The Extragalactic Infrared Background and its Cosmological Implications
IAU Symposium, Vol. 204, 2001
Martin Harwit and Michael G. Hauser, eds.

The Structure of Symposium 204

Martin Harwit
511 H Street, SW, Washington, DC 20024-2725, USA; also Cornell University

Abstract. The extragalactic infrared background touches on many topics: The rate at which energy was generated in stars at different epochs; the corresponding number counts of galaxies observed at different redshifts; the related rate at which non-primordial helium and the heavy chemical elements were produced at these same epochs; the abundances of these elements that can be found in damped Lyman-alpha absorbers at commensurate redshifts; the abundances of the same elements in Galactic stars formed at similar epochs; the integrated supernova rates over all epochs, and the number of neutron stars and black holes in our locale within the Universe today. The distances from which TeV gamma-rays at different energies can reach us are also intimately related to the infrared background spectrum. The purpose of this Symposium was to seek a coherent picture into which all these pieces of observational evidence can be satisfactorily fitted. This was the rationale in setting up the invited talks.

1. Introduction

Over the past three years, observations carried out with the Cosmic Background Explorer, COBE, in the early 1990's have begun to yield increasingly reliable measurements of the strength and spectrum of the diffuse cosmic infrared background. The origin of this background is still vigorously debated, making Symposium 204 both timely and instructive. The structure of the Symposium (Figure 1) was designed to bring together experts from a variety of different fields with distinct skills and independent perspectives.

The diffuse infrared background radiation reaching us from the cosmos reflects the history of the Universe since the first stars and galaxies began to shine. Jim Peebles was asked to launch the Symposium with a talk on "Keeping Book on the Universe", to summarize our knowledge at the start of our discussions. In the three-and-a-half days to follow, we considerably advanced our understanding of the background through presentations of new results and lively debate.

Early attempts to measure the infrared background were thwarted by the Earth's atmosphere, which is largely opaque to infrared radiation. To overcome this difficulty we constructed instruments to be flown above the atmosphere. The first rocket payloads, however, revealed a further impasse. A cloud of tiny dust grains orbiting throughout the Solar System brightly radiates at infrared wavelengths. This zodiacal dust emission, first fully mapped by the Infrared

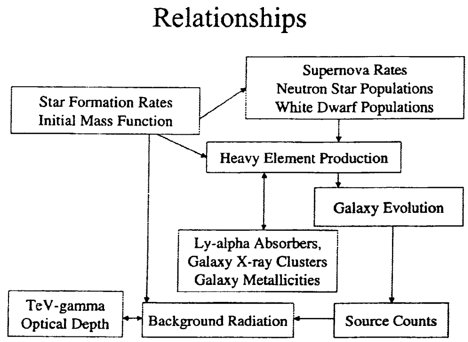

Figure 1. Block diagram illustrating the relationship between different fields of research.

Astronomical Satellite, IRAS, had to be modeled and subtracted out, before a diffuse glow from greater distances could be detected. But then radiation emitted by the Milky Way's myriad stars and diffuse clouds of dust revealed itself as a yet another dominant hindrance. This again had to be modeled and subtracted before the faint infrared glow of cosmic origin could be extracted. The Symposium's first morning session was dedicated to a thorough discussion on how to best model the extraneous foreground emissions in order to reliably establish the spectrum and strength of the ubiquitous infrared background.

Powerful optical telescopes on the ground and in space have permitted us to count individual galaxies out to great distances and to measure their brightness. Does the sum of the inferred infrared emissions add up to the background observed by COBE? Or is there an even more diffuse component we have not yet identified? To resolve such questions, galaxies ranging out to the greatest distances, highest redshifts, and earliest stages in the evolution of the Cosmos have been inventoried in the past few years, with the Hubble Space Telescope, the Infrared Space Observatory, and a variety of optical, near-infrared and submillimeter observatories on the ground. The Symposium was designed to bring together all the latest results on galaxy counts at different wavelengths and the redshifts associated with these sources. This should encourage comparisons, help to resolve differences, and determine the extent to which discrete sources observed to date might account for the estimated background.

Present indications from surveys conducted at wavelengths ranging from the near-infrared to the submillimeter regime yield a picture in which the most prominent sources, perhaps the most powerful contributors to the background, appear to be galaxies in collision. But what produces the observed energy outflow? Is it the formation of supermassive, highly luminous stars or could it be the accretion of giant black holes in the nuclei of these active galaxies?

Recent observations from the Chandra X-ray observatory indicate that much of the X-ray background emanates from active galactic nuclei, but that the spectrum of the background differs from that of the AGNs in a way that suggests strong absorption of X-rays within these sources. This could imply that these AGNs are dusty and that the absorbed radiation may be emitted in the

https://doi.org/10.1017/S0074180900225837 Published online by Cambridge University Press

infrared. The total X-ray background, however, is substantially weaker than the observed infrared background, giving a first indication that the infrared radiation may largely come from massive stars. Richard Mushotzky told us about these observations as well as a follow-up with the Submillimeter Common User Bolometer Array, SCUBA, which shows that very few of the X-ray sources are detected at submillimeter wavelengths, and vice versa.

But what about starburst galaxies? Massive stars cannot shine without producing and explosively ejecting heavy elements. If the bulk of the background is produced by distant, luminous stars, then the star formation rate observed at each epoch, should be precisely commensurate with an enrichment of the elements helium, carbon, oxygen and iron, as the Universe evolves. To bring clarity to this issue, several talks on the chemical composition of the cosmos at different redshifts were included.

Any science is fortunate if it can face a moment of truth. Our colleagues working with huge ground-based arrays capable of detecting terravolt gamma-rays are gearing up to check on our best estimates based on direct infrared observations. To date, the most distant galaxy detected at energies exceeding 10 TeV is Markarian 501 at a distance of about 150 Mpc. Apparently, gamma-rays at these high energies collide with infrared background photons to produce electron-positron pairs, and are prevented from traversing greater distances. Floyd Stecker and Alexander Konopelko addressed this question. Eventually, a careful analysis of distances from which gamma-rays at different energies can be detected may yield an entirely independent check on the spectrum of the infrared background.

Finally, no Symposium would be complete without plans for the future. On the last day of our meeting we looked ahead to the future with predictions by theorists, and a presentation of space missions planned to yield greater clarity on the background and its origins. All this was topped off by Malcolm Longair who kindly agreed to give a final summary of what we may have learned at this Symposium, what remains to be done, and how we might best get there.

Acknowledgments. My research in infrared astronomy is supported by grants and contracts from the National Aeronautics and Space Administration.

https://doi.org/10.1017/S0074180900225837 Published online by Cambridge University Press