Transition Redshift: New constraints from the age of galaxies and Strong lensing

Nisha Rani

Department of Physics and Astrophysics
University of Delhi
Delhi, 110007

Plan of the Talk

1. Evidence of accelerated expansion of Universe
2. Why kinematic approach
3. Parameterization used
4. Model, Data and Methodology
    - Age Of Galaxies
    - Strong Lensing
5. Results and Conclusion
6. Future Aspects

Evidence of accelerated expansion of Universe

Results obtained by the SCP and HZSST team from the analysis of the Supernovae Ia are as follows:

- $\Omega_m = 0.25$
- $\Omega_\Lambda = 0.75$
- $q_0 = \frac{3}{2}\Omega_{mo} - 1 = -0.63$

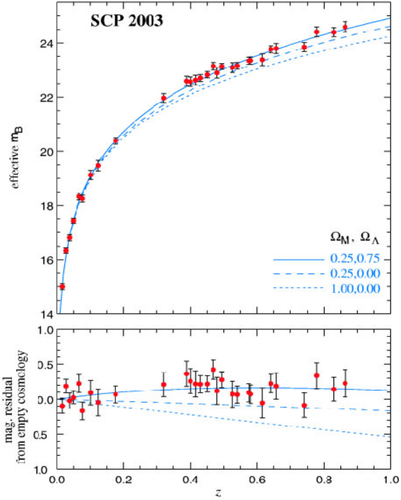


image credit : caltech.edu

Why kinematic approach?

- It is believed that expansion of the Universe was decelerated in the early epoch.

Why kinematic approach?

- It is believed that expansion of the Universe was decelerated in the early epoch.
- Present results indicate the accelerated expansion of the Universe.

Why kinematic approach?

- It is believed that expansion of the Universe was decelerated in the early epoch.
- Present results indicate the accelerated expansion of the Universe.
- Transition Redshift: The redshift at which this decelerated expansion of Universe switches to accelerated expansion.

Why kinematic approach?

- It is believed that expansion of the Universe was decelerated in the early epoch.
- Present results indicate the accelerated expansion of the Universe.
- Transition Redshift: The redshift at which this decelerated expansion of Universe switches to accelerated expansion.
- This route is independent of the validity of any metric theory of gravity and on the matter-energy content of the Universe.

Why kinematic approach?

- It is believed that expansion of the Universe was decelerated in the early epoch.
- Present results indicate the accelerated expansion of the Universe.
- Transition Redshift: The redshift at which this decelerated expansion of Universe switches to accelerated expansion.
- This route is independent of the validity of any metric theory of gravity and on the matter-energy content of the Universe.
- It depends on the assumption that the Universe is homogeneous and isotropic at large scales.

Why kinematic approach?

- It is believed that expansion of the Universe was decelerated in the early epoch.
- Present results indicate the accelerated expansion of the Universe.
- Transition Redshift: The redshift at which this decelerated expansion of Universe switches to accelerated expansion.
- This route is independent of the validity of any metric theory of gravity and on the matter-energy content of the Universe.
- It depends on the assumption that the Universe is homogeneous and isotropic at large scales.
- Different forms of q_z are discussed in the literature.

Parametrization Used

1. $q_I(z) = \frac{1}{2} + \frac{q_0}{(1+z)^2}$ (R. Nair et al. 2012)
2. $q_{II}(z) = q_1 + q_2 z$ (Lima et al. 2009)
3. $q_{III}(z) = q_3 + q_4 log(1+z)$

Model, Data and Methodology

- The theoretical age of galaxies can be calculated as follows

$$t(z, p) = \frac{1}{H_0} \int_z^\infty \frac{dx}{(1+x)E(x, p)}$$

$$E(x, p) = \frac{H(x, p)}{H_0}$$

Model

Corresponding Hubble parameter for this analysis are following-

$$H_I(z,p) = H_0(1+z)^{3/2} exp\left[\frac{q_0}{2}\left(\frac{z^2+2z}{(1+z)^2}\right)\right]$$

$$H_{II}(z,p) = H_0(1+z)^{(1+q1-q2)} exp(q_2 z)$$

$$H_{III}(z,p) = H_0(1+z)^{(1+q_3)} exp\left[\frac{q_4}{2}(log(1+z))^2\right]$$

Data

1. Data from the age of passively evolving galaxy.
   - Data is taken from the L. Samushia et al. 2010, arXiv: 09062734v3
   - Redshift range: 0.1171 to 1.845
2. Strong lensing data.
   - Data is taken from the Shuo Cao et al 2012
   - Redshift range of lens: 0.106 to 1.004
   - Redshift range of source: 0.1965 to 3.9

Method: Age of Galaxies

To constrain cosmological parameters using age of passively evolving galaxies, chisquare technique is employed

$$\chi^2 = \sum_{i=1}^{n} \frac{(t_i^{th} - t_{age}^{obs})^2}{\sigma_i^2}$$

$$\chi^2 = \sum_{i=1}^{n} \frac{(t_i^{th} - t_i^{z} - \tau)^2}{\sigma_i^2}$$

Method: Age of Galaxies

After minimization over nuisance parameter τ and H_0, chisquare becomes

$$\tilde{\tilde{\chi}}^2 = M - \frac{J^2}{C} - \frac{(GC - JE)^2}{C(CD - E^2)}$$

where

$$M = \sum_{i=1}^{n} \frac{[t_{obs}(z_i)]^2}{\sigma_i^2}, \quad J = \sum_{i=1}^{n} \frac{t_{obs}(z_i)}{\sigma_i^2}, \quad C = \sum_{i=1}^{n} \frac{1}{\sigma_i^2}$$

$$G = \sum_{i=1}^{n} \frac{\Delta(z_i) t_{obs}(z_i)}{\sigma_i^2}, \quad E = \sum_{i=1}^{n} \frac{\Delta(z_i)}{\sigma_i^2}, \quad D = \sum_{i=1}^{n} \frac{[\Delta(z_i)]^2}{\sigma_i^2}$$

$$\Delta(z_i) = \frac{t(z_i)}{H_0^{-1}}$$

Method: Age of Galaxies

Corresponding expression for the age of galaxies are following:

$$t_I(z_i, p) = H_0^{-1} \int_0^{\frac{1}{1+z}} x^{1/2} exp\left[\frac{-q_0}{2}(1 - x^2)\right] dx$$

$$t_{II}(z_i, p) = H_0^{-1} \int_0^{\frac{1}{1+z}} x^{q_1 - q_2} exp\left[-q_2\left(\frac{1 - x}{x}\right)\right] dx$$

$$t_{III}(z_i, p) = H_0^{-1} \int_0^{\frac{1}{1+z}} \frac{x^{q_3}}{exp\left[\frac{q_4}{2}(log\ x)^2\right]} dx$$

Strong Lensing(SL)

- Whenever the source, the lens and the observer are aligned in such a way that the observer-source direction lies inside the Einstein ring of the lens, strong gravitational lensing occurs.

Strong Lensing(SL)

- Whenever the source, the lens and the observer are aligned in such a way that the observer-source direction lies inside the Einstein ring of the lens, strong gravitational lensing occurs.
- In strong lensing, cosmological model enters through the ratio of the angular diameter distances between lens and source and between observer and lens.

Strong Lensing(SL)

- Whenever the source, the lens and the observer are aligned in such a way that the observer-source direction lies inside the Einstein ring of the lens, strong gravitational lensing occurs.
- In strong lensing, cosmological model enters through the ratio of the angular diameter distances between lens and source and between observer and lens.
- This method is independent on the Hubble constant value and is also not affected by the source evolution.

Strong Lensing

To constrain cosmological parameters, chisquare technique is used again-

$$\chi^2 = \sum \frac{(d^{th} - d^{obs})^2}{\sigma_D^2}$$

Here,

$$d^{th}(z_i, p) = \frac{d_{ls}}{d_s}$$

$$d_{ls} = \frac{c}{(1 + z_s)} \int_{z_l}^{z_s} \frac{dx}{H(x; p)}$$

$$d_s = \frac{c}{(1 + z_s)} \int_{0}^{z_s} \frac{dx}{H(x; p)}$$

Results

Parametrization I $q_I(z) = \frac{1}{2} + \frac{q_0}{(1+z)^2}$

Dataset	q_0	$q(0)$	χ^2	χ^2_ν	z_t
Age	-2.58	-2.08	12.47	0.40	1.3
SL	-2.14	-1.64	66.13	1.9	1.09
Age+SL	-2.19	-1.69	78.68	1.2	1.06

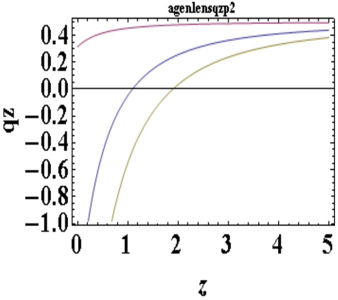


Figure: Fig. 1.1

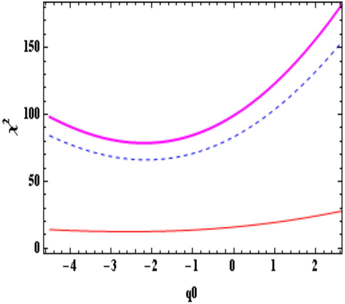


Figure: Fig. 1.2

Results

Parametrization II $q_{II}(z) = q_1 + q_2 z$

Dataset	q_1	q_2	$q(0)$	χ^2	χ^2_ν	z_t	FOM
Age	-1.68	1.55	-1.68	12.28	1.1	1.3	0.71
SL	-0.85	0.23	-0.85	64.71	1.9	3.7	4.62
Age+SL	-0.91	0.50	-0.91	77.47	0.65	1.8	6.3

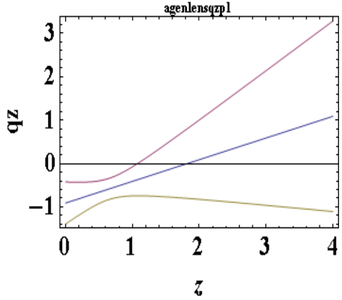


Figure: Fig. 2.1

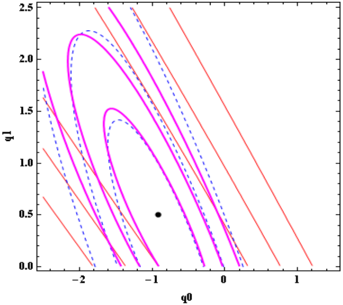
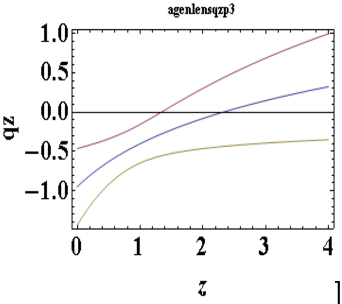


Figure: Fig. 2.2

Results

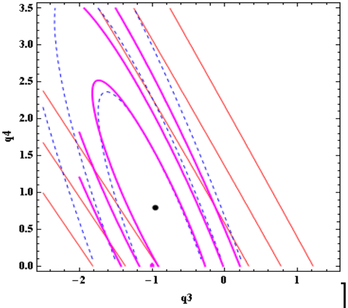
Parametrization III $q_{III}(z) = q_3 + q_4 log(1+z)$

Dataset	q_3	q_4	$q(0)$	χ^2	χ^2_ν	z_t	FOM
Age	-1.88	2.54	-1.88	12.35	0.41	1.0	0.39
SL	-0.84	0.30	-0.84	64.76	1.9	6.6	2.58
Age+SL	-0.95	0.79	-0.95	77.56	1.2	2.3	3.7



]

Figure: Fig. 3.1



]

Figure: Fig. 3.2

Conclusion

1. The value of deceleration parameter at present epoch according to the recent Planck's result is -0.53.
2. Value of transition redshift coming out from the strong lensing is greater than one.
3. The dataset for the age of galaxies also gives transition redshift higher than one.
4. Strong lensing data is not very precised due to the assumptions considered while collecting data.

Future Aspects

1. Using the precised strong lensing dataset tighter constraints can be obtained.
2. Combining other datasets like data from the GRB's can minimize the cosmological parameter space.

THANK YOU

Data: Age of Galaxies

Table: :Dataset for the ages of galaxies

L. Samushia et al. 2010, arXiv:09062734v3

S.No.	z_i	t_i^{obs}	σ_i
1	0.1171	10.2	1.224
2	0.1174	10.0	1.2
3	0.2220	9.0	1.08
4	0.2311	9.0	1.08
5	0.3559	7.6	0.912
6	0.4520	6.8	0.816
7	0.5750	7.0	0.84
8	0.6440	6.0	0.72
9	0.6760	6.0	0.72
10	0.8330	6.0	0.72
11	0.8360	5.8	0.696

Data: Age of Galaxies

S.No.	z_i	t_i^{obs}	σ_i
12	0.9220	5.5	0.66
13	1.179	4.6	0.552
14	1.222	3.5	0.42
15	1.224	4.3	0.516
16	1.225	3.5	0.42
17	1.226	3.5	0.42
18	1.340	3.4	0.408
19	1.380	3.5	0.42
20	1.383	3.5	0.42
21	1.396	3.6	0.432
22	1.430	3.2	0.384
23	1.450	3.2	0.384
24	1.488	3.0	0.360
25	1.490	3.6	0.432

Data: Age of Galaxies

S.No.	z_i	t_i^{obs}	σ_i
26	1.493	3.2	0.384
27	1.510	2.8	0.336
28	1.550	3.0	0.360
29	1.576	2.5	0.300
30	1.642	3.0	0.360
31	1.725	2.6	0.312
32	1.845	2.5	0.3

Data: Strong Lensing

Table: :Strong lensing dataset

Reference: Shuo Cao et al. 2012

S.No.	z_l	z_s	D_i^{obs}	σ_i
1	0.1955	0.6322	0.6825	0.1026
2	0.3317	0.5235	0.3632	0.0684
3	0.3223	0.5812	0.3039	0.0458
4	0.1642	0.324	0.5325	0.0789
5	0.2318	0.795	0.6179	0.0996
6	0.2479	0.7933	0.8114	0.1347
7	0.2285	0.4635	0.5531	0.0951
8	0.1553	0.517	0.8651	0.1519
9	0.938	2.941	0.6834	0.1377
10	0.497	2.092	0.929	0.2067

Data: Strong Lensing

S.No.	z_l	z_s	D_i^{obs}	σ_i
11	1.004	3.263	0.5035	0.1234
12	0.1196	0.1965	0.3877	0.0573
13	0.3507	1.0709	0.8498	0.2109
14	0.3475	0.467	0.1926	0.0437
15	0.1109	0.3159	0.8571	0.159
16	0.2369	0.5315	0.5599	0.1152
17	0.273	0.6295	0.5052	0.0885
18	0.2218	0.5039	0.6967	0.1735
19	0.106	0.4019	0.8061	0.1182
20	0.1644	0.6307	0.6381	0.1132
21	0.215	0.4808	0.5365	0.0803
22	0.1229	0.6402	0.5783	0.0883
23	0.135	0.7172	1.0498	0.158
24	0.1888	0.473	0.6352	0.1332

Data: Strong Lensing

S.No.	z_l	z_s	D_i^{obs}	σ_i
25	0.123	0.6643	1.1048	0.1662
26	0.2852	0.8049	0.775	0.1563
27	0.1338	0.4187	0.6439	0.1
28	0.1254	0.5203	0.7262	0.1275
29	0.3583	0.7173	0.6526	0.1611
30	0.1596	0.7439	0.7628	0.1147
31	0.1428	0.5312	0.972	0.172
32	0.2449	0.6021	0.8042	0.1765
33	0.1371	0.7126	1.1248	0.1812
34	0.36	1.41	1.3103	0.1474
35	0.11	1.17	0.5728	0.1194
36	0.32	3.9	0.8526	0.305