Ultraviolet Spectroscopy: Reinforcing the LWS Program

Introduction: This poster addresses some recommended changes to the SEC science objectives and their research focus areas with particular emphasis on the objectives relevant to the Living with a Star (LWS) program. We show how LWS missions (or other focused missions such as those in the Explorer Program) can exploit ultraviolet spectroscopy to determine the physical processes that control the Sun-Earth system.

Fundamental Question: What is the nature and source of the solar variations that affect life and society?

Relevance to NASA/OSS: Solar activity can affect space-based technological systems, ground-based power distribution systems, and the safety of human space exploration.

Science Objectives:

Top Level SEC Science Objectives and Research Focus Areas:

I. Understand the origins, evolution, and near-Earth impacts of solar variability.
   a. Develop the capability to predict solar activity on both short (hours to days) and long (months to years) time scales.
   b. Develop an understanding of the evolution of solar phenomena and how the associated particles, magnetic fields, and radiation propagate from the Sun to the Earth.
   c. Develop the capability to specify and predict variations in the near-Earth radiation and particle environment.
   d. Develop the capability to specify and predict the responses of the Earth's magnetosphere, ionosphere, and upper atmosphere to solar drivers.

II. Chart our destiny in the solar system.
   a. Develop the capability to predict both short-term space weather and long-term space climate.

Sub-objectives that can be accomplished with UV Spectroscopy:

1. Understand the physical processes responsible for heating and accelerating the primary and secondary plasma components of the solar wind.
2. Understand how subphotospheric magnetic energy that is transported into the corona is dissipated as heat and is responsible for mass flows.
3. Understand how CMEs are heated and accelerated, and define their role in the evolution of the solar magnetic field.
4. Understand the roles of active regions and flares in producing solar ejecta, and determine the physical processes involved in momentum and energy deposition in flares.

Mission Description:

Advanced Spectroscopic and Cronagraphic Explorer (ASCE), a proposed MIDEX mission, complements SDO by providing high-resolution UV spectroscopy of the lower atmosphere and extended corona out to 10 $R_\odot$. ASCE also has a high cadence visible polarimetric imager that will provide natural eclipse-like clarity down to 1.15 $R_\odot$. Additional information can be found at URL: http://cfa-www.harvard.edu/∼asce/

Measurement Strategy:

- Line widths probe line-of-sight velocity distributions to reveal evidence of nonthermal heating.
- Doppler shifts indicate LOS bulk velocities to constrain 3D motions.
- Line ratios provide electron temperatures and densities of thermalized plasmas.
- Intensities of high-temperature lines reveal the presences of hot plasmas at reconnection sites.

Technology Requirement:

- Large format ICCD detectors provide 1″ high-resolution spectroscopy on the solar disk with a 10-second cadence.
- ASCE has a 14.7-m long external occulter system to provide improved diffraction limited imaging and more than an order of magnitude improvement in sensitivity over SOHO coronagraphs.

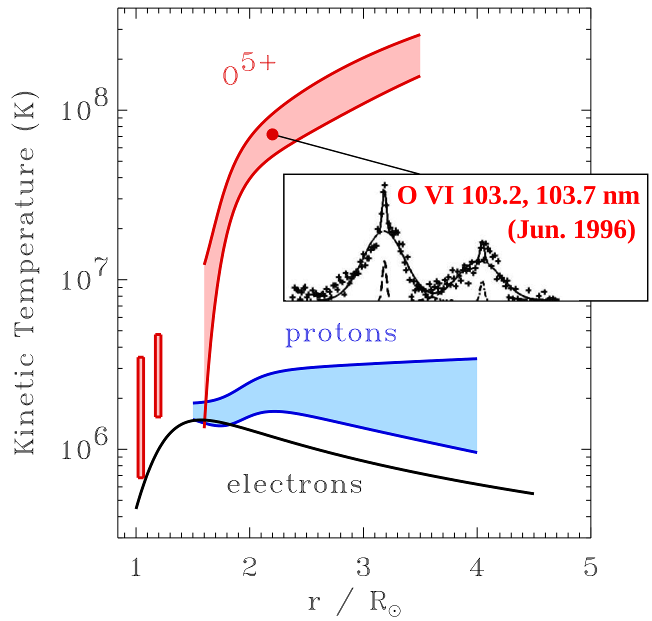
UV Spectroscopy provides an in-depth understanding of Solar Wind Variations

PHYSICAL PROCESSES PROBED BY SPECTROSCOPY

- ⋆ collisionless heating of protons, electrons, and minor ions
- ⋆ MHD turbulence (generation, wavenumber cascade, and damping)
- ⋆ suprathermal velocity filtration
- ⋆ time-dependent dynamics of jets and plumes

SPECTROSCOPIC DIAGNOSTICS:

- ⋆ Line widths probe velocity distributions along the line of sight (i.e., kinetic temperatures mainly perpendicular to the magnetic field). Coronal holes at solar minimum exhibit extreme departures from thermal equilibrium (see image at right; Kohl et al. 1998, ApJ, 501, L127).
- ⋆ Doppler dimming/pumping of scattering line intensities constrains bulk outflow speeds and non-Maxwellian temperature anisotropies.
- ⋆ Spectroscopic measurements of the wind acceleration region have been linked with *in situ* particle data (e.g., Ulysses–SOHO) to track fast and slow streams from their origin into the interplanetary medium.
- ⋆ Line intensities of multiple species allow elemental abundances and ionization fractions to be determined, which are useful probes of the near-Sun origins of solar wind parcels.



RELEVANCE TO NEAR-EARTH ENVIRONMENT

- ⋆ wind-speed and density variations drive **geomagnetic storms**
- ⋆ transitions from fast to slow wind modulate the flux of **galactic cosmic rays**
- ⋆ coronal hole area (and fast wind filling factor) correlated with Earth's **climate?**

UV Spectroscopy provides an in-depth understanding of Coronal Mass Ejections

PHYSICAL PROCESSES PROBED BY SPECTROSCOPY

- ⋆ magnetic reconnection ("tether-cutting" versus "breakout")
- ⋆ shock acceleration and current sheet formation/evolution
- ⋆ magnetic helicity (build-up and release)
- ⋆ plasma heating mechanisms (collisional and collisionless)

SPECTROSCOPIC DIAGNOSTICS:

- ⋆ On the disk, Doppler shifts probe shear flows along polarity inversion lines and upflows associated with CME eruptions.
- ⋆ In the extended corona, Doppler shifts measure the handedness and untwisting rates of helical CME structures (thus constraining helicity conservation models and determining where reconnection occurs).
- ⋆ Simultaneous measurements of lines formed from 10^4 to 10^7 K probe different CME components; from the cool prominence ejecta to extremely hot ($T_e \gtrsim 6$ MK) reconnection-driven current sheets (see image at right; see also Lin & Forbes 2000, JGR, 105, 2375).
- ⋆ Line width measurements measure differences between proton, electron, and ion temperatures, which will constrain theoretical models of energy deposition in the CME acceleration region.