SOAR measurements of thermospheric plasma

Sachin A. Reddy[1 *], Dhiren Kataria[2], Anasuya Aruliah[3], Gethyn Lewis[1], Daniel Verscharen[1], and Joel Baby Abraham[1]

[1]UCL Mullard Space Science Laboratory [2]Southwest Research Institute [3]UCL Dept. of Physics & Astronomy *sachin.reddy.18@ucl.ac.uk

UCL

Introduction

The Upper Thermosphere (U-T) is a region within the ionosphere that stretches from roughly 300 – 500 km. The U-T is a mixture of ionized and neutral particles, which mainly consists of oxygen and electrons. During the day, photo-ionisation of the U-T increases the density and temperature of the plasma. Plasma drift velocities are higher at night.

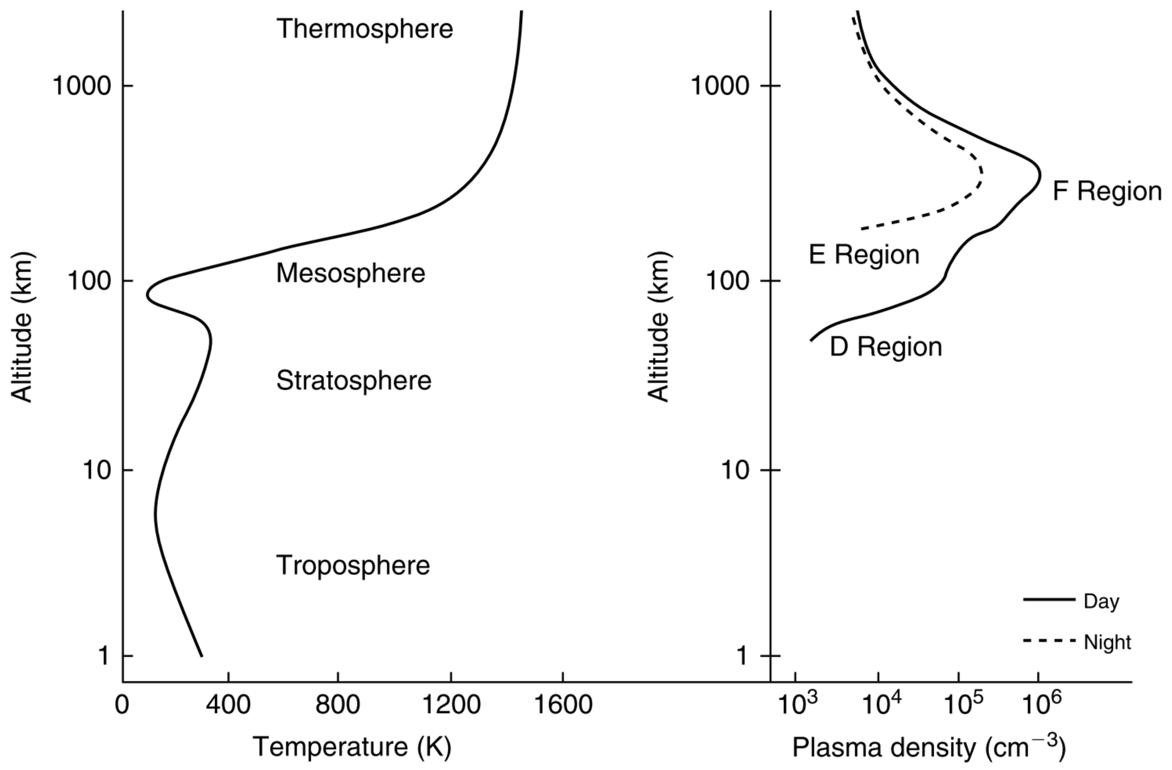

Figure 1: Typical densities and temperatures in the ionospheric sub-regions (Kelley, 2009)

Understanding these plasma characteristics is essential for space weather monitoring, but the calculation of density *(n)*, temperature *(T)* and bulk speed *(v)* is not without difficulty.

The Mission

Satellite for Orbital Aerodynamics Research (SOAR) launched in June 2021 and is currently operating at ~360km. One of its payload's is an Ion and Neutral Mass Spectrometer (INMS), that was designed and built at the UCL Mullard Space Science Laboratory.

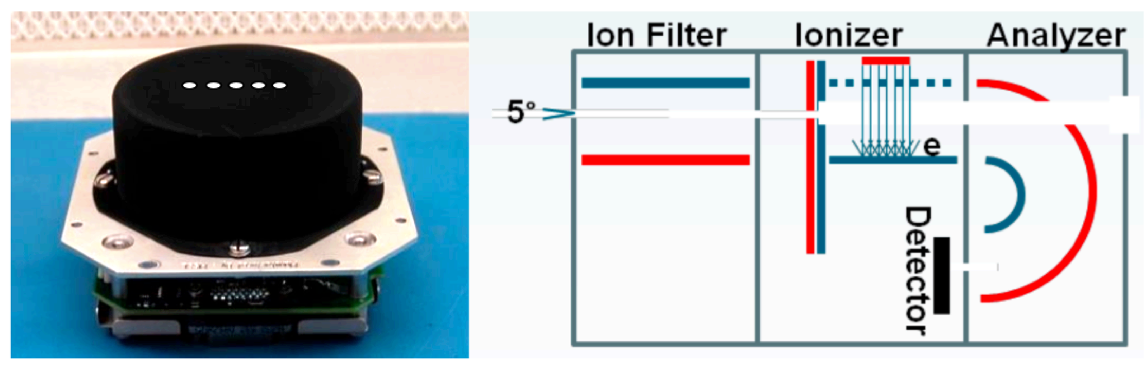

Figure 2: The INMS. Left: external design. Right: internal architecture

Results

The presence of an electric potential on the spacecraft surface poses a threat to the accurate measurement of charged particles. Any potential ($\varphi \neq 0$), shifts the distribution function in velocity space, which affects the moments calculation. We use the Spacecraft Plasma Interaction Software (SPIS) to simulate surface potentials on SOAR.

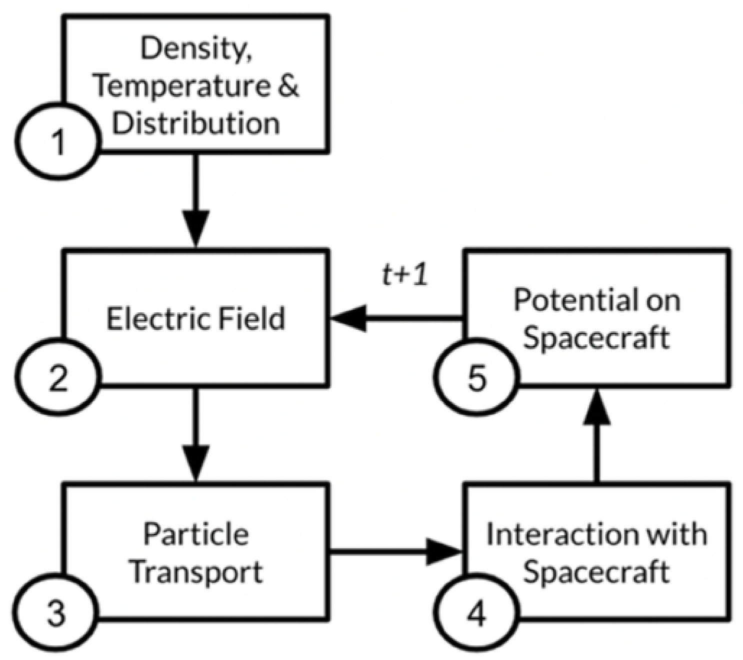

Figure 3: SPIS processing schema

Inputs for box 1 are provided by the International Reference Ionospheric (IRI-16) model and ESA's SWARM Mission.

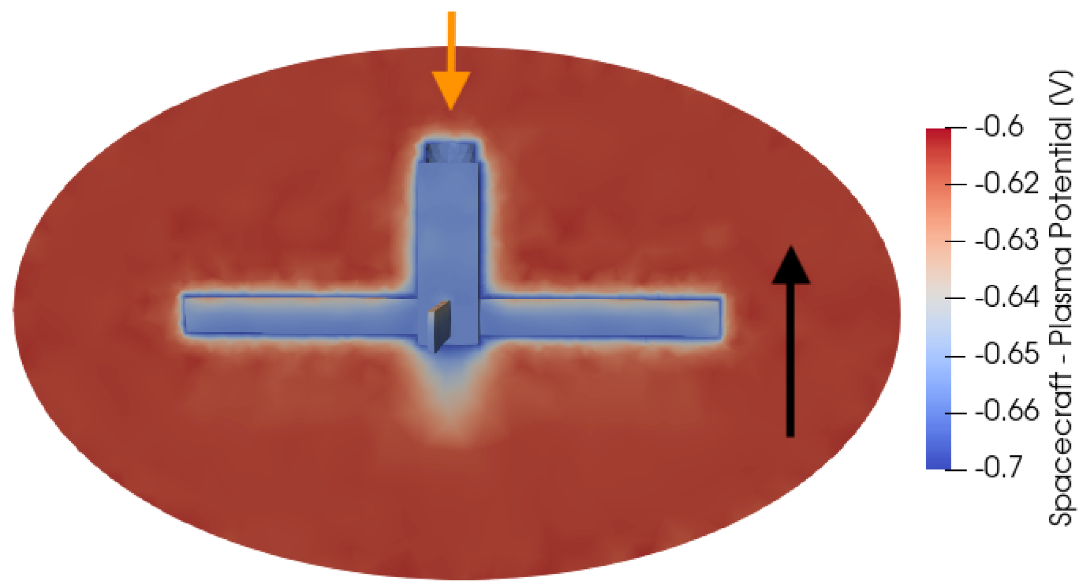

Figure 4: SPIS Simulations of SOAR. Orange arrow is Ions entering the INMS. Black arrow is direction of flight.

These results are then input into a modified kinetic equation which includes the surface potential, φ.

$$E = \frac{1}{2}mv^2 + q\varphi \tag{1}$$

To enable this transformation we assume there is no diffusion within the electrostatic sheath, which is in accordance with Liouville's theorem. We extract n, T and v using a damped least-squares fitting routine. We assume that the particle distribution in the U-T is Maxwellian.

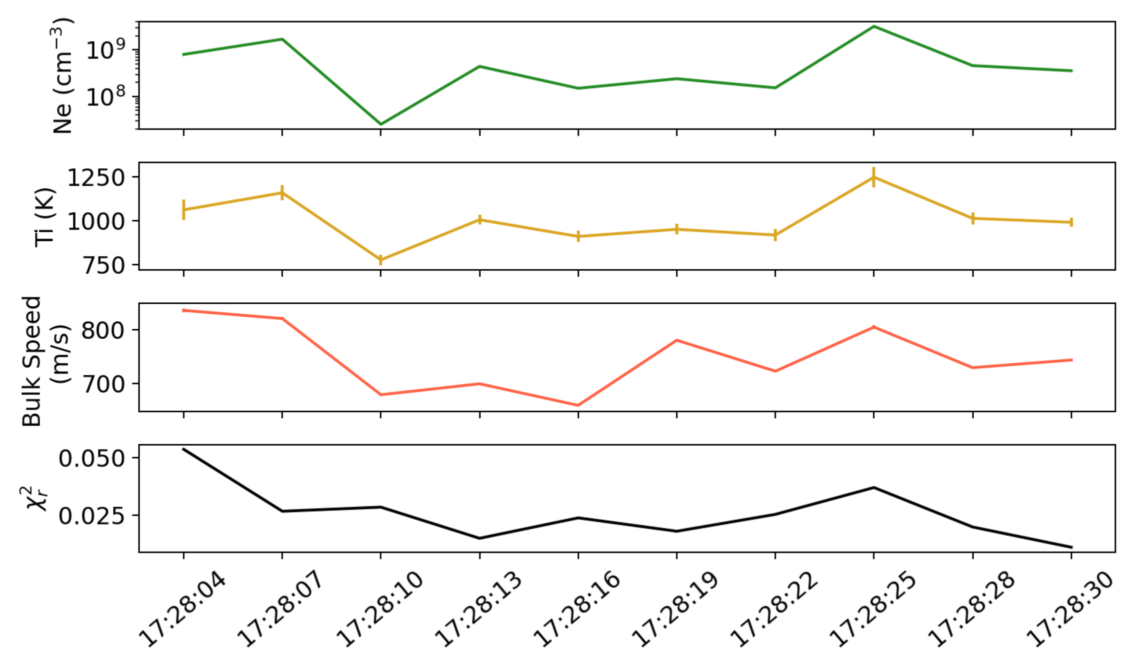

Figure 5: O^+ moments and χ^2_r captured by SOAR-INMS on 03/12/21

We use the reduced chi-squared metric, χ^2_r, to quantitatively assess the fits and reject where $\chi^2_r > 0.1$. n and T align with existing work, but v is much faster than expected. We also observe an additional ion species in the INMS data.

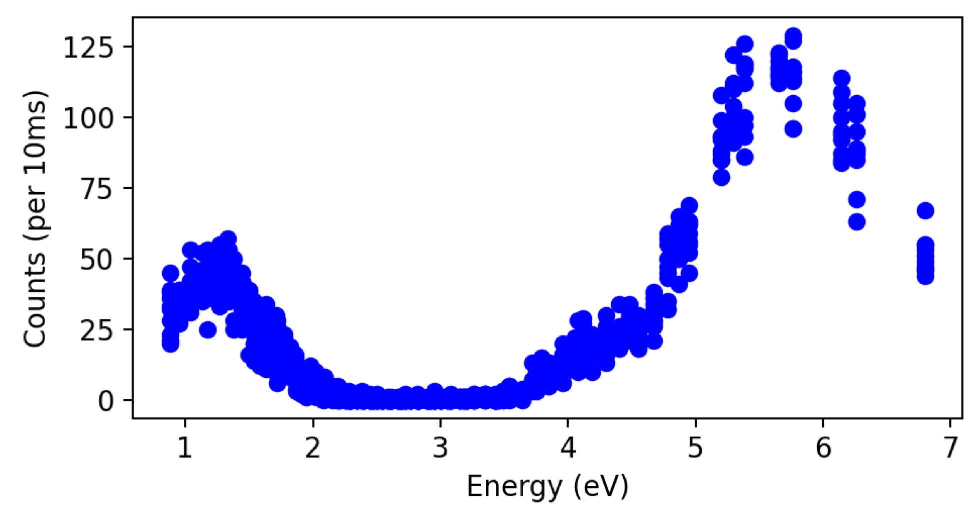

Figure 6: Counts as a function of sampling energy. O^+ is at ~5.5eV and either *H*'6+ or He^+ is at ~1eV. The former was expected, the latter was not.

If confirmed, neither H+ or He+ were expected in such quantities at this altitude. The 2nd species also only appears in the dayside and dawn.

Future Work

At present the fitting routine takes static inputs for density (n) and temperature (T). We are developing a Gaussian-Maxwellian method to take a dynamic value for n and T based on the number counts and the position of the peak. In tandem, we are developing a machine learning model to automatically classify ionospheric phenomena using SWARM data. It is our ambition to deploy such a model on a CubeSat like SOAR.

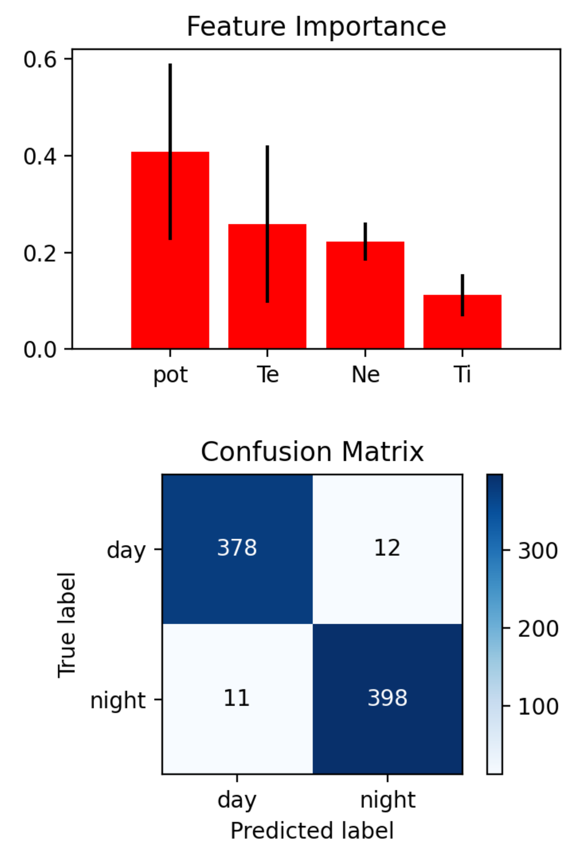

Figure 7: Random Forest Classifier trained on SWARM data. Spacecraft potential (pot), is the most important feature in determining diurnality.

Summary: SOAR launched in 2021 and we analyse the data from the INMS payload. We correct for spacecraft charging and then derive ion moments. Future work will make improvements to the fitting routine and explore the use of machine learning.

Key Partners

DISCOVERER

MANCHESTER 1824 The University of Manchester

GOMSPACE