Hubble Tension

or

a Late Fundamental Physics Transition

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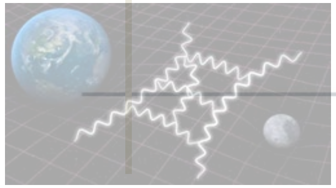
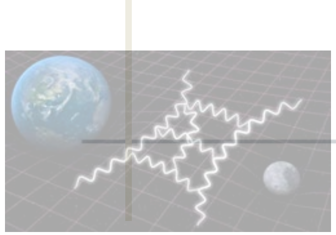
Structure of talk



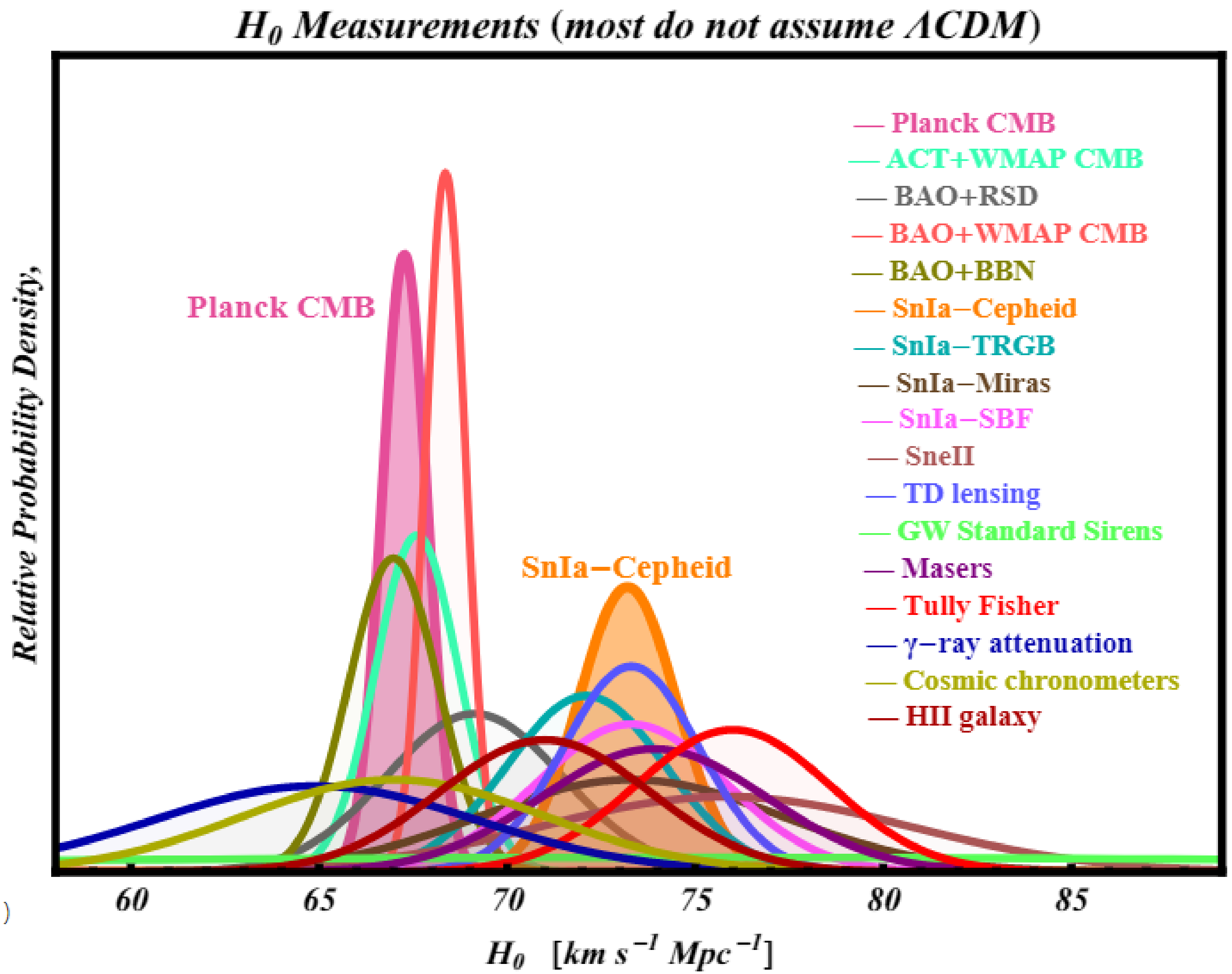
1. The Hubble tension and the M tension
2. The transition approach to the Hubble tension
3. Searching for a transition in the Cepheid data
4. Tully Fisher data and solar system history
5. Theoretical models: Late false vacuum decay
6. Conclusions

The Hubble tension



Q.: What is the feature that distinguishes the two groups of H_0 values?

Is it cosmic time or is it the assumption of distance ladder effects and fixed low z-high z gravitational physics?

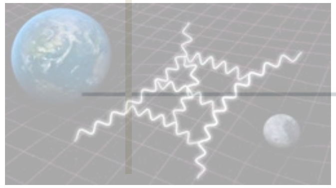


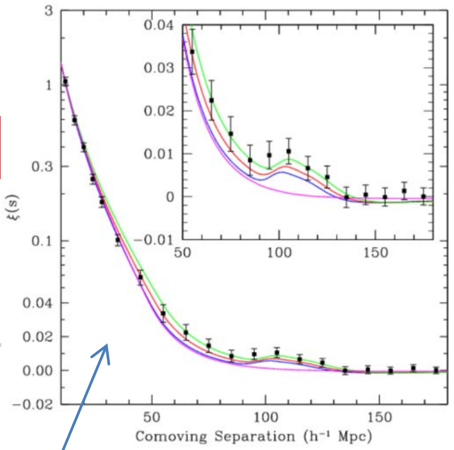
Challenges for ΛCDM: An update

Leandros Perivolaropoulos (Ioannina U.), Foteini Skara (Ioannina U.) (May 11, 2021)

e-Print: 2105.05208 [astro-ph.CO]

Measuring H_0-$H(z)$ with a stand early time calibrators





Sound Horizon at Recombination Standard Ruler (Early Universe):

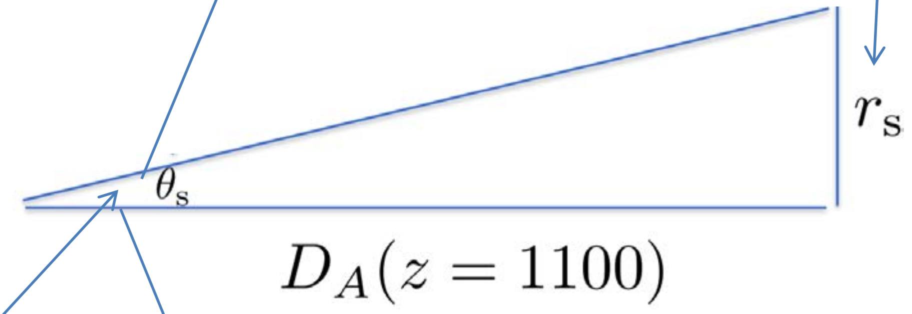
$$r_s = \int_0^{t_d} c_s dt/a = \int_0^{a_d} c_s \frac{da}{a^2 H(a)}$$

Depends on ρ_b, ρ_γ and ρ_{CDM}

r_s=147.6 Mpc from Planck and BBN values of ρ_b, ρ_γ and ρ_{CDM}

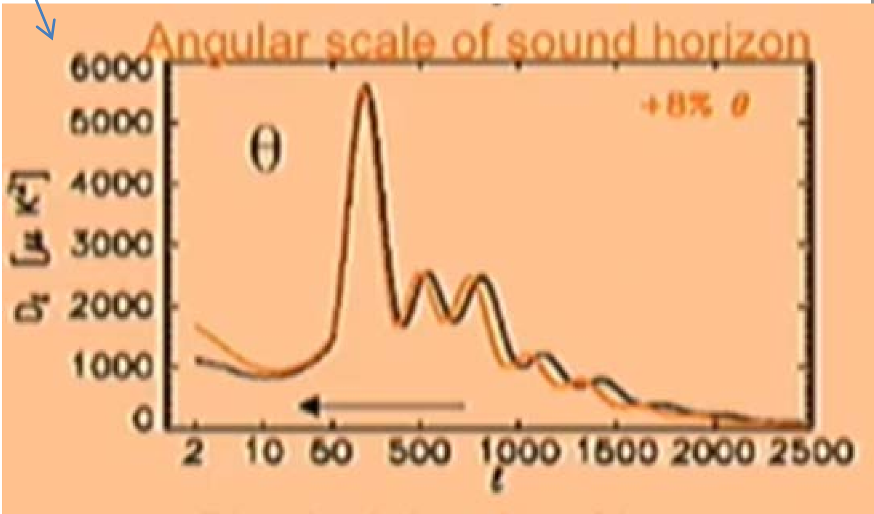
inferred

calculated



measured

$$\theta_s = \frac{r_s}{D_A(z)}$$



comoving

$$E(z) = \left[\Omega_{0m}(1+z)^3 + (1-\Omega_{0m})\right]^{\frac{1}{2}}$$

Degeneracy between r_s and H_0 and $E(z)$.

Measuring H_0–H(z) with standard candles: late time calibrators

Fit SnIa Standard Candles for H_0, z<0.1:

fit with kinematic expansion (z<0.1)

$$D_L(z, q_0) = cz\left[1 + \frac{1}{2}(1-q_0)z\right]$$

$$m_{th}(z) = M + 5\,log_{10}\left[\frac{d_L(z)}{Mpc}\right] + 25$$

$$d_L = c(1+z)\int_0^z \frac{dz'}{H(z')}$$

$$D_L(z) = \frac{H_0\, d_L(z)}{c}$$

$$m_{th}(z) = M + 5\,log_{10}\left(D_L(z)\right) + 5\,log_{10}\left(\frac{c/H_0}{1Mpc}\right) + 25$$

measure

measure locally (z<0.01, 40Mpc) using relative distance indicators (eg Cepheids)

fit

Degeneracy between M (measured at z<0.01) and H_0 (fit at z> 0.01).

Fit for H(z) and cosmological parameters (Ω_{0m}) z_{max}~2.

Parametrize H(z): $H(z)^2 = H_0^2\left[\Omega_{0m}(1+z)^3 + (1-\Omega_{0m})\right]$

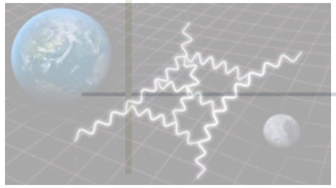
$$m_{th}(\Omega_{0m}, \mathcal{M}) = 5\,log_{10} D_L(z;\Omega_{0m}) + \mathcal{M}(M, H_0)$$

Minimize: $\chi^2(\mathcal{M}, \Omega_{0m}) = \sum_i \left[\frac{m_{obs,i} - m_{th}(z_i;\Omega_{0m},\mathcal{M})}{\sigma_i^2}\right]$

$$D_L(z, \Omega_{0m}) = c(1+z)\int_0^z \frac{dz'}{\left[\Omega_{0m}(1+z')^3 + (1-\Omega_{0m})\right]^{1/2}}$$

$$\mathcal{M} = M + 5log\frac{c/H_0}{Mpc} + 25$$

H_0 tension or M tension?



H_0 measurement using sound horizon standard ruler (inverse distance ladder):

$$\theta_s = \frac{r_s}{D_A(z)} = \frac{H_0\, r_s}{\int_0^z \frac{dz}{E(z)}} \qquad r_s = \int_0^{t_d} c_s dt/a = \int_0^{a_d} c_s \frac{da}{a^2 H(a)}$$

Assumptions: P18ΛCDM E(z), Standard expansion before z_{rec}

$$H_0^{\rm P18} = 67.36 \pm 0.54 \text{ km s}^{-1}\text{Mpc}^{-1}$$

$$\mathcal{M} = M + 5log\frac{c/H_0}{Mpc} + 25 \qquad \mathcal{M}_{z>0.01} = 23.80 \pm 0.01$$

M tension.

$$M^{P18}_{z>0.01} = -19.401 \pm 0.027 < M^{R20}_{z<0.01} = -19.244 \pm 0.037$$

M depends on G_{eff}.

H_0 measurement using distance ladder:

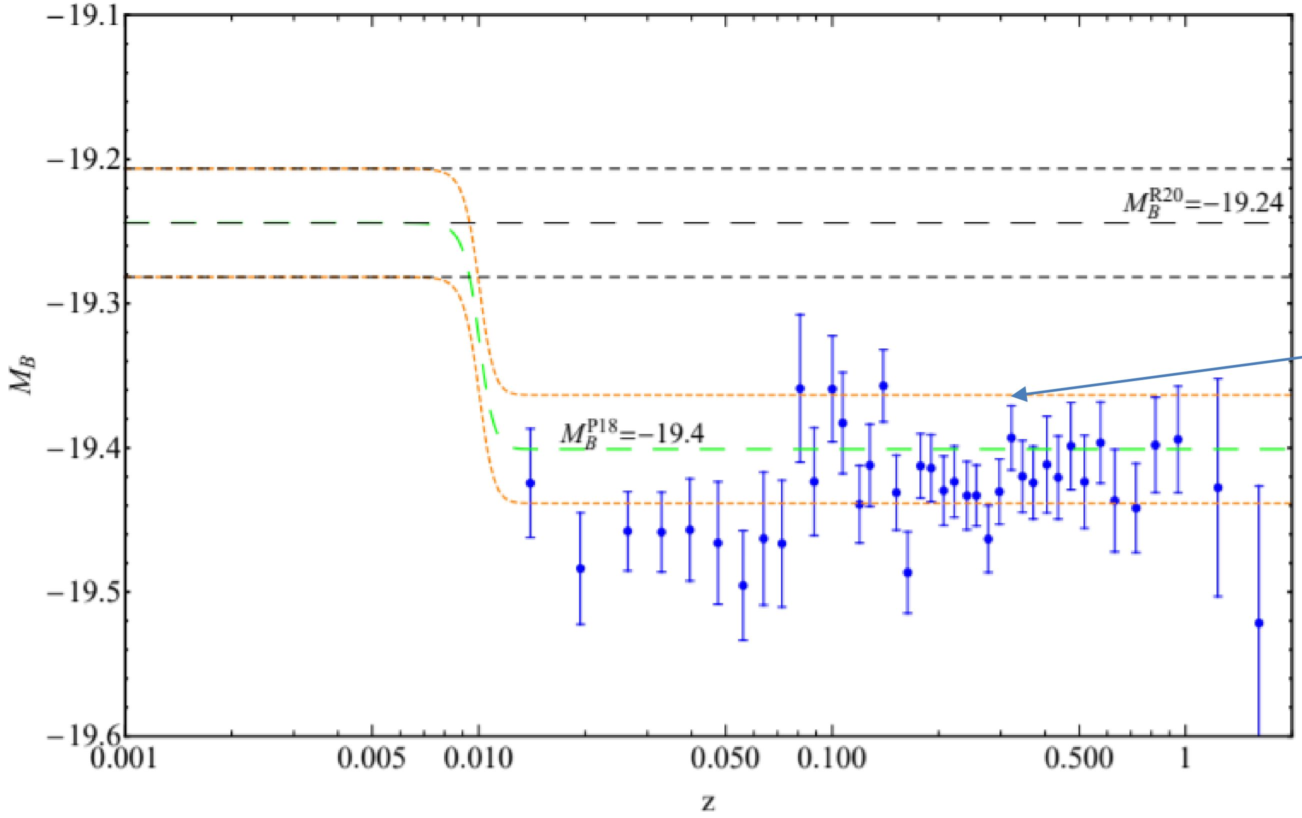
$$\left.\begin{aligned} \mathcal{M}_{z>0.01} &= 23.80 \pm 0.01 \\ M^{R20}_{z<0.01} &= -19.244 \pm 0.037 \end{aligned}\right\} \quad \begin{aligned} &\mathcal{M} = M + 5log\frac{c/H_0}{Mpc} + 25 \\ &M_{z>0.01} = M^{R20}_{z<0.01} \\ &G_{\rm eff}(z<0.01) = G_{\rm eff}(z>0.01) \end{aligned}$$

H_0 Tension

$$H_0^{\rm R20} = 73.2 \pm 1.3 \text{ km s}^{-1}\text{Mpc}^{-1} > H_0^{\rm P18} = 67.36 \pm 0.54 \text{ km s}^{-1}\text{Mpc}^{-1}$$

Assumption: $G_{eff}(z<0.01)=G_{eff}(z>0.01)$

The M transition hypothesis



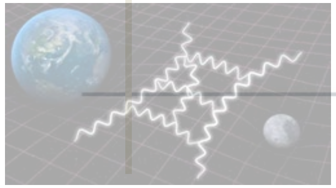
$$M_i = m(z_i) + 5\log_{10}\left[H_0^{P18}\cdot \mathrm{Mpc}/c\right] - 5\log_{10}(D_L(z_i)) - 25$$

A fundamental physics transition induces a transition of M (absolute magnitude or luminosity) at $z<0.01$.

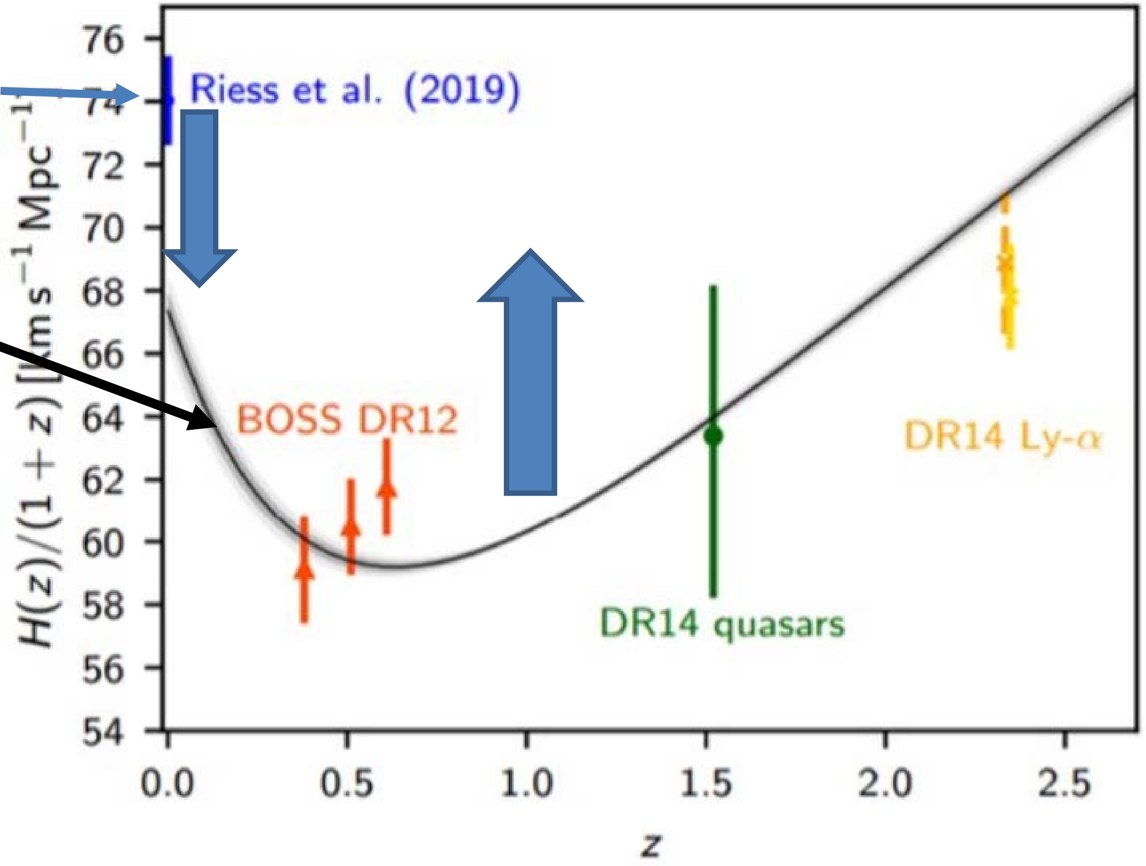
Resolves M tension and Hubble tension.

Can potentially also resolve growth tension if the transition is connected with weaker gravity at $z>z_t$

The Hubble Crisis Approaches



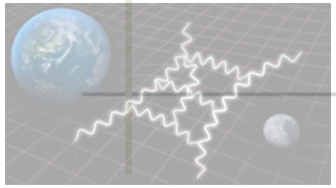
How can H(z) derived from late time calibrators (blue point) become consistent with H(z) derived from early time calibrator (black line)?



Change SnIa Intrinsic Luminosity.
(move blue point down)

Change sound horizon scale.
(shift black line up)

The Hubble Crisis Approaches

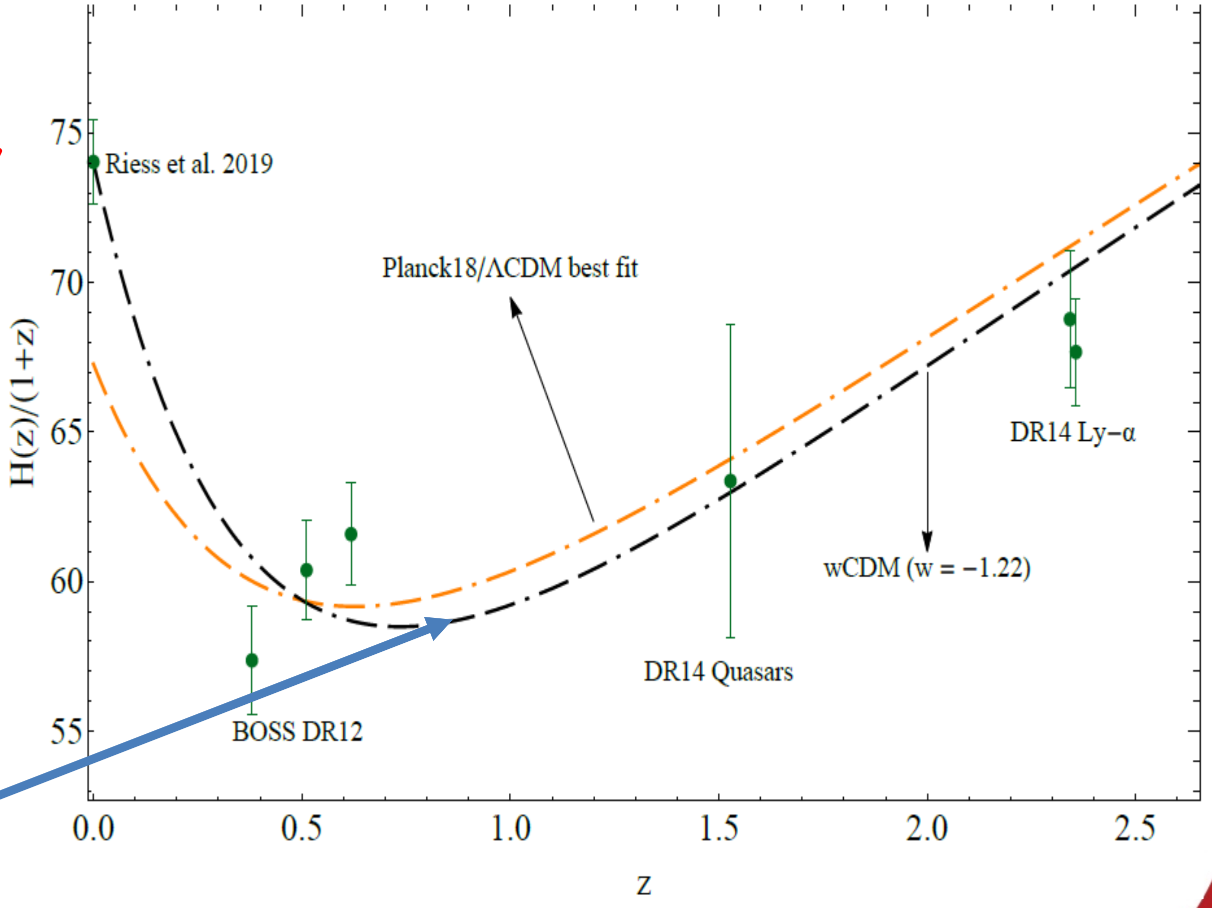


How can H(z) derived from late time calibrators (blue point) become consistent with H(z) derived from early time calibrator (black line)?

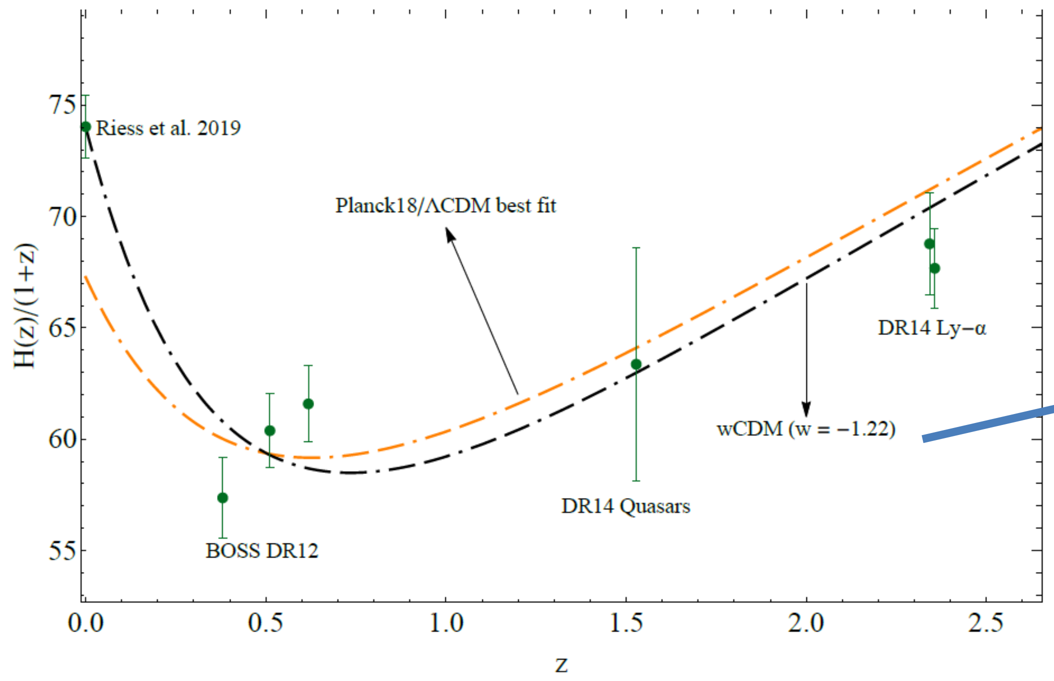
Change SnIa Intrinsic Luminosity.
(move blue point down)

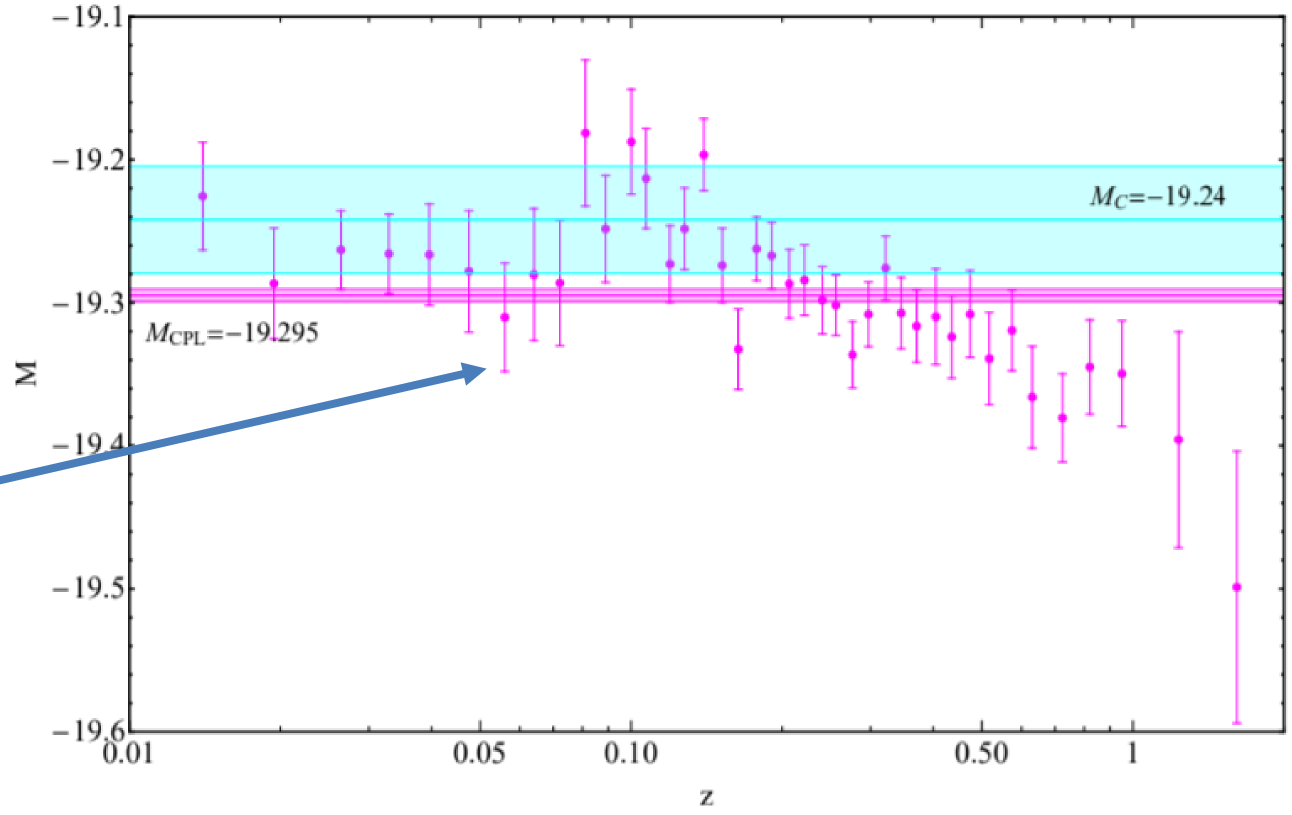
Change sound horizon scale.
(shift black line up)

Deform H(z) by eg dynamical dark energy.
(distort black line)



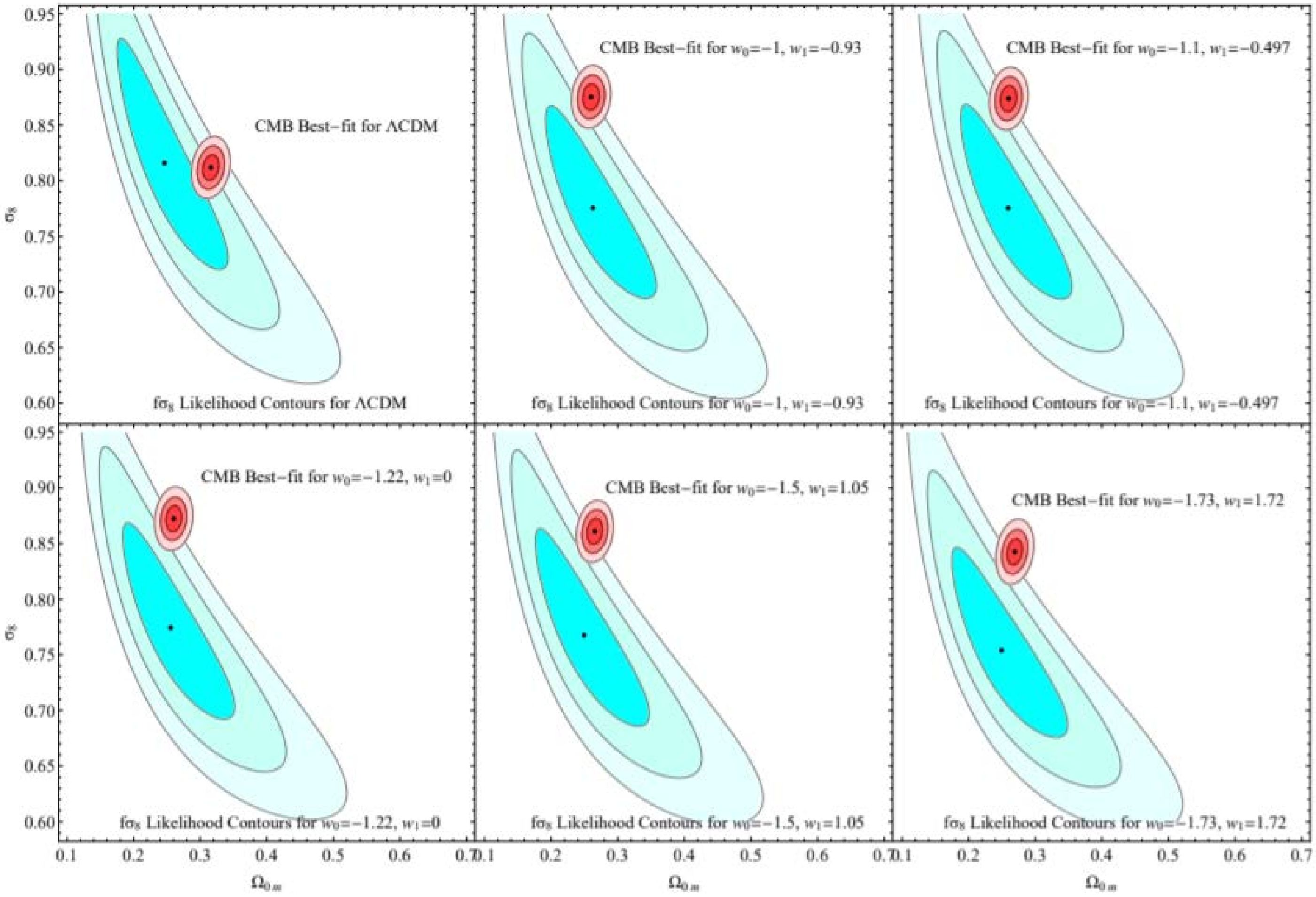
The M problem of H(z) deformations





$$m(z_i) = M - 5\log_{10}\left[H_0 \cdot \mathrm{Mpc}/c\right] + 5\log_{10}(D_L(z_i)) + 25 \;\Rightarrow\; M_i = m(z_i) + 5\log_{10}\left[H_0^{R19} \cdot \mathrm{Mpc}/c\right] - 5\log_{10}(D_L(z_i)) - 25$$

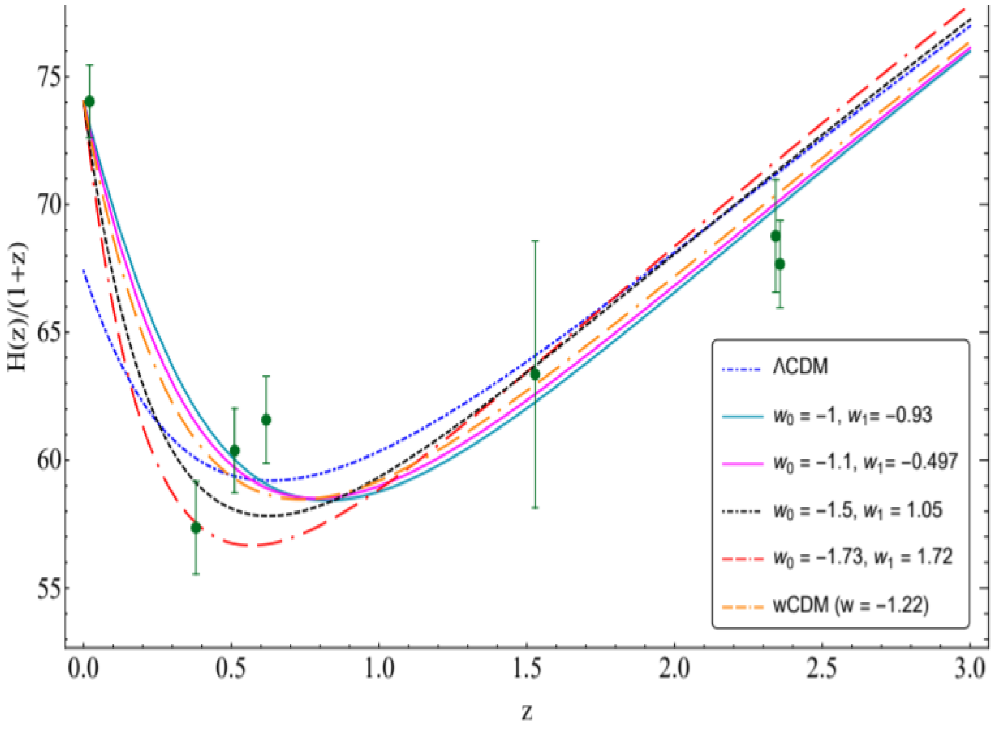
The growth problem of H(z) deformations



Late time approaches to the Hubble tension deforming $H(z)$, worsen the growth tension

George Alestas (Ioannina U.), Leandros Perivolaropoulos (Ioannina U.) (Mar 6, 2021)

e-Print: 2103.04045 [astro-ph.CO]



Construct H(z) deformations that appear to resolve the H_0 tension

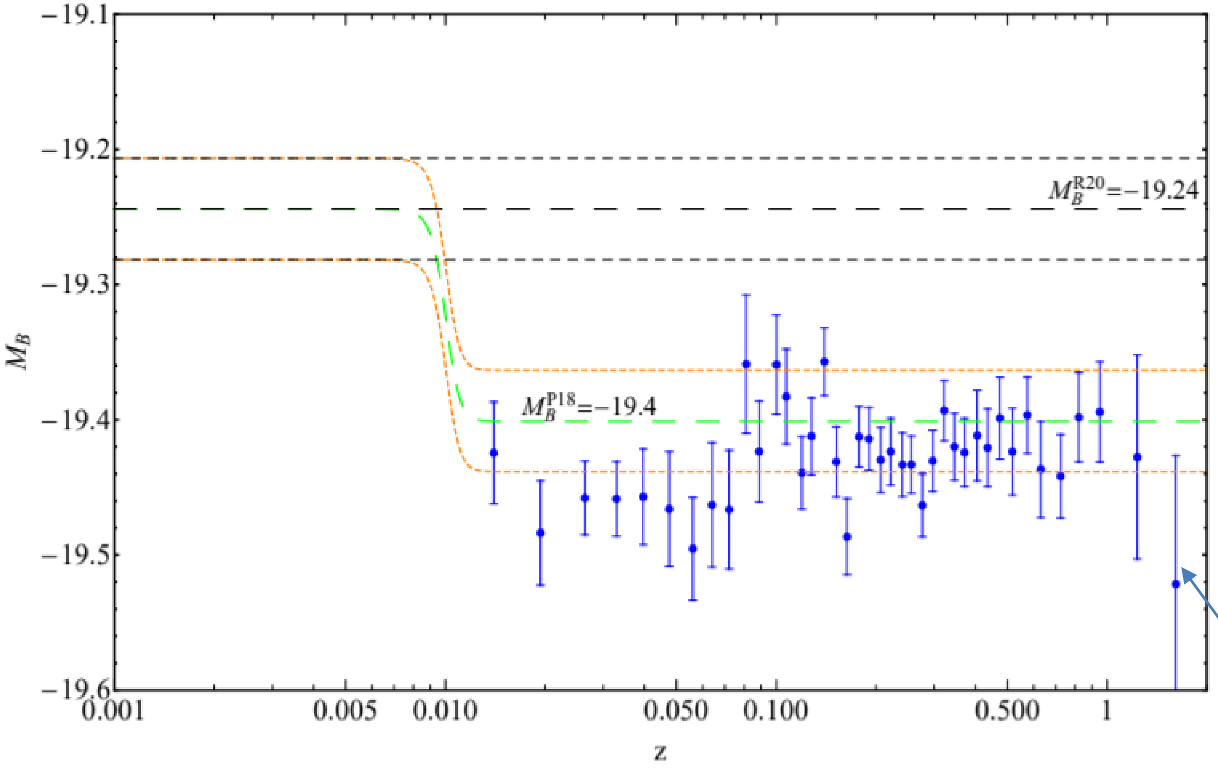
$$H^2\,\delta_m'' + \left(\frac{(H^2)'}{2} - \frac{H^2}{1+z}\right)\delta_m' \approx \frac{3}{2}(1+z)H_0^2\frac{G_{\rm eff}(z)}{G_{N,0}}\,\Omega_{m,0}\,\delta_m$$

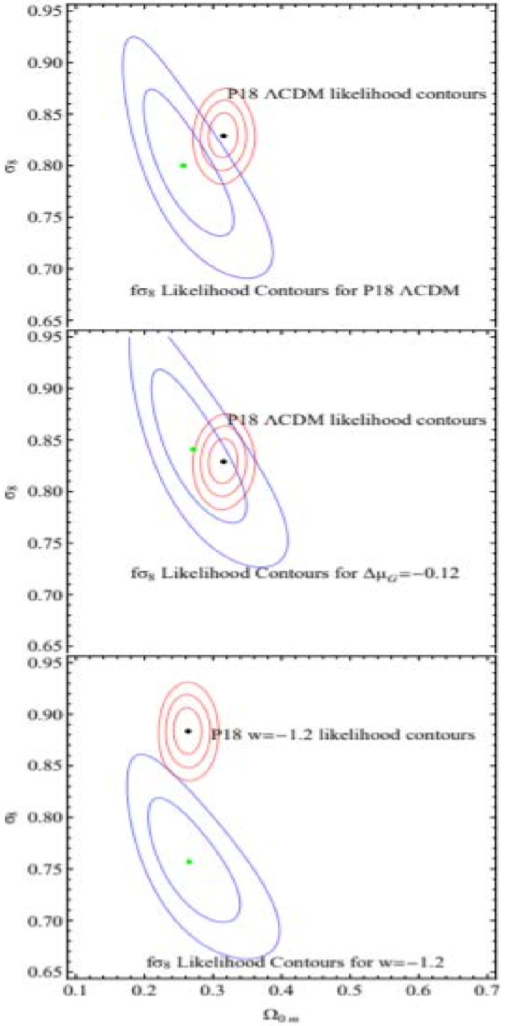
H_0 tension, phantom dark energy, and cosmological parameter degeneracies

G. Alestas (Ioannina U.), L. Kazantzidis (Ioannina U.), L. Perivolaropoulos (Ioannina U.) (Apr 23, 2020)

Published in: *Phys.Rev.D* 101 (2020) 12, 123516 • e-Print: 2004.08363 [astro-ph.CO]

Gravitational Transition





The reduced value of G_{eff} leads to a higher σ_8 value thus resolving the growth tension

X^2 problem is resolved.
Growth tension resolved.
M problem resolved

A 10% transition of G_{eff} is required for the reproduction of the required ΔM~0.2 for a pure Planck/ΛCDM background.

SnIa luminosities in the context of a Planck/ΛCDM background

A rapid transition of $G_{\rm eff}$ at $z_t \simeq 0.01$ as a solution of the Hubble and growth tensions

Valerio Marra, Leandros Perivolaropoulos (Feb 11, 2021)

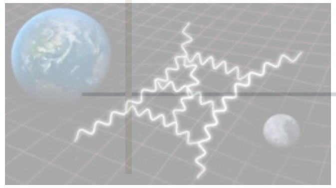
e-Print: 2102.06012 [astro-ph.CO]

$$\mu \equiv \frac{G_{\rm eff}}{G_N}$$

$$L \sim G_{\rm eff}^b \quad \Longrightarrow \quad \Delta M = \frac{15}{4} log_{10}\left(\mu\right)$$

$$L \sim M_{Chandr} \sim G^{-3/2}$$

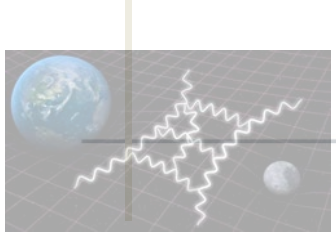
Main Questions



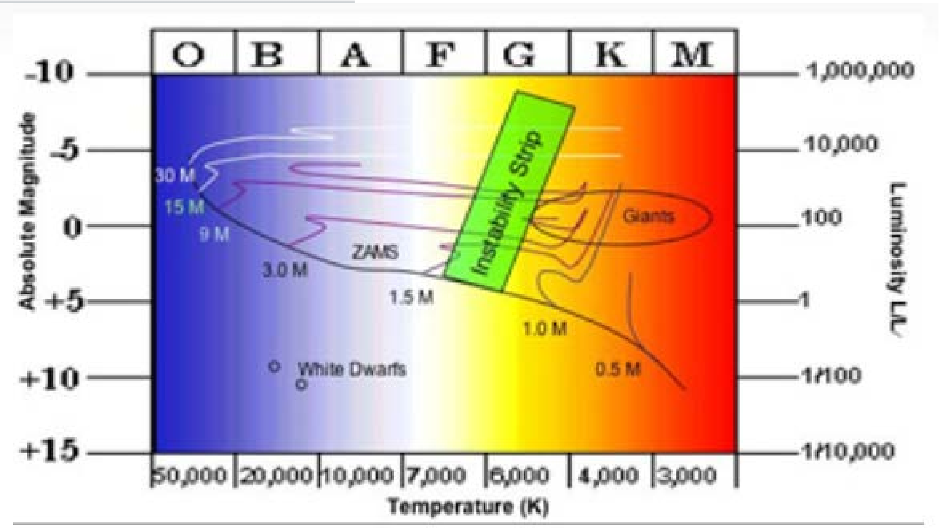
Are there hints for a gravitational fundamental physics transition is astrophysical data on scales less than 40Mpc (z_t<0.01)?

Are there theoretical models that naturally and generically predict this type of transition?

Cepheid Calibrators



Stars more massive than the Sun enter the instability strip and become variable suffering instabilities that cause them to pulsate in size and vary in luminosity.



Cepheid variable stars: Good standard candles:

high luminosity up to 40,000 times more luminous than the Sun obtained from a Period-Luminosity Relation.

Cepheid Period-Magnitude relation:

$$m_H - R_H E(V-I) = \mu + M_H + b_H[P] + Z_H[M/H]$$

$$\Big\downarrow \; E(V-I) \to V-I$$

$$E(V-I) \equiv A_V - A_I = (V-I) - (V-I)_0$$

$$[P] \equiv \log P - 1$$

$$[M/H] \equiv \log(M/H) - \log(M/H)_\odot = \Delta \log(M/H)$$

Wesenheit

$$m_H^W \equiv m_H - R_W(V-I) = \mu + M_H^W + b_W[P] + Z_W[M/H]$$

Calibrating SnIa with Cepheids

R_W

Use the following system of equations fit for unknown parameters

$$m^W_{H,i,j} \equiv m_{H,i,j} - R_W(V-I)_{i,j} = \mu_i + M^W_H + b^s_W[P]^s_{i,j} + b^l_W[P]^l_{i,j} + Z_W[M/H]_{i,j}$$

$$m_{B,i} = \mu_i + M_B$$

output

jth Cepheid in ith galaxy

For the anchors MW, NGC4258 and LMC the distance moduli are also measured with other methods (parallaxes (MW), water maser (NGC4258), eclipsing binaries (LMC))

$$\mathbf{Y} = \begin{pmatrix} m_{\pi,j} \\ m_{H,1,j} \\ \vdots \\ m_{H,19,j} \\ m_{H,N4258,j} \\ m_{H,M31,j} \\ m_{H,LMC,j} \\ \mu_{N4258} \\ \mu_{LMC} \\ m_{B,1} \\ \vdots \\ m_{B,19} \end{pmatrix} \qquad \mathbf{X} = \begin{pmatrix} R_{W,LMC} \\ R_{W,MW} \\ R_{W,1} \\ \vdots \\ R_{W,19} \\ R_{W,N4258} \\ R_{W,M31} \\ \mu_1 \\ \vdots \\ \mu_{19} \\ \mu_{N4258} \\ \mu_{M31} \\ \mu_{LMC} \\ M^W_{H,MW} \\ M^W_{H,1} \\ \vdots \\ M^W_{H,19} \\ M^W_{H,N4258} \\ M^W_{H,M31} \\ M^W_{H,LMC} \\ b^s_W \\ b^l_W \\ Z_W \\ zp \\ M_B \end{pmatrix}$$

input

output

Express the system as linear vector transformation

$$M^{R20}_{z<0.01} = -19.244 \pm 0.037$$

$$\mathbf{Y} = \mathbf{AX}$$

Minimize χ^2: $\chi^2 = (\mathbf{Y} - \mathbf{AX})^{\mathbf{T}}\mathbf{C}^{-1}(\mathbf{Y} - \mathbf{AX})$

Generalized Approach I: Individual Galaxy Parameters

Allow for variation of the color-luminosity parameter R_W among individual galaxies

$$m_{H,i,j}^W \equiv m_{H,i,j} - R_{W,i}(V-I)_{i,j} = \mu_i + M_H^W + b_W^s[P]_{i,j}^s + b_W^l[P]_{i,j}^l + Z_W[M/H]_{i,j}$$

$$m_{B,i} = \mu_i + M_B$$

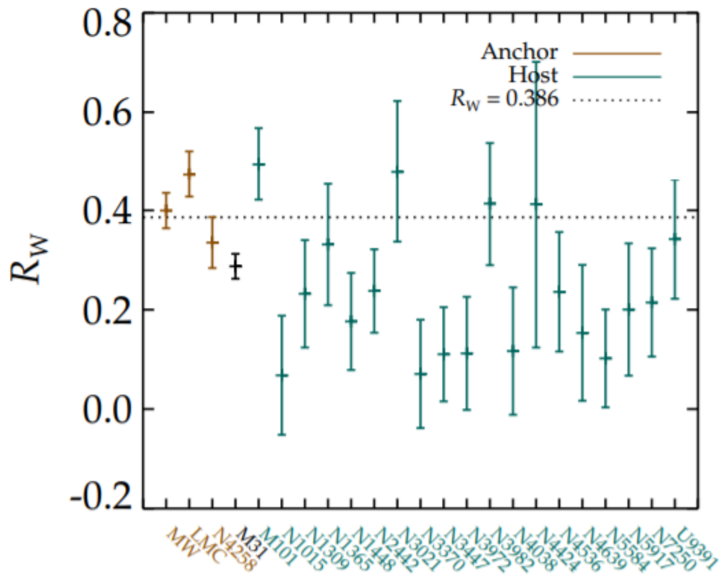
output

jth Cepheid in ith galaxy

$$\mathbf{Y} = \begin{pmatrix} m_{\pi,j} \\ m_{H,1,j} \\ \vdots \\ m_{H,19,j} \\ m_{H,N4258,j} \\ m_{H,M31,j} \\ m_{H,LMC,j} \\ \mu_{N4258} \\ \mu_{LMC} \\ m_{B,1} \\ \vdots \\ m_{B,19} \end{pmatrix} \qquad \mathbf{X} = \begin{pmatrix} R_{W,LMC} \\ R_{W,MW} \\ R_{W,1} \\ \vdots \\ R_{W,19} \\ R_{W,N4258} \\ R_{W,M31} \\ \mu_1 \\ \vdots \\ \mu_{19} \\ \mu_{N4258} \\ \mu_{M31} \\ \mu_{LMC} \\ M_{H,MW}^W \\ M_{H,1}^W \\ \vdots \\ M_{H,19}^W \\ M_{H,N4258}^W \\ M_{H,M31}^W \\ M_{H,LMC}^W \\ b_W^s \\ b_W^l \\ Z_W \\ zp \\ M_B \end{pmatrix}$$

input

output



Hints for a transition in R_W.

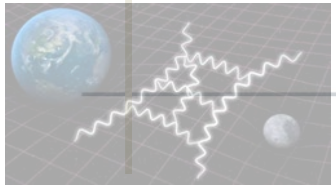
Problem: Too many new parameters

The Hubble Tension Bites the Dust: Sensitivity of the Hubble Constant Determination to Cepheid Color Calibration

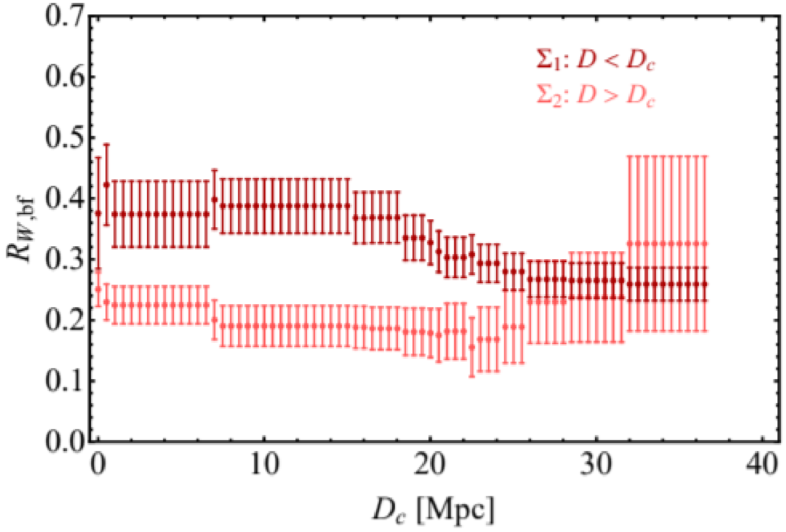
Edvard Mortsell, Ariel Goobar, Joel Johansson, Suhail Dhawan (May 24, 2021)

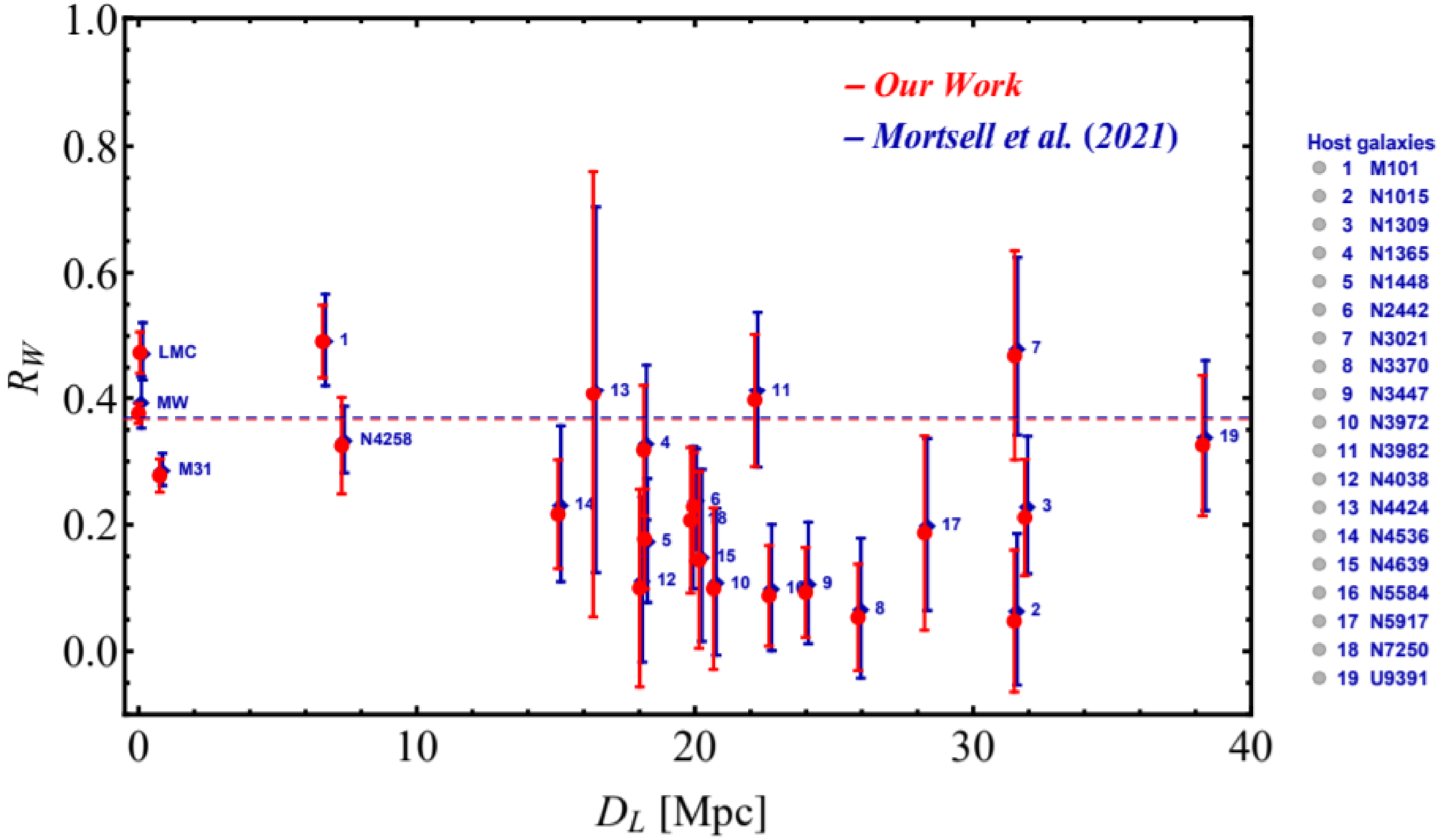
e-Print: 2105.11461 [astro-ph.CO]

Allow different parameter variations: Search for Transition



I. Repeat previous study for consistency





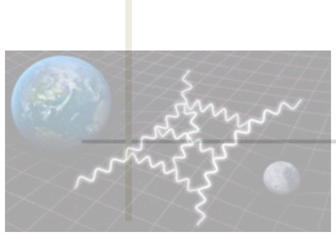
3σ indication for a transition at $10\text{Mpc} < D_c < 20\text{Mpc}$

Hubble tension or a transition of the Cepheid SnIa calibrator parameters?

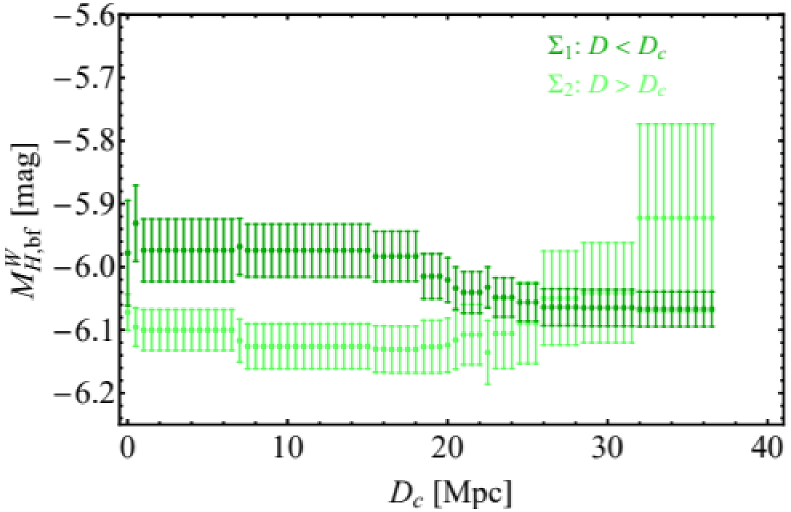
Leandros Perivolaropoulos (Ioannina U.), Foteini Skara (Ioannina U.) (Sep 9, 2021)

e-Print: 2109.04406 [astro-ph.CO]

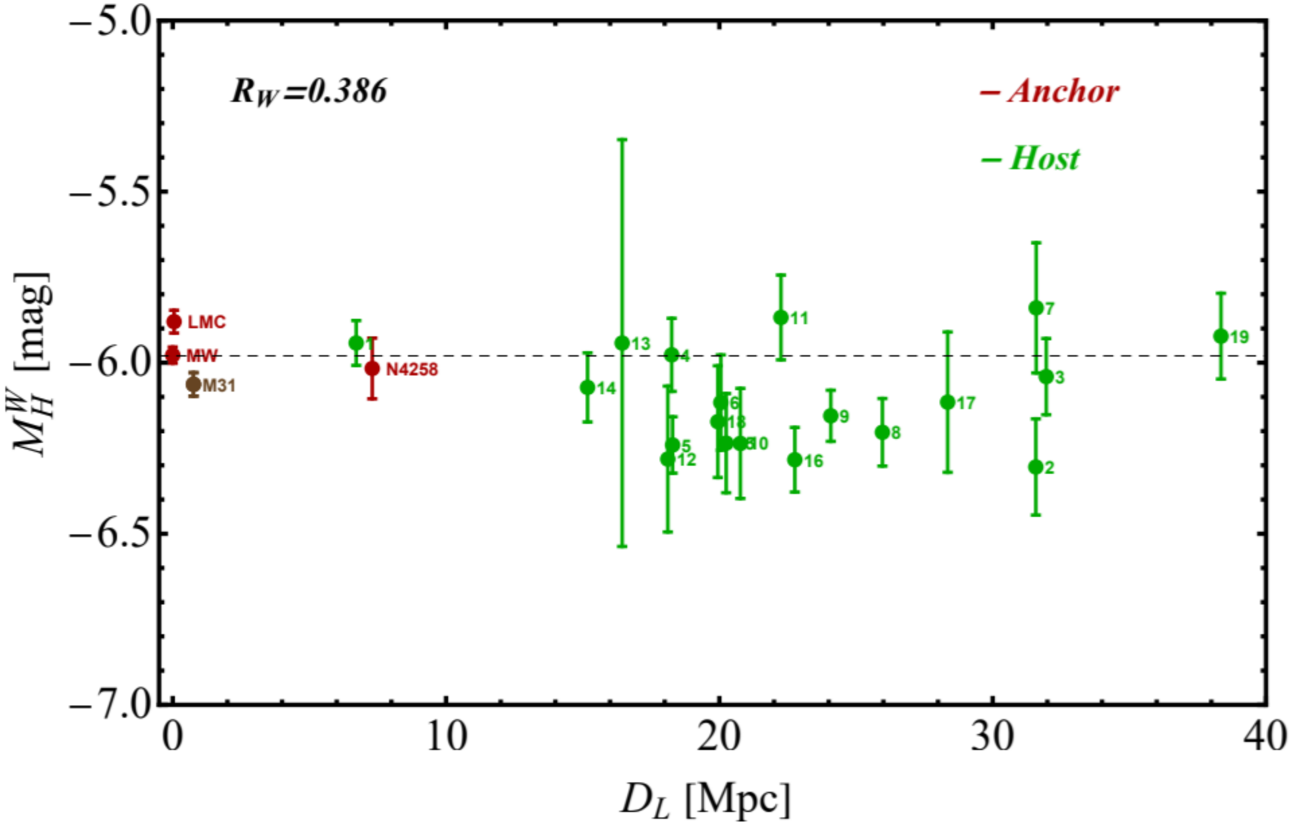
Allow different parameter variations: Search for Transition



II. Allow for variation of absolute magnitude in individual galaxies



3σ indication for a transition at $10\mathrm{Mpc} < D_c < 20\mathrm{Mpc}$ with $\Delta M \sim 0.15$



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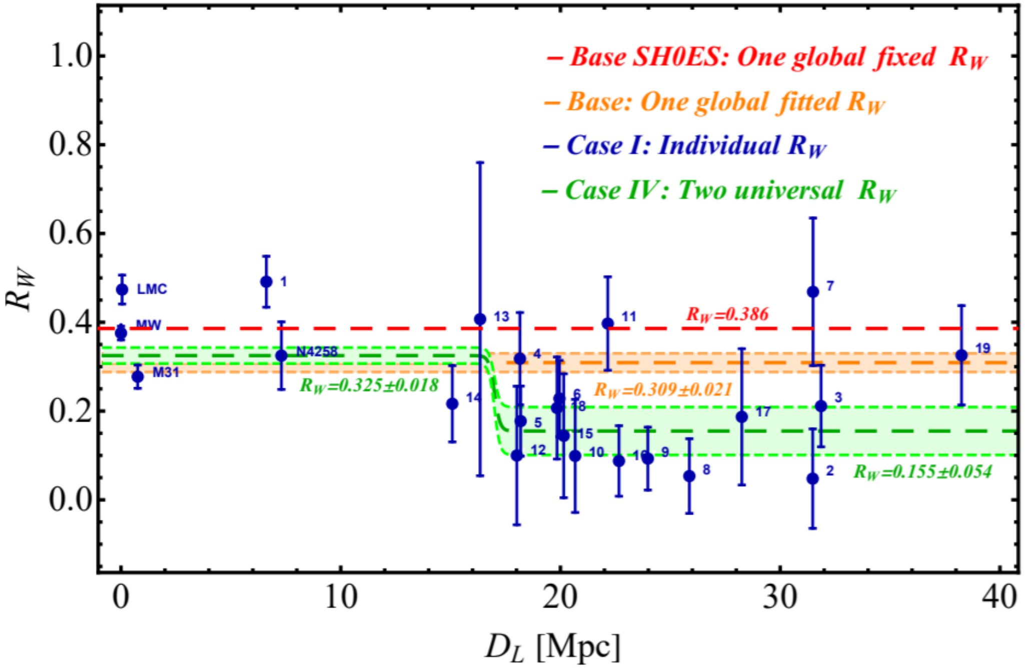
e-Print: 2109.04406 [astro-ph.CO]

R_W Transition Model: Single new parameter

$$AIC = -2ln\mathcal{L}_{max} + 2M = \chi^2_{min} + 2M$$

$$BIC = -2ln\mathcal{L}_{max} + MlnN = \chi^2_{min} + MlnN$$

Model	Best Fit Parameters (with 1σ ranges) $\sigma_{LMC} = 0.08$ ($\sigma_{LMC} = 0$)	Model Selection Criteria	Intrinsic scatter of LMC Cepheids $\sigma_{LMC} = 0$	 $\sigma_{LMC} = 0.08$
Base-SH0ES Global R_W Global M_H^W $N = 1650$ $M = 28$ $dof = 1622$	$R_W = 0.386$ (fixed) $M_H^W = -5.958 \pm 0.028$ $\mathbf{M_B = -19.251 \pm 0.057}$ ($M_B = -19.261 \pm 0.057$) $\mathbf{H_0 = 72.86 \pm 1.95}$, $\mathbf{H_0 = 73.50 \pm 1.96}$ ($H_0 = 72.53 \pm 1.93$, $H_0 = 73.17 \pm 1.94$)	χ^2_{min} χ^2_{red} AIC ΔAIC BIC ΔBIC	1767.48 1.089 1823.48 7.65 (0) 1974.92 2.25 (0)	1644.79 1.014 1700.79 17.97 (0) 1852.23 12.57 (0)
IV Two universal R_W Global M_H^W $N = 1650$ $M = 30$ $dof = 1620$	$R_W^< = 0.325 \pm 0.018$ $R_W^> = 0.155 \pm 0.054$ $M_H^W = -5.885 \pm 0.028$ $\mathbf{M_B = -19.399 \pm 0.057}$ ($M_B = -19.447 \pm 0.054$) $\mathbf{H_0 = 68.06 \pm 1.80}$, $\mathbf{H_0 = 68.66 \pm 1.81}$ ($H_0 = 66.59 \pm 1.66$, $H_0 = 67.17 \pm 1.67$)	χ^2_{min} χ^2_{red} AIC ΔAIC BIC ΔBIC	1744.19 1.077 1804.19 -13.34 (-18.99) 1966.44 -6.23 (-8.48)	1611.65 0.995 1671.46 -11.36 (-29.33) 1833.91 -5.75 (-18.32)



M_B and H_0 become consistent with CMB and inverse distance ladder.

Favored by model selection criteria

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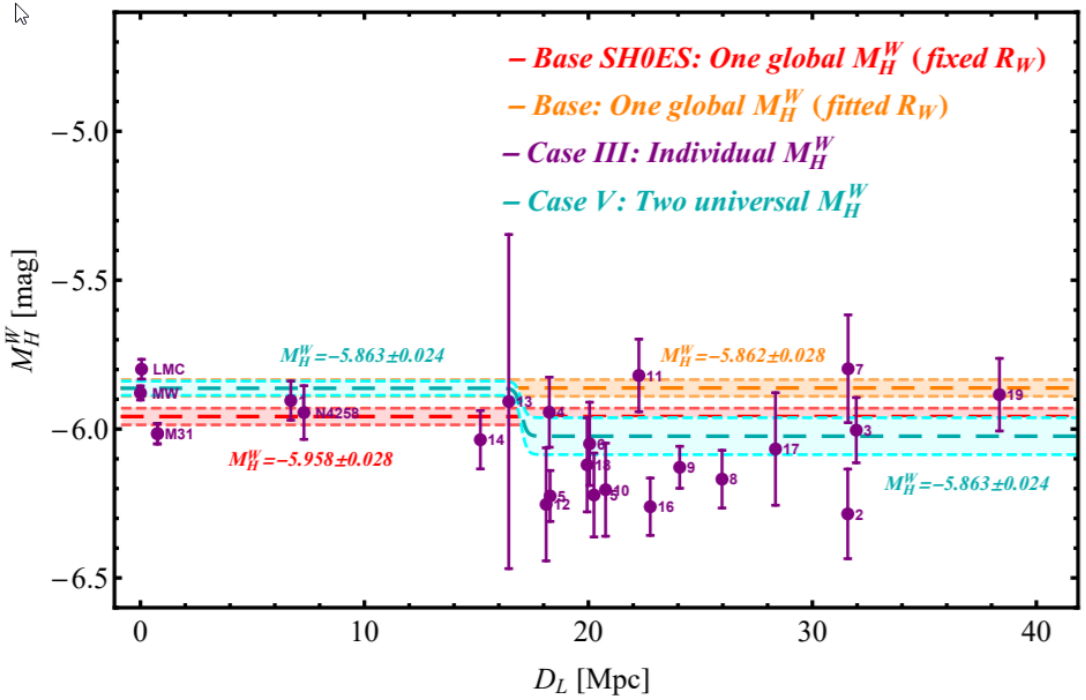
M_W Transition Model

Model	Best Fit Parameters (with 1σ ranges) $\sigma_{LMC}=0.08$ ($\sigma_{LMC}=0$)	Model Selection Criteria	Intrinsic scatter of LMC Cepheids $\sigma_{LMC}=0$	$\sigma_{LMC}=0.08$
Base-SH0ES	$R_W=0.386$ (fixed)	χ^2_{min}	1767.48	1644.79
Global R_W	$M_H^W=-5.958\pm0.028$	χ^2_{red}	1.089	1.014
Global M_H^W	$\mathbf{M_B=-19.251\pm0.057}$	AIC	1823.48	1700.79
$N=1650$	($M_B=-19.261\pm0.057$)	ΔAIC	7.65 (0)	17.97 (0)
$M=28$	$\mathbf{H_0=72.86\pm1.95}$, $\mathbf{H_0=73.50\pm1.96}$	BIC	1974.92	1852.23
$dof=1622$	($H_0=72.53\pm1.93$, $H_0=73.17\pm1.94$)	ΔBIC	2.25 (0)	12.57 (0)

V	$R_W=0.308\pm0.021$	χ^2_{min}	1757.15	1621.98
Global R_W	$M_H^{W,<}=-5.863\pm0.024$	χ^2_{red}	1.085	1.001
Two universal M_H^W	$M_H^{W,<}=-6.024\pm0.062$	AIC	1817.15	1681.98
$N=1650$	$\mathbf{M_B=-19.361\pm0.057}$	ΔAIC	1.32 (-6.33)	-0.84 (-18.81)
$M=30$	($M_B=-19.399\pm0.057$)	BIC	1979.41	1844.23
$dof=1620$	$\mathbf{H_0=69.27\pm1.82}$, $\mathbf{H_0=69.88\pm1.83}$ ($H_0=68.06\pm1.81$, $H_0=68.65\pm1.82$)	ΔBIC	6.74 (4.49)	4.57 (-8.0)



M_B and H_0 become consistent with CMB and inverse distance ladder.

Favored by model selection criteria

Hubble tension or a transition of the Cepheid SnIa calibrator parameters?

Leandros Perivolaropoulos (Ioannina U.), Foteini Skara (Ioannina U.) (Sep 9, 2021)

e-Print: 2109.04406 [astro-ph.CO]

Model Selection

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$M=28$	$\mathbf{H_0=72.86\pm1.95}$, $\mathbf{H_0=73.50\pm1.96}$	BIC	1974.92	1852.23
$dof=1622$	($H_0=72.53\pm1.93$, $H_0=73.17\pm1.94$)	ΔBIC	2.25 (0)	12.57 (0)
Base	$R_W=0.309\pm0.021$	χ^2_{min}	1759.47	1624.82
Global R_W	$M_H^W=-5.862\pm0.028$	χ^2_{red}	1.084	1.002
Global M_H^W	$\mathbf{M_B=-19.225\pm0.057}$	AIC	1815.83	1682.82
$N=1650$	($M_B=-19.246\pm0.054$)	ΔAIC	0 (-7.65)	0 (-17.97)
$M=29$	$\mathbf{H_0=73.73\pm1.96}$, $\mathbf{H_0=74.38\pm1.97}$	BIC	1972.67	1839.66
$dof=1621$	($H_0=73.03\pm1.86$, $H_0=73.67\pm1.86$)	ΔBIC	0 (-2.25)	0 (-12.57)
	$R_{W,i}$ red points in Fig. 3			
I	$R_W^<=0.388\pm0.045$ (using DSS)	χ^2_{min}	1676.76	1564.06
Individual R_W	$R_W^>=0.206\pm0.033$ (using DSS)	χ^2_{red}	1.049	0.978
Global M_H^W	$M_H^W=-5.958\pm0.028$	AIC	1778.76	1666.06
$N=1650$	$\mathbf{M_B=-19.43\pm0.056}$	ΔAIC	-37.07 (-44.72)	-16.76 (-34.73)
$M=51$	($M_B=-19.491\pm0.056$)	BIC	2054.59	1941.9
$dof=1599$	$\mathbf{H_0=67.11\pm1.76}$, $\mathbf{H_0=67.69\pm1.77}$	ΔBIC	81.92 (79.67)	102.24 (89.74)
	($H_0=65.24\pm1.71$, $H_0=65.81\pm1.72$)			
	$R_W=0.386$ (fixed)			
II	$M_{H,i}^W$ points in Fig. 6	χ^2_{min}	1732.05	1611.04
Global R_W	$M_H^{W,<}=-5.974\pm0.042$ (using DSS)	χ^2_{red}	1.083	1.007
Individual M_H^W	$M_H^{W,>}=-6.126\pm0.036$ (using DSS)	AIC	1832.05	1711.04
$N=1650$	$\mathbf{M_B=-19.394\pm0.057}$	ΔAIC	16.22 (8.57)	28.22 (10.25)
$M=50$	($M_B=-19.404\pm0.055$)	BIC	2102.48	1981.47
$dof=1600$	$\mathbf{H_0=68.22\pm1.82}$, $\mathbf{H_0=68.82\pm1.83}$	ΔBIC	129.81 (127.56)	141.81 (129.24)
	($H_0=67.90\pm1.75$, $H_0=68.50\pm1.76$)			
	$R_W=0.310\pm0.021$			
III	$M_{H,i}^W$ points in Fig. 11	χ^2_{min}	1726.7	1592.09
Global R_W	$M_H^{W,<}=-5.904\pm0.042$ (using DSS)	χ^2_{red}	1.079	0.996
Individual M_H^W	$M_H^{W,<}=-6.092\pm0.035$ (using DSS)	AIC	1828.7	1694.09
$N=1650$	$\mathbf{M_B=-19.428\pm0.057}$	ΔAIC	12.87 (5.22)	11.27 (-6.7)
$M=51$	($M_B=-19.424\pm0.056$)	BIC	2104.53	1969.93
$dof=1599$	$\mathbf{H_0=67.17\pm1.79}$, $\mathbf{H_0=67.76\pm1.80}$	ΔBIC	131.86 (129.61)	130.27 (117.7)
	($H_0=67.28\pm1.75$, $H_0=67.87\pm1.76$)			
IV	$R_W^<=0.325\pm0.018$	χ^2_{min}	1744.19	1611.65
Two universal R_W	$R_W^>=0.155\pm0.054$	χ^2_{red}	1.077	0.995
Global M_H^W	$M_H^W=-5.885\pm0.028$	AIC	1804.19	1671.46
$N=1650$	$\mathbf{M_B=-19.399\pm0.057}$	ΔAIC	-13.34 (-18.99)	-11.36 (-29.33)
$M=30$	($M_B=-19.447\pm0.054$)	BIC	1966.44	1833.91
$dof=1620$	$\mathbf{H_0=68.06\pm1.80}$, $\mathbf{H_0=68.66\pm1.81}$	ΔBIC	-6.23 (-8.48)	-5.75 (-18.32)
	($H_0=66.59\pm1.66$, $H_0=67.17\pm1.67$)			
V	$R_W=0.308\pm0.021$	χ^2_{min}	1757.15	1621.98
Global R_W	$M_H^{W,<}=-5.863\pm0.024$	χ^2_{red}	1.085	1.001
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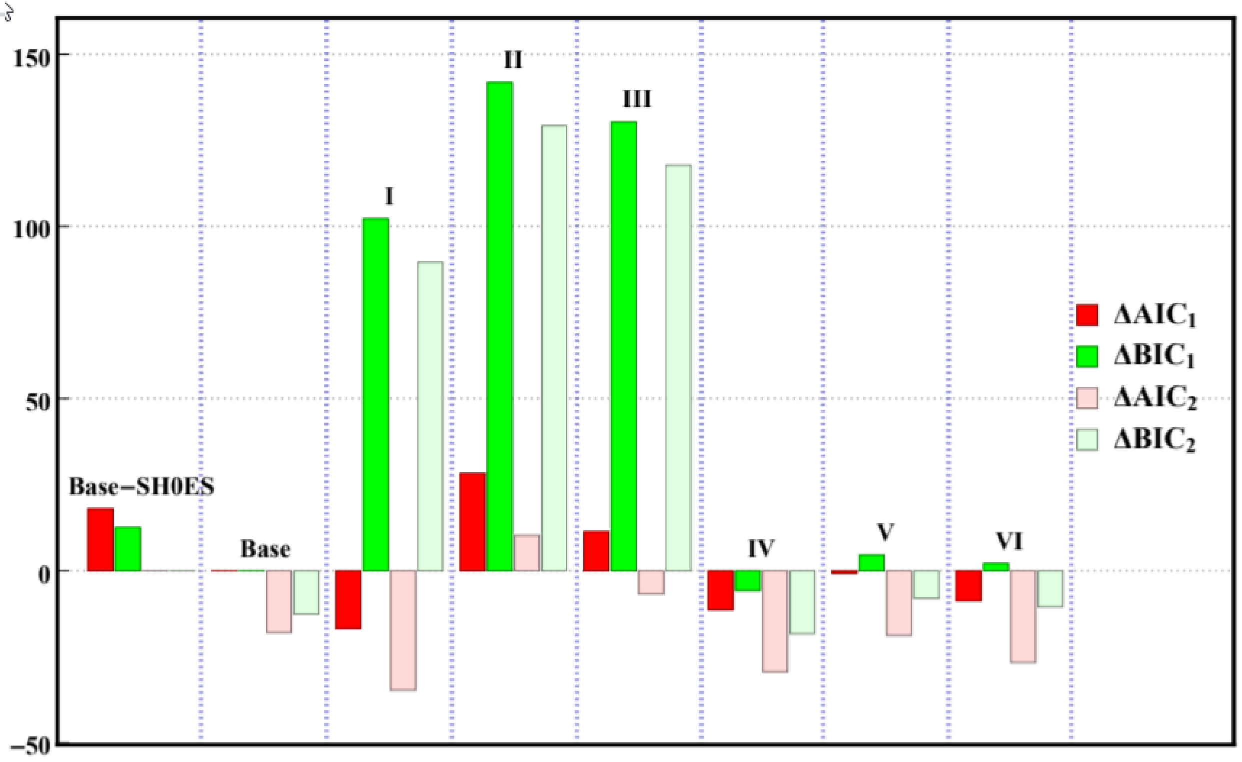
$M=30$	($M_B=-19.399\pm0.057$)	BIC	1979.41	1844.23
$dof=1620$	$\mathbf{H_0=69.27\pm1.82}$, $\mathbf{H_0=69.88\pm1.83}$	ΔBIC	6.74 (4.49)	4.57 (-8.0)
	($H_0=68.06\pm1.81$, $H_0=68.65\pm1.82$)			
	$R_W^<=0.329\pm0.018$			
VI	$R_W^>=0.151\pm0.053$	χ^2_{min}	1743.26	1612.09
Two universal R_W	$M_H^{W,<}=-5.891\pm0.024$	χ^2_{red}	1.077	0.996
Two universal M_H^W	$M_H^{W,>}=-5.900\pm0.063$	AIC	1805.26	1674.09
$N=1650$	$\mathbf{M_B=-19.413\pm0.052}$	ΔAIC	-10.57 (-18.22)	-8.73 (-26.7)
$M=31$	($M_B=-19.379\pm0.056$)	BIC	1972.93	1841.75
$dof=1619$	$\mathbf{H_0=67.62\pm1.64}$, $\mathbf{H_0=68.22\pm1.65}$	ΔBIC	0.26 (-1.99)	2.09 (-10.48)
	($H_0=68.70\pm1.81$, $H_0=69.30\pm1.81$)			



Hubble tension or a transition of the Cepheid SnIa calibrator parameters?

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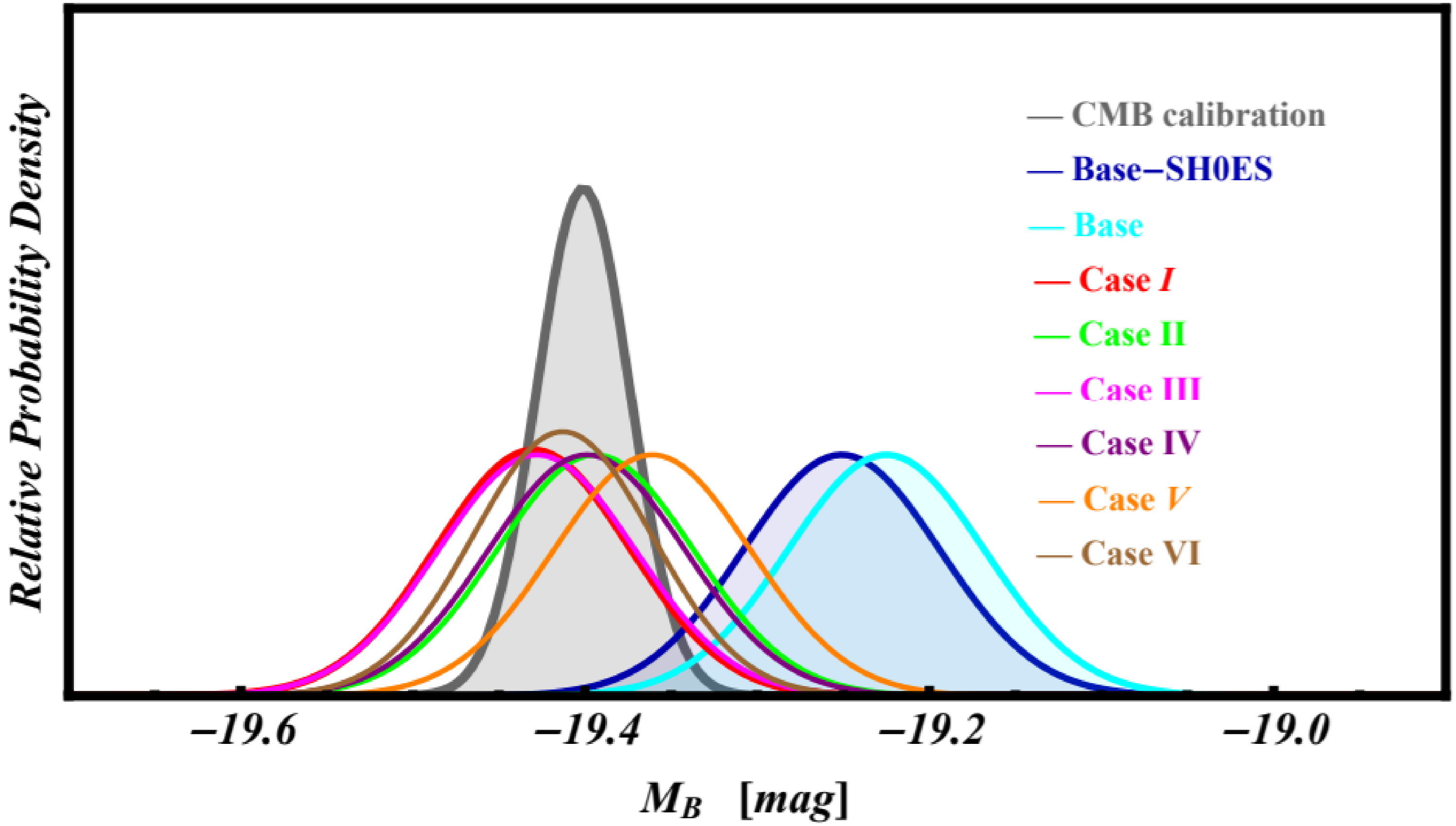
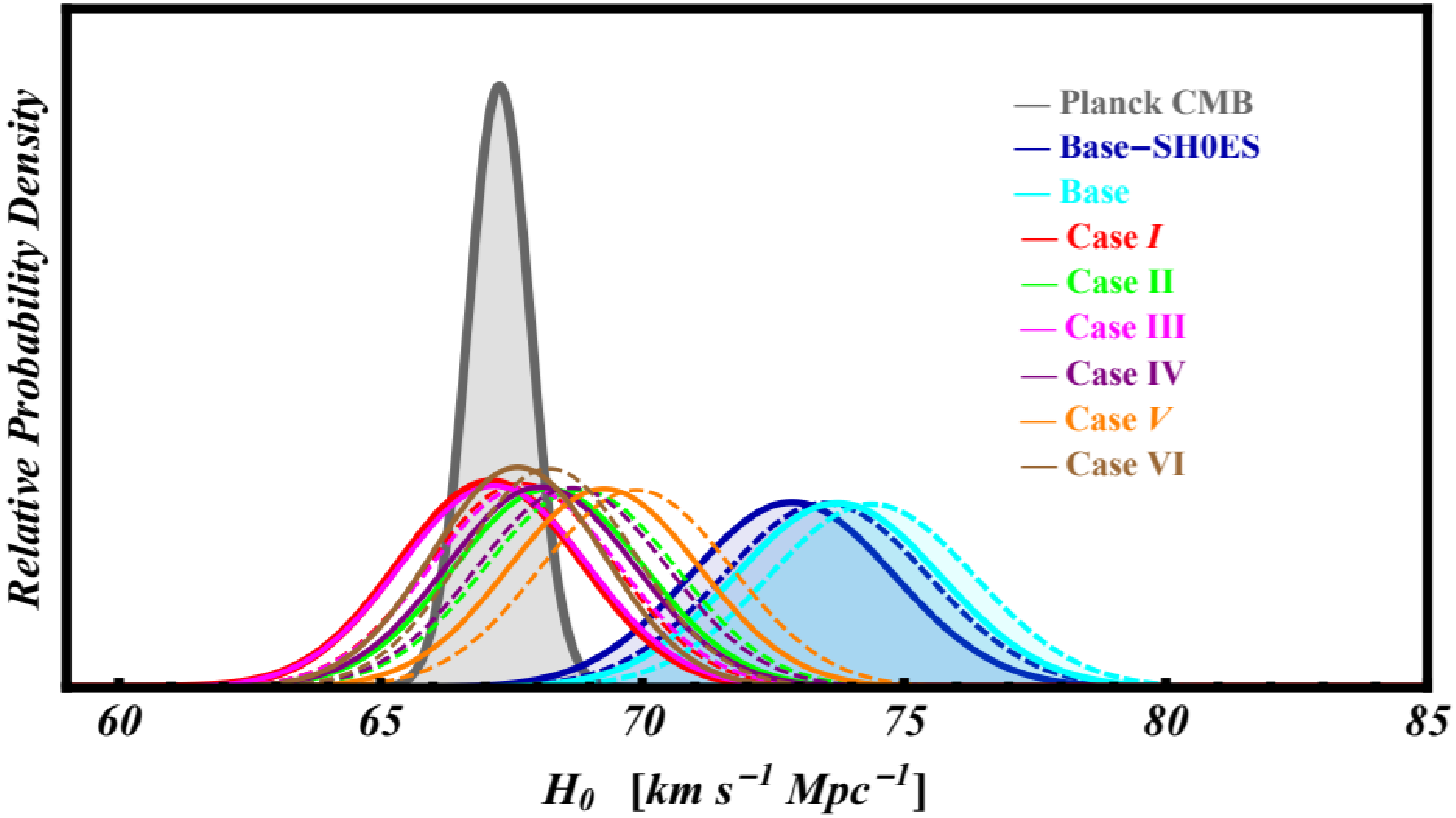
e-Print: 2109.04406 [astro-ph.CO]

Model Comparison: Resolution of the M tension



In the context of transition models the M tension is not present.

Model Comparison: Resolution of the H_0 tension



In the context of transition models the Hubble tension is not present.

Tully-Fisher Data

Tully-Fisher relation: Baryonic mass of galaxies proportional to power (s~4) of rotation velocity

$$S \equiv M/R^2$$

$$v^2 = G_{\rm eff} M/R \implies v^4 = (G_{\rm eff} M/R)^2 \sim M\ S\ G_{\rm eff}^2 \quad \Longrightarrow \quad M_B = A_B v_{rot}^s \qquad A_B \sim G^{-2} S^{-1}$$

Q: Is there a hint for a transition of the best fit value of A_B at some z_t<0.01 (D<40Mpc)?

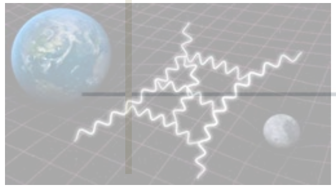
Tully-Fisher dataset: Updated SPARC database (Lelli et al. 2019,2016), 118 (D, M_B, v_{rot}) datapoints

Split in two subsets: Σ_1: D> D_c, Σ_2: D<D_c.

Find σ-distance between the best fit parameters of each subset.

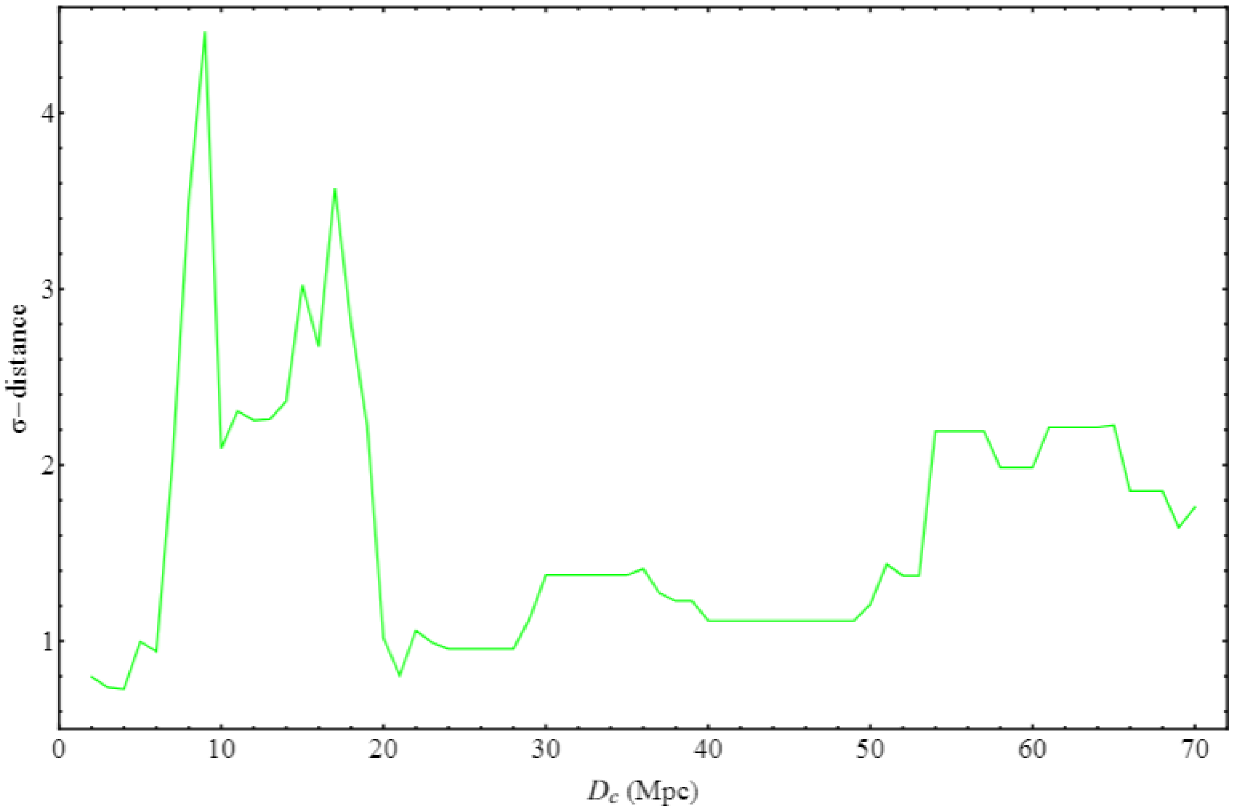
$$logM_B = s\, logv_{rot} + \log A_B \equiv s\ y + b$$

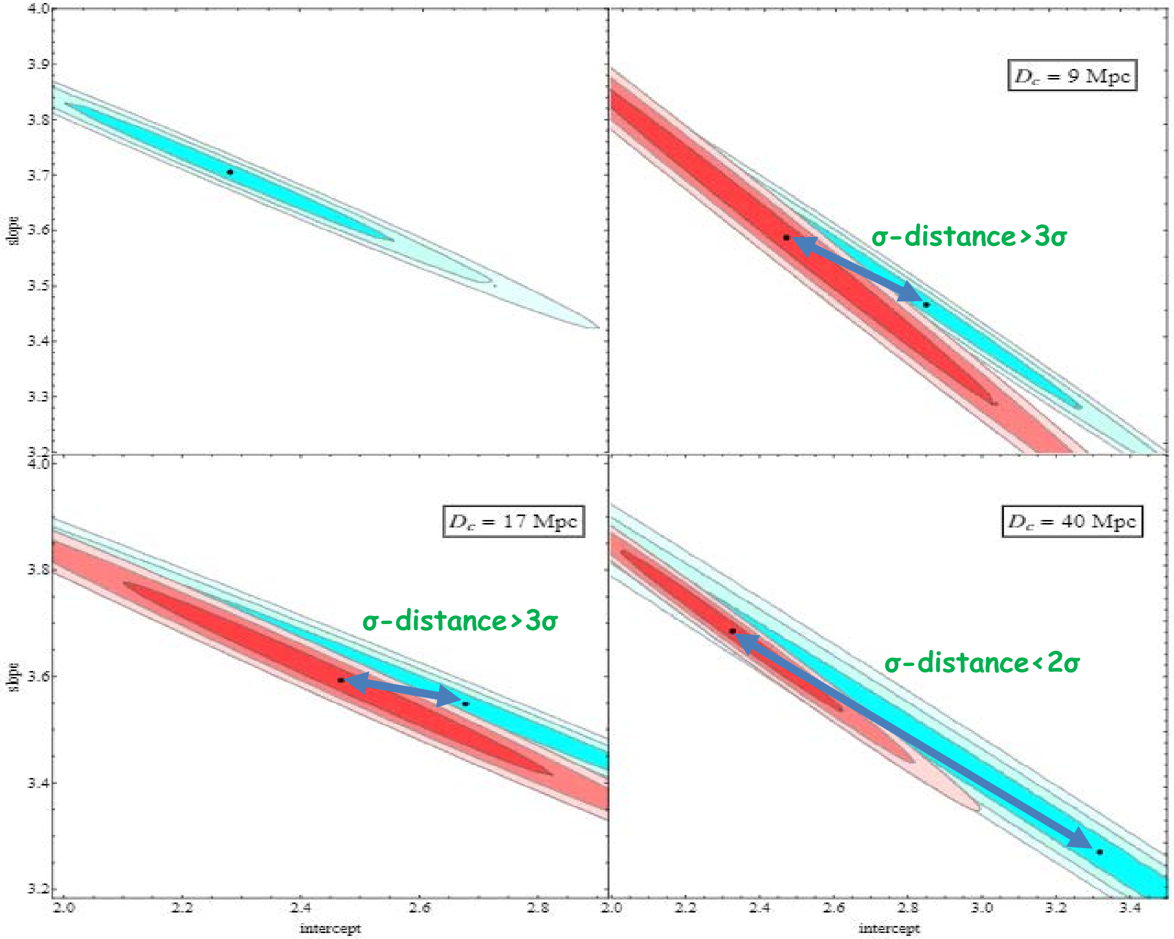
Tully-Fisher Data: Hints for transition



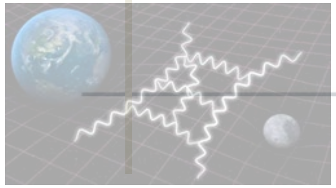
Split in two subsets: Σ_1: $D>D_c$, Σ_2: $D<D_c$.

Find σ-between the best fit parameters of each subset.



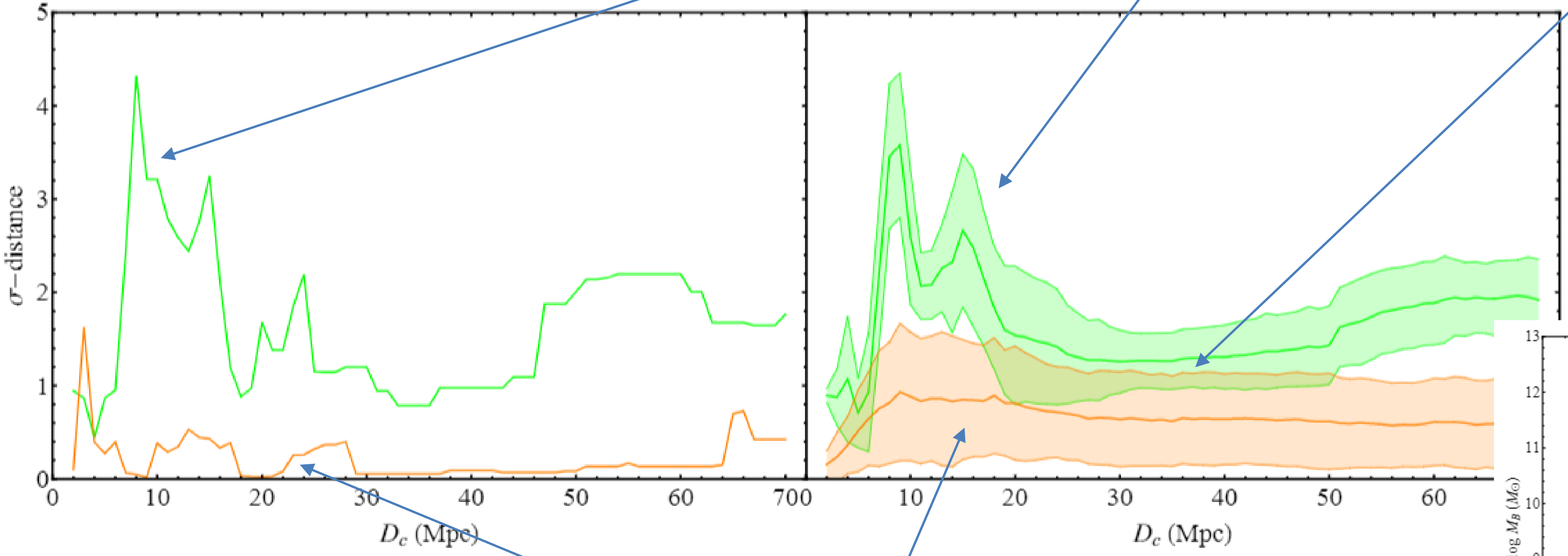


Monte Carlo Analysis

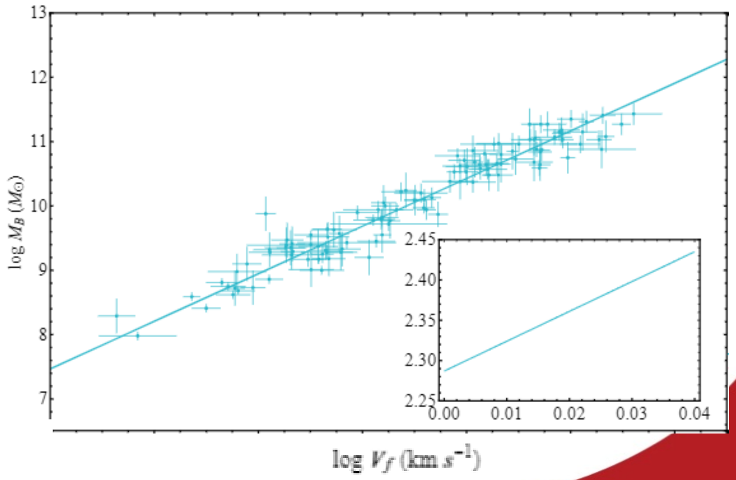


Sample of real data with gaussian randomized distances

Real data are inconsistent with homogenized Monte Carlo data.

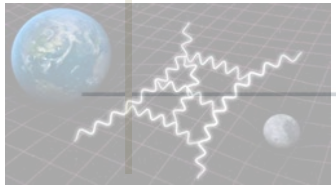


Real data with global TF best fit



Sample of Homogenized Monte Carlo Data with gaussian randomized distances assuming TF global best fit

Tully-Fisher Data: Hints for transition

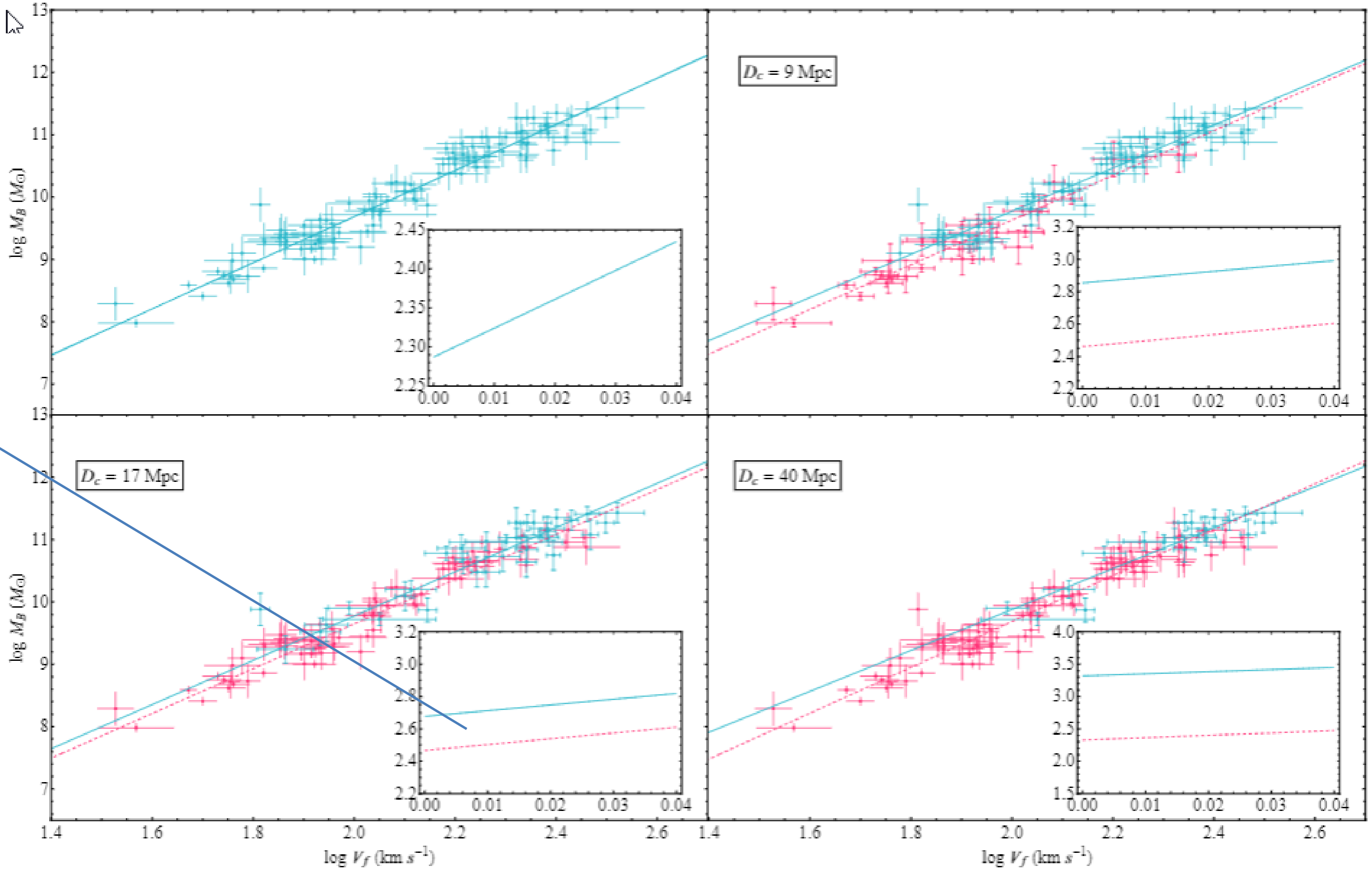


Split in two subsets: Σ_1: $D>D_c$, Σ_2: $D<D_c$.
Find σ-between the best fit parameters of each subset.

$$\log M_B = s \log v_{rot} + \log A_B \equiv s\ y + b$$

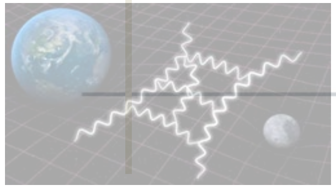
$$A_B \sim G^{-2} S^{-1}$$

$$\frac{\Delta A_B}{A_B} = -2\frac{\Delta G_{eff}}{G_{eff}} \Longrightarrow \frac{\Delta G_{eff}}{G_{eff}} \simeq -0.1$$

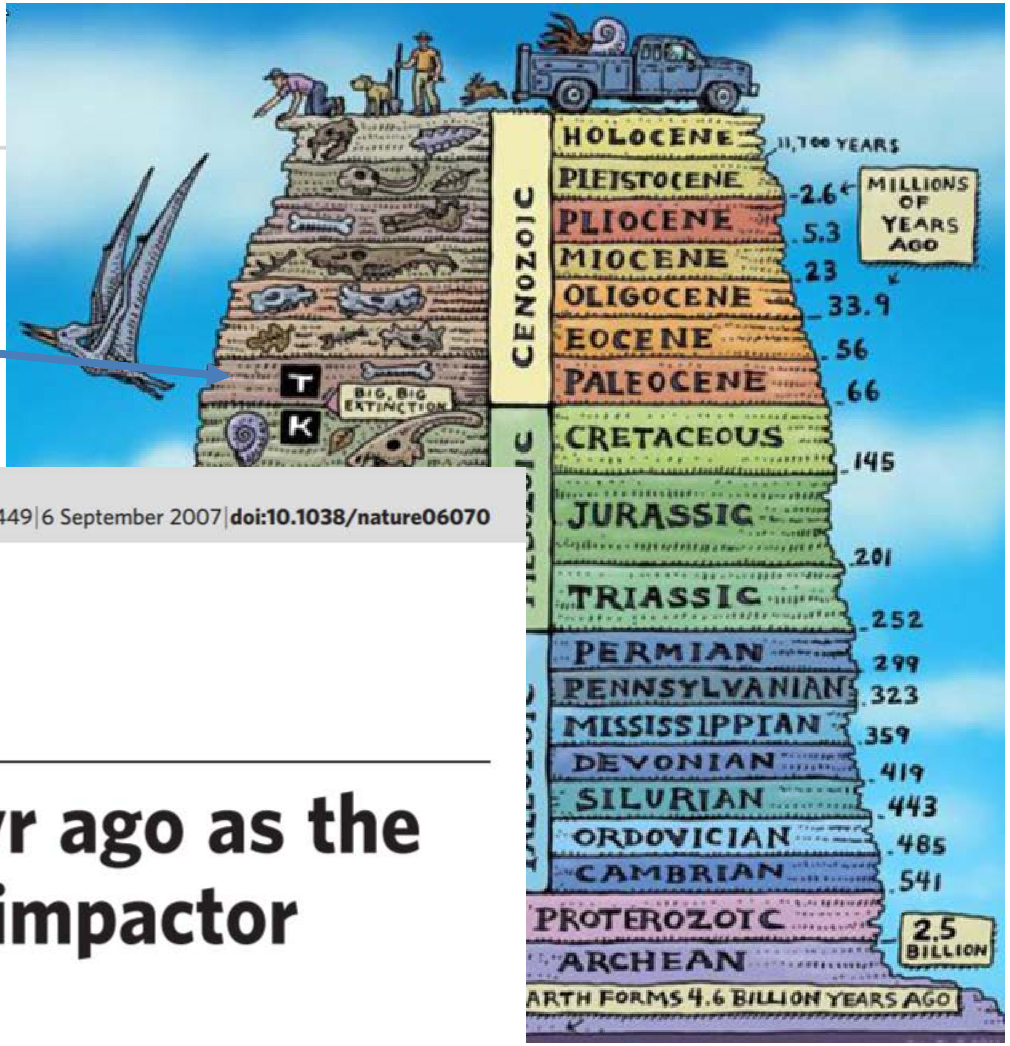


Galaxies further away have higher A_B by 20% and thus lower G_{eff} by about 10% (3σ distance).

Speculation: Extinction of Dinosaurs



Massive extinction: K/T Impactor



nature Vol 449|6 September 2007|doi:10.1038/nature06070

ARTICLES

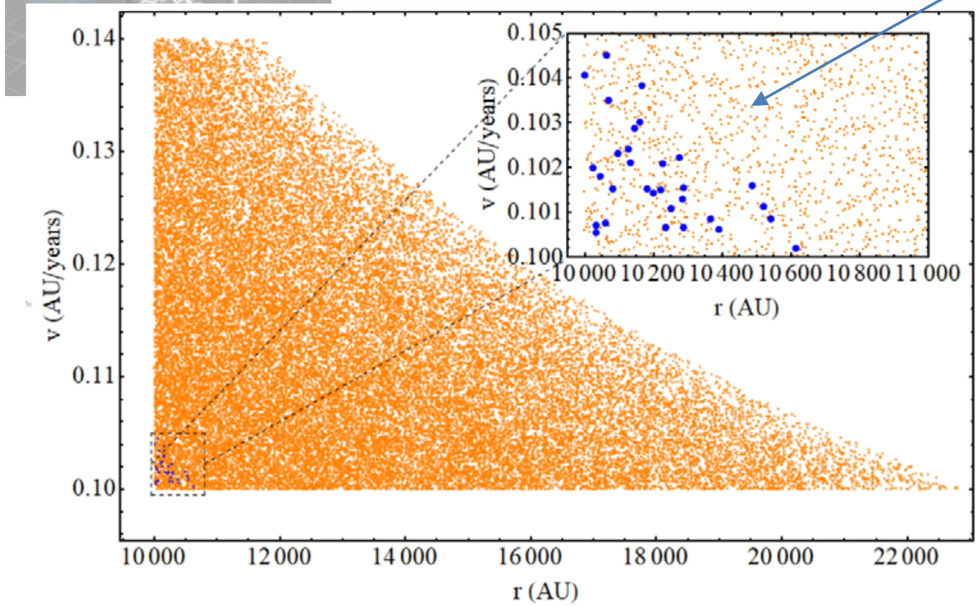
An asteroid breakup 160 Myr ago as the probable source of the K/T impactor

William F. Bottke[1], David Vokrouhlický[1,2] & David Nesvorný[1]

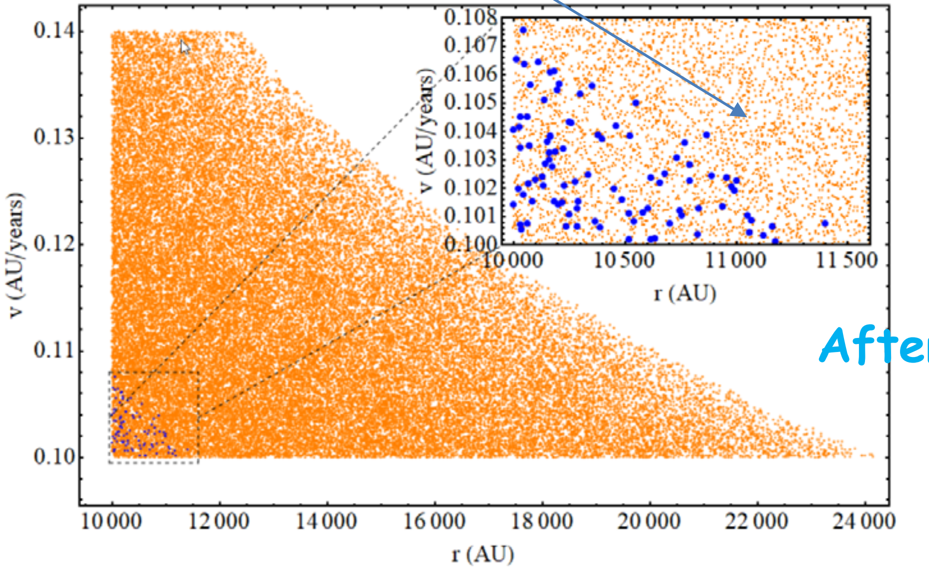
The terrestrial and lunar cratering rate is often assumed to have been nearly constant over the past 3 Gyr. Different lines of evidence, however, suggest that the impact flux from kilometre-sized bodies increased by at least a factor of two over the long-term average during the past ~100 Myr. Here we argue that this apparent surge was triggered by the catastrophic disruption of the

Perturbed Comets that Hit the Solar System

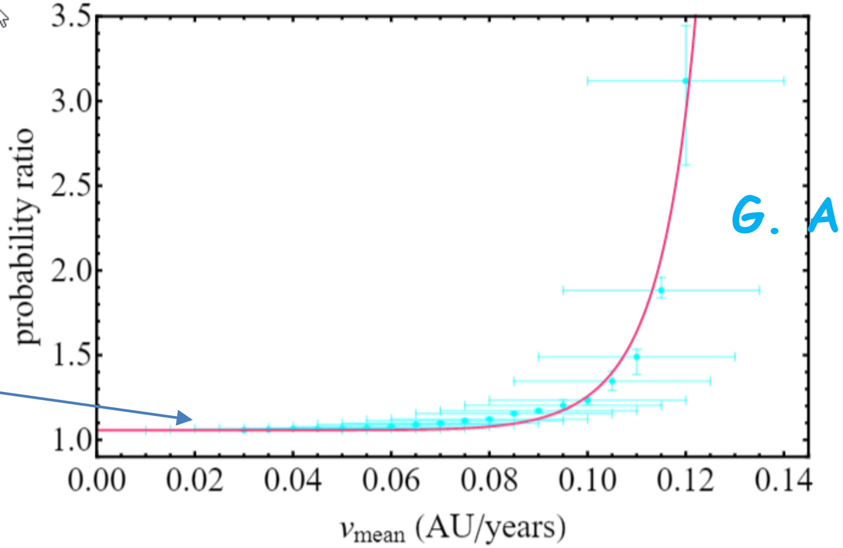
Comets that hit the solar system after a given set of random velocity perturbations.



Before a 10% gravitational transition.



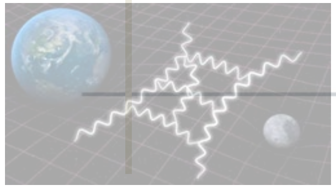
After a 10% gravitational transition.



G. Alestas, LP in progress

Larger velocity perturbations of comets can lead to large probability enhancement for entering the solar system after a gravitational transition.

Theoretical Model: Scalar Tensor Theory



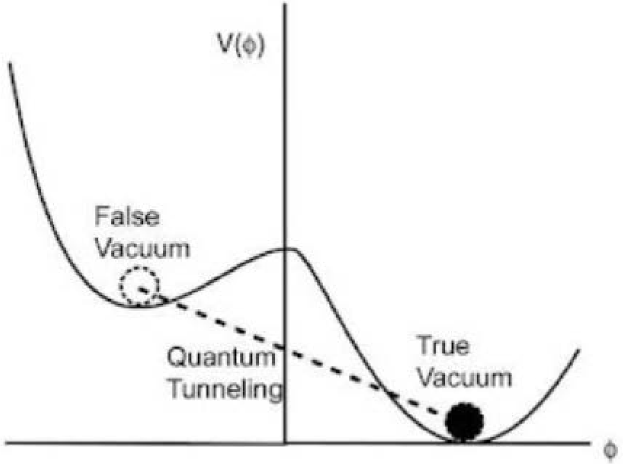
Scalar Tensor Transition:

$$S=\int d^4x\sqrt{|g|}\left[\frac{1}{2}\xi\varphi^2R-\frac{1}{2}(\partial\varphi)^2-V(\varphi)+\mathcal{L}_m\right],\qquad 8\pi G_N=\xi^{-1}v^{-2}$$

v: potential minimum

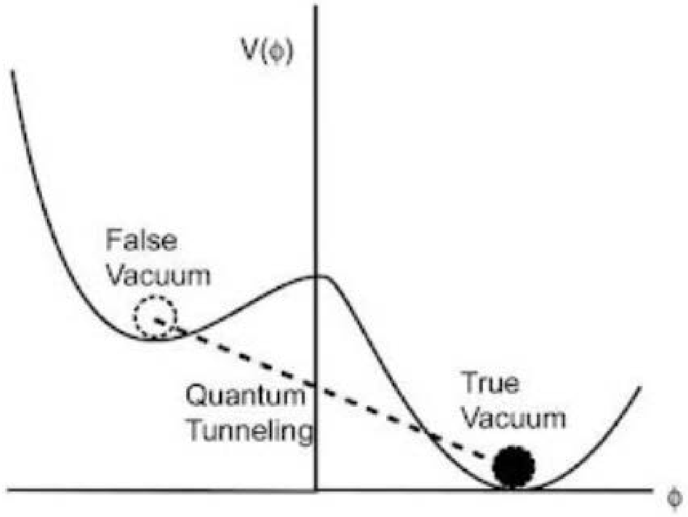
$$v=\frac{1}{\sqrt{8\pi G_N}}=M_{\rm Pl}\sim 10^{19}{\rm GeV},$$

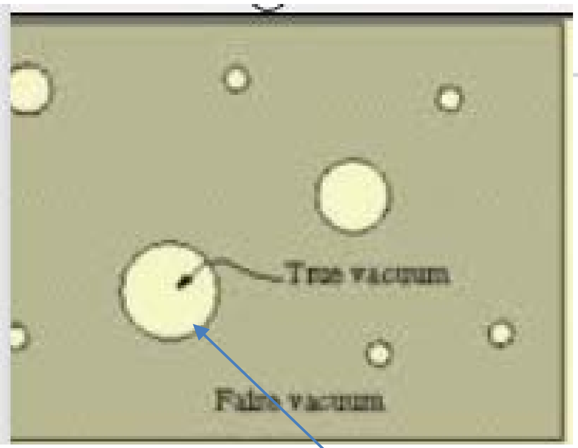
Cosmological Constant: Λ=V(v)



A phase transition (false vacuum decay) would induce a transition in the strength of gravity as well

Generic Distance Scale





In the context of false vacuum decay bubbles of true vacuum form

Predicted bubble scale is close to favored scale of transition

Scale of True Vacuum Bubbles:

$$R_b = \delta / H_0$$

$$\delta \simeq [4B_1 \ln (M_P / T_c)]^{-1}$$

O(1) Planck mass

$$H_0 = 70\, km\, s^{-1}\, Mpc^{-1}$$

$$T_c = 2.7^\circ K \simeq 2 \times 10^{-4} eV$$

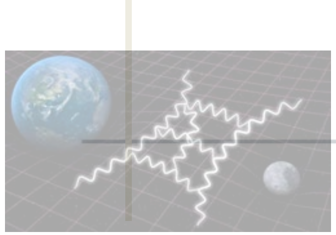
R_b~15Mpc

Late-time vacuum phase transitions: Connecting sub-eV scale physics with cosmological structure formation

Amol V. Patwardhan, George M. Fuller (Jan 9, 2014)

Published in: *Phys.Rev.D* 90 (2014) 6, 063009 • e-Print: 1401.1923 [astro-ph.CO]

Conclusion



Late time H(z) deformation approaches to the Hubble tension suffer from 3 problems: the χ^2 problem, the growth tension worsening and the M problem.

These problems are avoided if the H(z) deformation is replaced by a sudden diming of the SnIa intrinsic luminosity occurring less than 150 million years ago ($z_t<0.01$).

Such a diming may be due to a sudden increase of the strength G_{eff} of gravitational interactions by about 10% at $z_t<0.01$. This is a viable and testable conjecture.

There are hints for such a transition in recent Cepheid and Tully-Fisher data at z~0.005 (R~15-20Mpc) which probe the dynamics of galaxies at low z.

The favored transition distance scale (15Mpc) is consistent with the generic prediction of false vacuum decay models where the true vacuum has a similar energy scale as the observed cosmological constant scale (0.002eV).