ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **120,** 43-47 (1996)

The early days of gamma-ray astronomy

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Received January 10; accepted February 20, 1996

Abstract. The aims of gamma-ray astronomy were to establish both, the sources of cosmic rays and the seats of nucleosynthesis. The 1950's could be called the decade of predictions, when both roots came together and source strengths were predicted on the basis of radio-astronomical data and expectations of steady state cosmology. The 1960's were the decade of disappointment, because detectors employed then had too little sensitivity and too high background. The 1970's, the decade of discoveries were opened with OSO III seeing the milky way in gamma-rays, followed by SAS 2, Cos-B, SMM and others. And the 1980's were the decade of preparation for the Compton gamma-Ray Observatory: by now, gamma-ray observation have turned into a real astronomy and many of the original hopes have been fulfilled.

Key words: history of astronomy — Sun: gamma rays — cosmic rays — gamma rays: observations

1. Introduction

I believe gamma-ray astronomy has two roots, cosmic ray physics and nucleosynthesis. The cosmic ray root was evident very early. My first picture shows a cutting from the Pasadena Star News of Dec. 30, 1932 showing Millikan and Compton "battling" over the origin of cosmic rays – one type of origin thought to be gamma rays. Gamma rays were known to be a product of decaying nuclei, charged particles were known to be produced in collision, in which also "new matter" was being created. The production of cascade showers by electrons and photons had been observed, and their attenuation studied. The great names of that time are Blackett, Occhialini, Rossi, Bothe, Kohlhörster, Gentner. The triggered cloud chamber was the leading instrument of experimental work at that time (Fig. 2).

After the war, the nature of the cosmic radiation as being a predominantly nucleonic particle stream had been established, and spallation processes observed (Fig. 3).

Both roots came together in the 1950's as I will explain shortly. The development of gamma-ray astronomy can perhaps best be described as wave curve with ups and downs of a half-period of a decade: the 1950's as the decade of predictions, the 1960's as the decade of disappointment, the 1970's as the decade of discoveries, the 1980's as the decade of preparation, the 1990's as the decade of the Compton GRO. As I go through the early part of that wave, please forgive me if I give you a very personal account. As far as first predictions and first discoveries are concerned, I would like to refer you to the papers by Lingenfelter & Ramaty (1979), Lingenfelter (1988), and Virginia Trimble (1994) for example, or to the text books of Chupp (1976) or Fichtel & Trombka (1981). This being a personal account, I will also concentrate on high energy gamma rays.

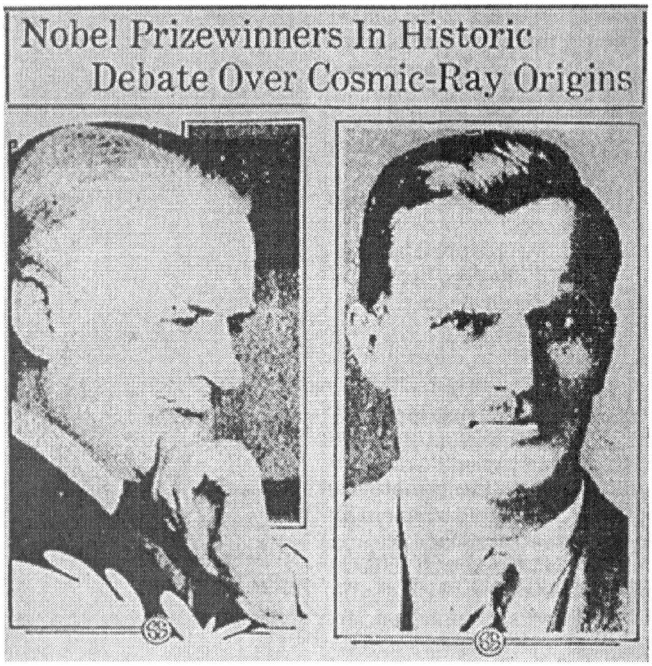

Fig. 1. Millikan and Compton debating the origin of cosmic rays (Pasadena Star News, Dec. 30, 1932)

2. The 1950's, the decade of predictions

Soon after the discovery of the π-Meson by the Bristol group, Hayakawa (1952) predicted the diffuse gamma-ray emission following the decay of π_0-mesons from cosmic ray - interstellar matter interactions, thus indicating where the cosmic rays are and where the matter is. Hutchinson (1952), in the same year predicted the gamma-ray emission from cosmic ray bremsstrahlung.

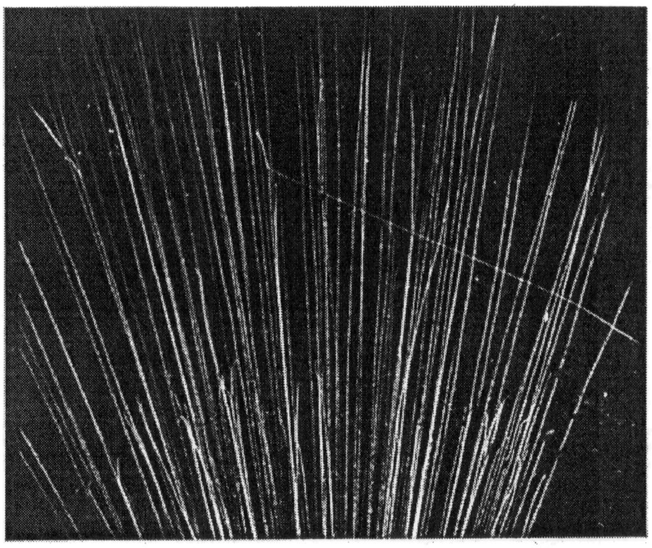

Fig. 2. Cloud chamber traces of incident 3.9 MeV α particles and generated ^{17}O nuclei and protons from ^{14}N(α,p) reactions

Nuclear research was forbidden in Germany until 1954; I joined the Bristol group in 1955 at the age of 24, arriving from a physics laboratory in Hamburg, later Kiel, led by Erich Bagge. J. Trümper was also there. In the laboratory, the first spark chamber (dc) had been operated as early as 1952 or so. Later, cosmic ray cascades were studied as extensive air showers.

At Bristol, we saw the nuclear interactions producing photons and particle showers, we saw the photons producing electron pairs. We knew the difficulties of background, and the secondary photon production. Balloons did not fly high enough, so that the atmospheric gamma rays overwhelmed the primary radiation.

I was fully immersed in the worlds of Powell, Occhialini, Dilworth, Perkins, Fowler, Rossi's book on "High Energy Particles", and his and Kenneth Greisen's work on cascade development. British cosmic ray work was not restricted to Bristol: Durham (Wolfendale), Leeds (Wilson), and Imperial College (Elliot) were great schools. Until about 1960, cosmic ray work was both, astrophysics and high energy elementary particle physics. With the advent of the large accelerators, we split. I decided to go into astrophysics.

The big years are 1957 und 1958, with the bedrock-paper on nucleosynthesis by Burbidge, Burbidge, Fowler & Hoyle, Morrison's paper on gamma-ray astronomy in the Nuovo Cimento, and the first observations of solar gamma ray lines by Peterson & Winckler (1959). These predictions, on the one hand, raised high hopes to discover gamma rays from excited nuclei (^{254}Cf) in supernova explosions, or the annihilation of radio galaxies - and as Virginia Trimble has observed, these high expectations "came out of the Steady State stable". On the other hand, all these high expectations were shattered during the next decade, all the instruments had too little sensitivity, too much background.

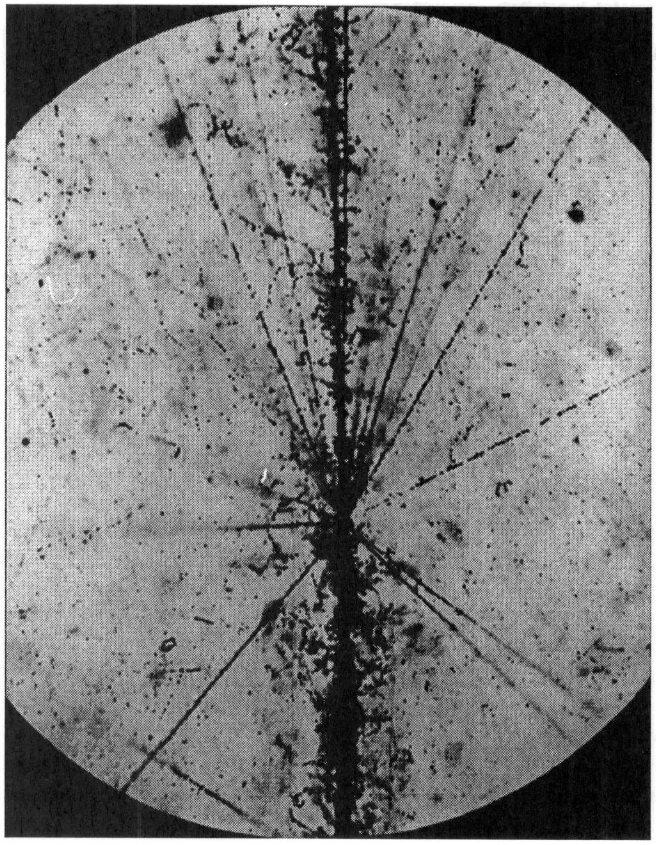

Fig. 3. Observation of spallation processes

3. The 1960's, the decade of disappointment

Following Morrison's predictions, numerous balloon-experiments were performed, looking for the galactic plane, the Crab, Cygnus A with no significant results. In 1970, W.L. Kraushaar could say that the only firm gamma-ray data (high-energy, I should say) had been obtained with the OSO-III experiment, following the similar earlier Pioneer XI attempts.

In the middle of this decade, we said to ourselves: how can we get out of the 2σ-club? It was very clear that, as far as high energy gamma-ray astronomy was concerned (say, above some tens MeV) we needed good background rejection, and good event identification. This meant a good satellite orbit, good anticoincidence, no mass in the wrong place, and track registration equipment, which turned out to be spark chambers.

When I joined the Max-Planck-Institut in 1965, Sommer and Mayer had started to develop a wire spark chamber. In February 1966, we proposed a gamma-ray experiment for the so-called German A3 mission. NASA - which was to launch this mission - politely declined, saying that Germany should first demonstrate its space ability.

In 1966, experiment space became available on the ESRO TD-1 satellite, because G. Hutchinson could not obtain British funding for his experiment. The gap was filled by a small gamma-ray experiment with a vidicon spark chamber provided by a collaboration between Milano, Monaco, and Saclay, the Mimosa collaboration. It

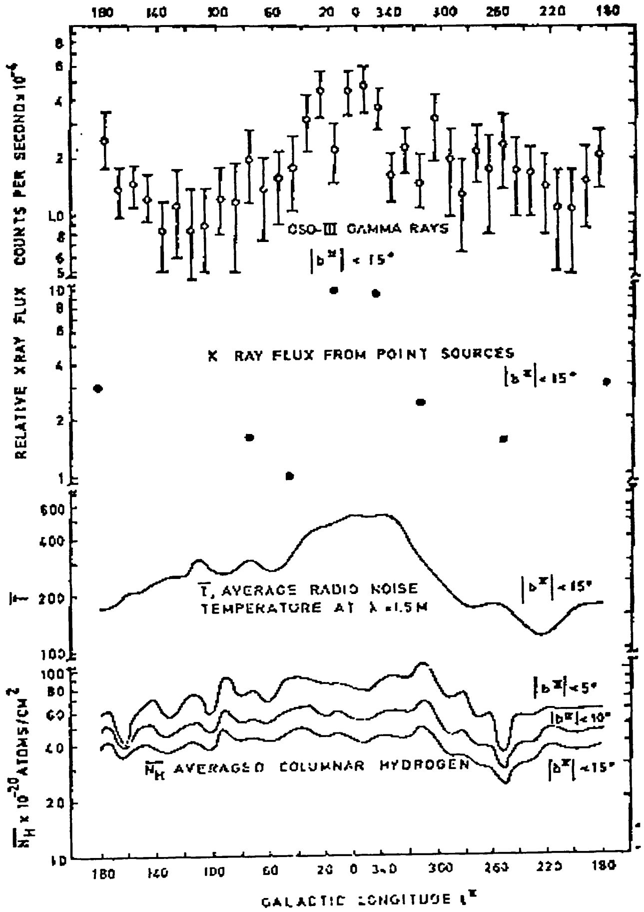

Fig. 4. OSO-III detection of Galactic gamma-rays (Kraushaar et al. 1972)

actually had two sources: on the one hand, Occhialini, Labeyrie & Lüst had come together in the framework of ESRO on the S-111 experiment, on the other hand, I found much of my old Bristol background within ESRO's COS-group.

The TD-1 experiment was not successful due to high background and the failure of the vidicon system. Its impact was two-fold: it was the beginning of the later Caravane-COS-B collaboration with Leiden and ESTEC as additional partners, and it cleared the way for the acceptance of the wire spark chamber in Europe.

In 1967 it was clear that our only path to success was the European Space Programme. Within the German programme we had not been successful and this was devoted entirely to magnetospheric and interplanetary space plasma physics: finally the Helios-Satellite. To go to NASA directly to compete in the Small Astronomical Satellite Programme appeared hopeless, since Cline, Fichtel & Kniffen had proposed the SAS-2 experiment in 1967.

Thus, in 1967, the COS-collaboration, called Caravane Collaboration established itself. In the end, it consisted of groups at Palermo, Milan, Munich, Saclay, Leiden and ESTEC at Nordwijk. COS B had a most difficult and tortuous path of approval. It first had to compete within

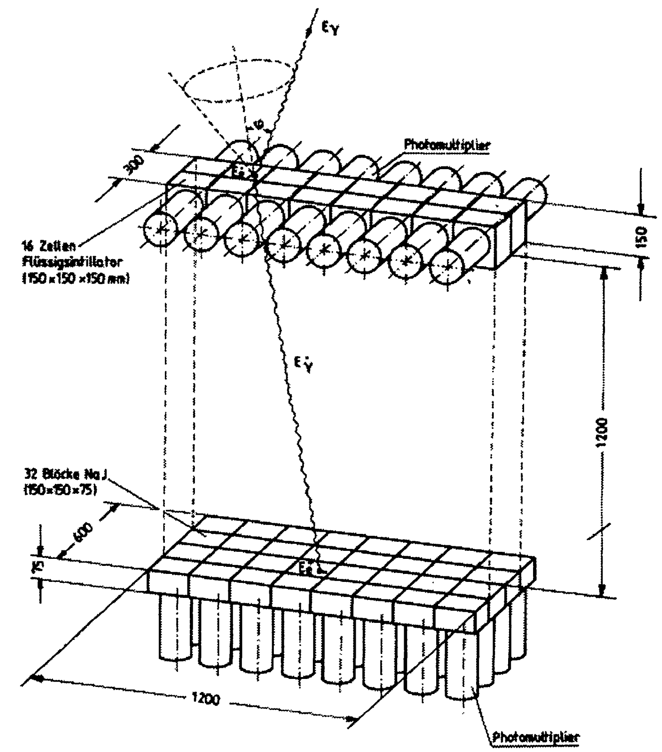

Fig. 5. Compton telescope

the field of astronomy, first against optical and UV astronomy, later against X-ray astronomy. In the end it was chosen, because it was sufficiently cheap and simple - a secret which also was important for the ROSAT mission for example.

Then, it had to compete against magnetospheric and interplanetary physics. This was achieved by it being so cost-effective, that COS B could be selected for ESRO's space programme together with GEOS.

Let me tell you a secret of how to be selected with your project and how to beat your competitors. The secret to be selected is, financially, to stay just below refusal. If you are too far below refusal, the science that you offer is not optimal. If you are above refusal - well, then you have had it. And your competitors? Just tell them that their proposal is so good that it would be important to add this or that bit of science to be perfect. Then, in the end, they will end up above the limit of refusal.

Thus, at the end of the decade of disappointment, when Kraushaar et al. (1972) first demonstrated that the Milky Way could be seen in the light of gamma rays (Fig. 4), we were in the situation of having two powerful spark chamber experiments about to make their impact, SAS-2 and COS B.

There was the beginning of another branch of gamma-ray astronomy in the 1960's. In 1968, we proposed to NASA to fly a neutron-astronomy experiment on balloons, measuring the energy and direction of arrival of neutrons from the Sun or as albedo neutrons from the atmosphere. It used a double scattering technique to achieve that goal. Volker Schönfelder graduated with this work and one can

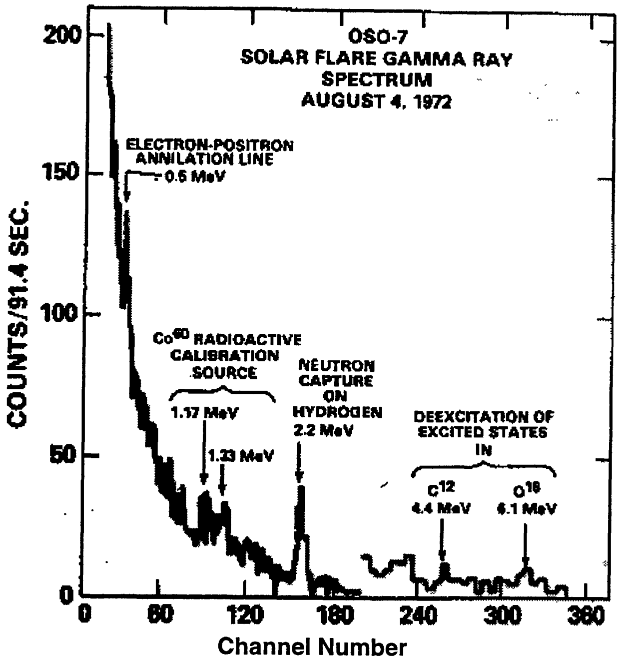

Fig. 6. Discovery of solar gamma-ray lines by the OSO-7 mission (Chupp et al. 1973)

see the beginning of COMPTEL here, because the principle is the same for elastic neutron scattering, or Compton collisions (Fig. 5).

4. The 1970's, the decade of discoveries

I have mentioned OSO-III already. Let me remind you that the beginning of this decade saw major restructuring efforts in the US and Europe. In the US, as a consequence of the success of the Apollo programme, but also as a consequence having reached this goal, NASA got into a crisis, and it decided in favour of the Shuttle. NASA also launched the HEAO-project. There were to be 4 HEAO spacecrafts, the first of a survey type, the latter pointing. They were to investigate X- and gamma-ray astronomy from 1 MeV to 10 GEV, cosmic rays - nucleons and electrons including isotopic composition. The total weight of the spacecraft was to be 19.000 pounds, 12.500 pounds for the payload.

It must have been in Rome in 1969, when Carl Fichtel and I agreed to collaborate on a gamma-ray experiment for HEAO. The HEAO gamma-ray proposal later turned into EGRET, launched on the Compton Gamma-Ray Observatory in 1991, 22 years to completion.

For gamma-ray astronomy, HEAO-C was important, because it discovered the 1.8 MeV ^{26}Al line in Jacobsen's experiment (Mahoney et al. 1982).

Then, of course, there was Ed Chupp (1972, Fig. 6) with his solar flare experiment on OSO-7 and the discovery of solar gamma-ray lines in two flares of August 1972 (Aug. 4 and Aug.7). This important work on solar gamma-ray astronomy culminated in the Solar Maximum Mission. And if we think that 70 keV are gamma rays, there was the

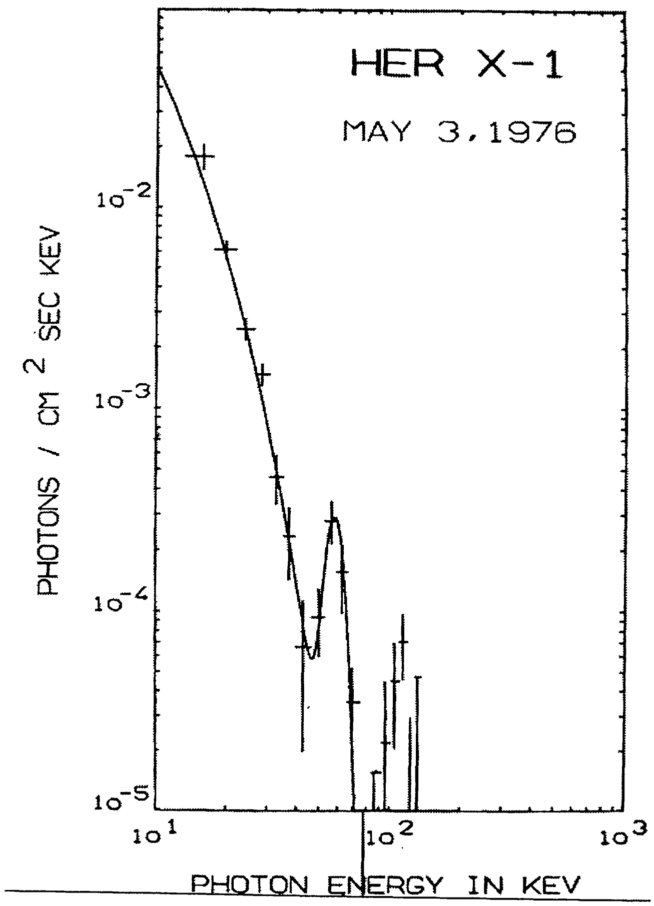

Fig. 7. Discovery of a cyclotron line from Her X–1 (Trümper et al. 1978)

cyclotron line discovered by J. Trümper and collaborators on Her X–1 in 1976 (Fig. 7).

For high energy gamma-ray astronomy, SAS-2 and COS B were the main sources of information. The SAS-2 results were presented here in Munich at the 14th International Cosmic Ray Conference in 1975. SAS-2 saw the Crab, the Vela Pulsar the band of the Milky Way (Fig. 8). Unfortunately, a failure of the tape recorder gave it only limited lifetime.

COS B had been designed for a highly eccentric orbit, because Europe had bad luck with tape recorders before, our own ground stations and the success of HEOS favoured the excentric orbit. It had a slightly larger effective area than SAS-2, and better energy resolution. Its main luck, and the main source of success was that the spark chamber was much better than anticipated, using much less gas, and a very careful operations strategy gave it a total lifetime of 7 years in orbit.

The results were phenomenal; a complete map of the milky way in various energy bands, the COS B catalogue of point sources, detailed studies of several of them, Pulsars, events of large time variability. At least in European terms, COS B was one of its very big achievements. As I mentioned before, the end of the decade saw the Solar

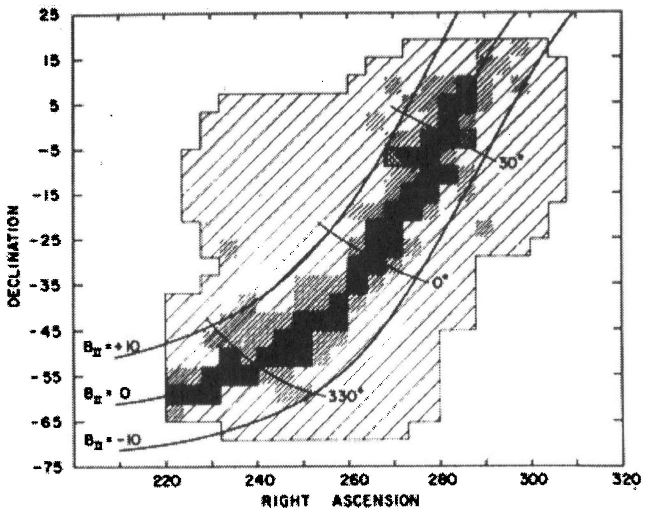

Fig. 8. The inner Galactic plane as seen by SAS-2

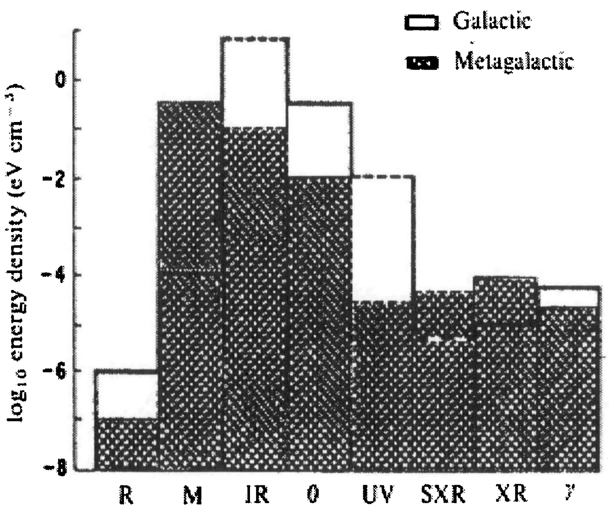

Fig. 9. Photon energy density versus wavelength domains

Maximum Mission - and SMM led gamma-ray astronomy into the 1980's.

5. The 1980's, the decade of preparation

I want to stop here. You know better than I what happened in the 1980's. You know of the difficulties to establish the Compton Gamma-Ray Observatory out of the collapse of the HEAO missions, to run large collaborations, to meet the safety requirements of the shuttle launch. You know the worries and the sleepless nights of those responsible for proper functioning of equipment. When I once said to George Pieper that I had vowed a candle if my experiment worked, he replied that on one occasion just before a sounding rocket launch he had said to his colleague: our only hope is that the rocket aborts.

Gamma-ray astronomy has come a long way from the 2σ-club. Let me congratulate you all on this achievement. But there are still many photons in the cosmos to be discovered (Fig. 9). Go and look at them.

References

Burbidge E.M., Burbidge G.R., Fowler W.A., Hoyle F., 1957, Rev. Mod. Phys. 29, 457
Chupp E.L., et al., 1973, Nat 241, 337
Chupp E.L., 1976, in "Gamma-Ray Astronomy". D. Reidel Publishing Company, Dordrecht, Holland
Fichtel C.E., Trombka J.I., 1981, "Gamma-Ray Astrophysics, New Insight into the Universe", Washington DC: NASA, NASA SP 453
Hayakawa S., 1952, Progr. theor. Phys. 8, 571
Hutchinson G.W., 1952, Philos. Mag. 43, 847
Kraushaar W.L., 1972, ApJ 177, 341
Lingenfelter R.E., 1988, in "Nuclear Spectroscopy of Astrophysical Sources", Neil Gehrels & Gerald Share (eds.), AIP Conf. Proc. 170, 17
Lingenfelter R.E., Ramaty R., 1979, Xth Leningrad seminar on cosmophysics, V.A. Dergachev, G.E. Kocharov (eds.), Leningrad
Mahoney W.A., Ling J.C., Jacobson A.S., Lingenfelter R.E., 1982, ApJ 262, 742
Morrison P., 1958, Nuovo Cimento 7, 858
Peterson L.E., Winckler J.R., 1959, J. Geoph. R. 64, 697
Trimble V., 1994, in "The Second Compton Symposium", Carl E. Fichtel, Neil Gehrels, Jay P. Norris (eds.), AIP Conf. Proc. 304, 40
Trümper J., et al., 1978, ApJ 219, L105