A Mid-UV Spectroscopic Search for Formaldehyde (CH_2O) in Titan's Atmosphere using HST

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ABSTRACT

Voyager 1 discovering HCN (Hydrogen Cyanide) in Titan's atmosphere in 1980 (Hanel et al, 1981) surprised many while being a precursor for DNA.

A laboratory experiment involving HCN and Formaldehyde (CH_2O) was performed (*Schwartz and Bakker, 1989*) and the results have direct implications for Titan's chemistry. HCN oligomerizes when added with CH_2O in quantities of 1.0 and 0.5 molars respectively.

With enough CH_2O together with the HCN, purines such as Adenine - one of the four components for DNA could form.

If such a reaction would occur Titan's north polar and equator regions contain the highest abundance of HCN.

Methane-rich atmospheres, such as Titan's can produce substantial quantities of HCN and CH_2O (*Schlesinger and Miller, 1983*), aiding in the synthesis of amino acids.

This HST observation occurred as part of the Cycle Two program for *amateur astronomers* originated by the first Space Telescope Science Institute (STScI) Director, Riccardo Giacconi in 1996.

OBJECTIVES

Observed a high-resolution spectrum of the full disk of Titan in the middle ultraviolet region using the orbiting HST. This spectrum will be used to search for the presence of formaldehyde and other species.

Formaldehyde (methanal) is an organic molecule and the simplest member of the aldehyde group. Slso a known polyatomic molecule of astrophysical interest with a high abundance in the interstellar medium (ISM), which is present in comets, galaxies and tentatively the planet Mars.

Laboratory and reference spectra of formaldehyde at various resolutions and temperatures in the UV was used from several sources

formaldehyde has an absorption system in the near UV extending from 3700 - 2300 A with the maximum absorption feature appears roughly at 2935 A with variances due to different resolutions, temperatures and instruments.

The region of 2909 - 2956 A was chosen to search for at its absorption maximum of 2935 A (*Pearse & Gaydon; Rogers*), which is also the central wavelength for this observation.

Observations, not to mention UV data of Titan has not been studied in such detail since the Voyager encounters, and previous International Ultraviolet Explorer (IUE) observations but all at a lower resolutions with an optimal resolution of 0.7 - 5 A.

Previous IUE observations could only produce at the most six spectral resolution elements across the region being studied in this paper, making any molecular detection quite difficult.

Even both Voyager spacecraft's only studied the extreme UV region from 550 - 1700 A at a resolution of ~33 A.

This region of Titan's UV spectrum is inaccessible to ground-based observatories due to the strong UV absorptions by ozone (O_3) in Earth's atmosphere and has not been observed previously at such high resolution.

Sources of UV (Ultraviolet) Spectra and Atmospheric data

CH_2O (Formaldehyde)	University Corporation for Atmospheric Research (UCAR) Federal Aviation Administration (FAA) & EPA General Motors Other Sources and publications (Pearse & Gaydon) ***(Sources: Calvert, Cantrell, Rogers, Pope, Smith, Moortgart)***
Solar	Skylab, Naval Observatory, Balloon & Rocket (Air Force), Solar Maximum Mission (SMM) satellite – **highest resolution for my data from Harvard - Center for Astrophysics (Kurucz)** G2V stars **(Sallie Baliunas)** - same spectral type as our Sun (HST, IUE, others)
Atomic & Molecular	Identifcation of Molecular Spectra (Pearse & Gaydon); Charlotte Moore;
Titan	International Ultraviolet Explorer (IUE) **(very low resolution)** Voyager 1 - not same UV region
Other	private collections - Peter Smith - Harvard CFA ; Robert Kurucz, Harvard-CFA private collections - Arthur L. Lane, JPL private collections - Gerhard Herzberg published line lists & cross sections of UV absorptions for my region (2909-2956 A)

OBSERVATION

Spectral data was collected of Titan's upper atmosphere on September 21, 1993 using the Goddard High Resolution Spectrograph (GHRS) in the ACCUM mode [*table 1*].

GHRS is a Czerny-Turner spectrograph which was used to observe the wavelength range of 2909 - 2956 A. Tracking and acquisition of Titan was performed using a single guide star, while using the Large Science Aperture (LSA), which is 2.0 arc seconds in diameter to acquire and observe the full disk of Titan.

Grating chosen was the G270M, yielding a sampling of ~ 0.14675 A per pixel. Since a long exposure was necessary to obtain a high signal to noise ratio, and due to spacecraft limitations ten sub-exposures of fourteen minutes apiece were taken and then compared individually and combined to form a single exposure of 140 minutes.

More technical information about the GHRS instrument is described by Soderblom (1993), in the pre-COSTAR (Corrective Optics Space Telescope Axial Replacement) Hubble Space Telescope Goddard High-Resolution Spectrograph Instrument Handbook.

The Goddard High-Resolution Spectrograph (GHRS) was one of the 4 original axial instruments aboard the Hubble Space Telescope (HST). The GHRS was designed to take spectral observations of astrophysical sources from 1150 to 3200 Angstroms. The instrument was removed from HST during Servicing Mission 2 in February, 1997. HST's spherical aberration wasn't a factor for my observation or delaying it.

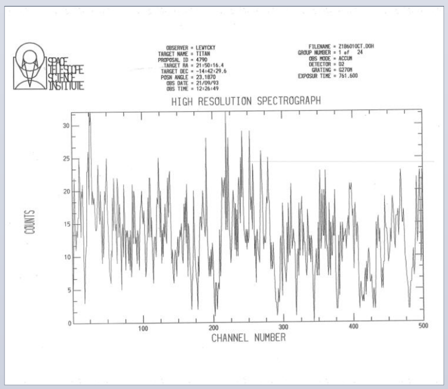
Table 1: HST Observation Parameters

Exposure Duration (s)	Instrument	Grating/ Aperture	Central Wavelength	Wavelength Coverage	Resolution	S/N
8400	GHRS	G270M/LSA	2935	2909-2956	.14675 A	~40

Table 2: Summary of Comparable UV Albedo Observations of Titan

Wavelength Coverage (A)	Resolution (A)	Observatory	Year
2100 – 4300	20	OAO-2	1972 (Caldwell, 1975)
2100 – 3200	0.7 - 5	IUE/LWR	1978 (Caldwell et al, 1978)
2200 - 3350	0.7 - 5	IUE/LWP	1987 (Courtin et al, 1987)
2909 - 2956	0.14675	HST/GHRS	1993 present work

Raw Spectra taken of the observation



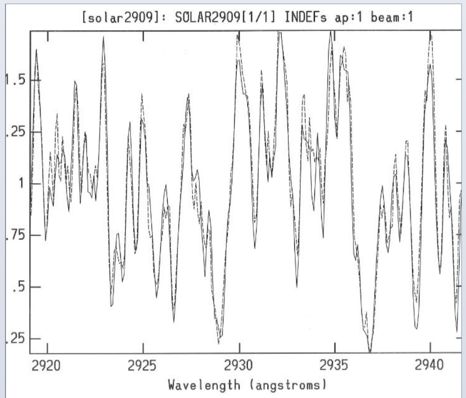
DATA REDUCTION, ANALYSIS & RESULTS

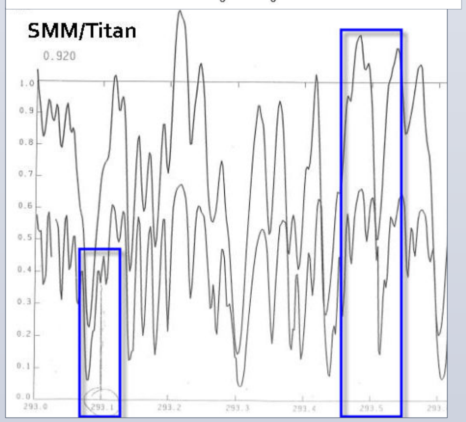
Calibration lamp spectra taken before each science observation with same grating configuration provided vacuum wavelength calibration covering doppler and radial velocity corrections of the HST, Titan and Earth. Wavelengths converted to vacuum wavelengths, were also performed through the standard "pipeline" routine at GSFC or after the observation.

Compared 10 sub-exposures revealed identical spectral features with minimal noise. The sub-exposures combined to form a single exposure, producing both a higher flux and signal to noise of ~40. IRAF/STSDAS software were both used for data reduction and analysis of the spectra. Solar spectra acquired and compiled from several sources especially from balloon (**Hall LA, Anderson GP),** and Solar Maximum Mission's (SMM) satellite (**Kurucz,R.L.)** being the highest resolutions of .12A and ~.04A respectively. Balloon spectra was only available at time of observation.

Titan's spectra (.14675 A) was slightly coarser than the solar (.12A), so Titan's spectra was resampled in order to accurately match and remove the solar features. Solar spectra converted from vacuum UV to air UV to agree with Titan's spectra and the solar, atomic and molecular line lists. Both the Titan and the solar had to be scaled by dividing the spectra by their respective averages due to their fluxes. \

AFGL & Titan (top); SMM & Titan (bottom)





CONCLUSIONS

Differences with best solar UV spectra at different resolutions from both balloon and SMM's instrument Ultraviolet Spectrometer and Polarimeter.

Determining true absorptions and other features was tried via both dividing or subtracting solar spectra and spectra of Titan

Was alerted of a OH transition in my spectra by several at JPL which I'm still investigating.

G2.5V spectra taken by HST of 16CygB (similar to our Sun) at advice of T. Owen (personal communication) which was useful. But A.L. Lane (personal communication) said to rely on the Sun since my observation wasn't affected by 16CygB.

Obstacles such as very strong solar lines, different spectral data (Titan, Solar) and the different instruments and resolutions have made the data analysis difficult to finalize since features were lost.

Still collecting solar, atomic, molecular and even ion line lists in the UV region observed to account for spectral features. While reviewing ~500 books in ~15 government and university libraries throughout the U.S. proved to be a difficult task also.

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