



Introductory remarks

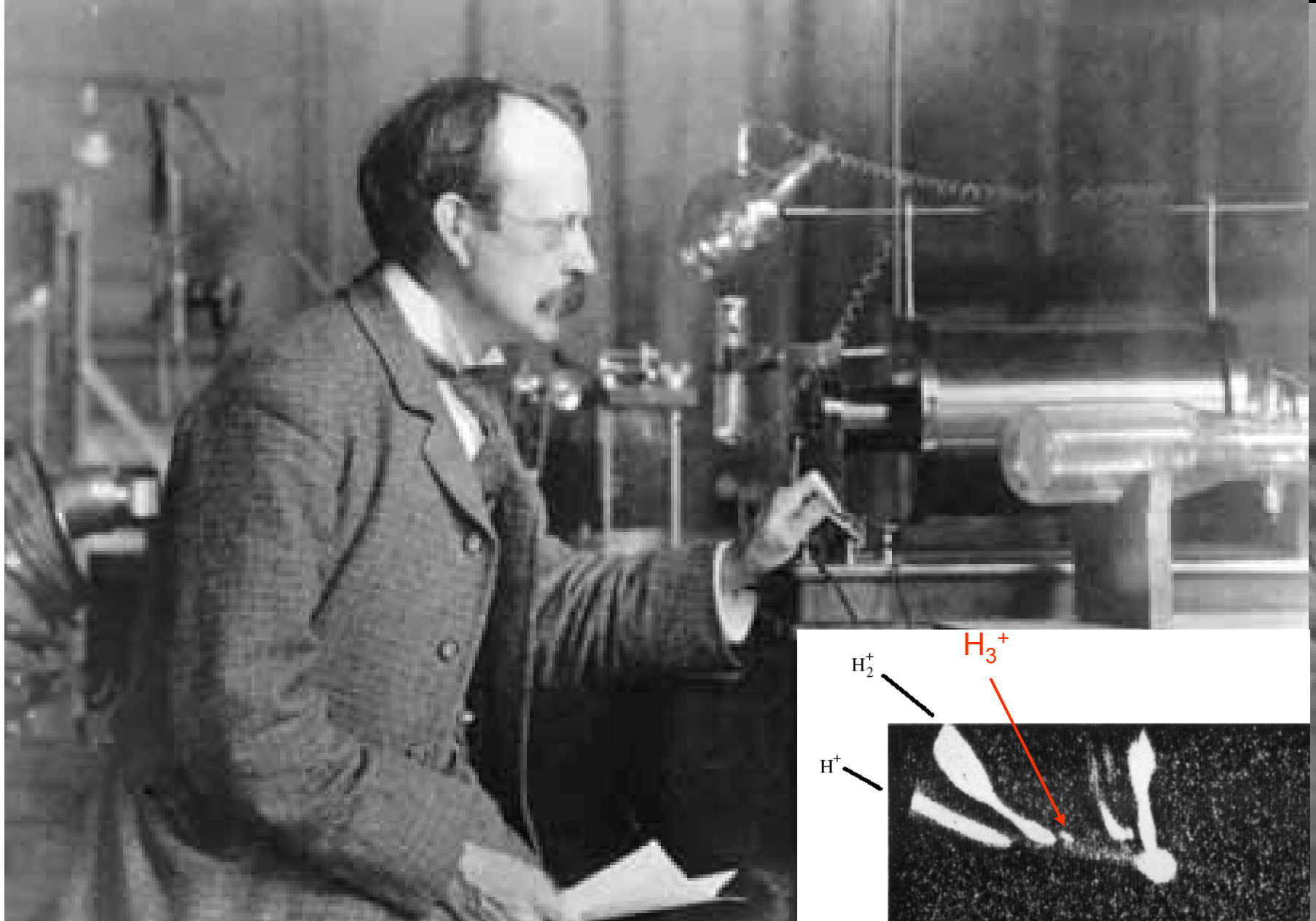
Takeshi Oka

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and Department of Chemistry,

The Enrico Fermi Institute, the University of Chicago

The Royal Society Discussion Meeting and Satellite Meeting

Kavli Centre, February 9, 2012



Thomson, J. J. 1911 Rays of positive electricity. *Phil. Mag.* 21, 225-249.
Thomson, J. J. 1912 Further experiments on positive rays. *Phil. Mag.* 24, 209-253.

Chemistry, astronomy and physics of H_3^+

Takeshi Oka

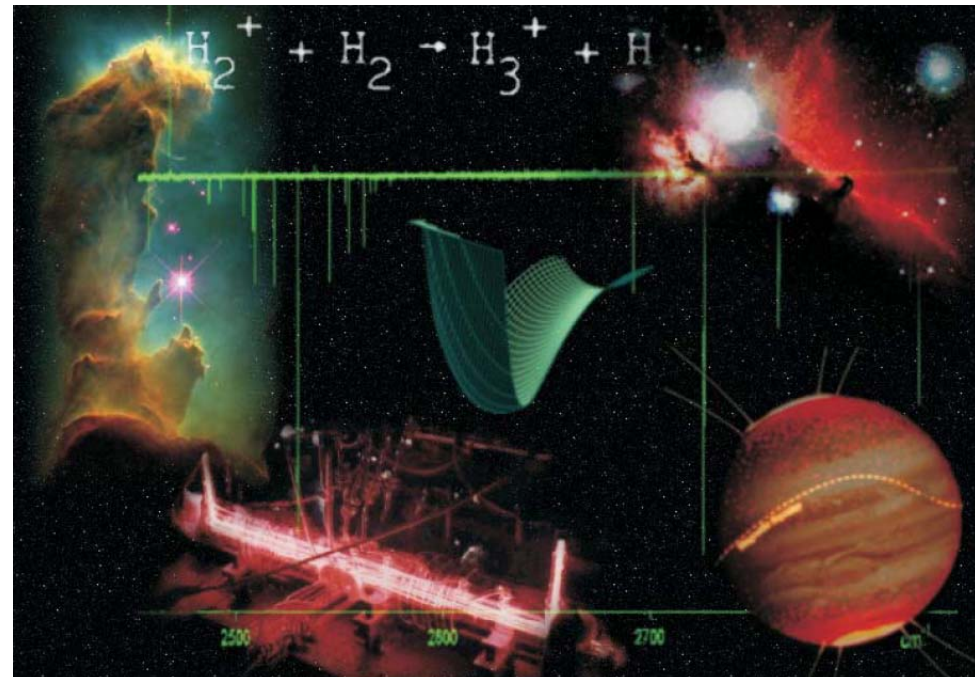
Mats Larsson

Steve Miller

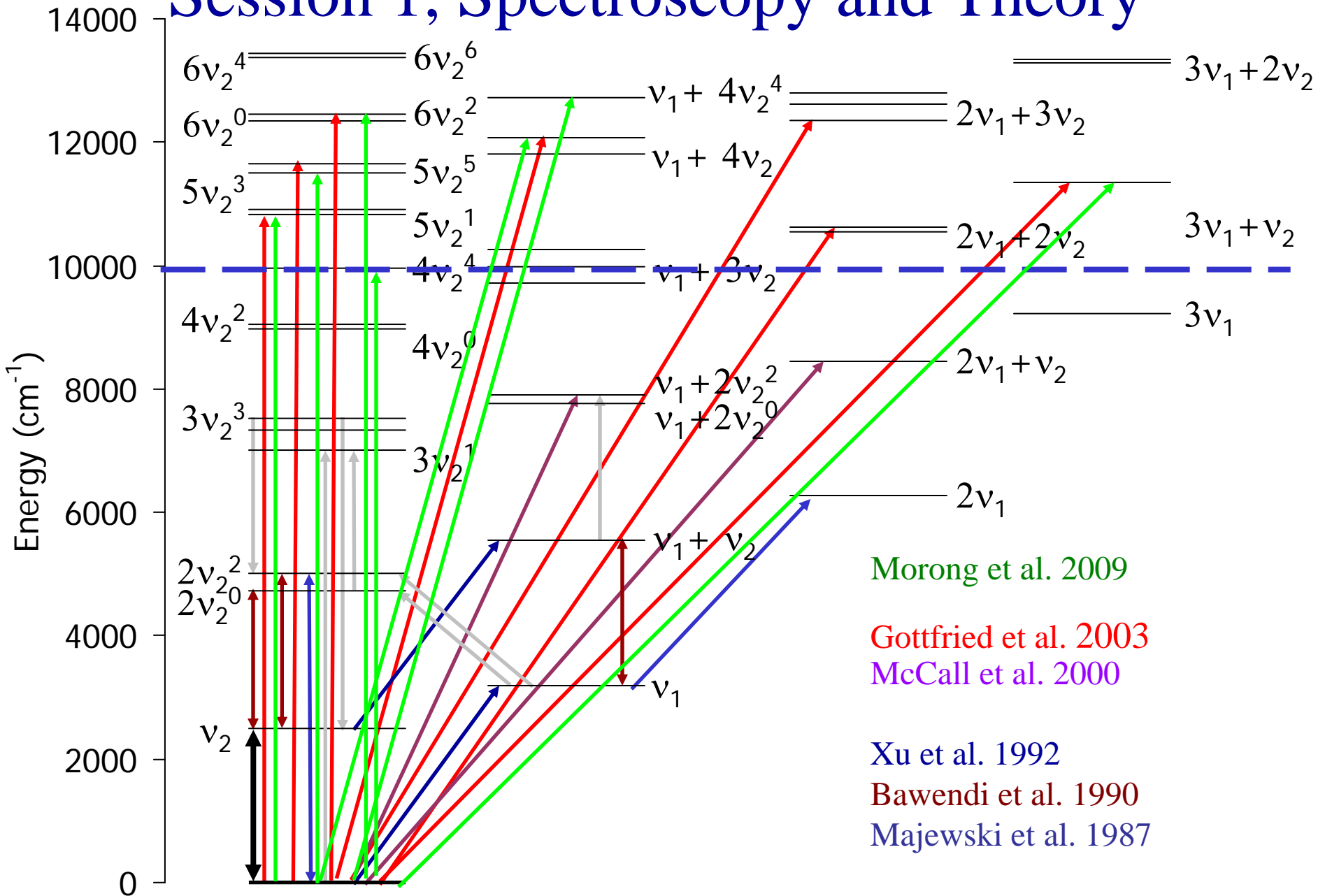
Stephan Schlemmer

Secretary Ben McCall

Tracey Wheeler



Session 1, Spectroscopy and Theory



Morong et al. 2009

Gottfried et al. 2003

McCall et al. 2000

Xu et al. 1992

Bawendi et al. 1990

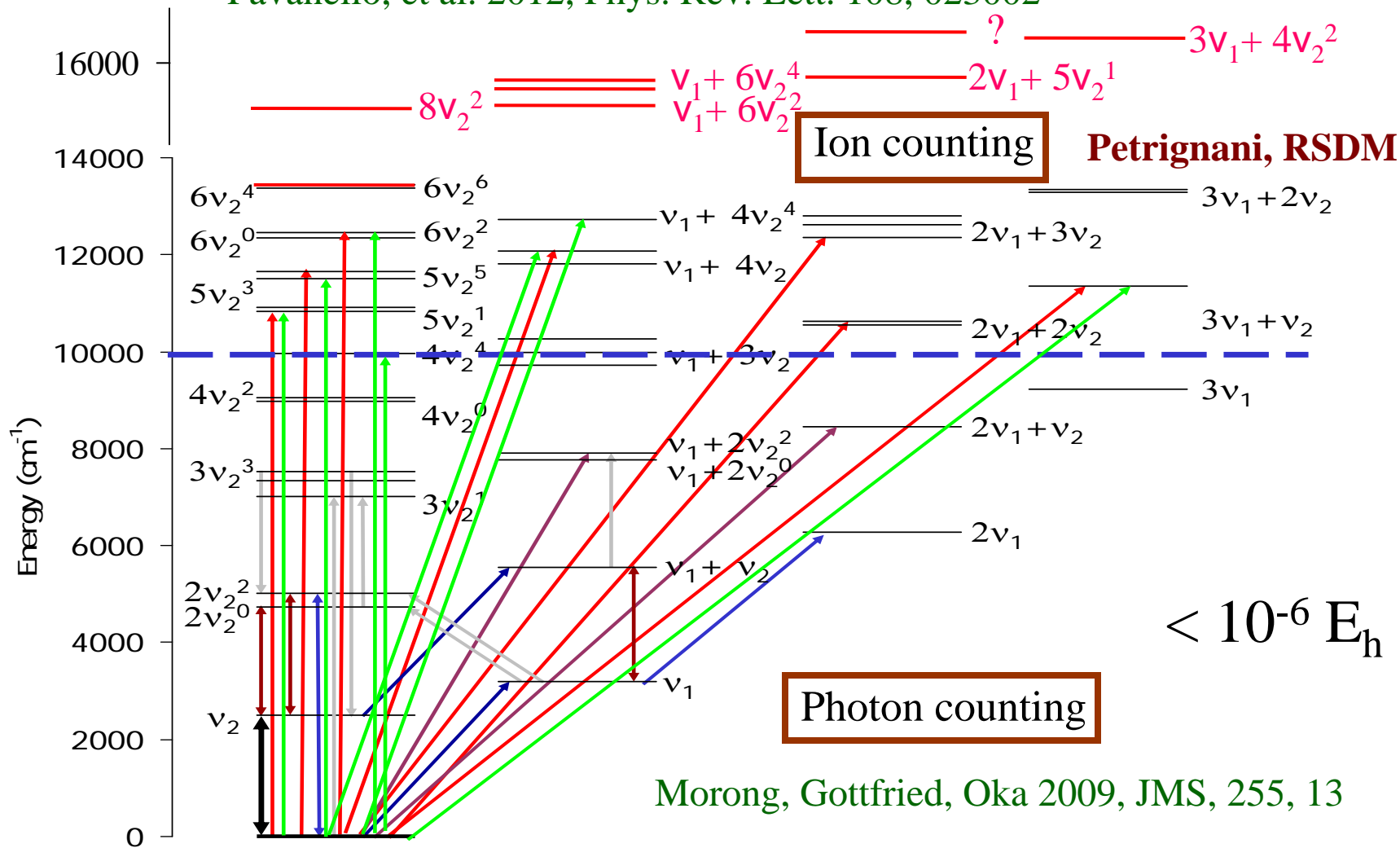
Majewski et al. 1987

Oka 1980

Session 1, Spectroscopy and Theory

non-adiabatic corr. **Jaquet SM** **Polyansky RSDM** **Adamowicz RSDM** $10^{-8} E_h$

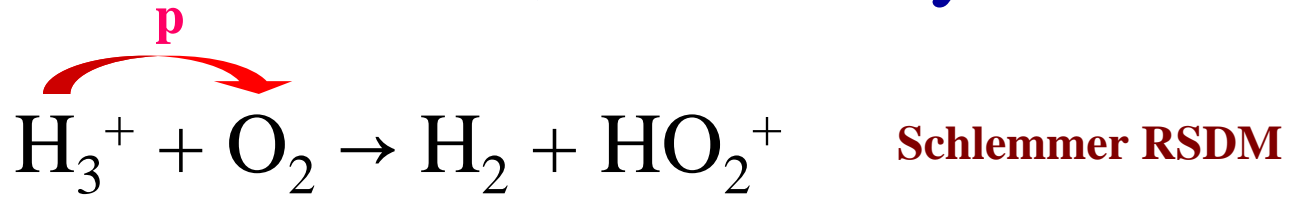
Pavanello, et al. 2012, Phys. Rev. Lett. 108, 023002



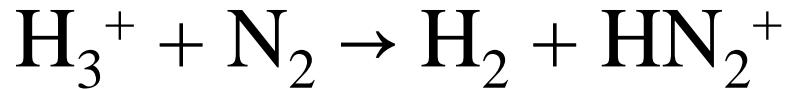
Morong, Gottfried, Oka 2009, JMS, 255, 13

Sub-Doppler **Shy, Amano SM, P**

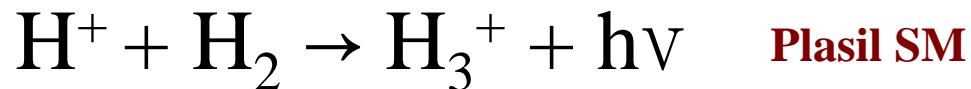
Session 2, Chemistry



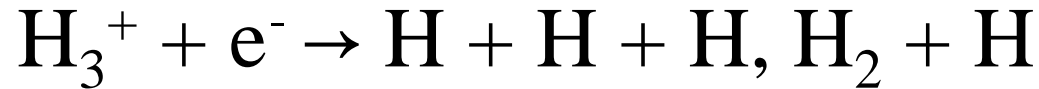
He-HO₂⁺, Ne-HO₂⁺ Nizkorodov et al. 1997 CPL, 278, 26
Widucus Weaver et al. 2009 ApJ, 679, 601





Crabtree, Tom, McCall, 2011, J. Chem. Phys. 134, 194310
Crabtree et al. 2011, J. Chem. Phys. 134, 194311
Crabtree et al. 2011, ApJ, 729:15 (12pp)



Session 3, Dissociative recombination



$$\zeta L = 2 k_e N(\text{H}_3^+) (n_{\text{C}}/n_{\text{H}})_{\text{SV}} R_{\text{X}} / f(\text{H}_2)$$

 Cloud length
 Cosmic ray ionization rate

Oka et al. 2005, ApJ, 632, 882

Larsson RSDM Johnsen SM

$10^4 \rightarrow 3$

20 – 30 K
380 K

McCall et al. 2004, PR A70, 052716
Petrigani et al. 2011, PR A83, 032711

ortho- H_3^+ , para- H_3^+

Glosik SM

Kreckel RSDM

Cation + anion

Thomas SM

H_3O^+ CH_3^+ NH_4^+ **Douquet P**

D_3^+

Dohnal P

Help!!! Theory for H_3^+ Recombination Badly Needed

Oka 2001

Kokooline, Greene, Esry, 2001, Nature, 412, 891

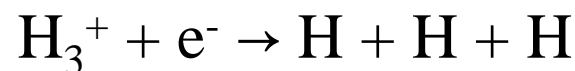
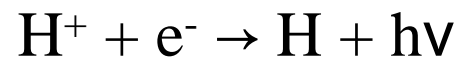
Kokooline, Greene, 2003, Phys. Rev. Lett. 90, 133201

Kokooline, Greene, 2003, Phys. Rev. A68, 012703

Jungen, Pratt, 2009, Phys. Rev. Lett. 102, 023201

Jungen RSDM

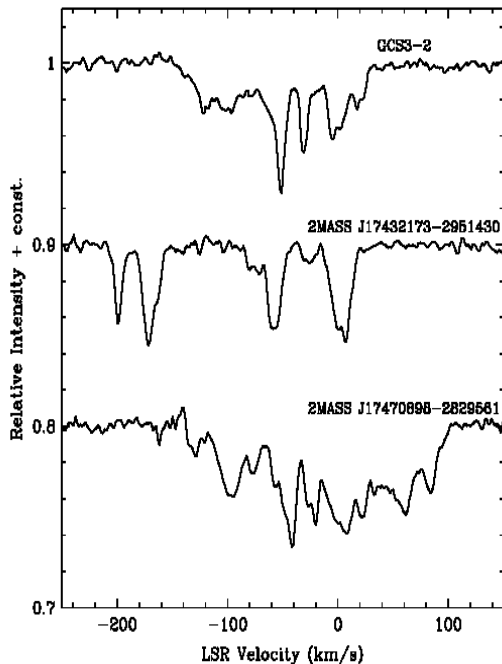
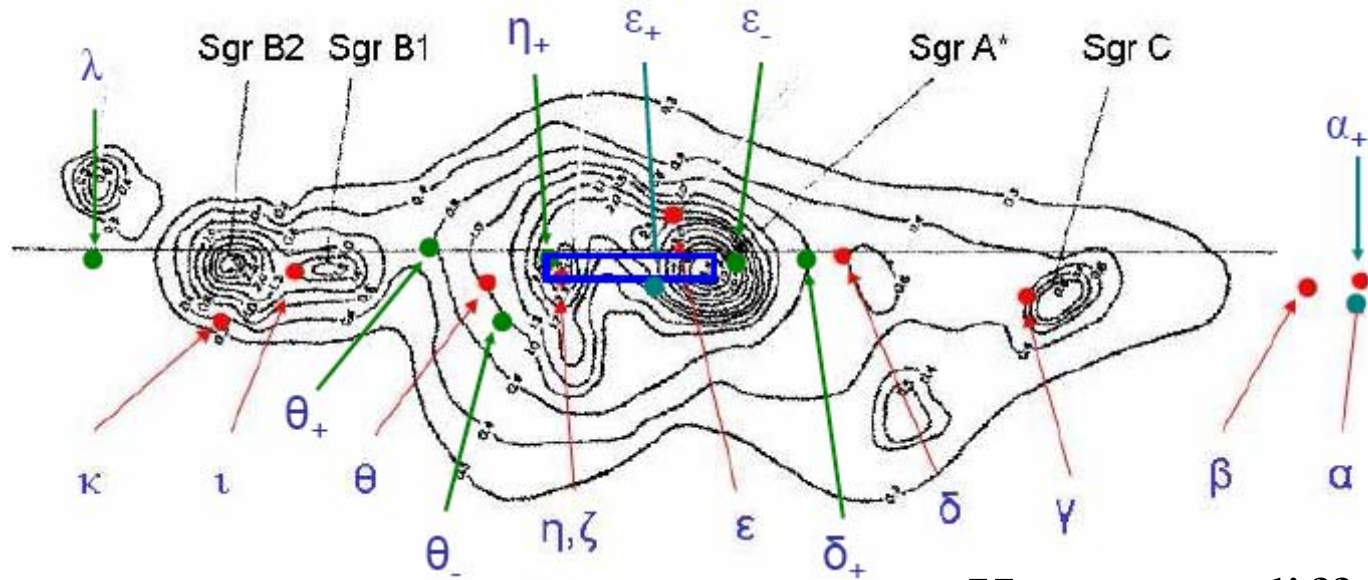
Session 4, H_3^+ as best Probe for Cosmic Rays



	Spitzer Tomasko 1968	ζ
Dense cloud	$\zeta\mathcal{L} = (0.32 - 1.50) \times 10^2 \text{ cm s}^{-1}$ McCall et al. 1999, ApJ, 522, 338	$7 \times 10^{-18} \text{ s}^{-1}$ $3 \times 10^{-17} \text{ s}^{-1}$
Diffuse cloud	$\zeta\mathcal{L} = (0.48 - 4.40) \times 10^4 \text{ cm s}^{-1}$ Indriolo et al. 2007 ApJ, 671,1736 Indriolo, McCall, 2012, ApJ, 745, 91	$5 \times 10^{-16} \text{ s}^{-1}$
Galactic center	$\zeta\mathcal{L} > (1.2 - 6.3) \times 10^5 \text{ cm s}^{-1}$	$> 2 \times 10^{-15} \text{ s}^{-1}$

Black RSDM Indriolo RSDM

Session 5, Galactic center



H_3^+ warm diffuse cloud

Oka et al. 2005, *ApJ*, 632, 882

$T \sim 250 \text{ K}$

Goto et al. 2008, *ApJ*, 688, 306

$n < 100 \text{ cm}^{-3}$

Geballe, Oka, 2010, *ApJ*, 709, L70

Geballe RSDM

Goto SM

Lis RSDM

H_3O^+ hot dense cloud

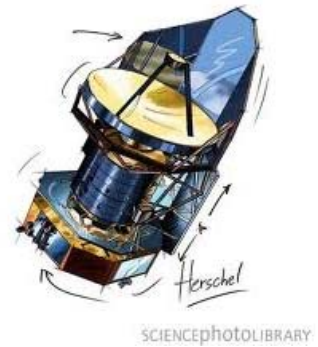
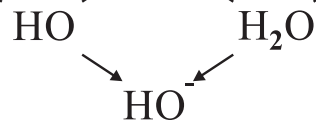
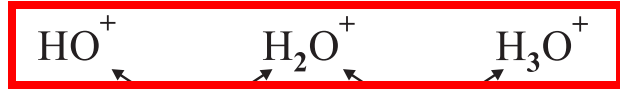
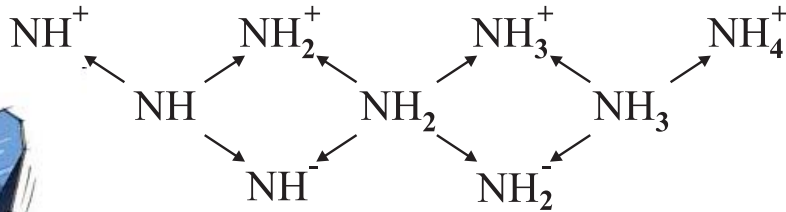
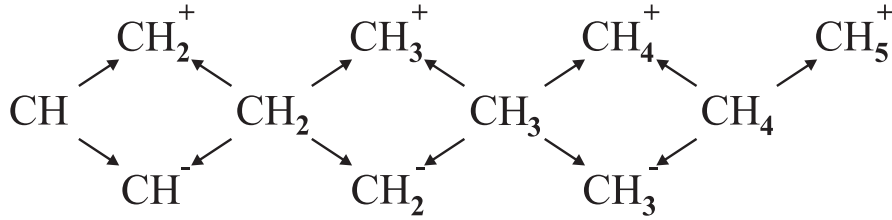
Active Galactic Nucleus

$T \sim 700 \text{ K}$

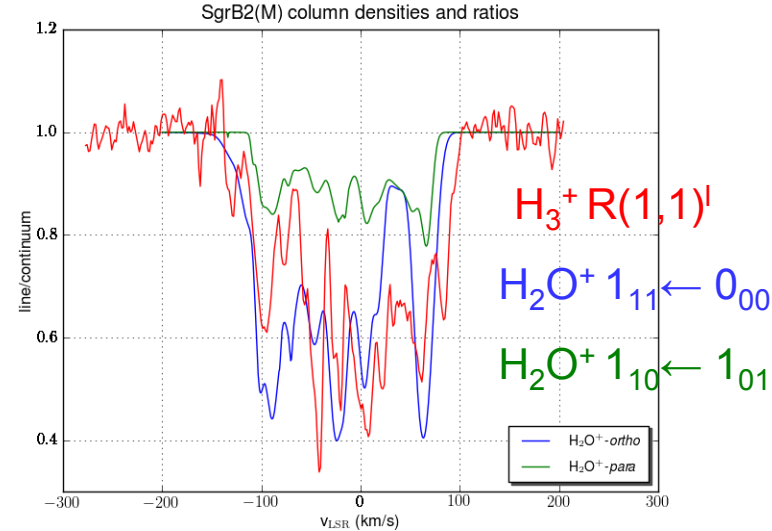
Meijerink SM

$n \sim 10^4 \text{ cm}^{-3}$

Session 6, Interstellar Chemistry

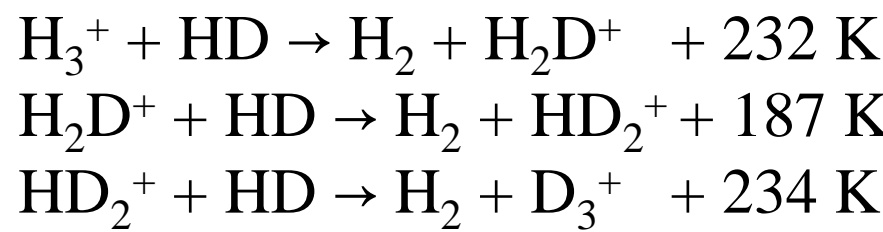
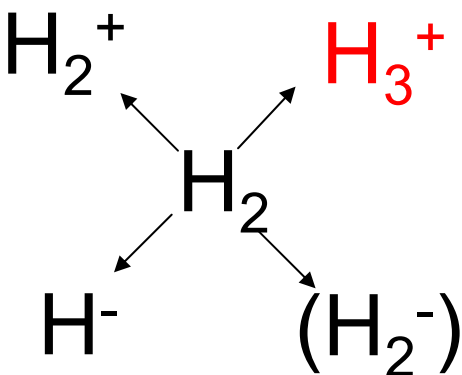


Gerin RSDM
Schilke SM



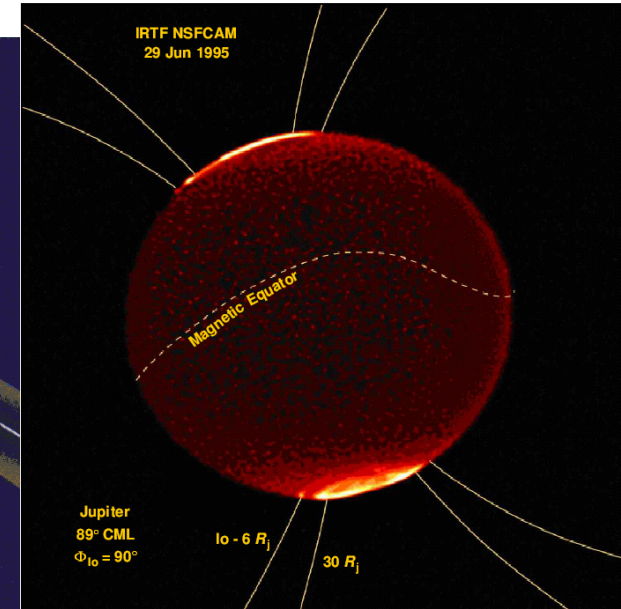
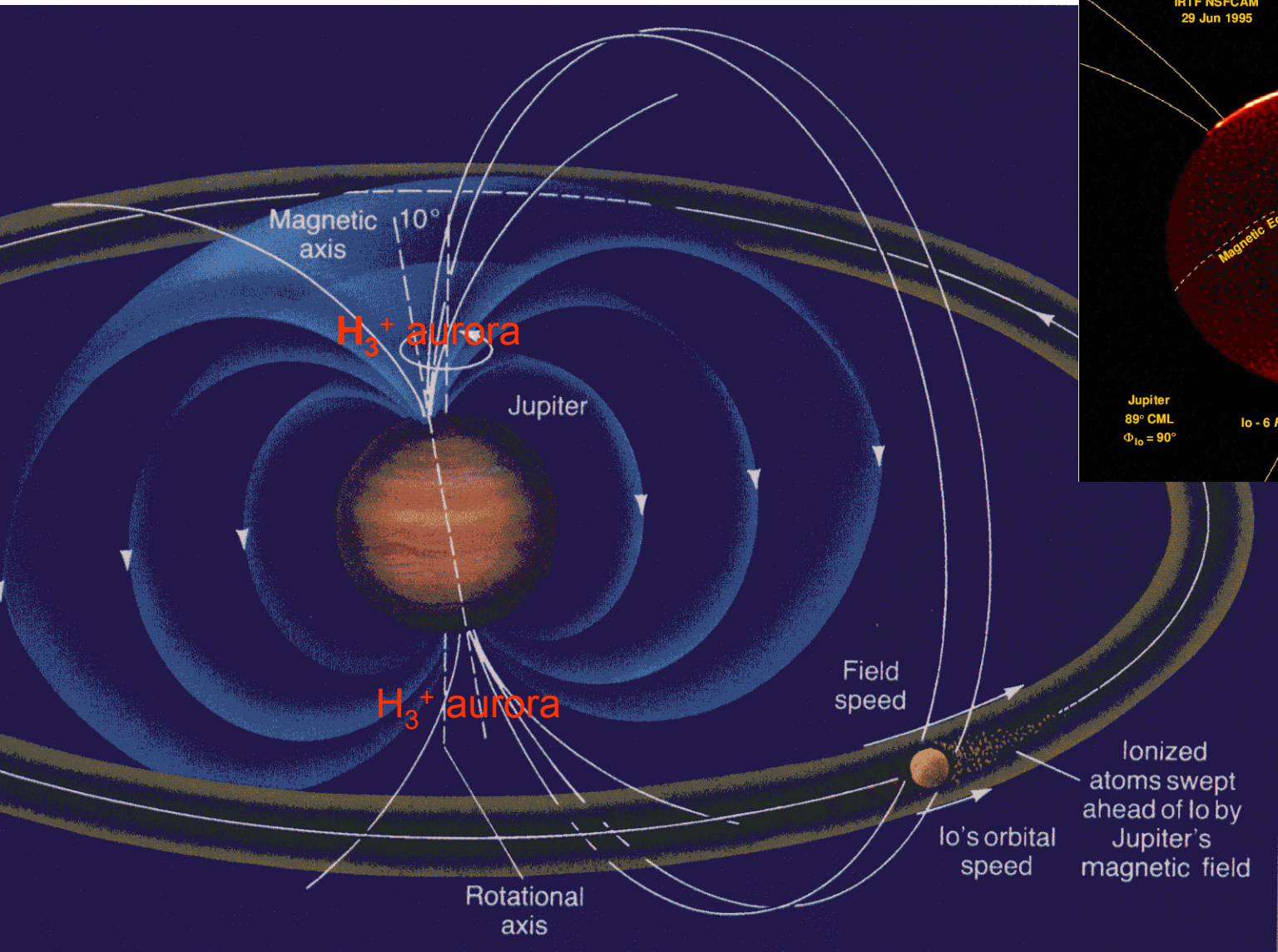
Schilke et al. 2011, *A&A*, 521, L11
Geballe & Oka, 2010, *ApJ*, 709, L70

Van der Tak RSDM
Pagani RSDM



Robert, Herbst, Millar, 2003, *ApJL* 591, L41

Session 7, Planetary ionosphere



Other hydrogenic species

H_2^+ H_3 **Black RSDM**

H_3^- **Kokoouline SM**

H_5^+ **Prosmi SM Valdes P**

H_7^+ **Prosmi P**

H_4^+ in solid Ne **Correnti P**

H_6^+ in solid H_2 **Kumagai P**