Evolution of Solar Active Regions Observed by MaGIXS-1 Sounding Rocket Flight

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Abstract

The first rocket flight of the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS-1) was successfully launched on 30 Jul 2021. MaGIXS-1 observed portions of two active regions 12846 and 12847 for about 300 sec from 18:23 to 18:28 UT. We studied these two active regions using SDO/AIA data from July 28, 2021 to July 31, 2021 to understand how temperature evolves with time. We evaluated two bright points in active region 12846 and the bright areas of active region 12847. For this task, we considered 30 minute interval data sets at the following times (i) 48 hours before launch, (ii) 24 hours before launch, (iii) 6 hours before launch, (iv) at the time of MaGIXS-1 launch, and (v) 6 hours after launch. First, we compiled movies of different time interval data sets to understand what time brightenings occurred at different AIA filter channels. By using a mask of bright pixels, we made intensity (DN/pixel) light curves to understand if the brightenings shown on the light curve appeared at the same time as the movie. Then we derived Differential Emission Measure (DEM) maps using SPARSE DEM inversion (Cheung, M.C., et al. 2015) and determined the evolution of DEM weighted temperature. Light curves that showed a steady intensity and movies that showed steady brightenings had a DEM Temperature of 2-3 MK, while movies that showed rapid brightenings and the light curves showed spikes of intensity had a DEM Temperature that reached between 3-4 MK. Here, we will present our findings on the temperature evolution of these active regions and discuss how it compares/supports the inferences from MaGIXS-1 observations.

Figure 1: This picture is of the effective slot of view where MaGIXS-1 could see and collect data on July 30, 2021 at 18:23 U.T.

Methods

We use SDO/AIA data in all of the wavelengths to make movies, contour images, light curves, EM Maps, and DEM Time vs. Temperature graphs for the 30 minute time intervals between July 28, 2021 to July 31, 2021. We made movies to understand what time the brightenings occurred at over a 30 minute interval. The use of contour images came when we decided we needed to know if there was any noise that got picked and if the threshold was too strong or not strong enough for minimizing noise. We use 335 Å to create a mask for the bright pixels and select a greater than 40% of max intensity threshold. Using the mask we made a light curve with error bars for all AIA wavelengths to understand the intensity of the Active Regions. For the error bars we used aia_bp_estimate_error which is in the AIA SolarSoft package. Then we derived Differential Emission Measure (DEM) maps using SPARSE DEM (Cheung, M.C., et al. 2015) inversion and determined the evolution of DEM weighted temperature to understand how the temperature evolves over a 30 minute time interval.

Results

For Active Region 1, MaGIXS-1 observed two different spots among the active regions. For Active Region 1 Spot 1 ,we took data over a 30 minute interval on July 30, 2021 from 18:15 U.T.-18:45 U.T. The light curves for all wavelengths show steady intensity because the curve stays within the error bars among the 30 minute time interval.

Figure 2: 94 Å (Top Left), 131 Å (Top Middle), 171Å (Right Middle), 193 Å (Middle Left), 211 Å (Middle), 335 Å (Middle Right), Normalized DN/pixel/s (Bottom Right), Weighted DEM Temperature (logT) (Bottom Middle), Weighted DEM Temperature (MK) (Bottom Right) Light Curves for Active Region 1 Spot 1 on July 30, 2021 from 18:15-18:45 U.T.

Figure 3: Four EM Maps on the left showing the different logT values that are 6.0-6.2 (Top Left), 6.2-6.4 (Top Right), 6.4-6.6 (Bottom Left), 6.6-6.8 (Bottom Right) on July 30, 2021 at 18:15 U.T of Active Region 1 Spot 1.

Figure 4: A contour map on the right to show that the 40% threshold is masking for only bright pixels on July 30, 2021 at 18:23 U.T. of Active Region 1 Spot 1.

For Active Region 1 Spot 2, the light curves for all wavelengths show steady intensity because the curve stays within the error bars among the 30 minute time interval. Some of the lower temperature wavelengths (171,193, and 211 Å) show spikes but they are not above the error bars and not in other wavelengths so we do not consider those brightenings.

Figure 5: 94 Å (Top Left), 131 Å (Top Middle), 171Å (Right Middle), 193 Å (Middle Left), 211 Å (Middle), 335 Å (Middle Right), Normalized DN/pixel/s (Bottom Right), Weighted DEM Temperature (logT) (Bottom Middle), Weighted DEM Temperature (MK) (Bottom Right) Light Curves for Active Region 1 Spot 2 on July 30, 2021 from 18:15-18:45 U.T.

Figure 6: Four EM Maps on the left showing the different logT values that are 6.0-6.2 (Top Left), 6.2-6.4 (Top Right), 6.4-6.6 (Bottom Left), 6.6-6.8 (Bottom Right) on July 30, 2021 at 18:15 U.T of Active Region 1 Spot 2.

Figure 7: A contour map on the right to show that the 40% threshold is masking for only bright pixels on July 30, 2021 at 18:23 U.T. of Active Region 1 Spot 2.

For Active Region 2, we took data over a 30 minute interval on July 30, 2021 from 18:15 U.T.-18:45 U.T. The light curves showed a brightening right before 18:20 U.T. We know this is brightening because the intensity increases past the error bars on all of the wavelengths. Also, we confirmed this brightening with a movie of the active region with the brightening occuring. The normalized light curve shows the brightening because all of the wavelengths increase in intensity right before 18:20 U.T. The weighted DEM temperature (MK) vs. time plot shows steady temperature between 2-3 MK except for the time the brightening occured the temperature spikes up to above 3 MK.

Figure 8: 94 Å (Top Left), 131 Å (Top Middle), 171Å (Right Middle), 193 Å (Middle Left), 211 Å (Middle), 335 Å (Middle Right), Normalized DN/pixel/s (Bottom Right), Weighted DEM Temperature (logT) (Bottom Middle), Weighted DEM Temperature (MK) (Bottom Right) Light Curves for Active Region 2 on July 30, 2021 from 18:15-18:45 U.T.

Figure 9: Four EM Maps on the left showing the different logT values that are 6.0-6.2 (Top Left), 6.2-6.4 (Top Right), 6.4-6.6 (Bottom Left), 6.6-6.8 (Bottom Right) on July 30, 2021 at 18:15 U.T of Active Region 2.

Figure 10: A contour map on the right to show that the 40% threshold is masking for only bright pixels on July 30, 2021 at 18:23 U.T. of Active Region 2.

Since, we saw a brightening over this time interval we cropped the images down to the subregion that was brightening and created light curves and DEM Temperature plots (logT and MK). Both of the light curves and the DEM Temperature plots (logT and MK) show very similar data to the Active Region 2 data.

Figure 11: 94 Å (Top Left), 131 Å (Top Middle), 171Å (Right Middle), 193 Å (Middle Left), 211 Å (Middle), 335 Å (Middle Right), Normalized DN/pixel/s (Bottom Right), Weighted DEM Temperature (logT) (Bottom Middle), Weighted DEM Temperature (MK) (Bottom Right) Light Curves for Active Region 2 Subregion on July 30, 2021 from 18:15-18:45 U.T.

Figure 12: Four EM Maps on the left showing the different logT values that are 6.0-6.2 (Top Left), 6.2-6.4 (Top Right), 6.4-6.6 (Bottom Left), 6.6-6.8 (Bottom Right) on July 30, 2021 at 18:15 U.T of Active Region 2 Subregion.

Figure 13: A contour map on the right to show that the 40% threshold is masking for only bright pixels on July 30, 2021 at 18:23 U.T. of Active Region 2 Subregion.

Conclusion

On July 30, 2021 from 18:23-18:28 U.T., MaGIXS-1 showed that the active regions have high frequency heating (Winebarger,A., et al. 2021). During this same time period, the AIA light curves for all wavelengths show that the two active regions are consistent with high frequency heating. Looking at the EM Maps shows that the active regions are between a temperature (logT) of 6.3-6.4 which is consistent with DEM Temperature (logT) plots. Looking at the DEM Temperature (MK) plots, plasma temperatures between 2-3 MK are consistent with stable intensity light curves. When the DEM Temperature (MK) plots spike above 3 MK that is consistent with when a brightening occurs on the light curve for these two active regions from July 28 to July31, 2021.

References

- Winebarger, A., Savage, S., Kobayashi, K., Champey, P., Golub, L., Walsh, R., Athiray, P. S., Bradshaw, S., Cheimets, P., Cirtain, J., DeLuca, E., De Zanna, G., Mason, H., McKenzie, D., Ramsey, B., Reeves, K., Testa, P., Vigil, G., & Warren, H. (2021). Preliminary Results from the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS). *Astrophysics Data System.* https://ui.adsabs.harvard.edu/abs/2021AGUFMSH51A..06W/exportcitation.
- Cheung, M. C., Boerner, P., Schrijver, C. J., Testa, P., Chen, F., Peter, H., & Malanushenko, A. (2015). Thermal diagnostics with the Atmospheric Imaging Assembly on board the Solar Dynamics Observatory: A validated method for differential emission measure inversions. *The Astrophysical Journal,* 807(2), 143. https://doi.org/10.1088/0004-637x/807/2/143

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