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A Positron Annihilation Radiation Telescope Using Laue Diffraction in a Crystal Lens.*

R.K. Smither
Experimental Facilities Division
Advanced Photon Source
Argonne National Laboratory
Argonne, Illinois 60439

Peter von Ballmoos
Centre d'Etude Spatiale des Rayonnements
Toulouse, France

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A POSITRON ANNIHILATION RADIATION TELESCOPE USING LAUE DIFFRACTION IN A CRYSTAL LENS

Robert K. Smither¹ and Peter von Ballmoos²

1 Argonne National Laboratories, Illinois, USA

2 Centre d'Etude Spatiale des Rayonnements, Toulouse, France

ABSTRACT

We present a new type of gamma-ray telescope featuring a Laue diffraction lens, a detector module with a 3-by-3 germanium array, and a balloon gondola stabilized to 5 arc sec pointing accuracy. The instrument's lens is designed to collect 511 keV photons on its 150 cm² effective area and focus them onto a small detector having only ≈ 14 cm³ of equivalent volume for background noise. As a result, this telescope overcomes the mass-sensitivity impasse of present detectors in which the collection areas are identical to the detection area. The sensitivity of our instrument is anticipated to be 3×10^{-5} ph cm⁻² s⁻¹ at 511 keV with an angular resolution of 15 arc sec and an energy resolution of 2 keV. These features will allow the resolve of a possible energetically narrow 511 keV positron annihilation line both energy-wise and spatially within a Galactic Center "microquasar" as 1E1740.7-2942 or GRS1758-258. In addition to the galactic "microquasars," other prime objectives include Cyg X-1, X-ray binaries, pulsars, and AGNs.

1. INTRODUCTION

The concept that it is "impossible to reflect or refract gamma-rays," has been commonly accepted by astrophysics community. Thus high energy astronomy has always used "telescopes" in which the detector area was identical to the photon collecting area. Today, gamma-ray astronomy is in a mass-sensitivity impasse because large collection areas are synonymous with large detectors and thus high background noise: achieving a good signal-to-noise ratio results in trade-off between signal (detector-surface) and background (detector-volume). We believe that the instrument presented in this work is a way out of this dilemma. For the first time, a crystal diffraction lens will concentrate photons from a large photon collecting area onto a small detector.¹⁻³ In addition to its

very good sensitivity, the telescope has outstanding angular and energy resolution. The primary scientific objectives of this instrument is the 511 keV emission of a class of recently discovered objects called "galactic microquasars." Gamma-ray line emission at 511 keV from an astrophysical source in the Galactic Center region was first detected in the early seventies and has since been observed with numerous balloon and satellite experiments (see e.g. Lingenfelter and Ramaty [1989] for a review).⁴ Originally, the gamma-ray flux in the line was of the order of 10^{-3} ph cm⁻²s⁻¹. Within half a year, the positron annihilation source supposedly disappeared (in 1979/80). Until 1988, instruments with a narrow field of view (FOV) measured only upper limits for its flux, while the gamma-ray spectrometer on board the SMM spacecraft observed a steady flux from the galactic center region within its wide field of view (1300 FOV). It is now generally believed that these apparently conflicting results can be explained by a two-component model: an extended steady component, and a variable component that is strongly peaked towards the galactic center. The extended component can be understood as being due to the annihilation in the interstellar medium of positrons released by the radioactive decay of unstable isotopes created in the sites of ongoing galactic nucleosynthesis (supernovae, novae, and other massive stars such as WR). Recent results from GRO-OSSE (Kurfess et al., 1993)⁵ suggest that the extended component can be divided in a galactic bulge and a galactic ridge component (see Table 1).⁶⁻⁸ The galactic center source of narrow 511 keV emission has traditionally been attributed to a variable point source. According to GRO-OSSE (Johnson et al. 1992),⁷ the source at the galactic center has a flux of 2.4×10^{-4} ph cm⁻²s⁻¹ and is consistent with a point source or a source that cannot be resolved by the OSSE collimator. To date, the OSSE data do not show any evidence for time variability of this component. Also, recent data of large balloon borne gamma-ray spectrometers (GRIS, HEXAGONE) show that there is no compelling evidence for variability of the 511 keV line (for a review see e.g., von Ballmoos, 1991⁹; for latest GRIS results see Leventhal et al., 1993¹⁰). Furthermore, the compact galactic center sources observed by the imaging SIGMA telescope (Bouchet, 1992)⁸ have never detected a narrow 511 keV line (2σ upper limits of the order of 5×10^{-4} ph cm⁻²s⁻¹). All these arguments could be understood in the sense that the peaked galactic center component of the 511 keV line is not associated with compact objects. Yet, the recent discovery of broad annihilation features in

several compact sources has shown that there is one or several types of objects that obviously can produce intense eruptions of positron. The question is now whether these broad class annihilators also generate the positrons that produce the narrow 511 keV line.

2. SCIENTIFIC OBJECTIVES

The primary scientific objectives for this telescope are galactic microquasars, broad class annihilators and related compact objects. 1E1740-2942 has now twice been observed by the SIGMA telescope to emit strong spectral features in the energy interval 300-700 keV emanating and vanishing within days. A comparison of the location and angular resolution of different experiment are compared in Figure 1. The first time SIGMA detected one of these "annihilation radiation" outbursts was on October 13 (Bouchet et al., 1992).⁸ The flux in the broad annihilation line is $1.3 \times 10^{-2} \text{ ph cm}^{-2} \text{ s}^{-1}$ and corresponds to the injection of $\approx 10^{10}$ tons of positron/second into the supposed accretion disk of a black hole. 1E1740-29 and GRS1758-258 (which resembles the former source) have recently been identified at cm-wavelengths. Both of the radio observations reveal the presence of an active-galactic-nucleus (AGN) like structure with double sided radio jets emanating from a compact and variable core. Whereas the SIGMA telescope indicated the existence of a hot ion plasma near 1E1740.7-2942, the sensitivity of current imaging instruments only allows one to derive upper limits on the order of $5 \times 10^{-4} \text{ ph cm}^{-2} \text{ s}^{-1}$ for the narrow 511 keV line. If this "broad class annihilator" really is associated with the radio source, the origin of the high energy emission within the microquasar becomes a key question for gamma-ray astronomy. Ramaty, Leventhal, Chan and Lingenfelter (1992)¹¹ have suggested that such microquasars contribute to the narrow 511 keV line if the ejected positrons escape to the surrounding gas where they would slow down before annihilating. They predict a narrow and variable 511 keV line emission from a region that could be as large as large as 20 arc sec and emit a flux of 10^{-4} to $10^{-3} \text{ photons cm}^{-2} \text{ s}^{-1}$. Featuring a sensitivity of $3 \cdot 10^{-4} \text{ ph cm}^{-2} \text{ s}^{-1}$ and an angular resolution of 15 arc sec, our proposed instrument can test hypotheses on the intensity and site of the narrow 511 keV line. An observation of the lower predicted flux of $10^{-4} \text{ photons cm}^{-2} \text{ s}^{-1}$ (Ramaty et al. 1992)¹¹ would result in a 7s to 10s detection. The angular resolution element of the telescope is compared with the extent

of the radio source associated with 1E1740.7-2942. If the radio lobes really track twin jets of positrons out to their annihilation sites in the superposed molecular cloud, the telescope could localize the annihilation regions.

Other scientific objectives for this instrument are other compact objects that are candidates for narrow 511 keV line emission. Sources that have been proposed for such emission include Cyg X-1, x-ray binaries (e.g., Nova Musca), pulsars (e.g., Crab, Vela, Geminga), active galactic nuclei and solar flares.

3 THE POSITRON ANNIHILATION RADIATION TELESCOPE

It is a conjunction of recent developments in high energy astronomy and instrumental techniques that make feasible today a 511 keV crystal diffraction telescope. A fundamental condition is the exact knowledge of the positions (≈ 1 arc sec) of candidate annihilation radiation sources. Currently, the identification of SIGMA- and GRO-sources at other wavelengths (i.e. VLA observations of microquasars, see Figure 1), has opened the way for a gamma-ray telescope with very high angular resolution. Likewise, the technologies that are required to build such an instrument have become available only very recently: With the construction of third generation synchrotron facilities (like the Advanced Photon Source at the Argonne National Laboratory) renewed interest has developed in the diffraction of energetic gamma-rays. The new high energy synchrotron beams will require monochromators that are efficient at energies up to 1 MeV. This activity has generated new interest in the art of crystal diffraction of energetic gamma-rays and has lead to a prototype lens that is suitable for an astronomical instrument. The focal plane of this lens will accommodate a new solid state detector that allows one to take maximum advantage of the focused nature of the gamma-ray beam. The high purity Germanium Matrix Detector (3x3 elements) of the CESR laboratory in Toulouse is ideally suited to resolve the diffracted beam from the lens, both energetically and spatially. Efficient suppression of the remaining background noise will be possible using the nine segments of the detector. The very narrow angular acceptance width of the lens puts considerable constraints on the stability of the telescope structure and on the gondola pointing. CNES laboratory in Toulouse has developed a large balloon gondola with 5-arc-sec pointing capabilities that will make its maiden flight in September 1993. Table 2 summarizes the structure and

performance of the major components in the crystal lens telescope.

3.1 THE LENS MODULE

The crystal diffraction lens that will be used in this experiment is designed to accommodate eight rings of single crystal cubes, 1 cm on a side (see Figure 2). Each ring uses a different set of crystalline planes to diffract the gamma-rays. The eight rings accommodate 600 germanium crystals. The crystals are oriented so that they all diffract incident radiation of the same energy to the same focal point. The diameter of the lens frame, including the outer support ring, is 45 cm. The focal length of this lens for the 511 keV positron annihilation line is 8.29 m.

The intensity of the diffracted beam is proportional to the square of the sum of the amplitudes of the scattered beam, so the intensity of the diffracted beam from 100 layers of atoms will be 10,000 times larger than the intensity of the reflected beam from one layer. Under most diffraction conditions, 1000 to 10,000 layers are involved in the diffraction process, so the gain in intensity can be very large. It is this large gain in reflectivity or cross section for diffraction that makes the crystal lens an efficient collector of radiation. As the diffracted photon beam passes through the crystal, photons are diffracted back and forth between the incident beam and the diffracted beam. If the crystal is relatively thick, the two beams will emerge from the opposite side of the crystal with equal intensities. Thus the maximum intensity that one can expect in the diffracted beam for the Laue geometry (transmission case) for thick crystals is 50% rather than 100%, which is possible for the Bragg case (surface diffraction). The second major difference between Bragg and Laue diffraction is that, in the Laue case, all of the photons pass through the full thickness of the crystal and, as a result, are absorbed to the same degree. When the crystal is close to perfect, this thickness for maximum efficiency can be less than 1 mm even for energetic gamma-rays such as the 661.65 keV line from ^{137}Cs (Smither, 1989).³ For thin perfect crystals, the 50% rule does not hold, and, if just the right thickness is chosen, the intensity in the diffracted beam can be appreciably greater than 50 %. In practice, one increases the thickness of the crystal until the product of the diffraction efficiency times the transmission through the crystal is a maximum. This maximizes the

intensity in the diffracted beam.

The main drawback in using perfect crystals is that the range of acceptance angles for which the diffraction process works is quite narrow. This means that only a very small range of incident angles will produce diffraction. A very good germanium crystal will have a range of acceptance angles of less than one arc second. This effect will be an important consideration in the design of a crystal lens. A very narrow acceptance angle for a finely tuned crystal lens, results in a narrow field of view. If one wishes to increase the acceptance angle for diffraction, one can use an imperfect crystal that is grown with many dislocations and/or impurity atoms. This generates a mosaic structure in the crystal that results in different parts of the crystal having slightly different orientations, which translates into a wider range of acceptance angles and more intensity in the diffracted beam. As the mosaic structure increases, a thicker crystal is required to obtain the maximum diffraction efficiency.

The range of acceptance angles for incident photons on a crystal is often referred to as the rocking curve for the crystal. This term comes from the way this quantity is measured. To generate or measure a rocking curve, one measures the intensity of the diffracted beam as a function of the incident diffraction angle for a well collimated monochromatic beam of x-rays or gamma-rays. The efficiency of the Laue Diffraction Process (LDP) for thick imperfect crystals is the product of two functions, the fraction of the incident beam that is diffracted, given by equation 1.

$$\text{Crystal Diffraction Fraction} = 1/2 [1 - e^{-\sigma x}], \quad (1)$$

where σ is the diffraction cross section per unit thickness, and x is the thickness of the crystal. The transmission of the beam through the crystal is given by equation 2

$$\text{Transmission} = e^{-\alpha x}, \quad (2)$$

where α is the cross section for absorption per unit thickness. This gives the full crystal diffraction efficiency,

$$\epsilon_d = 1/2 [1 - e^{-\sigma x}] [e^{-\alpha x}]. \quad (3)$$

For a 10-mm-thick Ge (400) crystal, this function results in an efficiency of approximately 28% at 511 keV.

Based on the data taken with the prototype lens constructed at Argonne National Laboratory, the effective collection area of the lens is estimated to be between 140 cm² and 160 cm². This means that the flux incident on 140 cm² of area will be concentrated on a focal spot 1.2 cm in diameter (FWHM). This assumes nearly perfect alignment of the crystals in the lens. The width of the field of view will depend on the angular width of the mosaic structure of the crystals. The calculations presented here assume a mosaic structure width of 10 arc seconds. This would generate a FWHM for the field of view of 16 arc seconds with near perfect alignment of the crystals. This is attainable in the laboratory but in the field some misalignment is expected, so a more likely value for the FWHM of the field of view is 20 arc seconds. If the crystals are more perfect than the 10 arc second mosaic structure, then the field of view could be narrower. However, if this is undesirable for the experiment, one can de-tune the lens and recover the 20 arc second FWHM value.

3.2 THE DETECTOR MODULE

The choice of a high purity Germanium Matrix Detector used in the proposed instrument has several advantages. Within the narrow energy-bandwidth of the lens, the detector will resolve the line width and measure the broadening of the 511 keV line, relative to the natural line width for cold material to better than 2 keV FWHM. The "pixel-size" of 1.5 cm by 1.5 cm is well adapted to the size of the focal spot of 1.2 cm diameter. The segmentation of the 3x3 Ge matrix detector together with the concentrated beam from the crystal lens allows one to apply new techniques for background reduction (segmentation). According to the telescope rigidity and gondola stabilization, the focal spot might move over the surface of the detector. This movement will be sensed by the segmented detector and by the star tracker and taken into account in the data analysis. The spatial resolution of the interaction sites is used to keep the equivalent background volume as small as possible. A schematic view of the Ge matrix and the layout of a possible shield are sketched in Figure 3. The corresponding background rates used in the sensitivity estimate presented here for the detector system assume an anticoincidence shield consisting of a 5-cm-thick BGO shield (density 7.3

g/cm³). The total weight of such a detector/shield module is estimated to be ≈ 100 kg.

3.3 GONDOLA: STABILITY AND POINTING

The 15-20 arc second angular beam width of the lens requires excellent stability of the telescope structure and very fine gondola pointing. Figure 4 illustrates the stability/pointing constraints by means of a general block diagram. Actually, only the lens module has to be pointed on the source to within 5 arc sec. At a distance of 8.29 m, the detector module can be 'anywhere' in the focal spot area as long as its position on the Ge-array is known (1 mm corresponds to 30 arc sec). The constraints on the pointing/stability of the gondola can be summarized as follows:

absolute pointing accuracy of the optical axis (lens only): 5" pointing accuracy of the telescope axis; lens weight to be stabilized: ≈ 15 kg; telescope weight to be stabilized : ≈ 200 kg.

Among the carrier options discussed is the NAPS (NAcelle Pronaos Stabilisie) bus,¹² a balloon gondola developed for the 2 m infrared telescope Pronaos. With its height of 7 m, the NAPS gondola can carry an instrument as long as the positron annihilation radiation telescope; its achievable pointing accuracy is 5". The NAPS bus is operational at CNES/Toulouse and will make its maiden flight in September 93.

4 PERFORMANCE

Field of view: The FWHM of the response function of the lens will be in the 10 to 20 arc second range and can be tailored to what is required (astrophysics) or possible (gondola stabilization) by defocusing the lens and/or broadening the rocking curves of the germanium crystals. A 16 arc sec number for the FWHM of the angular response of the lens assumes an average crystal mosaic structure width of 10 arc seconds. A 10 arc second FWHM for the angular response is possible but it would require very careful alignment and crystals with a smaller mosaic structure.

Energy bandwidth: Assuming a 16 arc sec FWHM for the response function the energy bandwidth of the largest diameter ring of the crystal lens and

the smallest diameter ring are

$$\begin{aligned}\Delta E(440) &= (\Delta\Theta/\Theta) E(511) = 3.26 \text{ keV} \\ \Delta E(111) &= (\Delta\Theta/\Theta) E(511) = 10.65 \text{ keV}\end{aligned}$$

Thus each ring has a different bandwidth. The average bandwidth will be about 6 keV. Each ring of crystals will be weighted by its diffraction efficiency and the number of crystals in the ring.

Spatial resolution: According to the operation mode chosen, the angular response can be used to obtain information on the structure of the observed sources. Possible operation modes include temporal and spatial modulation for background subtraction: e.g., the classical "ON/OFF" mode for different parts of the source region (core, jets) or scans of the source region with background monitoring within the Ge array. The expected angular resolution of the system given by the angular response is 16 arc sec FWHM.

Energy resolution: The energy resolution of single detectors of the Ge array has been measured to be 2.1 keV at 1.33 MeV. We therefore anticipate a resolution of <2 keV FWHM at 511 keV for single and multiple interactions.

Effective area: The total efficiency of the telescope is composed of the diffraction efficiency ϵ_d of the lens and the full energy peak (FEP)

efficiency ϵ_{fep} of the Ge array. The diffraction efficiency of each crystal varies between 10 and 30 percent depending on which planes are used and the mosaic structure of the crystal. The lens is constructed of germanium crystals in the shape of cubes 1 cm on a side. The germanium lens is 45 cm in diameter and has 8 rings of crystals. The crystal area A_g of the full lens is about 600 cm². The maximum theoretical efficiency, defined as the percentage of the gamma-rays that enter the front of the crystal that are then focused on the detector, is 35 percent. Thus the maximum effective area of the crystal lens is about 210 cm². The measured efficiency on a part of the actual lens is $\approx 25\%$. Using this measured efficiency, the effective area of the lens will be about 150 cm². For 511 keV gamma rays incident on a 1.2-cm-diameter focal spot on the center element, the Ge

array is expected to have a FEP efficiency of 33%. (as a results of Monte Carlo simulations performed by E. Naya for the 3x3 Ge matrix).¹³ It is worth mentioning that the full energy peak efficiency of this "lens-detector" arrangement is improved by 25% compared to an ordinary (non-focused) illumination! The total effective area A_e of the instrument is thus

$$A_e = A_g \times \epsilon_d \times \epsilon_{fep} = 50 \text{ cm}^2. \quad (4)$$

Sensitivity: The sensitivity estimate for the proposed telescope is different from the usual sensitivity computations in various ways. To our knowledge this is the first astronomical instrument in the energy range of nuclear gamma-rays in which we expect our statistics not to be dominated entirely by the background noise, but rather, by the signal strength. We, therefore, had to abandon the commonly accepted expression of the type

$$f_n = n [B(1+a)]^{-0.5} / E \quad (5)$$

which is only correct for $f_n E \ll B$, where B is the number of background counts, E is the exposure [$\text{cm}^2 \times \text{sec}$], n is the wanted number of standard deviations, and "a" is the ratio of the statistical sample sizes in the on/off measurement). The expression below of the sensitivity is derived from the standard way of calculating detection significances (see e.g. Staubert 1985).¹⁴ Because it includes the signal component in the background estimation, it corresponds to a solution of a quadratic equation:

$$f_n = n [n + (n^2 + 4N)^{0.5}] / 2E \quad (6)$$

$$N = b(1+a) v_{on} T_{on}$$

$$E = A_g \epsilon_d \epsilon_{fep} t_a T_{on},$$

with N representing the equivalent measure of the background counts (on and off, weighted with a), b is the volume specific background count rate [$\text{cts}, \text{cm}^{-3}, \text{s}^{-1}$], v_{on} is the effective source detection volume, T_{on} is the observing time "on" source, and t_a is the mean atmospheric transmission.

The mosaic structure of the detector allows for different ways to subtract the background and thus affect the sensitivity (via the parameter a). Because it is desirable to make " a " as large as possible without making too important compromises on the effective exposure of the source, we will evaluate several modes of operation. The one operation mode we envisage is classic "on/off" subtractions with a time dedicated to the observation of the source (T_{on}) and a time of background monitoring (T_{off}). Another operation mode is particularly adapted to the segmentation of the Ge mosaic. It consists of simultaneous source observation and background monitoring taking advantage of the independent equivalent regions that can be defined within the detector array.

CONCLUSIONS

We propose to investigate the recently discovered galactic microquasars, broad class annihilators, and related compact objects with a telescope using fundamentally novel techniques in the domain of high energy astrophysics.

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REFERENCES

1. Smither, R.K., 1982, Rev. Sci. Instrum. 63, 131
2. Smither, R.K., 1984, U.S. Patent No. 4,429,411
3. Smither, R.K., 1989, Proc. of the GRO science workshop
4. Lingenfelter, R.E., and Ramaty R., 1989, Ap.J. 343, 686
5. Kurfess, J. et al., 1993, these proceedings

6. GRONEWS, OSSE from 15-JAN-1993
7. Johnson, W.N., 1992, to appear in A&A supplement series
8. Bouchet, L., 1992, Ph.D. Thesis No. 1166, University Paul Sabatier, Toulouse
9. von Ballmoos, P. ,1991, Ap.J. 380, 98
10. Leventhal, M., et al., 1993, Proc. of the Compton Symposium, St. Louis
11. Ramaty, R, Leventhal M., Chan, & Lingenfelter, R, 1992, Ap.J. 392 L63
12. PRONAOS June 1988, Phase B- itude de difin. prelimnaire, CNES
13. Naya, E., Monte Carlo simulations performed at CESR in Toulouse.
14. Staubert, 1985, 19 th ICRC, San Diego, OG9.5-10

Table 2 : Instrument characteristics and performance .

Crystal lens

diffracting medium	: 600 Ge crystals (1 cm^3) in 8 rings
diameter of frame	: 45 cm
focal length	: 8.292 m
diameter of focal spot	: 1.2 cm FWHM
acceptance angle (FOV)	: 10"-20" FWHM
energy bandwidth	: 6 keV FWHM
diffraction efficiency	: 25%
effective collection area	: 150 cm^2

Detector matrix

detector type	: 9 high purity Germanium, coaxial, $1.5 \times 1.5 \times 4.0 \text{ cm}$
energy resolution	: 2 keV (@ 511 keV)
total detecting volume	: 81 cm^3
total detector area	: 20.25 cm^2
equivalent effective area	: 6.7 cm^2 (operation in focal spot)

Pointing requirements

absolute pointing	: 5" (optical axis - lens only)
telescope axis pointing	: 5' (entire telescope)
lens weight to be stabilized	: 15 kg (approx.)
telescope weight	: 200 kg (approx.)

Telescope performance

system effective area	: 50 cm^2
angular resolution / FOV	: 15 arc sec
energy range	: 508 - 514 keV (FWHM)
energy resolution	: 2 keV (FWHM)
effective volume for BG	: $13 - 15 \text{ cm}^3$
3s sensitivity	: $3 \times 10^{-5} \text{ ph cm}^{-2} \text{ s}^{-1}$ (20 h observation - Australia or 5 d observation - Antarctica)

FIGURE CAPTIONS

Figure 1. Schematic sky map of 1E1740.7-2942 comparing the VLA structure with error circles of high energy instruments and the beam width of the proposed telescope. The SIGMA error circle stands for the uncertainty on the origin of the "broadened" $e+e^-$ emission.

Figure 2. The lens module with 8 rings of diffraction crystals

Figure 3. Detector module and BGO anticoincidence shield.

Figure 4. Schematic view of the telescope system and the elements used for the alignment.

Fig 1 : VLA structure and high energy error circles of 1E1740.7-2942

Comparison of the error circles for the position of 1E1740.7-2942 with the beamsize of the proposed instrument

FIG. 2

Fig.3. Detector module
possible shield layout

Fig 4 lens- and detector-modules of a possible crystal diffraction telescope

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