Expansion of Universe Driven by Gravitational Waves

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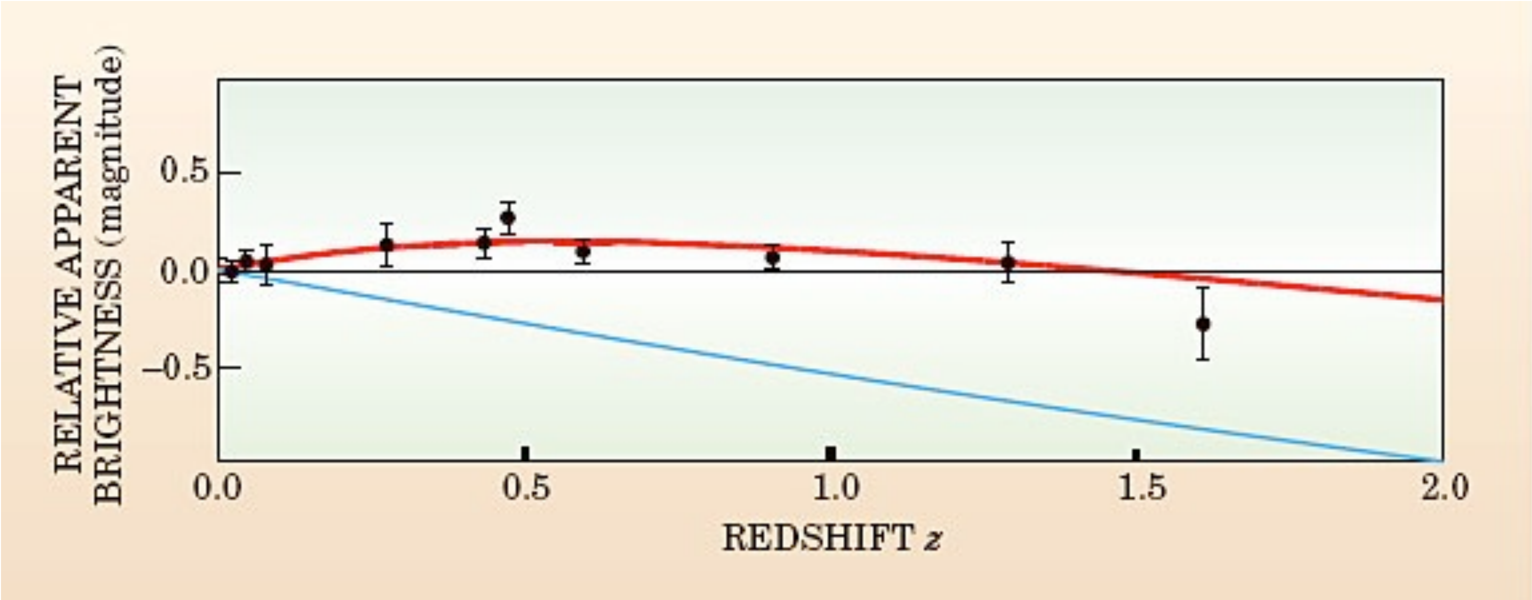
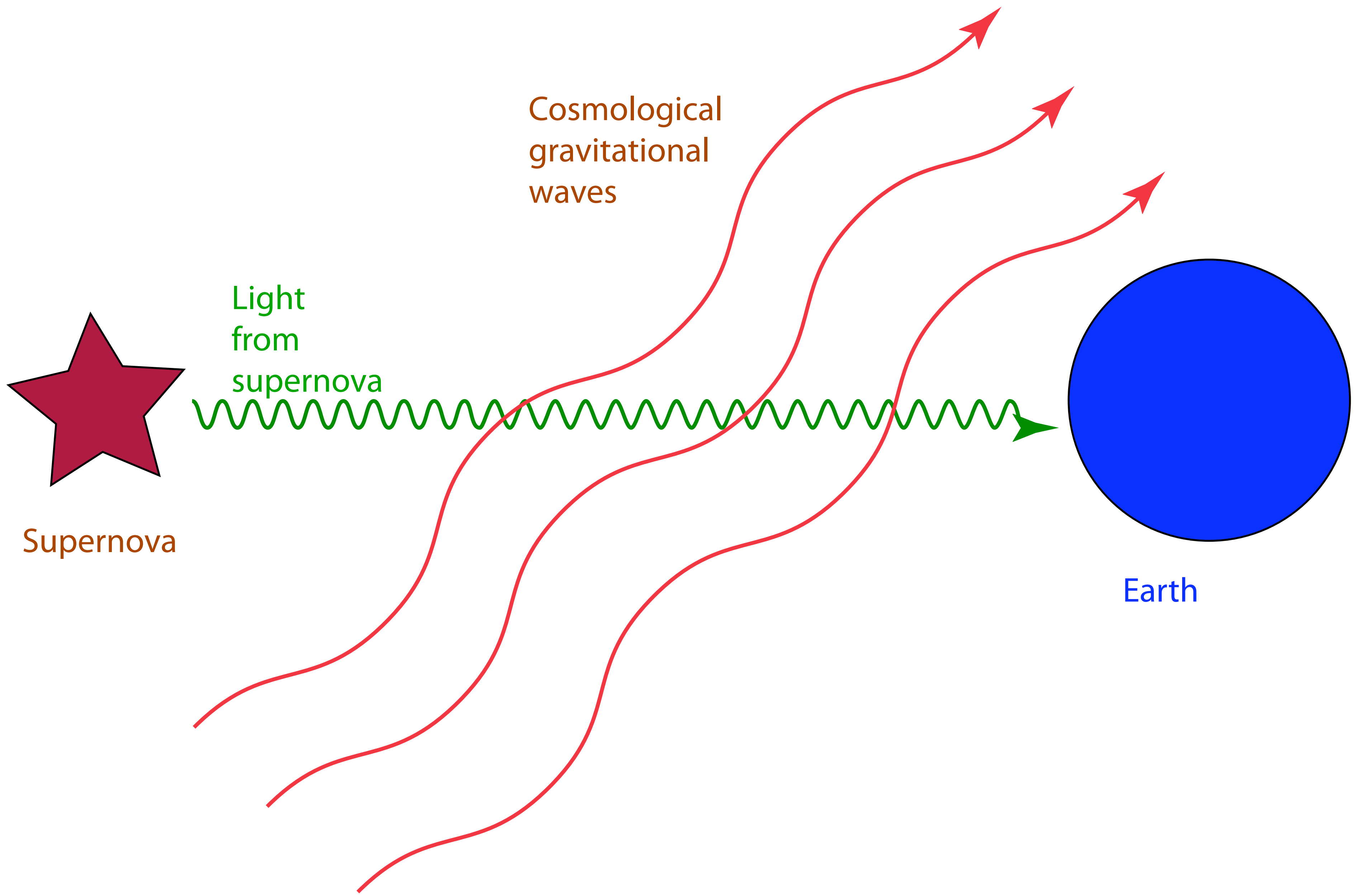


- Red: 71% of cosmological attributed to dark energy $\Omega_M = 0.29, \quad \Omega_\Lambda = 0.71, \quad k = 0$
- Blue: assumes no cosmological constant
- Black: empty universe with no cosmological constant



New interpretation

Effect on measurements

- Excessive redshift
- Light travel time increased
- Supernova "dimming"

Properties of gravity waves

- Early universe: High density: force of gravity exceeds gas pressure: *deceleration*
- Transition phase: force of gravity equals gas pressure: *steady* expansion
- Current universe: Low density: force of gravity less than gas (radiation) pressure: *acceleration*

Model of Gravity Waves

- All permeating potential energy

$$U = -\frac{Gm^2}{R}$$

- m : mass equivalent of gravity waves

$$p = -\frac{\partial U}{\partial V} = -\frac{1}{4\pi}\frac{Gm^2}{R^4} = -\frac{4\pi G}{9}\rho^2 R^2$$

Stress Tensor

- Isotropic fluid: traceless stress tensor
- $$T^{\mu}_{\nu} = \begin{bmatrix} \rho c^2 - \dfrac{4\pi G}{3}\rho^2 R^2 & 0 & 0 & 0 \\ 0 & -p & 0 & 0 \\ 0 & 0 & -p & 0 \\ 0 & 0 & 0 & -p \end{bmatrix}$$

Energy conservation

- Covariant divergence = 0

$$T^{\mu\nu}_{;\nu} = 0$$

- Evaluate Christoffel symbols from

$$ds^2 = dt^2 - \frac{a^2(t)}{1-kr^2}\left(dr^2 + r^2 d\theta^2 + r^2 \sin^2\theta \, d\phi\right)$$

Equation of state

$$\frac{d\rho}{da} = \frac{\rho}{a}\left[\frac{-4 + \alpha\rho a^2}{1 - \frac{\alpha}{3}\rho a^2}\right]$$

$$\boxed{\rho = \frac{3a \pm \sqrt{9a^2 + \alpha K}}{\alpha a^3}}$$

$$a = \frac{R(t)}{R(t_0)};\ \alpha \equiv \frac{8\pi G R_0^2}{c^2}$$

Einstein equation

- Perfect fluid 00-component

$$\dot{R}^2 + k = \frac{8\pi G R^2}{3}\left(\rho c^2 - \frac{4\pi G}{3}\rho^2 R^2\right); \quad k = -1, 0, +1$$

$$\frac{\dot{R}^2}{R_0^2} + \frac{k}{R_0^2} = \frac{8\pi G}{3}\left(\rho c^2 - \frac{4\pi G}{3}\rho^2 R_0^2\right);$$

- $$H_0^2 + \frac{k}{R_0^2} = \frac{8\pi G}{3}\rho_0^T$$

$$\frac{\rho_0^T}{\rho_C} - \frac{k}{H_0^2 R_0^2} \equiv \Omega_\Gamma^p + \Omega_k = 1; \quad \Omega_k = 1 - \frac{\rho_0^T}{\rho_C}$$

Compare with data $\mu_P \; vs \; z$

Empty space d_L vs z $$d_L = \frac{c(1+z)}{H_0} \sinh \ln(1+z)$$

$$\rho_C = \frac{3H_0^2}{8\pi G}; \quad q = \alpha K = K \frac{8\pi G R_0^2}{c^2}$$

$$\Omega_\Gamma^p \equiv \frac{\rho_0}{\rho_C}; \; \Omega_k \equiv -\frac{kc^2}{H_0^2 R_0^2}; \; \Omega_\Gamma^p + \Omega_k = 1$$

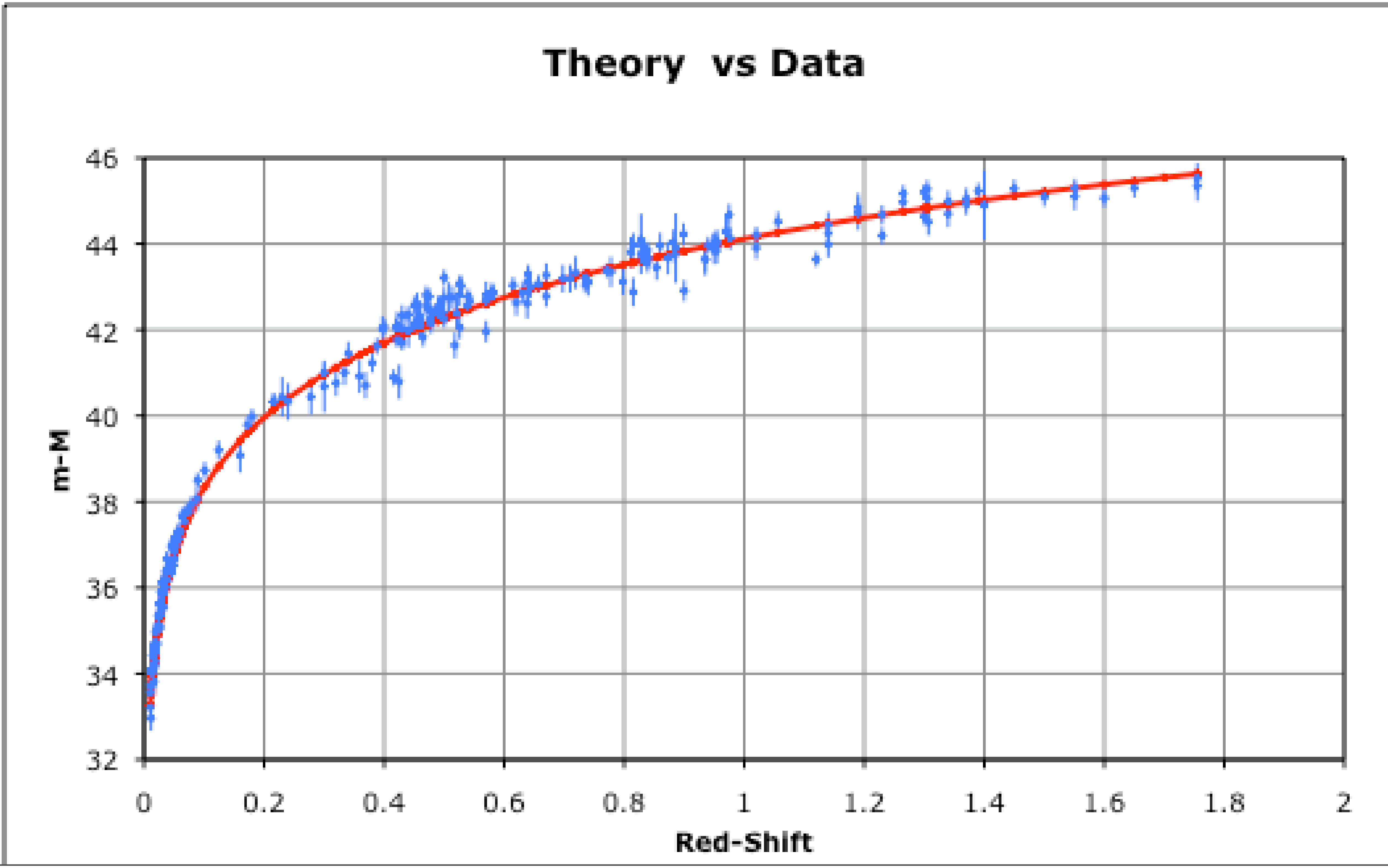
Luminosity vs distance

$$d_L = \frac{c\left(1+z\right)}{H_0\left|\Omega_\Gamma^p + \Omega_\Gamma^q - 1\right|^{1/2}}$$

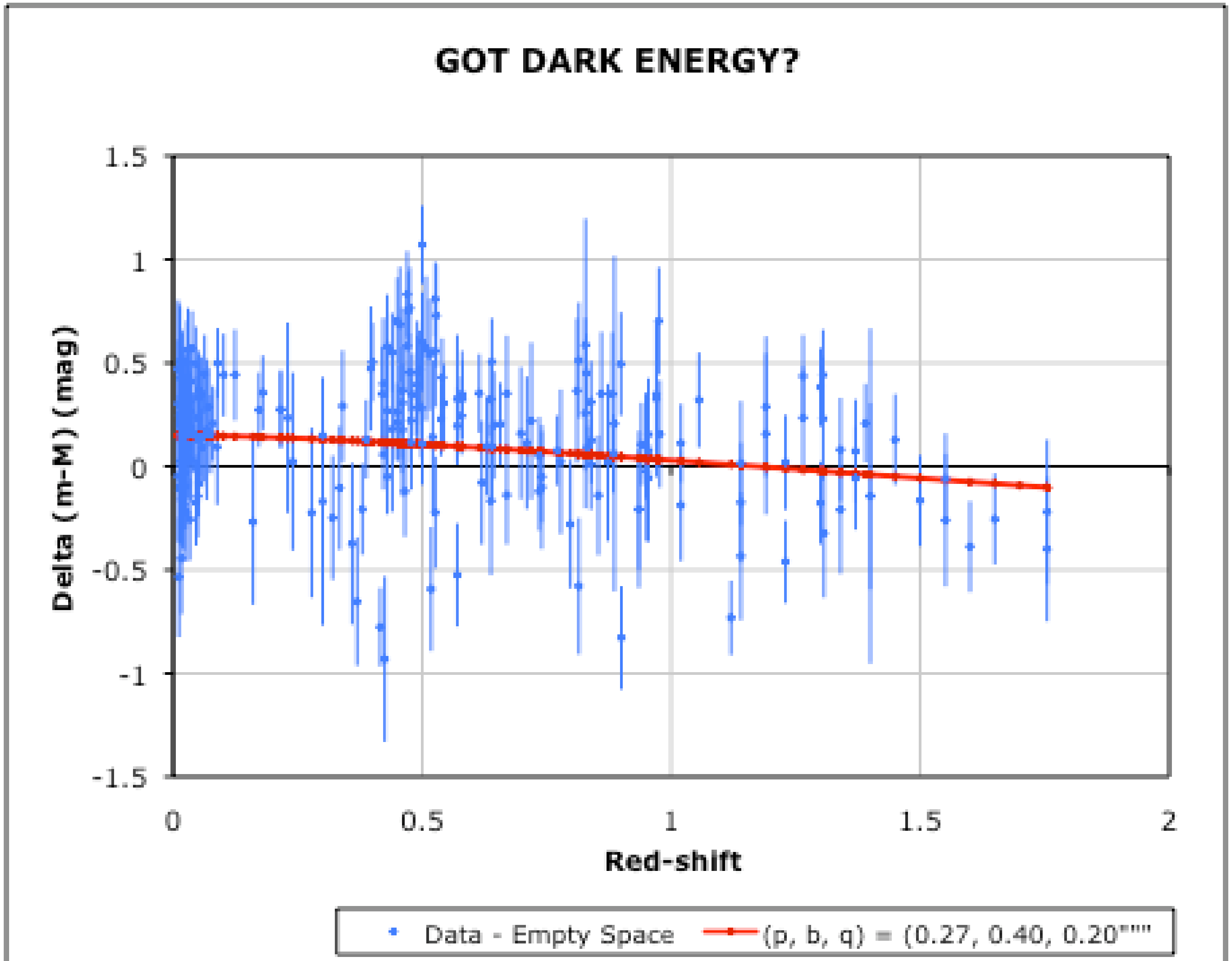
$$\times \sinh\left\{\left|\Omega_\Gamma^p + \Omega_\Gamma^q - 1\right|^{1/2}\int_0^{z_1}\frac{dz}{\left(1+z\right)}\frac{1}{\sqrt{\left[\left(\Omega_\Gamma^p\left(1+z\right)\frac{\left(1+z\right)^{-1}+\sqrt{\left(1+z\right)^{-2}+q}}{1+\sqrt{1+q}}\right)-\Omega_\Gamma^q+1\right]}}\right\}Mpc$$

Distance modulus: $\mu_P = m - M = 5\log d_L + 25$

Supernova data (Riess 2006)



Fit to data minus empty space



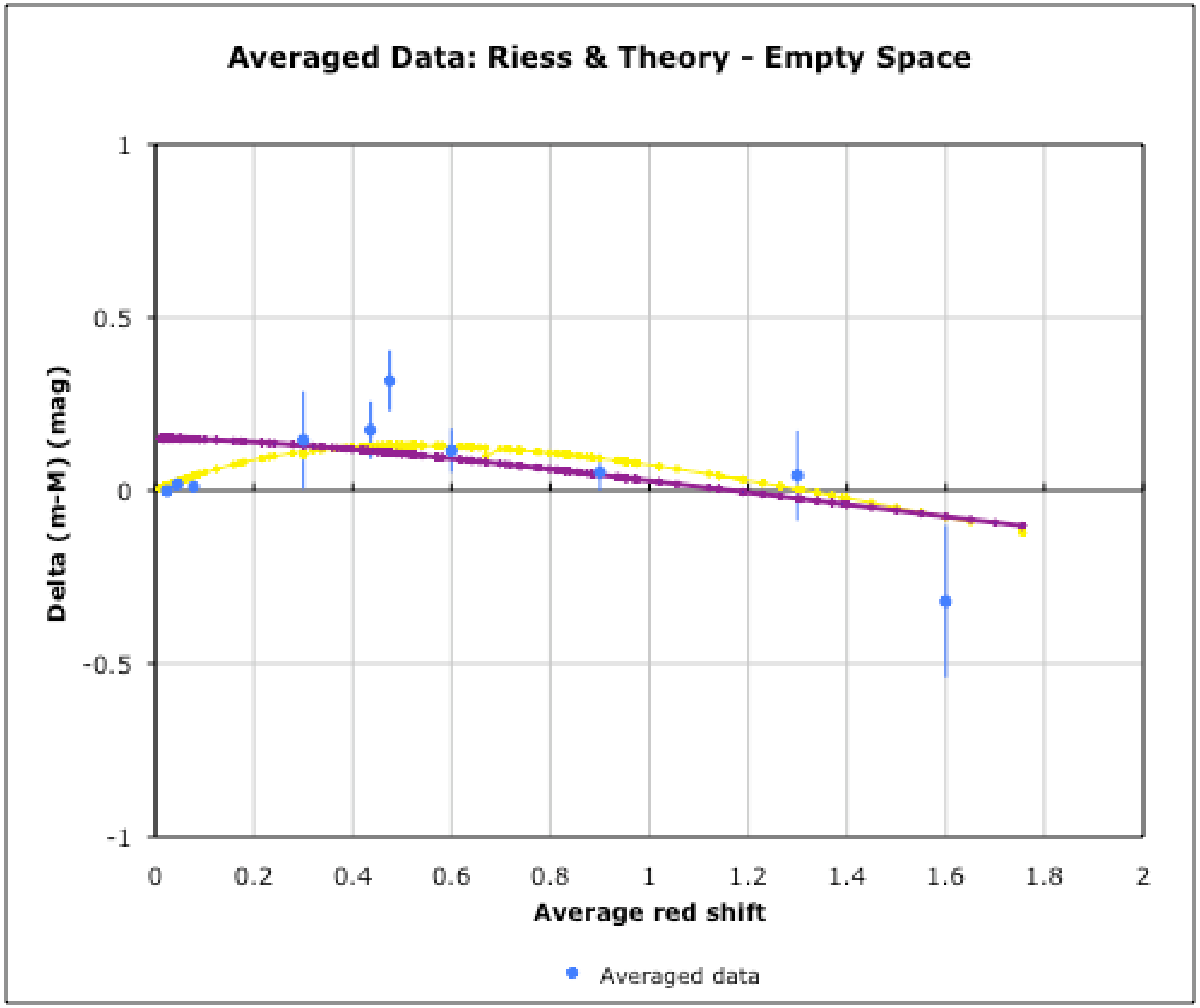
Aggregate Data

Yellow:

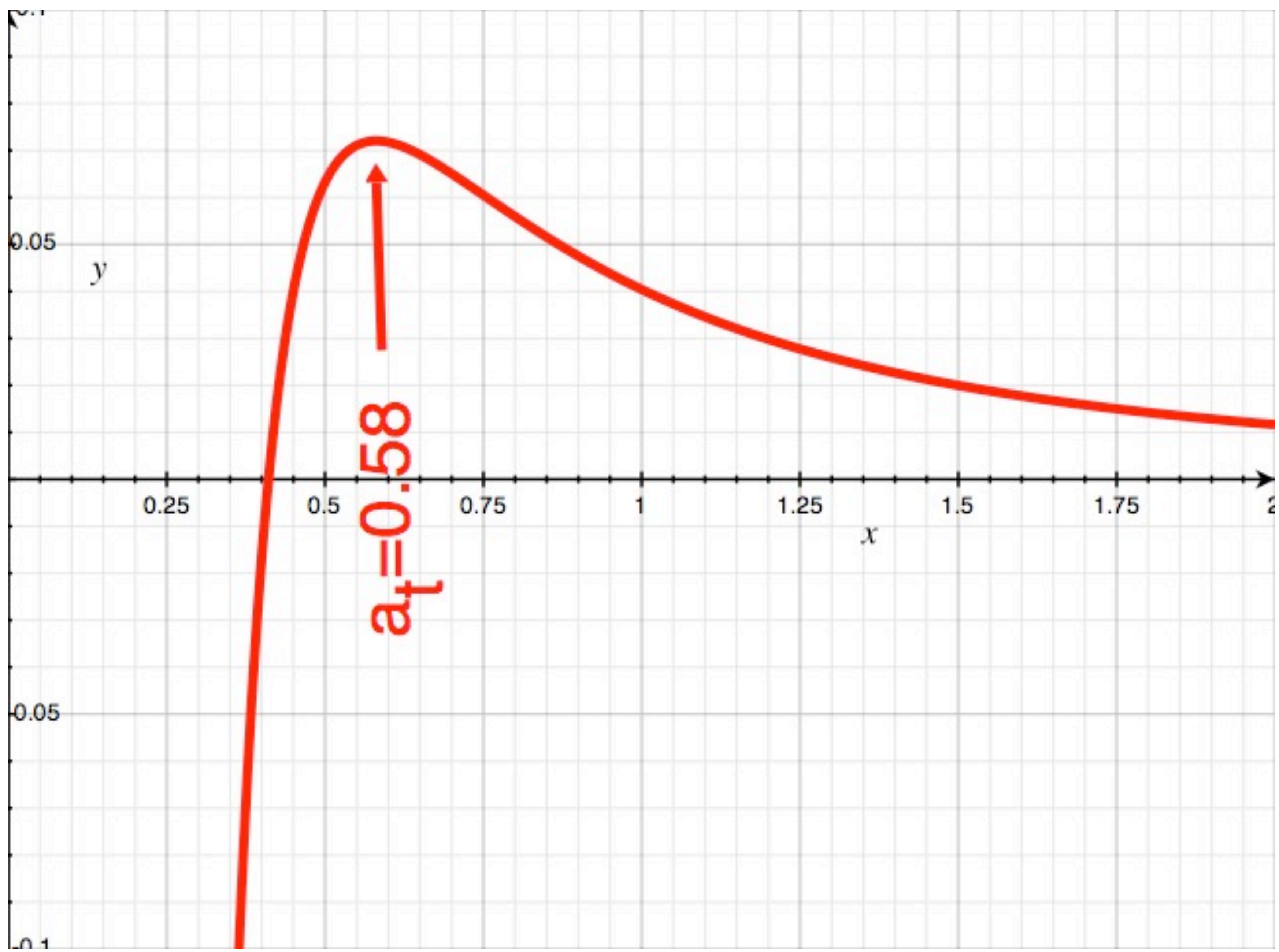
$\Lambda = 0.7,\ M = 0.3, k = 0$

Purple:

$\rho_0 / \rho_c = 0.4, k = -1$

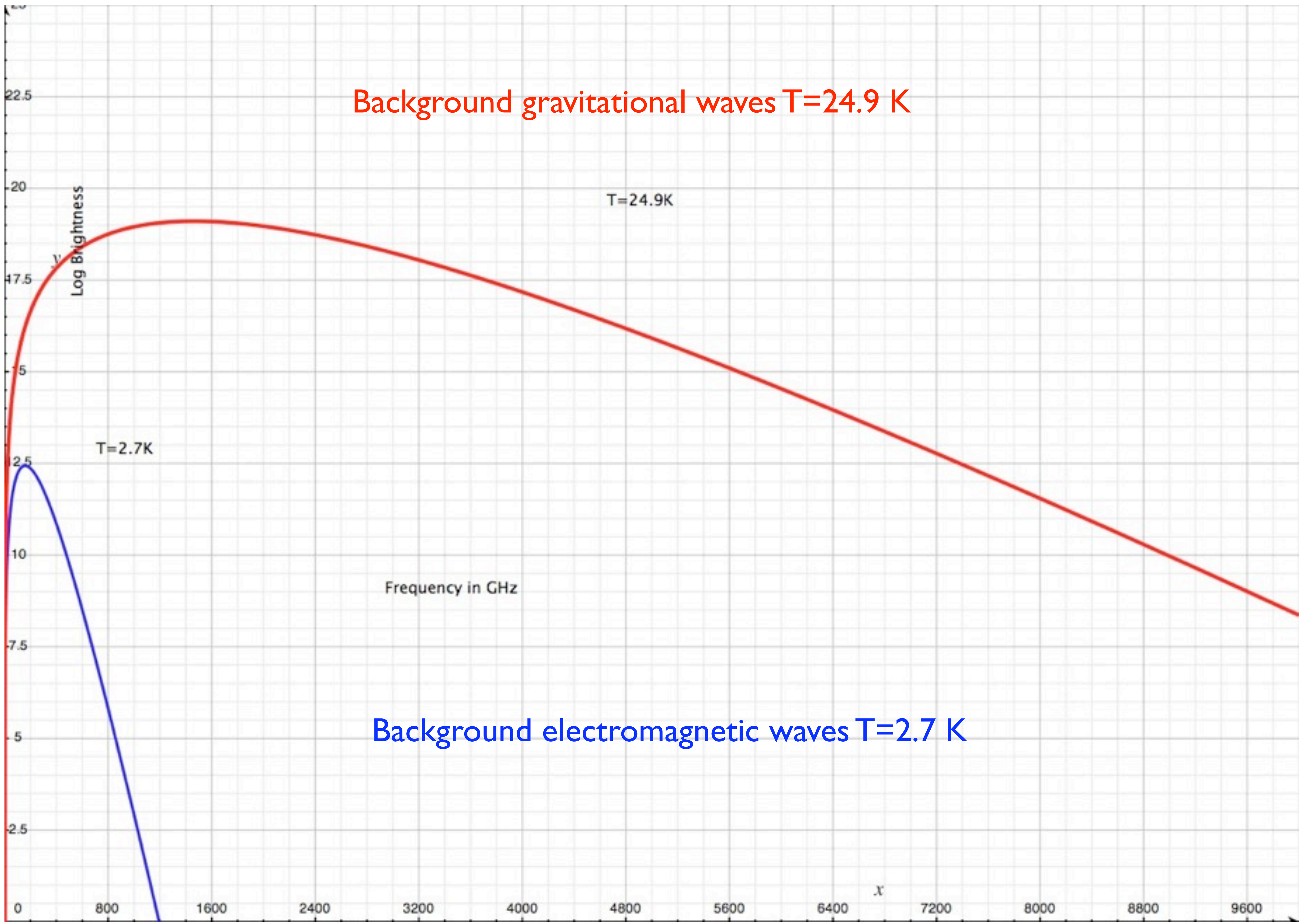


Pressure vs "a" (z_t=0.7)



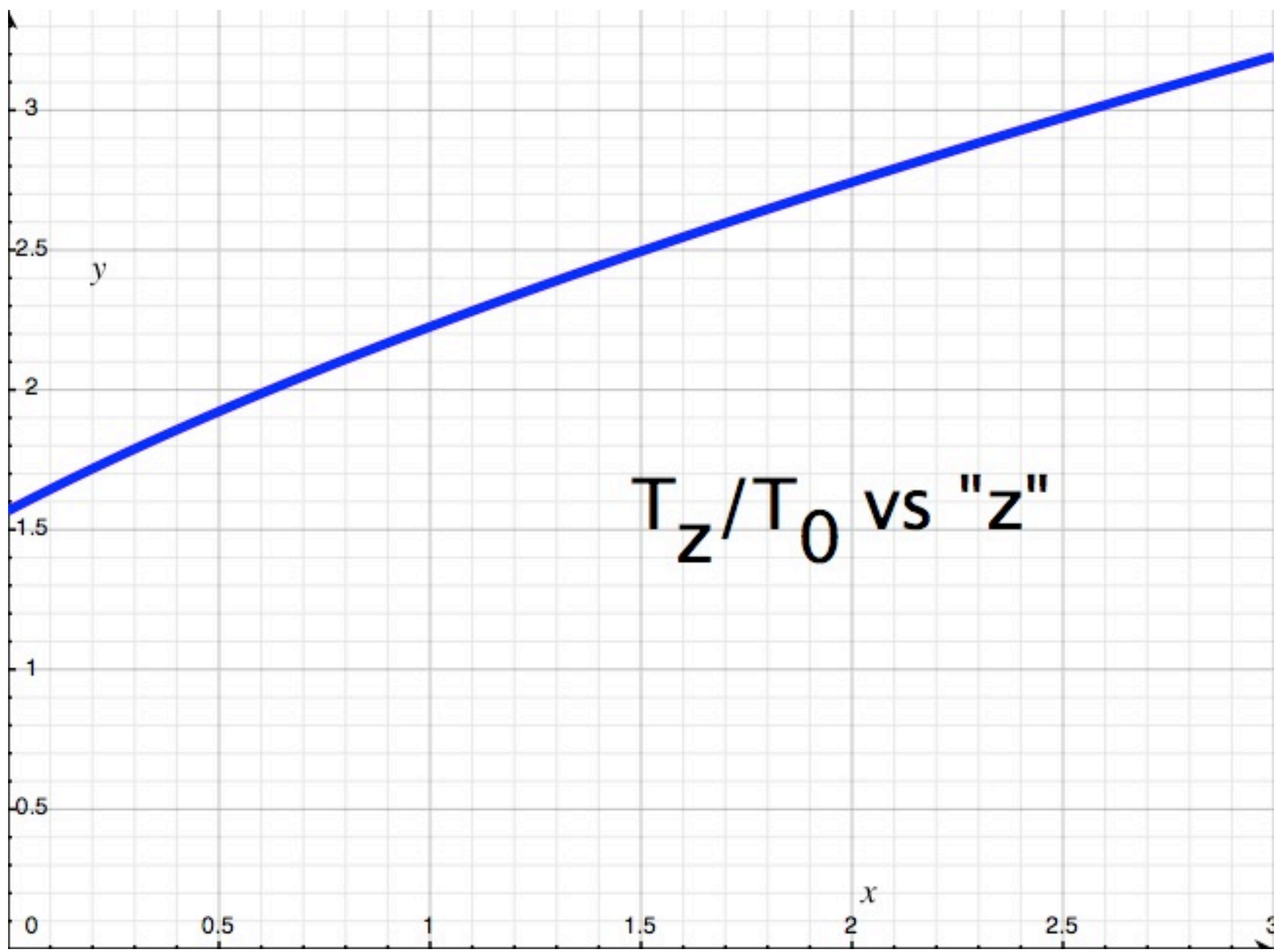
Solution Properties

- Exact solution of Einstein equations
- Free of free parameters
- Fit solution to distance modulus vs red-shift data
- Yields density from the Big Bang to now
- Map evolution of Universe



Background gravitational waves T=24.9 K
Background electromagnetic waves T=2.7 K
T=24.9K
T=2.7K
Log Brightness
Frequency in GHz
22.5
20
17.5
15
12.5
10
7.5
5
2.5
0
800
1600
2400
3200
4000
4800
5600
6400
7200
8000
8800
9600
x
y

Temperature vs redshift

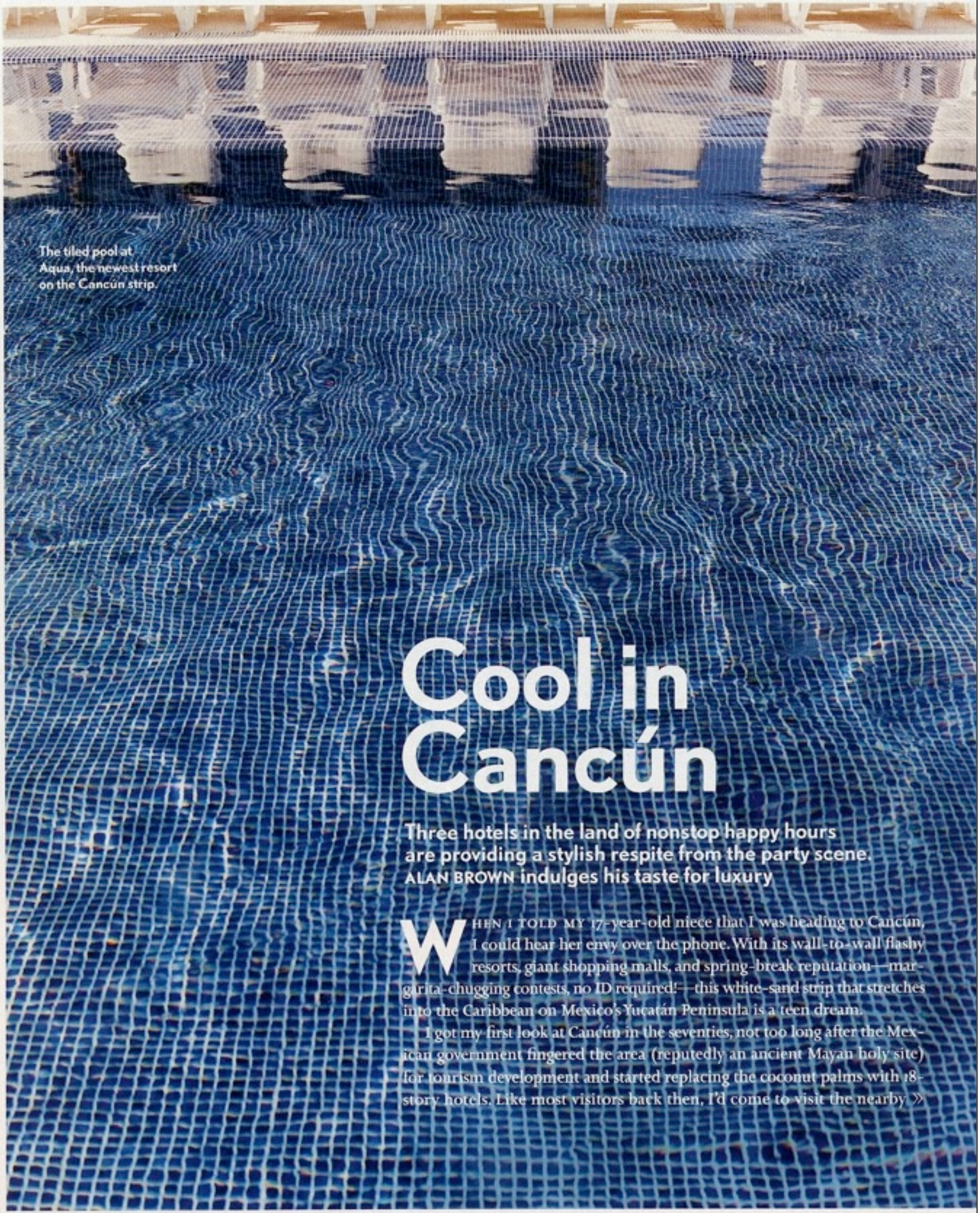


Conclusion

- Non-uniform expansion of Universe driven by gravitational radiation
- Source of *outward* pressure is gravitational radiation
- Source of *inward* pressure is gravitation
- Both properties attributed to “Dark Energy”

Fluctuations of pulsar signals

- Upper limit (Kaspi, Jenet) $\Omega_g\left[1/8\ yr\right]h^2 \le 10^{-8}$
- Energy density of Galactic halo $6\times10^{-12}\ J/m^3$
- Field is static - no oscillations
- Source outside Galaxy



The tiled pool at Aqua, the newest resort on the Cancún strip.

Cool in Cancún

Three hotels in the land of nonstop happy hours are providing a stylish respite from the party scene. ALAN BROWN indulges his taste for luxury

WHEN I TOLD MY 17-year-old niece that I was heading to Cancún, I could hear her envy over the phone. With its wall-to-wall flashy resorts, giant shopping malls, and spring-break reputation—margarita-chugging contests, no ID required!—this white-sand strip that stretches into the Caribbean on Mexico's Yucatán Peninsula is a teen dream.

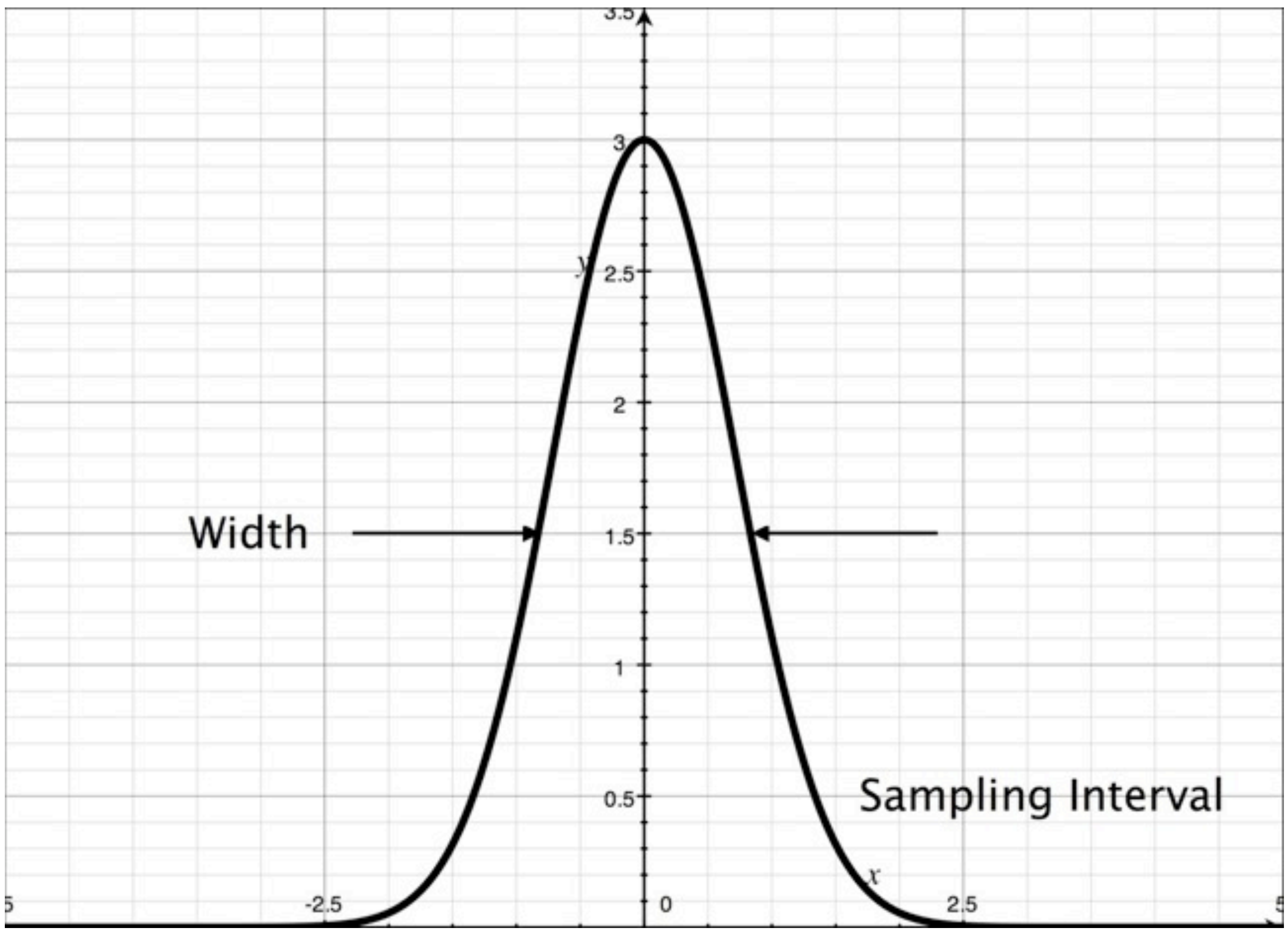
I got my first look at Cancún in the seventies, not too long after the Mexican government fingered the area (reputedly an ancient Mayan holy site) for tourism development and started replacing the coconut palms with 18-story hotels. Like most visitors back then, I'd come to visit the nearby »

João Canziani

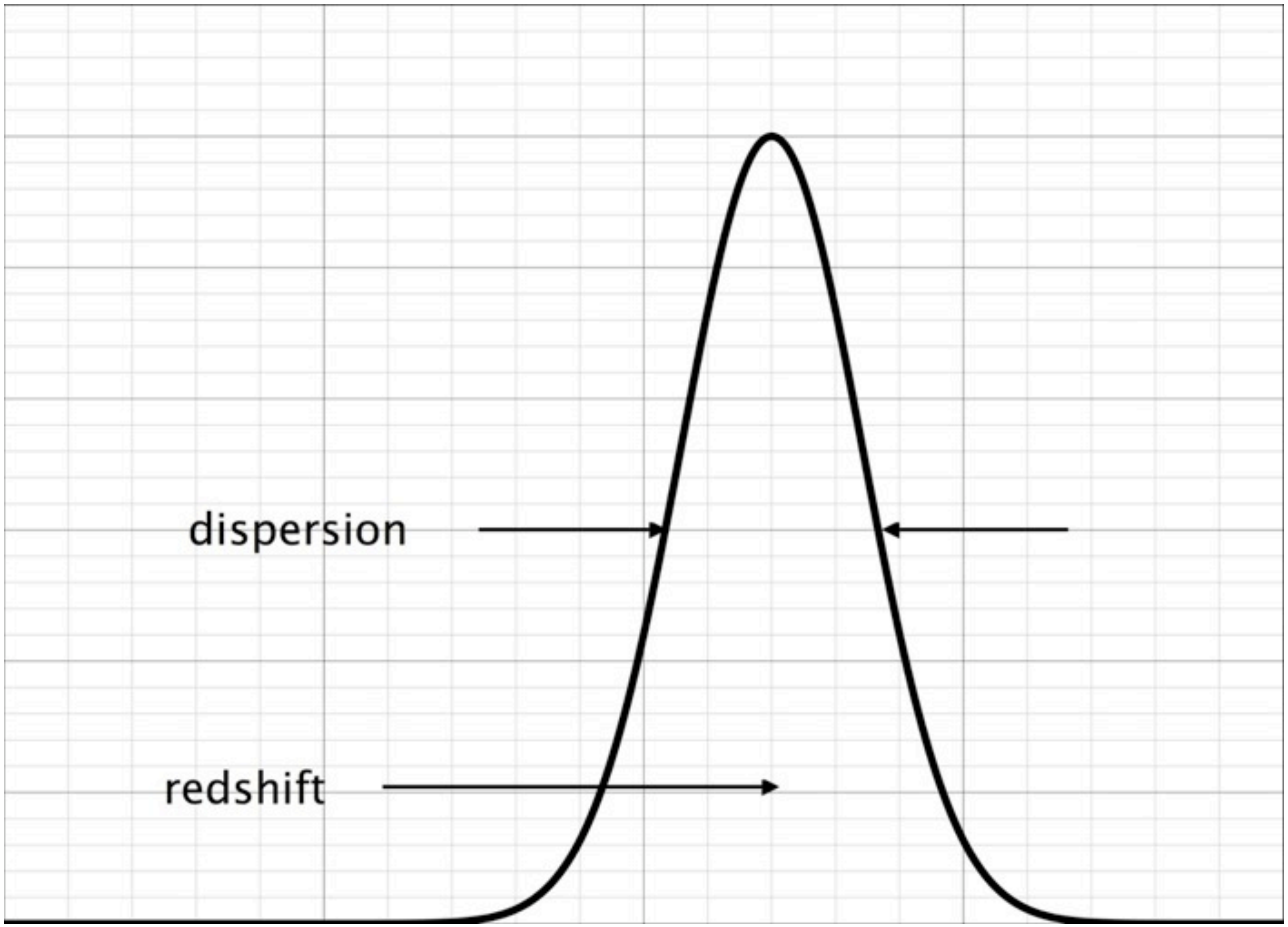
New experiment: Measure dispersion vs z

- (i) Dispersion of supernova position (x-y)
- (ii) Dispersion of light arrival time
- (iii) Dispersion of redshift
- Measure dispersion of sources at different redshifts
- Window to Planck moment

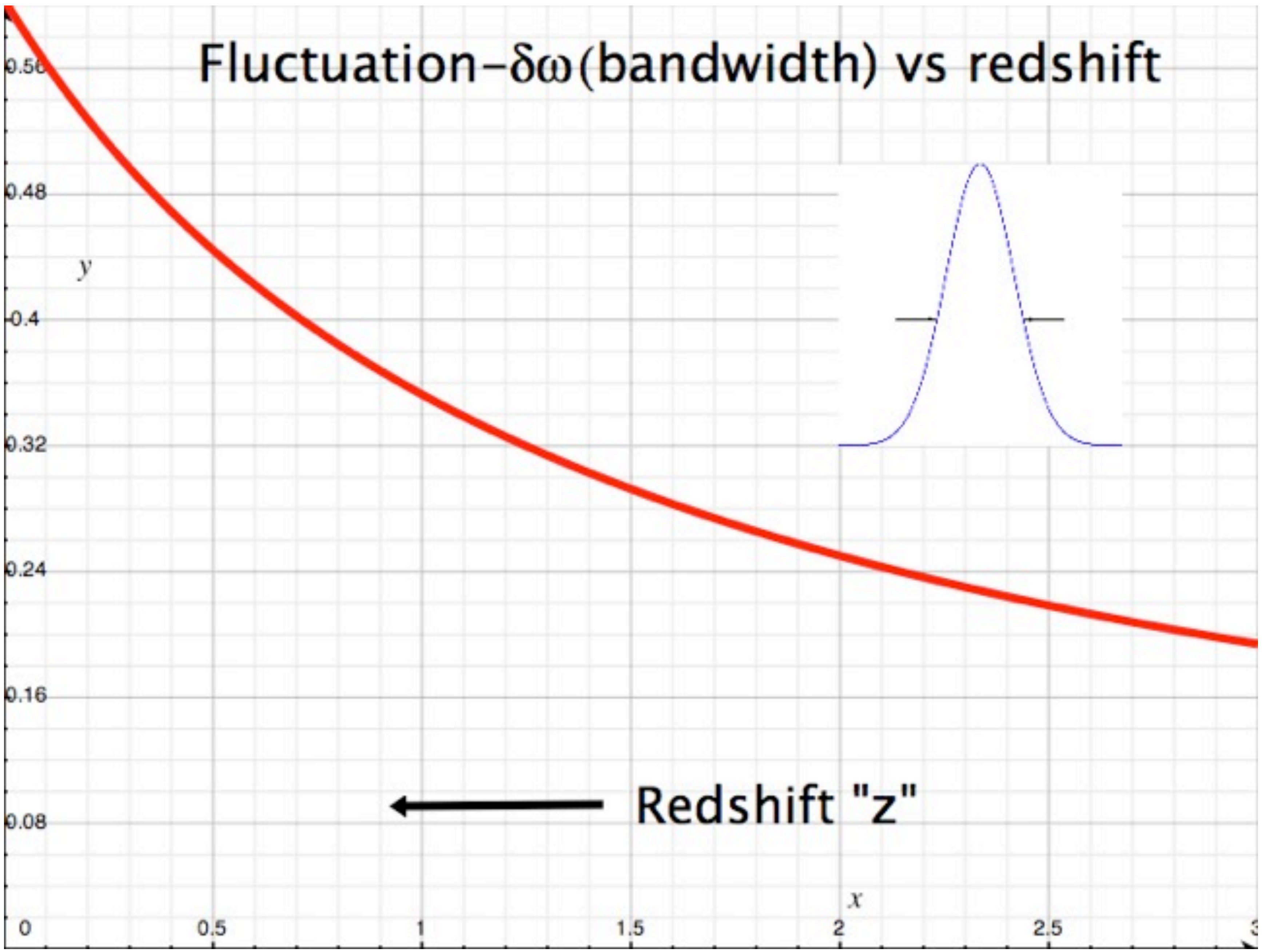
Dispersion of supernova light



Dispersion in redshift



Width of peak vs redshift



Results 1

- Deviation from Hubble line caused by cosmological gravity waves (dark energy)
- Universe is open $k = -1$
- Current temperature is $T_\Gamma = 25K$

Results 11

- Current density is $\rho_0 / \rho_c = 0.4$ of critical density
- At $z_T = 0.77$ Universe transitions from deceleration to acceleration
- Mass of Universe is $10^{54}\ kg$

THANK YOU!