BigBOSS Introduction

November 18, 2009

BigBOSS Collaboration Meeting

Lawrence Berkeley National Laboratory

Michael Levi

Status

- **Objectives:**
  - —Large Spectroscopic Survey for NSF astro community
  - —Stage-IV Dark Energy performance for DOE & NSF

- **Proposal/Cost Study Expected**

- **Process:**
  - —BigBOSS invented March 3rd!! (But not really)
  - —April 1 submission to decadal survey
  - —Potential joint agency DOE-NSF as model (eg. DES)
  - —Proposal submitted to DOE R&D which triggered PASAG review
  - —HEPAP/PASAG subpanel recommendation
  - —Good Technical Start

- **R&D Technical Start**

Origins of BigBOSS

- **From SNAP proposal for JDEM.**
- **Stipulated that a ground-based telescope outfitted with a grism could survey the sky in 5 years.**

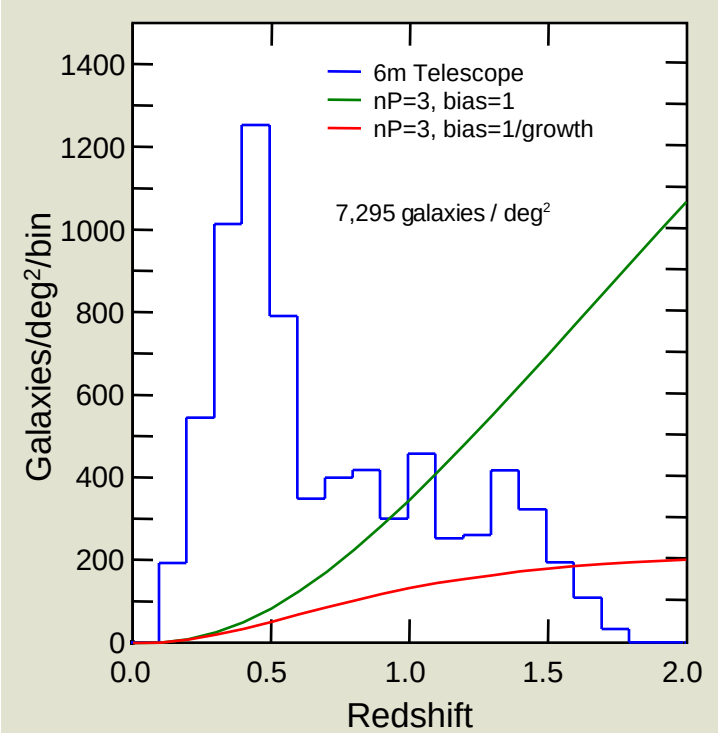
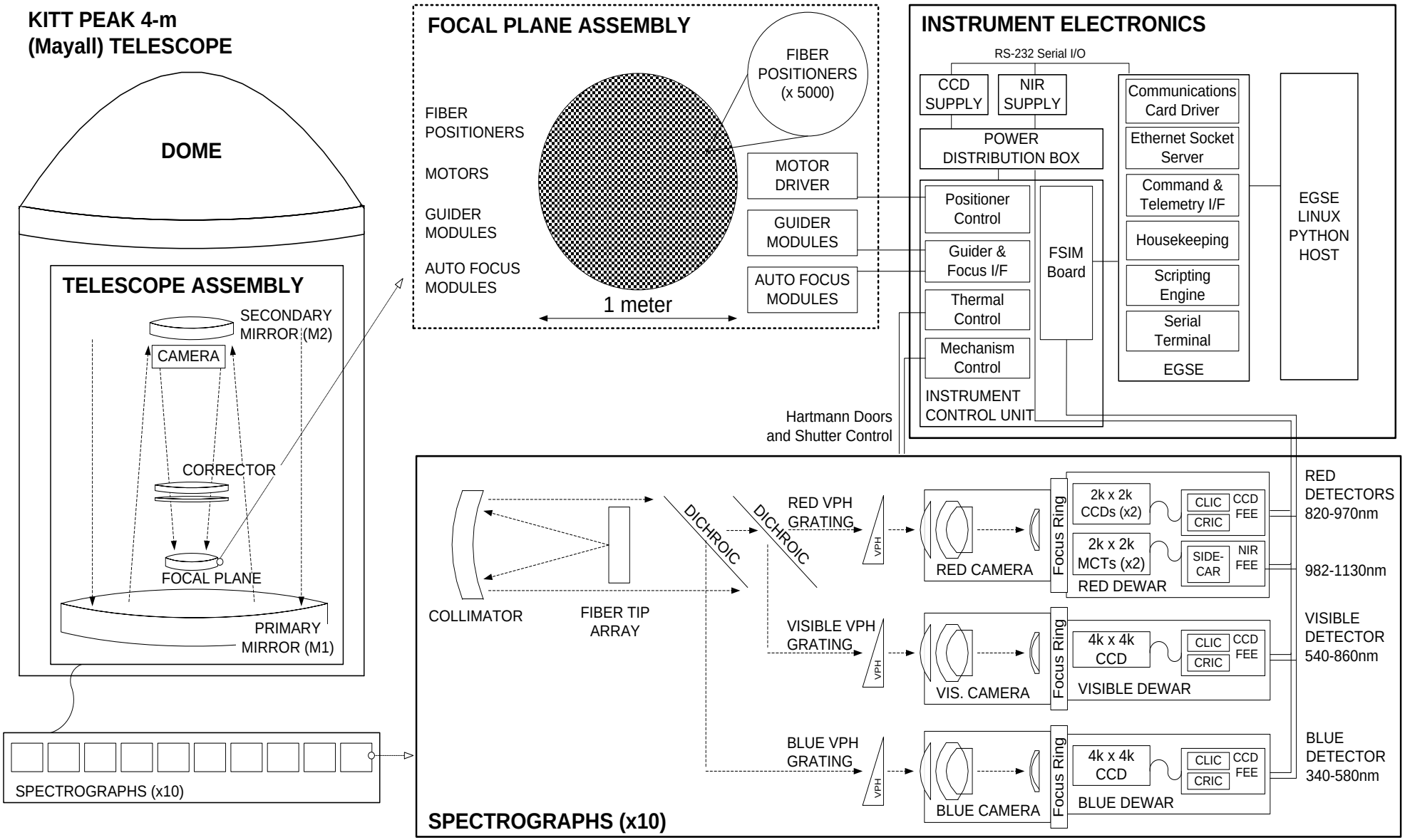


Figure 8: Redshift distribution of detected galaxies using 4 hours of exposure on a ground-based f/1.23 telescope of 6 m (w/ grisms) with median seeing of 0.65 arcsec. We have limited the grism bandpass from 740-1050nm to utilize the OII[3727], Hb, and OIII[5007] emission lines while avoiding bright NIR sky emission lines. Assuming a field of view of 9.6deg^2, a dedicated 5 year survey with 200 nights/year could cover ~24,000deg^2 of sky with a redshift limit of z<1.6. The red and green lines are the contours which approach the shot noise limit (nP>3) under two assumptions regarding the bias factor.

BigBOSS Functional Block Diagram



Block diagram: Ellen Taylor (SSL/UCB)

BigBOSS – Telescope Assembly

KITT PEAK 4-m (Mayall) TELESCOPE

SECONDARY MIRROR (M2):
- New Zerodur 1.5m mirror
- F/humber = f/5
- Enables 3 degree FOV
- Convex, hyperbolic

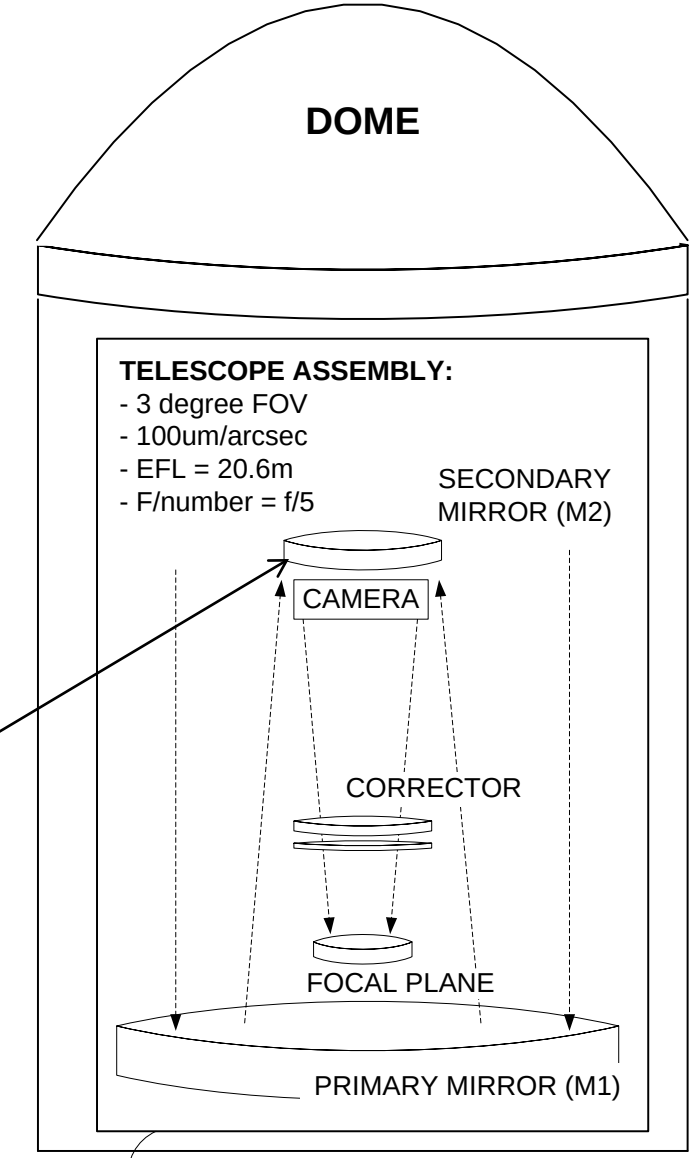
CAMERA:
- Fiber camera at M2 dark spot
- Measures fiber location
- Fairchild 9k x 9k CCD
- 9216 x 9216 pixels
- 8.75 micron pixel length
- 100% fill factor
- 8x8cm focal plane

CORRECTOR:
- 3-element field flattener
- Fused Silica elements
- Departure <200 microns

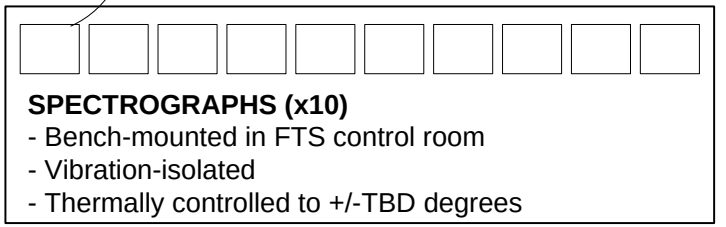
FOCAL PLANE and FIBERS:
- 1-m Flat Surface
- 5000 Fibers
- Broad Spectrum Optical Fibers
- Polymicro PBP
- Fibers 150um cores
- Provides 1.5 arcsec dia on sky

PRIMARY MIRROR (M1):
- Existing 4m mirror
- Concave, hyperbolic

OBSCURATION (not shown):
- 2m obscuration
- Required for stray light



FIBER RUNS (10 Runs x 500 Fibers each):
- 15m fiber run from Focal Plane to Spectrographs
- Provides maximum attenuation of 30% @ 340nm



BigBOSS – FPA and Electronics

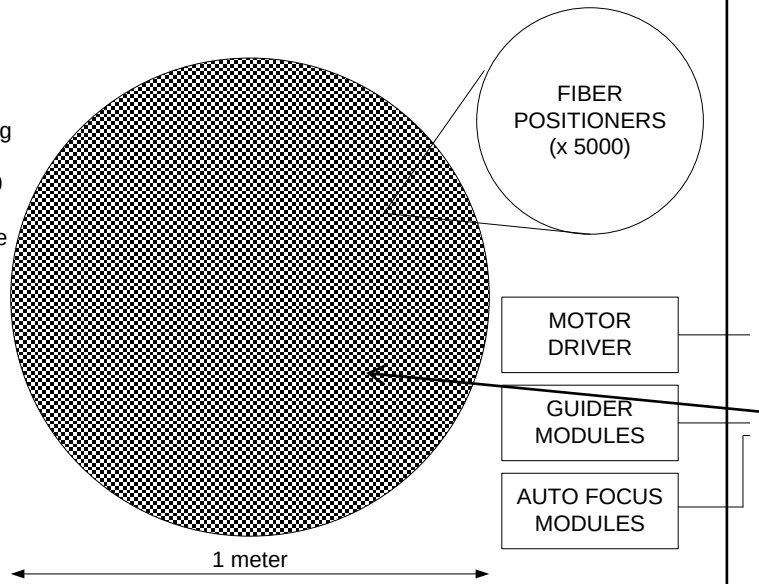
FOCAL PLANE ASSEMBLY:
- 1-m diameter flat focal surface
- 5000 hex cells for fibers

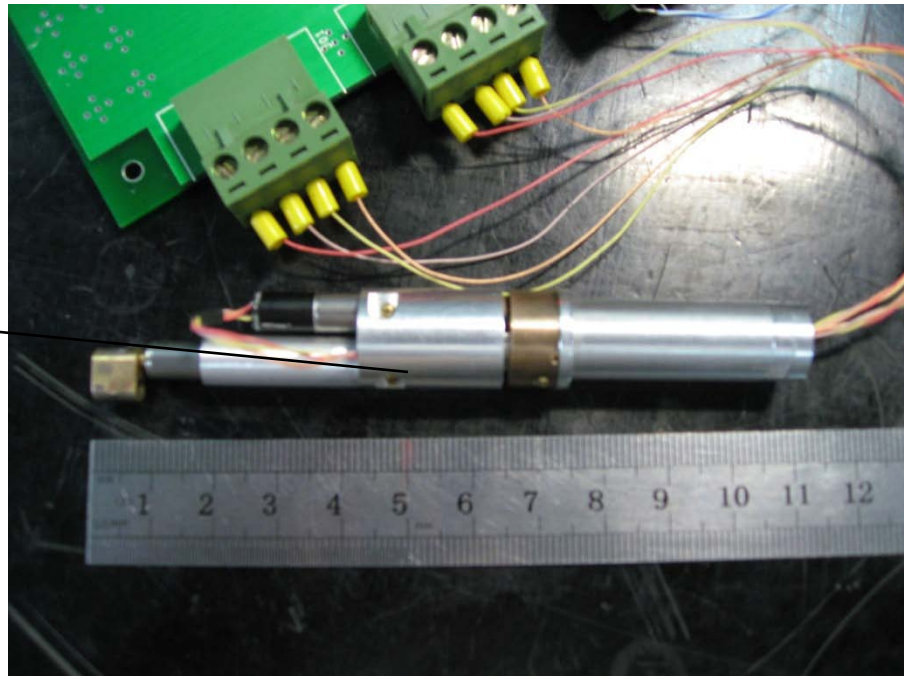
FIBER POSITIONERS:
- 1.10cm center-to-center spacing
- Each fiber individually actuated
- Local accuracy = 1 part in 1000
- Precision accuracy = +/-20um
- Reconfiguration time < 1 minute

MOTORS:
- Micromo 6mm motors
- 1 rotational axis motor
- 1 translation axis motor

GUIDER MODULES:

AUTO FOCUS MODULES:





USTC ϕ=15mm fiber positioner

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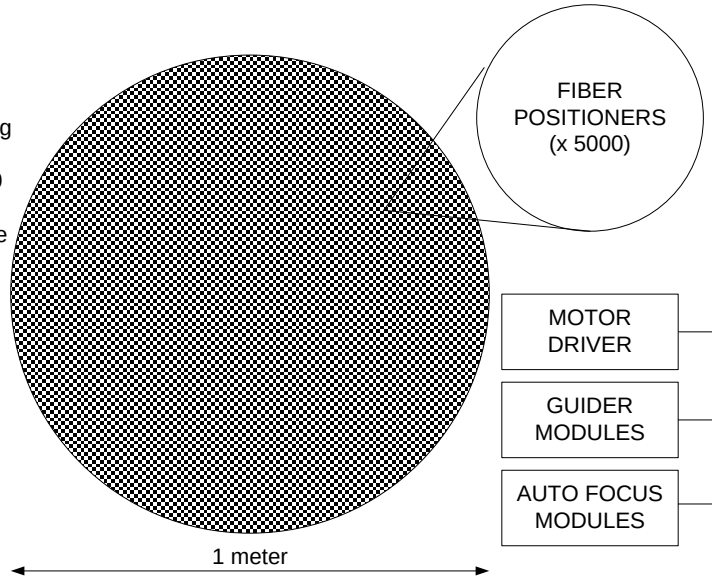


MOTOR DRIVER

GUIDER MODULES

AUTO FOCUS MODULES

INSTRUMENT ELECTRONICS

RS-232 Serial I/O

CCD TRIPLE OUTPUT SUPPLY BANK

NIR TRIPLE OUTPUT SUPPLY BANK

POWER DISTRIBUTION BOX

Positioner Control (w/ Camera I/F)

Guider and Focus I/F

Thermal Control

Mechanism Control

INSTRUMENT CONTROL UNIT

FSIM Board

Communication Card Driver

Ethernet Socket Server

Command and Telemetry I/F

Housekeeping

Scripting Engine

Serial Terminal

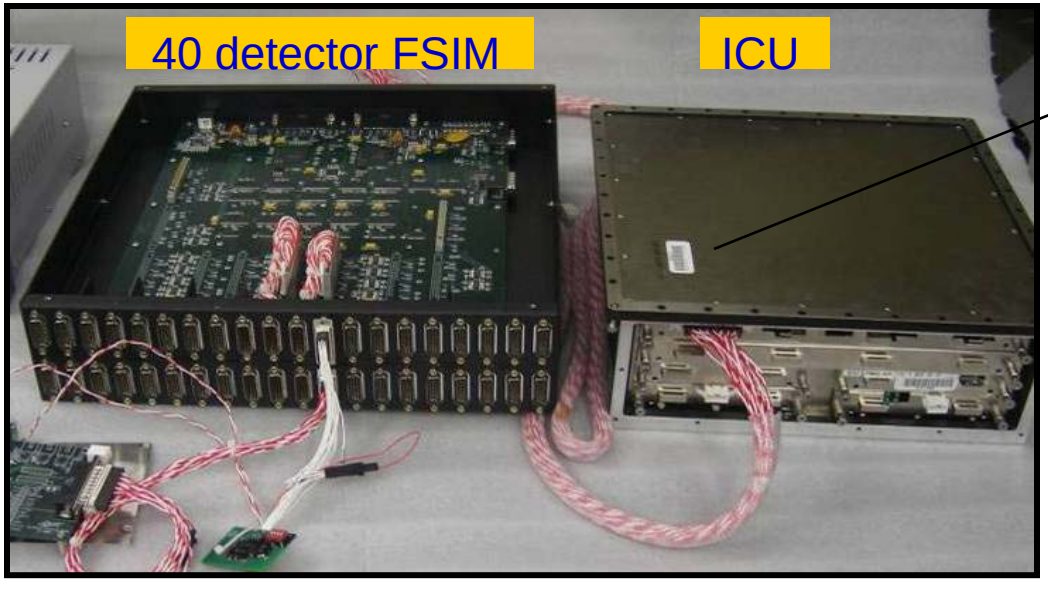
EGSE

EGSE LINUX PYTHON HOST

Spectrograph Hartmann Doors & Shutter Control

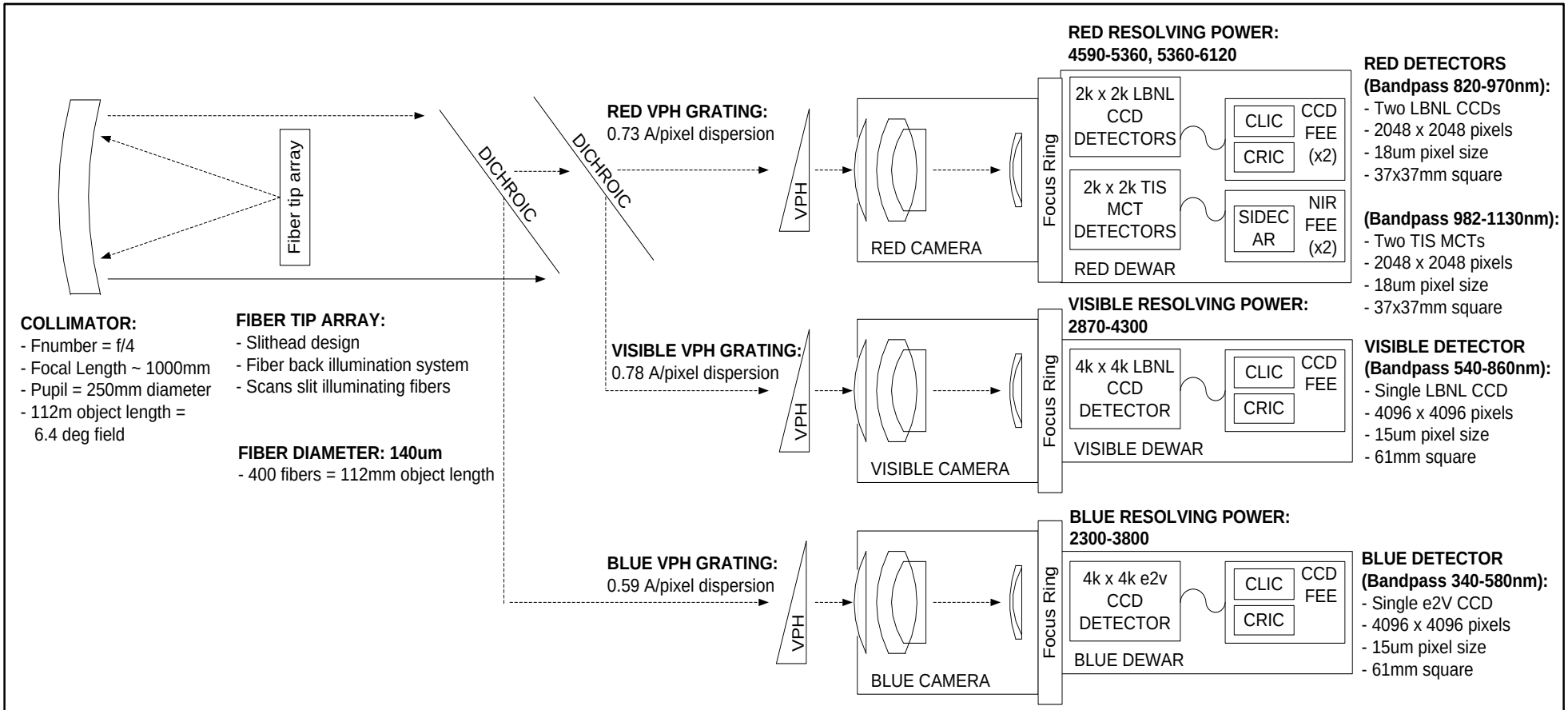
Power to Detectors
Data from Detectors

LINUX HOST:
- User control and data analysis platform
- Interactive Python shell to actively control ICU
- Scripting
- Graphical User Interface (GUI)
- Data Archive
- Post Processing



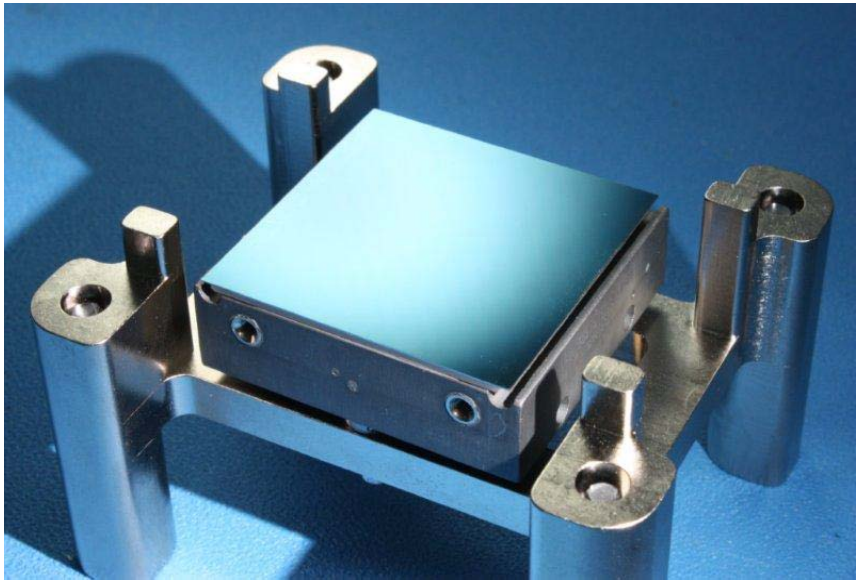
Shown is system that handles 40 detectors and 2 Guiders.

BigBOSS - Spectrographs

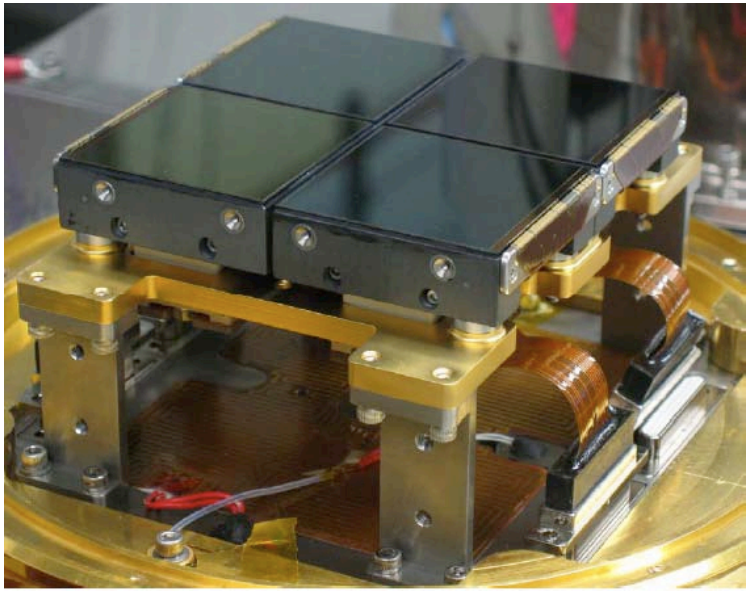


Focal Plane Ready Components

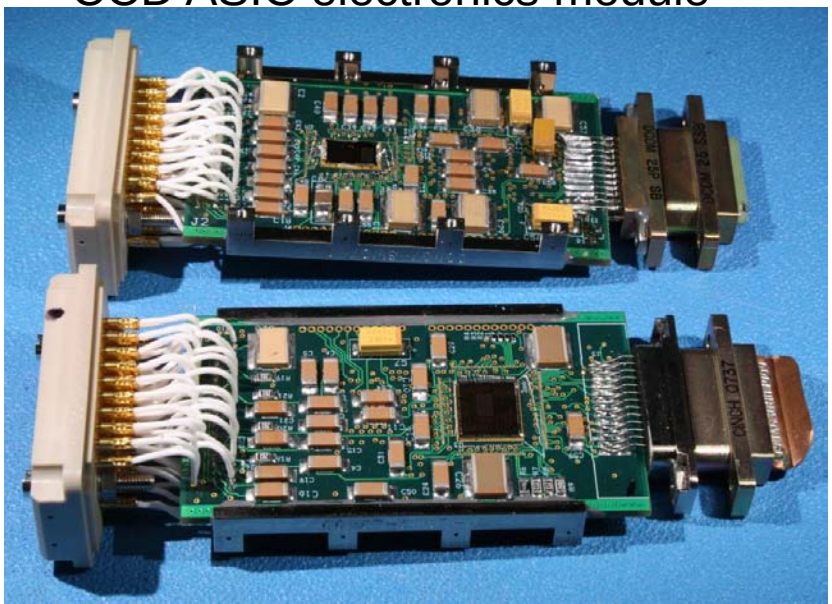
CCD on SiC



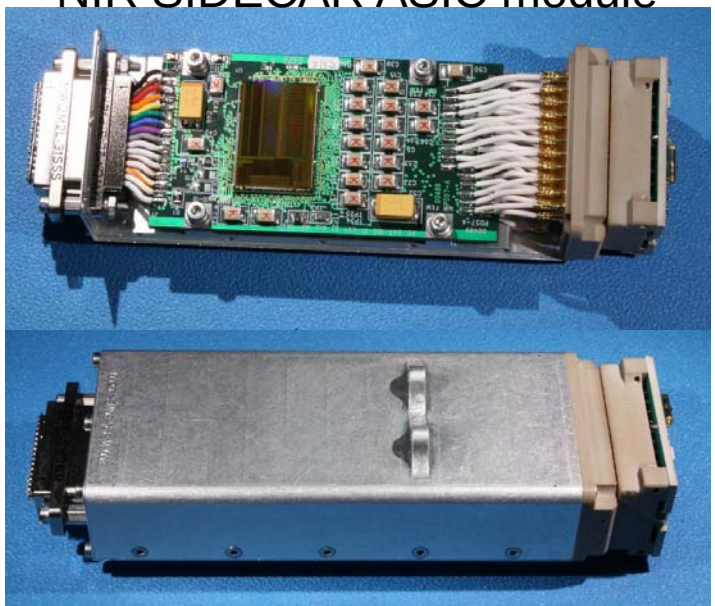
NIR on SiC



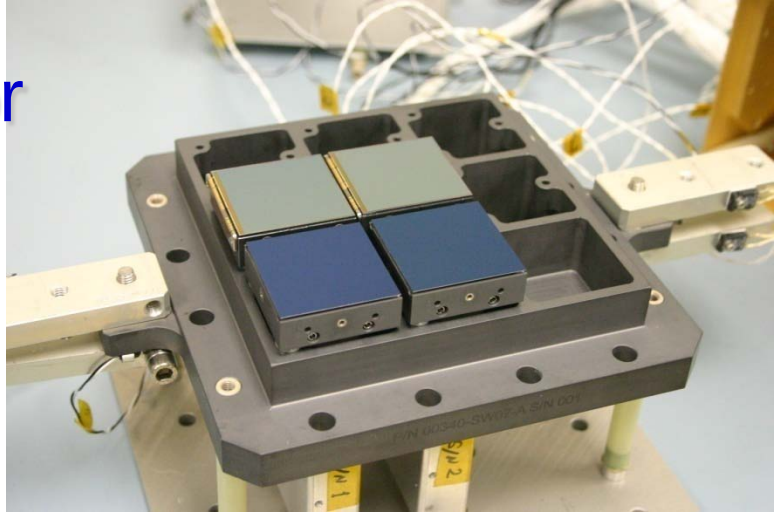
CCD ASIC electronics module



NIR SIDECAR ASIC module



JDEM 4 x 8 focal plane demonstrator



- Components
  - 16 CCD and electronics
  - 16 NIR and electronics
  - 2 guiders and electronics

- A step beyond current CCD & NIR demonstrator in system level complexity

- Could be of interest for target selection

Preliminary Project Organization

LBNL – Lead DoE Institution

- Construction Management - LBNL
- Spectrograph Optics - France
- Spectrograph Detectors & Electronics - LBNL
- Spectrograph Dewars - Yale & Others
- Fiber Positioner - China
- Fiber Control and FiberView Camera - Yale
- Focal Plane Mechanics & Guiding - LBNL
- Optics Assembly - NOAO, LBNL, Arizona
- Instrument Operations - Various
- Telescope Operations - NOAO
- Data Management - NYU
- Data Reduction - Utah

BigBOSS Top-Level WBS

WBS 1.0
Project Management
$5.1M

1.1 Project Management
1.2 Systems Engineering

WBS 2.0
Spectrographs and Instrument Electronics
$30.9M

2.1 Structure and Bench
2.2 Optics
2.3 Detector Assy 1
2.4 Detector Assy 2
2.5 Detector Assy 3
2.6 Digital Electronics System

NIR Arm = $12M, is that necessary?

WBS 3.0
Fiber System with Positioners
$5.4M

3.1 Fiber Assembly
3.2 Positioner Assembly
3.3 Fiber Support Tray

WBS 4.0
Optics
$8.4M

4.1 Upper Mechanical Structure
4.2 Secondary Mirror
4.3 Fiber Position Camera Assy
4.4 Lower Mechanical Structure
4.5 Cassigrain Cell Assy
4.6 ADC Assy
4.7 Focal Plane Assy

WBS 5.0
Instrument & Data Operations
$20.1M

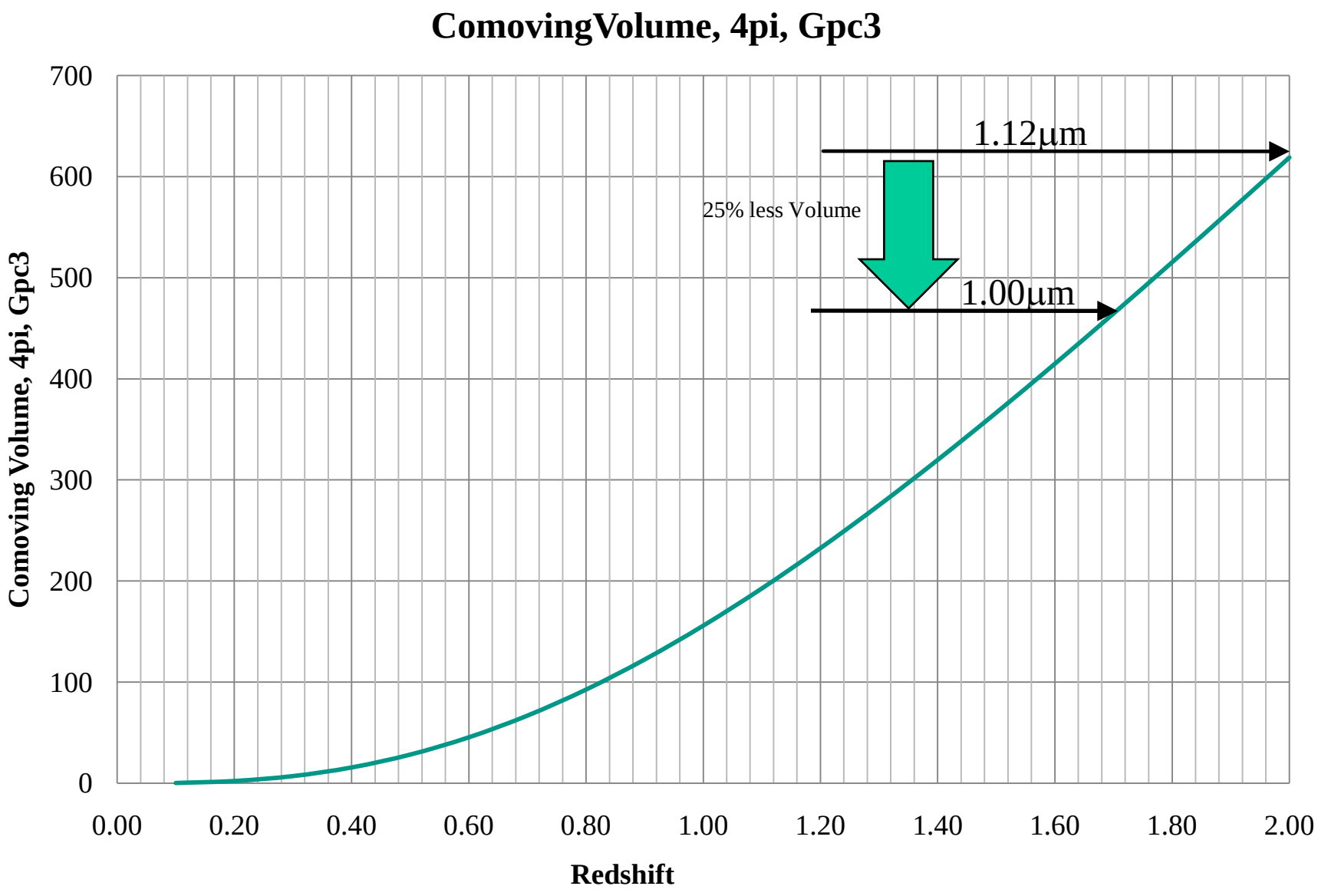
WBS 6.0
R&D Phase
$4.3M

6.1 Optics Design
6.2 Spectrograph Prototype
6.3 Fiber Positioner Prototype

WBS 7.0
Contingency
$15.0M

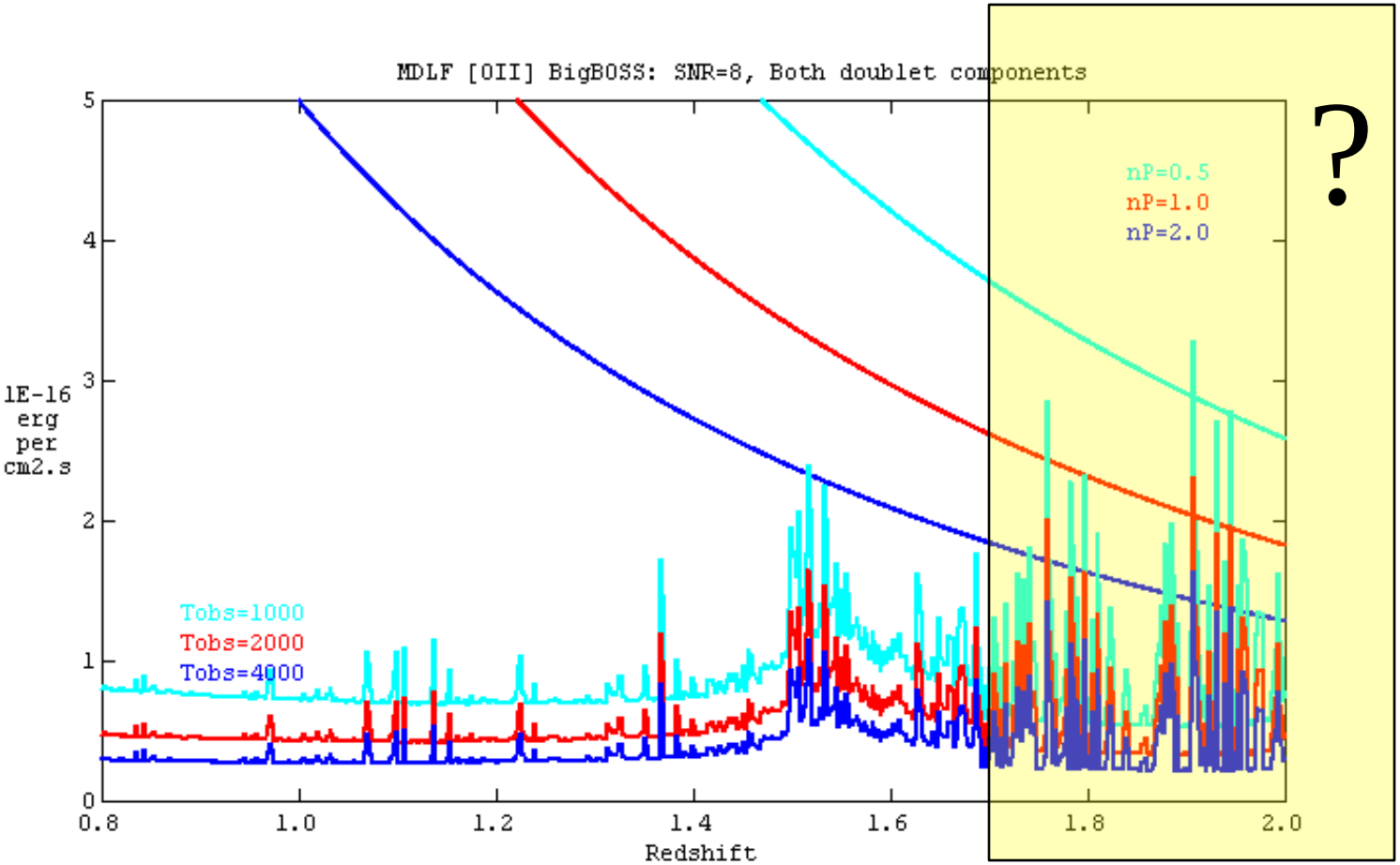
All costs, US + Foreign + Operating

Cosmic Volume Decision (NIR?)



MDLF Results for BigBOSS

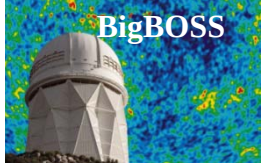
Goal is to use < 1 hour exposures and get SNR=8 (see chart 23)…



At Tobs = 1 h, 4000 fibers and 200 nights/year at 8h/night is 6 million targets per year -- and of course there is additional yield since most targets have z<2.0 and so won't need the full 4000 seconds of exposure each,so smart fiber reallocation can improve yield rather than SNR.

M.Lampton Sept 2009

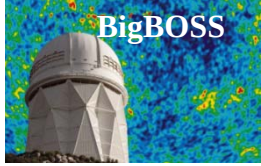
PASAG Recommendations



"The BigBOSS project proposes to greatly extend ground-based capabilities for galaxy redshift surveys by constructing a new 4000-fiber visible/NIR spectrograph for the existing NOAO Mayall 4-meter telescope in Arizona. With full-time use of the Mayall for 6 years, the BigBOSS spectrograph could acquire ~$10^{7.5}$ redshifts of galaxies at $0<z<2$ over 14,000 deg^2 of sky. An additional million quasar spectra could measure BAO features to $z<\sim3.5$ using intervening absorption systems. The survey could be extended to 24,000 square degrees with 4 additional years of full-time use of the Blanco telescope, a twin of the Mayall at NOAO's Chilean site. Galaxy redshifts will come primarily from the 373 nm [OII] line. BigBOSS can resolve this doublet for secure line identification, and the spectral resolution is high enough to enable the redshift-space distortion method as well. The BigBOSS concept has only been developed in the past year but has quickly built on experience with the SDSS and stage-III BOSS surveys.

"BigBOSS will require full-time use of NOAO 4-meter telescopes for a decade. These are important resources for the astronomical community so this is a major commitment. There is precedent: the stage-III Dark Energy Survey has been granted 1/3 of the Blanco time over 5 years. The BigBOSS survey will also require an extensive imaging survey to provide targeting information for its spectrograph. Clearly the BigBOSS project will require extensive cooperation with the astronomy community and agencies even if the construction and operations are fully funded by DOE.

PASAG Recommendations



"Further R&D is needed to produce BigBOSS engineering and cost estimates as secure as those of LSST. The dark energy performance of BigBOSS can be more securely predicted than that of LSST because the BAO method is less likely than the SN and WL methods to be limited by hard-to-predict astrophysical and instrumental systematic errors.

"BigBOSS is in the early planning stages, but presents a legitimate possibility of achieving a significant fraction of the BAO science goals for JDEM at <$100M cost. Substantial immediate support is recommended for BigBOSS R&D so that ground BAO possibilities are known for timely planning of a coherent ground-space dark energy effort. The ground astronomy agencies (NSF/NOAO) are essential partners in the BigBOSS project and planning.

"A coherent overall strategy, optimizing observations both from the ground and space, taking into account the priorities of both the astronomy and physics communities, has been lacking. As described in Sections 1 and 6, PASAG is not constituted to do this. However, as dark energy is a very high scientific priority, PASAG sought to define the scope of dark energy within the broader particle astrophysics program. The detailed allocation to projects in the different budget scenarios awaits a coherent plan. The Astro2010 Survey, which is ongoing, will presumably play a key role in this planning.

Dark Energy Roadmap - France

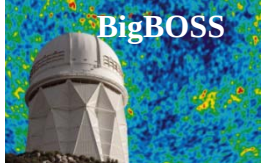
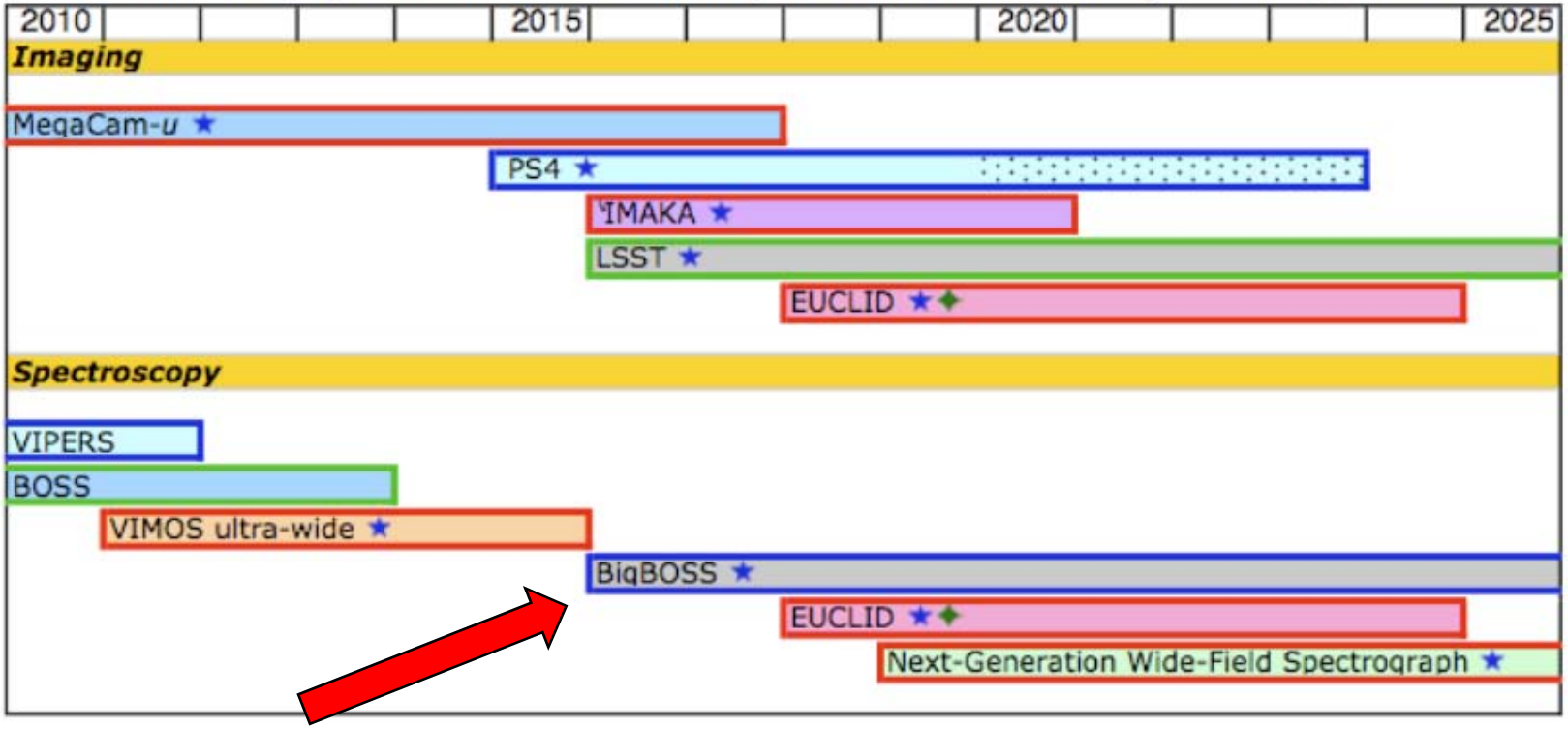


***Tableau 6** : proposition de feuille de route pour la communauté française Energie Noire*



French leadership — Main French partnership — Minor French participation

★ Project not yet approve

✦ Data from DES (2011-2

Spectro MOS sur 4m ou 8m (> "a lot of objets", R = 5000 à 100000)

En fait 2 types de besoin scientifique

- oscillations baryoniques à partir des galaxies lointaines (énergie noire) => R = 5000 P0: PNCG
- archeologie galactique => R = 100 000 (spectro type OKAPI/VLT) P0: PNPS, ASGAIA

Projet BigBOSS: 1e7 galaxies jusqu'à z= 3.5

5000 fibres au foyer de 7° carré du 4m de Kitt Peak puis CTIO 5 M€ + 26 ept Fr. (60 M€ tot.)

Example: 2004 NOAO call for new instrument on the Blanco 4m. Resulted in the formation of DES.

Announcement of Opportunity for Blanco Instrumentation Partnership

NOAO announces a partnership opportunity to develop a major new instrument for the Blanco 4 meter telescope of Cerro Tololo Inter-American Observatory. Although there are no restrictions on the type of instrument that can be proposed, in order to build on the Blanco telescope's particular strengths we see a special opportunity to exploit the wide field capability of the prime or RC focus of the telescope. Additionally, any proposed instrument should be, consistent with a system-wide view of facilities available to the US community, in particular those in the southern hemisphere. Guidance on the US system can be obtained from the report on the first workshop on the ground-based O/IR system, see http://www.noao.edu/gateway/oir_workshop/

By the likely time of commissioning of the new instrument solicited here, we expect to have retired the RC and Echelle spectrographs since their capabilities will have been replaced by new instrumentation on SOAR and Gemini. We plan to begin sharing the wide-field IR imager NEWFIRM with the KPNO Mayall 4-m in 2006, NEWFIRM is described at http://www.noao.edu/ets/newfirm/. A technical description of the telescope will be accumulated here.

Proposers will need to submit a science plan, a technical plan, and a management plan. The science plan should include a description of compelling science to be undertaken by the proposing team, which may be in partnership with NOAO, and also an outline of anticipated astronomy community use of the instrument through merit based proposals. The technical plan should present a conceptual design of the instrument in sufficient depth for peer reviewers to assess the feasibility of the project with the resources to be committed. The management plan should outline the proposed sharing of responsibilities for optomechanical, focal plane, data acquisition, and data management work packages between the proposer and NOAO. A general management structure along with a schedule of project reviews (PDR, CDR) and acceptance testing should be included. The management plan should include a plan for public and educational outreach and explain the broader impacts of the project.

Up to 30% of the Blanco telescope time for 5 years commencing in 2007 or 2008 is available for the science project. NOAO will contribute the operation of the telescope and an upgraded control system with a combined nominal annual value of $4M at real year prices. NOAO would expect to partner with the successful proposer in developing a data management system, (including data acquisition) which is compatible with the National Virtual Observatory. The successful proposer can expect to work with an engineering interface at NOAO with optomechanical and other expertise.

Letters of intent are due at NOAO on March 15, 2004. At that time an NOAO contact

Example: DES Proposal to NOAO

A Proposal to NOAO for the Dark Energy Survey

July 15, 2004

Submitted by

Fermilab
B. Flaugher, J. Frieman, M. Gladders*, L. Hui, S. Kent, H. Lin, V. Scarpine, A. Stebbins, C. Stoughton, D. Tucker, W. Wester
* Carnegie Observatories

University of Illinois at Urbana-Champaign
ner, I. Karliner, J. Mohr, R. Plante, M. Selen, J. Thaler

University of Chicago
Dodelson, J. Frieman, W. Hu, S. Kent, E. Sheldon, R. Wechsler

alifornia Berkeley and Lawrence Berkeley National Laboratory
Aldering, N. Roe, C. Bebek, M. Levi, S. Perlmutter

In collaboration with:

Cerro Tololo Inter-American Observatory
T. Abbott, R. C. Smith, N. Suntzeff, A. Walker

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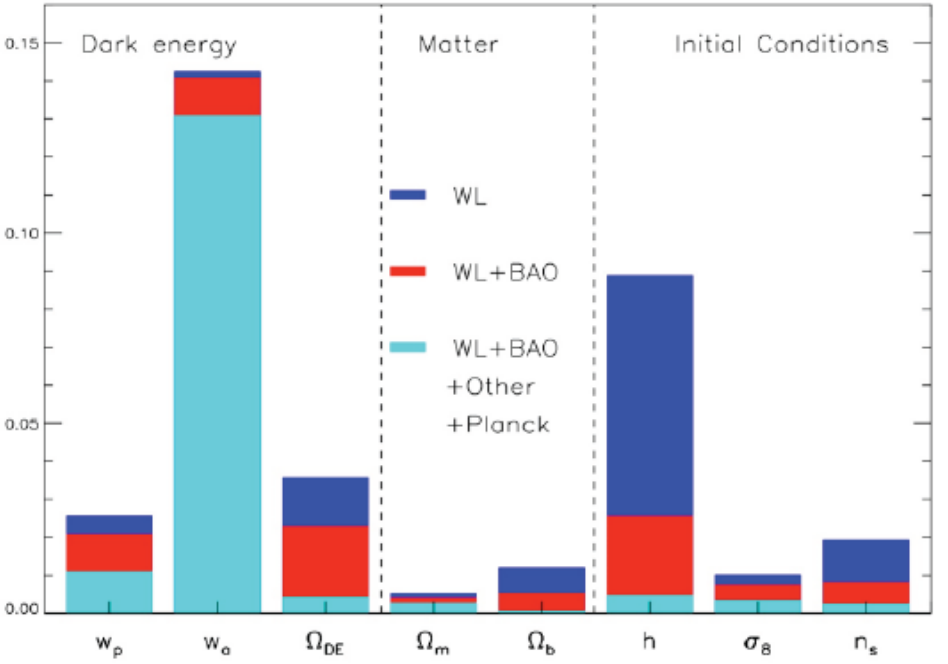
Overall Impact on Cosmology

EUCLID



Euclid will challenge all sectors of the cosmological model:

- Dark Energy: w_p and w_a with an error of 2% and 13% respectively (no prior)
- Dark Matter properties: test of CDM paradigm, precision of 0.04eV on sum of neutrino masses (with Planck)
- Initial Conditions: constrain amplitude, slope and higher order parameters of primordial power spectrum, constrain primordial non-gaussianity
- Gravity: Distinguish G

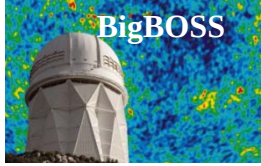
2% on the growth expon

→ Uncover new physics

→ Map LSS at 0<z<2: I

Sum of neutrino masses	0.019 eV
Number of relativistic species	0.12
Curvature	0.0006
Spectral Index/ Running	0.0030/0.0018

BigBOSS: The Stage IV Ground-Based BAO Experiment



Important!

	BOSS	BigBOSS-N	JDEM-BAO	BigBOSS-N+S
Redshift	0.2<z<0.7	0.2<z<3.5	0.7<z<2.0	0.2<z<3.5
Sky Coverage	10000 deg^2	14000 deg^2	20000 deg^2	24000 deg^2
Field-of-View	7.0 deg^2	7.0 deg^2	0.6 deg^2	7.0 deg^2
Number of Fibers	1000	4000	Slitless	4000
Angular size of Fibers	2”	1.5”	n/a	1.5”
Wavelength Range	360-1000 nm	340-1130 nm	1100–2000 nm	340nm–1130 nm
Spectral Resolution	1600-2600	2300-6100	200	2300-6100
DETF FoM	57	175	250	286
DETF FoM w/Stage III	107	240	313	338

BigBOSS-North and the full BigBOSS experiment compared to the current BOSS experiment (under construction) and JDEM (the only other stage-IV BAO project currently proposed). The DETF FoMs include Planck priors or Planck plus Stage III supernova and weak lensing experiments per FoMSWG. JDEM (also known as IDECS) FoM entries are for JDEM BAO parameters as determined by the JDEM Science Coordination Group, and are consistent with the version submitted to Astro2010.

Conclusion

- Lots of R&D going on
- Some important decisions that will touch science/design/cost
- Preparations for proposal
- Communications