Frequency Comb Assisted IR Measurements of H_3^+, H_2D^+ and D_2H^+ Transitions

Pavol Jusko, Oskar Asvany, Stephan Schlemmer

1. Physikalisches Institut
Zülpicher Straße 77
50937 Köln

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COLTRAP and FELion (and photoshop)

Outline

- COLTRAP in Cologne
- ro-vibrational spectroscopy
- rotational spectroscopy

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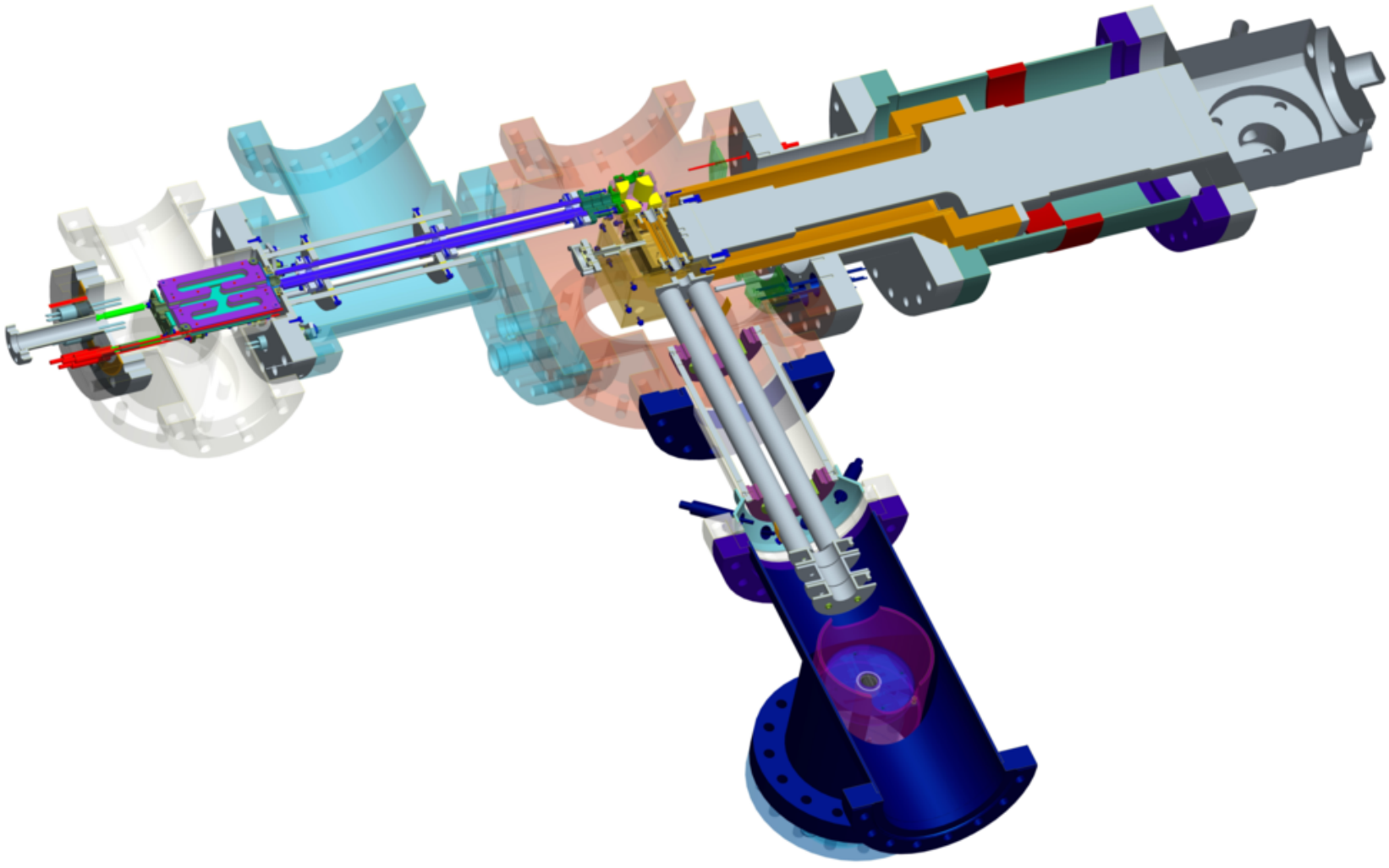
COLTRAP



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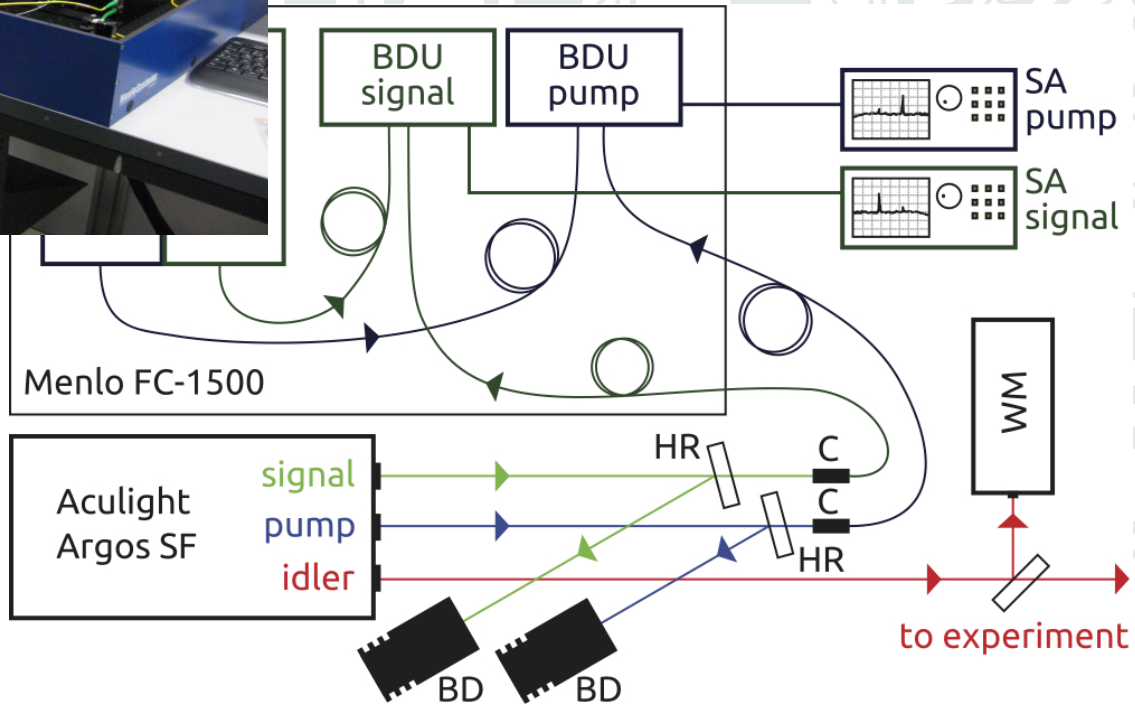
Frequency Comb and 22-pole Trap



Asvany Rev. Sci. Instrum 83, 093110 (2012)

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LIR and LIICG of H_3^+

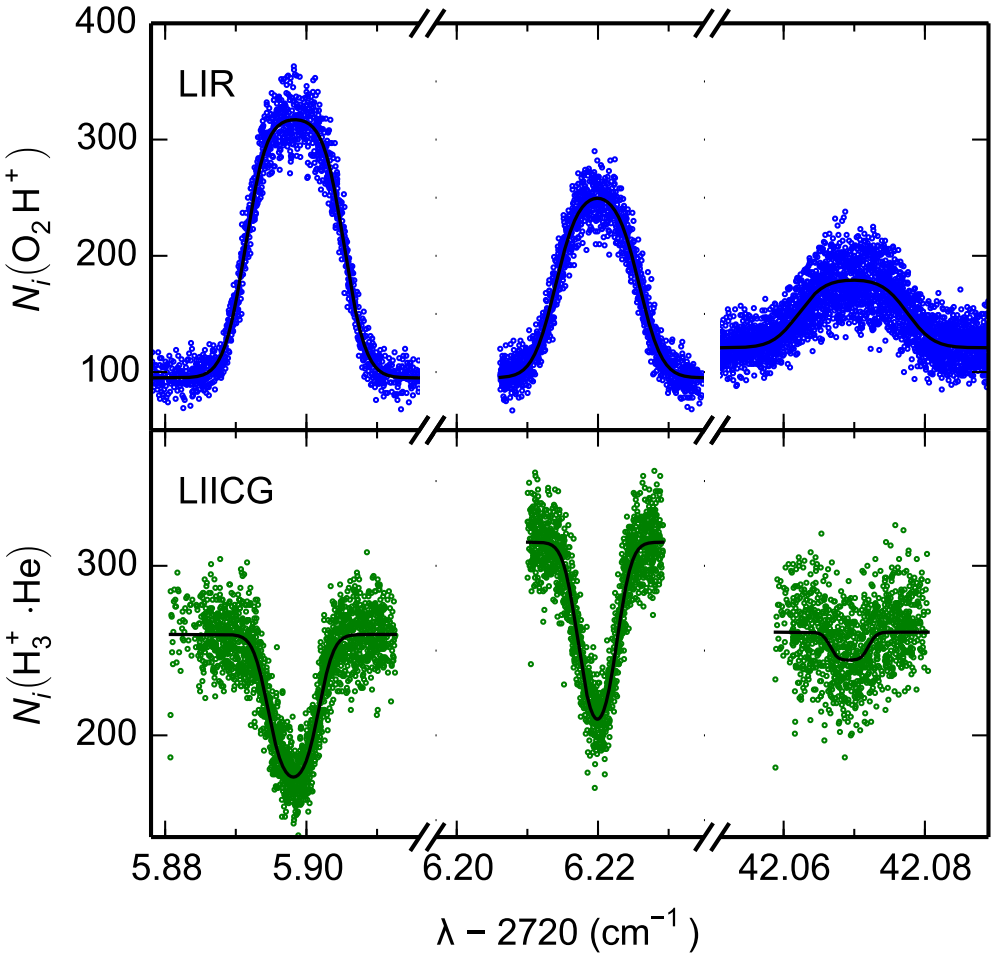
Suitable reaction:

- $H_3^+ + O_2 \rightarrow O_2H^+ + H_2$
- $T_a \approx 170$ K
- $T_i \approx 20$ K

- $T_i \ll 20$ K

LIICG: Chakrabarty JPCL 4, 4051 (2013)

Spectrum ν_2 band:



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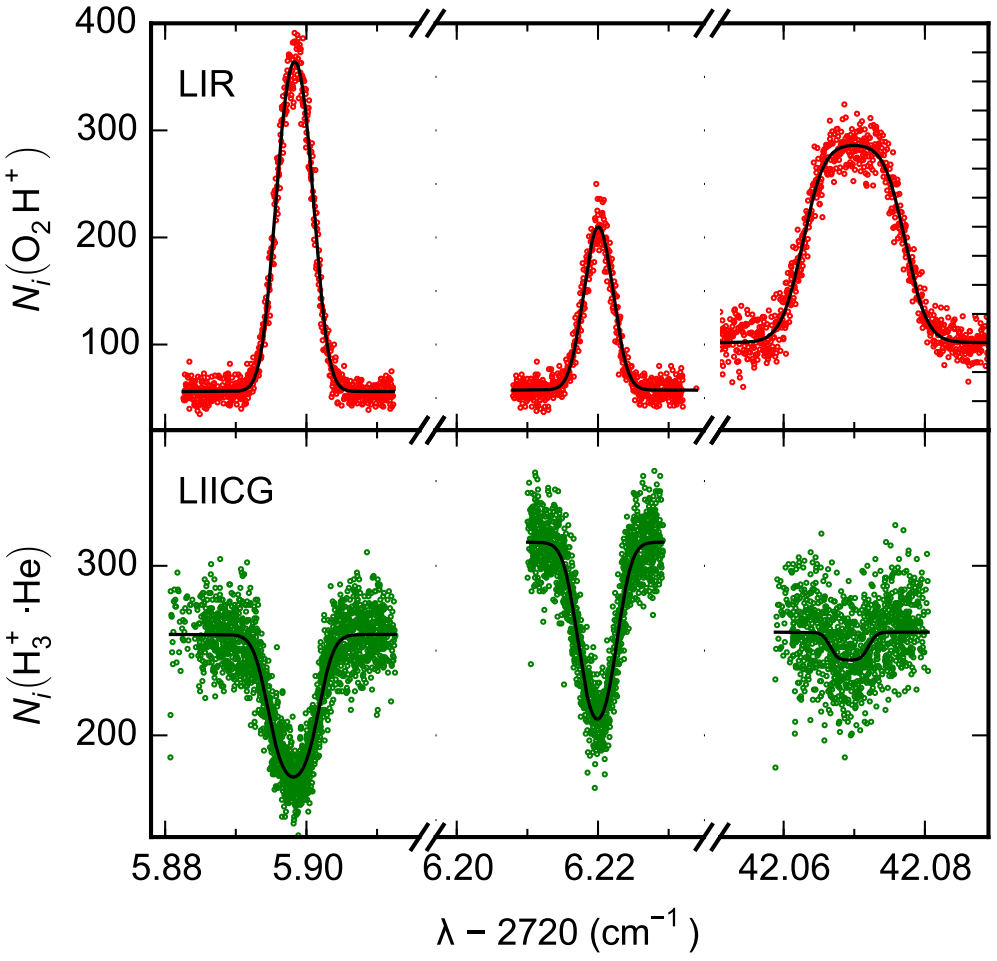
LIR and LIICG of H_3^+ Revised

Suitable reaction:

- $H_3^+ + O_2 \rightarrow O_2H^+ + H_2$
- $T_a \approx 170$ K
- $T_i \approx 20$ K

- $T_i \ll 20$ K

Spectrum ν_2 band:



LIICG: Chakrabarty JPCL 4, 4051 (2013)
H_3^+: Jusko J.Mol.Spec 319, 55 (2016)

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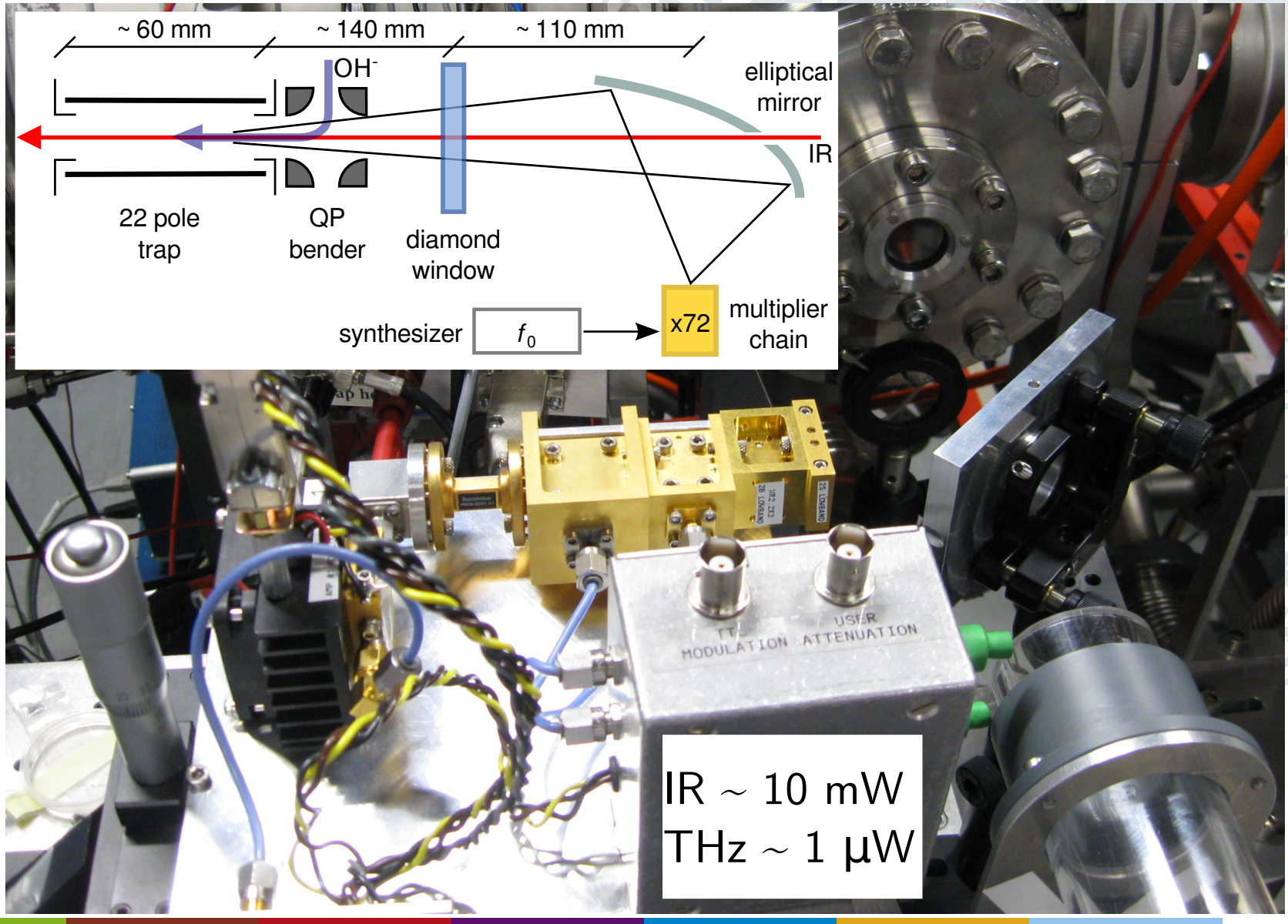
LIR and LIICG of H_3^+

Different results between different groups:

MHz	R(1,0)	R(1, 1)^u	R(2, 2)^l
Hodges JCP, (2013)	81720377.29	81730020.44	82804769.99
Shy (2013)	81720371.55	81730028.33	82804761.12
This work 2013	81720376.57	81730019.99	82804770.08

MHz	R(1,0)	R(1, 1)^u	R(2, 2)^l
Hodges JCP, (2013)	81720377.29(23)	81730020.44(38)	82804769.99(31)
Shy (priv.)	81720376.14(18)	81730019.95(28)	82804769.75(33)
This work 2016	81720376.62(11)	81730019.82(20)	82804769.99(65)

Two Photon Process (IR + THz Photon)



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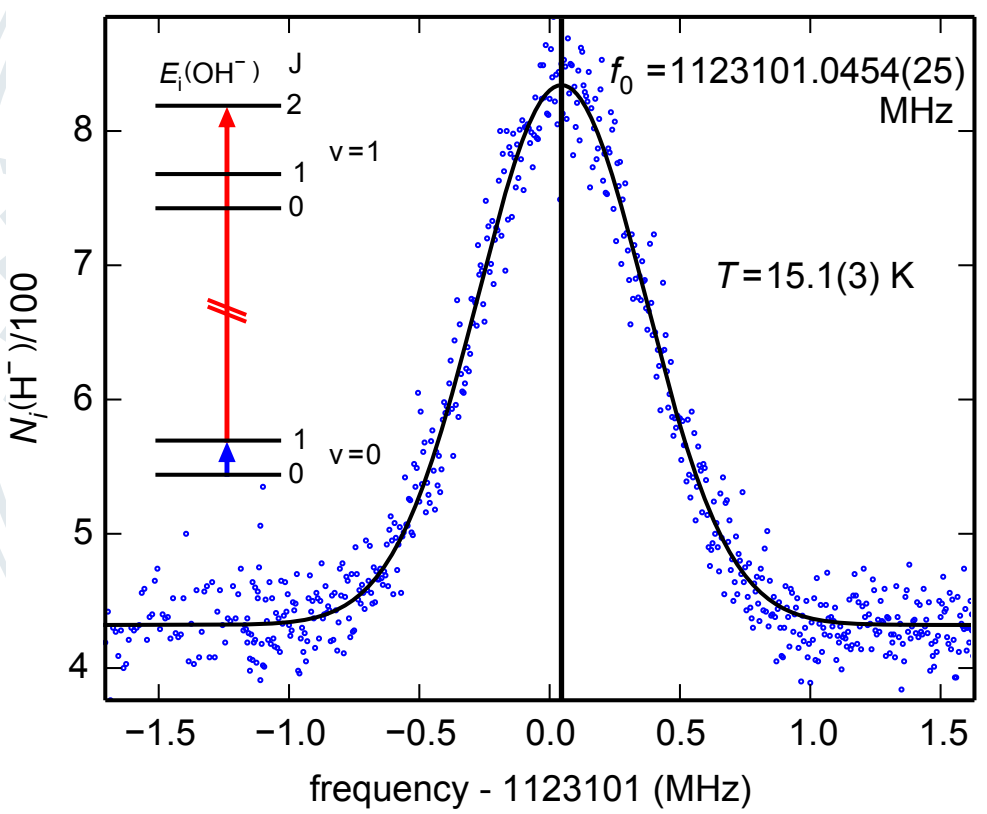
Two Photon Process: OH^- $J = 1 \leftarrow 0$ Transition

Sequence:

1. $OH^- (\nu = 0, J = 0) + h\nu_1 \rightarrow$
   $OH^- (\nu = 0, J = 1)$
2. $OH^- (\nu = 0, J = 1) + h\nu_2 \rightarrow$
   $OH^- (\nu = 1, J = 1)$
3. $OH^- (\nu = 1, J = 1) + H_2 \rightarrow$
   $H^- + H_2O$

$h\nu_1$ – THz photon
$h\nu_2$ – NIR photon



this work	1123101.0410(14) MHz
prev. work	1123100.985(324) MHz

Jusko PRL 112, 253005 (2014)
Matshushima JMS 235, 261 (2006)

Combination Differences – Prediction of Pure Rotational Transitions

H_2D^+:

Type	Transition	MHz	Ref.
prediction	$2_{12} \leftarrow 1_{11}$	2363241.71(70)	
measurement		2363242.82(69)	Yonezu JMS 256 2009
prediction	$2_{02} \leftarrow 1_{01}$	2576756.5(16)	
measurement		2576756.6(10)	Amano PTRS A 364 2006
prediction	$2_{11} \leftarrow 1_{10}$	3102324.2(35)	
measurement		3102329.28(56)	Yonezu JMS 256 2009

D_2H^+:

Type	Transition	MHz	Ref.
prediction	$2_{02} \leftarrow 1_{11}$	1572823.78(76)	
prediction	$2_{12} \leftarrow 1_{01}$	2258688.28(80)	

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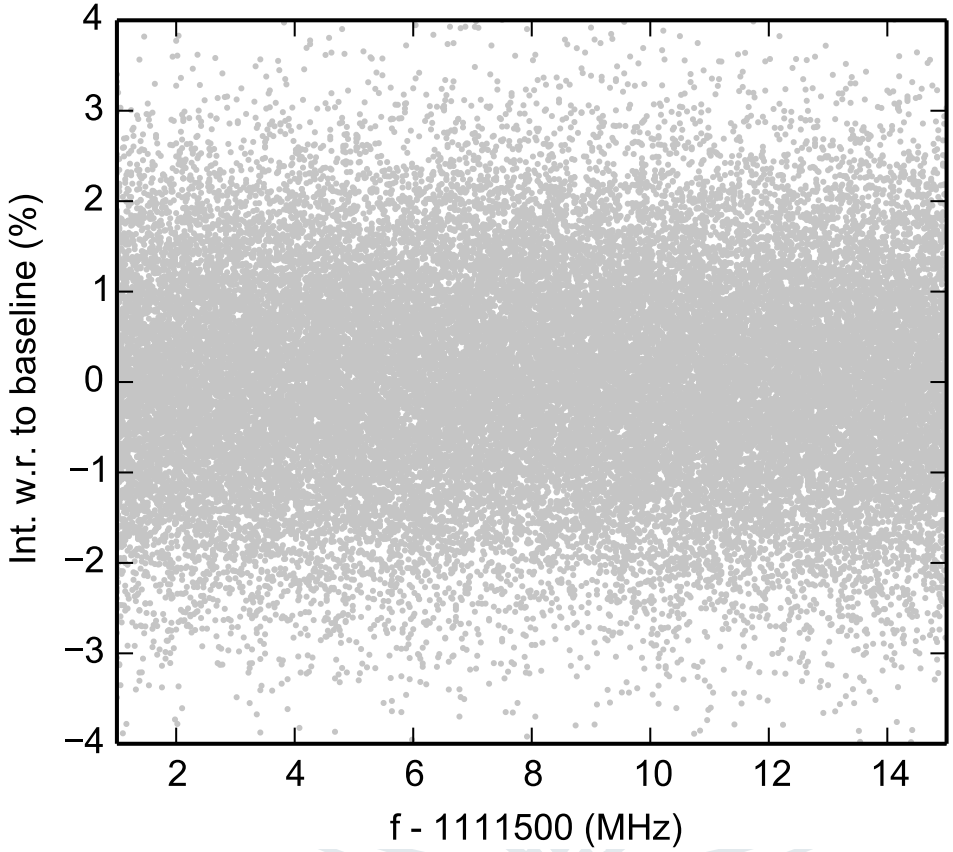
Two Photon Process:

Sequence:

1. $H_2D^+(2_{12}) + h\nu_1 \rightarrow$
   $H_2D^+(2_{11})$
2. $H_2D^+(\nu = 0, 2_{11}) + h\nu_2 \rightarrow$
   $H_2D^+(\nu = 1, 1_{10})$
3. $H_2D^+(\nu = 1, 1_{10}) + H_2 \rightarrow$
   $H_3^+ + HD$

$h\nu_1$ – THz photon
$h\nu_2$ – NIR photon



Prediction (CDMS) 1111509.2 MHz

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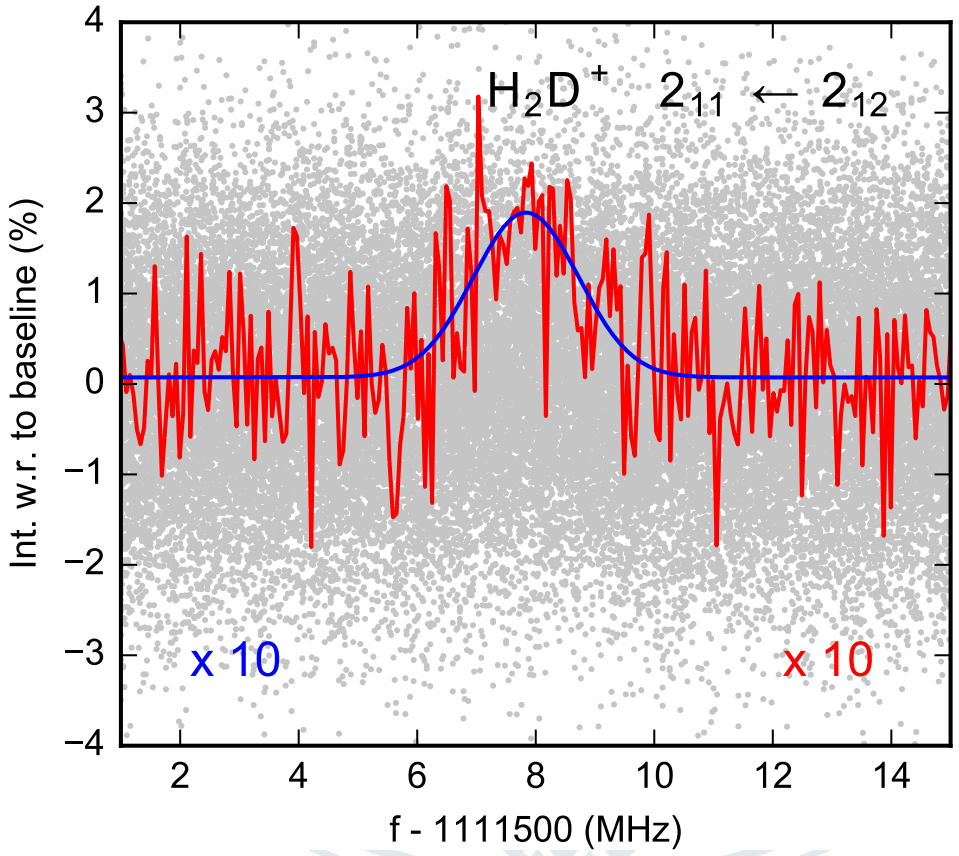
Two Photon Process: H_2D^+ $2_{11} \leftarrow 2_{12}$

Sequence:

1. $H_2D^+(2_{12}) + h\nu_1 \rightarrow$
   $H_2D^+(2_{11})$
2. $H_2D^+(\nu = 0, 2_{11}) + h\nu_2 \rightarrow$
   $H_2D^+(\nu = 1, 1_{10})$
3. $H_2D^+(\nu = 1, 1_{10}) + H_2 \rightarrow$
   $H_3^+ + HD$

$h\nu_1$ – THz photon
$h\nu_2$ – NIR photon

Center position ± 100 kHz



Prediction (CDMS) 1111509.2 MHz

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Cologne Group

$$$:
DFG,
SFB 965,
Alexander von Humboldt

Thanks:
Cologne workshop

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Thank You for Your Attention