BULK MATTER AND COSMIC ACCELERATION

First annual school of the EU network - "UniverseNet"

C. Bogdanos, University of Ioannina

C.B. and K.Tamvakis, Phys.Lett. B 646:39-46, hep-th/0609143

C.B., A. Dimitriadis and K.Tamvakis, Phys. Rev. D 75 :087303, hep-th/0611094

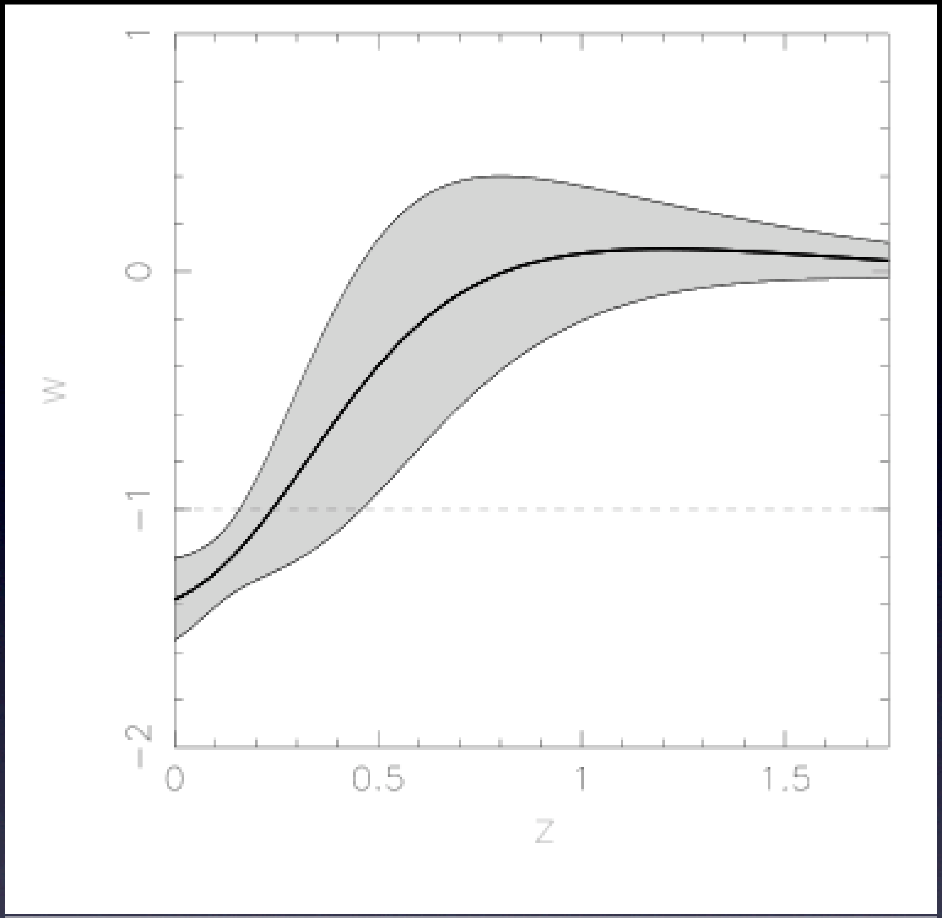
C. Bogdanos, S. Nesseris, L. Perivolaropoulos, K. Tamvakis, Phys. Rev. D, arXiv:0705.3181 [hep-ph]

RECENT OBSERVATIONAL FINDINGS

- The universe appears to be spatially flat
- It is matter dominated, with a low matter density, $\Omega_m \approx 0.27$
- Supernova Ia data indicate that the universe currently undergoes accelerated expansion (Riess et al., 2006, Astier et al., 2005)

WHAT IS CAUSING ACCELERATION?

- Accelerated expansion can be attributed to some short of dark energy
- Simplest explanation for dark energy: cosmological constant
- Numerous other candidates: Scalar Fields (Quintessence), Phantom Fields, Hessence, Chaplygin Gass, Modified Gravity, Extra Dimensions.....



- Results are still not conclusive, cosmological constant is still not ruled out
- Fits of the supernova data seem to favor a variable equation of state parameter w, which crosses the w=-1 line (Sahni et al.)

$p=w\rho$

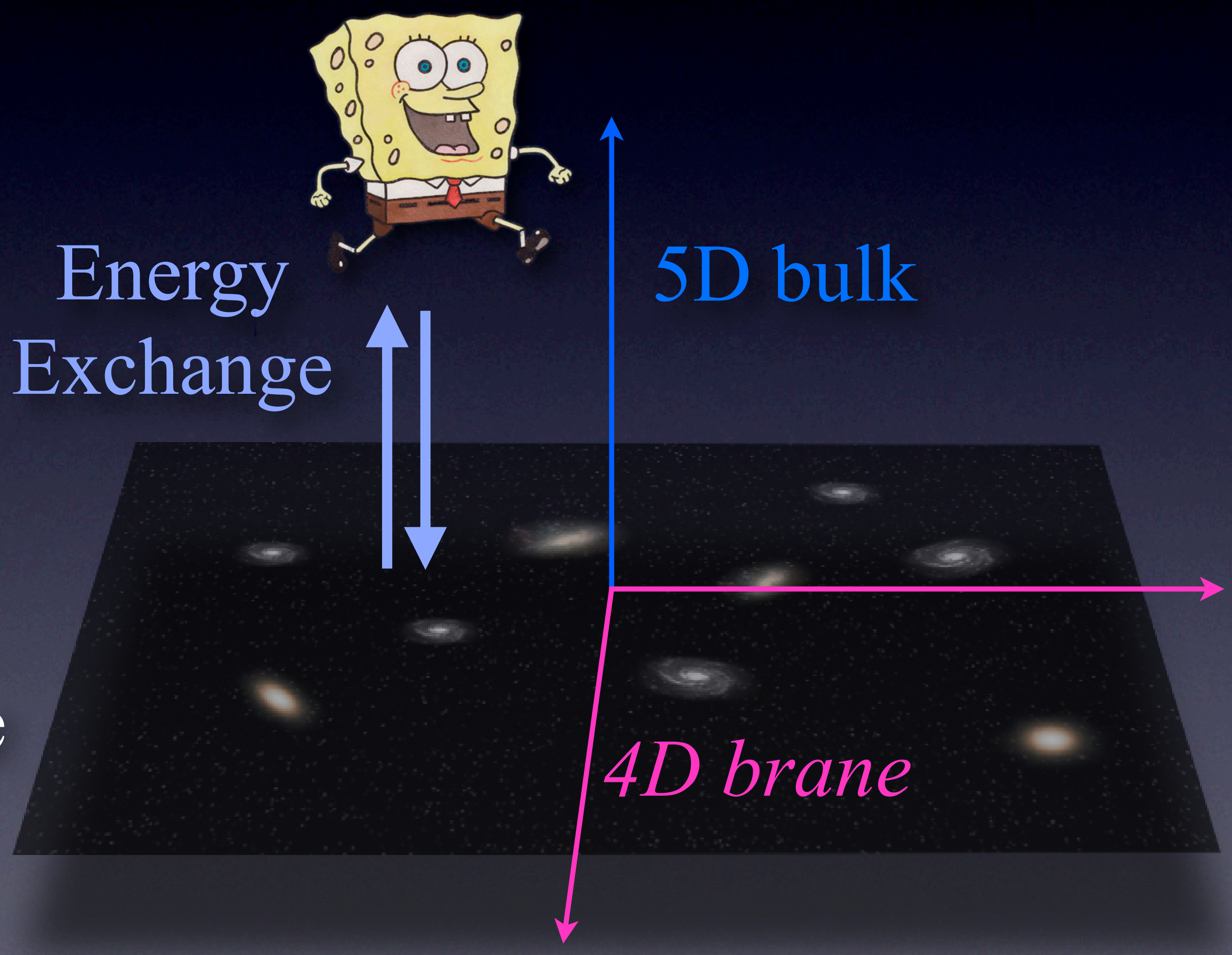
EQUATION OF STATE

A POSSIBLE CANDIDATE FOR DARK ENERGY

- The usual approach: Conventional geometry - unconventional matter fields
- Our approach: Conventional matter fields - unconventional geometry
  - Assume the presence of five dimensional bulk matter and energy exchange between brane and bulk

BRANE COSMOLOGY WITH BULK MATTER

- Ordinary matter trapped on 4D hypersurface
- Additional 5D matter, as well as energy exchange between the brane and the bulk is allowed



ENERGY-MOMENTUM TENSOR OF THE BULK

$$ds^2 \;=\; -n^2(y,t)dt^2 \;+\; a^2(y,t)\gamma_{ij}dx^i dx^j \;+\; b^2(y,t)dy^2$$

$$T^{(B)}_{MN} \;=\; \begin{pmatrix} \rho_B n^2 & 0 & -n^2 P_5 \\ 0 & P_B a^2 \gamma_{ij} & 0 \\ -n^2 P_5 & 0 & \overline{P}_B b^2 \end{pmatrix}$$

To lowest order, a perfect fluid moving slowly along the fifth dimension has an energy-momentum tensor of this structure

GENERAL EQUATIONS OF THE MODEL

Energy Conservation

$$\dot{\rho} + 3\,(\,\rho + p\,)\,\frac{\dot{a}_0}{a_0} = -2P_5$$

brane-bulk energy exchange term

Friedmann Equation

$$\frac{\ddot{a}_0}{a_0} + \left(\frac{\dot{a}_0}{a_0}\right)^2 + \frac{k}{a_0^2} = \frac{1}{(24M^3)^2}(\sigma + \rho)\,(2\sigma - \rho - 3p) + \frac{1}{12M^3}\left(\,\Lambda - \overline{P}_B\,\right)$$

Bulk pressure

brane content
(ordinary matter)

FURTHER ASSUMPTIONS

- Usually one assumes that the bulk pressure is negligible and only keeps the energy exchange term. Here we assume that the bulk pressure is also significant and keep both terms. This opens up the question of bulk dynamics
- We are interested in the behavior of the universe at late times only.
- We also assume a low density content on the brane and thus dismiss ρ^2 terms in the Friedmann equation

SOLVING THE MODEL

- We adopt an ansatz for the bulk matter pressure and energy exchange terms that renders the system of equations solvable
- This ansatz can be justified when we model the bulk content as a perfect fluid

$$\overline{P}_B = D\, a^{\nu}$$

$$P_5 = F\left(\frac{\dot{a}}{a}\right) a^{\mu}$$

REMARKS ON THE BULK FLUID ANSATZ

- The effects of dark matter can be interpreted as the consequence of extra dimensions and bulk matter being present
- Both the bulk pressure and the brane-bulk energy exchange can affect the cosmic evolution on the brane
- The model can reproduce the observed cosmic acceleration and account for an effective energy density of dark matter which crosses the w=-1 line without the bulk fluid violating energy conditions
- Potential problem: The negative sign of the dark radiation term

GOING FURTHER

- We showed that acceleration and $w=-1$ crossing is possible for the bulk fluid model. Can we reproduce the temporal evolution of w_{eff} and q in the range $0 \leq z \leq 1$ as deduced from observations, at least at a qualitative level?
- Analysis of observational data suggests a crossing of the $w_{eff}=-1$ line at a redshift $z \approx 0.2$ and a current value of $w_{eff}=-1.21$. Also, $q=0$ for $z \approx 0.5$
- Can we achieve the desired temporal profile without demanding a negative dark radiation term?

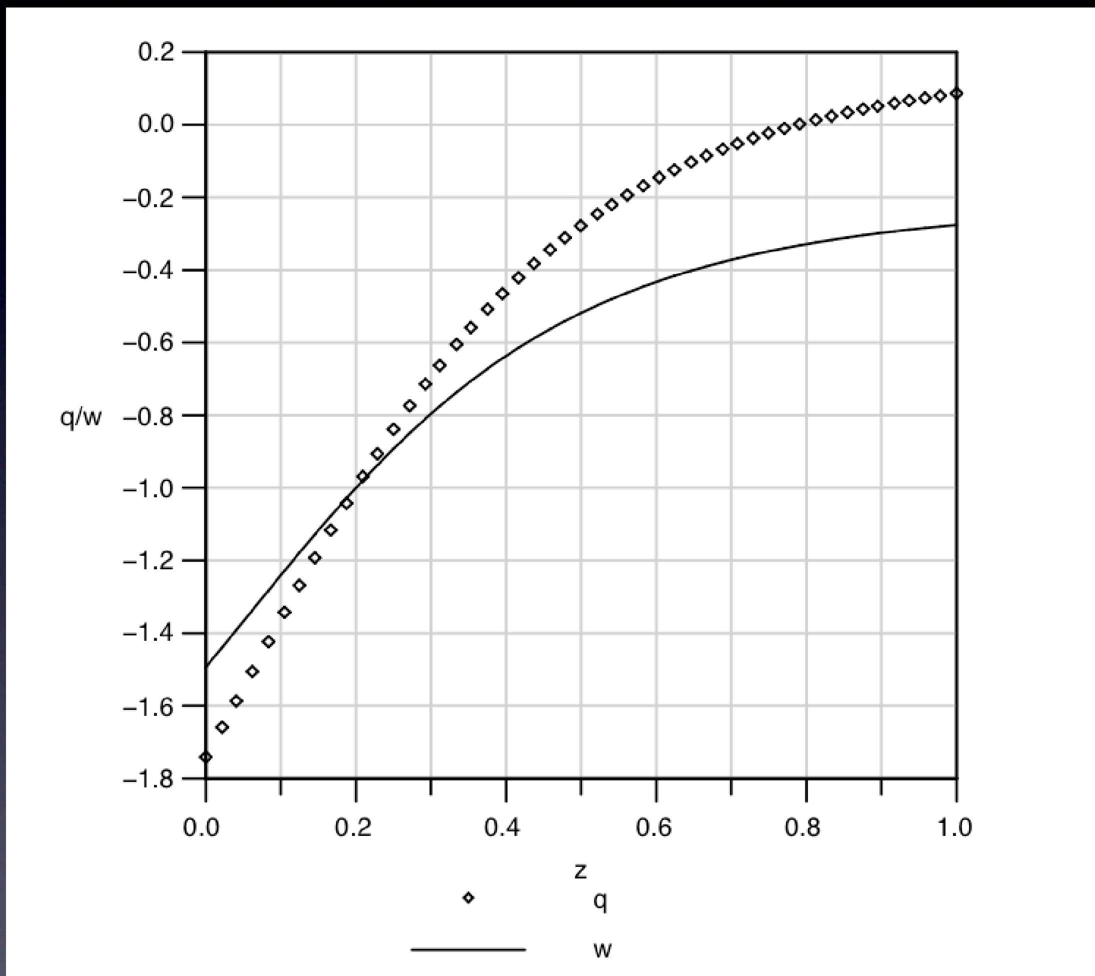
QUALITATIVE ANALYSIS

- We can meet these requirements if we depart from the simple interpetation of the bulk fluid, which restricts the two contribution to have the same power of α, μ=ν
- If we keep the powers different from each other and assume that at late times the dark radiation term is negligible, we can get constraints on the range of parameters for the model

$$\overline{P}_B = D\,a^{\nu}$$

$$P_5 = F\left(\frac{\dot{a}}{a}\right)a^{\mu}$$

TEMPORAL PROFILE



A=-1, B=-2,
μ=3.41, ν=-2.375

GOING EVEN FURTHER: FITING SUPERNOVA DATA

- We can go one step ahead and fit the model to the GOLD SNIa dataset, keeping the dark radiation term.
- Parameter space contains 4 parameters μ,ν, Ω_{DR},Ω_B, induces large degeneracies (multiple minima)
- Two approaches:

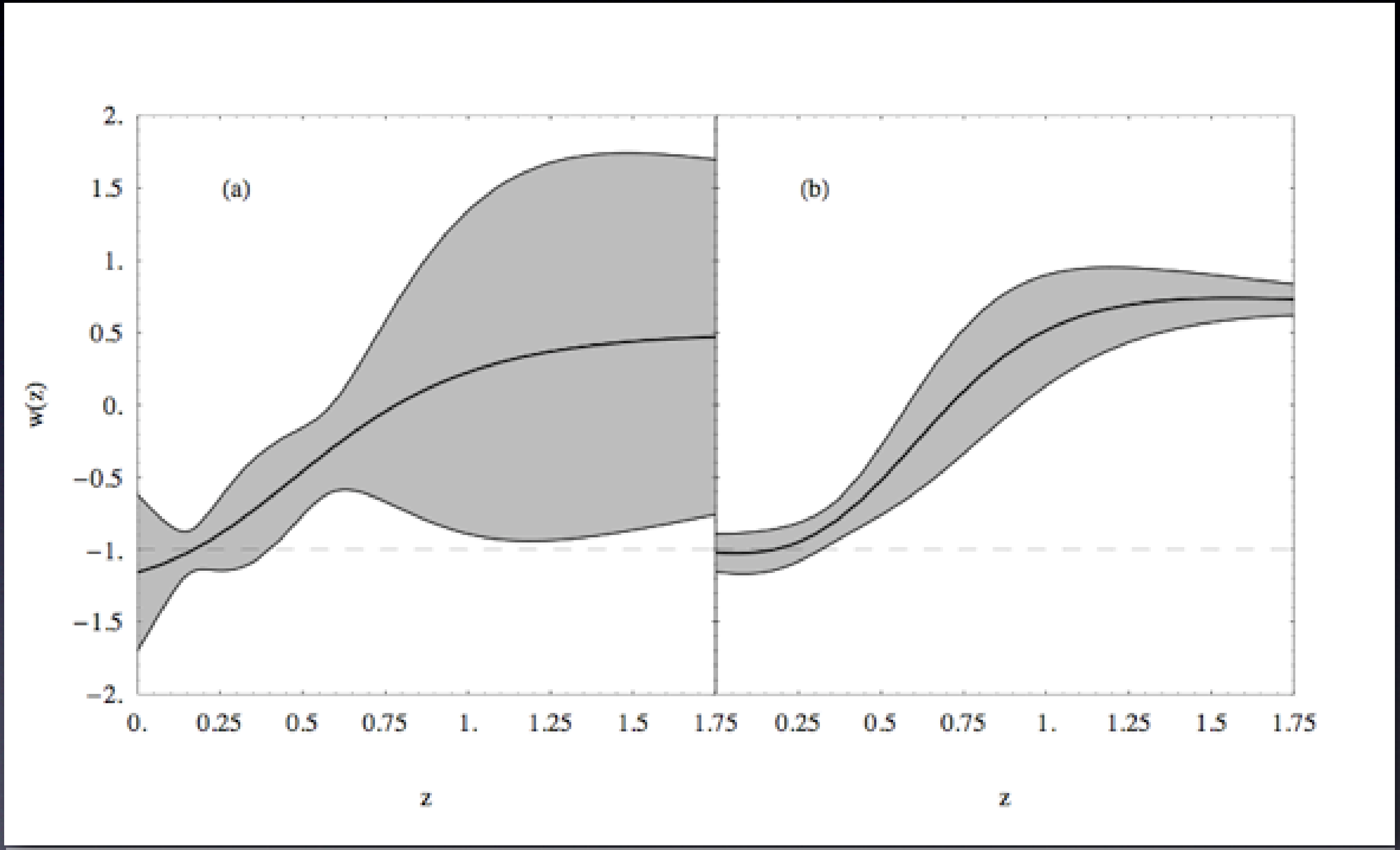
1. Direct minimization
2. Marginalization - minimization

GOING EVEN FURTHER: FITING SUPERNOVA DATA

Method	ν	μ	Ω_{DR}	Ω_B	Ω_5
Direct Minimization	0.75±5.09	-3.55±5.77	0.29±2.45	3.39±0.76	-0.27±2.57
Marginalization -minimization	-3.0±1.1	-0.8±0.3	0.49±0.25	-1.00±0.49	1.24±1.23
Marginalization -averaging	-3.0±1.1	-0.8±0.3	0.52	-1.05	1.26

- A double component fluid interpretation with energy inflow on the brane is favored
- Ω_{DR} is positive
- Marginalization-averaging confirms marginalization-minimization results

GOING EVEN FURTHER: FITING SUPERNOVA DATA



a)Direct minimization

b)Marginalization-minimization

SUMMARY

- Brane models with bulk matter content provide an interesting framework to explain dark energy
- Cosmic acceleration and w=-1 crossing is achieved without invoking exotic forms of matter that violate energy conditions
- The above effects can be reproduced with a simple relativistic bulk fluid
- More complex structure is required to accurately reproduce the cosmic evolution at late times