

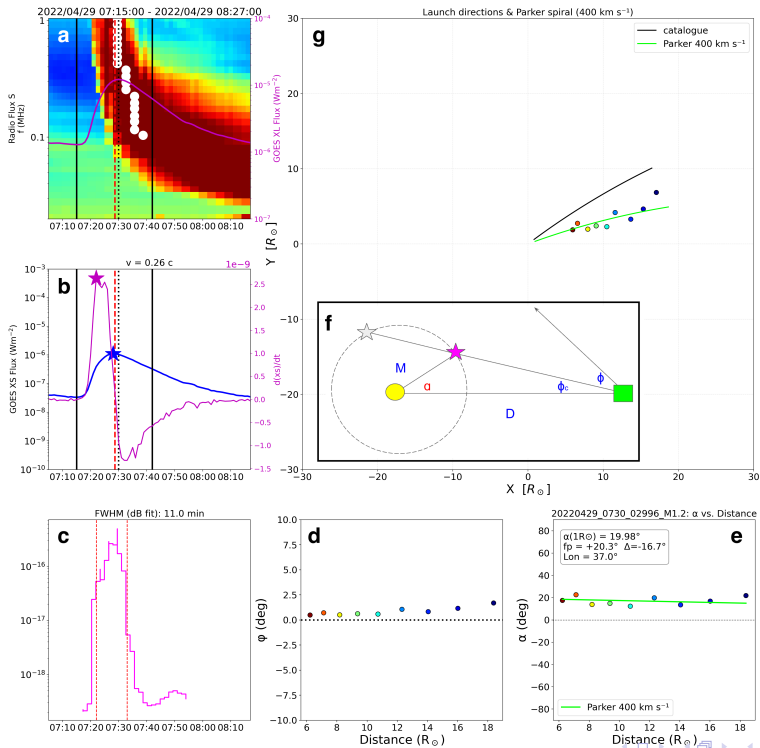
Exploring Interplanetary Type III Radio Bursts as Proxies for Flare-Site Reconnection

Vratislav Krupar^{1,2} Oksana Kruparova^{1,2} Adam Szabo² Milan Maksimovic³ Hamish Reid⁴ Katerina Pesini³ Juan Carlos Martinez Oliveros⁵ Ondrej Santolik^{6,7}

¹Goddard Planetary Heliophysics Institute, University of Maryland, Baltimore County, Baltimore, MD 21250, USA ²Heliospheric Physics Laboratory, Heliophysics Division, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA ³LESIA, Observatoire de Paris, Université PSL, CNRS, Sorbonne Université, Université de Paris, F-92195 Meudon, France ⁴Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking Surrey, RH5 6NT, UK ⁵Space Sciences Laboratory, University of California, Berkeley, CA, USA ⁶Faculty of Mathematics and Physics, Charles University, 121 16 Prague, Czech Republic ⁷Department of Space Physics, Institute of Atmospheric Physics of the Czech Academy of Sciences, 141 00 Prague, Czech Republic

Introduction

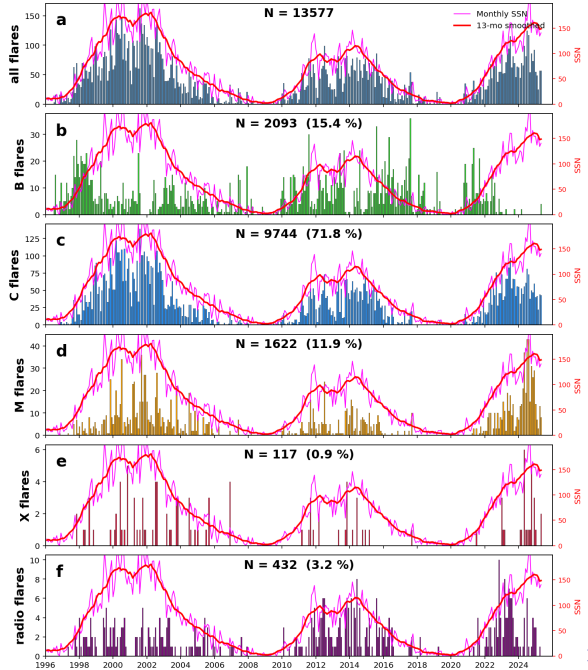
- ▶ We analyzed NOAA reports to retrieve a large number of solar flares between 1996 and 2025 that were also localized at $H\alpha$.
- ▶ Wind/WAVES RAD1 data were checked to associate these flares with type III radio bursts.
- ▶ Events with data gaps and complex structures (multiple injections/eruptions) were excluded to retain only simple flare + type III events.



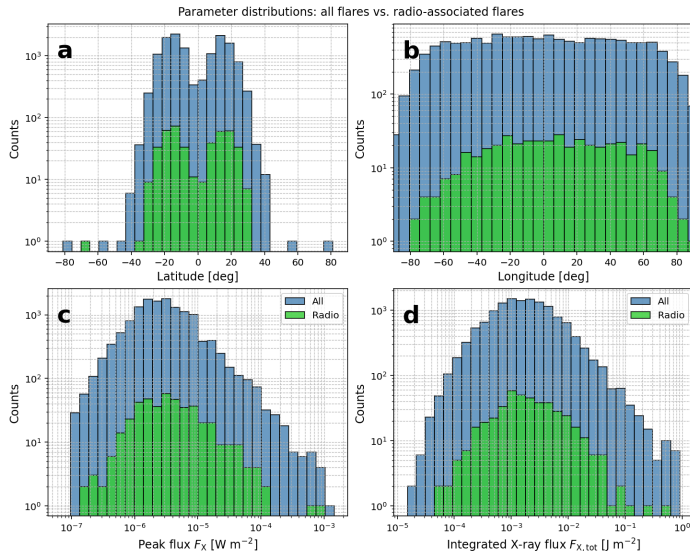
Flare Occurrence and Selection

- Found $\sim 13,600$ flares (1996–2025) localized at $H\alpha$. Their occurrence correlates well with the solar cycle.
- Only 3.2% of flares meet our criteria (simple events with good data), after excluding events with data gaps or complex structures.

Monthly GOES Flare Counts vs. Sunspot Number (1996–2025)

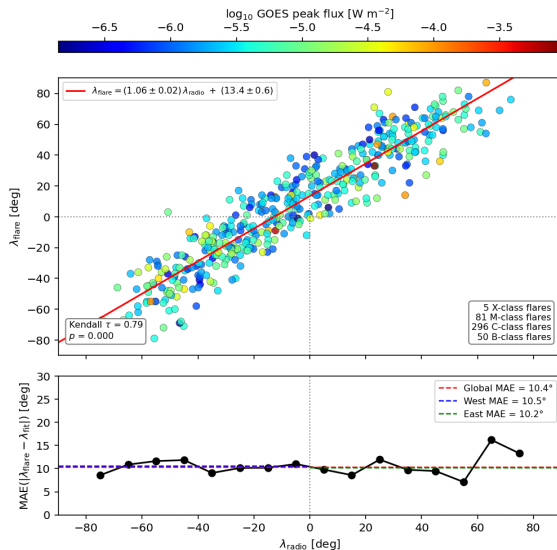


All Flares vs. Radio-Associated Flares



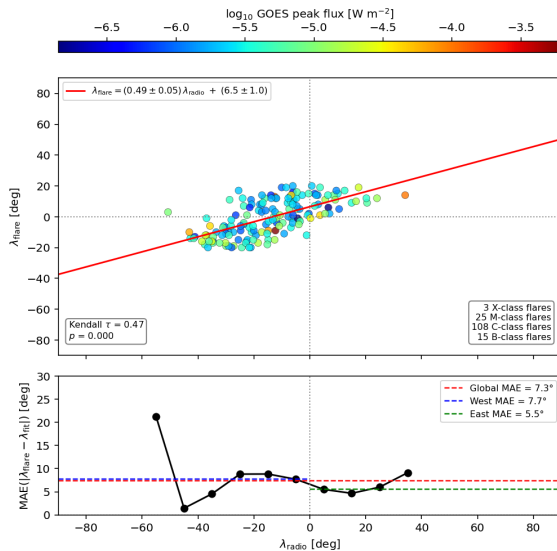
Spatial and energetic coverage of flares are about the same for radio-quiet (blue) and radio-loud (green). Only the most intense flares tend to produce complex radio bursts (excluded from our sample), so there are not many extreme cases included.

Longitude Prediction for All Flares

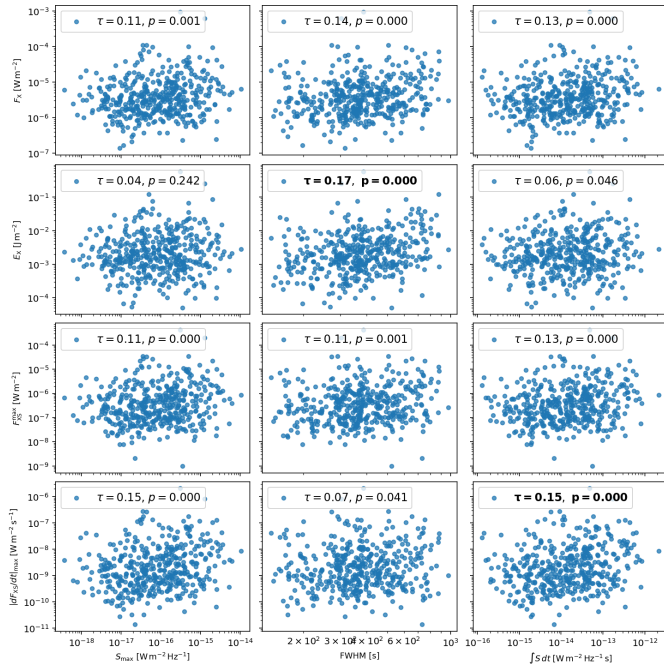


We observe an eastward drift of $\sim 13^\circ$ in predicted flare longitude (from Parker spiral fitting), and the mean absolute error (MAE) is about 10° .

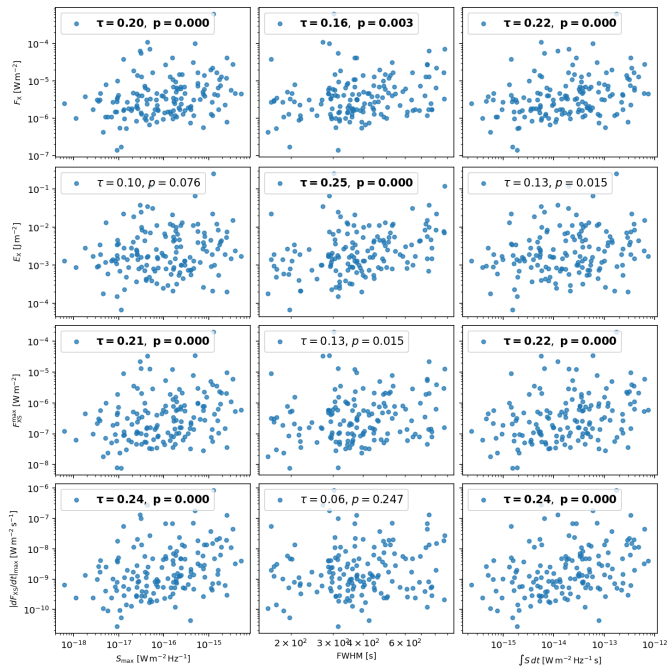
Longitude Prediction for Central Flares ($\pm 20^\circ$)



Restricting to flares within $\pm 20^\circ$ of the Sun's central meridian, the prediction improves: the MAE is about 7° .



Correlation analysis for all flares (Kendall's τ coefficients and p -values shown).



Correlation analysis for flares within $\pm 20^\circ$ of central meridian.

Discussion: Radio Proxies for Flare Physics

- ▶ Solar Orbiter's 1 MHz beacon streams burst flux to Earth within minutes
- ▶ Beacon currently lacks direction-finding capability
- ▶ Future beacon payloads could include simple DF sensors for real-time source localization
- ▶ SunRISE mission will offer limited beacon data and—hopefully—basic DF testing
- ▶ A dedicated radio-space-weather satellite (or small constellation) with beacon + interferometric DF could provide continuous, rapid flare longitude and intensity diagnostics

Summary

- ▶ Largest clean sample of simple flare–type III pairs; radio-only longitude errors as low as 7° for central events
- ▶ Three 1 MHz metrics (peak flux, burst duration, integrated flux) carry significant flare-energy information
- ▶ Real-time application already feasible via Solar Orbiter beacon
- ▶ Next step: add DF capability to beacon payloads for direct localization SunRISE will test beacon/DF concepts soon
- ▶ A purpose-built radio-weather constellation could deliver uninterrupted, high-precision flare forecasts