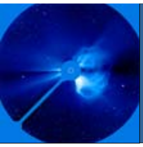

Imaging Geospace Electrons Using Thomson Scattering

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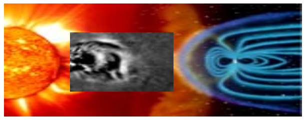
I. Introduction

Observing Thomson scattered, visible solar radiation provides a means to **directly** and **globally** image the electron distributions in the Earth's ionosphere, plasmasphere, and the magnetosphere. Images of Thomson scattered light have been used successfully by SOHO and STEREO SECCHI to observe the solar electron corona and heliospheric structures such as coronal mass ejections (CMEs) and co-rotating interaction regions (CIRs).



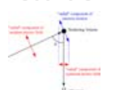
Thomson scattering observations of geospace electrons will complete our chain of Sun-to-Earth observations, enabling global specification and forecasts of the geospace system in response to solar drivers.

We investigate the feasibility of adapting this remote sensing technique to directly image the electrons in the magnetosphere-plasmasphere-ionosphere system for the first time.

Main Science Objectives:

- Determine how electrons in the magnetosphere, plasmasphere, and ionosphere are redistributed in response to solar wind forcing.
- Understand mechanisms of solar wind plasma entry into the magnetosphere by globally imaging structures along the magnetopause and magnetospheric boundary layers.
- Determine how variations of the duskside plasmasphere and plasmapause are coupled to the global dynamics of the magnetosphere.
- Establish sensitivity of space weather forecasts to initial conditions in the magnetosphere and provide global boundary conditions to geospace specification models.

II. Scene Simulations: Thomson Scattering and Background Sources



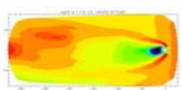
The Thomson scattering geometry is shown to the **left**. We compute the Thomson scattering intensity from electrons in the near-Earth space environment as:

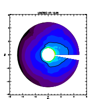
$$I = g\varphi(\theta)\int n_e(r)ds(r) \qquad (1)$$

The integral expression in Equation 1 is the column density of electrons along a line of sight, $\varphi(\theta) = (3/16\pi)(1 + \cos^2\theta)$ is the scattering phase function, where θ is the scattering angle, and *g* is the scattering rate of solar white-light photons (*g*-factor) given by:

$$g = \sigma_{TS} F \qquad (2)$$

Here, σ_{TS} is the Thomson scattering cross section and *F* is the solar flux. We compute *F* using SORCE Spectral Irradiance Monitor (SIM) data, integrated between 490-870 nm.

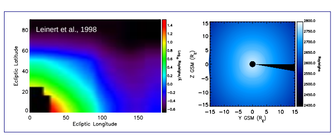


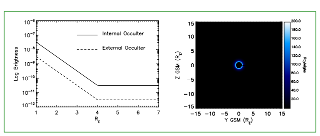


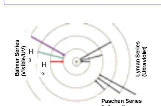
Column-densities of electrons in the ionosphere, plasmasphere, and magnetosphere (e.g. total electron content (TEC)) are provided by the Lyon-Fedder-Mobarry (LFM) magnetohydrodynamic (MHD) model for radial distances R > 4.5 R_E and the SAMI3 model for R < 4.5 R_E. Line-of-sight electron column densities and Thomson scattering brightnesses from geospace electrons are computed from two viewing locations:

- Sun-Earth L1 Lagrange point
- Polar orbit, looking down at equatorial plane of magnetosphere from 30 R_E altitude.

Background Sources: We compute the brightness of the following background sources expected in our observed scene: **Zodiacal light (left) and instrumental scattered light (right)**





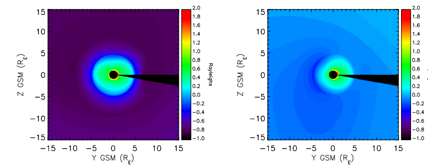


Emission lines from the hydrogen geocorona exist in the visible that fall near or within our expected band pass. These are the Balmer series H-α (656.3 nm) and H-β (486.1 nm) lines. We have chosen the short wavelength cut off of our band pass (490-870 nm) to exclude the H-β line. On the other hand H-α falls within our band pass and it will be necessary to filter out this emission line.

III. Modeled Thomson Scattering Images of Geospace Electron Density Distributions

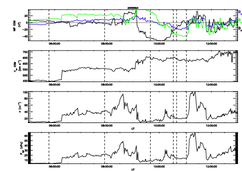
Viewing Geospace from L1:

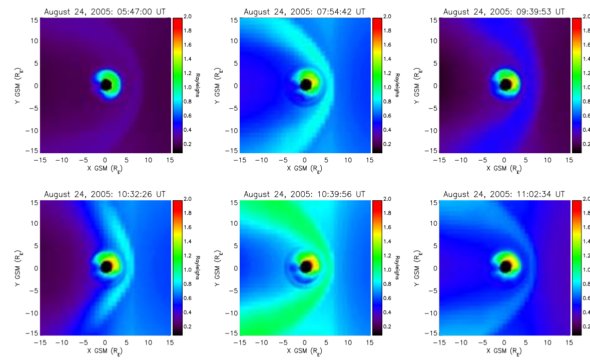
We compute the Thomson scattering brightness from geospace electrons as viewed from a location at the Sun-Earth L1 Lagrange point. The Thomson scattering brightness is computed for quiet-time (**left**) and storm-time (**right**) conditions.



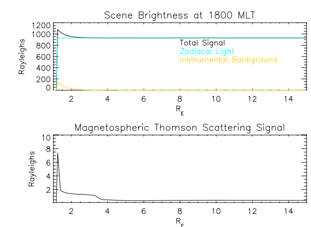
Viewing Geospace from Polar Orbit:

The Thomson scattering brightness from geospace electrons is also computed from a viewing location at 30 R_E above the north pole. These Thomson scattering scenes were computed at a cadence of 7.5 minutes during a 15 hour period of the August 24, 2005 magnetic storm event. The solar wind data (WIND) for this period are shown below.



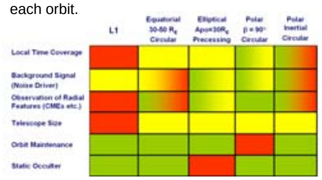


The plot below shows a radial cut of the Thomson scattering signal and background brightnesses at 1800 MLT at 12:02:45 UT.

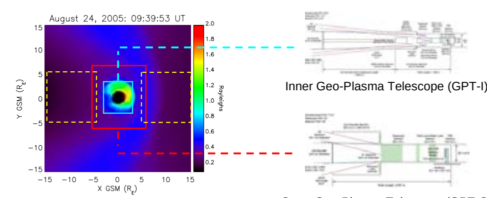


IV. Orbits and Instrument Concept

We evaluated the suitability of various orbits for making Thomson scattering observations of electrons in geospace. The table below summarizes the benefits and disadvantages of each orbit.

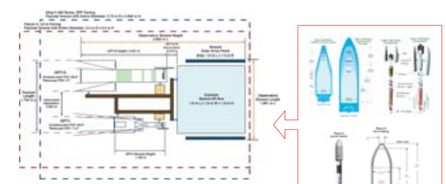


Our instrument concept is a suite of white-light imagers adapted from proven solar coronagraph designs with flight heritage from SOHO LASCO and STEREO SECCHI: Outer Geo-Plasma Telescope (GPT-O), Inner Geo-Plasma Telescope (GPT-I), and two identical Magnetospheric Imagers (MI-L, MI-R).



Inner Geo-Plasma Telescope (GPT-I)

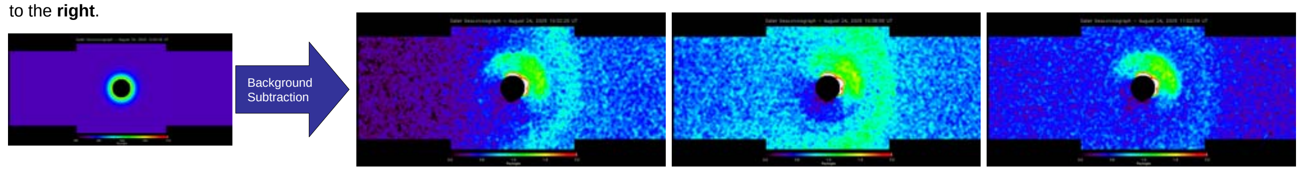
Outer Geo-Plasma Telescope (GPT-O)



Spacecraft concept fits within envelope of existing EELV-class launch vehicles

V. Simulated Observations

Simulated observations from the Outer Geo-Plasma Telescope (GPT-O) and Magnetospheric Imagers (MI-L and MI-R) are shown below. We assume an aperture size of 27.8 cm^2, a pixel plate scale of 270 km, and an integration time of 7.5 minutes per frame. Shot noise is added to images. A simulated observation showing the total scene brightness including the Thomson scattering signal and all background sources is shown on the **left**. Background subtraction yields the simulated GPT-O images to the **right**.



VI. Conclusions

- It is feasible to detect the Thomson scattering signal from electrons in the near-Earth space environment.
- Circular polar (inertial) orbit is most suitable for monitoring geospace electron density variations in response to solar wind forcing.
- Instrument(s) to measure Thomson scattering signal are feasible but still require pushing the current state-of-the-art in optical and detector designs.

Enabling Technologies Required: Large format CCD detector arrays, large, light-weight optics, and potentially formation flying satellites. Data produced by our mission will enable and benefit next generation space environment forecasting models that include and couple all regions of geospace out to the bow shock, magnetosheath, and magnetopause regions.