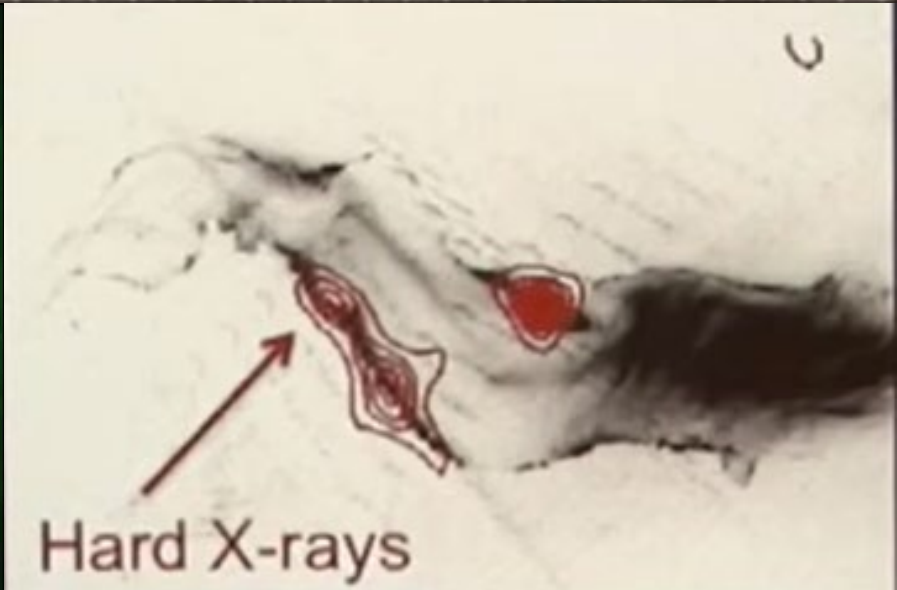
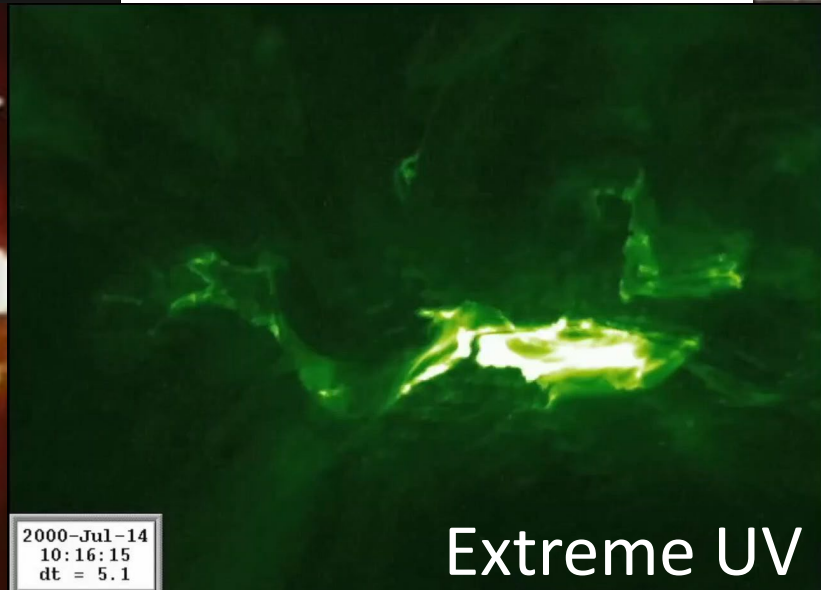
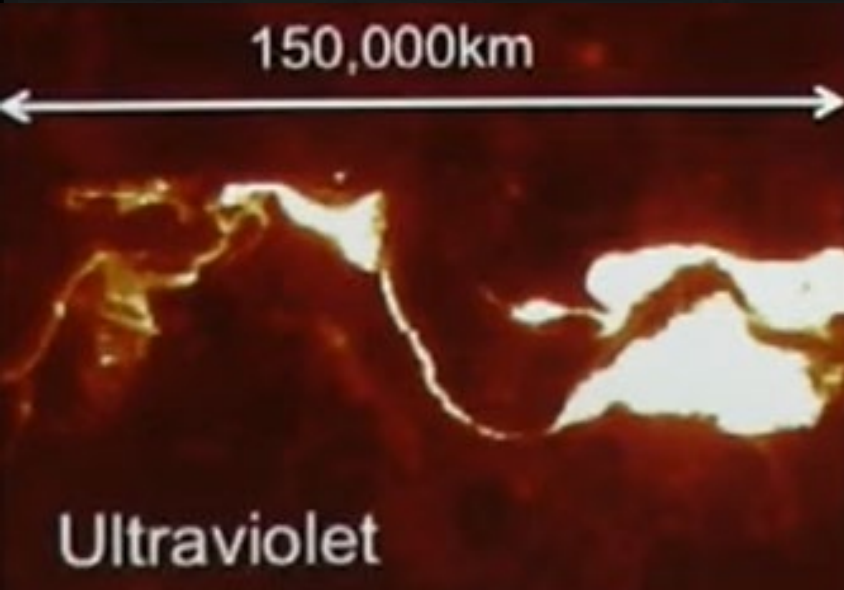
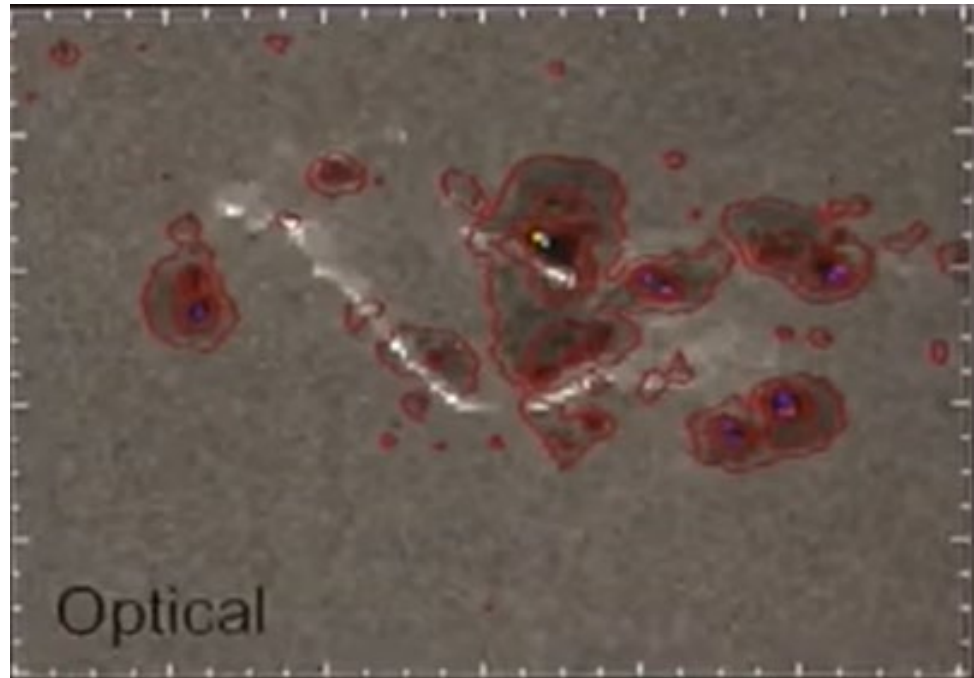
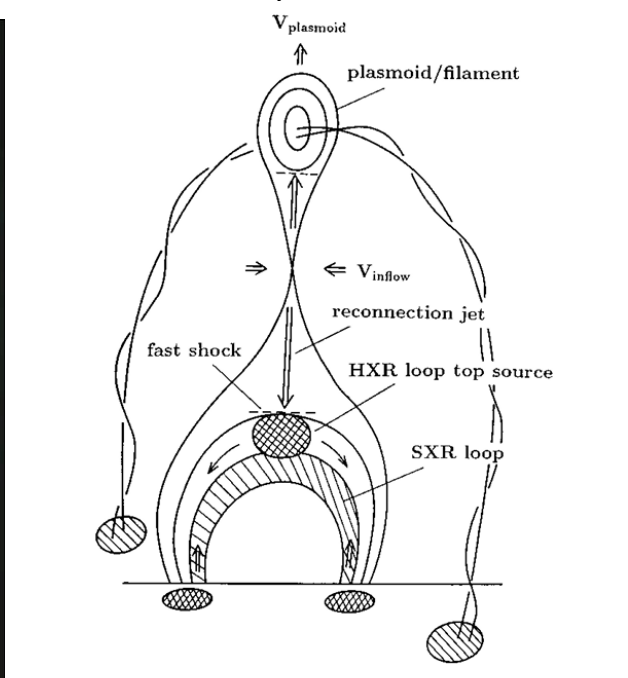
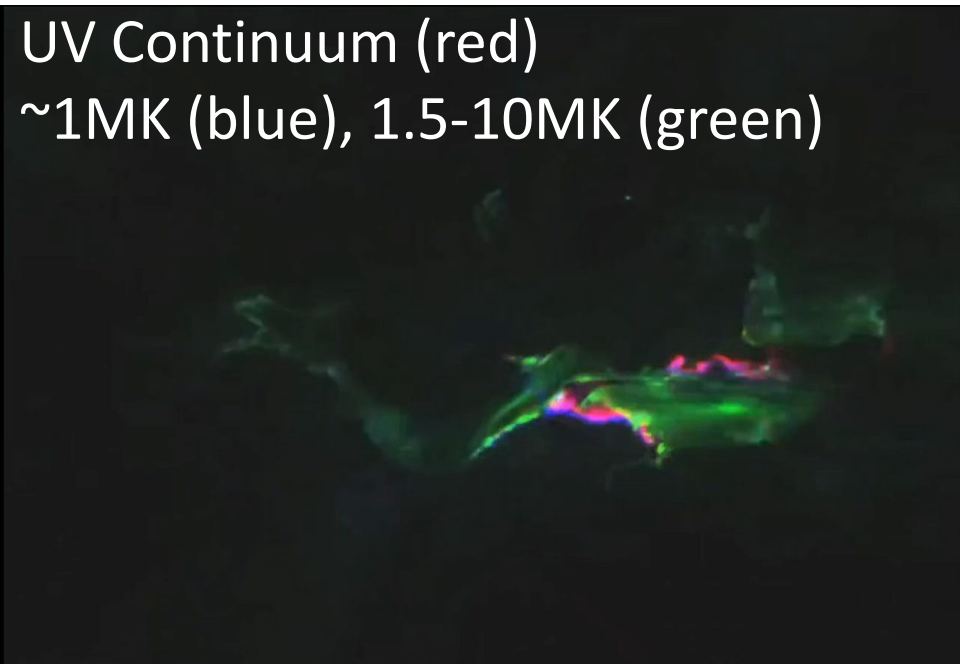


Multi-Instrument Observations of Solar Flares

James Kavanagh-Cranston

1. Why do Multi-Wavelength Observations Matter?

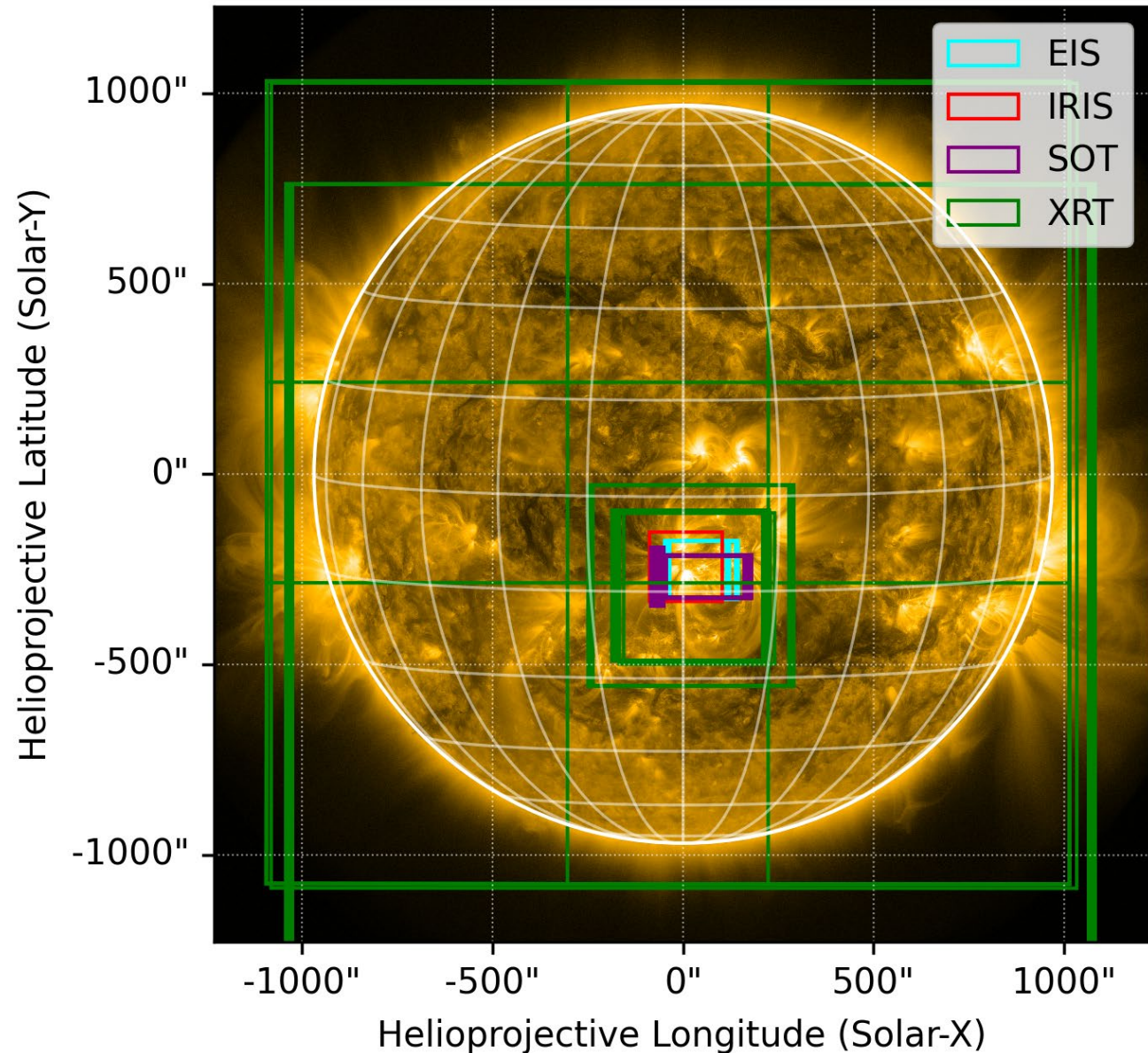
Fletcher, L. (2021). Solar Flares - How the Sun Relaxes [Video]. YouTube. Hosted by E. DeLuca, Harvard CfA.



3. Challenges of Multi-Wavelength Observations

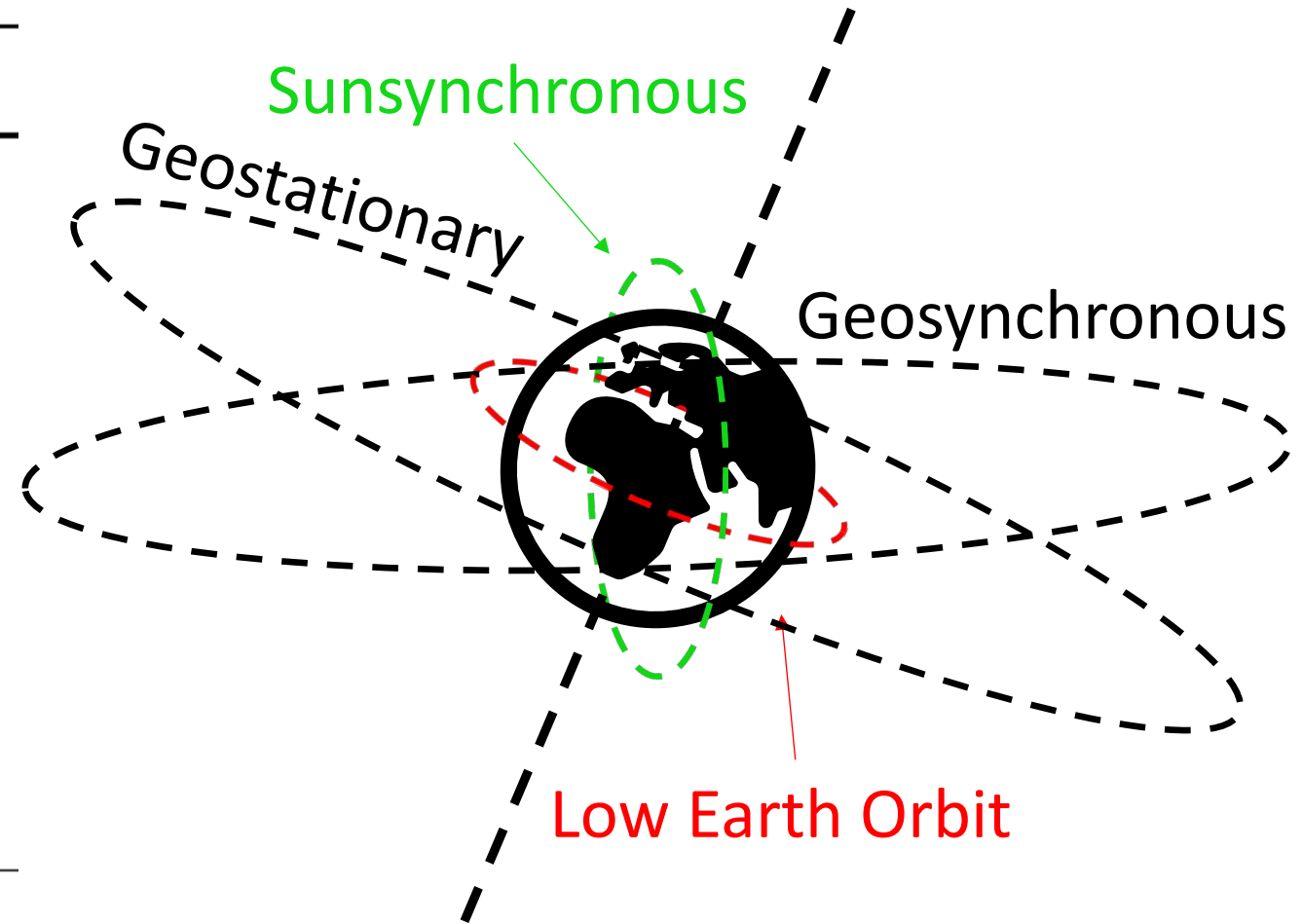
AIA 171 Å 2013-11-09 06:38:11

Instrument
RHESSI
FERMI GBM
SDO/EVE MEGS-A
SDO/EVE MEGS-B
Hinode/EIS
Hinode/SOT
Hinode/XRT
IRIS



3. Challenges of Multi-Wavelength Observations

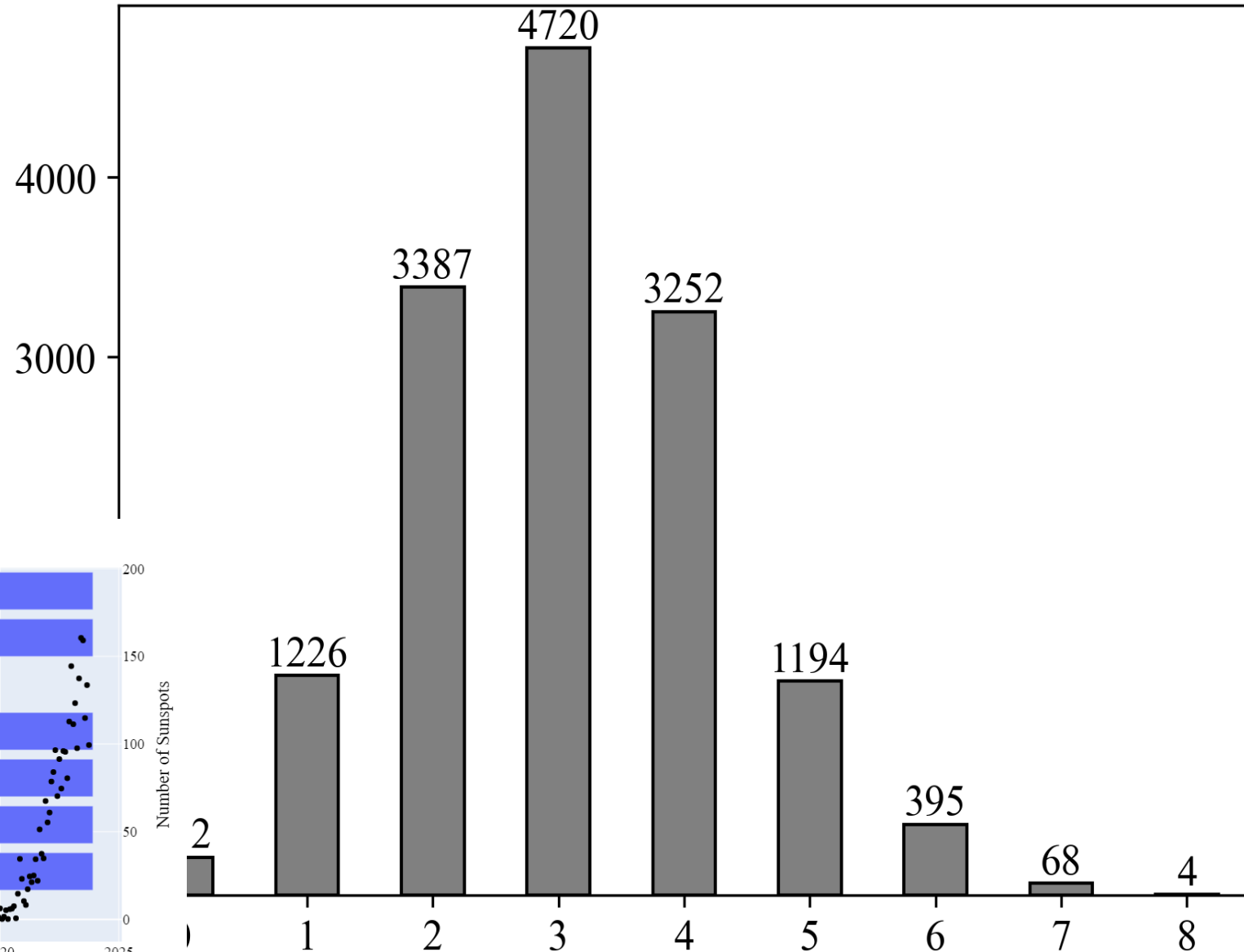
Instrument	%FOV	Orbit
RHESSI	100%	Low Earth Orbit
FERMI GBM	100%	Low Earth Orbit
SDO/EVE MEGS-A	100%	Geosynchronous
SDO/EVE MEGS-B	100%	Geosynchronous
Hinode/EIS	2-25%	Sunsynchronous
Hinode/SOT	1-17%	Sunsynchronous
Hinode/XRT	25-100%	Sunsynchronous
IRIS	0.5-3%	Sunsynchronous



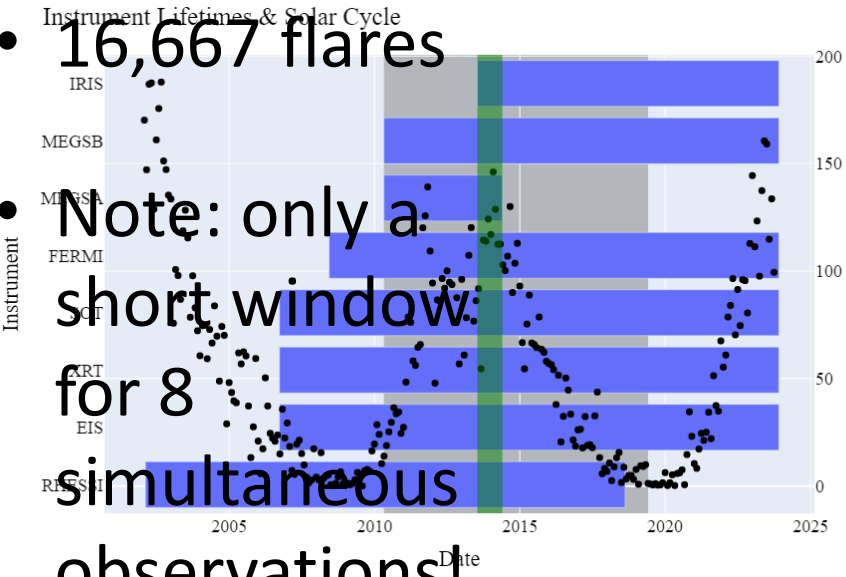
3. Challenges of Multi-Wavelength Observations

- 2010-04-13 to 2019-05-30 (~9 years)
- Within solar cycle 24

Instrument	%FOV
RHESSI	100%
FERMI GBM	100%
SDO/EVE MEGS-A	100%
SDO/EVE MEGS-B	100%
Hinode/EIS	2-25%
Hinode/SOT	1-17%
Hinode/XRT	25-100%
IRIS	0.5-3%



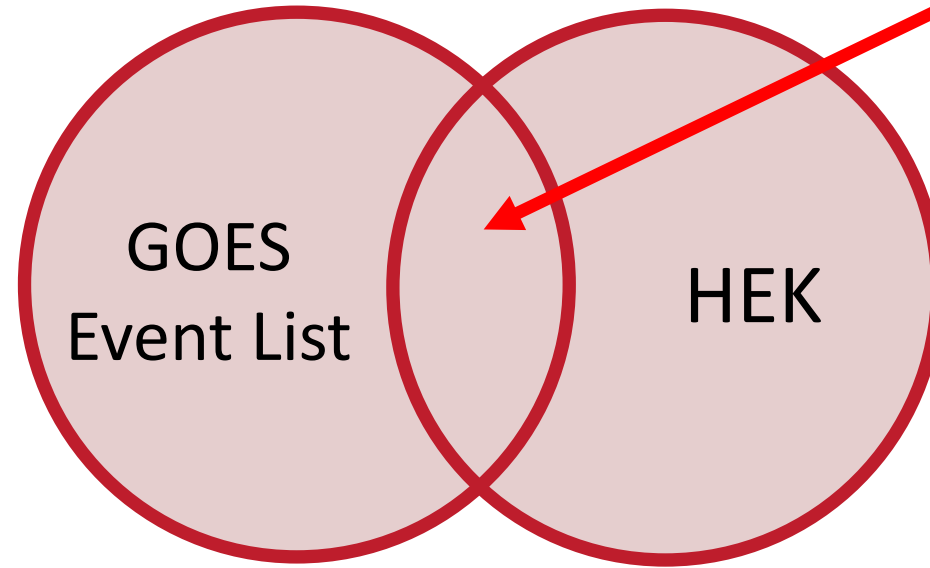
- 16,667 flares
- Note: only a short window for 8 simultaneous observations!



4. What did I do?

Create a reliable list of flares that occurred on the sun.

Overall Flare List



Flares in both lists are not duplicated!

- GOES – Geostationary Observational Environmental Satellite
- Heliophysics Events Knowledgebase
- 1975 - present

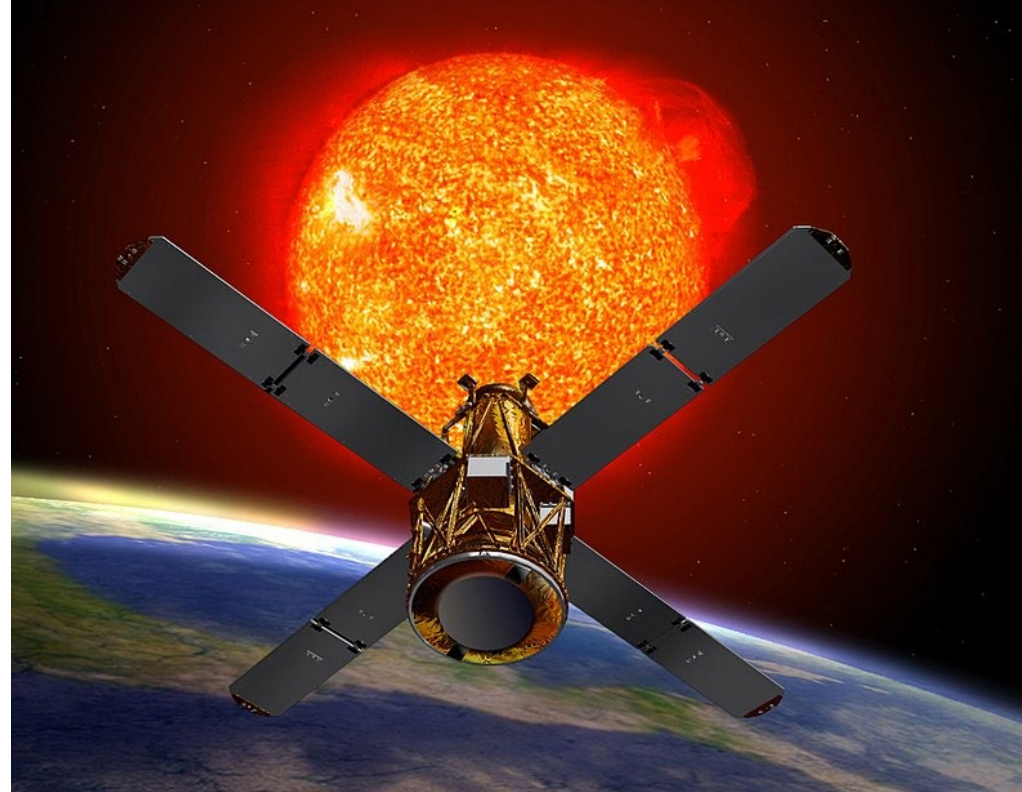
4. What did I do?

Create a reliable list of flares that occurred on the sun.



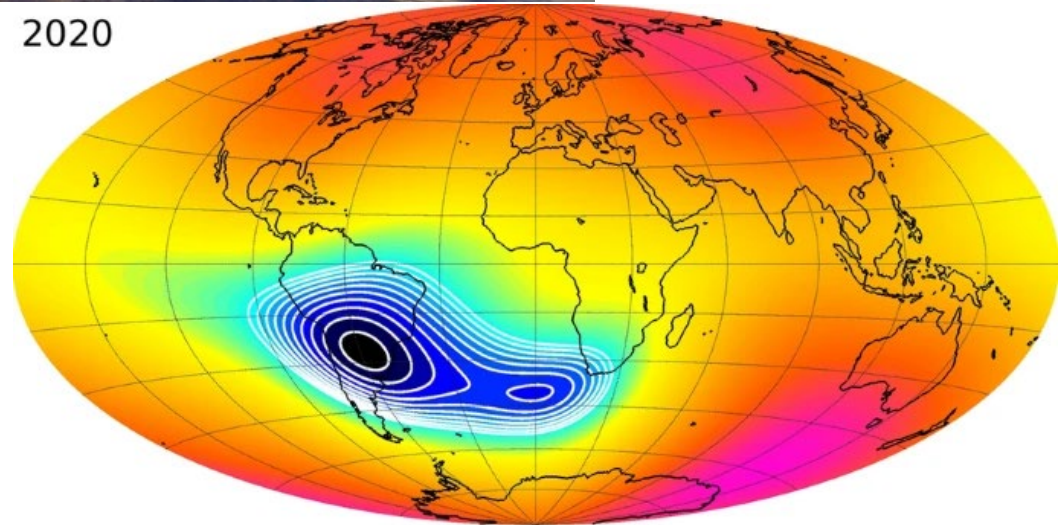
For each flare, determine if each of the 8 instruments observed.

- Could the instrument see the sun at the time?



NASA

Finlay+ 2020



2020

22000 32000 42000 52000 62000 nT

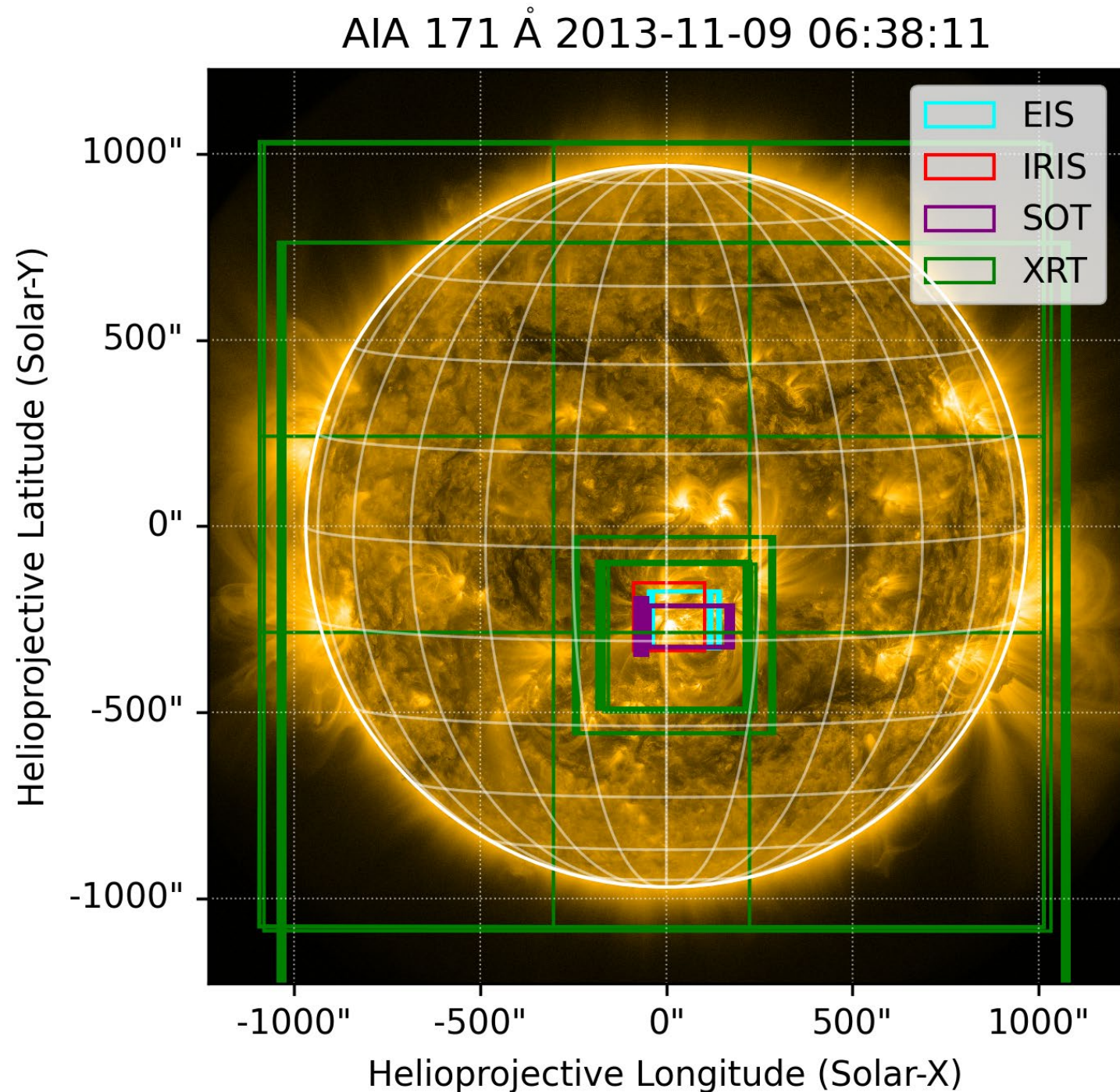
4. What did I do?

Create a reliable list of flares that occurred on the sun.



For each flare, determine if each of the 8 instruments observed.

- Could the instrument see the sun at the time?
- Was the instrument pointed in the right direction?



5. Statistics of Multi-Wavelength Observations

Milligan & Ireland (2018)¹

Instrument/Database	C-class	M-class	X-class	Total	Success rate over 6.5 years ^{a,b}
NOAA/GOES	7360	685	45	8090	100%
SSW Latest Events	6339	581	33	6953	86%
RHESSI	3673	370	23	4066	58%
SDO/EVE-MEGS-A ^a	3825	343	19	4187	100%
SDO/EVE-MEGS-B	787	97	8	892	12%
<i>Hinode</i> /EIS	496	54	6	556	8%
<i>Hinode</i> /SOT	1167	177	15	1359	20%
<i>Hinode</i> /XRT	3739	357	26	4122	59%
IRIS ^b	523 (3349)	76 (335)	5 (16)	604 (3700)	16%

New Study

Instrument/Database	B-class	C-class	M-class	X-class	Total	Success rate over 9.1 years
GOES/HEK	6,998	8,788	822	59	16,667	100%
RHESSI	4,474	6,433	643	49	11,599	71%
SDO/EVE MEGS-A	3,696	5,538	496	36	9,766	100%
SDO/EVE MEGS-B	829	1,271	170	14	2,284	14%
<i>Hinode</i> /EIS	512	721	84	11	1,328	8%
<i>Hinode</i> /SOT	665	1,357	206	19	2,247	14%
<i>Hinode</i> /XRT	3,873	4,950	493	44	9,360	56%
IRIS	690	694	89	5	1,478	17%
FERMI GBM	5,237	6,746	680	54	12,717	76%

- $$\text{Success Rate} = \frac{\text{Num. Observed Flares}}{\text{Num. Observable Flares}} \times 100$$

Num. Observable Flares = the number of flares that occurred during an instrument's lifetime.

[1] Milligan, R. O., & Ireland, J. (2018). On the performance of multi-instrument solar flare observations during Solar Cycle 24. *Solar Physics*, 293(2).

5. Statistics of Multi-Wavelength Observations

Flare Start	Flare Peak	Flare End	Class
2013-11-09 06:22	2013-11-09 06:38	2013-11-09 06:47	C2.6*
2014-02-01 15:58	2014-02-01 16:05	2014-02-01 16:14	C2.3
2014-02-03 15:40	2014-02-03 15:43	2014-02-03 15:48	C4.6
2014-02-04 15:25	2014-02-04 16:02	2014-02-04 16:49	M1.5

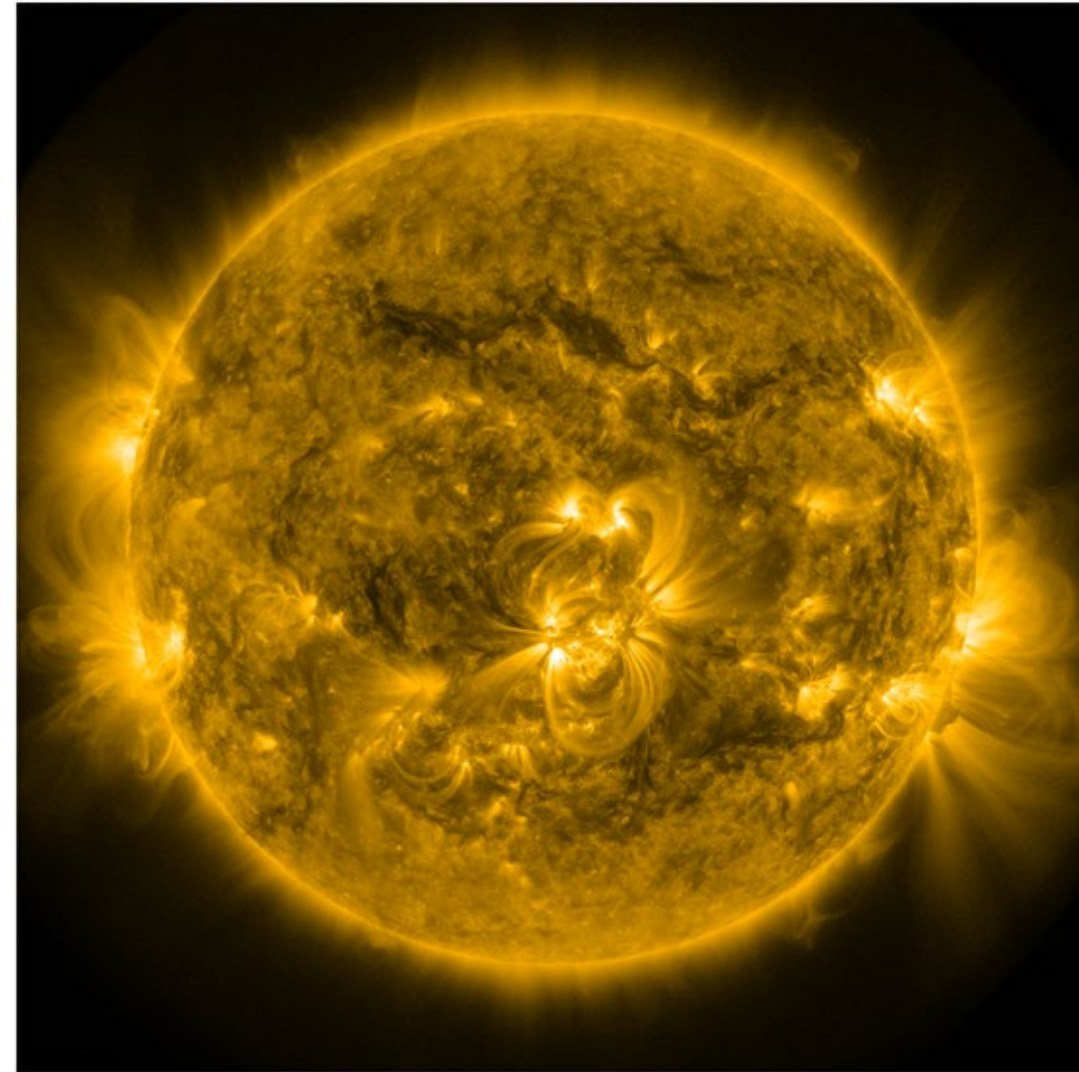
* Newly found flare with 8 simultaneous observations.

- Previously published by Milligan & Ireland (2018), also observed by Fermi.

6. Summary & Further Study

- Included FERMI + 7 previously investigated instruments.
- Catalogued 16,667 solar flares.
- Uncovered new C-class flare observed by 8 instruments.
- + Conversion to Python
- + Additional instruments.
- + Off Earth-Sun axis instruments.
- + Online dashboard.
- + Online hosting?

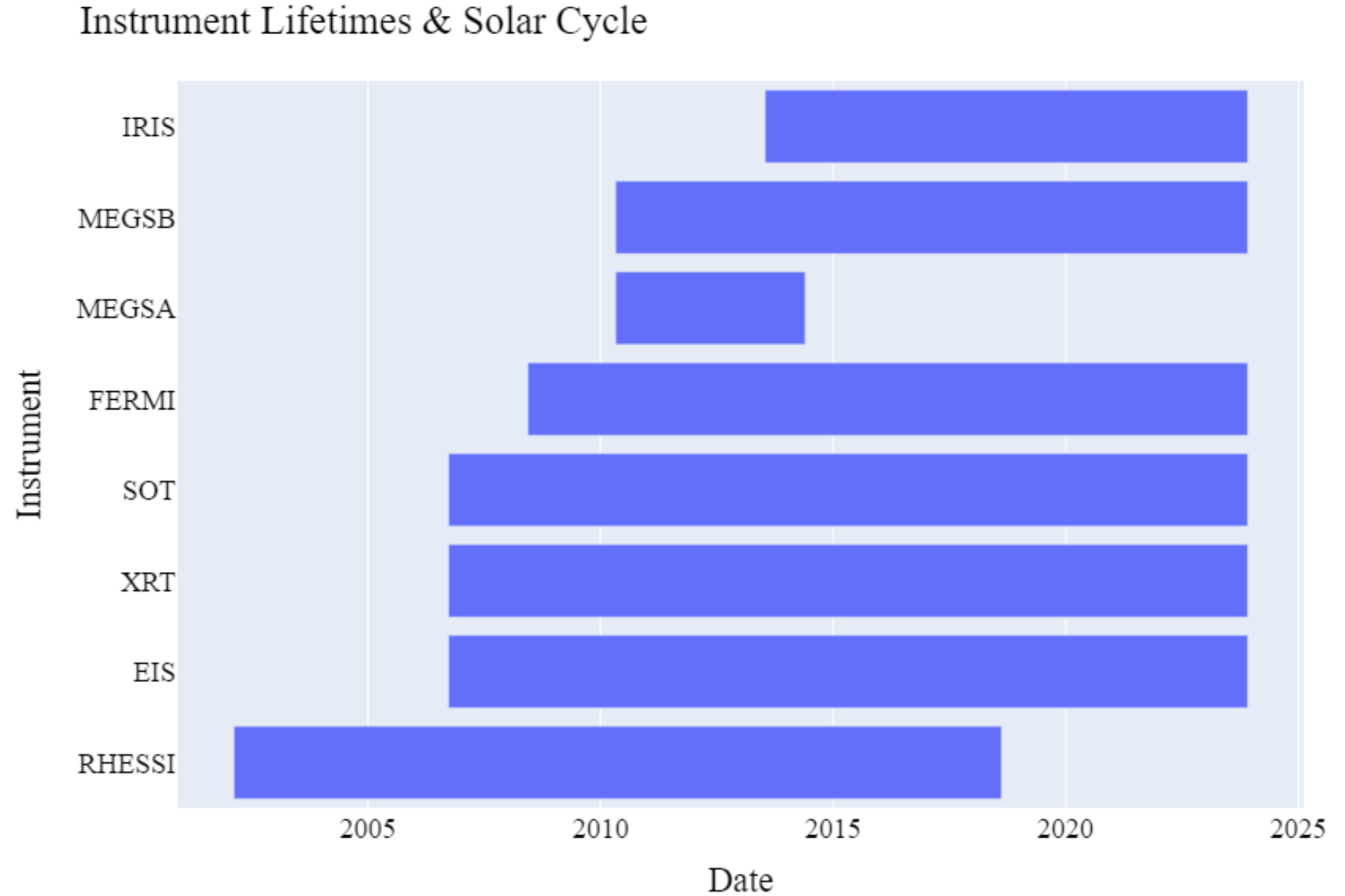
AIA 171 Å 2013-11-09 06:38:11



Backup Slides

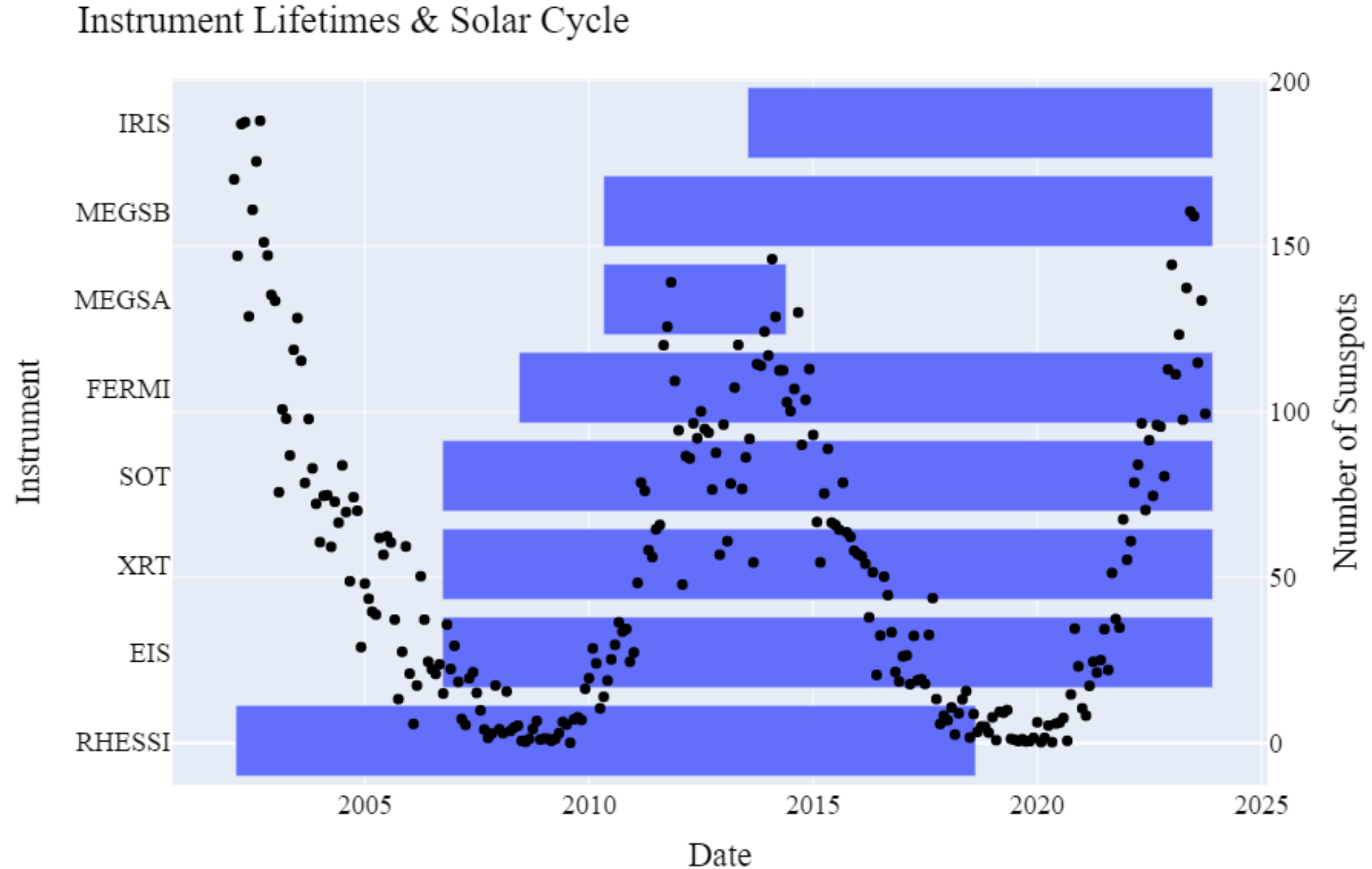
What did I do?

- Majority of instruments active



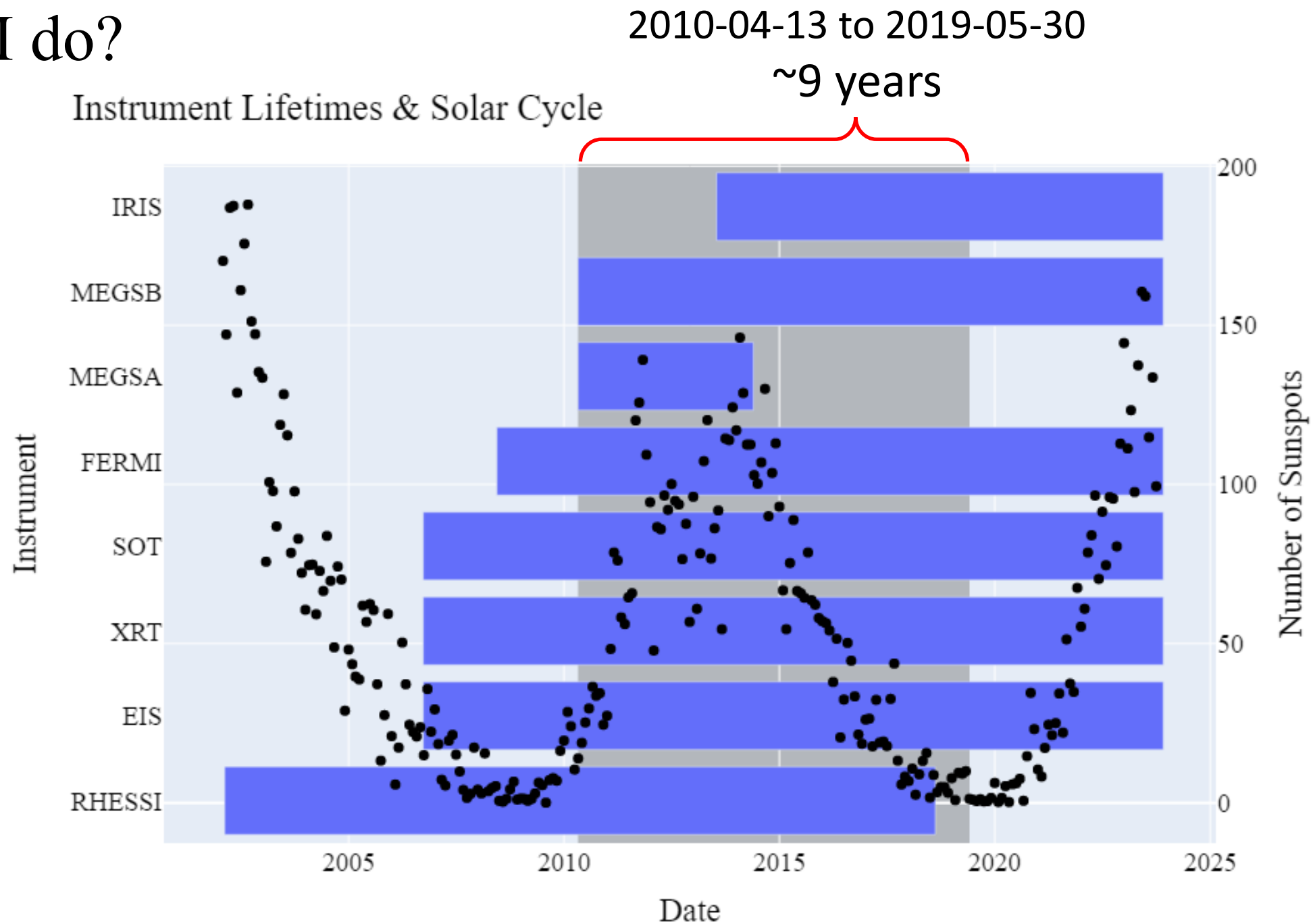
What did I do?

- Majority of instruments active
- Within solar cycle 24



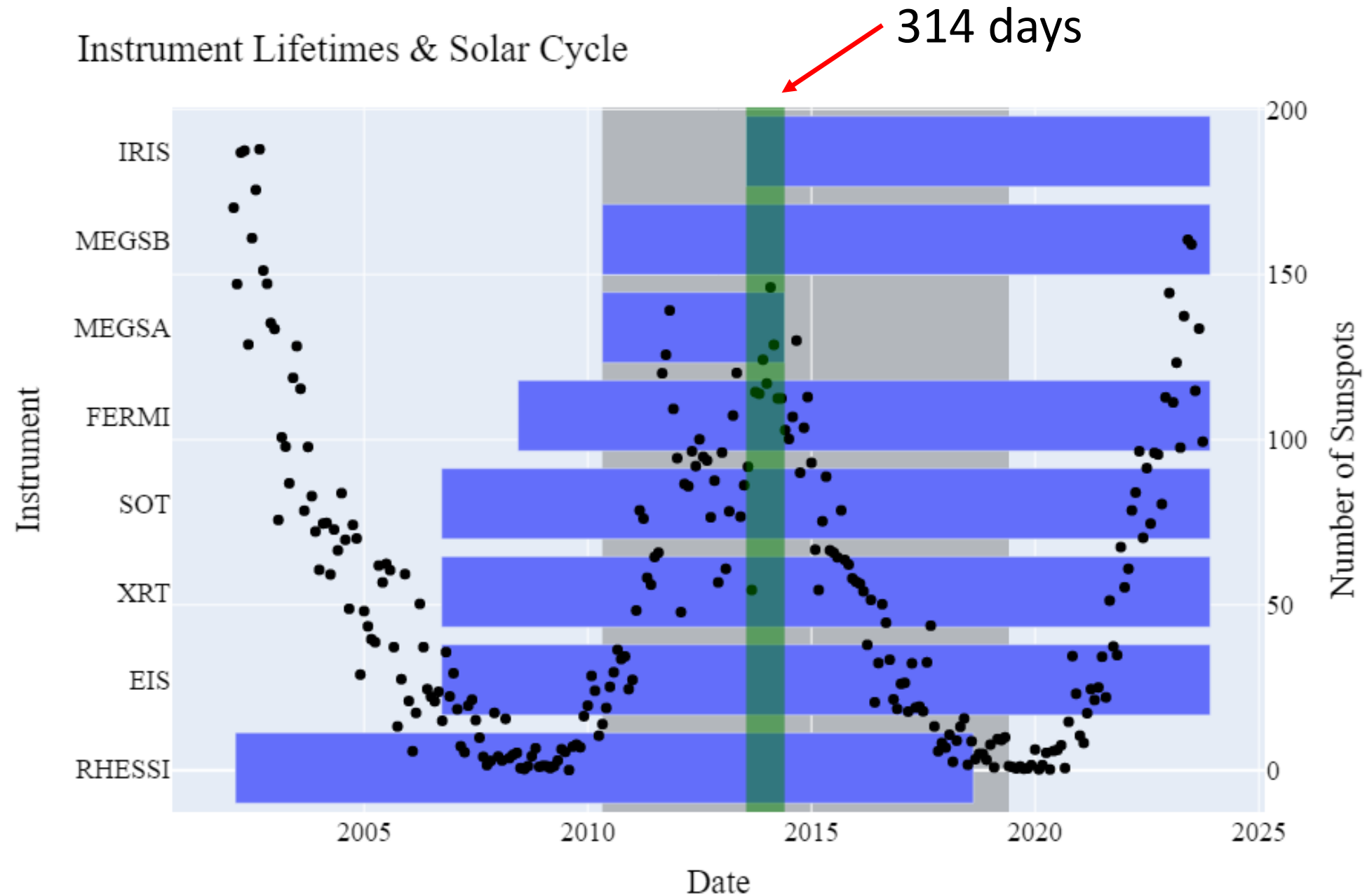
What did I do?

- Majority of instruments active
- Within solar cycle 24
- 16,667 flares



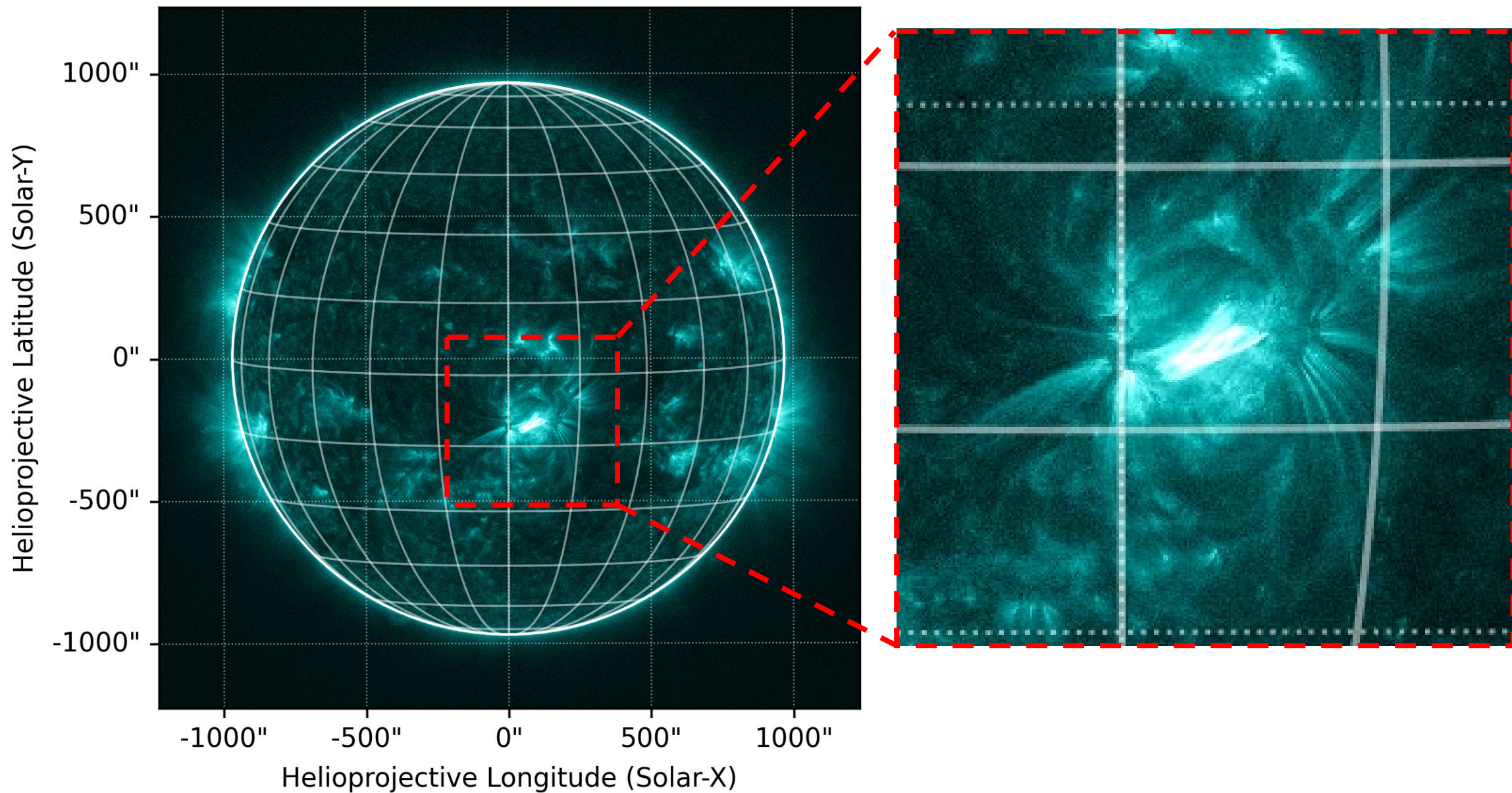
What did I do?

- Majority of instruments active
- Within solar cycle 24
- 16,667 flares
- Note: only a short window for 8 simultaneous observations!



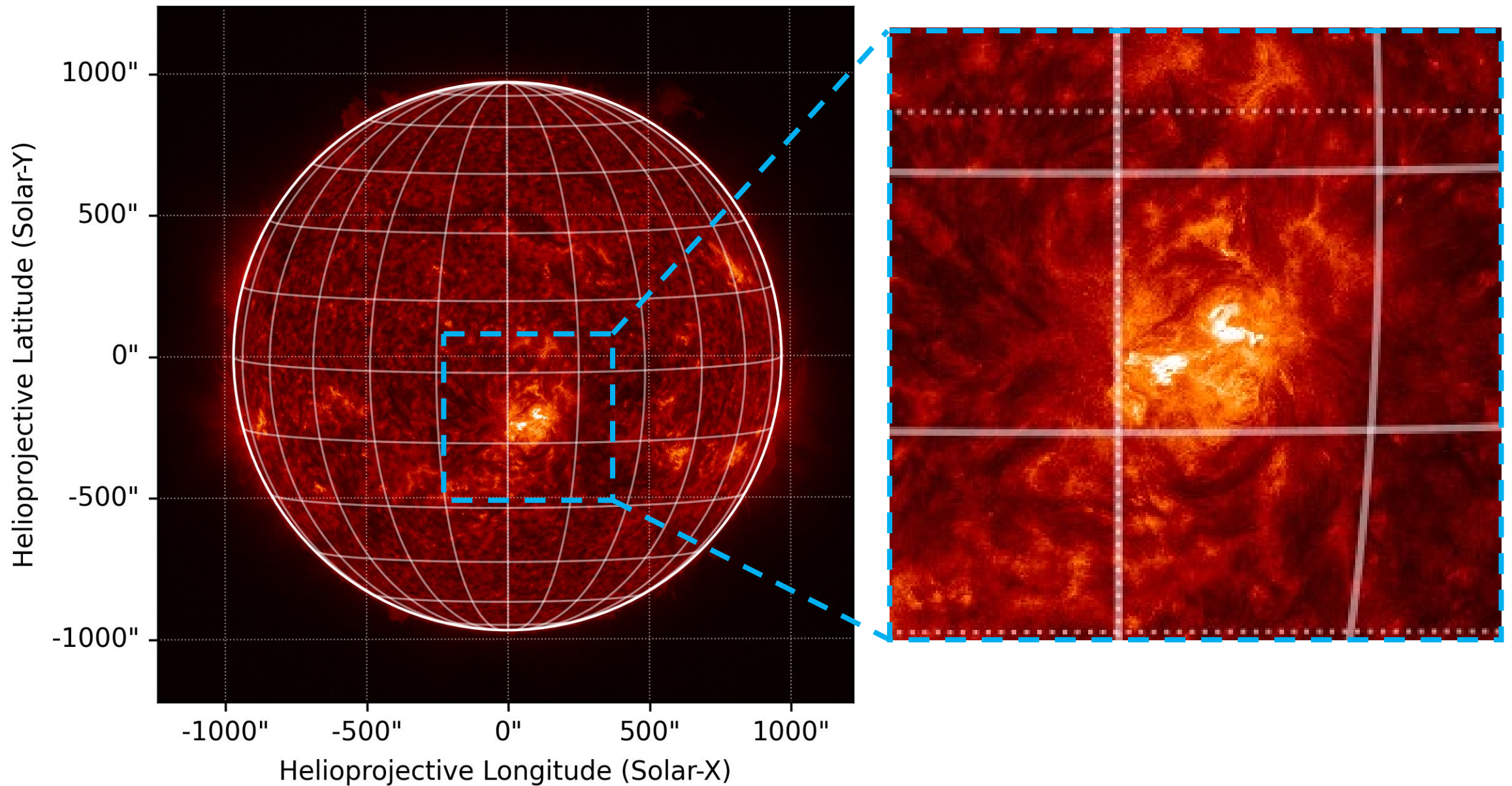
2013-11-09 06:38 C2.6 Flare

AIA 131 Å 2013-11-09 06:38:08



2013-11-09 06:38 C2.6 Flare

AIA 304 Å 2013-11-09 06:38:07



What is a Solar Flare?

The standard model of a solar flare:

1. Magnetic reconnection
2. Acceleration of electrons
3. Non-thermal electron bombardment of chromosphere
4. Chromospheric evaporation/condensation

