Detection of Chemical Species in Titan's Atmosphere using High-Resolution Spectroscopy

José Ribeiro (1), Pedro Machado (1), João Dias (1), Constança Freire (2)

1 – Instituto de Astrofísica e Ciências do Espaço, Portugal; 2 – Faculdade de Ciências da Universidade de Lisboa, Portugal;

Titan's Atmosphere

- Before the Voyager several molecules, apart from methane, were detected by infrared spectroscopy (C_2H_6, CH_3D, and C_2H_2).
- After the observations by the spaceprobe the following molecules were identified: N_2, H_2, HCN, C_3H_8, C_2H_4, C_3H_4 (CH_3C_2H), C_4H_2, HC_3N, C_2N_2, and CO_2;
- The Cassini-Huygens mission confirmed that the primary constituents of Titan's atmosphere were nitrogen and methane. It measured the vertical distribution of methane, the isotopic ratio of N in N_2 and the abundances and isotope ratios of noble gases;
- With the end of the Cassini-Huygens mission, the only way to obtain information about the chemical and physical properties of the atmosphere of Titan is trough ground base observations;

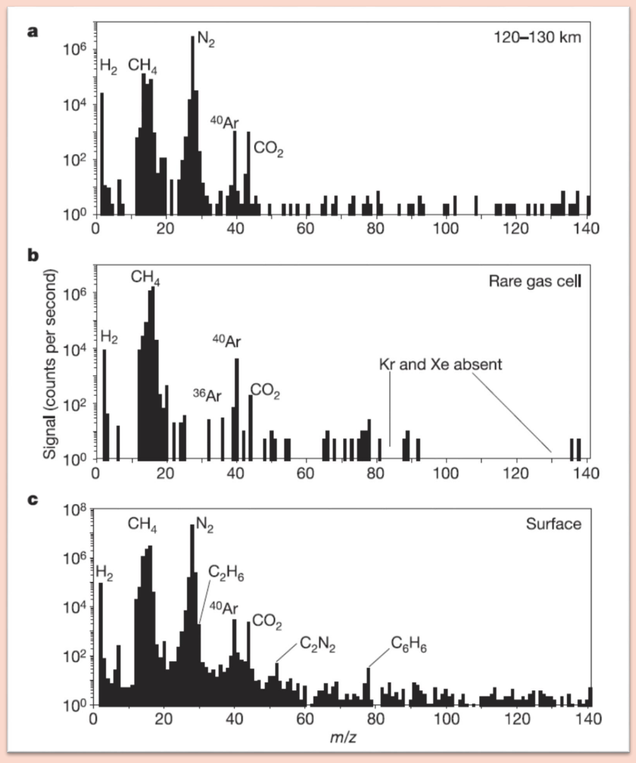

Fig 1:Sample-averaged mass spectra, showing ion count rates per second versus mass per unit charge (m/z) from direct atmospheric sampling. **a**, An upper atmosphere spectrum from altitudes of approximately 120 to 130 km, averaging 104 mass spectra over 244 s. **b**, The rare-gas cell measurements (about 75–77 km, averaging 43 mass spectra over 81 s), showing the lack of heavy primordial noble gases. c, A surface spectrum, averaged over 70 min (432 mass spectra) from surface impact until loss of signal.

Detection of Chemical Species and Determination of the Temperature and Pressure Profiles

- Observations done with VLT using the blue arm of the UVES instrument;
- Scientific data processed using the ESO's UVES pipeline using the EsoReflex software;
- HITRAN and ExoMol databases will be used to identify the presence of chemical species in the spectra;
- NEMESIS Radiative Transfer model will be used to obtain the temperature and pressure profiles and constrain the altitude level;
- Doppler wind velocities will be retrieved as well as the related dynamic atmospheric study as a side product;

Fig 2: Section of the output file produced by the EsoReflex's UVES pipeline viewed using the SAOImageDS9 software for the UVES.2018-06-21T05_25_37.027.fits science file.

Preliminary and Expected Results

- Possible detections of H_2 and HD transitions

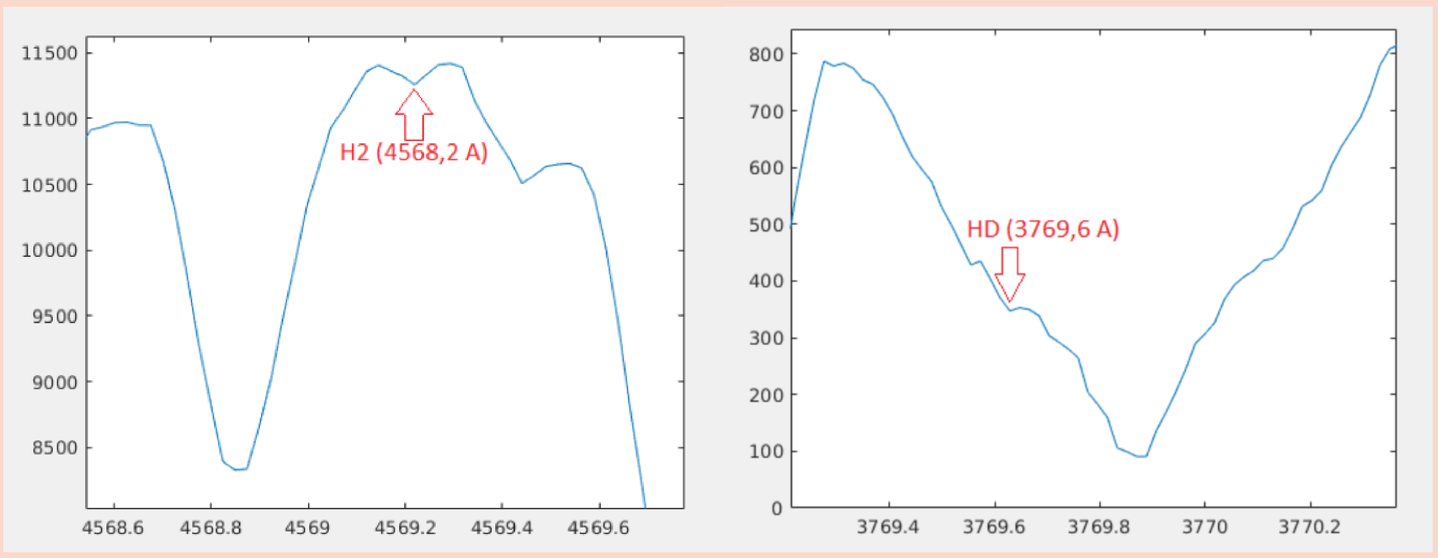

Fig 3: Location of possible transitions of H_2 and HD in the UVES.2018-06-21T05_25_37.027.fits file after data reduction, taking into account the Doppler effect due to the relative motion of Titan, calculated using the HORIZONS Web-Interface tool.

- Expected kind of results

Fig 4: Example of a NEMESIS thermal emission temperature retrieval for a Cassini/CIRS near-nadir observation of Titan.
a – Measured spectrum and error limits in grey in the ν_4 methane absorption band between 1240 and 1360 cm−1 and the solid line is the NEMESIS fitted spectrum.
b– Retrieved vertical temperature profile, where the solid line is the retrieved profile and the grey shaded regions is the error.

Acknowledgements

Dr. Santiago Pérez Hoyos for his availability to teach the group how to use the NEMESIS Radiative Transfer model.

References

R. A. Hanel, B. J. Conrath, D. E. Jennings, and R. E. Samuelson. *Exploration of the Solar System by Infrared Remote Sensing*. Cambridge University Press, 2nd edition, 2003; P. Irwin. *Nemesis*. Atmospheric, Oceanic and Planetary Physics, Oxford, April 2012. Doc No. CIRS/OX/TR/1392; P. Irwin, et al. *The NEMESIS planetary atmosphere radiative transfer and retrieval tool*. Journal of Quantitative Spectroscopy & Radiative Transfer, 109:1136–1150, 2008; P. Irwin. *Giant Planets of Our Solar System*. Springer, 2nd edition, 2009; A. Kaufer, et al. *UV-VisualEchelle Spectrograph User Manual*. European Southern Observatory, December 2007. Doc.No. VLT-MAN-ESO-13200-1825; H. B. Niemann, et al. *The abundances of constituents of Titan's atmosphere from the GCMS instrument on the Huygens probe*. Nature, 438:779–784, December 2005. doi:10.1038/nature04122; Agustín Sánchez-Lavega. *An Introduction to Planetary Atmospheres*. CRC Press, 1st edition, 2010; T.Encrenaz, et al. *The Solar System*. Springer, 3rd edition, 2003;