Systematic variations of the Hubble flow

Alpine Cosmology Workshop 2015

by

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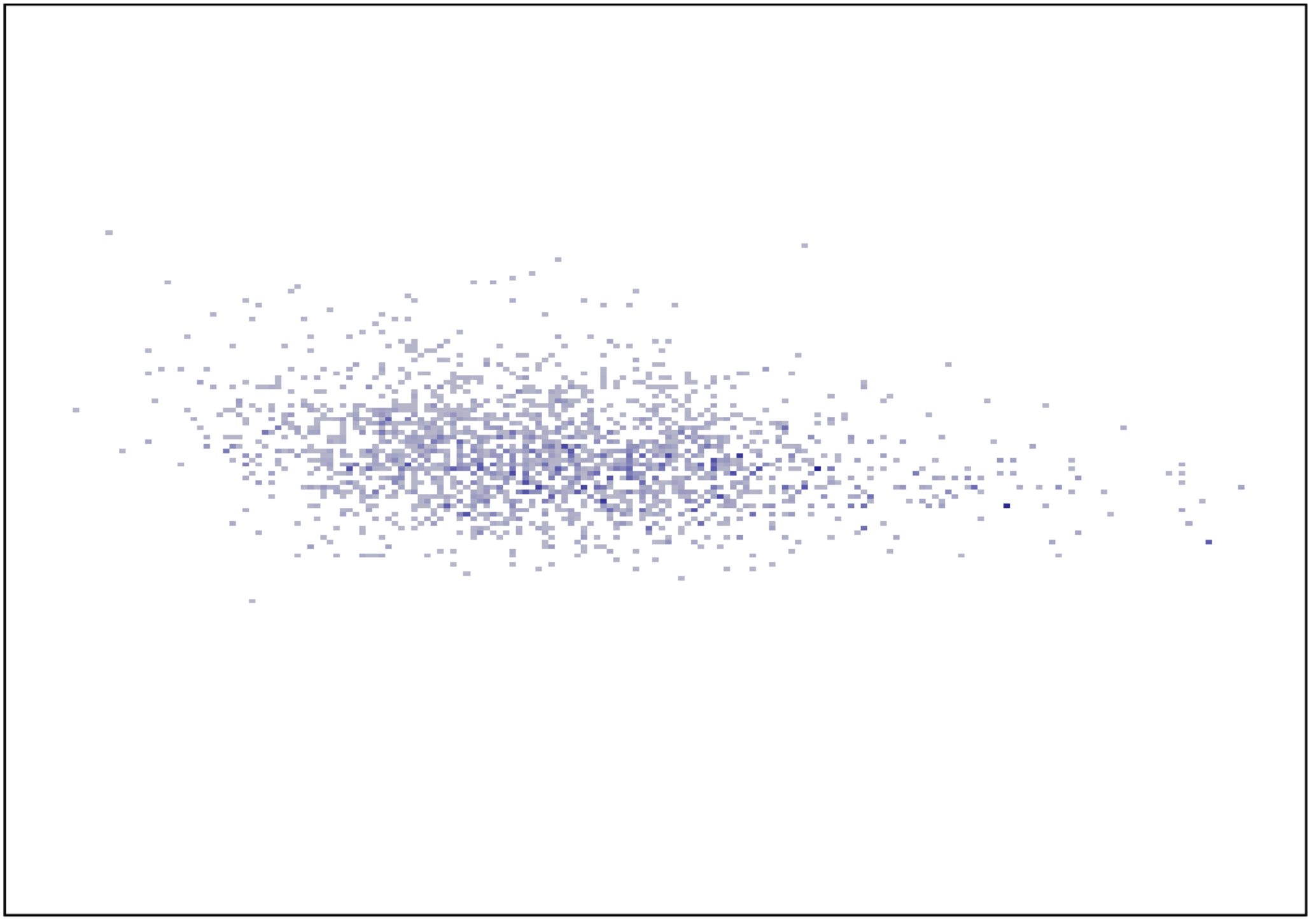
www.eso.org



Collaborators and more

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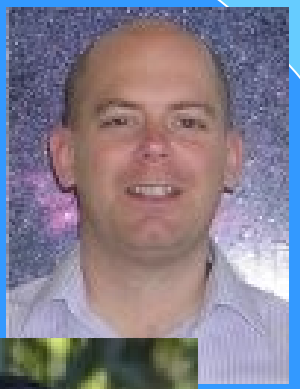
Werner W. Zeilinger

University of Vienna

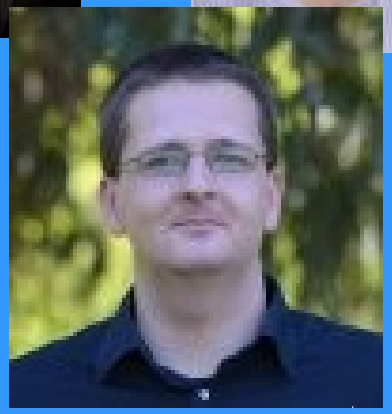
Steffen Mieske

ESO Chile



Eelco van Kampen

ESO Garching



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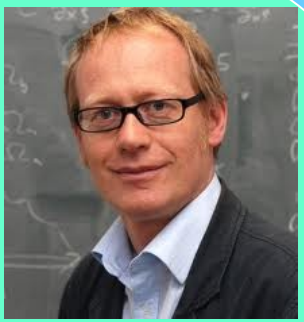

Dominik Schwarz

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Standard cosmology

- Einstein's field equation of general relativity
- + assumption of **homogeneity**

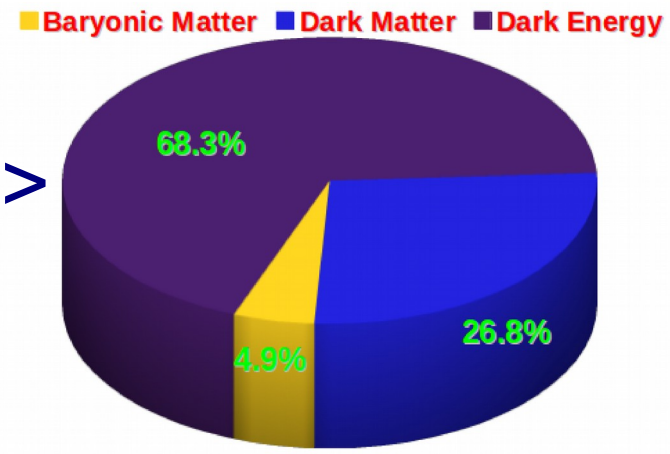
  & isotropy

- = Friedmann-Lemaître-Robertson-Walker metric

  ==> Friedmann equations

- Best fit on observational data ==>

  Λ-CDM model



Why do we need Dark Energy?

- Only to explain the **accelerated expansion** of the universe (distant supernovae type Ia – Nobel prize 2011)

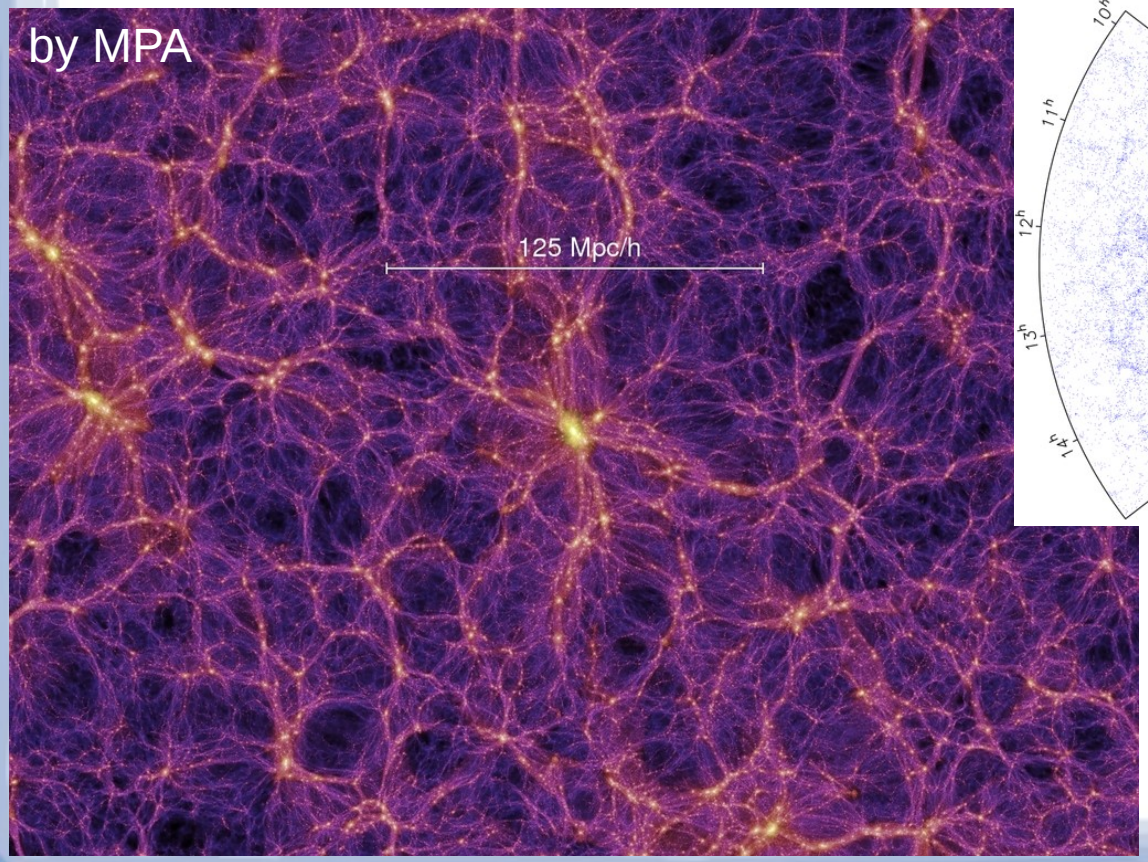
What is Dark Energy?

- We do **not know**!!!
  - Simplest assumption: cosmological constant Λ
  - Phantom dark energy or quintessence
  - Many other models without any proof

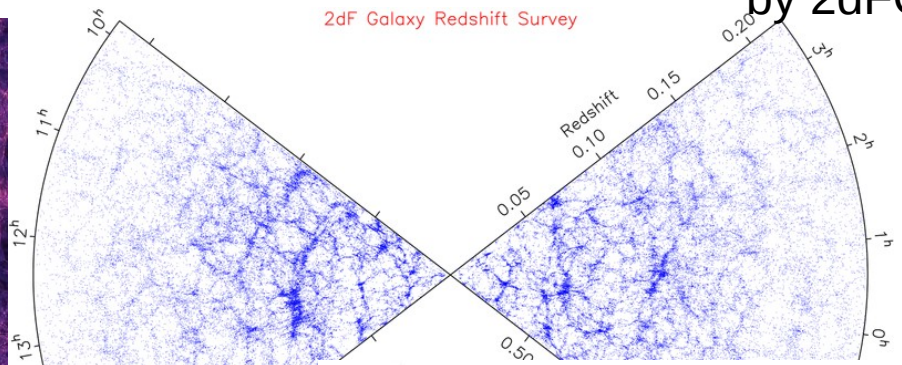
Timescape Cosmology

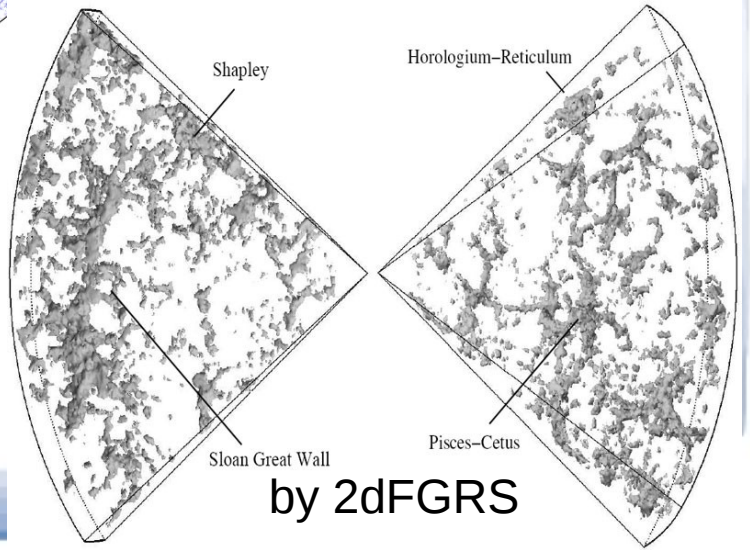
- cosmological model based on the assumption that the universe is **NOT** homogeneous

  ==> voids and clusters+filaments (walls)



by 2dFGRS





by 2dFGRS

- We live in an inhomogeneous universe (**FACT**).
- General Relativity is a non-linear theory (**FACT**).
- ==> averaging over large scale and high density contrast has to be modified.
- Back-reactions from inhomogeneities expected
- A pertubative approach to this problem is insufficient, it is more complicated.

- Dropping the cosmological time parameter (Wiltshire, 2007) and increasing the importance of the local metric.

- Assuming a two phase model (voids and walls) ==> Swiss-cheese model (or fractal bubble model)

***Voids**: empty = open geometry*

***Walls**: renormalized critical density = flat geometry*

Consequences of this theory

- At last scattering the universe was very close to homogeneity (**FACT**).
- Today the matter distribution in the universe has void-dominated fractal bubble structure (**FACT**).

- Voids expand faster than walls
- Structure formation made it inhomogeneous and caused the apparent accelerated expansion

One naturally gets an

accelerated expansion

without

the need of

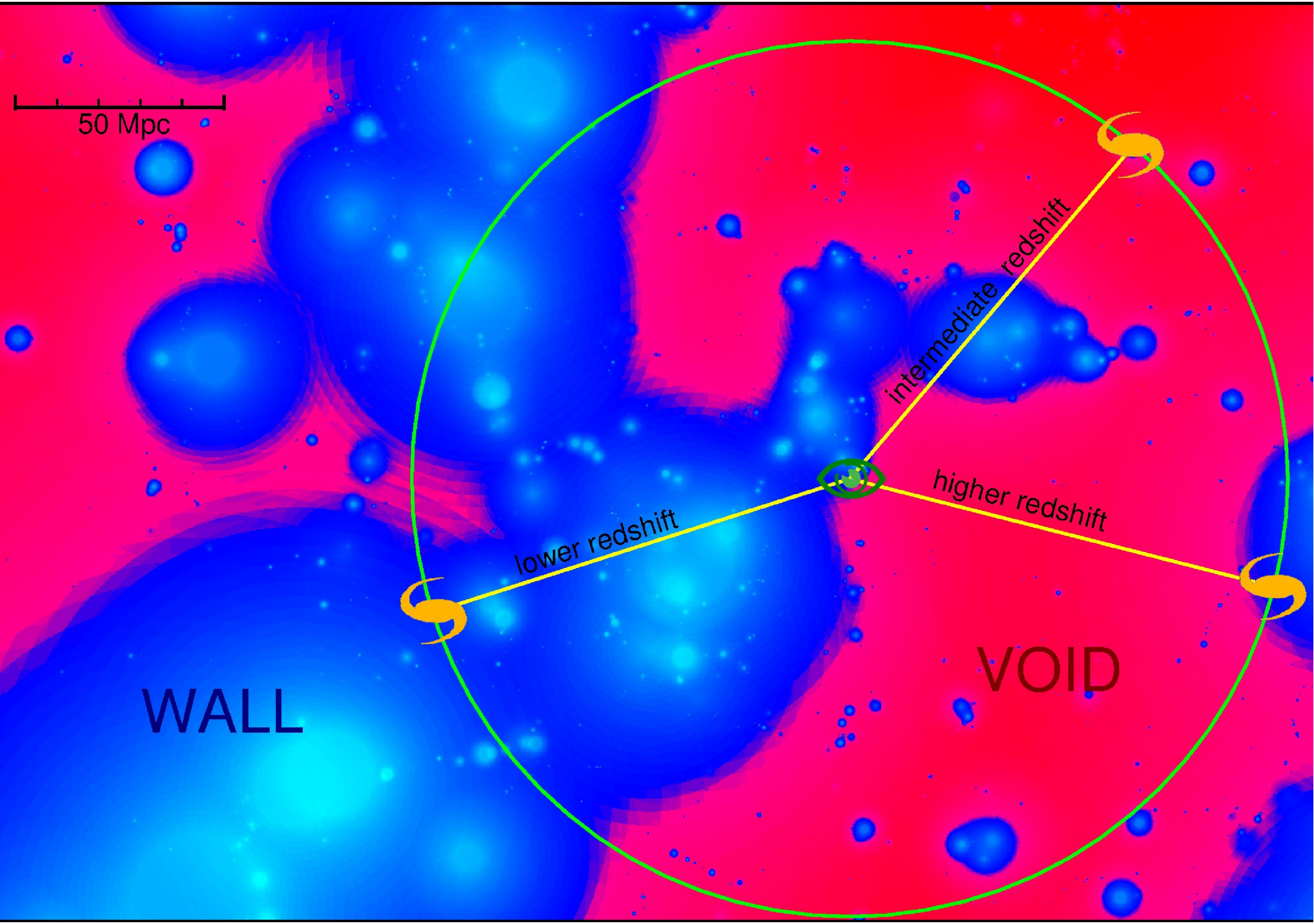
Dark Energy!

- Nice theory, isn't it?

  BUT

- Are these back-reactions strong enough to explain the cosmic acceleration?
- Proper calculations (beyond two-phase models) are hard to make due to the complexity of the equation of General Relativity
- Estimates are ranging from negligible to extremely important (Marra et al. 2010, Mattsson et al. 2010, Kwan et al. 2009, Clarkson et al. 2009, Paranjape 2009, van den Hoogen 2010)

Only a test can provide an answer!


50 Mpc
intermediate redshift
higher redshift
lower redshift
WALL
VOID

Designing the test

- In timescape cosmology

  voids expand faster than walls.

  We need:

- Measuring the distance independently from the redshift.
- Large sample distributed over a large area of the sky to avoid biases and get good statistics.
- Model of matter distribution in the local universe

Preparing the test

- A huge and homogeneous dataset with spectroscopic redshifts

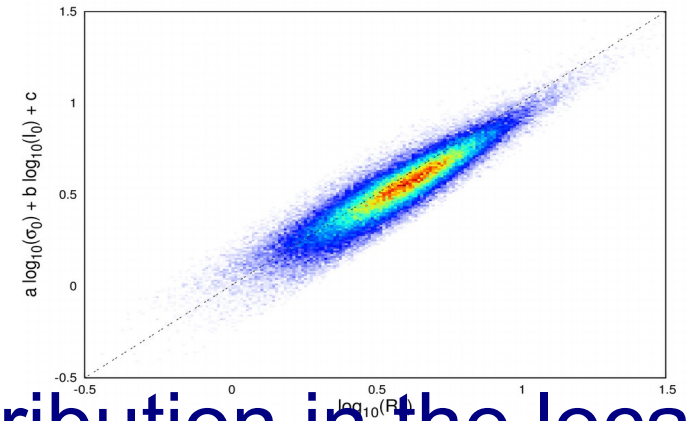
  ==> **SDSS** + **2MRS**

- A redshift-independent distance indicator

  ==> **fundamental plane**

  of elliptical galaxies

  see Saulder+2013 & Saulder+2015a

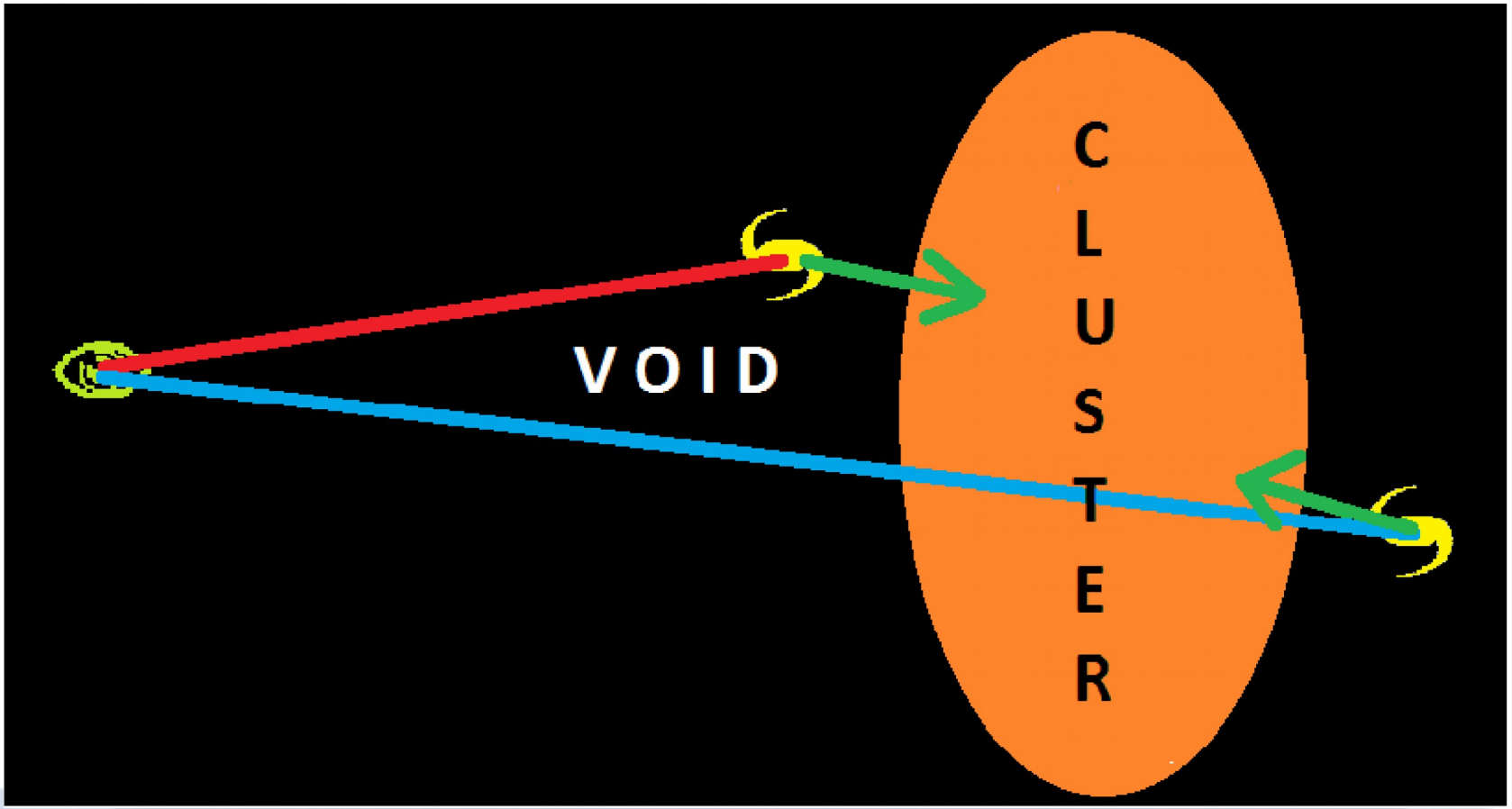


- A model of the mass distribution in the local universe ==> SDSS&2MRS based **group catalogue** in Saulder+2015b, submitted

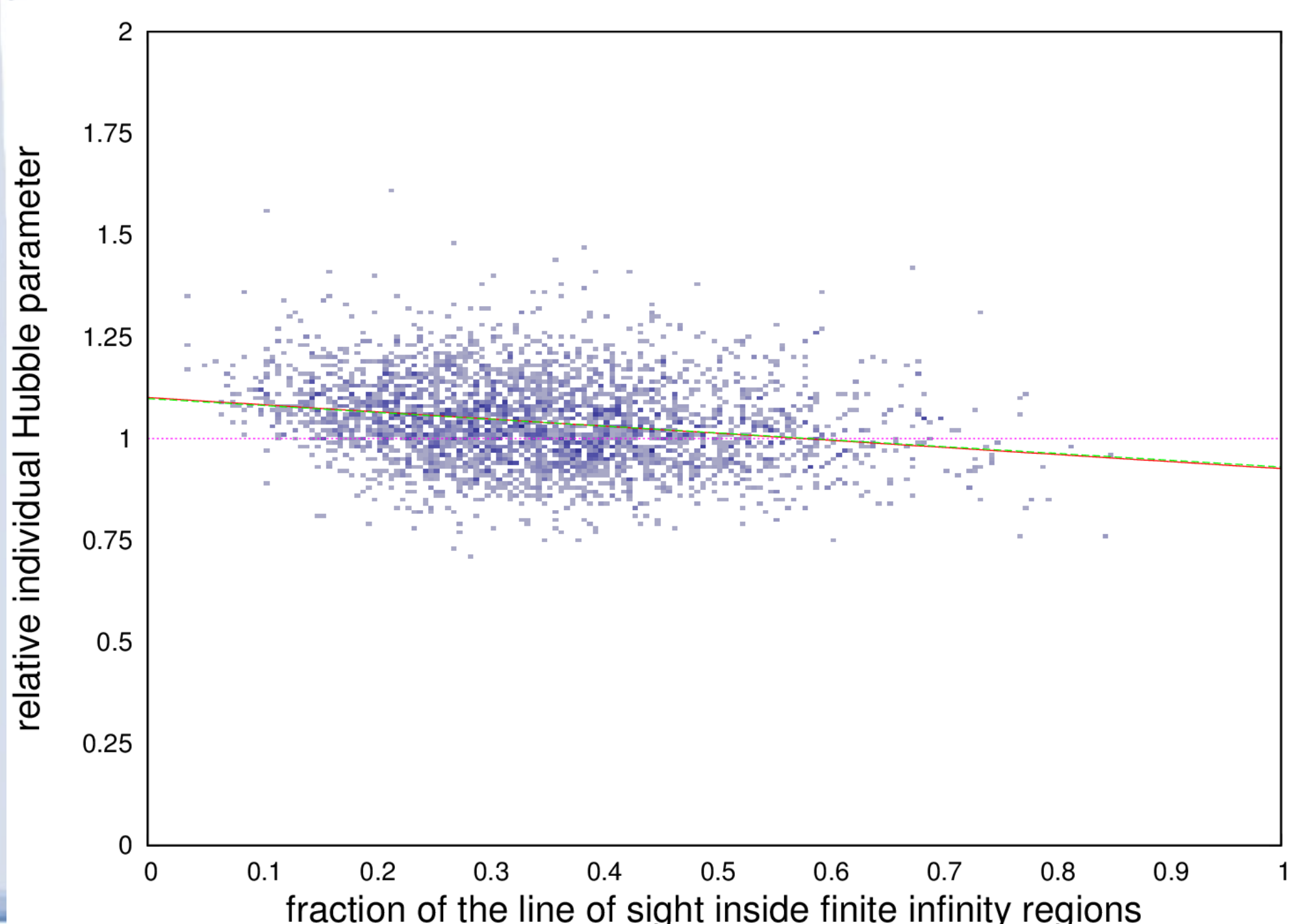
- Simulated data to estimate potential biases

  ==> **Millennium simulation**

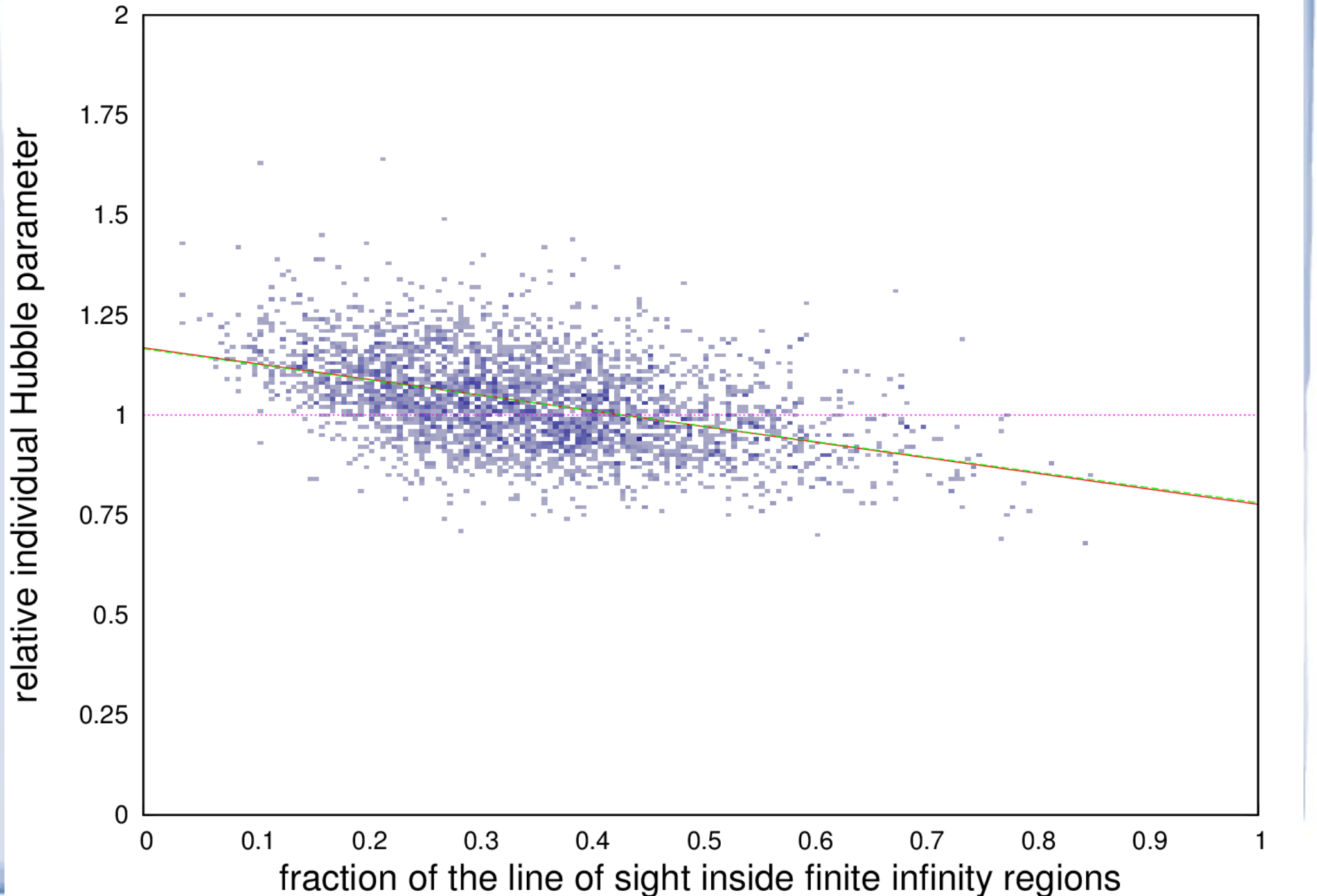
- Selection effects of SDSS (e.g. fibre collisions in dense clusters), Malmquist bias, peculiar motions, coherent infall into clusters



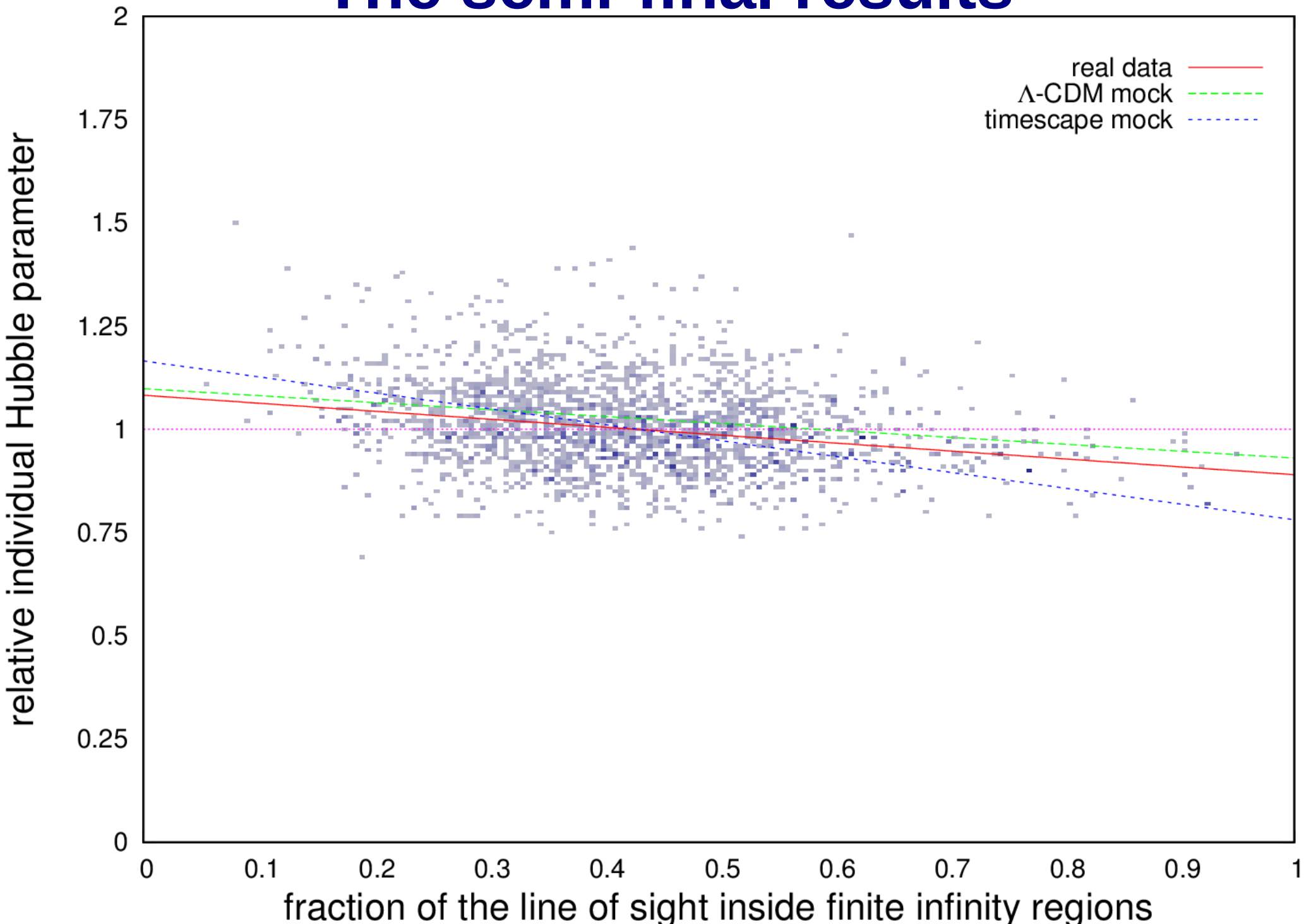
Expectations Λ-CDM cosmology



Expectations timescape cosmology



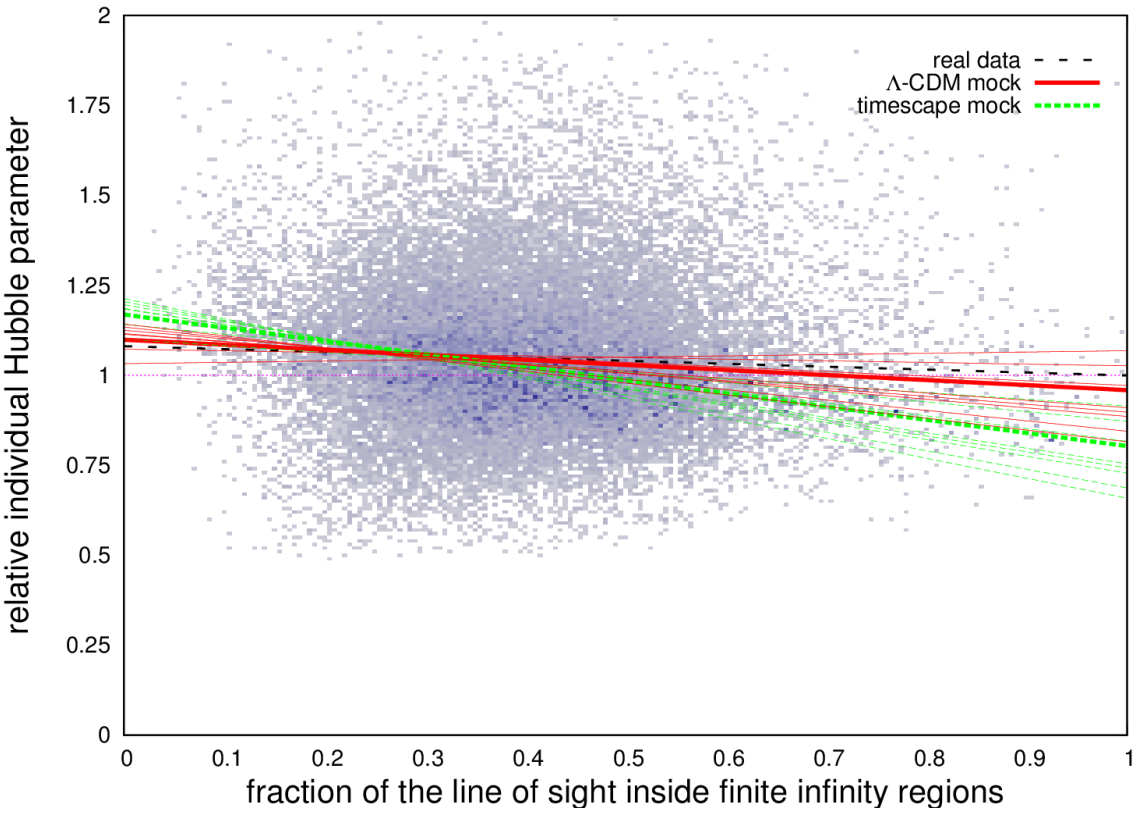
The semi-final results



Conclusions & Summary

- We managed to perform a meaningful test for timescape cosmology against the standard model with **public survey data** and **simulated data** only.

- Surprising diversity of our observational parameters between the different mock catalogues for the same cosmological model.



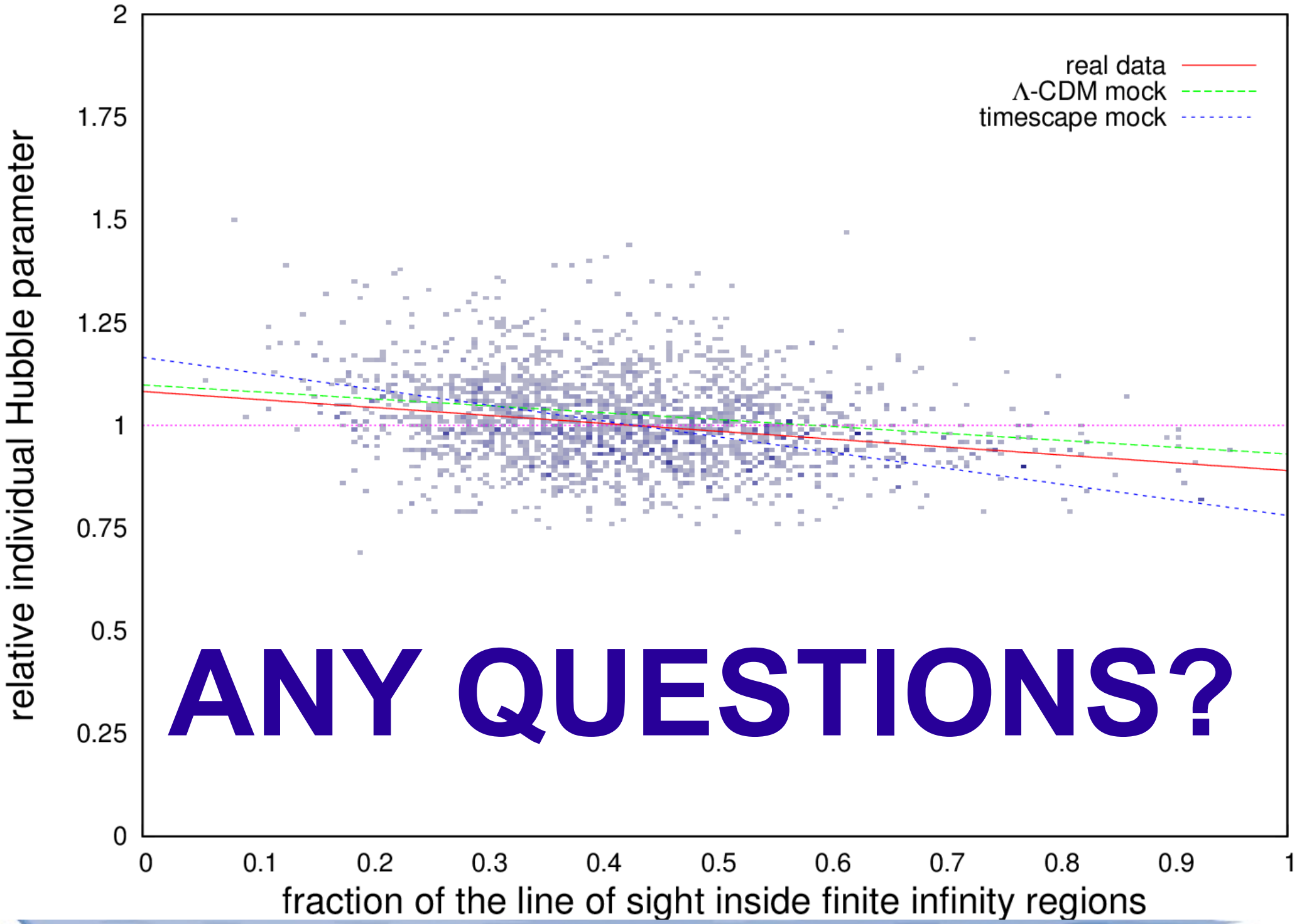
- **Final results in preparation** (Saulder+2015c, in prep.)

- **Statistical analysis** is still work in progress

  (least squares, binning, KS-test, etc.)

- So far, the data seems to **favour Λ-CDM**, but its significance depends on the analysis method.

- Repeat the test with more data and different distance indicator to reduce systematics

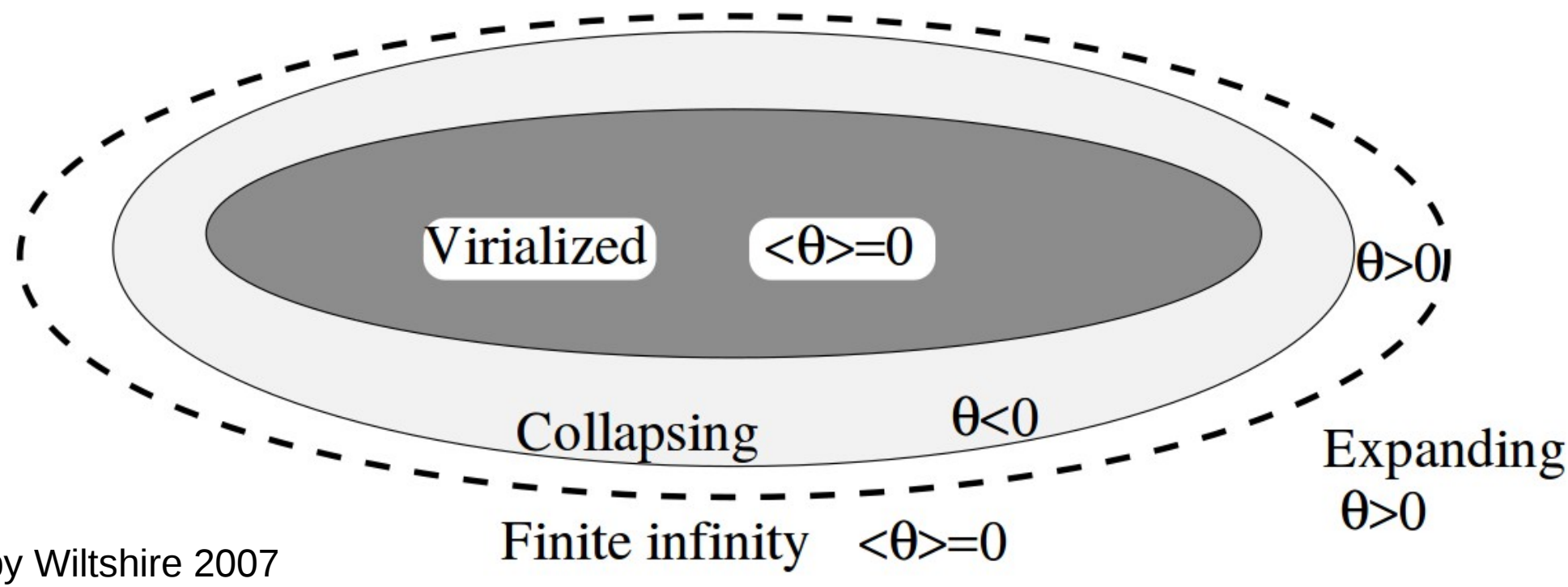


ANY QUESTIONS?

Supplementary slides

Only for Q&A … if asked for.

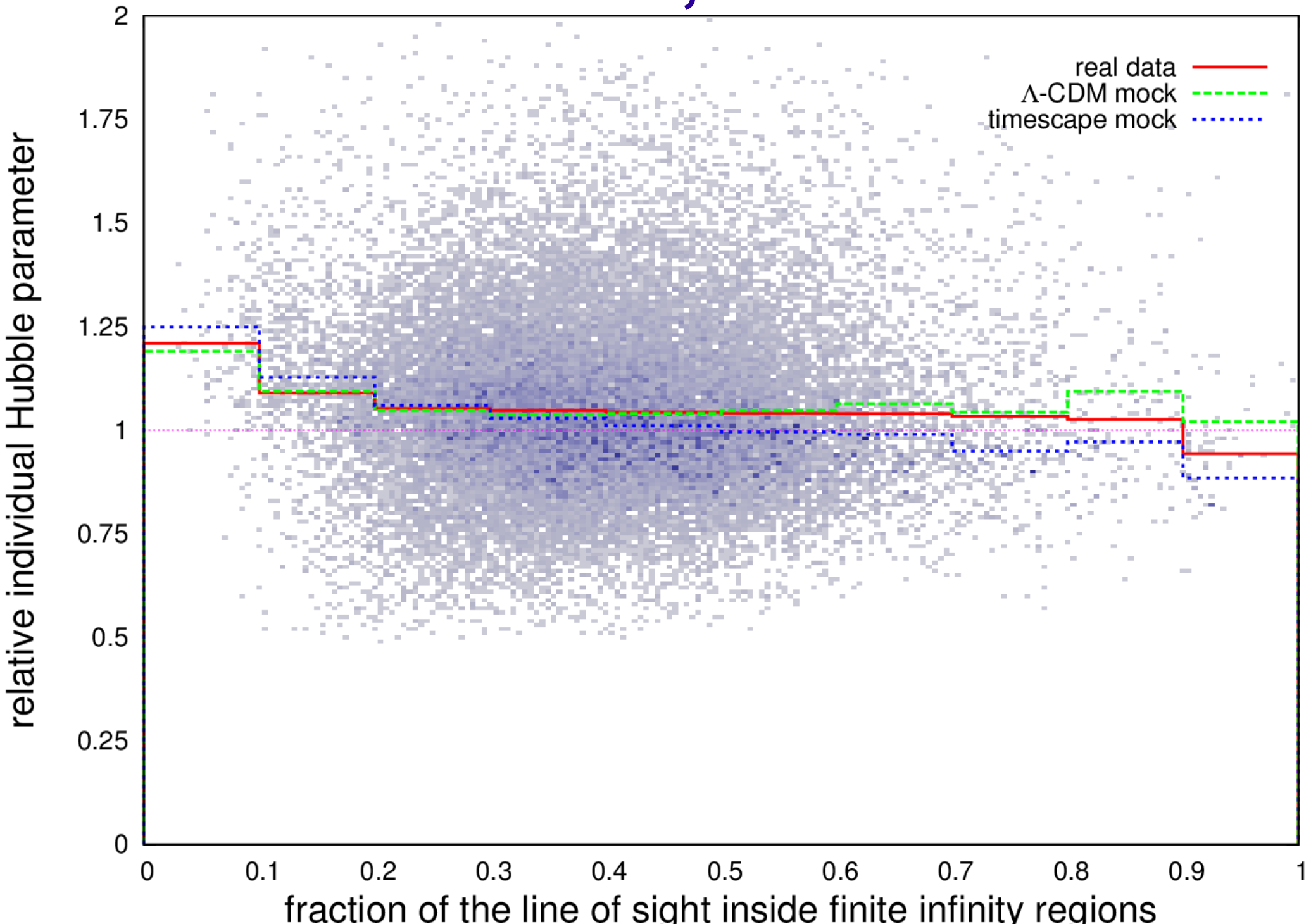
Finite infinity regions



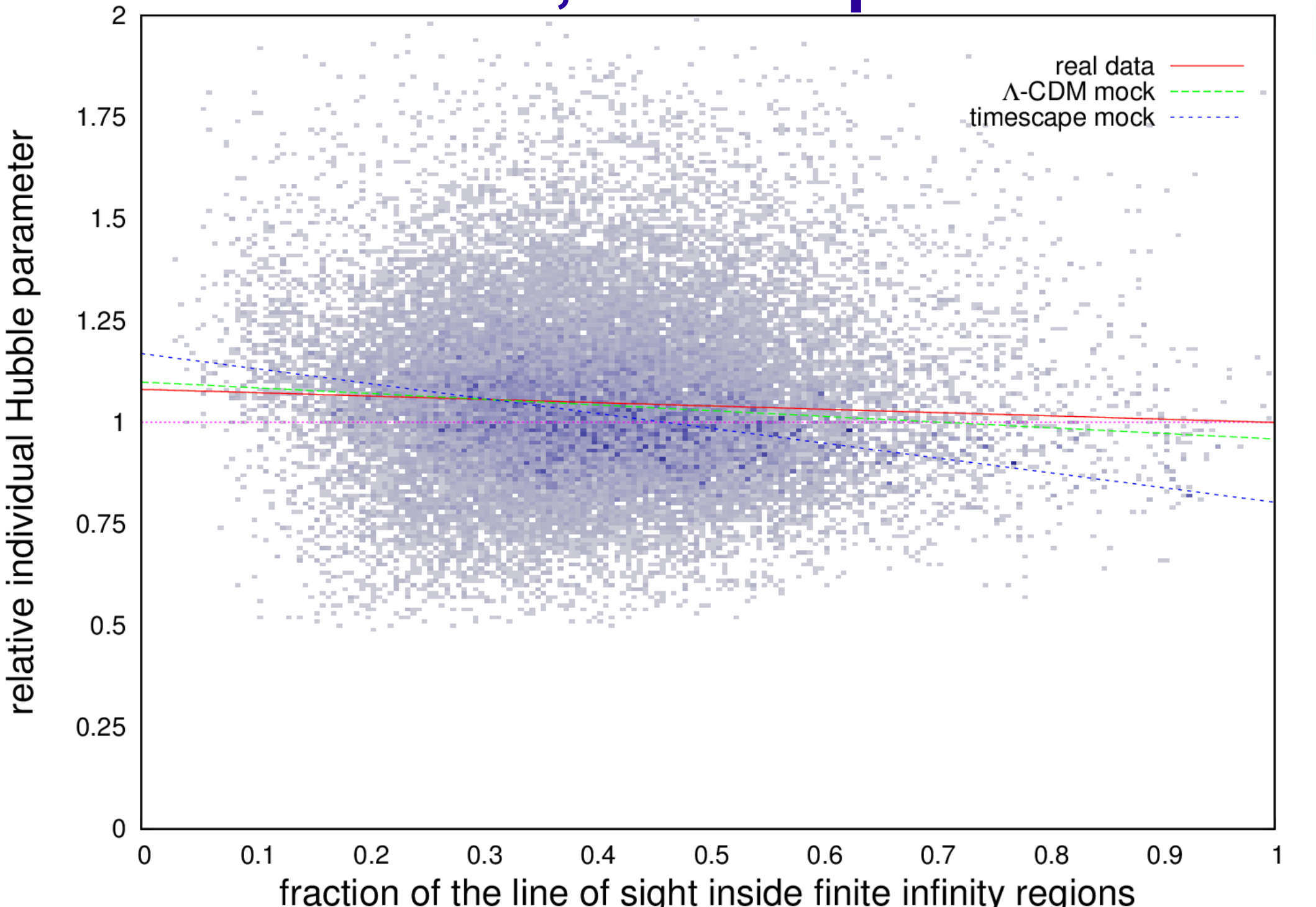
by Wiltshire 2007

- Approximated by (overlapping) spherical regions with an average density equal to the renormalized critical density in timescape cosmology.

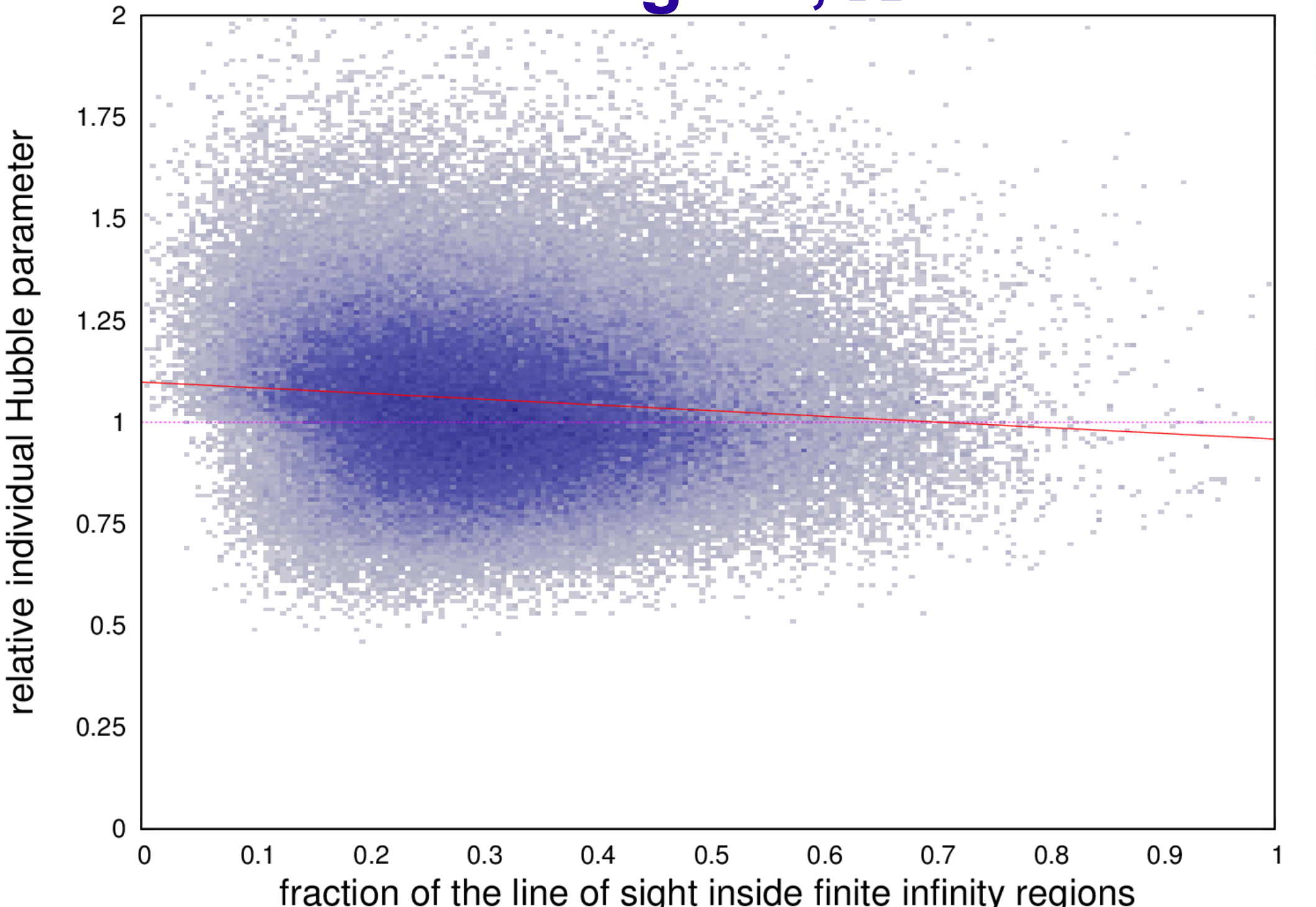
Full data, binned



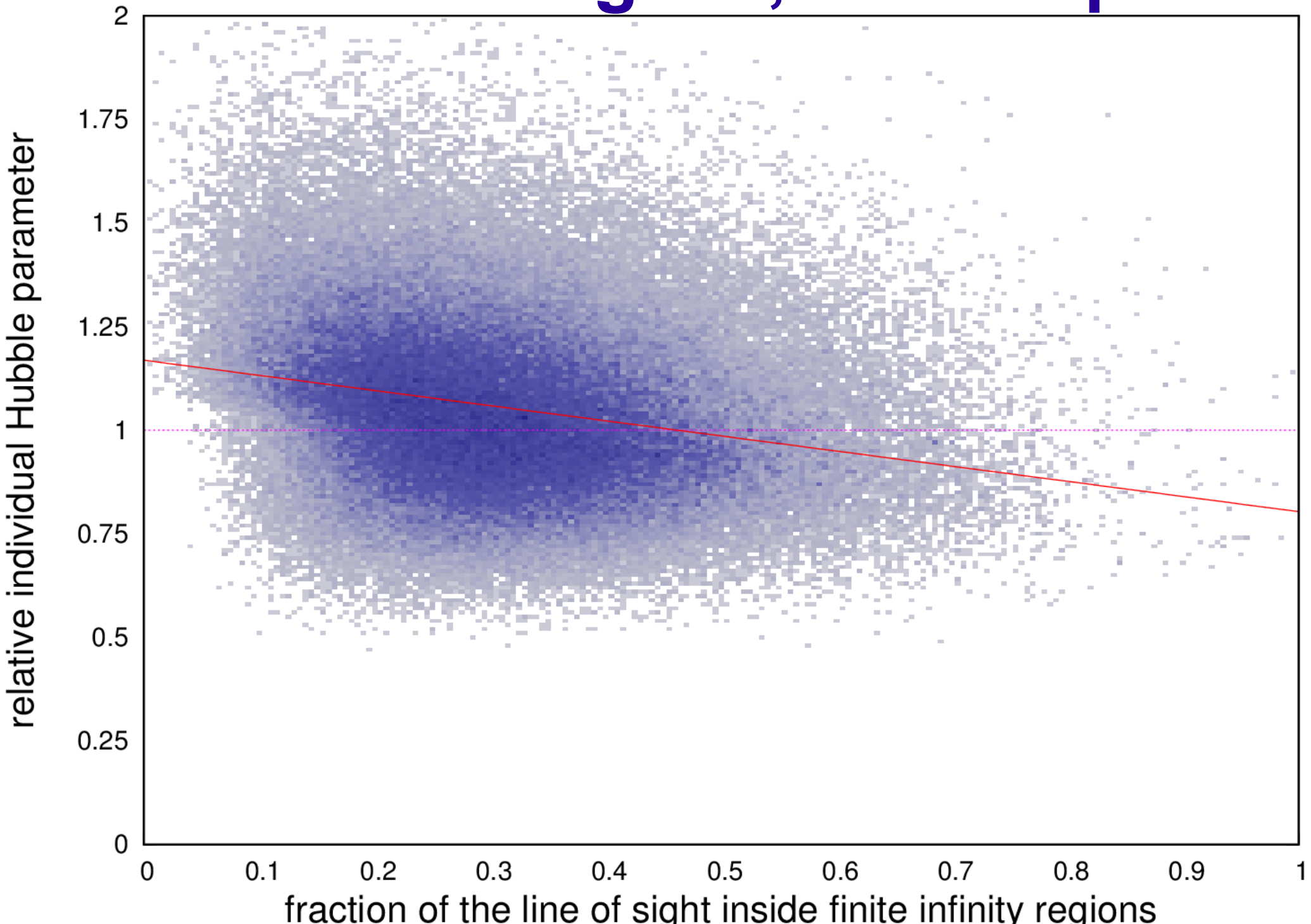
Full data, least squares



Mock catalogues, Λ-CDM



Mock catalogues, timescape



N/A

Sorry,

but I haven't prepared a slide for this question.