Cosmic Rays : Perspectives for the Future

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***Abstract*— A brief summary is given of the author's 'perspectives for the future'. Essentially, they represent a recommendation that effort should be devoted to some of the great problems of science, from 'the Origin of the Universe' to the Earth's Climate.**

I. INTRODUCTION

'Perspectives for the future' are safer to make than 'predictions for the future', but not much. Concerning the latter, some of the greatest names in science have made very unfortunate predictions and I have listed these in the Appendix. They show the hazards in making any sort of predictions or even perspectives. Thus, I tread with care.

II. THE PERSPECTIVES TO BE EXAMINED

My recommendation is that we should tackle some of the great problems of science, including:

1 The Origin of the Universe
2 Cosmic Rays and Climate
3 Structure in the CR Energy Spectrum
4 CR of the highest energies.

III. THE ORIGIN OF THE UNIVERSE

Figure 1 shows the so-called WMAP-3 (1,2) derived from 3-years' worth of data. Its pattern is very well known and its study has led to the development of a specific model of the origin and early development of the Universe. The map relates to temperature variations (red, hot; blue, cold) in the Cosmic Microwave Background. The variations are several times 10^{-5} of the mean temperature.

In the map, the lines represent mean polarization directions. Insofar as there is a marked difference in the spread of directions between the Inner and Outer Galaxy it is very likely that there is still some Galactic contamination, a result that confirms our earlier analysis [3] of the first year's worth of data which showed a variety of Galaxy-related features.

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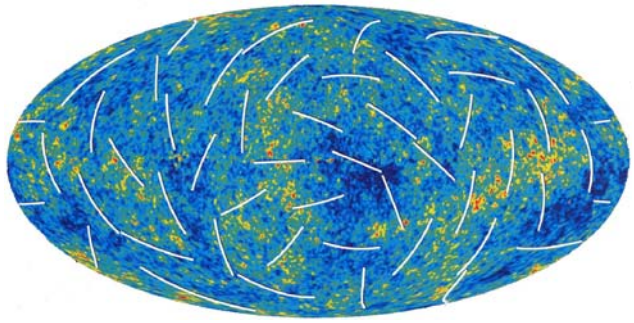

Fig 1 Fluctuations in the Early Universe (WMAP-3). The vectors correspond to mean polarization directions.

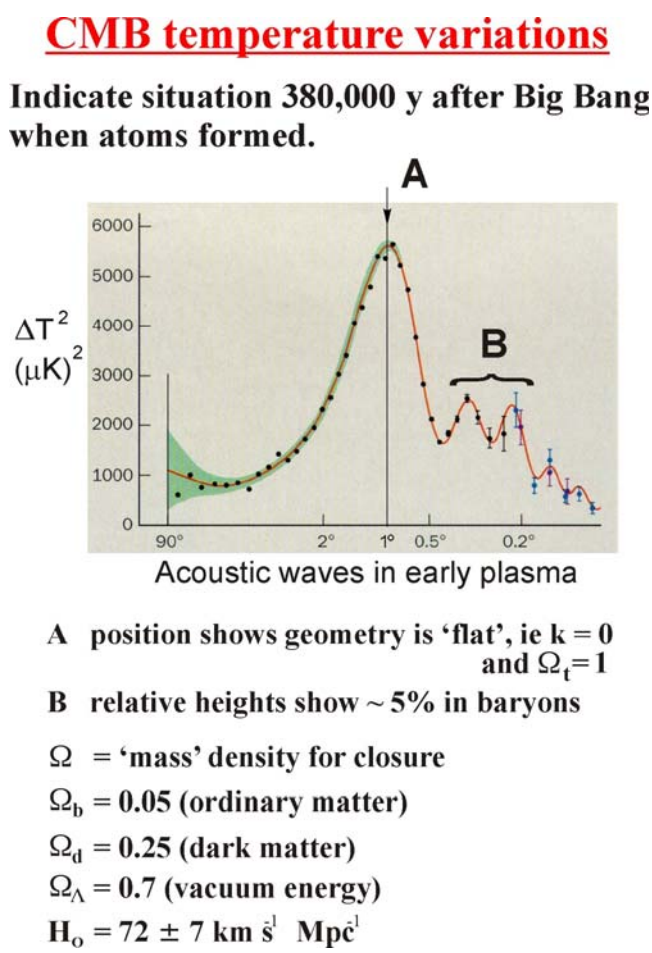

Fig 2 The power spectrum for the fluctuations in Figure 1. The information derived from the peaks is shown in the list. The omega values and the value of the Hubble constant, H_0, come from the parameters of the power spectrum plus data from other sources.

Figure 2 indicates the physics gained from its study, some of the parameters being derived from the addition of other results, too.

The map, of course, relates to radiation emitted at the very early epoch when the temperature dropped sufficiently for atoms to form. Now 'cosmic rays' come into the argument in a number of ways.

Firstly, we have consideration of the period when the plasma was 'condensing out' into atoms. It seems inescapable that there should have been non-Maxwellian tails to the distributions (viz low energy cosmic rays) which should be included. They seem not to have been.

Secondly, we have the rather more straightforward problem of the Galactic foreground to the CMB measurements. Since we see the CMB from a point immersed in the Galaxy, it would have been remarkable had there not been a contribution from cosmic rays. There is, of course, such a contribution and this is caused by electron synchrotron at 'low' frequencies (mainly below 60 GHz) and dust emission, mainly at higher frequencies. The dust is heated, in part, by cosmic rays. The experimenters themselves endeavour to remove the cosmic ray signal but the removal is model-dependent. We, Wibig and Wolfendale [3], claim that there is a serious Galactic signal remaining and that this is due either to cosmic rays or something mirroring it. An interesting feature is that when adding the synchrotron and the dust spectra the result is a spectrum of similar shape to that of the CMB in the region of the important optimum frequency of 60 GHz.

This area will be of increasing importance as CMB measurements of higher and higher precision are made.

If, in fact, the Galactic foreground is bigger than had previously been thought then the integrated contribution of other galaxies and clusters of galaxies will be similarly larger – and significant.

There are also other areas of cosmology involving galaxy – and star-formation where cosmic ray effects are expected.

This whole area is ripe for exploitation by cosmic ray astrophysicists.

IV. COSMIC RAYS AND CLIMATE

I start with a quotation from Gordan Manley, a distinguished Geographer who contributed mightily to the subject by producing a very carefully cross-calibrated survey of mean UK temperature over the past 200 years, and more.

> "I feel strongly… no heedless drawing of frontiers between subjects… the geographer can, and should, carry his capacity for integrating observed material to that of integrating results derived from the peripheral sciences."
>
> (*G Manley, Inaugural lecture, Bedford College, London, 1950's*)

We can regard physics and astronomy as being 'peripheral sciences in this context'!

My perspective is that the astrophysics/climate connection will soon be a powerful growth area in our subject. Certainly, in view of global warming, the topic is of considerable importance.

I will take just one example, the by-now well known relationship between cloud cover and cosmic ray intensity. Figure 3 shows the situation. For this period at least there is strong correlation between the cosmic ray flux (from the Climax-neutron monitor) and low cloud.

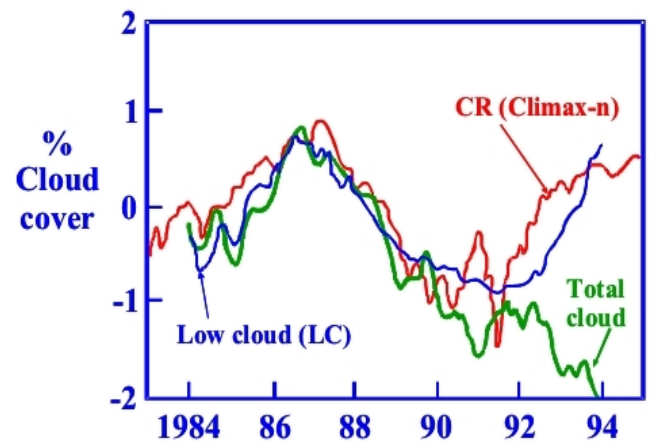

Fig 3: Correlation of cloud cover over the oceans with the cosmic ray flux (CR (Climax-n)), ie the flux derived from neutron monitor data. The correlation is best for low cloud.

This is exciting but worrying. The worry comes from the fact that the ionization produced by cosmic rays is mainly at great heights, ~10 km, whereas low clouds are at perhaps l km. Efforts are currently being made to solve this problem and also a related one of the correlation of mean temperature with zodiacal dust.

The full explanation of global warming hangs in the balance.

V. STRUCTURE IN THE COSMIC RAY ENERGY SPECTRUM

Important information is available in the detailed shape of the CR energy spectrum. Well known are the 'knee' and 'ankle' but there must be other 'structure', too. Even the two known features have not yet been studied adequately; many experiments have detected them but the numerical 'sharpness', ie the second differential of the log intensity versus log energy, is rarely given. This quantity is an important diagnostic and should surely be quoted [see, eg 4,5]

VI. THE HIGHEST ENERGIES

The need for more data on the showers produced by particles of the highest energies is self-evident and such data are slowly being accumulated. Studies on related topics are less common, however; these include the likely distribution of magnetic fields in the intergalactic medium and that of the spatial distribution of likely sources. The environments of the

sources (such as AGN in galaxy clusters) are also of considerable importance insofar as interactions of energetic particles with the ambient radiation fields (IR) will be important [6].

A whole neglected, and difficult, field is the likelihood of extragalactic intermittent sources. Likely sources, such as galaxy-galaxy collisions and AGN (which are commonly 'on' for only about 1% of the time) should leave rather specific 'signatures'.

Hopefully, measurements will allow a distinction to be made between the different models.

The measurement, so far, of featureless spectra in the Auger experiment, yet differences in energy estimates using different combinations of measured quantities, alerts us to the continuing need to study variants of the contemporary interaction models. Interesting suggestions have already been made [7] but much more needs to be done.

VII. Conclusion

The perspectives just described are necessarily incomplete and brief. However, it is hoped that what shines through is that the subject is in a healthy state, with research needing to be intensified in many areas, including some that relate rather strongly to the human condition.

APPENDIX

'Heavier than air flying machines are impossible'.
(Lord Kelvin, 1885)

'I have not the smallest molecule of faith in aerial navigation other than ballooning'.
(Lord Rayleigh, 1889)

'The abdomen, the chest and the brain will forever be shut from the intrusion of the wise and humane surgeon'.
(Sir John Erickson, Surgeon Extraordinary to Queen Victoria, 1873)

'Anyone who expects a source of power from the transformation of [the nuclei of] atoms is talking moonshine'.
(Lord Rutherford, 1933)

'A few decades hence, energy may be free, just like unmetered air'.
(J. Von Neumann, 1956)

'The possibility of travel in space seems at present to appeal to schoolboys more than to scientists'.
(Sir George Paget Thomson, 1956)

'Space-travel is utter bilge'.
(Sir Richard Van Der Riet Woolley, Astronomer Royal, 1956)

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