

# QSO Cosmology via eROSITA+4MOST

Tom Shanks (Durham University)

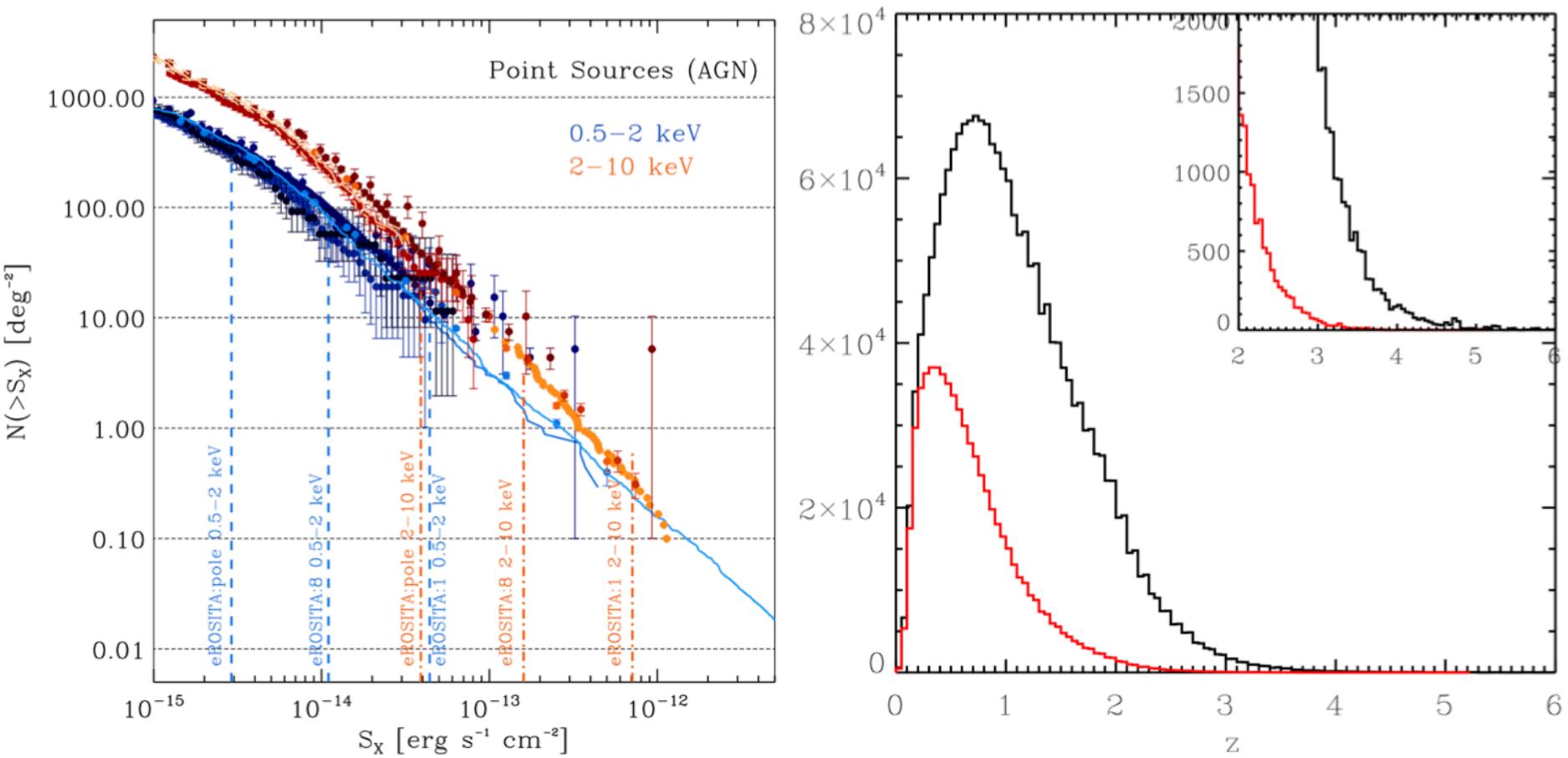
# 4MOST Projects

- eROSITA X-ray AGN follow-up
- eROSITA X-ray galaxy clusters follow-up
- WAVES – galaxy evolution
- Cosmology Z Survey – LRGs+ELGs+LyA+QSOs

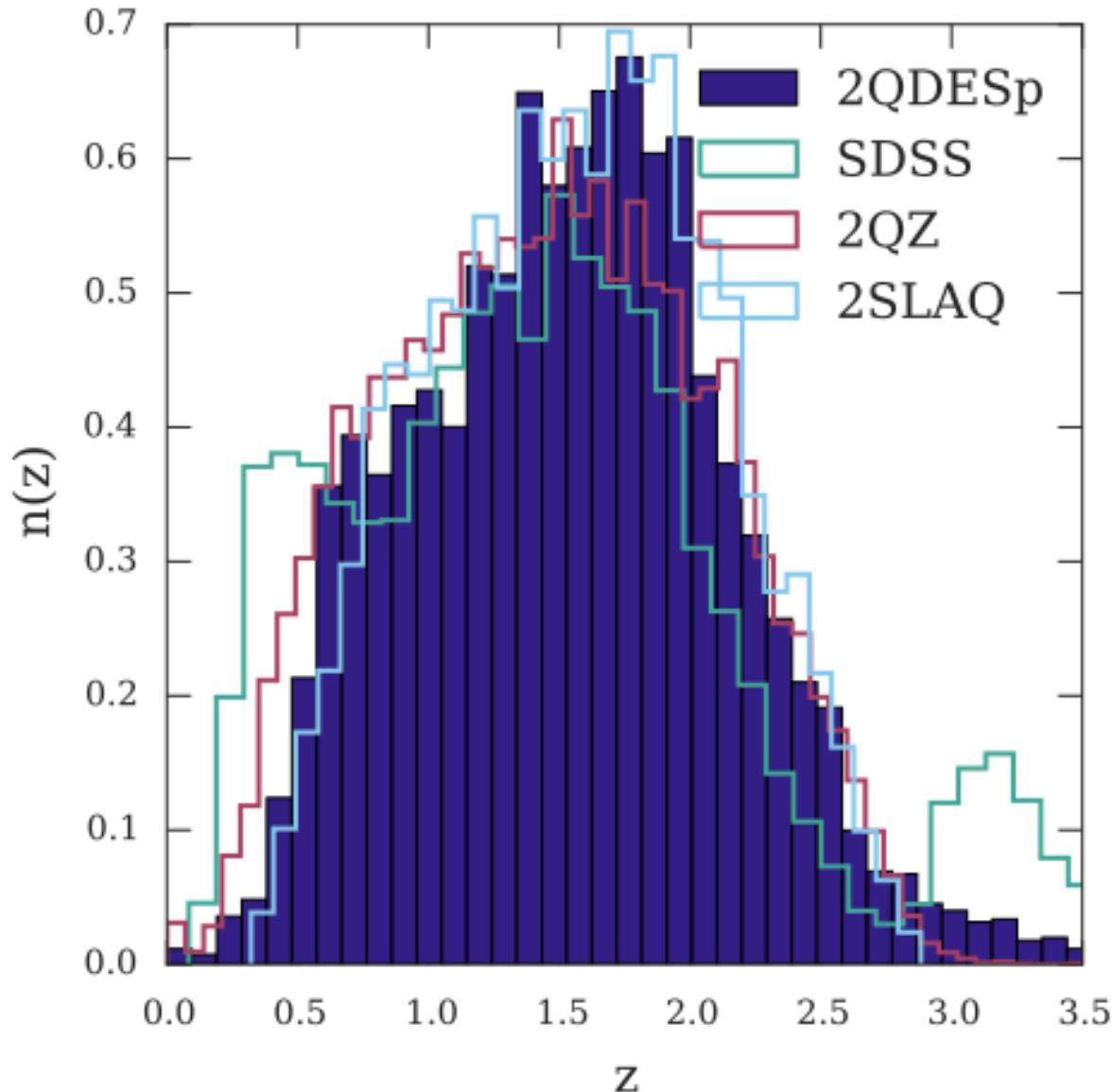
Can 4MOST AGN play a complementary role  
as a competitive cosmology survey?

Aim – to beat eBOSS quasar survey 2% BAO  
error by a factor of 2 – high AGN sky density key

# eROSITA $N(>S_x) + N(z)$

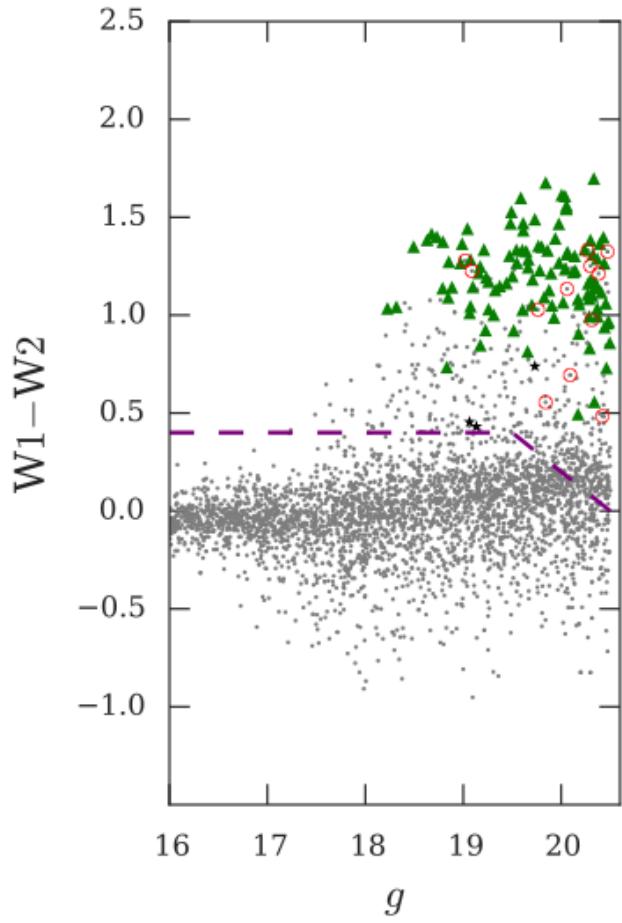
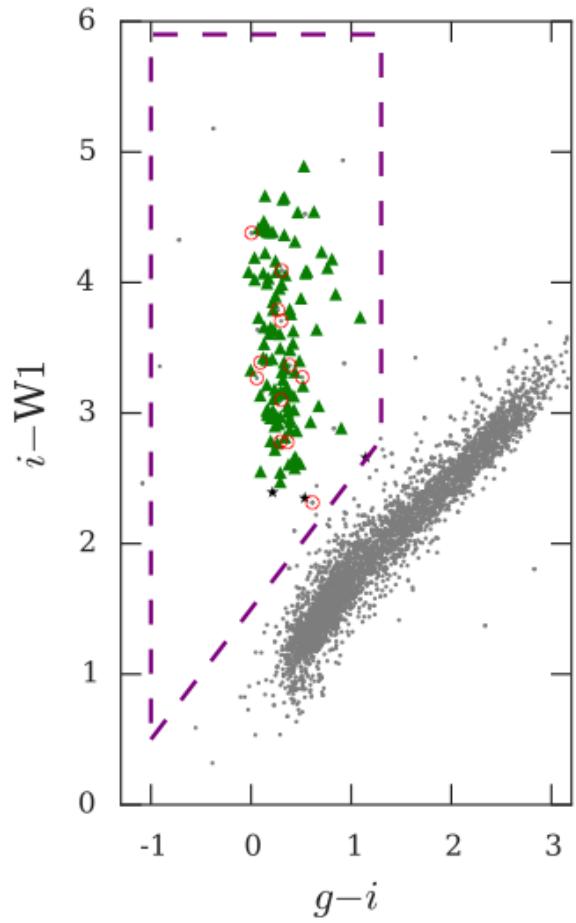
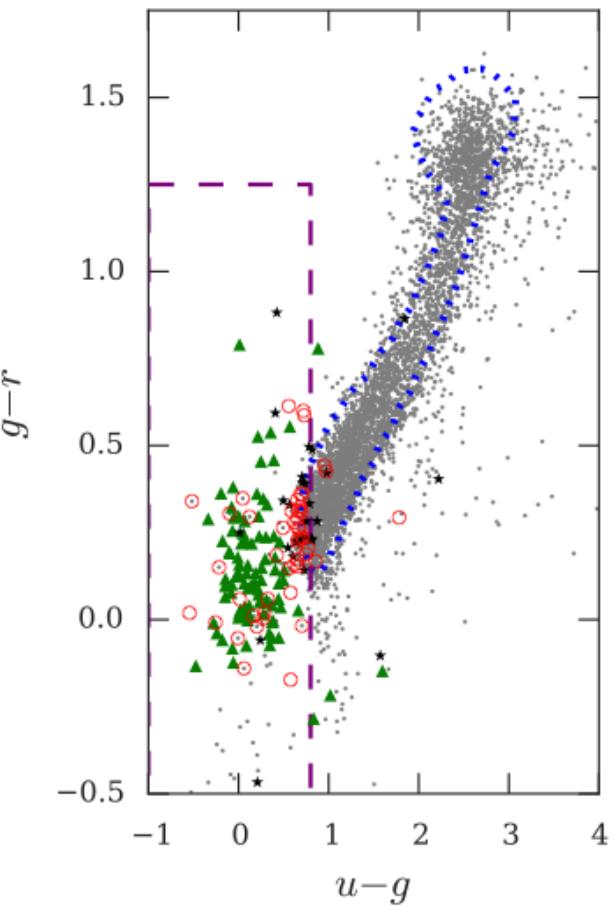


# Optical quasar $n(z)$



In 17 nights of 2dF time,  
2QDES pilot measured  
~10000 QSO redshifts over  
~150 deg<sup>2</sup>  
(Chehade et al 2016, arXiv:  
1603.04849)

# 2QDESp quasar selection



Combining UVX+IRX:  
quasar density  $\rightarrow 67\text{deg}^{-2}$

Chehade et al (2016)

# UVX v IRX quasar selections

Chehade et al (2016)

		Selection	Spectroscopic I.D.			
16<g<20.5	QSO (0.8<z<2.5)		QSO (0.3<z<3.5)	Stars	Non-id	
		$giW1W2\dagger$	84 (74)	106 (85)	3	12
	XDQSO†	75		86	15	21
20.5<g<22.5	$giW1W2\dagger$	78 (39)		4	86	
	XDQSO‡	74	84 (40)	77	4	93
16<g<22.5		Total	208/3deg <sup>2</sup> →67deg <sup>-2</sup>	228→76deg <sup>-2</sup>		

→Need ~0.<sup>m</sup>7 fainter in u and ~0.<sup>m</sup>7 fainter in W1 to reach 130deg<sup>-2</sup>  
(ACE+DEUCE) (NEOWISE)  
+eROSITA!

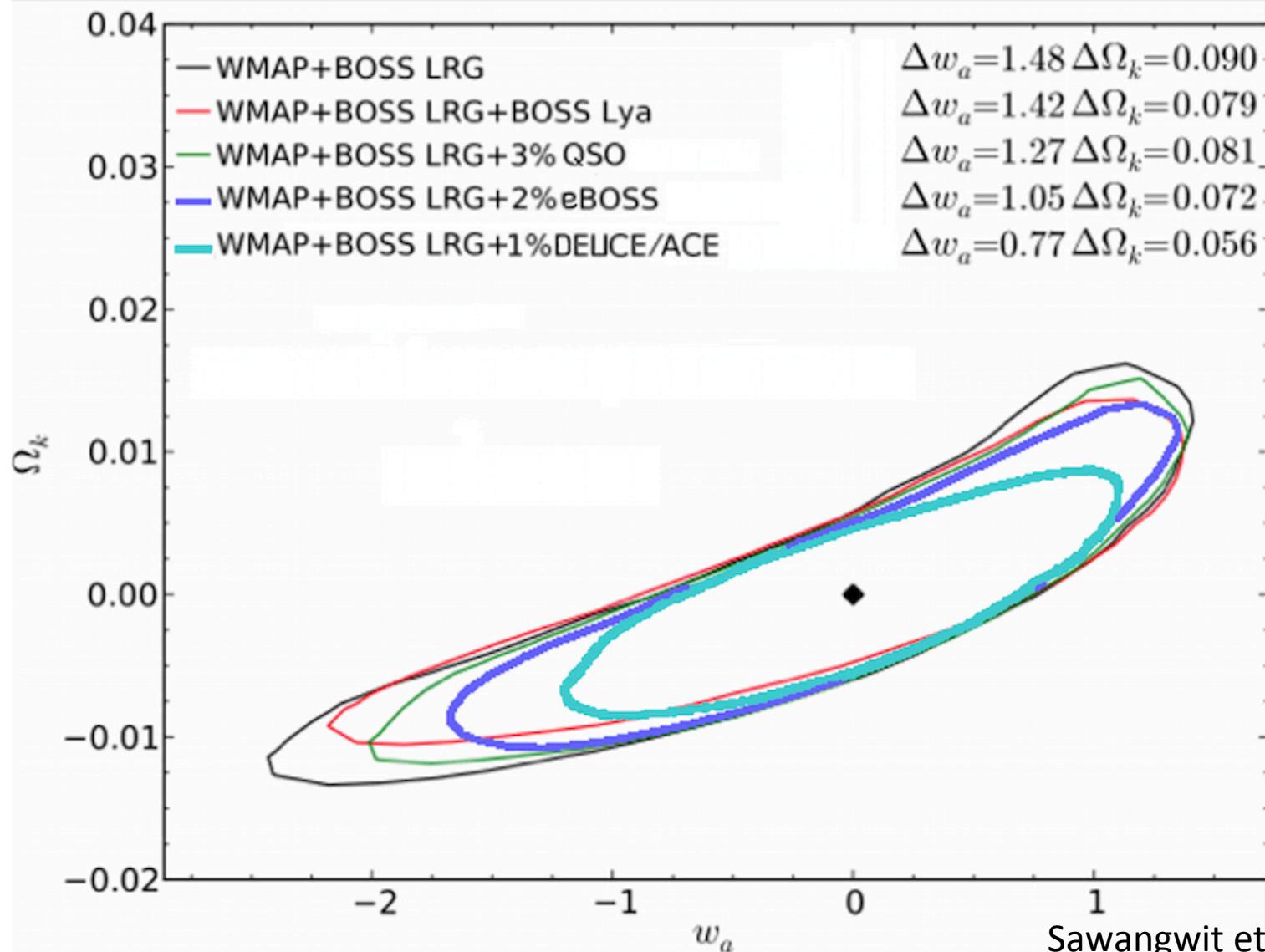
# QSO correlation function errors

- $D_x \propto 1/\sqrt{\text{sky area}}$
- $D_x \propto 1/\text{sky density}$
- So 2x the sky density  $\Leftrightarrow$  4x the sky area
- eBOSS 2% BAO error from  $7500\text{deg}^2$  @  $65\text{deg}^{-2}$

eROSITA+ATLAS+WISE+4MOST →  
1% BAO error from  $7500\text{deg}^2$  @  $130\text{deg}^{-2}$

Quasar sky density is  $\sim 130\text{deg}^{-2}$  at  $g < 22.5$

# DE forecasts



Sawangwit et al (2011)

# DEUCE – DES u + Chilean extensions

- Need  $\sim 7500 \text{deg}^2$  with 240s u band coverage
- $4700 \text{deg}^2$  comes from ATLAS+Chile u extension - ACE
- Need  $2800 \text{deg}^2$  240s u band on DES area
- DEUCE – Takes  $\sim 40$  nights of VST “filler” time

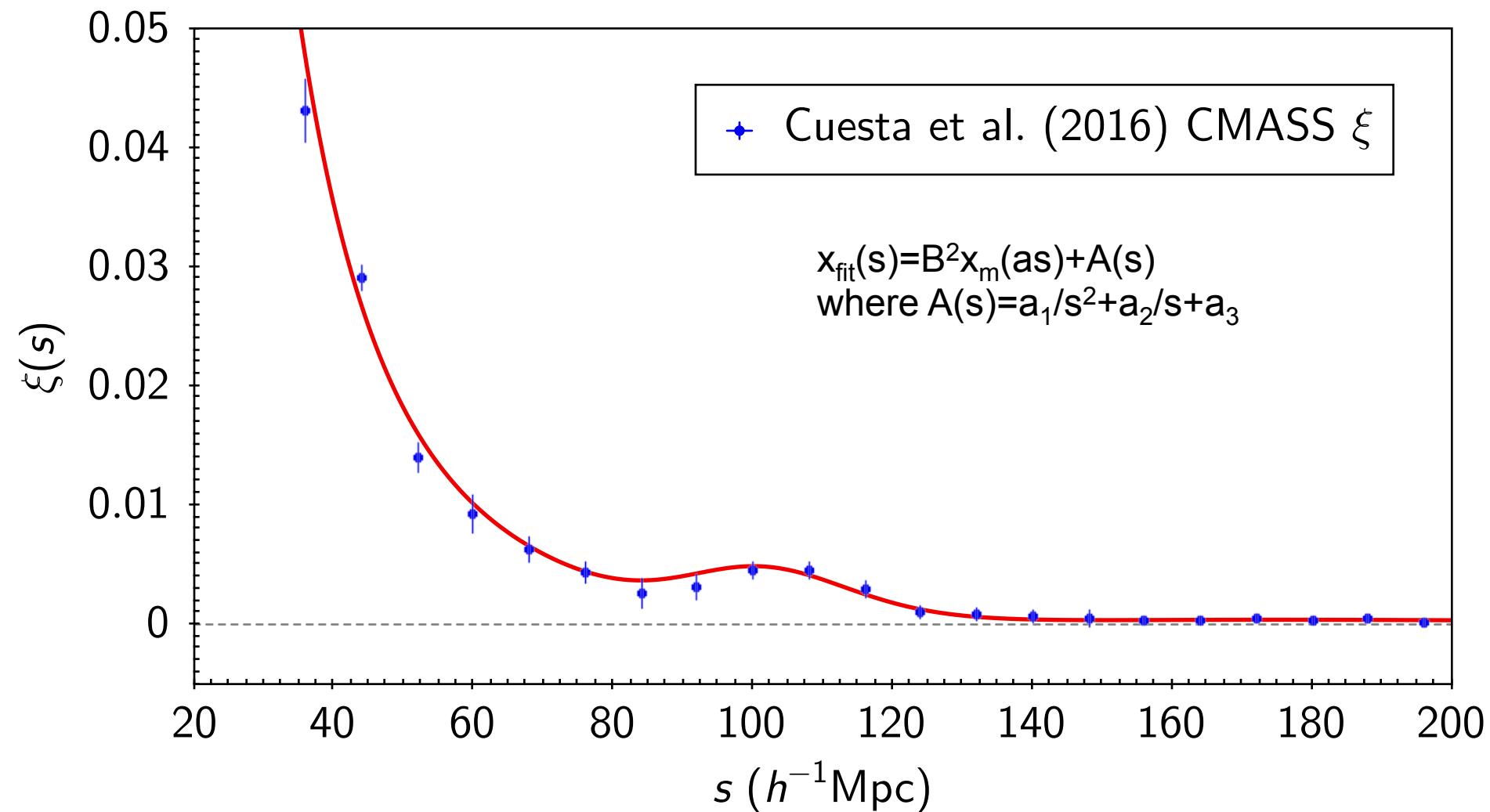
⇒ 4QDES: ~1million AGN z in ~100 4MOST nights!

# Simon White's RAS 12/2015 challenge

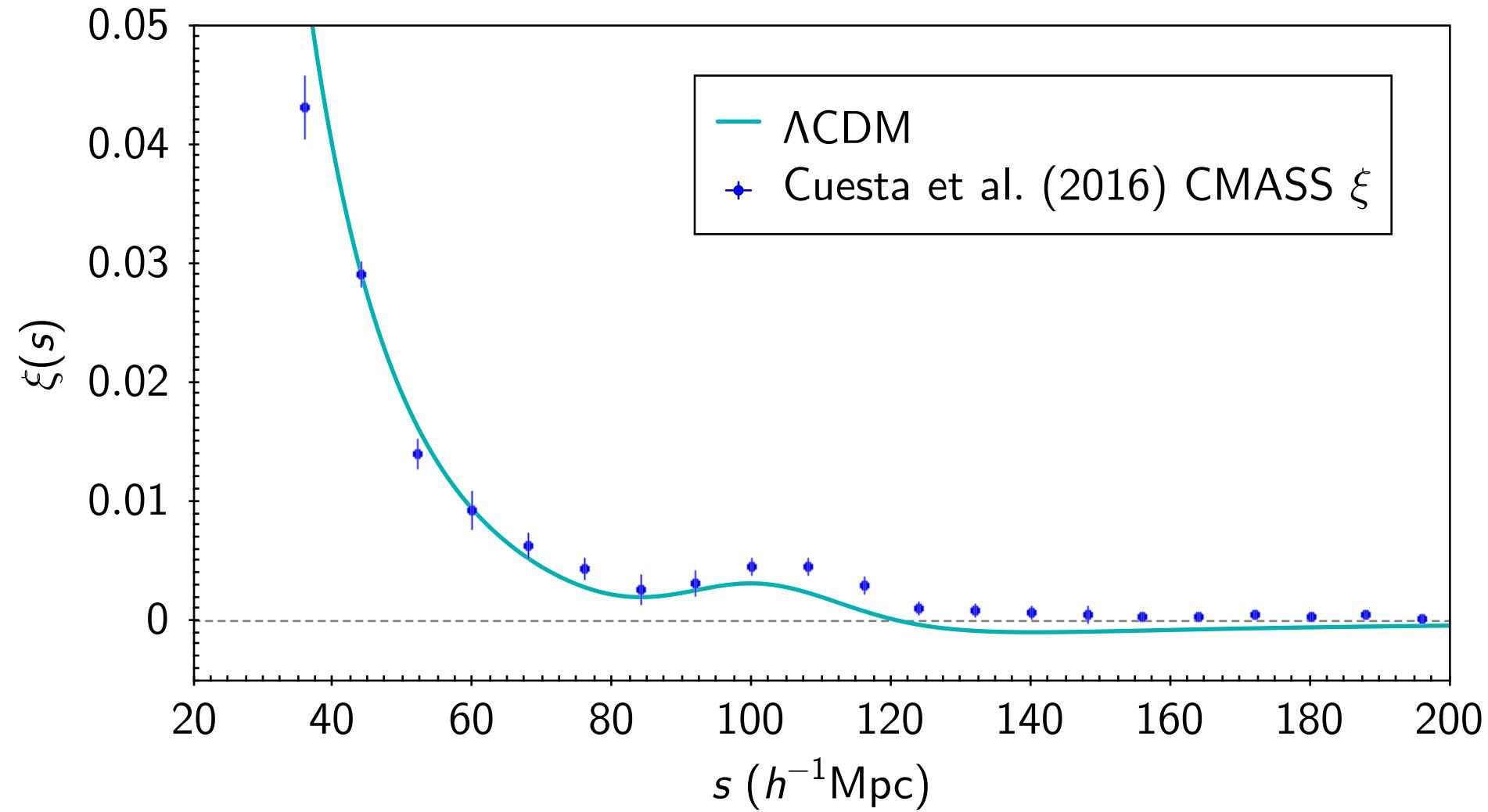


- “4MOST will have to do really well to beat the BOSS LRG  $\sim$ 40s BAO results”
- True that BOSS DR12 measures BAO to  $\pm 1\%$  accuracy at  $z=0.57$
- However, significance of BAO detection is  $\sim 4\text{-}5\sigma$  ( $\sim 8\sigma$  post-reconstruction)

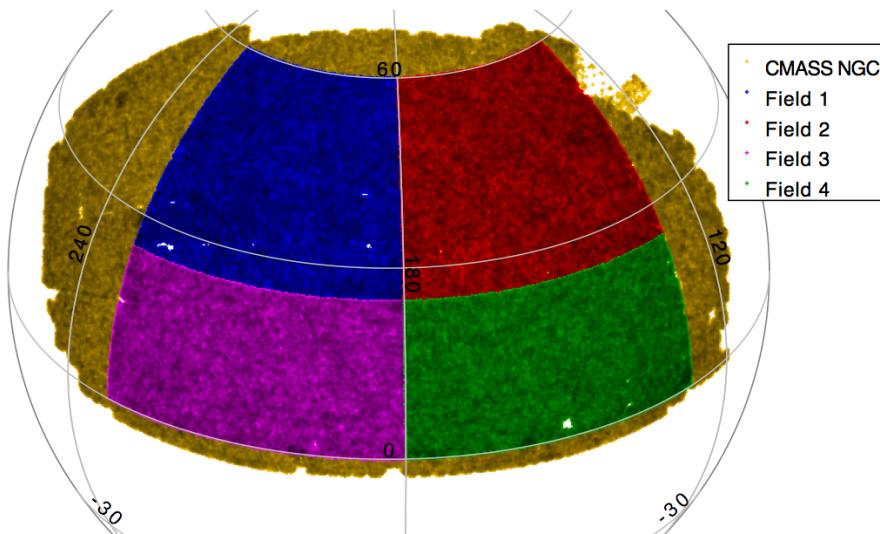
# CMASS $z \sim 0.57$ LRG BAO result



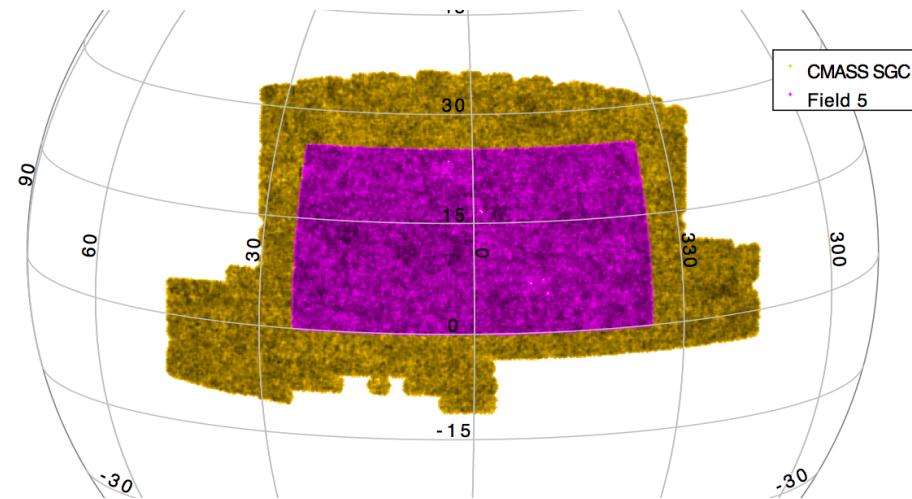
# CMASS LRGs



# SDSS CMASS LRGs – 5 subsets

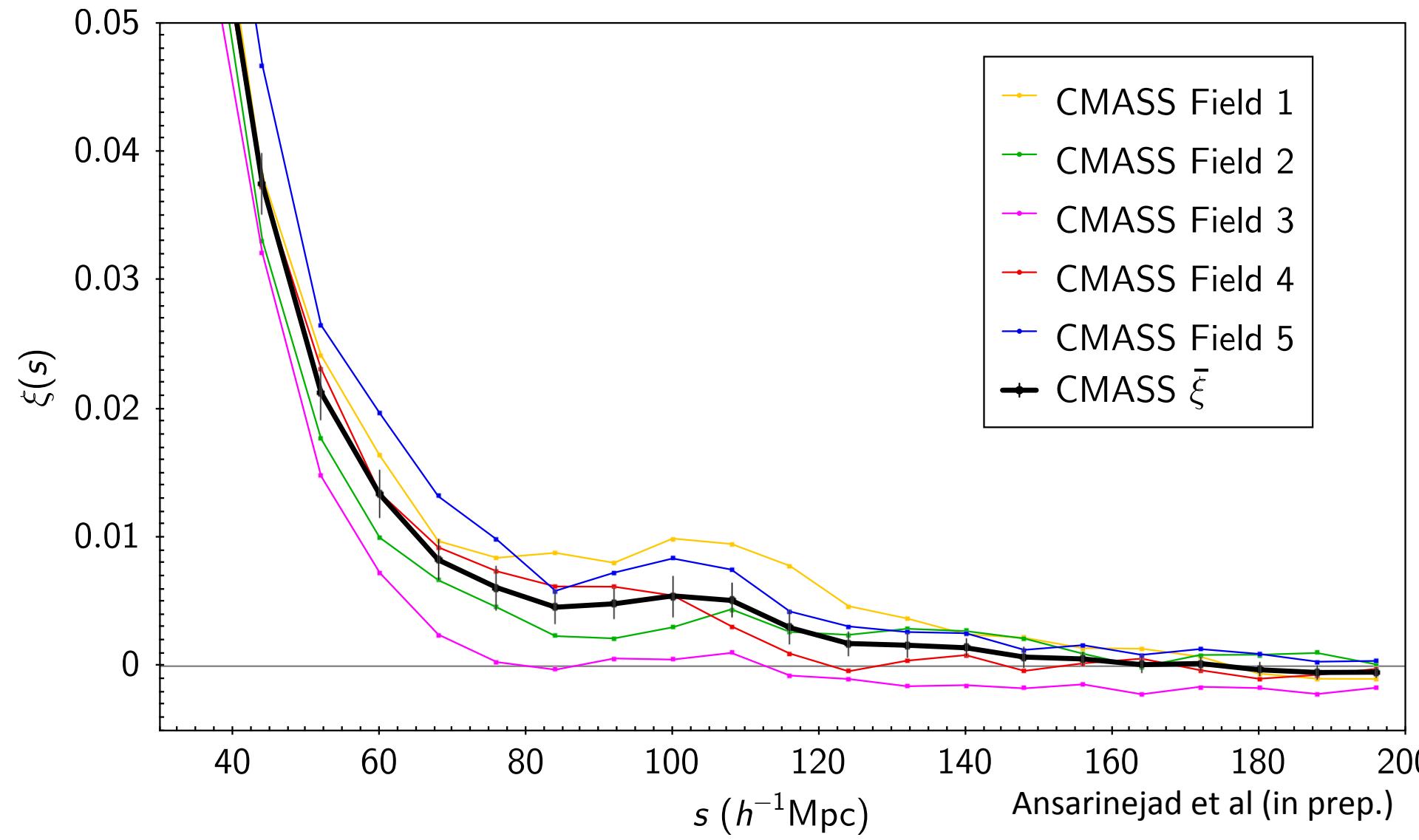


NGC

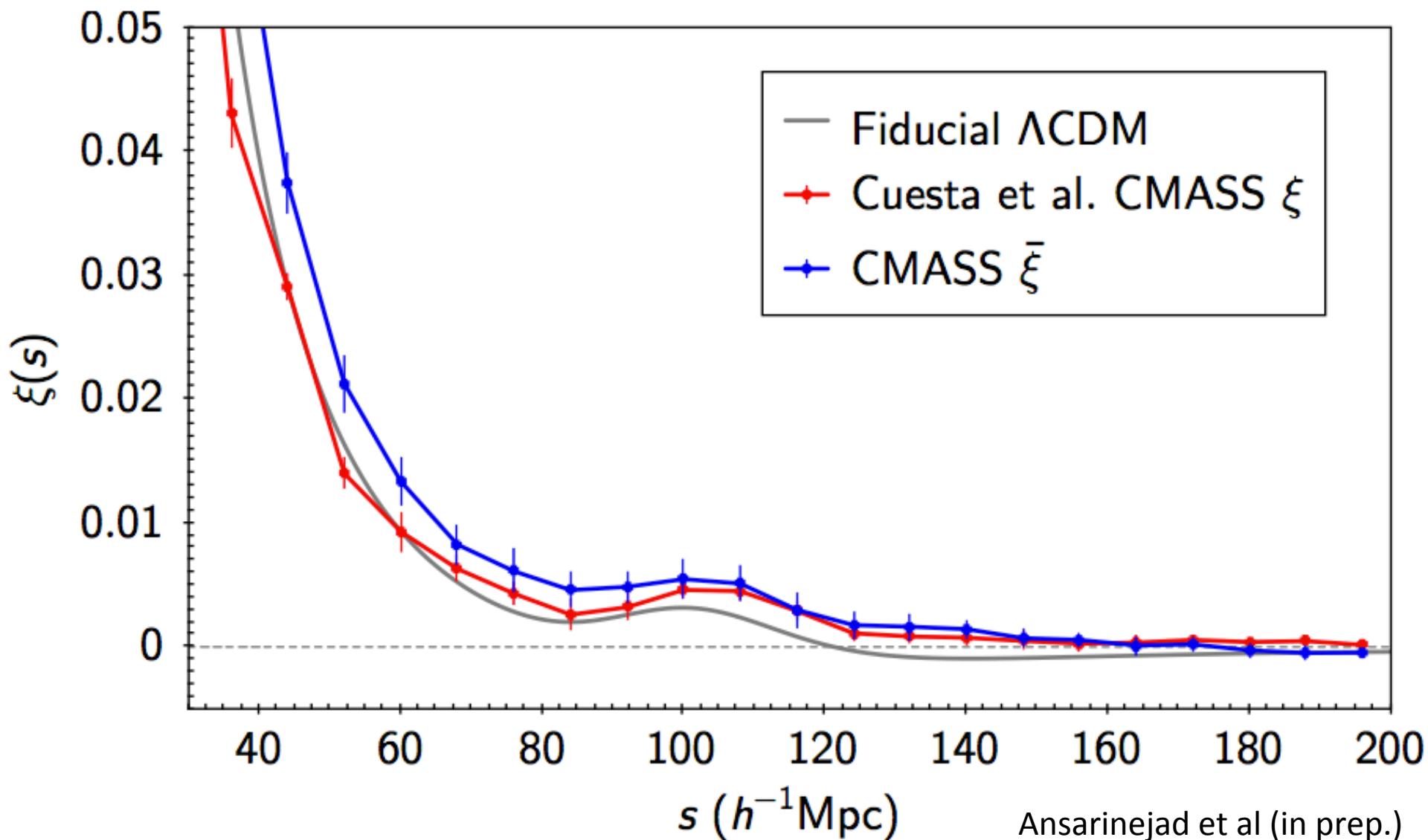


SGC

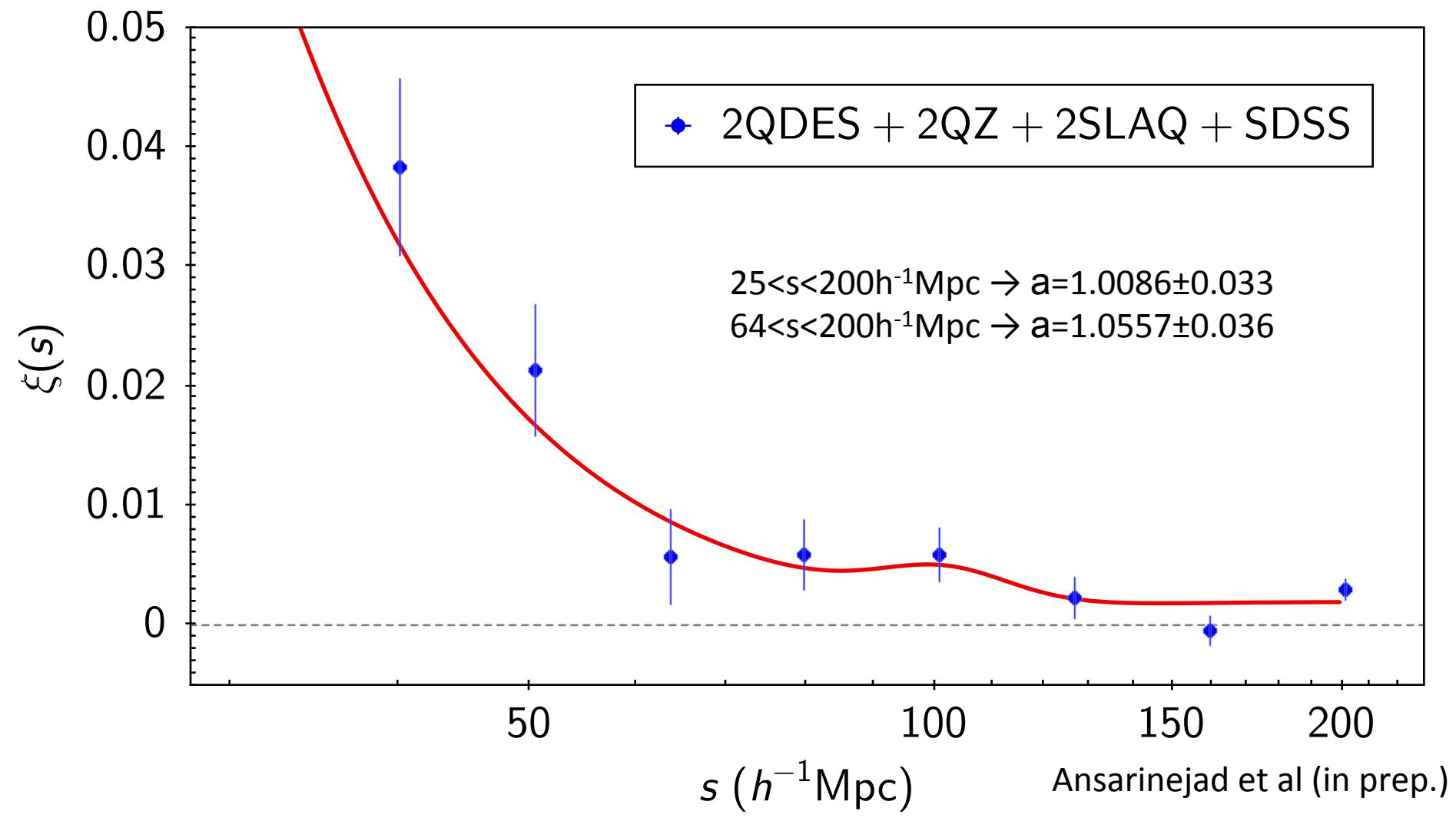
# $x(s)$ in 5 CMASS sub-fields



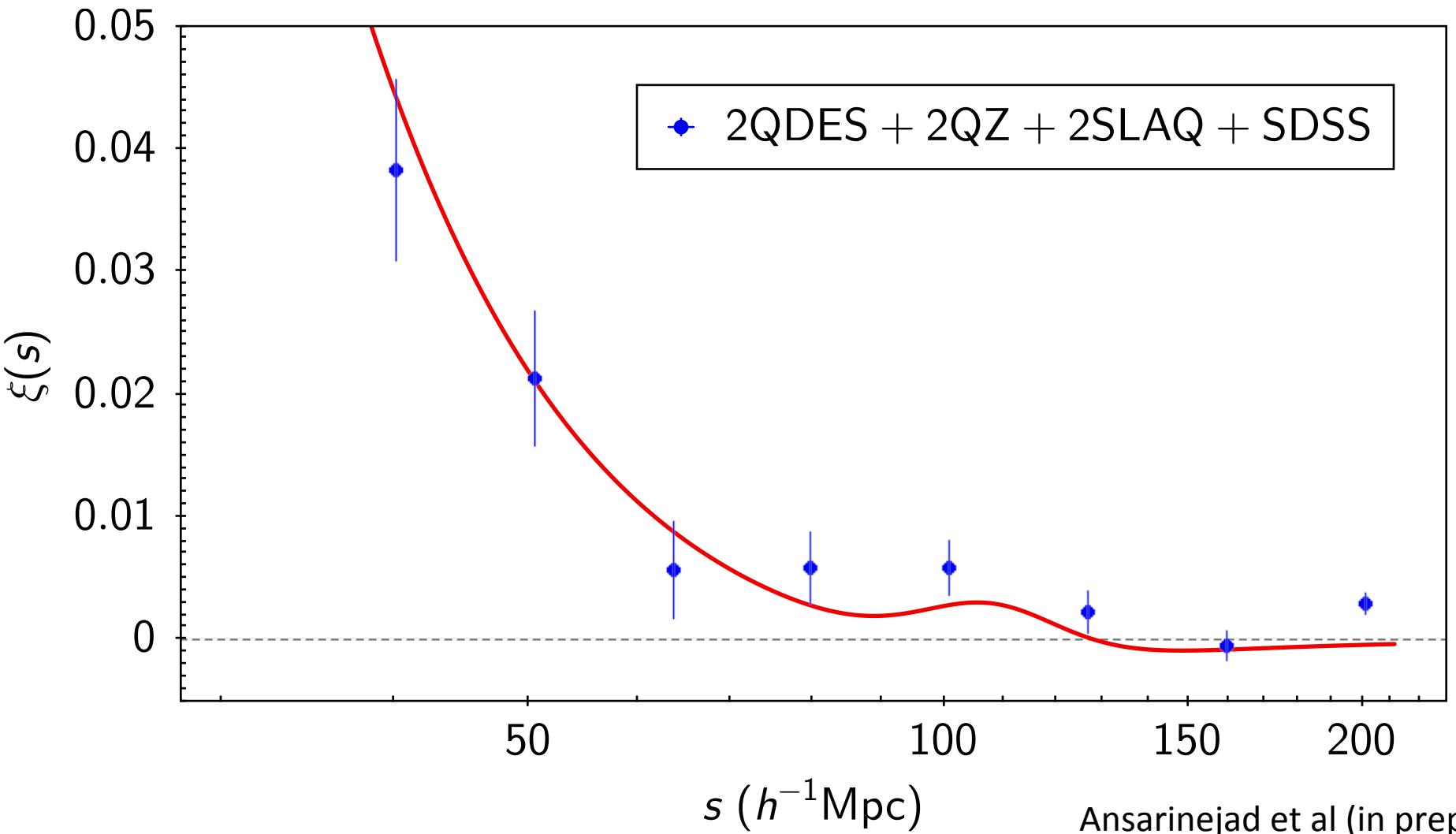
# CMASS LRGs

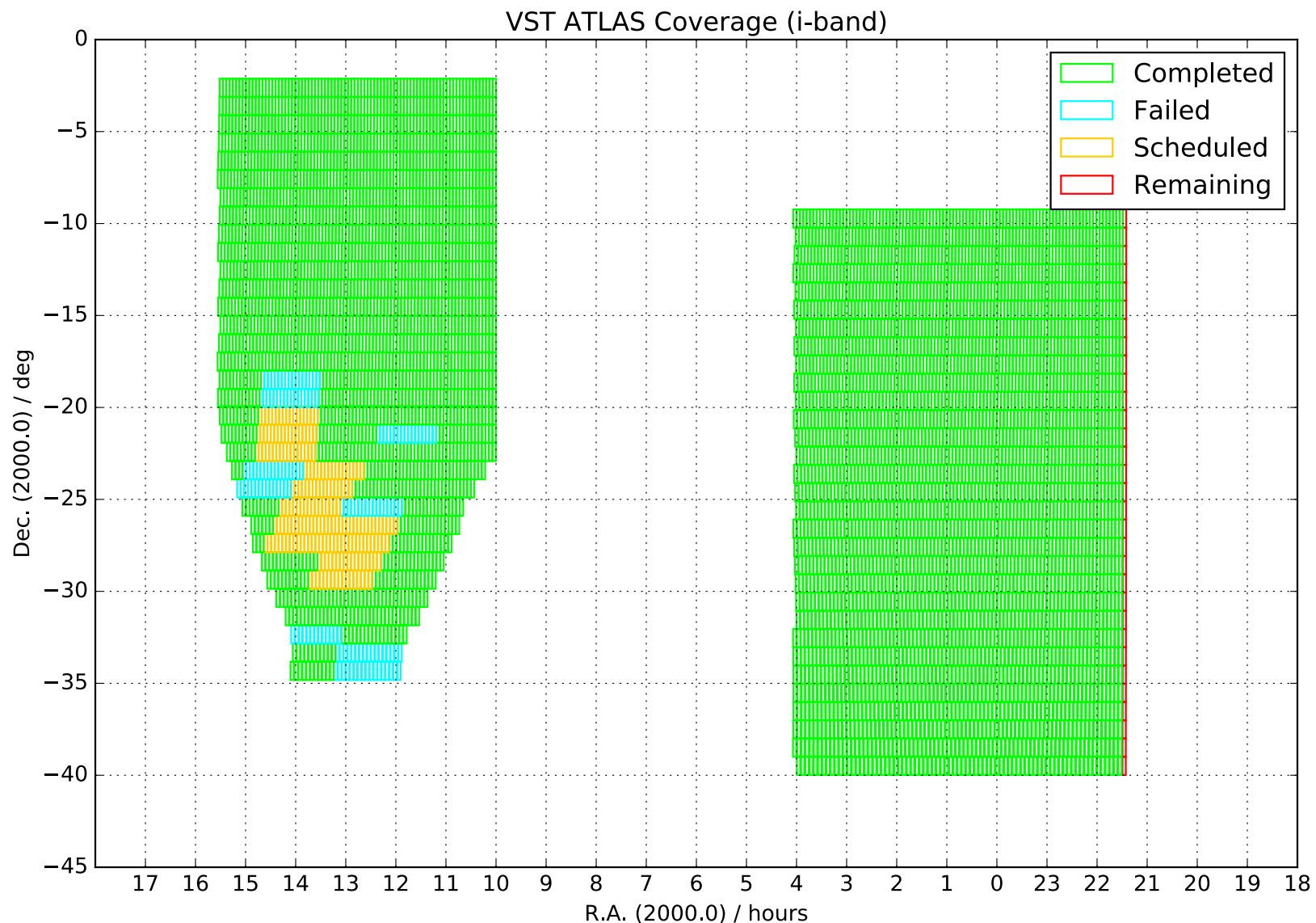


# Quasar clustering BAO results



# Quasar clustering BAO results – fitting without nuisance parameters

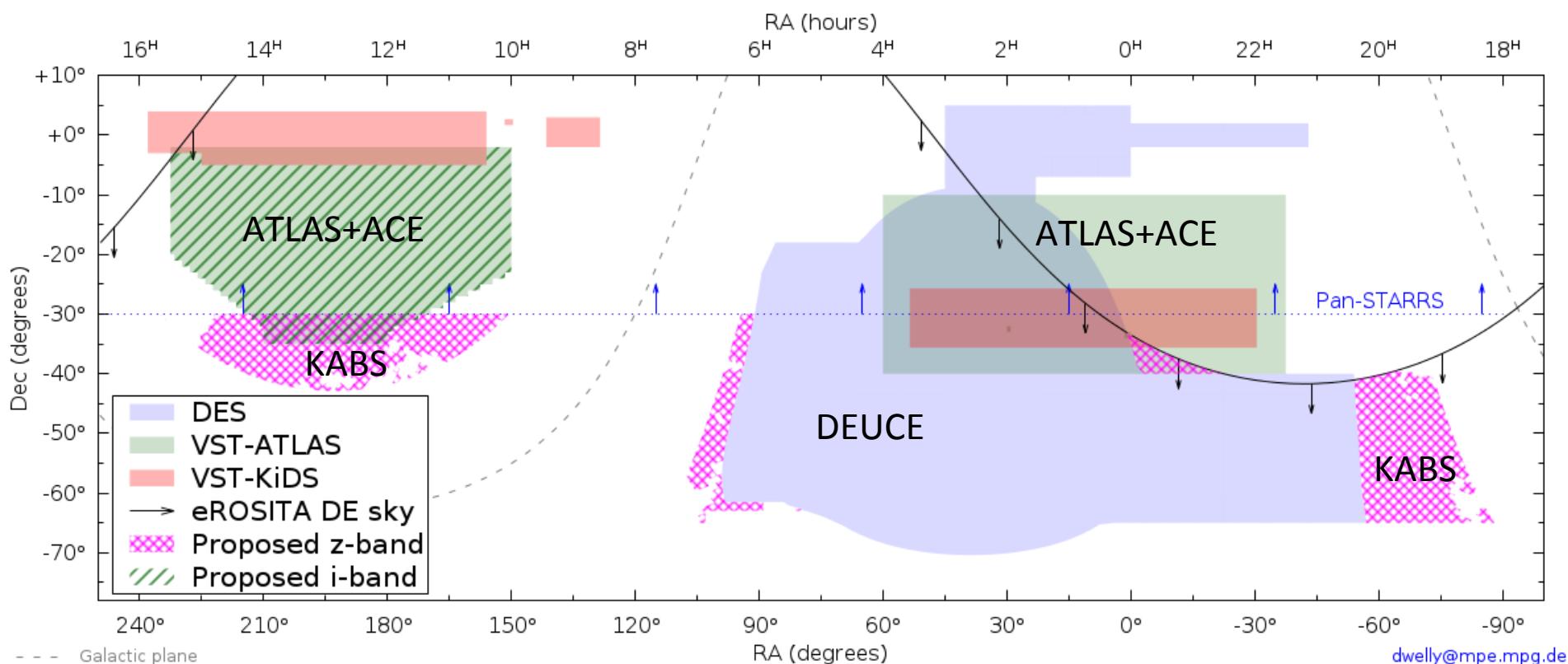




# u-band surveys for 4QDES

- To turn eROSITA AGN 4MOST survey into powerful cosmology survey with ~1million quasars:
  - VST ATLAS+ACE Chilean u extension:  $\sim 4700 \text{deg}^2$
  - +DEUCE DES ATLAS extension:  $\sim 2800 \text{deg}^2$  u-band survey in 40 VST “filler” nights
  - +KABS (Napolitano et al, INAF GTO) ugriz extension:  $\sim 1000 \text{deg}^2$

# ATLAS+DEUCE+KABS footprints



# Conclusions

- BOSS CMASS  $z=0.57$  LRG BAO result may be less robust than advertised
- But following their procedures  $\rightarrow 3.6\%$  BAO scale in current 2QDES+... quasar surveys!?
- 4QDES - need deeper u from VST ATLAS+ACE+DEUCE+KABS
- + deeper W1, W2 from NEOWISE
- + eROSITA!
- $\rightarrow 7500 \text{deg}^2$  4QDES survey @  $130 \text{deg}^{-2}$   $\rightarrow 1\%$  BAO
- i.e.  $\sim 2x$  smaller error than eBOSS!
- (+ X-ray/optical ratios, qso halo and black hole masses.....)

# Expansion rate vs redshift

