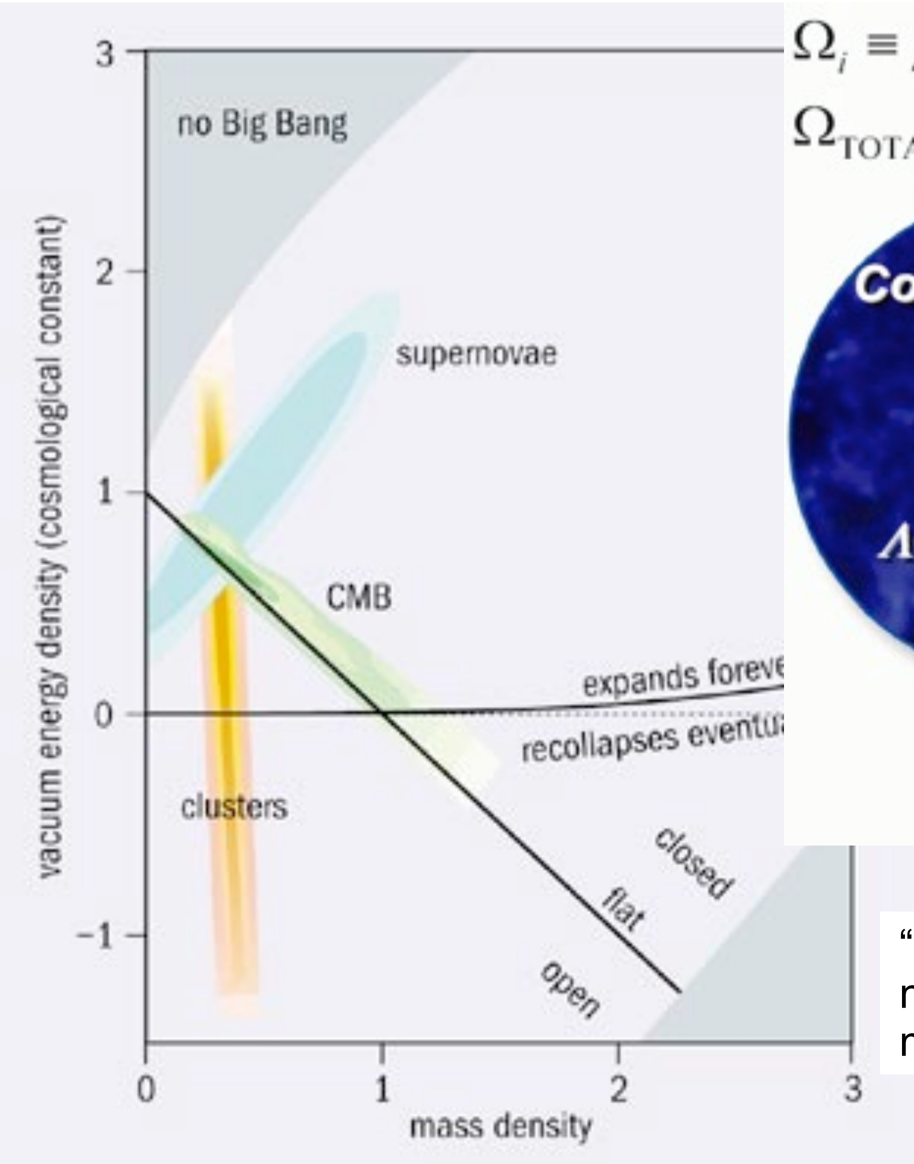
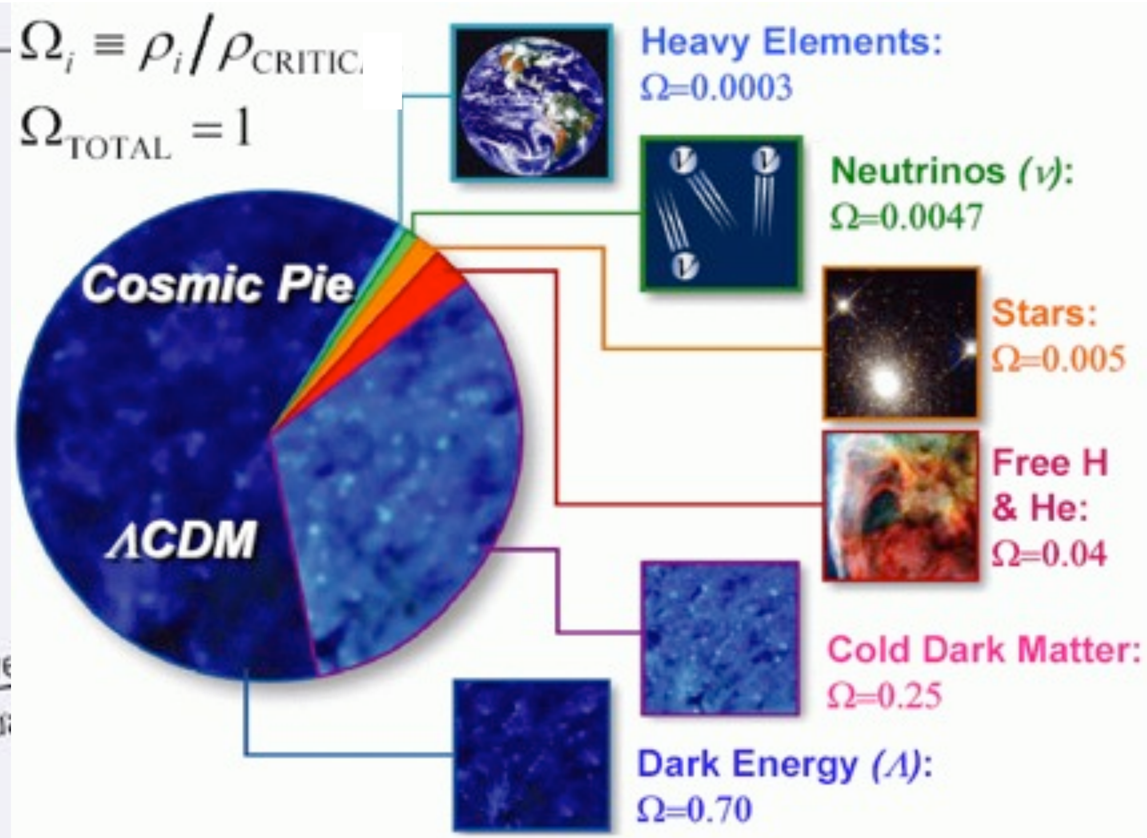
The PAU Survey at the WHT

Enrique Gaztañaga
ICE, IEEC/CSIC
Barcelona

INAOE 12 oct 2012 (supported by to LACEGAL network)

The New Standard Model





"The last Copernican revolution. (...) Not only we are not at the center of the universe, we are not even made of the stuff most of the universe is made of."

B. Sadoulet

Dark Energy(cosmic acceleration) studies

- What is causing the acceleration of the expansion of the universe?
  - Einstein's cosmological constant Λ?
  - Some new dynamical field ("quintessence," Higgs-like)?
  - Modifications to General Relativity?

$\Big\}$ "Dark Energy"

- Dark energy effects can be studied in two main cosmological observables:
  - The history of the expansion rate of the universe: supernovae, weak lensing, baryon acoustic oscillations, cluster counting, etc.
  - The history of the rate of the growth of structure (galaxies) in the universe: weak lensing, large-scale structure, cluster counting, etc.
- For all probes other than SNe, large galaxy surveys are needed:
  - Spectroscopic: 3D (redshift), medium depth, low density, selection effects
  - Photometric: "2.5D" (photo-z), deeper, higher density, no selection effects

Observing DE: H(z) & D(z) & more

1. Expansion history:

$$R_{\mu\nu} + \Lambda g_{\mu\nu} = -8\pi G \left(T_{\mu\nu} - \frac{1}{2} g_{\mu\nu} T \right)$$

$$H^2(z) = H^2_0 \ [\ \Omega_M (1+z)^3 + \Omega_R (1+z)^4 + \Omega_K (1+z)^2 + \Omega_{DE} (1+z)^{3(1+w)}\ ]$$

matter radiation curvarure dark energy $w=p/\varrho$

- Measurements are usually integrals over H(z) $r(z) = \int dz/H(z)$
- Standard Candles (supernova) $d_L(z) = (1+z)\, r(z)$
- Standard Rulers (BAO) $d_a(z) = (1+z)^{-1}\, r(z)$ or $H(z)=cdz/r$ directly
- Volume Markers (clusters) $dV/dzd\Omega = r^2(z)/H(z)$

2. Linear Growth history:

$$\delta T^{\mu\nu}_{;\nu} = 0$$

$$\frac{d^2\delta_k}{d\tau^2} + \mathcal{H}\frac{d\delta_k}{d\tau} - \left(\frac{3}{2}\mathcal{H}^2\Omega_m - k^2 v_s^2\right)\delta_k = 0$$

$$\delta = D(z)\,\delta_0$$

3. Non-linear Growth history

- Higher order correlations, Cluster abundance, profiles

4. Solar & Astro test of gravity

Figure of Merit ($\mathrm{FoM}_{w\gamma} \times 10^3$) Expansion x Growth

$$H = H(w)$$

w(z) -> Expansion History (background metric)
we will use w0 and wa

$$f \equiv \frac{d\ ln\ D}{d\ ln\ a} = \frac{\dot{\delta}}{\delta} \equiv \Omega_m^\gamma(a)$$

γ -> Growth History (metric perturbations)
probably need one more parameter here

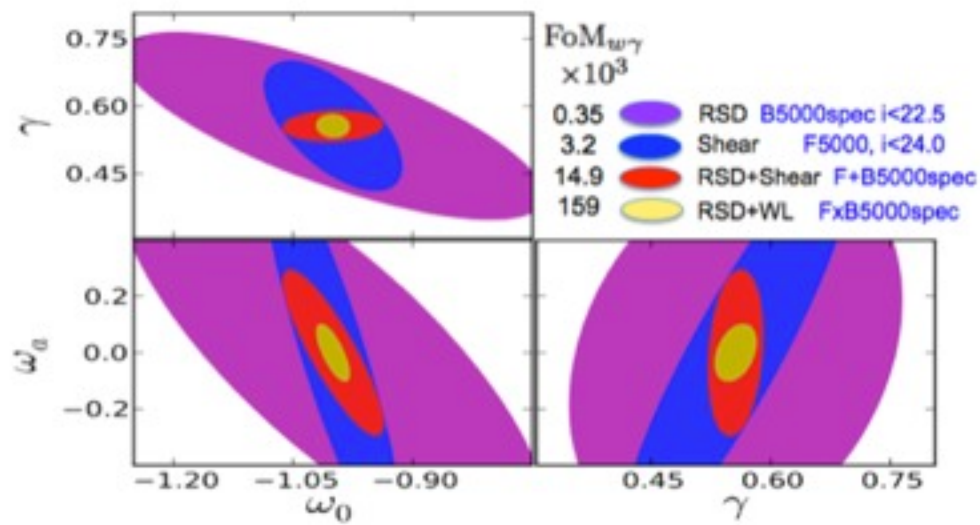
$$\delta = D(a)\delta(0)$$

Linear Theory: P(k,z) ~D^2(z) P(k,0)

+
mass conservation

$$\dot{\delta} = \quad -H\theta$$

$$\boxed{\theta = -f(\Omega)\ \delta}$$



f = Velocity growth factor: tell us if gravity is really responsible for structure formation!
Could also tell us about cosmological parameters or Mod Gravity

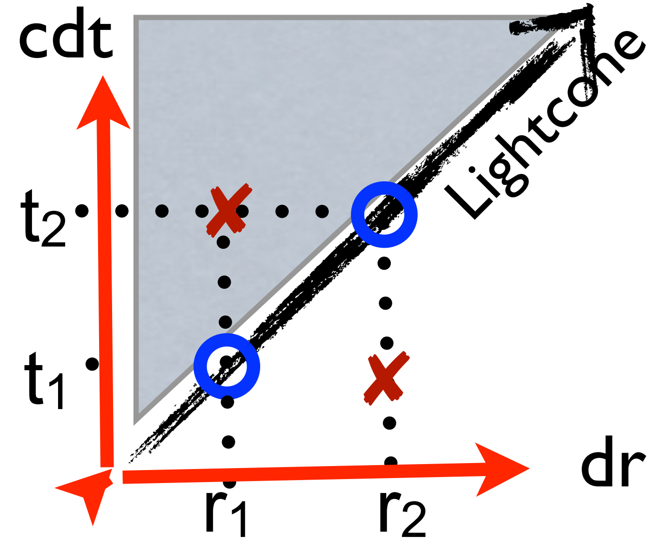
$$FoM_S = \sqrt{\frac{1}{det[F^{-1}]_S}} = \frac{1}{\sigma(w0)\ \ \sigma(wa)\ \sigma(\gamma)}$$

Is this the best
choice for 3 parameters?

Om - ODE - h - sig8 - Ob - **w0 - wa -γ-** ns - bias(z)

Need for Statistical Approach

$$\frac{d^2\delta_k}{d\tau^2} + \mathcal{H}\,\frac{d\delta_k}{d\tau} - \left(\frac{3}{2}\,\mathcal{H}^2\,\Omega_m - k^2\,v_s^2\right)\,\delta_k = 0$$



This is a initial condition problem, we need:

$$\delta(r_2,t_2) = D(t_1,t_2)\ \delta(r_2,t_1)$$

$$\delta(r_1,t_2) = D(t_1,t_2)\ \delta(r_1,t_1)$$

but we can only measure: $\delta(r_1,t_1)$ & $\delta(r_2,t_2)$

Statistically this is possible (in homogeneous universe):

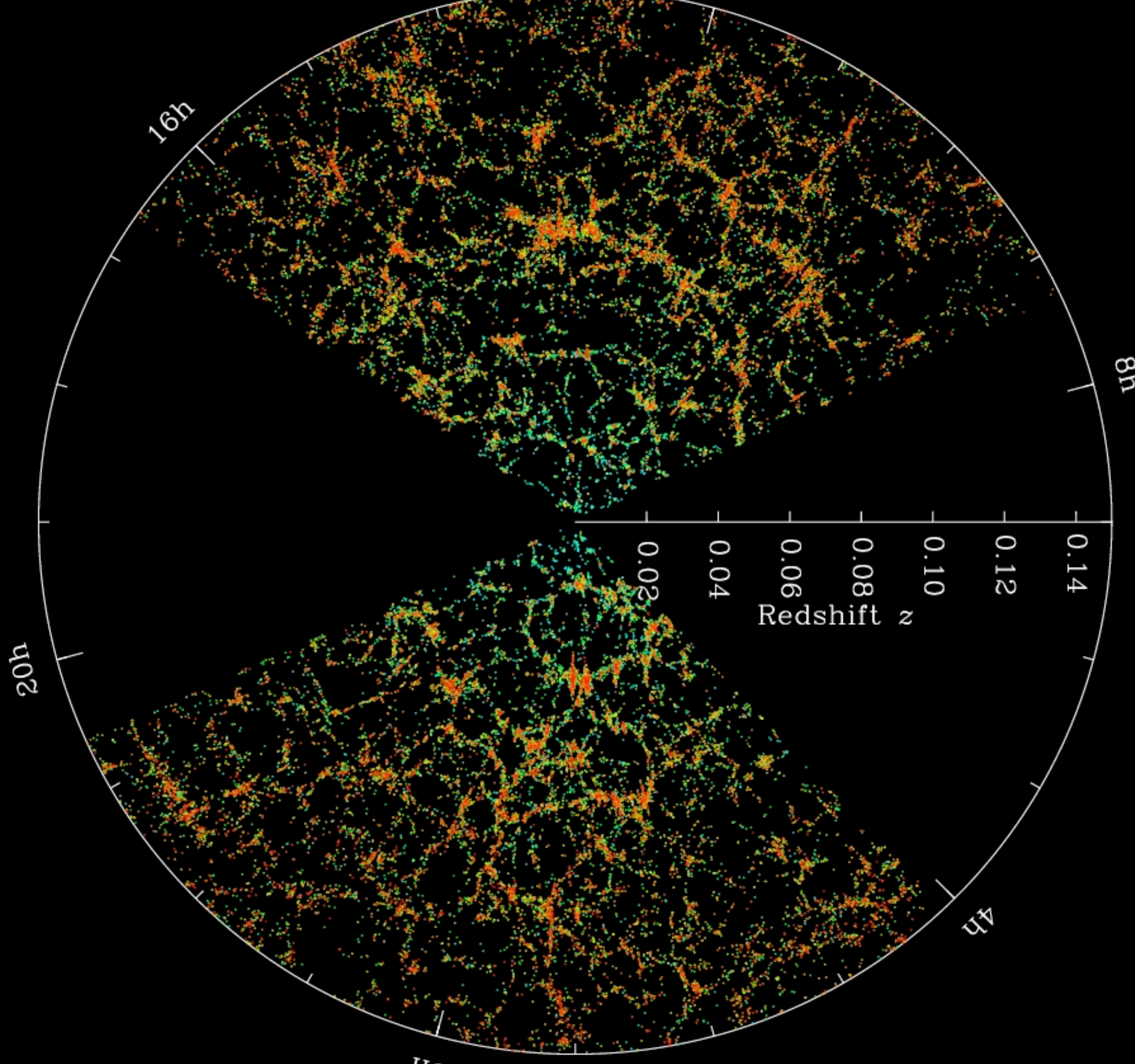
$$\xi_2(r,t_2) \equiv \langle\delta(x,t_2)\delta(y,t_2)\rangle_{xy} = D^2(t_1,t_2)\ \langle\delta(x,t_1)\delta(y,t_1)\rangle_{xy} = D^2(t_1,t_2)\ \xi_2(r,t_1)$$

$r=|x-y|$

$$P(k,z) = D^2(z)\ P(k,0)$$

This is limited by *sampling variance*: need large Volume (3D)

Can produce ***biases*** in statistical measures


16h
8h
20h
4h
0.02
0.04
0.06
0.08
0.10
0.12
0.14
Redshift z

Galaxy Surveys

Photometric:

poor radial (redshift) resolution (~300 Mpc/h) but more Volume

DES, VISTA, Pan-STARRS, Subaru/HSC, Skymapper, LSST

PAU

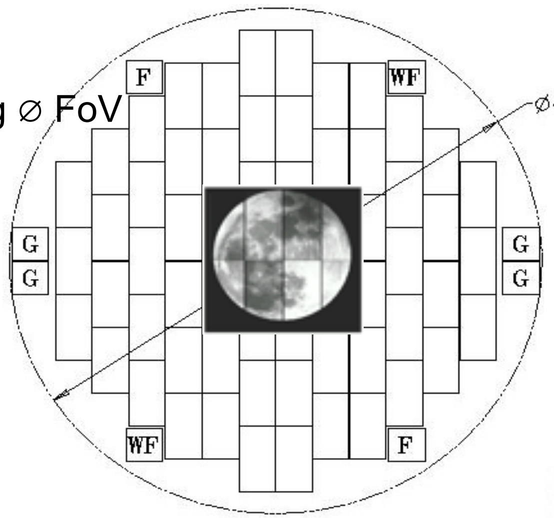
Spectroscopic:

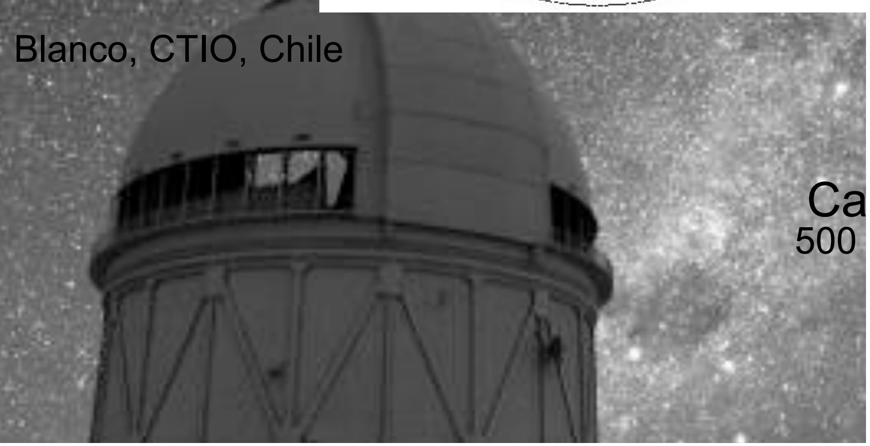
good or very good radial resolution (1-20Mpc/h), smaller Volume

WiggleZ, BOSS, e-BOSS, Subaru/Sumire, BiggBOSS, DESpec, HETDEX, SKA, VISTA/Spec

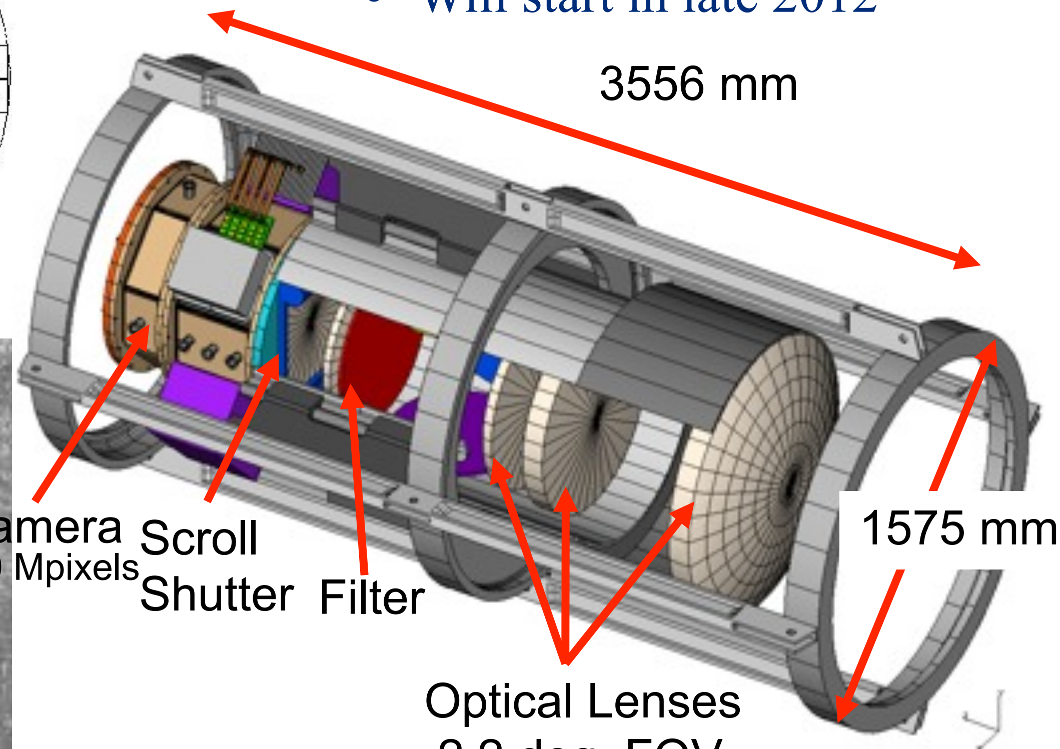
Dark Energy Survey (DES)

- 5000 deg^2 galaxy survey in 5 bands. 300M galaxies up to z < 1.4. Also ~4000 SNe.
- Involves groups in USA, Spain, UK, Brazil, Germany, Switzerland.



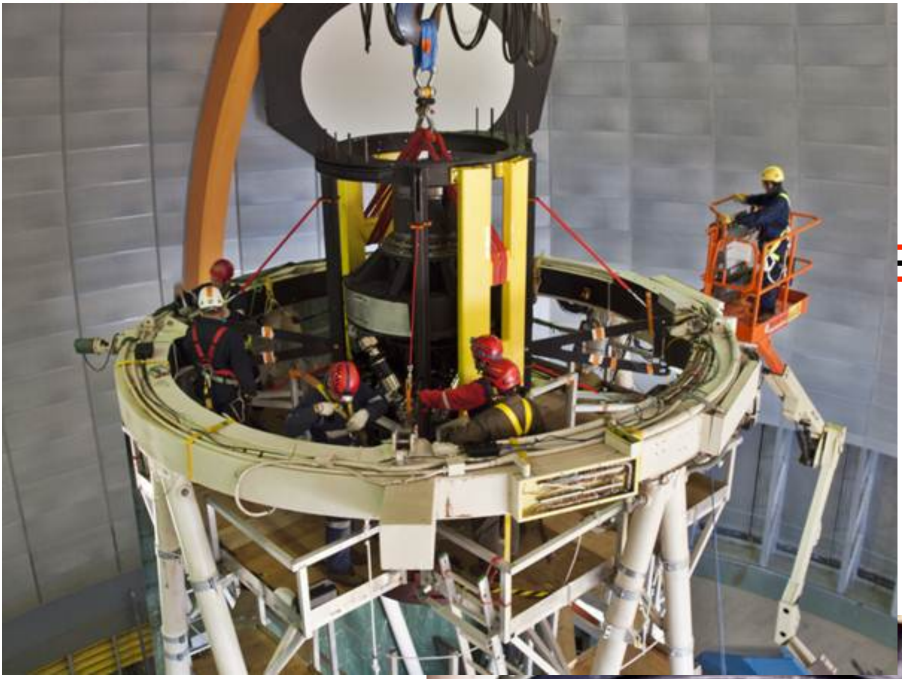


- 525 nights in 5 years
- Will start in late 2012

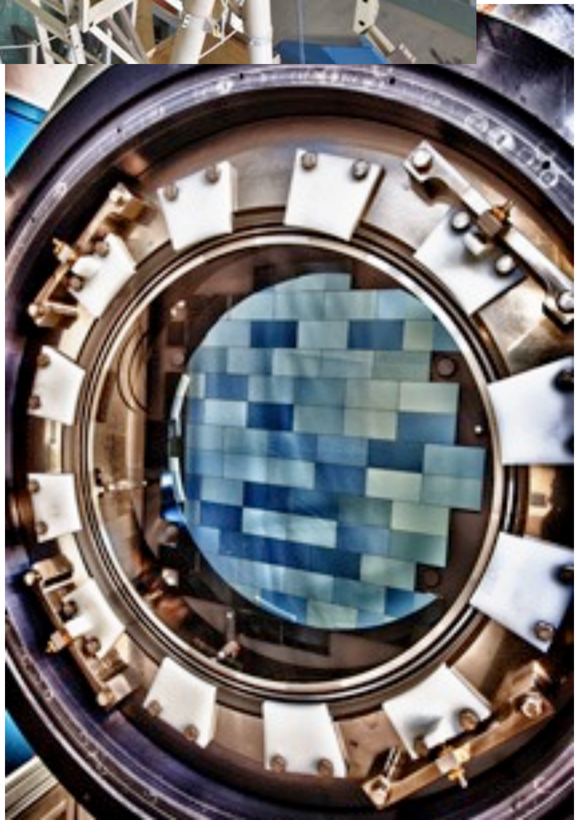


DES Camera Installation

May 2012

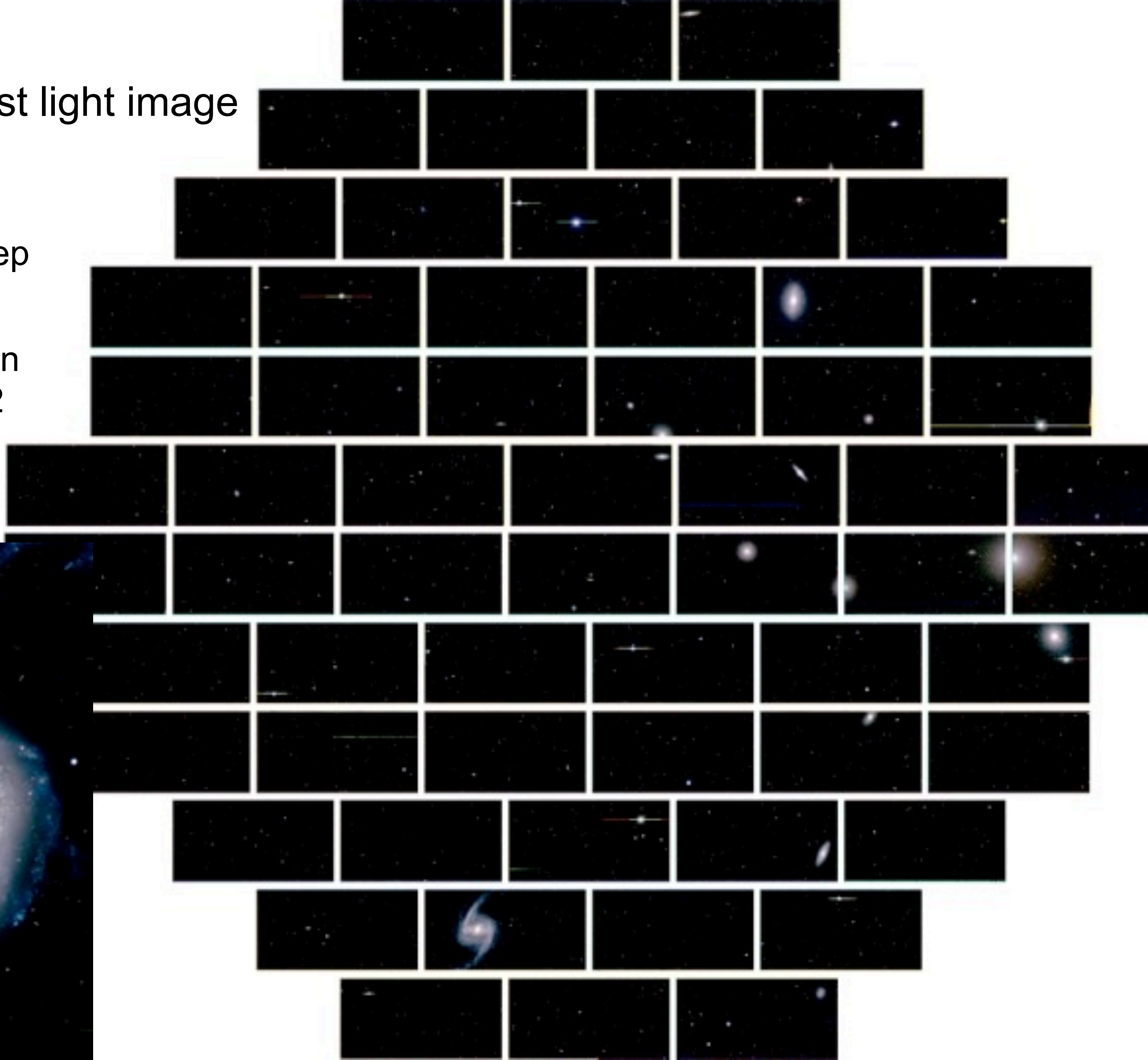


July 2012



DECam First light image

- First light in Sep 12th, 2012
- Survey starts in Dec, 1st 2012



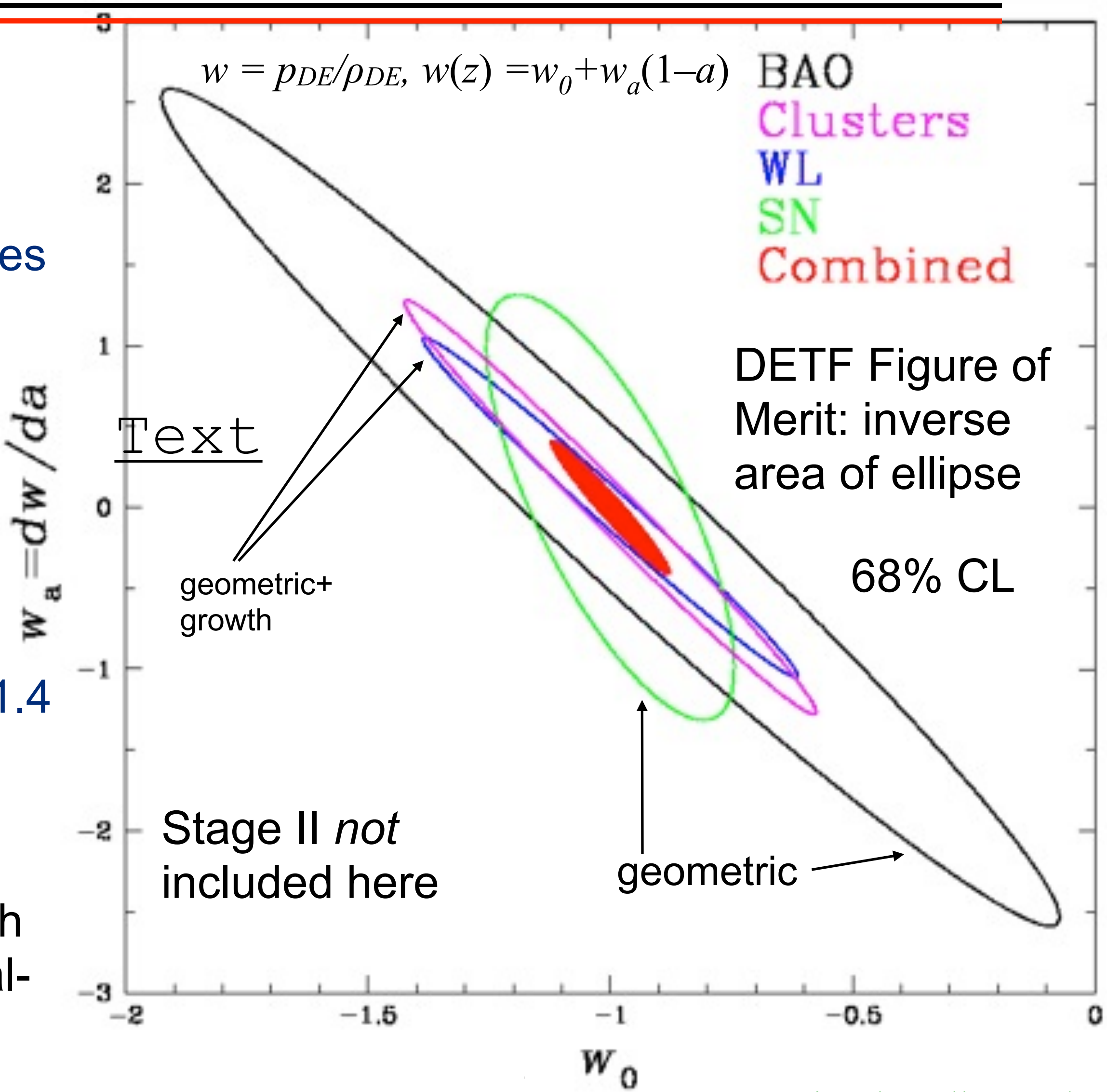
DARK ENERGY SURVEY

DES Science Reach

Four Probes of Dark Energy

- Galaxy cluster counting: N(M,z)
  - Measure redshifts and masses
  - ~10,000 clusters to z=1 with M > 2×10^{14} $M_\odot$
- Weak lensing (shear)
  - ~300 million galaxies with shape measurements
- Galaxy distribution (incl. BAO)
  - ~300 million galaxies to z ~ 1.4
- Supernovae
  - ~4000 type-Ia SNe to z ~ 1

Probes are complementary in both systematic error and cosmological-parameter degeneracies

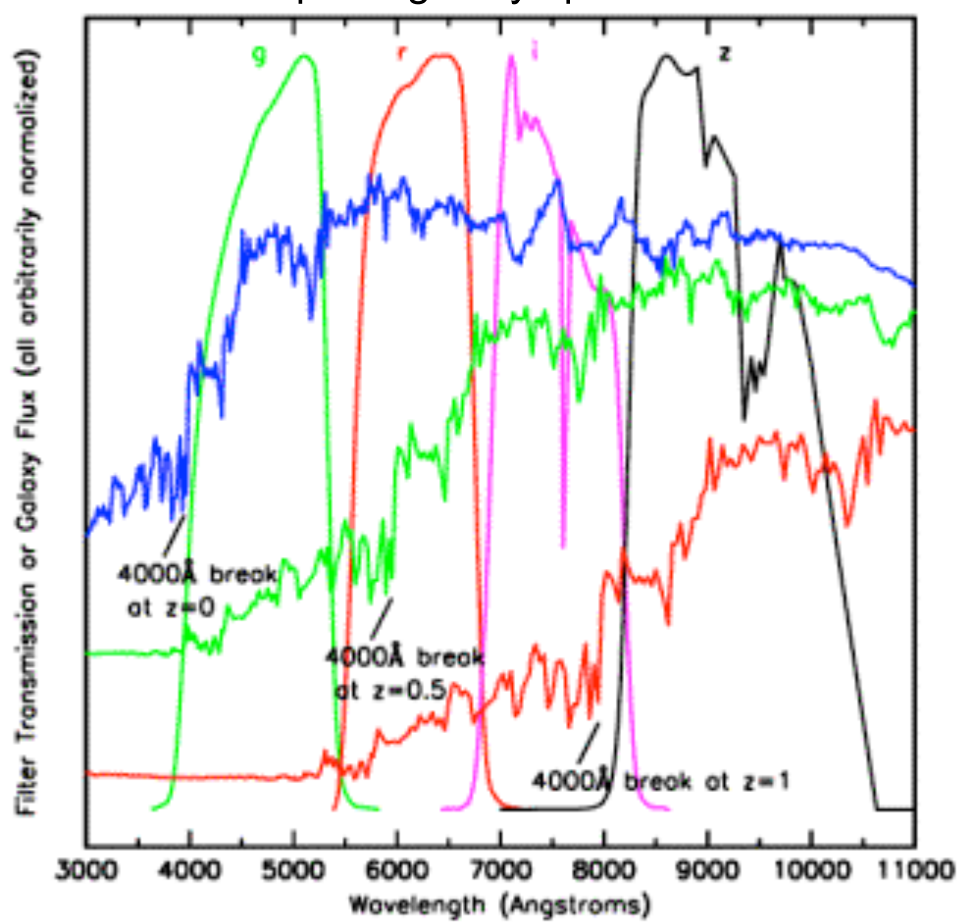


Huterer, Ma, Miquel, Weller, et al.

Photometric Redshifts

- Measure relative flux in multiple filters: track the 4000 A break
- Estimate individual galaxy redshifts with accuracy $\sigma(z) < 0.1$ (~0.02 for clusters)
- Precision is sufficient for 2D Dark Energy probes, provided error distributions well measured.
- Good detector response in *z* band filter needed to reach z>1

Elliptical galaxy spectrum



DES Photo-z Precision

DARK ENERGY SURVEY

DES +VHS

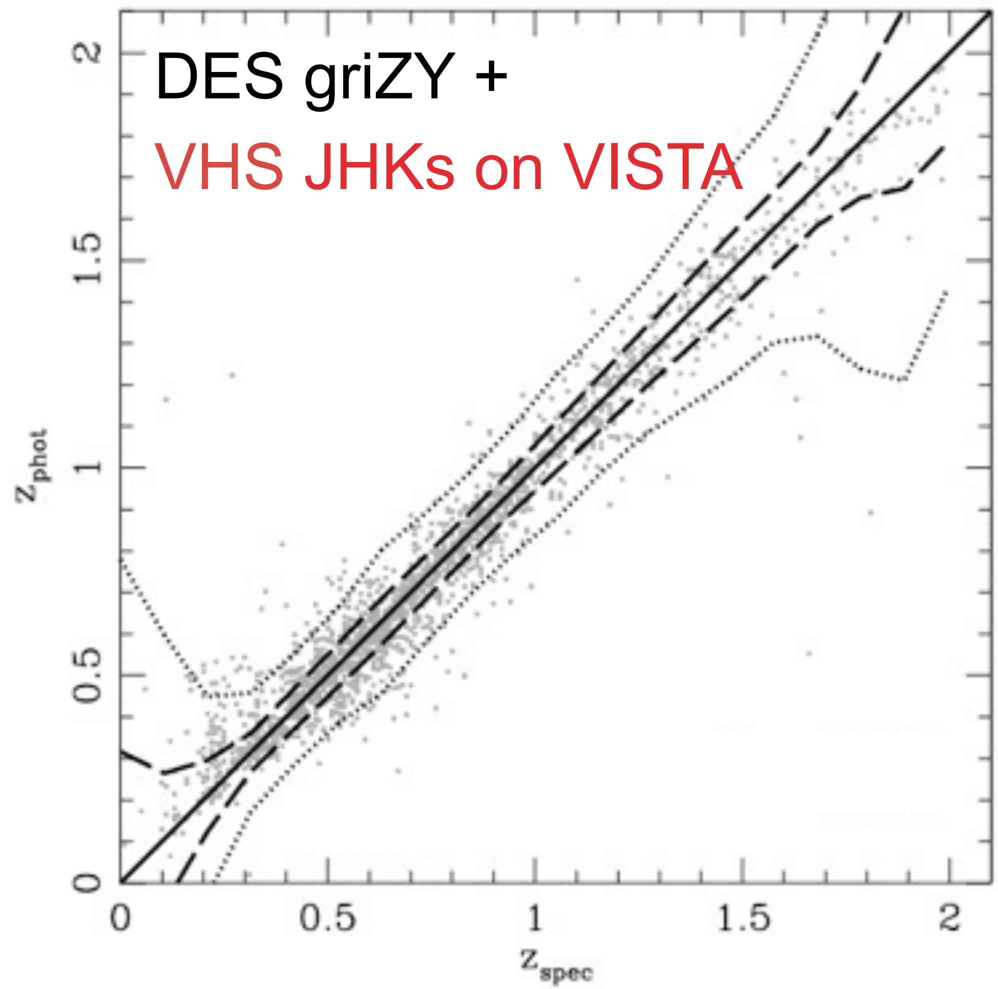
10σ Limiting Magnitudes

g	24.6
r	24.1
i	24.0
Z	23.8
Y	21.6

J	20.3
H	19.4
Ks	18.3

+2% photometric calibration error added in quadrature

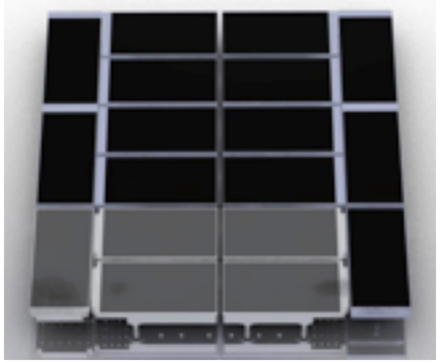
$\sigma(z) \sim 0.05\times(1+z)$

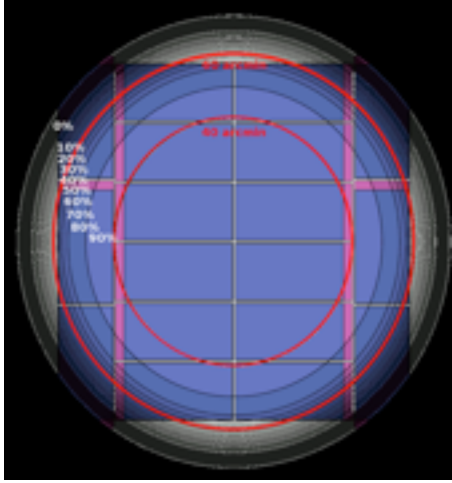


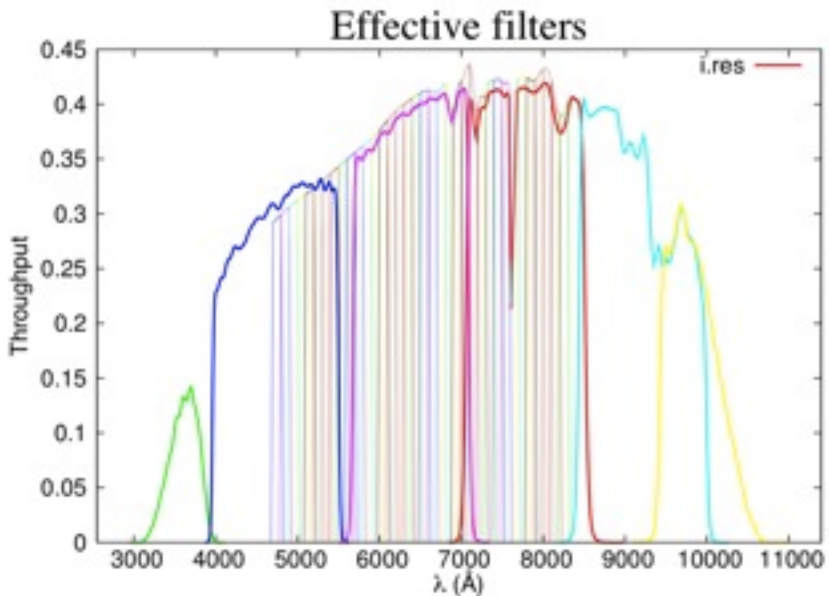
Motivation:

PAU Survey @WHT

18+4 Hamamatsu CCD





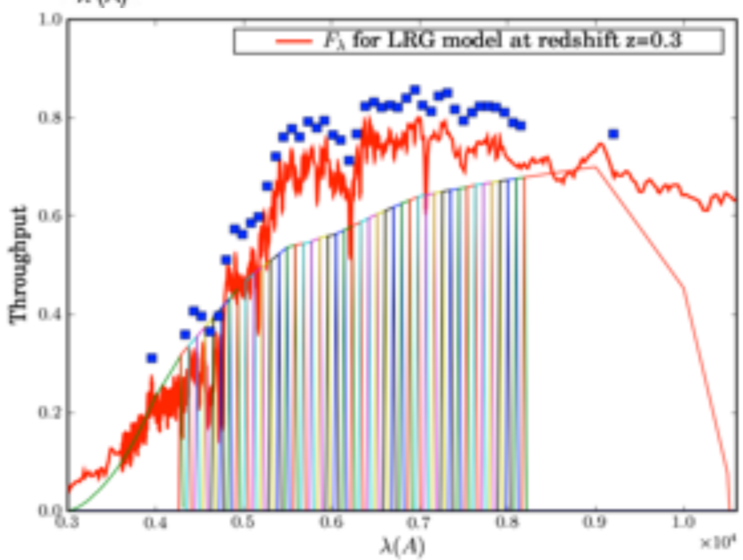


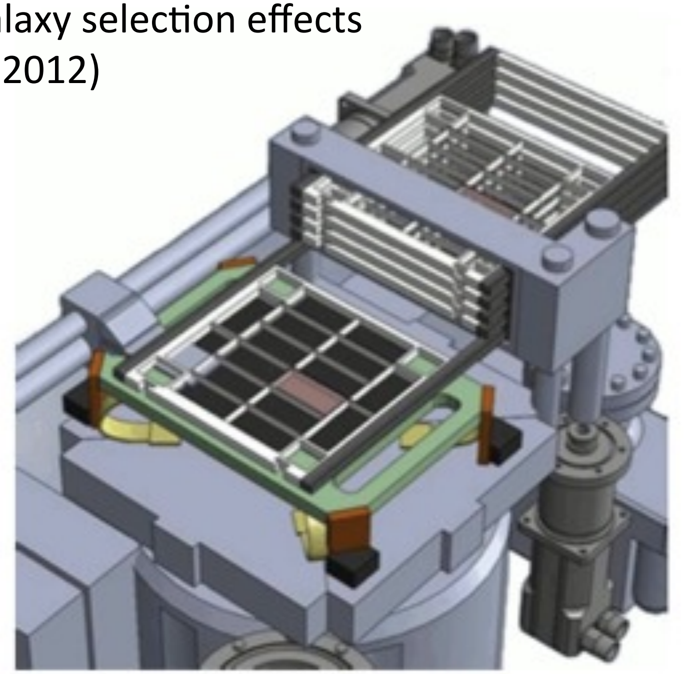
In 1 night can do 2(4) sqr.deg. to i~22.5
in 36 narrow + 6x2 broad (i~24 survey)
To get R=1/100 spectra (900 Km/s)
for 30,000 galaxies (15,000/sd)
And R=1/10 photo-z for 120,000 galaxies
No galaxy selection effects
(end 2012)

Sim
Photometric (i~24)
& Spectroscopic (i~22.5)
Surveys

Photo-z of 0.03/0.003
(10/100Mpc)

For linear P(k)
reconstruction





PAU = Physics of the Accelerating Universe

- ~45 particle physicists (theoreticians and experimentalists), astronomers, astrophysicists, cosmologists…
- Awarded in 2007 a Spanish Consolider-Ingenio 2010 project (€5M over 5 years). PI: Enrique Fernández (IFAE)
- Main goals:
  - Design, build and commission a large FoV CCD camera
  - Perform a galaxy survey with it
  - Understand dark energy from theory point of view
- Telescope not part of Consolider project

Main Deliverable

- Build a large FoV camera, equipped with a large number of narrow-band filters (~40). Use Consolider funds (€5M) for this purpose.

- Place the camera in a suitable telescope. At the time of the proposal:
  - Javalambre telescope (new project)
  - ING (Isaac Newton Group of Telescopes, UK+NL+ES) at La Palma
  - ESO telescopes in Chile

- In the summer of 2009 we started contacts with the WHT telescope (part of the ING). The ING board agreed to host PAU in June of 2010. MoU signed in February 2012.

- PAUCam will be a visiting instrument at the WHT, and will be available to the community when not used by PAU.

PAU@WHT

Among other things the MoU establishes that:

- PAUCam will be a visitor instrument **also available for public use**.
- We will station a support astronomer at La Palma integrated with the WHT personnel.
- We will also provide a public data-reduction pipeline.

PAU@WHT Personnel

Senior Scientists
Post-docs
PhD Students
Engineers
Technicians

CIEMAT

E. Sánchez, F. J. Rodríguez, I. Sevilla, R. Ponce, F. J. Sánchez
J. Castilla, J. de Vicente

ICE/IEEC

F. J. Castander, E. Gaztañaga, P. Fosalba, A. Bauer, C. Bonnet, M. Crocce, S. Farrens, S. Jouvel,
J. Asorey, M. Eriksen, K. Hoffman, A. Izard, C. López, A. Pujol
R. Casas, F. Madrid, S. Serrano

IFAE

E. Fernández, R. Miquel, A. Pacheco, C. Padilla, S. Heinis (from September), P. Martí,
C. Sánchez
O. Ballester, L. Cardiel, F. Grañena, C. Hernández, J. Jiménez, L. López, M. Maiorino, C. Pío,
C. Arteche, J. Gaweda

PIC

M. Delfino
V. Acín, J. Carretero, M. Caubet, J. Flix, C. Neissner, E. Planas, P. Tallada, N. Tonello

UAM

J. García-Bellido, S. Nesseris, D. Sapone, D. Alonso, A. Bueno

PAU@WHT Personnel

PI : E. Fernández (UAB/IFAE)
Co-Is: E. Sánchez (CIEMAT), E. Gaztañaga(IEEC/CSIC), R. Miquel (IFAE/ICREA), J. García-Bellido (IFT/UAM), M. Delfino (PIC)

PAU Camera PI: F. Castander
Project Manager: C. Padilla. **Systems Engineer**: L. Cardiel
DAQ: J. de Vicente. **Mechanics**: F. Grañena. **Control**: O. Ballester. **Optics and integration**: R. Casas, J. Jiménez

PAUDM & Science PI: E. Gaztañaga
Simulations: F. Castander. **Operations**: N. Tonello. **Data Reduction**: S. Serrano. **QA & Validation**: I. Sevilla

The Survey Team

D. Alonso[4], J. Asorey[2], O. Ballester[3], A. Bauer[2], C. Bonnett[2], A. Bueno[4], J. Campa[1], L. Cardiel[3], J. Carretero[2], R. Casas[2], F. Castander[2], J. Castilla[1], M. Crocce[2], M. Delfino[5], J.F. de Vicente[1], M. Eriksen[2], S. Farrens[2], E. Fernández[3], P. Fosalba[2], J. García-Bellido[4], E. Gaztañaga[2], F. Grañena[3], A. Izard[2], J. Jiménez[2], C. López[2], L. C. López[3], F. Madrid[2], M. Maiorino[3], P. Martí[3], G. Martínez[1], R. Miquel[3], C. Neissner[5], L. Ostman[3], A. Pacheco[5], C. Padilla[3], C. Pio[3], A. Pujol[2], J. Rubio[4], E. Sánchez[1], D. Sapone[4], S. Serrano[2], I. Sevilla[1], P. Tallada[5], N. Tonello[5].

1 Ciemat — Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

2 IEEC — CSIC — Institut de Ciències de l'Espai CSIC — ICE

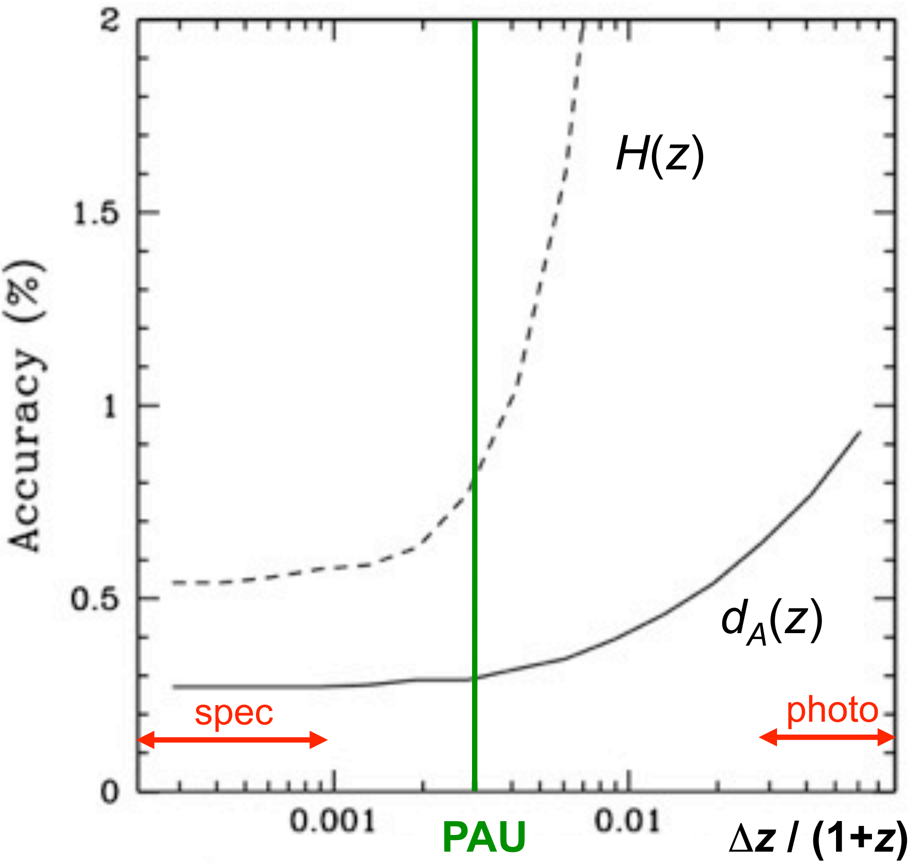
3 IFAE — Institut de Física d'Altes Energies — UAB Universitat Autònoma de Barcelona

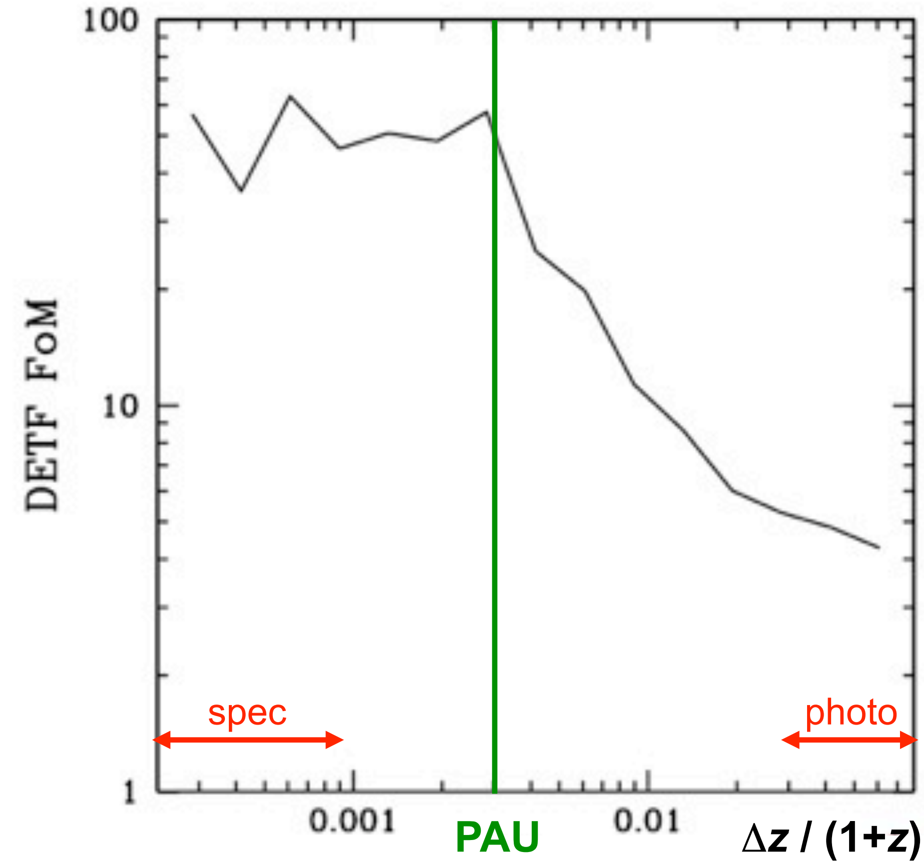
4 ift — Instituto de Física Teórica UAM/CSIC

5 PIC port d'informació científica

Requirements on Redshift Precision (BAO)

- σ(z) ~ 0.003×(1+z) ~ 12.5 Mpc/h at z=0.5





N. Padmanabhan

$$\frac{\Delta P(k)}{P(k)} \propto \frac{1}{\sqrt{V}}\left(1+\frac{1}{nP(k)}\right)$$

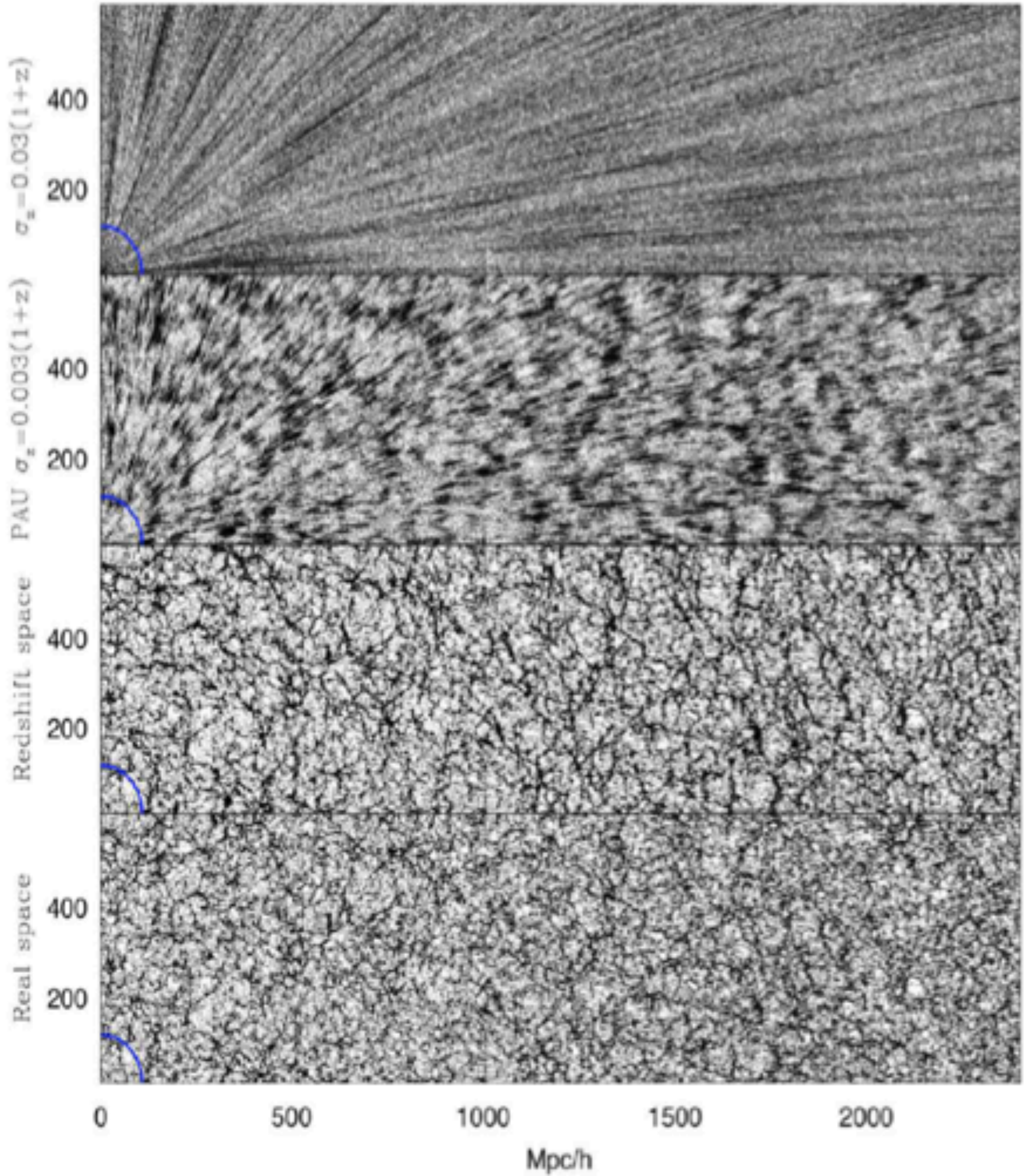
The Importance of Redshift Resolution

z-space, Δz = *0.03(1+z)*
+ peculiar velocities
(DES)

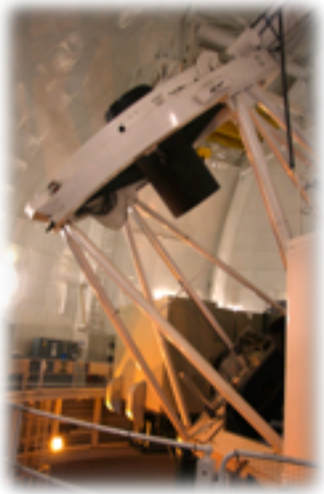
z-space, Δz = *0.003(1+z)*
+ peculiar velocities
(PAU)

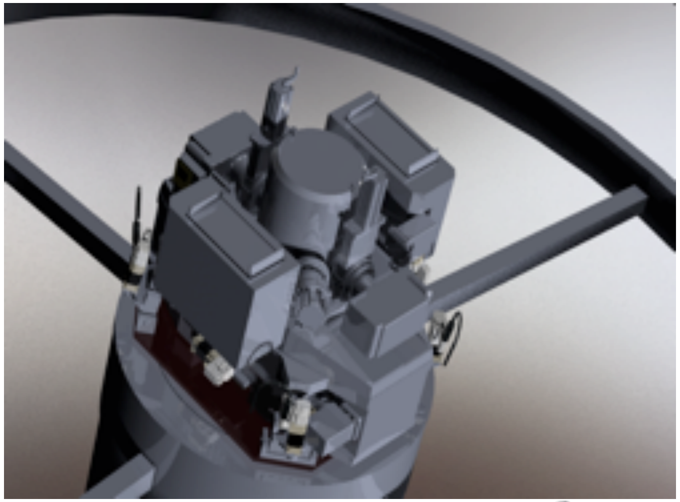
z-space, perfect resolution
+ peculiar velocities

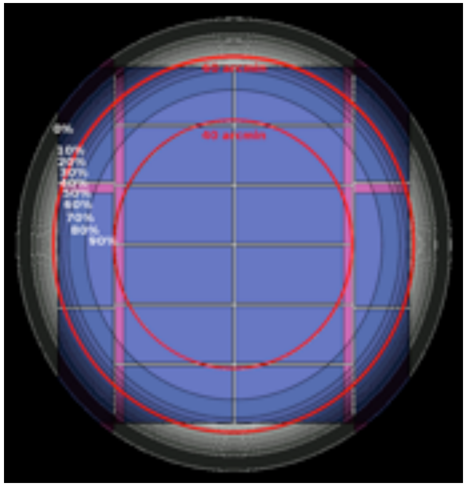
Real space

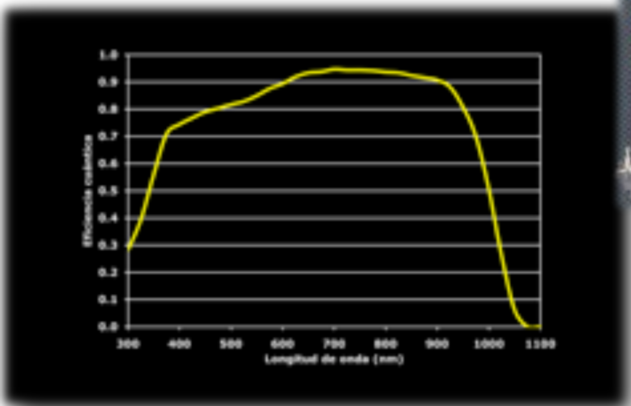


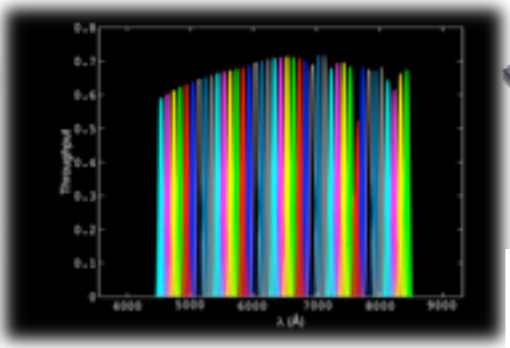
The PAU Camera at WHT in Pictures

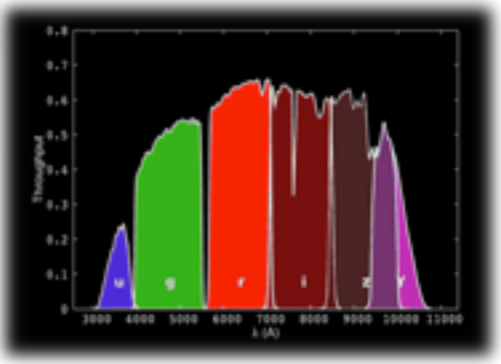


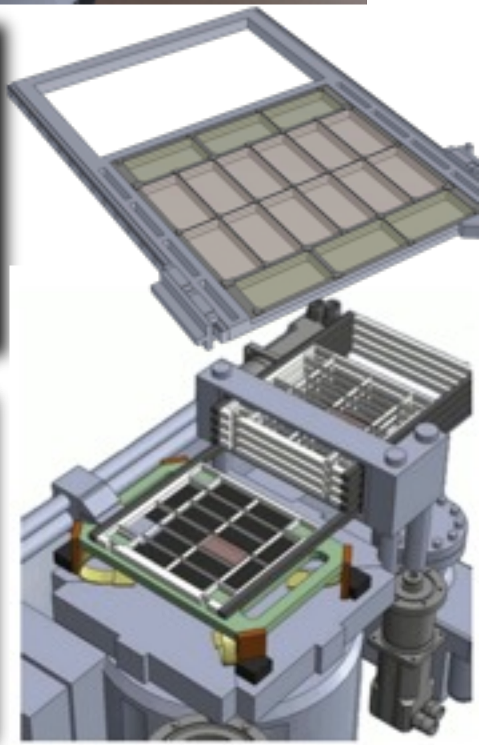






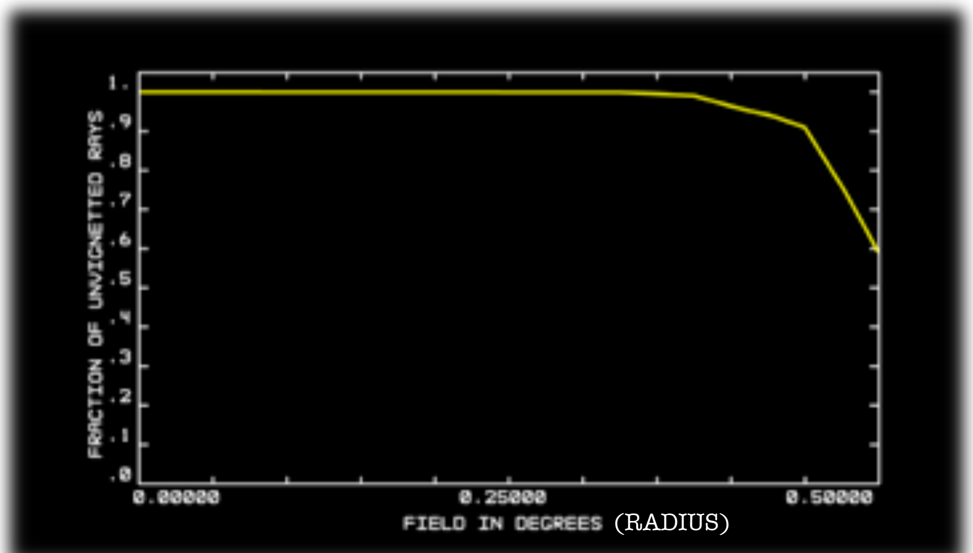


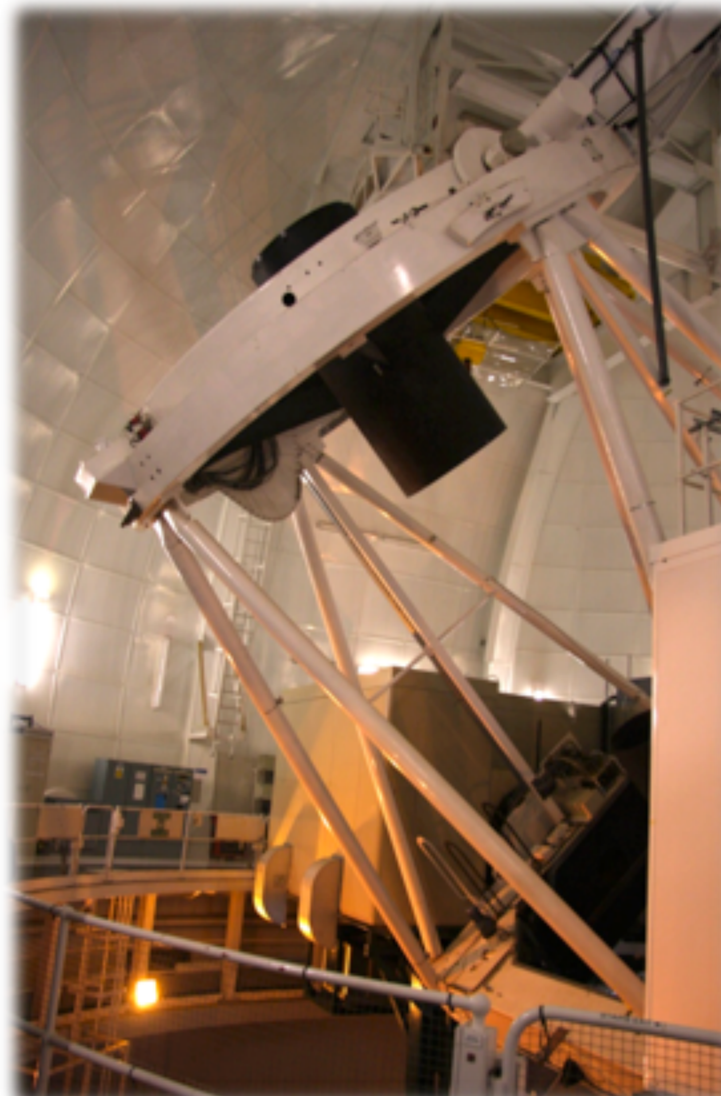




William Herschel Telescope (WHT)

- Located in the ORM, La Palma
- Used by UK, Netherlands & Spain
- Highly oversubscribed
- High scientific output so far
- Diameter: 4.2 m
- Prime focus: 11.73 m
- Focal ratio: f/2.8
- FoV: 1 deg ∅, 40’ unvignetted
- Scale: 17.58’’/mm ⇔ 0.26”/pixel

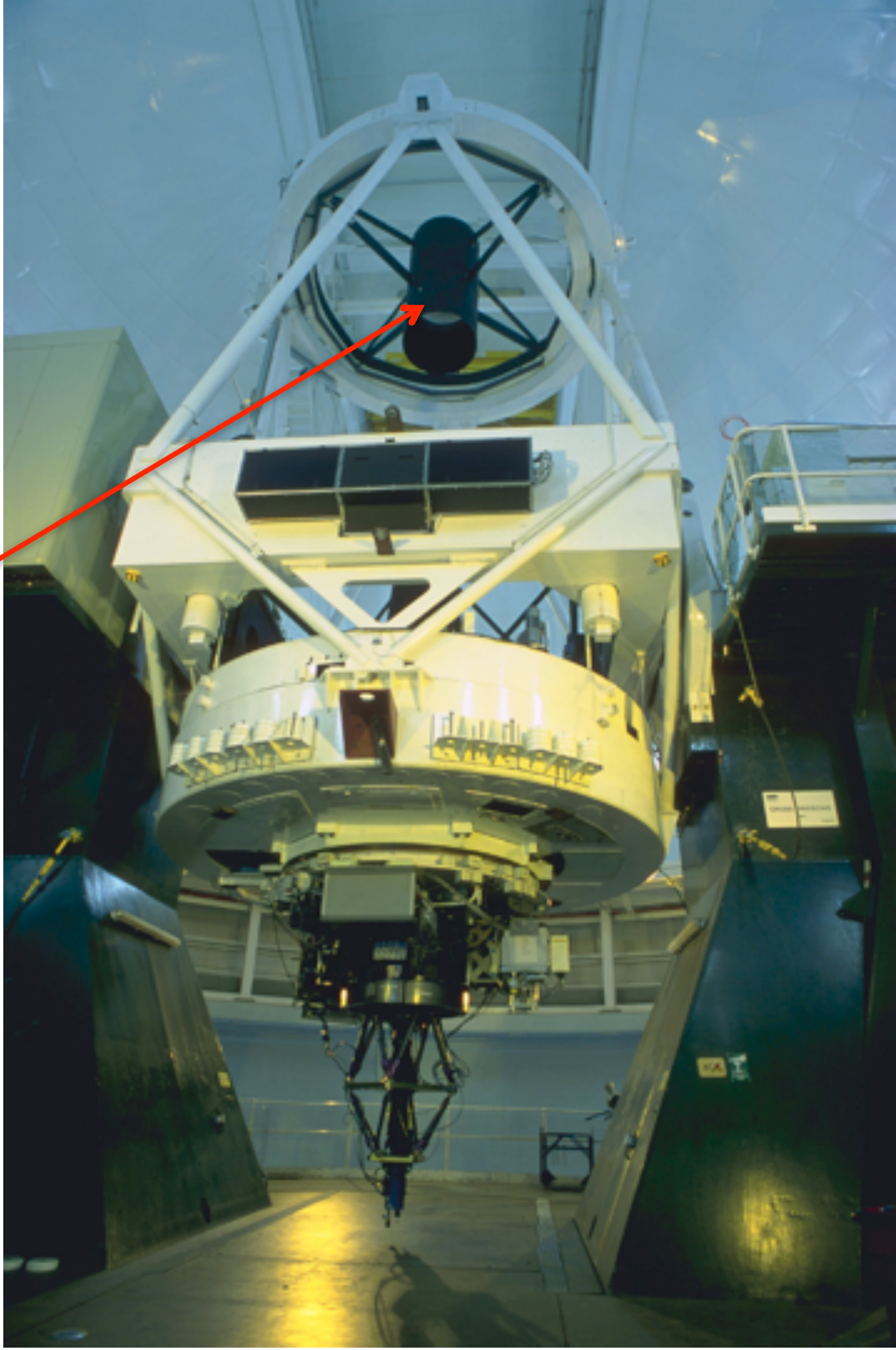




PAUCam

PAUCam will be mounted at the prime focus of the WHT:

Strong limitation in weight: max. 235 kg



PAUCam

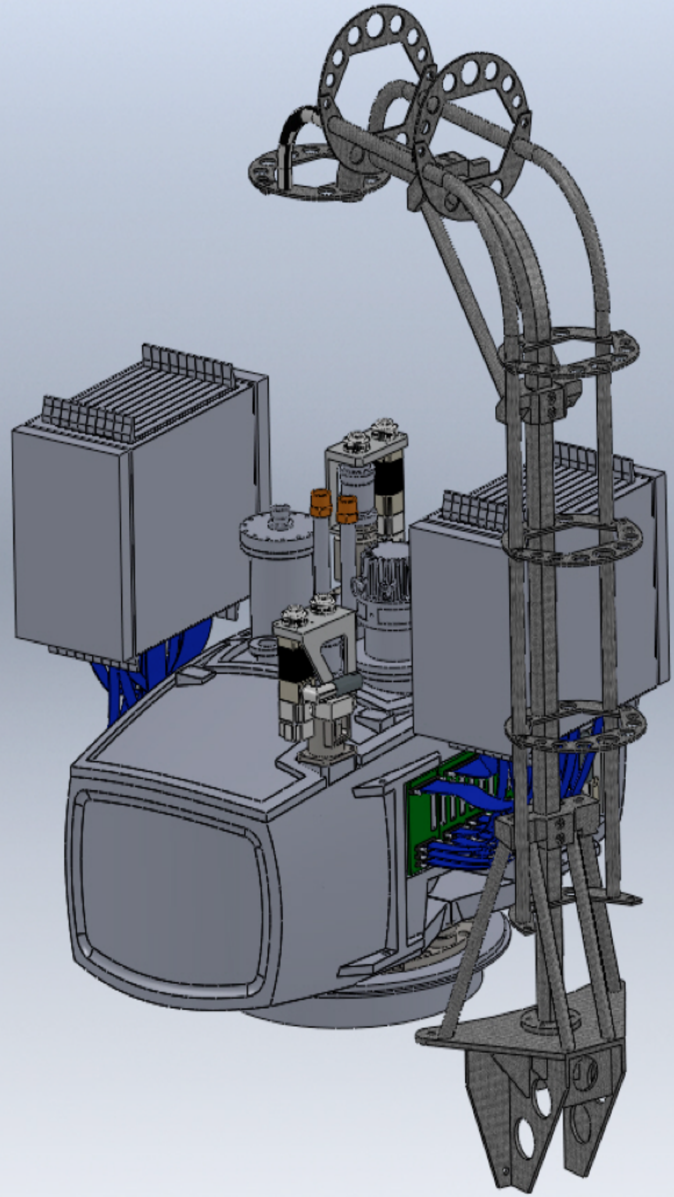
We appointed an External Review Panel for the design of the camera (193 pp. document), which convened in December 2010.

Members: D. Baade, O. Boulade, M. Riva, O. Iwert, R. Sharples, F. Zerbi.
Also attended: M. Balcells (ING Director) and D. Cano (WHT chief engineer).

From the report:

> The Board wishes to compliment the PAUCam team for the great amount of work done in the definition and preliminary study of the instrument, as well as in the assembly of a complete and comprehensive document such as the one the Board examined.
>
> The Board wishes to underline the very well shaped and focussed Science Case for PAUCam presented in the document under scrutiny. The science objectives are indeed well defined and worthwhile. The Board is convinced that the Team has deep and active expertise at the engineering level for most of the areas related with this specific instrument design and construction.

PAUCam

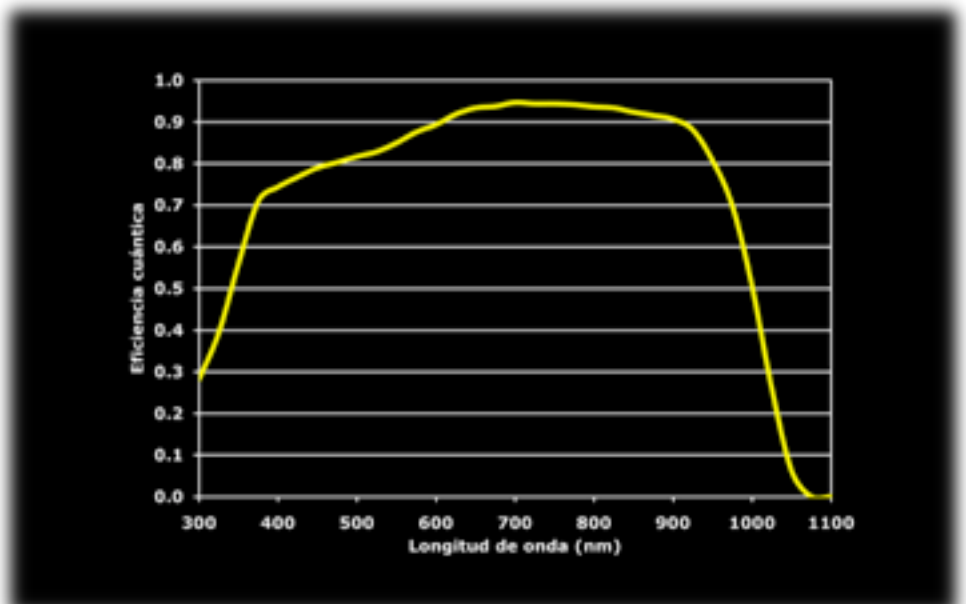


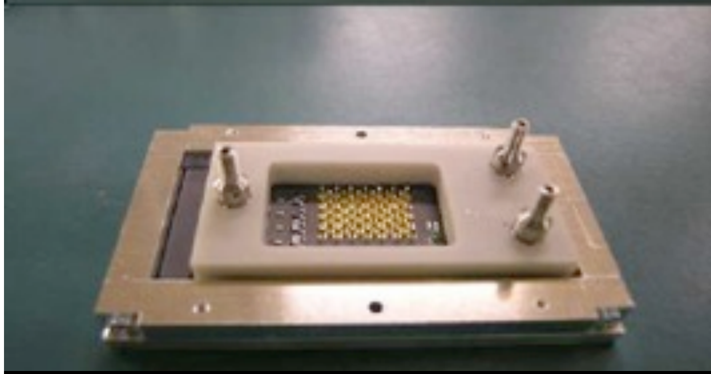
Body of camera made of carbon fiber, shaped to minimize wall thickness

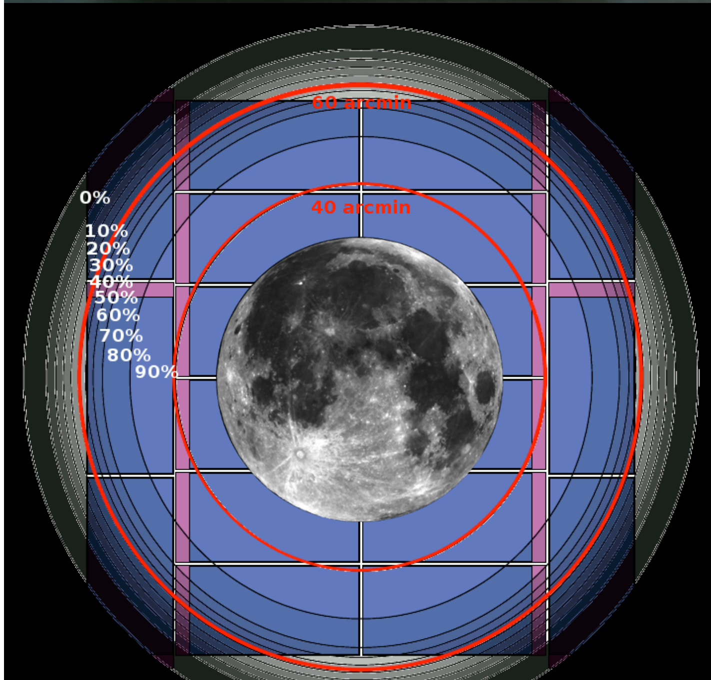
PAUCam Detectors

Hamamatsu new CCDs:

- 18 4k x 2k 15 µm pixels
- Excellent sensitivity across the entire wavelength range from 0.3 to over 1 µm.
- 20 delivered, being characterized at CIEMAT and IFAE



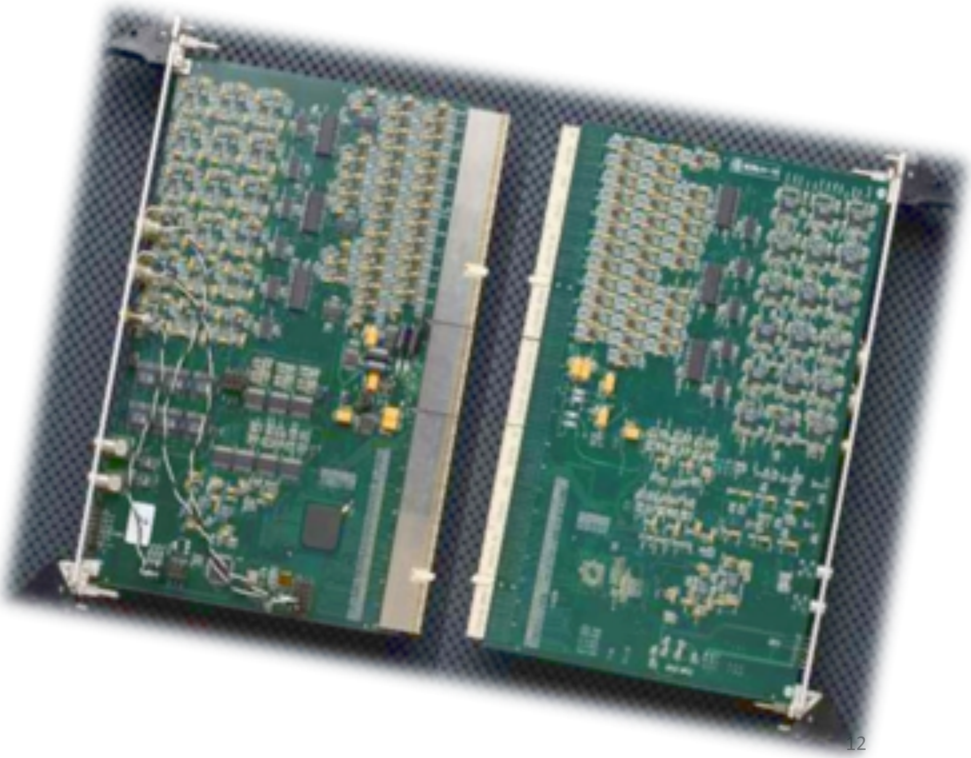




PAUCam Electronics

Monsoon architecture (NOAO)

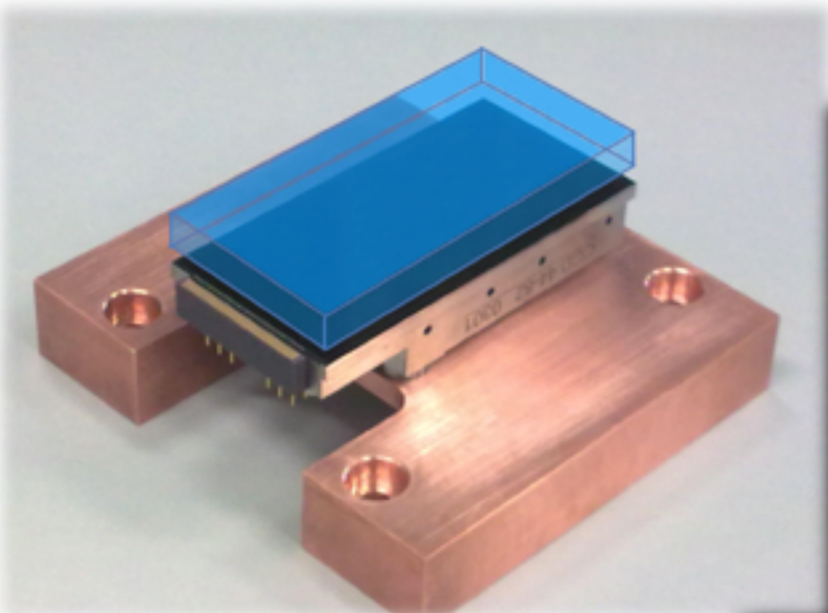
- Same as used for DES (CIEMAT and IFAE)
- 3 clock and bias board
- 7 acquisition boards
- 3 master control boards
- 18 pre-amp & routing boards

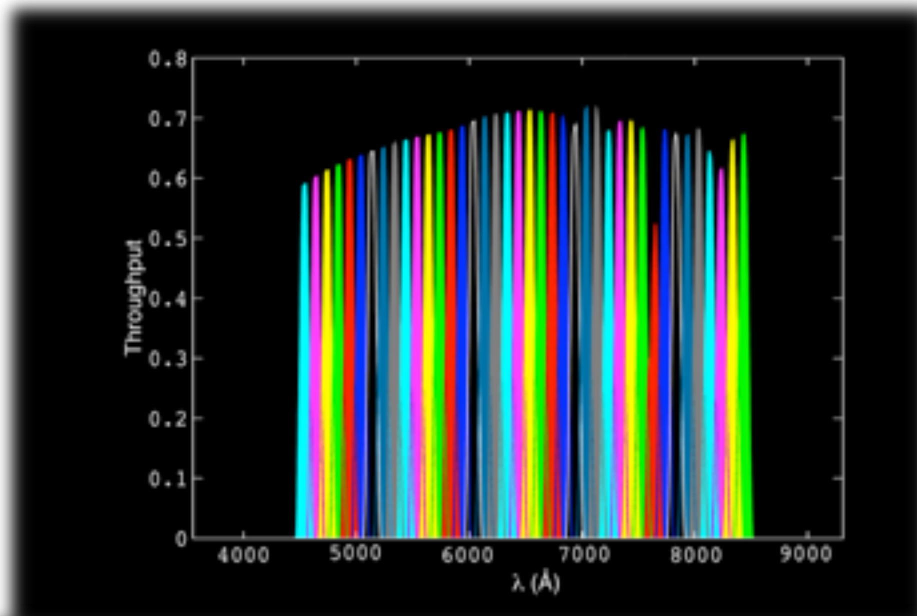


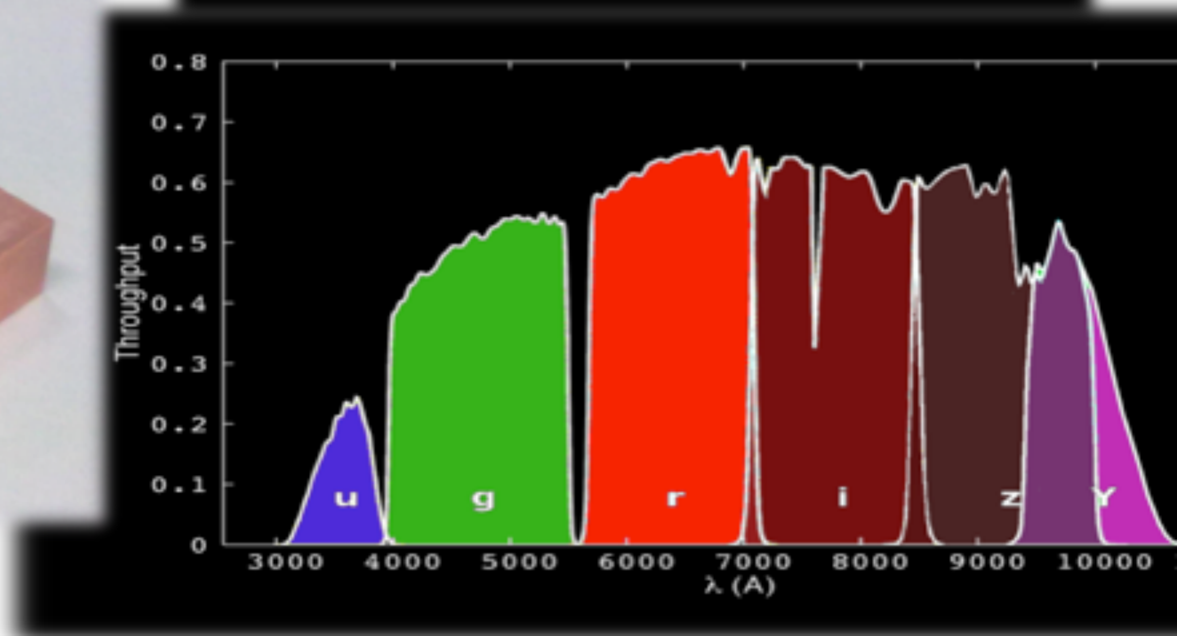
PAUCam Filter System

- 42 narrow-band filters
- FWHM = 100 Å
- Spectral range: λ=4300-8600 Å
- Rectangular transmission profile

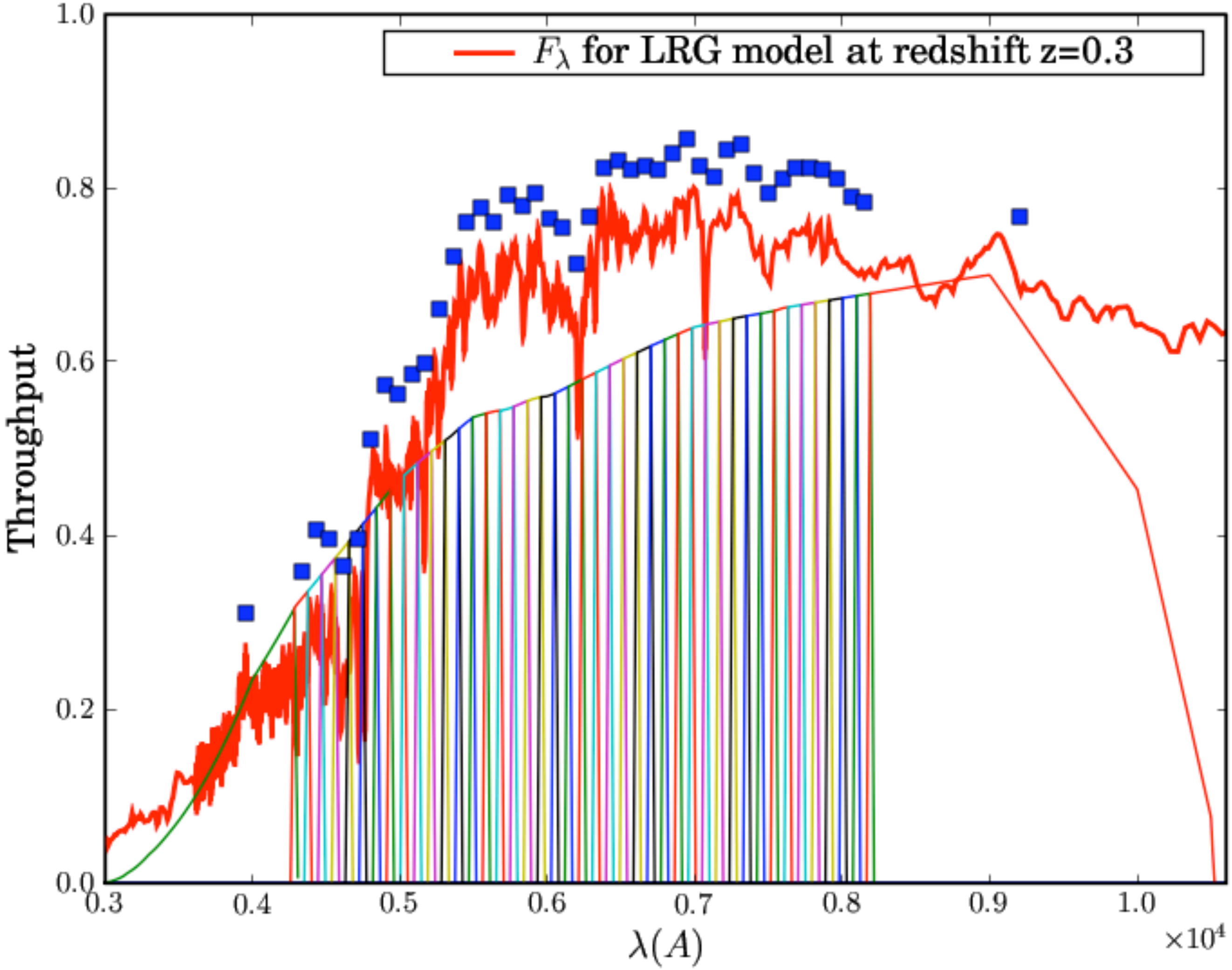
- 6 broad-band filters
- ugriZY (SDSS & DES)





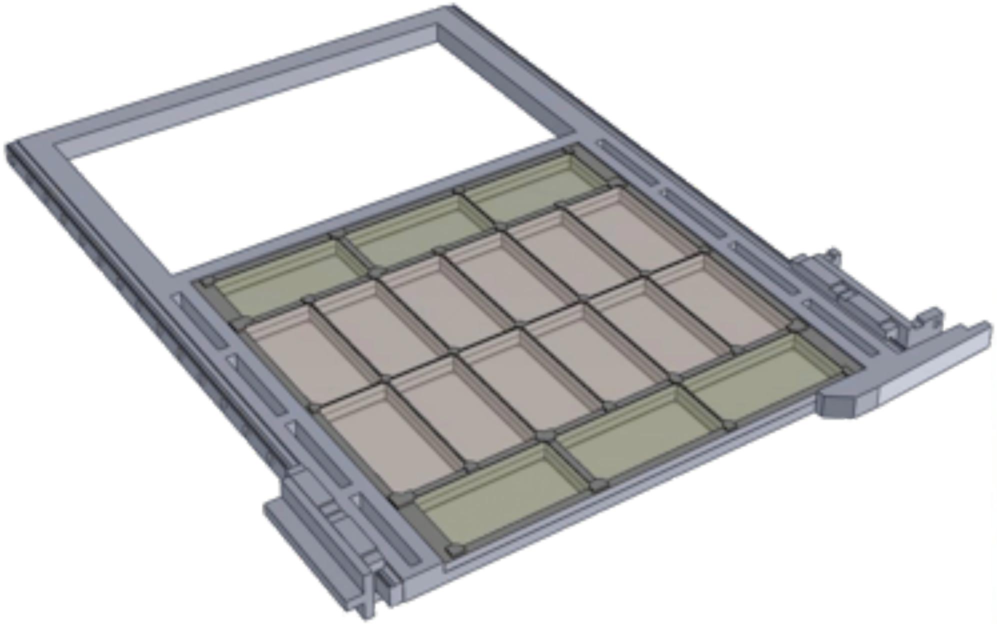


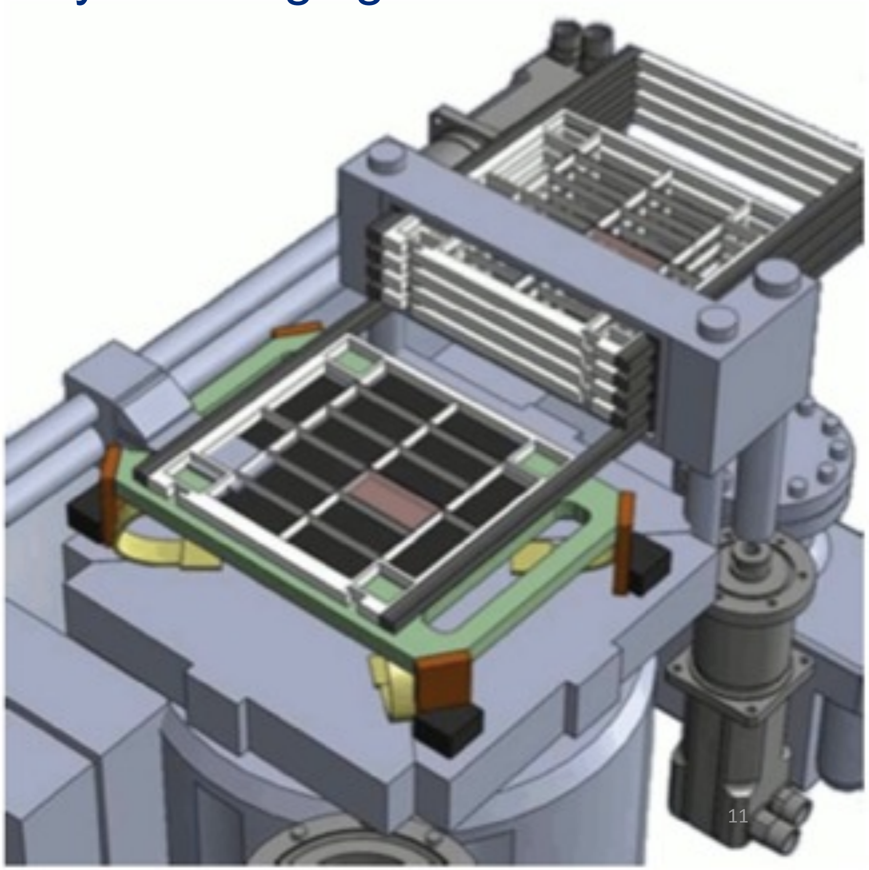
PAUCam Filter System



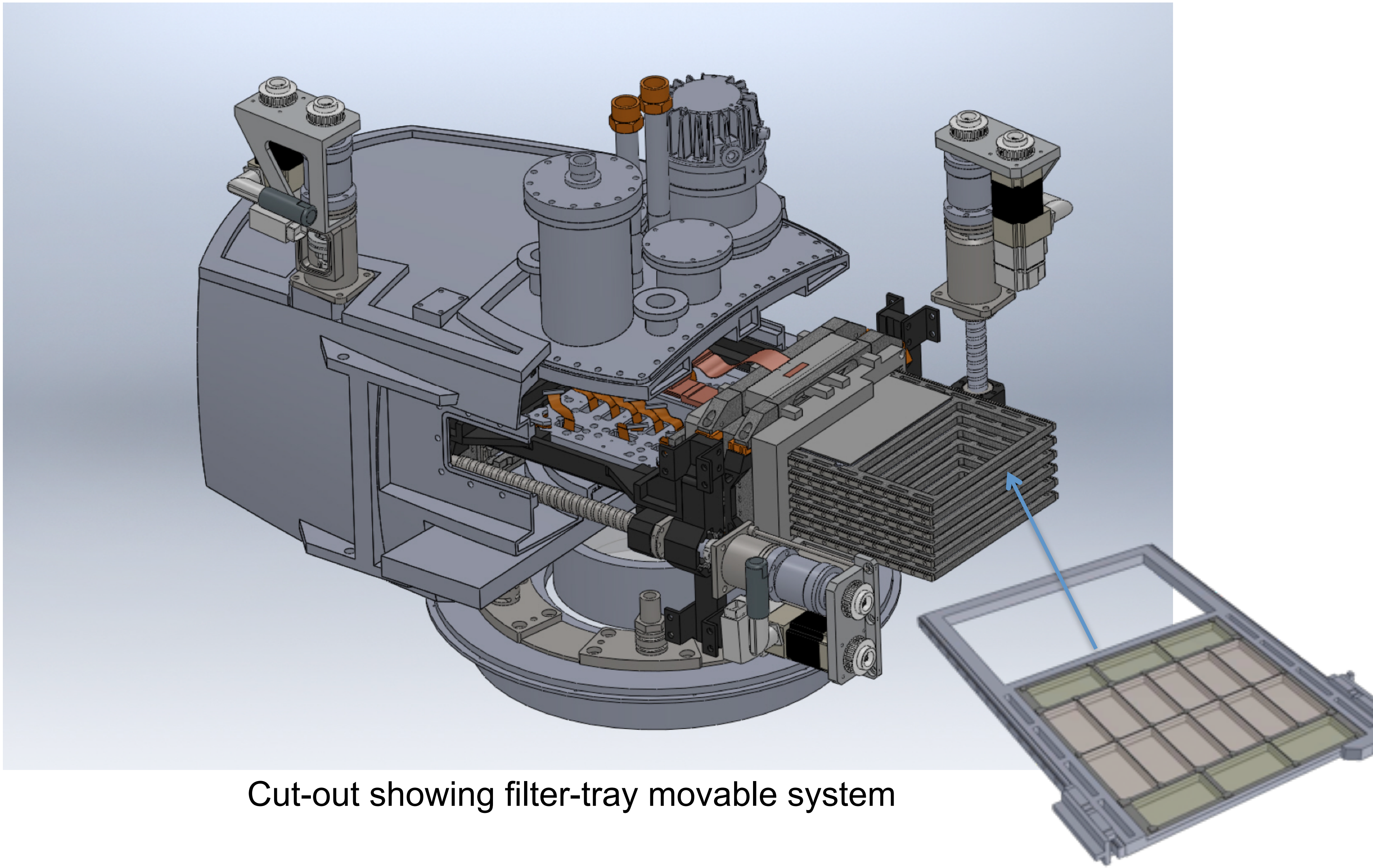
PAUCam Filter Trays

- Efficiency: filters need to be very close to sensors to avoid vignetting
- More filters than CCDs ➜ movable trays
- Jukebox-like system
- Movements in vacuum are technologically challenging



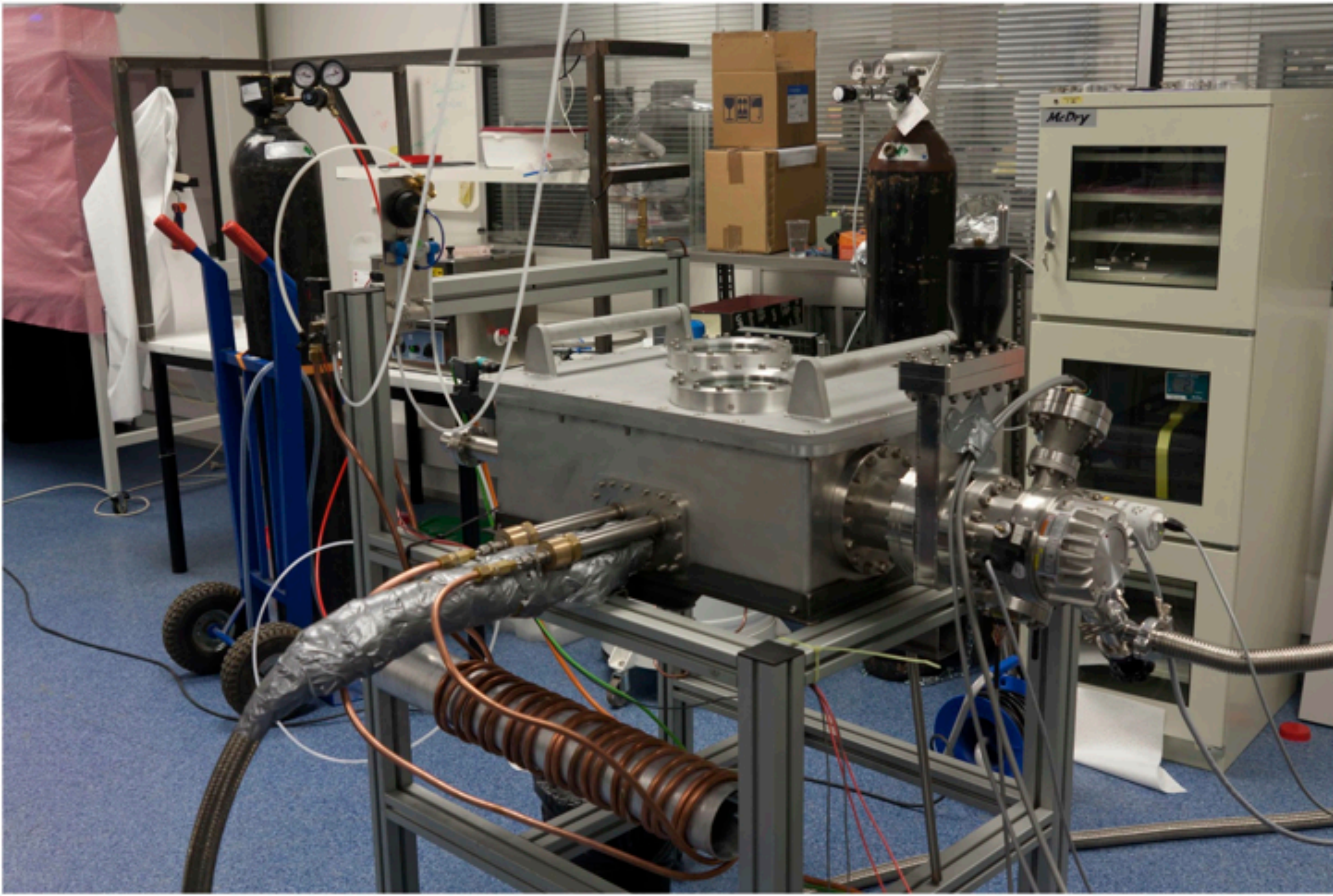


PAUCam Filter Trays

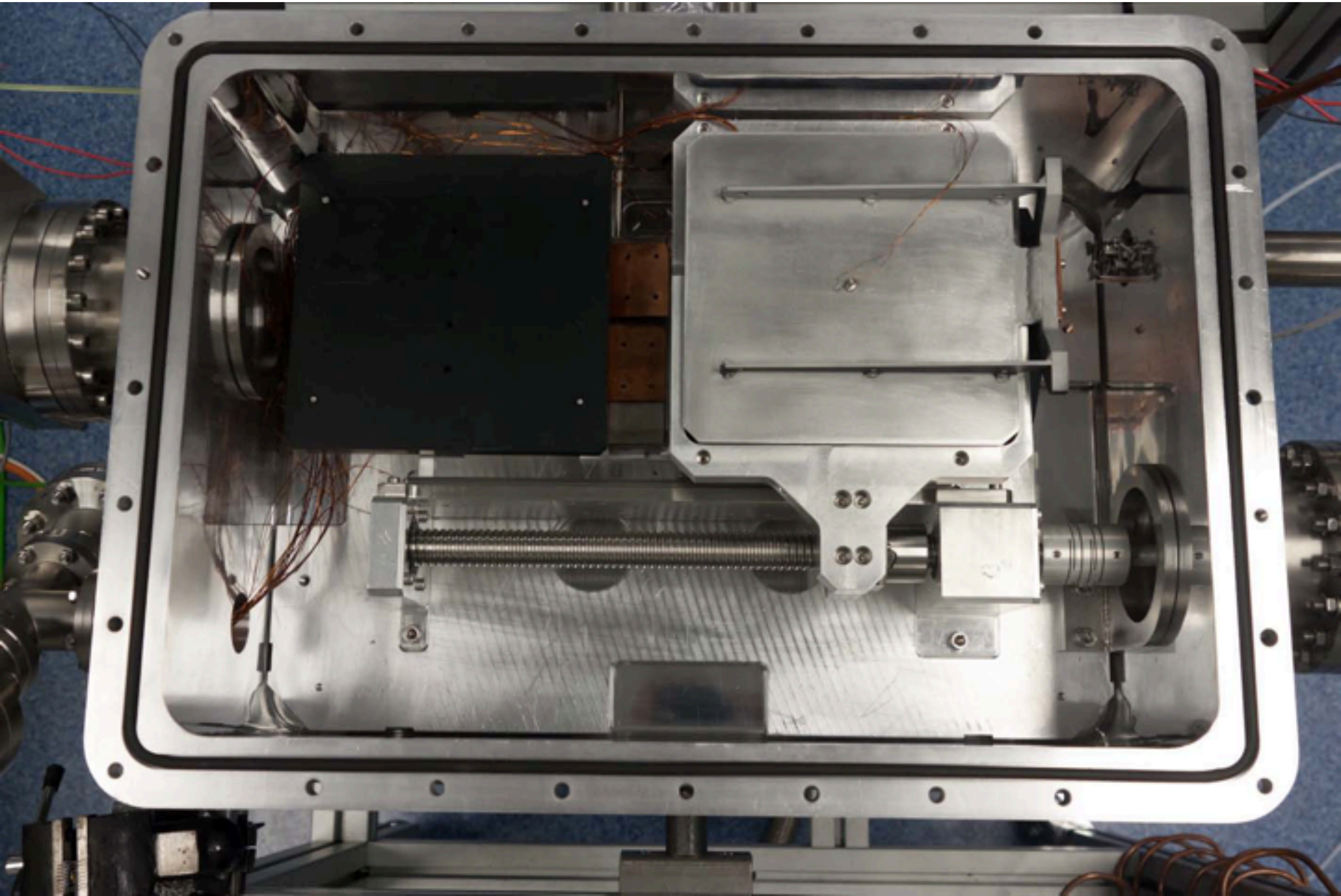


Cut-out showing filter-tray movable system

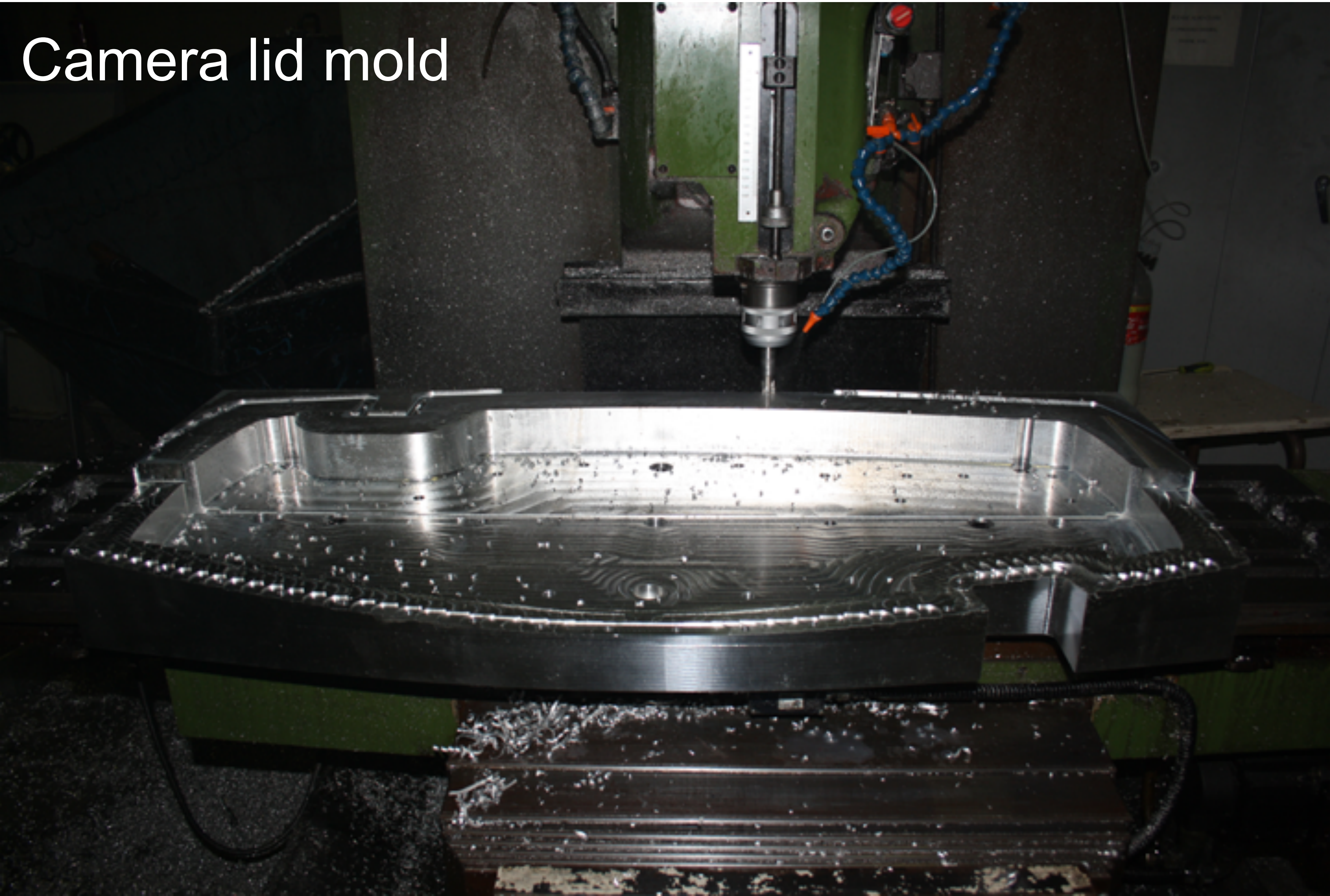
First protoype (summer 2011)



First protoype (summer 2011)



In-house fabrication of camera mold in Al

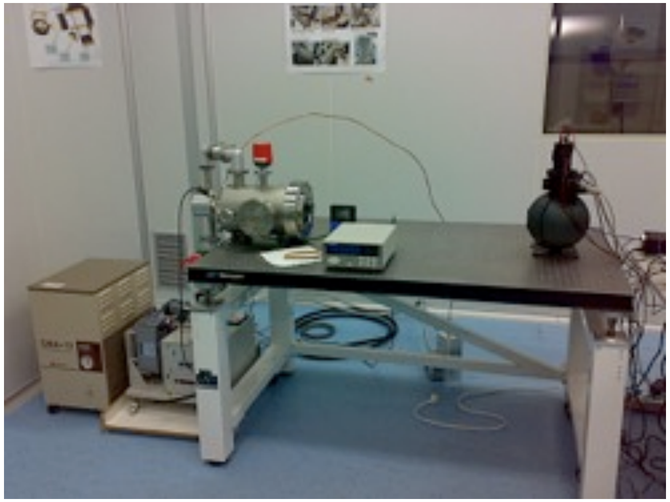


Mold pieces

PAU Camera Construction

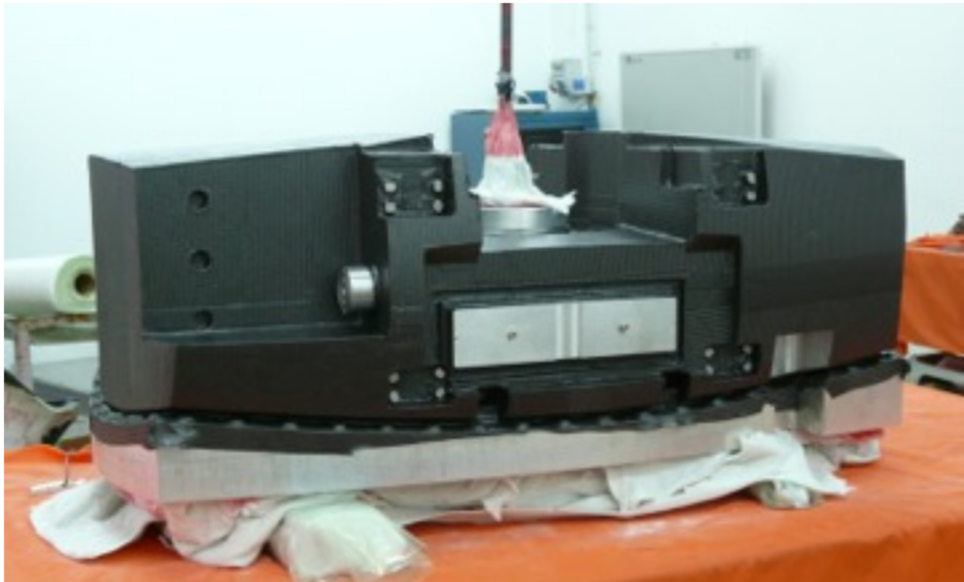
Cryogenics and vacuum tests on prototype

CCD test station



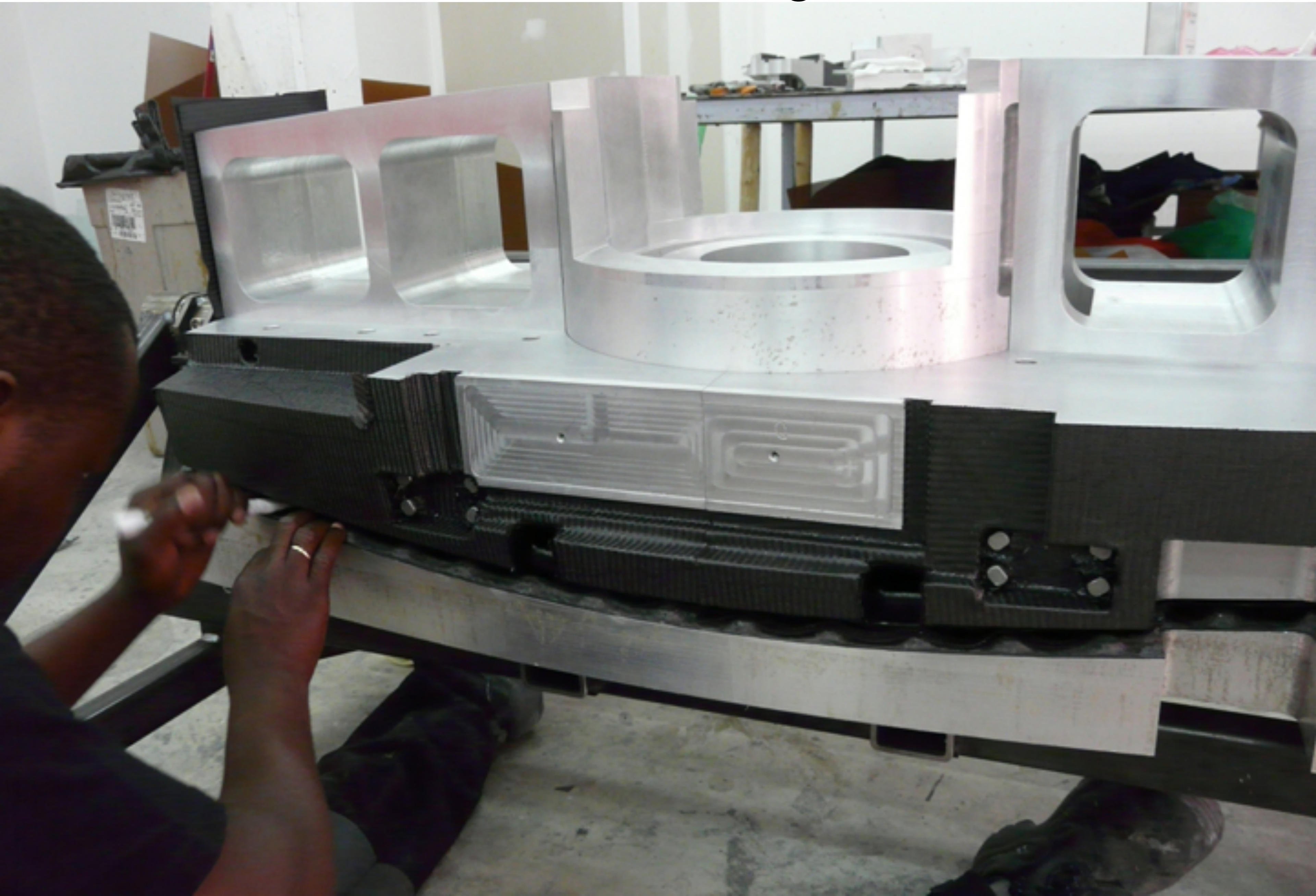
Aluminum mold of camera body

Camera body in carbon fiber



Complete mold

Mold covering



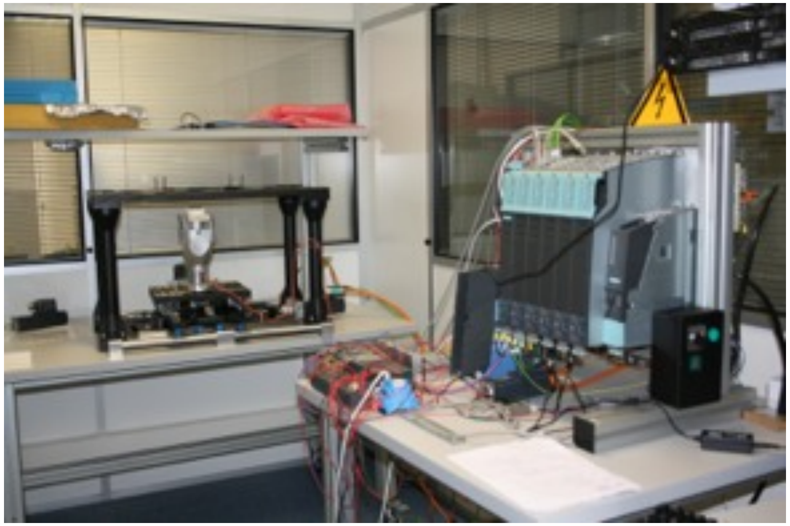
Camera body in carbon fiber

PAU Camera Construction

Many other elements of the camera are either ready or being fabricated. Examples:

- Optics (entrance window): INAOE
- Shutter: design ready, contract will go out soon.
- Cryotigers: one received one order, first tests show excellent behavior.
- Assembly done in house. New clean room (a crucial infrastructure) is ready.

Lab Infrastructure for DES/PAU



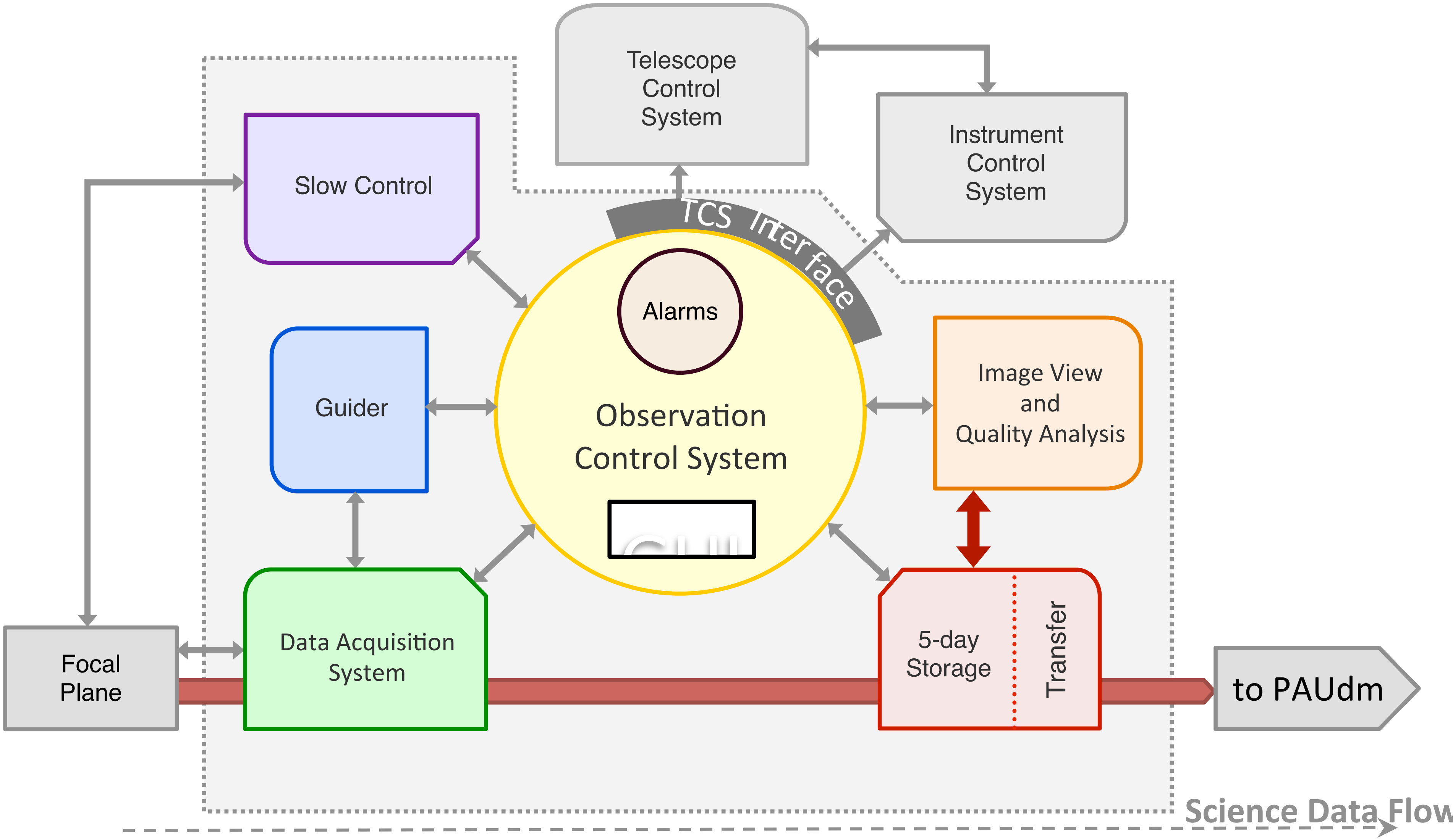
3D metrology bench

CCD test station

Clean room class 10K, 1K, 100

Fully computerized machining tool (lathe)

PAUCam Control System



One computer already installed at the WHT. Tests of interface are already taking place.

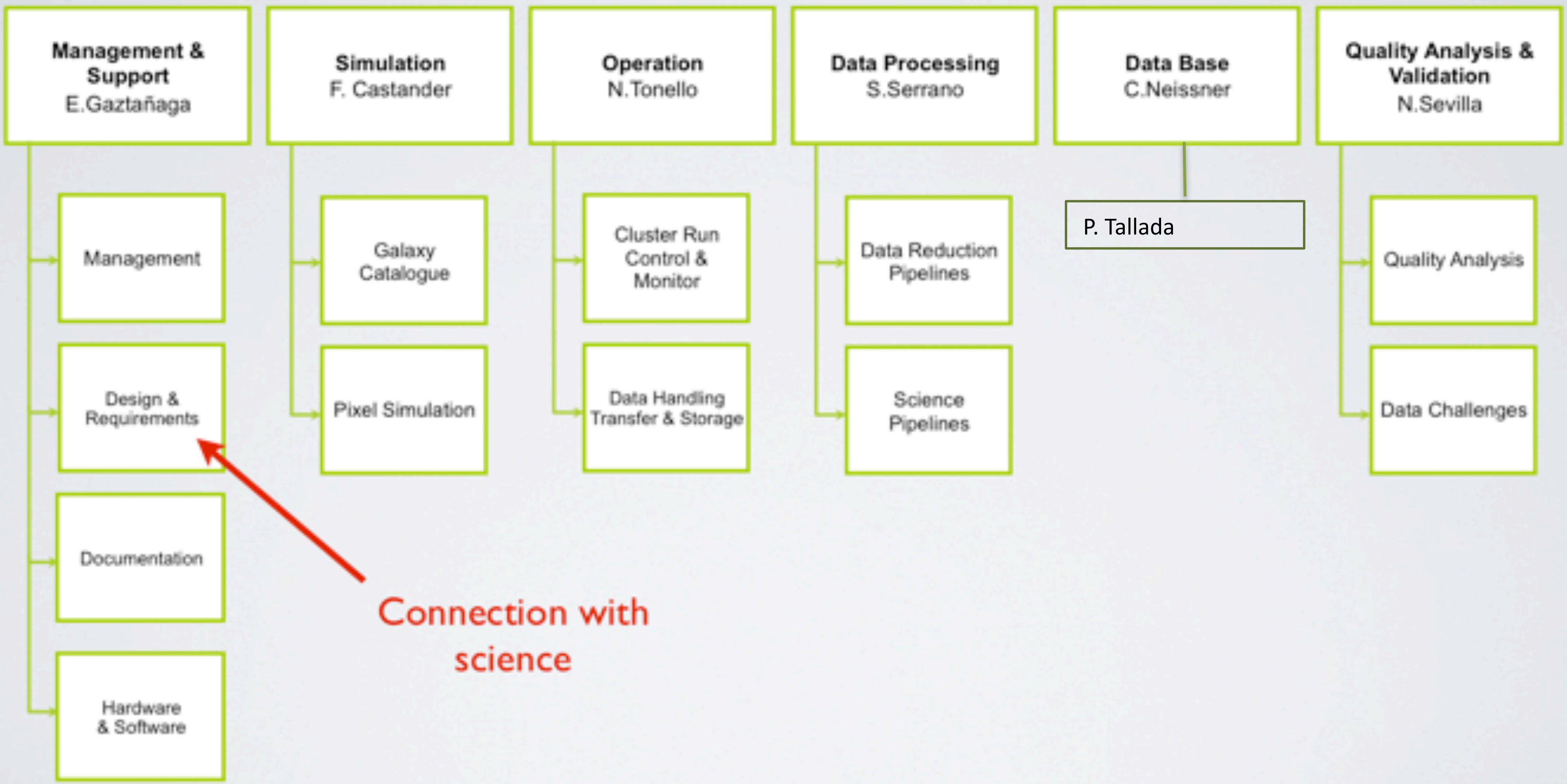
Status of PAUCam

Construction of the PAU camera is well under way:

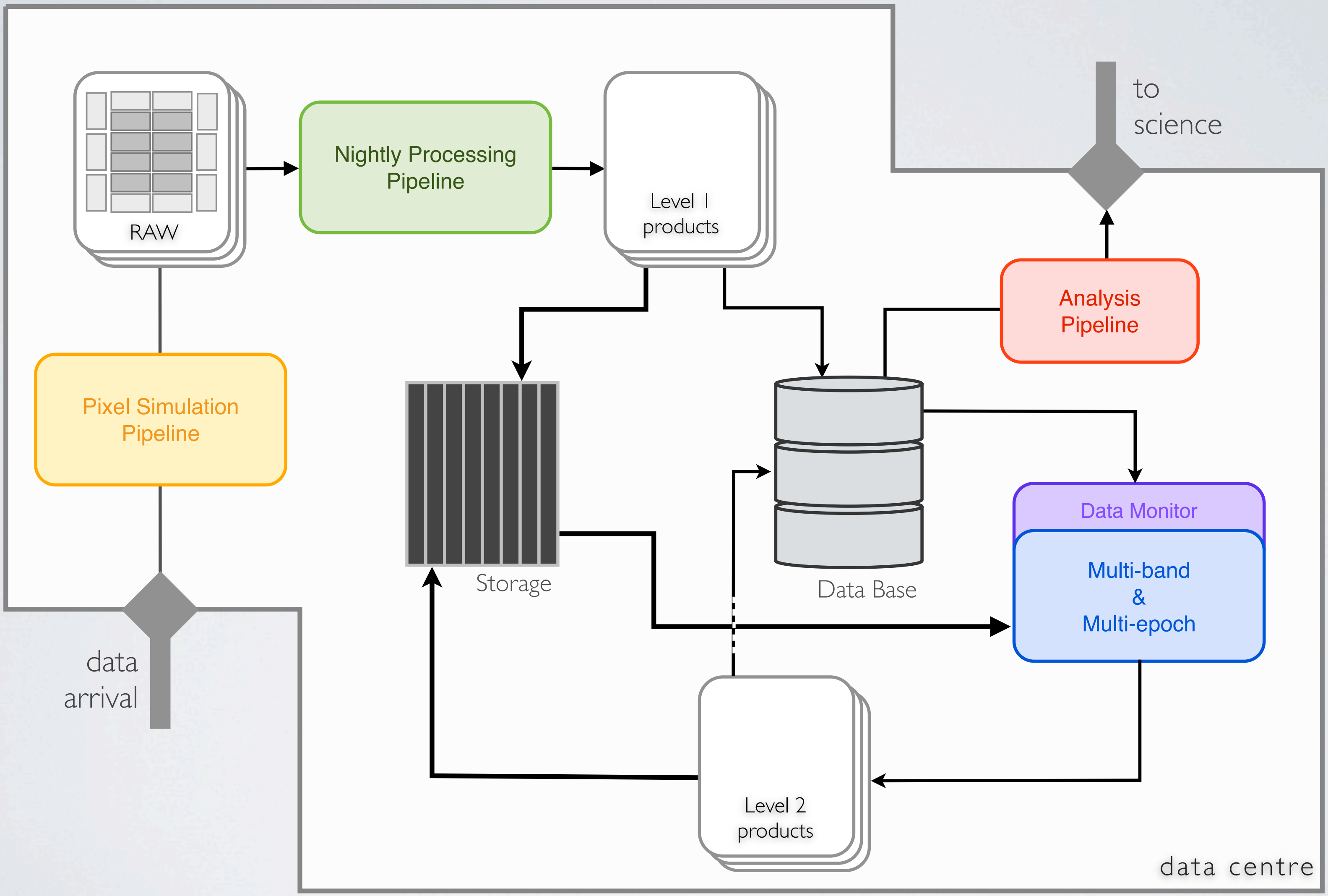
- Mechanical, vacuum and cryogenic challenges solved. Camera body just built. Vacuum tests started. All internal pieces are built.
- Electronics is produced and being tested
- CCDs in hand and on specs, being characterized.
- Filters being ordered.
- Control system hardware in hand, software being integrated.
- Transportation, instal and test tools design and in construction
- Window lens is on its way (INAOE)

Data Management System

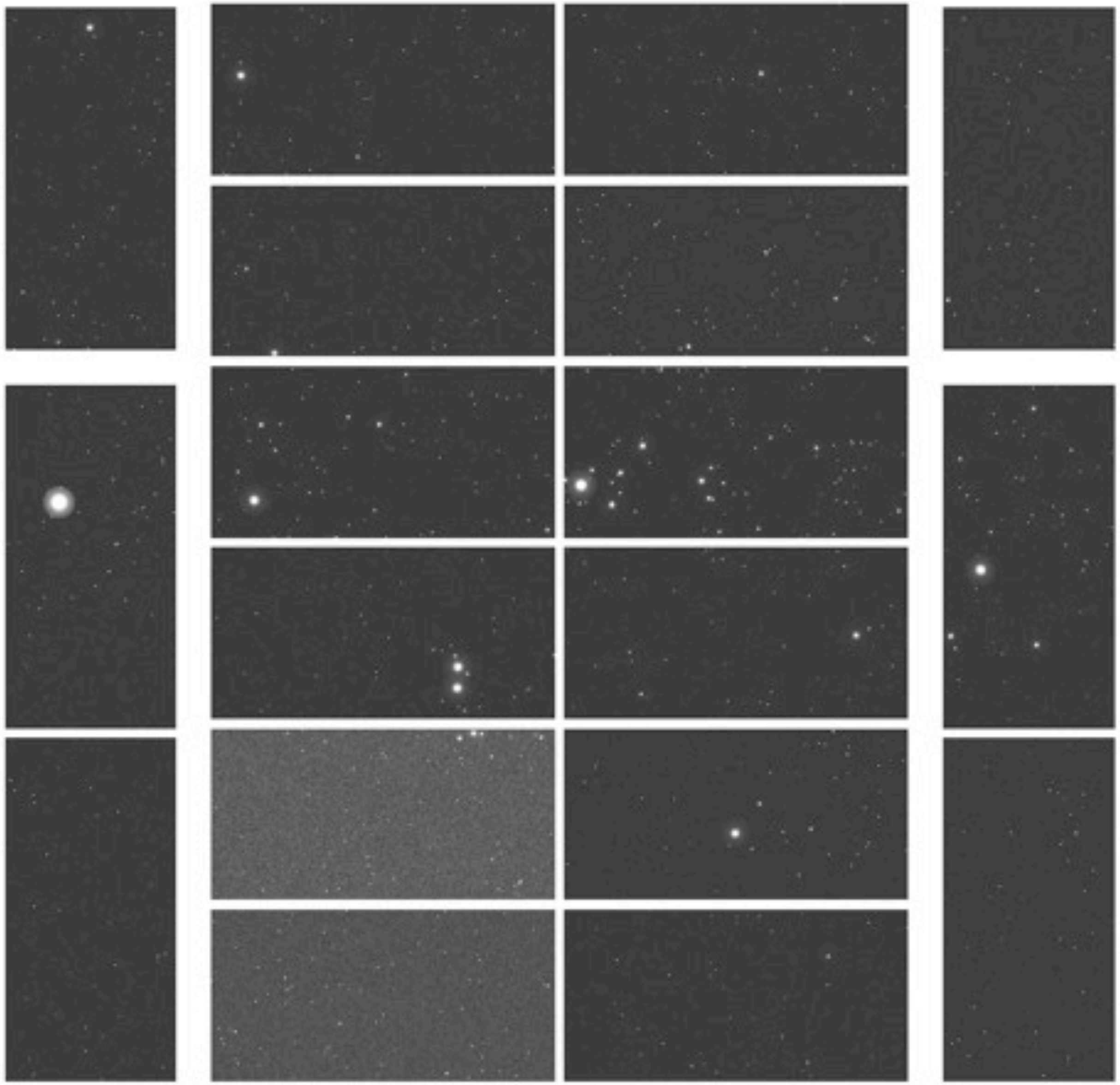
PAUdm Working Packages

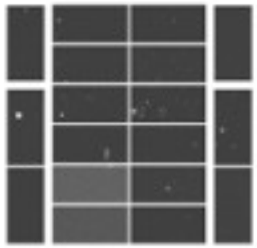


Pipelines


RAW
Nightly Processing Pipeline
Level 1 products
to science
Analysis Pipeline
Pixel Simulation Pipeline
Storage
Data Base
Data Monitor
Multi-band & Multi-epoch
data arrival
Level 2 products
data centre

PAUCam Simulations

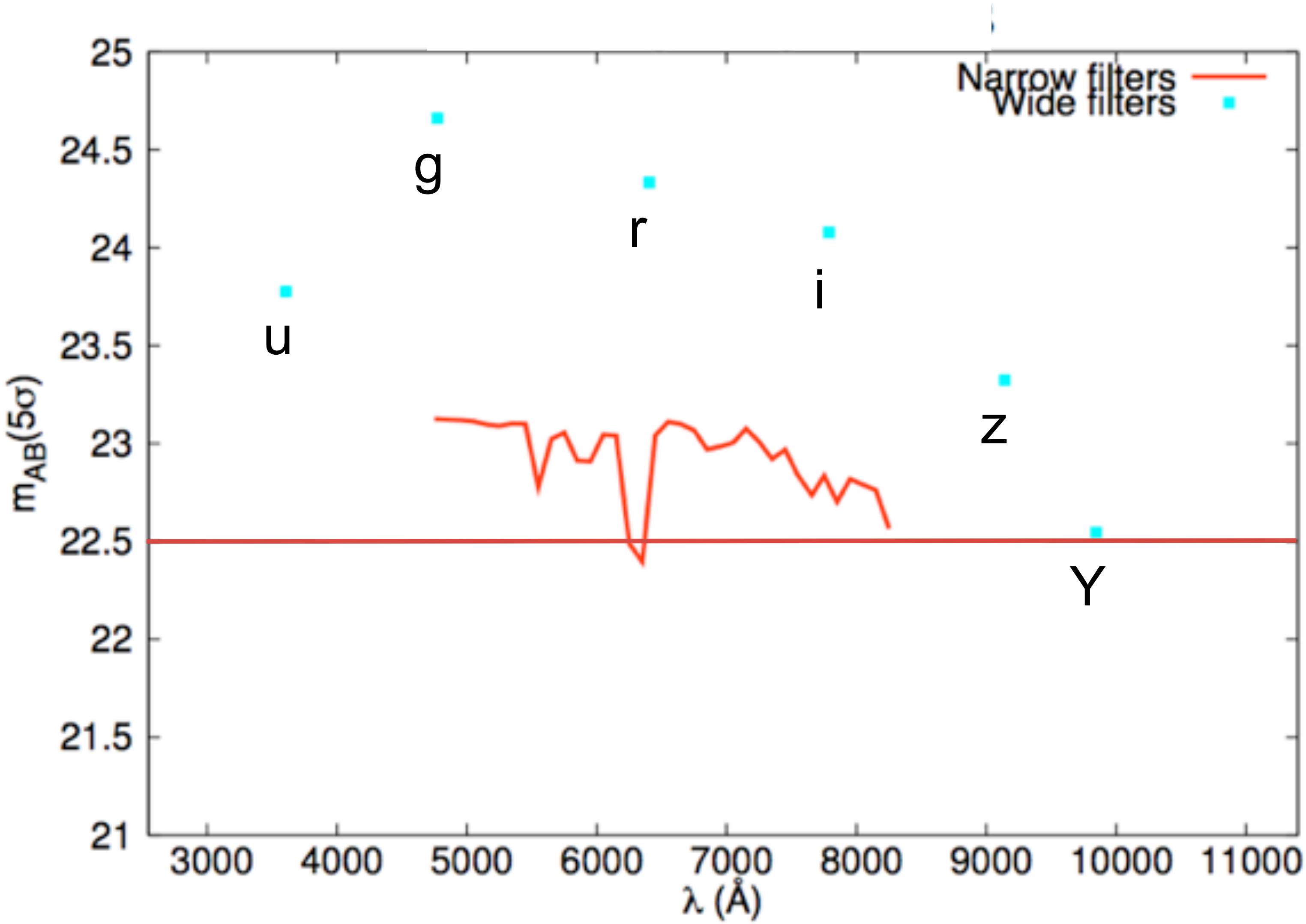




PAU Survey Strategy

- Use 8 central CCDs to define the survey footprint, use the other CCDs to increase S/N.
- Each central CCDs covers the whole survey area twice.
- 6 filters trays with 8 central filters (7 NB + 1 BB).
- Broad bands reach ~1.4 magnitudes deeper than narrow bands.
- Detect objects in the broad bands, and then get flux in the narrow bands.
- Push to low signal to noise.
- Surveying capability: sample 2 deg^2 / night to $i_{AB} < 22.7$ mag in all NBs and $i_{AB} < 24.1$ in all BBs ➜ >30000 galaxies / night
- Exposure times depend on tray: ~100 s for bluest, ~250 s for reddest.
- No selection effects.

Limiting Magnitudes (5σ)



2 exposures of ~100 s. Total time: 2 x 4174 s

PAU Science

- Survey strategy produces two samples:
  - "Spectroscopic" sample: excellent photo-z's with NB filters to $i_{AB} < 22.7$
  - "Photometric" sample: medium photo-z's with BB filters to $i_{AB} < 24.1$
- Science case depends on amount of time available
- Current science case, assuming 100 nights (200 deg^2):
  - Use bright sample for redshift-space distortions (typical of spectroscopic surveys)
  - Use faint sample for weak lensing magnification and/or shear (typical of imaging surveys)
  - Exploit the gains of cross-correlating both samples on the same area

Gaztañaga et al. 2012, MNRAS 422 2904 (astro-ph/1109.4852)

PAU Survey Samples

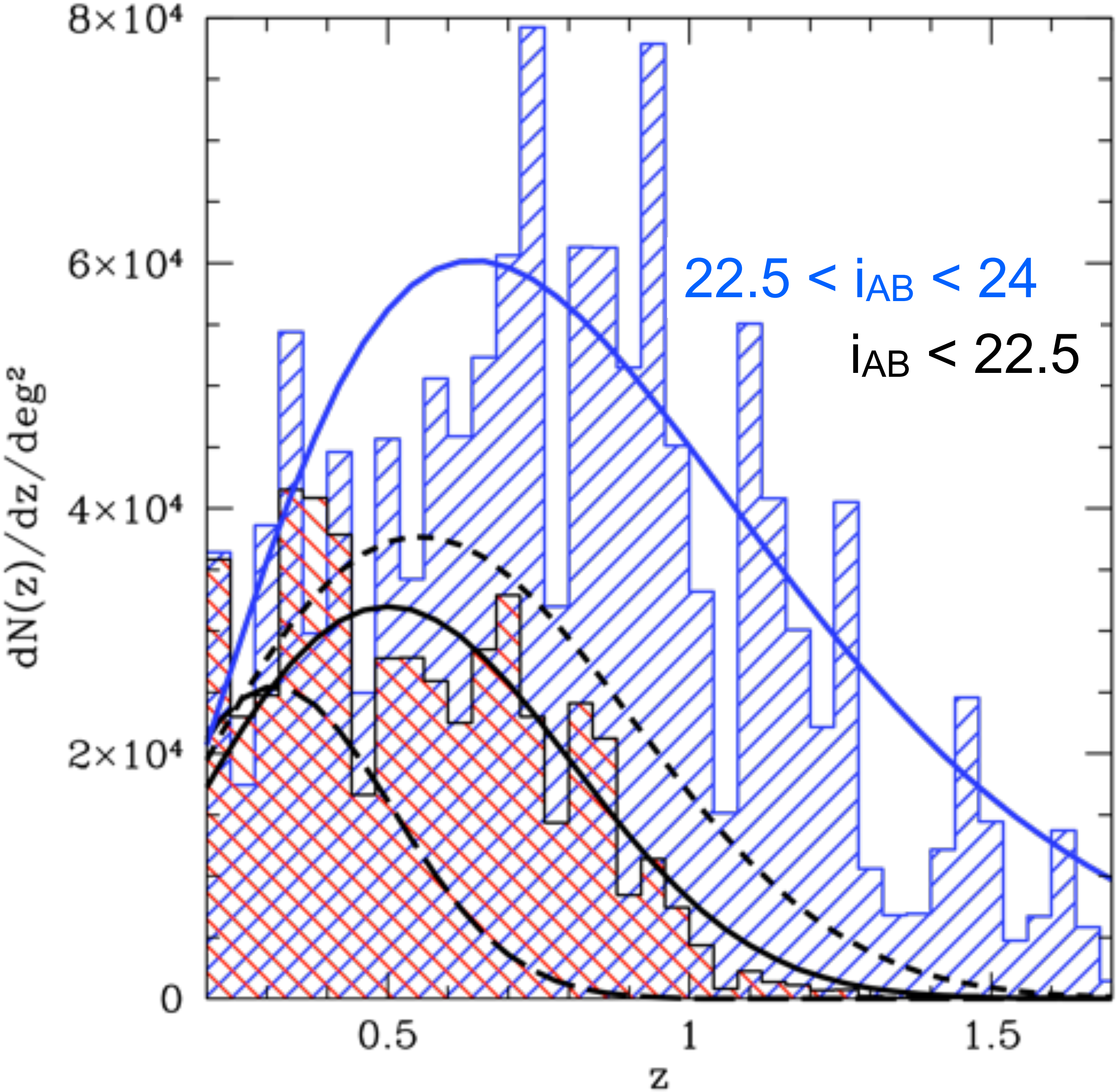


Photo-z Performance (Bright sample: i_{AB} < 22.5)

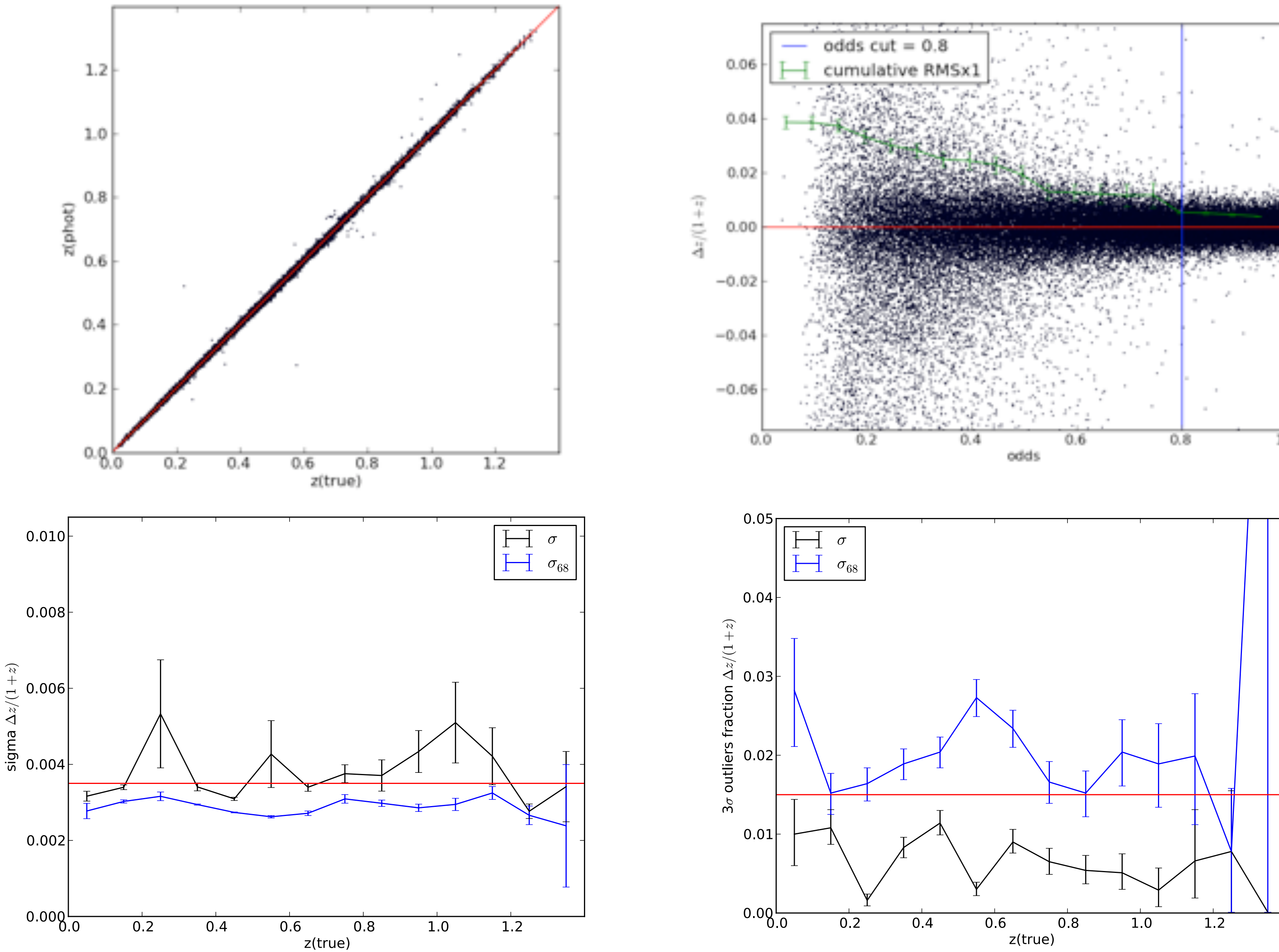
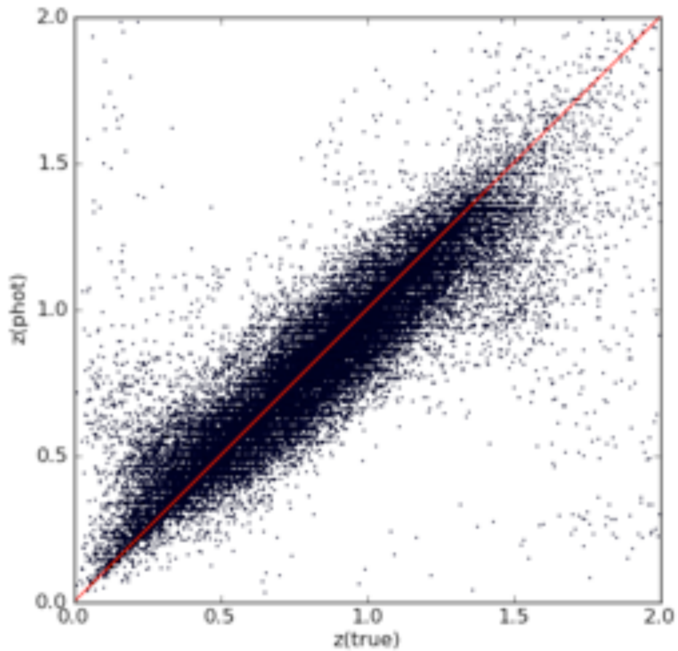
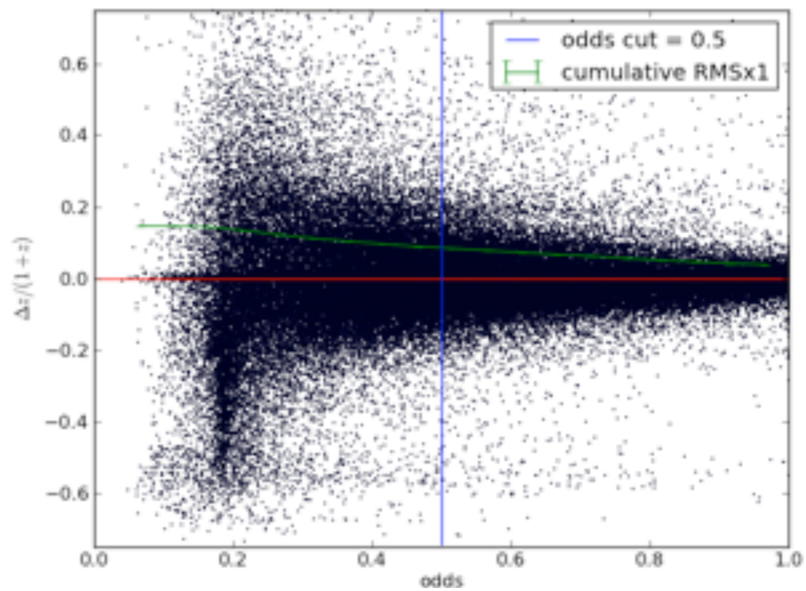
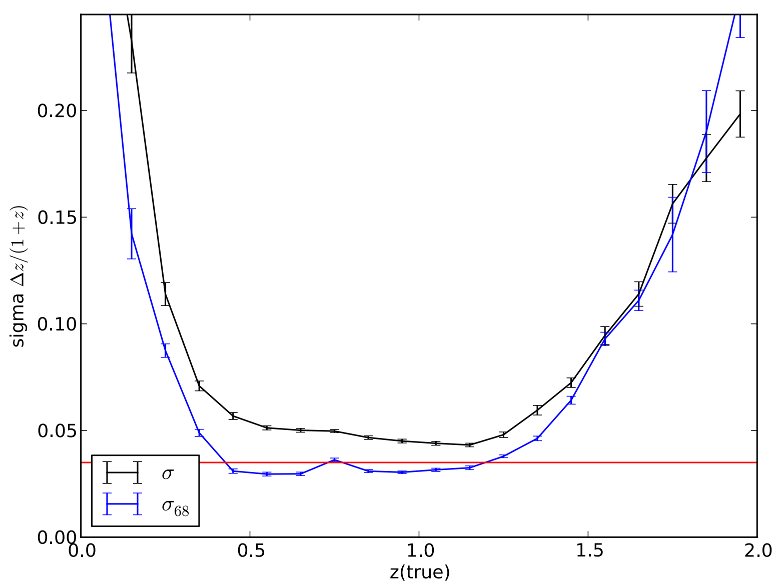
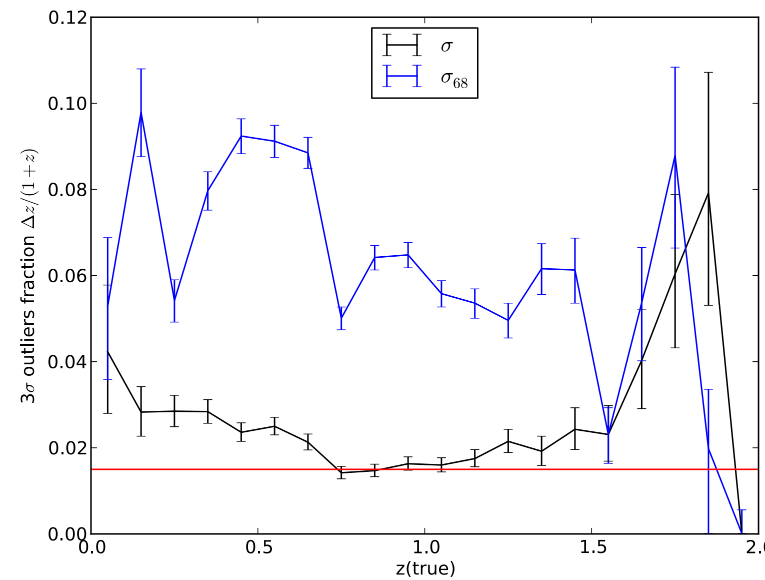


Photo-z Performance (Faint sample: $22.5 < i_{AB} < 24$)

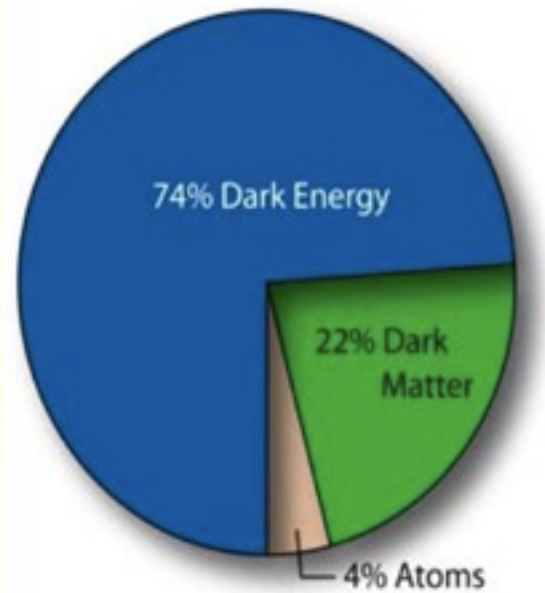








Problem Using Galaxy Surveys:



light is a biased DM tracer

Possible Solutions:

*Avoid **bias**:*

CMB, SNIa
Clusters, BAO
Use redshift space distortions <= only sensitive to ratios
Do weak lensing (to avoid bias) <= is 2D

*Measure **bias***

learn about galaxy formation => put priors on bias
higher order correlations

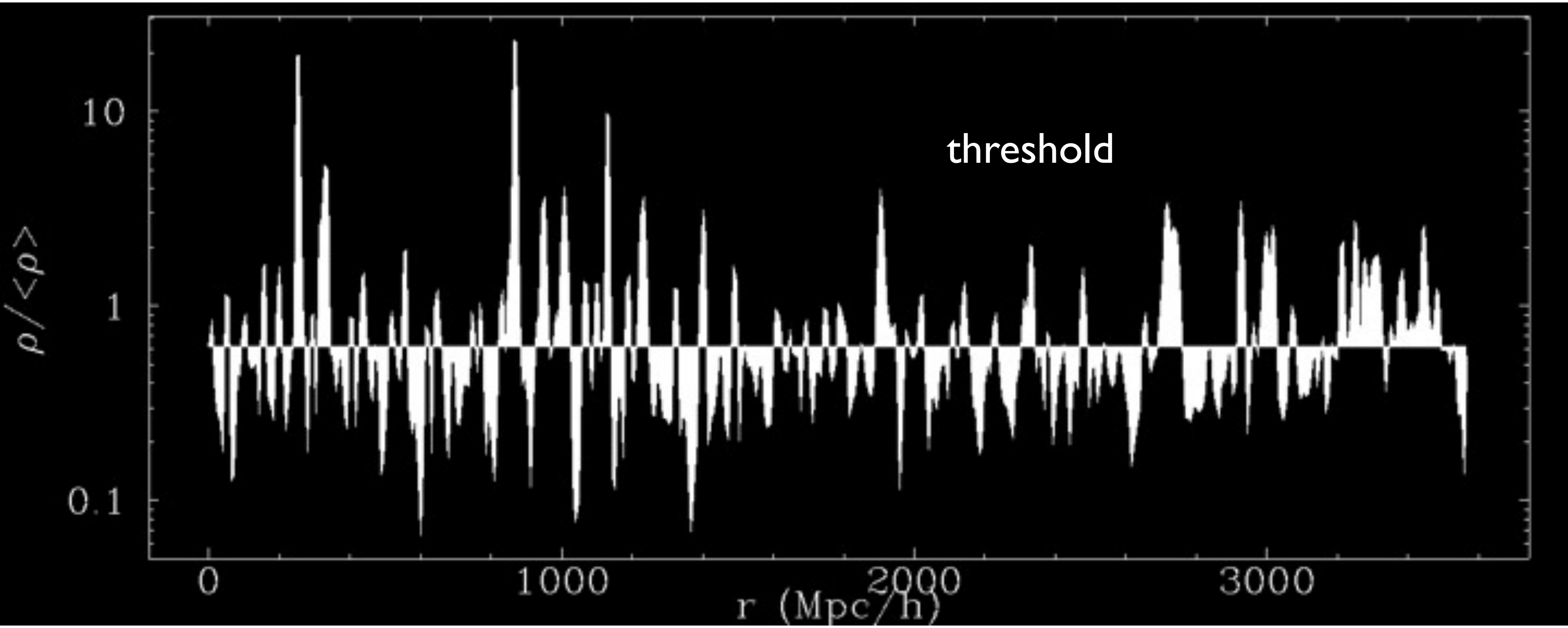
Combine the best of both: Do cross-correlations

Bias: a simple model.

rare peaks in a Gaussian field (Kaiser 1984, BBKS)

Linear bias "b": $\delta\,(\text{peak}) = b\ \ \delta(\text{mass})$ with $b = \nu/\sigma$ (SC: $\nu = \delta_c/\sigma$)

$$\rightarrow \xi_2\,(\text{peak}) = b^2\,\xi_2\,(m)$$



Biasing: does light trace mass?

On large scales 2-pt Statistics is linear

$$\left.\begin{aligned} \delta_g &= b\,\delta_m \\ \delta_m &= \delta_L = D\,\delta_0 \end{aligned}\right\}$$

$$< \delta_g^{\,2} > = b^2 < \delta_m^{\,2} >^2 = b^2 D^2 < \delta_0^{\,2} >^2$$

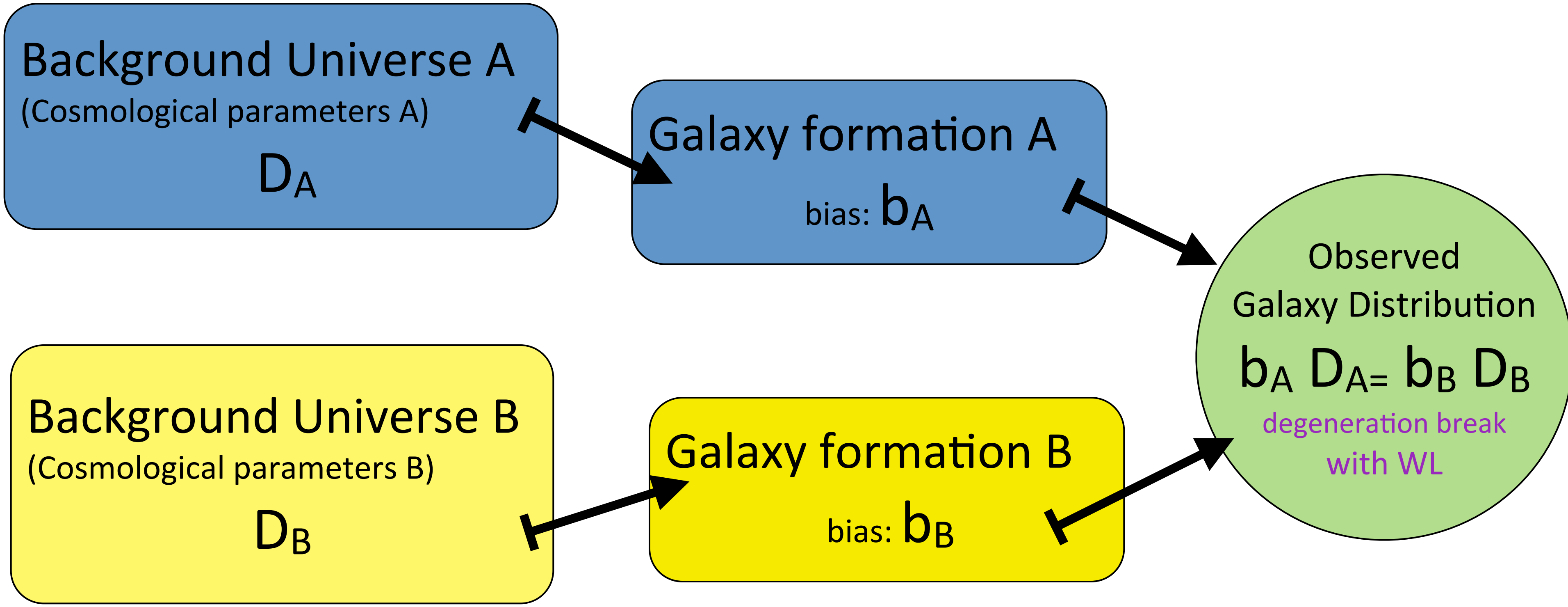
Gravity (D) or Cosmology is DEGENERATE WITH Galaxy formation (b)

Our motivation (to make galaxy simulations):

Degeneracy?

- Want to measure geometry H(z) and dynamics D(z) of the Universe using clustering in galaxy maps: this requieres understanding galaxy bias (otherwise you can only use very limited information: eg BAO):
- Validate with simulations new ways to measure galaxy bias in real data
- Estimate errors using simulations

We will ***bias*** (HOD) a DM simulation so as it ***look*** similar to the large scale galaxy distribution. There might be different ways to fake this galaxy biasing, but this is not totally degenerate with the cosmological information (if you combine different probes, i.e. WL+RSD) and hopefully we can still recover H(z) and D(z).



If we know GF/Cosmology we can learn about Cosmology/GF

astro-ph:1109.4852

Forecast: Planck+SNII priors

5000 sq.deg.

$\mathrm{FoM}_{w\gamma} \times 10^3$	RSD	RSD +BAO	WL Shear-Shear	Galaxy-Galaxy WHEN BIAS IS KNOWN
Photometric (i<24)			**3.2**	**8.4**
Spectroscopic (i<22.5)	**0.5**	**2.7**		**17**

Motivation to learn about bias

XTalks in Galaxy Clustering

1. Galaxy Clustering 2pt: 3D, all info but biased
2. Galaxy Clustering 3pt: 3D (bias can be measured)
3. Weak Lensing: 2D (unbiased but degenerate & few modes)
4. Redshift Space Distortions: ratios, (unbiased but few radial)
5. BAO: 1.5 D (unbiased)

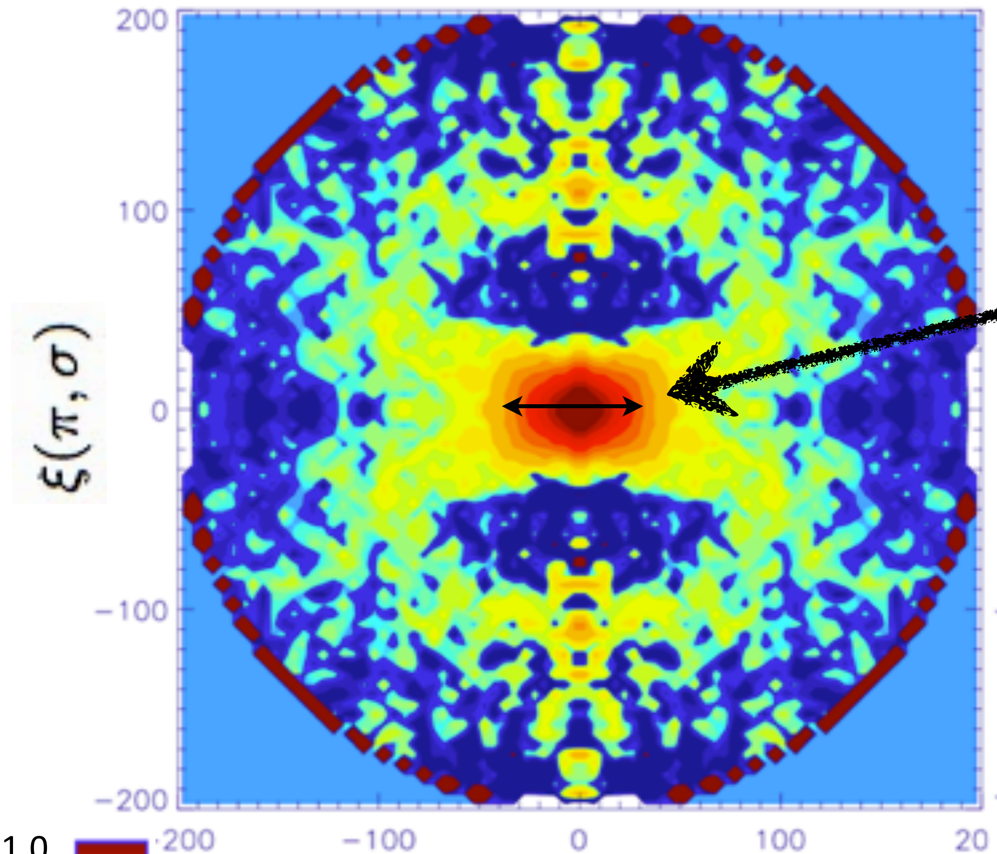
Combine (cross-correlate) Photometric & Spectroscopic Surveys

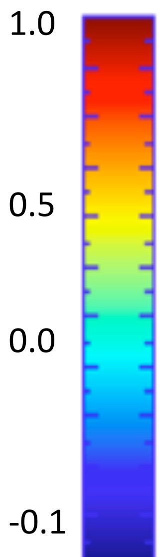
and all different probes (XTalks)

and all systematics (bias, photo-z, IA)

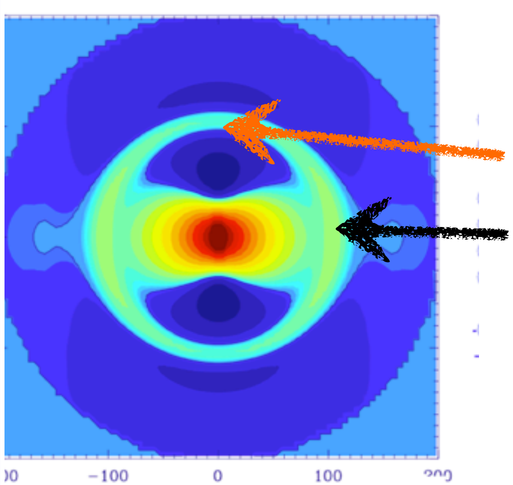
astro-ph:1109.4852

Redshift Space Distortions (RSD)



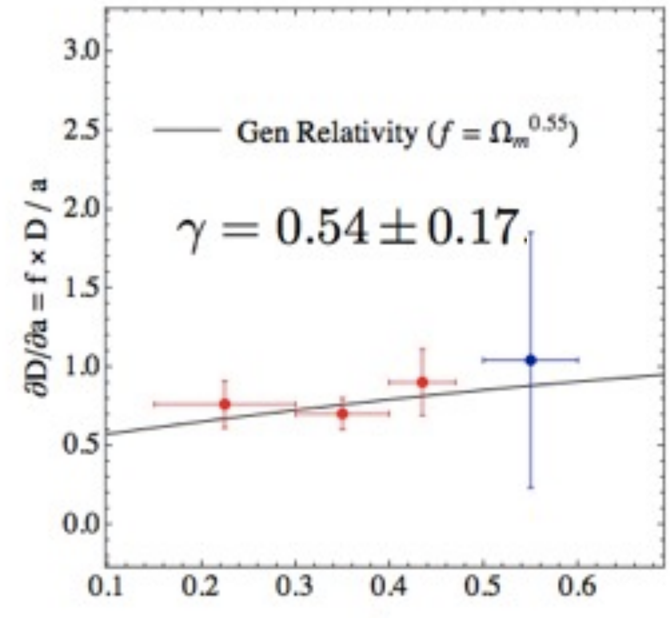


Anna Cabré's PhD Thesis arXiv:0807.3551



$$\delta_g(k,\mu) = (b + f\mu^2)\delta(k)$$

Measure both bias and growth!



FoMγ= 6 Crocce etal 2011

(Forecast for DES: Ross etal 2011)

BAO: $\xi(\pi,\sigma)$

radial H(z)

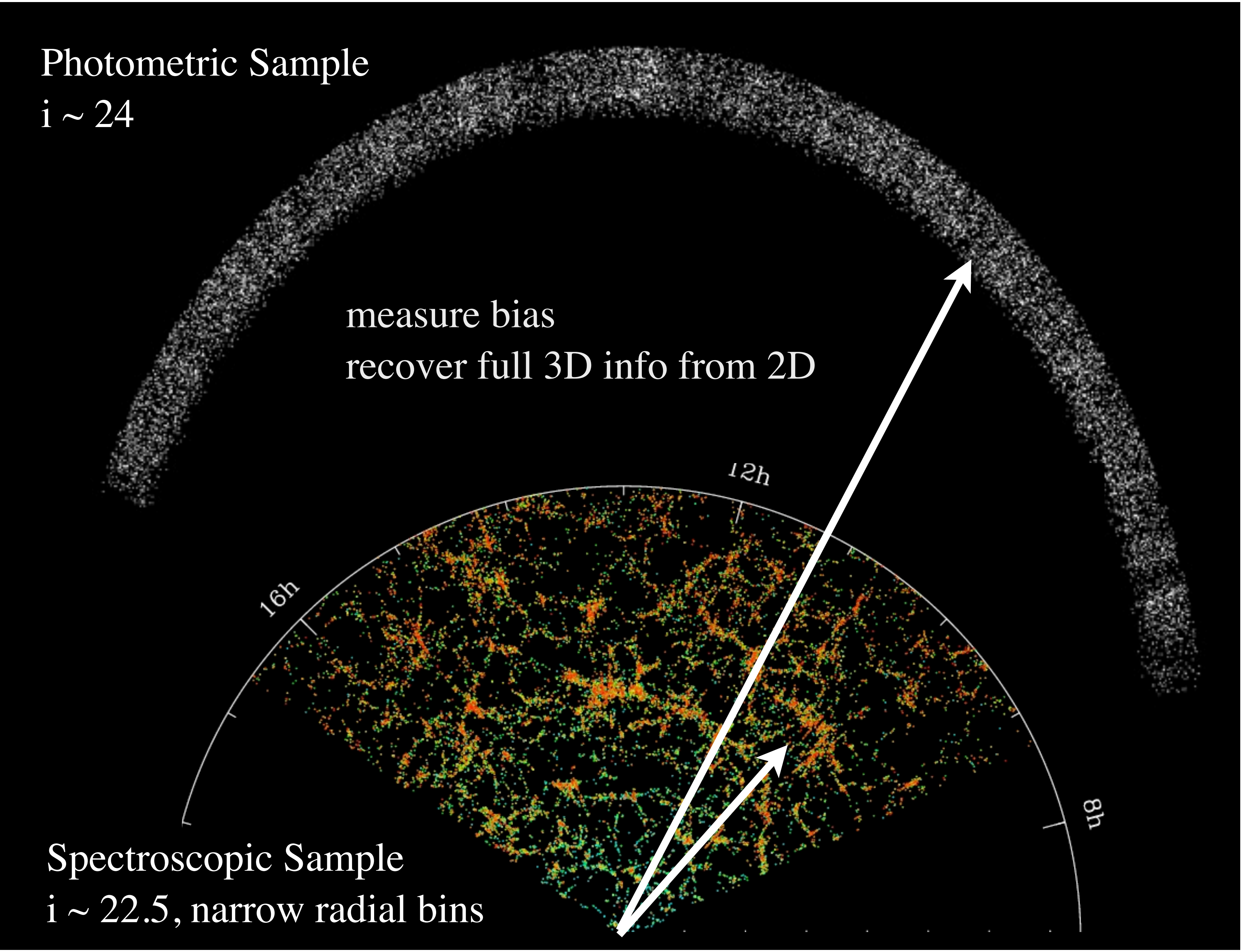
H(z=0.34) = 83.8 ±3.0± 1.6

EG, Cabre & Hui (2009)

Transverse $\int$ cdz/H(z)

θ(z=0.34) = 3.90 ± 0.38

Carnero etal 2011


Photometric Sample
i ~ 24
measure bias
recover full 3D info from 2D
12h
16h
8h
Spectroscopic Sample
i ~ 22.5, narrow radial bins

Forecast: Planck+SNII priors 5000 sq.deg.

$\mathrm{FoM}_{w\gamma} \times 10^3$	RSD	RSD + BAO	WL Shear-Shear	WLxG + RSD + BAO	RSD + WLxG or just MAG (den/mag)	RSD + WLxG or just MAG (den/mag)	RSD+ WLxG + BIAS IS KNOWN (eg 3pt)
Photometric DES (i<24)			**3.2**				
Spectroscopic eBOSS+ (i<22.5)	**0.5**	**2.7**					
Combine both as Independent				**40**			
PAU: Cross Correlated over same Area					**251** **30/72**	**5.2** **1.8/2.5**	**26** **7.7/10**

5000 sq.deg. 200 sq.deg.

WLxG: shear-shear, galaxy-shear, galaxy-galaxy (including MAG from counts or MAG from magnitudes and counts)

astro-ph:1109.4852

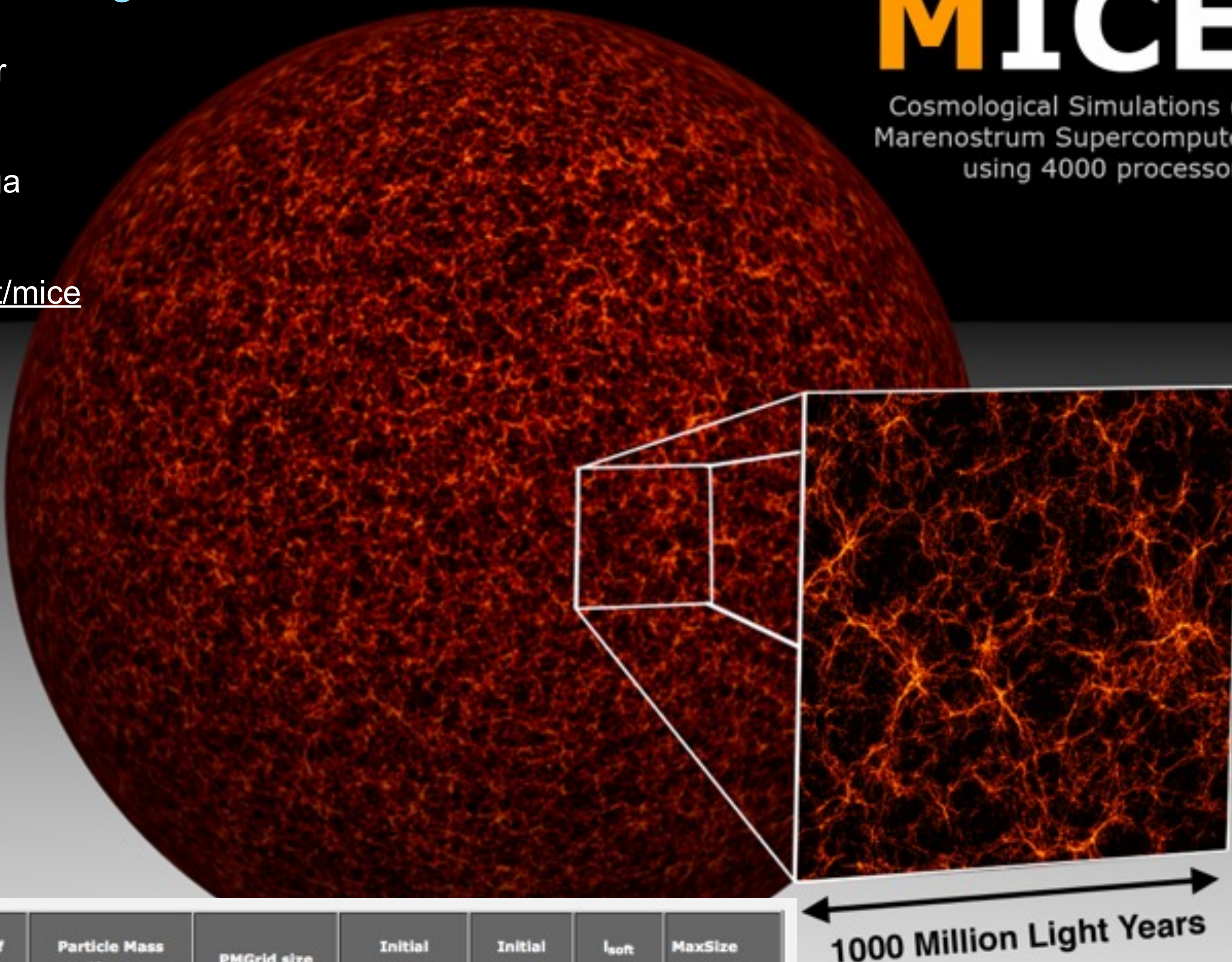
Grand Challenge Sim

F.Castander
M.Crocce
P.Fosalba
E.Gaztanaga

www.ice.cat/mice

MICE

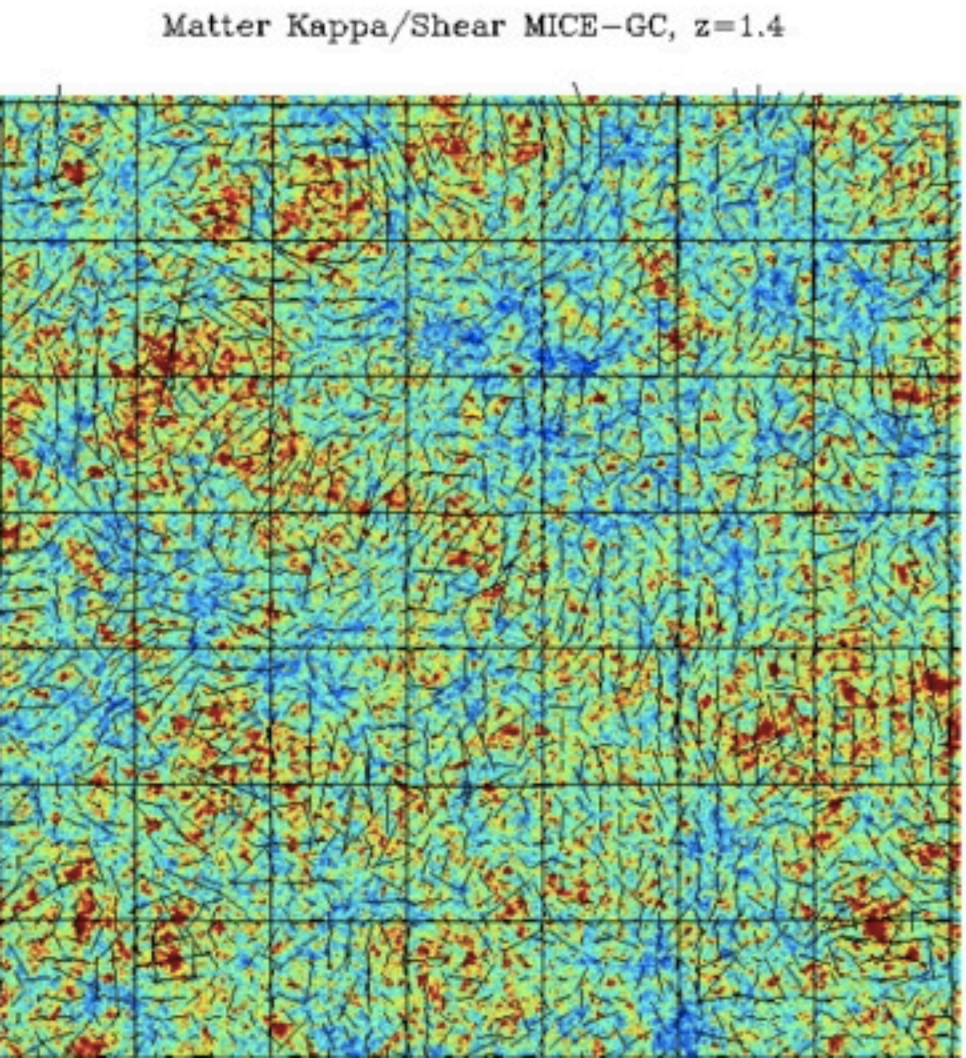
Cosmological Simulations @
Marenostrum Supercomputer
using 4000 processors

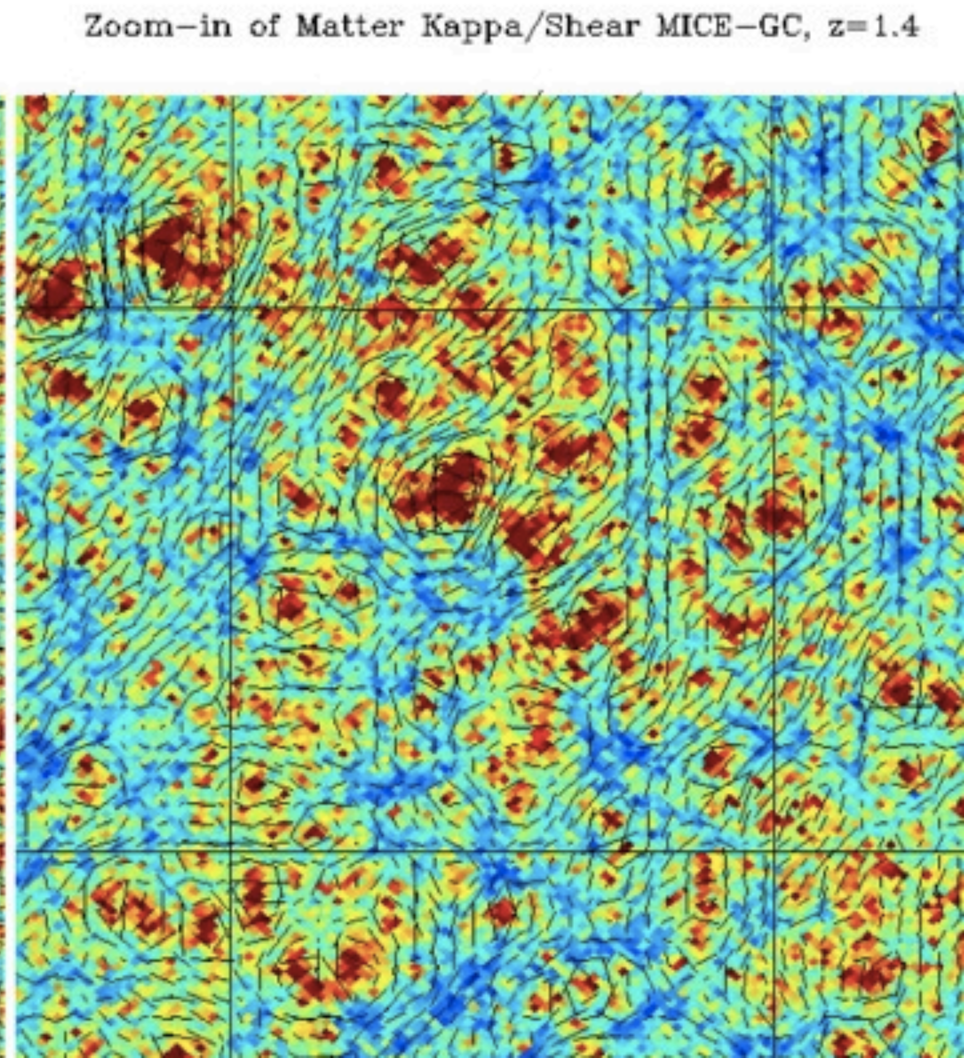


Box Size (Mpc/h)	Number of Particles	Particle Mass ($\times 10^{10}$ Msun/h)	PMGrid size	Initial conditions	Initial redshift	l_{soft} (kpc/h)	MaxSize Timestep
3072	4096^3	2,927	4096^3	ZA	100	50	0,02

DES-MICE v0.3r2.0

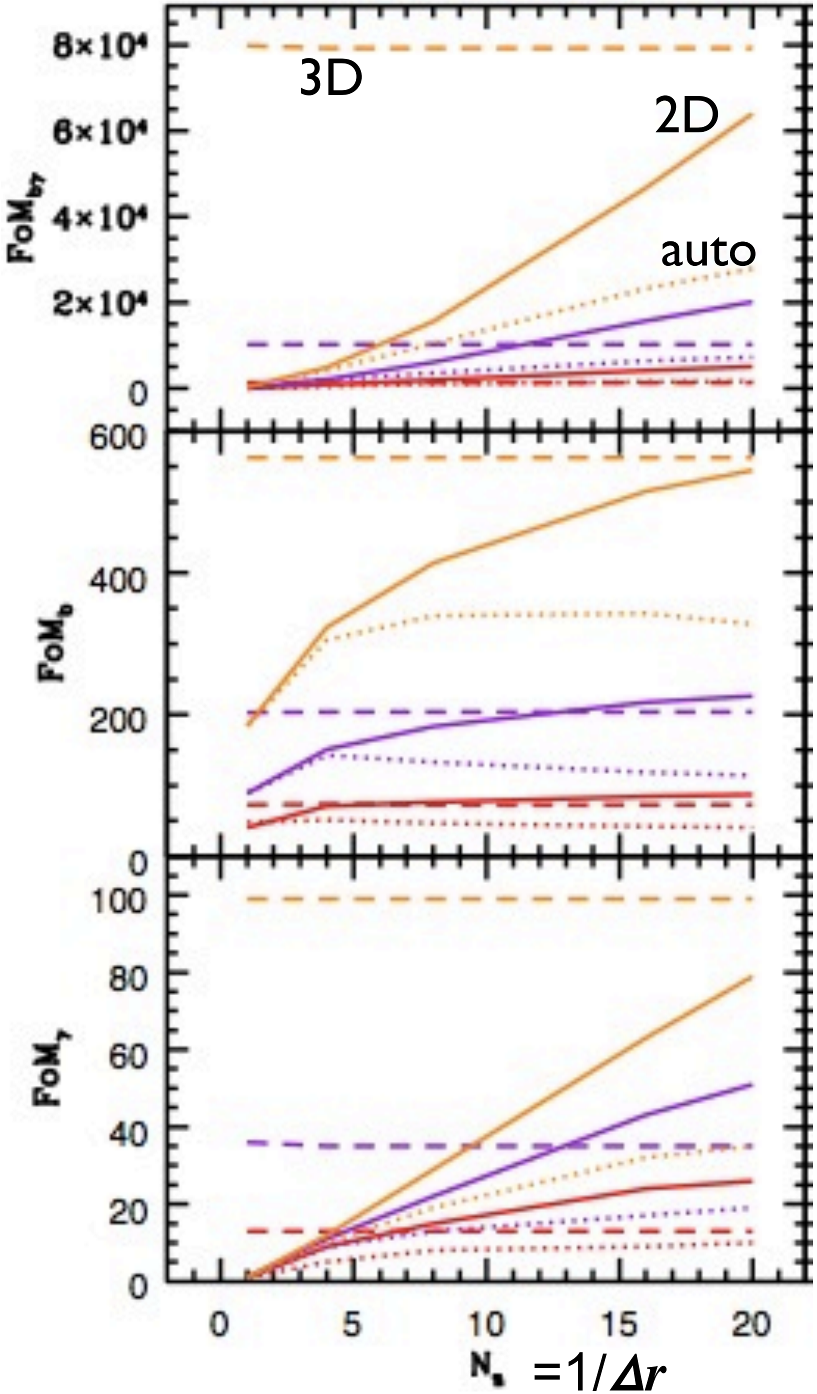
ice.cat/mice

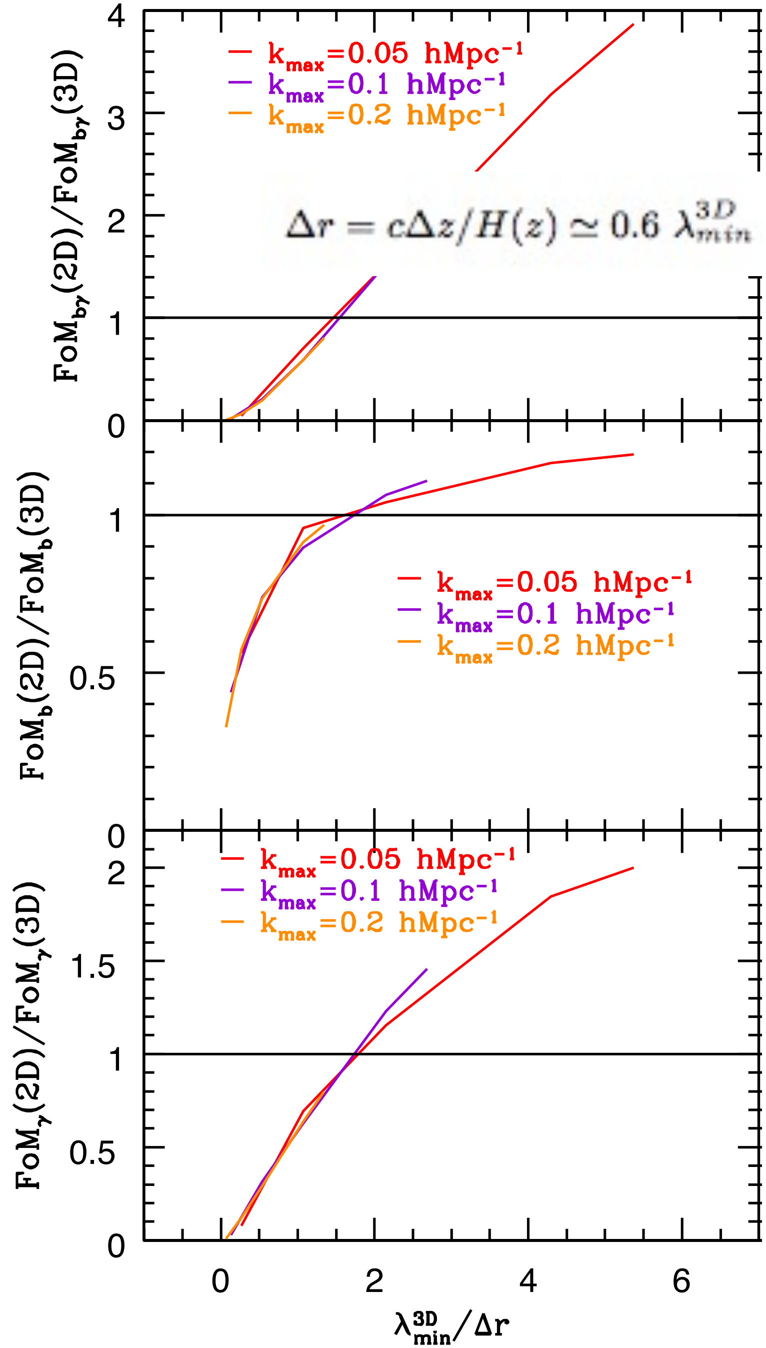




arXiv:1207.6487

Jacobo Asorey





Other Science

- Baryon Acoustic Oscillations
- Large Scale Structure
- Galaxy clusters
- Galaxy evolution
- Quasars and the Lyα forest
- Multiply imaged gravitational lenses
- High redshift galaxies
- Low surface brightness galaxies
- Intergalactic dust
- Halo stars
- Local group stars
- Brown dwarfs and cool stars
- Exoplanets
- ....

Summary

- Construction of PAUCam is well under way.
  - Mechanical, vacuum and cryogenic challenges solved. Camera body in carbon fiber being tested.
  - CCDs in hand, being characterized. Filters being ordered this month.
  - Control system hardware in hand, software being written.
- Data management system designed, being written.
- An MoU with ING was signed earlier this year.
  - MoU contemplates ample time allocation for the survey (for a price...).
- Compelling science case based on complementarity of spectroscopic and imaging characteristics.
- Everything is on schedule to have first light in **early 2013**. The survey will start soon thereafter. **The PAU camera at WHT will be the most powerful imaging instrument at El Roque.**