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Very High Energy Cosmic Gamma Radiation:

A Crucial Window on the Extreme Universe

甚高能宇宙伽马辐射

——研究极端宇宙的关键窗口

（影印版）

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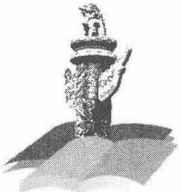

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《中外物理学精品书系》
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序　言

物理学是研究物质、能量以及它们之间相互作用的科学。她不仅是化学、生命、材料、信息、能源和环境等相关学科的基础，同时还是许多新兴学科和交叉学科的前沿。在科技发展日新月异和国际竞争日趋激烈的今天，物理学不仅囿于基础科学和技术应用研究的范畴，而且在社会发展与人类进步的历史进程中发挥着越来越关键的作用。

我们欣喜地看到，改革开放三十多年来，随着中国政治、经济、教育、文化等领域各项事业的持续稳定发展，我国物理学取得了跨越式的进步，做出了很多为世界瞩目的研究成果。今日的中国物理正在经历一个历史上少有的黄金时代。

在我国物理学科快速发展的背景下，近年来物理学相关书籍也呈现百花齐放的良好态势，在知识传承、学术交流、人才培养等方面发挥着无可替代的作用。从另一方面看，尽管国内各出版社相继推出了一些质量很高的物理教材和图书，但系统总结物理学各门类知识和发展，深入浅出地介绍其与现代科学技术之间的渊源，并针对不同层次的读者提供有价值的教材和研究参考，仍是我国科学传播与出版界面临的一个极富挑战性的课题。

为有力推动我国物理学研究、加快相关学科的建设与发展，特别是展现近年来中国物理学者的研究水平和成果，北京大学出版社在国家出版基金的支持下推出了《中外物理学精品书系》，试图对以上难题进行大胆的尝试和探索。该书系编委会集结了数十位来自内地和香港顶尖高校及科研院所的知名专家学者。他们都是目前该领域十分活跃的专家，确保了整套丛书的权威性和前瞻性。

这套书系内容丰富，涵盖面广，可读性强，其中既有对我国传统物理学发展的梳理和总结，也有对正在蓬勃发展的物理学前沿的全面展示；既引进和介绍了世界物理学研究的发展动态，也面向国际主流领域传播中国物理的优秀专著。可以说，《中外物理学精品书系》力图完整呈现近现代世界和中国物理

科学发展的全貌，是一部目前国内为数不多的兼具学术价值和阅读乐趣的经典物理丛书。

《中外物理学精品书系》另一个突出特点是，在把西方物理的精华要义“请进来”的同时，也将我国近现代物理的优秀成果“送出去”。物理学科在世界范围内的重要性不言而喻，引进和翻译世界物理的经典著作和前沿动态，可以满足当前国内物理教学和科研工作的迫切需求。另一方面，改革开放几十年来，我国的物理学研究取得了长足发展，一大批具有较高学术价值的著作相继问世。这套丛书首次将一些中国物理学者的优秀论著以英文版的形式直接推向国际相关研究的主流领域，使世界对中国物理学的过去和现状有更多的深入了解，不仅充分展示出中国物理学研究和积累的“硬实力”，也向世界主动传播我国科技文化领域不断创新的“软实力”，对全面提升中国科学、教育和文化领域的国际形象起到重要的促进作用。

值得一提的是，《中外物理学精品书系》还对中国近现代物理学科的经典著作进行了全面收录。20 世纪以来，中国物理界诞生了很多经典作品，但当时大都分散出版，如今很多代表性的作品已经淹没在浩瀚的图书海洋中，读者们对这些论著也都是“只闻其声，未见其真”。该书系的编者们在这方面下了很大工夫，对中国物理学科不同时期、不同分支的经典著作进行了系统的整理和收录。这项工作具有非常重要的学术意义和社会价值，不仅可以很好地保护和传承我国物理学的经典文献，充分发挥其应有的传世育人的作用，更能使广大物理学人和青年学子切身体会我国物理学研究的发展脉络和优良传统，真正领悟到老一辈科学家严谨求实、追求卓越、博大精深的治学之美。

温家宝总理在 2006 年中国科学技术大会上指出，“加强基础研究是提升国家创新能力、积累智力资本的重要途径，是我国跻身世界科技强国的必要条件”。中国的发展在于创新，而基础研究正是一切创新的根本和源泉。我相信，这套《中外物理学精品书系》的出版，不仅可以使所有热爱和研究物理学的人们从中获取思维的启迪、智力的挑战和阅读的乐趣，也将进一步推动其他相关基础科学更好更快地发展，为我国今后的科技创新和社会进步做出应有的贡献。

《中外物理学精品书系》编委会 主任

中国科学院院士，北京大学教授

王恩哥

2010 年 5 月于燕园

Very High Energy Cosmic Gamma Radiation

A Crucial Window on the Extreme Universe

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Max-Planck-Institut für Kernphysik
Heidelberg, Germany

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Preface

The branch of high energy astrophysics that studies the sky in energetic γ-ray photons – *gamma-ray astronomy* – is destined to play a crucial role in the exploration of non-thermal phenomena in the Universe in their most extreme and violent forms. The great potential of the discipline allows an impressive coverage of a diverse range of "hot topics" in modern astrophysics and cosmology, in particular (i) the origin of galactic and extragalactic Cosmic Rays, (ii) acceleration and radiation processes in extreme astrophysical conditions, e.g. in pulsar magnetospheres, in the vicinity of accreting black holes, in relativistic outflows like the quasar jets and the pulsar winds; (iii) the nature of enigmatic transient phenomena like the γ-ray bursts (GRBs); (iv) cosmological issues connected with the diffuse background radiation and intergalactic magnetic fields; the search for dark matter in the form of WIMPs through their characteristic annihilation radiation, and tests of non-acceleration ('top-down') scenarios for the production of the highest energy particles observed in Cosmic Rays, *etc.*

The results from the Compton Gamma Ray Observatory (GRO) have confirmed a number of these prime motivations of gamma-ray astronomy. Many classical representatives of different galactic and extragalactic source populations, e.g. pulsars, supernova remnants, giant molecular clouds, quasars, which were predicted as potential MeV/GeV γ-ray emitters, are now among the almost 300 γ-ray sources detected by EGRET, and approximately 30 sources detected by COMPTEL. The nature of most of these sources remains, however, unknown. Moreover, the origin of γ-radiation from even firmly identified objects is poorly understood. This clearly justifies future gamma ray missions with new generation detectors like the Gamma-ray Large Area Space Telescope (GLAST). GLAST, with its advanced performance, has been carefully designed for deep surveys of the

sky in γ-rays with an ambitious aim of providing *"γ-ray astronomy with thousands of sources"* in the energy region from tens of MeV to 10 GeV. Also, since most EGRET sources do not exhibit spectral cutoffs in the 1-10 GeV region, the extension of their study into the unexplored region beyond 10 GeV is another important issue for the GLAST. Meanwhile, the area limitations of space-borne detectors compels the study of Very High Energy (VHE) photons above 100 GeV to remain (except for the specific topic related to the diffuse extragalactic γ-ray background) the domain of ground-based gamma-ray astronomy.

The recent exciting observational results and theoretical predictions supply a strong rationale for the systematic study of primary γ-radiation in the VHE domain. Further improvement of the detection technique will be linked to stereoscopic observations of air showers with imaging Cherenkov telescope arrays with energy thresholds as low as 10 GeV, angular resolutions better than a few arcminutes, and flux sensitivities approaching to $10^{-13}\,\mathrm{erg/cm^2 s}$. This will elevate the status of the field, which currently can be characterised as an *"astronomy with a few sources"*, to the level of truly *observational* discipline.

The further study of the sky in high energy γ-rays promises a new path towards understanding of the non-thermal phenomena in the Universe. It is expected that with forthcoming powerful space-borne and ground-based detectors, gamma-ray astronomy will enter a new era with an objective of providing crucial insight into a number of fundamental problems of astrophysics and cosmology. This necessitates a comprehensive discussion of major motivations and objectives of this rapidly developing field.

When writing this book, I tried to highlight the principal objectives of the field, as well as to demonstrate its relevance and links to other branches of Astronomy and Cosmology. Preference has been given to three topical areas - the *Origin of Cosmic Rays*, the *Physics and Astrophysics of Relativistic Jets*, and *Observational Cosmology*. One chapter of the book is devoted to the discussion of principal γ-ray production and absorption mechanisms, with emphasis upon the processes that play dominant roles in the high and very high energy domains.

The chosen topics are among the scientific interests of the author. Also, a substantial part of the book is based on my own studies performed in close collaboration with my colleagues. Many results and conclusions reflect, to a large extent, my understanding of the subject in general, and my assessment of the achievements, as well as existing difficulties, ambiguities and "nasty problems" of the field. Therefore I cannot exclude a somewhat subjective

(but hopefully not completely wrong) character of some parts of the book concerning both the interpretation of observations and the preference given to certain methods and approaches in phenomenological and theoretical studies.

This book would have not been possible without intensive collaboration with my co-workers. Also, I have profited and learned a lot from discussions with numerous colleagues working in the field of high energy astrophysics. Special thanks must go to Armen Atoyan and Paolo Coppi for many years of fruitful collaboration. I am indebted to a large number of friends and colleagues for their invaluable contributions to the different aspects of our joint projects in several areas of high energy astrophysics: C. Akerlof, S.Bogovalov, J. Cronin, L. Costamante, E. Derishev, L. Drury, G. Heinzelmann, W. Hofmann, D. Horns, T. Kifune, S. Kelner, J. Kirk, H. Krawczynsky, A. Plyasheshnikov, G. Rowell, V. Sahakian, D. Schramm (deceased), R.A. Sunyaev, T. Takahashi, A. Timokhin, Y. Uchiyama, V. Vardanian (deceased), H.J. Völk. Finally, I am grateful to Phil Edwards for his careful reading of the manuscript and important comments.

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