Effect of Cosmological Gravity Waves on Expansion of the Universe

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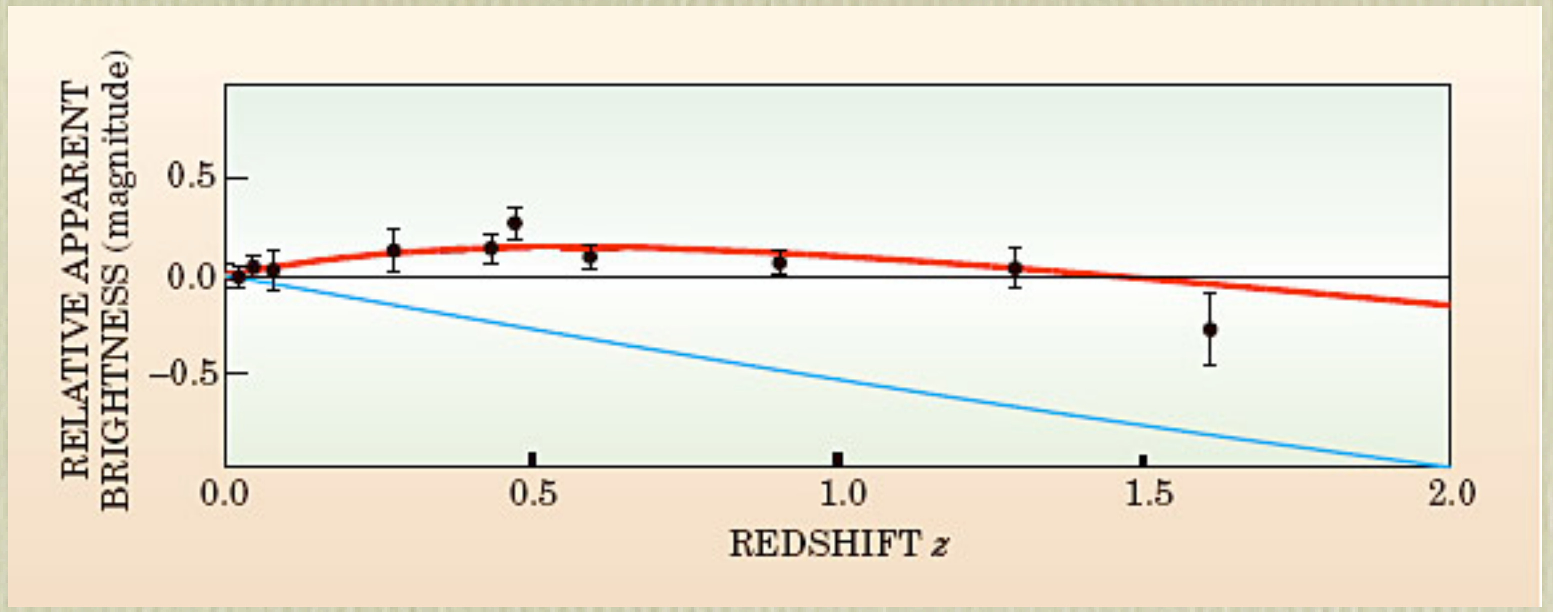
Outline of presentation

- Explain deviations from Hubble line
- Dimming of distant supernovae
- Cosmological gravity waves affect supernova data
- Light travels through a sea of gravity waves
- New experiment



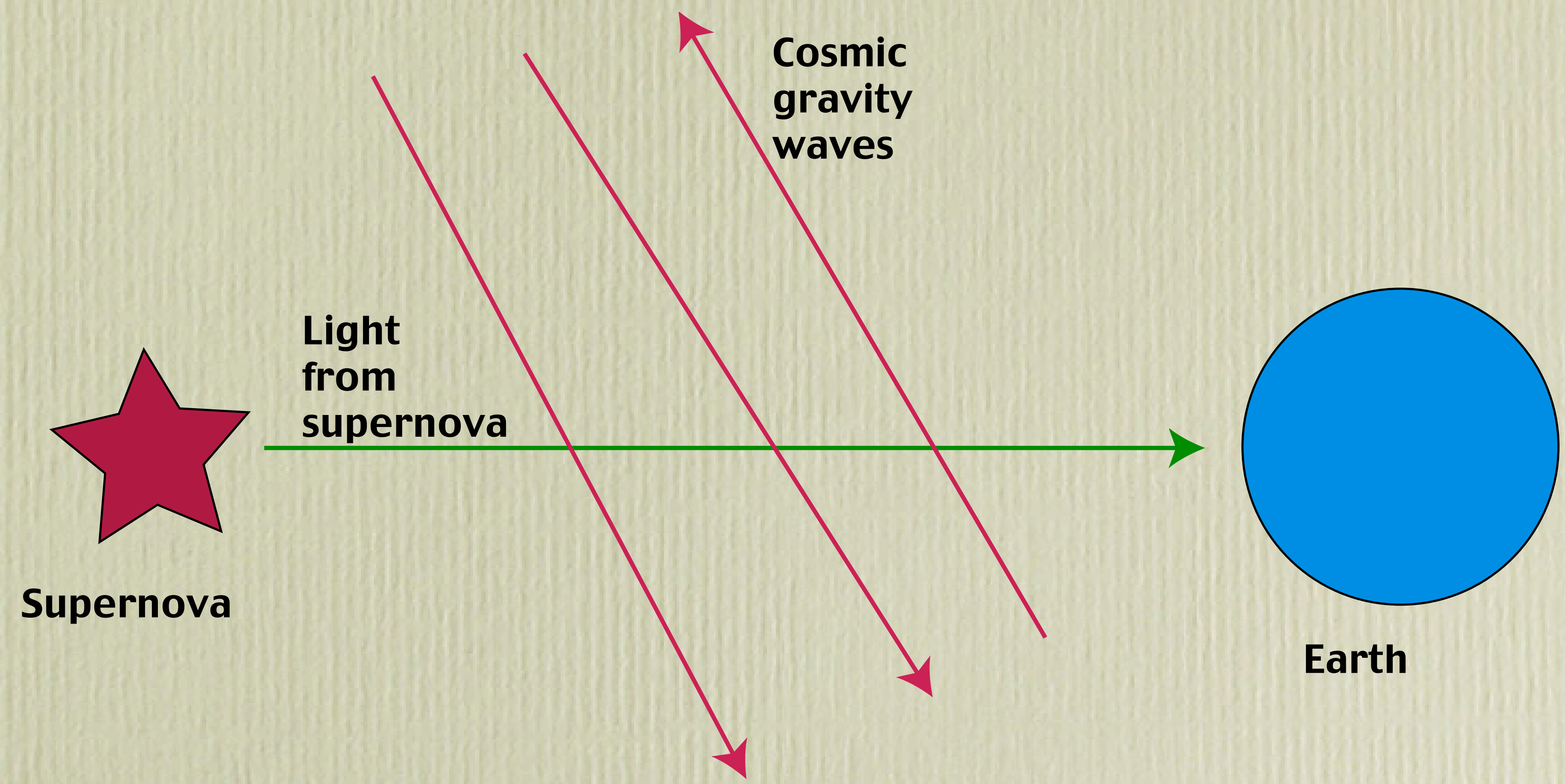
- Red: 71% of cosmological attributed to dark energy $\Omega_M = 0.29, \quad \Omega_\Lambda = 0.71$
- Blue: assumes no cosmological constant
- Black: empty universe with no cosmological constant

Observations

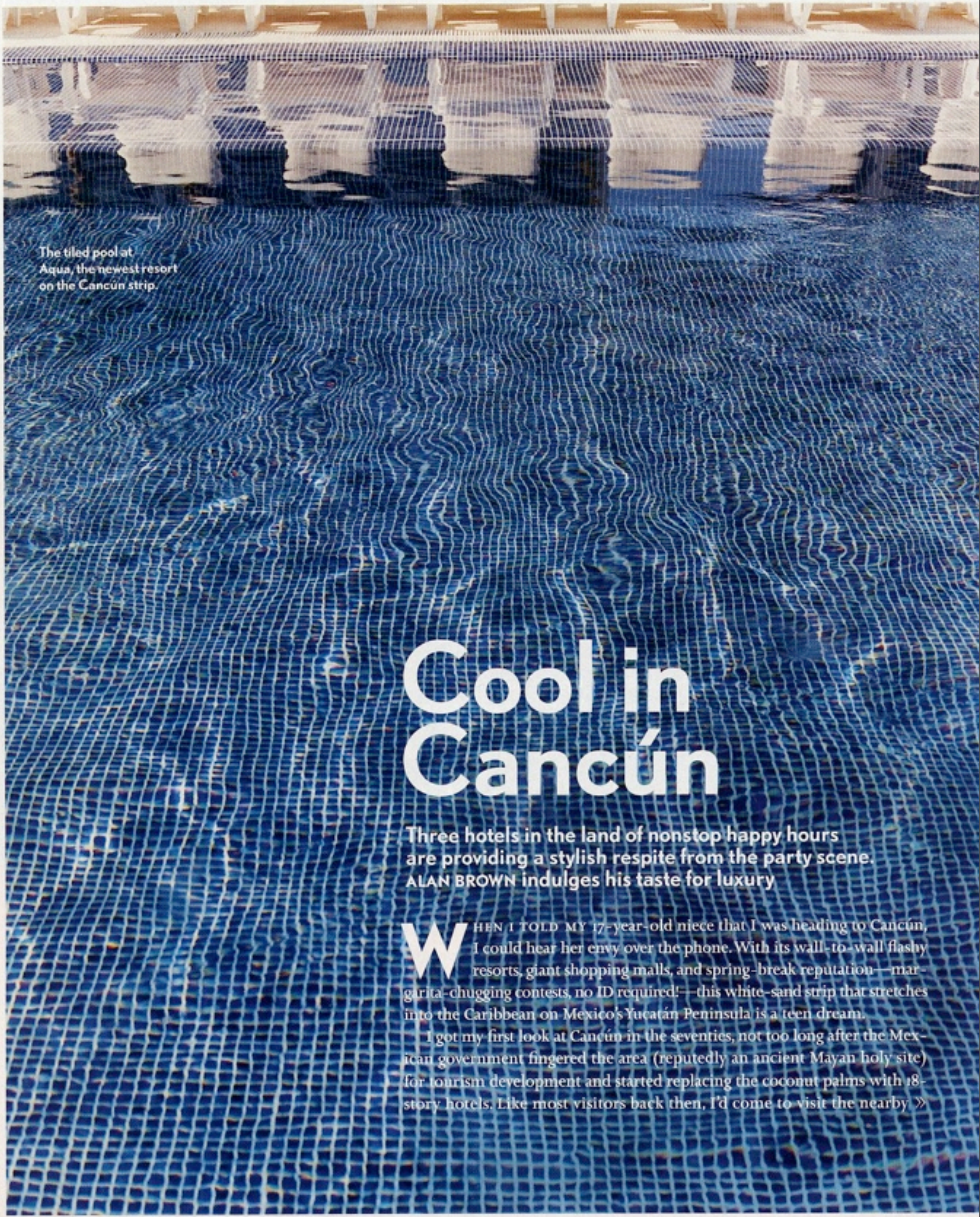
- Deviation from Hubble line
- Data indicate:
- (i) Early universe was *decelerating*
- (ii) Current universe is *accelerating*

Interpretations

- Universe expansion not uniform
- Cosmological constant? Does not fit data
- Dark matter?
- Dark energy?



Cosmic gravity waves
Light from supernova
Supernova
Earth



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

Simpler explanation

- Cosmological gravity waves
- All pervasive from Planck era to present
- Gravity decouples: Planck era: 10^{-43} to 10^{-35} secs
- Cosmological gravity waves emerge
- Gravity waves expand with Universe

Effect on measurements

- Excessive redshift
- Light travel time increased

Properties of graviton gas

- 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*

Solve Einstein equation for gas of gravitons

- Van der Waals type gas, except gravity gravitates, interaction is long range
- Calculate altered expansion rate
- Compare with supernova data
- Deduce energy content of Universe

Cosmological Gravity Waves

- Pressure vs density of gravity waves as perfect fluid

$$p = \frac{1}{3}\rho c^2 - \frac{4\pi G}{9}\rho^2 R^2$$

$$\frac{d}{dR}\left(\rho R^3\right) = -3pR^2$$

- Equation of state
- $\rho = \left[\frac{2\pi G}{3c^2}R^2 + FR^4\right]^{-1}$

Stress Tensor

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

Einstein equation

- Perfect fluid

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

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

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

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

Compare with data

- Total energy density content defined as "b"
- $R_0 = R(t_0); \quad R_F^2 = \dfrac{2\pi G}{3c^2 F}; \quad \rho_C = \dfrac{3H_0^2}{8\pi G}; \quad b^2 = \dfrac{R_F^2}{R_0^2}$

Luminosity distance d_L vs z

$$d_L = \frac{c(1+z)}{H_0 \left| \frac{\rho_0^T}{\rho_C} - 1 \right|^{1/2}}$$

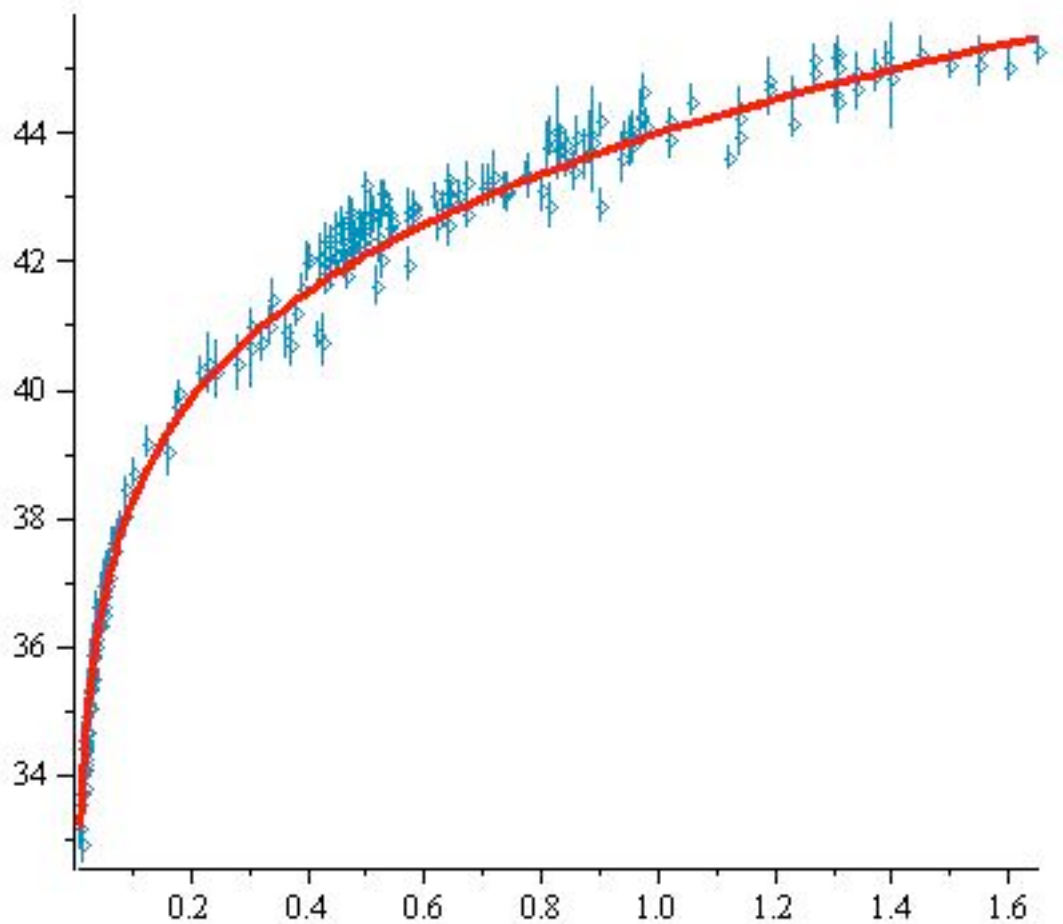
$$\times \sinh \left\{ \left| \frac{\rho_0^T}{\rho_C} - 1 \right|^{1/2} \int_0^{z_1} \frac{dz}{(1+z)} \frac{1}{\sqrt{\frac{\rho_0^T}{\rho_C} \left[\left(\frac{(1+b^2)(1+z)^2}{b^2(1+z)^2+1} \right)^2 \frac{1-b^2(1+z)^2}{(1-b^2)(1+z)^2} - 1 \right] + 1}} \right\} Mpc$$

$$\frac{\rho_0^T}{\rho_C} = 0.3625 \frac{b^2(1-b^2)}{(1+b^2)^2}$$

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

Supernova data (Riess 2006)

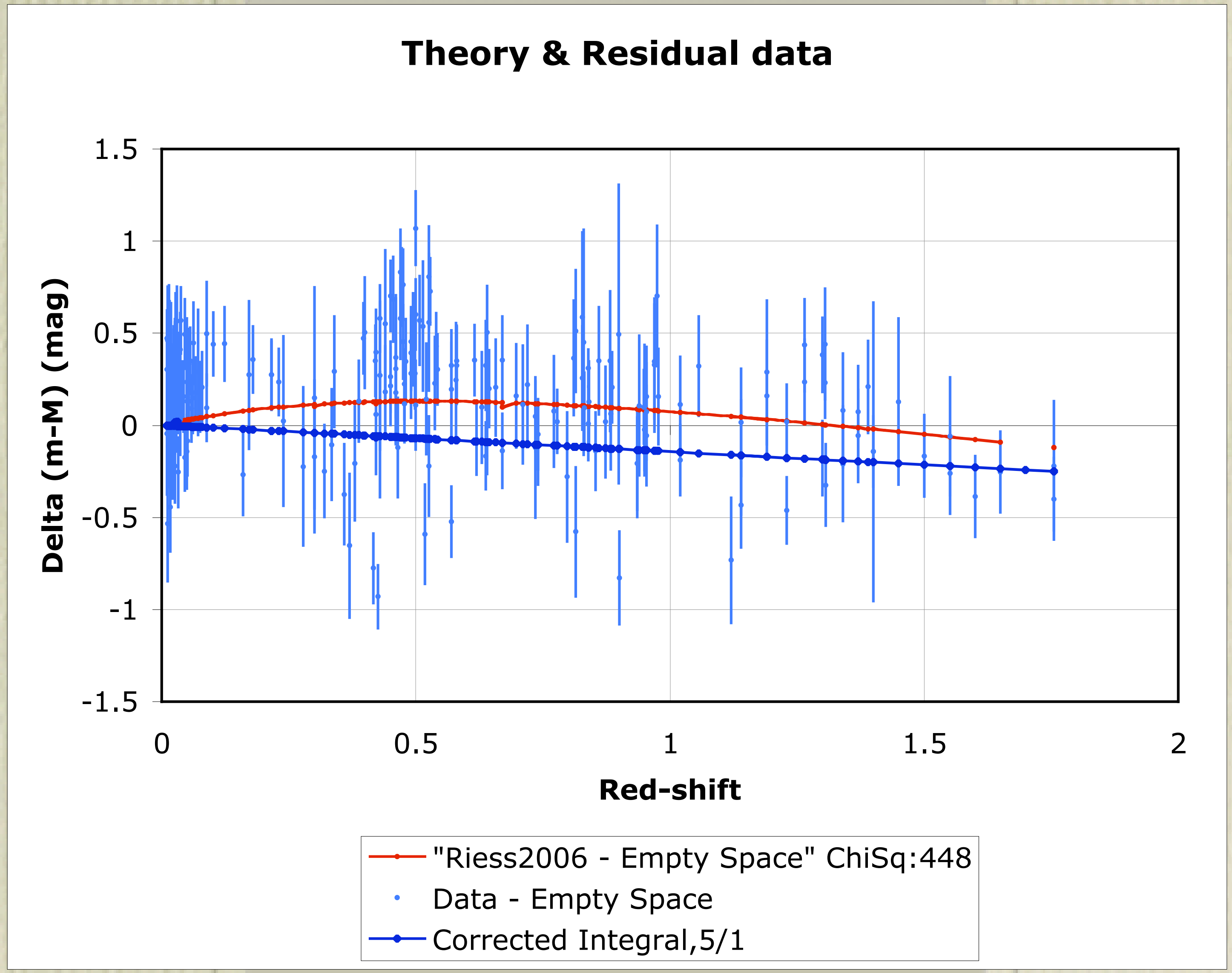
- Curve fit to data
- Distance modulus vs redshift spread over 13 orders



Plot of data (with error bars) in blue and approximation from integral, black, with p0/pc = 0.04531186438 and b = 0.335. Total error = 639.5597468.

Curve fit to all data

- Distance modulus vs redshift data; (minus expansion of empty Universe)
- Blue: fit with b=0.335
- Red:
- $\Omega_M = 0.29, \Omega_\Lambda = 0.71$

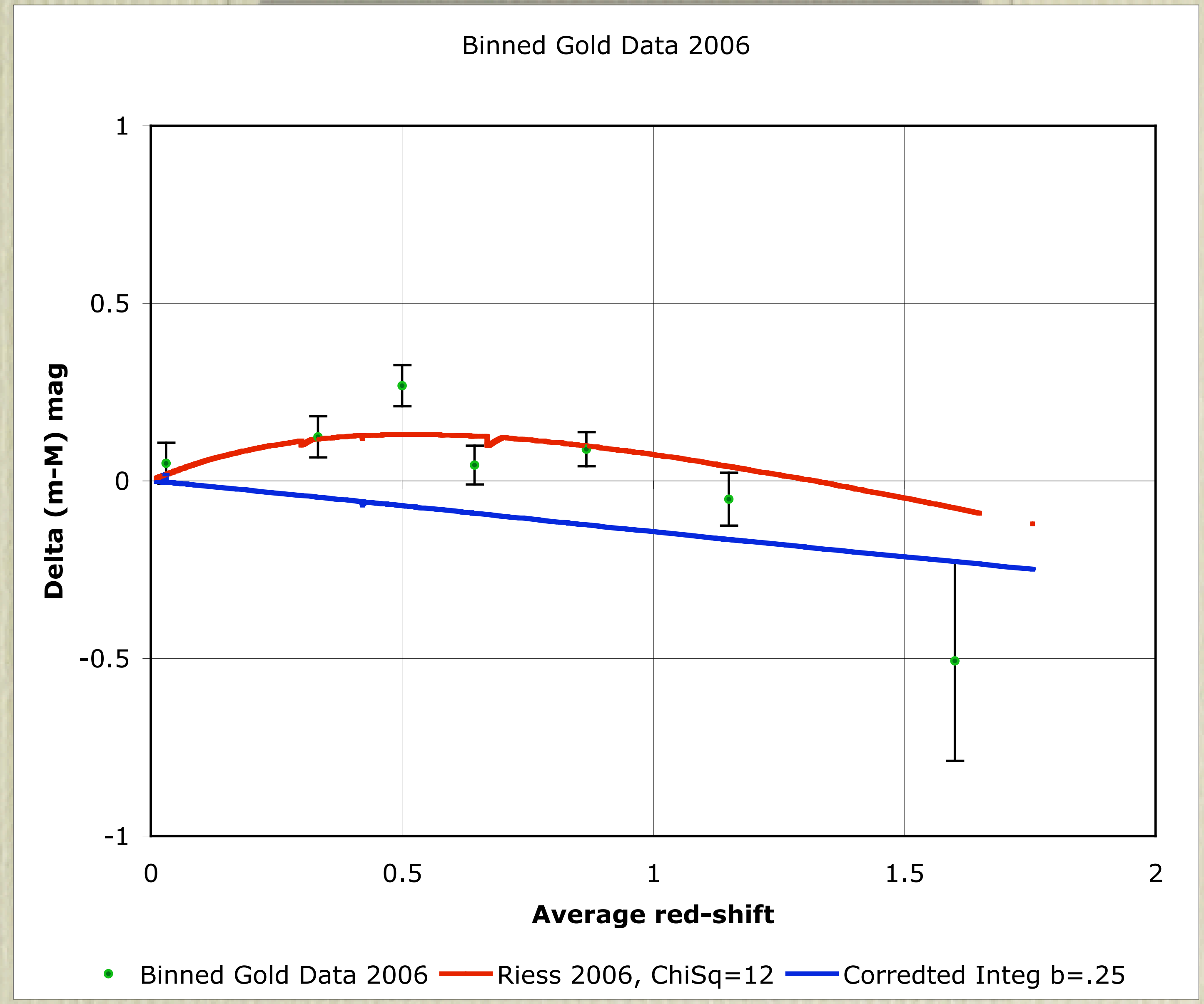


Aggregate data

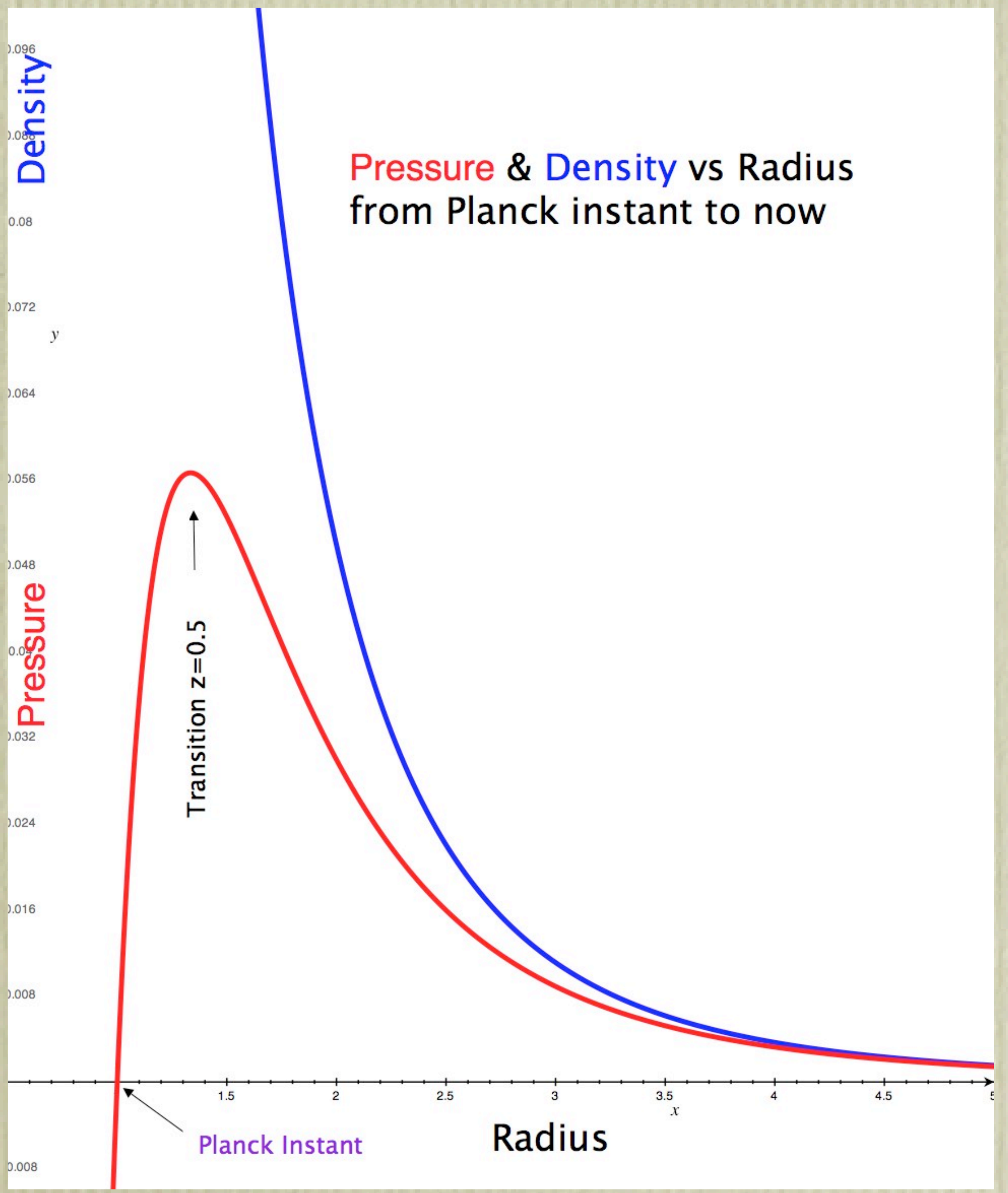
- Red:

  $$\Omega_M = 0.29, \Omega_\Lambda = 0.71$$

- Blue: exact solution, purely gravity waves



Evolution of Universe



- Pressure & density vs radius: equation of state
- From Planck moment to present
- Deceleration - coasting - acceleration
- z_t=0.5

Results

- 5×10^{54} kg of cosmological gravity waves in Universe

- At z=0.5 Universe transitions from deceleration to acceleration

- Current density is $\dfrac{\rho_0}{\rho_C} = 0.0725$ of critical density

- $\Omega_k \equiv -\dfrac{k}{R_0^2 H_0^2} = -0.9275$ (Universe is open)

Conclusion

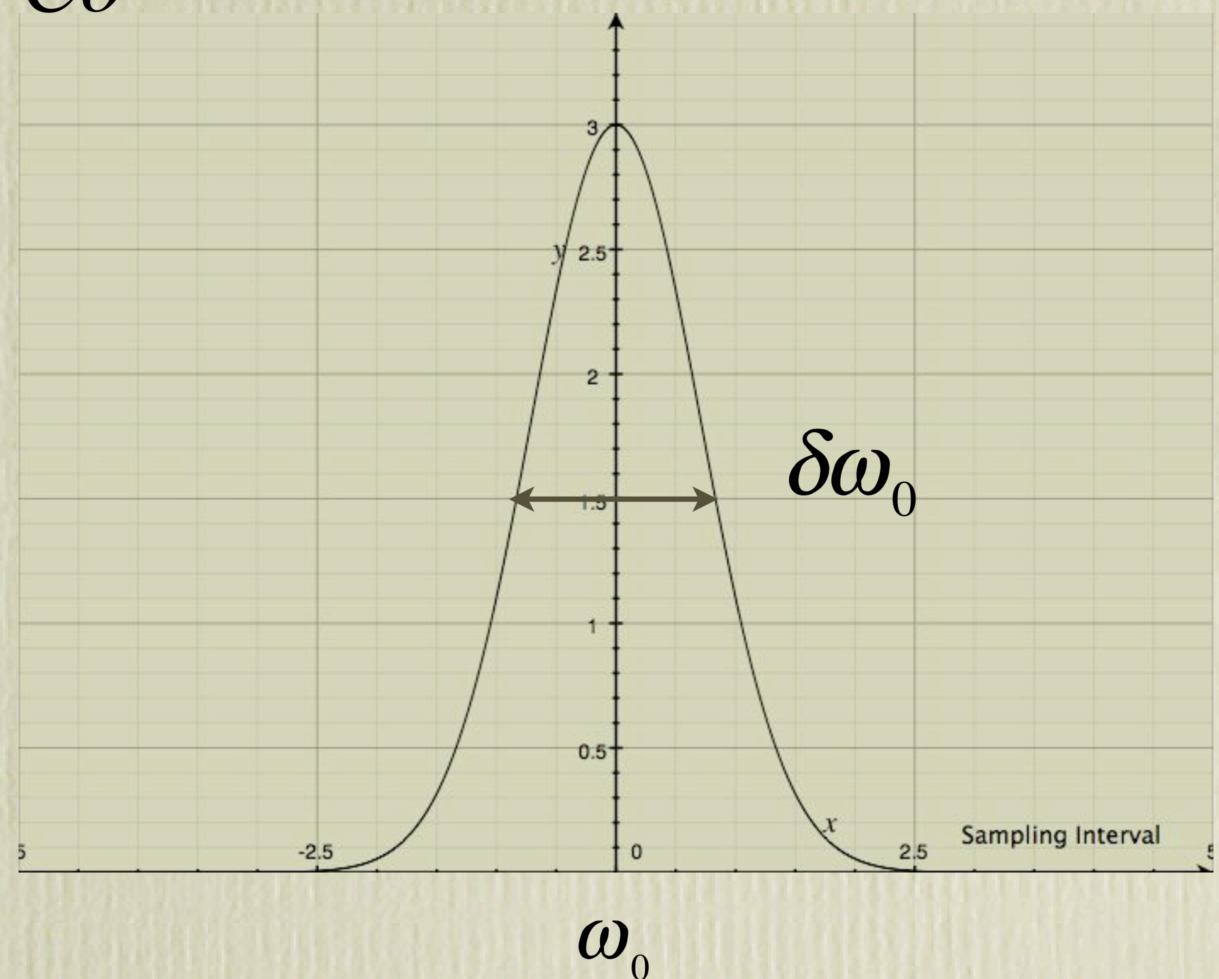
- Non-uniform expansion of Universe driven by gravitational radiation
- Source of *outward* pressure is gravitational radiation
- Source of *inward* pressure is gravitation
- Both properties attributed to “Dark Energy”
- Interpretation of *mass* and *cosmological constant*

Open question

- Light from supernovae is redshifted
- Is it possible to distinguish between gravitational redshift and Doppler redshift?
- Source stationary or receding?
- Both are independent of wavelength
- Is the redshift due to either or both?

Suggested measurements

- Sample spectral lines $^{56}Ni, ^{56}Co$
- Width of light scattered from gravity waves: $Q \propto \omega_0$
- Redshift independent of frequency
- Graph $Q \propto \omega_0$



Deductions

- From $Q \propto \omega_0$ (constant z) graph and intercept, identify Doppler vs gravity redshift
- Slope: (σ_x, σ_y) correlation lengths
- $Q \propto z$ constant ω_0 :time correlation length

THANK YOU