LISA-GPCOS Titan’s Investigations

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Fifth Workshop on ‘Titan - Observations, Experiments, Computations, and Modeling’
Poipu Koloa, Kauai, Hawaii, April 11-14, 2011
Aim of the studies - outline

determine the nature and estimate the relative abundances of organic species present in the atmosphere of the satellite

❖ Low temperature high resolution spectra (UVIS data)
❖ New infrared line list (CIRS data)

establish their mechanisms of formation and evolution in Titan’s environmental conditions

❖ Titan’s laboratory simulations:
  ★ DC Current plasma experiments-tholins
  ★ Microwave plasma experiments-gas phase
  ★ Afterglow plasma experiments-gas phase
determination of near VUV absorption coefficients (and their T dependence)

Synchrotron radiation (VUV-UV)

Studies on gas phase species $\text{HC}_3\text{N}$, $\text{HC}_5\text{N}$, $\text{C}_4\text{H}_2$ already published
New results:

<table>
<thead>
<tr>
<th>Wavelength range (Å)</th>
<th>Resolution (Å)</th>
<th>T(K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCN</td>
<td>1150-1850</td>
<td>0.6</td>
</tr>
<tr>
<td>C₂N₂</td>
<td>1150-1900</td>
<td>1</td>
</tr>
<tr>
<td>C₄N₂</td>
<td>1150-1850</td>
<td>1</td>
</tr>
</tbody>
</table>

Temperature variations! Saturation!

Still a lot to do
....on longer chains species such as C₆H₂
.....as well as C₆H₆....
Application to UVIS occultation data

- All spectra obtained used for reanalysis of TB data: Lambda Scorpio -> nice fit obs/updated model data
- new retrieval of density profiles from UVIS observations of Titan's atmosphere
  - example HCN

In accordance with W&A model data as well as those retrieved from observations in the sense that the general shape is well reproduced

Observations: UVS Vervack et al. (2004), UVIS Shemansky et al. (2005)
determination of IR linelists

Linelist for $\text{HC}_3\text{N} (+^{13}\text{C} + ^{15}\text{N})$, $\text{C}_2\text{HD}$ and $\text{C}_4\text{H}_2$ ($^{13}\text{C}$) already published

New results: $\text{C}_2\text{N}_2$

Soleil Synchrotron facility (AILES):

- band intensity measurement for $\text{C}_2\text{N}_2$ and $^{15}\text{N}$ isotopologue
  (resolution: 0.1 and 0.5 cm$^{-1}$)

- high resolution spectra: 0.0015 cm$^{-1}$
  and complete analysis of the $v_5$ band system

New line list allowed a better agreement with exp data than the one of Geisa database

- First line list for the $^{13}\text{C} + ^{15}\text{N}$ isotopologues now available

→ A. Jolly
CIRS detection and quantification in Titan using new line list

already done for $\text{HC}_3\text{N}(^{13}\text{C})$, $\text{C}_2\text{HD}$ and $\text{C}_4\text{H}_2\left(^{13}\text{C}\right)$

Looking for $^{15}\text{N}$ species: (it turns to be difficult for $\text{HC}_3\text{N}$)

The recent work on $\text{C}_2\text{N}_2$ should provide the opportunity to search for $\text{C}_2\ ^{15}\text{N}_2$ even if this task remains difficult as the line between the isotopes are still close...

Important to provide new constraint on $^{15}\text{N}/^{14}\text{N}$ in Titan’s atmosphere
Direct current plasma discharge experiments

Devoted to the characterization of Titan’s Tholins

May Titan’s aerosols efficiently interact with the surface to produce compounds of Astrobiological interest ???

\[ \text{N}_2 + 2\% \text{CH}_4 \]

low P (\(\sim 1\) mbar)

–room or low T (\(\sim 200\)Km)

<table>
<thead>
<tr>
<th>Recovery</th>
<th>Solution of 10 mg of tholins</th>
<th>GCMS analysis after derivatization</th>
</tr>
</thead>
</table>

in liquid water (4 mL) to 6°C in ammonia 25% (4 mL) to 6°C and –20°C for 10 weeks
Results:

**Chromatogram**
Tholins hydrolyzed in water

Identification and quantification by standards

Formation of compounds of prebiotic interest, Urea = main compound of tholins hydrolysis in ammonia (production yield 10%); amico acids: glycine, alanine and aspartic acid (low yields < 0.35%)

After sedimentation on Titan’s surface, the aerosols could undergo chemical evolution in liquid ammonia-water aera leading to molecule of astrobiological interest
Microwave plasma discharge experiments

(S.E.T.U.P. Experimental and Theoretical Simulations Useful of Planetology)

Simulations of Titan’s atmosphere

Experiment devoted to the characterization of the gaseous phase in terms of composition and evolution

N₂/CH₄ gas mixture with various mixing ratio, in flow conditions

Ex-situ IRTF analysis of the resulting gas mixture recovered in a cold trap

Methane’s dissociation in the plasma discharge

\[ CH₄ + e^- \]

Exp conditions: 100W, Total pressure: 3.6 torr
Total flow rate: 50 sccm
New results:

Typical spectrum obtained revealing the formation of several compounds including C$_6$H$_2$ and HC$_5$N.

For each exp., the respective abundance of the products has been derived:

N$_2$/CH$_4$: 70/30

Comparison between exp. and obs. data:

Plasma experiments  Upper atmosphere
high energetic e$^-$  high energetic e$^-$ + photons
T gas ~ 1000K  T lower than 180 K

Microwave plasma exp. can not be considered as representative simulations
**Afterglow microwave plasma experiments**

**Plasma $N_2$**

$CH_4$ added in the post discharge (afterglow region)

$T_{\text{gas}} \sim 300 \, \text{K}$ (representativeness improved)

Various $(N_2/CH_4)$ mixing ratio

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A self-consistent kinetic model for the afterglow of a flowing microwave discharge in pure $N_2$, in which various % of $CH_4$ are introduced has been developed by Pintassilgo and co-workers.
New results:

Only HCN and NH₃ are formed!

\[ N₂/CH₄: 70/30 \]

Fit exp/observational data improved

Strong desagreement for NH₃

Need for description of surface reactions
Work in progress:

Coupled experiments are currently performed: CH$_4$ injected into the post discharge downstream from the N$_2$ discharge is submitted to UV photons (H$_2$/He lamp) -> disentangle the processes that occurs in the plasma from those due to the methane photochemistry itself.

Next step:
Implementation of in situ analysis by CRDS time resolved technique (quantitative data) → Achieve a better understanding of the chemical mechanisms involved
THANKS TO COLLABORATORS!

Low temperature high resolution spectra (UVIS data)
  Guillemin J.-C., Yelle R.

New infrared line list (CIRS data)
  Fayt A., Jacquemart D., Nixon C.A., Jennings D.E., Teanby N.A.

DC Current plasma experiments-tholins
  Ramirez S., Buch A., Szopa C., Munoz O.

Microwave plasma experiments-gas phase

Afterglow plasma experiments-gas phase
  Pintassilgo C.

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[logos for CNES, CNRS, Île-de-France]
THANKS FOR YOUR ATTENTION!