Martín López Corredoira

Tests for the expansion of the Universe

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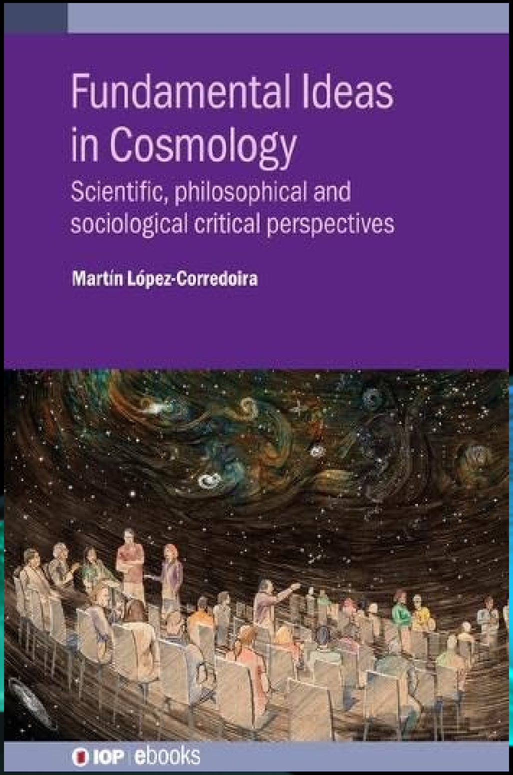


IS THE UNIVERSE IN EXPANSION?

QUESTION FOR AN ASTROPHYSICIST::

Has anybody observed a galaxy to increase the distance from us?

IS THE UNIVERSE IN EXPANSION?

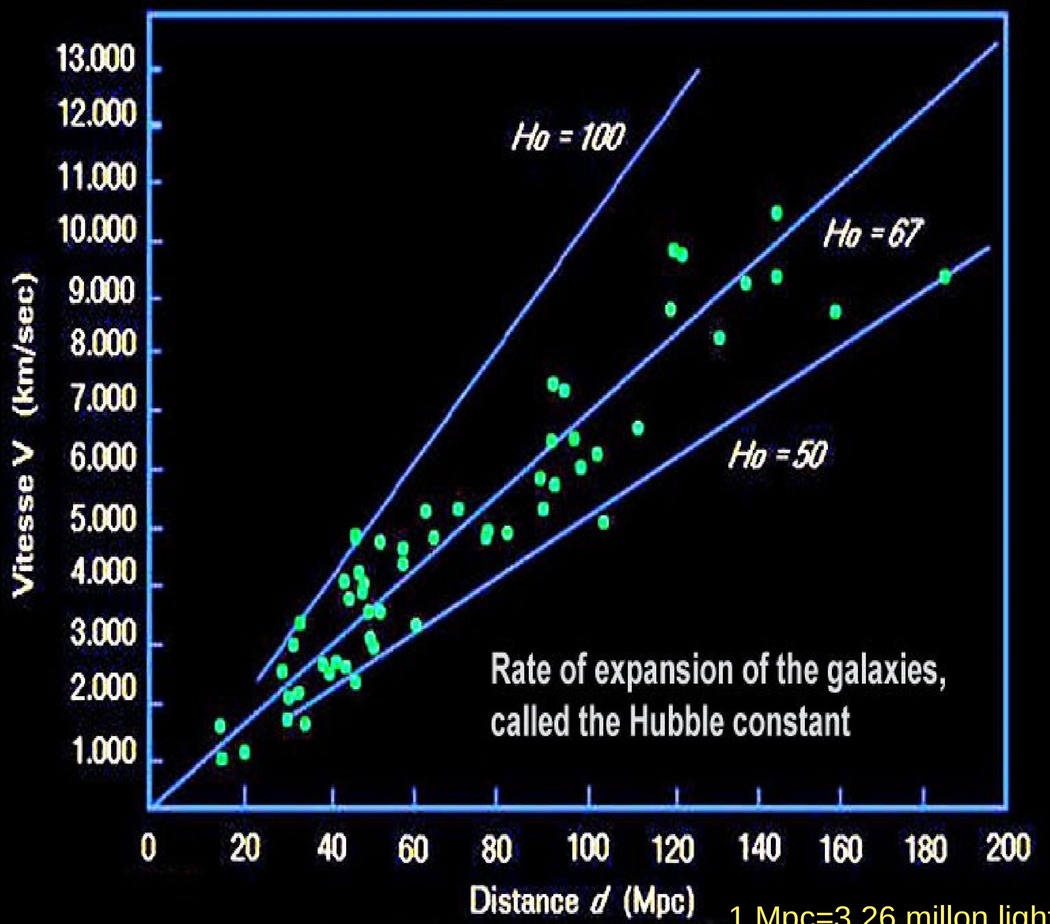
QUESTION FOR AN ASTROPHYSICIST::

Has anybody observed a galaxy to increase the distance from us?

REPLY

No. The expansion is very slow, it cannot be measured
(in a century, the distance of galaxy varies 0,0000007%)

Hubble-Lemaître constant



1 Mpc=3,26 millon light-year

H_0=70 km/s/Mpc

= 77000 km/h for each million light-year

1 million de light-year= $9{,}46 \times 10^{18}$ km

Expansion of the Universe

1) Is a static Universe theoretically impossible?

- Collapse solved by Einstein with general relativity introducing a cosmological constant.

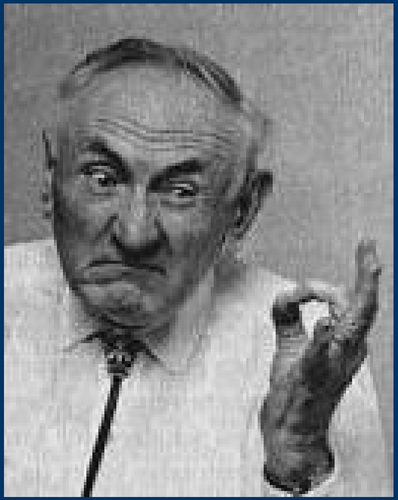
- Stability can be solved: e.g. some variations of the Hoyle-Narlikar conformal theory of gravity (Narlikar & Arp 1993); considering homogeneous scalar perturbations in the context of f(R) modified theories of gravity (Boehmer et al. 2007), variation of fundamental constants (Van Flandern 1984, Troiitski 1987), etc.

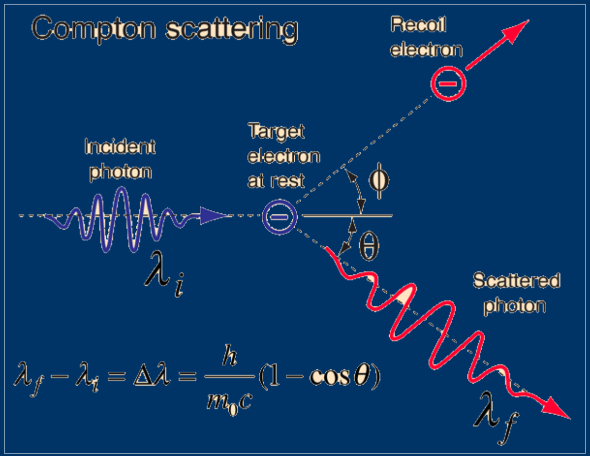
- Olber's paradox solved with extinction, absorption and reemission of light, fractal distribution of density and the mechanism which produces the redshift of the galaxies (Bondi 1961) .

Expansion of the Universe

Does redshift mean expansion?

Fritz Zwicky
(1898-1974)





Tired light hypothesis:

Proposed by Zwicky in 1929:

$$E(r)=h\nu(r) = h\nu_{emisión}\, e^{-H0\, r/c}$$

Due to the interaction of the photon with matter or other photons, it loses energy (E) along its path; therefore, it loses frequency(ν), i.e. a redshift is produced.

PROBLEMS *(with some solutions in the literature)*:

- The interaction of the photon should not give a straight path, so blurring is expected in the images.
- Scattering depends on frequency.

Expansion of the Universe

Does redshift mean expansion?

Tired light. Recent solutions:

- Interactions in “Raman” coherent scattering with atoms of H in state 2s or 2p (Moret-Bailly; Gallo); or with electrons (Marmet & Greber; Brynjolfsson)

- Scattering when crossing an inhomogeneous and turbulent plasma (Wolf; Roy et al.) [blurring]

- Interference with vacuum excitations, which behave as an ether (Vigier); non-linear electrodynamics in photon propagation through the intergalactic magnetic fields (Mosquera et al.); or grav. interaction with wave packets of the space-time curvature (Crawford) or with gravitons (Ivanov; Van Flandern)

Expansion of the Universe

Does redshift mean expansion?

Other solutions in terms of gravitation:

- Ordinary gravitational redshift of general relativity (Bondi; Baryshev) between two regions of different potential; differences of Weyl curv. of space-time between two regions (Lunsford; Krasnov & Shtanov; Castro)

- Inertial induction (machian) in which the gravity depends on the relative velocity and acceleration between two Bodies (A. Ghosh)

- Gravity quantization (Broberg)

Variable mass, time,…:

- Variable mass in particles, growing with the age of the objects, and the frequency of spectral lines depends on the electron mass (Hoyle & Narlikar).

- The photon loses energy because it emits other photons of lower energy (3 K?) (Roscoe; Joos & Lutz; Mamas)

- Photon has mass (Roscoe; Bartlett & Cumalat; Spallicci) and it may grow secularly (Barber).

- Time scale variations instead of a unique cosmological time (Garaimov; Segal; Budko; Fischer) due to exotic cosmological effects or due to quantum effects (Alfonso-Faus; Urbanowski)

Expansion of the Universe

anomalous z

NGC 4319+Mrk 205

QSO
z=0.070

z=0.006

Original HST image processed by Lempel 2002

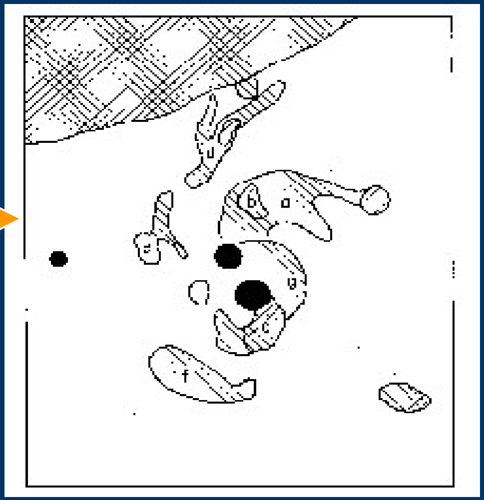
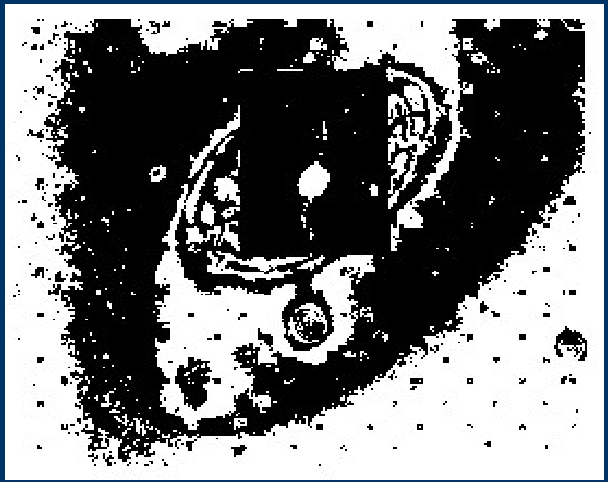


Diagram of features observed in the median filtered image by Cecil & Stockton (1985)



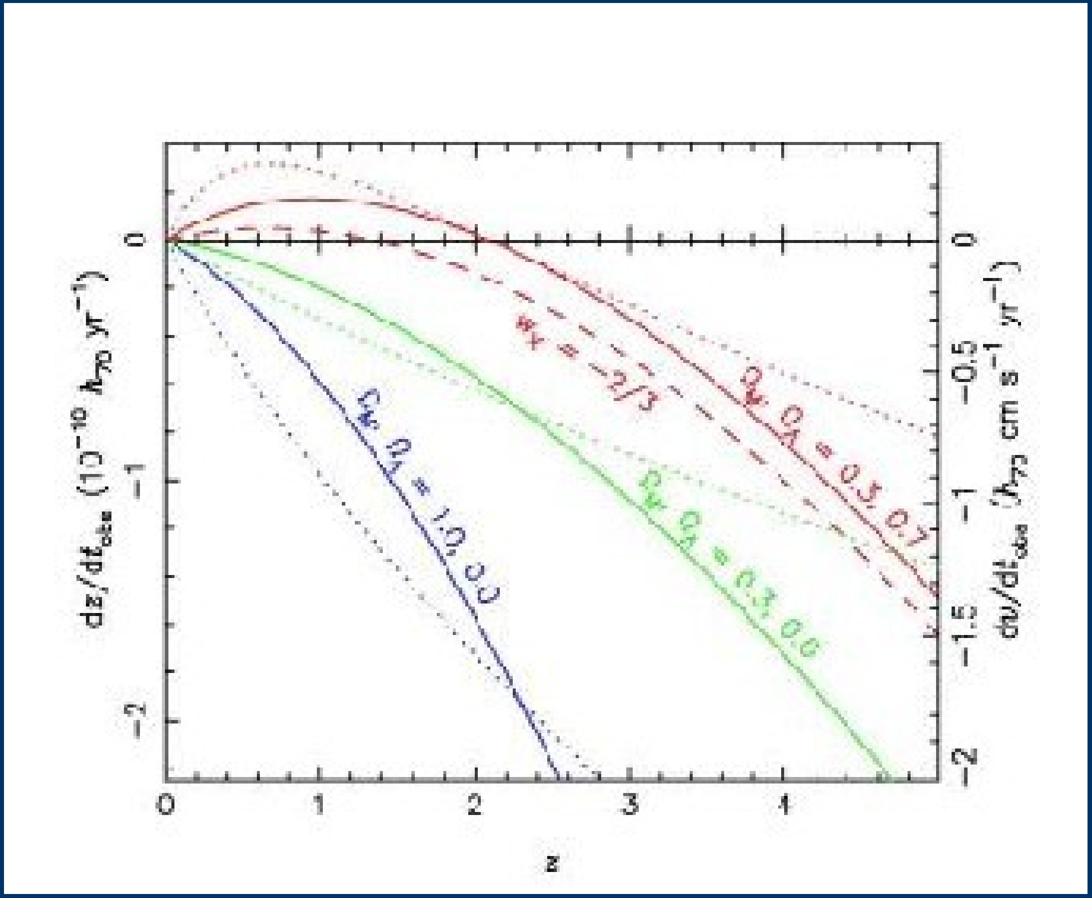
High-pass filtered image (Sulentic & Arp 1987)

TEST	EXPANSION	STATIC
$T_{CMBR}(z)$	*Good fit.*	*Tired light redshift of a CMBR coming from very high z.*
Time dilation	*Good fit for SNIa. Unexplained absence of time dilation for QSOs and GRBs.*	*Selection effects, or ad hoc modification of the theory or the zero point calibration, or evolution of SNIa periods.*
Cosmic chronometers	*Good fit but by chance, measurements of differential age are incorrect.*	*Bad fit, but measurements of differential age are incorrect.*
Hubble-Lemaître diagram	*Good fit but requires the introduction of dark energy and/or evolution of galaxies.*	*Good fit for galaxies. Good fit for SNIa with some models.*
Galaxy counts	*Good fit for galaxies with evolution*	*Good fit.*
Tolman (SB)	*Requires strong evolution of SB.*	*Good fit.*
Angular size	*Requires too strong evolution of angular sizes.*	*Good fit.*
UV SB limit	*Anomalously high UV SB at high z.*	*Good fit.*
Alcock-Paczynski	*Good fit*	*Good fit for tired light.*

(Chapter 4 of *Fundamental Ideas in Cosmology*, López-Corredoira 2022)

Expansion of the Universe

Redshift variations (redshift drift)



Liske et al. (2008): solid dz/dt, dotted dv/dt

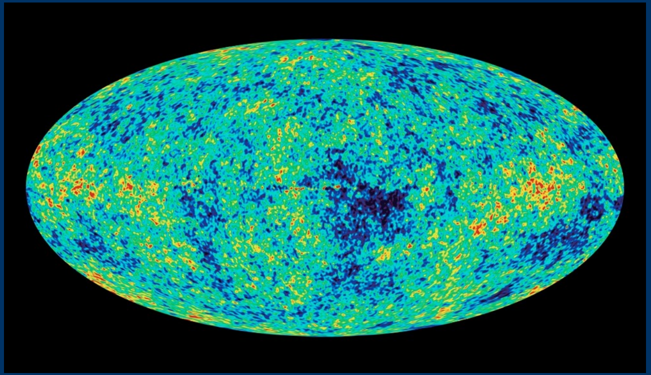
First proposed by Sandage (1962):

$$dz/dt=(1+z)H_0-H(z)$$

(~ 1 cm/s/yr).

This is possibly observable with a 40 m. telescope over a period of ~20 yr using 4000 h of observing time (Liske et al. 2008)

Expansion of the Universe



6) $T_{CMBR}(z)$ test

Variation of microwave background radiation temperature with z. This temperature is obtained from its relationship with the excitation in atomic/molecular transitions due to the absorption of radiation.

- MacKellar (1941) detects with this method in Cyan molecules a background radiation temperature of 2.3 K

Universe in expansion:

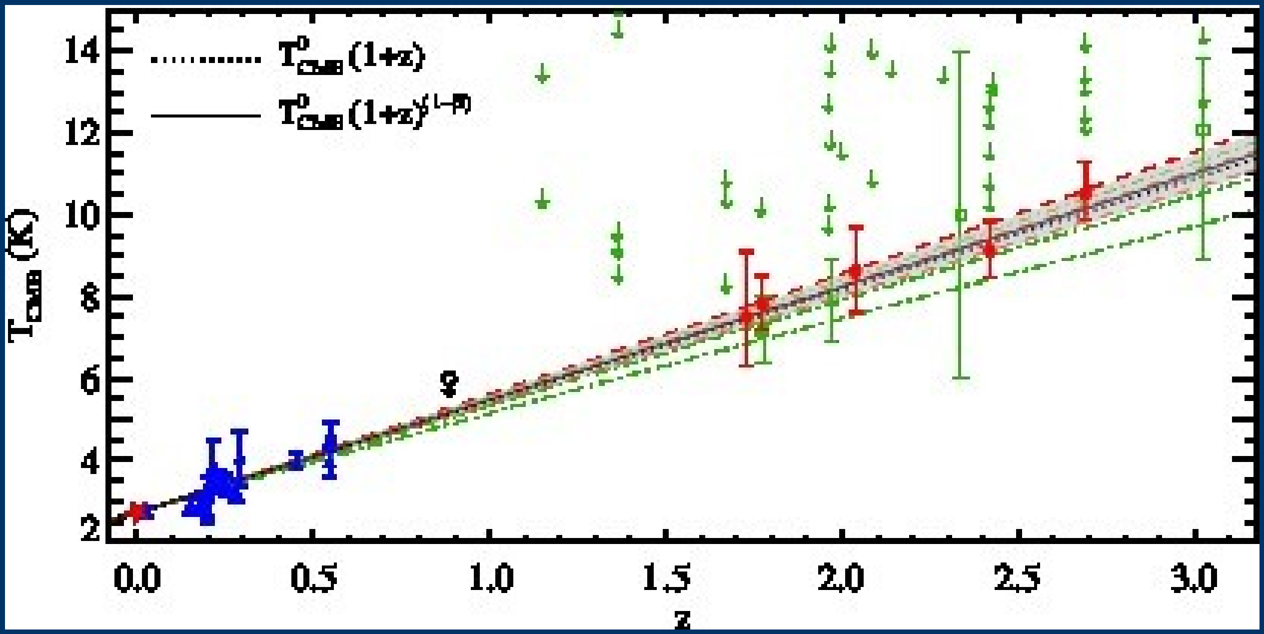
$T_{CMBR}(z)=2.73(1+z)$ K

Static Universe:

$T_{CMBR}(z)=2.73$ K (local CMBR origin)
$T_{CMBR}(z)=2.73(1+z)$ K (distant CMBR origin with tired light)

Expansion of the Universe

6) $T_{CMBR}(z)$ test

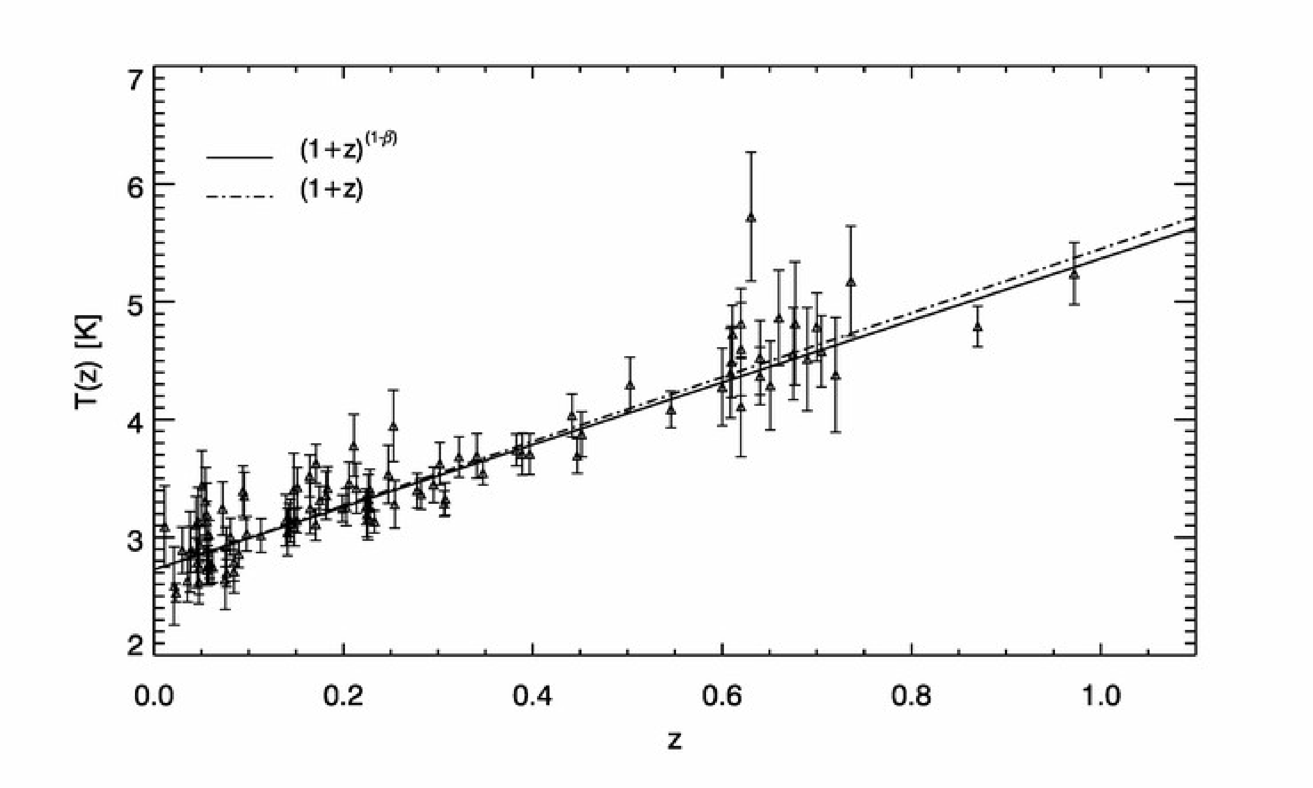


Nonetheless, there are other results which disagree this dependence (Krelowski et al. 2012; Sato et al. 2013). There might be some excess temperature due to collisional excitation (Molaro et al. 2002) or bias due to unresolved structure in low space resolution mapping (Sato et al. 2013).

Noterdaeme et al. (2011): $T_{CMBR}(z) = (2.725 \pm 0.002) \times (1 + z)^{1.007 \pm 0.027}$

Expansion of the Universe

6) $T_{CMBR}(z)$ test



With thermal Sunyaev Zel'dovich effect

Luzzi et al. (2015): $T_{CMBR}(z) = T_{CMBR,0} \times (1 + z)^{0.978 \pm 0.018}$

Expansion of the Universe

Time dilation test

Proposed by Wilson (1939)

Universe in expansion:

- Due to the motion, pulses of intrinsic period T are observed with period T(1+z).

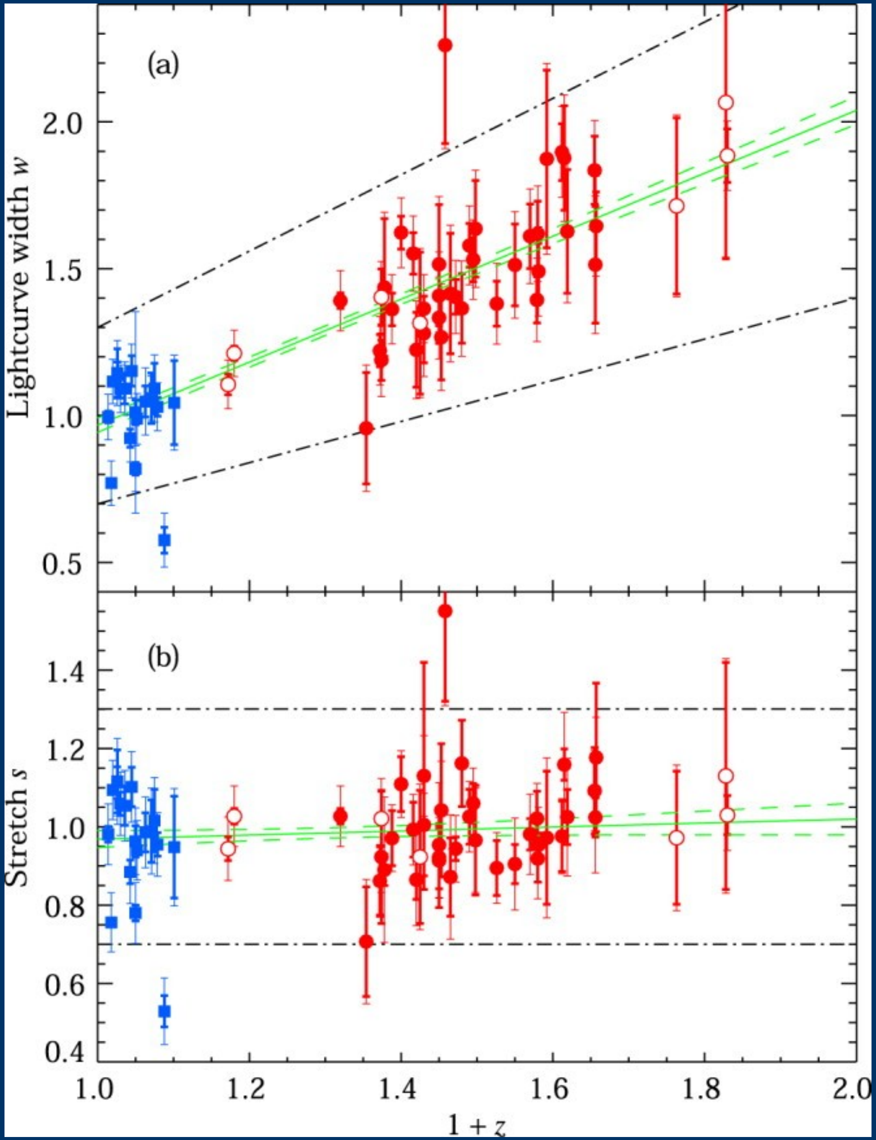
Static Universe:

- Pulses of intrinsic period T, are observed with period T.

Other hypotheses without expansion (eg., variable mass [Narlikar & Arp 1997], cosmochronometry [Segal 1997], variable speed of light [Holushko 2012]) also predict a factor (1+z)

Expansion of the Universe

7) Time dilation test



Test with SNIa by Goldhaber et al. (2001):

Dilation width (w) vs. (1+z);

s=w/(1+z)

Expansion of the Universe

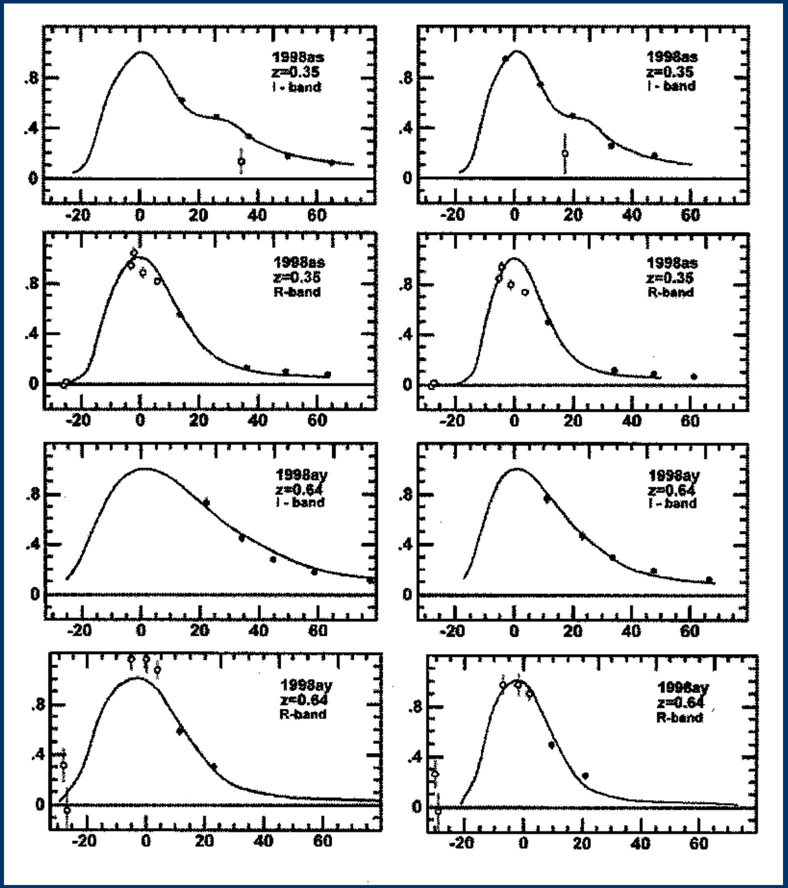
7) Time dilation test

Skepticism on the result with SNIa:

- Leaning (2006): most (18/22) SNIa light curves can be fitted without time dilation by allowing a modificacion of zero-point of the calibration within the uncertainties (see also Brynjolfsson 2004).

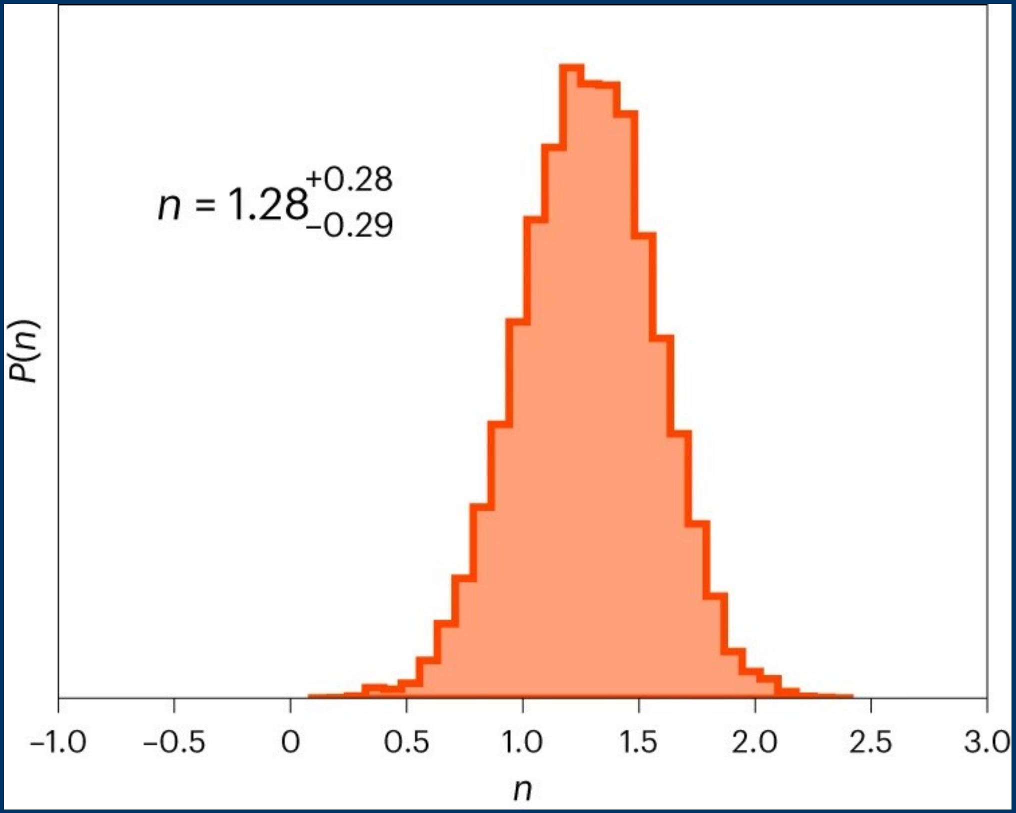
- Selection effects (Crawford 2011, LaViolette 2012, Ashmore 2012).

- Are not there variations of T due to evolution?



Expansion of the Universe

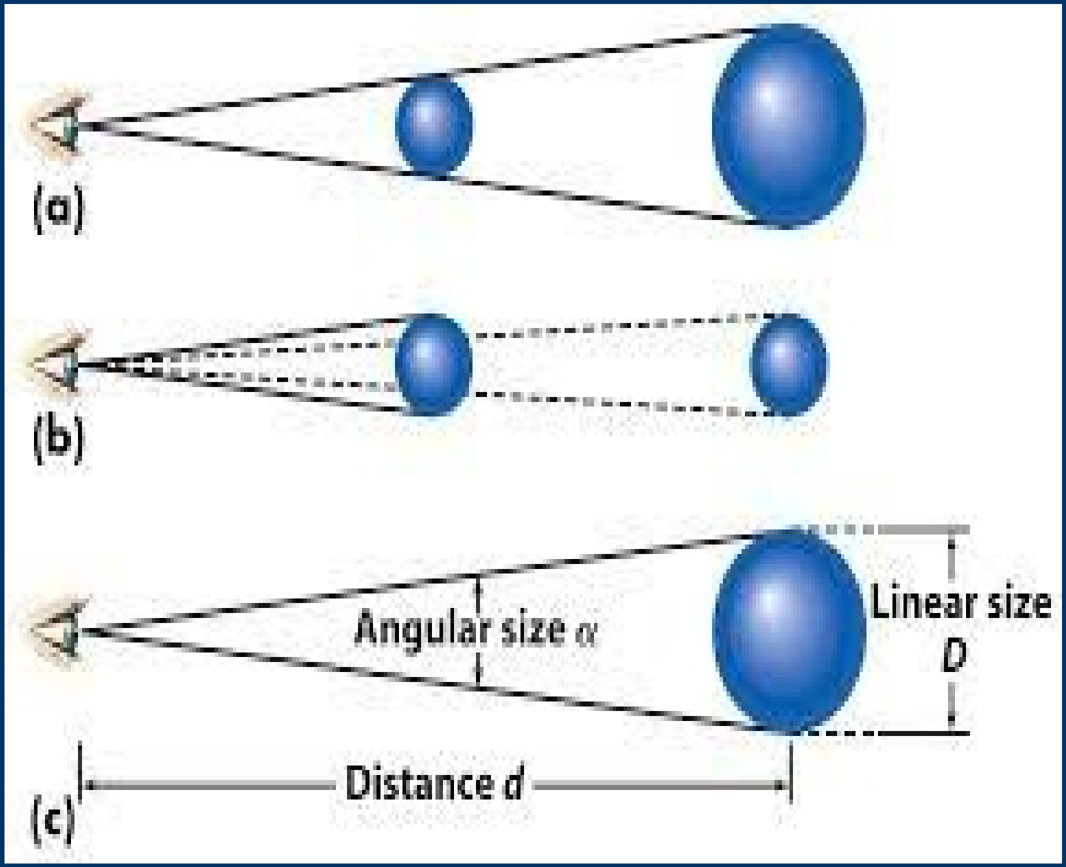
Time dilation test in QSOs



Lewis & Brewer (2023):
The posterior distribution of n, where the redshift dependence of the observed time dilation is given by $(1 + z)^n$.

Expansion of the Universe

Angular size test



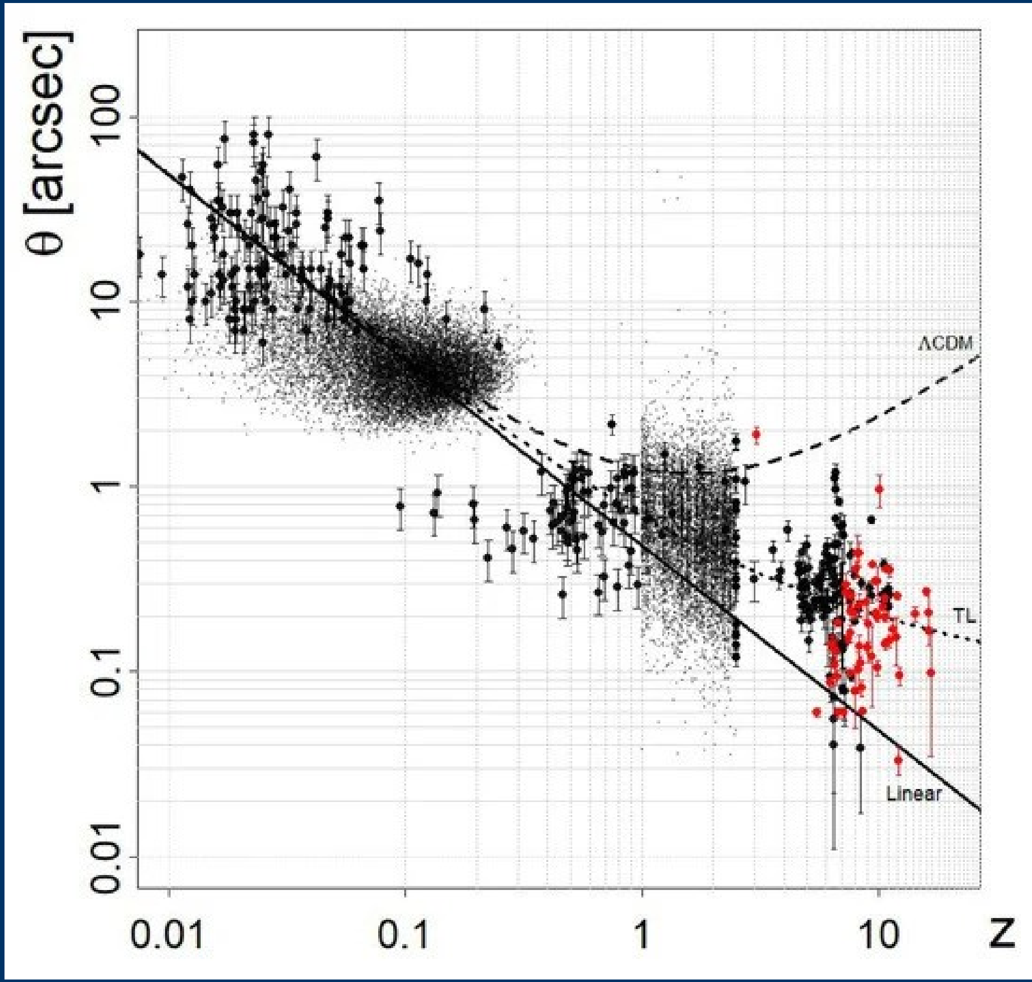
In a static Euclidean Universe:

Angular size ≈ constant / z

(with expansion is something very different)

Expansion of the Universe

Angular size test



JWST data up to z=15

The test favours the static rather than ΛCDM with expansion.

Standard cosmology claims that evolution of galaxies size explains the discrepance with the expanding model but this evolution is too strong: a factor 10 at z=10.

Lovyagin et al. (2022): angular sizes found in the recent JWST observations (red points) and some pre-JWST observations (black points).

Expansion of the Universe

Angular size test

The necessary evolution to make compatible the standard cosmology is too strong and it cannot be explained by:

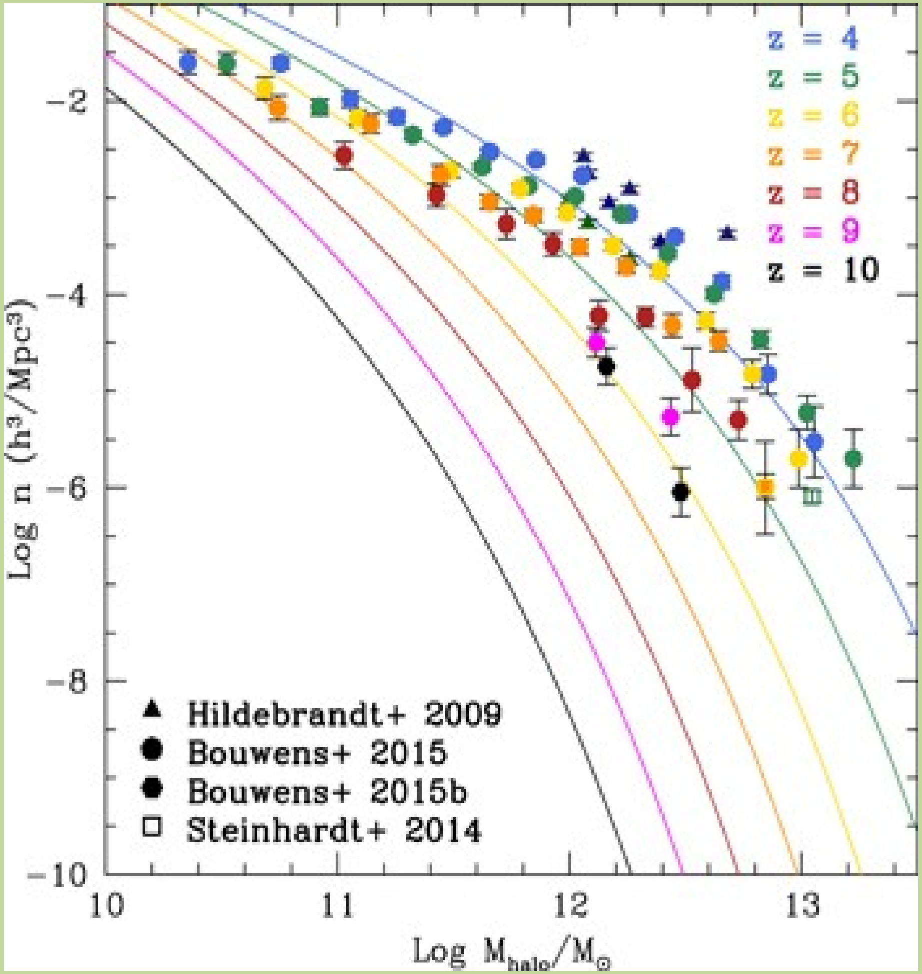
- Early galaxy formation with much higher densities.
- Evolution of mass/luminosity ratio.
- Merger ratio.
- Massive outflows due to a quasar feedback mechanism.

(López-Corredoira 2010)

Formation and evolution of structures and galaxies

Distant galaxies. Evolution.

Very massive galaxies at high z (not predicted by the downsizing scenario of galaxy formation)



Steinhardt et al. (2016): Theoretical halo number density as a function of halo mass and redshift for the most massive halos at $4<z<10$ (shown as solid lines, with redder colors at higher redshift) compared with observational number densities of estimated halo masses corresponding to observed star-forming galaxies at similar redshifts.

“THE IMPOSSIBLY EARLY GALAXY PROBLEM”

Formation and evolution of structures and galaxies

Distant galaxies. Evolution.

Very massive galaxies at high z (not predicted by the downsizing scenario of galaxy formation)

Labbé et al. (2023):

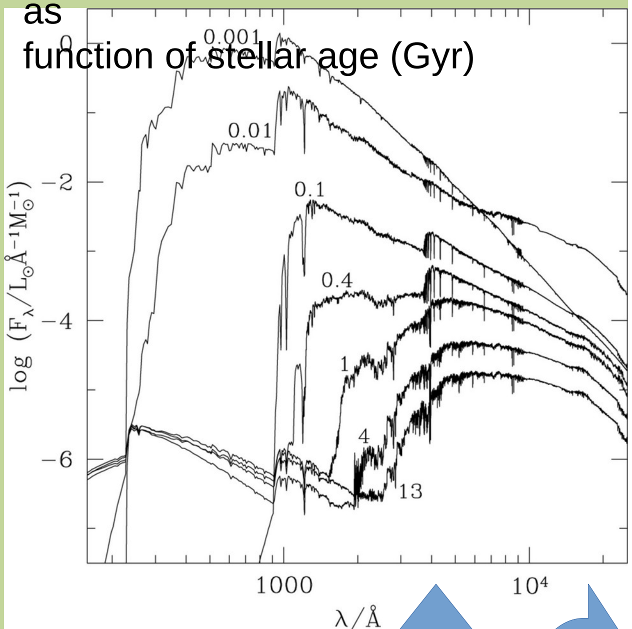
“we find six candidate massive galaxies (stellar mass > 10^{10} solar masses) at 7.4 ≤ z ≤9.1, 500–700 Myr after the Big Bang, including one galaxy with a possible stellar mass of ~10^{11} solar masses. If verified with spectroscopy, the stellar mass density in massive galaxies would be much higher than anticipated from previous studies based on rest frame ultraviolet-selected samples.”

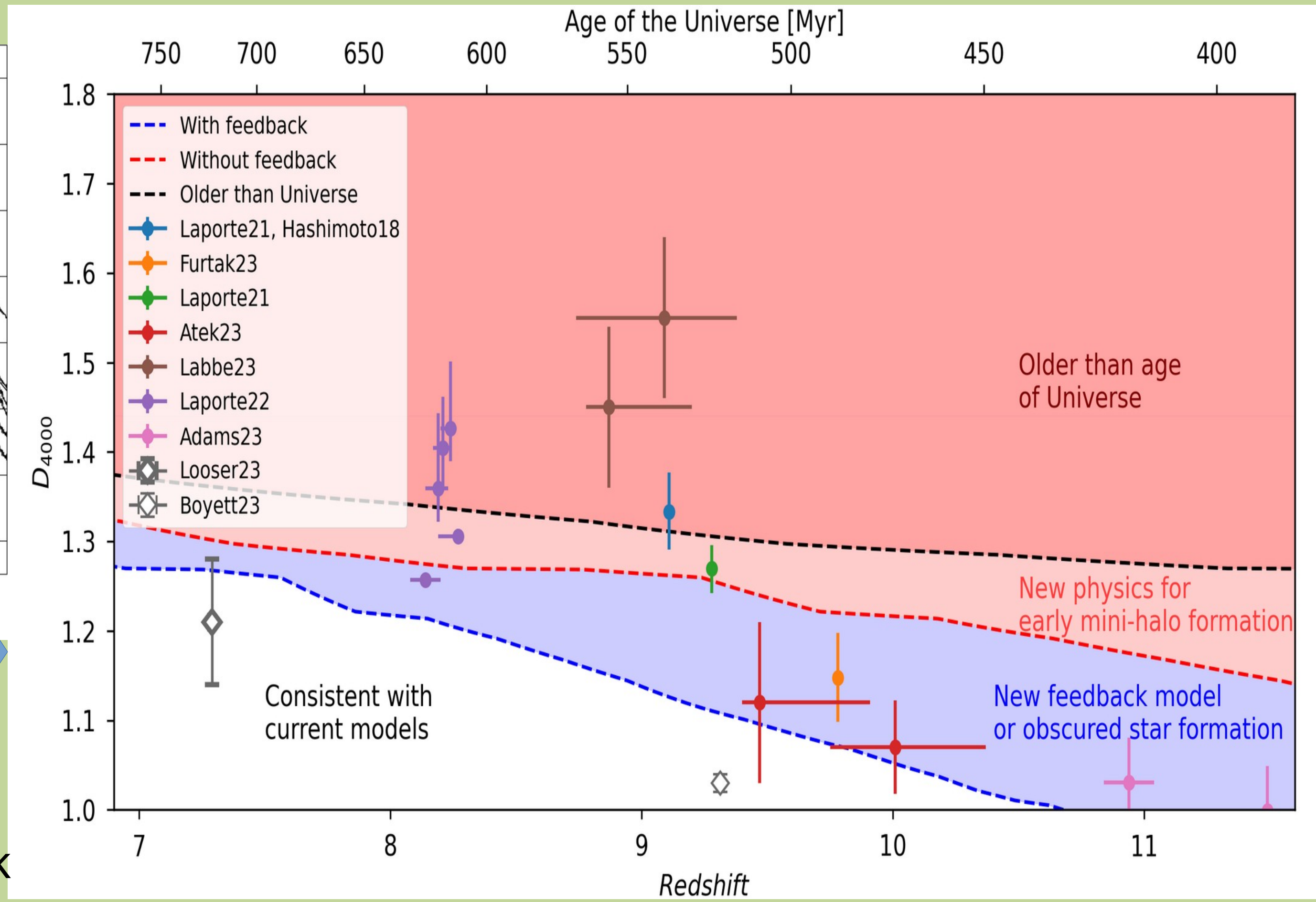
NOTE: Four of these galaxies have been confirmed spectroscopically to have redshifts compatible with photometric redshifts within errors.

Formation and evolution of structures and galaxies

Distant galaxies. Evolution.

Bruzual & Charlot (2003): SED as function of stellar age (Gyr)





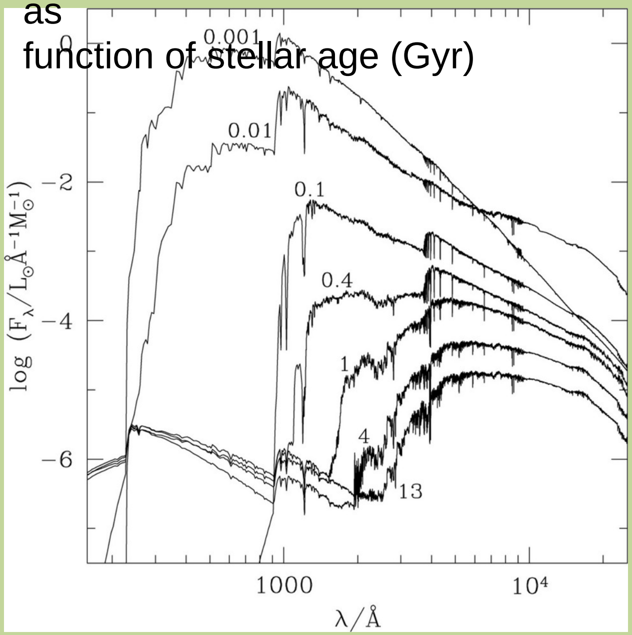
Balmer break

Steinhardt et al. (2023): A selection of galaxies with photometrically-selected Balmer breaks (indicator of age)

Formation and evolution of structures and galaxies

Distant galaxies. Evolution.

Bruzual & Charlot (2003): SED as
function of stellar age (Gyr)



López-Corredoira et al. (2024):

“Here we analyze these observations [Labbé et al. JWST massive galaxies] more deeply by fitting a stellar population model to the optical and near-infrared photometric data. (...) with an average $\langle z\rangle \approx 8.2$, when the ΛCDM Universe was only ≈600 Myr old. This result conflicts with the inferred **ages of these galaxies, however, which were on average between 0.9 and 2.4 Gyr old within 95% CL.** Given the sequence of star formation and galaxy assembly in the standard model, these galaxies should instead be even younger than 290 Myr on average, for which our analysis assigns a probability of only $<3\times10^{-4}$ ($\gtrsim 3.6\sigma$ tension).”

IS THE UNIVERSE IN EXPANSION?

MY CONCLUSION:

There are possible theoretical scenarios in which a static Universe with galaxy redshifts produced by a mechanism different from expansion or the Doppler effect is plausible.

Nonetheless, some observational tests favour an expanding Universe rather than a static one, and the few arguments against expansion are not very strong yet.

Does this mean that we can be 100% sure that the expansion of the Universe is truly established beyond speculative hypotheses? I would not go so far. In cosmology, very few ideas are worth staking one's life on them. I would bet on expansion, but I think definitive proof of it has yet to be produced.