Dark light in the Universe

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KIAS Cosmology Workshop 2016

Our own dark matter

Physical Review Letters, vol. 110, Issue 21, 2013

Dark-Disk Universe
Fan, JiJi; Katz, Andrey; Randall, Lisa; Reece, Matthew

We point out that current constraints on dark matter imply only that the majority of dark matter is cold and collisionless. A subdominant fraction of dark matter could have much stronger interactions. In particular, it could interact in a manner that dissipates energy, thereby cooling into a rotationally supported disk, much as baryons do. We call this proposed new dark matter component double-disk dark matter (DDDM).

Why not a clef?

DM

Lisa Randall and
dinosaurs

864 pp.

Öpik-Oort comet home

Heavy dark disk, 30-million-year periods

Other problems, but they keep fighting

Comet bombardment

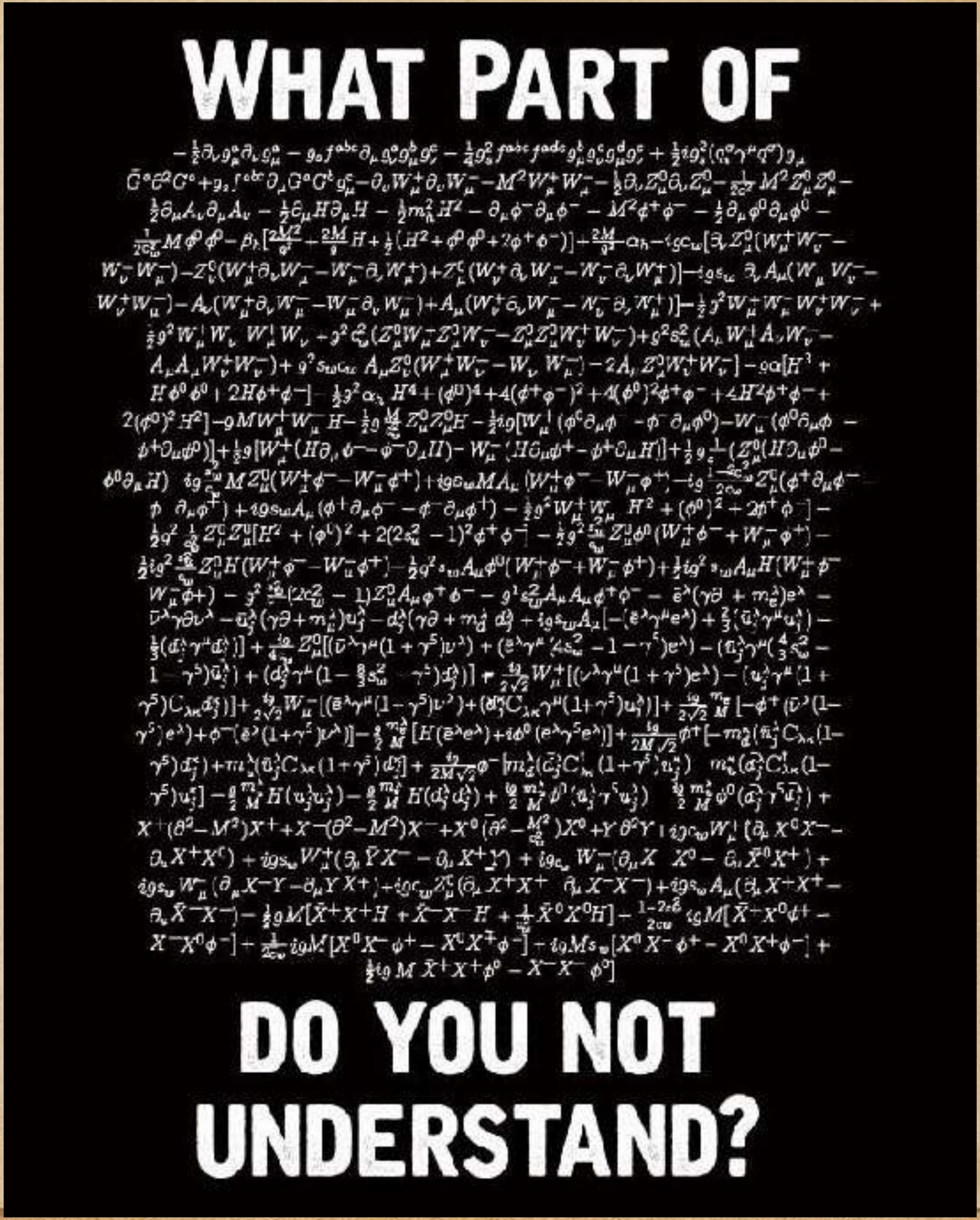
Dinos gone

Recommend the book

(Dinosaur lore, period search, phycisists vs astronomers, etc.)

Theory for 1/5 of matter:

The Standard Model



Dark Sector? After 20 years?!

Discworld,
Terry Pratchett,
>40 cosmology
books

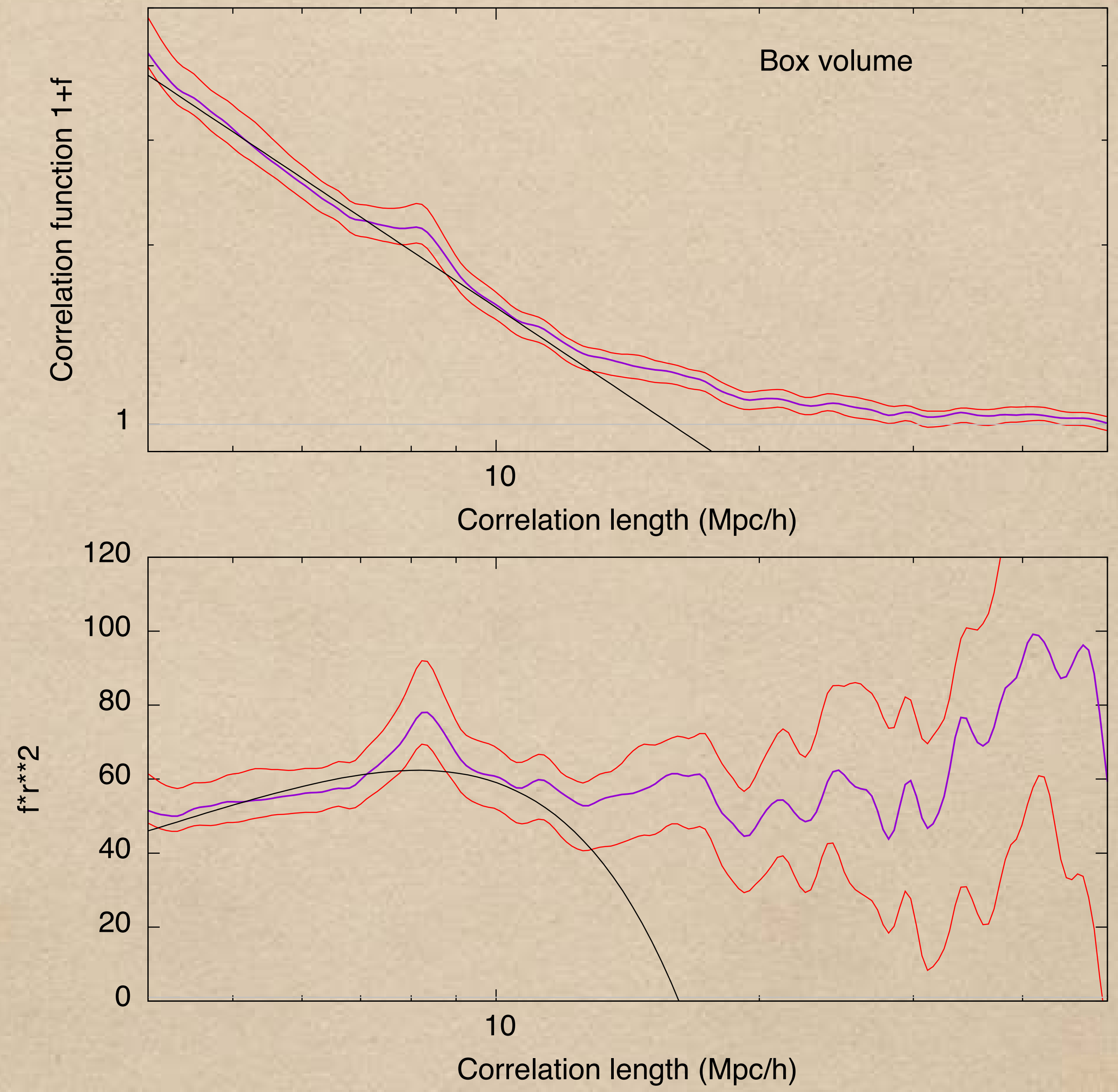
Terry Pratchett:
Light thinks it travels faster than anything but it is wrong. No matter how fast light travels, it finds the darkness has always got there first, and is waiting for it.

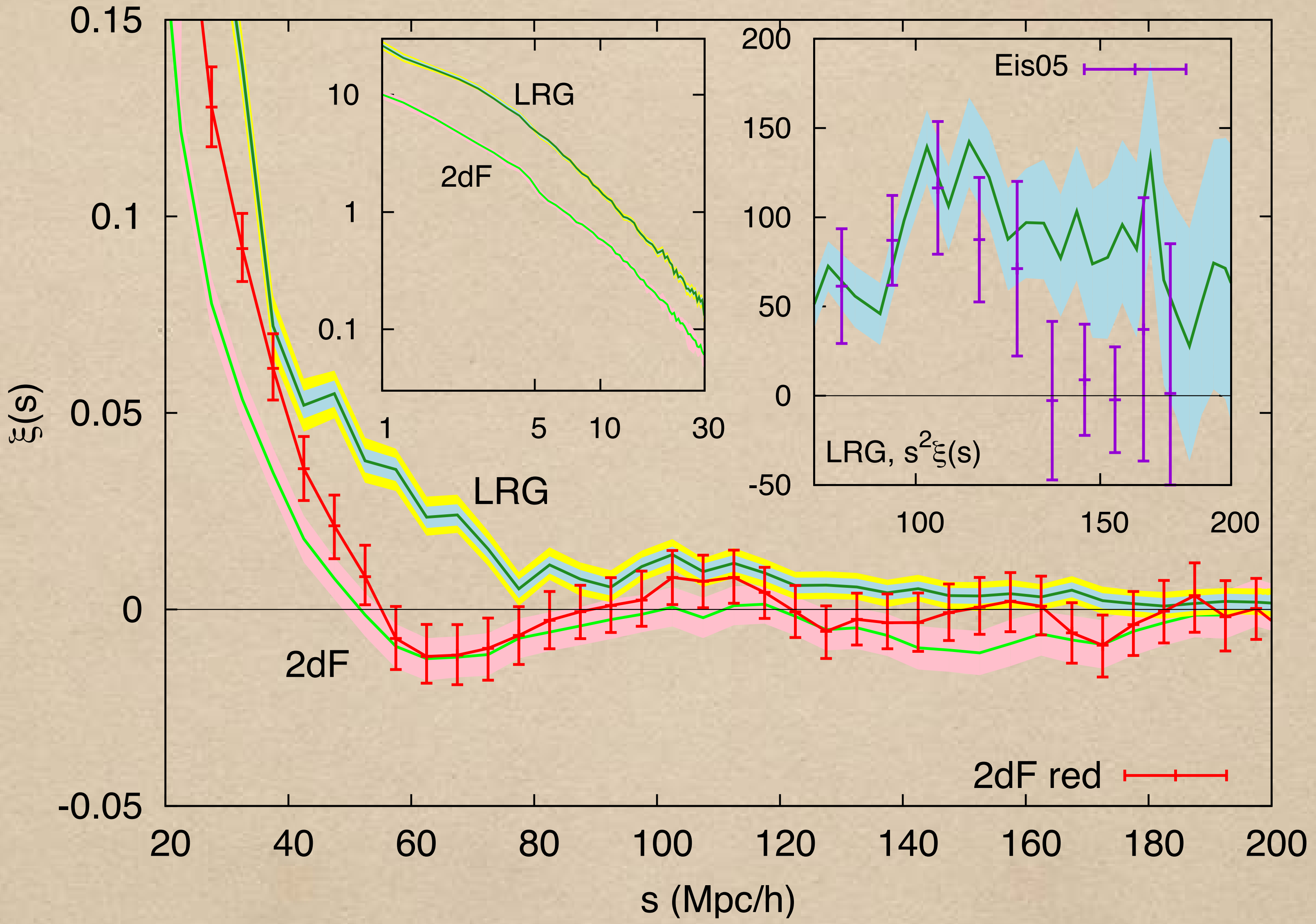
Dark light?

Story started at AIP 2014

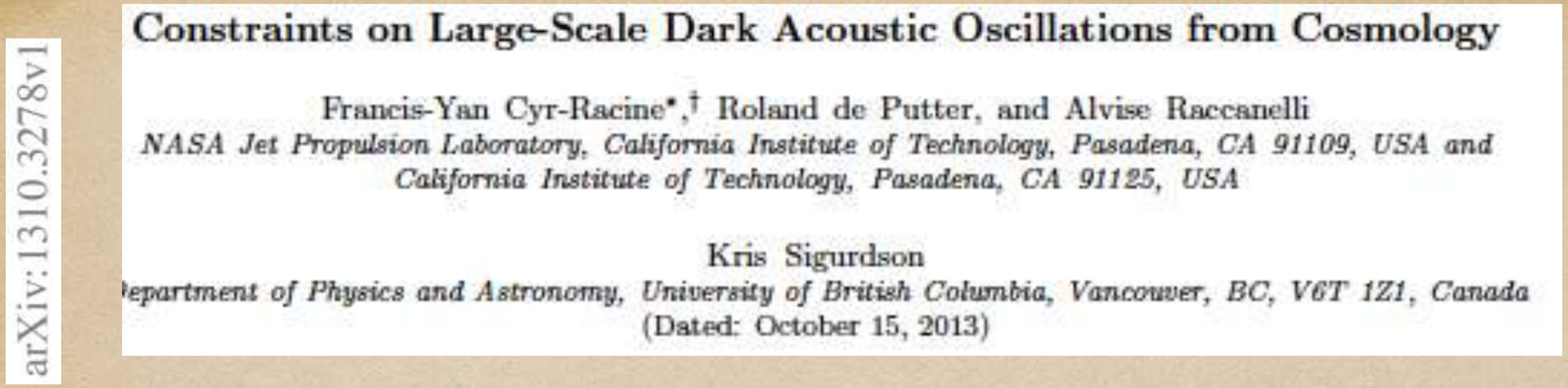
Elmo Tempel

& DAO





BAO signature



arXiv:1310.3278v1

Constraints on Large-Scale Dark Acoustic Oscillations from Cosmology

Francis-Yan Cyr-Racine*,† Roland de Putter, and Alvise Raccanelli
NASA Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA and
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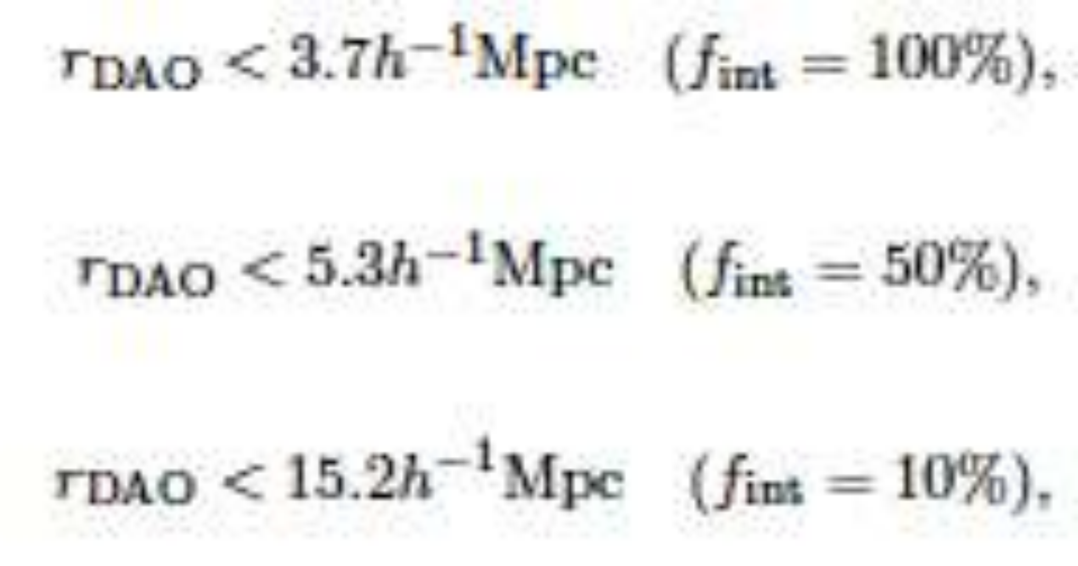
epartment of Physics and Astronomy, University of British Columbia, Vancouver, BC, V6T 1Z1, Canada
(Dated: October 15, 2013)

If all or a fraction of the dark matter (DM) were coupled to a bath of dark radiation (DR) in the early Universe, we expect the combined DM-DR system to give rise to acoustic oscillations of the dark matter until it decouples from the DR. We model the interacting component as dark atoms coupled to a bath of dark photons. Interestingly, we find that at most ˜5% of all DM can be very strongly interacting with DR.



$$r_{\rm DAO} < 3.7h^{-1}{\rm Mpc} \quad (f_{\rm int} = 100\%),$$

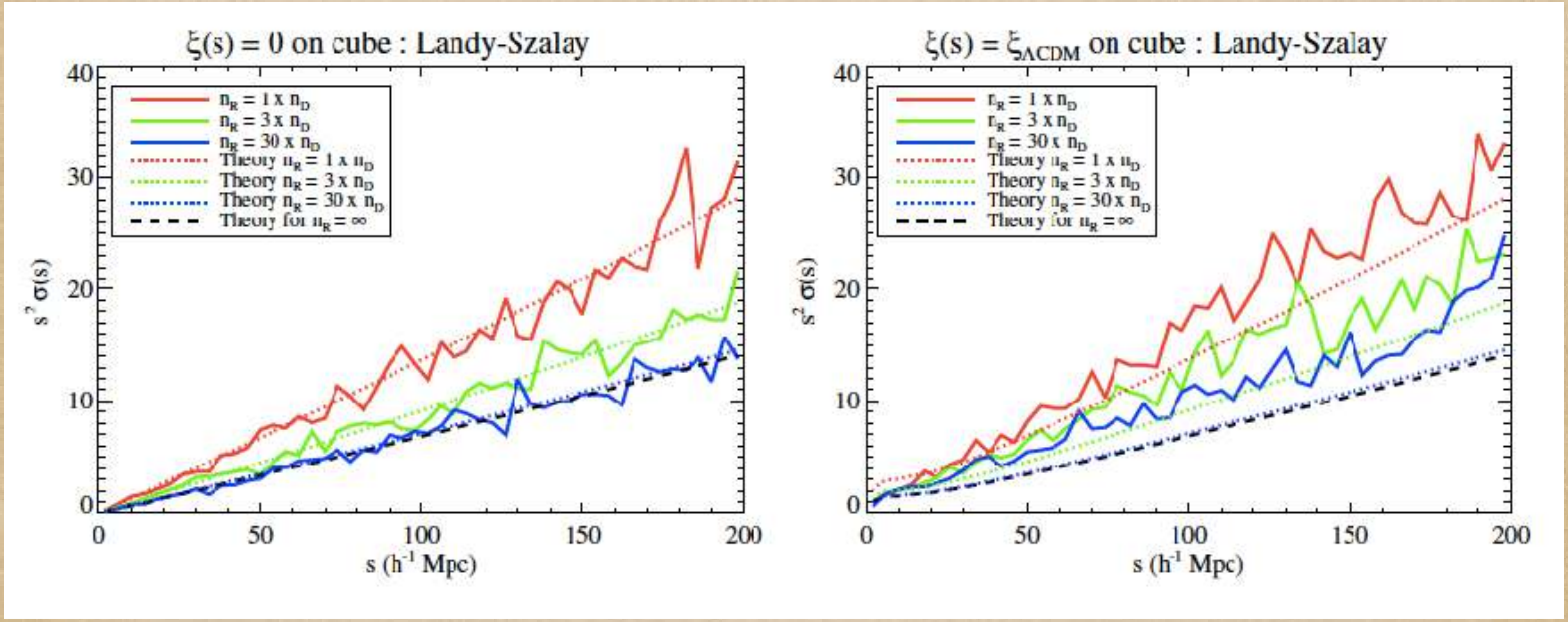
$$r_{\rm DAO} < 5.3h^{-1}{\rm Mpc} \quad (f_{\rm int} = 50\%),$$

$$r_{\rm DAO} < 15.2h^{-1}{\rm Mpc} \quad (f_{\rm int} = 10\%),$$

Border correction?

arXiv:1211.6211, Astronomy & Astrophysics, Volume 554, 06/2013

M. Vargas-Magaña, Julian. E. Bautista, J.-Ch. Hamilton, N.G. Busca, É. Aubourg, A. Labatie, J.-M. Le Goff, Stephanie Escoffier, Marc Manera, Cameron K. McBride, Donald P. Schneider, Christopher N. A. Willmer



$$\xi(r) = \frac{DD}{RR} - \frac{2DR}{RR} + 1 = \frac{(D-R)(D-R)}{RR}$$

Unstable signal

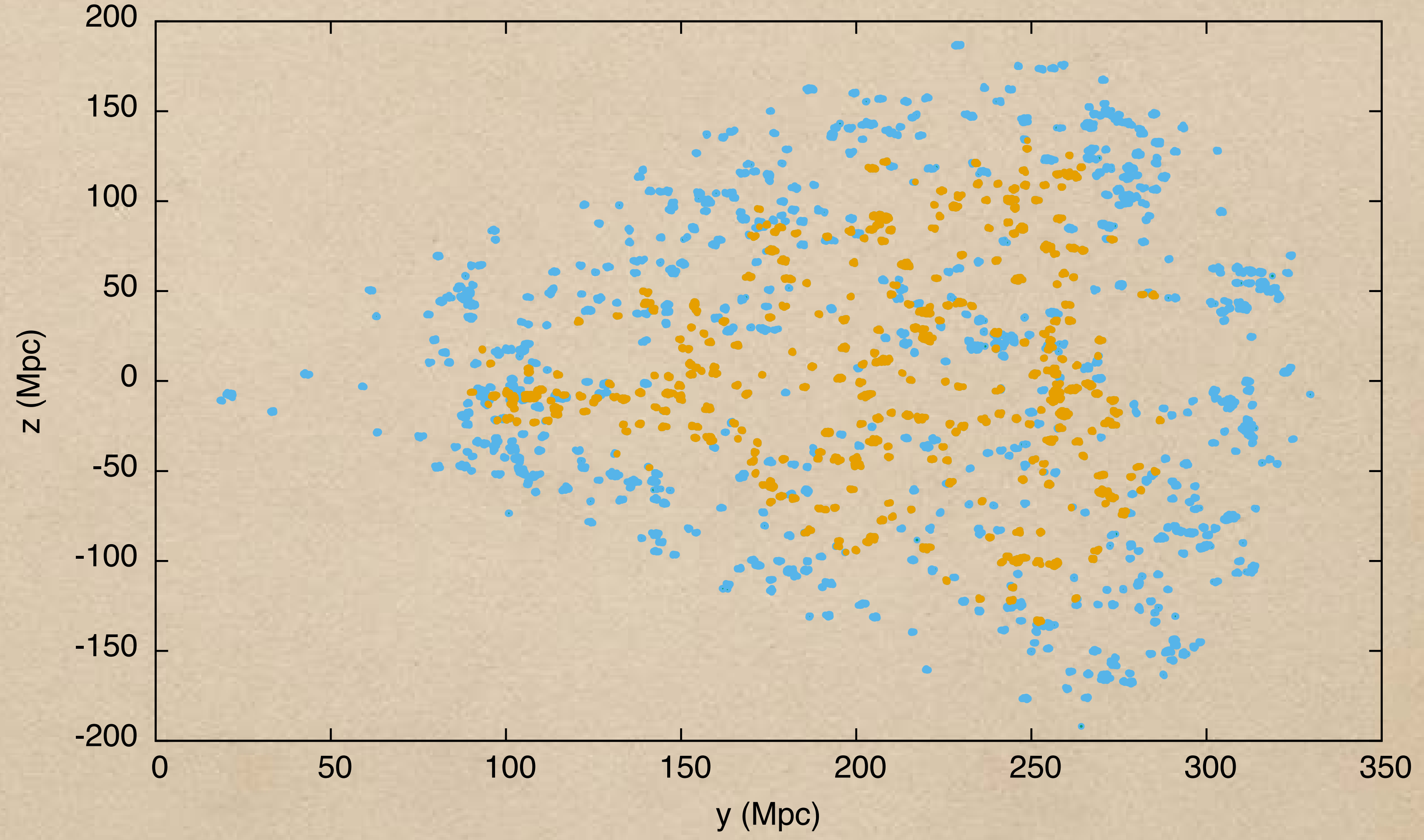
Enn: A year later, again:

Minus-estimator

$$\hat{\xi}_{minus}(r) = \frac{V}{V_{sh}(r)} \frac{1}{N N_{int}} \sum_{i=1}^{N_{int}} n_i(r)$$

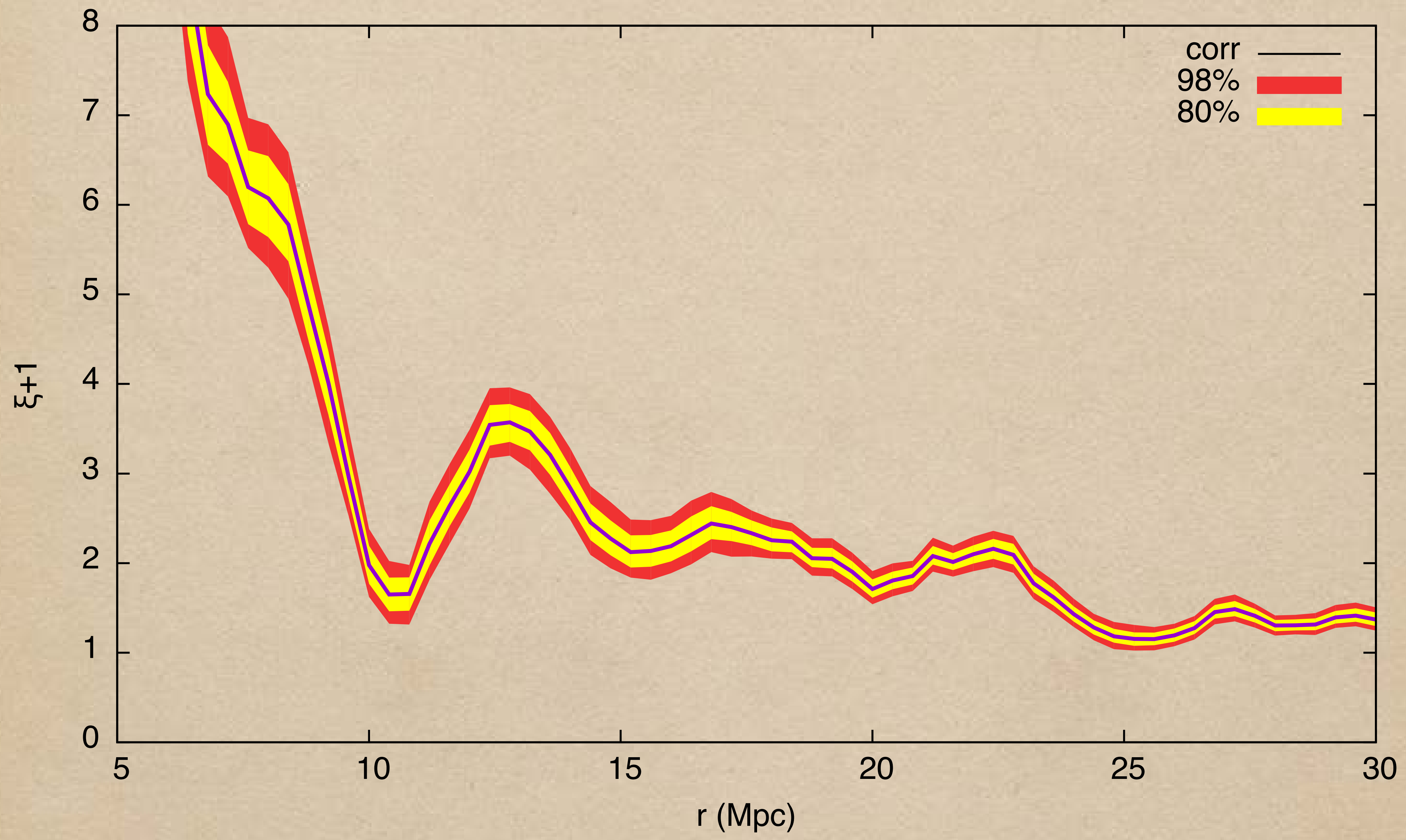
Volume-limited (constant-density) samples

Real space



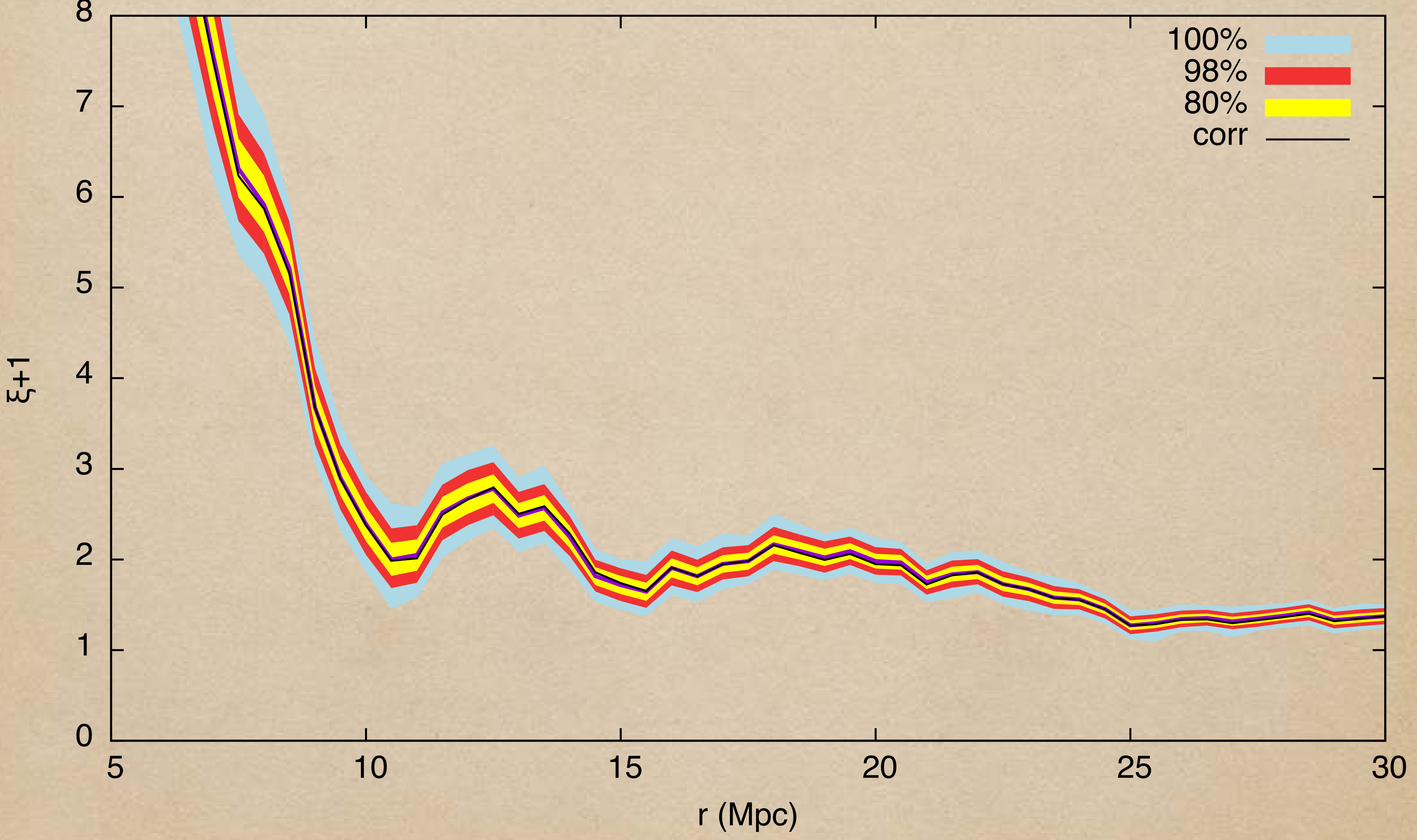
40 Mpc to the border

SDSS DR12, trimmed groups — real space



$$H_0 = 67.8\,\mathrm{km/sec}\cdot\mathrm{Mpc}$$

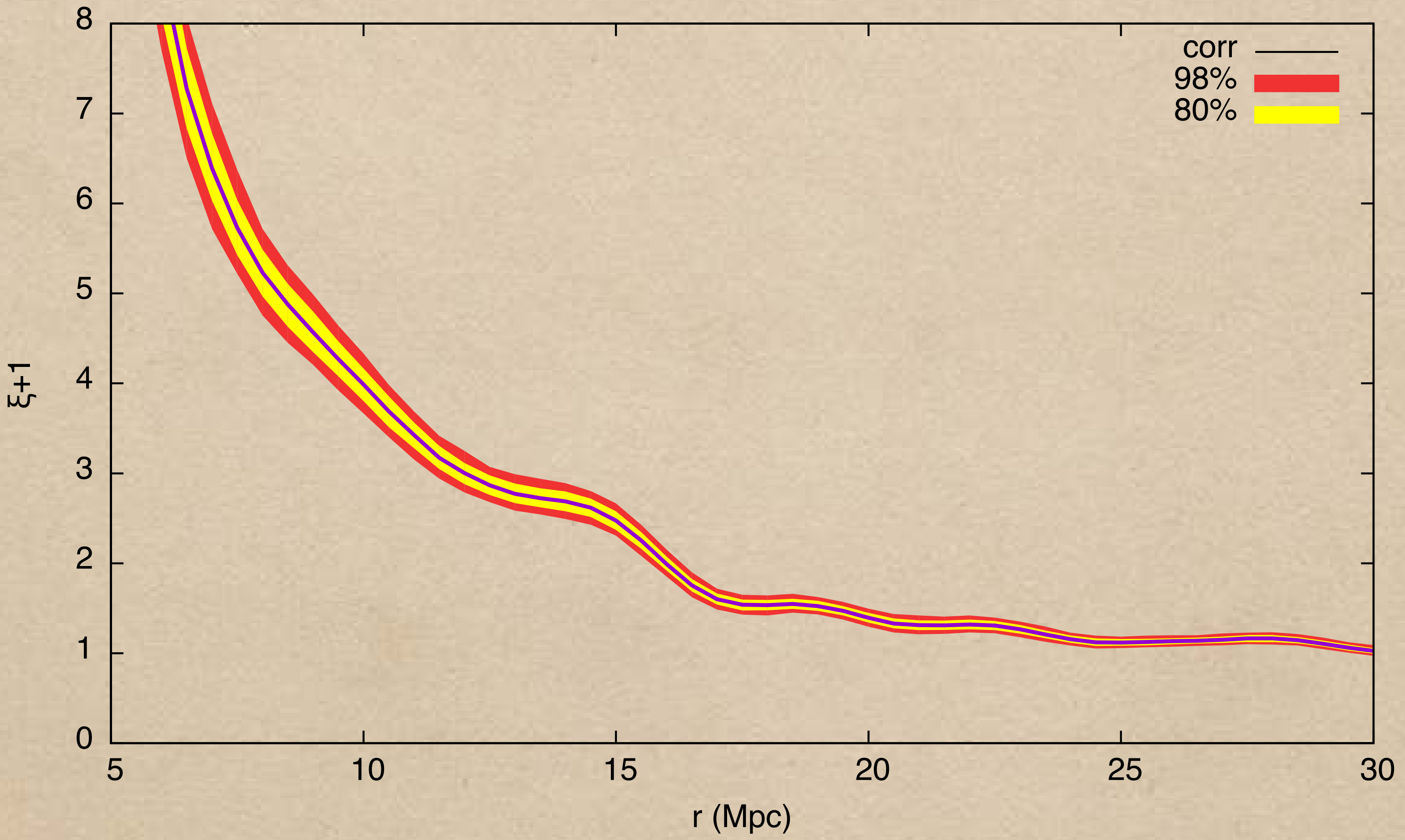
groups n>=10



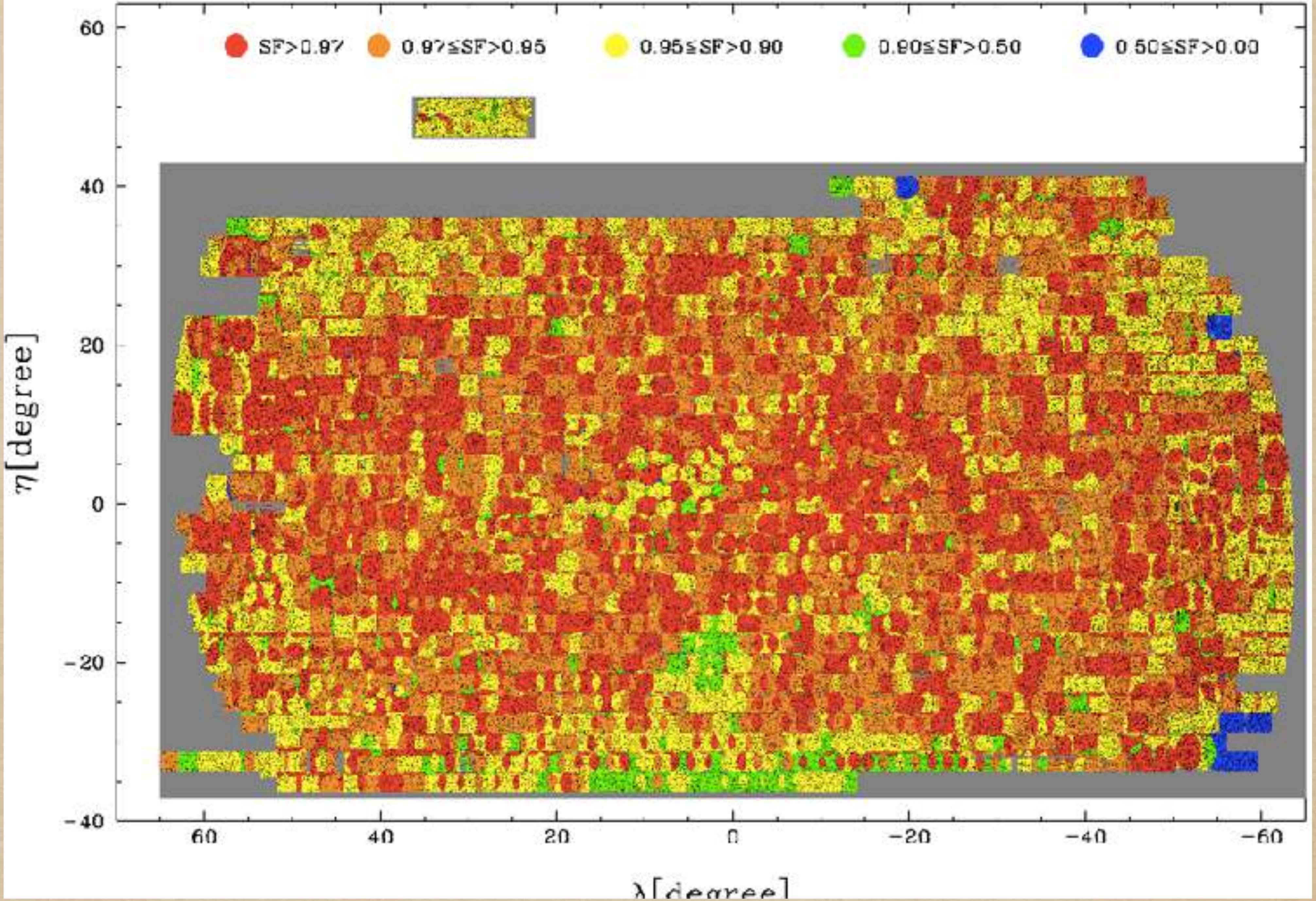
Mocks

International Virtual Observatory Alliance

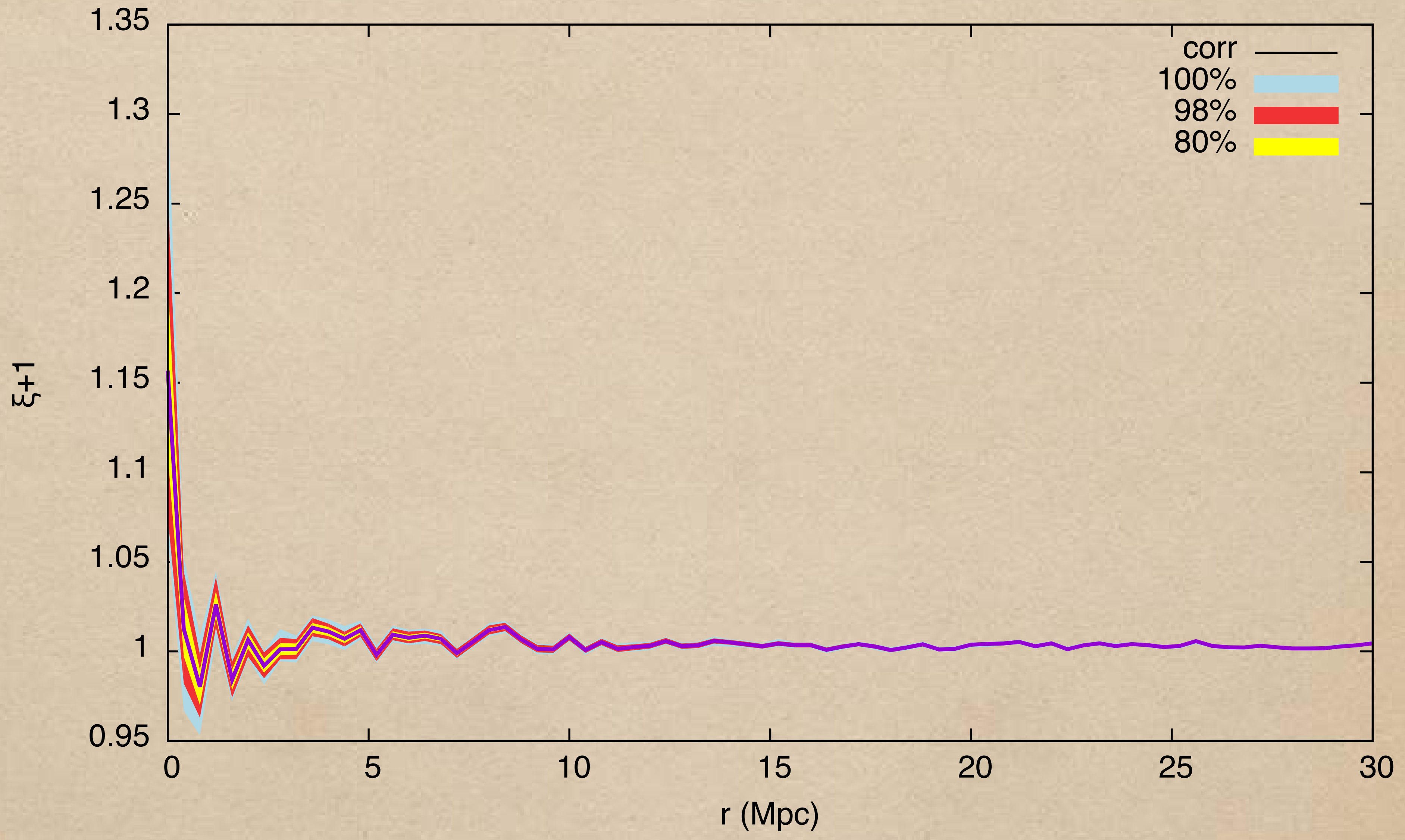
www.ivoa.net



Gert: completeness problems?

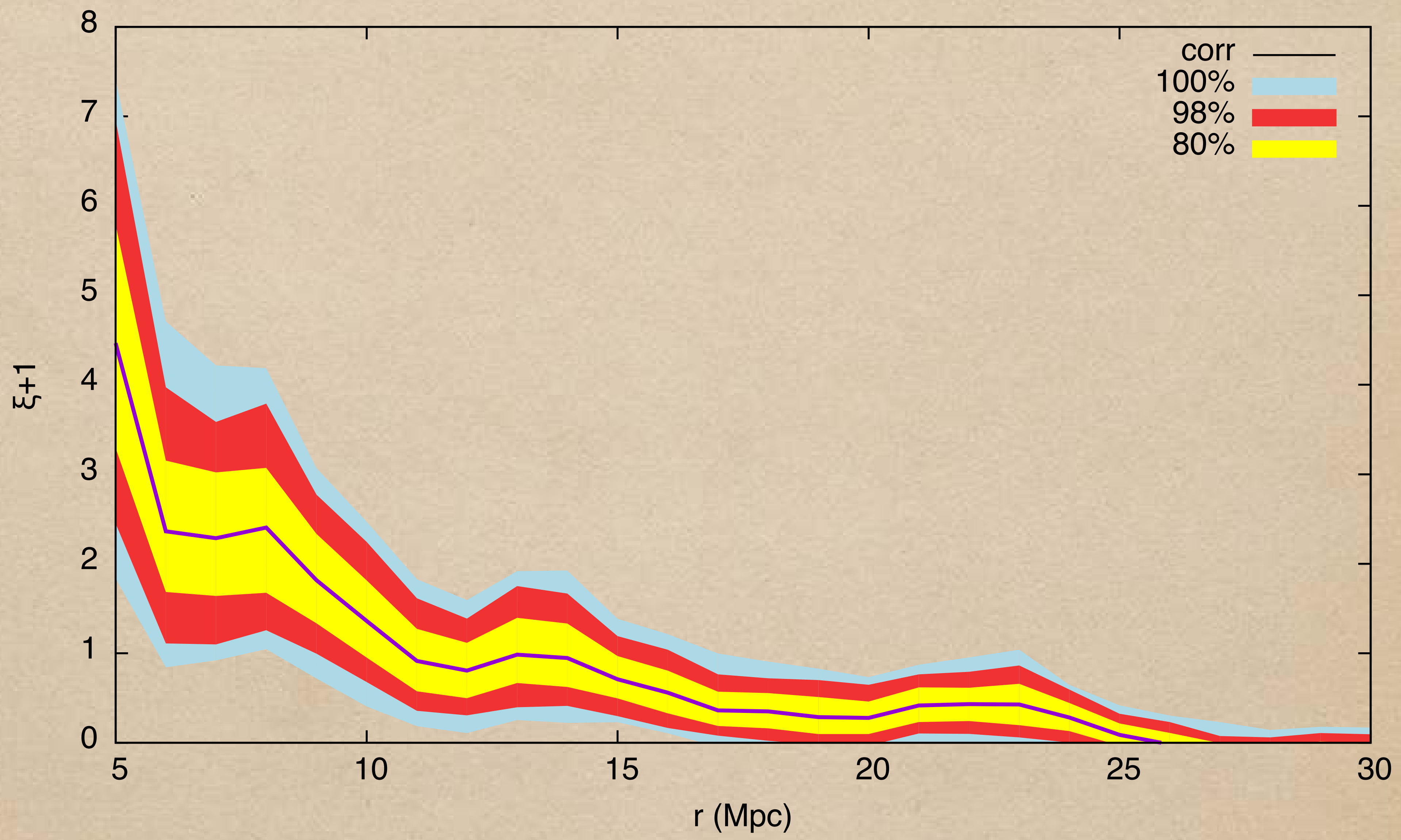


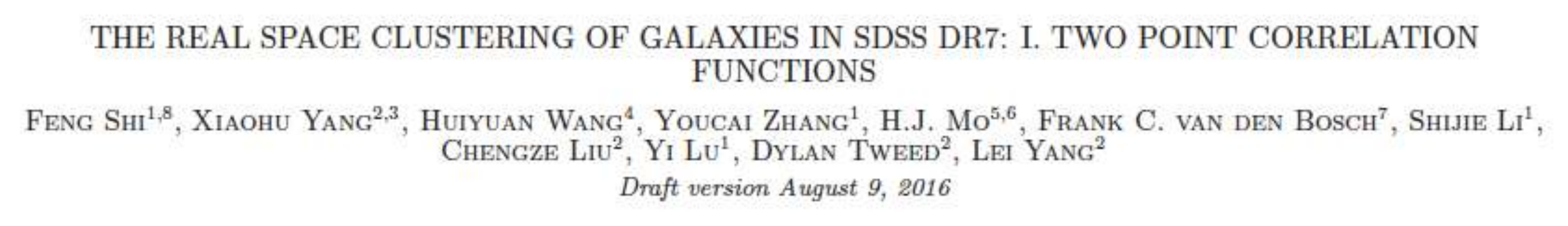
DR12 completeness map



Completeness map correlation

DR10, n>=10 vollim sample





THE REAL SPACE CLUSTERING OF GALAXIES IN SDSS DR7: I. TWO POINT CORRELATION FUNCTIONS

FENG SHI[1,8], XIAOHU YANG[2,3], HUIYUAN WANG[4], YOUCAI ZHANG[1], H.J. MO[5,6], FRANK C. VAN DEN BOSCH[7], SHIJIE LI[1],
CHENGZE LIU[2], YI LU[1], DYLAN TWEED[2], LEI YANG[2]

Draft version August 9, 2016

BUT?

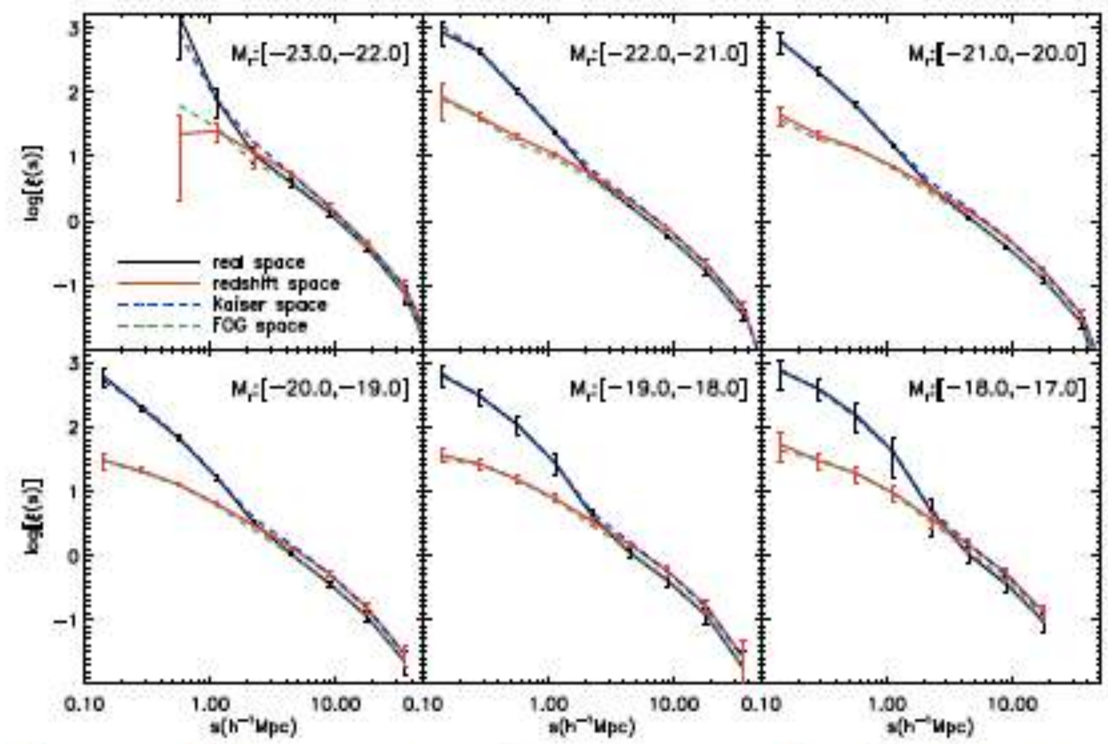
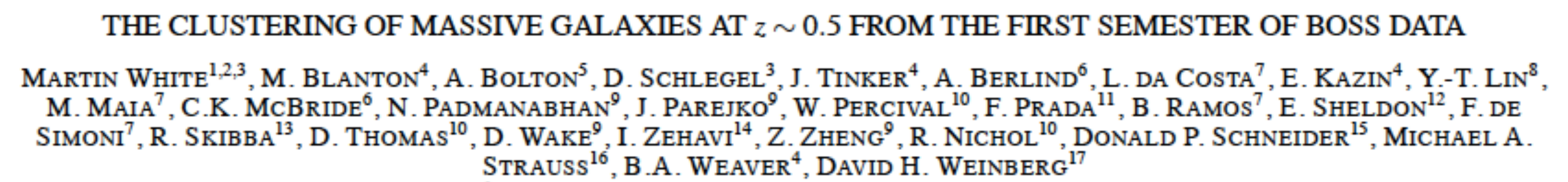


FIG. 3.— The two-point correlation functions of mock galaxies in different true spaces. Results are shown for six different intervals in absolute r-band magnitude, as indicated. For clarity, we only plot error bars (expressing the variance among our 10 mock samples) for the real and redshift space results.



THE CLUSTERING OF MASSIVE GALAXIES AT $z \sim 0.5$ FROM THE FIRST SEMESTER OF BOSS DATA

MARTIN WHITE[1,2,3], M. BLANTON[4], A. BOLTON[5], D. SCHLEGEL[3], J. TINKER[4], A. BERLIND[6], L. DA COSTA[7], E. KAZIN[4], Y.-T. LIN[8], M. MAIA[7], C.K. MCBRIDE[6], N. PADMANABHAN[9], J. PAREJKO[9], W. PERCIVAL[10], F. PRADA[11], B. RAMOS[7], E. SHELDON[12], F. DE SIMONI[7], R. SKIBBA[13], D. THOMAS[10], D. WAKE[9], I. ZEHAVI[14], Z. ZHENG[9], R. NICHOL[10], DONALD P. SCHNEIDER[15], MICHAEL A. STRAUSS[16], B.A. WEAVER[4], DAVID H. WEINBERG[17]

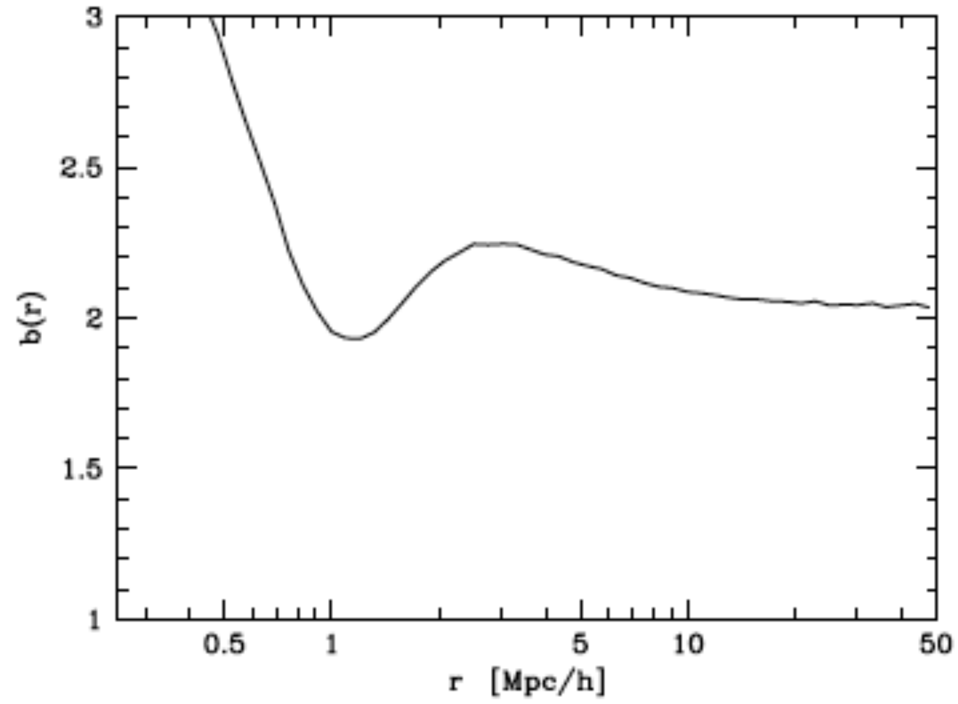
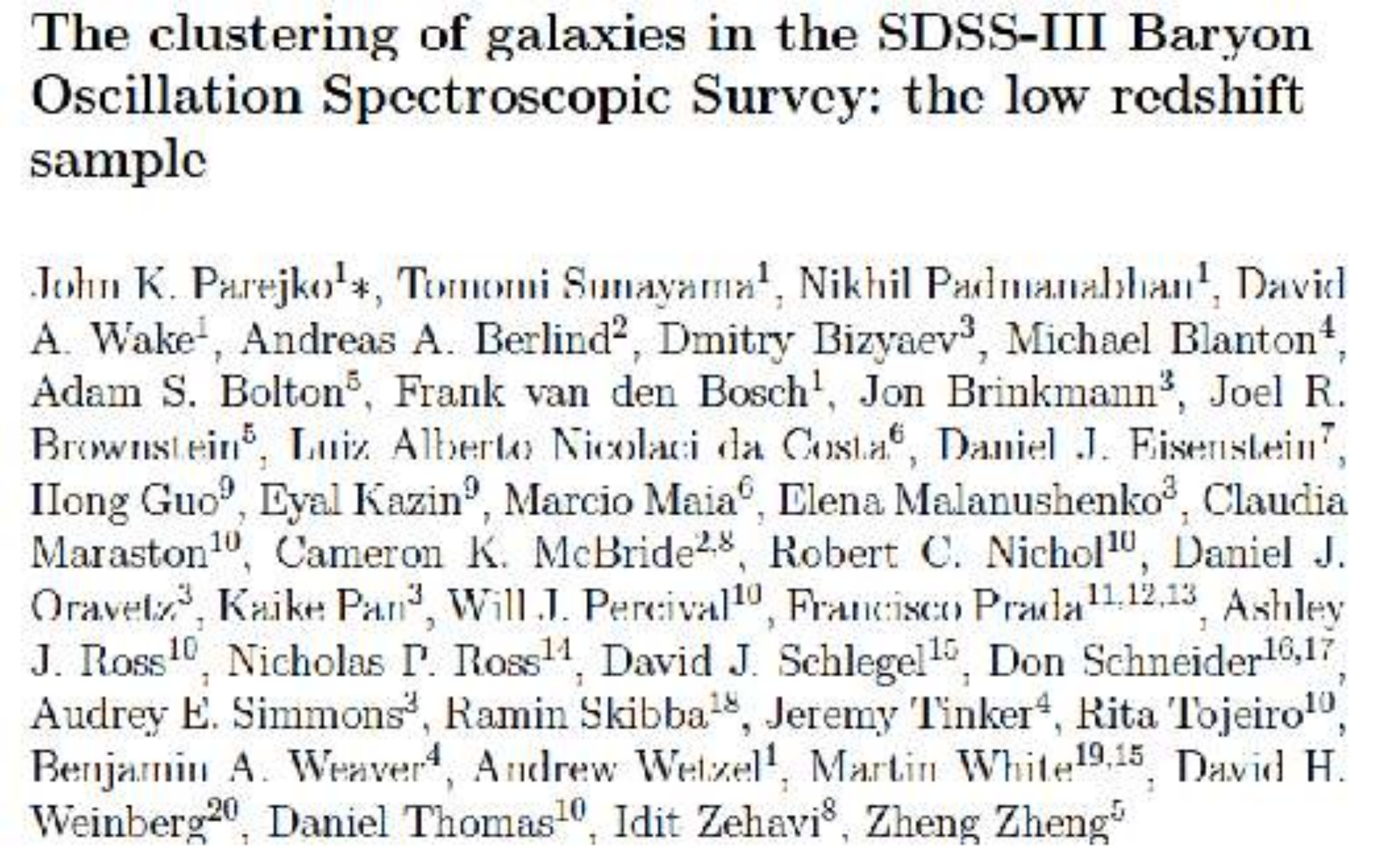


FIG. 12.— The scale-dependence of the bias, $b(r) \equiv [\xi_{\rm gal}(r)/\xi_{\rm dm}(r)]^{1/2}$, predicted from our best-fit halo model and N-body simulations. The feature at a few Mpc has been seen in other analyses and occurs at the transition between the 1- and 2-halo contributions (see text). Note that the bias asymptotes to a constant, $b \simeq 2$, on large scales.

Something similar ?



The clustering of galaxies in the SDSS-III Baryon Oscillation Spectroscopic Survey: the low redshift sample

John K. Parejko[1]*, Tomomi Sunayama[1], Nikhil Padmanabhan[1], David A. Wake[1], Andreas A. Berlind[2], Dmitry Bizyaev[3], Michael Blanton[4], Adam S. Bolton[5], Frank van den Bosch[1], Jon Brinkmann[3], Joel R. Brownstein[5], Luiz Alberto Nicolaci da Costa[6], Daniel J. Eisenstein[7], Hong Guo[9], Eyal Kazin[9], Marcio Maia[6], Elena Malanushenko[3], Claudia Maraston[10], Cameron K. McBride[2,8], Robert C. Nichol[10], Daniel J. Oravetz[3], Kaike Pan[3], Will J. Percival[10], Francisco Prada[11,12,13], Ashley J. Ross[10], Nicholas P. Ross[14], David J. Schlegel[15], Don Schneider[16,17], Audrey E. Simmons[3], Ramin Skibba[18], Jeremy Tinker[4], Rita Tojeiro[10], Benjamin A. Weaver[4], Andrew Wetzel[1], Martin White[19,15], David H. Weinberg[20], Daniel Thomas[10], Idit Zehavi[8], Zheng Zheng[5]

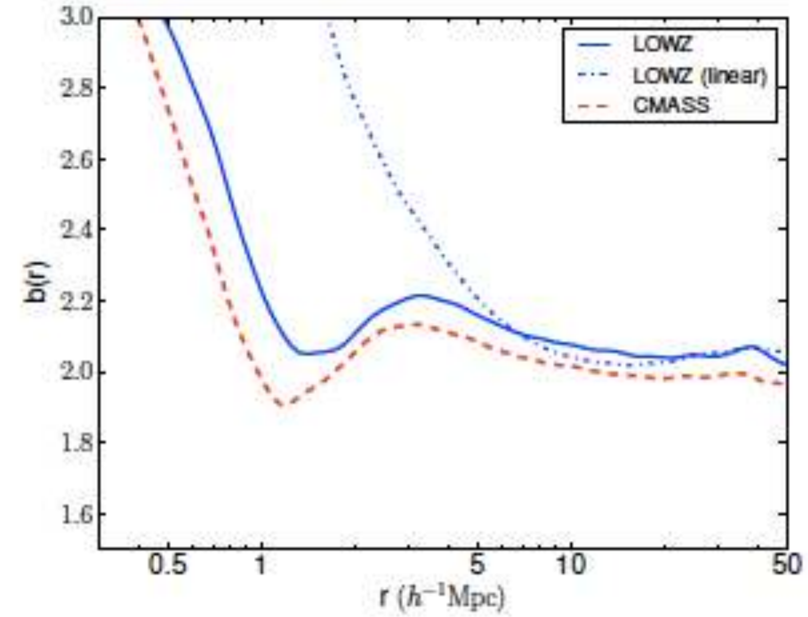
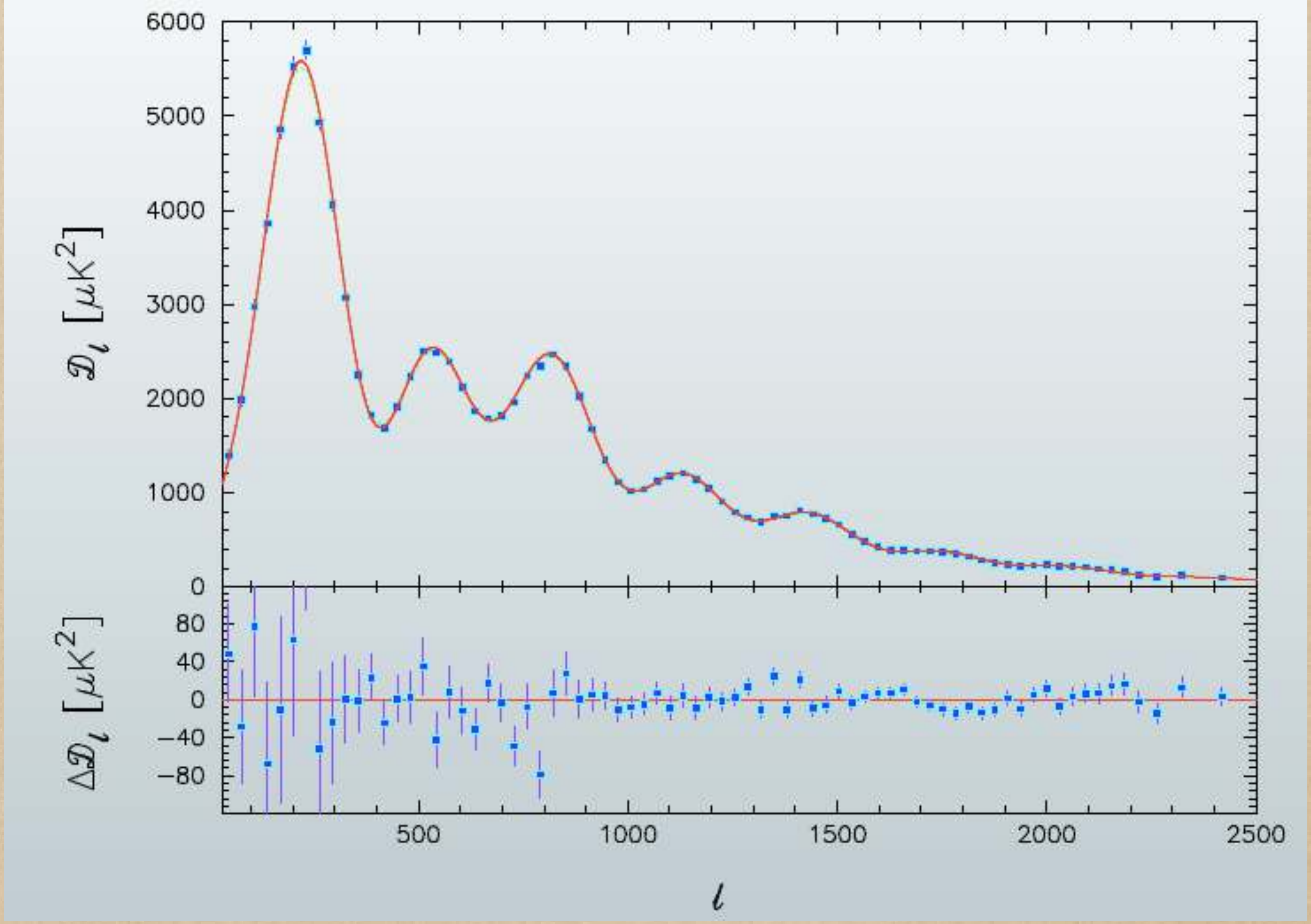


Figure 10. The scale dependence of the galaxy bias, $b = \sqrt{\xi_{gal}/\xi_{DM}}$, for the LOWZ sample. The large-scale bias asymptotes to ~ 2.0. The strong increase toward scales below $1h^{-1}$Mpc appears because of the strong clustering of galaxies within halos, while the bump at the few h^{-1}Mpc scale is due to one-halo/two-halo transition. The dashed red line shows the galaxy bias of the CMASS sample of White et al. (2011), while the dot-dashed blue line shows the LOWZ galaxy bias relative to the linear theory $\xi_{\rm DM}$ computed with CAMB.

CMB power



6000
5000
4000
3000
2000
1000
0
$\mathcal{D}_\ell$ [μK^2]
80
40
0
−40
−80
$\Delta\mathcal{D}_\ell$ [μK^2]
500
1000
1500
2000
2500
ℓ

Martti:

Sigma?

Dark sector (DS)

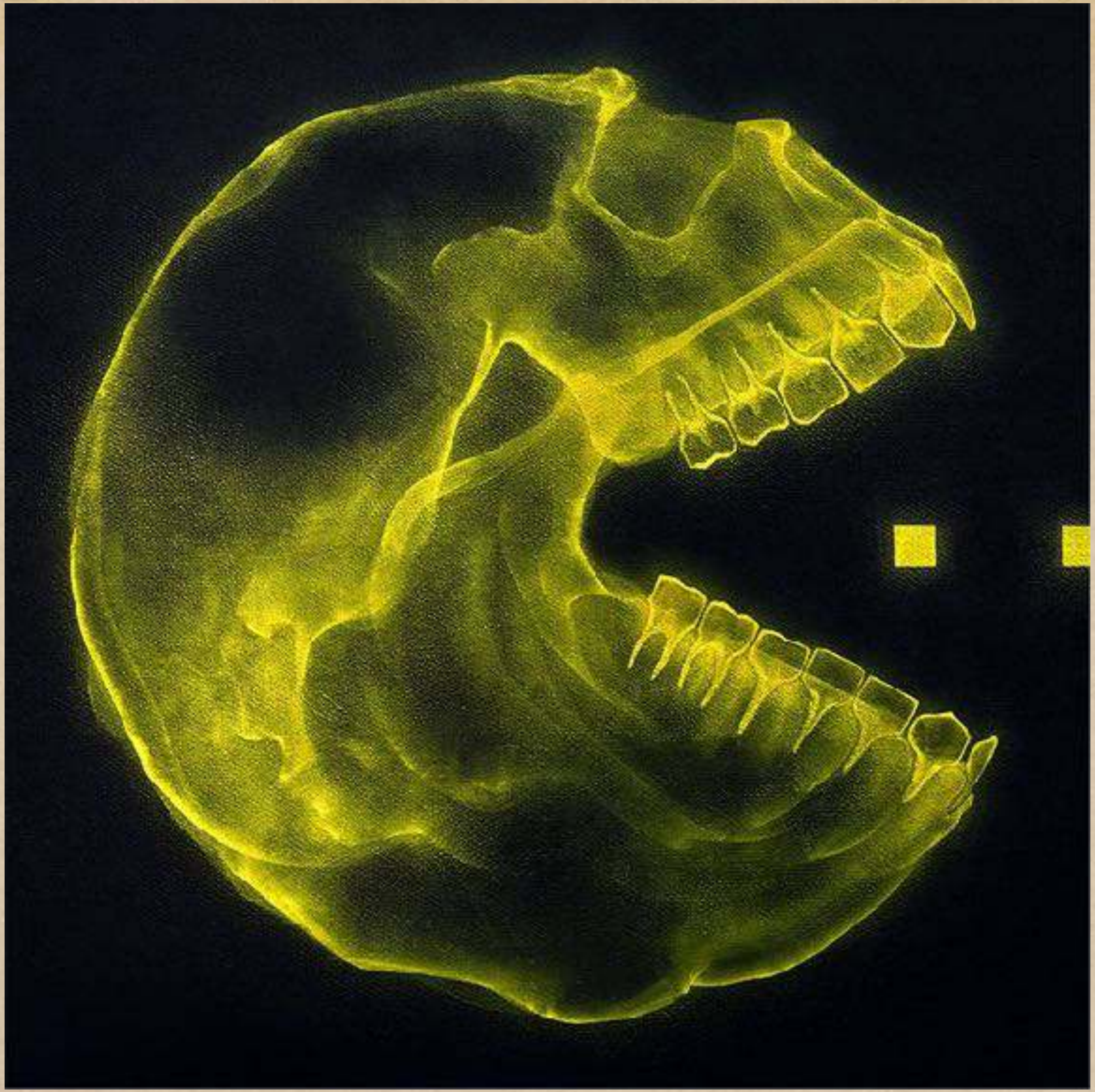
Not much of it charged (CDM success)

Does not mean that DS is simple

Consider strange cluster collisions

(dark plasma?)

Dark neutron stars?



Dark sector

If you stare into the abyss, the abyss stares back at you (F.W. Nietzsche)

The right block bootstrap

$$DD(r) = \frac{1}{N^2}\sum_i\sum_j 1(r <= |x_i - x_j| < r + dr) = \frac{1}{N}\sum_i D_i(r)$$

- Bootstrap DD(r) - resample pair distances
- DR(r) requires bootstrapping starting points
- Solution - resample points with all their distance distributions(a marked point process)

Recipe:

1. Find $DD_i(r), DR_i(r), \quad \forall x_i$
2. $\forall x_i$, find its block: $|x_i - x_j| >= r_0 \quad (\xi(r_0) = 1)$

   n_i is #-of-points in the block
3. Average: $BDD_i(r) = \langle DD_j(r) \rangle, \quad j \in$ block
4. Bootstrap $BDD_i(r), BDR_i(r),$ so as

   $\sum n_{i,\mathrm{used}} <= N$

The Astrophysical Journal, 681:726Y734, 2008 July 1

A VALID AND FAST SPATIAL BOOTSTRAP FOR CORRELATION FUNCTIONS

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RELIABILITY OF THE DETECTION OF THE BARYON ACOUSTIC PEAK

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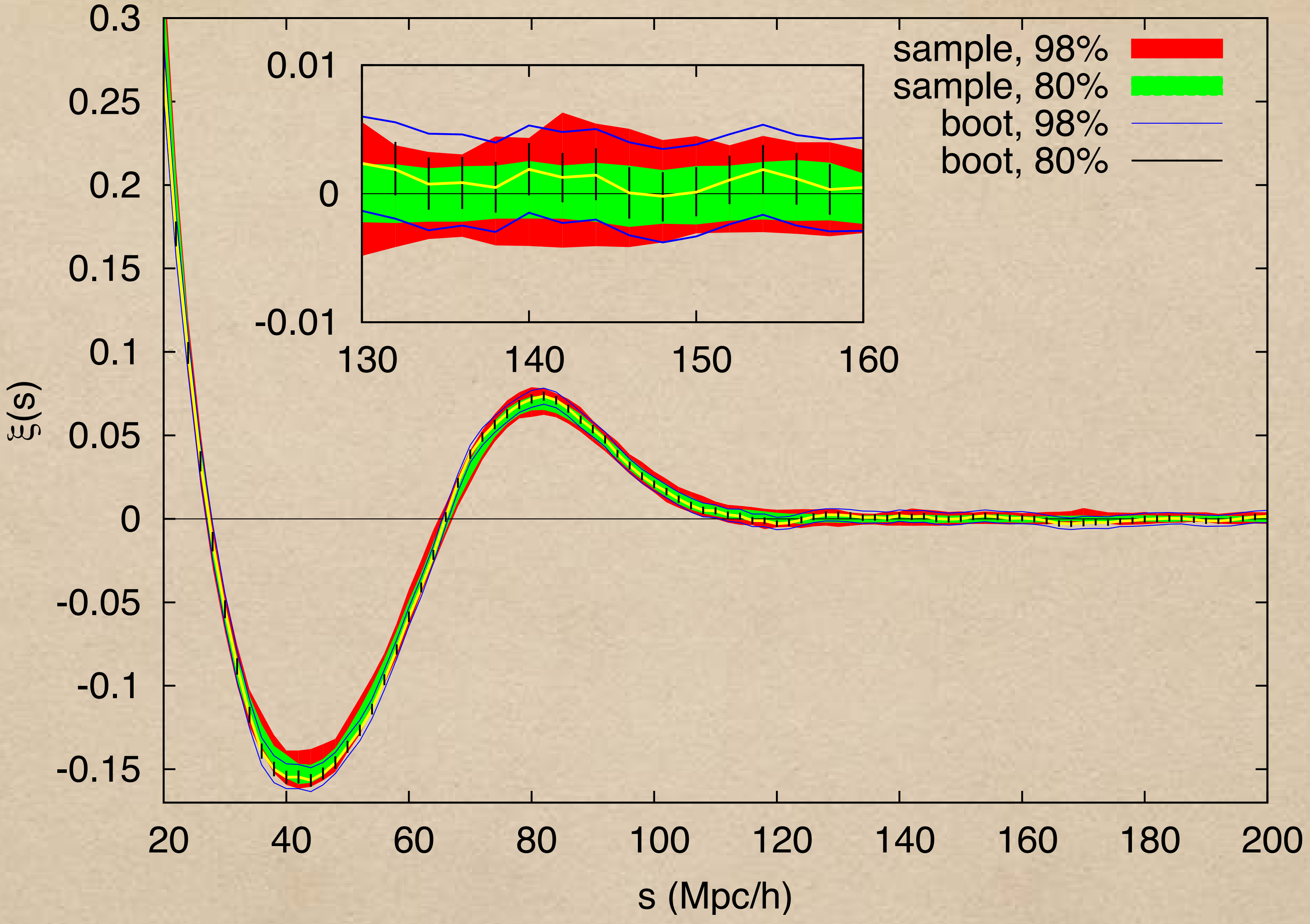

Poisson-Voronoi process, block bootstrap