Reanalysis of Cassini Huygens GCMS results- an effort to extract composition of trace gases

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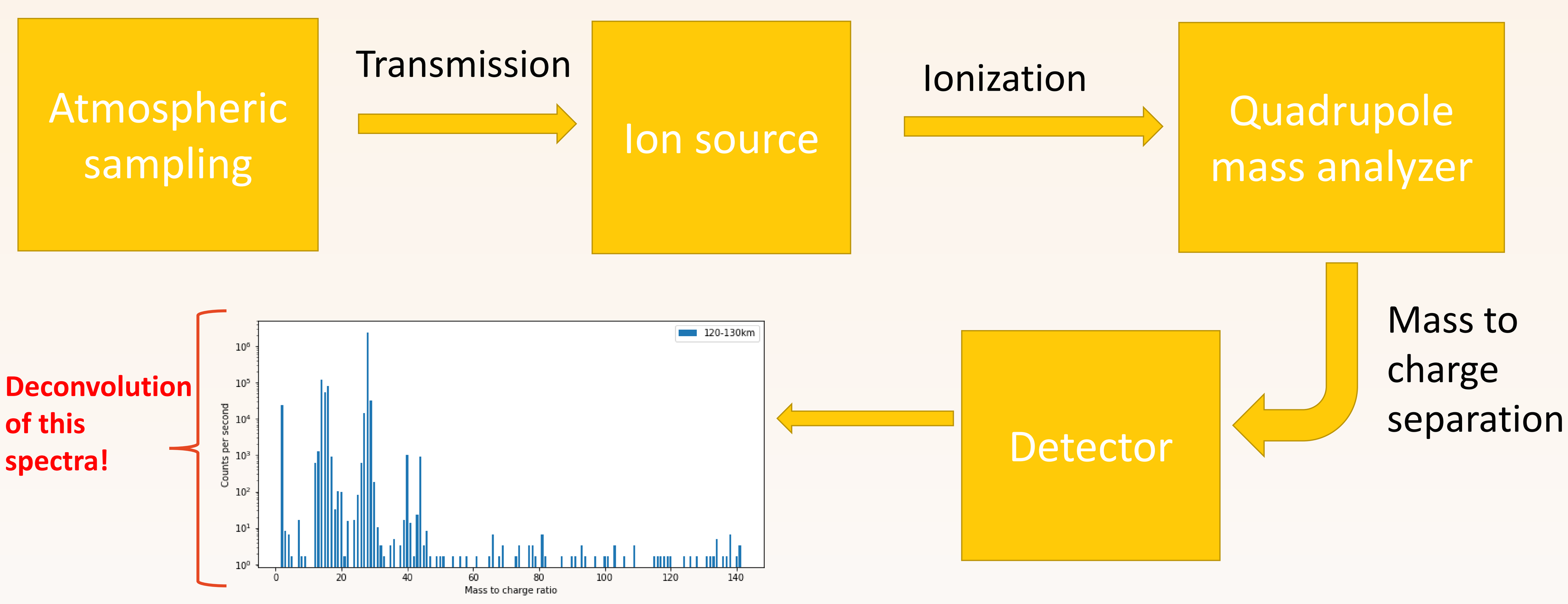
Introduction

In Titan, the two major species N_2 and CH_4 are ionized and/or photolyzed at high altitudes by the sunlight and the energetic particles from Saturn's magnetosphere, resulting in rich atmospheric chemistry and a wide variety of carbon and nitrogen-bearing atmospheric compounds.

Huygens GCMS: The mission was conducted on 14 January 2005 for nearly 3.5 hours. GCMS sampled data from an altitude of 147 km. In our work we focus on the atmospheric segment only and use measured spectra from one of the five ion sources (in the spectrometer) that directly samples from the atmosphere. The process is shown below:



Objective

To quantify the trace gases in Titan's atmosphere using the Gas Chromatograph Mass Spectrometer (GCMS) onboard the Cassini Huygens probe. We have used a mass spectra deconvolution code (Gautier et. al. 2019) that runs Monte Carlo simulations to vary the peak intensities of some species and measure their mixing ratios.

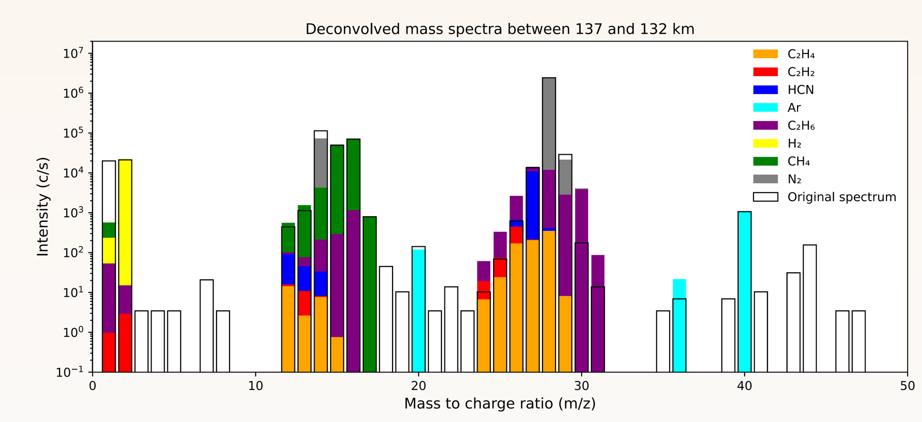
Methodology

Data treatment:

1. Pulse pile up correction *(Niemann et.al.2010)*
2. Correcting mass-28 saturation using a proxy peak (of mass-29) *(Gautier et.al. in prep)*
3. Background removal

Mass spectra deconvolution code *(Gautier et.al.2019)*:

- A database containing the mass spectra of ten species-N_2, CH_4, C_2H_2, HCN, H_2, C_2H_4, C_2H_6, Ar, CO_2, Ne (taken from Cassini INMS and NIST calibrations).
- Monte Carlo simulations by varying the database by ± 30% (100,000 runs).
- Implementing ionization and transfer cross sections to the code.



Results and discussions

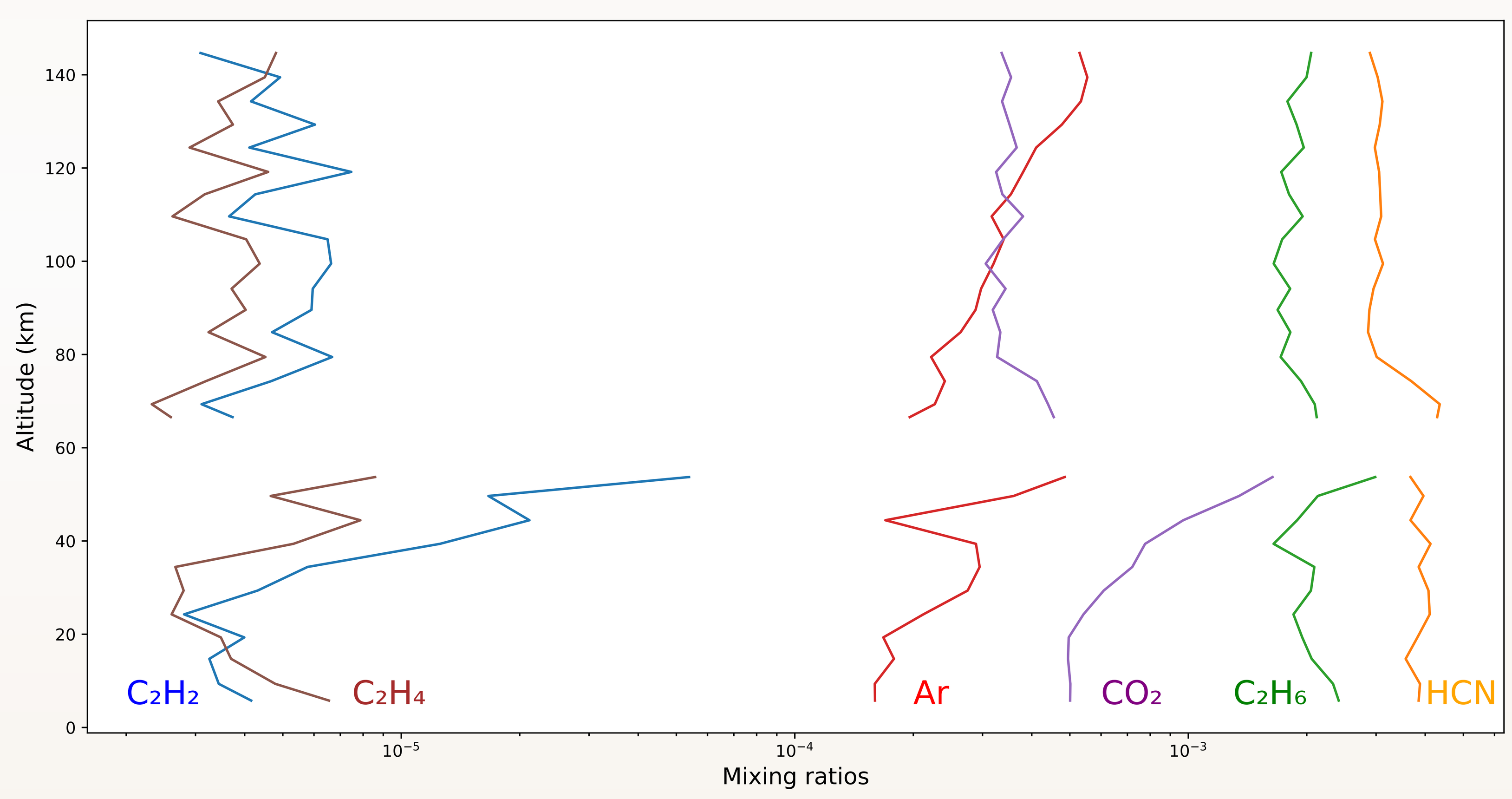


Figure 1: Vertical profiles of six trace gases

For trace gases in lower atmosphere, GCMS results do not agree with results from CIRS and other microphysical models (figure 2).

- Mixing ratios of HCN, C_2H_6, C_2H_4 is higher.
- CO_2 was present as a background in the ion source. Hence this might be the reason for its high mixing ratio.
- C_2H_2 mixing ratio is similar.

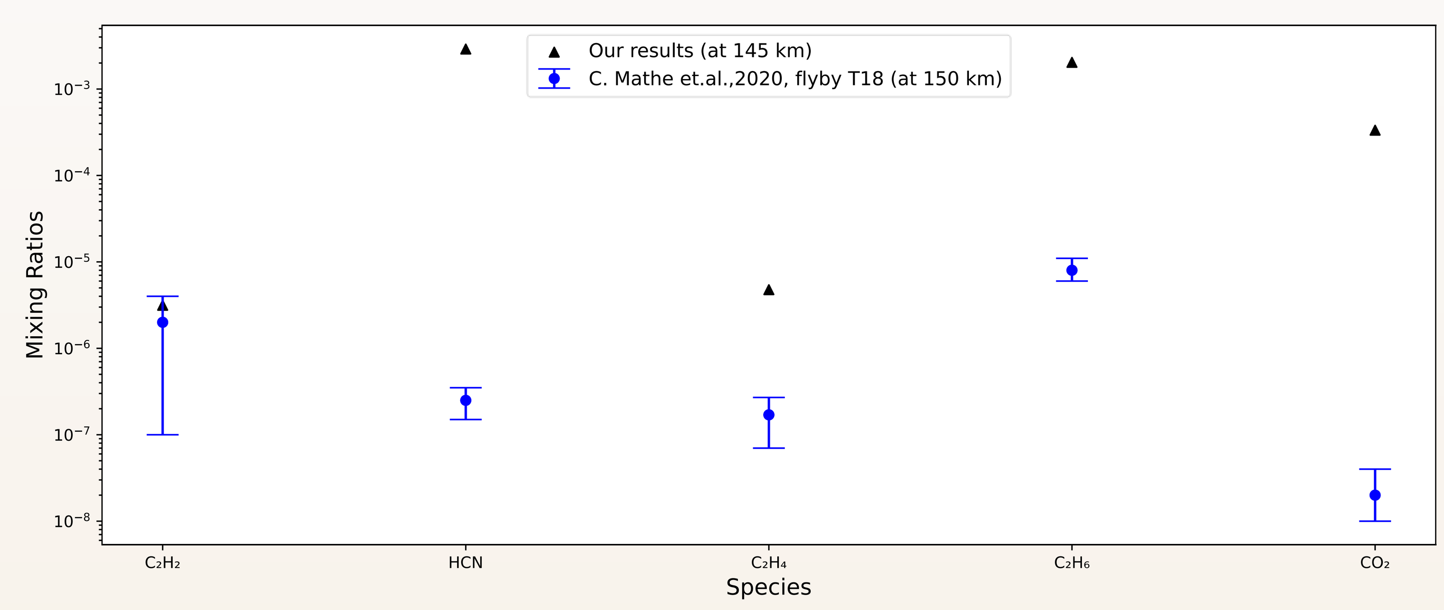


Figure 2: Comparison between our results and those calculated using CIRS results for flyby T18

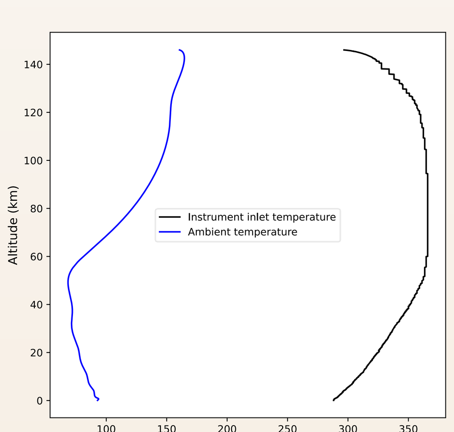


Figure 3: Vertical profile of ambient and instrument temperature

Possible hypotheses:

- Aerosol outgassing –
  - Instrument inlet temperature higher than ambient temperature (figure 3) -> possible that some aerosols might have evaporated at the entrance.
  - Experimental results show that it is possible for light molecules (like HCN, C_2H_2, C_2H_4) to outgass at this temperature (Morisson et. al. 2016).
- Recombination inside ion source –
  - Possible that fragments inside ion source might have recombined if the pressure inside the ion source changed during descent.
  - Do not have information on ion source pressure.
  - No change in the filament current in the first 2000 seconds of the descent (no data on the later part of the mission though) -> recombination might be negligible.
- Deposition of ice on the instrument –
  - Possible that at high altitudes (when the instrument did not start working), ice might have gotten stuck at the entrance.
  - By the time the instrument started to sample, it had evaporated and thus was measured.
- Cross contamination between two consecutive peaks –
  - If one mass peak has a very high count rate, it is possible that some of it's counts might have been detected at it's previous or next peak.
  - Might explain why we see such a high mixing ratio in HCN.
  - We see cross talk between m/z 27,28,29 (figure 4). Currently trying to correct for this!

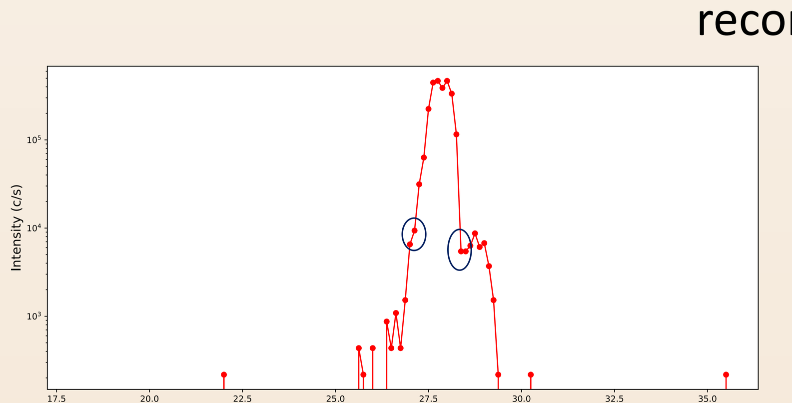


Figure 4: Fractional mass scan between m/z 17 and 35. The cross talk between the three peaks is shown by blue circles.

Future work and it's impact

- Find an efficient way to correct for the cross talk between mass peaks- hopefully that will reduce the mixing ratios of some gases.
- Look for a way to separate aerosol contribution from the measured data.
- Study of these results can be beneficial to the future Dragonfly mission which will be landing on the surface for measurements.

References

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