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Observations of the extragalactic background light have been made at three wavelengths using our CCD system with a large angular field of view on the McGraw-Hill 1.3 m telescope. Data has been obtained at high galactic latitudes to reduce complications resulting from foreground stars and galaxies and from infrared cirrus. Exposures from overlapping fields were obtained to check the internal consistency of the data. Also, a grid of scattering profiles was obtained in which a star was imaged at many different positions on and off the CCD to take account of scattering contributions. Because the fields contained so many foreground stars and galaxies, it was necessary to develop an automated technique using a matched filter to pick out these objects and to then subtract them from the data. This has been accomplished for fields consisting of one-quarter of a CCD field. Our data analysis has yielded an amplitude for the power spectrum which is about 2.5 times larger than calculated using a model with no galaxy luminosity evolution. Recently, Tyson has shown some clear evidence for galaxy luminosity evolution which while not quantitative qualitatively explains our data. Other work during this funding period has been on the nature of dark matter, speckle inteferometric resolution of the binary star system Mu Cassioppeiae, and a measurement of the temperature of the cosmic background radiation at 2.64 mm.

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Studying the universe at $z > 1$ is difficult. The classic global cosmological tests, the redshift-magnitude test and the metric angular diameter-redshift test, both require information derived from images of individual galaxies. The problem is that the images of distant galaxies have surface brightnesses which are proportional to $(1-z)^4$. Thus, galaxies at, for example, $z = 1$ have surface brightnesses which are reduced by a factor of 16 compared to nearby galaxies.

It is unlikely that there will be quick solutions to the problem of obtaining cosmological information from the images of *individual* galaxies in the foreseeable future. Space based observations will have to contend with the same $(1-z)^4$ reduction in surface brightness as ground based observations. Though space based observations will not have to contend with the airglow, they will have the zodiacal light as a background. Secondly, the quantum efficiency of current detectors is typically within a factor of two of unity and so it will not be possible to make substantial improvements in this area. Taken together, it appears that there are substantial problems associated with using the images of individual galaxies to collect information about the universe at large redshifts.

There is another approach to the problem of obtaining information about the universe at large z's, measuring the power spectrum of the extragalactic background light (PSEBL). Spelled out in more detail, this means taking a deep image of the sky, removing any foreground contamination such as foreground stars and galaxies and their scattering halos, and then taking the two dimensional Fourier transform from which the power spectrum is obtain by squaring the Fourier amplitudes. This approach is sufficiently powerful so that in three hours of integration time using a 1.3m telescope and a CCD, it is possible to obtain a power spectrum in which 50 per cent of the signal is from a $z > 1.1$.

It is worth explaining why the PSEBL is so effective obtaining cosmological information at large redshifts. To the extent that the shape of clusters of galaxies are similar for clusters at the same redshift, their Fourier transforms are similar except for a phase factor which describes the relative position of the clusters in the field. However, if one considers the power spectrum, the phase factor drops out, and so by taking the power spectrum of the image of a field of galaxies, the signal in the images of individual galaxies adds coherently. This is true even if the signal to noise ratio of the image of an individual galaxy is less than unity, *i.e.* the images are subthreshold. On the other hand, the white noise due to the sky brightness and photon statistics add incoherently.

We can summarize our work measuring the PSEBL by dividing it into three subsections: instrument development, data taking technique, data reduction including software development.

In order to obtain the highest signal to noise ratio measurements of the PLEBL for a given telescope, it is advantageous to image the largest angular field of view. The McGraw Hill 1.3 m telescope which we have been using for our observing has an f/7.5 optical system. We have constructed an f/1.5 optical reducing system to image an area of the sky $(7.5/1.5)^2 = 25$ times larger than would be possible with our direct imaging CCD. We pay a small price in terms of decreased resolution: our pixel size is now about 3 arc seconds which makes it slightly more difficult to detect foreground stars and galaxies. Also, there is some scattering from the optics but the increased field of view more than makes up for this. The advantages of the large field of view are that the amplitude of the PSEBL is larger at lower angular frequencies and that we are collecting many more photons.

Originally, we found an internal reflection in the optical system that was not easy to solve. It was due to light reflected from the CCD back into the optics where it was again reflected back onto the CCD. Our solution to this problem was to insert a circular polarizer into the beam which absorbed the reflected beam. It works quite effectively.

In order to measure the PSEBL, it is necessary to have a very stable detector. We have tested and verified that our CCD is stable enough by observing dome flats over a period of several hours at an exposure level that corresponded to our signal from the sky. Even though each exposure has some structure from the inside of the dome, it did not change over time though the intensity was not precisely constant. However, the intensity appears as a simple multiplicative factor and does not affect the tests. By dividing two images and plotting the power spectrum of the division, it is possible to look for structure in the CCD which is not constant over the time during which the exposure were made. This is an important test of the system in that it showed that the power spectrum was consistent with white noise at the part in 100,00 level and that the CCD was reproducible and stable over time.

The data taking technique that we have developed allows us to obtain a flat field calibration for the CCD, obtain information about emission lines in the night sky which cause fringing in the CCD, collect data with a built in self-consistency test to be sure that no artifacts are being introduced anywhere into the system, and obtain calibration information about the scattering halos surrounding stars and galaxies. Our technique is to obtain two series of overlapping exposure on a relatively starless region of the sky in the vicinity of the galactic poles that is also relatively far from bright stars. The exposures were chosen to overlap so that the power spectrum that would be in common between the two regions would be imaged on two different portions of the CCD and the power spectrum calculated from these two regions could be checked for consistency. It is an overall test of the system. Also, two overlapping series of exposures can be used to determine a flat field which takes account of variable night sky emission but which contains data on the PSEBL. In addition to obtaining data on the sky, it is necessary to obtain some information about scattering due to the atmosphere, telescope, and the optics. This calibration was obtained by imaging a star on a grid of points both on and off the CCD to obtain a grid of scattering profiles that could be used to fit the scattering halos of both stars in the field and stars outside the field but whose scattering halos contributed to the light in the field.

Next, we shall discuss software development. One of the first issues that was apparent with our new optical system was that because it imaged an area 25 times larger than our previous system, we had 25 times as much data to analyse and it was necessary to automate many aspects of the data reduction procedure that was previously done interactively without much thought. This took a substantial amount of time. It is quite difficult to automate a relatively simple interactive task as anyone who has tried it knows. The second issue was that the data reduction procedure was so slow on a VAX 780 that we had to find ways of reducing the data reduction time substantially or it would be impossible to complete it.

One particularly large task in the data reduction procedure was to locate stars and their halos and remove them from the data. Initially, the stars were located interactively and then they were fit to the scattering calibration stars using least squares. After some experimenting, we found that stars could be located quite well with a match filter approach. A matched filter is the optimal way of detecting an image whose functional form is known, in the presence of noise. Our matched filter program works very well and we are using it to identify, label, and calculate the controids of the light distribution of each star. The coordinates and intensity of the stars serve as the starting point of a least squares program that divides stars up into groups (so that all stars do not have to be fit simultaneously which would be impossible) and fits each group with a scattering halo calibrated from that portion of the CCD. The scattering halos are position dependent. Using this approach, we are able to increase our data reduction rate by a factor of between 20 and 40 which has been essential.

We have made two observing trips a year for the last three years to the Mc-Graw Hill Observatory were we have been using the 1.3 m telescope. We lost several runs due to poor weather, but have obtained good data on the last three trips. We have about 40 hours of data in several colors on selected regions of the sky.

With these improvements discussed above, we have been reducing one-quarter size data frames to verify that the method works as expected. After photometrically calibrating the power spectrum, we find that the amplitude of the power spectrum is 2.5 times larger than what we predict using a no evolution model for galaxy luminosity evolution. Thus, it appears that galaxies do evolve in the sense that they were brighter in the past. There have been suggestions to this effect in the literature, but in is only in the last few months that Tyson has shown using number counts of galaxies that galaxies were definitely brighter in the past. An important benefit to us is that since galaxies were brighter in the past, more of our information is coming from larger distances and so we are sampling the universe more deeply than our no evolutionary calculations would indicate.

There is one systematic error which we have not yet dealt with, cirrus clouds in the galaxy. The variable extinction and backscattering of these clouds could seriously contaminate the PSEBL. We have taken data at three different wavelengths to deal with this issue. It has been shown that the cirrus is brighter in the blue than in the red, *i.e.*, dust is more strongly scattering in the blue. We will use the wavelength dependence of the scattering to pick out the contributions of the cirrus to the PSEBL. In addition, we will correlate the IRAS 100 micron emission from the cirrus with the blue exposures to further study the cirrus.

In addition to the work on the PSEBL, we have done research on a number of other areas: the nature of the dark matter, a measurement of the primordial helium abundance, and a measurement of the temperature of the cosmic background radiation temperature. We shall briefly discuss these topics.

There is dark matter on many different scales in the universe. On the smallest scale, the thickness of the disk of the galaxy, about half of the matter is dark. We have shown that this matter is not in the form of black holes. Previously, we had argued that the dark matter in the halo of spiral galaxies is not baryonic. Now we have extended those arguments to ellipitical galaxies and have shown that the dark matter in this type of galaxy is also unlikely to be baryonic. Our approach was to consider each type of baryonic matter and show the contradictions that would exist if the dark matter were made up of each form of baryonic matter.

A topic that could be of direct interest to AFOSR is our resolution of the binary star system Mu-Cassiopeiae with a direct imaging CCD system. It is a difficult system to resolve because the stars differ in intensity by a factor of about 100 and they are slightly over one arc second apart. We have been able to resolve the system at three different epochs by taking good quality data and by carry out an image analysis that deals explicitly with the character of the system noise. Our approach is a much more precise treatment of CCD system noise than anything in the literature.

We have also continued our work on measuring the temperature of the cosmic background radiation temperature using interstellar CN molecules. We have just measured the contribution of local sources of excitation to the temperature of the CN molecules in the interstellar cloud in front of ζ Oph. This radio measurement and a reanalysis of the data has made it possible for us to make a very precise measurement, about one per cent accuracy, of the temperature of the cosmic background radiation at 2.64 mm.

Several communications have resulted from our research:

1. Black Holes and the Local Dark Matter, D.J. Hegyi, E. W. Kolb, and K. A. Olive, Astrophysical Journal **300**, 492 (1986).
2. A Case Against Baryons in Galactic Halos, D.J. Hegyi and K.A. Olive, Astrophysical Journal **303** (1986).
3. A Case Against Baryons in Galactic Halos, D.J. Hegyi and K.A. Olive, in *Inflationary Cosmology*, edited by L. F. Abbott and S.Y. Pi, (World Scientific, Singapore, 1986), Pg. 55.
4. Cosmic Background Radiation Temperature from CN Absorption, P. Crane, D.J. Hegyi, N. Mandolesi, and A.C. Danks, Astrophysical Journal **309**, 822, (1986)

5. Detection of Interstellar ^{13}CN Towards ζ Ophuchi, P. Crane and D.J. Hegyi, Astrophysical Journal Letters **326**, L35 (1988).

There are also several manuscripts that remain to be published:

1. A New Limit on Scalar and Vector Contributions to Gravity, G.W. Ford and D.J. Hegyi, submitted to Physics Letters
2. Evidence Against Dark Matter in Elliptical Galaxies, D.J. Hegyi and K.A. Olive, submitted to the Astrophysical Journal.
3. Two Color CCD Photometry of the Cluster of Galaxies Abell 1689, D.H. Gudehus and D.J. Hegyi, in preparation.
4. Accurate Masses for the Population II Subswarf Mu Cassiopeiae, J. Haywood and D.J. Hegyi, in preparation.
5. The Masses and Helium Abundance of Mu Cassiopeiae, J. Haywood, D.J. Hegyi, and D.H. Gudehus, in preparation.