A SYSTEMATIC SEARCH FOR MEV EMISSION FROM GALACTIC BLACK HOLE CANDIDATES

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ABSTRACT

The COMPTEL instrument on CGRO has surveyed the entire sky in the energy range of 0.75-30 MeV. These data provide the opportunity to perform a systematic search for MeV emission from galactic black hole candidates. The COMPTEL team has previously reported on the positive detection of both Cygnus X-1 and GRO J0422+32 at energies up to 2 MeV (and even higher for Cygnus X-1). Although these sources appear to be dominated by thermal emission, the spectrum of Cygnus X-1 as measured by COMPTEL suggests the need to re-evaluate the standard Sunyaev-Titarchuk Comptonization model as an acceptable explanation for the observed spectrum. Also of interest are those models which predict pion emission from accreting black hole systems, resulting from ion temperatures in excess of $10^{12}K$; the signature of black hole pion emission is expected to peak in the COMPTEL energy range. The detection of other black hole systems at these energies may therefore provide further clues towards a better understanding of these objects. Not only would such data help to further our understanding of the electron component of the emission, but observations at these energies would also constrain the extent of any emission related to the ion population. Towards this end, we are using the available COMPTEL data to search for MeV emissions from all known galactic black hole candidates. Here we report on the status of this search.

The Candidate List

The list of galactic black hole candidates is taken largely from Cowley (1992), supplemented with some additional sources listed by Paciesas et al. (1994). It includes both quasi-steady and transient sources. Although the transient sources may not be expected to exhibit high energy emissions except during an outburst, they are included here for completeness.

Source	*Alternate Name*	ℓ	b
0142+614		129.4	-0.4
GRO J0422+32	X-Nova Per 1991	165.9	-11.9
LMC X-3		273.6	-32.1
LMC X-1		280.2	-31.5
CAL 87		281.8	-30.7
A0620-00	X-Nova Mon 1975	210.0	-6.5
GRS 1009-45	X-Nova Vel 1993	275.8	9.3
GS/GRS 1124-68	X-Nova Mus 1991	295.3	-7.0
GS 1354-64	Cen X-2?	310.0	-2.8
A1524-62	TrA X-1	320.3	-4.4
4U 1543-475		330.9	5.4
4U 1630-472		336.9	0.3
GX 339-4		338.9	-4.3
GRO 1655-40	X-Noca Sco 1994	344.9	2.5
H 1705-250	X-Nova Oph 1977	358.6	9.1
GRO 1719-24	X-Nova Oph 1993, GRS 1716-249	0.2	7.0
1E 1740.7-2942		359.1	-0.1
XT 1741-322	H 1743-322		
1755-338		357.2	-4.9
GS 1826-24		9.3	-6.0
EXO 1846-031		29.9	-0.9
SS433		39.7	-2.2
Cyg X-1	V1357 Cyg	71.3	3.1
1957+115		51.3	-9.3
GS 2000+251	X-Nova Vul 1988	63.4	-3.1
GS 2023+338	X-Nova Cyg 1989, V404 Cyg	73.2	-2.2

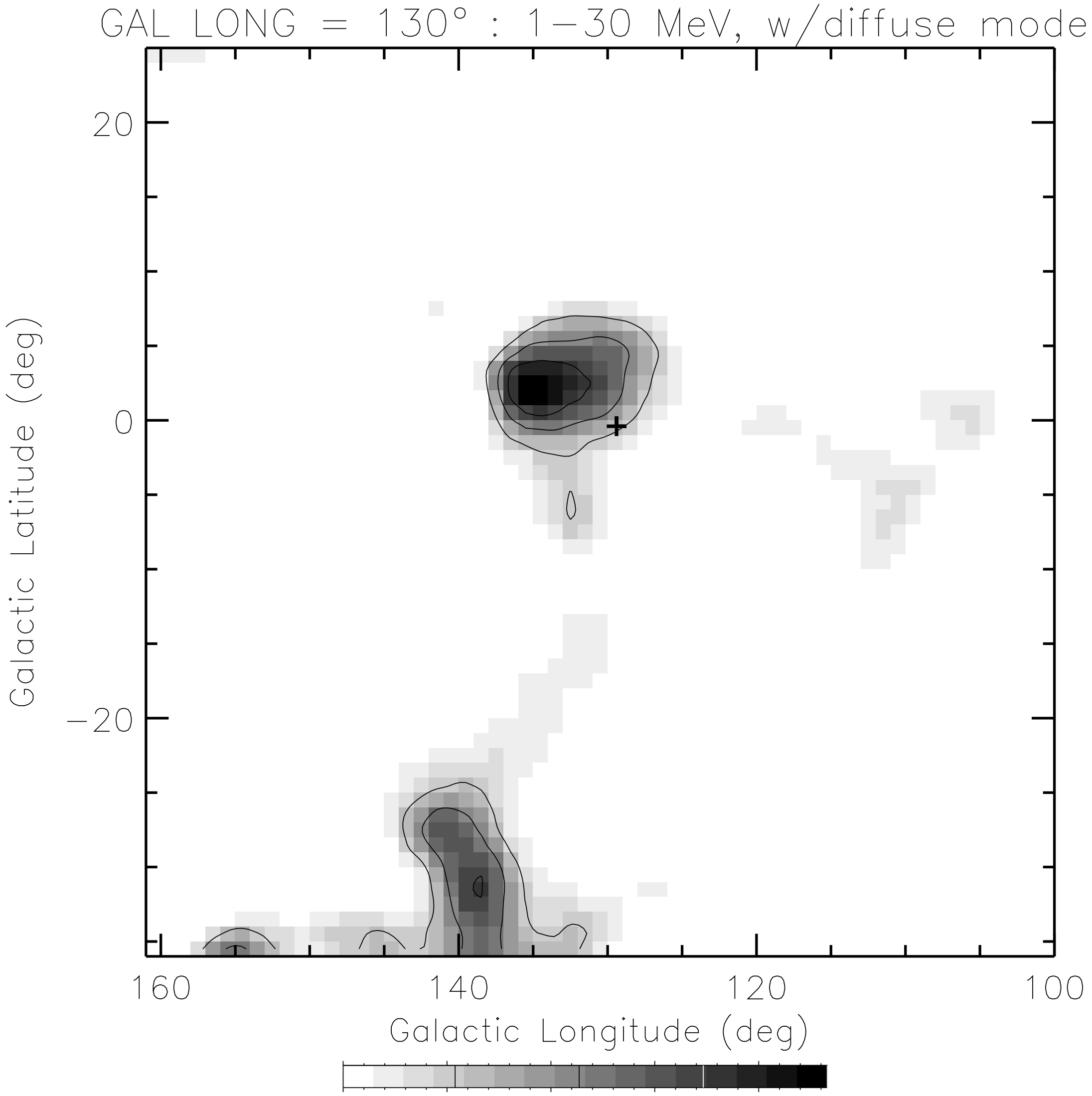
Data Analysis

The analysis involves the imaging of data from five sky regions which contain all of the candidate sources. Data from all of phase 1 and phase 2 of the CGRO mission have been combined in order to derive the images shown here. Although only the combined 1-30 MeV data is presented here, the analysis of individual energy bands (0.75-1.0 MeV, 1-3 MeV, 3-10 MeV, and 10-30 MeV) is in progress.

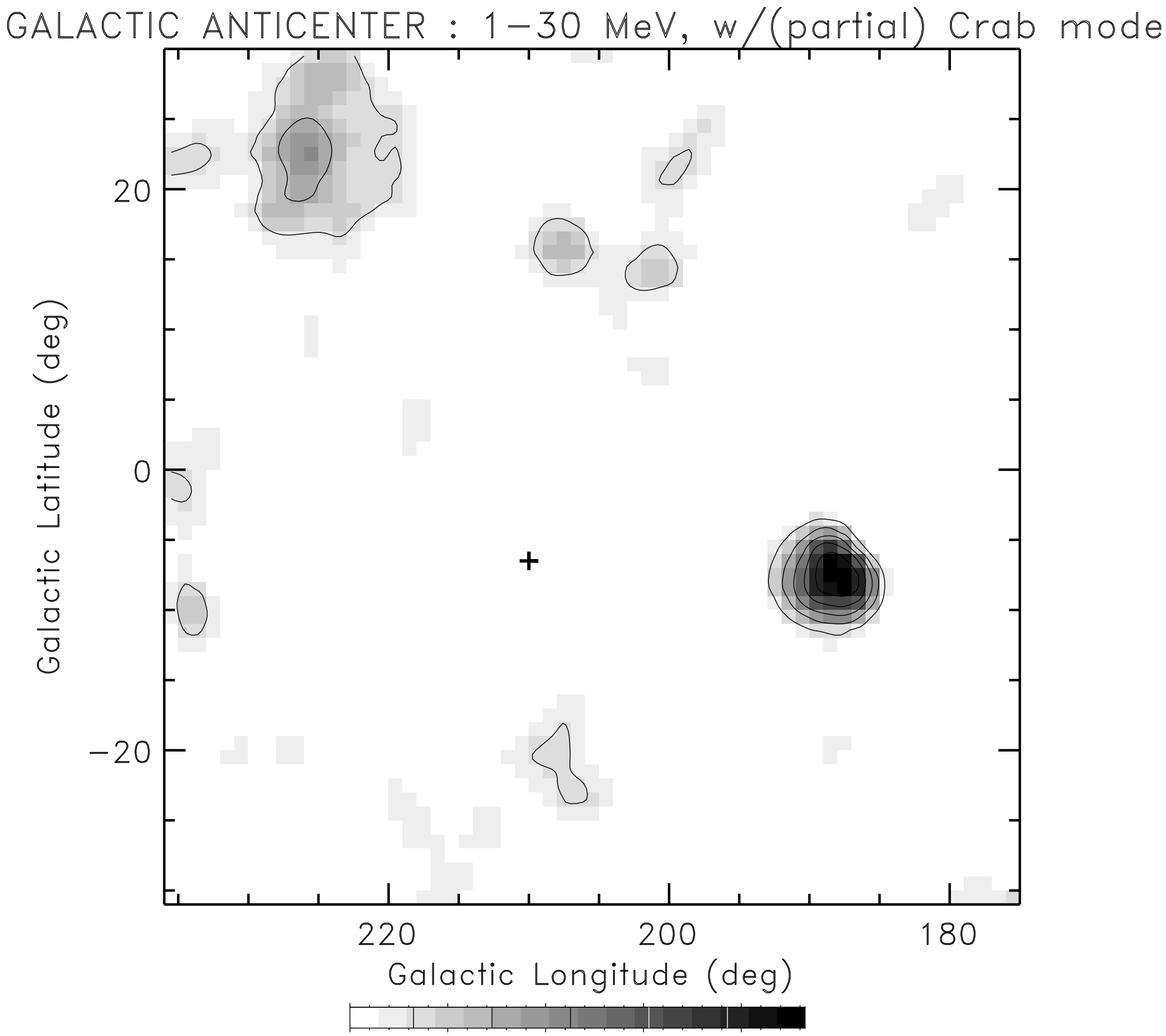
The data are analyzed using a maximum likelihood technique which results in a likelihood map for each sky region. The analysis includes an estimate of the galactic diffuse component based on the measured distributions of both atomic and molecular hydrogen (HI and H_2, respectively). The background estimate is derived from both the source data and the galactic diffuse model by an averaging technique which suppresses the source signal while preserving the general background structure.

In the following panels, we show the results for each of the five sky regions. The images are likelihood maps which give, for each point in the map, the likelihood ratio for a point-source plus background model versus a background model. This statistic is distributed as a χ^2 statistic with three degrees of freedom. Given a known source position, a likelihood ratio greater than 11.3 at that location formally gives a source detection at a 99% confidence level. However, *we must also determine whether an excess at a given location is consistent with a point source signature in the COMPTEL dataspace.* Only then can we be prepared to claim a source detection.

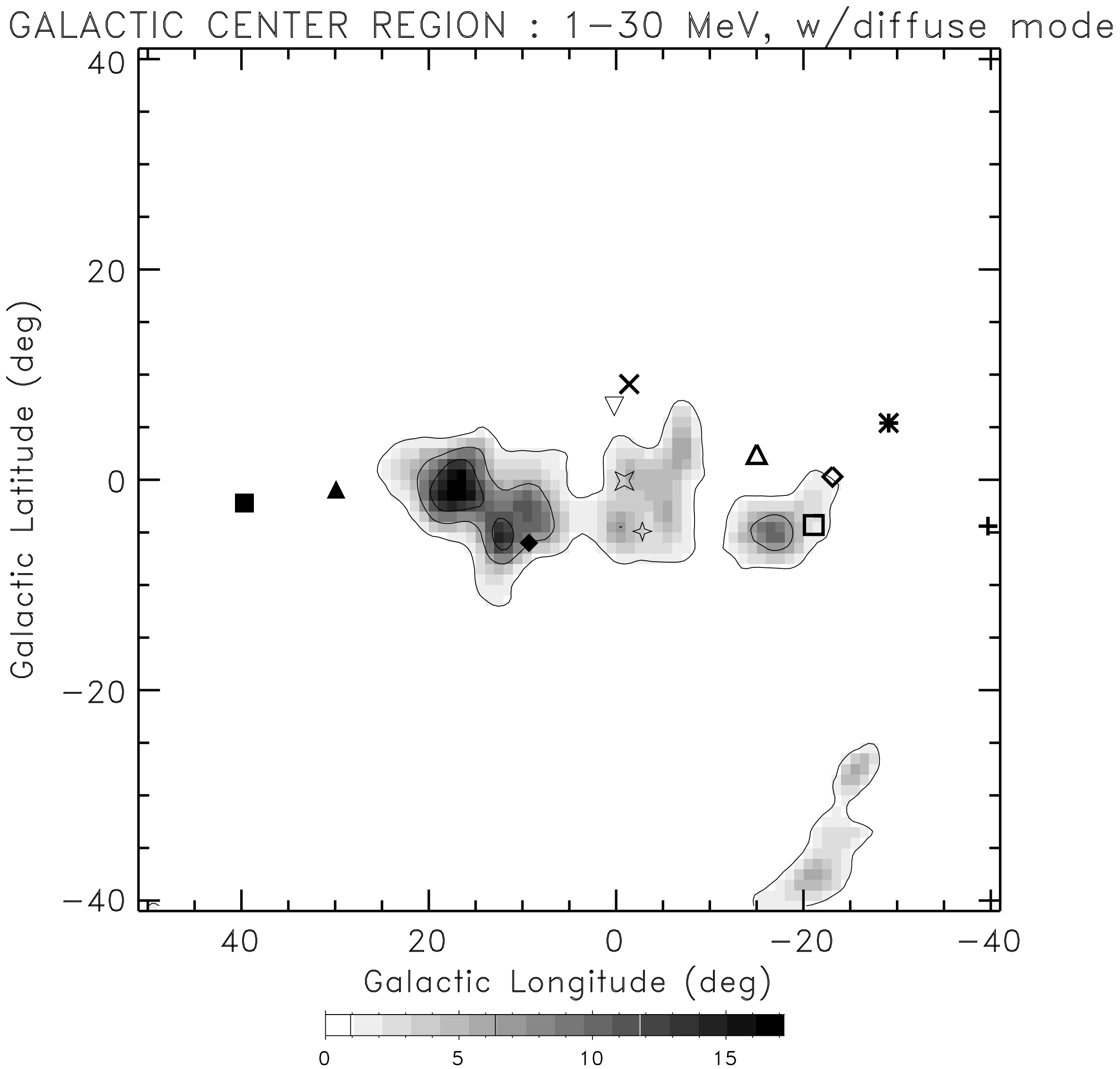
We also include for each sky region a table of results for those sources falling within that field. Results are quoted as 2σ upper limits in those cases where the source significance is below 2σ. Otherwise, the result is quoted as a positive flux value with 1σ uncertainty.



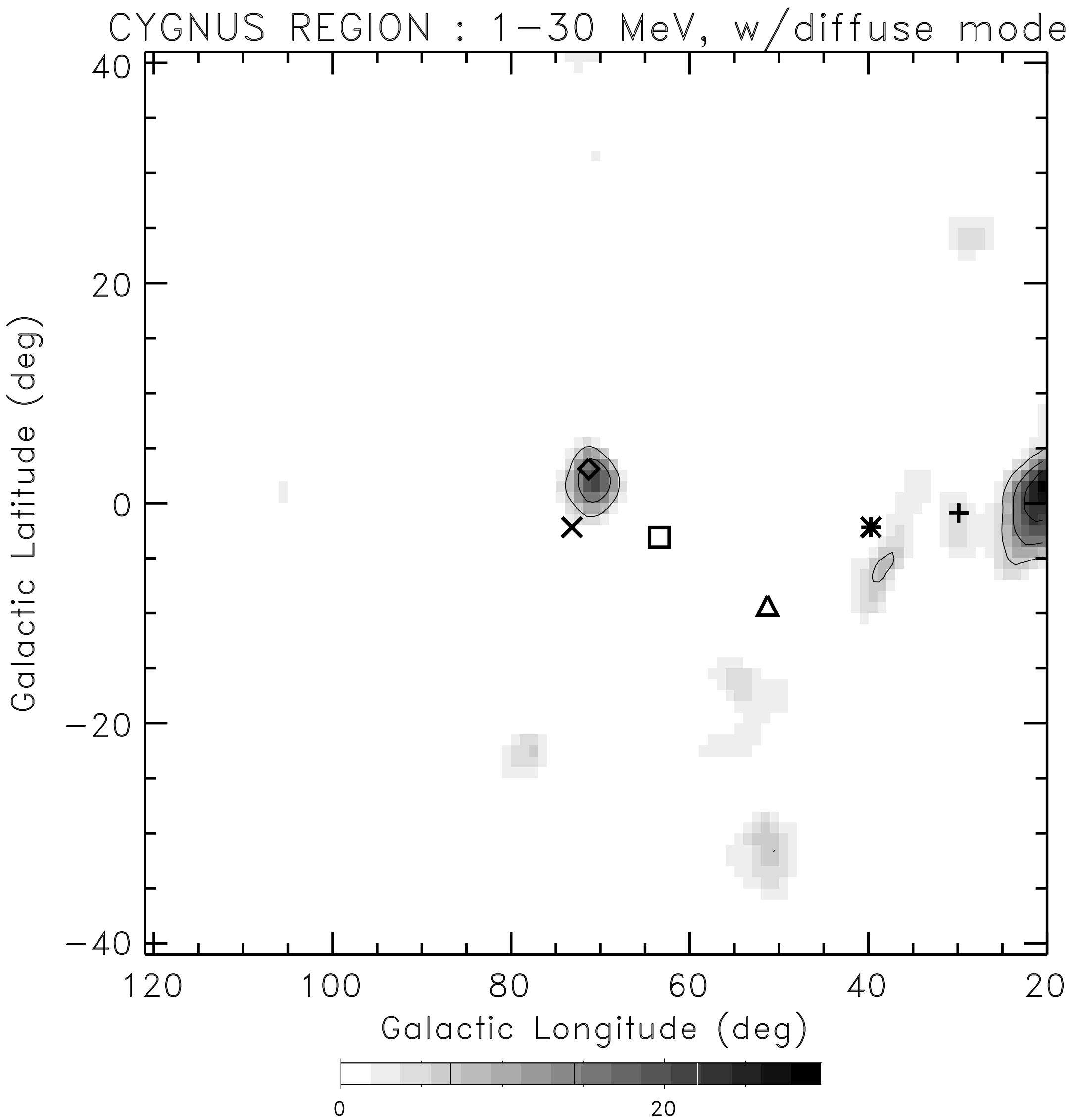
Source	*symbol*	ℓ	b	n_σ	*Flux (ULs are 2σ)* $cm^{-2}s^{-1}MeV^{-1}$
0142+614	+	129.40	-0.40	2.47	$3.3(\pm1.3)\times10^{-6}$



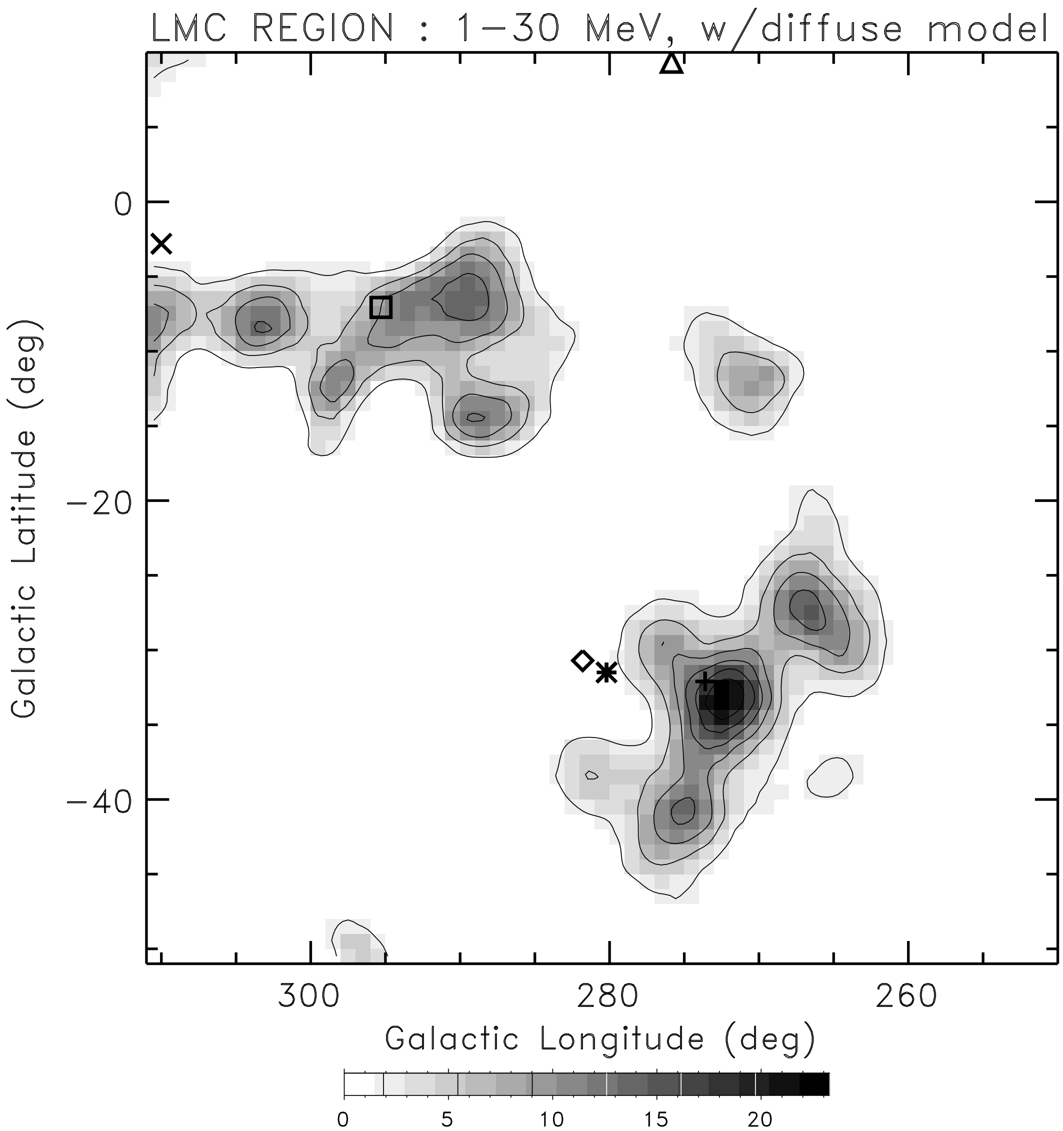
Source	symbol	ℓ	b	n_σ	Flux (ULs are 2σ) $cm^{-2}s^{-1}MeV^{-1}$
A0620-00	+	210.00	-6.50	-0.61	$< 3.5 \times 10^{-6}$



Source	*symbol*	ℓ	b	n_σ	*Flux (ULs are 2σ)* $cm^{-2}s^{-1}MeV^{-1}$
A1524-62	+	320.30	-4.40	-1.40	$< 3.5 \times 10^{-6}$
4U 1543-475	$*$	330.90	5.40	-1.73	$< 2.2 \times 10^{-6}$
4U 1630-472	◇	336.90	0.30	0.89	$< 2.9 \times 10^{-6}$
GRO 1655-40	△	344.99	2.45	-0.13	$< 1.9 \times 10^{-6}$
GX 339-4	□	338.90	-4.30	1.41	$< 3.4 \times 10^{-6}$
H 1705-250	×	358.60	9.10	-0.77	$< 1.8 \times 10^{-6}$
GRO 1719-24	▽	0.20	6.99	0.20	$< 2.0 \times 10^{-6}$
1E 1740.7-2942		359.12	-0.11	2.03	$1.9(\pm 0.9) \times 10^{-6}$
1755-338		357.20	-4.90	1.69	$< 3.3 \times 10^{-6}$
GS 1826-24	◇	9.30	-6.00	2.40	$2.2(\pm 0.9) \times 10^{-6}$
EXO 1846-031	△	29.90	-0.90	-0.05	$< 2.8 \times 10^{-6}$
SS433	□	39.70	-2.20	-1.50	$< 3.9 \times 10^{-6}$



Source	*symbol*	ℓ	b	n_σ	*Flux (ULs are 2σ)* $cm^{-2}s^{-1}MeV^{-1}$
EXO 1846-031	+	29.90	-0.90	2.98	$4.0(\pm1.3)\times10^{-6}$
SS433	$*$	39.70	-2.20	1.43	$< 3.6\times10^{-6}$
Cyg X-1	◇	71.30	3.10	4.09	$3.6(\pm0.9)\times10^{-6}$
1957+115	△	51.30	-9.30	0.58	$< 2.5\times10^{-6}$
GS 2000+251	□	63.40	-3.10	-1.51	$< 1.8\times10^{-6}$
GS 2023+338	×	73.20	-2.20	1.85	$< 3.4\times10^{-6}$



Source	*symbol*	ℓ	b	n_σ	*Flux (ULs are* 2σ*)* $cm^{-2}s^{-1}MeV^{-1}$
LMC X-3	+	273.60	-32.10	3.74	$3.8(\pm1.0)\times10^{-6}$
LMC X-1	*	280.20	-31.50	0.97	$<3.0\times10^{-6}$
CAL 87	◇	281.80	-30.70	0.71	$<2.7\times10^{-6}$
GRS 1009-45	△	275.85	9.35	0.22	$<7.7\times10^{-6}$
GS/GRS 1124-68	□	295.30	-7.07	3.03	$5.5(\pm1.8)\times10^{-6}$
GS 1354-64	×	310.00	-2.80	0.73	$<8.0\times10^{-6}$

Discussion

Region near $\ell = 130^\circ$

Candidate source 0142+614 is located near a (possibly extended) feature in the likelihood map. This feature has been tentatively identified with the high energy source 2CG135+1 (= GT 0236+610; van Dijk et al. 1994). It is unlikely that 0142+614 is associated with this feature; the significance is too weak ($< 3\sigma$) to claim a detection.

Galactic Anticenter

The modeling of the Crab and the quasar PKS0528 is somewhat incomplete in this image. There is no evidence for the single black hole candidate in this field (A0620-00).

Galactic Center

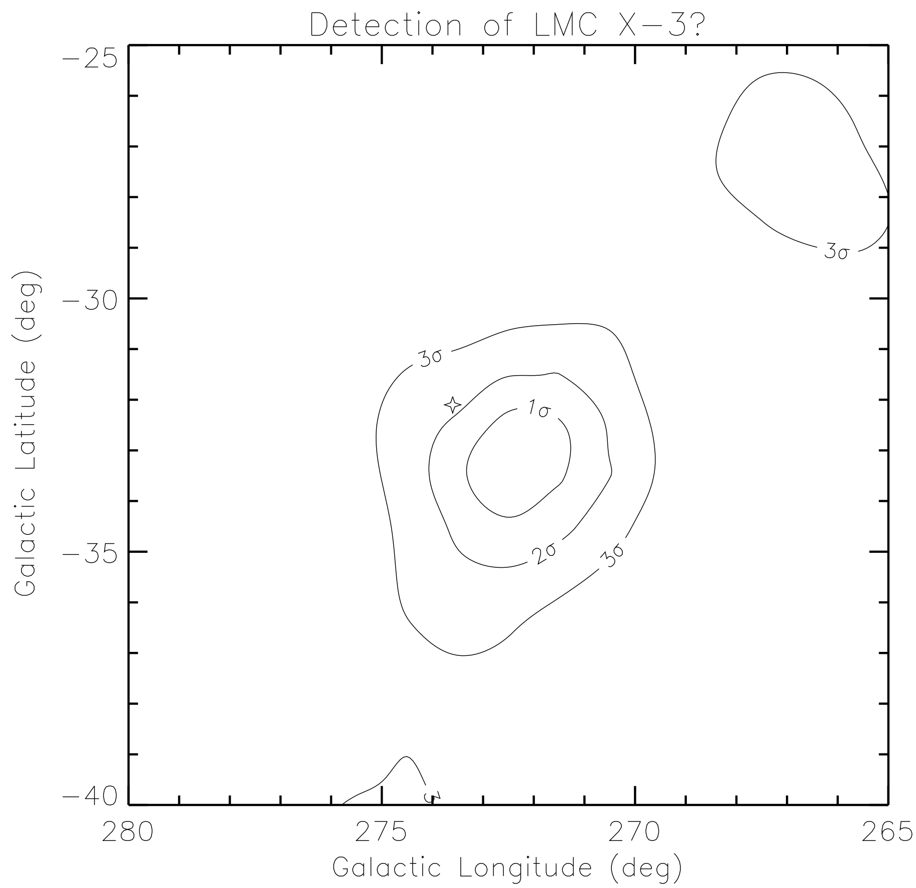
Point-like feature near $\ell = 20^\circ$ (which is under study by the COMPTEL team; Bloemen et al. 1993) does not appear to be associated with any black hole candidate. No sources are detected at a level $> 3\sigma$.

Cygnus Region

Cygnus X-1 and the point source near $\ell = 20^\circ$ are the dominate features of this image. The relatively low significance of the Cygnus X-1 detection results from the fact that all of the detected emission lies below 5 MeV, covering only a fraction of the energy range considered here. Detection of the source EXO 1846-031 is near the 3σ level, but the image shows that this is more likely a noise feature.

LMC Region

There exists a strong point-like feature near the location of LMC X-3. This has been tentatively identified with the blazar source PKS 0506-612 (Bloemen et al. 1994), which has also been noted as a weak source by EGRET (Fichtel et al. 1994). The COMPTEL data alone, however, cannot rule out the association of this feature with LMC X-3, since LMC X-3 is near the 2σ location contour level for this source (as shown in the figure below). If we associate this feature with LMC X-3, then the implied 1-30 MeV luminosity (at the 50 kpc distance of the LMC) is 3×10^{38} ergs s^{-1}. Further study is warranted before any firm conclusion can be drawn regarding the association of this feature with LMC X-3. Detection of the source GRS 1124-68 is near the 3σ level, but the image shows that this is more likely a noise feature.



Summary

There is no convincing evidence for the detection of any other black hole candidate besides Cygnus X-1 in the present data.

Typical 1-30 MeV upper limits are in the range of a few $\times 10^{-6}$ cm^{-2} s^{-1} MeV^{-1}. For a measured upper limit of 5×10^{-6} cm^{-2} s^{-1} MeV^{-1}, the corresponding limit on the 1-30 MeV luminosity is 1.4×10^{36} $(d\ /\ 3\,kpc)^2$ ergs s^{-1} .

The present survey is somewhat limited in two respects. First, the data are averaged over all phase 1 and phase 2 observations. This limits the sensitivity of this search to steady (or quasi-steady) sources. Second, the full 1-30 MeV energy range may not be the most sensitive energy band to search. The measured emission from Cygnus X-1, for example, is all found at energies below 5 MeV. Both of these limitations will be overcome by work that is presently in progress. This effort should provide somewhat better constraints on the γ-ray emission from black hole candidates than those that are provided by this preliminary study.

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