GAMMA RAY ASTROPHYSICS AT ENERGIES UP TO 10 GeV

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ABSTRACT. During the last two decades, gamma-ray astronomy has
developed into a quantitative science, with accurate flux measurements
from several sources. The Crab pulsar emits $6.17 \times 10^{-4} \ E^{-2.2}$ photons
cm$^{-2}$ s$^{-1}$ MeV$^{-1}$ from 50 KeV to 5 GeV. This corresponds to about $2 \times 10^{35}$
erg s$^{-1}$ in each of two decades of energy. The Vela pulsar emits $3.6 \times$
$10^{-4} \ E^{-1.6}$ photons cm$^{-2}$ s$^{-1}$ MeV$^{-1}$ at energies 1 to 30 MeV. The luminosity
of gamma rays between 10 MeV and 1 GeV is about $2 \times 10^{34}$ erg/s. For
the Crab nebula, the gamma ray flux is $3 \times 10^{-3} \ E^{-2.3}$ photons cm$^{-2}$ s$^{-1}$
MeV$^{-1}$ from 1 KeV to 3 GeV. The flux of the $^{26}$Al line of 1.81 MeV (if
assumed to be an extended source) is $(4 \pm 0.4) \times 10^{-4}$ photons cm$^{-2}$ s$^{-1}$
rad$^{-1}$. The $e^+$ annihilation line in the Galactic plane is $(1.6 \pm 0.3) \times$
$10^{-3}$ photons cm$^{-1}$ s$^{-1}$ rad$^{-1}$ on which a variable flux of $\leq 1 \times 10^{-3}$ cm$^{-1}$ s$^{-1}$
from the Galactic center is superimposed at certain times. Theoretical
models of the sources and observations relate gamma-ray astrophysics to
pulsars, neutron stars, black holes, and interstellar clouds, supernovae and supernova remnants. The processes of nucleosynthesis in
supernovae and novae, and pair production near black holes yield gamma-
ray lines. Gamma-ray observations are also related to particle
acceleration processes at pulsars, neutron stars, supernova remnants,
and near black holes.

Outline of Topics and Sections

1. INTRODUCTION
2. EARLY HISTORY OF MEDIUM ENERGY GAMMA RAY OBSERVATIONS
3. GAMMA RAY DETECTORS AND TELESCOPES
4. GALACTIC SOURCES
5. GALACTIC LINES
6. NUCLEOSYNTHESIS OF GAMMA RAY EMITTING NUCLEI
* 7. GAMMA RAY BURSTS
8. GEMINGA
* 9. CYG X-1, PROBABLY ACCRETING BLACK HOLE
10. GAMMA RAYS FROM THE INTERSTELLAR MEDIUM
*11. GAMMA-RAY LINES FROM NUCLEAR EXCITATION AND SPALLATION, AND FROM THE SUN
12. ACTIVE GALACTIC NUCLEI
13. THE GAMMA RAY OBSERVATORY (GRO)

* Brief Highlights, for details refer to 1988 Erice lectures in NATO ASI book, see references to Hurley, Epstein, Liang and Silberberg et al. (1989) in this paper.

1. INTRODUCTION

Gamma-ray observations permit the study of many important problems in high-energy astrophysics, e.g. sites of acceleration of particles, explosive nucleosynthesis, pulsars, accreting neutron stars and black holes, active galactic nuclei, and nuclear and electromagnetic interactions of cosmic rays. Gamma rays can also serve as tracers of antimatter and the decay of massive particles postulated in some recent cosmological theories. Observational gamma-ray astrophysics is a rapidly developing new field--less than a quarter century old. The year (1991) will see the launch of the Gamma Ray Observatory (GRO) and some of the lecturers during the next course of the International School of Cosmic-Ray Astrophysics will be able to discuss the new observations based on GRO.

In the allotted time, we cannot present an in-depth review of the field, but present briefly the history, experimental techniques and problems and highlights of numerous topics. The latter include gamma rays from (a) pulsars and supernova remnants, (b) time-variable electron-positron pair production at the Galactic center, and diffuse emission of $e^+$ annihilation - probably generated from radioactive nuclei produced in nucleosynthesis, (c) the observation of the $^{26}$Al line, and possible sites of its nucleosynthesis, (d) nucleosynthesis of gamma-ray emitting nuclei in supernovae and novae, which are prime candidates for observation by the GRO OSSE experiment, (e) the gamma-ray burst objects - still poorly understood, giving rise to numerous speculative theories, (f) the gamma-ray source, Geminga, whose