Cosmic Matter Dipole and *non-Gaussianity* with the **Square Kilometre Array** and its *Pathfinders*

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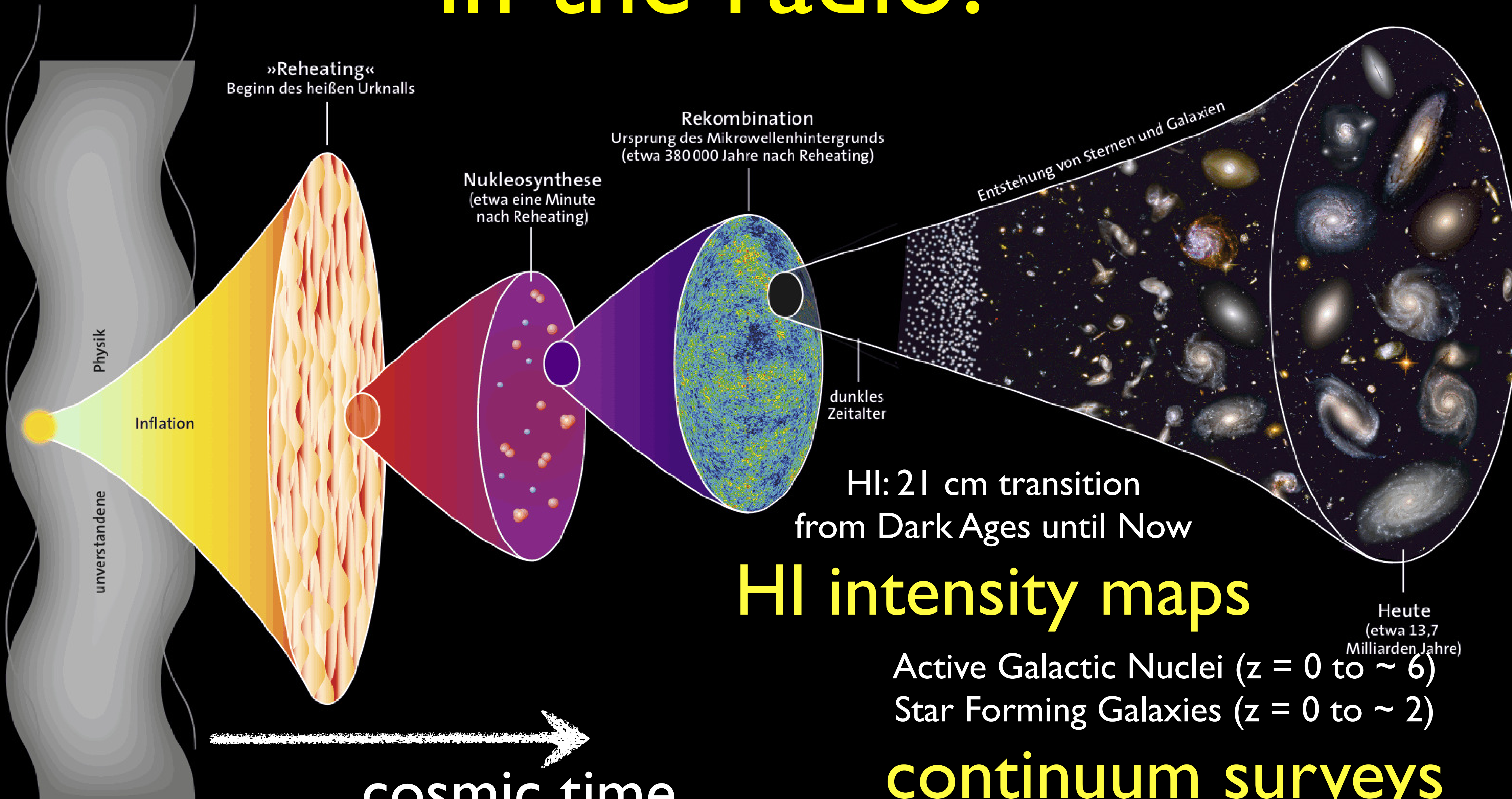
GLOWSKA 2016, Karlsruhe

What do we probe in the radio?



cosmic time

HI: 21 cm transition
from Dark Ages until Now

HI intensity maps

Active Galactic Nuclei ($z = 0$ to ~ 6)
Star Forming Galaxies ($z = 0$ to ~ 2)

continuum surveys

HI galaxy surveys

Testing fundamental cosmological assumptions

Cosmic reference frame:

observed CMB dipole & proper motion hypothesis

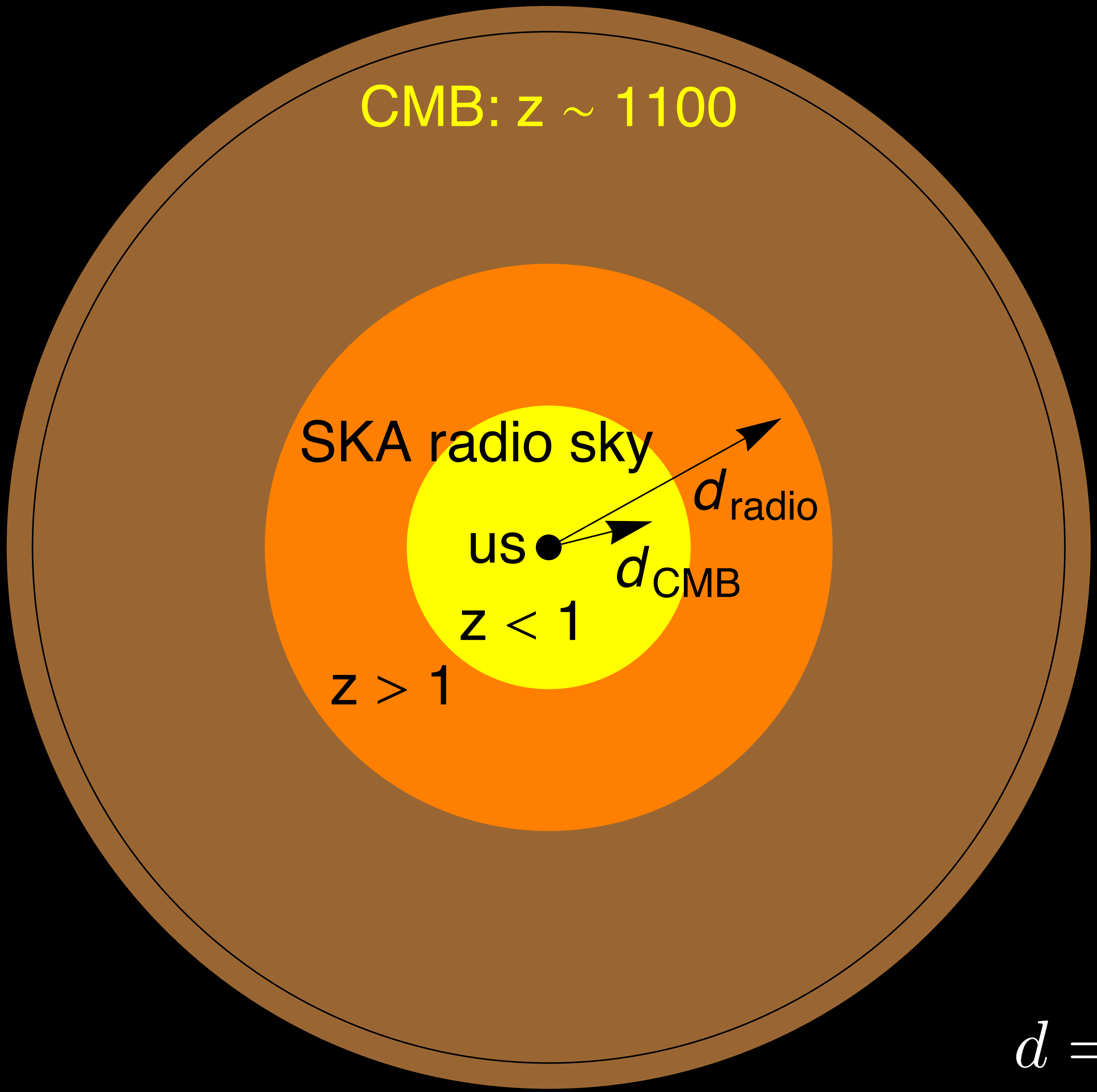
Quantum origin of structure:

vacuum initial conditions predict gaussianity of matter distribution with tiny deviation

$\Phi = \Phi_G + f_{nl} (\Phi_G)^2$

Both aspects can be tested by means of continuum radio galaxy surveys

Cosmic Radio Dipole



$d_{cmb} \Leftrightarrow d_{radio}$?

kinetic dipole

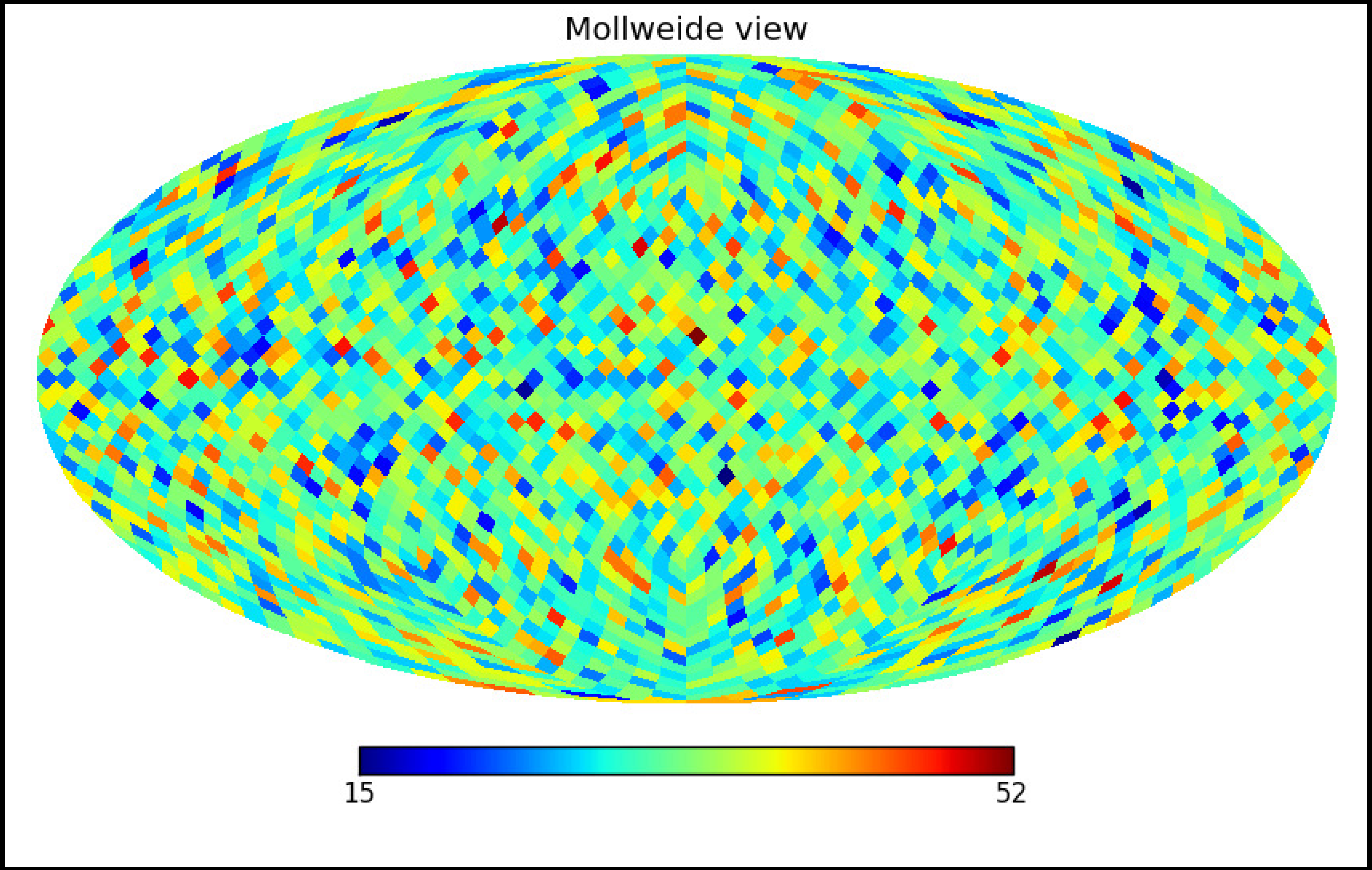
Ellis & Baldwin 1984

mean z of radio galaxy catalogues > 1, but only distribution in z known

$$\frac{\mathrm{d}N}{\mathrm{d}\Omega}(> S) = aS^{-x}[1 + d\cos\theta + \ldots]$$

$$d = [2 + x(\alpha + 1)]\frac{v}{c}, \quad S \propto \nu^{-\alpha}$$

The Challenge



Simulated pixelated sky map of 100,000 sources including expected kinetic dipole: shot noise dominated

➔ need huge catalogues (> 10^6 sources) and large sky coverage (> 20.000 sqdeg)

CMB Dipole

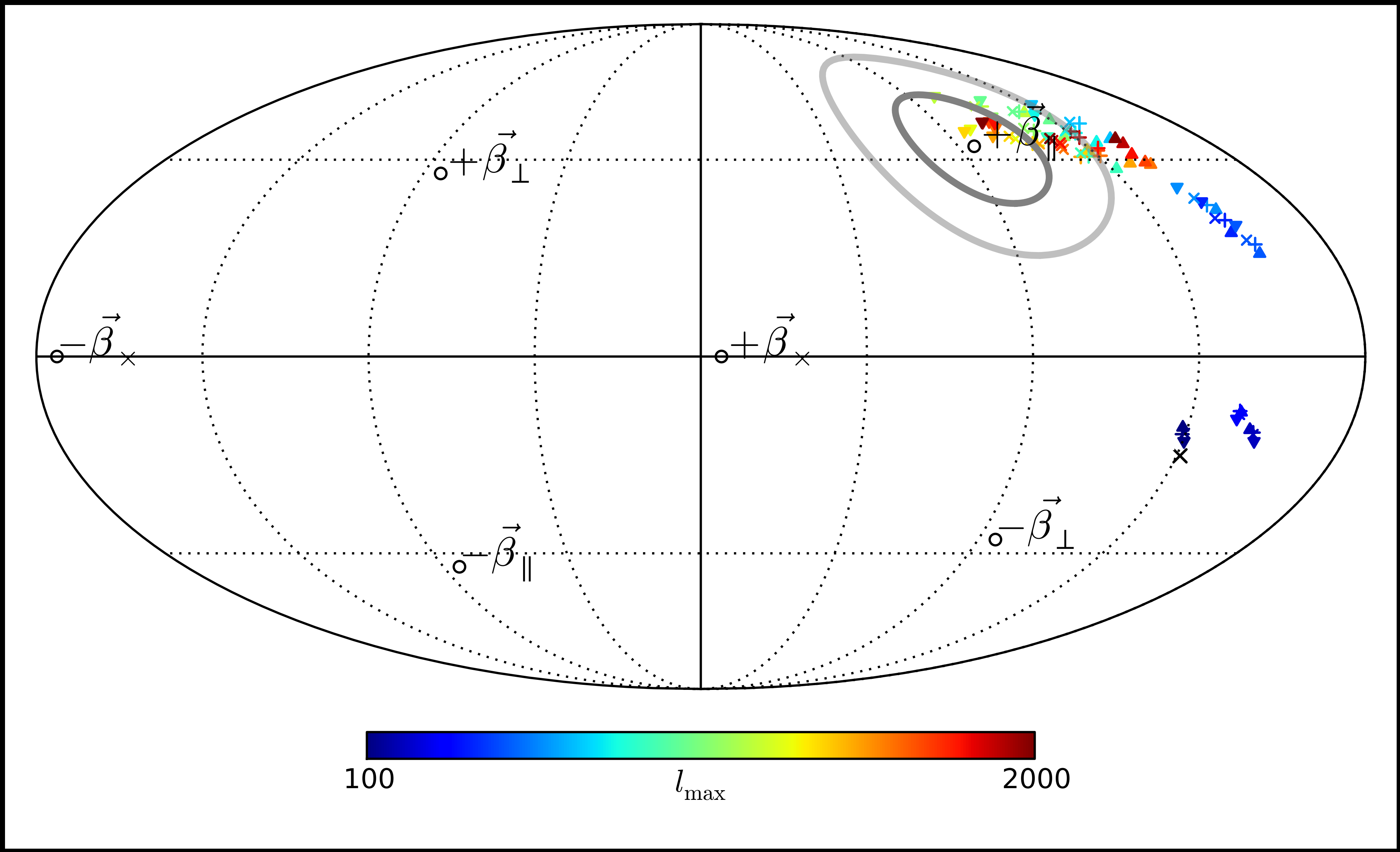
hypothesis: cmb dipole is due to peculiar motion
$v = (369 \pm 0.9)$ km/s

prediction:
Doppler shift and aberration
for all objects at cosmological distances and at any frequency

test with high l multipoles in CMB Planck 2013/2015

test with radio sky

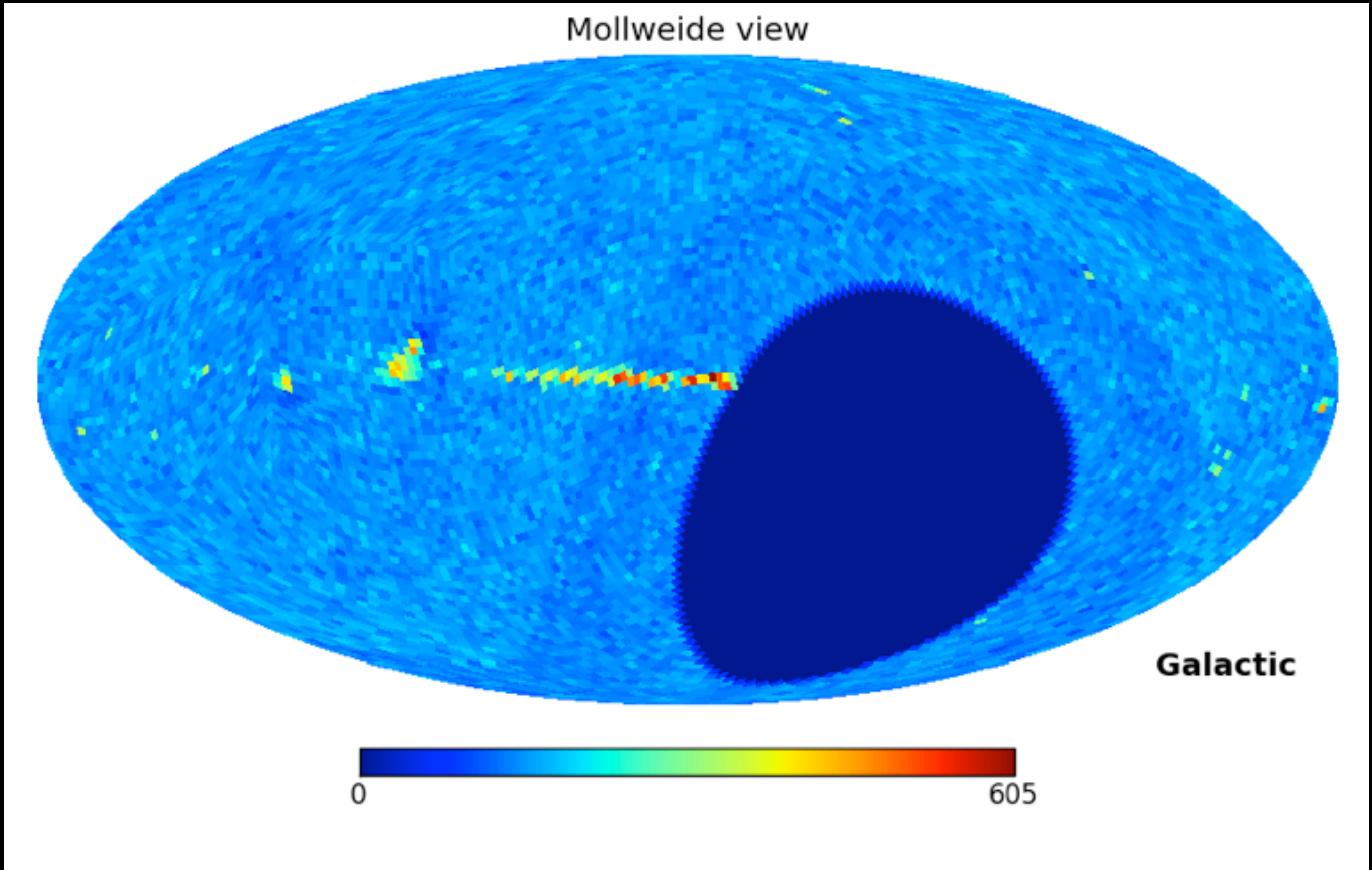
Kinetic CMB Dipole



v = 384 km/s ± 78 km/s (stat.) ± 115 km/s (sys.)

Planck 2013

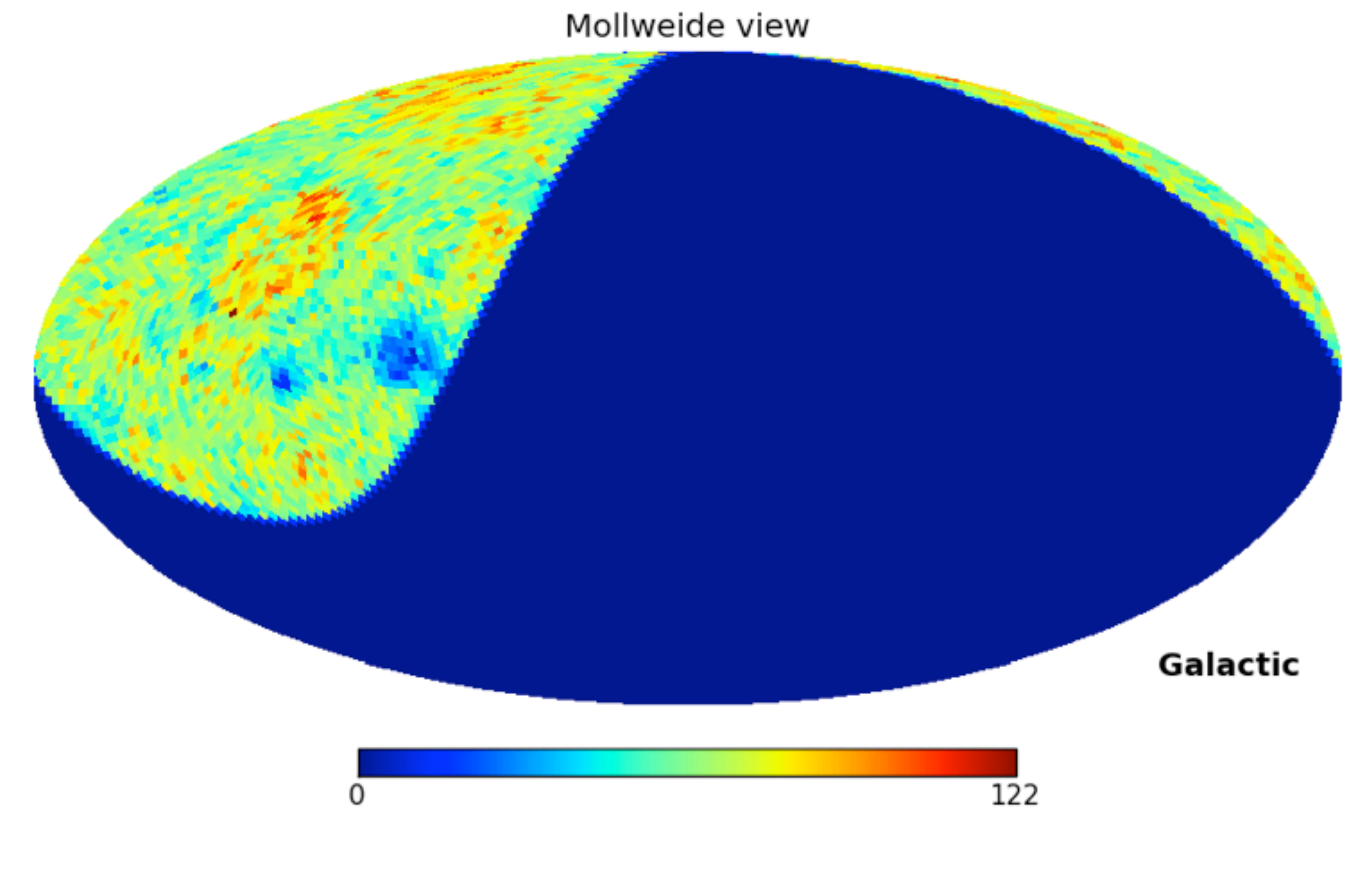
NVSS @ 1.4 GHz



S > 25 mJy

Condon et al. 2002

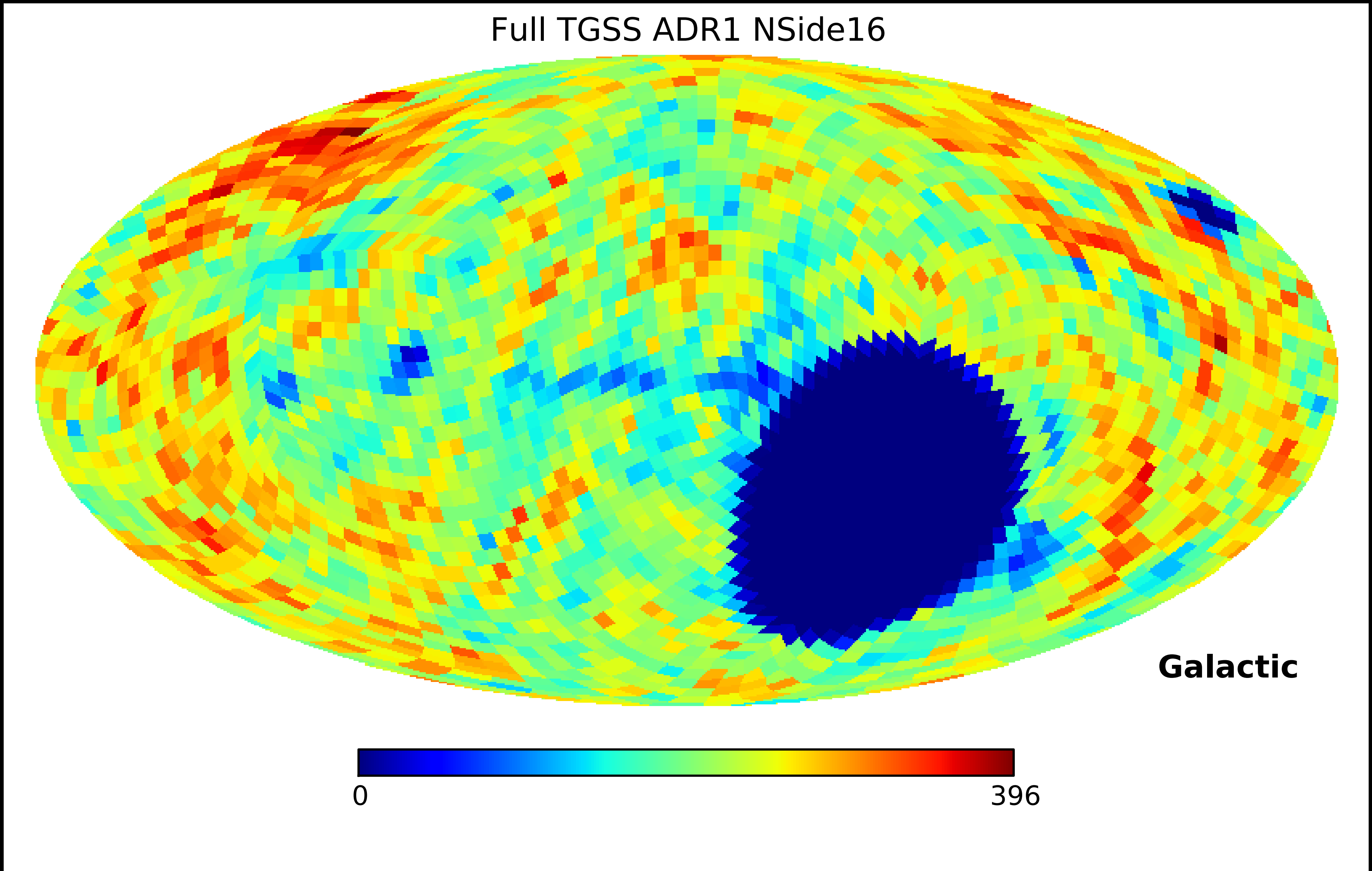
WENSS @ 325 MHz



S > 25 mJy

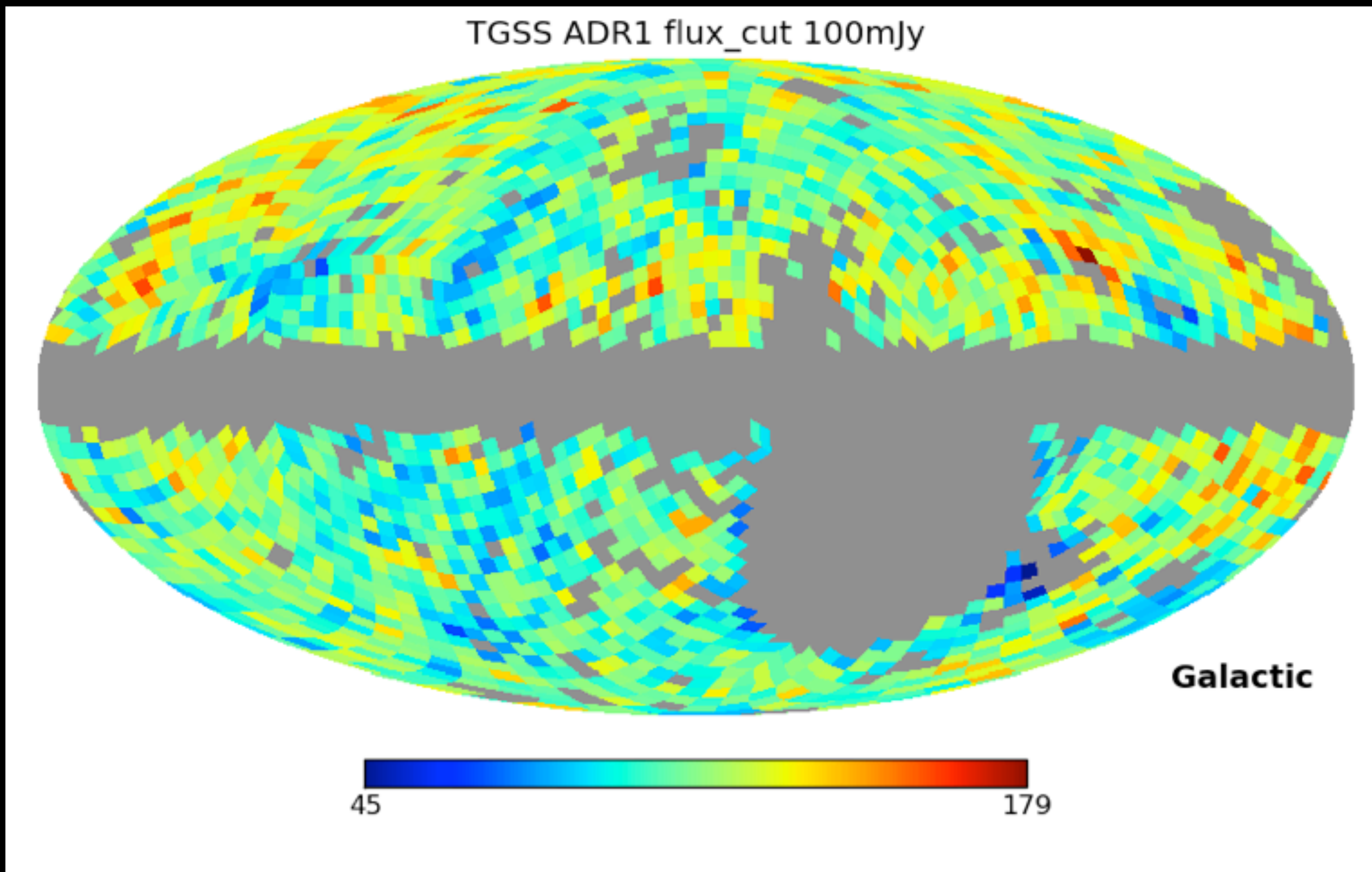
Rengelink et al. 1997

aTGSS @ 150 MHz



Intema et al. 2016

aTGSS (alternative DR1 TIFR GMRT SS)
90% of sky @ 150 MHz



S > 100 mJy

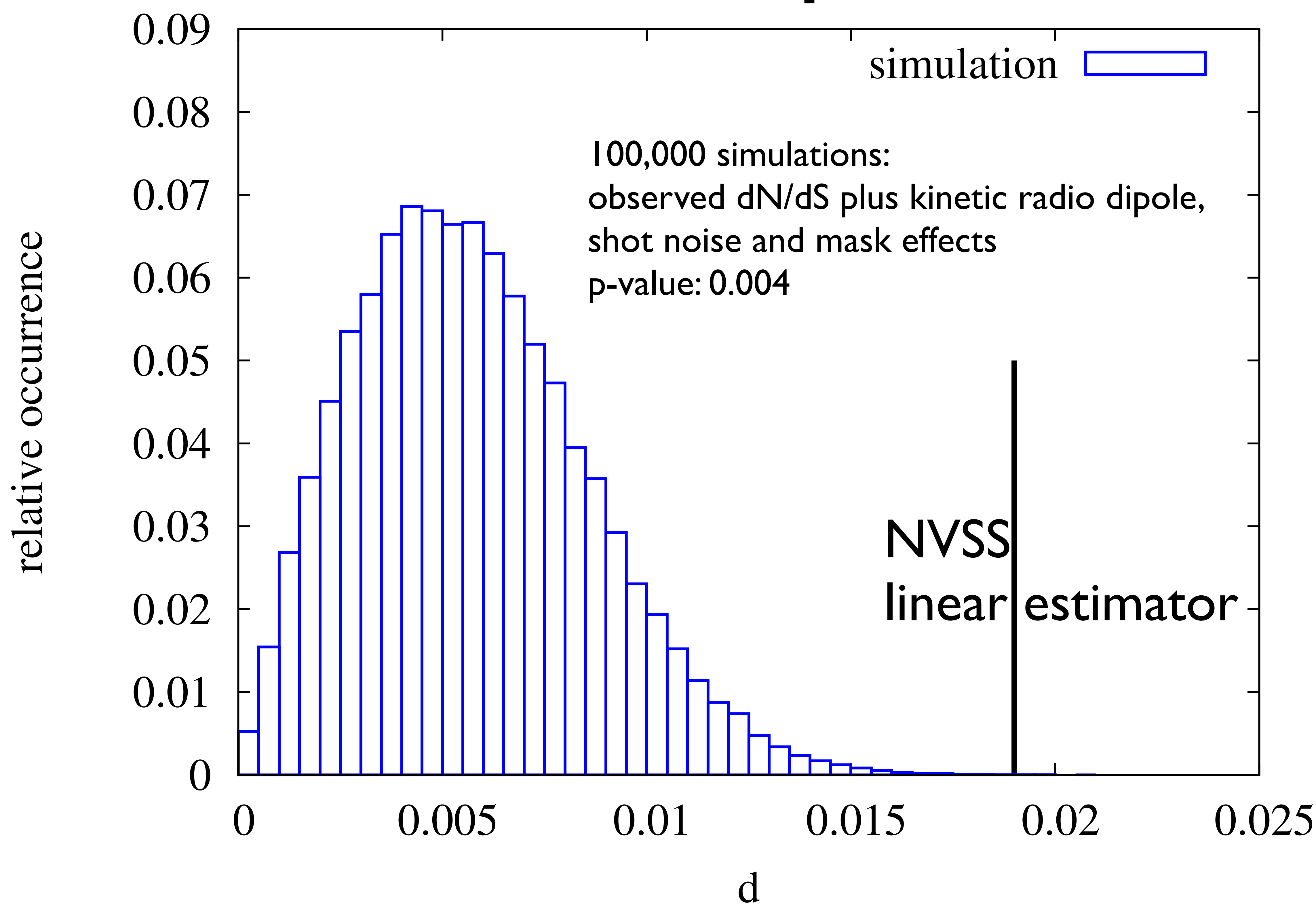
Rubart, Schwarz & Siewert, in prep.

Cosmic dipole @ 3 freq.

	Smin [mJy]	N	α [deg]	δ [deg]	d (0.01)	est.
NVSS	25	197,998	153±30	-4±34	1.1±0.3	**quad. harm.
NVSS	25	185,649	158±21	-2±21	1.6±0.6	lin.
NVSS	25	220,237	143±12	-11±15	1.8±0.5	*quad.
NVSS	15	298,289	149±19	17±19	1.4±0.5	lin.
WENSS	25	92,600	117±40		2.9±1.9	lin.
aTGSS	150	162,331	135±?	75±?	2.4±?	*quad.
aTGSS	100	229,235	123±?	72±?	2.2±?	*quad.
expect.	-	-	168	-7	0.4	

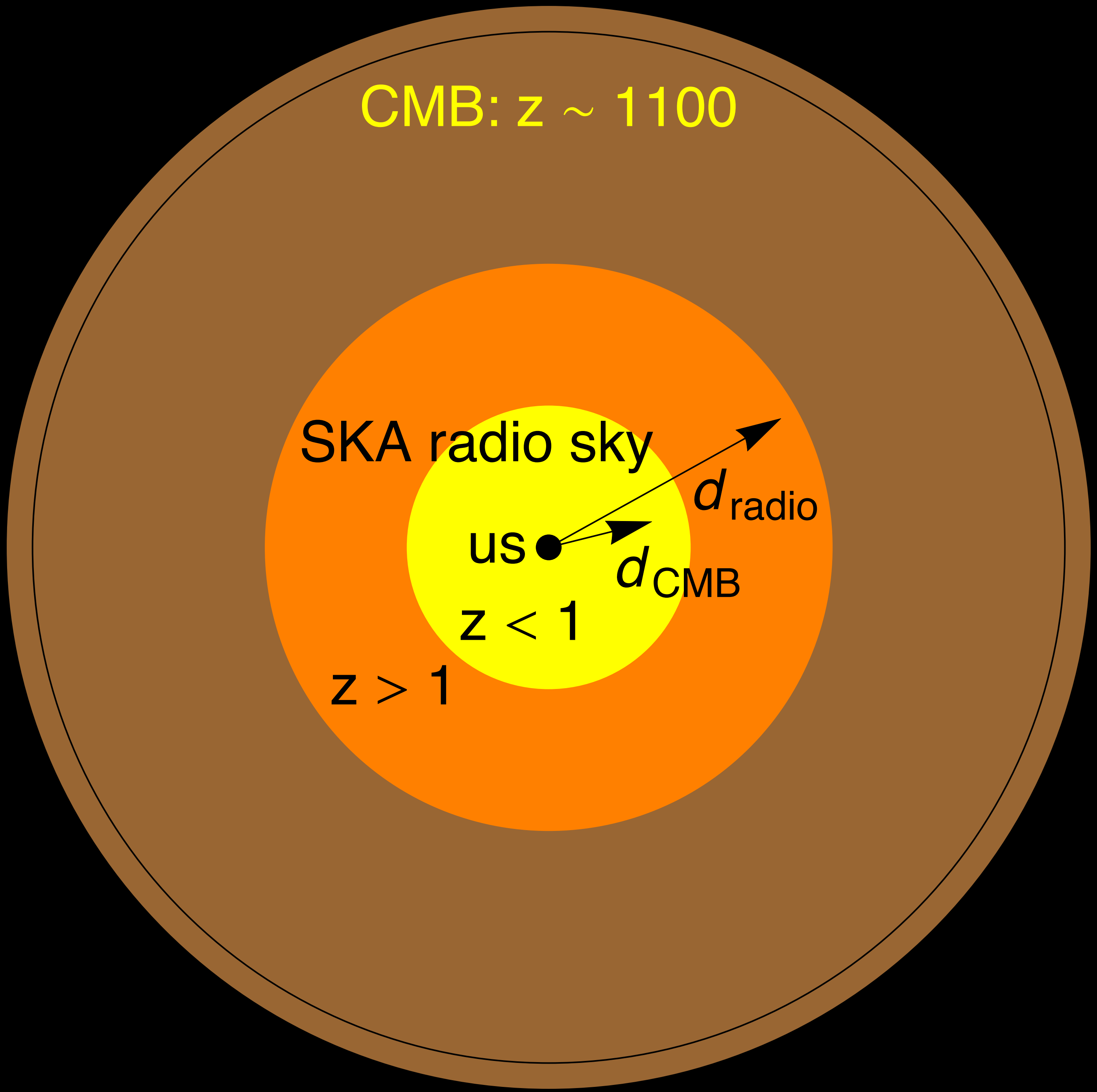
*preliminary **Blake & Wall 2002 Rubart & Schwarz 2013 & in prep.

NVSS Dipole <z> ~ 1.2



Rubart & Schwarz 2013

Cosmic radio dipole



$d_{cmb} \Leftrightarrow d_{radio}$?

NVSS (1.4 GHz) & WENSS (345 MHz): directions consistent, amplitude 2 - 4 times too large

Blake & Wall 2002
Rubart & Schwarz 2013

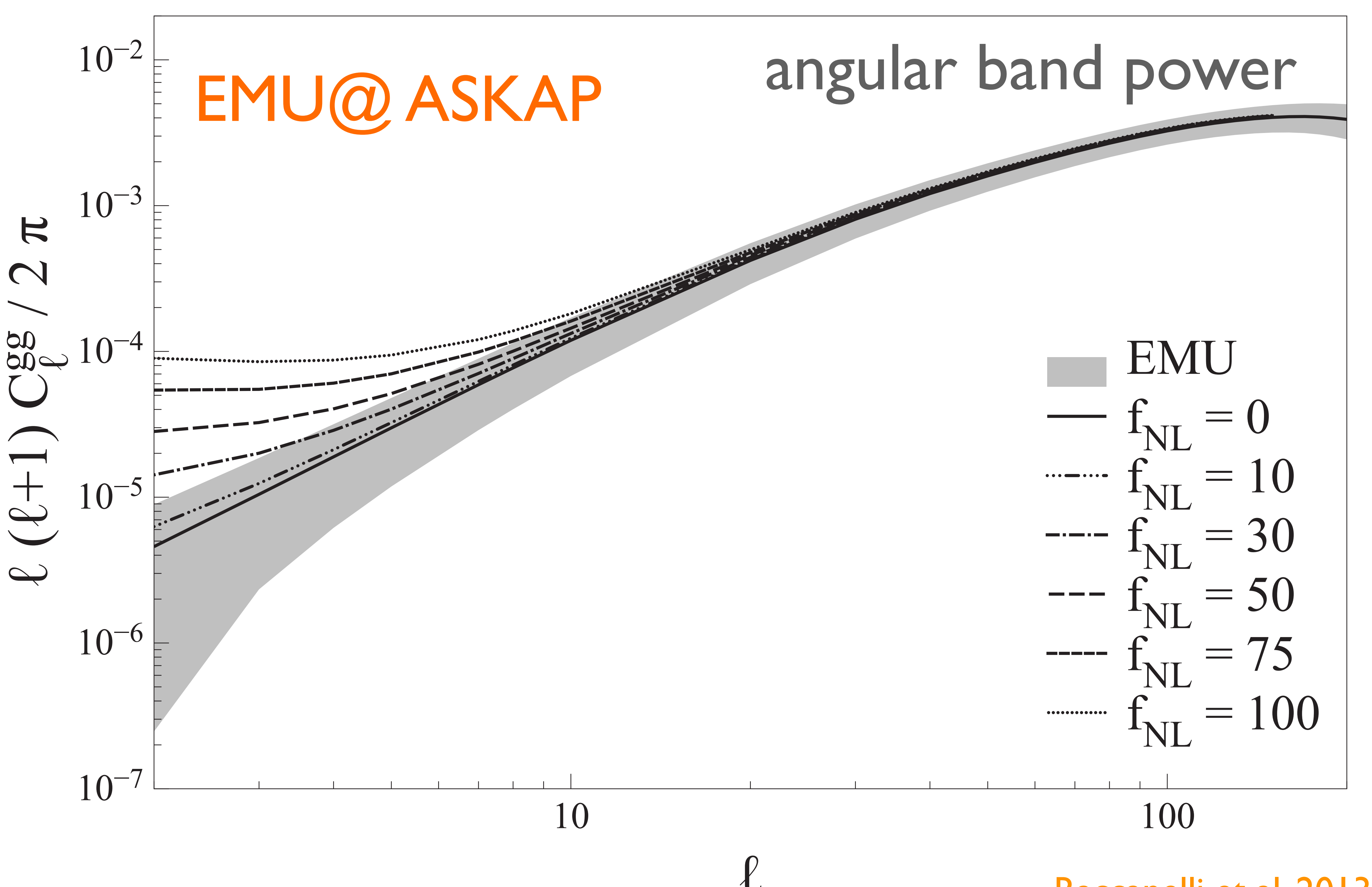
bulk flows?

Watkins & Feldman 2014
Atrio-Barandela et al. 2014

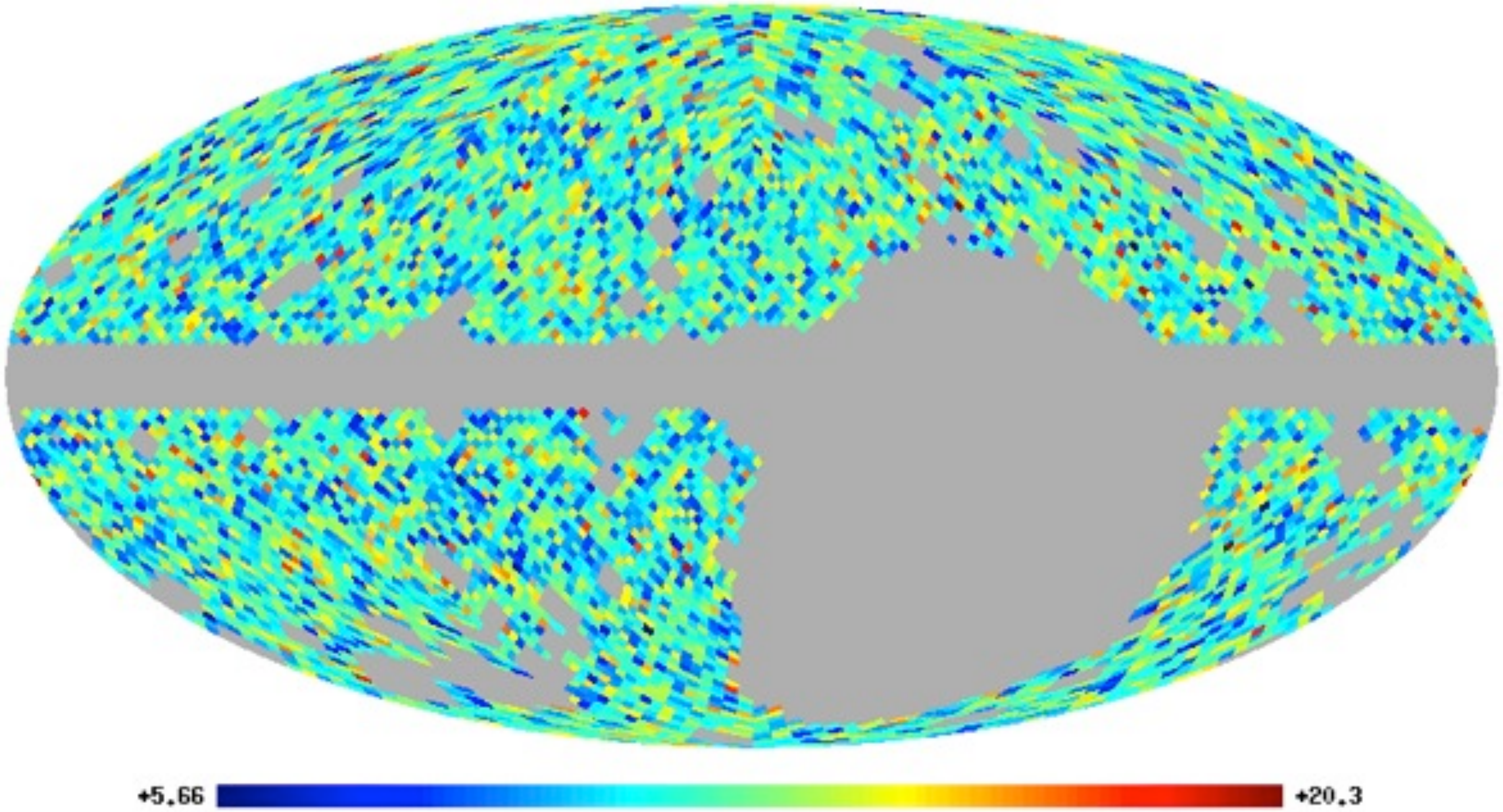
local structure dipole?

Rubart, Bacon & Schwarz 2014
Nusser & Tiwari 2016

Primordial Non-Gaussianity



Raccanelli et al. 2013



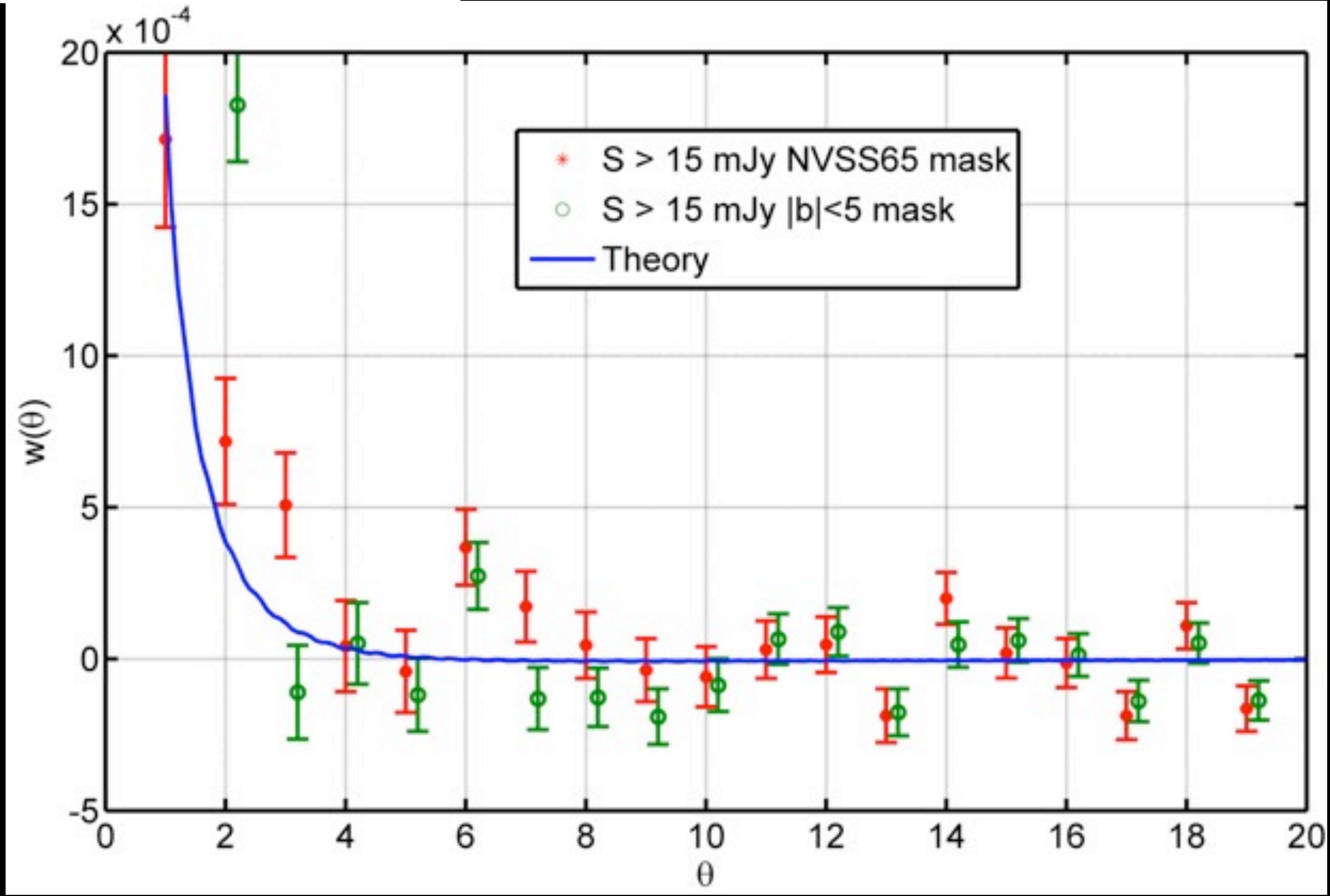
NVSS map of surface density

S > 15 mJy
f = 1.4 GHz

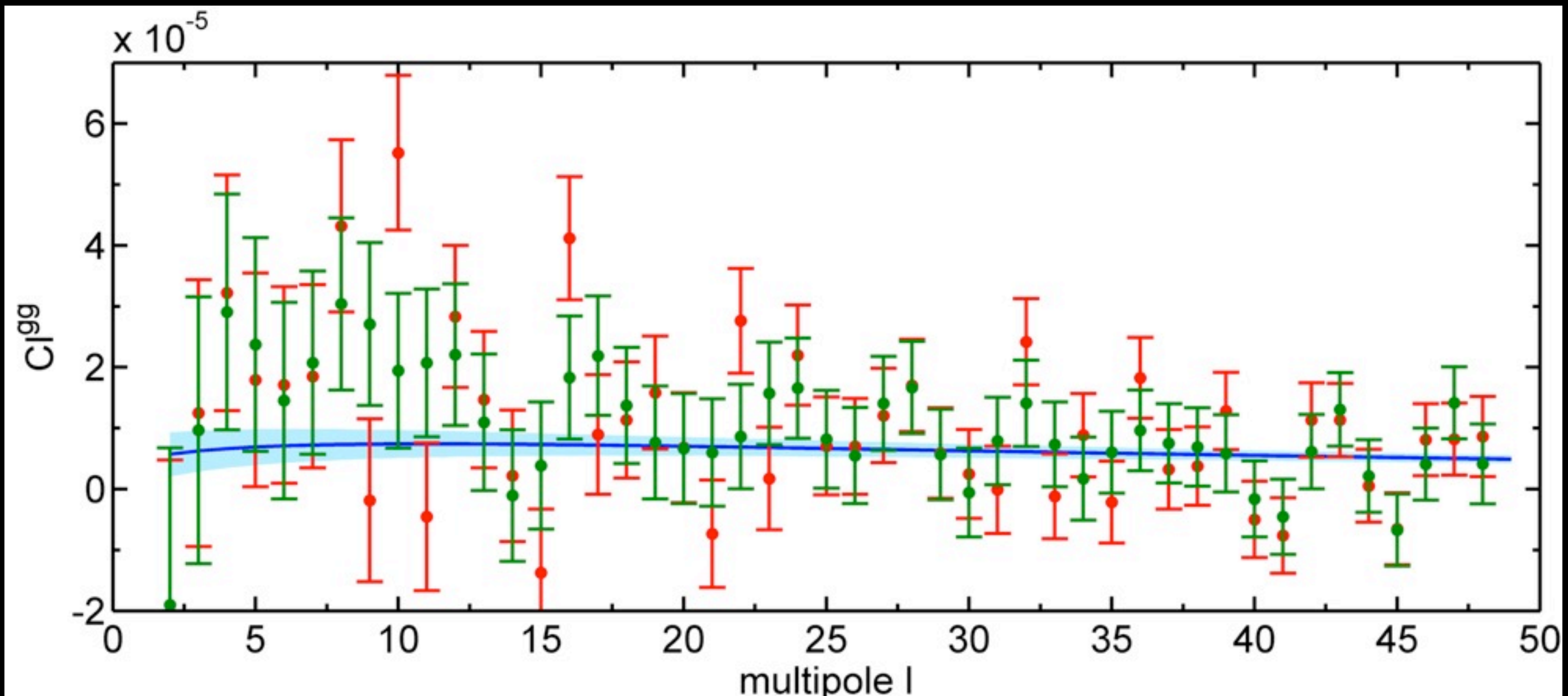
Chen & Schwarz 2015

2pt correlation: consistent with Planck best-fit model and CENSOR redshift distribution

claims on Non-Gaussianity (Xia et al.) can be explained by systematic effects of NVSS data



NVSS angular power spectrum

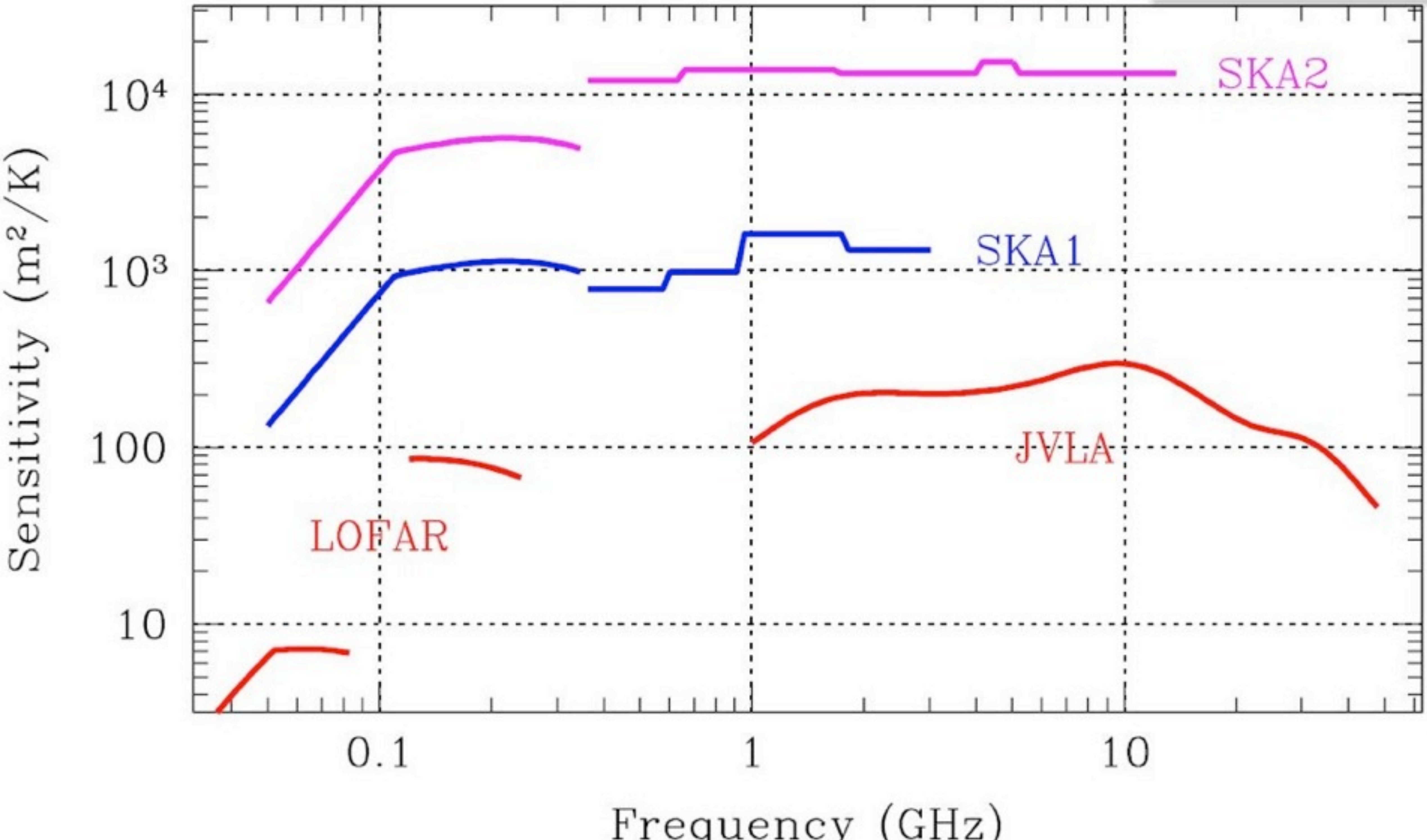


Planck best-fit cosmology

→ consistent but noisy

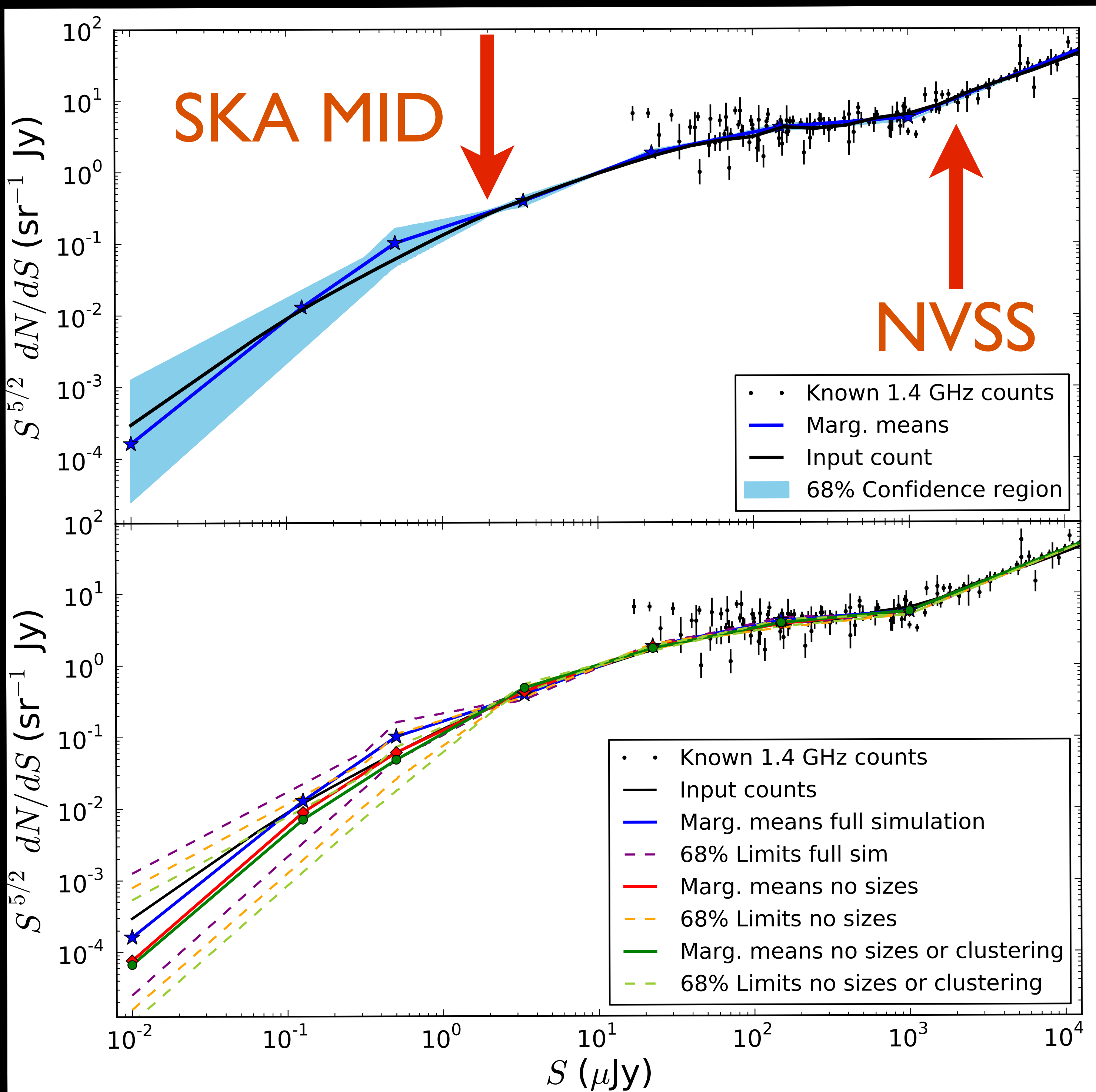
Chen & Schwarz 2015

Sensitivity comparison



Braun

Cosmic Radio Sources



JVLA, Vernstrom et al. 2013

two populations:

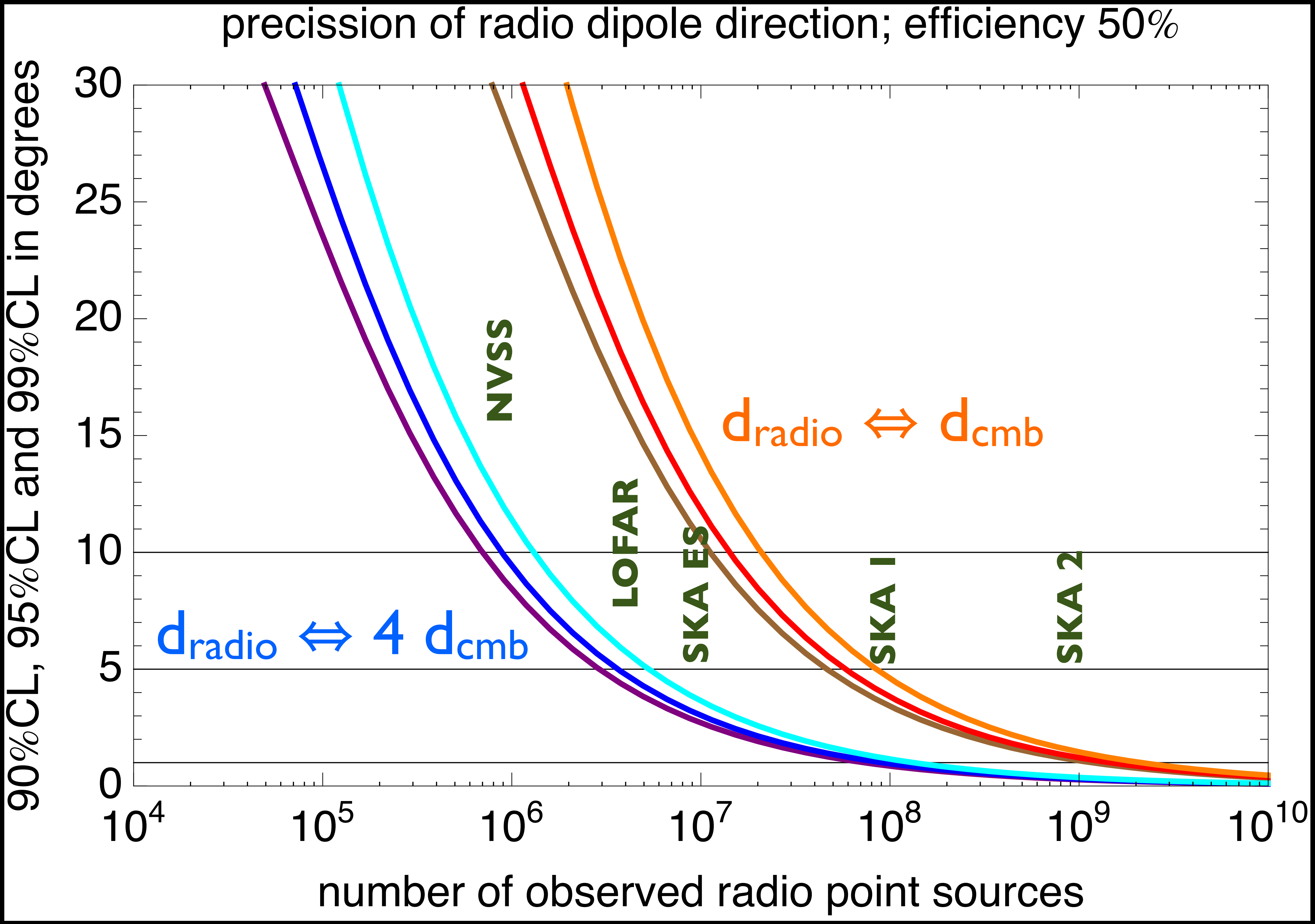
* AGNs (FRI-II, RQQ)
* galaxies (SFG, SBG)

AGNs dominate at large fluxes

star forming galaxies dominate below ~ 1 mJy

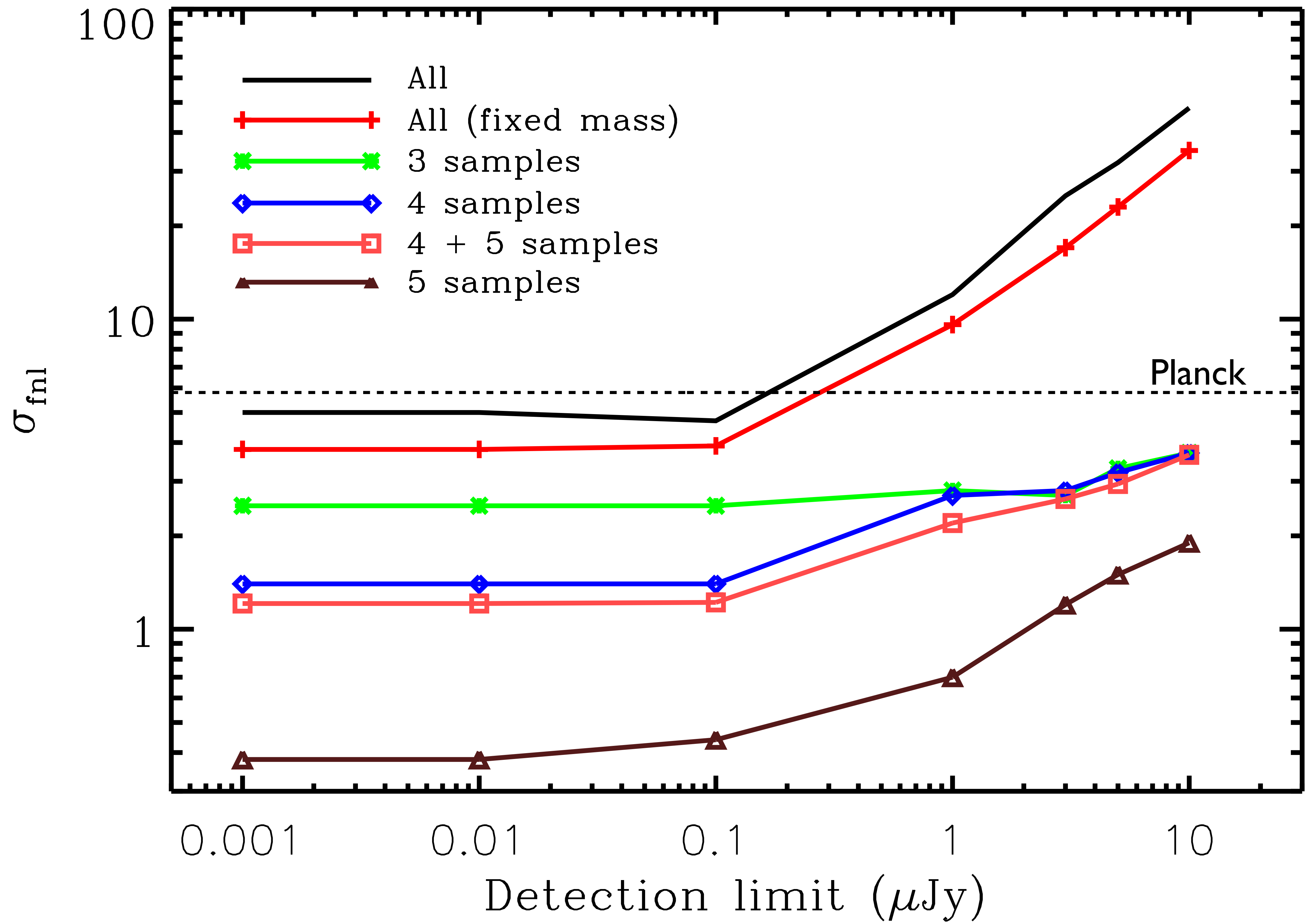
identification of morphology for angular resolution 0.5”

Cosmic radio dipole



Schwarz et al., 2015, SKA Science Book

Constraints on non-Gaussianity with SKA



Camera et al., 2015, SKA Science Book

Conclusion

LOFAR (MSSS, Tier1), ASKAP (EMU), MeerKAT and SKA will open new windows for cosmological tests

the radio sky still hides more unexplored cosmic structure modes than any other waveband