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# Experimental Study of the Asymmetric Time Varying Exosphere by Lyman-alpha Detectors on the TWINS Mission

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## Abstract

The tenuous extension of Earth's neutral atmosphere, the upper exosphere, consists predominantly of atomic hydrogen (H). Exospheric H atoms resonantly scatter solar Lyman-α radiation, creating a phenomenon known as the geocorona. The Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) mission images the magnetosphere in energetic neutral atom (ENA) fluxes and additionally carries Lyman-α Detectors (LADs) to investigate exospheric H atoms. We use LAD measurements to reconstruct global H density distributions for geocentric distances above 3 $R_E$. Our obtained distributions reveal asymmetries from day to night, north to south, and dawn to dusk. The sequence of such distributions enables studying of the response of the exosphere to seasonal (solstice and equinox), solar, and geomagnetic variations.

## 1. Introduction

The most abundant neutral constituent in Earth's upper exosphere, atomic hydrogen (H), resonantly scatters solar Lyman-α (121.567 nm) radiation – creating a phenomenon known as the geocorona. Space-based measurements of the geocorona allow reconstruction of the global H density distribution over timescales which depend on observational coverage. We use such measurements by TWINS to obtain global H density distributions with three-dimensional asymmetries on a daily basis when the LADs have adequate coverage of the near-Earth region. The exosphere is not only important for understanding properties of geospace but it is also essential for science reduction of observations of the magnetosphere in ENA fluxes.

## 2. Instrumentation

The TWINS mission [4] consists of two instruments, TWINS-1 and TWINS-2, on two separate satellites launched in 2006 and 2008 to stereoscopically image the magnetosphere in ENA fluxes. In addition to an ENA imager, each TWINS instrument includes a pair of identical LADs to register line-of-sight resonance scattered intensities of the geocorona. In each LAD, the incident radiation passes through a collimator followed by an optical interference filter centered at the wavelength 122 nm with a bandwidth 10 nm [5]. The Lyman-α photons are then counted by a channel electron multiplier. The collimator on each LAD defines an aperture angle of 4° full width at half maximum. The sensor sensitivity is approximately (2 cts $s^{-1}$)/R, where 1 R = 1 Rayleigh = $10^6/(4\pi)$ phot $cm^{-2}$ $s^{-1}$ $sr^{-1}$.

## 3. Observational Coverage

The TWINS instruments fly on two satellites in widely spaced highly elliptical Molniya-type orbits, providing observational coverage from very different vantage points. On each satellite, two LADs, LAD-1 and LAD-2, observe the geocorona for several hours per orbit, where the orbital period is one half of a sidereal day. The TWINS instrument is located on a platform that rotates about a nominally nadir-pointed axis in a ±99° windshield wiper motion with a rotational rate of approximately 3° per second. Thus, it takes about 1 min for the LADs, pointed at ±40° with respect to the rotation axis (Figure 1), to sweep a full circle around the Earth. As the spacecraft proceeds along the orbit, the detectors cover the geocorona, allowing reconstruction of the global exospheric H density distribution based on several hours of observations.

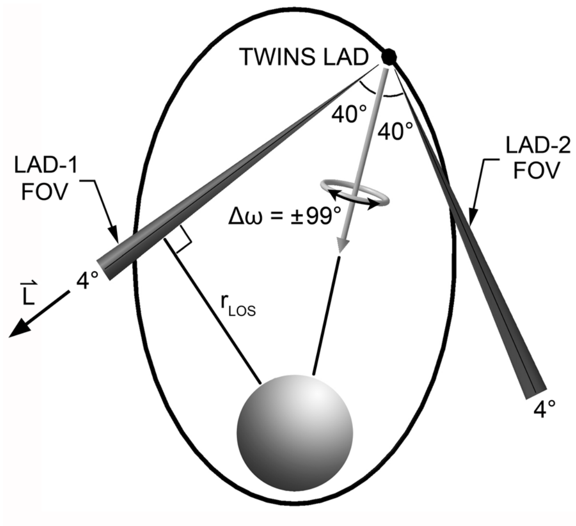


Figure 1: Observational geometry of LAD-1 and LAD-2 on a TWINS satellite, which is in a highly elliptical Molniya-type orbit with an apogee at a geocentric distance of 7.2 $R_E$ over the Northern Hemisphere, inclination of 63.4°, and orbital period of half a sidereal day.

## 4. Exospheric H Distributions

We model the three-dimensional distribution of H number densities using an analytical expression expanded from earlier investigations [3, 5, 6] to include 18 free parameters which are best fit to LAD observations [1]. Our analysis reveals an asymmetric and time-dependent exosphere. A seasonal north-south asymmetry occurs as solar illumination differs between the summer and winter polar regions. Pole-equator and less pronounced dawn-dusk asymmetries also appear, possibly due to a coupling effect via charge exchange with the polar wind and plasmasphere, respectively. We also report observed variations of the exosphere during five geomagnetic storms that occurred in the 3-month time period from 1 August 2011 to 1 November 2011 [2]. Our preliminary finding that exospheric H densities temporarily increase during geomagnetic storms may provide insight into specific mechanisms of interaction between the exosphere and magnetosphere as well as exospheric effects on ring current decay rates. In addition, the interpretation of magnetospheric images in ENA fluxes relies on a line-of-sight integration that directly depends on the H number density distribution.

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