Accurate Quantification of Atomic Hydrogen Density in the Terrestrial Thermosphere and Exosphere

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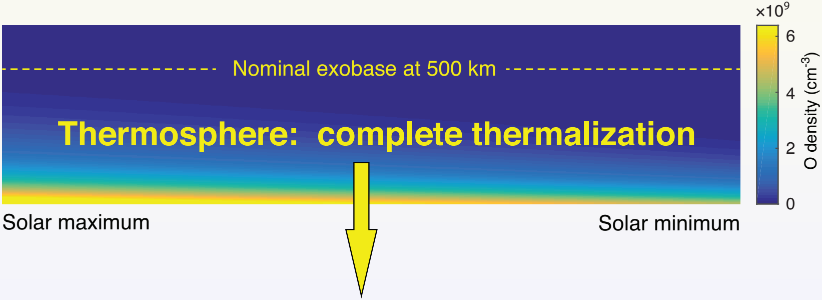
Terrestrial Hydrogen Population is Poorly Understood

Model predictions based on the Chamberlain [1963] theory and Monte Carlo simulations have long-standing discrepancies with ultraviolet remote sensing measurements, indicating likely deficiencies in conventional theories.

Exosphere: nearly collisionless

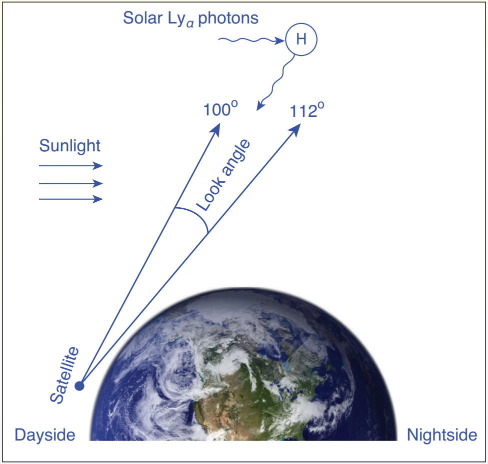


Hydrogen temperature = ambient oxygen temperature

Outstanding Questions in Geocoronal Research

- How to accurately quantify the terrestrial H density?
  - We will show that inversion of satellite limb scanning of Ly_α emission based on radiative transfer modeling can be a very useful technique to quantify atomic hydrogen density in the thermosphere and exosphere.
- How to reconcile model predictions and observations?
  - We will present a major finding, showing the existence of **Non-Thermal Hydrogen Atoms in the Terrestrial Upper Thermosphere**, where the hydrogen temperature increases significantly with declining solar activity, in direct contrast to the fundamental assumption of conventional theories.

Observational Geometry of the GUVI Instrument

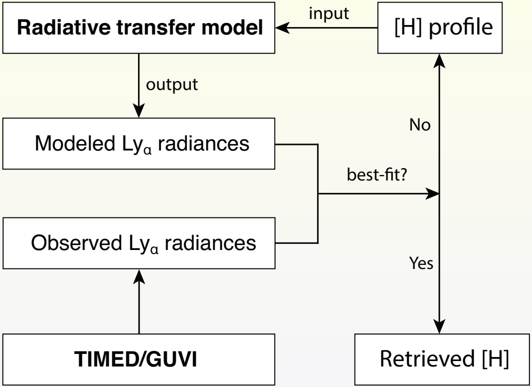


The satellite orbits at 625-km altitude with an inclination of 74° from the equator. The measured Ly_α emission is attributed to resonant scattering of solar Ly_α photons by hydrogen atoms in the geocorona.

The Radiative Transfer Model

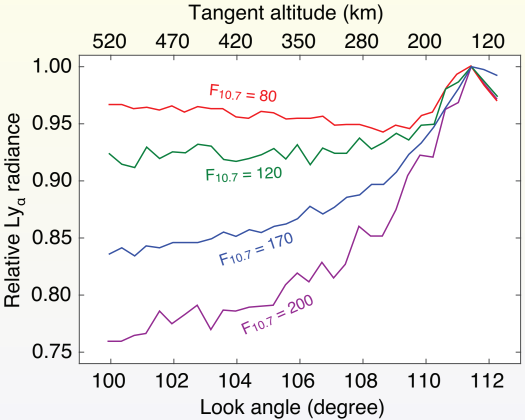
- The radiative transfer model named *Lyao_rt*, originally developed by the late *J. Bishop*, has been thoroughly reexamined and modified.
- The radiative transfer model can be used to calculate the transport of atomic hydrogen and helium emissions in the geocorona, such as:
  - Solar Lyman series
  - Balmer alpha emission
  - Helium 58.4-nm emission
- The model can be used to analyze satellite and ground-based measurements.

The Inverse Model



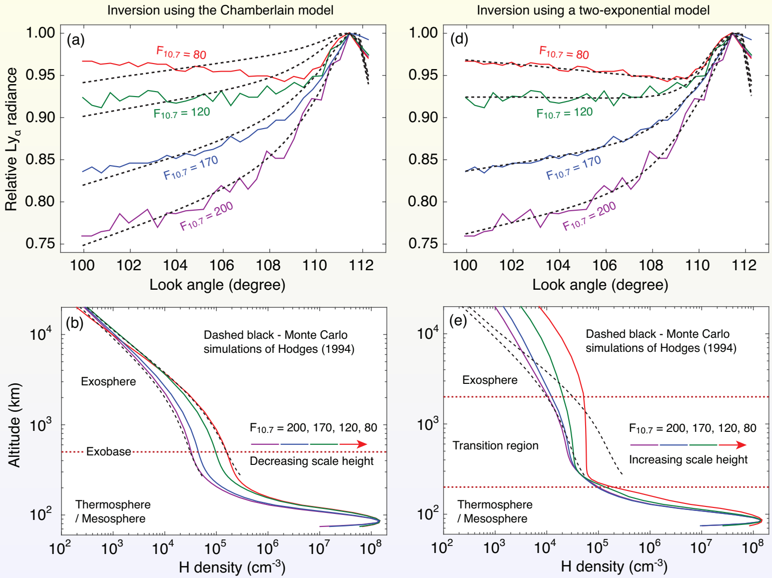
The inverse problem is an underdetermined non-linear least squares problem, which is solved through an iterative process using the Gauss-Newton method.

Binned Ly_α Radiances Over SZA from 20°-22°

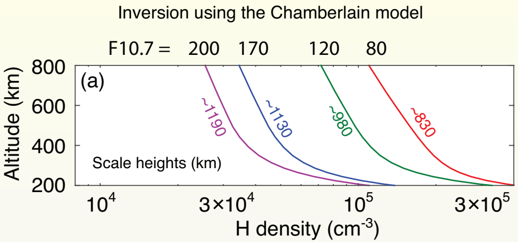


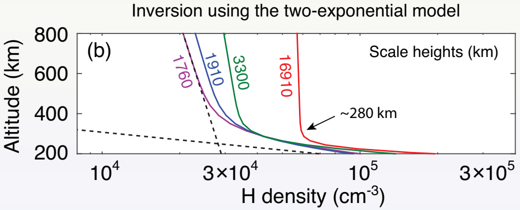
With the decrease of solar activity, the relative Ly_α radiances decrease more slowly or even increase with decreasing look angle, implying the existence of **Non-Thermal Hydrogen Atoms in the Terrestrial Upper Thermosphere**.

Inversion using Different Physical Constraints



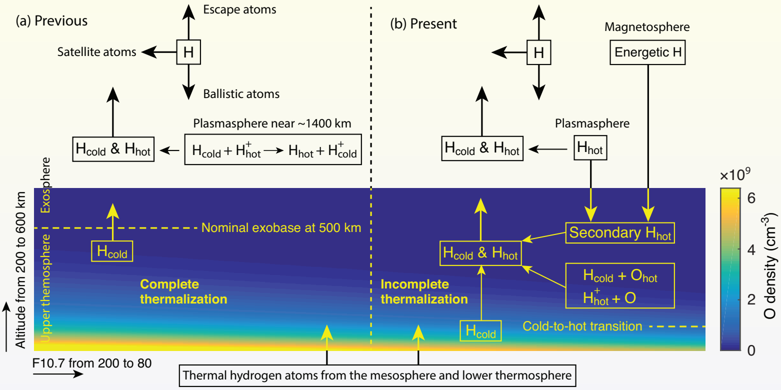
Comparison of Thermospheric Scale Heights





The hydrogen temperature, or more precisely, the mean kinetic energy of the hydrogen population, increases significantly with declining solar activity.

Implications on Geocoronal Physics



Possible source mechanisms of the hot hydrogen atoms: (1) Interaction of thermal hydrogen atoms with the hot oxygen geocorona; (2) Charge exchange of the thermal hydrogen or oxygen atoms with the ionospheric hot protons; (3) Downward transport of the charge-exchange induced hot hydrogen atoms from plasmasphere; and (4) Precipitation of the charge-exchange induced energetic hydrogen atoms from the magnetosphere.

Conclusions

- Satellite limb scan measurements of Ly$_\alpha$ emission is a very useful technique for quantifying the atomic hydrogen density in the terrestrial thermosphere and exosphere.
- Analysis of GUVI measurements reveals that the upper thermospheric hydrogen temperature increases significantly with declining solar activity, contrary to the fundamental assumptions of conventional theories.
- The new physics reported in this study suggests that the influence of ion-neutral coupling between the atmosphere, plasmasphere, and magnetosphere on geocoronal structure has been significantly underestimated for decades.
- The present analysis provides essential knowledge for advancing development of geocoronal theory.

Acknowledgements

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