MOCCA – an MMC based 4k pixels molecule camera for studying electron-ion interactions at the Cryogenic Storage Ring CSR



K. Blaum, O. Novotný, S. Spaniol, A. Wolf Max Planck Institute for Nuclear Physics, Heidelberg, Germany

S. Allgeier, C. Enss, A. Fleischmann, L. Gamer, L. Gastaldo, <u>S. Kempf</u>, D. Schulz *Kirchhoff-Institute for Physics, Heidelberg University, Germany*

18th International Workshop on Low Temperature Detectors 22-26 July, 2019 – Milano, Italy

Session: LM004 – Low Temperature Detector Applications

MOCCA – an MMC based 4k pixels molecule camera for studying electron-ion interactions at the Cryogenic Storage Ring CSR



K. Blaum, O. Novotný, S. Spaniol, A. Wolf Max Planck Institute for Nuclear Physics, Heidelberg, Germany

S. Allgeier, C. Enss, A. Fleischmann, L. Gamer, L. Gastaldo, <u>S. Kempf</u>, D. Schulz *Kirchhoff-Institute for Physics, Heidelberg University, Germany*

18th International Workshop on Low Temperature Detectors 22-26 July, 2019 – Milano, Italy

Session: LM004 – Low Temperature Detector Applications

stars born by the collapse of interstellar gas clouds that are made mostly of hydrogen

stars born by the collapse of interstellar gas clouds that are made mostly of hydrogen

but: "complex" molecules observed

2 atoms	3 atoms	4 atoms	5 atoms	6 atoms	7 atoms	8 atoms	9 atoms	10 atoms	11 atoms	12 atoms	>12 atoms
H ₂	C ₃ *	c-C ₃ H	C ₅ *	C₅H	C ₆ H	CH ₃ C ₃ N	CH ₃ C ₄ H	CH ₃ C ₅ N	HC ₉ N	c-C ₆ H ₆ *	HC ₁₁ N
AIF	C ₂ H	4C₃H	C4H	/H₂C₄	CH ₂ CHCN	HC(O)OCH ₃	CH ₃ CH ₂ CN	(CH ₃) ₂ CO	CH₃C ₆ H	n-C ₃ H ₇ CN	C ₆₀ *
AICI	C ₂ O	C3N	C ₄ Si	C ₂ H ₄ *	CH₃C₂H	СН₃СООН	(CH ₃) ₂ O	(CH ₂ OH) ₂	C₂H₅OCHO	∔C ₃ H ₇ CN 2014	C ₇₀ *
C2**	C ₂ S	C3O	AC₃H₂	CH3CN	HC5N	C ₇ H	CH ₃ CH ₂ OH	CH ₃ CH ₂ CHO	CH3OC(O)CH3	C ₂ H ₅ OCH ₃ ?	C ₆₀ +*
СН	CH ₂	C3S	c-C ₃ H ₂	CH3NC	СН ₃ СНО	C ₆ H ₂	HC ₇ N				
CH⁺	HCN	C ₂ H ₂ *	H ₂ CCN	СН₃ОН	CH ₃ NH ₂	CH ₂ OHCHO	C ₈ H				
CN	НСО	$\rm NH_3$	CH ₄ *	CH₃SH	c-C ₂ H ₄ O	/HC ₆ Η*	CH ₃ C(O)NH ₂				
со	HCO+	HCCN	HC ₃ N	HC3NH+	H ₂ CCHOH	CH ₂ CHCHO (?)	C ₈ H−				
CO+	HCS+	HCNH ⁺	HC ₂ NC	HC ₂ CHO	C ₆ H⁻	CH ₂ CCHCN	C ₃ H ₆				
СР	HOC+	HNCO	нсоон	NH ₂ CHO	CH ₃ NCO 2015	H ₂ NCH ₂ CN	CH ₃ CH ₂ SH (?)				
SiC	H ₂ O	HNCS	H ₂ CNH	C ₅ N		CH3CHNH					
HCI	H ₂ S	HOCO+	$H_{2}C_{2}O$	/HC₄H*							
KCI	HNC	H ₂ CO	H ₂ NCN	/HC₄N					cologn	e database	(excerpt)

stars born by the collapse of interstellar gas clouds that are made mostly of hydrogen

but: "complex" molecules observed



stars born by the collapse of interstellar gas clouds that are made mostly of hydrogen

but: "complex" molecules observed

reaction network of early universe chemistry



stars born by the collapse of interstellar gas clouds that are made mostly of hydrogen

but: "complex" molecules observed

reaction network of early universe chemistry



dominant processes:

ion-neutral reactions dissociative recombination neutral – neutral reaction photon induced reaction

$AB^+ + C \longrightarrow$	AC+ + B
$AB^+ + e^- \longrightarrow$	A + B
$AB + C \longrightarrow$	AC + B
$AB^+ + hv \longrightarrow$	A+ + B

investigating dissociative recombination rate coefficients

interaction of molecule ions inside storage ring with collinear electron beam

example: dissociative recombination of HeH⁺



rate coefficient for dissociative recombination of HeH⁺



electronic, vibrational and rotational energy levels of molecules

Hydrogen Molecule



W. Kolos *et al.*, J. Chem. Phys. **43**, 1965

rate coefficient for DR of $\rm HeH^{\scriptscriptstyle +}$



Cryogenic Storage Ring CSR

electrostatic ion storage ring designed, built and commissioned at Max Planck Institute for Nuclear Physics (MPIK) in Heidelberg



Cryogenic Storage Ring CSR



mass spectrometry

mass determination through measurement of kinetic energy



mass spectrometry with MMCs



mass resolution of one atomic mass unit

O. Novotný et al., J. Appl. Phys. 118, 104503 (2015)

mass spectrometry with MMCs



mass resolution of one atomic mass unit

degradation of measured linewidth due to energy loss varying from event to event



effect inherent to any detector using massive absorbers

MOCCA – 4k pixels MMC based molecule camera



single sensor cell of MOCCA



two-dimensional readout scheme



in total: 16 + 16 SQUIDs



absorber readout

target: four-headed hydra with target rise times of 4 µs, 8 µs, 20 µs, and 80 µs





measured rise times of $1 \mu s$, $5 \mu s$, $15 \mu s$, and $60 \mu s$

demonstration of readout scheme



demonstration of readout scheme





MOCCACINO

spectrum of single sensor (column coincident with row)



what's next? - MOCCA @ CSR



what's next? - MOCCA @ CSR



what's next? - MOCCA @ CSR



conclusion and outlook

- laboratory astrophysics to reveal chemistry in interstellar clouds
 - **Cryogenic storage ring CSR**
 - MOCCA 4k pixels molecule camera
 - what's next?
 - software, system integration
 - end 2020: MOCCA at ion source of CSR (dedicated setup)
 - mid 2021: installation of MOCCA at CSR

conclusion and outlook

- laboratory astrophysics to reveal chemistry in interstellar clouds
 - **Cryogenic storage ring CSR**
 - MOCCA 4k pixels molecule camera
 - what's next?
 - software, system integration
 - end 2020: MOCCA at ion source of CSR (dedicated setup)
 - mid 2021: installation of MOCCA at CSR