Hubble Diagram from the 4D Spherical Universe

(Nature of the time and 4DS model - Part 3)

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< Part 1 >

1. Nature of the time
2. 4-D Spherical Model of the universe
3. Michelson-Morley experiment
4. Acceleration factor
5. Expansion of the universe

< Part 2 >

6. Light speed
7. ~~Redshift~~
8. ~~Light propagated distance~~

< Part 3 >

9. **Redshift for cosmological observation (revised)**
10. **Factors affecting the brightness**
11. **Hubble diagram**
12. **Comparison with Hubble diagrams from the Supernova Cosmology Project**

Definition of terms related to Time

x (Radius of universe):	Radius of the 4D sphere of universe, equal to the Observed Time (T)
CU (Cosmic Unit):	Unit of x and T, being 1 at its maximum when the space expansion stops. Time-related variables are expressed in the CU.
T_E (Time of Emission):	Time when the light was emitted.
T_P (Present Time):	Present Time of universe, when the light reaches us.
T_{ER} (Relative Time of Emission):	Relative ratio of T_E to T_P. $T_{ER} \equiv T_E / T_P$
T_B (Back in Time):	Back in Time from present when the light was emitted. $T_B \equiv T_P - T_E$
T_{BR} (Relative Back in Time):	Relative ratio of T_B to T_P. $T_{BR} \equiv T_B / T_P$
T_C (Time Clear):	Time when the space became transparent to light.
T_{CR} (Relative Time Clear):	Relative ratio of T_C to T_P. $T_{CR} \equiv T_C / T_P$

t, time (Original time), ***T, Time*** (Observed Time): See for definition in the Part 1.

9. *Redshift for cosmological observation*

Revision after newly reported energy circulation theory and quantum particles

Spectrum comparison with the present atom of the same element:

emitted at T_E reaches us at T_P

$$\nu_0(T_E), \lambda_0(T_E) \quad \longrightarrow \quad \nu(T_P), \lambda(T_P)$$

$$\nu_0(T_P), \lambda_0(T_P)$$ (present atom)

$$z+1 = \frac{\lambda(T_P)}{\lambda_0(T_P)} = \frac{\nu_0(T_P)}{\nu(T_P)}$$ not compare $\lambda(T_P), \nu(T_P)$ with $\lambda_0(T_E), \nu_0(T_E)$

Light speed:

$$C(T_E) = \nu_0(T_E) * \lambda_0(T_E) \quad \longrightarrow \quad C(T_P) = \nu(T_P) * \lambda(T_P)$$

Present atom: $C(T_P) = \nu_0(T_P) * \lambda_0(T_P)$

Redshift from values at the emission

Wavelength-based redshift:

By space expansion: Wavelength is stretched by n.

$$z_\lambda^e + 1 = \frac{\lambda(T_P)}{\lambda_0(T_E)} = n = \frac{T_P}{T_E} = \frac{1}{T_{ER}}$$

Frequency-based redshift:

$$z_\nu^e + 1 = \frac{\nu_0(T_E)}{\nu(T_P)} = \frac{C(T_E)}{\lambda_0(T_E)} \frac{\lambda(T_P)}{C(T_P)} = n \frac{C(T_E)}{C(T_P)} = \frac{1}{T_{ER}} \frac{C(T_E)}{C(T_P)}$$

n: Expansion ratio of universe

T: Observed Time = Radius of universe

Redshift of actual measurement

From the **energy circulation theory**:

Atomic energy varies by the space expansion.

Energy of the single circulation iS in hidden-space dimensions:

$$E_{(iS)} = m_0 c^2 = m_0 {v_c}^2 = m_0 {\mu_0}^2 {\omega_0}^2$$

Light energy / Photon energy:

$$E_\gamma = h\nu^2 = \hbar\omega^2 \quad , \quad E_p = E_\gamma / \nu = h\nu = \hbar\omega$$

Space expansion by $n \implies E_{(iS)},\ c^2$ and ${\omega_0}^2$ decrease by $1/n^3$. (m_0, μ_0: invariant)

Present atom of the same element: Light energy decreases by $1/n^3$ at emission.

$$E_\gamma(T_E) = h{\nu_{0(T_E)}}^2 \propto m_0 {C_{(T_E)}}^2 \quad , \quad E_\gamma(T_P) = h{\nu_{0(T_P)}}^2 \propto m_0 {C_{(T_P)}}^2$$

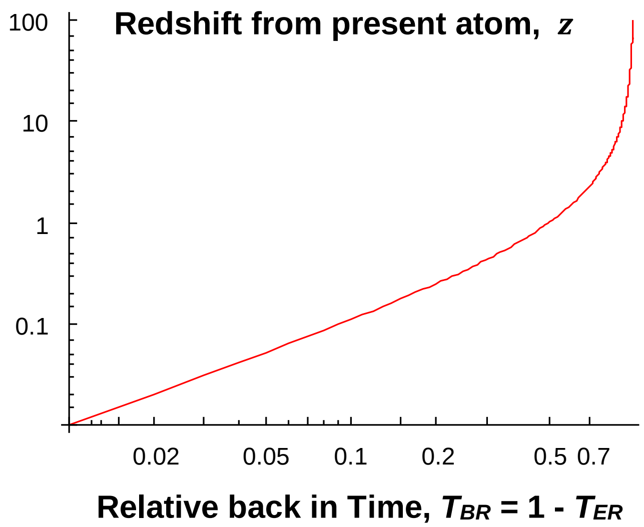
$$\frac{\nu_0(T_P)}{\nu_0(T_E)} = \frac{C(T_P)}{C(T_E)}$$

Redshift from the present atom

$$z_\lambda + 1 = \frac{\lambda(T_P)}{\lambda_0(T_P)} = \frac{\lambda(T_P)}{\lambda_0(T_E)} \times \frac{\lambda_0(T_E)}{\lambda_0(T_P)} = n \times \frac{C(T_E)}{\nu_0(T_E)} \frac{\nu_0(T_P)}{C(T_P)} = n = \frac{1}{T_{ER}}$$

$$z_\nu + 1 = \frac{\nu_0(T_P)}{\nu(T_P)} = \frac{\nu_0(T_E)}{\nu(T_P)} \times \frac{\nu_0(T_P)}{\nu_0(T_E)} = n \frac{C(T_E)}{C(T_P)} \times \frac{C(T_P)}{C(T_E)} = n = \frac{1}{T_{ER}}$$

$$z_\lambda = z_\nu = z = \frac{1}{T_{ER}} - 1$$



10. Factors affecting the brightness

(i) Factor by **wavelength prolongation**

Along with space expansion:

- Wavelength: stretched by $n \equiv T_P / T_E = 1/T_{ER}$
- Energy of a single photon $h\nu$: decreases to $1/n$
- Number of photons: increase to *n*-fold (preservation of the total energy)
- $h\nu$ times the number of photon: no change
- No effect by wavelength prolongation on the luminosity (total energy per unit time)

(ii) Factors by **scattering**

Light speed: $$C(x) = K * f_D * f_{EM} = K * \frac{1}{x\sqrt{1-x}} * \left(1 - \frac{T_C{}^3}{x^3}\right)$$

- Electromagnetic interaction factor f_{EM} is effect of scattering.
- Plural Time Clear T_C values:
  - For Cosmic Microwave Background radiation: 380,000 years after Big Bang
  - For "Reionization" of interstellar hydrogen by stars: 150 - 1,000 million years after Big Bang
  - For light propagation in substances
- If the density is constant, the transmittance is $I(x) = I_0\left(1 - \int (T_C\rho)^3 dx\right) = I_0(1 - kx)$.
- Light from stars emitted during the reionization period: Not reach us or be darken by scattering
- Stellar light emitted later ($T_{ER} > 0.072$, $z < 12.8$): Factor by scattering is negligible.

(iii) Factor by **variation of the space energy density**

- Luminosity: energy per unit-time

  Flux: energy per unit-time per unit-area $F = \frac{L}{4\pi r^2}$

- Luminosity varies depending on the light speed at the time of detection because it is a per unit-time value. L: function of the time of detection $T = x$

$$F(x) = \frac{L(C(x))}{4\pi r^2} = \frac{L(x)}{4\pi r^2}$$

- For our observation, the variable x is fixed to the present time T_P. Luminosity and Flux are invariant by the time of emission T_E.
- No effect by variation of the space energy density on brightness for our observation.

11. Hubble diagram – Magnitude of flux and distance

Light of luminosity L was emitted at T_E and reaches us now at T_P.

Flux we observe now: $$F(T_E) = \frac{L}{4\pi \cdot LD(T_E)^2}$$

Define its magnitude: $$m(T_E) \equiv -2.5 \cdot \lg F(T_E)$$

Define the relative magnitude to the same luminosity with $z = 0.05$:

$$DM_{0.05}(T_{ER}) \equiv m(T_{ER}) - m(z = 0.05) = m(T_{ER}) - m(1/1.05)$$

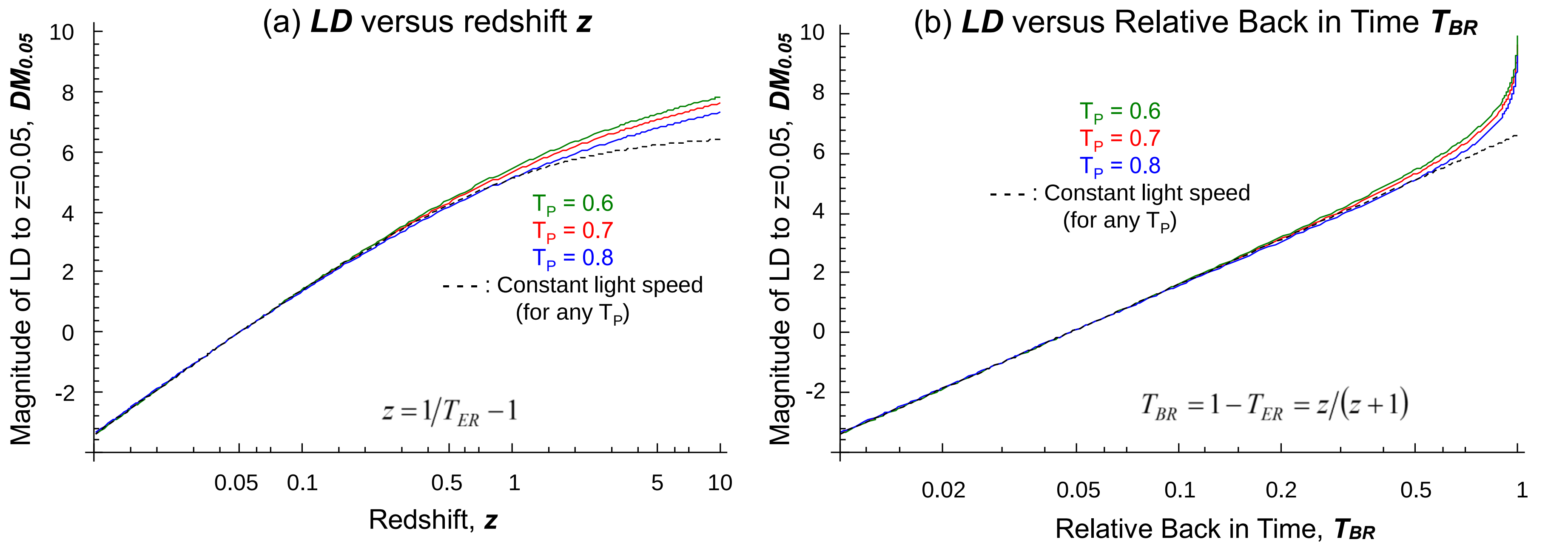
- This is a distance modulus : referred to as the "**magnitude of LD to z=0.05**"
- Light propagated distance *LD*: f_{EM} can be ignored if $z < 12.8$

$$LD(T_E) \approx \int_{T_E}^{T_P} \frac{K}{x\sqrt{1-x}} dx = K\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}}\right) - \log\left(\frac{1-\sqrt{1-T_E}}{1+\sqrt{1-T_E}}\right)\right)$$

$$DM_{0.05}(T_{ER}) = 5 \cdot \lg\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}} \cdot \frac{1+\sqrt{1-T_P T_{ER}}}{1-\sqrt{1-T_P T_{ER}}}\right)\right) - 5 \cdot \lg\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}} \cdot \frac{1+\sqrt{1-T_P/1.05}}{1-\sqrt{1-T_P/1.05}}\right)\right)$$

Magnitude of light propagated distance LD to $z = 0.05$

$$DM_{0.05}(T_{ER}) = 5 \cdot \lg\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}} \cdot \frac{1+\sqrt{1-T_P T_{ER}}}{1-\sqrt{1-T_P T_{ER}}}\right)\right) - 5 \cdot \lg\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}} \cdot \frac{1+\sqrt{1-T_P/1.05}}{1-\sqrt{1-T_P/1.05}}\right)\right)$$



Hubble diagram

3-D space expansion speed: $\frac{dr}{dT} = \frac{dr}{dx} = \frac{d(x\theta)}{dx} = \theta \qquad r = \theta \cdot x$

For a given angle θ, variable x: constant θ

For a given radius x, variable θ: proportional to θ and to r $\rightarrow$ **Hubble's law**

Hubble diagram: To discuss the recessive velocity of the **proper distance**

Tentatively provide that light speed has been constant.

Light propagated distance: $LD_C = c \cdot (T_P - T_E) = c \cdot T_P \cdot (1 - T_{ER}) = c \cdot T_P \frac{z}{z+1}$

Multiply by $(1+z)$ (**time dilation**): $(1+z) \cdot LD_C = c \cdot T_P \cdot z \equiv k \cdot z \rightarrow$ proportional to z

$\Delta t' = (1+z)\Delta t$ Light-curve width of supernovae: dilated by $1+z$

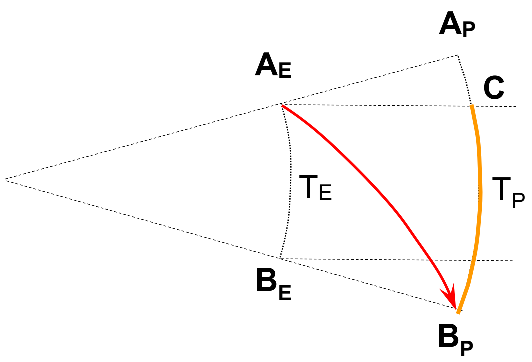
Conversion of LD to PD:

A_P-B_P: proper distance at T_P ("**present distance, PD**")

C-B_P: light propagated distance (LD)

$n = T_P / T_E = 1/T_{ER}$

$\frac{CB_P}{A_E B_E} = 1 + \frac{1}{2}(n-1) = \frac{1}{2}(n+1), \qquad \frac{PD}{LD} = \frac{2n}{n+1} = \frac{2(z+1)}{z+2} = \frac{2}{1+T_{ER}}$



Adjusted magnitude of PD for Hubble diagram

In order to compare the present distance with reported Hubble diagrams, take the following value:

$$(1+z)\cdot PD=(1+z)\cdot\frac{2(z+1)}{z+2}\cdot LD \quad \text{or} \quad \frac{1}{T_{ER}}\cdot PD=\frac{1}{T_{ER}}\cdot\frac{2}{1+T_{ER}}\cdot LD$$

Time dilation ***LD-PD conversion***

In actual cosmological observation, in addition to the time dilation, K-correction is made to flux.

K-corrections: convert a measurement at redshift z to that in the rest frame at z = 0. Cross-filter adjustment in abs-Mag + difference in distance modulus between the two frames.

Theoretical part of K-corrections correspond to the LD-PD conversion.

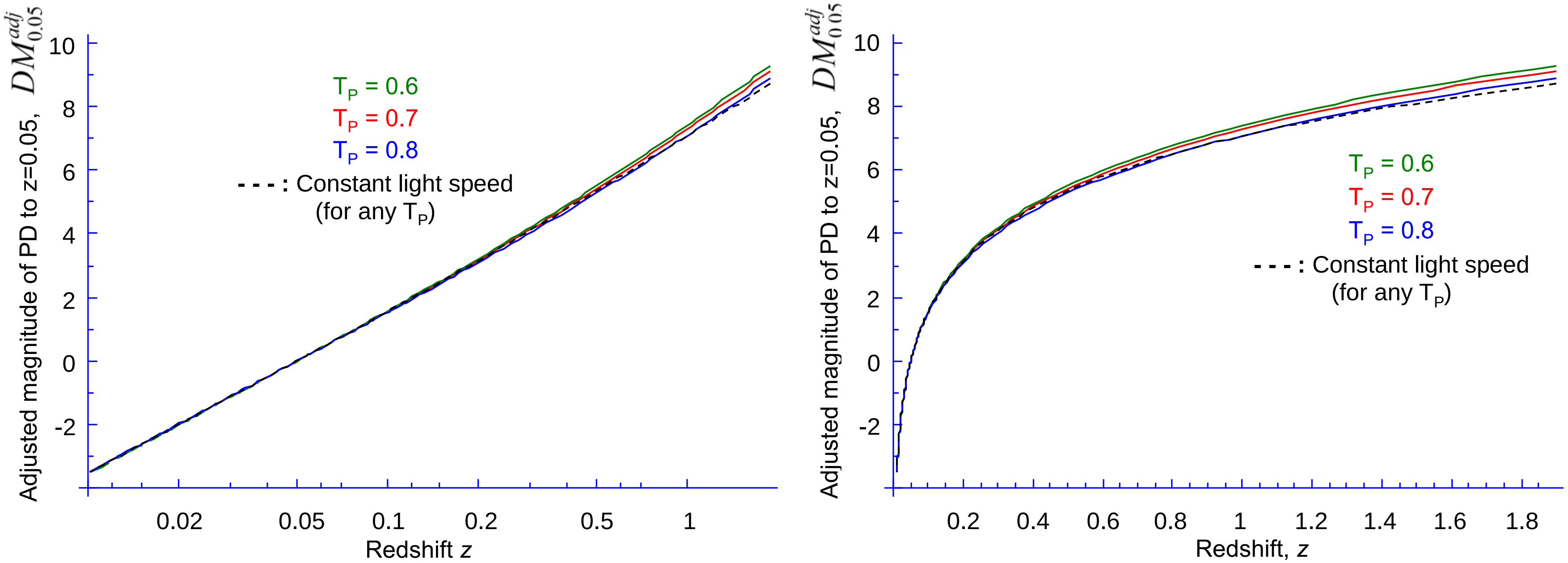
Adjusted magnitude of PD to $z=0.05$, $DM_{0.05}^{adj}$: Add ***Time dilation*** and ***LD-PD conversion*** to $DM_{0.05}$

$$\begin{aligned} DM_{0.05}^{adj}(T_{ER}) &= 5\cdot\left(\lg LD(T_{ER})+\lg(1/T_{ER})+\lg(2/(1+T_{ER}))-\lg LD(1/1.05)-\lg 1.05-\lg(2*1.05/2.05)\right)\\ &= 5\cdot\left(\lg LD(T_{ER})-\lg(T_{ER})-\lg(1+T_{ER})-\lg LD(1/1.05)-2\cdot\lg 1.05+\lg 2.05\right)\end{aligned}$$

$$\begin{aligned} DM_{0.05}^{adj}(T_{ER}) = {} & 5\cdot\lg\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}}\cdot\frac{1+\sqrt{1-T_P T_{ER}}}{1-\sqrt{1-T_P T_{ER}}}\right)\right)-5\cdot\lg\left(\log\left(\frac{1-\sqrt{1-T_P}}{1+\sqrt{1-T_P}}\cdot\frac{1+\sqrt{1-T_P/1.05}}{1-\sqrt{1-T_P/1.05}}\right)\right)\\ & -5\cdot\lg T_{ER}-5\cdot\lg(1+T_{ER})-10\cdot\lg 1.05+5\cdot\lg 2.05\end{aligned}$$

Hubble diagram of adjusted PD vs redshift

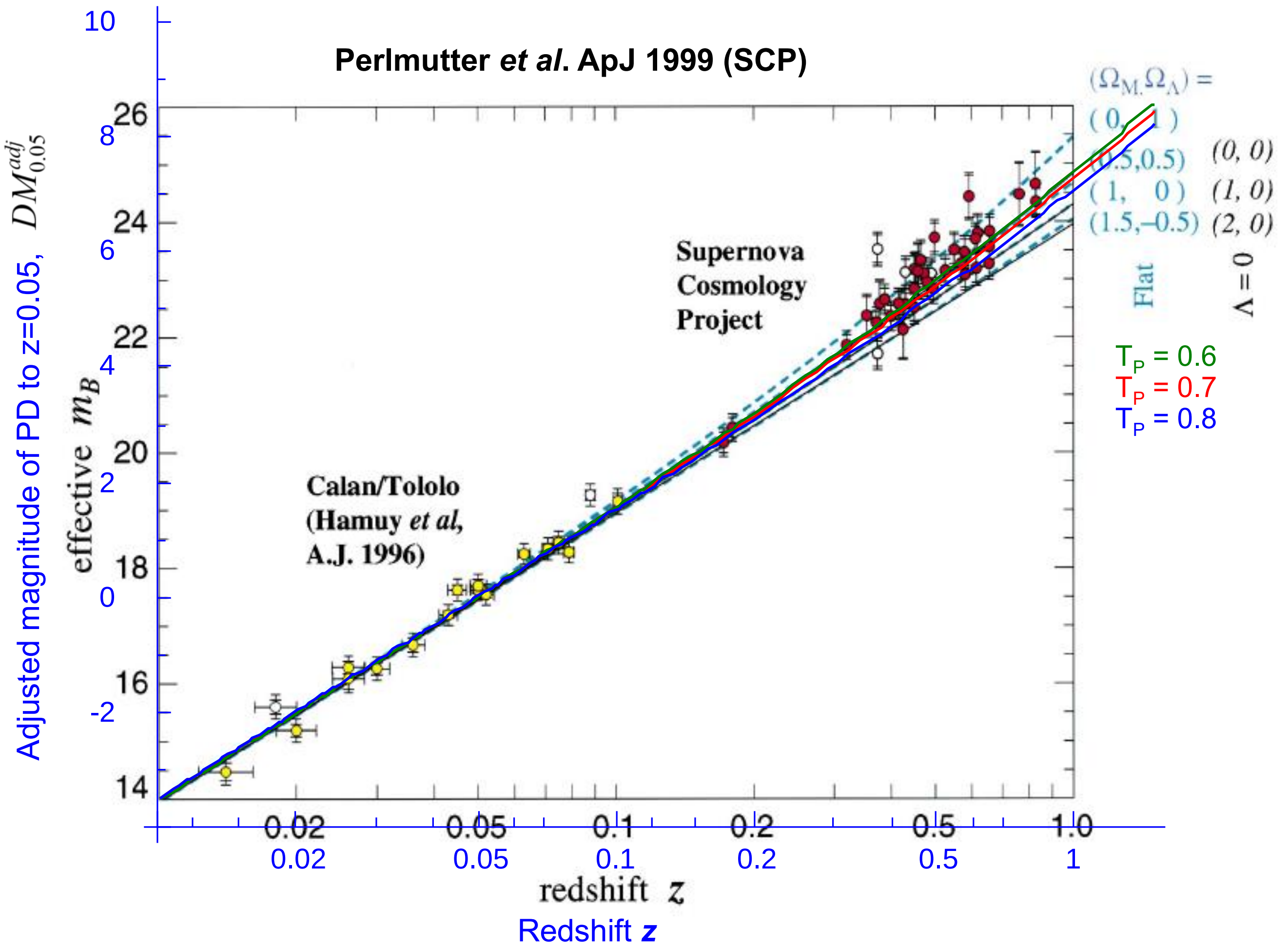
The adjusted magnitude of PD to $z = 0.05$, $DM_{0.05}^{adj}$ **versus the redshift** $z = 1/T_{ER} - 1$



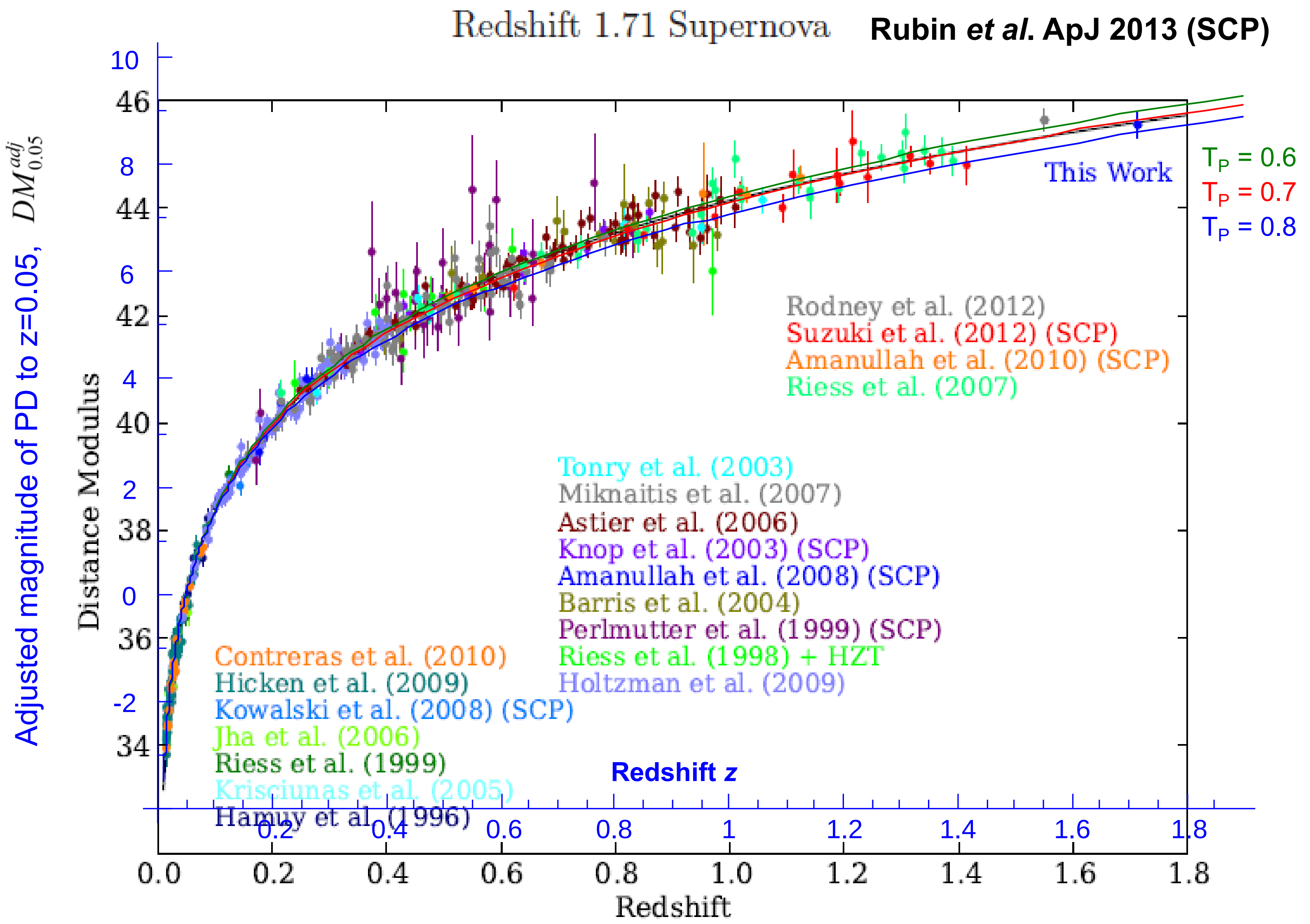
- - - - : reference $DM_{0.05}^{adj}$ based on $LD_C = c \cdot T_P (1 - T_{ER})$ subject to constant light speed

12. Comparison with Hubble diagrams from the SCP

Superimposition on the Hubble diagram by Perlmutter et al, z in a logarithmic scale



Superimposition on the latest Hubble diagram from the SCP, z in a uniform scale



Conclusion of comparison with the SCP

- Observed redshift is from values of the present atom.
- Light propagated distance LD is equal to the luminosity distance.
- Ratio of converting LD to the present distance PD (proper distance at present) is given.
- The frame-conversion part of the K-correction corresponds to the LD-PD conversion.
- Magnitude of $(1+z) \cdot PD$ to $z = 0.05$ was compared with reported Hubble diagrams from the SCP, which were time-dilated by $1+z$ and K-corrected.
- Superimposition on the reported Hubble diagrams from the SCP showed an excellent fit. The graph for the Present Time $T_P = 0.7$ very closely overlaps the line of flat $\Omega_{\mathrm{m}} = 0.27$ ΛCDM universe that Rubin et al concluded as the best fit.

The **expansion of universe** is **not** accelerating.

Decelerating by the Original time

Constant by the Observed Time.