magnetic and electric quadrupole moments of the W boson.

At UCLA, Hiro Aihara (Berkeley) and Theresa Fuess (Argonne) summarized the CDF and D0 results from the 1992-93 run. Information on potential ZZ-gamma interactions can also be gained from single photon production at CERN's LEP electron-positron collider, as detailed by Peter Maettig (Bonn), and from rare B meson decays, reviewed by Steve Playfer (Syracuse).

Theoretically, the production of W-gamma and WZ pairs in hadronic collisions is of special interest due to zeroes when effects cancel each other out. These correspond to the absence of dipole radiation by colliding particles with the same charge/mass ratio, and are a sensitive test of the electroweak picture. The theoretical foundations of these zeroes were reviewed by Robert Brown (Case Western), while Tao Han (Davis) discussed ideas and developments to verify the effects experimentally.

Wider theories give more scope for deviations from the electroweak picture. However, if the scale at which new physics becomes apparent is of the order of 1 TeV, as is widely believed, such deviations will be much smaller than current experimental limits.

Future experimental data from vector boson pair production processes, however, are expected to dramatically improve the present limits. Numerical simulations, described by several speakers, indicate that new data at the Tevatron and LEP2 will be able to provide a 10% measurement of the self-couplings of W, Z and photons, whereas CERN's LHC proton-proton collider and a linear electron-positron collider with a collision energy larger than 500 GeV would reach sensitivities of better than 1% and 0.1%, respectively. Important cross-checks could also come from HERA electron-proton experiments.

While probing the self-interactions of W and Z bosons may not be the best way to discover new physics, as emphasized by summarizer Ian Hinchliffe (LBL), it constitutes a very important test of the electroweak picture. Furthermore, the experimental techniques developed to perform these precision measurements will be useful also in the search for the higgs boson and for new physics.

From Ulrich Baur, Steven Errede and Thomas Mueller

Primordial nuclei

The recent detection of intergalactic helium by NASA's Astro-2 mission backs up two earlier measurements by ESA and the University of California, San Diego, using instruments aboard the Hubble Space Telescope. Taken together, these results give strong evidence that this helium is primordial, confirming a key prediction of the Big Bang theory. The amount of helium the results imply could also account for some of the Universe's invisible dark matter - material which affects galactic motion but is otherwise undetectable.

According to theory, helium nuclei formed at around 100 seconds after the Big Bang, but the amount of helium depended on even earlier events. Initially, protons turned into neutrons with the same probability that neutrons turned into protons. But after about one second, the Universe had cooled down enough for the weak interaction to freeze out. Neutrons continued to decay into the slightly lighter protons, whilst the opposite reaction became much more scarce. At around 100 seconds, thermonuclear fusion reactions could begin, and all the neutrons that were left became absorbed into helium nuclei, leaving the remaining protons locked up in hydrogen.

The ratio of helium to hydrogen was therefore determined by events occurring when the Universe was just one second old. Standard models of primordial nucleosynthesis fix this ratio at slightly less than 25% by mass. All heavier elements were cooked up much later in the stars, and amount to less than 1% of the Universe's mass. These predictions have been borne out remarkably well by observation, although proof of the primordial origins of hydrogen and helium has remained elusive until now. Big Bang nucleosynthesis goes on to estimate that primordial baryonic matter in the form of light nuclei could account for around 10% of the Universe's dark matter.

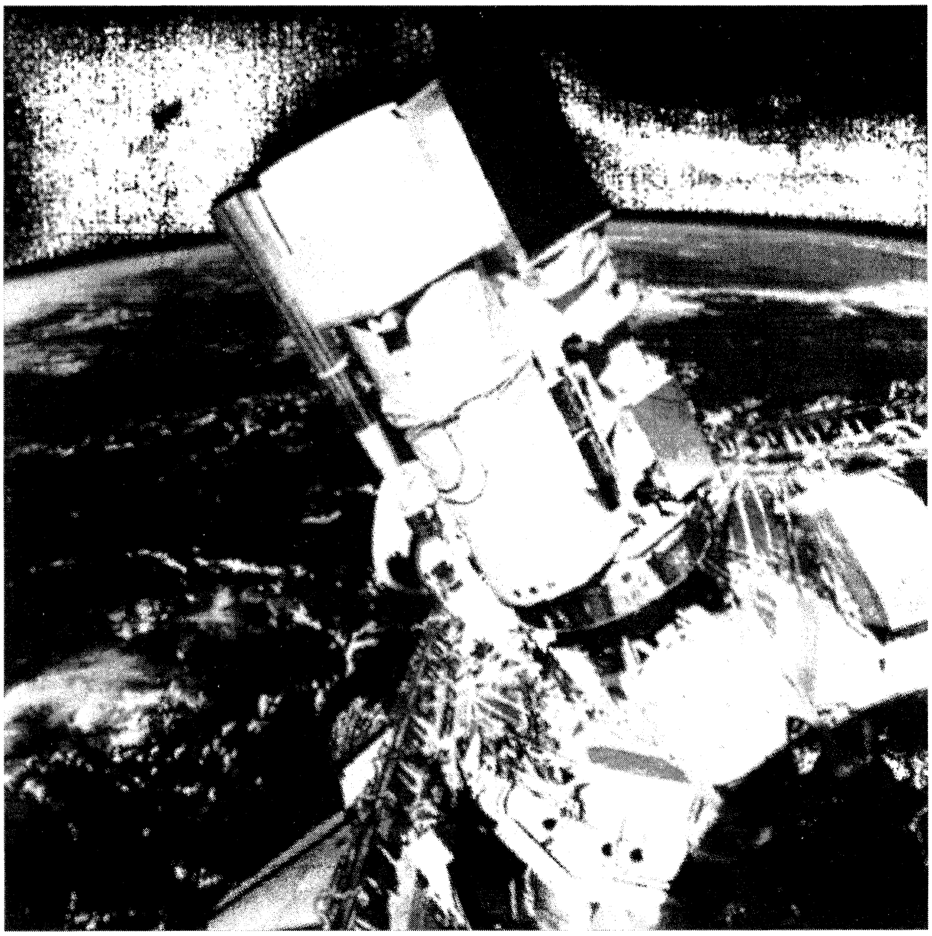
All three recent measurements used the same technique of looking at distant quasars, some of the most luminous objects in the Universe, to search for the wispy intergalactic medium. This was first applied 30 years ago by James P. Gunn and Bruce Peterson to look for neutral hydrogen. They reasoned that if hydrogen existed, it would absorb characteristic wavelengths of the quasar's spectrum as the atom's electron moved from orbit to orbit, removing spectral lines. When their search revealed nothing, it was postulated that in the extreme heat of the early Universe, all the hydrogen would have remained ionized, and therefore unable to absorb the quasar's light. So the hunt then switched to helium.While this normally has two electrons, it could have existed in a partially ionized state with just a single electron.

The first successful detection of this spectral absorption came in January 1994 when an ESA group looked at quasar Q0302-003 using the Hubble Space Telescope's (HST) Faint Object Camera. The number of suitable quasars available for Hubble to study is limited by the instrument's sensitivity. Such quasars must be very distant, and therefore receding very fast, giving a high redshift so that the quasar's absorption lines are redshifted into the range of the telescope. To compound the problem, they must also be unobscured by intervening galaxies. Quasar Q0302-003, with a redshift of 3.28 (some 10 billion light-years away), appears to be just such an object, and the absorption occurs exactly where calculations predicted it would.

When the ESA group's results were first published, and later backed up by the San Diego measurement using HST's Faint Object Spectrograph to observe another high redshift quasar, they were hailed as the first detection of the diffuse intergalactic medium. But the case was not yet proven, since similar absorption could have been caused by intergalactic gas clouds.

NASA's Astro-2 measurement in March this year chose a nearer quasar, HS1700+64, with a redshift of 2.73. This is a much brighter quasar than those used in the two previous measurements, and so provided a clearer signal. Nevertheless, the NASA result suffers exactly the same dilemma as ESA's; is the absorption due to gas clouds, or does it really come from the intergalactic medium between the clouds?

According to the Big Bang model, the more remote the galaxy, or equivalently, the higher the redshift, the more helium should be visible (up to a certain limit), because less of it will have been mopped up by nascent stars. This is precisely what the combined ESA and NASA results appear to show. There is still some debate about the precise nature of this helium, however. Could some, or even all of the absorption be due to clouds of gas obscuring distant quasars, or has the diffuse intergalactic medium finally been discovered? The answer has important consequences for the amount of baryonic dark matter locked up between the galaxies, but either way these results represent another feather in the cap of the Big Bang model.



The Hopkins Ultraviolet Telescope, seen here aboard the Space Shuttle Endeavour, provided a clear detection of intergalactic helium during NASA's Astro-2 mission earlier this year. This result, combined with earlier measurements made by ESA and the University of California, San Diego, brings important evidence for the Big Bang origin of the Universe.

(Photo Johns Hopkins University)