of social roles, wealth and status[9], potentially providing other benefits to the 'greatest potlatches'. The significance of gift-giving has been discussed by economists, many of whom believe that gifts may serve as signals of a person's intention about future investment in relationships.

Experiments with children showed that they give more to friends than non-friends in some situations (as one would expect if friendship is the outcome of trust building up between partners). In one study[10], for example, children gave more trinkets to friends than to non-friends. But they tended to decrease the amount given to friends after receiving many trinkets from them, and to increase the number given after receiving few. The reverse occurred with neutral or disliked partners. When little was received from a friend it was interpreted as punishment for previous selfishness, and a lot was returned. When a lot was received from a non-friend, it was interpreted as an invitation to friendship (and interpersonal gain) and a lot was given in return[10]. These experiments show that although levels of cooperation genuinely correlate with friendship, in accordance with the Roberts and Sherratt models, other factors such as reconciliation after perceived punishment and honest signalling of willingness to cooperate in the future may also affect the magnitude of dispensed cooperation, at least in humans. We suspect that such cases will be explained by models of cooperation that also take into account the preferential assortment of cooperators according to cooperative history[11] or need (individuals having the same status or age, for instance).

An important and welcome feature of Roberts and Sherratt's new models is that they make predictions that can be easily tested. For example, several systems exist in which changes in the levels of investment between partners can be followed over time. It is to be hoped that Roberts and Sherratt's models (and future models, similarly inspired by the details of how animals actually behave) will forge a stronger link between theoretical and empirical studies — allowing theoreticians and empiricists to build trust and cooperate to a greater extent in testing evolutionary models of cooperation. □

Laurent Keller is in the Department of Zoology and Animal Ecology, Bâtiment de Biologie, University of Lausanne, 1015 Lausanne, Switzerland.
e-mail: laurent.keller@izea.unil.ch
H. Kern Reeve is in the Section of Neurobiology and Behavior, Seeley G. Mudd Hall, Cornell University, Ithaca, New York 14853, USA.
e-mail: hkr1@cornell.edu

1. Roberts, G. & Sherratt, T. N. *Nature* **394,** 175–179 (1998).
2. Axelrod, R. & Hamilton, W. D. *Science* **211,** 1390–1396 (1981).
3. Axelrod, R. *The Evolution of Cooperation* (Basic Books, New York, 1984).
4. Dugatkin, L. A. *Cooperation Among Animals. An Evolutionary Perspective* (Oxford Univ. Press, New York, 1997).
5. Connor, R. C. *Trends Ecol. Evol.* **10,** 84–86 (1995).
6. Noe, R. *Anim. Behav.* **39,** 78–90 (1990).
7. May, R. M. *Nature* **327,** 15–27 (1987).
8. Wedekind, C. & Milinski, M. *Proc. Natl Acad. Sci. USA* **93,** 2686–2689 (1996).
9. Camerer, C. *Am. J. Sociol.* **94,** S180–S214 (1988).
10. Krebs, D. L. *Psychol. Bull.* **73,** 258–302 (1970).
11. Wilson, D. S. & Dugatkin, L. A. D. *Am. Nat.* **149,** 336–351 (1997).

Galaxy clusters

Well of darkness

August E. Evrard

Astronomers have gone to the well and come back perplexed. Galaxy clusters should contain large quantities of dark matter, trapped in their potential well, and we expect that matter to be sharply concentrated near the centre. But using a new method for interpreting the effects of gravitational lensing, Tyson *et al.*[1] have inferred a much smoother and less centrally concentrated distribution of dark matter in one cluster. If this distribution is confirmed, and seen in other clusters, it is likely to produce insights into the mechanisms governing galaxy-cluster formation. A less likely, but more exciting, possibility, is that it is a clue to the very nature of dark matter.

The standard mechanism of large-scale structure formation is gravitational instability[2]. Small irregularities in density grow with time, collecting matter into an evolving, web-like network. Within this large-scale network, collapsed, nearly spherical, quasi-equilibrium structures called 'haloes' form, their internal gravitational attraction balanced by pressure from the random motions of their elements. As the Universe ages, collections of bound haloes merge, and an evolving hierarchy of collapsed structures is established. Clusters of galaxies mark the apex of this process — they are the biggest collapsed structures around.

Over the past decade, this has been scrutinized using numerical simulations of gravitational clustering. To produce anything like the current distribution of clusters, there must be a great deal of dark matter present as well as the luminous matter that we see. Most simulations predict similar internal structures for clusters; recent work[3] even points to a 'universal profile' for the radial dark-matter density distribution — a simple function with one free parameter that is sensitive mainly to the underlying cosmology (the Universe's density and expansion rate). The main caveat is that these numerical studies neglect the 10–30% of clusters that have had recent mergers. But the universal profile is still a tempting target for observers to shoot at.

Tyson *et al.*[1] took their shots using the Hubble Space Telescope. Although the telescope was pointed at the cluster of galaxies 0024+16, at a moderate redshift of 0.39, the real target was the backdrop of faint galaxies lying behind the cluster. Light from these galaxies is deflected by the gravitational field of the intervening cluster, as predicted by Einstein's theory of General Relativity, and the deflection warps the images of the galaxies. The effect is weak in the outer parts of the cluster but becomes strong in the centre, where the density is highest and the gravitational potential well is deepest.

Strong lenses such as 0024+16 create multiple images of background objects, and the appearance of such a multiply-imaged system is sensitive to the central structure of the cluster's potential well. Potential and mass density are related by Poisson's equation, so the image structure can be 'inverted' by numerical methods to constrain how mass is distributed within the cluster core.

Recent simulations[4] have revealed central potential wells that are 'cuspier' (more sharply peaked in the centre) than the universal type described earlier. But to the theorists' dismay, Tyson *et al.* infer a core structure for 0024+16 that not only differs from the universal prediction, but also differs in the direction opposite to that seen by the new simulations. Their cluster reconstruction has a much flatter central peak (Fig. 1).

What to make of this unpleasantness? Do the simulators need to reprogramme? Is this a hint of new physics? Or is it merely accidental? Before getting too excited, we should keep in mind that the size of the discrepancy is small: the difference in core mass between theory and the new observation is only 1% of the total mass inferred for the cluster.

Simulators hammering at the structure of clusters have come a long way since the pioneering numerical work of Peebles[5] in 1970. A recent comparison of 13 simulation codes shows agreement in the dark-matter density structure at the 5% level. However, a fair criticism of the numerical models is that the very highest-resolution versions, which probe the core region best, do not take into account the gravitational coupling of the dark matter to ordinary 'baryonic' matter — the galaxies and intracluster plasma. Overall, these contribute nearly 20% of the total mass budget. It is conceivable, at least on energetic grounds, that dynamical mechanisms could pump enough heat into the dark matter to alter the structure of its inner 1%. Furthermore, the predicted 'universal mass profile' strictly applies only to the dark-matter component, whereas the observations constrain the structure of all matter outside

G. KOCHANSKI, I. DELL'ANTONIO & T. TYSON/BELL LABS, LUCENT TECHNOLOGIES

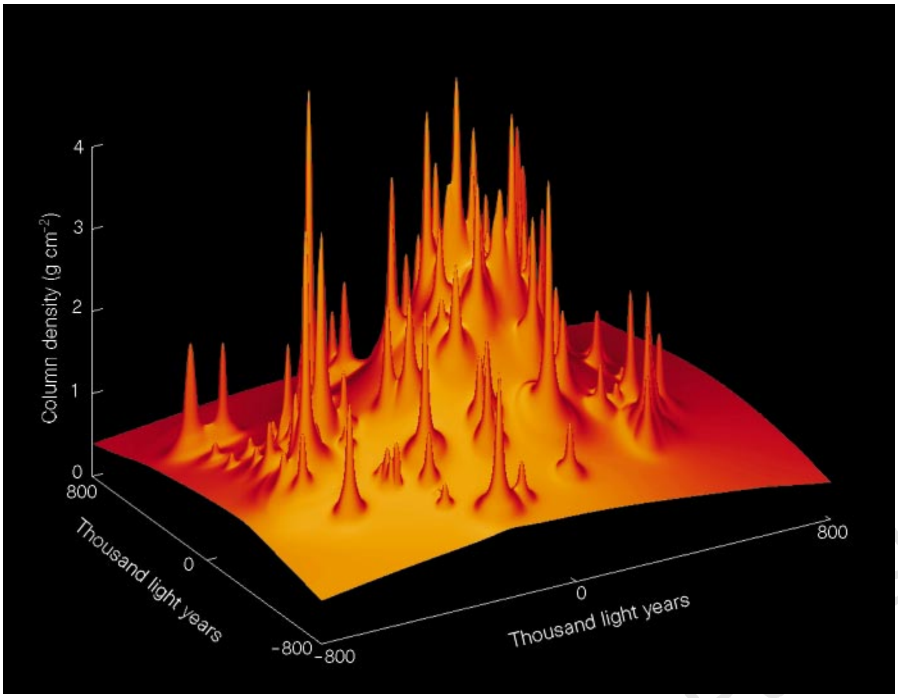

Figure 1 **Profile of a lens. This is a projected density plot of the galaxy cluster CL0024+1654, inferred from the cluster's gravitational effect on the images of more distant objects. (The sharp peaks are added to mark single galaxies in the cluster.) The mass in the cluster is less centrally concentrated than theories predict. Is this just an unusual cluster, or could it be a sign of the existence of 'hot' dark matter?**

galaxies, including the intracluster plasma. Because the plasma is known to be less centrally concentrated than the dark matter, its effect on the mass profile would tend to reconcile theory and experiment.

New fundamental physics is always more fun than new astrophysics as a solution to cosmic mysteries. A possible solution from this category is that the dark matter is not all cold. A hot, relativistic component would have too low a phase space density to create a very cuspy potential[6], so it would lower the inner parts of the cluster density profile, perhaps enough to satisfy the observations[7]. The new evidence for flavour oscillations of atmospheric neutrinos from Super-Kamiokande[8], discussed in these pages by Frank Wilczek[9], may mean that neutrinos have enough mass to do this.

More mundane solutions exist, of course. Tyson and colleagues use a complex fitting procedure, summing the effects of many individual mass concentrations ('mascons'), and end up with a model that has 512 free parameters — a frighteningly large number. One might be suspicious of finding a global best fit in such a large parameter space. But the much larger number of independent pixels (3,800) in the multiple galaxy images provides the grist for this modelling mill; and the end result, that just two superimposed mascons contain 98% of the non-galaxy mass, has a ring of trustworthiness about it.

Finally, 0024+16 may just be a bad egg. Because of their immense gravitational fields, clusters are constantly attracting and swallowing nearby cosmic debris. When smaller objects are absorbed they usually plunge near to the heart of the cluster while gravitational tides deform and ultimately dissolve them. If 0024+16 is in the process of digesting such a snack, that would invalidate comparison with simulation predictions that select against such objects.

What is ironic about this finding is a sense of inverted déjà vu. Only a few years ago, Tyson and co-workers stirred up the waters by revealing cluster cores that were *more* centrally cusped than the ageing, but still popular, theoretical model then in use. That finding helped spur the theoretical investigations that resulted in the universal density profile's enshrinement. Let's see: first time to the well came up too sharply cusped; second time, not cusped enough. One more time, perhaps, and it will come out just right. □

August E. Evrard is in the Physics Department, University of Michigan, 500 East University, Ann Arbor, Michigan 48109-1120, USA.
e-mail: evrard@umich.edu

1. Tyson, J. A., Kochanski, G. P. & Dell'Antonio, I. P. *Astrophys. J. Lett.* **498,** L107–L110 (1998).
2. Peebles, J. *Principles of Physical Cosmology* (Princeton Univ. Press, NJ, 1993).
3. Navarro, J. F., Frenk, C. S. & White, S. D. M. *Astrophys. J.* **490,** 493–508 (1996).
4. Moore, B., Governato, F., Quinn, T., Stadel, J. & Lake, G. *Astrophys. J. Lett.* **499,** L5–L10 (1998).
5. Peebles, J. *Astron. J.* **75,** 13–19 (1970).
6. Tremaine, S. & Gunn, J. E. *Phys. Rev. Lett.* **42,** 407–419 (1979).
7. Kofman, L., Klypin, A., Pogosyan, D. & Henry, J. P. *Astrophys. J.* **470,** 102–114 (1996).
8. http://www-sk.icrr.u-tokyo.ac.jp/doc/sk/index.html
9. Wilczek, F. *Nature* **391,** 123–124; **394,** 13–14 (1998).

NATURE

100 YEARS AGO

In India, as elsewhere, the general doctrine of disease prevails that all abnormal and morbid states of body and mind are caused by *demons*, who are conceived either as attacking the body from without, or as temporarily entering the body of man. The consequence is that primitive medicine consists chiefly in chasing away or exorcising these hostile spirits. This is done, in the first instance, by *charms*. The spirit of the disease is addressed with coaxing words and implored to leave the body of the patient, or fierce imprecations are pronounced against him, to frighten him away. But these charms, powerful as they are (in fact, there is nothing more powerful to the primitive mind than the human *word*, the solemn blessing or curse), are yet not the only resource of the ancient physicians or magicians. From the earliest times people had become aware of the curative power of certain substances in nature, especially of herbs. … The principle that *similia similibus curantur* prevails throughout the whole range of folk-medicine. Thus dropsy is cured by water.

From *Nature* 7 July 1898.

50 YEARS AGO

Previous methods do not appear to give any indication of how to distinguish between young and old Colorado beetles, except during the first few days following the emergence of the young beetle. I have found evidence that it is possible to separate young and old beetles for a period of at least fourteen days after the emergence of the young adult by means of colour changes in the membranous wings. This fact is of considerable practical importance and assistance to entomologists, especially in countries where the beetle has not yet become an endemic pest. … The membranous wings of the fresh emergent are transparent and devoid of colour, while those of the mature beetle are red except for the apex and anal border of the wing. The wings remain colourless for at least four to five days after emergence, and afterwards develop a pink colour which gradually deepens and diffuses over the greater part of the wing surface … until the pink colour has given place to a distinct red hue.

From *Nature* 10 July 1948.