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XMDS beyond the VVDS 4 σ catalogue

A status report

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For internal circulation

Abstract. I report on the work I have done in the last quarter of 2005 to extend what originally done for the XMDS/VVDS 4 σ catalogue to the entire sample of objects in the XMDS, at any significance, inside and outside the VVDS area. In this work I used all database tables available to me in the Milan database at end of summer 2005, and attempted to automatize the procedure as far as possible. We intend to use this catalogue to extract subsets for further work.

Key words: LSS – XMDS –

1. Introduction

We presented in Chiappetti et al. (2005) (hereafter Paper I) a catalogue of 286 tentative identifications for the X-ray sources detected in the XMDS fields at a significance above 4σ, and falling in the area covered by the VVDS survey (Le Fèvre et al., 2004). Such identifications were based on an highly manual procedure, described, together with its input tables, in section 6 of Paper I.

Since then I tried to generate a further working catalogue using all XMDS sources, inside and outside the VVDS area, using additional data tables which became available in the meantime (e.g. CFHTLS and SWIRE), and automatizing the procedure as much as possible.

This report gives a short account of such procedure. For more details one can consult the web page `http://sax.iasf-milano.inaf.it/~lucio/LSS/NewIdent/procedure.html` which also contains a reference to a similar page for the XMDS/VVDS 4σ catalogue.

In section 2 I list the input database tables used as starting point for the identification. The procedure is described step-by-step in the various subsections of section 3. In particular the pre-ranking (see 3.6) is now generated almost automatically from positional probabilities (see 3.5), although a final rank is assigned only after visual inspection (see 3.7).

In section 3.8 I give some information on the astrometric correction, while in other sections there are some simple statistics and the coverage of the different surveys (see 3.9) and a brief comparison with `may05` (see 3.10).

We intend to use the updated complete catalogue as the source from which to extract subsamples for further work (e.g. Tajer, Polletta et al. in preparation).

2. Data sources

As starting point, similarly to what described in section 6.1 of Paper I, I generated a *glorified correlation table* using all possible combinations of database tables, each one correlated with the `xmdsepic` table with a "standard" correlation radius or criterion.

Below I list such database tables with their name, giving also an indication of the correlation table used, and indicating if they are "new" or have been updated with respect to the time when the XMDS/VVDS 4σ catalogue was initialized. In some cases I also supply some additional details.

- `xmdsepic` is the reference table with XMDS X-ray sources resulting from the Milan pipeline.
- `xmdsdup` is a clone of the same table, used to tag sources detected more than once in overlapping fields (uses an adhoc correlation condition within 6″ excluding of course associations of a source with itself)
- `may05` (**new**) is the table of X-ray sources from the Saclay pipeline correlation in same field, within 10″ in uncorrected coordinates (since both X-ray analyses are affected by the same astrometric issues)
- `virphot` is the table with "authorized" and "good photometry" VVDS sources. It is accessed via a correlation table using a 6″ distance (with the astrometrically corrected X-ray position for fields handled in Paper I, with the uncorrected position otherwise). Note that a similar correlation is implied below whenever not otherwise stated.
- `bad loiano vimos` are other views inside "authorized subsets" of the VVDS catalogues, respectively for sources with "bad photometry", for entries with U in the Loiano filter, and for spectroscopic information. They share a system of identifiers with `virphot`, in particular `bad` and `virphot` are disjoinct sets, while

the other two are subsets of the union of `virphot` and `bad` (in terms of sources, but they contain columns not present in the main photometric tables).

- `sacphot` is the table containing I magnitudes from the CFH12K observations made by Saclay outside of the VVDS area (it might include also some older data inside the VVDS area, in which case shares identifiers with `virphot`)
- `virradio` (correlated using a box of 40″ side) contains the VIRMOS1.4GHz catalogue (Bondi et al., 2003)
- `radio` (also correlated using a box of 40″ side) contains our own ("Leiden") VLA radio catalogue (Cohen et al., 2003)
- `specfup` currently containing information on the spectroscopy campaign of Oct 2002
- `xlssc` (**new**) is a small table with the list of XLSSC clusters (derived from Andreon's web site), with a reverse correlation table within 2 ′ .
- `loto` (**updated**) is based on the Lotoweb at 15 Jun 2005 and uses a correlation radius of 10 ″ (uncorrected coordinates)
- `d1` (**new**) is a table (so far not yet released) containing photometry from the CFHTLS D1 field extracted from the files supplied via IPAC in Feb 2005 taking all positions within 9″ from the X-ray source (and viewed via a correlation within 6″ uncorrected coordinates). Note that such IPAC files were based on a correlation with the Saclay Nov04 release.
- `w1` (**new**) is a table (so far not yet released) containing photometry from the 11 CFHTLS W1 fields extracted from the files supplied via IPAC in July 2005 (using as input the $ML > 20$ Saclay May05 release sources *plus the few residual XMDS sources in the outermost part of the FOVs*). Similar population within 9″ and correlation within 6″ uncorrected coordinates.
- `swire` (**new**) is a table (so far not yet released) containing SWIRE data from the previously cited IPAC releases (same population and correlation radii as for D1 and W1). Note that almost all data kept in the table comes from the July 2005 IPAC release (flagged as `dataset=3`). Data from the February 2005 IPAC release have been removed whenever duplicated by a July detection (if not, a few entries are kept flagged as `dataset=1|2`).
- `galex` (**new**) is a tentative table populated from a FITS file available to us within the VVDS framework. It does not contain any scientific information, but is used only to assess whether it is worth asking to proceed for a more formal collaboration.
- `simbad` (**updated**) contains SIMBAD sources within 20′ via a natural correlation table (now duplicated entries are omitted). Note that now SIMBAD includes also data from some of our catalogues (radio and XLSSC).
- `ned` (**updated**) contains NED sources within 20″ with similar procedure and problems as for SIMBAD.
- `usno` (**new**) contains data from the USNO A2 catalog as kept at ST-ECF. Data have been extracted within 20″ and are viewed via a correlation of 6″.

Note that the above method of joining correlations between couples of tables (of which the first member is always the XMDS X-ray table) is a brute force method which initially generates lots of spurious combinations. Namely we start from 1322 X-ray *detections* (with 374 entries "duplicated" with an entry in another field), and at first go generate a "glorified correlation table" with 198294 records !

3. The procedure

It is obvious from the above that cleaning of spurious records is necessary. The details of our procedure are given in `http://sax.iasf-milano.inaf.it/~lucio/LSS/NewIdent/procedure.html` or in internal notes.

Some of the steps listed there, and summarized below, have been in practice applied more than once at different stages (sometimes altogether repeated), not necessarily in the order in which they are listed.

3.1. Pre-flagging

As for the XMDS/VVDS 4σ catalogue, I associate with each entry in the glorified correlation table (which is a list of associations between an X-ray source and a particular set of possible counterparts in other bands) a number of flags divided among

- identification flags : blank field, field without catalogued sources, unique counterpart, brightest counterpart, closest counterpart, ambiguous
- classification flags : star, galaxy or faint source, saturated source (all defined only for VVDS counterparts), possible cluster candidate
- external flags : only radio counterpart, radio counterpart is pointlike or extended, there is an externally catalogued counterpart (i.e. SIMBAD, NED or USNO)

Most of these flags can be assigned almost automatically (issuing some sequences of `mysql` commands) at any time irrespective of cleanup, and in fact I have repeated pre-flagging at least 3 times.

3.2. Cleanup

Cleanup of spurious entries can be largely semi-automatized issuing manual sequences or scripts of `mysql` commands. This includes removing cases when the identifier between the entries for different counterparts do not match (for instance all entries in VVDS-related tables, like `virphot`, `vimos`, `loiano`, `bad` shall be associated only if they have the same id ; the same holds for `sacphot` entries with VVDS-style id's and for radio or XLSSC sources listed in SIMBAD or NED).

In addition one can perform a cleanup for couples of optical counterparts (e.g. VVDS with D1 or W1, D1 with W1) or optical and IR (SWIRE) using a more restrictive criterion on distance, or even a criterion on distance and magnitude (but one has to pay attention to the `bad` sources).

This procedure reduces the number of entries by a factor 20 (to 9508).

The above procedure is not perfect, in fact it leaves around some cases with an exaggerate multiplicity (like X-ray source 755 with a multiplicity of 912 !), and a number with large enough multiplicity (10-20). These cases have been examined semi-manually and resolved (in part jointly with the pre-ranking described below), with a cut of a factor 2 (4107 entries).

3.3. Technical pre-ranking

In the XMDS/VVDS 4σ catalogue there was a parameter called rank, now called more properly *autorank* because it is assigned automatically and objectively whenever possible.

It can assume values 0-4 which are an indicator of quality for sources which are retained (see 3.6), but also some *technical rank* values which are assigned to entries which are not normally taken into consideration, but which are kept in the file for possible future use. Technical ranks are defined below and were assigned as described.

- *autorank 8* is used in case of duplicated detections between 2 (sometimes 3 or 4) overlapping fields. In this case the "best" X-ray source is kept, and the entries relevant to the other X-ray sources are hidden assigning rank 8.
  The "best" source is selected assigning a vote based on 5 criteria (s/n ratio, countrate, flux, number of counts, detection probability) in the best X-ray band, and using s/n ratio as a tie break in case of ex aequo votes.
- *autorank 6* is used to flag "pointers" keeping tracks of multiple duplications. In the worst case when an X-ray source is detected in 4 overlapping fields (this occurs only once), say with X-ray identifiers x1, x2, x3 and x4, if x1 is the "best" source, and x2 the second best, all entries for x2, x3 and x4 are given rank 8, the entries with `xmdsepic=x1, xmdsdup=x2` are kept for further processing, and those with x1,x3 or x1,x4 are assigned rank 6.
- *autorank 5* was intended for rank 8 duplicated with indication of variability, but it has been found that variability analysis is not worth doing, and therefore this rank is not used.
- *autorank 7* is used for pointers to multiple associations between one XMDS X-ray detection and an X-ray detection by the May05 Saclay pipeline. In 1170 cases the association is 1:1, but there are 146 cases 1:2 and 6 cases 1:3. The "best" association is kept for further processing and the discarded ones are assigned autorank 7 (where best is defined according to distance). See also section 3.10.

After this pre-ranking the number of entries with non-technical ranks remaining is 3393.

Note that, concerning duplications, of 4107 entries for 1322 detections, 1150 entries made reference to a duplicated X-ray source, corresponding to 374 combinations of two detections in different fields (for 334 sources). At the end the number of distinct X-ray sources with non-technical ranks is 1147.

In the VVDS 4σ area/sample the above (automatic) procedure for autorank 8 duplicates finds the same results as the manual procedure used in Paper I (which chose one source in a couple and rejected the other on the basis of various criteria including proximity to chip gaps) with the exception of just 2 cases in which ranks are inverted.

3.4. More cleanup

Some further cumbersome, semi-manual cleaning was done removing spurious couples involving tables not listed above (e.g. radio and external catalogues), when the elements of a couple are too distant. However in some cases this resulted in the *splitting* of the entry in two separate entries, as the association between the X-ray source and the two counterparts of the couple remained plausible, although the two counterparts are clearly not associated.

A further cleanup was done (in practice after the step described in 3.6) to remove the case of multiple detections in the SWIRE and W1 datasets (due to overlapping of *their* fields). For SWIRE first of all I prefer any entry of the July 2005 release to earlier ones, and then I prefer the one with the best s/n in any band, with a tie-break on distance. For W1 I prefer the one with the best s/n in the i' band. I temporarily assign a negative autorank to the rejected entries (total of 372 entries), which should be later deleted.

Some obviously spurious cases to be eliminated have been found also during the following steps, and all of them have also be assigned a negative autorank (flag for future removal).

3.5. Computing probabilities

I have decided to add three more fields to the glorified correlation table, giving the probability of chance coincidence between the X-ray source and its counterparts, based on the X-ray to optical (or IR) distance, the optical or IR

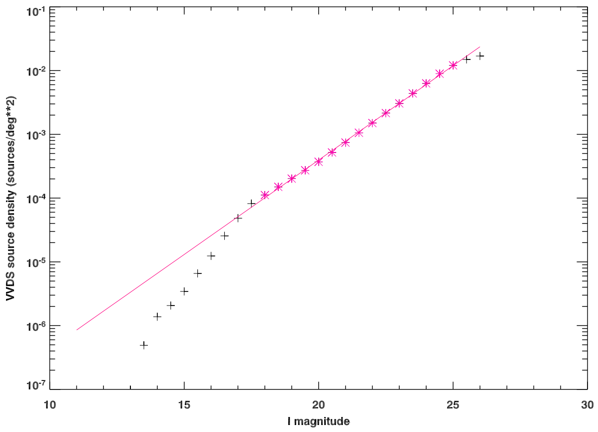

Fig. 1. Source count density for the VVDS. The range $18 < I < 25$ (in colour) has been used to produce the fits shown, whose parameters are given in the text.

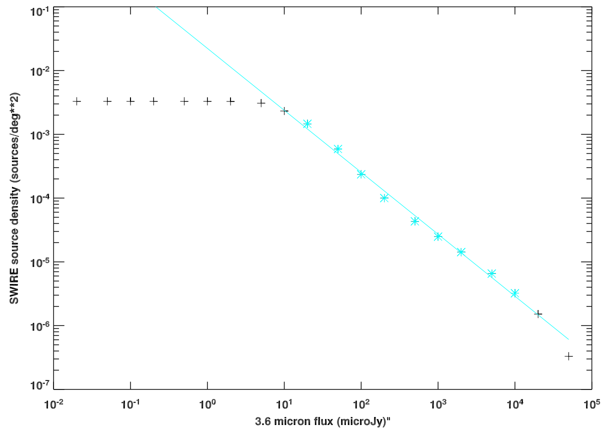

Fig. 3. $3.6\mu m$ source count density for SWIRE. The flux range indicated in colour has been used to produce the fit shown whose parameters are given in the text.

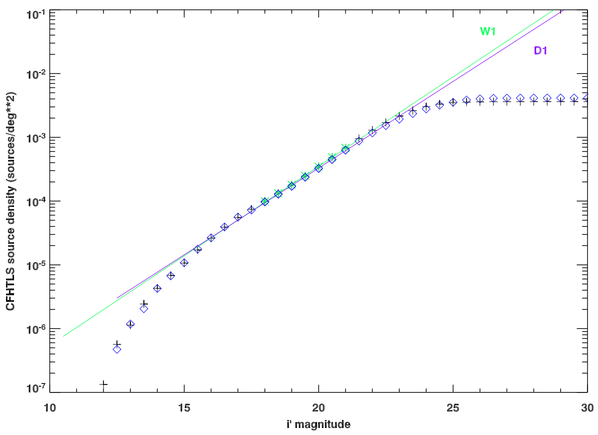

Fig. 2. Source count density for the CFHTLS D1 (crosses) and W1 (blue diamond) fields. The range $18 < i' < 21$ (in light colours) has been used to produce the two fits shown, whose parameters are given in the text.

intensity, and the density of sources brigther than a given intensity.

Probability *probvvds* is computed for sources with a `virphot`, `bad` or `sacphot` counterpart using the I magnitude (with preference to the `virphot` or `bad` one) and the formula used in Paper I

$$probvvds = 1 - exp(-\pi\ n(< I)\ r^2)$$

Probability *probd1* is computed for sources with a `d1` or `w1` counterpart using the i' magnitude (with preference to D1) and formula

$$probd1 = 1 - exp(-\pi\ n(< i')\ r^2)$$

Probability *probswire* is computed for sources with a $3.6\mu m$ SWIRE counterpart using the flux at such wavelength and formula

$$probd1 = 1 - exp(-\pi\ n(> F_{3.6})\ r^2)$$

A probability of 99 ("undefined") is assigned whenever it cannot be computed.

The density of VVDS sources is interpolated using the same formula used for Paper I (see Fig. 1) i.e. $n(< I) = 10^{-9.32636+0.29614I}$

The density of D1 sources has been derived from the *totality* of the sources in the files obtained in February 2005 via IPAC (ingested in a temporary table), with a coarse fit to the data in Fig. 2 as $n(< i') = 10^{-8.92093+0.271888i'}$

For W1 sources similarly the files obtained in July 2004 via IPAC (see also Fig. 2) gave $n(< i') = 10^{-9.06924+0.280627i'}$

Finally for SWIRE (see Fig. 3) I used all data available to me to derive $n(< F_{3.6}) = 10^{-1.65199-0.971587*log(F_{3.6})}$

The computation of density is based on source counts, but requires the knowledge of a sky area. Since this is not explicity known to me, I made a grid of cells 0.01×0.01 degrees and counted how many cells contain at least one object. I obtained for D1 an area of 0.9787 deg^2, for W1 6.9574 deg^2 and for SWIRE 7.2673 deg^2.

If anybody has better and more official information on densities for CFHTLS or SWIRE, I would appreciate to know.

3.6. Pre-ranking on probabilities

Once the probabilities have been computed, they can be used to assign *a priori* a preliminary rank (the *autorank*) to a particular association. For this I consider an individual probability p according to the following classification (more or less consistent with the *a posteriori* computation of *probvvds* in Paper I) :

- good if $p < 0.01$
- fair if $0.01 < p < 0.03$
- bad if $p > 0.03$
- undefined if $p = 99$

An *autorank=4* has been used to flag the blank fields (X-ray source is unidentified, has no counterpart)

An *autorank=0* has been assigned to the case where all three probabilities (or the largest number of probabilities which are not undefined) are all good.

An *autorank=1* has been assigned when all non-undefined probabilities are at least fair (excepting of course those already ranked 0).

Combinations are assigned *autorank=2* if not already ranked, and at least one of the probabilities is fair (but not all).

Any entry where no probabilities are fair has received *autorank=3* if at least one probability is not undefined.

This left 23 cases with no VVDS, CFHTLS or SWIRE counterpart, and 123 with all probabilities undefined (i.e. no valid optical magnitude or no SWIRE flux at 3.6μm). The majority of the latter (94) are taken from the `bad` table. Here I assigned *autorank=1* if the optical position is within the nominal X-ray error circle, *autorank=2* if it is within 4″ and *autorank=3* otherwise. A similar arrangement was used for the case of other counterparts, except that the limit for *autorank=2* is extended to 6″.

At this stage I also compared the new autoranks with the manual ranks (0-4) assigned in Paper I to the XMDS/VVDS 4σ sample (where the catalogue included only ranks 0-2 and 4) and found that for 381 entries, in 38% of the cases the new autorank is the same as the old rank, in 35% is better, and in 27% is worse. Essentially I found no serious discrepancies. The differences are due to the modified (and more objective) logics, so my feeling is that we can trust the probability-based autoranks and in the future use then for the entire LSS sample.

We note that the pre-ranking (and the prerequisite probability computation described in section 3.5) have to be repeated if any celestial position is updated. In fact this was the case after the astrometric correction described in 3.8.

3.7. Visual inspection

At the end of the previous stages, 1897 entries remain with autoranks 0-4 corresponding to 1147 distinct X-ray sources. I then proceeded to a visual inspection of all of them, similarly to what done for Paper I, according to the following procedure.

For each X-ray source I generate a `ds9` region file containing all possible counterparts (autorank 0-4) coded with particular symbols and colours (for details see `http://sax.iasf-milano.inaf.it/~lucio/LSS/NewIdent/colourcodes.html`). The regions are *tagged* so that in `ds9` I can list the regions, and click on the tag to identify each one of them. The tag contains a link to the entry in the glorified correlation table, so it is easy to go back to the database to fix things.

I displayed each region file over a reference image. For the sources in the VVDS fields, these are the standard FITS $20 \times 20''$ thumbnail images in the I band, available as data products. For the other sources, I used larger $20 \times 20'$ DSS-II IR images obtained from ESO (apparently only the IR band is available for our area in DSS-II).

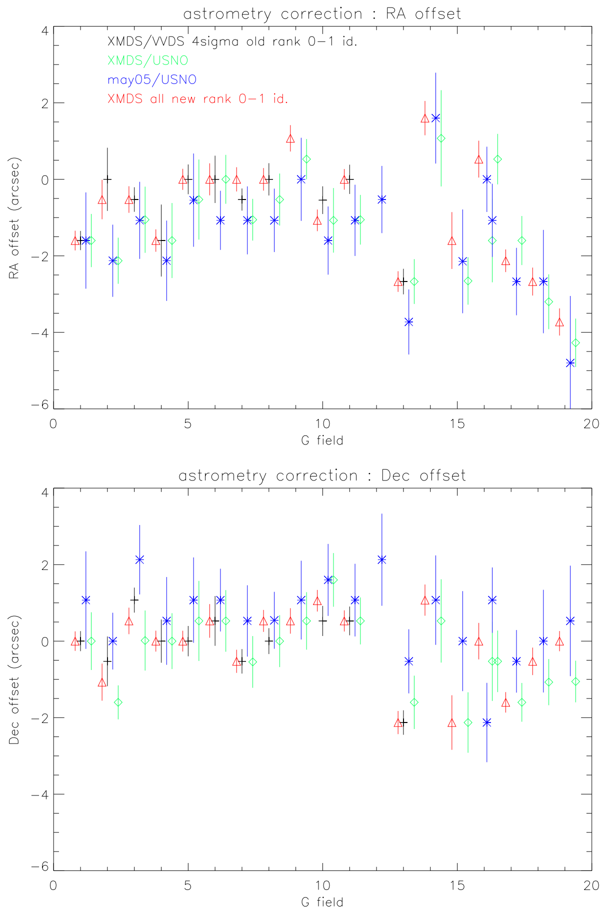

Fig. 4. The offset in RA (top panel) and Dec (bottom panel) as function of the G field. Black crosses are the corrections used in Paper I. Green diamonds are corrections computed using USNO A2 data and XMDS position and have never been used. Blue stars are the corrections based on USNO A2 data used to correct `may05` X-ray positions. Red triangles are the corrections computed in the present report, which have been applied where no previous Paper I corrections existed. Error bars are the nominal errors given by `eposcorr`. Measurement of different origin relevant to the same G field are slightly displaced horizontally for clarity.

Despite the poorer quality, these substrate images, associated with the region files, are enough to spot and solve a number of residual erroneous associations (the presence of `sacphot` sources gives rise to a number of them, probably because it was not accounted for completely in the previous steps). Again sometimes this has implied deletions, and sometimes splitting an entry in two distinct associations with separate counterparts.

The main purpose of the visual inspection was to assign a final *rank* to the valid identifications. For this I initially assigned a default value of *rank=-1* to all entries (i.e. "entry to be ignored"), and then assigned *rank=0* to identifications which are clearly unambiguous (inclusive of blank fields !). In case of multiple counterparts, I always forced a tie-break, with a single "best identification" (selected usually on the base of autorank and probabilities) being assigned *rank=1* and the remaining entries being assigned *rank=2*.

In some cases (with annotations saved in comments) it is possible to have a single counterpart ranked 1, or multiplets of a rank 0 with some rank 2 entries.

However single rank 2 entries never occur. To allow easy spotting of X-ray sources with more than one counterpart, I systematically set flag 09 "ambiguous" for all entries corresponding to an X-ray source with more than one (rank 0-2) counterparts.

Therefore in the database one can combine rank, (autorank) and flag to select counterparts by quality. E.g. an expression like `rank=0 and not find_in_set('09',flags)` locates the single rank 0 sources (the best), while `rank=1 and find_in_set('09',flags)` locates the best counterpart of the "classical ambiguous" cases.

3.8. Astrometry

Readers are reminded that in Paper I we used the best (VVDS) identifications as input to the SAS task `eposcorr` to generate an astrometric correction (rigid shift) to be applied to all X-ray source positions (in the `xmdsepic` table, for the G fields covered by the VVDS i.e. those considered in the top section of `http://cosmos.iasf-milano.inaf.it/~lssadmin/Website/LSS/List/.report.html`).

We remind also that X-ray positions in the `may05` table were corrected in a similar way using unverified positional coincidence with the USNO A2 catalogue. This allowed to correct also the remaining G fields and the B fields, but with large uncertainties on the RA and Dec shifts, because of the limited number of optical counterparts.

I proceeded to a computation of the astrometric correction for all G fields using as input optical list to `eposcorr` all the rank 0 and 1 candidates. Actually I experimented with more restrictive conditions, but found no improvements in the uncertainty on the shifts.

The optical position used was the CHFTLS D1 position if available, otherwise the CFHTLS W1 position, and otherwise the VVDS (`virphot` or `bad`) position. Sources with counterparts in `sacphot` or SWIRE only were not considered, as well as sources with no optical counterparts (and of course those with no counterpart at all).

The resulting corrections are plotted in Fig. 4 and compared to the previously available corrections. It can be noted that they confirm the previous values but allow to decrease the size of the error bars.

Since they are consistent with the previous VVDS-based correction for all the G fields which were processed at the time of Paper I, I have not updated the X-ray corrected coordinates (`ra_corr`,`dec_corr`) for the sources in such fields, but, as stated in the bottom section of the web page quoted above, applied the new correction only to sources in G09 and G14 to G19 (excluding G16a, which however contains only rank 8 sources, duplicated with G16b, which has been corrected).

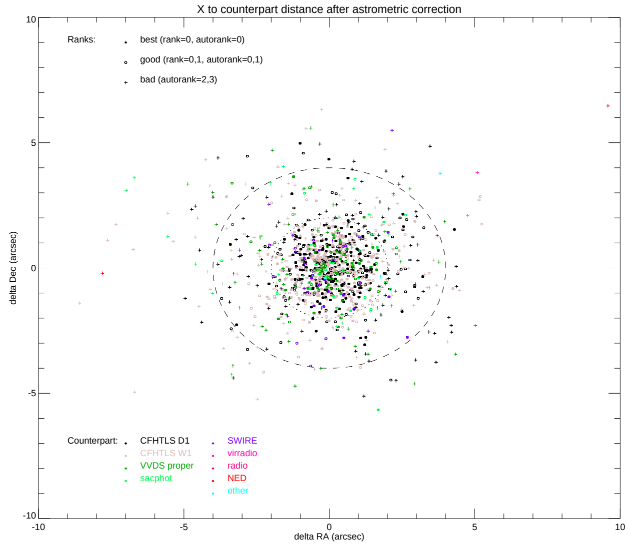

Fig. 5. Distances in RA and Dec between the X-ray corrected position and the best counterpart position. Different symbols indicate the identification quality. Only sources with rank=0 or 1 are plotted. A circle is plotted when the autorank is 0 or 1, and it is filled when both rank and autorank are 0, i.e. for the best candidates). A cross is plotted for lower autoranks (2 and 3) irrespective of rank. Different colours (as shown on figure) indicate the origin of the counterpart position for the distance calculation. Two fiducial radii of 2 and 4″ are also shown.

I have also produced a figure (Fig. 5) comparable with Fig. 9 of Paper I, which gives the distances in RA and Dec between the X-ray corrected position and the best counterpart position. By "best" I mean both that only entries with rank 0 or 1 are considered, but also that I selected as reference counterpart position the CFHTLS D1 coordinates if available, then in the following order W1, VVDS (i.e. `virphot` or `bad`), `sacphot`, SWIRE, `virradio`, `radio` and NED.

Despite the fact that the new catalogue comprises sources at lower significance than those in Paper I, the results in term of positional accuracy are quite similar. In particular 97% of the sources have both RA and Dec offsets lower than 4″ , and 84% have both within 2″ (and only a single source has *both* offsets above 4″).

In terms of true distance 91% of the total is within 4″, which makes 98% of the good identifications (the circles in Fig. 5) and 99% of the best (the filled circles in Fig. 5).

After the correction of the X-ray coordinates, all probabilities (see 3.5) and autoranks (see 3.6) were recomputed. The ranking changed only for a limited number of

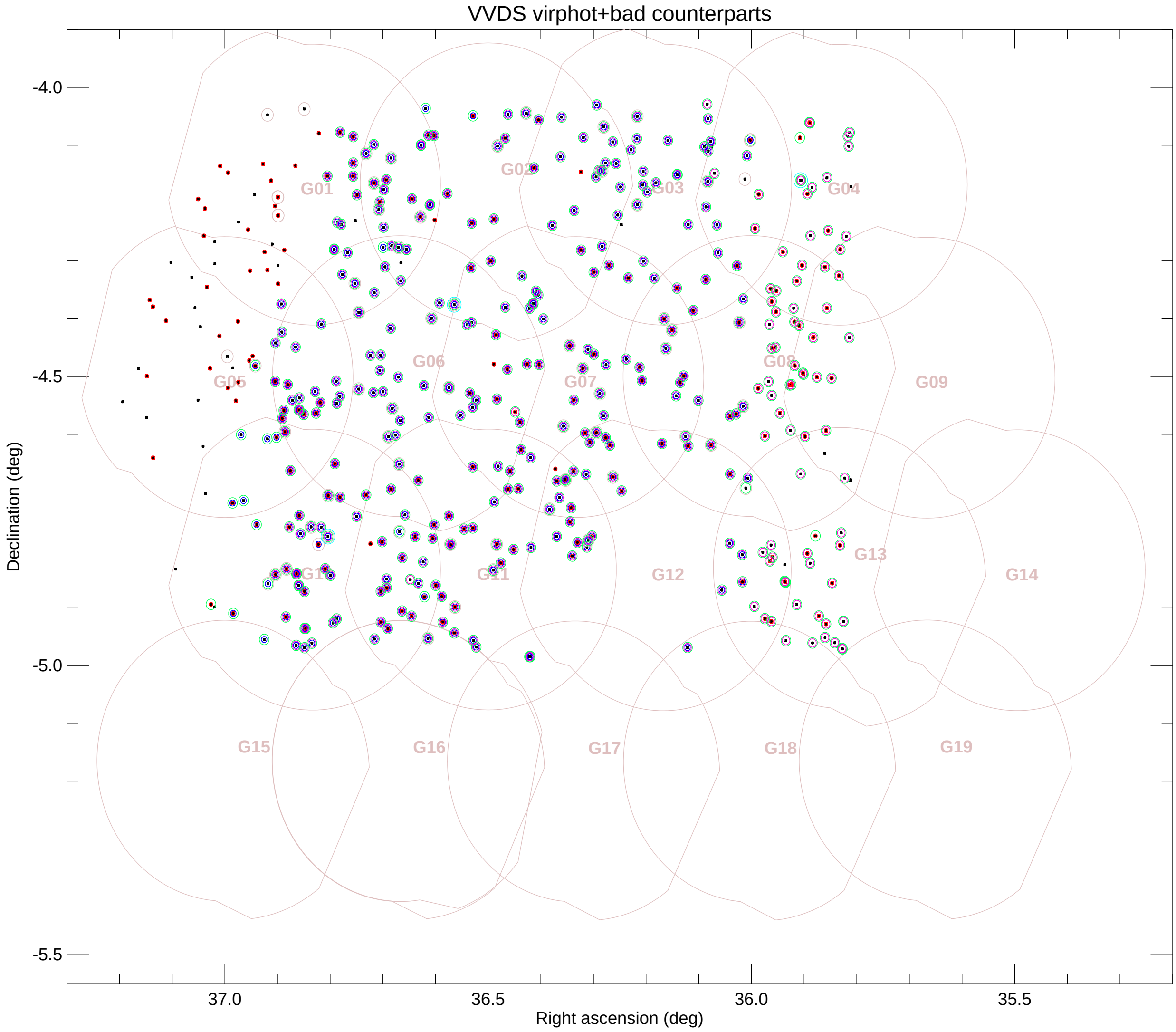

Fig. 6. Positions of the X-ray sources with a VVDS counterpart. For symbols see 3.9 in text. The VVDS covers almost entirely the top three rows of fields, with the main exception of the rightmost part of G04, G09, G13 and of G14. Note that the leftmost parts of G01 and G05 are covered only by the VVDS (and `sacphot` which here should be the same).

entries (193 improved, 70 worsened), for which the visual inspection (see 3.7) was also repeated.

3.9. General properties

At the end of the identification procedure, the catalogue contains 1400 valid entries (i.e. those with rank 0-2) corresponding to 1147 distinct X-ray sources.

Namely there are 911 rank 0 and 236 rank 1 identifications (each one corresponding by construction to a single X-ray source). In addition there are 253 entries with rank 2 corresponding to 220 distinct X-ray sources (43 of them have a rank 0 entry, i.e. are "sub-ambiguous" and 177 have a rank 1 entry, i.e. are "classical ambiguous"). 59 rank 1 sources are single entries for which the identification may have some reasons to doubt (see individual source comments).

33 of the rank 0 entries have `autorank=4`, i.e. are blank fields (X-ray sources with no counterpart). There is an entry currently flagged as rank 1 and autorank=4 which is not a blank field, but spoiled by a bright uncatalogued star (X-ray source #624). There are two more entries with flag 01 set (which should indicate blank fields), but autoranks not equal to 4 : one is source #526, whose field contains a bright source, which however is the counterpart of nearby #528 ; the other is #542 for which the only possible counterpart is very weak and far.

I summarize some more statistical information in Table 1, giving a breakdown by significance, identification reason, autorank or kind of counterpart(s).

One can notice the way the various optical surveys extend each other (in particular there is a gain of 50 identifications only using the `sacphot` table, which can be examined also in conjunction with the plots presented below.

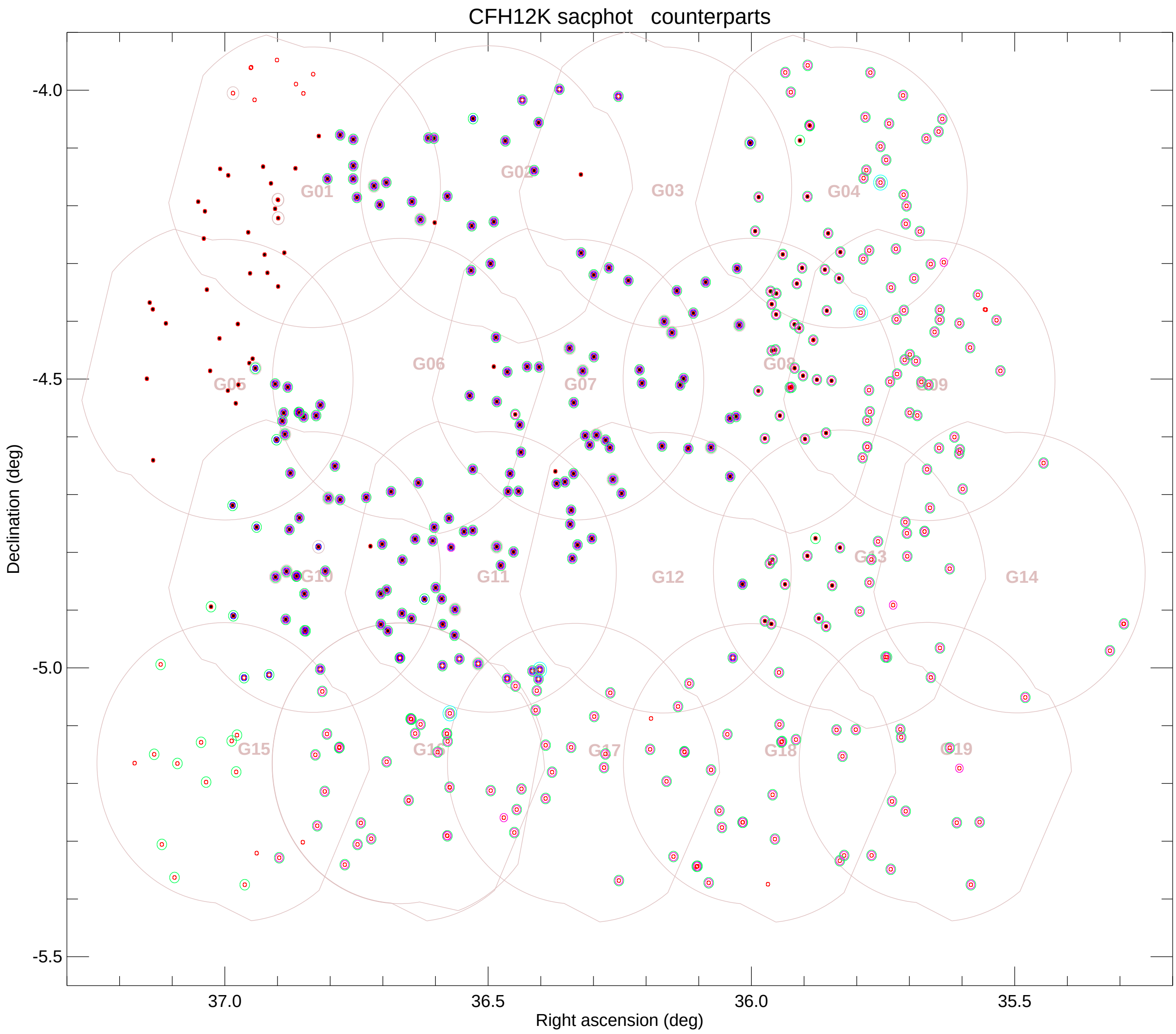

Fig. 7. Positions of the X-ray sources with a `sacphot` counterpart. For symbols see 3.9 in text. The reasons of the sparse coverage of the `sacphot` data, in particular the "holes" in G03 and G06 where VVDS data "coincident" with `sacphot` should exist, is unclear.

Of the 43 objects without an optical or SWIRE identification (the difference from 1109 in the penultimate row of Table 1 to the total of 1147), 36 are the already discussed "pretended" blank fields, while the remaining are mostly (5 out of 7) with flag 02 ("weak sources") set. In fact of those one has 1 case with the field containing a VIRMOS1.4GHz counterpart (#151), 2 with a NED counterpart (#221 and #474), and 2 with only a GALEX counterpart (#400, #423), plus 1 with a brighter NED object (#1060), and 1 with an USNO "star" which is also a 325 MHz radio source (#905).

I note also that, not obvious from the table, there are also 45 objects which have a SWIRE counterpart without an optical counterpart in our catalogues. The majority of them have flag 02 ("weak sources") set (but not when the association is with a relatively bright SWIRE source and absolutely unambiguous : these include two already known cases, the "pseudo globular cluster" point-like source behind a bright spiral (#233), and the uncatalogued source behind a BD star (#444)). Also the majority of them has *just* a SWIRE counterpart, but there are also the following cases : 3 SWIRE and radio counterparts, 2 SWIRE and GALEX counterparts, 1 SWIRE object which is a SIMBAD BD star (#1276), 2 SWIRE objects also in NED (#1307 and #462 which is an MCG galaxy), and 9 SWIRE objects also in USNO (#645, #688, #877, #879, #885, #899, #910, #1306, and #869 which should be close to a ROSAT source).

I note that there are 246 objects with a GALEX counterpart, concentrated in the three field rows G01/02/03, G05/06/07 and G10/11 (where the 43has a GALEX counterpart). Since I do not have information about the full coverage of the GALEX observations, I'm not in a po-

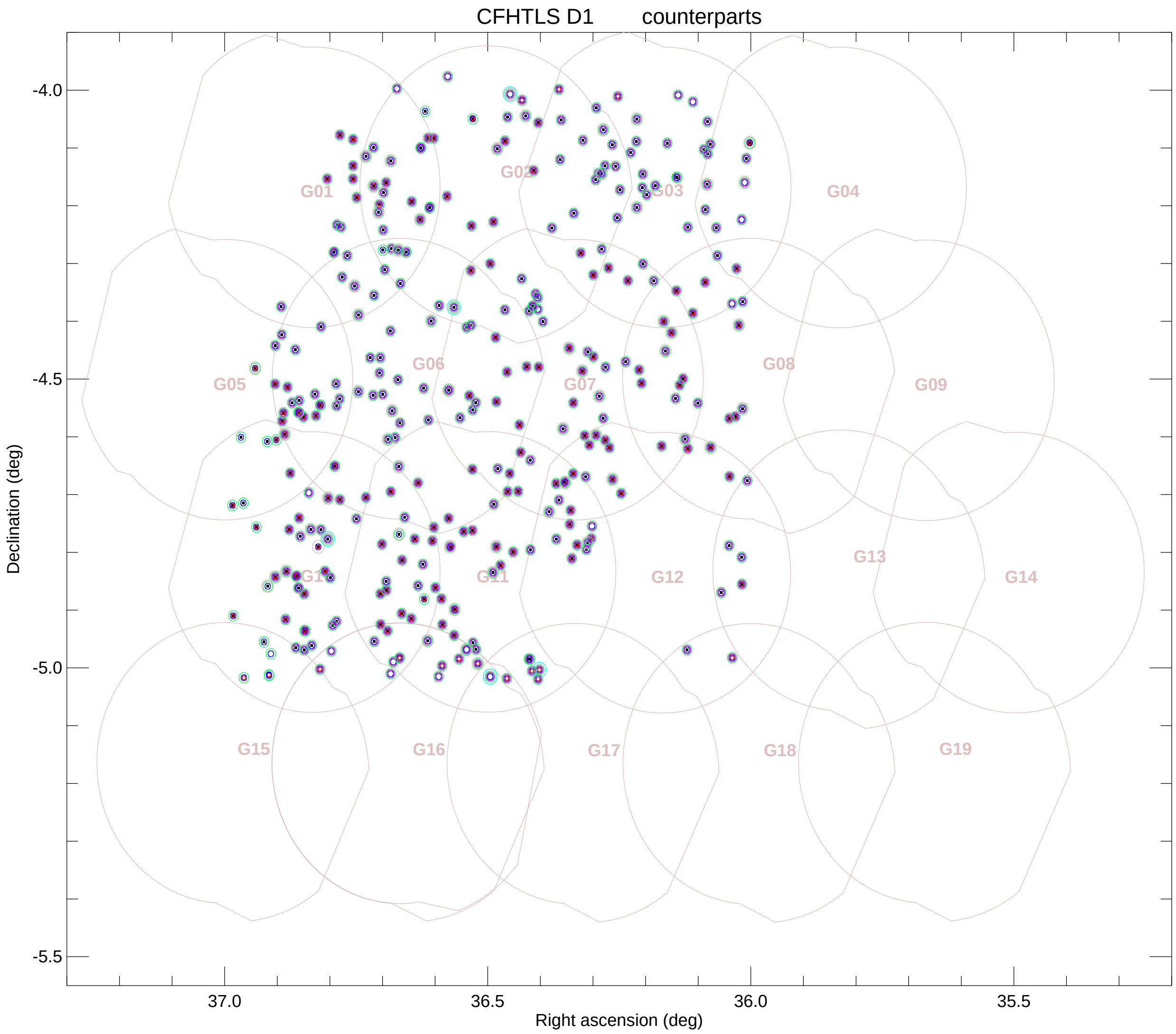

Fig. 8. Positions of the X-ray sources with a CFHTLS D1 counterpart. For symbols see 3.9 in text. The CFHTLS D1 covers the central part of the top three rows of fields. In particular there is a corner cut out in G01. I wonder if that is real, or due to the fact we got the data via IPAC, and are therefore conditioned by the absence of SWIRE data there. Do data in such area exist at Saclay ?

sition to comment whether this is of interest to solicit further formal contacts.

Also in order to evaluate whether in a given region we do not find counterparts in a given table because either they do not exist or the region has not been observed, I also include 6 figures (from Fig. 6 to Fig. 11) which give the sky areas covered by the various surveys used by us overplotted on the footprint of the FoV of our fields. Each figure lists `only` the (autorank 0-1) sources with a counterpart in a `given` table (i.e. a non null entry in the glorified correlation table). The symbols used indicate in which other tables there is *also* a counterpart.

Such symbols are concentric circles of different colours, corresponding from the inner to the outer to :

– a small black dot indicates a VVDS counterpart (`virphot` or `bad`, thus any circle with the centre filled is also a VVDS source
– a small red circle indicates a `sacphot` (CFH12K) source
– a slightly larger blue circle indicates a CFHTLS D1 source
– an even larger magenta circle a CFHTLS W1 source
– a larger green circle a SWIRE source
– a larger pink circle a `virradio` source
– the largest cyan circle a `radio` source

It has to be clarified when we do not have data in a particular catalogue because the position was not observed (or if observed nothing was detected) and when instead there is no data in the database table because I was not

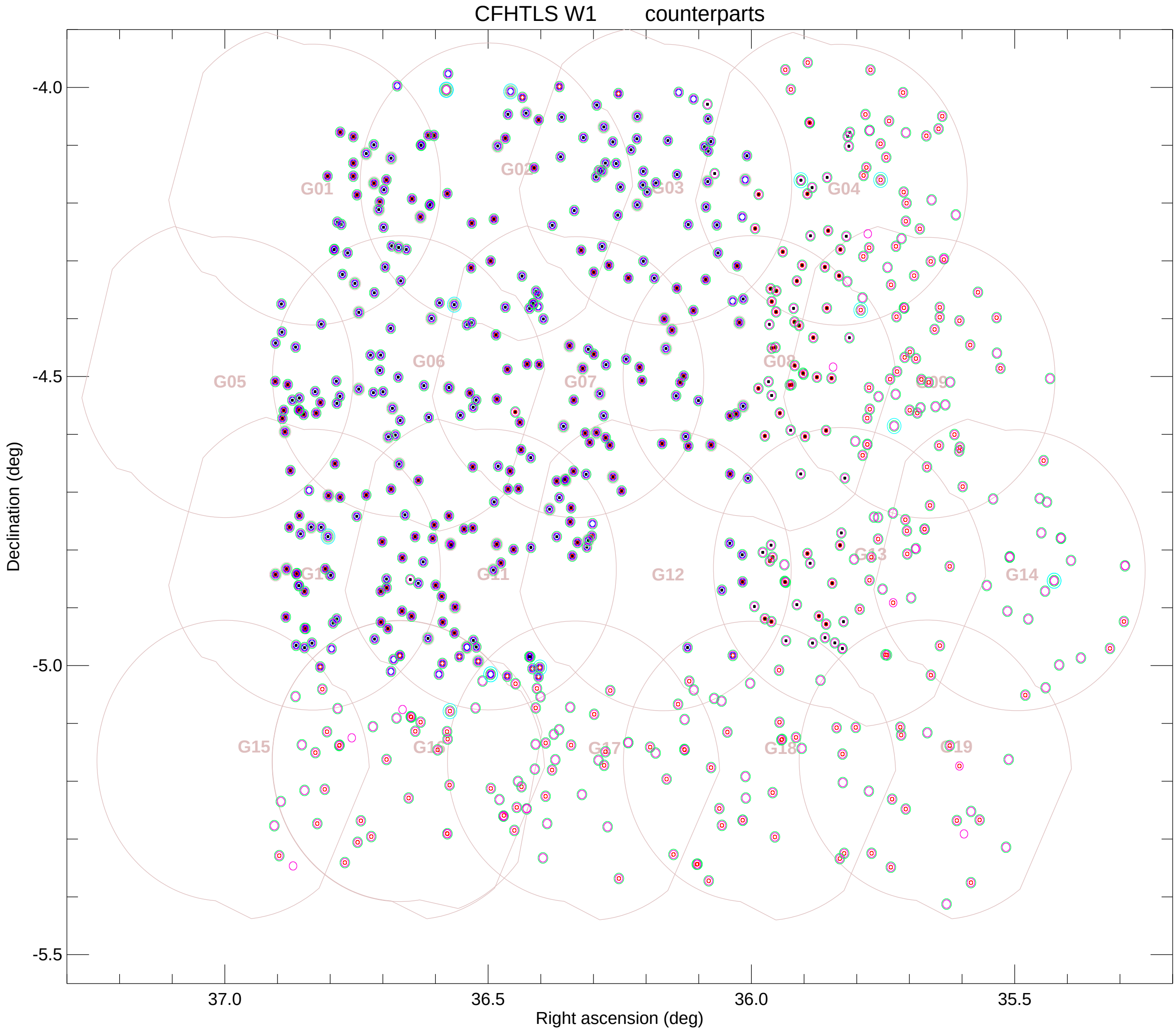

Fig. 9. Positions of the X-ray sources with a CFHTLS W1 counterpart. For symbols see 3.9 in text. The CFHTLS W1 covers all fields also outside the D1 area, but excludes the leftmost parts of G01 (also with the useal cut-out corner), G05, G10 and G15. Here too I wonder whether that's real or is due to the way I got the data.

supplied a complete dataset. Please make reference to the notes in captions to the various figures and let me know.

I also inspected the relative distance between the positions of counterparts in different input catalogues tables associated between them (and of course with the same X-ray source). This can be used for future processing of the entire LSS.

Not surprisingly the `virphot` to `sacphot` distance is always $< 0.02''$ because the data originate from the same observations.

The optical-to-optical distance for D1 and W1 sources peaks at $0.1''$ and is usually contained within $0.4''$.

The optical-to-optical distance between VVDS and CFHTLS sources peaks at $0.3''$ and is usually contained within $0.8''$.

The optical to IR distance peaks at $0.3''$ for CFHTLS to SWIRE, and at $0.5''$ for VVDS to SWIRE, usually contained within $1''$.

Given the smaller number of radio sources, the distribution of the optical to radio distances is more noisy. The distances peak around 0.5-0.8$''$ but in some cases can extend to more than $4''$(in two of them this simply means that the X-ray and optical position is just within the extent of a large extended radio source).

3.10. XMDS vs may05

I also did a quick comparison between our XMDS sources and the sources in the `may05` table derived from the Saclay pipeline.

Of our 1147 XMDS sources, all but 125 have a `may05` counterpart. Most of the latter are in the outermost area

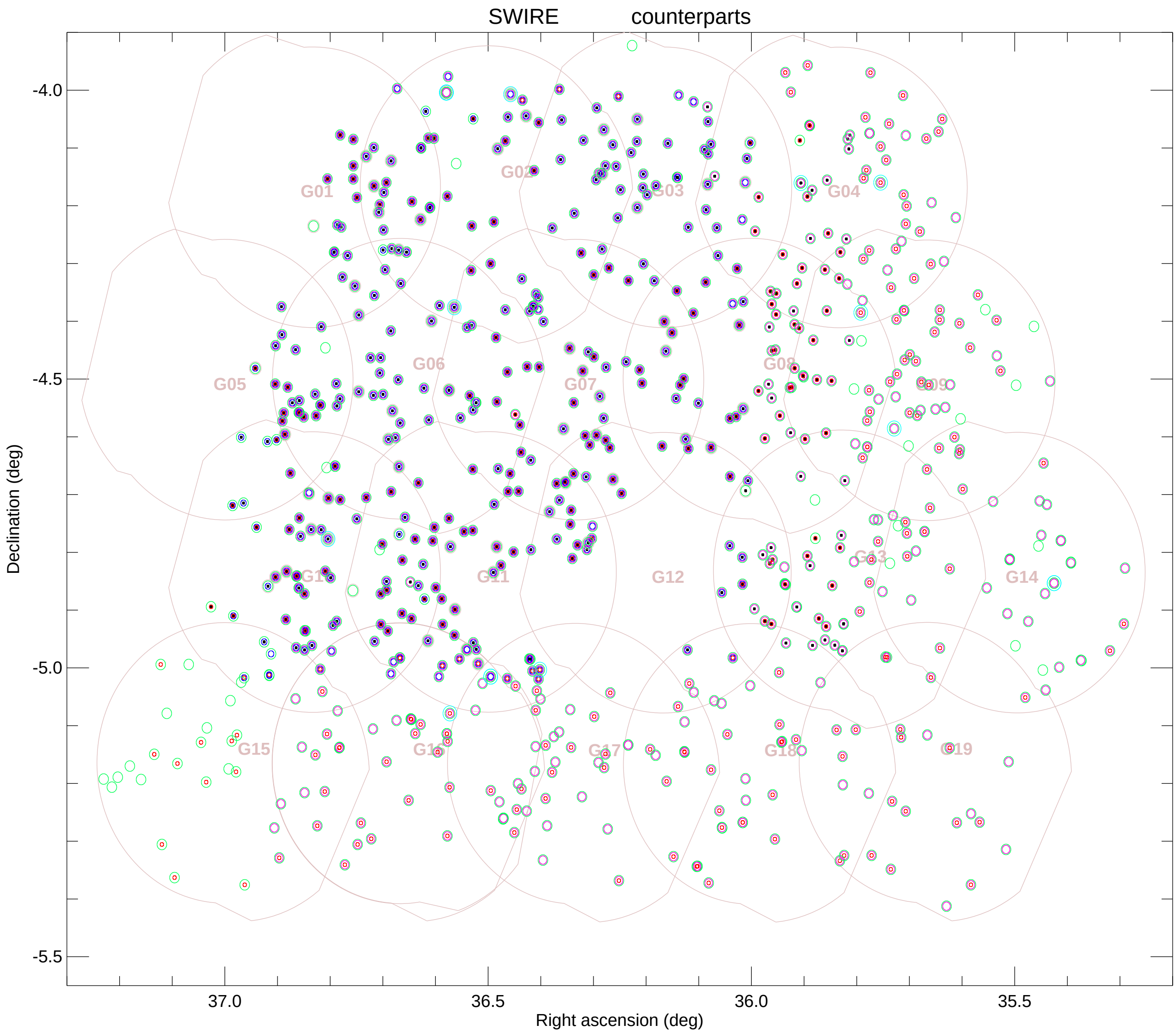

Fig. 10. Positions of the X-ray sources with a SWIRE counterpart. For symbols see 3.9 in text. SWIRE covers almost all the fields (including G15 and G10 where not covered by the optical surveys), but excludes most of G05 and G01.

of the FoV's (10 to 16.5′ off-axis) which was not covered by the Saclay pipeline. Only 32 of such cases are below 10′ off-axis, of which 14 below 8′. The latter are almost all very weak sources (s/n between 2 and 2.9σ, only 2 at 3.3σ) and one at 4.1σ). This distribution (78% below 3σ) is rather different with respect to the total (27% below 3σ).

For common sources the distance between the XMDS and `may05` X-ray positions (uncorrected, but derived from the same raw X-ray data) peaks at 1.5″ with a tail between 6 and 10″. The distribution of distances in corrected coordinates (with two *different* astrometric corrections !) "retracts" to 1″, but a lesser tail extends to 12″.

Of the 1022 common sources one can note that 953 are flagged non-spurious ($ML > 20$), 29 have $15 < ML < 20$ i.e. should be considered OK with the new criteria in Pacaud et al. (2005), and 40 remain definitely spurious in `may05`. Of these the majority is below 3σ in the XMDS (6 between 3 and 4σ, 3 around 4σ and one at 6σ).

15 of the 1022 objects are extended sources (one only in band CD, sic!).

1012 `may05` counterparts are flagged as "non suspect", one as `suspect=1` (i.e. the inter-band distance is above 10″), and 9 as `suspect=2` i.e. there are two possible candidates (one of which is by definition assigned autorank 7) resulting from the merging of a band B detection with two separate band CD detections or viceversa.

385 objects are detected by Saclay in a single band (342 in B, 43 in CD). The remaining 637 objects are detected in both bands (usually B is the best, but for 62 CD is the best). For them the inter-band distance peaks at 1.5″ (2.5″ when the best band is CD) with some tail. XMDS does not have a comparable parameter to the `may05` inter-band distance, as we characterize a source in all bands simulta-

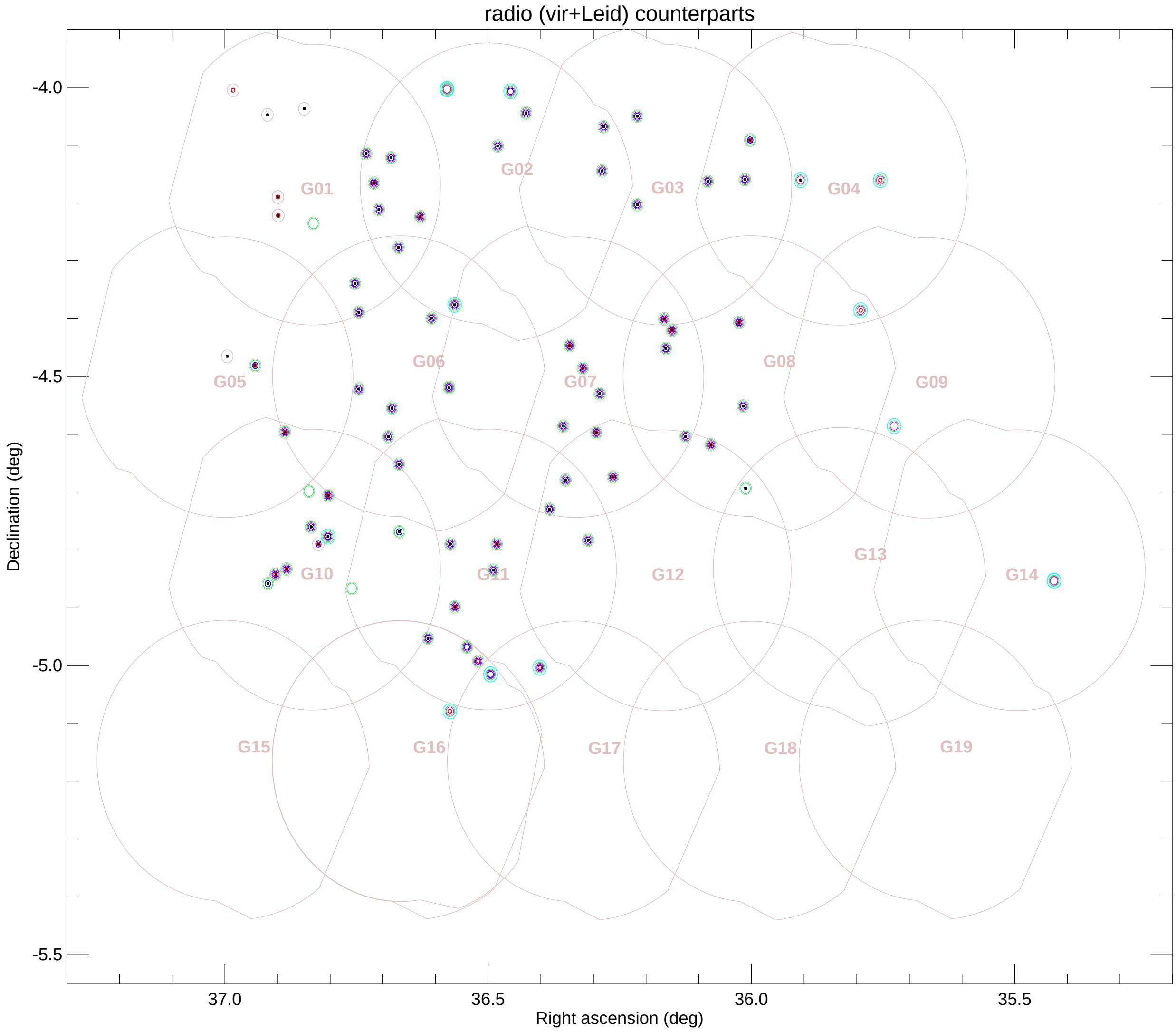

Fig. 11. Positions of the X-ray sources with a radio counterpart at 1.4GHz or at 74 and 325 Mhz. For symbols see 3.9 in text.

neously. We can however note that for our "duplicated" sources (detected in more fields) the distance between two detections of the same object peaks at 1″ in uncorrected coordinates (with a distribution somehow retracted in corrected coordinates).

Since I used our own XMDS position for all the identification work, I enquired a little also about the difference when using the `may05` position, computing the X-ray to optical distance for both X-ray positions. I have taken as counterpart position, as usual, the D1, W1, VVDS, `sacphot`, SWIRE, radio or NED one in this order of preference.

In the 341 cases the `may05` position is *closer* to the counterpart than our XMDS position (better coincidence), and the difference between the two distances is always less than 4″ , in 88% of the cases less than 2″.

In 654 cases the `may05` position is *farther* from the counterpart, but in 76% of the cases the two distances differ anyhow less than 2″ and in 93% of the cases less than 4″.

This leaves 42 cases in which there are larger differences. They are however substantially less than the 128 objects for which the XMDS-`may05` X-to-X distance is larger than 4″, which means that possibly some objects have X-ray positions on either side of the counterpart, but still compatible with it! Of the 42 objects, 17 have been detected by Saclay in 2 bands, and their inter-band distance is always higher than 3″, peaking at 7″ (while the inter-band distance typically peaks at 2.5″, see above).

Of the 654 sources with a worse May05-to-optical coincidence, 420 have been detected in 2 bands by Saclay, and in 358 of them the difference between the X-ray-to-optical distances is less than the interband distance, i.e. the error in identification is smaller than the energy-dependent position uncertainty of `may05`. In the other 62 cases where the difference between the X-ray-to-optical distances is larger

Objects	Total	$> 4\sigma$	$> 3\sigma$	$> 2\sigma$	
detections[a]	1322				
independent sources	1147	541	833	1144	
Condition	**Total**	**unique**	**B & C[b]**	**blank fields**	**other**
rank 0 singles	868	222	450	35[c]	161
rank 1 singles	59	19	15	1[d]	24
rank 0 (sub)ambiguous	43	0	6	0	37
rank 1 ambiguous	177	0	47	0	130
Condition	**Total**	**autorank=0**	**autorank=1**	**autorank=2**	**autorank=3**
rank 0 singles	868	538	159	96	42
rank 1 singles	59	3	4	13	38
rank 0 (sub)ambiguous	43	33	9	1	0
rank 1 ambiguous	177	54	41	27	55
Rank 0 and 1 identifications					
with VVDS counterpart	592		+		
with CFHTLS D1 counterpart	421	+			
with CFHTLS W1 counterpart	843	=			
with either D1 or W1		884	=		
with either VVDS or CFHTLS			1009		
with VVDS, CFHTLS or `sacphot`				1059	+
with SWIRE counterpart	957				=
with optical or SWIRE counterpart					1104
other identified	7				

Table 1. Basic statistics ot the present XMDS catalogue

a at p $< 2 \times 10^{-4}$
b brightest and closest
c blank fields flagged as autorank=4 or flag 01 set, see text
d affected by bright uncatalogued star (#624, see text)

than the interband distance, for 57 the interband distance (`maxdist`) is $< 4''$ i.e. they are relatively well-positioned `may05` sources. The remaining 5 are probably just normal fluctuations.

Also among the objects with a large interband distance ($> 4''$), with a larger X-ray to optical distance in May05 than in XMDS, which are 115, in the majority of cases the two optical distances do not differ much (103 within $4''$, 75 within $2''$), i.e. the "preferred" `may05` position (in the "best band") is indeed consistent with the XMDS position!

4. Conclusions

The tentative identifications described above are of quality comparable to those published in the XMDS/VVDS 4σ catalogue, and include a quite larger sample, and are based on a more objective procedure.

We plan to use them as starting point to extract subsamples for our further works, in particular for photometric redshifts.

A collateral development planned on my part is the replacement of the rates and fluxes of the "duplicated" sources (where presently only the X-ray entries *not* flagged as autorank=8 are used) with a "stacking" of the local results in the overlapping images).

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