NASA/TP-1999-209477

September 1999

Addendum to Gamma-Ray Astrophysics

New Insight Into the Universe
Second Edition (RP 1386 - October 1997)

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Introduction

We have been encouraged by the positive reactions that we have received to the second edition of the publication *Gamma-Ray Astrophysics, New Insight into the Universe*, and therefore, wish to make a few additions. In this addendum there are three small parts: A. Comments on New Findings since October 1997, B. Figures, and C. Corrections. In part B, some of the figures that were in the book have been reproduced here in larger form so that they are easier to read. In part C, the corrections that have come to our attention since the original publication are included.

Part A. Comments on New Findings since October 1997

Chapter 3

The use of remote sensing gamma-ray spectroscopy was discussed in Chapters 2 and 3. The lunar prospector gamma-ray remote system has successfully obtained global gamma-ray and neutron maps of the lunar surface during 1998 and continuing in 1999. The neutron maps have been used to map the presence of hydrogen over the lunar surface. A study of both the neutron and gamma-ray maps indicates the possibility of subsurface water at the lunar poles. Thorium, potassium, and iron count rate maps have been obtained. The thorium and potassium maps show that these radioactive elements are highly concentrated in and around the near side western maria and less so in the South-Aiken basin. These data suggest that the thorium was excavated by impacts of asteroids and comets and then distributed around craters, rather than being deposited by volcanic activity. Higher spatial resolution data will be obtained from orbital data gathered at lower altitudes. For further detail see Lawrence et al., 1998. The data obtained is consistent with that obtained with the Apollo and Clementine orbital observations.

The gamma-ray spectrometer aboard the Near Earth Asteroid Rendezvous mission (NEAR) has been operating successfully in the cruise phase and has implemented a burst detection system. This system has been incorporated in the Inter Planetary Network for gamma-ray burst detection. The operation and data obtained with the NEAR gamma-ray spectrometer during the cruise phase of the mission can be found in Trombka et al. 1997. It is planned that the NEAR spacecraft will be in orbit around the asteroid 433Eros in January 2000.

Chapter 8

Concerning active galaxies, some new information now exists on the high-energy gamma radiation, and it is largely contained in the Third EGRET Catalog (Hartman et al., 1999). The additional information, although representing only a modest increase in statistical weight, supports the trends and conclusions discussed in the book. For example, the distribution in z of active galaxies emitting high energy gamma rays retains the same general character as that shown in Figure 8.16. Further, the distributions of BL Lacs and FSQR's in z have the same general appearance as before and, therefore, both are also at least similar to the distributions of these objects in radio emission, if not essentially the same. At this time, it is perhaps also worth calling attention to the summary of this chapter, section 8.8, and especially the last sentence, which reads "Since there is now a good knowledge of the basic properties of the high-energy gamma-ray emission and its implication for the parent relativistic particles, a challenge exists to formulate a quantitative theoretical explanation of exactly how these particles are accelerated."

Chapter 10

There have been some important developments in our understanding of Gamma-Ray Bursts (GRB) since the publication of this book. In the past two years, over a dozen GRB's have been associated with x-ray or optical, and radio counterparts. The redshifts of some of these objects have been measured, giving $z \gtrsim 1$, and in one case a color redshift suggesting $z > 5$, indicating that the bursts occurred when the Universe was just a small fraction of its current age.

These new results are consistent with the previous evidence discussed in the book and make the discussion of possible origins in cosmological terms more meaningful. For clarification, the energy available according to collision or hypernovae hypotheses seems to be adequate only if there is beaming. Without beaming, energies as high as 10^{53} to 10^{54} ergs would be required, and that amount seems inconsistent with the calculations of expected energy. Including beaming, the energy can be reduced to 10^{49} to 10^{50} and the statement in the book that "The expected number of occurrences per unit time may also be sufficient," still is thought to be correct.

The observed optical afterglow of the GRB's has never reached a magnitude greater than 19, and fades quickly after passing their peak intensity. It has been observed that the luminosity declines proportional to $t^{-1.3}$. Therefore, in order to observe these transient sources, accurate positions must be obtained within hours after the initial explosion and with a spatial resolution compatible with the field of view of a large telescope. Accurate GRB positions can be obtained if the GRB occurs in the field of an imaging gamma-ray telescope and is followed by a more accurate imaging by a focussing x-ray telescope. Accurate positions also can be measured by the Inter-Planetary Network (IPN).

A soft gamma-ray repeater flare was detected on August 27, 1998 (Hurley et al. 1999). These soft gamma-ray repeaters can be attributed to transient sources of high-energy photons. The transient sources emit sporadic and short bursts of lower energy gamma rays during periods of activity, which are often broken by long stretches of quiescence. The duration of these bursts is of the order of 0.1 seconds. The only previous measurement which showed a clear periodicity in its signal was detected March 5, 1979 (Mazets et al. 1982 and Barat et al. 1979). It is believed that the burst was most probably initiated by a massive disruption of the crust of the neutron star, followed by an outflow of energetic particles rotating with the period of the star (magnetar).

New results and the latest information can be found on the Web. The results obtained up to this time make the discussion in our book of possible origins in cosmological terms more meaningful.

Part B. Figures

Some of the figures in the book were small for the amount of information involved or a bit fainter than desired, at least in part because of the book's page size. To provide those who have the book with easily available better versions of these figures, larger and clearer versions are included on the next several pages.

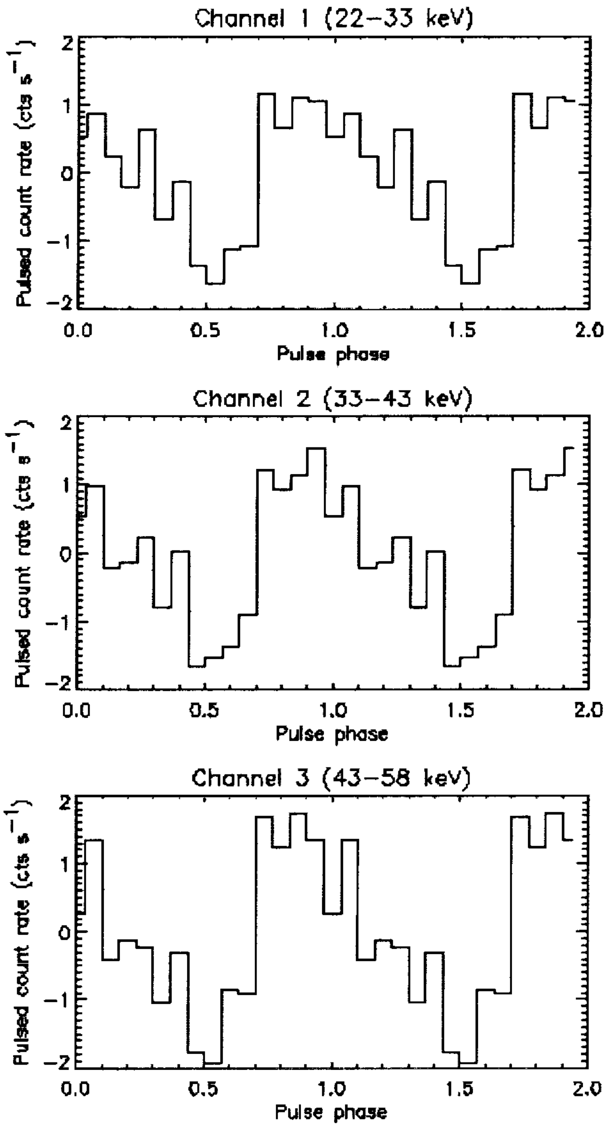

Figure 6.13. Pulse profiles as a function of energy for GRO J1948+32 during the interval MJD 49462-49468. Two pulses are shown for each energy channel. The energy edges for CONT channels 1-3 of BATSE detector 0 are indicated. These pulse profiles are overresolved by a factor of 1.7. Note that the pulse shapes are uncorrected for the rapid change in detector response as a function of energy in the 20-100 keV range. The figure is reproduced with the permission of Chakrabarty et al. (1996).

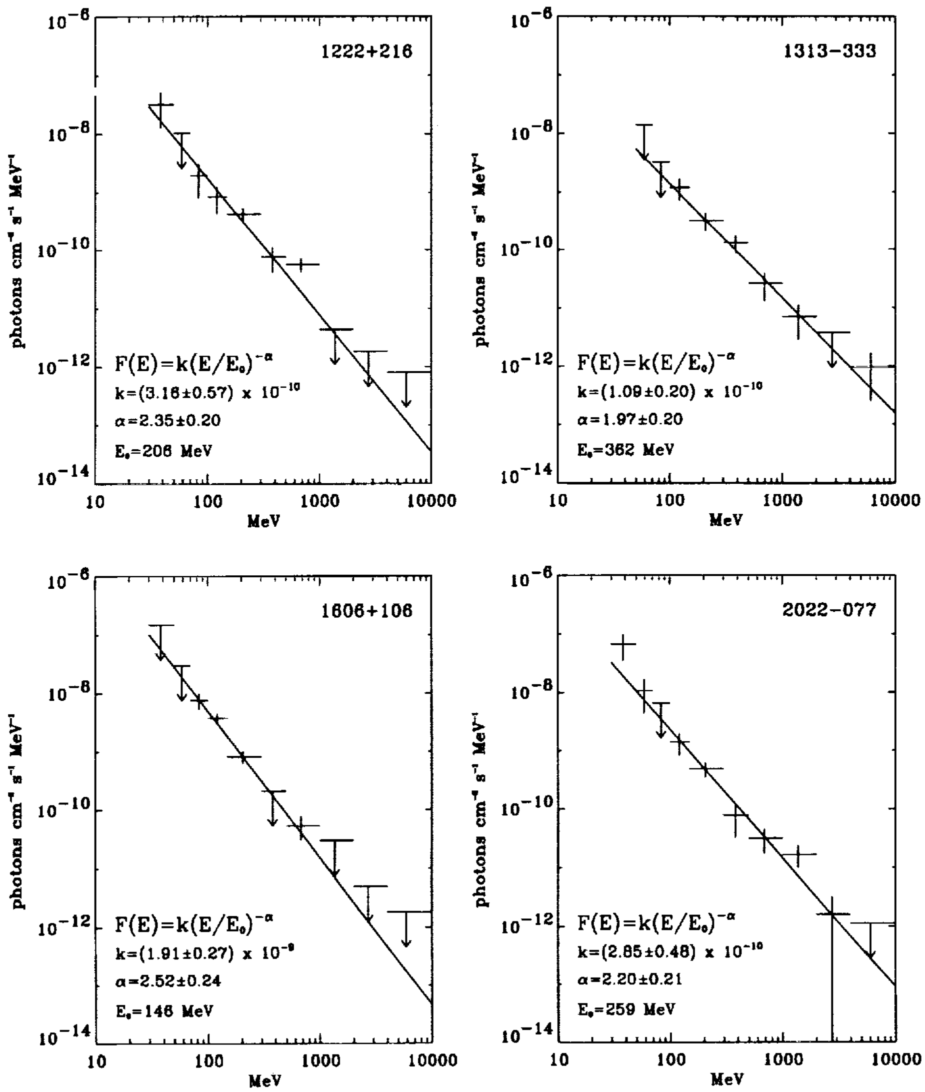

Figure 8.4 The energy spectrum of several blazars as a function of gamma-ray energy. The figure is adapted from von Montigny et al. (1995a) and reproduced with their permission.

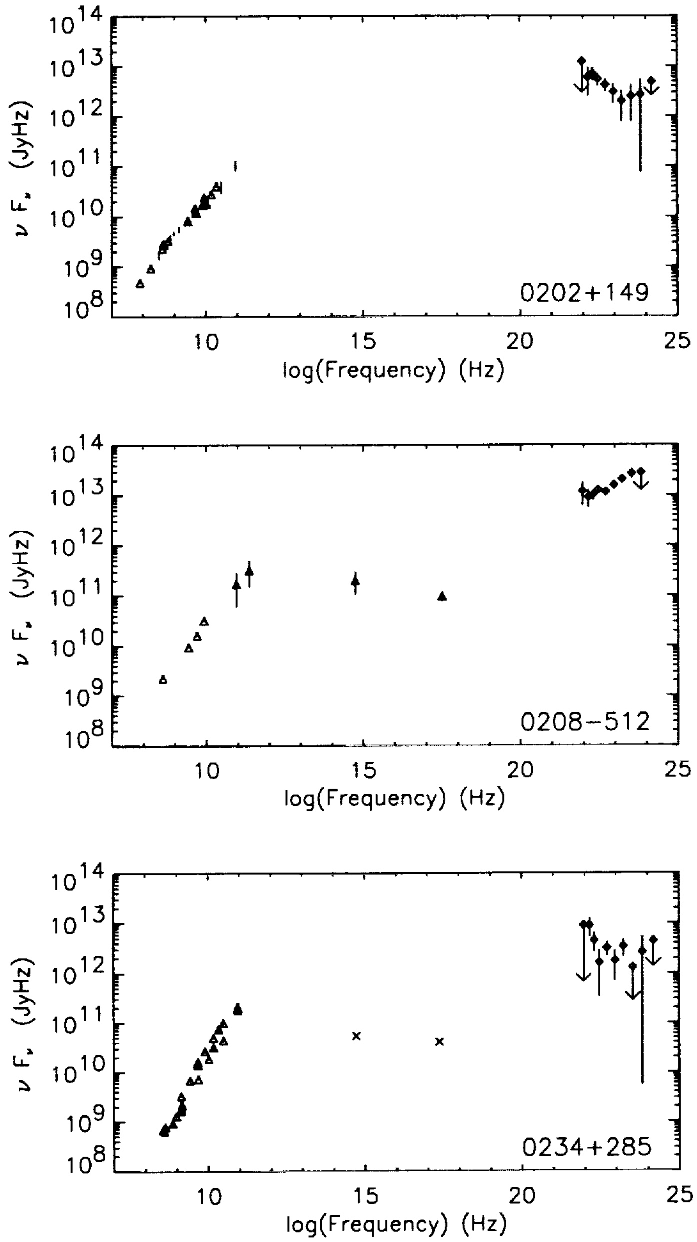

Figure 8.7 The energy observed from several gamma-ray-emitting blazars by Jy Hz as a function of Hz. The figure is reproduced with the permission of von Montigny et al. (1995a).

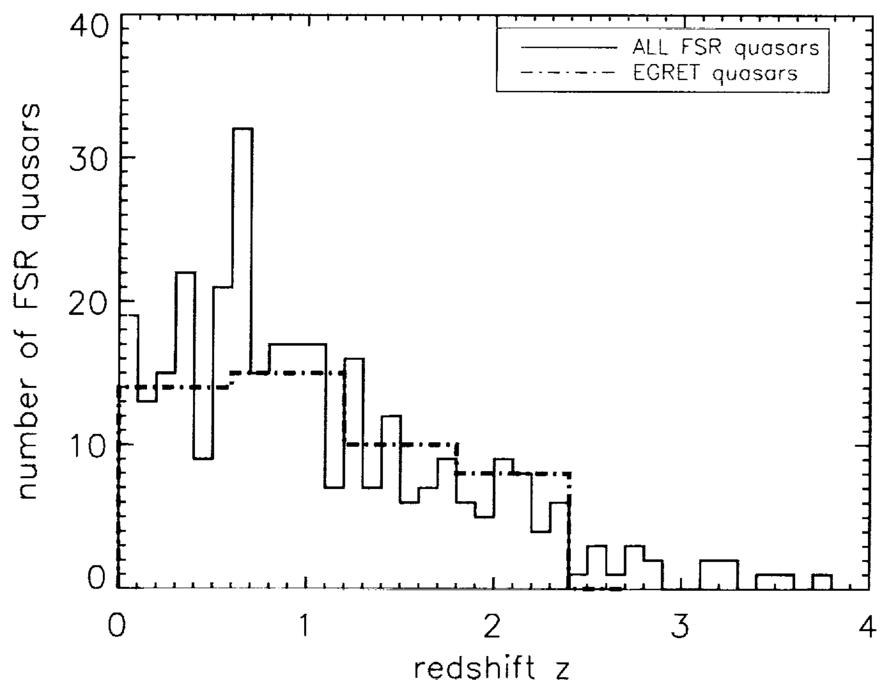

Figure 8.11. The distribution in z for flat-spectrum, radio-loud quasars and high-energy gamma-ray -emitting blazars (EGRET). Note that the number scale for the radio quasars is on the left, and the gamma-ray-emitting blazars is on the right. The figure was developed from the work of Fichtel et al. (1996) and Mukherjee et al. (1997).

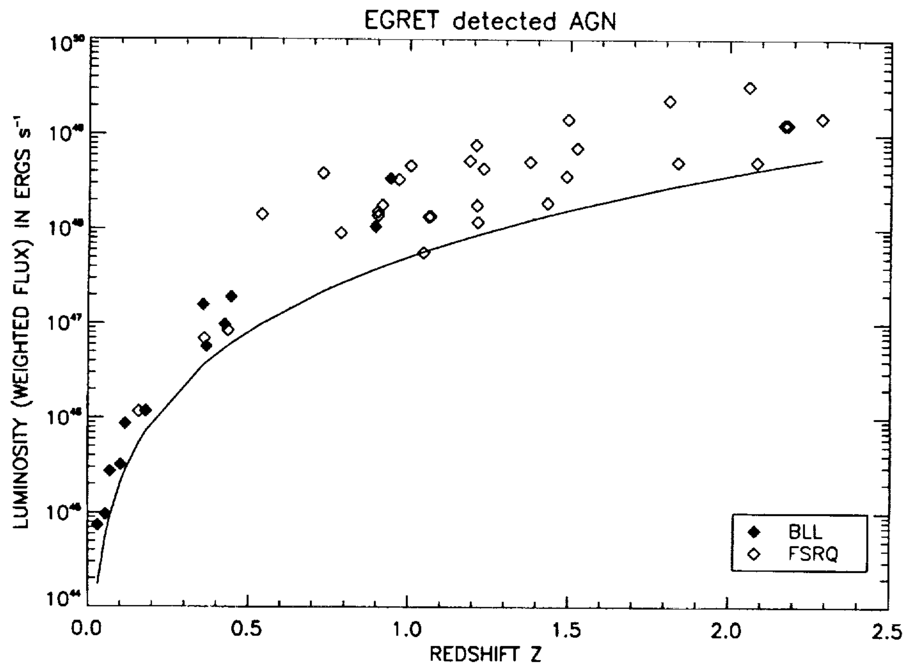

Figure 8.12. The weighted average luminosity divided by the beaming fraction in high-energy gamma rays of blazars detected by EGRET as a function of z. FSRQs are shown as open diamonds and BL Lacs as solid diamonds. The curve is the detection threshold for EGRET as a function of z for relatively good conditions of exposure and diffuse background. The typical threshold is somewhat higher. The figure is reproduced with the permission of Mukherjee et al. (1997).

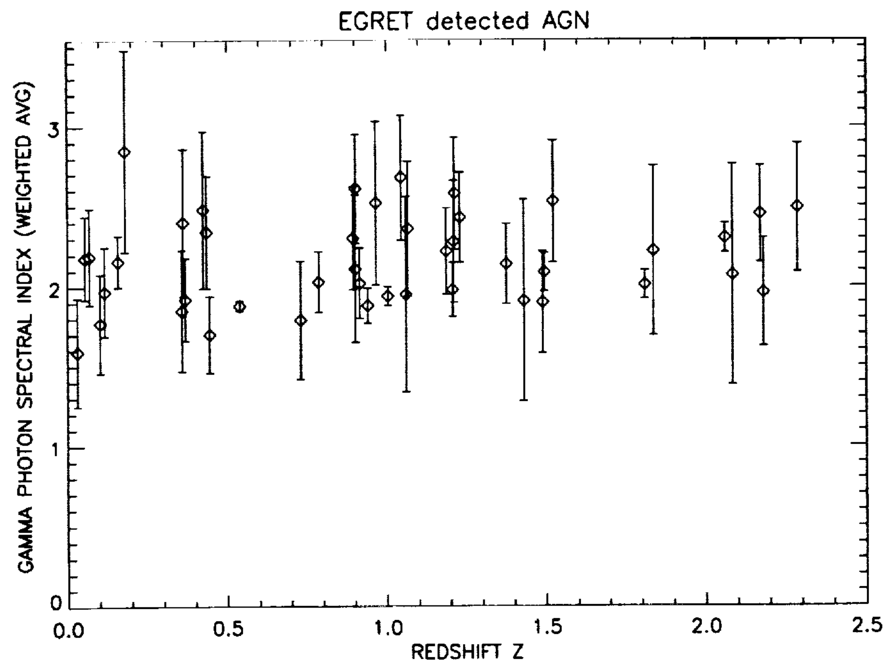

Figure 8.13. The spectral index of individual high-energy gamma-ray blazars detected by EGRET plotted as a function of z. This figure is developed from the work of Fichtel et al. (1996) and Mukherjee et al. (1997).

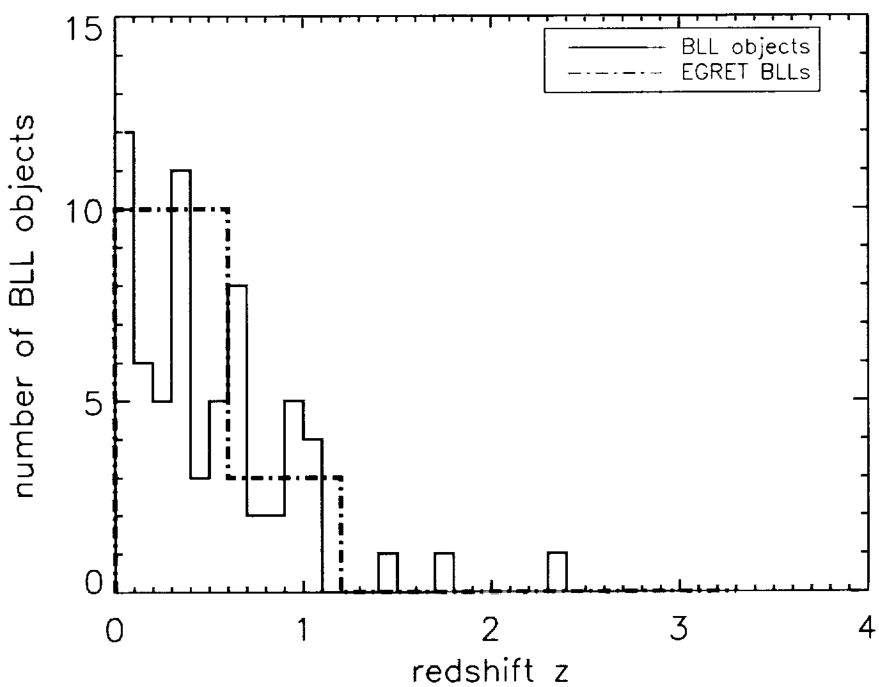

Figure 8.14. The distribution of BL Lacs as a function of z detected in the radio-frequency range, shown as a solid line, and in the high-energy gamma-ray range, shown as a dot-dash line. This figure is reproduced with the permission of Mukherjee et al. (1997).

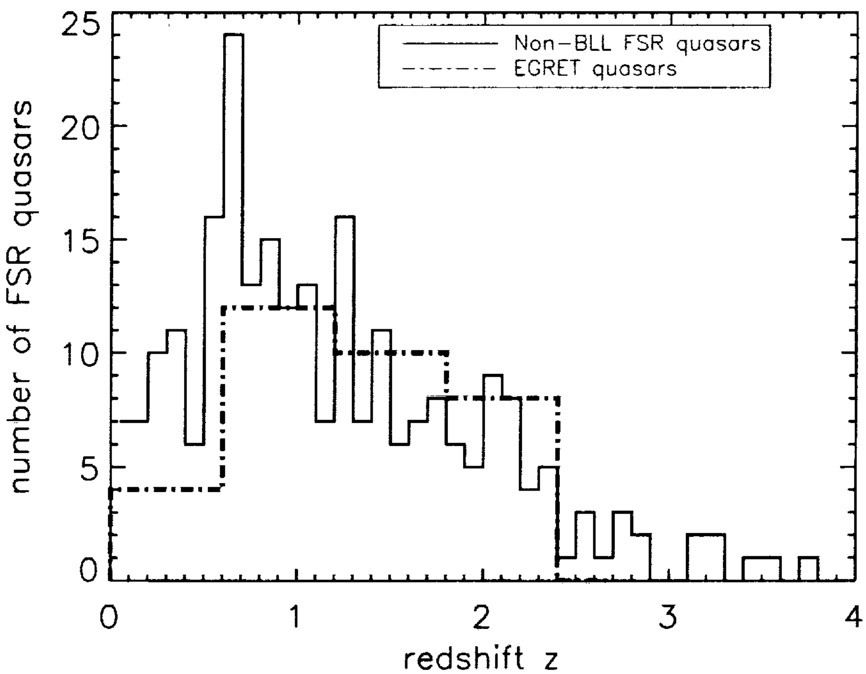

Figure 8.15. The distribution of FSRQ as a function of z detected in the radio-frequency range, shown as a solid line, and in the high-energy gamma-ray range, shown as a dot-dash line. The figure is reproduced with the permission of Mukherjee et al. (1997).

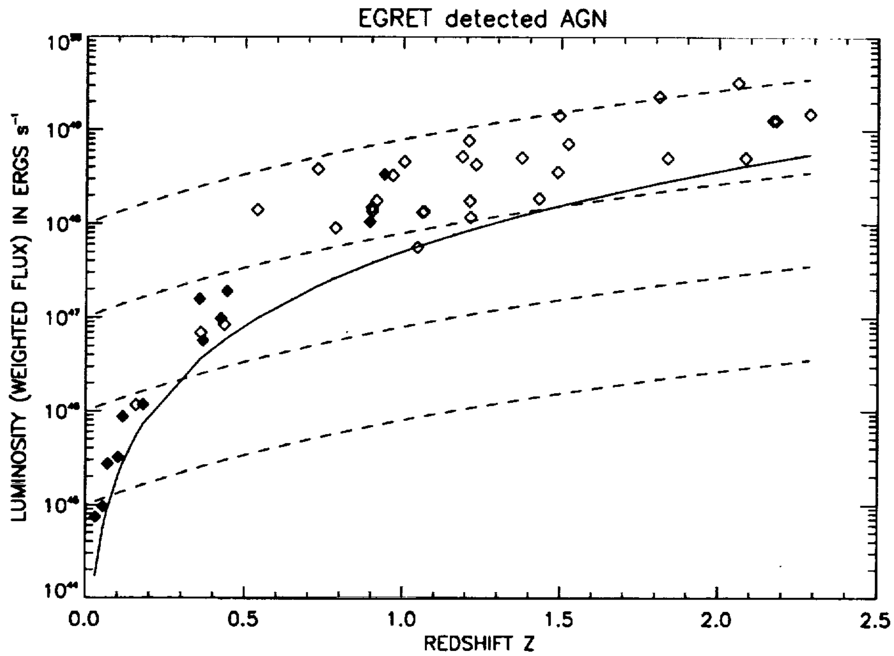

Figure 8.16. The weighted average luminosity in high-energy gamma rays of AGN detected by EGRET as a function of z. FSRQs are shown as open diamonds and BL Lacs as solid diamonds. The solid curve is the detection threshold for EGRET as a function of z for relatively good conditions of exposure and diffuse background. The typical threshold is somewhat higher. The dashed curves are for an evolution function of the form $(1+z)^3$.

Part C. Corrections

Page

V The title for section 10.4 should be: "High-Energy Gamma-ray Emission"

161 The caption for Figure 6.14 should read: "Distribution of the high-energy gamma-ray sources seen by EGRET; diamonds: active galactic nuclei; circles: unidentified EGRET sources; squares: pulsars; and triangles: LMC. The figure is from the EGRET catalog and its supplement (Thompson et al., 1995, 1996)."

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1999	Technical Report

4. TITLE AND SUBTITLE
Addendum to Gamma-Ray Astrophyics New Insight into the Universe-Second Edition (RP 1386)

5. FUNDING NUMBERS

6. AUTHOR(S)
C. Fichtel[1], J. Trombka[2]

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
99B00069

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TP—1999–209477

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category: 90
Report available from the NASA Center for AeroSpace Information, Parkway Center/7121 Standard Drive, Hanover, Maryland 21076-1320

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS
Galaxies; cosmic rays; gamma-ray spectroscopy; galactic centers; quasars; pulsars; and gamma-ray burst.

15. NUMBER OF PAGES
16

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39.18
298-102