The KMOS Multi-Object Near-Infrared Integral Field Spectrograph

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and the KMOS Team

ESO 3D2014 11th March 2014

Talk Outline

- Science Requirements
- Technical Description
- Commissioning Results
- Data Reduction Pipeline
- Early GTO/SV Science

Science Case

[1] Cluster Formation and Morphology-Density Relation

[2] The Masses and Growth of Field Galaxies

[3] Extremely High-Redshift Galaxies and Re-ionisation

[4] The AGN-Galaxy Formation Connection

[5] Age-Dating Ellipticals at z=2 to 3

[6] Stellar Populations in Nearby Galaxies

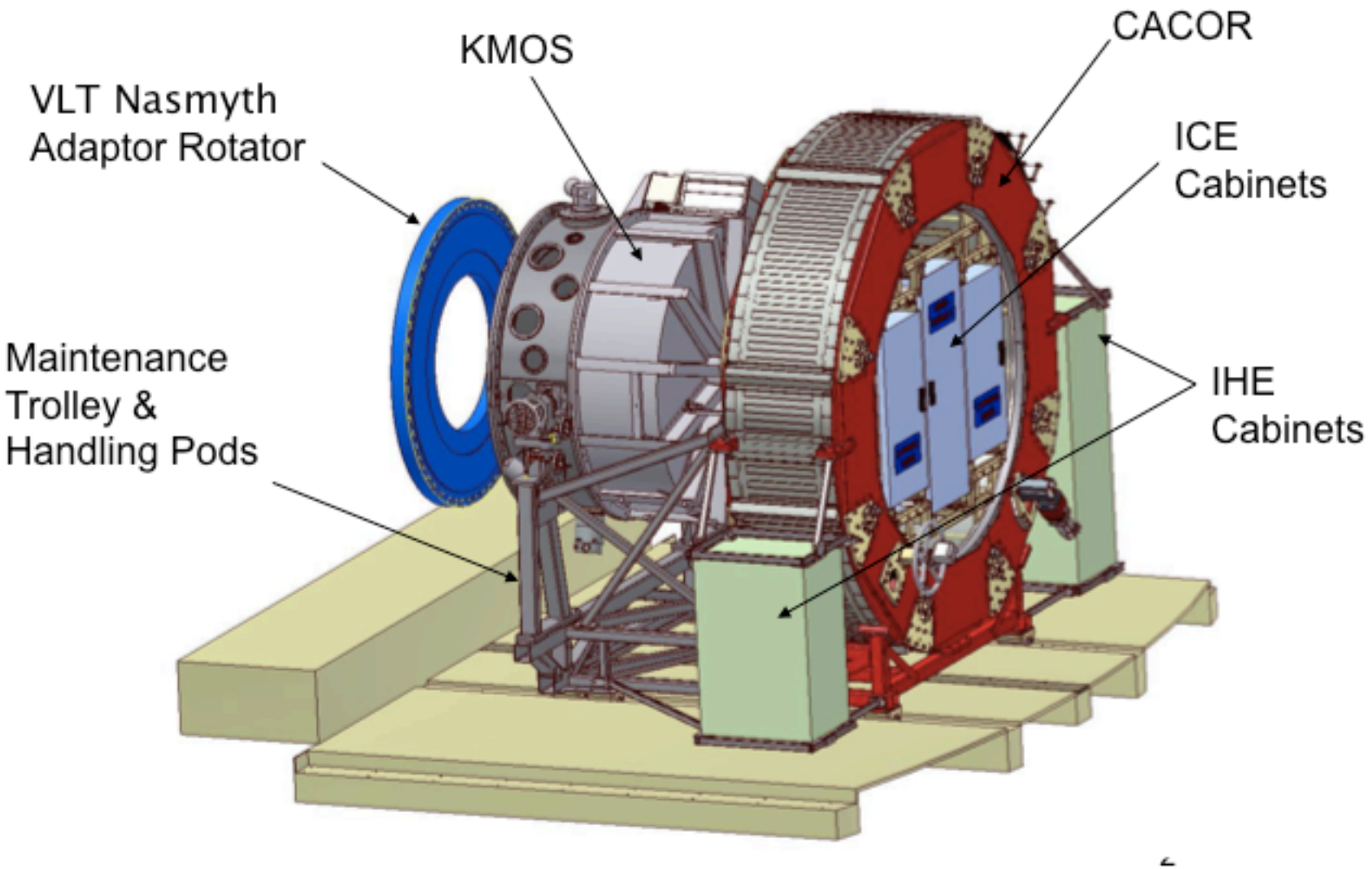
[7] Galactic Astronomy

(Phase A Report Sep 2003)

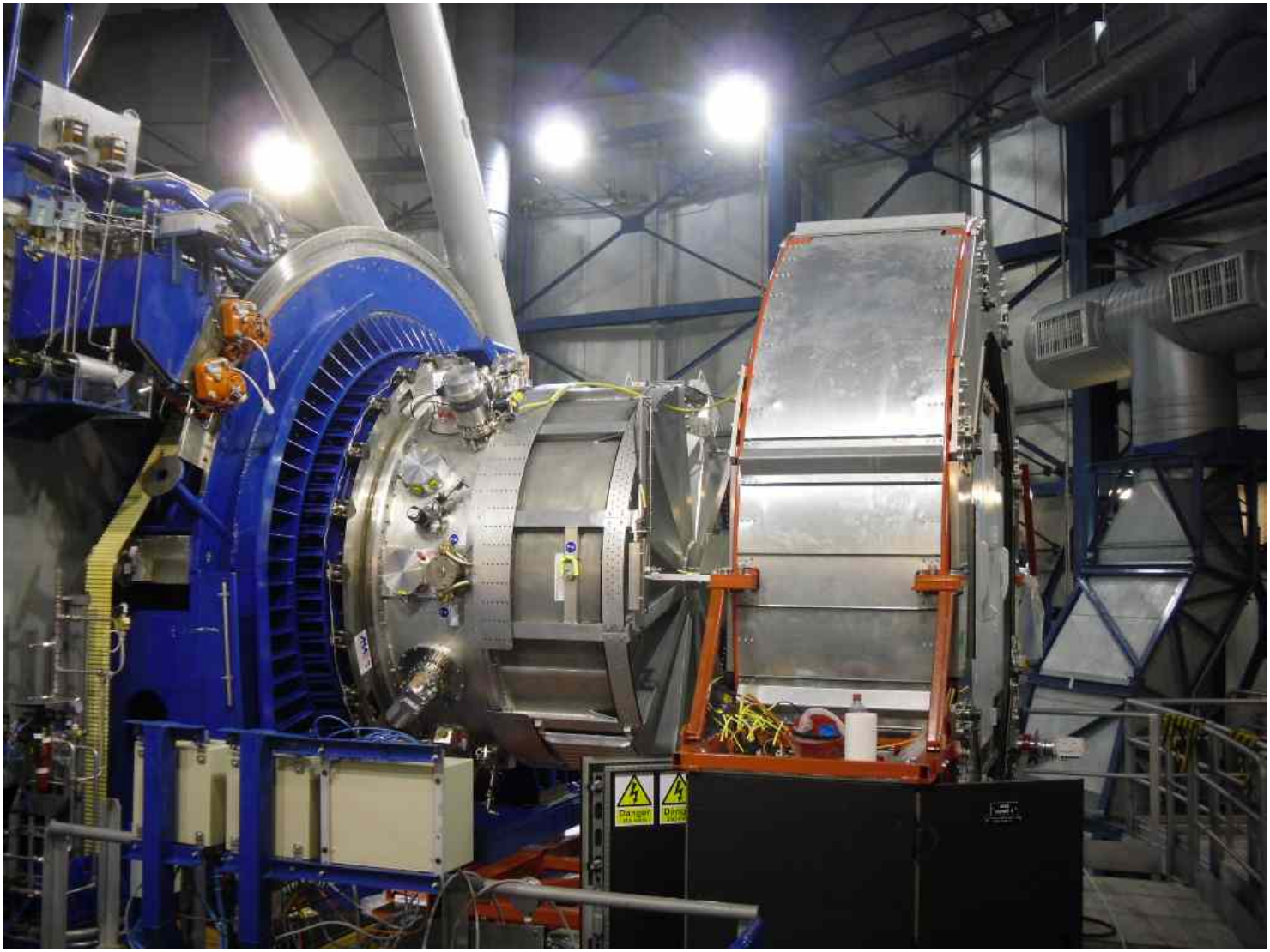
Functional Requirements

Requirement	Value
Throughput	IZ>20%, YJ>20%, H>30%, K>30%
Wavelength coverage	0.85 to 2.5 μm
Spectral Resolution	R>3300,3400,3800,3800 (IZ,YJ,H,K)
Number of IFUs	24
Extent of each IFU	2.8 x 2.8 sq. arc seconds
Spatial Sampling	0.2 arc seconds
Patrol field	7.2’ diameter field
Close packing of IFUs	≥3 within 1 sq arcmin
Closest approach of IFUs	≥2 pairs separated by 6 arcsec

Instrument Overview



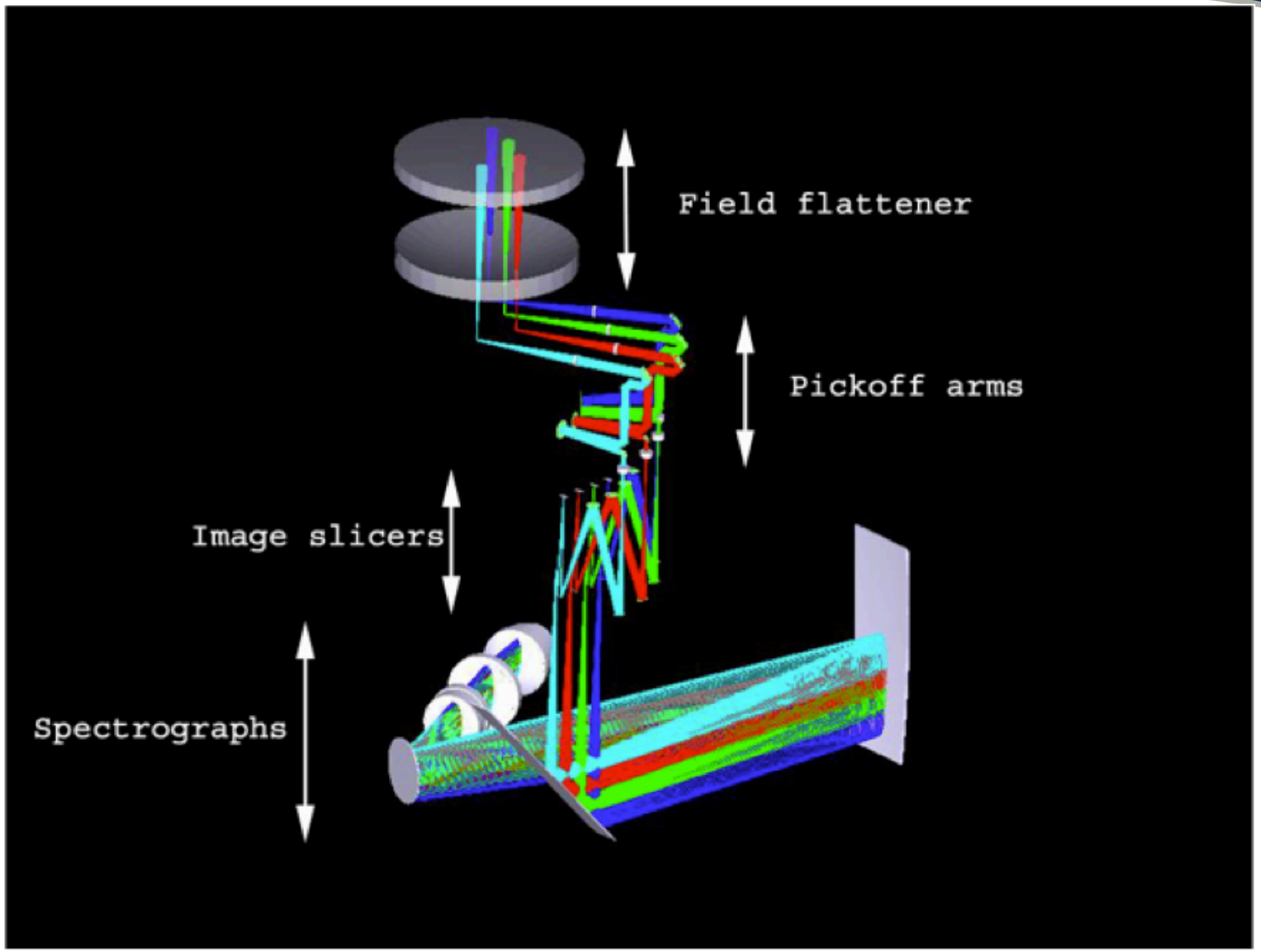
KMOS @ UT1 (Antu)



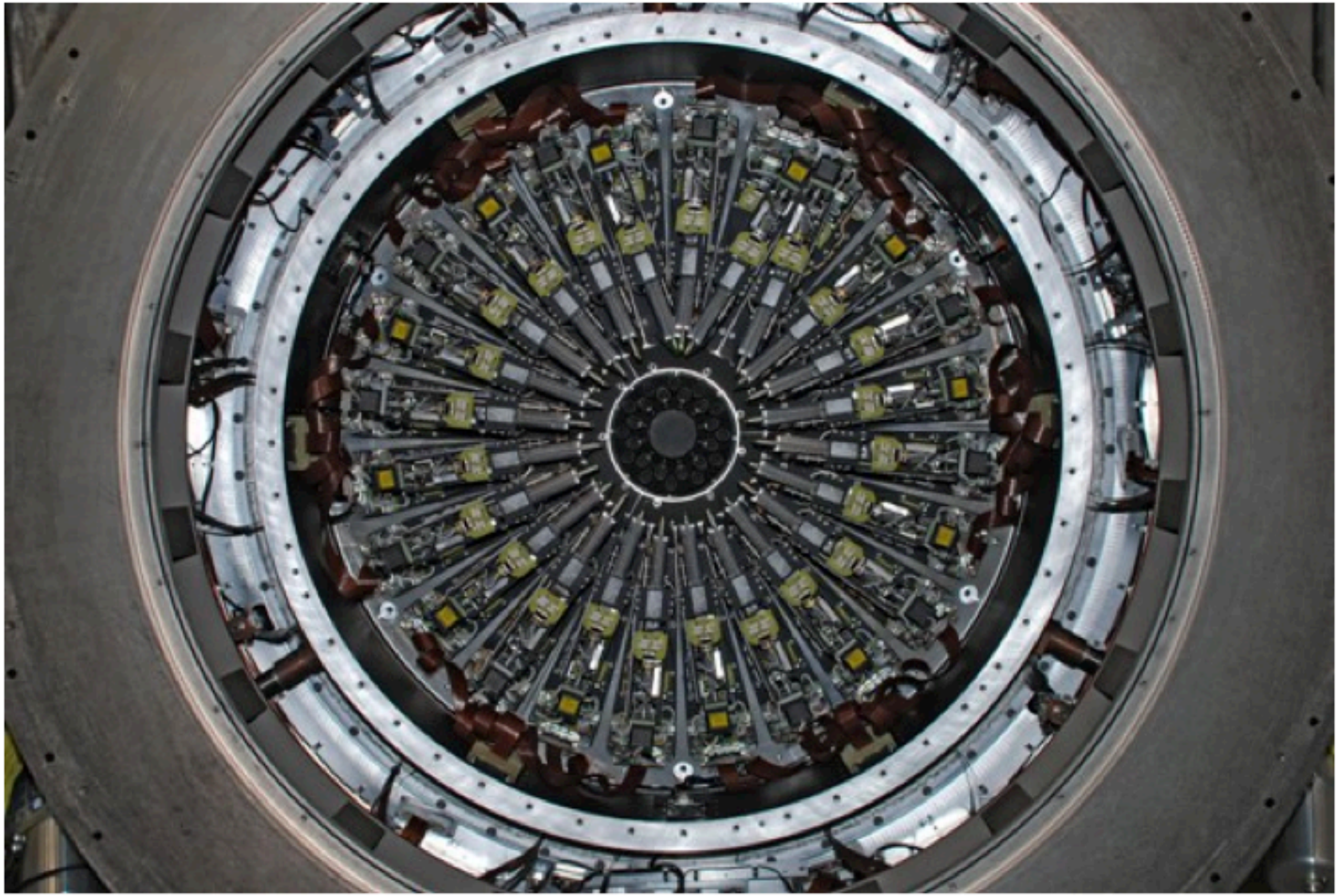
Key Milestones

• Phase A Report	Sep 2003
• Preliminary Design Review	May 2006
• Final Design Review	Apr 2008
• Prelim Acceptance Europe	Jul 2012
• First Light	Nov 2012
• Commissioning 1	Nov 2012
• Commissioning 2	Jan 2013
• Commissioning 3	Mar 2013
• Science Verification	Jun/Sep 2013
• Start of Operations	Oct 2013

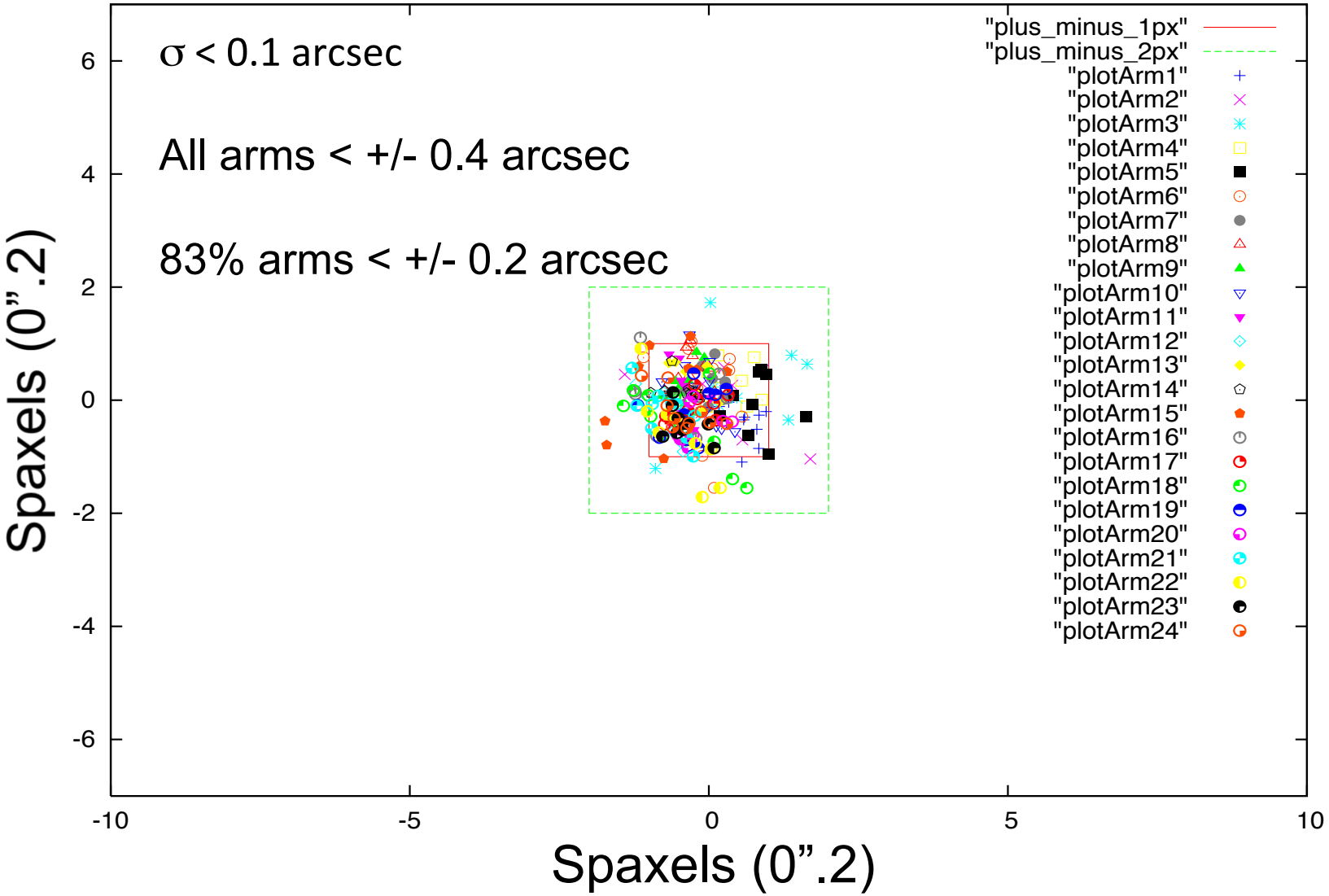
Optical Layout (8 arms)



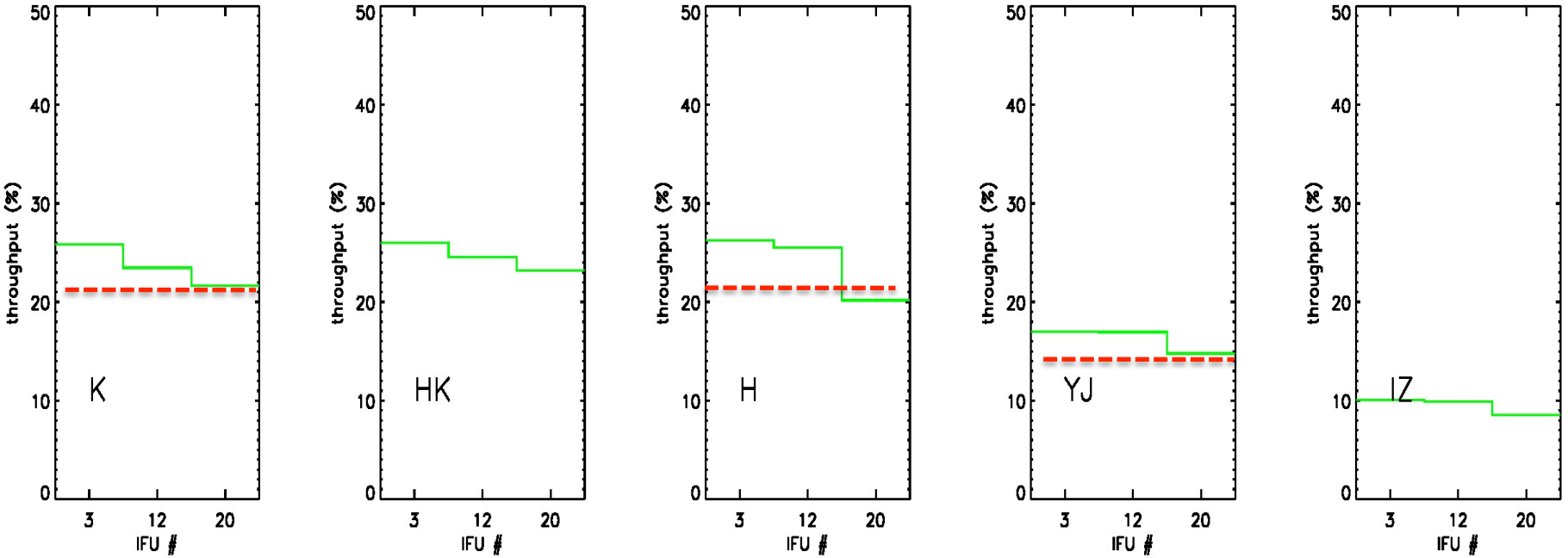
Pickoff Module: 24 arms



Pickoff Arm Accuracy

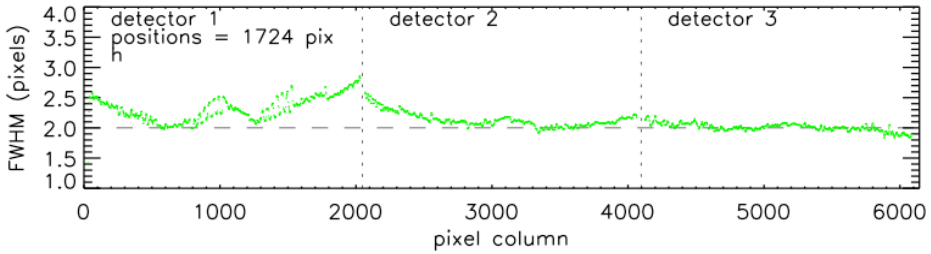


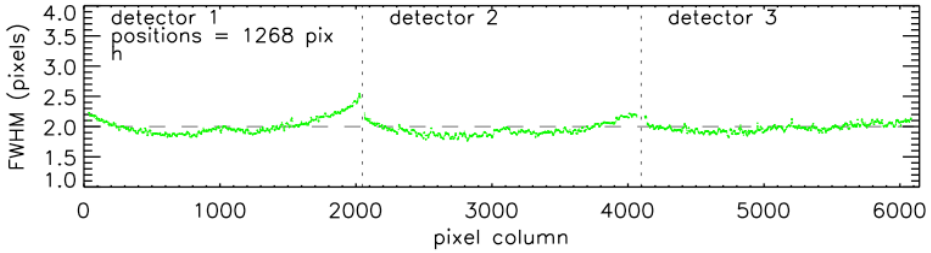
Total System Throughput

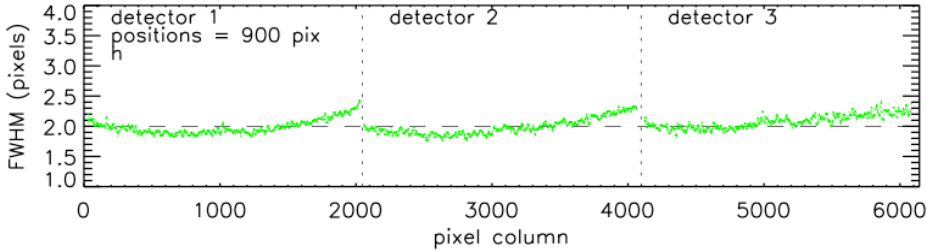


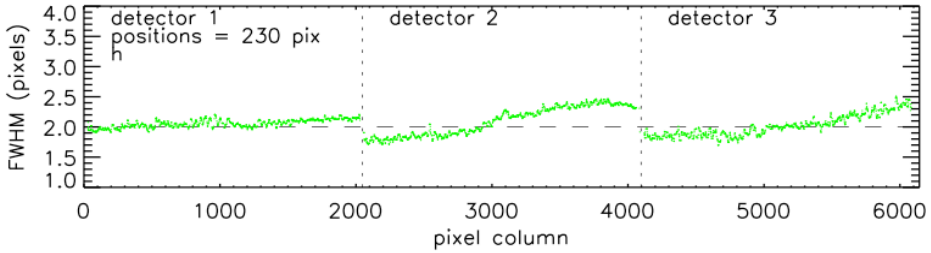
Red dotted lines show the minimum requirements from the Tech Spec scaled by 90% for the detector, 85% for the telescope, and 95% for the atmosphere. Segment#3 has worst performance.

Spectral Resolution

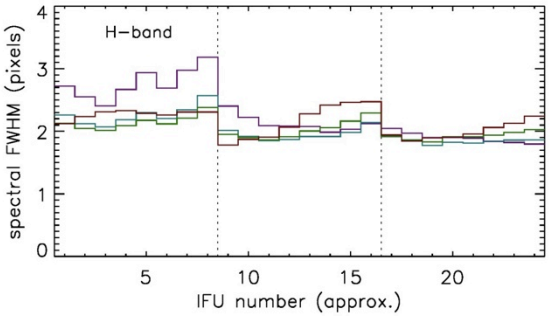




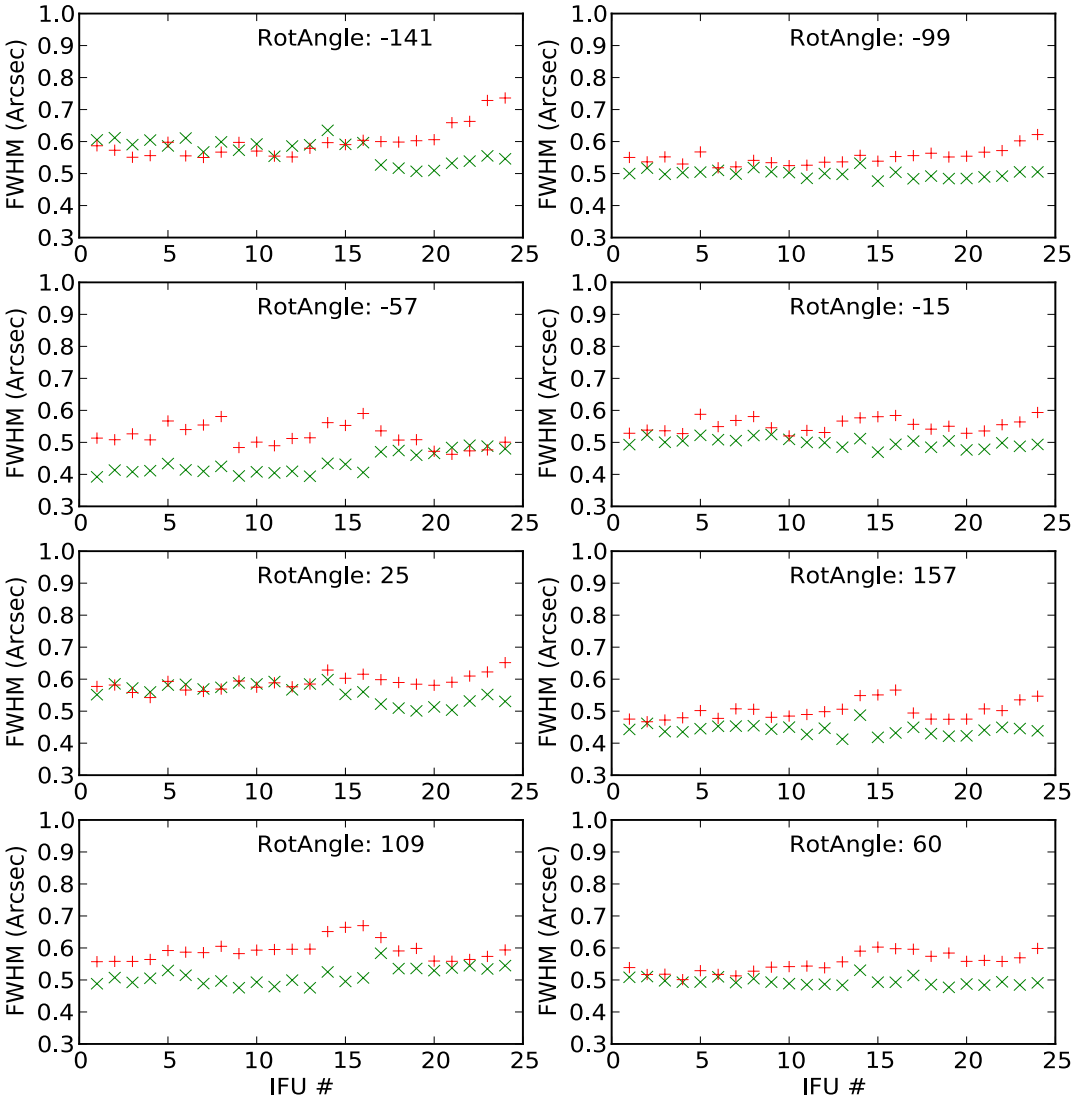




- Resolution is close to two pixels FWHM over all spatial channels.
- Graphs show the measurements in four quartiles of H-band.
- Segment #3 seems slightly better than Segment #1



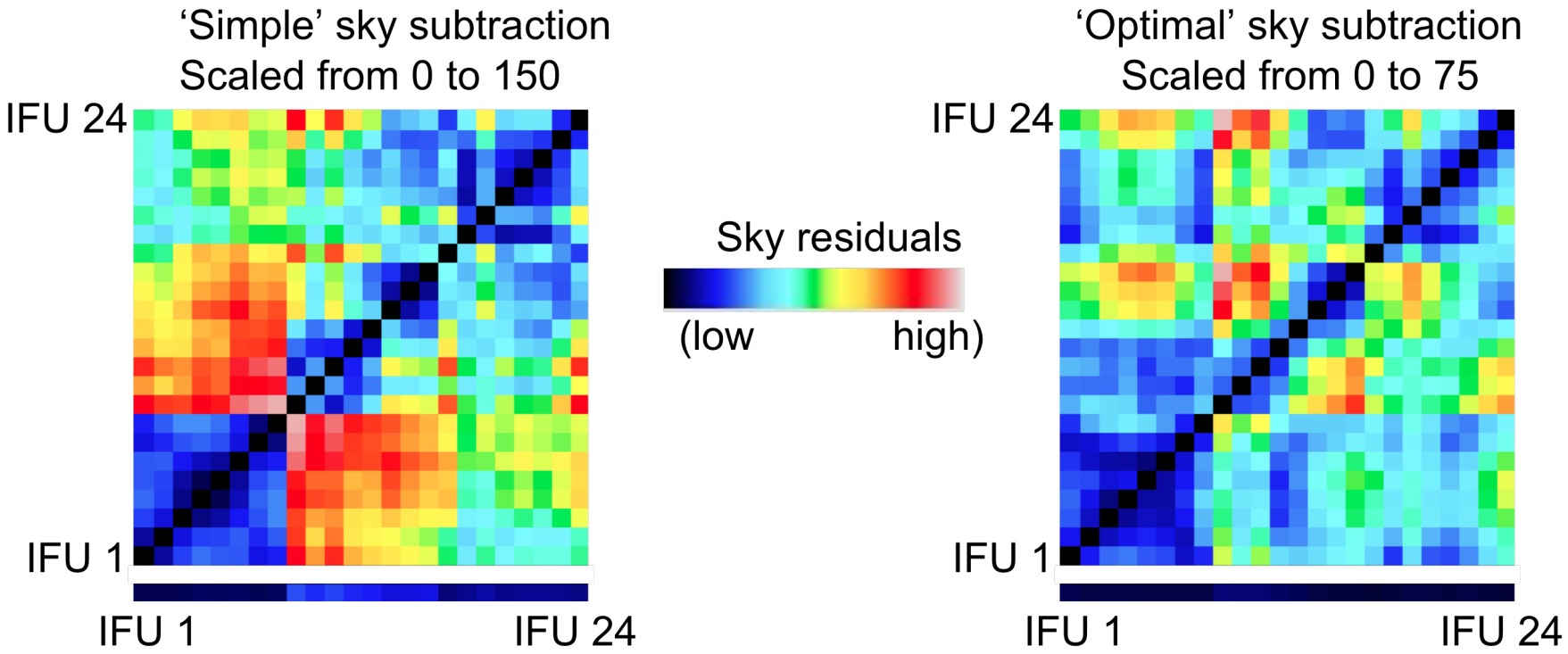
Spatial Resolution



Rot. Angle:	-141	-99	-57	-15	25	157	109	60
<FWHM_Y>	0".57	0".50	0".43	0".50	0".56	0".44	0".51	0".49
<FWHM_Z>	0".60	0".55	0".52	0".55	0".60	0".50	0".59	0".55

- In good seeing and S/N the PSF in reconstructed cubes are well-behaved.
- FWHM along the slice (red) is slightly broader (0".05) due to the additional aberrations in spectrograph (consistent with FWHM~0.2 pixel instrumental PSF)
- Worse in IFU#17-24 at some Nasmyth PAs (still investigating)

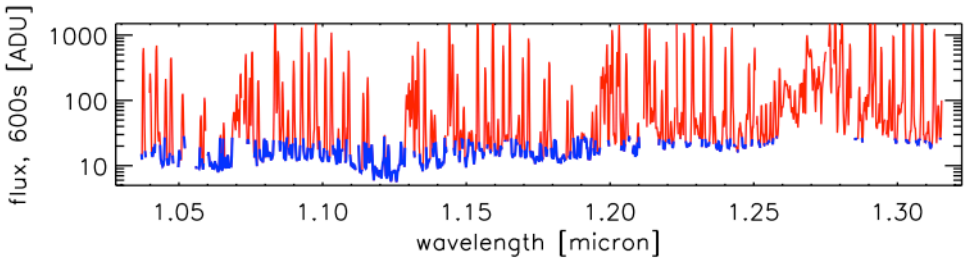
Sky Subtraction



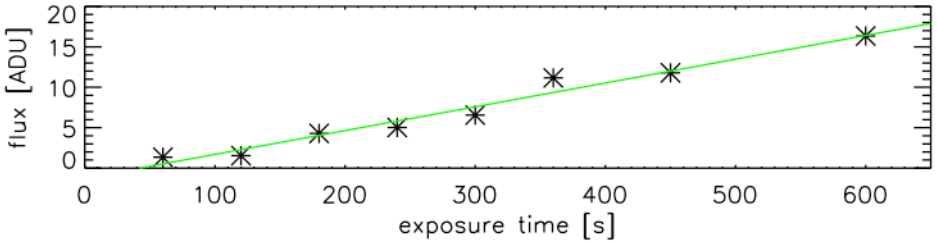
Conclusions:

- arm-to-arm sky subtraction is best within Segment#1
- in Segment#1 about as good as simple subtraction from a subsequent exposure
- optimal subtraction from subsequent exposure is significantly better than any of above

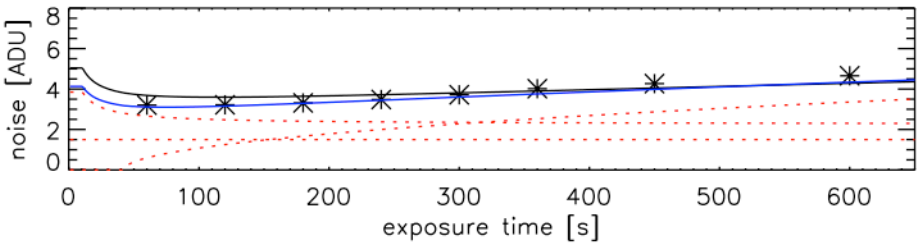
Background Noise Limit



Blue = inter-line continuum



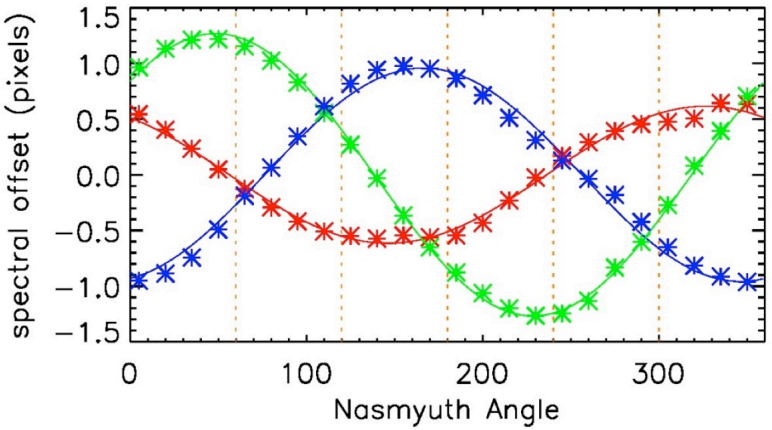
YJ band 1.025-1.344μ



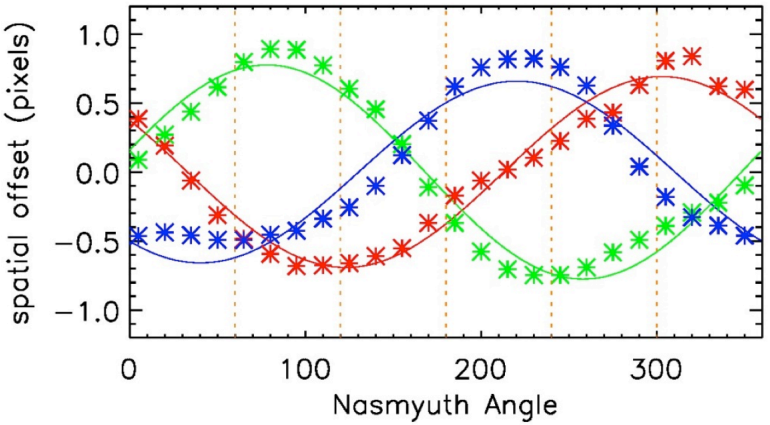
Gain 2.08 e^-/adu

Photon-noise limited exposure times (DIT) of 300 sec.

Instrument Flexure

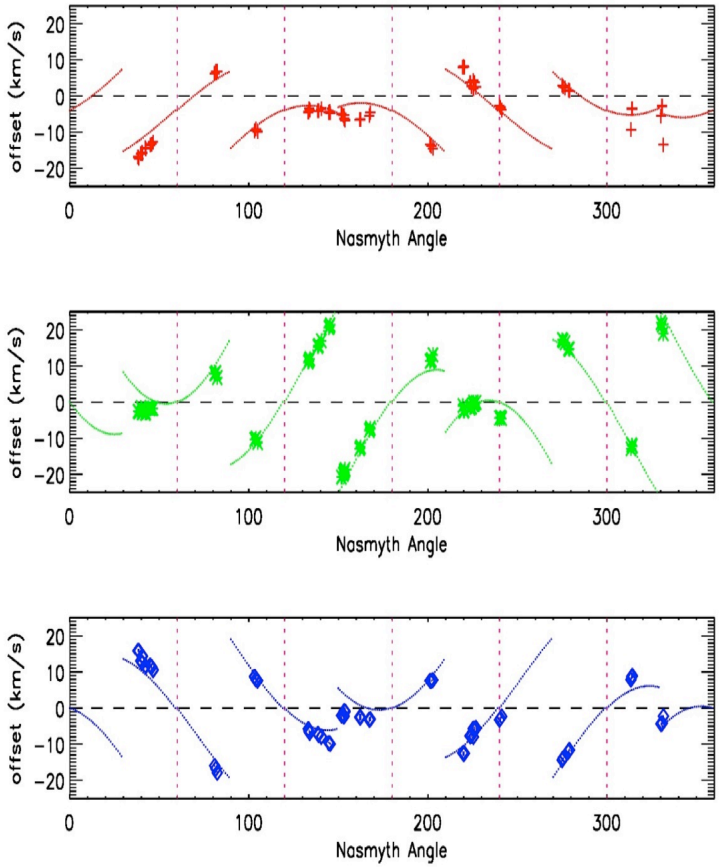


Spectral



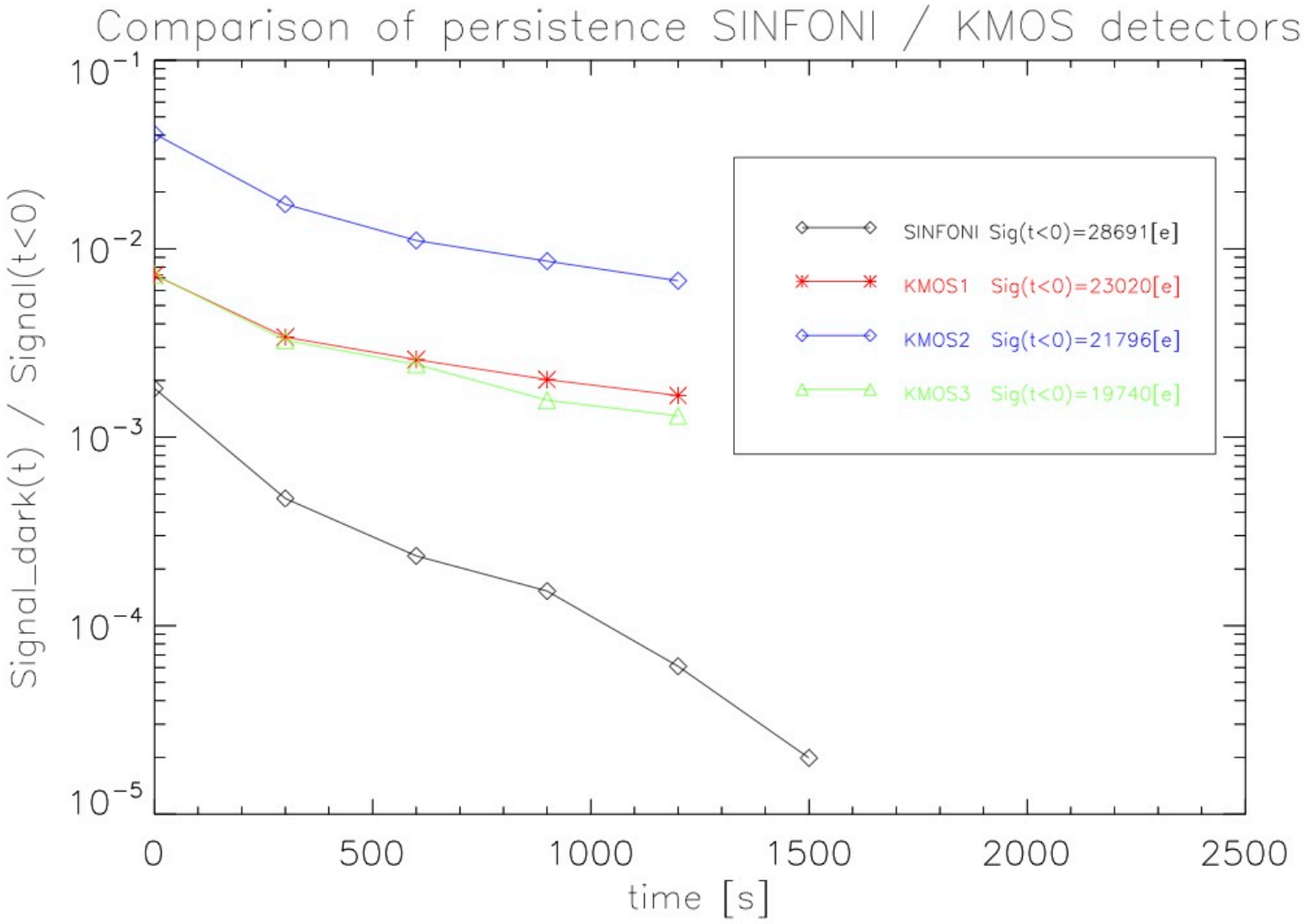
Spatial

Arcs/Flats taken every 60 degrees

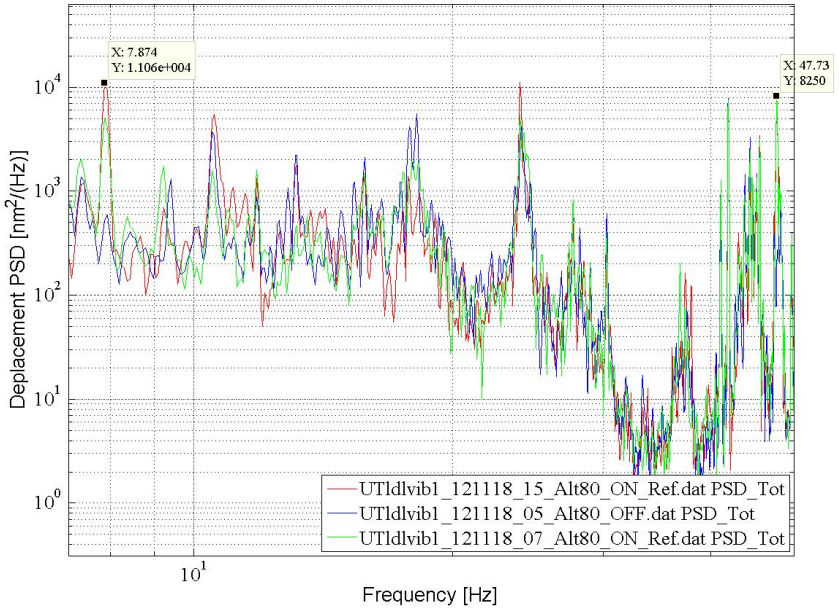


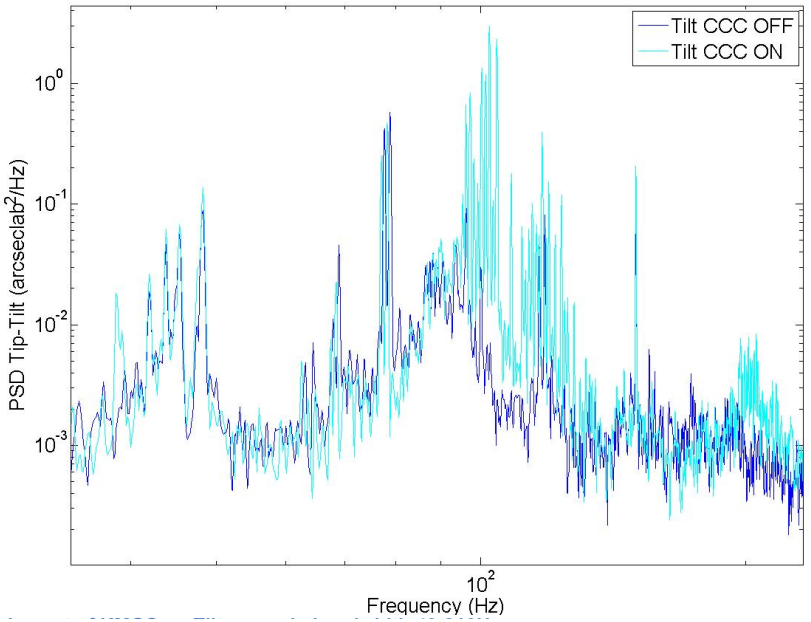
Residual Night Sky
(5 km/s)

Detector Persistence



Cold Head Vibrations



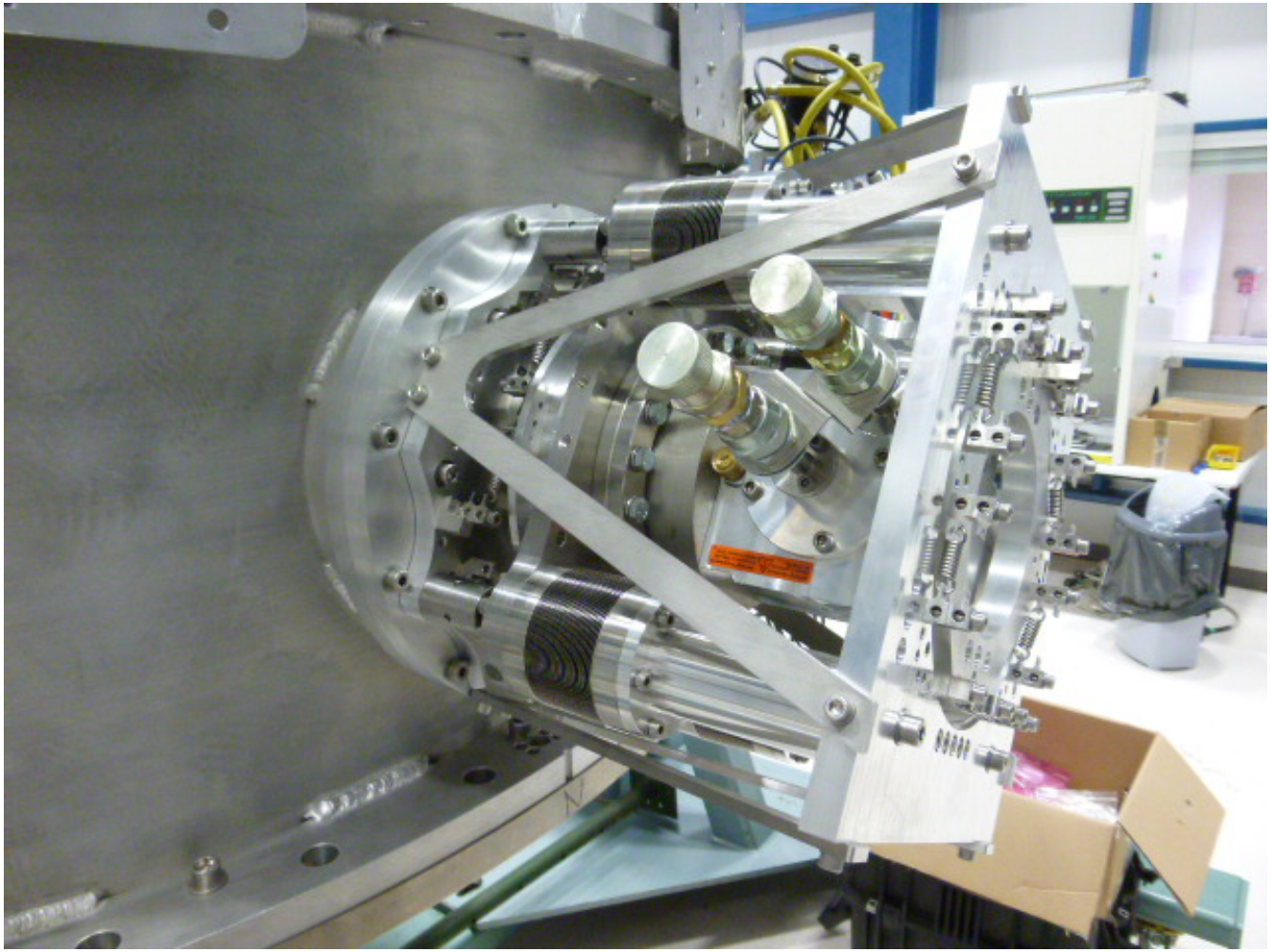


M1-M3 accelerometer test - OK

UT1 Coude test (IRIS) – deemed unacceptable

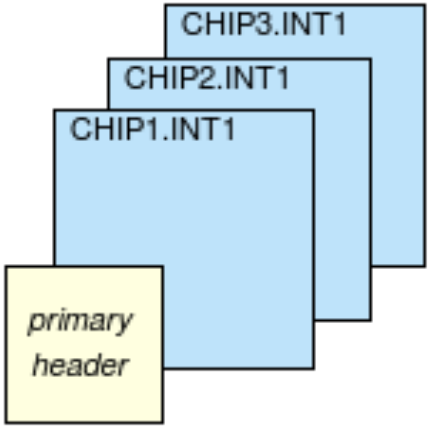
KMOS operations since Comm-1 have required closed cycle coolers to be switched off during all VLTI runs. Adverse impact on arm reliability.

Cold Head Vibrations



Anti-vibration mounts fitted Feb 2014.

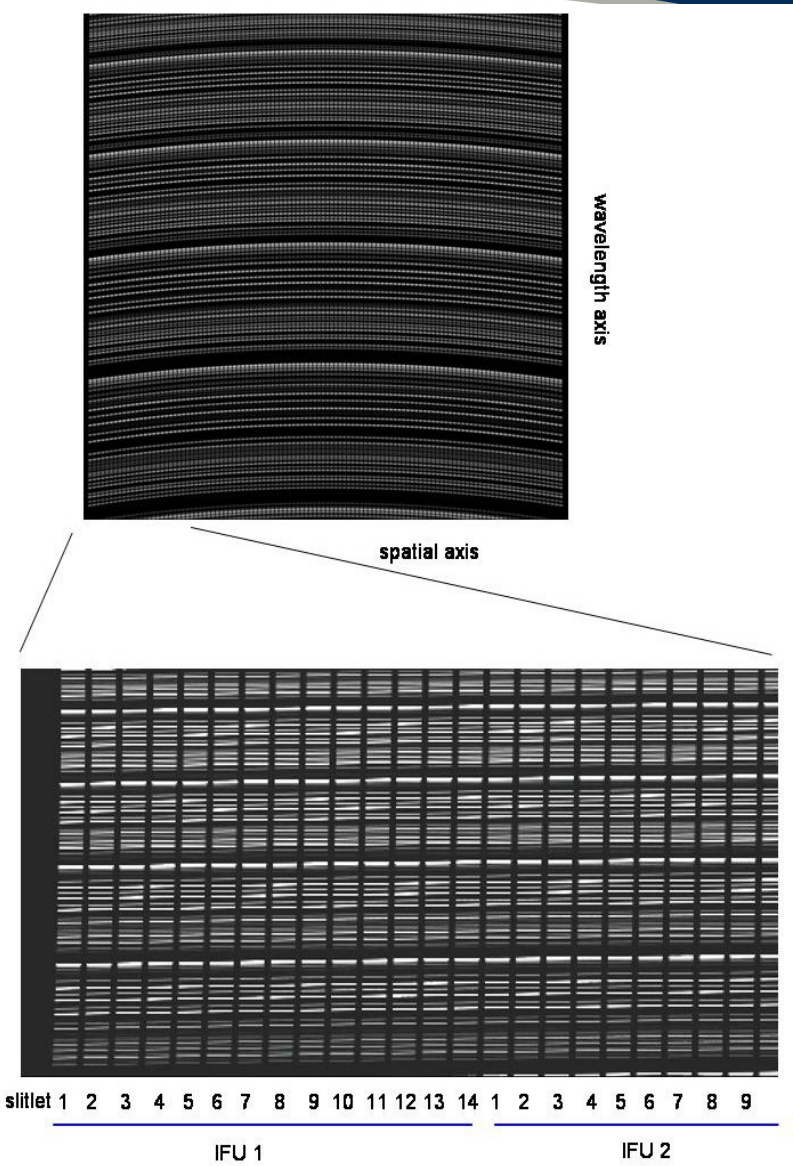
Raw Data Format



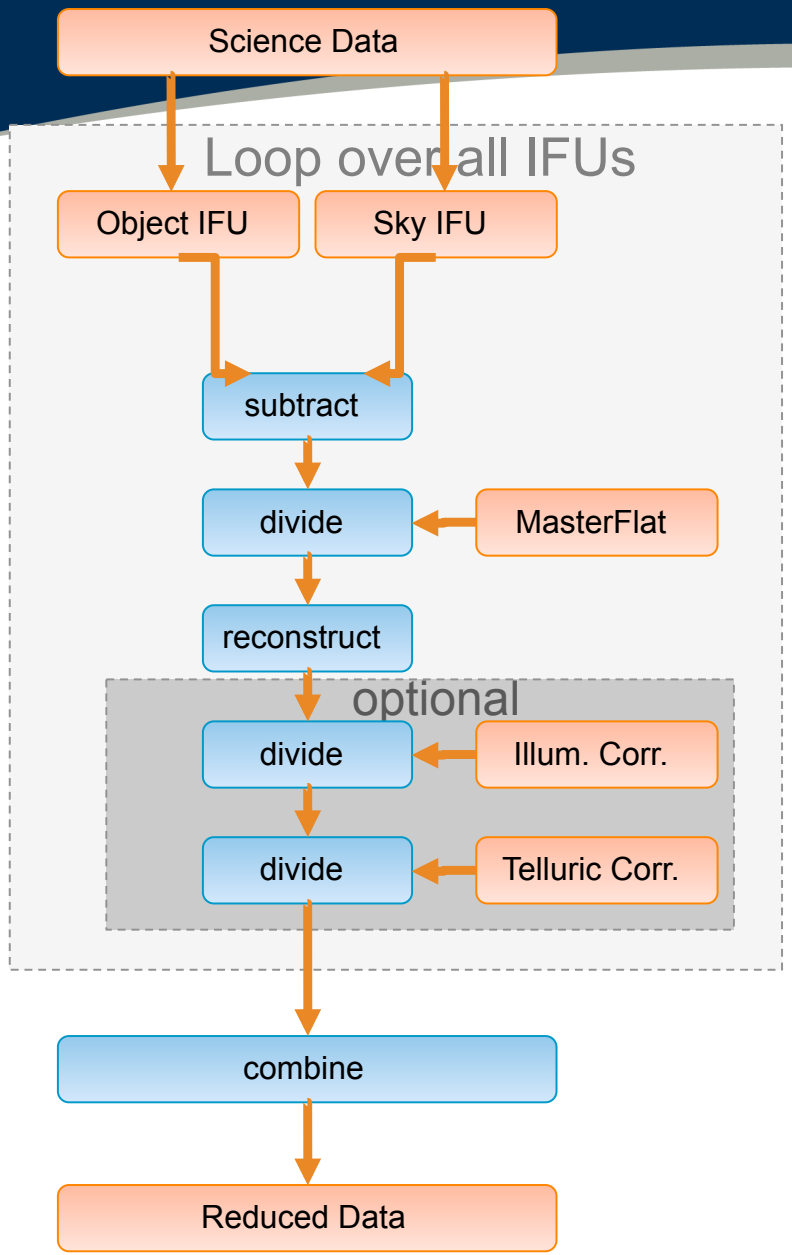
- Primary Header
- Empty data section
- 3 data extensions

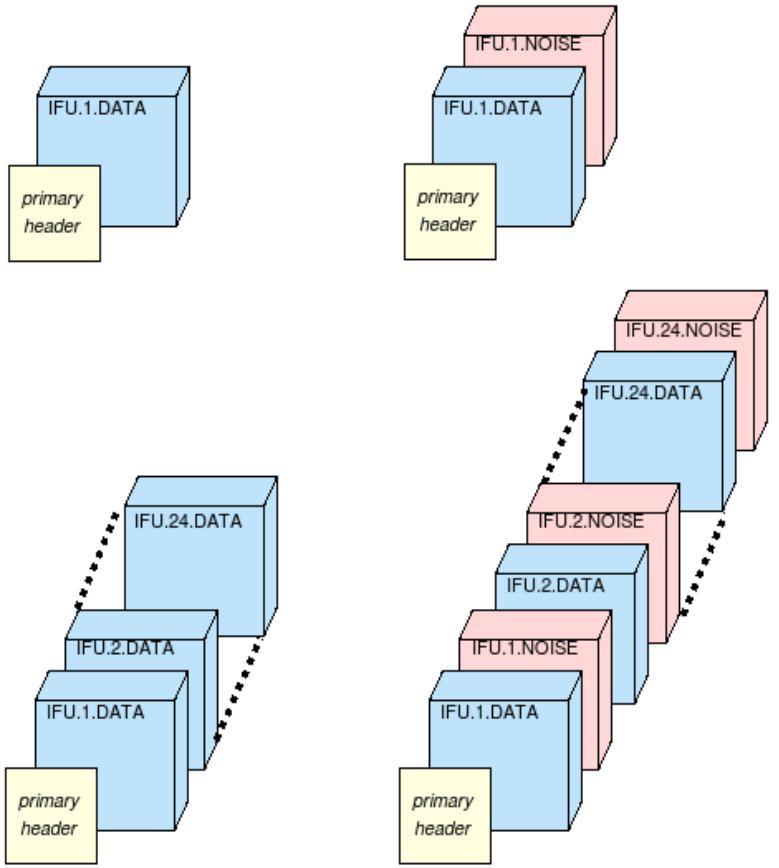
- 8 IFUs per detector
- Each IFU sliced into 14 slitlets, 14 pix width
- Each slitlet is a dispersed pseudo-longslit, 2040 pix length

- Exposure size: 48 MB
- 4 pix border around each frame reserved for detector readout electronics



KMOS Pipeline (SPARK)

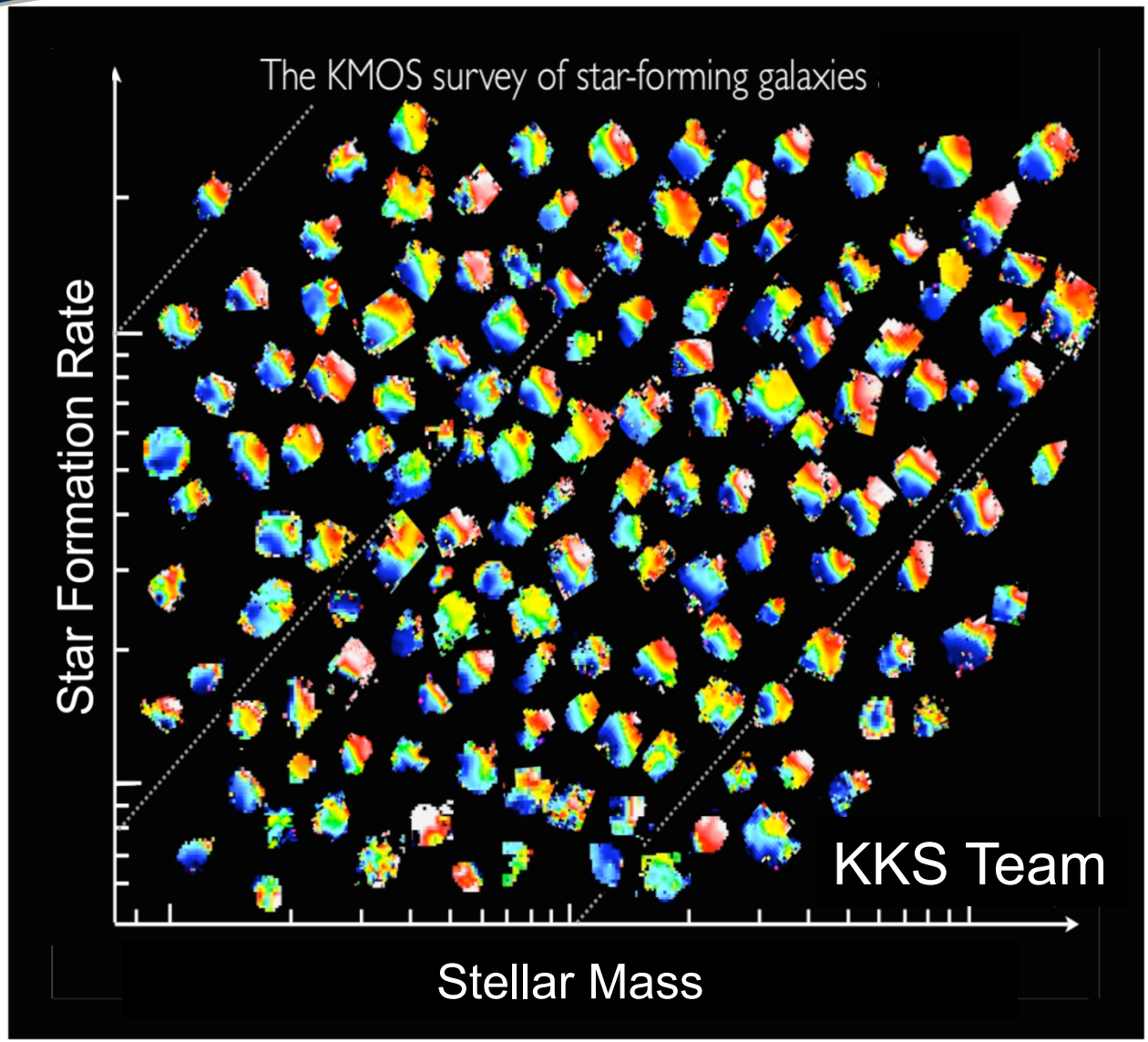




SV/GTO programmes

- Science Verification (21 proposals):
  - KMOS confirmation of Spitzer-selected galaxy clusters at z > 1.4
  - Looking for low luminosity lensed galaxies with KMOS
  - Near-Infrared line strength gradients in IC4296
  - Outflows from massive young stellar objects
  - Exoplanet transits with KMOS
- Guaranteed Time Observations (8 projects underway):
  - KMOS^{3D}
  - KMOS Deep Survey
  - KMOS Kinematic Survey
  - Chemical Evolution of Galaxies using AGB Stars
- UT1 oversubscription: P92 (7.8), P93 (6.7)

Resolved Galaxy Kinematics



$0.7<z<1.5$

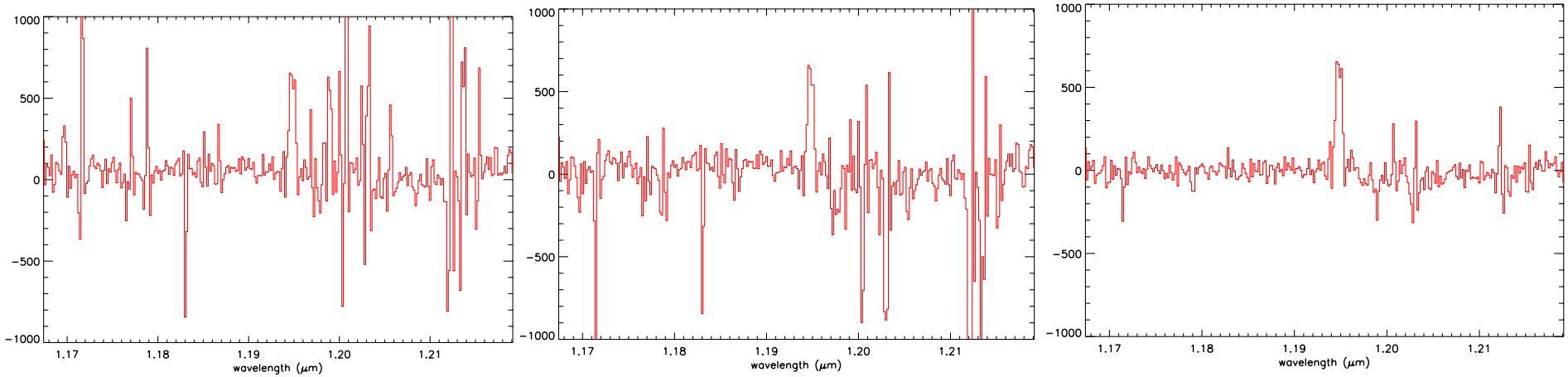
$10^9<M^*<10^{11}$

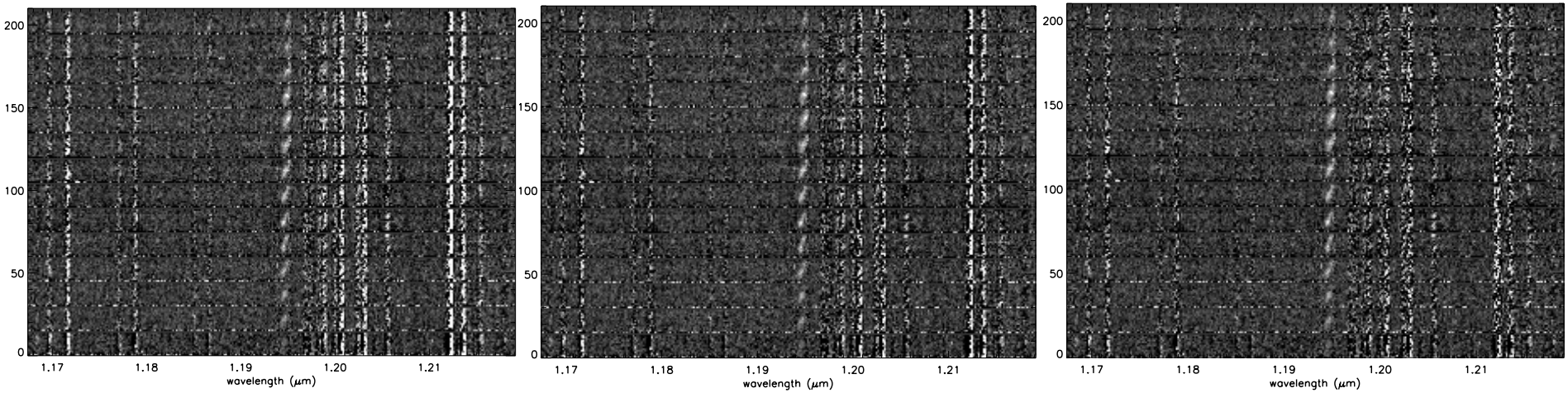
Resolved 185 galaxies out of 258 targetted

See also the presentation by David Sobral on Thu morning

Resolved Galaxy Kinematics

Sky subtraction



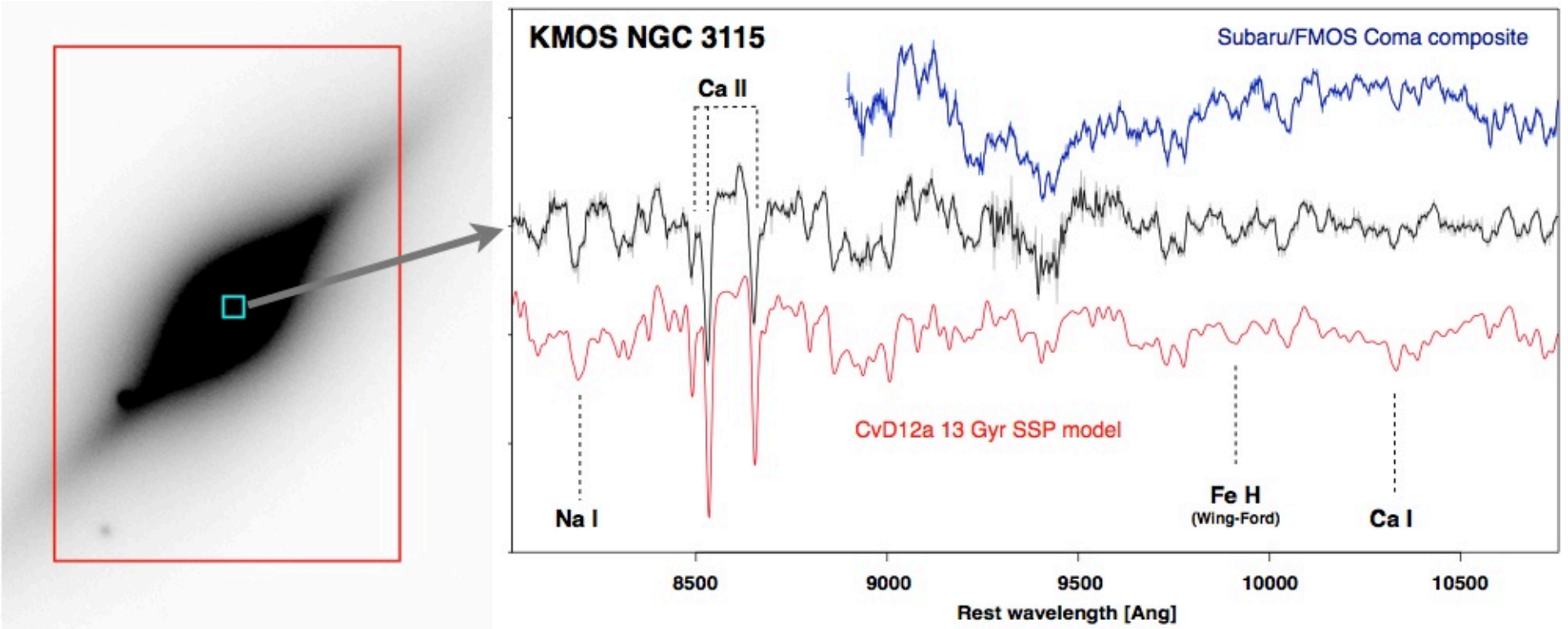


ABA

ABA + Davies SS

Bootstrap all IFUs

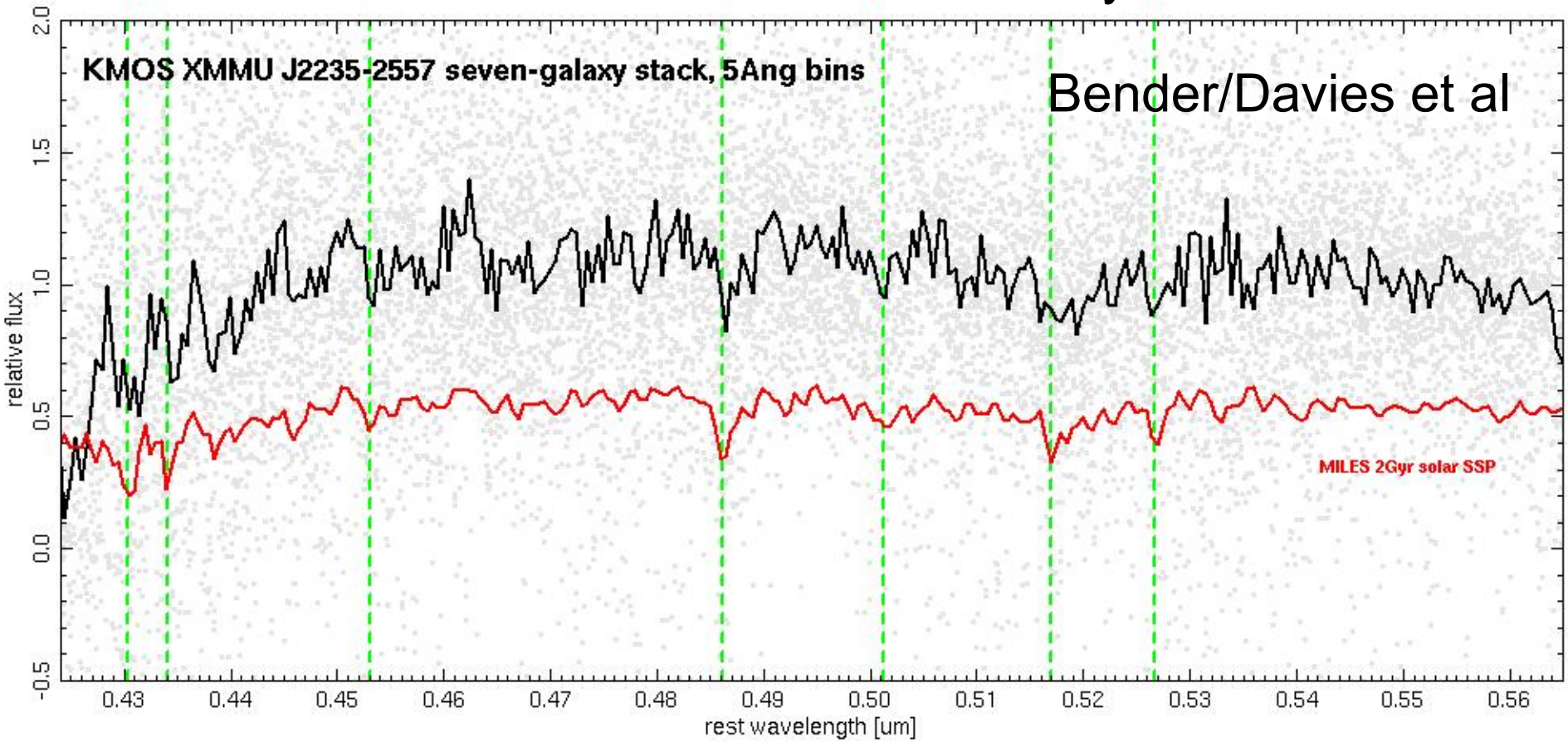
Low-Z Galaxies (IZ)



Russell Smith et al.

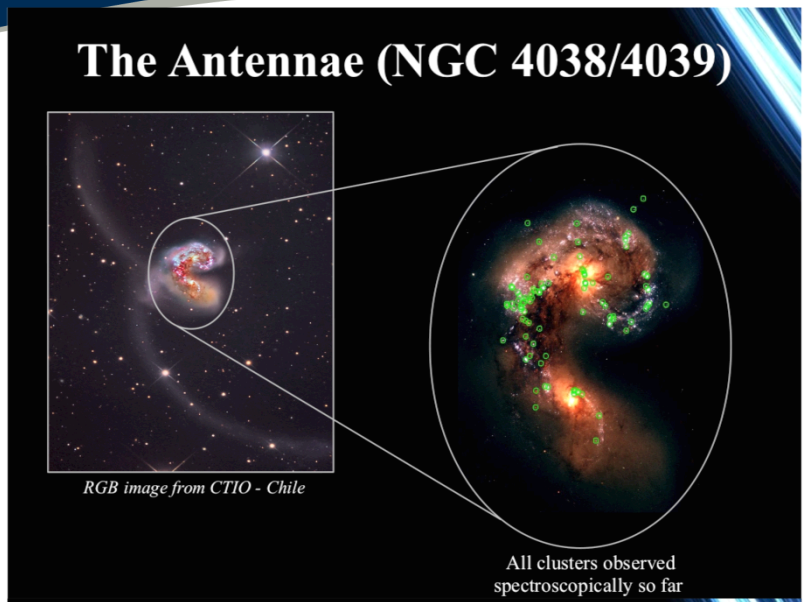
High-Z Clusters

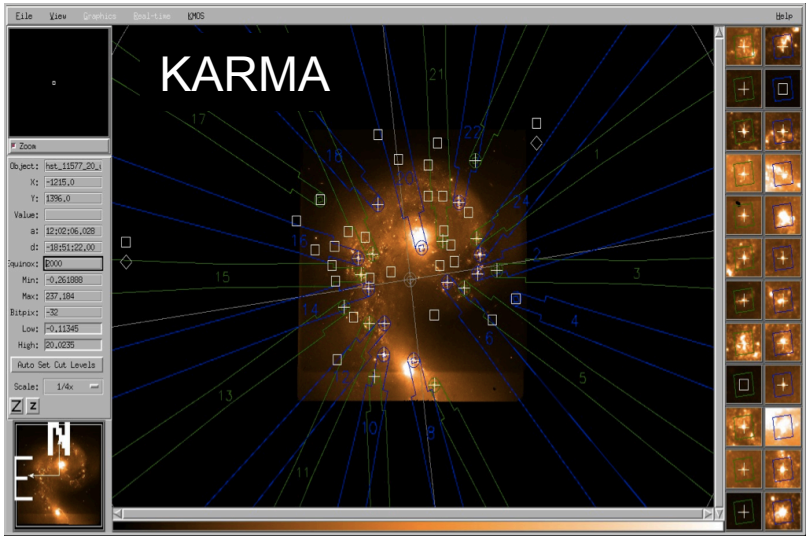
Z=1.39 Lookback time ~ 9Gyr

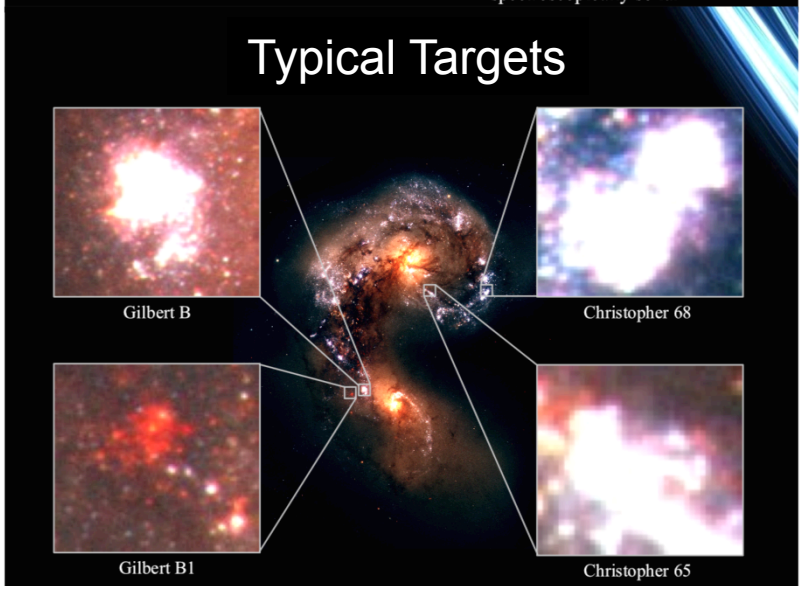


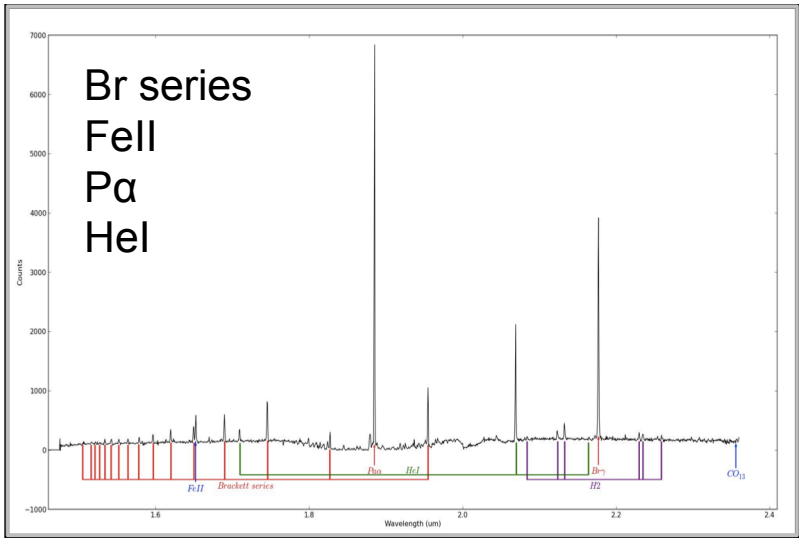
See presentations by Houghton, Beifiori, Rettura (cluster gals) and Forster Schreiber, Cirasuolo, Mendel (field gals) on Thu/Fri.

Star Clusters (Antennae)



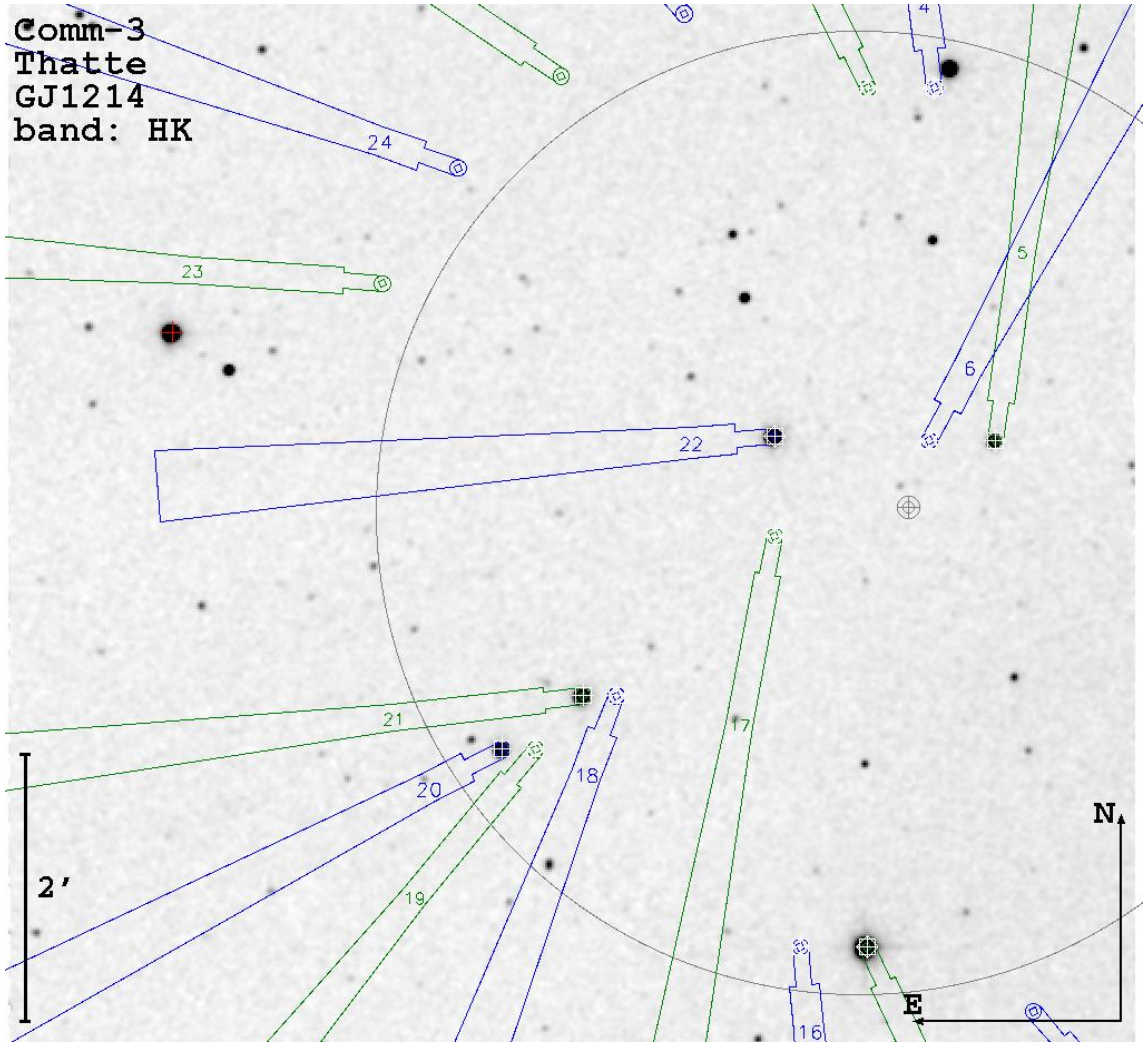


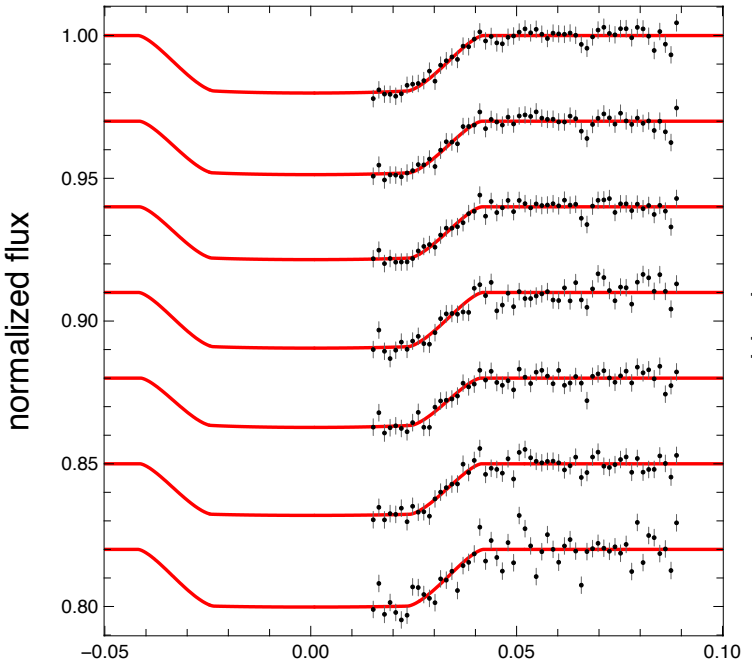




Transit Spectroscopy (?)

HK 1.484 – 2.442 μm



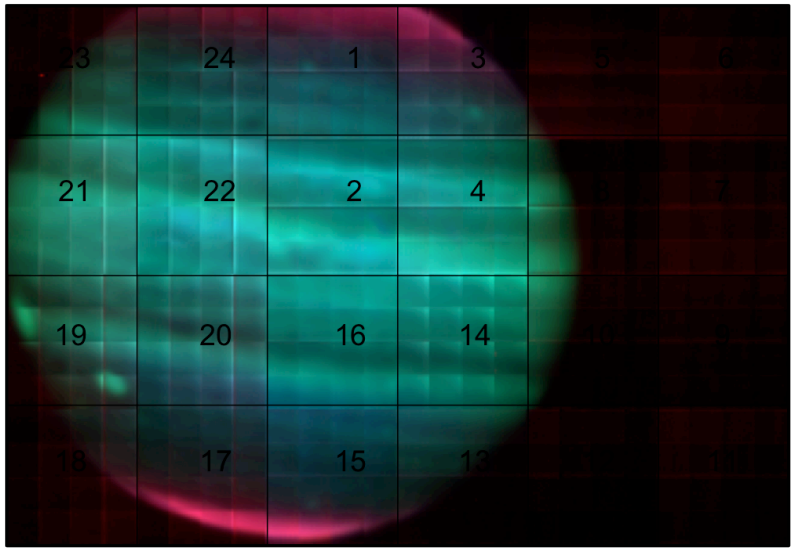


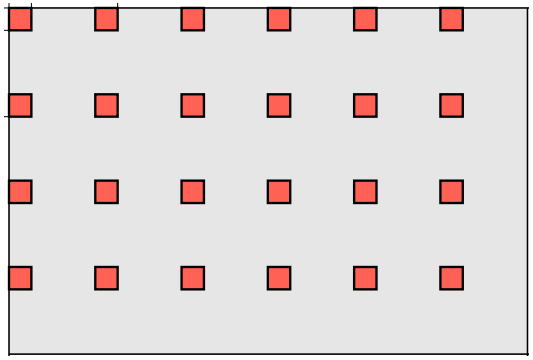
1	1.5-1.6 μm
2	1.6-1.7 μm
3	1.7-1.8 μm
4	1.95-2.05 μm
5	2.05-2.15 μm
6	2.15-2.25 μm
7	2.25-2.35 μm

Saglia, Koppenhoefer et al

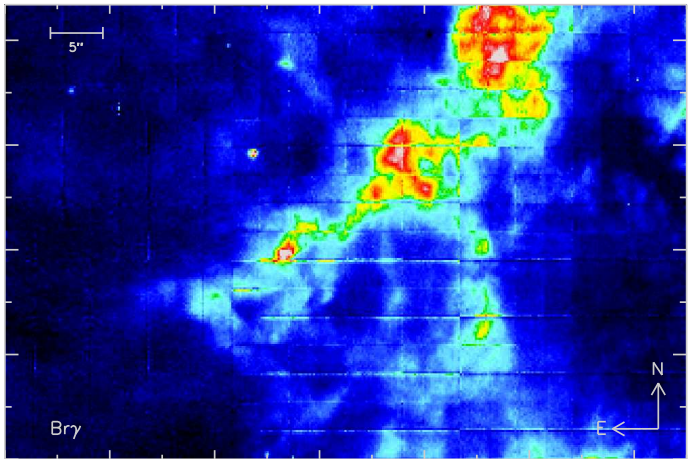
KMOS Mosaic Mode

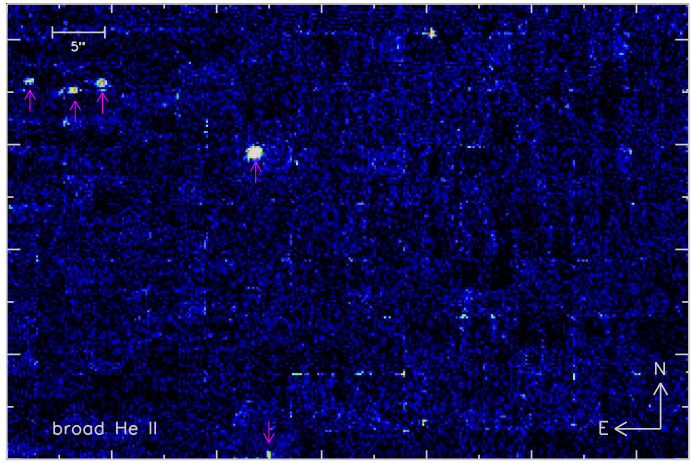
Jupiter methane bands





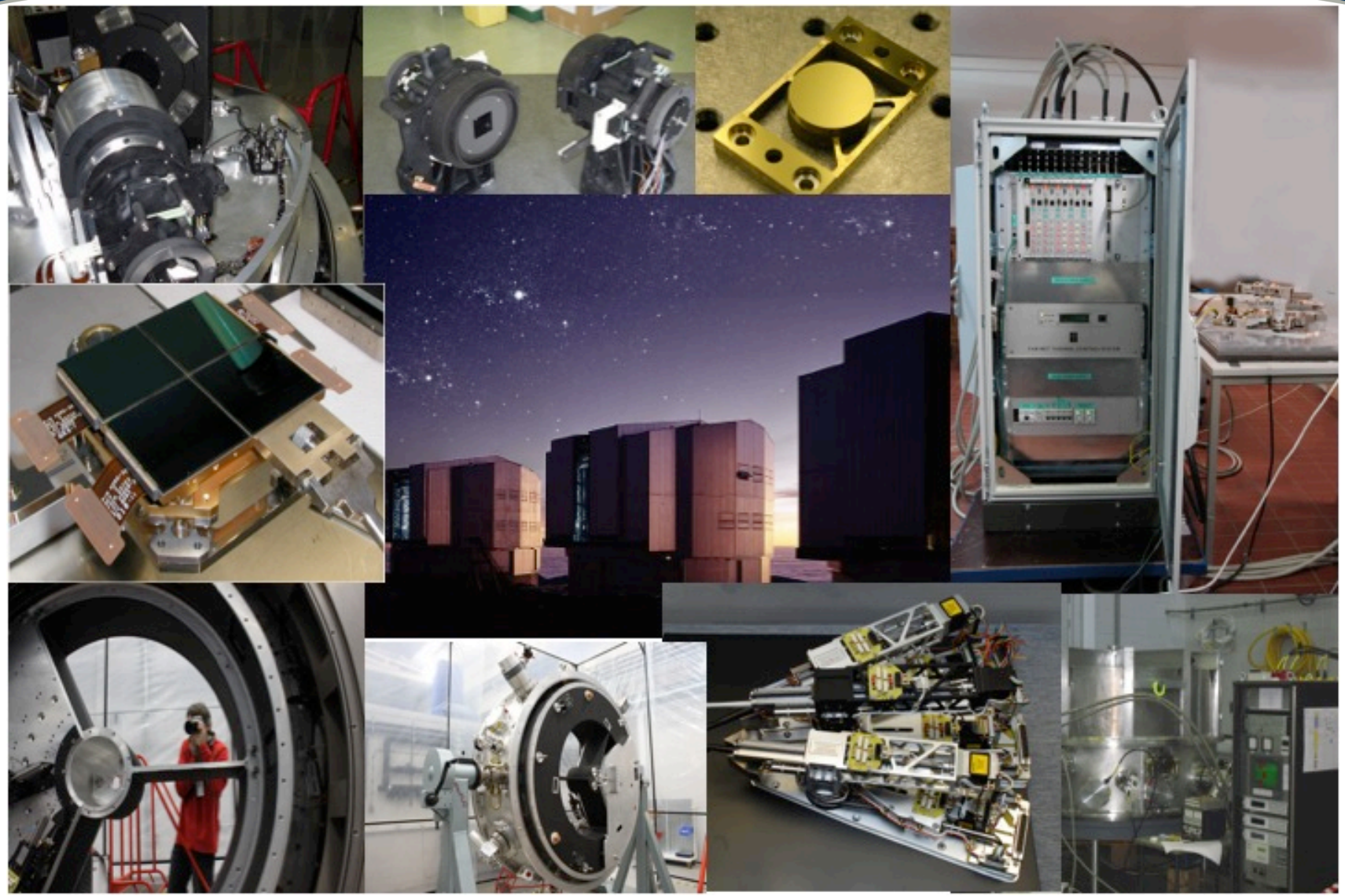
65” x 43”
16 pointings
384 IFUs





R136 (30 Dor)
R Davies et al
A&A 558, 56 (2013)

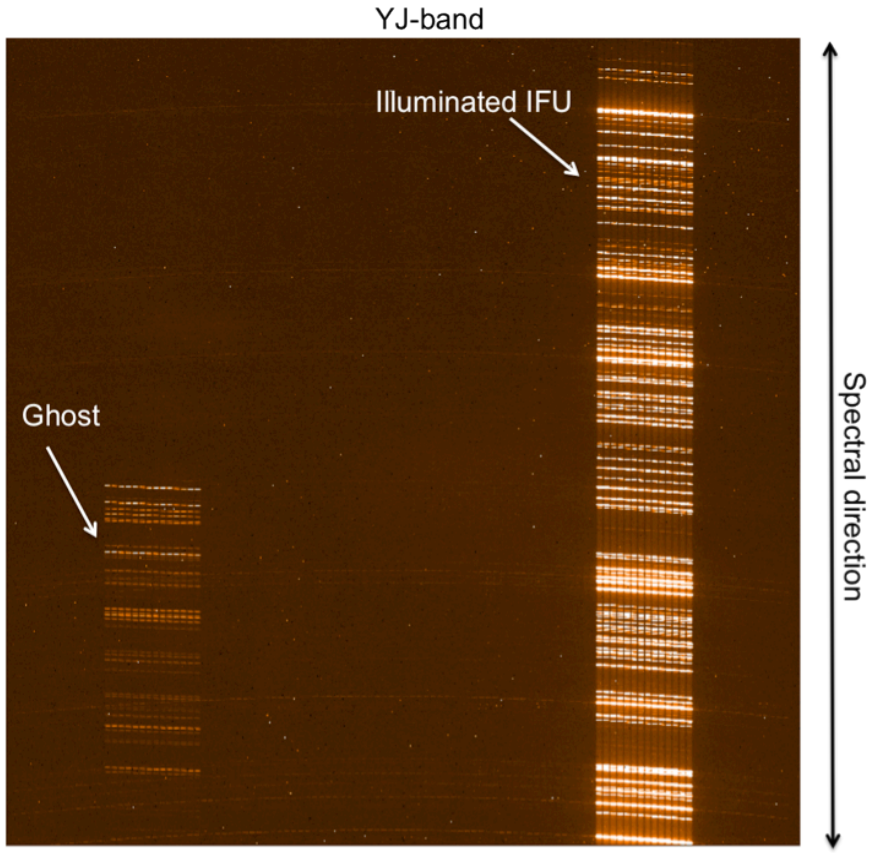
Thank You

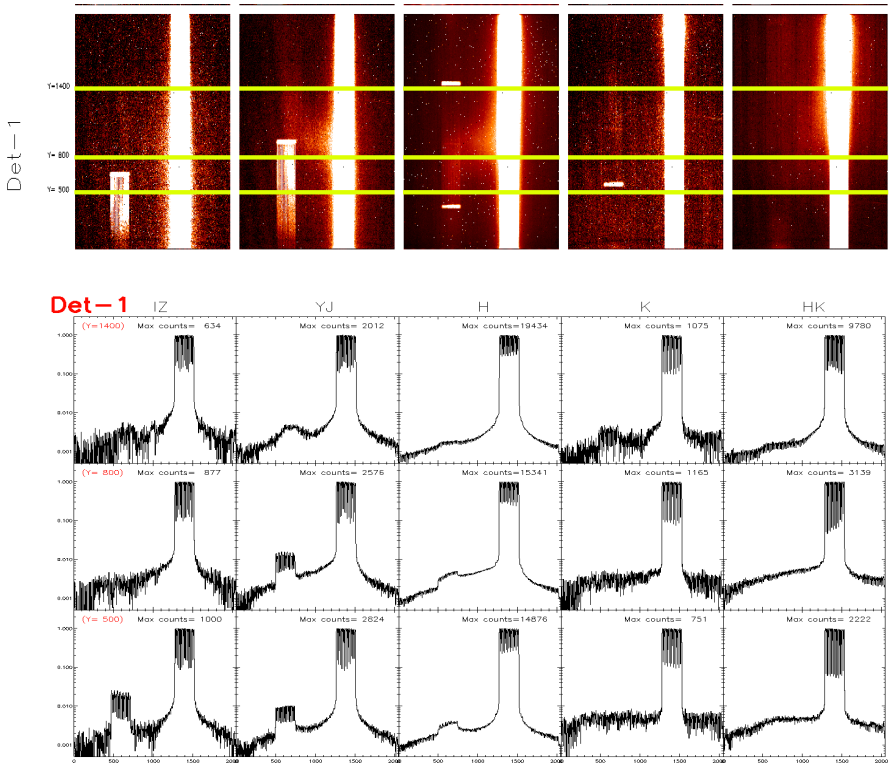


Additional slides

Ghosts

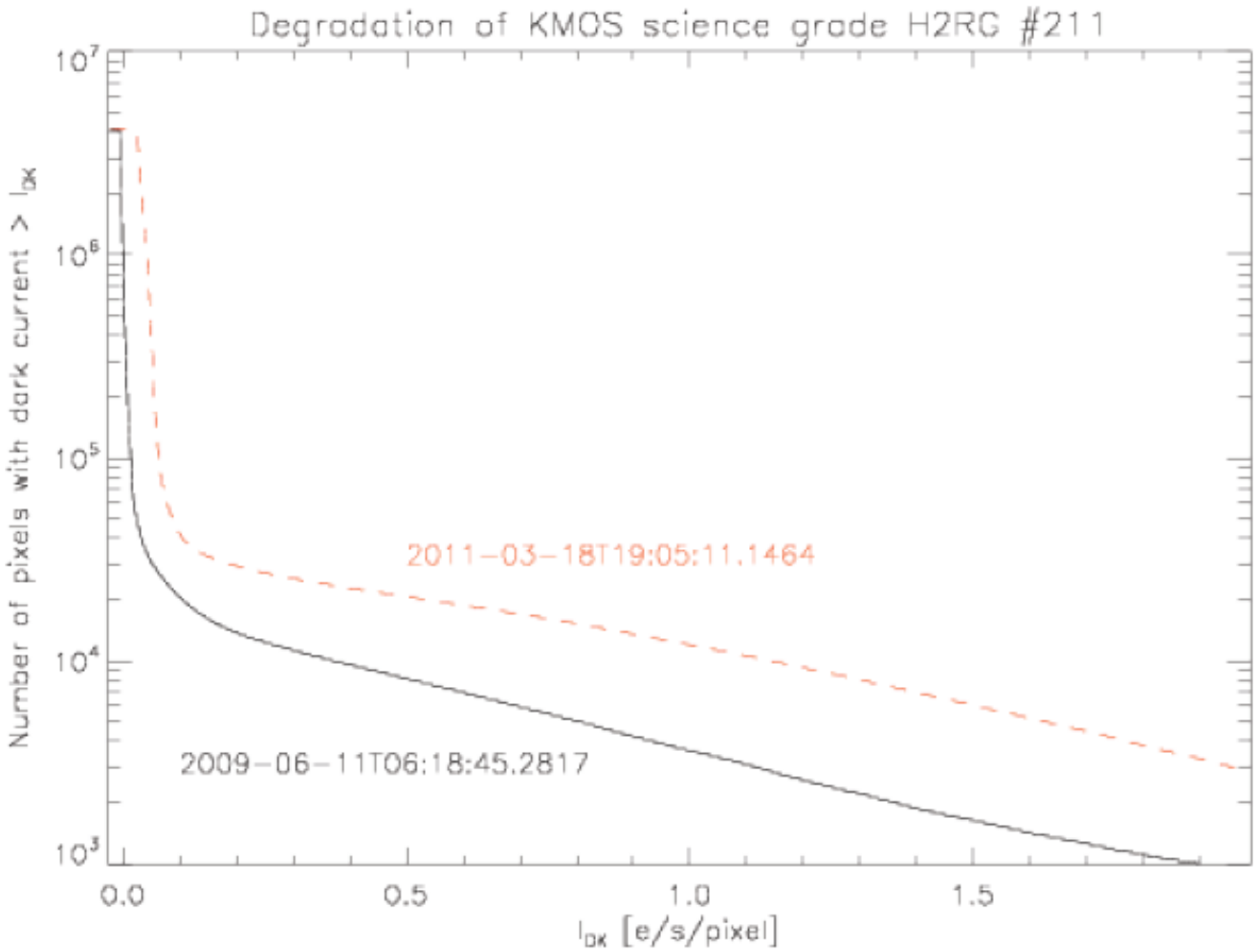
Grating ghost: 2% (IZ), 1% (YJ), 0.5% (H), <0.5% (K)

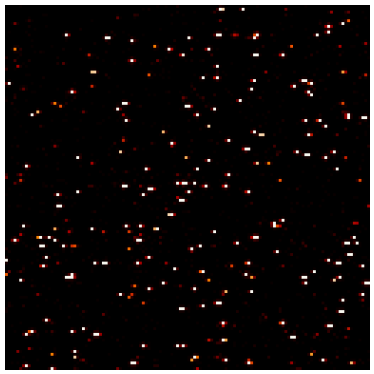




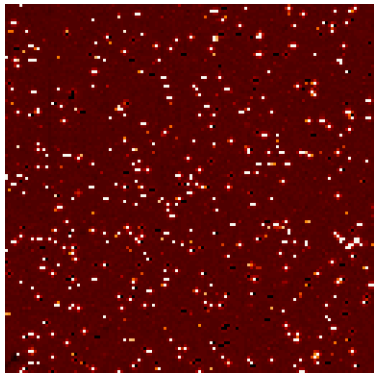
All other ghosts/scattered light <1%

H2RG Detectors



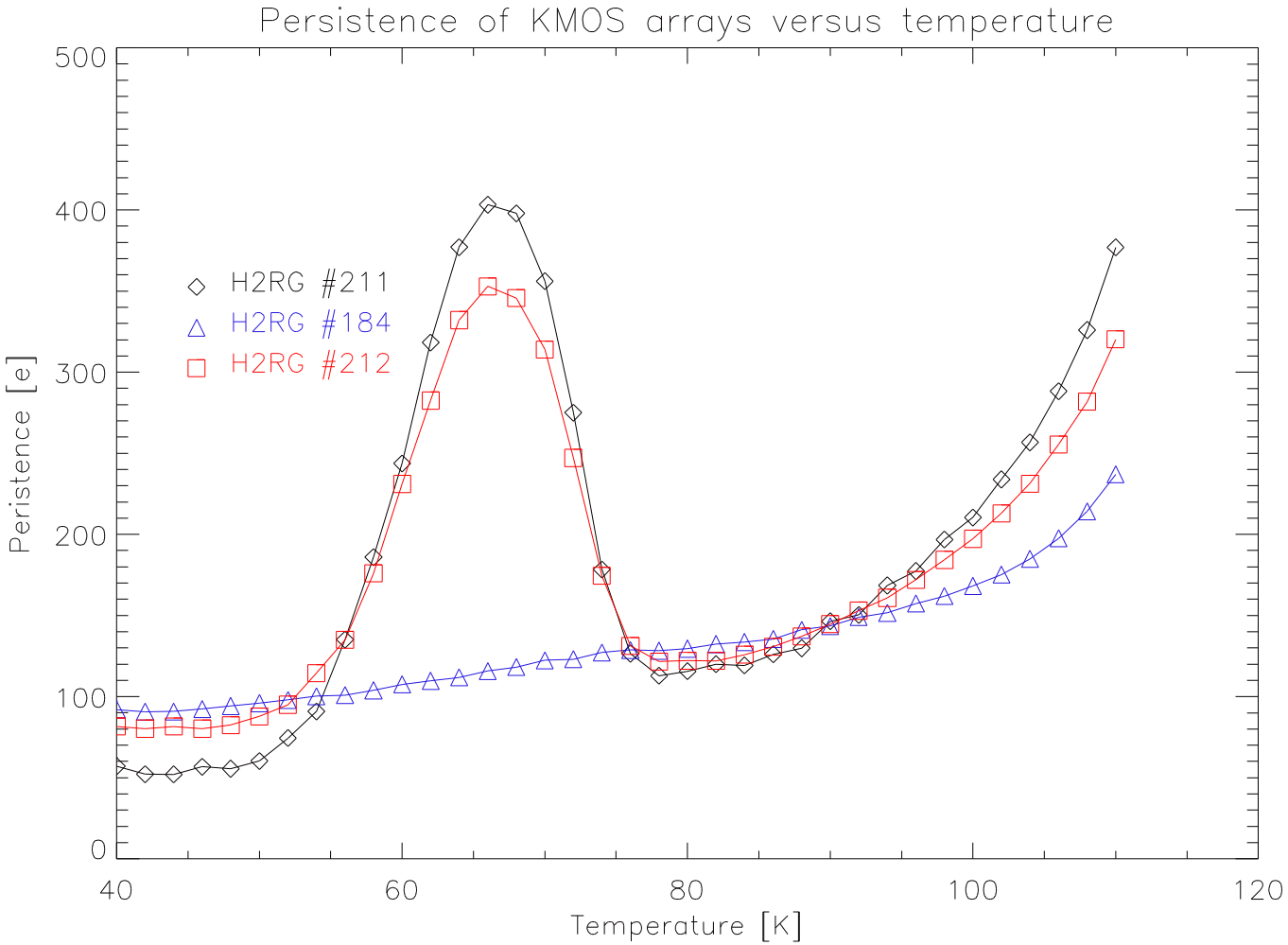


June 2009



March 2011

Detector Persistence



#211 KMOS-1

#212 KMOS-2

#184 KMOS-3