

Astronomy sets new targets

This month Astrowatch travels to Manchester for the meeting of the International Astronomical Union. *Emma Sanders* reports on two weeks of discussion and discoveries, from the distant universe to new planets on our doorstep.



A cosmic milestone: the Hubble Space Telescope detects Cepheid variable stars in the spiral galaxy NGC 4603. (NASA/ESA.)

Recent years have seen a transformation of many areas of astronomy. New instrumentation makes arcsecond resolution almost commonplace across the whole electromagnetic spectrum, where previously it was the domain of just radio and optical observations. New satellites have opened up windows on the universe in wavelengths such as ultra-violet, X-ray and infrared, where little was previously known. The International Astronomical Union conference in Manchester

underlined the new science that can now be done. New precision measurements are settling old problems – how galaxies formed, how the universe will end – and providing new tests for fundamental physics, such as general relativity and magnetic field theory.

Cosmological parameters

“We are entering a new era of precision cosmology,” said Malcolm Longair of Cambridge, kicking off the session on New Cosmological

Data and the Value of Fundamental Parameters.

His remark provoked a response from Wendy Freedman of Carnegie Observatories in the conference newsletter. She pointed out the need to control systematic effects and to target high accuracy as well as precision. She noted welcome progress with new experiments designed to reduce the systematic errors that have historically dogged all measurements of cosmological parameters. “My ▷

Meeting highlights

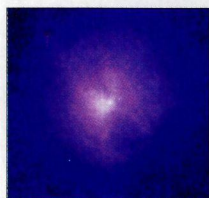
"For me the highlight has to be the convergence of different cosmological parameters: microwave background measurements, supernovae studies, large-scale structure and gravitational lensing...all the numbers agree!"

Virginia Trimble, chair of the Division of Astrophysics of the American Physical Society, works at California, Irvine

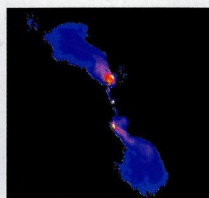
"I'm very excited about the discovery of a planet around Epsilon Eri, because it's an old friend – I have studied it in the past."

Indeed, the discoveries of no fewer than nine new planets were announced in Manchester. Epsilon Eriidani is particularly interesting as it has a size and orbit similar to those of Jupiter and the observations suggest that there may also be an Earth-sized planet orbiting the central star.

Carole Jordan, University of Oxford



X-ray image.
(Chandra/NASA.)



Radio image.
(VLA/NRAO.)

"With the first results from Chandra and XMM, it is the first time there is comparable resolution between X-ray and radio observations. One thing I learned this morning was that new X-ray maps of galaxy clusters show the holes where the hot X-ray emitting gas of 100 million degrees has been blown out by the relativistic plasma in the radio jets...they match perfectly with the radio images!"

Sir Martin Rees, Institute of Astronomy in Cambridge

own definition of precision would be restricted to measurements at the few percent level, and we are not there yet," she said. "However, I



The Antarctic launch site of the Boomerang balloon-borne mission.

believe we have entered the realm where 10% measurements are possible and factors of two are behind us."

The Hubble constant This sector is an excellent example of such new optimism. Hubble's law states that the further away a galaxy, the faster it appears to recede. The constant of proportionality – the Hubble constant – fixes the age of the universe.

After years of conflict between those who believed the Hubble constant to be 50 and those who found 100, different determinations of this fundamental distance measure are now converging on a value of around 75. Freedman used a new calibration of the period-luminosity relation for Cepheid variable stars and got a value of 75 ± 10 using data from the Hubble Space Telescope. The big uncertainty now comes in the local calibration of the Cepheids: if we knew the exact distance to our nearest neighbour galaxy (the Large Magellanic Cloud), the uncertainty in the Hubble constant would be less than 5%.

However, a word of warning came from Tom Shanks of Durham. The method of using Cepheid variables as standard candles is highly dependent on the composition of these stars: estimations of distances could be in error by as much as 25%.

The symposium also highlighted recent progress in measuring the Hubble constant using the Sunyaev Zel'dovich effect. This occurs when hot gas in clusters of galaxies

scatters the cosmic microwave background (CMB) radiation. Values for the constant of 75 and 65 were reported with uncertainties of around 15%. The accuracy of this technique will improve as the resolution of X-ray telescopes increases.

The problem of the oldest stars appearing older than the universe (the "old wine in new bottles" dilemma) seems to have been solved following adjustments of the local distance scale after the Hipparcos mission. Calculations now place the oldest stars at $11-12 \times 10^9$ years old, consistent with the latest value for the age of the universe.

The microwave background Observations of the CMB are the closest that astronomers can get to the beginning of the universe. The CMB dates from 300 000 years after the Big Bang, when radiation uncoupled from matter.

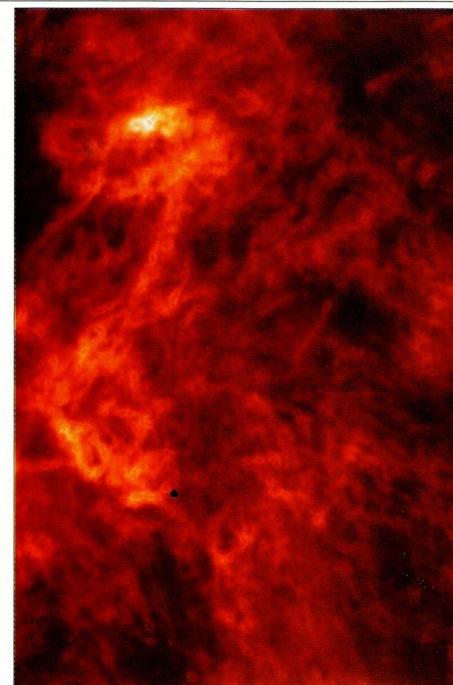
Experimental advances in CMB astronomy mean that high-resolution maps of the sky are becoming available for the first time. The conference was excited about results from the Boomerang and Maxima balloon missions (March p12).

The balloon results have confirmed an overall picture of a spatially flat universe, where $\Omega = 1$ (where Ω is the ratio of matter in the universe to the critical level needed to halt the universe's expansion). This is consistent with the inflation model of the Big Bang.

"The glorious thing is that the peak is right where it should be," said Jim Peebles of



The interacting antennae galaxies imaged by the Hubble Space Telescope. In the infrared, the point between the two galaxies contains 50% of the total luminosity because a bright starburst is completely hidden by the dust. (NASA/ESA.)



Infrared image of the sky from the old IRAS satellite. ISO improves resolution by a factor of 100, showing the background to be composed of many discrete sources. (IRAS.)

Princeton, commenting on the CMB angular power spectrum. The peak shows that the characteristic scale of coherent patches on the CMB sky is about one degree.

However, there are calibration problems with the balloon experiments. Paul Richards from California commented that, to obtain the fit, it was necessary to reduce the values found by Maxima by one standard deviation (8%) and increase those from Boomerang by one standard deviation (20%).

The next set of detectors is not far behind. Three different interferometer arrays will survey small patches of the CMB: the Cosmic Background Imager, the Degree Angular Scale Interferometer and the Very Small Array (November 1999 p13). These instruments are best for the detailed study of CMB structure. Astronomers are eagerly awaiting the next meeting of the American Association for the Advancement of Science in February 2001, when the first results are expected.

An accelerating universe Large-scale structure surveys, such as the Anglo-Australian 2dF and the US Sloan Survey, are starting to yield their first results, giving a better understanding of the evolution of large-scale clustering. Astronomers do not observe enough baryonic or dark matter in the universe to account for a Ω value of 1. This has led to a resurrection of the "cosmological

constant" – a kind of vacuum energy density that changes the acceleration of the universe.

This picture is confirmed by observations of type 1a supernovae, which have always essentially the same luminosity and can therefore be used for distance calculations. Observing how their light is redshifted shows how much the universe has expanded. Saul Perlmutter of Berkeley told the conference about plans for a space-based supernova detector called SNAP (SuperNova Acceleration Probe), which would dramatically increase both the statistics – detecting up to 2000 supernovae per year – and the redshift of the supernovae observed.

"What's amazing now is that different lines of analysis are coming together in a story that agrees with what theory tied down years ago," Peebles told *CERN Courier*. "This is deeply impressive and has caused me to up my grades," he said. "A year ago I was against this convergent model; now, if I were writing a report card, I'd say: 'Lambda [cosmological constant] shows great promise, low mass density – very good, homogeneity – excellent!'"

In his summary of the symposium on fundamental cosmological parameters, Martin Rees of Cambridge brought the meeting back down to the ground. It's all very well measuring these parameters with incredible precision, but

maybe what we are observing now is just a special case. Just as the ellipse of the Earth's orbit changes each time, are there lots of different versions of these "fundamental" parameters? He added that, in his view, there were two types of cosmologists: the theoretical astrophysicists and the mud wrestlers. He included himself in the latter category.

The formation of galaxies

The optimism from cosmologists was not mirrored in the sessions on the extragalactic infrared background. "We still don't have the right story for how galaxies form," said Peebles.

Michael Harwit of Cornell set the meeting some ambitious targets. What were the first galaxies and how did they evolve? When did stars start to form and how can we explain the distribution of the heavy elements that we observe today? Our understanding of the evolution of galaxies and stars is far from complete and observations are fraught with difficulties. Important clues are certainly to be found in the cosmic infrared background, first detected in 1996. The infrared emission comes from light reprocessed by dust.

Reviewing the current state of affairs, Peebles explained that, looking back to a redshift of 1, galaxy formation had already

finished – galaxies looked as they do today. However, models of star formation suggest that approximately half of all stars formed after this time.

Even less well understood is the nature of galaxies between a redshift of 1 and 2. "Is this the era when galaxies formed?" asked Peebles, "and if the first galaxies were formed by dark matter halos merging at high redshift, why don't we see knots of mass at such distances that would be evidence of this kind of merger?" Different presentations underlined the difficulty in estimating star light in real terms – some estimations varied by a factor of two.

Michael Rowan Robinson from London's Imperial College commented that the majority of the mass of the universe is in low-mass stars that are in low-mass, gas-rich spiral galaxies. High-mass elliptical galaxies formed during the early part of the universe, then after a redshift of 1 came the low-mass stars.

Infrared surveys Catherine Cesarsky, director of the European Southern Observatories (ESO), spoke of a survey conducted at a 15 μm wavelength using ISOCAM, the camera on board the Infrared Space

Observatory. A total of 1000 galaxies were observed and the team was looking for comparisons in the Hubble deep field of distant galaxies. She found that the galaxies got brighter as their redshift increased. Most were members of a class of ultraluminous infrared galaxies with a density peak between redshifts of 0.7 and 0.8. These galaxies have been resolved for the first time and account for about 50% of the infrared background radiation. Their study will reveal much about the origins of galaxies that we see today.

Later, Simon Lilly of Toronto explained how he combined results from ISOCAM with observations using SCUBA, the infrared camera on Mt Wilson. This, Cesarsky told *CERN Courier*, was her highpoint of the symposium. She was enthusiastic about the possibilities revealed by the ISOCAM survey, which bode well for similar studies at other infrared wavelengths. "To understand what is going on we really need to find out what the infrared sources are. This is what we are now starting to do for the first time." Cesarsky is keen to work with ESO's Very Large Telescope on the optical identification of ISOCAM sources.

Rees stressed the need to push the observational boundary even further to improve the study of the early galaxies. "The Next Generation Space Telescope will be detecting pregalaxies in the infrared beyond redshifts of 5 – high redshift galaxies are only 1 arcsecond across and very weak, so we need better sensitivity and resolution," he said.

NASA's Space Infrared Telescope Facility (SIRTF) is scheduled for launch in December 2001 and ESA is preparing the Far Infrared and Submillimetre Telescope (FIRST), which is due to be launched in 2007.

The latest advance in instrumentation was a key theme running through the whole conference. Nowhere was this more obvious than in the session on galaxies and their constituents at the highest angular resolutions. This will be covered in part two of the IAU meeting report in next month's *CERN Courier*. Discover the latest observations of black holes, megamasers and jets, and find out about new IAU president Franco Pacini's plans for greater collaboration between particle physics and astronomy.

Emma Sanders, CERN.

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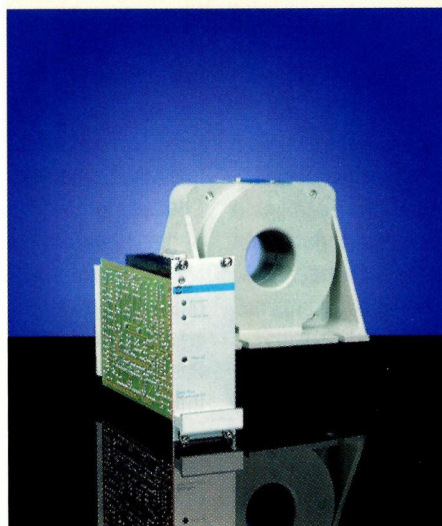


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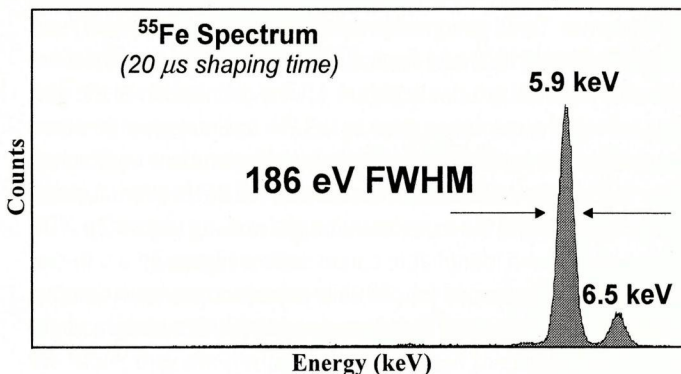
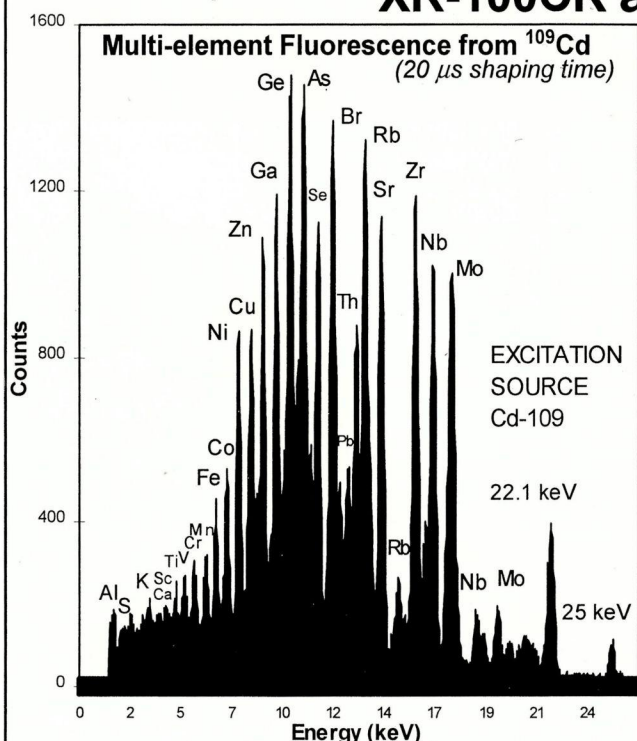
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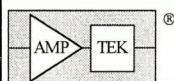
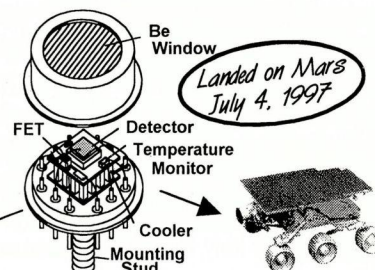
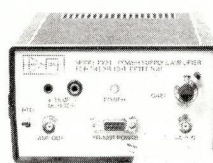
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