The Evolution of Solar EUV Irradiance During the TIMED Mission: Evidence from Solar EUV Measurements and Models, and GUVI Terrestrial FUV Dayglow Observations

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Outline

- TIMED Solar and Terrestrial Observations
  - SEE solar EUV irradiance
  - GUVI FUV dayglow

- Solar-Upper Atmosphere Radiative Coupling

- Solar EUV Irradiance Variability

- Terrestrial FUV Dayglow
  - $Q_{EUV}$ ... energy to produce FUV dayglow
  - disk, limb & solar measurements and models

- Comparisons of Solar and Dayglow $Q_{EUV}$
  - solar rotation (and cycle), solar flares
TIMED Measures Solar EUV Radiation and FUV Dayglow Simultaneously

SEE
measures solar EUV irradiance
energy input in 1 nm bins

GuVI
measures FUV dayglow
spectra in five “colors”

HI Lyman α
119.3 – 123.7
OI 130.4 nm
134.2 – 137.7
N₂ LBH short
141.0 – 152.8
N₂ LBH long
167.1 – 181.2
\( Q_{\text{EUV}} \): The Energy Required to Produce the FUV Dayglow

Minimum energy to produce FUV dayglow: ~ 27 eV

- ~ 17 eV for photoionization
- ~ 10 eV for electron excitation

GUVI measures FUV dayglow emission between about 100 and 300 km - \( I_{1356} \) & \( I_{LBH} \)

**Modeling of disk dayglow by Strickland et al. (JGR 1995):**

\[
\begin{align*}
I_{1356} & \sim \left[ \text{O} \right]_{\text{column}} \times Q_{\text{EUV}} \\
I_{LBH} & \sim \left[ \text{N}_2 \right]_{\text{column}} \times Q_{\text{EUV}} \\
\left[ I_{1356} / I_{LBH} \right] & \sim \left[ \text{O}/\text{N}_2 \right]_{\text{column}}
\end{align*}
\]

\[
Q_{\text{GUVI}}^{\text{EUV}} = 135.6 \quad \frac{Q_{\text{EUV}}^{\text{obs}}}{135.6} = \frac{Q_{\text{EUV}}^{\text{table}}}{135.6}
\]

dayglow as a function of \([\text{O}/\text{N}_2]_{\text{column}}\) and zenith angle

**Table:**

- EUV photons with \( \lambda \leq 450 \, \text{Å} \)
Daily Mean Solar EUV Irradiance

Solar Cycle 23

TIMED

SOHO/SEM central order data

TIMED/SEE V7 data

NRLEUV model

HFG empirical model

SEE filter wheel malfunction
GUVI FUV Dayglow Observations

one day

one revolution

Rev 3550

O/N_2 composition

Q_{EUV} energy

GUVI 135.6
Day 216 (8/4) 2002

UT

500 800 1100

Radiance (Rayleighs)

17.18 13.94 10.70 7.47 4.22 0.98 21.74

Solar Zenith Angle (°)

1500 1000 500

Rayleighs

135.6 Dayglow

135.6/LBH_s

Ratio

mW m^{-2}

Q_{EUV}
GUVI and Solar $Q_{EUV}$ Variations:
July-August 2002 Rotation

Absolute Uncertainties:
- GUVI: $\pm 15\%$
- SEE: $\pm 10\%$ - goal
- NRLEUV: $\pm 50\%$

Strickland et al., GRL, 2004
GUVI and Solar $Q_{\text{EUV}}$ Daily Variations: 2002-2003

daily means

SEM
central order
0-45 nm

SEE
0-45 nm

HFG
0-45 nm but many missing soft X-ray lines

NRLEUV
5-45 nm $\times$ 1.15

~ 50% decrease from 2002 to 2004
GUVI Dayglow Enhancements During Solar Flares

clusters of GUVI $Q_{\text{EUV}}$ per orbit: each point within a cluster is an average over 14 along-track spatial pixels and 13 cross-track pixels

Strickland et al., GRL, 2004
GUVI and Solar $Q_{EUV}$ Variations During Solar Flares

- per min
- per rev (20 mins)
~ 3 mins
GUVI and Solar $Q_{EUV}$ Variations During October-November 2003

28 OCT

4 NOV

18 NOV

$Q_{EUV}$

28 OCT

4 NOV
Summary: SEE and GUVI $Q_{EUV}$

ABSOLUTE LEVELS:
- GUVI $Q_{EUV}$ is about half as bright as SEE and SEM
- increase needed for Hinteregger fluxes $< 20$ nm?

VARIABILITY:
- detailed tracking during solar cycle, rotation, flares
- $Q_{EUV}$ decreased 50% from Jan 2002 to Dec 2003
- GUVI $Q_{EUV}$ has factor of 3 smaller increase in flares than SEE
  .... GUVI $Q_{EUV}$ increases are similar to SEM
- TIMED orbit prevents observing all flares, all rotations

FUTURE:
- limb versus disk differences have spectral information
- SDO/EVE 10 sec EUV spectra; global FUV imager needed
GUVI Disk and Limb $Q_{EUV}$ Differences

EUV energy at different wavelengths is deposited at different altitudes.

$Q_{EUV}$ is derived by scaling the EUV and X-rays fluxes input to AURIC: limb signal is less sensitive than disk to $\lambda < 20$ nm → upper limit of $Q_{EUV}$
GUVI and Solar $Q_{\text{EUV}}$ Variations During Solar Flares

Strickland et al., GRL, 2004