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WHAT'S HOT IN... PHYSICS, January/February 2010

Combined Supernova Data Constrain Consensus Cosmology

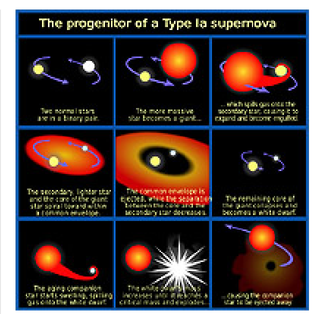
by Simon Mitton

PDF

Cosmology continues to top the Physics Top Ten (papers #1, #4, #8, and #9), but the superconductivity renaissance means that condensed matter physics now has five contenders (#2, #3, #5, #7, and #10). Paper #1, however, on the 5-year Wilkinson Microwave Anisotropy Probe (WMAP) dataset, has roared so far ahead (138 citations this period) that it would appear unlikely that laboratory physics can capture pole position any time soon. But who knows what mighty shake-up the Large Hadron Collider could achieve in a year or so?

Paper #9, a new entrant, is from the Supernova Cosmology Project, a consortium headed by Saul Perlmutter (Lawrence Berkeley National Laboratory, California); this team won a half share in the 2007 Gruber Cosmology Prize, the other laureate being the High-z Supernova Search Team led by Brian Schmidt (Australian National University). The supernova cosmology game compares the distance of Type Ia supernovae (SN Ia) with the redshifts of their parent galaxies. The supernova data provide the best fix on how fast the universe was expanding at different times in its history. Good results depend upon observing many SN Ia, both near and far. And in the quest for good results, #9 revisits old data, combines that with new data, and puts another turn on the ratchet that constrains the values of the cosmological parameters.

Historically, observational cosmology has been plagued by systematic errors. A new kind of telescope or detector may have instrumental bias that is initially poorly understood. More commonly, unknown bias creeps in when data obtained at different epochs or with different instruments are binned together. Since the purpose of observational cosmology is to detect how the universe has changed over time, it is essential that surveys do not introduce bias. Dealing with such error is mainly what #9 is all about: taking a heterogeneous compilation, laboriously winnowing out a reliable dataset, and then refining the cosmological models.



The Progenitor of a Type Ia Supernova.

[+] details

The backstory of #9 starts in 1998, when new surveys of SN Ia at high redshift (z ~ 0.5) were compared to data on low-redshift objects (z ~ 0.05). The literature for 1998 to 2007 includes several unrelated high-redshift samples that were analyzed independently of each other. Paper #9 sieves the original data to arrive at a more uniform sample. Selection cuts reduced the initial sample of 414 SN Ia to a union sample of 307.

The investigation achieved several major goals. Importantly, it includes a new sample of low-redshift SN Ia to complement the growing sample of high-redshift SN Ia. This is non-trivial because the volume of the nearby universe is far smaller than the distant universe: therefore local SN are rare, and the statistics get complicated by the paucity of the sample. It is still the case that most low-redshift SN are in a sample made 16 years ago. Nearby and faraway SN are both needed to constrain cosmological parameters.

The paper is highly cited because it reflects the current best knowledge of the world's SN Ia datasets, thanks to the addition of new datasets from the local universe. The sample is sufficiently large to permit the exclusion of outliers, and that's the main reason why the associated errors have been reduced. The future of SN cosmology is that high-quality data will improve our understanding of the accelerating universe, and that should provide insights into dark energy and dark matter.

Elsewhere in our current list, #8 is getting plenty of attention. This is a report on antiparticles in cosmic rays, and it looks at a relatively simple question: what is the source of cosmic ray positrons? Traditionally the answer has been that antiparticles result from a secondary source: collisions between cosmic ray particles and atoms in the interstellar medium. Paper #8 reports data from a satellite-borne experiment that detected electrons and positrons with energies 1.5 to 100 GeV between July 2006 and February 2008.

As reported in #8, the measured fraction of higher- energy positrons cannot be entirely explained by secondary sources; there have to be primary sources. There are several interesting candidates for the primary component, including the annihilation of dark matter particles in the vicinity of our galaxy or contribution from astrophysical sources, such as pulsars. Right now the data cannot tell the difference between dark matter annihilation or astrophysical sources. However, ongoing space missions are slowly improving the statistics. And then there's always the Large Hadron Collider...

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Physics Top 10 Papers

Rank	Paper	Citations This Period (Jul-Aug 09)	Rank Last Period (May-Jun 09)
1	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	138	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	62	8
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	9
4	J. Dunkley, *et al.*, "Five-year *Wilkinson Microwave Anisotropy Probe* observations: Likelihoods and parameters from the *WMAP* data," *Astrophys. J. Suppl. Ser.*, 180(2): 306-29, February 2009. [14 U.S. and Canadian institutions] *406EI	51	5
5	F.-C. Hsu, *et al.*, "Superconductivity in the PbO-type structure alpha-FeSe," *PNAS*, 105(38): 14262-4, 23 September 2008. [Acad. Sinica, Taipei, Taiwan; Natl. Tsing Hua U., Hsinchu, Taiwan; Duke U., Durham, NC] *353TY	46	†
6	F. Schedin, *et al.*, "Detection of individual gas molecules adsorbed on graphene," *Nature Mater.*, 6(9): 652-5, September 2007. [U. Manchester, U.K.; Inst. Microelectronics Tech., Chernogolovka, Russia; U. Nijmegen, Netherlands] *207FE	41	†
7	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	40	†
8	O. Adriani, *et al.*, "An anomalous positron abundance in cosmic rays with energies 1.5-100 GeV," *Nature*, 458(7238): 607-9, 2 April 2009. [17 institutions worldwide] *427RK	35	†
9	M. Kowalski, *et al.*, "Improved cosmological constraints from new, old, and combined supernova data sets," *Astrophys. J.*, 686(2): 749-78, 20 October 2008. [41 institutions worldwide] *364YB	32	†
10	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	30	†

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

KEYWORDS: COSMOLOGY, SUPERNOVA, WILKINSON MICROWAVE ANISOTROPY PROBE, WMAP, SAUL PERLMUTTER, TYPE IA SUPERNOVAE, SN IA.