The PAU Consolider

http://www.pausurvey.org

Ramon Miquel
ICREA / IFAE Barcelona

CPAN/Renata meeting, Barcelona, November 3rd 2011

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

PAU Consolider Personnel

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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 about to be signed.

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

The PAU@WHT Project in a Nutshell

- New camera for WHT with 18 2k x 4k CCDs covering 1 deg ∅ FoV.
- 36 100Å-wide filters covering 4650-8350 Å in 6 movable filter trays, which also include standard ugrizY filters.
- As a survey camera, PAUCam covers ~2 deg^2 per night in all filters.
- It can provide low-resolution (R~50) spectra for >30000 galaxies, 5000 stars, 1000 quasars, 10 galaxy clusters, per night.
- Main science goal is dark energy, with two main probes:
  - Redshift-space distortions
  - Weak-lensing magnification
- For both probes, PAU's large galaxy density (compared to spectroscopic surveys) and high redshift accuracy (compared to broadband photometric surveys) combine to provide a competitive determination of the dark energy parameters.
- First light expected in Fall 2012

PAU@WHT Personnel

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

PAUCam PI: F. Castander
Project Manager: C. Padilla. **System 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. **Operation**: N. Tonello. **Data Reduction**: S. Serrano. **QA & Validation**: I. Sevilla

The Survey Team

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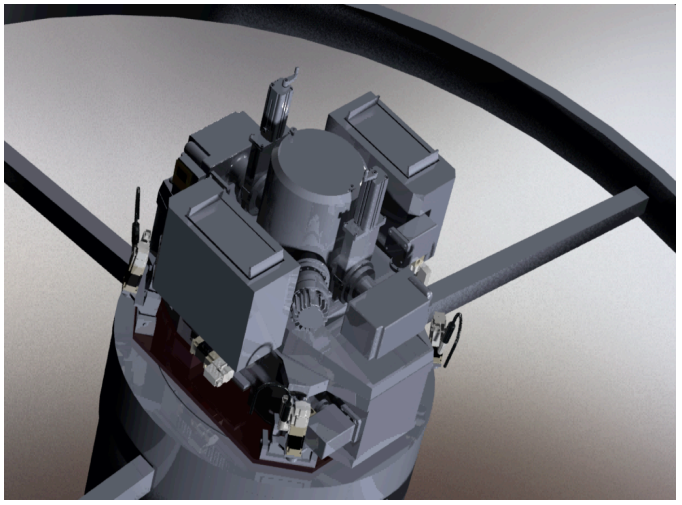
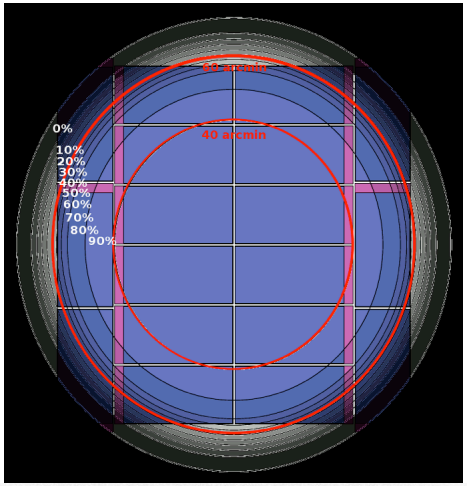
3 IFAE — Institut de Física d'Altes Energies — UAB Universitat Autònoma de Barcelona

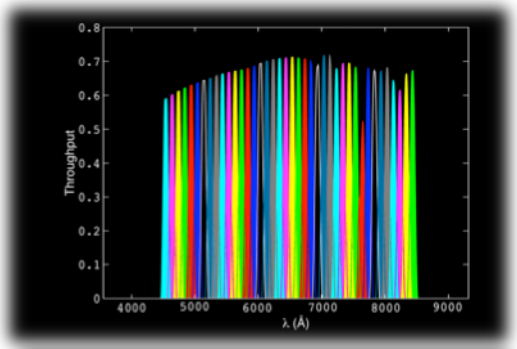
4 ift — Instituto de Física Teórica UAM/CSIC

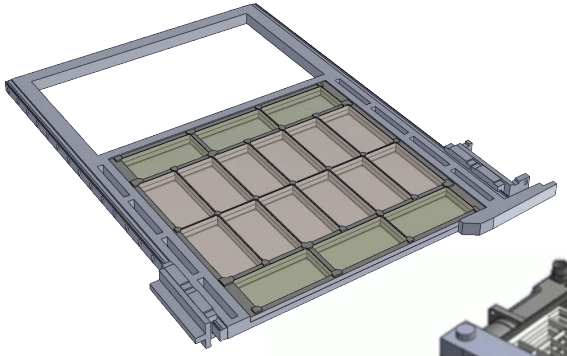
5 PIC port d'informació científica

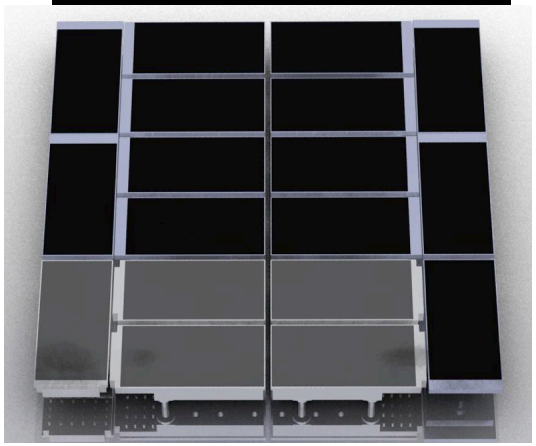
The PAUCam Camera at WHT in Pictures

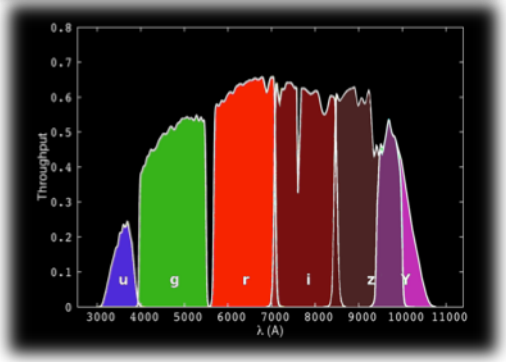


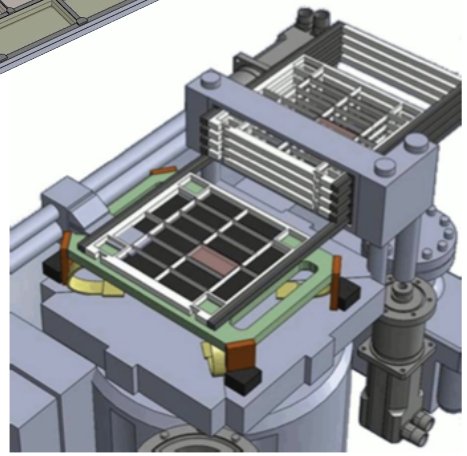






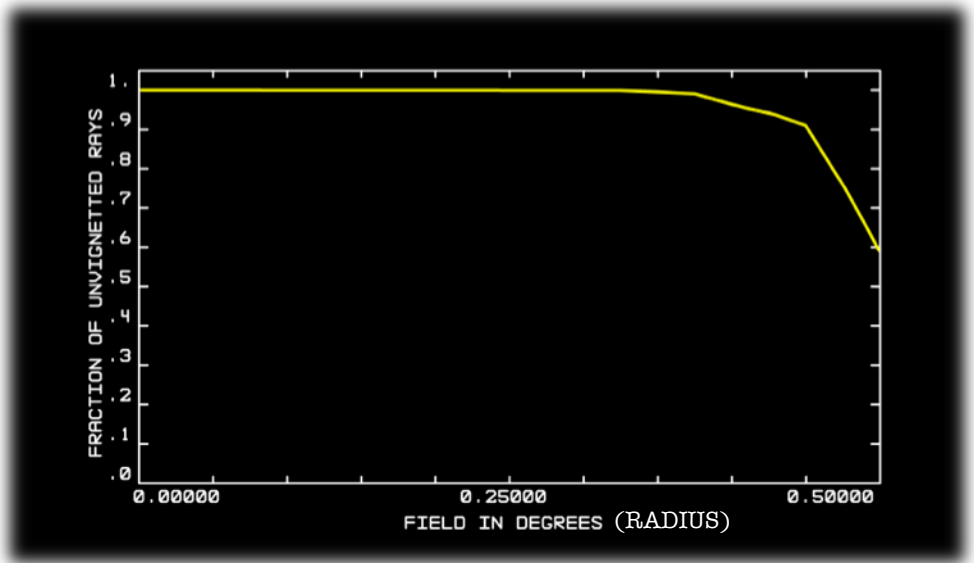


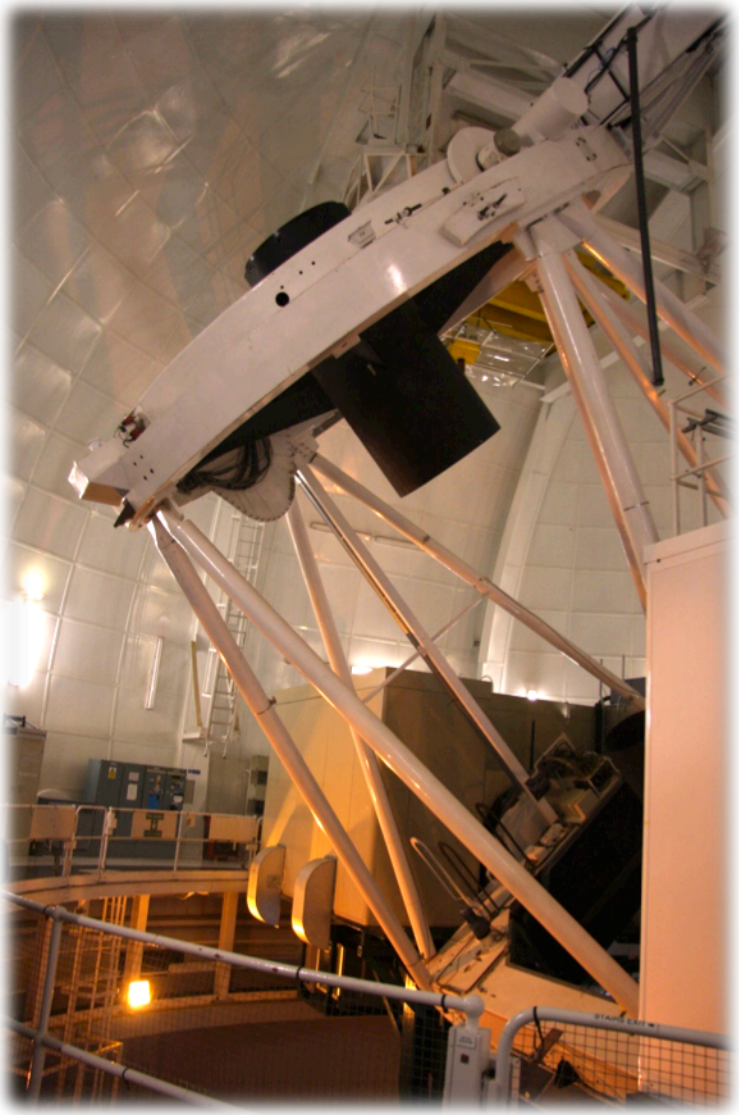




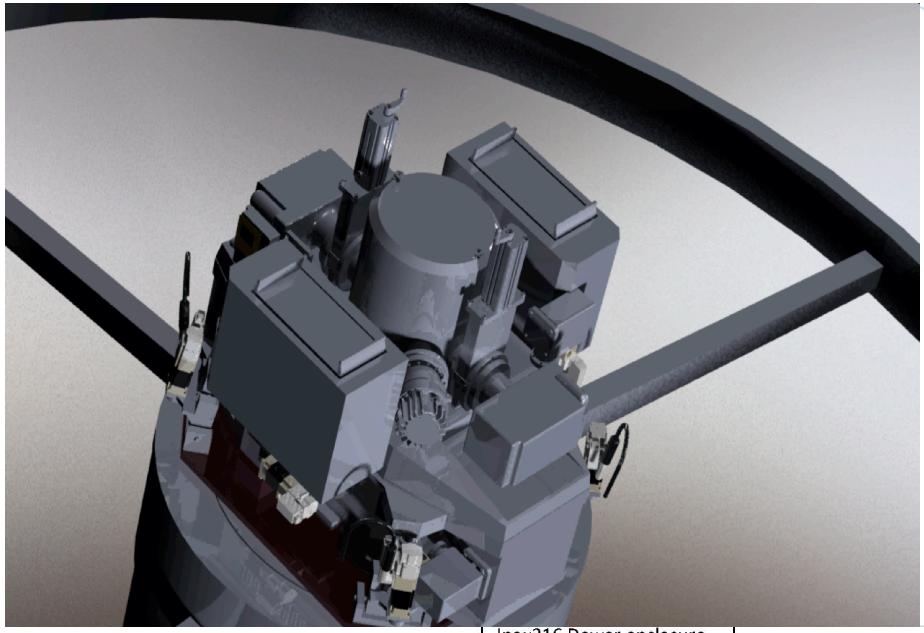
William Herschel Telescope (WHT)

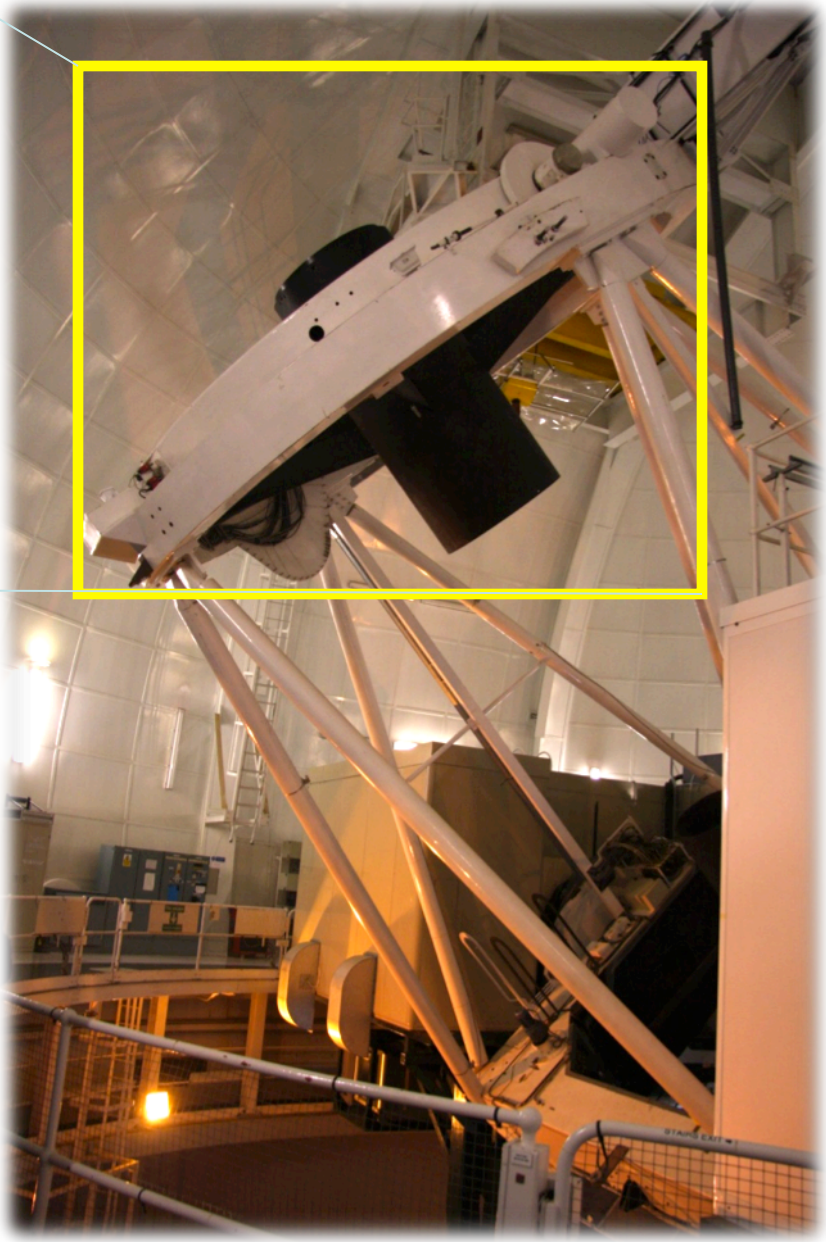
- Located in the ORM, La Palma
- Used by UK, Netherlands & Spain
- Highly oversubscribed
- High scientific output so far
- Diameter: 4.2 m
- Prime focus: 11.73 m
- Focal ratio: f/2.8
- FoV: 1 deg ∅, 40’ unvignetted
- Scale: 17.58”/mm ⇔ 0.26”/pixel

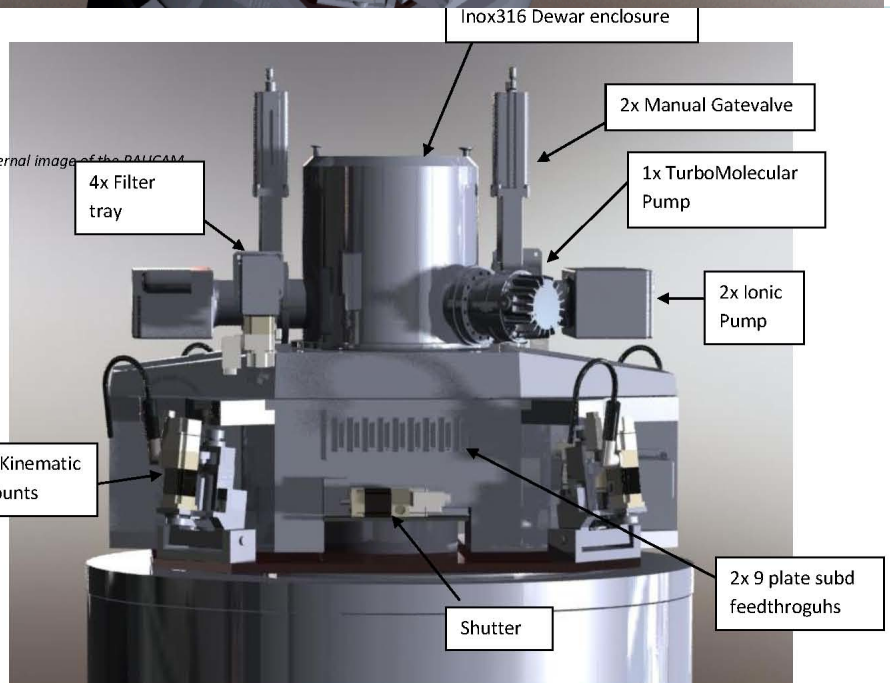




PAUCam



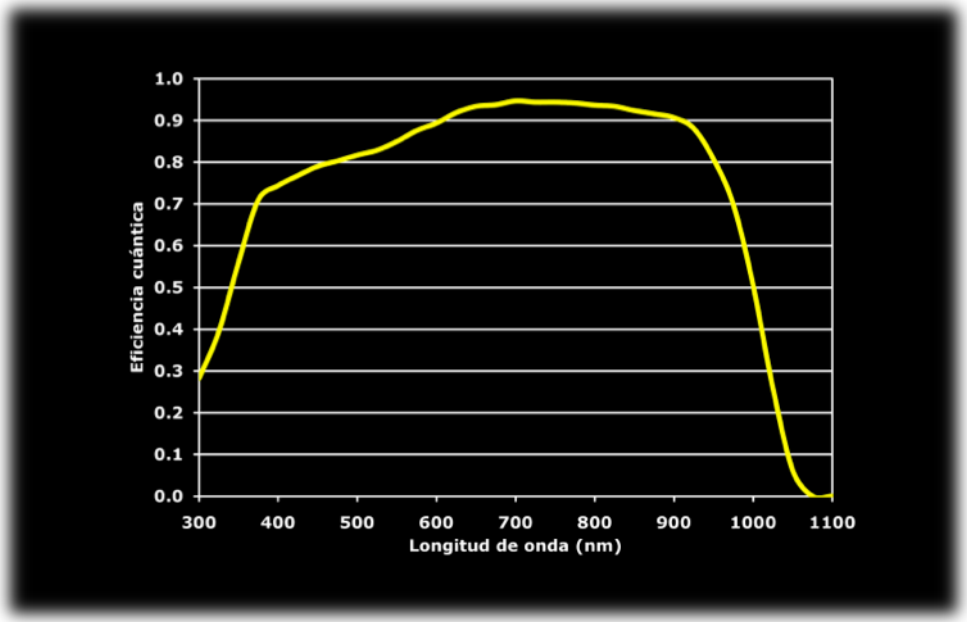


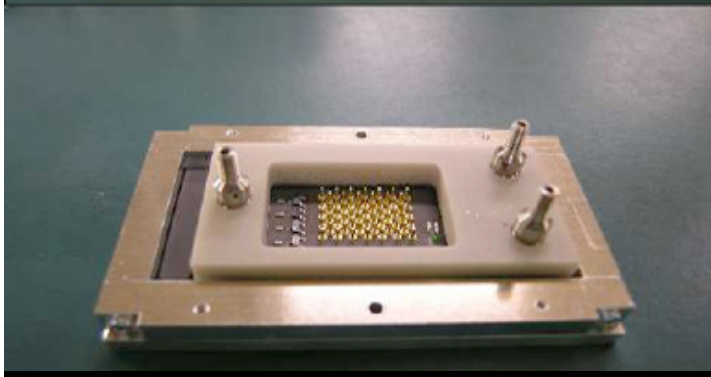

Inox316 Dewar enclosure
2x Manual Gatevalve
External image of the PAUCAM
4x Filter tray
1x TurboMolecular Pump
2x Ionic Pump
4x Kinematic mounts
2x 9 plate subd feedthroguhs
Shutter

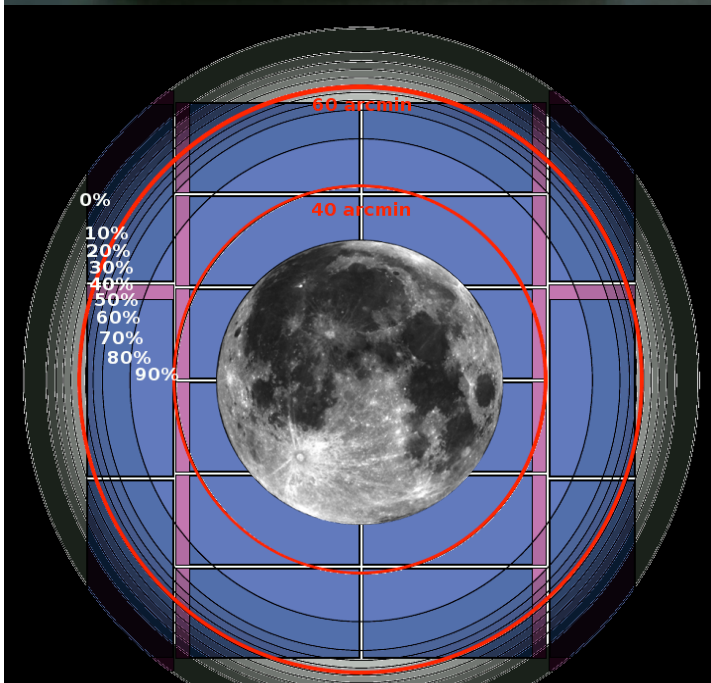
PAUCam Detectors

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



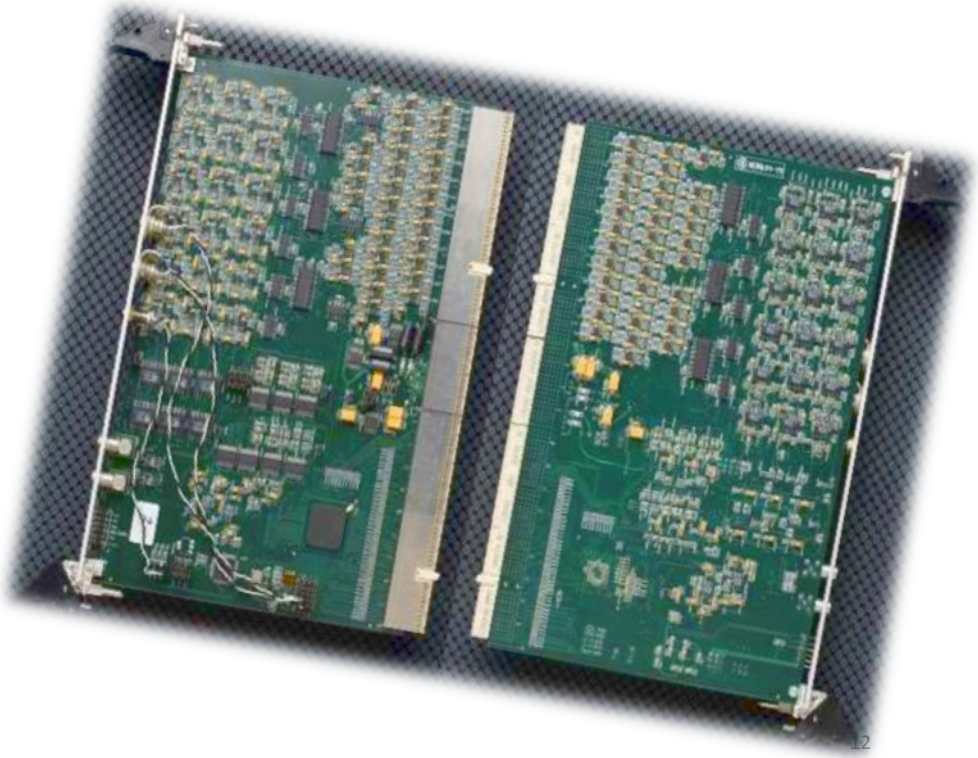




PAUCam Electronics

Monsoon architecture (NOAO)

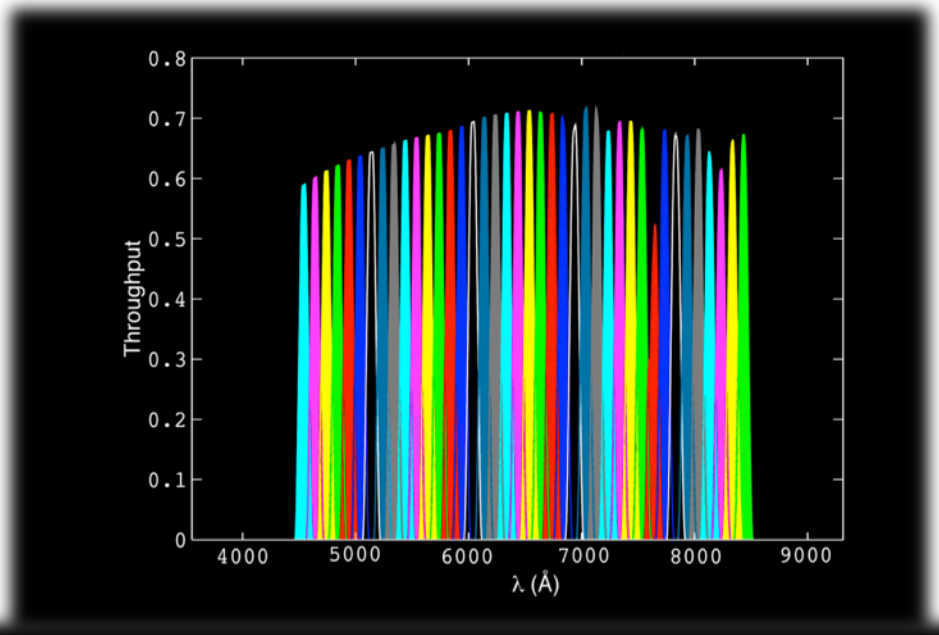
- Same as used for DES (CIEMAT and IFAE)
- 3 clock and bias board
- 7 acquisition boards
- 3 master boards
- 18 pre-amp & routing boards

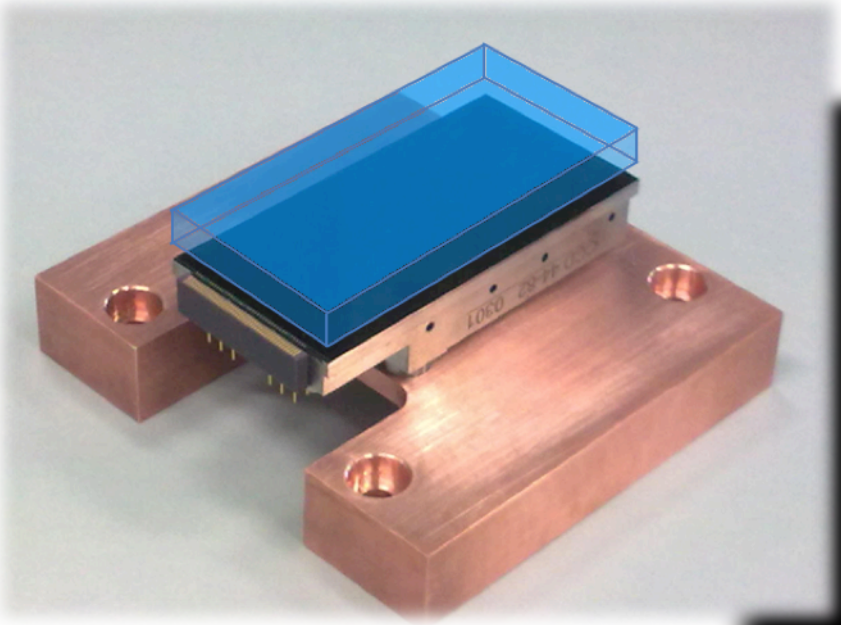


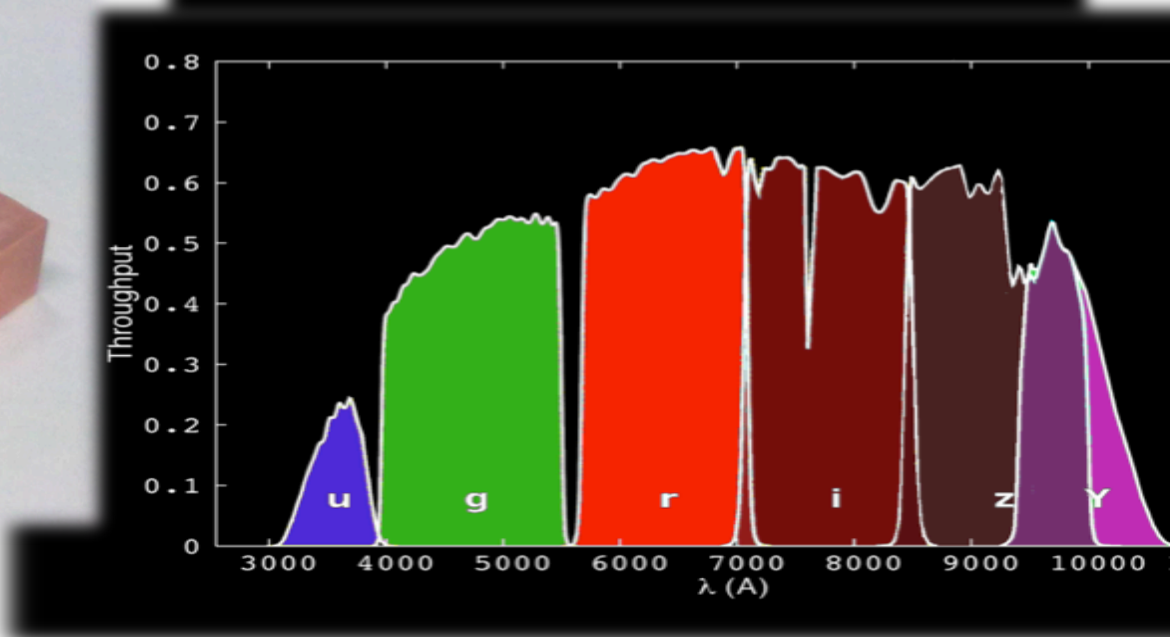
PAUCam Filter System

- 36 narrow-band filters
- FWHM = 100 Å
- Spectral range: λ=4650-8350 Å
- Rectangular transmission profile

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

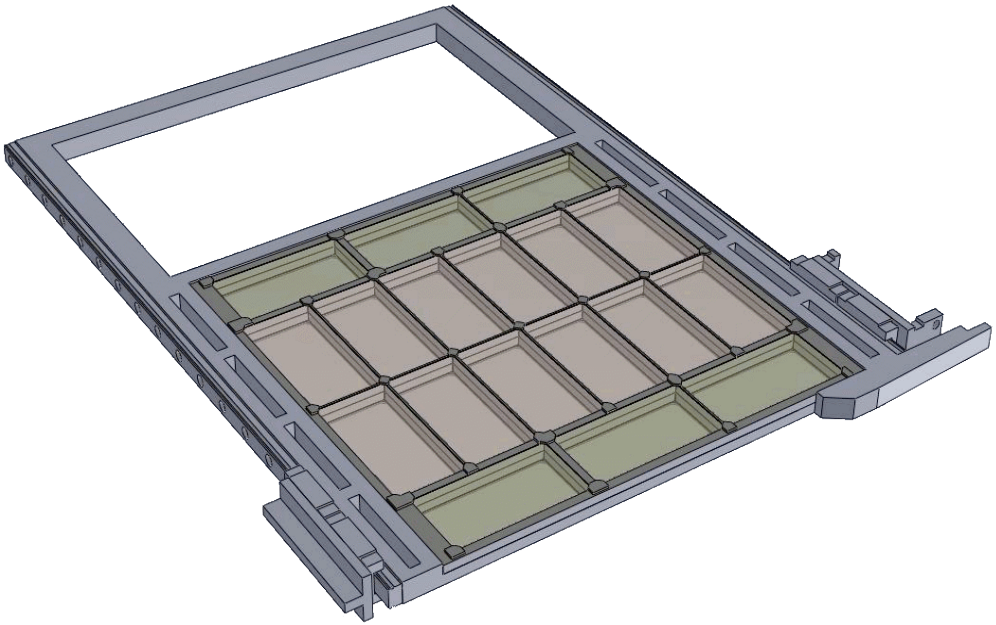


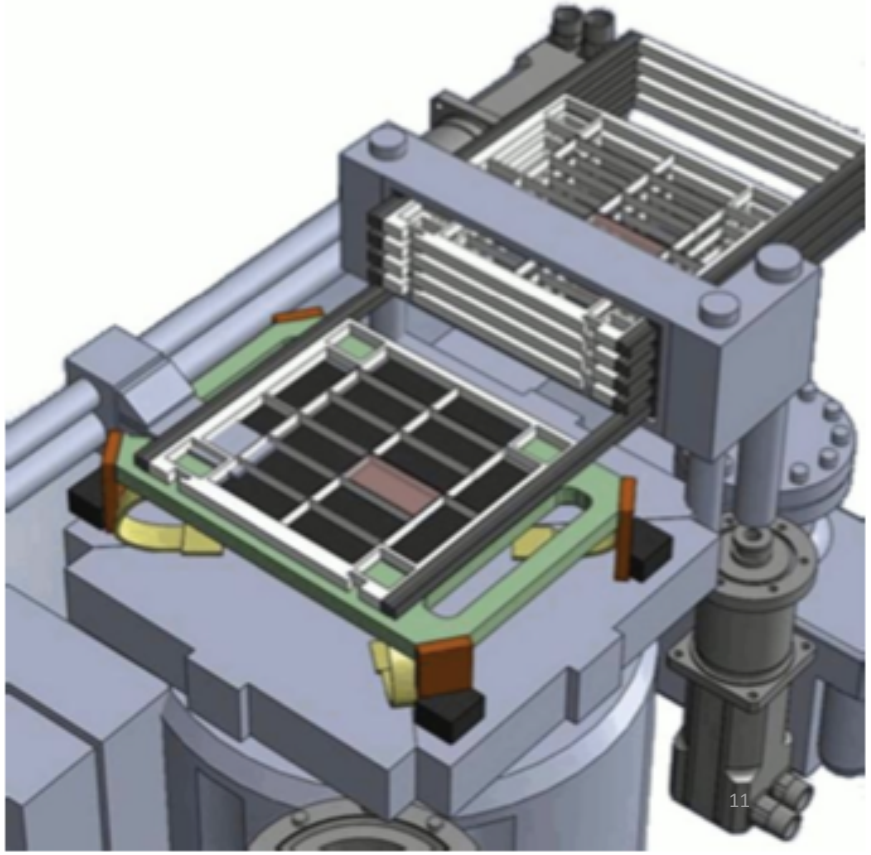




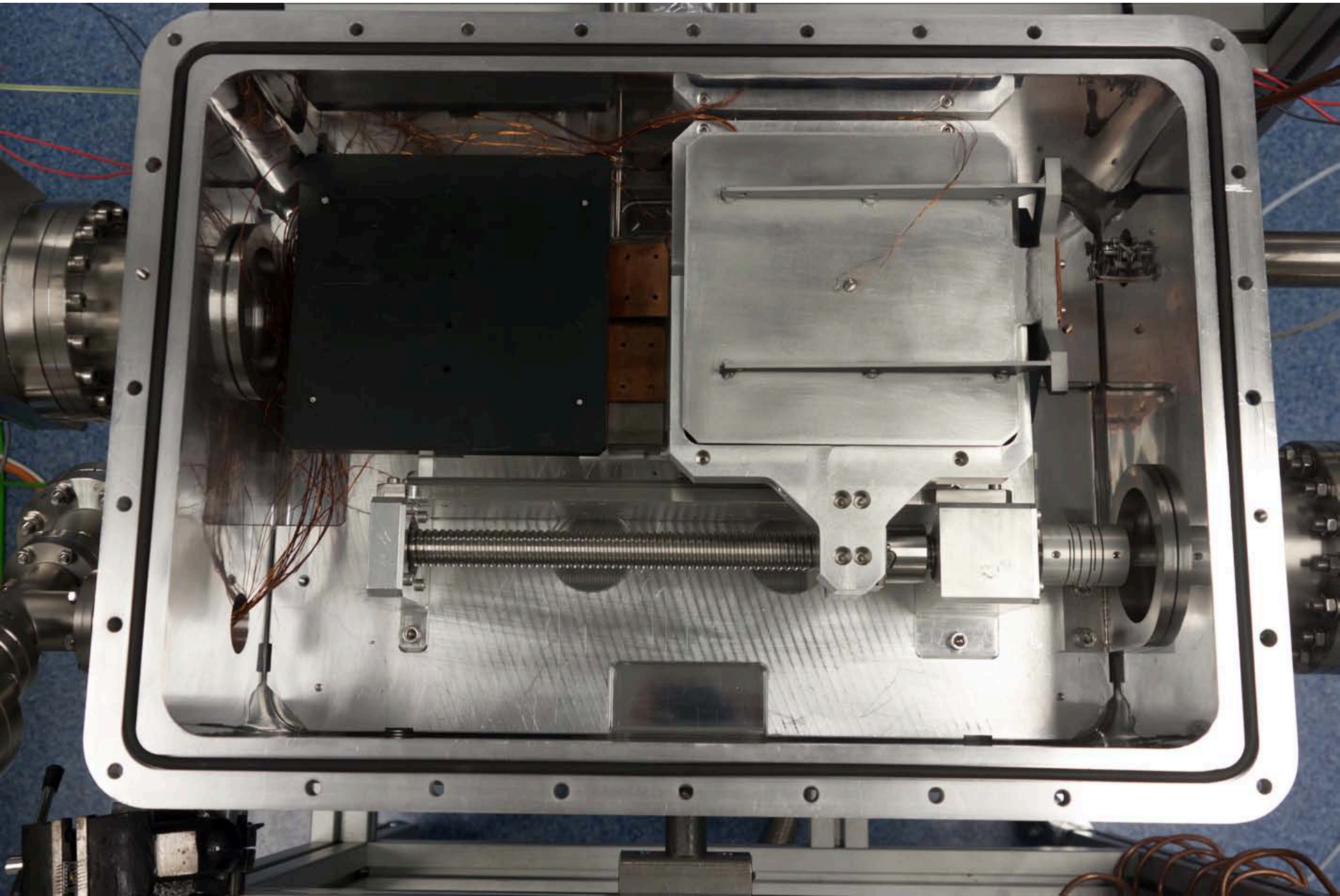
PAUCam Filter Trays

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

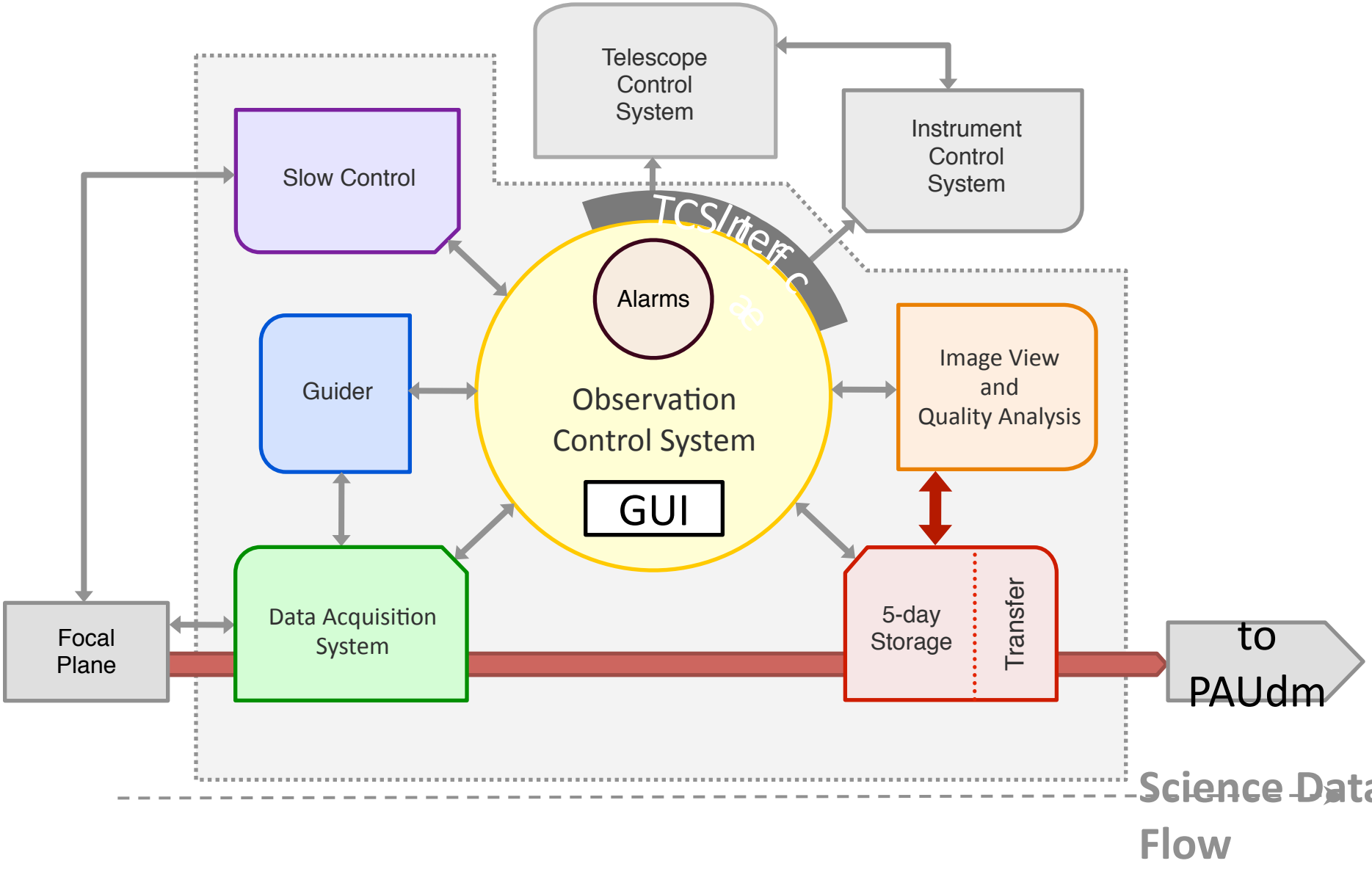




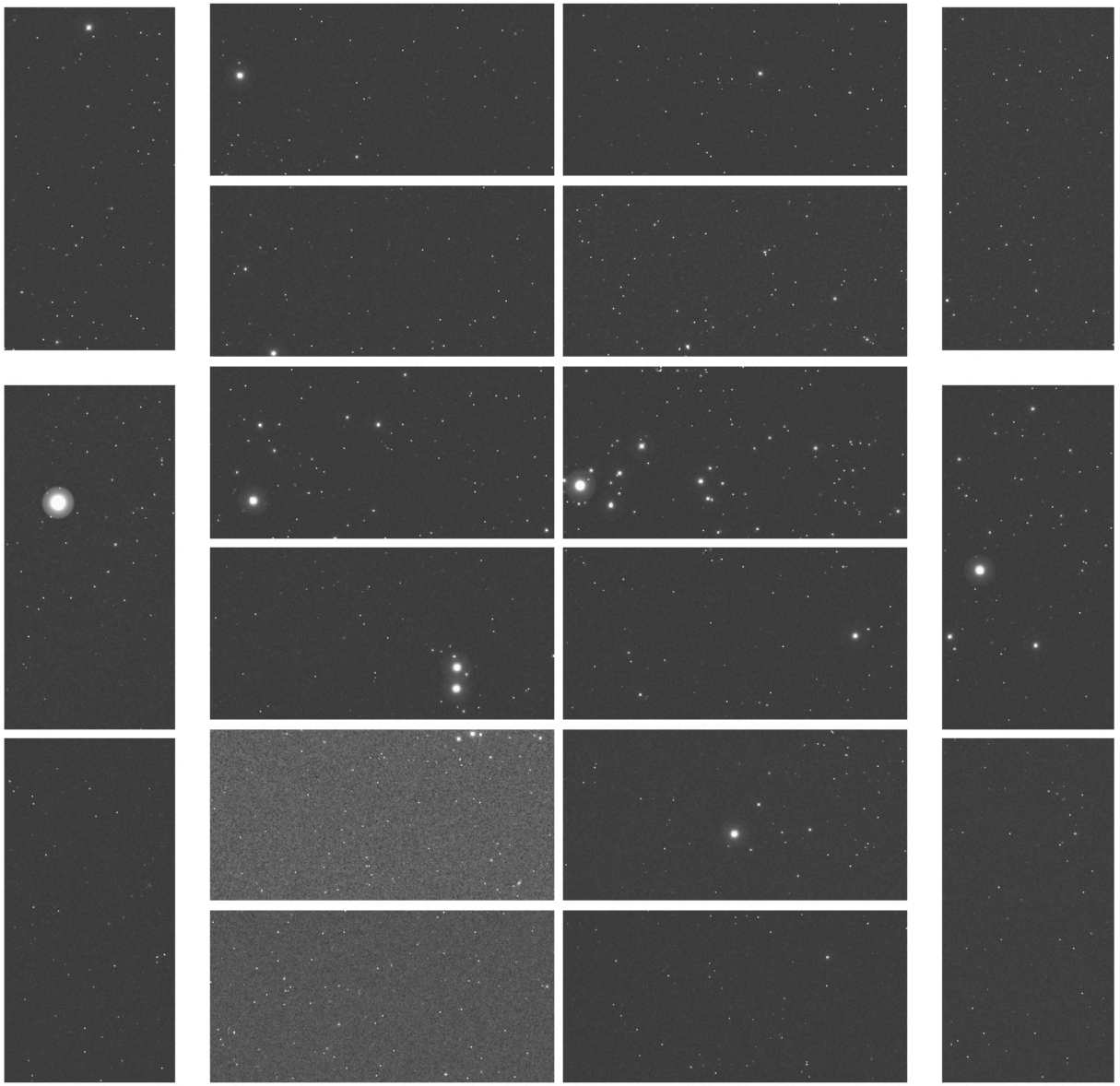
July 27th, 2011

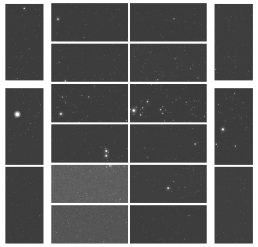


PAUCam Control System



PAUCam Simulations

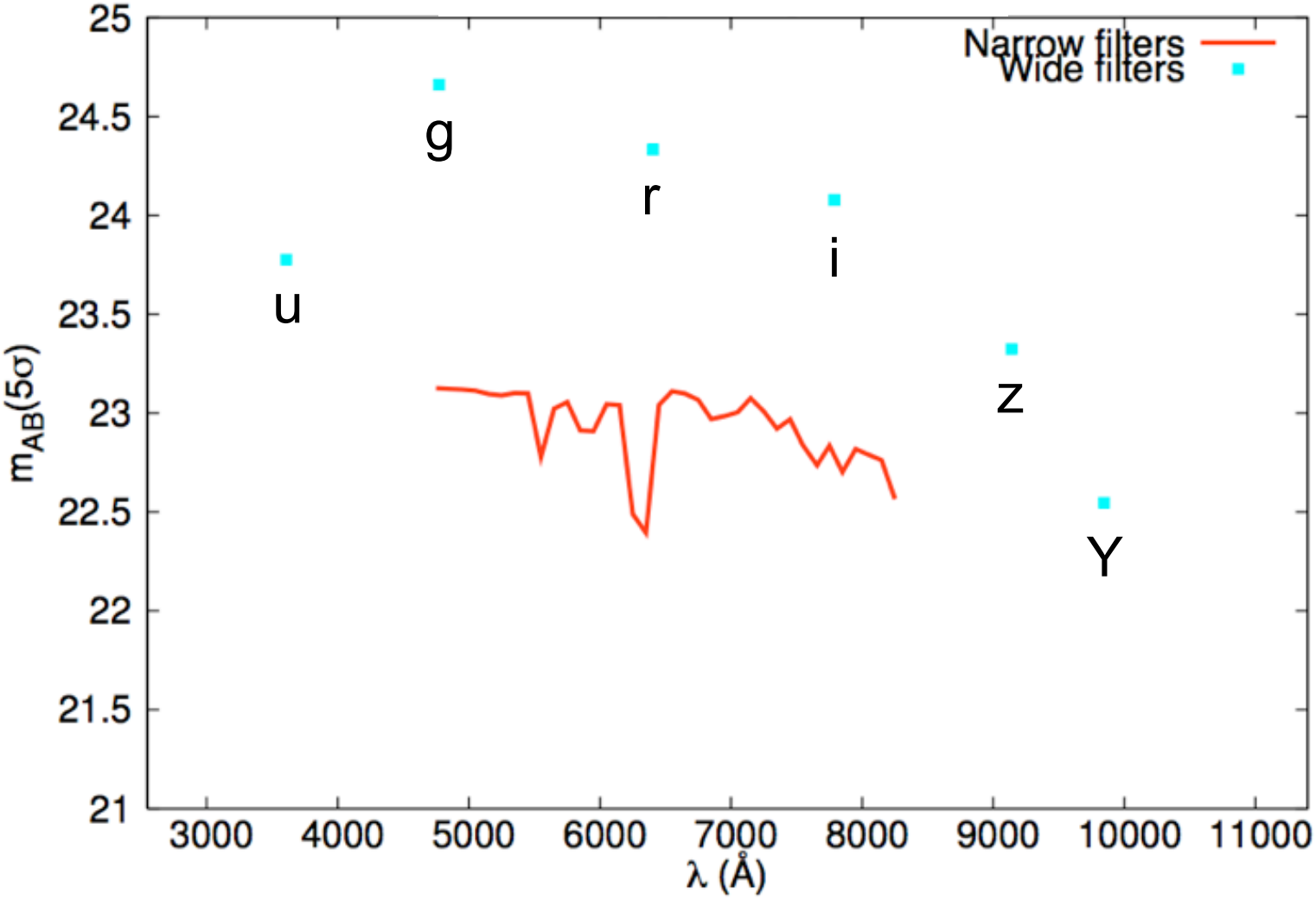




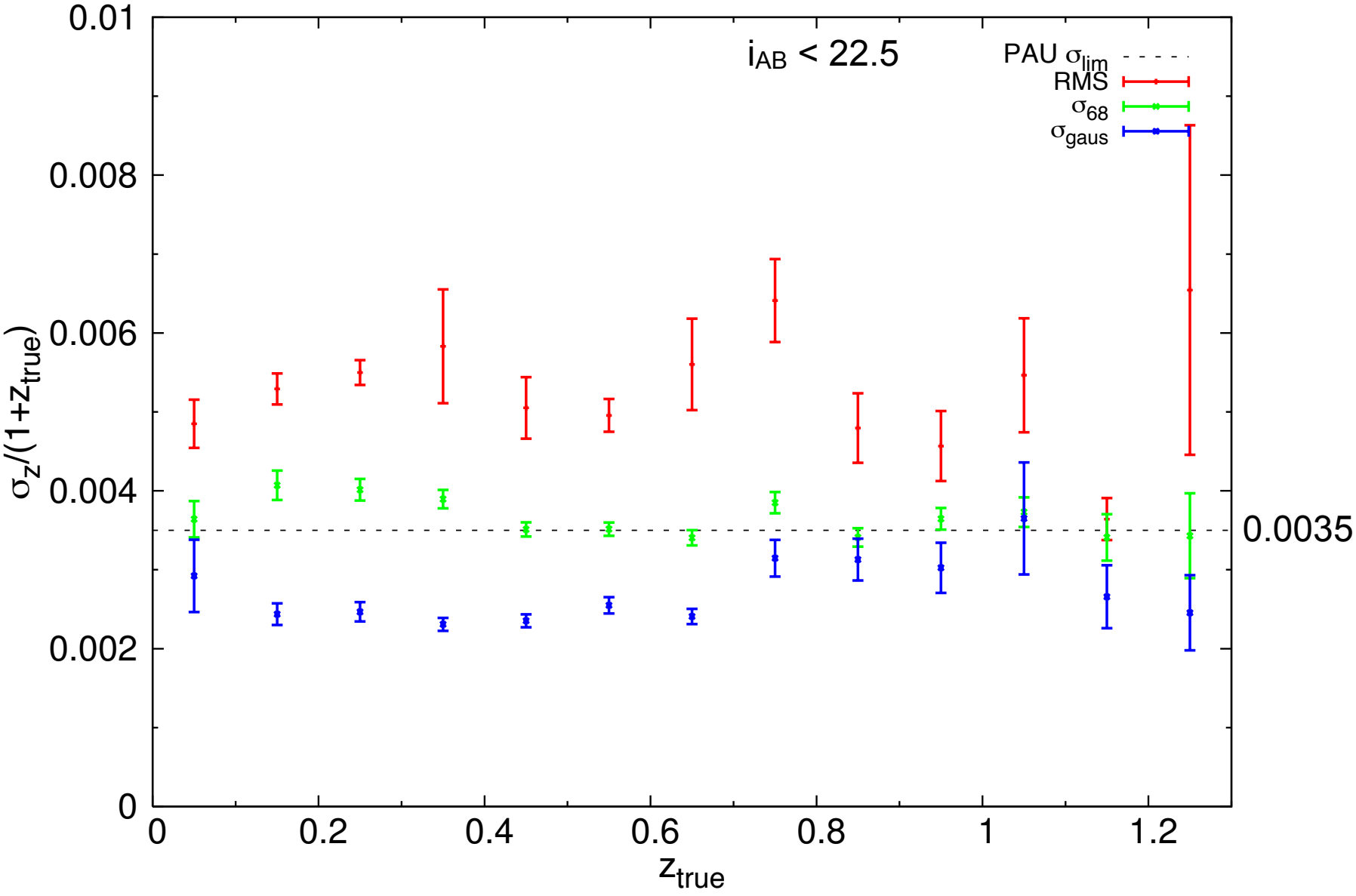
PAU Survey Strategy

- Use 8 central CCDs to define the survey strategy, use the other CCDs to increase S/N.
- Each central CCDs covers the whole survey area twice.
- 6 filters trays with 8 filters (6 NB + 2 BB).
- Broad bands reach 1.2 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)



Redshift Performance



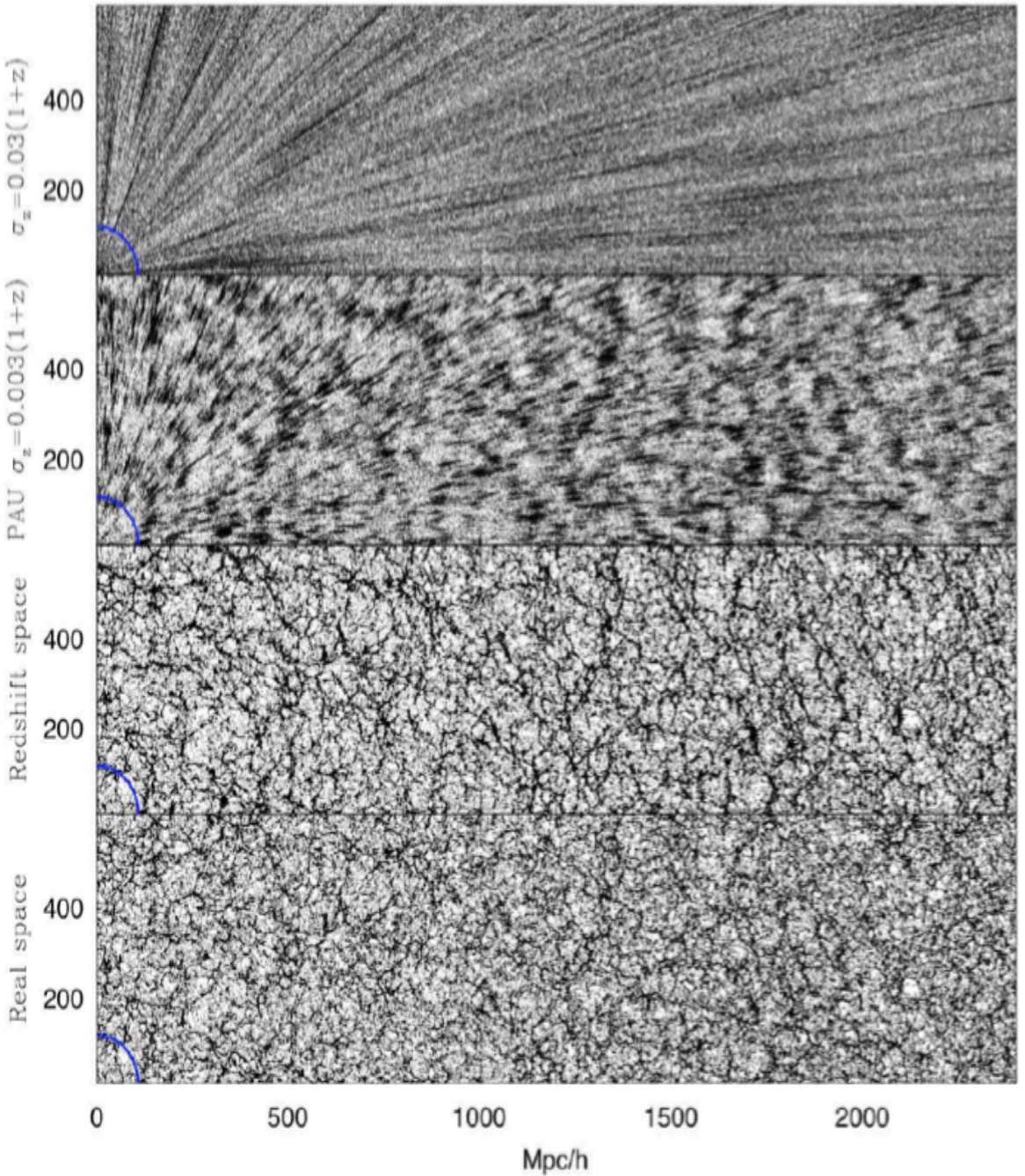
Visual illustration of the importance of redshift resolution

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

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

z-space, perfect resolution
+ peculiar velocities

Real space



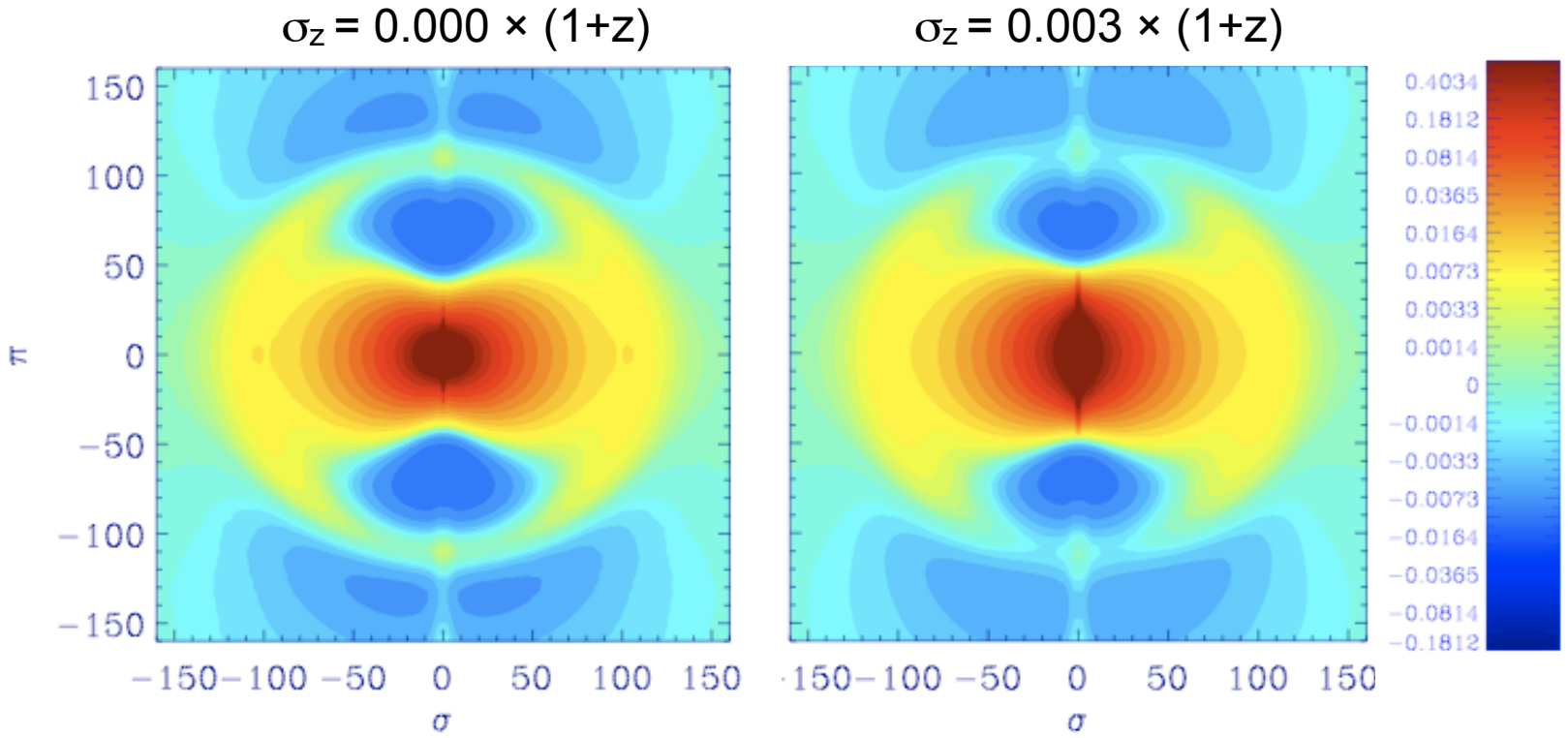
PAU Science

- Survey strategy produces two samples:
  - "Spectroscopic" sample: good 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 emphasis:
  - 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-correlations of both samples on the same area

Gaztañaga et al., astro-ph/1109.4852

PAU's Primary Science Drivers (I)

- Redshift-space distortions (RSD):
  - Peculiar velocities of galaxies trace the matter density fields
  - Anisotropies in the galaxy 2-point correlation function measure the growth of structure at a given redshift: probe of dark energy
  - Relevant scales are ~10 Mpc/h, well matched to PAU's z precision



PAU's Primary Science Drivers (II)

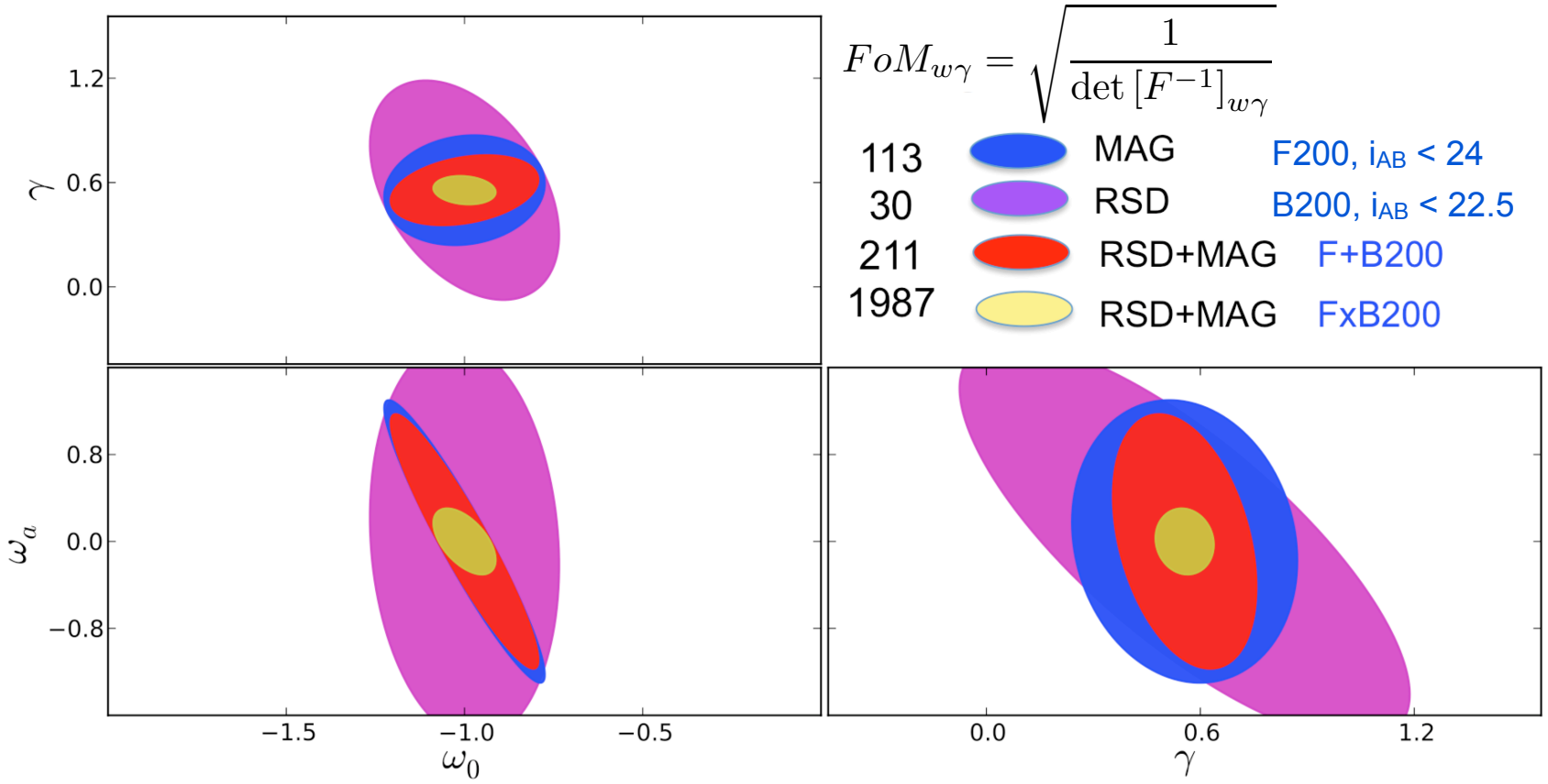
- Lensing magnification (MAG):
  - Gravitational lensing affects the measured galaxy number density
  - Main observable is the cross-correlation between galaxies in different redshift bins as a function of angular separation
  - Very precise photo-z's allow PAUCam to perform **cross-correlations between well-defined narrow redshift bins.**
  - Probes dark energy through both growth of structure and geometry

For both probes, PAU's large galaxy density (compared to spectroscopic surveys like BOSS) and high redshift accuracy (compared to broadband photometric surveys like DES) combine to provide a competitive determination of the dark energy parameters

PAU Survey Science Reach

- The **combination of RSD and MAG in the same data set** is very powerful in breaking degeneracies between cosmological parameters ➔ **a unique advantage of PAU.**

- **Figures of merit** with free Ω_m, Ω_{DE}, h, σ_8, Ω_b, w_0, w_a, γ, n_s, 4 bias parameters.



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
- ....

Status and Plans

- Construction of PAUCam has started.
  - Mechanical, vacuum and cryogenic challenges solved.
  - CCDs in hand, being characterized. Filters to be ordered this month.
  - Control system hardware in hand, software being written.
- Data management system designed, being written.
- An MoU is just being signed with ING.
  - MoU contemplates ample time allocation for the survey (for a price...).
- Discussions have started with a British group that wants to join the project.
- Compelling science case based on complementarity of spectroscopic and imaging characteristics.
- We hope to start the survey in late 2012.