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WHAT'S HOT IN... PHYSICS , Jul/Aug 2009

The Science Legacy of the Sloan Digital Sky Survey

by Simon Mitton

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The Hot Papers in Physics for this period include the fifth (paper #8) and sixth (#6) releases of data from the Sloan Digital Sky Survey (SDSS). The release of the seventh and final SDSS dataset, published in May 2009 (*Astrophys. J. Supp. Ser.*, 182[2]: 545-58), marks the completion of the original goals of the SDSS, launched a decade ago. Now is an appropriate time to review the science achievements of this remarkable project. All of the survey's data-release papers have featured as highly cited papers in *Science Watch*, because the data have supported a large number of research projects in the global community of astronomers.

The 2.5-m Sloan telescope is a comprehensive imaging and spectroscopic instrument at Apache Point Observatory in southern New Mexico. The original purpose of the survey was to map the structure of the universe and to understand how that structure arose. The most distant objects in the SDSS are approximately 13 billion light years away. SDSS has mapped the three-dimensional structure of a large slice of the universe, spanning the time and distance from the local universe to the early universe. Its 3D map shows how the structure of the universe has evolved.

The fundamental data of SDSS is freely available online to any user; #6 and #8 (and their predecessors) give the technical

Physics Top Ten Papers

Rank	Papers	Cites Jan-Feb 09	Rank Nov-Dec 08
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	101	1
2	X.H. Chen, *et al.*, "Superconductivity at 43K in SmFeAs $O_{1-x}F_x$," *Nature*, 453 (7196): 761-2, 5 June 2008. [U. Sci. & Tech., Hefei, China] *308UK	54	2
3	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	42	4
4	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	38	8
5	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	37	3

background required to analyze the data. Paper #6 proudly announces that the survey includes 1.27 x 10^6 spectra of stars, galaxies, and quasars. The stellar spectroscopy is far more detailed than previously, and the release includes detailed estimates of stellar temperatures and metallicities (a measure of chemical make-up).

SDSS has imaged 12,000 square degrees (over 1/4 of the sky) in five wavebands, and performed spectroscopy on 10^6 galaxies and 10^5 quasars to create the 3D structural map. In addition, SDSS has explored the structure and kinematics of the Milky Way galaxy and discovered more than 500 Type Ia supernovae, observations of which have transformed supernova cosmology.

In terms of its science legacy, SDSS has outperformed any previous surveys by a huge margin. Its discovery of the most distant quasars probe the transition phase of the universe, in which protons and electrons recombined to form neutral hydrogen. Quasars seen at the epoch when the universe was 10% to 25% of its present age cluster more tightly than in the nearby universe, which suggests they are surrounded by concentrations of dark matter, with an underlying distribution that can be measured with high precision. The high-quality images, distances, masses, and ages of galaxies have provided powerful insights into galaxy formation. SDSS is a potent tool for exploiting weak gravitational lensing, which has revealed the dark matter distribution in galactic haloes.

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	34	†
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	29	0
8	J.K. Adelman-McCarthy, *et al.*, "The Fifth Data Release of the Sloan Digital Sky Survey," *Astrophys. J. Suppl. Ser.*, 172 (2): 634-44, October 2007. [73 institutions worldwide] *212HY	28	†
9	G. Hinshaw, *et al.*, "Three-year *Wilkinson Microwave Anisotropy Probe* (*WMAP*) observations: Temperature analysis," *Astrophys. J. Suppl. Ser.*, 170(2): 288-334, June 2007. [14 U.S. and Canadian institutions] *178TD	26	†
10	Z.A. Ren, *et al.*, "Superconductivity at 52 K in iron based F doped layered quaternary compound $Pr[O_{1-x}F_x]FeAs$," <MI>Mater. Res. Innovat.<D>, 12(3): 105-6, September 2008. [Chinese Acad. Sci., Beijing] *362RG	25	†

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

Locally, SDSS has discovered many dwarf companions to the Milky Way: star mapping has revealed nine new satellites of our own galaxies, as well as two new dwarfs belonging to the Andromeda galaxy. These discoveries are important because theories of galaxy formation in a dark-matter universe had predicted that giant galaxies like the Milky Way should have numerous companions.

Up in the outer halo of the Milky Way, SDSS spied speeding stars close to or even exceeding escape velocity. Violent gravitation encounters with the supermassive black hole at the heart of the Milky Way have flung these escapees outwards by a slingshot effect. A new stellar population has come to light: sub-stellar objects, or "failed" stars that are too cool in their cores to ignite nuclear reactions.

And in our own backyard SDSS has provided new facts about the solar system. That's because moving objects, primarily asteroids, leave a trail in the images. SDSS hugely increased the number of known asteroids, and provided colors for them. As a result, planetary science now has better data on the size distribution of asteroids.

The SDSS telescope has entered on the third operational mission, SDSS-III. There are four goals: to increase the number of faint stars in the distant halo by a factor of 2.5; to perform spectroscopy on 1.5 x 10^6 red galaxies; to monitor any changes in the line of sight velocities of 11,000 stars as a means of detecting exoplanets; and to carry out spectroscopy on 10^5 giant stars for chemical studies of the Milky Way. The SDSS team expects data releases to continue until 2014.

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KEYWORDS: SLOAN DIGITAL SKY SURVEY, SDSS, APACHE POINT OBSERVATORY, STELLAR SPECTROSCOPY,

FAILED STARS, QUASARS, MILKY WAY, GRAVITATIONAL LENSING.

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