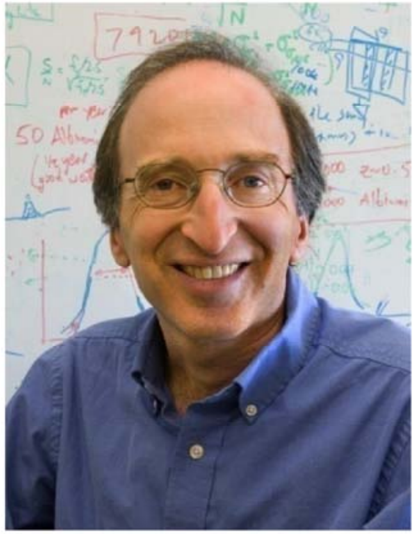
Nobel Prize 2011 in Physics
and
Dark energy & dark matter

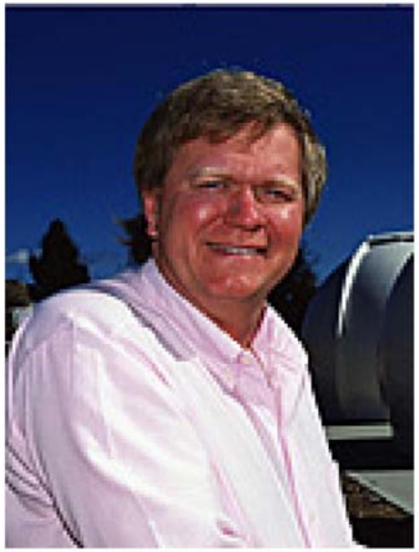
中科院高能所
张新民

2011年12月22日

2011年度诺贝尔物理奖

$1,460,000





Saul Perlmutter, 52 **Adam Riess, 42** **Brian Schmidt 44**

奖给宇宙加速膨胀的发现

1) 今年的诺奖是暗能量领域的第一个;
2)今年的诺奖与暗能量没有关系;

诺奖颁发的“**合理与不合理**”

“不合理”：之后大量的工作，CMB,
LSS, SN 等 ===〉
精确宇宙学?

“合理”：原创，冒‘风险’
如果没有证实怎么办?

诺奖：原创 + “运气”

（中微子超光速？？）

今年诺奖与暗能量无关吗?

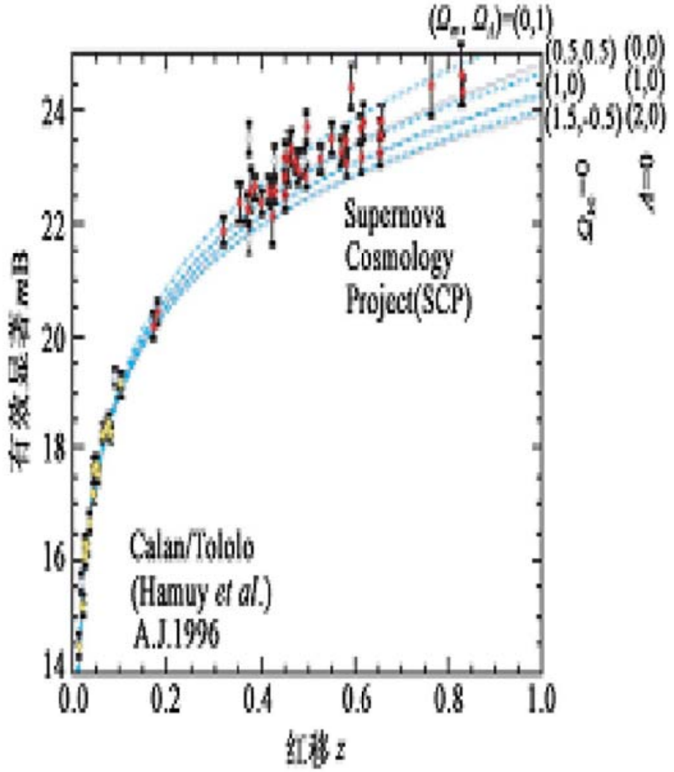


图 2 1998 年 SCP组观测得到的哈勃图. 取自文献[2]

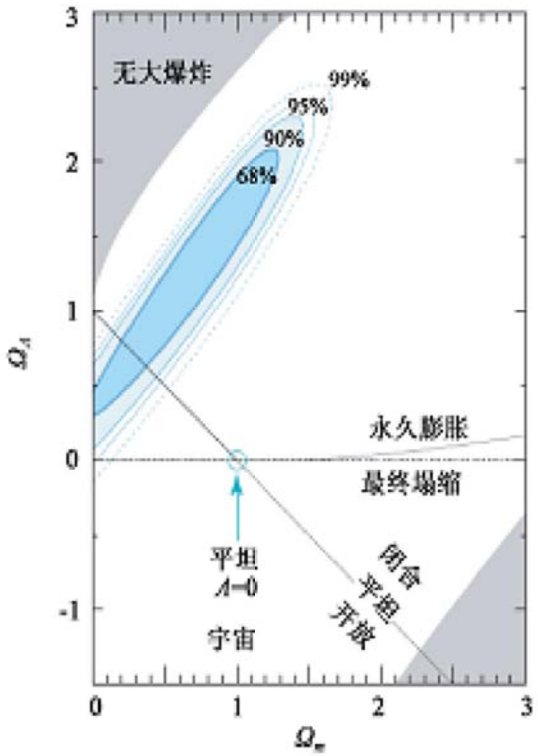
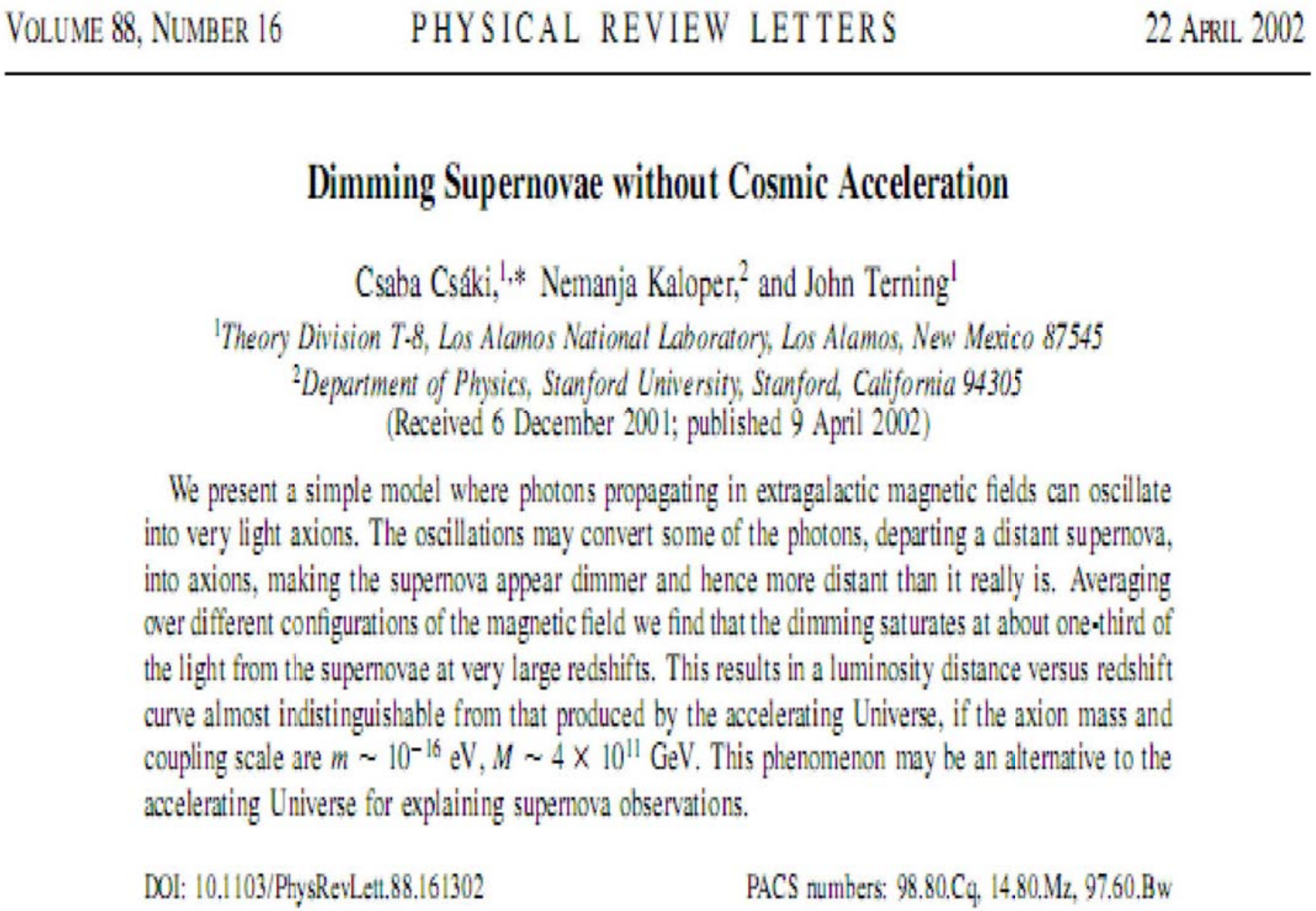


图 3 1998 年 SCP 研究组的数据拟合以 99% 的置信度排除了 $\Omega_\Lambda \leq 0$ 的情形. 取自文献[2]

SN=〉 加速? (CMB, LSS更重要!)



VOLUME 88, NUMBER 16 PHYSICAL REVIEW LETTERS 22 APRIL 2002

Dimming Supernovae without Cosmic Acceleration

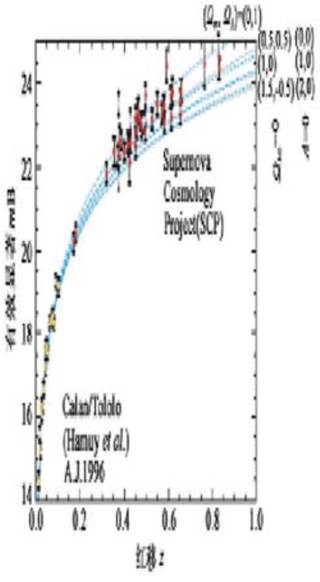
Csaba Csáki,[1],* Nemanja Kaloper,[2] and John Terning[1]
[1]*Theory Division T-8, Los Alamos National Laboratory, Los Alamos, New Mexico 87545*
[2]*Department of Physics, Stanford University, Stanford, California 94305*

(Received 6 December 2001; published 9 April 2002)

We present a simple model where photons propagating in extragalactic magnetic fields can oscillate into very light axions. The oscillations may convert some of the photons, departing a distant supernova, into axions, making the supernova appear dimmer and hence more distant than it really is. Averaging over different configurations of the magnetic field we find that the dimming saturates at about one-third of the light from the supernovae at very large redshifts. This results in a luminosity distance versus redshift curve almost indistinguishable from that produced by the accelerating Universe, if the axion mass and coupling scale are $m \sim 10^{-16}$ eV, $M \sim 4 \times 10^{11}$ GeV. This phenomenon may be an alternative to the accelerating Universe for explaining supernova observations.

DOI: 10.1103/PhysRevLett.88.161302 PACS numbers: 98.80.Cq, 14.80.Mz, 97.60.Bw

十年精确宇宙学成就了今年的诺奖



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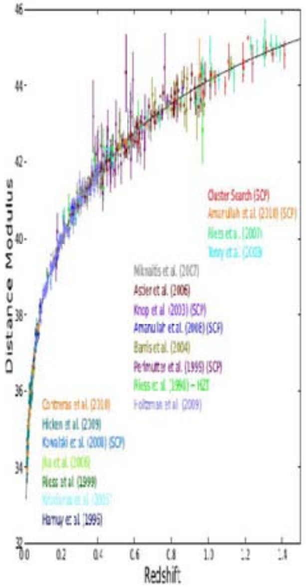

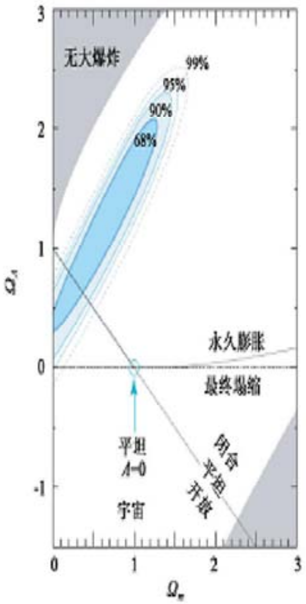

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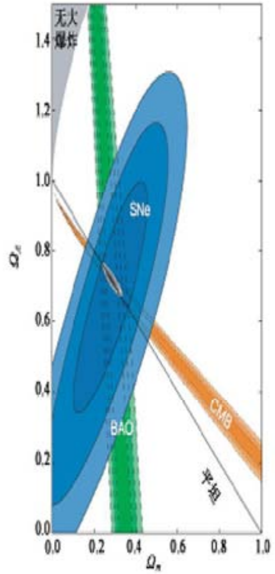


图 4 截至 2011 年，超新星(UNION2.1)，宇宙微波背景辐射(WMAP7)和大尺度结构(SDSS DR7)观测对暗能量的限制. 取自文献[3]

union2.1 580 SN Ia, arxiv: 1105.3470

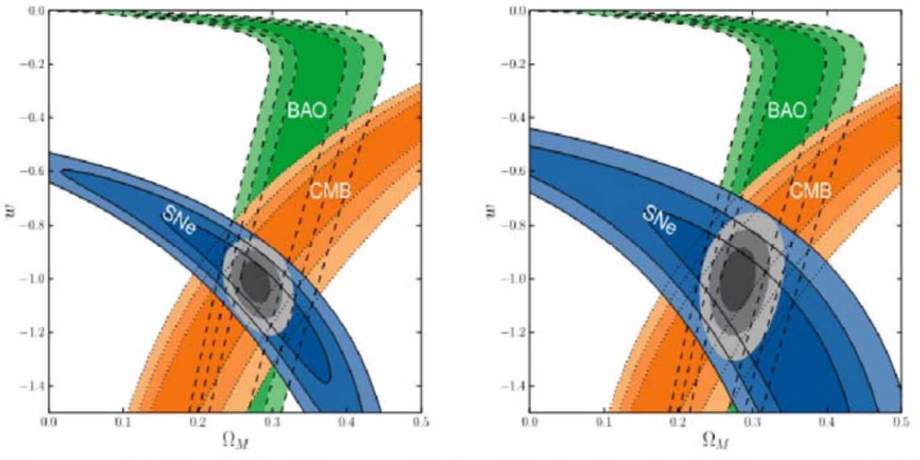
\rho_DE 确定很好，

但w误差大。

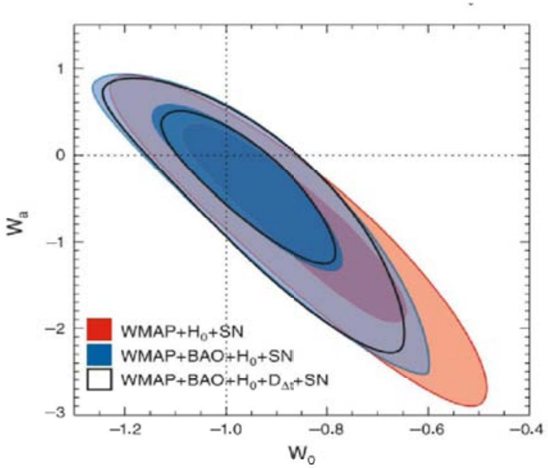
====〉存在证据（诺奖）

物理性质？？

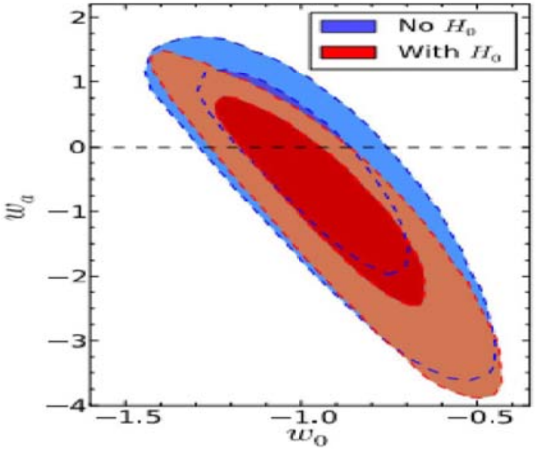
Spectra and Light Curves of Six SNe Ia and Union2



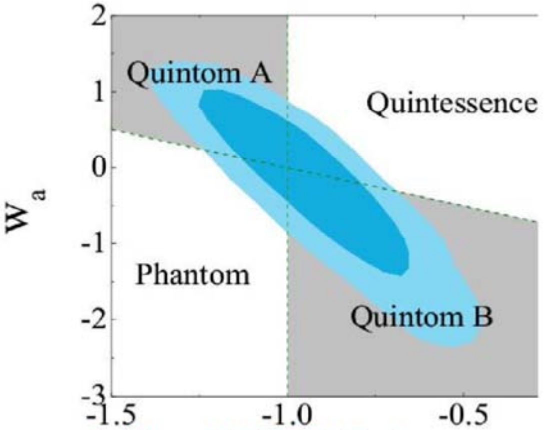
Current status in determining the EoS of dark energy

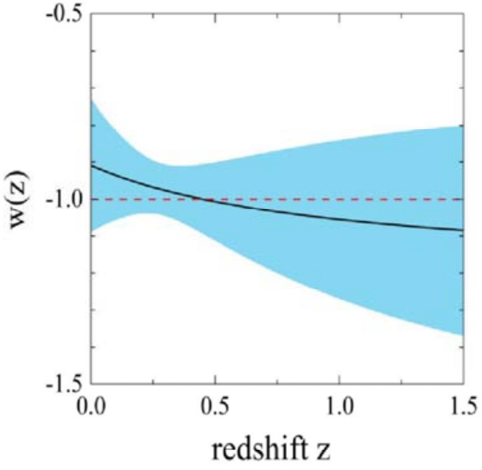


WMAP7 E. Komatsu *et al.*
e-Print: **arXiv:1001.4538**



SNLS3,
e-Print: arXiv:1104.1444





G. Zhao H. Li E. Linder
K. Koyama D. Bacon XZhang
arXiV: 1109.1846 Sep 2011
with WMAP7+Union2.1+BAO+…

Results:

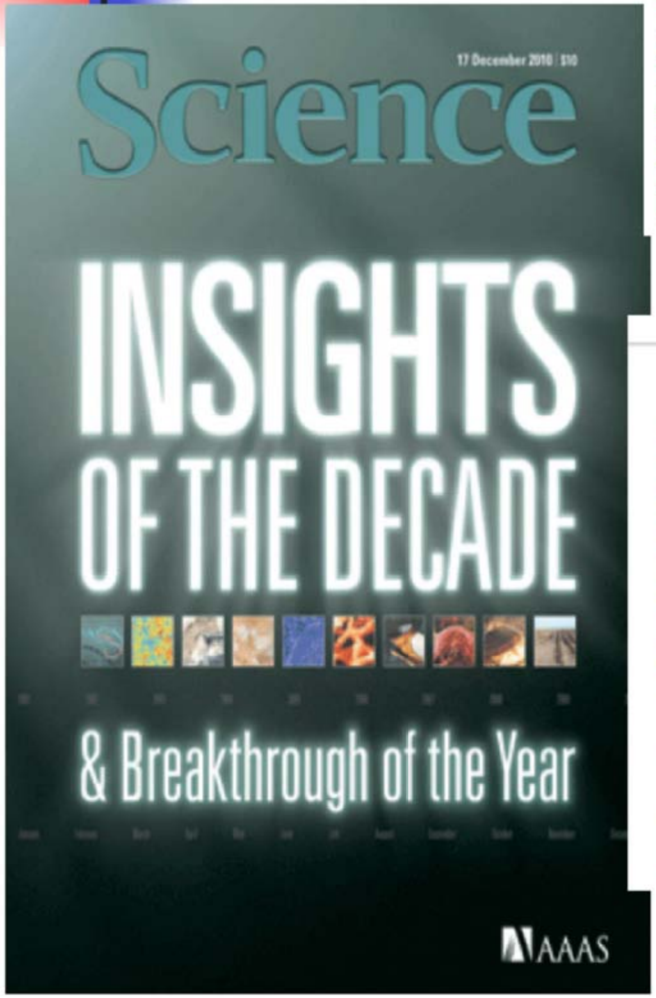
1) Current data has constrained a lot of the theoretical models;

2) Cosmological constant is consistent with the data;

3）dynamical models are not ruled out; quintom scenario mildly favored;

PRECISION COSMOLOGY

In the past decade, cosmologists have deduced a very precise recipe for the content of the universe, as well as instructions for putting it together, transforming cosmology from a largely qualitative endeavor to a precision science with a standard theory



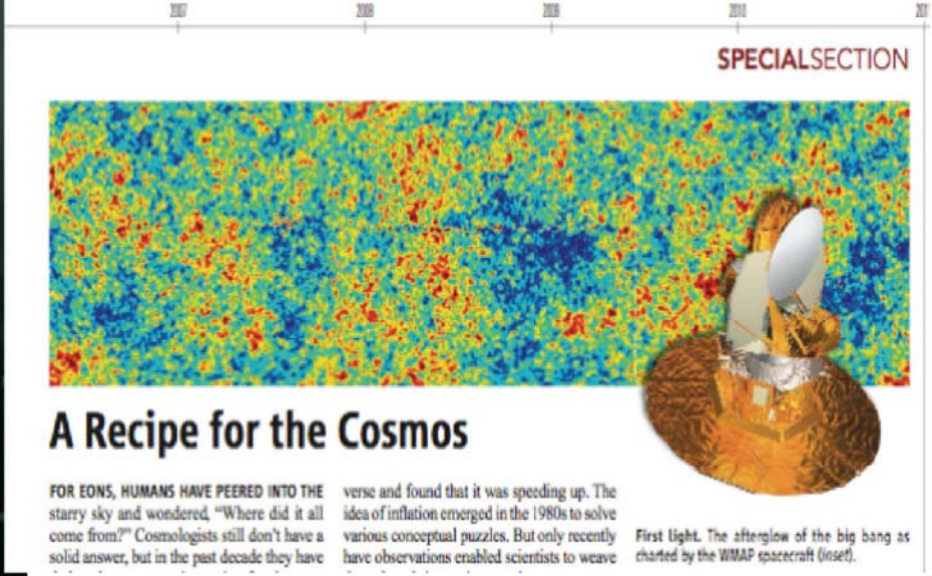
Science

17 December 2010 | $10

INSIGHTS OF THE DECADE

& Breakthrough of the Year

AAAS



SPECIALSECTION

A Recipe for the Cosmos

FOR EONS, HUMANS HAVE PEERED INTO THE starry sky and wondered, "Where did it all come from?" Cosmologists still don't have a solid answer, but in the past decade they have

verse and found that it was speeding up. The idea of inflation emerged in the 1980s to solve various conceptual puzzles. But only recently have observations enabled scientists to weave

First light. The afterglow of the big bang as charted by the WMAP spacecraft (inset).

本世纪前十年十大科学成就

本世纪首个十年即将结束之际，《科学》杂志的新闻记者和编辑潜心审视了进入新千年以来的那些改变科学面貌的进步，评选出了十项科学成作为“本十年卓见”（Insights of the Decade）。

精密宇宙学：在过去十年中，研究人员非常精确地推测出宇宙物质的成分是**普通物质**、暗物质和暗能量。同时，他们阐述了将这些成分组成宇宙的方法。这些进展将宇宙学转变成为一种有着标准理论的精确科学，而留给其他理论的活动空间已十分狭小。

1)accelerating universe=➔dark energy (2011 Nobel Prize)
2)Flat Universe (Boomerang, WMAP….Nobel Prize??)
3)Precision test of the cosmology (perturbation) theory
(similar to ‘t Hooft & Veltman,
Nobel Prize!?)
4)dark matter (evidence, cold&warm DM, Nobel prize?)
5)With Planck Inflation theory (Nobel Prize?)

21世纪第二个“十年 ” 的宇宙学研究重点

1）暗物质　(期待大的突破）

LHC, 地下直接，　地面空间间接探测实验

---------》WIMPs（ 锦屏地下，空间）

天文观测 （引力透镜。。。）------》cold, warm DM

天文+粒子 =======》cold，　warm WIMPs ,

SuperWIMPs, Decaying WIMPs, Asymmetric WIMPs

2) 暗能量

基本观点：　“需要更长时间”

答案：1）有道理， 比如“宇宙学常数”问题

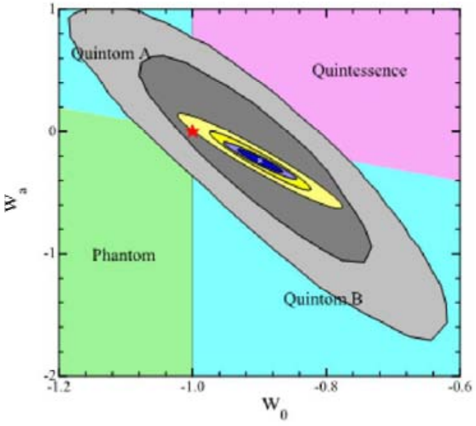
2）误解，

研究步骤：i)　确定w(z) ,

Beyond Einstein? 期待大

ii）模型确定 ?

（南极，　空间站）



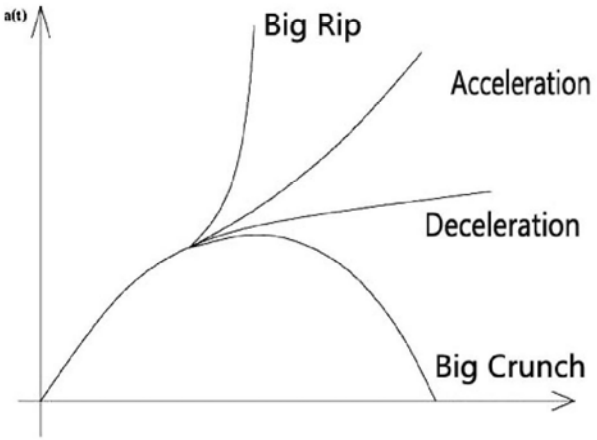
3）B-mode detection:

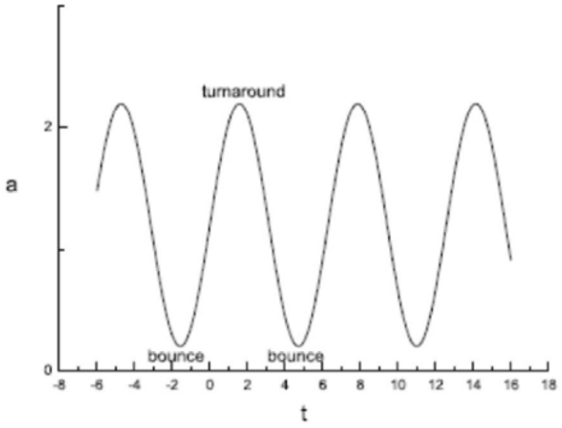
Planck, BICEP, 等实验

但理论模型确定难 （inflation, bounce,
CPT violation…)　　（WMAP分析，　CPT 检验）

宇宙学常数还是动力学其物理意义

预言宇宙演化的不同行为





Interacting Dark Energy
----non-gravitational method

- Coupling constant vary： $\boxed{QF_{\mu\nu}F^{\mu\nu}}$
- Mass varying neutrino： P.Gu, X.Wang and X.Zhang ***PRD68, 087301 (2003)***

Rob Fardon, Ann E. Nelson, Neal Weiner **JCAP 2004**.

G.Dvali, Nature 432:567-568,2004

R.D. Peccei, Phys.Rev. D71 (2005) 023527.

……

$\boxed{Q\bar{\nu}\nu}$

$$\rho = -p = \frac{\Lambda}{8\pi G} \approx (2\times 10^{-3}\, eV)^4$$

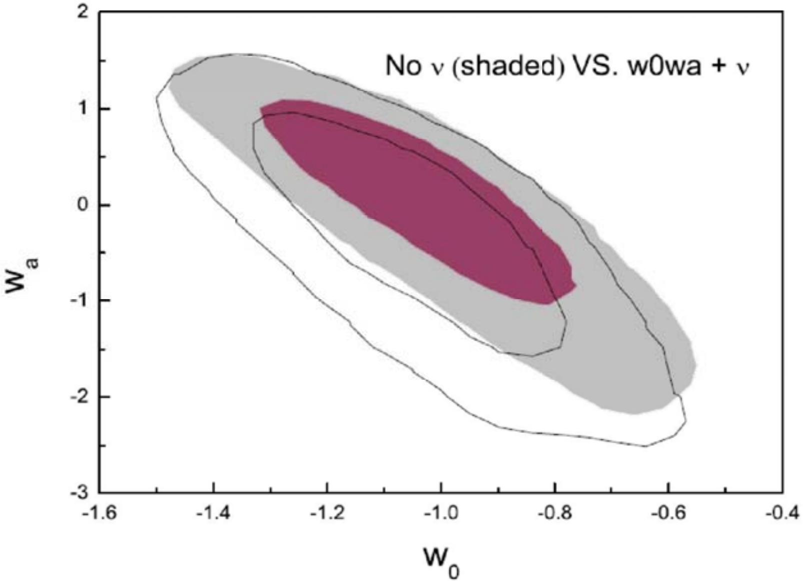
$$\downarrow$$

$$m_\nu \sim 10^{-3}\, \text{eV}$$

* Correlations between EoS of DE and neutrino mass

---------→

neutrino mass limit relaxed by factor 2



H. Li et al

Neutrino Dark Energy and
OPERA Neutrino Superluminal

1) 实验？验证了一次，进一步验证。。。
2）超光速意义！？
3）中微子超光速？
Why neutrino is so special ??

- Mass varying neutrino：

$$\boxed{Q\bar{\nu}\nu}$$

$$\rho = -p = \frac{\Lambda}{8\pi G} \approx (2\times10^{-3}\,eV)^4$$

$$\downarrow$$

$$m_\nu \sim 10^{-3}\ \mathrm{eV}$$

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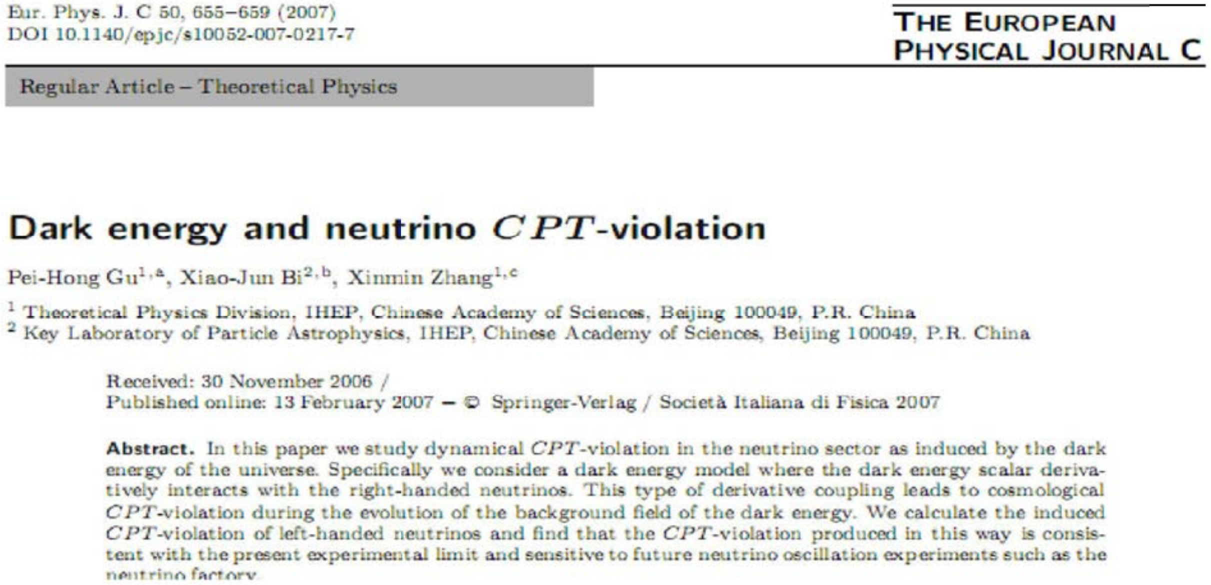

Eur. Phys. J. C 50, 655–659 (2007)
DOI 10.1140/epjc/s10052-007-0217-7

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article – Theoretical Physics

Dark energy and neutrino CPT-violation

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[2] Key Laboratory of Particle Astrophysics, IHEP, Chinese Academy of Sciences, Beijing 100049, P.R. China

Received: 30 November 2006 /
Published online: 13 February 2007 – © Springer-Verlag / Società Italiana di Fisica 2007

Abstract. In this paper we study dynamical CPT-violation in the neutrino sector as induced by the dark energy of the universe. Specifically we consider a dark energy model where the dark energy scalar derivatively interacts with the right-handed neutrinos. This type of derivative coupling leads to cosmological CPT-violation during the evolution of the background field of the dark energy. We calculate the induced CPT-violation of left-handed neutrinos and find that the CPT-violation produced in this way is consistent with the present experimental limit and sensitive to future neutrino oscillation experiments such as the neutrino factory.

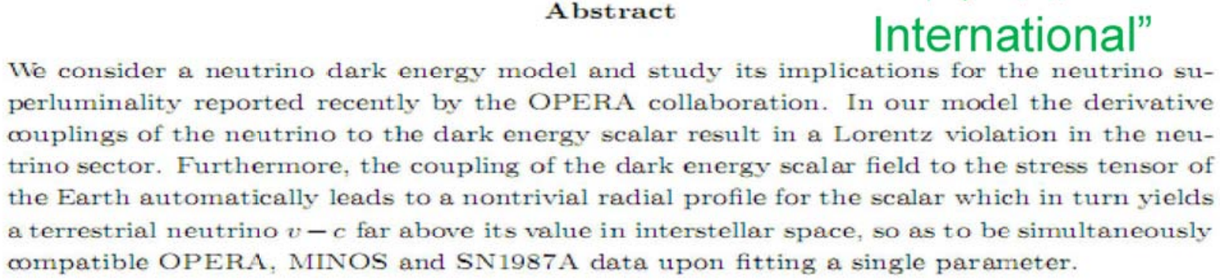
暗能量场：
以太"ether"
中微子传播时破坏Lorentz and CPT 对称性，但遗憾我们没有计算中微子"速度"
arXiv: e-Print: **hep-ph/0511027**

Opera and a neutrino dark energy model

Emilio Ciuffoli, Jarah Evslin, Jie Liu and Xinmin Zhang

ArXiv: 1109.6641

Interviewed by
美国 “discover magzine”
《科学新闻》《科技日报》
《科学时报》”China Radio International”



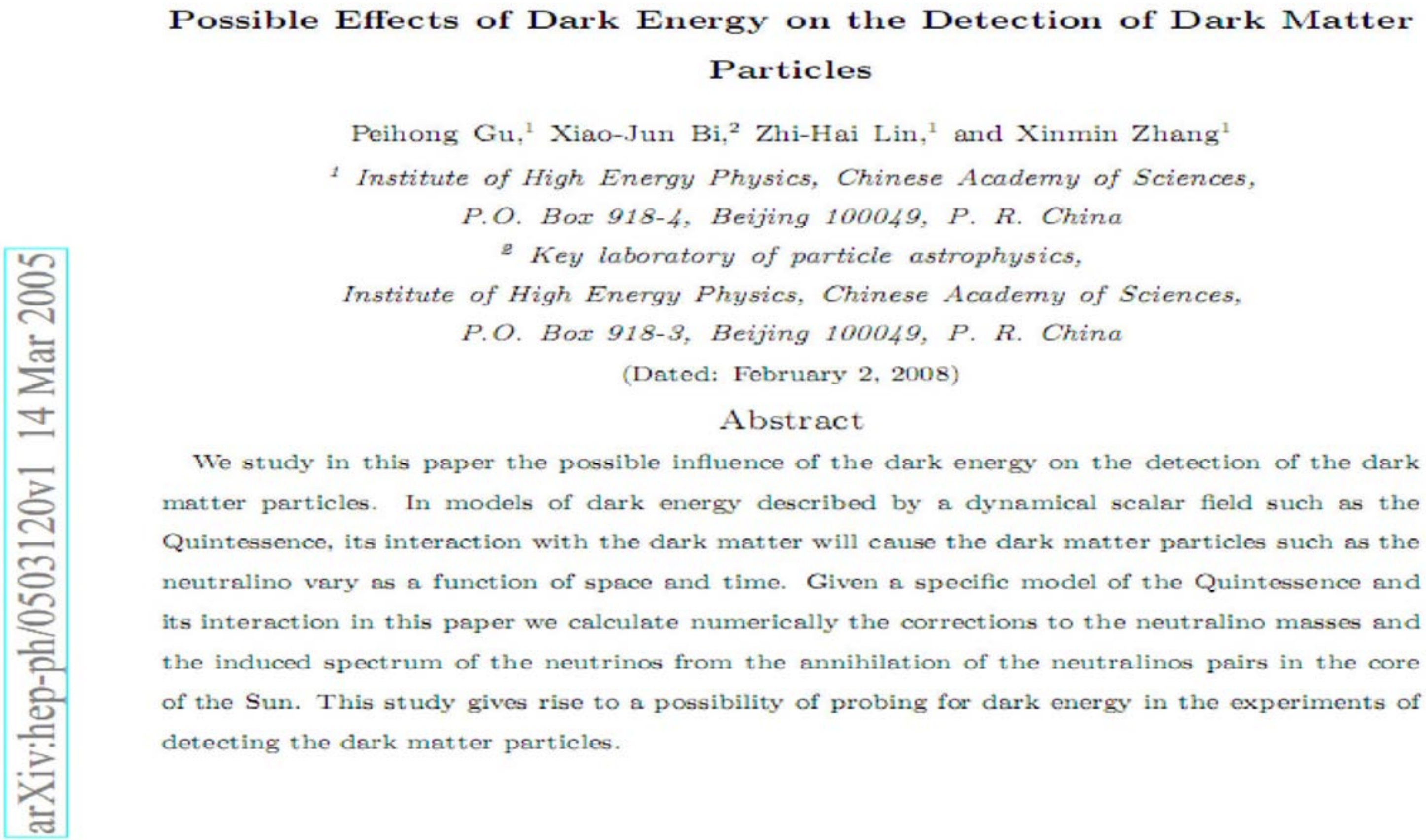
Abstract

We consider a neutrino dark energy model and study its implications for the neutrino superluminality reported recently by the OPERA collaboration. In our model the derivative couplings of the neutrino to the dark energy scalar result in a Lorentz violation in the neutrino sector. Furthermore, the coupling of the dark energy scalar field to the stress tensor of the Earth automatically leads to a nontrivial radial profile for the scalar which in turn yields a terrestrial neutrino $v-c$ far above its value in interstellar space, so as to be simultaneously compatible OPERA, MINOS and SN1987A data upon fitting a single parameter.

主要观点：中微子暗能量====〉质量改变；
Lorentz 破坏
随地域而改变===〉解释OPERA & SN1987;
Provide an answer to why neutrino is so special?（中微子超光速，其他却没有）
当然实验进一步证实至关重要！！！

暗物质暗能量相互作用

---大量工作关于宇宙演化，w across -1,
应关注暗物质粒子探测效应



arXiv:hep-ph/0503120v1 14 Mar 2005

Possible Effects of Dark Energy on the Detection of Dark Matter Particles

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P.O. Box 918-4, Beijing 100049, P. R. China
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P.O. Box 918-3, Beijing 100049, P. R. China

(Dated: February 2, 2008)

Abstract

We study in this paper the possible influence of the dark energy on the detection of the dark matter particles. In models of dark energy described by a dynamical scalar field such as the Quintessence, its interaction with the dark matter will cause the dark matter particles such as the neutralino vary as a function of space and time. Given a specific model of the Quintessence and its interaction in this paper we calculate numerically the corrections to the neutralino masses and the induced spectrum of the neutrinos from the annihilation of the neutralinos pairs in the core of the Sun. This study gives rise to a possibility of probing for dark energy in the experiments of detecting the dark matter particles.

InteractingDM&DE➔Quintessino As Dark Matter

(X. Bi, M. Li and *Zhang)*

- If susying the Quintessence:

Quintessence: Q
Squintessence: σ_q
Quintessino: $\tilde{Q}$

Similar to : Axion, Saxion, Axino
Majoron, Smajoron, Majorino *(R. Mohapatra and Zhang)*

- If $\tilde{Q}$ is lighter than χ , $\tilde{Q}$ could serve as Dark matter

- Susying the following interaction

$$\mathcal{L}^{eff} \sim i\frac{\partial_\mu Q}{\Lambda}[H^+ D^\mu H - (DH)^+ H]$$ (H: SU(2) doublet)

gives $\tilde{H} \to \tilde{Q}h^0$ *and* $\tilde{B} \to \tilde{Q}h^0$

$$\mathcal{L}^{int} \sim \frac{\partial_\mu Q}{\Lambda}[\bar{\tau}_R\gamma^\mu\tau_R + ...]$$ gives $\tilde{\tau_R} \to \tilde{Q}\tau$

* Prediction: long-lived charged particle: $\tau(\tilde{\tau}) \sim 10^7 Sec$

Interacting Dark Energy

with derivatives couplings

* Direct coupling with ordinary matter

strongly constrained by the long-range force limits
large radiative corrections to the DE potential

* Interaction with derivative

Goldstone theorem: Spin-dependent force

$$\mathcal{L}_{\rm int} = \frac{c}{M}\partial_\mu \phi J^\mu$$

⇒ **CPT violation when rolling down**

⇒ **Baryo/Leptogenesis in thermo equilibrium**

Quintessential Baryo/Leptogenesis

⇓ **Anomaly Equation**

$$\mathcal{L} \sim -\frac{1}{2} C \partial_\mu \phi K^\mu$$

⇒ **CMB polarization and CPT test**

$$K^\mu = A_\nu \tilde{F}^{\mu\nu} = \frac{1}{2} A_\nu \epsilon^{\mu\nu\rho\sigma} F_{\rho\sigma}$$

Cosmological CPT violation:

strength ~ O(H), unobservable in the laborary experiments
CMB: travelling around O(1/H),
so accumulated effect ~ O(1) observable !

Testing CPT symmetry with CMB polarizations

$$\mathscr{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + p_\mu A_\nu \widetilde{F}^{\mu\nu} \qquad p_\mu \ : \ (1)\ \text{Constant};\ (2)\ \frac{c}{M}\partial_\mu\phi\ ;\ (3)\ \partial_\mu f(R)$$

$$\Delta\alpha = \alpha_f - \alpha_i = \int_f^i p_\mu dx^\mu = \begin{cases} -p_0\Delta\eta\ ,(1) & p_i = 0 \\ -\dfrac{c}{M}\Delta\phi\ ,(2) & \\ -\Delta f(R)\ ,(3) & \end{cases}$$

i: source
f: observer

$$C'^{TT}_l = C^{TT}_l$$

$$C'^{EE}_l = C^{EE}_l \cdot \cos^2 2\Delta\alpha + C^{BB}_l \sin^2 2\Delta\alpha$$

$$C'^{BB}_l = C^{EE}_l \cdot \sin^2 2\Delta\alpha + C^{BB}_l \cos^2 2\Delta\alpha$$

$$C'^{TE}_l = C^{TE}_l \cdot \cos 2\Delta\alpha$$

$$C'^{TB}_l = C^{TE}_l \cdot \sin 2\Delta\alpha$$

$$C'^{EB}_l = \frac{1}{2}(C^{EE}_l - C^{BB}_l)\sin 4\Delta\alpha$$

CPT violation
predicting <TB> and <EB>

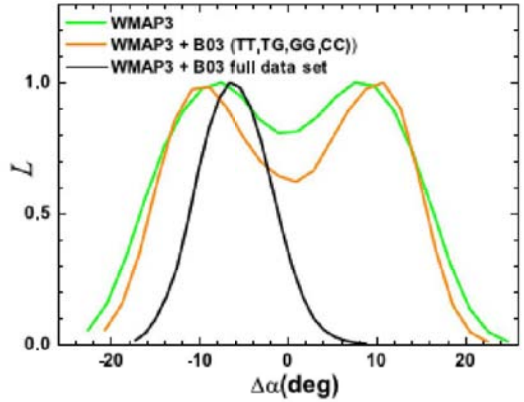


FIG. 1 (color online). One-dimensional constraints on the rotation angle $\Delta\alpha$ from WMAP data alone (green or light gray line), WMAP and the 2003 flight of BOOMERANG B03 TT, TG, GG and CC (orange or gray line), and from WMAP and the full B03 observations (TT, TG, GG, CC, TC, GC) (black line).

Bo Feng, Hong Li, Mingzhe Li and Xinmin Zhang
Phys. Lett. B 620, 27 (2005);
Bo Feng, Mingzhe Li , Jun-Qing Xia, Xuelei Chen
and Xinmin Zhang
Phys. Rev. Lett. 96, 221302 (2006)

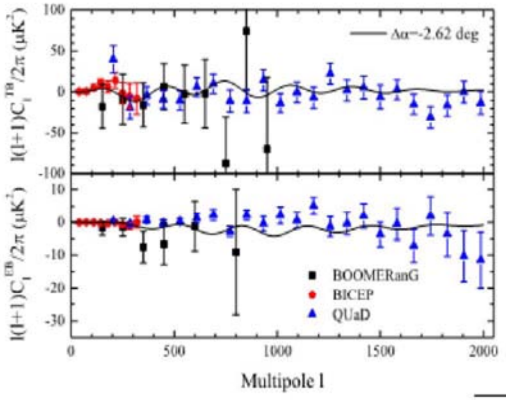
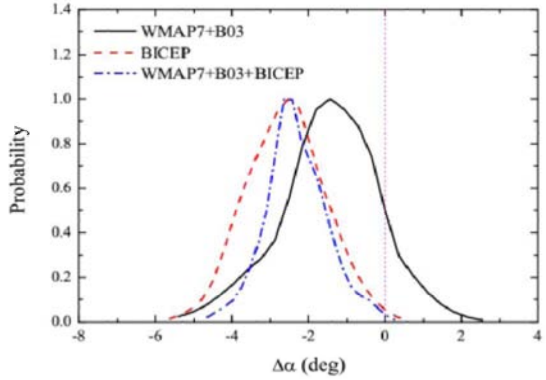


Fig. 1. The binned TB and EB spectra measured by the small-scale
of BOOMERanG (black squares), BICEP (red circles) and QUaD (b
black solid curves show the theoretical prediction of a model with
(For interpretation of colors in this figure, the reader is referred t
of this Letter.)

Current status on the measurements of the rotation angle



Group	$\Delta\alpha$ (degree)	Datasets
Feng et al	-6.0 ± 4.0	WMAP3+B03
Cabella et al	-2.5 ± 3.0	WMAP3
WMAP Collaboration	-1.7 ± 2.1	WMAP5
Xia et al	-2.6 ± 1.9	WMAP5+B03
WMAP Collaboration	-1.1 ± 1.4	WMAP7
QUaD Collaboration	0.64 ± 0.50	QUaD
Xia et al	-2.60 ± 1.02	BICEP
Xia et al	-2.33 ± 0.72	WMAP7+B03+BICEP
Xia et al	-0.04 ± 0.35	WMAP7+B03+BICEP+QUaD
Gruppuso et al	-1.6 ± 1.7	WMAP7

$3\,\sigma$ detection ===➔

$$PLANCK:\ \sigma = 0.057\ \mathrm{deg}$$

Understanding the nature of accelerating universe is a big challenge to particle physics

Current status

on constraints on EoS of dark energy

a) Cosmological constant fits data well;

b) Dynamical model not ruled out completely

future projects: w at level of O(1%), (w_0, w_a) O(10%);

c) Quintom model mildly favored

on modified gravity

a) GR works well;

b) Background evolution:

Quintom behaviour

"Testing Einstein Gravity with Cosmic Growth and Expansion"

Gongbo Zhao, Hong Li, Eric Linder, Kazuya Koyama, David Bacon, Xinmin Zhang,

arXiv: 1109.1846, Sept, (2011)

with **SN(Union2.1)+CMB(WMAP7) +WL(CFHTLS) + BAO + PV**

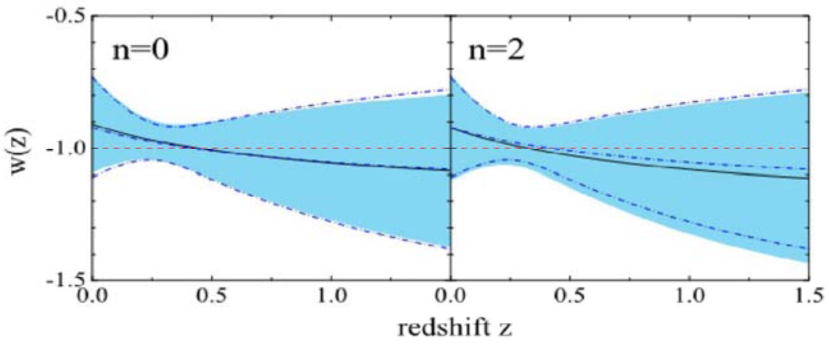


FIG. 4: The reconstructed $w(z)$ with 68% CL error are shown allowing for modified gravity (marginalized over c, s) in the scale independent (left panel) and scale-dependent k^2 (right panel) cases by the filled bands. The reconstruction for true dark energy, with gravity fixed to GR, is shown by the dash-dotted curves, the same in each panel.

125 GeV Higgs and
its implication in cosmology

i)Within the SM, it is all consistent:
precision measurement;
Vacuum stability;

Ii)Interesting implications for SUSY

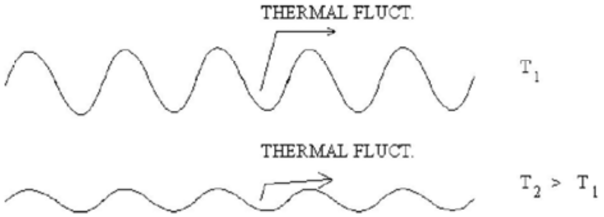
iii) Implications for cosmology:

a) Supporting for the idea of building dark energy models with fundamental scalar fields;

b)Electroweak baryogenesis =➔low cutoff

Electroweak baryogenesis
-----implies a light Higgs boson

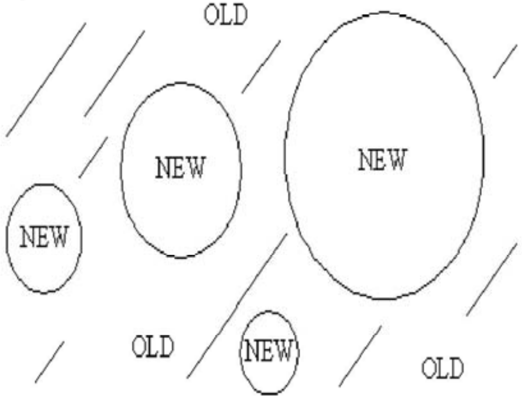
i) B violation ←----anomaly, non-trivial vacuum, sphaleron



ii) C and CP violation ←-----CKM mechanism

(however, too small-→new physics)

iii) First order phase transition



Need Higgs mass
< 40 GeV!→Need
New physics

Effective lagrangian approach to the electroweak baryogenesis

i) Need new physics

80年代末，2- Higgs，L-R symmetry, SUSY

ii) Effective lagrangian method ---→ anomalous couplings

$$\mathcal{L}^{\text{new}} = \sum_i \frac{c_i}{\Lambda^{d_i - 4}} O^i ,$$

iii) Operators relevant to electroweak baryogenesis

Higgs mass limit

generation of the baryon number asymmetry

Operator relevant to Higgs mass limit

$$O_3=\alpha\frac{\phi^6}{\Lambda^2} ,$$

Effective potential:

$$V_T^{\mathrm{eff}}=D(T^2-T_0^2)\phi^2-ET\phi^3+\tfrac{1}{4}\lambda_T\phi^4 ,$$

where

$$D=\frac{1}{8v^2}(2M_W^2+2m_t^2+M_Z^2) ,$$

$$T_0^2=\frac{1}{D}\left[\frac{m_H^2}{4}-2Bv^2\right] ,$$

$$B=\frac{3}{64\pi^2v^4}(2M_W^4+M_Z^4-4m_t^4) ,$$

$$E=\frac{1}{6\pi v^3}(2M_W^3+M_Z^3) ,$$

$$\lambda_T=\lambda-\frac{3}{16\pi^2v^4}\left[2M_W^4\ln\frac{M_W^2}{\alpha_BT^2}+M_z^4\ln\frac{M_Z^2}{\alpha_BT^2}-4m_t^4\ln\frac{m_t^2}{\alpha_FT^2}\right] ,$$

where $\ln\alpha_B=2\ln4\pi-2\gamma\simeq3.91$ and $\ln\alpha_F=2\ln\pi-2\gamma\simeq1.14$.

$$V_3^{(r)}=\alpha\frac{v^2}{\Lambda^2}\phi^2\left[-\phi^2+v^2+\frac{1}{3}\frac{\phi^4}{v^2}\right] .$$

$$O_3 = \alpha \frac{\phi^6}{\Lambda^2} \quad \Longrightarrow \quad m_H^2 < (35\ GeV)^2 + 8\alpha \frac{v^4}{\Lambda^2}$$

Xinmin Zhang PRD47, 3065 (1993)
Cedric Delaunay, Christophe Grojean,
James D. Wells
JHEP 0804:029,2008

Electroweak vacuum stability
A. Datta, B.-L. Young and X. Zhang
PLB385, 225 (1996)

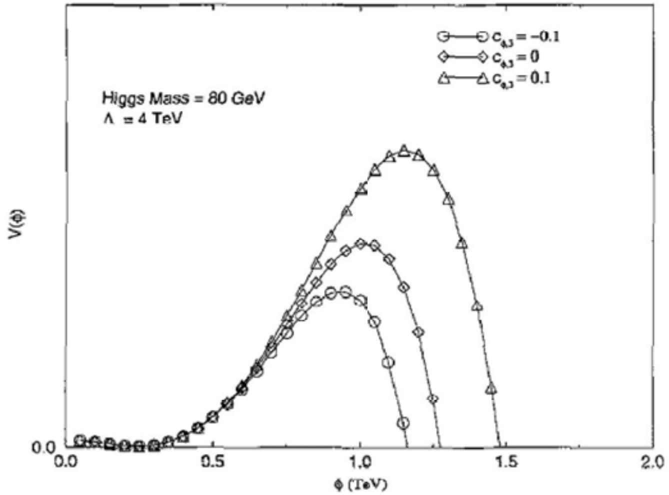


Fig. 1. The effective potential for various values of $c_{\phi,3}$. The Higgs mass is taken as 80 GeV and the scale of new physics $\Lambda = 4$ TeV. The curve with $c_{\phi,3} = 0$ corresponds to the standard model.

Operator relevant to baryon number generation

$$\mathcal{O}^t = c_t e^{i\xi} \frac{\phi^2 - v^2/2}{\Lambda^2} \Gamma_t \bar{\Psi}_L \tilde{\Phi} t_R, \quad \text{===}\!\!\Rightarrow \quad \Gamma_t^{\rm eff} = \Gamma_t \left\{ 1 + c_t e^{i\xi} \frac{\phi^2 - v^2/2}{\Lambda^2} \right\}.$$

$$\frac{n_B}{s} \sim \kappa c_t \sin\xi \times 10^{-9}. \quad \text{=====}\!\!\Rightarrow \quad \kappa c_t \sin\xi \geq 4.$$

Anomalous top-Higgs couplings:

$$\mathcal{L}^{\rm eff} \sim \frac{m_t}{t} \bar{t} \left\{ \left[1 + \left(\frac{c_t}{16} \right) \cos\xi \right] + i \left(\frac{c_t}{16} \right) \sin\xi \gamma_5 \right\} tH,$$

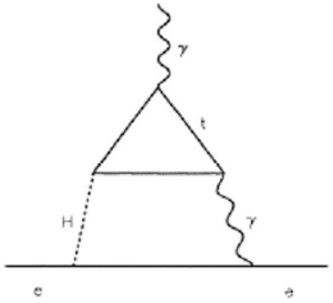
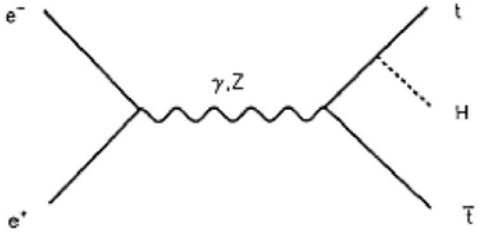


FIG. 1. Dominant contribution to d_e, the electric dipole moment of the electron.



X. Zhang et al,
PRD 50, 7042
(1994)

Lars Fromme,
Stephan J. Huber,
JHEP 0703:049,2007

Electroweak baryogenesis

and anomalous Top, Higgs couplings

$$O_3 = \alpha \frac{\phi^6}{\Lambda^2} \quad \Longrightarrow \quad m_H^2 < (35\ GeV)^2 + 8\alpha \frac{v^4}{\Lambda^2}$$

$$\mathcal{O}^t = c_t\, e^{i\xi} \frac{(\phi^2 - \frac{v^2}{2})}{\Lambda^2} \Gamma_t\, \overline{\Psi_L} \tilde{\Phi} t_R \quad \Rightarrow \quad \frac{n_B}{s} \sim \kappa\, c_t \sin\xi\ 10^{-9}$$

Probing for anomalous couplings at LHC, ILC…

再谈Nobel Prize 2011 in physics

1998年SN 观测：

i) 由于axion-like粒子造成；

ii）宇宙学常数===〉暗能量

iii）Modified gravity

精确宇宙学 （WMAP， SDSS， SN 等+ 宇宙学扰动理论）

i） “axion-like粒子造成”impossible!

ii) DE: \rho_de 已确定且精度高 （诺奖）；

w(z) ------------------------------------→

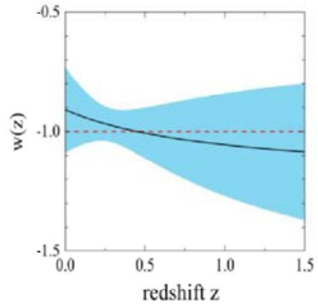
c_s^2 几乎没有限制

isocurvature perturbation：限制很差

iii)MG: =======➔

Einstein gravity + “effective DE”

consistent theory??



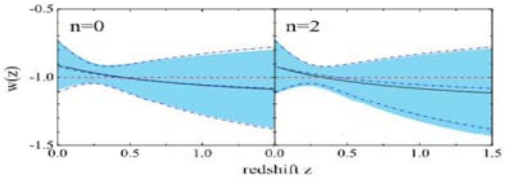


FIG. 4: The reconstructed $w(z)$ with 68% CL error are shown allowing for modified gravity (marginalized over c, s) in the scale independent (left panel) and scale-dependent k^2 (right panel) cases by the filled bands. The reconstruction for true dark energy, with gravity fixed to GR, is shown by the dash-dotted curves, the same in each panel.

International Journal of Modern Physics D
Vol. 17, No. 8 (2008) 1229–1243
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CONSTRAINTS ON THE SOUND SPEED OF DYNAMICAL DARK ENERGY

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and XINMIN ZHANG
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PO Box 918-4, Beijing 100049, P. R. China

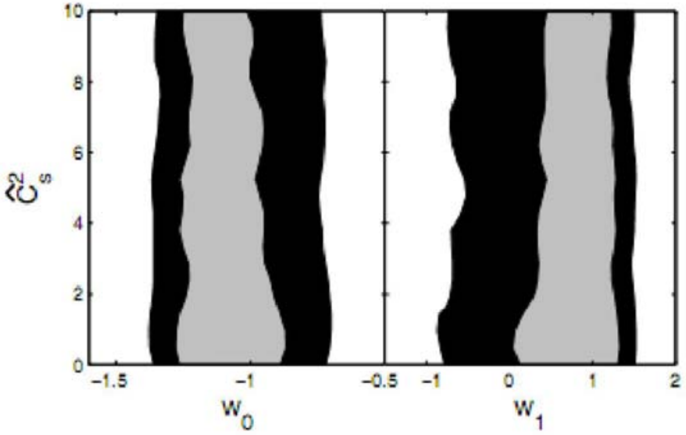


Fig. 2. Constraints in the $(w_0, \hat{c}_s^2)$ and $(w_1, \hat{c}_s^2)$ planes at 68% (dark) and 95% (light) CL from a combined analysis of CMB, LSS and SNIa observational data.

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

On dark energy isocurvature perturbation

Jie Liu,[a] **Mingzhe Li**[b,d] **and Xinmin Zhang**[a,c]

JC
(2011) 028

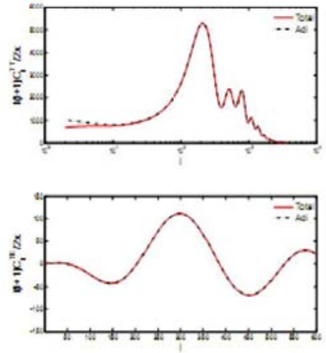


Figure 1. Top Panel: The angular power spectrum of CMB. Bottom Panel: The TE power spectrum of CMB. The red solid lines denote the spectrum obtained including the contribution of anti-correlated adiabatic and isocurvature perturbation, while the black dashed line is obtained by only including the adiabatic contribution.

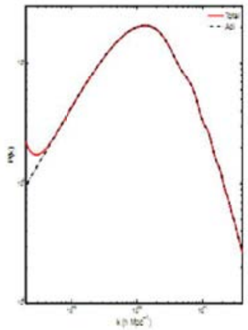


Figure 2. The matter power spectrum obtained with the cosmological parameters chosen to be the same as in figure 1. The red line denotes the total power spectrum and the black dash-dotted line is that with only the adiabatic component.

DE&DM 时间表

- LSST能解决暗能量问题吗？

  什么算解决了？

* 整个问题解决需要很长时间，但阶段性成果也很重要 （注意：1998年前，宇宙学常数问题已多年）

DM： Evidence (Rotation curve….)

--→Cosmological Properties (Hot, Cold&Warm)

---→particle properties(WIMPs? Axion?)

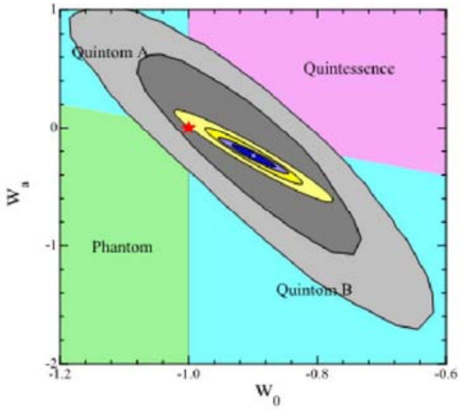
DE: Evidence(Accelerating Unicerse….)

-→Cosmological properties(W(z)=?

--→Particle properties (Quintessence.

“天文+物理”： cold WIMP， warm WIM

Interacting dark energy



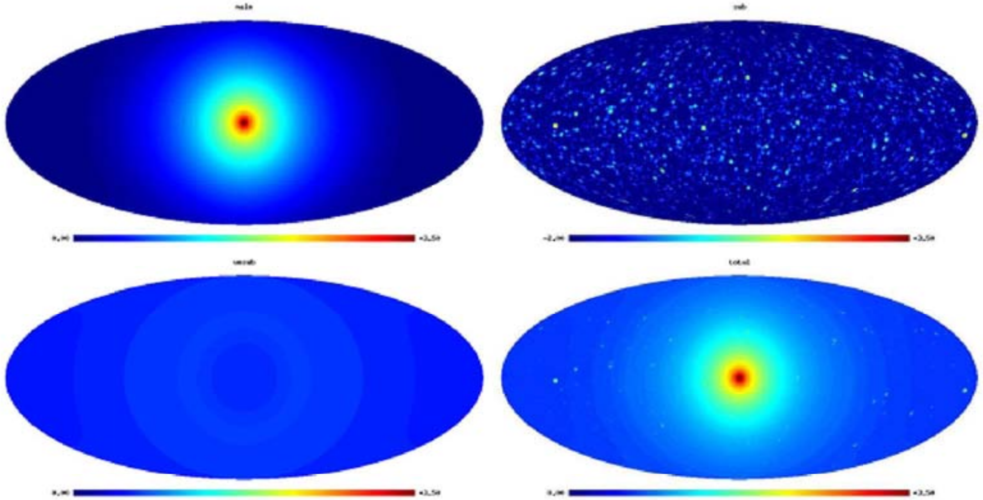


FIG. 4: Skymaps of the luminosity distributions of the main halo (top-left), resolved subhalos (top-right), unresolved subhalos (bottom-left) and total contribution (bottom-right) for CDM.

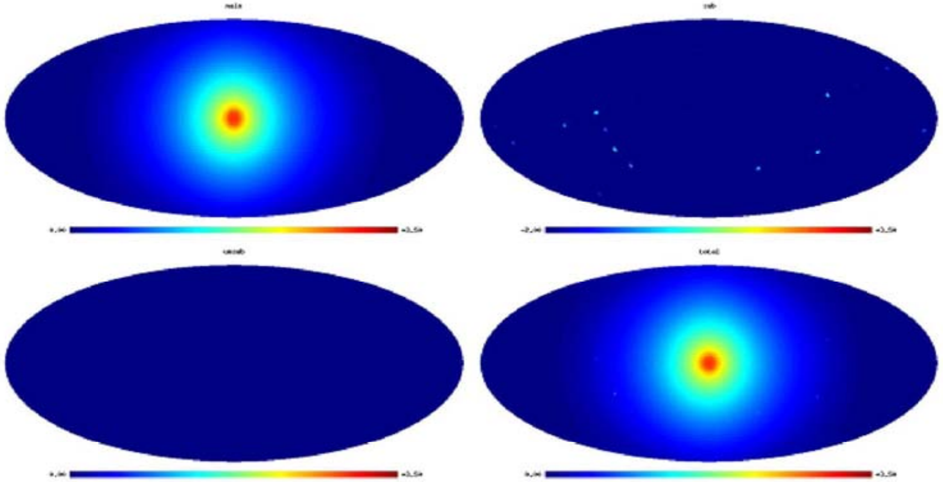
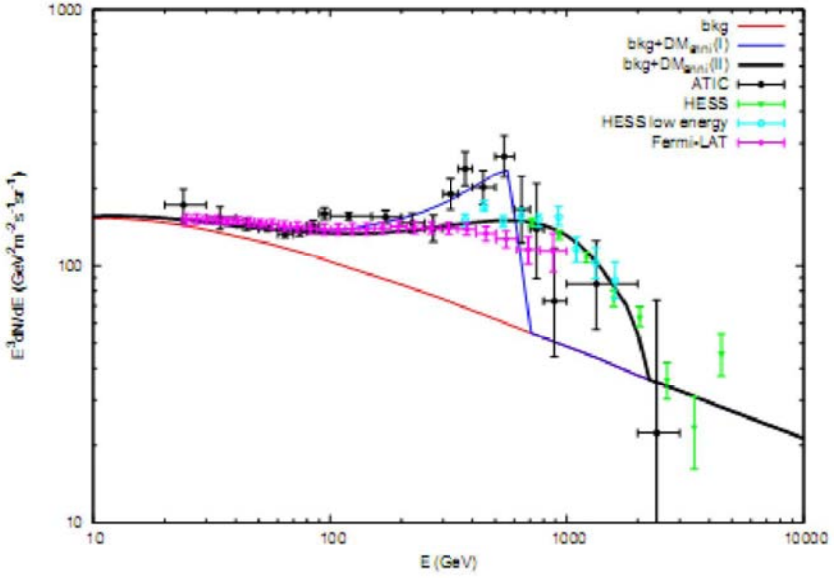
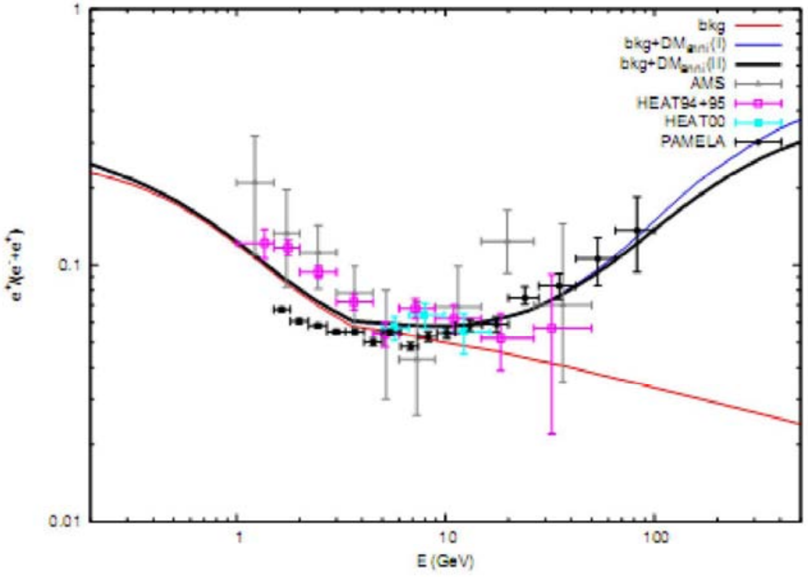


FIG. 5: Same as Fig. 4 but for WDM.





- The excess in the spectrum

1) Dark matter

2) Unknown astrophysical source（SN）

暗物质 CosRayMC

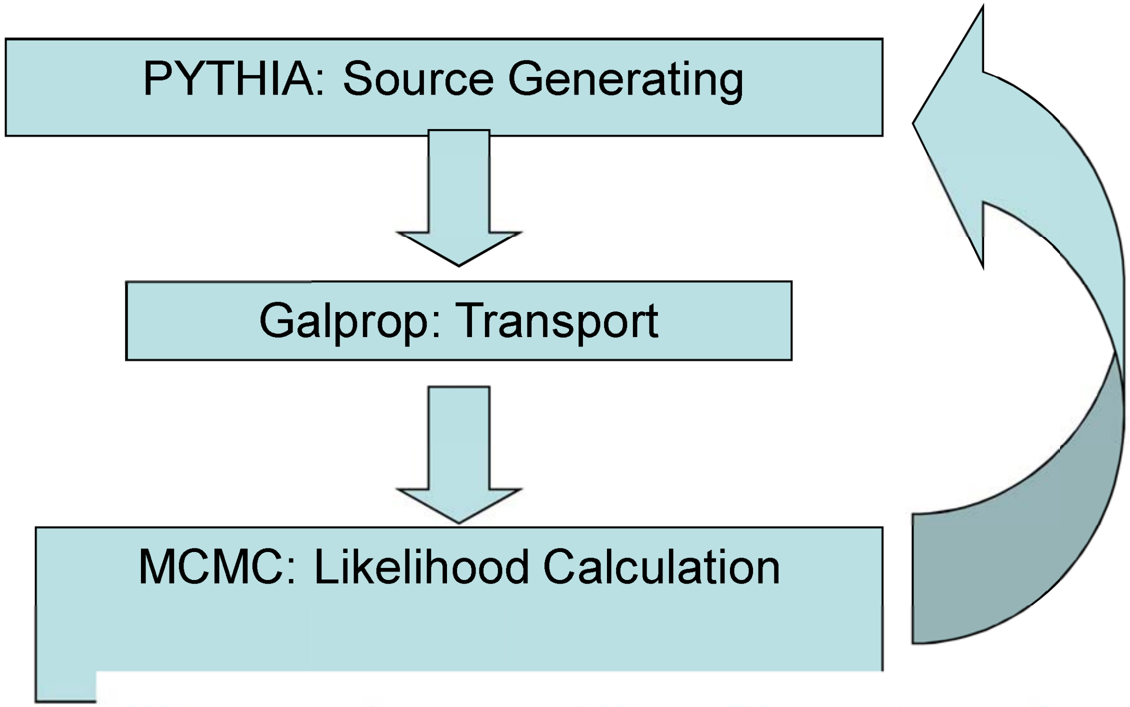
- CosRayMC (CosmicRay+MCMC)

Particle Physics: PYTHIA

Astrophysics : GalProp

Statistics : MCMC

CosRayMC: Cosmic Ray MCMC



PYTHIA: Source Generating

Galprop: Transport

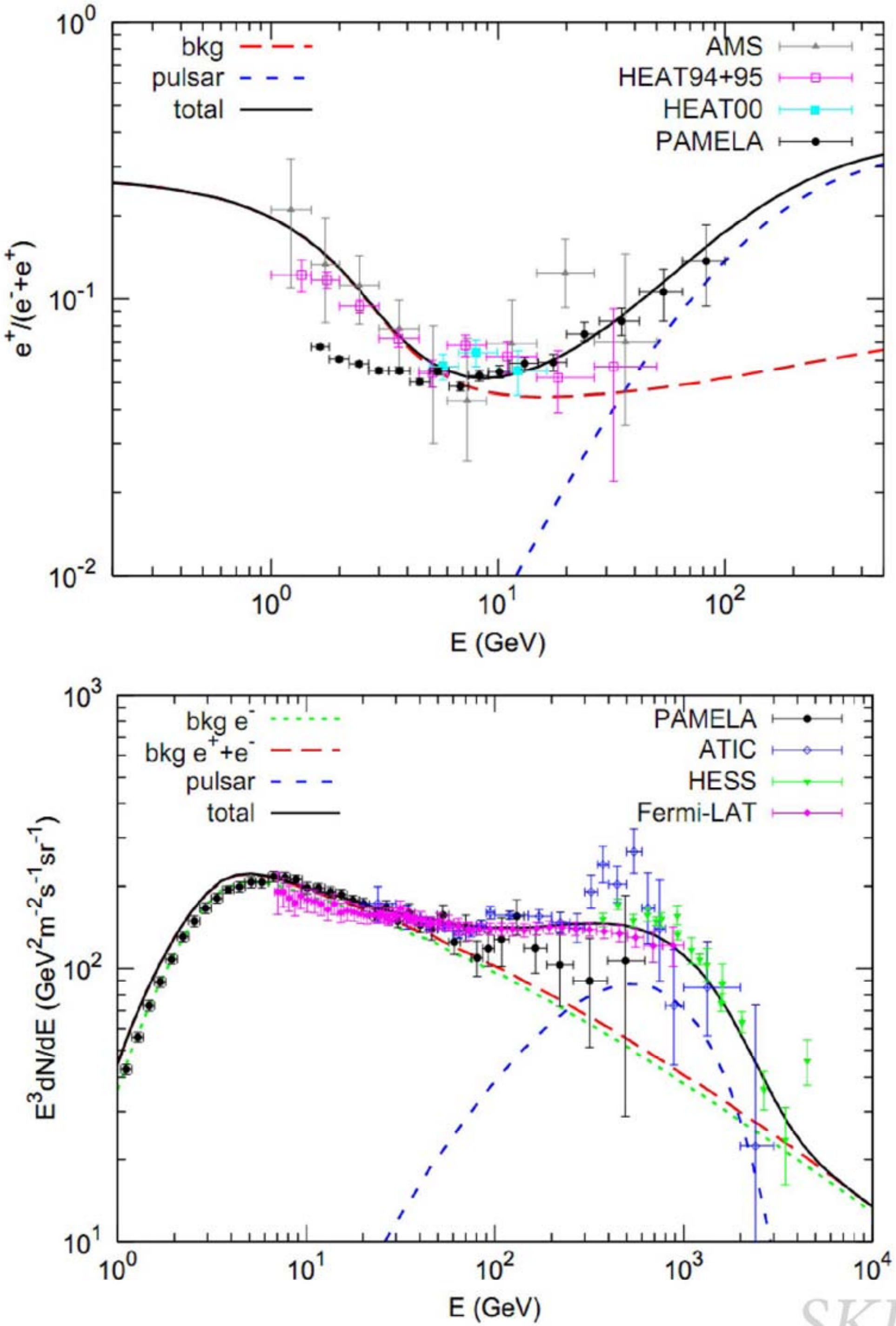
MCMC: Likelihood Calculation

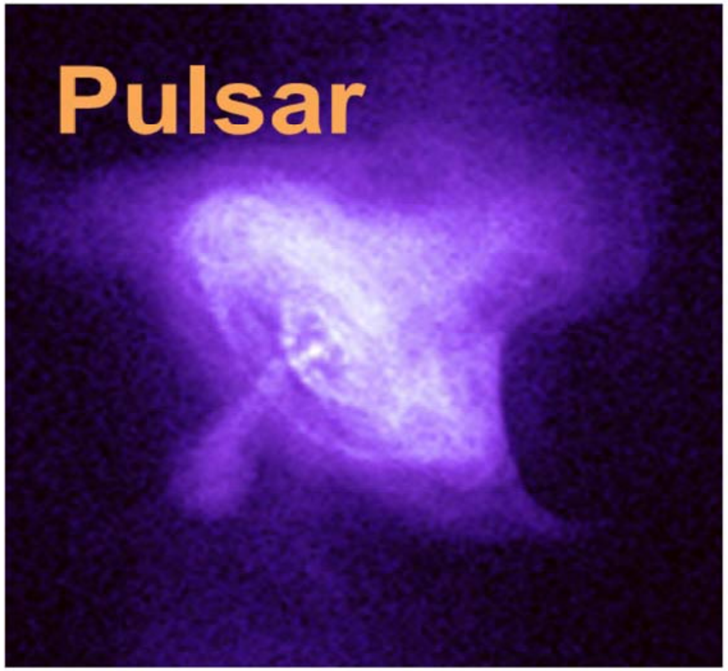
$$\mathcal{P}_{\rm bkg} = \{\gamma_1, \gamma_2, E_{\rm br}, A_{\rm bkg}, \phi, c_{e^+}\}$$

$$\mathcal{P}_{tol} = \begin{cases} \{\mathcal{P}_{\rm bkg}\}, & \text{background} \\ \{\mathcal{P}_{\rm bkg}, A_{\rm psr}, \alpha, E_c\}, & \text{pulsar} \\ \{\mathcal{P}_{\rm bkg}, c_{\bar{p}}, m_\chi, \langle\sigma v\rangle, B_e, B_\mu, B_\tau, B_u\}, & \text{DM.} \end{cases}$$

Pulsar && Dark Matter

$$\chi^2_{\text{red}} \approx 0.833$$





We can not distinguish dark matter from pulsar with present measurements

(微观） 粒子物理标准模型

LEP, Tevatron ……

三代夸克和轻子
SU(3) C × SU(2)L × U(1)Y

问题： Higgs not discovered;
symmetry breaking OK, but how?

-----》EW breaking 机制？
125 GeV Higgs !?

“ICFA 2011” meeting
CERN, 3-6 October, 2011

（宇观） 大爆炸宇宙模型

1998年，SN发现暗能量；（邵逸夫奖，Nobel prize 2011）
2000年，Maxima, BoomeranG
2003年，WMAP，SDSS，2dfGRS
2004年， “Golden Sample”, SNLS
2006年， WMAP3 COBE Nobel Prize!
2008年，WMAP5（2010年邵逸夫奖）
2008年， Pamela, ATIC
2009年， Fermi LAT
2010年， WMAP7
Inflation + Dark Matter + Dark Energy （一般意义）
\Lambda CDM model

问题： CDM: problem at small scale
warm dark matter
DM particles?
\Lambda: fine tuning
==➔dark energy?

2010年12月，<<科学>>杂志评出“精确宇宙学（**precision cosmology**）过去十年科学界的“十大成就” **(Insights of the decade)**之一 。这是近十余年宇宙学研究的重大成果。

十年中国宇宙学的发展和精确宇宙学

1） 观测宇宙学 （遗憾；SN，BoomeRANG。。
花钱并不多。。。。。。）

2）理论队伍：发展很快， 壮大很多；
在计算宇宙学（数据分析，数值计算，模拟）和
理论模型 都取得了重要的成果；

3）精确宇宙学 ===➔国际性重大成果---------》
中国人的贡献不能忽略！！！ （WMAP7 引用13篇文章）

4）“天文+物理”交叉研究的良好氛围已形成
======〉创新文化重大成就；
i）暗物质暗能量探测路线图
ii）“两暗一黑三起源”的提出

今天会议的参加者，氛围。。。。

Thank you !