HOLOGRAPHIC DARK ENERGY AT THE RICCI SCALE

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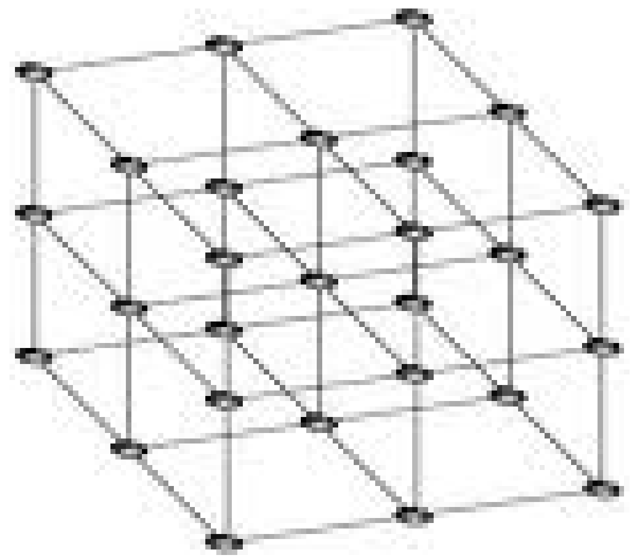
Abstract

We explore the consequences of identifying the Ricci's length with the infrared scale in the context of holographic dark energy, both when matter and dark energy evolve independently and when they interact with each other.

Entropy of a Spin Lattice



$$N(L^3) = 2^n$$

$$S \propto n \log 2 = \frac{L^3}{l^3} \log 2 \quad \Rightarrow \quad S \sim L^3 \Lambda^3 \qquad (\Lambda = 1/l)$$

However, in quantum theory of gravity there are good reasons to believe that

$$S \sim L^2$$

Recall that $$S_{BH} = \frac{\mathcal{A}}{4\,\ell_P^2}$$

Holographic Conjecture (` t Hooft, 1993)

It must be possible to describe all phenomena within V by a set of degrees of freedom which reside on the surface bounding V

Cohen et al. (1999) $L^3 \Lambda^3 \leq S_{BH}$

A more severe constraint imposes

$$L^3 \rho_X \leq L M_P^2 \qquad \rho_X = 3 M_P^2 c^2 L^{-2}$$

$$L^{-2} \equiv R_{cc}^{-2} = \dot{H} + 2H^2$$

Evolution of the fractional densities

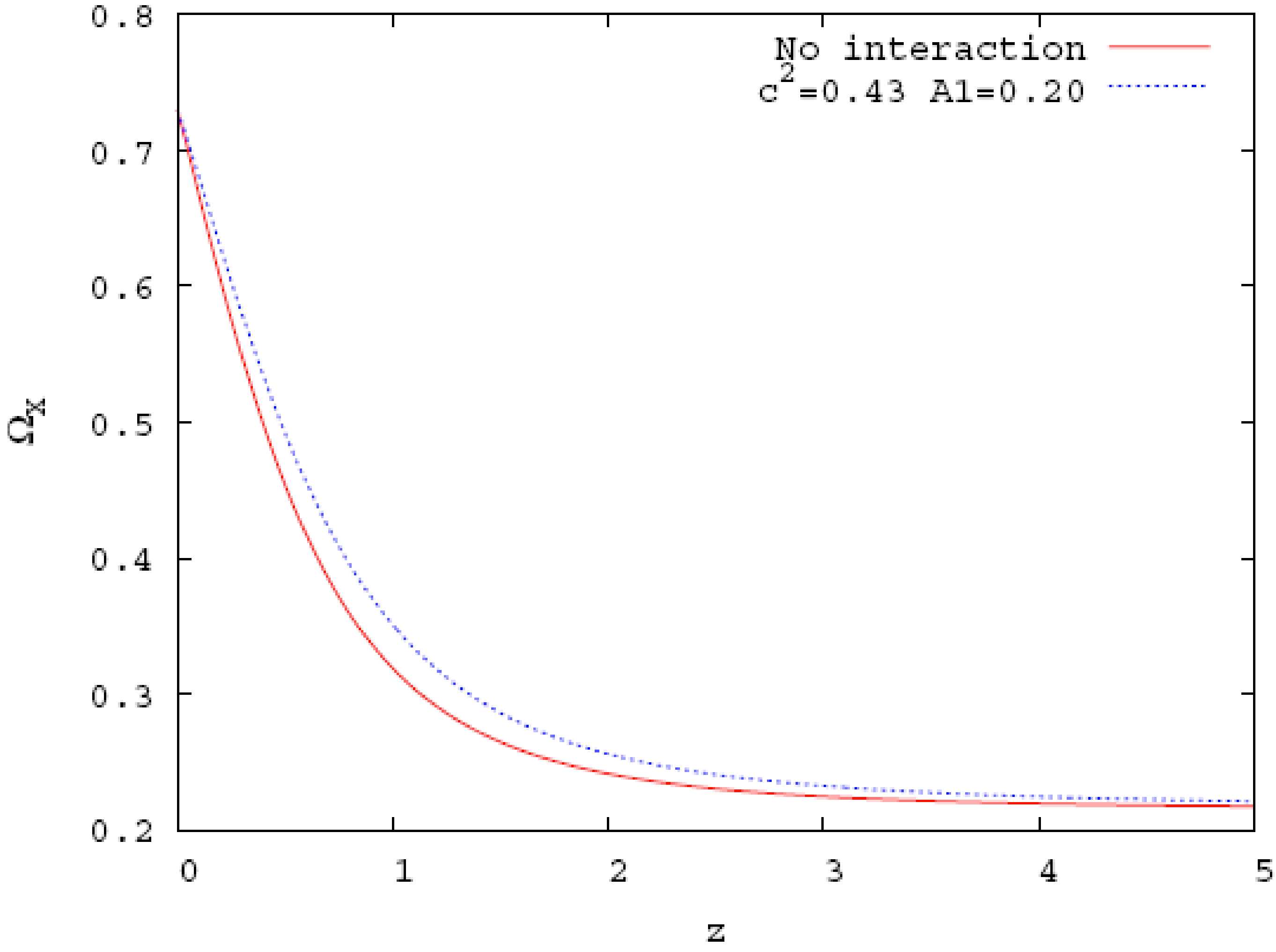
$$
\begin{aligned}
\dot{\Omega}_M - 3Hw(1-\Omega_X)\Omega_X &= Q \\
\dot{\Omega}_X + 3Hw(1-\Omega_X)\Omega_X &= -Q
\end{aligned}
$$

$$Q = \Gamma\,\Omega_X$$

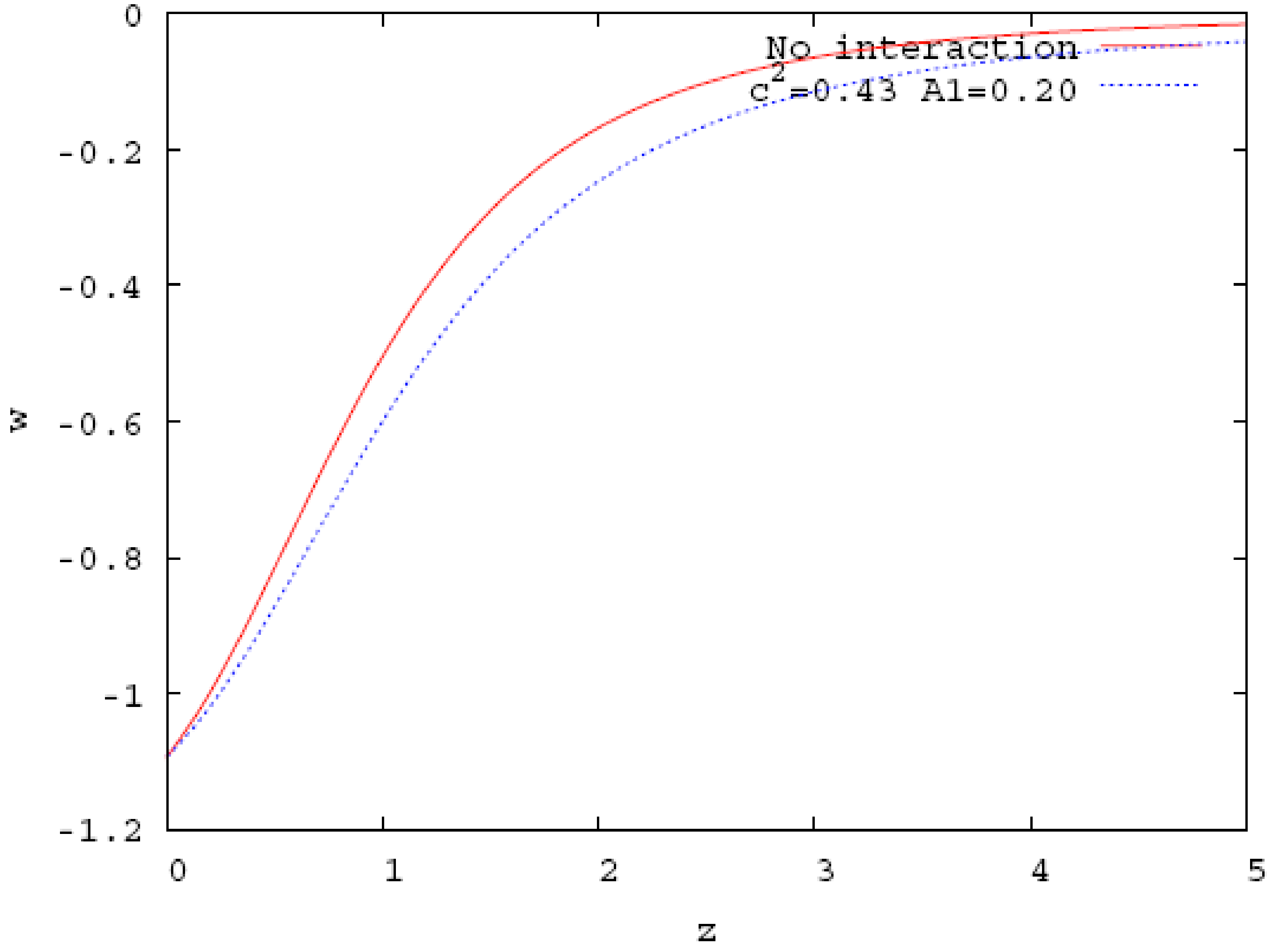
$$\dot{r} = 3Hwr + \Gamma(1+r) \qquad\qquad r \equiv \frac{\rho_M}{\rho_X}$$

$$\int_{\Omega_X}^{\Omega_{X0}} \frac{d\Omega_X}{2\Omega_X^2 - (2 + c^2(1-\frac{\Gamma}{H}))\Omega_X + c^2} = \frac{1}{c^2}\int_z^0 \frac{dz}{1+z}$$

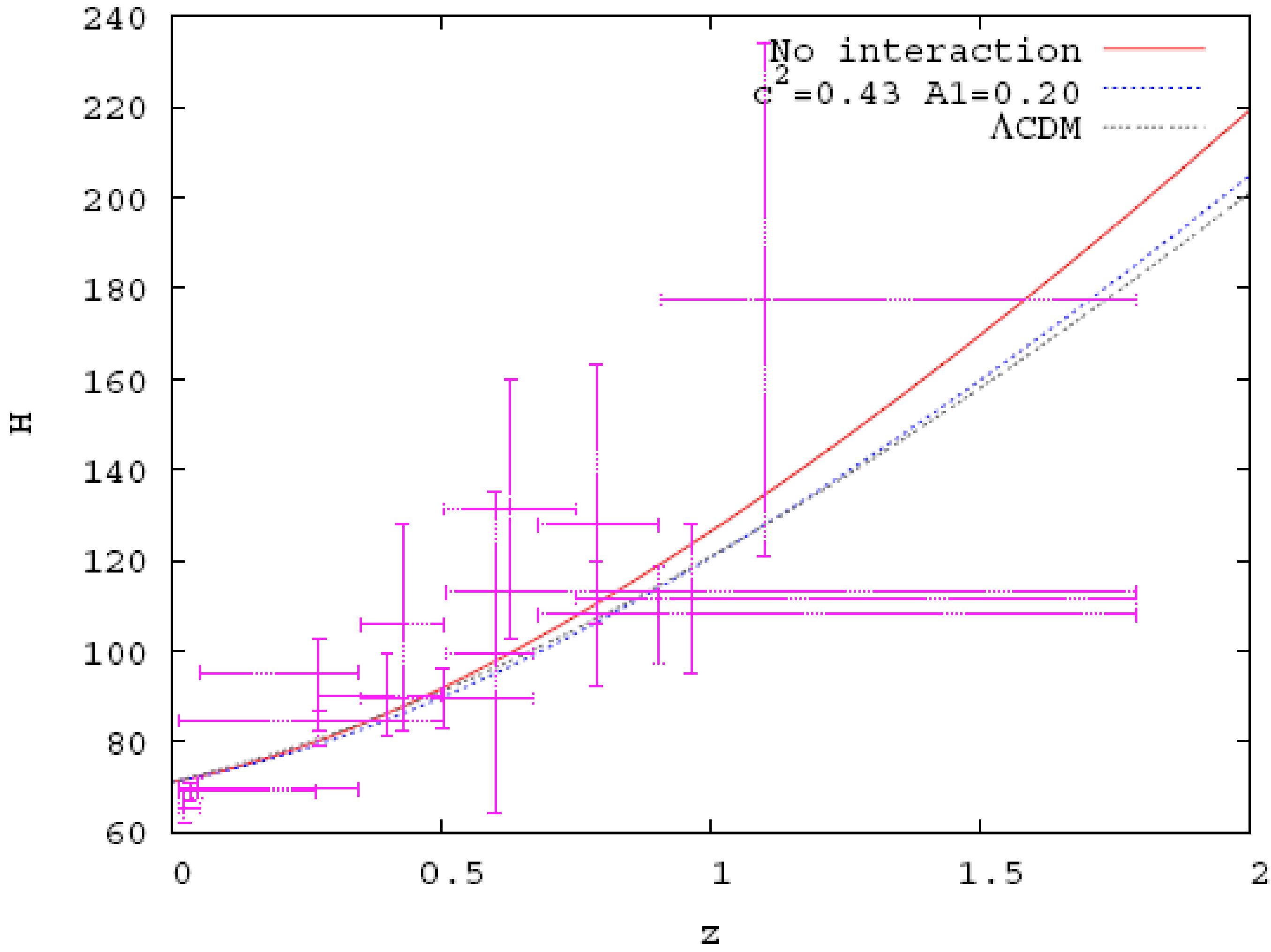
$$\frac{\Gamma}{H} = \frac{A_1}{1+z} + \frac{A_2}{(1+z)^2}$$



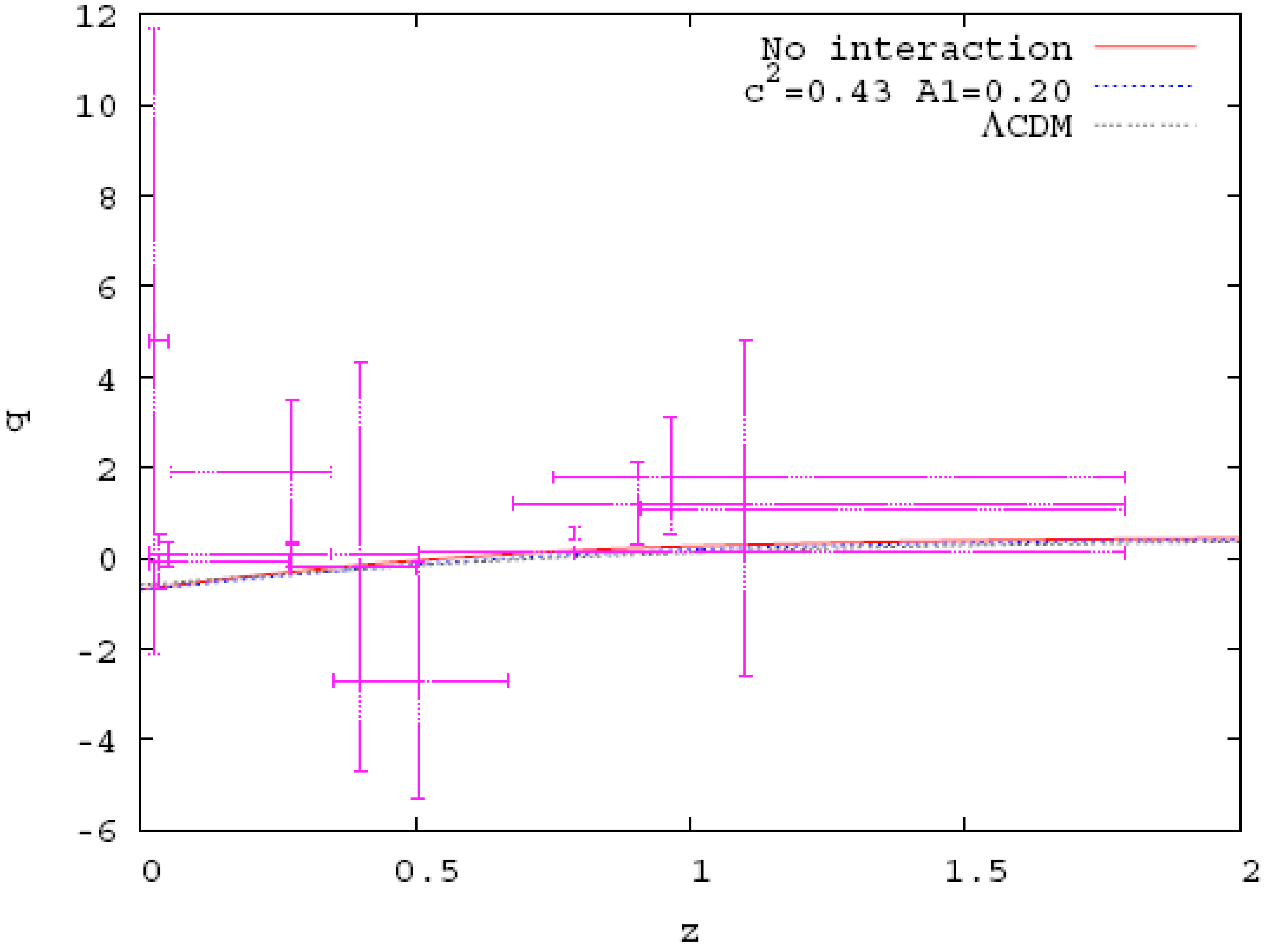
Dark energy fractional density vs redshift



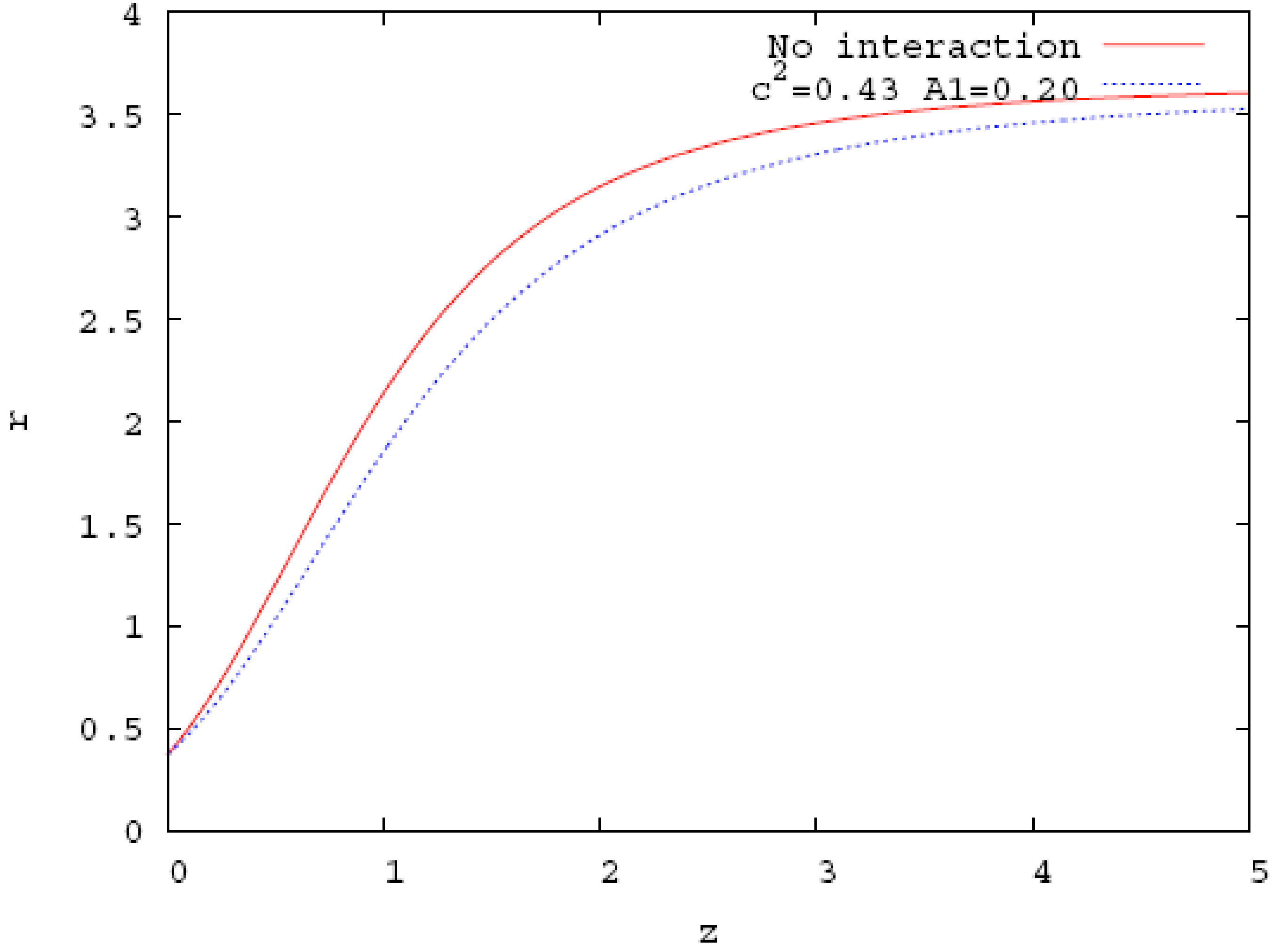
Equation of state parameter vs redshift



Hubble factor vs redshift



Deceleration parameter vs redshift

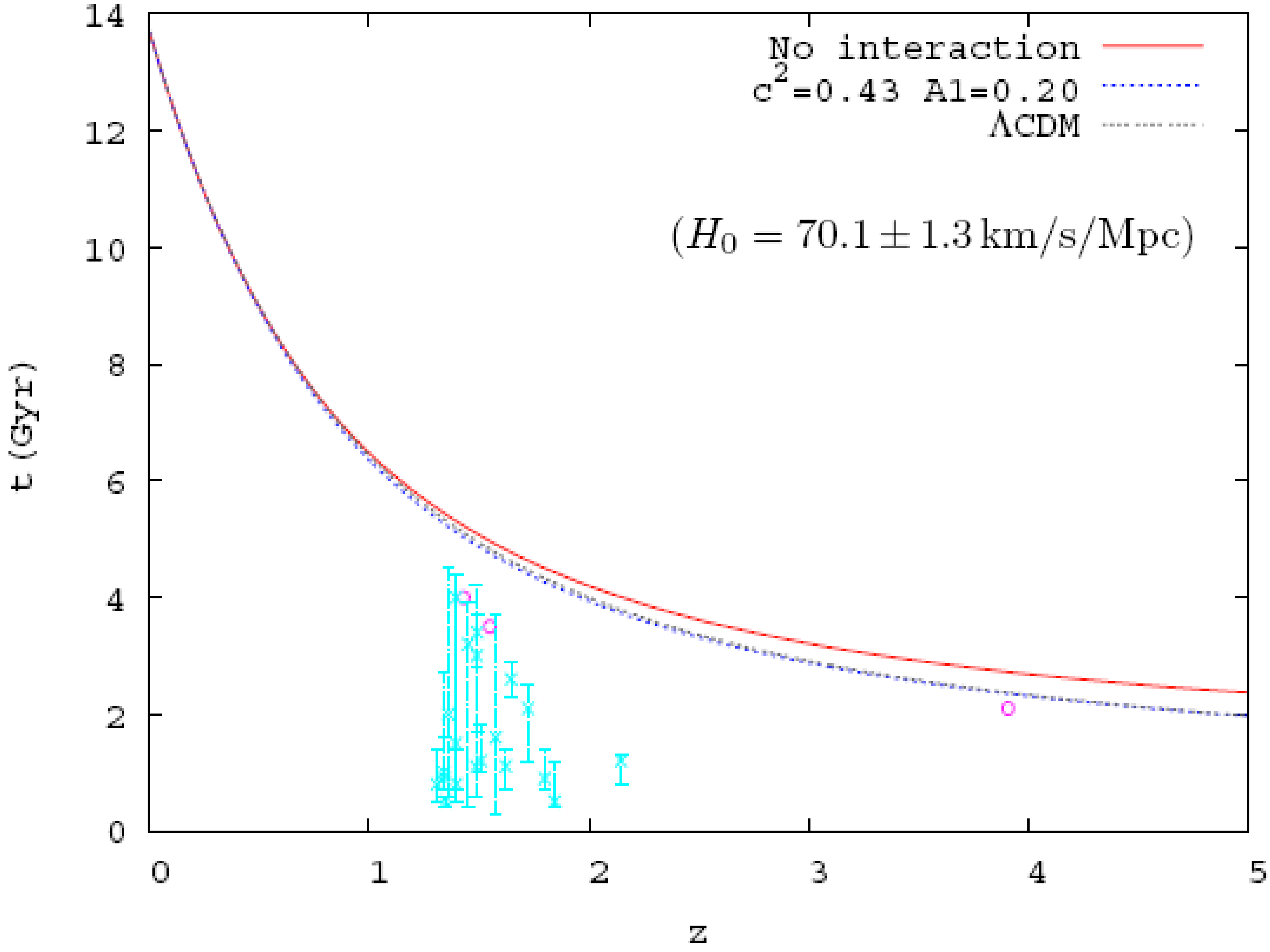


Ratio DM/DE vs redshift

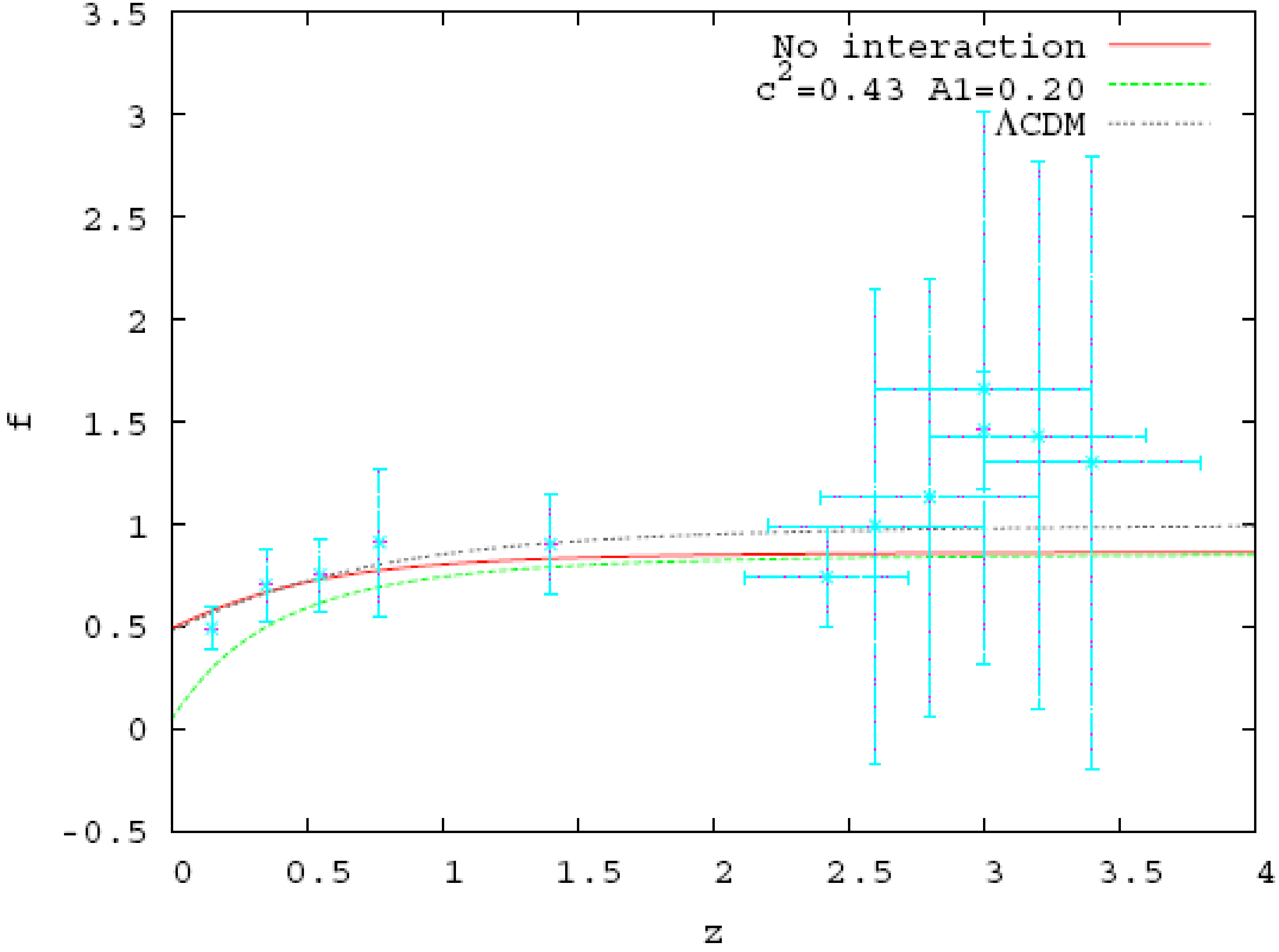
Age of some high redshift objects

LBDS 53W069 (z = 1.43, t = 4.0 Gyr)
LBDS 53W091 (z = 1.55, t = 3.5 Gyr)
APM 08279+5255 (z 3.91, t= 2.1 Gyr)

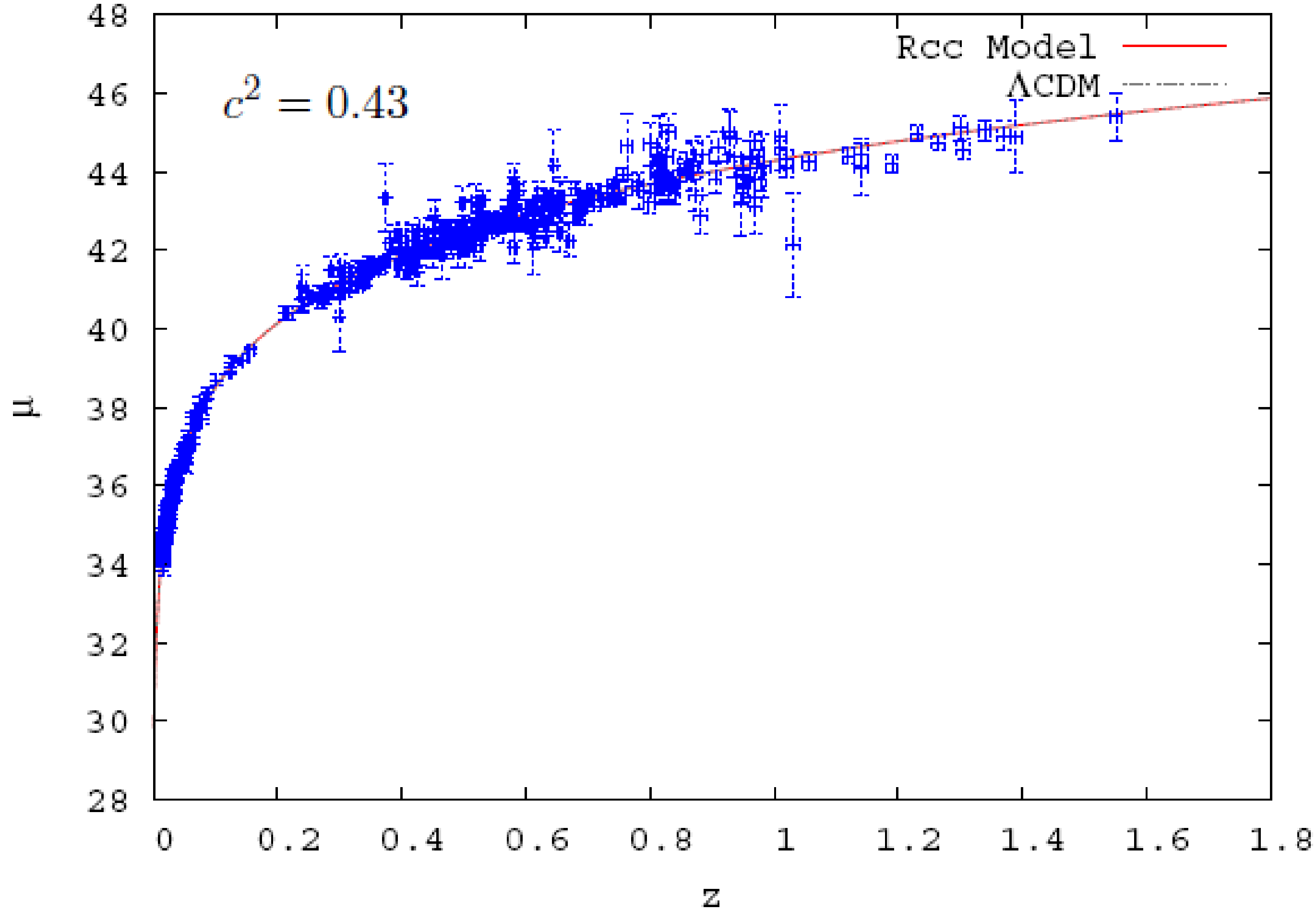
$$t(z) = t_0 - \int_0^z \frac{dz}{(1+z)\,H(z)}$$



Age of the Universe (in Giga years) vs redshift



Growth function vs redshift



Distance modulus vs redshift

Baryon acoustic oscillations

$$D_v(z) = \left[\frac{z}{H(z)} \left(\int_0^z \frac{dz}{H(z)} \right)^2 \right]^{\frac{1}{3}}$$

Z(BAO) = 0.35 & 0.2

$$D_v(0.35)/D_v(0.2) = 1.736 \pm 0.065$$

Eisenstein et al (2005)
& Percival et al (2007)

Shift of the first CMB peak

$$R = \sqrt{\Omega_{M_0}} \int_0^{z_{rec}} \frac{dz}{H(z)}$$

$$R(z_{rec}) = 1.710 \pm 0.019$$

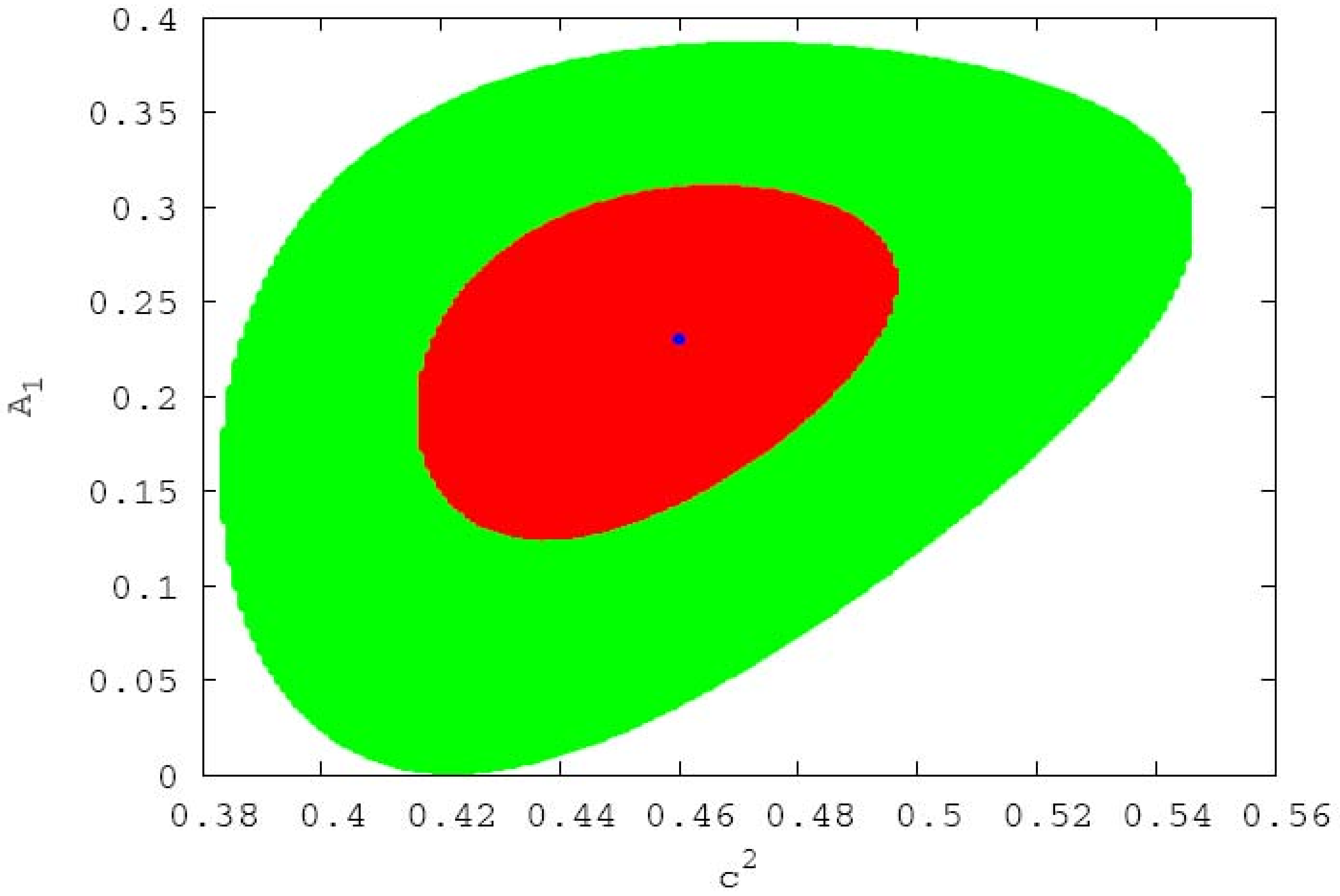
WMAP team (2009)

c^2	$R(z_{rec})$	$D_v(0.35)/D_v(0.2)$
0.40	1.625	1.673

Table I: No interaction

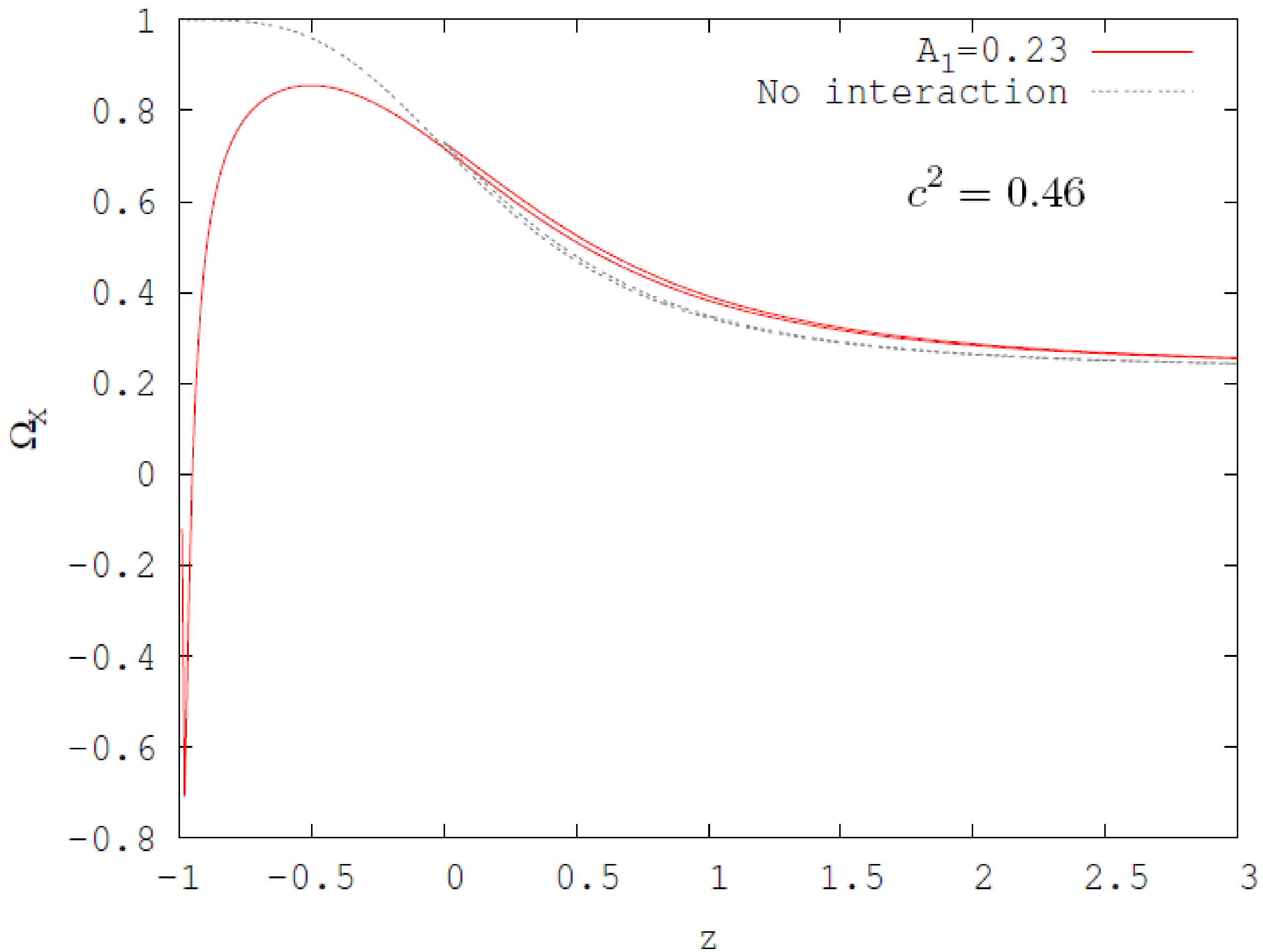
c^2	Int.	$R(z_{rec})$	$D_v(0.35)/D_v(0.2)$
0.43	A_1=0.20	1.707	1.672

Table II: Interaction



The 68% & 90% confidence level contours of c^2 and A1 using SNIa + BAO + CMB + x-ray data

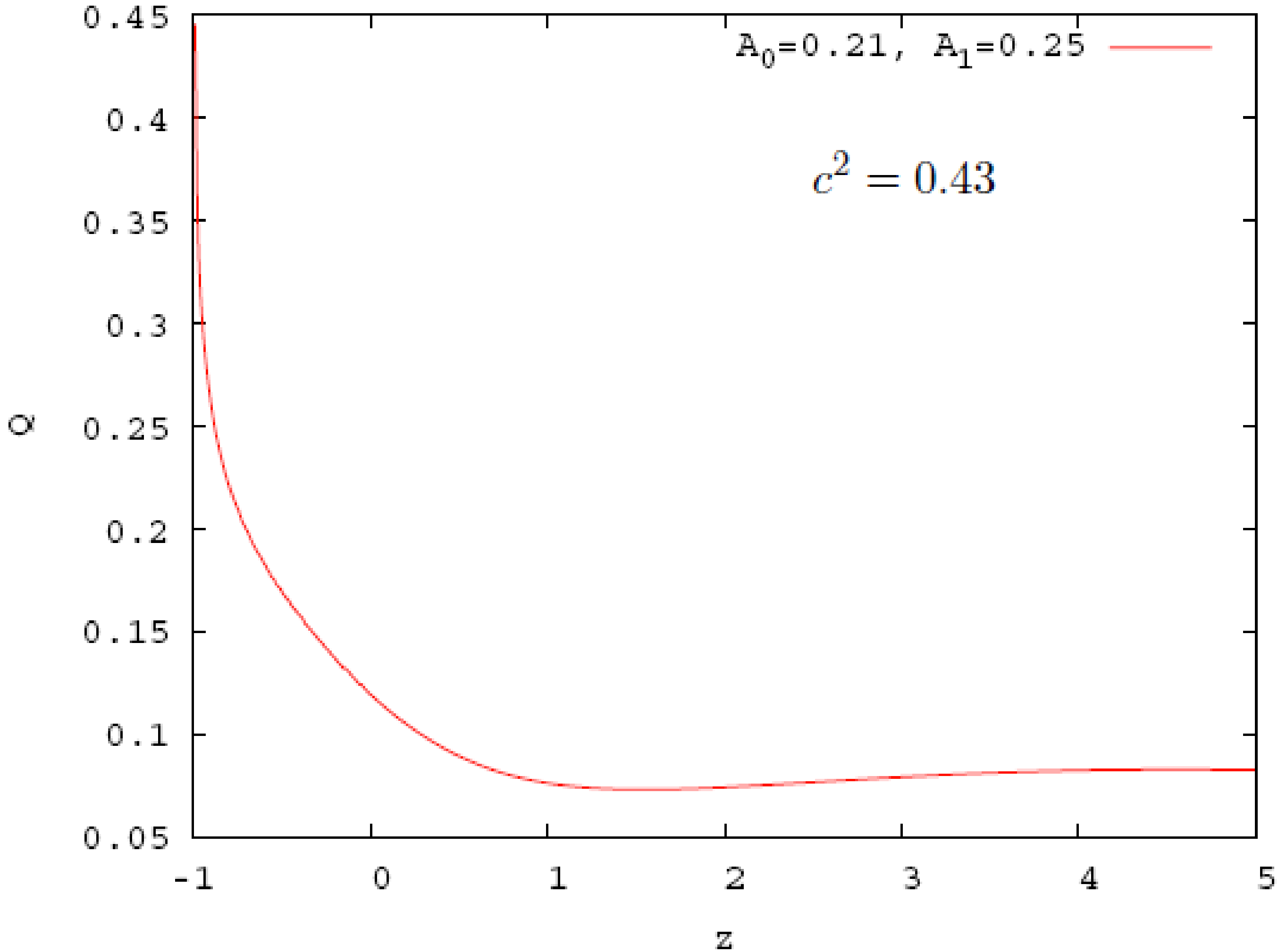
For the best fit model $(A_1 = 0.20\,, \quad c^2 = 0.43) \;\Rightarrow\; \chi^2 = 364.4$



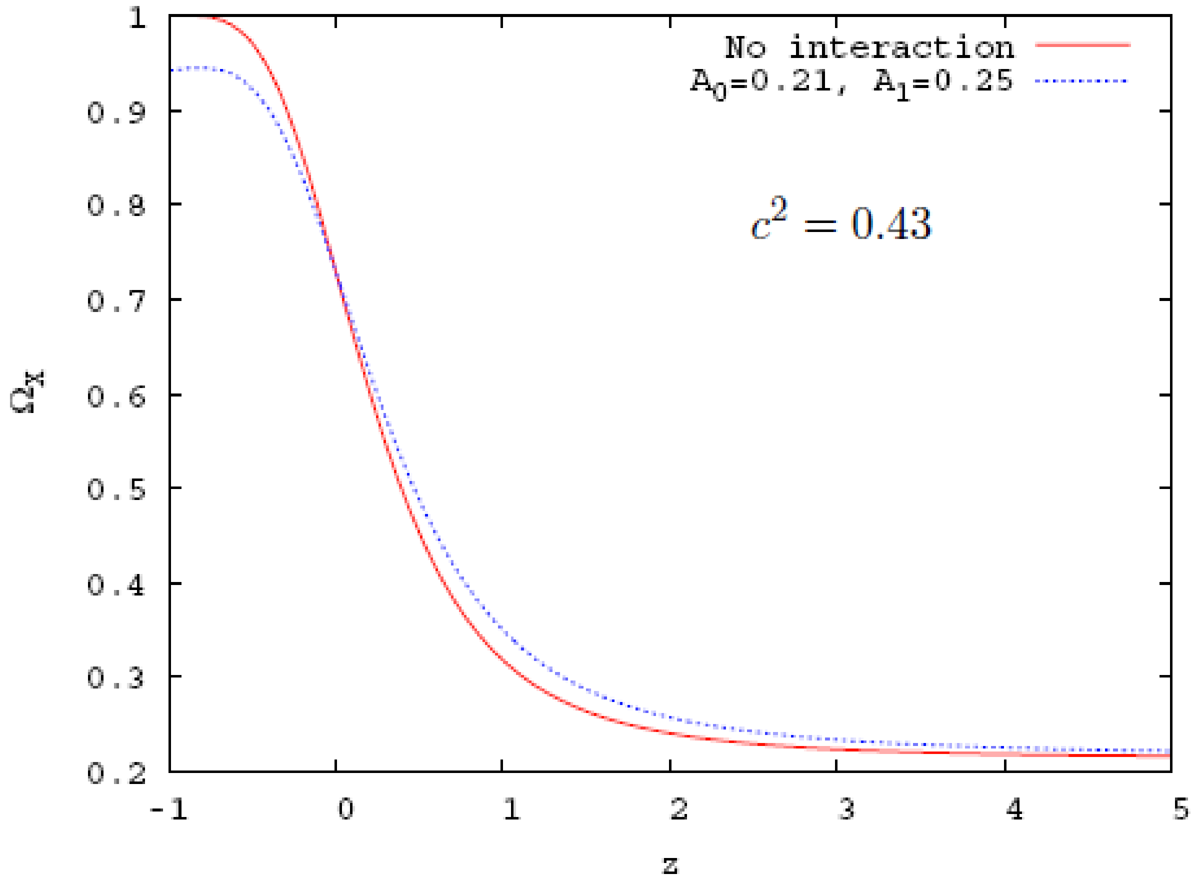
The fractional dark energy density becomes negative in the future

Exponential interaction

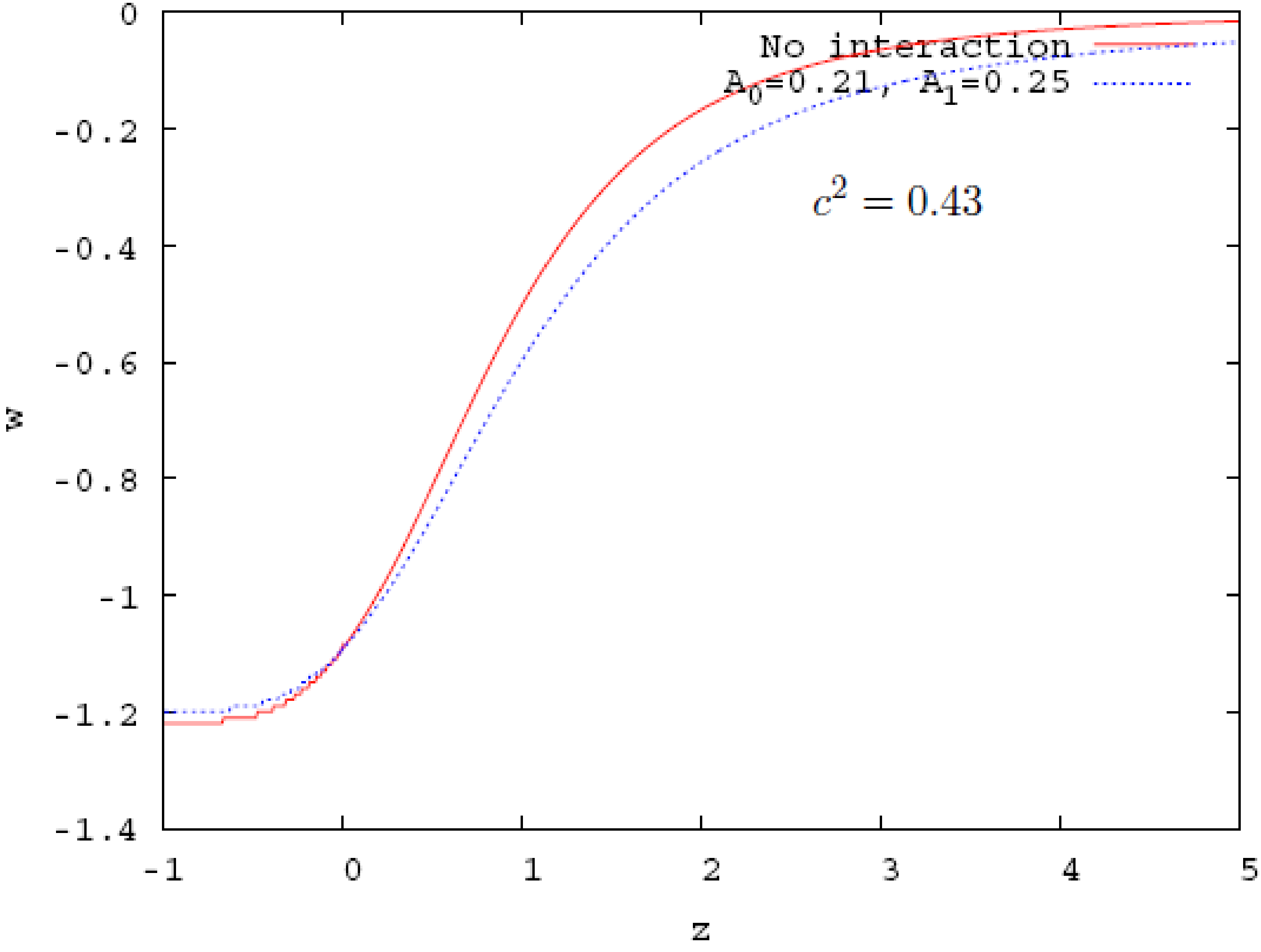
$$Q = \Gamma \, \Omega_X \qquad \frac{\Gamma}{H} = A_0 \exp[-A_1(1+z)]$$



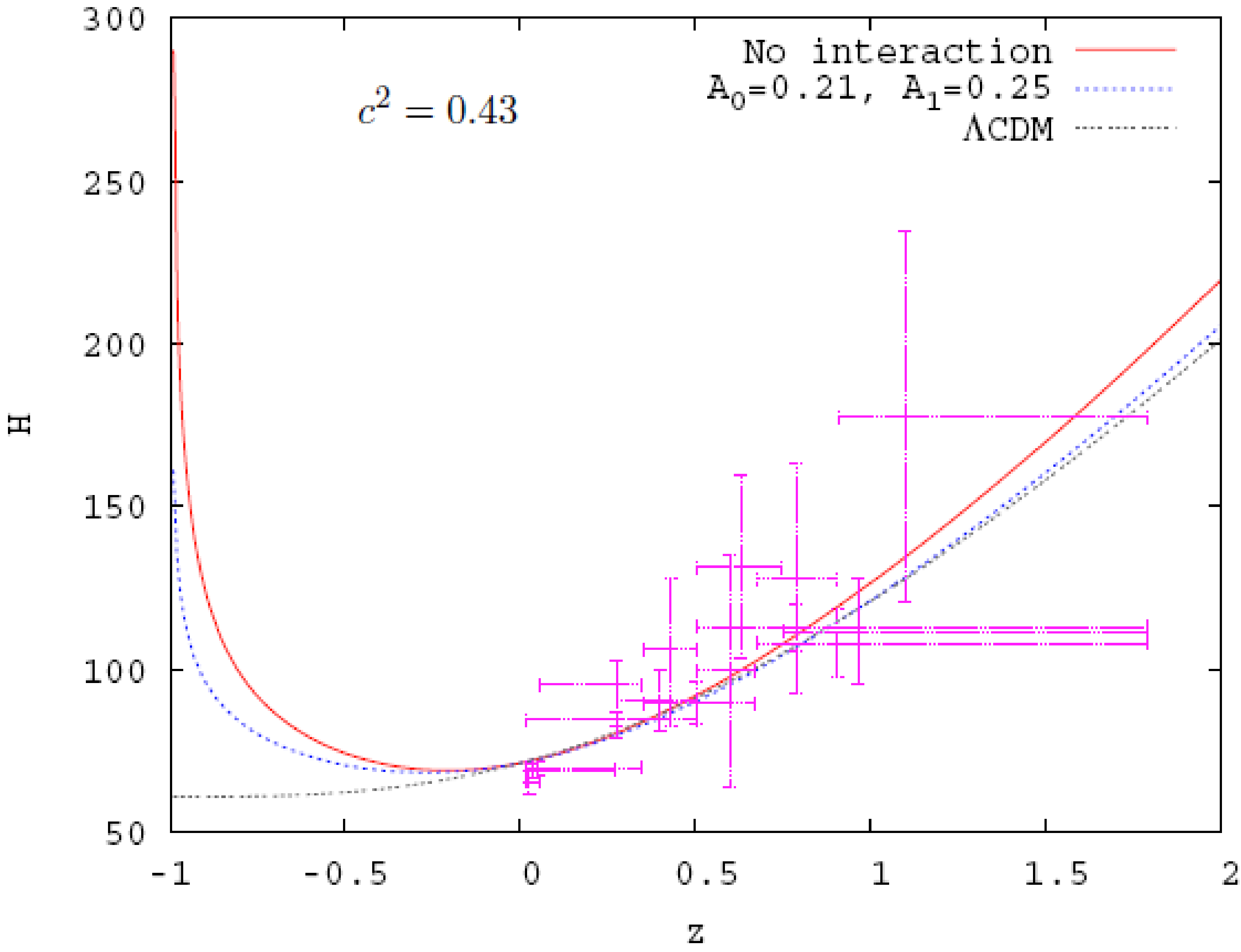
Evolution of the exponential interaction



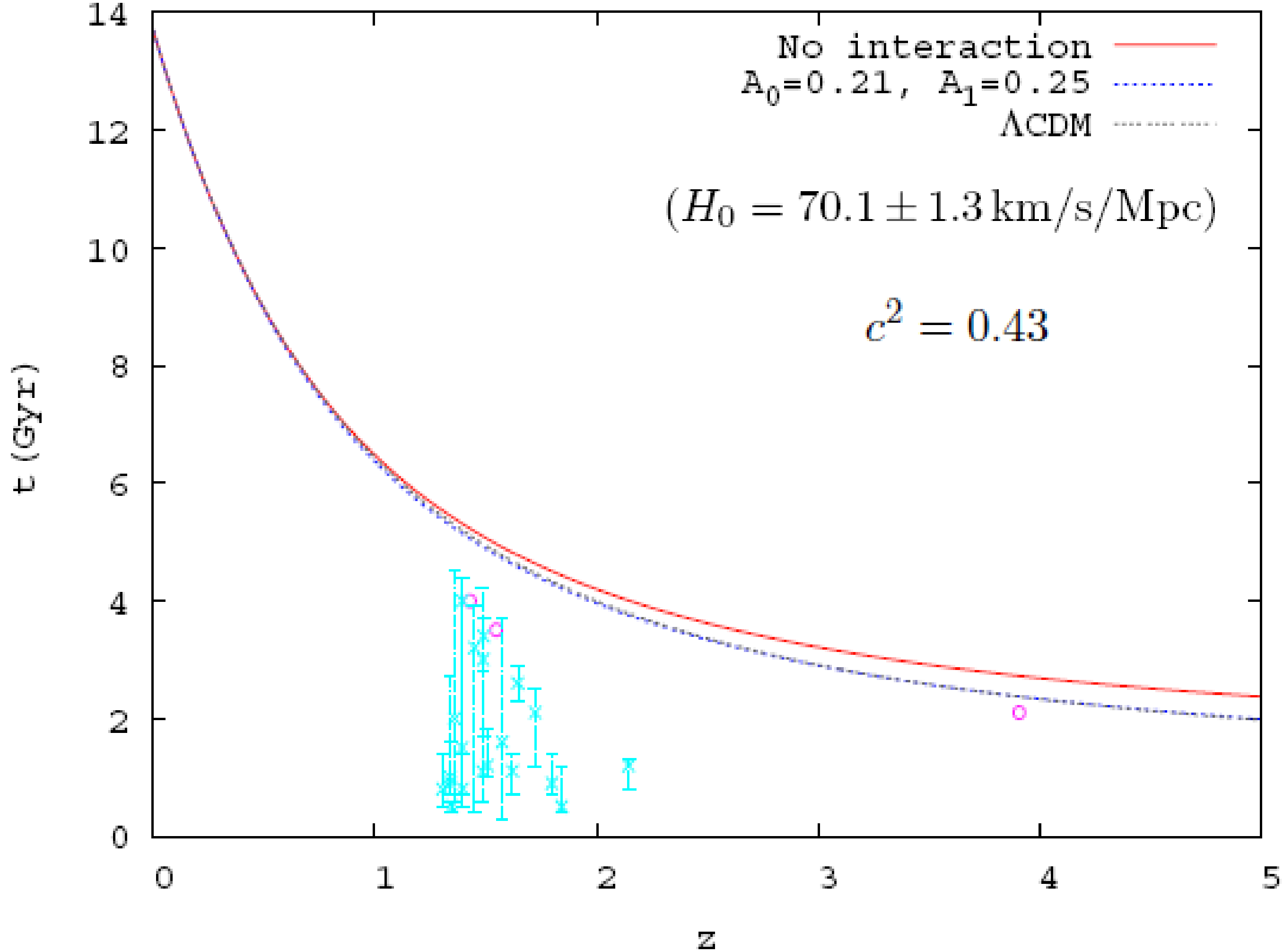
Dark energy fractional density vs redshift for exponential interaction



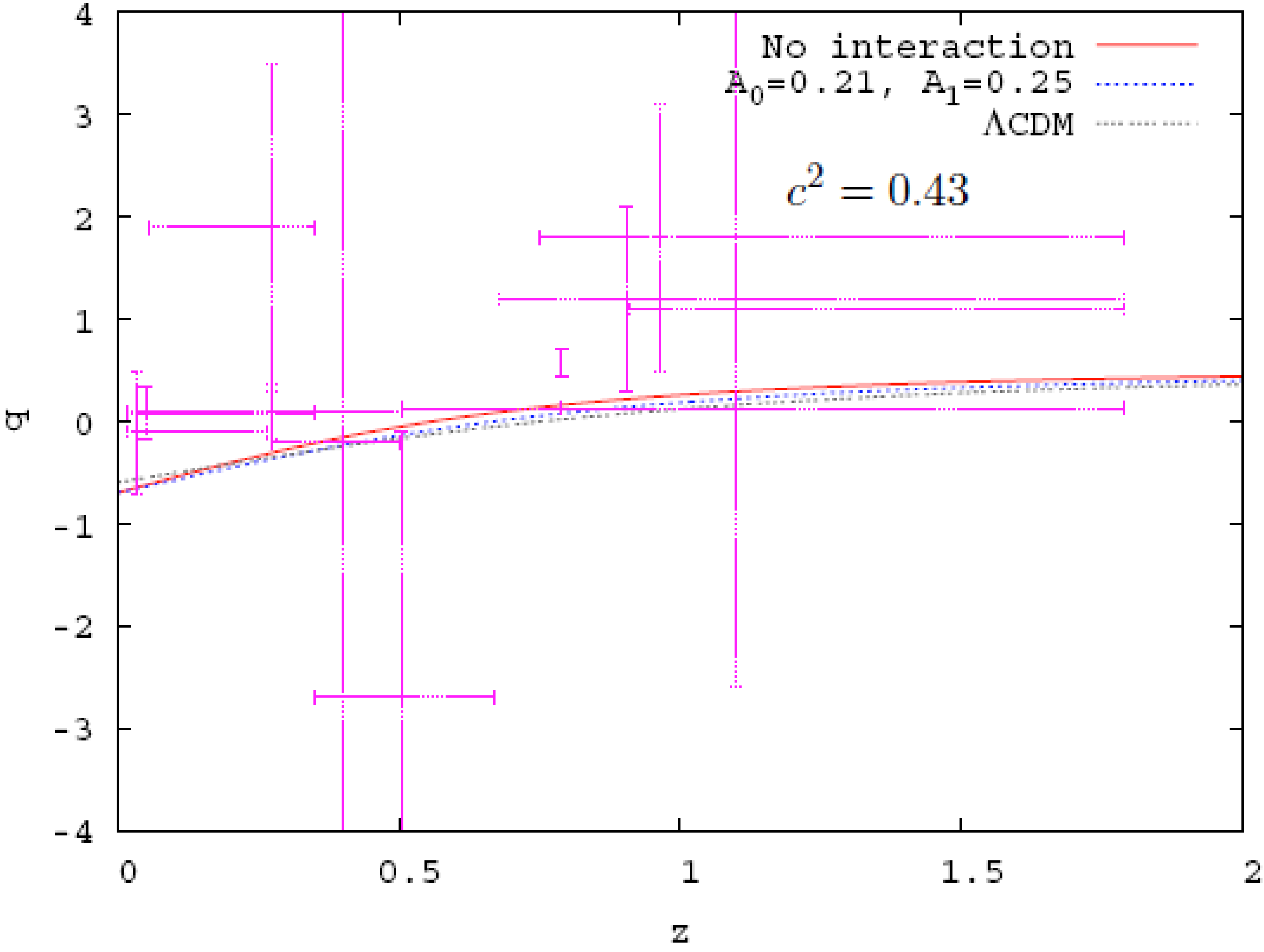
Equation of state parameter vs redshift for exponential interaction



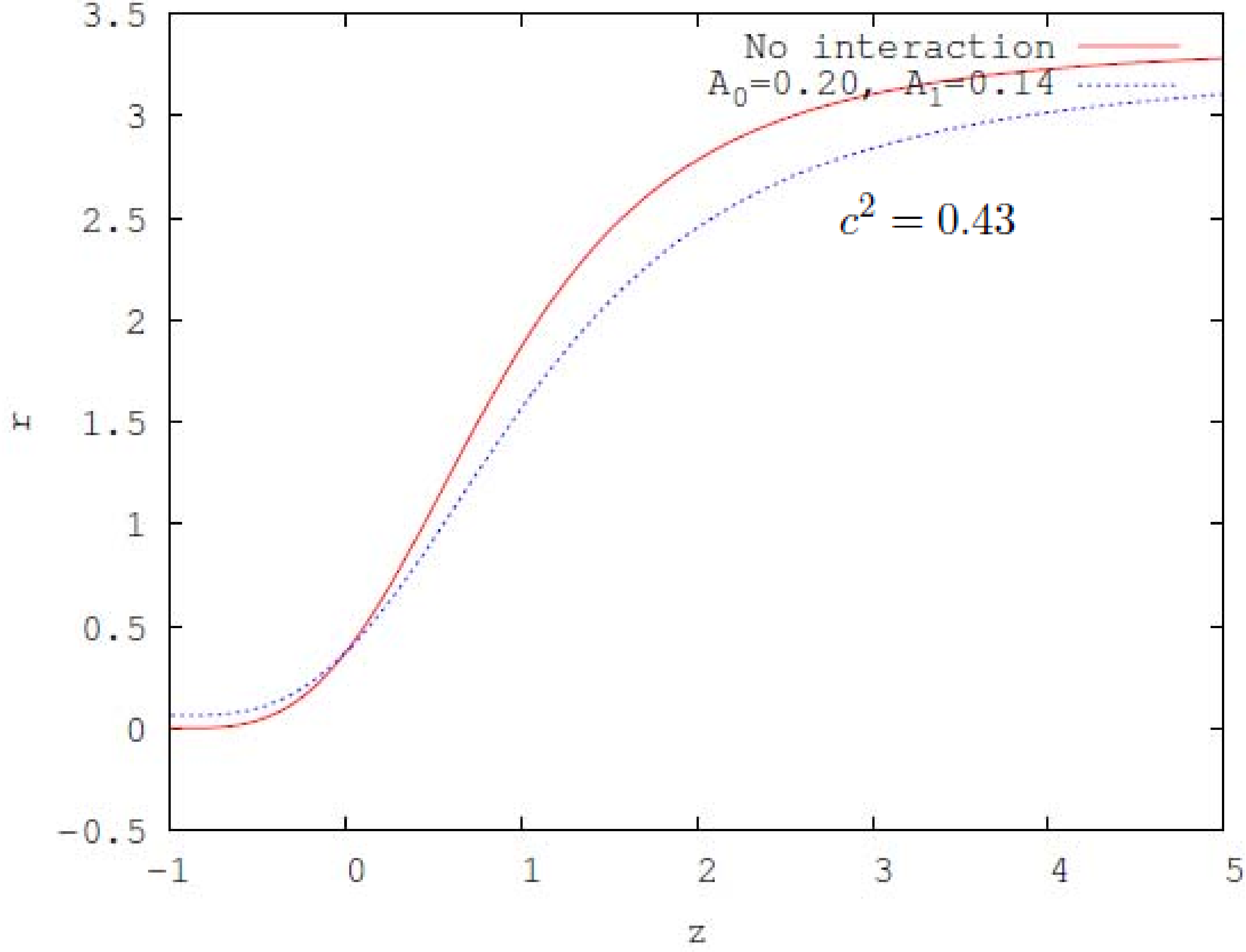
Hubble factor vs redshift for exponential interaction



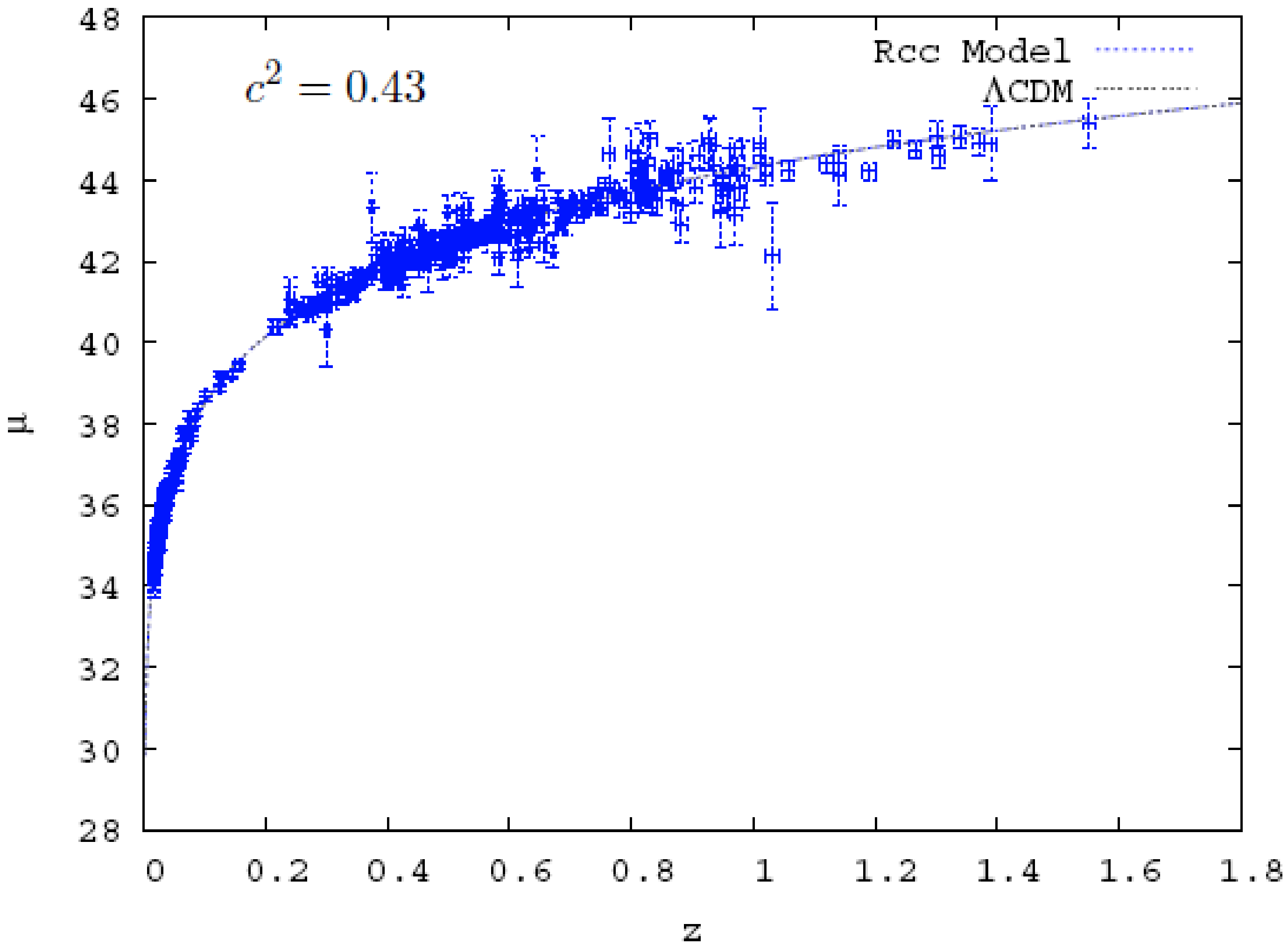
Age of the Universe vs redshift with exponential interaction



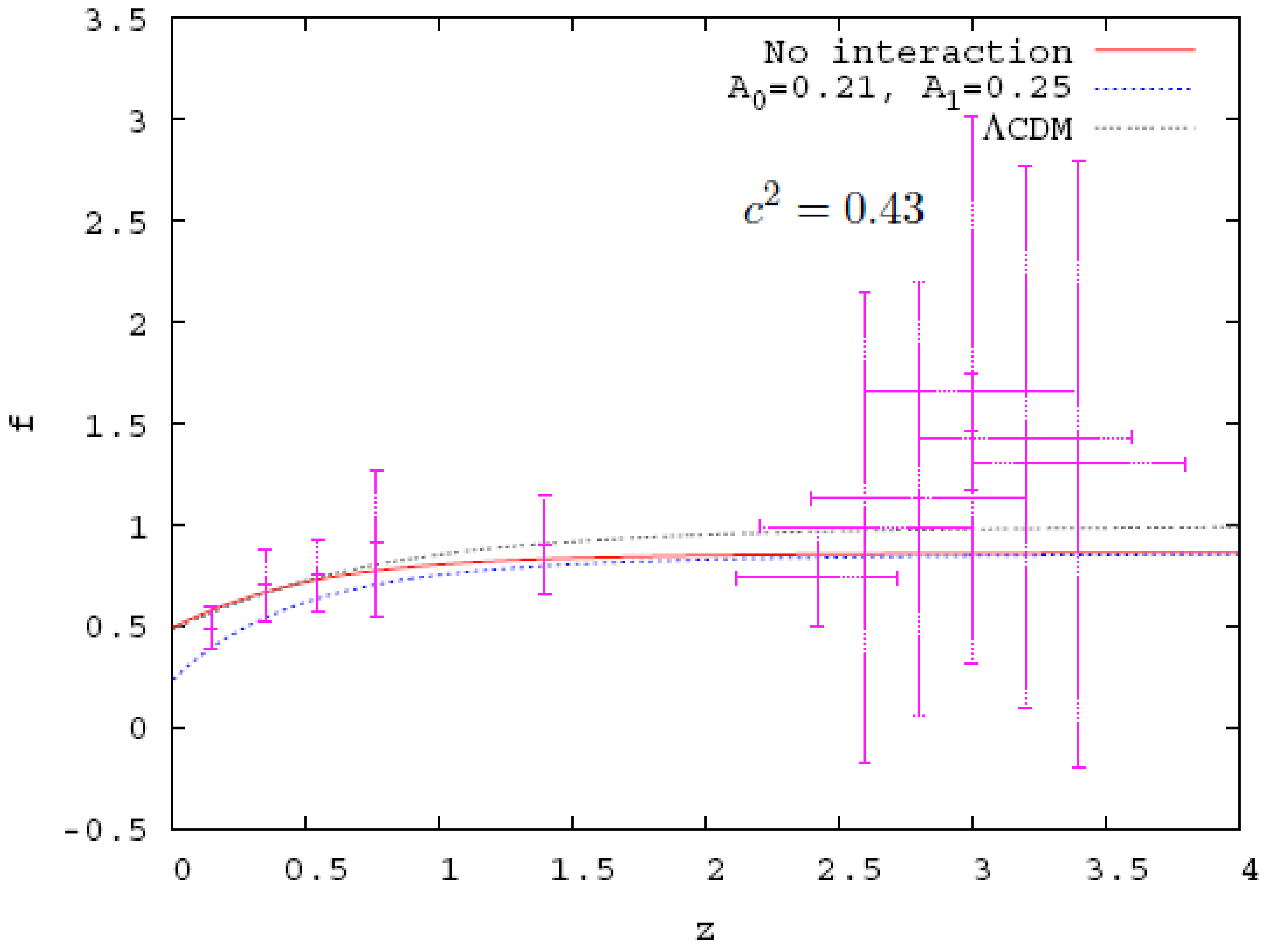
Deceleration parameter vs redshift for exponential interaction



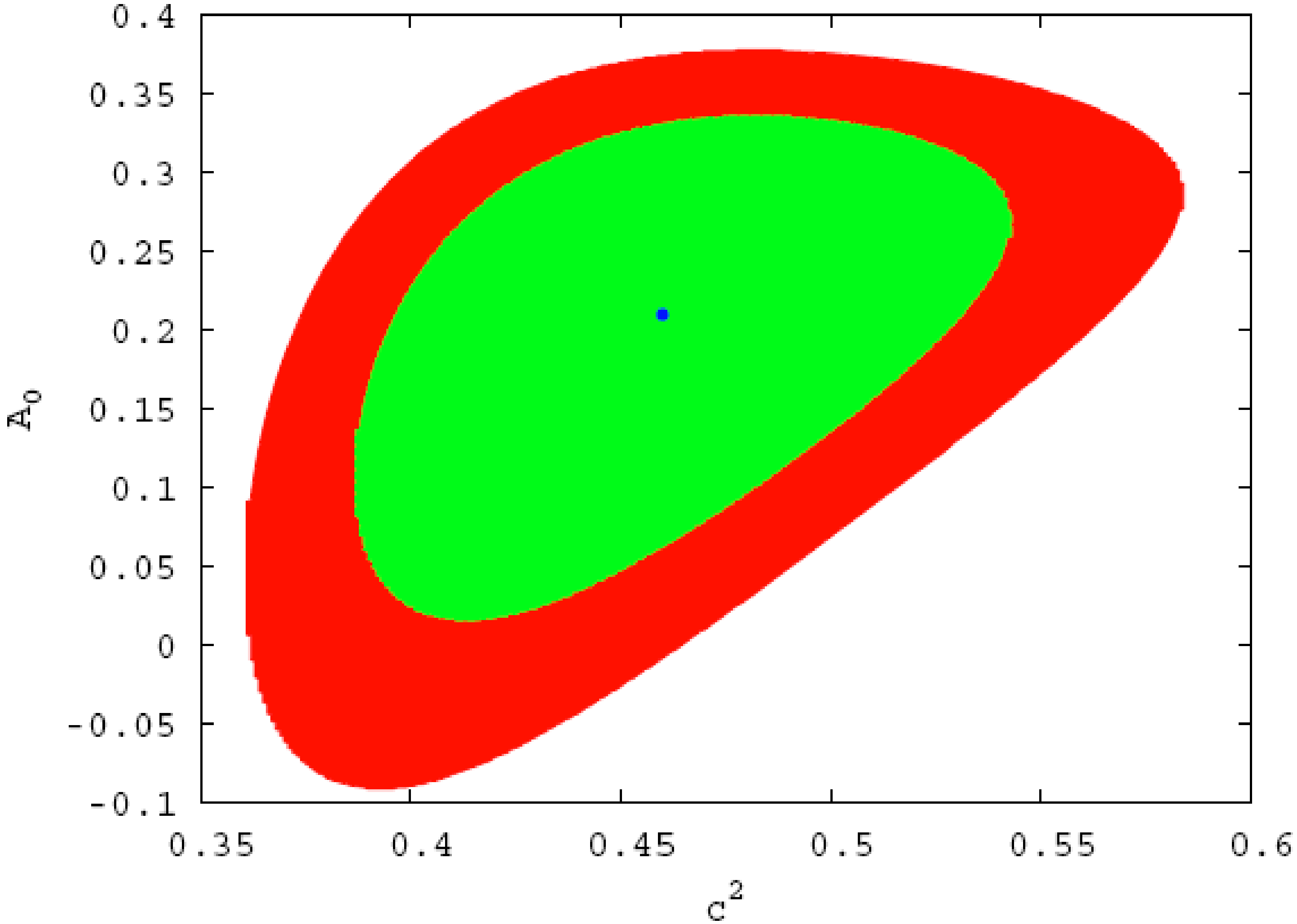
Ratio DM/DE vs redshift for exponential interaction



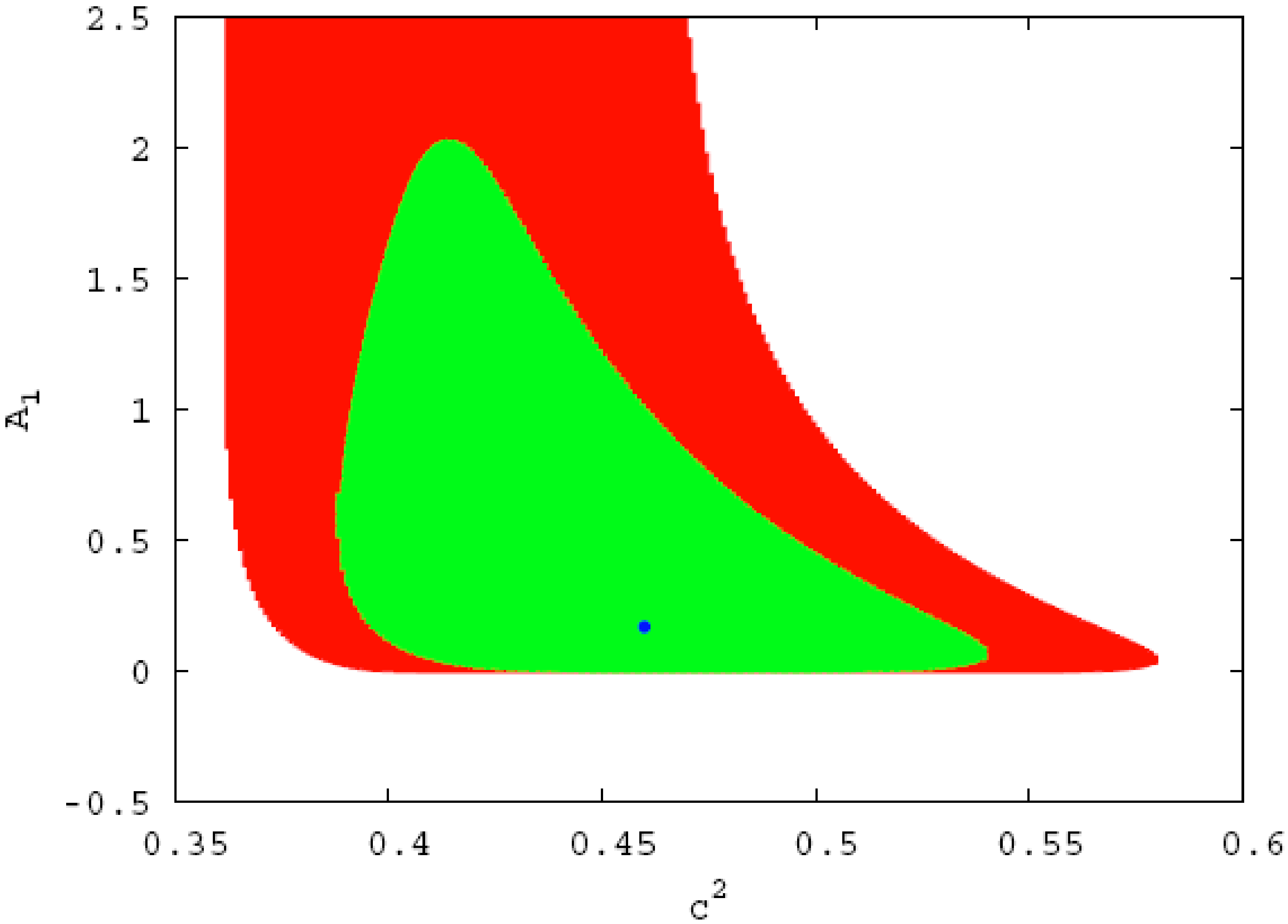
Distance modulus vs redshift



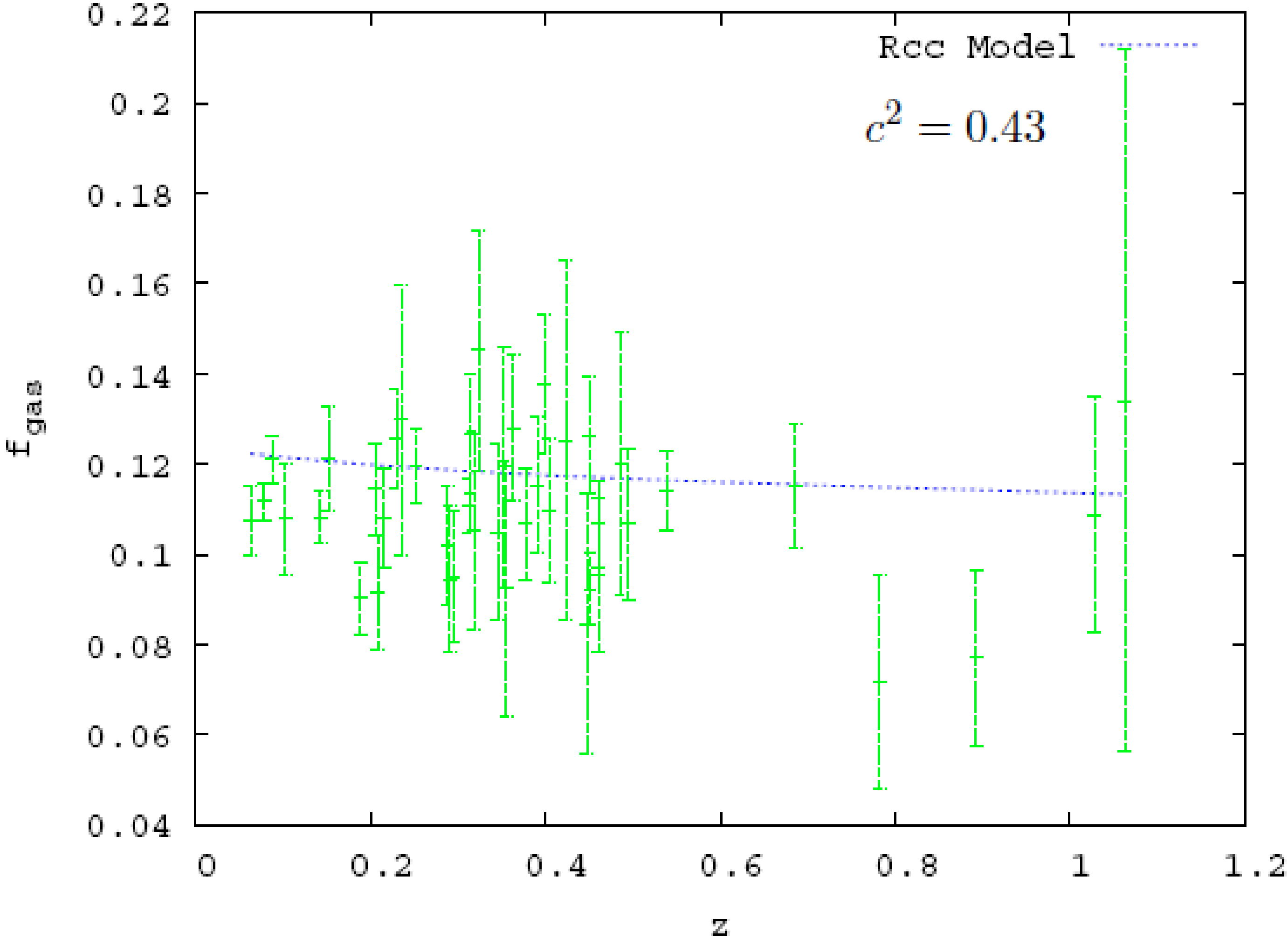
Growth function vs redshift for exponential interaction



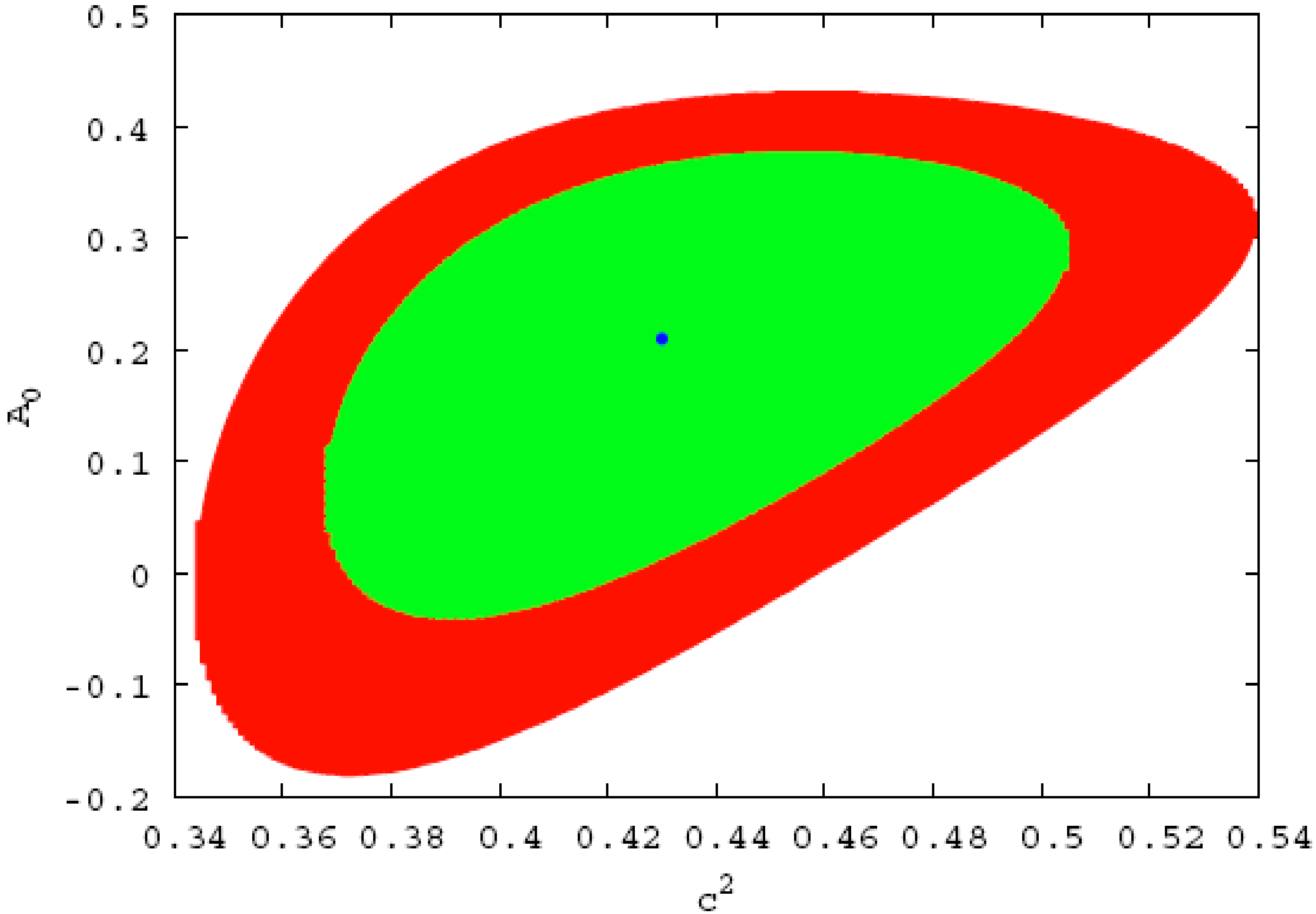
The 68% & 90% confidence level contours of Ao and A1 for the best fit model using SNIa + BAO + CMB



The 68% & 90% confidence level contours of A1
and c^2 for the best fit model using SNIa + BAO + CMB



Mass fraction of baryonic gas in clusters of galaxies.
The 42 data were borrowed from Allen et al (2008).



The 68% & 90% confidence level contours of c^2 and Ao
for the best fit model using SNIa + BAO + CMB + x ray data

For the best fit model $(A_0 = 0.21\,, \quad A_1 = 0.25\,, \quad c^2 = 0.43) \;\Rightarrow\; \chi^2 = 364.1$

c^2	Int.	$R(z_{rec})$	$D_v(0.35)/D_v(0.2)$
0.43	$A_0 = 0.21,\ A_1 = 0.25$	1.707	1.671

Table III: Exponential interaction

Observational data

$$R(z_{rec}) = 1.710 \pm 0.019$$

$$D_v(0.35)/D_v(0.2) = 1.736 \pm 0.065$$

Comments & Conclusions

(i) Interacting holographic dark energy at the Ricci scale shows compatibility with the observational data; it looks a promising candidate to account for the present accelerated phase and solve the coincidence problem.

(ii) Additional observational data are required to further constrain this class of models.

(iii) There is ample latitude about the specific expression of the interacting term, Q. We must establish criteria to determine this key quantity.

THANKS SO MUCH FOR YOUR KIND ATTENTION!!