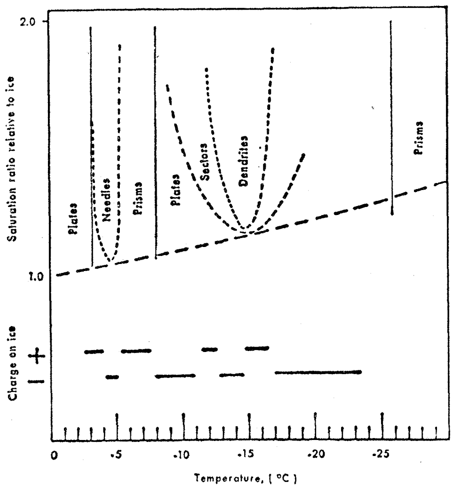

Fig. 2. Observed temperature-dependence of the charge of ice crystals compared with the temperature-dependence of the ice crystal habit [see Hallett and Mason (*1*)].

horizontal wires that were 0.2 mm in diameter and spaced 6.5 mm apart. For the slides in Fig. 1, the first and third wires from the right were maintained at +250 volts and the remaining wires at −250 volts with respect to the chamber walls. The ice crystals on the slide were replicated by the chloroform-vapor technique described by Schaefer (*4*). An examination of crystals that collected on the wires and the distribution and habit of those replicated on the slides indicated a relation between the charge and habit of the ice crystals. A series of these slides, photographed with dark-field illumination, and their corresponding temperatures are shown in Fig. 1. Satisfactory replication could not be obtained with fogs warmer than −1°C. The coldest supercooled fog obtained in the chamber was −24°C.

A charge separation was produced during the sublimation or condensation followed by freezing, or both. In these experiments, at nearly constant temperature, the majority of prisms and stars were found to be positively charged and the majority of the plates were negatively charged. A space charge of oppositely charged ions might possibly satisfy the charge conservation requirement, since there was no indication of variations of habit distribution in the chamber. The resultant charge and shape of an ice crystal were dependent on its growth history. Polarity of the charge, observed on the ice crystals as a function of temperature, is compared in Fig. 2 with the crystal habits observed by Hallett and Mason (*1*). Under the conditions of our experiment, most of the crystal growth occurs when the water-vapor pressure is near that of liquid water. This may account for the number of changes in the polarity of the charge. It might be expected from the habit-temperature data of Hallett and Mason (*1*) and Mason (*5*) that at lower vapor pressures, that is between those of water and ice, the ice crystals grown between −3° and −8°C would acquire a positive charge, and those grown between −8° and −25°C a negative charge.

The observed results suggest to us that the phenomenon responsible for the charge separation may have an important role in the processes of precipitation and cloud electrification.

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11 July 1967

X-rays from Sources 3C 273 and M 87

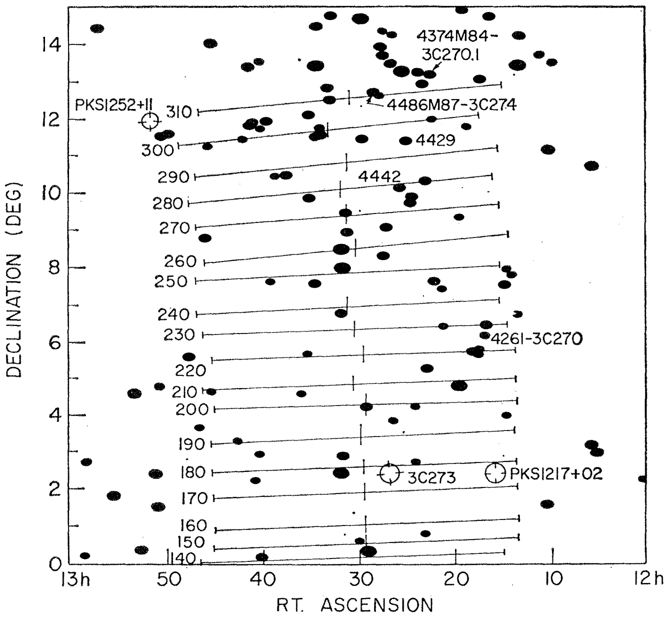
Abstract. *An x-ray survey of the Virgo region revealed signals from the directions of 3C 273 and M 87. Three other x-ray sources appear in the region scanned, but do not fit any known radio sources. The x-ray flux (1 to 10 angstroms) from the direction of 3C 273 is about 1000 times weaker than from the strongest x-ray source, Sco XR-1. If the source is located at the cosmological distance of 500 megaparsecs, the x-ray luminosity is 7.3 × 10^{45} ergs per second. The x-ray luminosity of M87 is 1.5 × 10^{43} ergs per second.*

An x-ray search of the Virgo region was performed from an Aerobee rocket, launched 17 May 1967 from White Sands, New Mexico. In order to attain high sensitivity and resolution, all available flight time was devoted to a single fan-beam scan along a strip of sky 14° long, which included the quasar 3C 273 and the radio galaxy Virgo A (M 87). The field of view was 1° wide in the scan direction by 8° long at right angles to the scan. Source positions were determined to about 0.1° by optical photography of the star field throughout the controlled portion of the flight. In addition to signals from the directions of 3C 273 and M 87, the survey detected three x-ray sources comparable in flux to 3C 273, but not coincident with any known quasar or radio galaxy. The high galactic latitudes of these unknown sources (about 70 degrees) favor their being extragalactic.

The instrumentation for this flight was similar to that used by Naval Research Laboratory (NRL) groups in previous surveys (*1*). Two proportional counters looked outward through the side of the rocket in the same direction and were baffled by an array of blades and honeycomb that limited the field of view to 1° by 8°, full width at half maximum (FWHM). The effective combined aperture through the collimator was 525 cm^2. Mylar film, ⅛ mil thick, was the window material, and the gas filling consisted of 90 percent argon and 10 percent methane at atmospheric pressure. Pulse amplitudes were sorted into six channels, and the outputs of the two counters were recorded independently. To reduce the cosmic ray background count, an anticoincidence counter was wrapped around the back and two sides of each soft x-ray counter. Above the atmosphere, the residual cosmic ray background count was 0.1 cm^{-2} sec^{-1}.

The Aerobee rocket was equipped with an ACS stabilizer (*2*) which was programmed to point to the Virgo region and then to perform a slow turn so that the detectors scanned along a line from 3C 273 to M 87. Figure 1 is a map of the region scanned. The orientation of the collimator is indicated at 10-second intervals from 140 seconds to 310 seconds after launch. The length of each bar represents the 8° FWHM of the baffled field of view, and the short vertical line marks the center of the field. The orientation of the collimator was determined from a succession of photographs of the field initiated every 10 seconds. The pointing directions determined in this way are accurate to 0.1°.

Figure 2 shows the observed combined counting rates from both counters as a function of time. The plotted counting rates are running means averaged over 10 seconds at intervals of 2 seconds. The controlled scan began to turn the rocket smoothly at



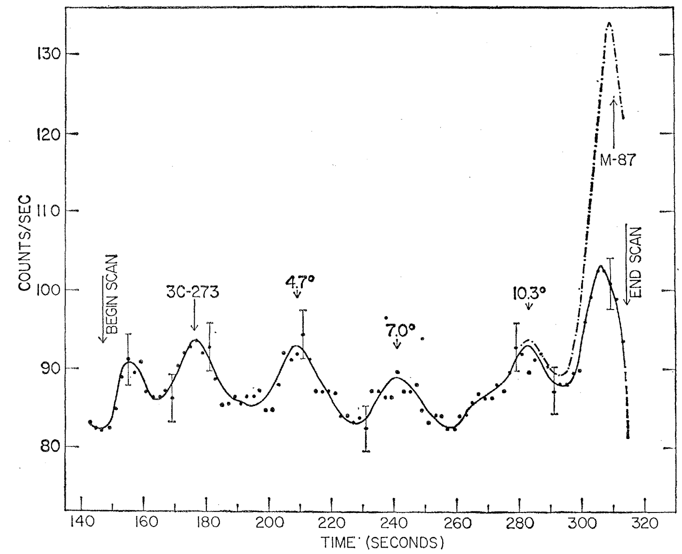


Fig. 1 (left). Map of Virgo region scanned for x-ray sources; 17 May 1967 flight. The field of view of the x-ray detector was split-shaped, 1° wide in the scan direction by 8° long at right angles to the scan track. A gyro-controlled stabilizer rolled the detector very slowly across the sky from 3C 273 to M 87. At 10-second intervals, photographic exposures were initiated to identify precisely the direction of view. The orientation of the collimator at the start of each exposure is indicated by the approximately horizontal bars (8° wide) marked with the time in seconds from start of flight. The vertical line intersecting each bar marks the center of the field of view. The black ellipses mark the positions of major elliptical galaxies in the Virgo cluster. 3C 273 and the PKS sources are quasars. Fig. 2 (right). X-ray flux plotted against time in flight. Points are running means of the numbers of counts per 10 seconds at 2-second intervals. A smooth motion began at 150 seconds and ended at 312 seconds. In addition to the signals from the directions of 3C 273 and M 87, three identified sources appear at declinations 4.7°, 7.0°, and 10.3°. The peak signal from the direction of 3C 273 is about $3\Sigma_{bgd}$; that from M 87 is about $6\Sigma_{bgd}$. The weakest signal, at 7.0° declination, is about $2.5\Sigma_{bgd}$. From 280 to 312 seconds, the rocket was reentering the absorbing atmosphere. The dash-dot curve is corrected for x-ray absorption in the air.

150 seconds and ended at 315 seconds when the rocket reentered the denser part of the atmosphere. As M 87 passed through the field of view, the rocket had already descended to where the atmospheric absorption was strong. The dash-dot curve was derived from the observed counting rate by correcting for atmospheric absorption. Although the correction is large, there is little uncertainty in the magnitude. The *COSPAR International Reference Atmosphere* (*3*) was used, and the rocket trajectory was measured to an accuracy of 0.1 km at the heights involved. At 105 seconds, the detectors pointed 20° below the horizontal, which was the closest approach to looking at the earth. The counting rate then was 70 per second, or 0.10 cm^{-2} sec^{-1}.

The signal peaks identified with 3C 273 and M 87 lie within 0.1° of the optical positions along the declination scan. Additional peaks appear at + 4.7°, + 7.0°, and + 10.3° declination. All five peaks appear in the individual records of the two counters in spite of the increased statistical scatter of the data.

The only previous evidence for a discrete x-ray source in the Virgo region was obtained from an Aerobee flight in April 1965 (*4*). The field of view in the scan direction then was 8 degrees, FWHM, and the scan rate was 24 degrees per second compared to an average of 0.077 degree per second during the present measurement. A peak signal of 0.2 count cm^{-2} sec^{-1} was observed within 1.5 degrees of M 87. If we assume a power law spectrum with an index of −1, the flux (1 to 10 Å) was 2×10^{-9} erg cm^{-2} sec^{-1}. The present measurement yielded 0.13 count cm^{-2} sec^{-1} and a flux (1 to 10 Å) of 8.7×10^{-10} erg cm^{-2} sec^{-1}. Since the wide field of view of the 1965 observations included the sources at + 7.0° and + 10.3° declination, and possibly additional sources at declinations higher than that of M 87, the 1965 measurement should have yielded a signal higher than that observed now for M 87 alone. If we allow for the statistical uncertainty [the 1965 signal was $3\Sigma_{bgd}$ (bgd, background)] the fluxes observed in 1965 and 1967 may be consistent. The x-ray luminosity (1 to 10 Å) derived for a distance of 10 Mparsec to M 87 is 1.5×10^{43} erg/sec, about 70 times the radio luminosity.

For the source in the direction of 3C 273, the counting rate was 0.025 cm^{-2} sec^{-1}. The corresponding flux (1 to 10 Å) for a power law spectrum of index −1 is 1.8×10^{-10} erg cm^{-2} sec^{-1}. If we use the cosmological distance of 500 Mparsec derived from the red shift of 3C 273, the computed x-ray luminosity is 7.3×10^{45} erg/sec. This x-ray luminosity is about 70 times the radio luminosity, about half the optical luminosity, and about 20 percent of the most recently determined infrared luminosity (*5*).

Several authors (*6–8*) have discussed the spectrum of M 87 (Virgo A) and pointed out that the radio, optical, and x-ray fluxes all fit approximately to a synchrotron spectrum of index −0.8. Virgo A is a core-halo type of radio galaxy. Most of the low-frequency radio emission comes from an extended halo, and the higher frequencies are confined to the central region of the galaxy. Optically, M 87 is an elliptical galaxy with an intense blue jet emerging from its core. The light of the jet is polarized, indicating its synchrotron character. It does not necessarily follow, however, that the x-ray source is associated with the jet. There is the well-recognized difficulty of the short life of energetic electrons responsible for x-ray emission by the synchroton process. As Felten points out in a recent discussion (*8*), the lifetime problem is already difficult to explain, even for the optical emission.

If the identification of the x-ray source with 3C 273 is correct, the x-ray luminosity is 500 times as great as that of M 87. The addition of the x-ray luminosity to the existing spectrum of radio, infrared, and visible luminosity does not significantly change the total energy budget of radiation. Most of the luminosity still appears in the infrared. The existence of at least three additional sources in the region scanned, at flux levels comparable to 3C 273 but without evidence of radio emission, is suggestive of radio-quiet and invisible quasars as proposed by Shklovsky (*9*). Both Shklovsky (*9*) and Burbidge, Burbidge, and Sandage (*10*) have remarked upon the quasar-like properties of Seyfert galaxies. Shklovsky has proposed that the high-excitation optical-emission lines may be x-ray excited and that those Seyfert galaxies, which are weak at long radio wavelengths have an "invisible quasar" luminosity in the sub-millimeter and infrared range. The x-rays may be produced by inverse Compton scattering of the relativistic electrons on the synchrotron radiation. Osterbrook (*11*) has also considered x-rays as the source of optical excitation in M 87, but attributed the x-ray emission to stellar coronas.

Byram, Chubb, and Friedman (*4*) had suggested, on the basis of their 1965 survey, that the so-called diffuse background was due to unresolved sources. The present survey of a limited region does not permit any clear resolution of the question of the existence of a truly diffuse background. It is surprising to find several x-ray sources as bright as 3C 273 in a region where no radio sources within a factor of 10 of the brightness of 3C 273 exist. Despite the statistical uncertainty of deductions from this small sample, it would not be inconsistent to consider the unresolved background underlying the observed sources to be composed of a host of weaker sources. The discrete sources, exclusive of M 87, constitute about 30 percent of the total flux, and there are suggestions of weaker unresolved features in the residual background. Inclusive of the discrete sources (except for M 87), the background flux (1 to 10 Å) is 9×10^{-8} erg cm^{-2} sec^{-1} $ster^{-1}$ if we assume a synchrotron spectrum of index −1. This is identical with the results obtained in 1965 with a pair of counters —one equipped with a 1-mil Mylar window, the other with ¼-mil Mylar. The counters with ⅛-mil Mylar windows, which were used in the present measurement, had a spectral efficiency (1 to 10 Å) 70 percent greater than the combination used in 1965. Most of the increased efficiency falls in the range 6 to 15 Å. We conclude that there is no evidence for interstellar absorption in the 6- to 15-Å range toward high galactic latitudes.

The question of the existence of a diffuse x-ray background is relevant to several major astrophysical concepts. It has been pointed out (*7, 12*) that evidence of such a background would test estimates of the density of intergalactic gas, the existence of the 3°K blackbody radiation, and the universality of the cosmic rays. It is, therefore, essential to survey additional regions of the sky and to improve resolution and sensitivity still further with a view to detecting the existence and level of a truly diffuse background. Unfortunately, it is difficult to achieve further gains in resolution and sensitivity with the Aerobee system. Larger rocket payloads and particularly the longer observing times of satellites are essential.

Before it is possible to do much more than speculate on the nature of the x-ray sources, tentatively identified with 3C 273 and M 87, it will be necessary to obtain evidence of the x-ray luminosities of other representative objects, to monitor their intensity variations, and to obtain more definitive spectral data. Again, progress can best be made with satellites affording pointing capabilities for the prolonged observation of discrete sources.

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Indium Variations in a Petrologic Suite of L-Group Chondrites

Abstract. *Indium concentrations have been determined by neutron activation in four members of each of the L3, L4, L5, and L6 chondritic meteorite classes. The range of concentrations is found to be from 0.14 to 22 parts per billion, with the highest values in L3 chondrites and the lowest values in the L5 and L6 classes. Plots of indium concentration versus relative mean deviation of pyroxene iron content, total carbon concentration, and primordial argon-36 concentration show positive correlations to varying degrees. Indium concentration appears to be a valuable parameter relating to variable formation conditions of the chondritic meteorites during the early history of the solar system.*

Van Schmus and Wood (*1*) have proposed a new classification of chondritic meteorites, in which they divide the various chondritic classes into subclasses based on petrologic type. The L-group ordinary chondrites are assigned by these authors to the four grades L3, L4, L5, and L6. We have determined indium by neutron activation in four members of each of these subclasses (*2*). The concentration of indium is found to range from 0.14 to 22 parts per billion, and to correlate well with such sensitive indicators of thermal history as primordial argon-36 concentration, carbon concentration, and the spread in composition of silicate minerals.

Results are listed in Table 1, as are the names and petrologic types of the chondrites (*3*). Each result is the mean of two or more replicate determinations made on separate 0.6-g chips