Wiltshire David L.

Position: Senior Lecturer, Department of Physics & Astronomy,
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Period covered: 2001-present

I Scientific Work

Prof. Wiltshire completed work for two research papers during his three month visit to ICRANet. Both papers relate to his current program of investigating the possibility that effects attributed to dark energy and cosmic acceleration have their origin in a misidentification of gravitational energy gradients within the inhomogeneous structure of the universe, once structures form. This "radically conservative" solution to the problem of dark energy has begun to attract a reasonable amount of interest, and has already featured prominently in the popular press, with a cover feature in *New Scientist* in March, 2008.

1. "Cosmological equivalence principle and the weak-field limit", Phys. Rev. D 78 (2008) 084032

The first paper he wrote in Pescara was a conceptual one, in which he returned to the first principles of general relativity, and posed the question: "what is the largest scale on which the Equivalence Principle can be applied?" His proposed solution involves an extension of the Strong Equivalence Principle in application to averaged dynamical fields in cosmology to include the role of the average density in the determination of inertial frames. He applied the resulting Cosmological Equivalence Principle is applied to the problem of synchronization of clocks in the observed universe.

Once density perturbations grow to give density contrasts of order one on scales of tens of Mpc, the integrated deceleration of the local background regions of voids relative to galaxies must be accounted for in the relative synchronization of clocks of ideal observers who measure an isotropic cosmic microwave background. The relative deceleration of the background can be expected to represent a scale in which weak-field Newtonian dynamics should be modified to account for dynamical gradients in the Ricci scalar curvature of space. He estimated the acceleration scale using the best-fit nonlinear bubble model of the universe with back-reaction. At redshifts $z<0.25$ the scale is found to coincide with the empirical acceleration scale of modified Newtonian dynamics. At larger redshifts the scale varies in a manner which is likely to be important for understanding dynamics of galaxy clusters, and structure formation. Although the relative deceleration, typically of order 10^{-10} ms^{-2}, is small, when integrated over the lifetime of the universe it amounts to an accumulated relative difference of 38% in the rate of average clocks in galaxies as compared to volume-average clocks in the emptiness of voids. He also discussed a number of foundational aspects of the cosmological equivalence principle, including its relation to Mach's principle, the Weyl curvature hypothesis and the initial conditions of the universe.

This paper was accepted "emphatically" by the referee, in an extremely positive report, just 10 days after he submitted it to the journal in September, and has already been published.

2. "Dark energy without dark energy: Average observational quantities", in preparation

The second paper he has been busy with in Pescara examines observational tests on the new cosmological paradigm he has developed, which will provide means for distinguishing it from the standard ΛCDM model, or other models for dark energy which modify gravity or add exotic fields while maintaining the absolute homogeneity and isotropy of space. Many observational projects are either already running, or being planned, which will be able to test some of these predictions. These include missions such as WiggleZ, Pan-STARRS, HETDEX, the Dark Energy Survey, JDEM, Euclid, and the ELT.

He firstly determined the equivalent of the commoving distance test, a measure equivalent to the determination of "the dark energy equation of state". He finds that the non-linear bubble model which best-fits type Ia supernovae (SneIa) without exotic dark energy effectively interpolates between the comoving distance of curves for ΛCDM models with different values of Ω_Λ at different redshifts. At redshifts $z<1.5$ it closely matches the curve for the ΛCDM model with the value of Ω_Λ which best-fits SneIa only, while at the largest redshifts near last scattering it closely matches the curve for the ΛCDM model with the higher value of Ω_Λ which best-fits WMAP5 measurements of the cosmic microwave background spectrum. At intermediate redshifts, $2 < z < 10$, it interpolates between the two curves. These differences are certainly in the regime which will be probed and tested by future dark energy surveys.

In addition, he determined quantities which are a test of the (in)homogeneity of the universe. In particular, Clarkson, Bassett and Lu (*Phys. Rev. Lett.* **101** (2008) 011301) have constructed quantities which have constant values for all redshifts for any cosmology which obeys the Friedmann equation, irrespective of the dark energy model, but is non-zero otherwise. In his model cosmology, which is inhomogeneous, the (in)homogeneity functions turn out to have a particular characteristic form with redshift, which again will be testable in the coming decade. The test of inhomogeneity ideally requires the determination of $H(z)$, the Hubble parameter as a function of redshift in model-independent way. This can be achieved over a 10-20 year period by a measurement of the time-variation of z, as might be achieved by precision measurements on the Lyman α forest over redshifts, $2 < z < 5$, with the next generation of Extremely Large Telescopes. This leads to a further refined test of inhomogeneity, as has been discussed by Uzan, Clarkson and Ellis (*Phys. Rev. Lett.* **100** (2008) 191303). Once again, he has determined the distinctive observational signature in his model cosmology.

At present he is completing the investigation of an equivalent of the Alcock- Paczynski test to wrap up the paper, and when this is completed he will submit the paper to arXiv.org, and to *Physical Review D*.

In addition to the above 2 papers, he also spent some time proof-reading the manuscript of *The Kerr Spacetime: Rotating Black Holes in General Relativity*, which he is editing with Matt Visser and Susan Scott, and to which both Prof. Kerr and Prof. Ruffini have contributed. Cambridge University Press inform him that the book should appear just before Christmas.

He presented two research seminars on his work in Pescara, on 4th August, and on 23rd October.

II Conferences and educational activities

Conferences and Other External Scientific Work

He presented a talk at the *3rd Bienniel Leopoldina Conference on Dark Energy,* at the Ludwig-Maximilians-University, Munich, Germany, 7-11 October 2008.

On his return from the conference, he presented a seminar in Pescara, giving an overview of the new scientific results presented at the Munich conference.

Work With Students

He participated in the interview of new students for the IRAP PhD program. (He also interacted with his own PhD student back in New Zealand, Peter Smale, by email.)

III Service activities

Within ICRANet

With Professor Ruffini he is planning to organize an ICRANet workshop/conference in Christchurch, New Zealand, in December 2009, to complete ICRANet's programme of activities to mark the *International Year of Astronomy*. He is also chairing a session on *Inhomogeneous Cosmologies, Averaging and Backreaction*, at the 12th Marcel Grossmann Meeting.

Outside ICRANet

He continued his usual refereeing duties for *Physical Review* and *Physical Review Letters,* and his activities as a committee member of the *Australasian Society for General Relativity and Gravitation*. He is also preparing a popular article on his solution to dark energy for the *Olbers Astronomical Society* in Bremen, Germany.

IV 2007-2008 List of Publications

Cosmic clocks, cosmic variance and cosmic averages, D.L. Wiltshire, New J. Phys. 9, 377. [arXiv:gr-qc/0702082]

Exact solution to the averaging problem in cosmology, D.L. Wiltshire, Phys. Rev. Lett. 99, 251101. [arXiv:0709.0732]

Gravitational energy as dark energy: Concordance of cosmological tests, B.M. Leith, S.C.C. Ng and D.L. Wiltshire, Astrophys. J. 672, L91{L94. [arXiv:0709.2535]

Gravitational energy and cosmic acceleration, D.L. Wiltshire, Int. J. Mod. Phys. D 17, 641-649. [arXiv:0712.3892]

Dark energy without dark energy, D.L. Wiltshire, in Dark Matter in Astroparticle and Particle Physics: Proceedings of the 6th International Heidelberg Conference, eds. H.V. Klapdor{Kleingrothaus and G.F. Lewis, (World Scienti_c, Singapore), pp. 565-596. [arXiv:0712.3894]

Cosmological equivalence principle and the weak{_eld limit, D.L. Wiltshire, Phys. Rev. D 78, 084032. [arXiv:0809.1183]

David Wiltshire was born in New Zealand in 1962, and did undergraduate studies at the University of Canterbury in Christchurch, NZ followed by a Ph.D. in the Relativity and Gravitation Group at the University of Cambridge, UK, in the mid 1980s. After a variety of postdoctoral research and lecturing positions in Trieste, Italy, Necastle{Upon{Tyne, UK, and Adelaide, Australia he returned to NZ in 2001, where he is now Senior Lecturer at the University of Canterbury, Christchurch. He is known for his work in higher{dimensional gravity, brane worlds, black holes and quantum cosmology. Most recently his research has turned to the problem of dark energy, the averaging of the inhomogeneous universe in general relativity, and its implications for the foundations of theoretical and observational cosmology.