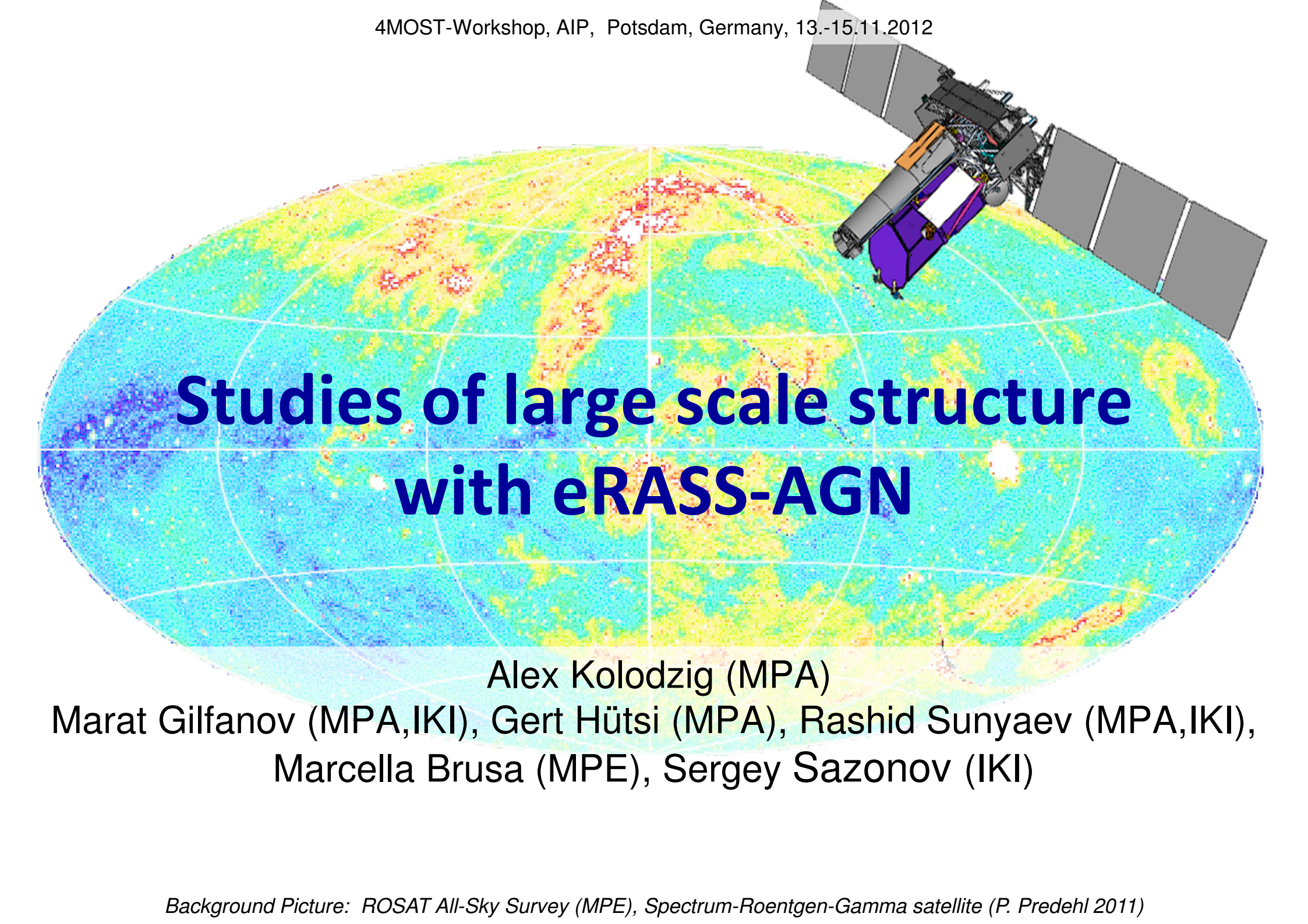




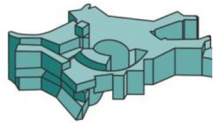
Studies of large scale structure with eRASS-AGN

Alex Kolodzig (MPA)

Marat Gilfanov (MPA,IKI), Gert Hütsi (MPA), Rashid Sunyaev (MPA,IKI),
Marcella Brusa (MPE), Sergey Sazonov (IKI)

eRASS-AGN

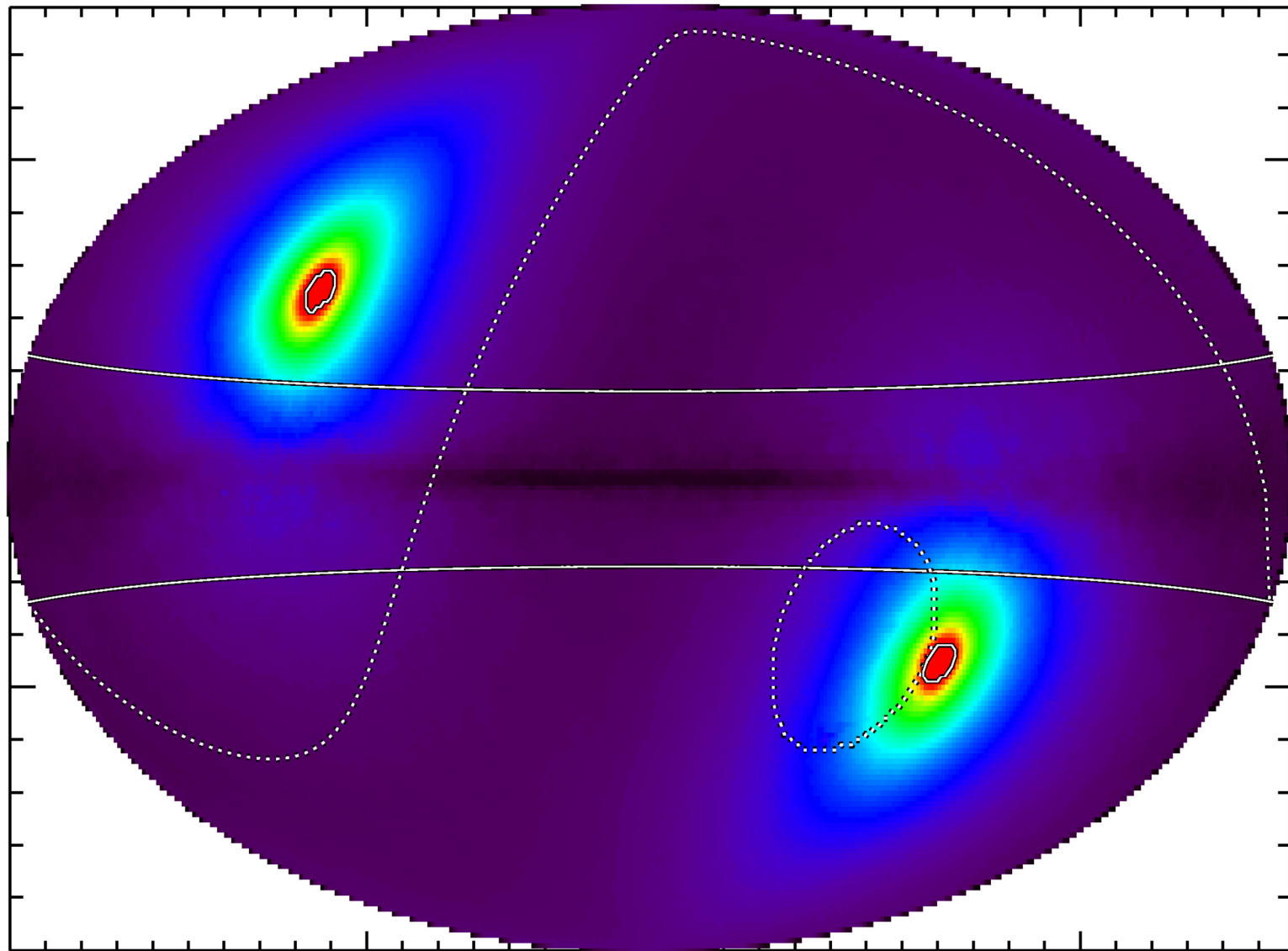
- AGN in the eROSITA all-sky survey (eRASS):
 - Point-source sensitivity: $\sim 1 \times 10^{-14} \text{ erg/s/cm}^2$ (0.5 - 2.0 keV)
 - AGN Number Density: $\sim 80 \text{ deg}^{-2}$
 - Extragalactic sky ($|b| > 10^\circ$): $\sim 34'100 \text{ deg}^2$ ($\sim 83\%$)
 - **~ 3 Million AGN** in 4 years will be detected
- 4MOST sky ($-70^\circ < \text{dec} < +20^\circ \wedge |b| > 15^\circ$): $\sim 20'000 \text{ deg}^2$
 - up to ~ 1.4 Million AGN available



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Galactic Latitude ($-90^\circ < b < +90^\circ$)

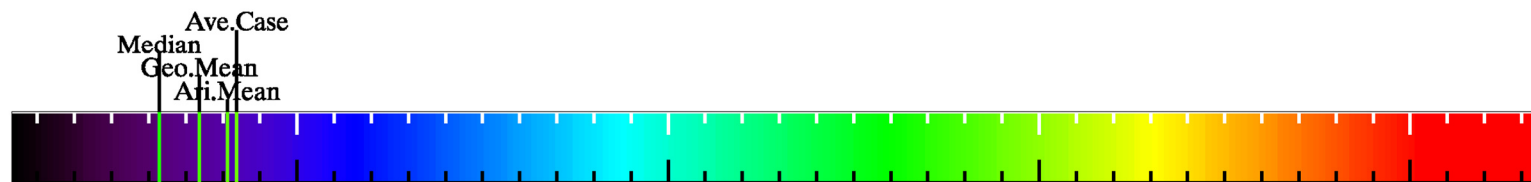
Number Density [deg^{-2}] (0.5-2.0 keV)



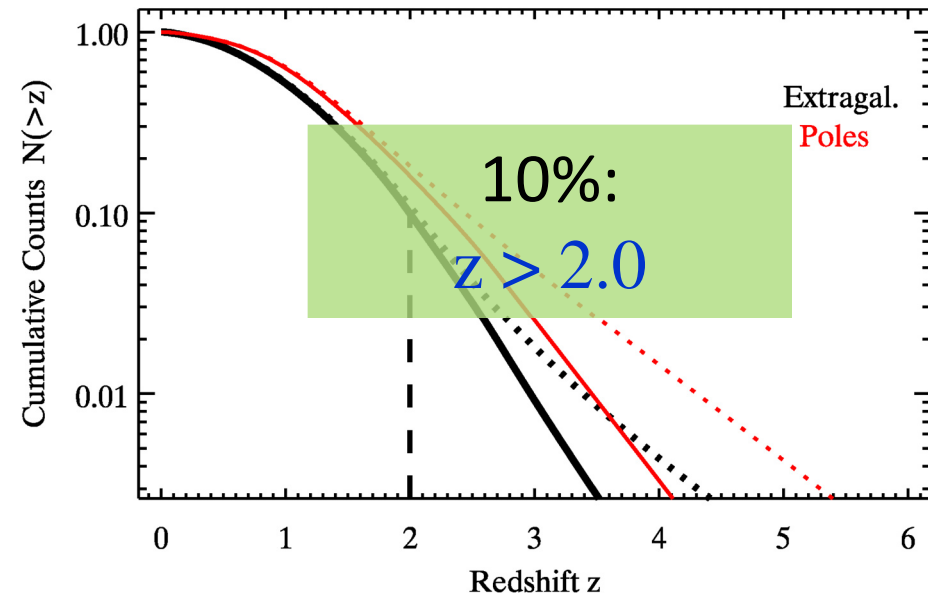
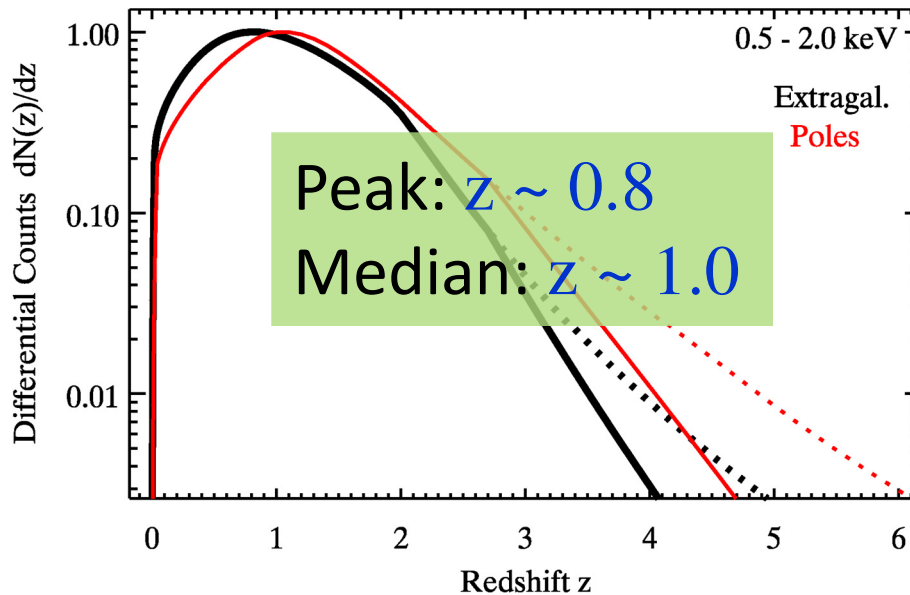
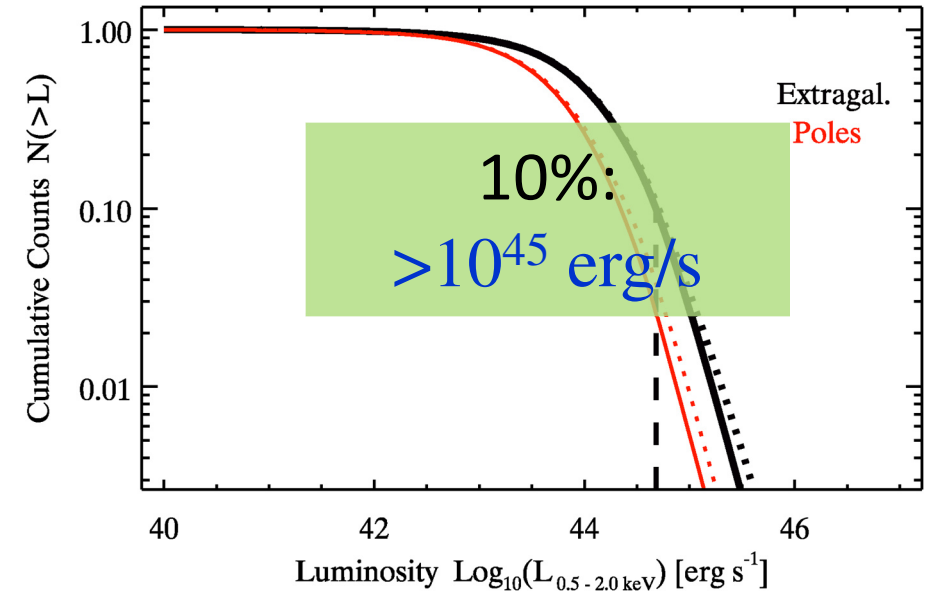
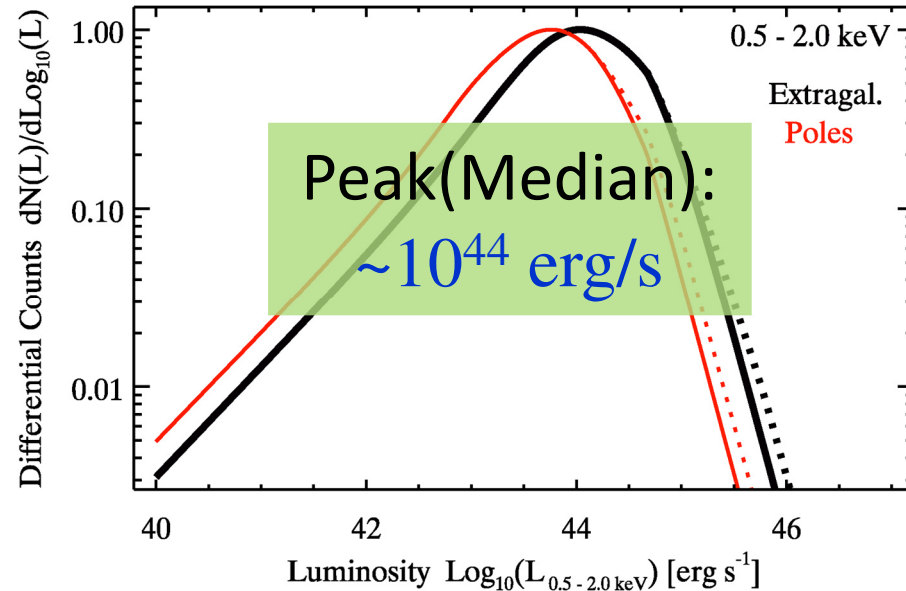
Galactic Longitude: ($+180^\circ > l > -180^\circ$)

Exposure Time
Map: **J. Robrade**

N_H -Map:
Kalberla+2005

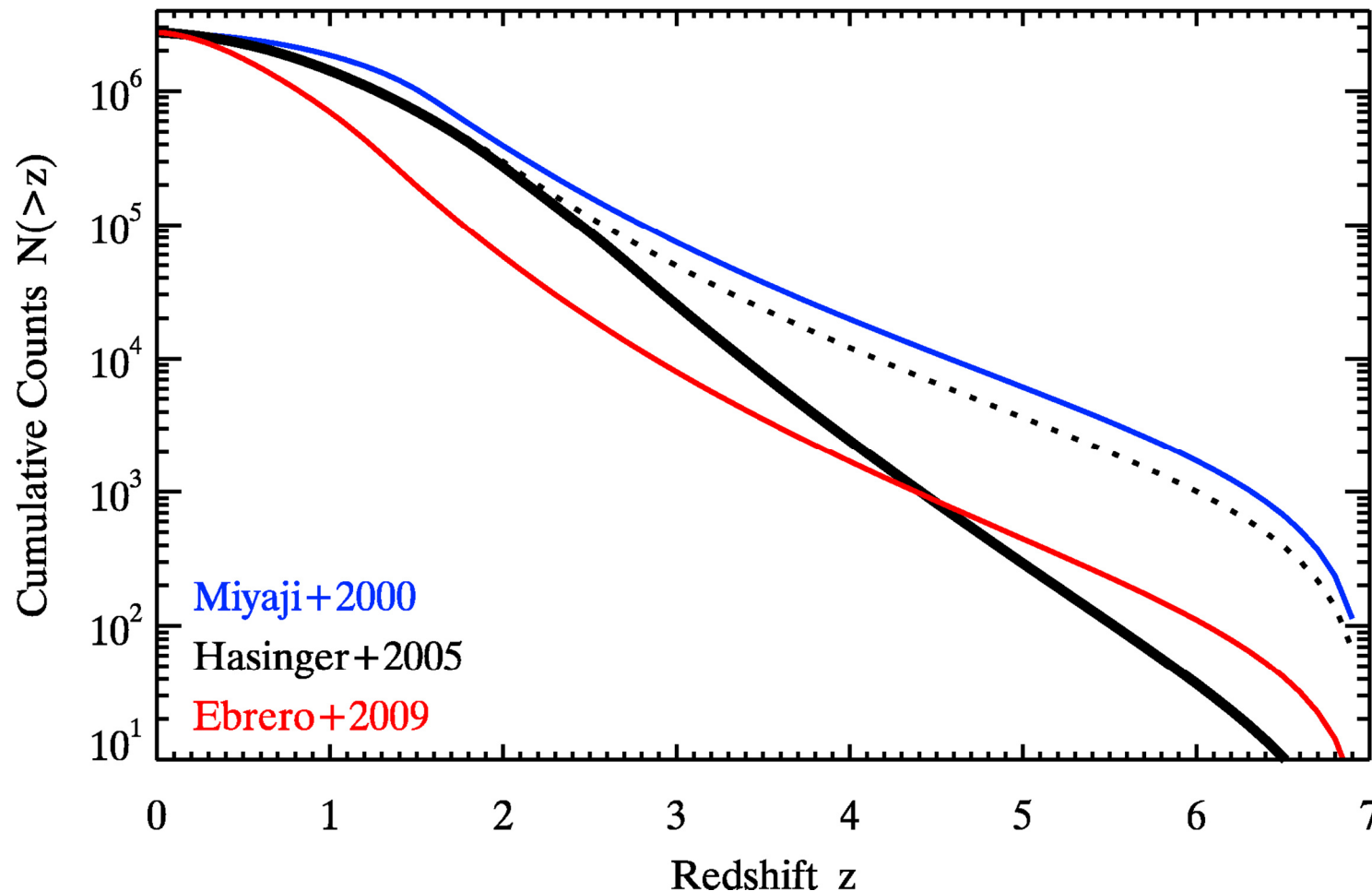


Statistical Properties of eRASS-AGN (0.5-2.0 keV)



High Redshift AGN (0.5-2.0 keV)

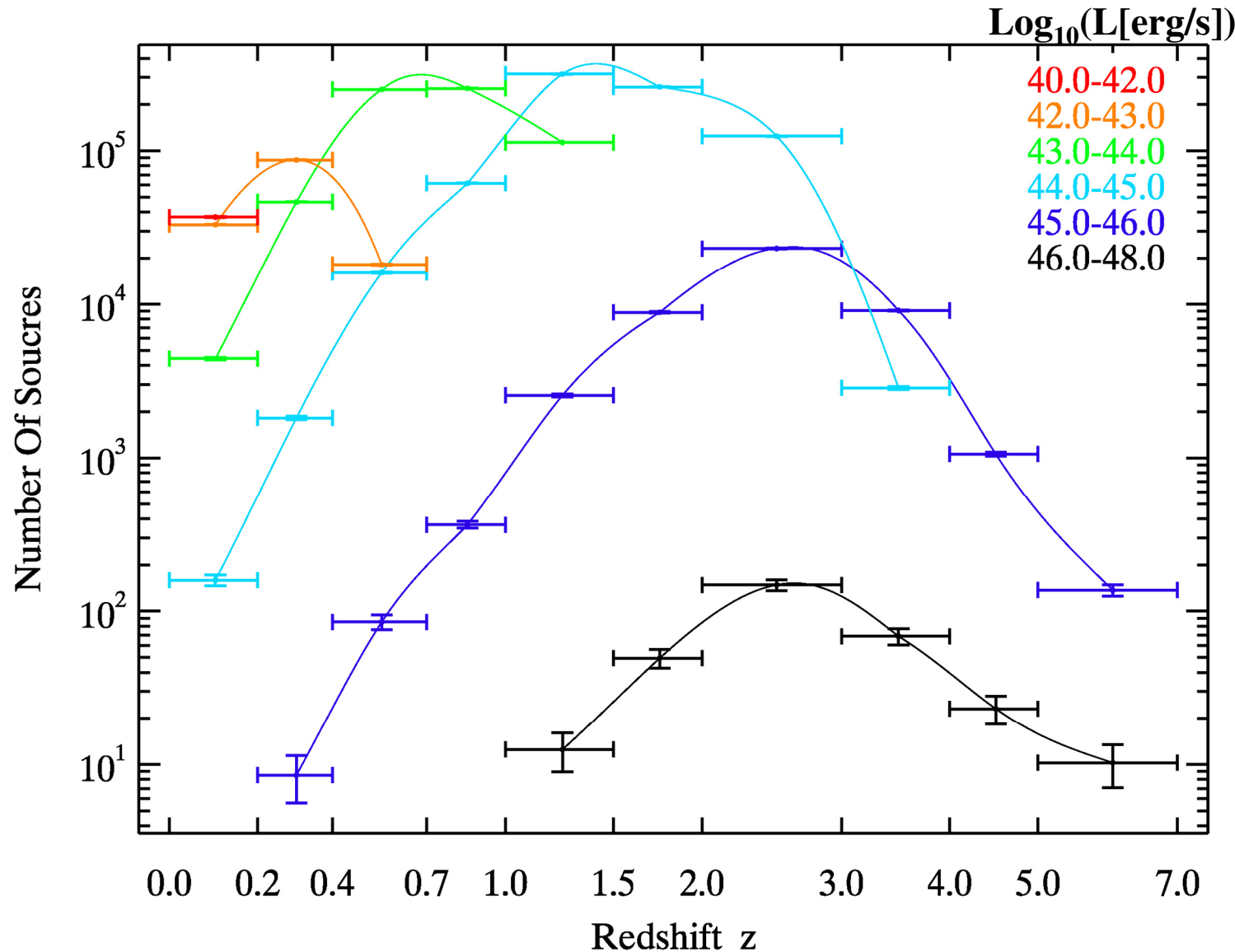
	extragalactic sky	4MOST sky (20'000 deg ²)
3<z<5	4'000 – 50'000	2'000 – 30'000
z<5	300 – 6'000	200 – 4'000



Number of AGN in 4MOST sky

for different luminosity groups
(0.5-2.0 keV)

4MOST sky
(20'000 deg²)

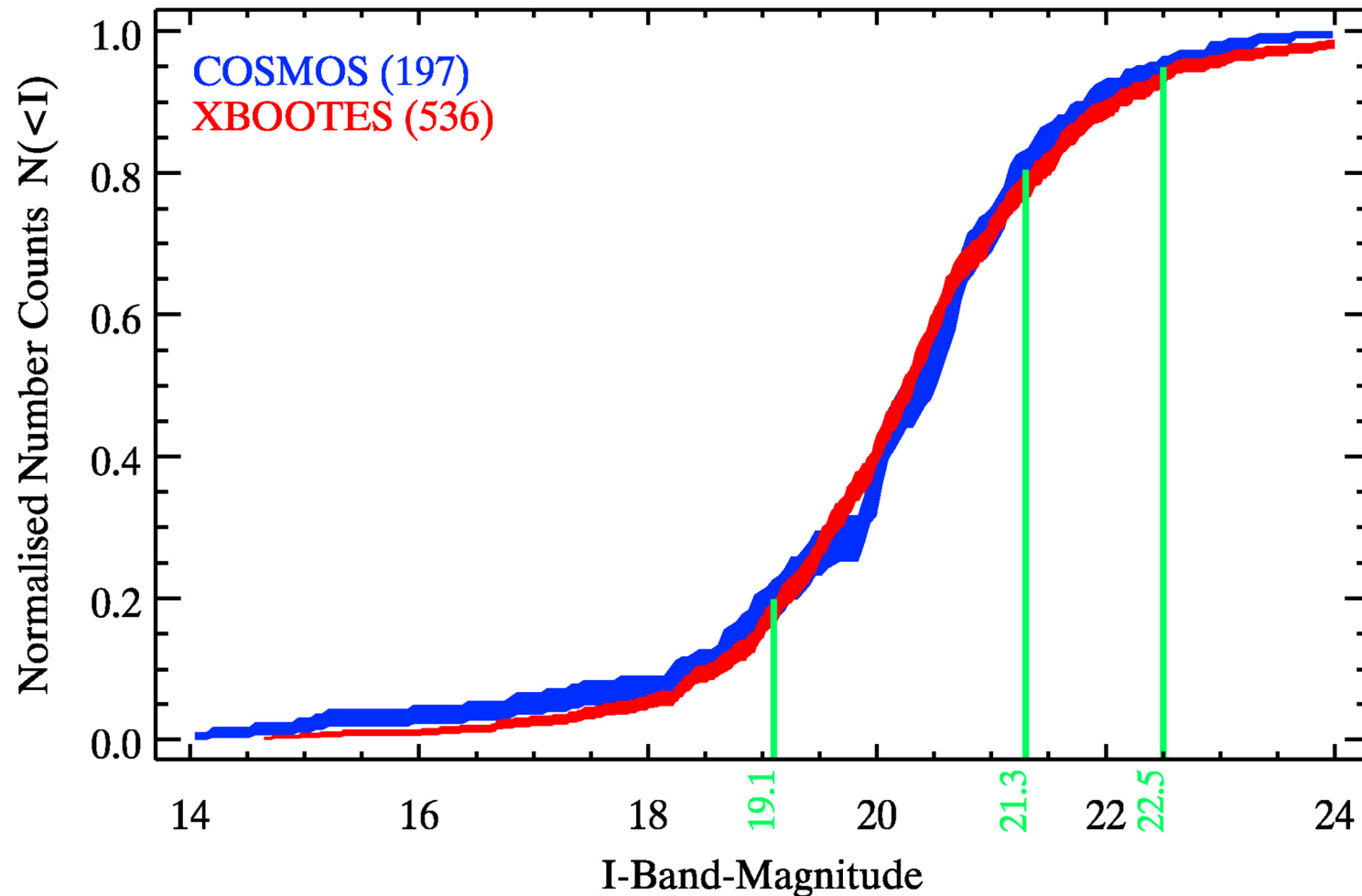


Assuming
X-ray luminosity
function of
Hasinger+2005
(with redshift cutoff of
Brusa+2009 at $z > 2.7$)

Optical counterpart (0.5-2.0 keV)

95% of eRASS-AGN have optical counterpart with:

- $< \sim 22.5$ mag in I_{AB} -Band
- $< \sim 23.0$ mag in R_{AB} -Band

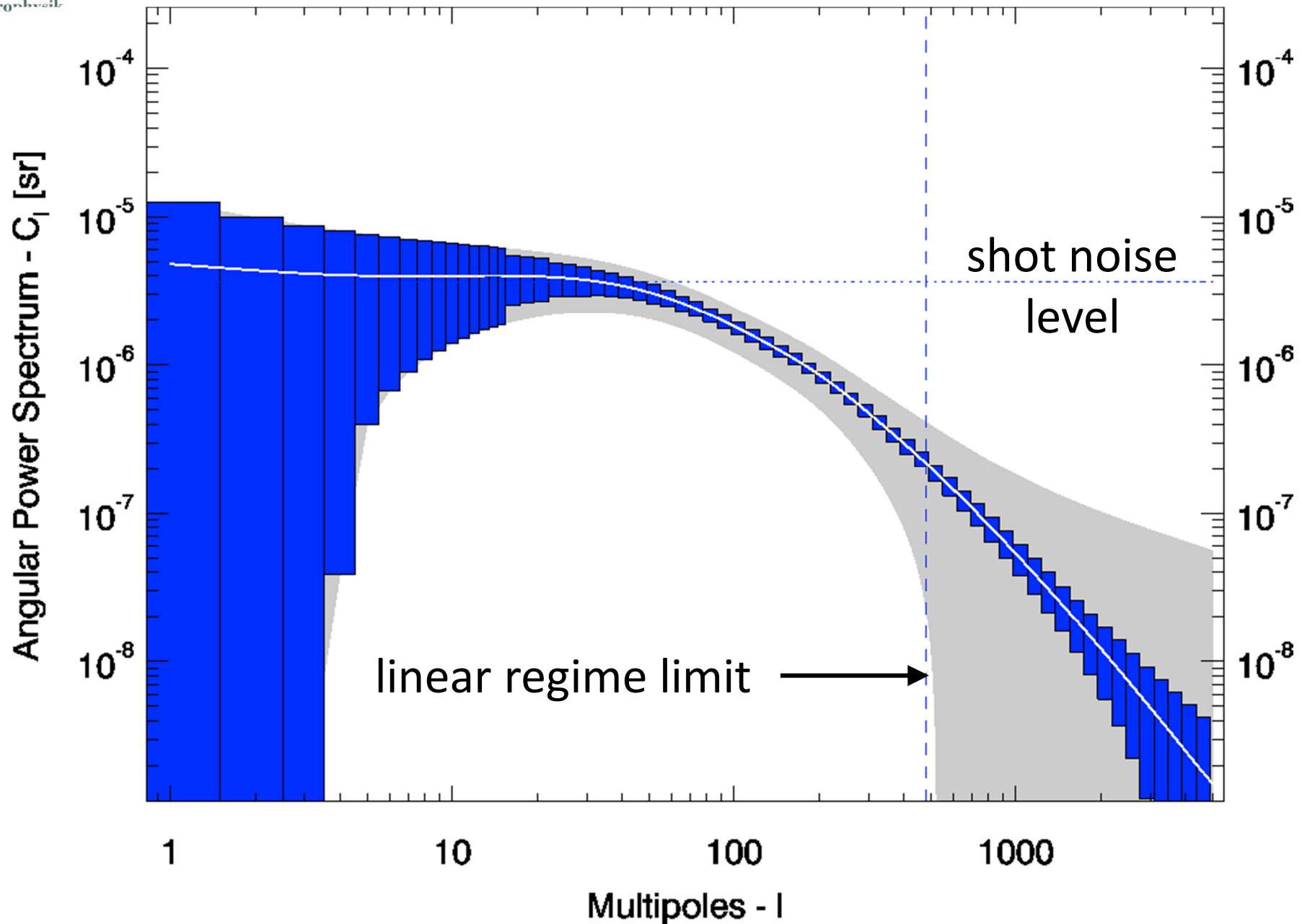


Angular Power Spectrum - C_l

- Our Model (**Hütsi,Gilfanov,Sunyaev2012**):
 - Cosmology:
flat Λ CDM, $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, $\Omega_b = 0.05$, $h = 0.7$, $\sigma_8 = 0.8$
 - Assume that AGN have a DM halo of:
 $M_{\text{DMH,eff}} = 2 \times 10^{13} M_\odot / h \rightarrow$ bias $b(z)$
(e.g. **Allevato+2011, Krumpe+2012**)
 - Use X-ray Luminosity Function of **Hasinger+2005** for flux-cut and redshift-evolution
(LDDE model, with redshift cutoff of **Brusa+2009** at $z > 2.7$)
 - Project 3D power spectrum onto 2D sphere

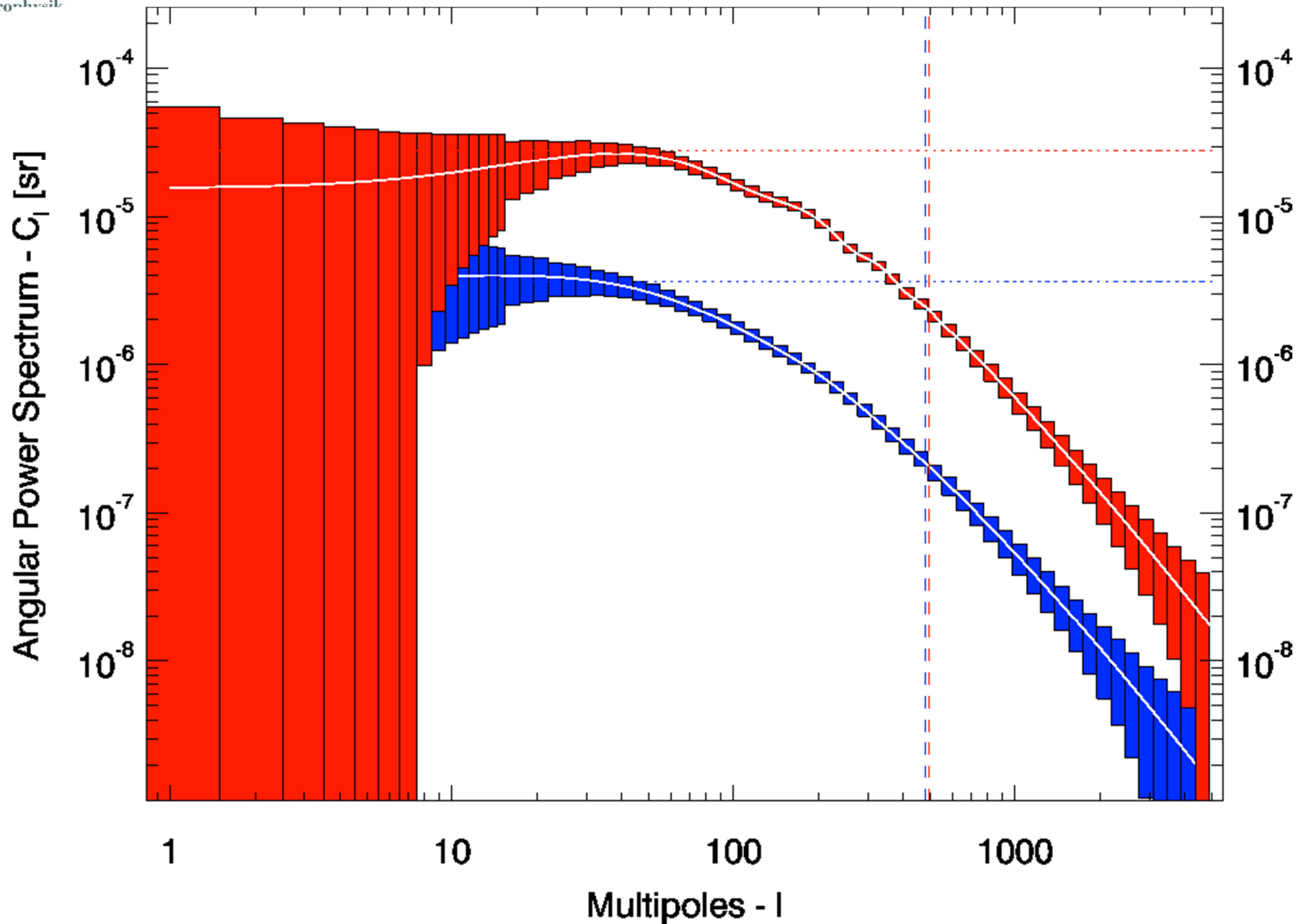
Angular Power Spectrum - C_l

full redshift range



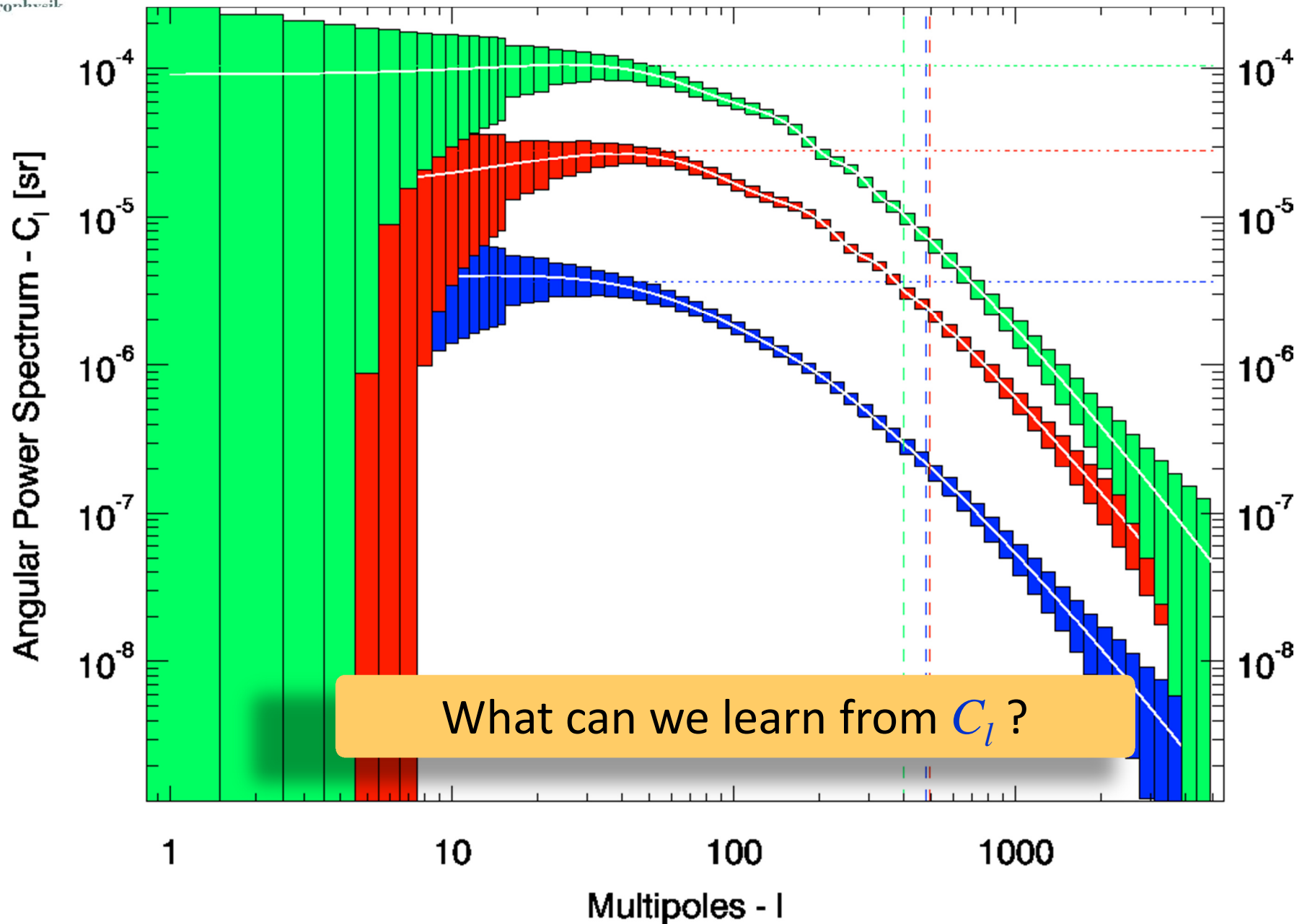
Angular Power Spectrum - C_l

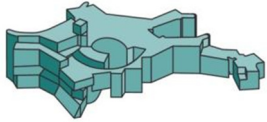
$0.80 < z < 1.00$



Angular Power Spectrum - C_l

$0.80 < z < 0.85$

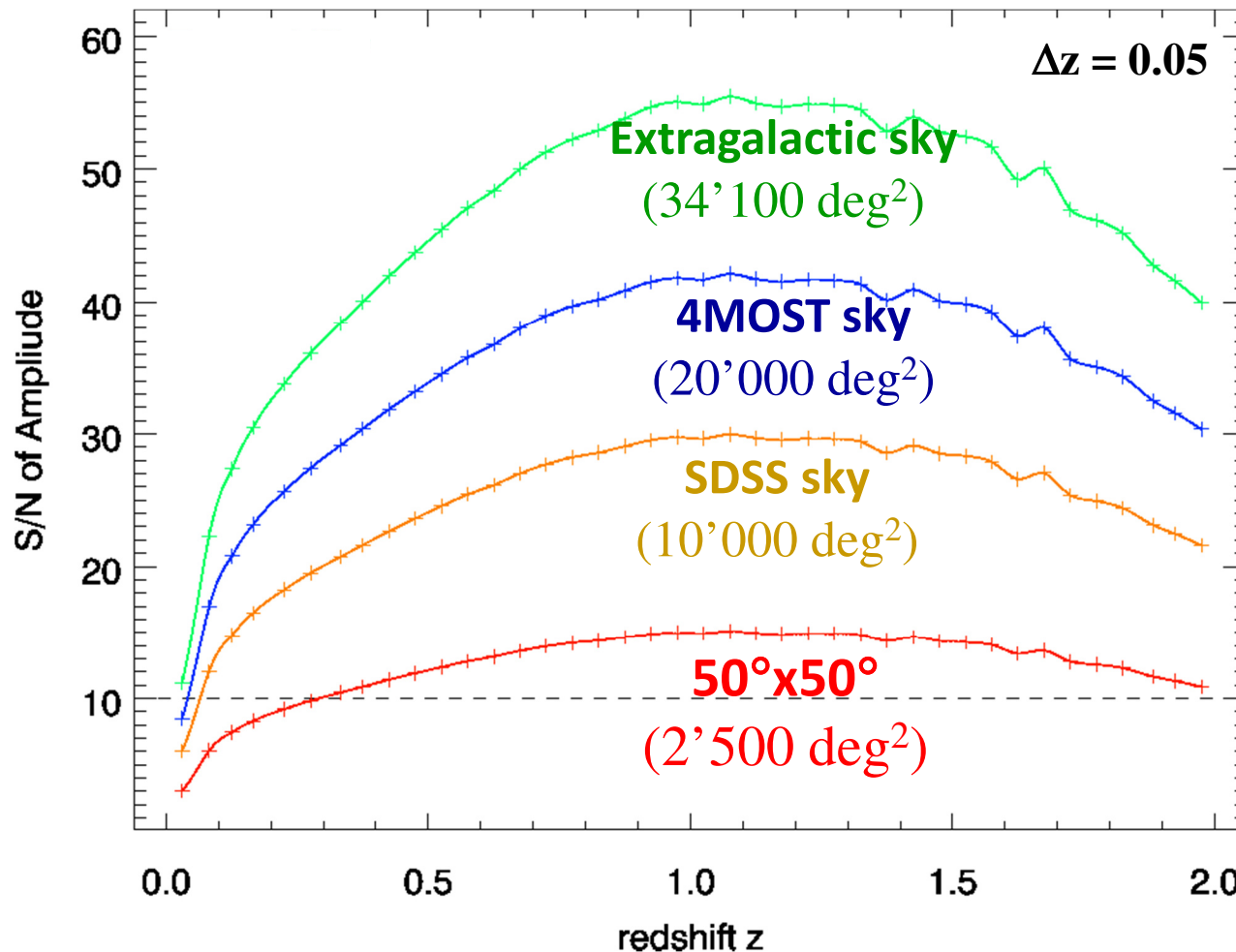




Amplitude of C_l

Since: $A \propto b^2$

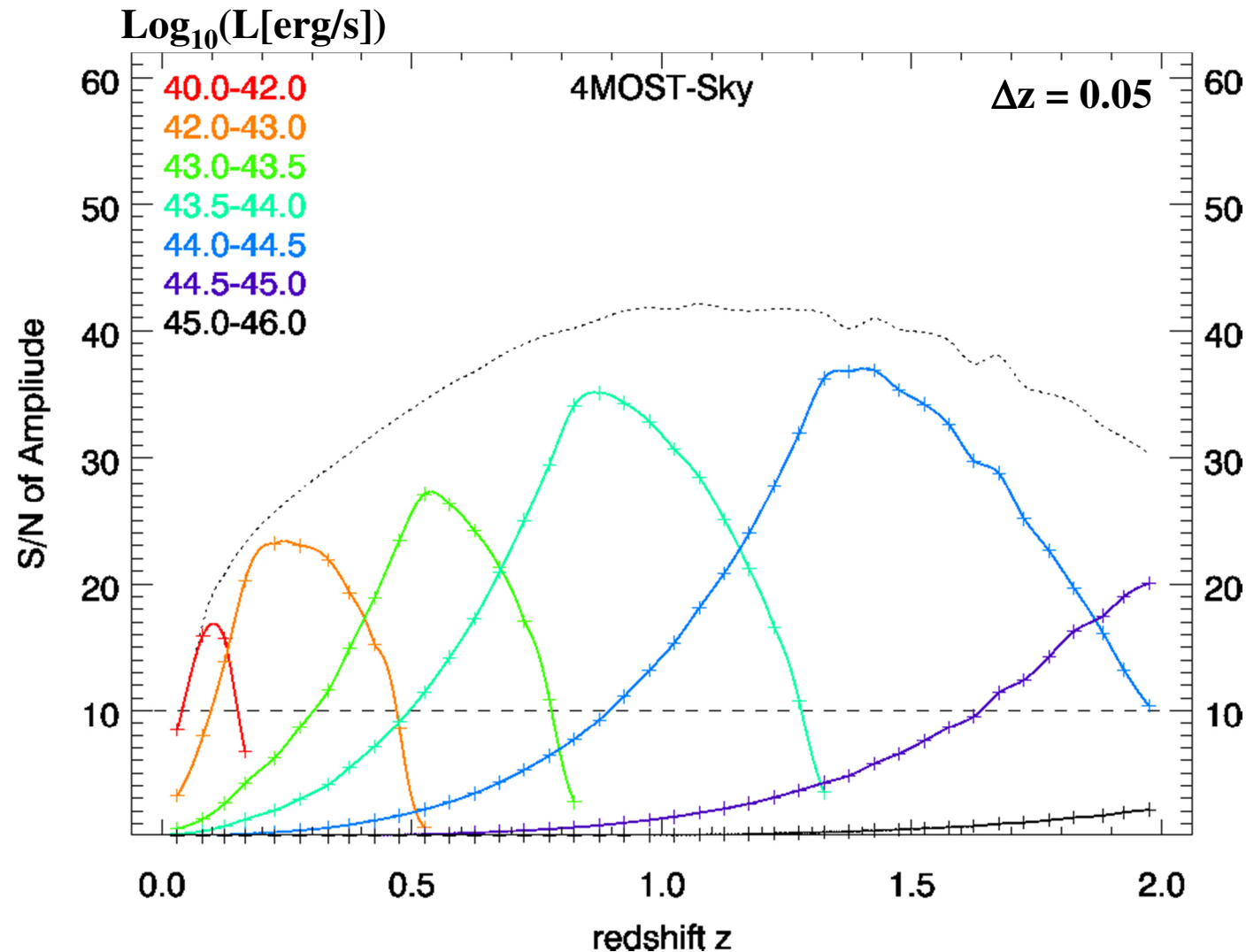
- Studies of redshift resolved bias-factor
- Studies at different sky directions
(fields of $50^\circ \times 50^\circ$ with $\sim 10\%$ accuracy)

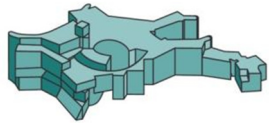


$$\frac{S}{N} = \frac{A}{\delta A} = \sqrt{\sum_{\ell=1}^{\ell(\bar{z})} \left(\frac{C_\ell}{\delta C_\ell} \right)^2}$$

Bias measurement for different luminosity groups

- Studies of luminosity and redshift resolved bias-factor



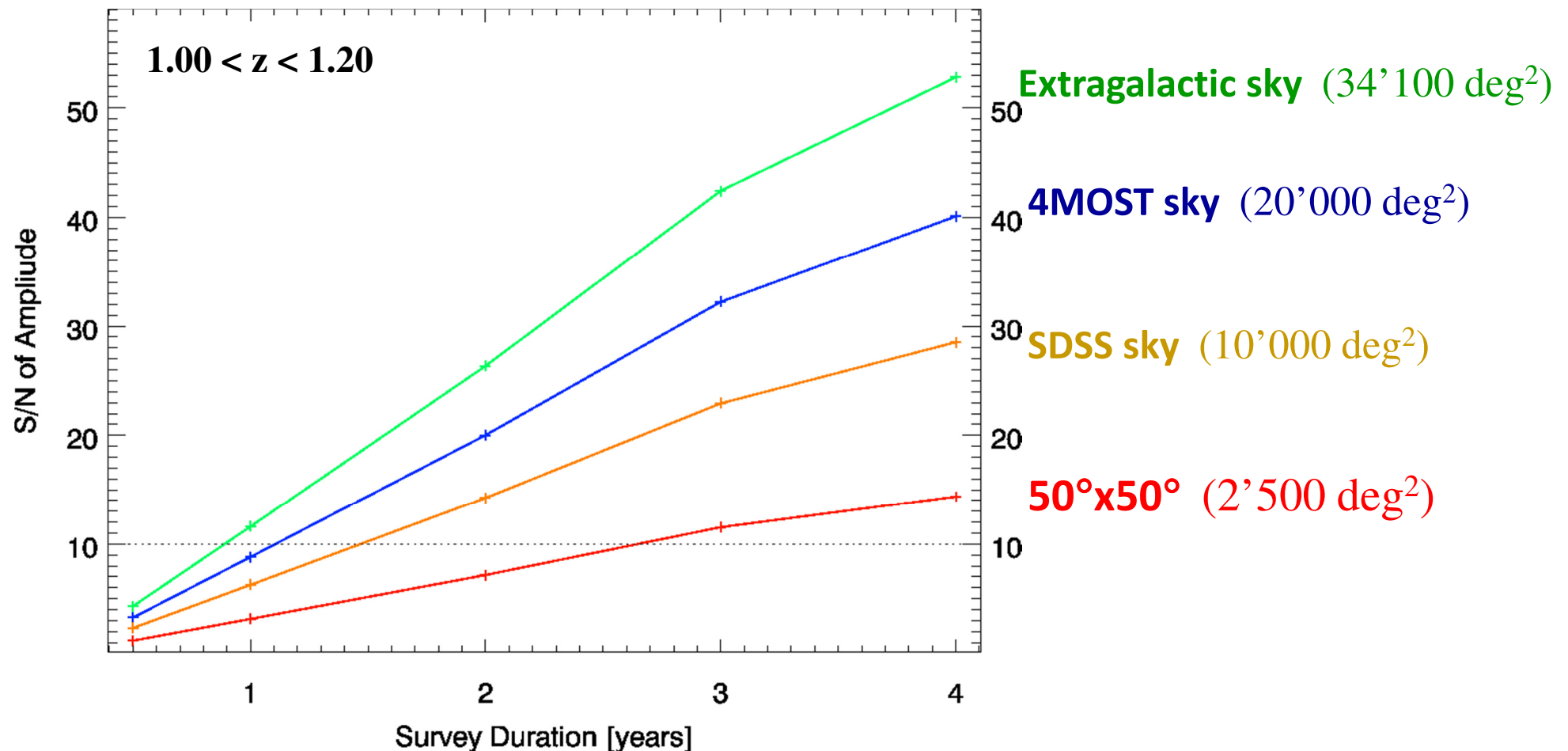


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Bias measurement after different survey durations

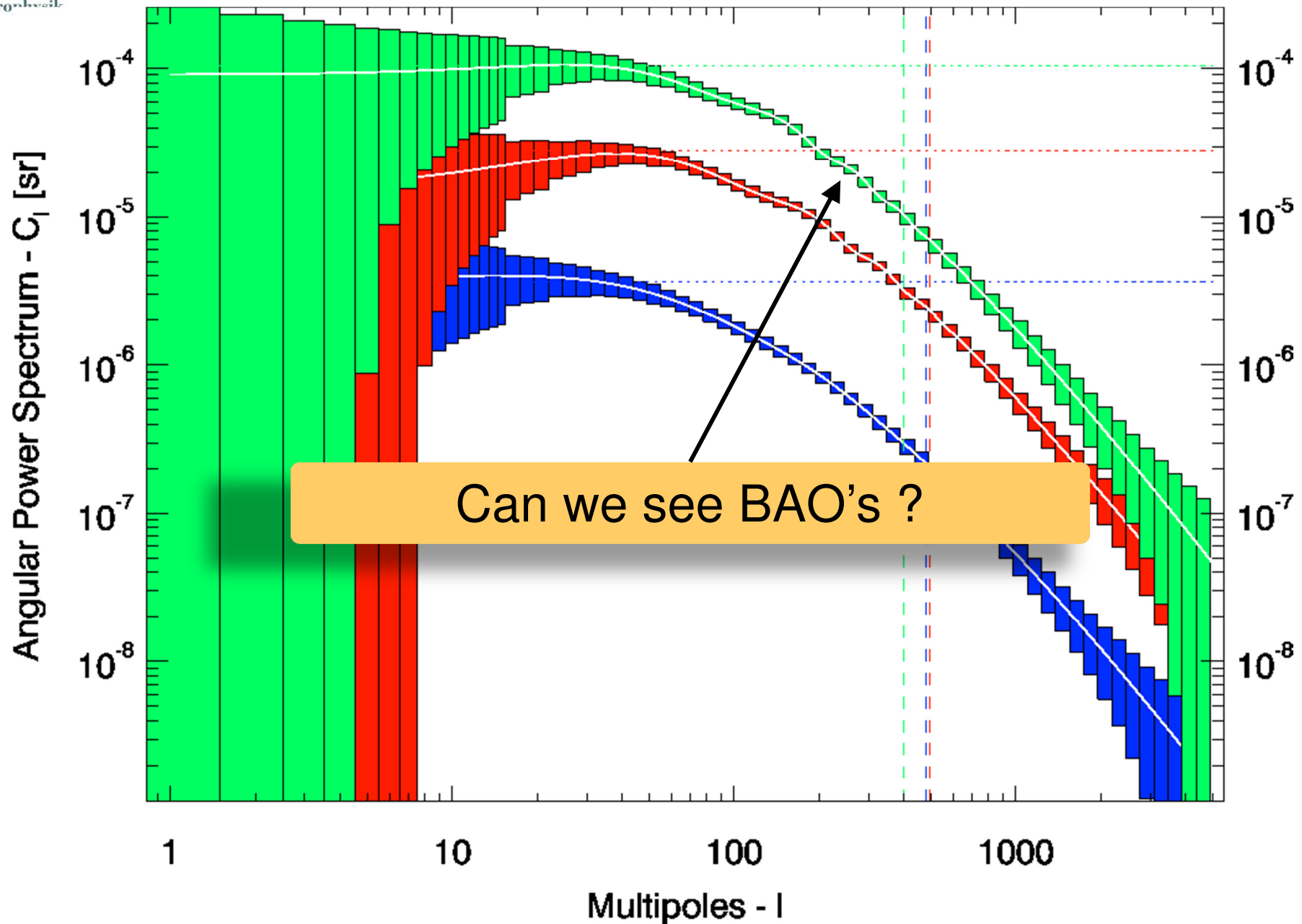
~10% accuracy

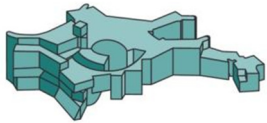
- 4MOST-Sky: after ~1.0 years (2 sky scans)
- SDSS-Sky: after ~1.5 years (3 sky scans)
- $50^\circ \times 50^\circ$: after ~2.5 years (5 sky scans)



Angular Power Spectrum - C_l

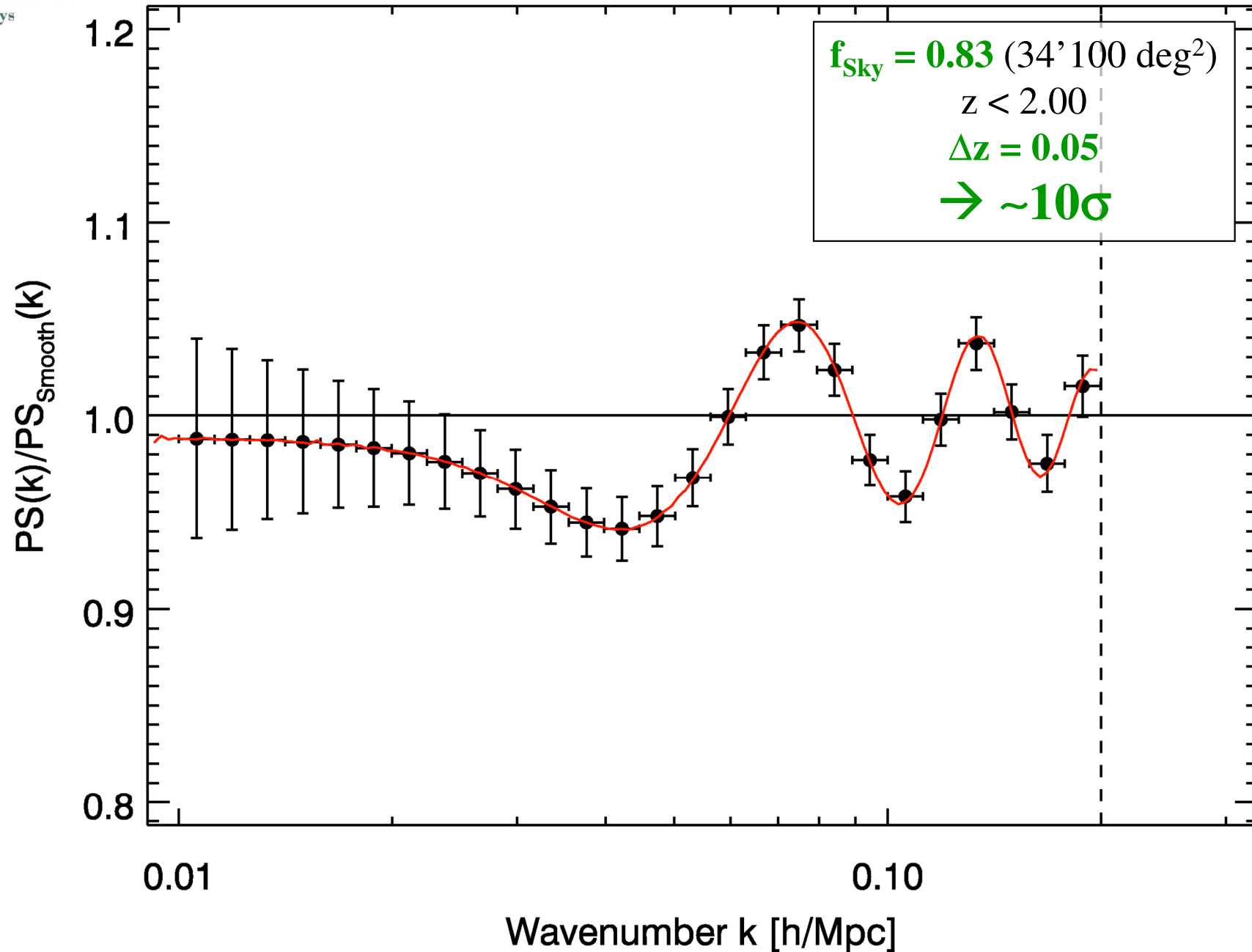
$0.80 < z < 0.85$

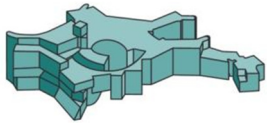




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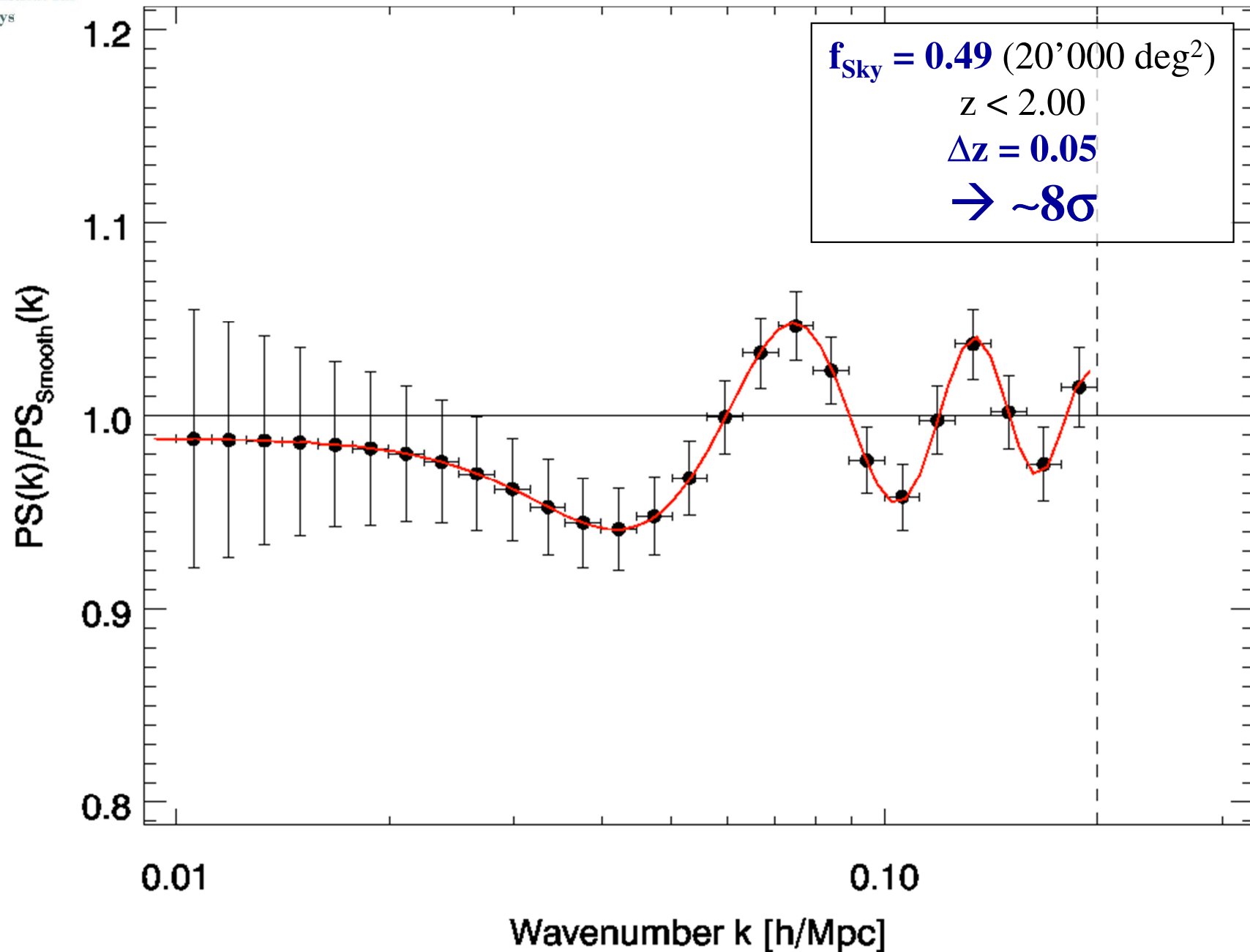
BAO's (Extragal. sky)

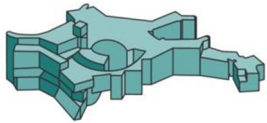




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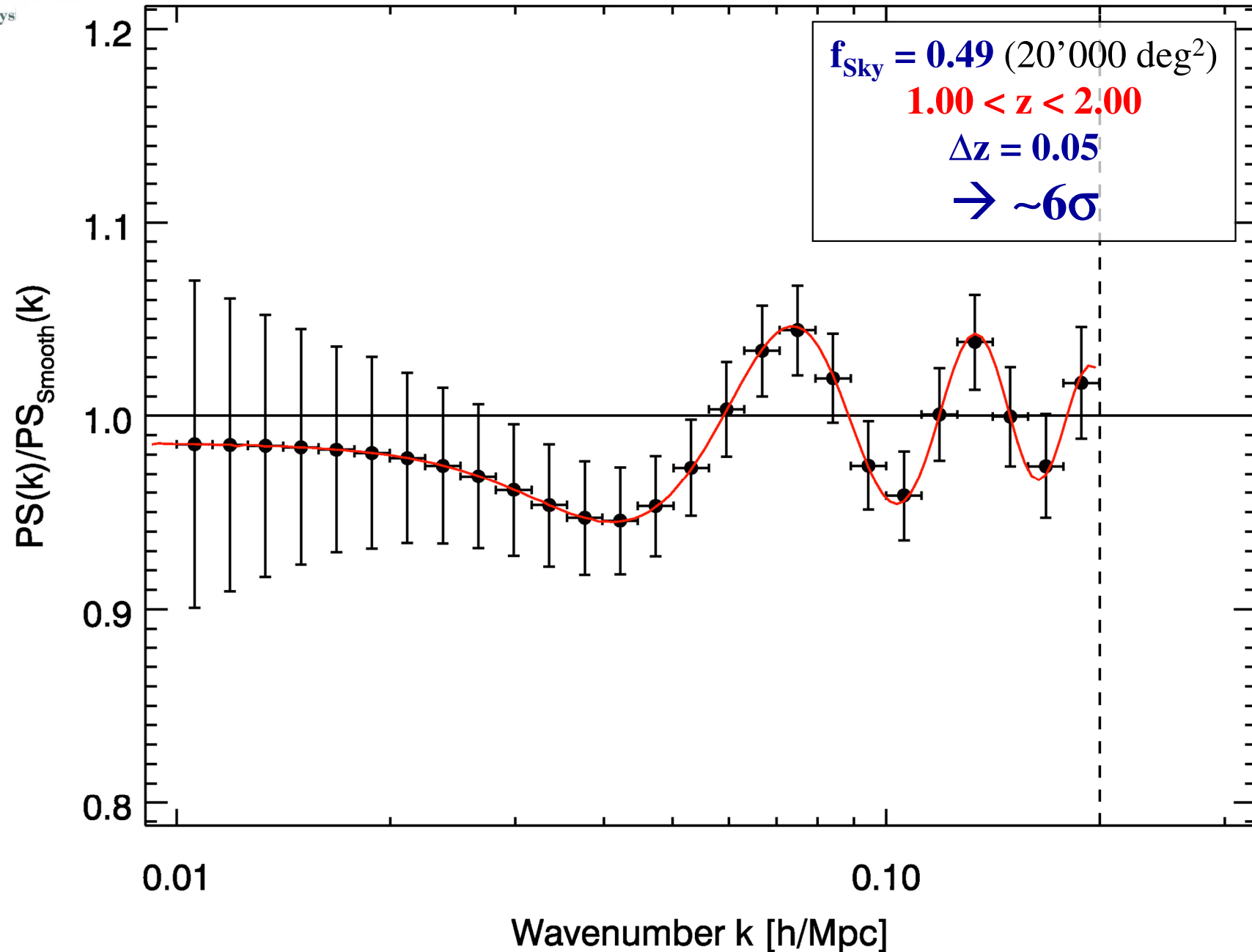
BAO's (4MOST sky)

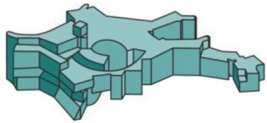




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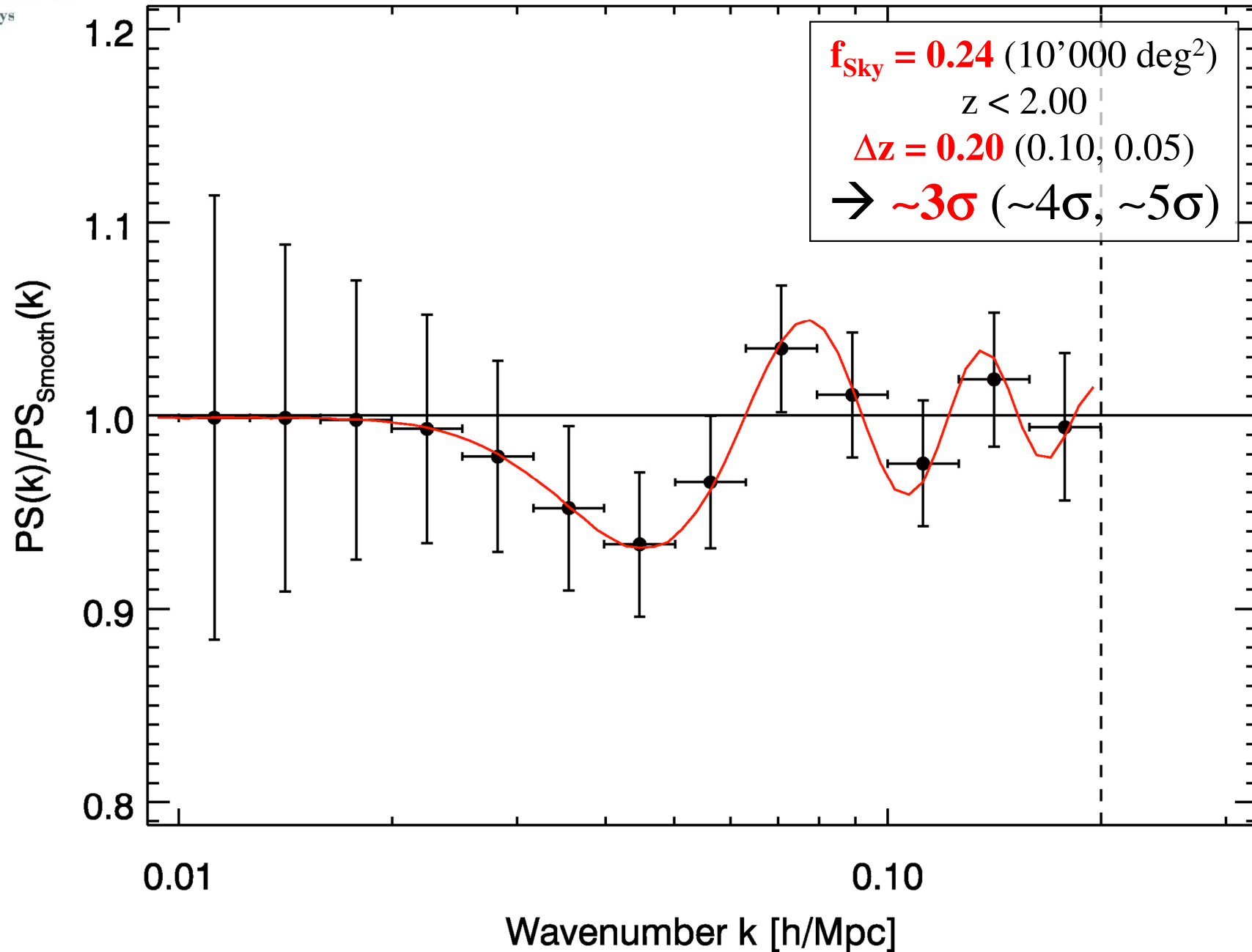
BAO's (4MOST sky)





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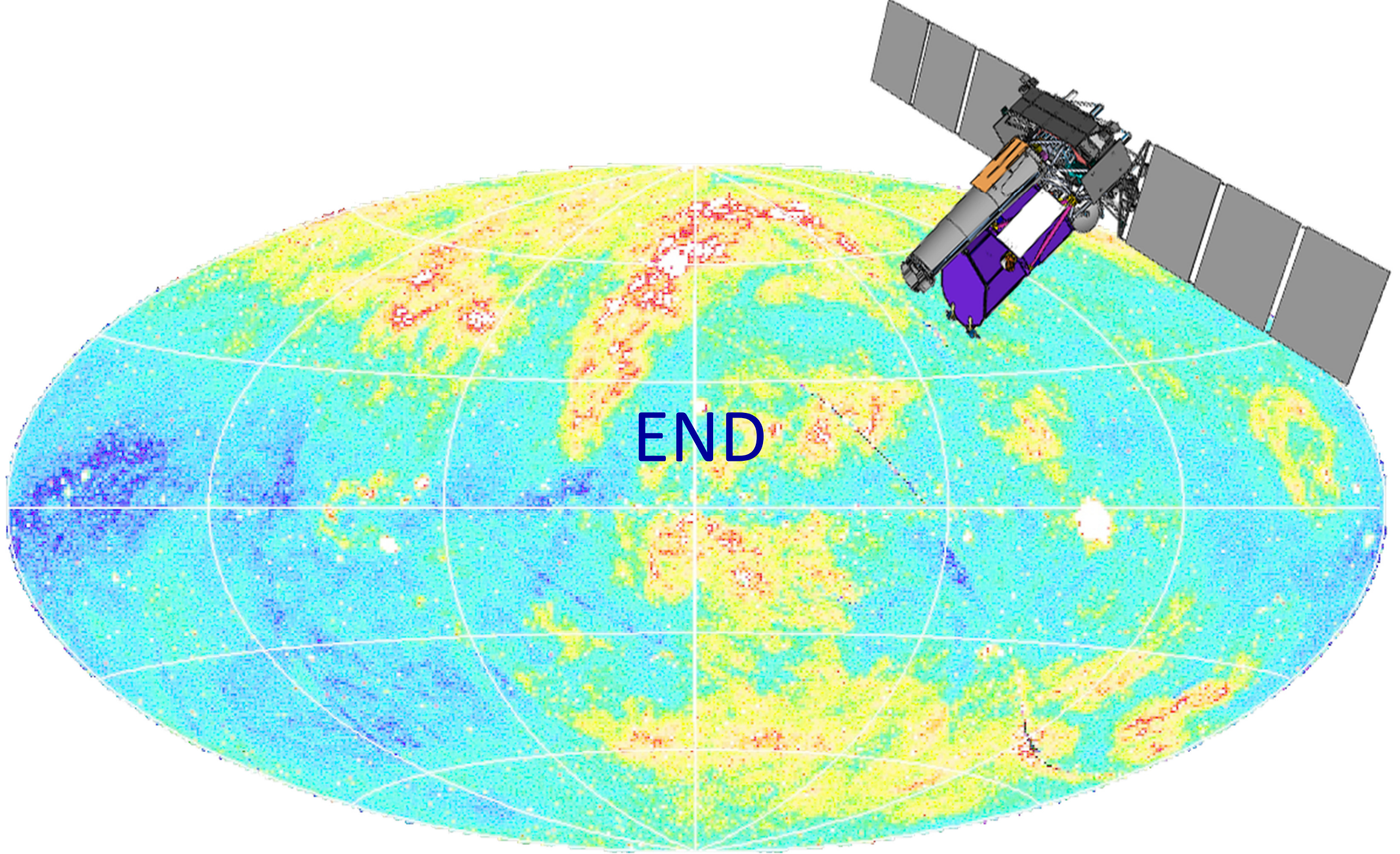
BAO's (SDSS sky)



Conclusion

- eRASS-AGN (0.5 - 2.0 keV)
 - 3 Million AGN
 - Median: $z \sim 1.0$, 40% within $1.0 < z < 2.0$
 - $> \sim 300$ AGN at $z > 5$
 - **Kolodzig+2012, in prep.** (inlc. also numbers for 2.0 -10.0 keV)
- LSS with eRASS-AGN (**Kolodzig+2013, in prep.**):
 - With 4MOST ($20'000 \text{ deg}^2$) :
 - Luminosity and redshift resolved studies of bias-factor of AGN
 - Competitive studies of BAO's with AGN

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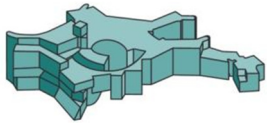
Studies of large scale structure

- study with Angular Power Spectrum (APS): C_l
(or angular two-point correlation function $\omega(\theta_{1,2})$)
- by observations:
 - Data: discrete positions $\mathbf{n} = (\theta, \phi)$ of tracer objects on the sky
 - spherical harmonic decomposition (Fourier transform for a sphere):

$$f(\theta, \phi) = \sum_{\ell} \sum_m a_{\ell, m} Y_{\ell, m}(\theta, \phi)$$
 - APS: expectation value of the spherical harmonic coefficient, averaged over all modes (isotropy)

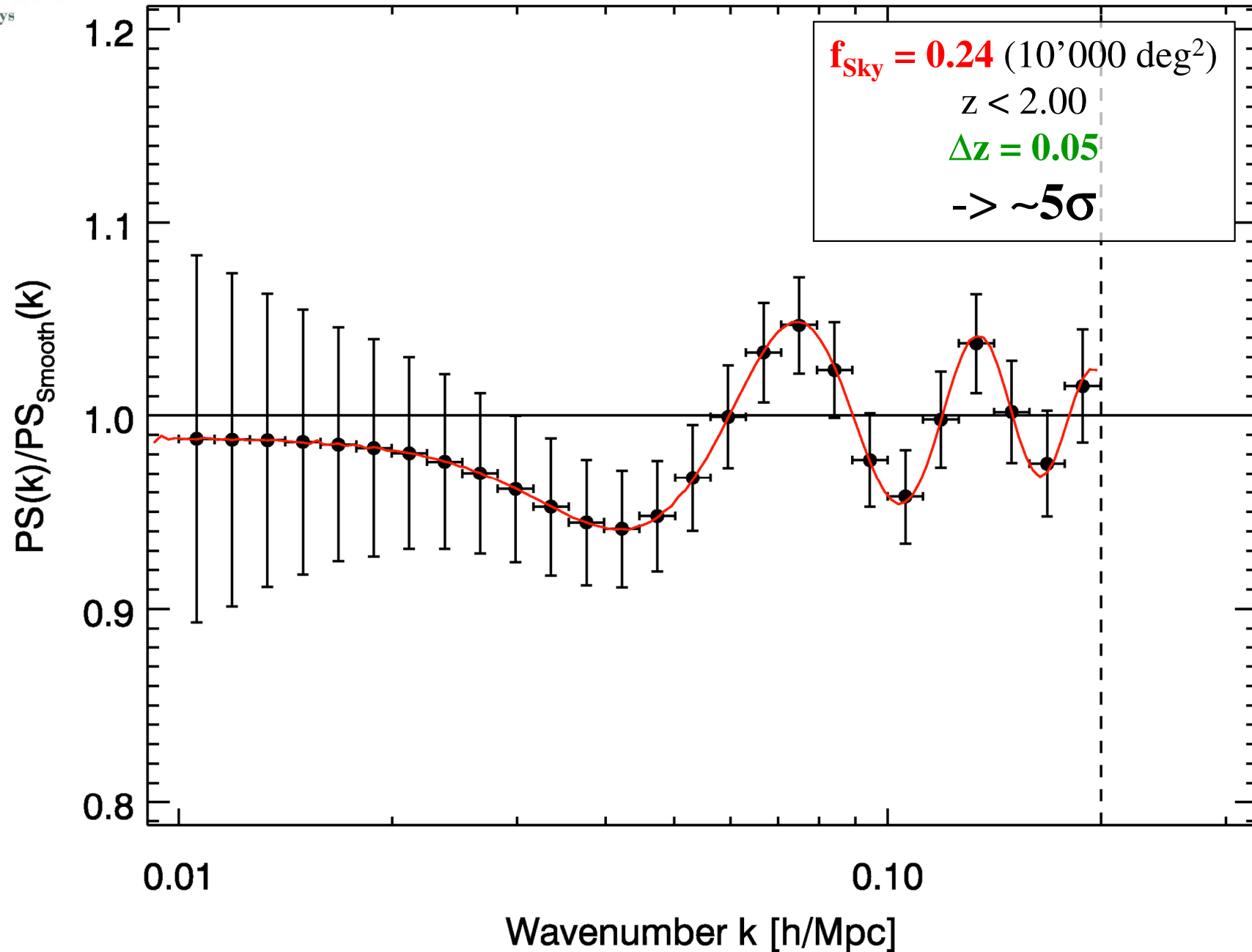
$$C_l = \sum_m (\langle |a_{l, m}|^2 \rangle - 1/n) / (2l+1)$$
 - Corrections for incomplete sky coverage (window function)
- uncertainty:
 - variance of $a_{l, m}$: $(C_l)^2$
 - reduced by number of modes $a_{l, m}$: $(2l+1)$
 - depends on sky fraction: f_{sky}

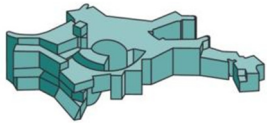
$$\delta C_{\ell} = \sqrt{\frac{2}{(2\ell+1)} \frac{1}{f_{\text{sky}}}} \left(C_{\ell} + \frac{1}{n} \right)$$



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BAO's (SDSS sky)





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BAO's (SDSS sky)

