RuG

HCI interactions with molecules - Molecules and clusters in strong fields

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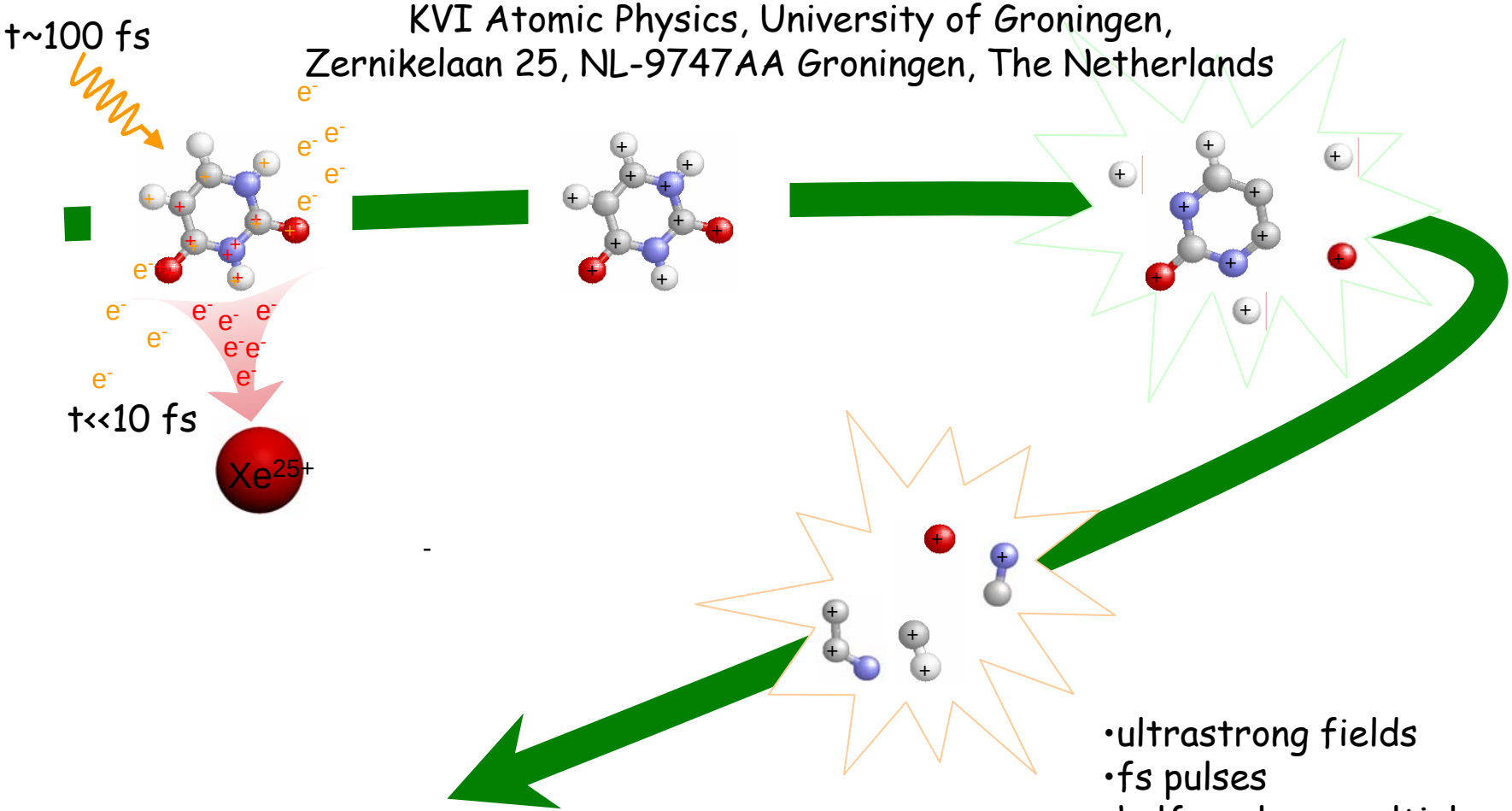


- ultrastrong fields
- fs pulses
- half-cycle vs multiple cycles

HCI induced ionization/fragmentation: influence of the target electronic structure

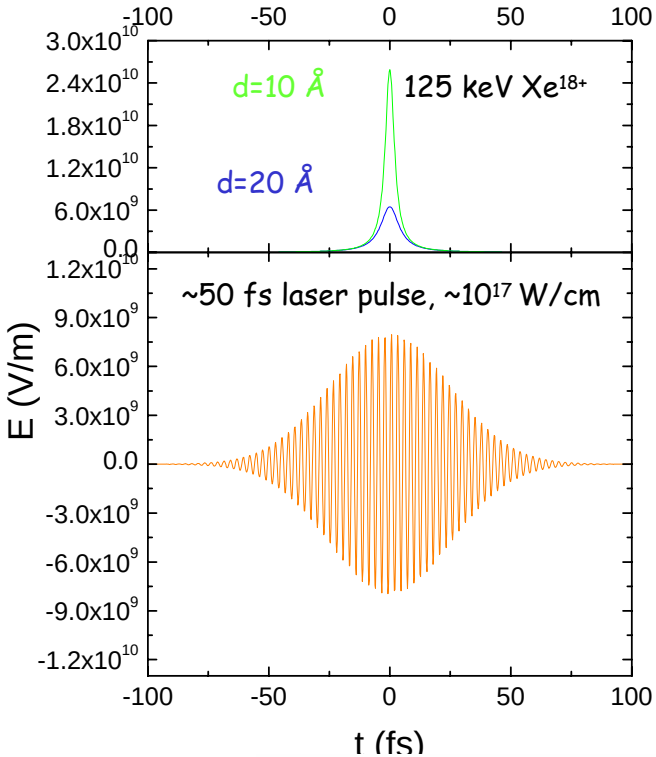
- metallic bonds – delocalized electrons
  (e.g. fullerenes, Na-clusters)
  - charge equilibration before fragmentation
  - few multiply charged atomic fragments

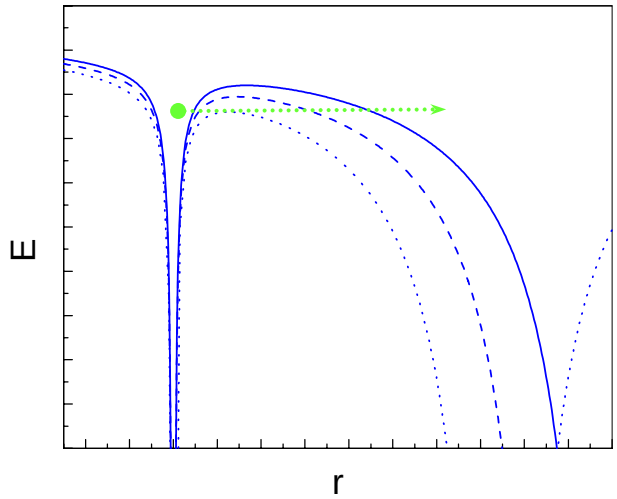
- van der Waals bond – localized electrons
  (e.g. Ar-clusters)
  - strong charge localization
  - highly charged fragments coinciding with singly charged fragments

- covalent bond – intermediate
  (e.g. S-clusters)
  - data under evaluation

- here: polyatomic (bio)molecules

laser and ion-induced fields

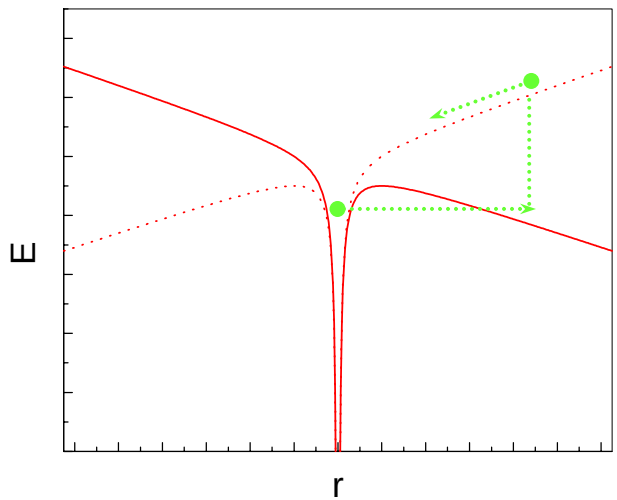




HCI

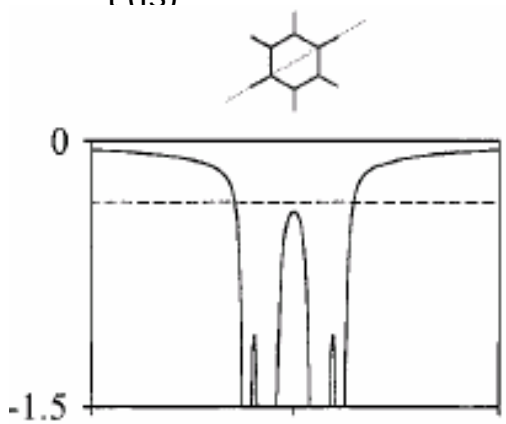
- "half cycle" or "DC" field
- overbarrier ionization
- ion charge state changes during interaction

- several 10 cycles, "AC" field
- overbarrier and tunnel ionization
- recollisions



fs-laser

molecule:

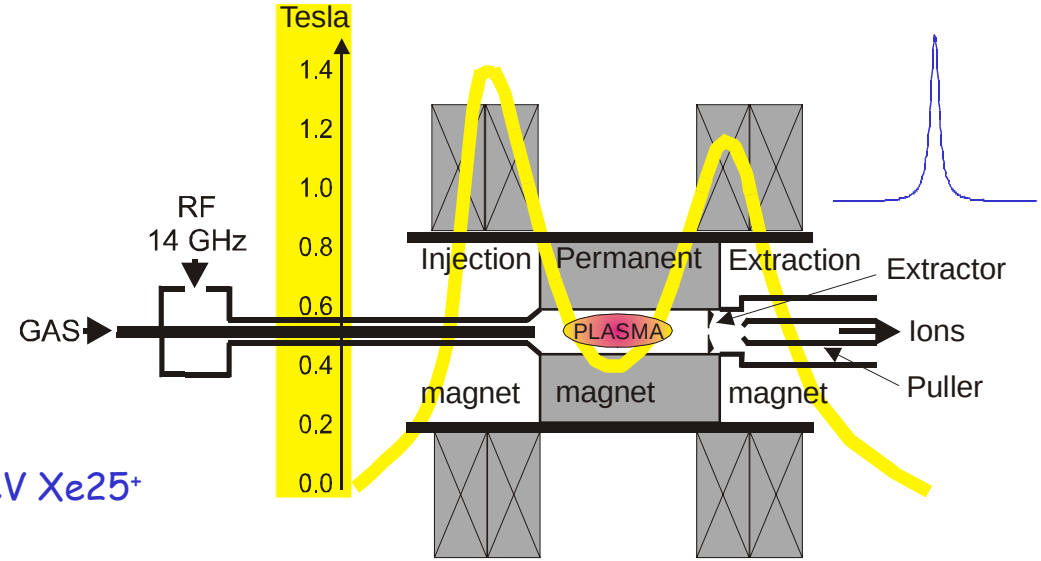


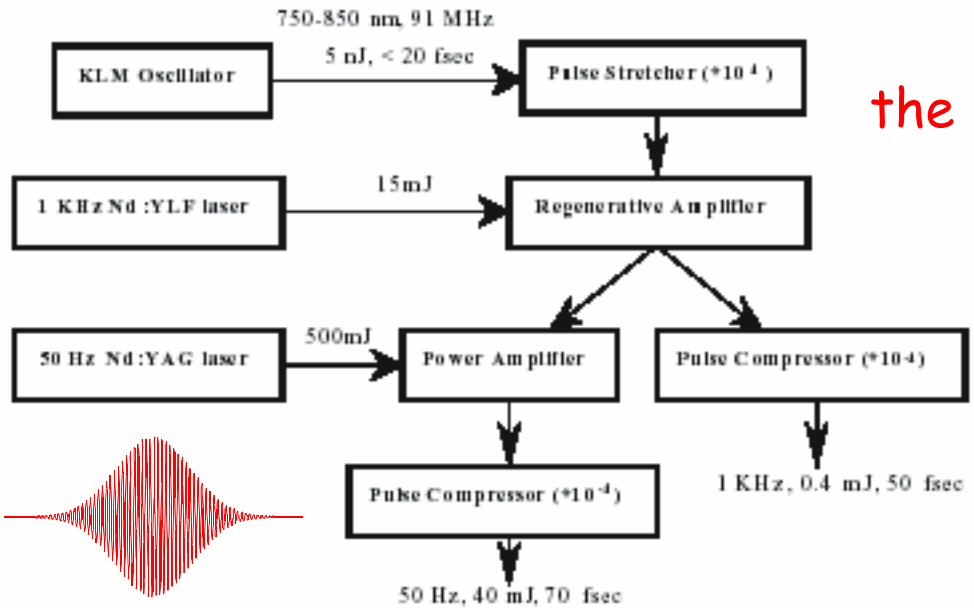
strong field generation

until now:
the KVI 14 GHz ECR source

- 14 GHz ECR source
- source potential 1kV to 25 kV
- He^+ - $Xe30^+$
- typical fast HCI beam: ~100 nA @ 0.5 MeV $Xe25^+$

soon HITRAP

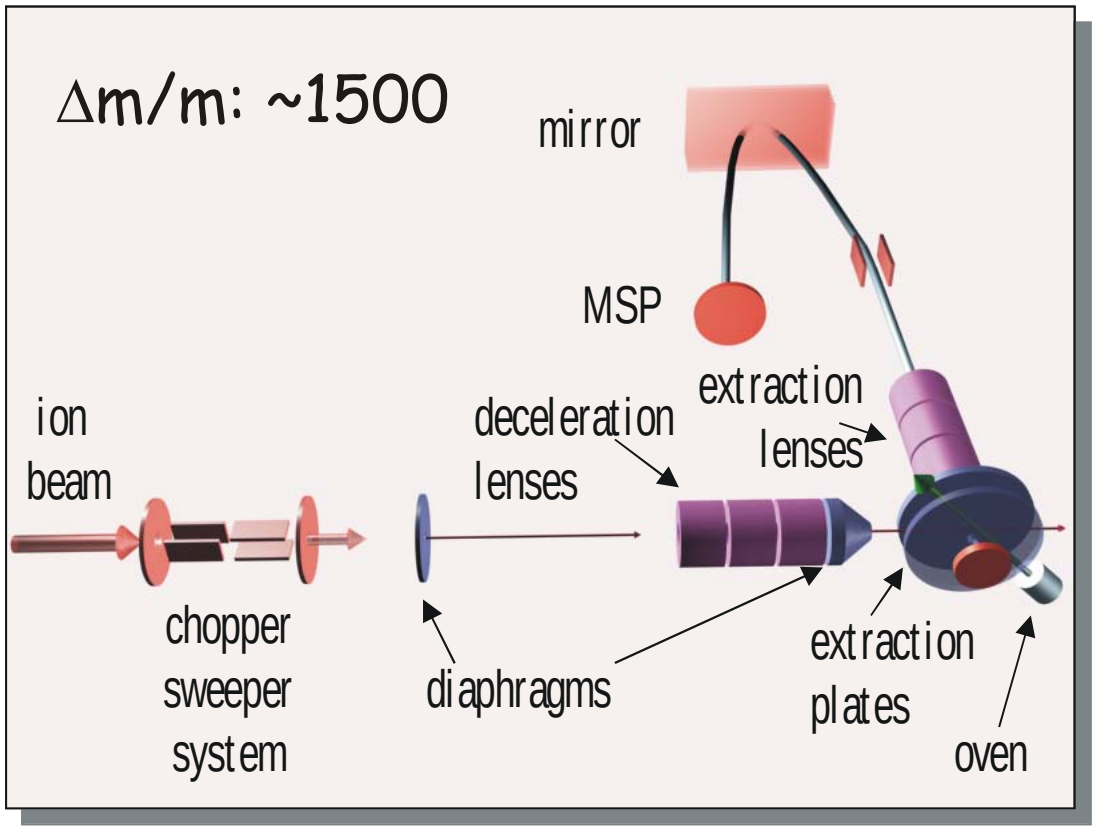




the AMOLF TeraWatt fs-laser system

- chirped pulse amplification
- typically ~10 mJ @ 100 fs / 50 Hz
- 1 cm beam diameter focused to ~ 10 μm
- typical maximum fields of ~ 5 x 10^{17} W/cm^2

setup



HCI induced collisions:

-fragment ion detection in event by event mode
(FAST P7888 TDC, 1 ns resolution)

-electron-fragment-fragment coincidences

under construction
reaction microscope for fragment ions
(for coincident multi-fragment detection)

laser induced collisions:

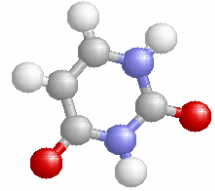
-fragment ion detection in analog mode
(HP Infinium digital storage scope, 1 GHz,1 ns res.)

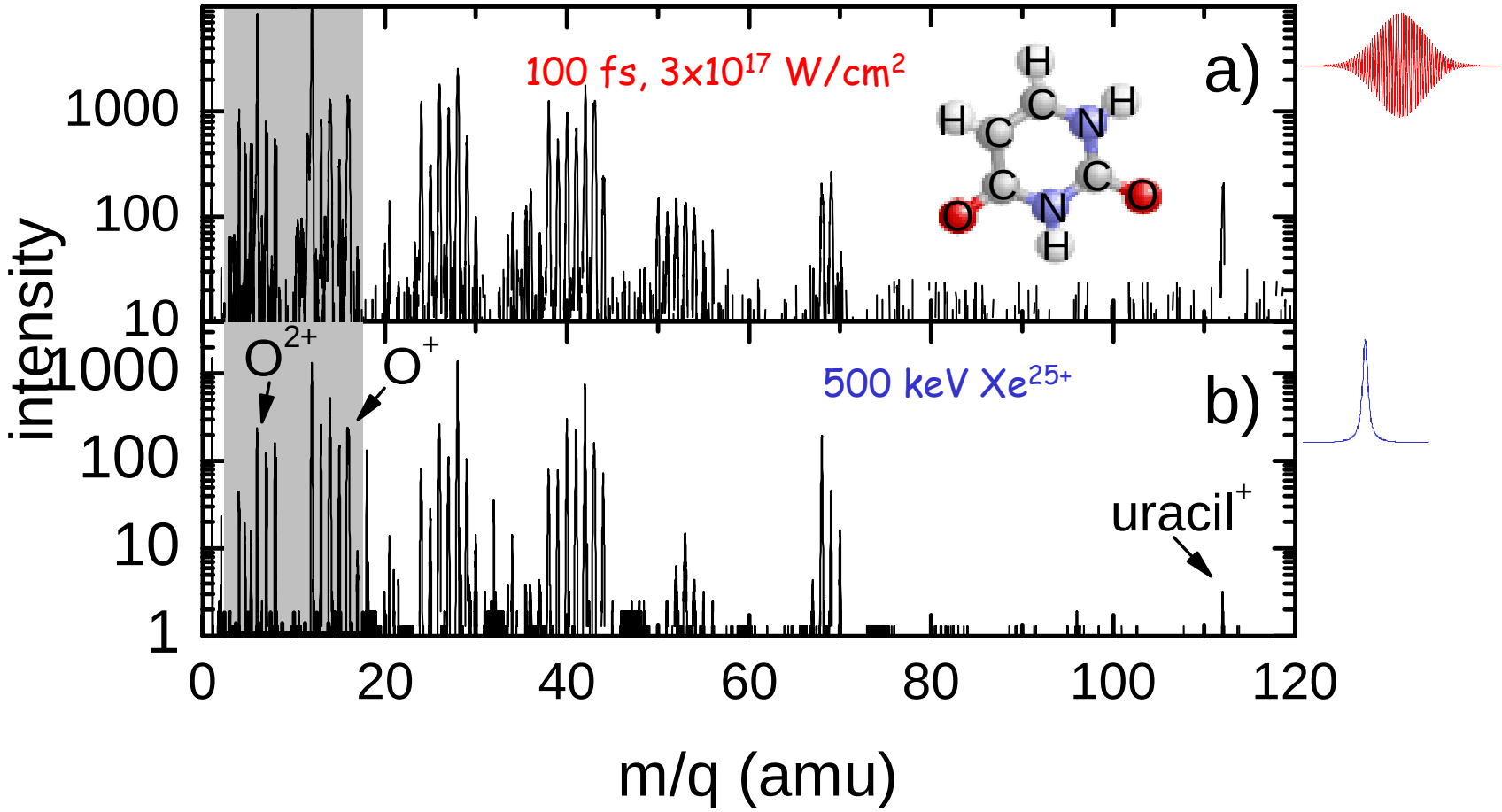
-only "singles" spectra

-no coincidence information

-additional parameter: laser polarization

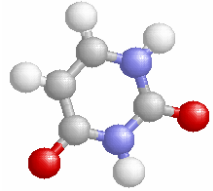
uracil mass spectra – HCI vs fs-laser

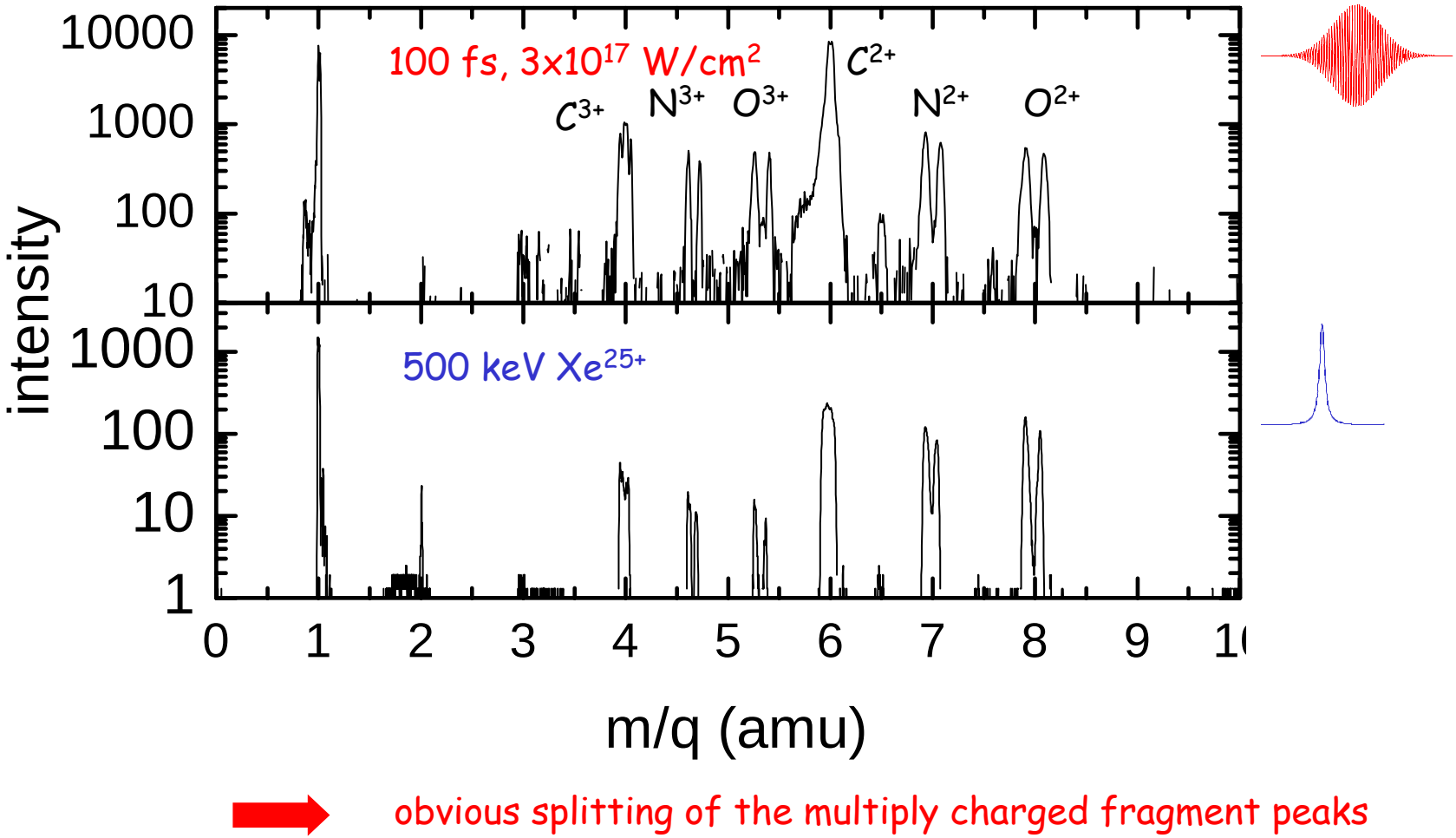




similar pattern for fs-laser and HCI

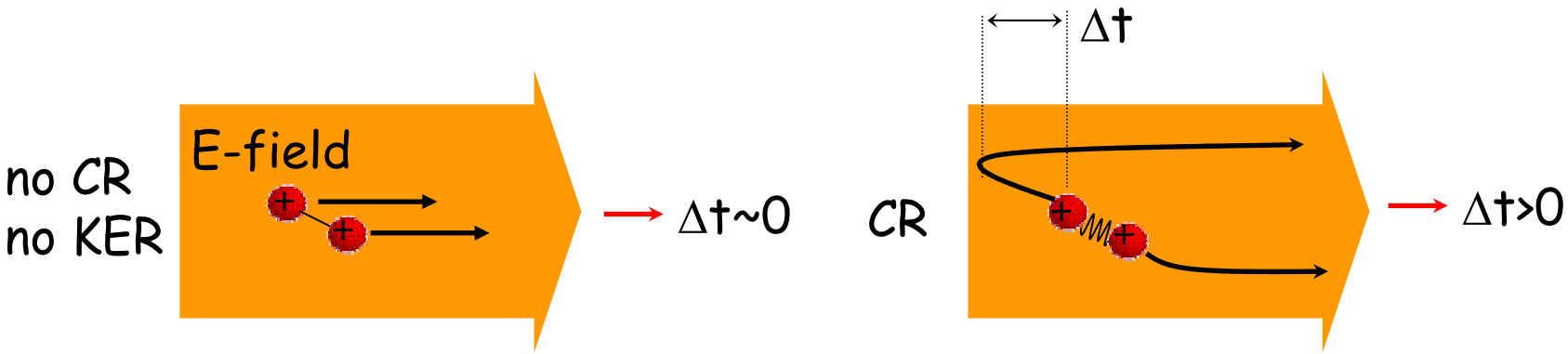
uracil mass spectra – HCI vs fs-laser (zoom)





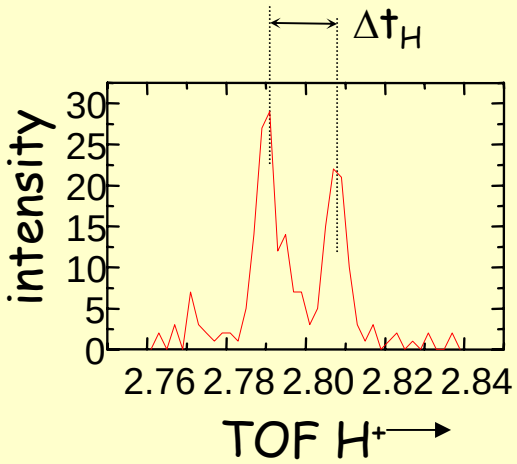
obvious splitting of the multiply charged fragment peaks

kinetic energy release – two bodies

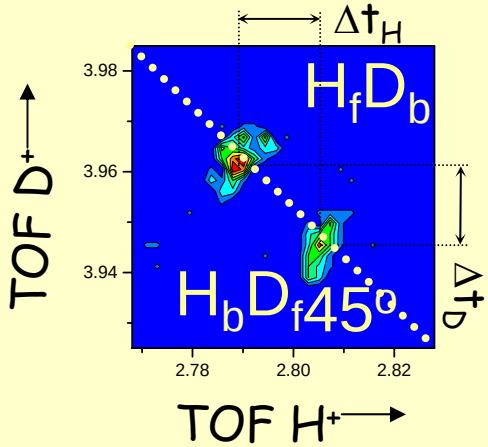


HD^{++} fragmentation

e^--ion coincidences

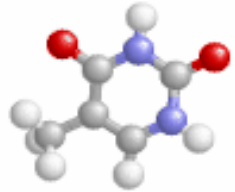


e^-- ion-ion coincidences

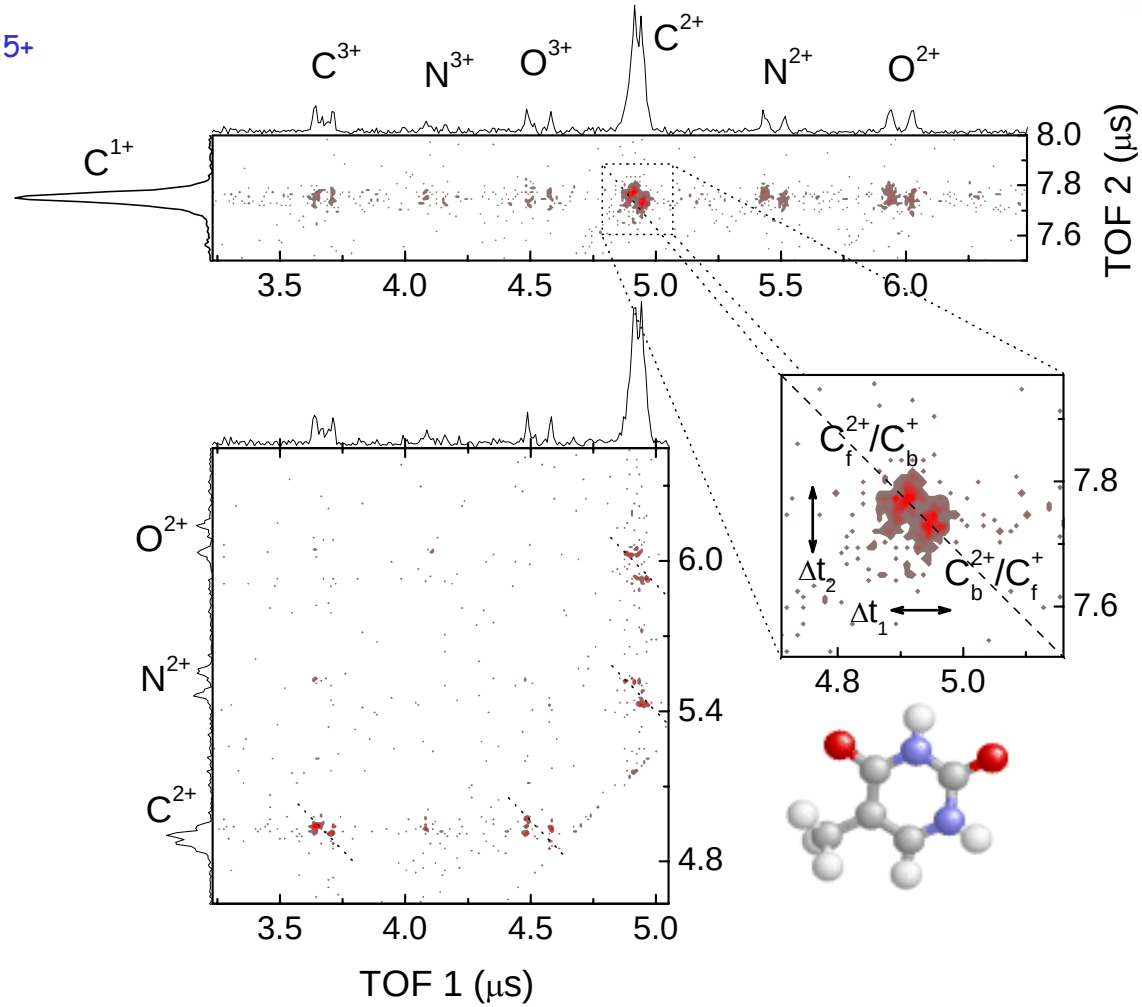


KER~19 eV
H forward/D backward
or
H backward/D forward

KER in the HCI case -coincidences



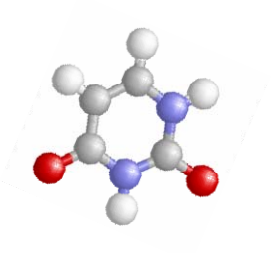
500 keV Xe^{25+}



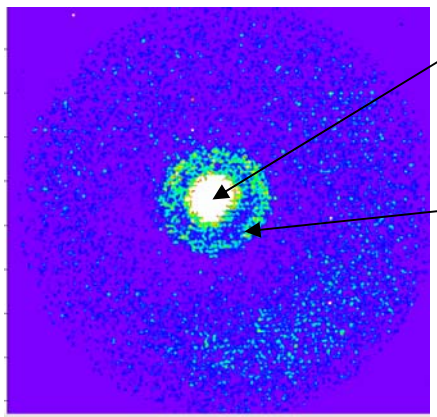
- "symmetric" fragmentation only for C^+/C^{2+}
- no full charge equilibration, e.g. C^+ with O^{3+}!

→ strong geometry effects!

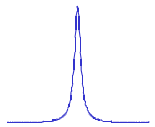
KER in the fs-laser case – velocity map imaging

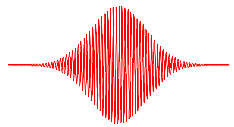


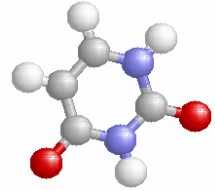
velocity map image of m=68 uracil fragment @ 40 mW, 100 fs



fragment kinetic energies

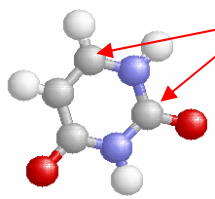


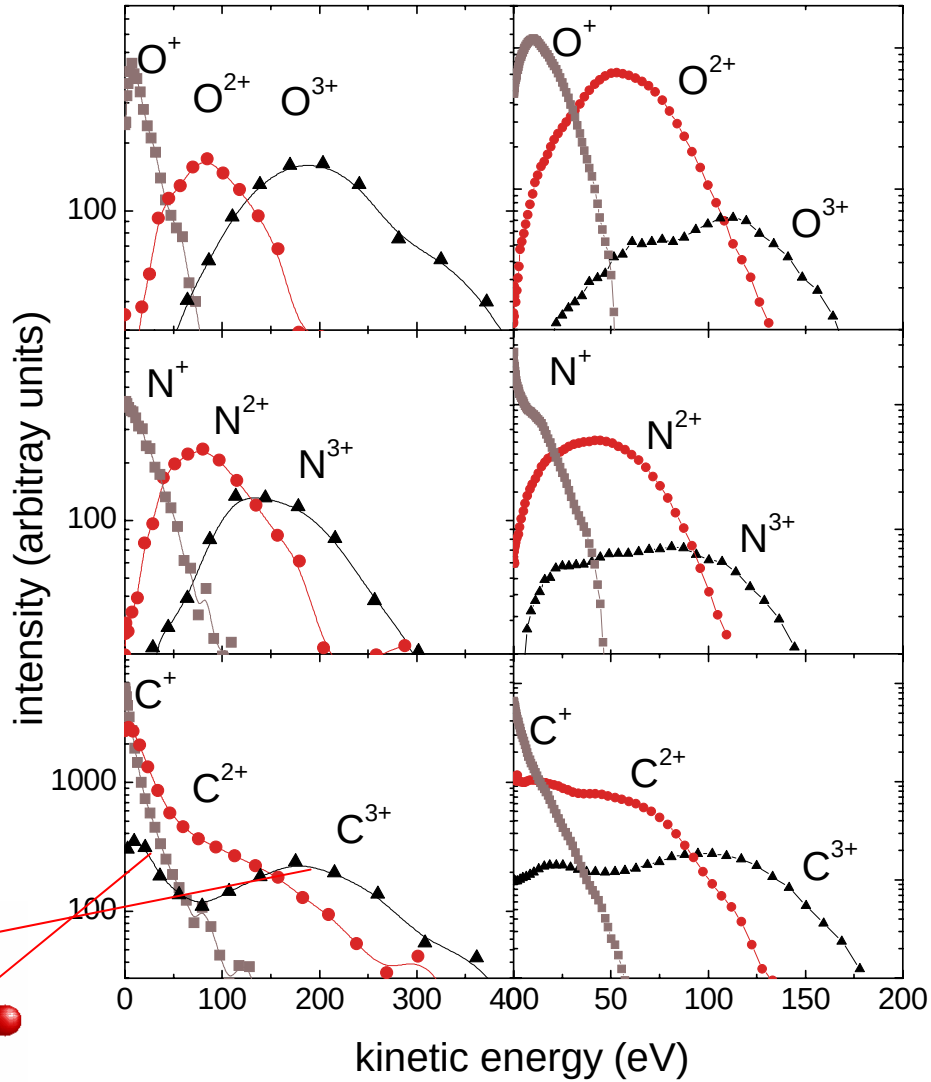




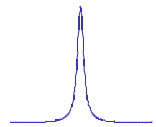
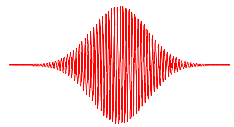
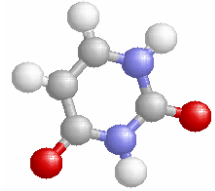
ion	E^{ion} peak	E^{ion} max	E^{laser} peak	E^{laser} max	E^{laser}/E^{ion} peak
O^{1+}	7.3	56	10	46	82%
O^{2+}	85	175	53	97	55%
O^{3+}	187	383	111	162	42%
N^{1+}	0	55	11	31	56%
N^{2+}	77	182	42	86	47%
N^{3+}	144	280	79	141	50%
C^{1+}	0	15	0	11	73%
C^{2+}	85	214	44	95	44%
C^{3+}	176	335	97	160	48%

q>1: E^{ion}(laser)~ 0.5 E^{ion}(ion)





simulation results

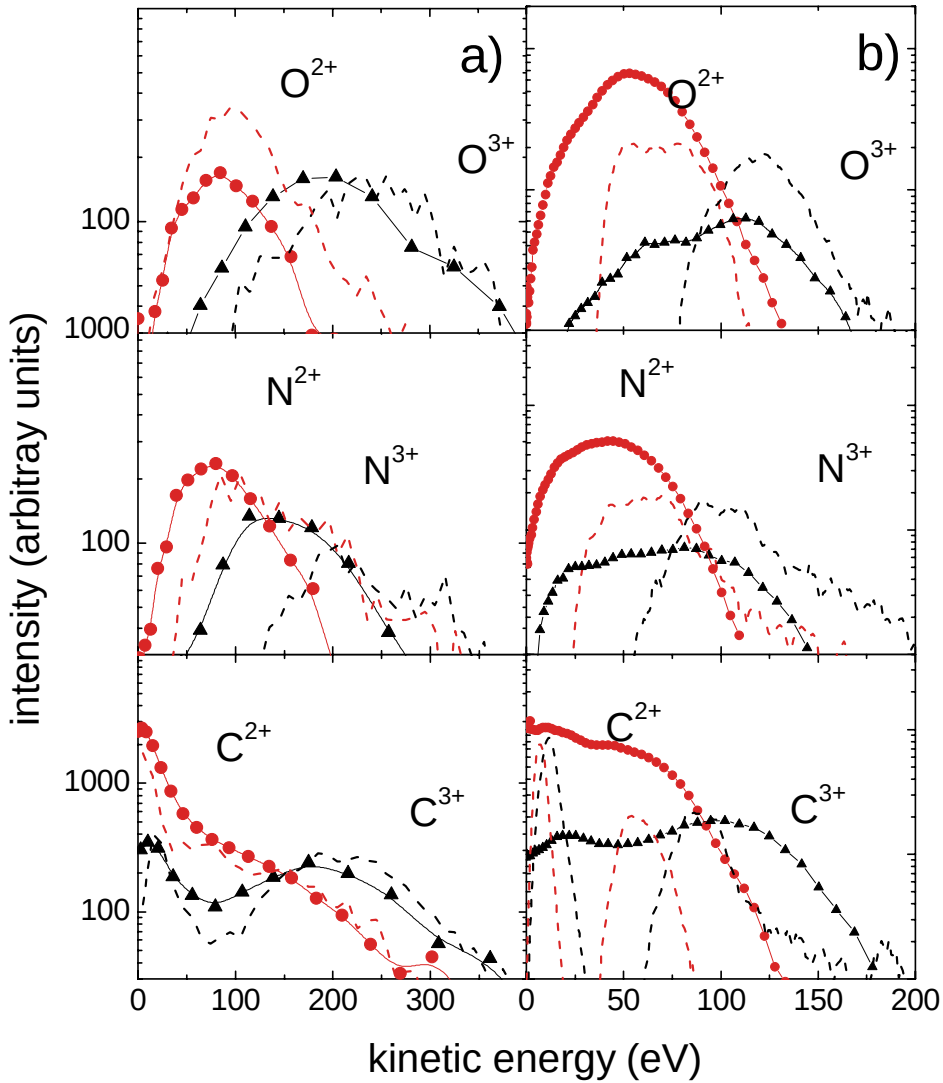




- interaction between charged particles
- soft-core Coulomb potential
- geometry taken from *ab initio* calc.
- outermost e^- placed into Coulomb well

- time dependent external dipole field
- moving Xe^{25+} ions (point charge)
- tunneling according to ADK model
- re-collisions allowed

newton's equations are num. solved

- propagation of the system until interaction becomes negligible



future perspectives for HCI –cluster/molecule interactions

two important issues:

1. need for kinematically more complete data

   reaction microscope + multicoincidence capabilities

2. ongoing fragmentation research with XFEL pulses

   need for VERY highly charged ions at various collisions energies for comparison

Both issues could be combined in future HITRAP experiments !

thanks

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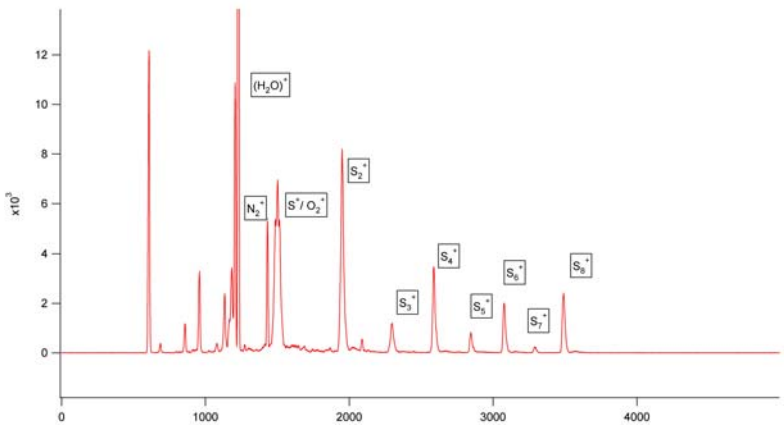
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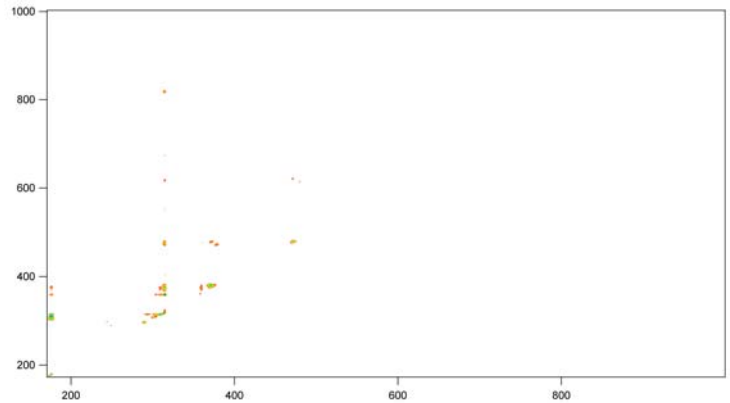
S5+
S6+
S7+
S8+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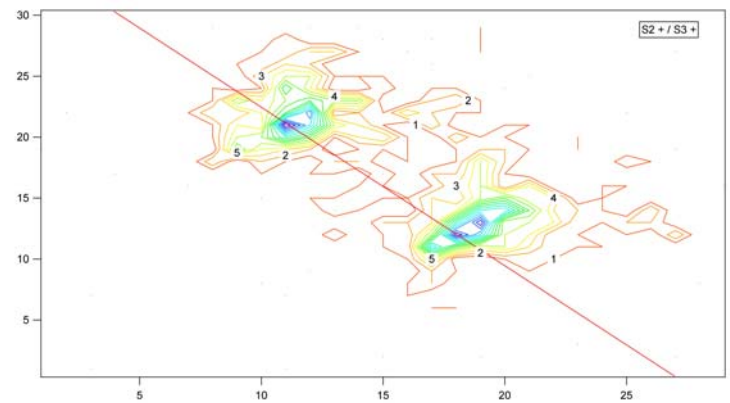
S2 + / S3 +
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