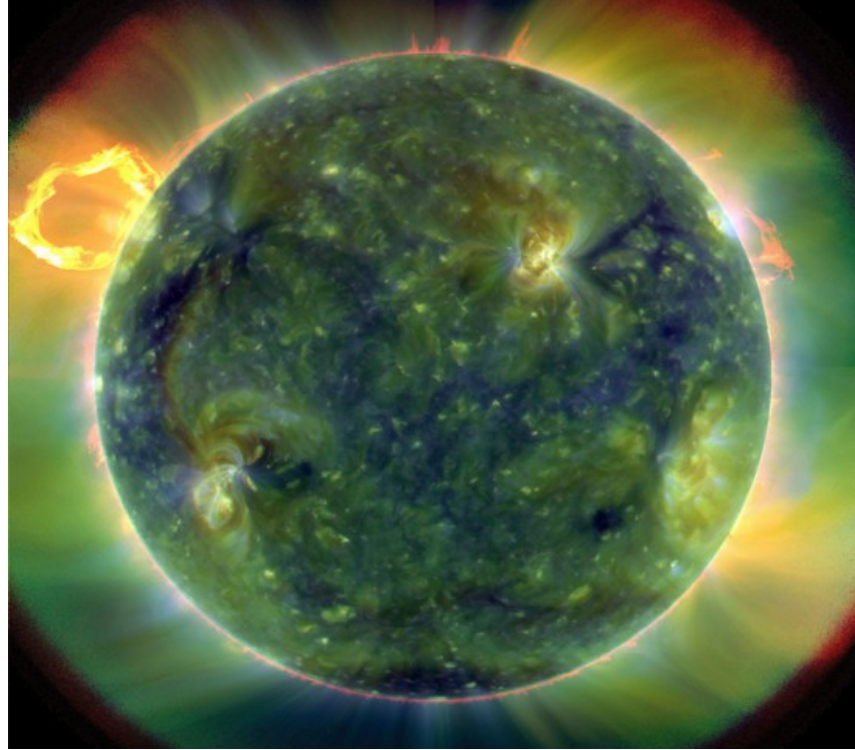


X-Ray Observation and Analysis of a M1.7 Class Flare



Courtney Peck

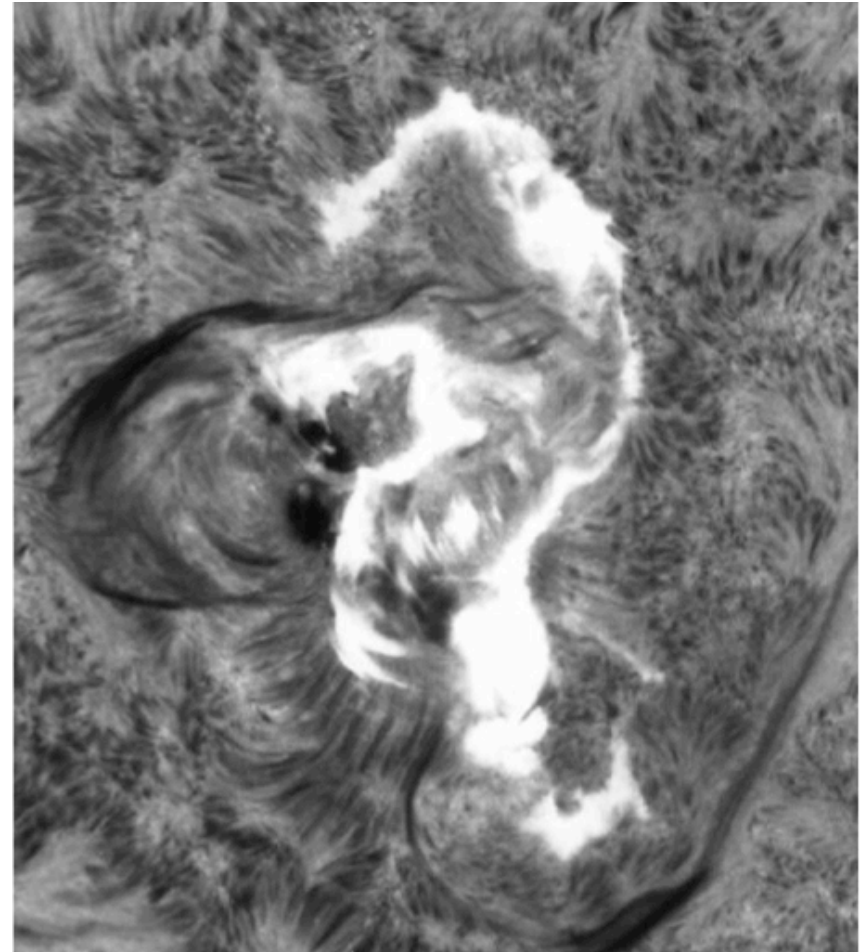
Advisors: Jiong Qiu and Wenjuan Liu

Project Outline

- Overview of Solar Flares
 - Solar Flare Model
 - Observing Solar Flares
- RHESSI Observation
 - Analyzing Lightcurve Data
 - Monitoring Footpoints and Loop-top
 - Calculating Spectra
- EBTEL/CHIANTI Predictions
 - Comparing Theory and Observations

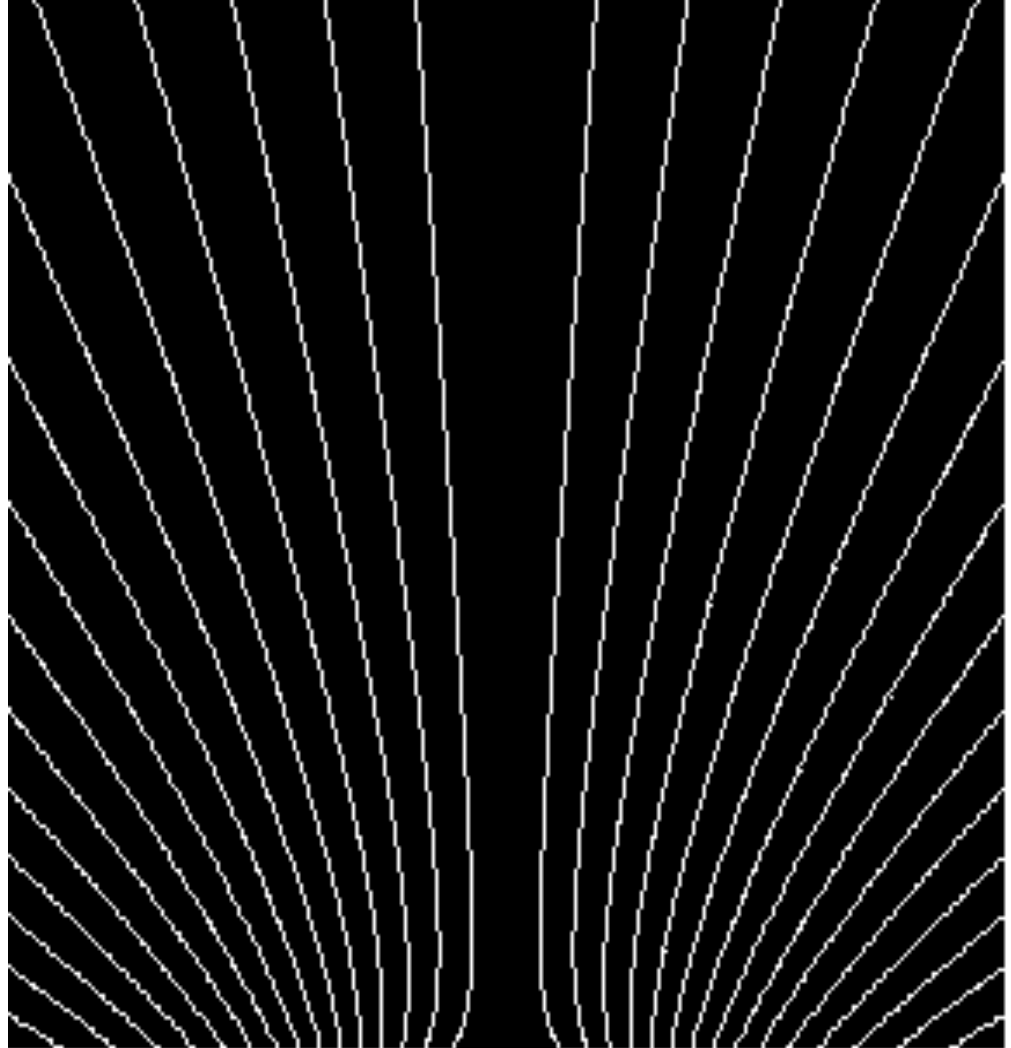
Solar Flare Basics

- Large release of magnetic energy at an active region causing radiation
- Emission ranges from radio to gamma rays
- Classified by soft x-ray flux:
 - B, C, M, X
- Two groups:
 - small, compact
 - large, two ribbon



Solar Flare Model

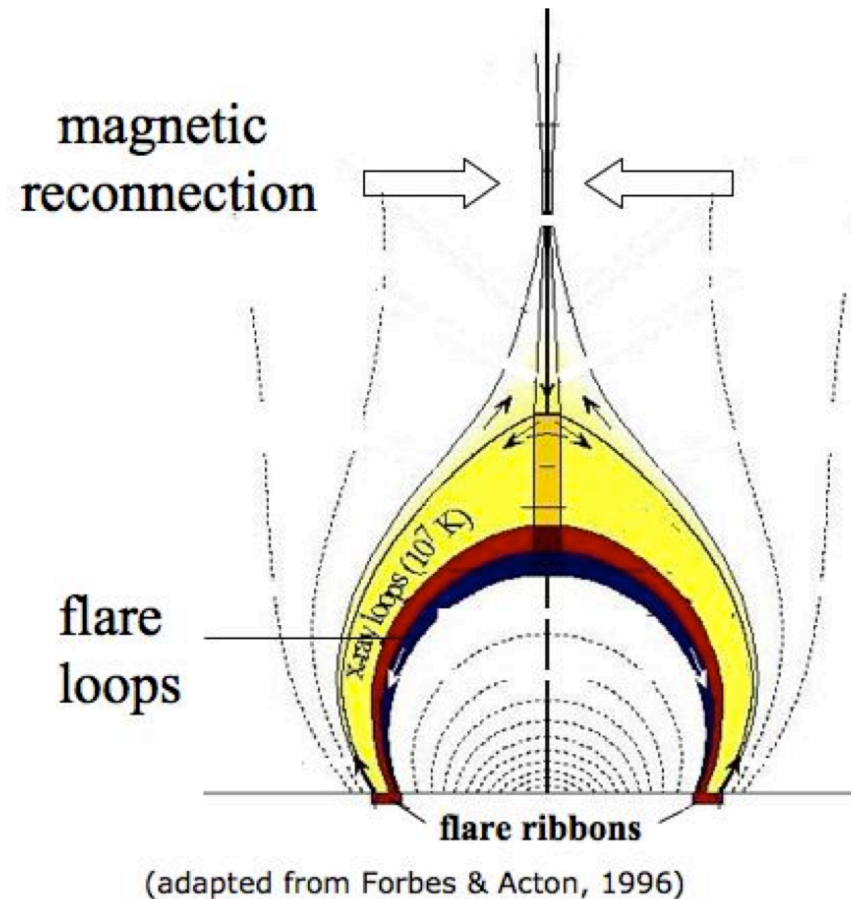
- Magnetic field emerges from solar surface and forms active region
- As field emerges, reconnection occurs and releases energy
 - Loop heating -> Thermal radiation
 - Particle acceleration -> Bremsstrahlung radiation
- Subsequent field lines go through reconnection giving illusion of moving footpoints and growing loops



(Forbes)

Viewing Solar Flares

- Monitoring Loops and Footpoints
 - UV and EUV
 - Thermal radiation -> loop and footpoint heating
 - X-Ray: Soft and Hard
 - Soft X-ray: 3-20keV
 - Thermal radiation -> loop-top heating
 - Hard X-ray: >10keV
 - Non-thermal radiation-> Bremsstrahlung radiation at footpoints

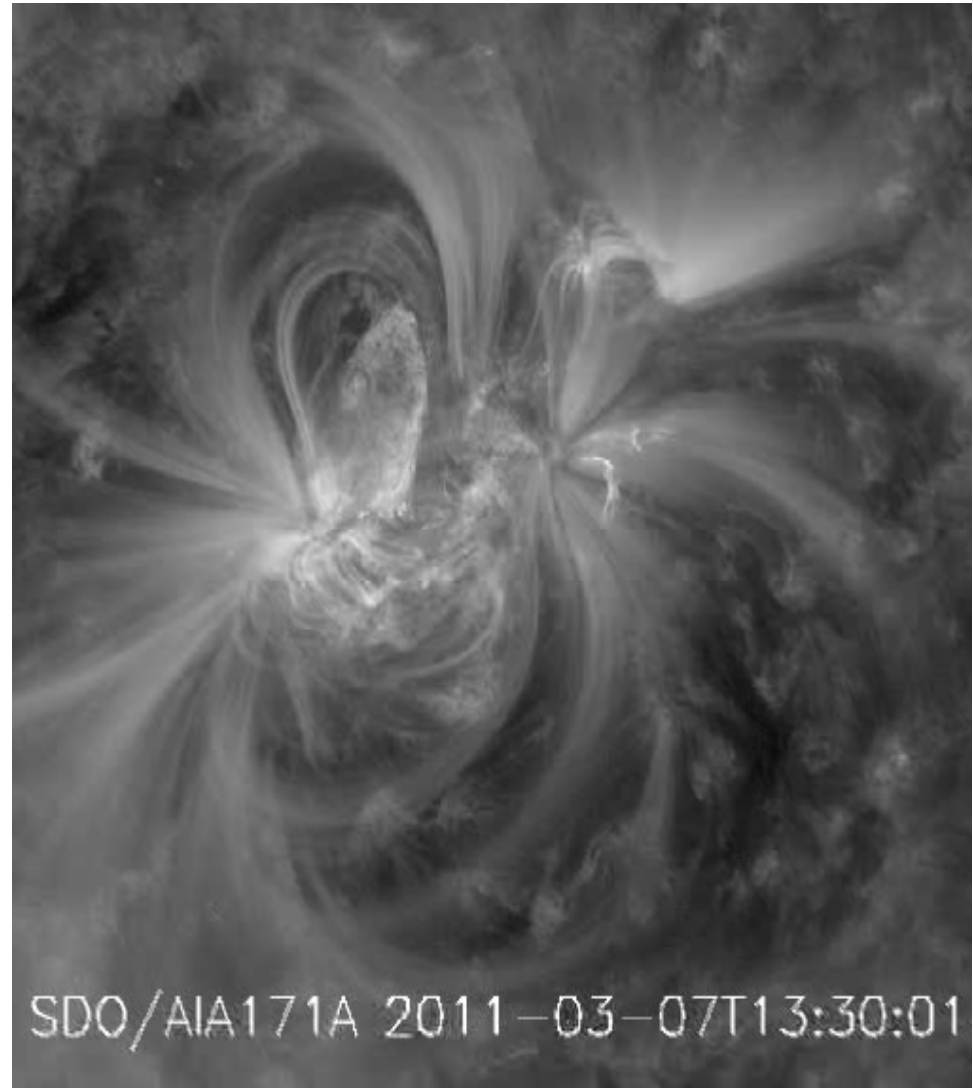


RHESSI X-Ray Observations

- Bridges footpoint and loop-top observations using HXR and SXR
 - Shows evolution of top and bottom of flare
- HXR
 - Highest energy band commonly observed in flare
 - Observes footpoints
 - First peak in lightcurve of flare event
- SXR
 - Lower energy than HXR
 - Observes loop-top radiation
 - Gradual rise of lightcurve to flare maximum

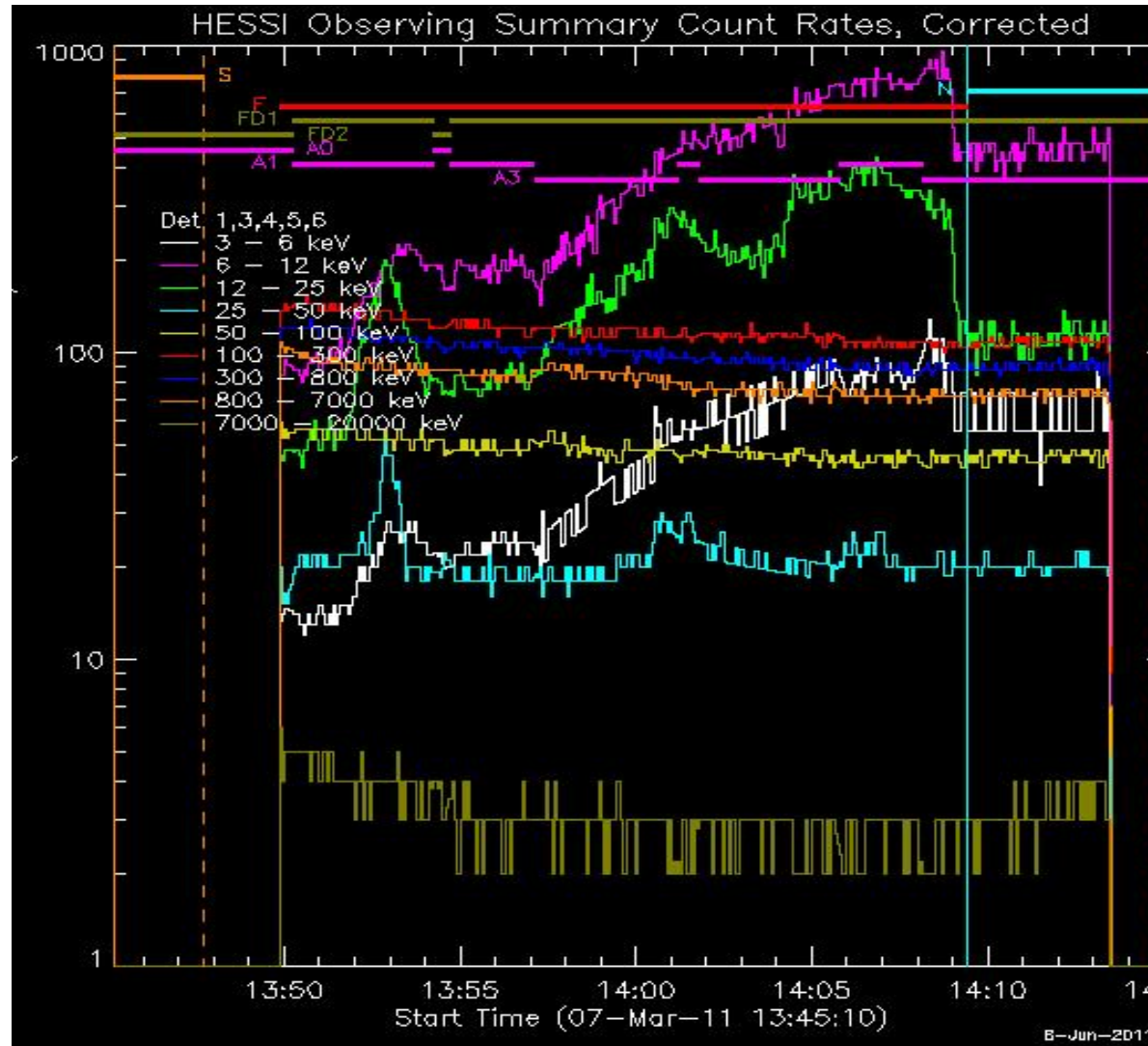
Flare to be Studied

- March 7th, 2011
- M1.7 flare in active region 11166
- Use RHESSI Software to construct an understanding of flare
 - Lightcurve
 - Image
 - Footpoint movement
 - Loop-top evolution
 - Spectra

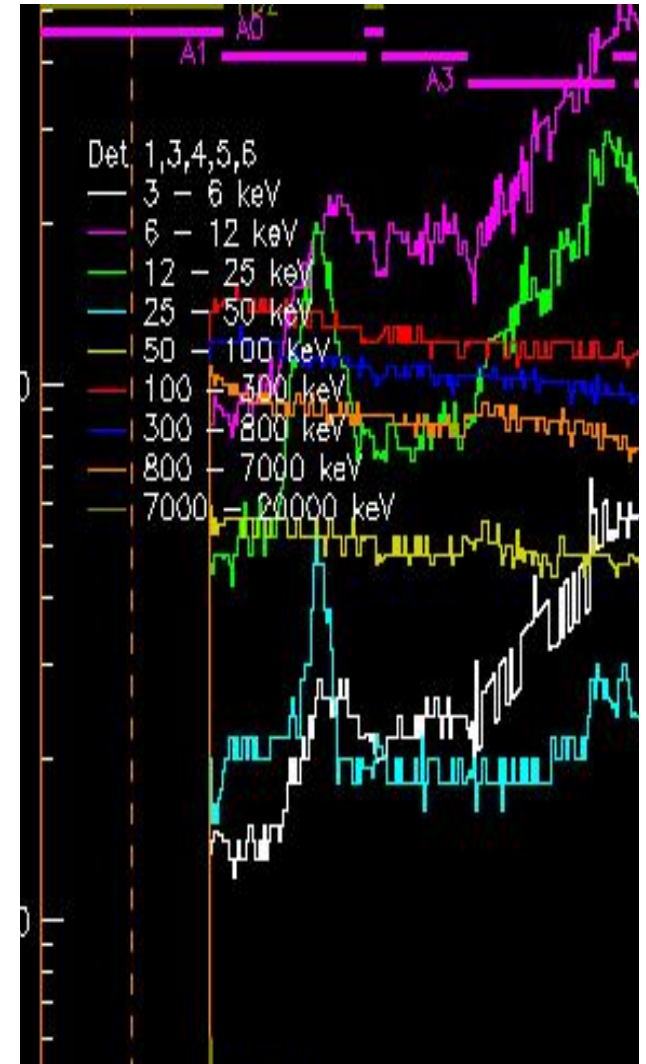
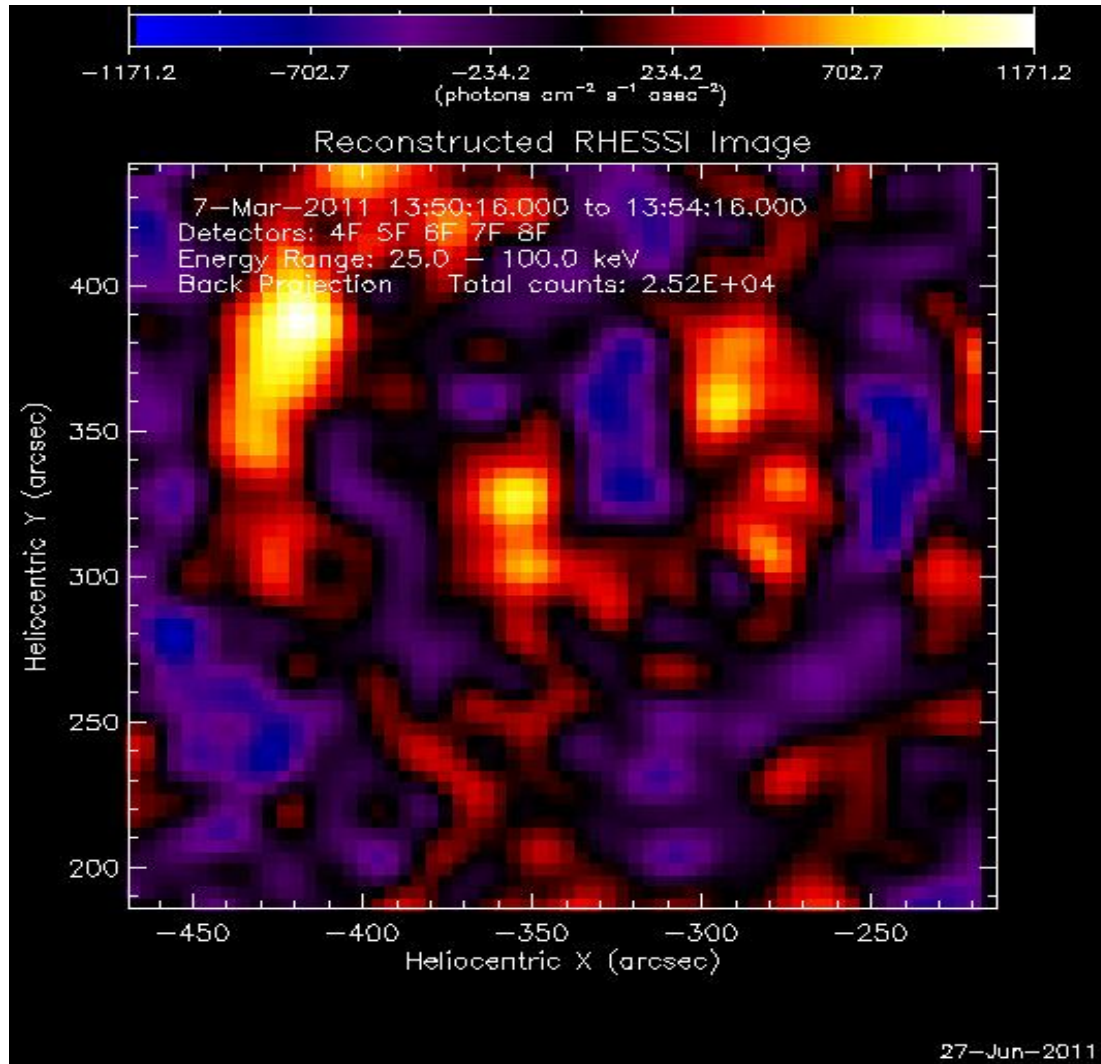


Using RHESSI Lightcurve

- Lightcurve
 - Time history of SXR and HXR
- Decide how to make images
 - Peaks
 - Attenuators
- Footpoints
 - First high-energy peak
- Loop-tops
 - Slowly rising lower energy peaks

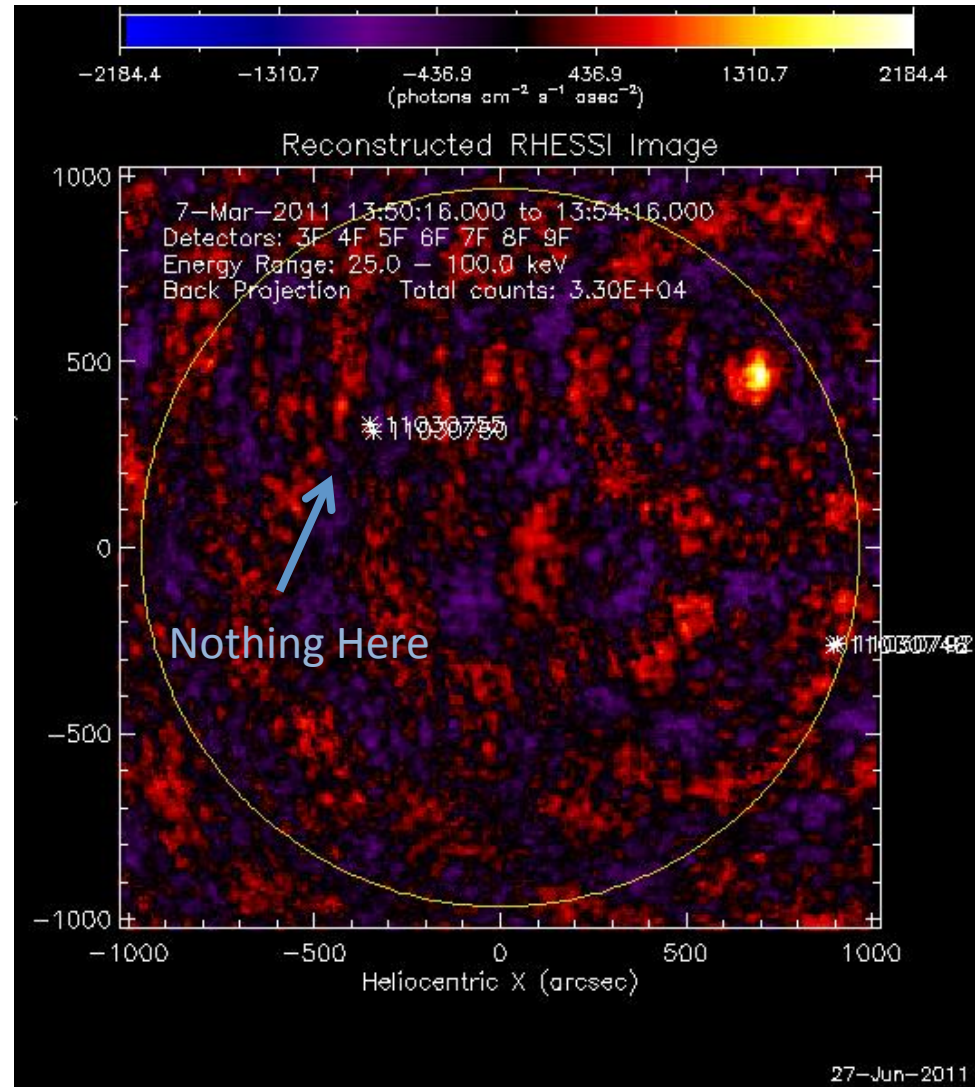


Where are the footpoints?



... Apparently Not Here

- All high energy HXR (>25keV) particles indicated in lightcurve were a result of different flare
- Other flare region not recognized by other flare catalogs
- Complicates analysis a bit

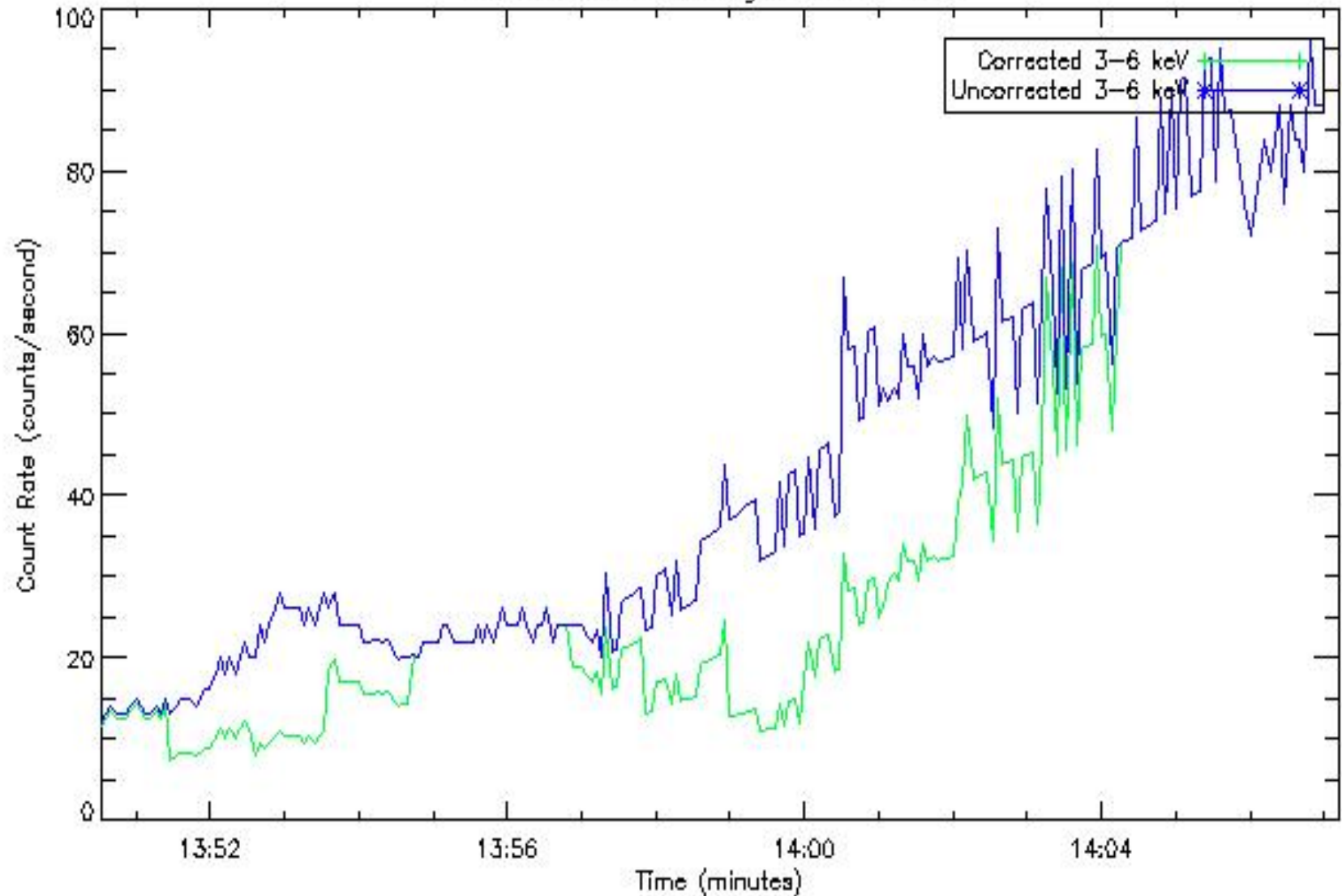


Solution

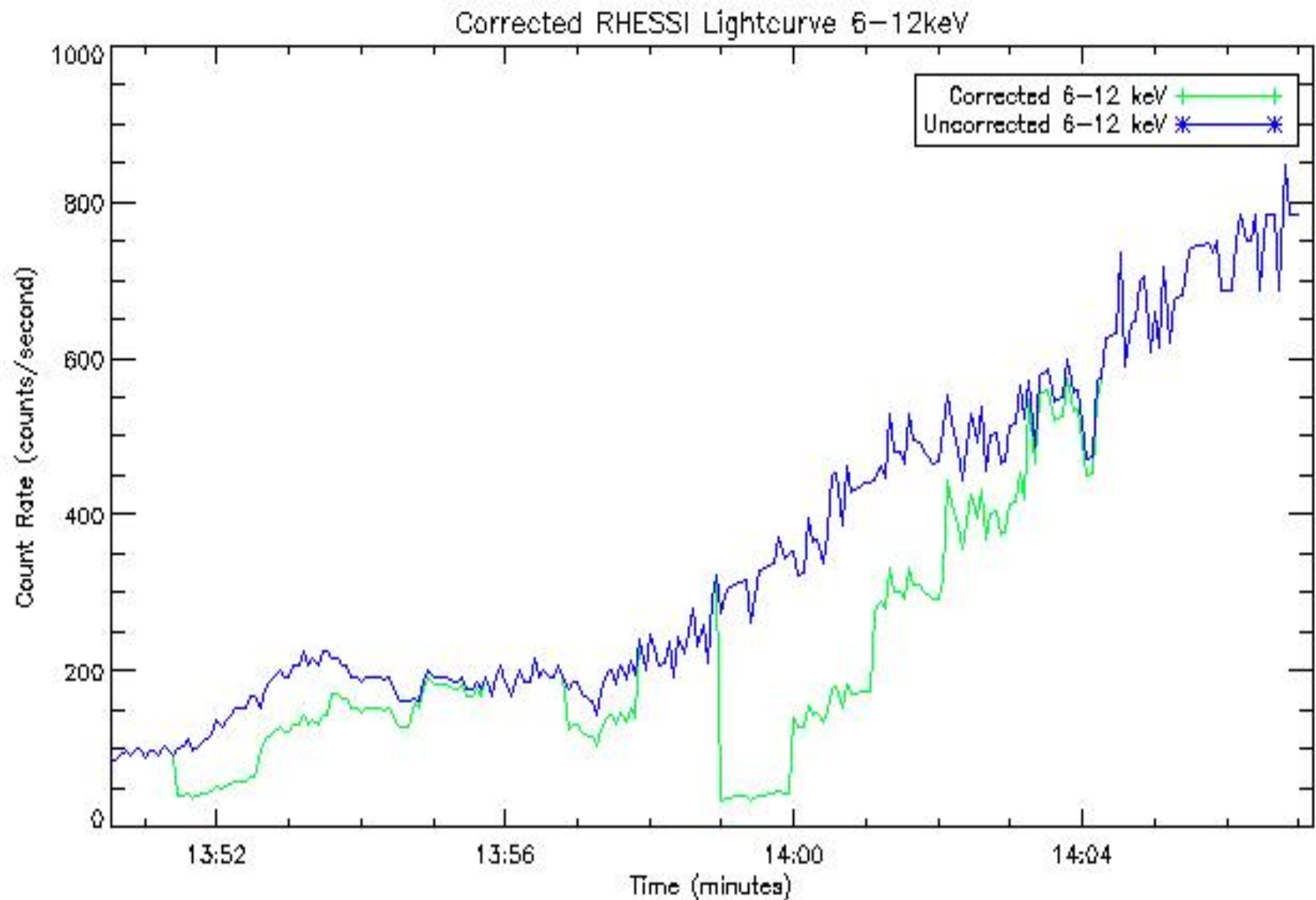
- Correcting the Lightcurves
 - Make images from both flaring regions
 - Use RHESSI to compute flux in each region
 - Make computer program to determine ratio of the flux in each region to total flux
 - Multiply original lightcurve by ratio to get lightcurve for our region
- Image Loop-top Evolution
 - Footpoints not seen in this flare
- Calculate Theoretical Spectra
 - Can no longer use RHESSI software to calculate spectra
 - Use EBTEL/CHIANTI to calculate theoretical spectra and lightcurve
 - Compare theoretical lightcurve to actual lightcurves to confirm spectra

Correcting Lightcurve for Extra Flare

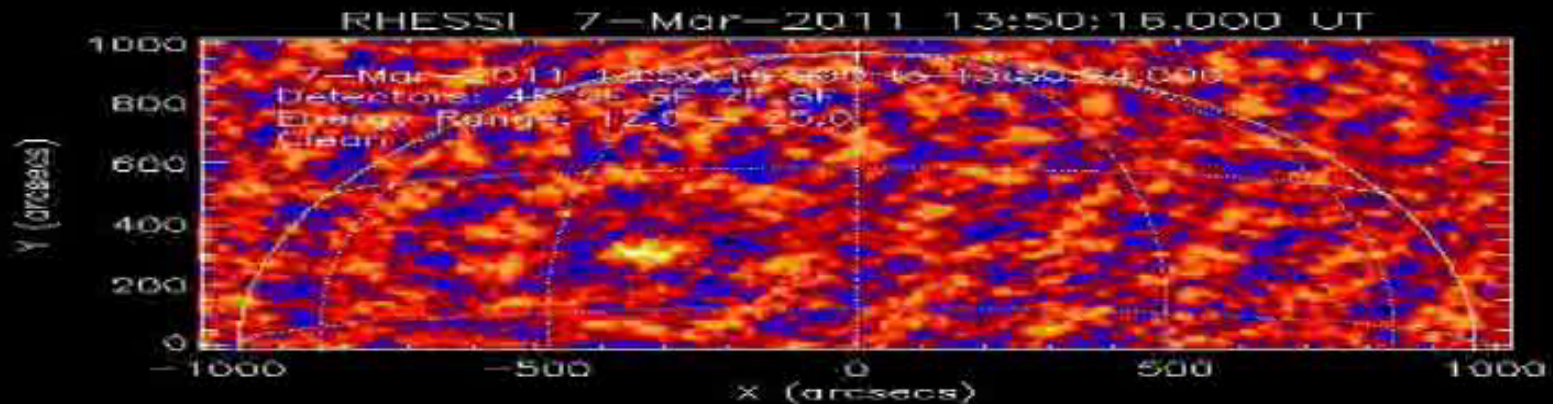
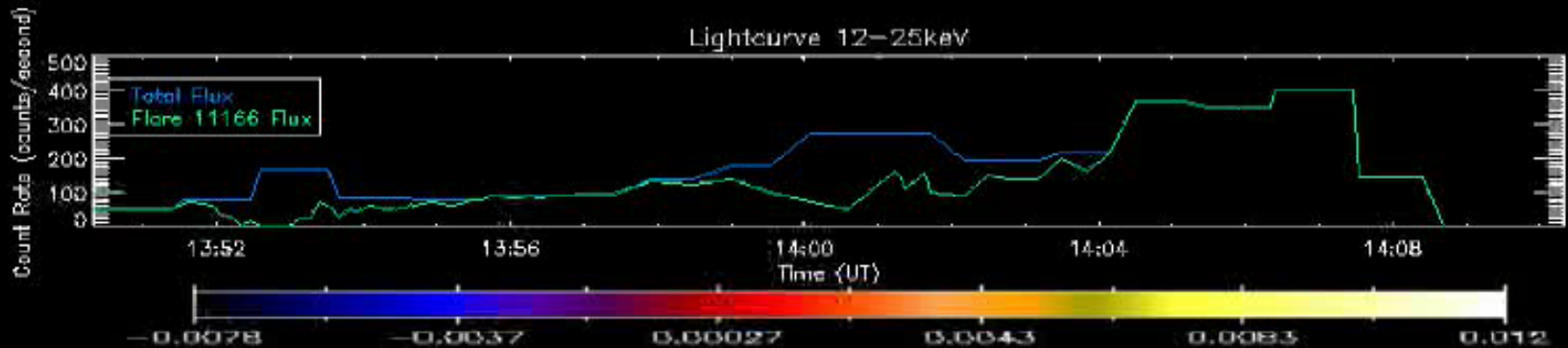
Corrected RHESSI Lightcurve 3-6keV



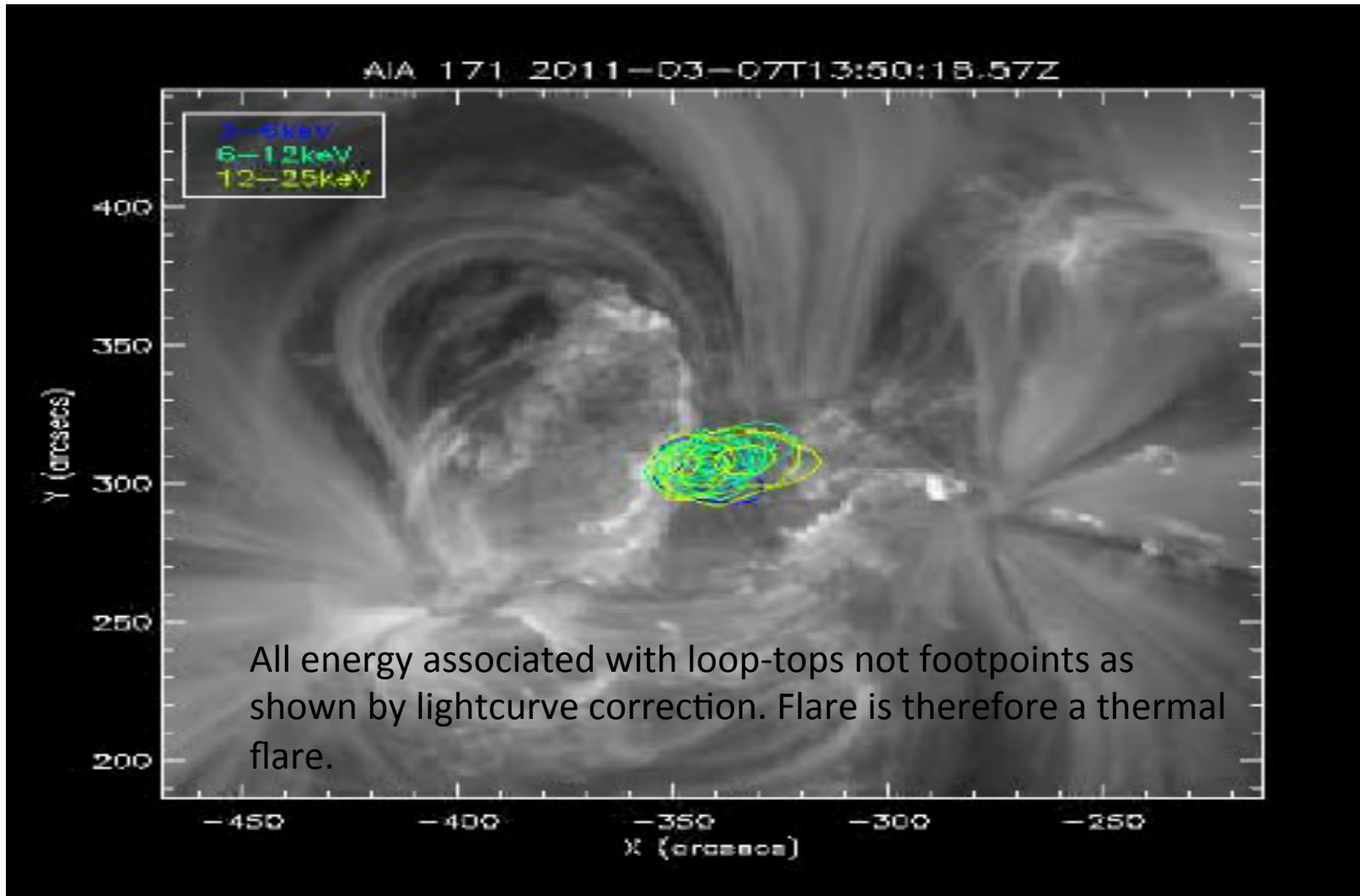
Correcting Lightcurve for Extra Flare



Correcting Lightcurve for Extra Flare



Monitoring loop-top Evolution

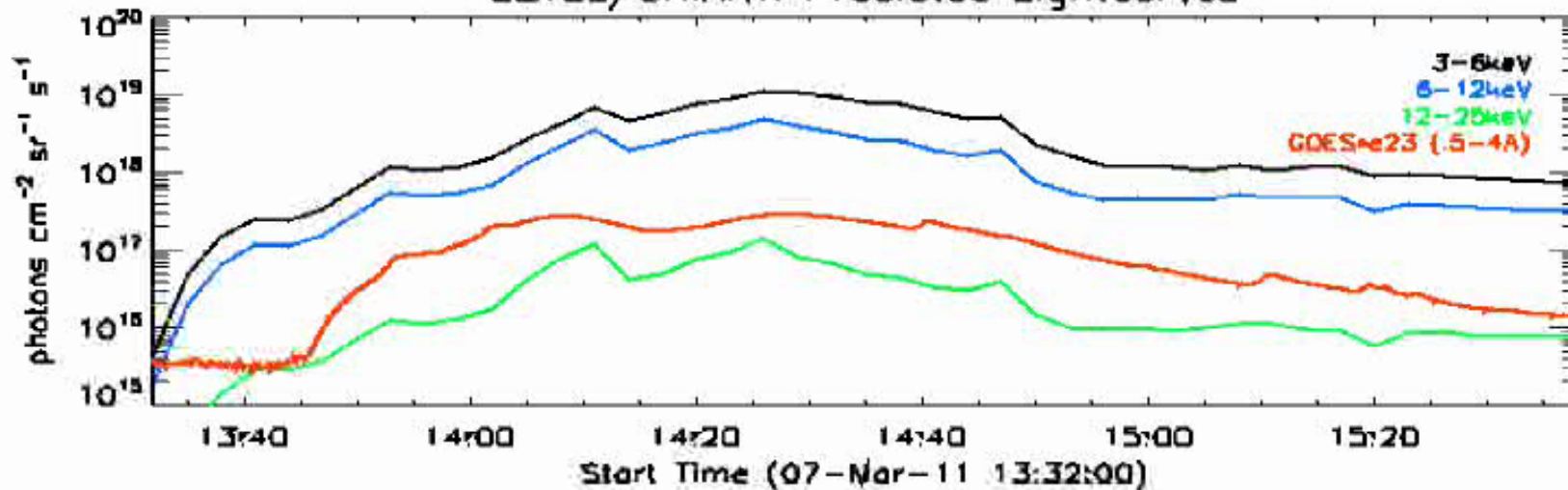


Comparing New Lightcurve with Theory

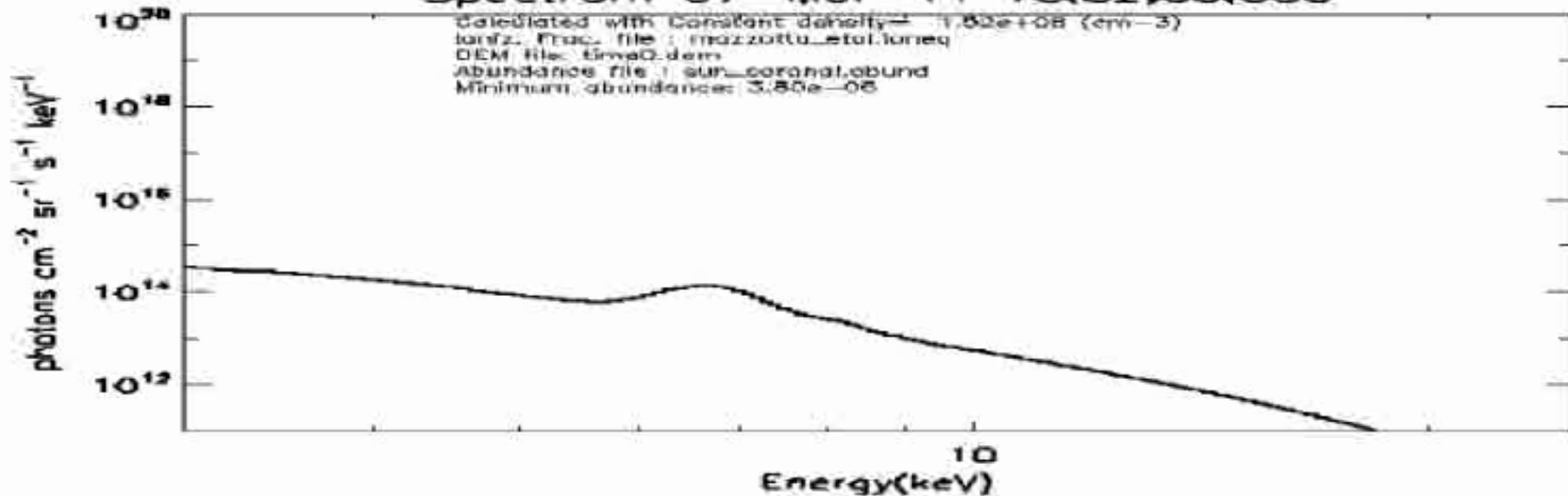
- EBTEL
 - Use actual UV data to best fit to EBTEL model
 - Find best-fit parameters for EBTEL
 - Considered thermal flare -> Fortunately
 - Find density and temperature parameters for loops
- CHIANTI
 - Atomic database
 - Uses EBTEL parameters to calculate differential emission measure (DEM)
 - Amount of plasma emitting radiation at a given temperature range
 - Plot predicted lightcurve and spectra for RHESSI energy ranges

Actual vs. Theoretical

EBTEL/CHIANTI Predicted Lightcurves

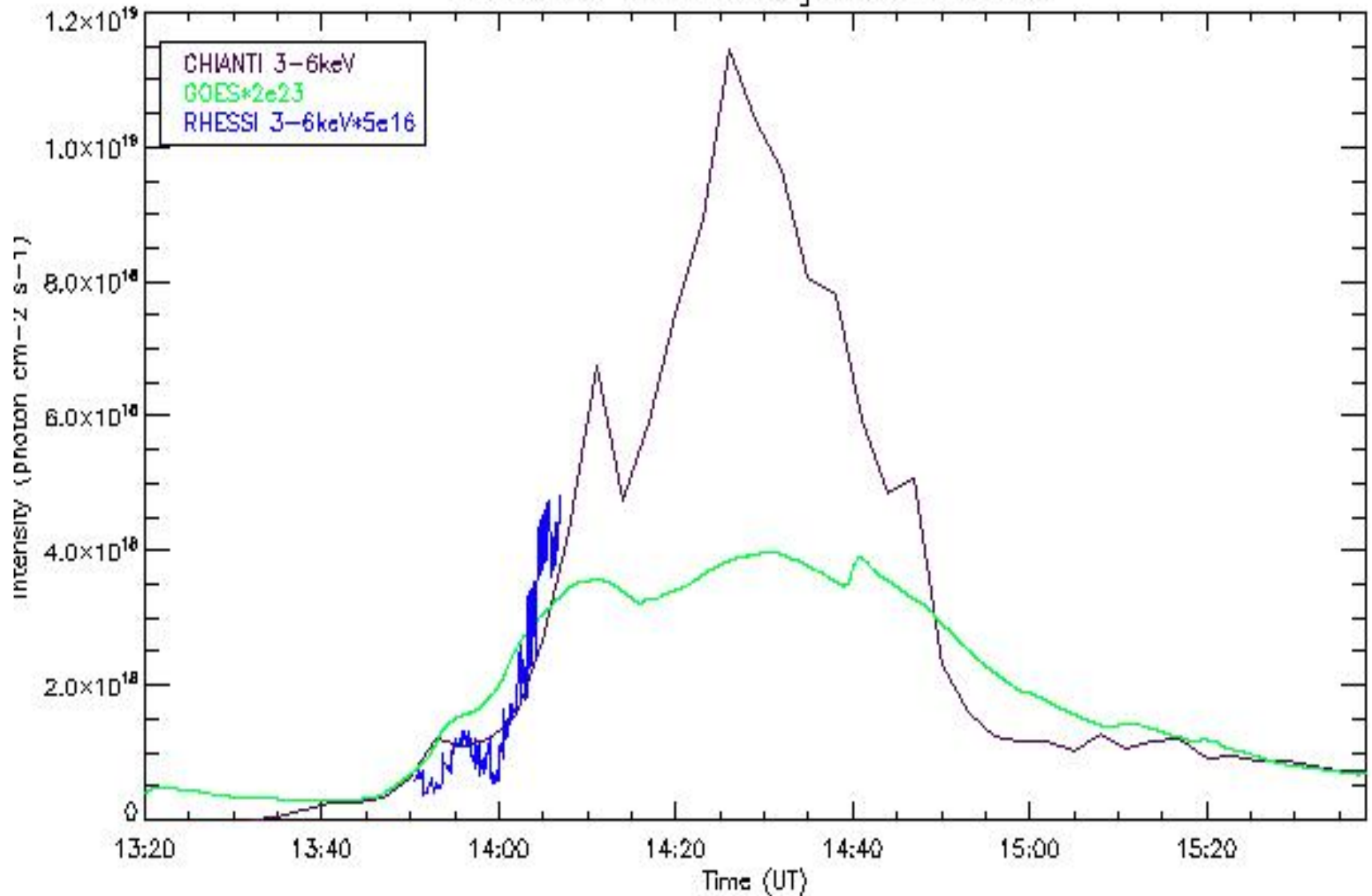


Spectrum 07-Mar-11 13:32:00.000

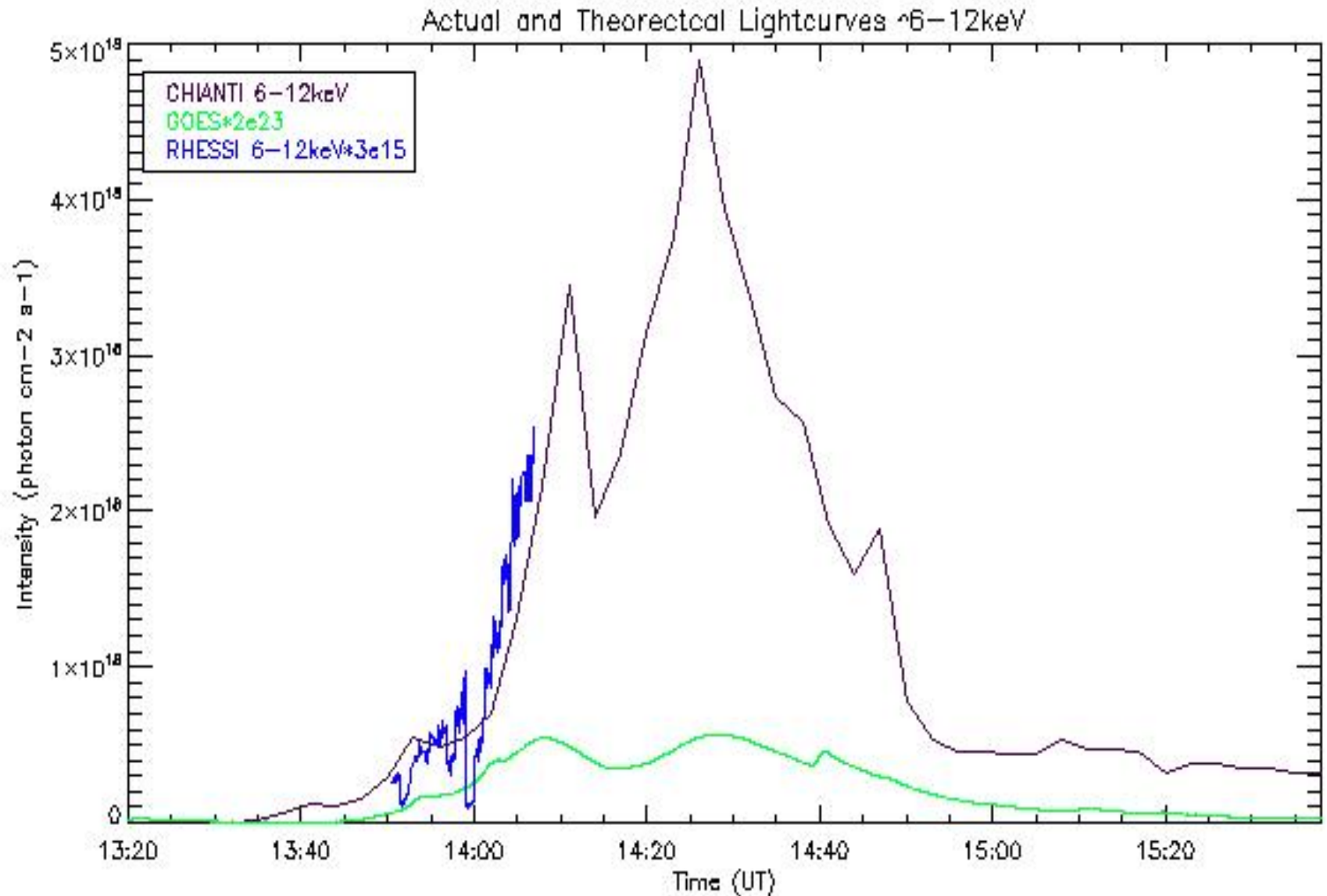


Actual vs. Theoretical

Actual and Theoretical Lightcurves $\sim 3-6\text{keV}$

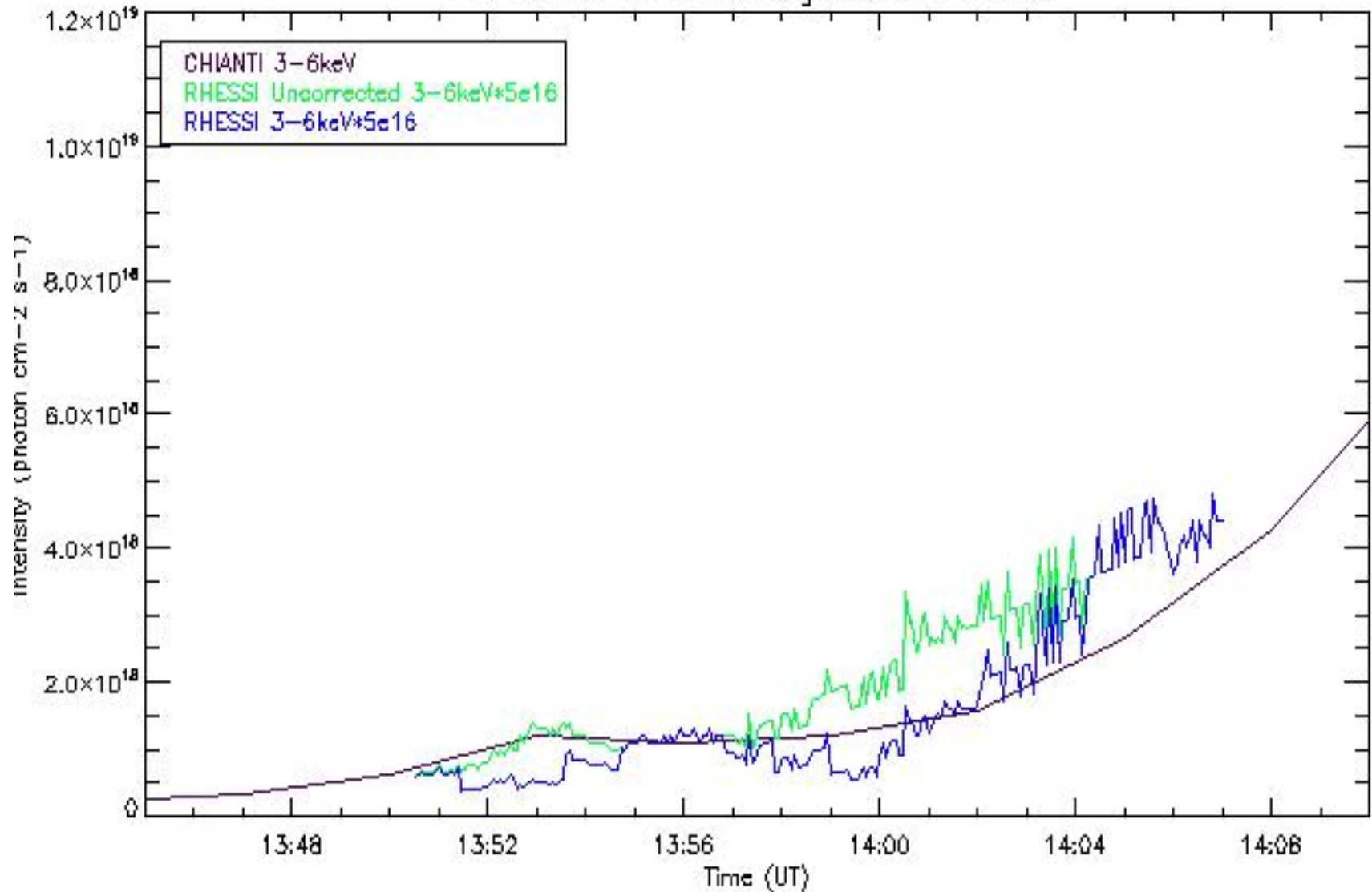


Actual vs. Theoretical



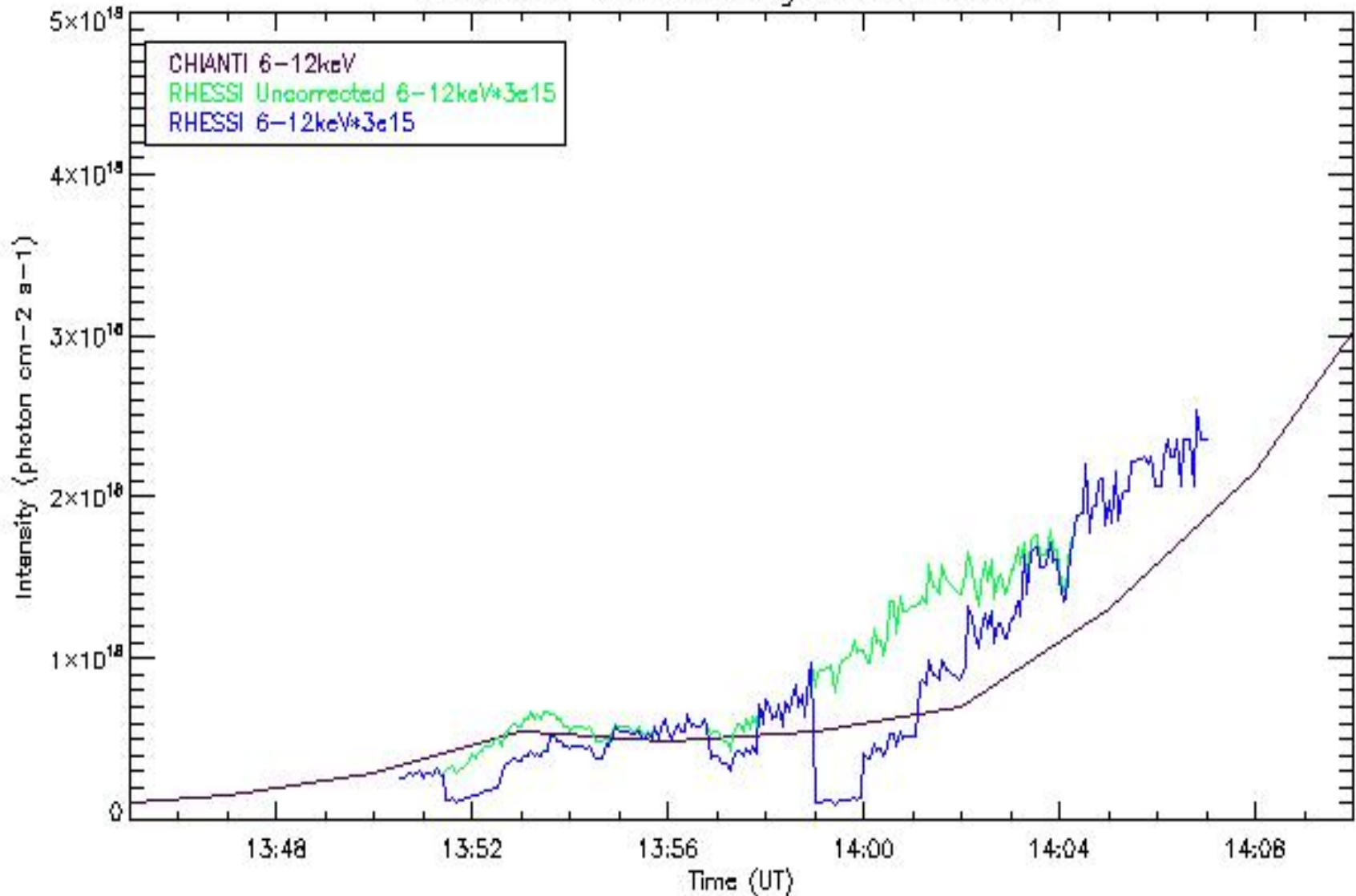
Actual vs. Theoretical

Actual and Theoretical Lightcurves $\sim 3-6\text{keV}$



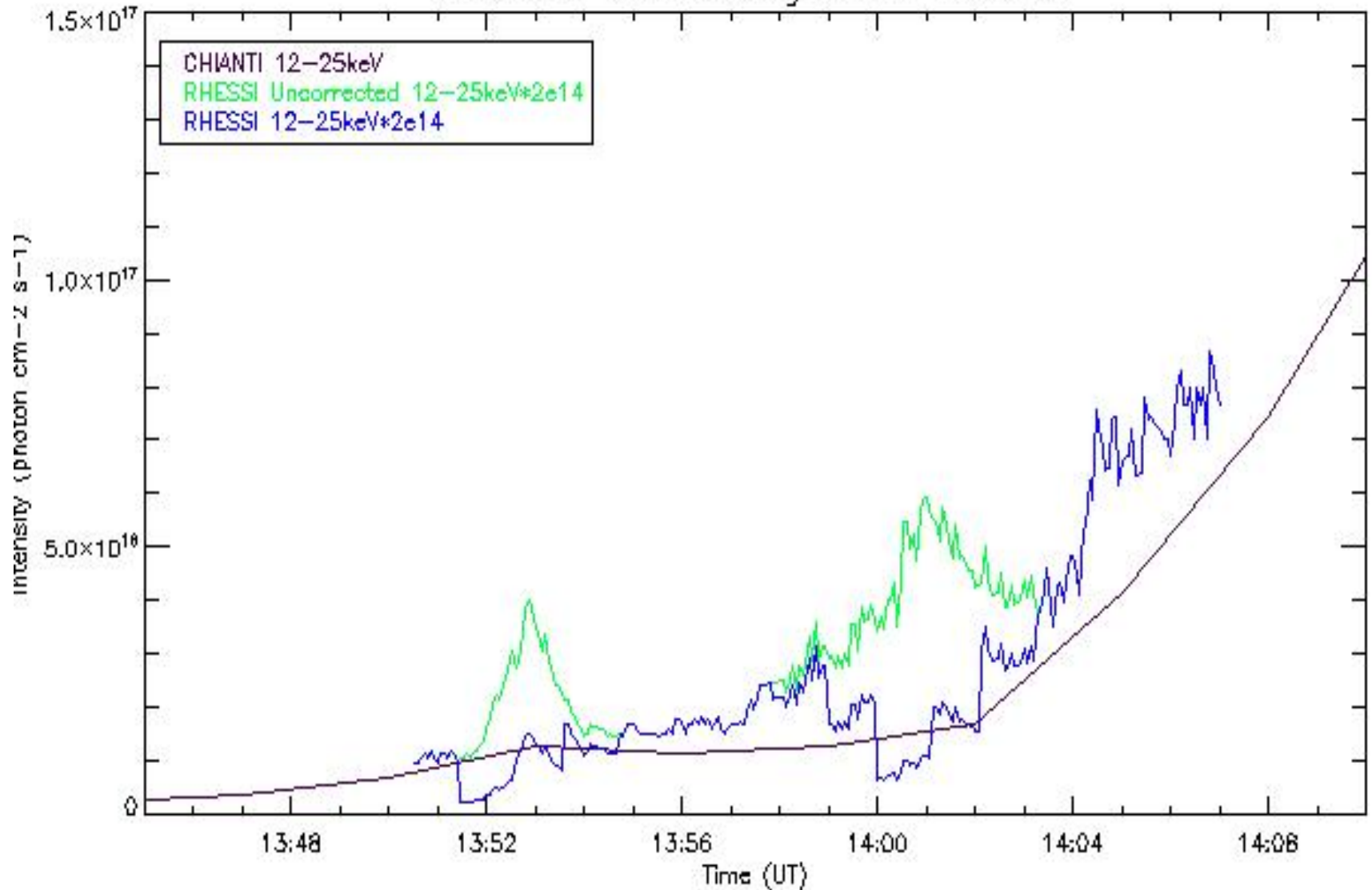
Actual vs. Theoretical

Actual and Theoretical Lightcurves ~6-12keV



Actual vs. Theoretical

Actual and Theoretical Lightcurves 12–25keV



Conclusions

- Predicted lightcurves for RHESSI closely correlated to actual lightcurves after correcting for extra flare
- First time RHESSI lightcurves predicted with EBTEL DEM and CHIANTI
- EBTEL/CHIANTI used DEM which better predicted the changing temperature across loops than isothermal models used by RHESSI
 - Isothermal model assumes constant temperature and density across all loops -> not often true
 - Better model for spectra than RHESSI spectra due to extra flare and strong correlation of lightcurves