WATER (AND CHEMISTRY) IN THE SOLAR SYSTEM

A GT-KP planetary program proposed for Herschel

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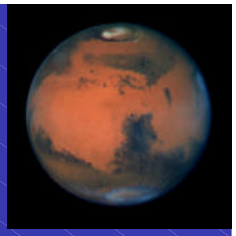
and the HIFI Solar System Team

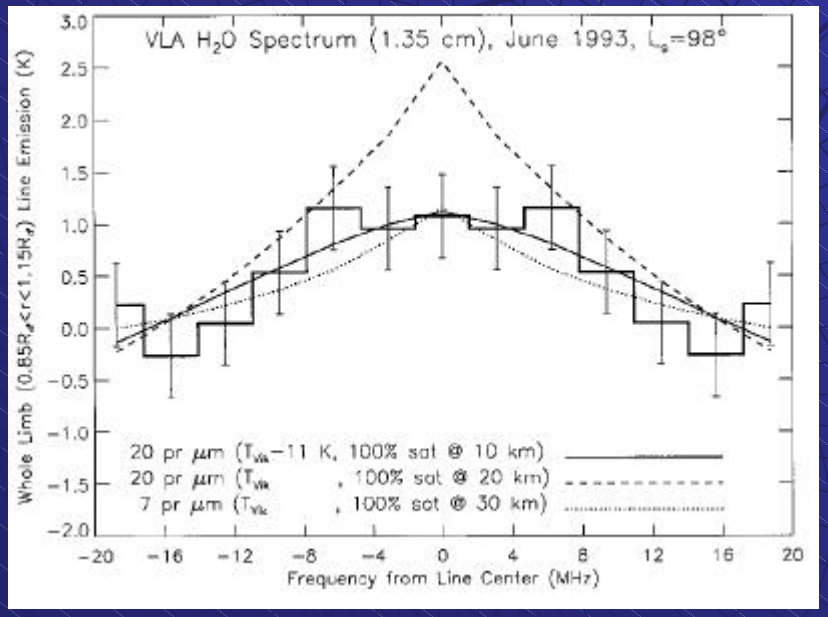
Science Objectives and Goals

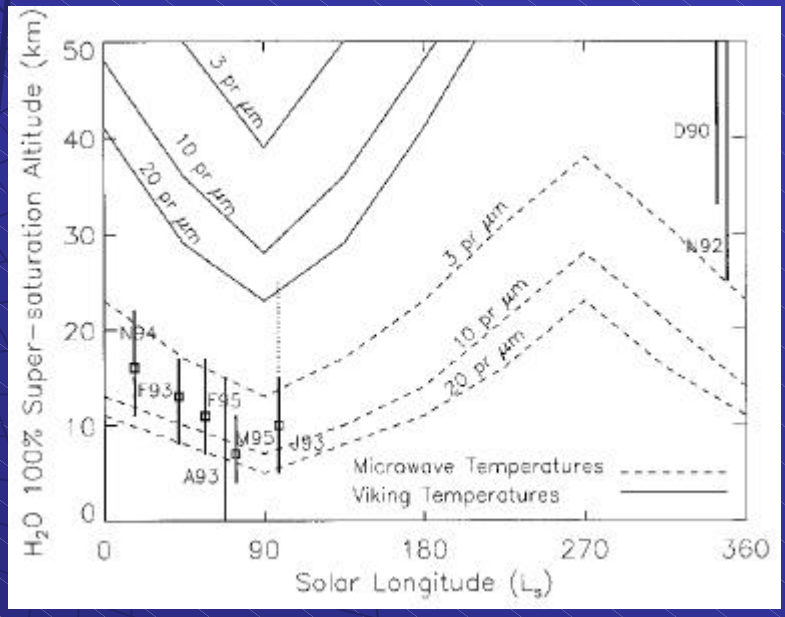
- The Martian water cycle and atmospheric chemistry
- Origin of water in the upper atmospheres of the outer planets
- Excitation of water in comets
- The D/H ratio and minor species
- Water in distant comets

Water in the Martian Atmosphere



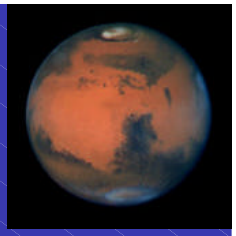
- Water cycle: Measurement of the vertical profile function of solar longitude (Ls) with HIFI. Variable hygropause from ground-based low quality measurements, cut off at 10 km at aphelion and 50 km at perihelion. **If true, strong impact on general circulation, water transport and chemistry: TBC by HIFI**



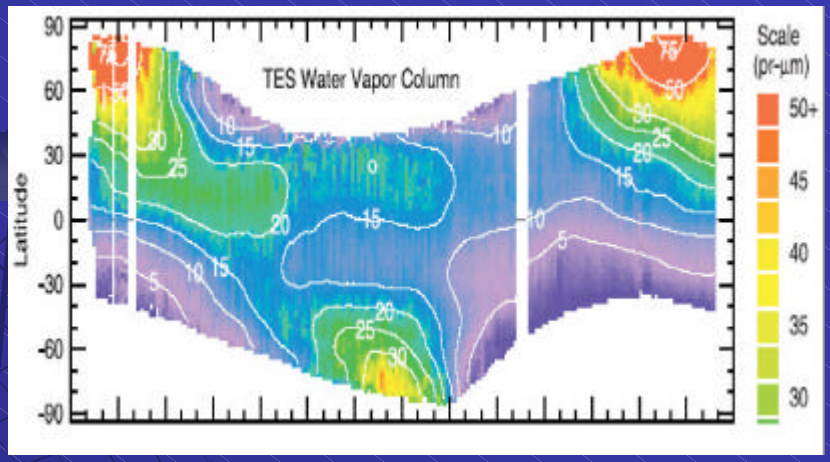


From Clancy *etal* (1996)

Water in the Martian Atmosphere

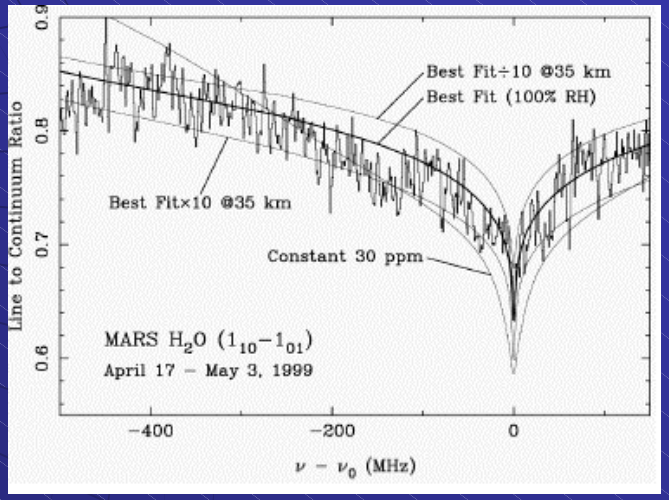


On Mars, the H_2O *column density* measured from Orbiter is strongly variable with seasons and latitudes. BUT, in the IR, the low spectral resolution do not allows to resolve lines

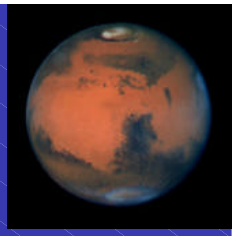


With HIFI, the H_2O vertical profile will be easily determined

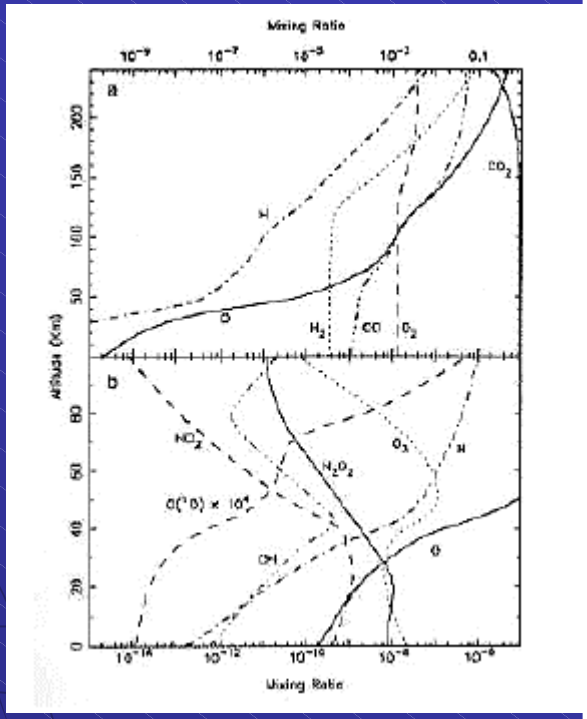
Example of H_2O at 557 GHz from SWAS (Gurwell *etal* 2000)



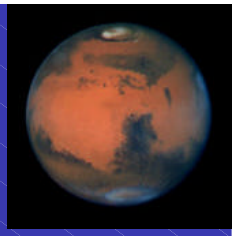
Chemistry in the Martian Atmosphere



- History of Martian atmosphere: Isotopic measurements : D/H about 5 times higher & $^{18}O/^{16}O$ about 10% and $^{17}O/^{16}O$ about 5 % lower than on Earth. **TBC by HIFI, i.e. observe CO, O_2 and O_3**
- HO_x-chemistry: H_2O, OH, HO_2,H_2O_2: confirm expected anti-correlation with O_3
- Chemistry: Search for minor components possibly based on PACS survey and moderate deep line survey in bands 4 and 5



HIFI Time Estimation (35.7h)



- Bands 1,4,5 and 6 (S/N = 100): O_2, H_2O_2, CO, ^{13}CO and 3xH_2O=28 observations of 0.5h = ***14h***

- Bands 5 (S/N = 100):
  - 2 lines of: HDO, $H_2{}^{18}O$, $H_2{}^{17}O$, OH = 8 obs.
  - 1 line of: HO_2, $C^{18}O$, $C^{17}O$ and 3 other species = 6 observations, i.e. 14 observations of 0.5h = ***7h***
  - 2x(seasonal) O_3, each observation of 4h = ***8h***

- Bands 4 and 5 Survey (S/N = 10-100): ***0.7h***
- PACS survey: ***6H***

Origin of water in outer planets

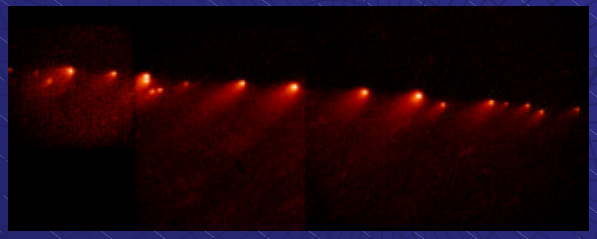
- *HIFI access only to upper atmospheric water in giant planets, since the continuum at ~1 bar, absorbs submm radiation and do not allows to probe the internal water located deeper (5-50 bar)*

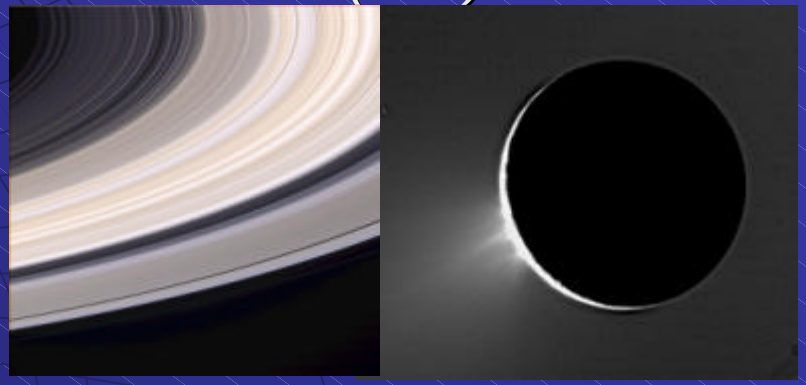
- *External sources required in order to explain the column amount found by ISO:*

  *Permanent **I**nterplanetary **D**ust **P**article flux (IDP)*

  Local sources (rings, satellites)

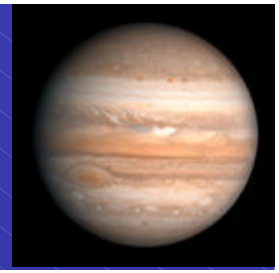
  cometary collisions (SL9)



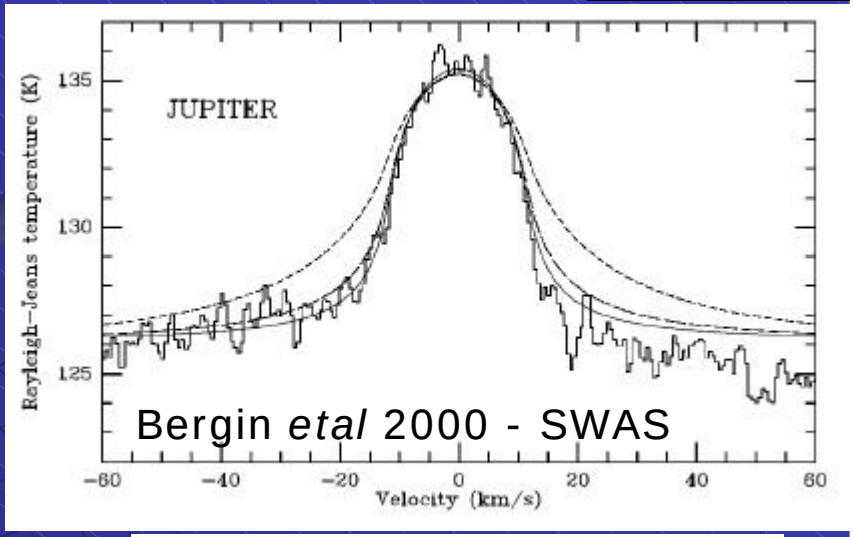


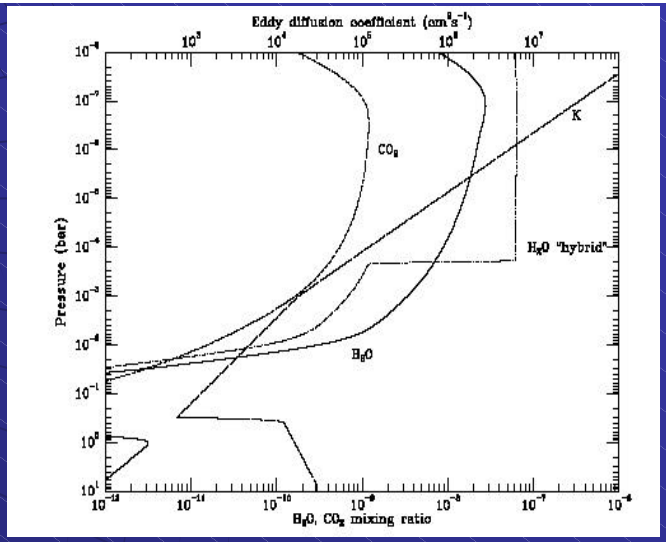
- *Impacts on transport and ionization of gas/solid material in planetary magnetospheres, frequency of cometary collision events*

Science Goals of the Program

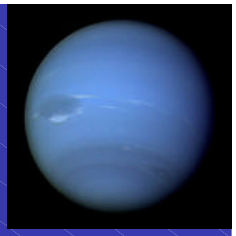


- Improve accuracy of disc-average water abundances to better characterize the budget of input fluxes
- Determine accurate vertical profiles: helps to discriminate between the different external sources
- Map latitudinal distribution of water at Jupiter: a maximum at poles imply satellites sources connected via magnetic field





Strategy and Target Lines



- *Observe 1 to 3 water lines with different strength during different seasons (4 times, i.e. once a year for variability study)*
- *Complementary observations: perform full spectral scans with PACS and SPIRE*
- *Map at shortest wavelength 5 latitudinal points on disc and 4 limbs of Jupiter in order to separate SL9 from possible polar sources*

Outer Planet Time Estimation

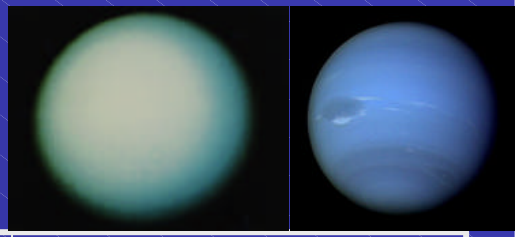
Jupiter (18.6H)

Instrument	Frequency	Time (h)	S/N	Repeat	Goal/Strategy
HIFI	557	0.2	100	4	H_20 Vertical distribution
HIFI	1097	0.2	100	4	
HIFI	1670	1*9	100	1	9 point map
PACS	2640	0.5	100	4	5x5 map
PACS	Full range	6	100	1	Explore

Saturn (14H)

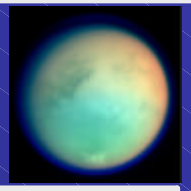
Instrument	Frequency	Time (h)	S/N	Repeat	Goal/Strategy
HIFI	557	1.0	100	4	H_20 Vertical distribution
HIFI	1097	0.5	100	4	
PACS	2640	0.5	100	4	3x3 map
PACS	Full range	6	100	1	Explore

Outer Planet Time Estimation



Uranus & Neptune (2x38=76H)

Instrument	Frequency/line	Time (h)	S/N	Repeat	Goal/Strategy
HIFI	1097	25	100	1	H_20 Vertical distribution
PACS	2640	0.5	100	4	Time variation
PACS	Full range	6	100	1	Explore
SPIRE	Full range	1	100	4	Explore + PH_3
PACS	HD (112 μm)	1	100	1	D/H



Titan (31.5H)

Instrument	Frequency	Time (h)	S/N	Repeat	Goal/Strategy
HIFI	1097	3	10	4	H_20 Vertical distribution
PACS	2640	3.5	100	1	Time variation
PACS	Full range	6	100	1	Explore
SPIRE	Full range	10	100	1	Explore + PH_3

Outer Planet Time Estimation

18.6+14+38+38+31.5 = 140.1 hours

(HIFI = 78.6 , PACS = 43.5, SPIRE = 18)

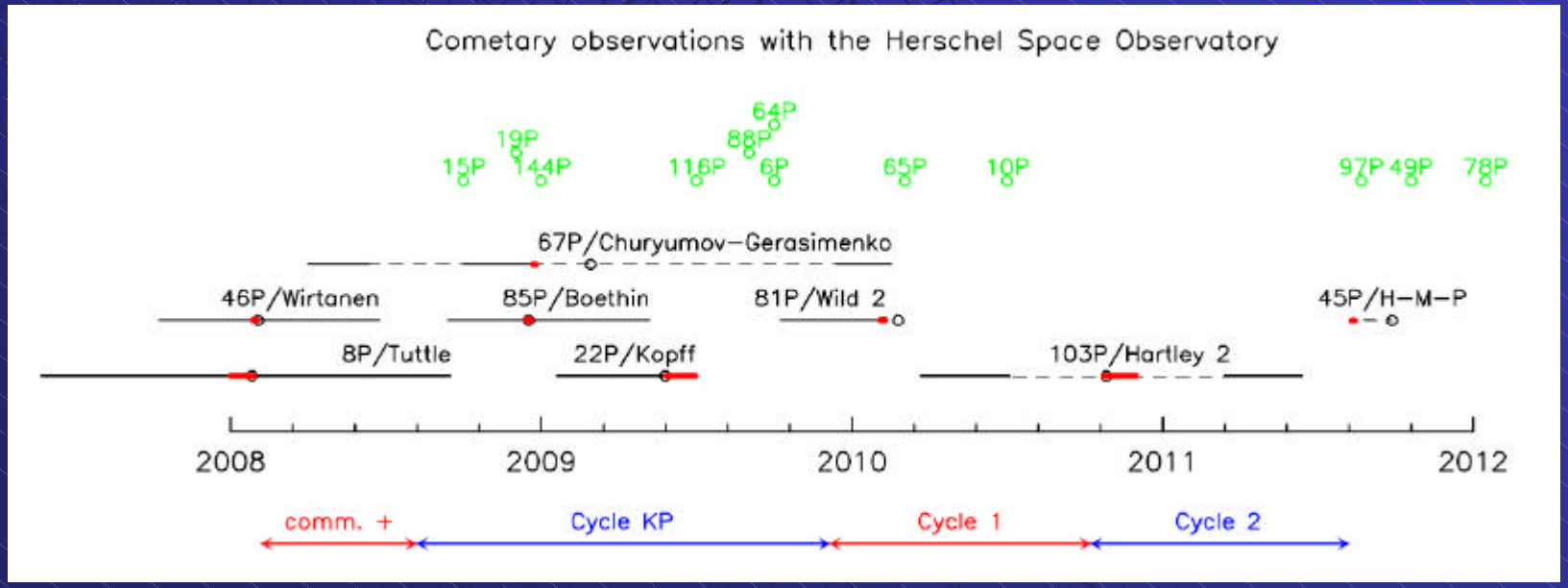
HIFI Planets Time Estimation (total)

35.7h + 140.1h =

176 h

Water in Comets

- Investigation of water excitation (HIFI SPIRE PACS)
- Measurement of the D/H ratio (from HDO) (HIFI)
- Water in a sample of weak comets (HIFI)



Constrain water excitation and physical conditions of comets

- *HIFI and SPIRE: Measure several water lines simultaneously over whole spectral range.* Monitor the water production rate Q=f(Rh) for bright comet TOO (HIFI)

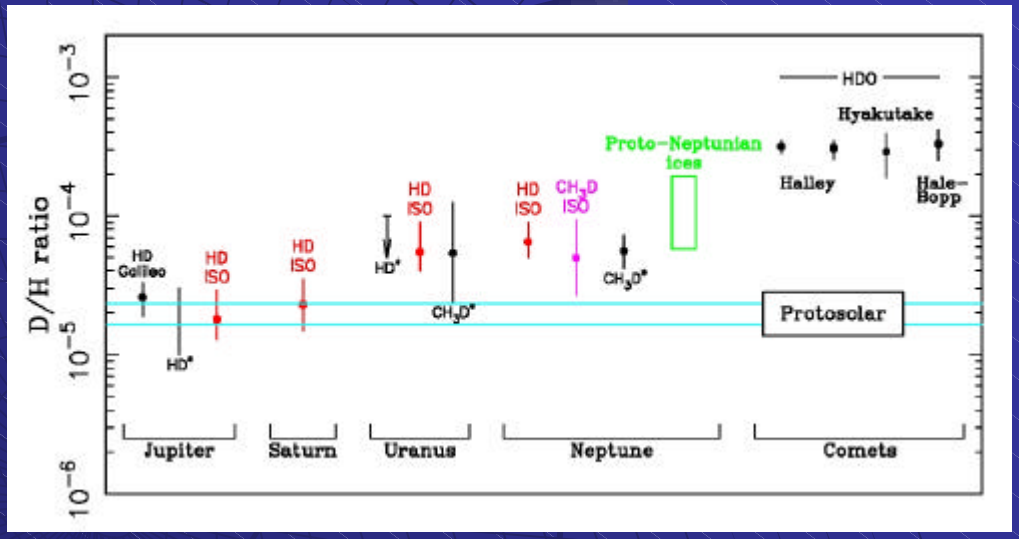
- *Measure asymmetric outgassing, velocity offsets, self absorption and observing lines of different excitation (transitions, map), ortho-to-para ratio*

- Constrains: Temperature and velocity profiles(r), collision rates (electrons, neutrals), role of water radiative cooling in the coma thermodynamics

- ***3-4 comets : 22P/Kopf, 103P/Hartley 2, TOO (x2)***
  Time estimation: = 46 h

HDO: search for D/H in Comets

- High priority: measure D/H for the first time in a Jupiter-family comets to constrain comet material origin (e.g. 103P/Hartley 2 : SNR ~ 10 in 10h)



- *Search for minor species together with H_2O: NH_3, or H_2O-18 and HNC*

- ***2 comets : 103P/Hartley 2, TOO***
  Time estimation: = 32 h

Search for water in weakly active objects

- *Short period comet: part of CO from the ice grains in extended source. Such grains could be a source of water -> 557 GHz water vapor*

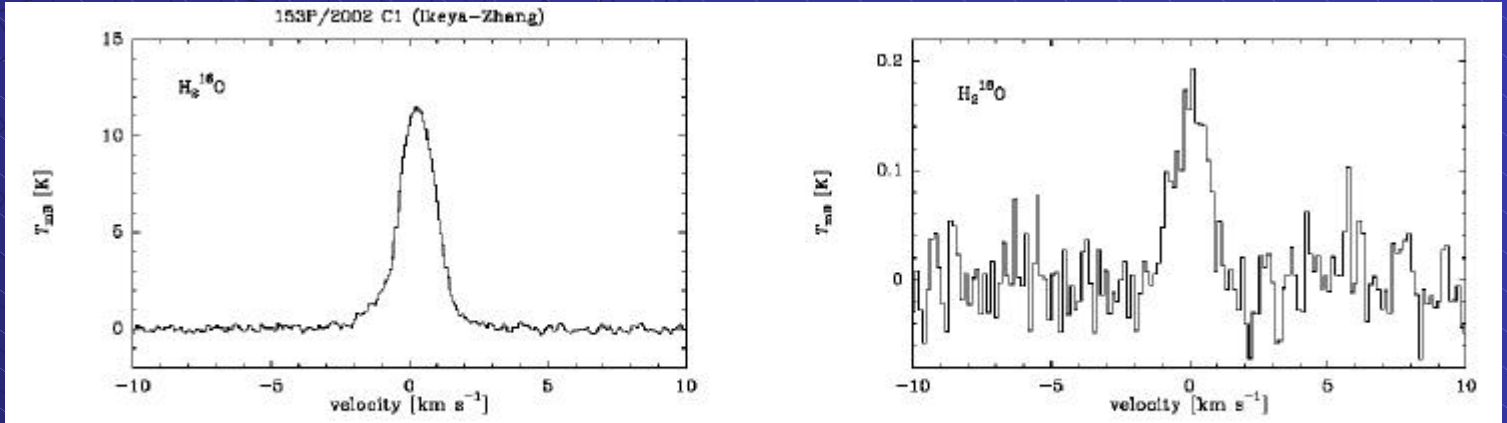


Figure 8: The 1_{10}–1_{01} lines of $H_2^{16}O$ (left) and $H_2^{18}O$ (right) observed in comet 153P/2002 C1 (Ikeya-Zhang) on 24–28 April 2002 by Odin. (From Lecacheux et al. 2003.)

- *Near Earth Objects (NEOs): extinct of dormant comets? Activity?*

- ***1 comet : 29P/Schwassmann-Wachmann 1***
  Time estimation: 3 h

HIFI Comets Time Estimation (total)

46h + 32h +3h +20h =

101 h

HIFI Solar System Time Estimation

176h + 101h =

277h

Science Demonstration Phase

- ***Detection of water lines on a planet and a comet*** visible during this phase, with **HIFI, PACS and SPIRE**