Isotopic Ratios in Comets

E. Jehin, J. Manfroid, D. Hutsemékers, C. Arpigny, J.-M. Zucconi

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Table1 : Isotopic ratios in comets. The terrestrial value is indicated for each ratio. When several references are available for one comet, the value quoted has been taken from the last citation. We give in column "Type" the comet classifications according to Levison (1996) : Halley-family (HF) ($T_J < 2$ and $a < 40$ AU), external (EXT) ($T_J < 2$ and $40 < a < 10000$), new ($T_J < 2$ and $a > 10000$) and Jupiter-Family (JF) ($2 < T_J < 3$) with T_J, the Tisserand parameter for Jupiter.

Isotopic ratio D/H :

Comets	Type	Method (facility)	Species	D/H ($1.56\ 10^{-4}$)	Ref.	Notes
1P/Halley	HF	mass spectro (Giotto)	H_2DO^+	$(3.08\pm0.5)\ 10^{-4}$	4	
1P/Halley	HF	mass spectro (Giotto)	H_2DO^+	$(3.06\pm0.34)\ 10^{-4}$	11	
8P/Tuttle	HF	near IR spectro (VLT CRIRES)	HDO	$(4.09\pm1.45)\ 10^{-4}$	33	
81P/Wild2	JF	laboratory NanoSIMS (Stardust)	D	$[10^{-4} - 10^{-3}]$	27	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	HDO	$(3.3\pm0.8)\ 10^{-4}$	28	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	DCN	$(2.3\pm0.4)\ 10^{-3}$	29	
C/1996 B2 (Hyakutake)	EXT	radio spectro (CSO)	HDO	$(2.9\pm1.0)\ 10^{-4}$	7	
C/2001 Q4 (NEAT)	NEW	UV spectro (HST STIS)	D	$(4.6\pm1.4)\ 10^{-4}$	34	
C/2002 T7 (LINEAR)	NEW	near UV spectro (VLT UVES)	OD	$(2.5\pm0.7)\ 10^{-4}$	13	

Isotopic ratio $^{12}C/^{13}C$:

Comets	Type	Method (facility)	Species	$^{12}C/^{13}C$ (89)	Ref.	Notes
1P/Halley	HF	optical spectro (AAT)	^{13}CN	89 ± 17	14	
1P/Halley	HF	optical spectro (1.9m Mt Stromlo)	^{13}CN	95 ± 12	20	
8P/Tuttle	HF	optical spectro (VLT UVES)	^{13}CN	90 ± 20	18	
9P/Tempel1	JF	optical spectro (VLT UVES)	^{13}CN	95 ± 15	16	Before impact
9P/Tempel1	JF	optical spectro (HIRES KeckI)	^{13}CN	95 ± 15	16	Just after impact
17P/Holmes	JF	radio spectro (30m IRAM)	$H^{13}CN$	114 ± 26	8	During outburst
17P/Holmes	JF	optical spectro (2DC McDonald + HIRES KeckI)	^{13}CN	90 ± 20	8	During outburst
73-B/SW3	JF	optical spectro (VLT UVES)	^{13}CN	100 ± 30	17	Split comet
73-C/SW3	JF	optical spectro (VLT UVES)	^{13}CN	100 ± 20	17	Split comet
122P/de Vico	HF	optical spectro (2DC McDonald)	^{13}CN	90 ± 10	15, 26	
153P/Ikeya-Zhang	EXT	optical spectro (2DC McDonald)	^{13}CN	80 ± 30	15, 26	
81P/Wild2	JF	laboratory NanoSIMS (Stardust)	$^{13}C^-$	[90 - 94]	27	
88P/Howell	JF	optical spectro (VLT UVES)	^{13}CN	90 ± 15	12, 26	
C/1963 A1 (Ikeya)	EXT	optical spectro (Hale Palomar Coudé)	$^{12}C^{13}C$	70 ± 15	31	
C/1969 T1 (Tago-Sato-Kosaka)	EXT	optical spectro (Hale Palomar Coudé)	$^{12}C^{13}C$	100 ± 20	30	
C/1973 E1 (Kohoutek)	NEW	optical spectro (2DC McDonald)	$^{12}C^{13}C$	115 ± 30	10	
C/1975 N1 (Kobayashi-Berger-Milon)	NEW	optical spectro	$^{12}C^{13}C$	100 ± 30	32	

C/ 1975 V1 (West)	EXT	optical spectro (2DC McDonald)	$^{12}C^{13}C$	[60-90]	21	
C/1989 X1 (Austin)	NEW	optical spectro (1.9m Mt Stromlo)	^{13}CN	85 ± 20	35	
C/1989 Q1 (Okazaki-Levy-Rudenko)	NEW	optical spectro (1.9m Mt Stromlo)	^{13}CN	93 ± 20	35	
C/1990 K1 (Levy)	NEW	optical spectro (1.9m Mt Stromlo)	^{13}CN	90 ± 10	35	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	$H^{13}CN$	111 ± 12	19	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (CSO)	$H^{13}CN$	90 ± 15	24	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (12m NRAO)	$H^{13}CN$	109 ± 22	36	
C/1995 O1 (Hale-Bopp)	EXT	optical spectro (2DC McDonald)	^{13}CN	90 ± 20	2, 3, 26	At R_h = 0.9 AU
C/1995 O1 (Hale-Bopp)	EXT	optical spectro (SOFIN NOT)	^{13}CN	100 ± 30	2, 3, 26	At R_h = 0.9 AU
C/1995 O1 (Hale-Bopp)	EXT	optical spectro (2DC McDonald)	^{13}CN	80 ± 25	26	At R_h = 2.7 AU
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	$H^{13}CN$	94 ± 8	8	
C/1996 B2 (Hyakutake)	EXT	radio spectro (CSO)	$H^{13}CN$	34 ± 12	23	Line contamination
C/1999 S4 (LINEAR)	NEW	optical spectro (2DC McDonald)	^{13}CN	90 ± 30	12, 26	
C/1999 T1 (McNaught-Hartley)	EXT	optical spectro (2DC McDonald)	^{13}CN	80 ± 20	26	
C/2000 WM1 (LINEAR)	NEW	optical spectro (VLT UVES)	^{13}CN	100 ± 20	3, 26	
C/2001 Q4 (NEAT)	NEW	optical spectro (VLT UVES)	^{13}CN	90 ± 15	25, 26	At R_h = 1.0 AU
C/2001 Q4 (NEAT)	NEW	optical spectro (VLT UVES)	^{13}CN	70 ± 30	25, 26	At R_h = 3.7 AU
C/2002 X5 (Kudo-Fujikawa)	EXT	optical spectro (VLT UVES)	^{13}CN	90 ± 20	26	
C/2002 V1 (NEAT)	EXT	optical spectro (VLT UVES)	^{13}CN	100 ± 20	26	
C/2002 Y1 (Juels-Holvorcem)	EXT	optical spectro (VLT UVES)	^{13}CN	90 ± 20	26	
C/2002 T7 (LINEAR)	NEW	optical spectro (VLT UVES)	^{13}CN	85 ± 20	26	

C/2003 K4 (LINEAR)	NEW	optical spectro (VLT UVES)	^{13}CN	80 ± 20	25, 26	At R_h = 2.6 AU
C/2003 K4 (LINEAR)	NEW	optical spectro (VLT UVES)	^{13}CN	90 ± 20	25, 26	At R_h = 1.2 AU
C/2006 M4 (SWAN)	NEW	optical spectro (2DC McDonald)	^{13}CN	95 ± 25	26	
C/2007 N3 (Lulin)	NEW	optical spectro (VLT UVES)	^{13}CN	105 ± 40	26	

Isotopic ratio $^{14}N/^{15}N$:

Comets	Type	Method (facility)	Species	$^{14}N/^{15}N$ (272)	Ref.	Notes
8P/Tuttle	HF	optical spectro (VLT UVES)	$C^{15}N$	150 ± 30	18	
9P/Tempel1	JF	optical spectro (VLT UVES)	$C^{15}N$	145 ± 20	16	Before impact
9P/Tempel1	JF	optical spectro (HIRES KeckI)	$C^{15}N$	165 ± 30	16	Just after impact
17P/Holmes	JF	radio spectro (30m IRAM)	$HC^{15}N$	139 ± 26	8	During outburst
17P/Holmes	JF	optical spectro (2DC McDonald + HIRES KeckI)	$C^{15}N$	165 ± 40	8	During outburst
73-B/SW3	JF	optical spectro (VLT UVES)	$C^{15}N$	210 ± 50	17	Split comet
73-C/SW3	JF	optical spectro (VLT UVES)	$C^{15}N$	220 ± 40	17	Split comet
81P/Wild2	JF	laboratory NanoSIMS (Stardust)	$C^{15}N^-$	[118 - 270]	27	
88P/Howell	JF	optical spectro (VLT UVES)	$C^{15}N$	140 ± 20	12, 26	
122P/de Vico	HF	optical spectro (2DC McDonald)	$C^{15}N$	145 ± 20	15, 26	
153P/Ikeya-Zhang	EXT	optical spectro (2DC McDonald)	$C^{15}N$	140 ± 50	15, 26	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	$HC^{15}N$	323 ± 46	19	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (12m NRAO)	$HC^{15}N$	330 ± 98	36	

C/1995 O1 (Hale-Bopp)	EXT	optical spectro (2DC McDonald)	$C^{15}N$	150 ± 30	2, 3, 26	At R_h = 0.9 AU
C/1995 O1 (Hale-Bopp)	EXT	optical spectro (SOFIN NOT)	$C^{15}N$	135 ± 40	2, 3 26	At R_h = 0.9 AU
C/1995 O1 (Hale-Bopp)	EXT	optical spectro (2DC McDonald)	$C^{15}N$	130 ± 40	26	At R_h = 2.7 AU
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	$HC^{15}N$	205 ± 70	8	
C/1999 S4 (LINEAR)	NEW	optical spectro (2DC McDonald)	$C^{15}N$	150 ± 50	12, 26	
C/1999 T1 (McNaught-Hartley)	EXT	optical spectro (2DC McDonald)	$C^{15}N$	160 ± 50	26	
C/2000 WM1 (LINEAR)	NEW	optical spectro (VLT UVES)	$C^{15}N$	150 ± 30	3, 26	
C/2001 Q4 (NEAT)	NEW	optical spectro (VLT UVES)	$C^{15}N$	130 ± 40	25, 26	At R_h = 3.7 AU
C/2001 Q4 (NEAT)	NEW	optical spectro (VLT UVES)	$C^{15}N$	135 ± 20	25, 26	At R_h = 1.0 AU
C/2002 X5 (Kudo-Fujikawa)	EXT	optical spectro (VLT UVES)	$C^{15}N$	130 ± 20	26	
C/2002 V1 (NEAT)	EXT	optical spectro (VLT UVES)	$C^{15}N$	160 ± 35	26	
C/2002 Y1 (Juels-Holvorcem)	EXT	optical spectro (VLT UVES)	$C^{15}N$	150 ± 35	26	
C/2002 T7 (LINEAR)	NEW	optical spectro (VLT UVES)	$C^{15}N$	160 ± 25	26	
C/2003 K4 (LINEAR)	NEW	optical spectro (VLT UVES)	$C^{15}N$	150 ± 35	25, 26	At R_h = 2.6 AU
C/2003 K4 (LINEAR)	NEW	optical spectro (VLT UVES)	$C^{15}N$	145 ± 25	25, 26	At R_h = 1.2 AU
C/2006 M4 (SWAN)	NEW	optical spectro (2DC McDonald)	$C^{15}N$	145 ± 50	26	
C/2007 N3 (Lulin)	NEW	optical spectro (VLT UVES)	$C^{15}N$	150 ± 50	26	

Isotopic ratio $^{16}O/^{18}O$:

Comets	Type	Method (facility)	Species	$^{16}O/^{18}O$ (499)	Ref.	Notes
1P/Halley	HF	mass spectro (Giotto)	$H_2{}^{18}O$	518 ± 45	4	

1P/Halley	HF	mass spectro (Giotto)	$H_2{}^{18}O$	470 ± 40	11	
81P/Wild2	JF	laboratory NanoSIMS (Stardust)	minerals	[490 - 520]	27	
153P/Ikeya-Zhang	EXT	radio spectro (Odin)	$H_2{}^{18}O$	530 ± 60	22, 5	
C/2001 Q4 (NEAT)	NEW	radio spectro (Odin)	$H_2{}^{18}O$	530 ± 60	5	
C/2002 T7 (LINEAR)	NEW	radio spectro (Odin)	$H_2{}^{18}O$	550 ± 75	5	
C/2002 T7 (LINEAR)	NEW	optical spectro (VLT UVES)	^{18}OH	425 ± 55	13	
C/2004 Q2 (Machholz)	EXT	radio spectro (Odin)	$H_2{}^{18}O$	508 ± 33	5	

Isotopic ratio $^{32}S/^{34}S$:

Comets	Type	Method (facility)	Species	$^{32}S/^{34}S$ (23)	Ref.	Notes
1P/Halley	HF	mass spectro (Giotto)	$^{34}S+$	23 ± 6	4	
17P/Holmes	JF	radio spectro (30m IRAM)	$C^{34}S$	16 ± 3	6	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (JCMT)	$C^{34}S$	27 ± 3	19	
C/1995 O1 (Hale-Bopp)	EXT	radio spectro (30m IRAM)	$H_2{}^{34}S$	16 ± 3	9	

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