PAU

Physics of the Accelerating Universe

survey

Francisco Javier Castander

Institut de Ciències de l'Espai, ICE (IEEC/CSIC), Barcelona

PAU survey collaboration: Barcelona (IFAE, ICE(IEEC/CSIC), PIC), Madrid (UAM & CIEMAT)

Probing Cosmology

- Cosmology is probed mainly measuring the expansion rate of the universe H(z), the rate growth of structure g(z) and the distribution of matter P(k,z) or any of its tracers

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

matter radiation curvature dark energy

g(z) in general a complicated function of cosmological parameters

P(k,z) matter power spectrum depends on universe composition

Probing Cosmology

- Geometric test: integrals over H(z):

Comoving distance		$r(z) = F[\int dz/H(z)]$
Standard Candles	Supernovae	$D_L(z) = (1+z)\, r(z)$
Standard Rulers	Baryon Oscillations	$D_A(z) = (1+z)^{-1}\, r(z)$
Standard Population	Clusters	$dV/dz d\Omega = r^2(z)/H(z)$

- Growth of Structure test: g(z)

  Clusters, Weak lensing, clustering, redshift space distortions

- Matter distribution: P(k,z)

  Galaxy clustering

Requirements for cosmology survey

- Weak lensing: volume, good PSF, photo-z
- Baryon acoustic oscillations: volume, redshifts
- Supernovae: repeated photometry, redshifts
- Clusters of galaxies: volume, observable for IDs
- Redshift space distortions: redshifts, volume
- Magnification bias: redshifts, photometry
- Power spectrum: volume, distances

Survey requirements

- The precision to which the galaxy power spectrum can be measured depends on:
  - Sample variance: how many independent samples of the relevant scale (150 Mpc) one has ⇒volume
  - Shot noise (Poisson): how many galaxies included in each sample ⇒density

Feldman, Kaiser, Peacock, ApJ 426,23 (1994)

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

P(*k*): power spectrum

n: galaxy density

Requirements for cosmology survey

- sample large volumes
- sample many (enough) objects
- measure distances

PAU survey

The trick

- Use photometry to obtain redshifts
- Many cosmological applications need only “rough” spectroscopic precision
- The scale of the transiction from linear to non-linear behaviour ~10Mpc
- Broad band imaging does not provide enough resolution
- Need sufficient spectral resolution as to obtain good photometric redshifts => narrow band imaging
- Previously: Combo-17, Alhambra, COSMOS, Subaru,…

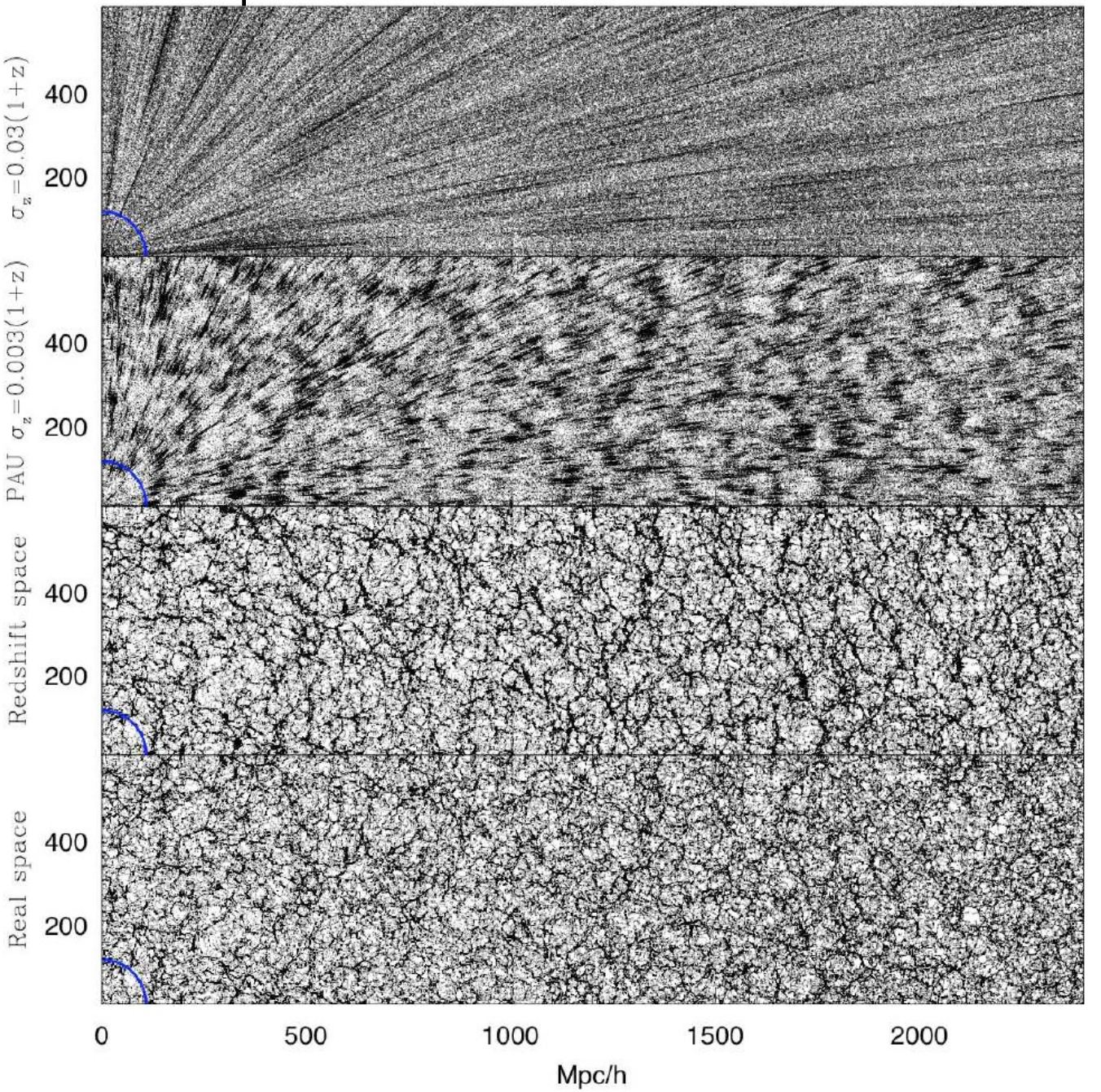
Visual illustration of the importance of z resolution

z-space, $\Delta z = 0.03(1+z)$ + peculiar velocities

z-space, $\Delta z = 0.003(1+z)$ + peculiar velocities

z-space, perfect z-resolution + peculiar velocities

Real space, perfect resolution

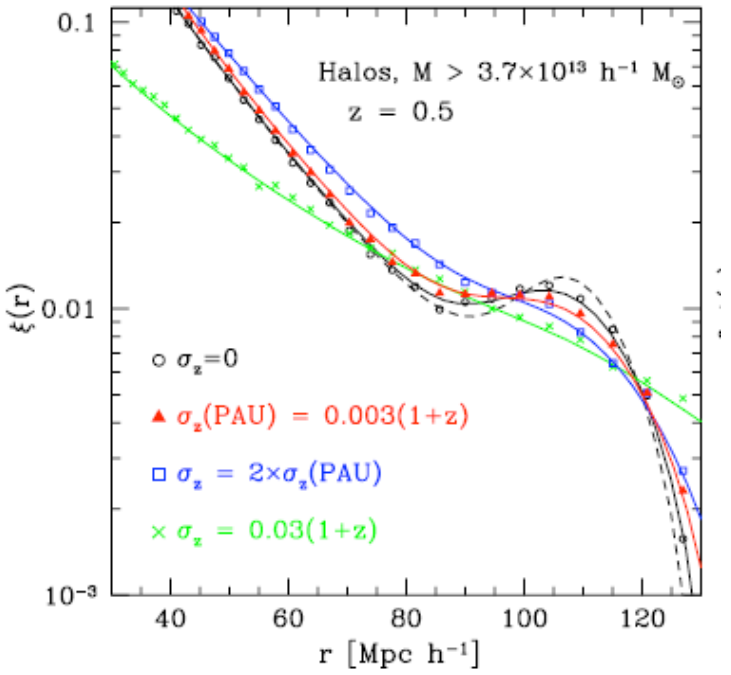


Size and resolution requirements for BAOs

To study the required precision in z the two-point correlation function of over 1M halos with $M>3.7\times10^{13}h^{-1}M_{sun}$ was studied.

The position of the halo was smeared with a Gaussian:

$$f(\delta r_z) \sim \exp\left[-\frac{1}{2}\left(\frac{\delta r_z}{\Delta z}\right)^2\right] \qquad \Delta z = \frac{\sigma_z (1+z) c}{H(z)}$$



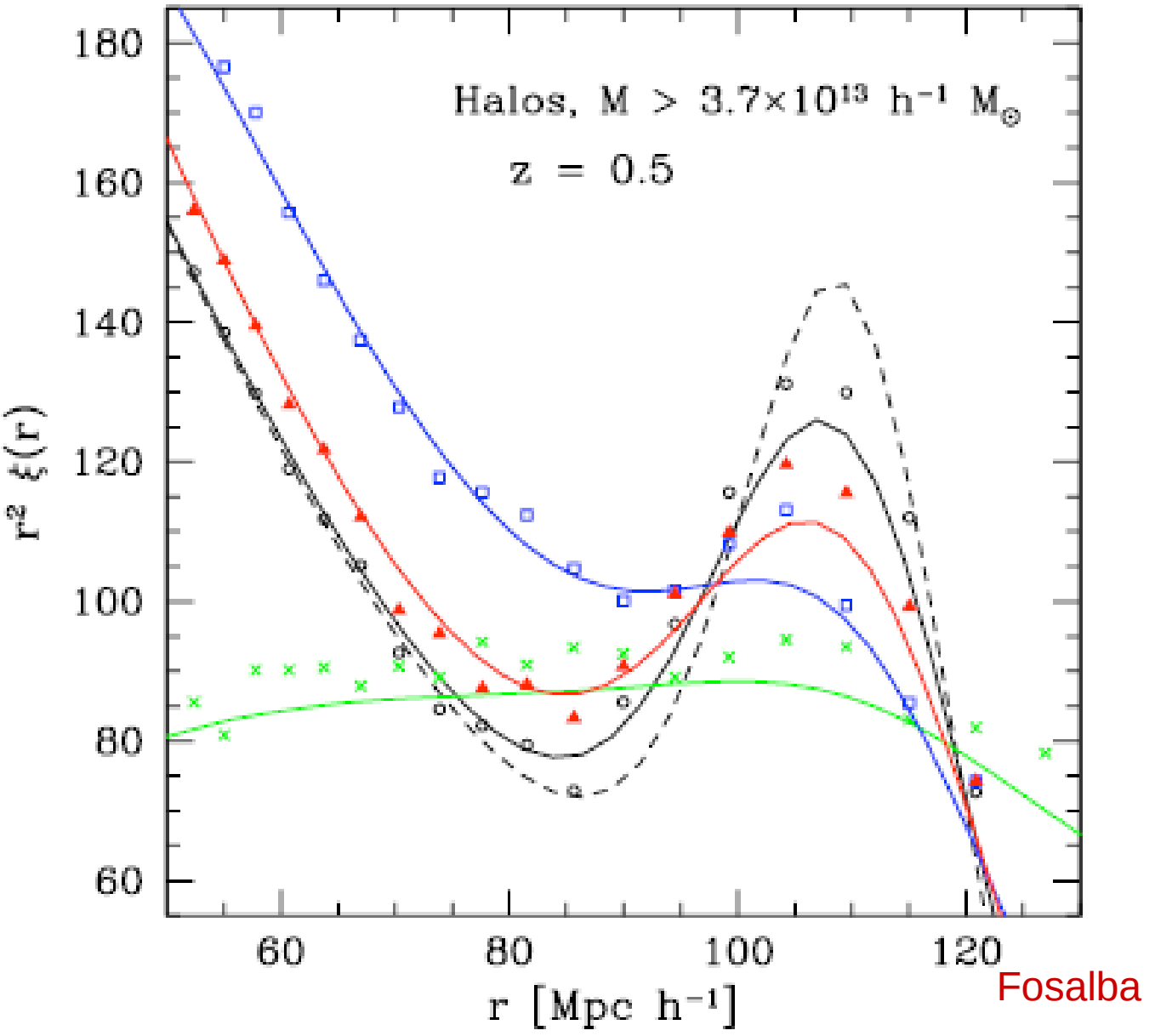
- - - linear corr. func. (b=3)

——— non-linear (RPT; Crocce-Scocimarro, 2008)

▲ $\sigma_z = 0.003\,(1+z)$

▯ $\sigma_z = 0.007\,(1+z)$

× $\sigma_z = 0.03\,(1+z)$

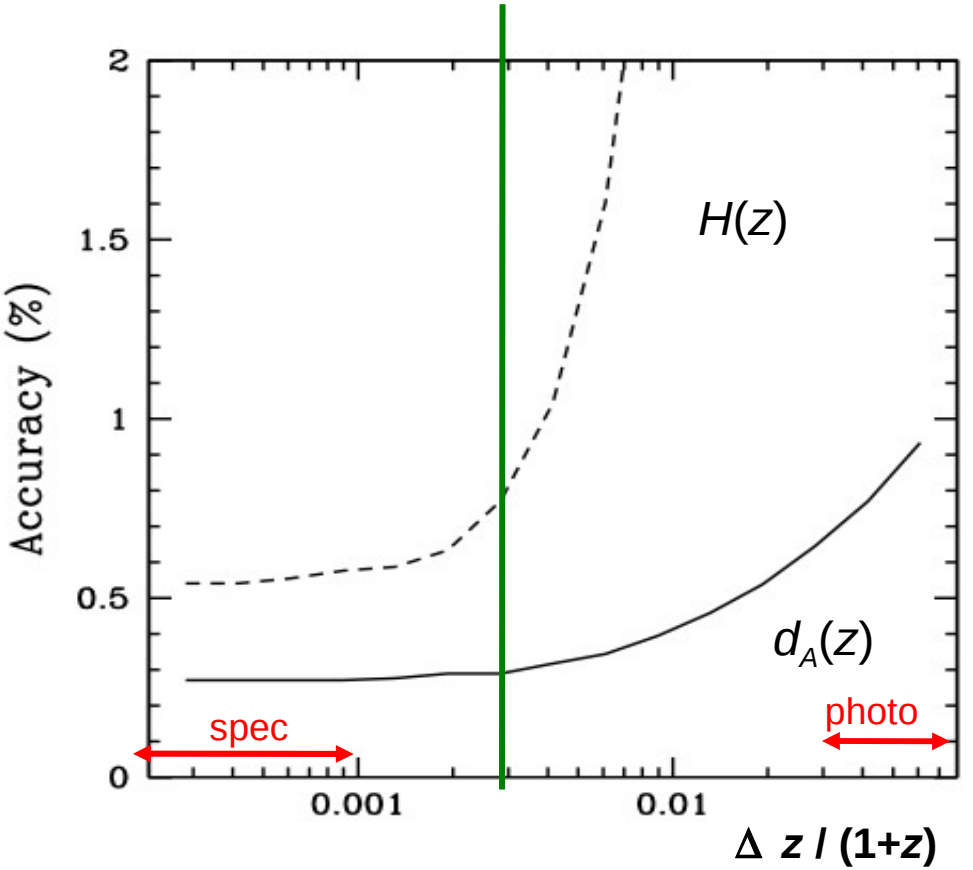


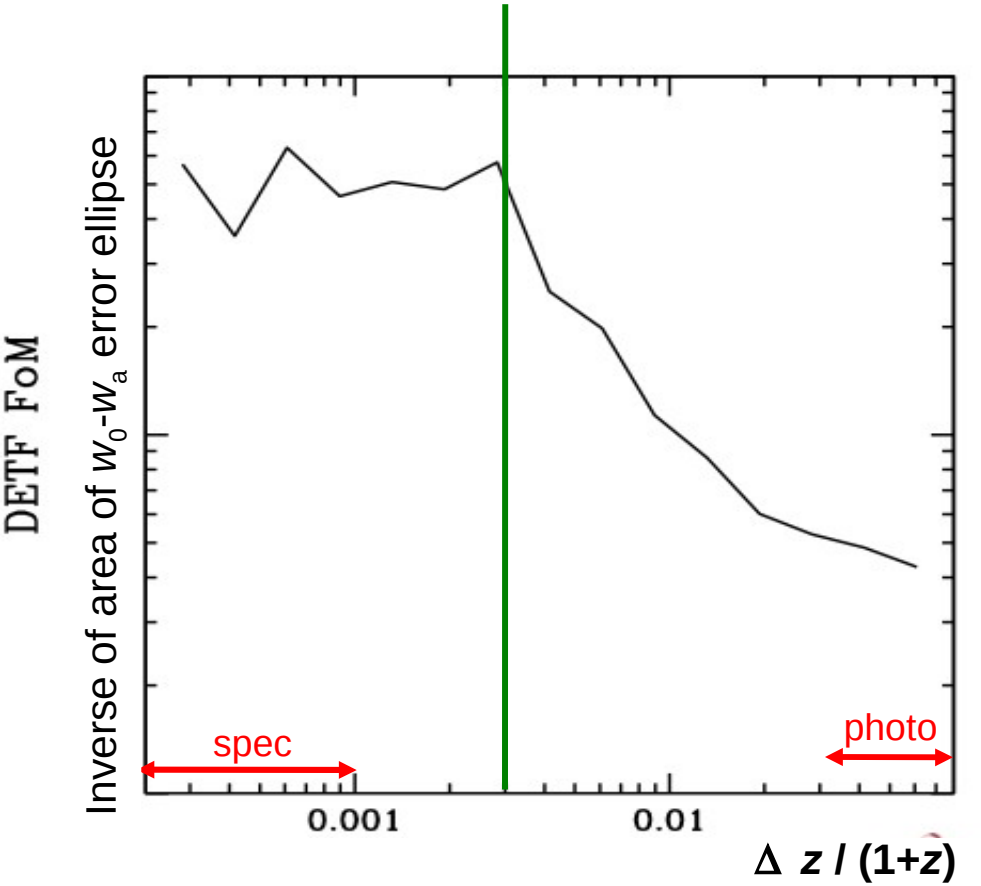
Fosalba

Curves are analytical predictions derived from

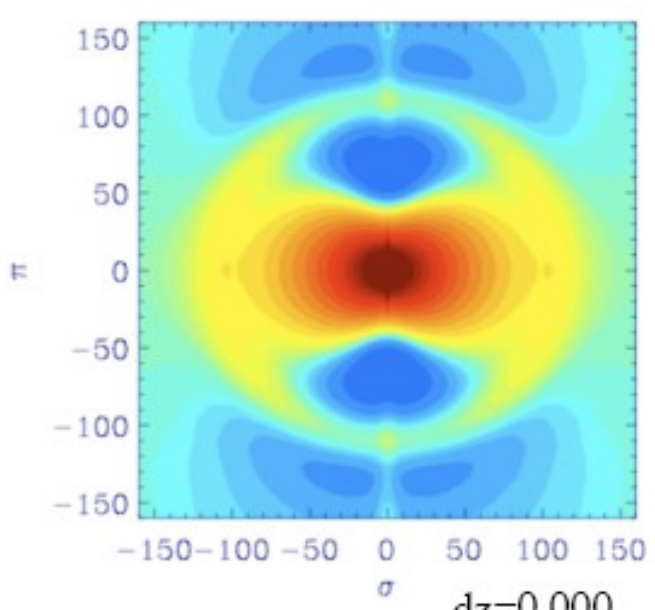
$P_\sigma(k_t,k_z) = P_{NL} \exp[-k_z^2 \Delta_z^2]$

Requirements on Redshift Precision



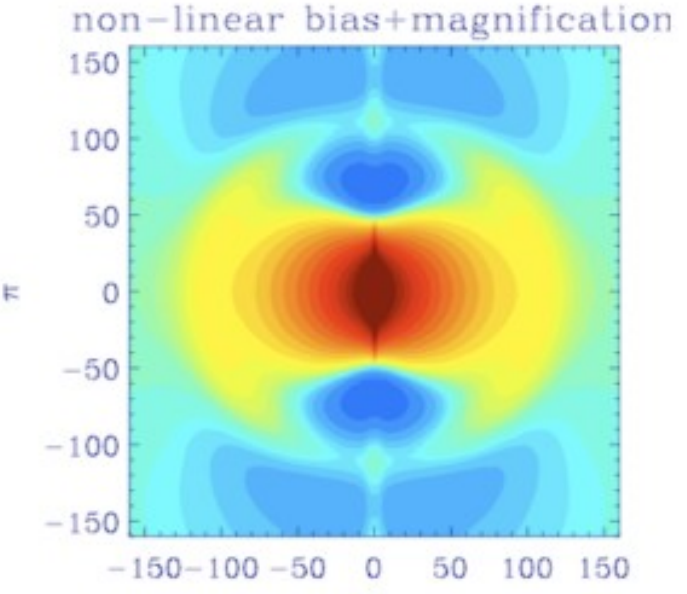


Padmanabhan

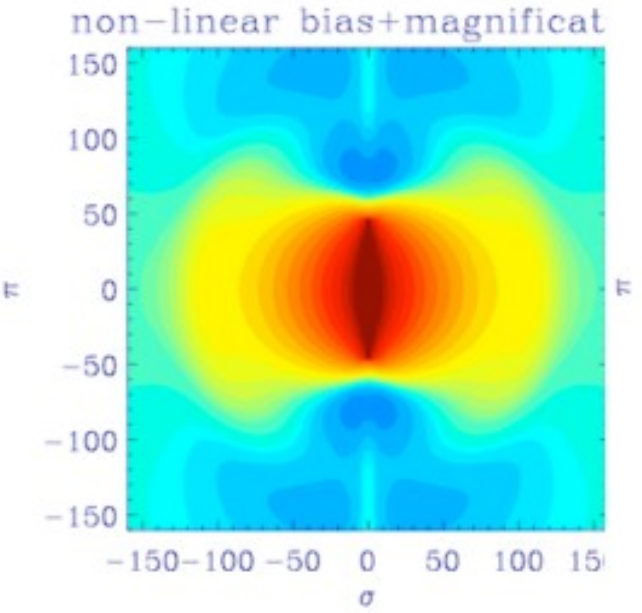


dz=0.000

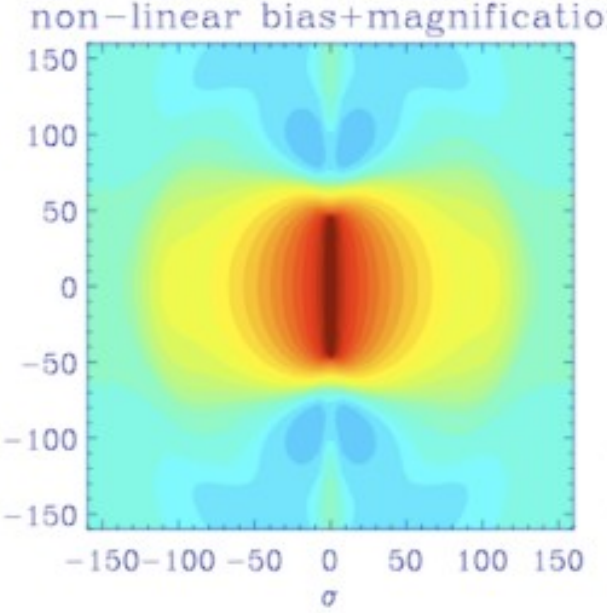
Redshift errors



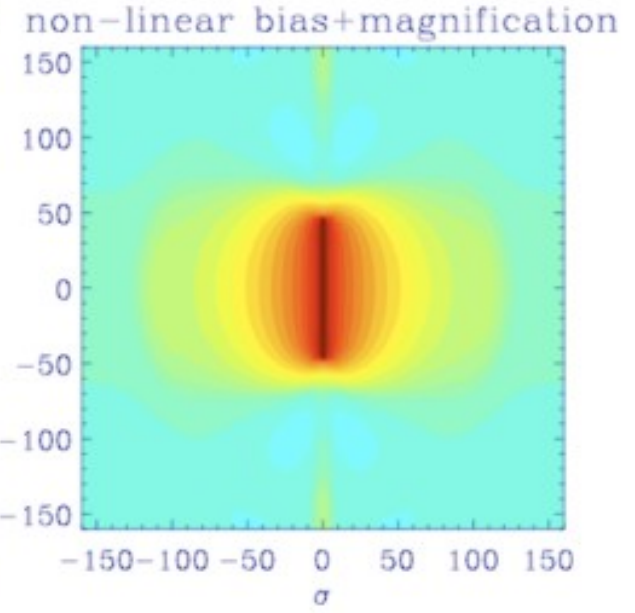
1000Km/s dz=0.003



2,000Km/s dz=0.006



5,000Km/s dz=0.016



10,000Km/s dz=0.033

PAU survey

- The main goal of the PAU survey is to study dark energy characterising the geometry and growth of structure of the universe
- Large volumes and moderately accurate redshift are needed for this purpose
- The idea is to use a large field of view camera and narrow band filters to achieve both
- The survey will use ~40 narrow band filters (~100 A wide) covering from 4500 to 8500 A supplemented by wide band filters to image the sky and measure the position and distance (using photometric redshift techniques) to millions of galaxies

PAU survey

- comparison with broad band imaging: ~20 times slower but gives access to science in the radial direction.
- comparison to multi-object spectroscopy: ~similar in surveying speed per unit area, but many more objects (no sparse sampling and the benefit of using several populations) and deeper

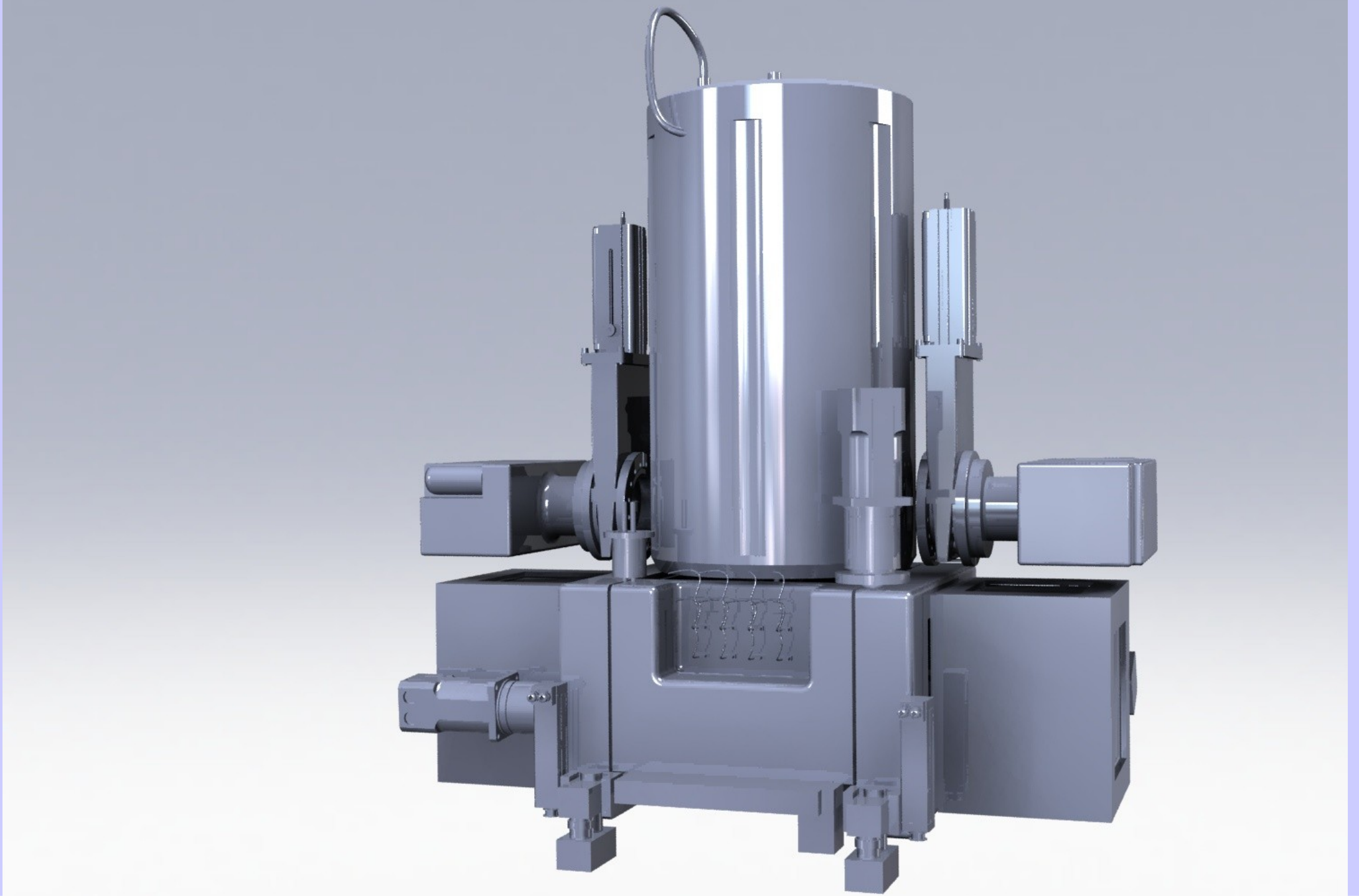
PAU survey

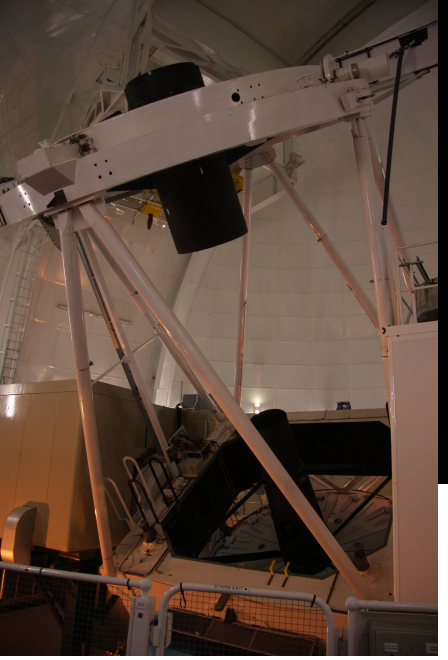
- The PAU collaboration is in the process of building a new large field-of-view camera to be installed in the current prime focus of the WHT reaching an etendue of ~7 to carry a large area survey

PAU camera

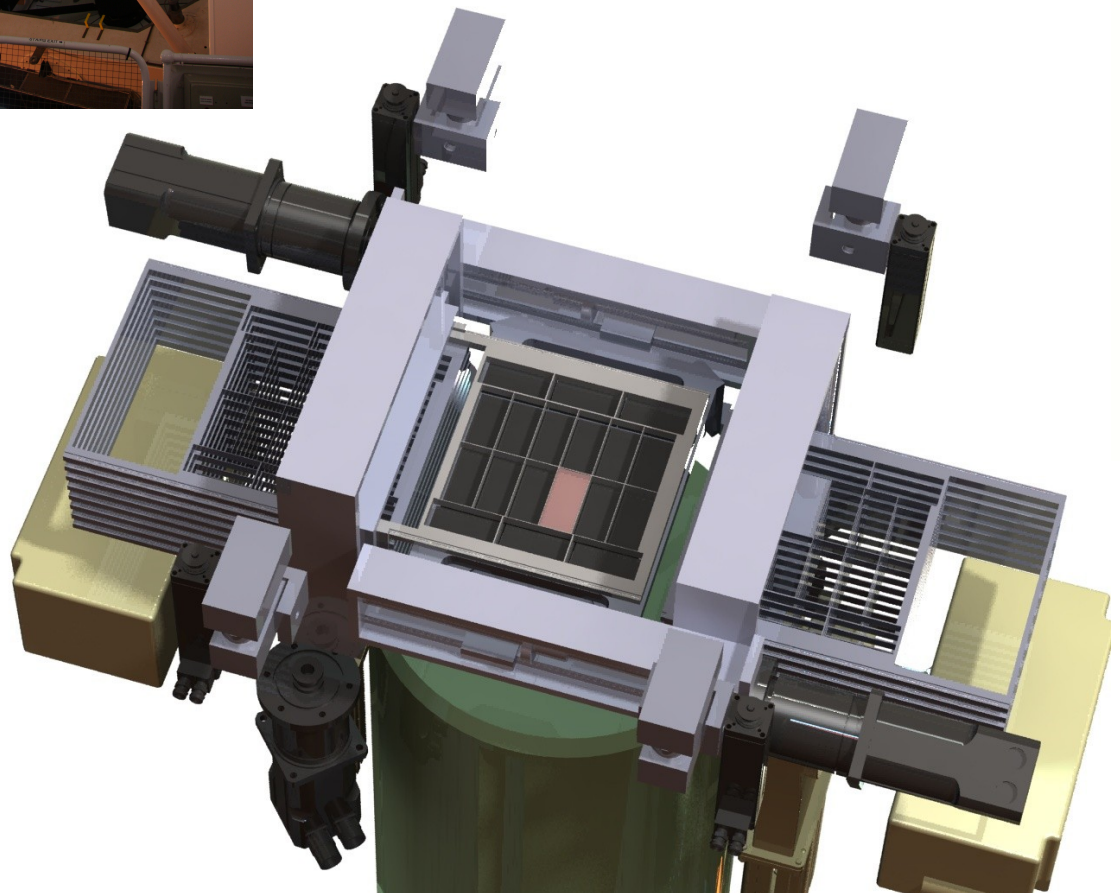
Main characteristics

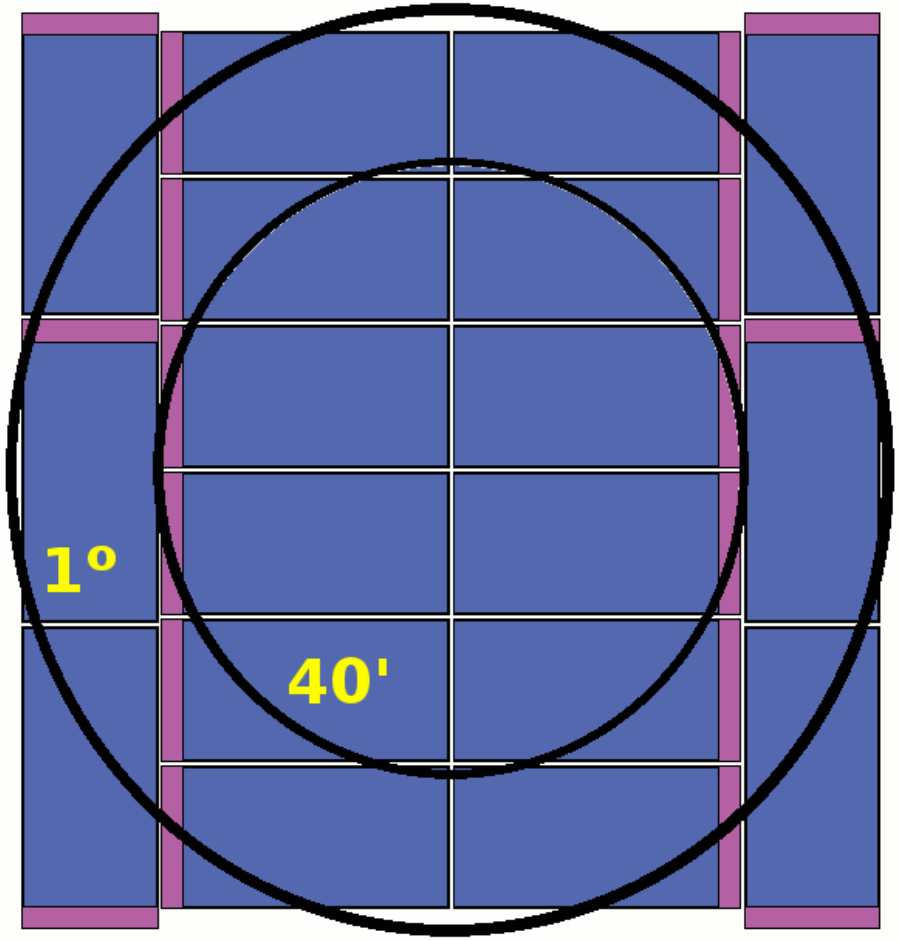
- Large field of view
- Narrow band filters + broad band filters
- good spectral sensitivity
- segmented filter trays

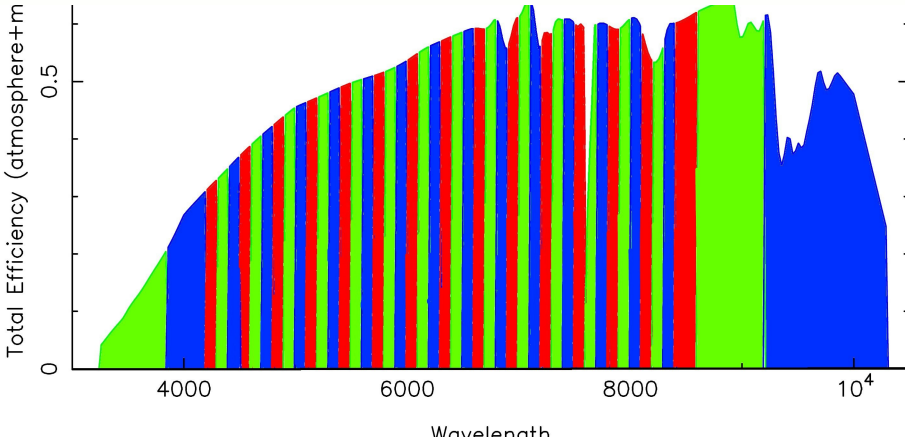




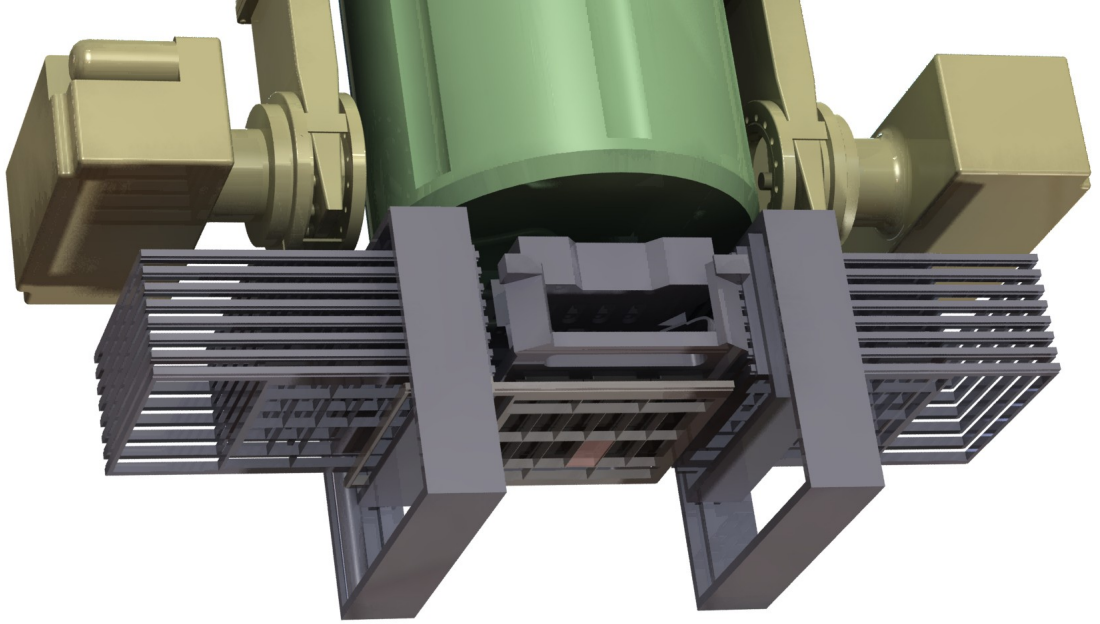
PAU camera

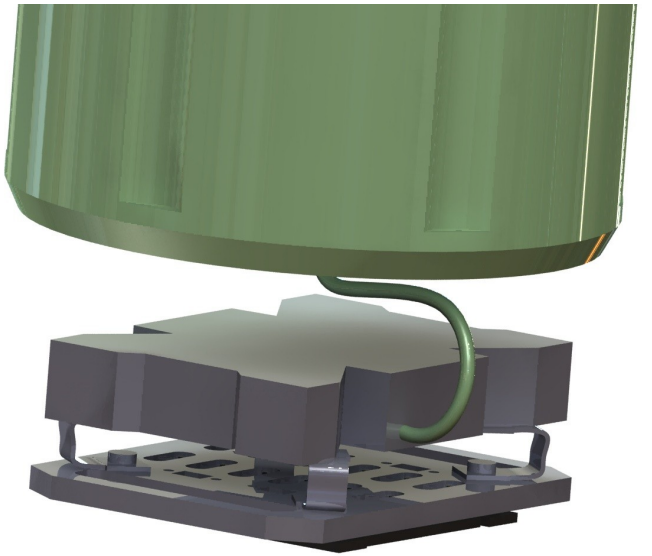


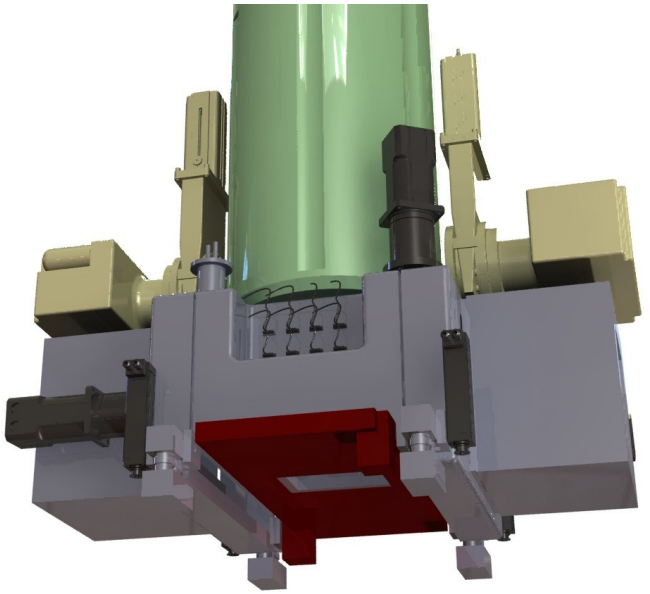

1º
40'

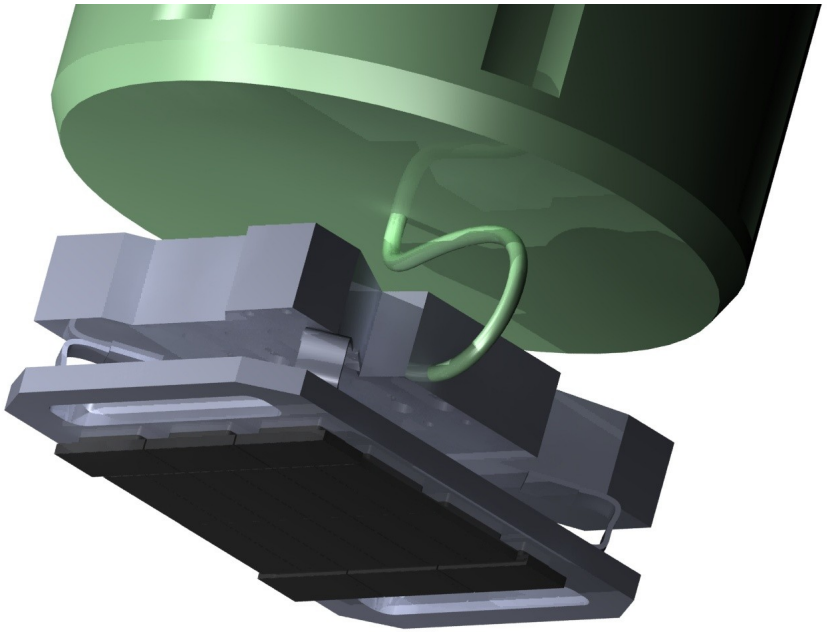

Total Efficiency (atmosphere+m
0
0.5
4000
6000
8000
10^4
Wavelength

PAU camera



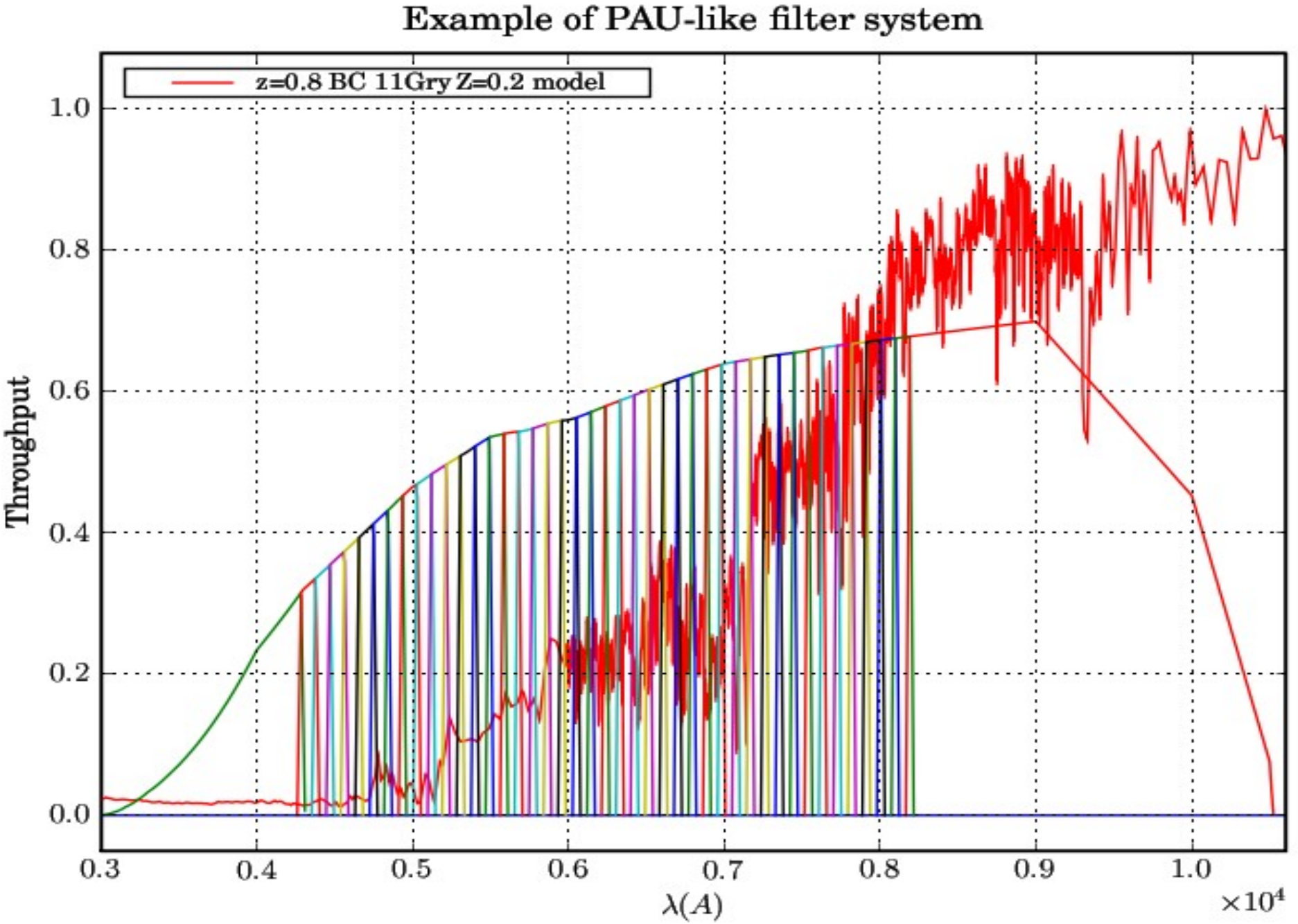






PAU survey

- The PAU collaboration is in the process of building a new large field-of-view camera to be installed in the current prime focus of the WHT reaching an etendue of ~7 to carry a large area survey
- The survey will obtain photometric redshift accuracy of dz/(1+z) <= 0.003 for early-type galaxies in the redshift range up to z~1


Example of PAU-like filter system
z=0.8 BC 11Gry Z=0.2 model
Throughput
1.0
0.8
0.6
0.4
0.2
0.0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
λ(A)
×10^4

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- It will have the surveying power of sampling ~2 deg^2/night to a depth of m_{AB}~23, obtaining simultaneously the SEDs of ~40000 galaxies, 5000 stars and 1000 quasars
- sampling the galaxy power spectrum will not be limited by shot-noise and could be traced with several tracers

PAU Survey & Camera

Although the survey is designed and optimized for cosmology, many other science topics could be addressed

- Galaxy evolution
- High redshift galaxies
- Interstellar dust
- Quasars and Lyα systems
- Clusters
- Weak gravitational lensing
- Strong gravitational lensing
- Galactic astronomy
- Stellar populations
- Halo stars
- Local group galaxies
- Serendipitous discoveries

PAU Camera at the WHT prime focus

- It will be the imaging system with largest surveying capabilities at the ORM
- It will be an instrument opento the use by the ING community: use it