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## GONG Inter-site H $\alpha$ Flare Comparison

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**Abstract.** A challenge of the past few decades for the Solar Observing Optical Network (SOON), operated by the United States Air Force Weather Agency (AFWA), has been to obtain consistent flare brightness reporting for the same flare from different sites. Flare area is usually considered to be a more reliable measure, but significant variation of values between sites still occurs. The Global Oscillation Network Group (GONG) deployed a H $\alpha$  patrol system in 2010. This provides a modern system with near identical equipment to compare flares from six different sites. The classification of flares and techniques of flare measurement will be briefly discussed. The results presented here suggest that even though different GONG sites report different flare areas and brightnesses, for some sites they vary in a consistent way allowing correction factors to be applied.

### 1. Flare Classification

H $\alpha$  flares are classified by their area (importance) and intensity (brightness). Area is measured in millionths of the solar hemisphere (usually referred to as mils). Intensity is compared with the background Sun, with the background given a value of 100%. For a flare to be placed in a particular brightness category, it must have at least 10 mils of area above the category threshold. This classification scheme was introduced after the International Astronomical Union meeting in 1964 [1]. Tables 1 and 2 show the area and intensity categories. Figures 1 to 4 show sample results from a flare observed by GONG H $\alpha$  at Big Bear. This flare reached the 1N category.

**Table 1.** Flare Area Categories.

Area Range (mils)	Importance
$10 \leq A < 100$	0
$100 \leq A < 250$	1
$250 \leq A < 600$	2
$600 \leq A < 1200$	3
$A > 1200$	4

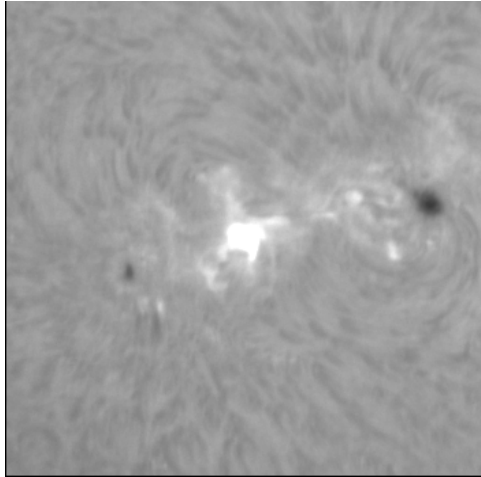
**Table 2.** Flare Brightness Categories.

Intensity Range (%)	Brightness
$150 < I \leq 250$	F (Faint)
$250 < I \leq 350$	N (Normal)
$I > 350$	B (Brilliant)

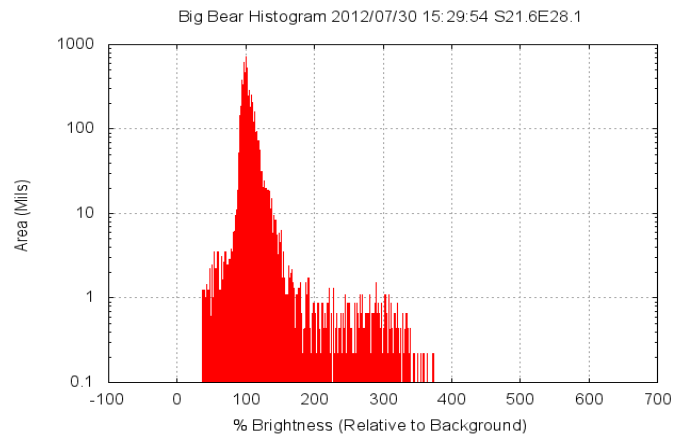
Most observatories report only those flares that have been continuously above the minimum flare thresholds for 2 minutes or more. Plage regions that have flaring areas that do not have an area greater than 10 mils are sometimes referred to as point brightenings. Flares that have long duration but low



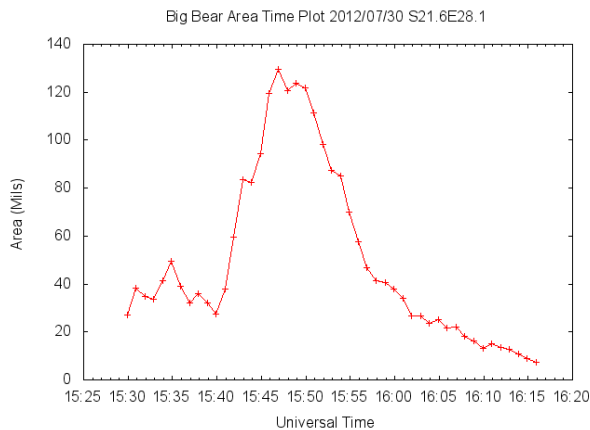
brightness, often briefly dropping below threshold levels may be referred to as plage fluctuations [2].



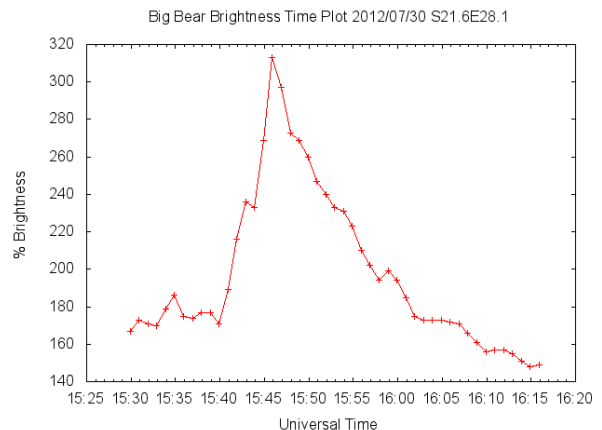
**Figure 1.** Sample flare image from GONG Big Bear obtained on 2012/07/30 at 15:45:54 UT (location S21.6E28.1). Image is 535 × 535 arcseconds.



**Figure 2.** Sample flare histogram from GONG Big Bear.



**Figure 3.** Sample Area vs Time Plot from GONG Big Bear.



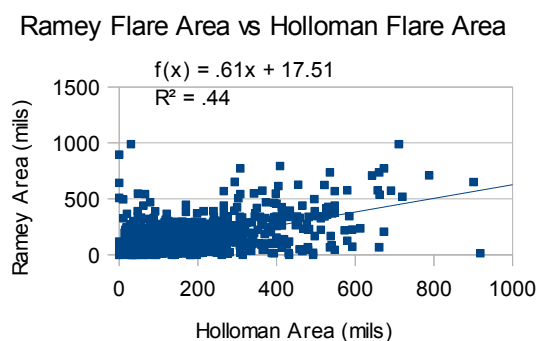
**Figure 4.** Sample Brightness vs Time Plot from GONG Big Bear.

## 2. AFWA Site Comparison

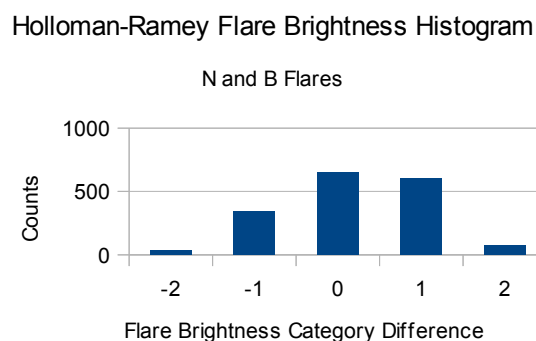
AFWA has been performing flare patrol since 1979. The SOON sites that have been operational for all or part of that time are Learmonth, San Vito, Holloman and Ramey. Flare importance and brightness were compared for the same flares from the different sites. The flare reports were obtained from the National Geophysical Data Center (NGDC) [3]. Figures 5 and 6 show results for the Holloman and Ramey comparison. These sites were chosen as they are close together (29 degrees apart in longitude). Ramey was closed in 2002.

A line can be fitted to the area, but the scatter in the points is quite high. Holloman recorded higher flare areas than Ramey. An analysis of flare brightness showed that Faint flares were in agreement

80% of the time. However when restricting analysis to Normal and Brilliant flares (as shown in figure 6), there was agreement between sites less than 50% of the time.



**Figure 5.** Ramey vs Holloman Flare Area.



**Figure 6.** Ramey vs Holloman Flare Brightness. Note that individual bin values are not available in archived data, thus only flare categories were used.

### 3. GONG Flare Analysis

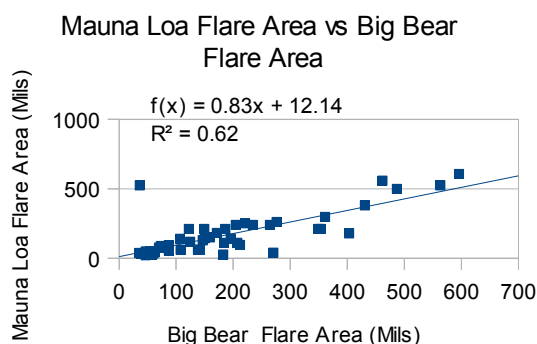
Each image is normalised by finding the central disk brightness and dark sky brightness. The images are limb darkening corrected by fitting a 5<sup>th</sup> order polynomial to the brightness at various radii of the disk. The images are checked to ensure they are cloud free. Using the limb corrected image, pixels which are 1.5 times brighter than the background Sun are flaring. Flaring pixels within 5 degrees of each other are grouped to create a flaring region. This region is analysed to produce a histogram (as shown in Figure 2). If the region meets flare criteria then the flare parameters are stored and updated as necessary. The entire process is automated in order to simulate a real time flare analysis system.

### 4. GONG Site Comparison

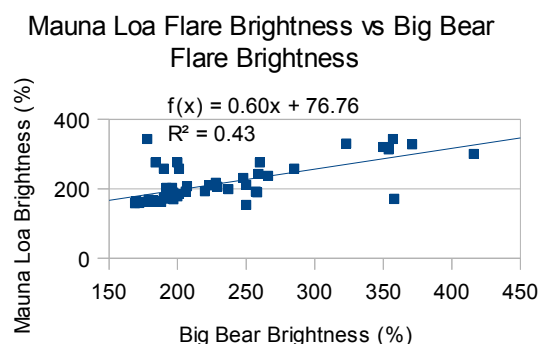
GONG H $\alpha$  images were obtained from the GONG website [4]. The images selected were for July 2012 and were chosen to be in the range 1 hour either side of flares found in the Solar Geophysical Activity Summaries obtained from the Space Weather Prediction Center (SWPC) [5]. July 2012 had a particularly high number of flares (for cycle 24). Once the images were processed, the same flares were compared between the different sites. In the case of flare brightness, we have the actual bin values for the flares, and not just the categories as was the case with the USAF data. Figures 7 and 8 show a sample GONG site comparison for flare area and brightness.

Table 3 shows the slope (m), intercept (b) and correlation coefficient (r) for all of the GONG sites. Mauna Loa shows the best correlation. Few flares were detected at Udaipur due to rain and cloud and thus Udaipur as been omitted from the analysis.

Since Mauna Loa has the best correlation with all of the sites, Mauna Loa is used as a standard. Simply inverting the lines of regression from Table 3 for site comparisons involving Mauna Loa produces the correction factors. These results are summarised in Table 4.



**Figure 7.** Mauna Loa Flare Area vs Big Bear Flare Area.



**Figure 8.** Mauna Loa Flare Brightness vs Big Flare Brightness

**Table 3.** Lines of Regression for GONG site Flare Comparison.

Sites Compared	Area			Brightness		
	m	b	r	m	b	r
Big Bear vs Cerra Tololo	0.84	88.97	0.51	1.00	38.51	0.64
Big Bear vs Learmonth	0.60	43.00	0.55	0.38	123.71	0.50
Big Bear vs Teide	0.70	150.06	0.44	1.25	6.67	0.66
Cerra Tololo vs Teide	1.19	28.21	0.93	0.89	41.46	0.70
Mauna Loa vs Big Bear	0.83	12.14	0.79	0.60	76.76	0.66
Mauna Loa vs Cerra Tololo	0.86	78.99	0.81	0.90	38.29	0.86
Mauna Loa vs Learmonth	1.17	-39.25	0.72	1.05	-19.50	0.97
Mauna Loa vs Teide	1.21	81.65	0.92	1.42	-47.24	0.91
Teide vs Learmonth	0.06	38.45	0.21	0.00	173.16	0.00

**Table 4.** Correction Factors for GONG H $\alpha$  Flares.

Site	Area Correction		Brightness Correction	
	m	b	m	b
Big Bear	1.20	-14.63	1.67	-127.93
Cerra Tololo	1.16	-91.85	1.11	-42.54
Learmonth	0.85	33.55	0.95	18.57
Teide	0.83	-67.48	0.70	33.27

## 5. Summary

GONG H $\alpha$  flares have been successfully corrected for all sites except for Udaipur. Mauna Loa had the best correlation with the other sites, and subsequently is being used as a standard. The corrections are a simple linear expression for each site for both flare brightness and area. This is an improvement over the USAF SOON sites, where none of the sites are able to regularly agree on flare brightness.

The disagreement between some sites could be due to cloud coverage which interrupted flares or variations in the H $\alpha$  filters. A longer term study needs to be conducted to determine which, if any of these effects is responsible for these discrepancies.

With further analysis as to the causes of the GONG sites that disagree, it can be expected that the correlation between sites will improve.

## 6. References

- [1] M. C. Ballario, A. Bruzek, E. E. Dubov, M. A. Ellison, E. R. Hedeman, V. Lincoln, R. Michard, Y. Ohman, H. J. Smith, C. S. Warwick, H. D. Prince, "H $\alpha$  Flare Classification: Report of the Working Committee on the Improvement in Assignment of H $\alpha$  Flare Importance", *Report to Commission on Solar Activity at the XII General Assembly of the International Astronomical Union*, Hamburg, 1964
- [2] AFWAMAN 15-2: <http://static.e-publishing.af.mil/production/1/afwa/publication/afwaman15-1/afwaman15-1.pdf>
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- [5] Space Weather Prediction Centre Solar Geophysical Activity Summary: <ftp://ftp.swpc.noaa.gov/pub/warehouse/2012/SGAS/>