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On the search for soft X-ray and optical counterparts of selected COS-B γ-ray sources

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The nature of the high-energy γ-ray sources† newly discovered by the COS-B satellite (Hermsen *et al.* 1977, Swanenburg *et al.* 1981) is a challenging astrophysical problem. In spite of much effort devoted to this subject, no identification has been possible so far for most sources, either individually or as a population. As is well known, there is a remarkable lack of obvious candidates, for example, strong X-ray sources, large dark clouds and identified radio pulsars, inside the COS-B error boxes, except for those few cases where a random coincidence can be expected.

In the pre-'Einstein' era, only a few of the COS-B error boxes had been, at least partially, covered at other wavelengths and had given rise to interesting astrophysical results (e.g. the discovery of the second nearest quasistellar object by Apparao *et al.* (1978) from the SAS-3 X-ray observation of 2CG 135 + 01); although of interest these observations had not given a general solution of the problem.

The advent of the Einstein Observatory, with its Guest Observer Programme, rendered possible a start on the systematic soft X-ray coverage of the COS-B sources, since they can be entirely covered with a limited number (three to five each) of I.P.C. (Imaging Proportional Counter) pointings (field of $60' \times 60'$), arranged in a mosaic fashion. Several workers are involved in this effort, with parallel (but sometimes slightly different in philosophy) guest observer investigations, and so far 17 γ-ray sources have been mapped. The present work is a status report on an *exploratory*, totally *unbiased*, mapping of five COS-B sources (2CG 121 + 04, 2CG 135 + 01, 2CG 195 + 04, 2CG 218–00, 2CG 284–00) chosen to be in regions of the Galaxy as uncrowded as possible and easily accessible by the Einstein Observatory. This programme, involving G. F. Bignami (I.F.C.), R. Lamb (I.S.U.), T. H. Markert (M.I.T.), and myself, has already been made by the Einstein Observatory and first-generation results are available.

Figures 1–3 show COS-B error boxes in the soft X-ray range. At the sensitivity level achievable with $1.5\text{–}2.0 \times 10^3$ s useful observing time, corresponding to a minimum detectable flux of the order of 10^{-13} erg s^{-1}‡ cm^{-2}, no source confusion is apparent in the data. Moreover, the number of new X-ray sources found is compatible with that obtained by extrapolating the Einstein lg *N* against lg *S* graph of Giacconi *et al.* (1979) down to the quoted flux level.

Figures 1–3 represent also three of the possible results from the mapping of the few square degrees of the galactic disc inside the COS-B error boxes. *Figure* 1 shows four adjacent pointings covering the error box of 2CG 121 + 4, an example of an 'empty' region, where no X-ray sources are evident. *Figure* 2 shows four adjacent pointings covering the error-box of 2CG 135 + 01, an example of a 'crowded' region: the I.P.C. field on the upper right contains QSO 0241 + 622

† A high energy γ-ray source is defined as one that produces 'a significant excess of photon counts, compatible with the instrument's angular resolution, or, in other words, with the instrument's point spread function'. Typical values for COS-B sources are: for between 50 and 500 detected photons, the corresponding error box radii range between 1.5–0.5°, dependent on the spectral shape of the radiation (for details see Hermsen 1980).

‡ 1 erg s^{-1} = 10^{-7} W.

(Apparao *et al.* 1978) and at least one other source easily identifiable with an SAO star; the field on the lower right contains an unidentified source, recently observed also with the H.R.I. (High Resolution Imager) instrument, with a suspected star-like counterpart. The field on the lower left contains a source coinciding (Bignami *et al.* 1980) with the variable radio star LSI + 61 303 (see Gregory *et al.* 1979 and references therein).

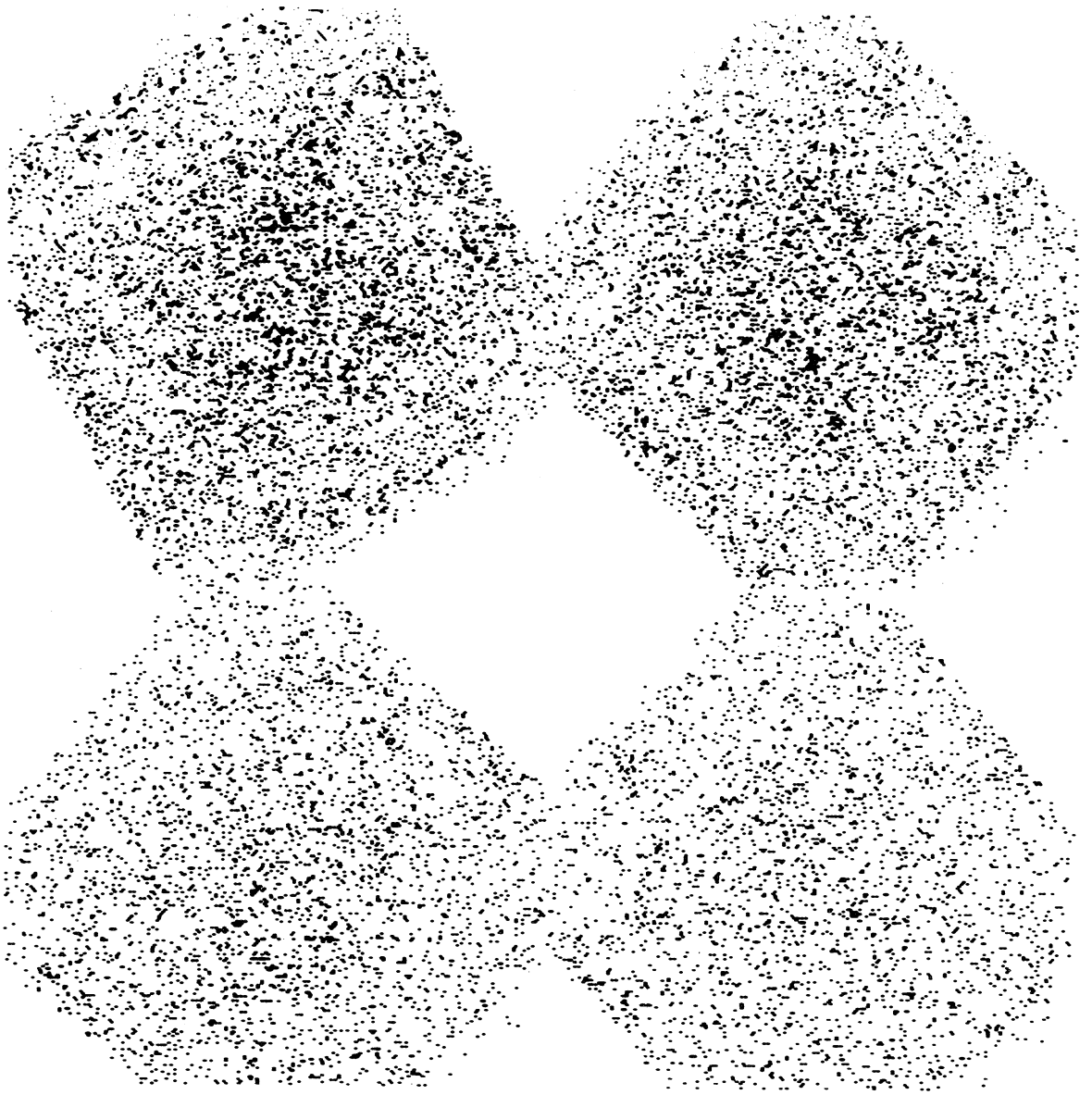

FIGURE 1. X-ray coverage of 2CG 121 + 4. The four I.P.C. fields (60′ × 60′), which appear fictitiously rotated when displayed together on the computer screen, are in fact mosaic-arranged and adjacent in the sky.

An H.R.I. pointing has already been performed and more I.P.C. data have been sought to study a possibly periodicity with the radio period of 26.5 days (Taylor & Gregory 1980). Analogous studies are being planned with the I.U.E. satellite.

Of the four X-ray sources found in the COS-B error box, at least two, the quasistellar object and

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the variable radio source, have already been proposed as possible counterparts (Apparao *et al.* 1978; Gregory *et al.* 1979; Maraschi & Treves 1980; Bignami *et al.* 1980) for the γ-ray excess. *Figure* 3 shows the coverage of the γ-ray source 2CG 195 + 04 ('Geminga') as an example of a '*promising*' situation. The three I.P.C. fields contain two clear sources but, owing to the shrinking of the COS-B error box (Swanenburg *et al.* 1981), only one, the brightest, is now positionally compatible with the COS-B source. Inspection of the Palomar Sky Survey plate shows a faint, 15th magnitude, star-like object along with few, much fainter images in the *ca.* 1′ error circle of the I.P.C. position. An H.R.I. observation of the field would then be of decisive importance, and has indeed been approved and planned; however, owing to the recent (autumn of 1980) malfunctions of the Einstein Observatory, it is doubtful whether it will be possible to perform it.

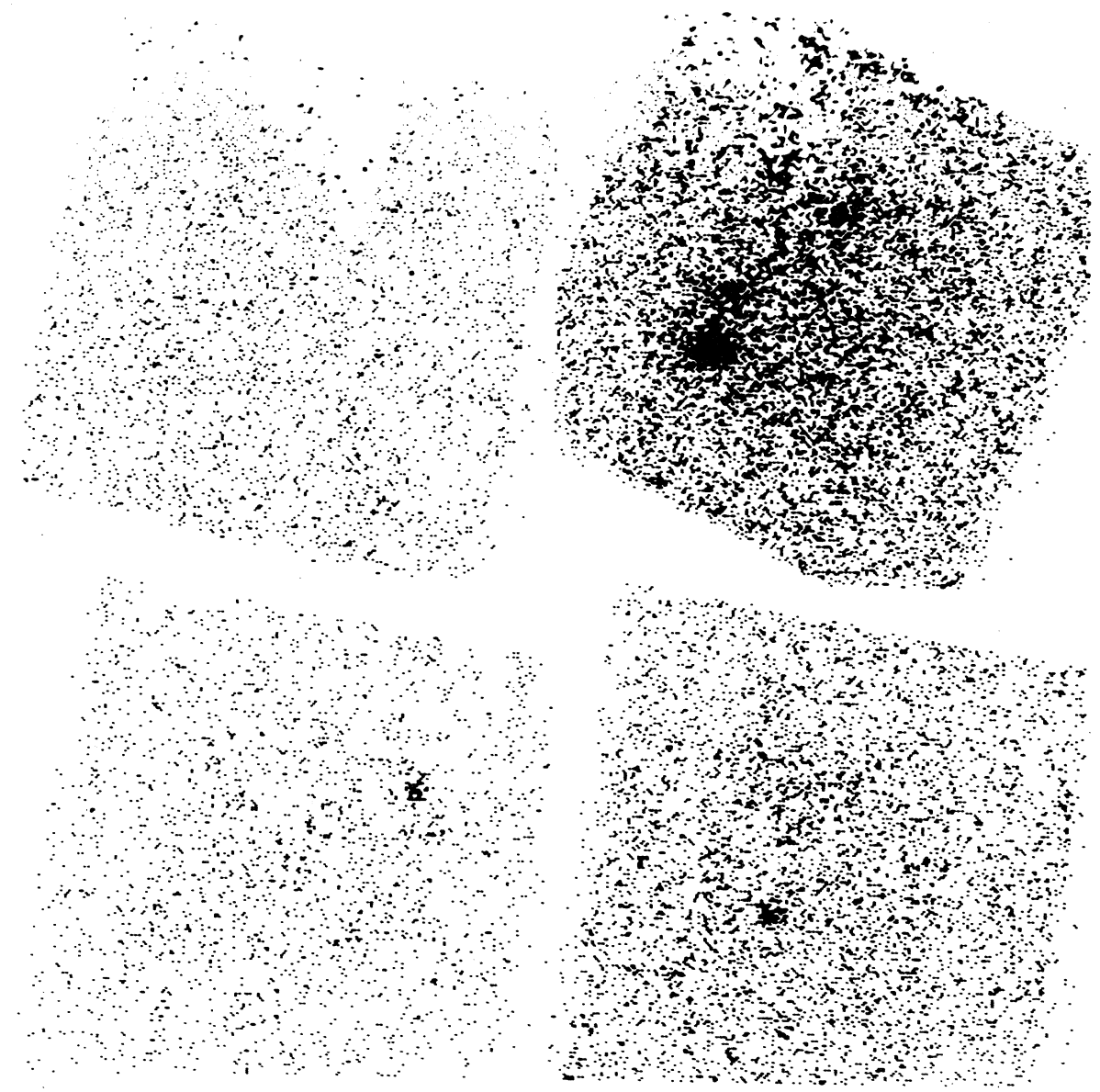

FIGURE 2. X-ray coverage of 2CG 135 + 1; details as for figure 1.

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Optical observations are in progress from the Lojano Observatory (near Bologna) in collaboration with Dr B. Marano, and radio observations will also shortly become available from the Algonquin Radio Observatory and the N.R.A.O., in collaboration with Dr Phil Gregory.

We hope to report very shortly on the identification of the Geminga γ-ray source; in parallel, a similar broader-range programme is in progress for several other new, unidentified I.P.C.–H.R.I. X-ray sources in the COS-B error boxes.

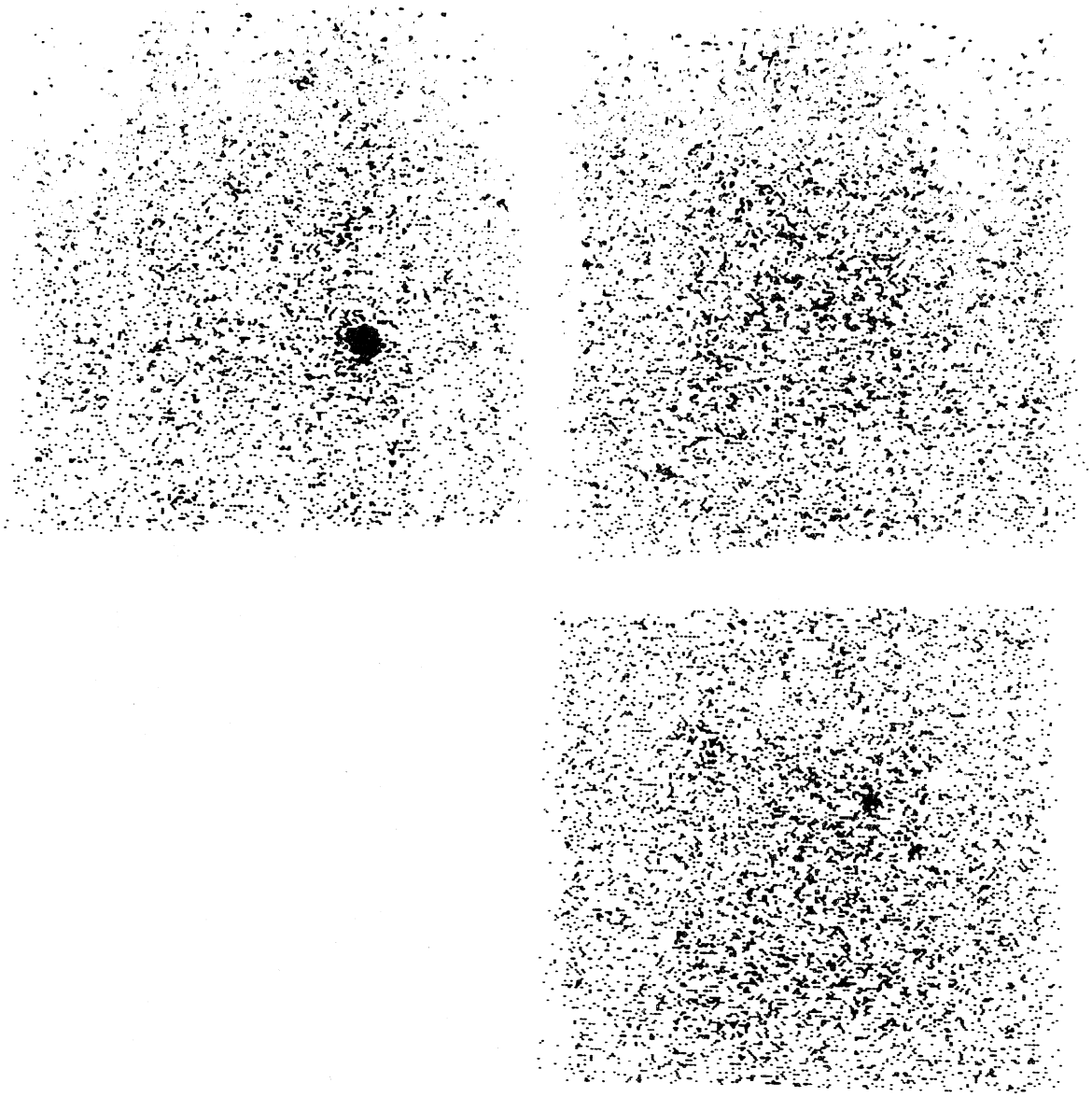

FIGURE 3. X-ray coverage of 2CG 195+4; details as for figure 1.

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