Why the Speed of Light is not a Constant

Paul Smeulders

paul.smeulders@btinternet.com

Why c has a constant value and is not a constant.

Introduction

- The variable speed of light concept (VSL) is supported by the fact that **all direct measurements of the speed of light are basically flawed**.
- This is, because the unit against which we measure this speed: "the **meter per second**" is itself **proportional** to the speed of light.

- [P.Smeulders, "*The measurement of the Speed of Light*" in Elsevier's "Superlattices and Microstructures, 43(2008)651-654"].

The principle of a <u>**good**</u> measurement

- It is essential that when making a measurement to make sure that the two quantities involved are **independent** of each other.
- When the two quantities are shown to be **proportional** to each other, one always obtains a **constant** value.
- This means that **this measurement is <u>invalid</u>**.

What is measured against what.

- One compares the speed of light with the unit **1m/s**
- The meter is **1.89 10^{10} a_0**, with a_0 the Bohr radius.
- The second is **6.58 10^{15} t_0**, with t_0 the time it takes for the electron to circle around the proton.
- Hence the speed of light is compared with **a_0/t_0** or with the **speed of the electron v** going around the proton.

What is measured against what.

- And therefore **c** is measured against **α.c**, α is the fine-structure constant.
- This α only changes **little** over time if at all.

(see J.D.Barrow et al, astr-ph/0511440 and J.K.Webb et al, Phys.Rev.Lett87,091301)

- **SO THE MEASUREMENT OF c IS FLAWED!**

Impulse Momentum & Energy Conservation

- Angular impulse momentum of the hydrogen atom is the Planck constant ħ:

$$\hbar = a_0.m_e.v = a_0.m_e.c.\alpha$$

$$\rightarrow \quad \boxed{a_0 = c \,.\, \hbar/(m_e.c^2.\alpha)}$$

- Our clock τ_0 is, (*Albrecht et al, Phys.Rev.D59,043516*):

$$\tau_0 = 2\pi.a_0/v \rightarrow \quad \boxed{\tau_0 = h/(m_e.c^2.\alpha^2)}$$

Apart from possible variations in α the clock is **constant**.

Looking for evidence for c(t).

- **Supernovas** that are further away are **fainter** than expected:

  this has been said to be due to an

  accelerating expansion

  or

  it can be due to an

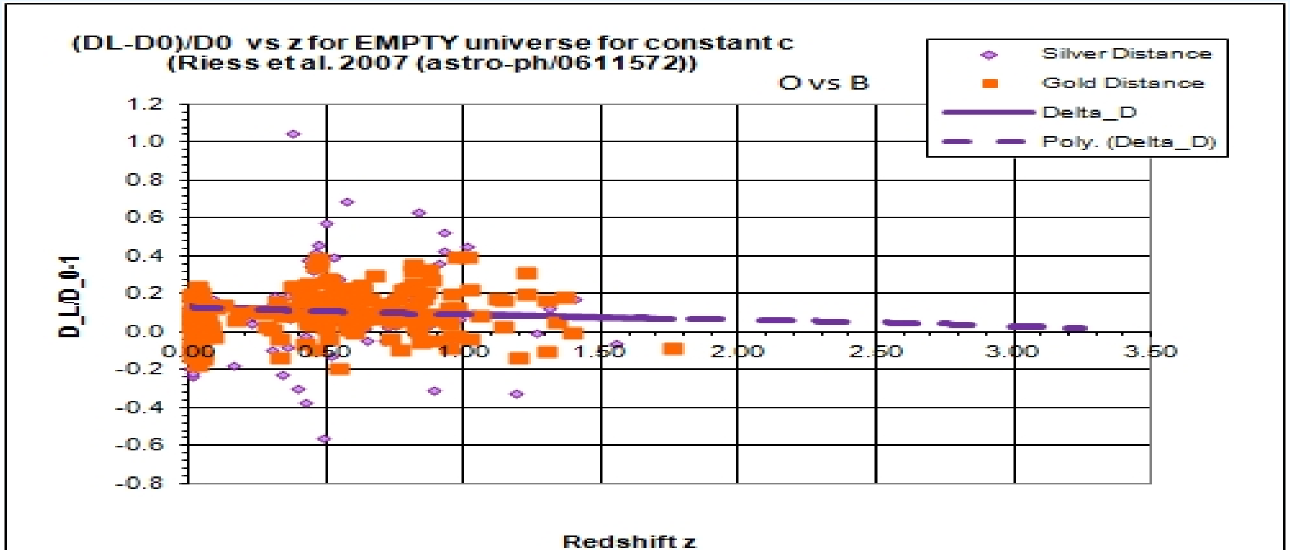
  larger speed of light in the past.

Variable Speed of Light :VSL

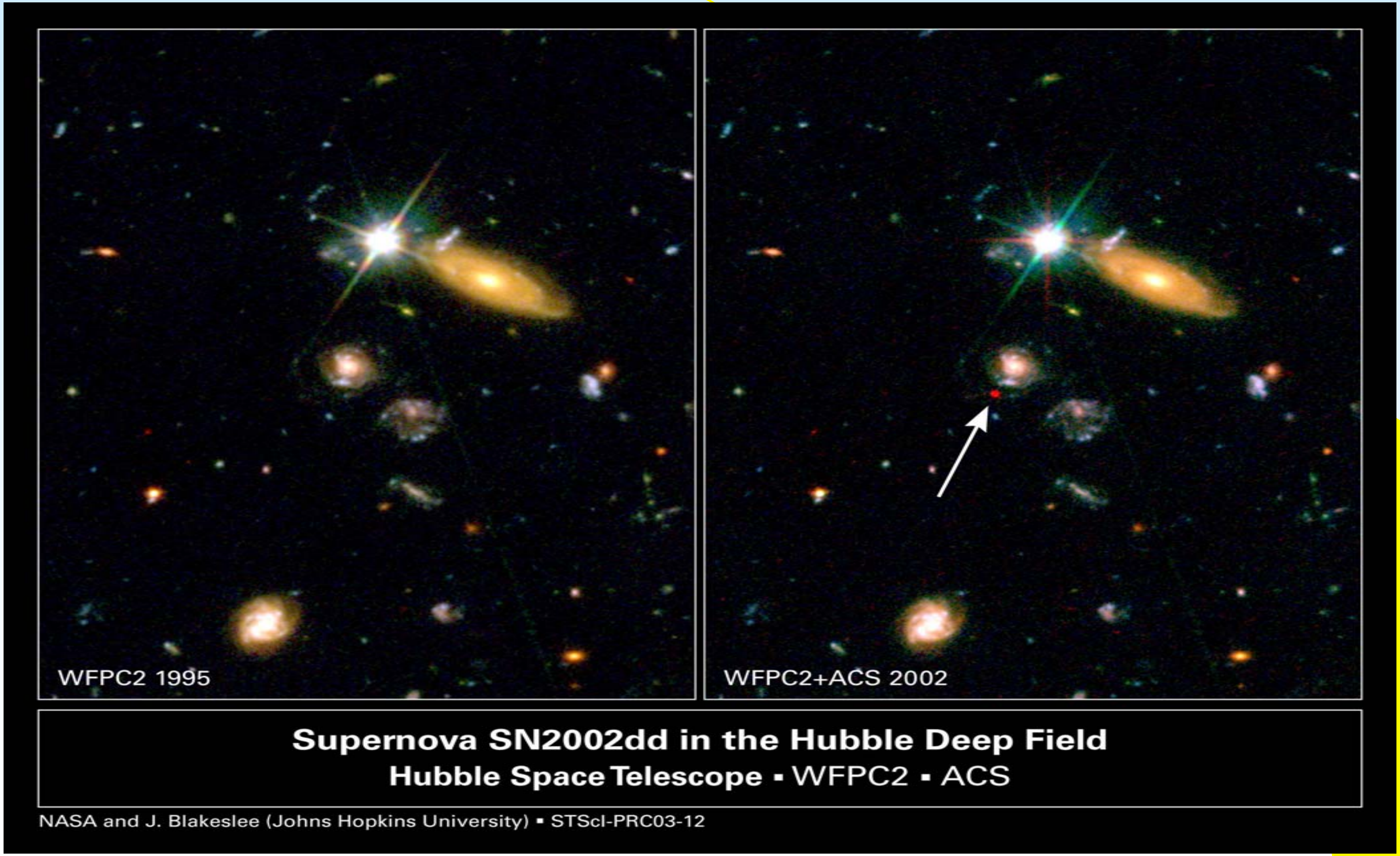
- There have been several publications in the recent past dealing with VSL in cosmology (Albrecht,Barrow,Casado,Moffat,Setterfield).
- But all of them do **NOT** conserve ENERGY
- These schemes conserve the **MASS** of the universe
- Here we will conserve **ENERGY**, and a ***special*** defined **IMPULSE MOMENTUM** and **ANGULAR** one.

Supernova data Adam Riess et al

- Relative difference between measured distance and the one calculated for a zero-density **expanding universe**
- The positive difference for 0<z<3.0 is evidence of **accelerating expansion** in more “recent” times
- The purple curve is the **difference** between accelerated expansion with n=1.15 and the 0 density one with n=1



One of the 292 supernova's Ia Z=0.95

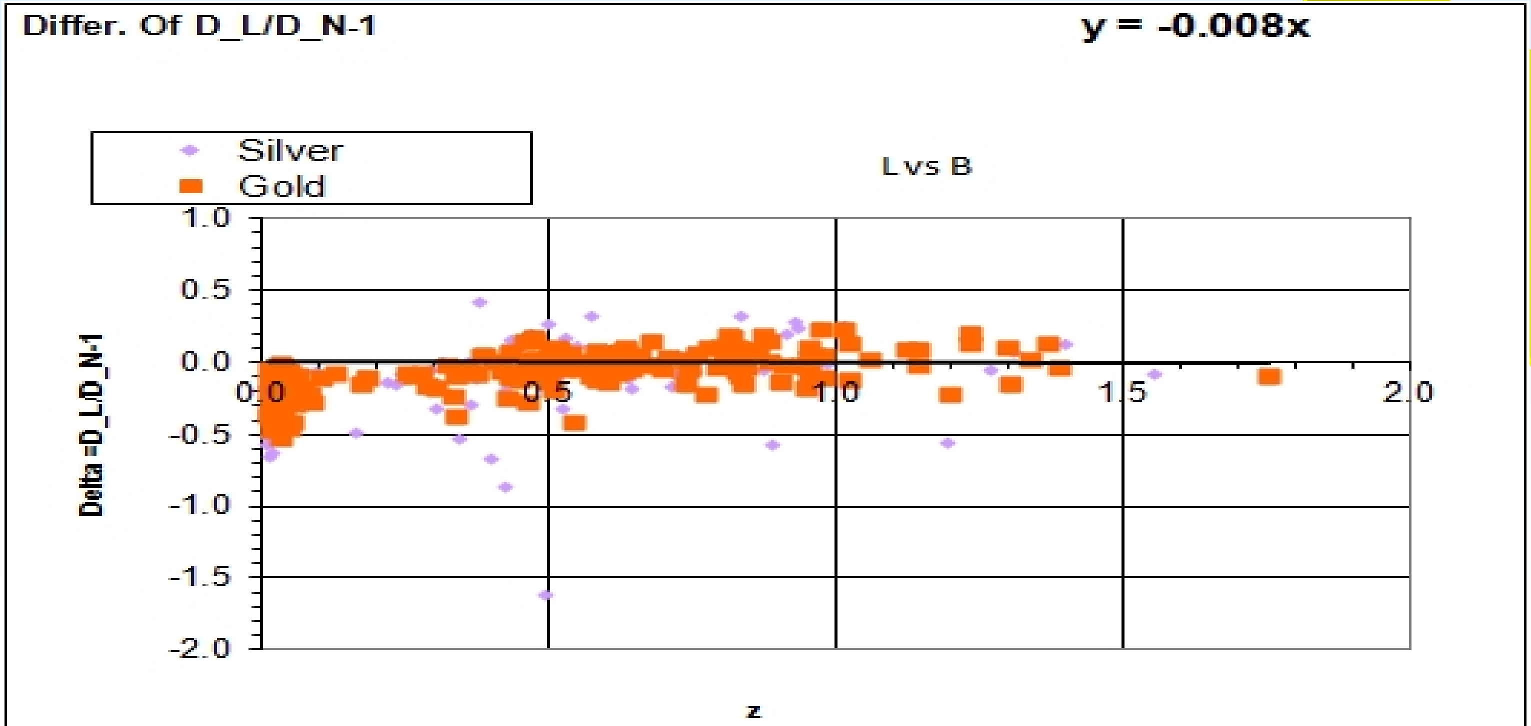


Used Equations and assumptions (N.Wright)

- Redshift: $1+z=\lambda_{obs}/\lambda_0=1/a(t)$, where $a(t)$ is the scale-length of the universe (for c constant).
- $1+z$ combined for $a(t)$ and $c(t)$ we get:
- $(\lambda_{obs}/\lambda_{em})/(\lambda_{em}/\lambda_0) = [1/a(t)]*[c(t)/c_0]$
- The distance is then: $D(t) = \int_{t}^{t_0} \frac{c(t)}{a(t)} dt$
- $D(t) = a(t)*D_L$ so $D_L = 1/a(t) \,.\, D(t)$
- D_L is the measured distance from the luminescence of the supernovae

Supernova data with c(t) and a(t)

- The c(t) variation over time changes the **positive** into slightly **negative** difference and hence a **slowing down** of the expansion of the universe has occurred. **c(t)** enhances **a(t)** variation and hence takes **away** the "**acceleration**".



If **power** scaling laws for a(t) are valid:

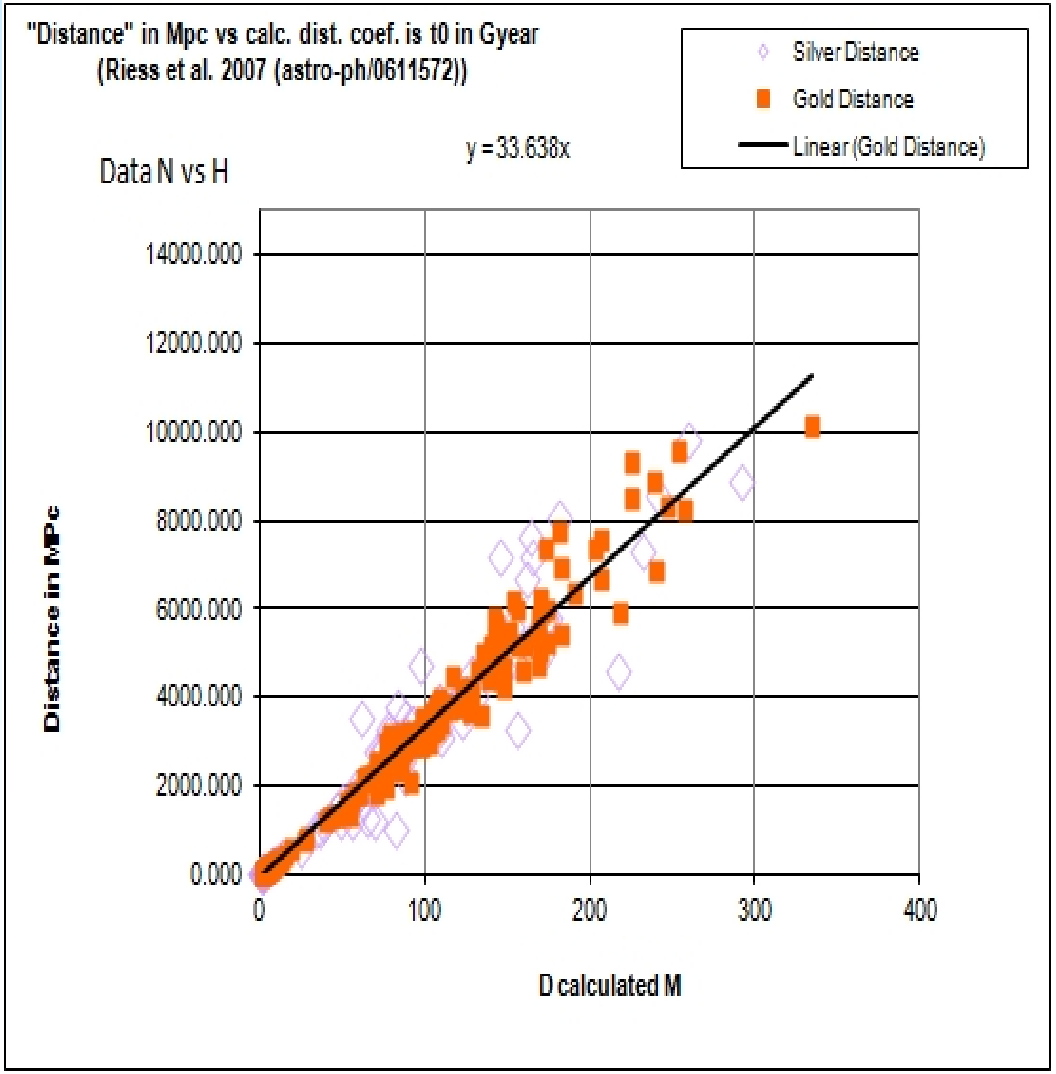
- **$a(t)=(t/t_0)^n$**
- $D(t)=c_0.t_0.[1 - (z+1)^{(1-1/p)}]/(1-p)$ with
- $p=2n$ (the "2" comes from c(t))
- Realistic n values are $2/3<n<1$

The scale factor n

- n=1 means an empty universe $\rho=0$
- n=2/3 means $\rho=\rho_{crit}$, the universe will just not collapse
- n>1 means an accelerated expansion
- n<2/3 means universe will collapse in the end.

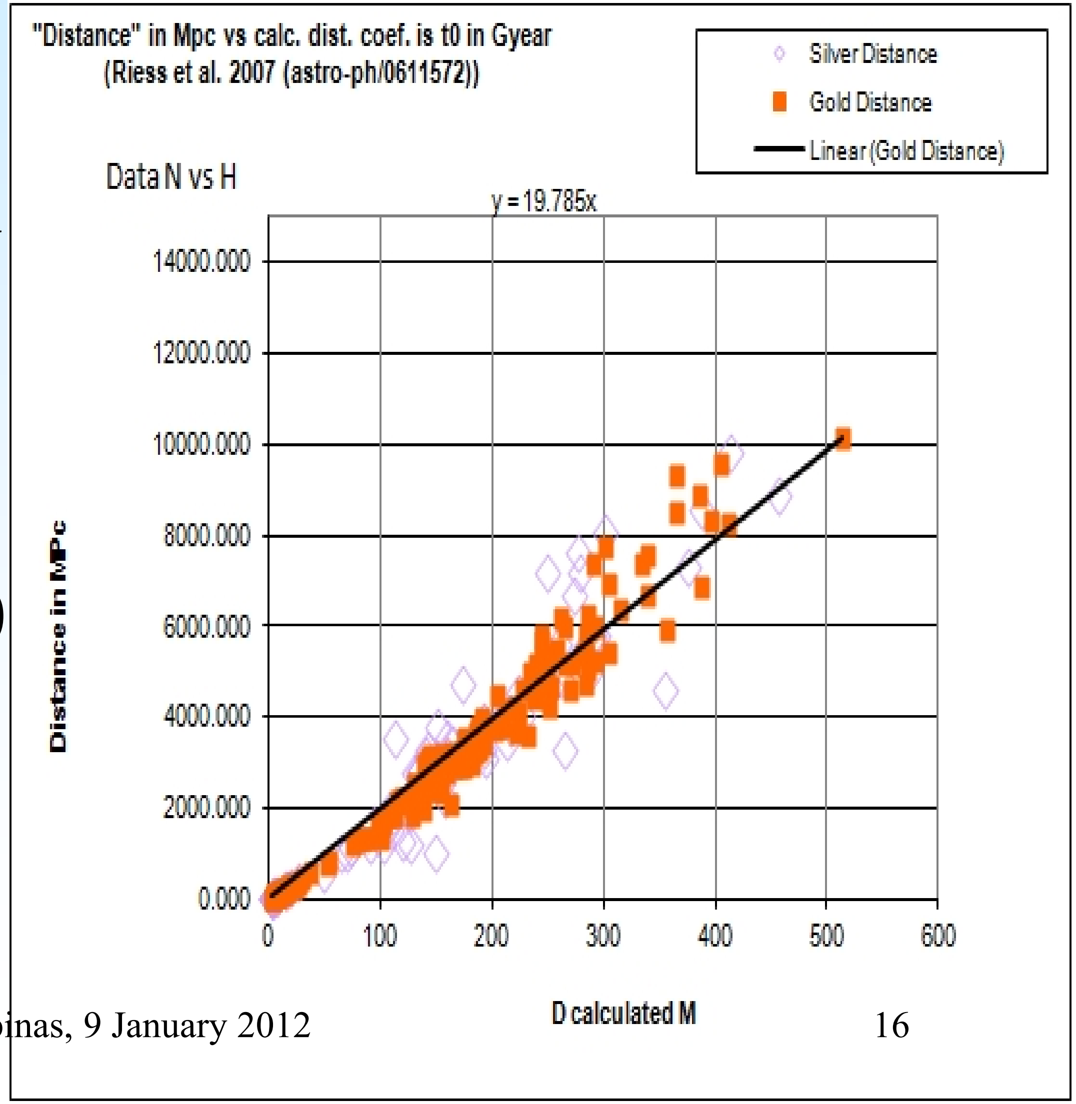
Power scaling of a(t) and c(t)

- t_0=33.63 Gyear
- Z+1=2.755 is 21.4 Gy ago.
- $a(t)=(t/t_0)^{1.0}$, universe is empty: $\Omega_M=0.0$



A dense universe with a(t) and c(t)

- t_0=19.785 Gyear
- Z+1=2.755 is 12.6 Gy ago.
- $a(t)=(t/t_0)^{1/2}$, universe is very dense: Ω_M>1.0
- For low z, t_0=12.6 Gy



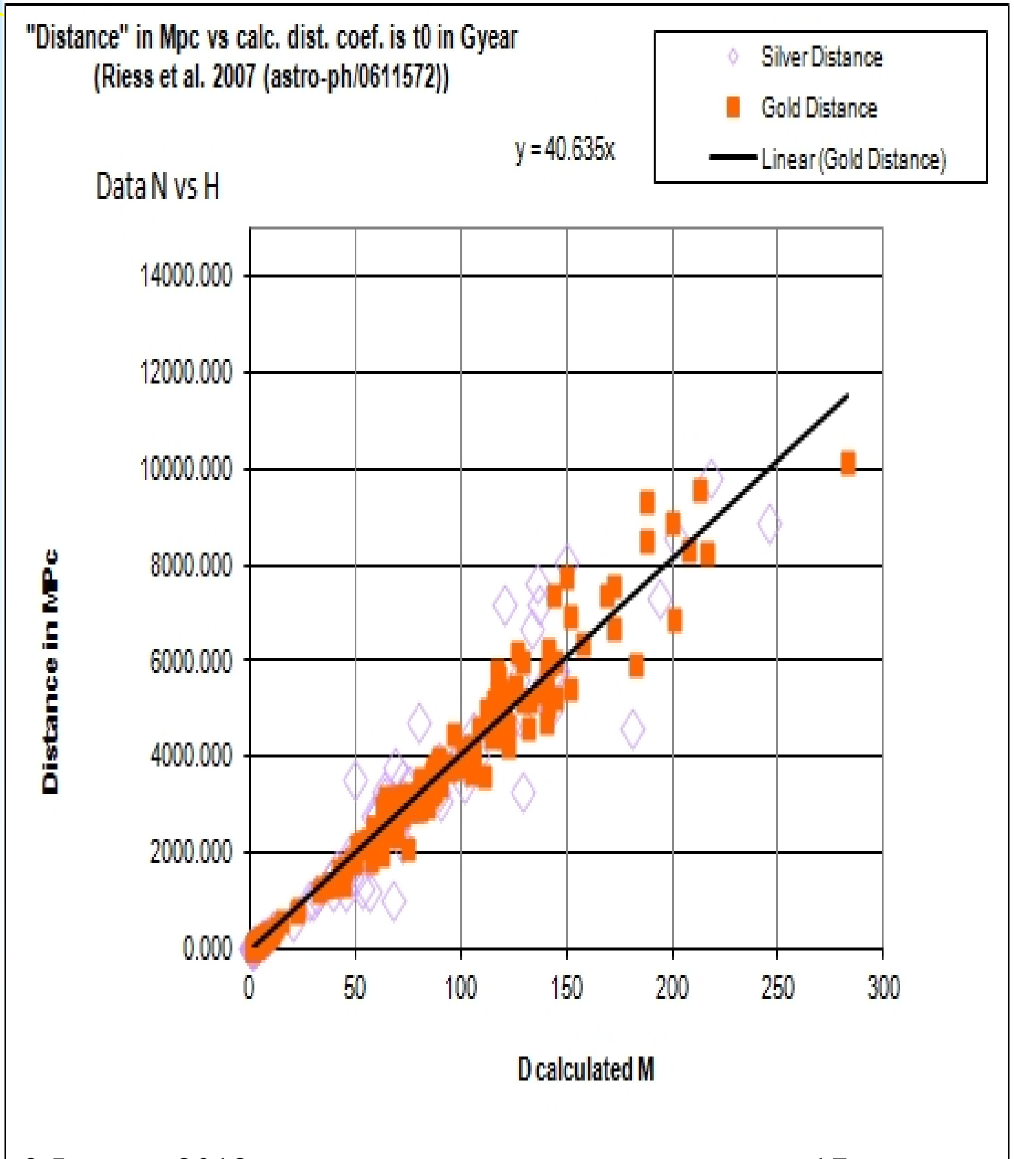
An accelerating expansion

t_0=40.6 Gyear

Z+1=2.755 is 13.5 Gy ago.

$a(t)=(t/t_0)^{1.25}$, expansion is **accelerating**

*Note this fit seems actually to be the **best**, but the universe is much **older***



One could conclude:

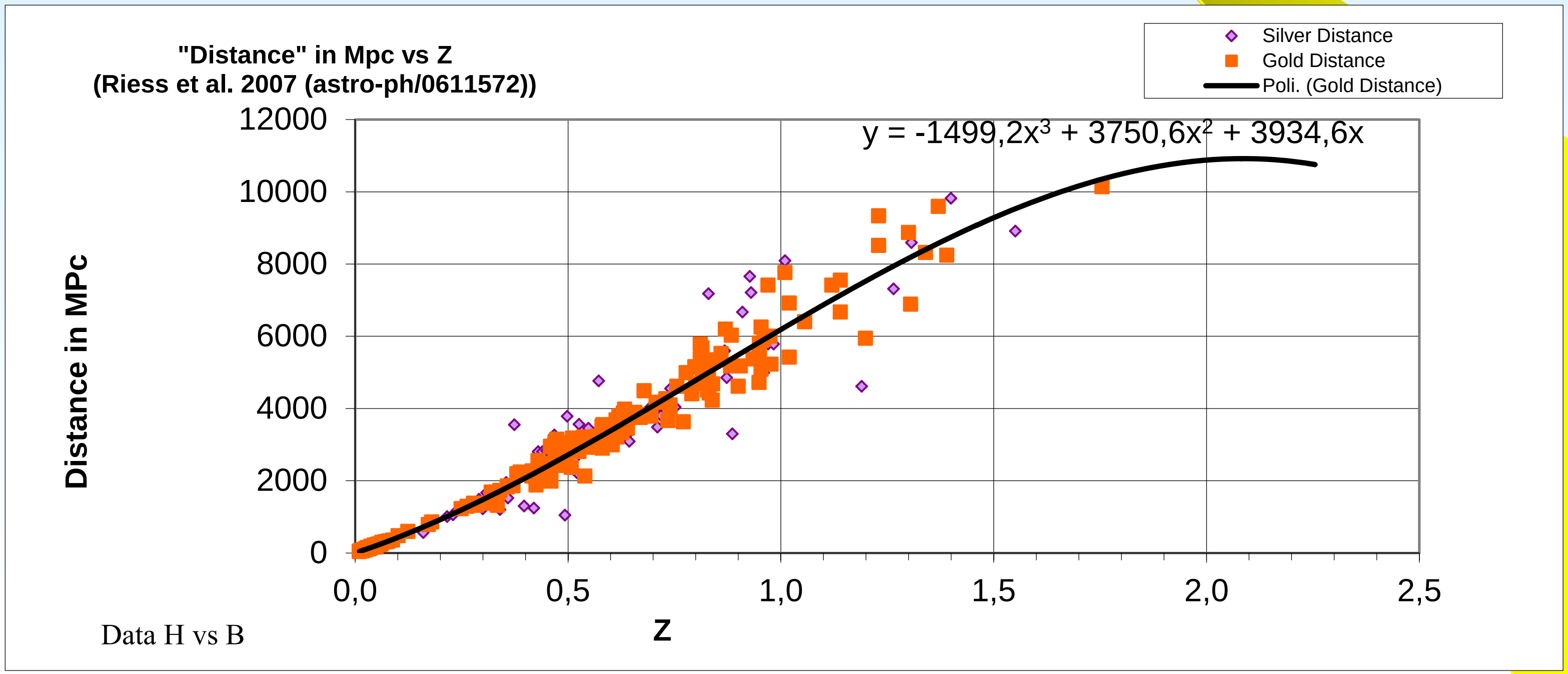
- That a reasonable agreement can be obtained between the measured data and an expanding universe gradually slowing down without an accelerated expansion
- But also that a fair agreement exist for an accelerating expansion
- **It appears that the power scaling is not very conclusive.**

However

- ***There is much more exciting data supporting a variation of c in time.***
- ***This yields a completely different picture of the universe with a MUCH clearer answer.***

Hubble Law

- If we display **"v"=c_0*z** vs **D_L**, we can see how the **Hubble law v=H_0*D** came about at **low** values of **c*z** (but **not so** at higher z values !!)

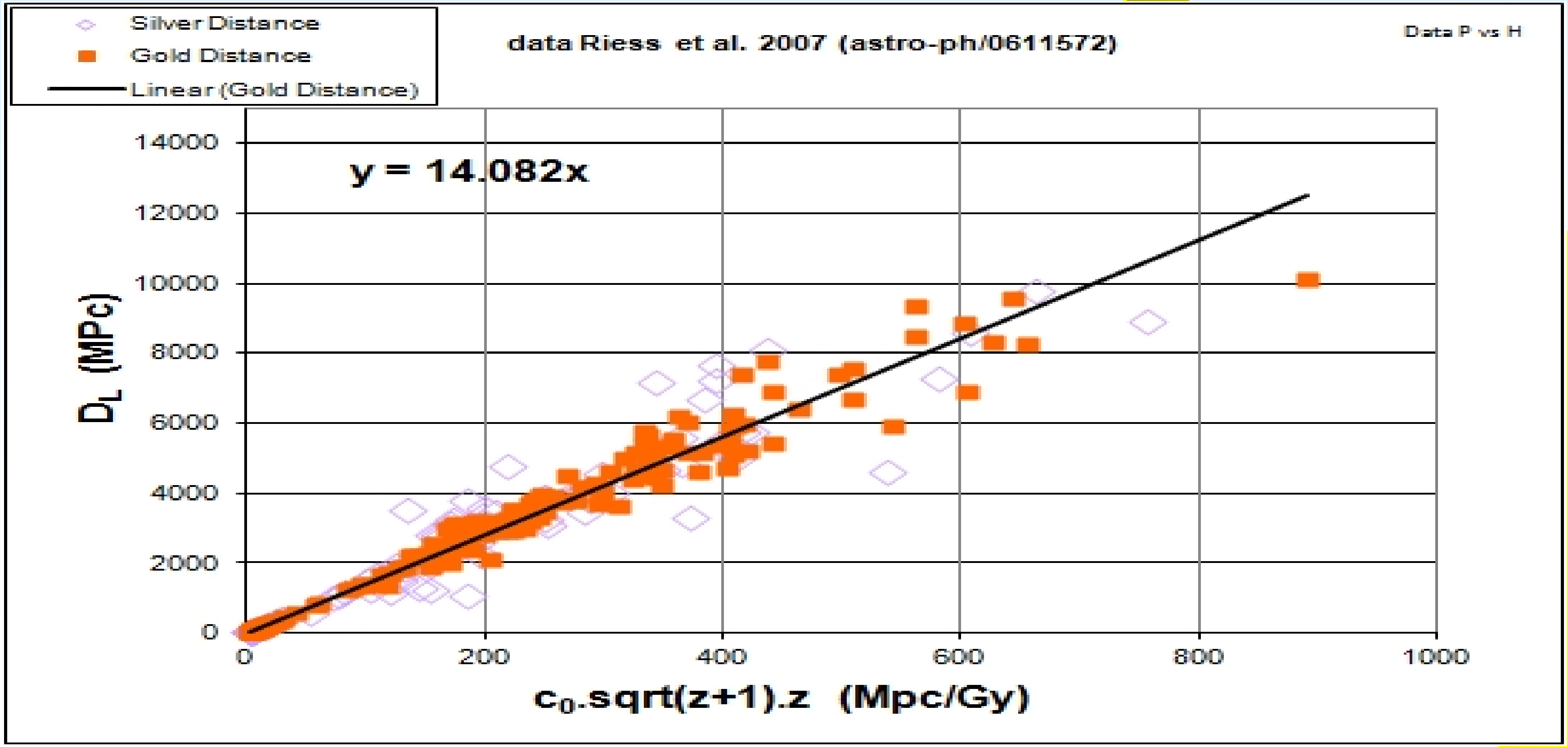


Hubble Law

- It is observed that for small **redshifts z**:
- The distances are: $\mathbf{D=c.z/H_0}$ where H_0 is the Hubble constant. *For an empty universe $H_0.t_0=1$, E.Wright.*
- Now let **c(t)** then z+1=c(t)/a(t) and if c(t)=c0/a(t) we get : $c(t)=c_0.(z+1)^{0.5}$
- $\mathbf{D=c_0.(z+1)^{0.5}.z/H_0}$

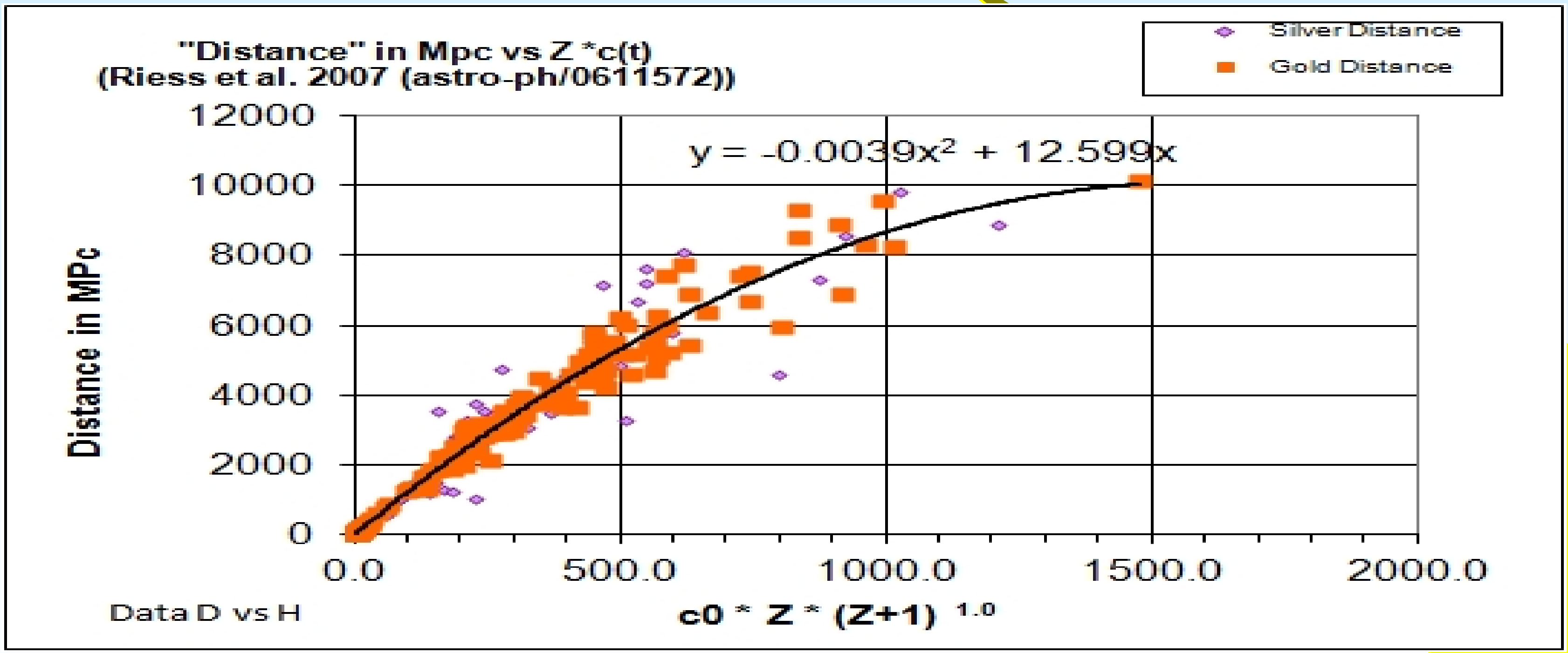
Varying c(t) into Hubble Law

- we get a **perfectly straight** line fit for $\mathbf{c(t)=c_0/a(t)}$ with t_0=14.082 Gyears



Now c(t)=c0 then a(t)=1/(Z+1)

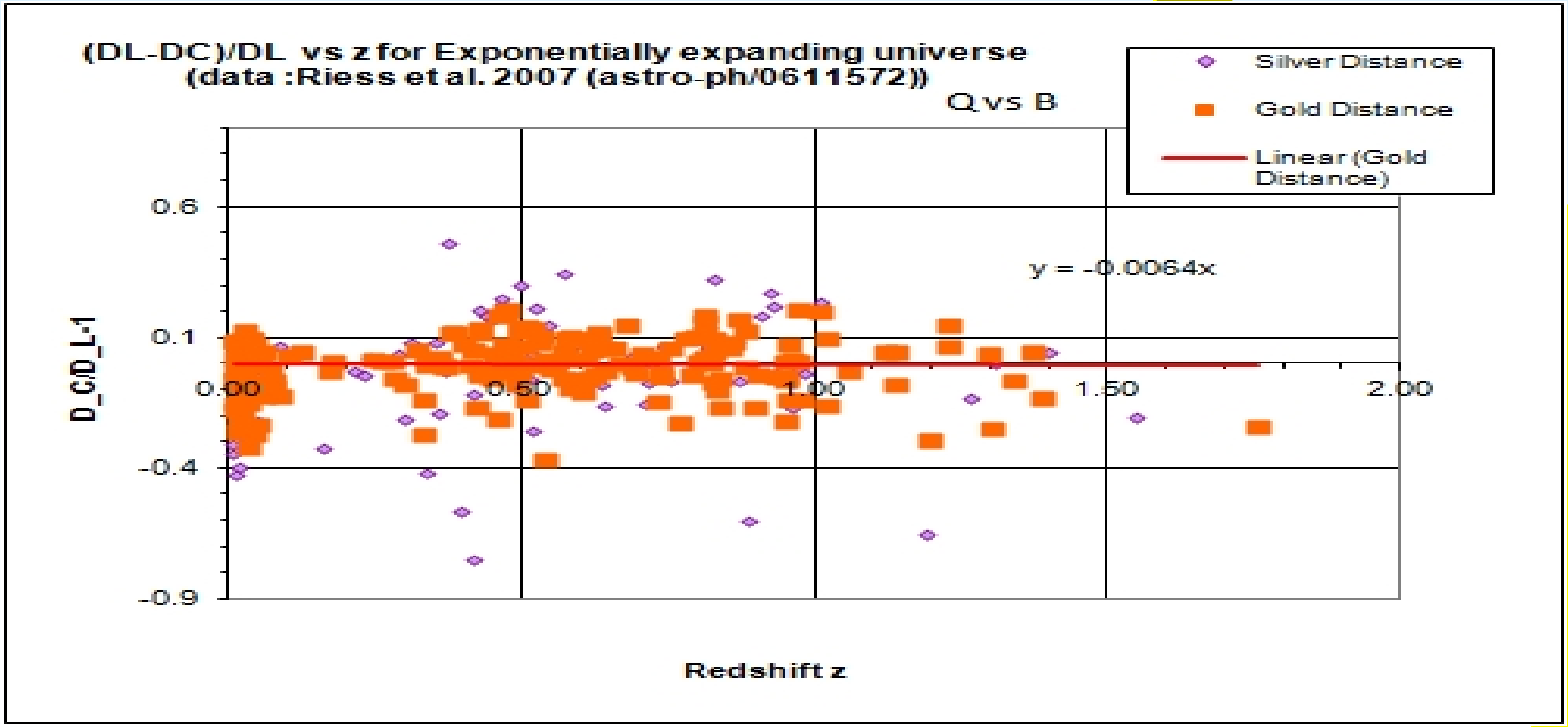
- For $D_L = c_0 . t_0 .(z+1).((z+1)-1)$ we get:



Clearly <u>VARYING</u> c(t) is MUCH better

How good is the fit for varying c?

- Just look this relative difference between measured and calculated distances:



What can we learn from this?

- 1. That $\mathbf{c(t)=c_0/a(t)}$
- 2. That $D_L = c_0 t_0 \sqrt{z+1}\{(z+1)-1\}$
- 3. Compare to: $D_0 = \dfrac{1}{a(t)} \displaystyle\int_t^{t_0} \dfrac{c(t)}{a(t)} dt$
- 4. Note: $z+1 = \dfrac{\lambda_{obs}}{\lambda_{em}} = \dfrac{c(t)}{c_0.a(t)} = \dfrac{1}{a^2(t)}$
- 5.So: $D_0 = c_0.t_0 \sqrt{z+1} \displaystyle\int_{t/t_0}^{1} (z+1).dx$
- 6. *$z+1 \approx exp(-x)$*

One way to have this: an ***<u>slow</u>*** **exponential** expansion

- because $z(t_0)=0$, **$z+1=\exp(1-t/t_0)$** and :
- $a(t)=\exp((t/t_0-1)/2)$
- $c(t)=c_0.\exp((1-t/t_0)/2)$
- **<u>THEN</u> WE FIT THE MEASUREMENTS *well*.**
- The **nature** of t_0 changes from age of the universe to a simple **e-folding** time

Exponential Expansion

- **Something is DRIVING this against the gravitational pull: back to DARK ENERGY**

Is an exponential expansion the only fit?

- Compare : $D_L = c_0 t_0 \sqrt{z+1}\{(z+1)-1\}$
- To : $D_0 = c_0 . t_0 \frac{1}{a(t)} \int_{t/t_0}^{1} (z+1).dx$
- Let us explore 2 cases:
- 1. a(t)=1 no expansion, after some maths one gets: $z+1 = [(x+\sqrt{x^2+8})/4]^2$
- With $x=t/t_0$ and x=1 leads to z=0, but x=0 does not lead to z+1=∞, but large negative x do not lead to large z+1 either

2-nd option

- Case of $c(t)=c_0$,$z+1=1/a(t)$ after some maths we get:

$$1-x=\frac{4}{3}-\frac{1}{\sqrt{z+1}}\left\{1+\frac{1}{3(z+1)}\right\}$$

- This means that for x=1 we have z=0, which is OK, but for x=0, again we do **not** find z=∞. And for x=-∞, z+1 must be zero.
- The second option can be **ruled out** and the first alternative most likely also.

A Revolution in Cosmology?

- There is **no beginning** only an e-folding time of $2.t_0 \approx 28$ Gyears of the slow **<u>exponential</u>** expansion a(t).

- There is no horizon, just an e-folding horizon of 28 G light-years

In any case…

- The speed of light **must** change n time.
- The most likely and most **elegant** scenario is where $\mathbf{c(t)=c_0/a(t)}$ AND $\mathbf{z+1=exp(1-x)}$, $\mathbf{x=t/t_0}$

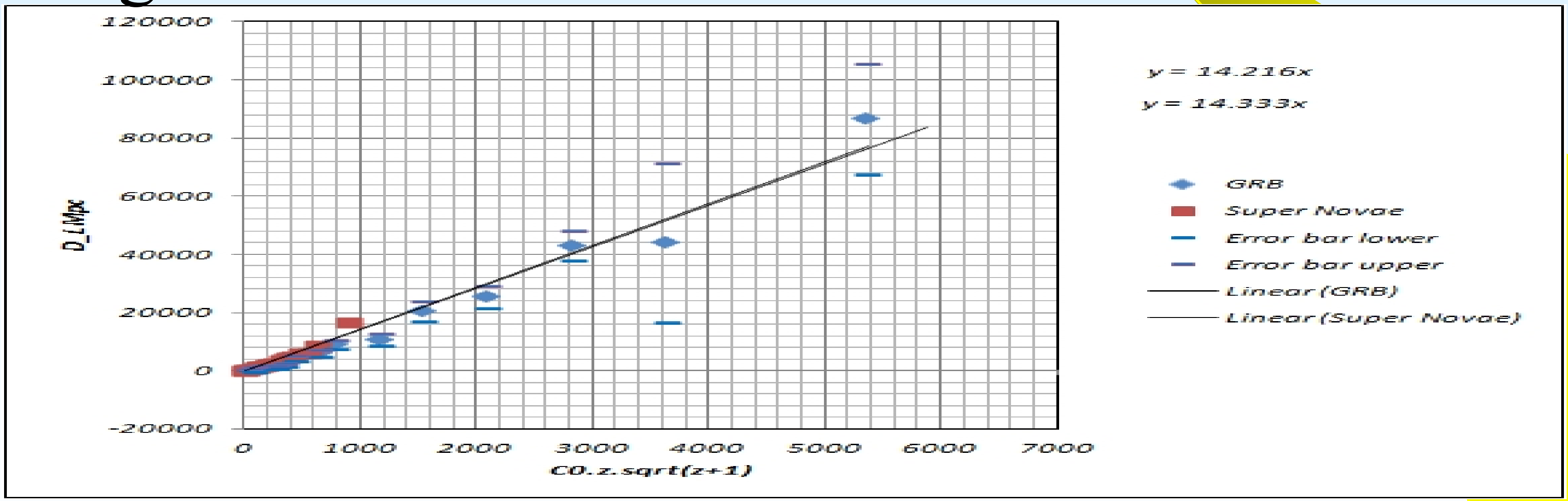
A Revolution in Cosmology?

- The expansion scale factor a(t) **does not follow a power scaling** (except for z<<1, n≈1/2 , $a(t)=\sqrt{e^{(\frac{t}{t_0}-1)}}\approx\left(\frac{t}{t_0}\right)^{\frac{1}{2}}$,which **did** mean a dense universe for this scaling).
- $a(t_0)=1$ and $a(-\infty)=0$
- Note z+1=2.755 corresponds 14.5 Gyears ago.

Gamma Ray Burst vs c(t)*z(t)

E.Wright at: http://www.astro.ucla.edu/~wright/sne_cosmology.html

- $t_0 \approx 14$ Gyear
- GRB (error bars ≈50%) can be made to agree with the SN distances.



- Data go back 30 Gyear, t=0 is now and then **$t=-t_0.\ln(z+1)$**

What about….. planets

- Energy of orbiting ($v^2=GM/r$) planet of mass m around a star of mass M is:

$$E = \tfrac{1}{2} m v^2 + G\frac{mM}{r} = \tfrac{3}{2} G\frac{mM}{r} = \tfrac{3}{2} m v^2$$

- **Conservation of energy** yields: $\mathbf{v/c=v_0/c_0}$
- (also for relativistic cases !!)
- **Angular impulse momentum** is: $m\underline{v}x\underline{r}$
- Conservation would yield: $\mathbf{r/c=r_0/c_0}$ and $\boldsymbol{\omega=\omega_0}$
- BUT then orbit radius is: $\mathbf{r(t)=r_0/a(t)}$ **: NO** scaling with expansion

Planetary orbits

- The **condition $r(t)=r_0*a(t)$** changes the angular impulse momentum conservation law **!!!!!!**

- Assume **m.v.r.f(t)** is conserved over time.
- What is then f(t) ?

Angular impulse momentum conservation

$$m.v.r.f(t) = E_m.\frac{v(t)}{c(t)}.\frac{r_0.a(t)}{c(t)}.f(t) = E_m.\frac{v_0}{c_0}.\frac{r_0}{c_0}$$

- It follows: $f(t) = \dfrac{c(t)}{c_0.a(t)} = z+1$
- Orbital frequency: $\omega(t) = \omega_0 \dfrac{c(t)}{c_0.a(t)} = \omega_0.(z+1)$
- **Conservation of :** *m.v x.r.(z+1), vectors*

And now…atoms.

- Conservation of $\hbar$ (very important to have a redshift!!) gives a modified angular conservation law:
- $m_e.v.a_0=\hbar.\ c_0.a(t)/c(t)$
- Bohr radius with $E_e=m_ec^2$ is then
- $a_0(t) = \hbar.c_0.a(t)/(E_e\alpha) = a(t)\ .\ a_0(t_0)$
- **Also Bohr radius scales with universe**

Redefine angular impulse momentum (AIM)

- Define $m_c = m.c^2$, so the mass is measured in energy units.
- Define $\underline{v}_c = \underline{v}/c$, so speed is relative to the speed of light c(t)
- Define $\underline{r}_0 = \underline{r}/a$, r is the radius in the past with the scale factor a(t). The radius r_0 is as seen by the observer at time t_0.
- The correct AIM is : $\mathbf{m_c . \underline{v}_c x \underline{r}_0}$

Atoms ….

- $\tau_0(t) = 2\pi . a_0(t)/v(t) = \tau_0(t_0) . a(t) . c_0/c(t) =$
  $\boldsymbol{\tau_0(t) = \tau_0(t_0) /(z+1)}$
- since $\varepsilon_0 \cong 1/c$, replace ε_0 with $\varepsilon_0 . c_0/c(t)$
- $\boldsymbol{e^2/[\varepsilon_0 . (c_0/c(t)) . a_0 . a(t)] = mc^2 . \alpha^2}$, the **electric charge** ***e*** changes in time:
- $\boldsymbol{e = e_0/(z+1)^{1/2}}$

Velocity of Light Measurement

- ***c*** is always measured against : ***v (t) = α.c(t)***
- ***We always measure the speed of light against itself at all times.***

Atoms and Planets

- So atoms and orbits of planets **can expand** with the universe.
- The scale of atoms and planetary orbits **scale with a(t).**
- This conserves a **special** angular impulse momentum (***m.v.r.c/a***) and a **special** impulse momentum (***m.v.c***). This essentially based on energy conservation: ***v/c*** is conserved

And ....

- **<u>Relativity</u>** : Einstein's equation of $\mathbf{E=mc^2}$ is perfectly valid and if the speed of light would change so should the **mass** of the objects: $\mathbf{m=m_0.exp(t/t_0-1)=m_0/(z+1)}$
- **Relativity unchanged <u>since</u>** ***v scales with c***.
- **<u>Quantum Mechanics</u>**: Note that **all energy levels** of the hydrogen atom can be written in units of $\boldsymbol{\alpha^2 m_e c^2}$ **—►** **Quantum mechanics unchanged**

SUMMARY and CONCLUSIONS

- The **exponential** scaling law gives a **very good match** to the observations
- Exponential expansion requires a driving force. **DARK ENERGY must be there**
- Power scaling laws are **not very suitable** to describe the evolution of the universe.
- Exponential expansion **COMPLETELY** changes the picture of the BIG BANG and its evolution.

Conclusions

- We found : a **speed of light varying inversely to the expanding universe** with **$c(t)*a(t)=c_0$**. This alone leads to $\boldsymbol{D_L=c_0.t_0.(z+1)^{1/2}.z}$ and then to an **exponential** scaling of the expansion rate.
- Of course this observation has been made over the last 14 Gyears when the **fine-structure constant** is “constant” within 10^{-5}

The End

- Thank you for your attention

References:

[1] P.Smeulders, Superlattices and Microstructures 43(2008) 651-654

[2] A.Riess, et al., 2007 astro-ph/0611572

[3] E.Wright, http://www.astro.ucla.edu /~wright/sne_cosmology.html

Escape Velocity

- Energy conservation yields:

$$G = G_0 . \frac{m_0}{m} . \frac{M_0}{M} . \frac{r}{r_0} = G_0 . \left(\frac{c(t)}{c_0} \right)^3 = G_0 . \left(\frac{1}{a(t)} \right)^3$$

- The critical mass density is obtained from:

- $\left(\frac{a(t)}{2t_0} \right)^2 = \frac{8\pi}{3} . G(t) . \rho_{cr}(t) \Rightarrow \frac{\rho}{\rho_{cr}}(t) = \frac{\rho}{\rho_{cr}}(t_0) . \frac{1}{a^6(t)}$

- Critical density **ended** 25 Gyears ago

Back to measurement of c

- The geographic clock is: $\tau_G = \sqrt{\frac{\ell}{g}} = \sqrt{\frac{\ell . r^2}{G.M}}$

- It follows: $\tau_G = \tau_{G0} . a^2(t) = \tau_{G0} /(z+1)$

- This dependence is the same as for the atomic time.

Expansion rate

- The expansion speed is: $v(t)=dR/dt=R_0.a / 2t_0$ From the D definition $v(t_0)=c_0$.
- Therefore $R_0=2c_0.t_0$.
- ***$v(t)/c(t) =1/(z+1)$ increasing in time.***
- **so** v/c<1 for all times in the past
- R_0 is an e-folding "Horizon"

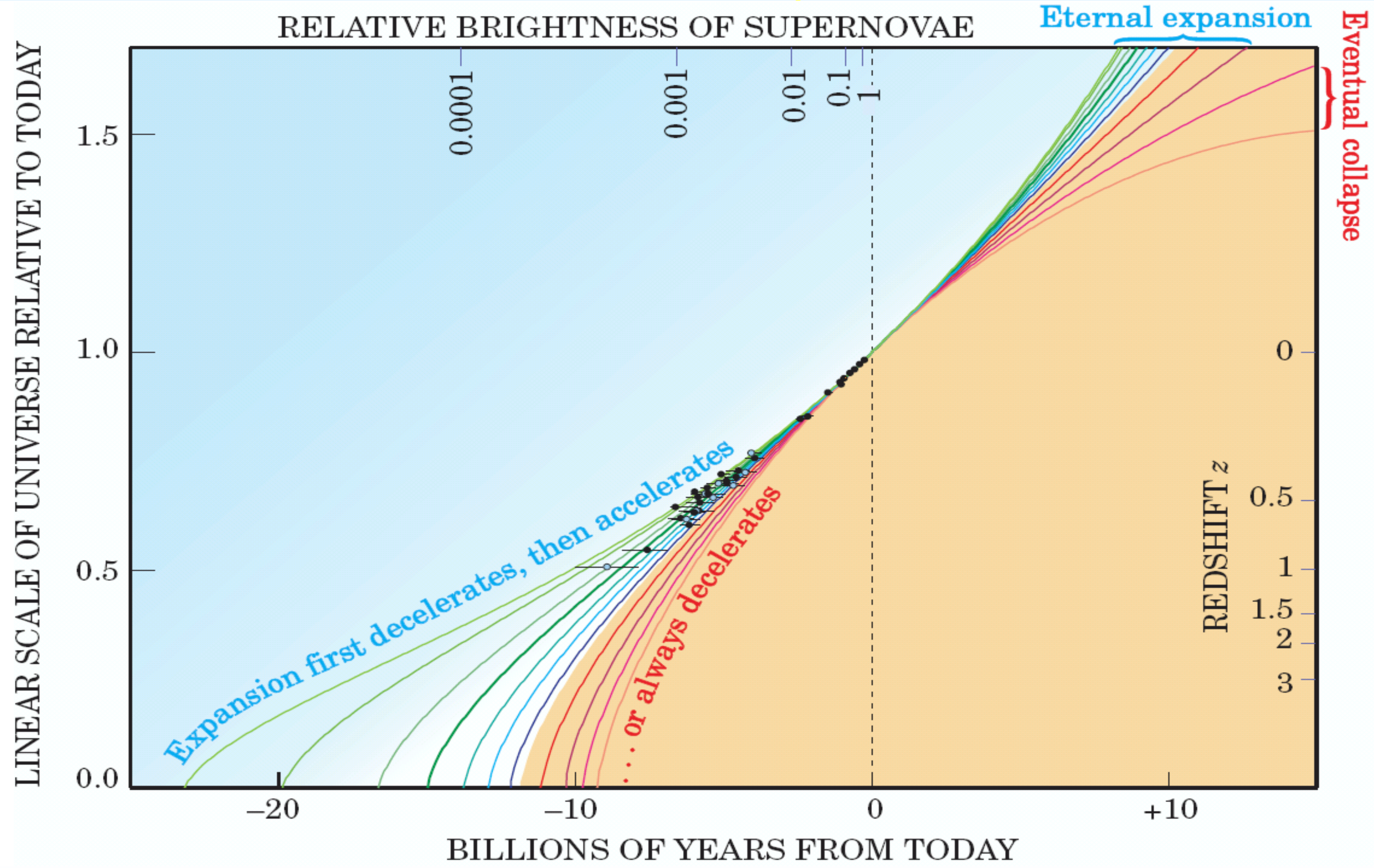
Lorentz Equations

- $x^2+y^2+z^2-c^2t^2=0$
- x,y,z scale with $a(t)=c_0/c(t)$
- In $\sqrt{1-\frac{v^2}{c^2}}$ the measured **v scales with c**

- It appears that relativity remains unchanged because relativity is based on velocities

Supernova data: S.Perlmutter et al.

Physics Today, April 2003



Consequences

- The world around us, **its size is set by the speed of light**. And hence any variation of the speed of light over time (or space) will **NOT** be directly apparent.
- The world around us is defined by the speed of light. And hence **nothing** can travel **faster** than the speed of light.