Response of the Mg II h & k lines to Solar Flares

Graham Kerr¹
Paulo Simões¹, Jiong Qiu,² Lyndsay Fletcher¹

¹School of Physics and Astronomy, University of Glasgow, Glasgow, Scotland
²Montana State University, Bozeman Mt, USA
Response of the Mg II h & k lines to Solar Flares

Graham Kerr
Paulo Simões, Jiong Qiu, Lyndsay Fletcher

1School of Physics and Astronomy, University of Glasgow, Glasgow, Scotland
2Montana State University, Bozeman Mt, USA
The Mg II h&k Resonance Lines

- Optically thick resonance lines that form from multiple layers in the atmosphere.

- Previously studied by Feldman, Doscheck, Lemaire and collaborators using balloon borne experiments, Skylab, and OSO-8 (one flare obs. from OSO-8)

- Now with IRIS we have routine observations, including of flares.

Bulk of the flare radiative output is from the chromosphere - important to study chromospheric emission from flares!

c.f Lemaire et al 1984; Leenaarts et al 2013a,b; Pereira et al 2013
2014 Feb 13th Flare

Overview

- M1.8 Class flare
- Well observed by RHESSI, SDO and IRIS
- 8 step raster (2")
- SG repeat cadence: 43s
- Few high energy counts from RHESSI; mostly 6-25 keV
- Compact thermal source spatially correlated with ribbon
- Accompanied by a failed filament eruption
2014 Feb 13th Flare

General Mg II Line Behaviour

Pre-flare: CR mostly absent or small

During Flare:
- Line intensity increase
- Line broadens
- Line is redshifted
- Some profiles show a blue wing asymmetry
- CR absent
- Subordinate lines significantly enhanced
2014 Feb 13th Flare

Integrated Intensity Maps

RHESSI thermal Sources are in this region

IRIS SJ 1330 Å: 13-Feb-2014 01:35:13 UT
2014 Feb 13th Flare  Mg k:h Intensity Ratio

In optically thin case the k/h ratio = 2 (ratio of oscillator strengths is 2)

Previous (on disk) measurements of k/h ratio have been ~ 1.14 – 1.46

In the pre-flare, and in the flaring pixels we measure

k/h ~ 1.07-1.19

Dispersion of k/h ratio reduces around flare peak in pixels where the flare sources are most intense.
There is no reason to fit optically thick lines with gaussians — we take a non-parametric approach to estimate the following measures:

\[ \lambda_c = Q_2 \]

\[ W = Q_3 - Q_1 \]

\[ S = \frac{(Q_3 - Q_2) - (Q_2 - Q_1)}{(Q_3 - Q_1)} \]

\[ Q_1 = \text{Wavelength corresponding to 25\% in the CDF etc.} \]
2014 Feb 13th Flare

Line Centroid Motion

k-line redshifts seem to be consistently larger than h-line redshifts

Centroid shifts decay to background much quicker than intensity.
Both h & k lines become broader during the flare.

Width increases to ~0.45-0.55Å.

k-line widths are somewhat larger than h-line widths.
Blue asymmetry only present in the strongest flaring sources.

Here the line is redshifted overall but contains a stronger blue wing compared to the red wing.
Interpreting Mg II Profiles

Next step in the study of potential diagnostics are to look at the output of advanced models.

**RADYN**

- 1D Radiation hydrodynamic code.
- Simulates the response of the solar atmosphere following energy input.
- Solves transitions of H, He, Ca & Mg in detail (using CRD).
- Outputs macroscopic variables (density, temperature etc.,) and synthetic spectra.

**RH**

- Advanced radiation transfer code with partial redistribution.
- Can simulate Mg II in a more physically realistic way (PRD vs CRD).
- Can take snapshots of RADYN output (macroscopic variables, e.g. density, temperature etc.,) to investigate the flaring atmosphere over time.

* Joel Allred and Mats Carlsson  
# Tiago Pereira & Han Uitenbroek
2015 Mar 11th X-Flare

- 2826Å Quasi-Continuum enhancements

IRIS SJI -1400Å: 2015-03-11 16:19:16

Hinode SOT: red cont 6684

16:17:05UT
16:17:25UT
16:17:45UT
16:18:04UT
16:18:25UT
16:18:44UT
16:19:05UT
16:19:24UT
16:20:00UT
16:20:19UT
16:20:38UT
16:20:57UT
16:21:16UT
16:21:35UT
16:21:55UT

Call H Line emission
During the flare:

- Significant intensity enhancement in both k & h lines, and subordinate lines.
- Lack of a central reversal during the flare, with k/h ratio ~1.15
- Line centroid redshifted at outer edge of ribbon
- Line broadened
- Line has a blue asymmetry at sites of strongest intensity

How do these properties vary between events (e.g. a flare with more non-thermal emission)? Analysis of 2015 Mar 11th X class flare underway (IRIS Mg II & NUV continua, and Hinode/SOT continua)

Why do the lines become broadened - flows or increased opacity broadening?

What do the model outputs tell us about potential resonance line flare diagnostics?

Are there any diagnostics that can exploit the subordinate lines? c.f Pereira et al 2015, submitted
2015 Mar 11th Flare

Continuum Enhancements

IRIS SG Quasi Continuum Spectra

2015 Mar 11

--16:18:40UT

--15:37:05UT
2014 Feb 13th Flare

IRIS Observations

8 step raster program

SJI cadence: 11s
SJI FOV: 119” x 119”

Slit step: 2”
Slit dimensions: 0.33” x 119”
Slit cadence: ~5s
Repeat Cadence: 42s

Level 2 data used.

Yellow region used to calculate average quiet Sun spectra.