On the orbital velocity of galaxy pairs

Riccardo Scarpa, I.A.C.

Renato Falomo, INAF

Aldo Treves, Insubria University

Sample of Isolated Galaxy Pairs

Nottale & Chamaraux 2018 Astrophysical Bulletin 73, 310

Nottale & Chamaraux 2018 A&A 614, 45:

From HyperLEDA catalog,
at that time: <u>4 million entries</u>

Selection criteria:

- Galaxy absolute B mag $M \leq -18.5$ (selects big galaxies)
- Projected separation $r_P < 1$ Mpc
- Radial velocity $3000 < V_r < 16000$ km/s
- Radial velocity difference $|\Delta V| < 500$ km/s
- No multiples: each member is the closest to the other one
- Isolation criteria $\rho = r_3/r_P$; where r_3 projected
  distance of nearest galaxy to the pair

Resulting sample of galaxy pairs

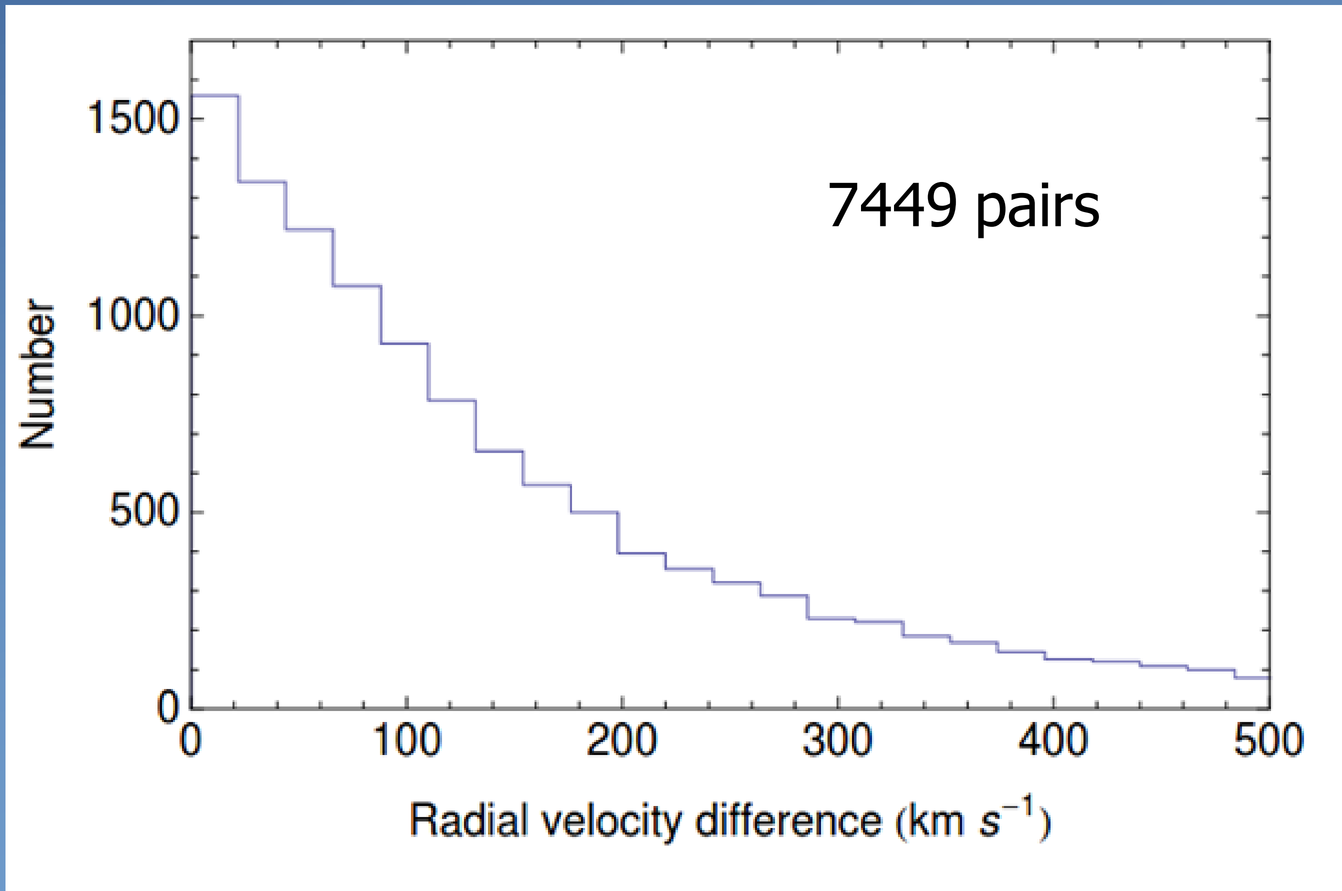
Sample size:

ρ≥2.5 N=13092 pairs

ρ≥5 N= 7449 pairs

ρ≥9 N= 4599 pairs

Intervelocity distribution monotonically decreasing. Nothing special.



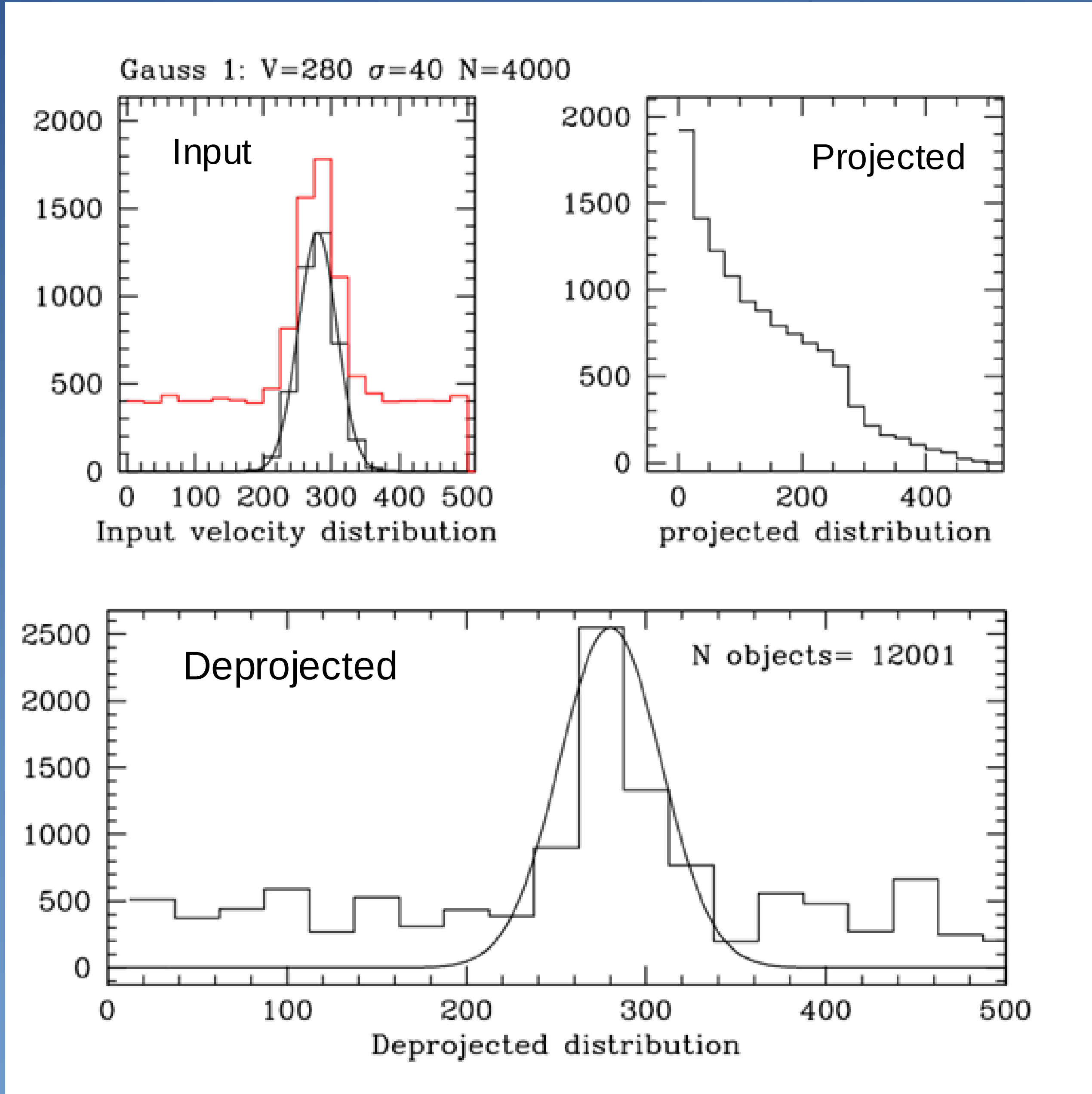
Deprojection technique:

Nottale and Chamaraux 2018 A&A, 614, 45

Deprojection based on the fact that a set of randomly oriented vectors V project uniformly from 0 to V on the radial direction.

Example:
One preferential velocity

Input values distributed as a Gaussian plus a *double* number of randomly distributed values representing unbound pairs: both average and dispersion retrieved properly

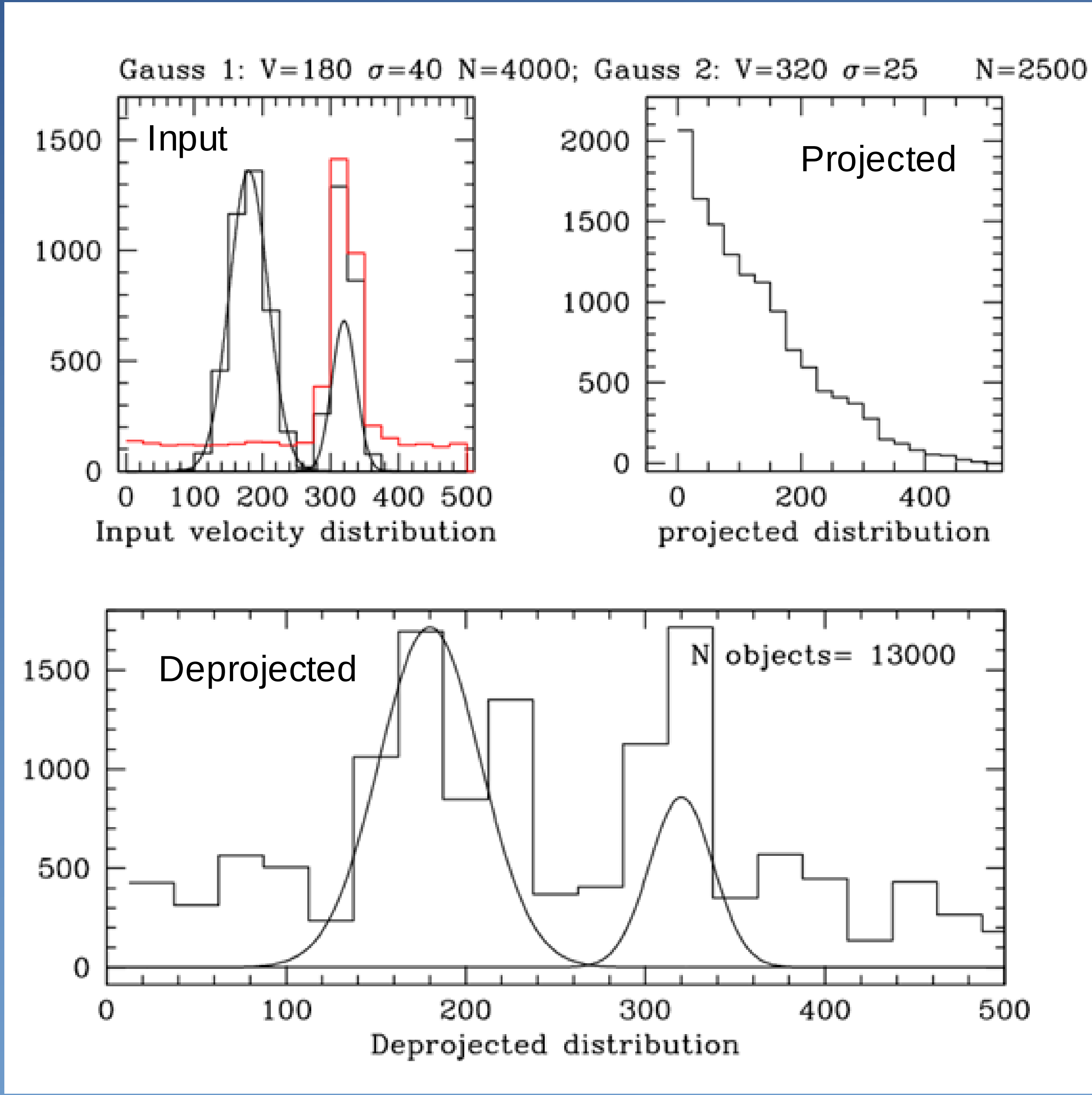


Deprojection technique:

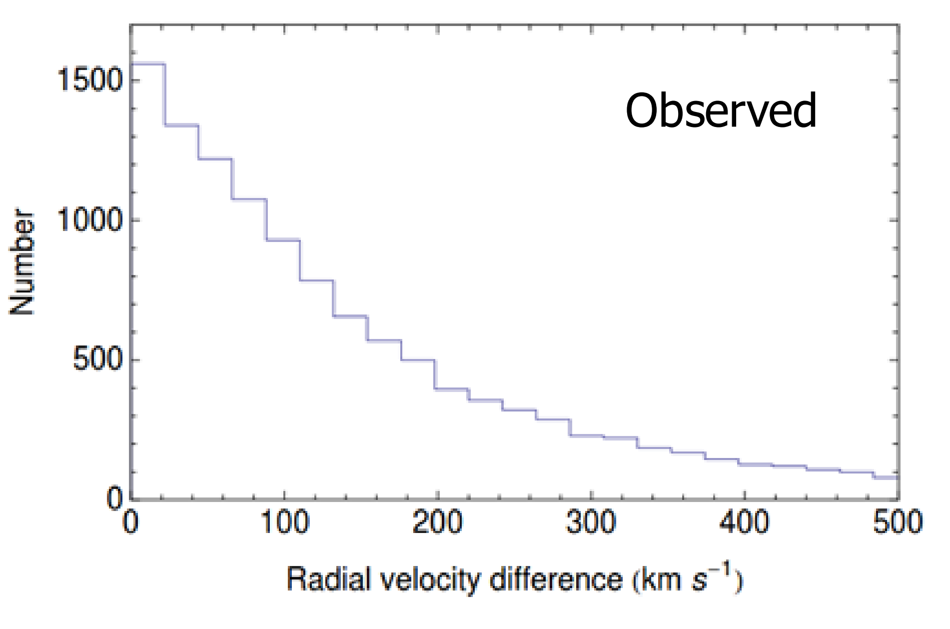
Nottale and Chamaraux 2018 A&A, 614, 45

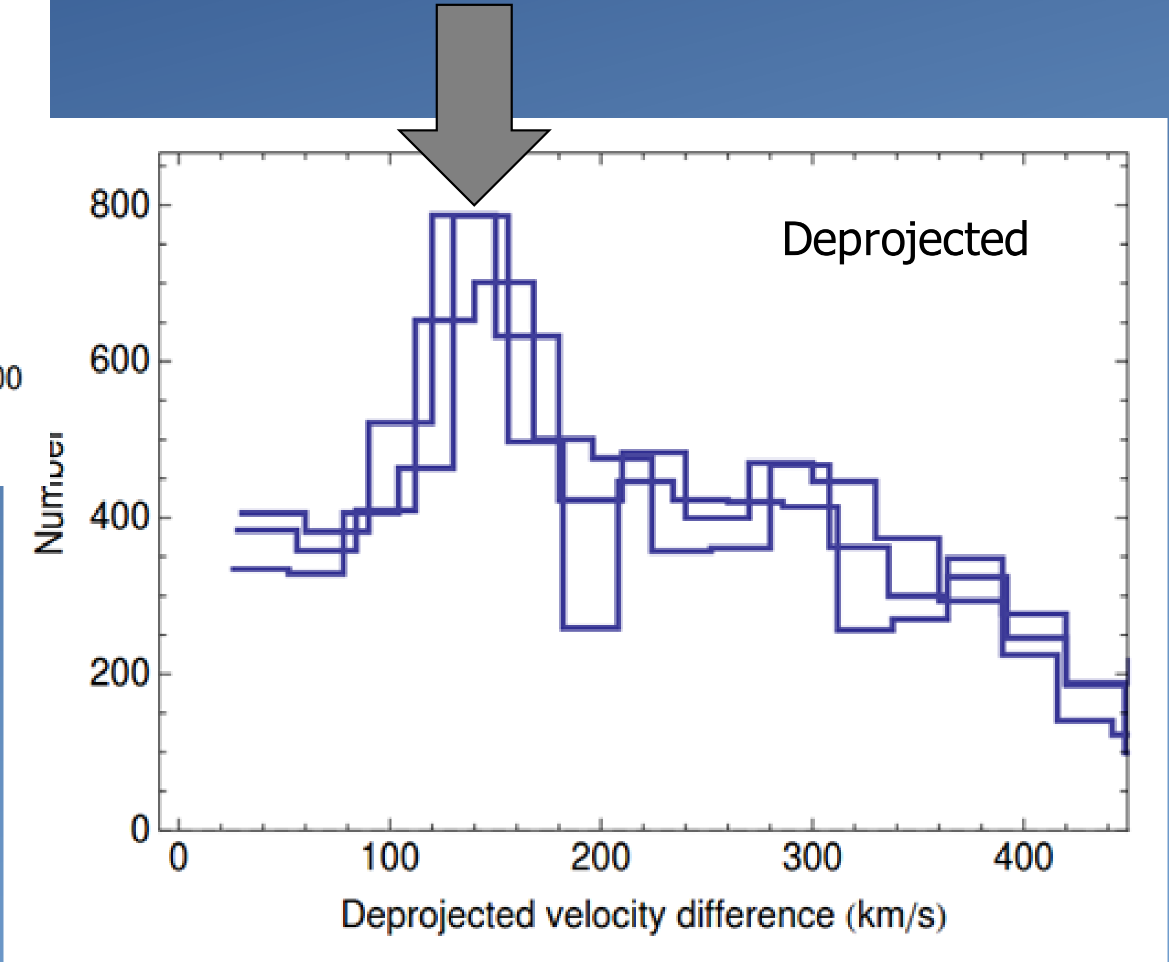
Example:
2 preferential values

Input values according to two separate Gaussian plus a similar number of randomly distributed values representing unbound pairs: even in this case the presence of two peaks is evident.



Nottale & Chamaraux discovered a preferential 3D intervelocity at ~150 km/s





A similar preferential intervelocity observed on a specific sample of exoplanet, so the peak is ascribed to a possible "universality of Keplerian structures".

No mention of MOND made to explain the peak

Extended Sample:

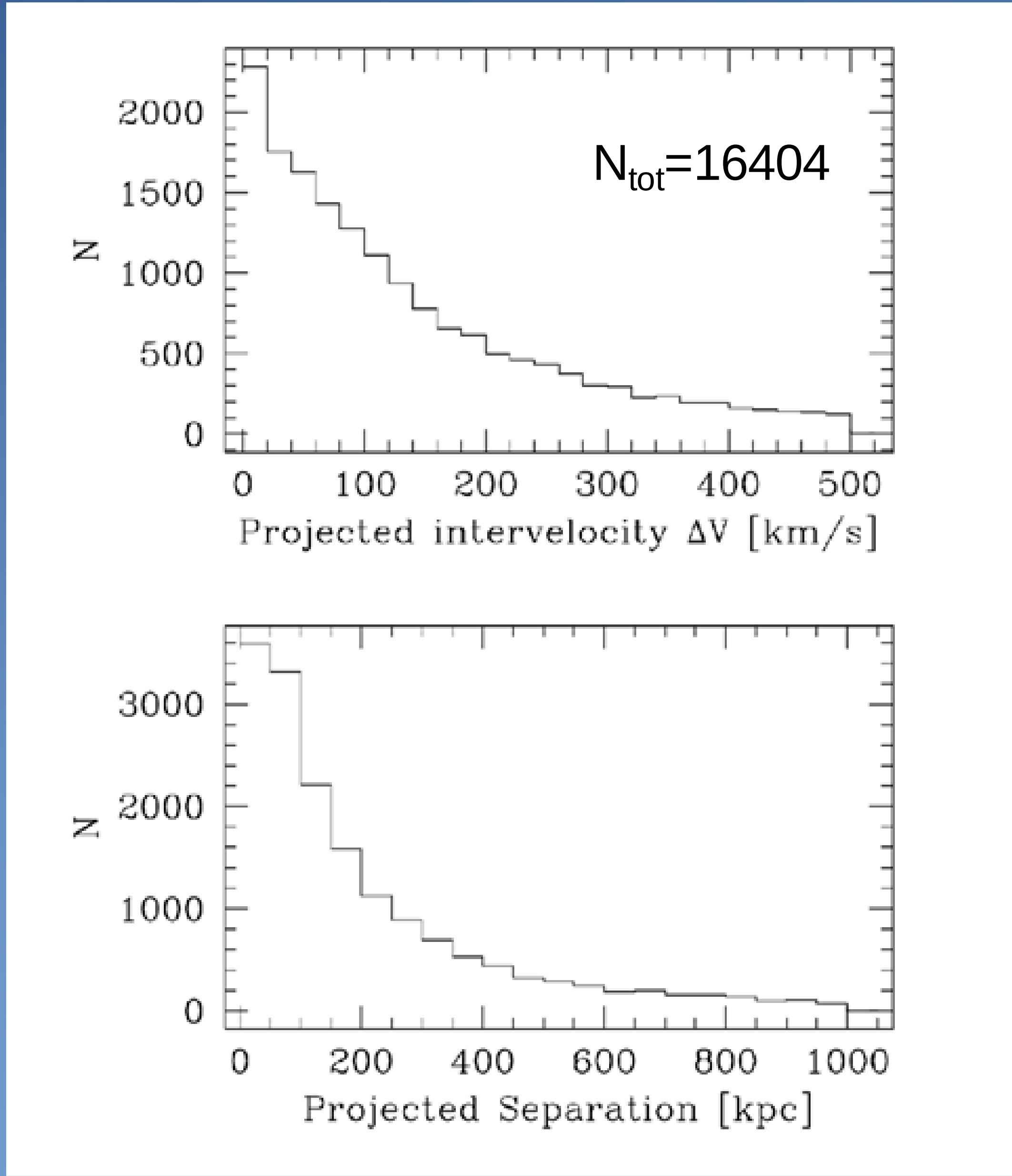
Scarpa Falomo Treves 2022

MNRAS 510, 2167

MNRAS 512, 544

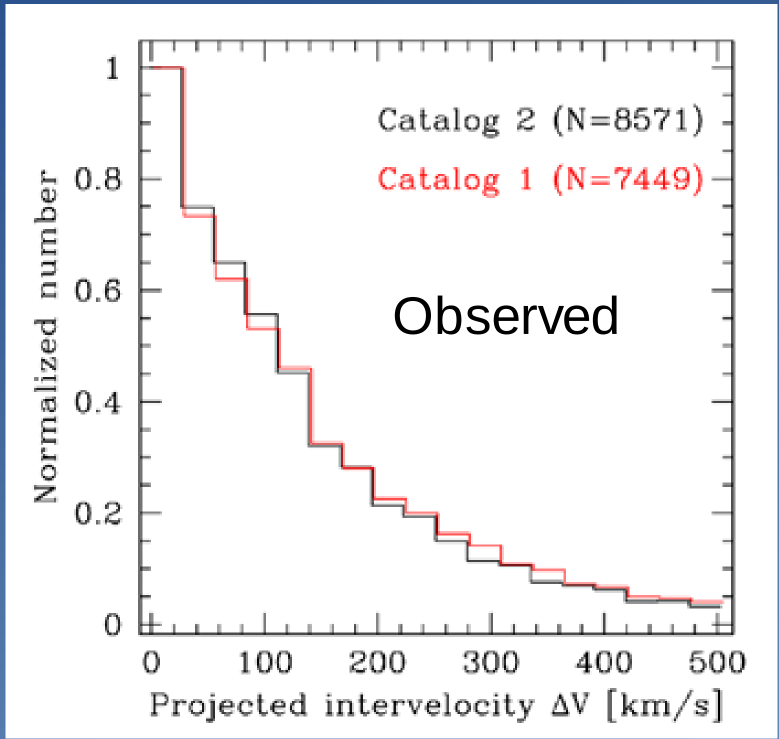
HyperLEDA 5 million entries. 20% increase

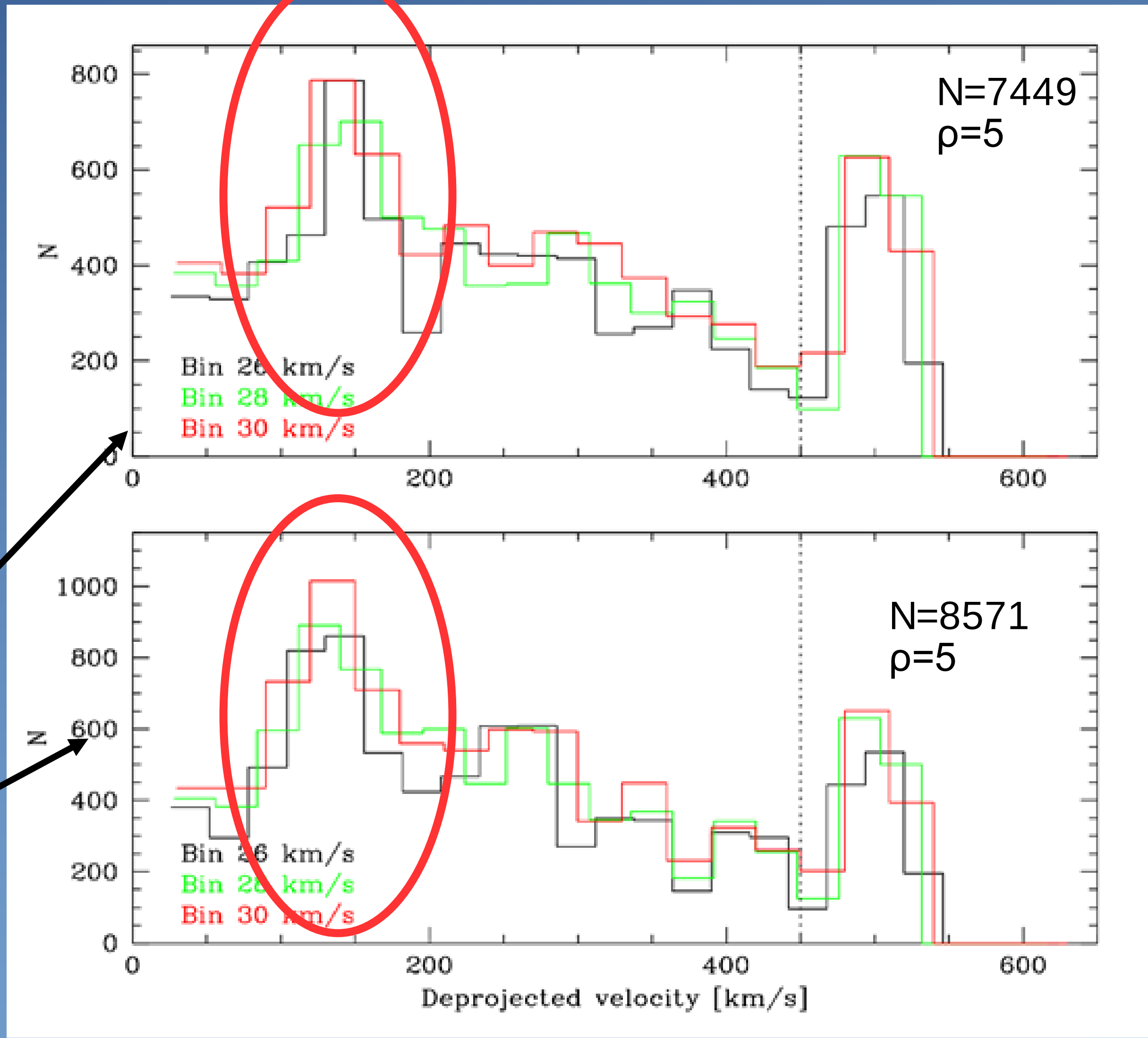
ρ ≥ 2.5 N = 16404 pairs
ρ ≥ 5 N = 8571 pairs
ρ ≥ 9 N = 4873 pairs



3D - intervelocity

A preferential value found around 150 km/s.





Initial result from Nottale & Chamaraux 2020, A&A 641, 115

Our result on extended catalog confirms previous results.

False pair contamination

- Pairs selected without knowledge of whether they are bound or unbound.
- Assuming the initial 170000 galaxies are randomly distributed on the sky, ~7000 pairs are expected (to be compared to 16404 “real” pairs with ρ=2.5).
- Random shuffling of distances (redshift) result in a number of false pairs ~25% of “true” pairs
- All this indicates a large number of pairs are random projection.

Our claim is that pairs outside the peak are unbound chance alignment

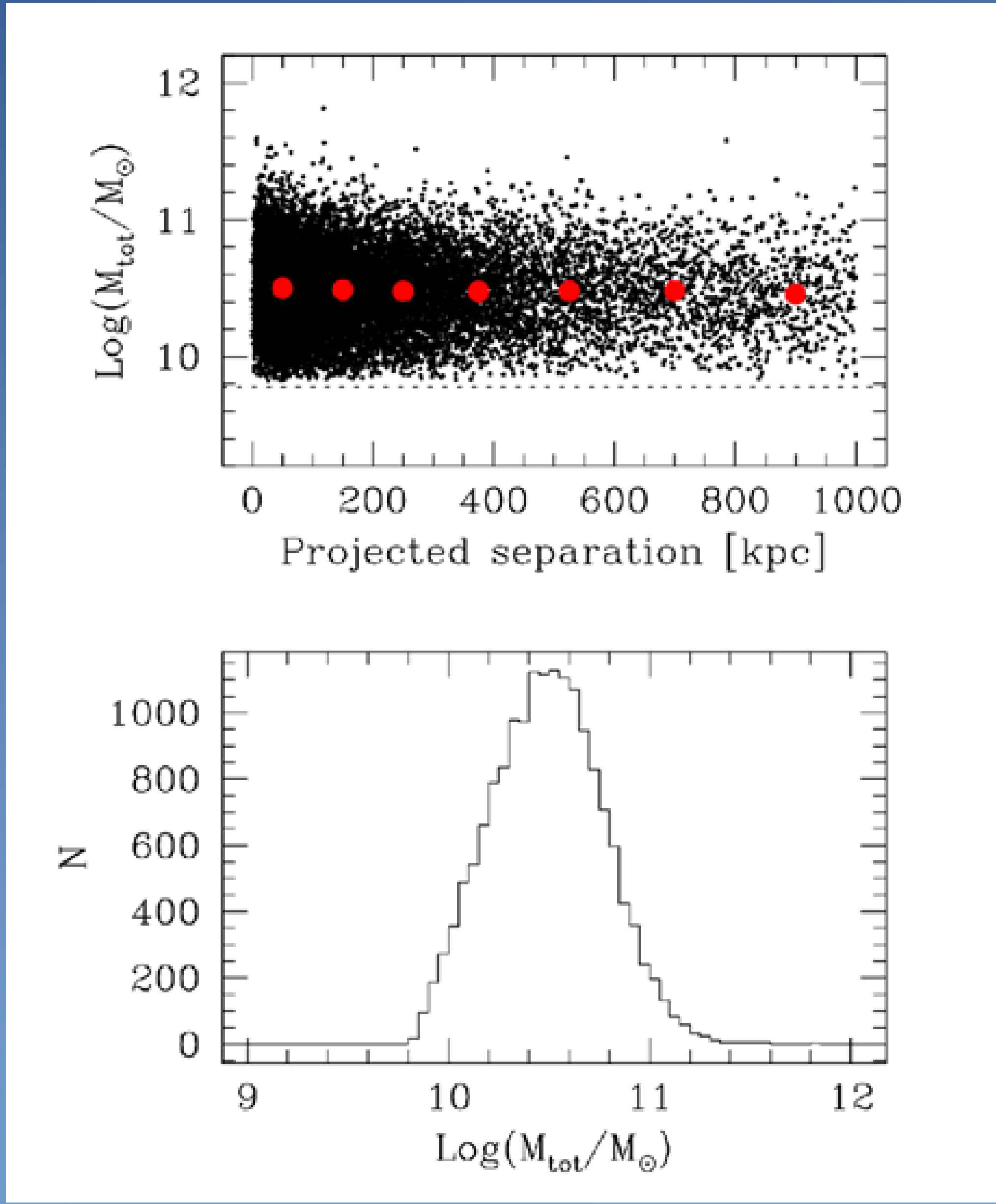
Explaining the peak

Mass distribution

Cut in luminosity M≤−18.5 impose a limit to total (luminous) mass.

Data cover ~1.5 orders of magnitude

No mass dependence on separation



Predictions

Newtonian

- For a given pair mass, intervelocity ***decreases*** with separation according to Kepler's law.
- Velocity has mild dependence on mass: $V \propto m^{1/2}$
- Hence, even for constant mass, the varying separation implies:

no preferential

intervelocity expected.

MOND

- For a given pair mass, intervelocity ***do not vary*** with separation
- Weak dependence

on mass: $V \propto m^{1/4}$

- Hence, for a sample covering a limited range of masses:

a preferential

intervelocity expected.

Our proposal: the peak is a direct consequence of MOND

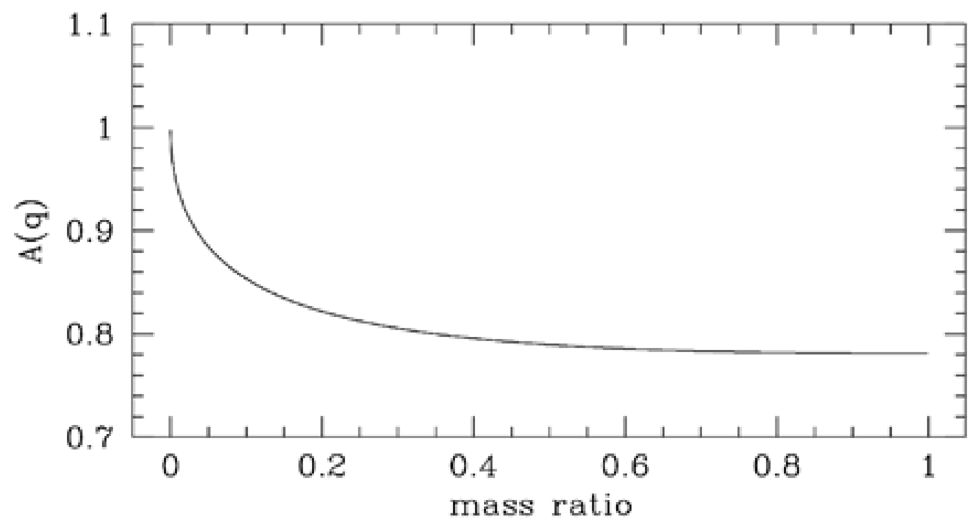
Two body force in deep MOND

Milgrom 1994 ApJ 429, 540

$$F(m_1, m_2, s) = \frac{m_1 m_2}{s}\sqrt{\frac{Ga_0}{m_1+m_2}}A\left(\frac{m_1}{m_2}\right)$$

with

$$A(q) = \frac{2\sqrt{1+q}}{3q}\left[(1+q)^{\frac{3}{2}} - q^{\frac{3}{2}} - 1\right]$$



For circular orbit of radius r =s/2
and equal masses $m_1 = m_2$

then $V_1 = V_2 = V$

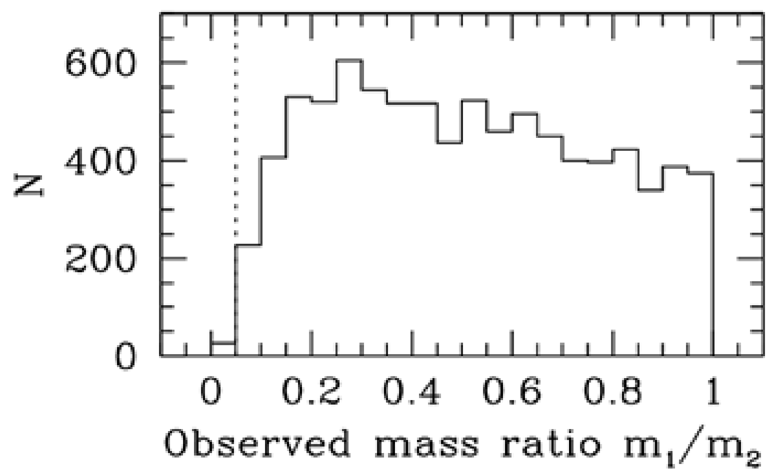
and the intervelocity $\Delta V = 2V$ reads:

$$\Delta V^4 = 0.610\ Ga_0\ m_{tot}$$

Replace the traditional (Milgrom 1983)

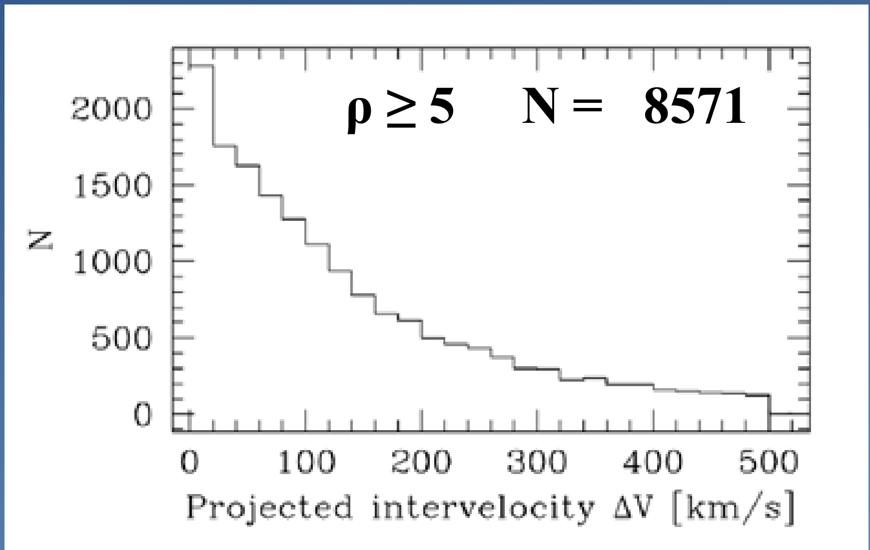
$$\Delta V^4 = 2Ga_0 m_{tot}$$

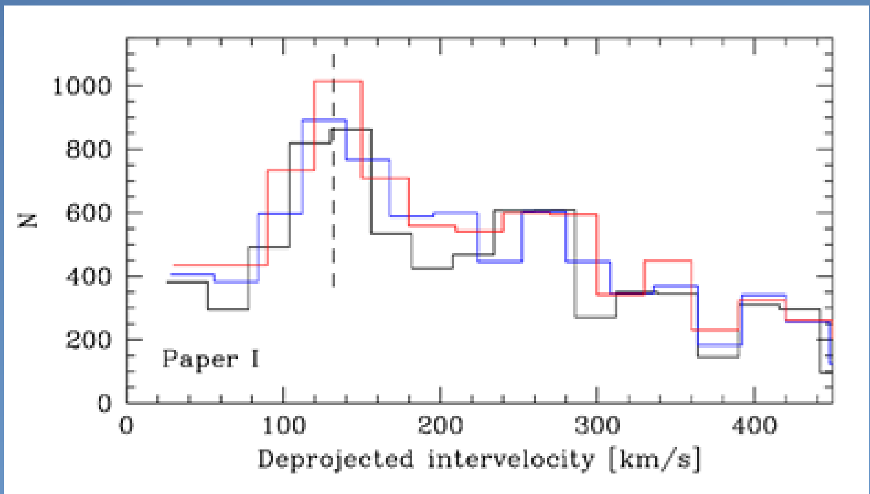
A reduction of about 25% on ΔV

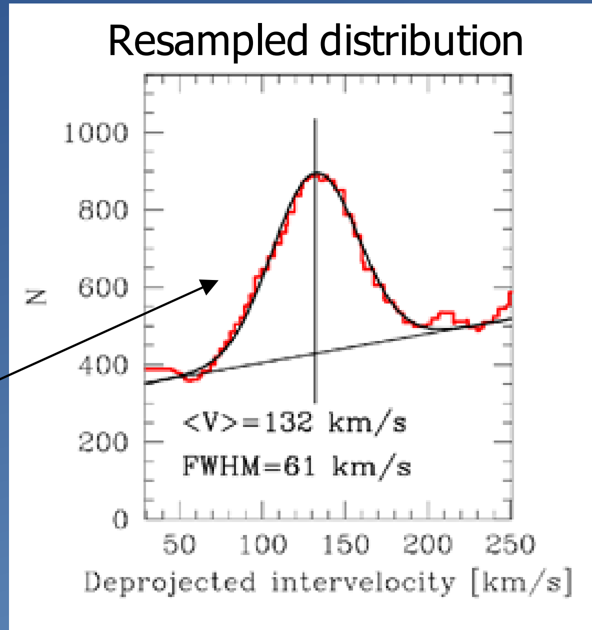


Best deep MOND fit

Deprojection repeated for several bin sizes, from 23 to 32 km, with step of 1 km. Then resampled to increase position accuracy.

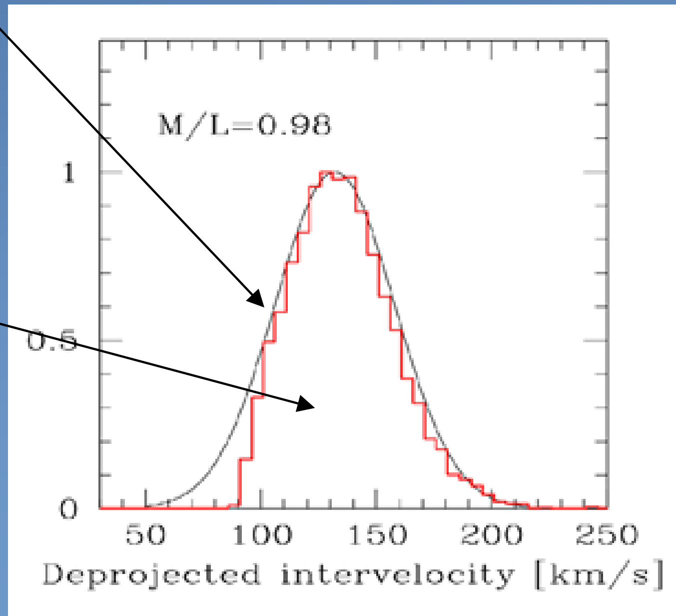






Best fit Gaussian
<V> 132 km/s
FWHM 61 km/s

MOND velocity distribution from luminous mass. M/L fixed for the whole population. Best fit: M/L=0.98



MOND fully consistent with observations.

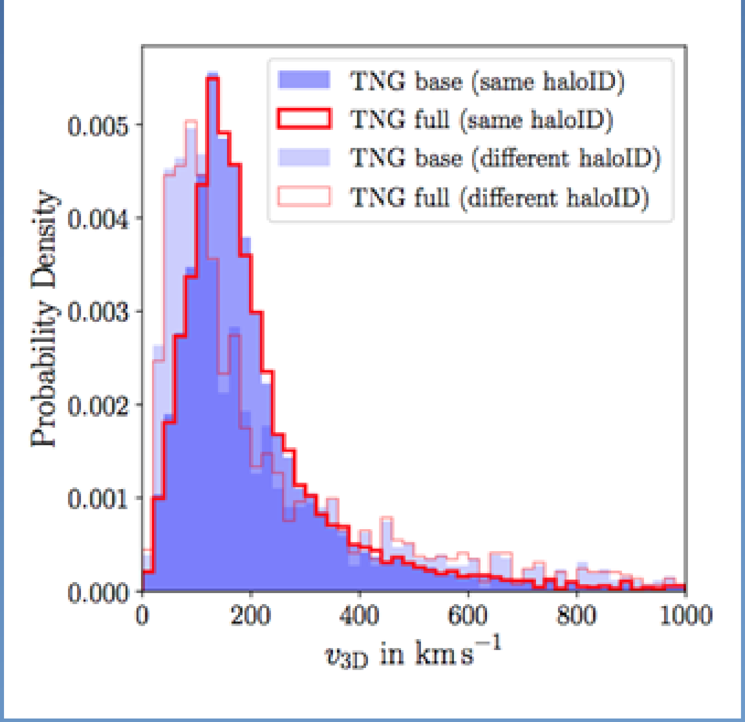
Alternative explanations ?

Pawlowski et al. 2022 A&AL 664, 6

Analyze the de-projected velocity difference in the Illustris TNG-300 cosmological simulations for a “similar” sample of galaxy pairs.

Dark Matter Halos designed to recover the Tully Fisher relation.

Find a peak at ~ 150 km/s is present also in LCDM simulations.



- impose Tully-Fisher relation
- the peak is significantly larger than that observed
- unknown false pairs contamination

see Pawlowski talk for details

Going further

HyperLEDA includes most galaxies in the local universe. A large independent sample requires moving to much higher radial velocities. Cosmology becomes important

But which cosmology?

No sense to stick to LCDM in the framework of MOND, the main claim of which is that DM doesn't exist

Move to a new cosmology and use galaxy rotation curve + MOND to discriminate

Challenging the basic

Redshift of light proportional to distance, Hubble law

$V=H_0 d$

INTERPRETED as due to expansion

Cosmic Microwave Background
INTERPRETED as the remnant of the Big Bang

Then there is a plethora of additional indirect (circumstantial) results supporting this vision like, i.e., Big Bang nucleosynthesis, and of course numerical simulations

Is there an alternative?

Euclidean Static Universe plus redshift

Please be patient with me

I am aware the following is highly unconventional

just concentrate on the data

Euclidean static Universe with redshift

Extend the Hubble law to all z

Distance from Hubble low extended at all z

$$d = \frac{cz}{H_0}$$

Flux-Luminosity relation

$$F = \frac{L}{4\pi d^2(1+z)}$$

Luminosity distance

$$d_L = \frac{cz}{H_0\sqrt{(1+z)}}$$

Angular size distance from Hubble law.
Size of distant object

$$\propto \frac{1}{z}$$

Redshift is an observational fact that must be taken into account, also needed to solve Olbers' paradox

Please don't ask. I don't have an answer:

redshift due to something else other than expansion, i.e. light ageing.

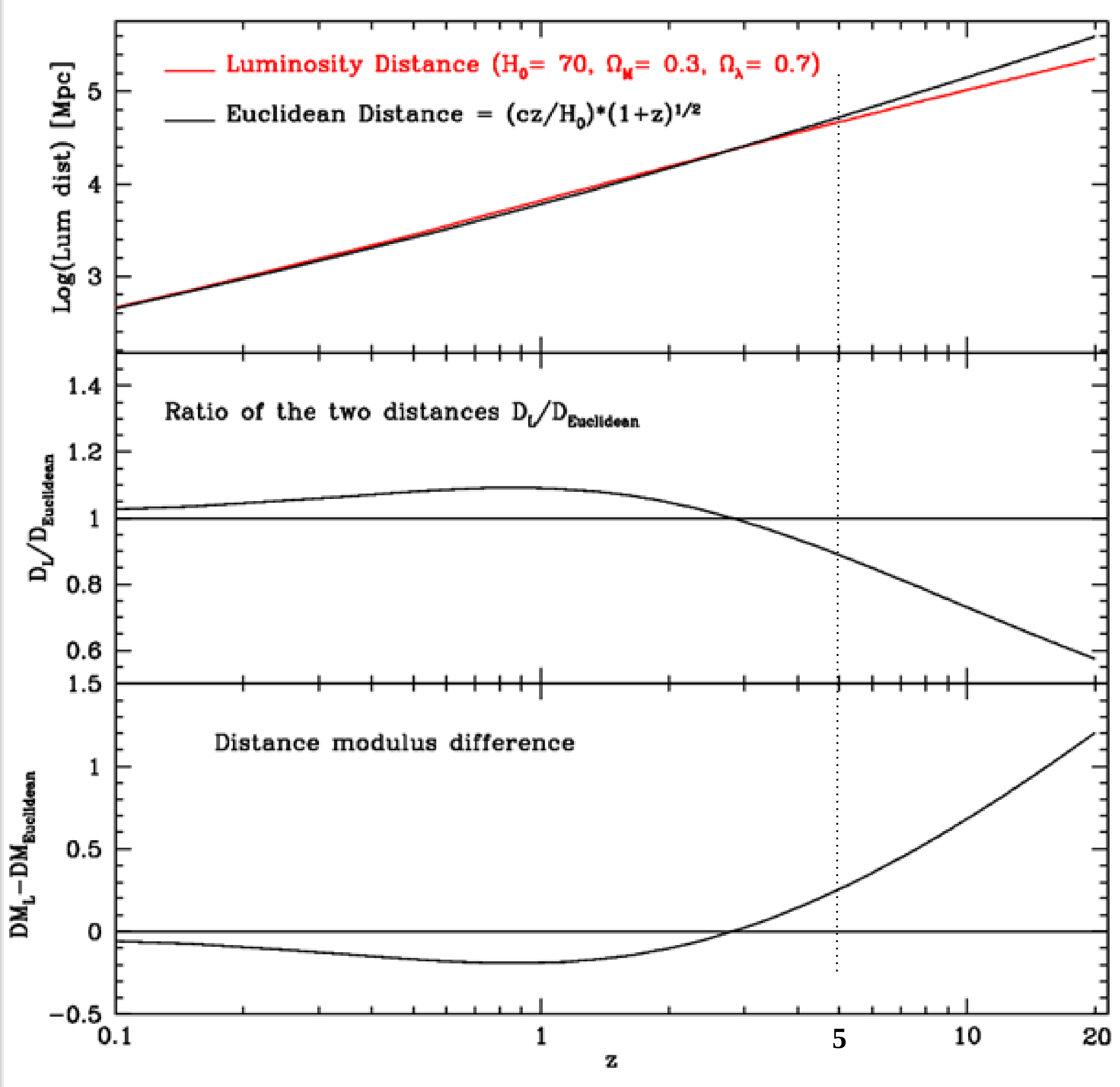
CMB must be a local phenomena, not the remnant of the Big Bang.

Euclidean vs LCDM luminosity distance

First unexpected result: luminosity distance numerically very similar to LCDM case

Within 10% all the way to z<5

The two diverge for z>10

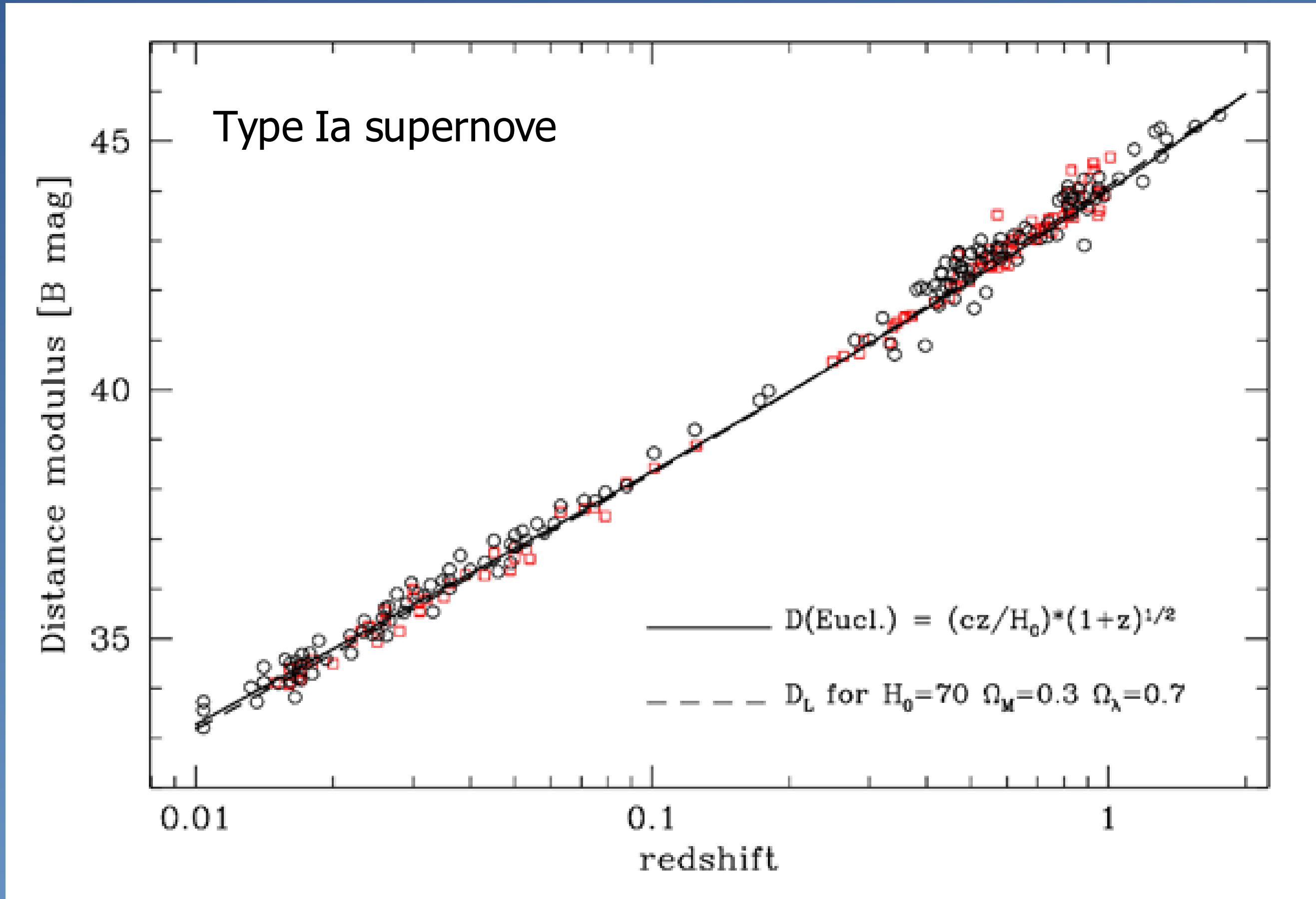


Euclidean Hubble diagram

Euclidean luminosity distance scores as well as LCDM one, with **no free parameter**

Data considered conclusive in favor of LCDM are equally well described by a STATIC MODEL

That is, luminosity is the same in the two cosmologies at least up to z=5.



See Scarpa & Lerner 2022 for details. To be found at https://www.academia.edu/81139660/Will_LCDM_cosmology_survive_the_James_Webb_Space_Telescope

Size of distant sources

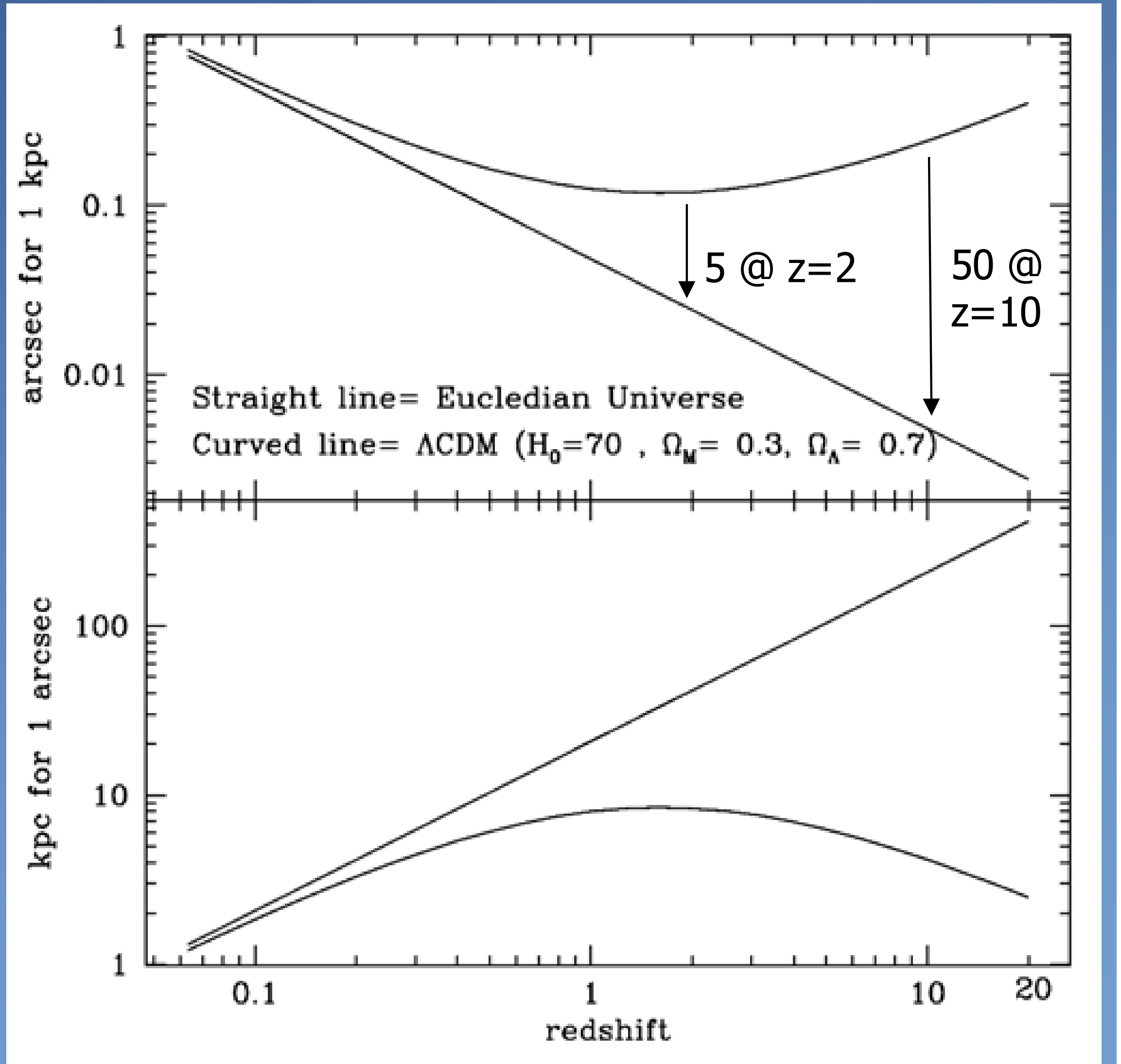
expected to be proportional to 1/z

sources became vanishly small (as indeed observed)

A given apparent size correspond to **larger** object.

factor 2 difference at z=0.6,

factor 5 at z=2.



Tolman test

- Surface brightness constant in a static Universe (in AB mags)

- In the case of expansion dimming proportional to

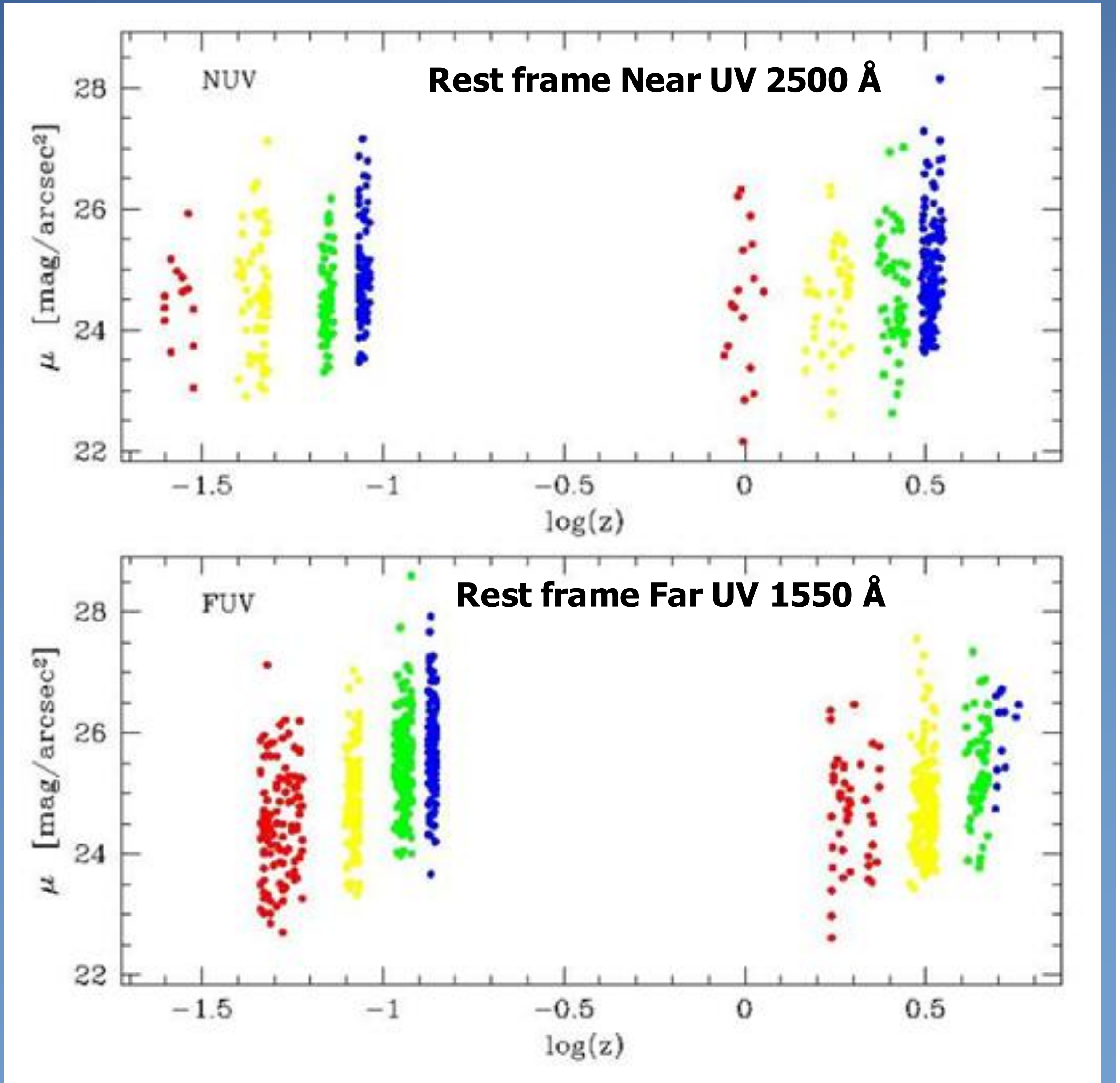
  $(1+z)^3$ in AB mags

Tolman test for surface brightness dimming

Lerner, Scarpa, Falomo 2014 IJMPD 235, 58

High and low z samples matched in luminosity (valid in BOTH cosmologies!) <M>=-18.2 in far UV.

UV wavelengths map the same young stellar population, insensitive to build up of red stars.



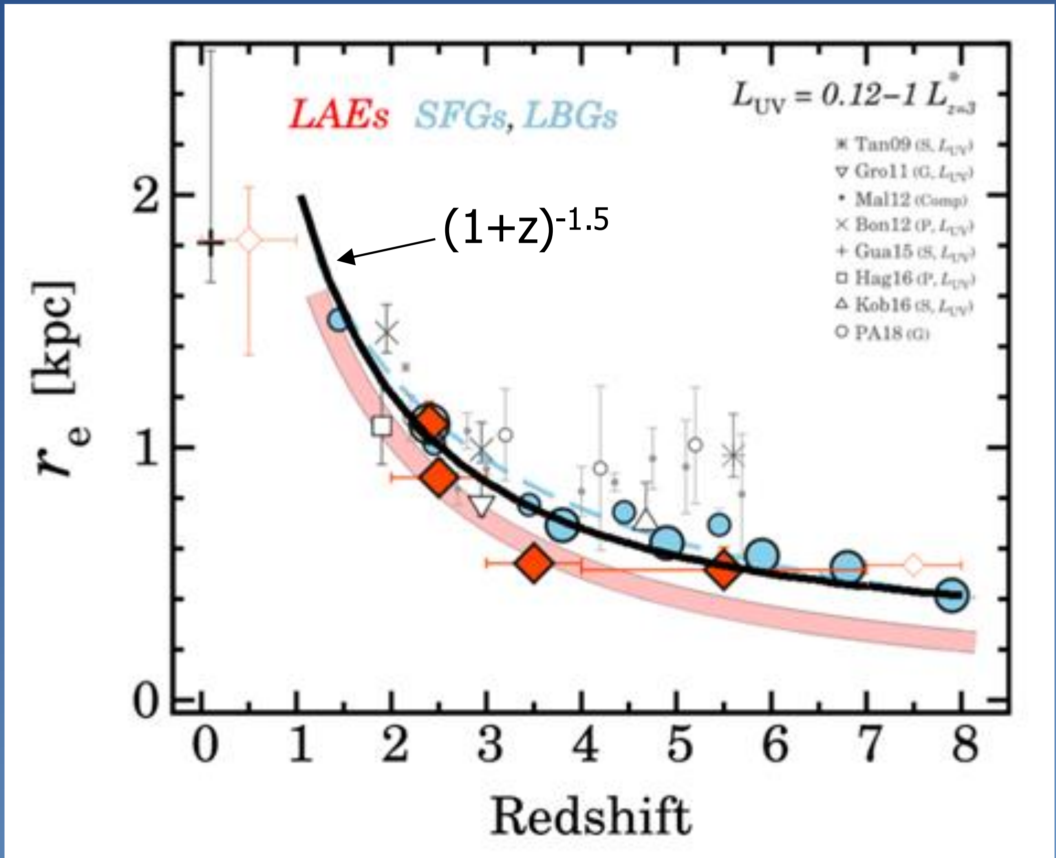
No dimming up to z=5 as expected in the static Euclidean framework

Size and stellar population evolution blamed to explain this fact in LCDM

Tolman test HST key project to demonstrate reality of expansion!

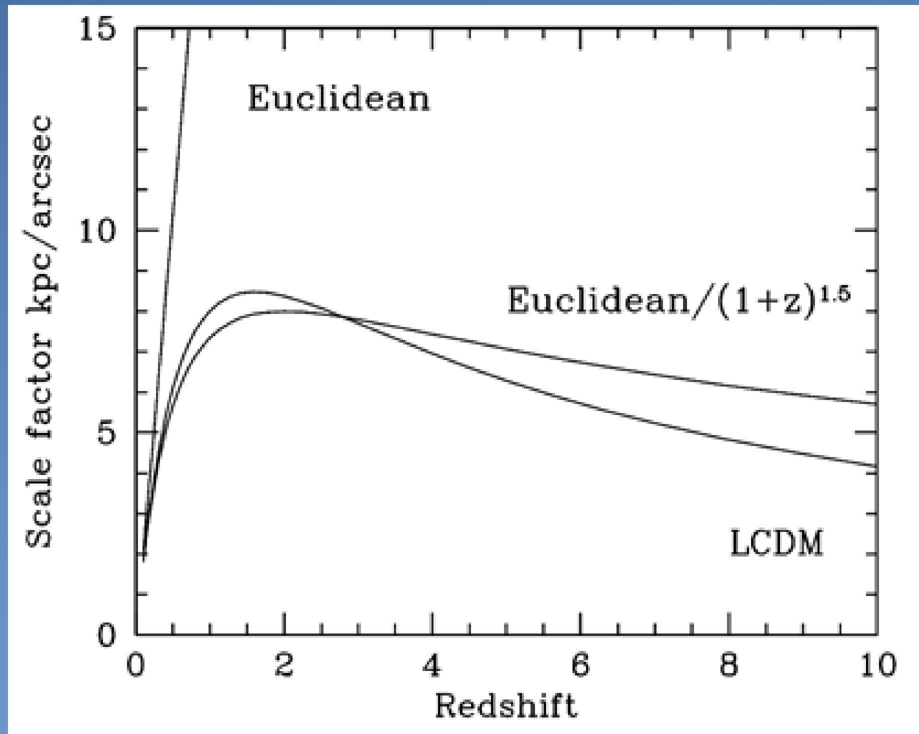
Claims a static Universe ruled out by Tolman test are plain wrong, e.g. Lubin & Sandage 2001 AJ 122, 1084

Galaxy Size evolution in LCDM



Adapted from Shibuya et al. 2019, ApJ 871, 164

Size of galaxies of comparable UV luminosity claimed to **evolve** with distance approximately as **$(1+z)^{-1.5}$**



"Size Evolution" induced by use of wrong cosmology as much as existence of dark matter induced by use of wrong dynamics!

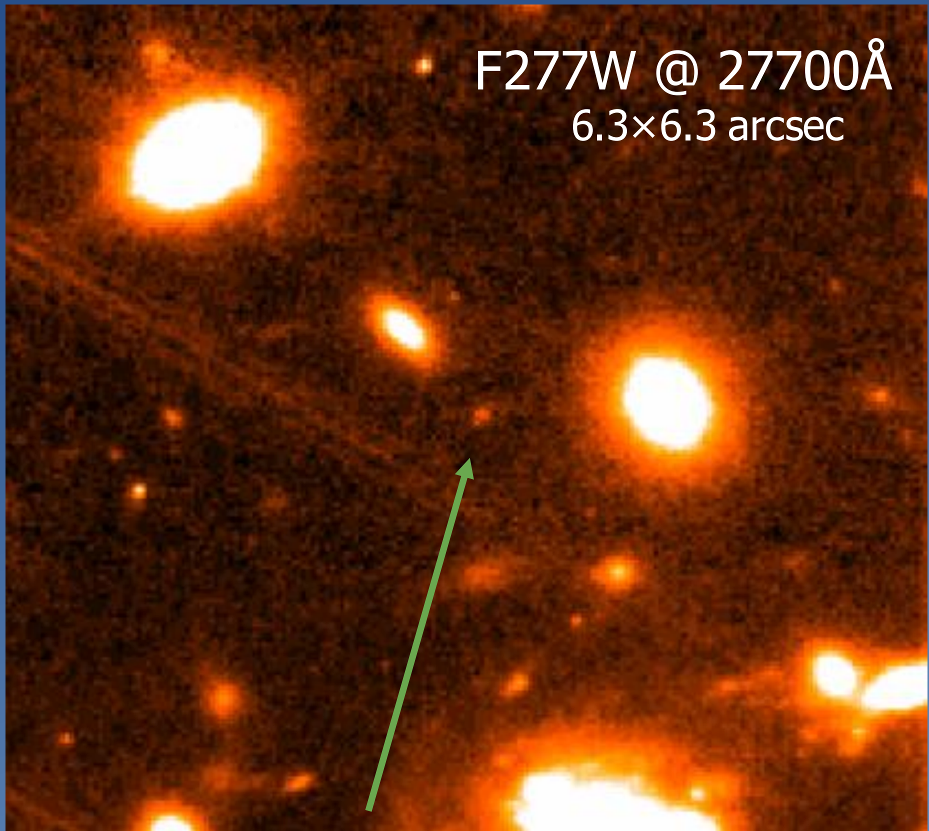
JWST looks at larger z: critical situation (work in progress)

Sizes and mass profiles of candidate massive galaxies discovered by JWST at $7 < z < 9$: evidence for very early formation of the central $\sim$100 pc of present-day ellipticals

Josephine F.W. Baggen, Pieter van Dokkum, Ivo Labbe, Gabriel Brammer, Tim B. Miller, Rachel Bezanson, Joel Leja, Bingjie Wang, Katherine E. Withaker, Katherine A. Suess

The first JWST data revealed an unexpected population of red galaxies that appear to have redshifts of $z \sim 7 - 9$ and high masses of $M_* \sim 10^{10}$ $M_\odot$ (Labbé et al. 2023). Here we fit Sérsic profiles to the F200W NIRCam images of the 13 massive galaxy candidates of Labbé et al., to determine their structural parameters. Satisfactory fits were obtained for nine galaxies. We find that their effective radii are extremely small, ranging from $r_e \sim 80$ pc to $r_e \sim 300$ pc, with a mean of $\langle r_e \rangle \approx 150$ pc. For their apparent stellar masses, the galaxies are smaller than any other galaxy population that has been observed at any other redshift. We use the fits to derive circularized three-dimensional stellar mass profiles of the galaxies, and

The JWST revolution:

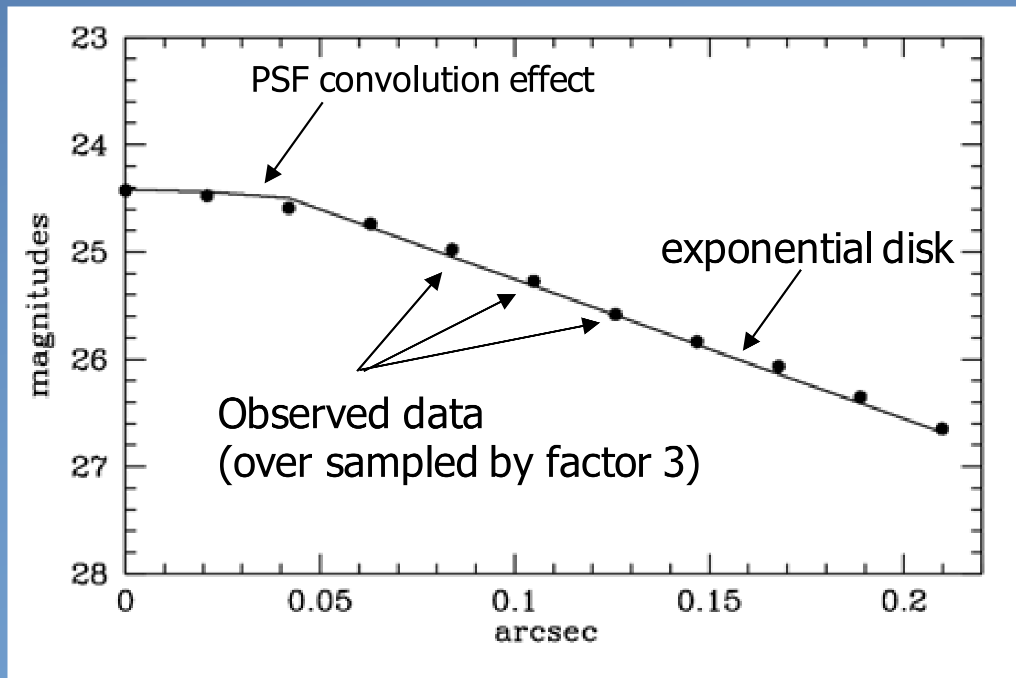


z16a at z=15.92 Age of Universe 250 Myr
Atek et al. 2022

SMACS early science program
(Pontoppidan et al. 2022)
Photometric redshift (dropout technique).

Far UV rest frame at this redshift

Measured effective radius r_e= 0".1
~0.3 kpc in LCDM vs ~30 kpc Euclidean



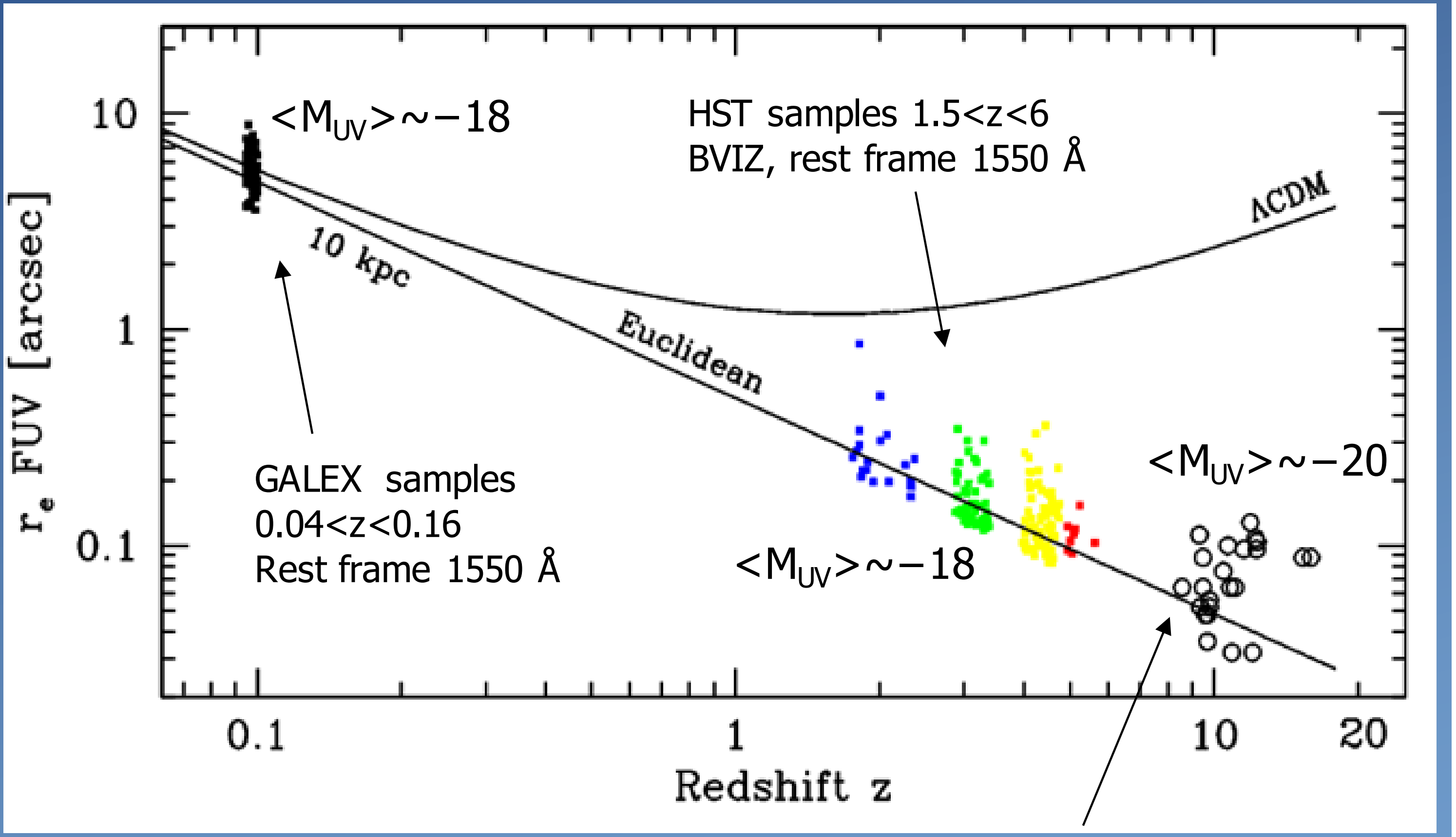
Probe Far UV rest frame at this z.
Observed profile as expected for fully formed relaxed disk galaxies.
Where is merging?!

Galaxies Apparent size agree with Euclidean prediction up to z=16

JWST sample

Estimated mass ~$10^{10} M_\odot$

On average more luminous than nearest samples ⇒ larger sizes expected



At this redshifts:
distances 35<d<70 Gpc.
Look back time 110-220 Gyr

JWST sample 9<z<16.
F150W and F277W filters
probing ~1550 Å rest frame

Data severely question the reality of expansion

MOND as a cosmology probe

In LCDM at z≫1 dynamical mass

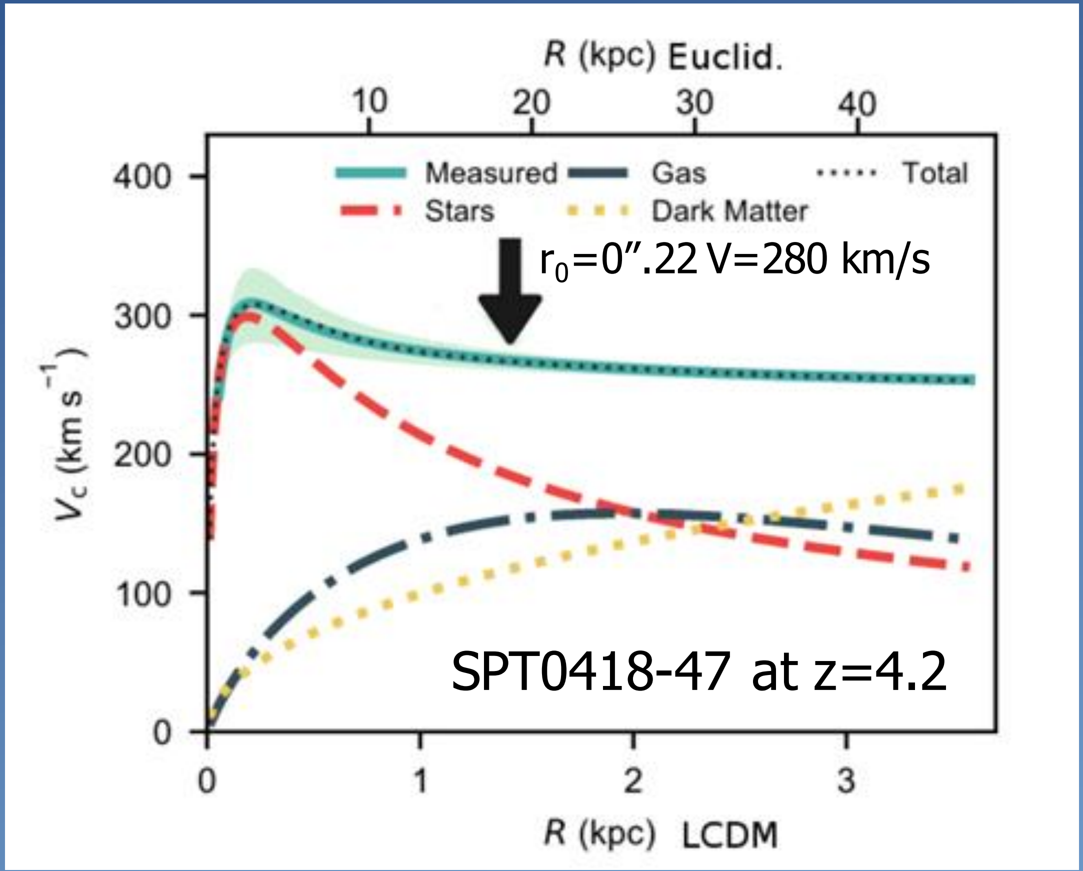
$M_d \propto V^2 r$

smaller than luminous mass
(Peralta de Arriba et al. 2015
MNRAS 453, 704)

Physically impossible!
Or negative dark matter!?

Use $V^2/r_0 = a_0$
for galaxy at z>1 to
derive real size and
probe cosmology

See Lelli's seminar for more…



In this case V^2/r_0

LCDM	Euclidean
r_0=1.5 kpc	r_0=19 kpc
a= 1.7×10^{-7} cm/s^2	a=1.4×10^{-8} cm/s^2
a~10a_0	a~a_0
Out of T-F	In T-F

Main lesson from MOND: don’t be afraid to be unorthodox

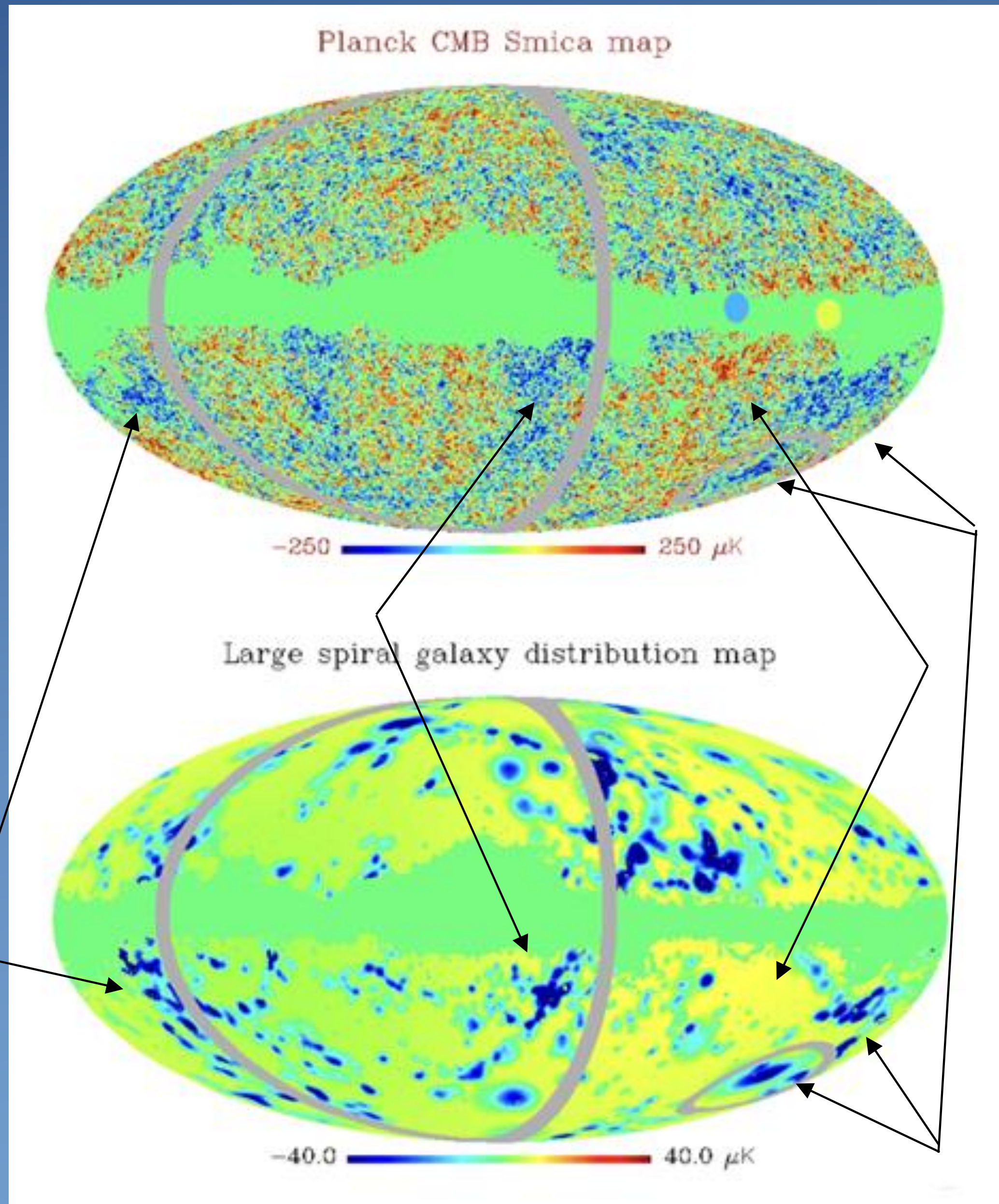
My last considerations follow from this perspective.

Thank you.

In this framework:

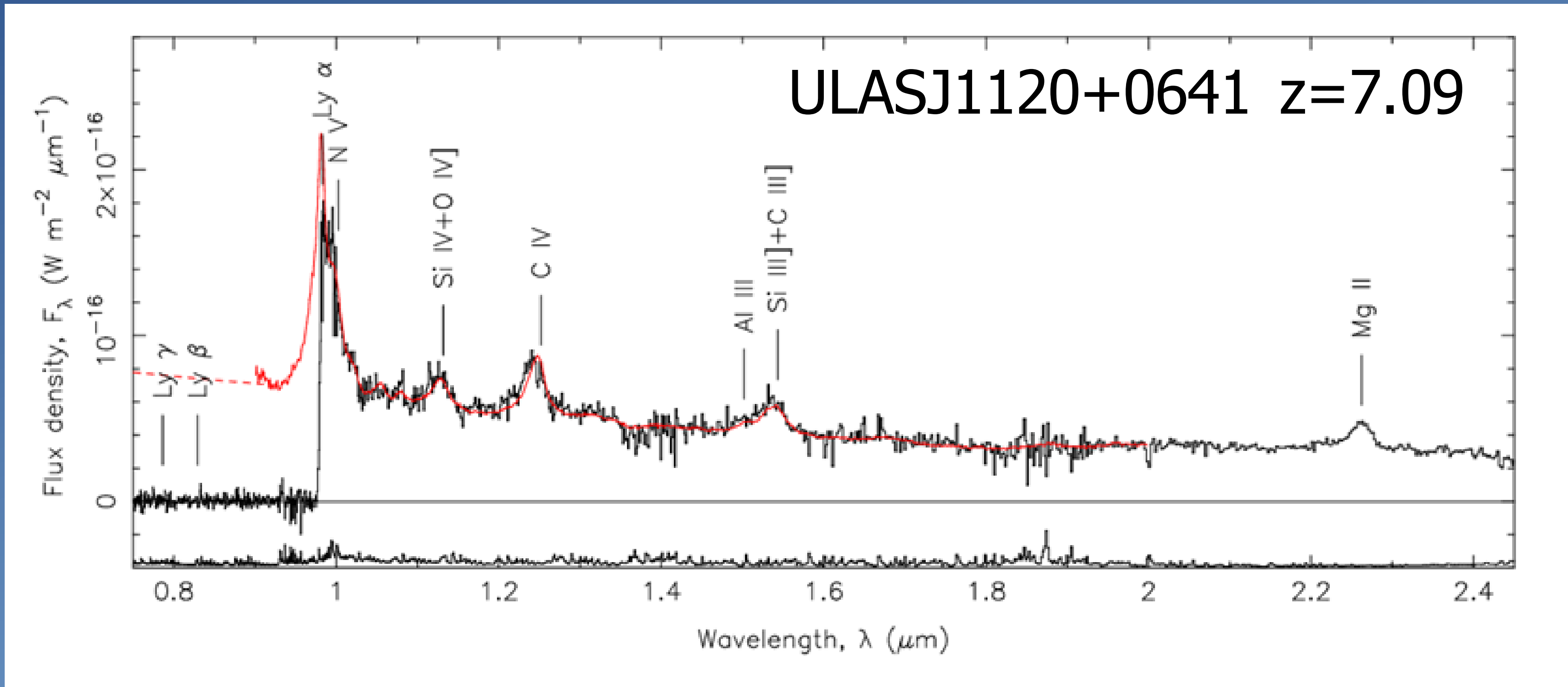
Redshift due to light ageing or new physics

CMB not the remnant of the Big Bang, must be a "local" phenomena.



Strong similarity among CMB temperature fluctuations and position of nearby galaxies reported by Hansen et al. 2023 (arXiv:2305.00268)

Spectra of distant and local QSO are identical. Where is the chemical evolution?



Average spectrum of local QSO shown in red. Figure from Mortlock, Warren, Venemans, et al. 2011, Nature 474, 616