Wide Field MOS (WFMOS) for Gemini/Subaru

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History

- *KAOS Purple Book (www.noao.edu/kaos)*
  - *Last edited 18th Feb 2003*
- *Aspen Meeting in June 2003*
  - *"Start a feasibility study for a wide-field multi-object fiber-fed spectrometer" (Nov03)*
- *WFMOS Feasibility Study*
  - *Feasible (3000 fibers over 1.5deg^2)*
- *Collaboration with Subaru*
- *WFMOS Conceptual Design Study ended Jan 2009*
  - *Two teams submitted (reviewed Feb 2009)*

WFMOS "Team A"

Anglo-Australian Observatory

University of Durham

National Optical Astronomy Observatory

Johns Hopkins University

Space Science and Technology Division of Rutherford Appleton Laboratory

University of Portsmouth

This is a competitive bid, so little information on other team and must be careful with aspects of our bid.

The Need for WFMOS

- Proliferation of wide-field imaging surveys
  - Billions of pounds!
- Spectroscopy yields astrophysics
  - kinematics, dynamics, distances, masses, temperatures, chemistry
- Key astrophysical questions require statistical precision
- Demonstrated legacy value from large uniform datasets
  - SDSS is “highest impact survey” in terms of paper citations (see Madrid & Macchetto 2006, 2009). ESO is 4th
  - SDSS-III is still exploiting the uniqueness of its WF spectroscopy

The Key WFMOS Science

- Innumerable uses, but original scientific motivation was 3-fold:

  1. Cosmological survey to constrain Dark Energy parameters
  2. Galaxy Evolution survey (done in parallel to the extent possible)
  3. Galactic archaeology of the Milky Way and Local Group

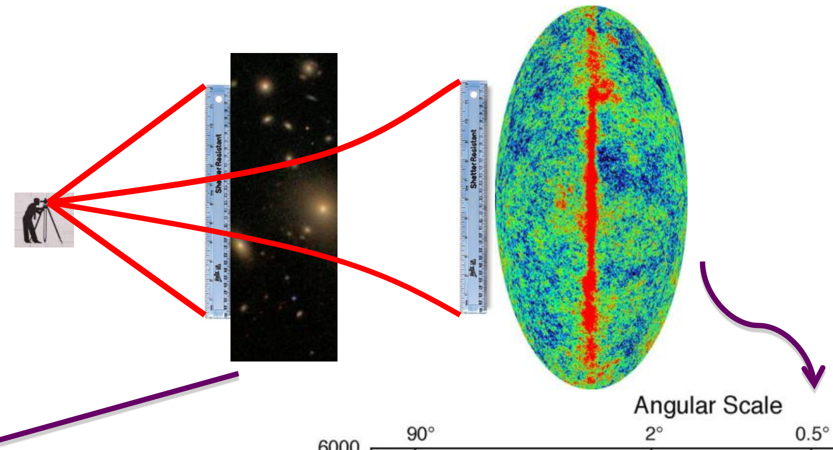
- Additionally, extensive PI usage of instrument for “small” projects

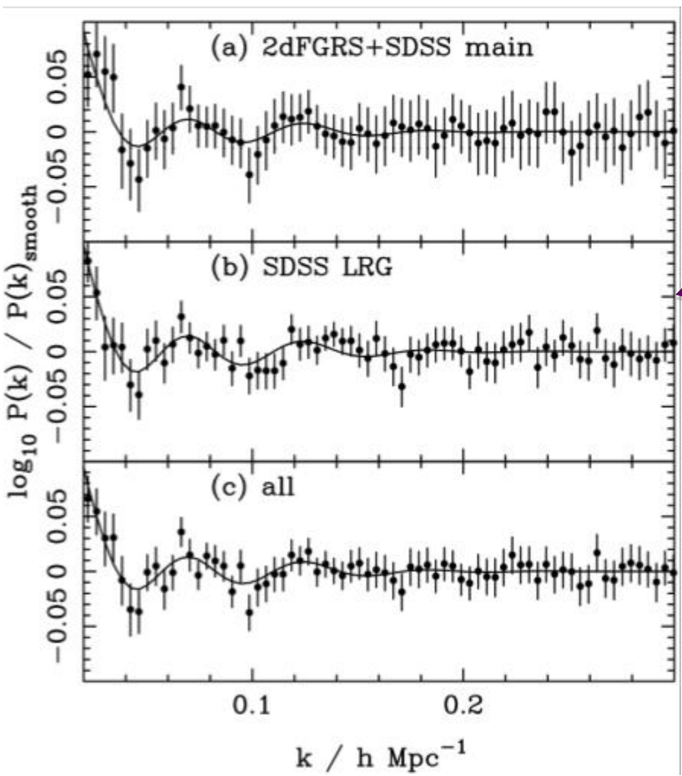
Focus on DE because of lack of time and drives much of the design (ask Josh!)

WFMOS DE Science Team

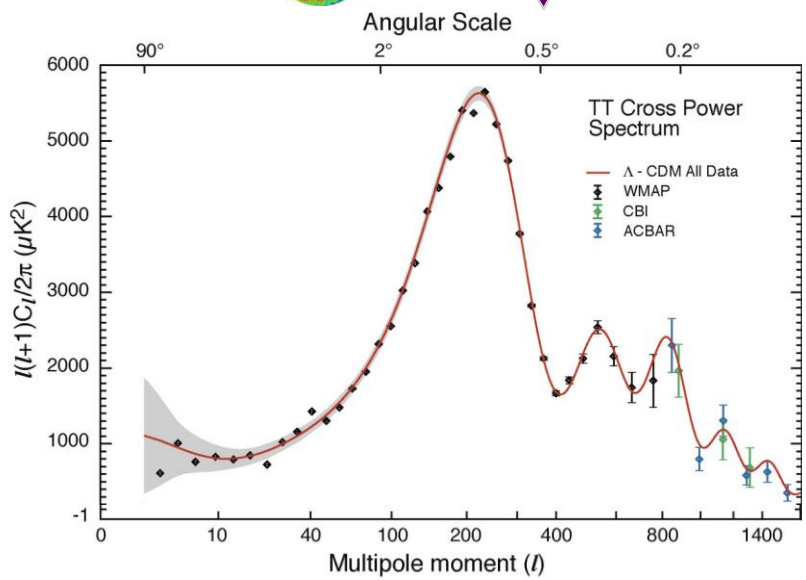
- ***Daniel Eisenstein* (US Lead) – University of Arizona**
- ***Bob Nichol* (UK Lead) – University of Portsmouth**
- ***Naoshi Sugiyama* (Japanese Lead) – Nagoya University**
- *Bruce Bassett* – South African Astronomical Observatory and University of Cape Town
- *Chris Blake* – Swinburne University
- *Matthew Colless* – AAO
- *Gavin Dalton* – University of Oxford
- *Roger Davies* – University of Oxford
- *Arjun Dey* – NOAO
- *Karl Glazebrook* – Swinburne University
- *Takashi Hamana* – NAOJ
- *Isobel Hook* – Oxford University
- *Martin Kunz* – University of Sussex
- *Andrew Liddle* – University of Sussex
- *Takahiko Matsubara* – Nagoya University
- *Chris Miller* – NOAO
- *Simon Morris* – Durham University
- *Masami Ouchi* – OCIW
- *David Parkinson* – University of Sussex
- *William Percival* – University of Portsmouth
- *Hee-Jong Seo* – Fermi National Accelerator Laboratory
- *Tomonori Totani* – Kyoto University
- *Benjamin Weiner* – University of Arizona
- *Martin White* – University of California at Berkeley
- *Kazuhiro Yamamoto* – Hiroshima University

Dark Energy and Cosmic Sound





Percival et al. 2007



Bennett et al. 2003

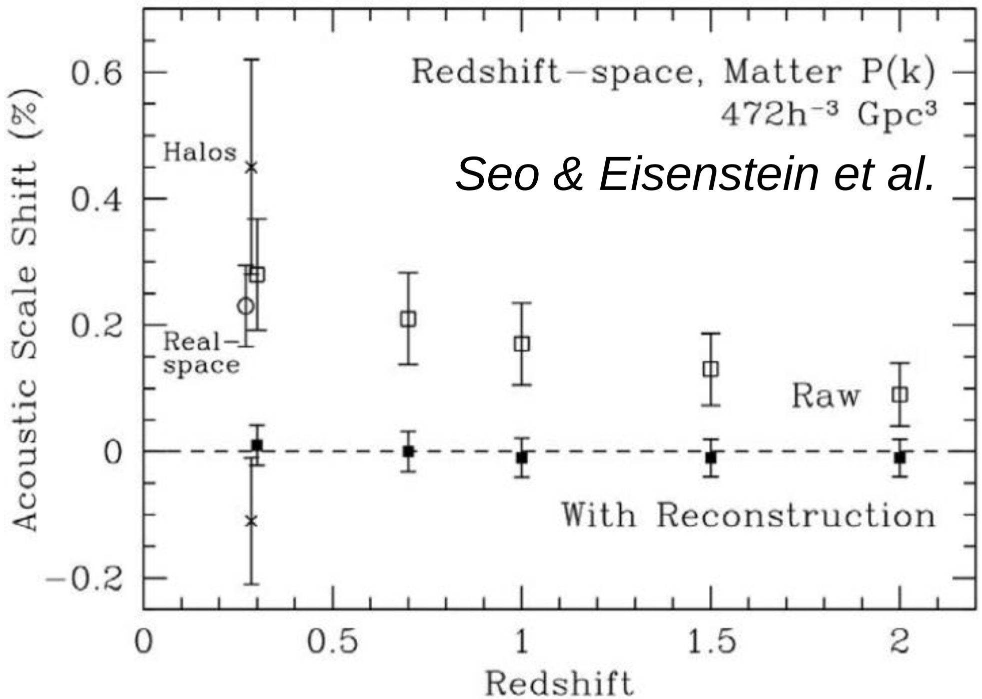
Acoustic oscillations provide a standard ruler. Detected at z=1000 and z~0.3. Emphatic demonstration that our model works!

Dark Energy and Cosmic Sound

BAO is "less affected by astrophysical uncertainties" than other three recommended methods for constraining DE (i.e., SNe, WL, clusters)

DETF Taskforce report

- *Acoustic scale is largely insensitive to non-linear effects of clustering.*
  - At z~1, systematic shifts are < 0.2% (< statistical uncertainties of WFMOS surveys!)
  - Systematic shifts can be corrected
  - (from 3 separate N-body simulations in very large volumes)



Dark Energy and Cosmic Sound

- Optimization of WFMOS surveys (D. Parkinson et al. 2007,2009)
  - Implements reconstruction technique, updated formulae for predicted D(z), H(z) uncertainties, cosmic curvature as free parameter, improved redshift binning, WFMOS efficiency
  - Includes predictions from other DE surveys (SDSS-III BOSS, WiggleZ, StageIII SNe, Planck priors)
  - Uses DETF Figure of Merit: $FoM=1/[\sigma(w_p)\sigma(w_a)]$ where $w(z)=w_0+w_a z/(1+z)$
- *Work in progress! Will modify as information improves.*

Dark Energy and Cosmic Sound

Optimization results:

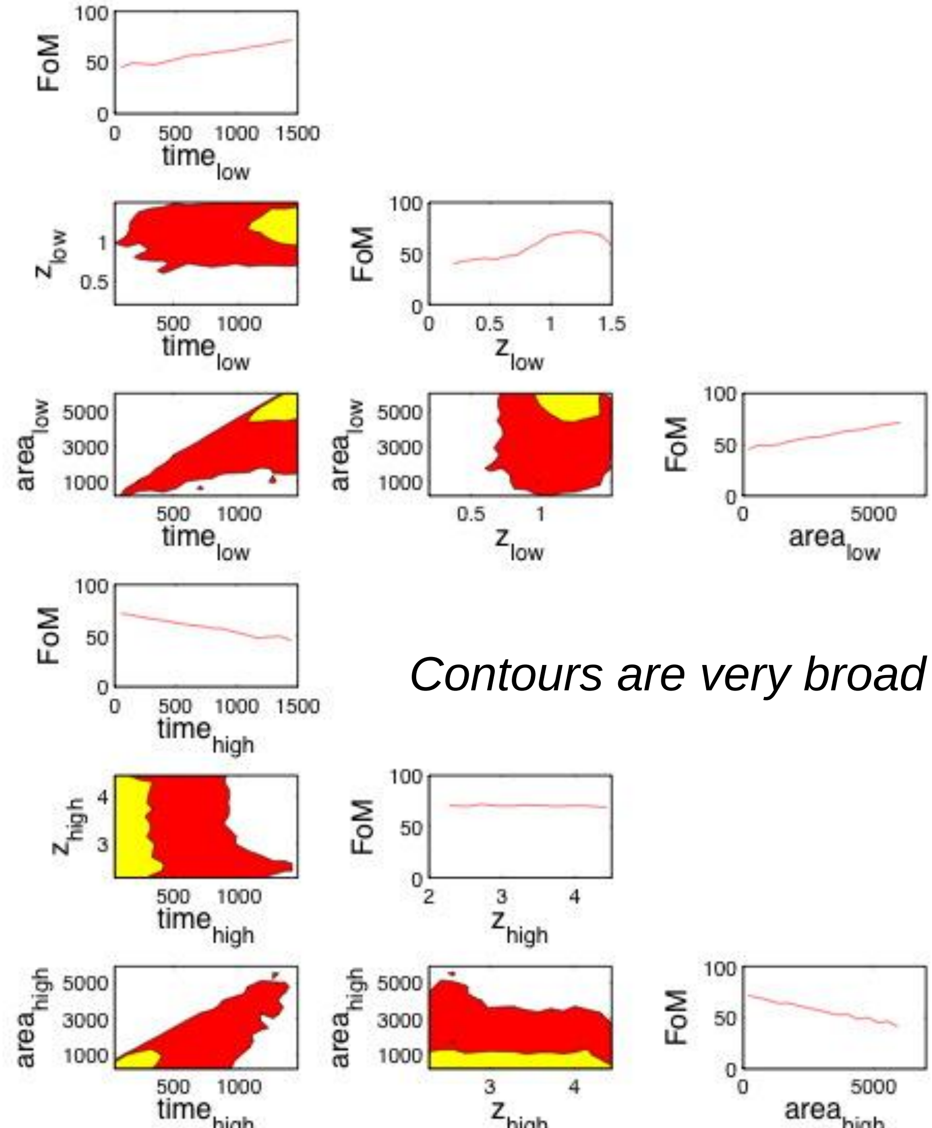
- Given other planned and ongoing DE surveys, WFMOS should target z~1 almost exclusively! **Need 8m telescope**

- Optimal survey ~ 6000 deg^2, 8.5 million galaxies, 150 nights

- Results in exquisite precision on D (0.5%) and H (0.8%)

- Assumptions of curvature have huge effect on FoM and optimal surveys

- Optimization prefers volume over shot noise



Contours are very broad

Survey	FoM	σ(w_0)	σ(w_a)	Curvature
WiggleZ	*5.5*	*0.58*	*1.59*	*Flat*
BOSS (no QSO)	*36*	*0.20*	*0.59*	*Flat*
BOSS (+ QSO)	*40*	*0.19*	*0.53*	*Flat*
WFMOS	*60*	*0.13*	*0.41*	*Flat*
Stage III SNe	*39*	*0.21*	*0.65*	*Flat*
COMBINED	**99**	**0.10**	**0.33**	

Survey	FoM	σ(w_0)	σ(w_a)	Curvature
WiggleZ	*1.1*	*1.11*	*4.25*	*Curved*
BOSS (no QSO)	*6.6*	*0.47*	*1.98*	*Curved*
BOSS (+ QSO)	*21.2*	*0.21*	*0.71*	*Curved*
WFMOS	*20.5*	*0.20*	*0.73*	*Curved*
Stage III SNe	*3.7*	*0.46*	*2.51*	*Curved*
COMBINED	**78.3**	**0.12**	**0.38**	

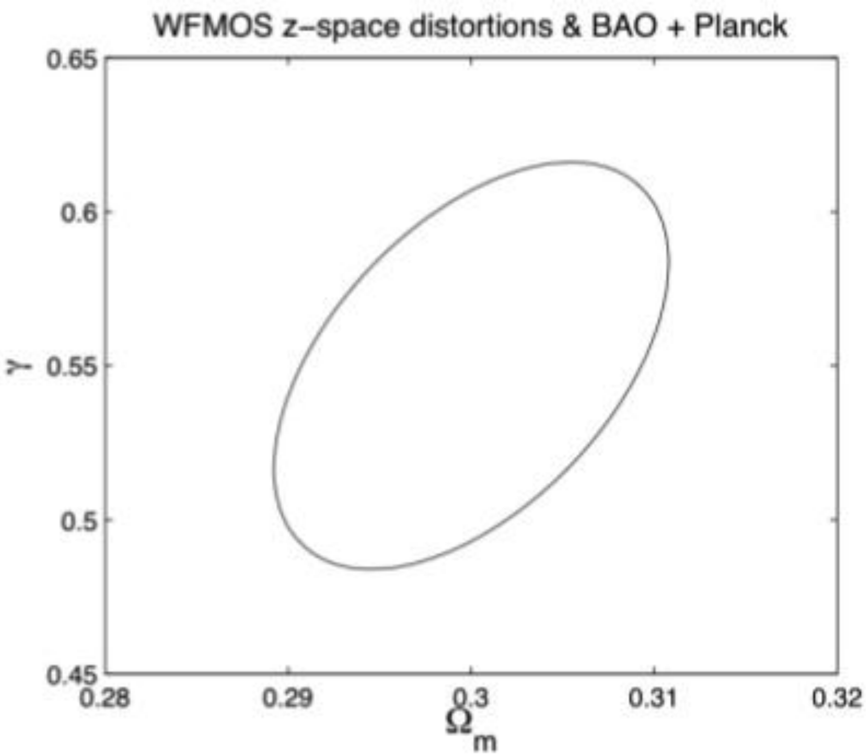
Dark Energy and Cosmic Sound

- DE-alone optimization is non-optimal for legacy value.
- Increasing exposure time to 60 min per target still results in a competitive DE survey
- Best options may be to:
  - Consider GE as separate key project
  - Significantly increase scope / time of DE survey
  - Compromise on FoM (70:30 approach only degrades FoM by 10%)

- *WFMOS DE survey should be designed with legacy value as an integral component*

Legacy science

- Cosmology:
  - Full power spectrum of galaxy clustering
  - Redshift space distortions
  - H(z) from radial BAOs
  - LyA BAOs with quasars (PI experiment?)
  - ~1000 SNe
- Galaxy Evolution:
  - SDSS @ z~1



10% measure of strength of gravity and 3% measure of matter density

Dark Energy and Cosmic Sound

- The Competition:
  - SDSS-II is done. SDSS-III/BOSS 2009-14 (z<0.7 LRGs; 1% distance measurement at z=0.3 and 0.6; possible 1.5% at z=2.5)
  - 2DF is done. WiggleZ is underway (0.5<z<1; 2% distance measurement at z~0.75)
  - LAMOST 2009?-? (z<0.6, r<19.8; low z constraint)
  - HETDEX 2010-2013? (1.9<z<3.5; 1% distance measurement at z=2.8)

- *WFMOS will provide unique constraints at z~1, an excellent complement to BOSS and WiggleZ, and result in excellent legacy value.*

Dark Energy and Cosmic Sound

- The Big Competition:
    - JDEM/EUCLID – 2018?
    - LSST – 2015?
- *WFMOS better get a move on! But technology is there and could be on-sky will before these.*

Overall Instrument Parameters

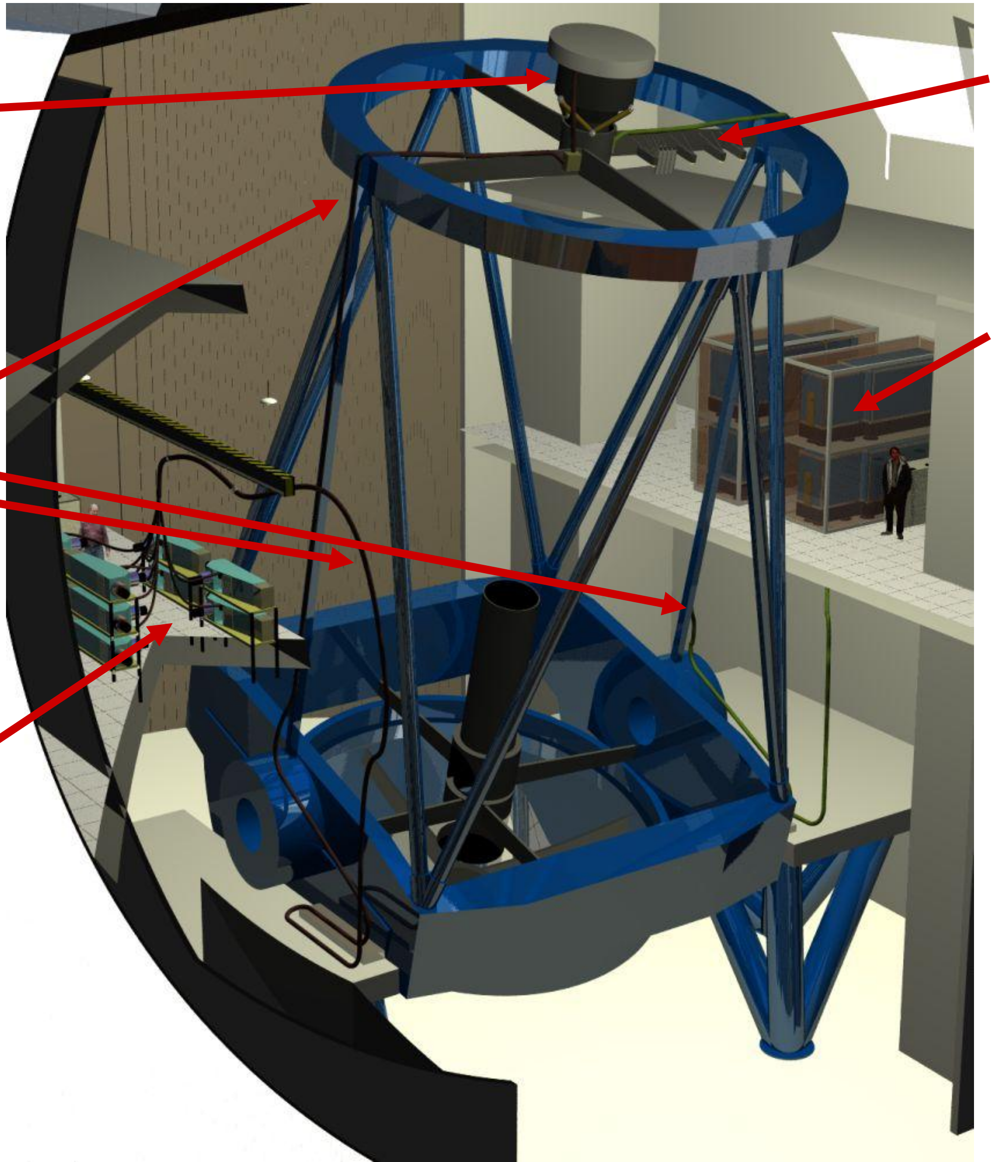
- Field of view – large! Need to do ~6000 deg2 efficiently
- Multiplex – large! Need to do ~8 million galaxies in a reasonable time
- Wavelength range – BAO needs mainly red. Galaxy evolution and high-z BAO needs blue. Also try QSOs like SDSS-III BOSS.
- Resolution – BAO only needs 300km/s redshift accuracy. But need good sky subtraction, resolve telluric emission, etc => R>2000
- Overhead – as short as possible! < 10 mins

WFMOS Overview on Subaru

Echidna Positioner
3000 spines
Proven (FMOS)

Fiber wraps

10 low res spectrographs
Proven (BOSS)



Calibration System

4 high res Spectrographs
Mostly GA science

Nightly data reductions
Proven (SDSS)

What next?

- Gemini/Subaru decision on construction team soon (this week?)
- Phase 2 proposals already submitted with fixed price contract and full schedule. These are binding
- Could be on sky by 2015 or sooner as LRS technology is proven

WFMOS Summary

- WFMOS would be a unique facility on a 8m class facility
- Unparalleled in this era of multi-band photometric surveys
- Would enhance all areas of astrophysics
- Huge legacy value and PI-driven science
- Lot of the technology is proven and ready