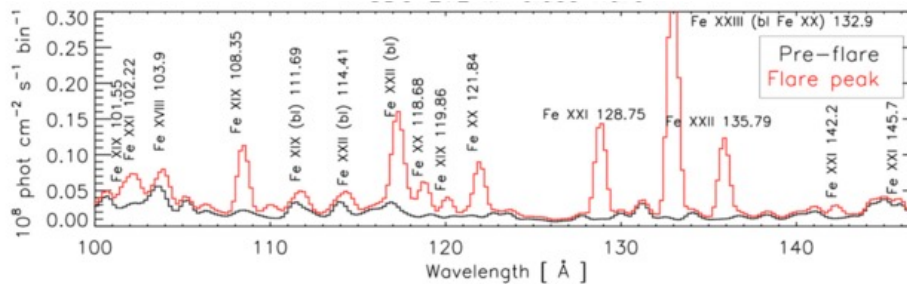# Lines, Lines, and More Lines

Plans for Enhanced Lines Data Product from SDO EVE

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Outline

- Solar Physics Examples with EVE spectra
  - Dynamics – Doppler Shifts
  - Energetics – Flare Spectra
  - CMEs – EUV Dimming

- Most of those results are enabled through analysis of EUV emission lines. EVE team is working on an enhanced EVE Lines Data Product (Level 4).
  - More lines
 - More information about the lines

Example of MEGS-A Doppler Shifts

- We did not design EVE-MEGS for Doppler measurements, so Doppler shift observations are providing bonus science from EVE
- Chamberlin, *Solar Phys.*, 2016
  - MEGS-A wavelength shifts can be <u>solar Doppler shifts</u> and/or <u>optical shifts</u> based on flare location on solar disk. Typical uncertainty of 1 km/s.
- Hudson et al., *Solar Phys.*, 2011
  - Small orbital shifts (3 km/s, 24-hours) and large flare shifts observed for MEGS-A
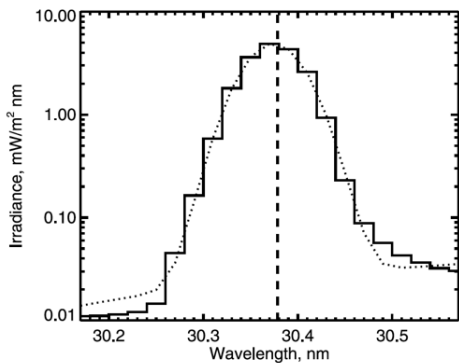
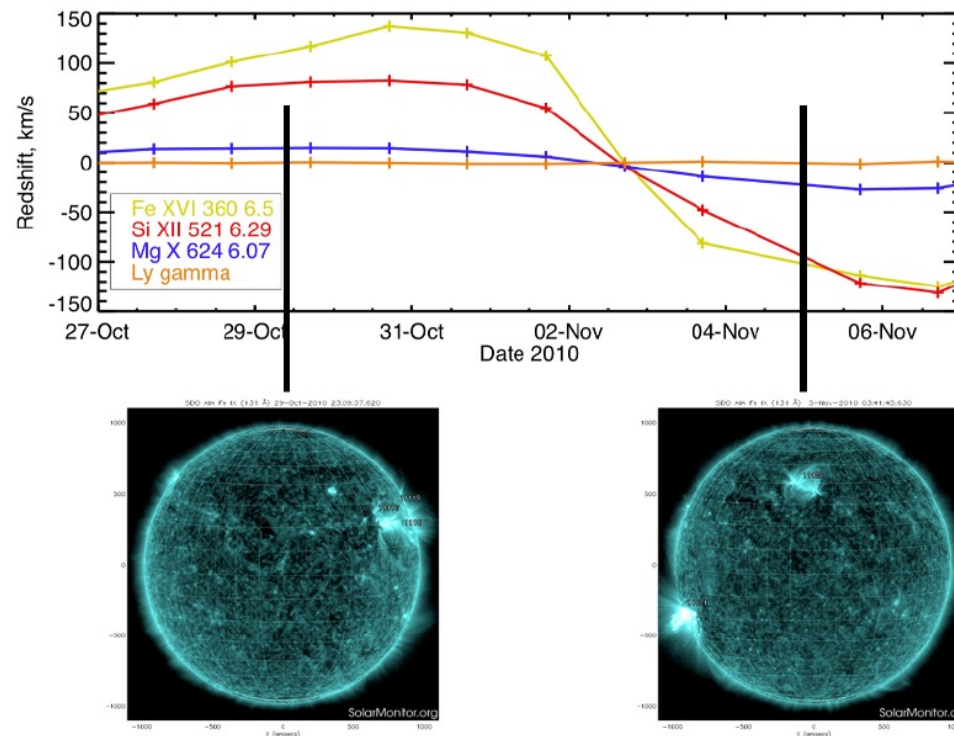Gaussian Fit
with Quadratic Background

±3 km/s

Fe XXIV
19.2 nm

100 km/s
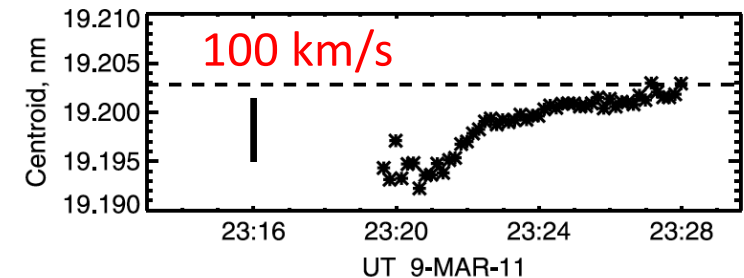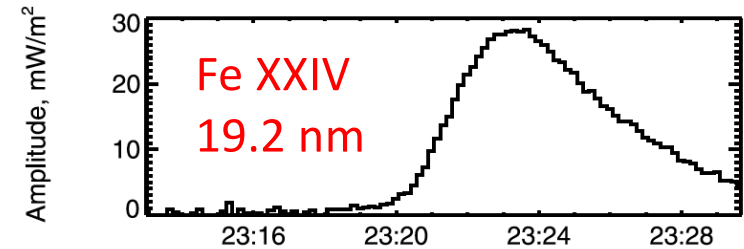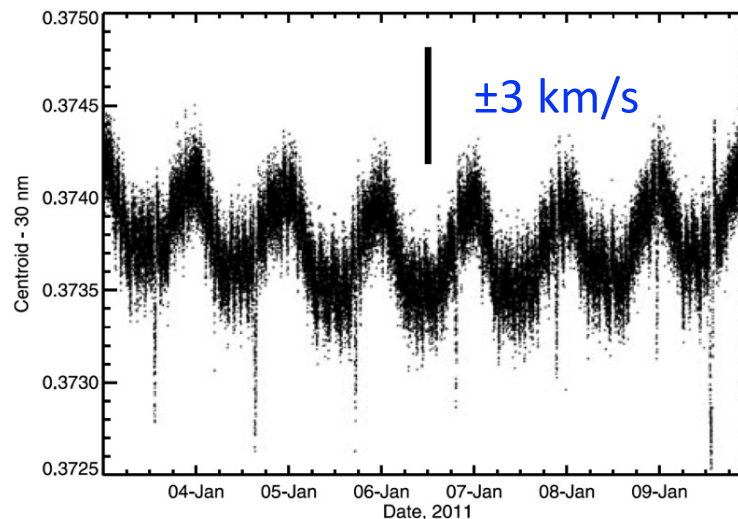
Example of MEGS-B Doppler Shifts

- MEGS-B wavelength shifts are just solar Doppler shifts as optical design is not sensitive to active region location

- Hudson et al., MNRAS, 2022
  - MEGS-B Doppler shifts indicate prograde movement for active regions at warm corona temperatures
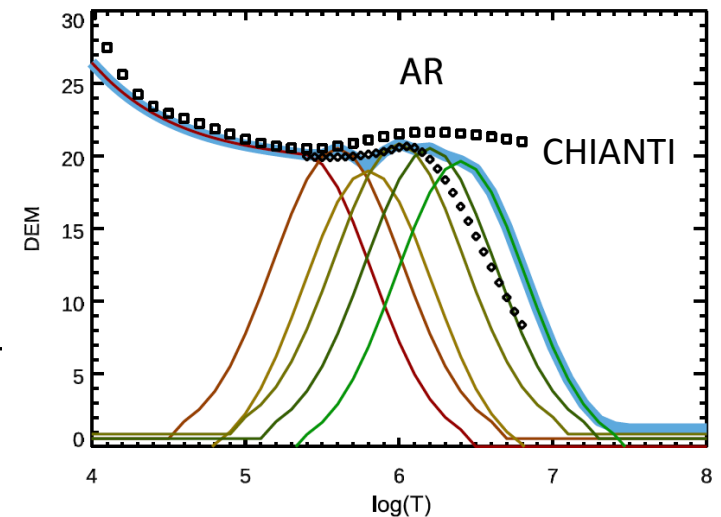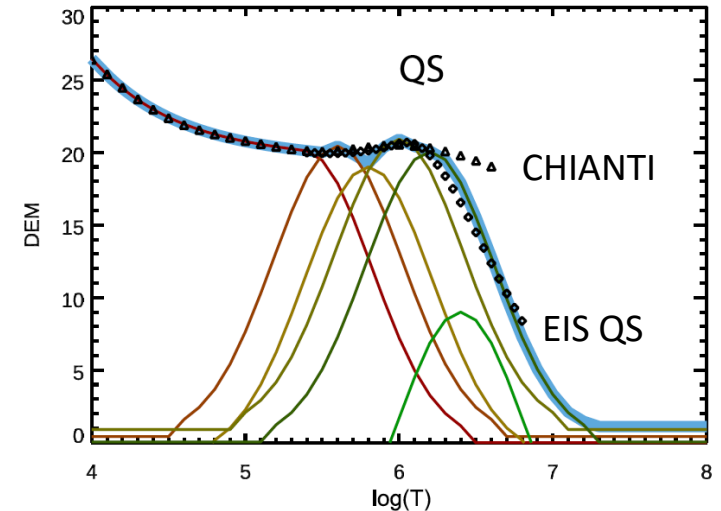
Example of Flare EUV Late Phase

- Early measurements (May 2010) of flares with EVE indicated that many flares had EUV enhancements without X-ray enhancements many minutes after the flare eruption. EVE team called those the EUV Late Phase – Woods et al., *Ap J,* 2011

- These are most common near solar cycle minimum and are caused by two sets of coronal loops cooling at different rates (longer loops cool slower) - Woods, *Solar Phys.,* 2014
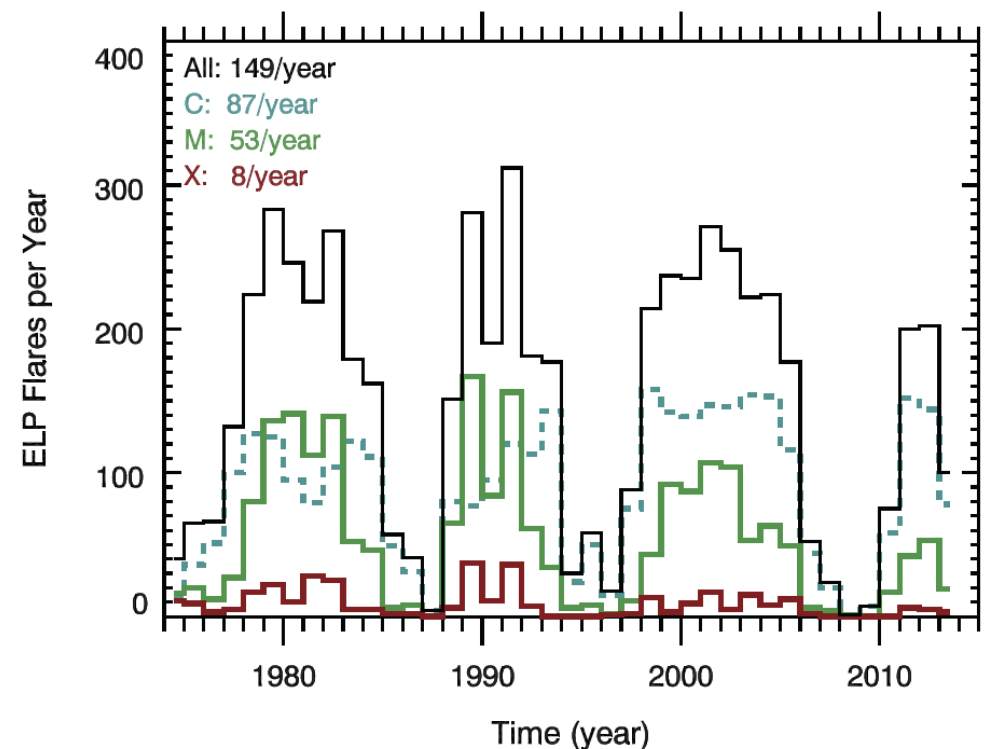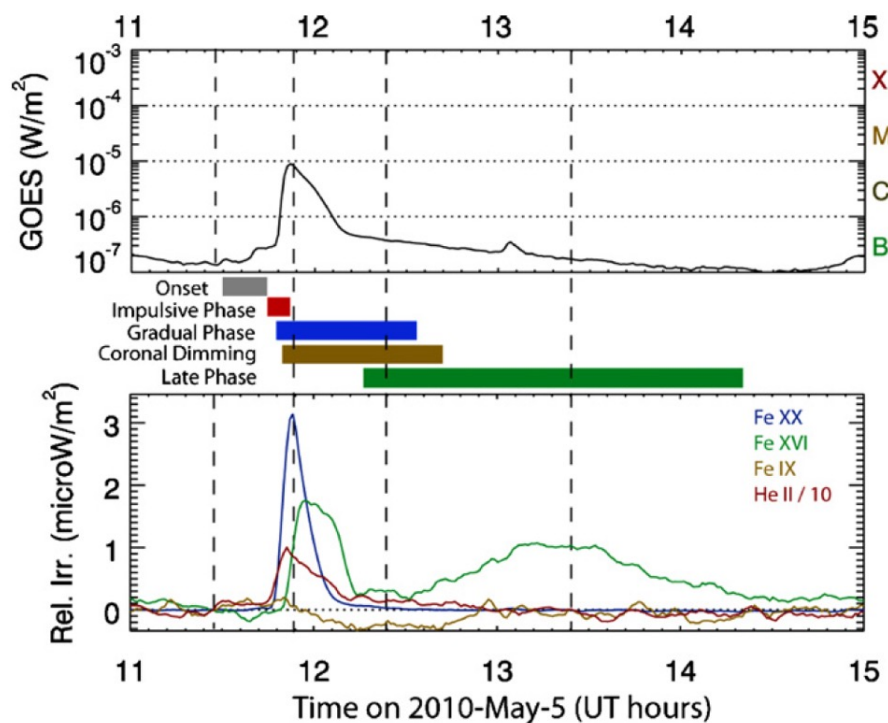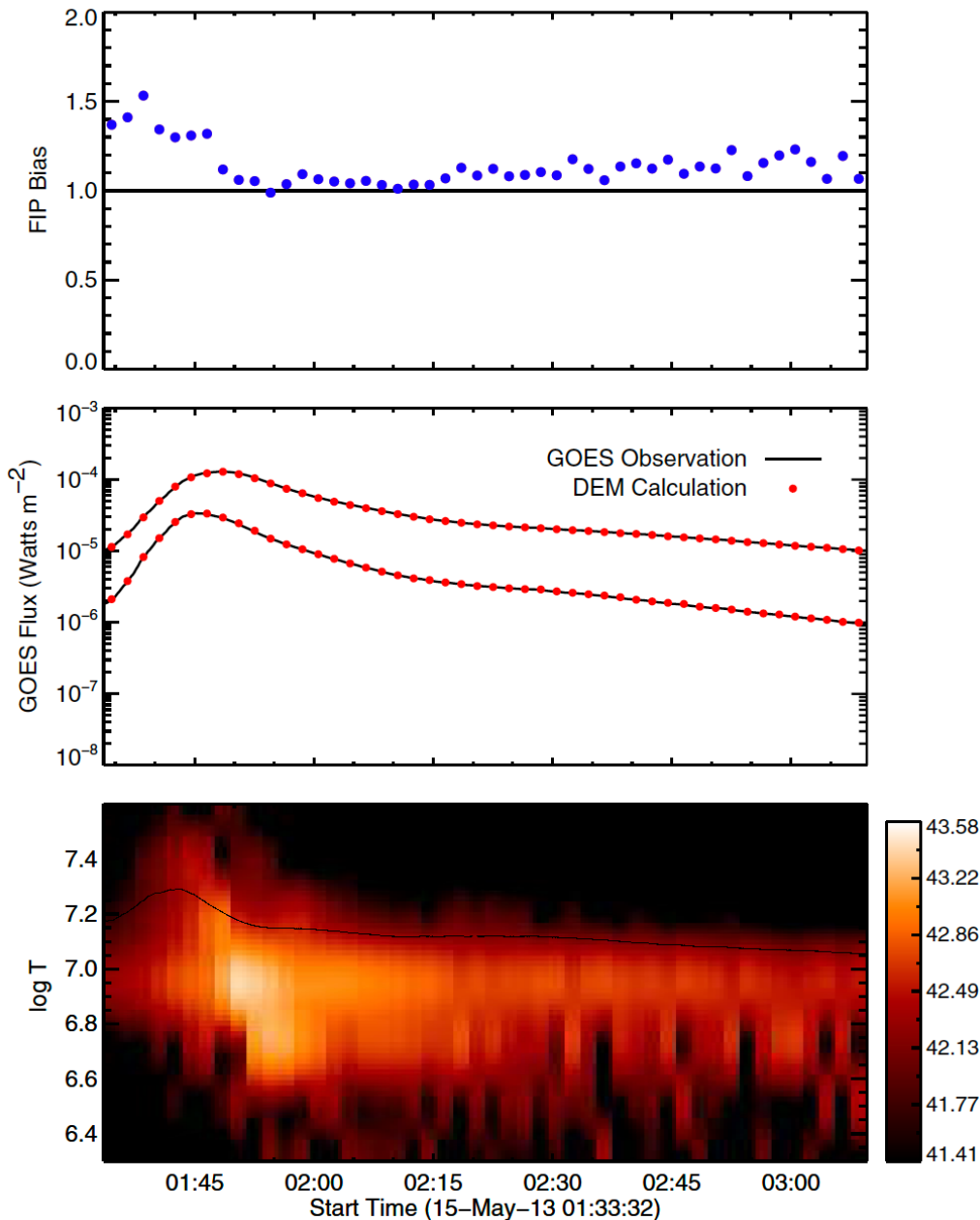
Example of DEM Modeling with EVE

- EVE Only: Warren (Ap J Lett, 2014) derived flare DEMs for 21 flares using EVE spectra between 70 and 190 nm

- EVE + RHESSI: Caspi et al. (Ap J Lett, 2014) derived flare DEM

- EVE + MinXSS: Woods (Solar Phys., 2022) derived QS and AR DEMs for XPS Level 4 Modeling


Warren Flare DEM Example
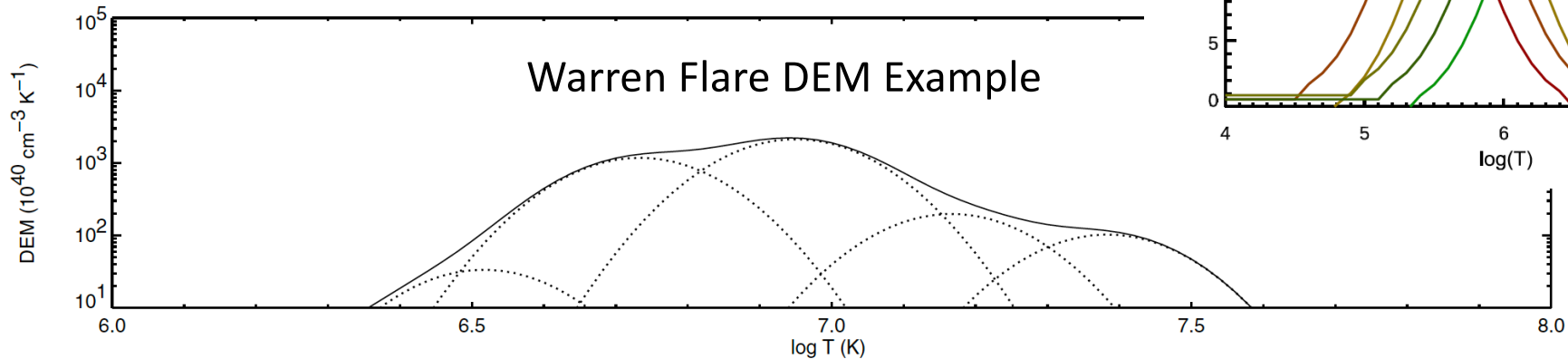
Example of Flare Abundance Changes

- Warren (Ap J Lett, 2014) shows that FIP bias is near photospheric level (1.0) during gradual phase

  – Average decrease of FIP bias for 21 flares is factor of 1.17 during impulsive phase using DEM analysis and factor of 0.85 using isothermal modeling

  – Note that QS FIP bias is about 4 and AR FIP bias is about 2.

Example of EUV Dimming for CME Detection

AIA 171Å Dimming Image

AIA 171Å Light Curves
AIA 193Å Light Curves
AIA 304Å Light Curves
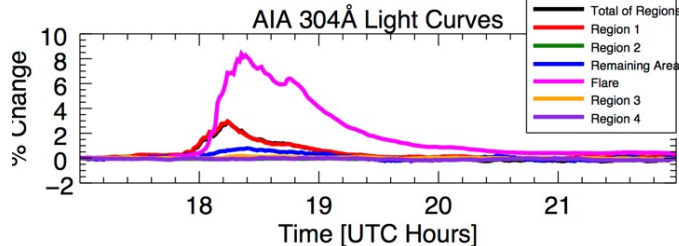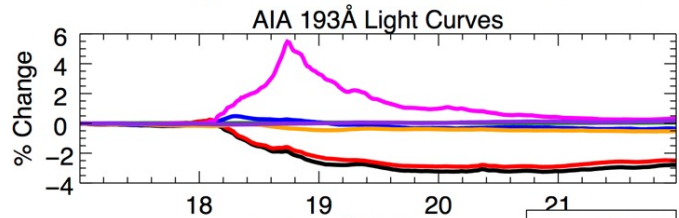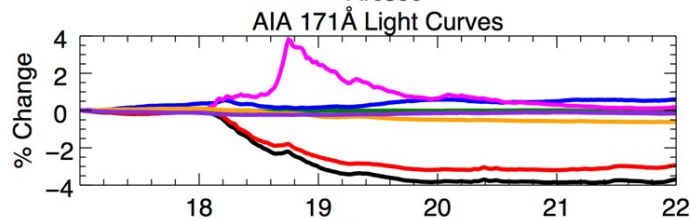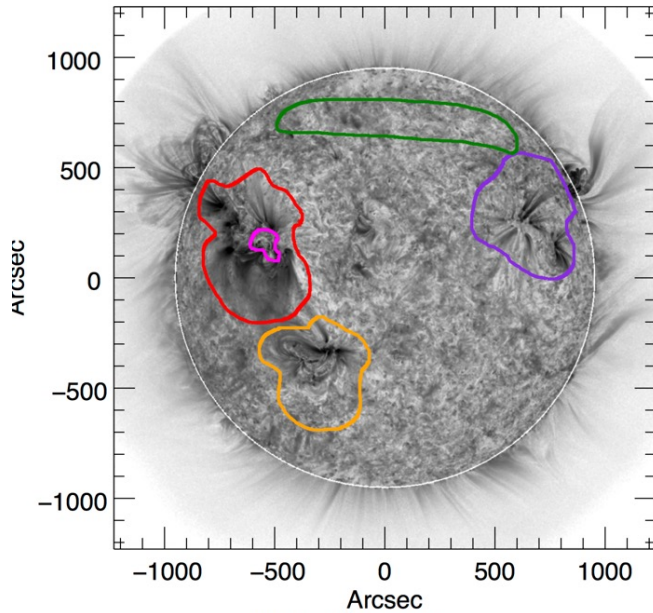
- EUV Dimming for cool corona emissions have been observed in SOHO EIT and SDO AIA images during CME events

- EVE irradiance spectra also show EUV dimming for many cool corona emissions at the few % level during CMEs. Mason et al. (Ap J, 2014; 2016) show that EUV dimming slope and depth are correlated with CME speed and mass, respectively.

$y = 7.55 \times 10^{15} x - 8.40 \times 10^{15}$
$y = 2.11 \times 10^{15} x + 2.35 \times 10^{14}$

- Woods   8
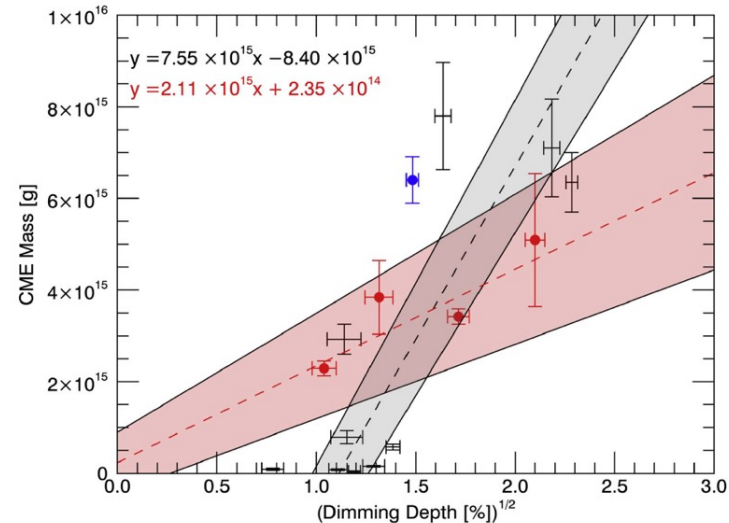
EVE Level 2 Lines Product – Version 7

- EVE Level 2 Lines (L2L) product has 38 emission lines
  - 15 features from MEGS-A (limited to 2010-2014)
  - 23 (14) features from MEGS-B (2010-2023, limited to 3-24 hours/day)
  - Line Irradiance is calculated by integrating over a limited wavelength range, includes background (continuum) in the irradiance
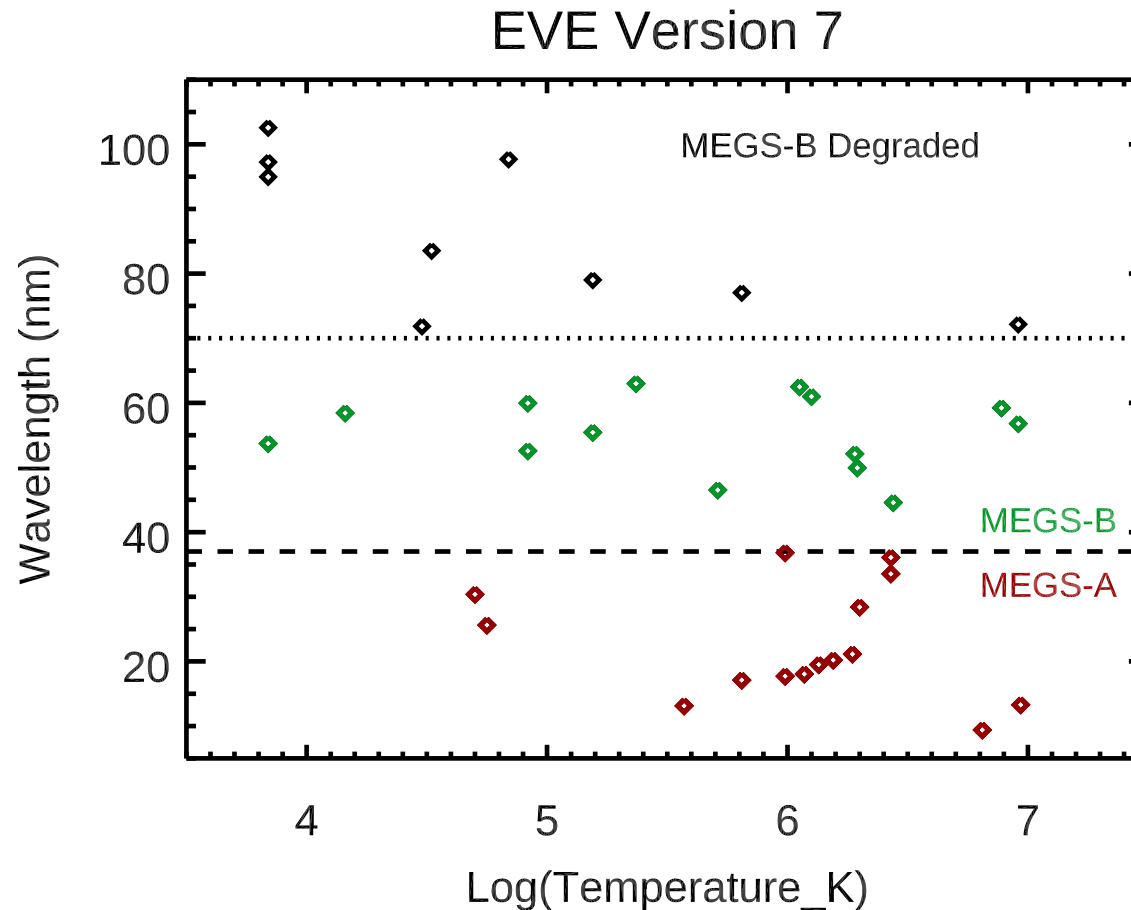
EVE Version 7

Future EVE Level 4 Lines – More Lines

- Future version of EVE Level 4 Lines (L4L) product will have more lines
  - CHIANTI version 10.2 used to identify hundreds of features at EVE's spectral resolution (0.1-nm) and over range of temperature for each feature
  - Selecting features for L4L whose blends are limited to single elements so can better support spectral modeling and studying abundance changes during flares

EVE Future V8
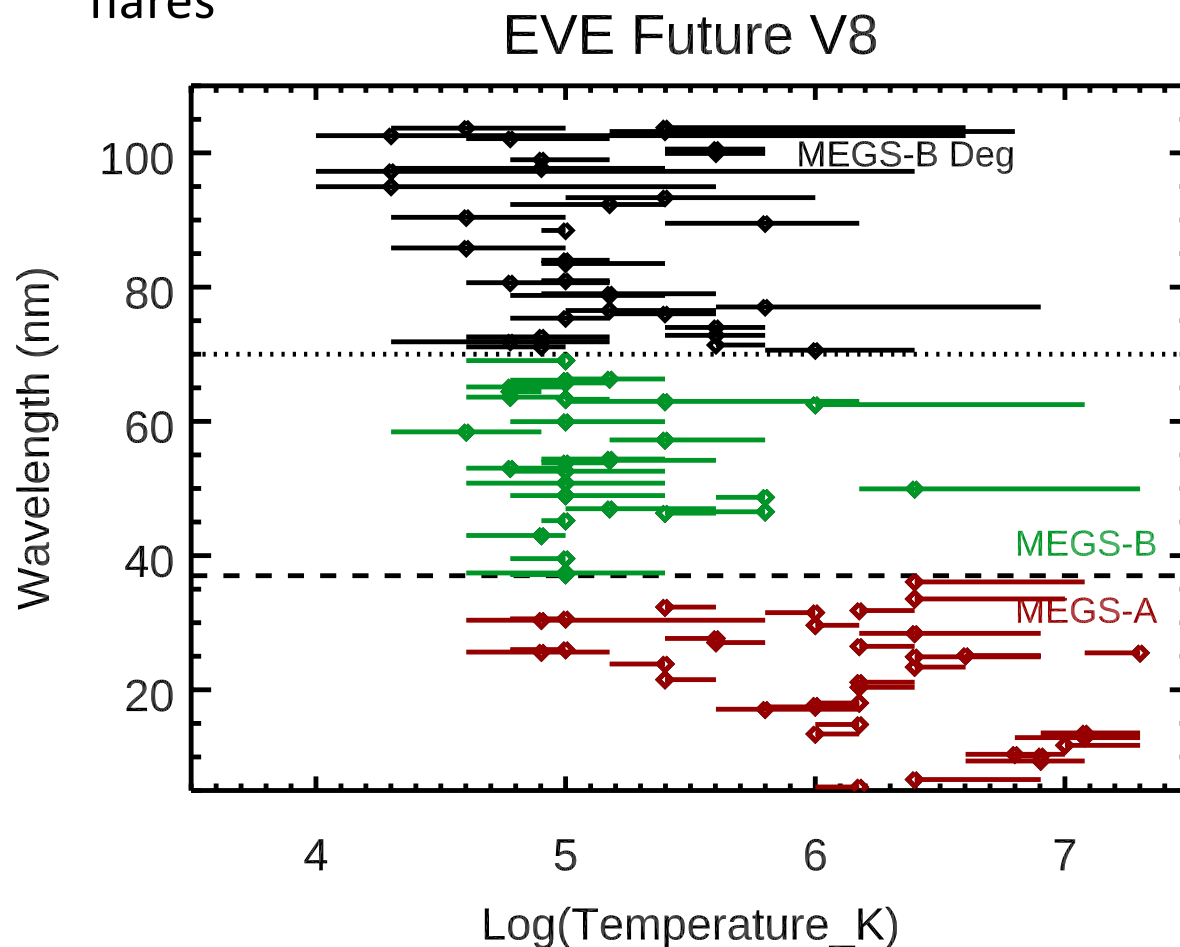
Diamonds are at temperature for peak intensity (constant EM)

Bars show range of temperature for when feature intensity is > 1.15 larger than background intensity

Future EVE Level 4 Lines– More Information

- Future version of EVE Level 4 Lines (L4L) product will have more lines and more information for each feature
  - Results from fitting the features will include feature irradiance, center wavelength (Doppler shift), feature width, background level, and uncertainties for those results

Example He II 30.4 nm feature fit with Gaussian function and quadratic background (Hudson et al., 2011)
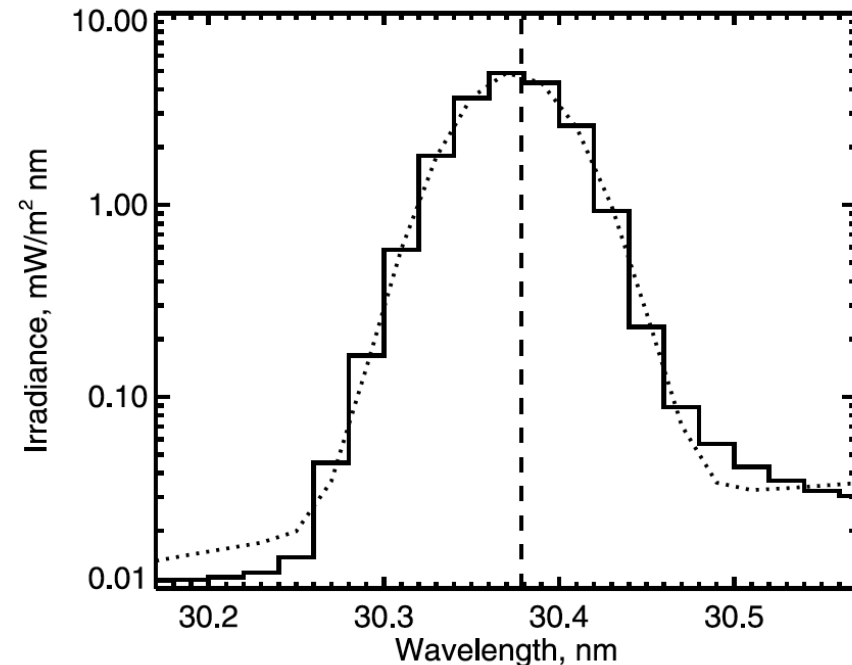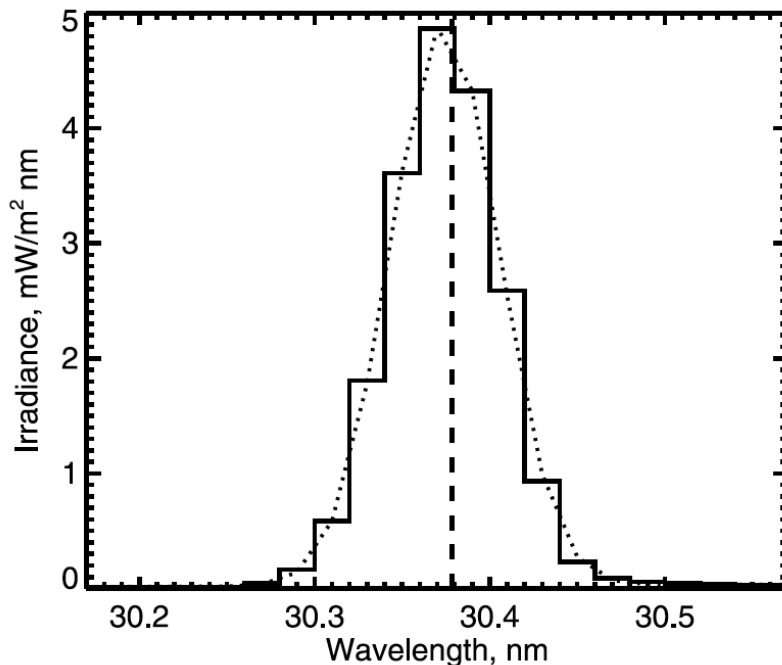
Plans for EVE Level 4 Lines Product

- First decide on feature fitting functions
  - Feature Function options: Gaussian, Lorentzian, Voigt, MEGS-ray-trace profiles, etc.
  - Background Function options: linear, quadratic, etc.
  - Number of features fit per feature: line blends, and/or adjacent features to help improve background function fit
  - Threshold level for line / background ratio for including line fit result in data product
- Second decision is selecting fit tool (e.g. in IDL: curvefit, mpfit, sff; e.g. in Python: line_fit)
- Then process limited time range to verify L4L product results
- Then process full mission (file per day & all files merged over the mission)