Dark Energy And The Accelerated Expansion

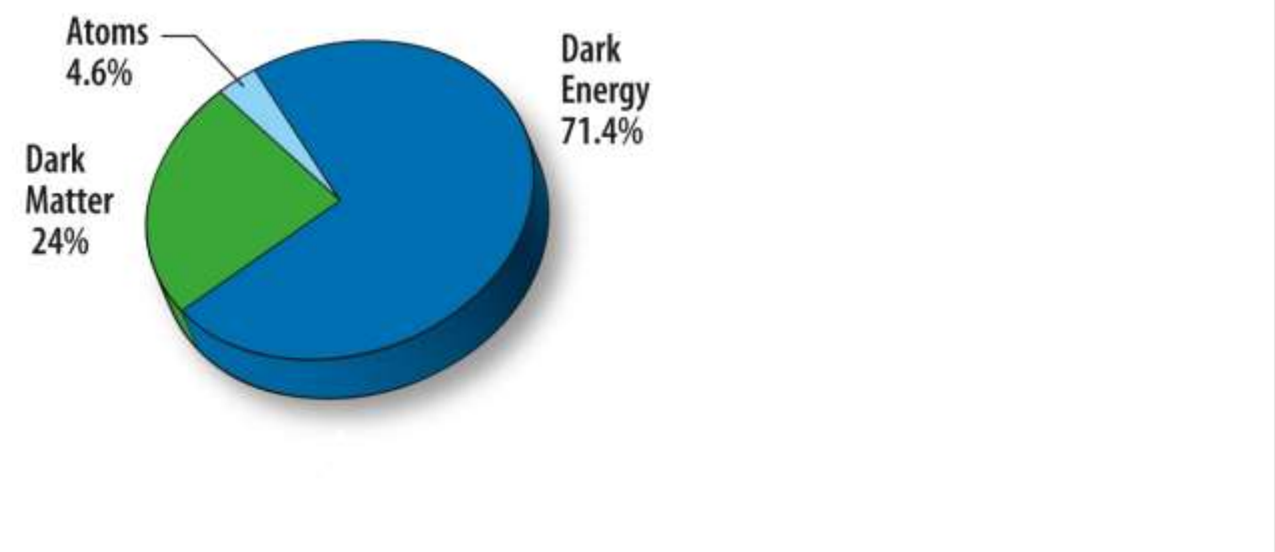
Chelsea Maria John, Shivi Baijal, Satvik Mishra, Dr. Sanil Unnikrishnan, Dr. Geetanjali Sethi
St.Stephen's College, University of Delhi, New Delhi-110007.

- **Abstract:**

In this poster we explore factors that drive the accelerated expansion of the Universe. An impressive amount of different astrophysical data converges towards the picture of a spatially flat universe undergoing a phase of accelerated expansion. Using the Friedmann equations we show a flat Universe cannot evolve to the present age if only matter and radiation are included. In this work, we used various combinations Matter, radiation and Vacuum and found that only the combination between matter and Vacuum is consistent with the current age observation. We then explored the possibility of presence of some unknown parameter which when combined with matter would result in similar consistency. The nature of this dark energy dominating the energy content of the universe is still unknown. From our plots, we found that a range of values for the density parameter of this unknown parameter are viable candidates to explain cosmic acceleration.

Cosmology

- It is a branch of physics and astrophysics dealing with the origin, evolution and the eventual fate of the universe.
- During the last two decades, cosmology has become a precision observational science.
- Observations indicate that about 96% of total content of the universe is unknown.
- Of which about 24% is Dark Matter and remaining 71% is what is known as Dark Energy.



Friedmann Equations

Two basic equations that govern the expansion of the universe:

$$\left(\frac{dR}{dt}\right)^2 = \left(\frac{8}{3}\right)\pi G \rho R^2 \text{- k} \qquad \text{---------- (1)}$$

$$\frac{d^2R}{dt^2} = -\left(\frac{4}{3}\right)\pi G(\rho + 3p)R \qquad \text{---------- (2)}$$

where R is the scale factor, ρ is the energy density, p is the pressure, k is a constant whose value 0,-1 or 1 indicates whether the universe is spatially flat, open or closed respectively.

$$\rho = \rho_m + \rho_r + \rho_d$$

$p_m = 0$, $p_r = 1/3\rho_r$, $p_d = w\rho_d$

- <u>Critical Density:</u>

When k=0 , the Friedmann equation says the density is.

$\rho_c = 3H^2/8\pi G$

This is called critical density. Let

$$\Omega = \rho/\rho_c$$

$\Omega<1$ when $k<0$

$\Omega=1$ when $k=0$

$\Omega>1$ when $k>0$

$\Omega_r = \rho_r/\rho_c$

$\Omega_m = \rho_m/\rho_c$

$\Omega_v = \rho_v/\rho_c$

- <u>Redshift Parameter(z):</u>

Letr = R/R_0

where $R_0$is the value of R now. Then at the time the light was emitted.

$r = 1/(1+z)$

where z is the redshift parameter

- <u>Age of the universe:</u>

$\boldsymbol{\tau}=H_0 t$,

where $\boldsymbol{\tau}$ is the dimensionless time and H_0 is the value of the Hubble's constant at the present epoch.

For a model of Universe comprising matter and some parameter(radiation, Dark Energy, etc.), the time the light takes to reach us, in units of $1/H_0$, as a function of the distance fraction r or redshift z is given by

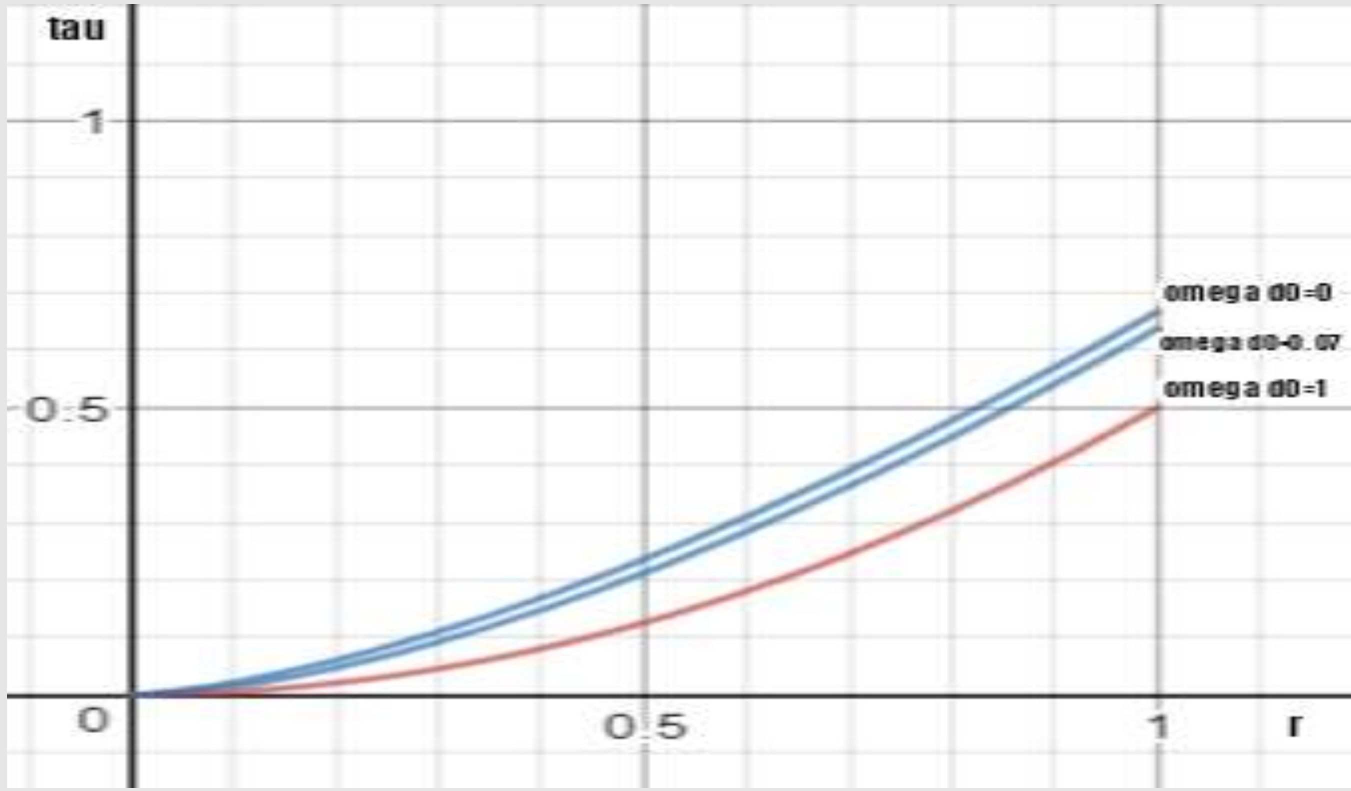
$$\boldsymbol{\tau}(\mathrm{r}) = \int_r^1 \left[\frac{r}{\Omega \mathrm{d}0/\mathrm{r}^{(3\mathrm{w})} - \Omega d0 + 1}\right]^{1/2} dr \qquad \text{.................................(1)}$$

where Ω_{d0} is the density parameter of the combined parameter and

w = p/ρ is the equation of state parameter.

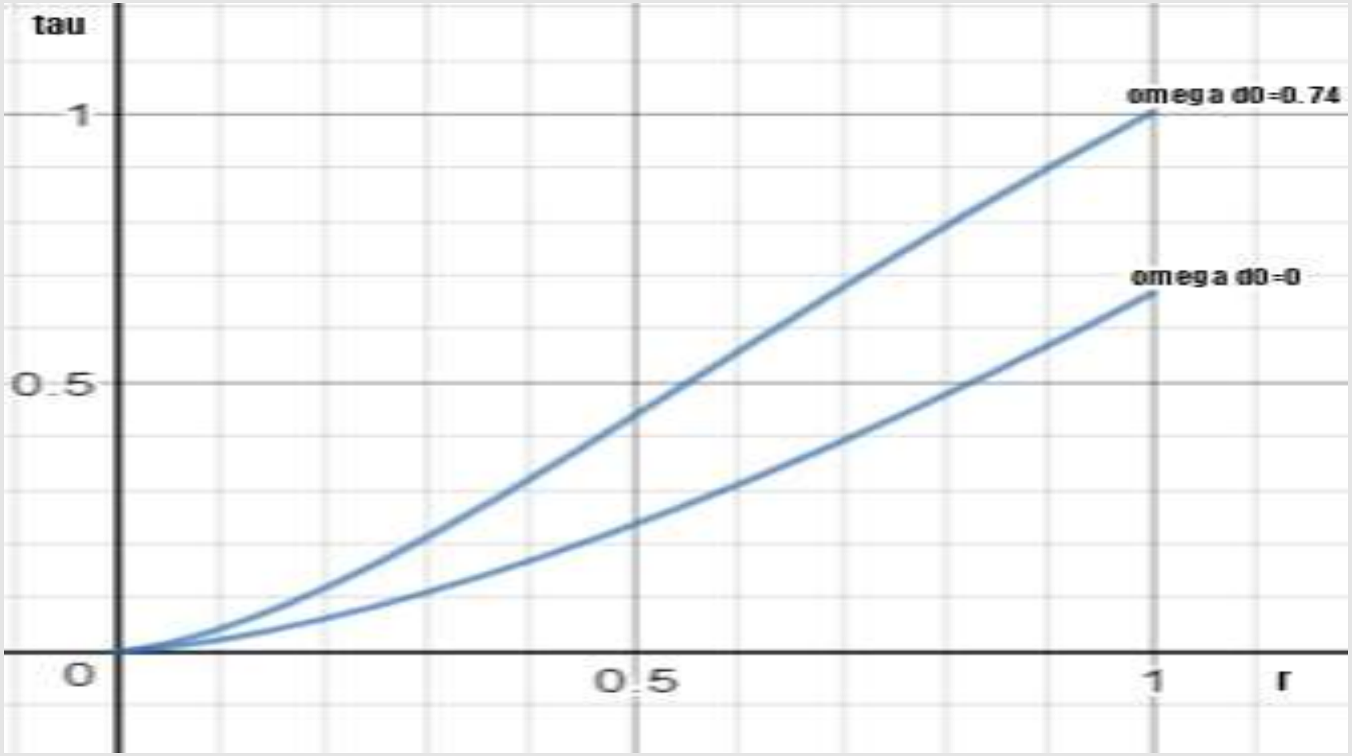
Extending the integral (1) to $\boldsymbol{\tau}(0)$ gives a very goof approximation to the age of the universe as a function of Ω_{d0}.

Case 1: Matter and radiation,w=1/3:



This graph shows that our universe couldn’t have evolved to its present age if it was composed entirely of matter and radiation only. The maximum age that it can evolve to is only 0.66 times of its present value.

Case 2:Matter and dark energy(ʌ) ,w=-1:

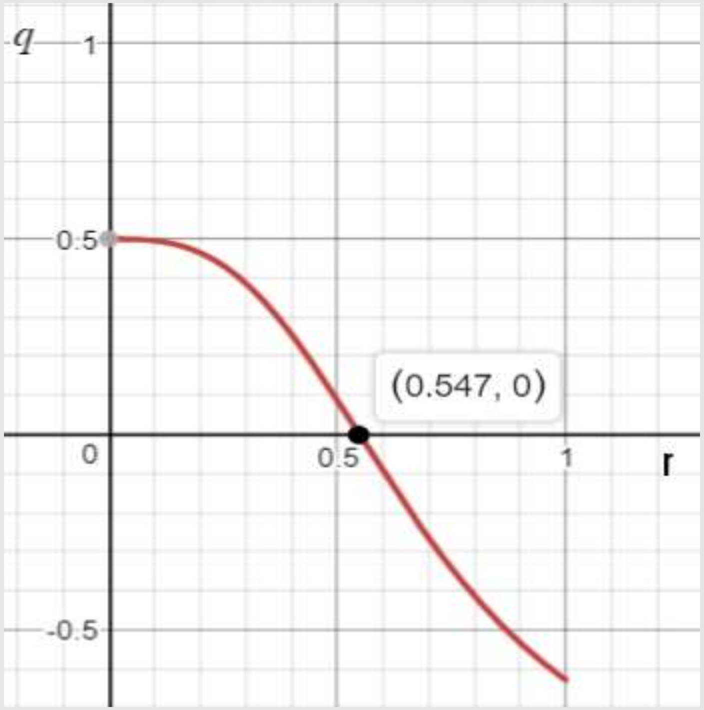


This graph shows that for the universe to evolve to the present epoch, it must be composed of around 74 percent of ʌ.

Deacceleration Parameter(q):

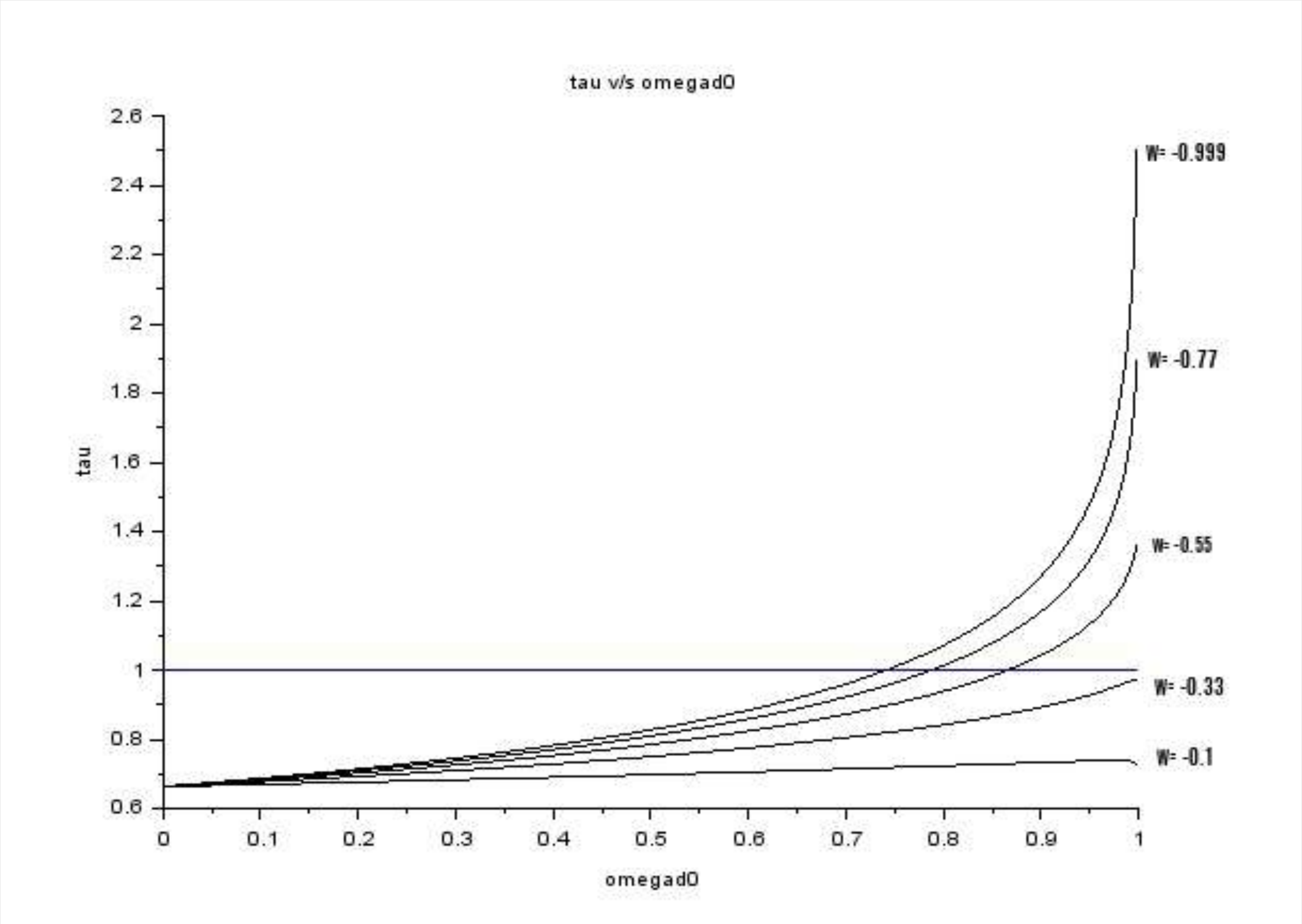
$$q = \frac{-\ddot{R}R^2}{R\dot{R}^2}$$

q<0 shows accelerated expansion
q>0 shows deaccelerated expansion



This graph shows that the universe underwent a transition from decelerated to accelerated expansion at r=0.547.

- In this graph we investigate what combination of Ω_{d0} and w satisfy the age constraint $\boldsymbol{\tau}$=H_0t=1.



This shows that Ω_{d0} <0.7 is not consistent with the age constraint.

Future Work

- Using the cosmological data ,we would like to constrain the parameters of dark energy(ie, whether **w** is constant or evolving).
- To investigate whether non-flat models of universe are ruled out by cosmological observations.

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