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

• 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?
Supernova

Earth

Light from supernova

Cosmic gravity waves
Cool In Cancun

Several hotels in the land of monsoon happy hours

W

Villa Padi's inclusions hit the nail for luxury

are promising a stylish respite from the party scene.

The pool pool pool

or the Cancun trip

April 2005
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: \textit{deceleration}.
- Transition phase: force of gravity equals gas pressure: \textit{steady} expansion.
- Current universe: Low density: force of gravity less than gas (radiation) pressure: \textit{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

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

\[ \frac{d}{dR} (\rho R^3) = -3pR^2 \]

- Equation of state

\[ \rho = \left( \frac{2\pi G}{3c^2} R^2 + FR^4 \right)^{-1} \]
Stress Tensor

- Isotropic fluid: traceless stress tensor

\[ T^{\mu\nu} = \begin{bmatrix}
\rho c^2 - \frac{4\pi G}{3} \rho^2 R^2 & 0 & 0 & 0 \\
0 & -p & 0 & 0 \\
0 & 0 & -p & 0 \\
0 & 0 & 0 & -p
\end{bmatrix} \]
Einstein equation

- Perfect fluid

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

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

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

- \[ \frac{\rho_0^T}{\rho_C} - \frac{k}{H_0^2 R_0^2} \equiv \Omega_R + \Omega_k = 1; \quad \Omega_k = 1 - \frac{\rho_0^T}{\rho_C} \]
• Total energy density content defined as "$b$"

• $R_0 = R(t_0)$; $R_F^2 = \frac{2\pi G}{3c^2 F}$; $\rho_c = \frac{3H_0^2}{8\pi G}$; $b^2 = \frac{R_F^2}{R_0^2}$
Luminosity distance $d_L$ vs $z$

$$d_L = \frac{c(1+z)}{H_0 \left| \frac{\rho_0^T}{\rho_C} - 1 \right|^{1/2}} \times \sinh \left[ \frac{\rho_0^T}{\rho_C} - 1 \left| \frac{1}{1+z} \int_0^{1+z} dz \right| \right]^{1/2} \sqrt{\frac{\rho_0^T}{\rho_C} \left[ \left( \frac{1+b^2}{b^2(1+z)^2 + 1} \right)^2 \frac{1-b^2(1+z)^2}{(1-b^2)(1+z)^2} - 1 \right] + 1} \ Mpc$$

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

$$\mu_p = m - M = 5 \log d_L + 25$$
Supernova data (Riess 2006)

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

• $5 \times 10^5$ kg of cosmological gravity waves in Universe

• At $z=0.5$ Universe transitions from deceleration to acceleration

• Current density is $\frac{\rho_0}{\rho_c} = 0.0725$ of critical density

• $\Omega_k \equiv -\frac{k}{R_0^2 H_0^2} = -0.9275$ (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: $(\sigma_x, \sigma_y)$ correlation lengths
- $Q \propto z$ constant $\omega_0$ : time correlation length
THANK YOU