CORNELL UNIVERSITY

Center for Radiophysics and Space Research

SPACE SCIENCES BUILDING

Ithaca, New York 14853-6801

Telephone (607) 255-4971

Fax (607) 255-9888

Laboratory for Planetary Studies

November 23, 1992

Mr. George R. Lewycky
7 Durst Drive
Milltown, N.J. 08850

Dear Mr. Lewycky:

Thanks for your recent letter. Enclosed is a recent review article from *Accounts of Chemical Research* on the organic chemistry of Titan. The major organic constituents of the Titanian atmosphere are almost certainly indigenous -- that is, produced there from the principal constituents of the atmosphere by ultraviolet and charged particle radiation sources. The evidence for this is in the enclosed. There might be small quantities of formaldehyde produced from CO and CO_2, again, in this atmosphere. Certainly, organic matter from comets is arriving in the atmosphere of Titan as it did in the atmosphere of the primitive Earth, but I would be very surprised if this dominated indigenous energy sources. On the latter point I am enclosing two other articles, one from *Science* and one from *Nature*.

Cordially,

Carl Sagan

CS:lkp
Enclosures

7 Durst Drive
Milltown, NJ 08850
Home: 908-846-1216 (after 8pm EST)
Work: 201-557-3578 (9:30am-5pm EST)
October 27, 1992

Dr. Carl Sagan
Labaratory for Planetary Studies
Space Science Bldg.,
Cornell University
Ithaca, NY 14853-6801

Dear Dr. Sagan,

I spoke to one of your secretaries about a week ago regarding information about your speech to AAS regarding Water on Titan. She later explained to you my situation and you offered some material to me about Titan.

As your secretary told you, I am one of the amateur astronomers selected to use the Hubble Space Telescope in Cycle II. My proposal is to search Titan's atmosphere in the UV using the Hubble's HRS at the wavelength range of 2915 A thru 2960 A. The key compound I am searching for is Formaldehyde.

During my research I found a link of Formaldehyde with HCN, ultimately leading to purines necessary for DNA - particularly Adenine. Also after I submitted my proposal I found that comets contain HCN, water and formaldehyde. So, I deduced that a comet could have delivered these and other compounds to Titan. Besides finding CH2O, this could also prove or disprove a comet's interaction with Titan and even Earth.

While I attended the Space Telescope Science Institute the week of October 5th, the public relations manager told me about your speech regarding Water on Titan in January of 1993. Due to work and my financial situtations I am unsure if I can attend. I would deeply appreciate an excerpt of your speech to help me in my research of Titan. Also at you convenience any reccomendations, references, ideas would also be appreciated. I have been in touch with numerous scientists including: Dr. Tobias Owen, Dr. Ellis Miner, Dr. Dennis Matson and many others for information about Titan and Cassini.

My observation from what I was told will take place sometime in the summer of 1993. I enclosed a copy of the original proposal and the final template of instructions, etc. necessary to schedule and send commands to the Hubble for my observation. Also myself and a close friend of mine would like a copy of your autograph (if possible).

Sincerely,

George R. Lewycky

7 Durst Drive
Milltown, NJ 08850
Home: 908-846-1216 (after 8pm EST)
January 2, 1993

Dr. Carl Sagan
Labaratory for Planetary Studies
Space Science Bldg.,
Cornell University
Ithaca, NY 14853-6801

Dear Dr. Sagan,

I deeply thank you for your time and assistance in providing me with feedback, articles and references towards my Hubble Space Telescope (HST) research on Titan.

I'm sorry I will not be able to attend your award speech this month, I was very interested in your speech, "Water on Titan". The scientist from the Netherlands, Alan Scwartz whose article influenced me to search for formaldehyde, indicated to me the reaction of HCN and CH2O needs water. So, your speech is of value to me and my research. If your speech becomes published I would deeply appreciate being notified about it. Or, any excerpt of your speech would be appreciated.

As for organic species arriving from comets, which compounds do you believe were delivered via a comet into Titan's atmosphere. In my research I noticed comets contain HCN and CH2O, and since HCN was already discovered and if it arrived via a comet, could the formaldehyde be present due to a comet also ? Could CH2O exist on Titan from both, CO and CO2 as well as a comet ?

I deeply appreciated your belief of formaldehyde existing on Titan, along with how it originated. Now, I just have to wait to analyze my spectra from HST. I recently found out my observation could occur as soon as April, 1993. I will keep you updated on the status.

Sincerely,

George R. Lewycky

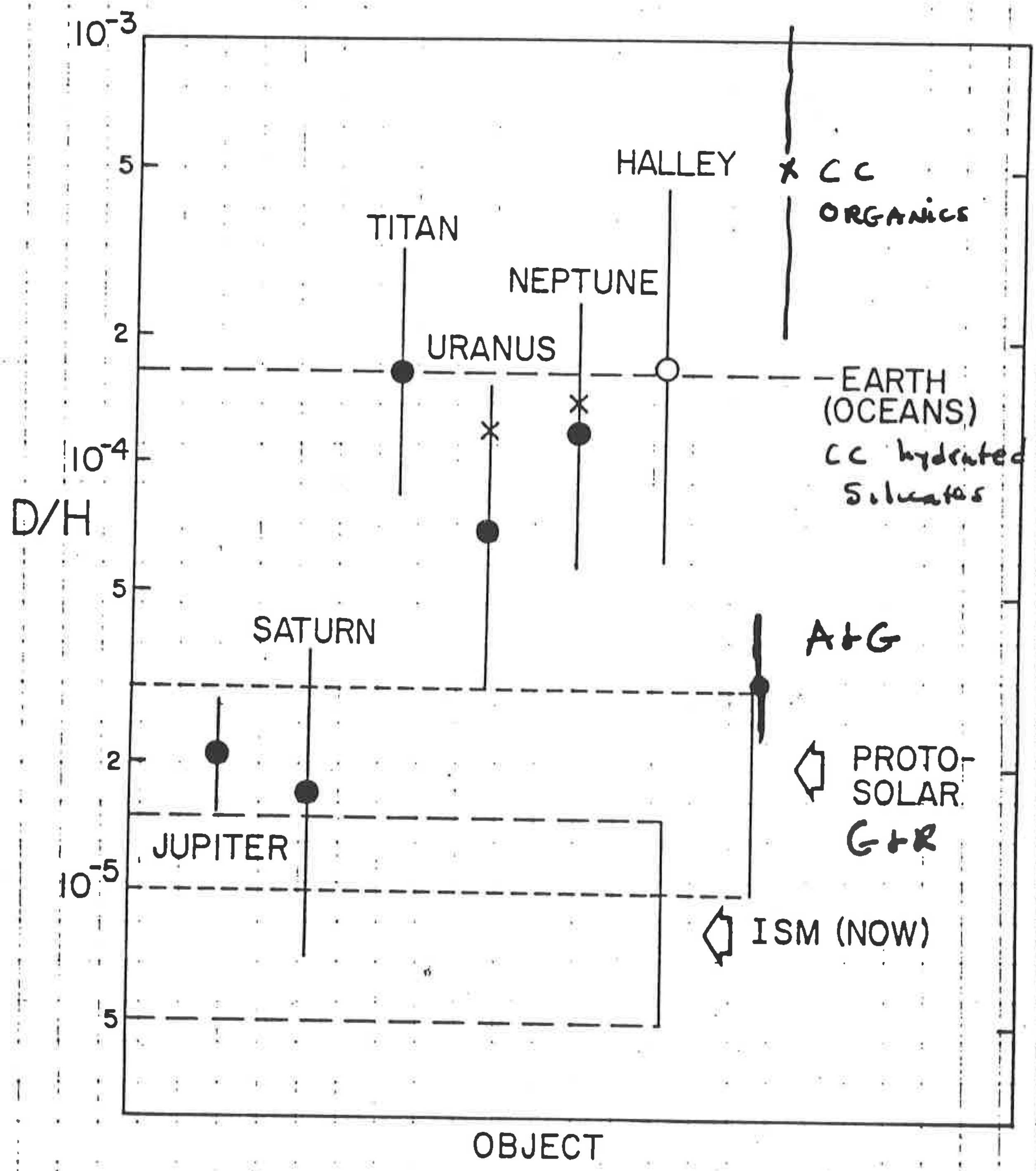
Table 1. Atmospheric Composition of Titan

Constituent Detected	Mixing Ratio	Constituent Detected	Mixing Ratio
Major species			
N_2	0.8-0.98		
Ar	$\leq 20\%$		
CH_4	$2x10^{-2}$ at 100 mbar		
	$(8 \pm 3)x10^{-2}$ at 10^{-10} bar ≤ 0.15 at the surface		
Minor species			
H Group		C-H Group	
H_2	$2\text{-}6x10^{-3}$	C_2H_6	$(1\text{-}2)x10^{-5}$
D/H	$\sim 1.5x10^{-4}$	C_3H_8	$10^{-5}\text{-}10^{-6}$eq. strat.
C-N Group			10^{-5}N-pole
C_2N_2	$10^{-8}\text{-}10^{-9}$	C_2H_2	$(1\text{-}2)x10^{-6}$
C_4N_2	condensed phase	C_2H_4	$(4\text{-}10)x10^{-7}$eq. strat.
C-N-H Group			$4x10^{-6}$N-pole
HCN	$(1\text{-}2)x10^{-7}$	CH_3C_2H	$(0.3\text{-}3)x10^{-8}$ eq. strat.
HC_3N	10^{-9} eq. strat. $3x10^{-7}$ N-pole		10^{-7} N-pole
		C_4H_2	$10^{-8}\text{-}10^{-9}$
C-O Group			
CO	$6x10^{-5}$troposphere		
	$4x10^{-6}$ stratosphere		
CO_2	$(0.33\text{-}1.1)x10^{-8}$		

RELATIVE ABUNDANCES

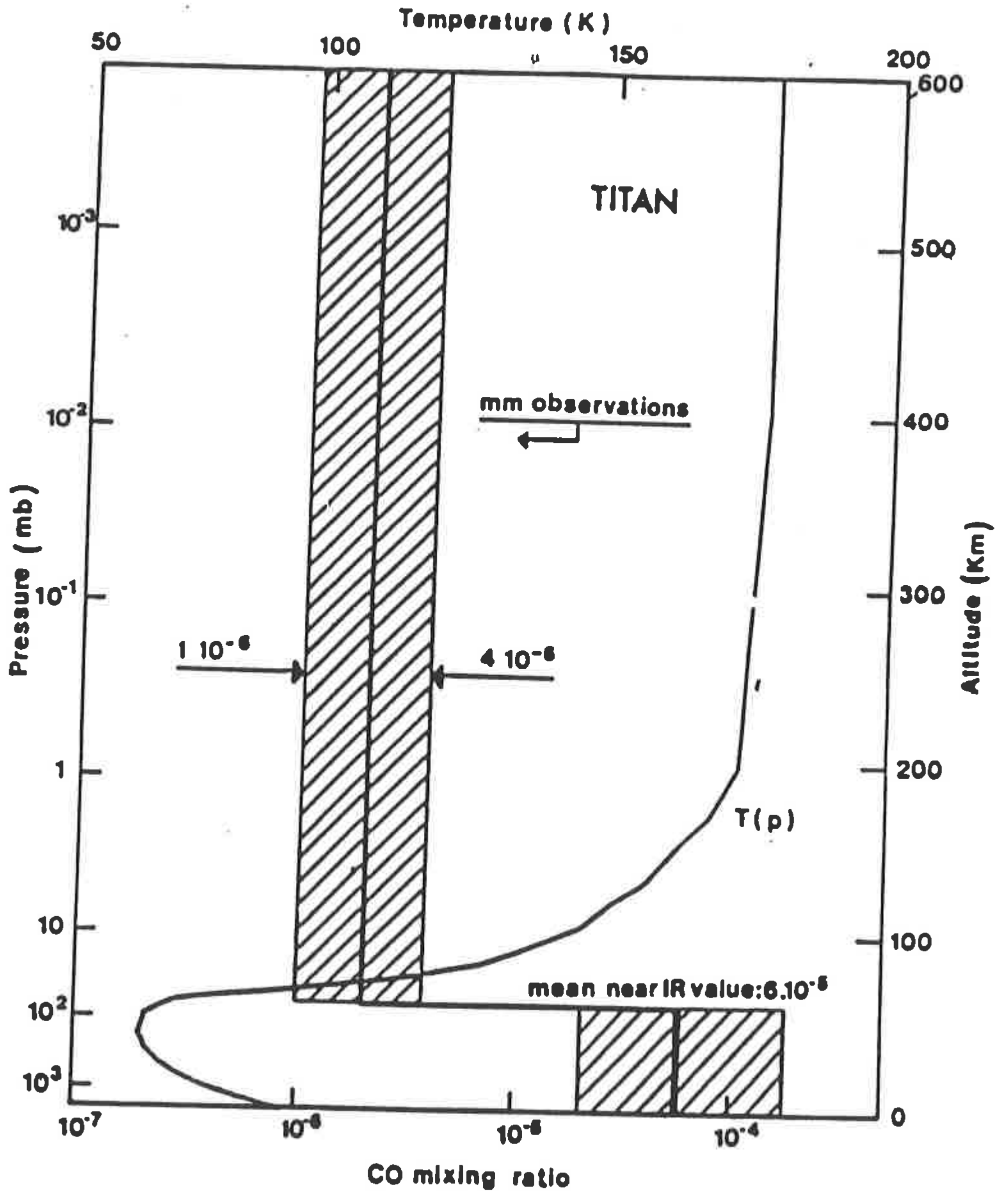
	Jupiter/sun	Saturn/sun
O	~ 2	~ 10 ?
C	2.3 ± 0.2	4 ± 2
N	~ 2	$\sim 3 \pm 1$
S	$< 10^{-3}$	?
P	0.9 ± 0.2	9 ± 2
As	0.5 ± 0.2	7 ± 2
Ge	~ 0.05	0.05 ± 0.05

Need: Better Precision
More Elements



10^{-3}
5
2
10^{-4}
5
2
10^{-5}
5
D/H
OBJECT
HALLEY
CC ORGANICS
TITAN
NEPTUNE
URANUS
EARTH (OCEANS)
CC hydrated Silicates
SATURN
A+G
JUPITER
PROTO-SOLAR
G+R
ISM (NOW)

NOTE


Temperature (K)
50
100
150
200
600
500
400
300
200
100
0
TITAN
10^{-3}
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
mm observations
1 10^{-6}
4 10^{-6}
T(p)
mean near IR value: 6.10^{-5}
Pressure (mb)
Altitude (Km)
10^{-7}
10^{-6}
10^{-5}
10^{-4}
CO mixing ratio

TITAN ATMOSPHERE

1. Major Constituents

$P_s = 1.5$

N_2	$\geq 80\%$
CH_4	$\sim 6\%$
$^{36}Ar, {}^{38}Ar$	$0 - 20\%$

MUST BE SECONDARY — $Ne < 1\%$

[Captured atm $\rightarrow$ $Ne \approx N$]

SOURCE?

2. Isotopes

In CH_4, $D/H = 1.5^{+1.5}_{-0.7} \times 10^{-4}$

This is 5 to 8 x Solar Nebula Value

SUGGESTS PRESERVATION OF ISM RATIO FOR "HYDROCARBONS"

NO EQUILIBRATION WITH H_2 IN SOLAR NEBULA OR SATURN SUB-NEBULA?

CO and CO_2

A. Production of CO_2

$$\boxed{CO + OH \rightarrow CO_2 + H}$$

B. Sources of OH

1. $H_2O + h\nu \rightarrow H + OH$

   H_2O from outside

2. $\underline{CO} + e \rightarrow C + O(^1D) + e$

   $O(^1D) + CH_4 \rightarrow OH + CH_3$

C. Sources of CO

1. $OH + CH_4 \rightarrow H_2O + CH_3$

   $CH_3 + OH \rightarrow CO + 2H_2$

2. Primordial

D. CO_2 freezes out on surface

If CO primordial $\rightarrow$ 10's of meters of CO_2

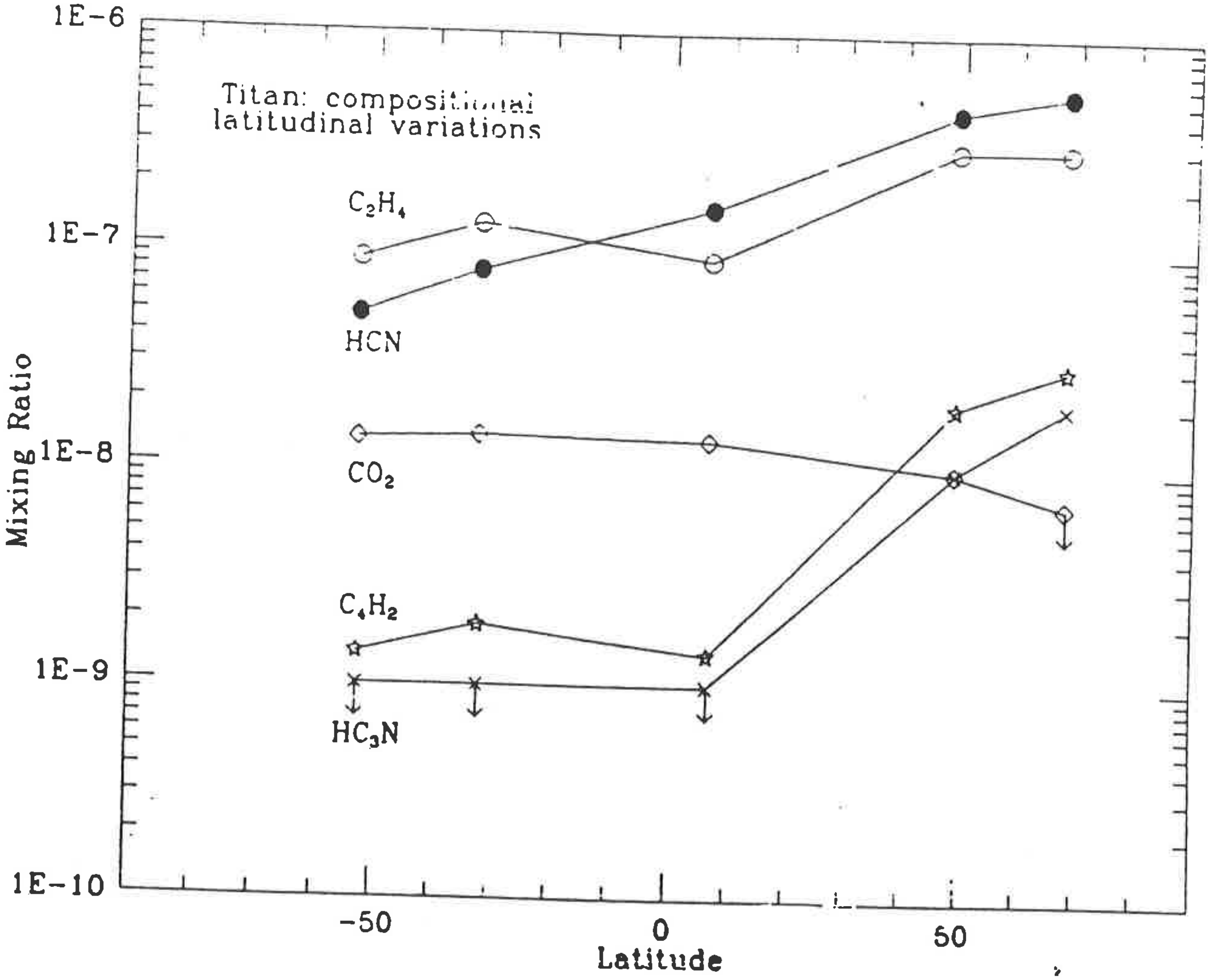


FIGURE 2

Compositional latitudinal variations of Titan
(from Coustenis, Bézard and Gautier, BAAS, 21, 959, 1989)

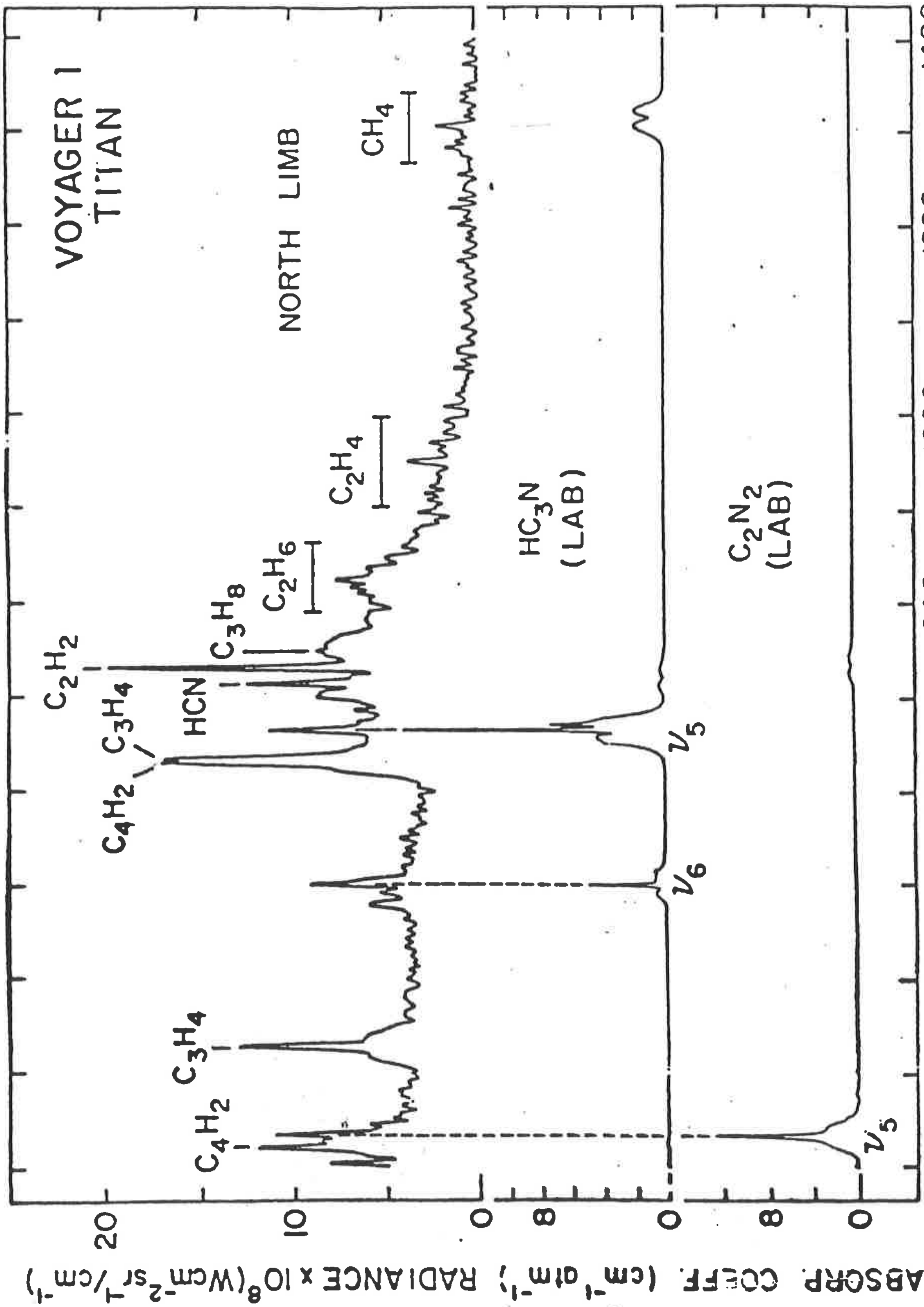
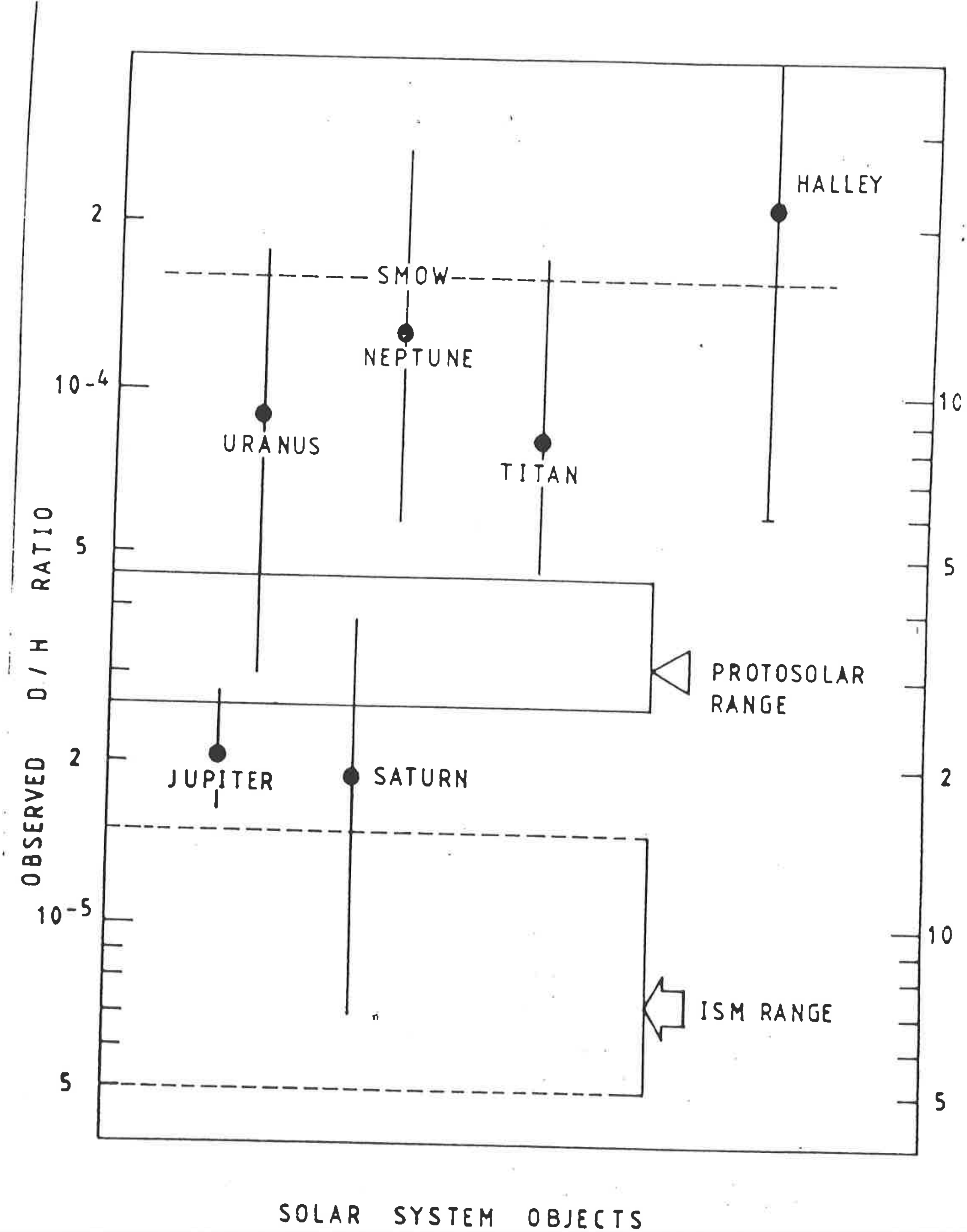


FIGURE 23 : Voyager 1 average spectrum recorded at the north pole limb of Titan, compared to laboratory spectra of cyanoacetylene (HC_3N) and cyanogen (C_2N_2). (from Kunde et al, 1981).


HALLEY
SMOW
NEPTUNE
URANUS
TITAN
PROTOSOLAR RANGE
JUPITER
SATURN
ISM RANGE
OBSERVED D/H RATIO
2
10^{-4}
5
2
10^{-5}
5
10
5
2
10
5
SOLAR SYSTEM OBJECTS

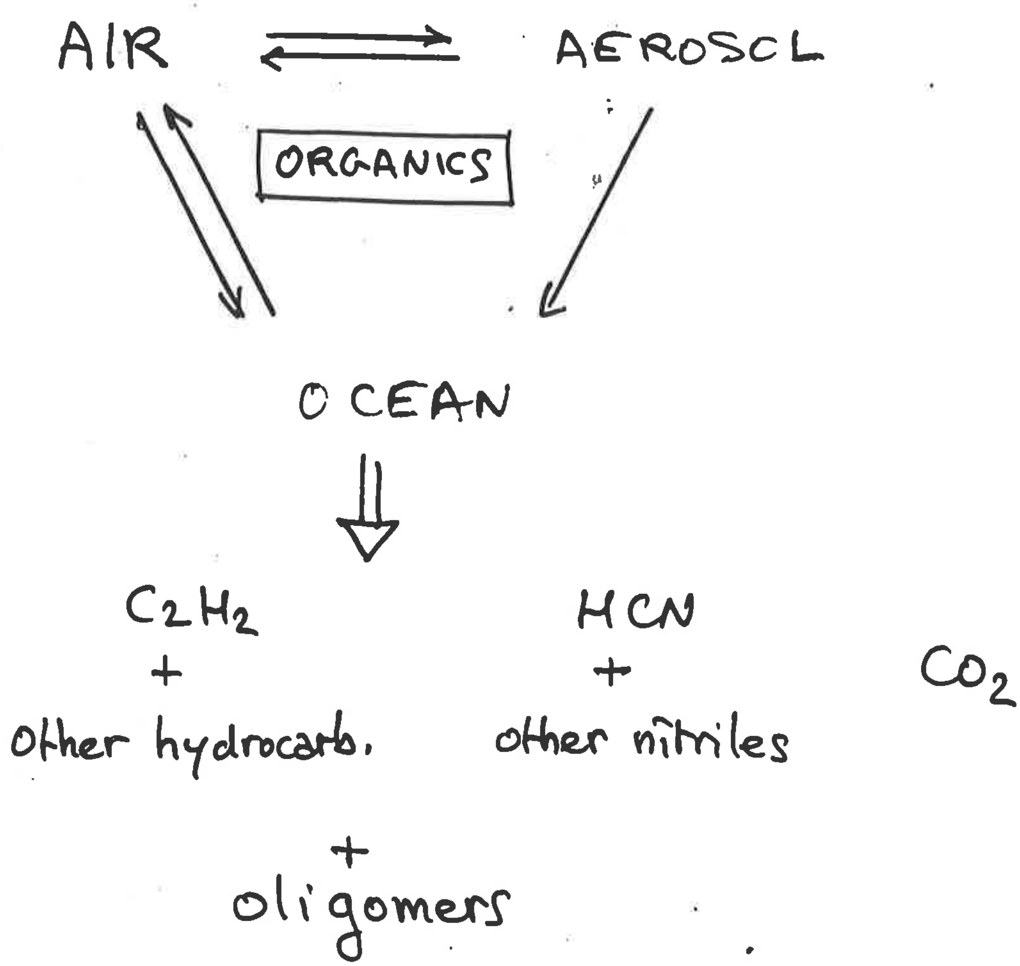
Cosmogonical Implications of a deuterium enrichment in Titan

$(D/H)_{Titan} \gg (D/H)_{protosolar}$

implies that grains which formed Titan were enriched in deuterium before the formation of the Solar System

Suggest N_2 in Titan coming from N_2 clathrates

and CH_4 from organics present in presolar grains


AIR
AEROSOL
ORGANICS
OCEAN
C_2H_2
+
other hydrocarb.
HCN
+
other nitriles
CO_2
+
oligomers

OCEAN	92.5 K $Y_{Ar} = 0$ $Y_{CH4} = 0.0155$		101 K $Y_{Ar} = 0.17$ $Y_{CH4} = 0.211$	
<u>Main composition</u>				
C_2H_6 (+ C_3H_8)	90.9 %		5 %	
CH_4	7.3 %		83.4 %	
N_2	1.8 %		6 %	
Ar			5.6 %	
$CO^{(c)}$	3.7×10^{-6}		9.2×10^{-6}	
$H_2^{(d)}$	9.0×10^{-7}		2.6×10^{-6}	
<u>Depth</u>				
current	695 m		9.4 km	
initial	1.3 km		10.1 km	
<u>CH4 depletion in</u> ...	140×10^{6} years		1.0×10^{9} years	
<u>solutes</u>	X	H_D(m)	X	H_D(m)
C_2H_2	4.1×10^{-4}	107	3.7×10^{-4}	123
C_3H_4	5.0×10^{-5}	6.5	2.9×10^{-5}	6.3
C_4H_2	8.3×10^{-7}	5.8	5.4×10^{-7}	5.9
CO_2	1.2×10^{-5}	1.5×10^{-2}	2.5×10^{-6}	--
HCN	8.5×10^{-6}	18.0	2.3×10^{-6}	18.8
CH_3CN	6.3×10^{-5}	0.20	1.5×10^{-5}	4.1×10^{-2}
C_2H_5CN	8.9×10^{-5}	0.11	1.1×10^{-5}	--
C_2H_3CN	2.2×10^{-5}	0.28	5.0×10^{-6}	0.22
C_2HCN	7.2×10^{-6}	2.2	2.0×10^{-6}	2.3
C_3H_3CN	1.6×10^{-6}	6.9×10^{-2}	4.1×10^{-7}	6.3×10^{-2}
C_2N_2	1.4×10^{-6}	0.83	1.5×10^{-7}	0.84