AAOmega

AAO Feb 2005

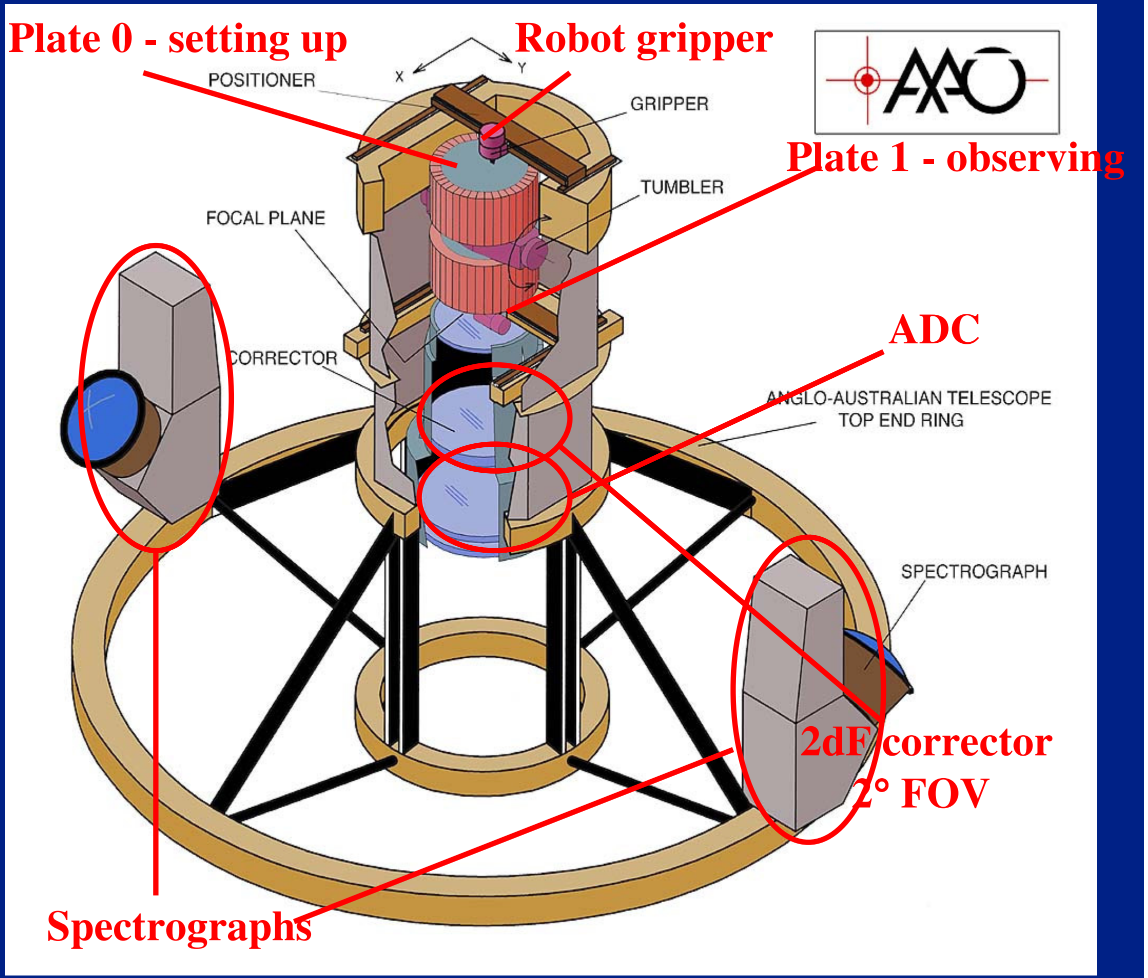
2dF and its Spectrographs

2dF spectrographs mounted on top end ring of AAT

- Designed for 2dFGRS

Limited in

- Efficiency: 4-7% peak
- Resolution: R<4000
- Detector area: 1K x 1K
- Stability: ~ few pixels



The AAOmega Project

- Refurbished 2dF top end
- 392 × 35m MOS fibres, 2.0'' diameter
- 8 guide bundles, with plate rotation
- New, stable, high efficiency, bench-mounted dual-beam, articulating spectrograph with VPH gratings and 2kx4k CCDs
- Major overhaul of 2dFDR
- Can also use with existing SPIRAL IFU at Cassegrain – 11 x 22'' field, 0.7'' /lenslet/fibre
- Commissioning Q4 2005

Science Requirements

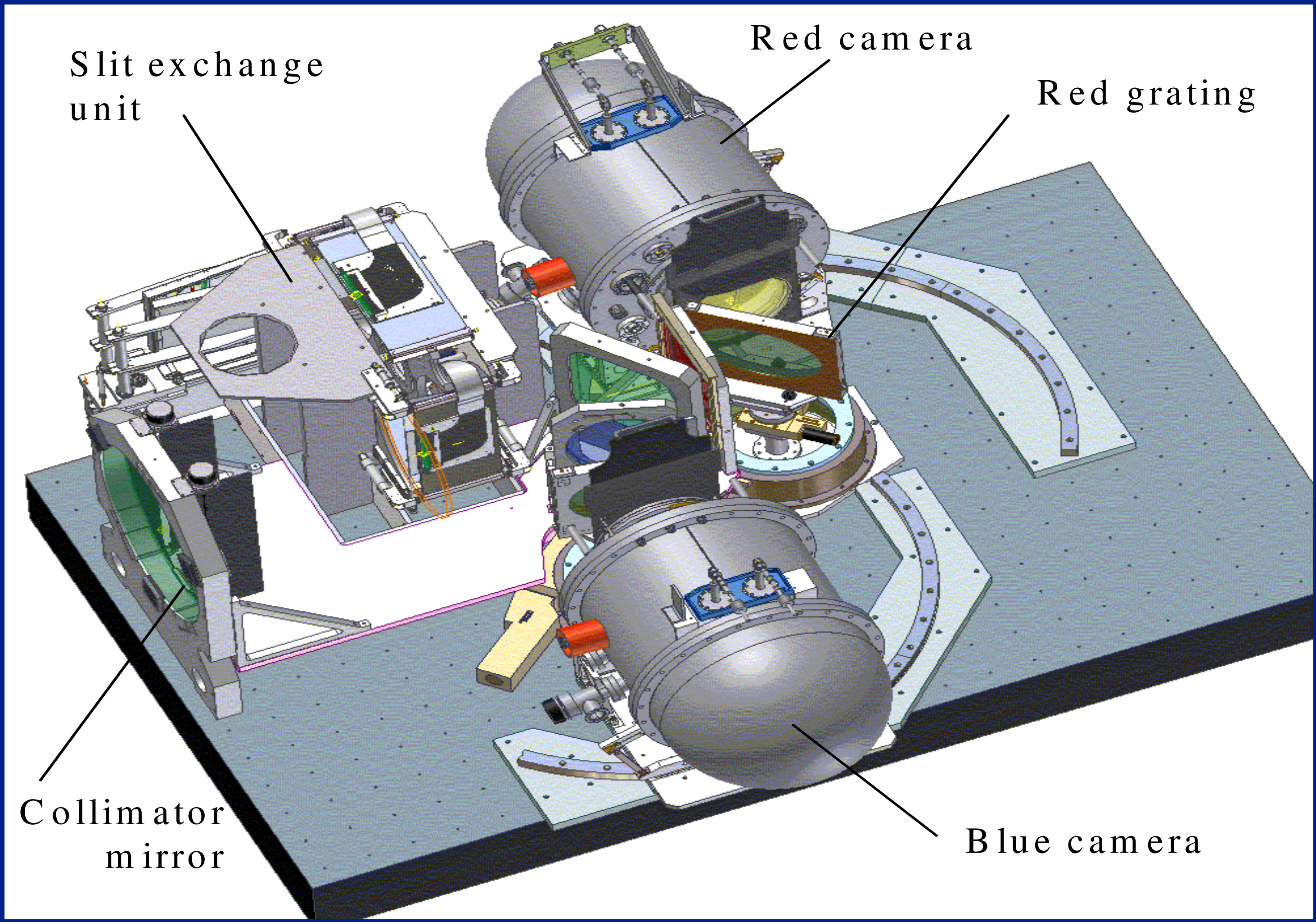
- **High spectral resolution:** need R ~ 10,000 to reach velocity precision 1 km/s
- **High S/N:** require S/N 50-100 to get best velocity precision
- **Good Sky Subtraction:** sky subtraction often to 1% or better, sometimes 0.1%
- **High stability:** <1/20 pixel over several hours, for velocity precision and sky subtraction.
- **Uniform PSF:** few % for velocity precision and sky subtraction.

Design Drivers

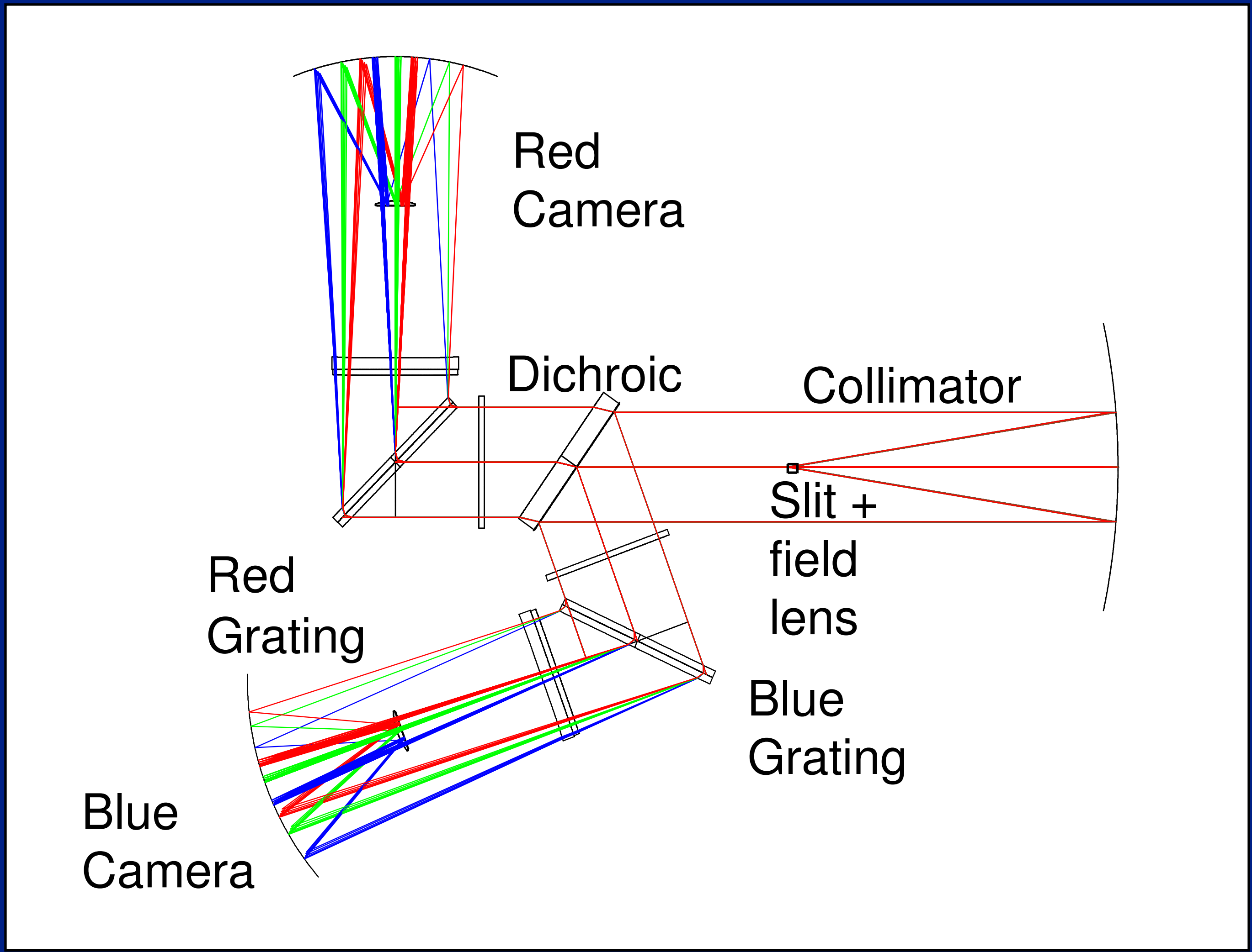
- Based on VPH gratings – efficient and flexible
- Maximise number of spectroscopic resolution elements
- Excellent optical performance for 370nm-950nm
- Resolution R=1500-10,000 at any wavelength
- Spectral stability better than 1/20 pixel
- Minimise scattered light and ghosting
- Maximise efficiency
- As few and as simple optical components as possible
- Uniform and well-sampled PSF
- Allow use with the existing SPIRAL (IFU) front end

All with limited budget and with minimal risk

Dual Beam Schmidt Spectrograph



Spectrograph layout



Optical Parameters

Schmidt Collimator:

- f/3.15 (f/3.4 prime focus + FRD + non-telecentricity)
- 392 (MOS) or 512 (SPIRAL IFU) fibres
- Field lens in contact with fibres
- 190 mm collimated beam diameter
- Dichroic acting at 570nm

Dispersers:

- VPH gratings used at angles 0-47°

Schmidt Cameras:

- f/1.3, fastest speed giving good optics
- 2.4 x demagnification
- 3.2 pixels/FWHM (MOS), 2.0 pixels/FWHM (IFU)
- Articulation angle range 0 - 94°

Detectors:

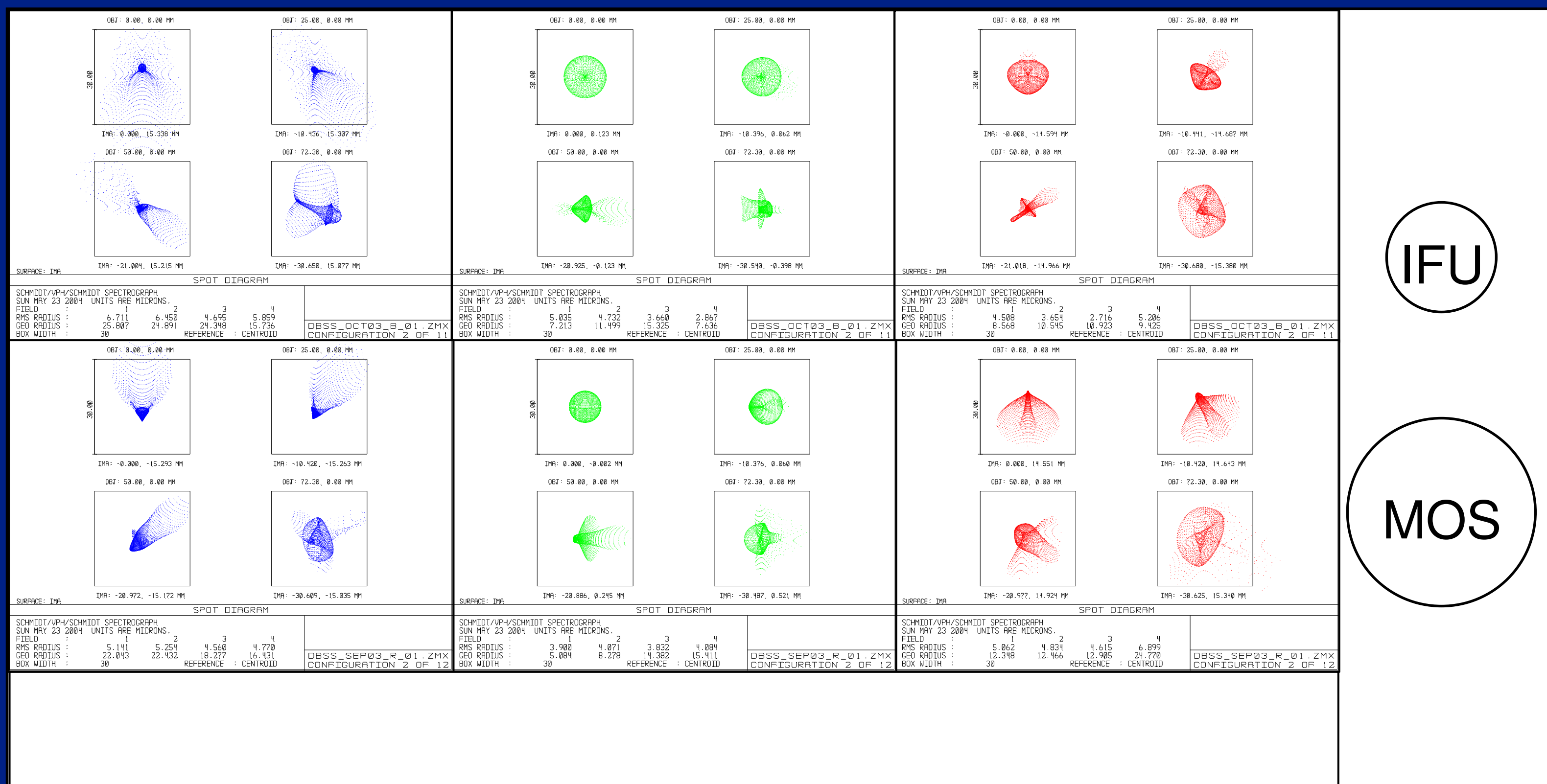
- 2 x E2V 4096 (spatial) x 2048 (spectral), 15μm pixels
- Deep depletion for red arm, back-illuminated for blue arm

Optical performance

Optimised for use 370-580nm (bue arm) and 560-950nm (red arm).

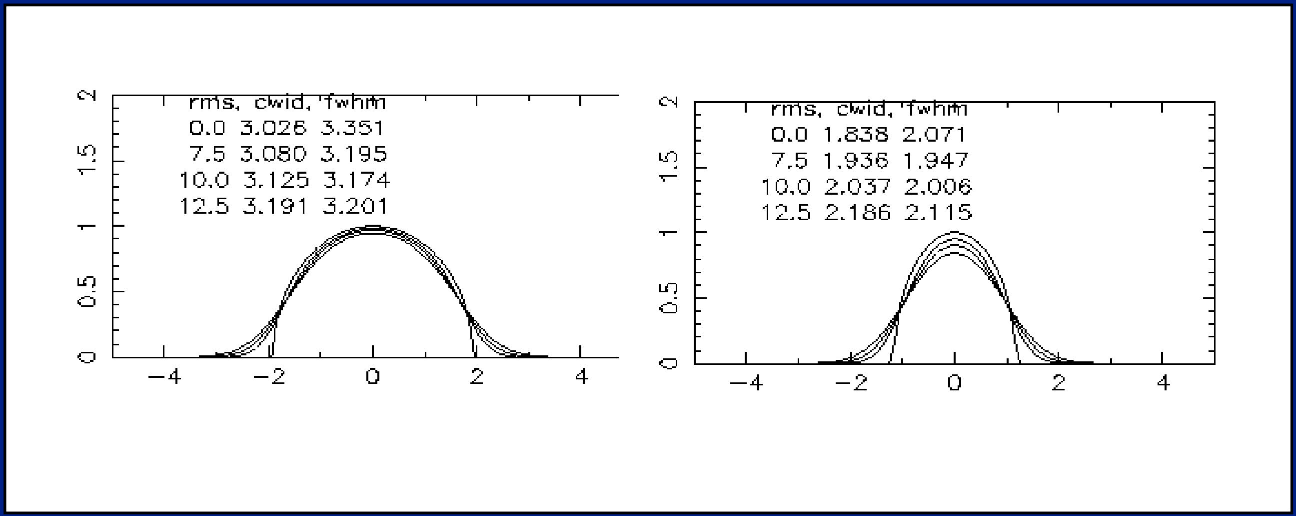
Spot size <7.8μm rms radius for all wavelengths and configurations,

=> PSF uniform to few % across field



PSF, FWHM, resolution

- Aberrations reduce FWHM!
- MOS PSF sampling: 3.2 pixels/FWHM
- IFU PSF sampling: 2.0 pixels/FWHM
- PSF uniform to few %
- MOS PSF occupies at most 7 pixels
- Boxy profile, true resolution better than FWHM indicates

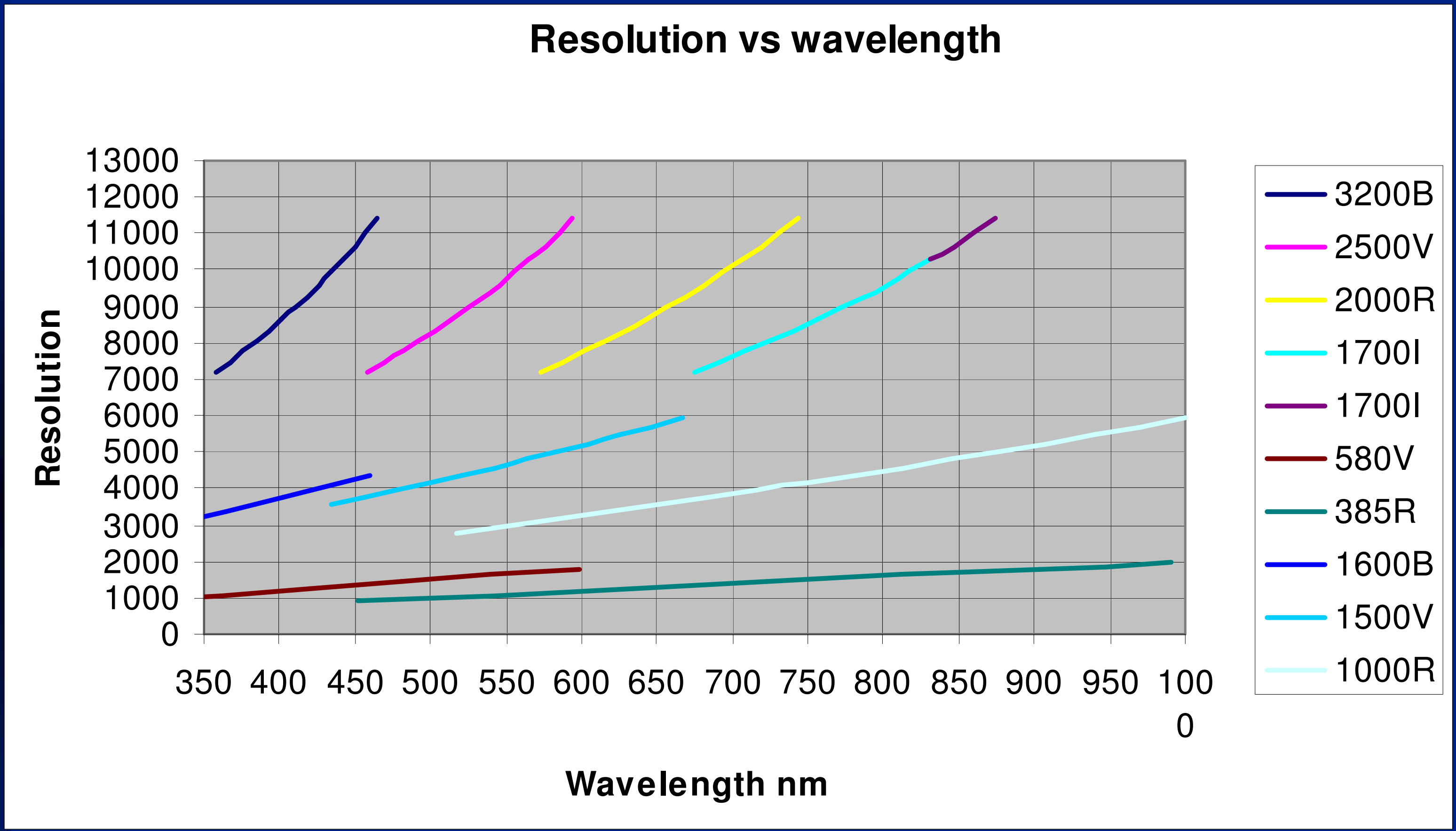


VPH Grating Set:

Name	Blaze (Å)	Δλ (Å)	Å/pix	Resn (MOS)
580V	4500	2100	1.0	1400
385R	7000	3200	1.6	1400
1600B	4000	800	0.38	3500
1500V	4750	800	0.37	4000
1000R	6750	1200	0.57	3700
3200B	4000	300	0.14	8500
2500V	5000	400	0.18	8500
2000R	6500	500	0.23	8500
1700I	8600	600	0.28	8500
1700D	8600	300	0.24	11000

- Grating set covers 370-950nm at R~1400, 3500, 8500
- R~11000 possible using Dixon gratings
- Resolution in IFU mode 1.6 times higher
- Other gratings (1400Z, 6000B ?) can be added

MOS Spectral resolution

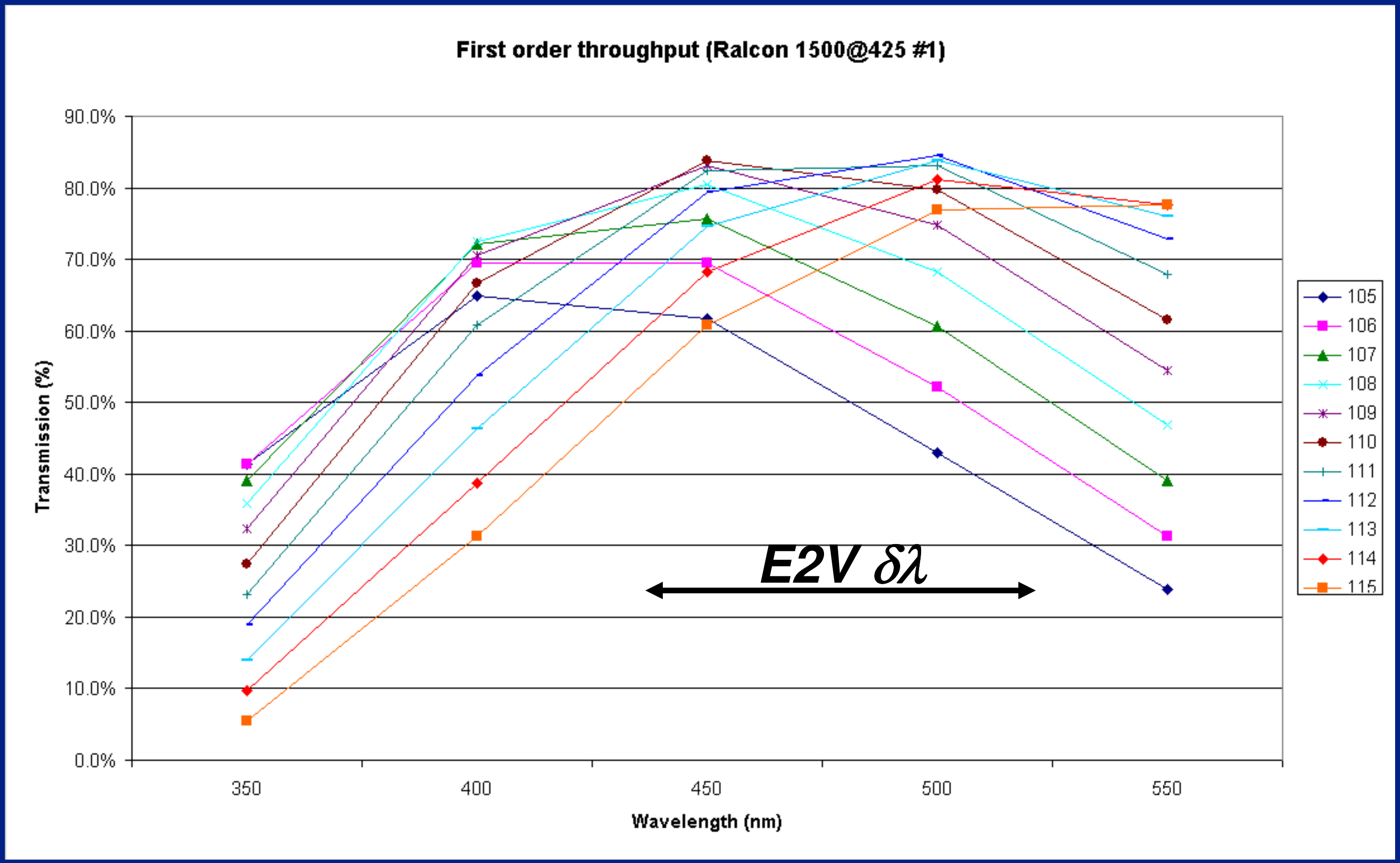


Blaze wavelength $\propto$ ***sinθ***

Dispersion $\propto$ ***secθ***

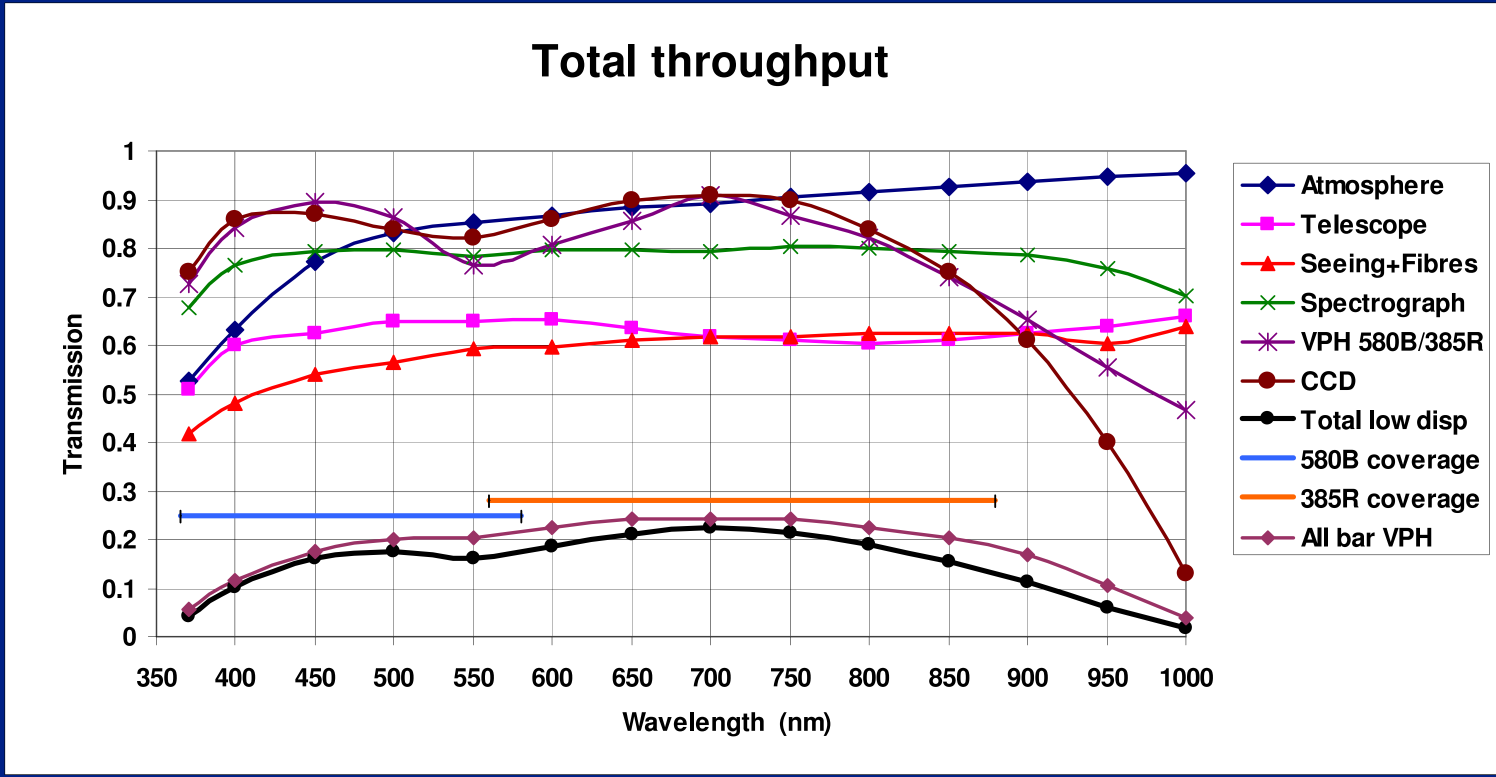
Resolution $\propto$ ***tanθ***

VPH gratings



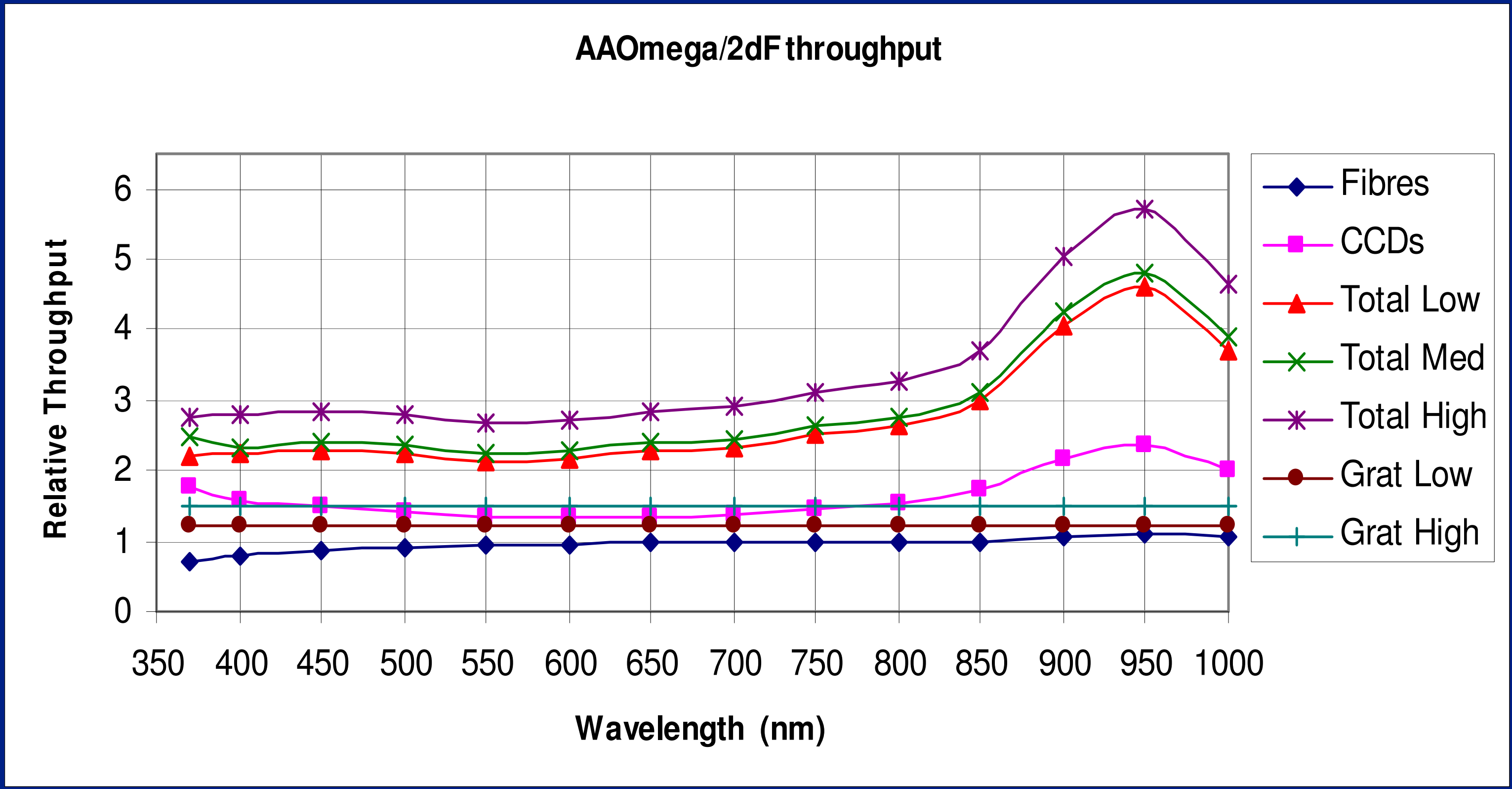
- Peak efficiency 80-90%
- FWHM $\delta\lambda/\lambda \sim 0.42$
- Superblaze FWHM $\delta\lambda/\lambda \sim 1$

Throughput



- Worst losses upstream of spectrograph
- Peak total throughput 18%(blue), 22% (red)
- Total throughput 10% at 400nm and 950nm

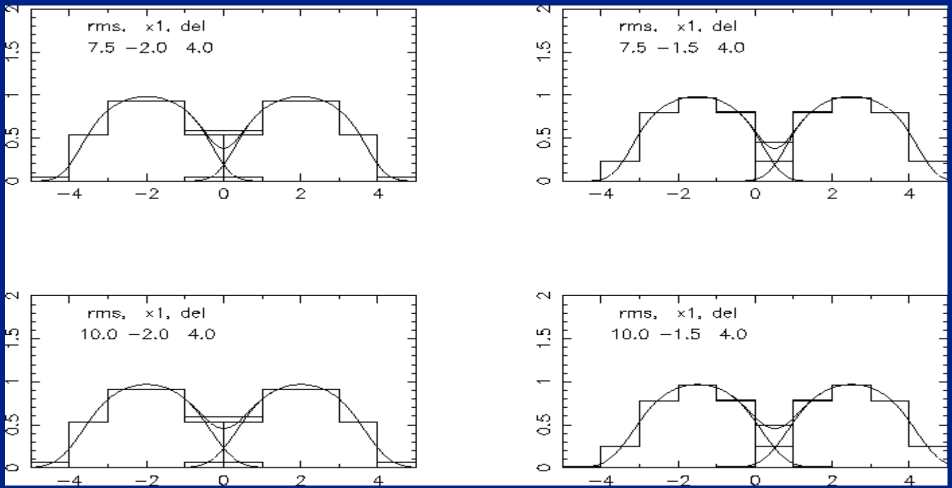
Comparison with 2dF



- At least 2-3 times better than 2dF
- More in red, and at high dispersion

Sky Subtraction methods

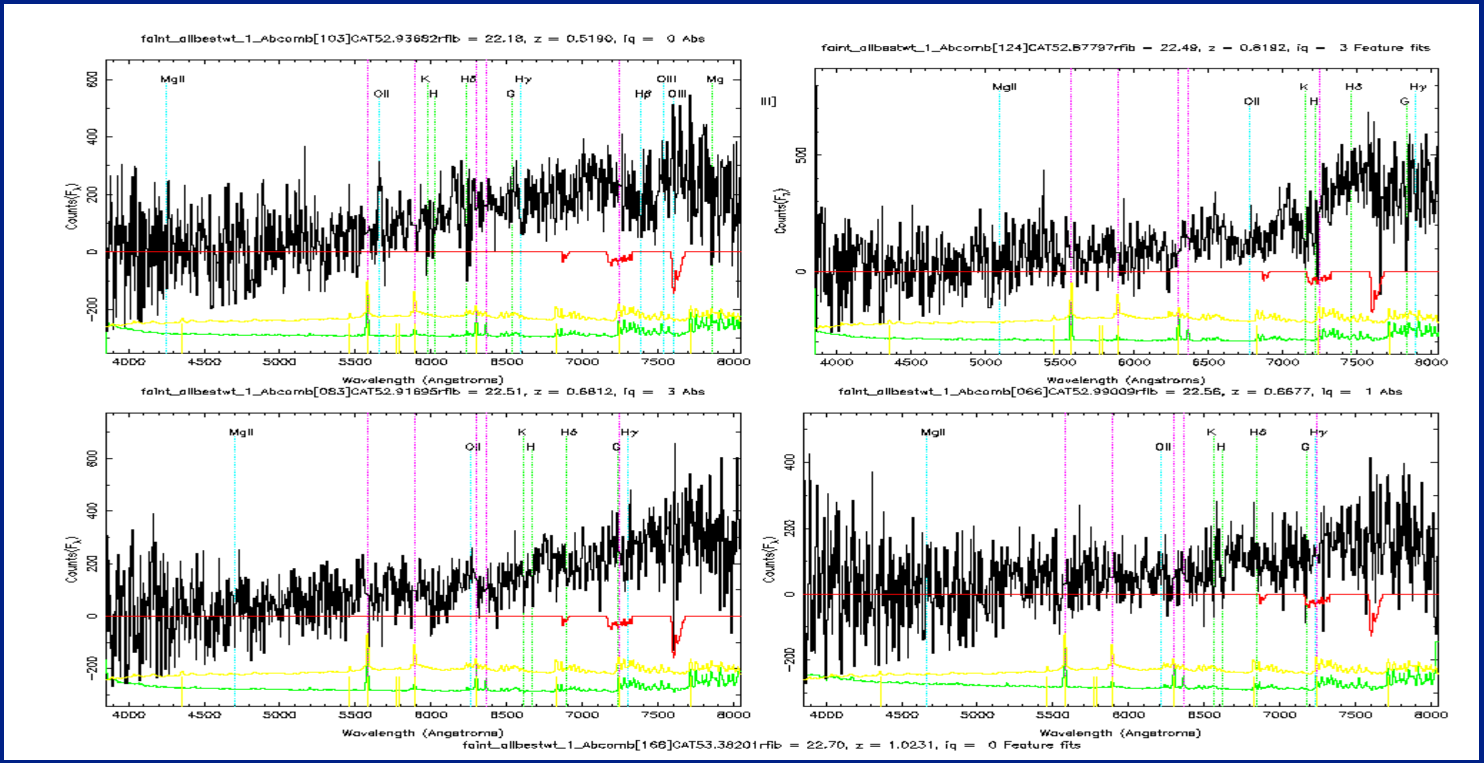
- **Traditionally poor with fibres**
- **Mean-Sky Method (MSM): 20-30 fibres are dedicated to sky. Target 1% accuracy (vs few % for 2dF and 6dF)**
- **Beam-Switching/ Cross Beam-Switching: telescope nodded between object & sky on 10-20 min timescales; good to ~1%. Factor 2 S/N penalty.**
- **Nod&Shuffle: combine beam-switching with charge shuffling; good to ~0.1% but only 200 fibres.**
- **Mini-shuffle: charge shuffle by few pixels to give blended ON/OFF pairs, good to 0.3%, and can use all fibres.**



N&S on Real Objects

Nov 2003, 9.5 hours 2dF N&S data, galaxies with $r \sim 22.5^m$

- **Sources 50 times fainter than sky**
- **Reduced spectra have no sky residuals, Poisson limited**
- **Will reach this depth with AAOmega in 4 hrs**



Signal/Noise estimates

	mag	seeing	moon	hours	sky sub	S/N/Å
gals	B=21	1.3"	dark	1	Sky fibres	10.4
gals	V=21.5	1.3"	dark	4	Sky fibres	8.0
gals	R=21	1.3"	dark	4	X-beam NS	6.1
qso's	B=22.5	1.3"	dark	4	Sky fibres	4.3
stars	I=18	1.3"	bright	1	Sky fibres	21
stars	I=20	1.3"	dark	4	Sky fibres	11.8

Anticipated median AAT seeing <1.3" with dome air-conditioning

AAOmega and AΩ

	AAΩ AAT	2dF AAT	Sloan	OzPoz VLT	VIMOS VLT	GWFMOS Gemini
Diameter (m)	3.9	3.9	2.5	8	8	8
Area (m^2)	11.9	11.9	4.9	50.3	50.3	50.3
Efficiency	0.2	0.07	0.2	0.15	0.3	0.15
FoV (deg)	2	2	3	0.42	0.42	1.5
FoV (deg^2)	3.1	3.1	7.1	0.14	0.14	1.8
No of objects	392	400	640	132	560	4500
No of photons per unit time	930	330	630	1000	8500	34,000
Time to cover Given area to fixed depth	1	2.9	1.1	7.0	3.5	0.5

AAOmega and ‘the AAT of the Future’

- Only 2 AAT dark time instruments (AAOmega, WFI)
- Large time allocations expected
- Long term survey projects specifically invited
- UK share of telescope time to decline (contribution halves in 2006-7, halves again 2007-8)
- UK applications requiring large allocations will depend on PATT funding proposals

Now is the time to be setting up large projects

Key Science Driver Projects

- Galactic Dynamics – origin of thin and thick discs, halo, bulge and bar: ~ 10^5 radial velocities; precision abundances for bright subset.
- 'CDM Archaeology' - evolution of the stellar population of galaxies: ~ 10^5 high S/N spectra of 2dFGRS-type galaxies
- Oldest stellar populations: UKIDSS/SDSS LRG survey out to z ~ 0.8
- Intracluster PN surveys
- '2QZ deep' to V=23 – Seyfert-luminosity QSO's, finding multiples
- Multiplexed QSO absorption system studies (Alcock-Paczynski test)!
- SWIRE, Astro-F followup
- Clustering beyond the power spectrum – mass-to-light ratios for bound structures? Stochastic biassing? Interrelation between colour, morphology, spectral characteristics, clustering? Void LF? Clustering of low-luminosity galaxies? – UKIDSS, SDSS allow precision selection.

Conclusions

- **AAOmega: high throughput, spectral resolution, stability, good sky subtraction**
- **Can do projects not possible with 2dF, or other instruments: *high quality spectra of faint objects over a wide field –***

  “Physics of the Local Universe”