A WEAK FERMI GAMMA-RAY EVENT ASSOCIATED WITH A HALO CME AND A TYPE II RADIO BURST

NAT GOPALSWAMY*[(1)], PERTTI MÄKELÄ[(2)], AND SEIJI YASHIRO[(2)]

(1) NASA GODDARD SPACE FLIGHT CENTER, GREENBELT MD 20771 USA

https://cdaw.gsfc.nasa.gov

(2) THE CATHOLIC UNIVERSITY OF AMERICA, WASHINGTON DC 20064 USA

*Corresponding author: nat.gopalswamy@nasa.gov

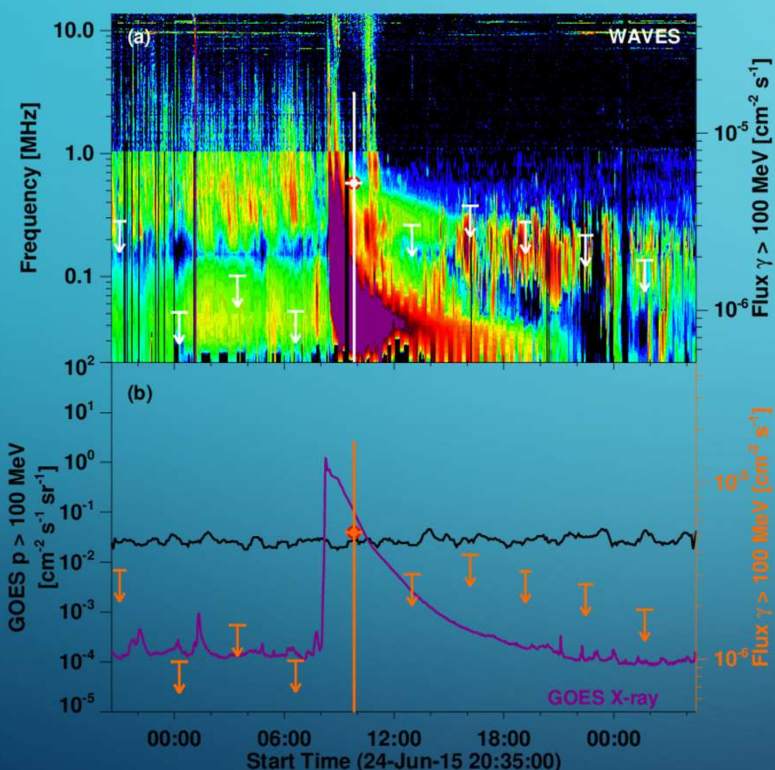
URSI GASS 2020, Rome, Italy, 29 August - 5 September 2020

H06 : Radio science for space weather science and operations

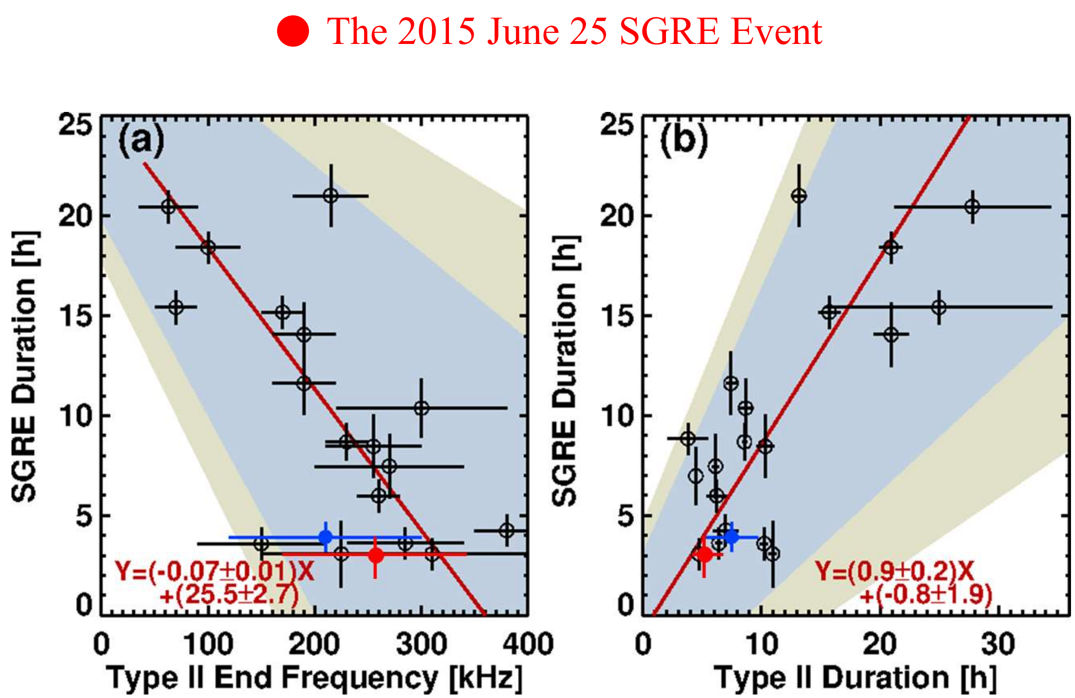
MOTIVATION

- The Sustained Gamma-ray Emission (SGRE) from the Sun is closely associated type II radio bursts in the decameter-hectometric (DH) wavelengths (Share et al. 2018; Gopalswamy et al. 2018; 2019; 2020)
- There exists a quantitative relation between the SGRE and type II durations indicating that the shock responsible for type II burst can also accelerate >300 MeV protons that produce SGRE via neutral pion production (Gopalswamy et al. 2018)
- The number of type II bursts after the launch of Fermi/LAT is an order of magnitude larger than the number of SGRE events
- The question is: why don't all DH type II bursts are associated with SGRE?
- While searching for potential SGRE signatures associated with DH type II bursts from Wind/WAVES, we came across an event on 2015 June 25. We show that this event is consistent with the SGRE – type II relationship

THE SGRE EVENT



- Type II burst in Wind/WAVES dynamic spectrum with superposed SGRE flux (>100 MeV) from Maximum Likelihood Method.
- GOES X-ray M7.9 flare (start: 08:02 UT, peak: 08:16 UT, end: 09:05 UT) from N09W42
- >100 MeV proton intensity along with the >100 MeV gamma-ray flux
- SGRE peak flux is only 2.21×10^{-5} cm^{-2} s^{-1} (Background flux ~1.66×10^{-5} cm^{-2} s^{-1})
- SGRE duration: 3.1 ± 0.79 hr.
- Type II duration: 6.13 ± 1.38 hr; ending frequency: 250 ± 100 kHz



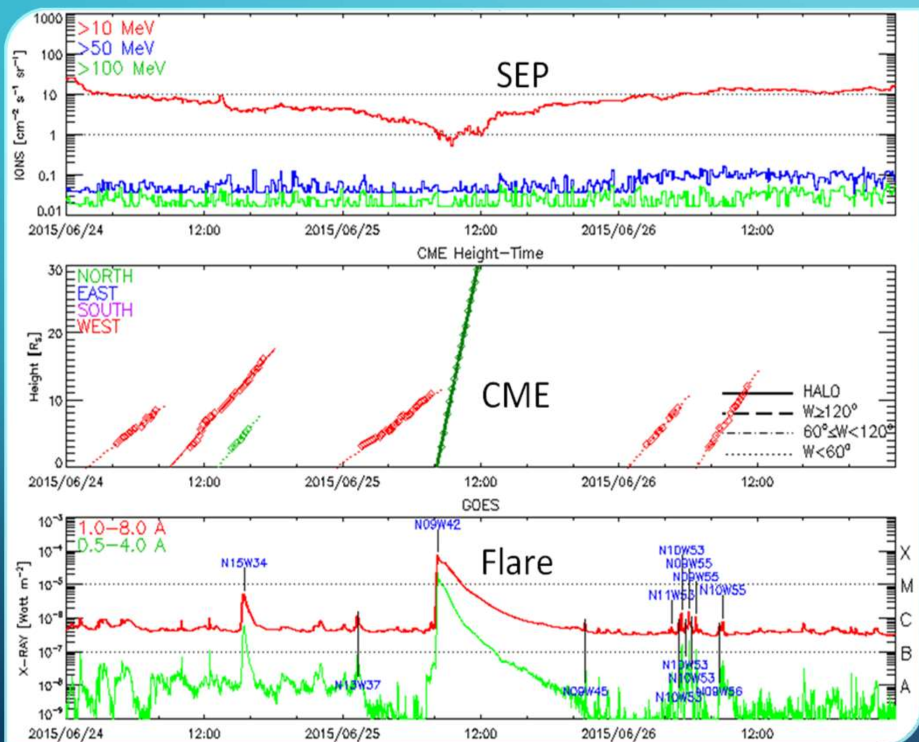
The longer the SGRE duration, the lower is the ending frequency

The longer the type II duration the longer is the SGRE duration

DURATION COMPARISON

- (a) Scatter plot between SGRE duration and type II ending frequency for 19 events with duration >3 h.
- (b) Scatter plot between SGRE duration and type II duration for 19 SGRE events
- The red data points: the 2015 June 25 SGRE event; agrees with the relationships
- The shaded areas correspond to 95% and 99% confidence intervals.

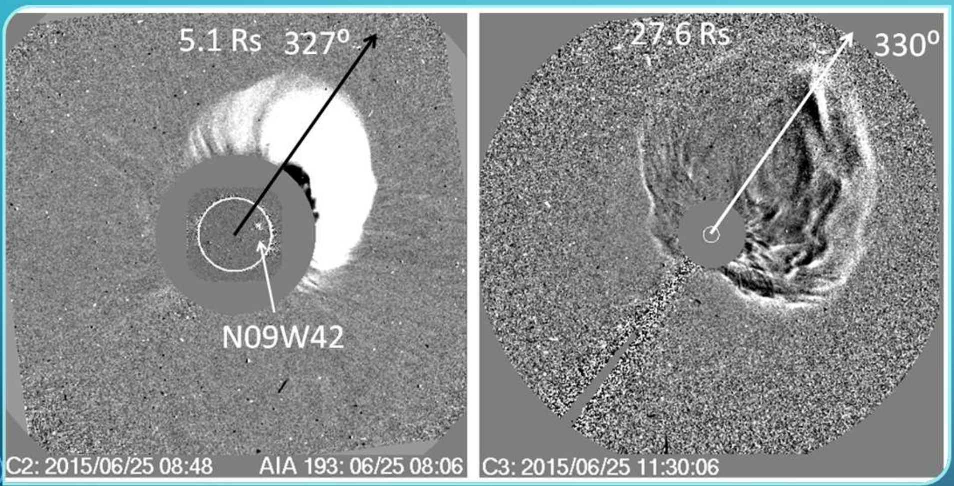
THE SOLAR ENERGETIC PARTICLE EVENT



- >300 MeV protons needed for SGRE events
- The SEP event is weak: barely exceeds 10 pfu (>10 MeV protons)
- Barely discernible at >50 MeV
- Similar to the strong 2011 March 7 SGRE
- How is this possible?

CORONAL MASS EJECTION

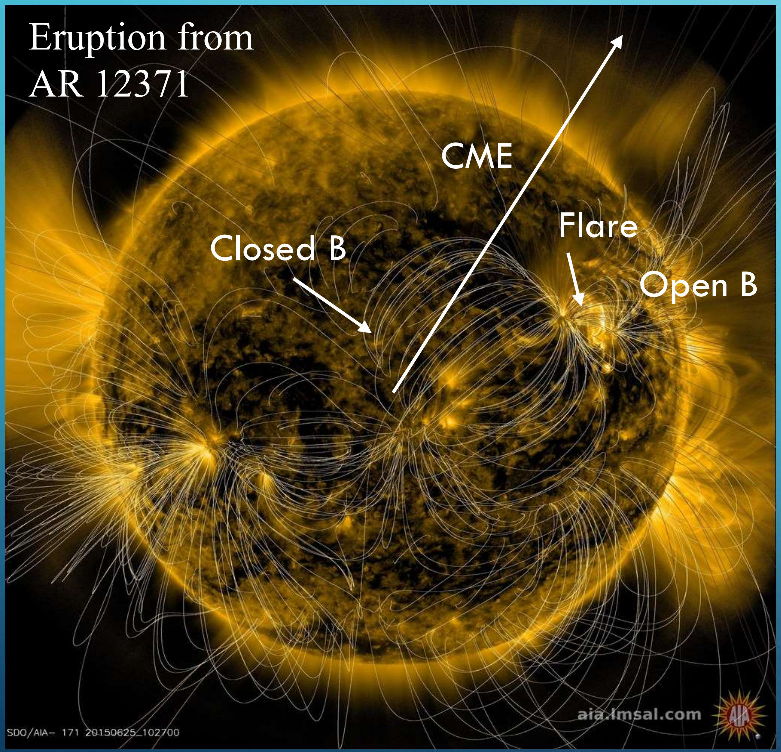
SGRE Ends when the CME is ~30 Rs from the Sun



The speed is similar to the typical CME speed (~2000 km/s) in SGRE events with duration >3 h

- SOHO/LASCO/C2 CME heading along position angle (PA) 327° from N09W42
- Halo CME
- Fast (sky-plane: 1627 km/s; deprojected: 1805 km/s)
- Fast enough to accelerate particles to >300 MeV
- Eruption longitude well-connected to Earth
- The discordance between source latitude and CME direction (about 60° from the ecliptic)
- The shock nose, where higher-energy particles are energized, is not connected to Earth observer
- Thus the soft spectrum (see Gopalswamy et al. 2018 for a similar event on 2011 March 7)

WHY THE CME NON-RADIAL MOTION?

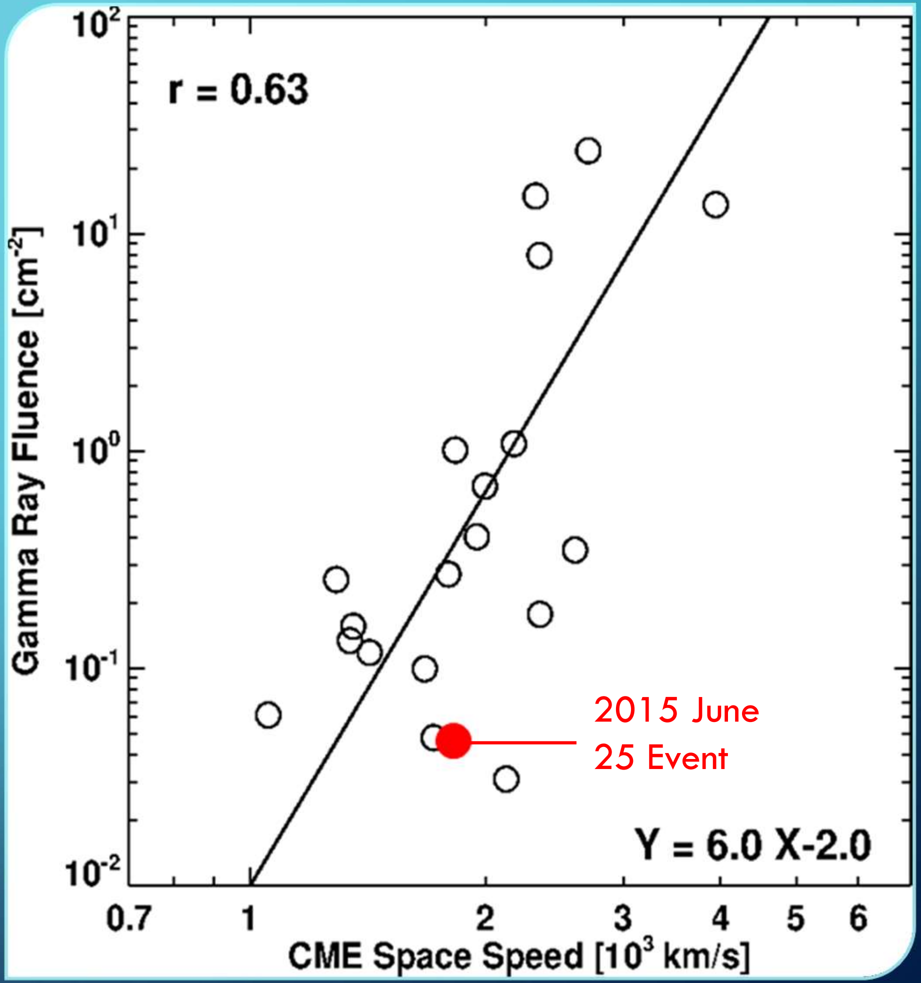


SDO/AIA Image at 171 A + PFSS field lines

- The magnetic environment of the eruption region is highly inhomogeneous
- The CME moves away from the large closed field region and the open field (coronal hole) region
- Such deflections are well known caused by pressure gradients surrounding the eruption region

CME SPEED & SGRE FLUENCE

- The SGRE fluence is correlated with CME speed (Gopalswamy et al. 2019)
- The 2015 June 25 SGRE event (red data point) agrees with the CME speed – SGRE fluence relationship
- Y = 6X – 2 (Y is the SGRE fluence in cm-2 and X is log of speed in 1000 km/s

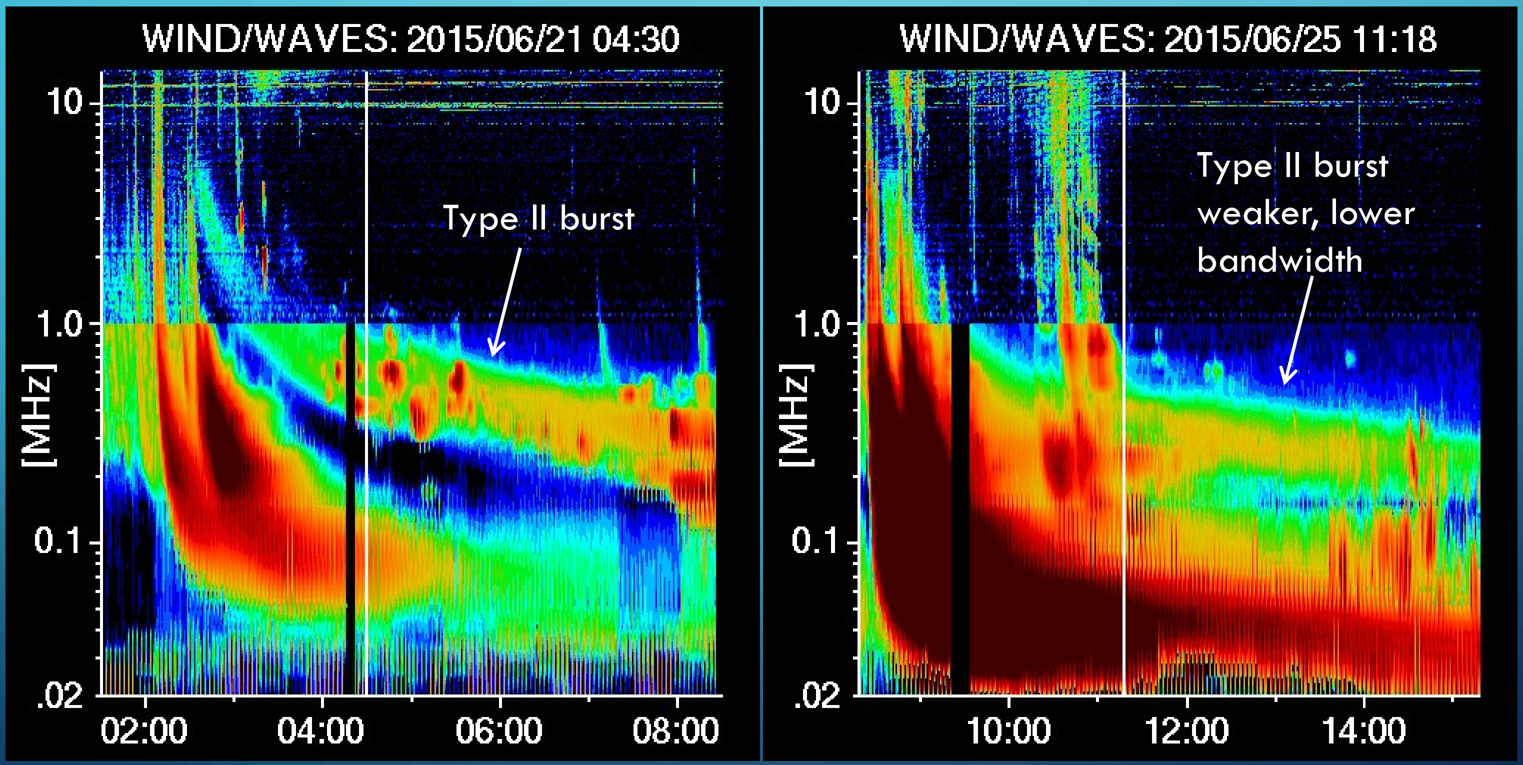


OTHER CMEs FROM AR 12371

Date	Location	Flare	V_{CME}	SGRE?
June 18	N12E47	C3.5	1398	No
June 21	N12E13	M2.6	1740	Yes
June 22	N12W08	M6.5	1573	No
June 25	N09W42	M7.9	1805	Yes
July 01	N09W118	????	1435	No

- SGRE events from the two highest-speed halos from AR 12371
- The fluence of the June 21 event was the highest among Fermi/LAT
- Why is this so?

COMPARING TYPE II BURSTS



Stronger Type II results in stronger, longer SGRE

SUMMARY

- The 2015 June 25 SGRE event had all the typical signatures of an SGRE event: a fast halo CME, a metric to kilometric type II radio burst, and a large SEP event.
- The SGRE event was identified based on the existence of type II burst, further strengthening the shock connection.
- The SGRE event is a strong evidence for the presence of >300 MeV protons in the event.
- The SEP event observed at Earth was of soft spectrum with not many high-energy particles observed because of the non-radial propagation of the associated CME.
- The previous SGRE event from the same active region occurred on June 21. This was much stronger event and had a more intense and broadband type II burst, consistent with the shock acceleration of >300 MeV particles.

ACKNOWLEDGMENTS

- Work supported by NASA's LWS and Heliophysics GI programs.
- Work benefited from NASA's open data policy in using data from SOHO, STEREO, SDO, and Wind missions