Dissecting the Region around *IC100608A*

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Abstract

The IceCube Neutrino Observatory has recently reported the detection of a highly-energetic neutrino, *IC100608A* [1] (MJD: 55355.00), with direction ra: 343.81°, dec: 24.17° in equatorial and l: 91.62°, b: -31.54° in galactic coordinates. Due to the high-energy and the track-like signature the event has a good pointing and is likely of astrophysical origin. With the goal of identifing the corresponding electromagnetic counterpart we report here on the muli-wavenlength dissection of the region around the event. This report was generated autmoatically on 2021-01-22 00:12:56.019 UTC.

1 Identifying Counterpart Candidates

The search for possible counterparts is based on the *VOU-Blazars* tool [1] and follows closely the pipeline developed in [2]. *VOU-Blazars* compares 32 multi-wavelength catalogs[2] to find all positions in the vicinity of the alert with a *blazar-like* emission profile in radio, optical and X-ray. Each of these matches is then additionally checked against existing catalogs to identify the associated object if possible.

In a second step a dedicated gamma-ray analysis is performed. In order to search for interesting emission features in the region we use *Fermi LAT* data around the event time and run three different analysis pipelines. Firstly, test-statistic maps are generated to search for unknown gamma-ray emmitters, e.g. indication for gamma-ray emission from the previously identfied *VOU-Blazars* source candidates. Subsequently SEDs and light curves are produced for each identified catalog source and interesting *VOU-Blazars* candidate. Based on these results we can finally search for specific features in flux and spectral shape around the neutrino arrival time.

The gamma-ray analyses are based on the latest version of the FSSC Tools v11r5p3 and the fermipy package [3]. We use the the standart procedures as described in the *Fermi LAT* Cicerone [4]. The dataset for the analysis contains events with photon energy above 0.1 GeV in a time window between 54682.7 and 59234.6.

[1]`NoGCNgiven`
[2]List of the 32 catalogs used in this analysis: SDS82 , 3HSP , Fermi8YR ,1BIGB, MST9Y, FIRST, SUMSS, WGACAT, IPC2E, ZWCLUSTERS, PSZ2, ABELL , SDSSWHL, CRATES, NVSS, SXPS, RASS, XMMSL, BMW , IPCSL, CHANDRA, MCXC, 5BZCat, SWXCS, PULSAR, F2PSR, 3FHL, 3FGL, 3XMM, MAXI, FermiMEV, AGILE

1.1 Catalog Sources in the Region around IC100608A

The following list gives a quick overview about the catalog blazars in the region. Sources are sorted by their angular distance to the neutrino direction.

4FGL J2255.2+2411 — Energy flux (E $\geq$ 100MeV): 1.13e-11 erg/cm^2/s [Top 18.7% in 4FGL]
ra: 343.82 deg — dec: 24.19 deg — distance: 0.02 deg [ra: 0.00 deg , dec: 0.02 deg]
Associations: 3FGL J2255.1+2411, 3FHL J2255.2+2410, 5BZB J2255+2410

2 Full Multi-Wavelength Study of the Region

2.1 Description of the Analysis

In this section we present a full multi-wavelength search for possible neutrino counterparts. Starting from 32 multi-wavenlength catalogs the VOU-Blazar tool [1] uses the all the available radio, optical and X-ray data in order to identify blazar-like counterparts candidates. The full output of the tool cand be found in the appendix.

The analysis pipeline consists of two parts: 1) The radio and x-ray data, as well as the resulting counterpart candidates are shown and compared to the *Fermi LAT* gamma-ray emission in the region around the neutrino alert 2) For all known blazars with a angular distance of less than 1.5 degrees a multi-wavelength SED is constructed, including also a gamma-ray analysis that is started at the time of the neutrino alert. For each source we also calculated a fixed-binning light curve. For details about the analysis see the appendix.

2.2 The Multi-Wavelength SED

The multi-wavelength SED collects and visualizes all the publicly available multi-wavelength data, as well as the result of the gamma-ray analysis. The time evolution of the source is decoded in a color gradient from grey (old) to red (recent). Here the grey SEDs point and bowties represent the *Fermi-LAT* gamma-ray spectrum integrated over the entire mission while the black SED points show the gamma-ray spectrum in a time window around the neutrino arrival time. Colored bands indicate the corresponing spectral fits at different (if available) energy thresholds if the significance of the measurement is above 3 σ. The green dashed and solid line show the sensitivity and discovery potential of the IceCube 7yr point-source analysis [5], respectively.

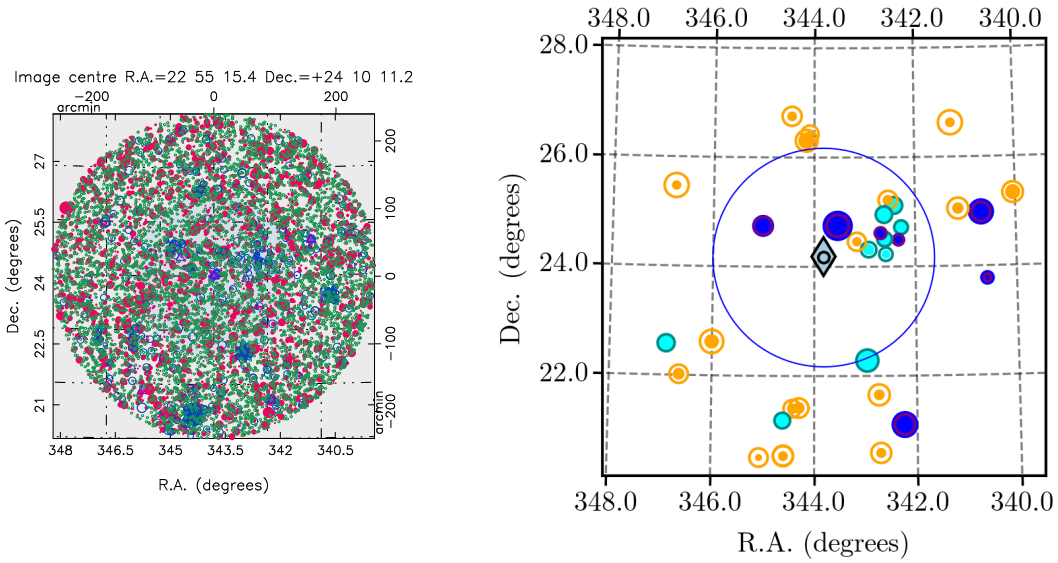

Figure 1: Left Plot: Radio and X-ray sources within 120 arc-minutes of the position of the neutrino event. Symbol diameters are proportional to source intensity. Radio sources appear as red filled circles, X-ray sources as open blue circles and gamma-ray sources as open triangles. Right Plot: Counterpart candidates in a 120 arc-minutes radius around the event direction. Dark blue circles represent LBL type candidates, that is sources with flux ratio in the range observed in the sample of LBL blazars of the latest edition of the BZCAT catalogue [6], cyan symbols are for IBL type candidates, and orange symbols are for HBL candidates. Known blazars are marked by a red diamond if they are included in the BZCAT catalogue or a star if they are part of the 2WHSP sample. The shaded area marks a circle of 90 arcmis around the events-best fit direction.

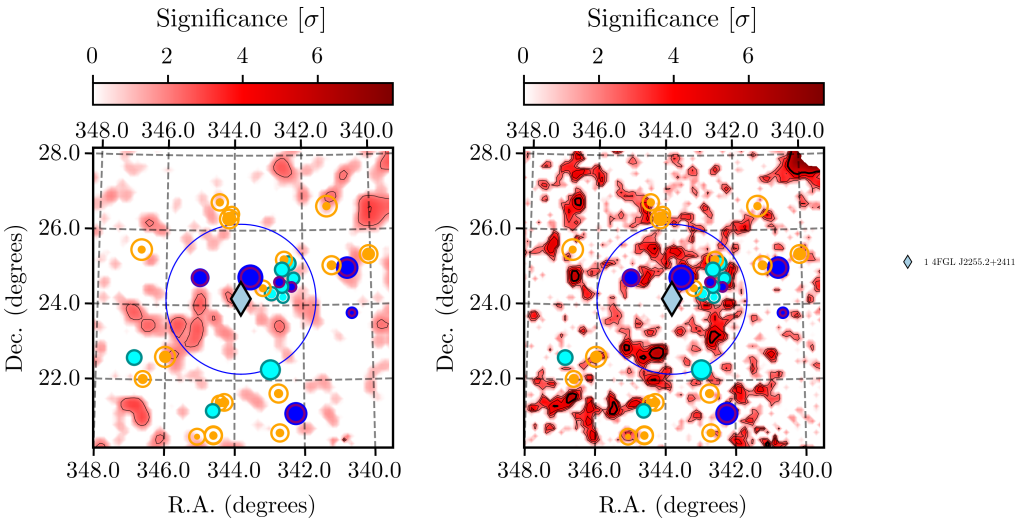

Figure 2: Test-statistic maps of the region after substracting know sources from the 4FGL catalog. The blue and black contours show the 90% and 50% error regions, respectively. Only photons with energies above 1.0 GeV are included. The map can be used to identify additional, yet unkown gamma-ray emitters, that coincide with multi-wavlength candidates. Contour lines are shown at 2,3,4,5 σ. **Left**: The map of the region for a time window of 200 days (MJD 55255.0, 55455.0) around the neutrino arrival time. **Right**: The map of the region for the entire *Fermi-LAT* mission (MJD 54682.7 to 59234.6).

3 SEDs and Light Curves

3.1 4FGL J2255.2+2411 | ra = 343.82°, dec = 24.19°, Σ= 30.3 σ, $\Delta\psi = 0.02°$

Associations: 3FGL J2255.1+2411, 3FHL J2255.2+2410, 5BZB J2255+2410

MJD	Probability [%]	Energy[GeV]
55486.28	99.71	108.77
55391.67	99.56	46.80
57533.87	99.62	39.25
58571.50	99.60	34.44
58375.87	98.48	29.08

Table 1: $\geq$ 5GeV photons with highest probability (p $\geq$ 90%) to be associated with the source

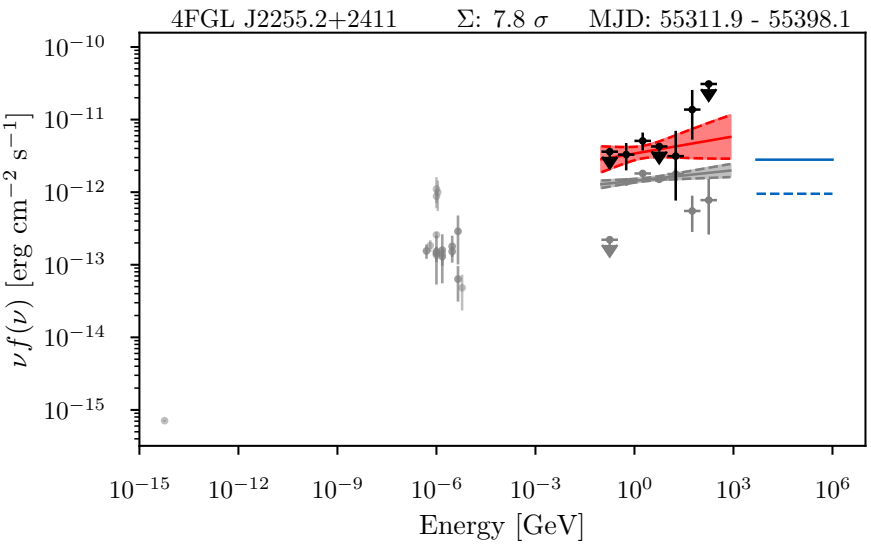

Figure 3: SED for 4FGL J2255.2+2411. See the description in section 2.2 for more details.

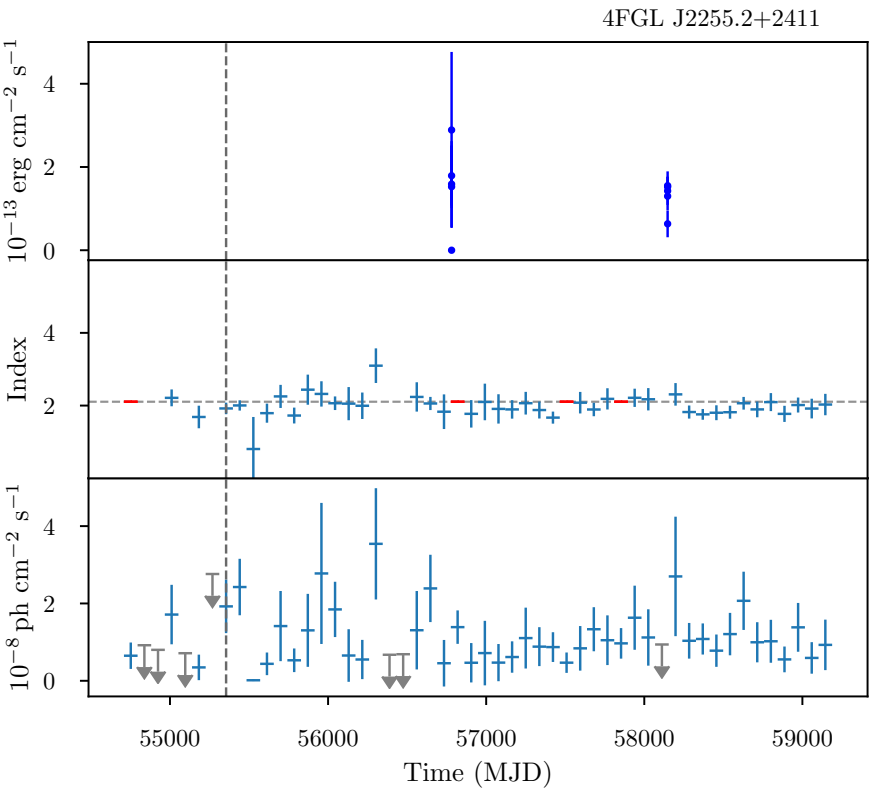

Figure 4: Light curve for 4FGL J2255.2+2411

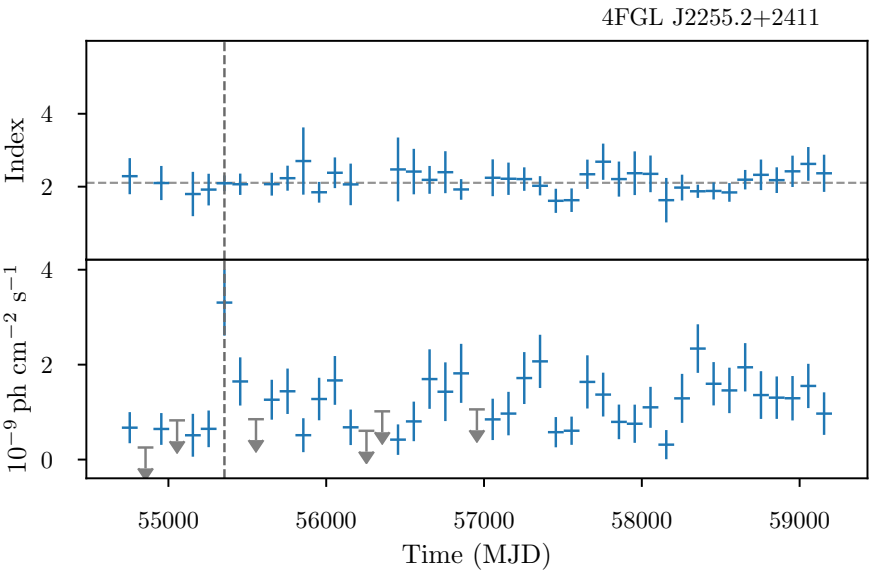

Figure 5: 1GeV light curve for 4FGL J2255.2+2411

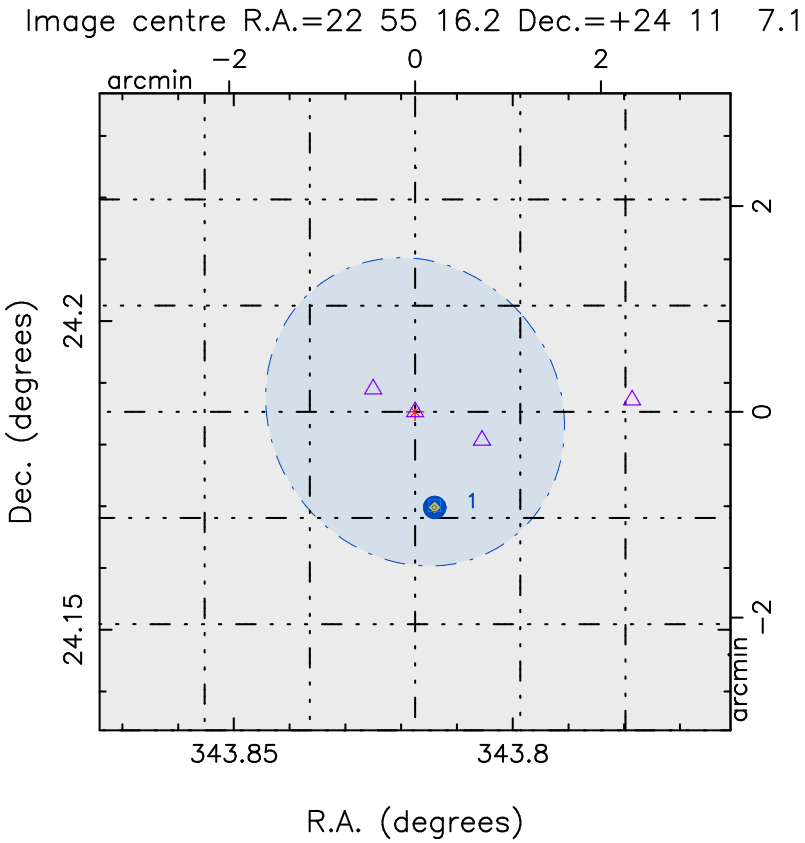

Figure 6: Possible couterparts for 4FGL J2255.2+2411

4 Appendix

4.1 Analyis Details - Light Curve

4.1.1 Ligh Curve Binning

Since we want to avoid running an extremly time consuming adaptive binning algorithm for all sources we try to estimate reasonable time windows for each source based on the following criteria:

- a) If possible we want to have a significant detection in each time bin
- b) IceCube needs on an order of $\mathcal{O}(100$ days) integration time to detect a significant neutrino singal in a point-source analysis
- c) following from b) we don't care too much about extremly short time-windows, since they are experimental hard to access
- d) unkown gamma-ray emitters are not expected to have a large time-integrated signal, but can still have gamma-ray outburst/flares

As a result of this we adapt the following procedure:

- For unkown gamma-ray emitters we built a light curve with time windows of 100 days, starting from the time of the neutrino alert. In case of subsequent measurements close to the detection threshold, an adaptive binning light curve can be run as a follow-up
- For known gamma-ray emitters, i.e. sources listed in the 4FGL catalog, we calculate the time window need for a 5σ (3σ) detection assuming a constant emission. This value is then used as time window, with the only limitation that we limit it to maximal 200 days in order to avoid missing interesting fluctuations around the neutrino arrival time.

The calculation of the time-windows for known-gamma ray emitters is based on the asymptotic behaviour of counting experiments combined with the information given in the 4FGL catalog. For a counting experiments with χ^2 background test-statistic distribution in the asymptotic limit the median test statistic value of a signal behaves as [7]

$$\mathcal{TS} = 2 \times \left[(s+b) \ln\left(1 + \frac{s}{b}\right) - s \right]. \tag{1}$$

As Fermi-LAT has only limited background we consider this equation in the limit of $s >> b >> 1$ and $s + b \to \infty$, hence we can simplify to

$$\mathcal{TS} \to 2 \times s \left[\ln\left(\frac{s}{b}\right) \right] \tag{2}$$

rewriting $s = s_0 t$ and $b = b_0 t$ we finally get

$$\mathcal{TS} \to 2 \times s_0 t \left[\ln\left(\frac{s_0}{b_0}\right) \right] \tag{3}$$

which scales linearly in time. The 4FGL catalog provides the 8 year time-integrated test-statistic values for each source in 7 energy bands. In order to calculate the total test-statistic value for our selection we sum up all the test-statistic values with energies larger than the minimimum (threshold) energy of this analysis. Finally we can calculate the integration time needed for 5σ ($\mathcal{TS} = 25$) and 3σ ($\mathcal{TS} = 9$) detection using equation (3)

$$t(5\sigma) = \frac{25}{\mathcal{TS}_{8years}} \cdot 2920\,[\text{days}] \tag{4}$$

4.2 Analyis Details - SED

The construction of the SED of the counterpart candiates is based on the *VOU-Blazars* tool [1]. For a given source position it identifies all the corresponding measurements based on likelihood ratios test taking into account the specific point spread functions of the 32 respective experiments/catalogs taken into account in our analysis [3]. This procedure works stable for multi-wavelength catalogs, as well as single band measurements except for gamma-ray catalogs where the point-spread function is comparably large. For the construction of the SED of Fermi-LAT counterparts the procedure is hence two-step. 1) We run a counterpart search in the given 95% confidence region of the source position. In most cases there is only one (or no) possible multi-wavelength counterpart candidate, in all other cases we assume the strongest source to be the countepart. 2) We construct the SED using the location of the indentified counterpart. In all of these cases the skymap in the vicinity with all the possible multi-wavelength counterparts is additionally shown in the source summary in section 3. Finally the IceCube point source sensitivity and discovery potential are taken from [5] and shown for reference.

[3] List of the 32 catalogs used in this analysis: SDS82 , 3HSP , Fermi8YR ,1BIGB, MST9Y, FIRST, SUMSS, WGACAT, IPC2E, ZWCLUSTERS, PSZ2, ABELL , SDSSWHL, CRATES, NVSS, SXPS, RASS, XMMSL, BMW , IPCSL, CHANDRA, MCXC, 5BZCat, SWXCS, PULSAR, F2PSR, 3FHL, 3FGL, 3XMM, MAXI, FermiMEV, AGILE

4.3 Full VOU Output

RASS/NVSS ra dec 22 40 12.1, 25 19 55.9 radio flux d. 25.100 X-ray/radio flux-ratio 1174. arx 0.627 Log(nu peak) 16.3+/- 1 possible HBL **Dist. 216.606 arcmin**
Match nr. 1 ra dec: 340.05029, 25.33219
.....Cataloged sources.....
MQ SDSS J224012.02+251956.0

OUSXG/NVSS ra dec 22 42 20.5, 23 46 52.9 radio flux d. 23.600 flux-ratio 6. arx 0.903 possible LBL **Dist. 178.521 arcmin**
SXPS/NVSS ra dec 22 42 20.5, 23 46 52.9 radio flux d. 23.600 flux-ratio 6. arx 0.905 possible LBL **Dist. 178.521 arcmin**
Match nr. 2 ra dec: 340.58558, 23.78136
.....Cataloged sources.....

RASS/NVSS ra dec 22 42 45.5, 24 59 26.2 radio flux d. 623.000 flux-ratio 24. arx 0.833 possible LBL **Dist. 177.456 arcmin**
Match nr. 3 ra dec: 340.68942, 24.99061
.....Cataloged sources.....

XMMSLEW/NVSS ra dec 22 44 36.6, 25 03 45.4 radio flux d. 9.100 X-ray/radio flux-ratio 9393. arx 0.518 Log(nu peak) 18.4+/- 1 possible HBL **Dist. 154.746 arcmin**
OUSXB/NVSS ra dec 22 44 36.6, 25 03 45.4 radio flux d. 9.100 X-ray/radio flux-ratio 935. arx 0.639 Log(nu peak) 16.0+/- 1 possible HBL **Dist. 154.746 arcmin**
SXPS/NVSS ra dec 22 44 36.6, 25 03 45.4 radio flux d. 9.100 X-ray/radio flux-ratio 890. arx 0.642 Log(nu peak) 16.0+/- 1 possible HBL **Dist. 154.746 arcmin**
Match nr. 4 ra dec: 341.15250, 25.06261
.....Cataloged sources.....
3HSPJ224436.7+250343
MQ 3FGLJ2244.6+2503

RASS/NVSS ra dec 22 45 4.7, 26 38 4.0 radio flux d. 5.800 X-ray/radio flux-ratio 17268. arx 0.486 Log(nu peak) 19.1+/- 1 possible HBL **Dist. 202.190 arcmin**
Match nr. 5 ra dec: 341.26967, 26.63444
.....Cataloged sources.....
mcxcJ2245.0+2637

OUSXB/NVSS ra dec 22 49 0.6, 21 07 3.1 radio flux d. 773.400 flux-ratio 38. arx 0.808 possible LBL **Dist. 202.521 arcmin**
Match nr. 6 ra dec: 342.25238, 21.11753
.....Cataloged sources.....
5BZQ J2249+2107
BROS J2249.0+2107
CRATES J224900+210719
MQ PKS 2246+208

WGA/NVSS ra dec 22 49 7.3, 24 43 31.6 radio flux d. 13.100 X-ray/radio flux-ratio 127. arx 0.745 Log(nu peak) 13.9+/- 1 possible IBL **Dist. 90.154 arcmin**
Match nr. 7 ra dec: 342.28054, 24.72544

.....Cataloged sources.....

WGA/NVSS ra dec 22 49 21.4, 24 29 35.9 radio flux d. 17.700 flux-ratio 32. arx 0.817 possible LBL **Dist. 82.949 arcmin**
Match nr. 8 ra dec: 342.33896, 24.49331
.....Cataloged sources.....
BROS J2249.3+2429

WGA/NVSS ra dec 22 49 40.6, 25 07 25.4 radio flux d. 22.000 X-ray/radio flux-ratio 265. arx 0.706 Log(nu peak) 14.7+/- 1 possible IBL **Dist. 95.204 arcmin**
Match nr. 9 ra dec: 342.41900, 25.12372
.....Cataloged sources.....

WGA/NVSS ra dec 22 50 11.6, 25 13 1.0 radio flux d. 6.800 X-ray/radio flux-ratio 1925. arx 0.601 Log(nu peak) 16.8+/- 1 possible HBL **Dist. 93.319 arcmin**
Match nr. 10 ra dec: 342.54833, 25.21694
.....Cataloged sources.....

WGA/NVSS ra dec 22 50 22.2, 24 13 42.2 radio flux d. 4.300 X-ray/radio flux-ratio 346. arx 0.692 Log(nu peak) 15.0+/- 1 possible IBL **Dist. 66.954 arcmin**
Match nr. 11 ra dec: 342.59238, 24.22839
.....Cataloged sources.....

WGA/NVSS ra dec 22 50 27.4, 24 30 21.0 radio flux d. 16.400 X-ray/radio flux-ratio 164. arx 0.731 Log(nu peak) 14.2+/- 1 possible IBL **Dist. 68.618 arcmin**
Match nr. 12 ra dec: 342.61433, 24.50583
.....Cataloged sources.....
MQ SDSS J225027.49+243024.3

WGA/NVSS ra dec 22 50 28.2, 24 57 43.2 radio flux d. 43.300 X-ray/radio flux-ratio 79. arx 0.769 Log(nu peak) 13.4+/- 1 possible IBL **Dist. 80.763 arcmin**
IPC/NVSS ra dec 22 50 28.2, 24 57 43.2 radio flux d. 43.300 X-ray/radio flux-ratio 164. arx 0.731 Log(nu peak) 14.2+/- 1 possible IBL **Dist. 80.763 arcmin**
Match nr. 13 ra dec: 342.61754, 24.96200
.....Cataloged sources.....

WGA/NVSS ra dec 22 50 46.1, 24 37 27.2 radio flux d. 15.100 flux-ratio 55. arx 0.789 possible LBL **Dist. 67.105 arcmin**
Match nr. 14 ra dec: 342.69196, 24.62422
.....Cataloged sources.....

RASS/NVSS ra dec 22 50 51.2, 20 35 59.6 radio flux d. 6.500 X-ray/radio flux-ratio 3170. arx 0.575 Log(nu peak) 17.3+/- 1 possible HBL **Dist. 222.724 arcmin**
Match nr. 15 ra dec: 342.71346, 20.59989
.....Cataloged sources.....

XMMSLEW/NVSS ra dec 22 50 58.4, 21 39 31.5 radio flux d. 8.000 X-ray/radio flux-ratio 6124. arx 0.540 Log(nu peak) 18.0+/- 1 possible HBL **Dist. 161.868 arcmin**
RASS/NVSS ra dec 22 50 58.4, 21 39 31.5 radio flux d. 8.000 X-ray/radio flux-ratio 2320. arx 0.591 Log(nu peak) 17.0+/- 1 possible HBL **Dist. 161.868 arcmin**
Match nr. 16 ra dec: 342.74317, 21.65875
.....Cataloged sources.....
MQ WISEA J225058.39+213927.1

WGA/NVSS ra dec 22 51 42.5, 24 19 23.1 radio flux d. 8.600 X-ray/radio flux-ratio 376. arx 0.687 Log(nu peak) 15.1+/- 1 possible IBL **Dist. 49.395 arcmin**
Match nr. 17 ra dec: 342.92700, 24.32308
.....Cataloged sources.....

RASS/NVSS ra dec 22 51 53.5, 22 17 37.9 radio flux d. 190.000 X-ray/radio flux-ratio 113. arx 0.751 Log(nu peak) 13.8+/- 1 possible IBL **Dist. 121.736 arcmin**
OUSXB/NVSS ra dec 22 51 53.5, 22 17 37.9 radio flux d. 190.000 X-ray/radio flux-ratio 229. arx 0.713 Log(nu peak) 14.5+/- 1 possible IBL **Dist. 121.736 arcmin**
SXPS/NVSS ra dec 22 51 53.5, 22 17 37.9 radio flux d. 190.000 X-ray/radio flux-ratio 379. arx 0.687 Log(nu peak) 15.1+/- 1 possible IBL **Dist. 121.736 arcmin**
Match nr. 18 ra dec: 342.97288, 22.29386
.....Cataloged sources.....
5BZQ J2251+2217
BROS J2251.8+2217
CRATES J225153+221724
MQ MGC J2251+2217

WGA/NVSS ra dec 22 52 40.5, 24 28 2.6 radio flux d. 5.600 X-ray/radio flux-ratio 1798. arx 0.605 Log(nu peak) 16.7+/- 1 possible HBL **Dist. 39.546 arcmin**
Match nr. 19 ra dec: 343.16875, 24.46739
.....Cataloged sources.....

RASS/NVSS ra dec 22 54 9.3, 24 45 23.5 radio flux d. 1888.900 flux-ratio 21. arx 0.840 possible LBL **Dist. 38.279 arcmin**
SXPS/NVSS ra dec 22 54 9.3, 24 45 23.5 radio flux d. 1888.900 flux-ratio 27. arx 0.825 possible LBL **Dist. 38.279 arcmin**
Match nr. 20 ra dec: 343.53888, 24.75653
.....Cataloged sources.....
BROS J2254.1+2445
MQ PKS 2251+24

RASS/NVSS ra dec 22 55 15.3, 24 10 12.5 radio flux d. 79.200 X-ray/radio flux-ratio 497. arx 0.673 Log(nu peak) 15.3+/- 1 possible IBL **Dist. 0.023 arcmin**
OUSXB/NVSS ra dec 22 55 15.3, 24 10 12.5 radio flux d. 79.200 flux-ratio 39. arx 0.807 possible LBL **Dist. 0.023 arcmin**
SXPS/NVSS ra dec 22 55 15.3, 24 10 12.5 radio flux d. 79.200 flux-ratio 44. arx 0.800 possible LBL **Dist. 0.023 arcmin**
Match nr. 21 ra dec: 343.81392, 24.17014
.....Cataloged sources.....
5BZB J2255+2410
BROS J2255.2+2410

MQ BZB J2255+2410

OUSXB/NVSS ra dec 22 56 24.1, 26 26 14.2 radio flux d. 3.100 X-ray/radio flux-ratio 2482. arx 0.588 Log(nu peak) 17.0+/- 1 possible HBL **Dist. 136.933 arcmin**
SXPS/NVSS ra dec 22 56 24.1, 26 26 14.2 radio flux d. 3.100 X-ray/radio flux-ratio 2802. arx 0.581 Log(nu peak) 17.2+/- 1 possible HBL **Dist. 136.933 arcmin**
Match nr. 22 ra dec: 344.10038, 26.43728
.....Cataloged sources.....

XMMSLEW/NVSS ra dec 22 56 39.1, 26 18 42.3 radio flux d. 43.600 X-ray/radio flux-ratio 2038. arx 0.598 Log(nu peak) 16.8+/- 1 possible HBL **Dist. 129.903 arcmin**
RASS/NVSS ra dec 22 56 39.1, 26 18 42.3 radio flux d. 43.600 X-ray/radio flux-ratio 1063. arx 0.632 Log(nu peak) 16.2+/- 1 possible HBL **Dist. 129.903 arcmin**
OUSXB/NVSS ra dec 22 56 39.1, 26 18 42.3 radio flux d. 43.600 X-ray/radio flux-ratio 1252. arx 0.624 Log(nu peak) 16.3+/- 1 possible HBL **Dist. 129.903 arcmin**
SXPS/NVSS ra dec 22 56 39.1, 26 18 42.3 radio flux d. 43.600 X-ray/radio flux-ratio 564. arx 0.666 Log(nu peak) 15.5+/- 1 possible IBL **Dist. 129.903 arcmin**
Match nr. 23 ra dec: 344.16279, 26.31175
.....Cataloged sources.....
5BZG J2256+2618
MQ PGC 1771379

RASS/NVSS ra dec 22 57 12.1, 21 25 10.5 radio flux d. 10.600 X-ray/radio flux-ratio 1472. arx 0.615 Log(nu peak) 16.5+/- 1 possible HBL **Dist. 167.191 arcmin**
Match nr. 24 ra dec: 344.30054, 21.41958
.....Cataloged sources.....
MQ WISEA J225712.09+212506.2

WGA/NVSS ra dec 22 57 45.0, 21 24 20.8 radio flux d. 7.100 X-ray/radio flux-ratio 1124. arx 0.630 Log(nu peak) 16.2+/- 1 possible HBL **Dist. 169.385 arcmin**
Match nr. 25 ra dec: 344.43733, 21.40578
.....Cataloged sources.....

RASS/NVSS ra dec 22 57 48.0, 26 45 25.5 radio flux d. 6.100 X-ray/radio flux-ratio 2471. arx 0.588 Log(nu peak) 17.0+/- 1 possible HBL **Dist. 159.013 arcmin**
Match nr. 26 ra dec: 344.45004, 26.75708
.....Cataloged sources.....

RASS/NVSS ra dec 22 58 24.7, 20 33 2.7 radio flux d. 4.500 X-ray/radio flux-ratio 8552. arx 0.523 Log(nu peak) 18.3+/- 1 possible HBL **Dist. 221.509 arcmin**
WGA/NVSS ra dec 22 58 24.7, 20 33 2.7 radio flux d. 4.500 X-ray/radio flux-ratio 990. arx 0.636 Log(nu peak) 16.1+/- 1 possible HBL **Dist. 221.509 arcmin**
Match nr. 27 ra dec: 344.60300, 20.55075
.....Cataloged sources.....

RASS/NVSS ra dec 22 58 26.2, 20 31 52.6 radio flux d. 5.900 X-ray/radio flux-ratio 6523. arx 0.537 Log(nu peak) 18.1+/- 1 possible HBL **Dist. 222.721 arcmin**
WGA/NVSS ra dec 22 58 26.2, 20 31 52.6 radio flux d. 5.900 X-ray/radio flux-ratio 755. arx 0.651

Log(nu peak) 15.8+/- 1 possible HBL **Dist. 222.721 arcmin**
Match nr. 28 ra dec: 344.60904, 20.53128
.....Cataloged sources.....

WGA/NVSS ra dec 22 58 29.8, 21 11 43.5 radio flux d. 24.400 X-ray/radio flux-ratio 169. arx 0.730 Log(nu peak) 14.2+/- 1 possible IBL **Dist. 184.009 arcmin**
Match nr. 29 ra dec: 344.62417, 21.19542
.....Cataloged sources.....

XMMSLEW/NVSS ra dec 22 59 33.1, 24 55 7.7 radio flux d. 3.700 flux-ratio 153469. arx 0.370 possible non-jetted AGN **Dist. 73.845 arcmin**
RASS/NVSS ra dec 22 59 33.1, 24 55 7.7 radio flux d. 3.700 flux-ratio 107270. arx 0.389 possible non-jetted AGN **Dist. 73.845 arcmin**
SXPS/NVSS ra dec 22 59 33.1, 24 55 7.7 radio flux d. 3.700 flux-ratio 108523. arx 0.389 possible non-jetted AGN **Dist. 73.845 arcmin**
Match nr. 30 ra dec: 344.88771, 24.91881
.....Cataloged sources.....
MQ KAZ 320

RASS/NVSS ra dec 23 00 4.6, 24 44 47.8 radio flux d. 181.500 flux-ratio 53. arx 0.790 possible LBL **Dist. 74.354 arcmin**
Match nr. 31 ra dec: 345.01904, 24.74661
.....Cataloged sources.....

WGA/NVSS ra dec 23 00 17.5, 20 30 14.6 radio flux d. 2.800 X-ray/radio flux-ratio 4012. arx 0.562 Log(nu peak) 17.6+/- 1 possible HBL **Dist. 230.768 arcmin**
Match nr. 32 ra dec: 345.07300, 20.50406
.....Cataloged sources.....
MQ SDSS J230016.66+203020.3

XMMSLEW/NVSS ra dec 23 04 2.6, 22 37 25.5 radio flux d. 22.500 X-ray/radio flux-ratio 4812. arx 0.553 Log(nu peak) 17.7+/- 1 possible HBL **Dist. 152.436 arcmin**
RASS/NVSS ra dec 23 04 2.6, 22 37 25.5 radio flux d. 22.500 X-ray/radio flux-ratio 4182. arx 0.560 Log(nu peak) 17.6+/- 1 possible HBL **Dist. 152.436 arcmin**
IPC/NVSS ra dec 23 04 2.6, 22 37 25.5 radio flux d. 22.500 X-ray/radio flux-ratio 1590. arx 0.611 Log(nu peak) 16.6+/- 1 possible HBL **Dist. 152.436 arcmin**
Match nr. 33 ra dec: 346.01088, 22.62375
.....Cataloged sources.....
MQ MARK 315

RASS/NVSS ra dec 23 06 34.6, 22 01 22.0 radio flux d. 10.800 X-ray/radio flux-ratio 1094. arx 0.631 Log(nu peak) 16.2+/- 1 possible HBL **Dist. 202.450 arcmin**
Match nr. 34 ra dec: 346.64417, 22.02278
.....Cataloged sources.....
MQ SDSS J230634.56+220120.2

IPCSLEW/NVSS ra dec 23 07 0.7, 25 28 20.2 radio flux d. 5.400 X-ray/radio flux-ratio 18738. arx 0.481 Log(nu peak) 19.2+/- 1 possible HBL **Dist. 178.086 arcmin**

Match nr. 35 ra dec: 346.75275, 25.47228
.....Cataloged sources.....

SXPS/NVSS ra dec 23 07 37.6, 22 35 14.5 radio flux d. 61.800 X-ray/radio flux-ratio 109. arx 0.753 Log(nu peak) 13.7+/- 1 possible IBL **Dist. 194.984 arcmin**
Match nr. 36 ra dec: 346.90662, 22.58736
.....Cataloged sources.....
BROS J2307.6+2235
MQ WISEA J230737.60+223514.9

Candidate nr. 37, Known blazar with no radio/X-ray match: 5BZQ J2244+2600 found at a distance of 182.055 arcmin
Candidate nr. 38, Known blazar with no radio/X-ray match: 5BZQ J2256+2301 found at a distance of 69.597 arcmin
Candidate nr. 39, Known blazar with no radio/X-ray match: 5BZQ J2304+2331 found at a distance of 134.102 arcmin
Candidate nr. 40, Known flat spectrum radio source with no radio/X-ray match: BROS J2247.0+2052 found at a distance of 228.556 arcmin
Candidate nr. 41, Known flat spectrum radio source with no radio/X-ray match: BROS J2247.2+2207 found at a distance of 165.422 arcmin
Candidate nr. 42, Known flat spectrum radio source with no radio/X-ray match: BROS J2252.8+2020 found at a distance of 232.603 arcmin
Candidate nr. 43, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.6+2029 found at a distance of 221.279 arcmin
Candidate nr. 44, Known flat spectrum radio source with no radio/X-ray match: BROS J2259.6+2047 found at a distance of 211.383 arcmin
Candidate nr. 45, Known flat spectrum radio source with no radio/X-ray match: BROS J2252.9+2148 found at a distance of 145.647 arcmin
Candidate nr. 46, Known flat spectrum radio source with no radio/X-ray match: BROS J2256.9+2127 found at a distance of 163.989 arcmin
Candidate nr. 47, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.4+2155 found at a distance of 135.085 arcmin
Candidate nr. 48, Known flat spectrum radio source with no radio/X-ray match: BROS J2252.7+2223 found at a distance of 111.670 arcmin
Candidate nr. 49, Known flat spectrum radio source with no radio/X-ray match: BROS J2256.2+2231 found at a distance of 99.141 arcmin
Candidate nr. 50, Known flat spectrum radio source with no radio/X-ray match: BROS J2256.4+2248 found at a distance of 83.113 arcmin
Candidate nr. 51, Known flat spectrum radio source with no radio/X-ray match: BROS J2258.6+2135 found at a distance of 161.819 arcmin
Candidate nr. 52, Known flat spectrum radio source with no radio/X-ray match: BROS J2258.4+2152 found at a distance of 144.131 arcmin
Candidate nr. 53, Known flat spectrum radio source with no radio/X-ray match: BROS J2258.4+2209 found at a distance of 128.872 arcmin
Candidate nr. 54, Known flat spectrum radio source with no radio/X-ray match: BROS J2239.3+2308 found at a distance of 227.183 arcmin
Candidate nr. 55, Known flat spectrum radio source with no radio/X-ray match: BROS J2243.3+2329 found at a distance of 168.600 arcmin
Candidate nr. 56, Known flat spectrum radio source with no radio/X-ray match: BROS J2249.0+2316 found at a distance of 100.594 arcmin
Candidate nr. 57, Known flat spectrum radio source with no radio/X-ray match: BROS J2238.7+2348 found at a distance of 227.789 arcmin
Candidate nr. 58, Known flat spectrum radio source with no radio/X-ray match: BROS J2239.3+2438

found at a distance of 219.229 arcmin
Candidate nr. 59, Known flat spectrum radio source with no radio/X-ray match: BROS J2239.9+2505 found at a distance of 216.074 arcmin
Candidate nr. 60, Known flat spectrum radio source with no radio/X-ray match: BROS J2242.4+2437 found at a distance of 177.332 arcmin
Candidate nr. 61, Known flat spectrum radio source with no radio/X-ray match: BROS J2243.0+2434 found at a distance of 168.144 arcmin
Candidate nr. 62, Known flat spectrum radio source with no radio/X-ray match: BROS J2245.5+2450 found at a distance of 138.968 arcmin
Candidate nr. 63, Known flat spectrum radio source with no radio/X-ray match: BROS J2246.6+2450 found at a distance of 124.464 arcmin
Candidate nr. 64, Known flat spectrum radio source with no radio/X-ray match: BROS J2253.3+2301 found at a distance of 73.260 arcmin
Candidate nr. 65, Known flat spectrum radio source with no radio/X-ray match: BROS J2252.6+2326 found at a distance of 56.256 arcmin
BROS J2256.1+2301, repeated with candidate nr. 38 5BZQ J2256+2301
Candidate nr. 66, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.4+2327 found at a distance of 43.939 arcmin
Candidate nr. 67, Known flat spectrum radio source with no radio/X-ray match: BROS J2251.2+2343 found at a distance of 61.650 arcmin
Candidate nr. 68, Known flat spectrum radio source with no radio/X-ray match: BROS J2251.3+2357 found at a distance of 54.410 arcmin
Candidate nr. 69, Known flat spectrum radio source with no radio/X-ray match: BROS J2255.4+2338 found at a distance of 31.661 arcmin
Candidate nr. 70, Known flat spectrum radio source with no radio/X-ray match: BROS J2256.5+2333 found at a distance of 41.055 arcmin
Candidate nr. 71, Known flat spectrum radio source with no radio/X-ray match: BROS J2256.4+2350 found at a distance of 25.180 arcmin
Candidate nr. 72, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.5+2354 found at a distance of 18.647 arcmin
Candidate nr. 73, Known flat spectrum radio source with no radio/X-ray match: BROS J2303.3+2316 found at a distance of 124.205 arcmin
Candidate nr. 74, Known flat spectrum radio source with no radio/X-ray match: BROS J2259.6+2338 found at a distance of 68.515 arcmin
Candidate nr. 75, Known flat spectrum radio source with no radio/X-ray match: BROS J2258.5+2407 found at a distance of 45.239 arcmin
Candidate nr. 76, Known flat spectrum radio source with no radio/X-ray match: BROS J2302.0+2352 found at a distance of 94.939 arcmin
Candidate nr. 77, Known flat spectrum radio source with no radio/X-ray match: BROS J2301.0+2414 found at a distance of 78.778 arcmin
Candidate nr. 78, Known flat spectrum radio source with no radio/X-ray match: BROS J2303.7+2426 found at a distance of 117.101 arcmin
Candidate nr. 79, Known flat spectrum radio source with no radio/X-ray match: BROS J2256.0+2426 found at a distance of 19.193 arcmin
Candidate nr. 80, Known flat spectrum radio source with no radio/X-ray match: BROS J2251.2+2512 found at a distance of 82.745 arcmin
Candidate nr. 81, Known flat spectrum radio source with no radio/X-ray match: BROS J2259.6+2424 found at a distance of 62.180 arcmin
Candidate nr. 82, Known flat spectrum radio source with no radio/X-ray match: BROS J2303.5+2542 found at a distance of 145.693 arcmin
Candidate nr. 83, Known flat spectrum radio source with no radio/X-ray match: BROS J2308.1+2134 found at a distance of 236.707 arcmin
Candidate nr. 84, Known flat spectrum radio source with no radio/X-ray match: BROS J2305.6+2217 found at a distance of 182.557 arcmin
Candidate nr. 85, Known flat spectrum radio source with no radio/X-ray match: BROS J2308.7+2216

found at a distance of 217.706 arcmin
Candidate nr. 86, Known flat spectrum radio source with no radio/X-ray match: BROS J2310.3+2220 found at a distance of 235.101 arcmin
Candidate nr. 87, Known flat spectrum radio source with no radio/X-ray match: BROS J2304.5+2230 found at a distance of 161.928 arcmin
Candidate nr. 88, Known flat spectrum radio source with no radio/X-ray match: BROS J2310.0+2238 found at a distance of 223.313 arcmin
Candidate nr. 89, Known flat spectrum radio source with no radio/X-ray match: BROS J2310.8+2246 found at a distance of 230.747 arcmin
Candidate nr. 90, Known flat spectrum radio source with no radio/X-ray match: BROS J2310.9+2305 found at a distance of 225.249 arcmin
Candidate nr. 91, Known flat spectrum radio source with no radio/X-ray match: BROS J2304.5+2302 found at a distance of 144.704 arcmin
Candidate nr. 92, Known flat spectrum radio source with no radio/X-ray match: BROS J2304.2+2318 found at a distance of 134.115 arcmin
Candidate nr. 93, Known flat spectrum radio source with no radio/X-ray match: BROS J2305.2+2318 found at a distance of 146.389 arcmin
BROS J2304.6+2331, repeated with candidate nr. 39 5BZQ J2304+2331
Candidate nr. 94, Known flat spectrum radio source with no radio/X-ray match: BROS J2309.7+2334 found at a distance of 201.913 arcmin
Candidate nr. 95, Known flat spectrum radio source with no radio/X-ray match: BROS J2306.5+2355 found at a distance of 155.323 arcmin
Candidate nr. 96, Known flat spectrum radio source with no radio/X-ray match: BROS J2307.5+2505 found at a distance of 177.030 arcmin
Candidate nr. 97, Known flat spectrum radio source with no radio/X-ray match: BROS J2307.8+2506 found at a distance of 180.771 arcmin
Candidate nr. 98, Known flat spectrum radio source with no radio/X-ray match: BROS J2304.0+2512 found at a distance of 135.112 arcmin
Candidate nr. 99, Known flat spectrum radio source with no radio/X-ray match: BROS J2305.0+2543 found at a distance of 162.327 arcmin
Candidate nr. 100, Known flat spectrum radio source with no radio/X-ray match: BROS J2305.1+2551 found at a distance of 168.998 arcmin
Candidate nr. 101, Known flat spectrum radio source with no radio/X-ray match: BROS J2307.6+2527 found at a distance of 185.155 arcmin
Candidate nr. 102, Known flat spectrum radio source with no radio/X-ray match: BROS J2309.1+2550 found at a distance of 214.113 arcmin
Candidate nr. 103, Known flat spectrum radio source with no radio/X-ray match: BROS J2311.3+2547 found at a distance of 239.800 arcmin
Candidate nr. 104, Known flat spectrum radio source with no radio/X-ray match: BROS J2239.9+2544 found at a distance of 227.911 arcmin
Candidate nr. 105, Known flat spectrum radio source with no radio/X-ray match: BROS J2242.2+2522 found at a distance of 191.873 arcmin
Candidate nr. 106, Known flat spectrum radio source with no radio/X-ray match: BROS J2241.3+2525 found at a distance of 203.454 arcmin
Candidate nr. 107, Known flat spectrum radio source with no radio/X-ray match: BROS J2243.4+2628 found at a distance of 211.828 arcmin
Candidate nr. 108, Known flat spectrum radio source with no radio/X-ray match: BROS J2247.4+2532 found at a distance of 134.075 arcmin
Candidate nr. 109, Known flat spectrum radio source with no radio/X-ray match: BROS J2248.3+2546 found at a distance of 134.731 arcmin
Candidate nr. 110, Known flat spectrum radio source with no radio/X-ray match: BROS J2248.5+2555 found at a distance of 139.228 arcmin
Candidate nr. 111, Known flat spectrum radio source with no radio/X-ray match: BROS J2247.9+2635 found at a distance of 176.113 arcmin
Candidate nr. 112, Known flat spectrum radio source with no radio/X-ray match: BROS J2244.5+2703

found at a distance of 226.344 arcmin
Candidate nr. 113, Known flat spectrum radio source with no radio/X-ray match: BROS J2246.9+2716 found at a distance of 217.139 arcmin
Candidate nr. 114, Known flat spectrum radio source with no radio/X-ray match: BROS J2247.5+2707 found at a distance of 205.916 arcmin
Candidate nr. 115, Known flat spectrum radio source with no radio/X-ray match: BROS J2246.3+2726 found at a distance of 229.566 arcmin
Candidate nr. 116, Known flat spectrum radio source with no radio/X-ray match: BROS J2246.7+2737 found at a distance of 236.924 arcmin
Candidate nr. 117, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.2+2601 found at a distance of 111.724 arcmin
Candidate nr. 118, Known flat spectrum radio source with no radio/X-ray match: BROS J2252.7+2628 found at a distance of 142.246 arcmin
Candidate nr. 119, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.2+2628 found at a distance of 139.461 arcmin
Candidate nr. 120, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.2+2636 found at a distance of 147.107 arcmin
Candidate nr. 121, Known flat spectrum radio source with no radio/X-ray match: BROS J2257.8+2606 found at a distance of 121.738 arcmin
Candidate nr. 122, Known flat spectrum radio source with no radio/X-ray match: BROS J2257.4+2616 found at a distance of 129.713 arcmin
Candidate nr. 123, Known flat spectrum radio source with no radio/X-ray match: BROS J2301.2+2550 found at a distance of 128.601 arcmin
Candidate nr. 124, Known flat spectrum radio source with no radio/X-ray match: BROS J2301.9+2615 found at a distance of 154.784 arcmin
Candidate nr. 125, Known flat spectrum radio source with no radio/X-ray match: BROS J2303.1+2614 found at a distance of 163.779 arcmin
Candidate nr. 126, Known flat spectrum radio source with no radio/X-ray match: BROS J2258.4+2642 found at a distance of 158.137 arcmin
Candidate nr. 127, Known flat spectrum radio source with no radio/X-ray match: BROS J2259.3+2636 found at a distance of 156.351 arcmin
Candidate nr. 128, Known flat spectrum radio source with no radio/X-ray match: BROS J2259.9+2643 found at a distance of 165.559 arcmin
Candidate nr. 129, Known flat spectrum radio source with no radio/X-ray match: BROS J2258.5+2646 found at a distance of 162.744 arcmin
Candidate nr. 130, Known flat spectrum radio source with no radio/X-ray match: BROS J2300.0+2654 found at a distance of 176.115 arcmin
Candidate nr. 131, Known flat spectrum radio source with no radio/X-ray match: BROS J2250.9+2726 found at a distance of 204.393 arcmin
Candidate nr. 132, Known flat spectrum radio source with no radio/X-ray match: BROS J2255.9+2740 found at a distance of 210.721 arcmin
Candidate nr. 133, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.8+2756 found at a distance of 226.155 arcmin
Candidate nr. 134, Known flat spectrum radio source with no radio/X-ray match: BROS J2254.9+2759 found at a distance of 229.185 arcmin
Candidate nr. 135, Known flat spectrum radio source with no radio/X-ray match: BROS J2257.0+2756 found at a distance of 227.399 arcmin
Candidate nr. 136, Known flat spectrum radio source with no radio/X-ray match: BROS J2300.4+2717 found at a distance of 200.127 arcmin
Candidate nr. 137, Known flat spectrum radio source with no radio/X-ray match: BROS J2259.0+2743 found at a distance of 219.637 arcmin
Candidate nr. 138, Known flat spectrum radio source with no radio/X-ray match: BROS J2302.6+2716 found at a distance of 211.705 arcmin
Candidate nr. 139, Known flat spectrum radio source with no radio/X-ray match: BROS J2302.2+2721 found at a distance of 213.111 arcmin

Candidate nr. 140, Known flat spectrum radio source with no radio/X-ray match: BROS J2302.4+2747 found at a distance of 237.958 arcmin
Candidate nr. 141, Known flat spectrum radio source with no radio/X-ray match: BROS J2306.8+2636 found at a distance of 214.229 arcmin
Candidate nr. 142, Known flat spectrum radio source with no radio/X-ray match: BROS J2308.3+2639 found at a distance of 232.039 arcmin
Candidate nr. 143, Known flat spectrum radio source with no radio/X-ray match: BROS J2305.0+2655 found at a distance of 211.771 arcmin
Candidate nr. 144, Known flat spectrum radio source with no radio/X-ray match: BROS J2307.2+2646 found at a distance of 224.899 arcmin
Candidate nr. 145, Known flat spectrum radio source with no radio/X-ray match: BROS J2304.4+2721 found at a distance of 228.199 arcmin
Candidate nr. 146, Known flat spectrum radio source with no radio/X-ray match: BROS J2304.1+2733 found at a distance of 235.701 arcmin
Candidate nr. 147, Known flat spectrum radio source with no radio/X-ray match: CRATES J223927+225959 found at a distance of 228.086 arcmin
CRATES J225610+230136, repeated with candidate nr. 38 5BZQ J2256+2301
CRATES J230437+233060, repeated with candidate nr. 39 5BZQ J2304+2331
CRATES J224434+260014, repeated with candidate nr. 37 5BZQ J2244+2600
CRATES J230428+272123, repeated with candidate nr. 145 BROS J2304.4+2721
Pulsar PSR J2307+2225 200.543 arcmin away

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