N90-23322

DIPOLE ANALYSIS ON EGRET DATA OF EXTRAGALACTIC GAMMA RAY BACKGROUND RADIATION

YING-CHI LIN
High Energy Physics Laboratory, Stanford University, Stanford, CA 94305

I. INTRODUCTION

A dipole analysis on the EGRET data seems to be one of the numerous subjects that we can investigate for the extragalactic gamma ray background radiation. By the end of the first one and half years after launch, the all-sky survey program of GRO will be completed. The EGRET detector will cover the full sky area fairly well by that time. We will then have at our disposal a set of gamma ray data suitable for dipole moment calculations. Furthermore, there now exist in the literature several dipole anisotropy results calculated for optical and infrared observations on the distribution of galaxies in the full sky. We can compare the results of dipole moment analysis from gamma ray observations with those at other wavebands, and hopefully we can gain some deeper understanding on the large scale structure of the Universe in the end.

II. CALCULATION OF DIPOLE MOMENT FOR EGRET DATA

The dipole moment of the gamma ray data from EGRET observations can be defined, in principle at least, in a straightforward way. For a sample of N gamma ray events distributed over the full sky, let $\hat{r}_i$ be a unit vector in the inverse direction of arrival of the i^{th} gamma ray, i.e., $\hat{r}_i$ is pointing at the source of the incoming photon. Then the dipole moment of the distribution of the N events can be defined as

$$\mathbf{D} = \frac{\sum_{i=1}^{N} \omega_i \hat{r}_i}{\sum_{i=1}^{N} \omega_i}, \tag{1}$$

where ω_i is a weighting factor for the i^{th} event, to normalize observations under different instrumental conditions, and to deal with uneven coverage of different parts of the sky. A nonzero value of $\mathbf{D}$ represents the direction and the magnitude of the dipole anisotropy of the N gamma ray events. On the other hand, a value of $\mathbf{D}$ consistent with zero means the gamma ray events are isotropic within the experimental errors.

In practice, however, obtaining a meaningful value for the dipole moment in a sample of EGRET observations may not be very simple. The variations of the instrumental conditions can probably be handled with fair amount of confidence. The EGRET detector has been studied in all aspects at great length over the years. We believe we can treat things like the variation of EGRET detection efficiency over long periods of observation quite well. Likewise the treatment of uneven coverage of the sky at different detector orientations and different observation times can be handled in a routine manner, although the rpocedure can be quite time-comsuming. What constitutes the most serious obstacle in the way of obtaining a meaningful value for **D** according to $Eq.(1)$ is probably the contamination of the galactic component in the full set of the diffuse background radiation data. From SAS - 2 observations (Fictel, Simpson and Thompson 1978; Thompson and Fichtel 1982), which provide the only existing information on the extragalactic diffuse background radiation at energies comparable to the dynamic range of EGRET, we can see that at low galactic latitudes, the galactic component completely dominates the observations. Even at high galactic latitudes, the diffuse background is still heavily tinted with the galactic component. In fact the galactic component extends all the way to the galactic poles. Then to what extent can we expect to see the global effect of the extragalactic component alone is not immediately clear. For this we will no doubt need extensive studies on different aspects of these two components once we have the actual data.

In addition to the galactic part of the diffuse radiation, the EGRET detector ifself will also generate a gamma ray background once in orbit. The cosmic ray protons may interact with EGRET window material at a grazing angle such that the protons will not intercept the anticoincidence scintillator dome to set off a trigger veto. The produced gamma rays will then be accepted by EGRET as valid incident photons. But preliminary studies on the results of the proton beam calibration at Brookhaven National Laboratory indicate that this locally generated gamma ray background will be very small. This background component will be isotropic on the average anyway, and will not contribute significantly to the value of **D** as calculated according to $Eq.(1)$. But still we should keep in mind this possible source of uncertainty in **D**. Furthermore, the known celestial gamma ray sources in the field of view of EGRET detector should be subtracted from the full data set.

We can make an order of magnitude estimate for **D** in this way. The GRO all-sky survey program calls for about 30 detector orientations, each with an observation time of two weeks. Ten of these sightings will be centered around the galactic plane, and thus will not be useful for extraglactic diffuse background studies. The other 20 or so sightings will have a combined total observation time of 40 weeks. Let us use a duty factor of 0.5, meaning that the EGRET detector will be actively taking data in about half of this time. From SAS-2 observations (Fichtel, Simpson and Thompson 1978), the extragalactic diffuse background radiation has been found to be $\sim 5 \times 10^{-5} cm^{-2} sr^{-1} s^{-1}$ for gamma ray energies greater than 35 MeV. If we take the average combined EGRET effective area and solid angle to be $\sim 500\ cm^2 sr$ above 35 MeV, then in 40 seeks we should be able to collect

$$5 \times 10^{-5} \times 500 \times 40 \times 7 \times 86400 \times 0.5 \approx 3 \times 10^5$$

extragalactic diffuse background gamma rays. If we also demand good energy measurement, this number will probably be cut in half. In any case, based on statistical uncertainties alone, if the dipole anisotropy has the magnitude of $>\sim 1.0\%$, we should be able to see it. If we can find a robust value for **D**, we can go one step further. We can try to determine the energy dispersion in it, or maybe some other properties too that we can conceive.

III. DIPOLE ANISOTROPIES AT OPTICAL AND INFRARED FREQUENCIES

Ever since the all-sky galaxy surveys became available in optical and in infrared observations, efforts have been made to determine the dipole anisotropy in the distribution of galaxies in the full sky (Yahil, Sandage and Tamman 1980; Davis and Huchra 1982; Yahil, Walker and Rowan-Robinson 1986; Meiksin and Davis 1986; Villumsen and Strauss 1987; Lahav 1987; Harmon, Lahav and Meurs 1987; Rowan-Robinson 1988; Lahav, Rowan-Robinson and Lynden-Bell 1988; Kaiser and Lahav 1989). This dipole anisotropy is then compared with the dipole moment of the cosmic microwave background radiation (MBR). Based on the proximity of these two dipole directions, a case can be made that the surface brightness dipole moment is a measure of the peculiar acceleration of the Local Group. Then a linear theory, as the one developed by P. J. E. Peebles (Peebles 1980) which tie the peculiar velocity, the peculiar acceleration and the cosmological density parameter together, can be used to determine the cosmological density parameter with a proper choice of the peculiar velocity. In the paper by Kaiser and Lahav (Kaiser and Lahav 1989), the dipole anisotropy in the distribution of galaxies is also interpreted as a manifestation of some Gaussian isentropic density fluctuations at some very early time in the cold dark matter model, a viewpoint not shared by the authors of the other dipole moment papers.

TABLE I
DIPOLE ANISOTROPIES IN OPTICAL AND INFRARED SURVEYS

Authors	*Survey Catalog*	*Dipole Anisotropy Direction (deg)* l	b	*Angle with MBR Dipole (deg)*	Ω_0
Yahil, Sandage and Tammann 1980	RSA	Centered on Virgo cluster			$\ll 0.5$
Davis and Huchra 1982	CfA	Toward Virgo cluster			$0.4 - 0.5$
Yahil, Walker and Rowan-Robinson 1986	IRAS	248 ± 9	40 ± 8	26 ± 10	0.85 ± 0.16
Meiksin and Davis 1986	IRAS	235	45	< 30	≈ 0.5
Villumsen and Strauss 1987	IRAS	239	36	28	1.2 ± 0.36
Lahav 1987	UGC,ESO	227 ± 23	42 ± 8	≈ 37	≈ 0.3
Harmon, Lahav and Meurs 1987	IRAS	274.6	31.3	7.2	——
Rowan-Robinson 1988	IRAS	248.2 ± 9.6	39.5 ± 9.5	20.7	≈ 1
Lahav, Rowan-Robinson and Lynden-Bell 1988	UGC,ESO	261	29	< 7	0.16 ± 0.07
	IRAS	250	38	—	—
Kaiser and Lahav 1989	UGC,ESO	261	27	—	0.3
	IRAS	259	34	—	0.5

In Table I, we summarize the typical results of these investigations. The directions of these calculated dipole moments all agree quite well with each other and with the cosmic microwave background radiation. But the magnitudes of these dipole moments can be quite different in different papers, although most of them are in the 10 – 20% range. Then, compounded with different choices of value for the peculiar velocity of the Local Group, the inferred cosmological density parameter Ω_0 exhibits a wide range of variation. It is difficult to see what one can make out of these Ω_0 values.

IV. DISCUSSIONS

At present the most promising explanation for the origin of the extragalactic gamma ray background radiation is the idea that these gamma rays are produced by active galaxies too far away or too weak to be resolved by the detecting instrument (Bignami, Fichtel, Hartman and Thompson 1979). Although there is only one active galaxy, the qusar 3C273, that has been identified with the only gamma ray source at high galactic latitude in the COS-B catalog, this situation will certainly change with the launch of GRO. We expect to see several more active galaxies as point gamma ray sources with the EGRET detector. Then the question as how the active galaxies combine to produce the extragalactic gamma ray background radiation will become more clear. Suppose that the idea of active galaxies as origin of extragalactic diffuse background radiation will be further strengthened under EGRET observation, which we have good reasons to believe will be the case. Then the study of the extragalactic gamma ray background radiation will be a study of the large scale distribution of active galaxies. We will then certainly take a critical look at the dipole anisotropy results in optical and infrared observations and compare with the gamma ray results. Hopefully we will gain some deeper understanding on the large scale structure of the Universe at that time.

REFERENCES

Bignami, G. F., Fichtel, C. E., Hartman, R. C., and Thompson, D. J. 1979, *Ap.J.*, **232**, 649.

Davis, M., and Huchra, J. 1982, *Ap.J.*, **254**, 437.

Fichtel, C. E., Simpson, G. A., and Thompson, D. J. 1978, *Ap.J.*, **222**, 883.

Harmon, R. T., and Lahav, O. 1987, *M.N.R.A.S.*, **228**, 5p.

Kaiser, N., and Lahav, O. 1989, *M.N.R.A.S.*, **237**, 129.

Lahav, O. 1987, *M.N.R.A.S.*, **225**, 213.

Lahav, O., Rowan-Robinson, M., and Lynden-Bell, D. 1988, *M.N.R.A.S.*, **234**, 667.

Meiksin, A., and Davis, M. 1986, *A.J.*, **91**, 191.

Peebles, P. J. E. 1980, *The Large Scale Structure of the Universe*, Princeton University Press, Princeton.

Rowan-Robinson, M. 1988, In: *Comets to Cosmology: 3rd IRAS Conference*, ed. Lawrence, A., Springer-Verlag.

Thompson, D. J., and Fichtel, C. E. 1982, *Astron.Astrophys.* **109**, 352.

Villumsen, J. V., and Strauss, M. A. 1987, *Ap.J.*, **322**, 37.

Yahil, A., Sandage, A., and Tammann, G. A. 1980, *Ap.J.*, **242**, 448.

Yahil, A., Walker, D., and Rowan-Robinson, M. 1986, *Ap.J.(Letters)*, **301**, L1.