Rapid Identification of Drug Seizures by ASAP-MS on a Low-Cost, Deployable, Single Quadrupole Instrument

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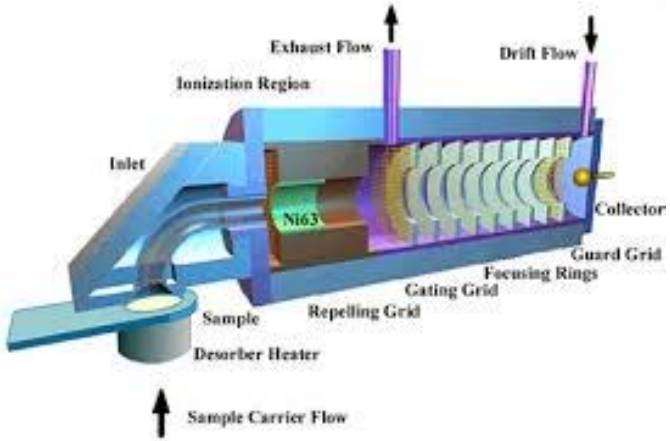
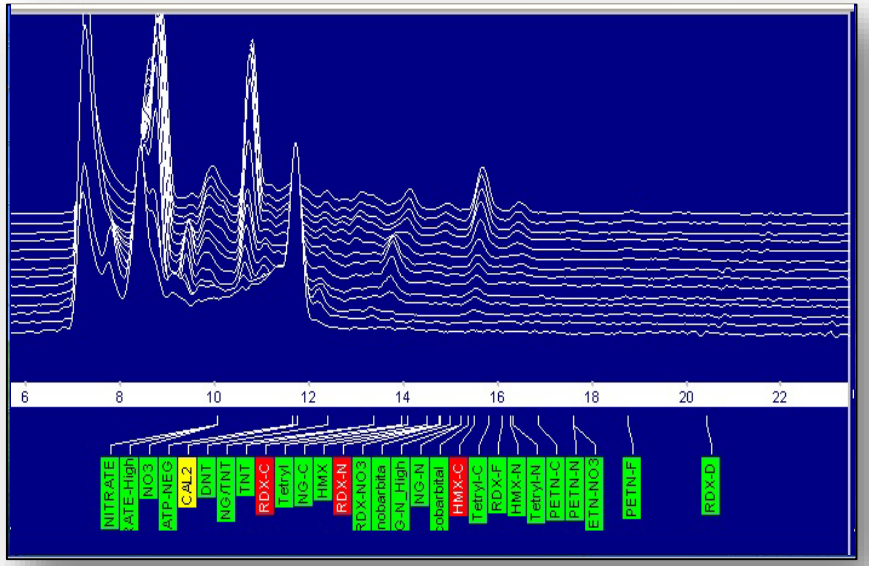
Analytical Chemistry Everywhere

Ion Mobility Spectrometry





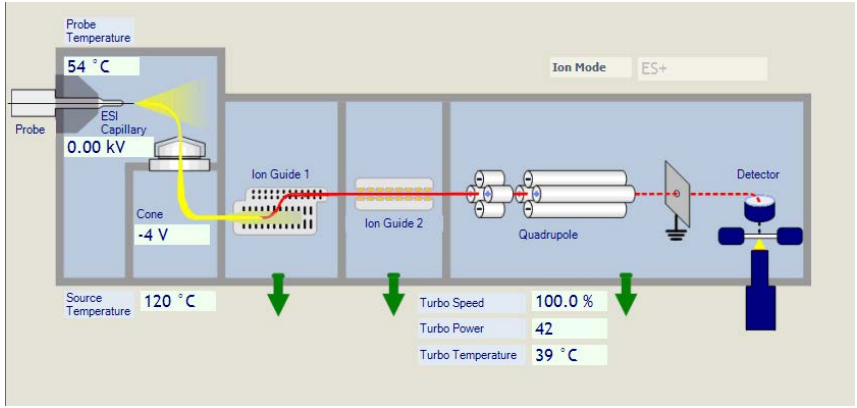
Transportable MS Wish List

- Small
- Cheap
- Easy to use
- Quick
- Robust
- High resolution
- Quantitative
- Linear
- High specificity
- Universal ambient MS source

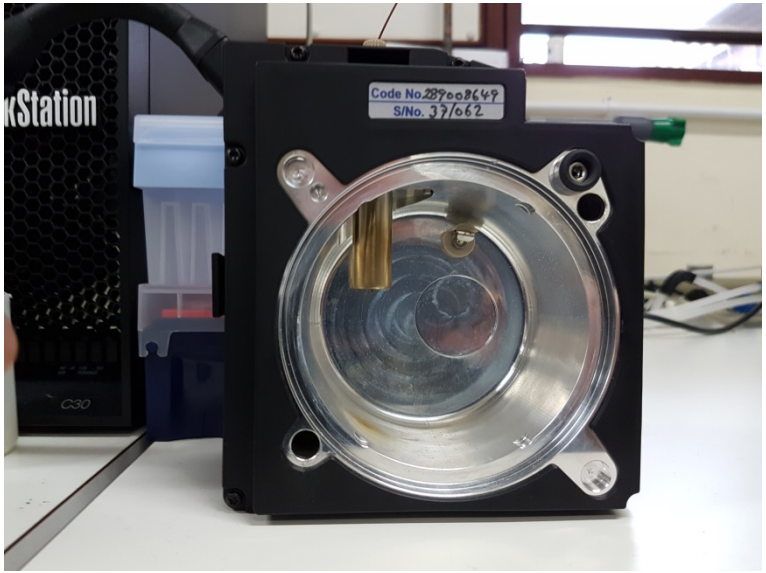
“Strong, light, cheap – pick two”
Keith Bontrager

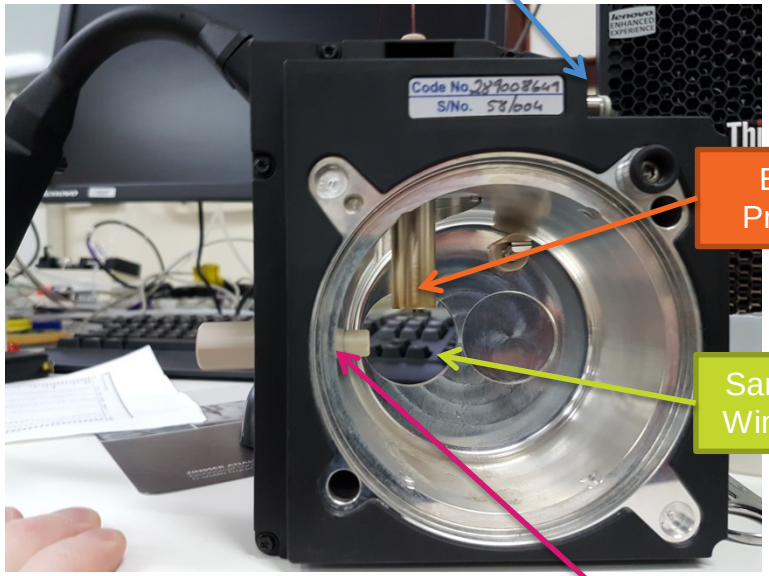
Waters QDa

- Costs ~ £35K
- Weight ~ 26 kg
- 20cm H, 35cm W, 65cm D
- Single Quad
- Either diaphragm pump or rotary pump
- 30 min from switch on to use
- SIM or Scan
- Fast electronics
- Cone energy ramping
- Designed for LC/MS use
- No ambient MS source



Source Modification



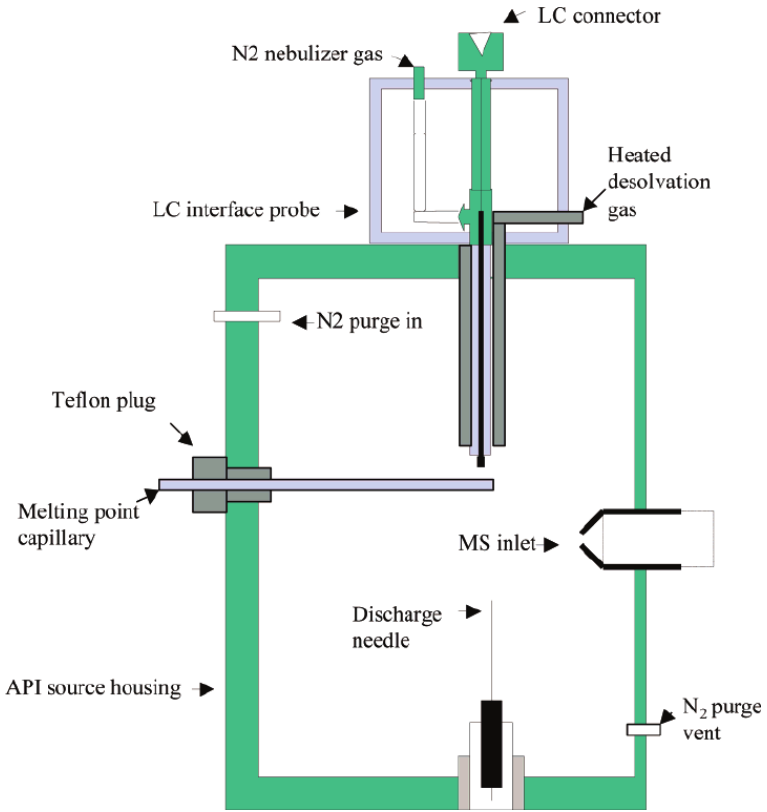


ESI only

ESI, SESI, APCI, ASAP

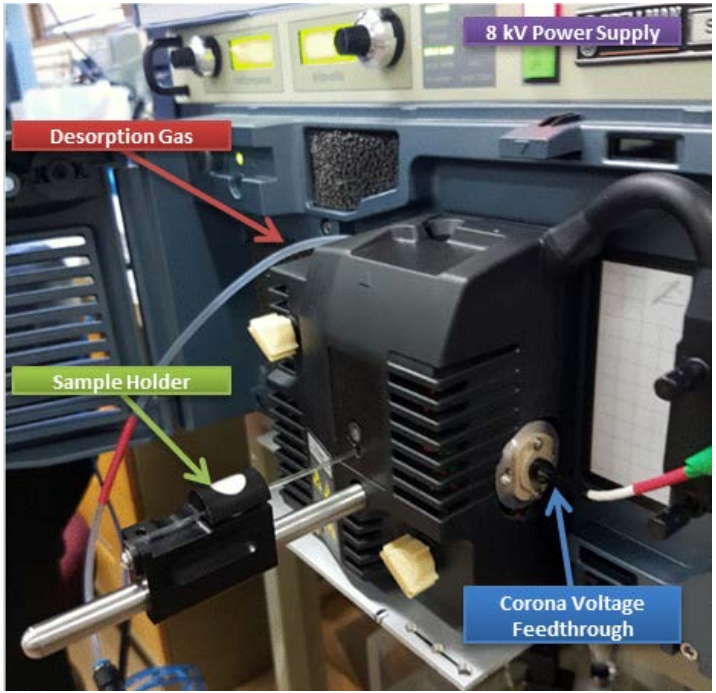
ASAP: Atmospheric Solids Analysis Probe

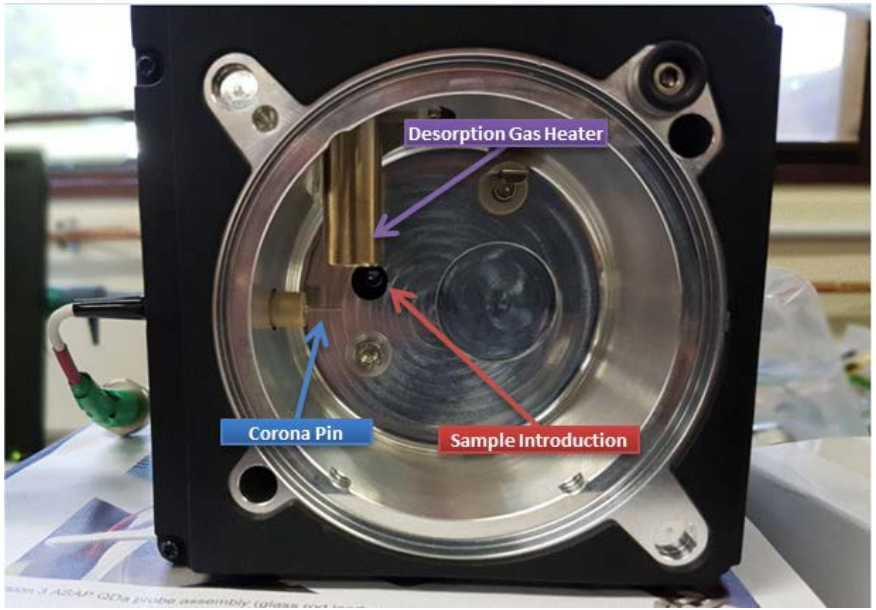
- **Sample introduced via solid probe (e.g. glass rod)**
  - > Can be solid or liquid
  - > Sampled by dipping or pipetting
- **Analytes desorbed using stream of heated nitrogen**
- **Ionisation via corona discharge**
- **Simple modification of standard APCI source**
- **Can be run using air**
- **Also available commercially (Advion, Waters, Ionsense)**



Source Modification

ASAP QDa Source Mk. III

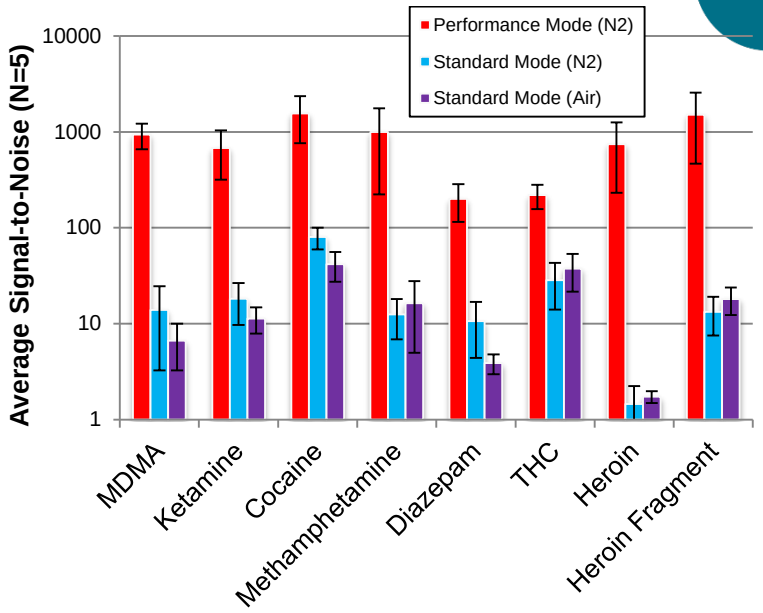




ASAP, CDI

Deployable Mode

	Performance mode	Deployable Mode
Backing Pump	Rotary Pump (floor)	Diaphragm Pump (instrument mounted)
Orifice	0.2 mm	0.09 mm
Computer	Standard Desktop	Mini-PC
Gas Supply	Lab nitrogen	Ambient air from diaphragm pump

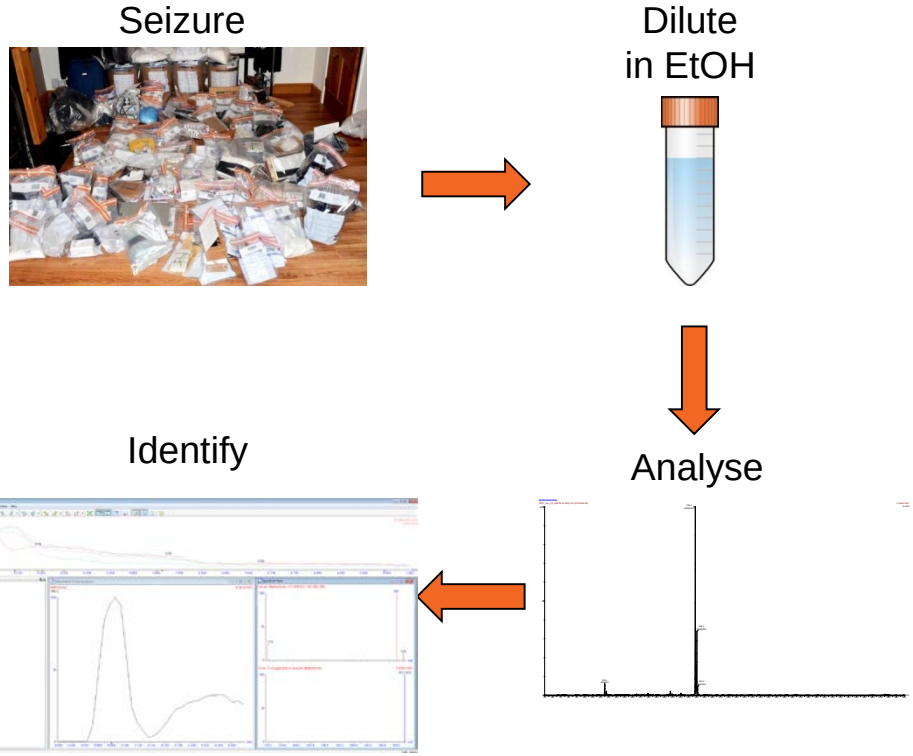


Typical LODs in deployable mode ~5 ng c.f. ~200 pg in performance mode

Drug Seizure Screening

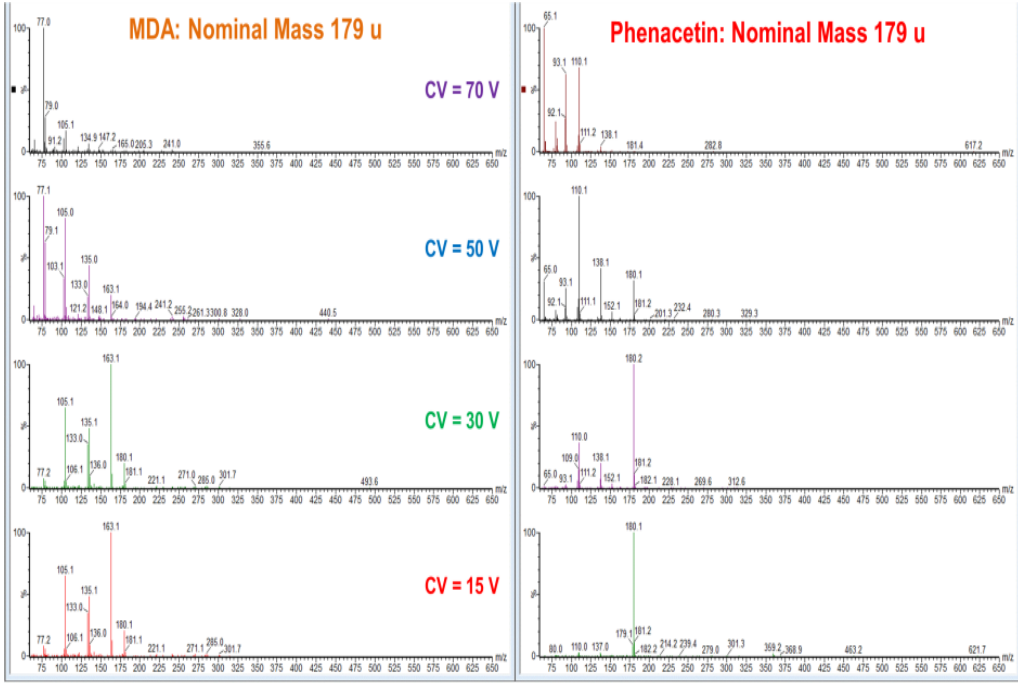
Bulk Drug Identification

- **Motivation**
  - > Speeding up charging process
  - > Complimentary technique to current processes (spot testing, IR etc…)
  - > Increased ID confidence
  - > Purity information
    - Cutting agents
    - Contamination (e.g. fentanyl)
- **Goal**
  - > Deployable solution
  - > Simple process
  - > Automated data analysis

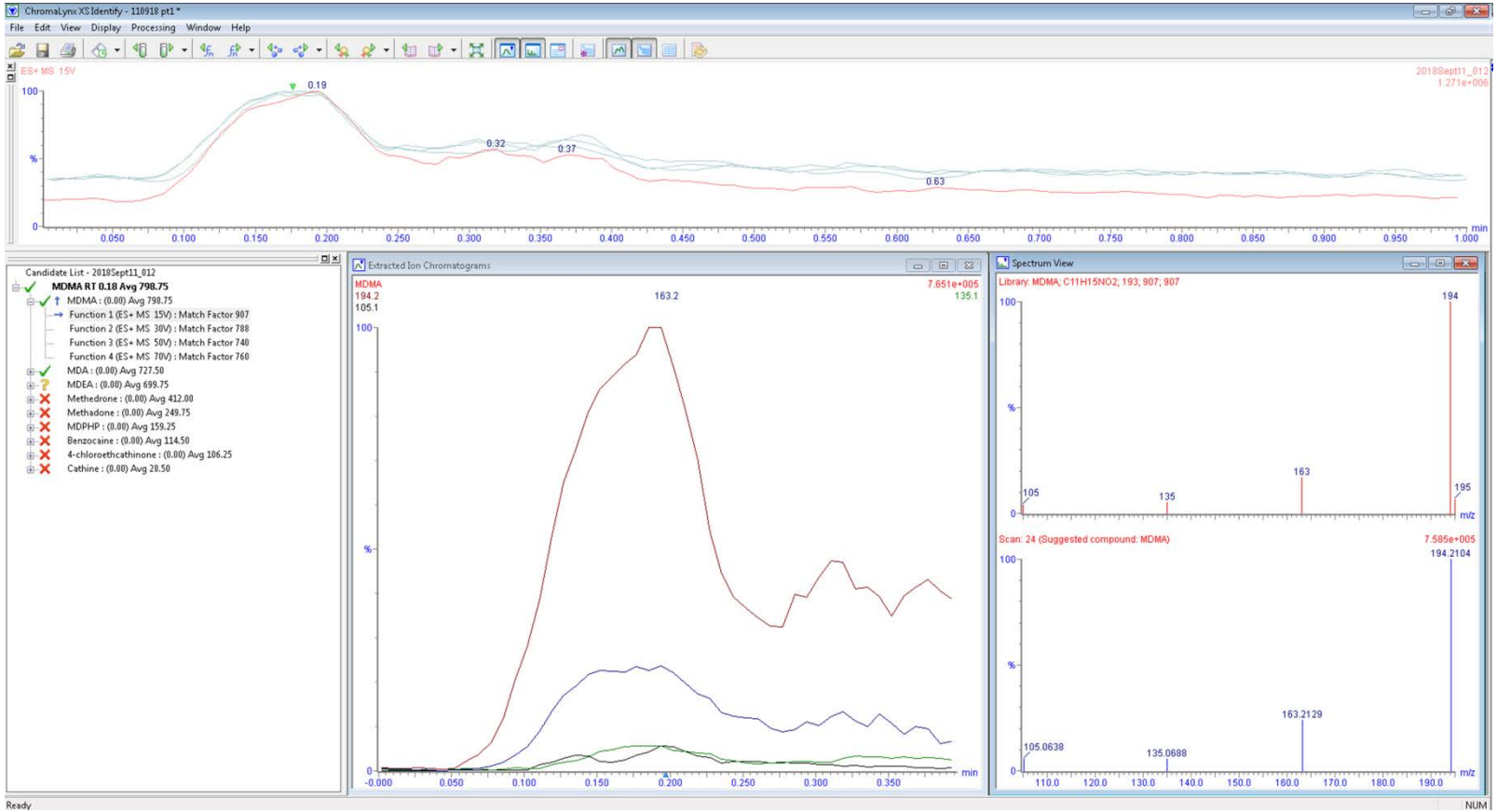


Analysis Method

- **Positive mode only**
  - > Constant voltage mode, 2.8 kV
- **Fixed Desorption Conditions**
  - > 450 °C
  - > 1 L/min air
  - > Fixed position
- **MS Method**
  - > Full scan, *m/z* 65-650
  - > 4 cone voltages
    - 10, 25, 50 and 75 V
  - > 1 minute acquisition time
- **Data Analysis using Chromalynx**
  - > In-house library built using commercial standards
  - > Current library contains 47 common drugs and cutting agents
- **Method performance assessed with real drug seizures provided by EFS**



Example 1: MDMA



Example 2: Heroin

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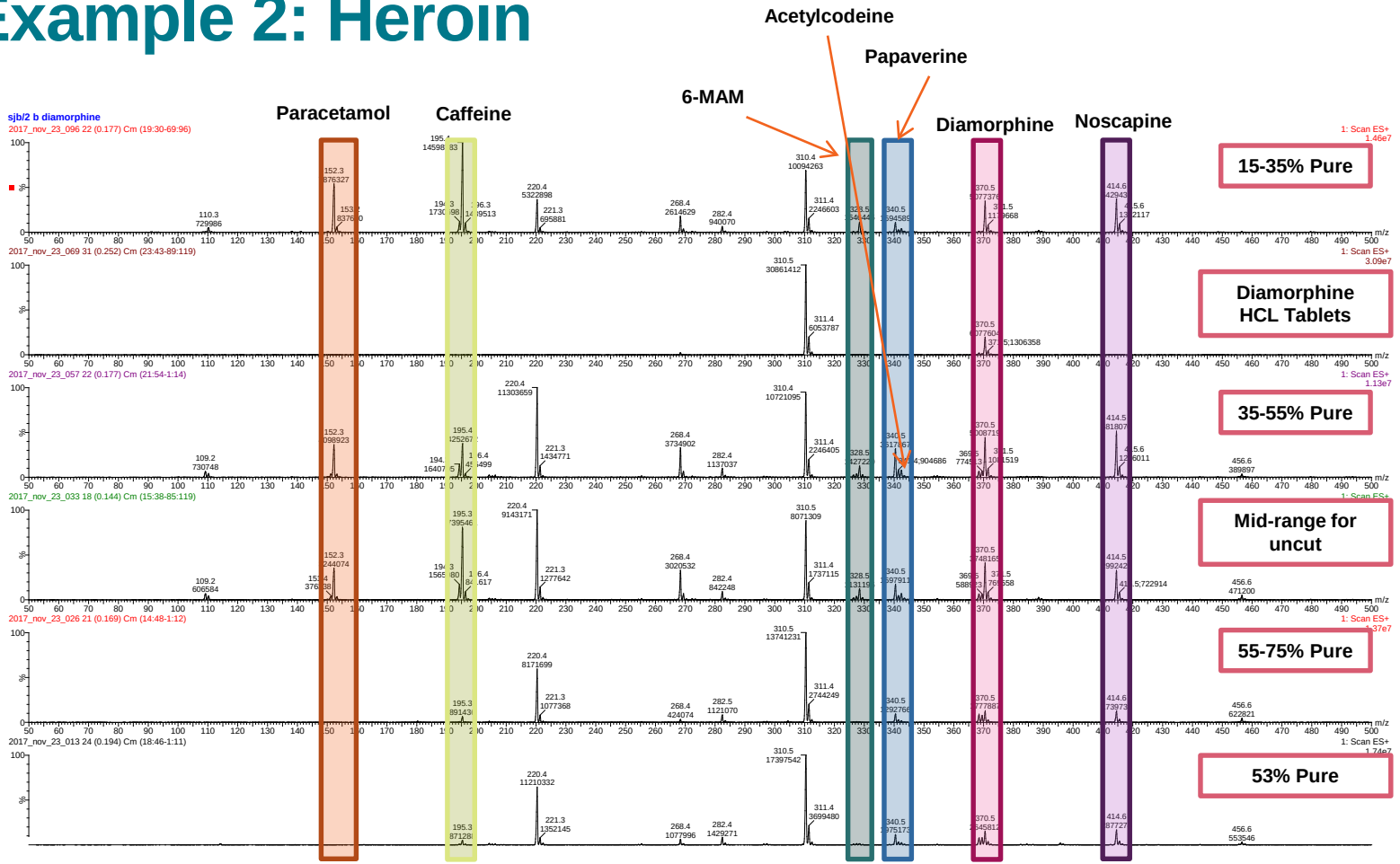
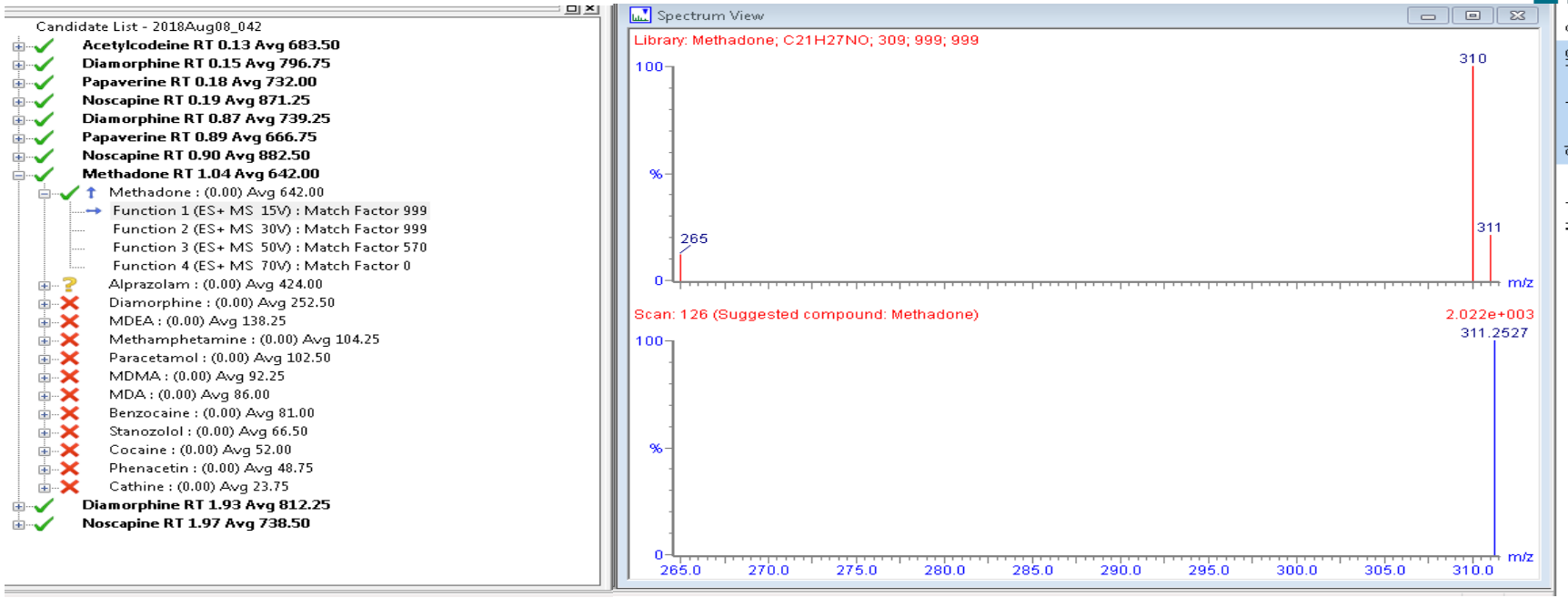


Weird things Chromalynx does…

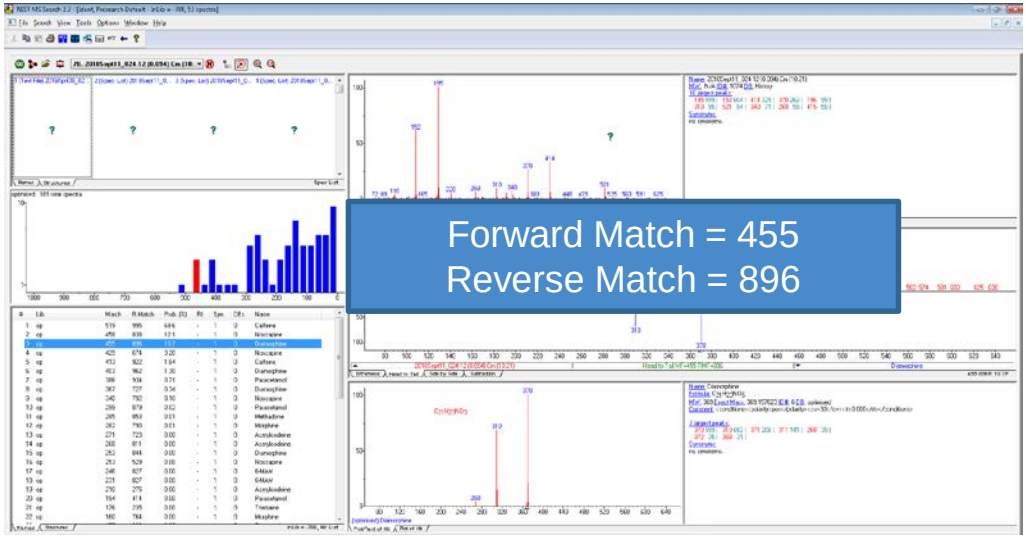


- Deconvoluted spectrum picks only isotope peak of peak of a diamorphine fragment at *m/z* 311
- scored against methadone as 999
- again at the next level and we get a strong hit.

Overall Performance

- **Chromalynx overall hit rate ~81% using current method (based on ~350 samples)**
- **False positive rate is low (~5%)**
  > Mostly hits for closely related compounds e.g. MDA for an MDMA sample
- **A better approach may be to remove deconvolution altogether and use reverse search only**

Diamorphine



Simple NIST Searching Approach

- **‘Dumb’ NIST searching approach**
  > Combine data across peak for each channel
  > No background subtraction, no deconvolution
  > Search each spectrum against Chromalynx database in NIST
  > Filter matches by cone voltage
- **Search channel 1 data, record scores for all compounds with R-Match ≥ 600**
- **Search channel 2-4 spectra and record R-match scores for all compounds identified from channel 1 search**
- **Identification criteria:**
  > Tentative: average score ≥ 600, scores in all channels ≥ 600
  > Hit: average score ≥ 700, scores in all channels ≥ 600

Example: Amphetamine

9045969	Amphetamine	Caffeine	Methamphetamine
Ch1	883	999	389
Ch2	940	973	844
Ch3	981	965	952
Ch4	896	933	936
Average	925	967.5	780.25
# >600	4	4	3

9045969	Amphetamine	Caffeine	Methamphetamine
Ch1	893	972	387
Ch2	952	966	891
Ch3	956	958	956
Ch4	856	927	894
Average	914.25	955.75	782
# >600	4	4	3

9045969	Amphetamine	Caffeine	Methamphetamine
Ch1	889	998	374
Ch2	941	971	884
Ch3	985	930	951
Ch4	902	958	842
Average	929.25	964.25	762.75
# >600	4	4	3

Only amphetamine and caffeine identified from first-pass filter (ch1≥600) so even though methamphetamine has an average score >700 in all cases it would not be counted as a hit due to the low Ch1 score

Results Summary: Amphetamines

Amphetamines

	NIST Searching				
Sample	Hit	Tentative	Miss	False Positive	False Tentative
9045969	3	0	0	0	0
9045677	3	0	0	0	0
8926574	3	0	0	0	0
8925010	3	0	0	0	0
9025133	3	0	0	0	0
8926571	3	0	0	0	0
8926575	3	0	0	0	0
8926572	3	0	0	0	0
Totals	24	0	0	0	0
%	100.0	0.0	0.0	0.0	0.0

Total	24

Caffeine cutting agent also correctly identified in all samples

- **Chromalynx Forward: 5 hits, 6 tentative, 13 misses, 3 false tentatives**
- **Chromalynx reverse: 16 hits, 7 tentatives, 1 miss, 2 false hits, 8 false tentatives**

Overall

Method	Hits	Tentative	Miss	False Positive	False Tentative
Chromalynx Forward	29	17	26	0	5
Chromalynx Reverse	45	12	13	2	11
NIST Reverse	69	0	3	12	0

‘Dumb’ NIST searching typically gives better results than either Chromlynx method.

However, the false positive rate is significantly higher than observed for the other methods.

This could be overcome by raising the thresholds used to, for example, 800 for a ‘hit’; this change would reduce the number of false positives to 1 but leave the number of hits unaffected.

Conclusions

- **Non-laboratory deployable MS system being developed**
  > Only power required for operation
- **Data is easy and quick to obtain**
  > ~1min a sample
- **Trained MS operator can quickly deduce compound**
  > Recognisable spectra for common drugs of abuse

- **Some work to do for automated identification**
  > Various approaches investigated, progress being made

Future Plans

- **Further Instrument Development**
  - > Source Mk. IV
    - Fixed geometry
    - Fixed gas flow
  - > Internal power supply
  - > Internal gas supply
- **Better Data Analysis Tools**
  - > Chromalynx
  - > LiveID
- **Deployment of ASAP QDa for drug seizures**
  - > Forensics laboratory (late 2018)
  - > Police forensics hubs (early 2019)

- **Application Development**
  - > Food
  - > Clinical
  - > Environmental
  - > Process monitoring

Acknowledgements

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