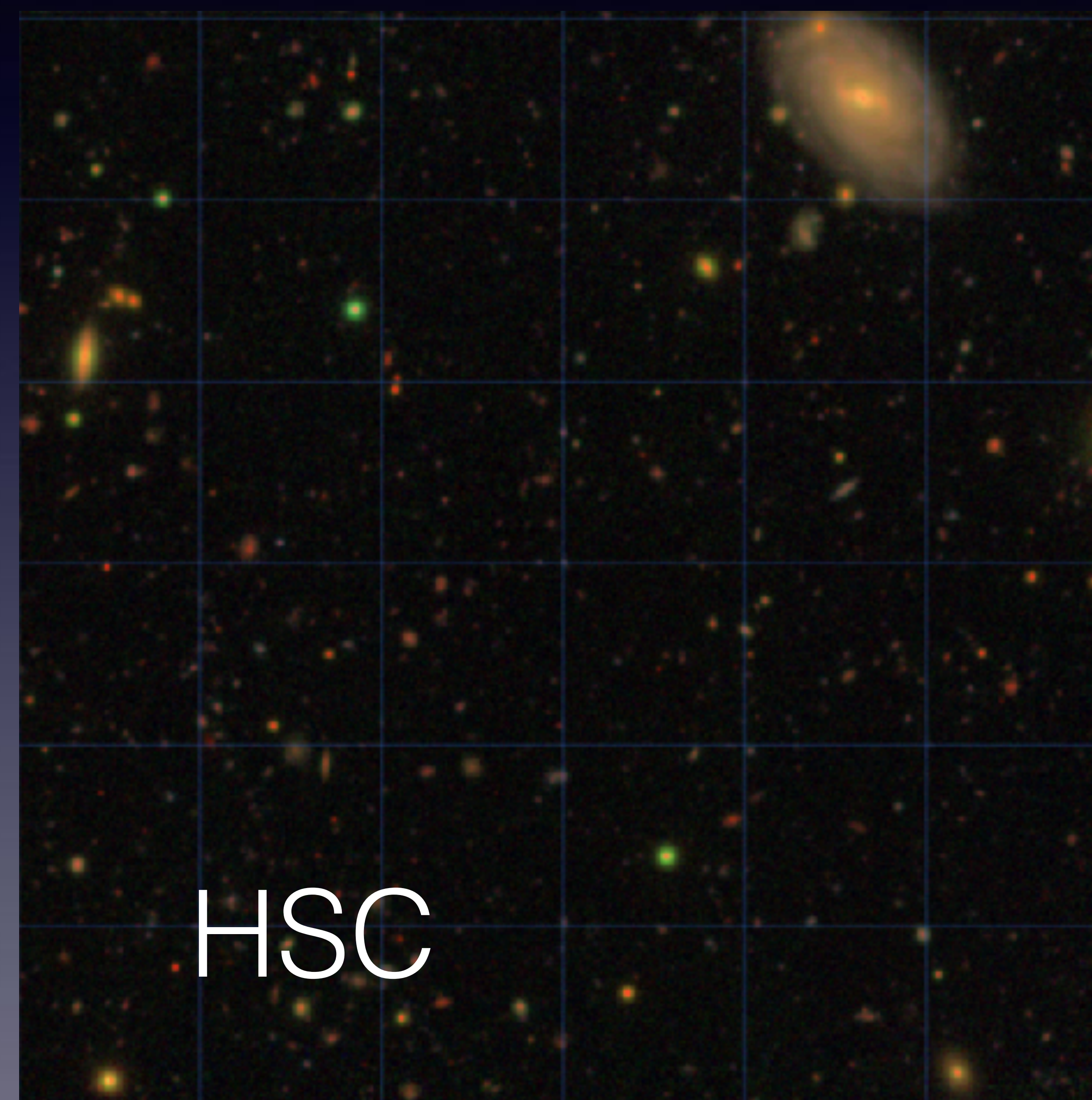
Towards ZTF-III

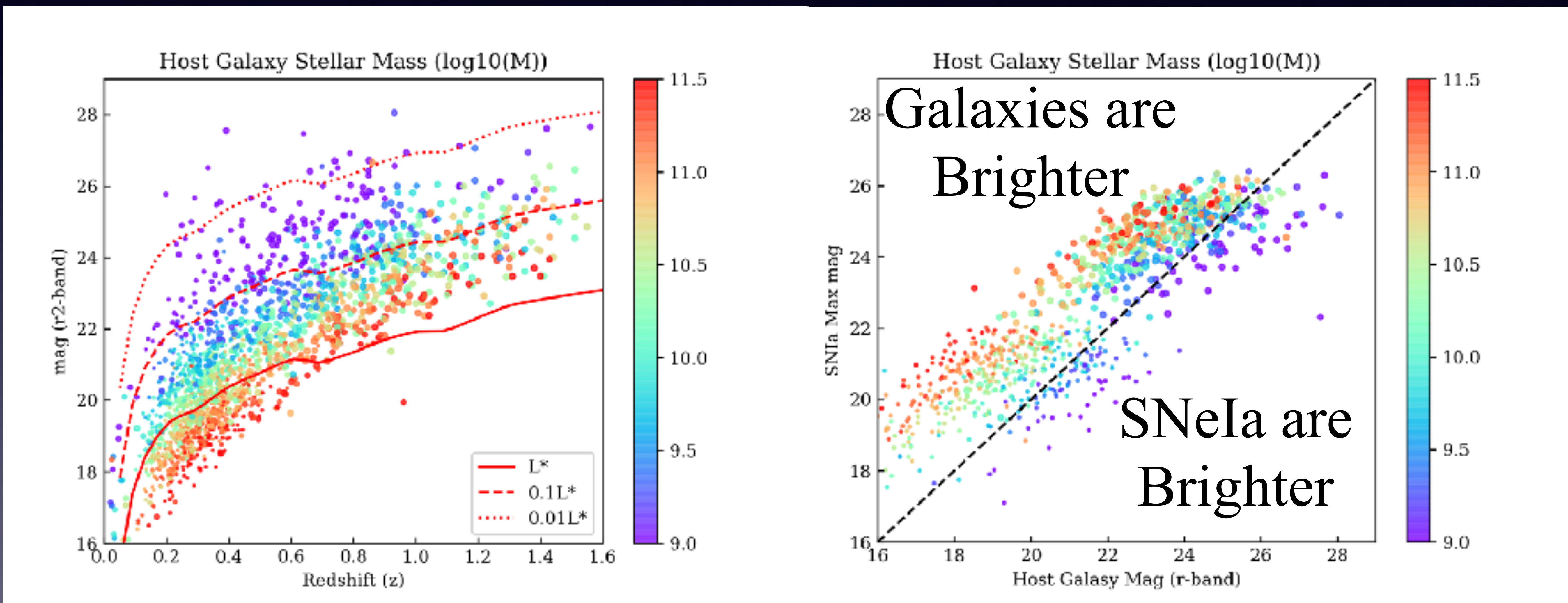
Nao Suzuki (Lawrence Berkeley National Lab / LPNHE)

- Multi SN Spieces (SNIb, SNIc, SNII)
- Probing Dark Galaxies
- RR Lyrae, Cepheid Variables (DESI-II Spectra)
- Mapping the local Universe

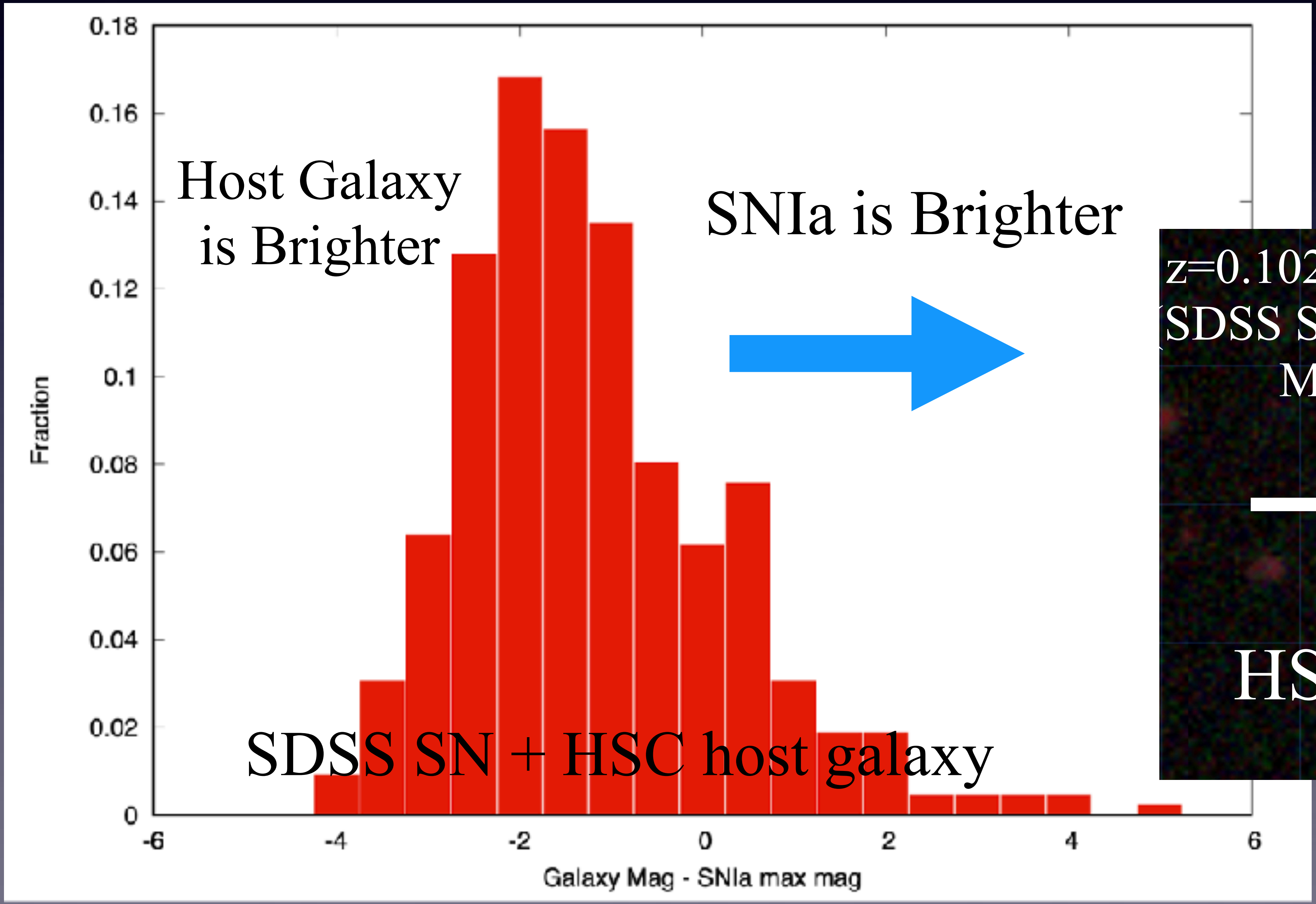
Probing “Dark” galaxies (1/3)
ZTF × LSST (Subaru/HSC)

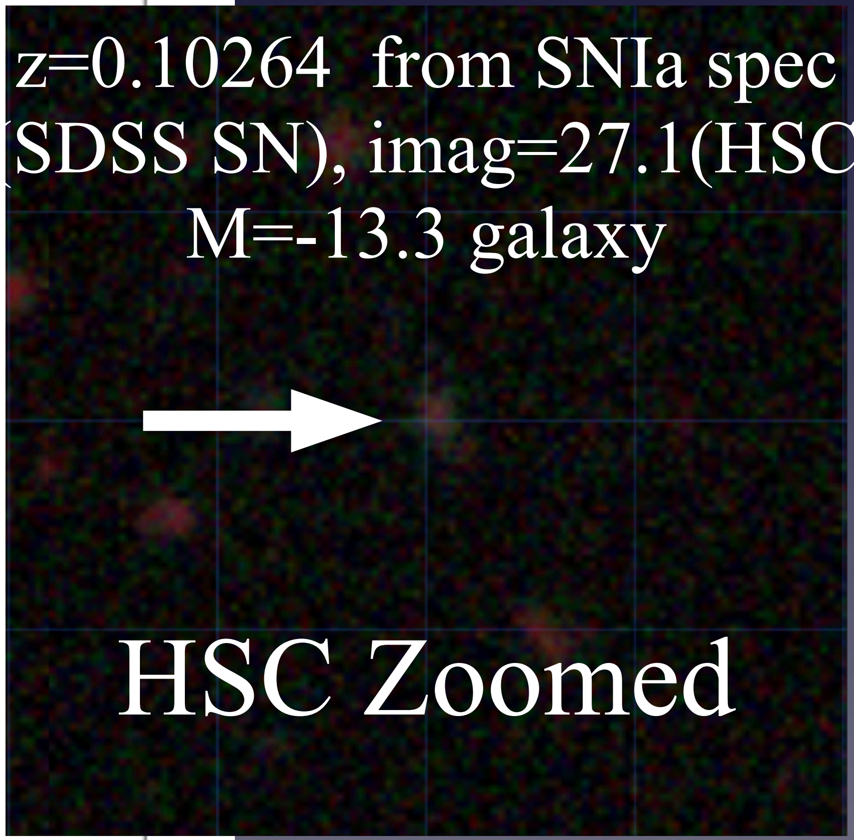


Probing "Dark" galaxies (2/3)
ZTF × LSST (Subaru/HSC)

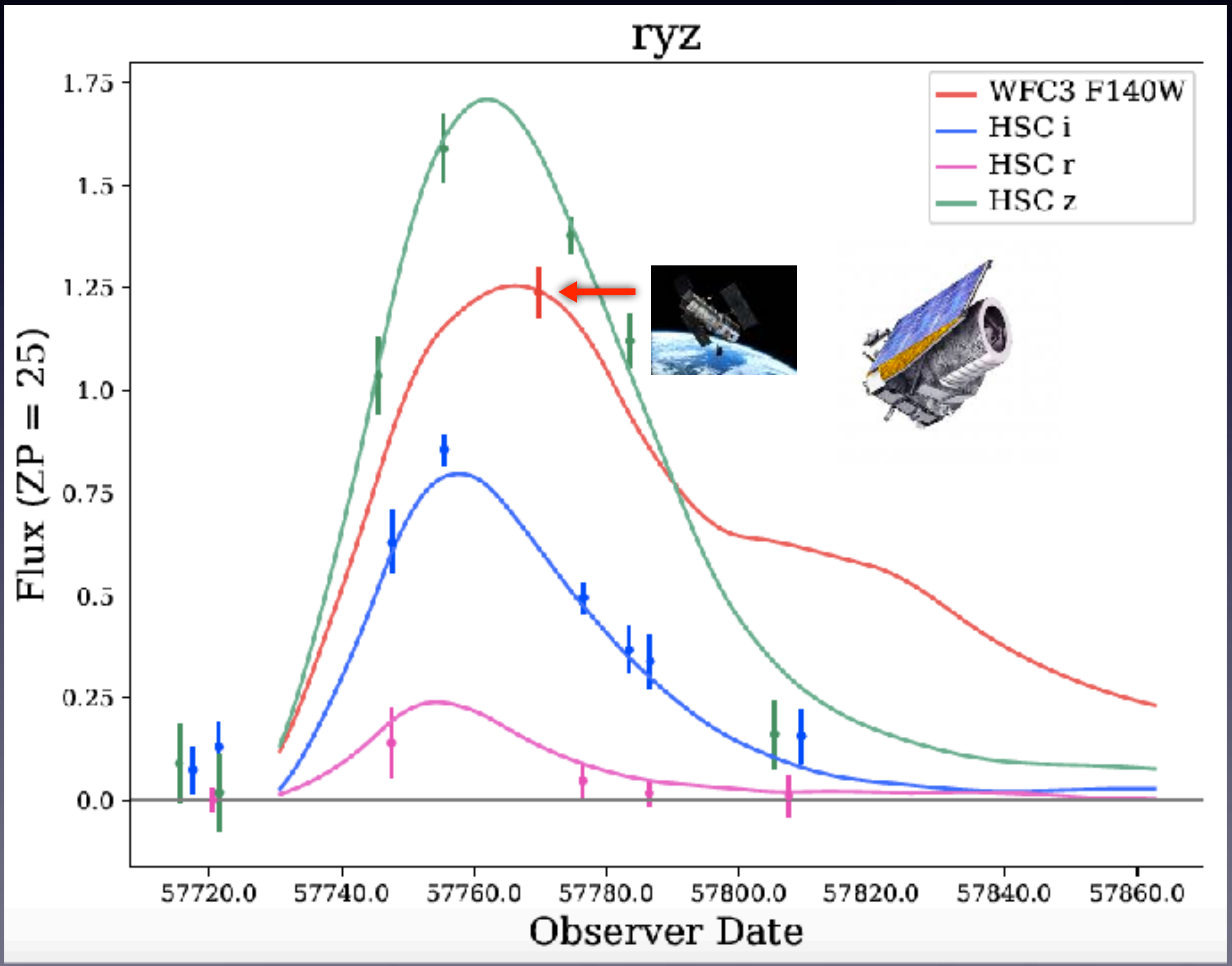


Probing "Dark" galaxies (3/3)
ZTF × LSST (Subaru/HSC)





Probing IR with Euclid
ZTF x Euclid (Image + Spec)



Euclid : J, H, K

Euclid : IR Spec

Schedule is fixed

for next 6 years

ZTF-III start observing Euclid field 2 weeks in advance

Pre-ZTF Meeting in Japan 2019

TDA-MMS 2019: Time Domain Astronomy in the Era of Massively Multiplexed Spectroscopy

February 8-10, 2019, Nikko, Japan

Distribution of Local Matter on BAO Scale
Nao Suzuki & Friends

Hubble's Law

$$v = H_0 d$$

v = recession velocity in km/sec

d = distance in Mpc

H_0 = expansion rate today (*Hubble Parameter*)

In words:

The more *distant* a galaxy, the *faster* its recession velocity.

General Relativity Metric

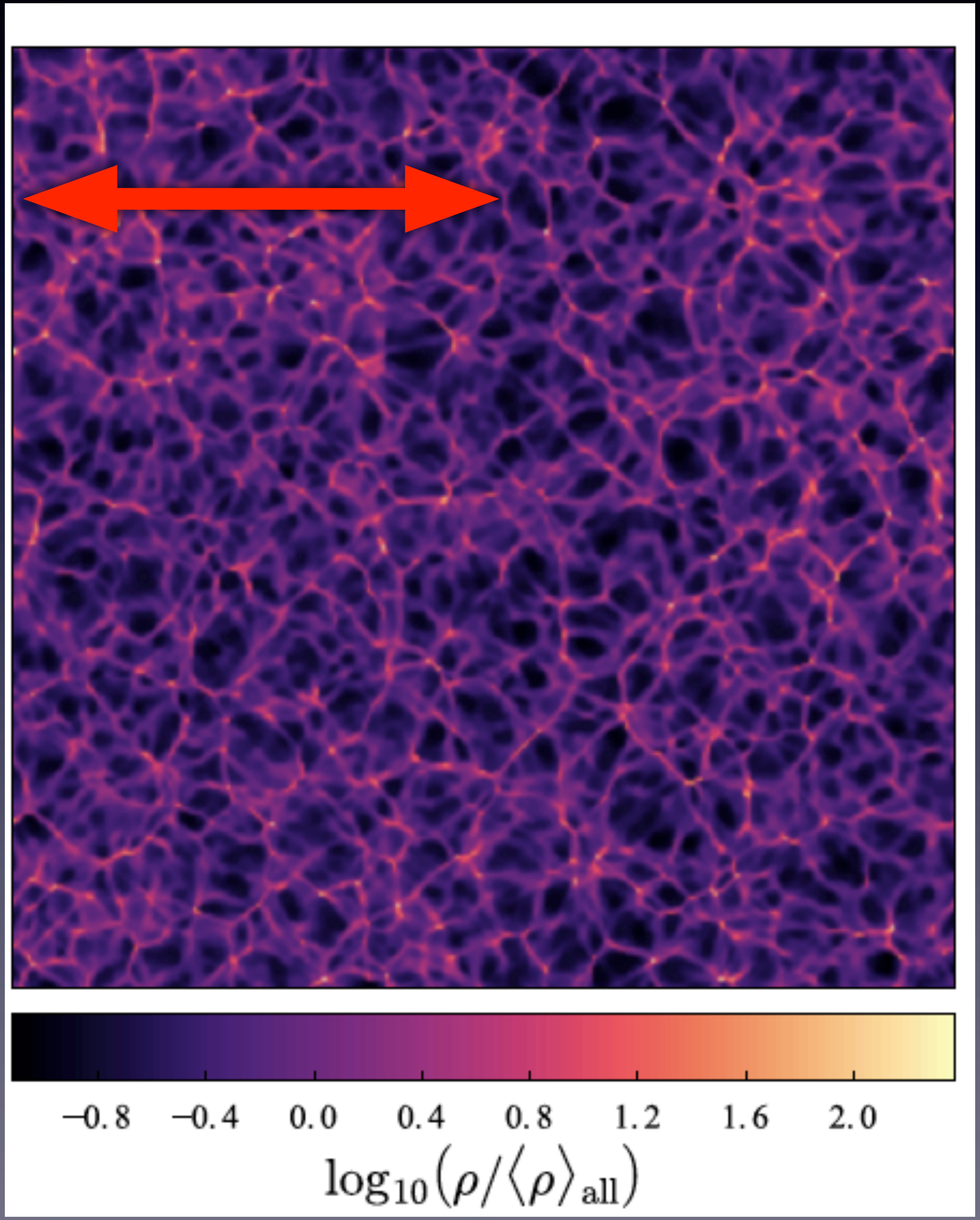
Robertson-Walker Metric

$$ds^2 = dt^2 - \frac{R^2(t)}{c^2}\left[\frac{dr^2}{1-kr^2} + r^2 d\theta^2 + r^2 sin^2\theta d\phi^2\right]$$

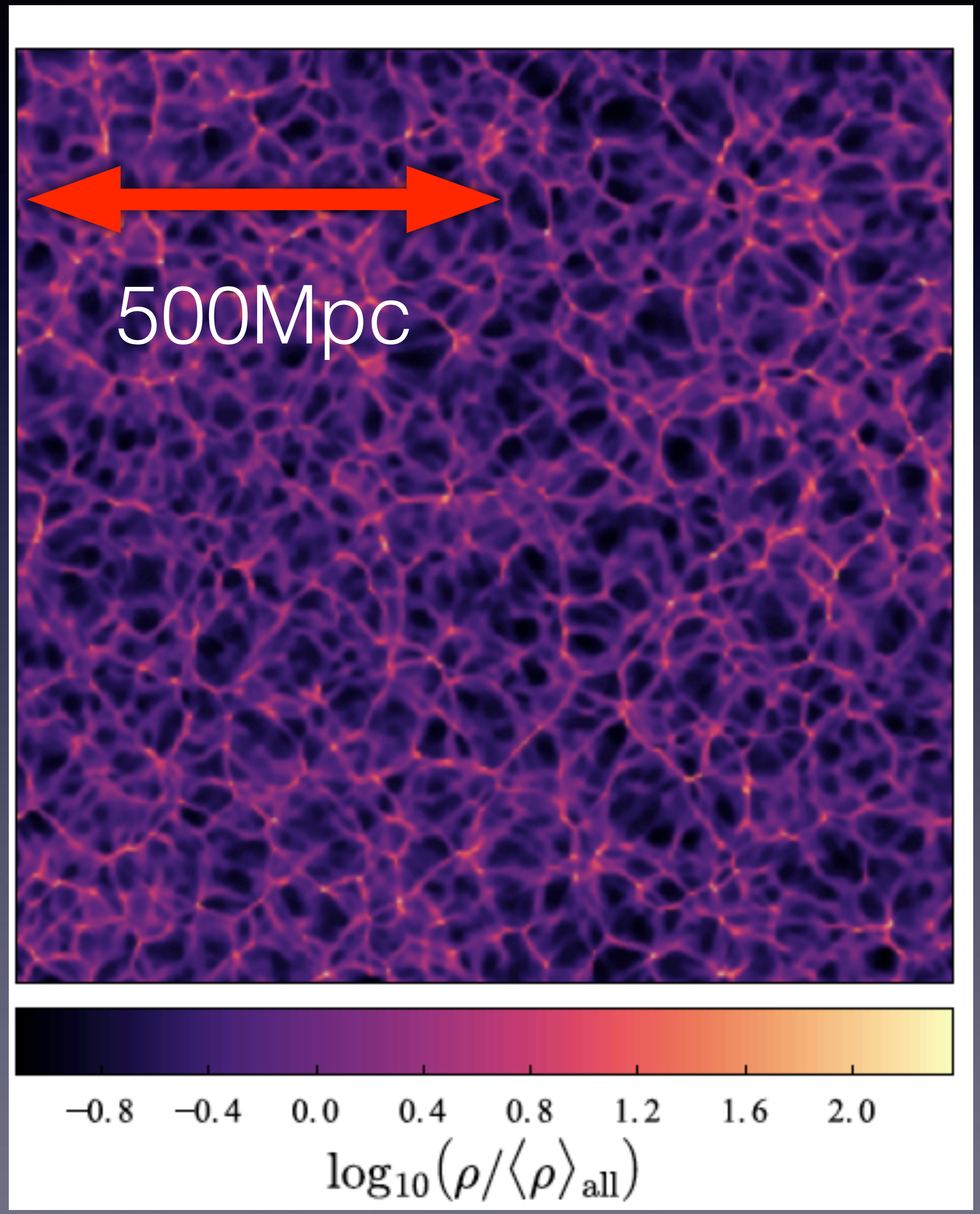
Schwartzschild Metric

$$ds^2 = \left(1 - \frac{2m}{r}\right)dt^2 - \frac{dr^2}{1 - \frac{2m}{r}} - r^2 d\theta^2 - r^2 \sin^2\theta\, d\varphi^2$$

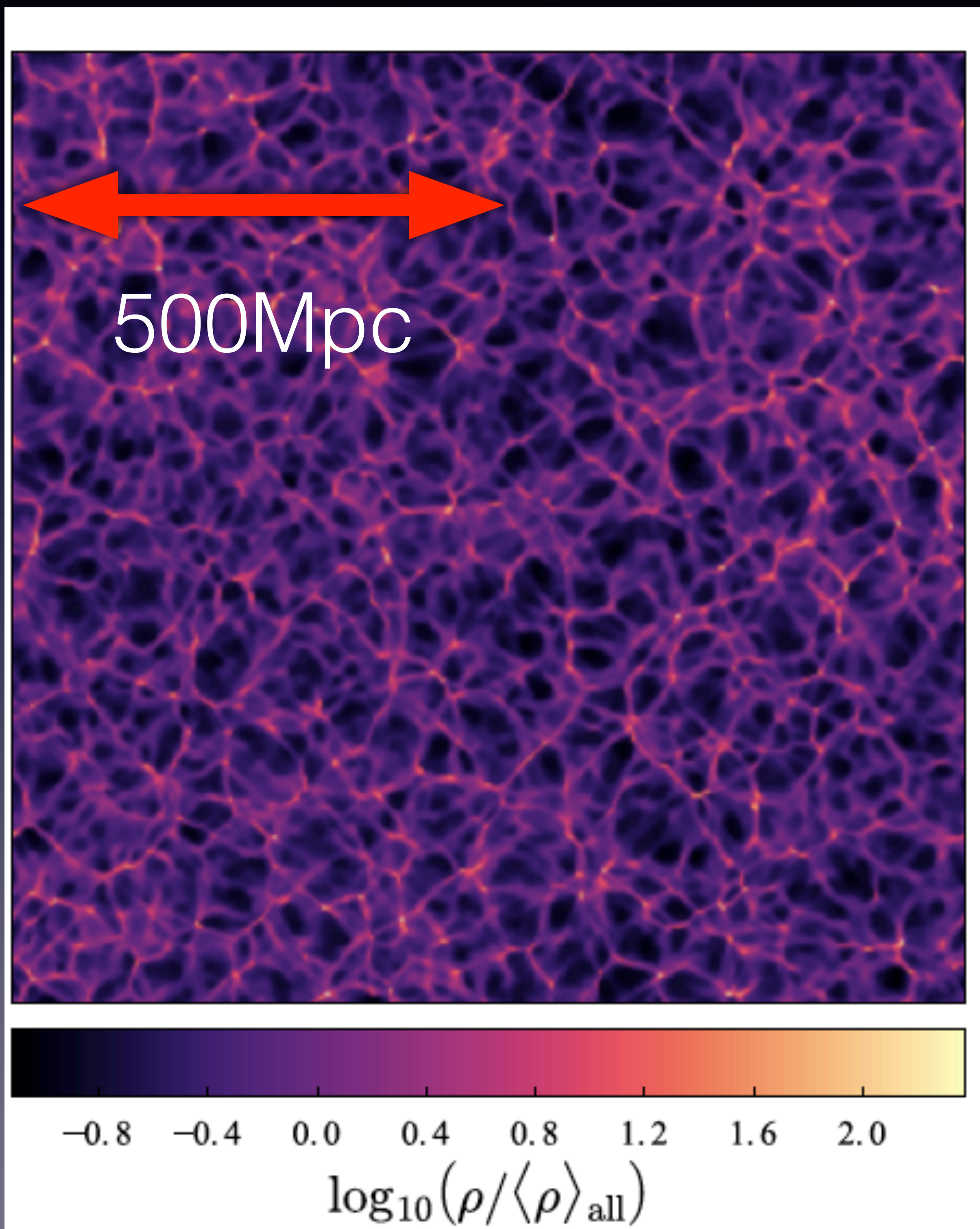
Density Field at z=0

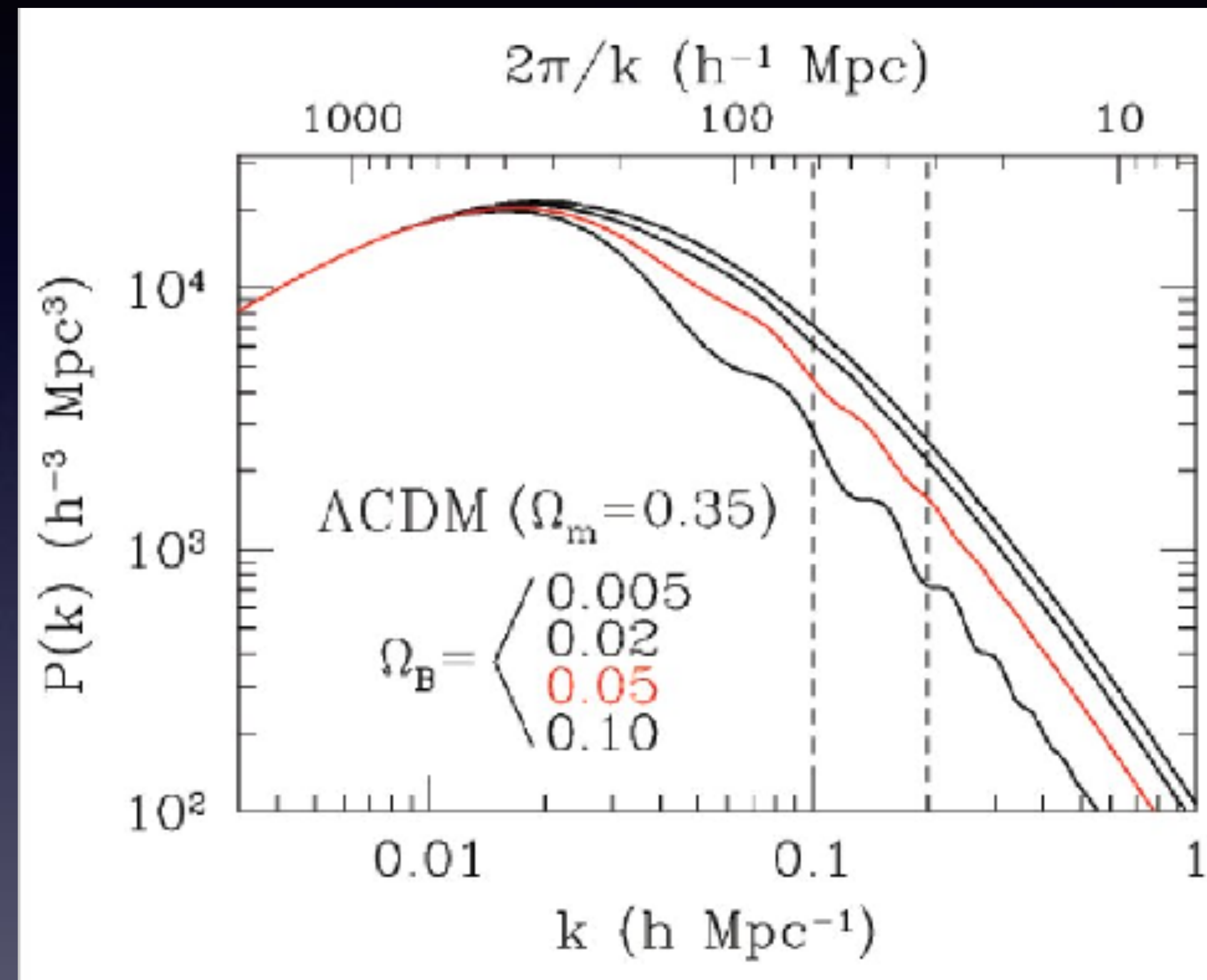


Density Field at z=0



How to quantify density fluctuation?

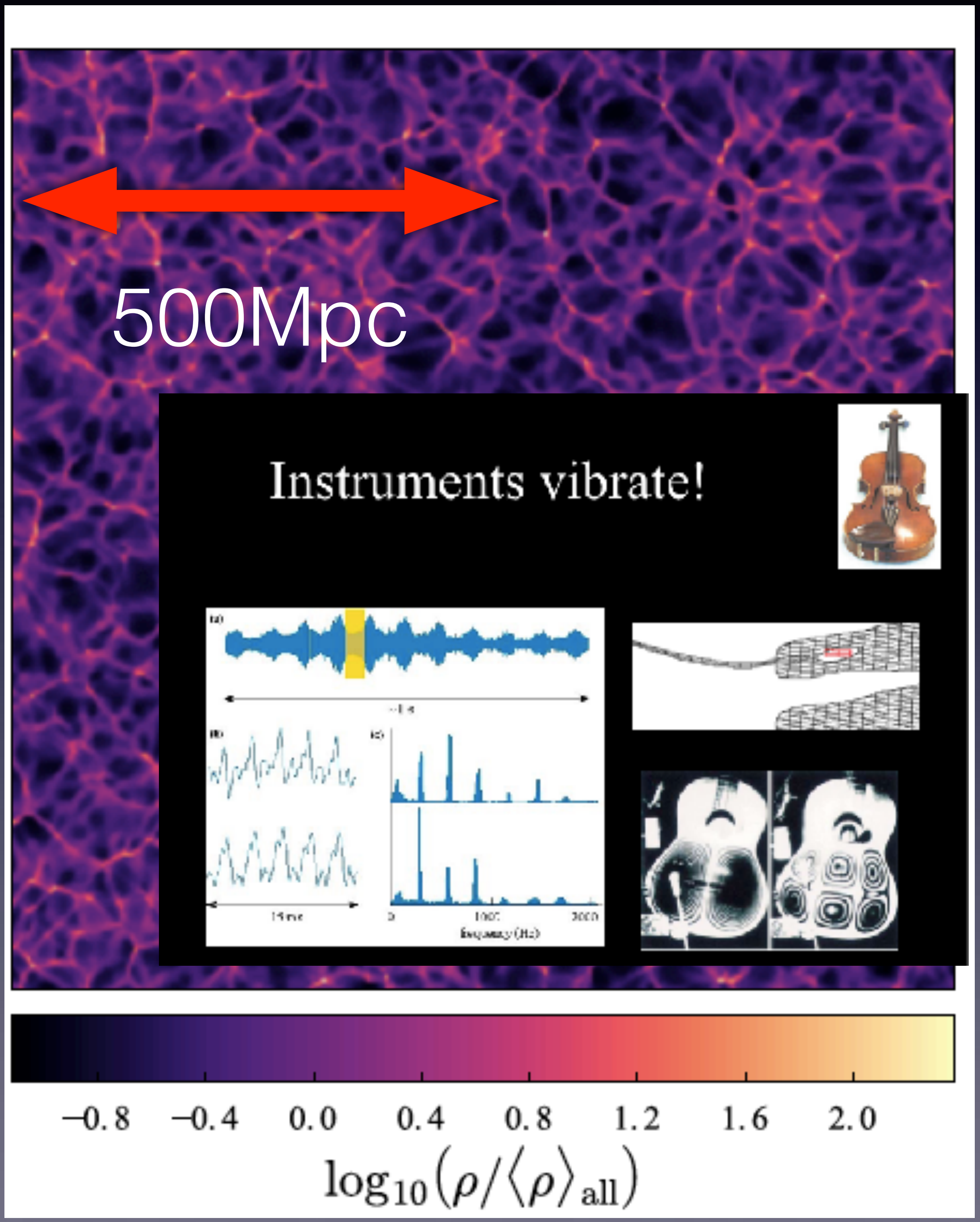


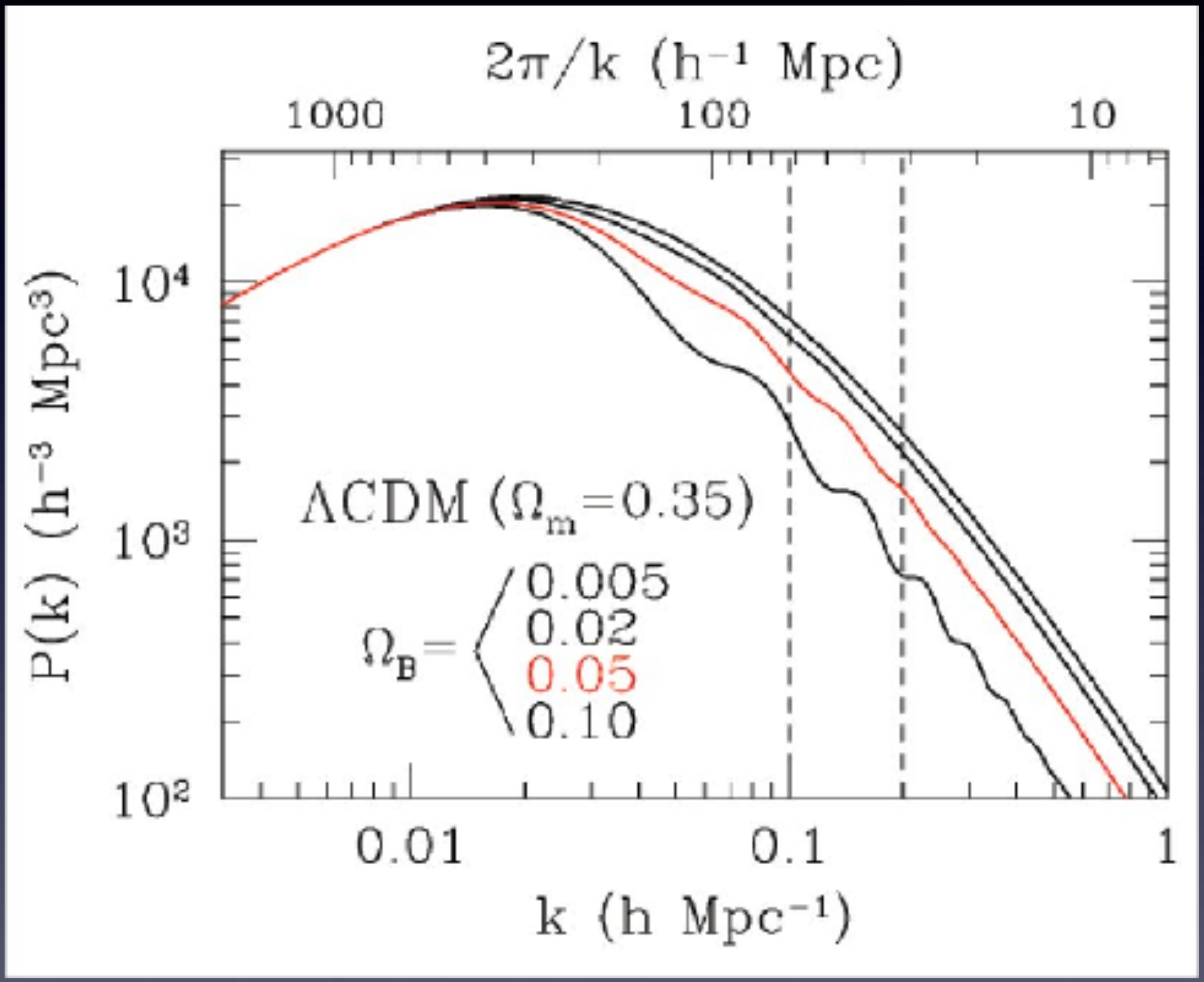


Einj said: ↑

Thanks a lot! Does that simply mean $\sigma_8 = \mathcal{P}(k = 1/8\, h/Mpc)$? Where $\mathcal{P}$ is the power spectrum.

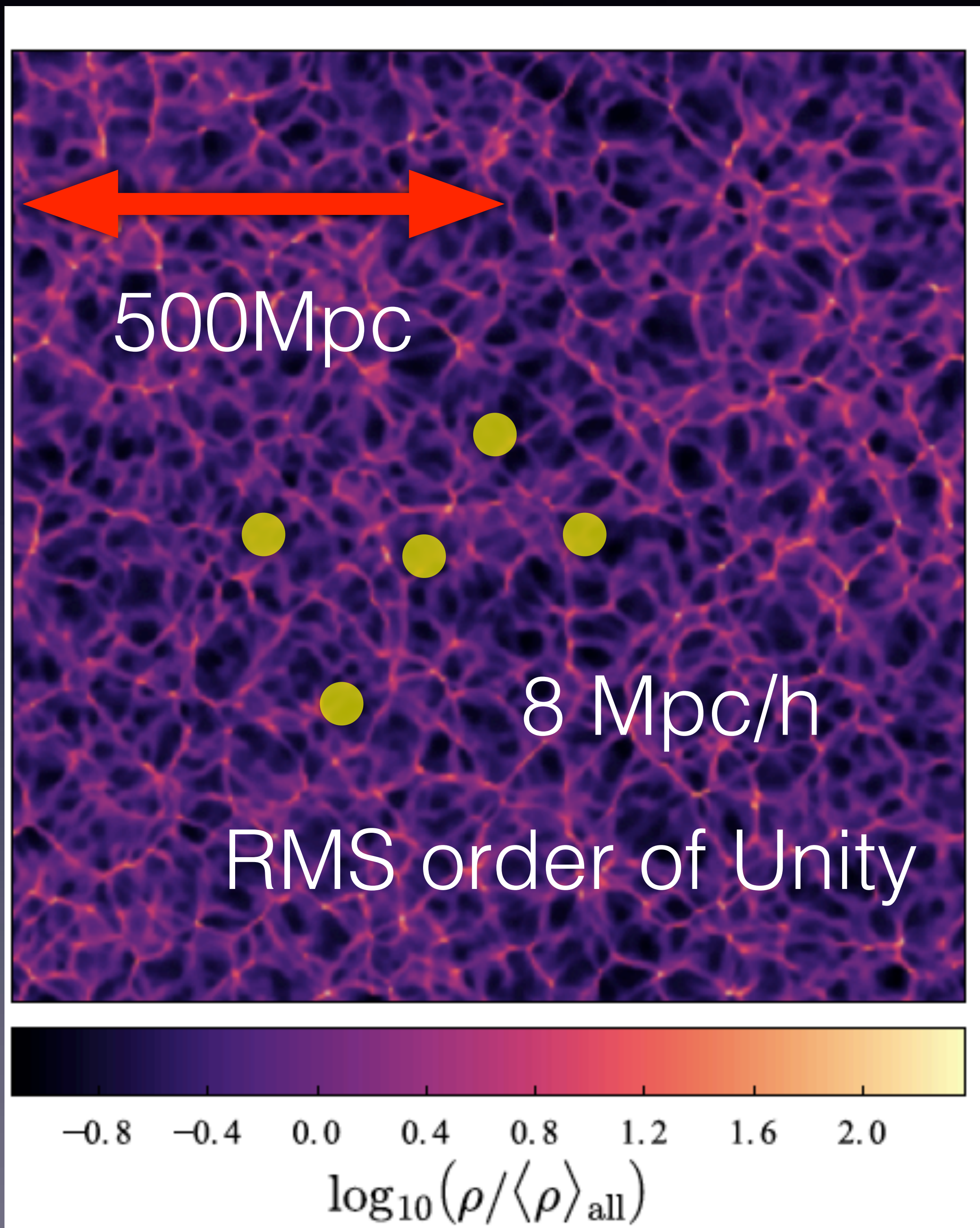
Harmonics has to be counted
Window Function W(kR)

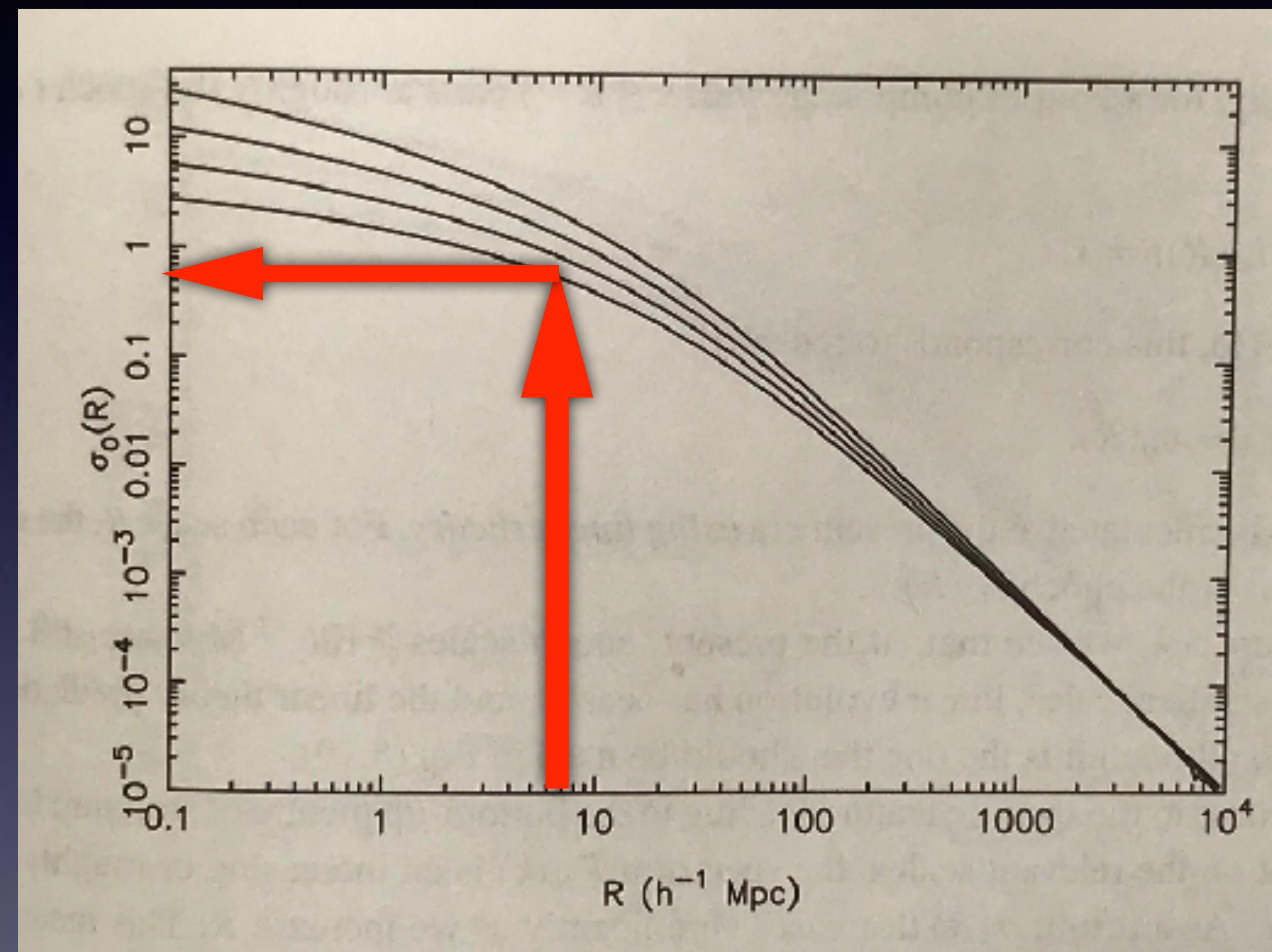




$$\sigma_0^2(R) = \int_0^\infty W^2(kR)\left(\frac{k}{a_0 H_0}\right)^4 T^2(k)\,\delta_{\mathrm{H}}^2(k)\frac{dk}{k}.$$

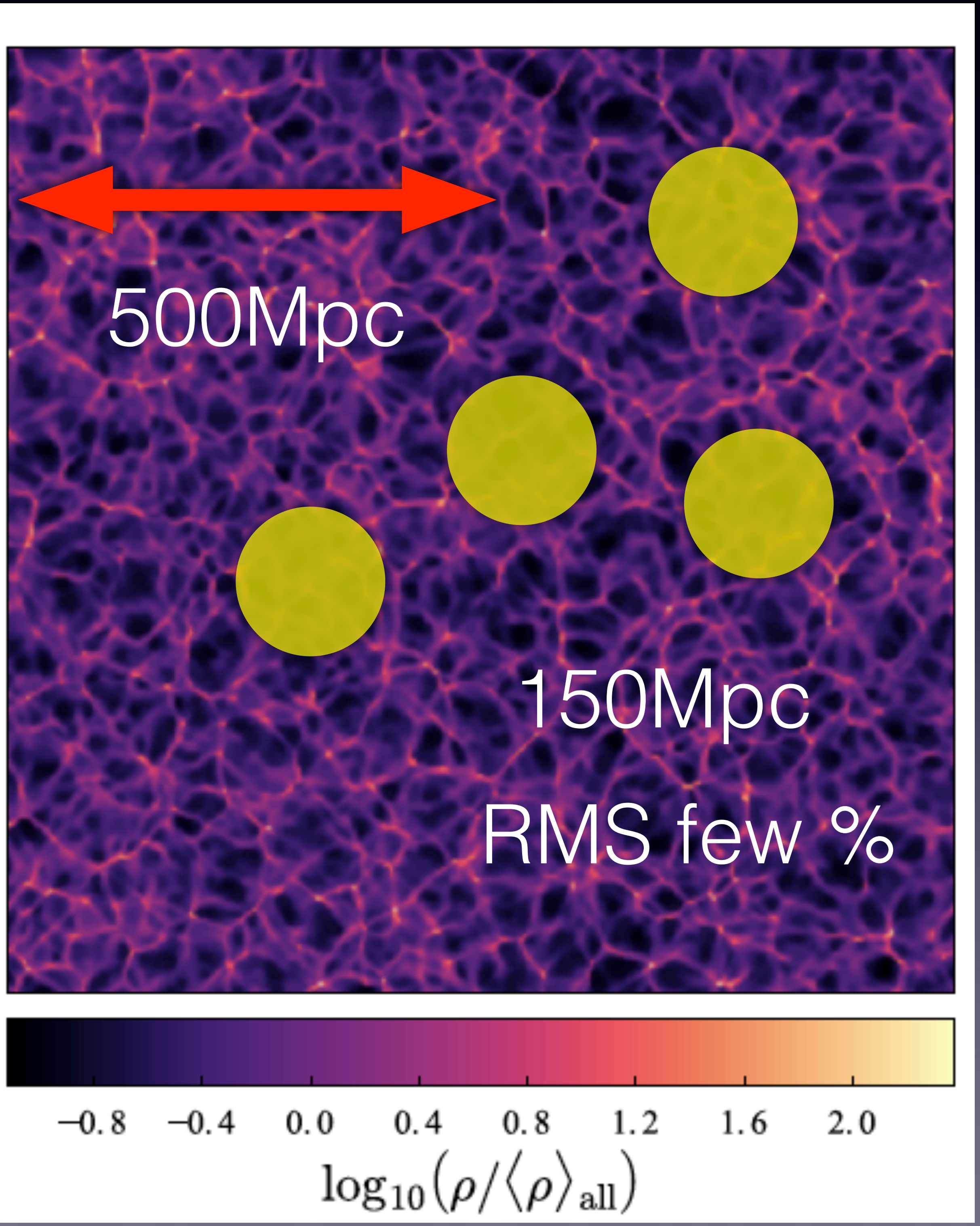
8 Mpc/h : RMS is Unity (0.8-ish)

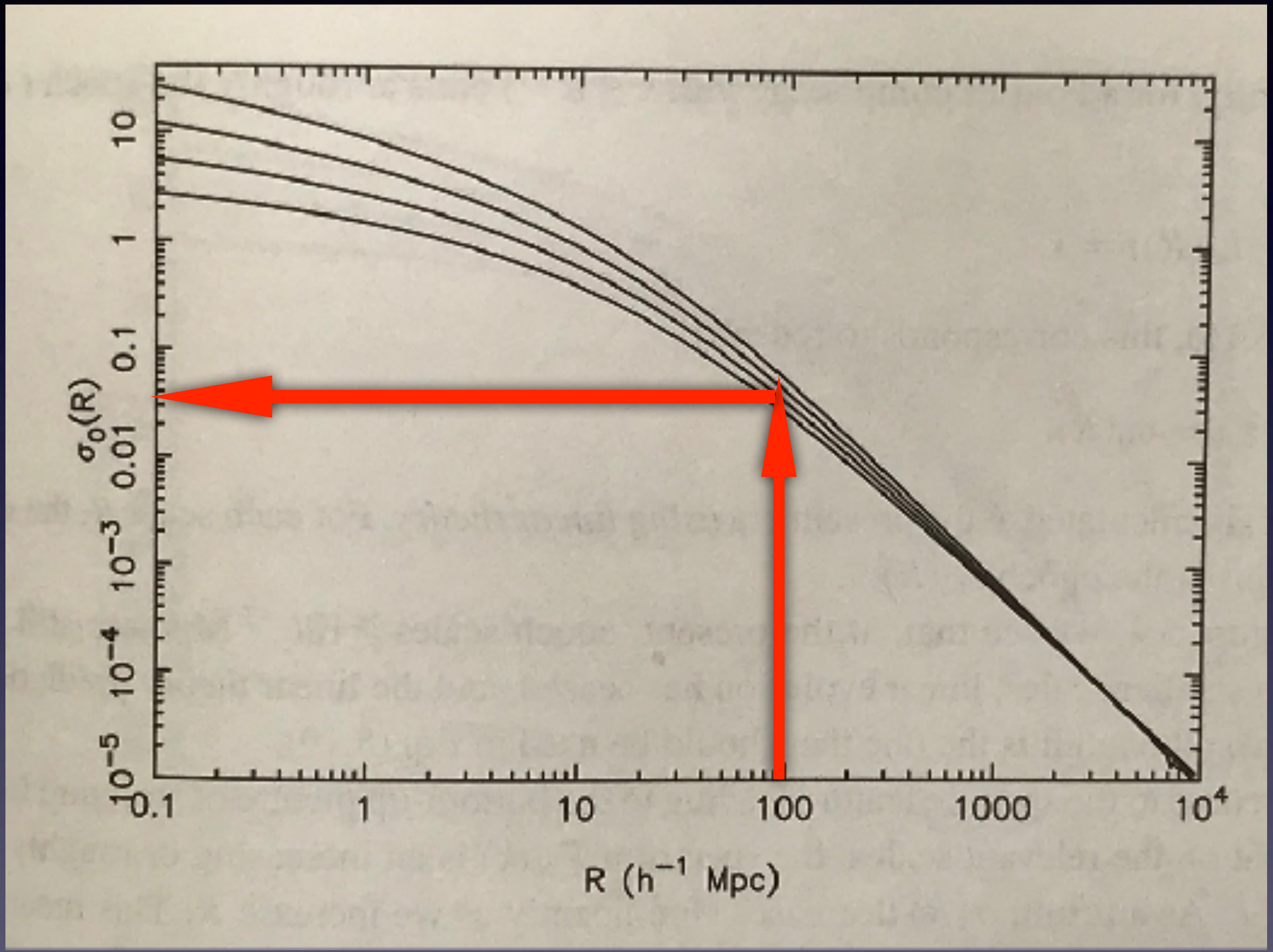




$$\sigma_0^2(R) = \int_0^\infty W^2(kR)\left(\frac{k}{a_0 H_0}\right)^4 T^2(k)\,\delta_{\rm H}^2(k)\frac{dk}{k}.$$

150Mpc represents the Universe





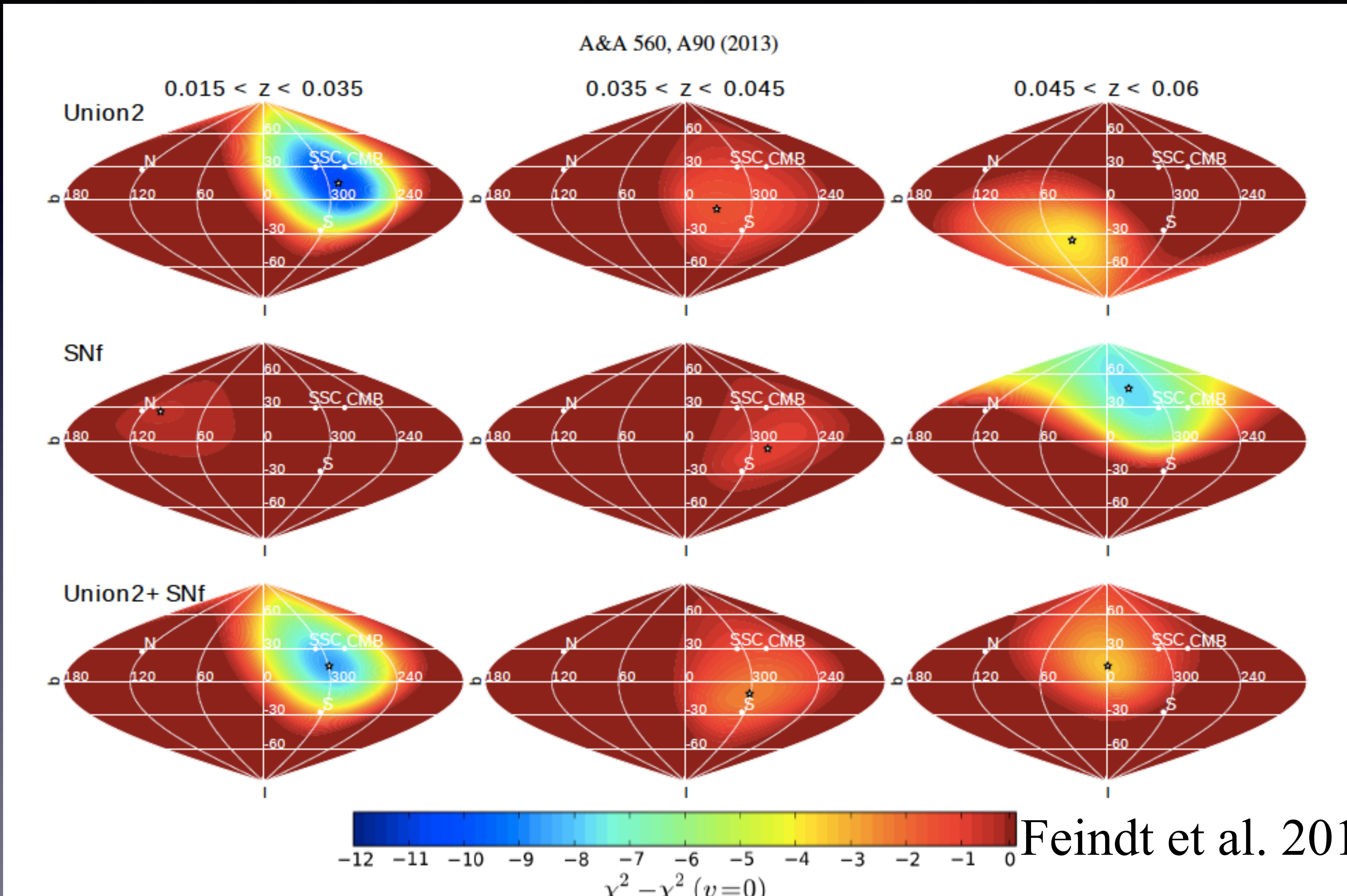
$$\sigma_0^2(R) = \int_0^\infty W^2(kR)\left(\frac{k}{a_0 H_0}\right)^4 T^2(k)\,\delta_{\rm H}^2(k)\frac{dk}{k}.$$

Q What is the area to study for 150Mpc?

Q1 : $z=2$

Q2 : $z=0$

CMB Dipole is seen by SNIa

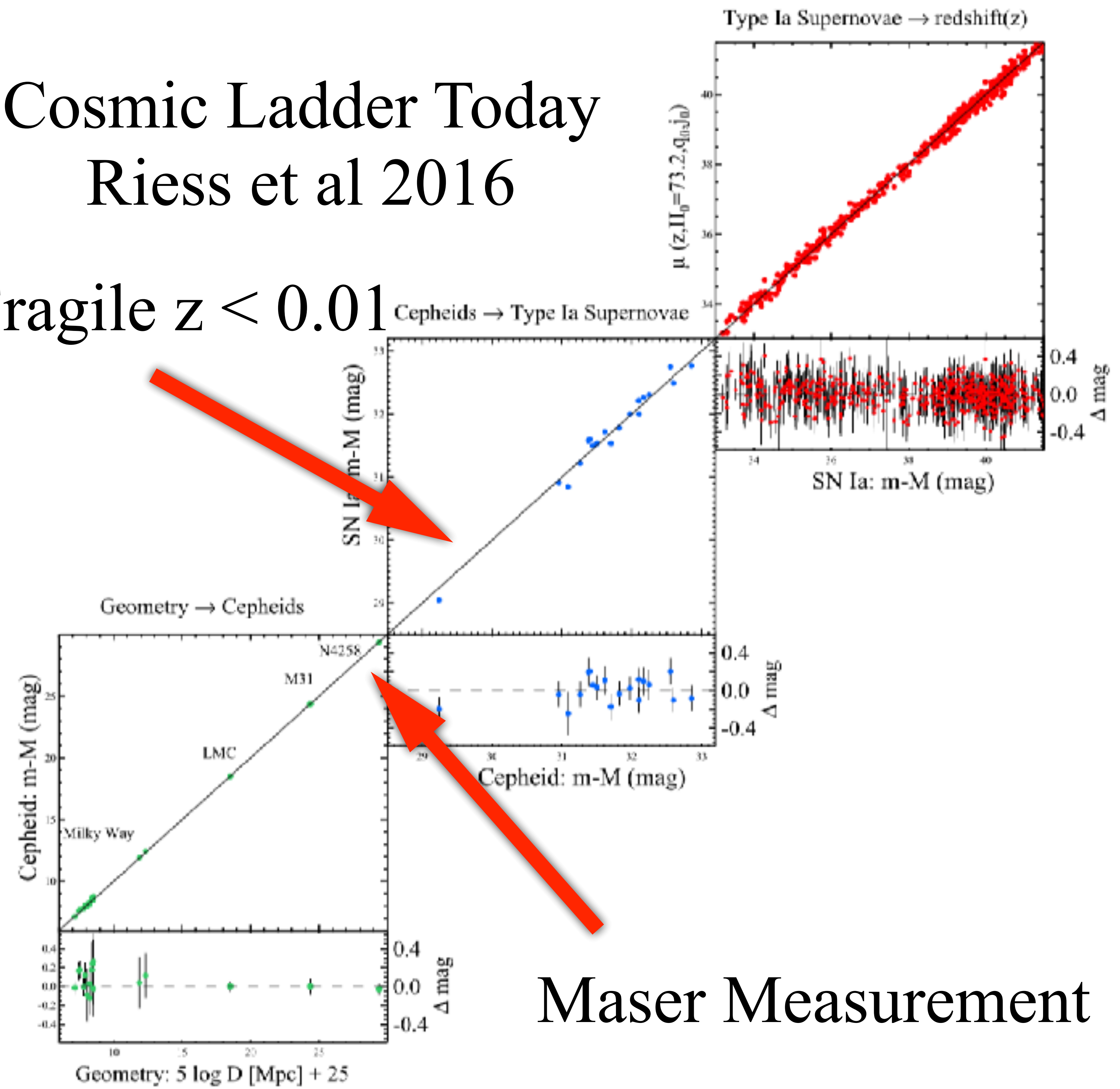


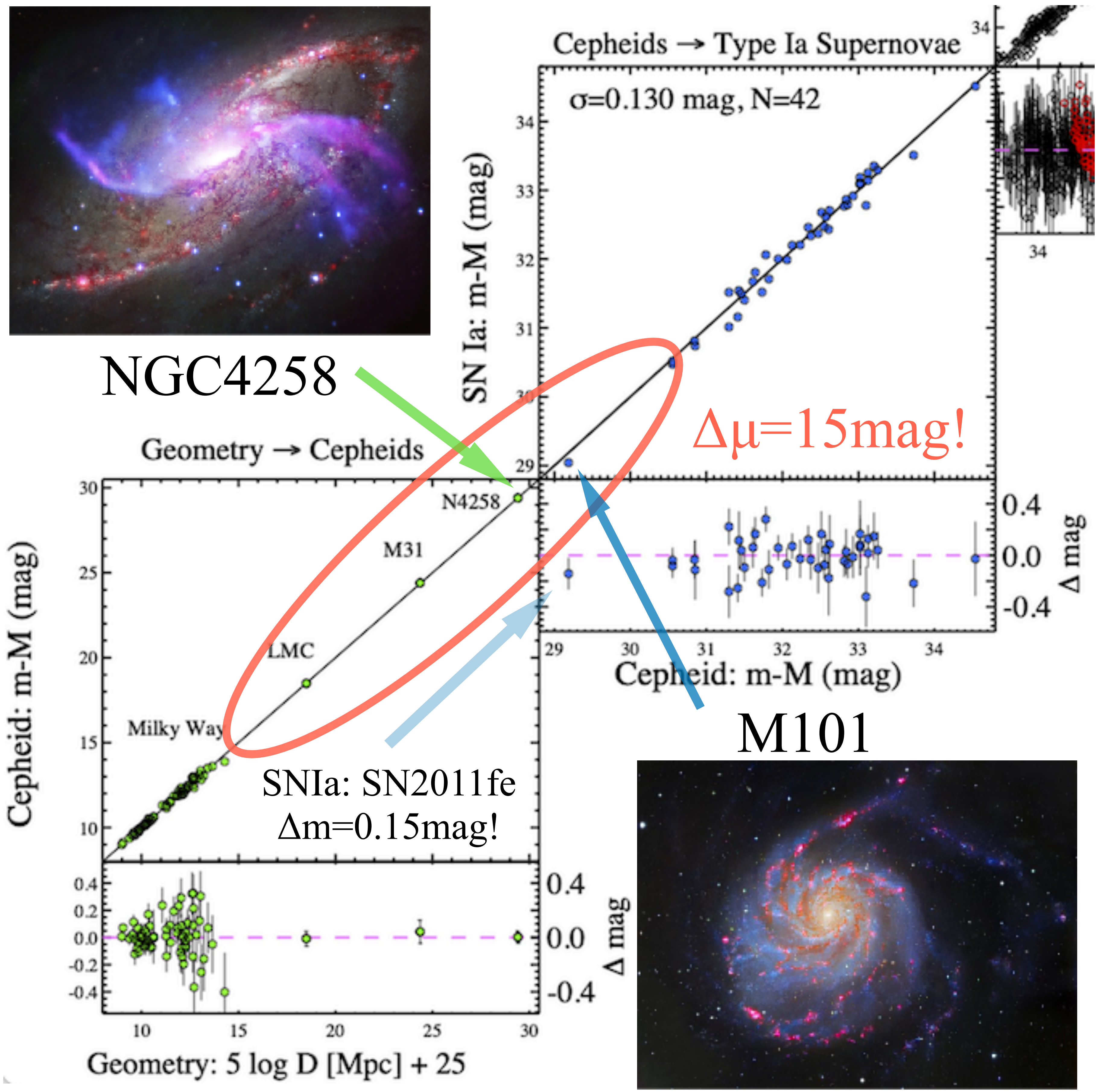
Feindt et al. 2011

Cosmic Ladder Today
Riess et al 2016

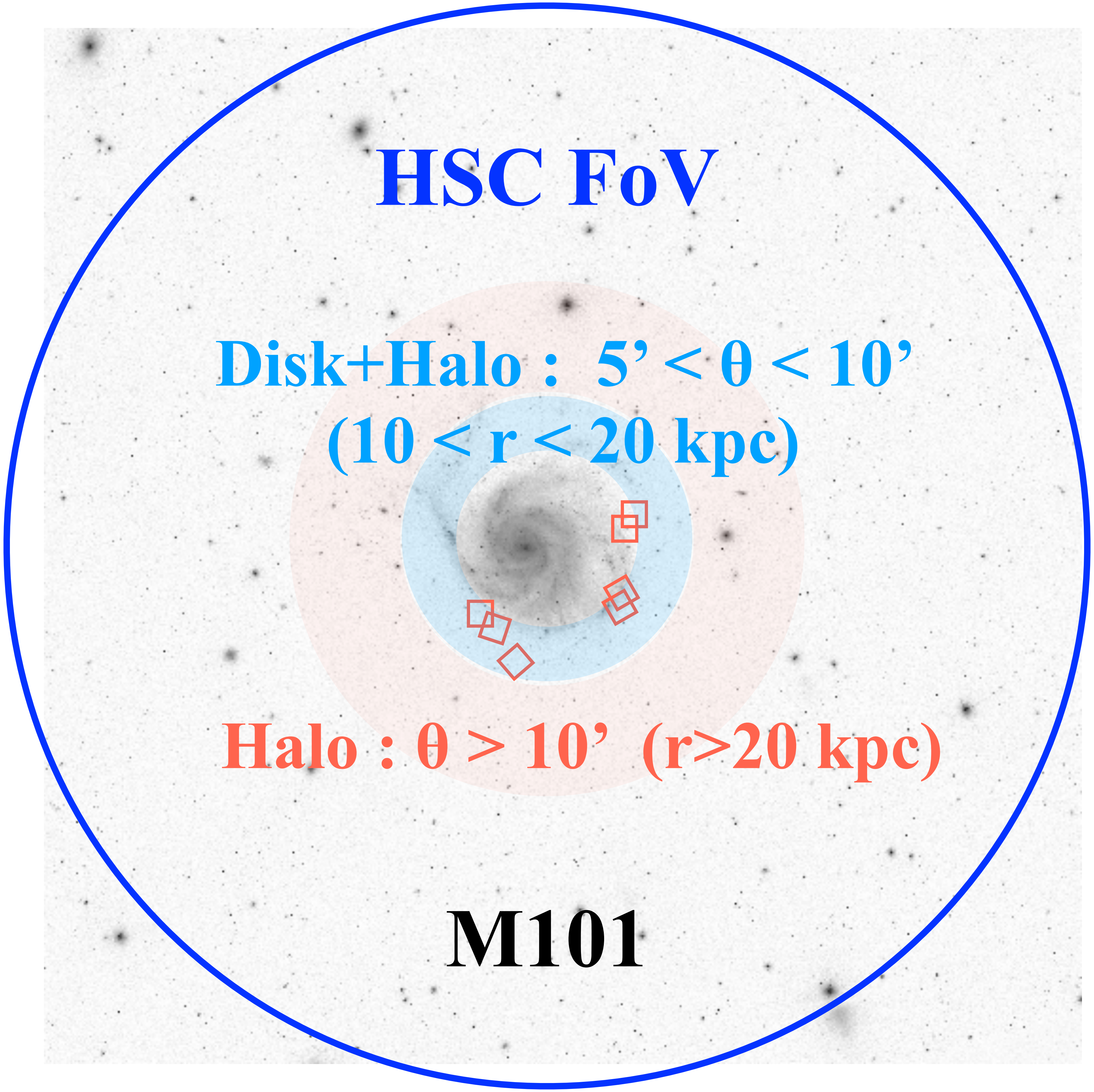
Fragile z < 0.01

Maser Measurement





Riess et al 2022


HSC FoV
Disk+Halo : 5’ < θ < 10’
(10 < r < 20 kpc)
Halo : θ > 10’ (r>20 kpc)
M101

Inhomogeneous Expansion of the Universe

Macpherson et al 2018

The trouble with Hubble: Local versus global expansion rates in inhomogeneous cosmological simulations with numerical relativity

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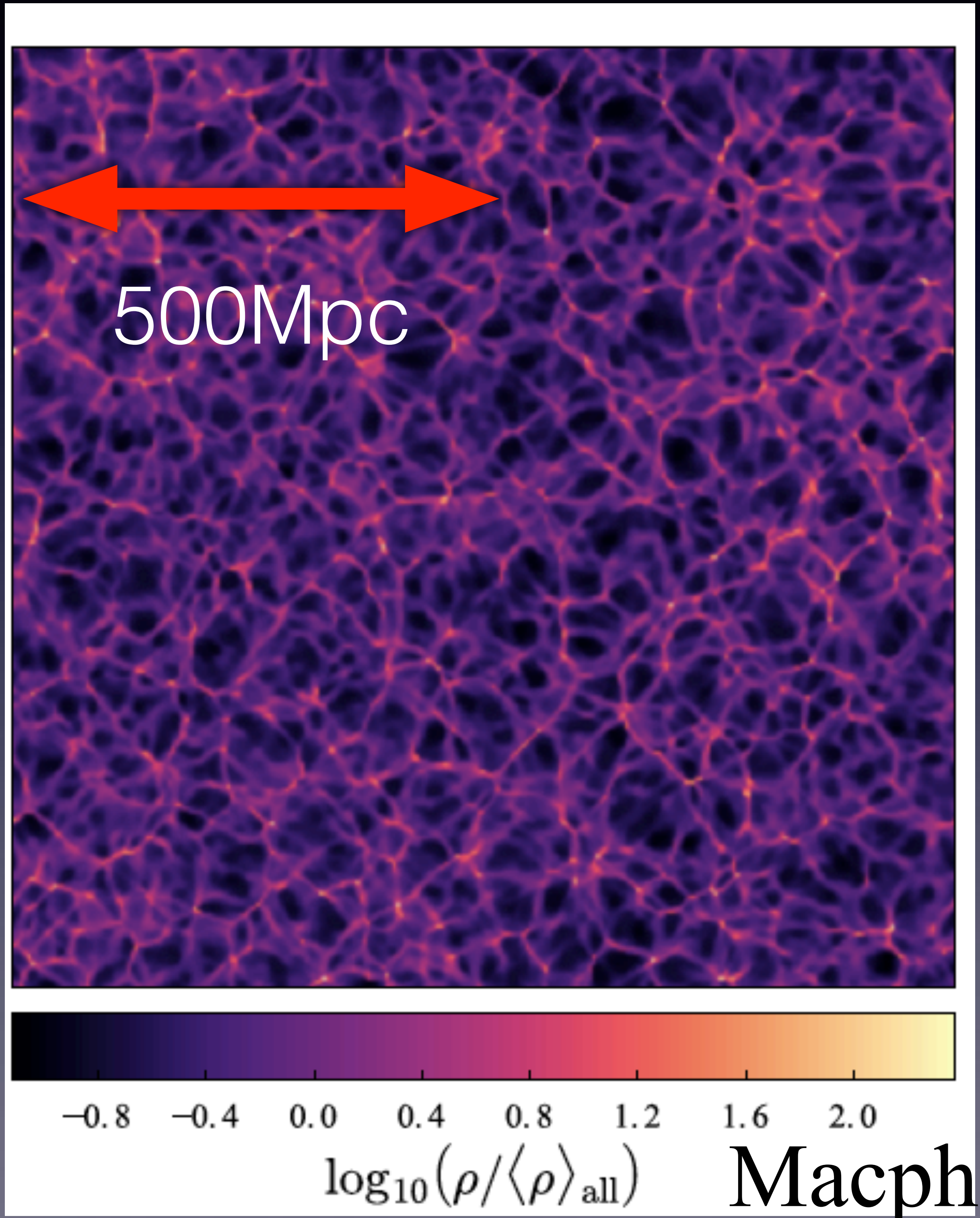
Submitted to ApJ

ABSTRACT

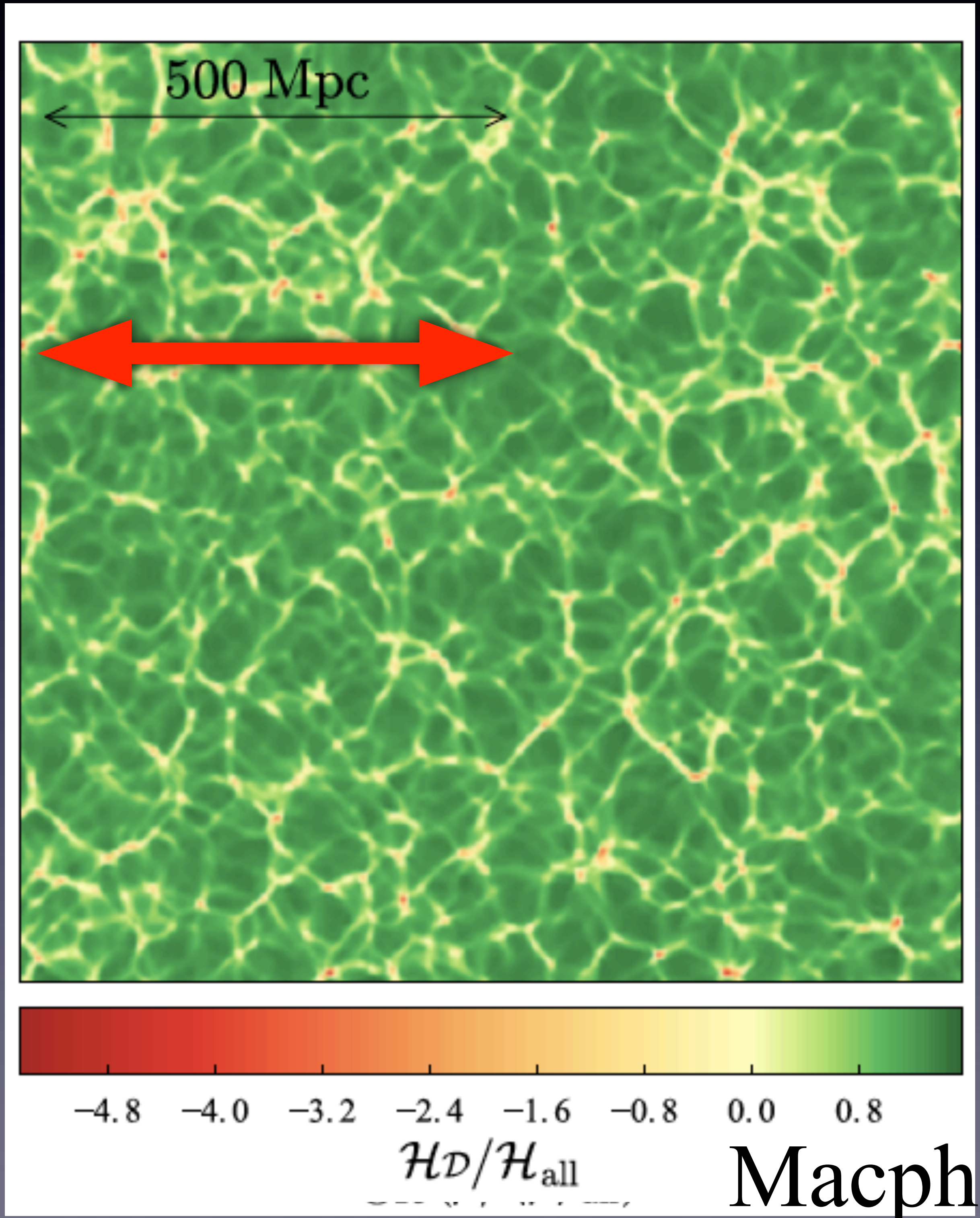
In a fully inhomogeneous, anisotropic cosmological simulation performed by solving Einstein's equations with numerical relativity, we find a local measurement of the effective Hubble parameter differs by less than 1% compared to the global value. This variance is consistent with predictions from Newtonian gravity. We analyse the averaged local expansion rate on scales comparable to Type 1a supernova surveys, and find that local variance cannot resolve the tension between the Riess et al. (2018a) and Planck Collaboration et al. (2018) measurements.

Density Field at z=0



Macpherson et al 2018

Expansion Rate at z=0 (normalized by global)
Inhomogeneous Expansion of the Universe



Macpherson et al 2018

Hubble Flow vs SNIa Cosmology

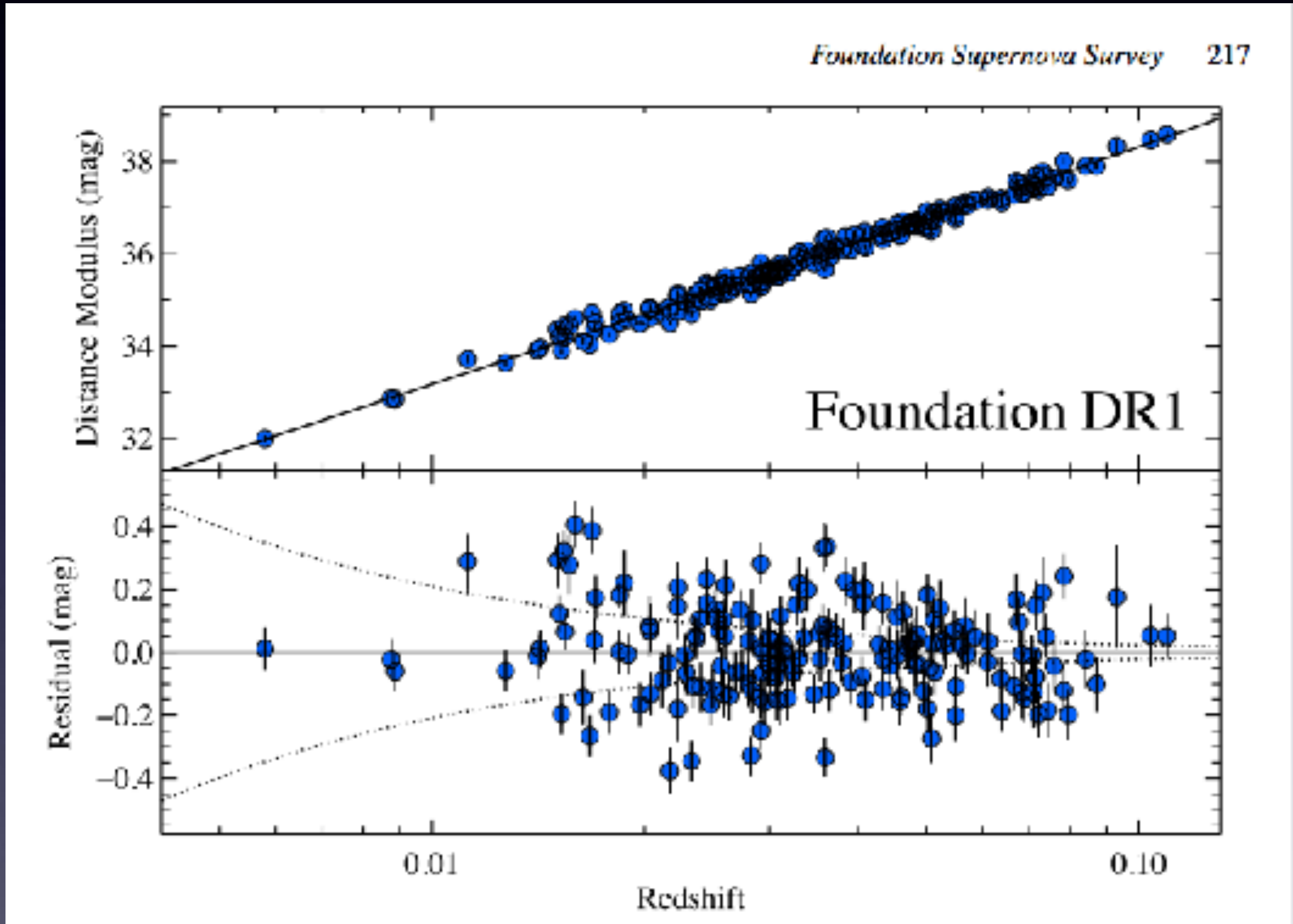
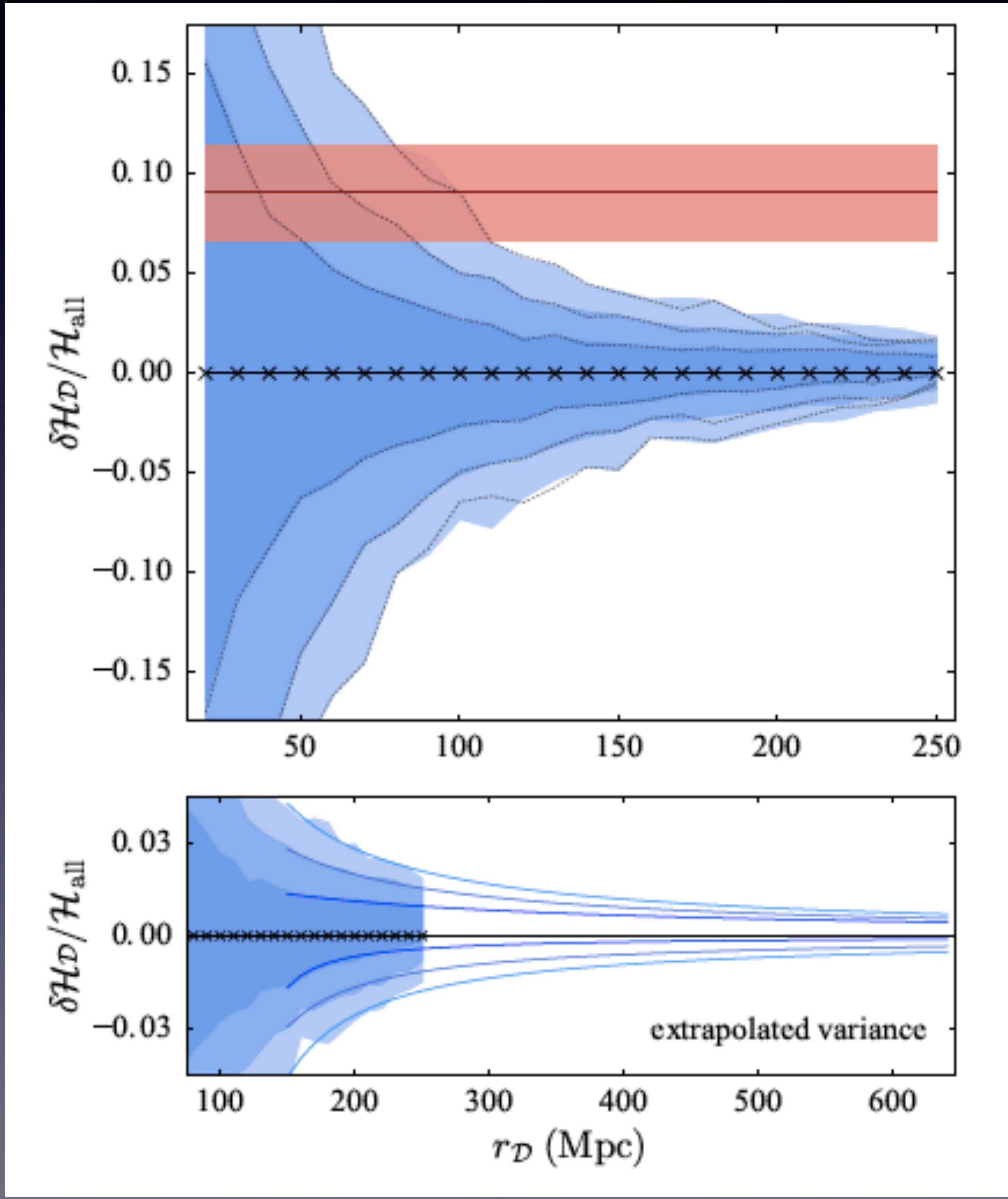


Figure 8. Hubble diagram for the Foundation DR1 sample and residuals to a fiducial ΛCDM model (lower panel). Error bars do not include uncertainties related to peculiar velocities (which are represented by the dotted curves in the lower panel) and redshift uncertainties.

Foley et al 2018



Macpherson et al 2018

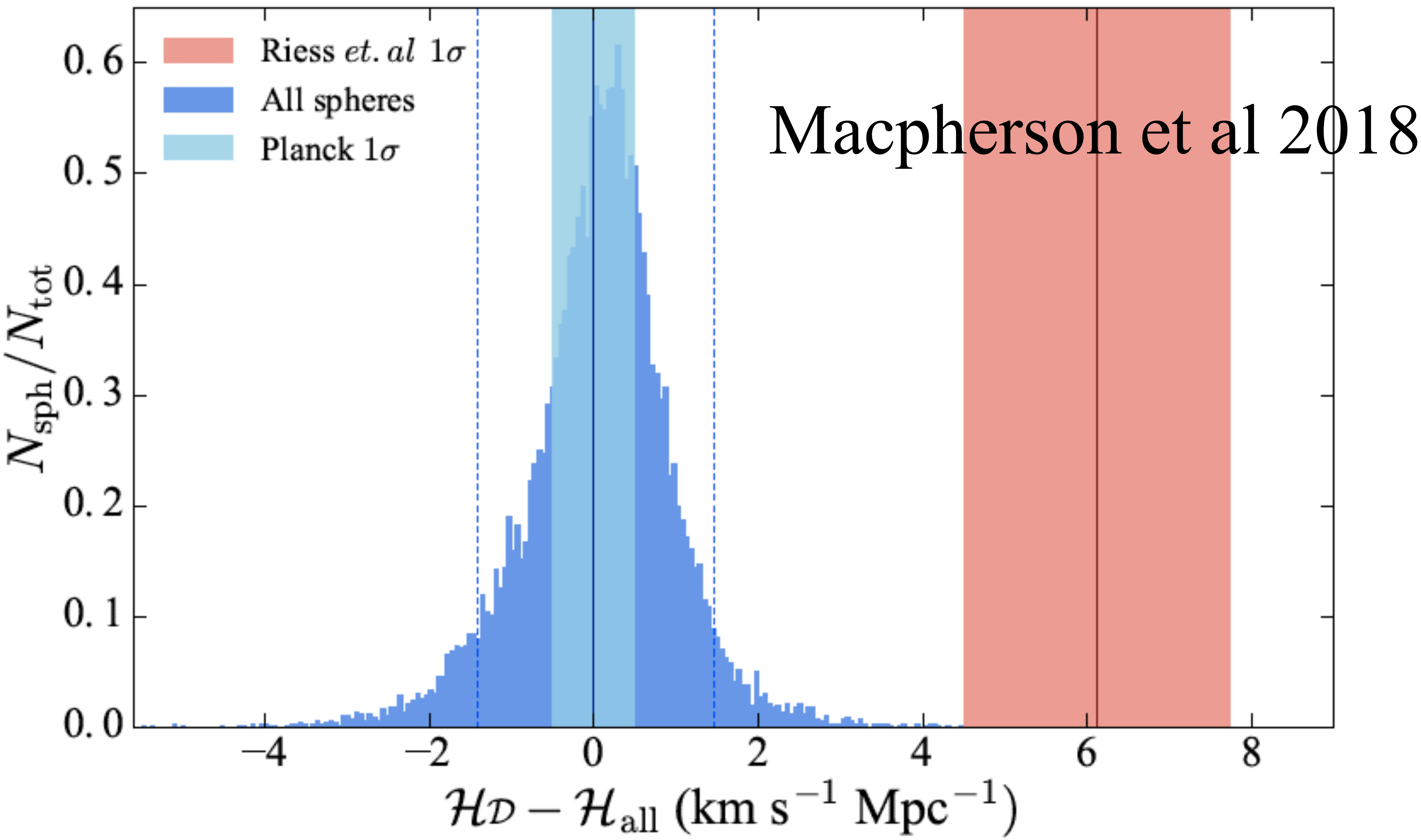


Figure 3. Local deviations in the Hubble parameter due to inhomogeneities. We show the full distribution of all spheres in the range $75 < r_\mathcal{D} < 180\,h^{-1}$ Mpc in blue. The dashed blue lines represent the 1σ deviation of the inhomogeneous distribution. The blue shaded region represents the 1σ uncertainties on the Planck Collaboration et al. (2016) measurement, while the solid red line and shaded region represent the mean and 1σ deviation in the Riess et al. (2018a) measurement, respectively.

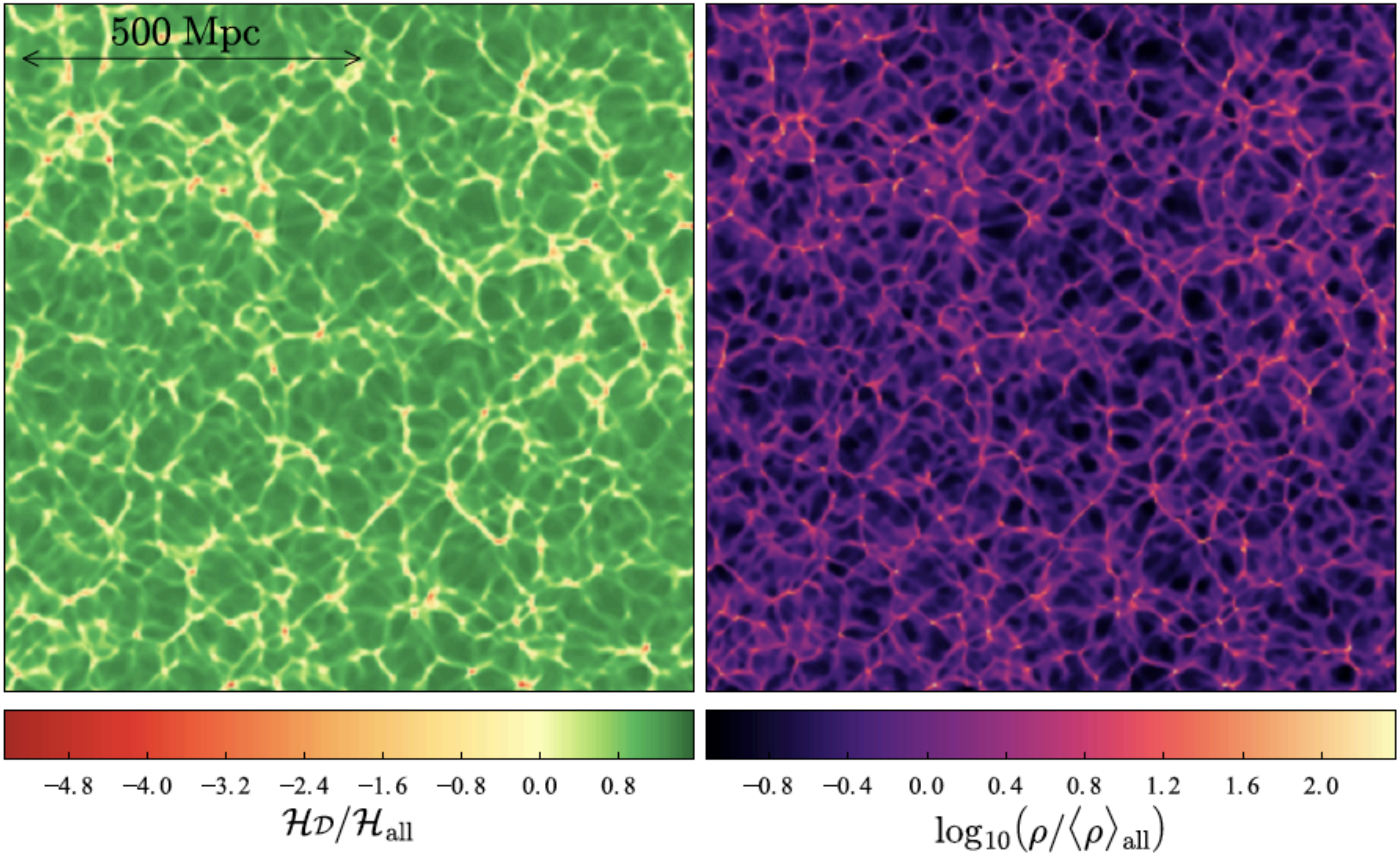


Figure 1. Expansion rate and density of an inhomogeneous, anisotropic universe. Left panel shows the deviation in the Hubble parameter relative to the global mean $\mathcal{H}_{\rm all}$. Right panel shows the density distribution relative to the global average, $\langle\rho\rangle_{\rm all}$. Both panels show a slice through the midplane of a 256^3 resolution simulation with $L = 1$ Gpc.

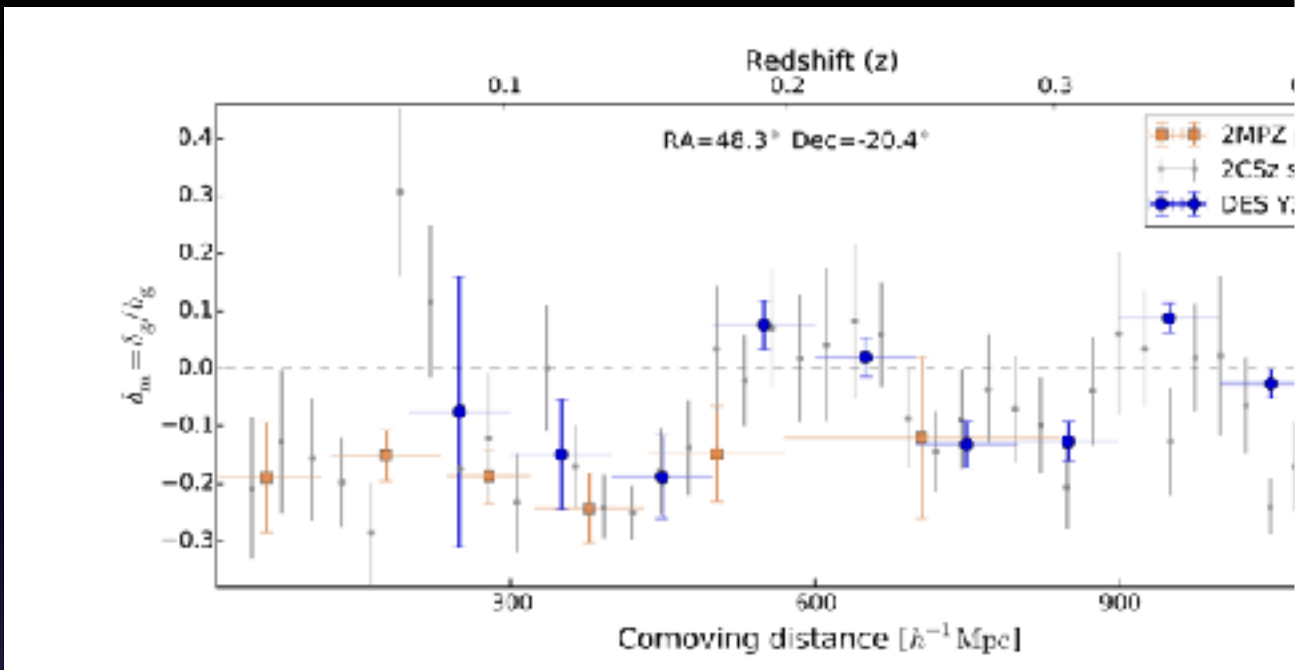
Macpherson et al 2018

Today (500 SNeIa z <0.1)

ZTFII (3000 SNeIa z <0.1)

ZTFIII (30,000 SNeIa)

Beginning to see the sign



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https://doi.org/10.1093/mnras/stab3309

The DES view of the Eridanus supervoid and the CMB cold spot

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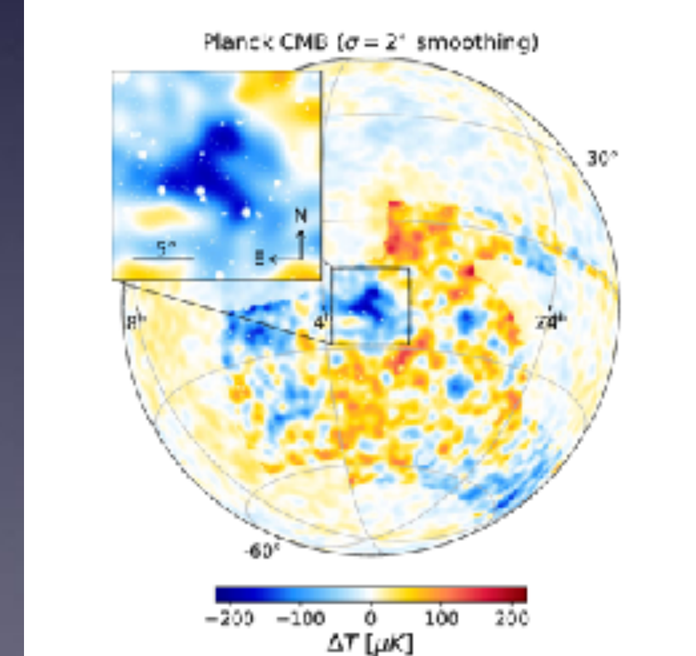
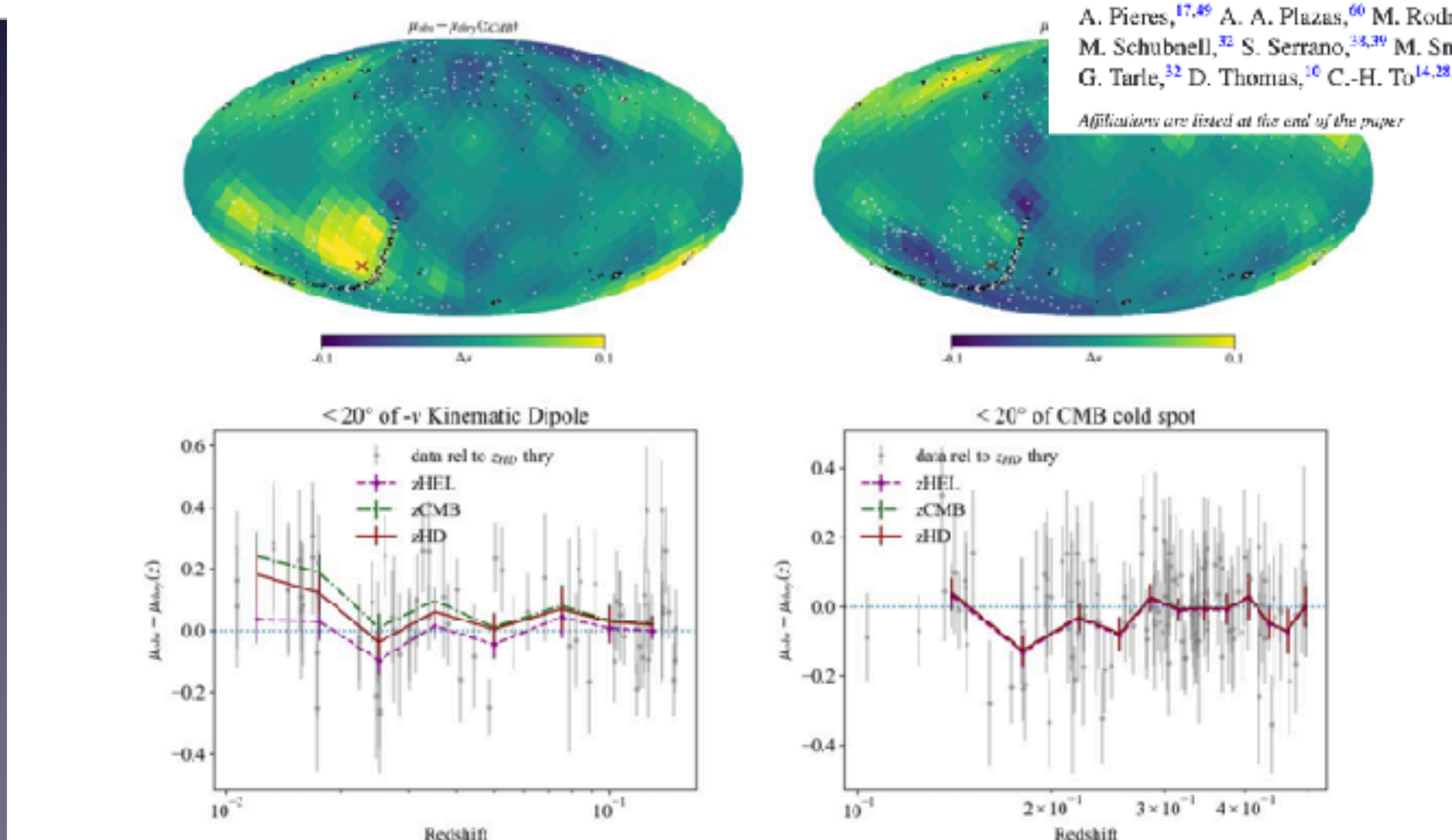
Affiliations are listed at the end of the paper





Brout et al. 2022

Summary : Fact Sheet

- 150Mpc (BAO scale) represents the local universe
- All Sky Survey is needed
- σ8 is the measure of fluctuation amplitude, σ100 is about 2%
- Redshift is a sum of peculiar velocity + Hubble Flow
- By using SNIa, we can extract peculiar velocity to prove local density fluctuations
- With 100 SNeIa, CMB Dipole is seen
- z<0.05 SNeIa were threw away in the past for SNIa cosmology business

Discussion (z<0.05 Science)

- Peculiar Velocity = Local Density Field
- Local Density Field can be modeled
- Supergalactic Plane can be mapped
- Are we in a void?
- Local Density Map can be drawn from 10,000 SNeIa
- How do we get SNIa Spectra?
- Southern Hemisphere Facilities are needed
- Inhomogeneous Expansion of the Universe should be detectable

- Backup Slides

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY

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Local gravity versus local velocity: solutions for β and non-linear bias

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2.2 TF sample

20 yr ago, the mis-calibration of full sky Tully–Fisher (TF) data was the problem that led to very discrepant results for the determination of $\beta \equiv \Omega/b$, with $\beta = 0.5 \pm 0.2$ (DNW96) and $\beta = 1.0 \pm 0.2$ (e.g. Dekel et al. 1993). The mistaken TF calibration led to a large-scale flow that confused both analyses, but in the end, it was a calibration error in the southern sky which made a false large-scale flow (Willick et al. 1997). In one analysis, this led to a higher χ^2 than was acceptable, and in the other it led to a biased result.

$$v_g(r) = \frac{2f(\Omega)}{3H_0\Omega} g(r).$$

3.2 Peculiar velocities from the inverse Tully–Fisher relation

Given a sample of galaxies with measured circular velocity parameters, $\eta_i = \log\omega_i$, linewidth ω_i, apparent magnitudes m_i and redshifts z_i, the goal is to derive an estimate for the smooth underlying peculiar velocity field. We assume that the circular velocity parameter, η, of a galaxy is, up to a random scatter, related to its absolute magnitude, M, by means of a linear ITF relation, i.e.

$$\eta = \gamma M + \eta_0. \quad (8)$$

One of the main advantages of inverse TF methods is that samples selected by magnitude, as most are, will be minimally plagued by Malmquist bias effects when analysed in the inverse direction (Schechter 1980; Aaronson et al. 1982). We write the absolute magnitude of a galaxy,

$$M_i = M_{0i} + P_i \quad (9)$$

where

$$M_{0i} = m_i + 5\log(z_i) - 15 \quad (10)$$

and

$$P_i = 5\log(1 - u_i/z_i), \quad (11)$$

where m_i is the apparent magnitude of the galaxy, z_i is its redshift in units of $\mathrm{km\,s^{-1}}$ and u_i is its radial peculiar velocity in the LG frame.

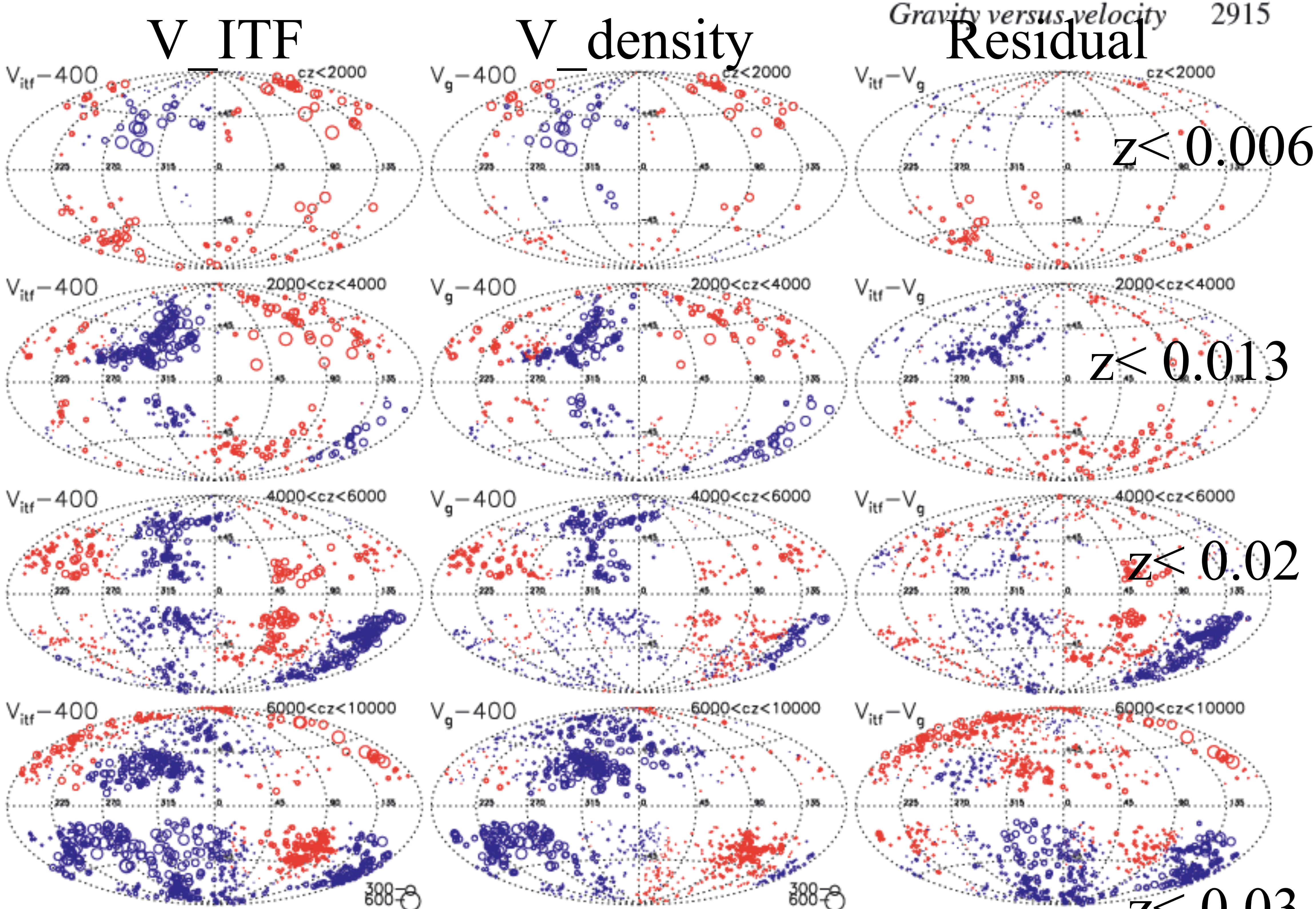

Figure 5. The derived peculiar velocities v_{ITF}, v_g and $v_{ITF} - v_g$ of galaxies on aitoff projections on the sky in galactic coordinates. The rows correspond to galaxies with $cz < 2000$, $2000 < cz < 4000$, $4000 < cz < 6000\,km\,s^{-1}$ and $6000 < cz < 10\,000\,km\,s^{-1}$, respectively. The size of the symbols is linearly proportional to the velocity amplitude (see key to the size of the symbols given at the bottom of the figure). In order to better see the differences, a $400\,km\,s^{-1}$ dipole, in the direction of the CMB dipole, has been subtracted from the v_{ITF} and v_g velocities. Note that $v_{ITF} - v_g$ is considerably smaller than v_{ITF} or v_g, even for the most distant galaxies.

Davis et al. 2011

SNIa Supernova (z<0.05)
Feindt et al 2013 : SN Factory

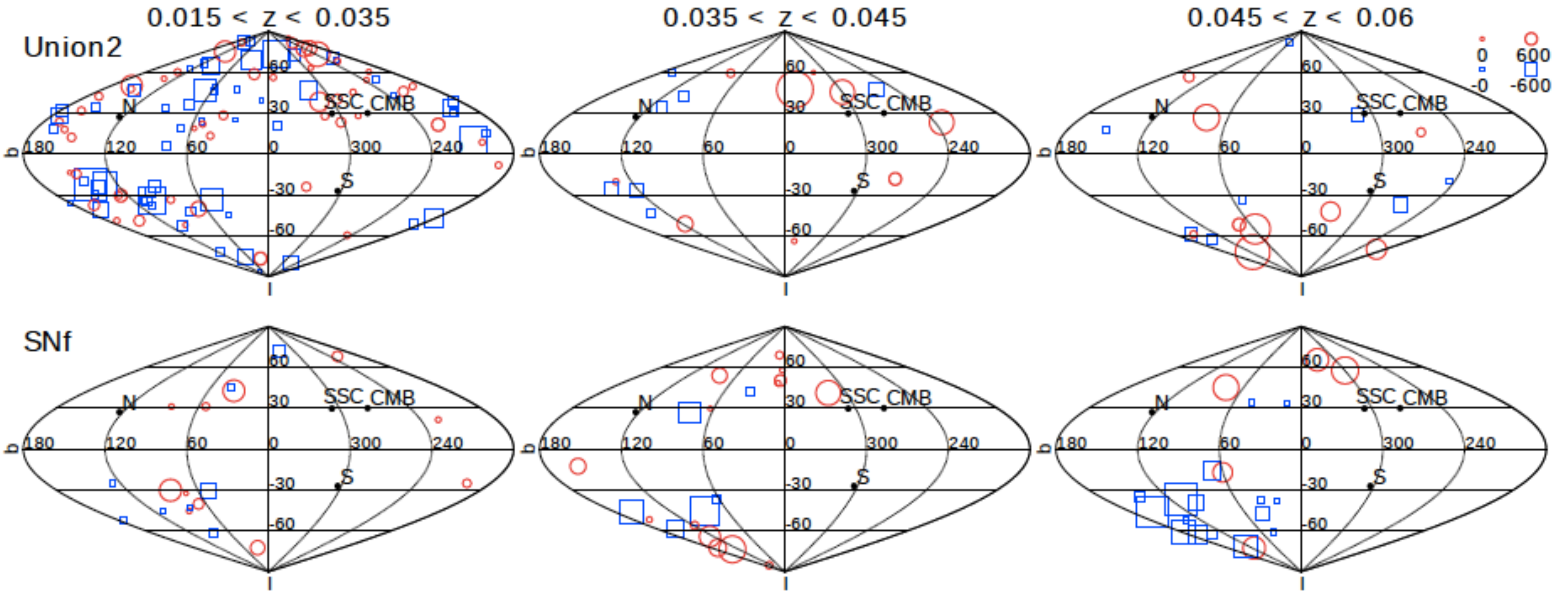

Fig. 1. Peculiar velocities of individual SNe determined from their distance moduli, μ_i, by solving Eq. (2) for $v_{\rm DF}$. The plots show the Union2 (*top row*) and SNFACTORY (*bottom row*) datasets in the redshift bins $0.015 < z < 0.035$ (*left column*), $0.035 < z < 0.045$ (*middle column*) and $0.045 < z < 0.06$ (*right column*). The marker diameter of each SN is proportional to the absolute value of the velocity plus an offset (see the scale at the top right), with red circles corresponding to positive velocities and blue squares corresponding to negative ones. For reference, the directions of the CMB dipole and the Shapley supercluster (SSC) are shown.