~14,000 deg



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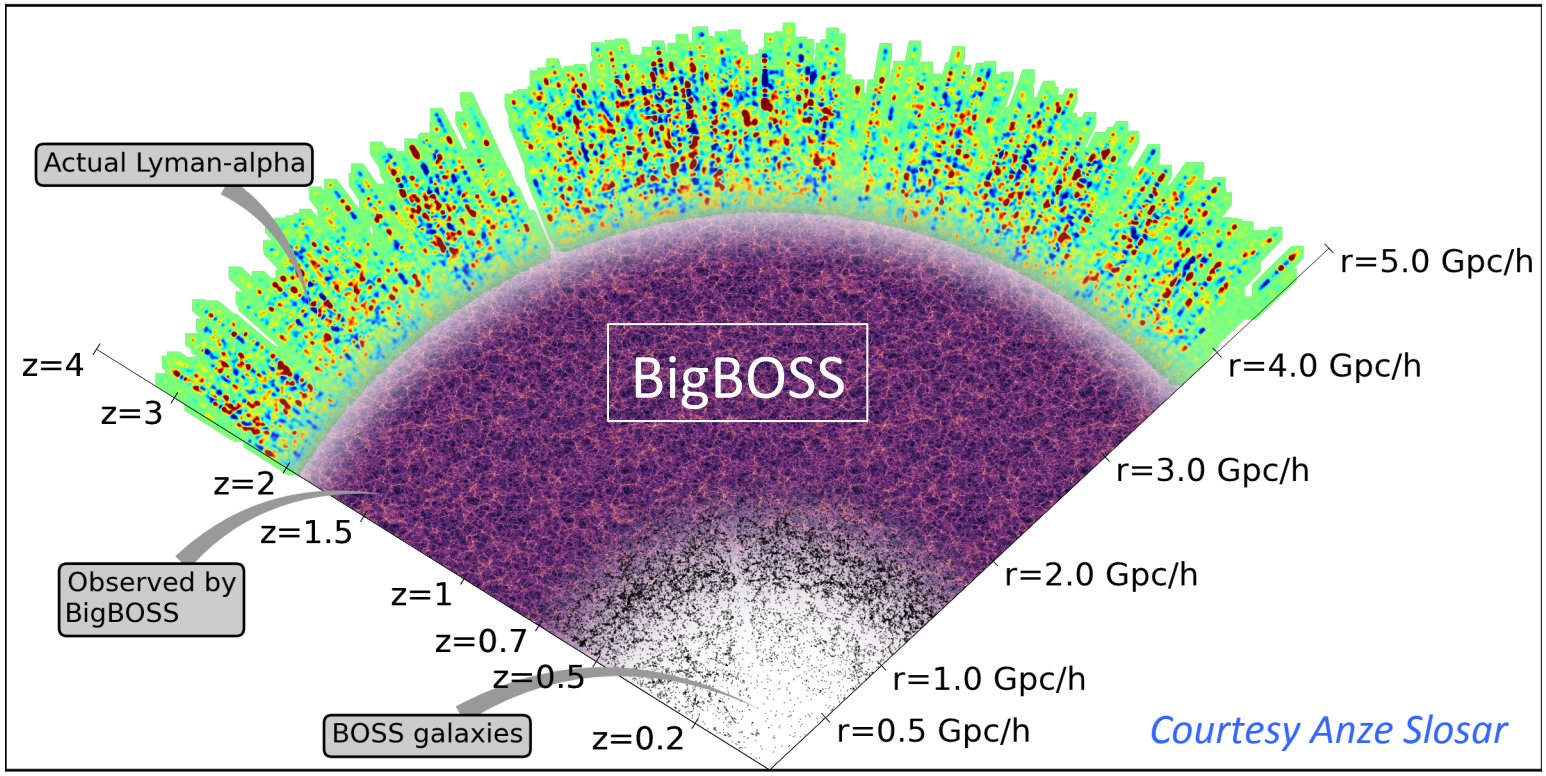
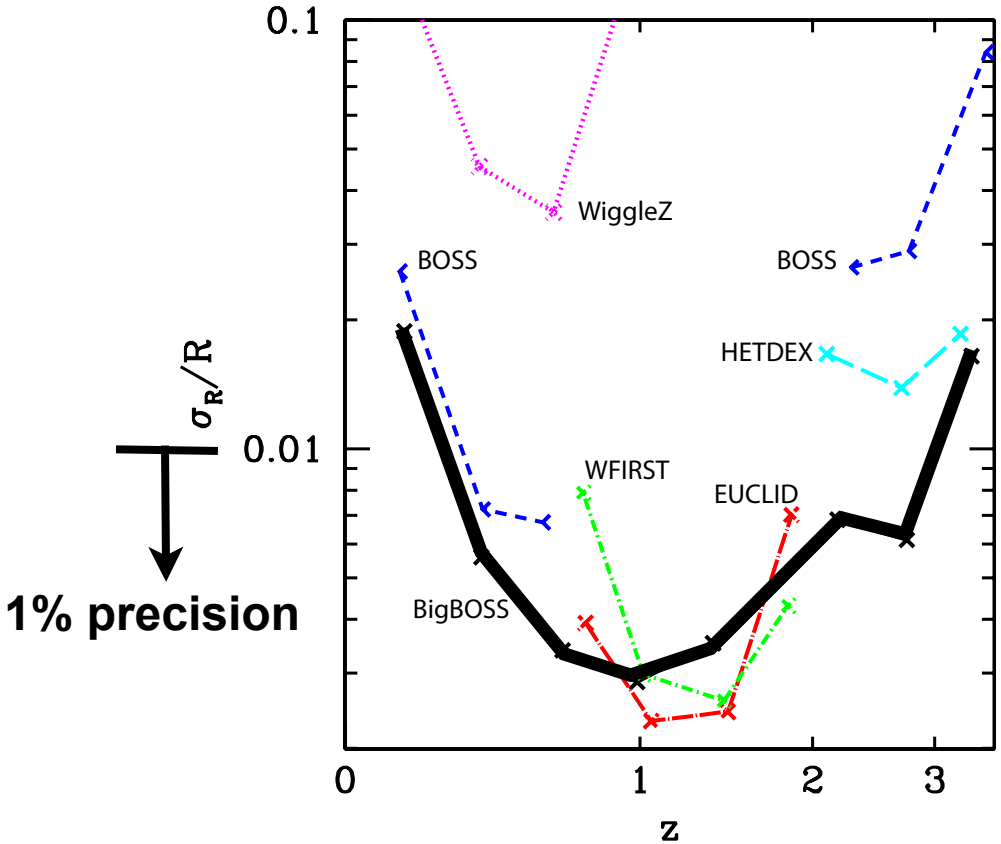
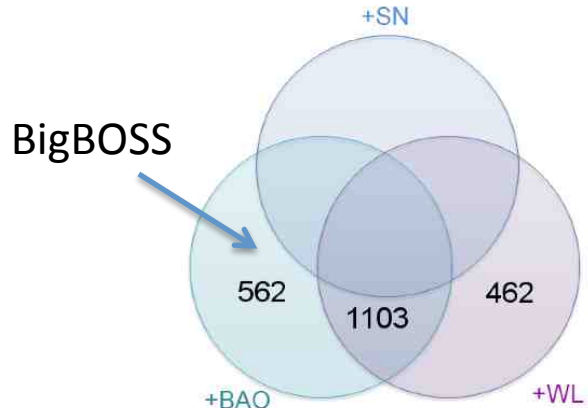


BigBOSS is Revolutionary!

BigBOSS will deliver a geometric probe of the distance scale with <1% precision
Compares well with other proposed Dark Energy projects.



LSST WL + BigBOSS BAO/RSD Optimistic



WFIRST Optimistic

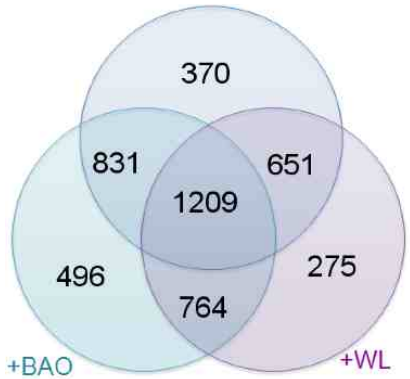
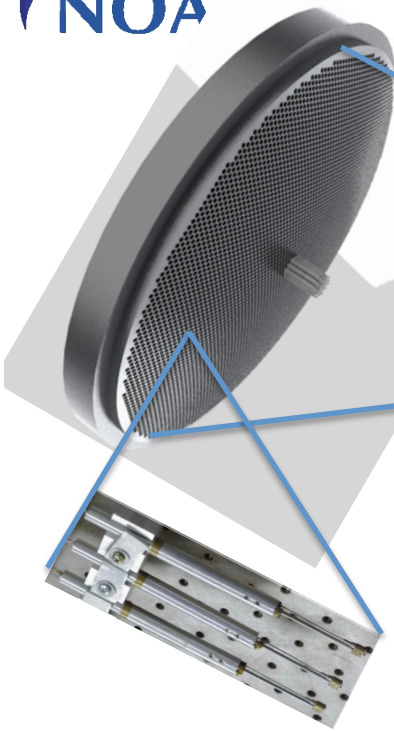
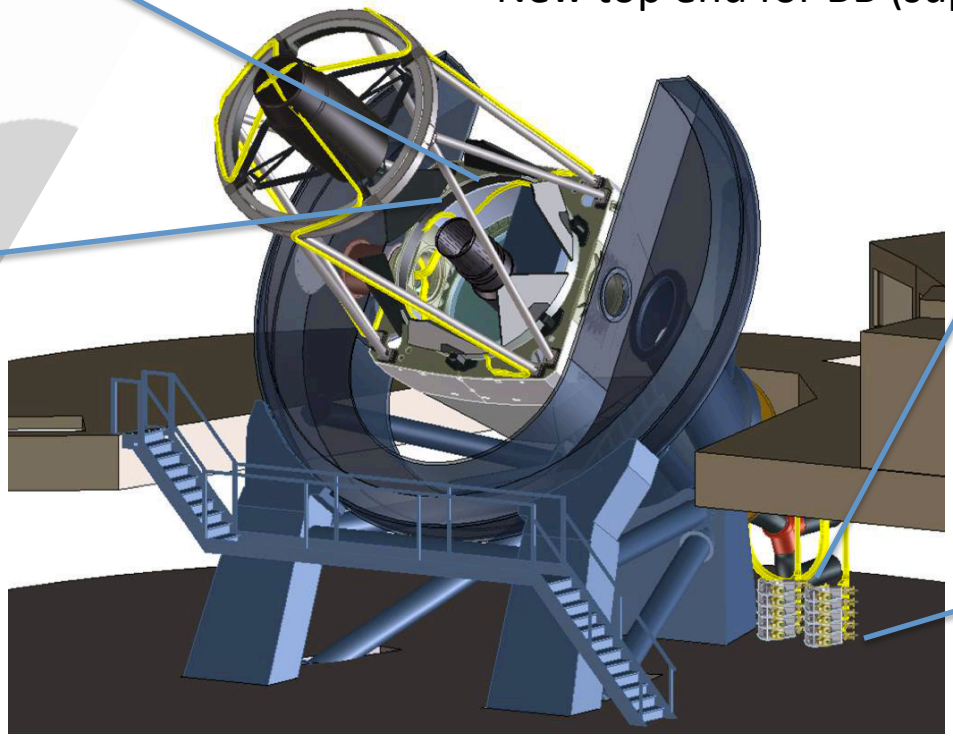


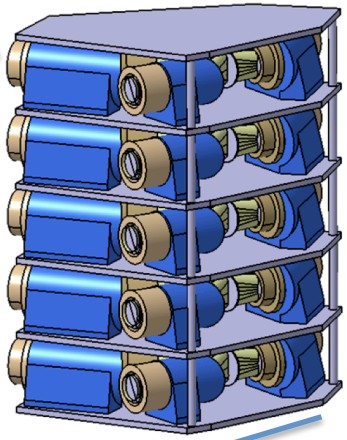
Fig. reproduced from WFIRST Science Definition Team report
http://wfirst.gsfc.nasa.gov/science/WFIRST_Interim_Report.pdf

The BigBOSS Capability



Mayall telescope at KPNO
+ New top end for BB (supports f/8)





- 3 deg dia FoV
- 5000 fibers

- Ten 3-arm spectrographs
- 380nm – 1µm

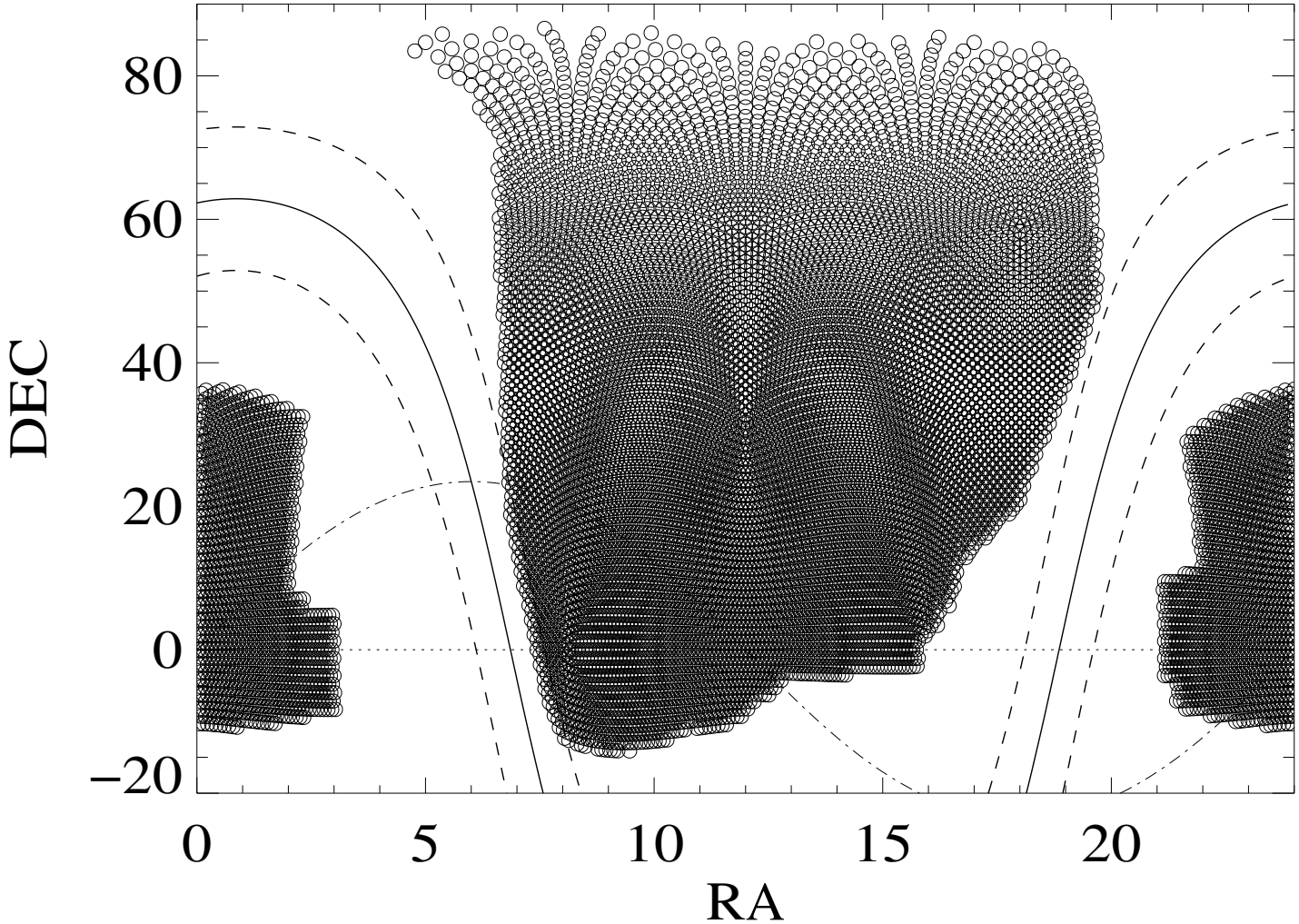
Nearly 40,000 spectra per night!!

See Natalie Roe's talk!

Baseline Survey

- 495 nights over 5 years
  - Many are partial nights
  - 10-20% of fibers available for ancillary science
- 14,000 deg^2 at (mostly) high Galactic latitude
  - survey footprint = SDSS+4000 deg^2 (~9800 pointings)
- Primary targets:
  - 17 million emission-line galaxies ($0.6<z<1.6$)
  - 4 million luminous red galaxies ($0.6<z<1$)
  - 2 million QSOs ($1<z<5$)
- Exposure times designed to provide redshifts
  - Typically: 15-20 min per ELG, 30-40 min per LRG, 60-90 min per QSO

BigBOSS Survey Footprint (2011)



Baseline strategy

- 14000 deg^2, 20 million galaxies, 2 million QSOs
- Five passes on full survey footprint
  - Year 1 - Focus on the QSO selection
- Roughly 20% of fibers/tile not allocated to primary targets:
  - Scattered randomly through FoV
  - Available for sky, standards, ancillary targets
  - Increasing fraction of available fibers in later passes

Calibration Fields

- 4 to 6 deep fields (~30 – 40 deg^2)
  - characterize instrument and survey performance, sampling / completeness / selection functions, etc.
- Targeted in Pilot Survey and also ~ 1 per run:
  - Denser sampling
  - Deeper exposures (~ 4.5 h for some targets)
  - Sampling / targeting TBD
- High legacy value for other science projects

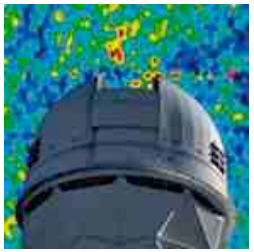
Community Observing Modes

- ***Synchronous Observing***
  - Tied to survey strategy
    - Survey pointing strategy known in advance: $\Delta t < -1$ day
  - Good for targets distributed across survey footprint
  - Could influence baseline survey strategy
- ***P.I.-driven projects***
  - Small: folded in through the BB Survey Queue
  - Large: (i.e., other surveys) – supported by proposing teams
- ***Projects using archival data***
  - Based on public release through NOAO or BB archives

NOAO's Role in BigBOSS

- Enable an unprecedented spectroscopic capability for US astronomy
- Enable both the BigBOSS science program (= Key Project) and community science programs
- Provide interface between BB and astronomy community (i.e., represent the astronomy community's interests to BB and vice versa)
- Collaborate with BB to ensure hardware / software performance for maximizing science output

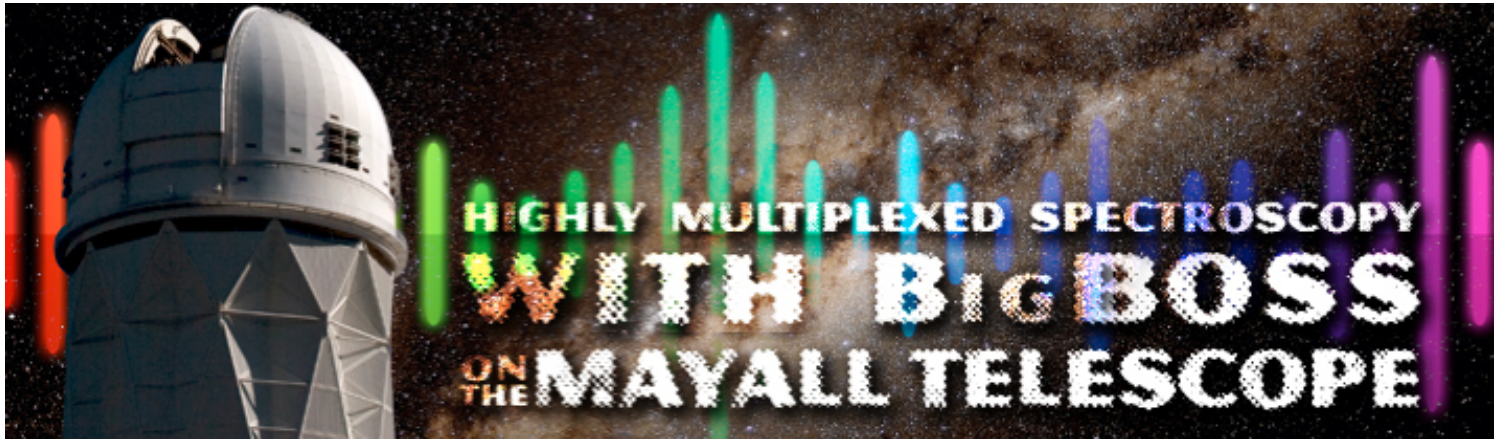
Survey Operations



- BigBOSS Queue jointly supported by BB Team and NOAO
- P.I.-programs interlaced into the Queue
- Other large survey programs may need to provide their own observing resources
- f/8 availability currently planned and will depend on demand (NEWFIRM, KOSMOS, +?)

BigBOSS Community Workshop

http://www.noao.edu/meetings/bigboss/



- Held in Tucson on 13,14 Sep 2011
- Attended by ~70 participants
- 4 break-out sessions:
  - Galactic *(Marla Geha, Yale)*
  - Extragalactic *(Eric Bell, U. Michigan)*
  - Transients *(Mansi Kasliwal, Carnegie Obs.)*
  - Diffuse Media *(Jason Prochaska, UCSC)*

See talks by:
Caty Pilachowski
Connie Rockosi
Martin White

⇒ *Community is very excited about BigBOSS!*

BigBOSS + NWNH

BigBOSS will have a major impact on many key science areas identified by Astro2010 Decadal Survey (New Worlds and New Horizons)

- Discovery
  - Time domain astronomy
  - Epoch of reionization
- Origins
  - Origin of galaxies and large scale structure
  - Origin of black holes
- Understanding the Cosmic Order
  - Flows of baryons into/out of galaxies and BHs
  - Mass / Energy / Chemical cycles within galaxies
  - Astrophysics of stellar evolution (esp. massive stars)
- Frontiers of Knowledge
  - *Nature of inflation*
  - *Accelerating universe*
  - *Nature of dark matter*
  - *Nature of neutrinos*
  - Nature of compact objects and probes of relativity
  - Chemistry of the universe

BigBOSS Key Project

Community Science

Future

- Future NOAO+LBNL+Community Workshops to detail scheduling / software / hardware requirements
- Establish a community-based group to focus on BigBOSS
- Optimistic goal: first light by 2018!
- Challenges:
  - Continued NSF support of KPNO and Mayall
  - Funding for full project
- We want to hear from you!

Backup Slides

BigBOSS
Science -> Instrument

BigBOSS Scientific Objective: Perform a Stage IV BAO Spectroscopic Survey

LEVEL 1
Scientific Requirements

- Measure the distance scale error σ_R/R to < 1% for $0.5 < z < 3.0$
  (in 6 bins with $\Delta \ln(1+z) = 0.2$)
- Measure H(z) to 1.5% up to z=2.5
  (in 4 bins at <z> = 0.7, 1.1, 1.5, 2.5)
- Constrain growth, $\sigma_8(z)$ f(z), with <2% relative error
  ($\Delta z = 0.1$ bins, $k_{max} = 0.2$, for $0.5 < z < 1.5$)
- Measure galaxy power spectrum to < 1% up to z=1.5
  ($\Delta k = 0.02$ Mpc/h bins, $k_{max} = 0.3$)

Additional Scientific Goals

- Inflation: constrain spectral index and its running to < 1%
- Measure the sum of neutrino masses Σm_ν with $\sigma < 0.020$ eV

LEVEL 2
Data Set Requirements

- Survey Area: 14,000 sq deg
- Redshift range:
  - LRGs $0.5 < z < 1.0$
  - ELGs $0.5 < z < 1.6$
  - Tracer QSOs $0.5 < z < 3.5$
  - Ly-α QSOs $2.2 < z < 3.5$
- Galaxy $dN/dV > 1\times10^{-4}$ (h/Mpc)^3
- Number of redshifts: 20M
- Redshift accuracy:
  - $\sigma_z < 0.001(1+z)$ rms
  - < 5% catastrophic failures
  - resolve OII doublet for $0.76 < z < 1.6$

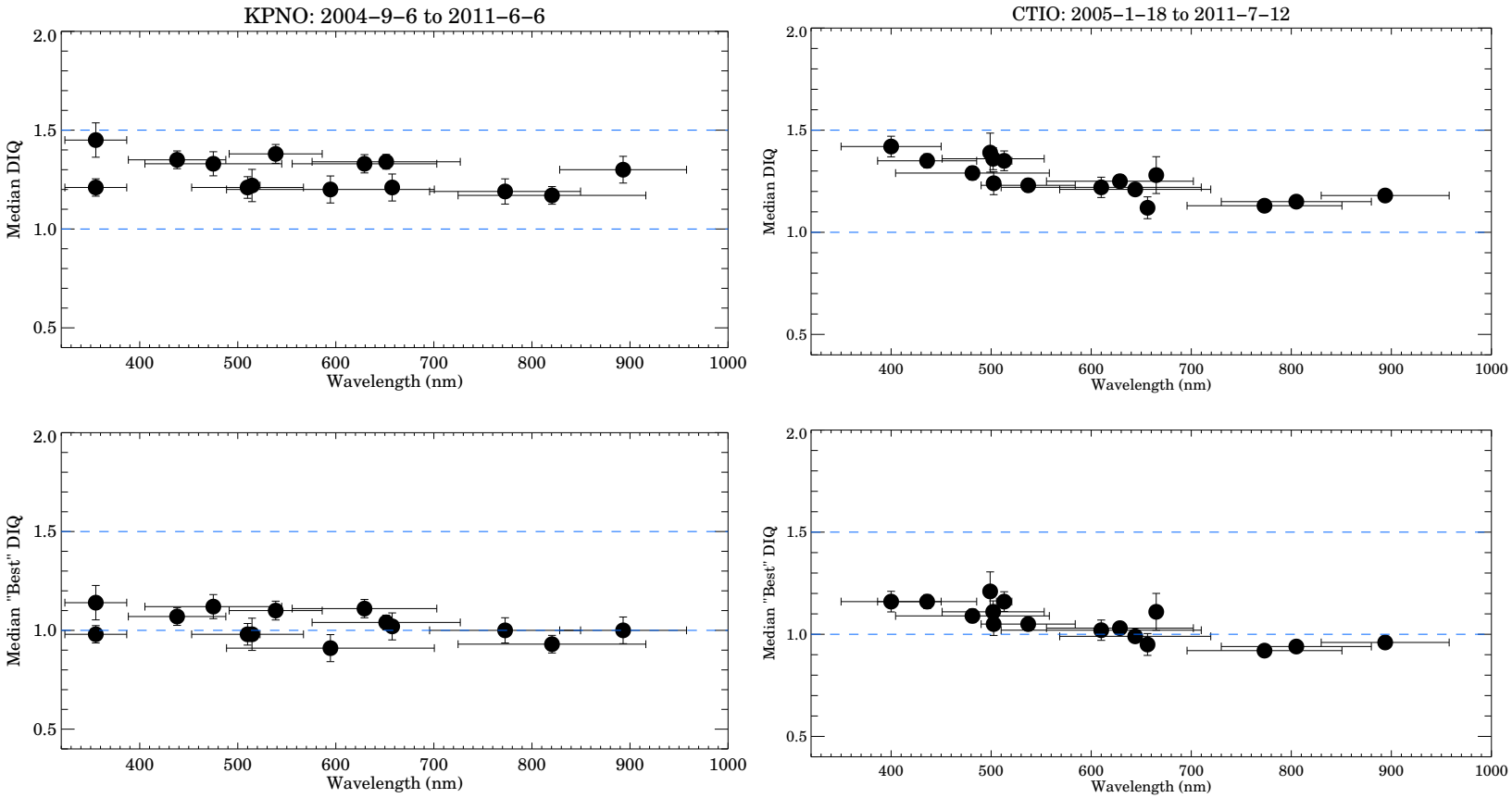
LEVEL 3
Instrument Requirements

- Operational Constraints
  - < 500 nights
  - Instrument compatible with Mayall telescope
  - Preserve use of f/8 secondary
  - Typical seeing, weather for site used in forecasts
- Field of View: 3 deg diameter
- Number of Fibers: 5000
- Operational overheads: total < 60 s/exposure
- Spectral Range and Resolution
  - 360 nm < λ <660 nm: R > 1500
  - 620 nm < λ <840 nm: R > 3000
  - 800 nm < λ <980 nm: R > 4000
- Optical Throughput vs λ
- Fiber Positioning Error < 0.35 asec (rms, includes actuators, guiding, tracking, target astrometry)

Delivered Image Quality at the Mayall and Blanco Telescopes

(from Dey & Valdes 2012)

Measured from 17,268 and 47,266 images from MOSAIC cameras from NOAO Science Archive



Community Science Needs

- Clear definition of calibration requirements (shared between all science projects?)
  - Relative flux calibration to few %
  - Relative velocity errors of 1-2 km/s (over 1 night)
  - Bright star limits clearly defined
  - Meta data / guide camera images / seeing carefully archived
- Ensure timely public release of data in a usable archive
- Enable community "plugins" to software pipeline
- Enable community time with instrument from year 1
- Enable proposal process for synchronous/small/medium/large projects, perhaps coupled with imaging facility (e.g., WIYN/ODI)