quarks' and this was reflected in the more than 800 original papers presented at the conference.

On the more traditional cosmic ray stage Price and Shirk also presented data on the distribution of heavy nuclei ($Z>65$) in cosmic rays obtained from a 1.3 m^2 lexan detector aboard Skylab. These researchers have obtained data with very high charge resolution and conclude that the measured charge distribution in the vicinity of the Earth at ~0.5 GeV per nucleon strongly favours synthesis of these cosmic rays by the r-process (rapid neutron capture) within the last 10^7 yr.

Measurements of cosmic ray particles at very high energies ($>10^{17}$ eV per nucleus) are made indirectly by means of the extensive air showers (EAS) produced in the atmosphere. Conclusions on the composition of the particles at these energies are still far from definite. The energy spectrum of the primary particles is however, now becoming well established up to 10^{20} eV per nucleus. Further analysis presented by the University of Leeds group, using data obtained at the Haverah Park EAS detector array, gives added weight to the evidence against there being a cut-off in the energy spectrum $\sim 5\times10^{19}$ eV. Such a cut-off has been predicted to arise from the interaction of the microwave background radiation (2.7 K) and the cosmic ray particles. The absence of a cut-off seems to be inconsistent with the universal abundance of both the microwave photons and the high energy cosmic ray particles.

Moreover, strong evidence seems to be accumulating for a distinct anisotropy in the celestial arrival direction of the highest energy cosmic rays ($\sim10^{19}$ eV). As A. A. Watson (University of Leeds) emphasised, the two highest energy events recorded at Haverah Park ($>10^{20}$ eV) both come from directions close to the North Galactic Pole—strongly indicating a non-Galactic origin. Arrival direction analysis of 'muon-rich' EAS (Nottingham University group) gives indication that heavy cosmic ray primaries at lower energies (10^{17}–10^{18} eV) may also show anisotropy in a similar direction.

From both interest and necessity cosmic ray physicists have to concern themselves with high energy nuclear physics as well as astrophysics. Previous claims for the detection of tachyons and mandelas (heavy, long interaction length particles) in cosmic rays have unfortunately had to be withdrawn at this conference. Moreover none of the recent searches for fractionally charged quarks amongst the secondaries of cosmic rays have proved positive. Other new phenomena still do seem to be present at these energies, however, most notably the X particles discovered by the Japanese emulsion group. Also it seems to be increasingly difficult to reconcile EAS data with the sealing model of nuclear interactions. □

The breakdown of physics?

from Malcolm MacCallum

A Relativity Workshop was held at Gregynog Hall of the University of Wales on September 1–3.

"GOD not only plays dice. He also sometimes throws the dice where they cannot be seen." This statement is made by S. W. Hawking (Cambridge University) in his recent work on black holes. About eighteen months ago he demonstrated that quantum processes could lead to the emission of thermal radiation from black holes, so evaporating them. This showed that the formal analogies between entropy and the area of the hole, and temperature and the surface gravity of the hole, are genuine identities. Now Hawking has circulated two preprints which develop this argument, which were discussed along with related papers at the workshop.

In the first he discusses the thermodynamics of black holes. He interprets the meaning of the entropy in terms of lost information about the initial state, proves that the second law of thermodynamics holds, and proceeds to argue, by considering a black hole in a box, that as a consequence of time-reversibility and ergodicity the emission from white holes (the time-reverses of black holes) must be thermal, and that hence black and white holes are indistinguishable.

In the second—"Fundamental Breakdown of Physics in Gravitational Collapse"—Hawking proves that the radiation has thermal statistics as well as spectrum, in agreement with independent work of L. Parker (University of Wisconsin) and R. M. Wald (University of Chicago). He argues that the random loss of information into the black hole implies the breakdown of S-matrix theory and that a density matrix formulation is all one can give. By considering further the white hole in a box he infers a 'Randomicity Principle' that singularities emit all possible configurations with equal probabilities, as pithily described above. Hawking asserts that this is necessitated by CPT invariance or by the non-existence of perpetual motion machines.

B. F. Schutz (University College, Cardiff), the organiser, opening the conference, pointed out that these two papers re-established the primacy of the thermodynamics. Various speakers emphasised the heavy dependence of Hawking's arguments on the full applicability of standard thermodynamic results such as the meaning of entropy and the ergodicity theorem, and questioned the correctness of these assumptions. Schutz pointed out that application of Hawking's black hole calculations to white holes led to a burst of radiation with Rayleigh-Jeans spectrum at infinite temperature, resulting from particle creation from an initial vacuum. This might upset the thermal nature of any emission from within the hole itself. Schutz suggested some ways out of this difficulty, including the existence of a remnant black hole after the white hole explosion. C. J. S. Clarke (University of York) similarly suggested that a black hole evaporation must leave behind a naked singularity.

M. Perry (Cambridge University) presented some work on the modification of Hawking's picture to allow for strong interactions between the particles produced at high temperatures. Unless a very soft equation of state is used, the only consistent picture is that this is unimportant.

R. Penrose (Oxford University) expressed disquiet with the idea of black holes in boxes re-forming by the time-reverse of the evaporation process, which is important to Hawking's argument about equivalence with white holes. He also offered a modification of Hawking's proposed fluctuation mechanism for temporary destruction of the black hole, and various participants did back-of-envelope calculations to substantiate his point.

S. Fulling (King's College, London) and P. Candelas (Oxford University) gave talks on the technical aspects of quantum field theory in curved space-time, focusing on the definitions of the creation and annihilation operators and the vacuum state, and on the Feynman propagator. These talks explored, *inter alia,* the fact that incautious use of Rindler coordinates in flat space produces results inequivalent to the usual quantisation. Fulling showed that the treatment of the Hawking mechanism due to D. G. Boulware (University of Washington), which predicted no radiation, has failings of this kind.

The meeting was highly informal and many short contributions were made in discussion. The consensus seemed to be that the broad sweep of Hawking's ideas involved a great many interesting points, whose further examination was necessary. This will be an extensive programme since conceptual problems in general relativity, in thermodynamics and in quantum theory and their relation with general relativity, as well as difficult calculations, will be involved. The meeting helped greatly in clarifying some of the questions to be studied. □

©1975 Nature Publishing Group