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Relativistic astrophysics

Moving targets old and new

Virginia Trimble

MODERN astrophysics has no one holy grail to guide its searches in the way that much of particle physics is currently focused by the possibility of grand or super-unification of forces. Rather, many apparently separate goals flicker with varying intensity on the horizon. The reaching of a few of these goals, the unexpected retreat of others, and the establishment of some new ones highlighted a recent meeting*.

On the theoretical front, Robert Wald (Univ. Chicago) reported that B. F. Whiting (DAMTP, Cambridge) has, at long last, found an analytical proof of the stability of the Kerr solution against all possible perturbation modes. This means that a black hole, characterized from outside by only its mass and angular momentum, is a permanent possible final state for astronomical objects. How many actually exist?

Convincing black-hole candidates at the moment include only two or three X-ray-emitting components of binaries in Cygnus and the Large Magellanic Cloud, but Jeffrey McClintock's (Center for Astrophysics) analysis of the 1975 X-ray nova A0620-00 has added its compact component to the inventory as, in some ways, the most persuasive case. A neutron star identification for SS433, on the other hand, cannot be ruled out, according to Jonathan Katz (Washington Univ. St Louis), who also reported from a previous workshop that the evidence for a nuclear γ -ray line from SS433 has gone away. Since modelling the line (attributed to magnesium) had been so far a particularly elusive goal, its flickering out was greeted with relief.

Two effects, sufficiently ancient and honourable to have names, have been looked for yet again, one remaining undetected, the other apparently now seen in several objects. The Gunn-Peterson effect is the absorption of photons in quasar spectra shortward of 1,216 Å that should be produced by diffuse neutral hydrogen gas between us and the quasars. Charles Steidel and Wallace L. W. Sargent (California Inst. of Technology; *Astrophys. J.*, in the press) conclude that the true ultraviolet continuum of 3C9 at redshift $Z=2.016$ goes right through the top of the 'forest' of Lyman- α lines. This means that the only intervening hydrogen is that in the clouds producing those lines, the diffuse density being less than $3 \times 10^{-11} \text{ cm}^{-3}$. Diffuse neutral gas thus contributes less than one ten-thousandth of the matter density needed to close the Universe.

The Sunyaev-Zeldovich effect is also a product of diffuse gas, but in a hot, ionized state. Such gas, which reveals its presence in many rich clusters of galaxies by emitting X-rays, should Compton scatter photons from the 3 K microwave background up to much higher energies. The scattered photons will make an undetectably small contribution to visible, ultraviolet and X-ray light from the clusters, but their absence from the microwave flux in the direction of the clusters should be noticeable. Detection of the deficit would provide unambiguous evidence that the microwaves come from behind the clusters and so are truly a universal phenomenon, whereas accurate measurements of the deficit can, in principle, provide determinations of distances to the clusters and of the Hubble constant that do not depend on the usual uncertain scales. Such detailed measurements remain for the future, but Mark Birkenshaw (Harvard) reported temperature deficits of about 0.85 mK in the direction of three clusters, Abell 655, Abell 2218 and 0016+16. Previous reports of such deficits have been disputed, and so may this one.

The microwave background radiation ought to display other kinds of variations as well. Twenty years of searching have, so far, established unambiguously only a dipole anisotropy reflecting our own motion through the photon sea and none of the smaller-scale features that could probe structure in the Universe at the time galaxies were forming or earlier. The existing upper limits already severely constrain models in which galaxies evolve naturally from adiabatic perturbations in baryon density. David Wilkinson's (Princeton Univ.) review presented two tentative detections of fluctuations in the 3 K background, though neither pertains to the galaxy formation scale (near 10^4) and each has a possible alternative interpretation.

First, R. D. Davies and Anthony Lasenby (Jodrell Bank; also Davies, R.D. *et al. Nature* **326**, 462-465; 1987) have seen 0.1 mK differences between sky regions about 8° apart (the scale corresponding to the size of parts of the Universe in communication with themselves at the time the photons were last scattered). The possibility that the fluctuations merely represent lumpiness in bremsstrahlung emission from our own Galaxy (synchrotron can already be ruled out by comparison with existing maps) can and will be tested by mapping at 5 GHz as well as the original 10 GHz.

Also, Edward Fomalont and colleagues (NRAO) have looked on the 10-30''

scales mappable with the Very Large Array telescope and find fluctuations as large as a 1 mK, some of which undoubtedly simply result from faint sources scattered over the sky. Computer simulations, based on extrapolations of counts of radio sources at other wavelengths and brighter fluxes, indicate that there is a real, residual lumpiness in the background radiation. Again, maps at additional frequencies can help to separate the effects.

Among the receding goals are a resolution of the solar neutrino problem and a persuasive model of galaxy formation. Two leading contenders for reducing the detectable electron neutrino flux at earth are neutrino oscillations (which convert up to two-thirds of the emitted flux to undetectable μ or τ neutrinos in the solar mantle or *en route*) and various mechanisms that cool the solar core so that fewer neutrinos are produced in the first place. Because the latter reduces the high-energy neutrino fraction more efficiently than does the former, an experiment with a lower energy threshold than the 0.814 MeV of Raymond Davis's chlorine detector ought to be able to distinguish between them. Unfortunately, calculations of the sensitivity of the most promising candidate experiment (a gallium detector), as presented by Davis (Univ. Pennsylvania) show that some forms of each explanation predict essentially the same total count rates in gallium. Though the counts would come from different proportions of high- and low-energy neutrinos in the two cases, there is no way to distinguish them.

Attempts to combine assorted physical processes to produce galaxies without ruffling up the 3 K background too much have multiplied beyond counting (let alone reading!) in recent years. At the Texas Symposium in Jerusalem two years ago, the combination of hot dark matter to provide most of the gravitating mass and cosmic strings to trigger condensation looked very promising, but, two years downstream, computer modelling by Adrian Melott (Univ. Kansas) and others strongly suggests structures made this way will not much resemble the ones we actually see.

In two cases, theory and observation have advanced to meet each other so expeditiously that it is hard to say which was the goal and which the pursuit. It has been clear for many years that the radio-emitting regions of giant elliptical galaxies were, on average, smaller in the past, but just how much and why has been debated. G. Krishna and Paul Wiita (Georgia State Univ.) have modelled the interactions among intergalactic, galactic and relativistic jet gases to predict that radio source diameter should decrease with redshift ($= \text{distance} = \text{look-back time}$) as $(1+Z)^{-1}$. And P. Katgert (Leiden Observatory) presented a survey of radio galaxies at varying redshifts whose sizes do scale as $(1+Z)^{-1}$.

*13th Texas Symposium on Relativistic Astrophysics, Chicago, Illinois, 15-19 December 1986.

A second rapid convergence has occurred for binary X-ray systems in globular clusters. The first well-established binary period has been with us for less than a year (11.3 min for the source in NGC6624; W. Priedhorsky *et al.* *IAU Circ.* No. 4247; 1986). Jonathan Grindlay (Center for Astrophysics) announced the second (8.5 h for the source in M15, based on archival data from HEAO-1 and Einstein) and, in the same talk, provided a model in which the two represent different evolutionary phases of the same sort of object. The longer orbit period is identified as the earlier evolutionary phases, in which rapid

mass transfer is driven by nuclear evolution of the companion star. The establishment and expulsion of a common envelope around the two stars drains angular momentum from the system, leaving a short-period object in which mass transfer is driven much more slowly by gravitational radiation. Thus we expect that the M15 source should eventually resemble the NGC6624 one! □

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Natural selection

Did Komodo dragons evolve to eat pygmy elephants?

Jared M. Diamond

WHEN Komodo dragons, the largest living lizards, were discovered on a small, remote Indonesian island in 1910, there was astonishment that these carnivores (see figure), up to 3 m long and 100 kg or more in weight, could have escaped attention for so long. How did such a large carnivorous lizard obtain its food, and why had it evolved on Komodo? Accumulating information suggests that oras (to use the local name for these lizards) evolved to prey on now-extinct pygmy elephants.

Oras belong to the genus *Varanus* (monitor lizards), which arose in Indonesia and then spread to produce several dozen modern species from Australia to Africa¹. The name Komodo dragon (*V. komodoensis*) for oras is somewhat misleading, as the animals inhabit Komodo, the adjacent, much larger island of Flores and three other nearby small islands, all of which formed one land-mass in the Pleistocene, when the sea level was low. The most detailed information about their diet comes from Auffenberg's field work¹. Although hatchling oras eat insects and lizards, medium-sized animals eat rodents and birds and full-sized adults prey on and scavenge large mammals — mainly deer and pigs, but also buffalo, horses, goats

and, occasionally, people. Victims are either caught asleep or ambushed from about 1 m away. In several cases oras have been observed to seek out pregnant ungulates close to term, in order to seize the newborn, precipitate a miscarriage or attack the incapacitated mother.

A clue to the evolution of oras on the Flores island group is the former existence in Australia of an even larger monitor lizard, *Megalania prisca*, which was up to 6 m long and 2,000 kg in weight^{2,3}. Although Pleistocene Australia supported many large marsupial herbivores (giant kangaroos, wombats and rhinoceros-like diprotodonts), only two species of large marsupial carnivores, the Tasmanian wolf (*Thylacinus*) and the marsupial lion (*Thylacoleo*), evolved there to prey on those herbivores³. The large carnivore niche left otherwise vacant by Australia's inaccessibility to the placental carnivores of Asia was filled by the evolution of *Megalania*, which disappeared, together with marsupial lions and large marsupial herbivores, at the end of the Pleistocene.

Between the Australian and Asian continental shelves lies the island region known to zoogeographers as Wallacea, which consists of the Flores group, Timor, Celebes and other islands. Like Australia,

the islands of Wallacea were inaccessible to Asia's placental carnivores, but Wallacea was also inaccessible to Australia's marsupial carnivores. But monitor lizards, being good swimmers, were able to reach Flores and evolved into the ora to fill the large carnivore niche there, just as *Megalania* did in Australia.

This reconstruction faces two serious objections. First, all the large mammal species on which oras now prey were introduced to Flores by humans after BC 3000 (refs 4,5). What did oras eat before then? During the Pleistocene, Flores supported two species of now-extinct elephants, the small *Stegodon trigonoccephalus florensis* and the pygmy *S. sompoensis* (also called *S. timoriensis*)^{6,7}. Hence Auffenberg's suggestion¹ that oras evolved as a specialized predator on pygmy elephants, formerly the sole large prey available on Flores. Because the spread of humans from Asia through Wallacea reached Australia and New Guinea by BC 4000 (ref. 8), humans must have reached Flores at least by then. But it remains unknown how much earlier humans were on Flores, how long it took them to exterminate the pygmy elephants and what oras were eating during the time (if any) between the elephants' demise and the arrival of domestic ungulates around BC 3000.

Second, pygmy stegodonts formerly occupied at least three other Wallacean islands (Timor, Sumba and Celebes) plus the Philippine island of Mindanao, as well as Flores^{6,7}. Why are oras confined to the Flores group? In fact, there is an unsubstantiated modern report of oras from Sumbawa (the next large Wallacean island west of Flores), and large monitor lizards variously attributed to *V. komodoensis* or related species are found as fossils in Timor and Java¹. Thus, ora-like monitors were formerly much more widespread in the Indo-Australian region. Populations other than those on the Flores group must have been eliminated by climatic changes, extermination of their native prey species, and depredations by humans and their associated dogs, pigs and monkeys. Had Alfred Russel Wallace been able to make his famous journey through the Malay Archipelago 50,000 years ago, he might have found giant monitors harassing pregnant pygmy elephants on many islands. □

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IMAGE
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The monstrous Komodo dragon, with a hearty appetite.