FLARE LIST FUN 🌞

Laura Hayes & Hannah Collier

STIX team meeting Wroclaw Nov 2023

→ THE EUROPEAN SPACE AGENCY

So What? Who cares?

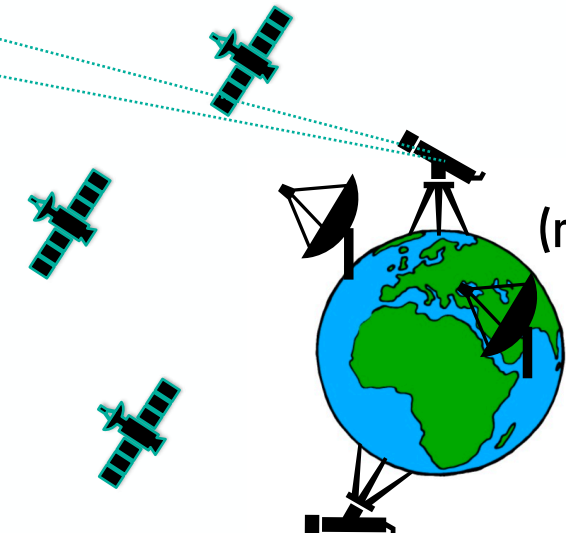# Flarelist importance

Ideally ....

```
>>> import heliomagic
>>> data = heliomagic.find_data(event="flare",
                                    data_type="all")
>>> results = heliomagic.analyse_data(data)
>>> paper = heliomagic.write_paper(results)
"Congratulations on your ground-breaking new paper!"
```
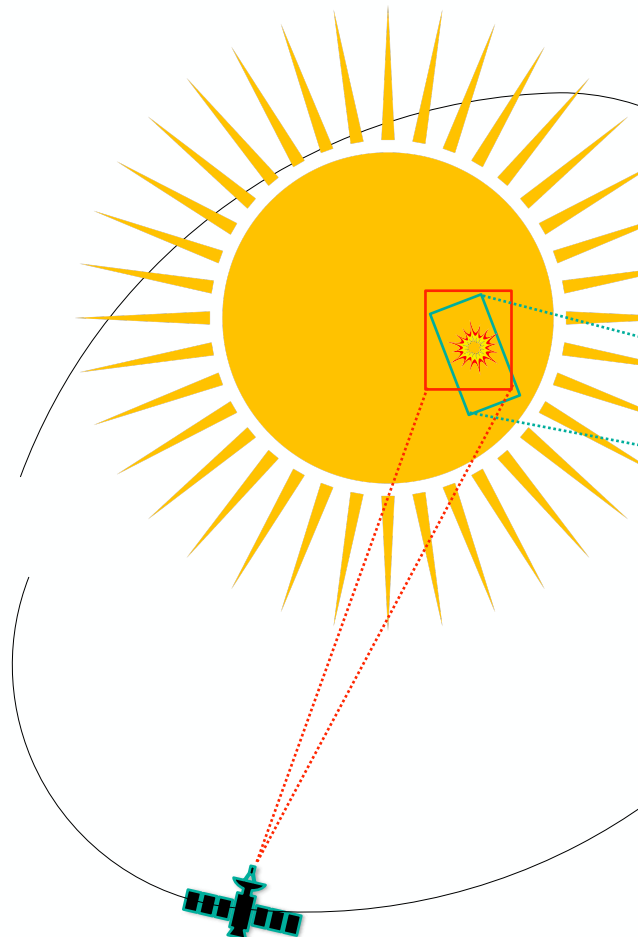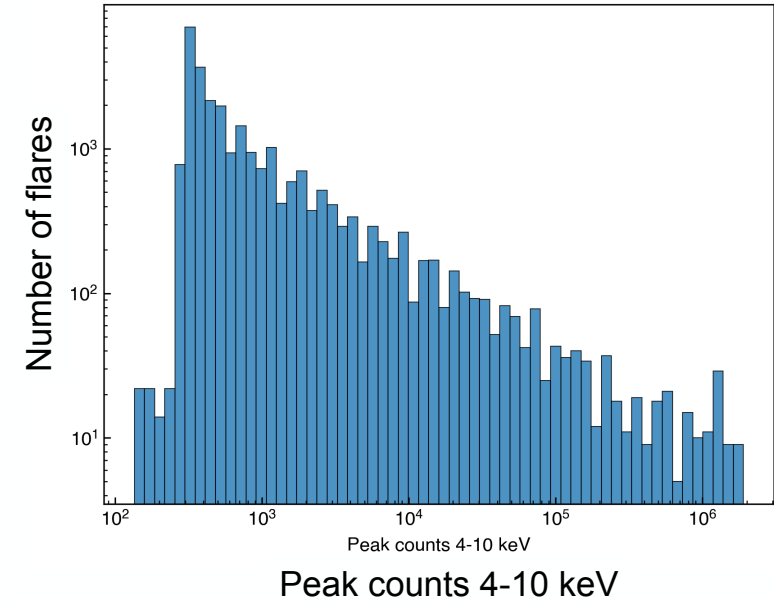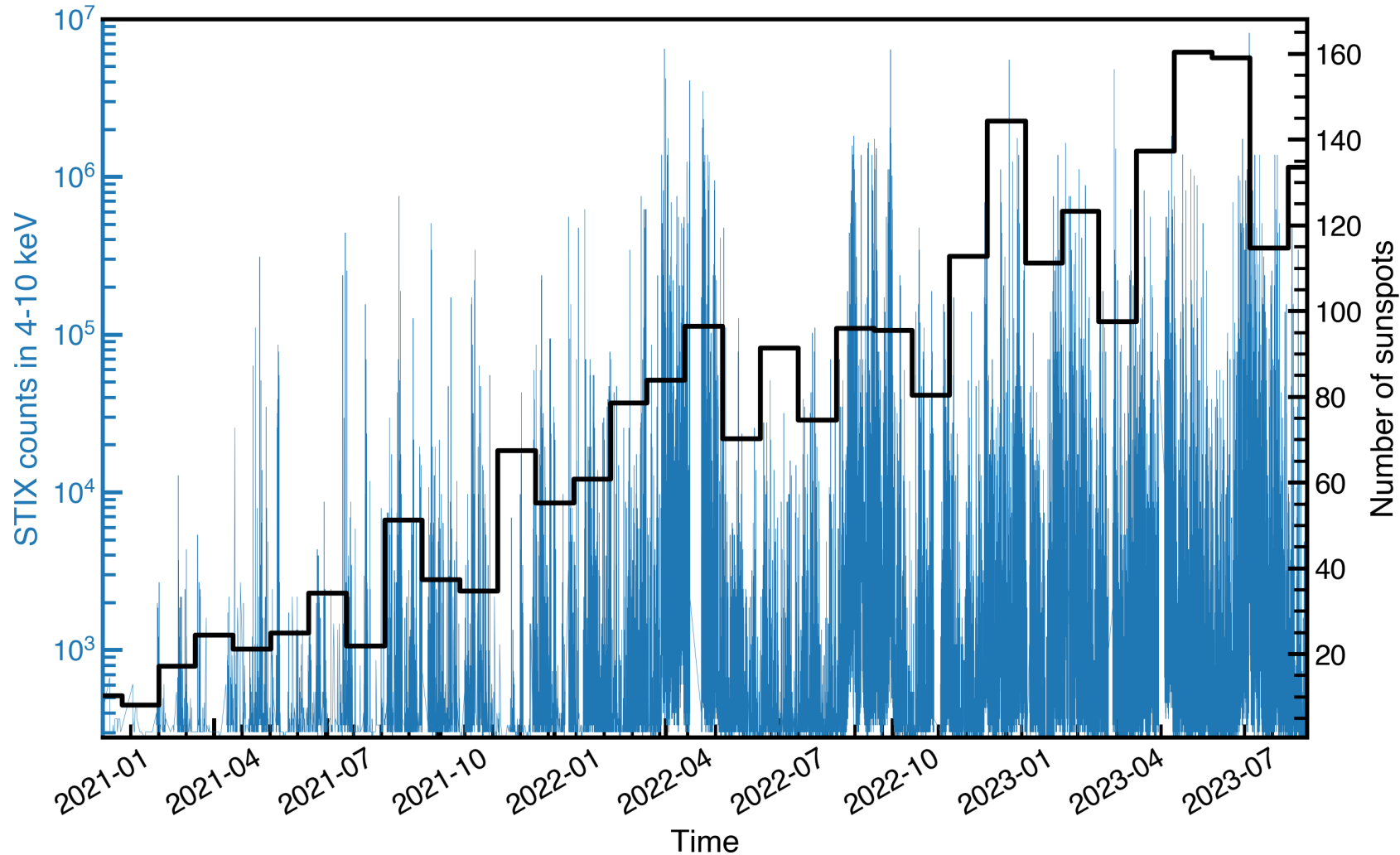
Coordinated campaigns

Ground-based
(radio, white-light,
monitors)

- Remote sensing (e.g. measurements at a distance)

- In-situ (e.g. directly measures particles)

Multi-messenger observatories

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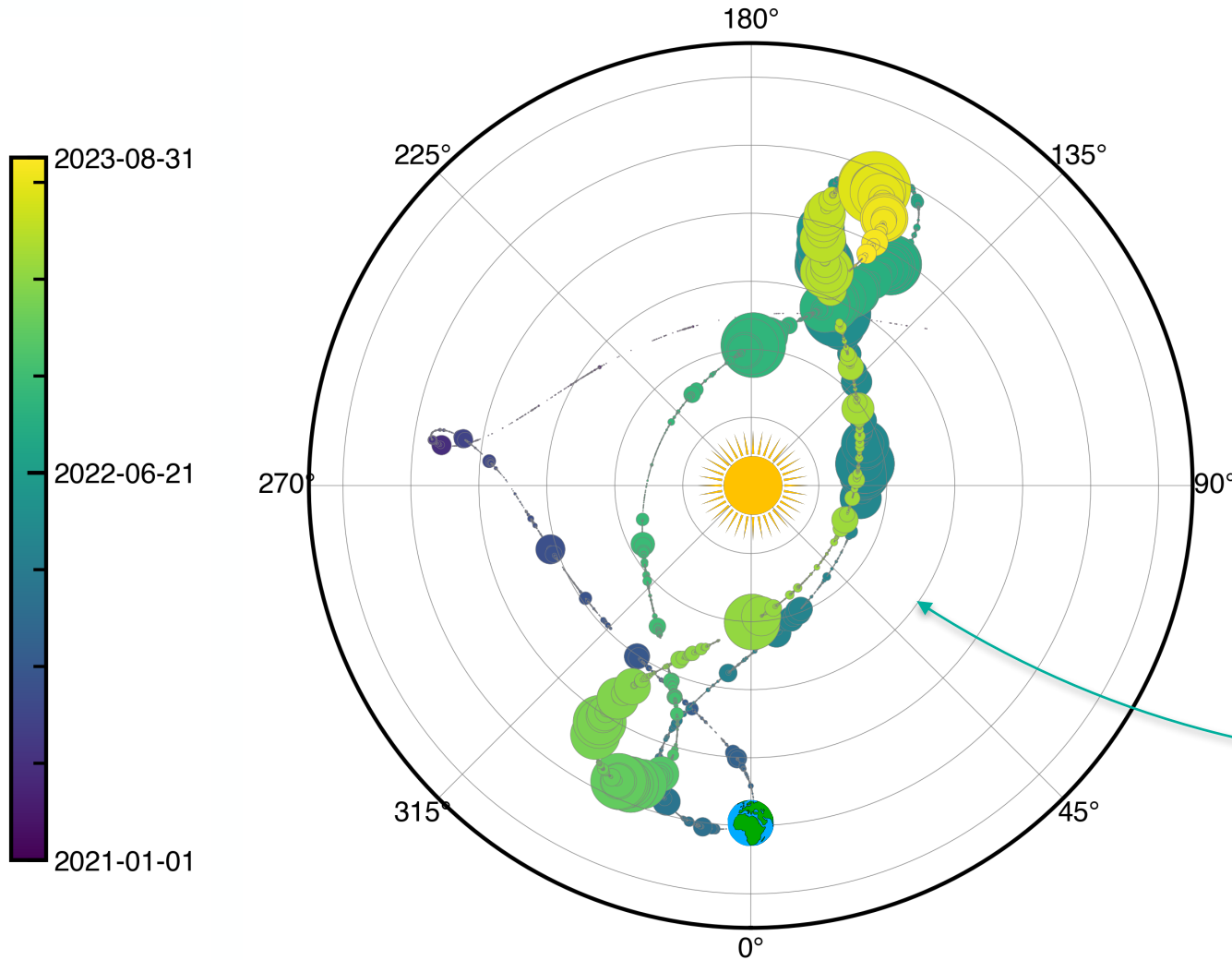
STIX flares to date

- STIX has observed thousands of flares (>38,000!)
- Continuously observing (since Jan 2021)

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STIX flares to date

All STIX flares from 2021-01-01 — 2023-08-31

Plot of flares observed on the trajectory of Solar Orbiter
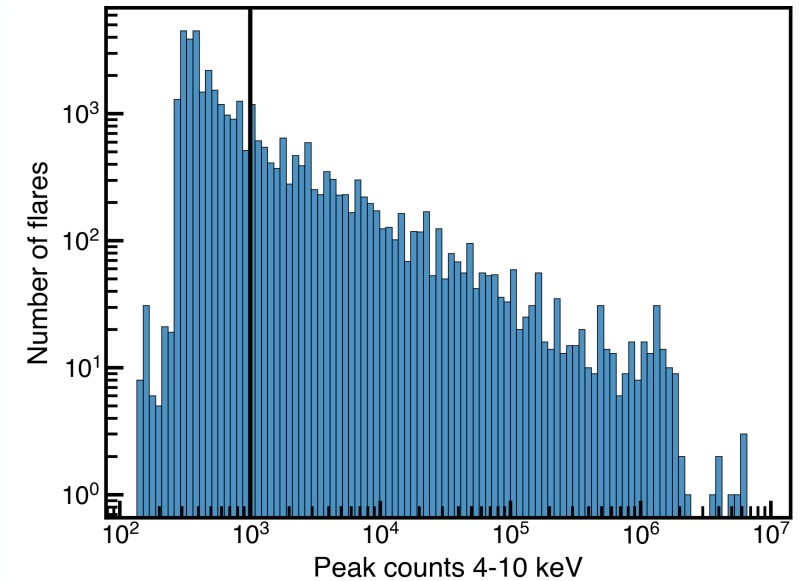
Size of circle = relative size of flare

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STIX list with flare locations - how we do it

1. Start with data centre operational flarelist (Hualin's list)

- get from `stixdcpy`
- trim for flares > 1000 counts in peak 4-10 keV channel
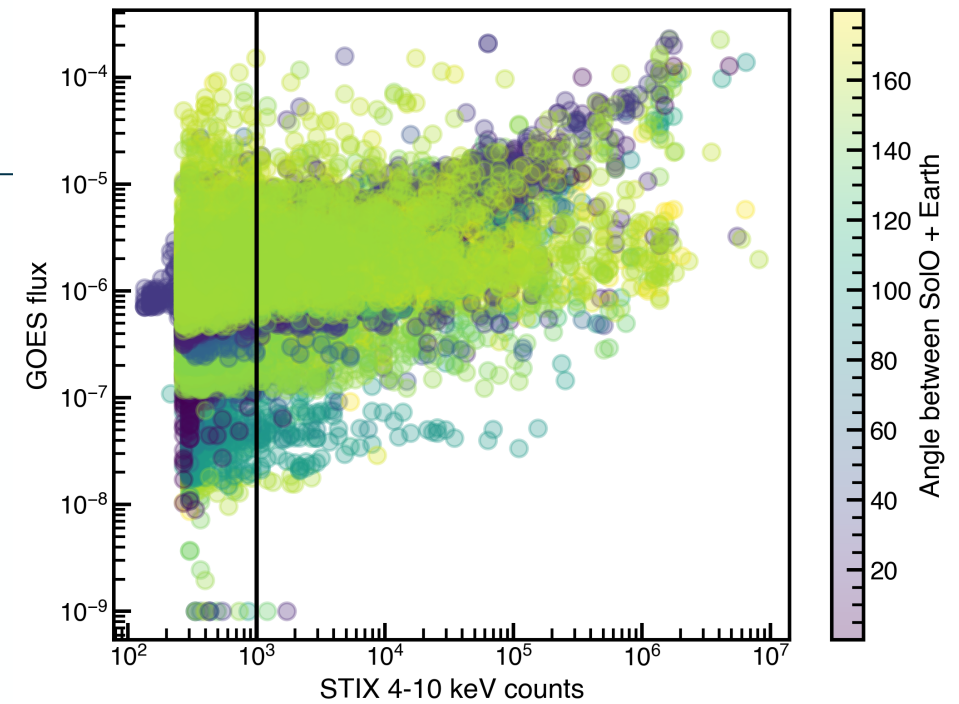
40,000 flares ->
10016 flares

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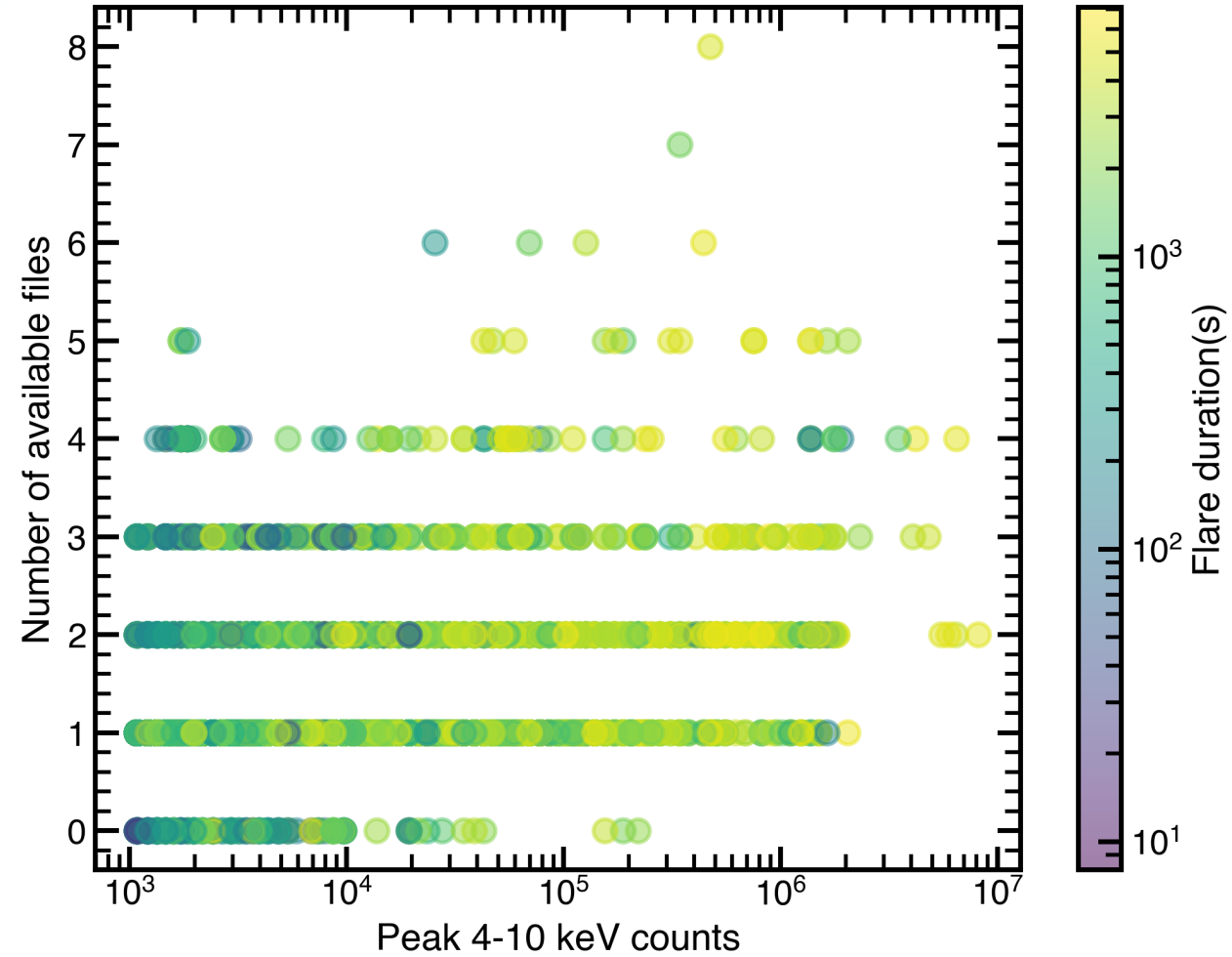
   40,000 flares ->
   10016 flares

2. **Search for available pixel**
   - query for Request IDs that are available over the time range of flare (start-end) Fido
   - For each Request ID pixel file, check that the peak of flare is within the file time range
   - save available Request IDs for each flare

   10016 flares ->
   9844 flares

Available pixel data

Pixel file availability for flares > 1000 counts at peak 4-10 keV

Available pixel data

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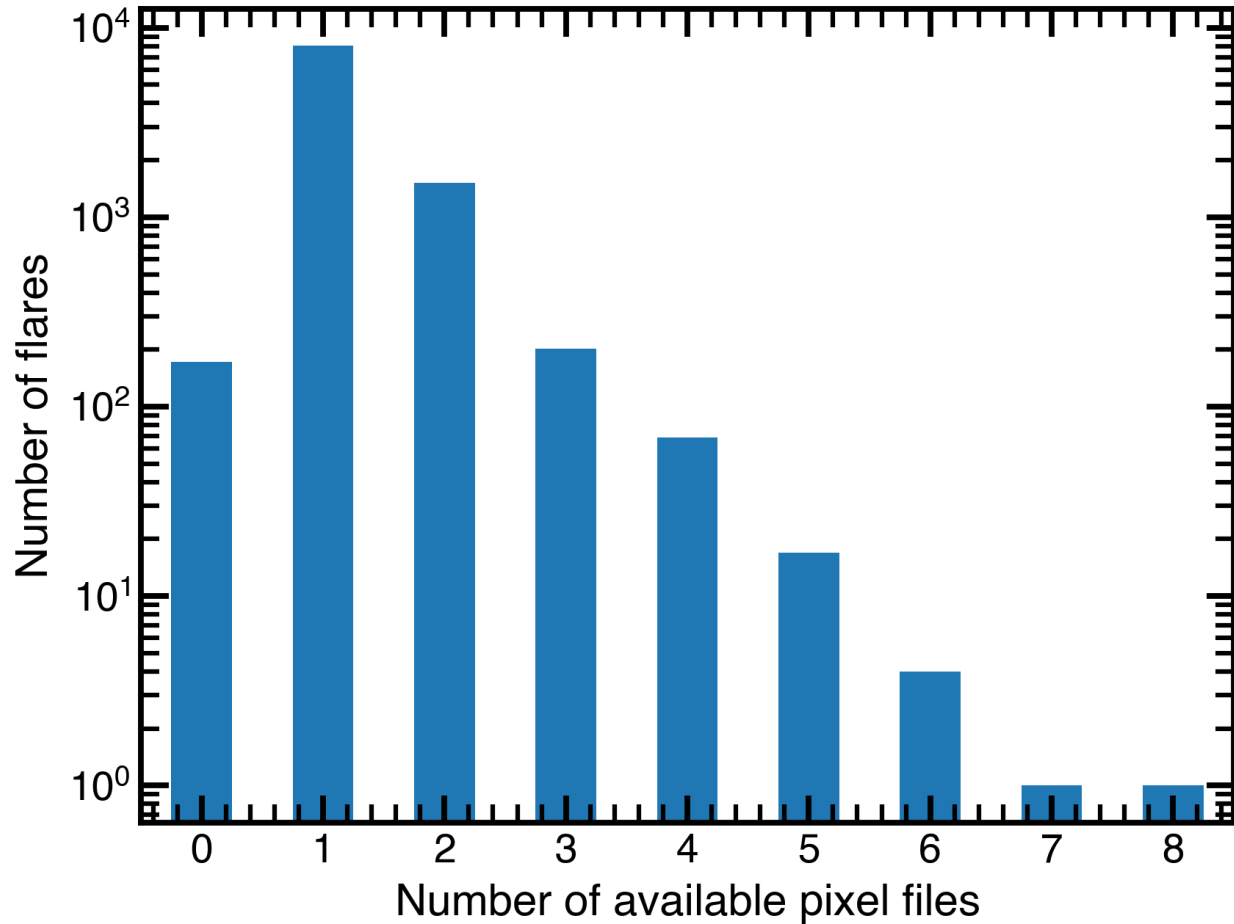
   40,000 flares ->
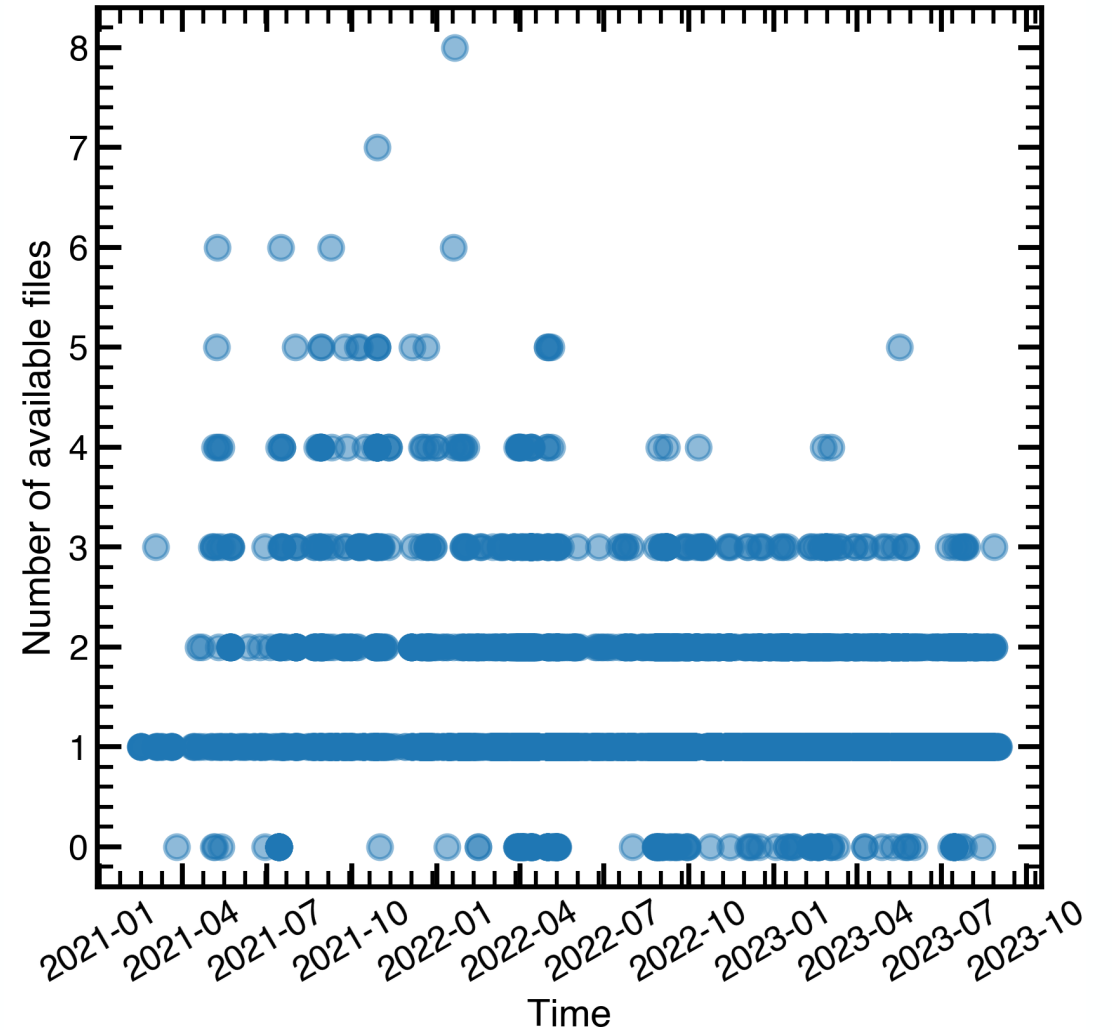   10016 flares
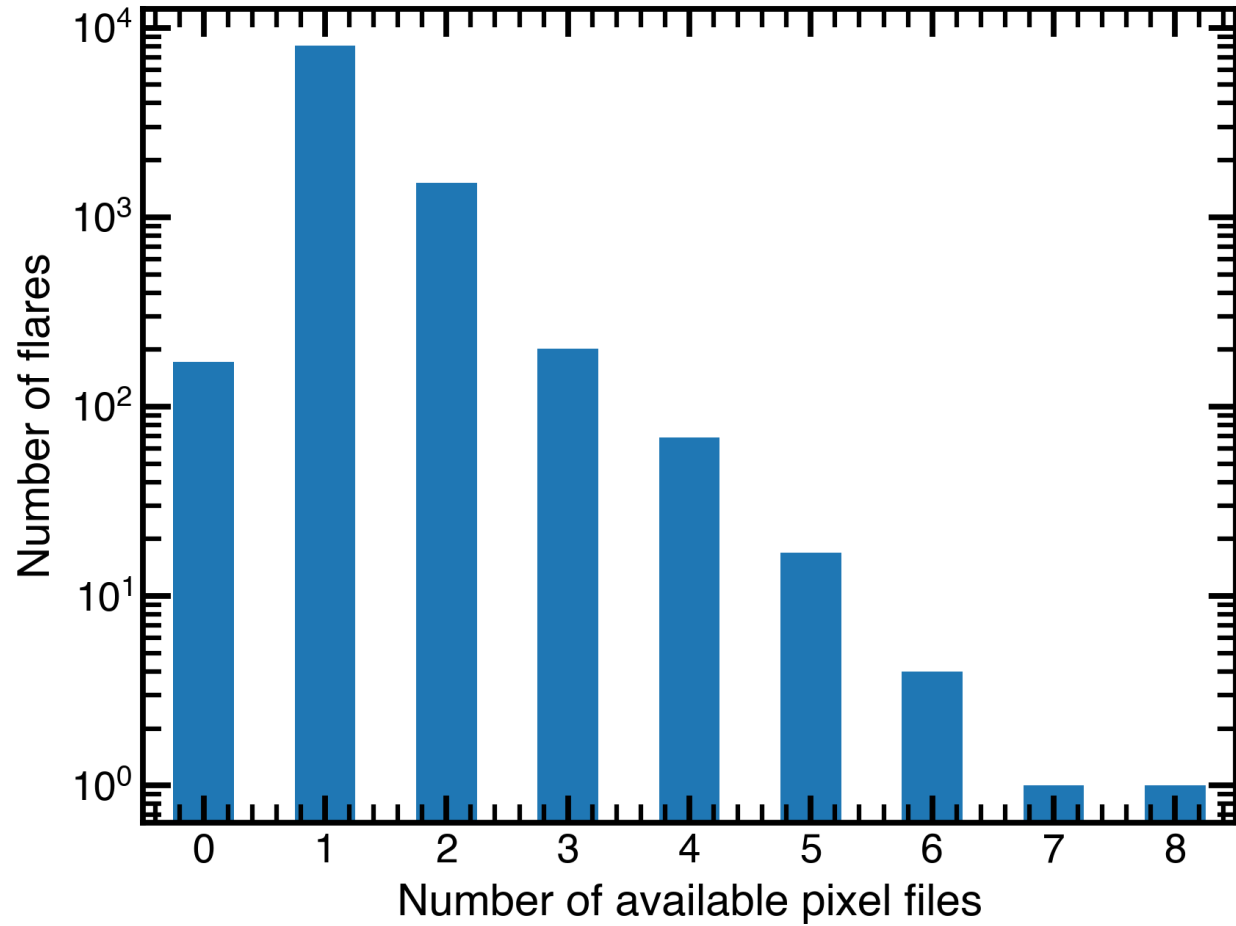
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   9844 flares

3. **Download the available pixel and auxiliary data for each event**
   - from database of Request IDs for each flare, (choose one for analysis) download data
   - remove events that do not have files or aux data.

   9844 flares ->
   9635 flares

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   9635 flares

4. **Run modified version of `stx_estimate_flare_location`**
   - 40s integration over peak of flare, 4-16 keV energy range
   - save the backprojection maps for testing

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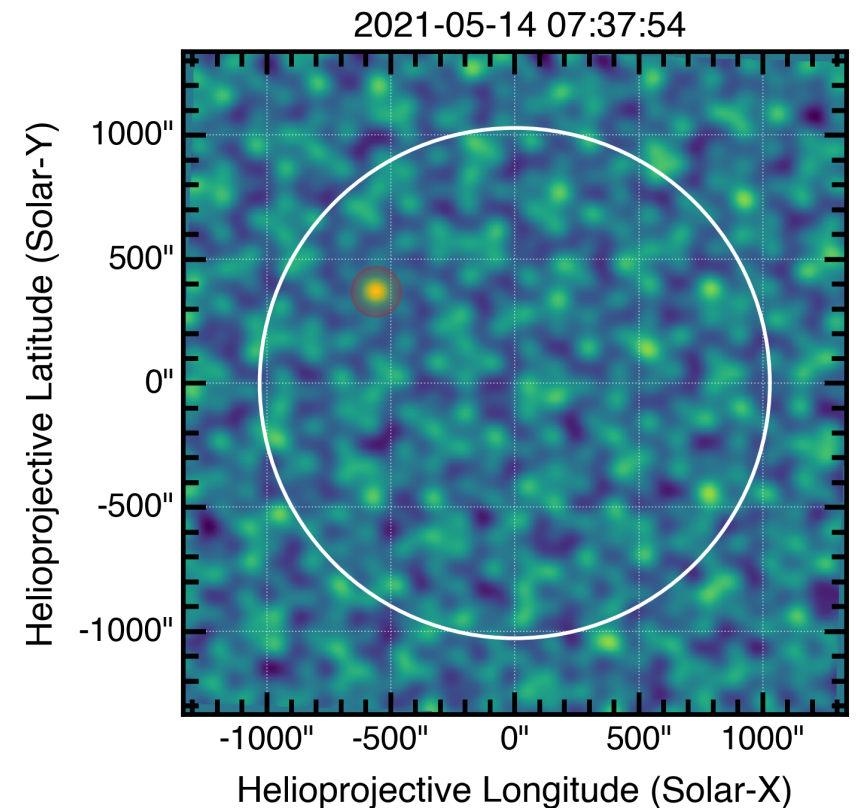- remove events that do not have files or aux data.

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5. Test "quality" of backprojection maps
- For back projection maps for each flare, if other maximia in the map is > 90% of flare location

10016 flares ->
<u>8598 flares</u>

2021-05-14 07:37:54

STIX list with flare locations - how we do it

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   - get from `stixdcpy`
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6. **Coordinate magic**
   - Using SPICE kernals and the sunpy coordinate stack, convert coordinates to different frames (HPC, HGS etc) and determine whether observed by Earth
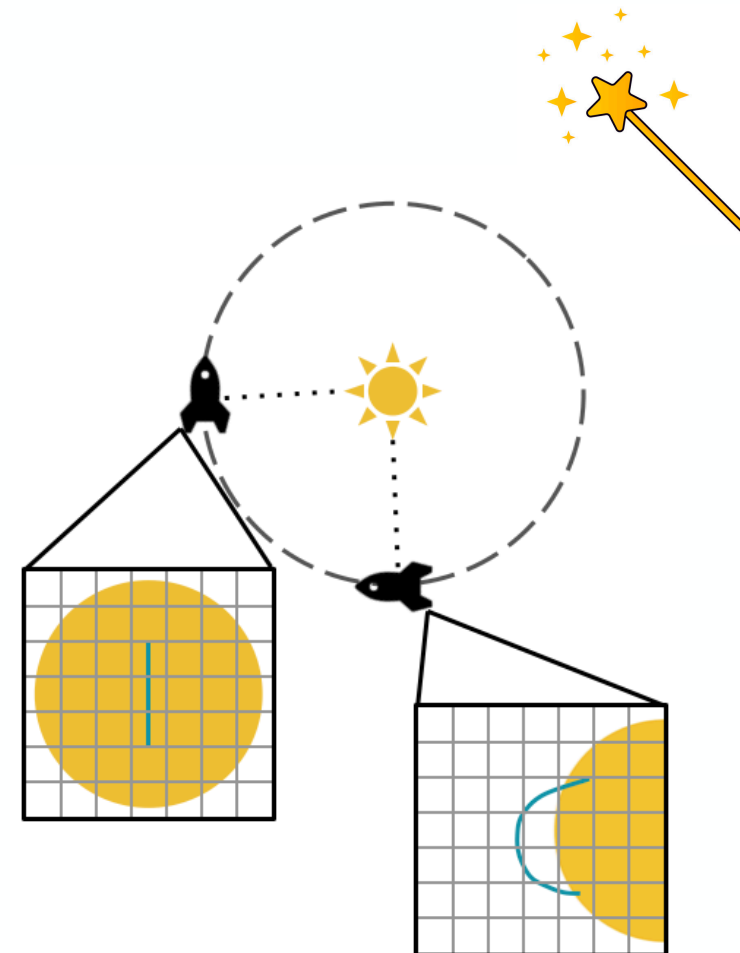
# Flarelist file - many different columns

```
>>> flarelist = pd.read_csv("STIX_flarelist_w_locations_20210214_20230928_version1.csv")
>>> flarelist
```

start_UTC	end_UTC	peak_UTC	4-10 keV	10-15 keV	15-25 keV	25-50 keV	50-84 keV	att_in	hpc_x_solo	hpc_y_solo	hpc_x_earth	hpc_y_earth	visible_from_earth	hgs_lon	hgs_lat	hgc_lon	hgc_lat
2021-02-14T01:41:06.670	2021-02-14T01:49:14.671	2021-02-14T01:44:14.670	1983	463	183	927	543	False	617.878235	706.284912	NaN	NaN	False	-139.884661	22.644694	279.867915	22.644694
2021-02-14T13:21:34.741	2021-02-14T13:33:02.742	2021-02-14T13:24:54.741	1855	271	151	927	543	False	813.800781	721.484314	NaN	NaN	False	-131.832973	23.132900	281.512729	23.132900
2021-02-14T19:34:46.779	2021-02-14T19:43:18.780	2021-02-14T19:36:46.779	1215	271	151	927	495	False	823.278748	709.062012	NaN	NaN	False	-130.979405	22.771634	278.965938	22.771634
2021-02-15T07:22:43.151	2021-02-15T07:34:43.153	2021-02-15T07:27:03.152	1343	215	91	927	543	False	970.853149	726.709595	NaN	NaN	False	-124.198594	23.339267	279.251963	23.339267
2021-02-15T08:14:39.159	2021-02-15T08:28:35.160	2021-02-15T08:16:35.159	1855	271	91	927	495	False	994.707275	724.366272	NaN	NaN	False	-123.217183	23.257777	279.780434	23.257777
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2023-08-26T21:45:44.446	2023-08-26T21:51:08.447	2023-08-26T21:47:20.447	14847	3199	2431	1727	543	False	-1195.603516	216.435303	934.560803	131.628447	True	84.582969	8.699326	188.141859	8.699326
2023-08-26T21:53:44.447	2023-08-26T23:34:16.458	2023-08-26T22:26:28.451	102399	6399	543	799	399	False	1335.155151	-196.268616	NaN	NaN	False	-115.996981	-8.362376	347.202822	-8.362376

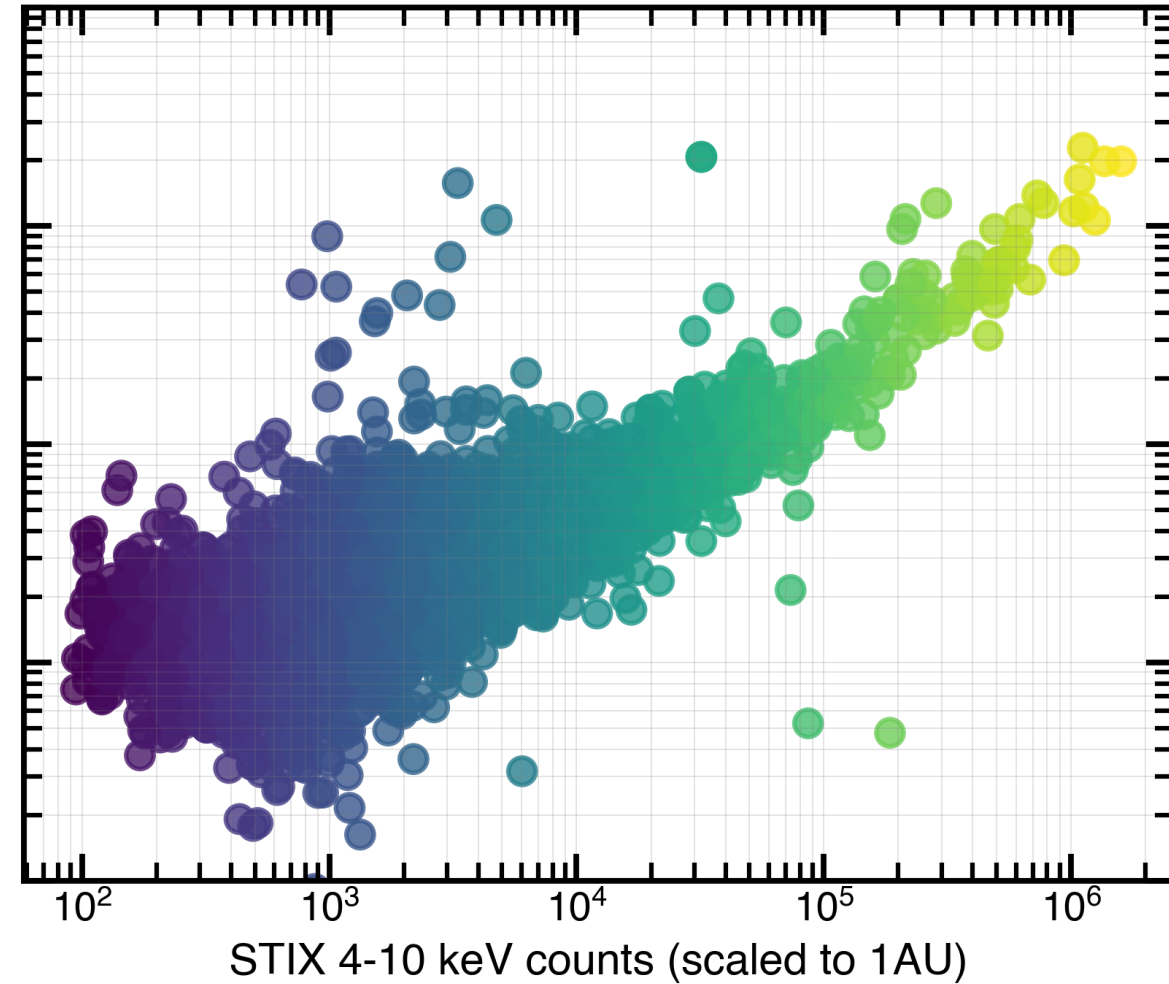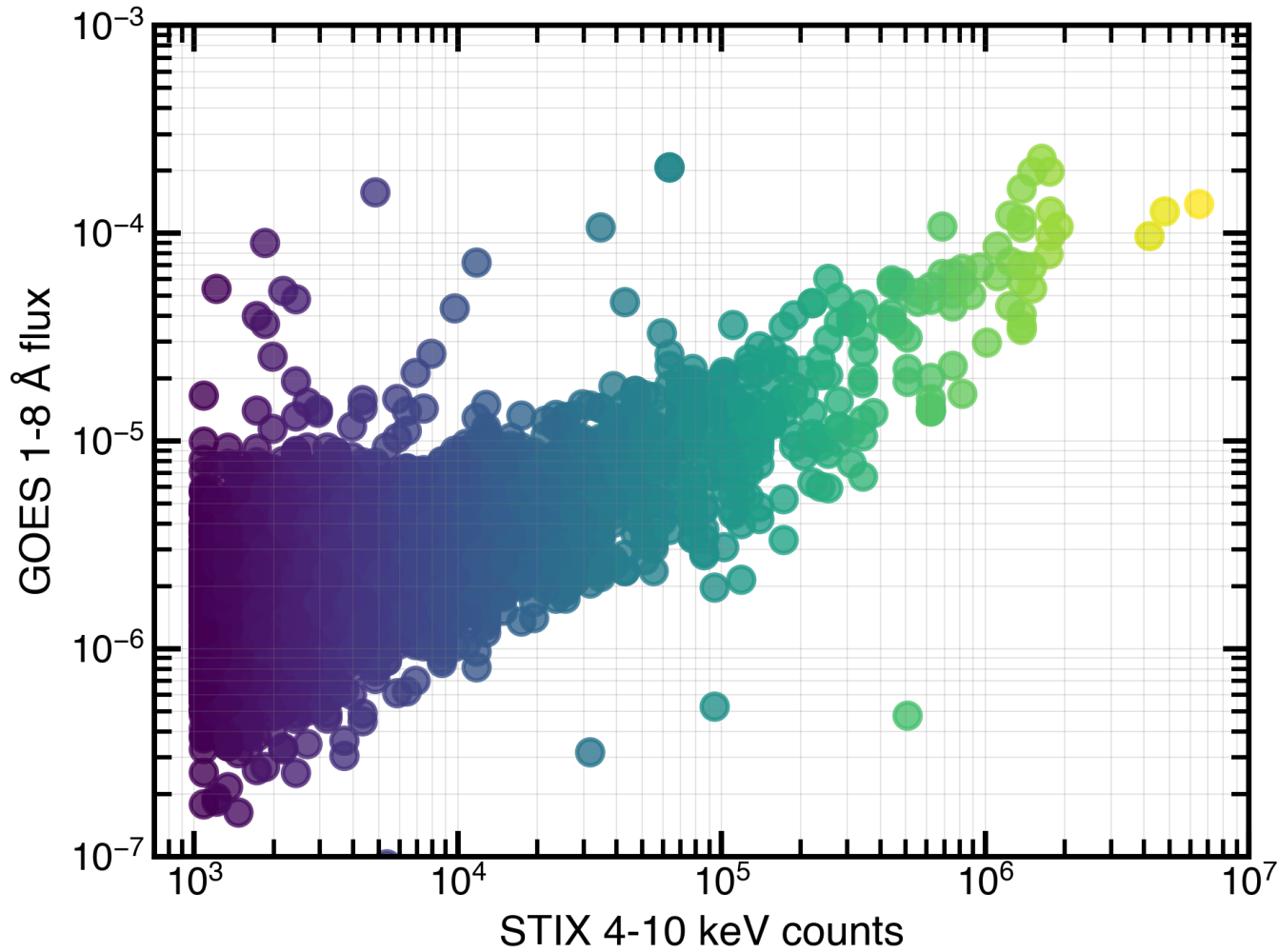## Currently (updated last night) 8598 flares in this list

STIX flares to date Jan 2021-Sept 2023

Solar Orbiter View 2021-02-14

Earth View 2021-02-14

Positions in Heliographic Stonyhurst
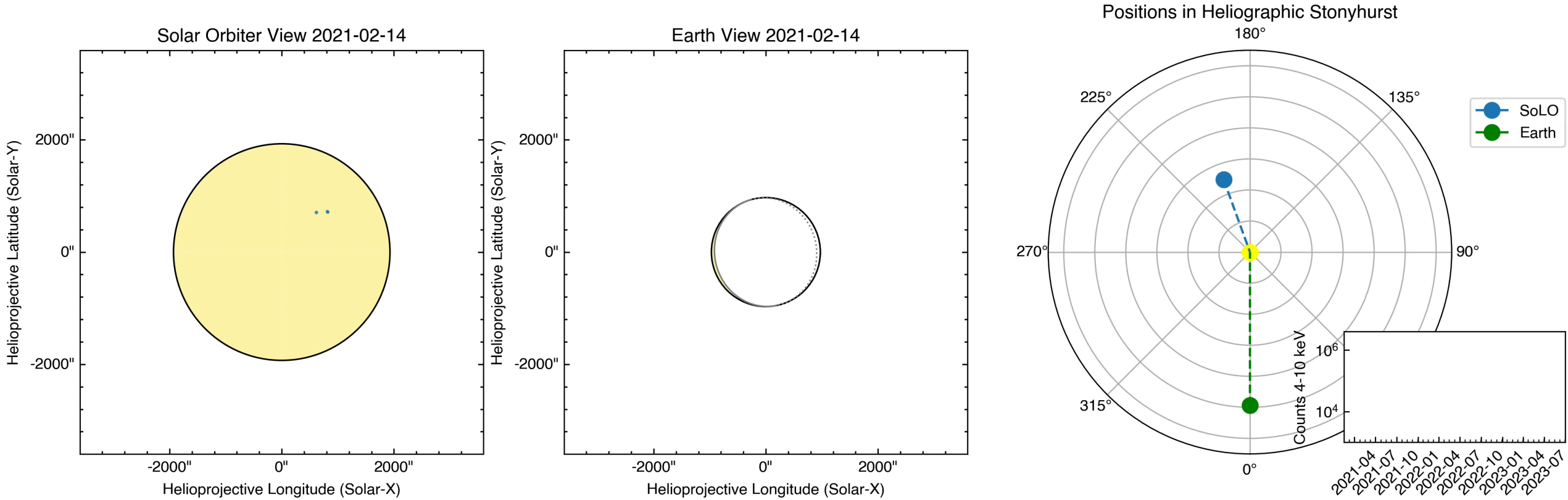
STIX flare list with locations:
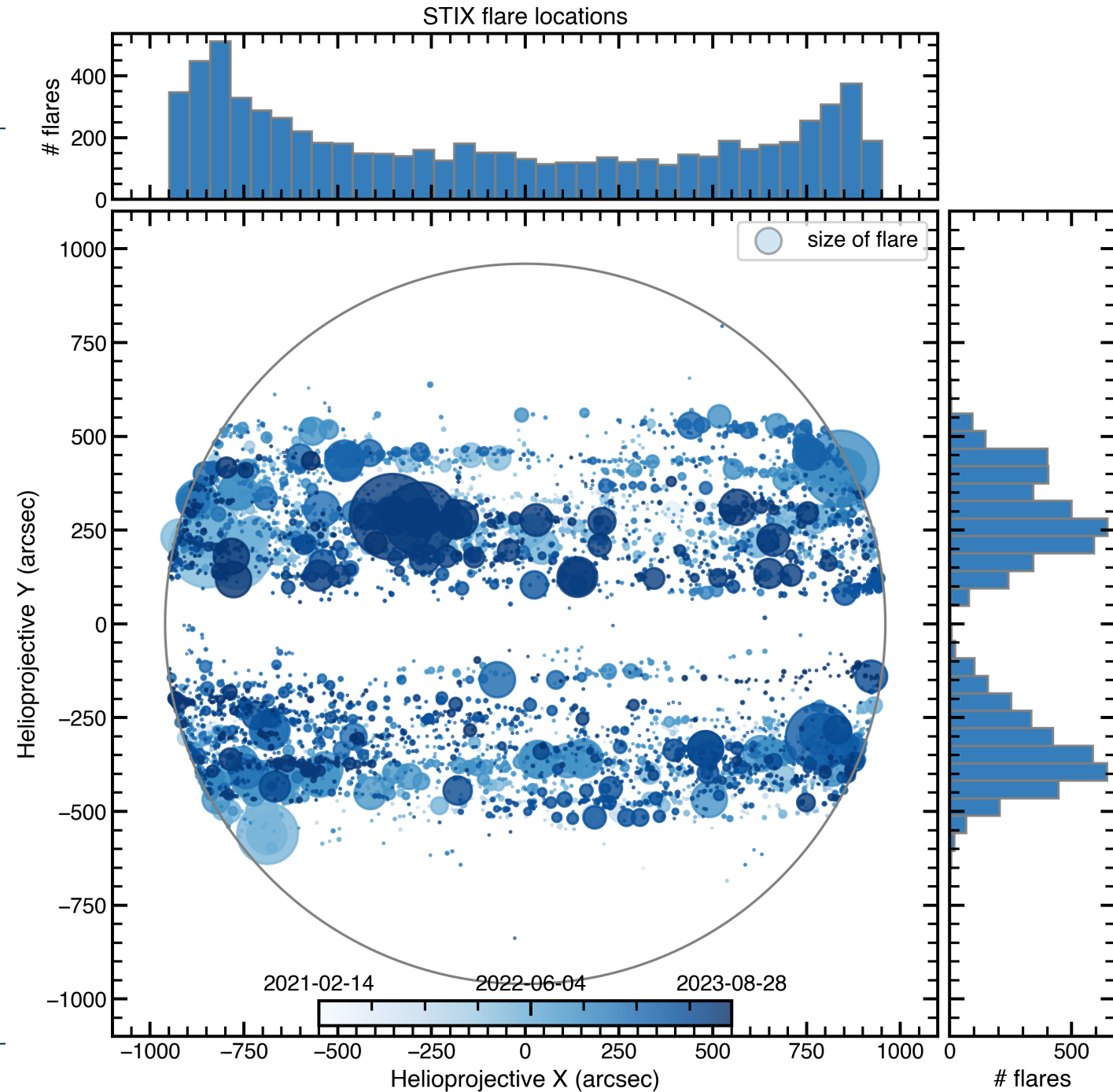https://github.com/hayesla/stix_flarelist_science

STIX flares to date Jan 2021-Sept 2023 : Earth-observed flares
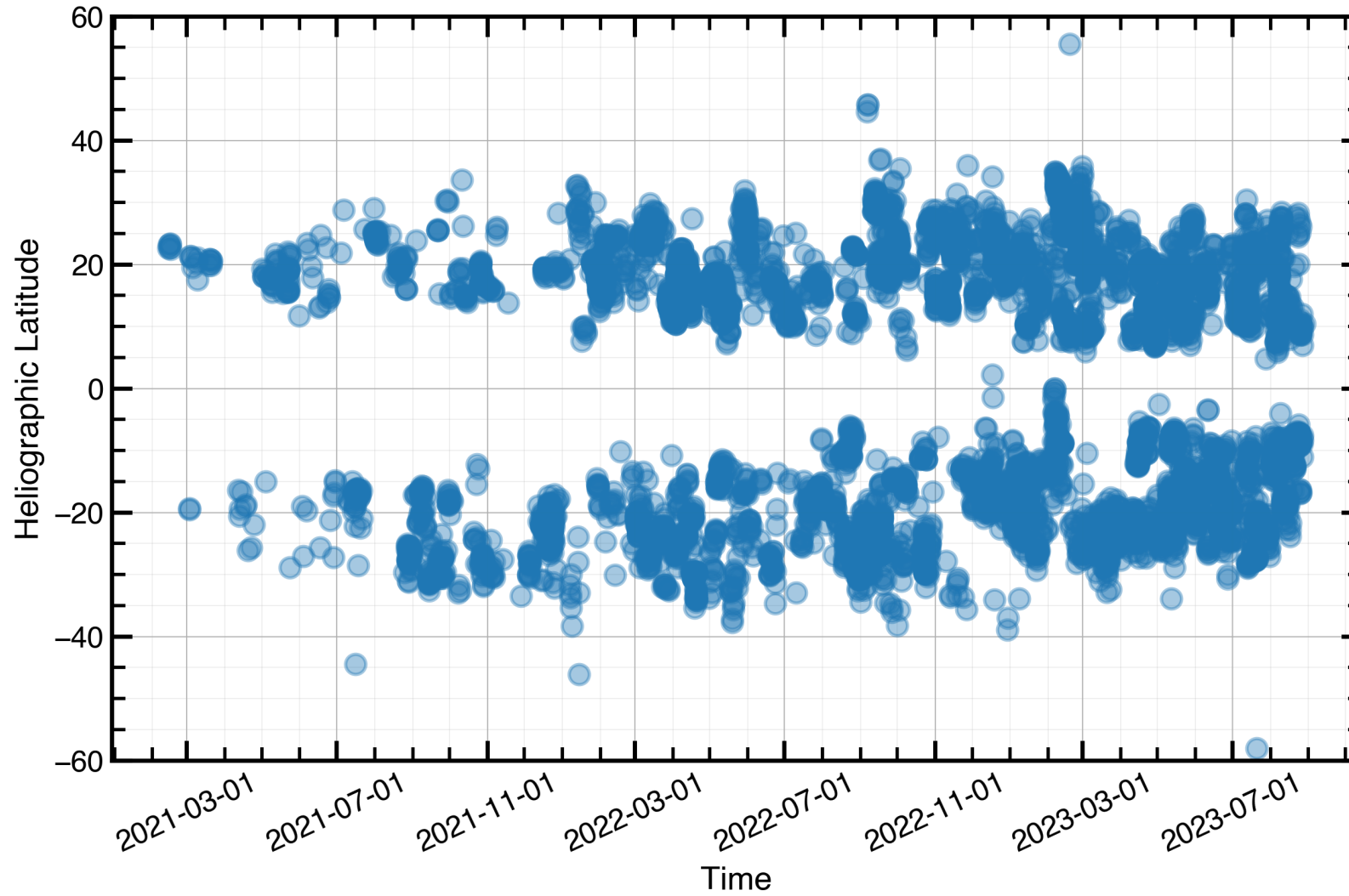
STIX flares : HPC at 1AU

Distribution of STIX flares
transformed to putting Solar Orbiter
at 1AU

More flares "appear" on limb due to
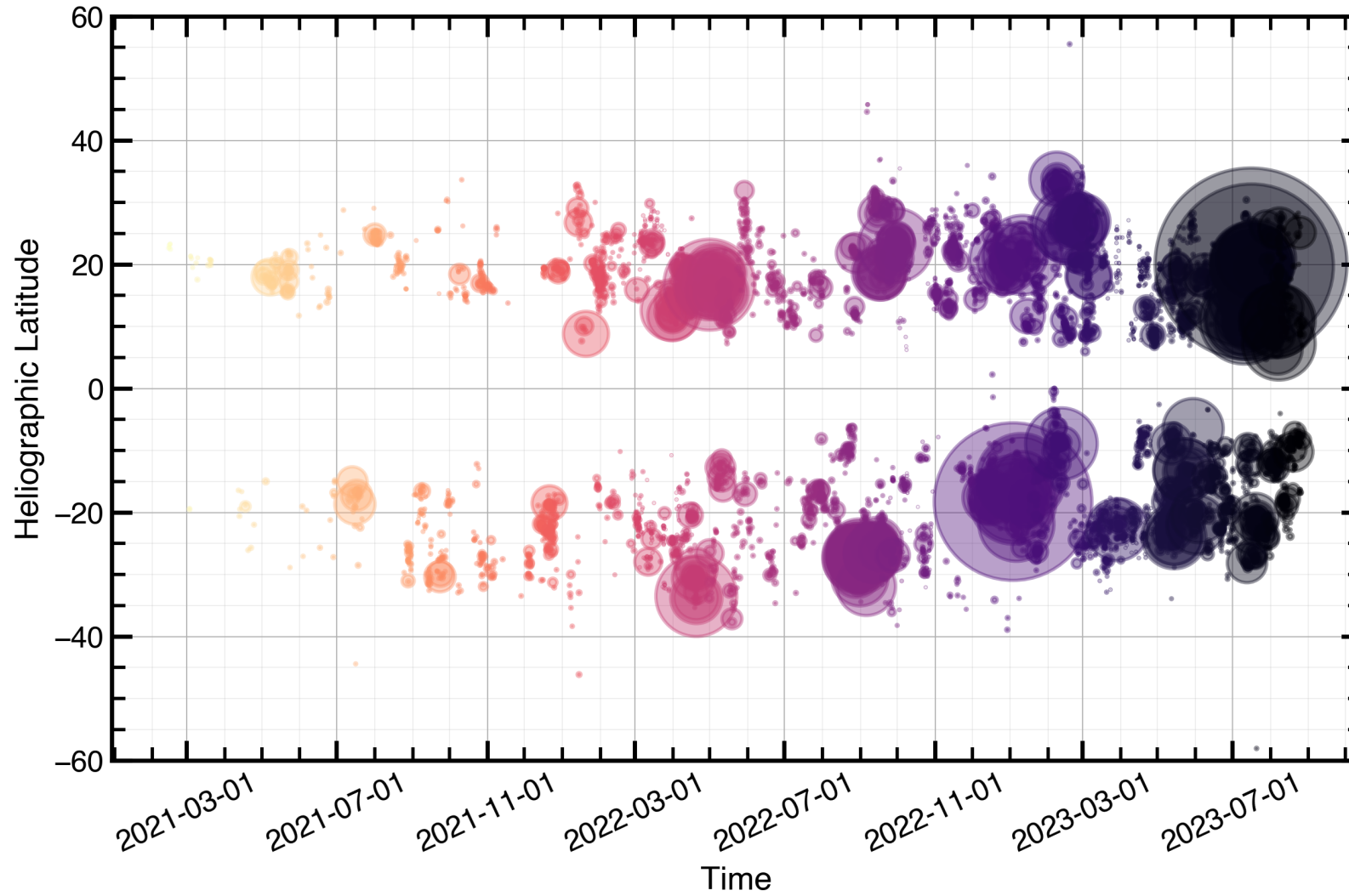solar surface sphere
Similar distrubution to what we see
with GOES/XRS and with RHESSI etc

STIX flares : Butterfly Diagram

STIX flares : Butterfly Diagram

Flare locations in Heliographic Stonyhurst

Flare locations in Heliographic Carrington

STIX flares : Distribution at limb
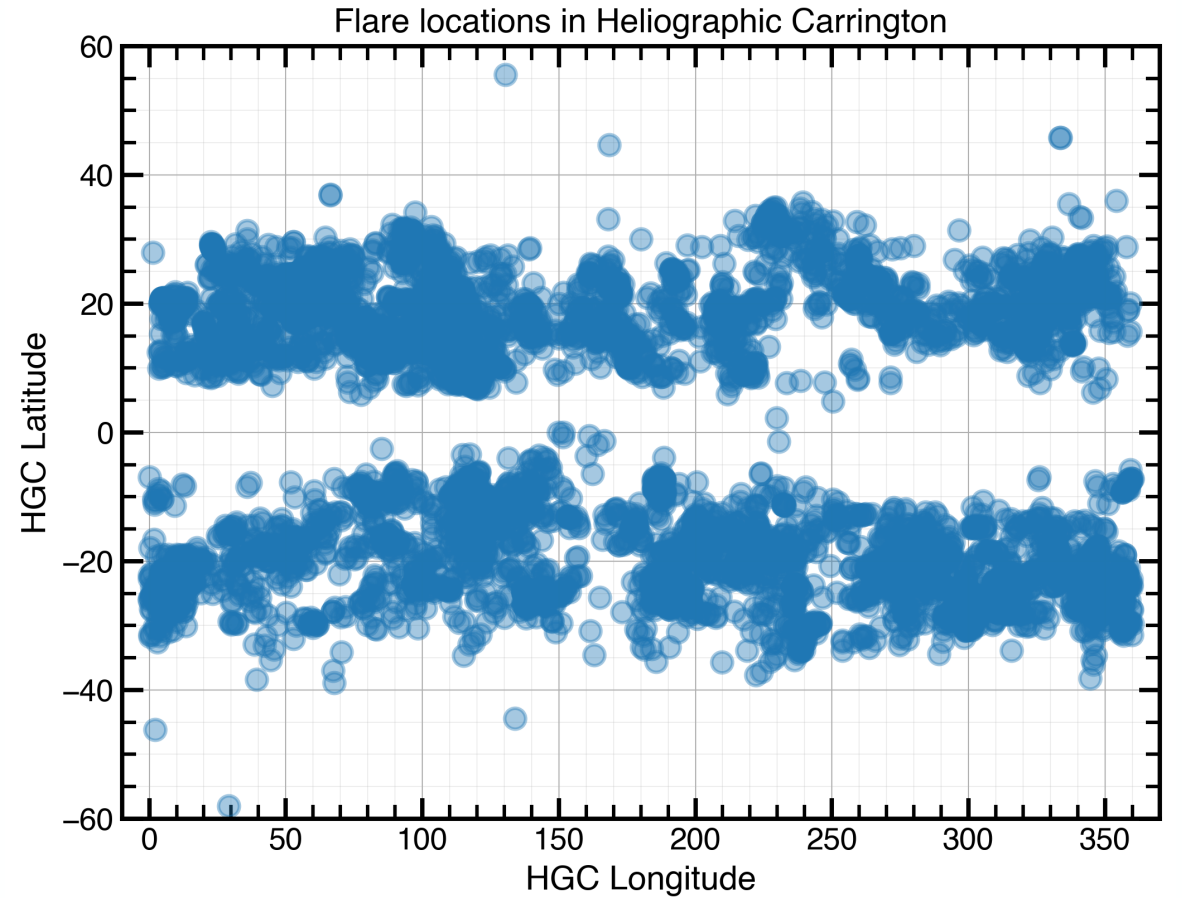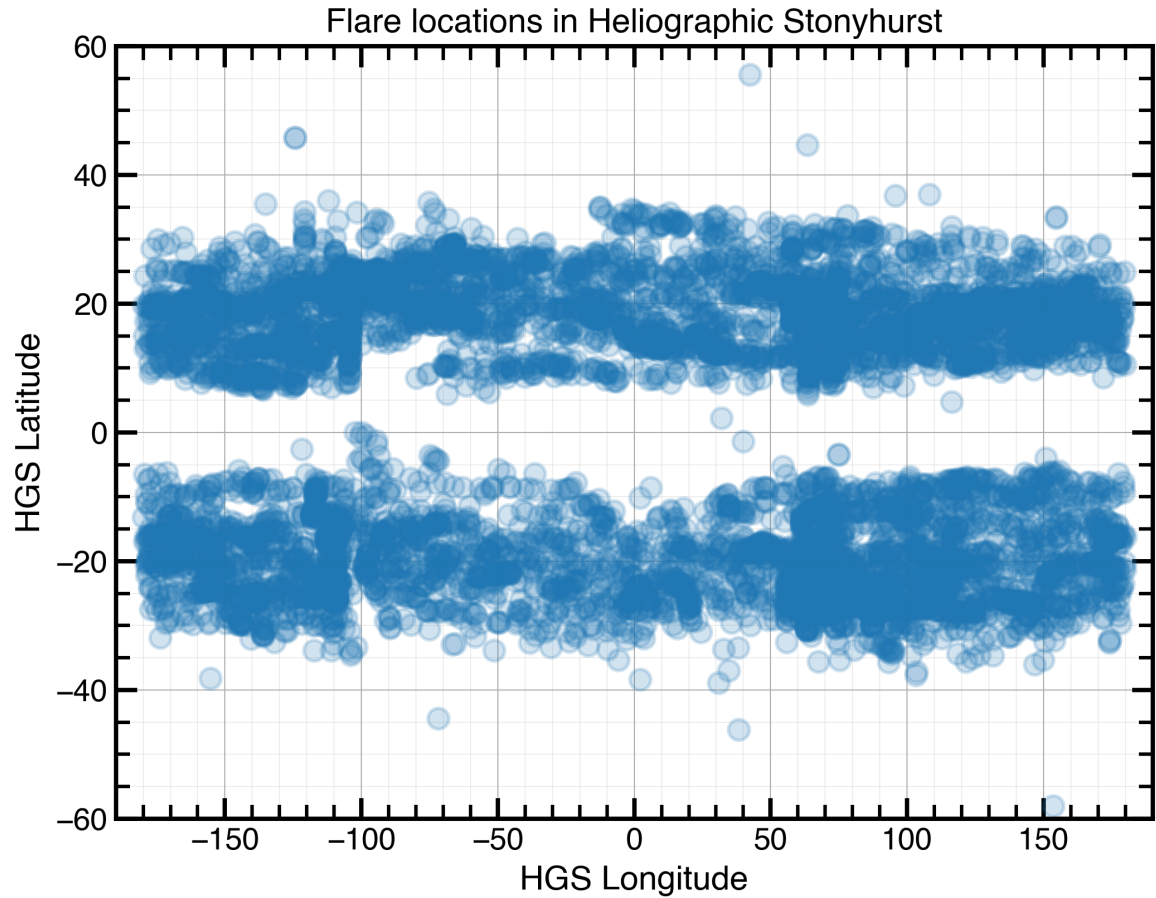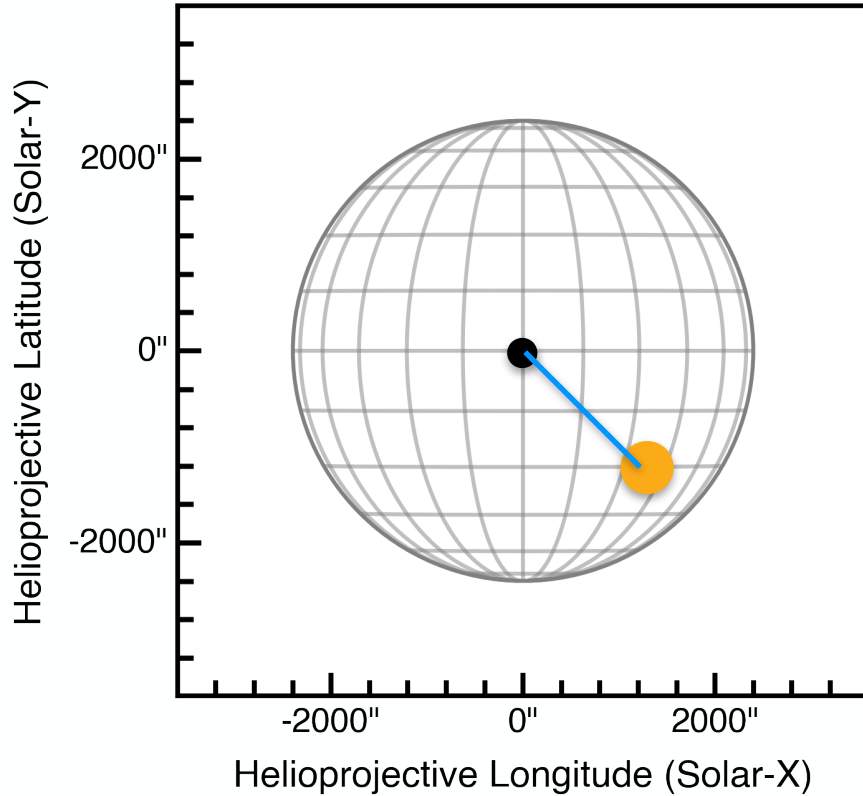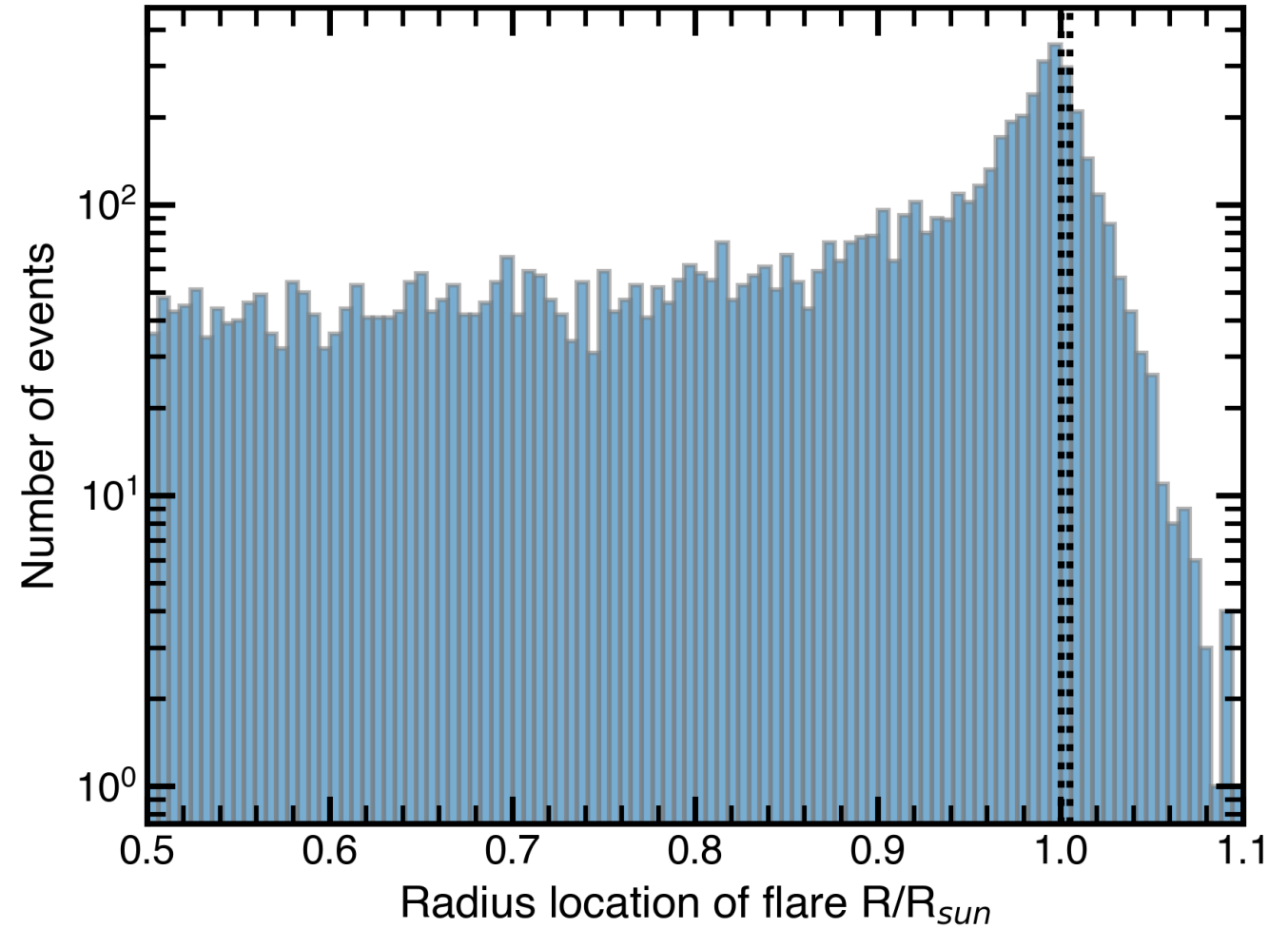
$$R = \sqrt{(x^2 + y^2)}$$

STIX flares : Distribution at limb

$$R = \sqrt{(x^2 + y^2)}$$

FERMI/GBM flare list

STIX peak counts (all channels) (scaled to 1AU) vs Fermi/GBM peak counts
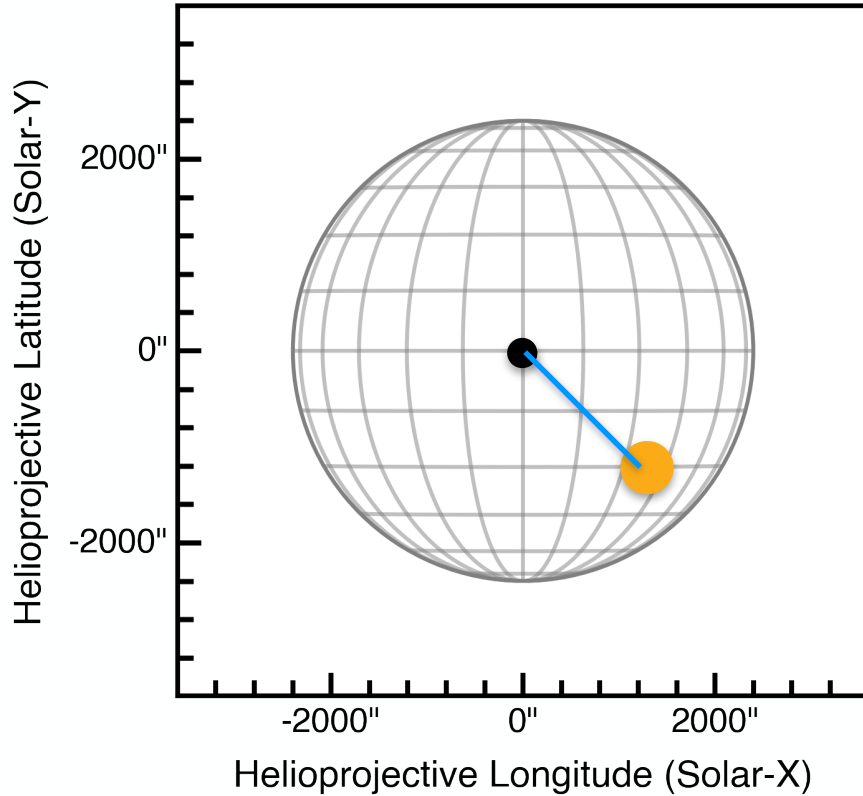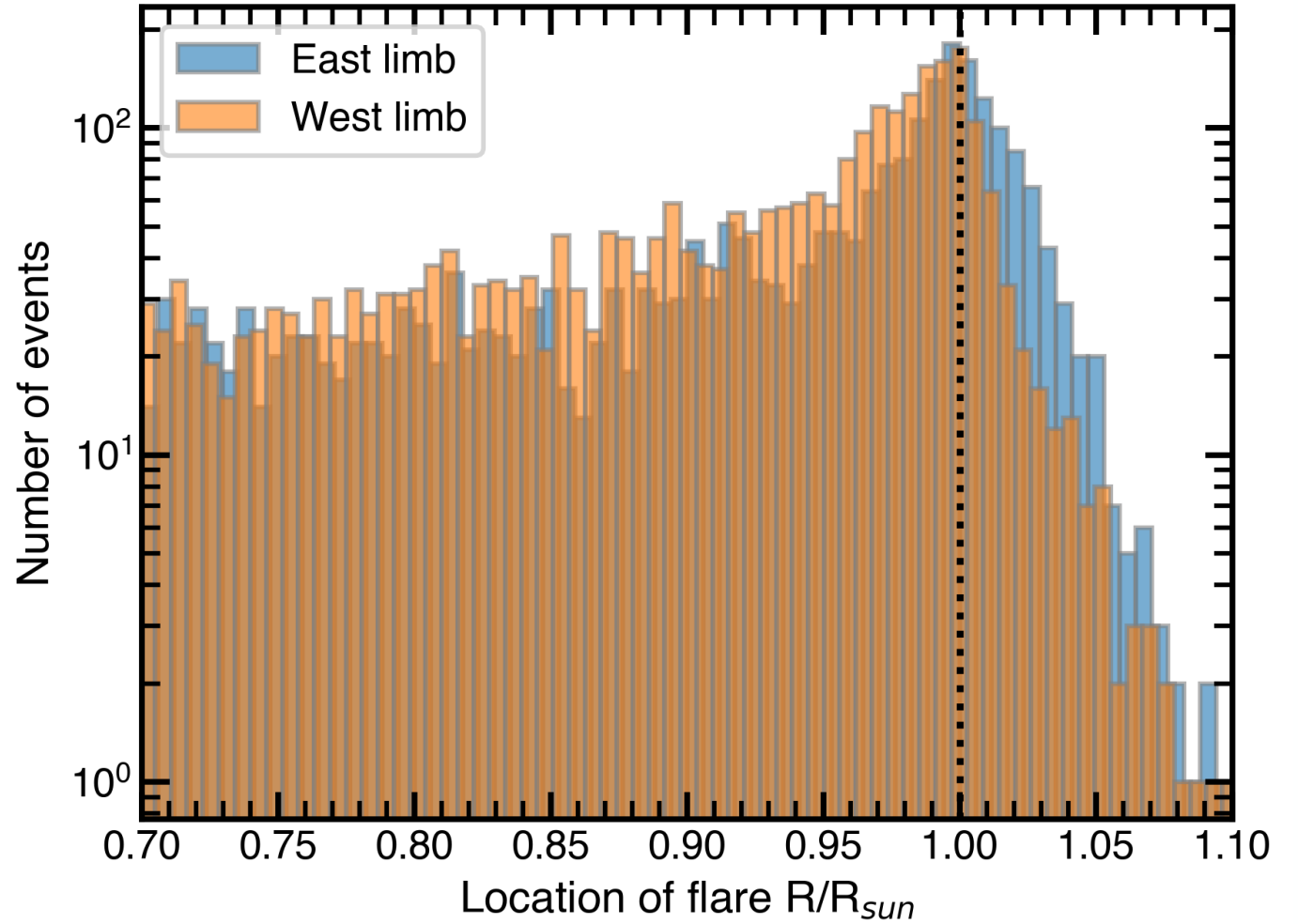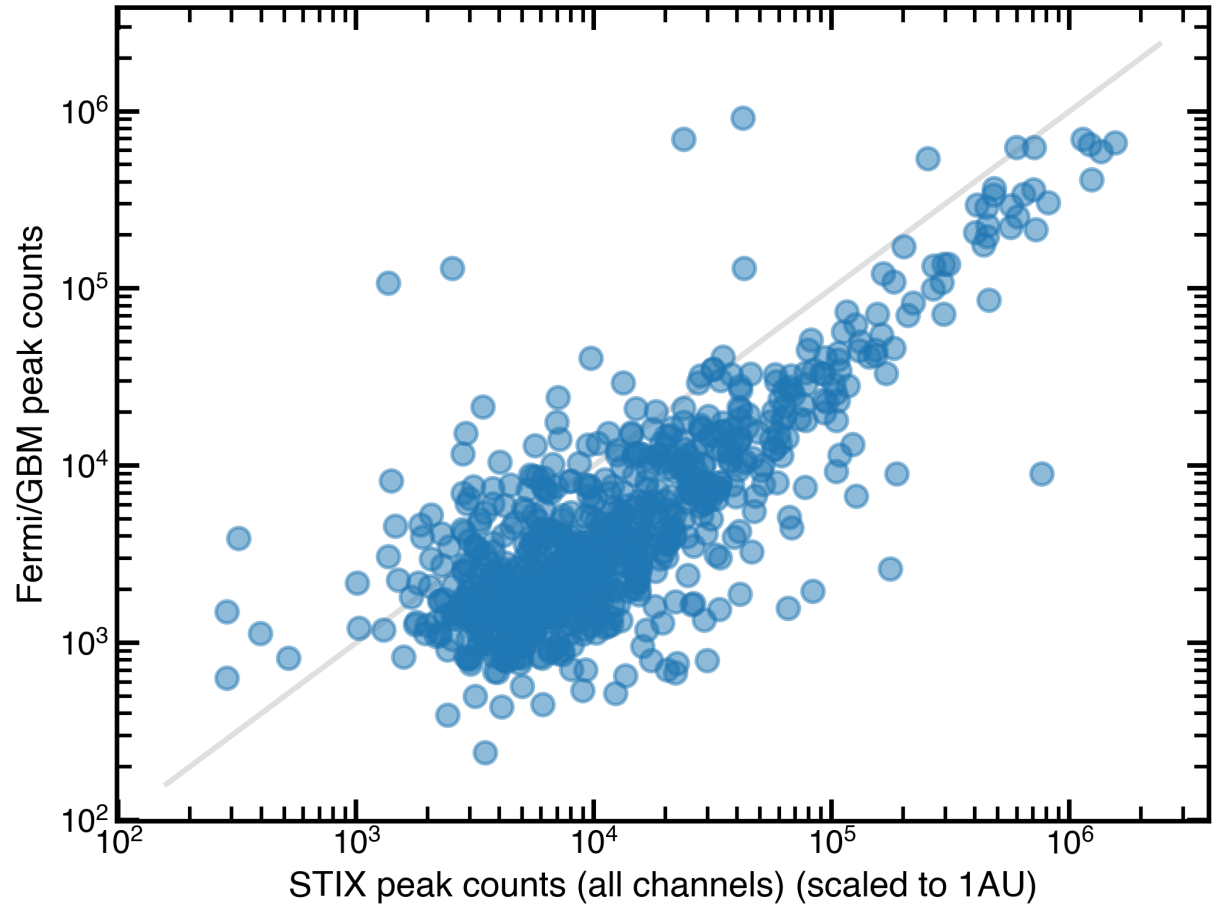
```
Fermi GBM Flare List  (generated  6-Nov-2023 11:07)

Total # flares: 7888  Time range: 12-Aug-2008 00:00:00.000 -  5-Nov-2023 00:00:00.000

   Flare         Start time       Peak      End       Dur     Peak      Total    Sunward        Trigger          RHESSI
                                                        s      c/s      Counts    Detectors                     Flare #

081102_2014   2-Nov-2008 20:14:55 20:15:07 20:16:12    78     3646     172685   n0 n3 n6 n1
081211_1142  11-Dec-2008 11:42:14 11:42:51 11:45:31   197     2408      90103   n5 n1 n3 n4                     8121110
090706_1702   6-Jul-2009 17:02:53 17:03:10 17:05:13   139     2434      45224   n5 n1 n3 n4                     9070609
091025_0216  25-Oct-2009 02:16:59 02:21:29 02:35:33  1114     3859     553653   n5 n1 n3 n4                     9102507
091026_2246  26-Oct-2009 22:46:41 22:49:41 22:51:56   315     7237     187108   n5 n1 n3 n4
091027_0152  27-Oct-2009 01:52:06 01:53:08 01:55:23   197     9016     163409   n5 n1 n3 n4
091027_1014  27-Oct-2009 10:14:23 10:16:46 10:24:37   614     1931     160397   n5 n1 n3 n0                     9102732
091027_1309  27-Oct-2009 13:09:51 13:10:48 13:13:07   197     3472      87347   n0 n3 n1 n6
091027_1936  27-Oct-2009 19:36:39 19:37:14 19:40:56   257     8006     522731   n0 n3 n1 n6   bn091027817
091210_1056  10-Dec-2009 10:56:24 10:57:13 10:59:20   176    19291    1003601   n5 n1 n3 n4   bn091210456
091216_0125  16-Dec-2009 01:25:13 01:25:29 01:55:43  1831     4177     600378   n5 n1 n3 n0                     9121601
091216_0836  16-Dec-2009 08:36:20 08:36:50 08:37:29    69     6875     203286   n0 n3 n1 n5                     9121619
091216_1252  16-Dec-2009 12:52:46 12:56:19 13:17:45  1499     5725     824575   n5 n4 n2 n1                     9121628
091218_1852  18-Dec-2009 18:52:30 18:54:10 19:01:34   543    48417    5589938   n5 n4 n2 n1   bn091218787
091219_0012  19-Dec-2009 00:12:49 00:13:50 00:17:23   274    29357     554041   n0 n6 n3 n1                     9121901
091221_0921  21-Dec-2009 09:21:11 09:21:52 09:27:24   373     2475     130561   n0 n3 n1 n6
091222_0453  22-Dec-2009 04:53:08 04:56:37 05:03:30   622    39943    7182012   n3 n1 n0 n5   bn091222203       9122206
100102_1415   2-Jan-2010 14:15:23 14:15:31 14:27:53   750     4575     257898   n5 n4 n2 n1
100104_0339   4-Jan-2010 03:39:16 03:39:48 03:42:03   168     9254     112310   n5 n1 n3 n4
100117_2224  17-Jan-2010 22:24:27 22:26:58 22:38:51   864     6989     474285   n5 n4 n2 n1
100118_1956  18-Jan-2010 19:56:41 19:57:58 20:01:52   311     3481     166591   n5 n4 n2 n1                    10011821
100118_2038  18-Jan-2010 20:38:23 20:41:52 21:10:53  1950     2601     688418   n5 n4 n2 n1                    10011827
100119_0834  19-Jan-2010 08:34:47 08:39:55 08:46:40   713    14954    1034931   n5 n1 n3 n4                    10011912
100119_1308  19-Jan-2010 13:08:25 13:08:29 13:33:36  1511    53429    6318626   n5 n1 n3 n0                    10011915
100119_1410  19-Jan-2010 14:10:03 14:17:54 14:26:10   967     3378     307788   n5 n1 n3 n4
100119_1745  19-Jan-2010 17:45:59 17:48:26 17:48:34   156     4727      86267   n3 n1 n0 n5
```

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FERMI/GBM flare list

What new science can we do with this - Fermi/GBM STIX flares?

Flare

Solar Orbiter

Fermi/GBM

Where should we put the STIX-Fermi/GBM list?
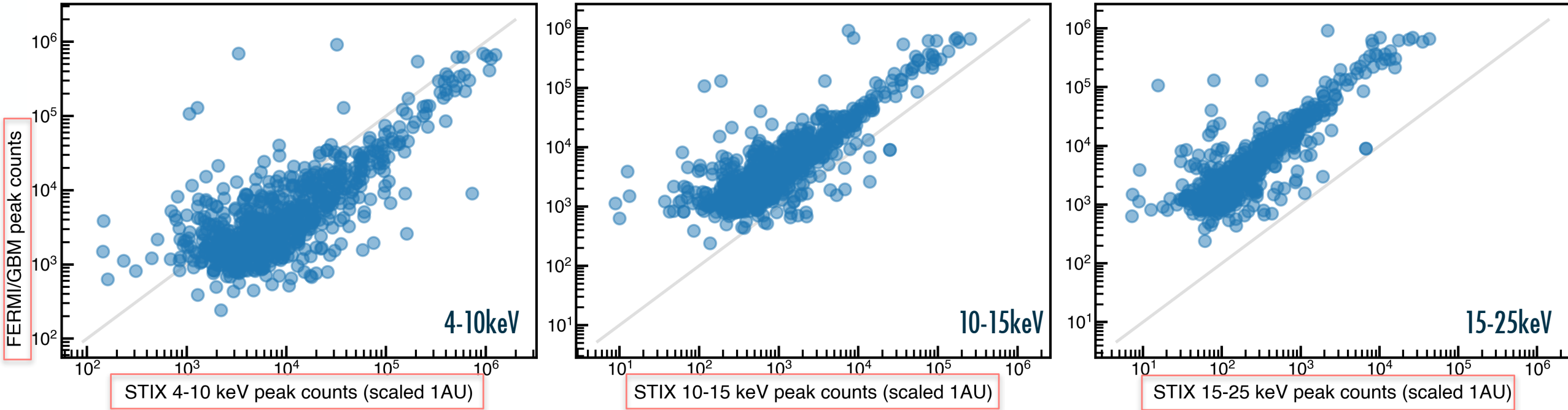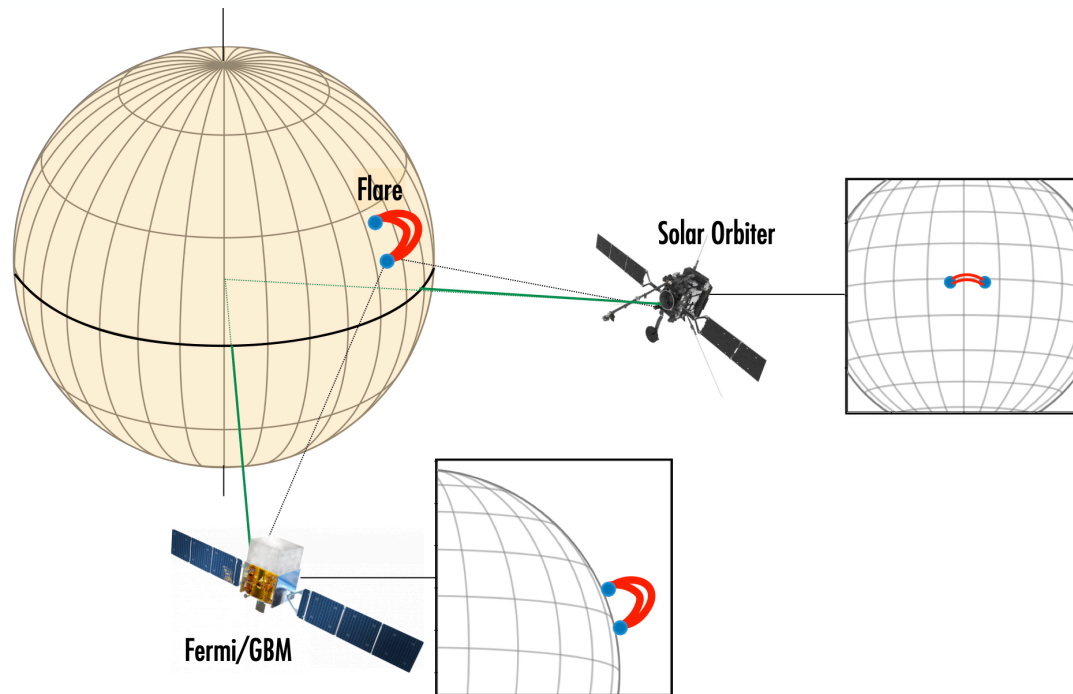
Occulted flares

- Can now do statistics with flares that were seen on limb from Fermi/STIX and on disk with STIX/Fermi.

Directivity studies (or tests)

- Now have many flares along Sun-Earth line for calibration - good for testing GBM pile-up
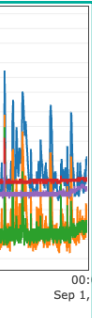- Can try find some good candidates for HXR directivity

Track flaring active regions over rotations - combine STIX + GOES/XRS

AIA 171Å

EUI/FSI 174Å

GOES/XRS

Flaring rates from STIX

From Hannah
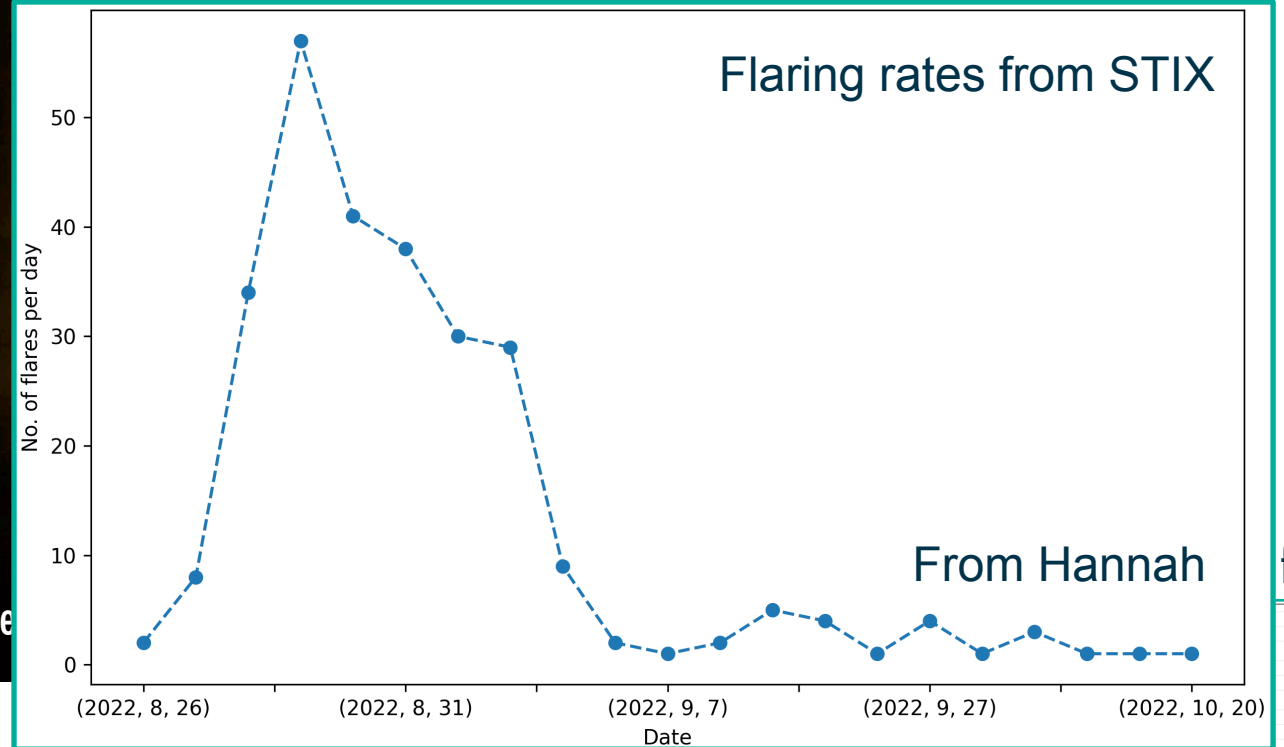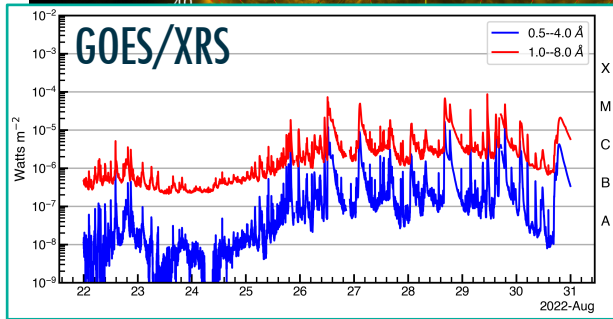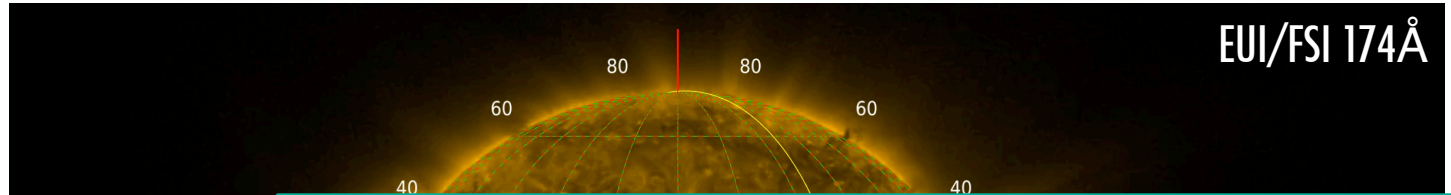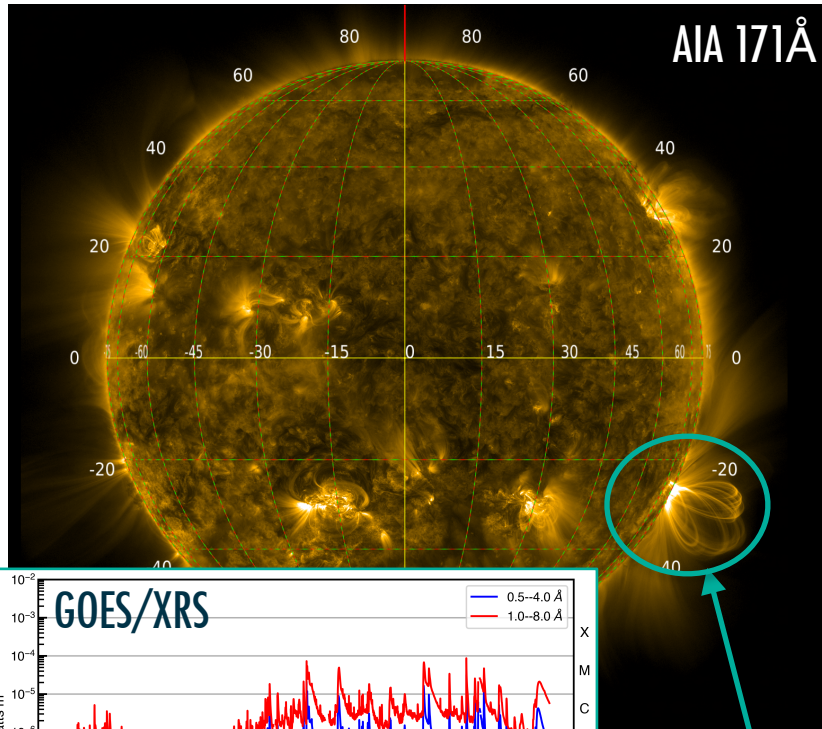
Solar Orbiter View
2022-08-29T22:01:00.264

Active region rotating off disk from Earth view

Rotating into view of Solar Orbiter/EUI

flares

Earth   Sun

SolO

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Updates and Plan
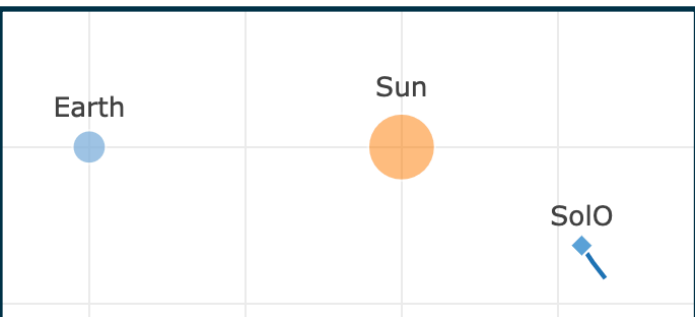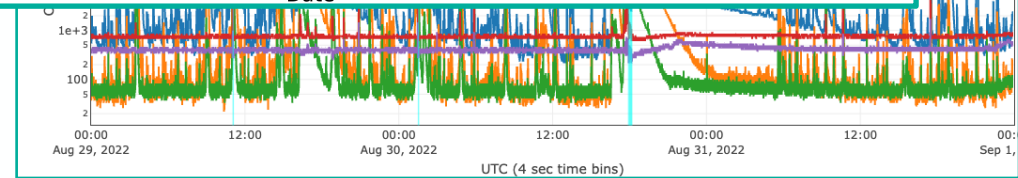
- STIX flare list with locations important - allows us to do new science

- What we can do?

  - should it also live on the Heliophysics Event Knowledgebase (HEK)? How do we deal with different coordinate frames? Carrrington coordinates?

  - How to run automatically? Event month? Wait for data to come down? Where should it live?

  - What else do people want? What do you need a flare list for?

  - Should think about "standards" for flare lists in general as a community (similar to the idea of SOL2002-02-02), will help compare across instruments

- In particular - what can we do with other Solar Orbiter instruments?
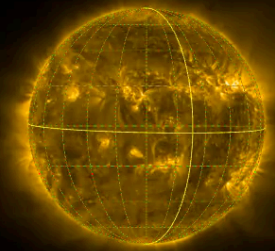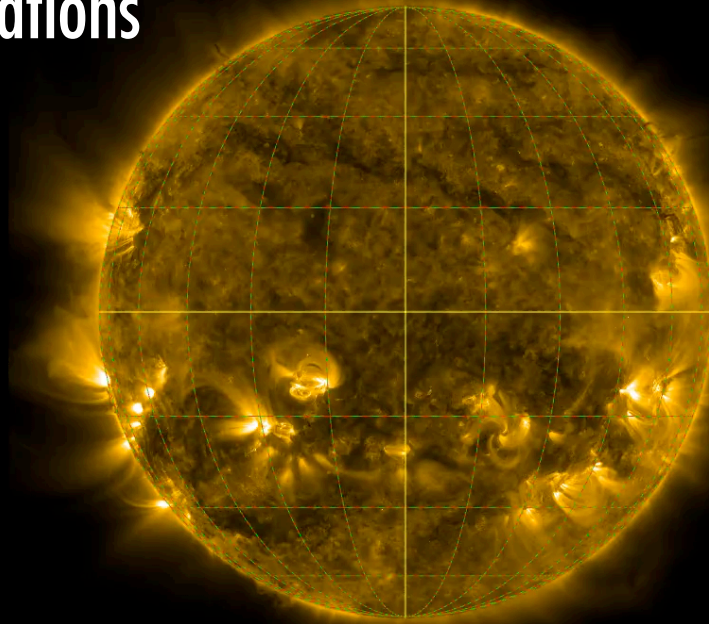
A girl can dream....

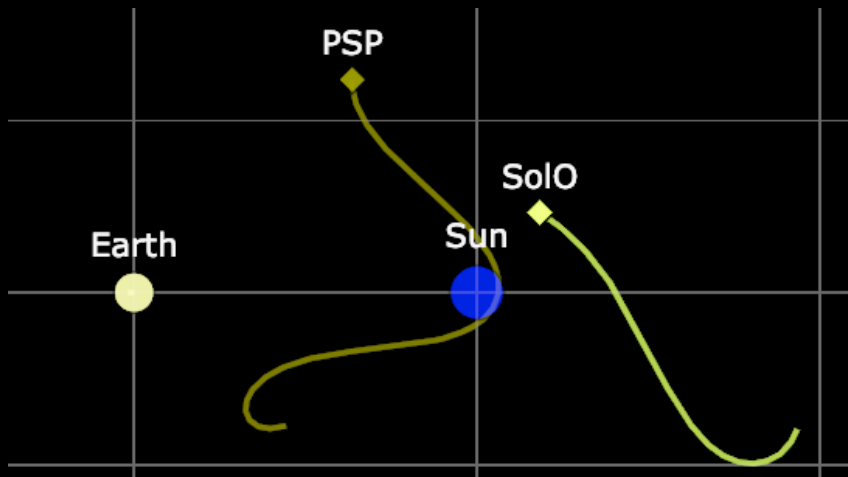# A girl can dream....

A girl can dream….

The 3D Sun : Labelling Events + Locations

- Need event lists for coordinate system in 3D - e.g. indexing events not solely on Earth side

    - Field of view of observations
    - Flares, eruptions
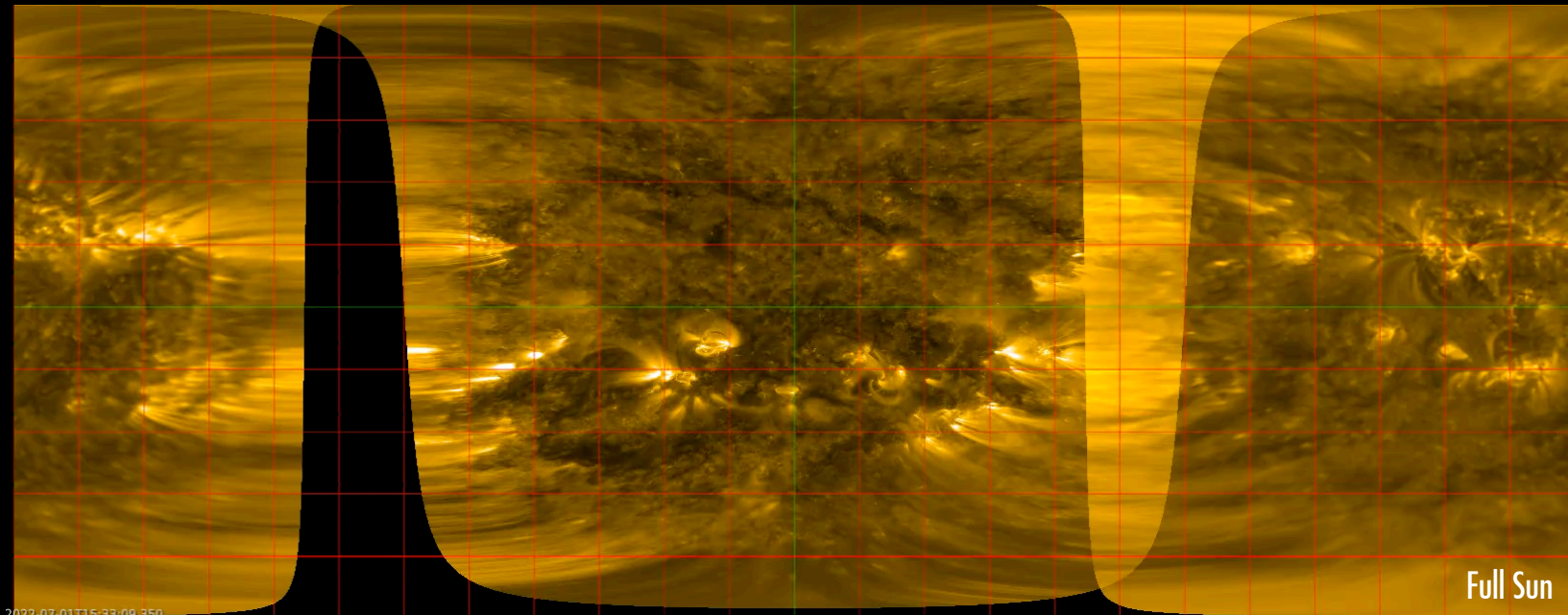   - Active regions
    - Filaments etc

AIA 171Å

SolO/EUI 174Å

Example July - Oct 2022

2022-07-01T15:33:09.350

Full Sun