KMOS: A multi-object deployable-IFU spectrometer for the ESO VLT

Ray Sharples

Durham University

For the KMOS consortium

Ralf Bender, Richard Bennett, Keith Burch, Paul Carter, Mark Casali, Paul Clark, Robert Content, Ric Davies, Roger Davies, Marc Dubbeldam, Gert Finger, Natascha Förster Schreiber, Reinhard Genzel, Achim Hess, Markus Kissler-Patiig, Ken Laidlaw, Matt Lehnert, Ian Lewis, Alan Moorwood, Bernard Muschielok, Jeff Pirard, Phil Rees, Josef Richter, David Robertson, Ian Robson, Suzie Ramsay-Howat, Roberto Saglia, Mathias Tecza, Naranjan Thatte, Stephen Todd, Bob Wall, Michael Wegner

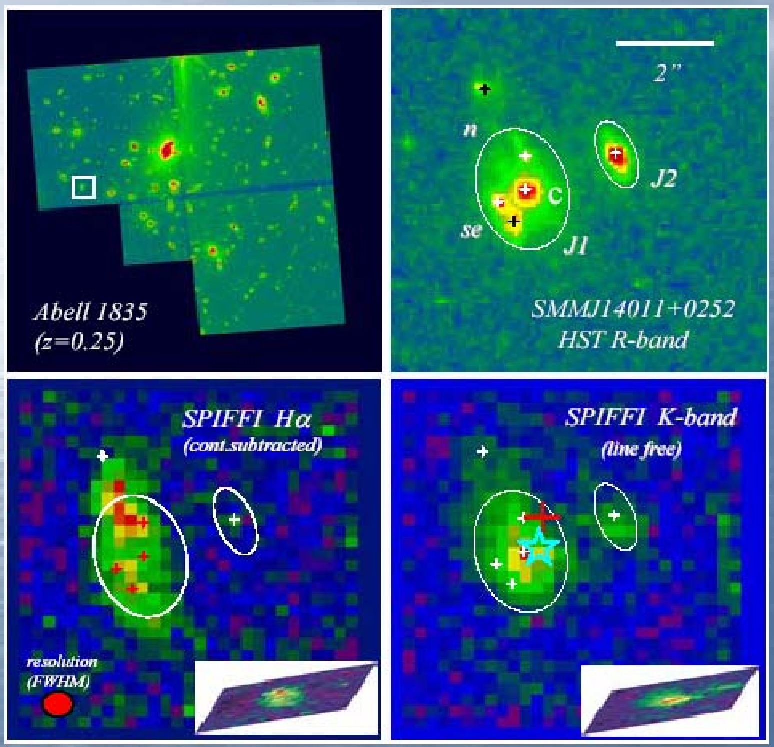
Consortium Members

- University of Durham
- University of Oxford
- Astronomy Technology Centre
- Universitäts-Sternwarte München
- MPI für Extraterrestrische Physik
- European Southern Observatory

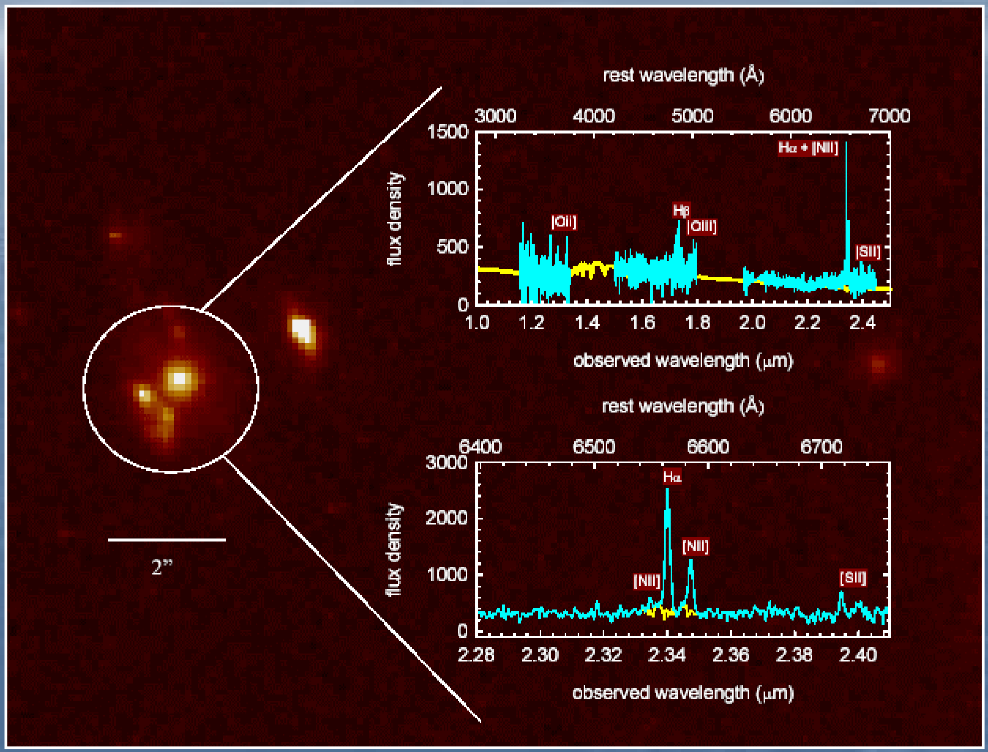
Top Level Scientific Drivers

- Investigate the physical processes which drive galaxy formation and evolution over redshift range $1<z<10$.
- Map the variations in star formation histories, spatially resolved star-formation properties, and merger rates
- Obtain dynamical masses of well-defined samples of galaxies across a wide range of environments at a series of progressively earlier epochs

I: The Masses and Growth of Galaxies

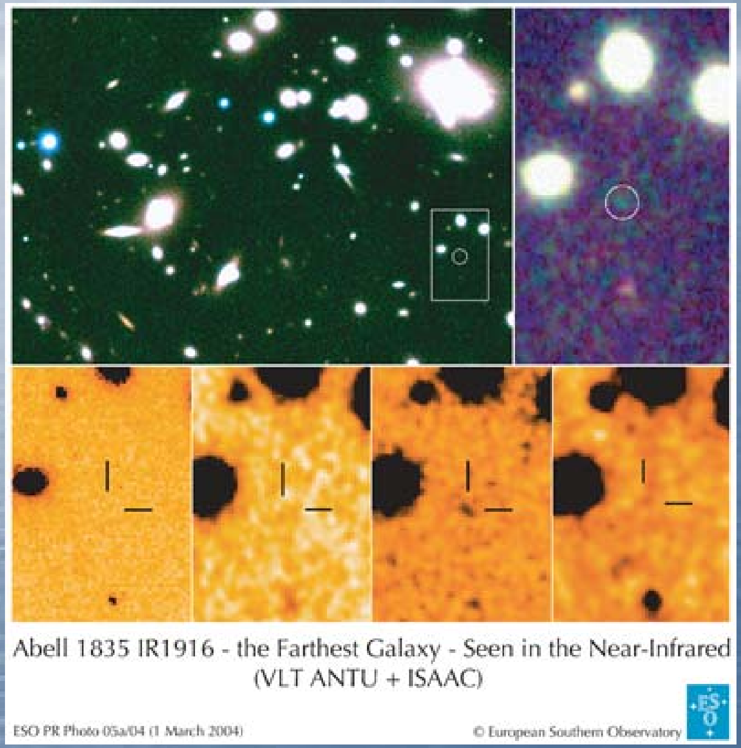


SCUBA galaxy SMM J14011+0252 (z=2.565)

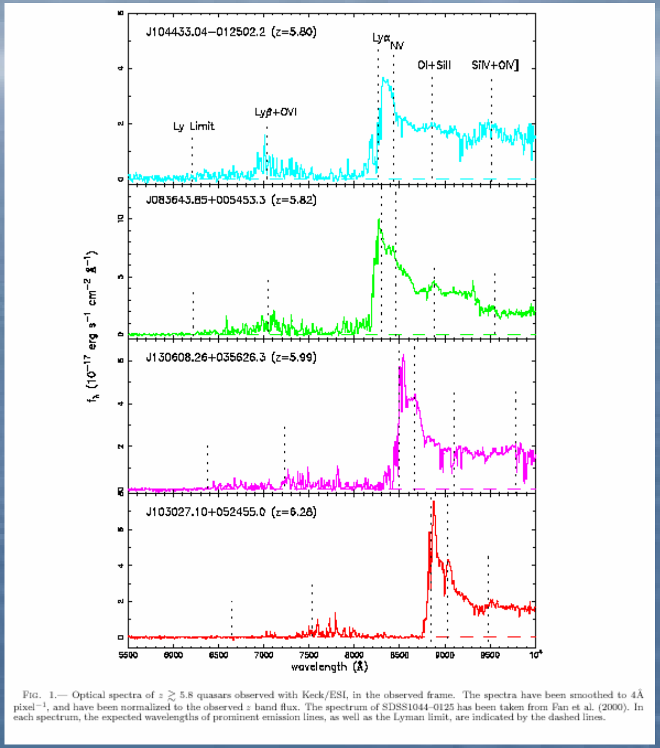


SPIFFI spectra of the central 2 arcsec of J1c indicates SMM J14011+0252 has been forming stars for several hundred Myrs

II: Extremely High-Redshift Galaxies and Re-ionisation

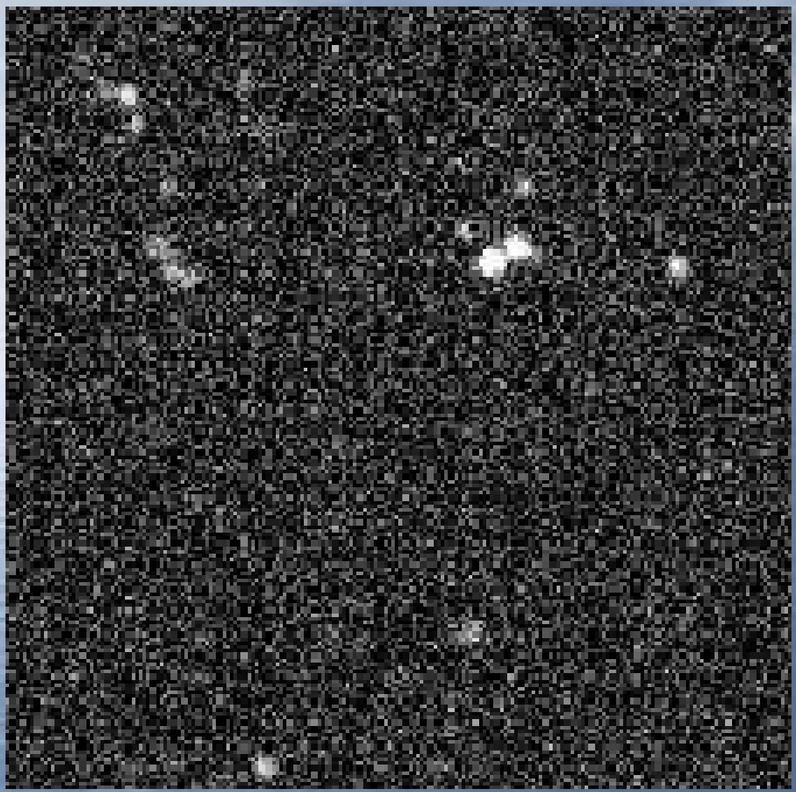


Abell 1835 IR1916 : I-band dropout gravitational arc



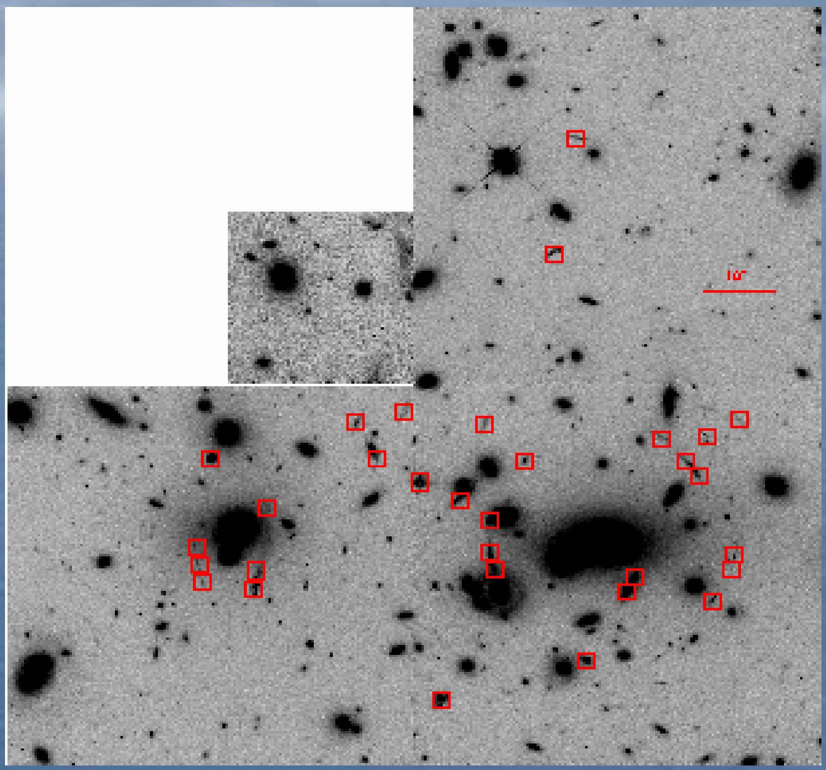
Gunn-Peterson trough in SDSS quasars
(Becker et al 2001 AJ 122,2850)

II: Extremely High-Redshift Galaxies and Re-ionisation



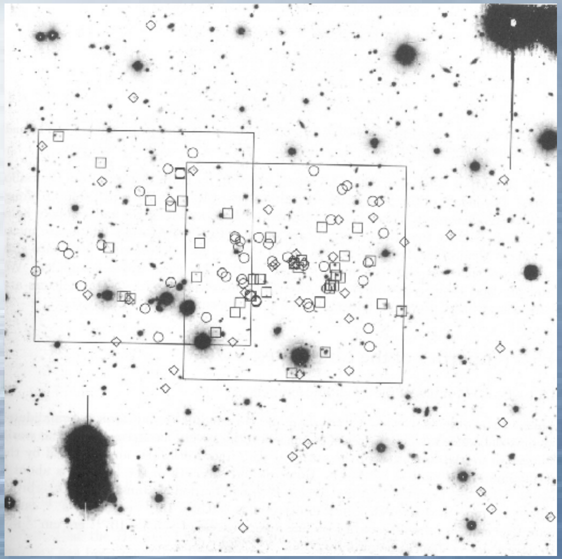
Surface densities of Lyman-α emitters in cosmological simulations (Barton et al., 2004, ApJ 604, L1)

2'

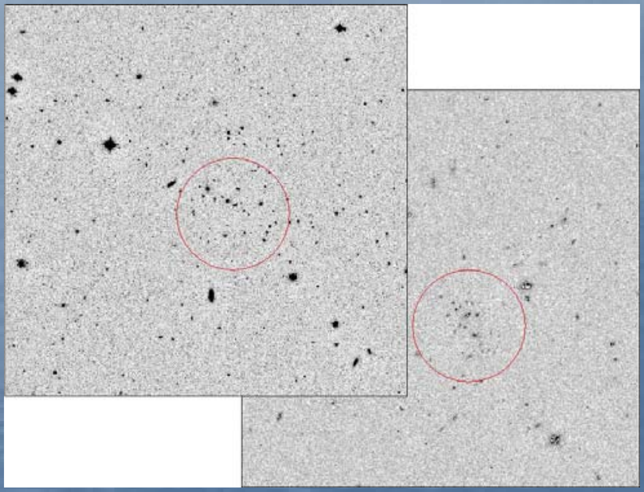


WFPC-2 image of A2218 with arclets marked

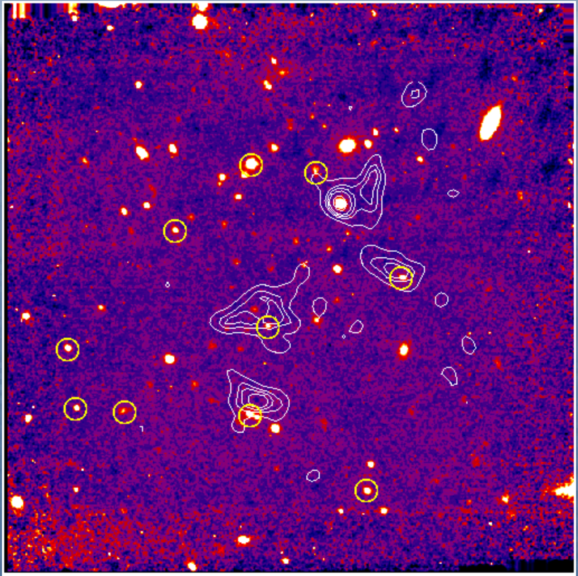
III: Cluster/Group Formation and the Morphology-Density Relation



7` x 7` *I*-band image of the $z = 2.2$ radio galaxy MRC 1138-262

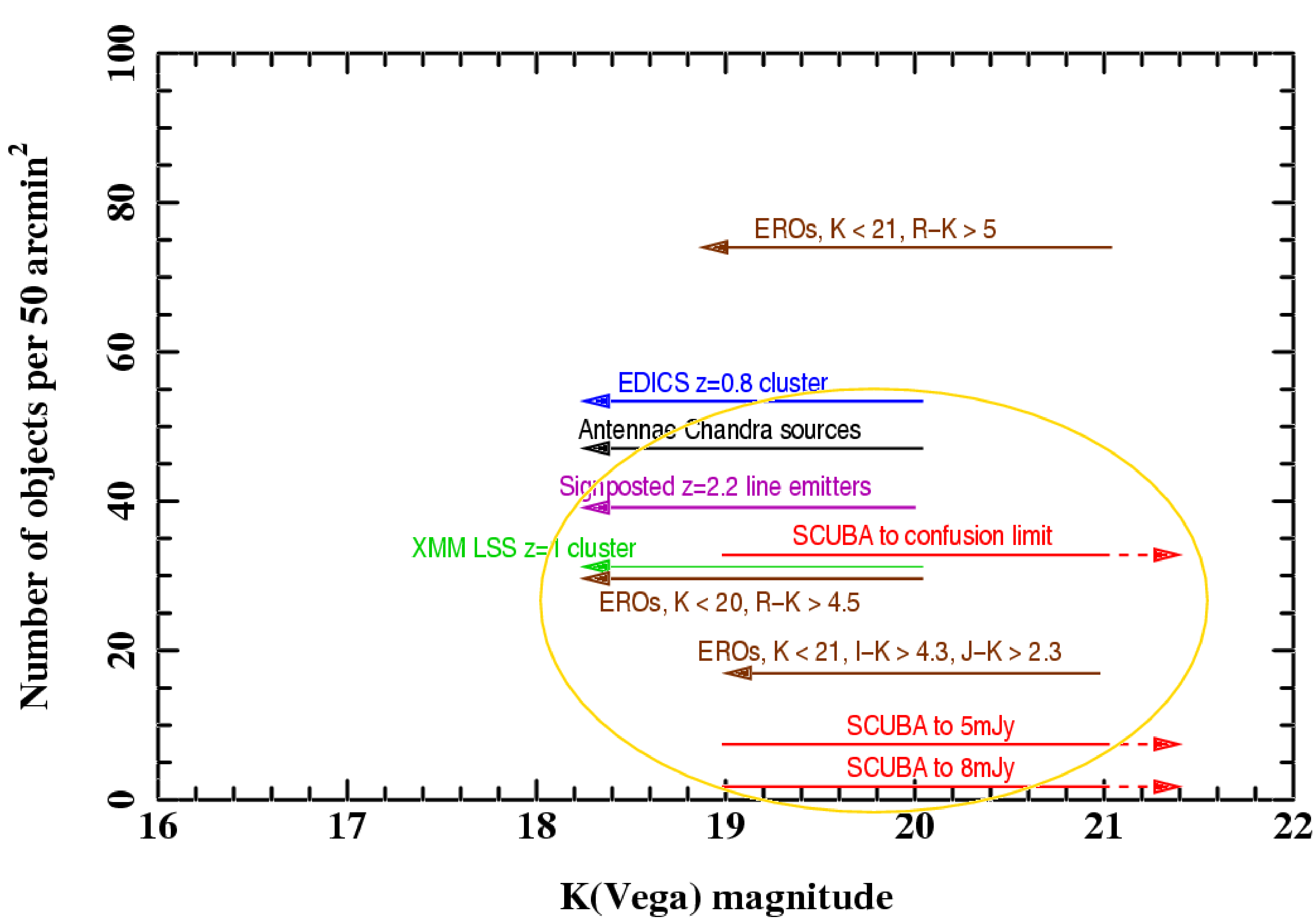


K-band images of clusters expected to lie at $z \sim 1$ detected in the LSS *XMM* survey



1`.5 x 1`.5 *K*-band image of a high-*z* X-ray-absorbed QSO showing fifteen EROs with $K < 21$ and $R - K > 5.3$

Multiplex advantage



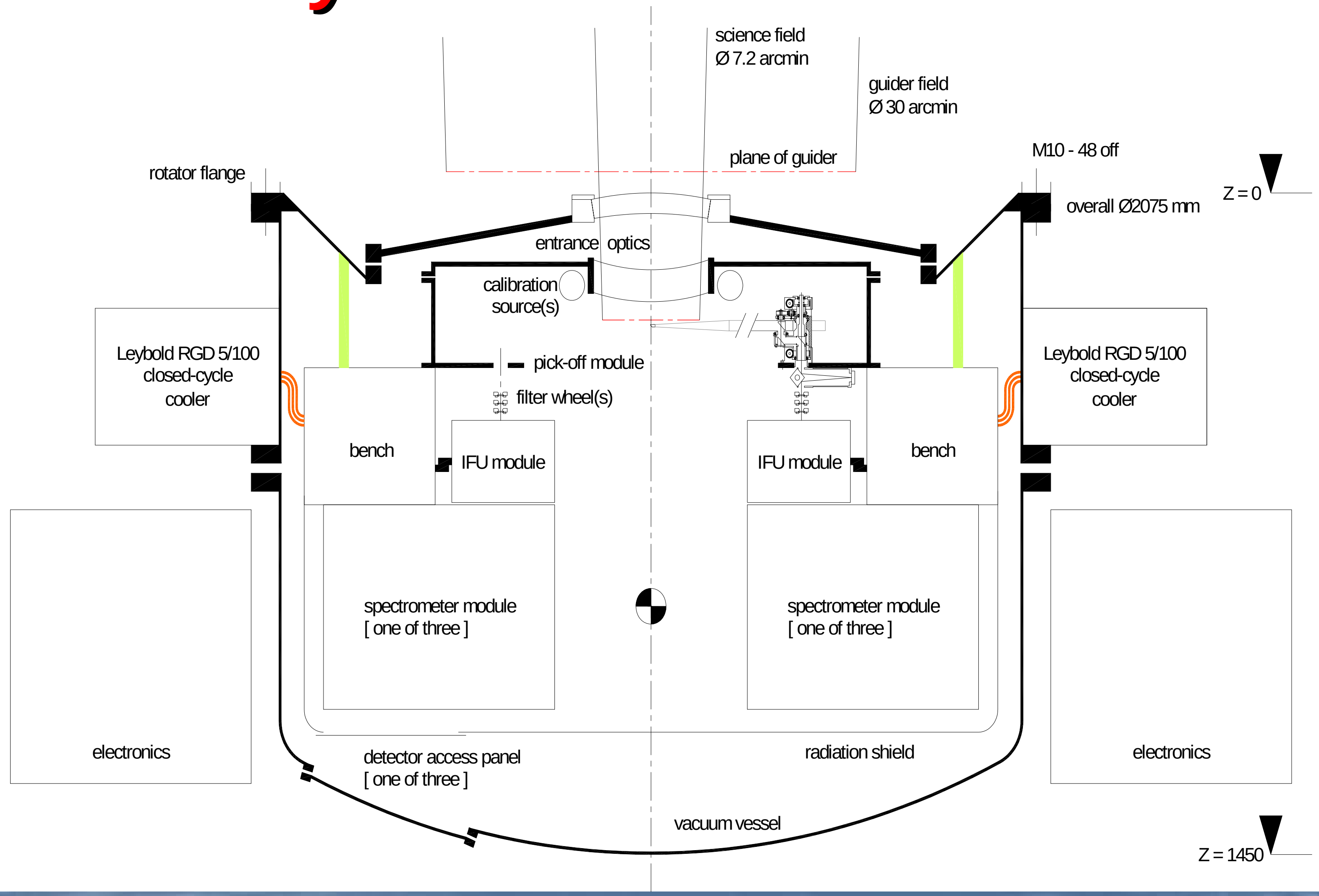
Top Level Requirements

- Spatially-resolved (3-D) spectroscopy
- Multiplexed spectroscopic observations
- Observations across the *J*, *H*, and *K* infrared atmospheric windows
- Versatile capability to address new scientific problems

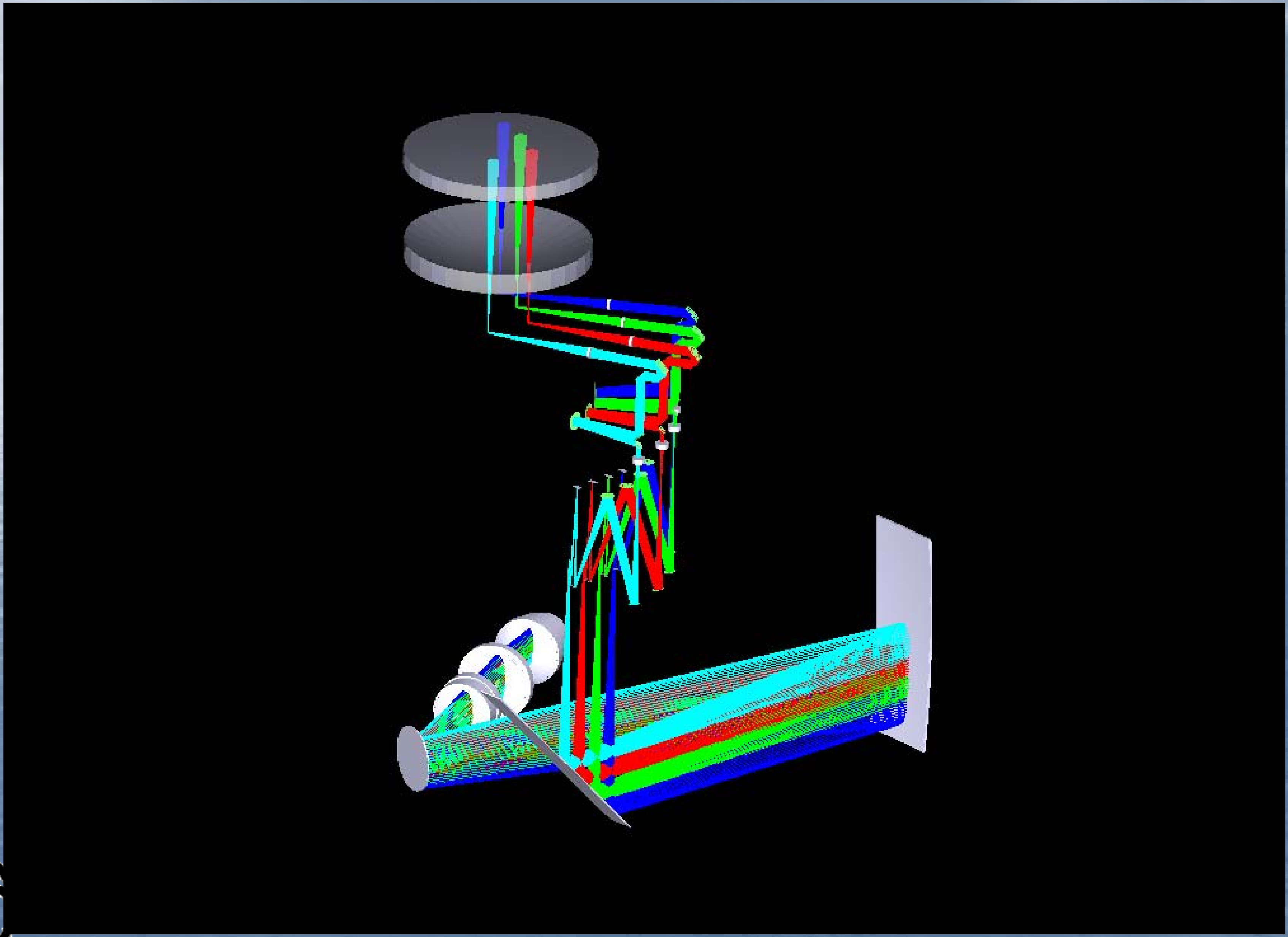
Science Requirements

Requirement	Baseline Design
Throughput (excl tel/atm/det)	J=20%, H=30%, K=30%
Sensitivity (0.6 arcsec seeing)	5σ 8hr: J=21.2, H=21.0, K=19.2
Wavelength coverage	1.0 to 2.45 μm
Spectral Resolution	R=3400,3800,3800 (J,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 arcmin diameter circle
Close packing of IFUs	≥3 within 1 sq arcmin
Closest approach of IFUs	≥3 pairs of IFUs separated by 6 arcsec

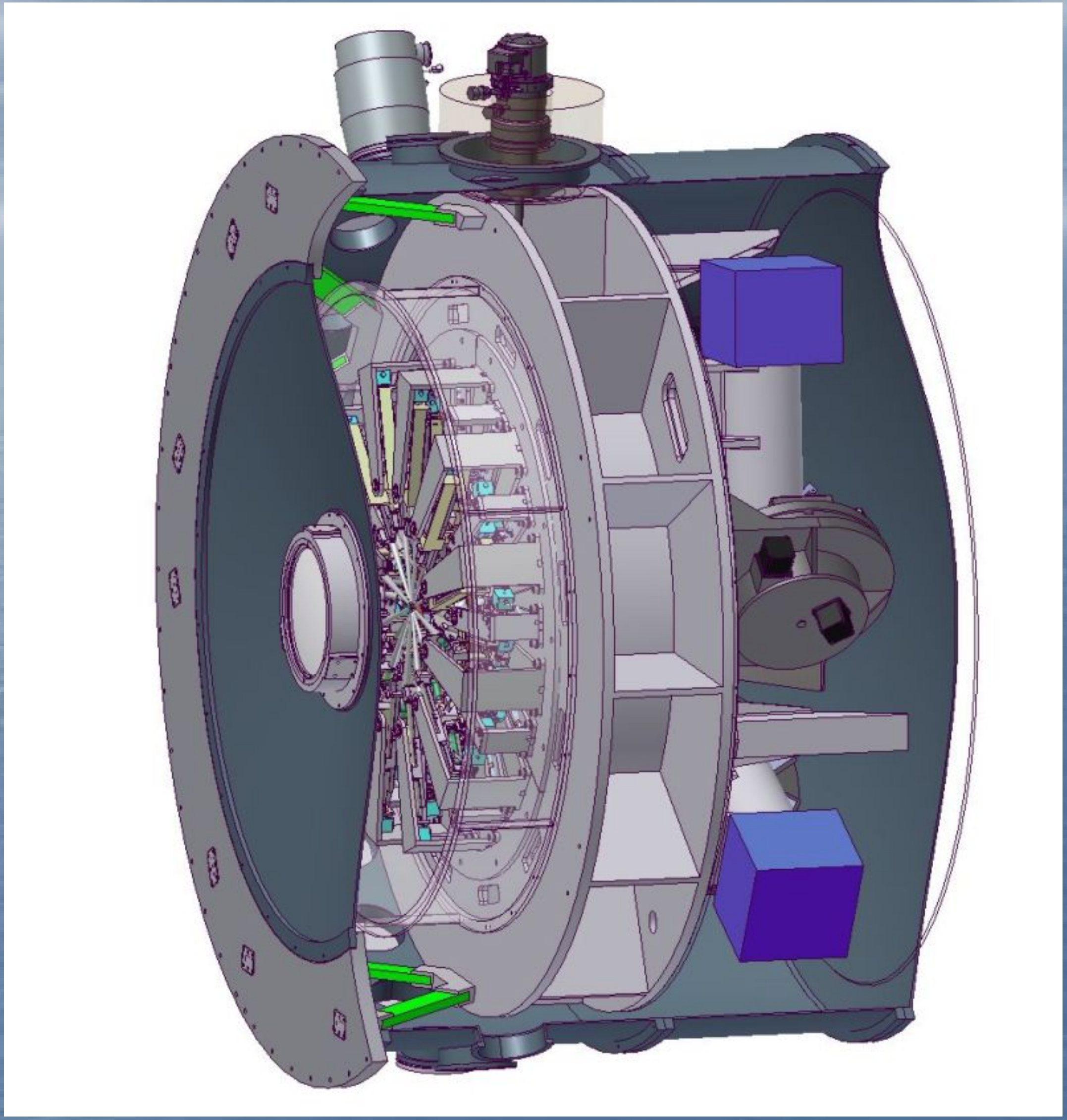
Systems Architecture



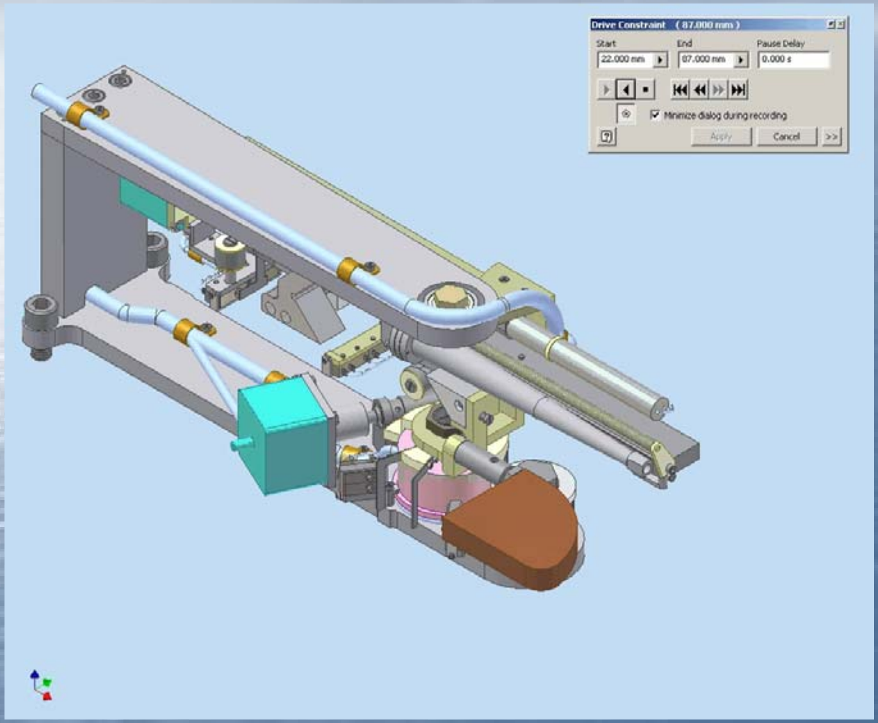
Optical Design

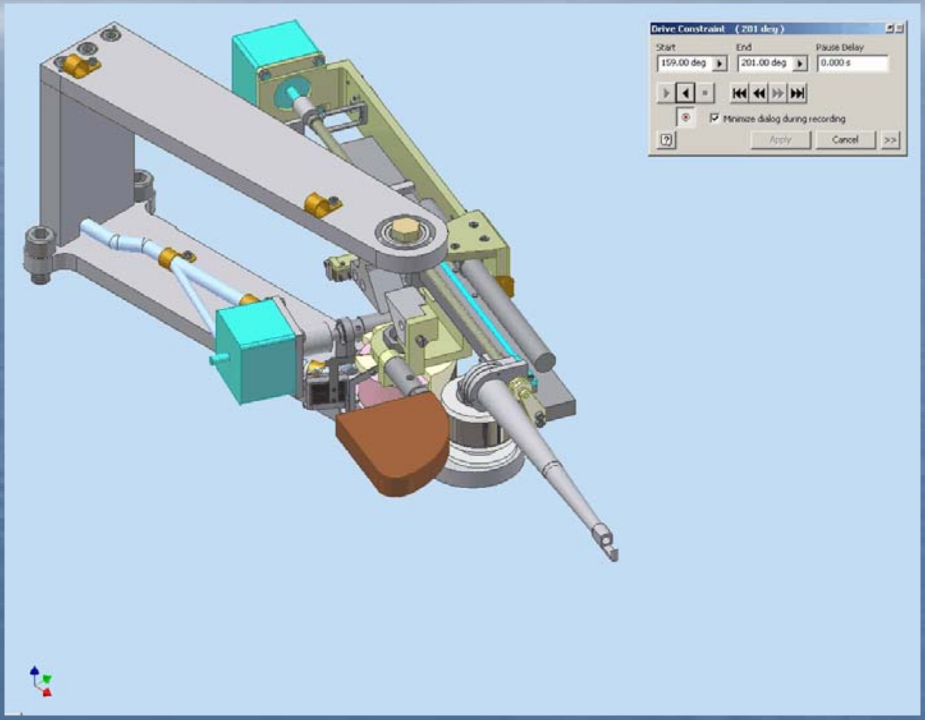


Systems Architecture

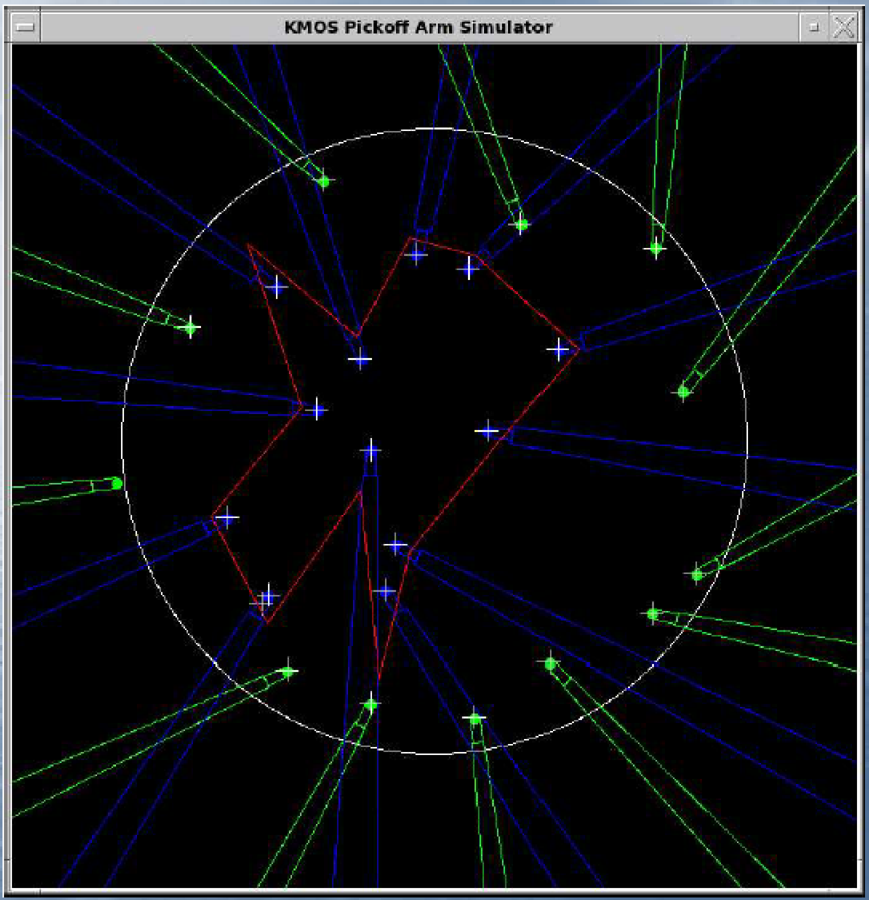


Arm movements

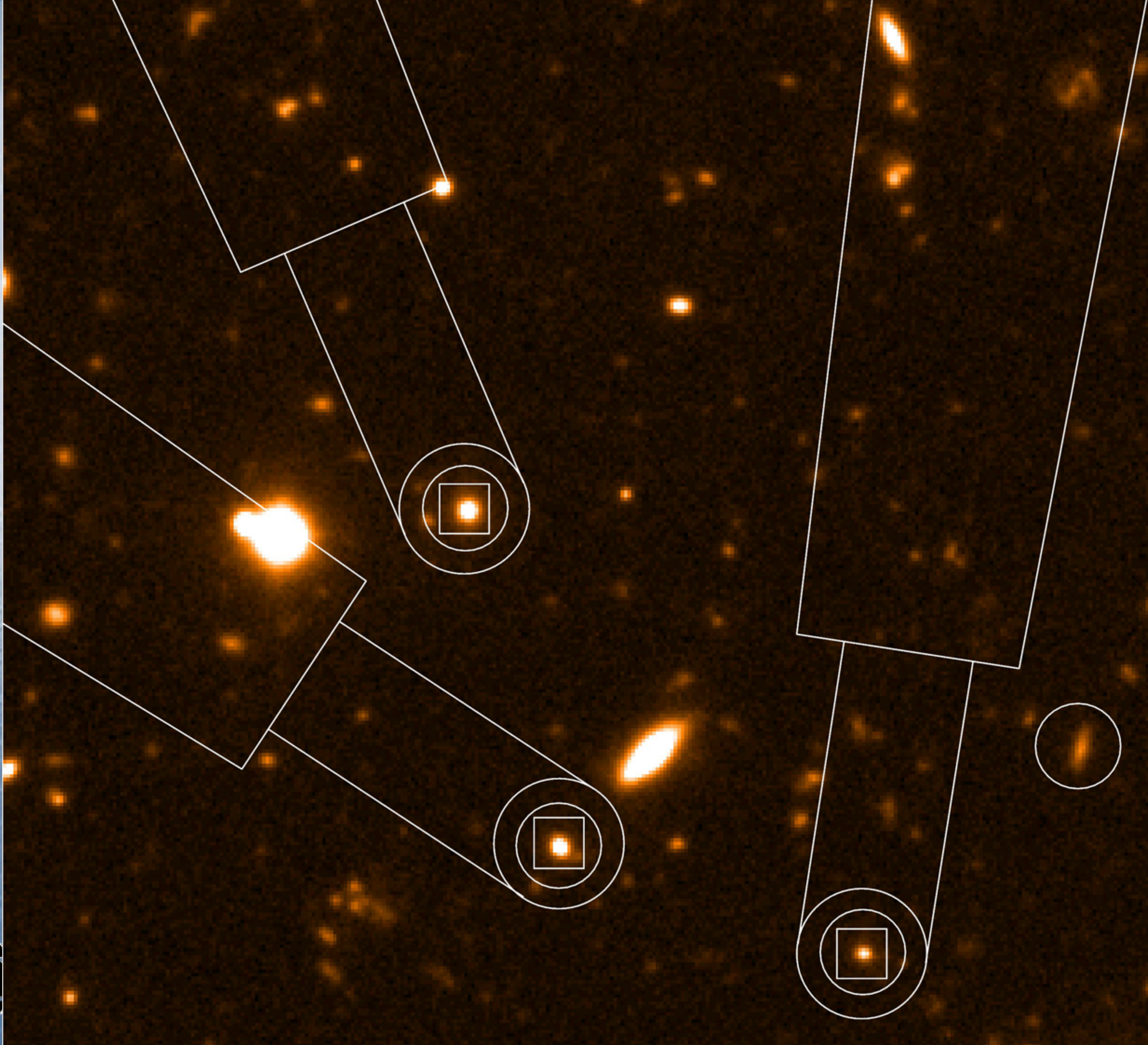




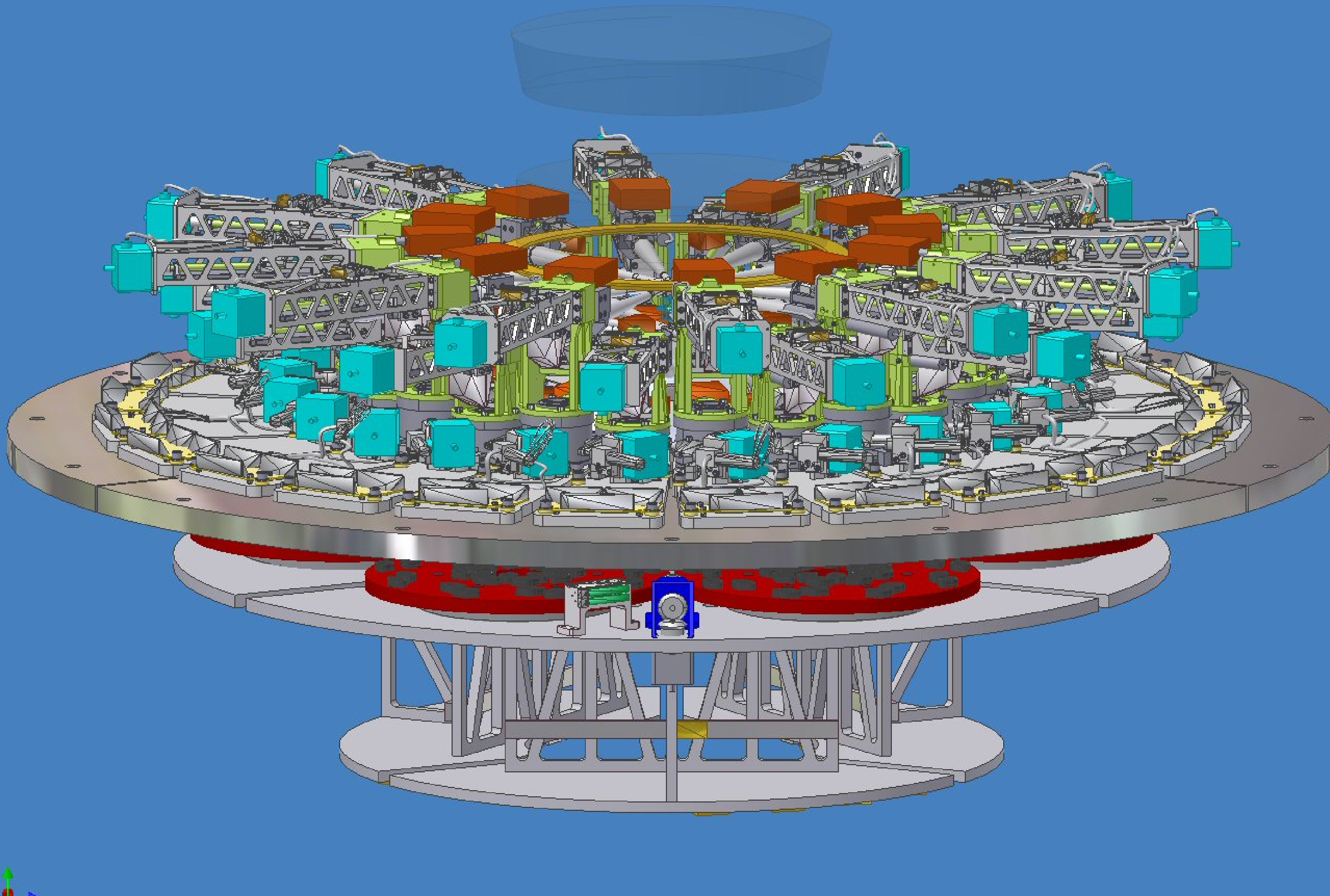
Simulations of the pick-offs

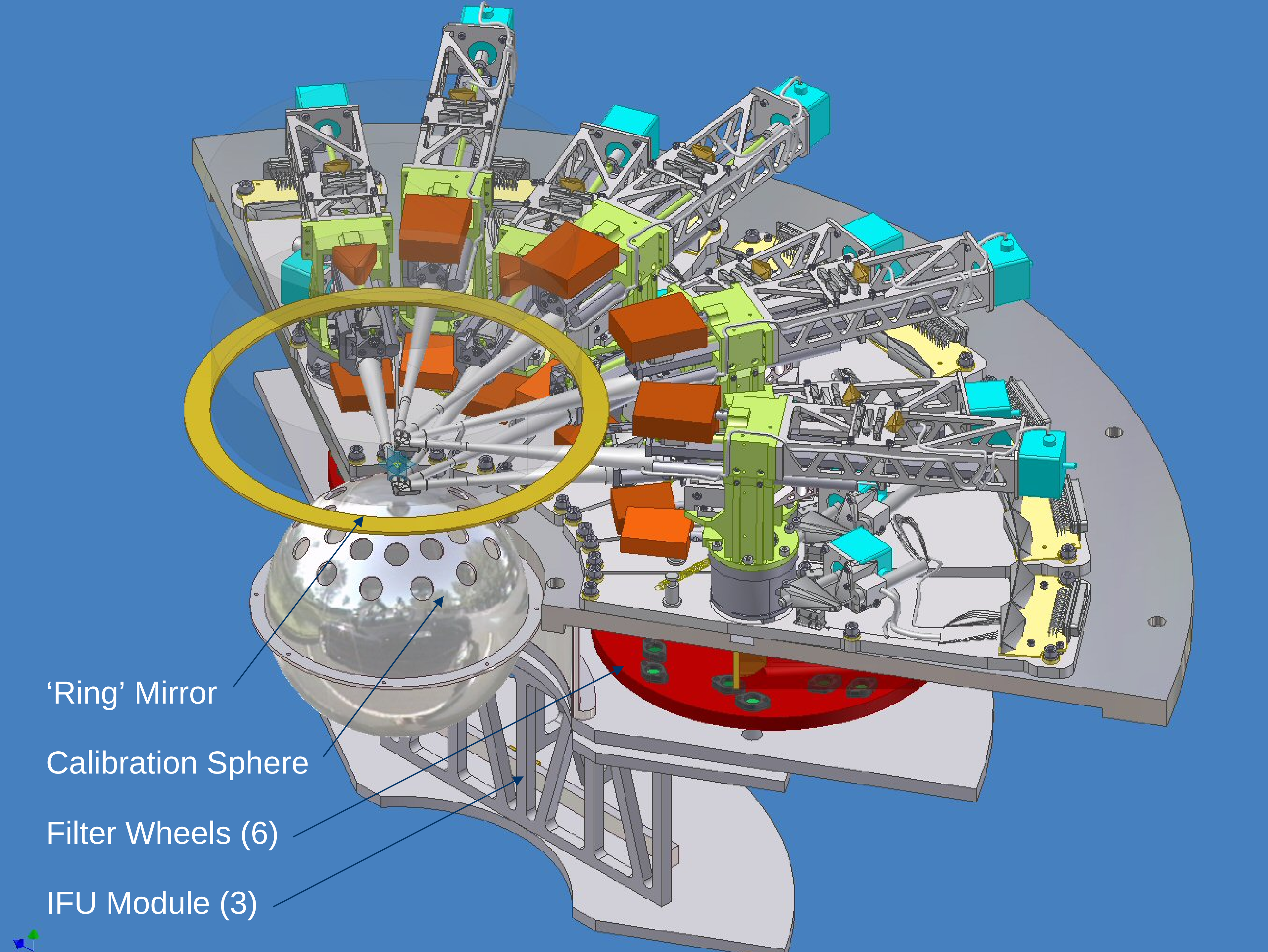


Science Case	Setup	No. Obects. Assigned N	%
1. EROS-1 NTT	1	24	80
30 objects	2	6	20
	Total	**30**	**100**
2. EROS-2 FDF	1	24	31
77 objects	2	24	31
	3	17	22
	Total	**65**	**84**
3. EROS-3 GOODS ACS	1	24	50
48 objects	2	20	42
	3	3	6
	Total	**47**	**98**
4. EROS-4 GOODS ACS	1	24	67
30 objects	2	10	33
	3	**30**	**100**
	Total		
5. EDISCS CLUSTER	1	24	44
55 objects	2	20	36
	3	10	18
	Total	**54**	**98**

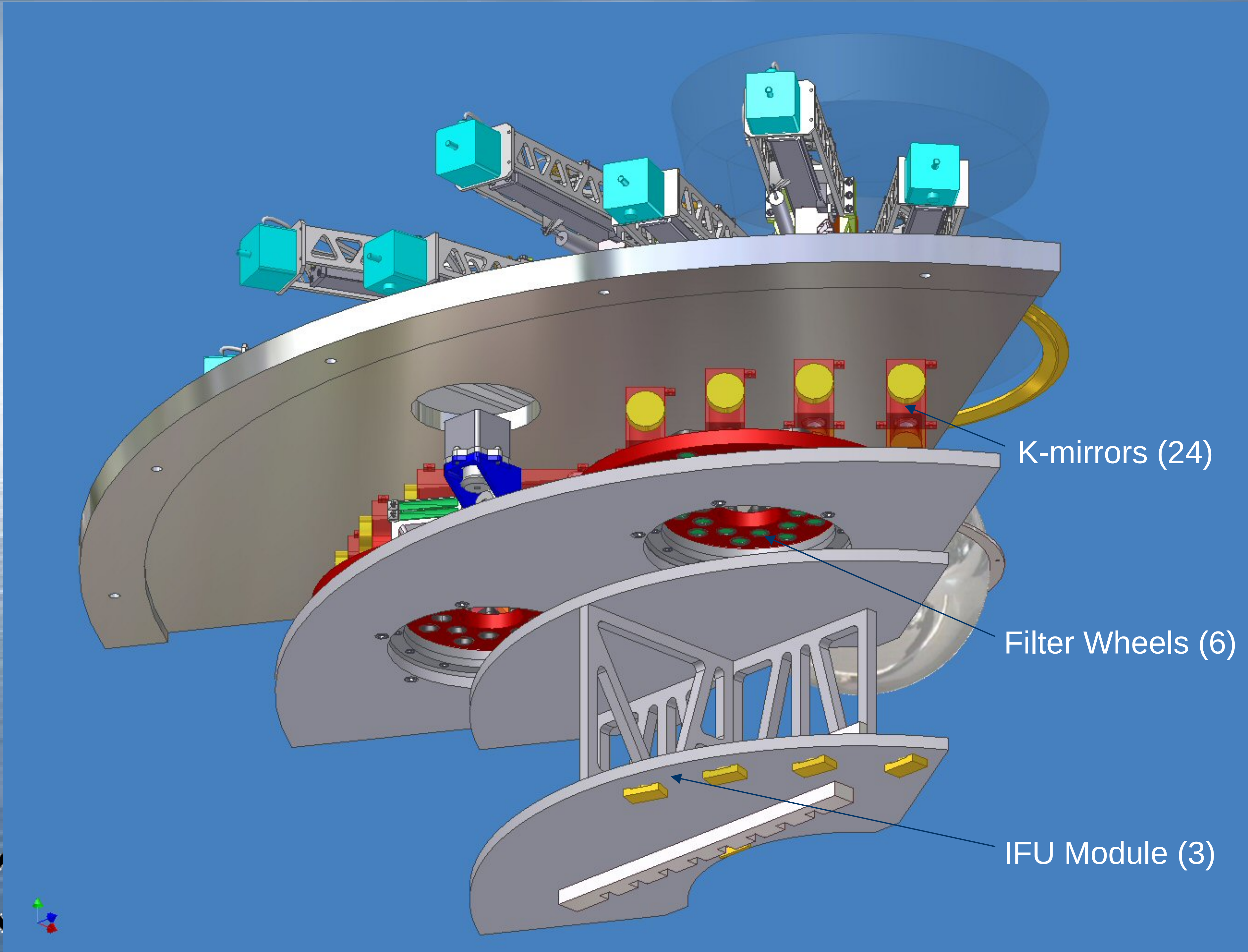


Pick-off Module





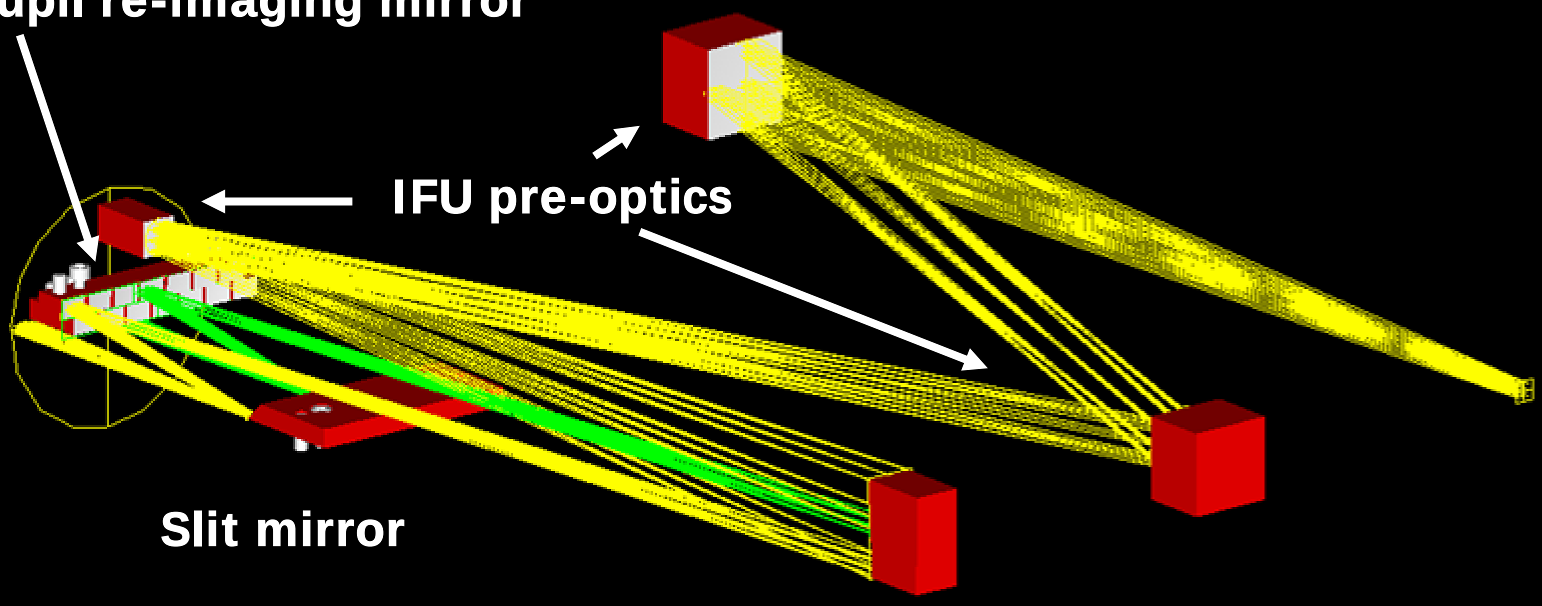
'Ring' Mirror
Calibration Sphere
Filter Wheels (6)
IFU Module (3)


K-mirrors (24)
Filter Wheels (6)
IFU Module (3)

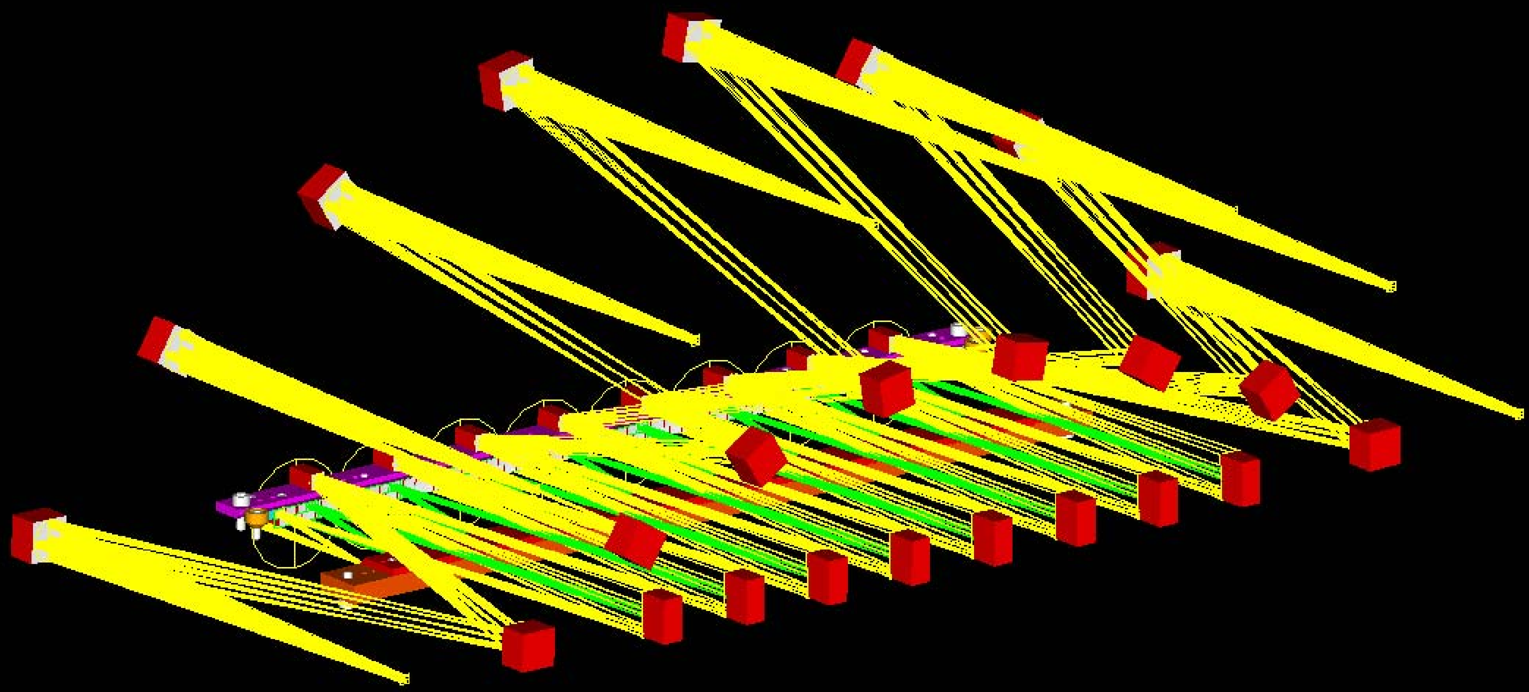
IFU Module

- 8 pickoff subfields combined to produce single output slit; each subfield re-imaged on to 14x14 element image slicer
- Diamond-machined monolithic optics (Al) to eliminate thermal effects and minimize alignment errors
- All reflective, gold-coated, achromatic design
- Anamorphic magnification produces regular spatial sampling on sky (0.2 arcsec) with Nyquist sampling of spectra

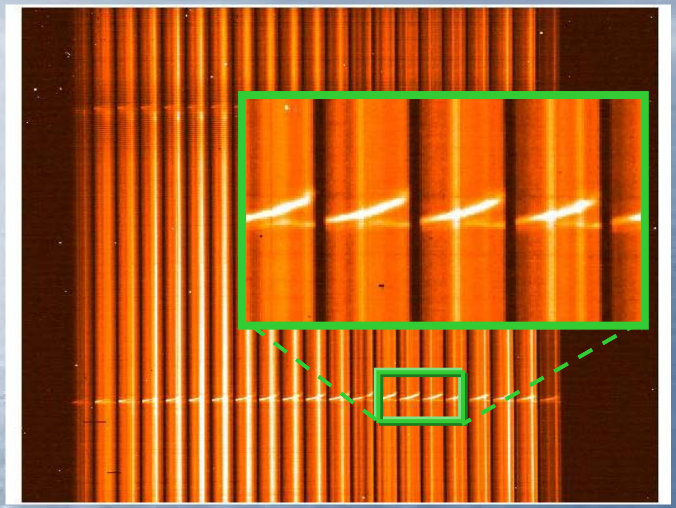
Single IFU optics

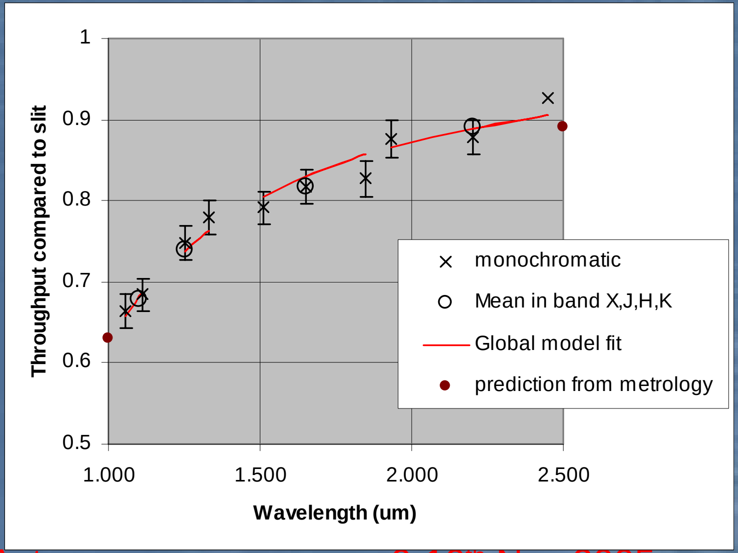


IFU optics for 1 spectrograph



IFU Production

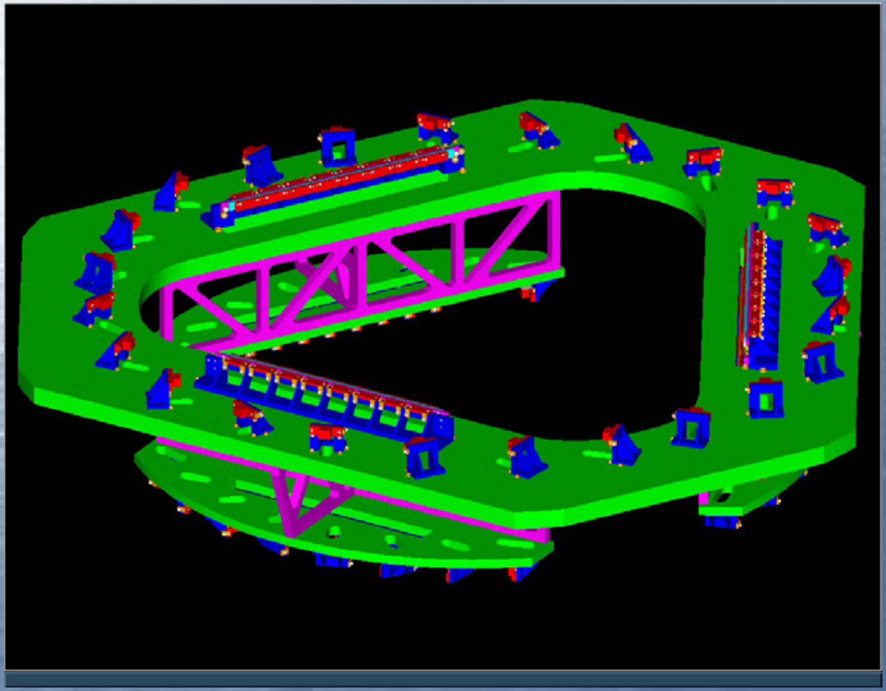


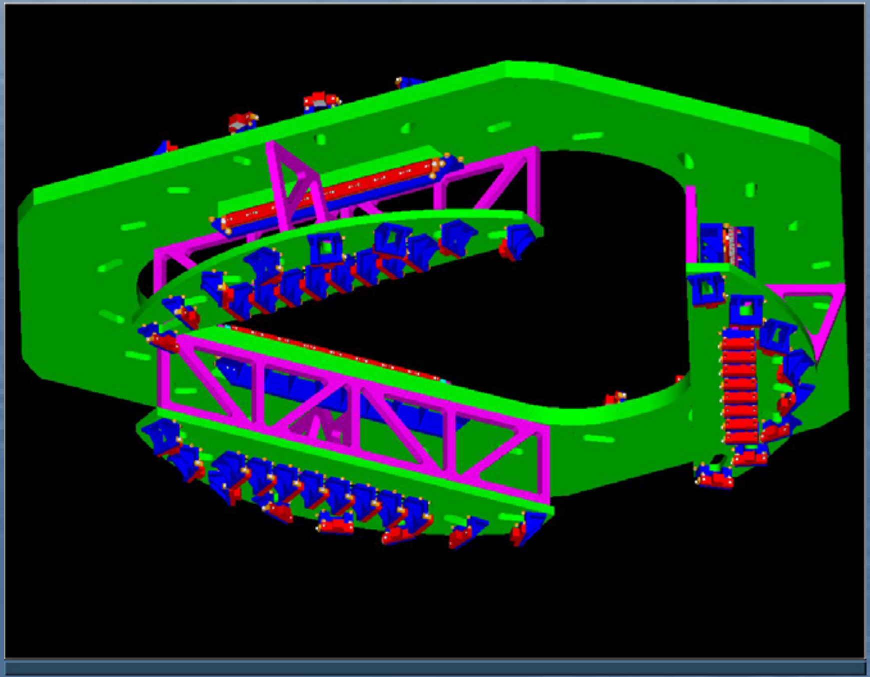


- Plug & play installation into GNIRS
- On-sky commissioning 5-8 April, 2004
- Throughput efficiencies:

  74% (J)
  82% (H)
  89% (K)

IFU Mechanical Design

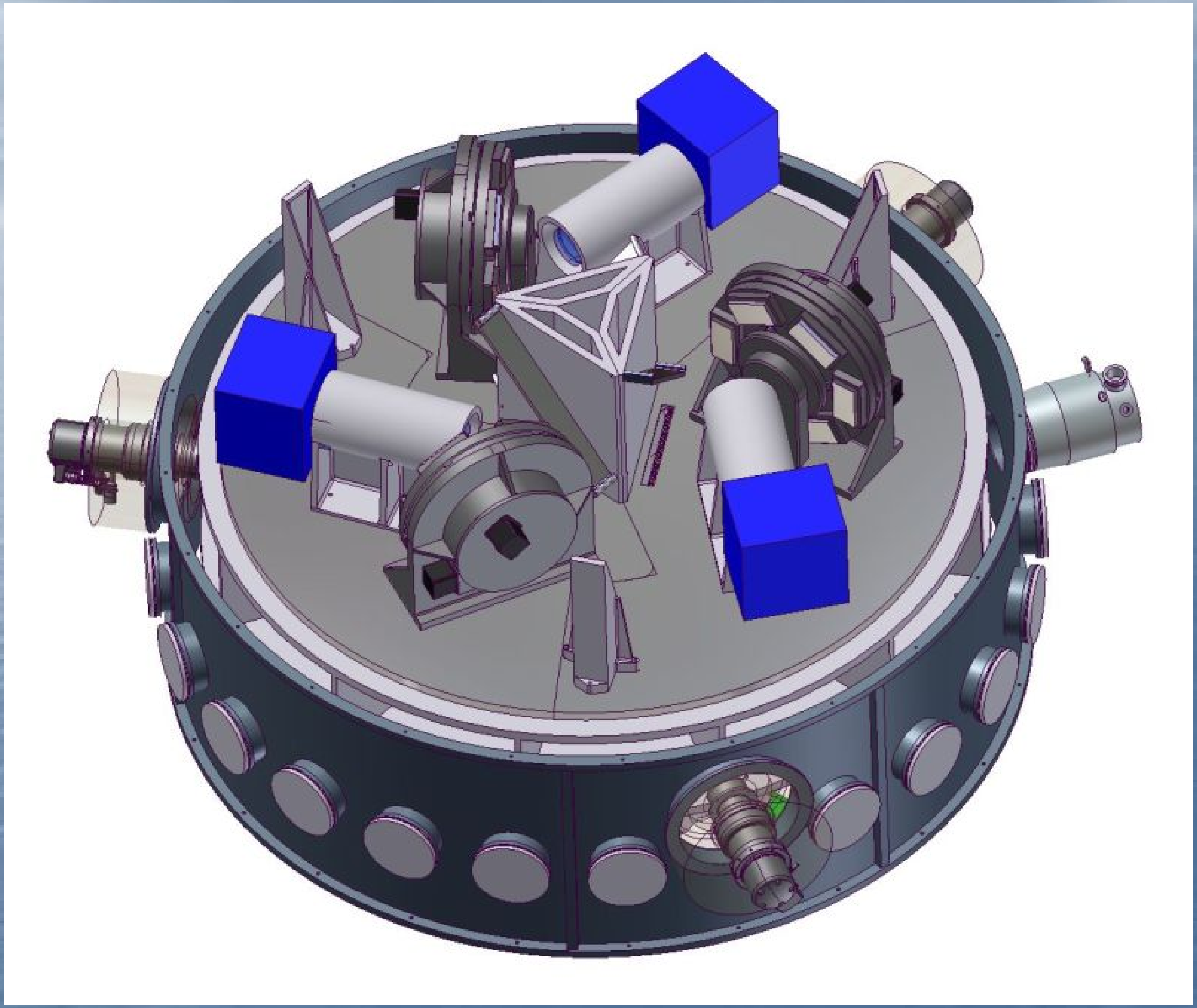




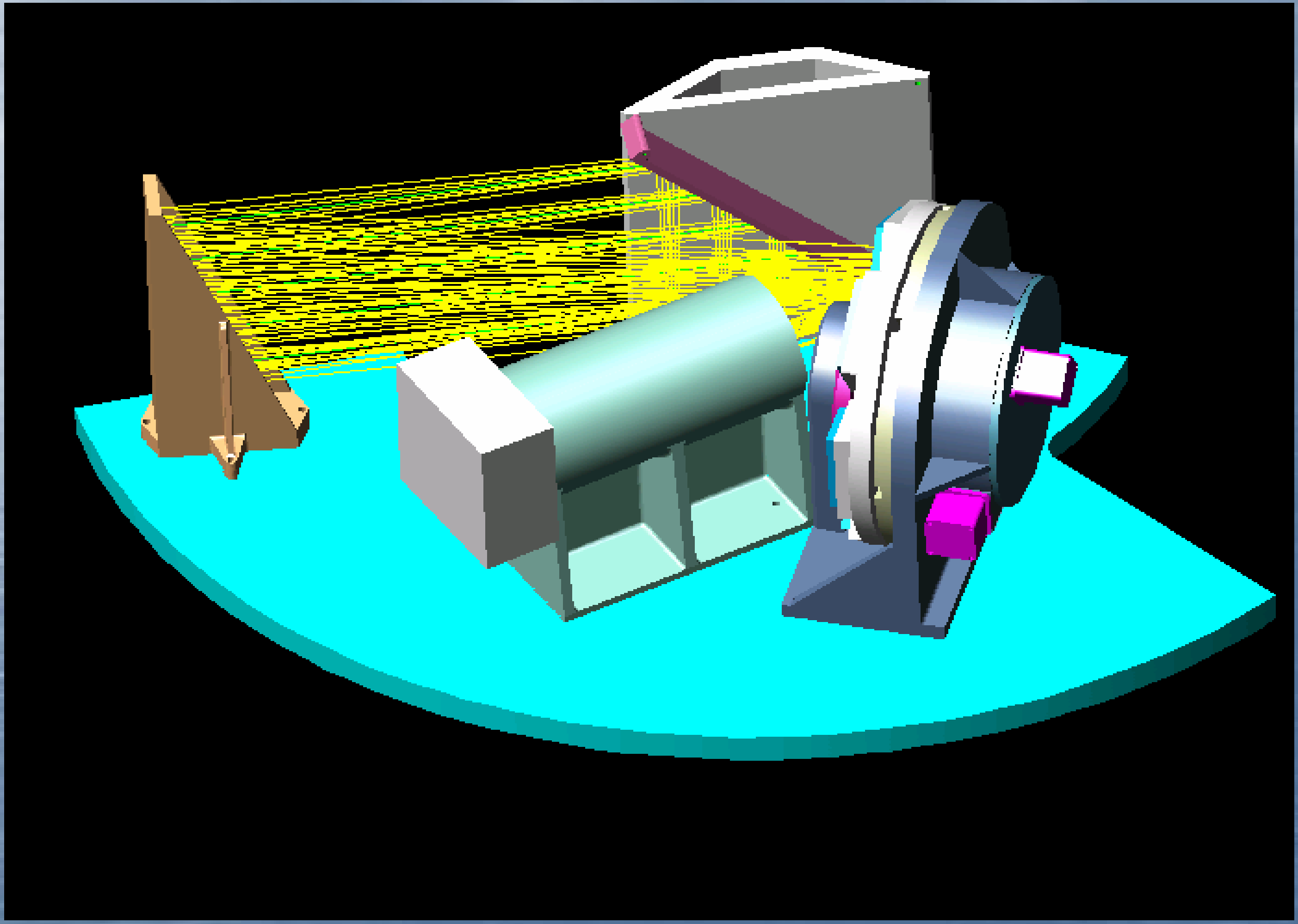
Spectrograph Module

- Modular spectrograph subsystems (3)
- Toroidal reflective collimator and 6-element transmissive achromatic camera
- 6-position grating wheel: optimized J,H,K gratings bands with options for a z-band grating and two lower resolution gratings
- Each with 1 Hawaii-2RG 2048x2048 detector

Spectrograph Layout



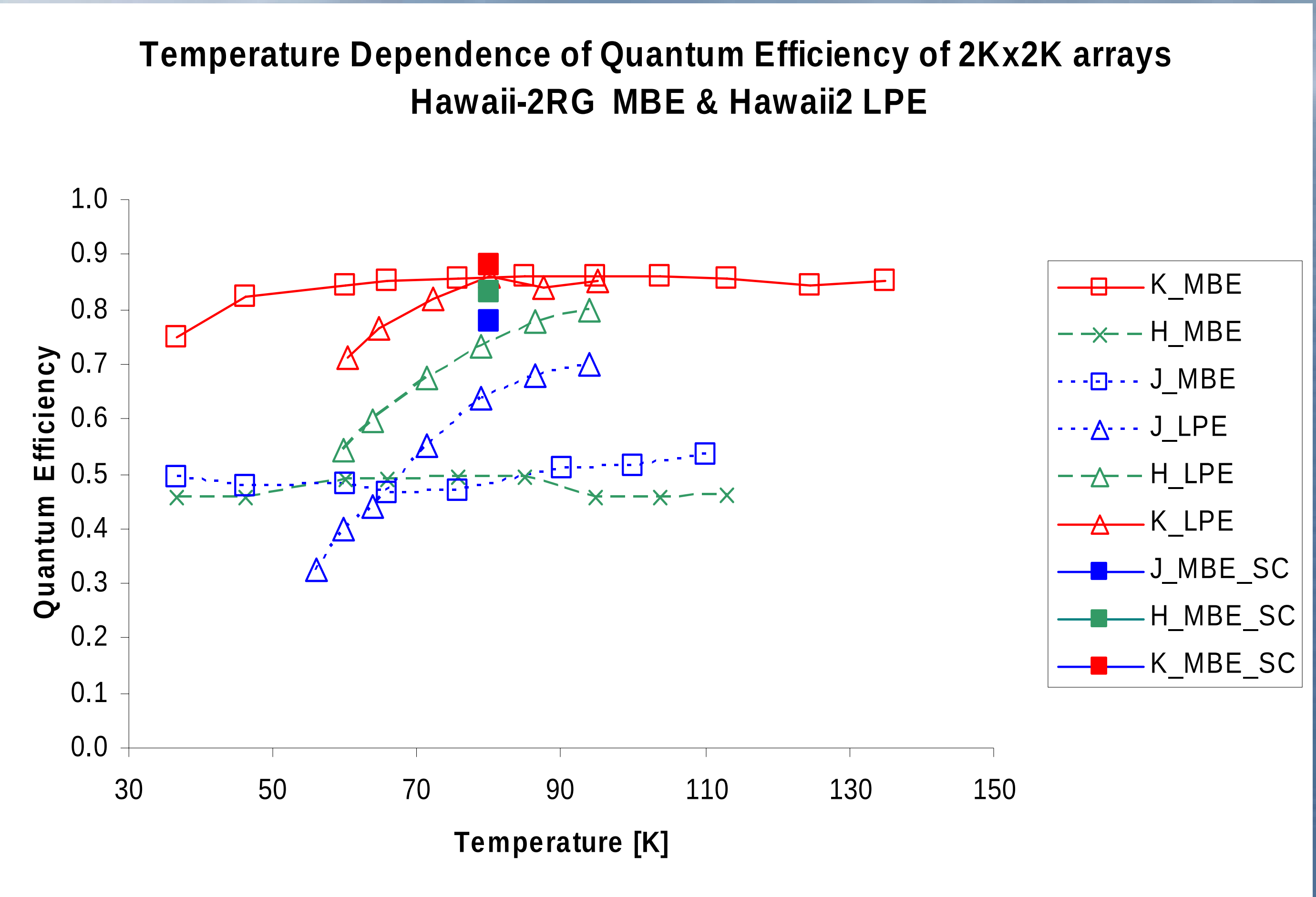
Spectrograph Design



Spectrograph Performance

Window	Wavelength range for the window	Spectral range (no overlap)	Resolution
$z^{\dagger}$	0.80-1.05um	0.25um	3380
J	1.05um-1.37um	0.32um	3380
H	1.45um-1.85um	0.4um	3800
K	1.95um-2.5um	0.55um	3750
JH	1.05um-1.85um	0.80um	1500
HK	1.45um-2.55um	1.10um	1500

Hawaii-2RG Detector



- Hawaii2 LPE QE drops with temperature
- Hawaii-2RG MBE QE does not dependent on temperature
- Science grade QE
  K-band: 0.88
  H-band: 0.83
  J-band: 0.80
  [z-band: 0.80]

Status and Schedule

- Preliminary Design Review March 2006
- Final Design Review March 2007
- Preliminary Acceptance Europe March 2010
- Prelim Acceptance Chile September 2010


The End
Kmos
Panoramic Near-Infrared Astronomy
9-10th Nov 2005