**Porozumienie**
**„Kosmologia i Cząstki Elementarne”**
Warszawa
19. 02. 2007

# Activities of the Dept. of Astrophysics and Cosmology U. of Silesia

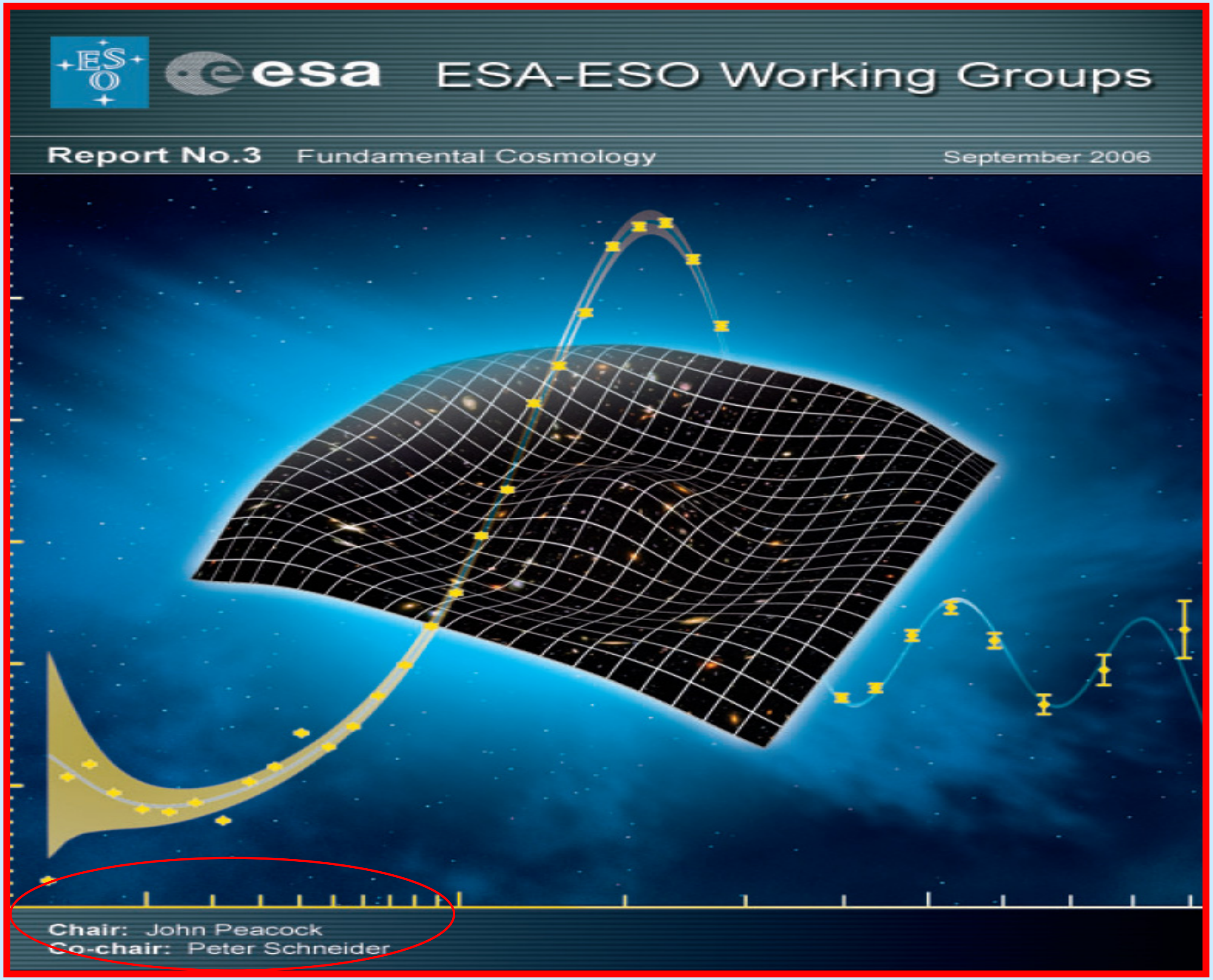
**Marek Biesiada**
Department of Astrophysics and Cosmology
**University of Silesia**
Katowice, Poland

# Activities of the Department - put in the PERSPECIVE

1. Dark matter/energy problem –fitting models to observations
2. Dark matter/energy problem as a problem of model selection -- information theoretic model selection approach
3. Astrophysical bound on exotic (non-stadnard) physics
4. Gravitational wave experiments in cosmological context

5. Last stages of stellar evolution
6. Model – theoretical approaches to Quantum Gravity

# What is the PERSPECIVE ?

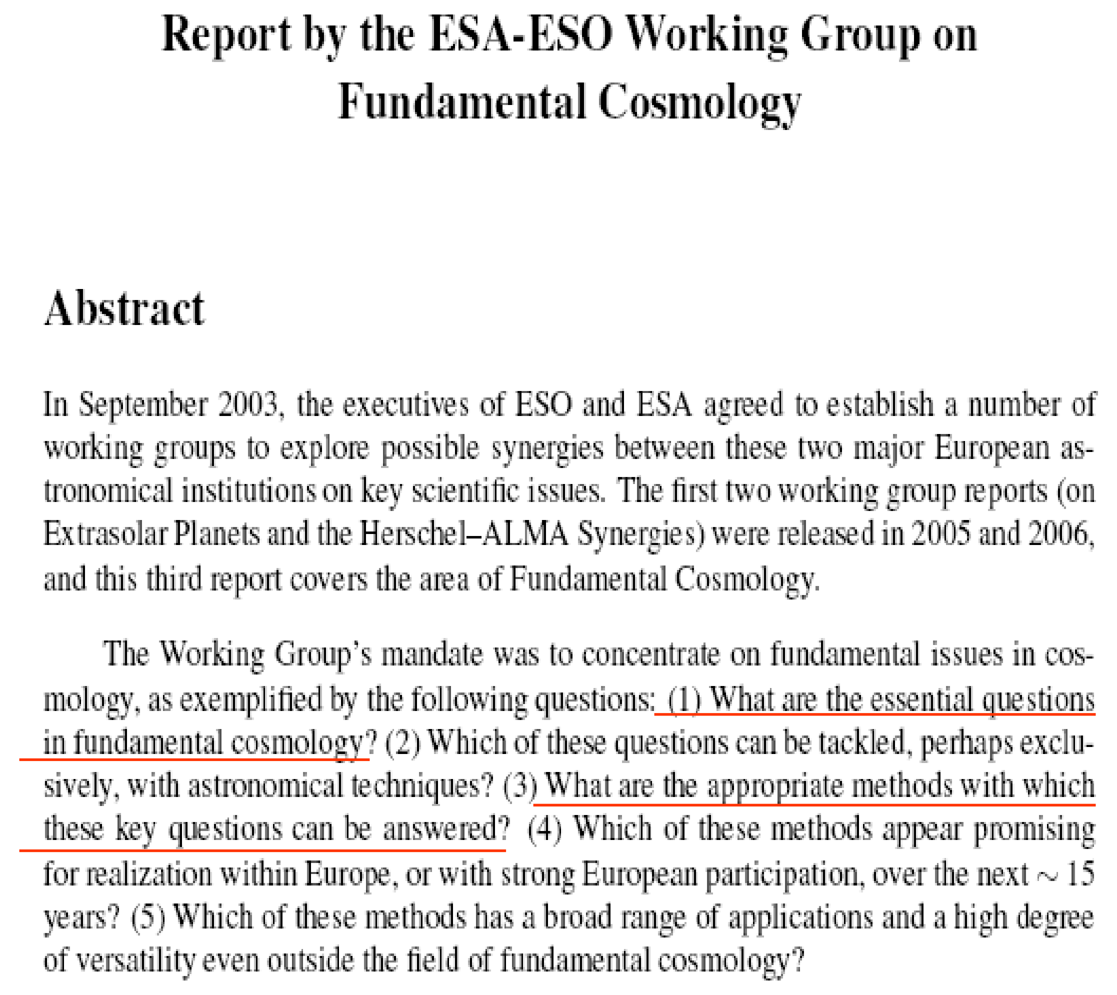


ESA-ESO Working Groups

Report No.3 Fundamental Cosmology September 2006

Chair: John Peacock
Co-chair: Peter Schneider

# Activities of the Department - put in the PERSPECIVE



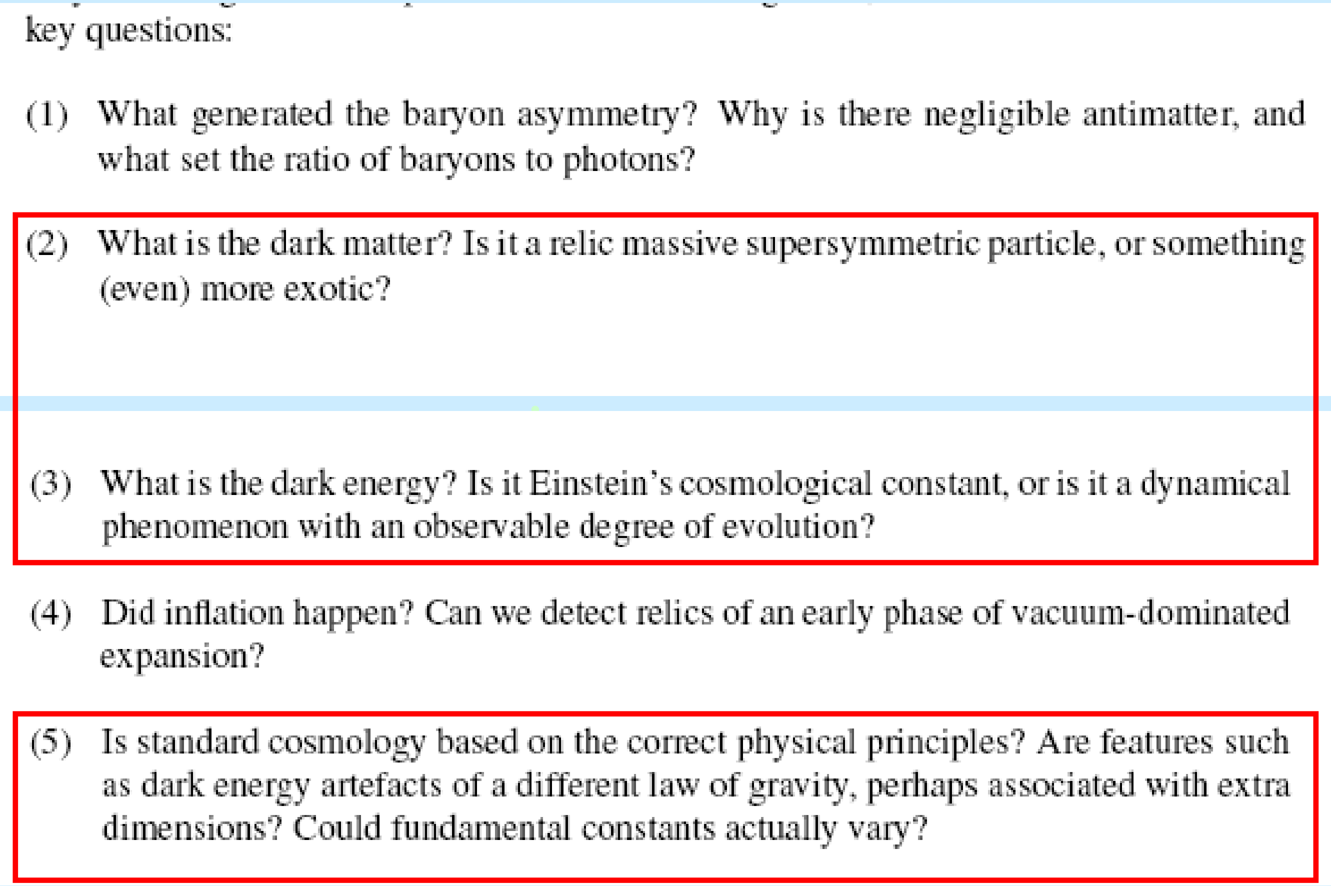
## Report by the ESA-ESO Working Group on Fundamental Cosmology

### Abstract

In September 2003, the executives of ESO and ESA agreed to establish a number of working groups to explore possible synergies between these two major European astronomical institutions on key scientific issues. The first two working group reports (on Extrasolar Planets and the Herschel–ALMA Synergies) were released in 2005 and 2006, and this third report covers the area of Fundamental Cosmology.

The Working Group's mandate was to concentrate on fundamental issues in cosmology, as exemplified by the following questions: (1) What are the essential questions in fundamental cosmology? (2) Which of these questions can be tackled, perhaps exclusively, with astronomical techniques? (3) What are the appropriate methods with which these key questions can be answered? (4) Which of these methods appear promising for realization within Europe, or with strong European participation, over the next ~ 15 years? (5) Which of these methods has a broad range of applications and a high degree of versatility even outside the field of fundamental cosmology?

# Key Questions:



key questions:

(1) What generated the baryon asymmetry? Why is there negligible antimatter, and what set the ratio of baryons to photons?

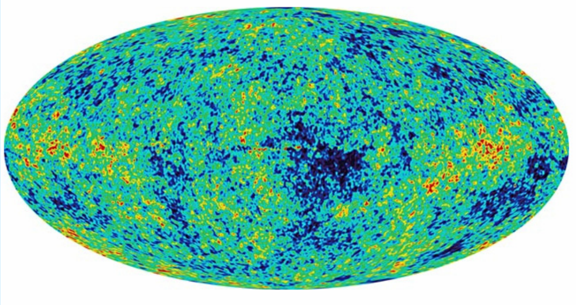
(2) What is the dark matter? Is it a relic massive supersymmetric particle, or something (even) more exotic?

(3) What is the dark energy? Is it Einstein's cosmological constant, or is it a dynamical phenomenon with an observable degree of evolution?

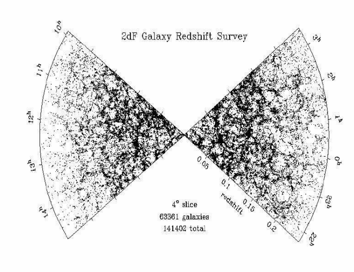
(4) Did inflation happen? Can we detect relics of an early phase of vacuum-dominated expansion?

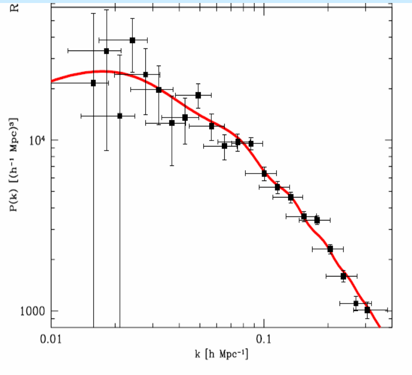
(5) Is standard cosmology based on the correct physical principles? Are features such as dark energy artefacts of a different law of gravity, perhaps associated with extra dimensions? Could fundamental constants actually vary?

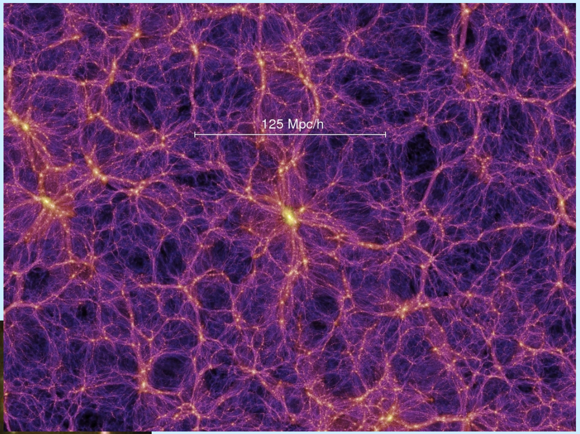
# Pillars of Modern Physical Cosmology



1. CMBR





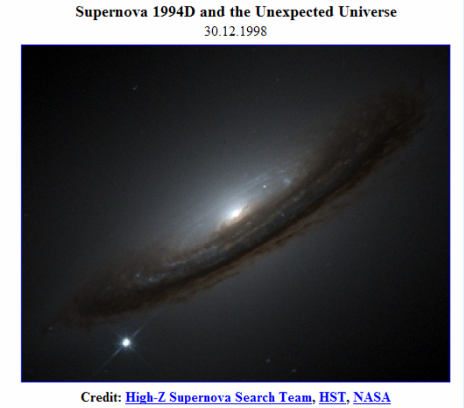


2. LSS

3. **Gravitational lensing**

4. Quasar spectra (La)

5. **High redshift SN Ia**



**Supernova 1994D and the Unexpected Universe**

30.12.1998

**Credit:** High-Z Supernova Search Team, HST, NASA

# Activities of the Department

**M. Biesiada**

- Dark energy in the Universe – tests and bounds

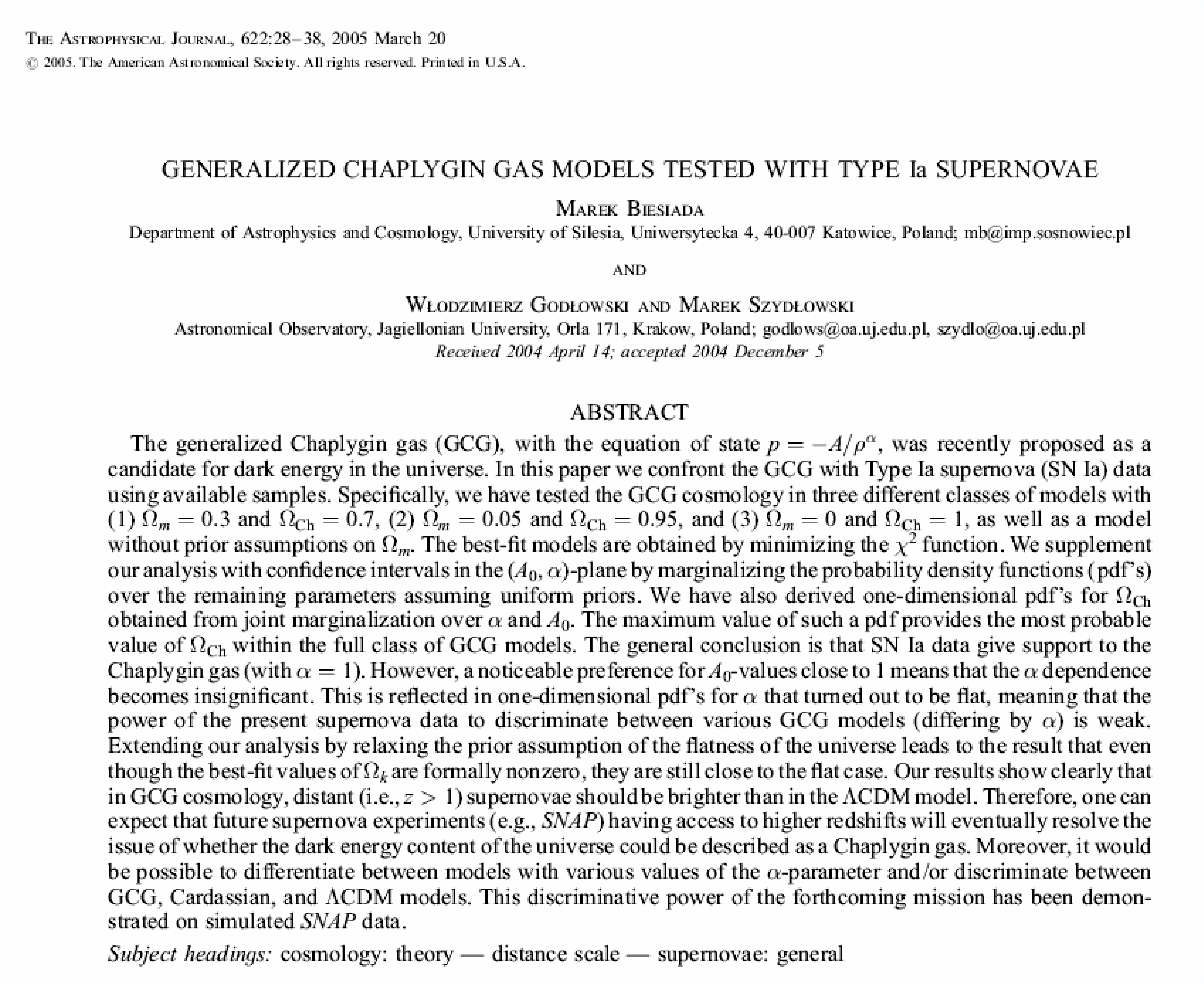
SNIa, BAO, acoustic peaks in CMBR

**(partly in collaboration with Cracow, OAUJ)**

Strong lensing systems as alternative test

- DE problem as a problem of model selection – many competing models with little theoretical guidance which is right ; **Which model (or a class thereof) is the most supported by the data ?**

**(partly in collaboration with Cracow, OAUJ)**



THE ASTROPHYSICAL JOURNAL, 622:28–38, 2005 March 20

# GENERALIZED CHAPLYGIN GAS MODELS TESTED WITH TYPE Ia SUPERNOVAE

MAREK BIESIADA
Department of Astrophysics and Cosmology, University of Silesia, Uniwersytecka 4, 40-007 Katowice, Poland; mb@imp.sosnowiec.pl

AND

WŁODZIMIERZ GODŁOWSKI AND MAREK SZYDŁOWSKI
Astronomical Observatory, Jagiellonian University, Orla 171, Krakow, Poland; godlows@oa.uj.edu.pl, szydlo@oa.uj.edu.pl
*Received 2004 April 14; accepted 2004 December 5*

## ABSTRACT

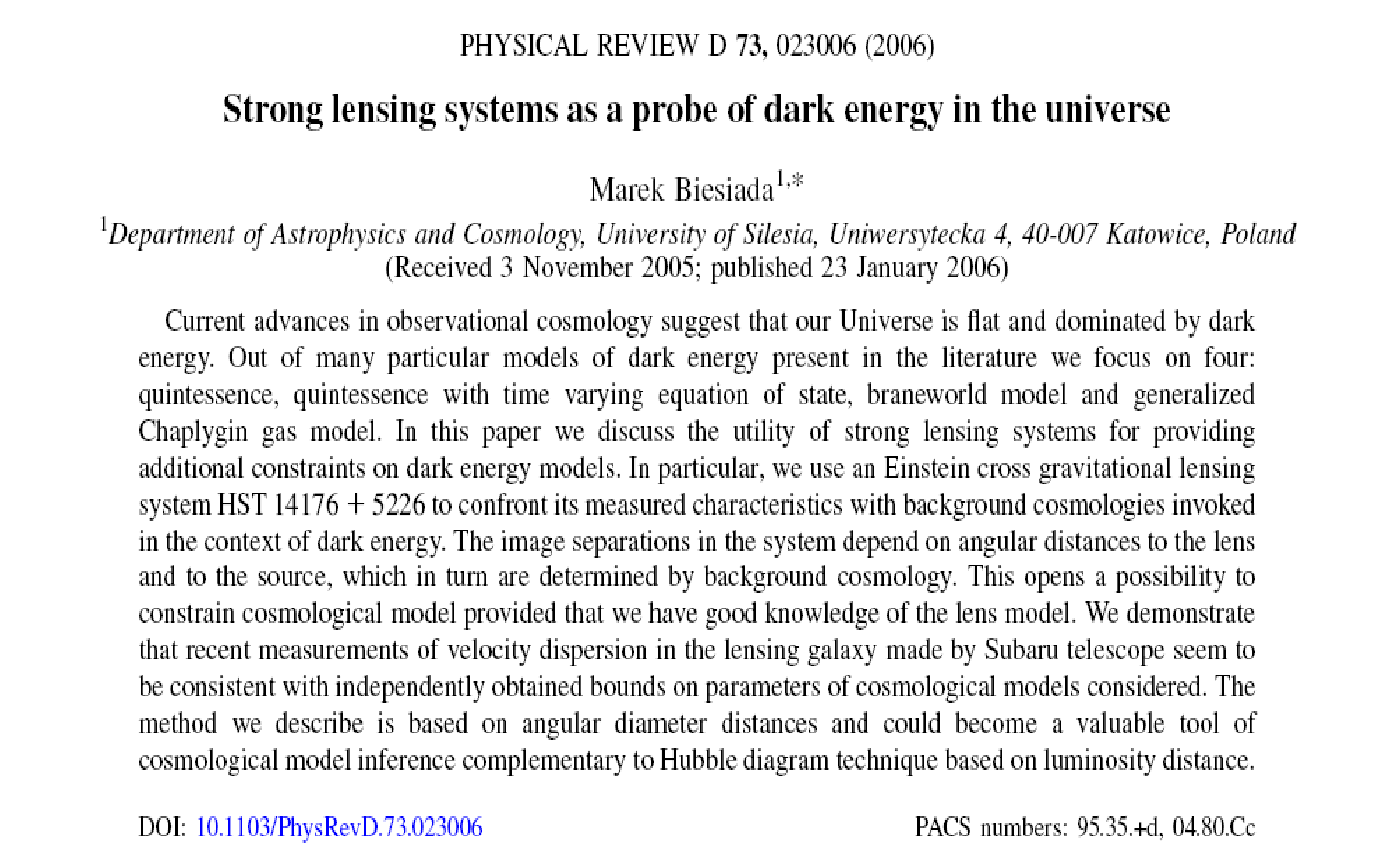
The generalized Chaplygin gas (GCG), with the equation of state $p = -A/\rho^{\alpha}$, was recently proposed as a candidate for dark energy in the universe. In this paper we confront the GCG with Type Ia supernova (SN Ia) data using available samples. Specifically, we have tested the GCG cosmology in three different classes of models with (1) $\Omega_m = 0.3$ and $\Omega_{\rm Ch} = 0.7$, (2) $\Omega_m = 0.05$ and $\Omega_{\rm Ch} = 0.95$, and (3) $\Omega_m = 0$ and $\Omega_{\rm Ch} = 1$, as well as a model without prior assumptions on $\Omega_m$. The best-fit models are obtained by minimizing the $\chi^2$ function. We supplement our analysis with confidence intervals in the $(A_0, \alpha)$-plane by marginalizing the probability density functions (pdf's) over the remaining parameters assuming uniform priors. We have also derived one-dimensional pdf's for $\Omega_{\rm Ch}$ obtained from joint marginalization over $\alpha$ and $A_0$. The maximum value of such a pdf provides the most probable value of $\Omega_{\rm Ch}$ within the full class of GCG models. The general conclusion is that SN Ia data give support to the Chaplygin gas (with $\alpha = 1$). However, a noticeable preference for $A_0$-values close to 1 means that the $\alpha$ dependence becomes insignificant. This is reflected in one-dimensional pdf's for $\alpha$ that turned out to be flat, meaning that the power of the present supernova data to discriminate between various GCG models (differing by $\alpha$) is weak. Extending our analysis by relaxing the prior assumption of the flatness of the universe leads to the result that even though the best-fit values of $\Omega_k$ are formally nonzero, they are still close to the flat case. Our results show clearly that in GCG cosmology, distant (i.e., $z > 1$) supernovae should be brighter than in the $\Lambda$CDM model. Therefore, one can expect that future supernova experiments (e.g., *SNAP*) having access to higher redshifts will eventually resolve the issue of whether the dark energy content of the universe could be described as a Chaplygin gas. Moreover, it would be possible to differentiate between models with various values of the $\alpha$-parameter and/or discriminate between GCG, Cardassian, and $\Lambda$CDM models. This discriminative power of the forthcoming mission has been demonstrated on simulated *SNAP* data.

*Subject headings:* cosmology: theory — distance scale — supernovae: general

# Perspectives

Hubble diagrams on GRB data – via Ghirlanda relation

Possible collaboration --- T. Bulik CAMK/OA UW



PHYSICAL REVIEW D **73,** 023006 (2006)

# Strong lensing systems as a probe of dark energy in the universe

Marek Biesiada[1,*]

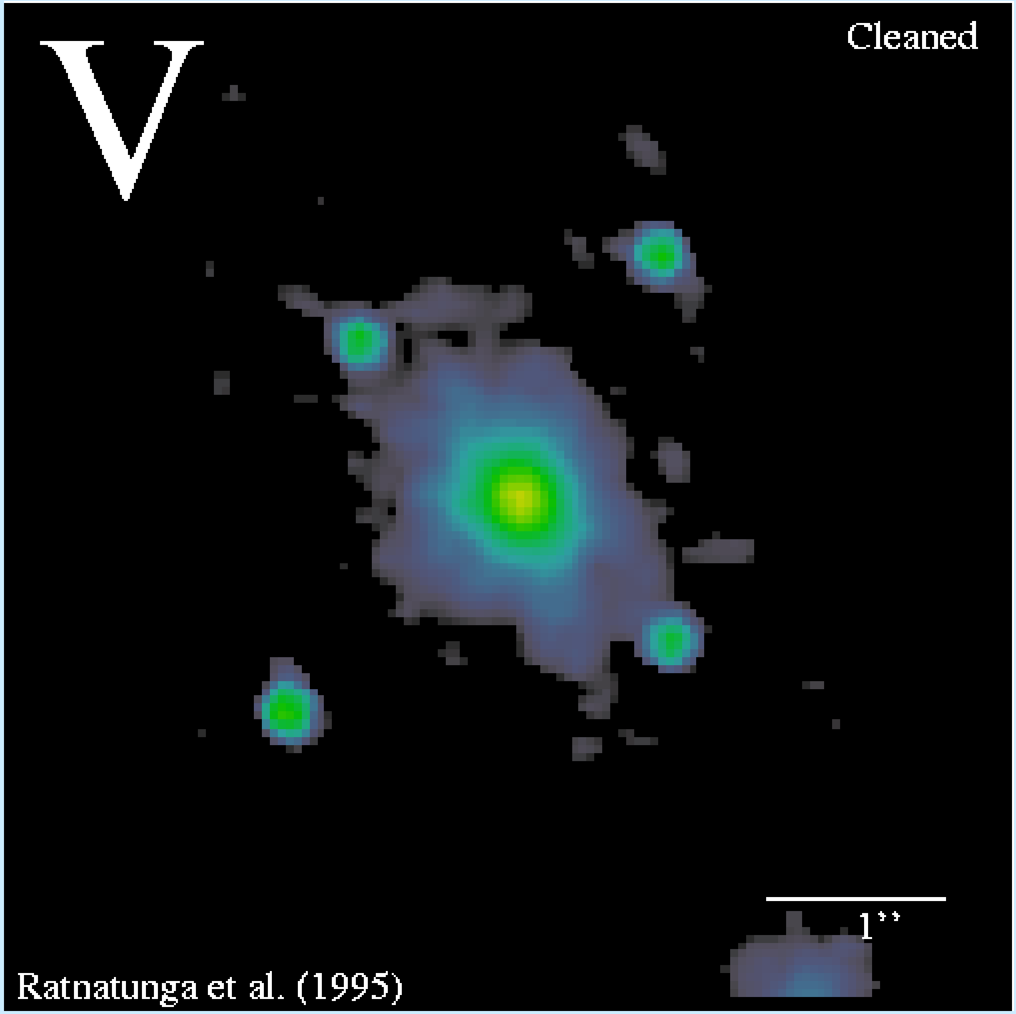
[1]*Department of Astrophysics and Cosmology, University of Silesia, Uniwersytecka 4, 40-007 Katowice, Poland*

(Received 3 November 2005; published 23 January 2006)

Current advances in observational cosmology suggest that our Universe is flat and dominated by dark energy. Out of many particular models of dark energy present in the literature we focus on four: quintessence, quintessence with time varying equation of state, braneworld model and generalized Chaplygin gas model. In this paper we discuss the utility of strong lensing systems for providing additional constraints on dark energy models. In particular, we use an Einstein cross gravitational lensing system HST 14176 + 5226 to confront its measured characteristics with background cosmologies invoked in the context of dark energy. The image separations in the system depend on angular distances to the lens and to the source, which in turn are determined by background cosmology. This opens a possibility to constrain cosmological model provided that we have good knowledge of the lens model. We demonstrate that recent measurements of velocity dispersion in the lensing galaxy made by Subaru telescope seem to be consistent with independently obtained bounds on parameters of cosmological models considered. The method we describe is based on angular diameter distances and could become a valuable tool of cosmological model inference complementary to Hubble diagram technique based on luminosity distance.

DOI: 10.1103/PhysRevD.73.023006

PACS numbers: 95.35.+d, 04.80.Cc



Ratnatunga et al. (1995)

# Lensing system HST 14176+5226 in V band

$z_L$=0.809
$z_s$=3.4
$\square_E$=1.″489

SIE Lens model

$$\theta_E = 4\pi\left(\frac{\sigma_v}{c}\right)^2 \frac{D_{LS}}{D_S}$$

**Idea**:
Take the expression for the Einstein ring

$$\theta_E = 4\pi\left(\frac{\sigma_v}{c}\right)^2 \frac{D_{LS}}{D_S}$$

From angular measurements of images ❑$_1$ and ❑$_2$

Determined by the cosmological model

$$\theta_1 = \theta_E\sqrt{1-\varepsilon}$$

$$\theta_2 = \theta_E\sqrt{1+\varepsilon}$$

$$D_{ls} = \frac{1}{1+z_s}\frac{c}{H_0}\int_{z_l}^{z_s}\frac{dz'}{\sqrt{\Omega_m(1+z')^3+\Omega_{Ch}\left(A_0+(1-A_0)(1+z')^{3(1+\alpha)}\right)^{\frac{1}{1+\alpha}}}}$$

From the SIE model fitting:
**e=0.4**
❑$_E$=1."489

SUBARU

LSD

**♦$_v$ = 290⊕8** km/s

# Quintessence

$w < -0.67$

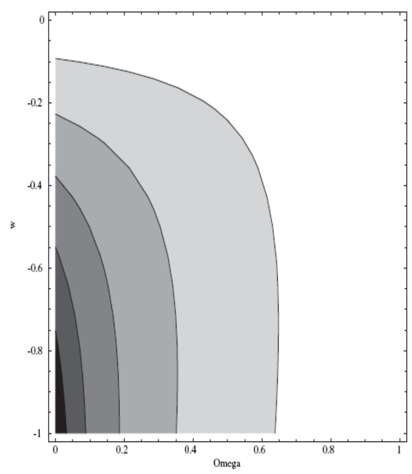


FIG. 1. Isolines of velocity dispersion $\sigma_v$ in km/s plotted in the $(w, \Omega_m)$ plane for constant $w$ quintessence models. Bands of $\sigma_v$ grow from 270 km/s to 310 km/s with 10 km/s step.

**Dynamical scalar field –**

$w(z) = w_0 + w_1 z$
$w_0 > -0.1$
$w_1 < -1.2$

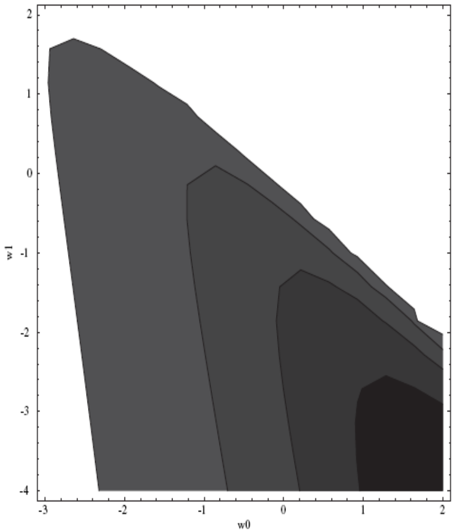


FIG. 2. Isolines of velocity dispersion $\sigma_v$ in km/s plotted in the $(w_0, w_1)$ plane for $w$ quintessence models with variable cosmic equation of state $w(z) = w_0 + w_1 z$ ($\Omega_m = 0.3$ assumed). Bands of $\sigma_v$ grow from 280 km/s to 310 km/s with 10 km/s step.

**Chaplygin Gas**

models with
$A_0$🕓1 preferred
i.e. equivalent to
☹CDM

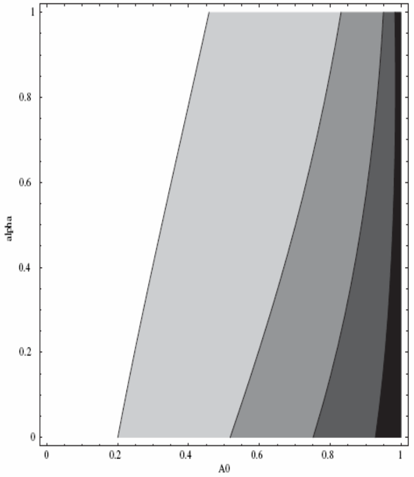


FIG. 3. Isolines of velocity dispersion $\sigma_v$ in km/s plotted in the $(A_0, \alpha)$ plane for generalized Chaplygin gas cosmology with $\Omega_m = 0.3$. Bands of $\sigma_v$ grow from 300 km/s to 315 km/s with 5 km/s step.

# Brane world

$$1.09H_0^{-1} < r_c < 1.39H_0^{-1}$$

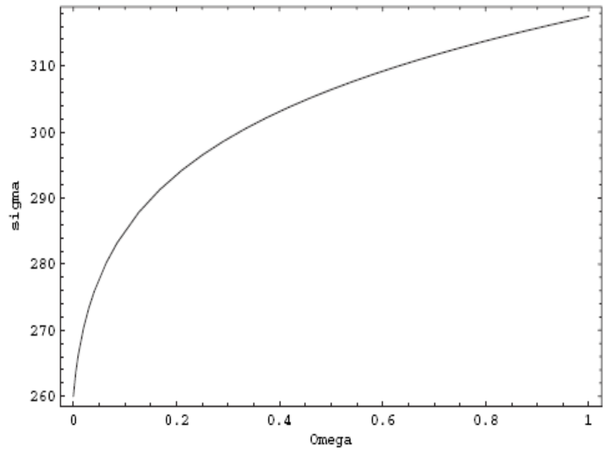


FIG. 4. Plot of $\sigma_v(\Omega_m)$ relation in braneworld model with flat spatial section.

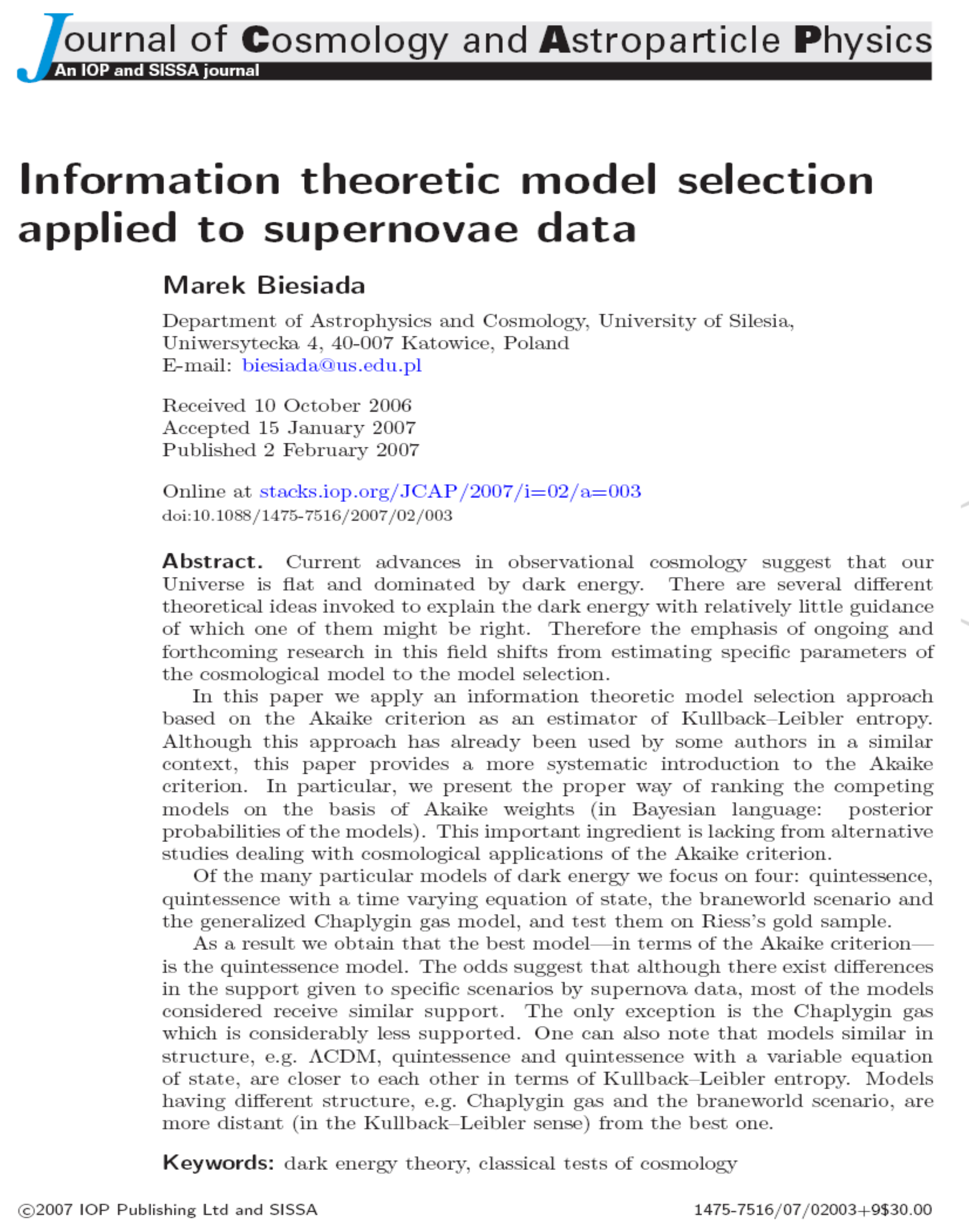
# Perspectives

Apply this for a sample of strong lensing systems from CLASS survey

**Pros.**

Method complementary to Hubble diagram
– different systematics

**Cons.**
Dependence on the lens model – mass density profile



Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

# Information theoretic model selection applied to supernovae data

**Marek Biesiada**

Department of Astrophysics and Cosmology, University of Silesia,
Uniwersytecka 4, 40-007 Katowice, Poland
E-mail: biesiada@us.edu.pl

Received 10 October 2006
Accepted 15 January 2007
Published 2 February 2007

Online at stacks.iop.org/JCAP/2007/i=02/a=003
doi:10.1088/1475-7516/2007/02/003

**Abstract.** Current advances in observational cosmology suggest that our Universe is flat and dominated by dark energy. There are several different theoretical ideas invoked to explain the dark energy with relatively little guidance of which one of them might be right. Therefore the emphasis of ongoing and forthcoming research in this field shifts from estimating specific parameters of the cosmological model to the model selection.

In this paper we apply an information theoretic model selection approach based on the Akaike criterion as an estimator of Kullback–Leibler entropy. Although this approach has already been used by some authors in a similar context, this paper provides a more systematic introduction to the Akaike criterion. In particular, we present the proper way of ranking the competing models on the basis of Akaike weights (in Bayesian language: posterior probabilities of the models). This important ingredient is lacking from alternative studies dealing with cosmological applications of the Akaike criterion.

Of the many particular models of dark energy we focus on four: quintessence, quintessence with a time varying equation of state, the braneworld scenario and the generalized Chaplygin gas model, and test them on Riess's gold sample.

As a result we obtain that the best model—in terms of the Akaike criterion—is the quintessence model. The odds suggest that although there exist differences in the support given to specific scenarios by supernova data, most of the models considered receive similar support. The only exception is the Chaplygin gas which is considerably less supported. One can also note that models similar in structure, e.g. ΛCDM, quintessence and quintessence with a variable equation of state, are closer to each other in terms of Kullback–Leibler entropy. Models having different structure, e.g. Chaplygin gas and the braneworld scenario, are more distant (in the Kullback–Leibler sense) from the best one.

**Keywords:** dark energy theory, classical tests of cosmology

1475-7516/07/02003+9$30.00

# Four classes of cosmological models invoked to explain accelerated expansion of the Universe

- Cosmological constant $\Lambda$
- Quintessence – dynamical scalar fields
- Chaplygin Gas
- Multidimensional models – braneworld scenarios

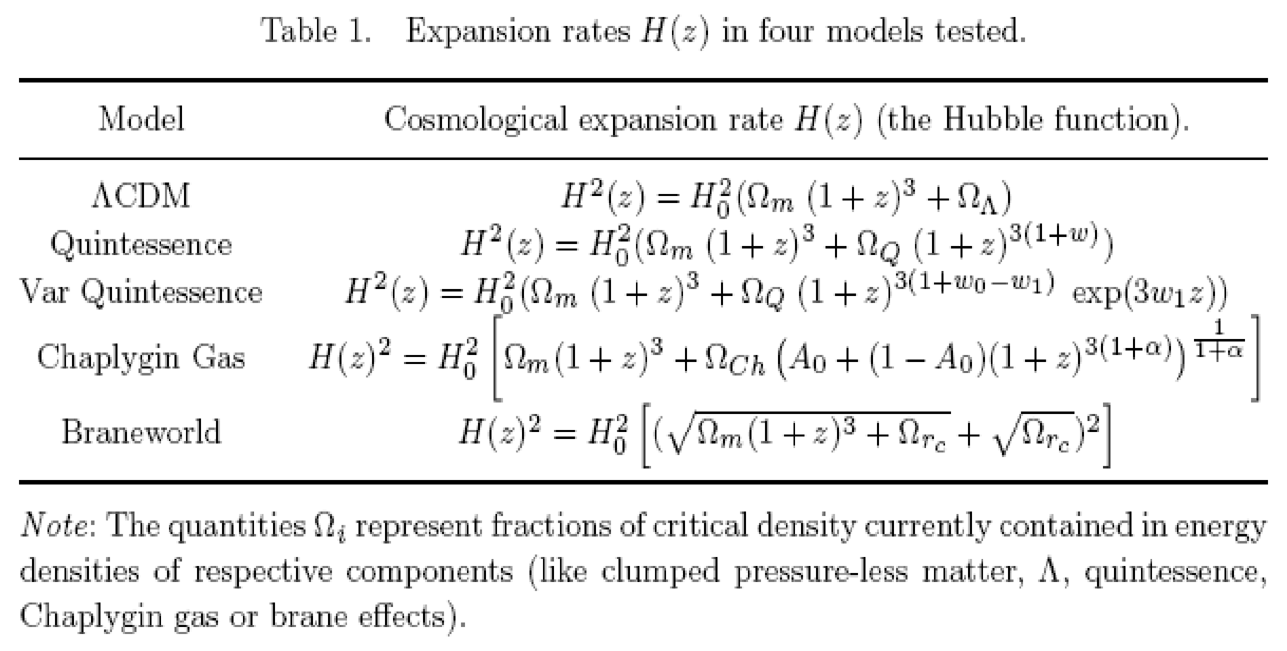


Table 1. Expansion rates $H(z)$ in four models tested.

| Model | Cosmological expansion rate $H(z)$ (the Hubble function). |
|---|---|
| $\Lambda$CDM | $H^2(z) = H_0^2(\Omega_m\,(1+z)^3 + \Omega_\Lambda)$ |
| Quintessence | $H^2(z) = H_0^2(\Omega_m\,(1+z)^3 + \Omega_Q\,(1+z)^{3(1+w)})$ |
| Var Quintessence | $H^2(z) = H_0^2(\Omega_m\,(1+z)^3 + \Omega_Q\,(1+z)^{3(1+w_0-w_1)}\ \exp(3w_1 z))$ |
| Chaplygin Gas | $H(z)^2 = H_0^2\left[\Omega_m(1+z)^3 + \Omega_{Ch}\left(A_0 + (1-A_0)(1+z)^{3(1+\alpha)}\right)^{\frac{1}{1+\alpha}}\right]$ |
| Braneworld | $H(z)^2 = H_0^2\left[(\sqrt{\Omega_m(1+z)^3 + \Omega_{r_c}} + \sqrt{\Omega_{r_c}})^2\right]$ |

*Note*: The quantities $\Omega_i$ represent fractions of critical density currently contained in energy densities of respective components (like clumped pressure-less matter, $\Lambda$, quintessence, Chaplygin gas or brane effects).

# Which model is the best?

- The one that is the most supported by data.
- Model selection based on information theory
- Starting point: Kullback - Leibler Information → AIC (Akaike Information Criterion)
- Also, BIC and Bayesian methods

# Cosmological models fitted to SN Ia data

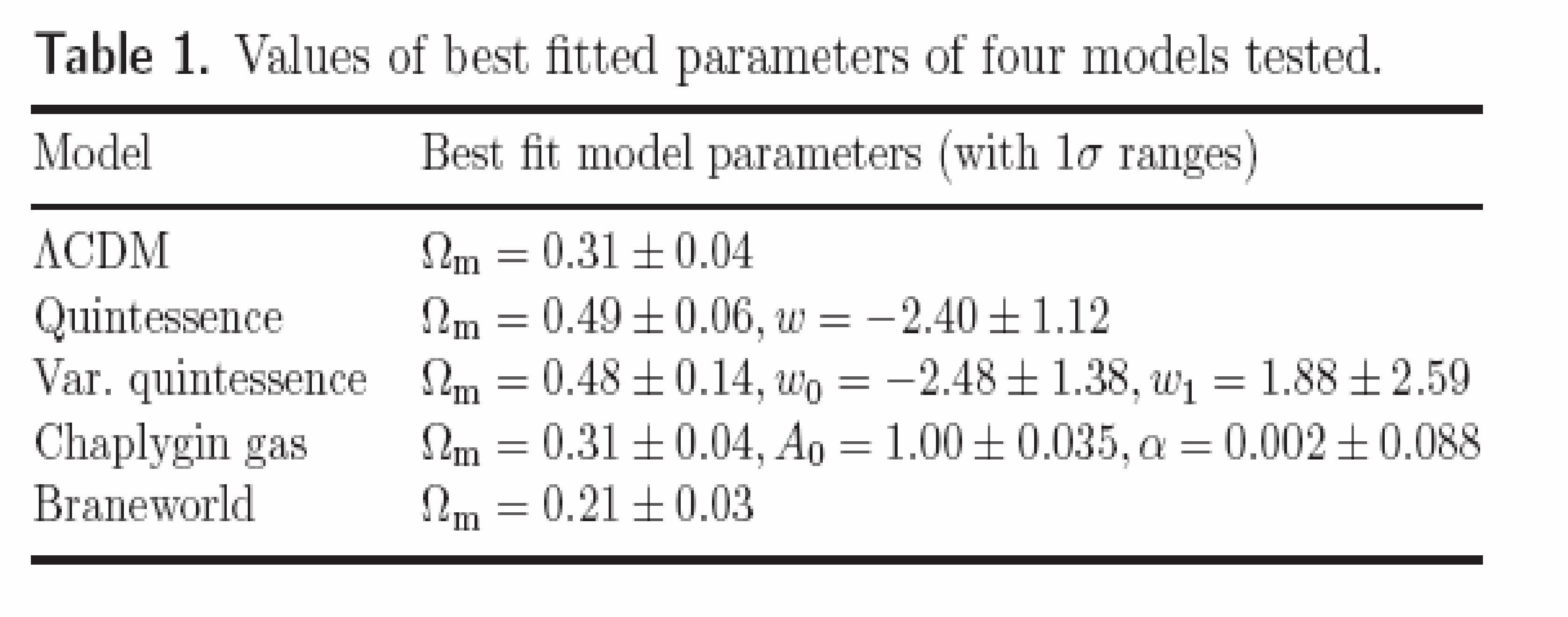


**Table 1.** Values of best fitted parameters of four models tested.

| Model | Best fit model parameters (with $1\sigma$ ranges) |
|---|---|
| $\Lambda$CDM | $\Omega_{\rm m} = 0.31 \pm 0.04$ |
| Quintessence | $\Omega_{\rm m} = 0.49 \pm 0.06, w = -2.40 \pm 1.12$ |
| Var. quintessence | $\Omega_{\rm m} = 0.48 \pm 0.14, w_0 = -2.48 \pm 1.38, w_1 = 1.88 \pm 2.59$ |
| Chaplygin gas | $\Omega_{\rm m} = 0.31 \pm 0.04, A_0 = 1.00 \pm 0.035, \alpha = 0.002 \pm 0.088$ |
| Braneworld | $\Omega_{\rm m} = 0.21 \pm 0.03$ |

# Comparative ranking

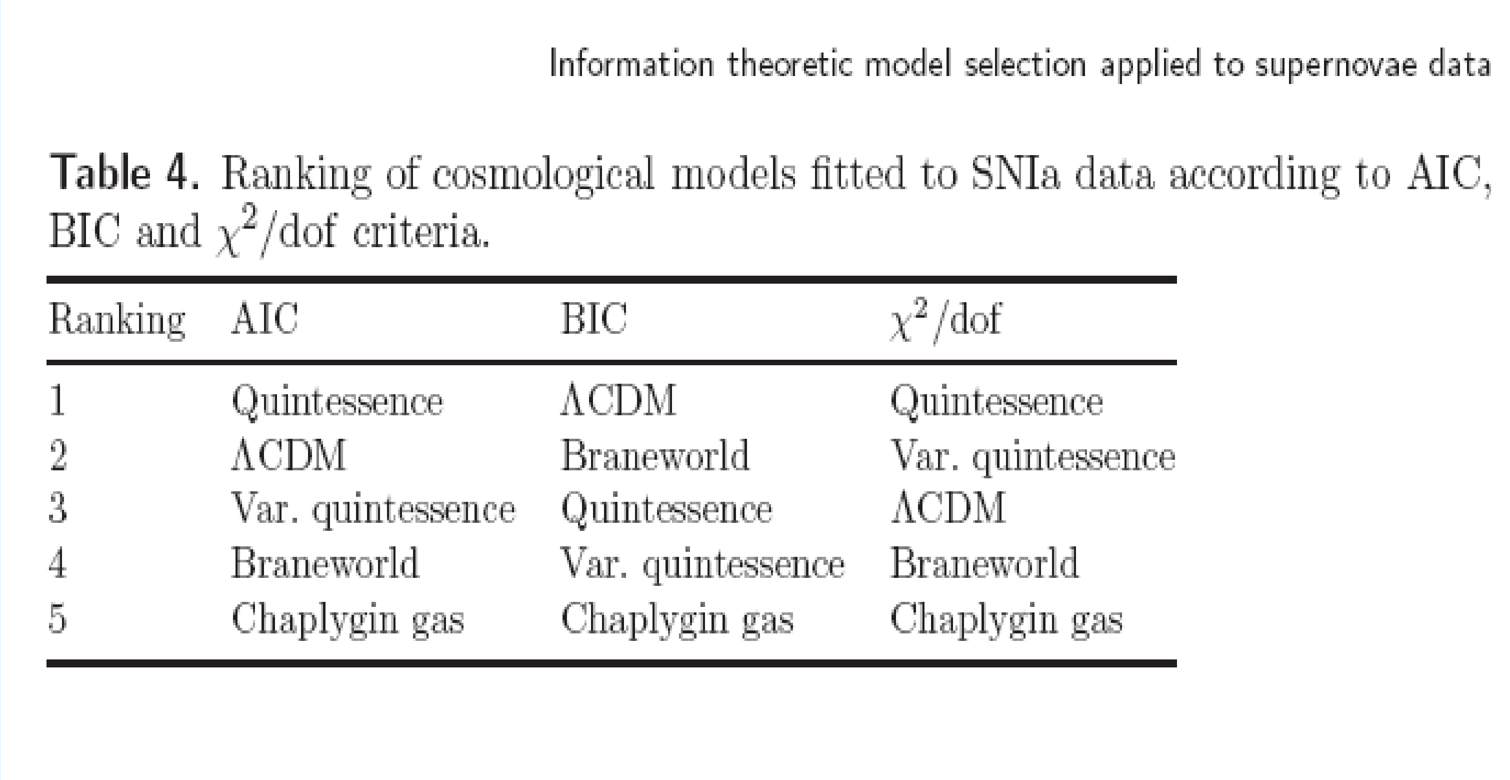


**Table 4.** Ranking of cosmological models fitted to SNIa data according to AIC, BIC and $\chi^2$/dof criteria.

| Ranking | AIC | BIC | $\chi^2$/dof |
|---|---|---|---|
| 1 | Quintessence | $\Lambda$CDM | Quintessence |
| 2 | $\Lambda$CDM | Braneworld | Var. quintessence |
| 3 | Var. quintessence | Quintessence | $\Lambda$CDM |
| 4 | Braneworld | Var. quintessence | Braneworld |
| 5 | Chaplygin gas | Chaplygin gas | Chaplygin gas |

# Perspectives

1. Test different models with different priors
   e.g. topology prior – Boud Roukema

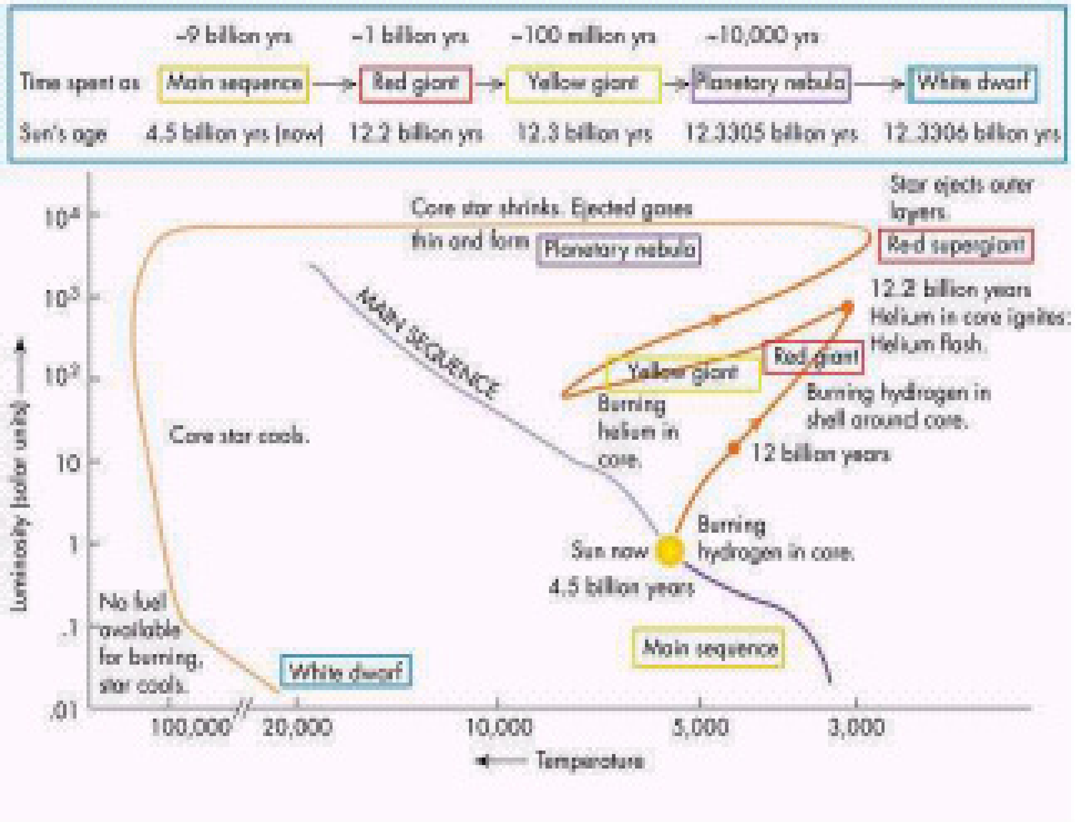
2. Model selection based on different tests: CMBR, BAO, LSS power spectrum, (ambitious task of self-consitency)
GRBs, SN Ia, lensing, Alcock-Paczynski
test for clusters

# Astrophysical bounds on Dark Matter canditaes

# idea

- **weakly interacting particles** (axions, Kaluza-Klein gravitons, etc. ) can be produced in stellar interiors and escape freely
- they become an **additional channel** of energy loss from stellar interiors (WIMPS too !)
- **new channel** of energy loss would **modify** stellar evolution

e.g. **Raffelt G.**, *Annu.Rev.Nucl.Particle Sci.*,**49**, 1999



Scheme of Evolutionary Track of a Star

# Instability strips on H-R diagram

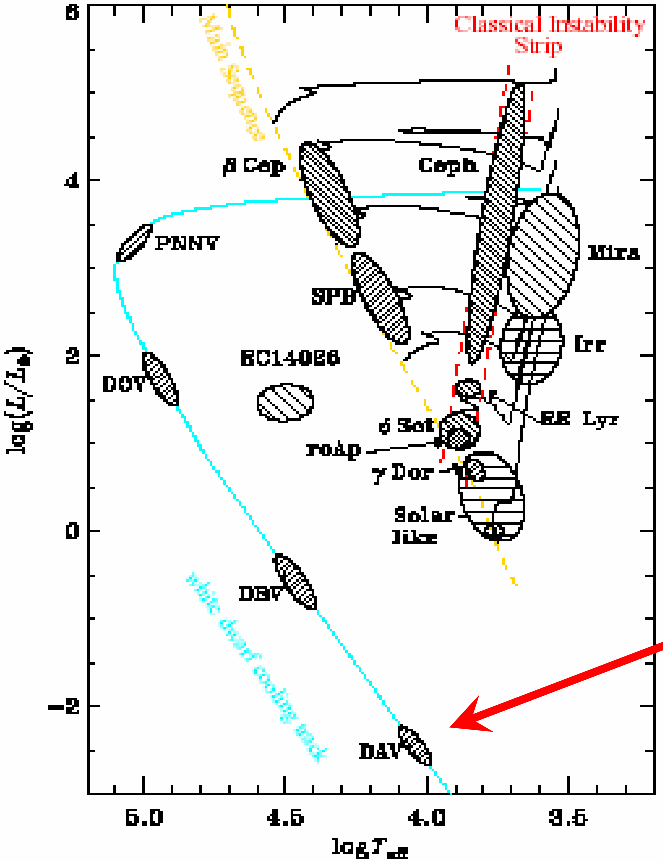


**Fig. 1.** H-R diagram showing the different classes of pulsating stars. In this article, we are interested in the DAV's.

ZZ Ceti

# What have we done with G117-B15A ?

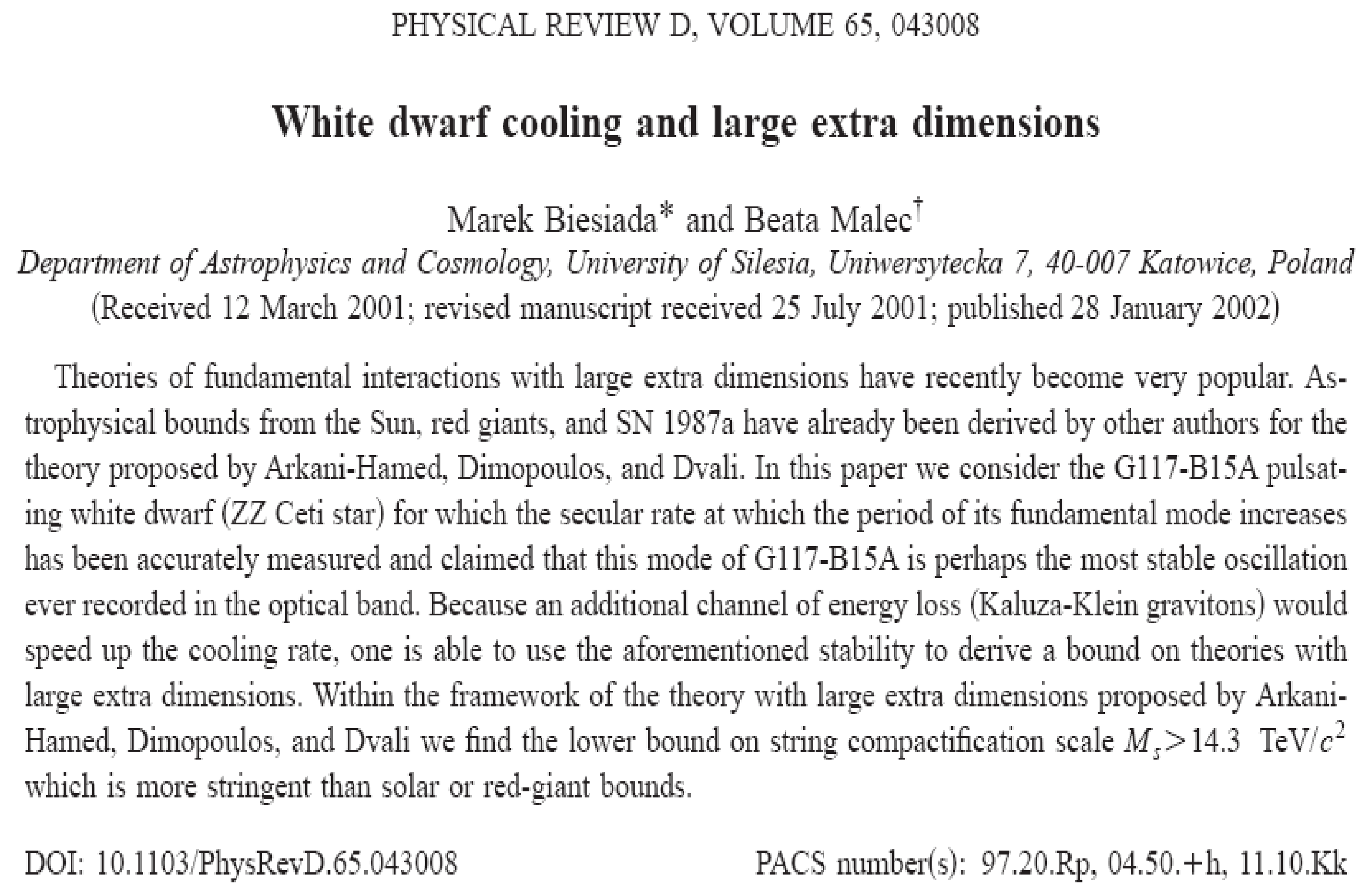
Biesiada & Malec *PhysRevD* **65**, 2002

- we have used this approach to constrain the **compactification mass scale $M_s$** (in **n=2** large extra dimensions)

Arkani-Hammed, Dimopoulos & Dvali (1998) model

the upper $2\sigma$ limit on $P_{OBS}$ translates into a bound:

$$L_{KK} = 5.86 \times 10^{-75} \frac{T^3 n_e}{\rho \cdot M_S^2} \sum_j n_j Z_j^2 \cdot M < \left( \frac{\dot{P}_{OBS}}{\dot{P}_O} - 1 \right) L_\gamma = 0.308 \cdot L_\gamma$$



PHYSICAL REVIEW D, VOLUME 65, 043008

# White dwarf cooling and large extra dimensions

Marek Biesiada* and Beata Malec†
*Department of Astrophysics and Cosmology, University of Silesia, Uniwersytecka 7, 40-007 Katowice, Poland*

(Received 12 March 2001; revised manuscript received 25 July 2001; published 28 January 2002)

Theories of fundamental interactions with large extra dimensions have recently become very popular. Astrophysical bounds from the Sun, red giants, and SN 1987a have already been derived by other authors for the theory proposed by Arkani-Hamed, Dimopoulos, and Dvali. In this paper we consider the G117-B15A pulsating white dwarf (ZZ Ceti star) for which the secular rate at which the period of its fundamental mode increases has been accurately measured and claimed that this mode of G117-B15A is perhaps the most stable oscillation ever recorded in the optical band. Because an additional channel of energy loss (Kaluza-Klein gravitons) would speed up the cooling rate, one is able to use the aforementioned stability to derive a bound on theories with large extra dimensions. Within the framework of the theory with large extra dimensions proposed by Arkani-Hamed, Dimopoulos, and Dvali we find the lower bound on string compactification scale $M_s > 14.3$ TeV/$c^2$ which is more stringent than solar or red-giant bounds.

DOI: 10.1103/PhysRevD.65.043008 PACS number(s): 97.20.Rp, 04.50.+h, 11.10.Kk

# comparison with other bounds

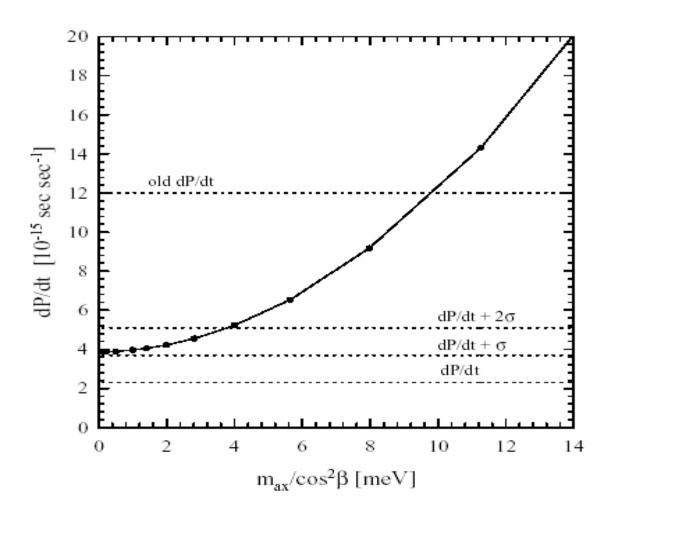
| | |
|---|---|
| LEP | $M_s > 1$ TeV/$c^2$ |
| The Sun | $M_s > 0{,}3$ TeV/$c^2$ |
| Red Giants | $M_s > 4$ TeV/$c^2$ |
| SN1987A | $M_s > 30\text{-}130$TeV/$c^2$ |
| White Dwarf | $M_s > 14{,}3$ TeV/$c^2$ |

# What have the others done with **G117-B15A** ?

Corsico et al. *New Astron.* **6**, 2001

- used G117-B15A to constrain the **mass of an axion**
- evolutionary and pulsational codes with axion emissivity added
- obtained bound to axion mass

$$m_{ax} \leq 4\cos^2\beta \quad meV$$



# Another issue - Varying G

- renewed debate over the issue whether the fundamental constants of nature (G, c, h or e) can vary with time

# MOTIVATION

- Dirac's Large Number Hypothesis
- Brans-Dicke Theory
- Theories with higher dimensions, superstring theories, M-theory etc.
- Claims that fine structure constant might vary

  **Webb & Murphy 2001**
- Gravity constant **G**:

  historically the first considered as varying

# Paper

M.Biesiada & B.Malec
*MNRAS* **350**, 644, 2004

Astroseismology

of

G117-B15A

Mon. Not. R. Astron. Soc. **350**, 644–648 (2004) doi:10.1111/j.1365-2966.2004.07677.x

## A new white dwarf constraint on the rate of change of the gravitational constant

Marek Biesiada* and Beata Malec*
*Department of Astrophysics and Cosmology, University of Silesia, Uniwersytecka 4, 40-007 Katowice, Poland*

Accepted 2004 January 26. Received 2004 January 22; in original form 2003 October 28

ABSTRACT

In this paper we derive a bound on the rate of change of the gravitational constant $G$ based on observations of the pulsating white dwarf G117-B15A. This star is a ZZ Ceti pulsator which has been extensively studied with astroseismological techniques for the last three decades. The most recent determination of $\dot{P} = (2.3 \pm 1.4) \times 10^{-15}$ s s$^{-1}$ for the 215.2-s fundamental mode agrees very well with predictions of the best-fitting theoretical model. The rate of change of the oscillation period can be explained by two effects: the cooling (dominant factor) and change of gravitational binding energy (residual gravitational contraction). Since the white dwarfs are pulsating in g-modes, the frequencies of which are related to the Brunt–Väisälä frequency (explicitly dependent on $G$), observational determination of the change of the period (more precisely the difference between the observed and calculated $\dot{P}$) can be used to set an upper bound on the rate of change of $G$. In light of the current data concerning G117-B15A we derive the following bound: $|\dot{G}/G| \leqslant 4.10 \times 10^{-10}$ yr$^{-1}$. We also demonstrate that a varying gravitational constant $G$ does not modify the cooling of white dwarfs in a significant way, at least at the luminosities where white dwarfs are pulsationally unstable.

**Key words:** gravitation – stars: individual: G117-B15A – stars: oscillations – white dwarfs.

## 1 INTRODUCTION

There is a renewed debate in the literature over the issue of whether the quantities known as the constants of nature (such as $G$, $c$, $h$ or $e$) can vary with time (Bekenstein 1982; Moffat 1993a,b; Barrow 2002; Barrow et al. 2002; Sandvik et al. 2002). One of the reasons for this debate is associated with the advances of string theory and associated ideas that the world we live in may have more than four dimensions.

String theory (Horava & Witten 1996; Witten 1996) is the only known framework which gives hopes of reconciling gravity theory with quantum mechanics and one of its hints is that the coupling constants appearing in low-energy Lagrangians are determined by the vacuum expectations of some a priori introduced massless scalar fields (dilaton or moduli fields). Interest in physical theories with extra spatial dimensions has also experienced considerable revival. In the framework of multidimensional theories (Antoniadis et al. 1998; Arkani-Hamed et al. 1998) the four-dimensional gravity constant, for example, is in fact an effective constant appearing when integrated over additional dimensions.

Another trigger for the interest in varying the fundamental constants is associated with recent observational evidence that the fine structure constant may indeed vary with time (Webb et al. 1999, 2001).

All this motivates us to take seriously the possibility that (at least some of) the fundamental constants could in fact vary in time. Although from a historical perspective the gravity constant $G$ was the first fundamental constant considered as a dynamical quantity (Dirac 1937), in fact it is not strongly constrained concerning its variability nor even measured with an accuracy comparable to other fundamental constants – the latest CODATA report raised the relative uncertainty of $G$ from 0.013 to 0.15 per cent (Grundlach & Merkowitz 2000). In the past, there were numerous attempts to constrain the possible temporal variability of $G$ as summarized in a recent review paper by Uzan (2003). White-dwarf cooling has already been used by Garcia-Berro et al. (1995) to constrain the temporal variation of $G$ at the level of the white dwarf luminosity function.

This paper is devoted to another constraint on $\dot{G}/G$ obtained from asteroseismological considerations of the ZZ Ceti pulsating star G117-B15A. More precisely, recent measurements of the rate of change of period of the 215.2-s pulsational mode (Kepler et al. 2000) turned out to be in a very good agreement with evolutionary models of DAV white dwarfs comprising cooling and gravitational contraction effects. Pulsations of DAV white dwarfs are excited as so-called g-modes, which arise due to the competition between buoyancy and gravity forces acting on an element of matter displaced in a stratified medium. We take advantage of this circumstance to derive a bound on the rate of change of the gravity constant.

---

*E-mail: mb@imp.sosnowiec.pl (MB); beata@server.phys.us.edu.pl (BM)

# **Nature of oscillations**: g-modes, Brunt - Väisälä frequency

$$N^2 = -gA = -g\left(\frac{\mathrm{d}\ln\rho}{\mathrm{d}r} - \frac{1}{\Gamma_1}\frac{\mathrm{d}\ln p}{\mathrm{d}r}\right)$$

Here is the dependence on ***G***

Asymptotic form

$$P^2 \approx -\frac{k^2 r^2}{Agl(l+1)}.$$

Rate of period change (classically)

$$\frac{\mathrm{d}\ln P}{\mathrm{d}t} = -a\frac{\mathrm{d}\ln T}{\mathrm{d}t} + b\frac{\mathrm{d}\ln R}{\mathrm{d}t}$$

**Cooling**

**Residual contraction**

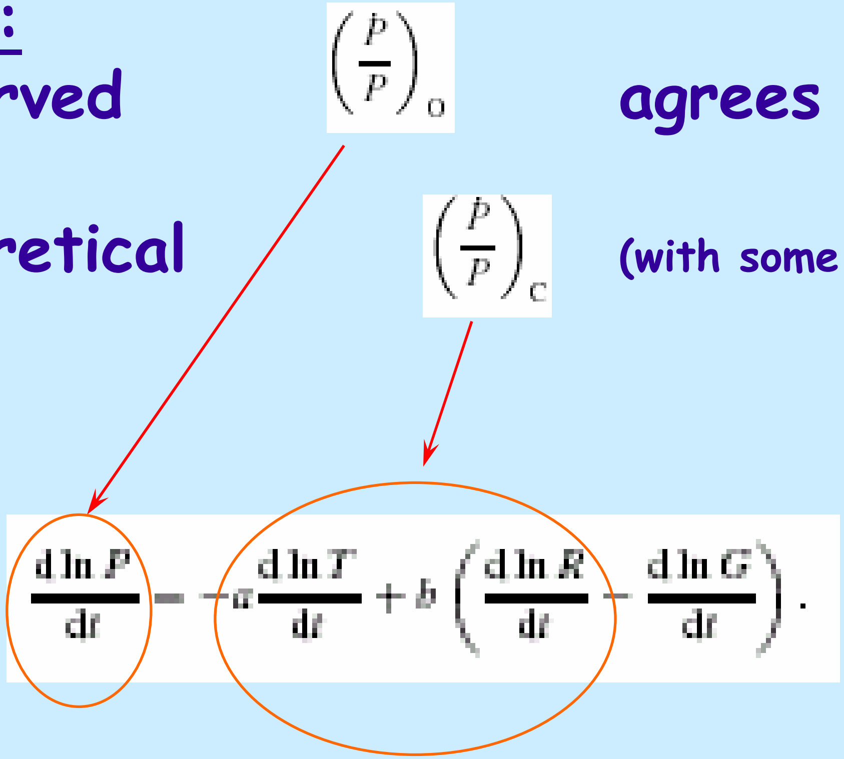
Modification for varying ***G***

$$\frac{\mathrm{d}\ln P}{\mathrm{d}t} = -a\frac{\mathrm{d}\ln T}{\mathrm{d}t} + b\left(\frac{\mathrm{d}\ln R}{\mathrm{d}t} - \frac{\mathrm{d}\ln G}{\mathrm{d}t}\right).$$

## Idea:

observed $\left(\frac{\dot{P}}{P}\right)_{o}$ agrees with

theoretical $\left(\frac{\dot{P}}{P}\right)_{c}$ (with some accuracy)



$$\frac{\mathrm{d}\ln P}{\mathrm{d}t} = -a\frac{\mathrm{d}\ln T}{\mathrm{d}t} + b\left(\frac{\mathrm{d}\ln R}{\mathrm{d}t} - \frac{\mathrm{d}\ln G}{\mathrm{d}t}\right).$$

[Theoretical model according to **Salaris et al. 1997**]

so

$$\left|\Delta\left(\frac{\dot{P}}{P}\right)\right| = \left|\frac{\dot{G}}{G}\right|.$$

We obtain the bound

$$\left|\frac{\dot{G}}{G}\right| \leqslant 4.10 \times 10^{-10}\,\mathrm{yr}^{-1}$$

# Perspectives

Use stellar evolution constraints (esp. Helio/astroseismology & WD cooling) for Supersymmetric particles

# Prof.Manka-Marcisz + Ilona Bednarek (+ PhD Students)

- Equation of state in (proto)neutron stars – field theoretical approach
- **Structure and evolution of strange and hybrid stars**
- some interesting results concerning mass distribution of hybrid stars

# Dr Jerzy Król

- Model theoretical approach to Quantum Gravity
- **Toposes as natural environment ….**

# Some current papers

Bednarek I. Mańka R., Properties of a protoneutron star in the Effective Field Theory, *Phys. Rev. C* **73**, 045804 (2006).

Król J., A model for spacetime. The role of interpretations in some Grothendieck topoi, *Found. Phys.* 36, No5, (2006).

Król J., A model for spacetime II. The emergence of higher dimensions and field theory/strings dualities, *Found. Phys.* 36, No12, (2006).