lamp_quick_start

October 31, 2024

1 Quick Start

In this vignette we will demonstrate how to use `LAMP` python package. The input data and reference files are located in https://github.com/wanchanglin/lamp/tree/master/examples/data.

1.1 Setup

To use `LAMP`, the first step is to import some python libraries including `LAMP`.

[1]:
```
import sqlite3
import pandas as pd
from lamp import anno, stats, utils
```

1.2 Data Loading

`LAMP` supports text files separated by comma (`,`) or tab (`\t`). The Microsoft's XLSX is also supported, provided that data set is in the first sheet.

Here we use a small example data set with `tsv` format. Load it into python and check its format:

[2]:
```
d_data = "./data/df_pos_2.tsv"
data = pd.read_table(d_data, header=0, sep="\t")
data
```

[2]:

	name	namecustom	mz	mzmin	mzmax	rt	\
0	M151T34	M150.8867T34	150.886715	150.886592	150.886863	34.152700	
1	M151T40	M151.0402T40	151.040235	151.040092	151.040350	39.838172	
2	M152T40	M152.0436T40	152.043607	152.043451	152.043737	40.303700	
3	M153T34	M152.8838T34	152.883824	152.883678	152.883959	34.174647	
4	M153T36	M153.0195T36	153.019474	153.019331	153.019633	35.785847	
..	…	…	…	…	…	…	
395	M283T339	M283.2646T339	283.264583	283.264341	283.264809	338.763489	
396	M284T60	M284.1953T60	284.195294	284.194939	284.195536	59.593561	
397	M284T108	M284.2235T108	284.223499	284.223156	284.223692	108.406389	
398	M284T339	M284.268T339	284.267962	284.267634	284.268204	338.725056	
399	M285T34	M284.775T34	284.775031	284.774635	284.775287	34.079641	

	rtmin	rtmax	npeaks	.	…	X210	X209	\
0	33.637595	35.465548	97	97	…	4.224942e+06	3.946599e+06	

```
1     37.556072   40.532315      95  95  …  1.419062e+06  1.251606e+06
2     38.092678   40.909428      81  81  …  1.203919e+05  9.970442e+04
3     33.637595   35.465548      98  98  …  5.592065e+06  5.761380e+06
4     34.130244   36.287354      98  98  …  7.284938e+06  1.083289e+07
..          …         …     …   ..  …           …            …
395  338.398380  339.165948      94  94  …  3.509767e+05  4.117633e+05
396   58.844217   60.107058      59  59  …           NaN           NaN
397  107.880510  108.971046      72  72  …  7.477652e+04  7.482219e+04
398  338.268300  339.370098      84  84  …  3.697604e+04  5.398264e+04
399   33.667172   35.198181      97  97  …  3.439330e+06  3.359842e+06

              X208          X207          X206          X205          X204  \
0    3.668948e+06  3.754321e+06  3.853724e+06  3.787350e+06  3.584464e+06
1    1.214826e+06  8.143028e+05  5.331963e+05  1.930928e+06  1.479001e+06
2    9.384000e+04  4.186335e+04           NaN  2.115447e+05  1.285713e+05
3    5.845419e+06  5.576013e+06  5.552878e+06  6.132789e+06  5.891378e+06
4    1.140072e+07  8.220552e+06  9.255154e+06  7.648211e+06  7.723814e+06
..            …             …             …             …             …
395  3.948000e+05  4.338804e+05  5.335221e+05  6.224684e+05  7.009340e+05
396           NaN           NaN           NaN  2.558004e+04  4.020517e+04
397  3.399667e+04  7.233564e+04  1.043879e+05  2.506785e+04  2.753769e+04
398  5.340109e+04  6.557698e+04  7.656575e+04  1.040606e+05  1.063727e+05
399  3.375577e+06  3.789056e+06  3.478506e+06  3.391588e+06  5.067802e+06

              X203          X202          X201
0    3.499711e+06  3.623205e+06  4.145770e+06
1    1.076354e+06  9.293218e+05  5.298062e+05
2    9.389346e+04  7.163655e+04  4.916483e+04
3    5.418082e+06  5.036840e+06  5.733794e+06
4    5.571163e+06  5.362560e+06  9.259675e+06
..            …             …             …
395  3.005173e+05  3.133173e+05  8.204783e+05
396           NaN  3.162670e+04  5.446684e+04
397           NaN           NaN           NaN
398           NaN  3.059370e+04  1.358056e+05
399  3.497546e+06  3.316025e+06  3.906000e+06

[400 rows x 110 columns]
```

This data set includes peak list and intensity data matrix. `LAMP` requires peak list's name, m/z value and retention time. User needs to indicate the locations of feature name, m/z value, retention time and starting points of data matrix from data. Here they are 1, 3, 6 and 11, respectively.

Load input data with `xlsx` format for `LAMP`:

[3]:
```
ion_mode = "pos"
cols = [1, 3, 6, 11]
# d_data = "./data/df_pos_2.tsv"
```

```
# df = anno.read_peak(d_data, cols, sep='\t')
d_data = "./data/df_pos_2.xlsx"                    # use xlsx file
df = anno.read_peak(d_data, cols)
df
```

[3]:

	name	mz	rt	QC9	QC5	\
0	M151T34	150.886715	34.152700	3.664879e+06	3.735147e+06	
1	M151T40	151.040235	39.838172	7.406381e+05	7.524075e+05	
2	M152T40	152.043607	40.303700	6.105241e+04	5.335546e+04	
3	M153T34	152.883824	34.174647	5.141479e+06	5.496344e+06	
4	M153T36	153.019474	35.785847	5.336758e+06	5.558265e+06	
..	…	…	…	…	…	
395	M283T339	283.264583	338.763489	7.330602e+05	8.243956e+05	
396	M284T60	284.195294	59.593561	2.310932e+04	NaN	
397	M284T108	284.223499	108.406389	3.748444e+04	2.993283e+04	
398	M284T339	284.267962	338.725056	1.161886e+05	1.476514e+05	
399	M285T34	284.775031	34.079641	4.063268e+06	3.807148e+06	

	QC4	QC3	QC26	QC25	QC24	\
0	5.190263e+06	2.742966e+06	3.824723e+06	3.722932e+06	3.804188e+06	
1	NaN	6.429245e+05	1.167016e+06	1.175981e+06	1.122533e+06	
2	NaN	NaN	6.875157e+04	7.807399e+04	8.943068e+04	
3	8.335846e+06	3.860588e+06	5.316874e+06	5.988232e+06	5.844917e+06	
4	1.118557e+07	6.876715e+06	9.967314e+06	9.073822e+06	9.328573e+06	
..	…	…	…	…	…	
395	NaN	1.159506e+06	4.294760e+05	4.641813e+05	4.570657e+05	
396	NaN	NaN	1.759336e+04	2.645392e+04	2.727266e+04	
397	NaN	NaN	3.175596e+04	3.879604e+04	4.299529e+04	
398	NaN	NaN	NaN	6.753490e+04	5.436219e+04	
399	4.645099e+06	2.232221e+06	4.576754e+06	4.533339e+06	4.559356e+06	

	…	X210	X209	X208	X207	\
0	…	4.224942e+06	3.946599e+06	3.668948e+06	3.754321e+06	
1	…	1.419062e+06	1.251606e+06	1.214826e+06	8.143028e+05	
2	…	1.203919e+05	9.970442e+04	9.384000e+04	4.186335e+04	
3	…	5.592065e+06	5.761380e+06	5.845419e+06	5.576013e+06	
4	…	7.284938e+06	1.083289e+07	1.140072e+07	8.220552e+06	
..	…	…	…	…	…	
395	…	3.509767e+05	4.117633e+05	3.948000e+05	4.338804e+05	
396	…	NaN	NaN	NaN	NaN	
397	…	7.477652e+04	7.482219e+04	3.399667e+04	7.233564e+04	
398	…	3.697604e+04	5.398264e+04	5.340109e+04	6.557698e+04	
399	…	3.439330e+06	3.359842e+06	3.375577e+06	3.789056e+06	

	X206	X205	X204	X203	X202	\
0	3.853724e+06	3.787350e+06	3.584464e+06	3.499711e+06	3.623205e+06	
1	5.331963e+05	1.930928e+06	1.479001e+06	1.076354e+06	9.293218e+05	

```
2             NaN  2.115447e+05  1.285713e+05  9.389346e+04  7.163655e+04
3    5.552878e+06  6.132789e+06  5.891378e+06  5.418082e+06  5.036840e+06
4    9.255154e+06  7.648211e+06  7.723814e+06  5.571163e+06  5.362560e+06
..            …             …             …             …             …
395  5.335221e+05  6.224684e+05  7.009340e+05  3.005173e+05  3.133173e+05
396           NaN  2.558004e+04  4.020517e+04           NaN  3.162670e+04
397  1.043879e+05  2.506785e+04  2.753769e+04           NaN           NaN
398  7.656575e+04  1.040606e+05  1.063727e+05           NaN  3.059370e+04
399  3.478506e+06  3.391588e+06  5.067802e+06  3.497546e+06  3.316025e+06

             X201
0    4.145770e+06
1    5.298062e+05
2    4.916483e+04
3    5.733794e+06
4    9.259675e+06
..            …
395  8.204783e+05
396  5.446684e+04
397           NaN
398  1.358056e+05
399  3.906000e+06

[400 rows x 103 columns]
```

Data frame `df` now includes only `name`, `mz`, `rt` and intensity data matrix.

1.3 Metabolite Annotation

To perform metabolite annotation, users should provide their own reference file. Otherwise, `LAMP` will use its default reference file for annotation.

[4]:
```
ref_path = ""  # if empty, use default reference file for matching
# load reference library
cal_mass = False
ref = anno.read_ref(ref_path, ion_mode=ion_mode, calc=cal_mass)
ref
```

[4]:
```
                          compound_name molecular_formula  monoisotopic_mass  \
34230                      (-)-Salsoline         C11H15NO2         193.110265
34231                  (-)-trans-carveol           C10H16O         152.120110
34232            (-)-ureidoglycolic acid          C3H6N2O4         134.032730
34233  (11R)-11-hydroperoxylinoleic acid          C18H32O4         312.230040
34234   (11Z,14Z)-eicosadienoylcarnitine         C27H49NO4         451.366135
…                                    …                …                  …
83155  N(6),N(6),N(6)-trimethyl-L-lysine        C9H21N2O2+         189.160301
83156    nicotinic acid D-ribonucleotide       C11H15NO9P+         336.048436
83157                      phosphocholine        C5H15NO4P+         184.073866
```

```
83158            S-adenosyl-L-methionine      C15H23N6O5S+         399.145060
83159          S-adenosylmethioninamine       C14H23N6O3S+         355.155232

       exact_mass  ion_type  ion_mode  \
34230  232.073425  [M+39K]+  positive
34231  191.083270  [M+39K]+  positive
34232  172.995890  [M+39K]+  positive
34233  351.193200  [M+39K]+  positive
34234  490.329295  [M+39K]+  positive
…           …        …        …
83155  189.159751        M+  positive
83156  336.047886        M+  positive
83157  184.073316        M+  positive
83158  399.144510        M+  positive
83159  355.154682        M+  positive

                                                  smiles  \
34230                          COc1cc2c(cc1O)CCN[C@H]2C
34231                    C=C(C)[C@@H]1CC=C(C)[C@@H](O)C1
34232                              NC(=O)N[C@@H](O)C(=O)O
34233                      CCCCCC=CC(C=CCCCCCCCC(=O)O)OO
34234  CCCCC/C=C\C/C=C\CCCCCCCCCC(=O)OC(CC(=O)[O-])C[…
…                                                    …
83155                        C[N+](C)(C)CCCC[C@H](N)C(=O)O
83156  O=C(O)c1ccc[n+]([C@@H]2O[C@H](COP(=O)(O)O)[C@@…
83157                             C[N+](C)(C)CCOP(=O)(O)O
83158  C[S+](CC[C@H](N)C(=O)O)C[C@H]1O[C@@H](n2cnc3c(…
83159  C[S+](CCCN)C[C@H]1O[C@@H](n2cnc3c(N)ncnc32)[C@…

                           inchikey  \
34230  YTPRLBGPGZHUPD-ZETCQYMHSA-N
34231  BAVONGHXFVOKBV-ZJUUUORDSA-N
34232  NWZYYCVIOKVTII-SFOWXEAESA-N
34233  PLWDMWAXENHPLY-UHFFFAOYSA-N
34234  OLZWDVKTOGTVLC-UTJQPWESSA-N
…                              …
83155  MXNRLFUSFKVQSK-QMMMGPOBSA-O
83156  JOUIQRNQJGXQDC-ZYUZMQFOSA-O
83157  YHHSONZFOIEMCP-UHFFFAOYSA-O
83158  MEFKEPWMEQBLKI-AIRLBKTGSA-O
83159  ZUNBITIXDCPNSD-LSRJEVITSA-N

                                                    inchi kegg_id      hmdb_id  \
34230  InChI=1S/C11H15NO2/c1-7-9-6-11(14-2)10(13)5-8(…  C09640          -X-
34231  InChI=1S/C10H16O/c1-7(2)9-5-4-8(3)10(11)6-9/h4…  C00964          -X-
34232  InChI=1S/C3H6N2O4/c4-3(9)5-1(6)2(7)8/h1,6H,(H,…  C00603  HMDB0001005
34233                                                -X-     -X-          -X-
```

```
34234  InChI=1S/C27H49NO4/c1-5-6-7-8-9-10-11-12-13-14…     -X-          -X-
…                                                    …     …         …
83155  InChI=1S/C9H20N2O2/c1-11(2,3)7-5-4-6-8(10)9(12…  C03793  HMDB0001325
83156  InChI=1S/C11H14NO9P/c13-8-7(5-20-22(17,18)19)2…  C01185          -X-
83157  InChI=1S/C5H14NO4P/c1-6(2,3)4-5-10-11(7,8)9/h4…  C00588  HMDB0001565
83158  InChI=1S/C15H22N6O5S/c1-27(3-2-7(16)15(24)25)4…  C00019  HMDB0001185
83159  InChI=1S/C14H23N6O3S/c1-24(4-2-3-15)5-8-10(21)…  C01137  HMDB0000988

           chebi_id pubchem_id lipidmaps_id
34230     CHEBI:112     442356          -X-
34231   CHEBI:15389        -X-          -X-
34232   CHEBI:15412     439269          -X-
34233  CHEBI:134247    5230520          -X-
34234   CHEBI:73119        -X-          -X-
…               …          …           …
83155   CHEBI:17311     440120          -X-
83156   CHEBI:15763   53477721          -X-
83157   CHEBI:18132       1014          -X-
83158   CHEBI:15414   16757548          -X-
83159   CHEBI:15625     439415          -X-

[39150 rows x 14 columns]
```

The reference file must have two columns: `molecular_formula` and `compound_name` (or `name`). The `exact_mass` is optional. if absent, `LAMP` will calculate 'exact_mass' based on the NIST Atomic Weights and Isotopic Compositions for All Elements. If your reference file has `exact_mass` and you want to calculate it using NIST database, set `calc` as True. The `exact_mass` is used to match against a range of `mz`, controlled by `ppm`, in data frame `df`.

Another reference file is HMDB database for urine:

[5]:
```
ref_path = "./data/hmdb_urine_v4_0_20200910_v1.tsv"
cal_mass = True  # there is no exact mass in reference file, so calculate them
ref = anno.read_ref(ref_path, calc=cal_mass)
ref
```

[5]:
```
                id molecular_formula                    compound_name  \
0     HMDB0000001         C7H11N3O2                1-Methylhistidine
1     HMDB0000002           C3H10N2               1,3-Diaminopropane
2     HMDB0000005           C4H6O3               2-Ketobutyric acid
3     HMDB0000008           C4H8O3            2-Hydroxybutyric acid
4     HMDB0000010          C19H24O3                 2-Methoxyestrone
…             …                 …                                …
1606  HMDB0012308           C8H8O3                         Vanillin
1607  HMDB0012322          C10H8O                         2-Naphthol
1608  HMDB0012325          C5H10O5                    Arabinofuranose
1609  HMDB0012451          C20H28O3  all-trans-5,6-Epoxyretinoic acid
1610  HMDB0012467         C15H13O9S           (-)-Epicatechin sulfate
```

```
                                                    inchi  \
0     InChI=1S/C7H11N3O2/c1-10-3-5(9-4-10)2-6(8)7(11…
1                    InChI=1S/C3H10N2/c4-2-1-3-5/h1-5H2
2       InChI=1S/C4H6O3/c1-2-3(5)4(6)7/h2H2,1H3,(H,6,7)
3     InChI=1S/C4H8O3/c1-2-3(5)4(6)7/h3,5H,2H2,1H3,(…
4     InChI=1S/C19H24O3/c1-19-8-7-12-13(15(19)5-6-18…
…                                                   …
1606  InChI=1S/C8H8O3/c1-11-8-4-6(5-9)2-3-7(8)10/h2-…
1607  InChI=1S/C10H8O/c11-10-6-5-8-3-1-2-4-9(8)7-10/…
1608  InChI=1S/C5H10O5/c6-1-2-3(7)4(8)5(9)10-2/h2-9H…
1609  InChI=1S/C20H28O3/c1-15(8-6-9-16(2)14-17(21)22…
1610  InChI=1S/C15H14O9S/c16-9-3-8-5-13(24-25(20,21)…

                         inchi_key  exact_mass
0     BRMWTNUJHUMWMS-LURJTMIESA-N  169.085127
1     XFNJVJPLKCPIBV-UHFFFAOYSA-N   74.084398
2     TYEYBOSBBBHJIV-UHFFFAOYSA-N  102.031694
3     AFENDNXGAFYKQO-VKHMYHEASA-N  104.047344
4     WHEUWNKSCXYKBU-QPWUGHHJSA-N  300.172545
…                             …          …
1606  MWOOGOJBHIARFG-UHFFFAOYSA-N  152.047344
1607  JWAZRIHNYRIHIV-UHFFFAOYSA-N  144.057515
1608  HMFHBZSHGGEWLO-HWQSCIPKSA-N  150.052823
1609  KEEHJLBAOLGBJZ-WEDZBJJJSA-N  316.203845
1610  WTXWEAXATVSZQX-AFYYWNPRSA-M  369.028028

[1611 rows x 6 columns]
```

Next we use HMDB reference file for compounds match. Here function argument `ppm` is used to control the m/z matching tolerance(range).

[6]:
```
ppm = 5.0
match = anno.comp_match_mass(df, ppm, ref)
match
```

[6]:
```
           id          mz molecular_formula              compound_name  \
0     M154T37  154.062402           C8H10O3              Hydroxytyrosol
1    M164T119  164.046774            C9H8O3         Phenylpyruvic acid
2    M164T119  164.046774            C9H8O3            m-Coumaric acid
3    M164T119  164.046774            C9H8O3     4-Hydroxycinnamic acid
4    M164T119  164.046774            C9H8O3     2-Hydroxycinnamic acid
5    M164T233  164.046832            C9H8O3         Phenylpyruvic acid
6    M164T233  164.046832            C9H8O3            m-Coumaric acid
7    M164T233  164.046832            C9H8O3     4-Hydroxycinnamic acid
8    M164T233  164.046832            C9H8O3     2-Hydroxycinnamic acid
9     M164T53  164.046825            C9H8O3         Phenylpyruvic acid
10    M164T53  164.046825            C9H8O3            m-Coumaric acid
```

11	M164T53	164.046825	C9H8O3	4-Hydroxycinnamic acid
12	M164T53	164.046825	C9H8O3	2-Hydroxycinnamic acid
13	M167T35	167.021095	C7H5NO4	Quinolinic acid
14	M173T36_3	173.104423	C8H15NO3	Hexanoylglycine
15	M174T35	174.088395	C8H14O4	Suberic acid
16	M181T36	181.060407	C6H7N5O2	8-Hydroxy-7-methylguanine
17	M212T39	212.067866	C10H12O5	Vanillactic acid
18	M276T36	276.077397	C10H16N2O5S	Biotin sulfone

	inchi
0	InChI=1S/C8H10O3/c9-4-3-6-1-2-7(10)8(11)5-6/h1…
1	InChI=1S/C9H8O3/c10-8(9(11)12)6-7-4-2-1-3-5-7/…
2	InChI=1S/C9H8O3/c10-8-3-1-2-7(6-8)4-5-9(11)12/…
3	InChI=1S/C9H8O3/c10-8-4-1-7(2-5-8)3-6-9(11)12/…
4	InChI=1S/C9H8O3/c10-8-4-2-1-3-7(8)5-6-9(11)12/…
5	InChI=1S/C9H8O3/c10-8(9(11)12)6-7-4-2-1-3-5-7/…
6	InChI=1S/C9H8O3/c10-8-3-1-2-7(6-8)4-5-9(11)12/…
7	InChI=1S/C9H8O3/c10-8-4-1-7(2-5-8)3-6-9(11)12/…
8	InChI=1S/C9H8O3/c10-8-4-2-1-3-7(8)5-6-9(11)12/…
9	InChI=1S/C9H8O3/c10-8(9(11)12)6-7-4-2-1-3-5-7/…
10	InChI=1S/C9H8O3/c10-8-3-1-2-7(6-8)4-5-9(11)12/…
11	InChI=1S/C9H8O3/c10-8-4-1-7(2-5-8)3-6-9(11)12/…
12	InChI=1S/C9H8O3/c10-8-4-2-1-3-7(8)5-6-9(11)12/…
13	InChI=1S/C7H5NO4/c9-6(10)4-2-1-3-8-5(4)7(11)12…
14	InChI=1S/C8H15NO3/c1-2-3-4-5-7(10)9-6-8(11)12/…
15	InChI=1S/C8H14O4/c9-7(10)5-3-1-2-4-6-8(11)12/h…
16	InChI=1S/C6H7N5O2/c1-11-2-3(9-6(11)13)8-5(7)10…
17	InChI=1S/C10H12O5/c1-15-9-5-6(2-3-7(9)11)4-8(1…
18	InChI=1S/C10H16N2O5S/c13-8(14)4-2-1-3-7-9-6(5-…

	inchi_key	exact_mass	ppm_error
0	JUUBCHWRXWPFFH-UHFFFAOYSA-N	154.06	-3.84
1	BTNMPGBKDVTSJY-UHFFFAOYSA-N	164.05	-3.47
2	KKSDGJDHHZEWEP-SNAWJCMRSA-N	164.05	-3.47
3	NGSWKAQJJWESNS-ZZXKWVIFSA-N	164.05	-3.47
4	PMOWTIHVNWZYFI-AATRIKPKSA-N	164.05	-3.47
5	BTNMPGBKDVTSJY-UHFFFAOYSA-N	164.05	-3.12
6	KKSDGJDHHZEWEP-SNAWJCMRSA-N	164.05	-3.12
7	NGSWKAQJJWESNS-ZZXKWVIFSA-N	164.05	-3.12
8	PMOWTIHVNWZYFI-AATRIKPKSA-N	164.05	-3.12
9	BTNMPGBKDVTSJY-UHFFFAOYSA-N	164.05	-3.16
10	KKSDGJDHHZEWEP-SNAWJCMRSA-N	164.05	-3.16
11	NGSWKAQJJWESNS-ZZXKWVIFSA-N	164.05	-3.16
12	PMOWTIHVNWZYFI-AATRIKPKSA-N	164.05	-3.16
13	GJAWHXHKYYXBSV-UHFFFAOYSA-N	167.02	-4.57
14	UPCKIPHSXMXJOX-UHFFFAOYSA-N	173.11	-4.45
15	TYFQFVWCELRYAO-UHFFFAOYSA-N	174.09	-4.67

```
16  VHPXSVXJBWZORQ-UHFFFAOYSA-N      181.06       2.39
17  SVYIZYRTOYHQRE-UHFFFAOYSA-N      212.07      -2.86
18  QPFQYMONYBAUCY-ZKWXMUAHSA-N      276.08      -2.16
```

`match` gives the compound matching results. `LAMP` also provides a mass adjust option by adduct library. You can provide your own adducts library otherwise `LAMP` uses its default adducts library.

The adducts library's format looks like:

[7]:
```
add_path = './data/adducts_short.tsv'
lib_df = pd.read_csv(add_path, sep="\t")
lib_df
```

[7]:

	label	exact_mass	charge	ion_mode
0	[M+H]+	1.007276	1	pos
1	[M+NH4]+	18.033826	1	pos
2	[M+Na]+	22.989221	1	pos
3	[M+Mg]+	23.984493	1	pos
4	[M+K]+	38.963158	1	pos
5	[M+Fe]+	55.934388	1	pos
6	[M+Cu]+	62.929049	1	pos
7	[M+2H]+	2.015101	1	pos
8	[M+3H]+	3.022926	1	pos
9	[M-H]-	-1.007276	1	neg
10	[M+35Cl]-	34.969401	1	neg
11	[M+Formate]-	44.998203	1	neg
12	[M+Acetate]-	59.013853	1	neg

The adducts library must have columns of `label`, `exact_mass`, `charge` and `ion_mode`.

We use this adducts file to adjust mass:

[8]:
```
# if empty, use default adducts library
add_path = "./data/adducts_short.tsv"
lib_add = anno.read_lib(add_path, ion_mode)
lib_add
```

[8]:

	label	exact_mass	charge
0	[M+H]+	1.007276	1
1	[M+NH4]+	18.033826	1
2	[M+Na]+	22.989221	1
3	[M+Mg]+	23.984493	1
4	[M+K]+	38.963158	1
5	[M+Fe]+	55.934388	1
6	[M+Cu]+	62.929049	1
7	[M+2H]+	2.015101	1
8	[M+3H]+	3.022926	1

Now use function `comp_match_mass_add` to match compounds:

[9]:
```
match_1 = anno.comp_match_mass_add(df, ppm, ref, lib_add)
match_1
```

[9]:

	id	mz	molecular_formula	compound_name
0	M152T40	152.043607	C5H8N2O2	Dihydrothymine
1	M154T37	154.062402	C8H8O3	p-Hydroxyphenylacetic acid
2	M154T37	154.062402	C8H8O3	3-Hydroxyphenylacetic acid
3	M154T37	154.062402	C8H8O3	ortho-Hydroxyphenylacetic acid
4	M154T37	154.062402	C8H8O3	Mandelic acid
5	M154T37	154.062402	C8H8O3	3-Cresotinic acid
6	M154T37	154.062402	C8H8O3	4-Hydroxy-3-methylbenzoic acid
7	M154T37	154.062402	C8H8O3	Vanillin
8	M157T35	157.036819	C4H10N2O2	2,4-Diaminobutyric acid
9	M157T35	157.036819	C4H10N2O2	L-2,4-diaminobutyric acid
10	M167T35	167.021095	C5H8N2O2	Dihydrothymine
11	M174T35	174.088395	C9H13NO	Phenylpropanolamine
12	M174T35	174.088395	C10H14O	Thymol
13	M174T35	174.088395	C10H14O	(S)-Carvone
14	M174T35	174.088395	C8H12O4	2-Octenedioic acid
15	M174T35	174.088395	C8H12O4	cis-4-Octenedioic acid
16	M181T36	181.060407	C8H8N2O3	Nicotinuric acid
17	M184T38	184.097942	C10H13N2	Nicotine imine
18	M185T39_2	185.082034	C5H15NO4P	Phosphorylcholine
19	M186T36	186.045606	C6H14N2O	N-Acetylputrescine
20	M187T38	187.097642	C5H15NO4P	Phosphorylcholine
21	M193T40	193.050761	C5H14N4	Agmatine
22	M200T36	200.061328	C7H16N2O	N-Acetylcadaverine
23	M201T39_1	201.051849	C10H10O3	4-Methoxycinnamic acid
24	M203T36_1	203.002108	C9H9NO	Indole-3-carbinol
25	M212T39	212.067866	C8H15NO3	Hexanoylglycine
26	M212T39	212.067866	C10H10O5	Vanilpyruvic acid
27	M217T37_1	217.018279	C10H11NO	Tryptophol
28	M221T37	221.012328	C9H11NO2	L-Phenylalanine
29	M223T38	223.008162	C4H10NO6P	O-Phosphothreonine
30	M223T40	223.096863	C12H14O4	Monoisobutyl phthalic acid
31	M226T44	226.128007	C8H18N4O2	Asymmetric dimethylarginine
32	M226T44	226.128007	C8H18N4O2	Symmetric dimethylarginine
33	M227T36	227.066175	C9H10N2O5	3-Nitrotyrosine
34	M229T38	229.069418	C4H10N3O5P	Phosphocreatine
35	M233T38	233.043479	C8H10N4O2	Caffeine
36	M245T44	245.045772	C7H15N3O3	Homocitrulline
37	M245T37_2	245.093315	C13H18O2	Ibuprofen
38	M249T38	249.038309	C8H10N4O3	1,3,7-Trimethyluric acid
39	M261T43	260.972975	C10H7NO4	Xanthurenic acid
40	M269T37_2	269.088048	C10H12N4O5	Inosine
41	M275T168	275.201932	C18H24O2	Estradiol
42	M275T168	275.201932	C18H24O2	17a-Estradiol

43	M277T181	277.217564	C18H28O2	19-Norandrosterone
44	M277T181	277.217564	C18H28O2	19-Noretiocholanolone
45	M278T71	278.148195	C11H20N2O6	Saccharopine
46	M279T233	279.233232	C18H30O2	alpha-Linolenic acid
47	M279T233	279.233232	C18H28O2	19-Norandrosterone
48	M279T233	279.233232	C18H28O2	19-Noretiocholanolone
49	M281T287	281.248903	C18H32O2	Linoleic acid
50	M281T287	281.248903	C18H30O2	alpha-Linolenic acid
51	M282T61	282.070271	C10H14N2O6	Ribothymidine
52	M282T61	282.070271	C10H14N2O6	3-Methyluridine
53	M283T37	283.103695	C11H14N4O5	1-Methylinosine

	inchi \
0	InChI=1S/C5H8N2O2/c1-3-2-6-5(9)7-4(3)8/h3H,2H2…
1	InChI=1S/C8H8O3/c9-7-3-1-6(2-4-7)5-8(10)11/h1-…
2	InChI=1S/C8H8O3/c9-7-3-1-2-6(4-7)5-8(10)11/h1-…
3	InChI=1S/C8H8O3/c9-7-4-2-1-3-6(7)5-8(10)11/h1-…
4	InChI=1S/C8H8O3/c9-7(8(10)11)6-4-2-1-3-5-6/h1-…
5	InChI=1S/C8H8O3/c1-5-3-2-4-6(7(5)9)8(10)11/h2-…
6	InChI=1S/C8H8O3/c1-5-4-6(8(10)11)2-3-7(5)9/h2-…
7	InChI=1S/C8H8O3/c1-11-8-4-6(5-9)2-3-7(8)10/h2-…
8	InChI=1S/C4H10N2O2/c5-2-1-3(6)4(7)8/h3H,1-2,5-…
9	InChI=1S/C4H10N2O2/c5-2-1-3(6)4(7)8/h3H,1-2,5-…
10	InChI=1S/C5H8N2O2/c1-3-2-6-5(9)7-4(3)8/h3H,2H2…
11	InChI=1S/C9H13NO/c1-7(10)9(11)8-5-3-2-4-6-8/h2…
12	InChI=1S/C10H14O/c1-7(2)9-5-4-8(3)6-10(9)11/h4…
13	InChI=1S/C10H14O/c1-7(2)9-5-4-8(3)10(11)6-9/h4…
14	InChI=1S/C8H12O4/c9-7(10)5-3-1-2-4-6-8(11)12/h…
15	InChI=1S/C8H12O4/c9-7(10)5-3-1-2-4-6-8(11)12/h…
16	InChI=1S/C8H8N2O3/c11-7(12)5-10-8(13)6-2-1-3-9…
17	InChI=1S/C10H13N2/c1-12-7-3-5-10(12)9-4-2-6-11…
18	InChI=1S/C5H14NO4P/c1-6(2,3)4-5-10-11(7,8)9/h4…
19	InChI=1S/C6H14N2O/c1-6(9)8-5-3-2-4-7/h2-5,7H2,…
20	InChI=1S/C5H14NO4P/c1-6(2,3)4-5-10-11(7,8)9/h4…
21	InChI=1S/C5H14N4/c6-3-1-2-4-9-5(7)8/h1-4,6H2,(…
22	InChI=1S/C7H16N2O/c1-7(10)9-6-4-2-3-5-8/h2-6,8…
23	InChI=1S/C10H10O3/c1-13-9-5-2-8(3-6-9)4-7-10(1…
24	InChI=1S/C9H9NO/c11-6-7-5-10-9-4-2-1-3-8(7)9/h…
25	InChI=1S/C8H15NO3/c1-2-3-4-5-7(10)9-6-8(11)12/…
26	InChI=1S/C10H10O5/c1-15-9-5-6(2-3-7(9)11)4-8(1…
27	InChI=1S/C10H11NO/c12-6-5-8-7-11-10-4-2-1-3-9(…
28	InChI=1S/C9H11NO2/c10-8(9(11)12)6-7-4-2-1-3-5-…
29	InChI=1S/C4H10NO6P/c1-2(3(5)4(6)7)11-12(8,9)10…
30	InChI=1S/C12H14O4/c1-8(2)7-16-12(15)10-6-4-3-5…
31	InChI=1S/C8H18N4O2/c1-12(2)8(10)11-5-3-4-6(9)7…
32	InChI=1S/C8H18N4O2/c1-10-8(11-2)12-5-3-4-6(9)7…
33	InChI=1S/C9H10N2O5/c10-6(9(13)14)3-5-1-2-8(12)…

34	InChI=1S/C4H10N3O5P/c1-7(2-3(8)9)4(5)6-13(10,1…
35	InChI=1S/C8H10N4O2/c1-10-4-9-6-5(10)7(13)12(3)…
36	InChI=1S/C7H15N3O3/c8-5(6(11)12)3-1-2-4-10-7(9…
37	InChI=1S/C13H18O2/c1-9(2)8-11-4-6-12(7-5-11)10…
38	InChI=1S/C8H10N4O3/c1-10-4-5(9-7(10)14)11(2)8(…
39	InChI=1S/C10H7NO4/c12-7-3-1-2-5-8(13)4-6(10(14…
40	InChI=1S/C10H12N4O5/c15-1-4-6(16)7(17)10(19-4)…
41	InChI=1S/C18H24O2/c1-18-9-8-14-13-5-3-12(19)10…
42	InChI=1S/C18H24O2/c1-18-9-8-14-13-5-3-12(19)10…
43	InChI=1S/C18H28O2/c1-18-9-8-14-13-5-3-12(19)10…
44	InChI=1S/C18H28O2/c1-18-9-8-14-13-5-3-12(19)10…
45	InChI=1S/C11H20N2O6/c12-7(10(16)17)3-1-2-6-13-…
46	InChI=1S/C18H30O2/c1-2-3-4-5-6-7-8-9-10-11-12-…
47	InChI=1S/C18H28O2/c1-18-9-8-14-13-5-3-12(19)10…
48	InChI=1S/C18H28O2/c1-18-9-8-14-13-5-3-12(19)10…
49	InChI=1S/C18H32O2/c1-2-3-4-5-6-7-8-9-10-11-12-…
50	InChI=1S/C18H30O2/c1-2-3-4-5-6-7-8-9-10-11-12-…
51	InChI=1S/C10H14N2O6/c1-4-2-12(10(17)11-8(4)16)…
52	InChI=1S/C10H14N2O6/c1-11-6(14)2-3-12(10(11)17…
53	InChI=1S/C11H14N4O5/c1-14-3-13-9-6(10(14)19)12…

	inchi_key	exact_mass	adduct	ppm_error
0	NBAKTGXDIBVZOO-VKHMYHEASA-N	152.04	[M+Mg]+	3.52
1	XQXPVVBIMDBYFF-UHFFFAOYSA-N	154.06	[M+2H]+	-0.28
2	FVMDYYGIDFPZAX-UHFFFAOYSA-N	154.06	[M+2H]+	-0.28
3	CCVYRRGZDBSHFU-UHFFFAOYSA-N	154.06	[M+2H]+	-0.28
4	IWYDHOAUDWTVEP-ZETCQYMHSA-N	154.06	[M+2H]+	-0.28
5	WHSXTWFYRGOBGO-UHFFFAOYSA-N	154.06	[M+2H]+	-0.28
6	LTFHNKUKQYVHDX-UHFFFAOYSA-N	154.06	[M+2H]+	-0.28
7	MWOOGOJBHIARFG-UHFFFAOYSA-N	154.06	[M+2H]+	-0.28
8	OGNSCSPNOLGXSM-UHFFFAOYSA-N	157.04	[M+K]+	-3.61
9	OGNSCSPNOLGXSM-VKHMYHEASA-N	157.04	[M+K]+	-3.61
10	NBAKTGXDIBVZOO-VKHMYHEASA-N	167.02	[M+K]+	-3.83
11	DLNKOYKMWOXYQA-VXNVDRBHSA-N	174.09	[M+Na]+	-3.10
12	MGSRCZKZVOBKFT-UHFFFAOYSA-N	174.09	[M+Mg]+	-3.23
13	ULDHMXUKGWMISQ-VIFPVBQESA-N	174.09	[M+Mg]+	-3.23
14	BNTPVRGYUHJFHN-HWKANZROSA-N	174.09	[M+2H]+	-1.52
15	LQVYKEXVMZXOAH-UPHRSURJSA-N	174.09	[M+2H]+	-1.52
16	ZBSGKPYXQINNGF-UHFFFAOYSA-N	181.06	[M+H]+	-1.99
17	GTQXYYYOJZZJHL-UHFFFAOYSA-N	184.10	[M+Na]+	4.61
18	YHHSONZFOIEMCP-UHFFFAOYSA-O	185.08	[M+H]+	4.80
19	KLZGKIDSEJWEDW-UHFFFAOYSA-N	186.05	[M+Fe]+	3.25
20	YHHSONZFOIEMCP-UHFFFAOYSA-O	187.10	[M+3H]+	4.52
21	QYPPJABKJHAVHS-UHFFFAOYSA-N	193.05	[M+Cu]+	-0.69
22	RMOIHHAKNOFHOE-UHFFFAOYSA-N	200.06	[M+Fe]+	3.39
23	AFDXODALSZRGIH-QPJJXVBHSA-N	201.05	[M+Na]+	-1.82
24	IVYPNXXAYMYVSP-UHFFFAOYSA-N	203.00	[M+Fe]+	-3.42

25	UPCKIPHSXMXJOX-UHFFFAOYSA-N	212.07	[M+K]+	-2.29
26	YGQHQTMRZPHIBB-UHFFFAOYSA-N	212.07	[M+2H]+	-0.28
27	MBBOMCVGYCRMEA-UHFFFAOYSA-N	217.02	[M+Fe]+	-0.79
28	COLNVLDHVKWLRT-QMMMGPOBSA-N	221.01	[M+Fe]+	-4.70
29	USRGIUJOYOXOQJ-GBXIJSLDSA-N	223.01	[M+Mg]+	-4.06
30	RZJSUWQGFCHNFS-UHFFFAOYSA-N	223.10	[M+H]+	1.69
31	YDGMGEXADBMOMJ-LURJTMIESA-N	226.13	[M+Mg]+	2.38
32	HVPFXCBJHIIJGS-LURJTMIESA-N	226.13	[M+Mg]+	2.38
33	FBTSQILOGYXGMD-LURJTMIESA-N	227.07	[M+H]+	-0.32
34	DRBBFCLWYRJSJZ-UHFFFAOYSA-N	229.07	[M+NH4]+	-0.94
35	RYYVLZVUVIJVGH-UHFFFAOYSA-N	233.04	[M+K]+	-0.23
36	XIGSAGMEBXLVJJ-YFKPBYRVSA-N	245.05	[M+Fe]+	0.17
37	HEFNNWSXXWATRW-UHFFFAOYSA-N	245.09	[M+K]+	-2.13
38	BYXCFUMGEBZDDI-UHFFFAOYSA-N	249.04	[M+K]+	-0.56
39	FBZONXHGGPHHIY-UHFFFAOYSA-N	260.97	[M+Fe]+	4.13
40	UGQMRVRMYYASKQ-KQYNXXCUSA-N	269.09	[M+H]+	0.01
41	VOXZDWNPVJITMN-ZBRFXRBCSA-N	275.20	[M+3H]+	5.00
42	VOXZDWNPVJITMN-SFFUCWETSA-N	275.20	[M+3H]+	5.00
43	UOUIARGWRPHDBX-CQZDKXCPSA-N	277.22	[M+H]+	4.90
44	UOUIARGWRPHDBX-DHMVHTBWSA-N	277.22	[M+H]+	4.90
45	ZDGJAHTZVHVLOT-YUMQZZPRSA-N	278.15	[M+2H]+	3.44
46	DTOSIQBPPRVQHS-PDBXOOCHSA-N	279.23	[M+H]+	4.93
47	UOUIARGWRPHDBX-CQZDKXCPSA-N	279.23	[M+3H]+	4.93
48	UOUIARGWRPHDBX-DHMVHTBWSA-N	279.23	[M+3H]+	4.93
49	OYHQOLUKZRVURQ-HZJYTTRNSA-N	281.25	[M+H]+	4.97
50	DTOSIQBPPRVQHS-PDBXOOCHSA-N	281.25	[M+3H]+	4.97
51	DWRXFEITVBNRMK-JXOAFFINSA-N	282.07	[M+Mg]+	2.10
52	UTQUILVPBZEHTK-UHFFFAOYSA-N	282.07	[M+Mg]+	2.10
53	WJNGQIYEQLPJMN-IOSLPCCCSA-N	283.10	[M+H]+	-0.01

1.4 Correlation Analysis

Next step is correlation analysis, based on intensity data matrix along all peaks. All results are filtered by the correlation coefficient, p-values and retention time difference. That is: keep correlation results in an retention time differences/window (such as 1 second) with correlation coefficient larger than a threshold (such as 0.5) and their correlation p-values less than a threshold (such as 0.05).

`LAMP` supports two correlation methods, `pearson` and `spearman`. Also parameter `positive` allows user to select only positive correlation results, otherwise positive and negative correlations will be used.

Two functions, `_tic` and `_toc`, record the correlation computation time in seconds.

[10]:
```
thres_rt = 1.0
thres_corr = 0.5
thres_pval = 0.05
method = "spearman"  # "pearson"
```

```
positive = True
```

[11]:
```
utils._tic()
corr = stats.comp_corr_rt(df, thres_rt, thres_corr, thres_pval, method,
                          positive)
utils._toc()
corr
```

```
Elapsed time: 0.7674360275268555 seconds.
```

[11]:

	name_a	name_b	r_value	p_value	rt_diff
0	M151T34	M153T34	0.80	1.267076e-23	0.02
1	M151T34	M155T34	0.71	1.752854e-16	0.20
2	M151T34	M161T34	0.78	1.869949e-21	0.14
3	M151T34	M163T34	0.69	3.239594e-15	0.20
4	M151T34	M167T35	0.51	5.776482e-08	0.73
…	…	…	…	…	…
1783	M283T34_1	M283T34_2	0.62	4.214876e-12	0.29
1784	M283T34_1	M285T34	0.82	5.937139e-26	0.08
1785	M283T34_2	M285T34	0.66	7.898957e-14	0.37
1786	M283T60	M284T60	0.86	1.033010e-29	0.15
1787	M283T339	M284T339	0.91	4.031333e-39	0.04

[1788 rows x 5 columns]

`corr` gives results of correlation coefficient(`r_value`), correlation p-values(`p_value`) and retention time difference(`rt_diff`).

Based on the correlation analysis, we can extract the groups and their sizes by:

[12]:
```
# get correlation group and size
corr_df = stats.corr_grp_size(corr)
corr_df
```

[12]:

	name	cor_grp_size	cor_grp
0	M219T35	52	M221T34::M223T34::M225T35::M226T35::M229T34::M…
1	M215T35	52	M216T35::M217T35::M218T35::M219T34::M219T35::M…
2	M216T35	52	M217T35::M218T35::M219T34::M219T35::M221T34::M…
3	M217T35	52	M218T35::M219T34::M219T35::M221T34::M223T34::M…
4	M218T35	51	M219T34::M219T35::M221T34::M223T34::M225T35::M…
..	…	…	…
335	M196T593	1	M200T593
336	M272T59	1	M271T59
337	M257T51	1	M258T51
338	M223T54	1	M269T53
339	M271T59	1	M272T59

[340 rows x 3 columns]

1.5 Summarize Results

The final step gets the summary table in different format and save for the further analysis.

[13]:
```
# get summary of metabolite annotation
sr, mr = anno.comp_summ(df, match)
```

This function combines peak table with compound matching results and returns two results in different formats. `sr` is single row results for each peak id in peak table `df`:

[14]:
```
sr
```

[14]:

	name	mz	rt	exact_mass	ppm_error	\
0	M151T34	150.886715	34.152700	NaN	NaN	
1	M151T40	151.040235	39.838172	NaN	NaN	
2	M152T40	152.043607	40.303700	NaN	NaN	
3	M153T34	152.883824	34.174647	NaN	NaN	
4	M153T36	153.019474	35.785847	NaN	NaN	
..	…	…	…	…	…	
395	M283T61	283.068474	60.739869	NaN	NaN	
396	M284T108	284.223499	108.406389	NaN	NaN	
397	M284T339	284.267962	338.725056	NaN	NaN	
398	M284T60	284.195294	59.593561	NaN	NaN	
399	M285T34	284.775031	34.079641	NaN	NaN	

	molecular_formula	compound_name	inchi	inchi_key
0	NaN	NaN	NaN	NaN
1	NaN	NaN	NaN	NaN
2	NaN	NaN	NaN	NaN
3	NaN	NaN	NaN	NaN
4	NaN	NaN	NaN	NaN
..	…	…	…	…
395	NaN	NaN	NaN	NaN
396	NaN	NaN	NaN	NaN
397	NaN	NaN	NaN	NaN
398	NaN	NaN	NaN	NaN
399	NaN	NaN	NaN	NaN

[400 rows x 9 columns]

`mr` is multiple rows format if the match more than once from the reference file:

[15]:
```
mr
```

[15]:

	name	mz	rt	molecular_formula	compound_name	inchi	\
0	M151T34	150.886715	34.152700	NaN	NaN	NaN	
1	M151T40	151.040235	39.838172	NaN	NaN	NaN	
2	M152T40	152.043607	40.303700	NaN	NaN	NaN	
3	M153T34	152.883824	34.174647	NaN	NaN	NaN	

```
4     M153T36  153.019474   35.785847               NaN           NaN   NaN
..        …        …          …                 …           …   …
404   M283T61  283.068474   60.739869               NaN           NaN   NaN
405  M284T108  284.223499  108.406389               NaN           NaN   NaN
406  M284T339  284.267962  338.725056               NaN           NaN   NaN
407   M284T60  284.195294   59.593561               NaN           NaN   NaN
408   M285T34  284.775031   34.079641               NaN           NaN   NaN

    inchi_key  exact_mass  ppm_error
0         NaN         NaN        NaN
1         NaN         NaN        NaN
2         NaN         NaN        NaN
3         NaN         NaN        NaN
4         NaN         NaN        NaN
..        …         …        …
404       NaN         NaN        NaN
405       NaN         NaN        NaN
406       NaN         NaN        NaN
407       NaN         NaN        NaN
408       NaN         NaN        NaN

[409 rows x 9 columns]
```

Now we merges single format results with correlation results:

[16]:
```
# merge summery table with correlation analysis
res = anno.comp_summ_corr(sr, corr_df)
res
```

[16]:
```
         name          mz          rt  exact_mass  ppm_error  \
0     M167T35  167.021095   34.882147      167.02      -4.57
1     M276T36  276.077397   36.385373      276.08      -2.16
2     M154T37  154.062402   37.183625      154.06      -3.84
3     M181T36  181.060407   35.734801      181.06       2.39
4     M174T35  174.088395   35.001130      174.09      -4.67
..        …         …          …          …         …
395   M279T50  279.159930   50.055451         NaN        NaN
396   M279T79  279.163910   78.758079         NaN        NaN
397   M282T85  282.207859   84.719202         NaN        NaN
398   M283T47  283.110871   46.822069         NaN        NaN
399  M284T108  284.223499  108.406389         NaN        NaN

    molecular_formula              compound_name  \
0              C7H5NO4            Quinolinic acid
1         C10H16N2O5S             Biotin sulfone
2              C8H10O3             Hydroxytyrosol
3            C6H7N5O2  8-Hydroxy-7-methylguanine
4              C8H14O4               Suberic acid
```

```
..                …                          …
395               NaN                          NaN
396               NaN                          NaN
397               NaN                          NaN
398               NaN                          NaN
399               NaN                          NaN

                                                    inchi  \
0    InChI=1S/C7H5NO4/c9-6(10)4-2-1-3-8-5(4)7(11)12…
1    InChI=1S/C10H16N2O5S/c13-8(14)4-2-1-3-7-9-6(5-…
2    InChI=1S/C8H10O3/c9-4-3-6-1-2-7(10)8(11)5-6/h1…
3    InChI=1S/C6H7N5O2/c1-11-2-3(9-6(11)13)8-5(7)10…
4    InChI=1S/C8H14O4/c9-7(10)5-3-1-2-4-6-8(11)12/h…
..                                                  …
395                                                NaN
396                                                NaN
397                                                NaN
398                                                NaN
399                                                NaN

                       inchi_key  cor_grp_size  \
0    GJAWHXHKYYXBSV-UHFFFAOYSA-N          25.0
1    QPFQYMONYBAUCY-ZKWXMUAHSA-N          13.0
2    JUUBCHWRXWPFFH-UHFFFAOYSA-N          12.0
3    VHPXSVXJBWZORQ-UHFFFAOYSA-N           9.0
4    TYFQFVWCELRYAO-UHFFFAOYSA-N           9.0
..                           …           …
395                          NaN           NaN
396                          NaN           NaN
397                          NaN           NaN
398                          NaN           NaN
399                          NaN           NaN

                                                  cor_grp
0    M171T34::M197T36::M209T34::M211T34::M213T34::M…
1    M277T36_2::M278T36::M173T36_2::M186T36::M187T3…
2    M155T38::M158T37_2::M164T36::M171T37_2::M173T3…
3    M224T36::M225T35::M226T35::M227T36::M269T37_2:…
4    M211T34::M213T34::M219T34::M221T34::M229T35::M…
..                                                  …
395                                                NaN
396                                                NaN
397                                                NaN
398                                                NaN
399                                                NaN

[400 rows x 11 columns]
```

The result data frame `res` is re-arranged as four parts from top to bottom:

- 1st part: identified metabolites, satisfied with correlation analysis
- 2nd part: identified metabolites, not satisfied with correlation
- 3rd part: no identified metabolites, satisfied with correlation
- 4th part: no identified metabolites, not satisfied with correlation

The users should focus on the first part and perform their further analysis.

You can save all results in different forms, such as text format TSV or CSV. You can also save all results into a `sqlite3` database and use DB Browser for SQLite to view:

[17]:
```
f_save = False          # here we do NOT save results
db_out = "test.db"
sr_out = "test_s.tsv"
```

[18]:
```
if f_save:
    # save all results into a sqlite3 database
    conn = sqlite3.connect(db_out)
    df[["name", "mz", "rt"]].to_sql("peaklist",
                                    conn,
                                    if_exists="replace",
                                    index=False)
    corr_df.to_sql("corr_grp", conn, if_exists="replace", index=False)
    corr.to_sql("corr_pval_rt", conn, if_exists="replace", index=False)
    match.to_sql("match", conn, if_exists="replace", index=False)
    mr.to_sql("anno_mr", conn, if_exists="replace", index=False)
    res.to_sql("anno_sr", conn, if_exists="replace", index=False)

    conn.commit()
    conn.close()

    # save final results
    res.to_csv(sr_out, sep="\t", index=False)
```

1.6 End User Usages

For end users, `LAMP` provides two computation options: command line interface(CLI) and graphical user interface (GUI).

To use GUI, you need to open a terminal and type in:

```
$ lamp gui
```

To use CLI, open a terminal and type in command with required arguments, something like:

```
$ lamp cli \
  --input-data "./data/df_pos_3.tsv" \
  --sep "tab" \
  --col-idx "1, 2, 3, 4" \
  --add-path "" \
```

```
--ref-path "" \
--ion-mode "pos" \
--cal-mass \
--thres-rt "1.0" \
--thres-corr "0.5" \
--thres-pval "0.05" \
--method "pearson" \
--positive \
--ppm "5.0" \
--save-db \
--save-mr \
--db-out "./res/test.db" \
--sr-out "./res/test_s.tsv" \
--mr-out "./res/test_m.tsv"
```

For the best practice, you can create a bash script `.sh` (Linux and MacOS) or Windows script `.bat` to contain these CLI arguments. Change parameters in these files each time when processing new data set.

For example, there are `lamp_cli.sh` and `lamp_cli.bat` in https://github.com/wanchanglin/lamp/tree/master/examples. You can run them and check the results in directory `examples/res`:

- For Linux and MacOS terminal:

  ```
  $ chmod +x lamp_cli.sh
  $ ./lamp_cli.sh
  ```

- For Windows terminal:

  ```
  $ lamp_cli.bat
  ```