ScienceWatch Home
Inside This Month...
Interviews

Featured Interviews
Author Commentaries
Institutional Interviews
Journal Interviews
Podcasts

Analyses

Featured Analyses
What's Hot In...
Special Topics

Data & Rankings

Sci-Bytes
Fast Breaking Papers
New Hot Papers
Emerging Research Fronts
Fast Moving Fronts
Corporate Research Fronts
Research Front Maps
Current Classics
Top Topics
Rising Stars
New Entrants
Country Profiles

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Methodology
Archives
Contact Us
RSS Feeds

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Interviews | Analyses | Data & Rankings

What's Hot In... : What's Hot in Physics Menu : Concordance Cosmology at WMAP's Quinquennium - Sep/Oct 2009

WHAT'S HOT IN... PHYSICS , September/October 2009

Concordance Cosmology at WMAP's Quinquennium

by Simon Mitton

PDF

The Hot Papers in physics are yet again dominated by cosmology, with two papers, #1 and #4, from the *Wilkinson Microwave Anisotropy Probe* (*WMAP*), and #6 on the latest data release from the Sloan Digital Sky Survey. Paper #4, the fifth in the annual series, published February 2009, has soared into the Top Ten just weeks after publication. Clearly that would not happen if the paper merely updated its forebears with slightly better data on the cosmic microwave background (CMB). So, what's new this time?

WMAP is of central importance to observational cosmology because its mission is to place *stringent* limits on six parameters that codify a cold-dark-matter universe with a cosmological constant lambda, that takes account of dark energy. This LCDM model is the foundation of concordance cosmology, the all-party consensus. So, to a certain extent, observational cosmology could have become a somewhat pointless quest for another place of decimals on just six numbers. But that's not how the game is being played, as #4 makes abundantly clear.

Concordance cosmology has provided stable answers to such questions as the age of the universe, its expansion

Physics Top Ten Papers

Rank	Papers	Cites Mar-Apr 09	Rank Jan-Feb 09
1	D.N. Spergel, *et al.*, "Three-year *Wilkinson Microwave Anisotropy Probe* (*WMAP*) observations: Implications for cosmology," *Astrophys. J. Suppl. Ser.*, 170(2): 377-408, June 2007. [13 U.S. and Canadian institutions] *178TD	123	1
2	X.H. Chen, *et al.*, "Superconductivity at 43K in $SmFeAsO_{1-x}F_x$, *Nature*, 453 (7196): 761-2, 5 June 2008. [U. Sci. & Tech., Hefei, China] *308UK	73	2
3	Z.A. Ren, *et al.*, "Superconductivity at 55 K in iron-based F-doped layered quaternary compound $Sm[O_{1-x}F_x]FeAs$," *Chinese Phys. Lett.*, 25(6): 2215-6, June 2008. [Chinese Acad. Sci, Beijing] *306MN	56	5
4	E. Komatsu, *et al.*, "Five-year *Wilkinson Microwave Anisotropy Probe* observations: Cosmological interpretation," *Astrophys. J. Suppl. Ser.*, 180 (2): 330-76, February 2009. [14 institutions worldwide] *406EI	48	†
5	J.Y. Kim, *et al.*, "Efficient tandem polymer solar cells fabricated by all-solution processing," *Science*, 317 (5835): 222-5, 13 July 2007. [U. Calif., Santa Barbara; Gwangju Inst. Sci. Tech., Korea] *189DC	47	5

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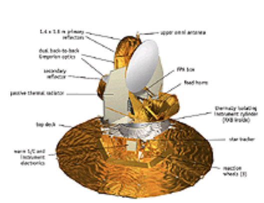

WMAP spacecraft diagram.

rate, its composition, and the origin of structure. *WMAP* contributed to this by measuring the statistical properties of temperature fluctuations in the CMB. The consensus is that the spatial geometry of the universe is flat, and it contains atoms, dark matter, and dark energy.

But, cosmologists ask themselves, is the universe really flat, and what are the equations of state for dark energy and dark matter? Then there is the vexed question of cosmic inflation: what is the correct model for that? Paper #4 is just one of seven *WMAP* five-year papers now providing intellectual turning points for these cosmological conundrums.

Inflation refers to an event 10-36 seconds after the Big Bang: the observable universe originated in a tiny causally connected region that suddenly ballooned from almost nothing to immensity. Because inflation smoothed out inhomogeneities and curvature, *WMAP* has by now become a formidable tool for discriminating between rival models of the inflationary universe: #4 reports there are already more than 100 candidates in the literature, and competition between them no doubt accounts for the continuing high citation rates of *WMAP* papers.

6	J.K. Adelman-McCarthy, *et al.*, "The Sixth Data Release of the Sloan Digital Sky Survey," *Astrophys. J. Suppl. Ser.*, 175 (2): 297-313, April 2008. [84 institutions worldwide] *327WN	45	6
7	J. Dong, *et al.*, "Competing orders and spin-density-wave instability in $La(O_{1-x}F_x)FeAs$," *EPL-Europhys. Lett.*, 83(2): no. 27006, July 2008. [Beijing Natl. Lab. Condensed Matter Phys., Chinese Acad. Sci.] *345TZ	38	7
8	H. Ding, *et al.*, "Observation of Fermi-surface-dependent nodeless superconducting gaps in $Ba_{0.6}K_{0.4}Fe_2As_2$," *EPL-Europhys. Lett.*, 83(4): no. 47001, August 2008. [Chinese Acad. Sci, Beijing; Adv. Inst. Mater. Res., Tohoku, Japan; Tohoku U., Japan; Boston Coll. MA] *345VP	37	†
9	M.Y Han, *et al.*, "Energy band-gap engineering of graphene nanoribbons," *Phys. Rev. Lett.*, 98(20): no. 206805, 18 May 2007. [Columbia U., New York, NY] *169WY	36	4
10	C. Wang, *et al.*, "Thorium-doping-induced superconductivity up to 56 K in $Gd_{1-x}Th_xFeAsO$," *EPL-Europhys. Lett.*, 83(6): no. 67006, September 2008. [Zhejiang U., Hangshou, China] *410SJ	36	†

SOURCE: Thomson Reuters Hot Papers Database. Read the Legend.

So, in this quinquennial report, the *WMAP* team led by Eiichiro Komatsu (Dept. of Astronomy, University of Texas at Austin) takes a close look at curvature in the universe. This fascinating area connects fundamental physics to observational cosmology via the predictions of the numerous models that were developed to make predictions testable by *WMAP*. The main conclusion of a highly technical analysis is a tight restriction on curvature, with complete flatness an allowable solution. A robust prediction of inflation is that the early universe has primordial gravitational waves, arising from the same generating mechanism as the primordial density fluctuations that explain the presence of structure (clusters of galaxies) in the universe. The *WMAP* data are sensitive to the presence of primordial gravitational waves, and when combined with results from supernova cosmology, the outcome disfavors a number of popular inflation models.

In terms of understanding dark energy, by placing tight limits on its equation of state, *WMAP* is making real progress. The observational issue is that the measured cosmic distances of Type Ia supernovae cannot fit the data unless accelerated expansion is allowed in the universe of today. This uptick in the expansion rate is presumed caused by an additional energy component that acts like negative pressure. This is not a new idea, but physicists have struggled for the better part of a decade to get to grips with the puzzle, only to find a growing circle of ignorance. The latest *WMAP* analysis suggests that dark energy is consistent with vacuum energy.

There is news about neutrinos. The limit on the total mass of massive neutrinos is given as < 0.67 eV. The result is significant because the neutrino mass is of fundamental importance in physics. *WMAP* has provided an upper limit from a cosmological point of view, which complements the laboratory results from atmospheric and solar neutrinos. Furthermore, *WMAP* confirms that the number of neutrino species in the early universe was three, just like today.

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