Flows

on

100 h^{-1} Mpc Scales

and

σ_8

Hume A. Feldman

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University of Kansas

UCL & Imperial College

The Expanding Universe

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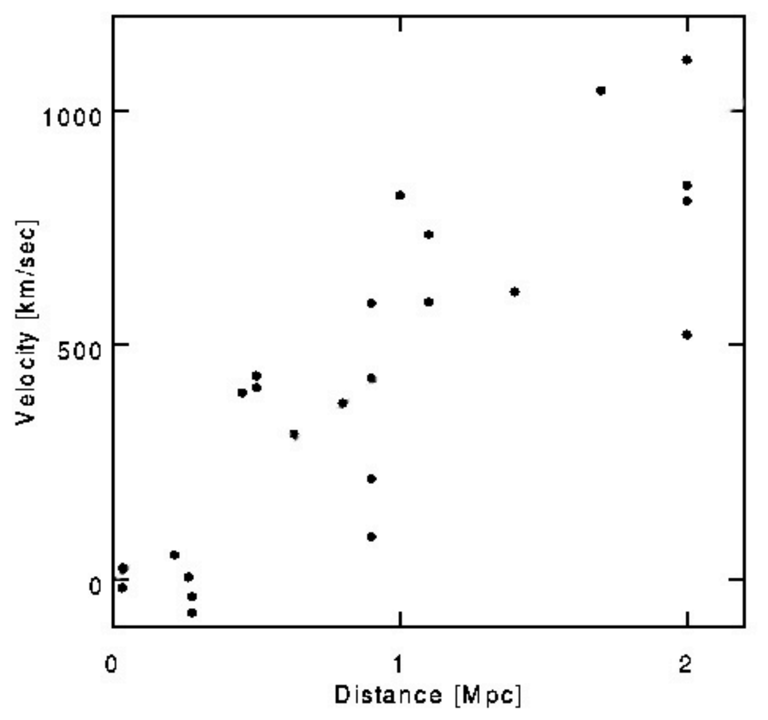

Hubble Original data

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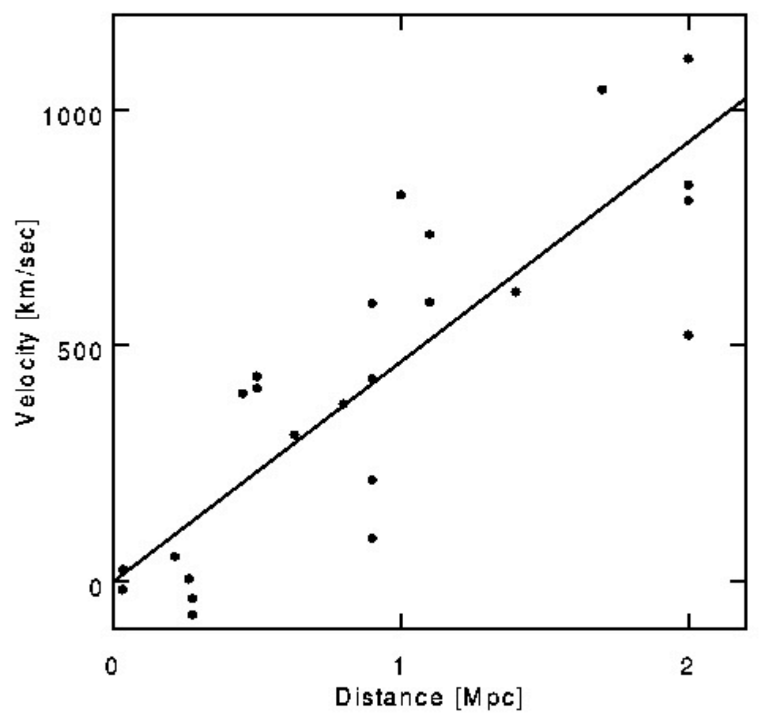

$H_o = 500$ km / s / Mpc

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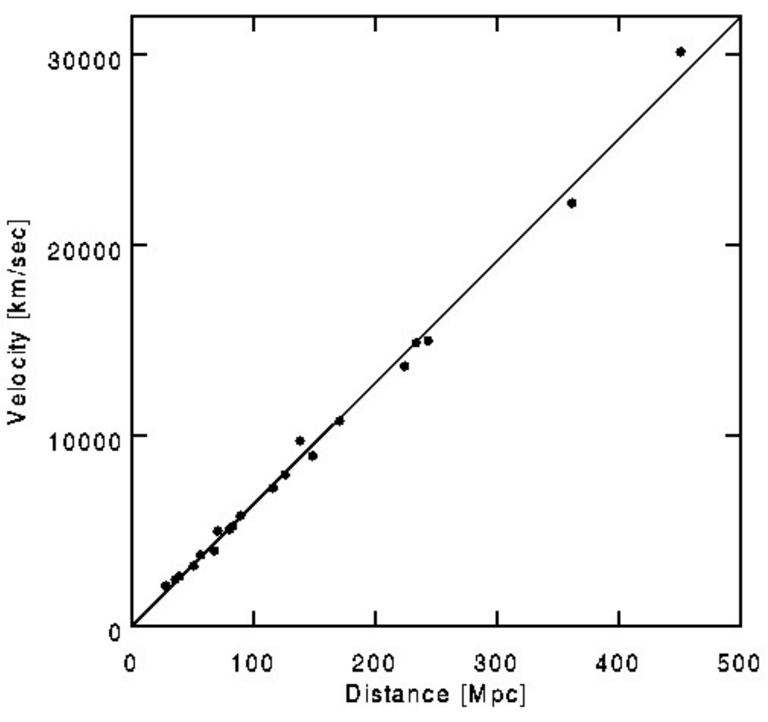

$H_o = 65 \pm 15$ km / s / Mpc

SN Ia 1996 data (RPK)

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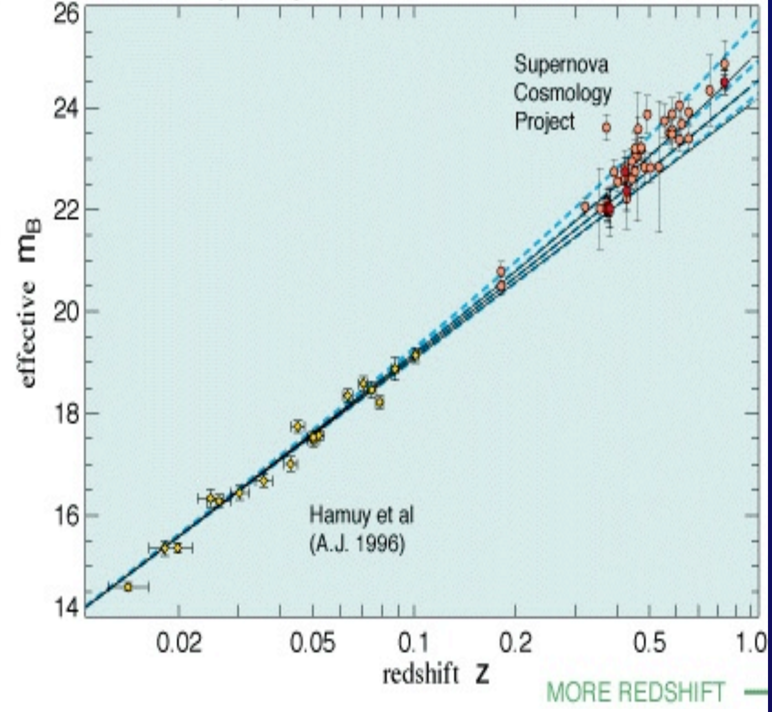

$H_o = 66 \pm 7$ km / s / Mpc

SN Ia 2005 data (High-z)

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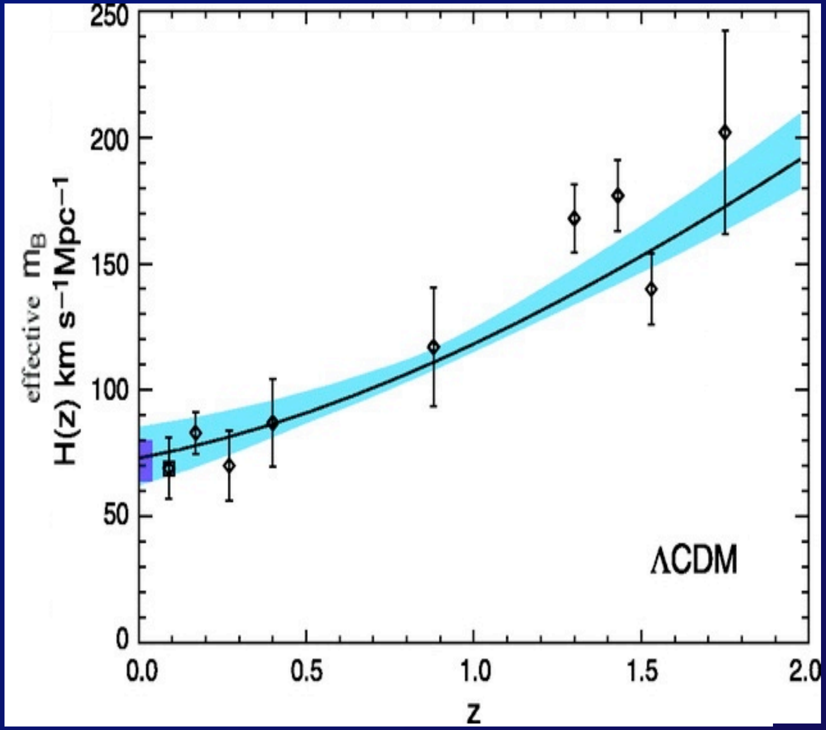

$H_o = 72 \pm 3$ km / s / Mpc

WMAP 3 year data

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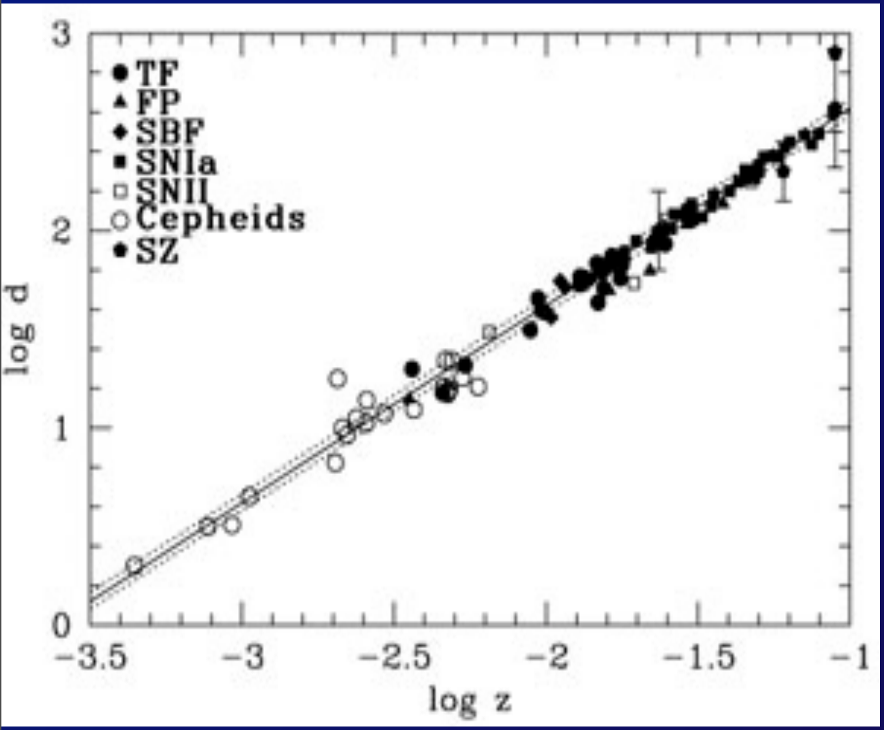

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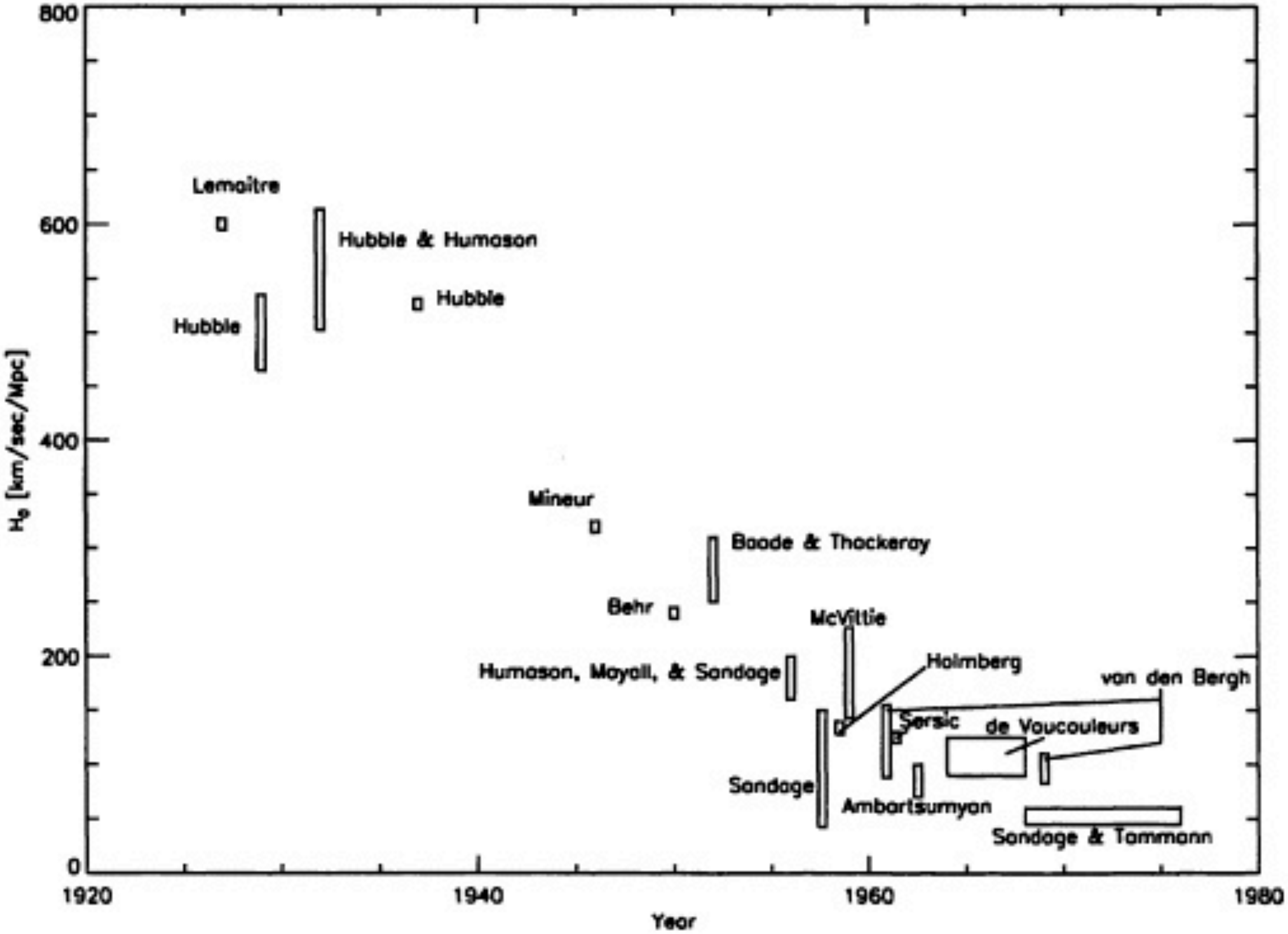
Freedman etal, 2003

TRIMBLE


Lemaitre
Hubble & Humason
Hubble
Hubble
Mineur
Baade & Thackeray
Behr
McVittie
Humason, Mayall, & Sandage
Holmberg
van den Bergh
Sersic
de Vaucouleurs
Sandage
Ambartsumyan
Sandage & Tammann
800
600
400
200
0
H_0 [km/sec/Mpc]
1920
1940
1960
1980
Year

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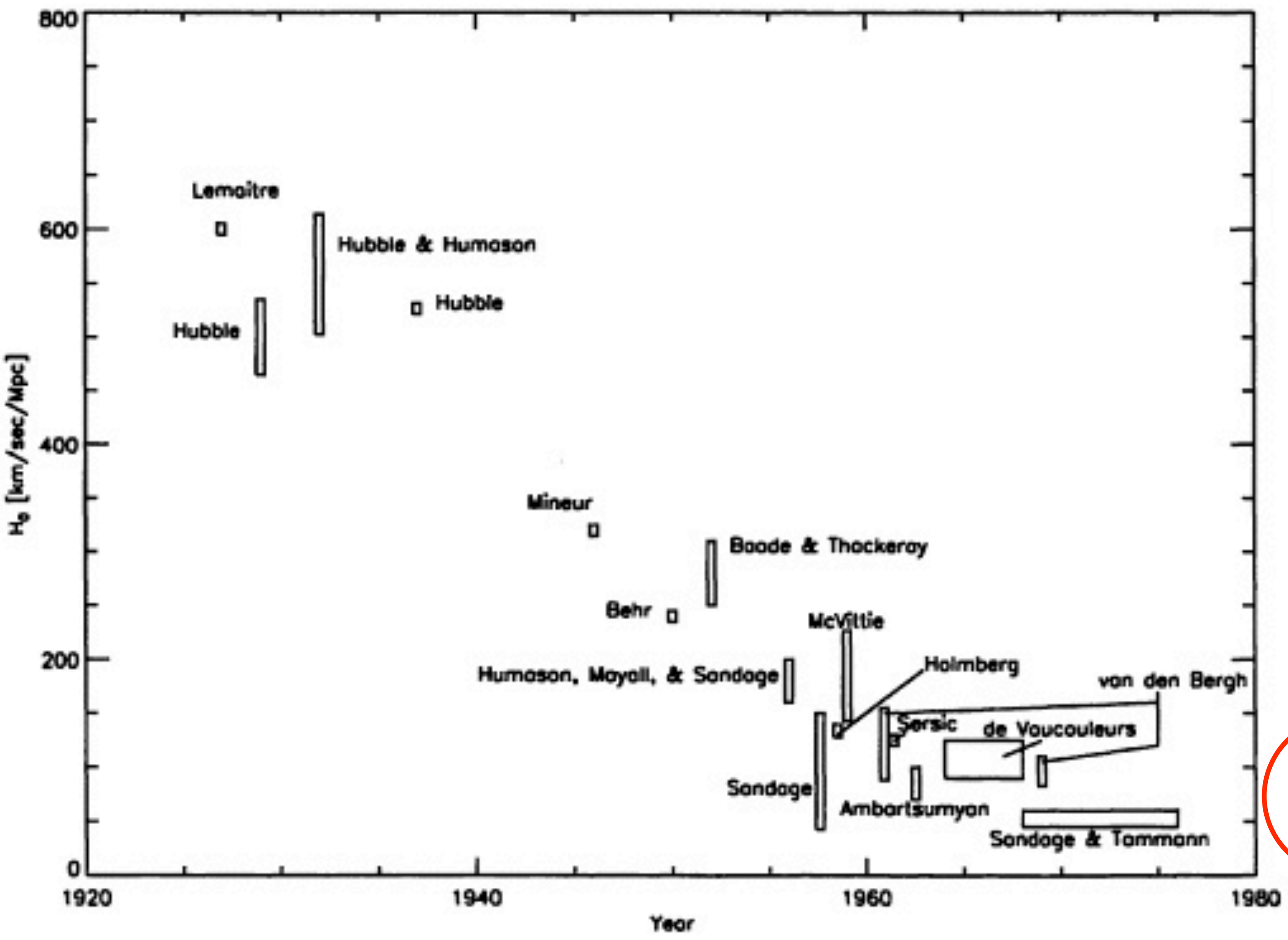
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Is the Universe Homogeneous ?

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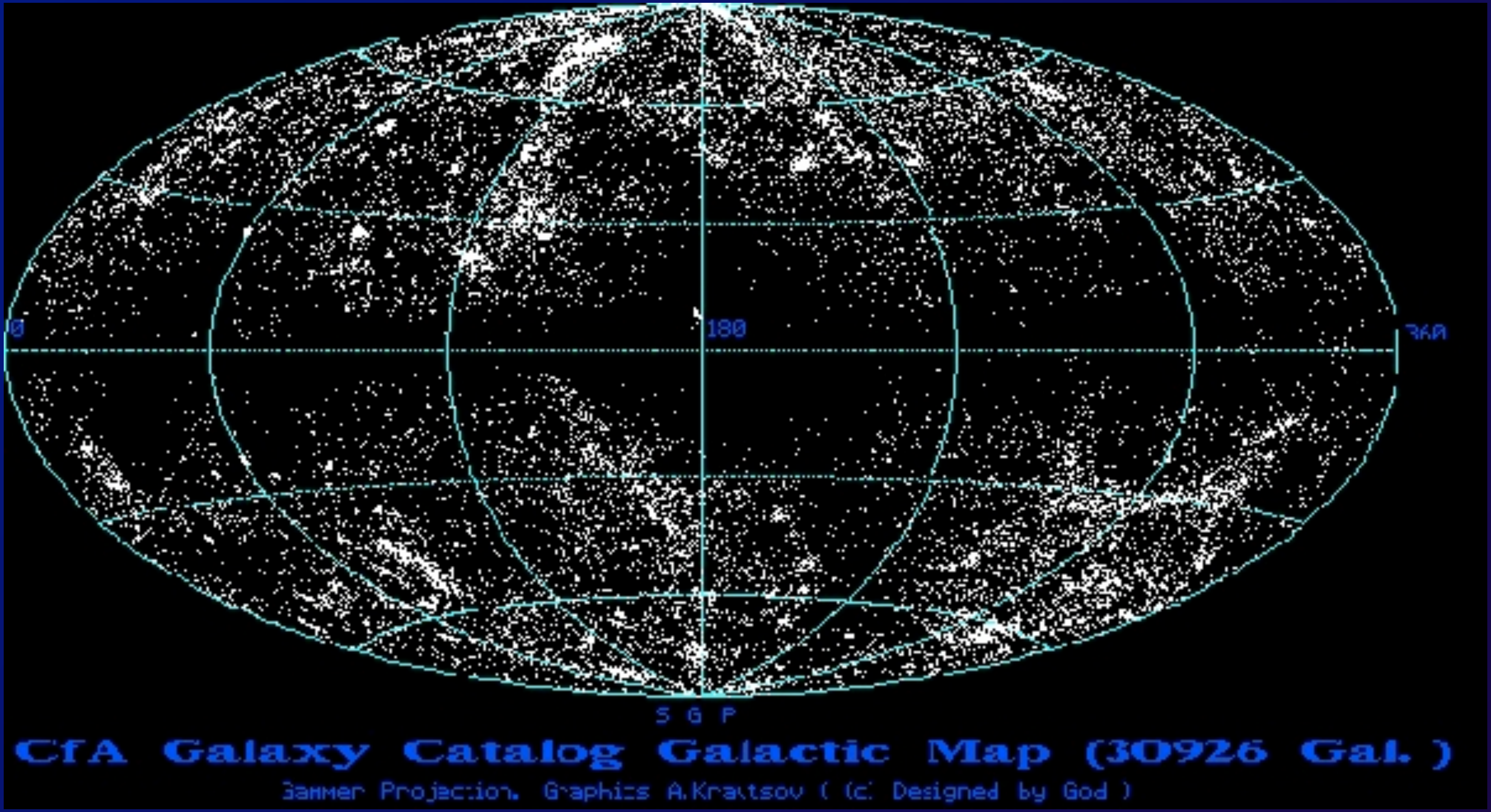

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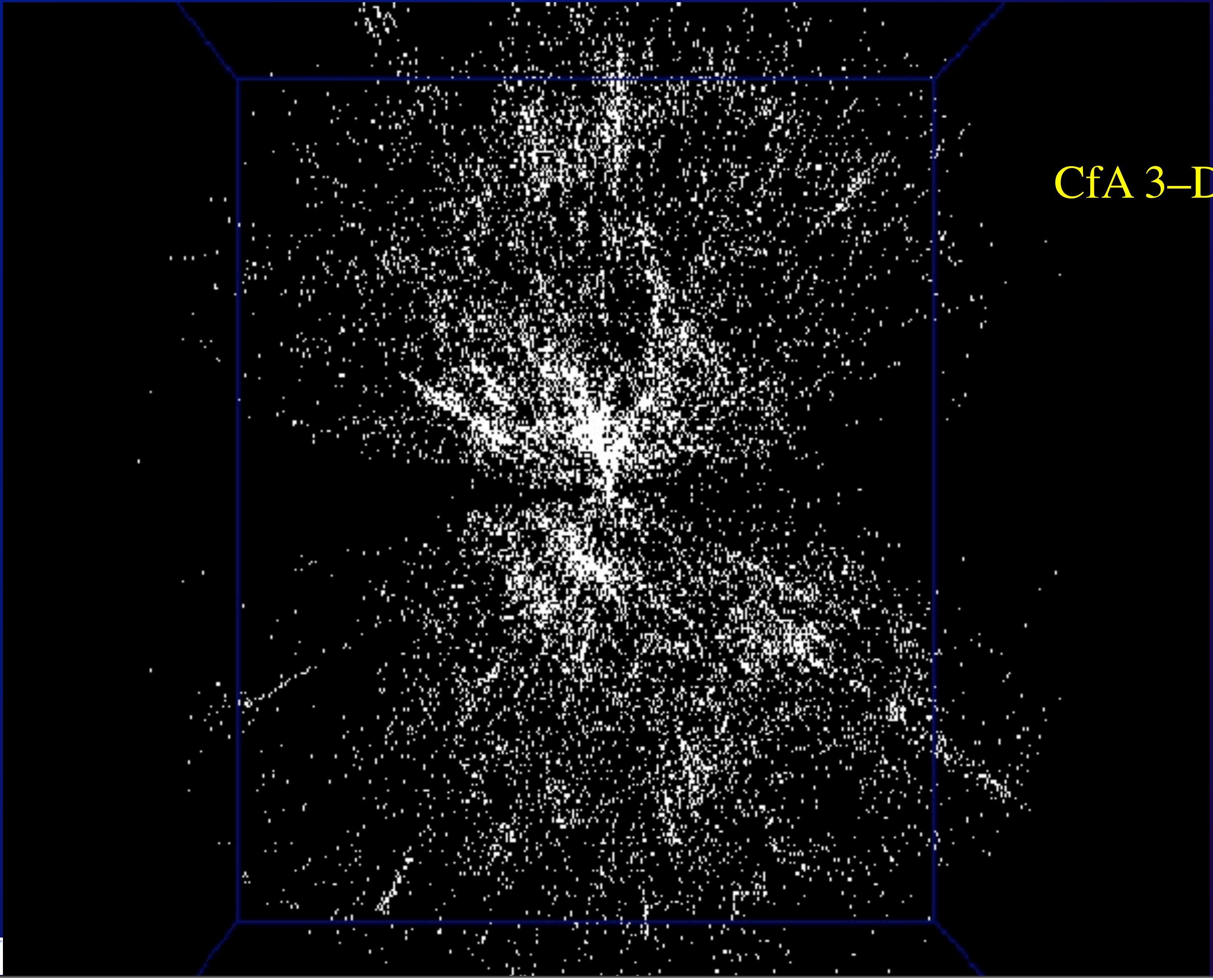

CfA 3–D

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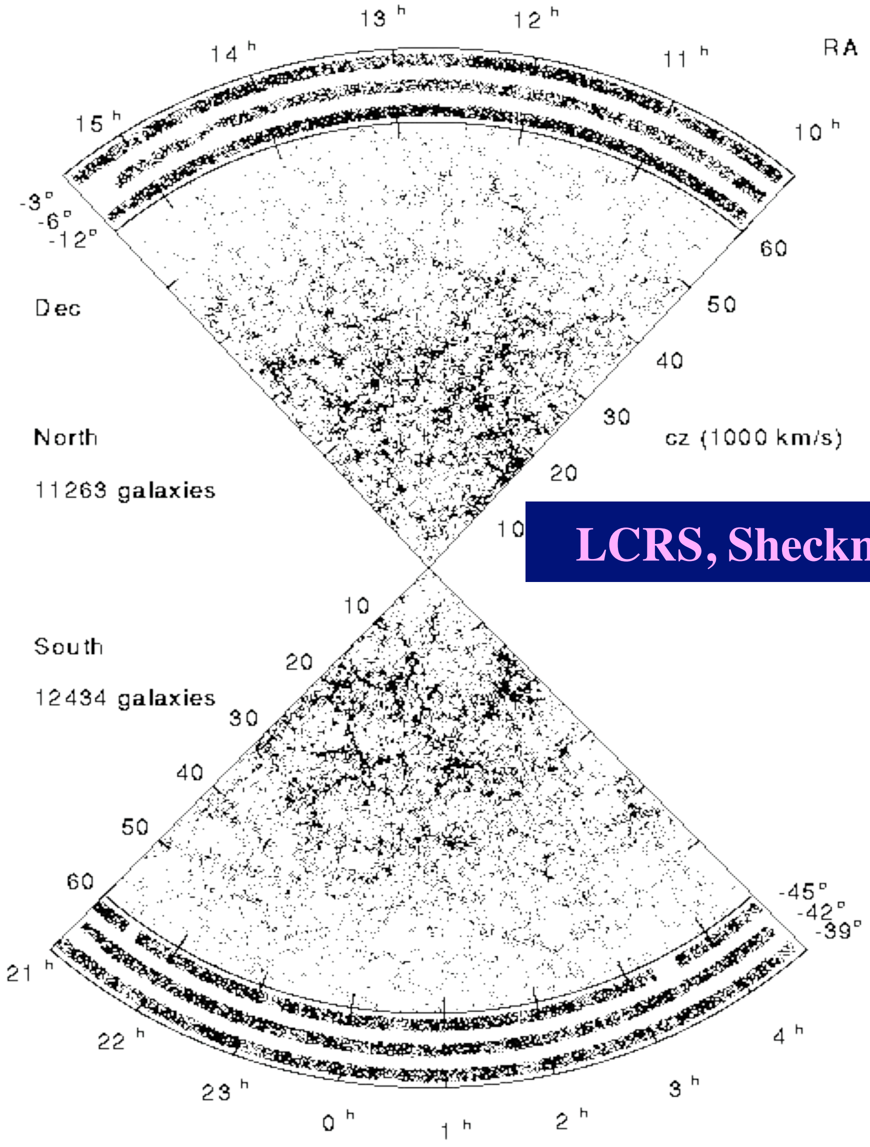
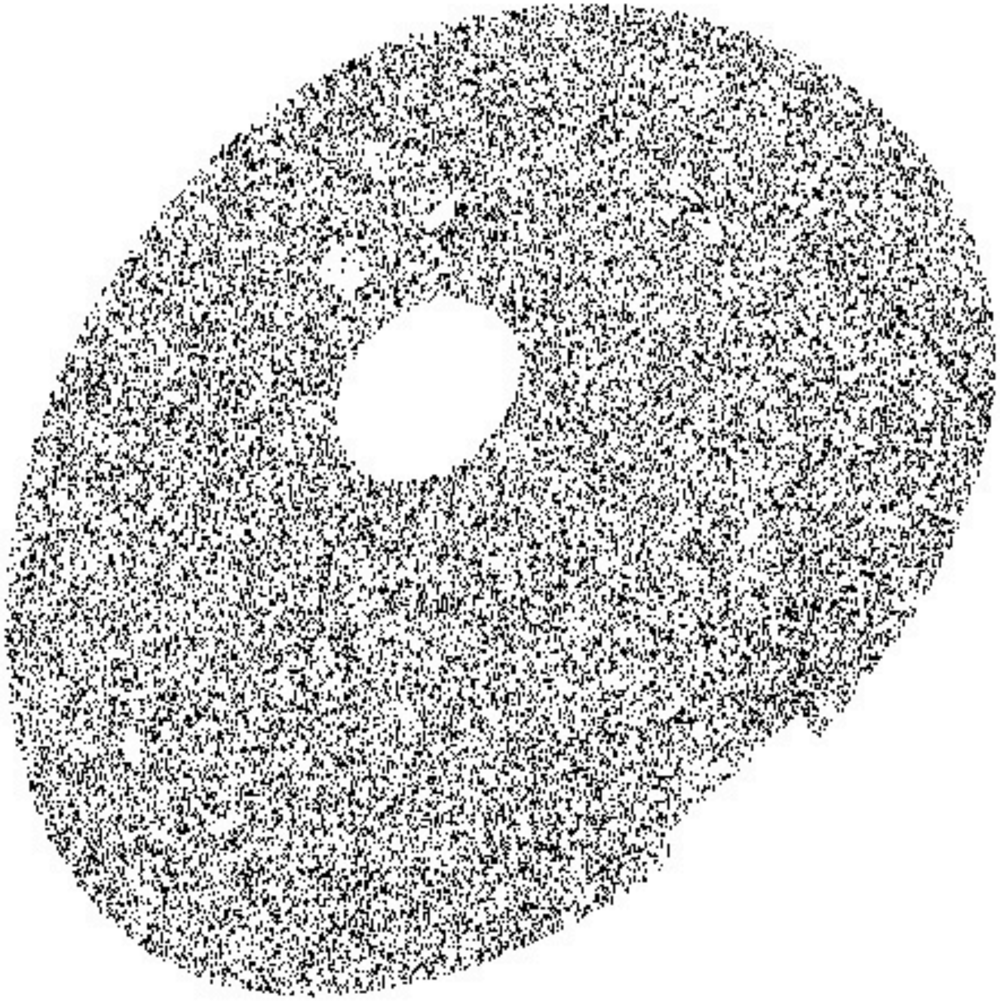


LCRS, Sheckman etal, 1996

Is the Universe Homogeneous ?

Angular Distribution of the ~34,000 brightest 6cm radio sources
(Gregory & Condon, 1991)



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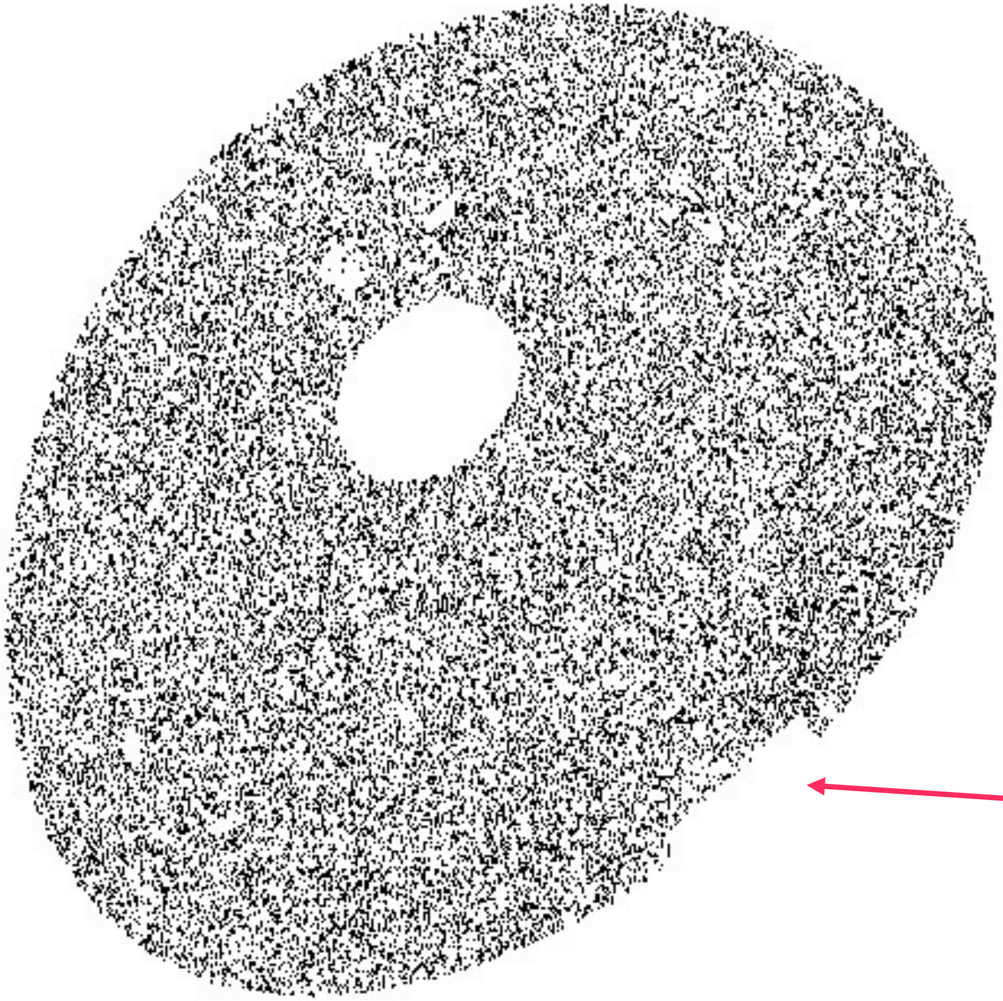

Interference from the sun

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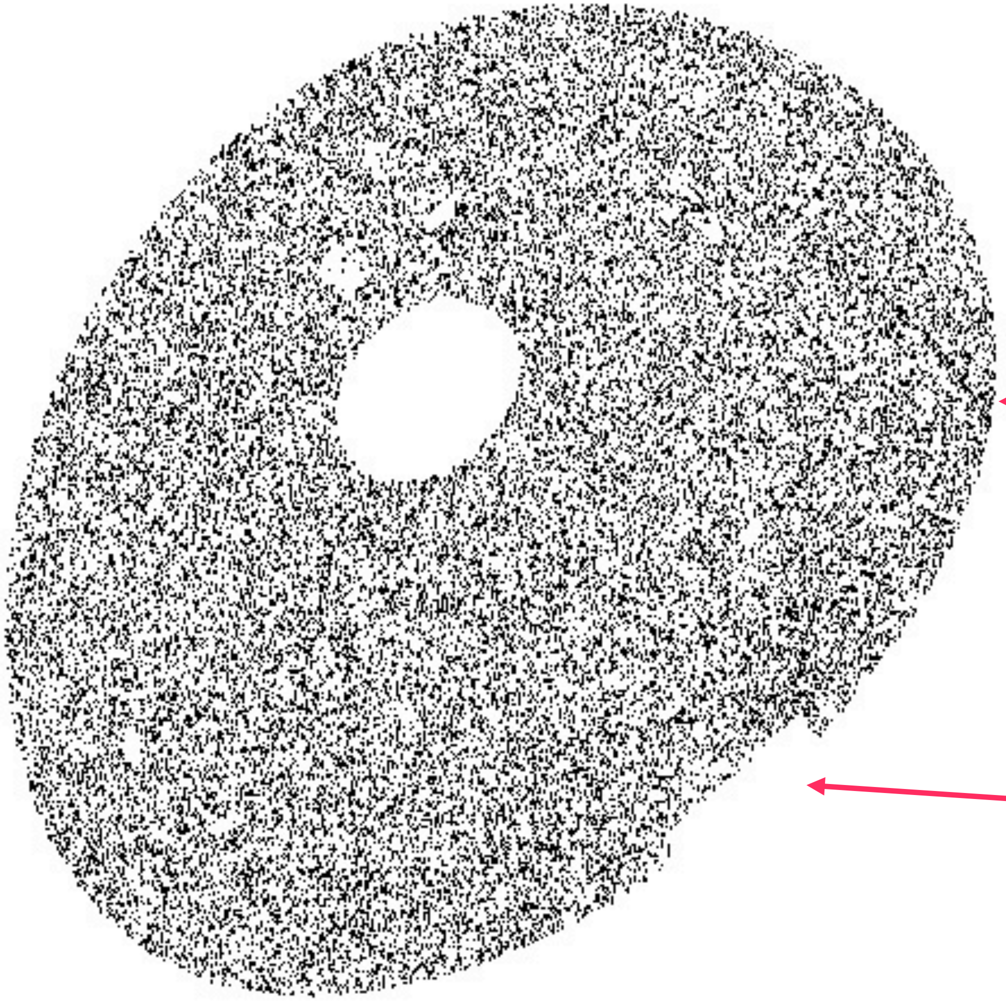

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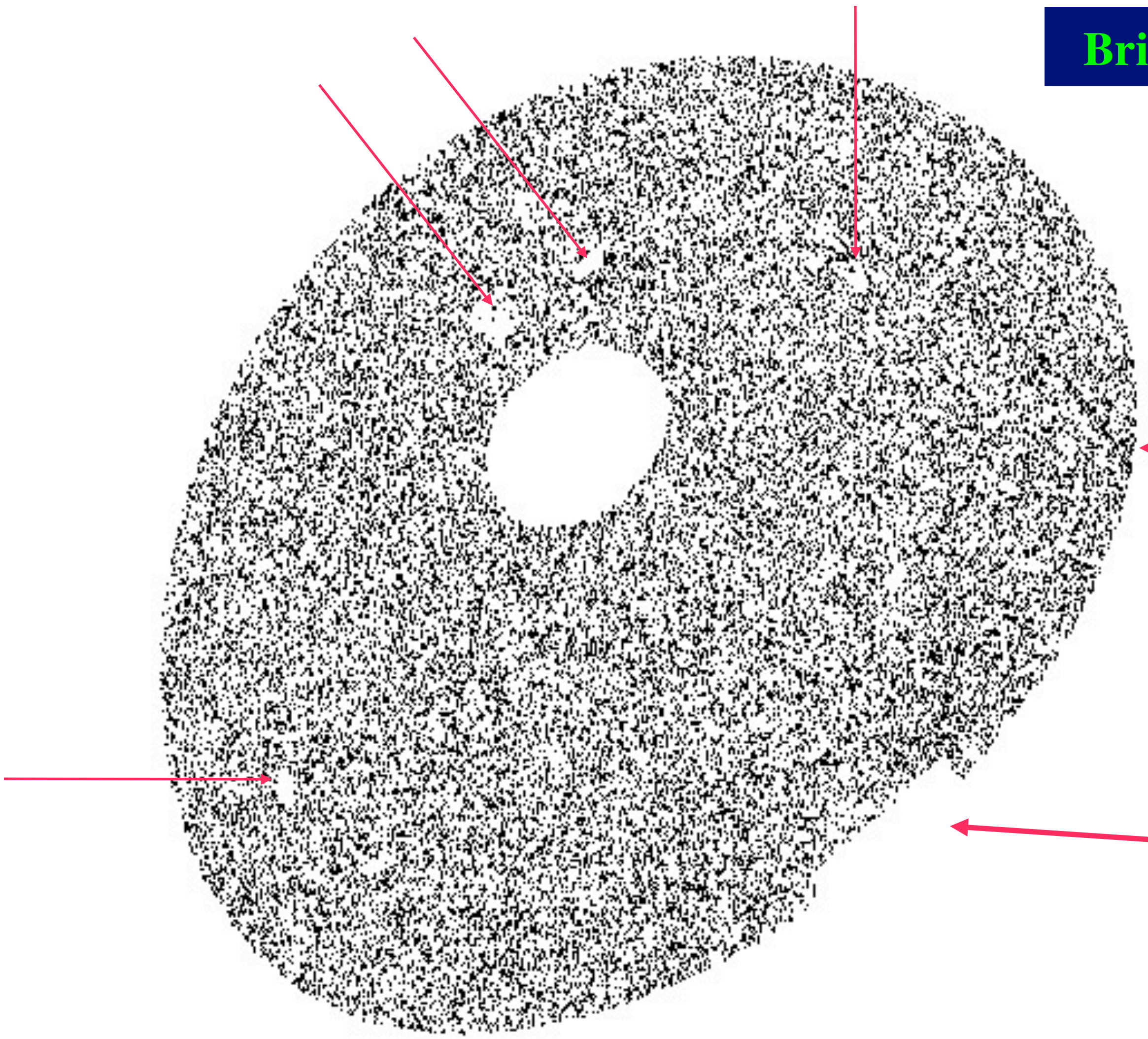

Bright sources in the Milkyway

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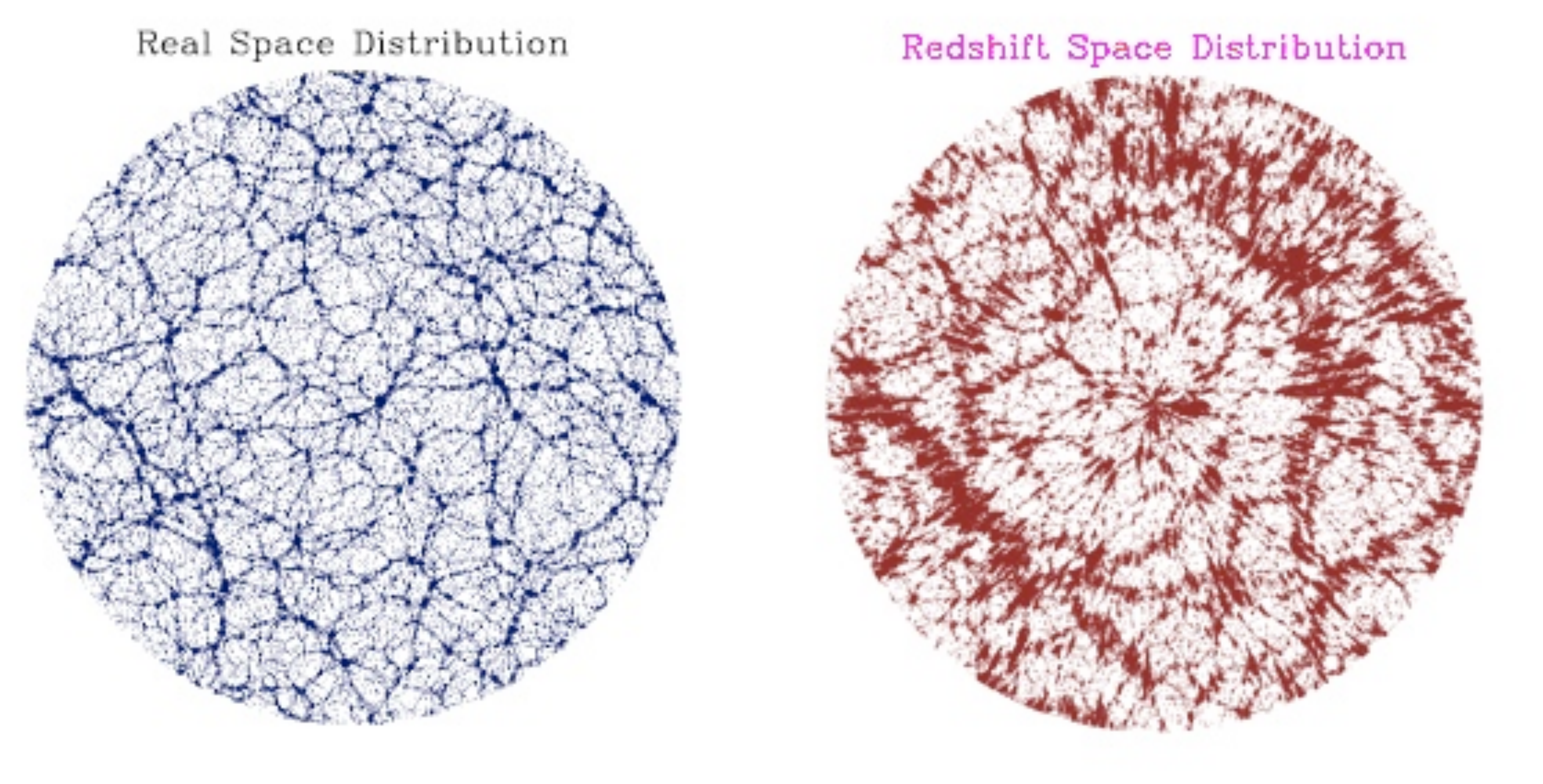
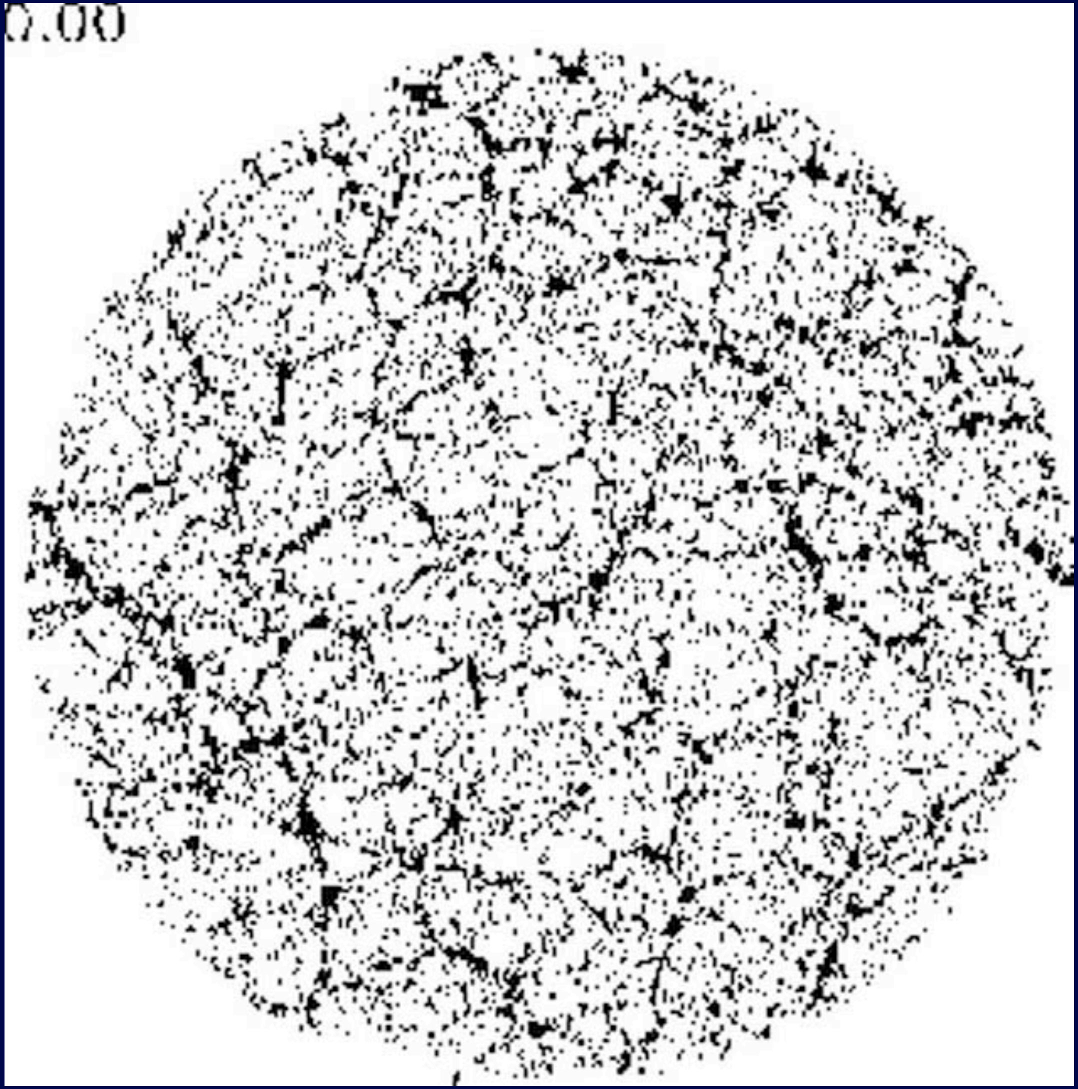


Thomas, Melott, **HAF** & Shandarin 2004

Redshift Distortions



HAF 2004

Peculiar Velocity Field

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Measure the line of sight peculiar velocities:

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$$v_p = cz - H_o r$$

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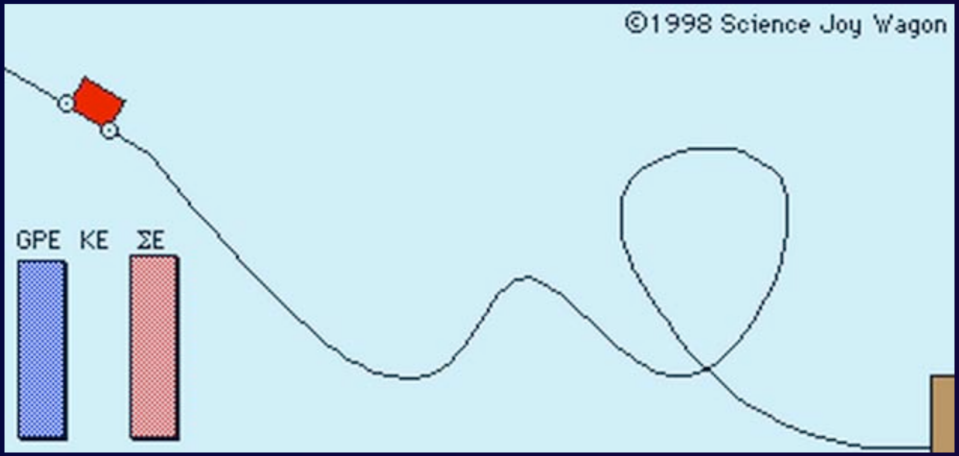
- Comparison of velocity fields & Luminous matter distribution → bias, Ω ...



- ★ **A direct probe of the mass distribution** $\vec{V} = -\vec{\nabla}\phi$

How to measure cosmological distances?

aka The Cosmic Distance Ladder

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A stepwise procedure: Errors proliferating

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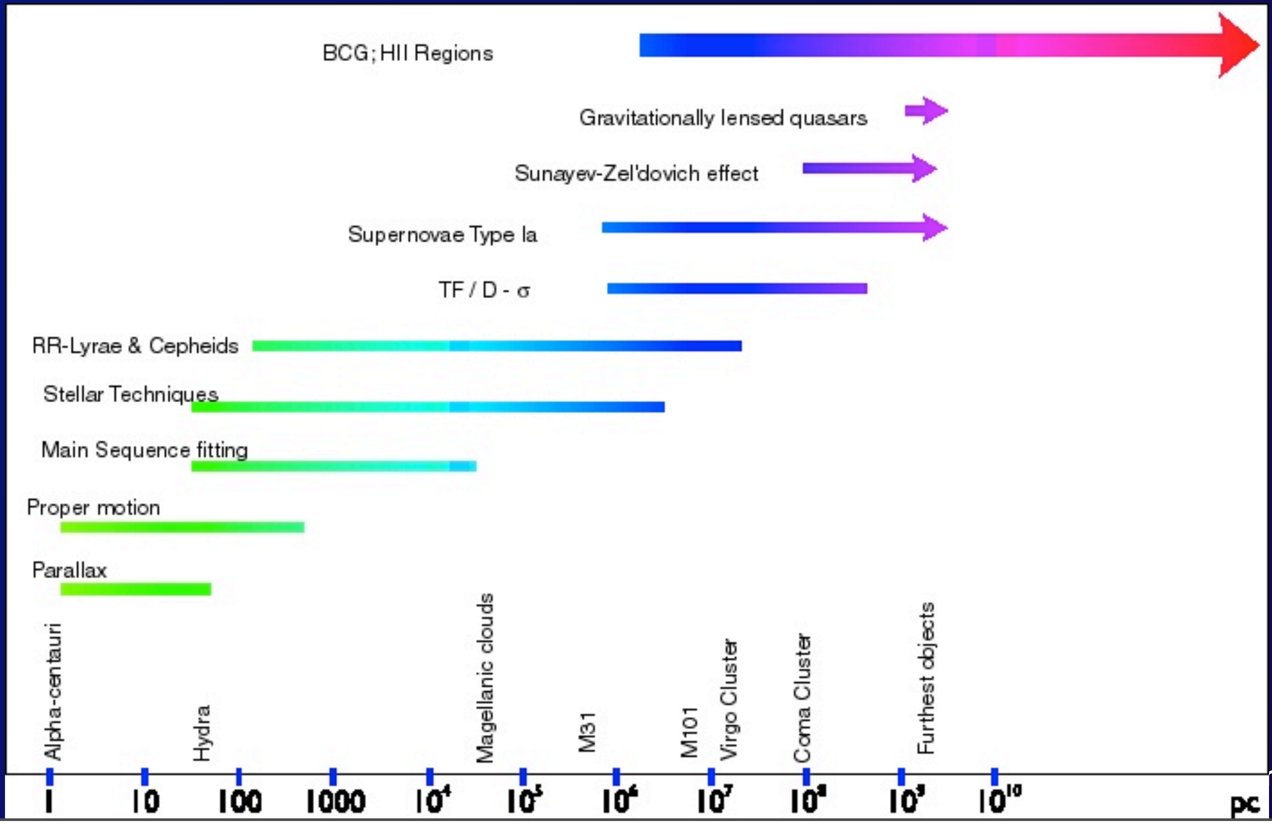

The Cosmic Ladder

- Find correlated observables:

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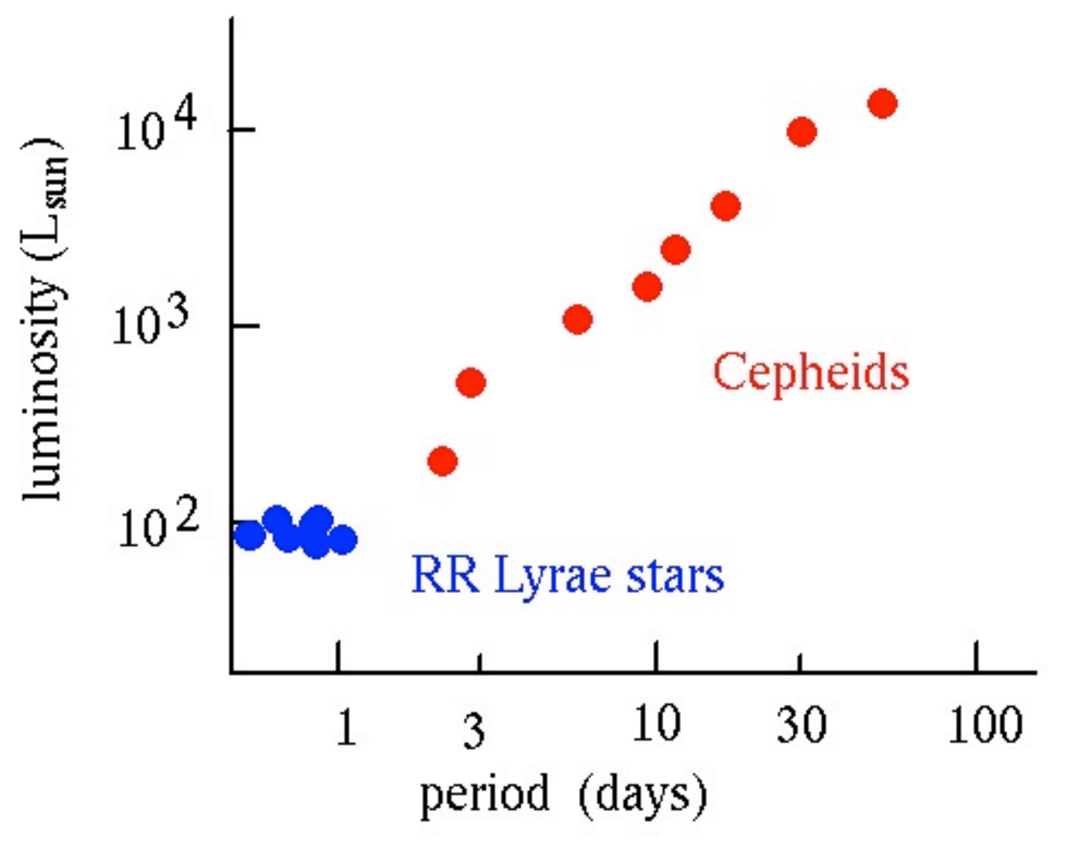

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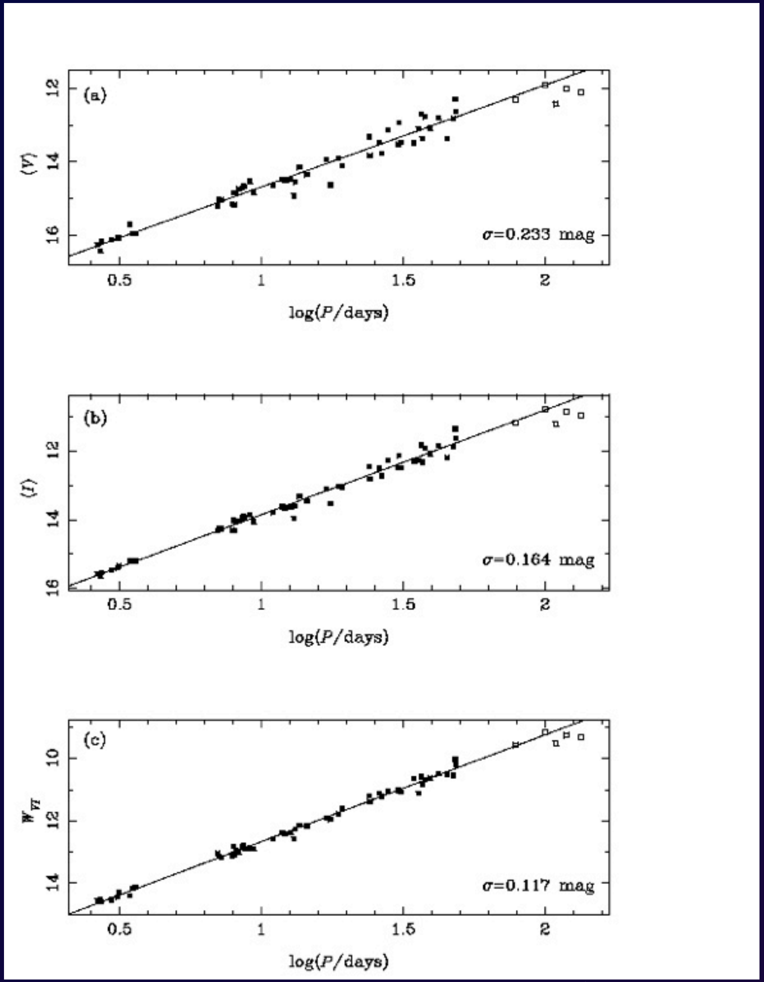

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Tully-Fisher

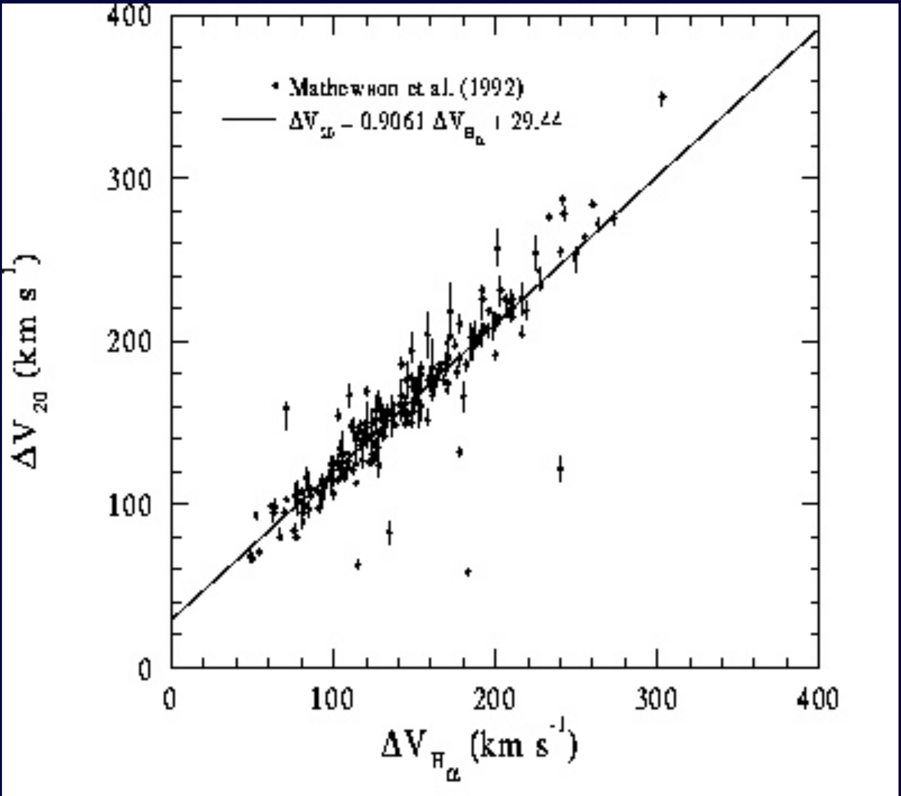
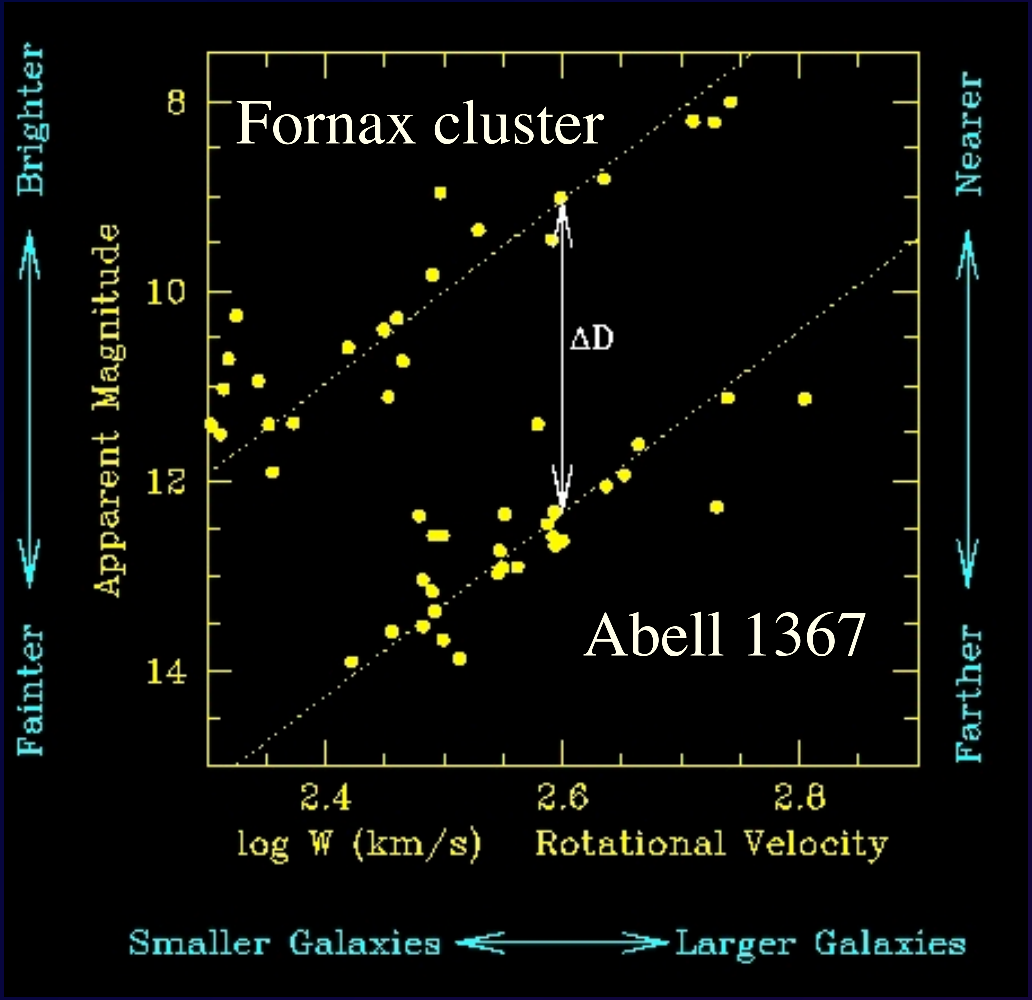


Figure 8.1: HI half-linewidth versus H_α rotation velocity for a sample of 204 nearby galaxies. Data taken from Mathewson *et al.* (1992)

Tully-Fisher



ΔD = *relative* difference between the distances of the two clusters

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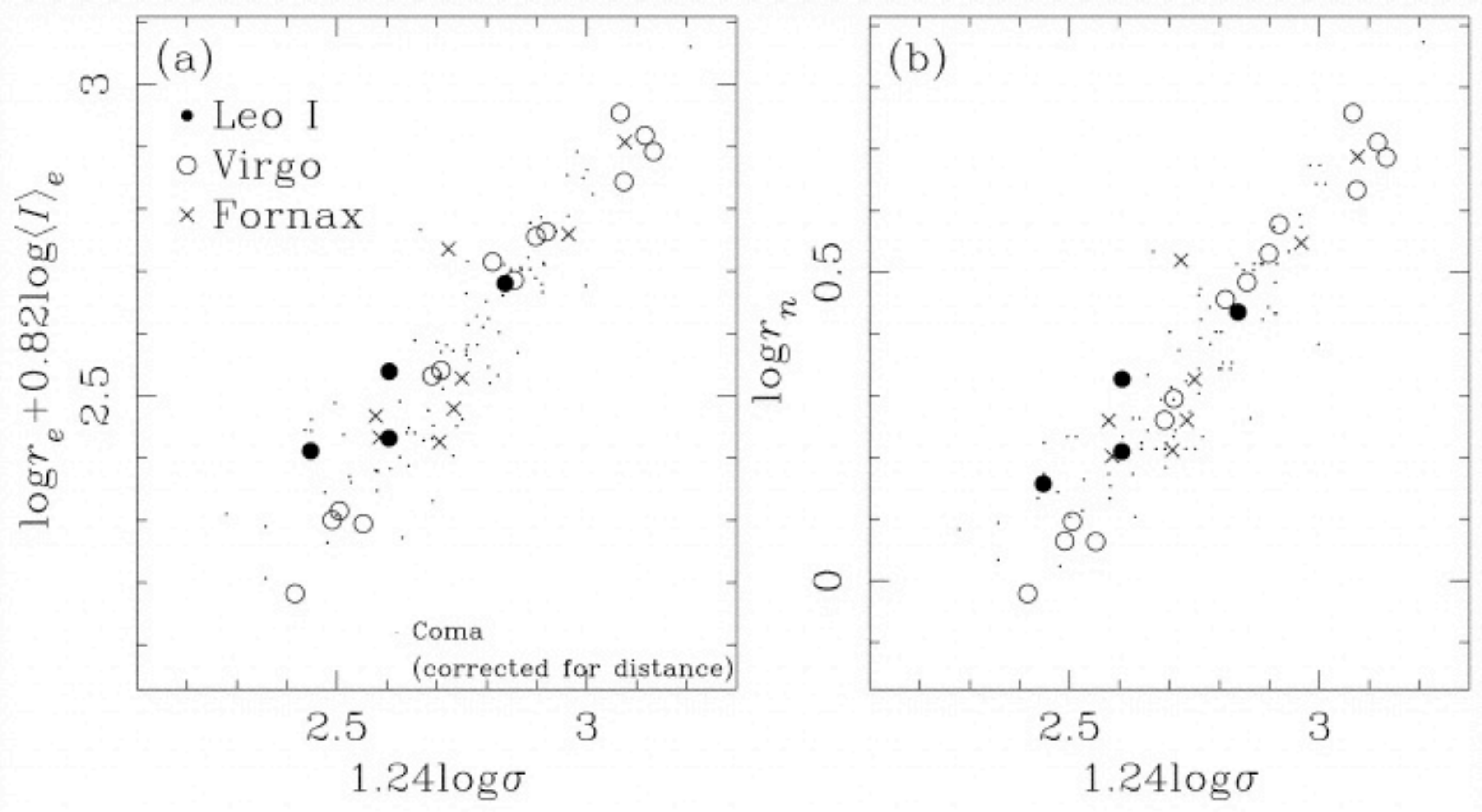
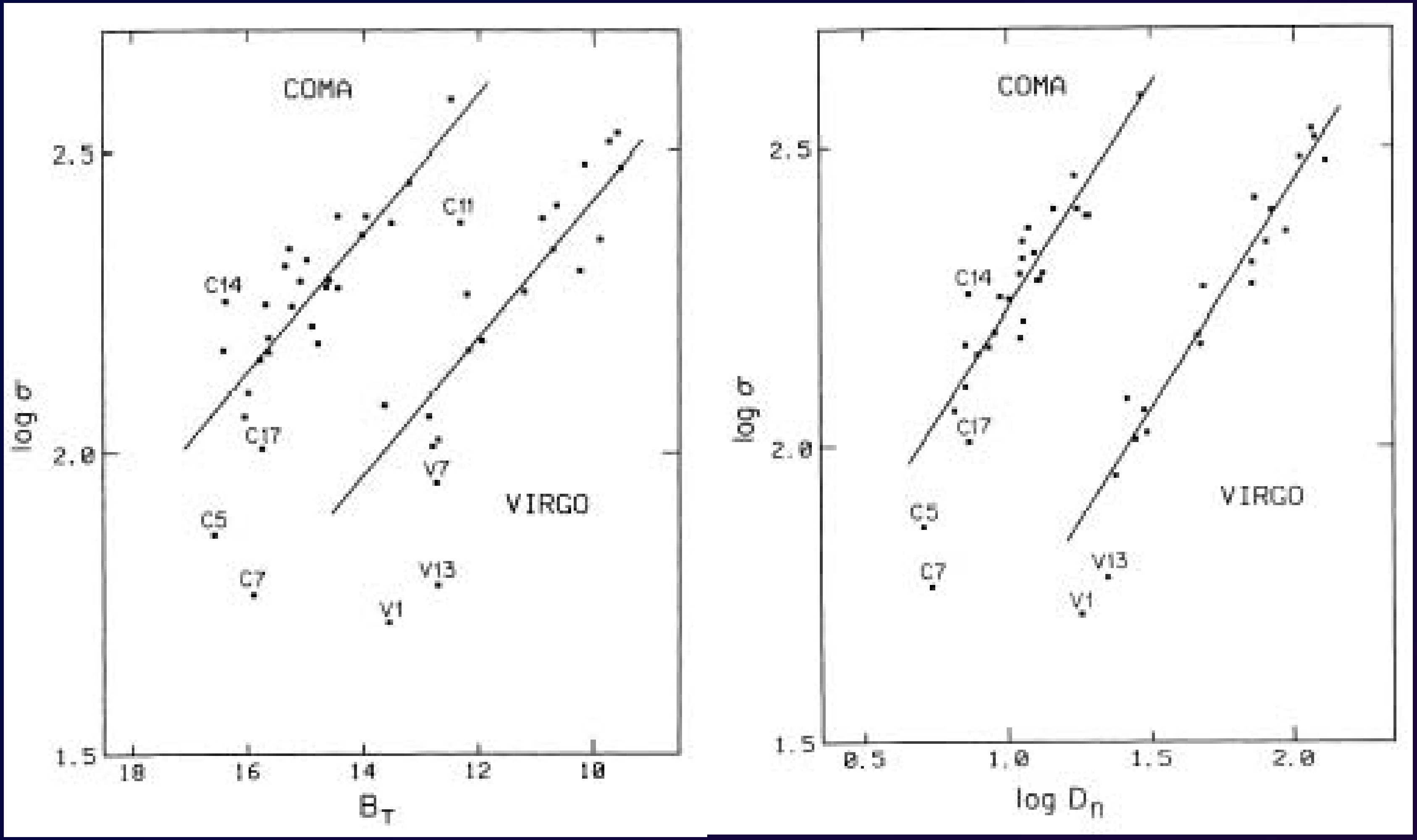
$$D_n \propto r_c < I >_c^{0.8}$$

$$\log D_n = 1.333 \log \sigma + \text{constant}$$

$D_n - \sigma$


(a)
• Leo I
○ Virgo
× Fornax
Coma
(corrected for distance)
$\log r_e + 0.82 \log \langle I \rangle_e$
3
2.5
2.5
3
$1.24 \log \sigma$
(b)
$\log r_n$
0.5
0
2.5
3
$1.24 \log \sigma$

$D_n - \sigma$


COMA
VIRGO
C14
C17
C11
C5
C7
V7
V13
V1
log σ
2.5
2.0
1.5
18
16
14
12
10
B_T
COMA
VIRGO
C14
C17
C5
C7
V13
V1
log σ
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1.0
1.5
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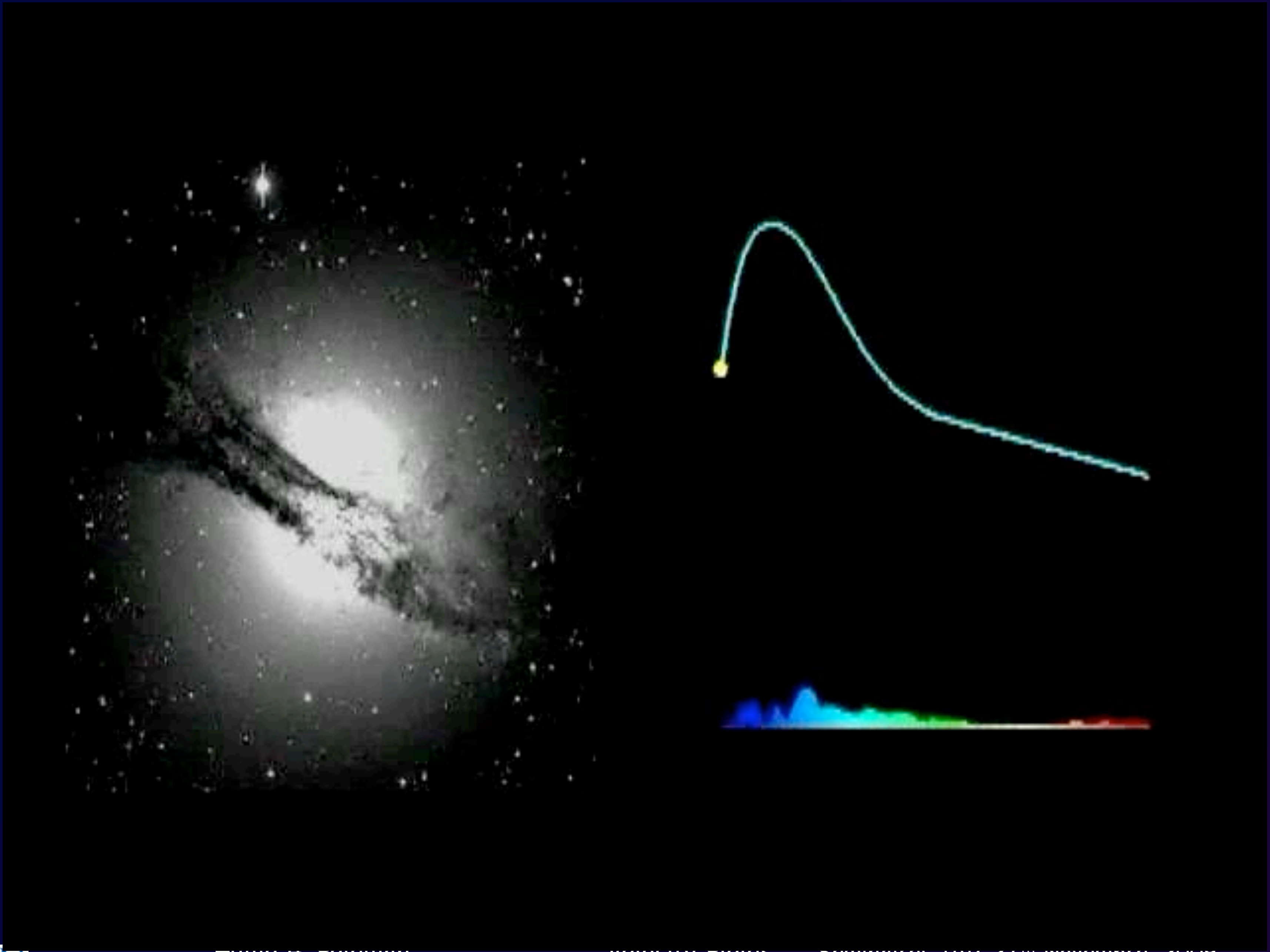
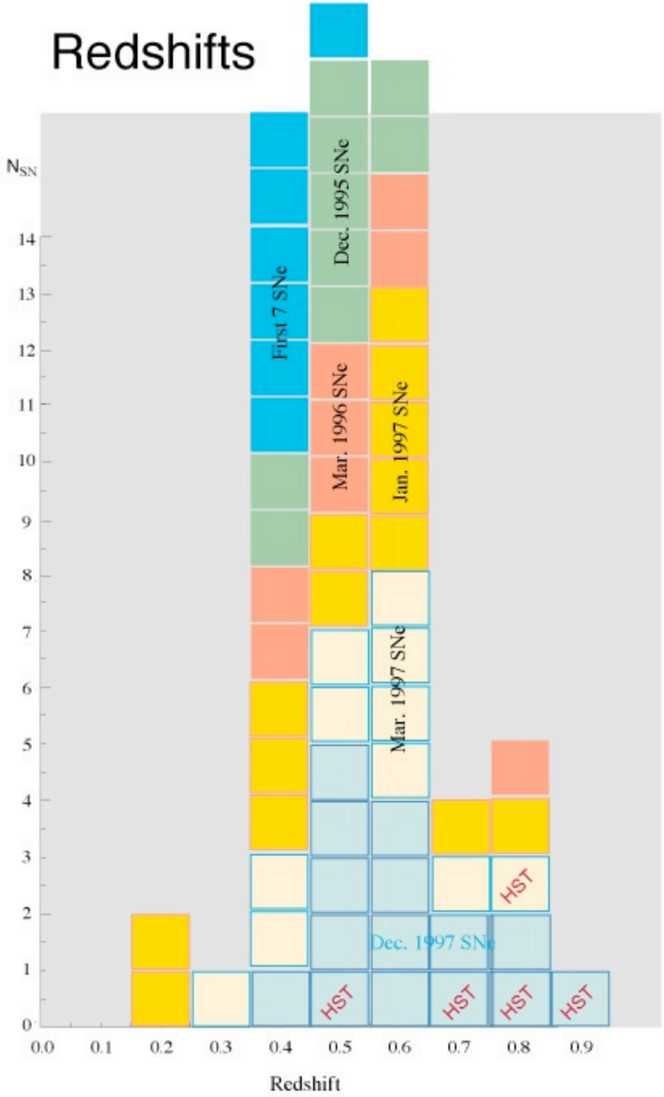


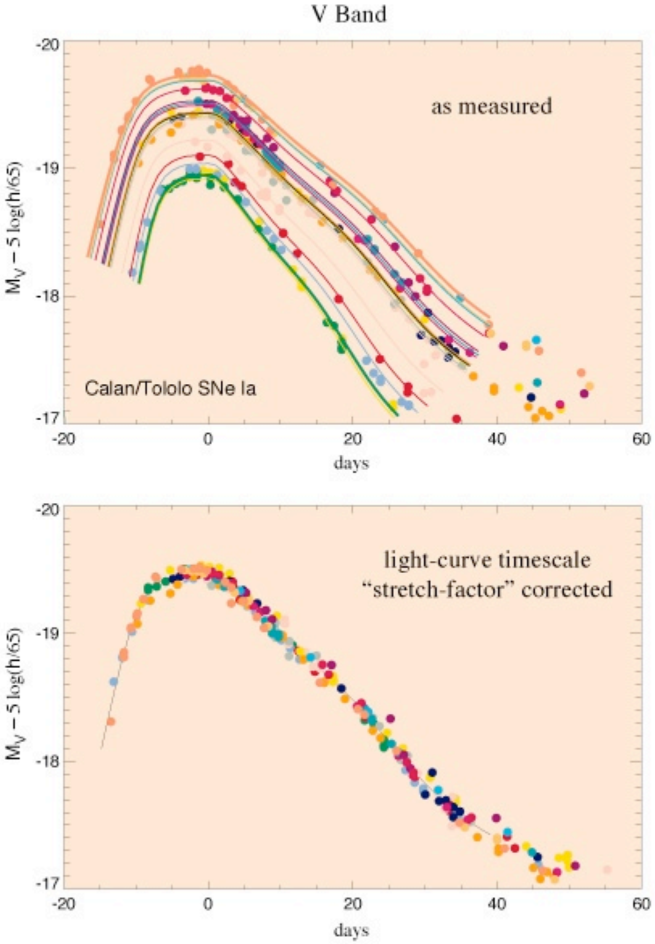
http://www-supernova.lbl.gov/

C. Pennypacker
M. DellaValle, Univ. of Padova
R. Ellis, R. McMahon, IoA, Cambridge
B. Schaefer, Yale University
P. Ruiz-Lapuente, Univ. of Barcelona
H. Newberg, Fermilab

Redshifts



Low Redshift Type Ia Template Lightcurves



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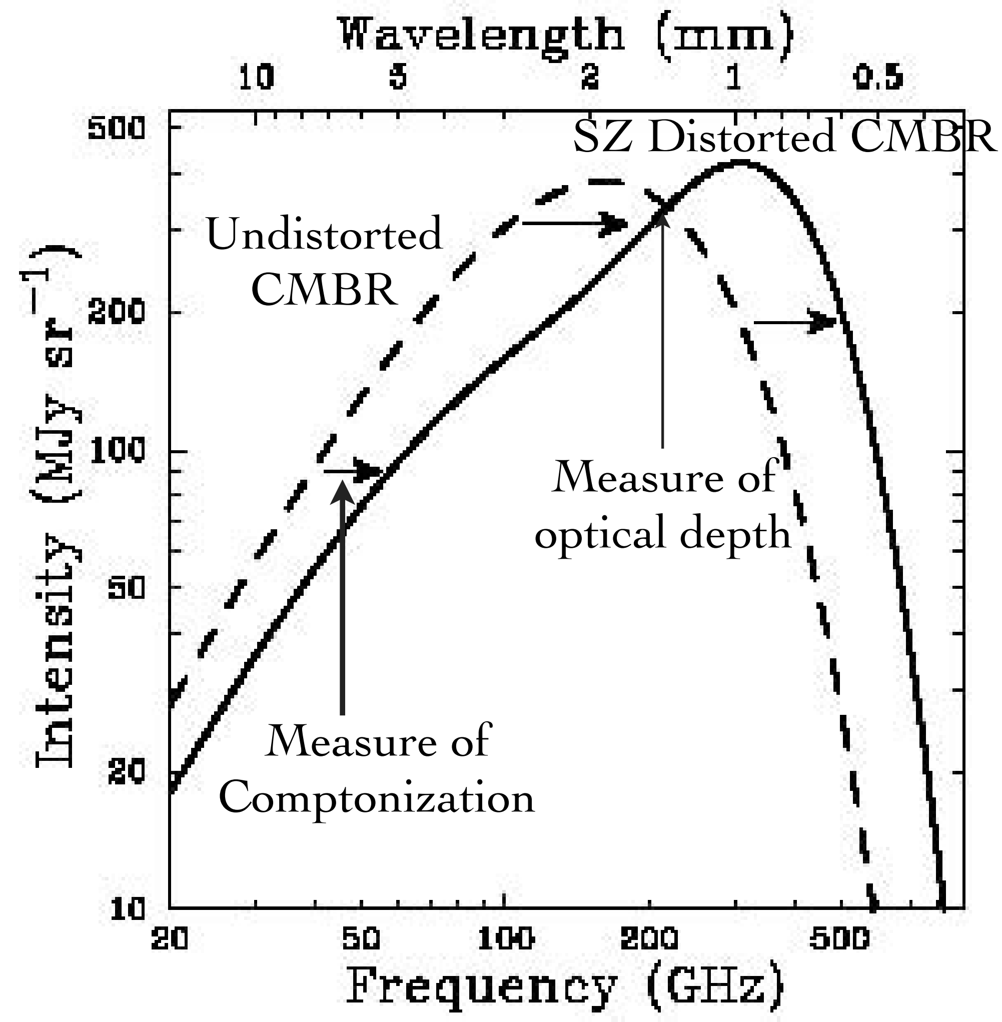
Kinetic SZE:

The bulk motion of the cluster red- or blue-shifts scattered γ

SZ Effect

Carlstrom etal , 2002



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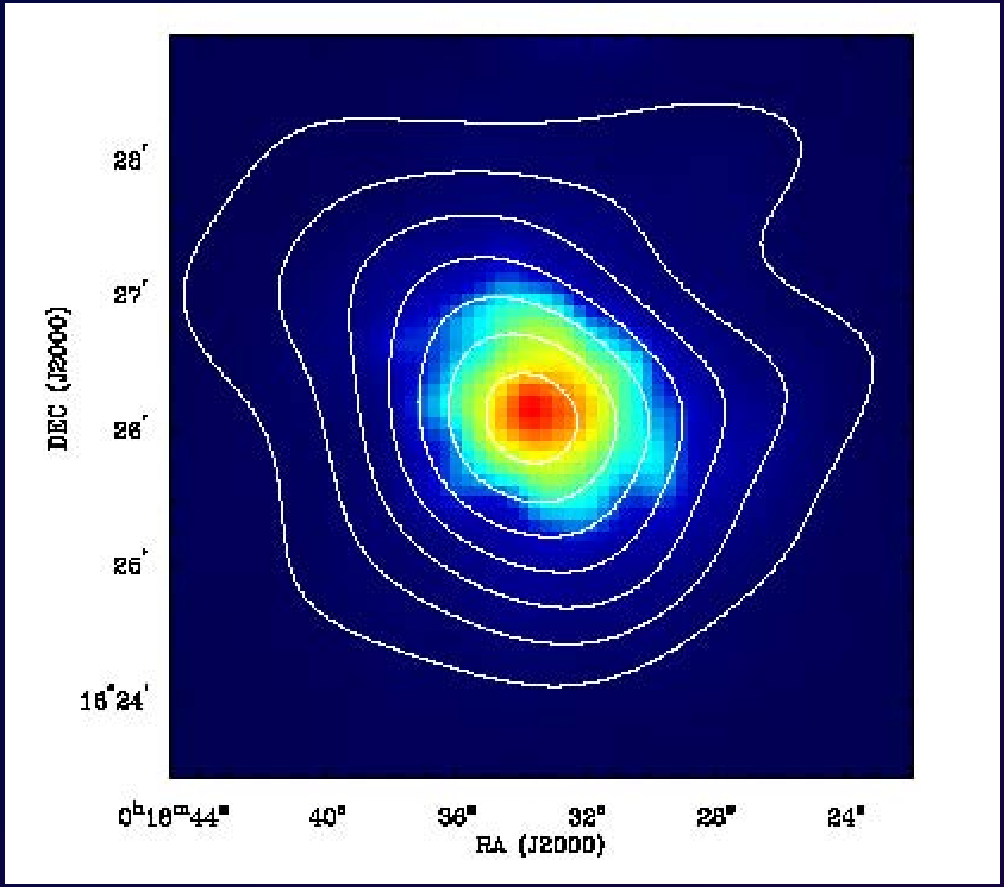

Carlstrom, 1997

$$L_{cl} \approx 10^{12} L_{\odot}$$

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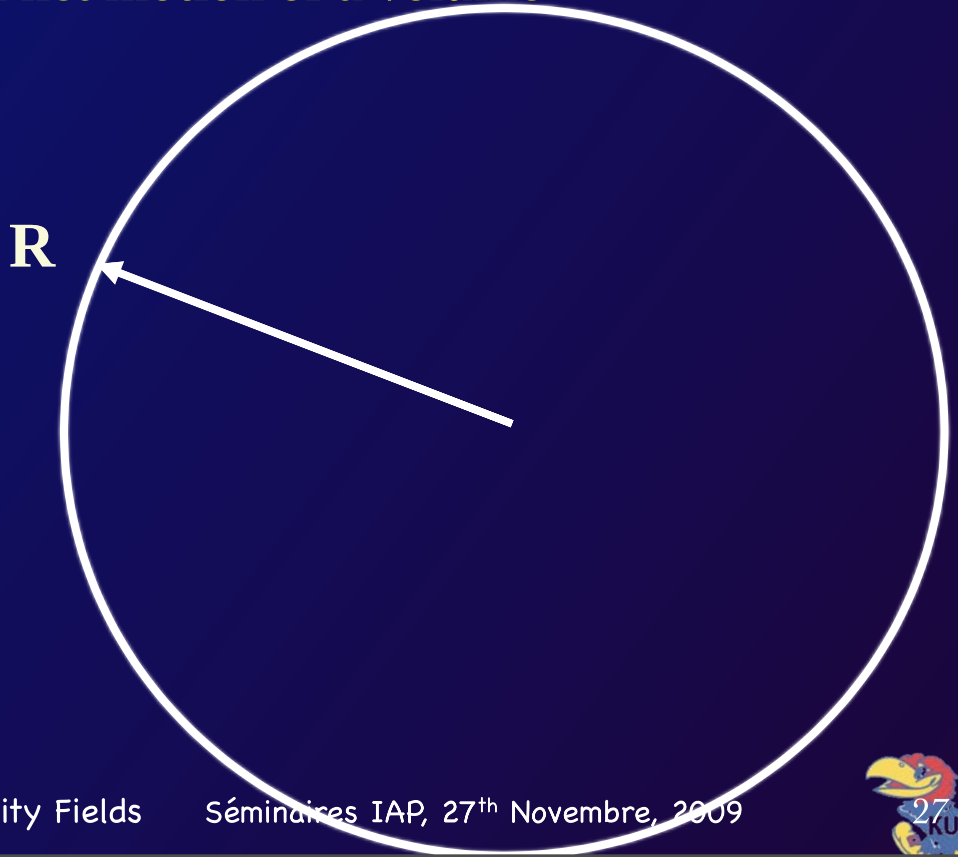

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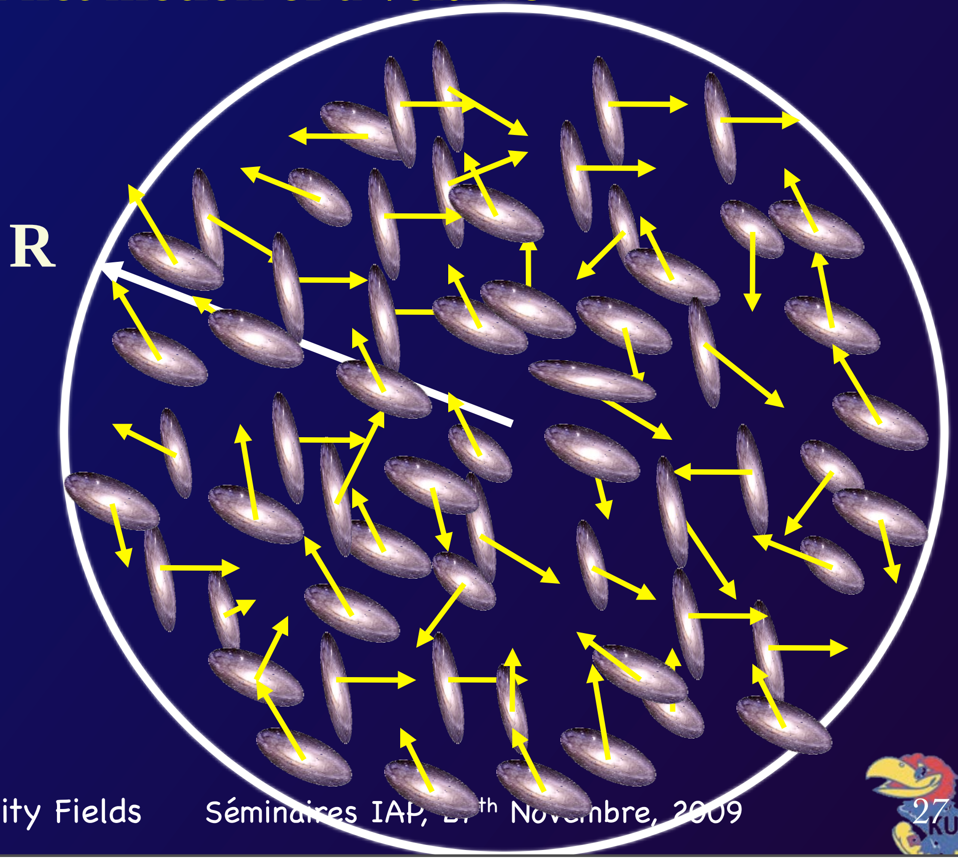

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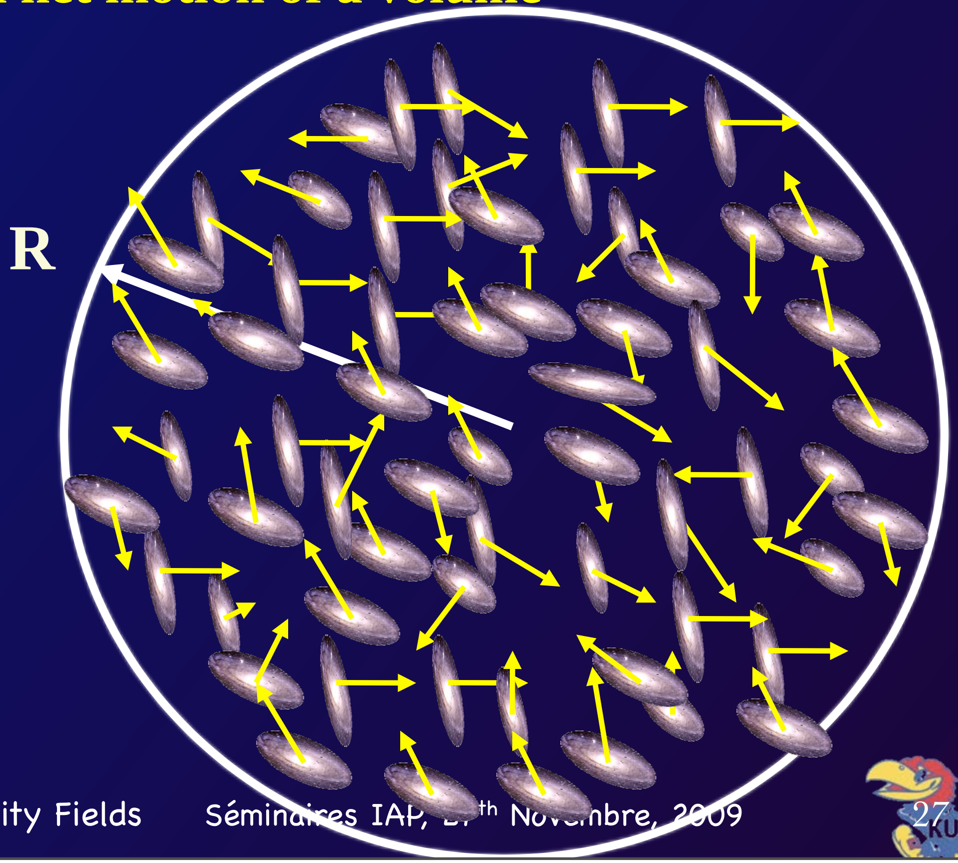

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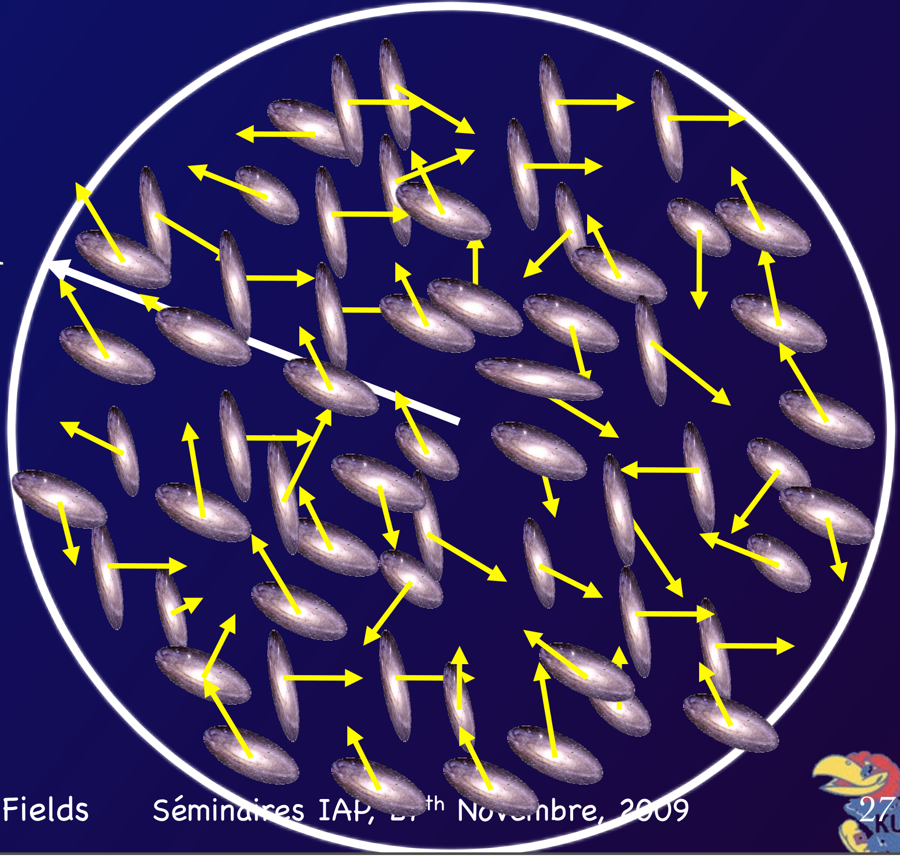
Combine data to find net motion of a volume

Beat down the error by √N



As R becomes large, expect $v_p \rightarrow 0$

Test homogeneity

Early Applications

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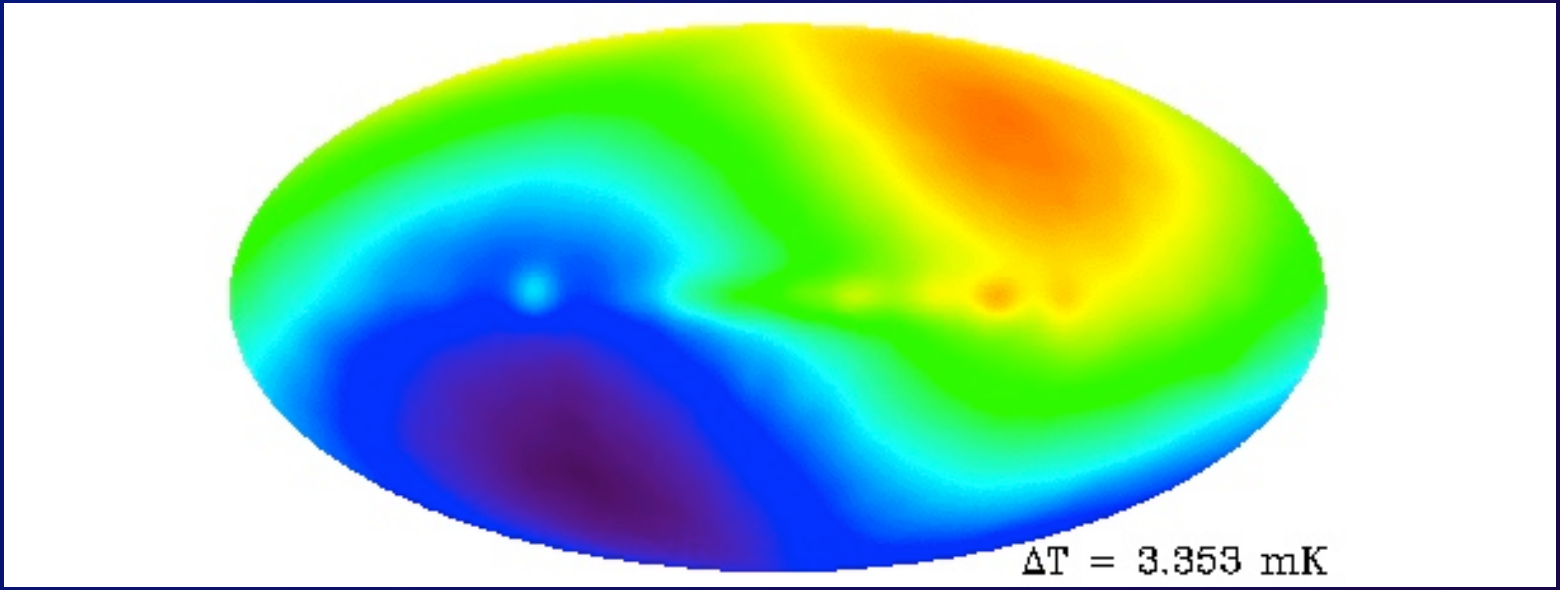

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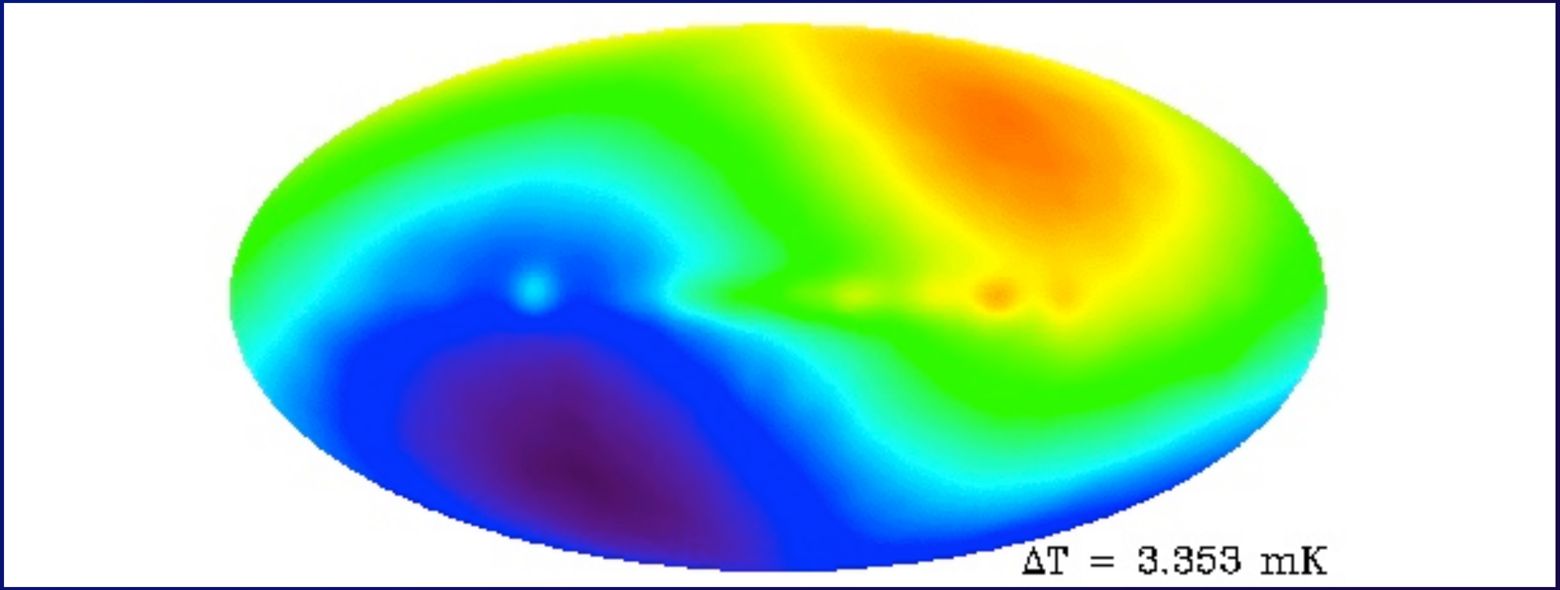

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Local Group Velocity

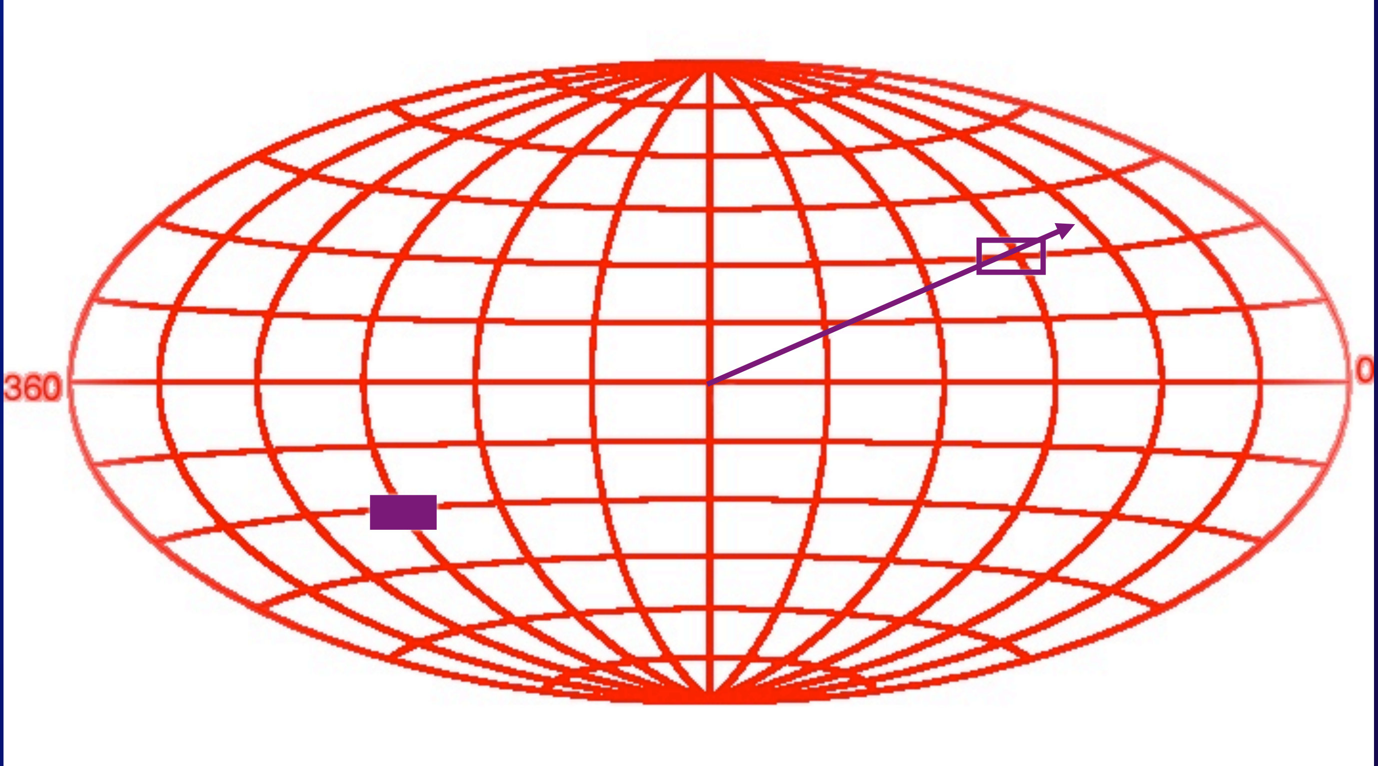
Cautionary history lesson

Imperial College London

Local Group Velocity

Cautionary history lesson

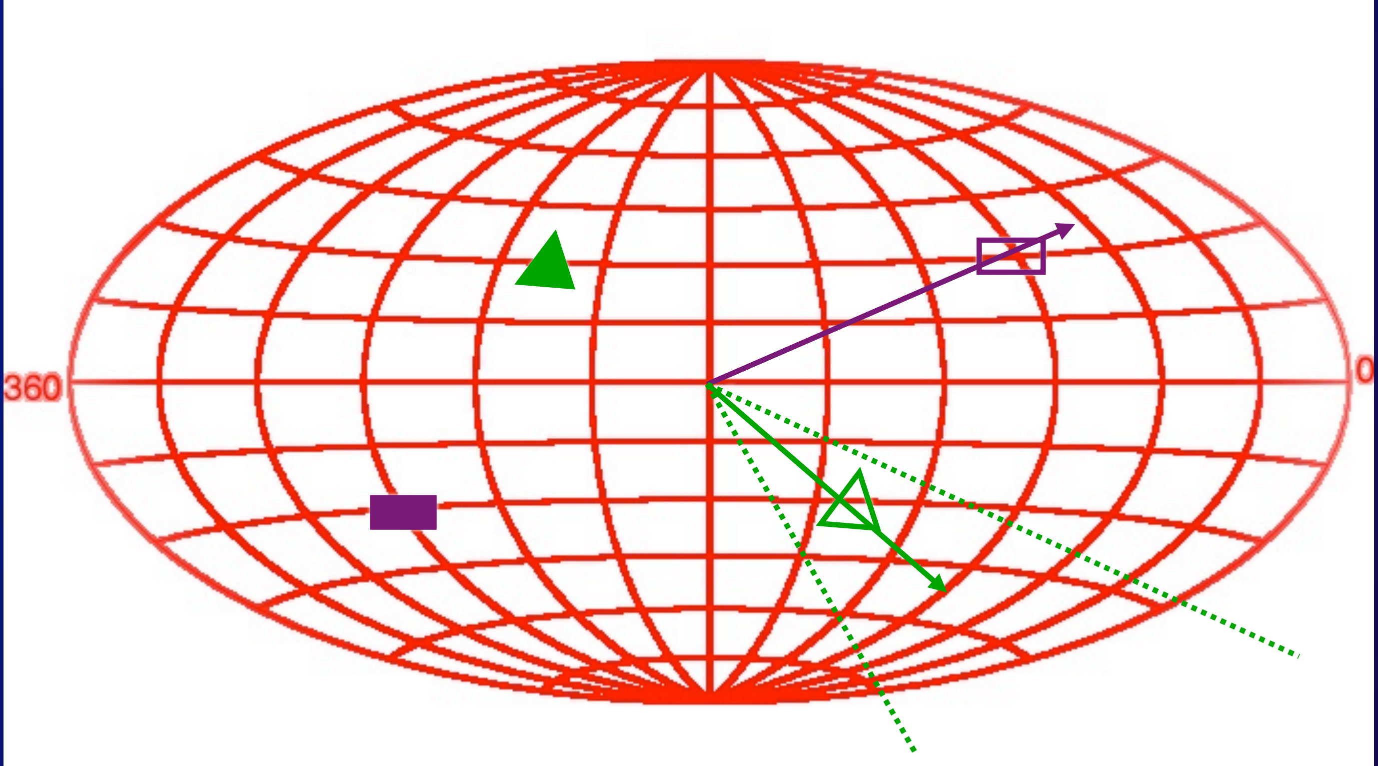
UCL



V_{CMB} 271° +29° 620 km / s

Local Group Velocity

Cautionary history lesson



V_{CMB} 271° +29° 620 km / s

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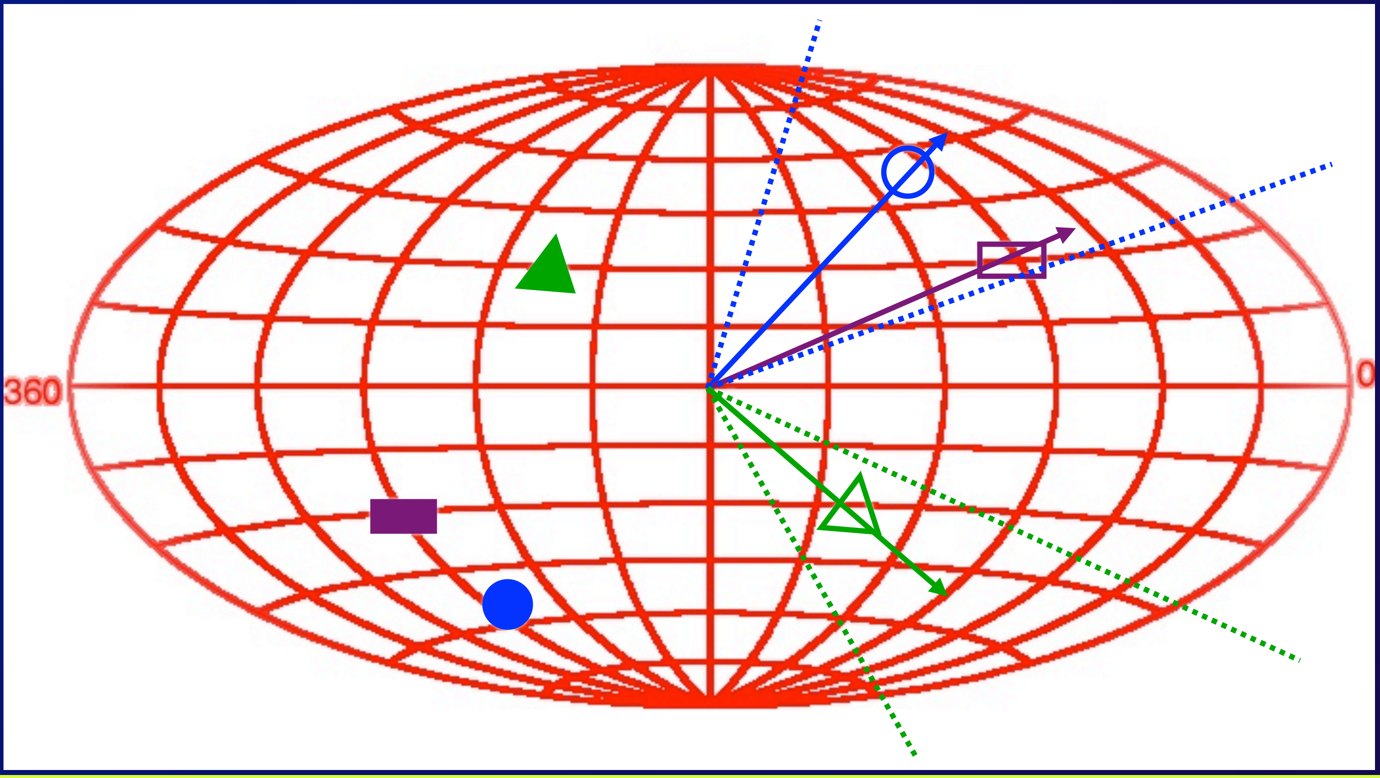

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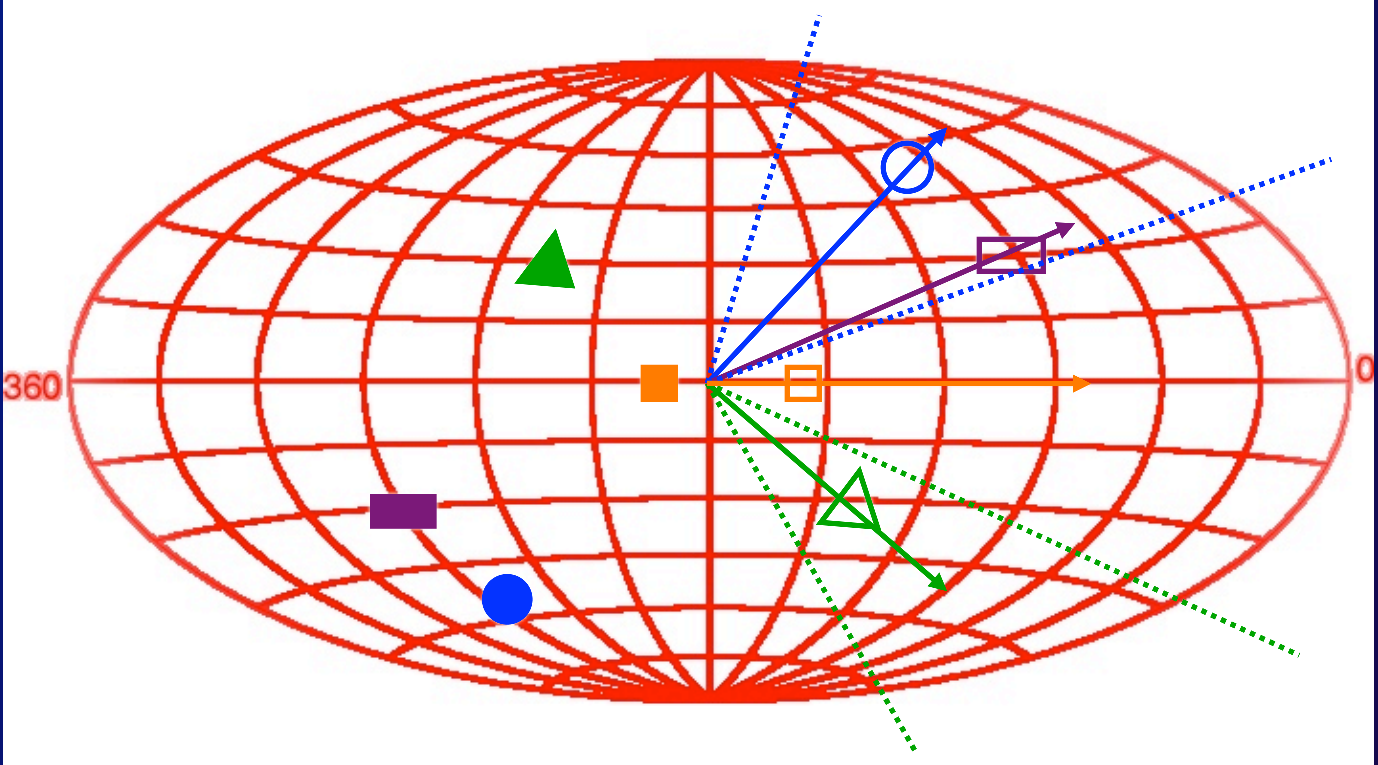

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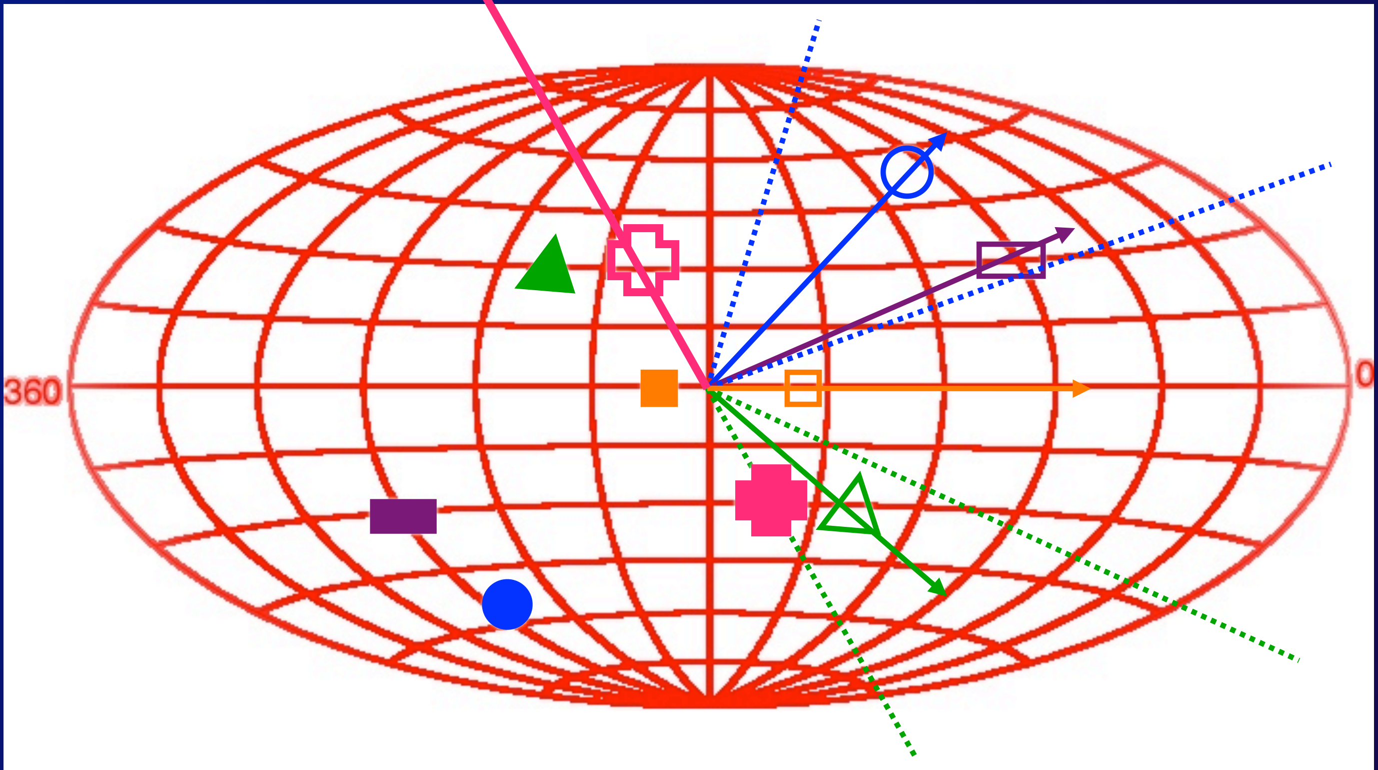

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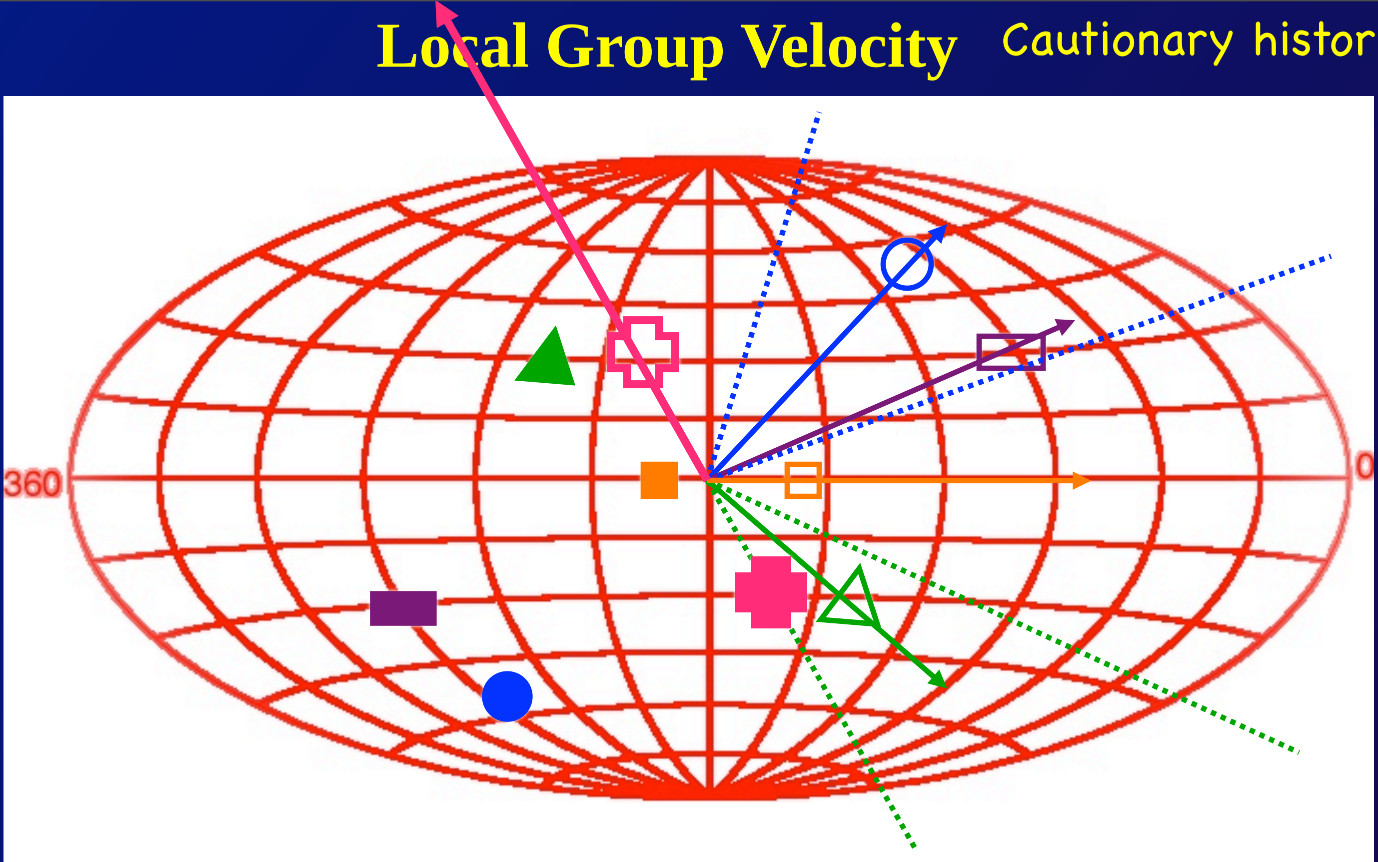

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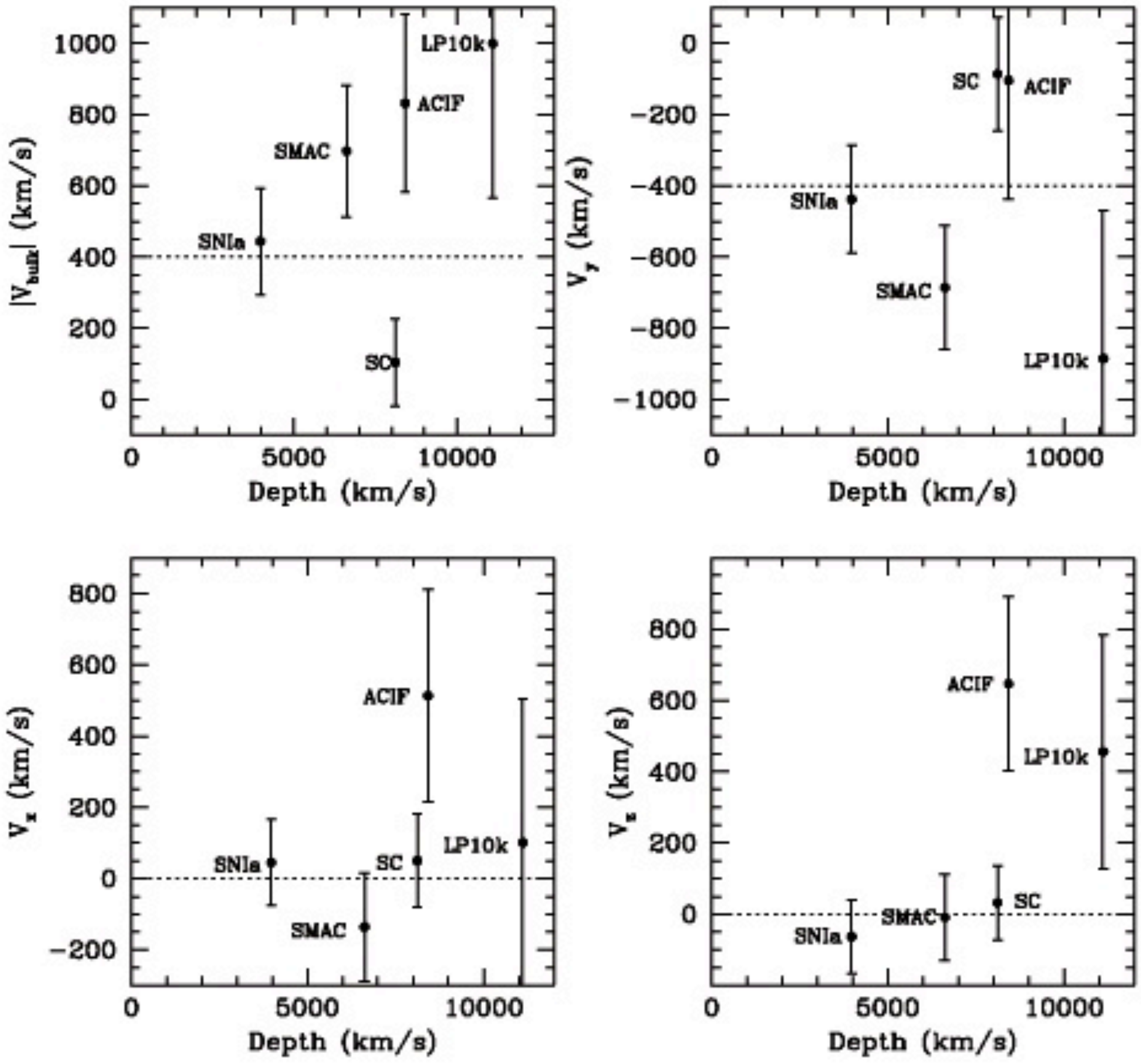
V_{SC}	180°	0°	100 ± 150 km / s



|V_bulk| (km/s)
1000
800
600
400
200
0
LP10k
ACIF
SMAC
SNIa
SC
V_y (km/s)
0
−200
−400
−600
−800
−1000
V_x (km/s)
800
600
400
200
0
−200
V_z (km/s)
5000
10000
Depth (km/s)

¿ Why ?

In large scale observations we look for

In large scale observations we look for

Estimators

In large scale observations we look for

Estimators

We try to estimate an underlying quantity

In large scale observations we look for

Estimators

We try to estimate an underlying quantity

Estimator = True quantity ⊗ Window function

e.g.

$$\tilde{p} = N\int \frac{d^3k}{(2\pi)^3}\, p\left(\vec{k}\right) W\left(\vec{k}\right)$$

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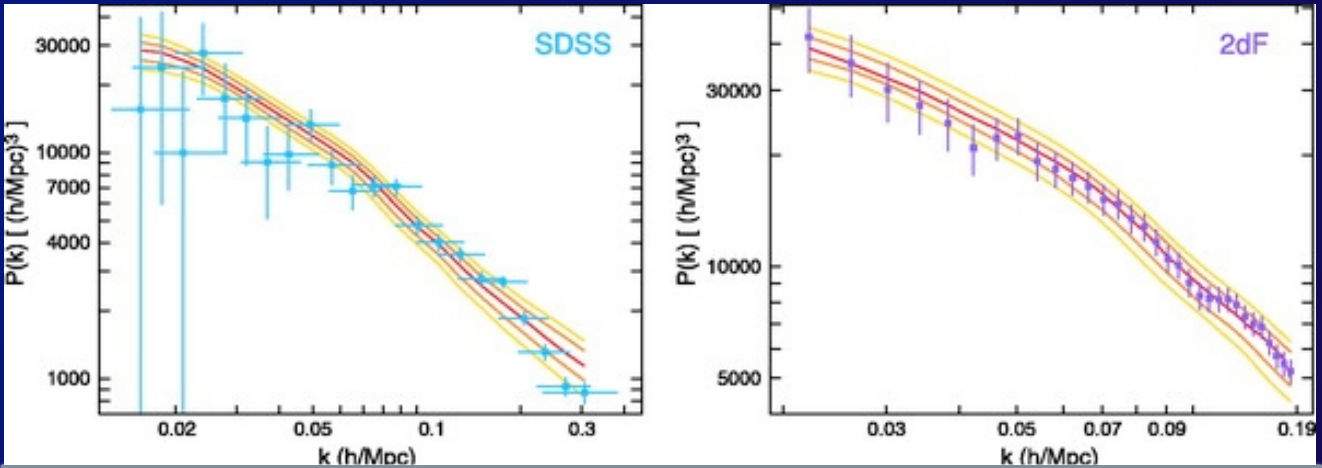

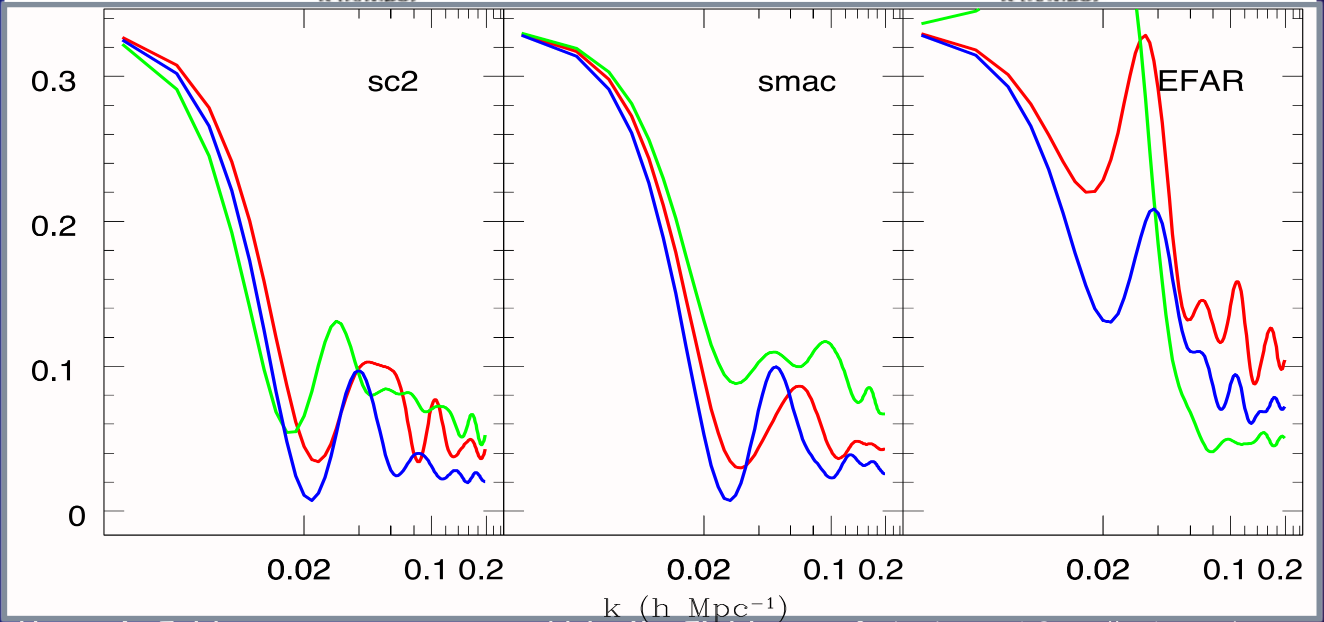

Velocity Fields

The Modern Version

HAF, Watkins & Hudson, In preperation (2009)

Watkins, HAF & Hudson, MNRAS, 392, 743-756 (2009)

HAF & Watkins, MNRAS 387, 825-829 (2008)

Watkins & HAF, MNRAS 379, 343-348 (2007)

Sarkar, HAF & Watkins, MNRAS 375 691-697 (2007)

Redshift-Distance surveys

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  - o measurement errors
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- The overall errors are
  - Statistical
  - Systematic
  - Aliasing

The Physics of Velocity Fields

On scales that are small compared to the Hubble radius, galaxy motions are manifest in deviations from the idealized isotropic cosmological expansion

$$cz = H_0 r + \hat{\mathbf{r}} \cdot [\mathbf{v}(\mathbf{r}) - \mathbf{v}(0)]$$

The redshift-distance samples, obtained from peculiar velocity surveys, allow us to determine the radial (line-of-sight) component of the peculiar velocity of each galaxy:

$$v(r) = \hat{\mathbf{r}} \cdot \mathbf{v}(\mathbf{r}) = cz - H_0 r$$

The Physics of Velocity Fields

Galaxies trace the large-scale linear velocity field v(r) which is described by a Gaussian random field that is completely defined, in Fourier space, by its velocity power spectrum $P_v(k)$.

Fourier Transform of the line-of-sight velocity

$$\hat{\mathbf{r}} \cdot \mathbf{v}(\mathbf{r}) = \frac{1}{(2\pi)^3} \int d^3\mathbf{k}\, \hat{\mathbf{r}} \cdot \hat{\mathbf{k}}\, v(\mathbf{k})\, \mathbf{e}^{\mathbf{i}\mathbf{k}\cdot\mathbf{r}}$$

Define the velocity power spectrum $P_v(k)$

$$\langle v(\mathbf{k}) v^*(\mathbf{k}') \rangle = (2\pi)^3 P_v(k) \delta_D(\mathbf{k} - \mathbf{k}')$$

Imperial College London

The Physics of Velocity Fields

In linear theory, the velocity power spectrum is related to the density power spectrum

$$P_v(k) = \frac{H^2}{k^2}\, f^2(\Omega_{m,0}, \Omega_\Lambda)\, P(k)$$

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The rate of growth of the perturbations at the present epoch

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The power spectrum provides a complete statistical description of the linear peculiar velocity field.

Likelihood Methods for Peculiar Velocities

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A catalog of peculiar velocities galaxies, labeled by an index n

Positions r_n

Estimates of the line-of-sight peculiar velocities S_n

Uncertainties σ_n

Assume that observational errors are Gaussian distributed.

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Model the velocity field as a uniform streaming motion, or bulk flow, denoted by U, about which are random motions drawn from a Gaussian distribution with a 1-D velocity dispersion σ_*

Likelihood Methods for Peculiar Velocities

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The measured peculiar velocity of galaxy n

$$S_n = \hat{r}_{n,i} v_i(\mathbf{r}_n) + \epsilon_n$$

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Theoretical covariance matrix for the bulk flow components

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$$R_{ij}^{(v)} = \frac{1}{(2\pi)^3}\int P_{(v)}(k) W_{ij}^2(k) d^3k$$

$$= \frac{H^2 f^2(\Omega_0)}{2\pi^2}\int P(k) W_{ij}^2(k) dk$$

Likelihood Methods for Peculiar Velocities

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★ surveys probe the velocity field in a different way

Recent Large-Scale Bulk Flow Results

Survey	Method	N	Depth km/s	V km/s	Random err (km/s)	l	b
LP	BCG	119	8400	830	220	330	39
SC	TF	63	7000	80	100	290	20
Willick	TF	15	11000	1100	450	270	27
SMAC	FP	56	6000	650	180	260	-4
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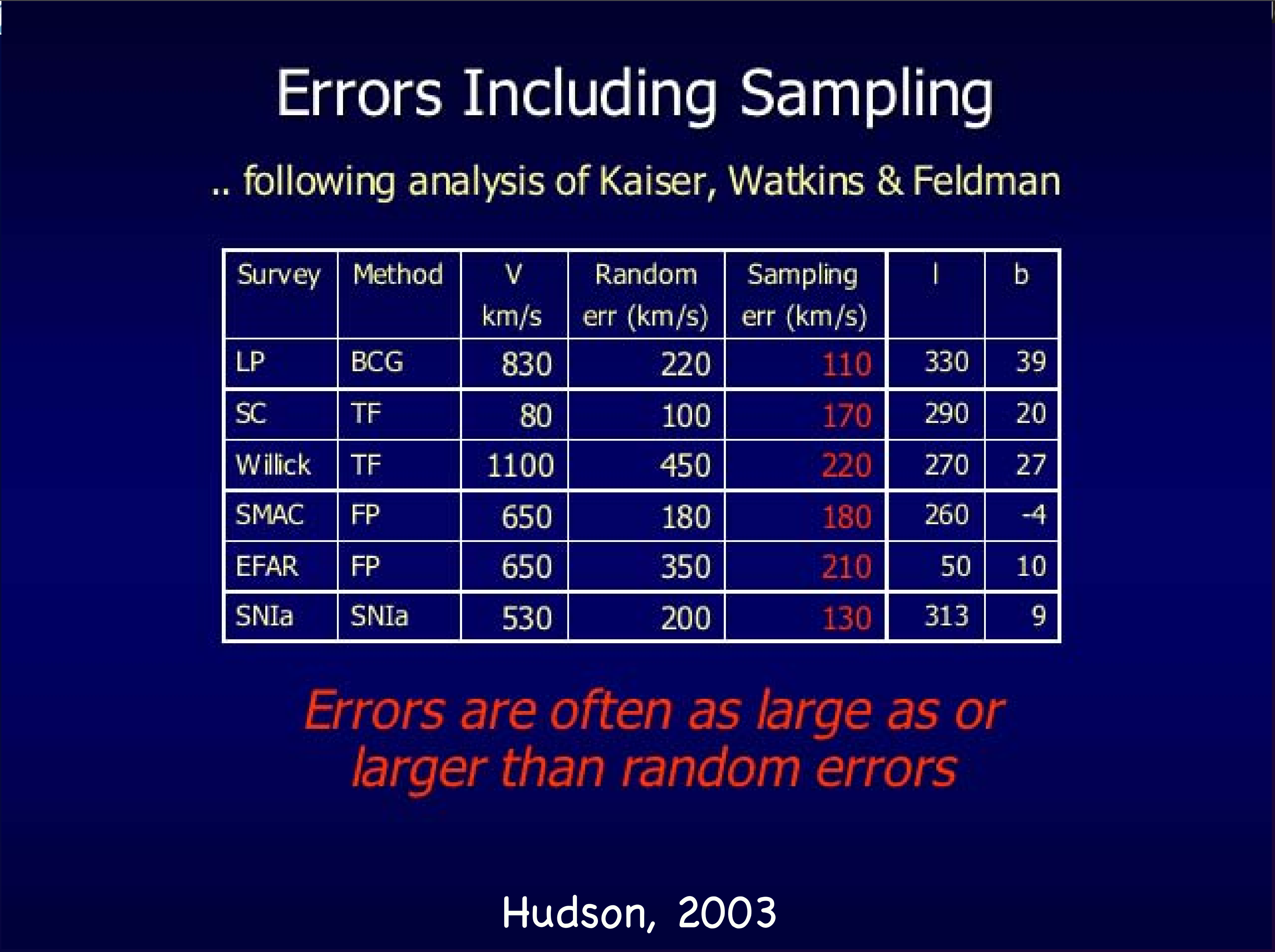
Are these consistent?

…errors do not allow for effects of sparse sampling



Errors Including Sampling

.. following analysis of Kaiser, Watkins & Feldman

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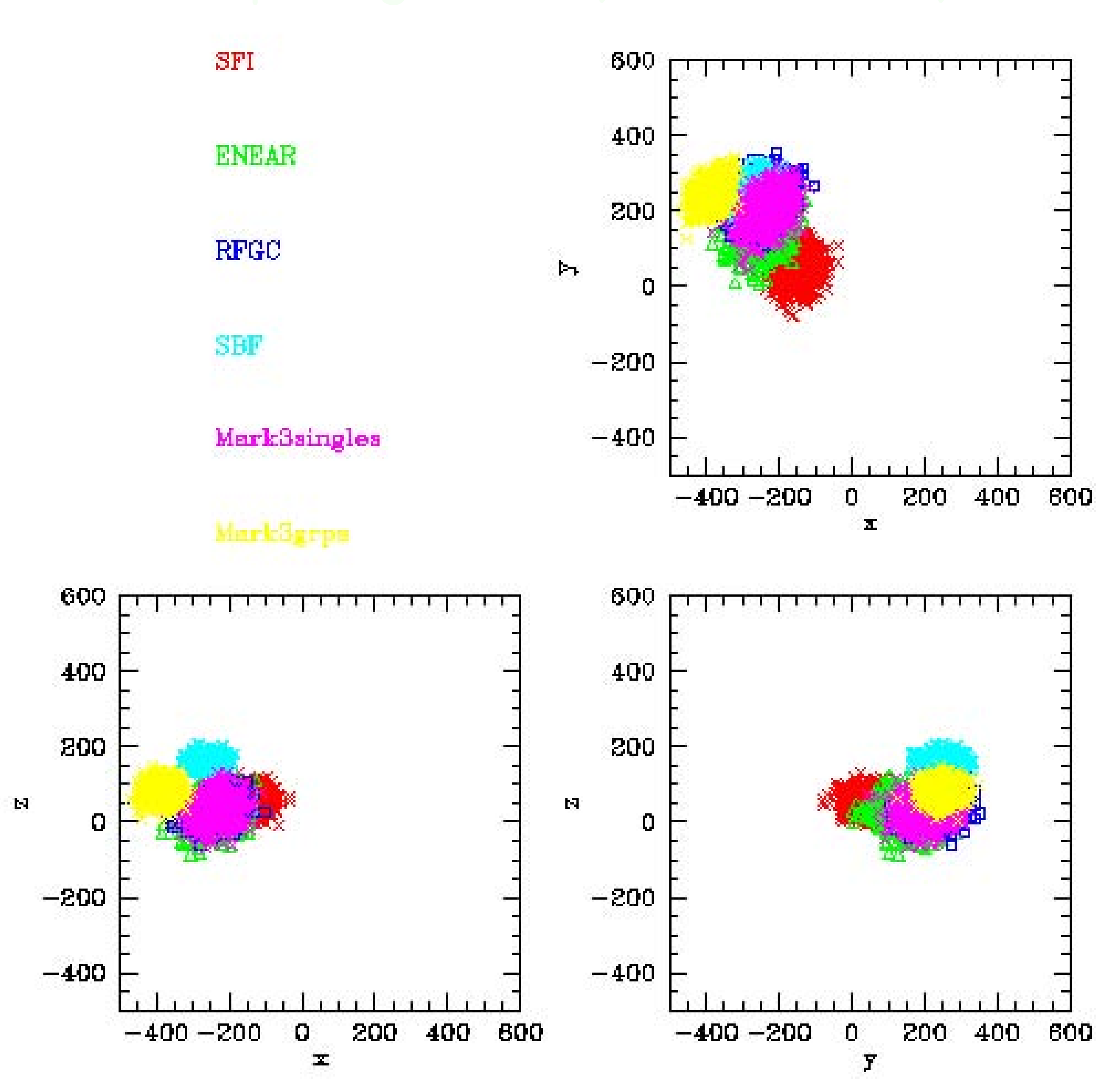
Errors are often as large as or larger than random errors

Hudson, 2003

Comparing Velocity Field Surveys



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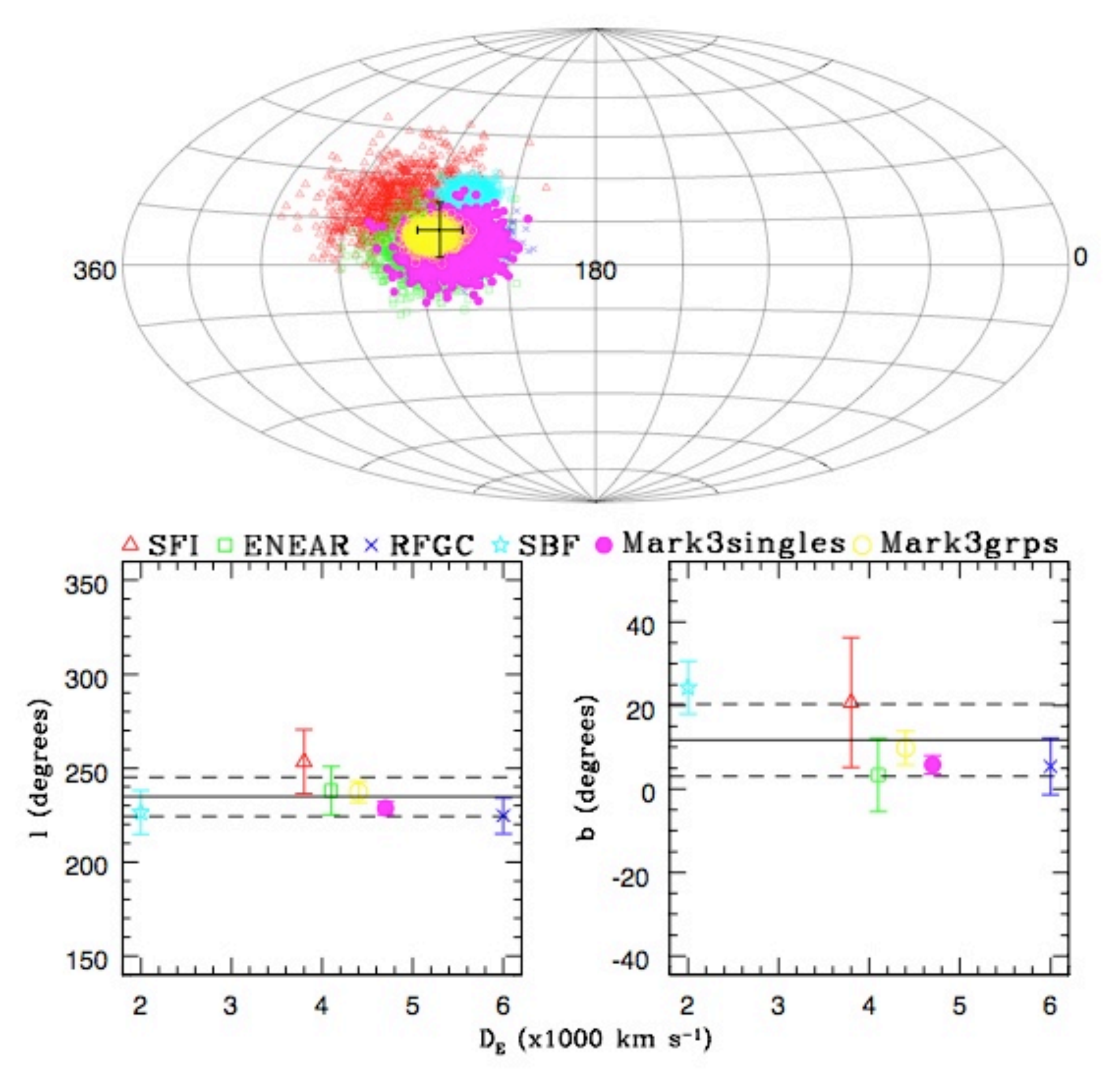

Can we do better?

Get rid of small scale aliasing?

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Improve the window function design

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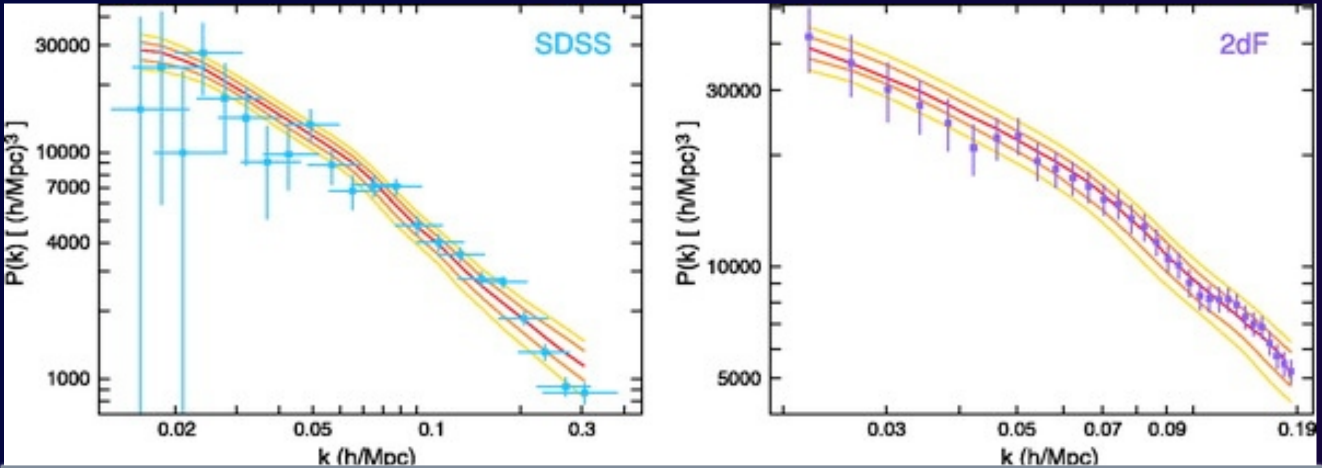

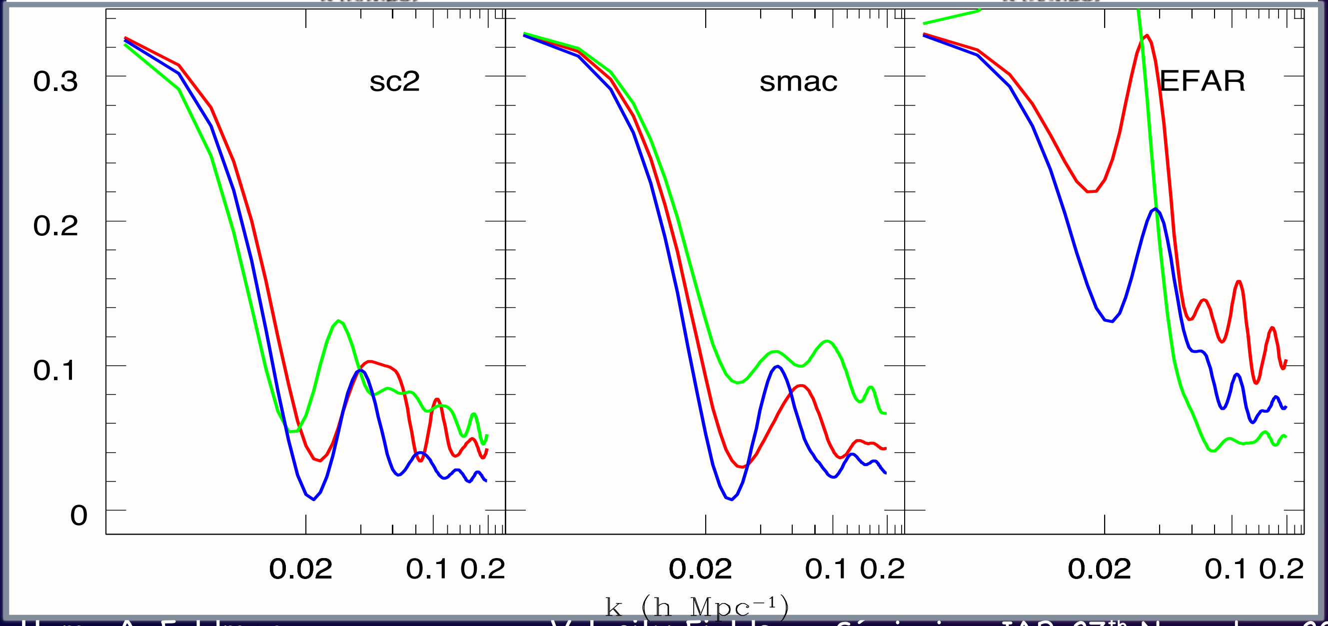

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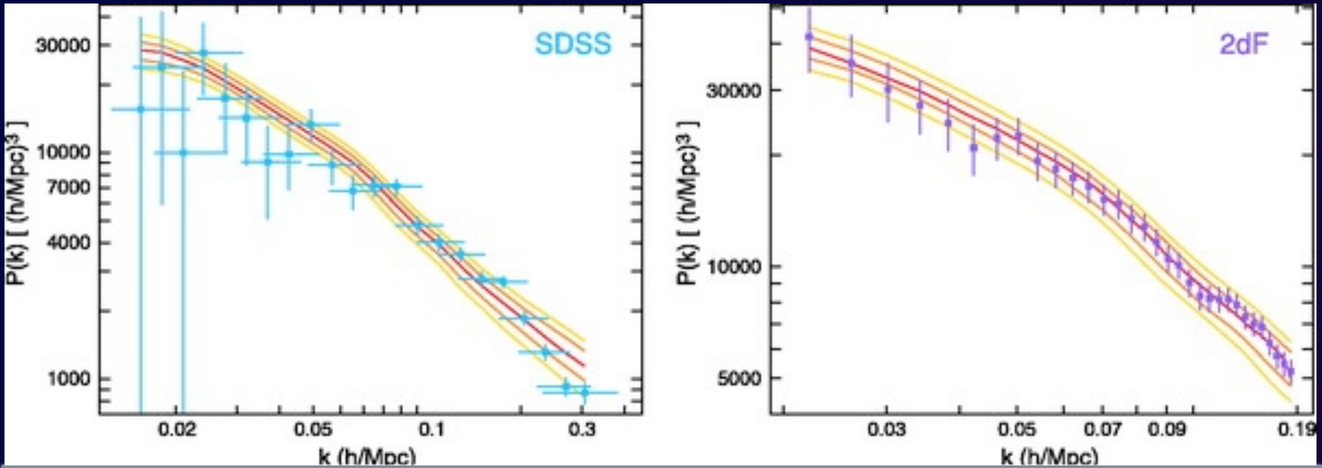

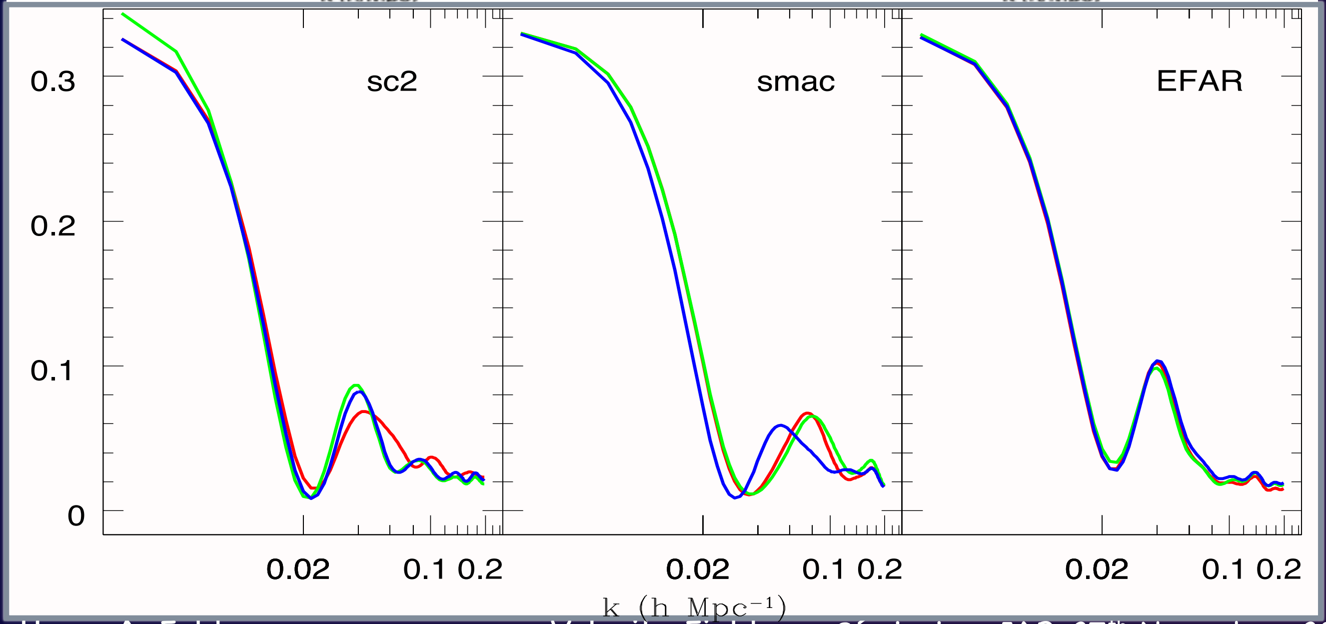

Window Function Design

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Decomposition of the velocity field

Kaiser 88, Jaffe Kaiser 95

$$v_i(\mathbf{r}) = U_i + U_{ij}r_j + U_{ijk}r_jr_k + \ldots$$

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If the velocity is a potential flow then both shear and octupole are symmetric (curl Free)

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> 3 DoF for BF
> 6 DoF for shear
> 10 DoF for Octupole

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- 3 DoF for BF
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} 19 Independent components

Window Function Design

Window Function Design

The BF Maximum Likelihood Estimates of the weights (MLE)

$$w_{i,n} = A_{ij}^{-1} \sum_n \frac{\mathbf{x}_j \cdot \mathbf{r}_n}{\sigma_n^2 + \sigma_*^2}$$

depends on the spatial distribution and the errors.

Window Function Design

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depends on the spatial distribution and the errors.

Goal:

- Study motions on largest scales
- Require WF that
    - have narrow peaks
    - small amplitude outside peak

Window Function Design

Consider an ideal survey

- Very large number of points
- Isotropic distribution
- Gaussian falloff $n(r) \propto \exp(-r^2/2R_I^2)$

R_I Depth of the survey

Find the weights that specify the moments

$$u_i = \sum_n w_{i,n} S_n$$

that minimize the variance $\langle (u_i - U_i)^2 \rangle$

Window Function Design

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Ideal velocity moments

$$U_p = \sum_n g_p(\mathbf{r}_n) s_n / N$$

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$$\sum_n w'_{p,n} s_n \qquad \text{where} \qquad w'_{p,n} = g_p(\mathbf{r}_n)/N$$

On average, the correct amplitudes for the velocity moments

$$\langle u_p \rangle = U_p$$

Window Function Design

Ideal velocity moments

$$U_p = \sum_n g_p(\mathbf{r}_n) s_n / N$$

Moment amplitudes are linear combinations of the velocities

$$\sum_n w'_{p,n} s_n \qquad \text{where} \qquad w'_{p,n} = g_p(\mathbf{r}_n)/N$$

On average, the correct amplitudes for the velocity moments

$$\langle u_p \rangle = U_p$$

Require that $$\sum_n w_{p,n} g_q(\mathbf{r}_n) = \delta_{pq}$$

Window Function Design

Window Function Design

Enforce this constraint using Lagrange multiplier

$$\langle (U_p - u_p)^2 \rangle + \sum_q \lambda_{pq} (\sum_n w_{p,n} g_q(\mathbf{r}_n) - \delta_{pq})$$

Window Function Design

Enforce this constraint using Lagrange multiplier

$$\langle (U_p - u_p)^2 \rangle + \sum_q \lambda_{pq} (\sum_n w_{p,n} g_q (\mathbf{r}_n) - \delta_{pq})$$

or expand out the variance

$$\langle U_p^2 \rangle - \sum_n 2 w_{p,n} \langle S_n U_p \rangle + \sum_{n,m} w_{p,n} w_{p,m} \langle S_n S_m \rangle +$$

$$\sum_q \lambda_{pq} \left(\sum_n w_{p,n} g_q(\mathbf{r}_n) - \delta_{pq} \right)$$

Window Function Design

Enforce this constraint using Lagrange multiplier

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$$\langle U_p^2 \rangle - \sum_n 2 w_{p,n} \langle S_n U_p \rangle + \sum_{n,m} w_{p,n} w_{p,m} \langle S_n S_m \rangle +$$

$$\sum_q \lambda_{pq} \left(\sum_n w_{p,n} g_q(\mathbf{r}_n) - \delta_{pq} \right)$$

Minimize with respect to $w_{p,n}$

Window Function Design

Window Function Design

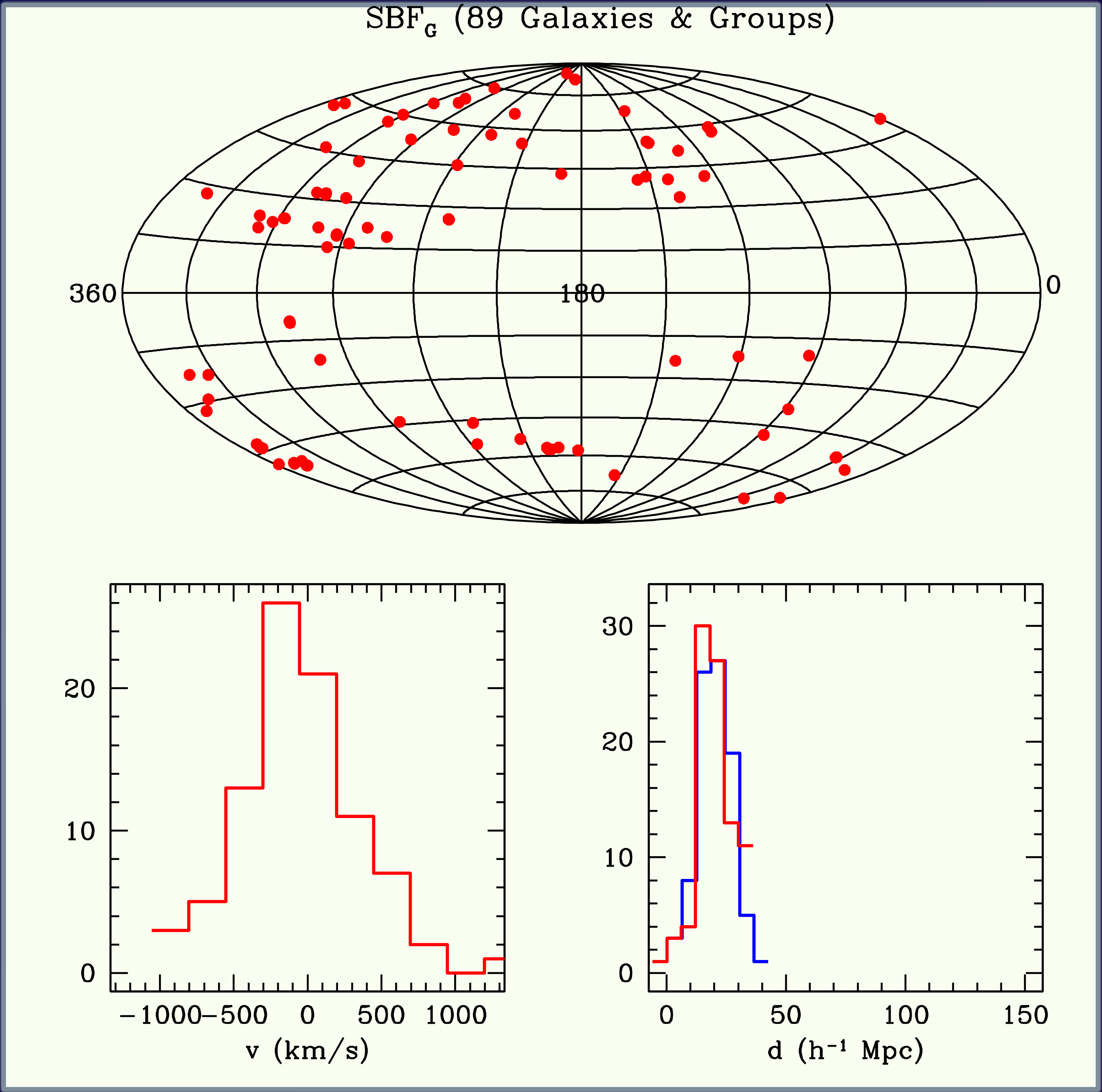
$$-2\langle S_n U_p \rangle + 2\sum_m w_{p,m}\langle S_n S_m \rangle + \sum_q \lambda_{pq} g_q(\mathbf{r}_n) = 0$$

Window Function Design

$$-2\langle S_n U_p\rangle + 2\sum_m w_{p,m}\langle S_n S_m\rangle + \sum_q \lambda_{pq} g_q(\mathbf{r}_n) = 0$$

$$w_{p,n} = \sum_m G^{-1}_{nm}\left(\langle S_m U_p\rangle - \frac{1}{2}\sum_q \lambda_{pq} g_q(\mathbf{r}_m)\right)$$

Peculiar Velocity Surveys



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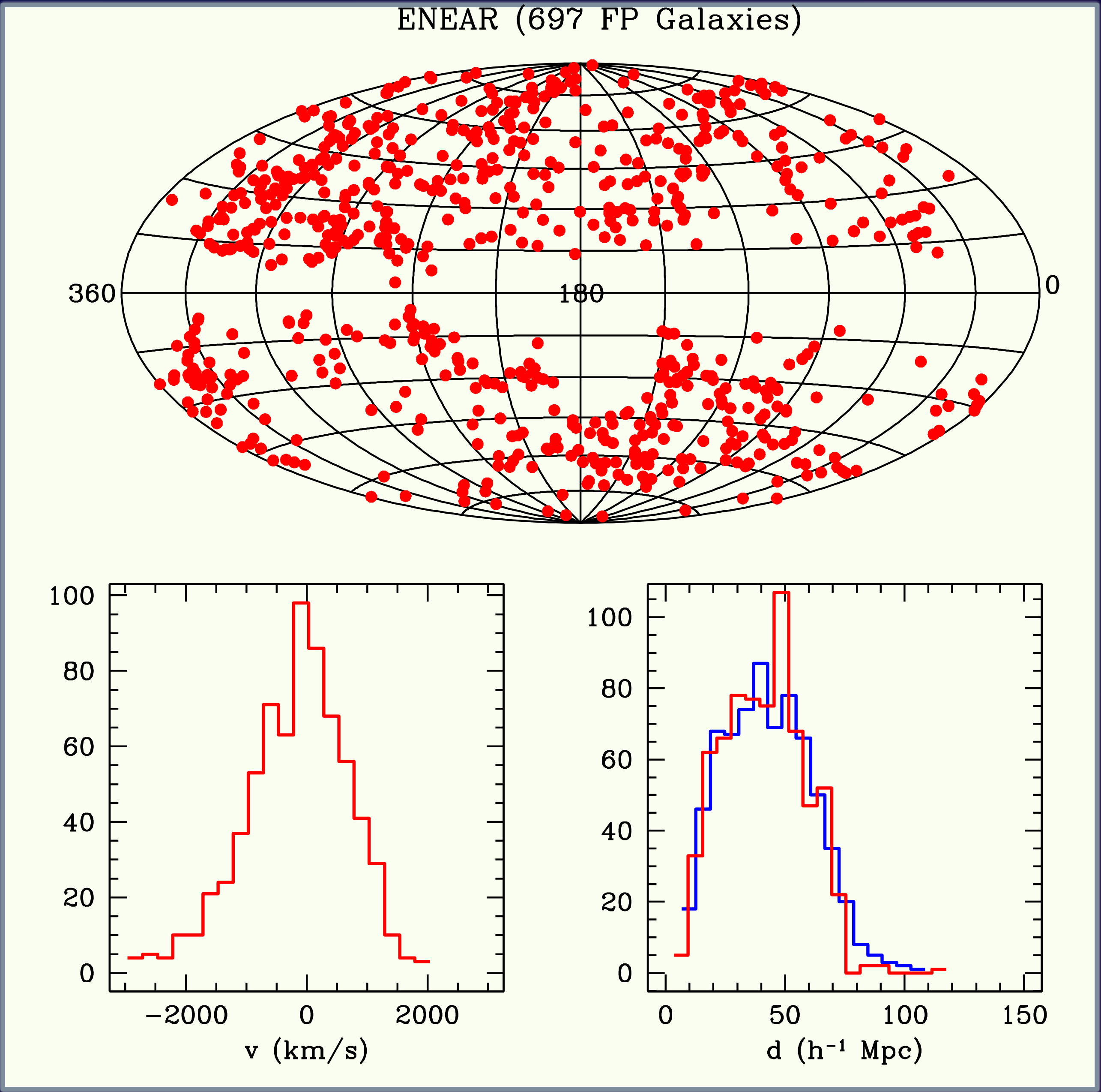

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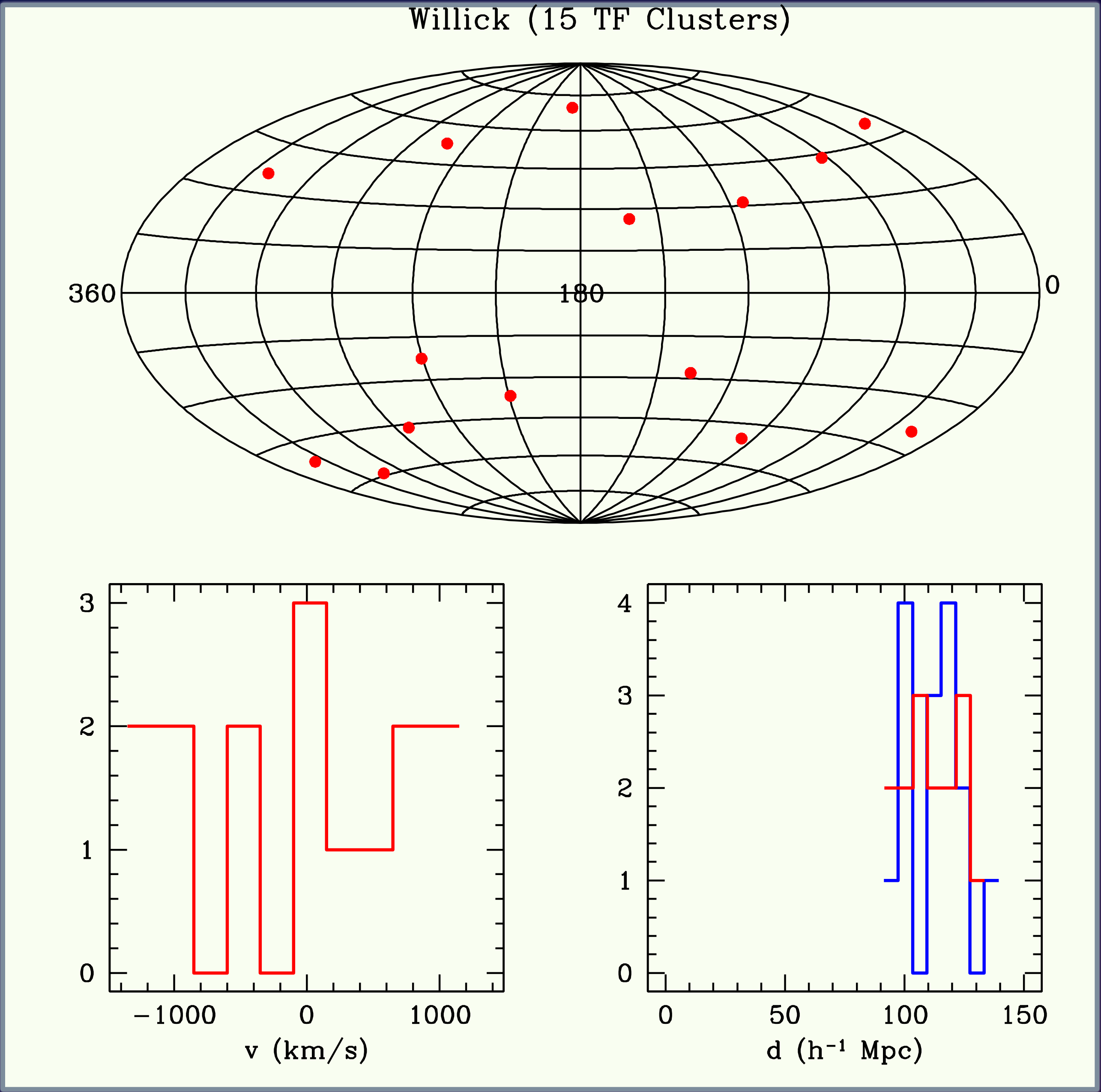

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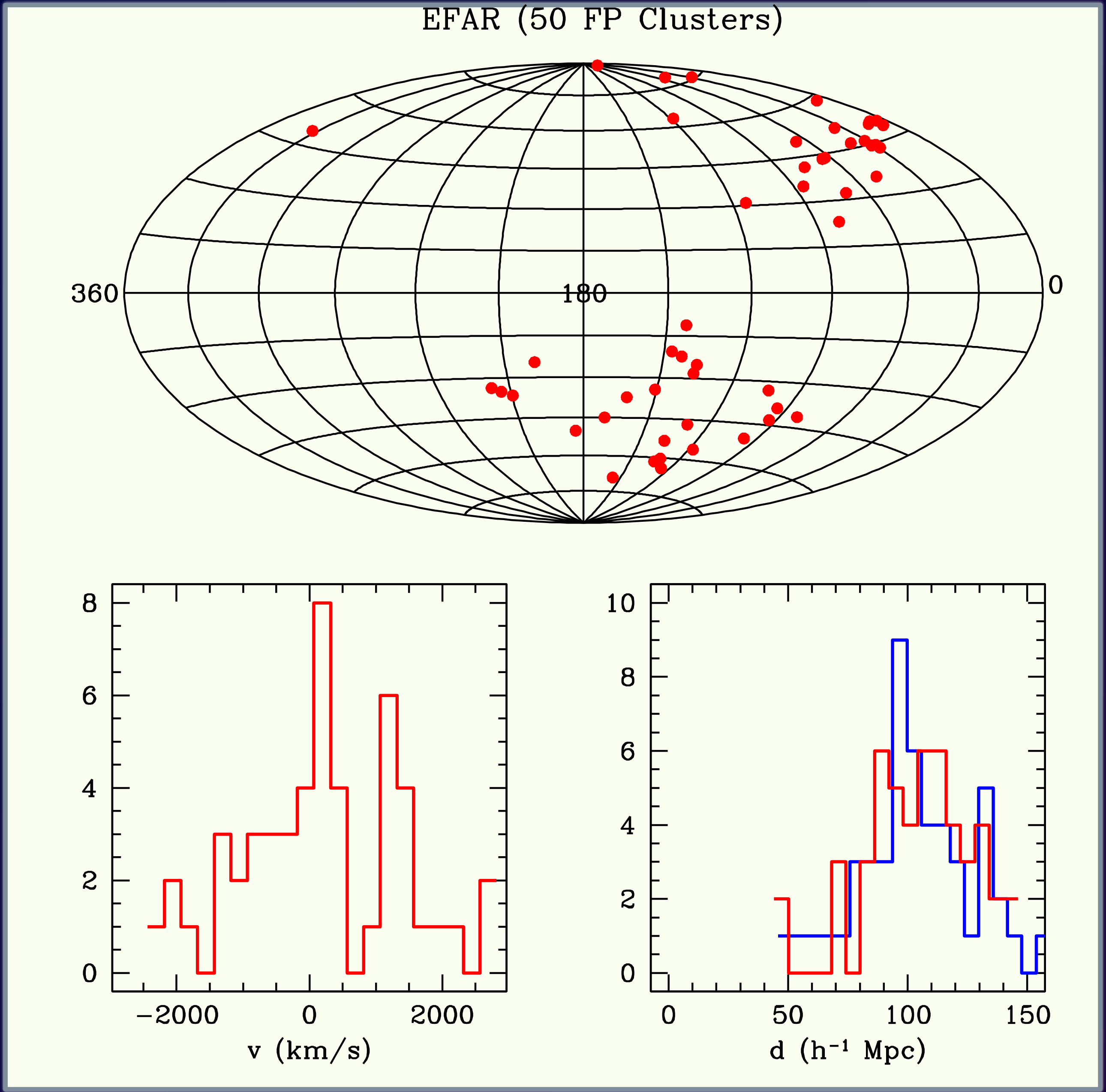

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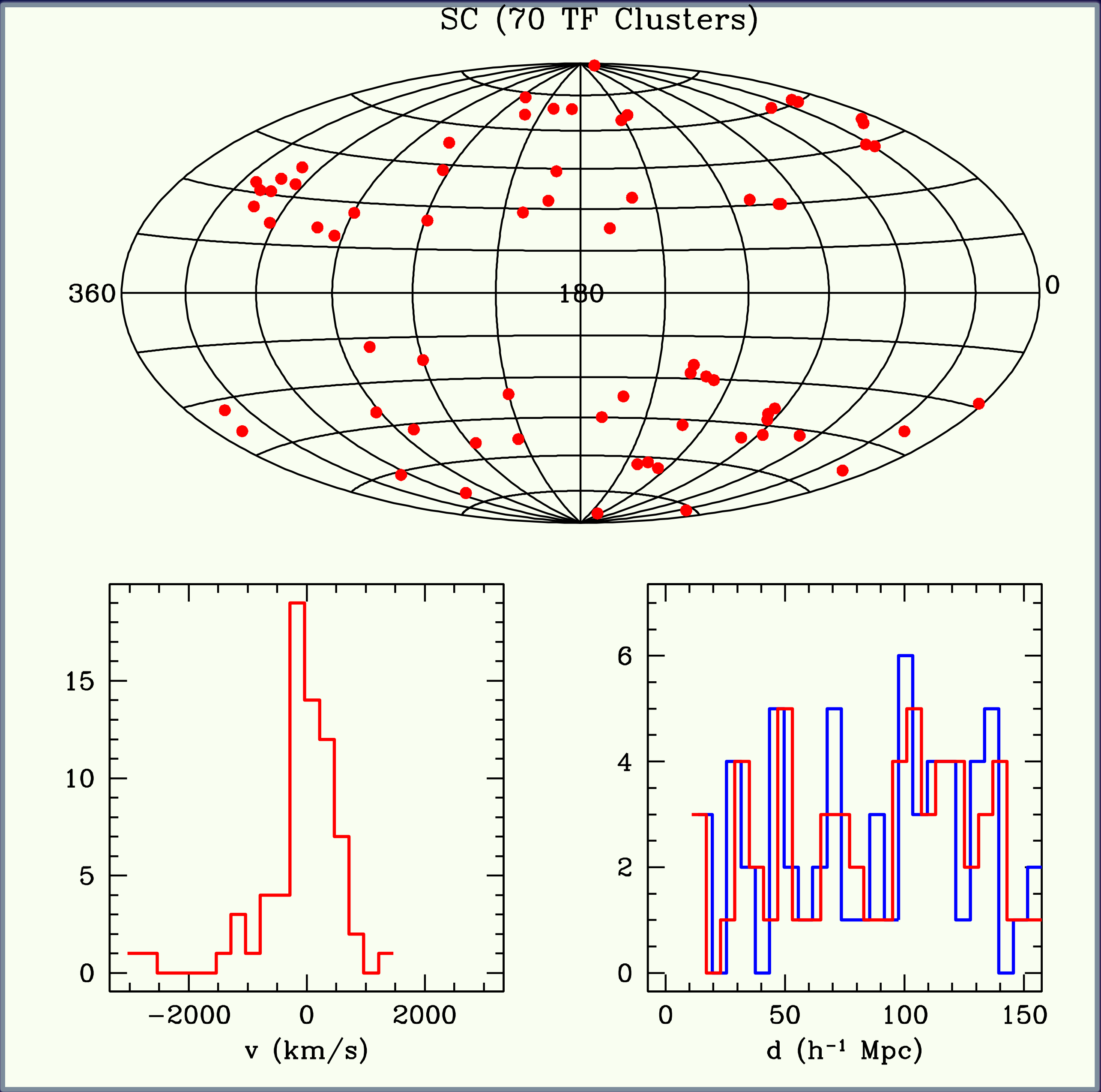

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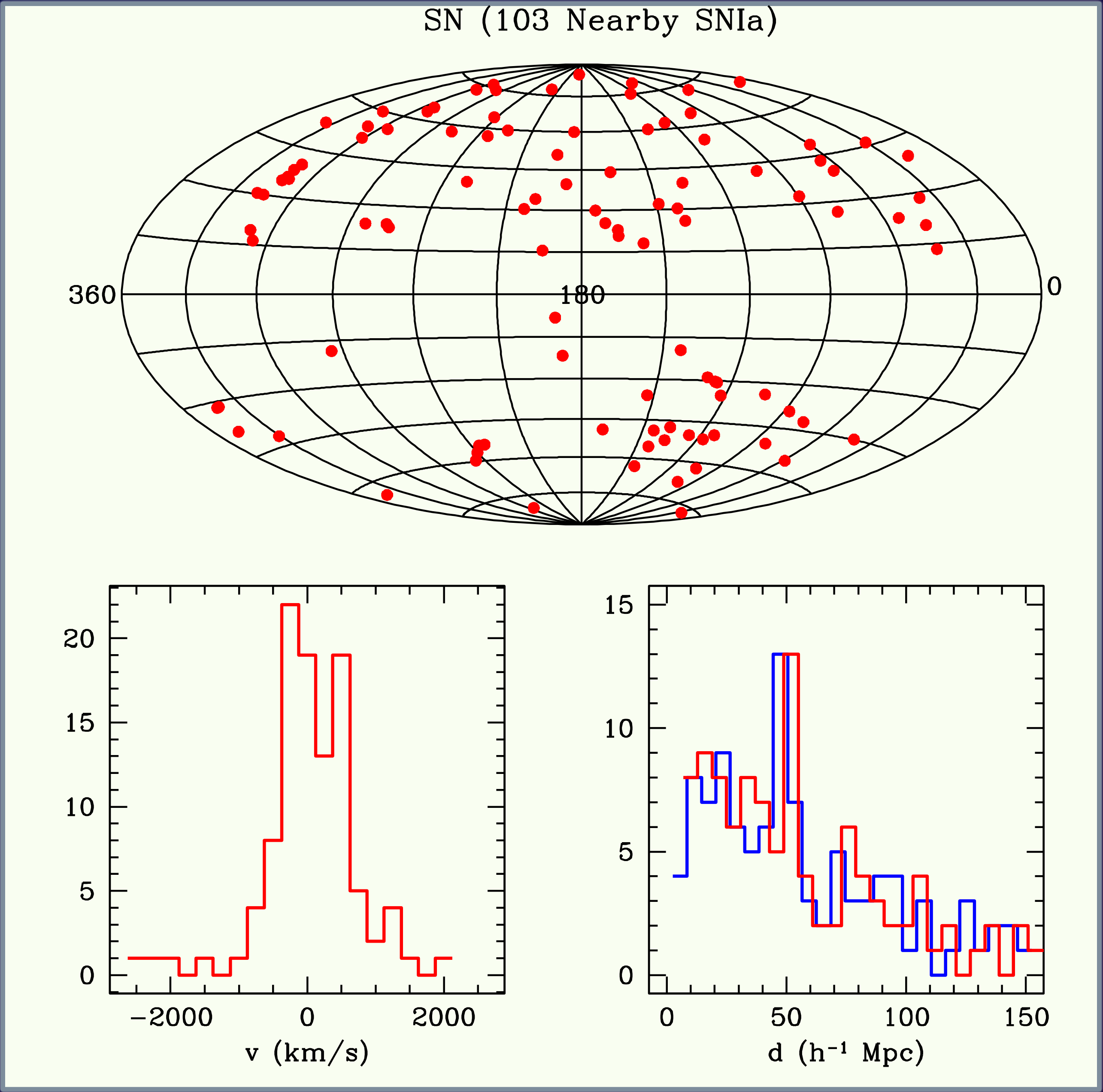

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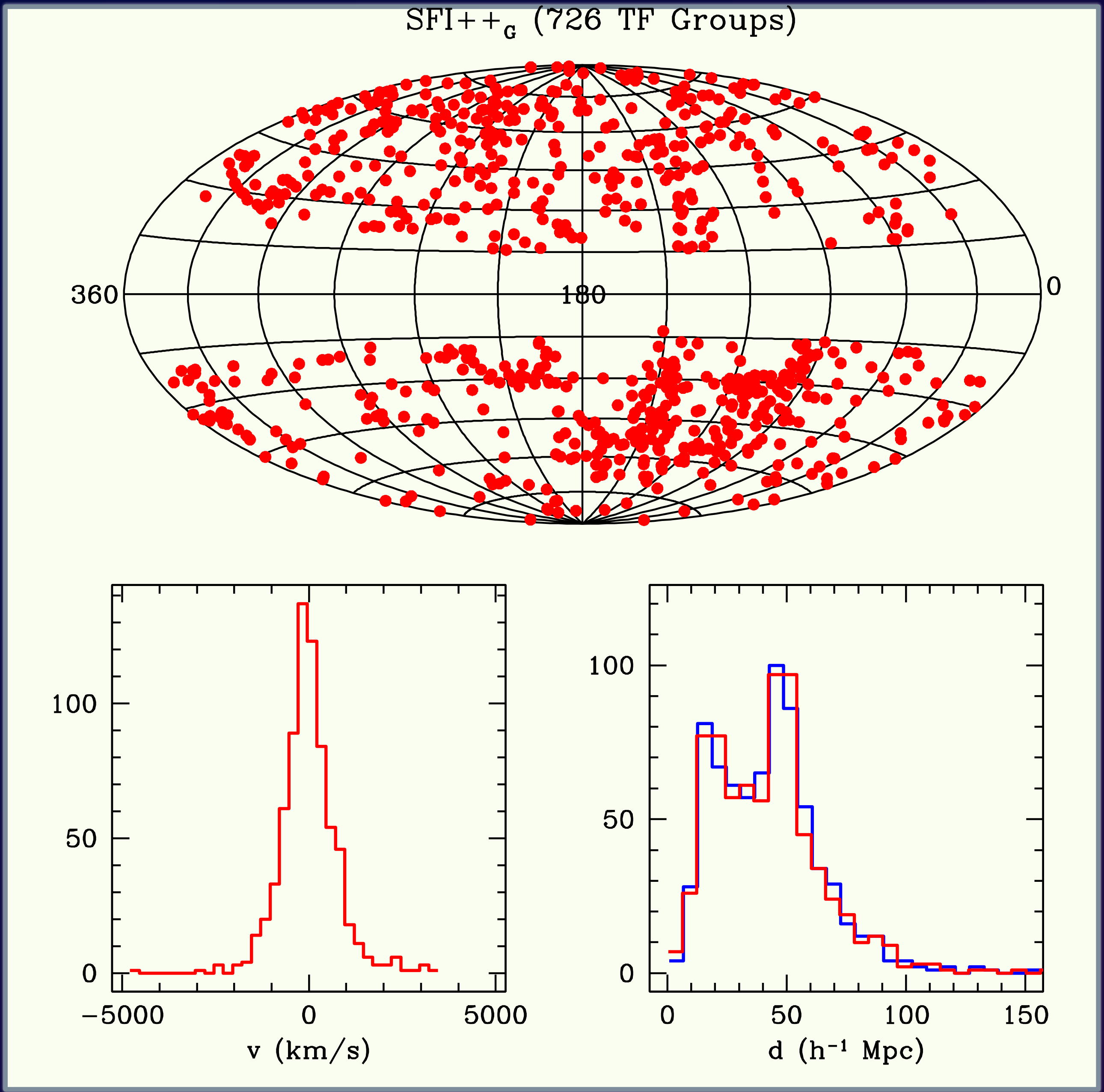

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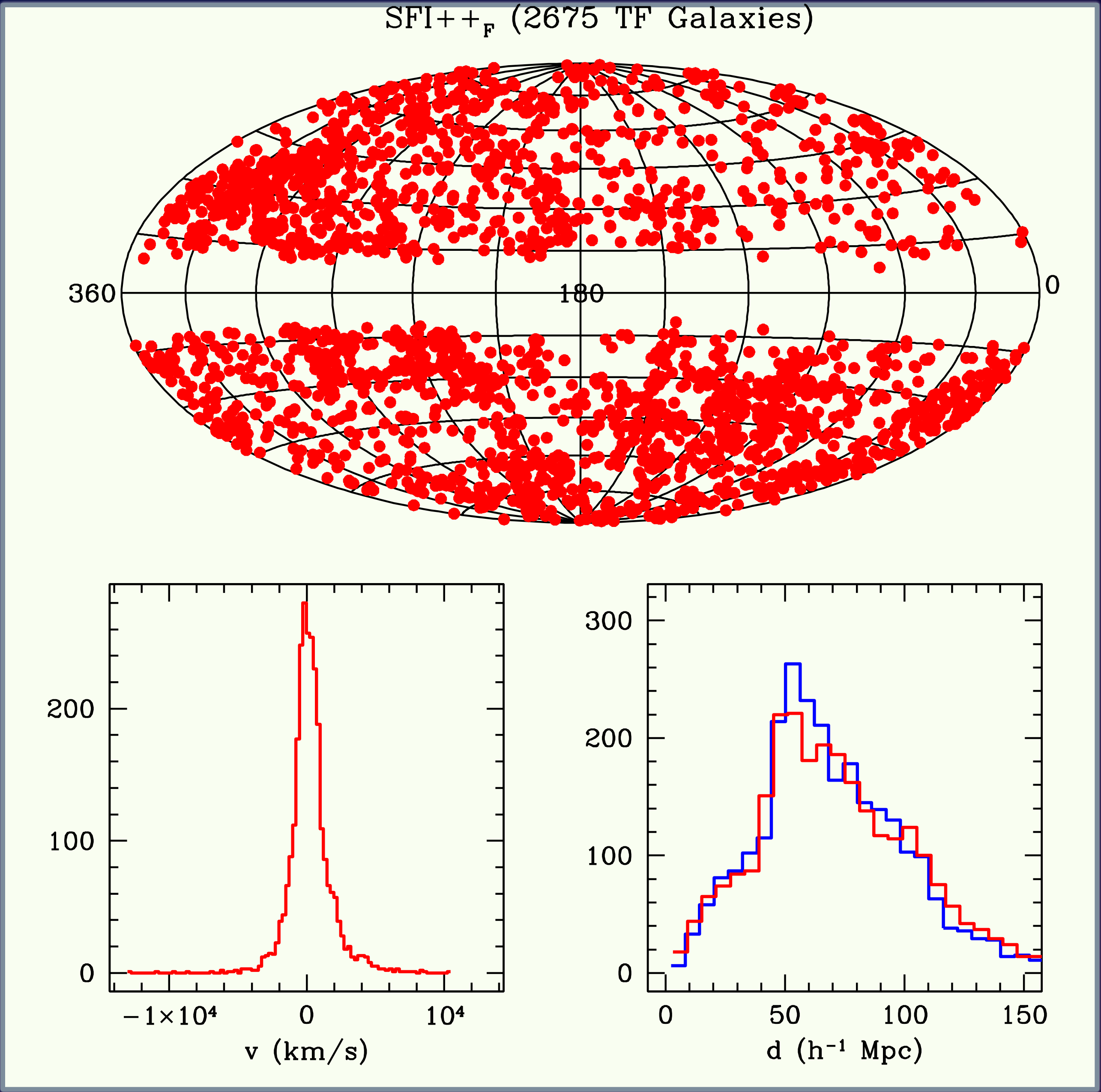

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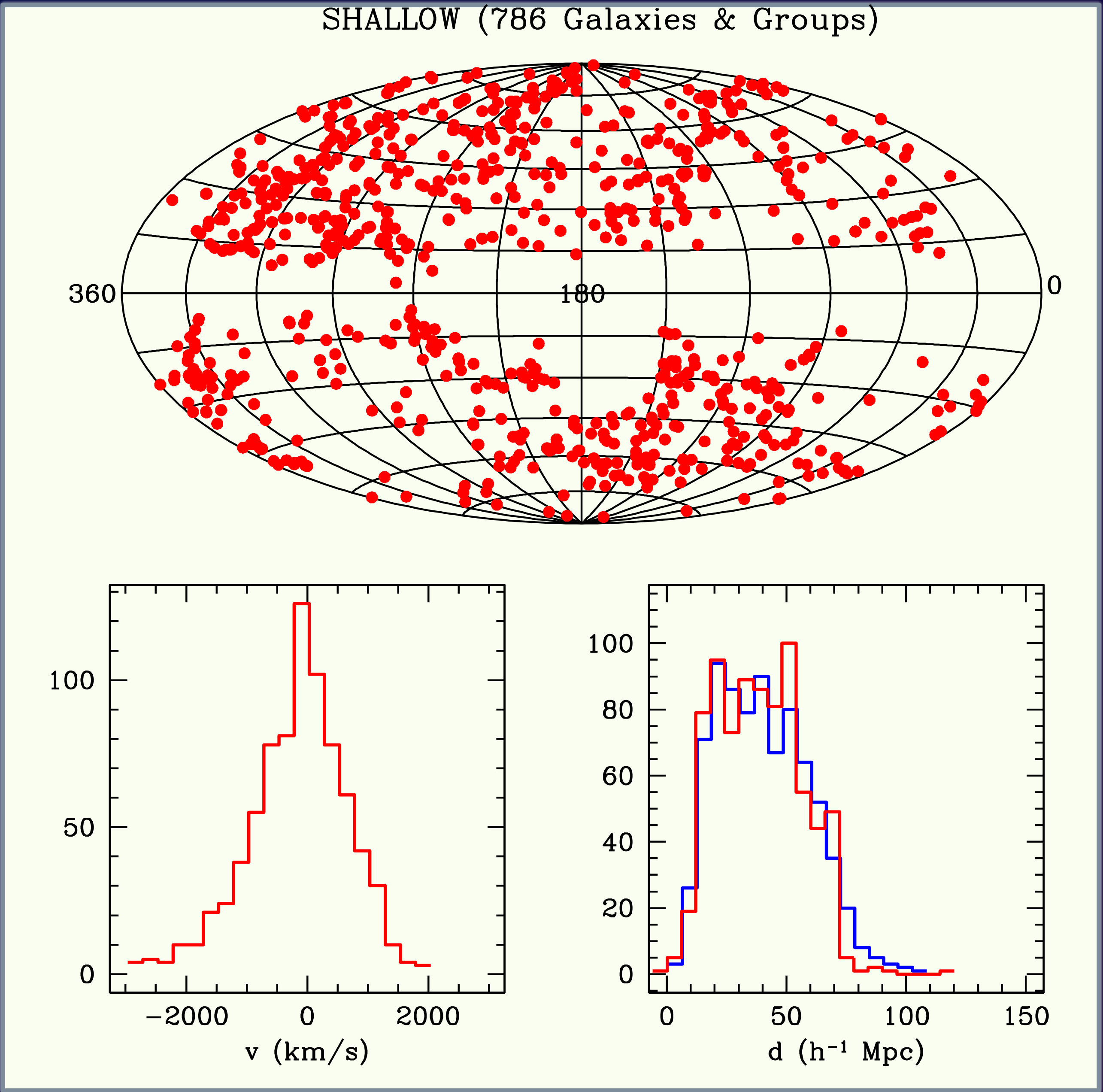

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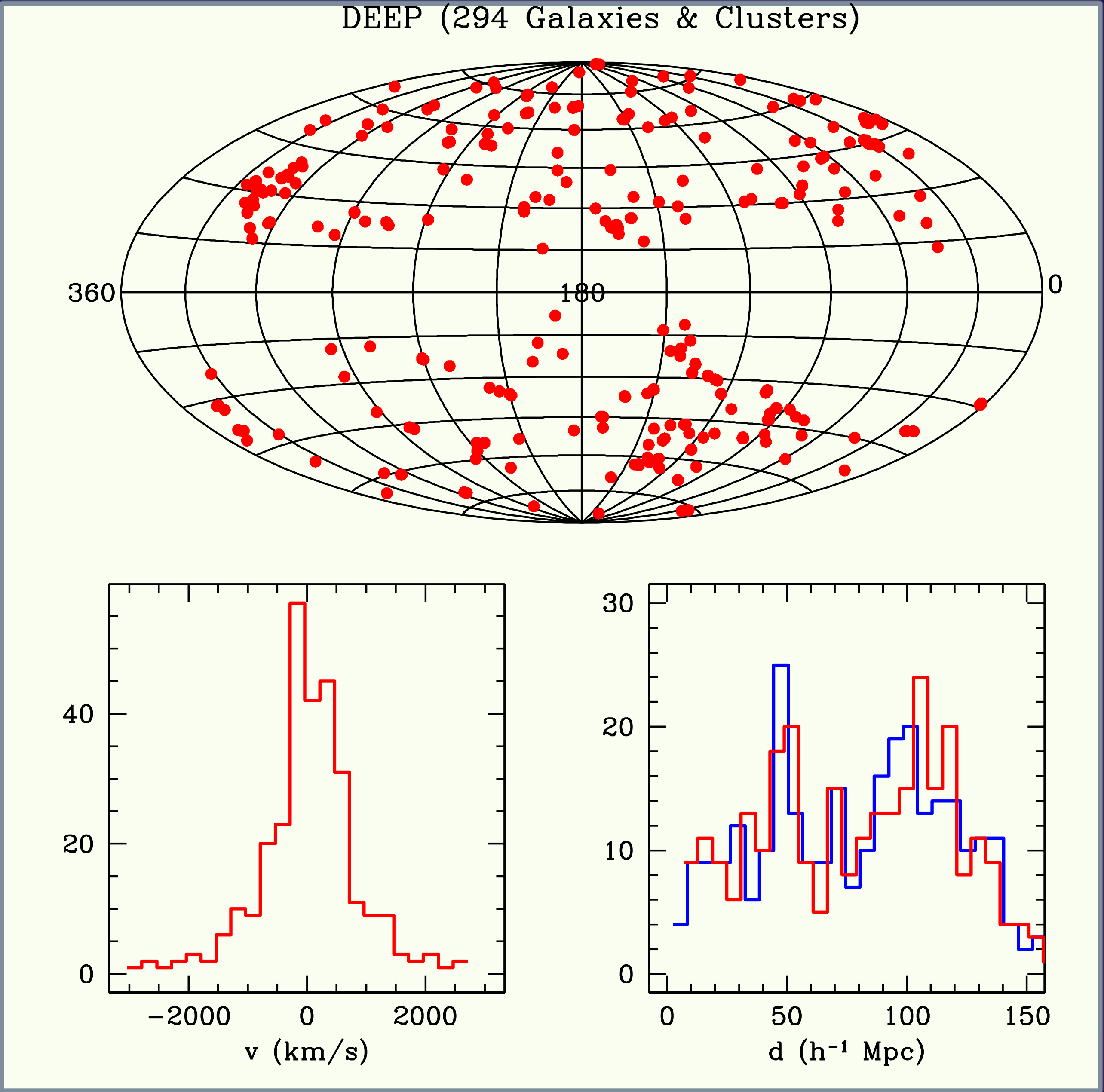

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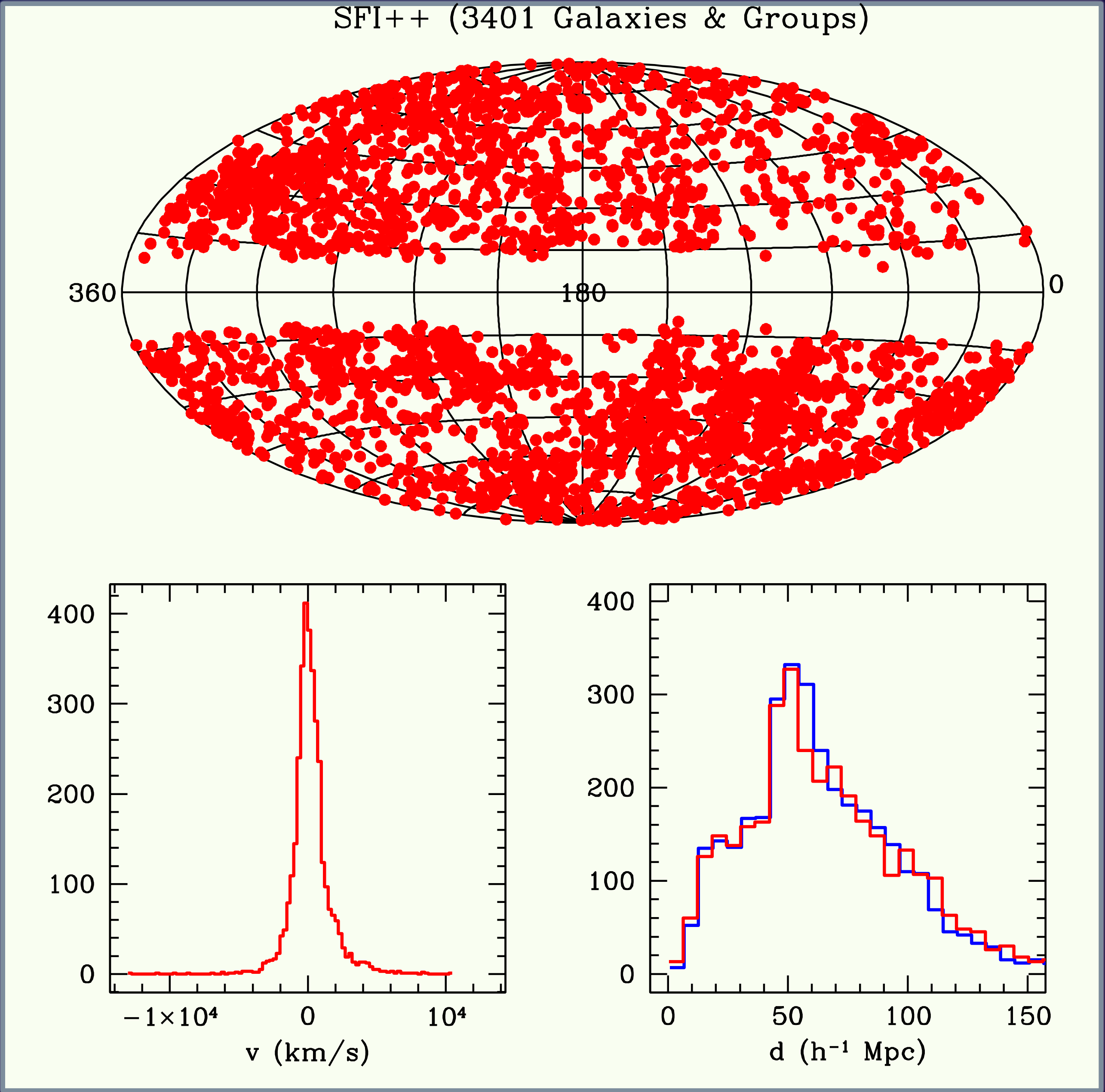

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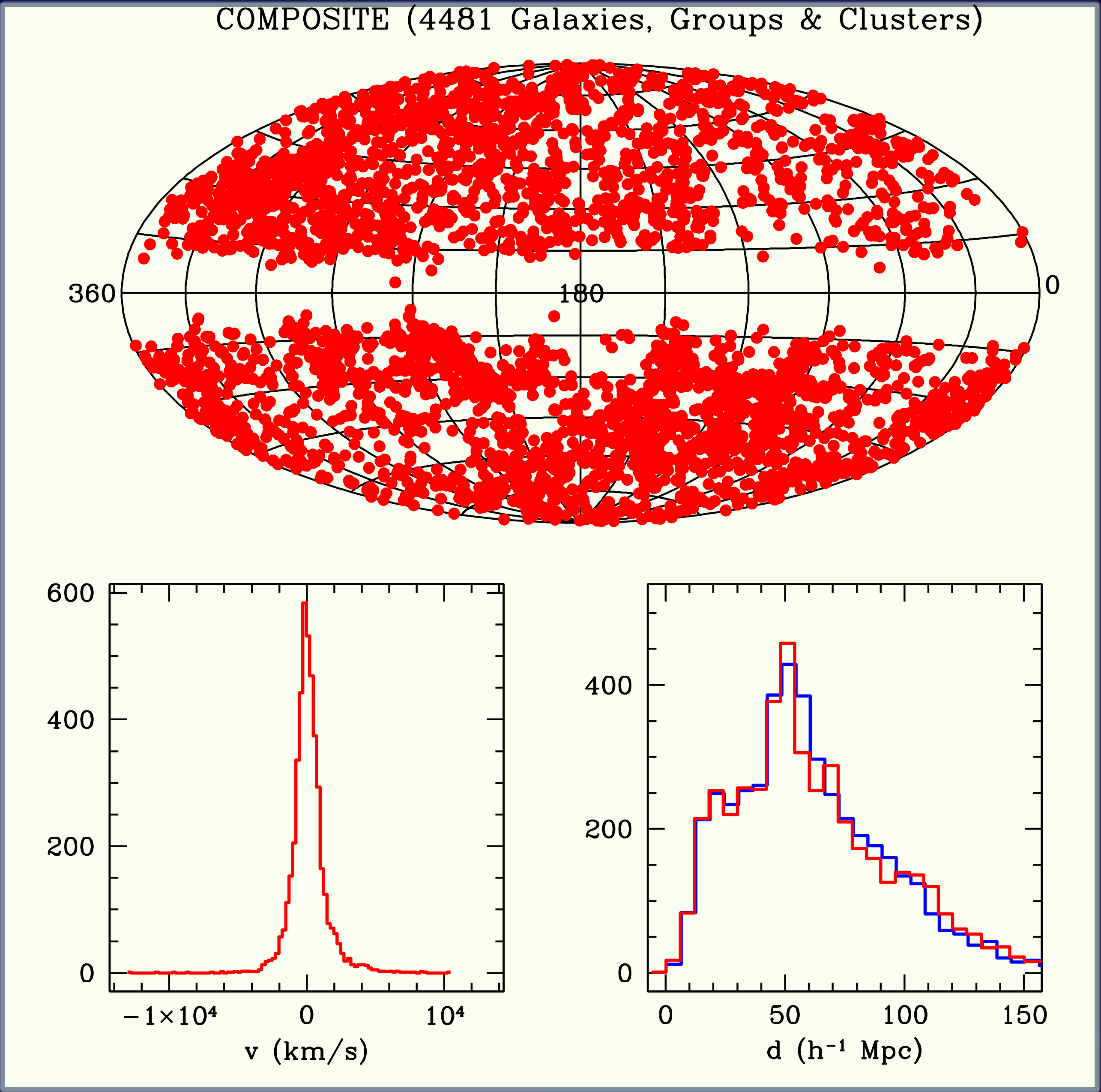
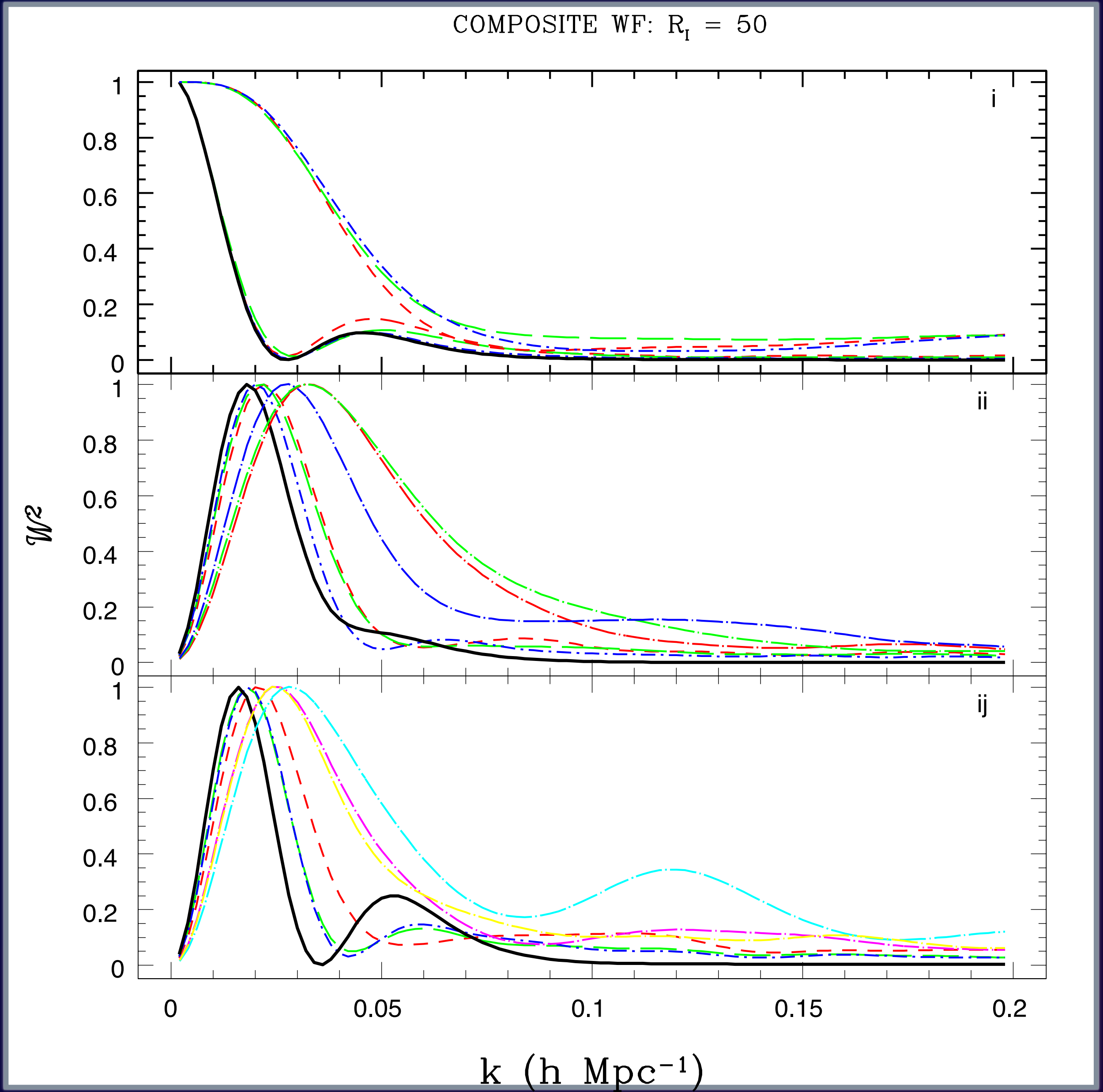


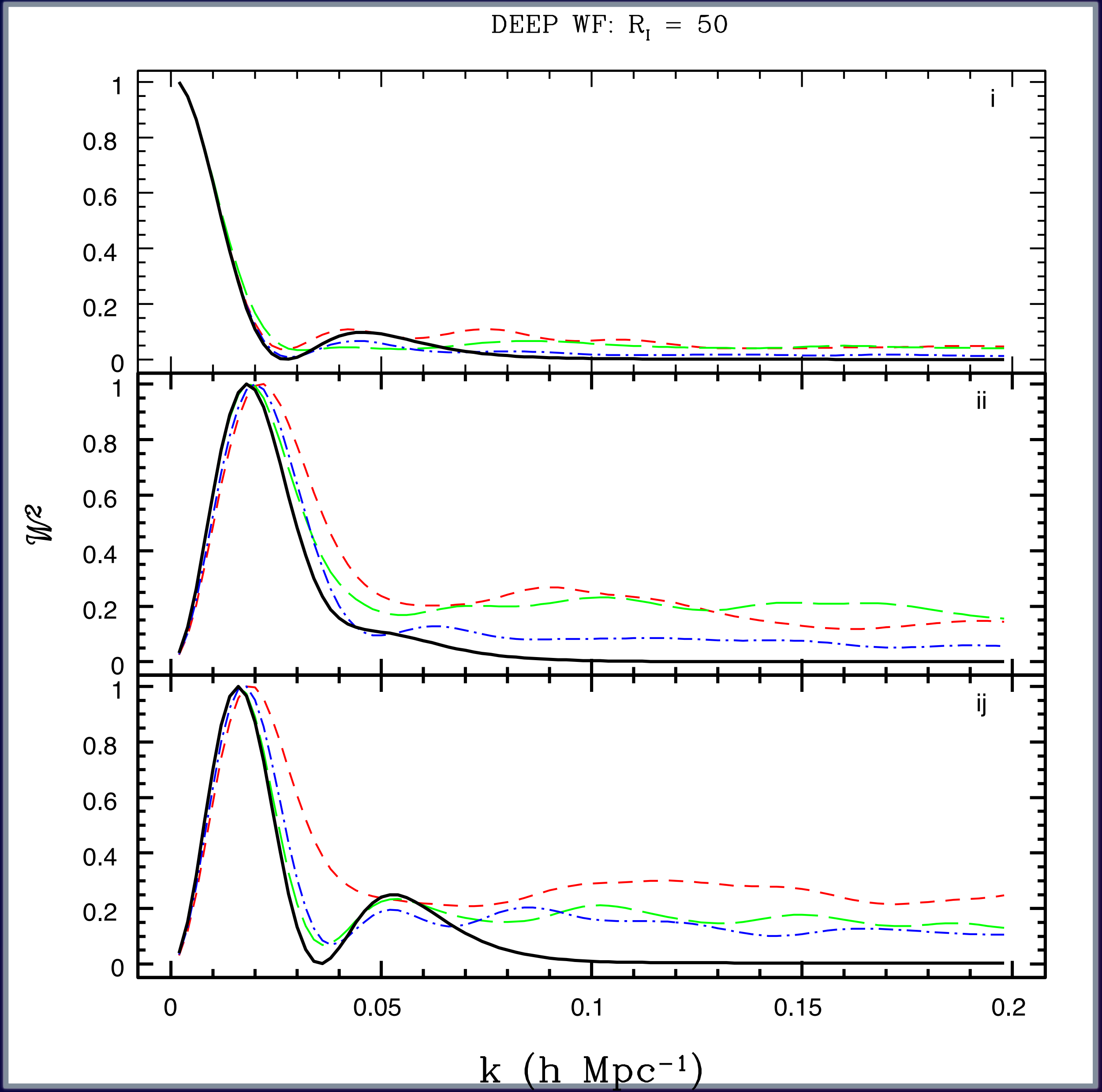
Window Function Design



Imperial College London

UCL

Window Function Design



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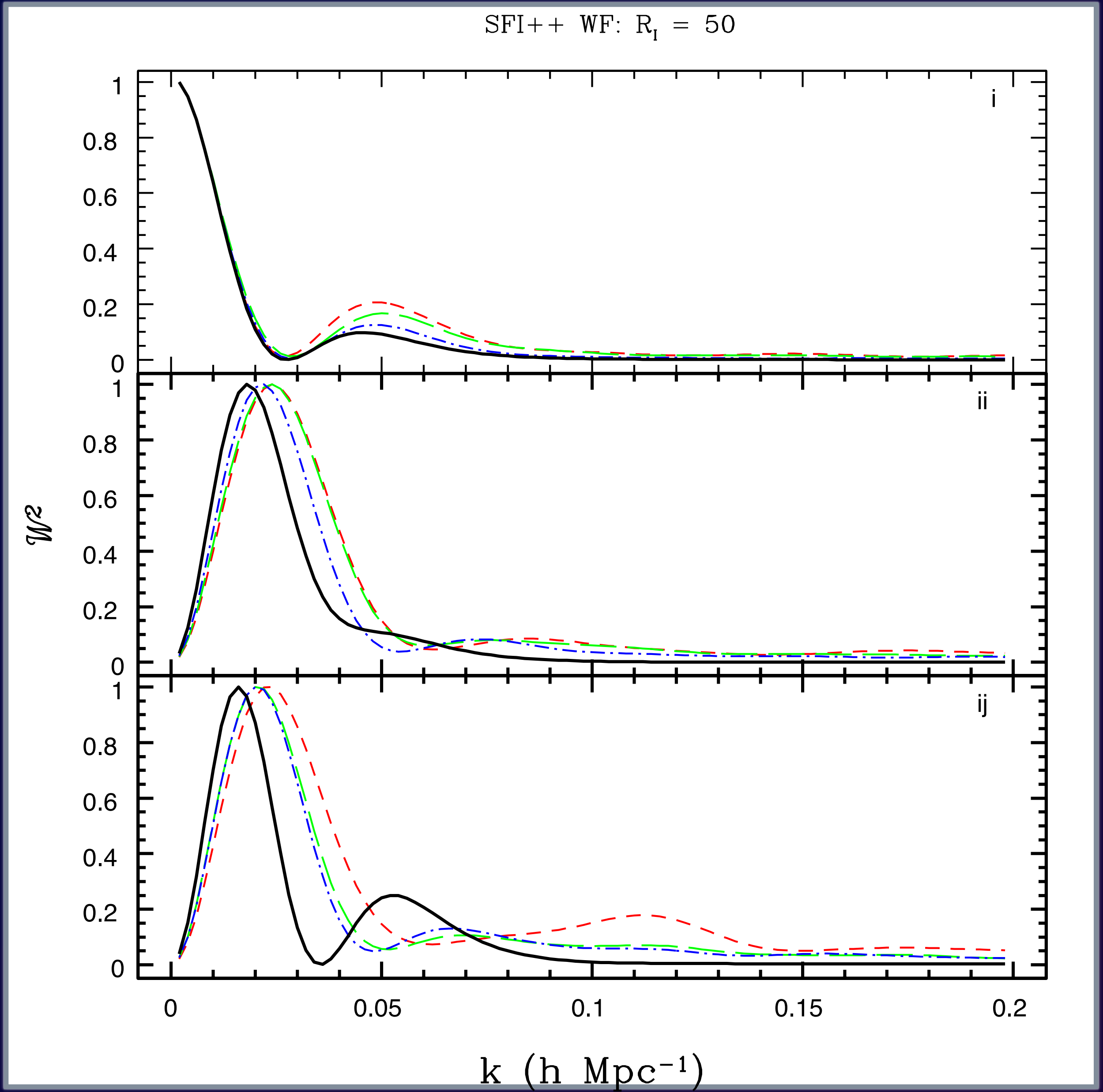

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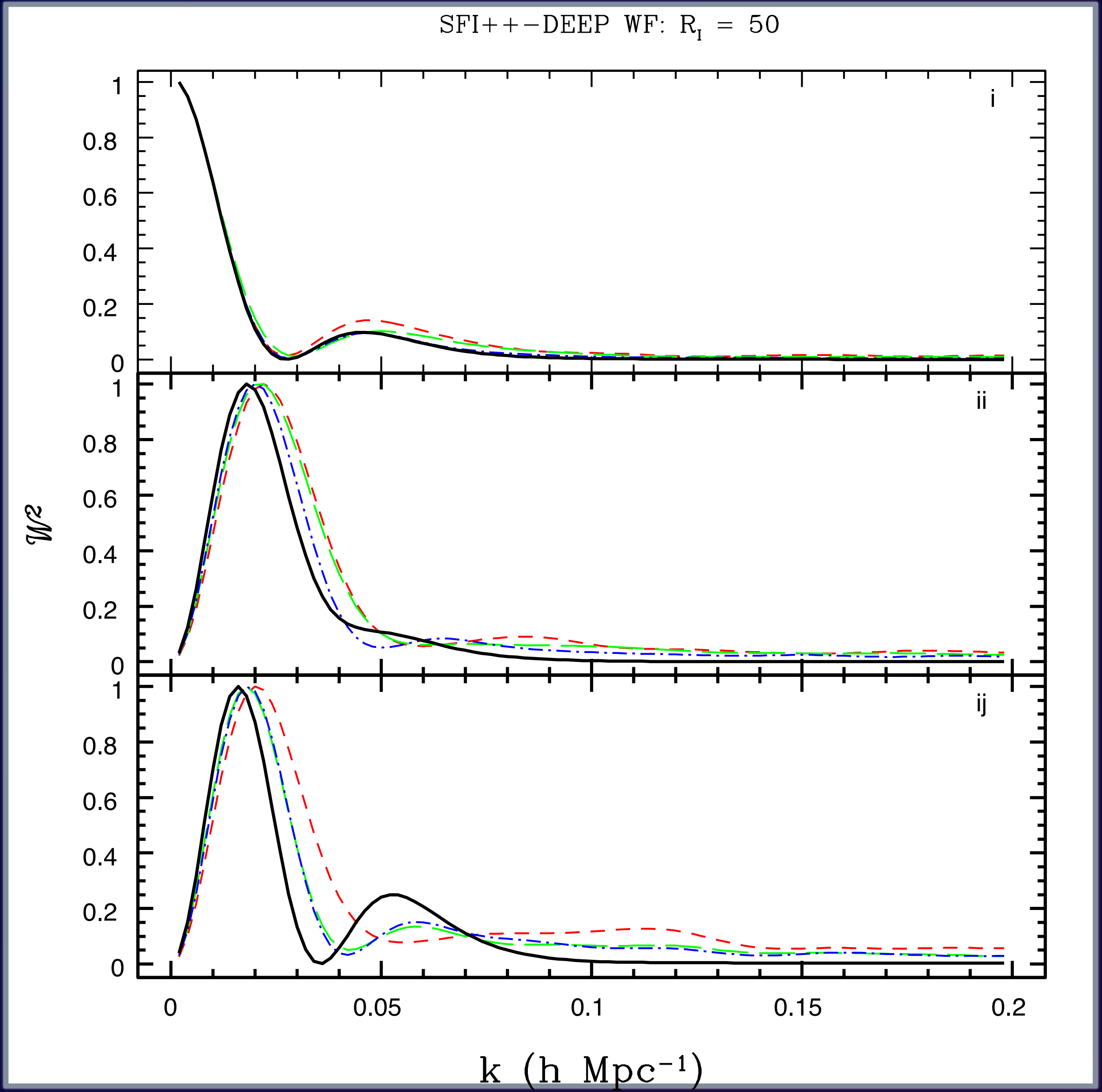

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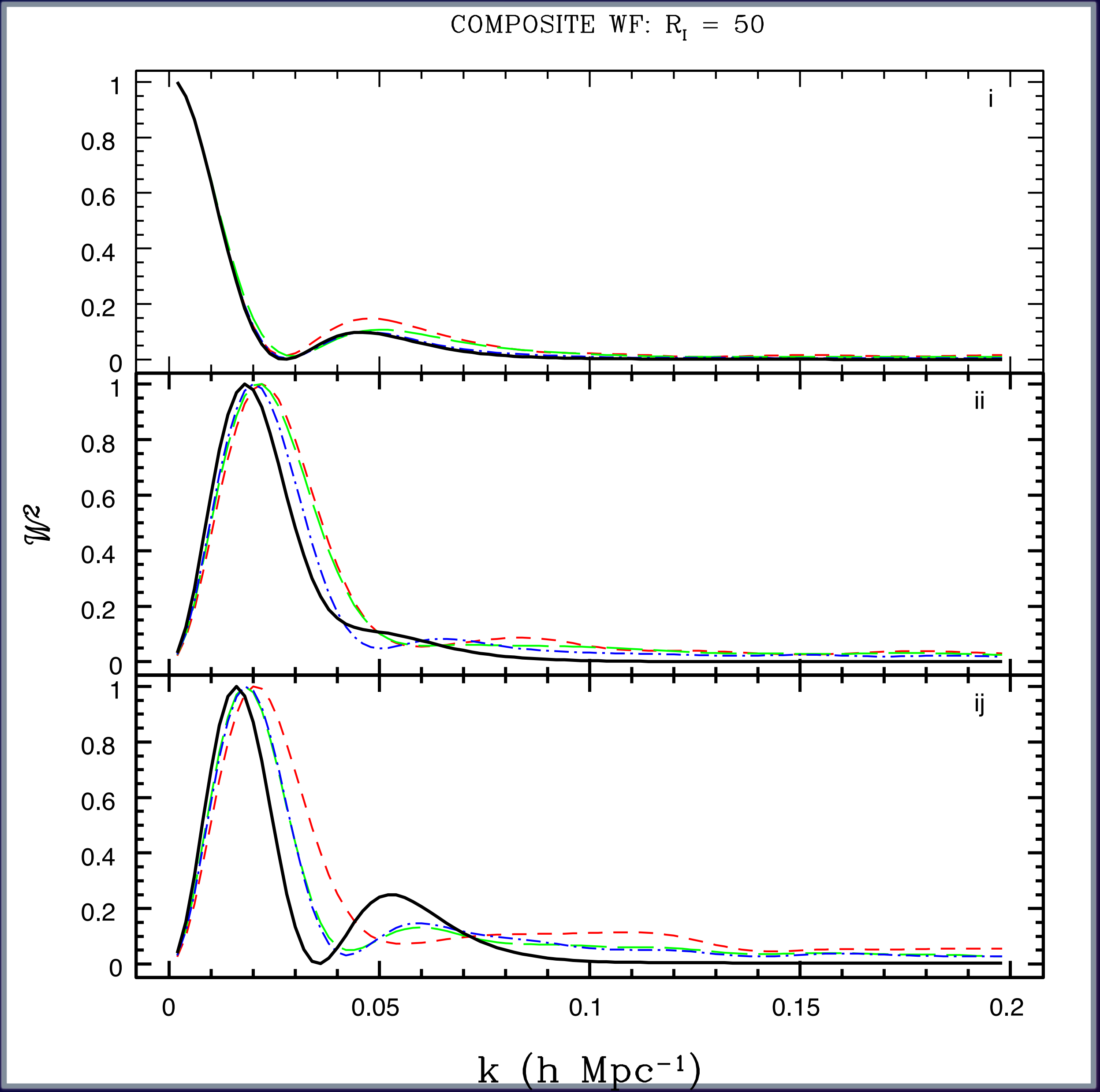
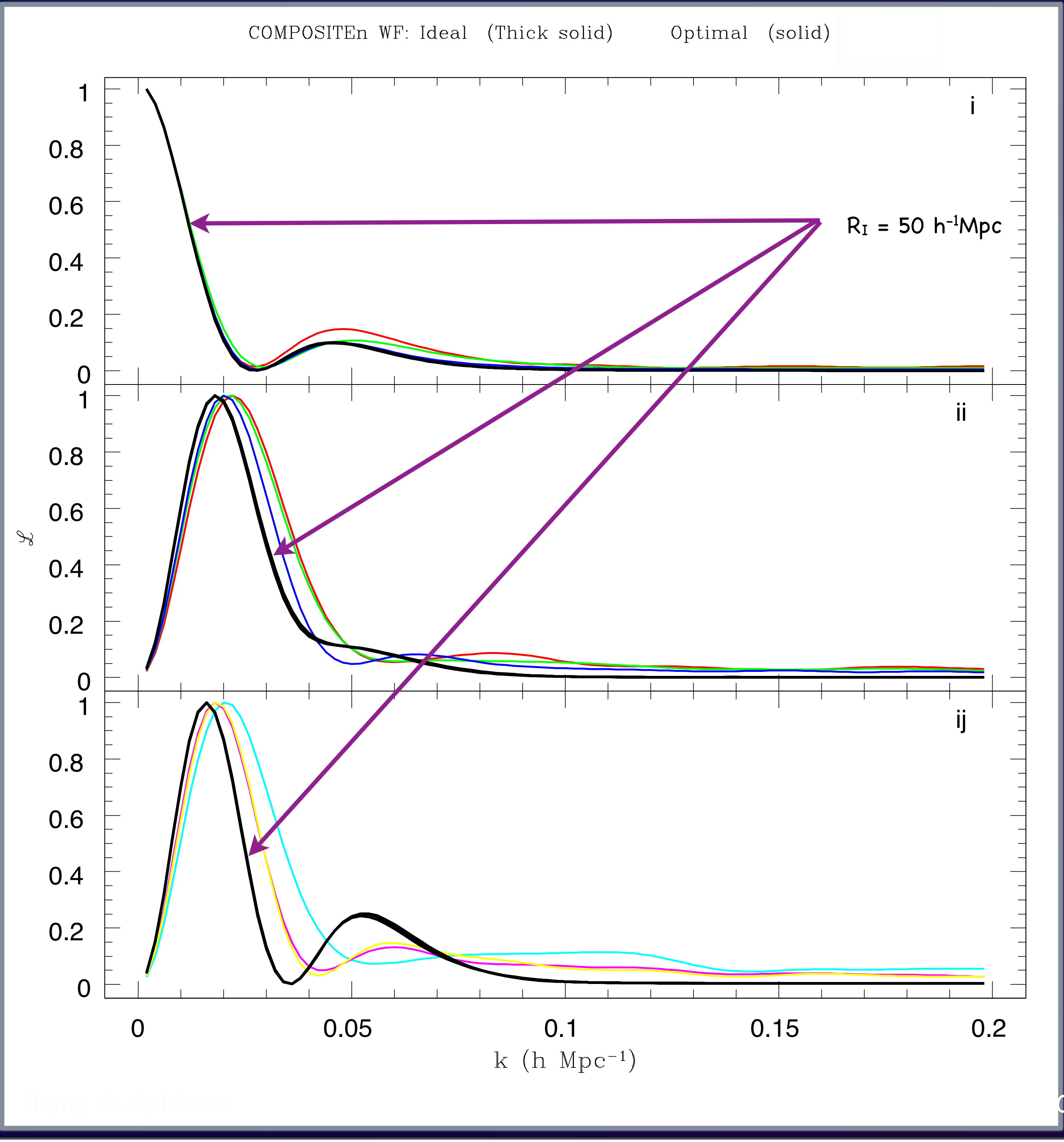
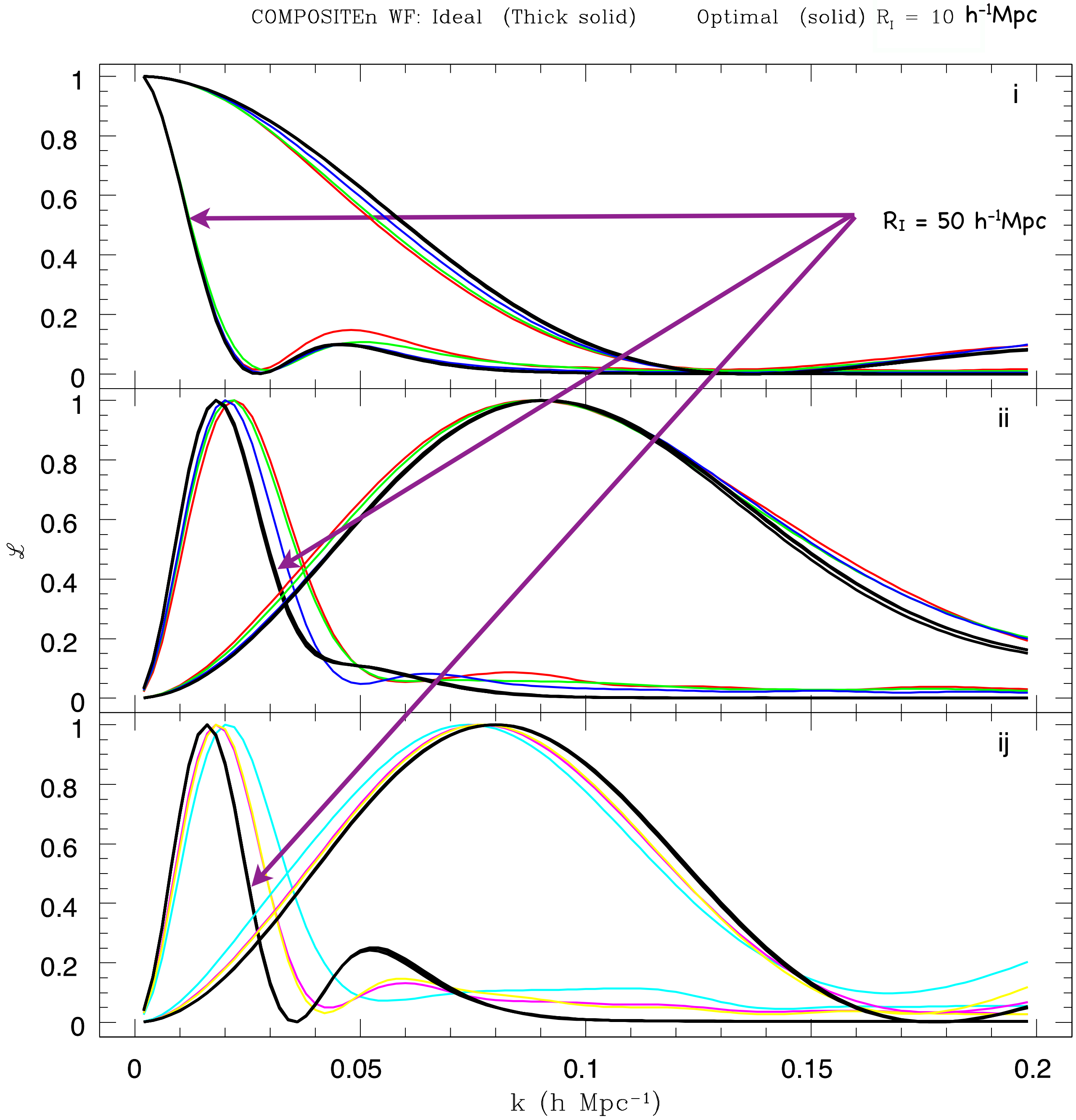



COMPOSITEn WF: Ideal (Thick solid) Optimal (solid)
i
ii
ij
R_I = 50 h^{-1}Mpc
$\mathscr{L}$
0
0.2
0.4
0.6
0.8
1
0
0.05
0.1
0.15
0.2
k (h Mpc^{-1})


COMPOSITEn WF: Ideal (Thick solid) Optimal (solid) R_I = 10 h^{-1}Mpc
R_I = 50 h^{-1}Mpc
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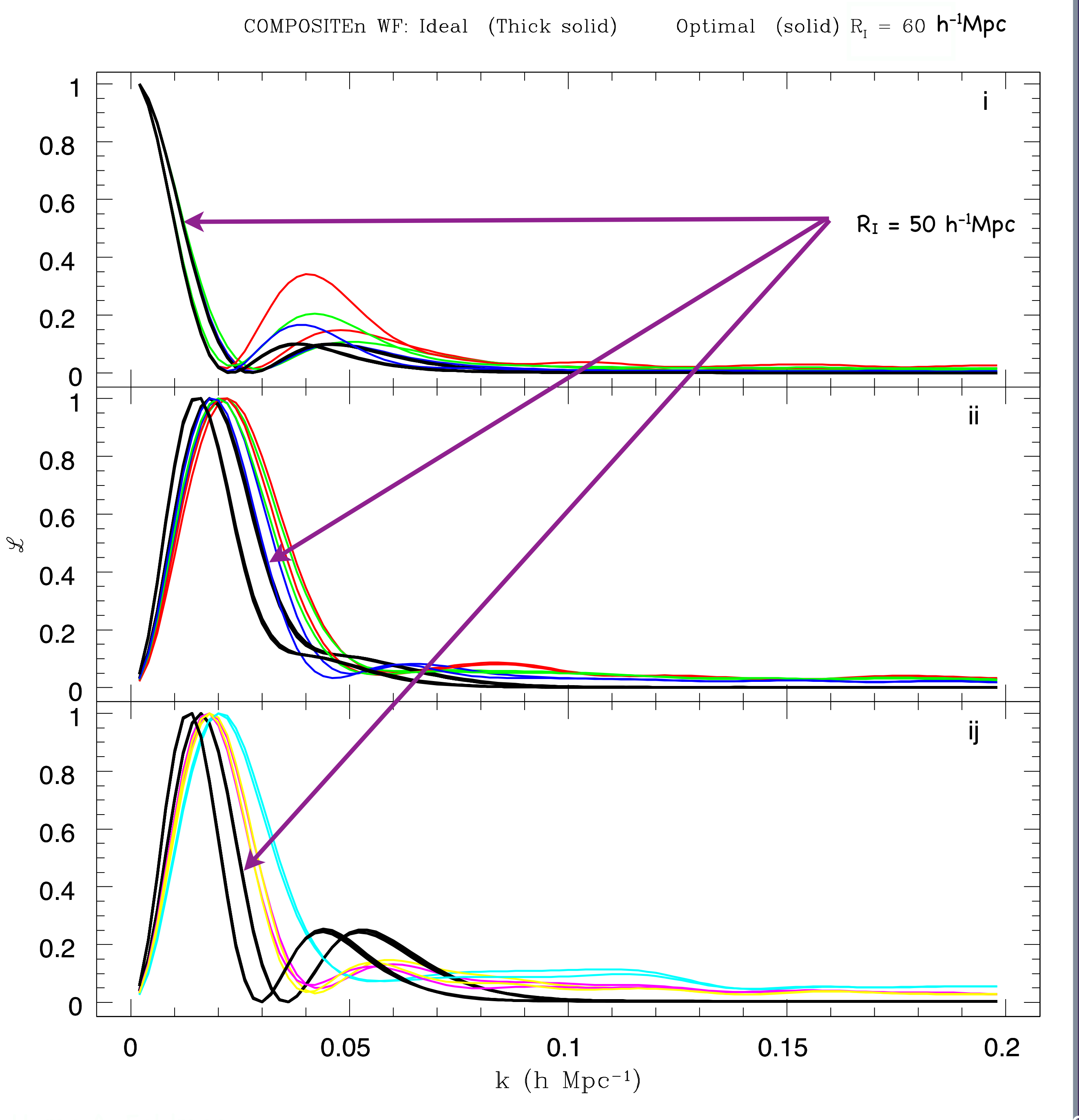
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R_I = 50 h^-1Mpc
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0.05
0.1
0.15
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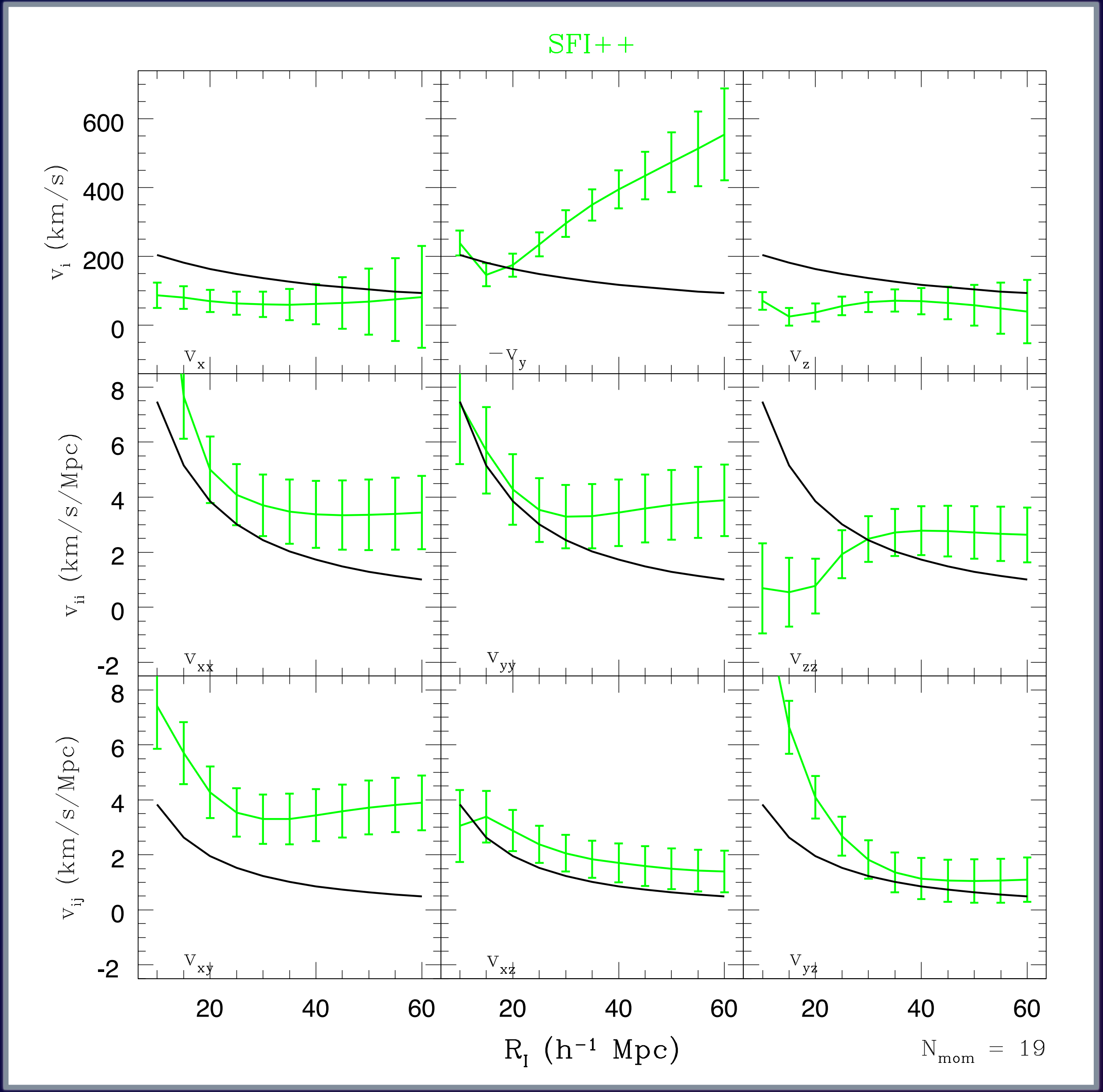
Imperial College London

UCL

Comparing Surveys



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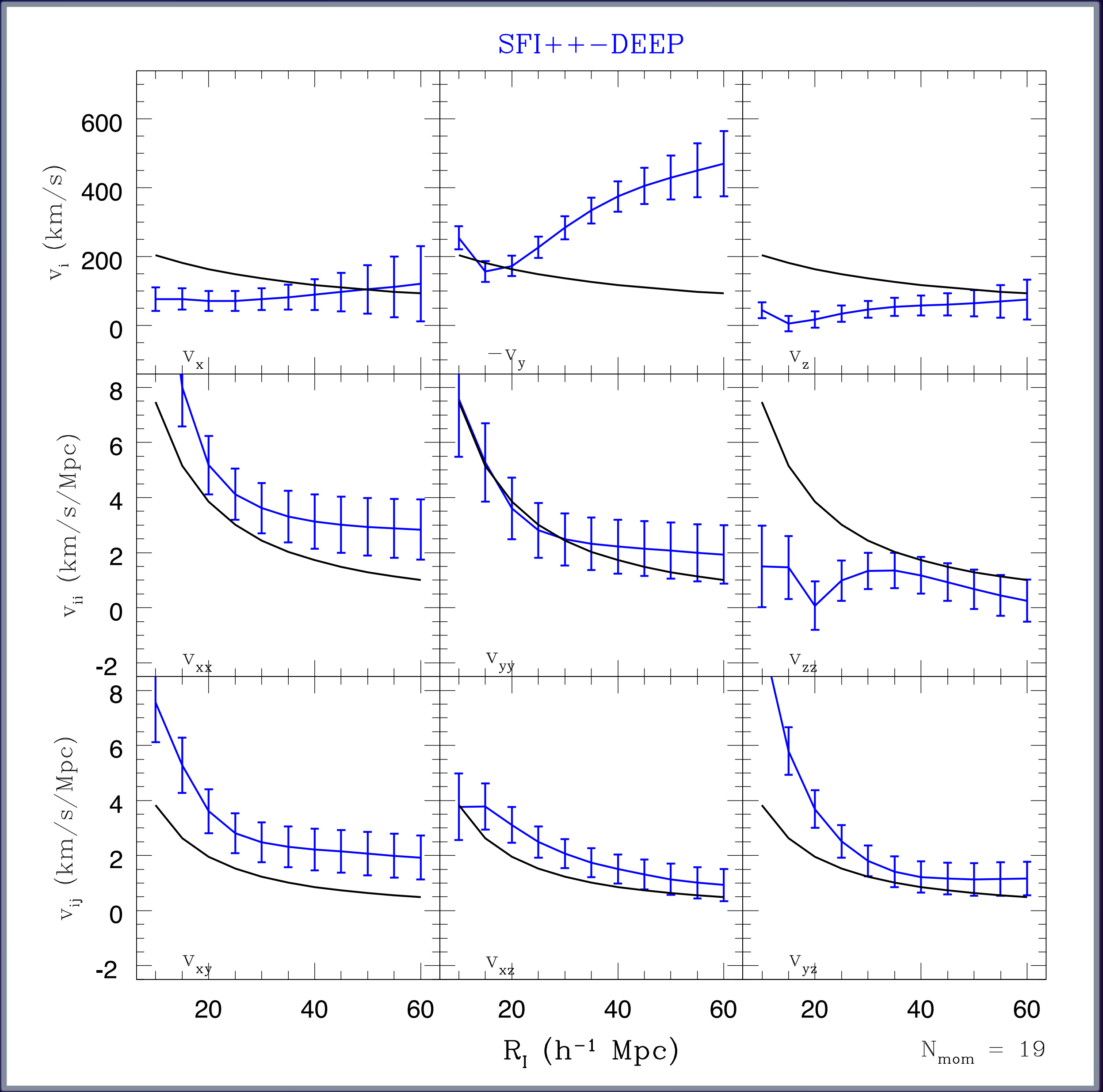

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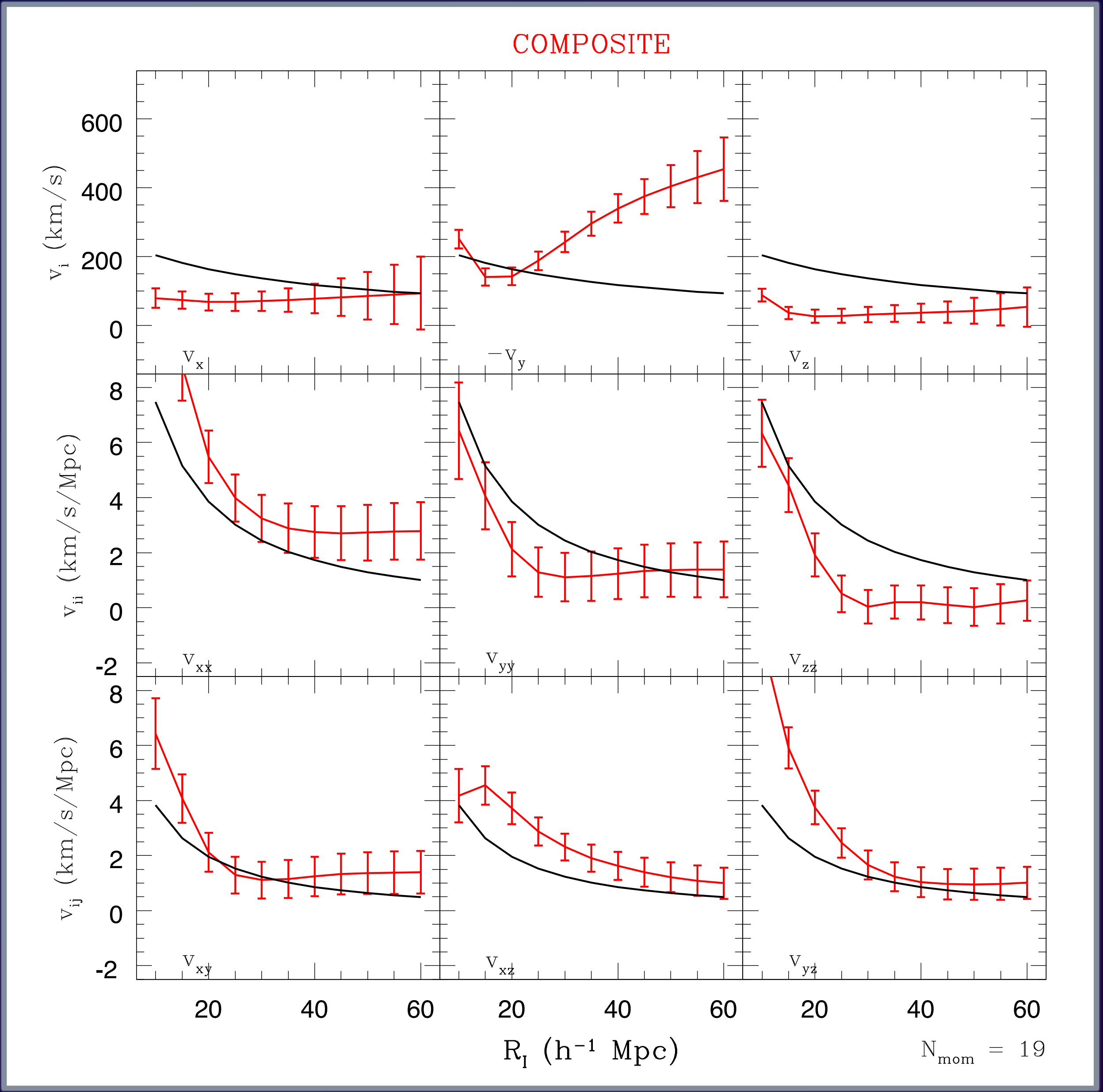

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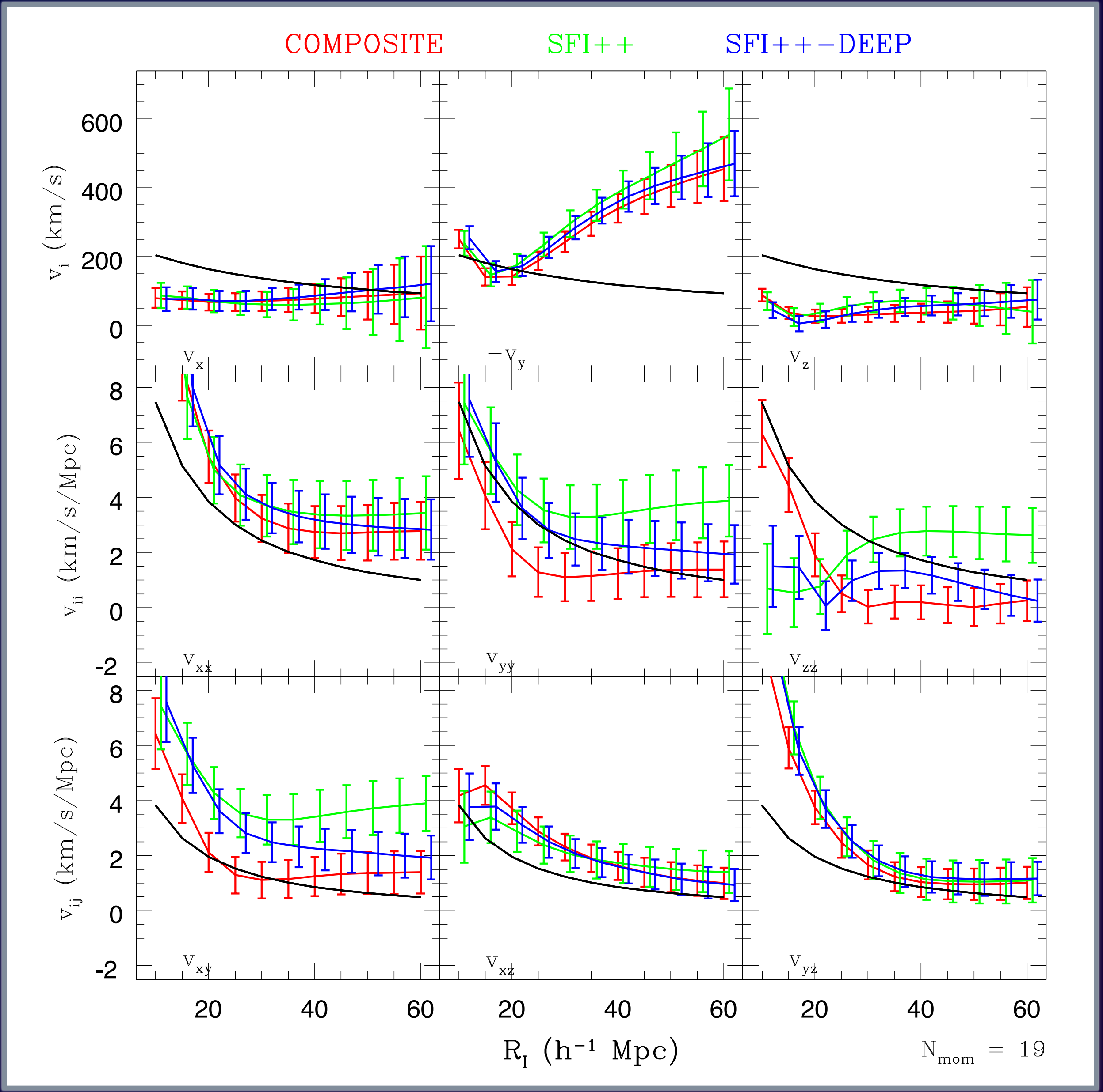
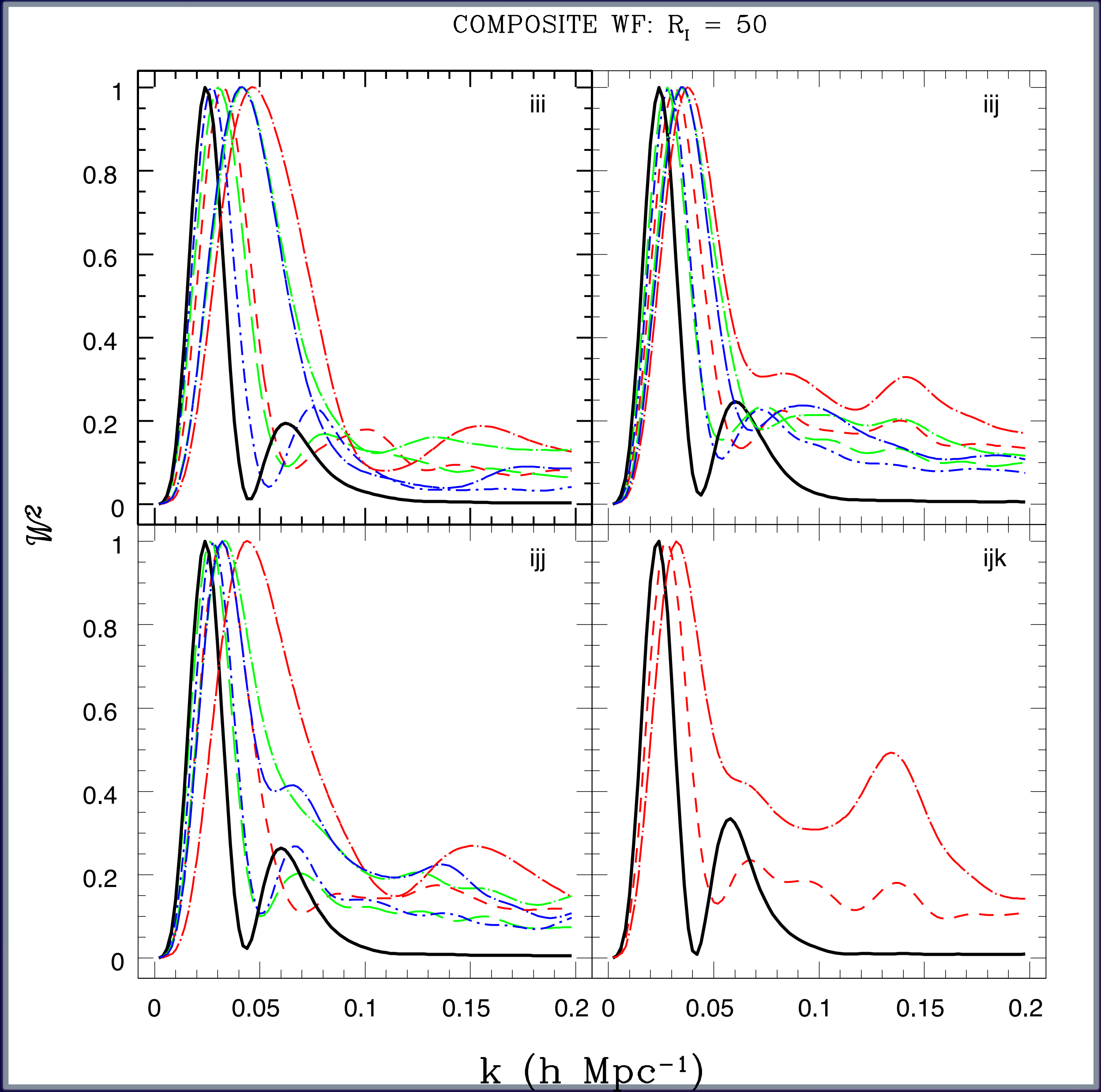


Window Function Design



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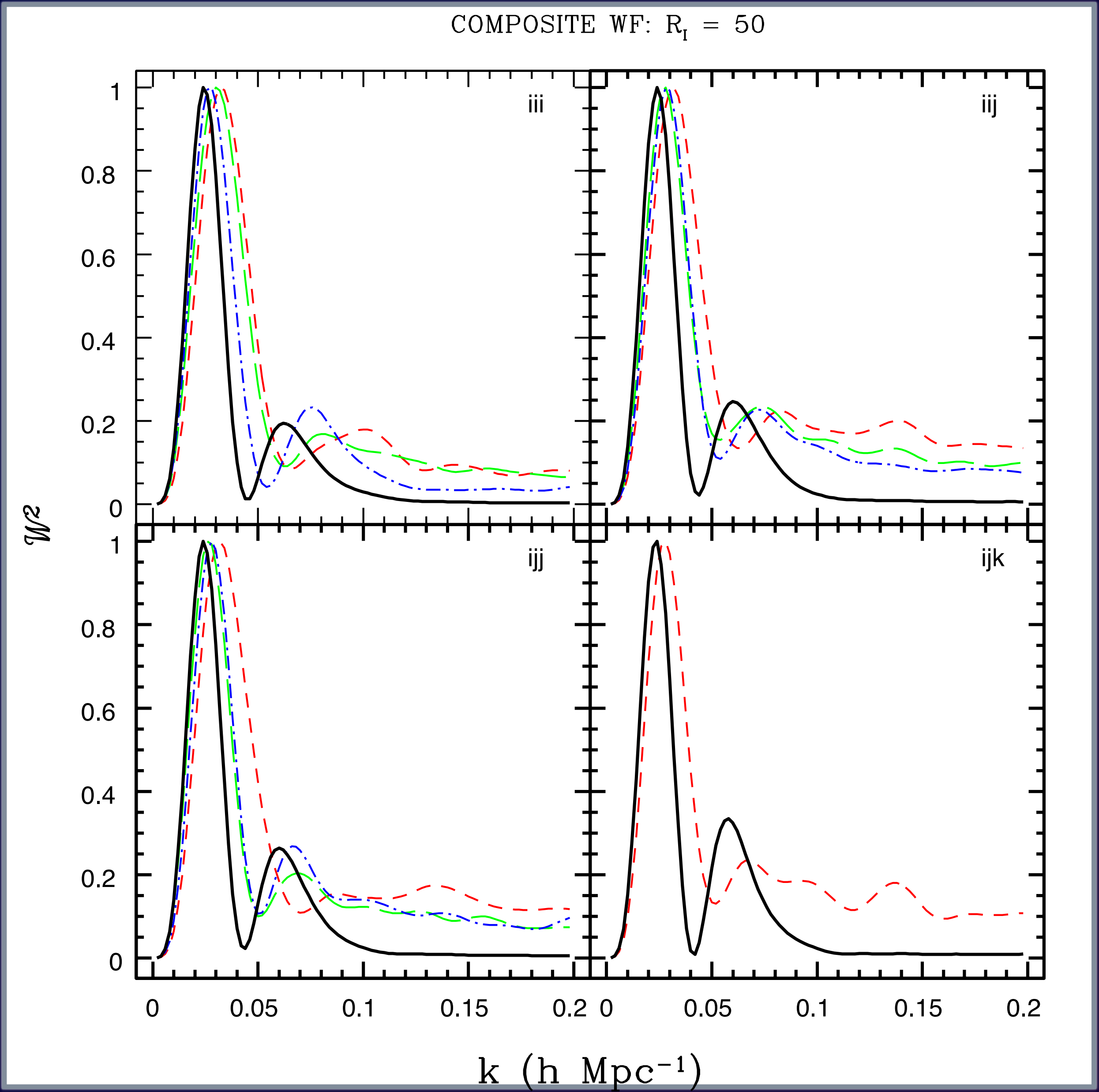

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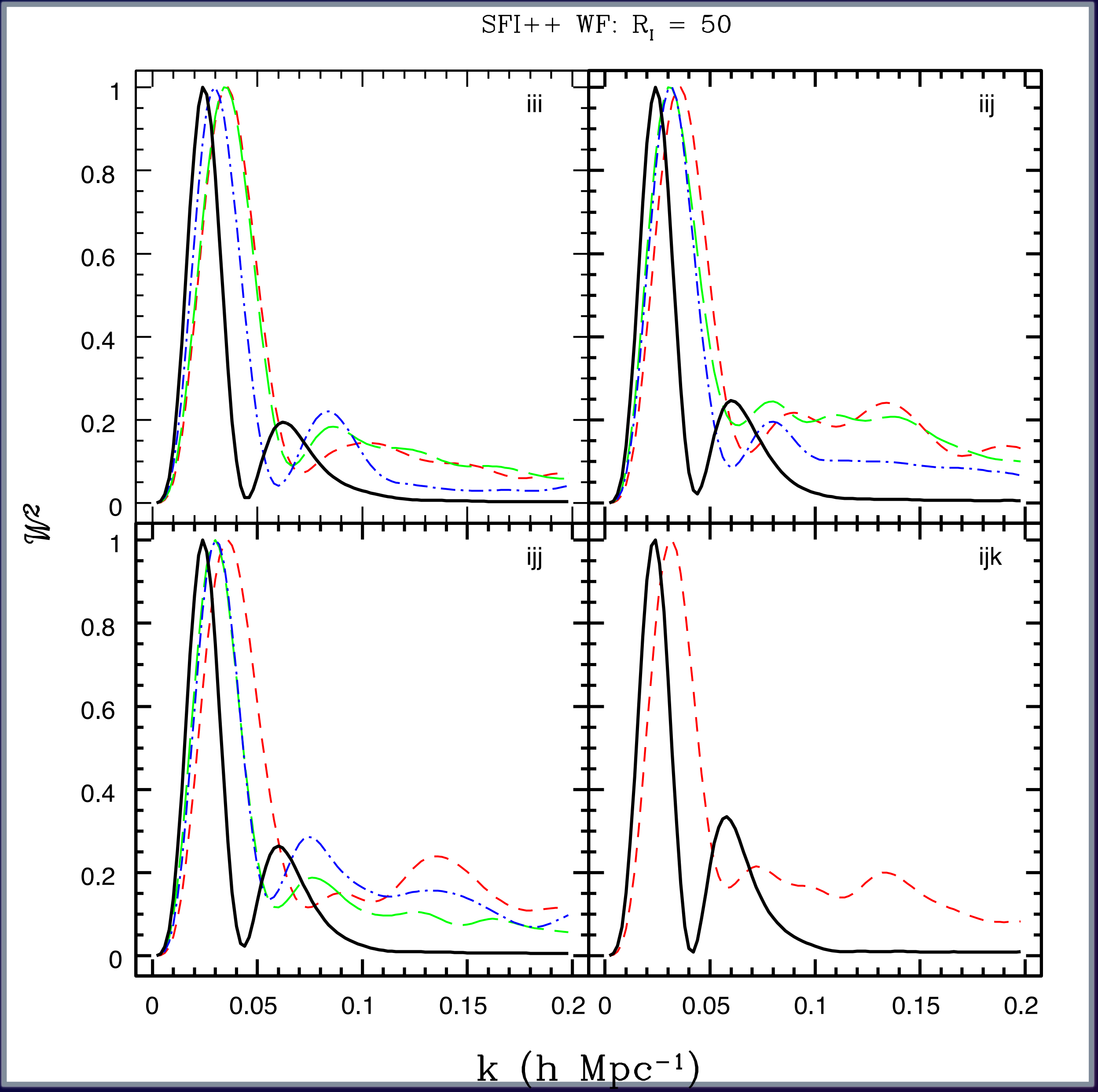

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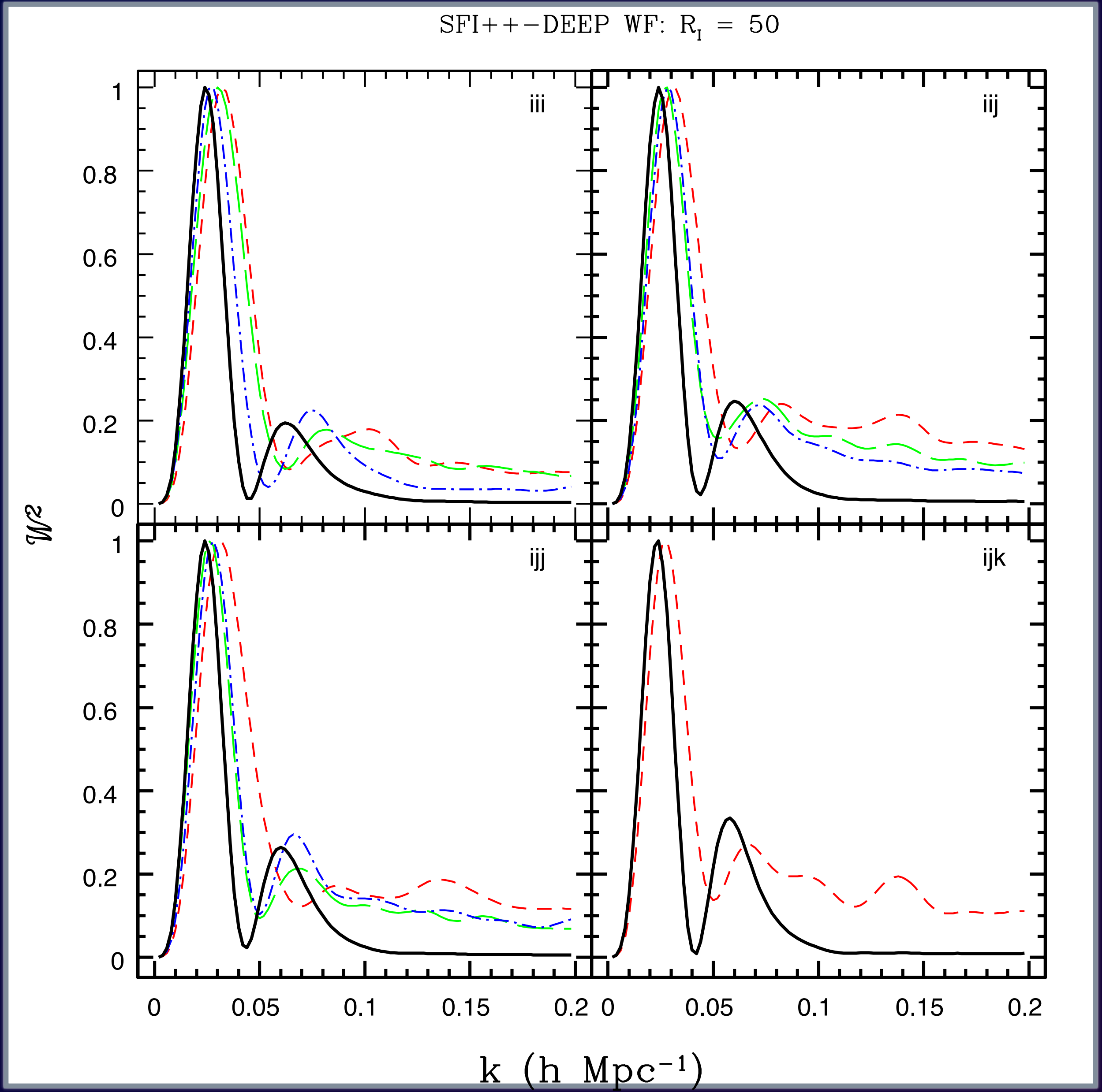
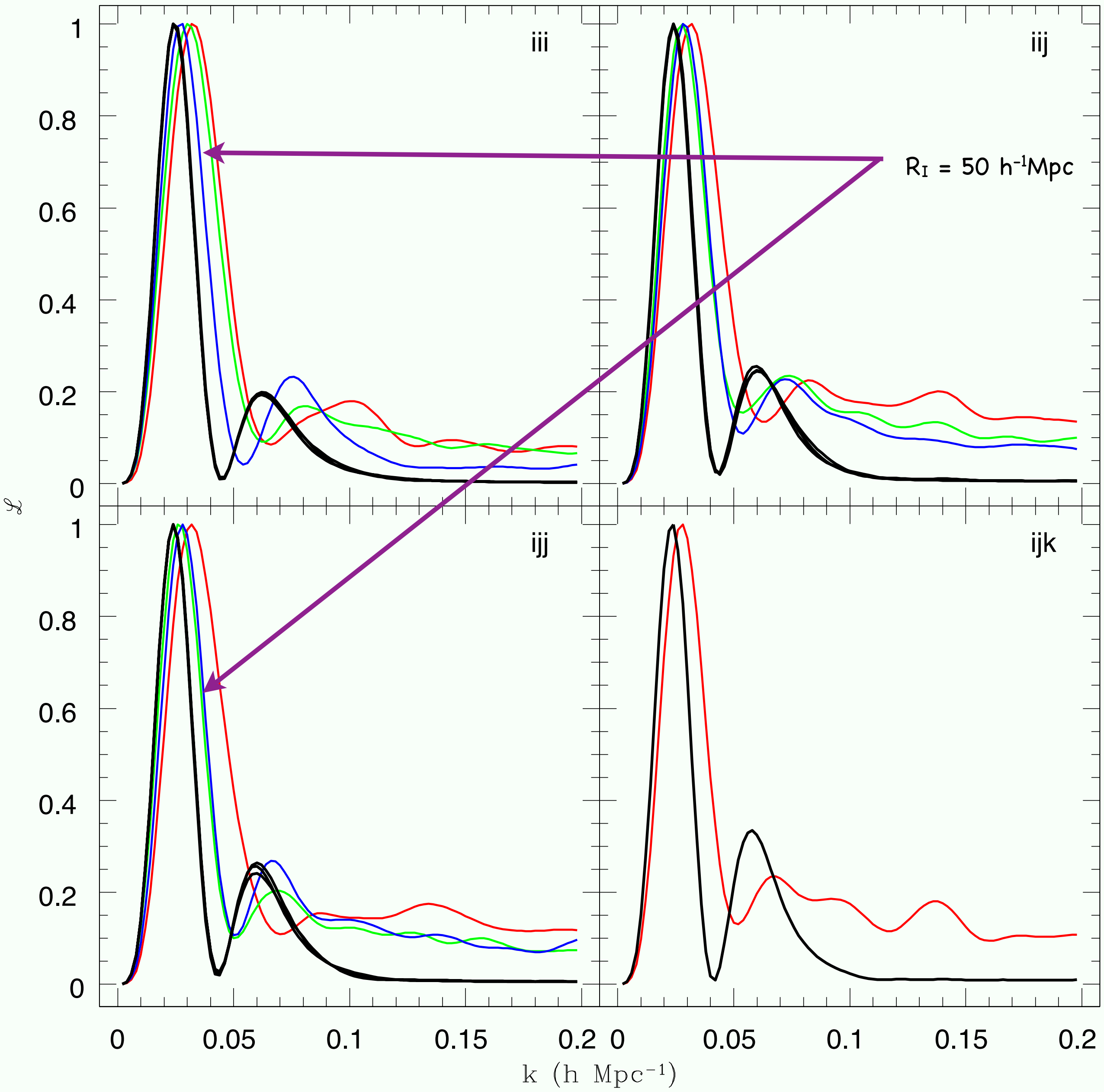


COMPOSITEn WF: Ideal (Thick solid) Optimal (solid)



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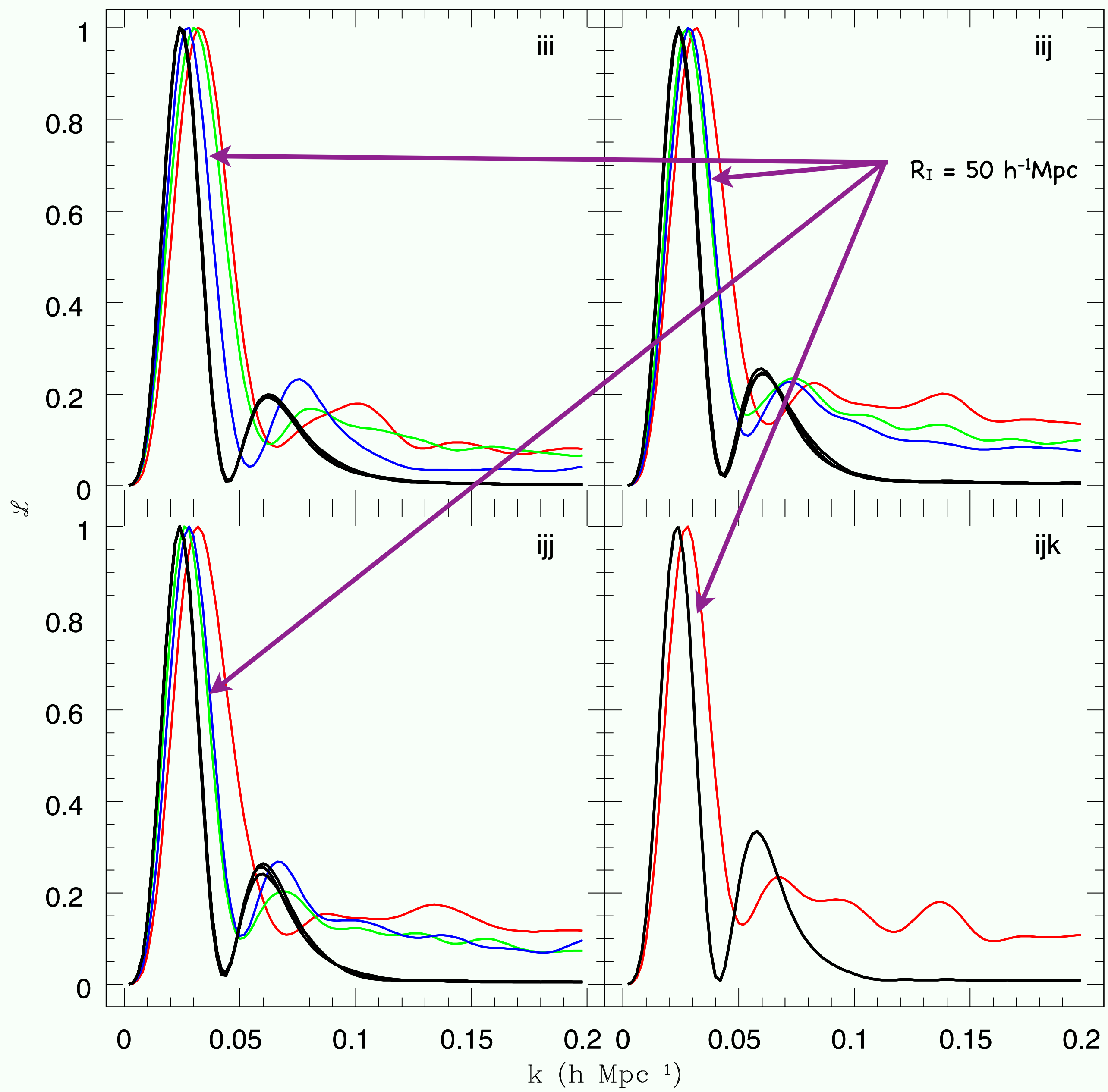
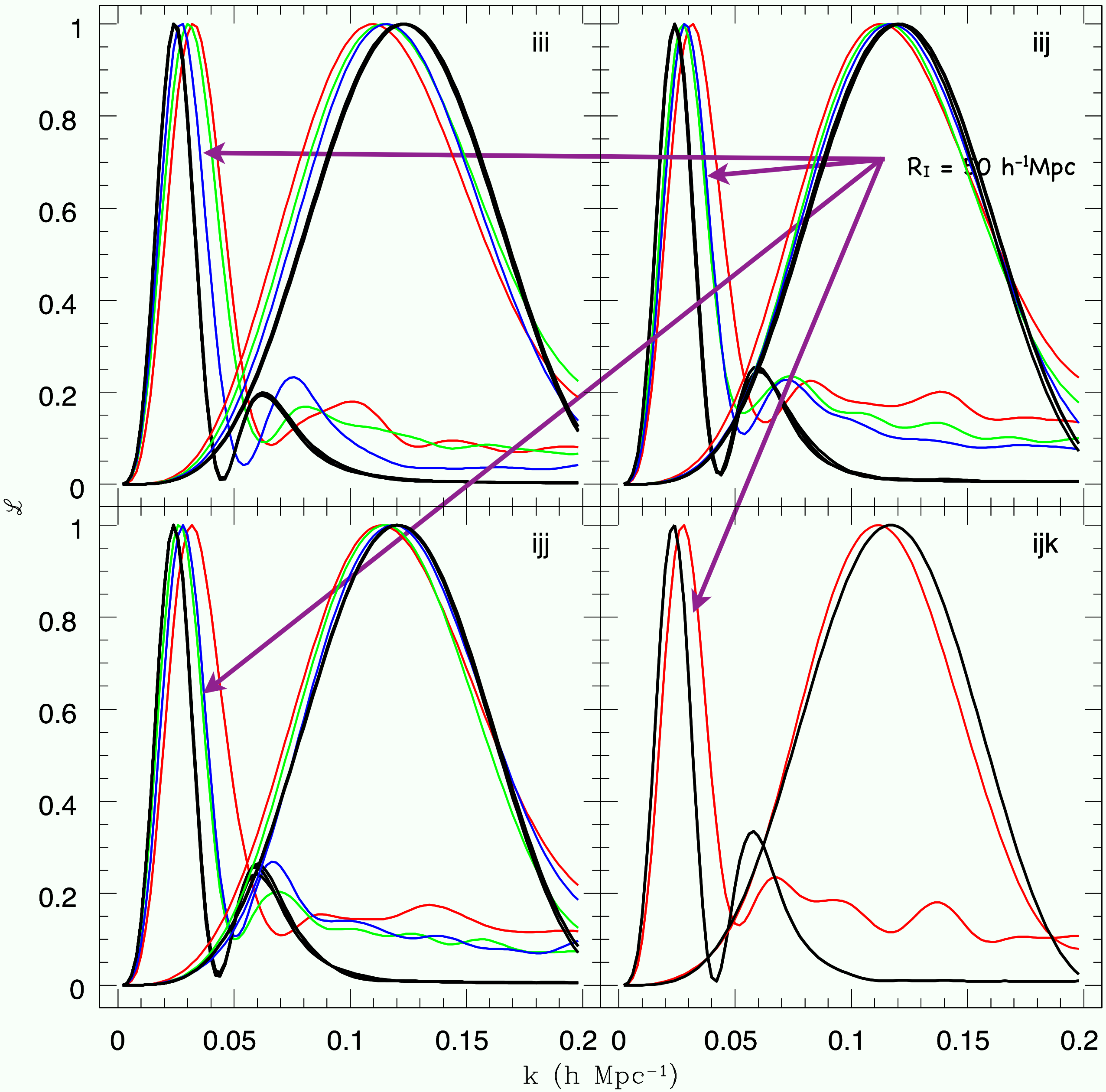
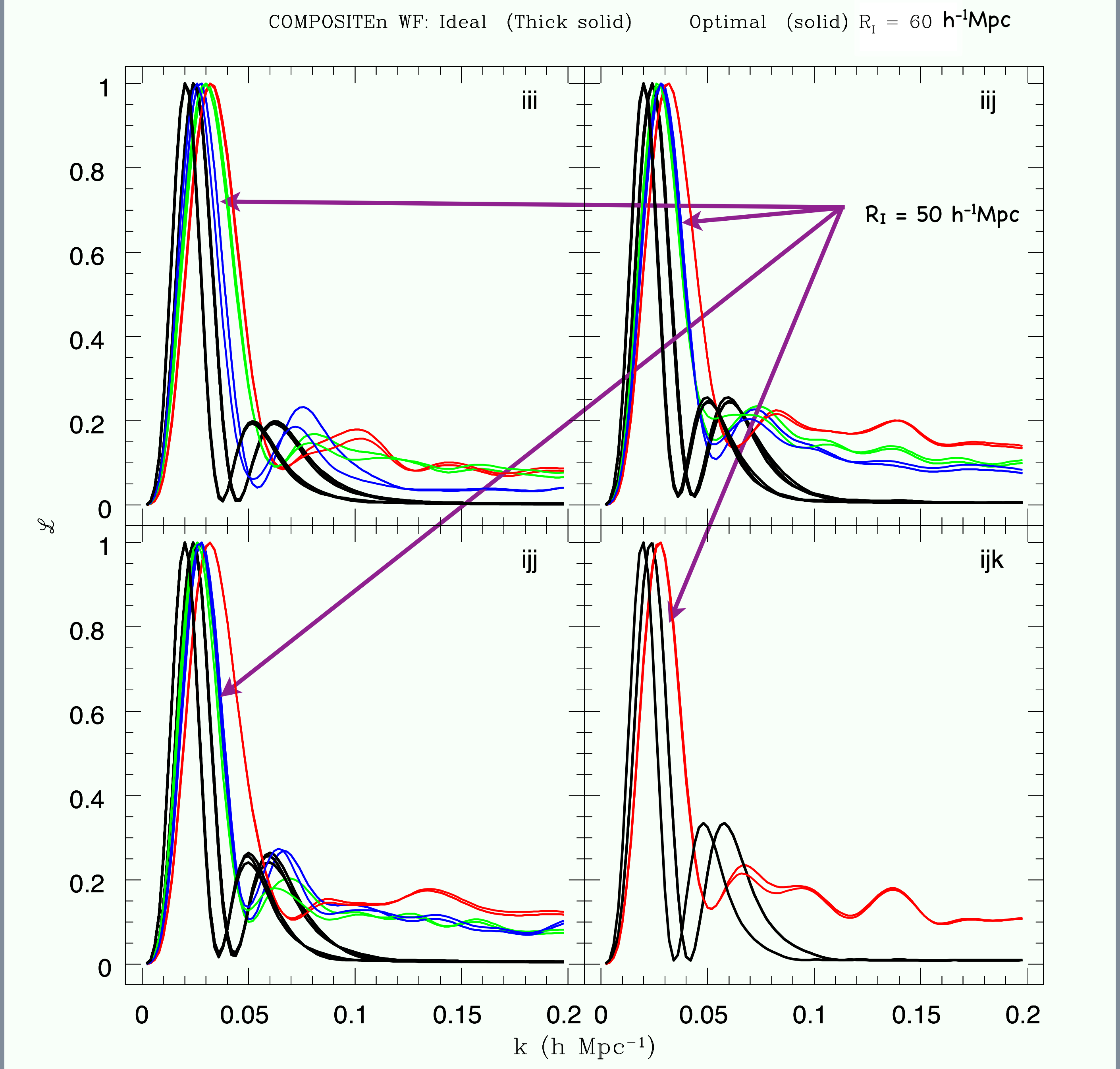


R_I = 50 h^{-1}Mpc

COMPOSITEn WF: Ideal (Thick solid) Optimal (solid) R_I = 10 h^{-1}Mpc

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iii
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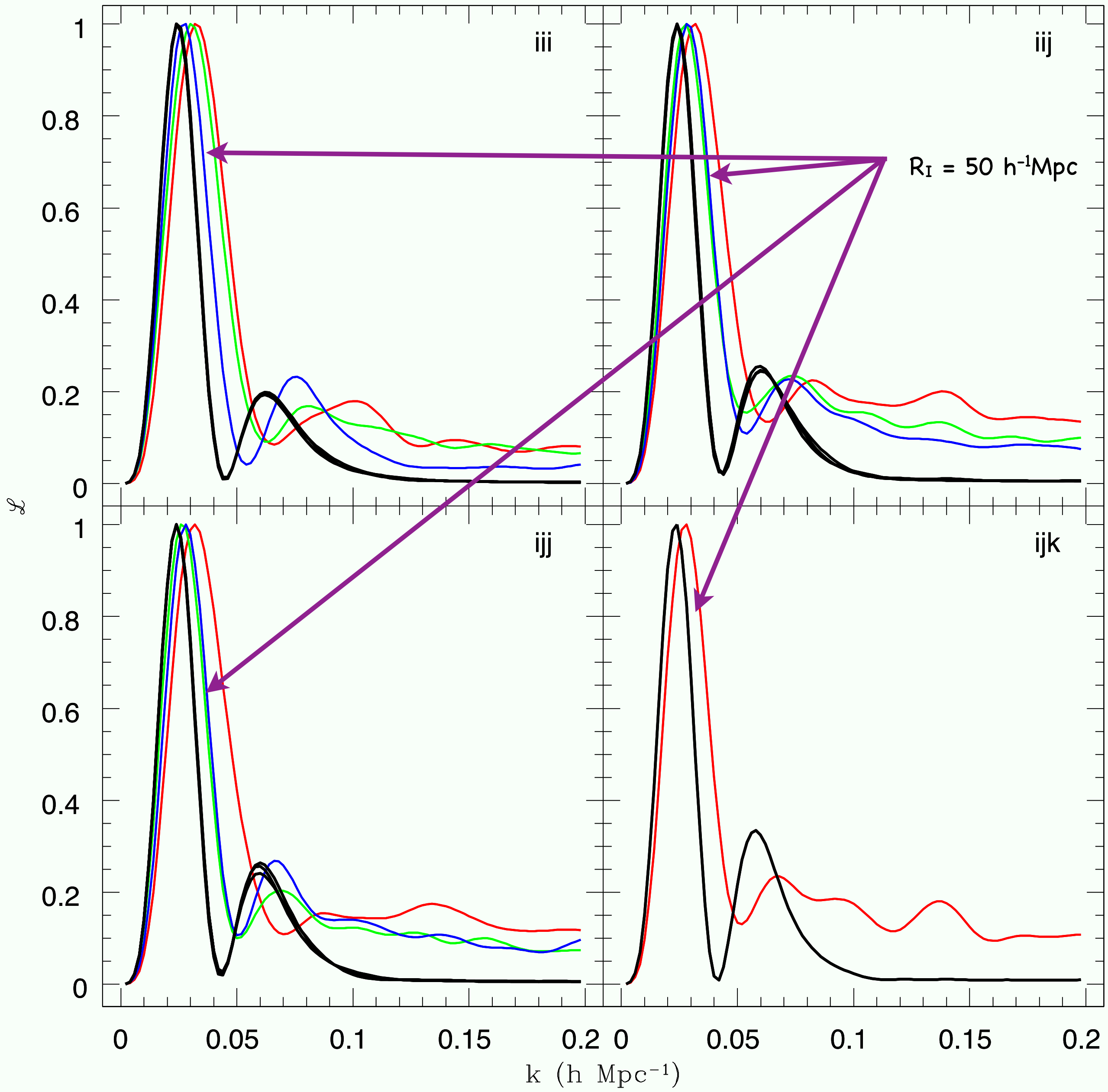
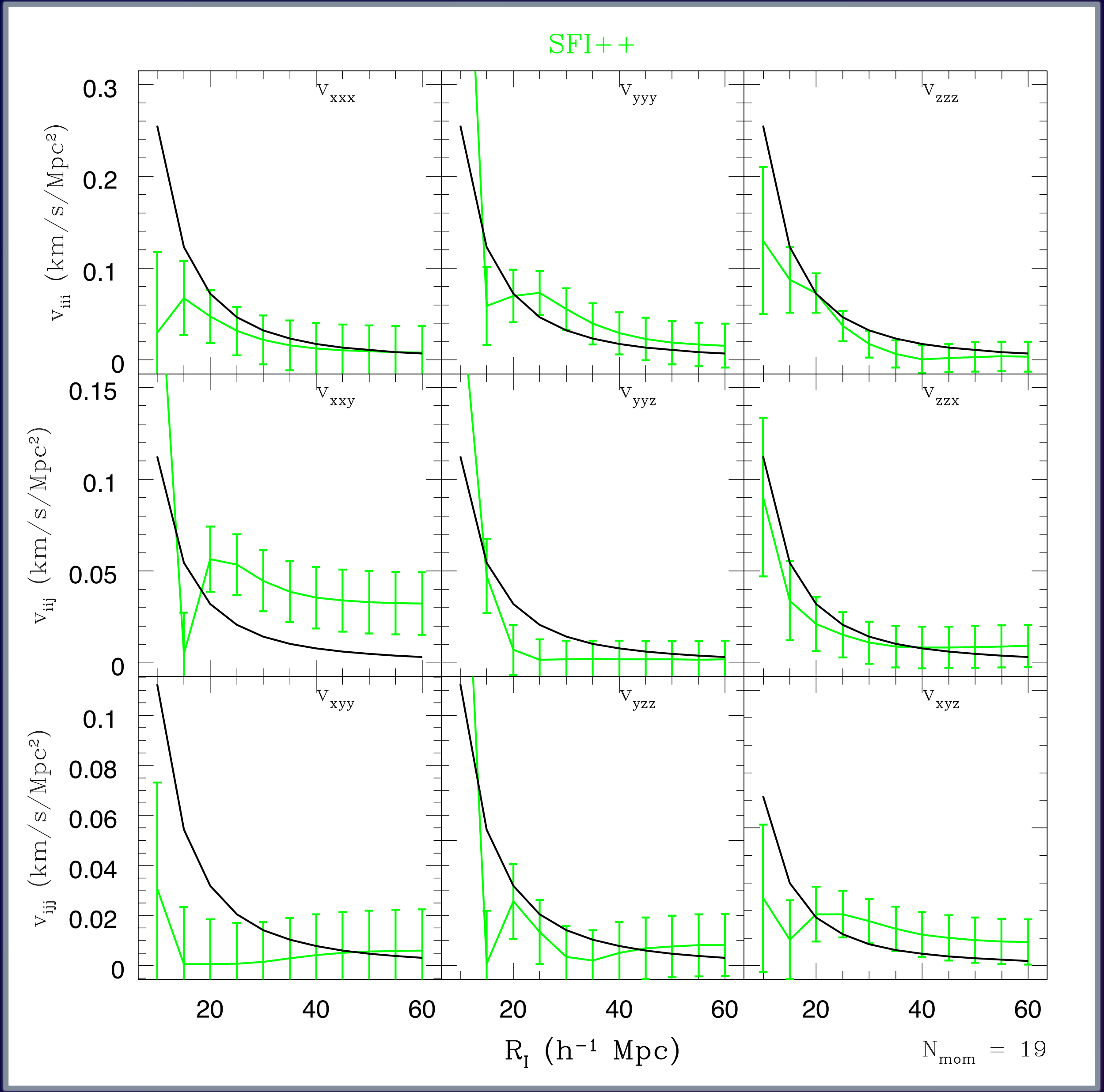


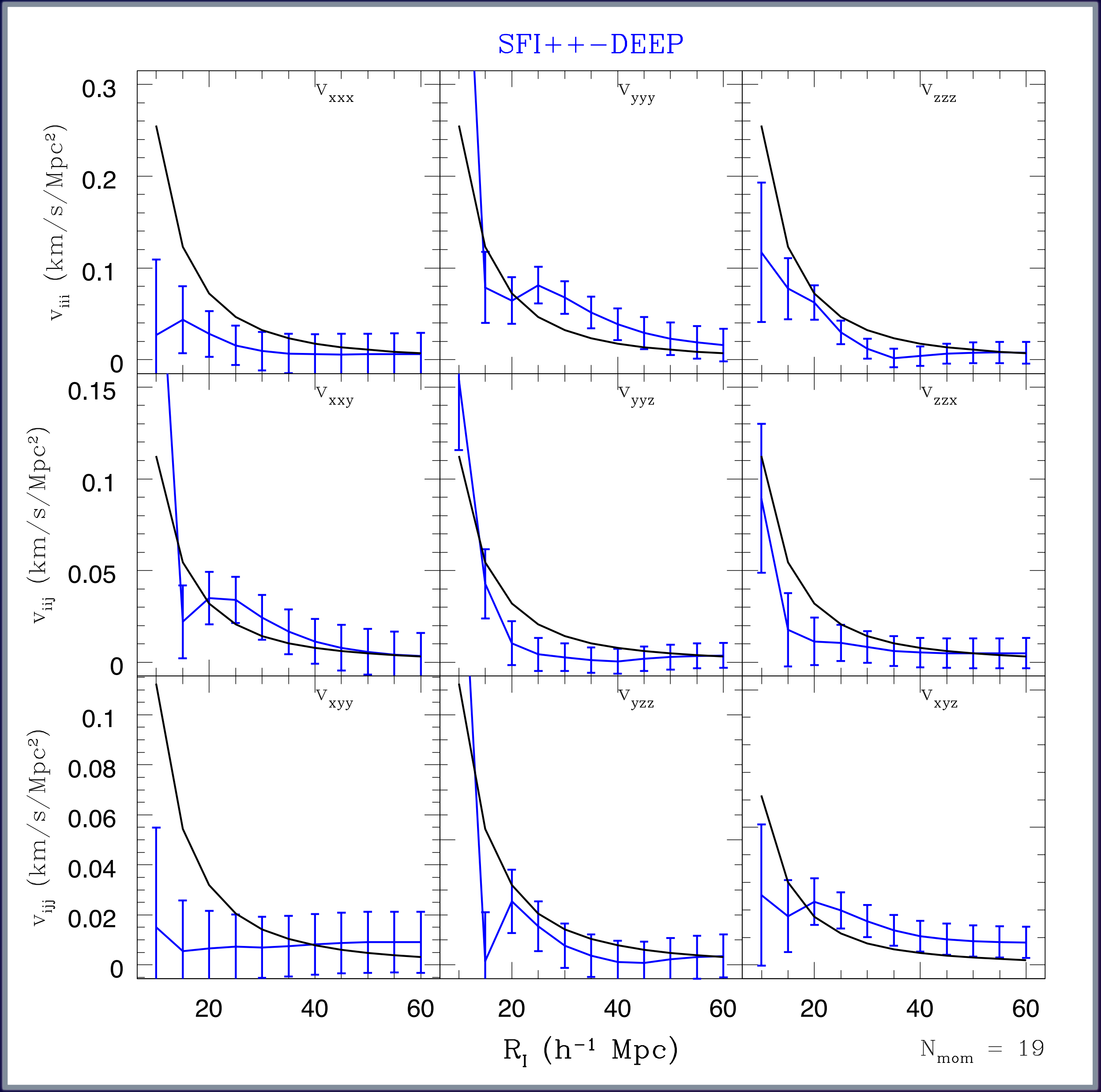
Comparing Surveys



Hume A. Feldman Velocity Fields Séminaires IAP, 27th Novembre, 2009

Friday, November 27, 2009

Comparing Surveys



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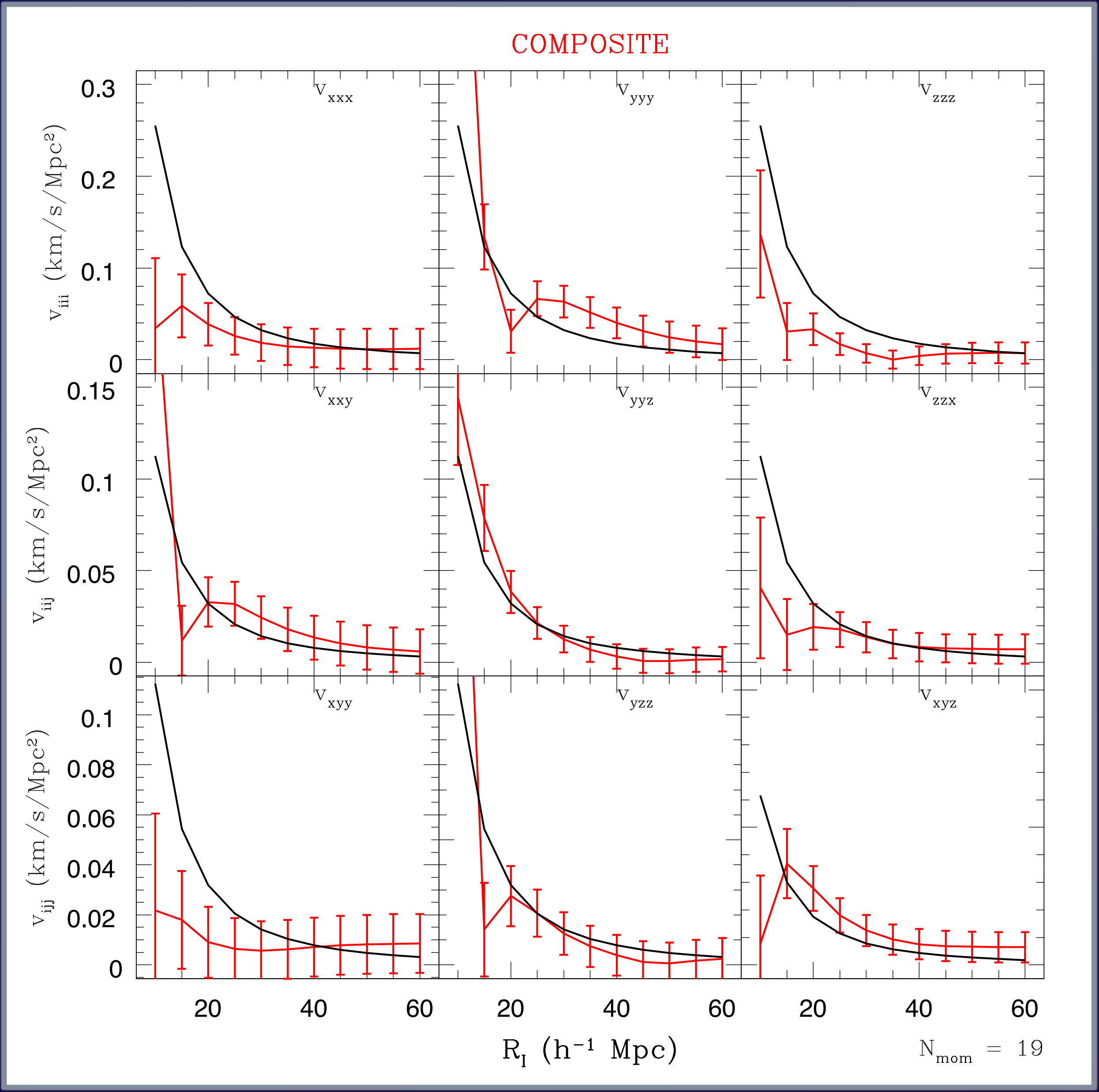

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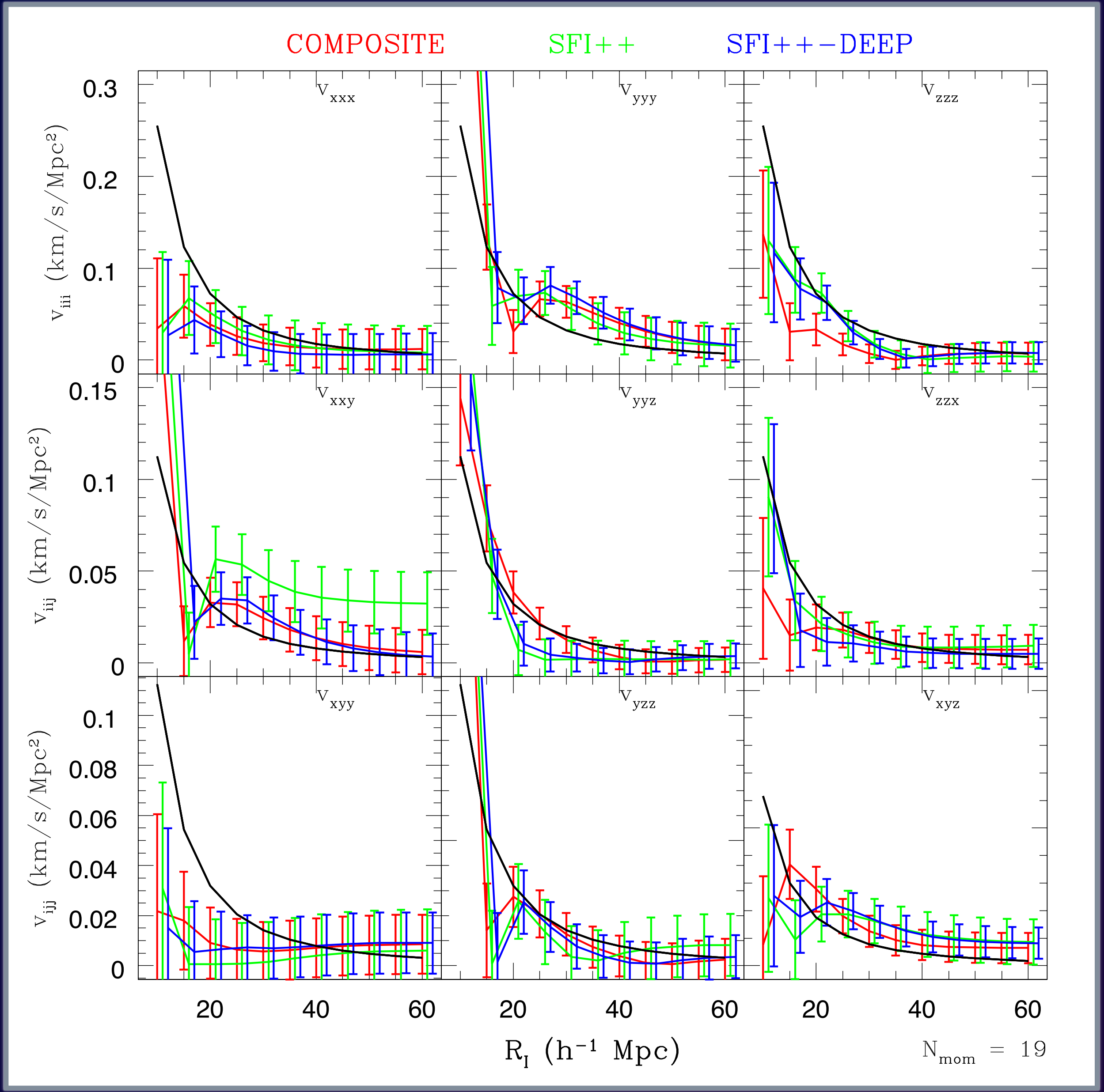
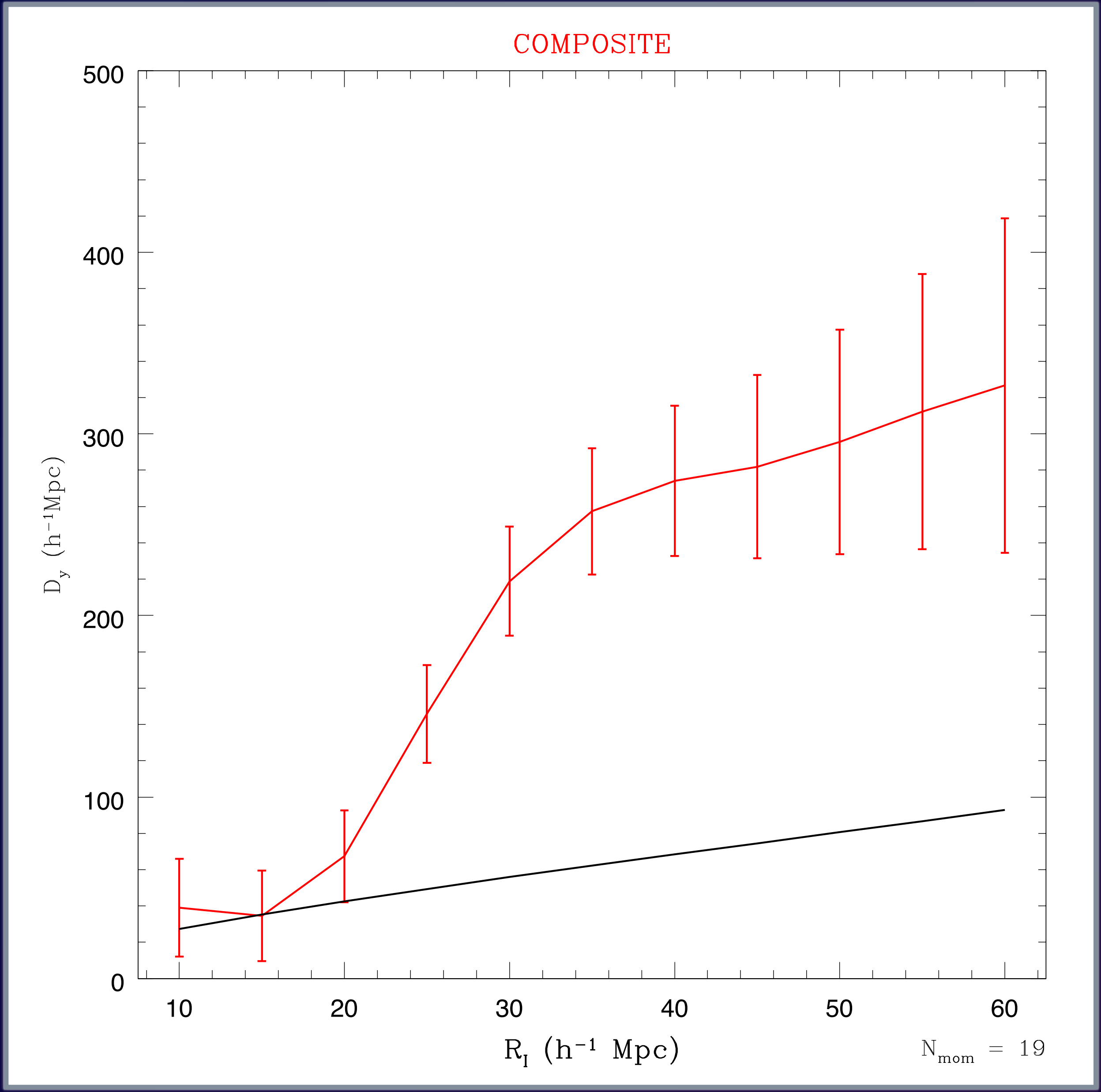


Sources of the Flow

Work in progress



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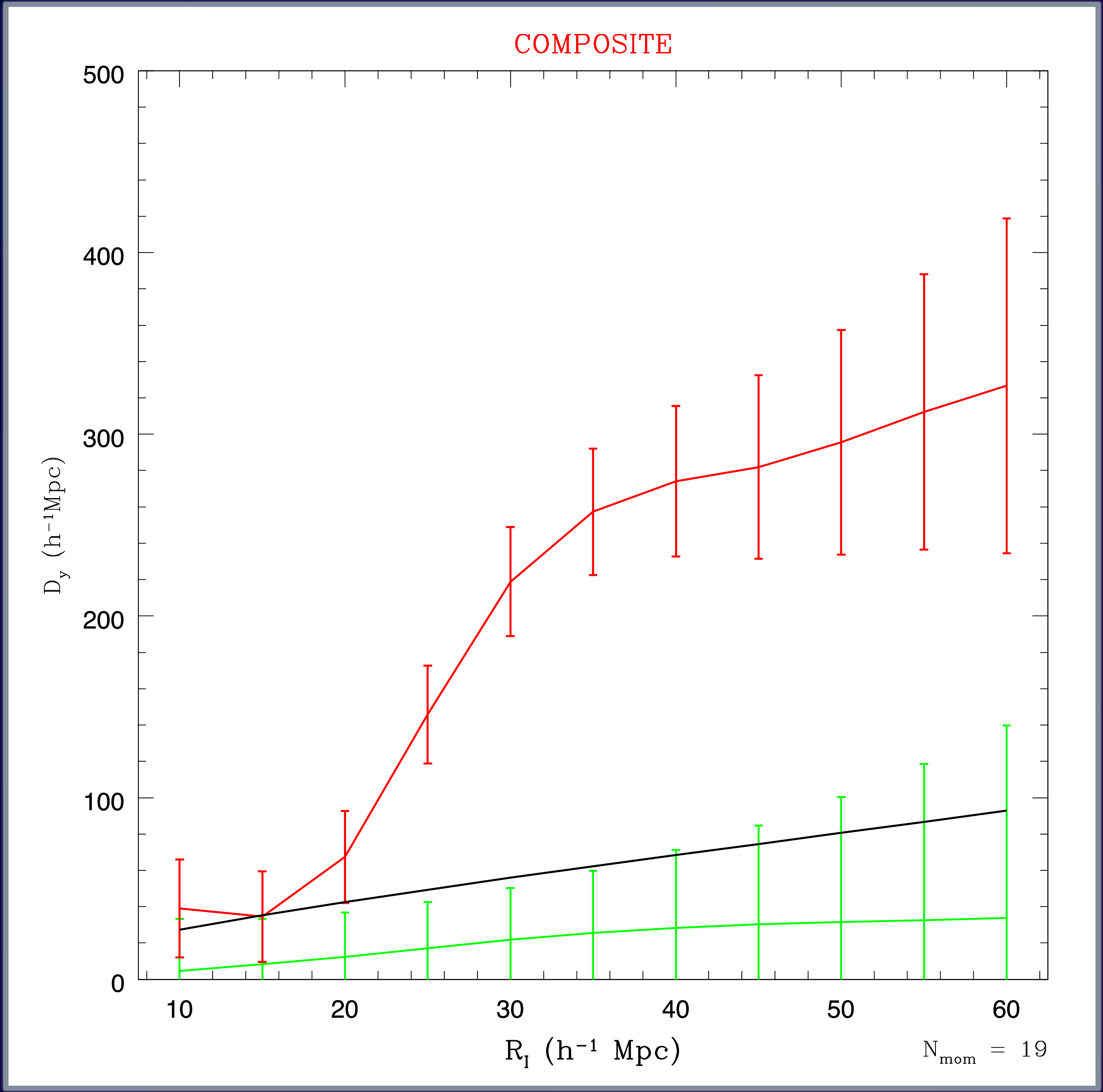
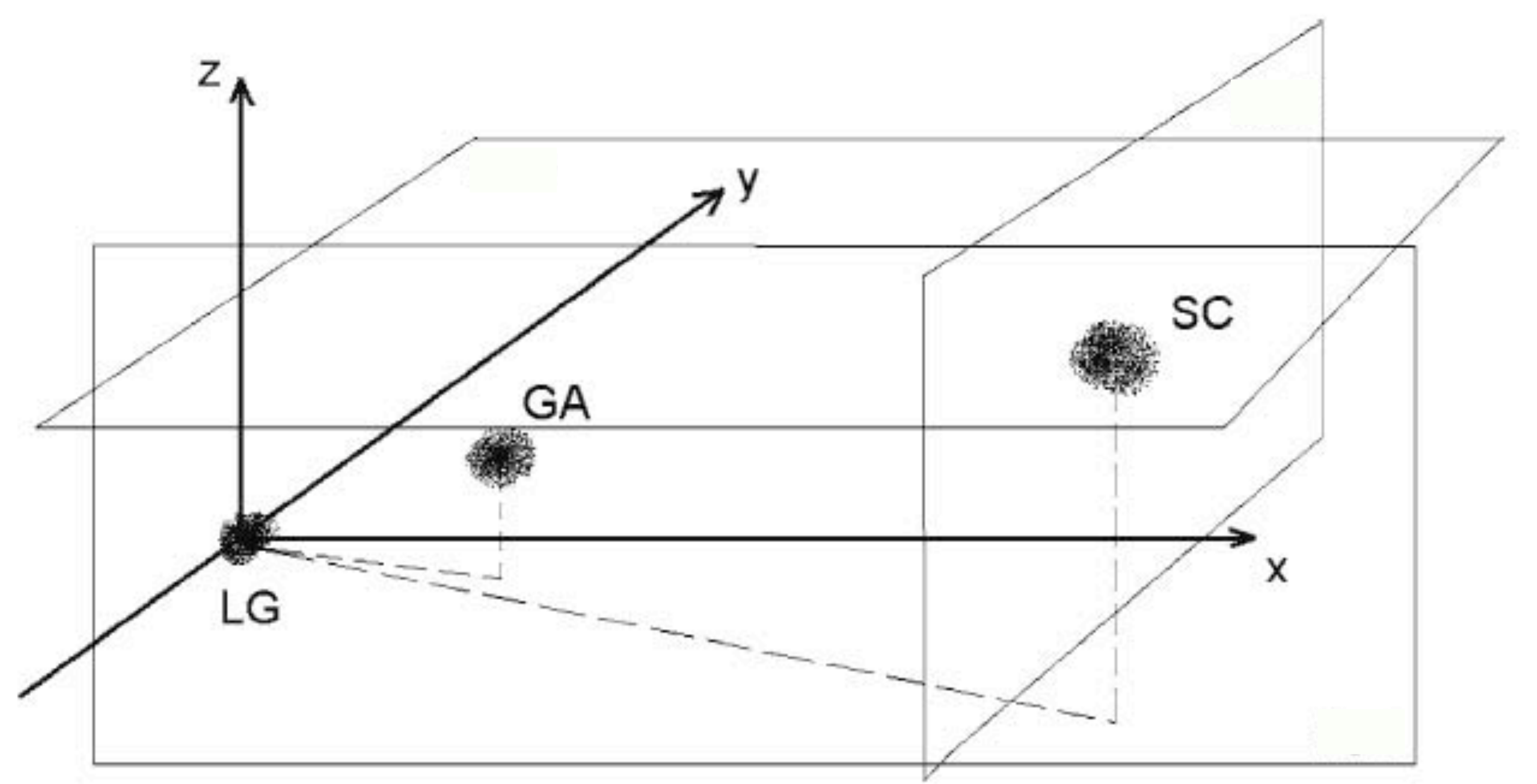


Is there an attractor?



Bolejko & Hellaby 2008

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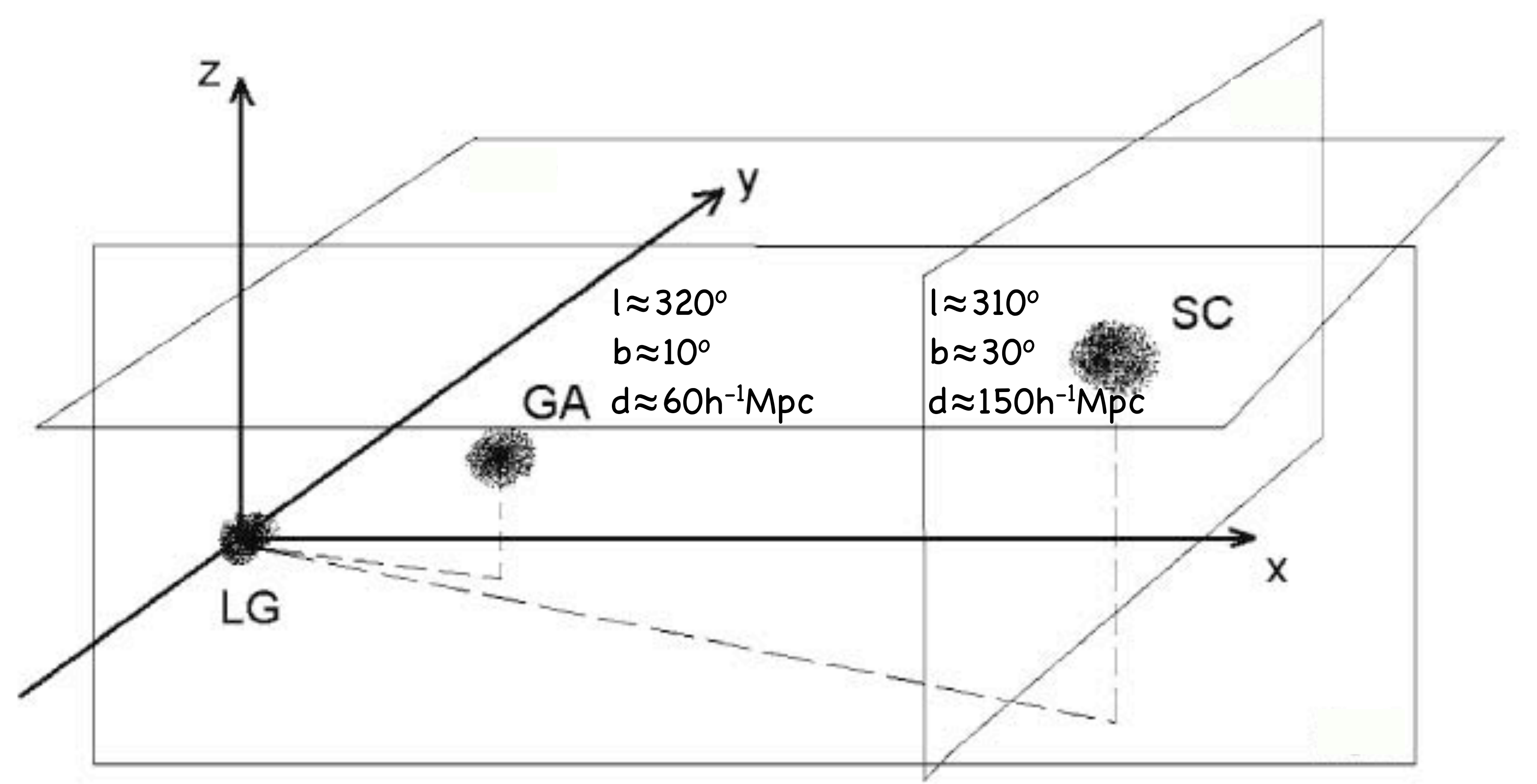

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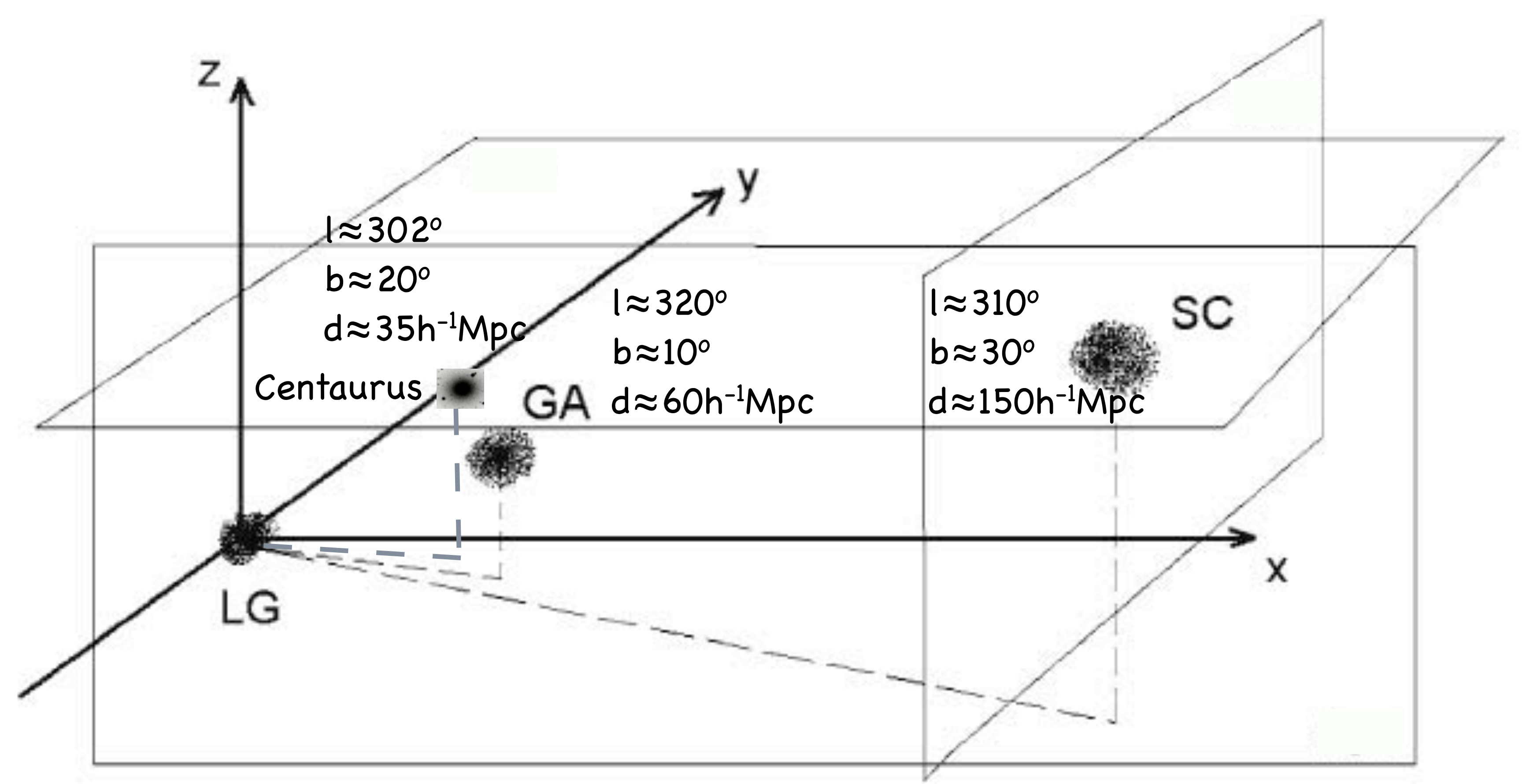

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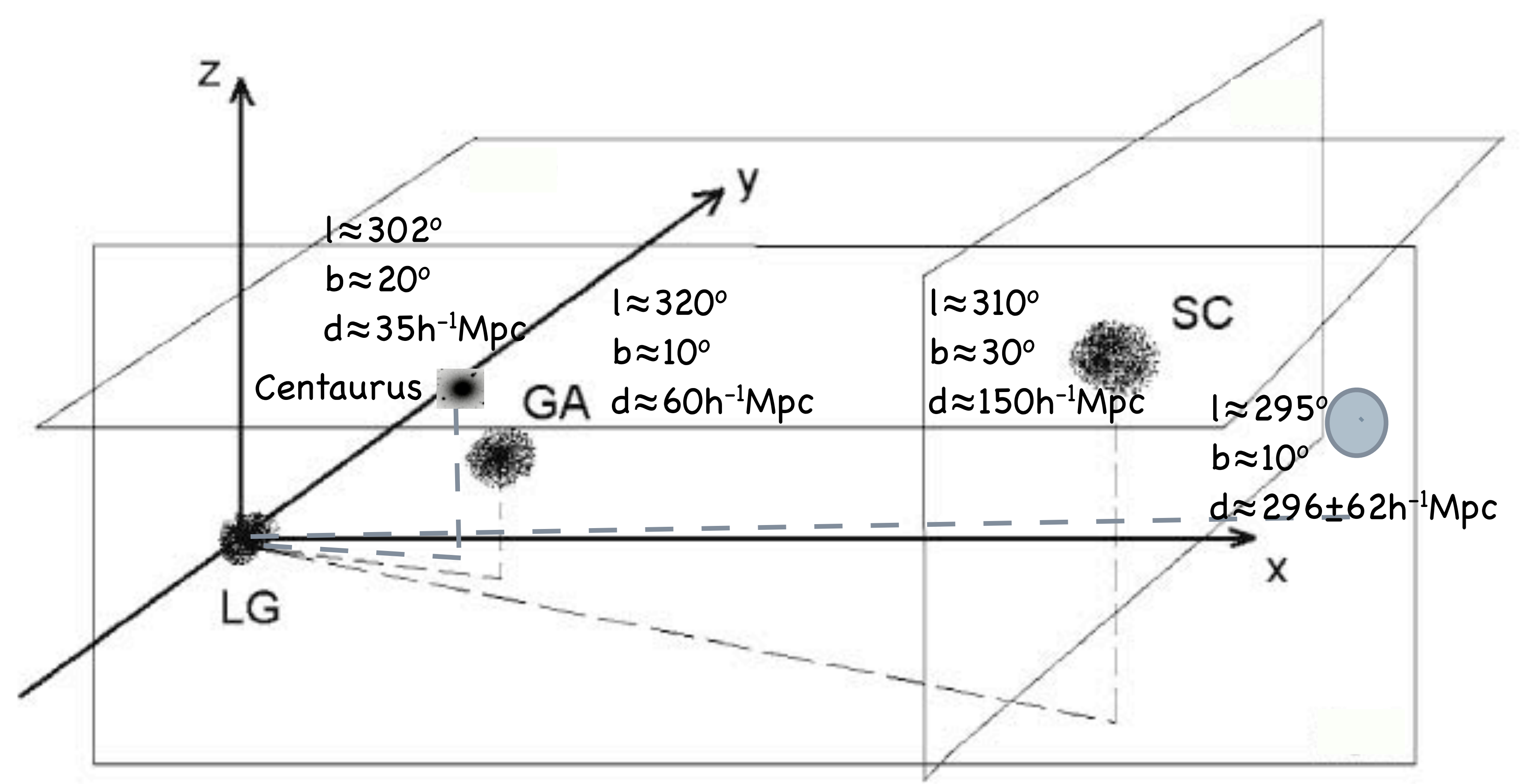

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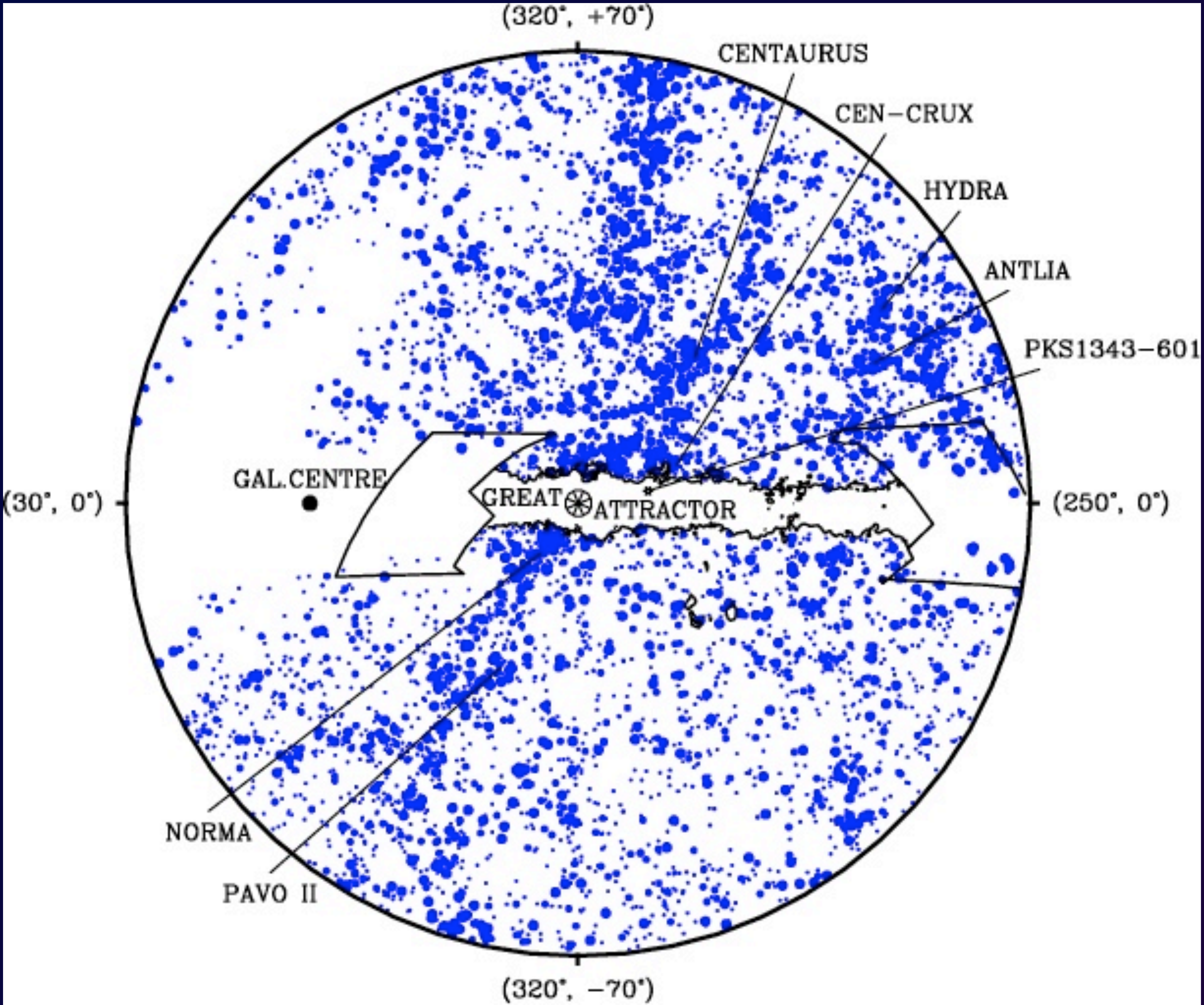

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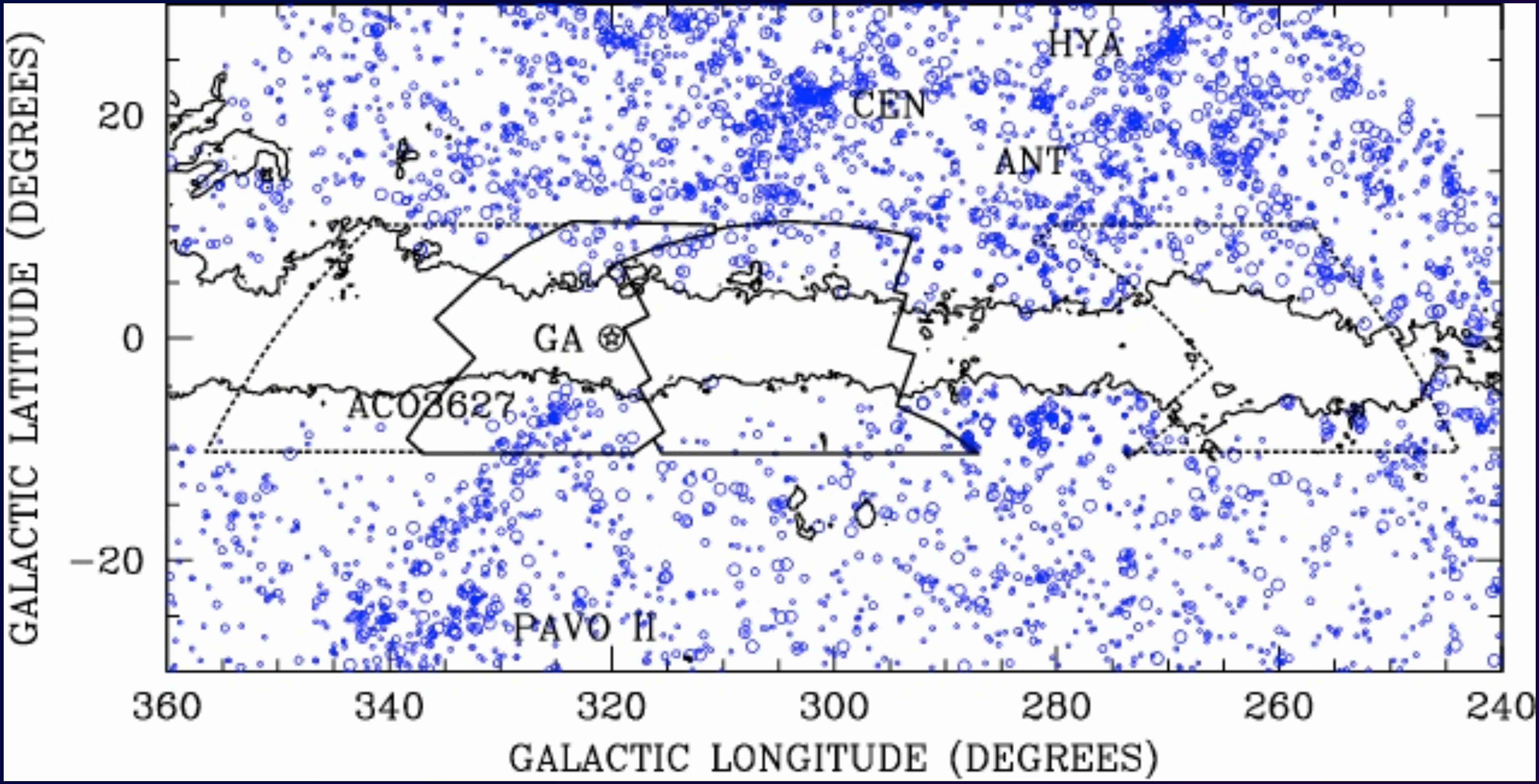

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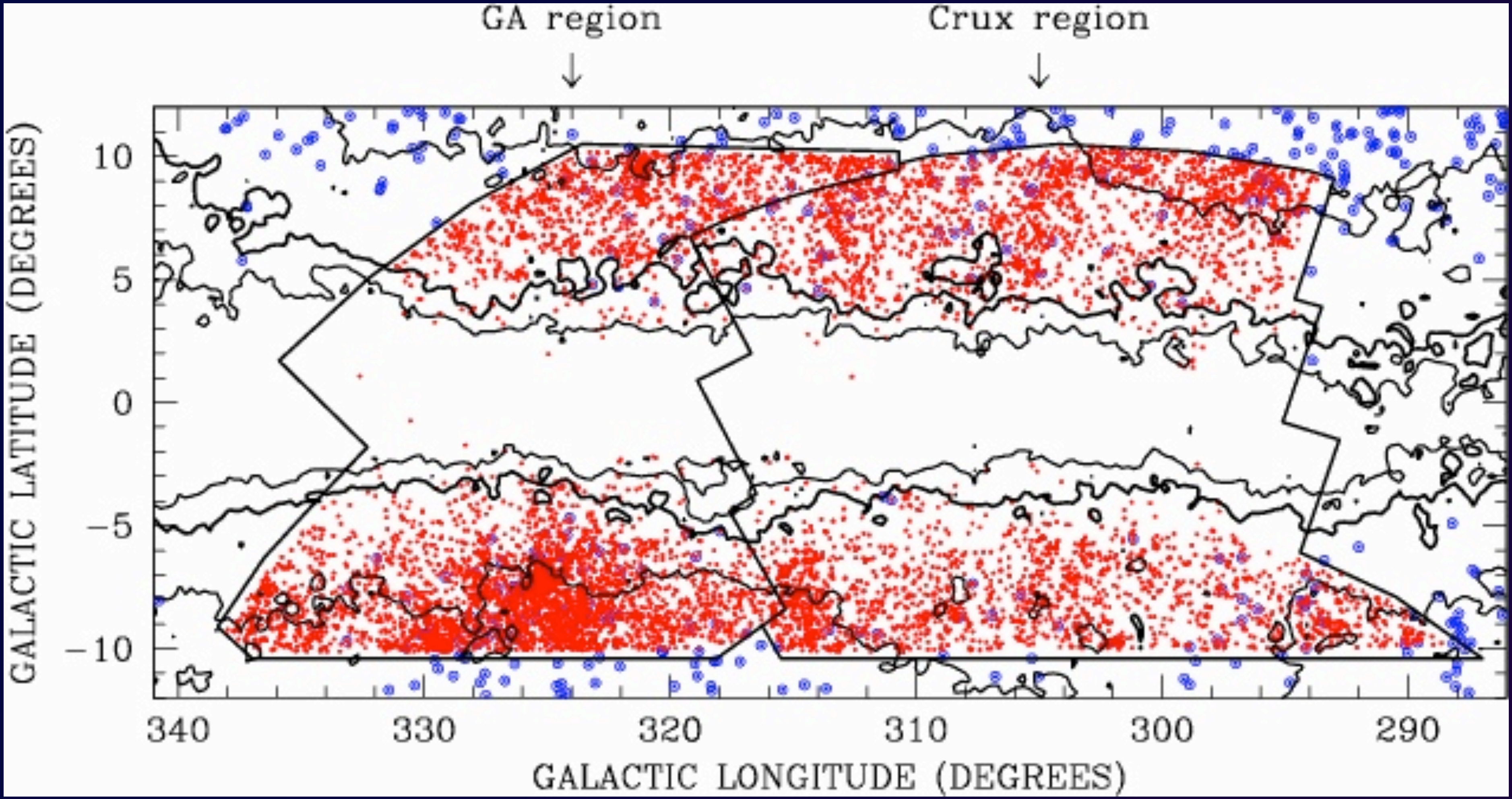

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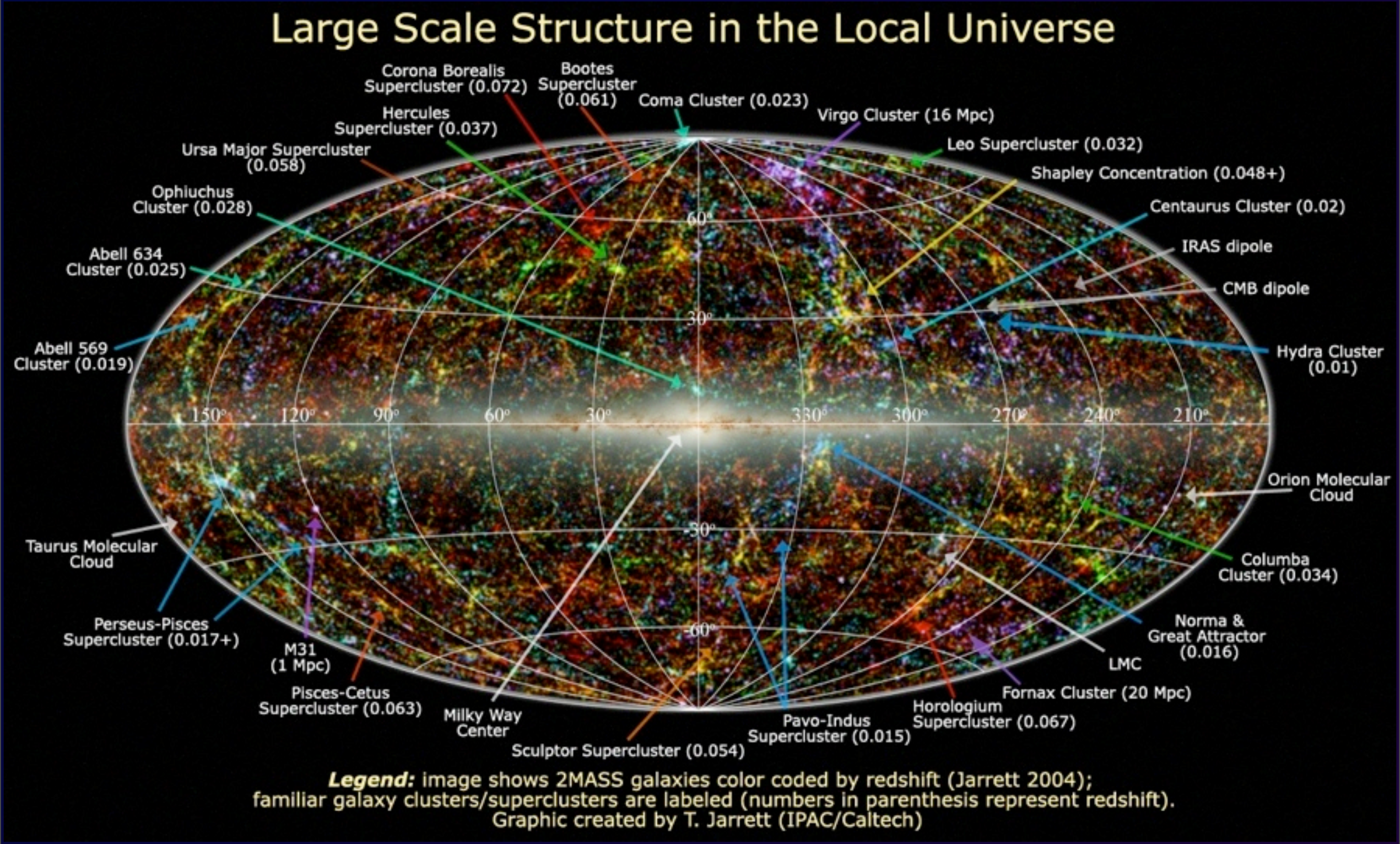

Large Scale Structure in the Local Universe

Legend: image shows 2MASS galaxies color coded by redshift (Jarrett 2004); familiar galaxy clusters/superclusters are labeled (numbers in parenthesis represent redshift). Graphic created by T. Jarrett (IPAC/Caltech)

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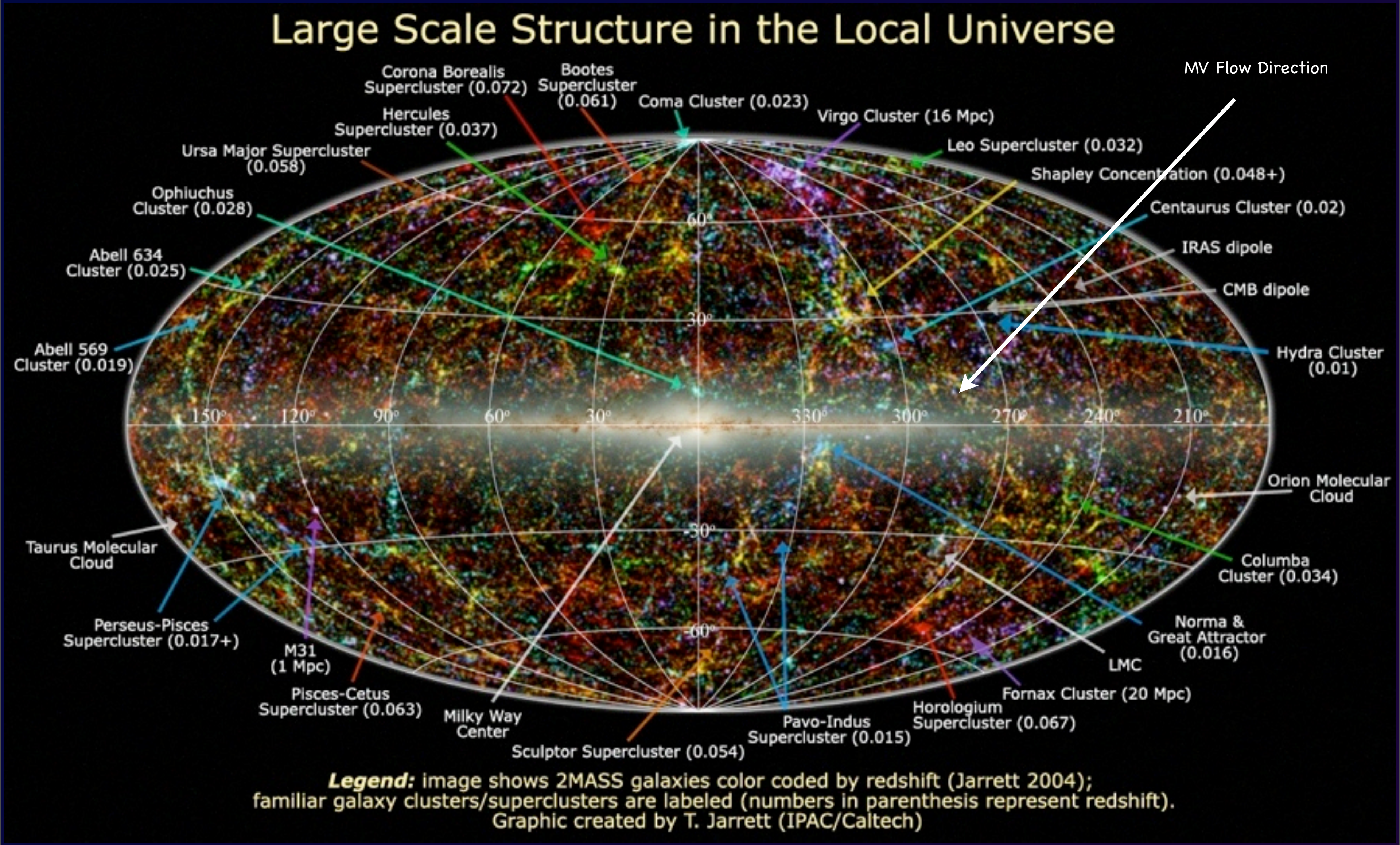

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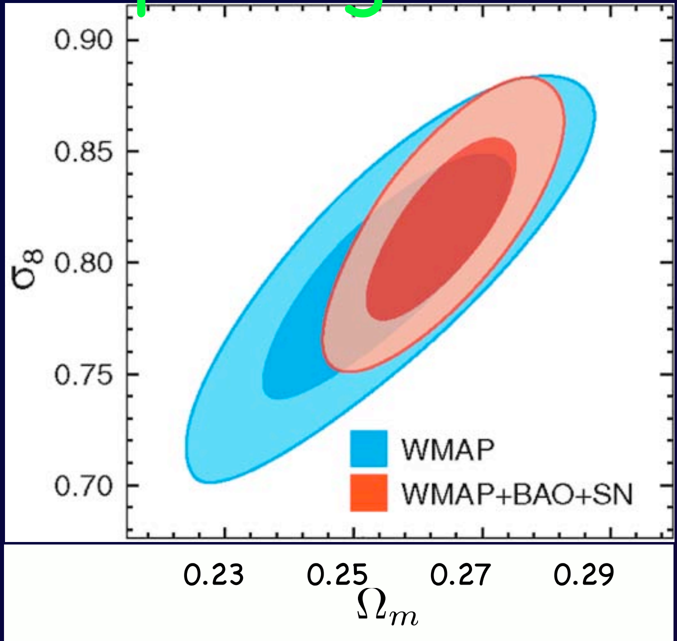
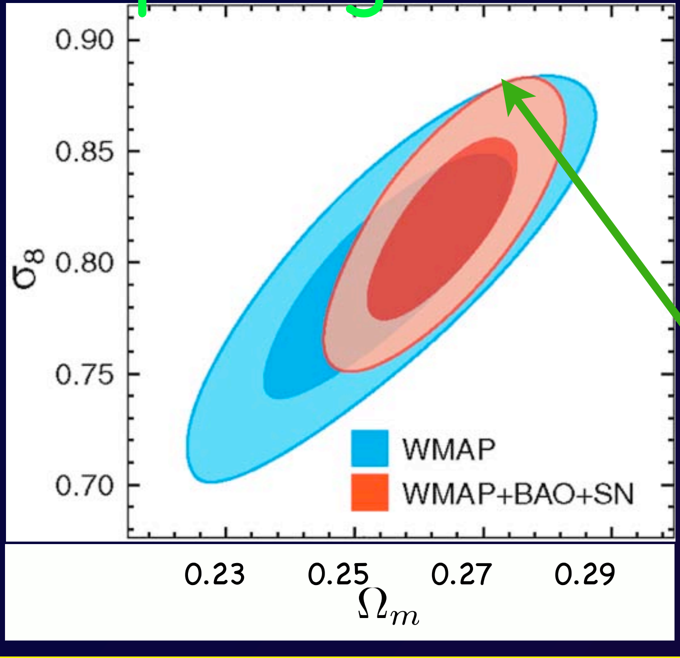
- ☑ Optimization of window functions removes the bias and shows the flow
- ☑ Bulk flow disagrees with the Standard ΛCDM parameters (WMAP5) to $\sim 3\sigma$

Comparing to WMAP



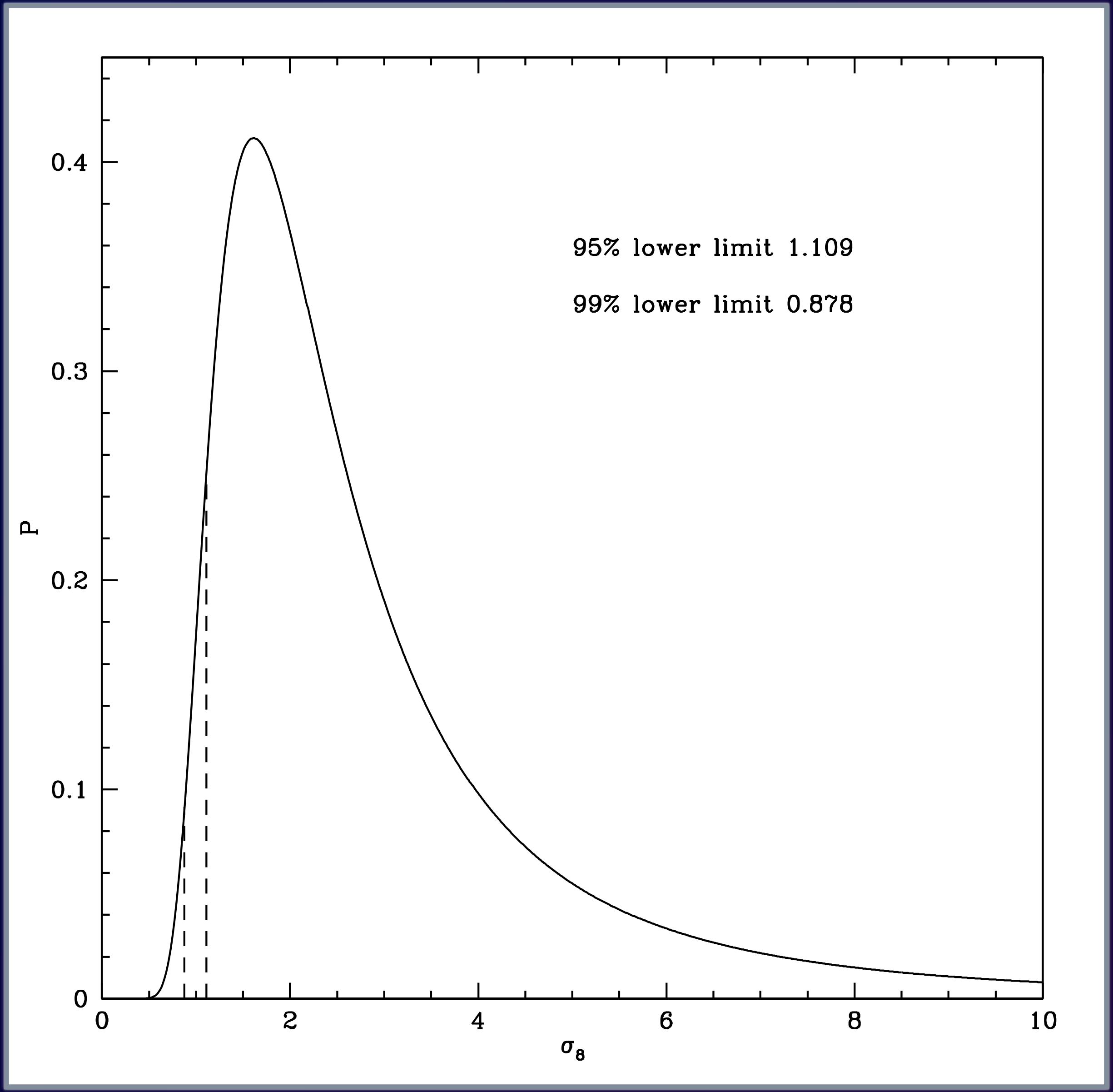
	ML	
	$\Omega_m = 0.258$	$\sigma_8 = 0.796$
Survey	$\chi2$	$P(>\chi2)$
SHALLOW	1.95	0.583
DEEP	8.75	0.033
SFI++	13.60	0.004
COMPOSITE	13.77	0.003
EXPECTED 1-D RMS	106 km/s	

Comparing to WMAP



	ML		BC	
	$\Omega_m = 0.258$	$\sigma_8 = 0.796$	$\Omega_m = 0.28$	$\sigma_8 = 0.86$
Survey	$\chi 2$	$P(> \chi 2)$	$\chi 2$	$P(> \chi 2)$
SHALLOW	1.95	0.583	1.83	0.608
DEEP	8.75	0.033	8.32	0.040
SFI++	13.60	0.004	12.85	0.005
COMPOSITE	13.77	0.003	13.02	0.005
EXPECTED 1-D RMS	106 km/s		109 km/s	

σ_8 lower limits from Flows



Reichardt et al 2008 (ACBAR)

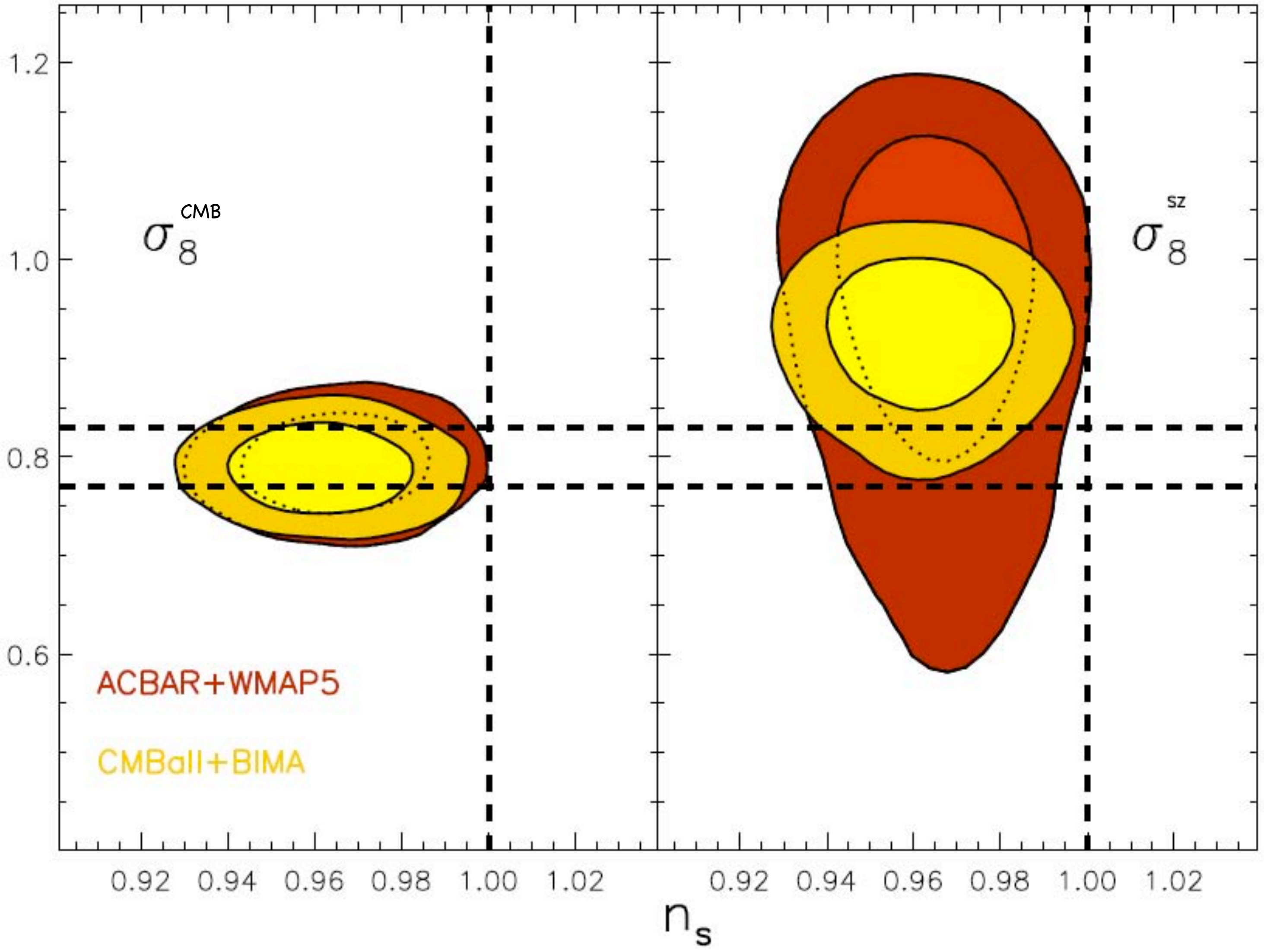


FIG. 13.— The figure contrasts the one and two sigma contour intervals for σ_8 determined from the primary anisotropy component of the CMB (left) with the value inferred from the SZE template transformation of q_{SZ} into $\sigma_8^{(SZ)}$ (right), assuming a uniform prior measure in q_{SZ}. Allowing for a point source contribution would decrease the tension between σ_8 and σ_8^{SZ} for the ACBAR+WMAP5 case. These panels also demonstrate the strength of the deviation of n_s from unity for the flat ΛCDM model.

Flows

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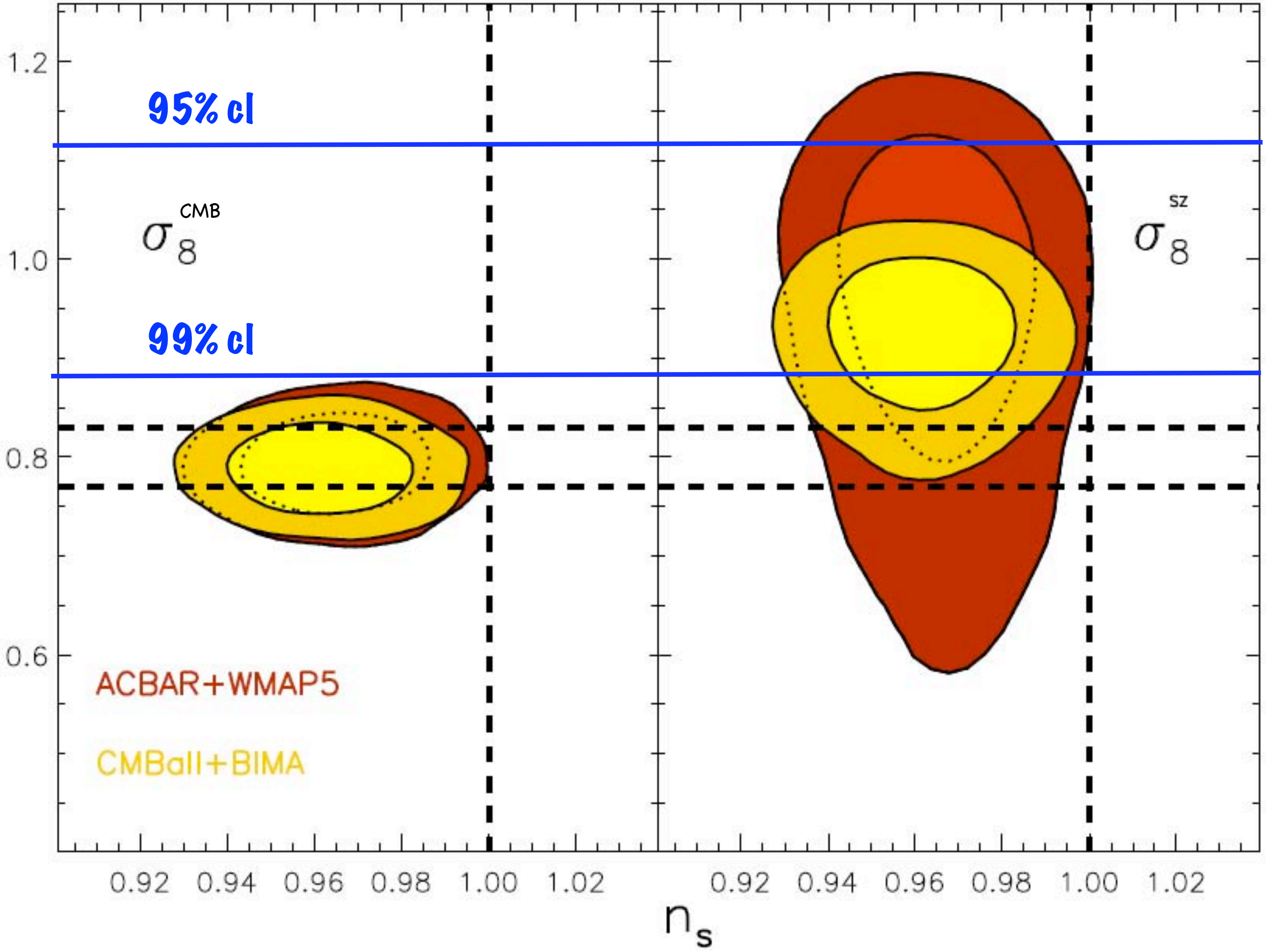

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Estimating the Nonlinear Evolution of σ_8 the Amplitude of Cosmological Density Fluctuations on 8 h^{-1}Mpc scale

Juszkiewicz, HAF, Fry, Jaffe

ArXiv:0901.0697 (2009)

Background

The variance of mass M in a volume element d^3z at position z relative to one of a pair of galaxies at separation r is

$$dM = \rho\xi(r)^{-1}\zeta_\rho(r, z, |\mathbf{r} - z|)d^3z$$

Davis & Peebles (1983)

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The values of the estimates vary considerably between the various probes.

However, different estimators probe the value of σ_8 in different cosmological scales and do not take into account the nonlinear evolution of the parameter at late times.

Conventional Wisdom

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- Octupole and higher moments...

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The mean square density contrast at redshift z in a spherical volume V with a comoving radius R is given by the expression

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The amplitude of cosmological density fluctuations in a sphere of 8 h^{-1} Mpc

$$\sigma_8 \equiv \sigma(8h^{-1}Mpc, 0)$$

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Galaxy surveys estimate σ_{gal}

Linear bias (Kaiser, 1988)

$$b^2 \equiv \frac{\sigma^2_{\rm gal}}{\sigma^2_{\rm mass}} = \frac{1}{\sigma^2_8}$$

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- Nonlinear evolution of gravitational clustering can be seen in redshift surveys (Feldman etal 2001, verde etal 2002)
- Differences between estimates of σ_8 from various probes:
  - CMB $\sigma_8 \approx 0.8$
  - z-surveys $\sigma_8 \approx 0.95$
  - cosmic flows $\sigma_8 \approx 1.1$

Nonlinear corrections to σ$_8$

Pair conservation, one-loop perturbative corrections to the leading order variance σ$_L$(r) for Power law spectrum

$$\sigma^2 = \sigma_L^2 + \beta\sigma_L^4$$

(Scoccimarro & Frieman, 1996)

(Lokas, Juszkiewicz, Bouchet & Hivon, 1996)

$$\beta = 1.843 - 1.168\gamma$$

$$\gamma(r) = -\frac{d\ln\xi}{d\ln r}$$

Logarithmic slope of ξ

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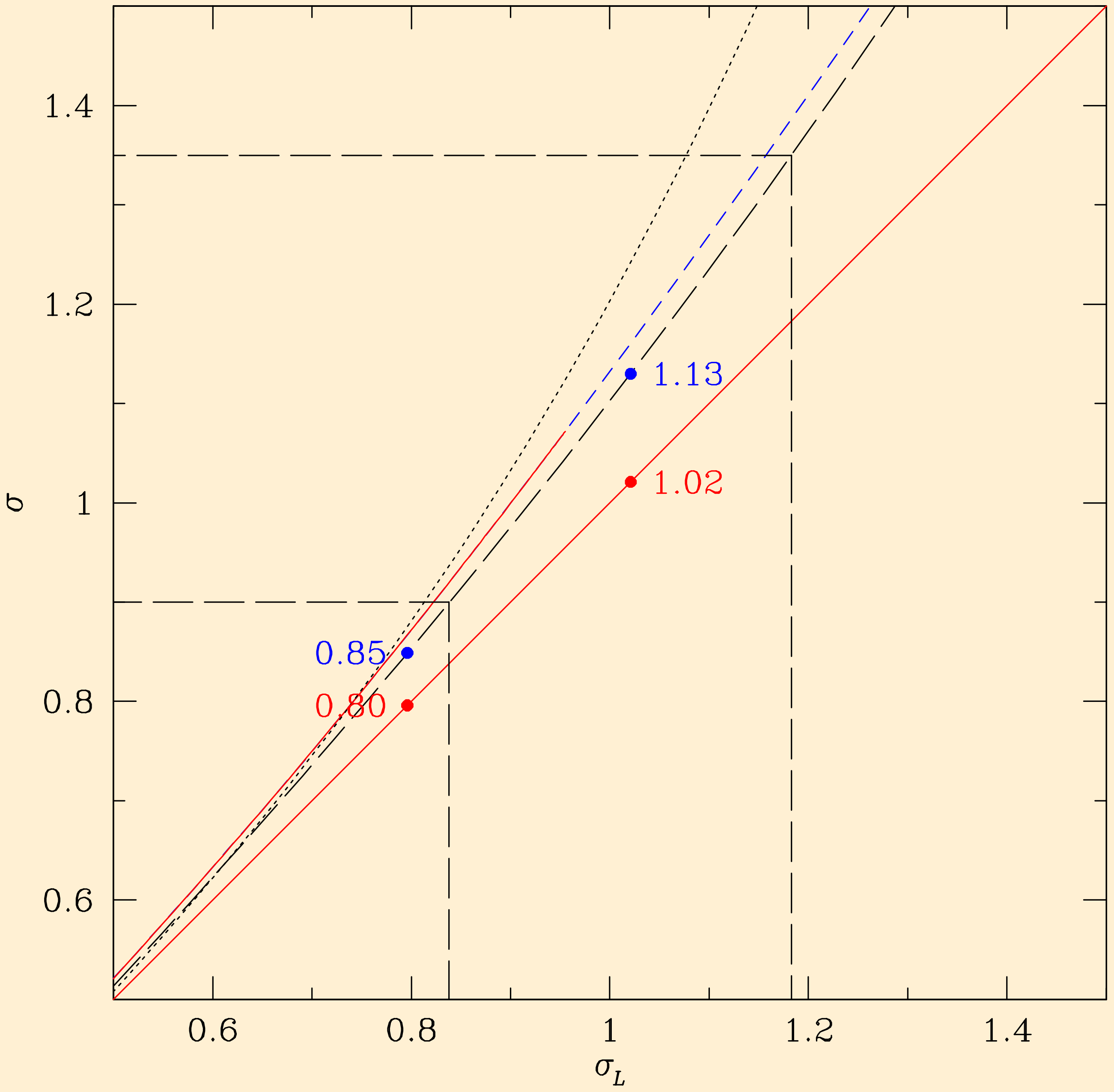
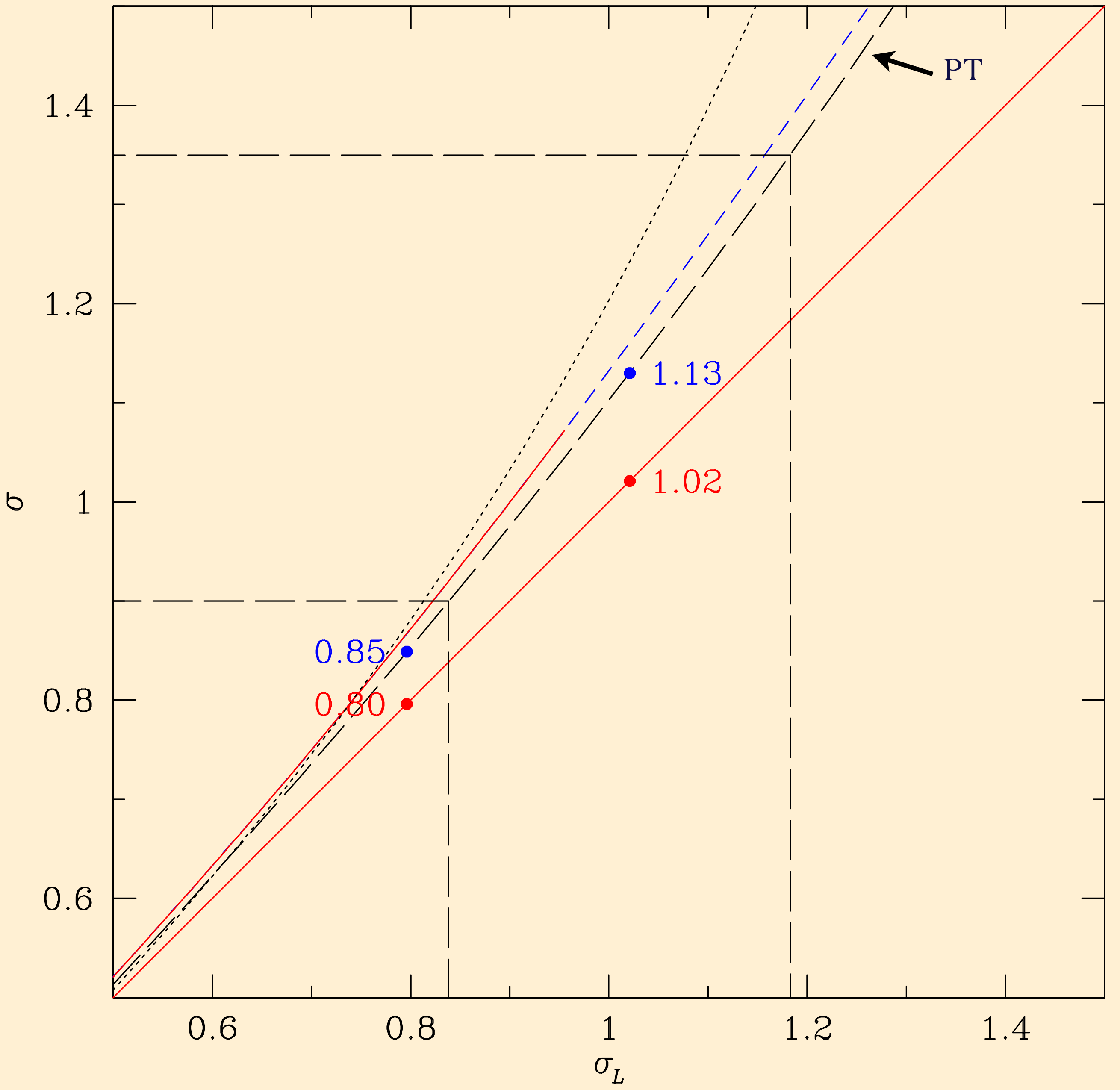
$$\sigma = 1.13^{+0.22}_{-0.23}$$ Pairwise velocity estimate

$$\sigma_L = 1.013^{+0.168}_{-0.183}$$ Linear evolution estimate



1.4
1.2
1
0.8
0.6
σ
0.6
0.8
1
1.2
1.4
σ_L
1.13
1.02
0.85
0.80


PT
1.13
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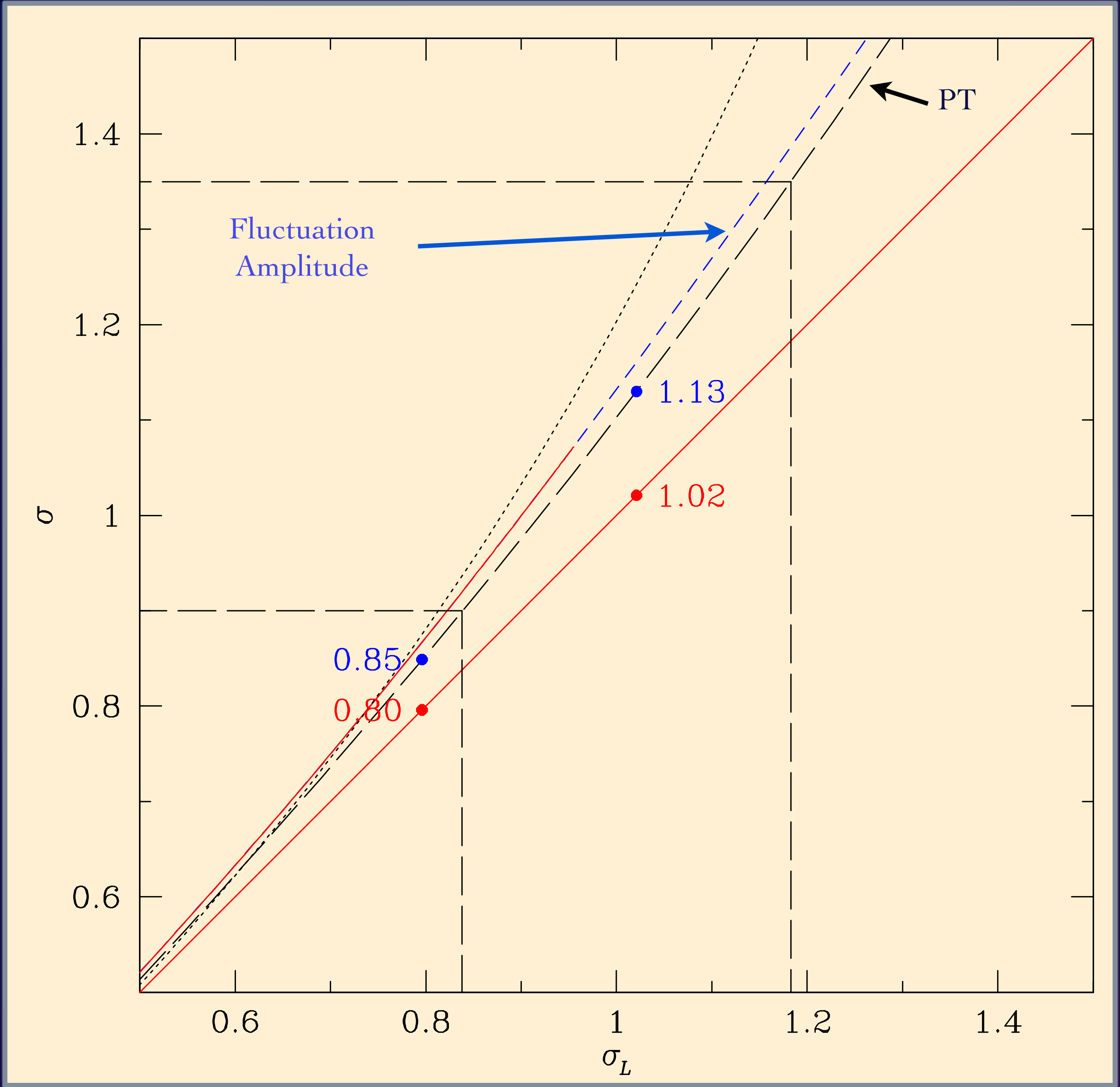
PT
Fluctuation Amplitude
1.13
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0.80
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σ
0.6
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1
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1.4
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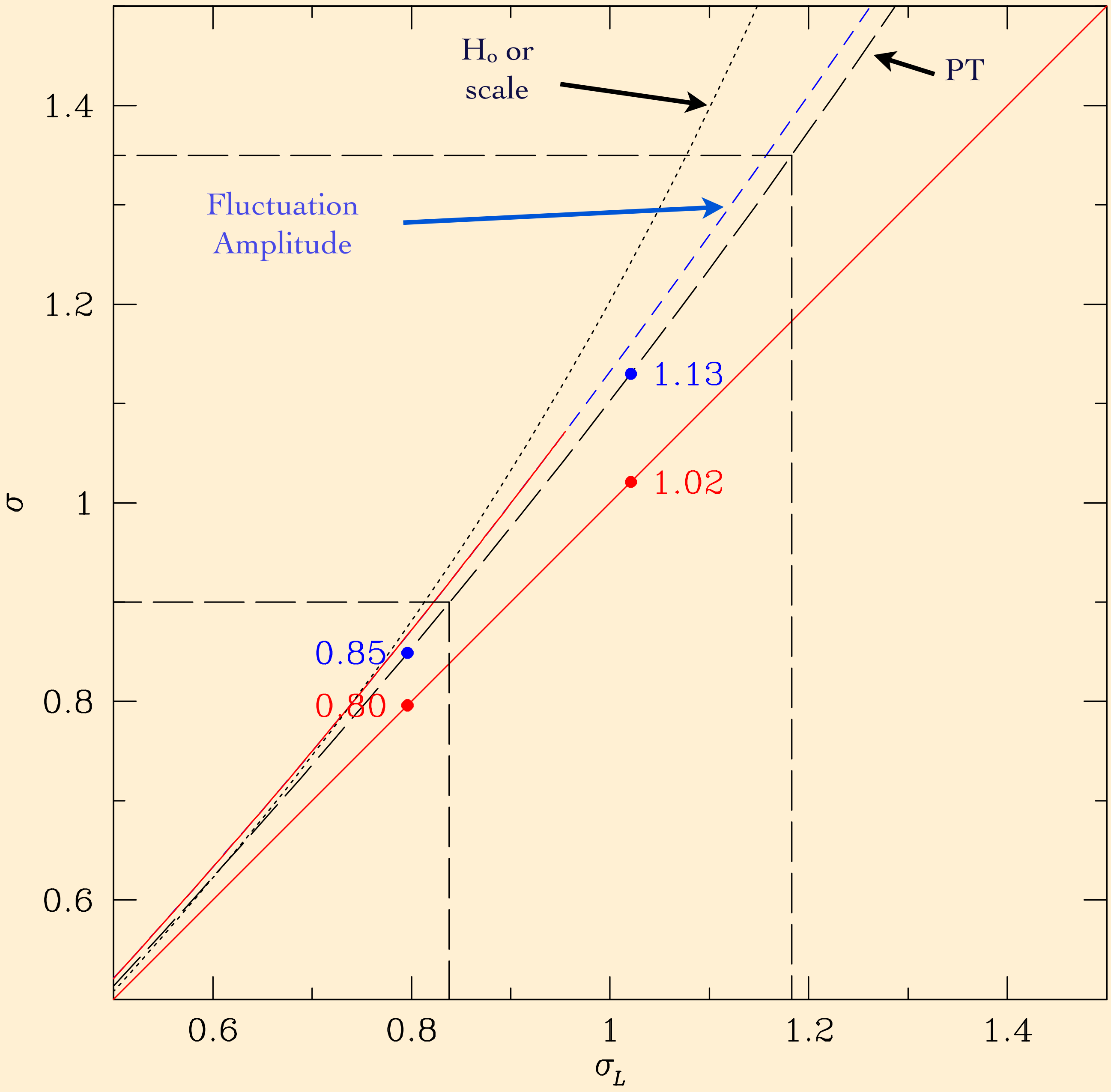
H₀ or
scale
PT
Fluctuation
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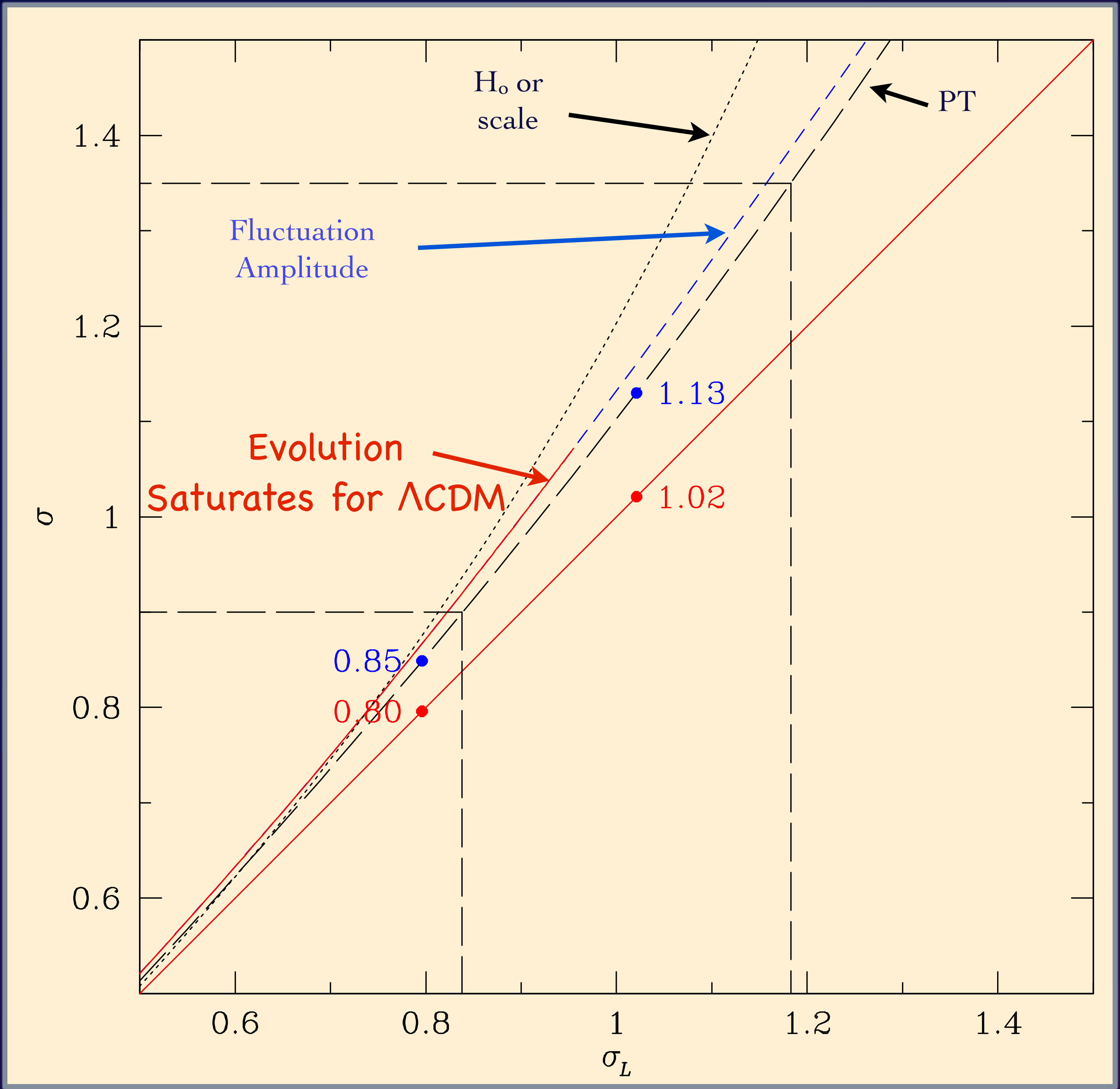
H₀ or scale
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Fluctuation Amplitude
Evolution Saturates for ΛCDM
1.13
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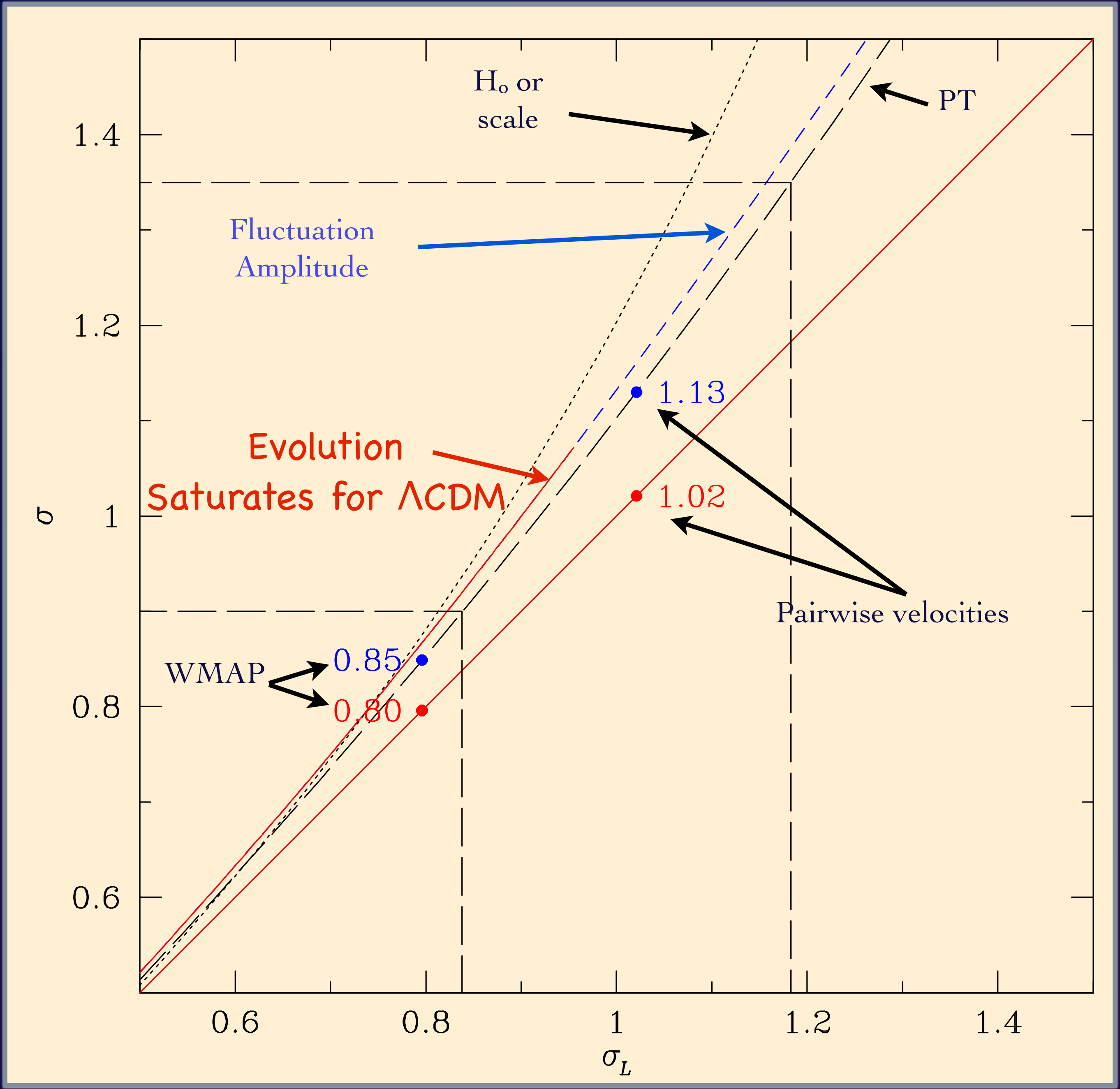
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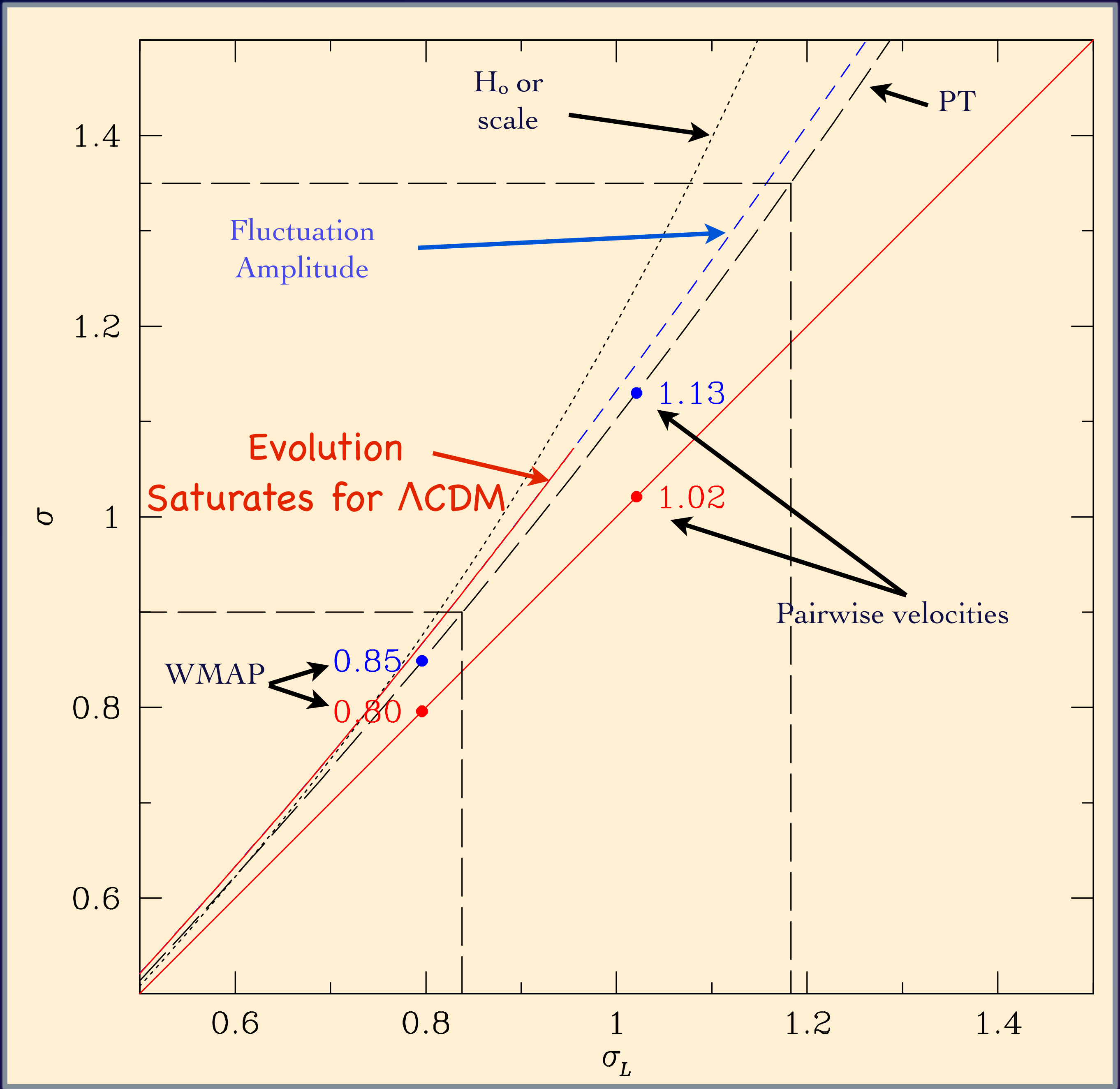
BBKS (1986)
Transfer Function

Peacock & Dodd
(1996) Fitting



An observable

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CMB $x_i = \mathcal{C}_\ell$

z-surveys $x_i = \mathcal{P}(k_i)$

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In ΛCDM, gravitational clustering is balanced by the effective force of accelerated expansion ⇒ saturate at maximum value

$$\begin{aligned}\lim_{t\to\infty} D(t) &= \frac{2\Gamma(2/3)\Gamma(11/6)}{\sqrt{\pi}}\left(\frac{\Omega_m}{1-\Omega_m}\right)^{1/3}\\ &\approx 1.01 \text{ for } \Omega_m = 0.26\ .\end{aligned}$$

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A fitting formula that works to the one-percent level in both the past and the future is

$$D(a) = \frac{a}{(1+a^{2.5})^{0.4}}$$

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$$\Delta^2(k) \equiv 4\pi\ k^3\ P(k)\ /\ (2\pi)^3$$

Linear

Peacock & Dodd (1996)

Smith etal (2003)

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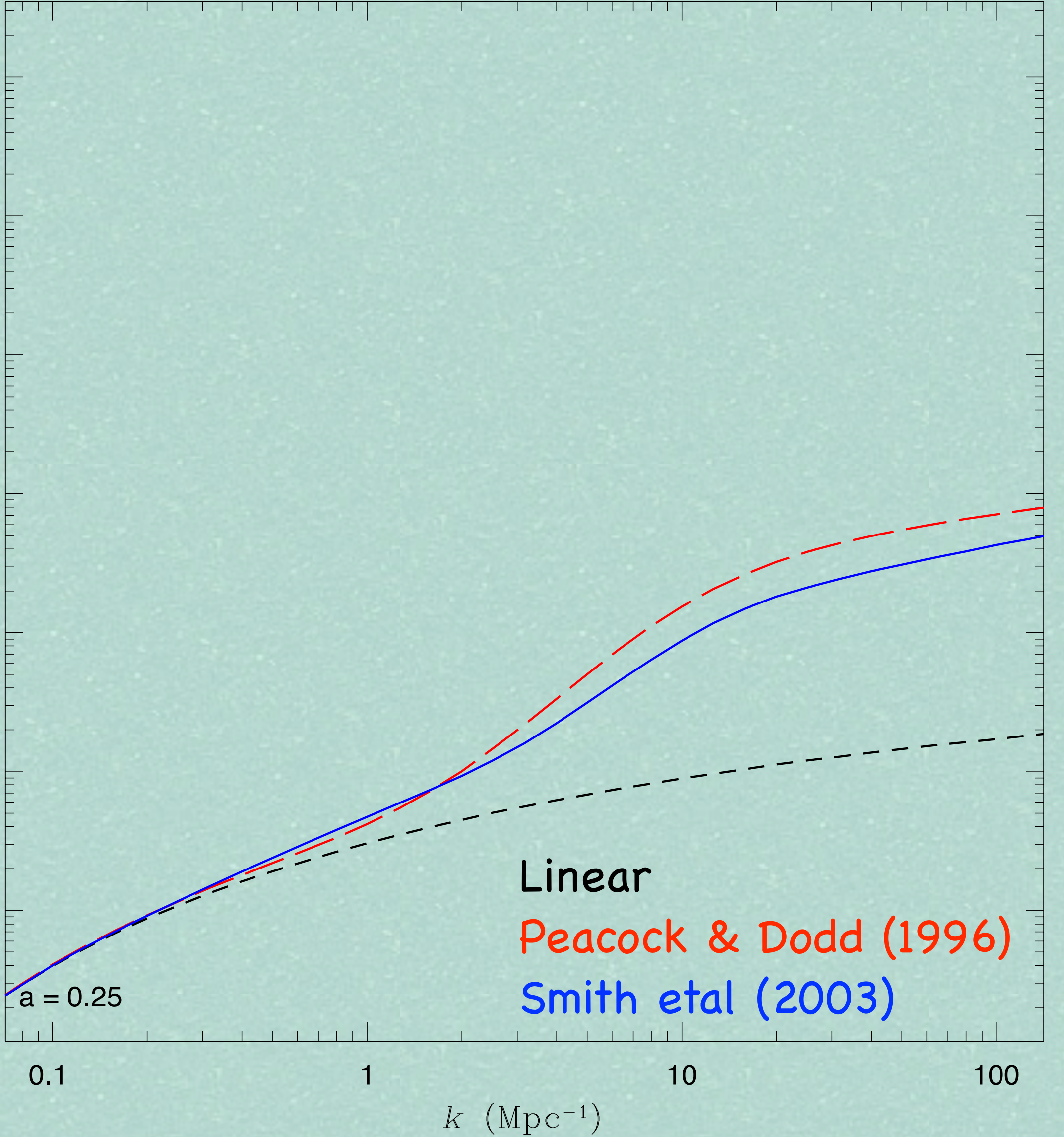

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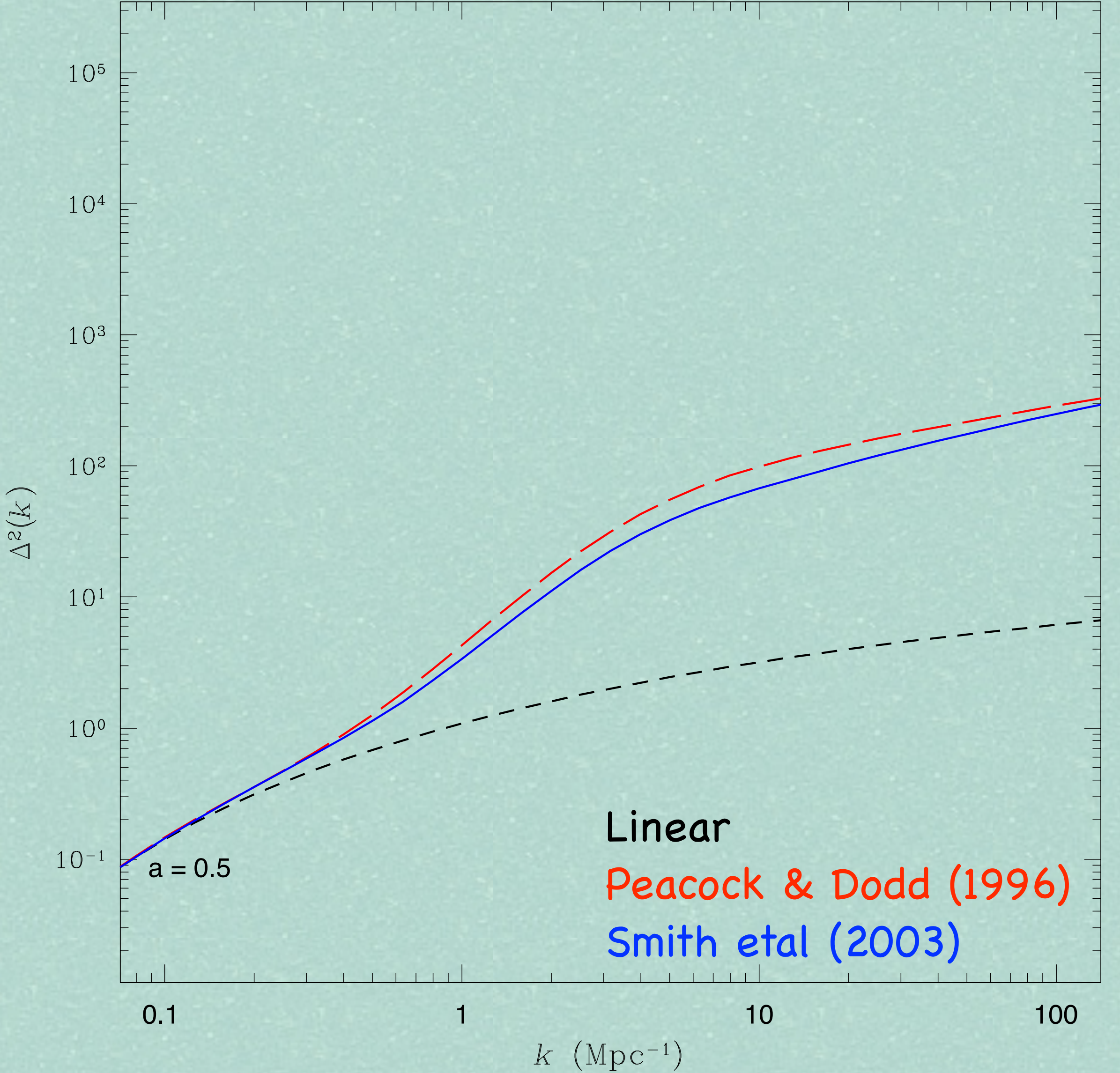

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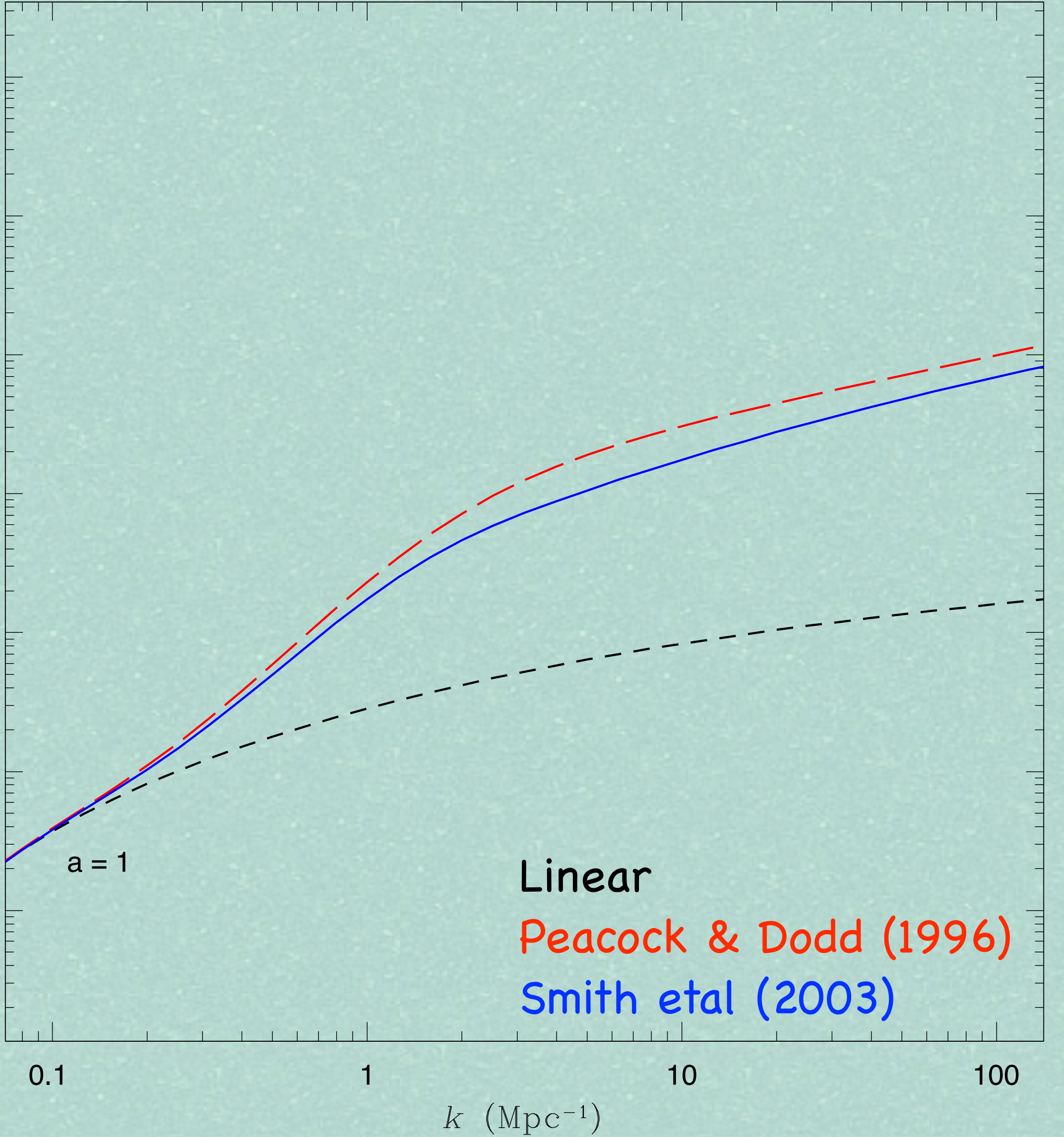

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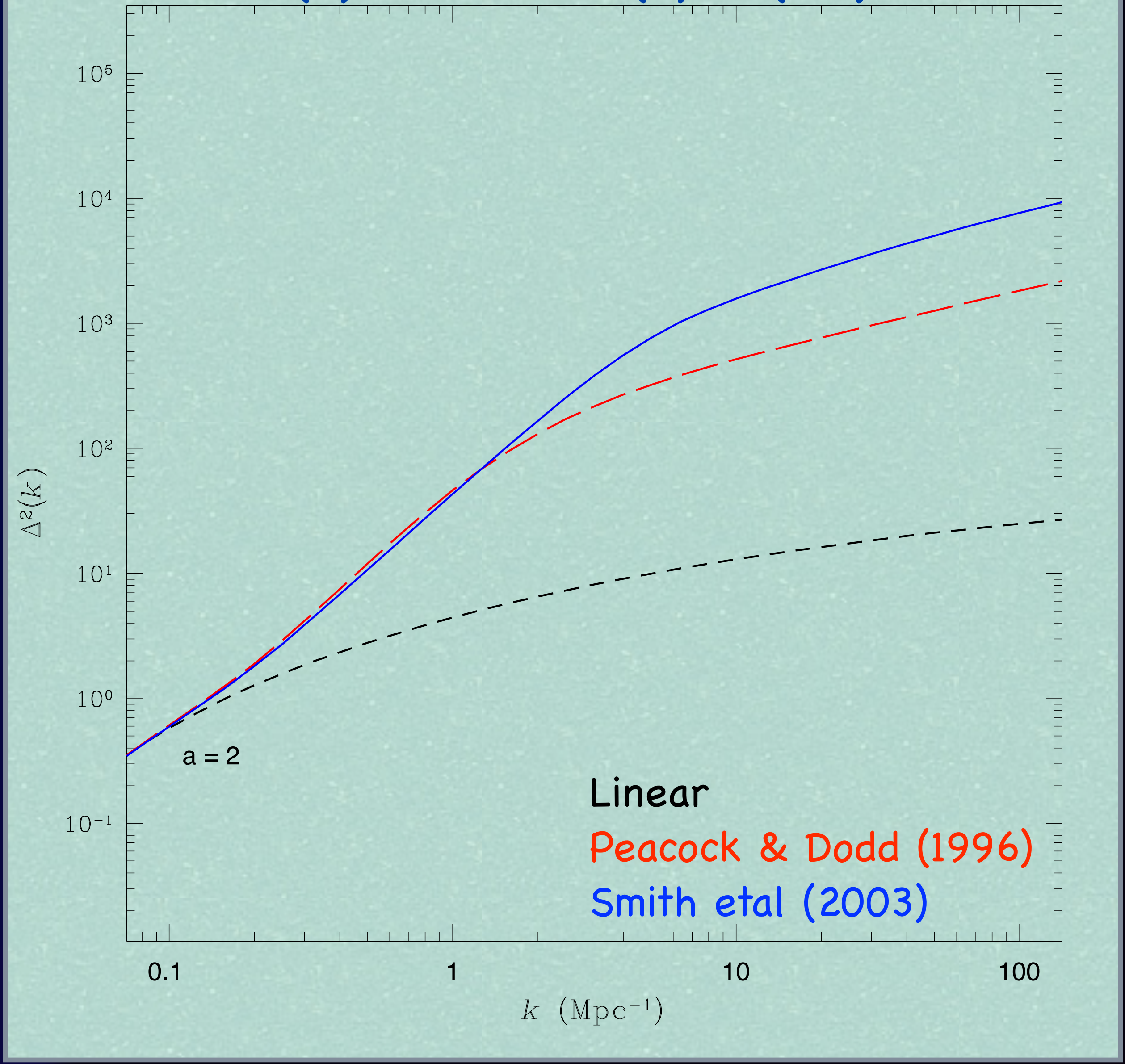

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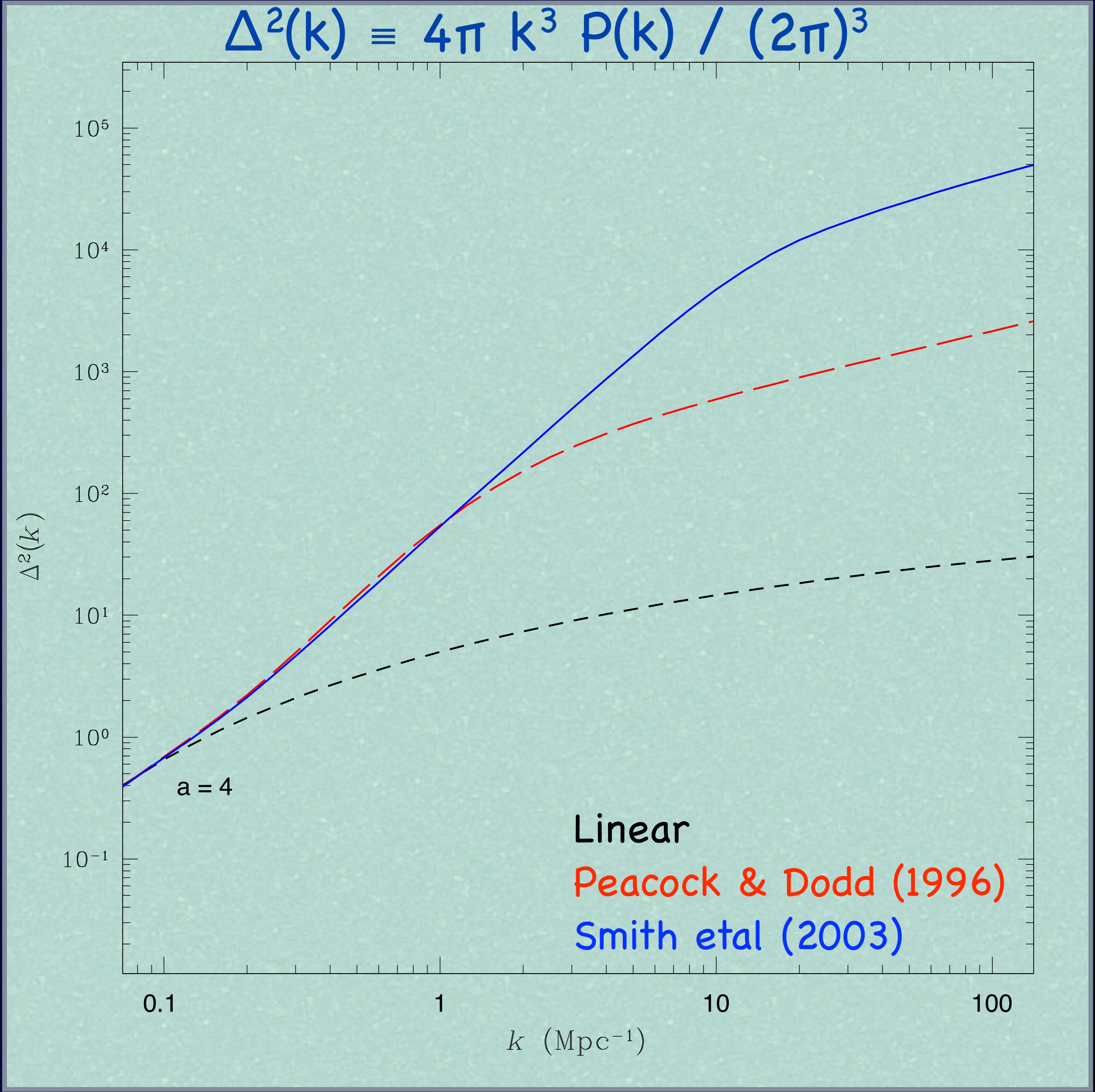

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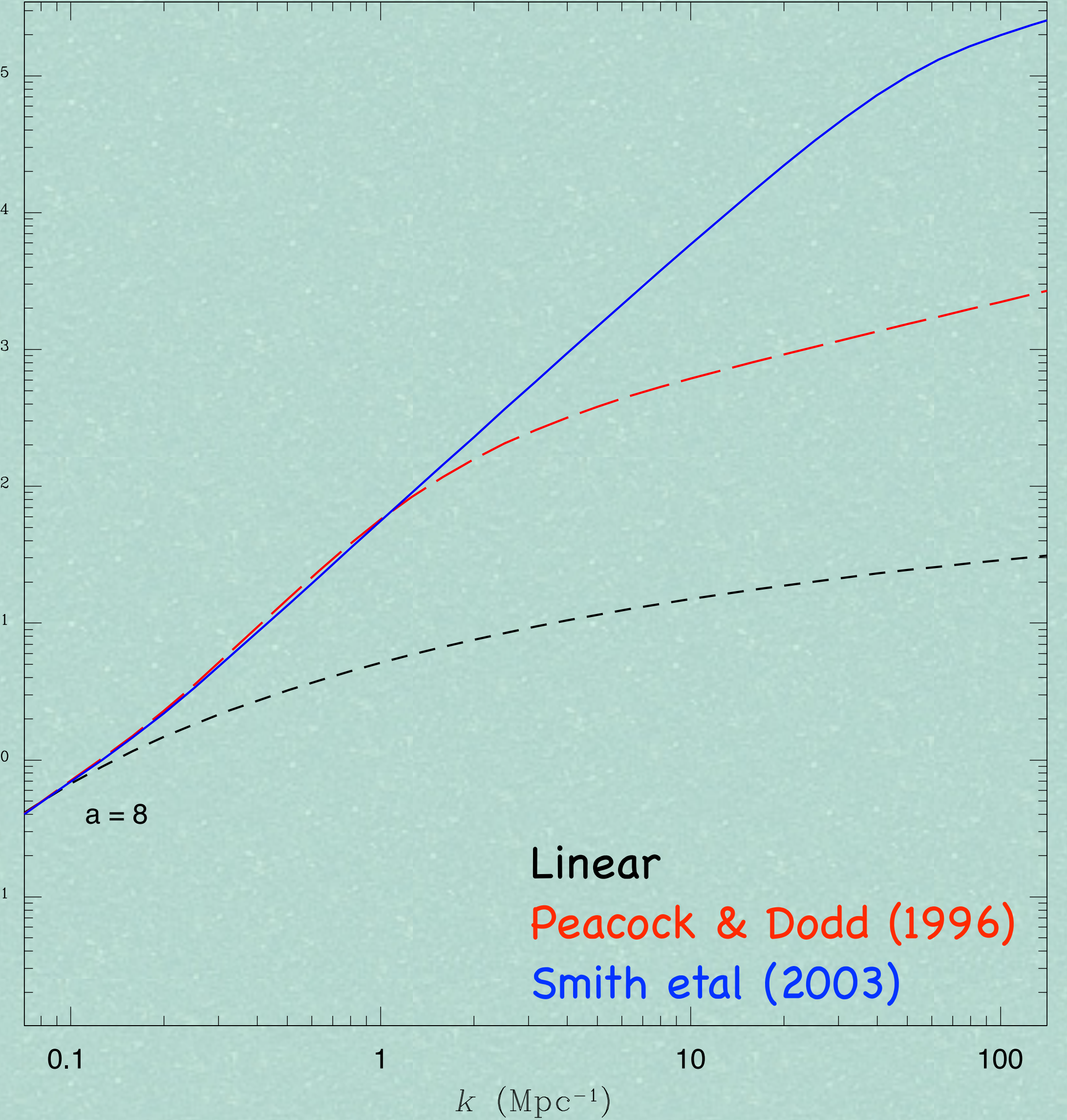

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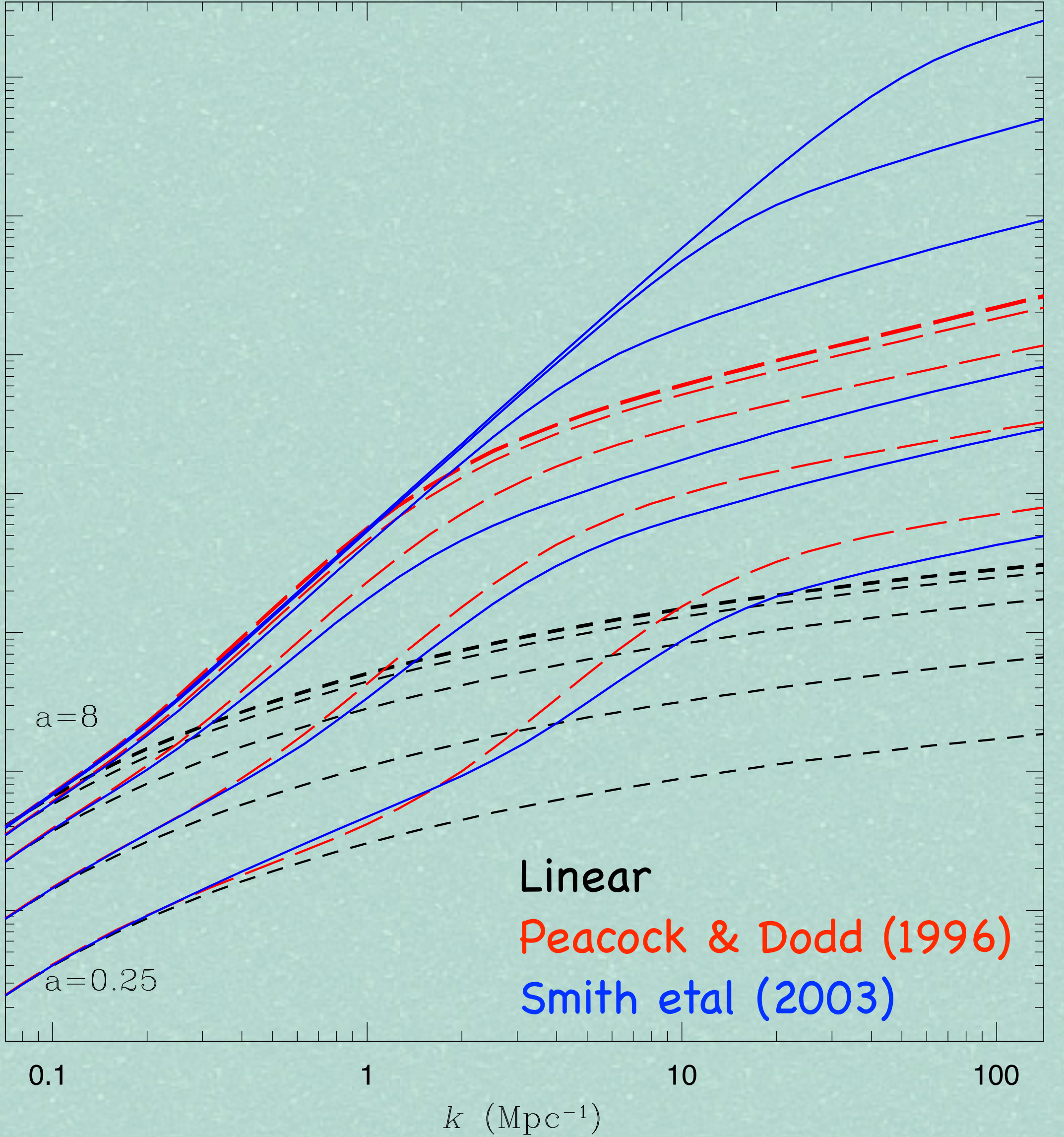

σ Past and Future

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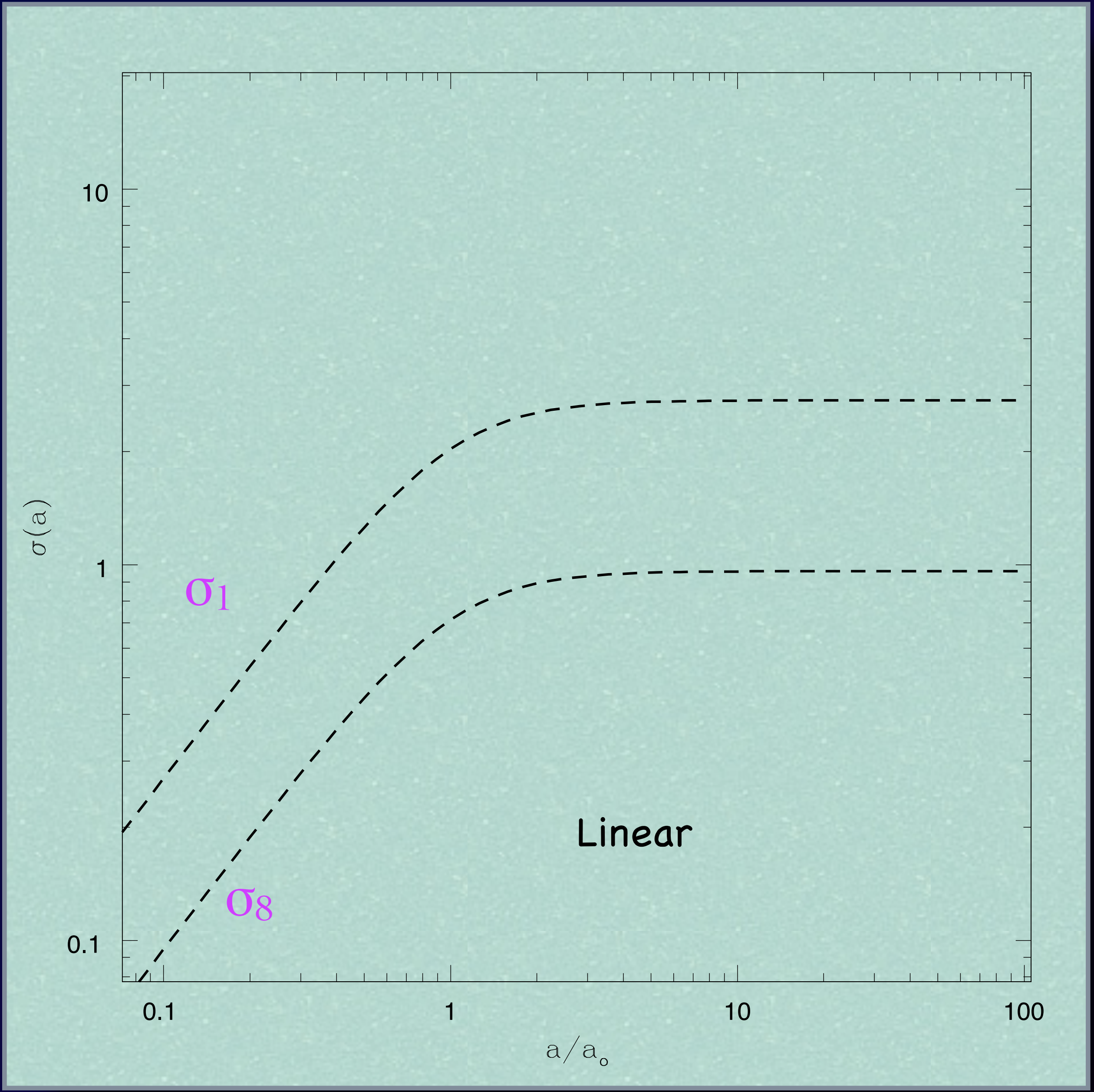

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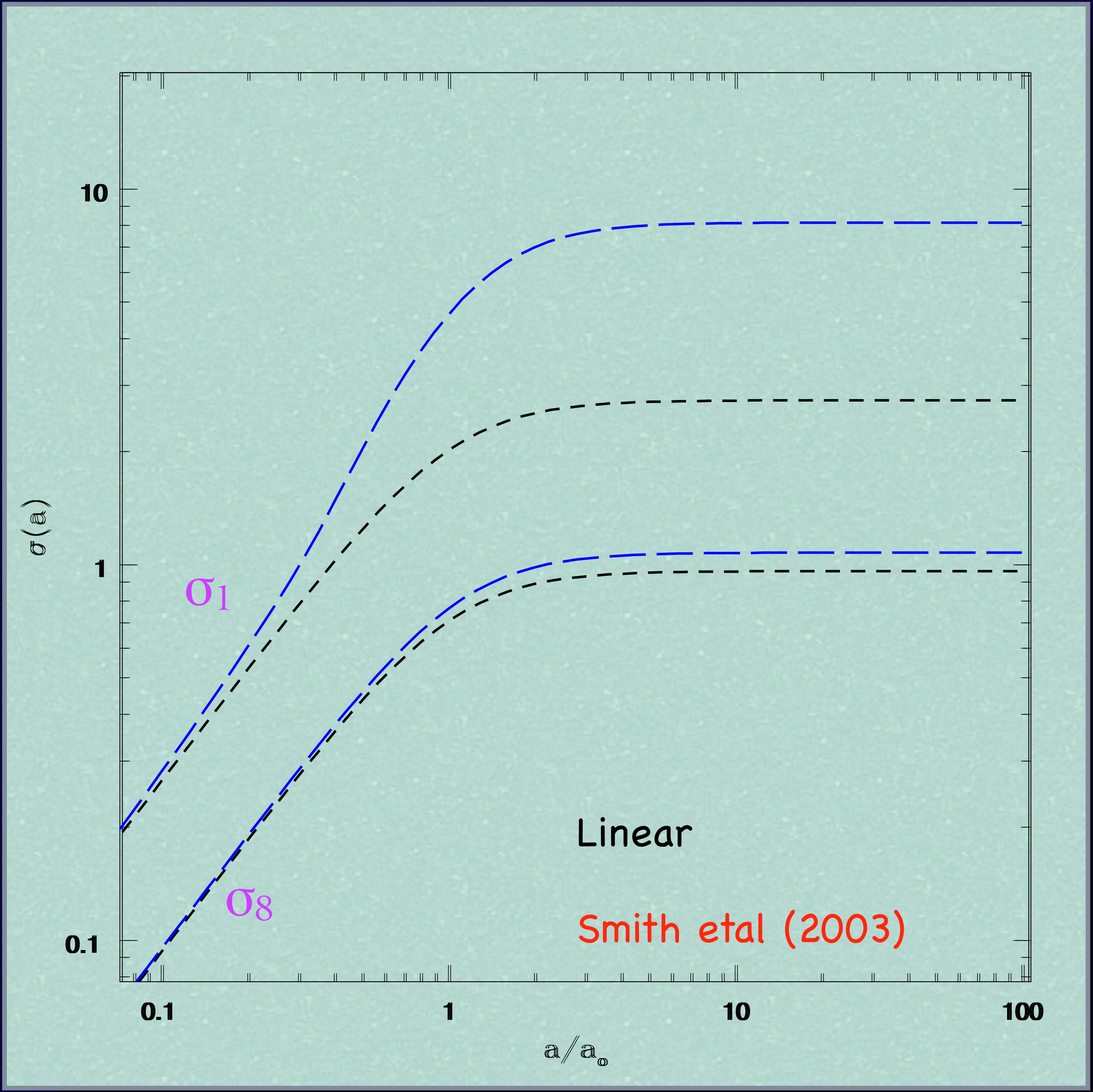

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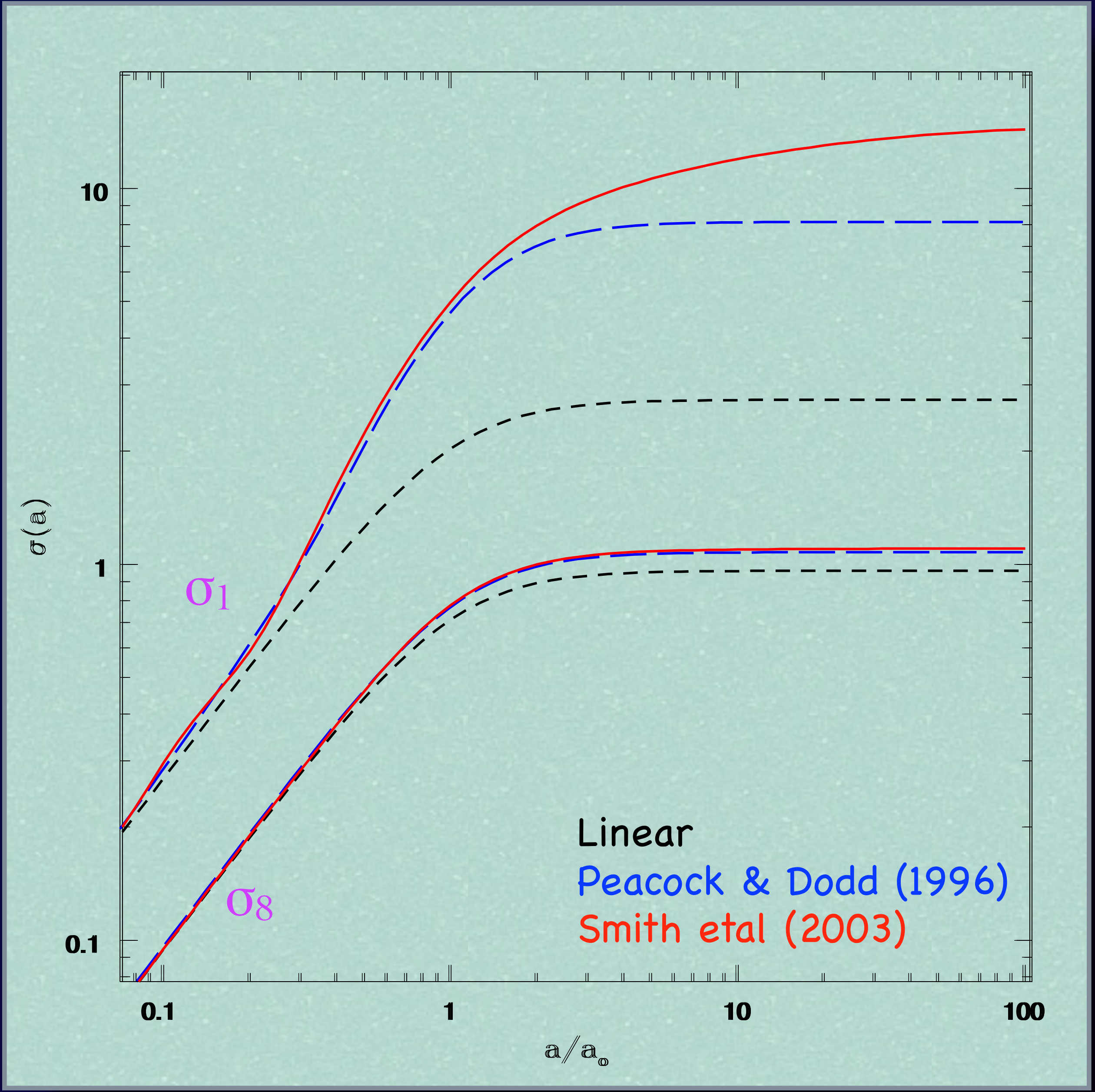

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Recently there were many attempts to estimate σ_8

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Recent Measurements

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- model dependent procedure
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Cluster measurements are sensitive to:

- comparison between observation and numerical models
- X-ray flux and optical richness can be confusing

$\sigma_8 = 0.786 \pm 0.011$ Vikhlinin etal 2008

Recent Measurements

Intermediate scale surveys

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- messy window functions
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- ✦ Amplitude ~ σ_8^7

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Galaxies measurements are sensitive to

- Amplitude - Shape degeneracies
- $\sigma_8{}^{gal}$ not σ_8

Cole etal 2005 2dF
Tegmark etal 2003 SDSS
Eisenstein etal 2005 SDSS

$$\sigma_8 = 0.915 \pm 0.06$$

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Local surveys

Recent Measurements

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$$\sigma = 1.13^{+0.22}_{-0.23}$$

Pairwise velocities

HAF etal 2008

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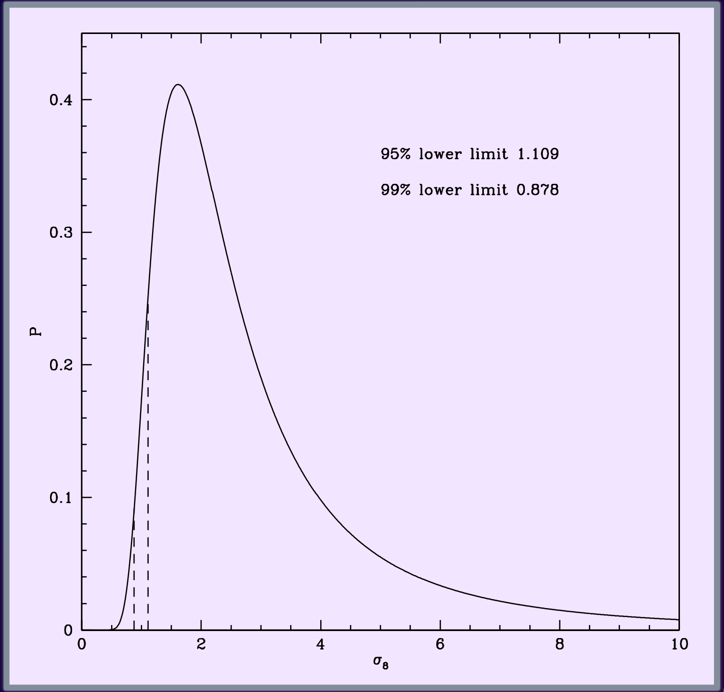
Bulk Flows

Lower limits

- $\sigma_8 > 1.109$ (0.878) at 95% (99%) CL
- $\sigma_L > 1.00$ (0.755) at 95% (99%) CL

Watkins, HAF & Hudson 2008



σ_8 from various estimators

Method	Parameter	value
CMB	σ_L	0.80 ± 0.04
LY-α	σ_L	0.85 ± 0.02
Clusters	σ_L	0.786 ± 0.011
Cosmic Shear	σ_L	0.84 ± 0.05
SZ (ACBAR)	σ_8	$0.94^{+0.03}_{-0.04}$
Galaxies	σ_8^{gal}	0.92 ± 0.06
Flows		
Pairwise velocities	σ_8	$1.13^{+0.22}_{-0.23}$
Bulk flow	σ_8	> 1.11 (0.88) at 95% (99%)

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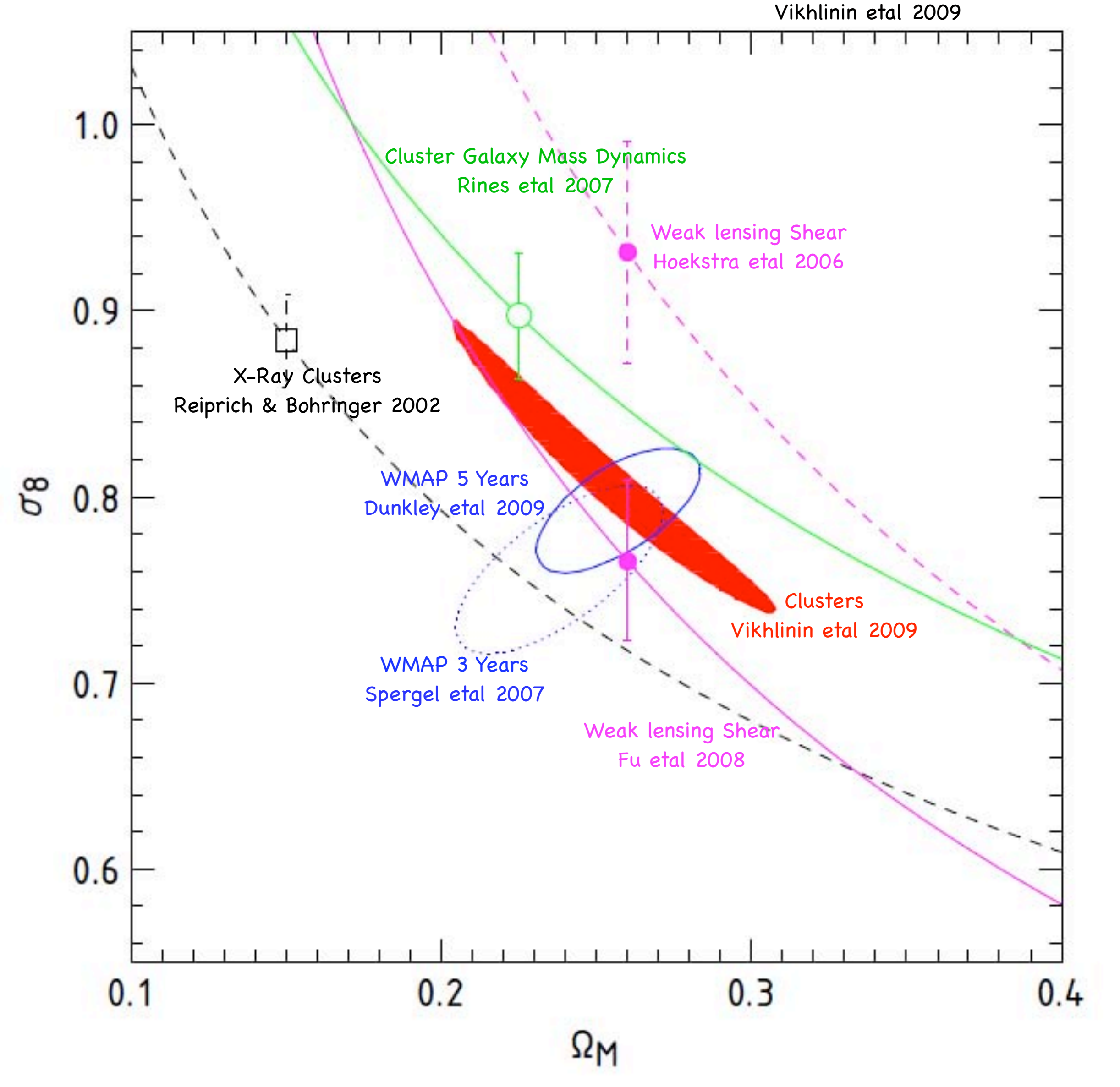
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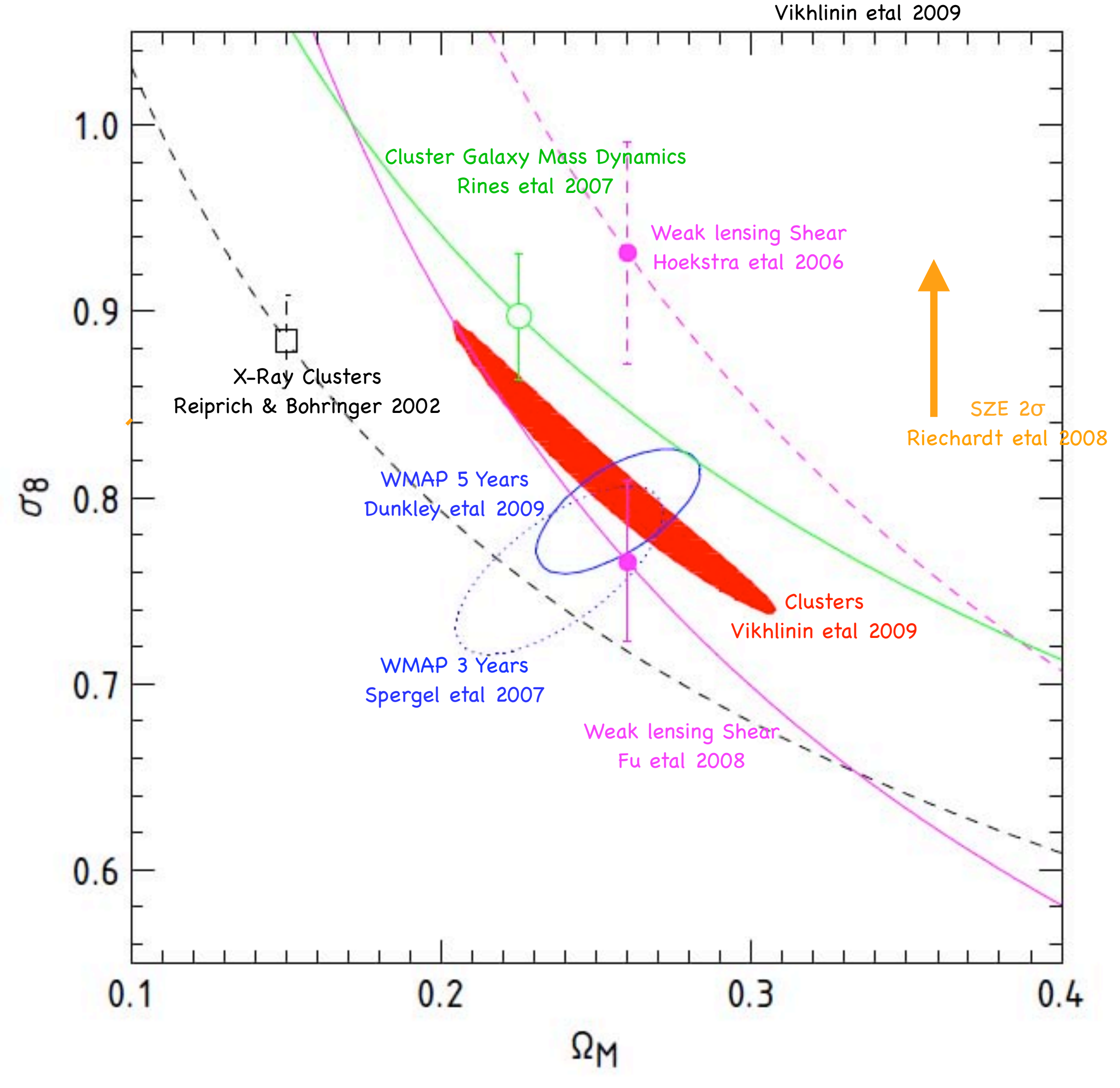
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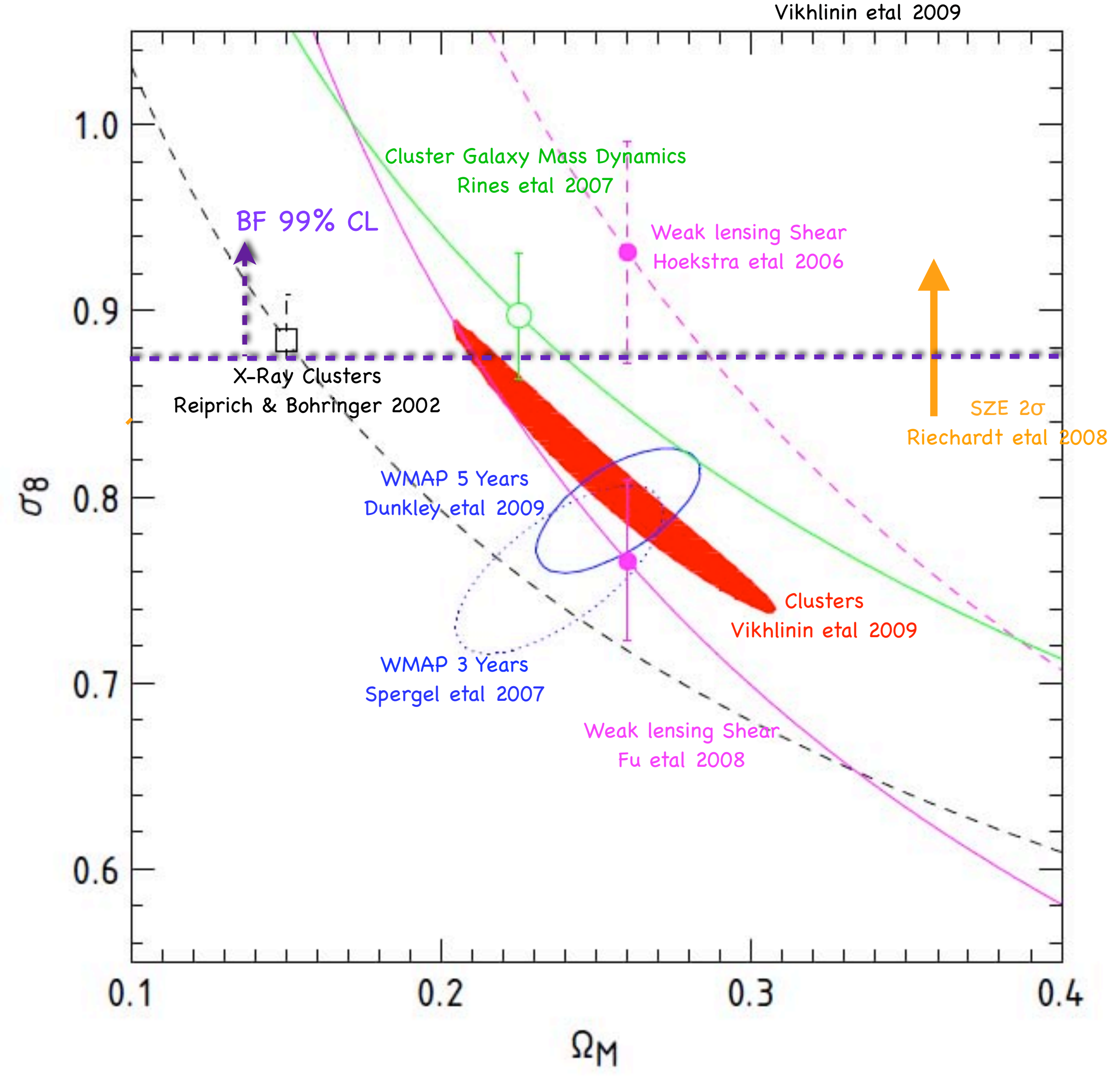
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Conclusions

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- When estimates from deep surveys are being corrected for nonlinearities, most estimates from various independent surveys agree quite well with each other.

Merci bien

Thank you