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Remote Sensing of the Tropical Arcs with LITES Observations from the ISS

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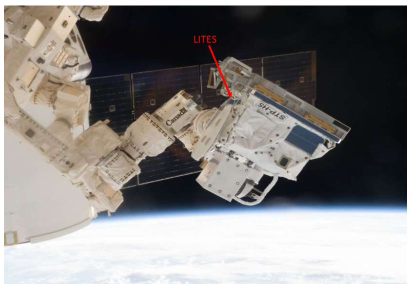
The Limb-imaging Ionospheric and Thermospheric Extreme-ultraviolet Spectrograph (LITES) has been collecting EUV and FUV altitude emission profiles since early 2017 from the International Space Station (ISS). LITES observes the limb in the altitude range ~150 to 350 km from 60 to 140 nm both daytime and nighttime. Nighttime measurements of 91.1 and 135.6 nm emission can trace the O^+ and electron density. The 400-km altitude orbit of the ISS provides an ideal vantage point for remotely sensing the ionosphere and features such as the tropical arcs. LITES observations are complementary to the other ionospheric missions, such as GOLD and ICON.

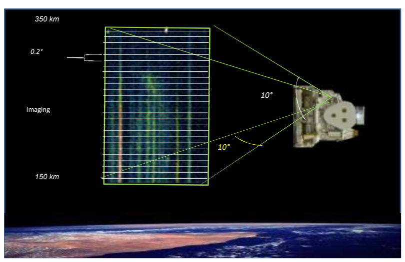
LITES on the ISS

- The LITES instrument is an imaging spectrograph aboard the ISS
- Observes one-dimensional, vertical (altitude) profiles of FUV/EUV airglow from Earth's limb with 10x10° FOV
- 60-140 nm wavelength coverage
- Observes both daytime and nighttime
- 3 second imaging cadence, corresponding to better than 25 km in-track resolution

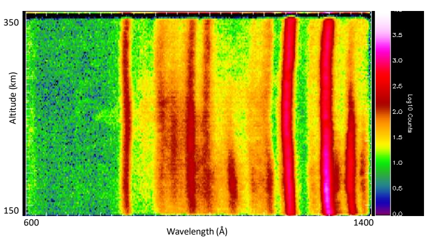
For more details, see Stephan et al. 2014.



STP-H5, with LITES, during installation on the ISS (February 2017).



(Left, top) The LITES FOV is in the aft direction as the ISS orbits, looking back toward Earth's limb. Every 3 seconds LITES returns a limb profile image (see example below) with wavelength on the x-axis, and angle (or tangent point altitude) on the y-axis.



(Left, bottom) Raw LITES data, with wavelength on the x-axis and angle (or tangent point altitude) on the y-axis. This is a daytime image, and is integrated over 10 frames (30 seconds). LITES measures emission from both ions and neutrals in the thermosphere and ionosphere (see table below for a few examples).

Physical Quantity/Objective	Measurement	Excitation Process(es)
$[e^-]$, $[O^+]$ Ionospheric density	***Nighttime:*** OI 91.1 nm cont., 135.6 nm	$O^+ + e^- \rightarrow O + h\nu$
$[O]$, T_n Atomic oxygen composition	***Daytime:*** OI 98.9, 130.4, 135.6 nm	$O + e^- \rightarrow O^* + e^-$
$[O^+]$ Ionospheric density	***Daytime:*** OII 61.7, 83.4 nm	$O^+ + h\nu \rightarrow O^{+*} + e^- + h\nu$ (61.7 nm) $O^+ + h\nu \rightarrow O^+ + e^- + h\nu$ (83.4 nm)
$[N_2]$, T_n Thermosphere N_2 density	***Daytime:*** N_2 LBH, 127.0-140.0 nm	$e^- + N_2 \rightarrow e^- + N_2^*$

Nighttime Ionosphere

Both OI 911Å and 1356Å emission features can be used to trace the F-region ionospheric density under nighttime conditions. LITES remotely senses both of these features from the ISS at ~400km altitude. These emission lines arise from radiative recombination of O^+ ions and electrons.

$$O^+ + e^- \rightarrow O(\,^5S) + h\nu_{1356}$$

$$O^+ + e^- \rightarrow O(\,^3P) + h\nu_{911}$$

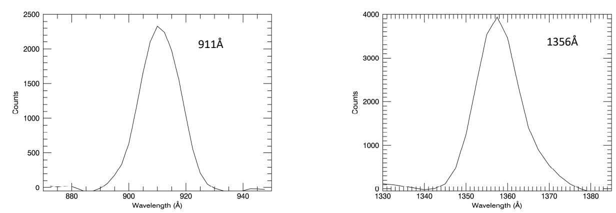
- O^+ is the dominant ion in the nighttime F-region
- The plasma is quasi-neutral (i.e., ions ≈ electrons)
- The OI 911Å and 1356Å emission is optically thin

Therefore, the observed nightglow brightness (4πI) of these lines provides a measurement of the electron density (in the equations below, J is the photon emission rate and α is the partial recombination rate).

$$J = \alpha n_e n_{O^+} \approx \alpha n_e{}^2$$

$$4\pi I = 10^{-6}\int_0^\infty J(z)dz = 10^{-6}\int_0^\infty n_e{}^2(z)dz$$

LITES 911Å and 1356Å at Night



(Above) The LITES nighttime 911Å (left) and 1356Å (right) emission integrated over two orbits from 4 April 2017, and summed over all altitudes. Nighttime data were chosen to have solar zenith angle (SZA) greater than 110°.

Summary

LITES observes nighttime OI emission brightness from the ISS, which can be used as a proxy for the electron density in the ionosphere.

Enhancements in brightness at low magnetic latitudes show the tropical arcs, with varying intensity over different days.

Longer term observations from LITES will provide coverage of all local times over each geographic/geomagnetic location.

We observe very bright emission near the SAA. When passing through this region the background on the detector is much higher than normal, and in addition the detector can pick up ions contributing to this bright emission.

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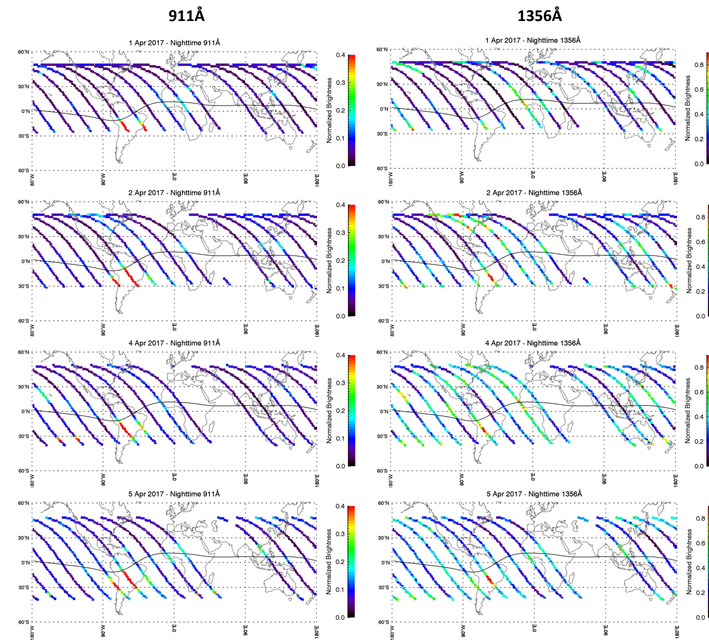
Global Observations and Tropical Arcs

The tropical (equatorial) arcs are a well-known feature of the low latitude ionosphere. The eastward electric field at the equator along with Earth's magnetic field produces an E×B drift causing plasma to flow upwards. The plasma then travels along the magnetic field lines and sinks back down due to gravity (the so-called "fountain effect"). The enhanced density at low latitudes produces an increase in airglow observed as the "tropical arcs."

LITES observes the upper atmosphere across all longitudes, all local times, and latitudes ±51°. The tropical arcs, and other features, are apparent in the airglow emission. Here we show data from nighttime ISS tracks during the first week of April 2017. For a look at daytime observations, see Stephan et al. Poster SA21A-3154 in this session.



(Above) Nighttime brightness of 911Å (left) and 1356Å (right) measured by LITES over multiple descending ISS orbits during the first week of April 2017. Each data point represents 15s (5 frames) of LITES data integrated. The color scale represents the relative brightness of the emission, normalized for each day (note, the color scale for 911Å is stretched to emphasize fainter emission). The tangent point altitude range of the measurements is ~200-300km. Data points are plotted at the LITES FOV tangent point latitude/longitude position. The magnetic equator is shown as a black line across each image. Data from April 3 is not shown, as the ISS performed a maneuver on that date altering the LITES FOV altitude range.

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