The evolution of an SEP event in the inner heliosphere

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&

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PUNCH 5 Meeting

Boulder, CO June 20-21, 2024

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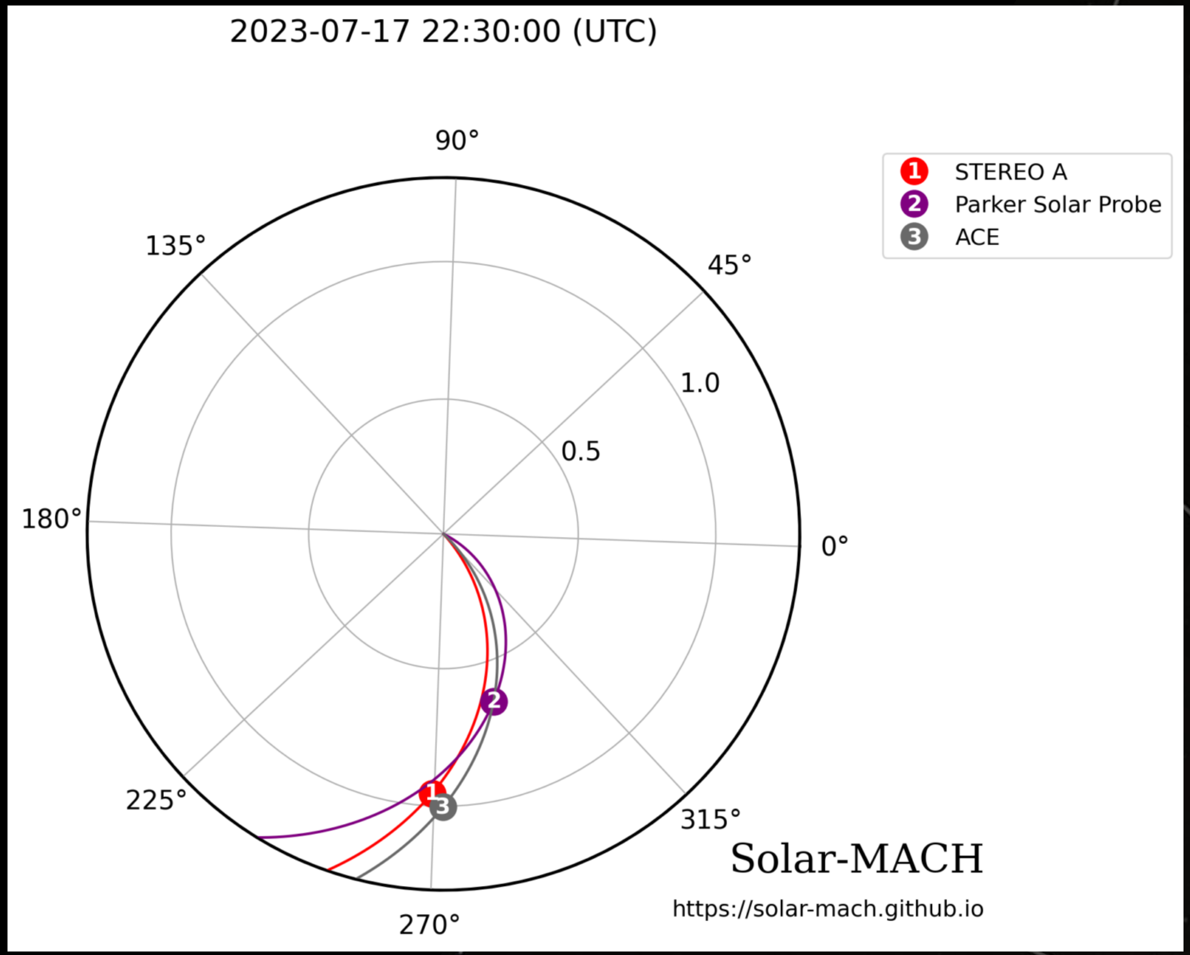
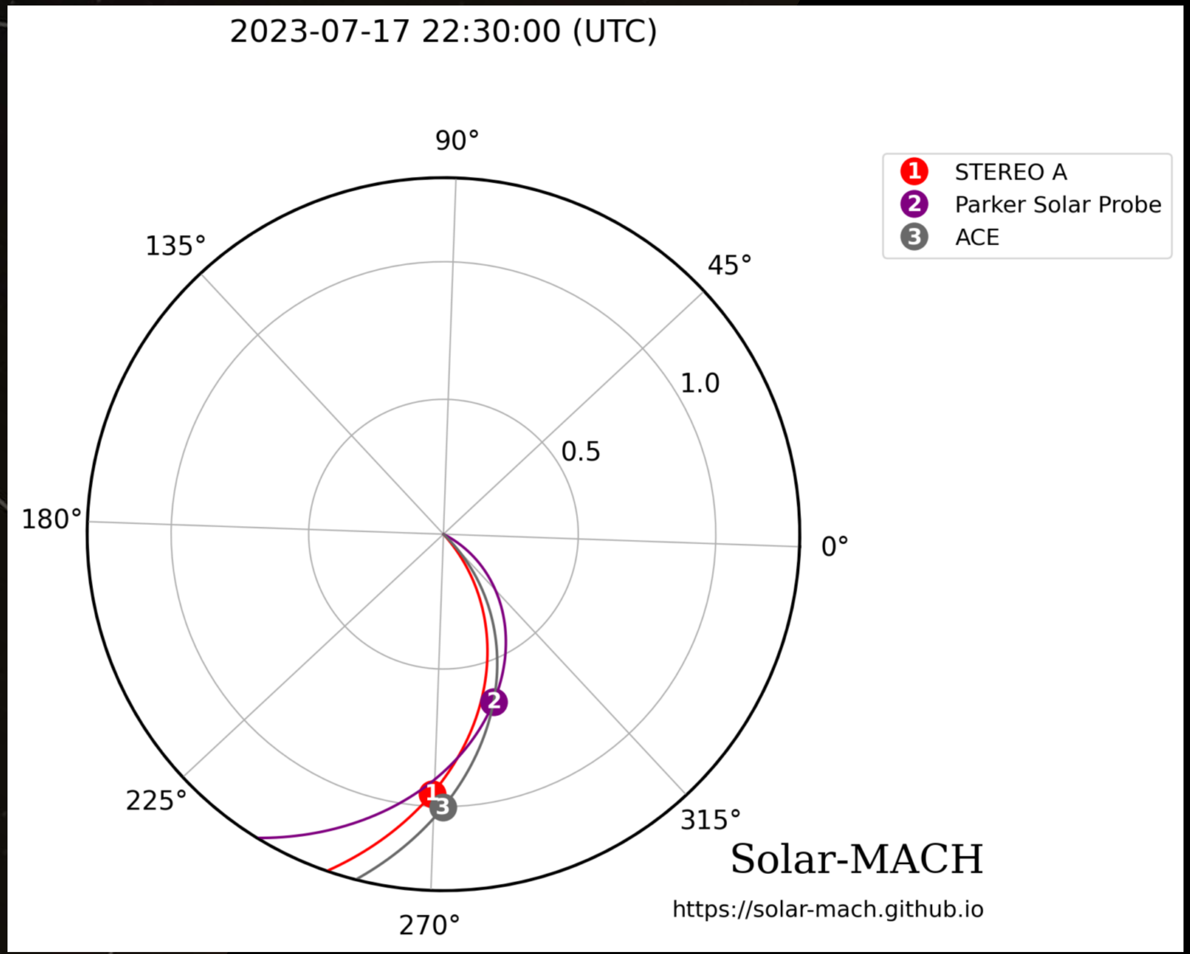
Spacecraft configuration

Pre-storm connection



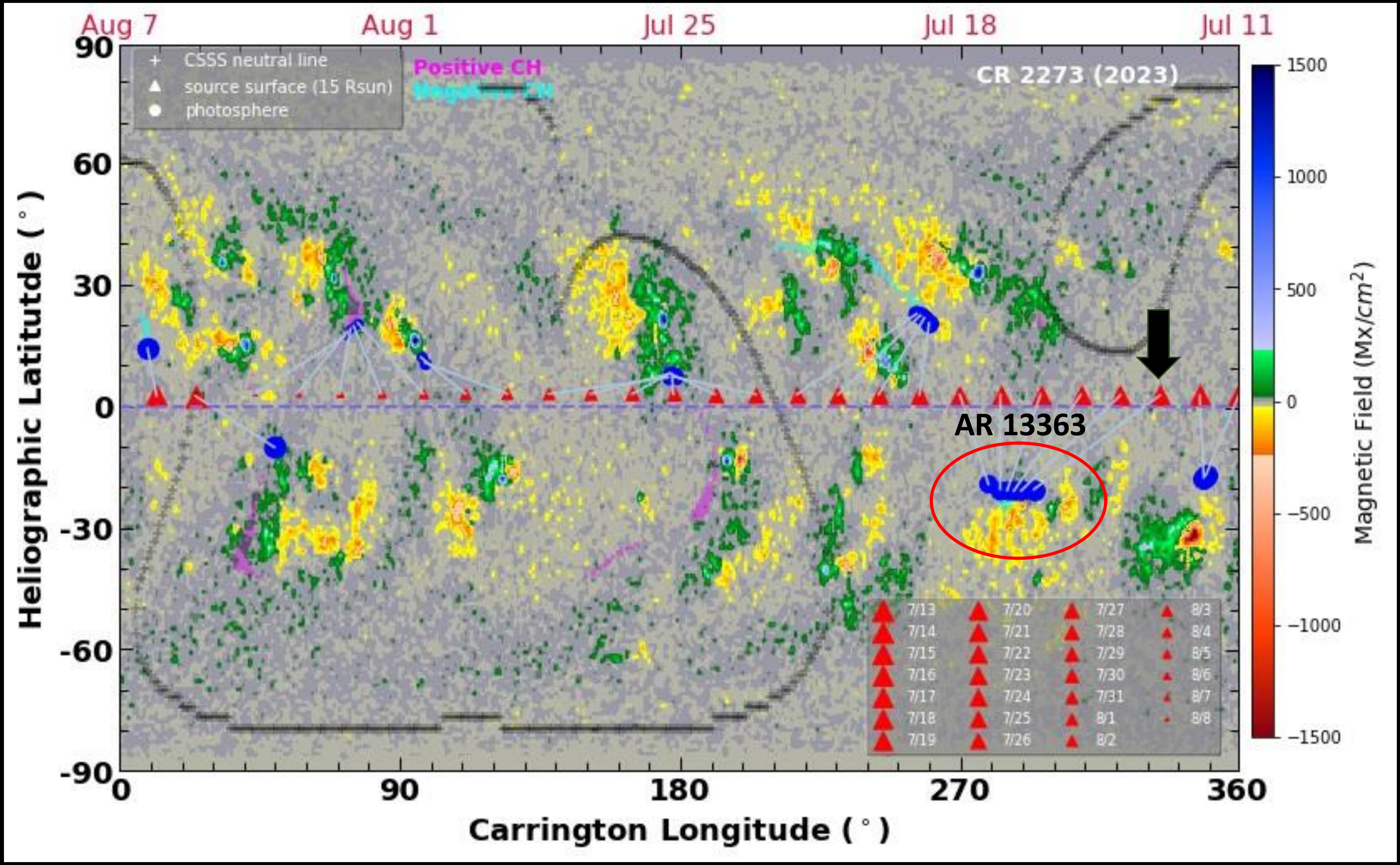
	ST-A	PSP	ACE
Carrington longitude [°]	269.5	288.7	271.9
Carrington latitude [°]	4.4	3.2	4.5
Heliocent. distance [AU]	0.96	0.65	1.01
Longitud. separation to Earth longitude [°]	-2.5	16.7	-0.1
Latitud. separation to Earth latitude [°]	-0.1	-1.4	-0.0
Solar wind speed [km/s]	531	343	535
Magnetic footpoint Carrington longitude [°]	314.3	335.6	318.7

Post-storm connection

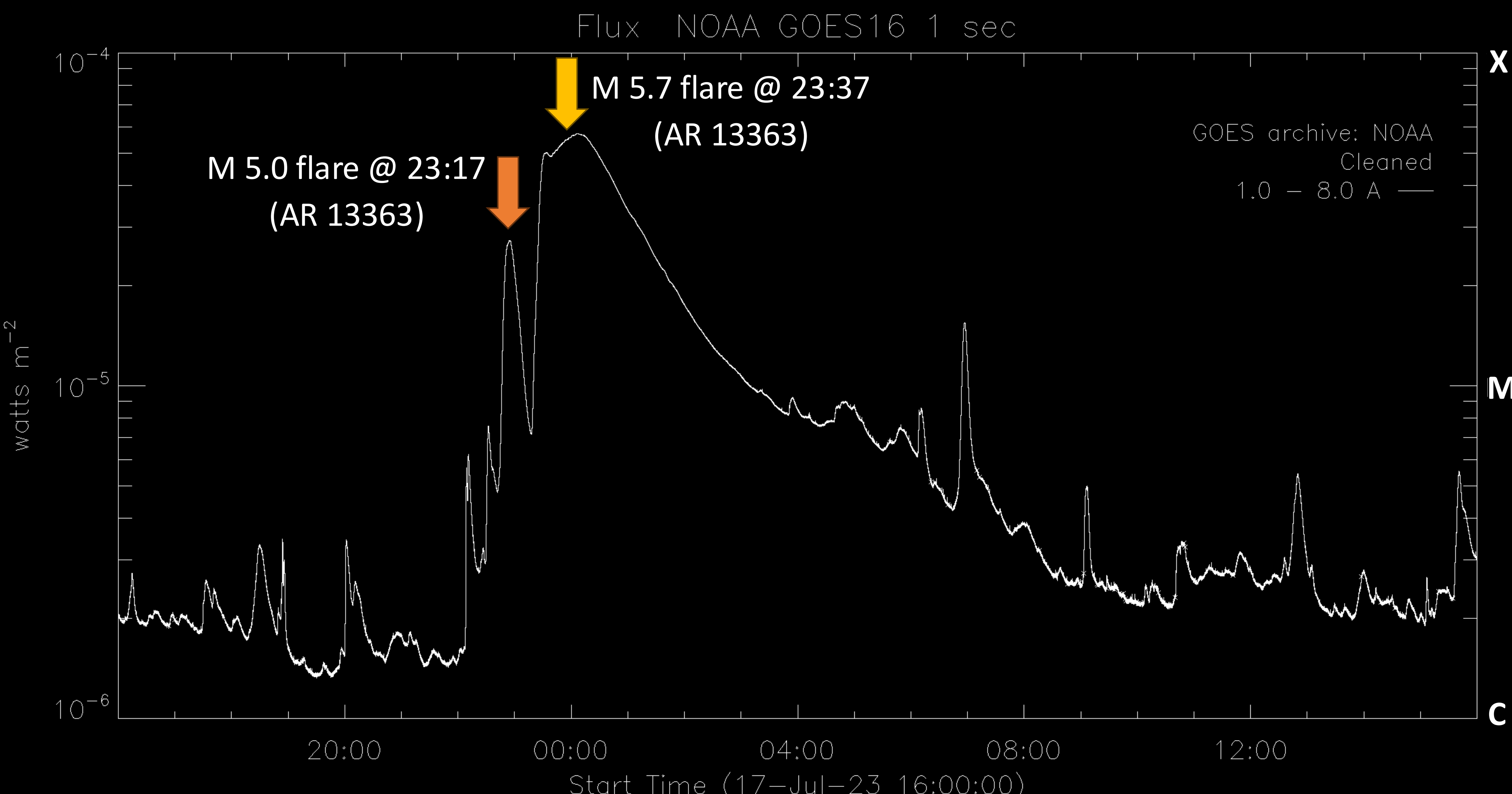


	ST-A	PSP	ACE
Carrington longitude [°]	252.0	270.9	254.3
Carrington latitude [°]	4.6	3.2	4.7
Heliocent. distance [AU]	0.96	0.66	1.01
Longitud. separation to Earth longitude [°]	-2.4	16.5	-0.1
Latitud. separation to Earth latitude [°]	-0.1	-1.4	-0.0
Solar wind speed [km/s]	390	510	426
Magnetic footpoint Carrington longitude [°]	313.0	303.1	313.0

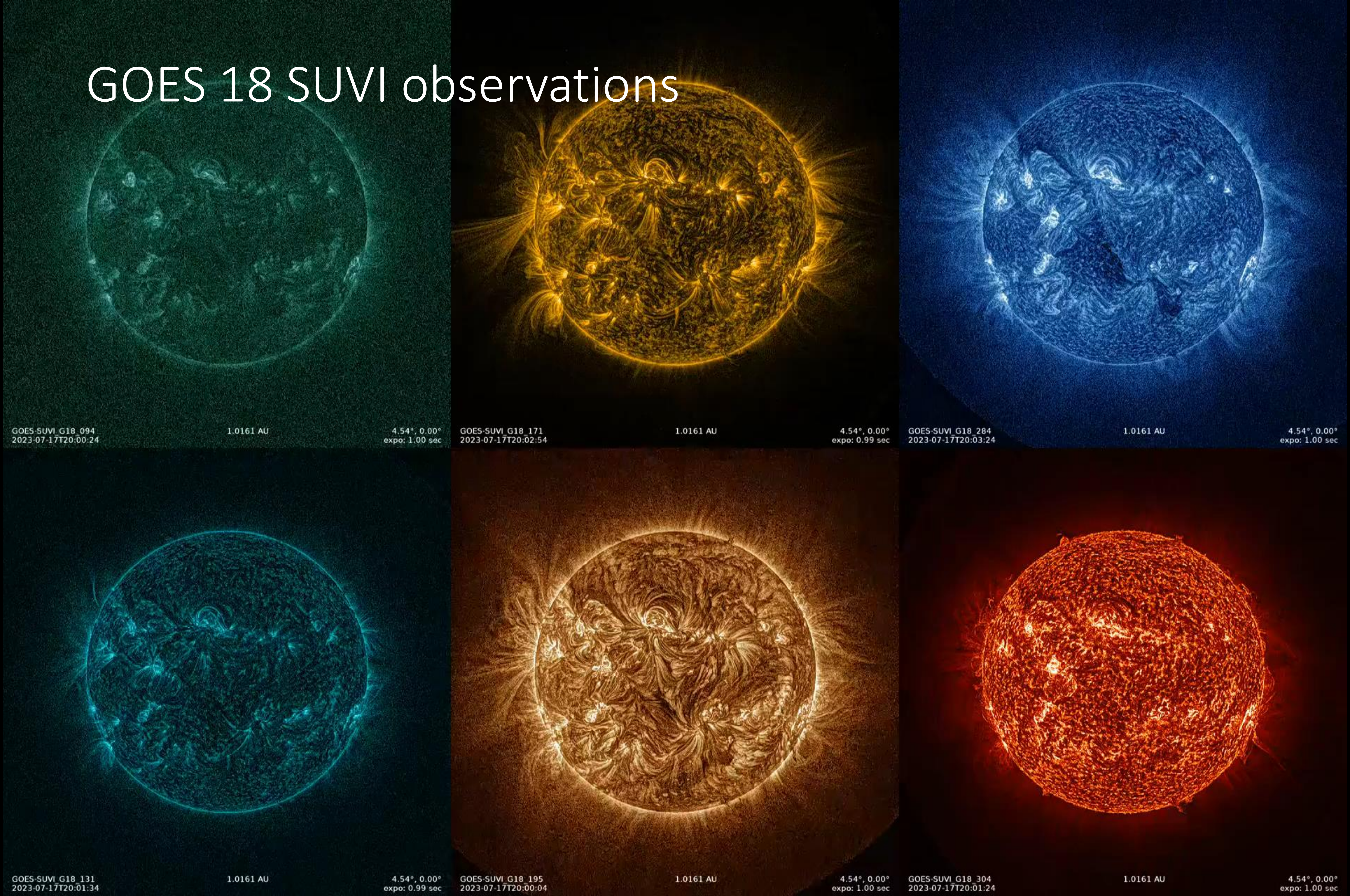
PFSS model connectivity to AR 13363



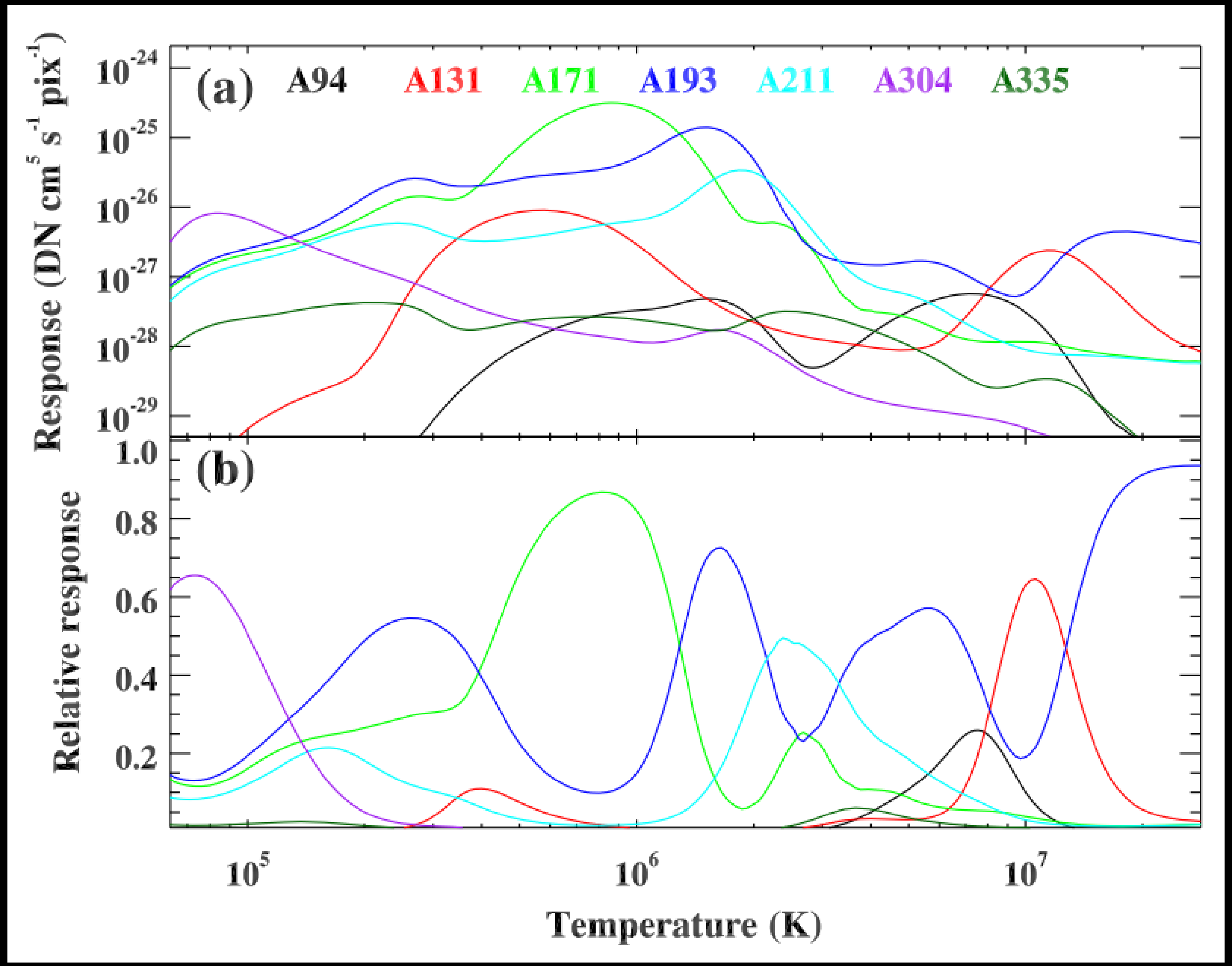
GOES 16 X-ray flux



GOES 18 SUVI observations

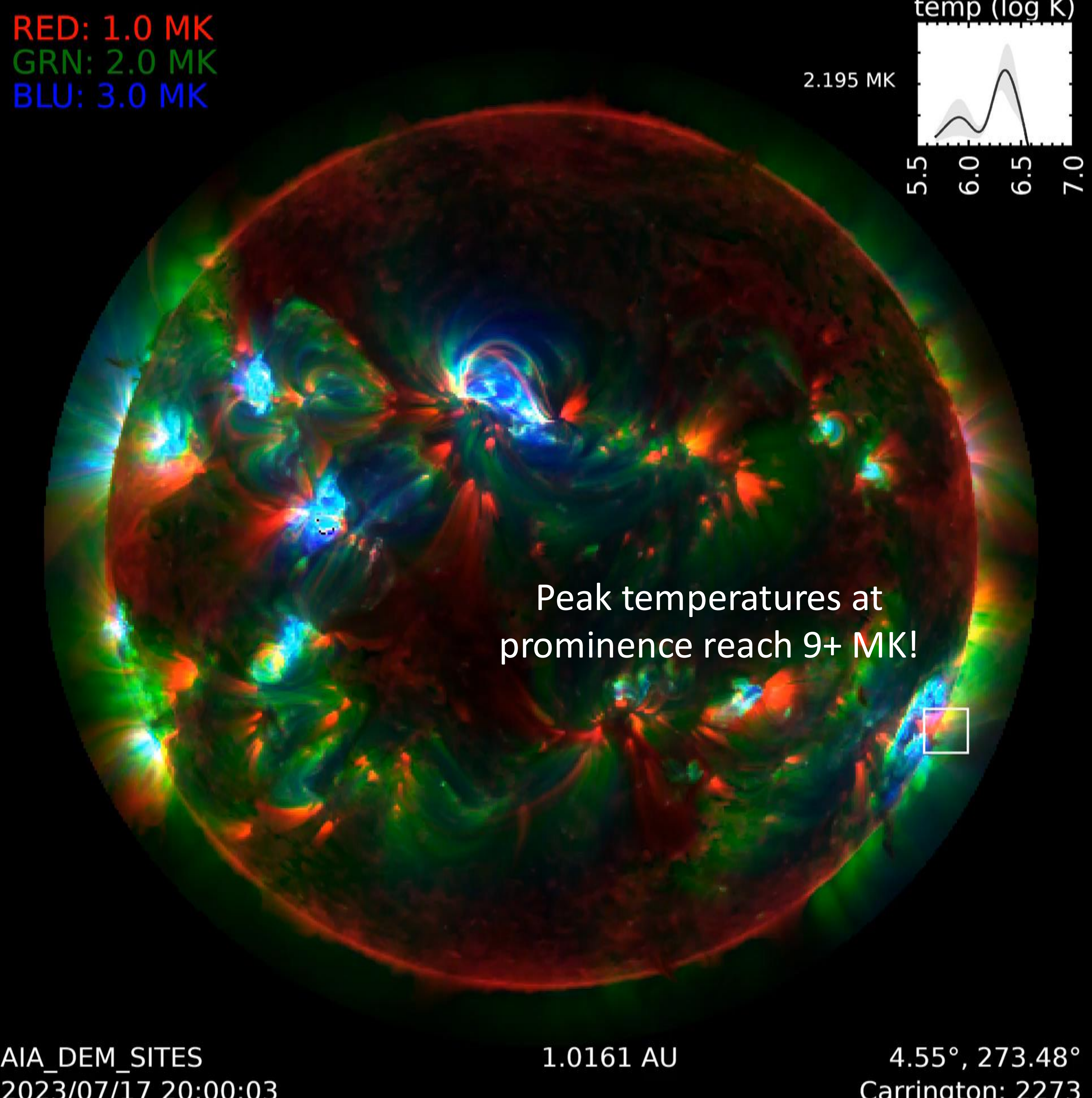


AIA DEM temperature map



Combine 3 consecutive binned images of 1024x1024 data in all 6 channels

Result is 6-min average temperature



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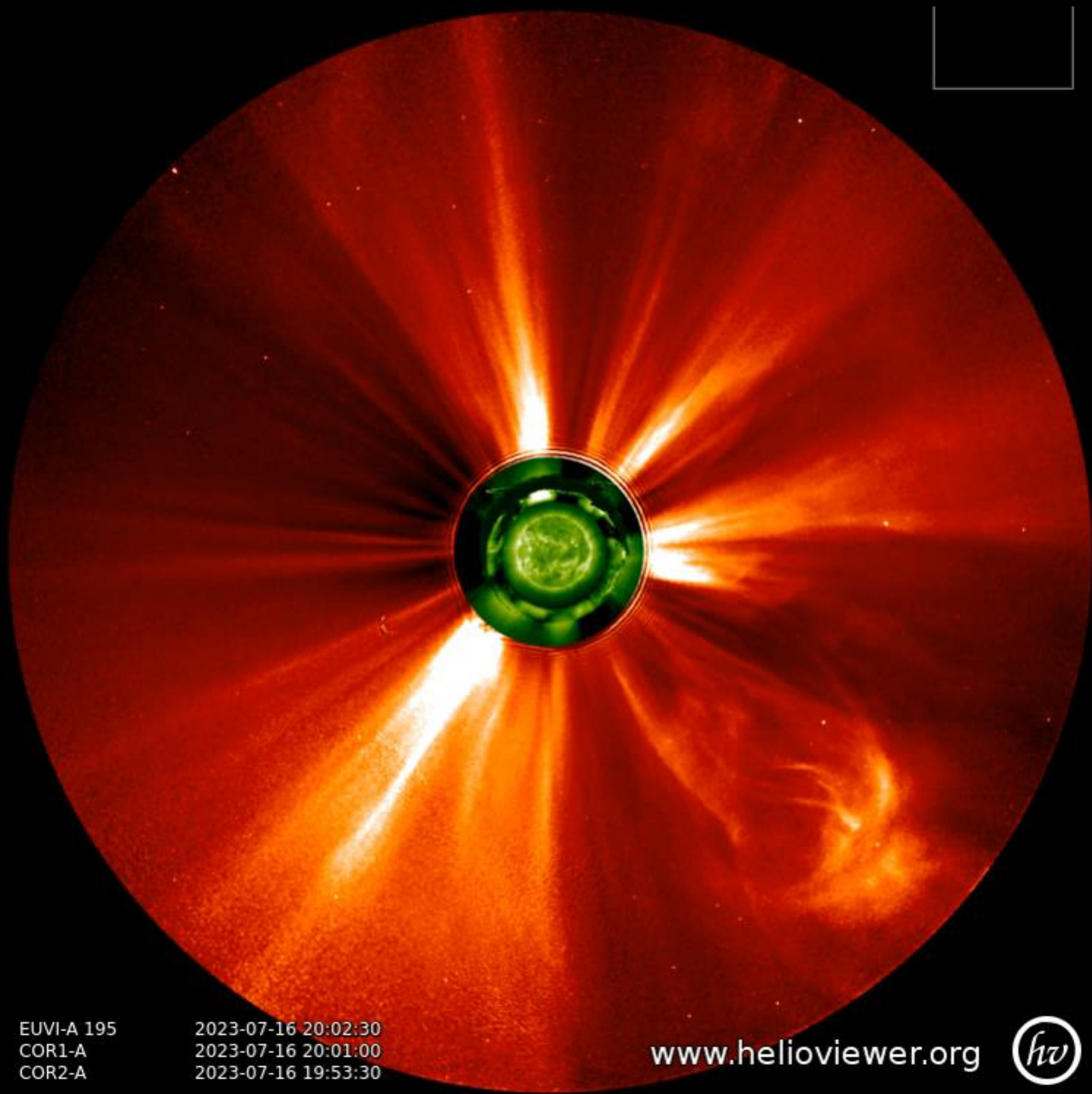
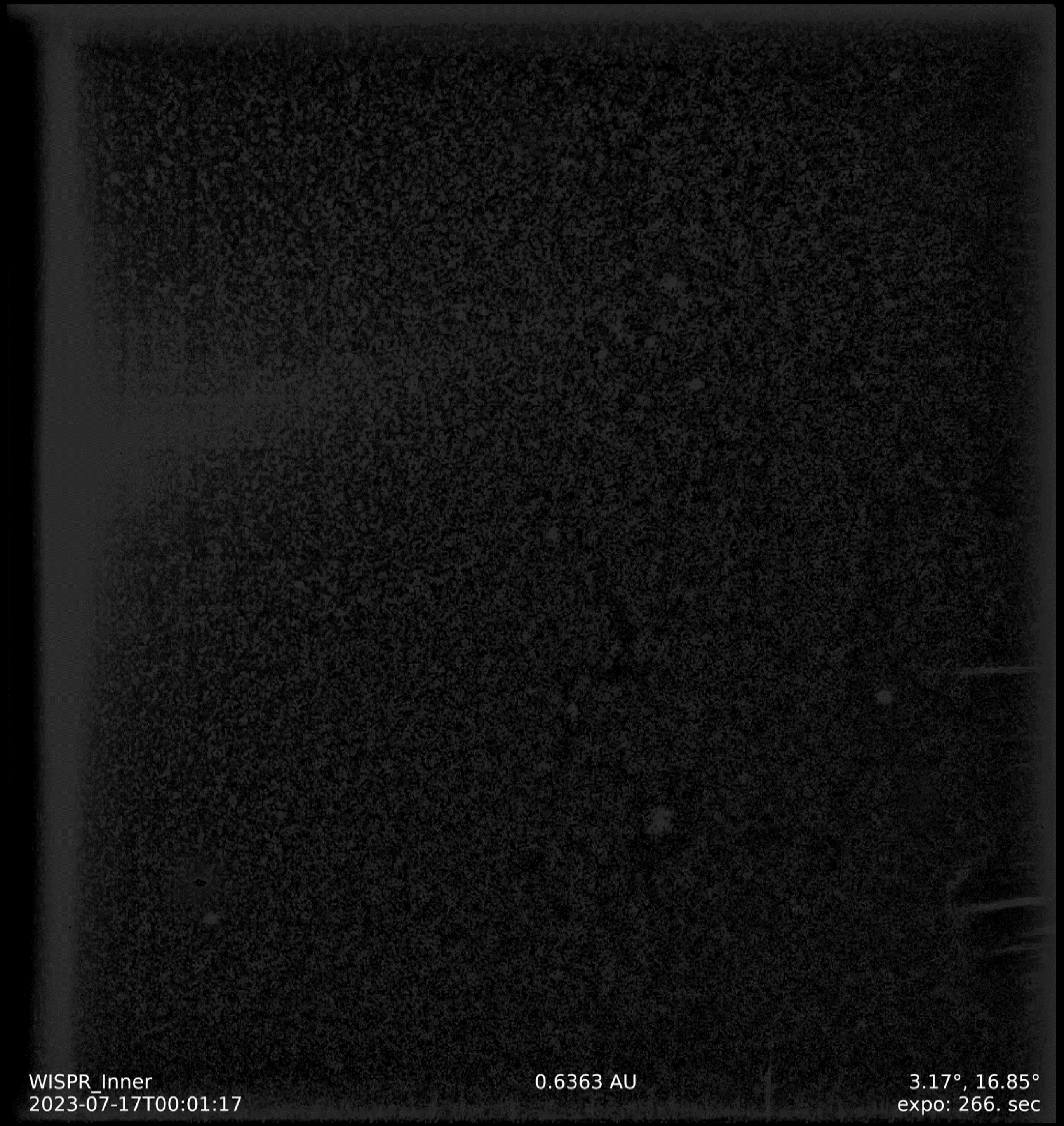
CME propagation

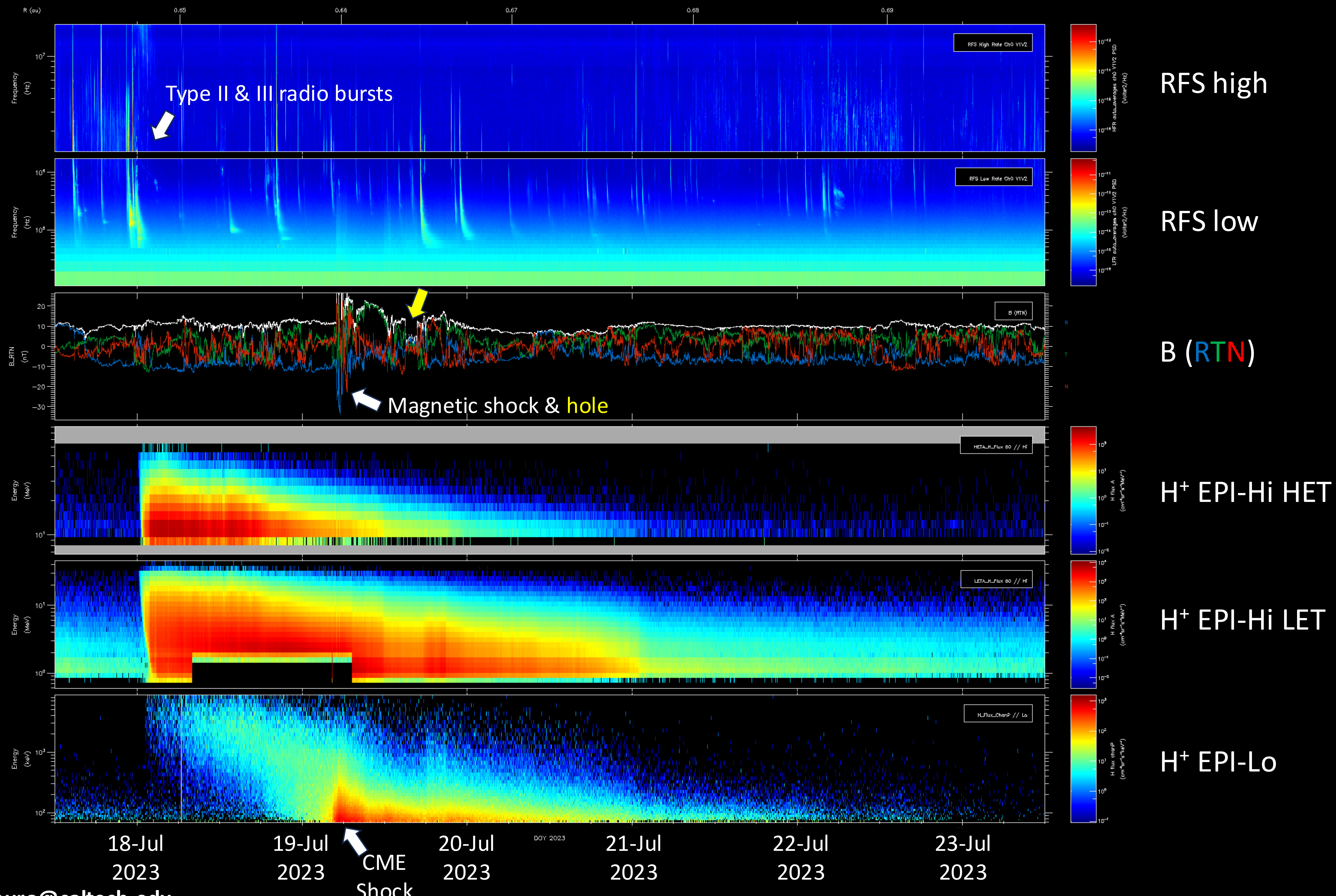
STEREO EUVI195/COR1/COR2



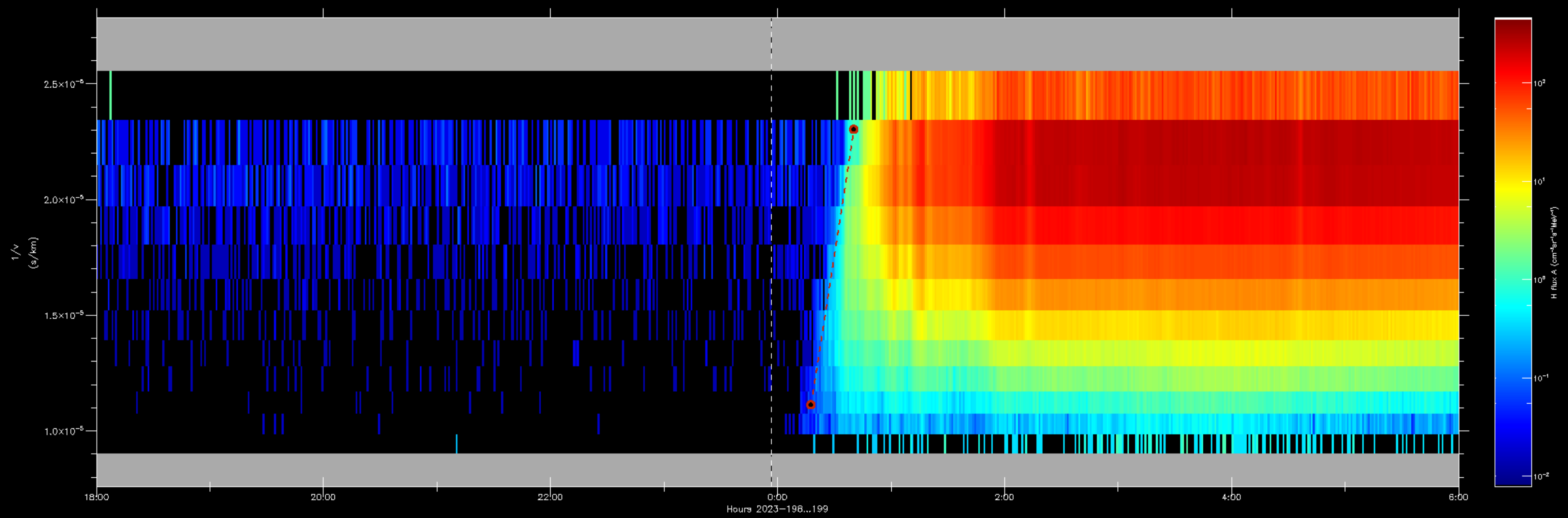
Parker Solar Probe WISPR



PSP measurements

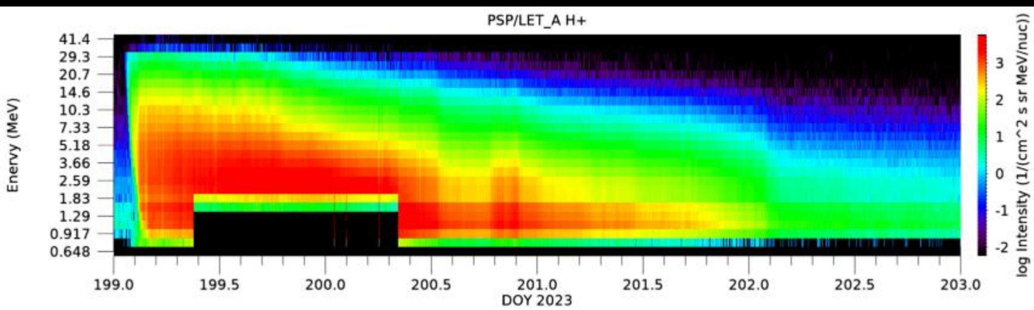


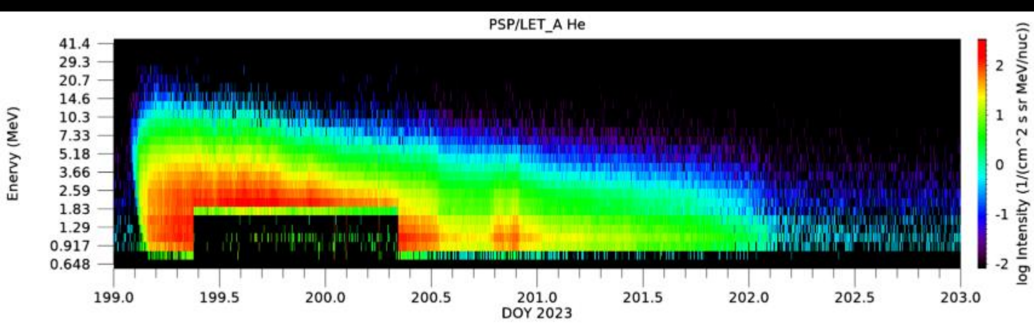
ISOIS HET-A proton velocity dispersion estimate

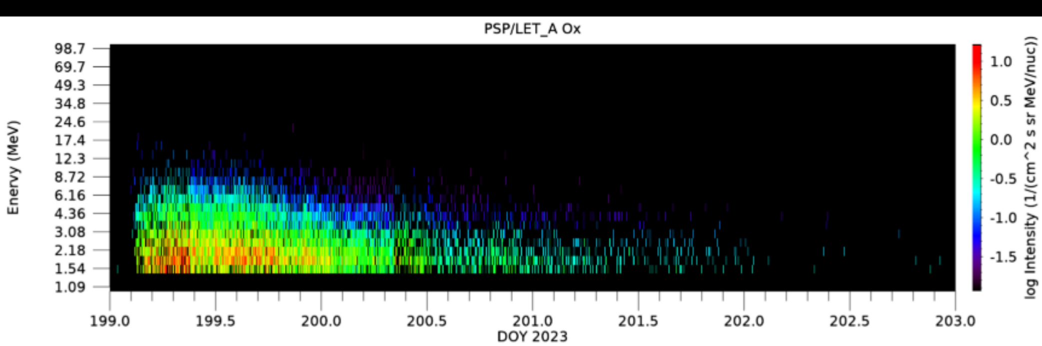


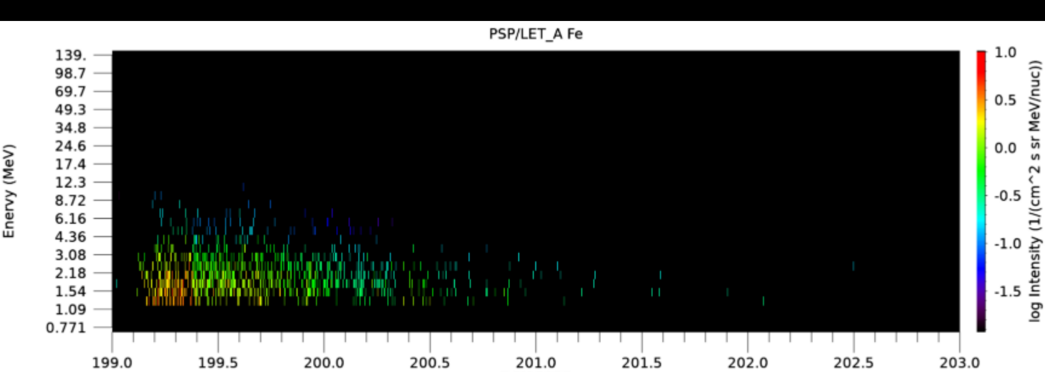
PSP radial distance	0.647 AU
SEP path length	0.762 AU
SEP start time	17-07-2023 @ 23:56
Proton peak speed	31664 kms^{-1}

PSP/LET

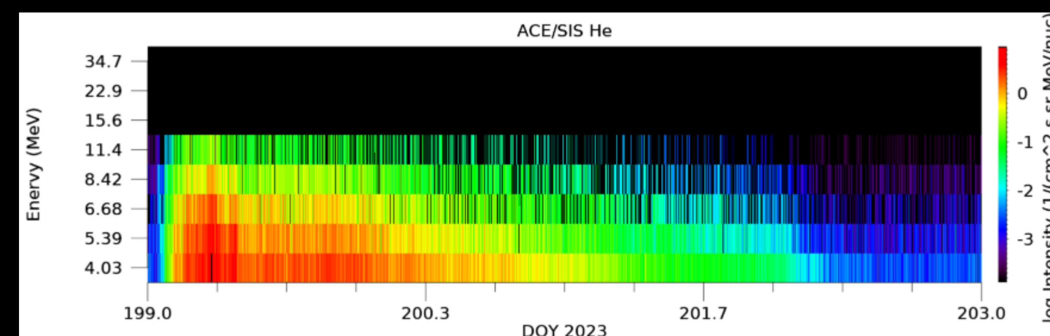


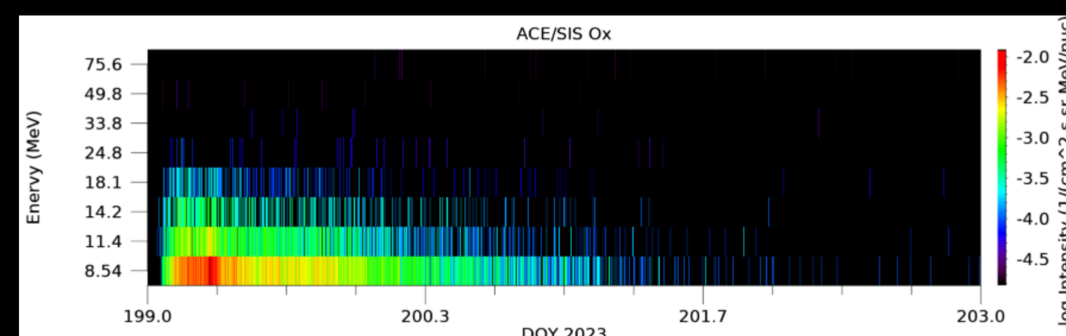


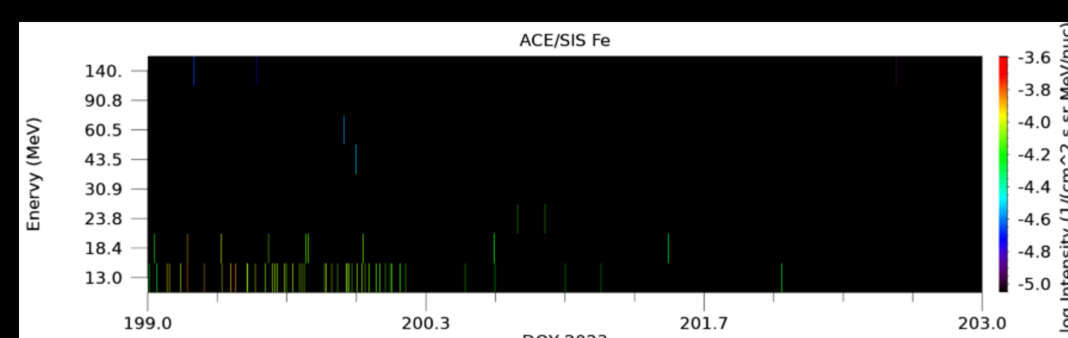




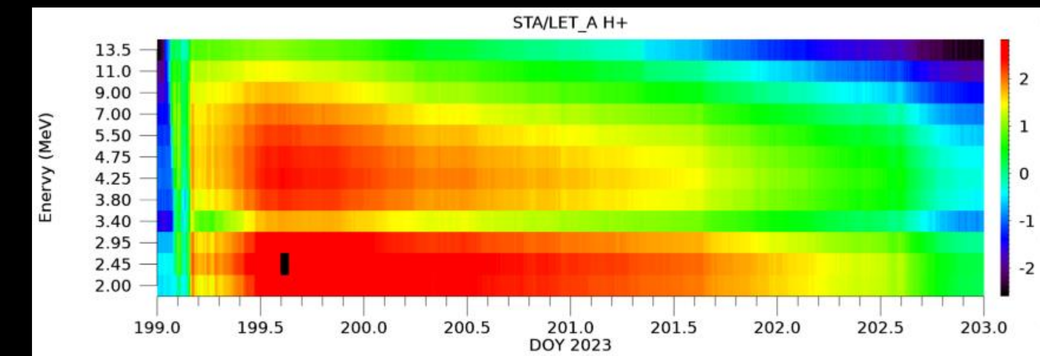
ACE/SIS

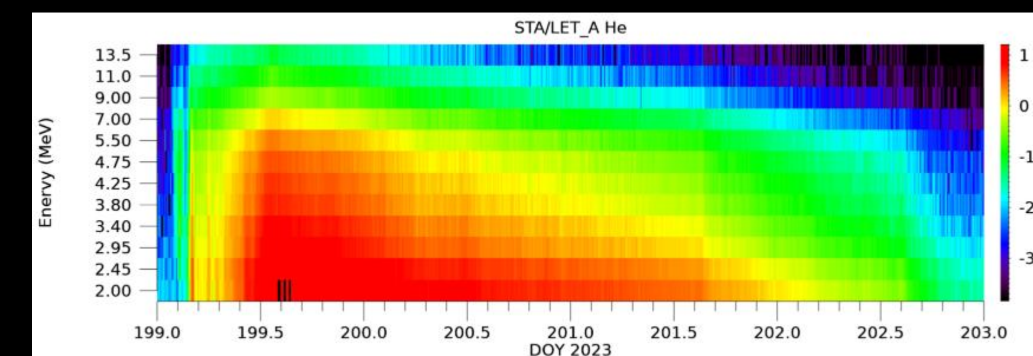


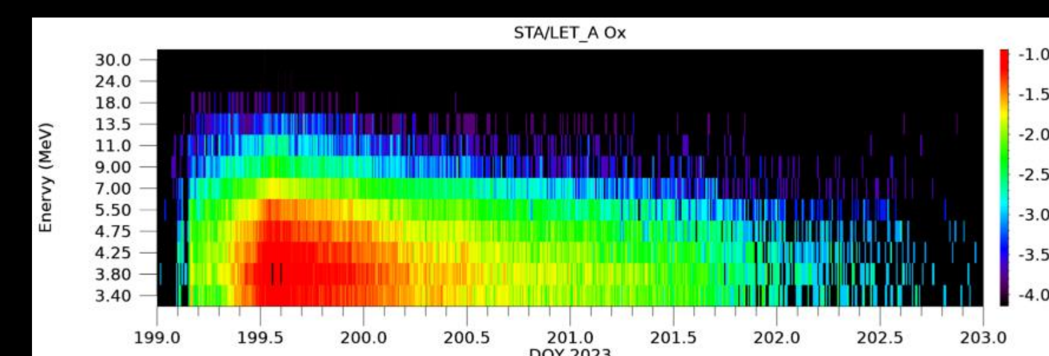


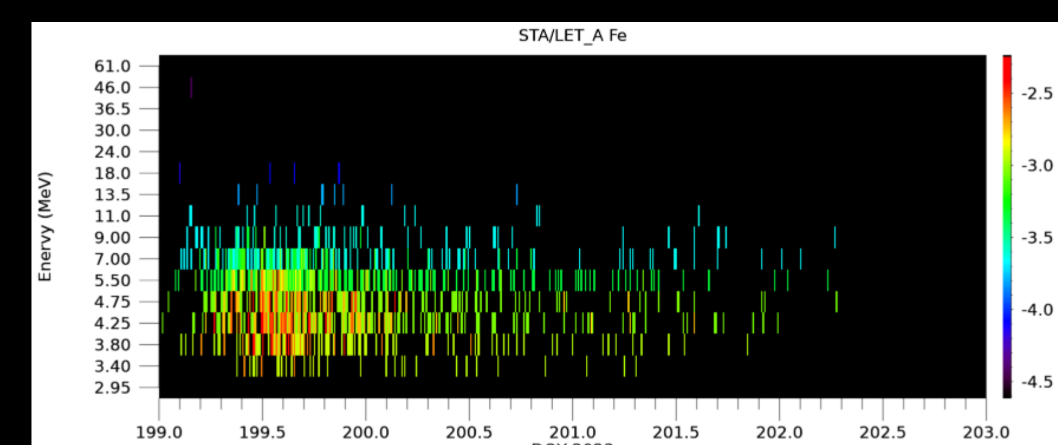


STEREO/LET

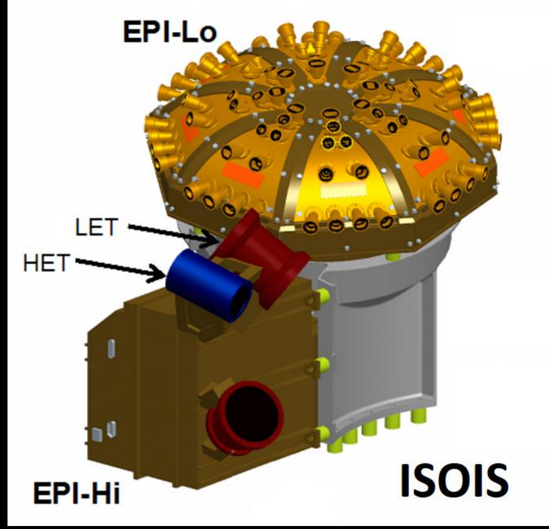






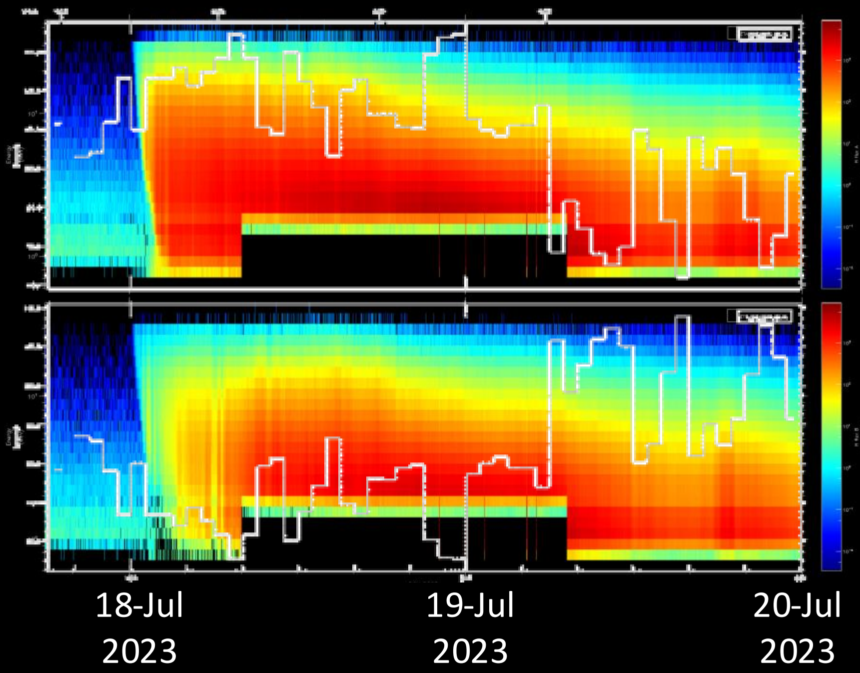


ISOIS ion LET (~1 to 20 MeV) anisotropies



H+ Epi-Hi LET A

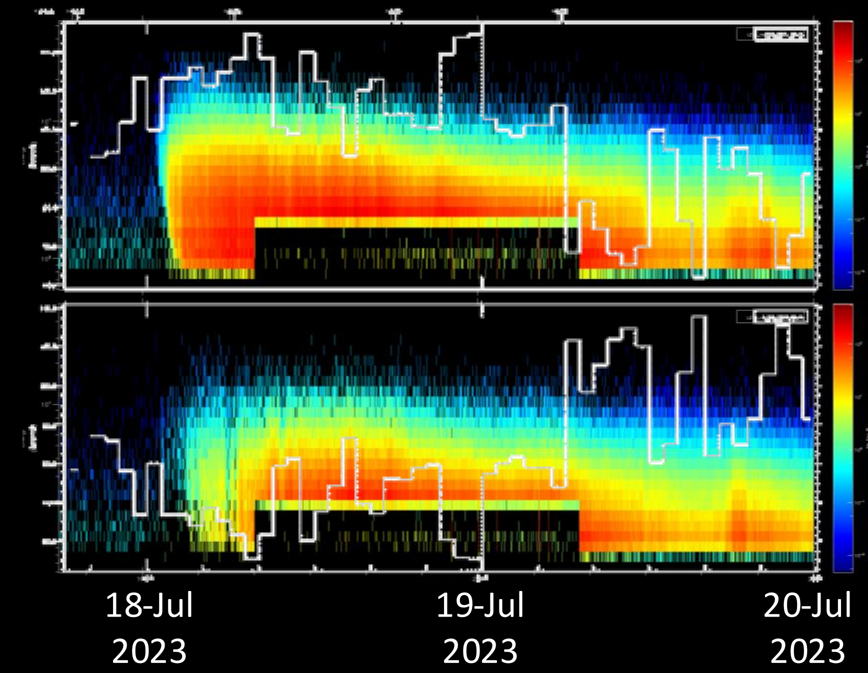
H+ Epi-Hi LET B



Energy spectra are overplotted with the A/B pitch angle

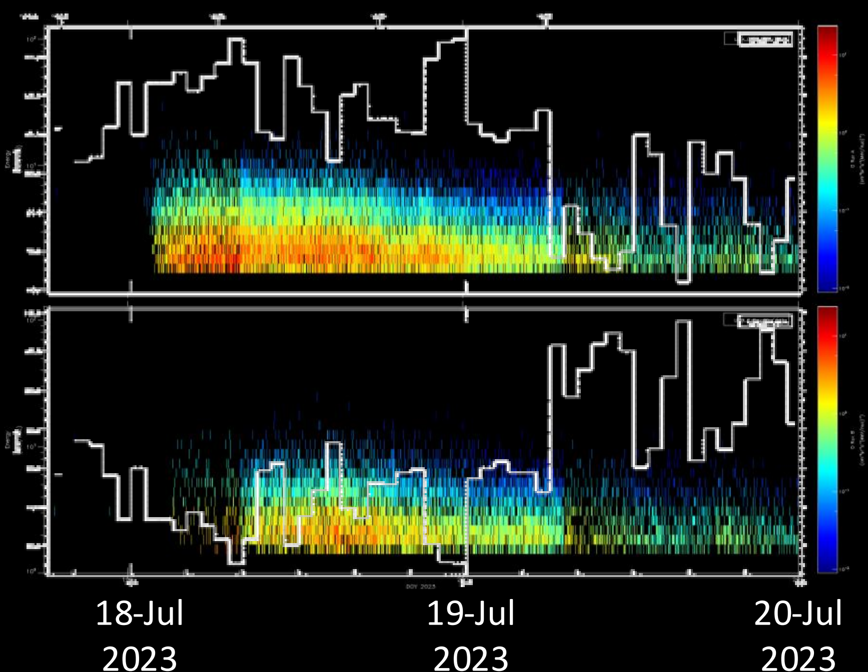
He Epi-Hi LET A

He Epi-Hi LET B



O Epi-Hi LET A

O Epi-Hi LET B

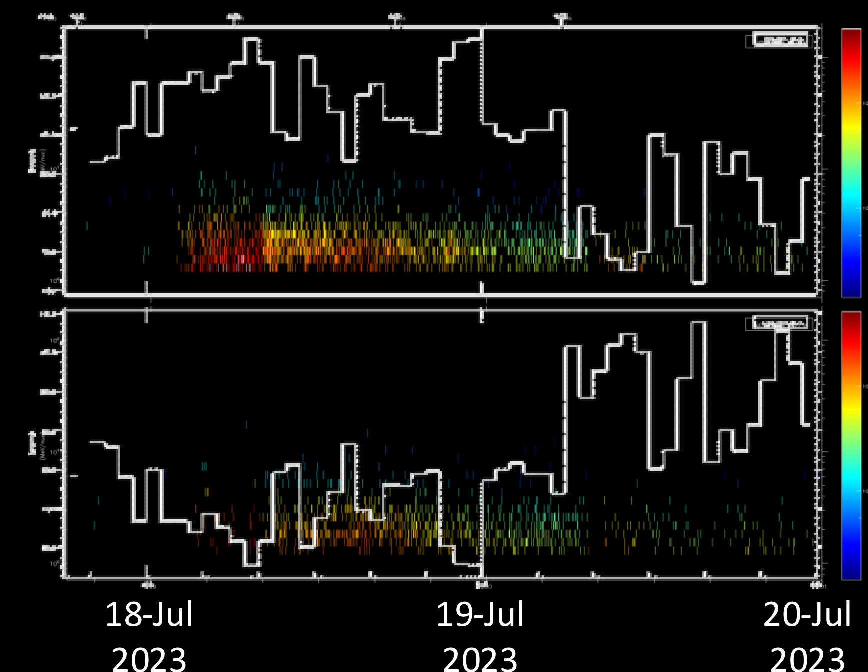


A – tick marks
Top: 160°
Bot: 40°

B – tick marks
Top: 140°
Bot: 20°

Fe Epi-Hi LET A

Fe Epi-Hi LET B



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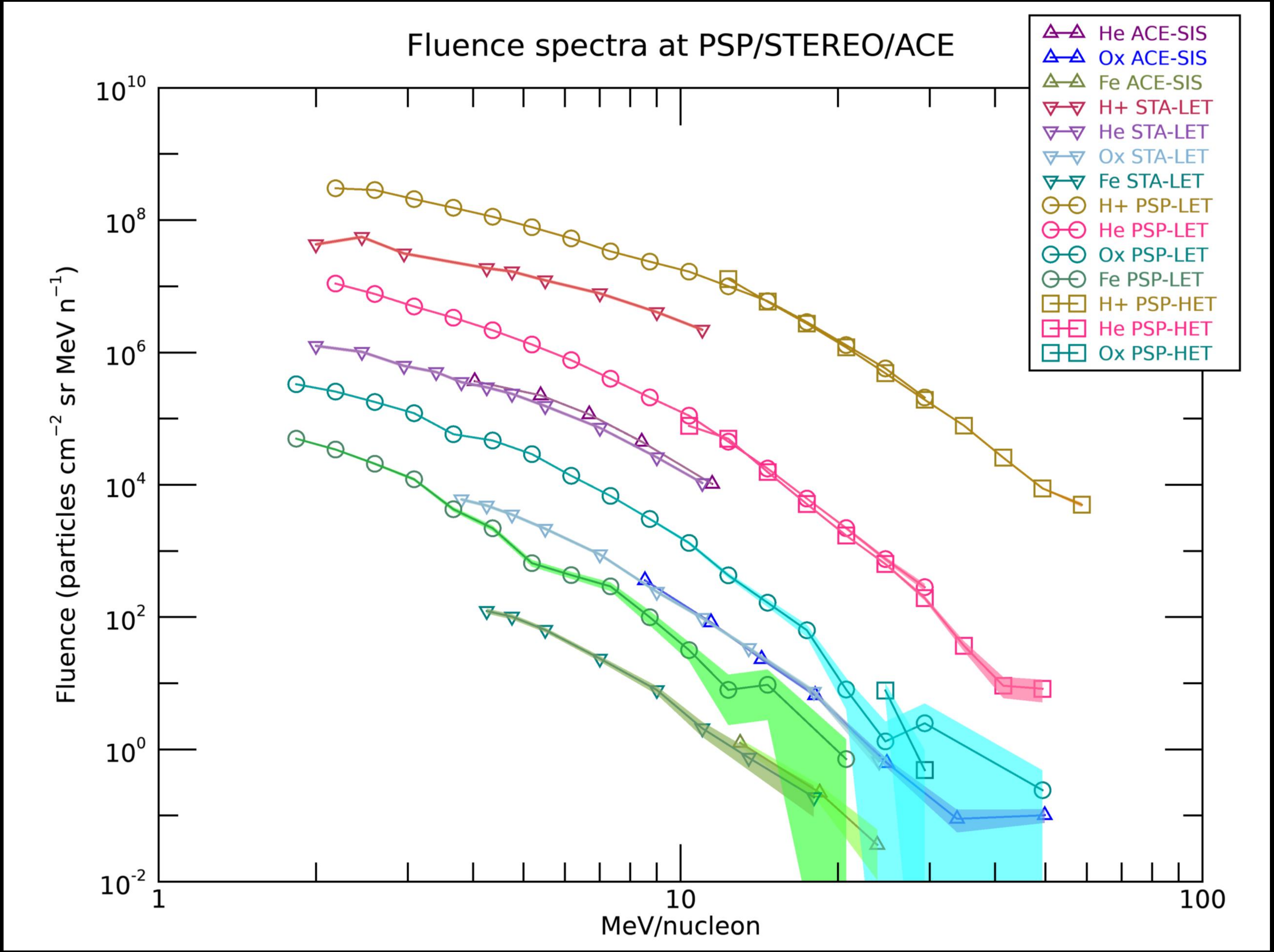
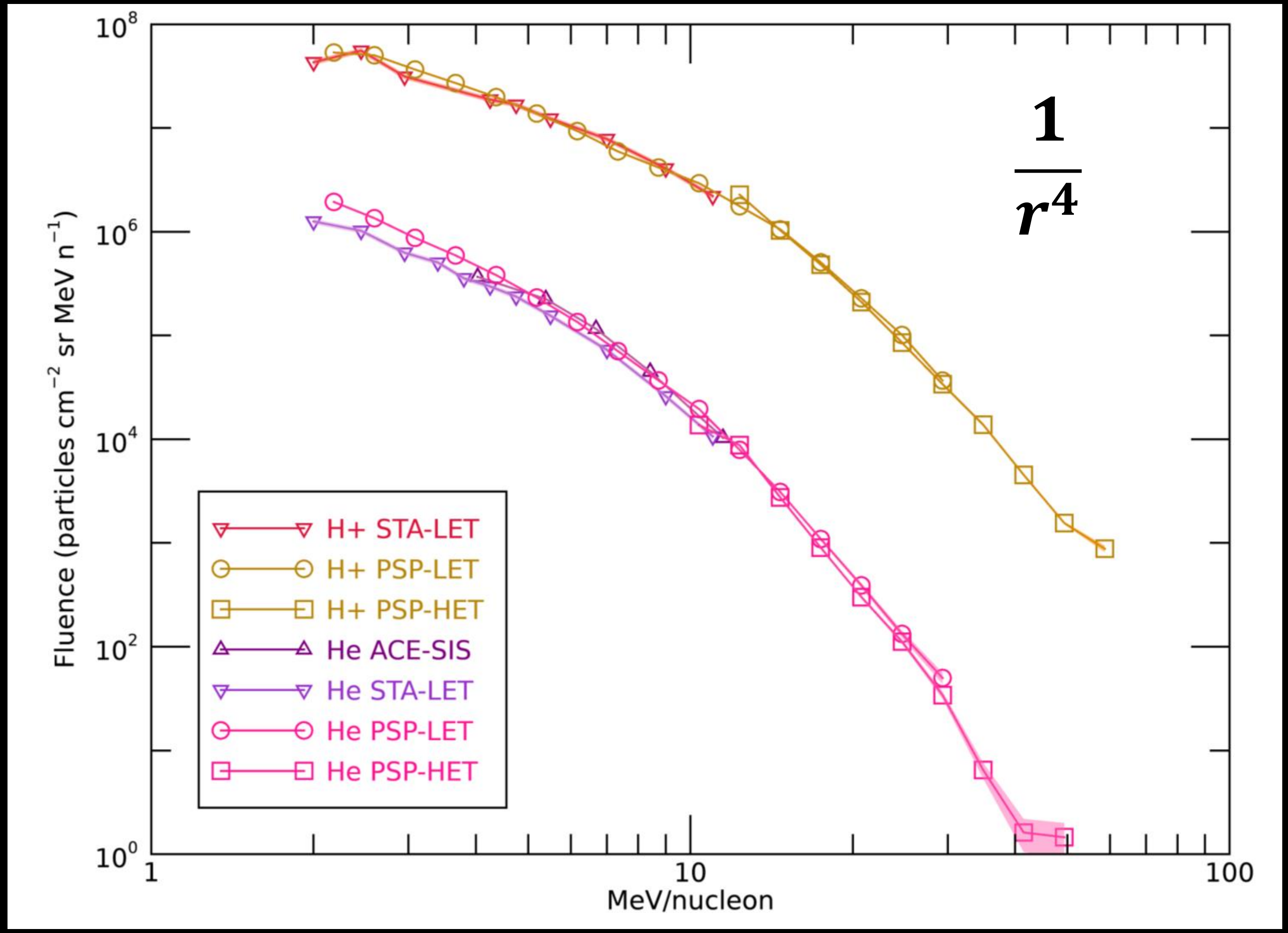


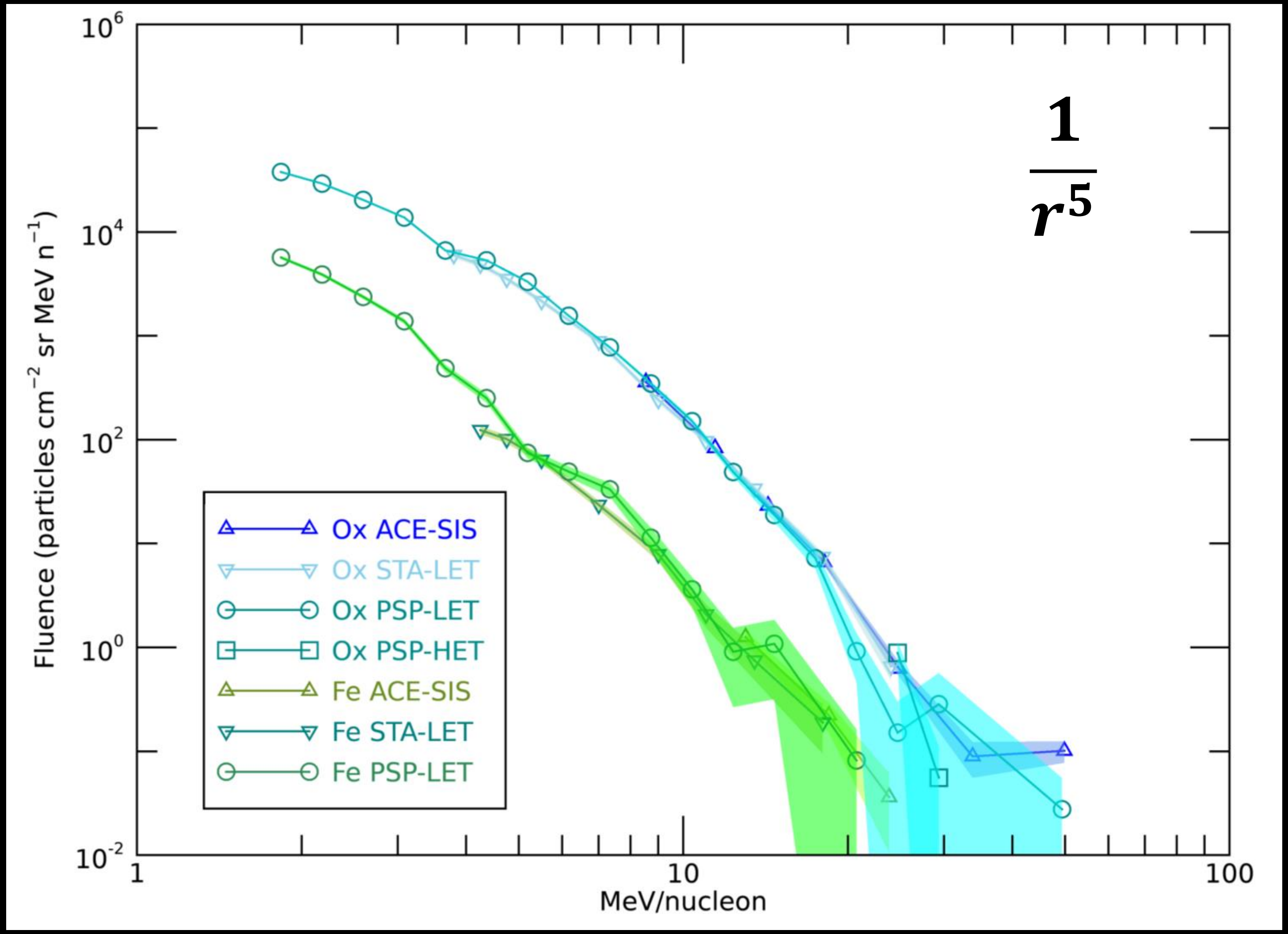
Fluence spectra at PSP/STEREO/ACE
He ACE-SIS
Ox ACE-SIS
Fe ACE-SIS
H+ STA-LET
He STA-LET
Ox STA-LET
Fe STA-LET
H+ PSP-LET
He PSP-LET
Ox PSP-LET
Fe PSP-LET
H+ PSP-HET
He PSP-HET
Ox PSP-HET
Fluence (particles cm^{-2} sr MeV n^{-1})
MeV/nucleon
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
10^{0}
10^{-2}
1
10
100

Radially adjusting the fluence spectra

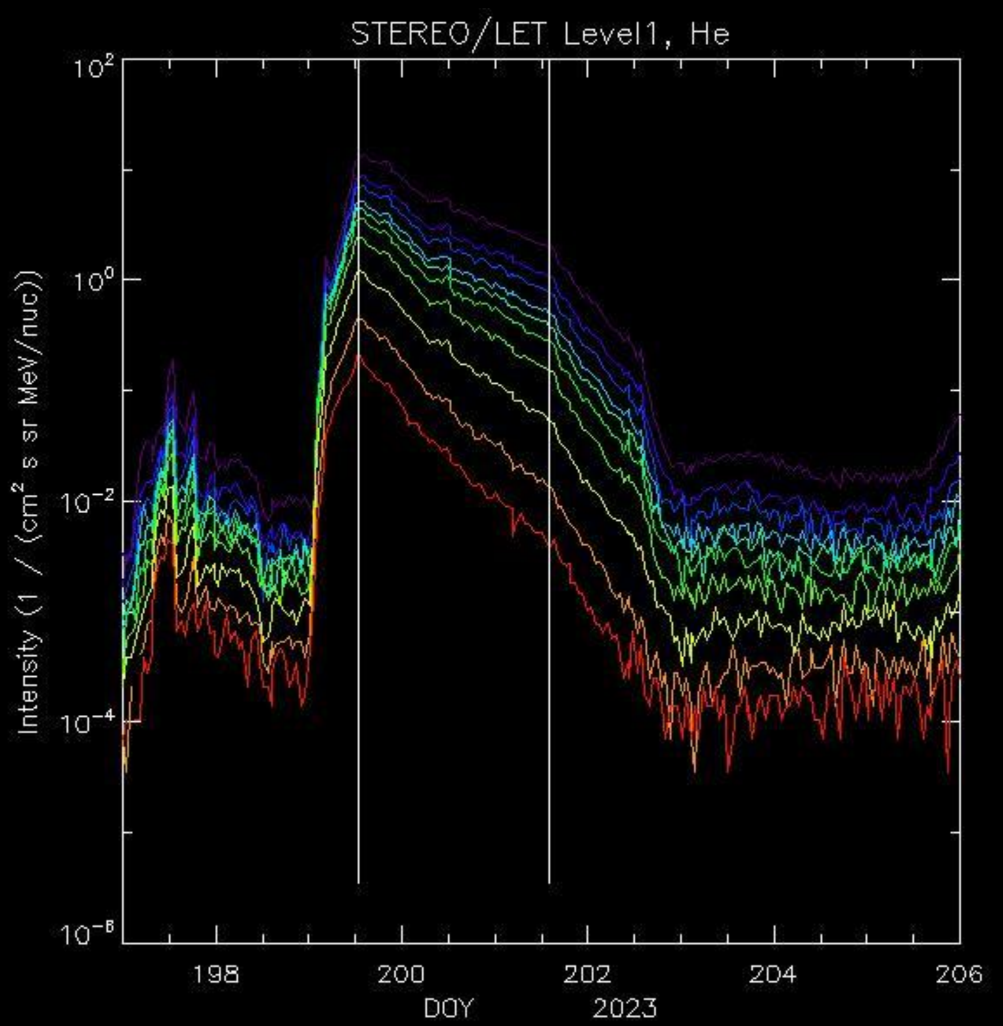
Lighter ions H+ and He

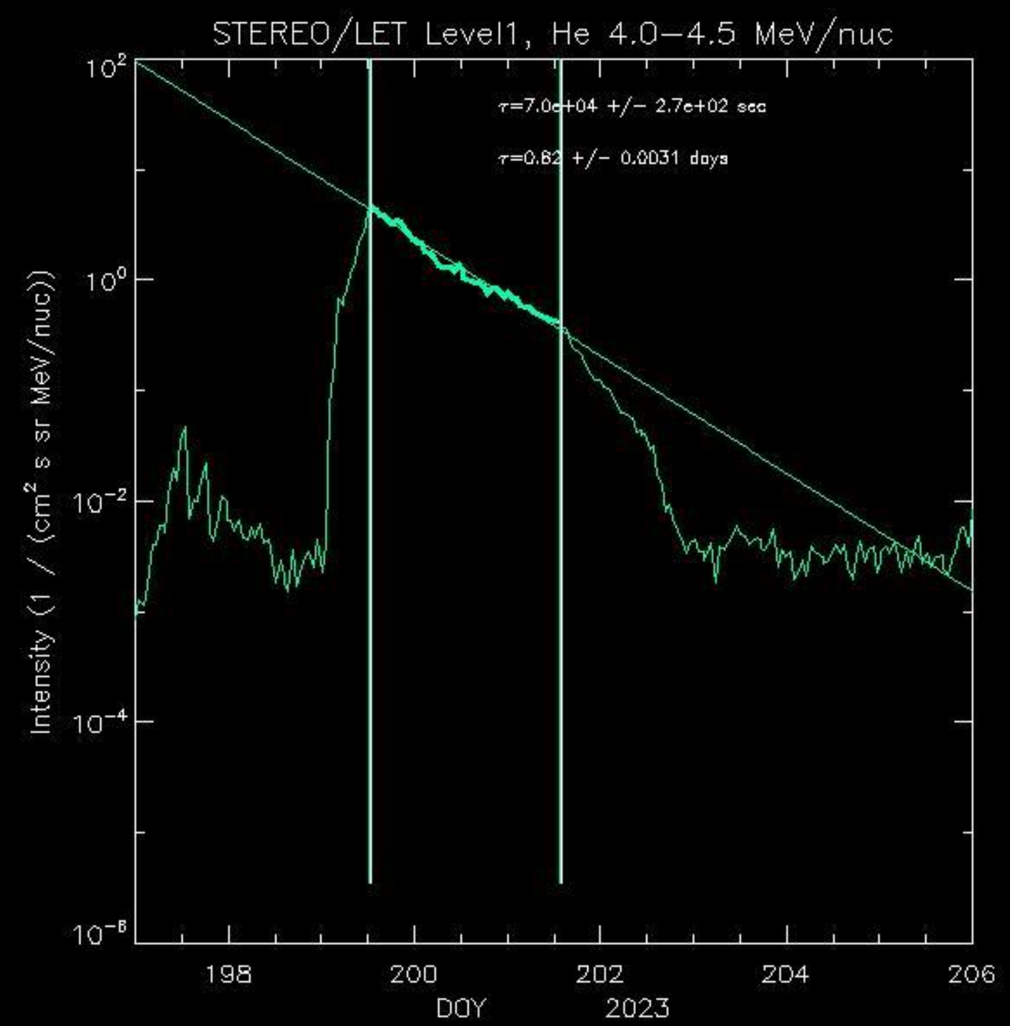


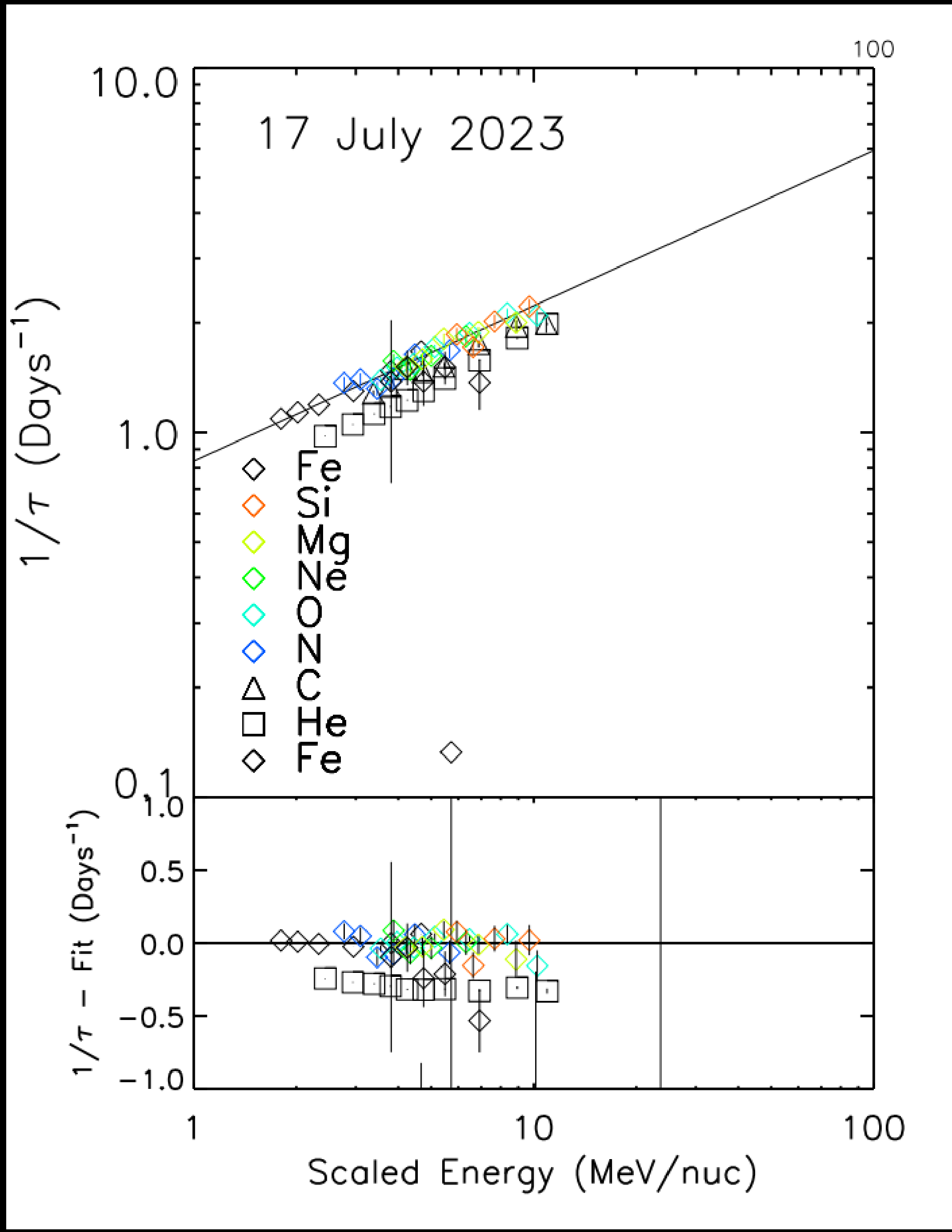
Heavier ions O and Fe



Estimating ionic charge dependence via decay profile (Working on it!)







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Thanks!

Conclusions

- Magnetic connection was ideal for all spacecraft and this flare-CME-SEP storm event provides a unique opportunity to analyze ion dependent acceleration.
- The failed prominence eruption as the SEP seed particle source depends can be revealed via ionic charge-to-mass ratio
- A possible explanation for the lower than expected fluences measured at ~1.0 AU can be inferred by the large anisotropy measured at PSP combined with Type III radio bursts from the extended flare, which has the appearance of an impulsive injection and could be driving suprathermal pick-up ions early on during the rise to peak ion acceleration.
- The fluence spectral intensities for each ion species should vary by $1/r^n$ during this early acceleration phase close to the Sun, but as the SEP event weakens towards isotropy during the decay phase the position angle scattering should increase and reduce the fluence ratios at ever increasing distances.

Future work

- We plan to compare the charge-to-mass ion ratio at each spacecraft as well as derive a rough ionic charge state estimate via SEP event decay slope.
- Comparing anisotropy histories for all spacecraft will be essential when discussing the differing $1/r^n$ fluence dependency at each location, because the magnetic connection to the flare are nearly optimal for all spacecraft.

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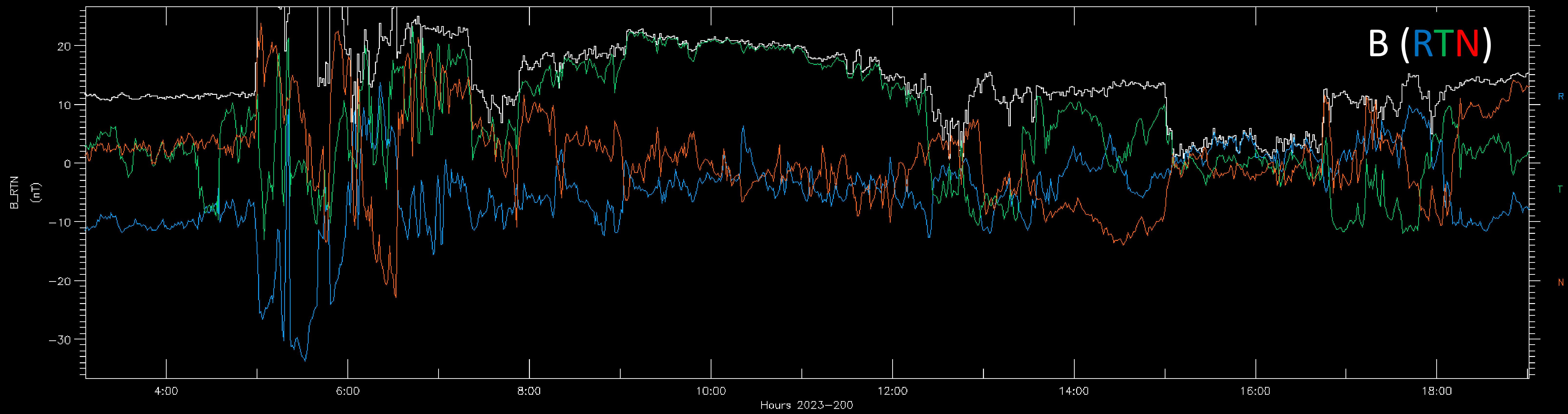
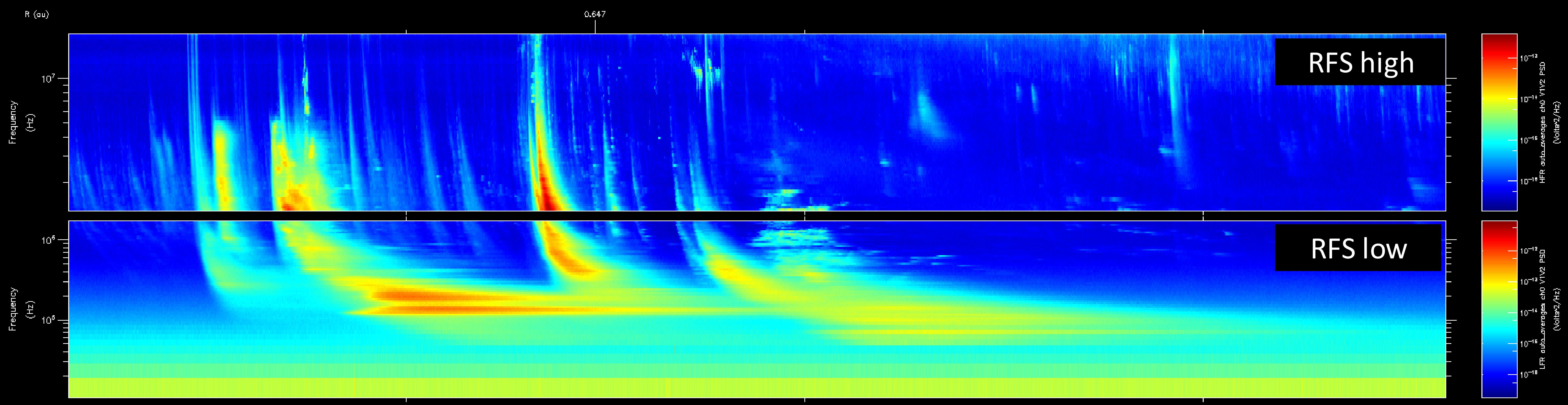
B-field measurements (zoomed in)

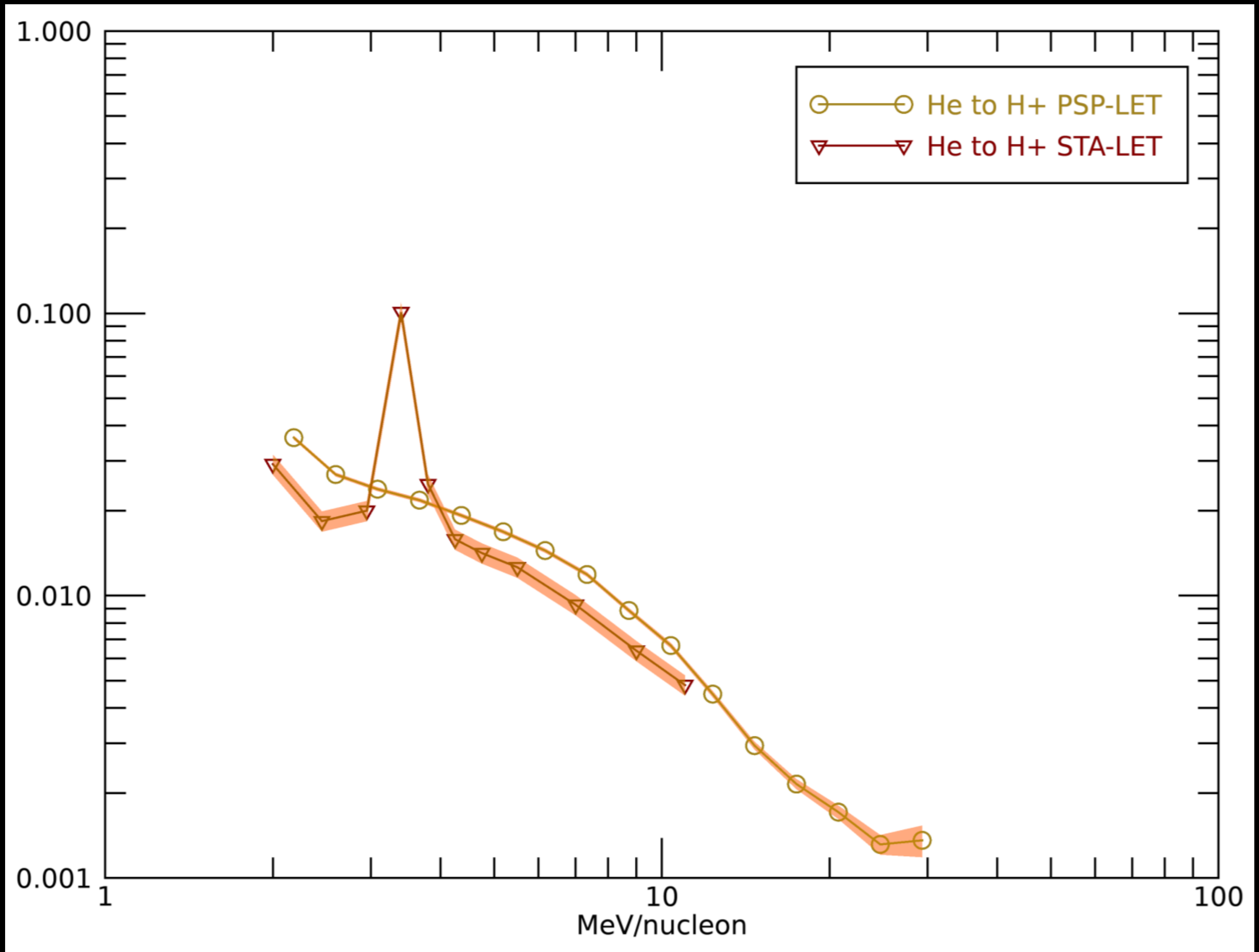


Radio measurements (zoomed in)

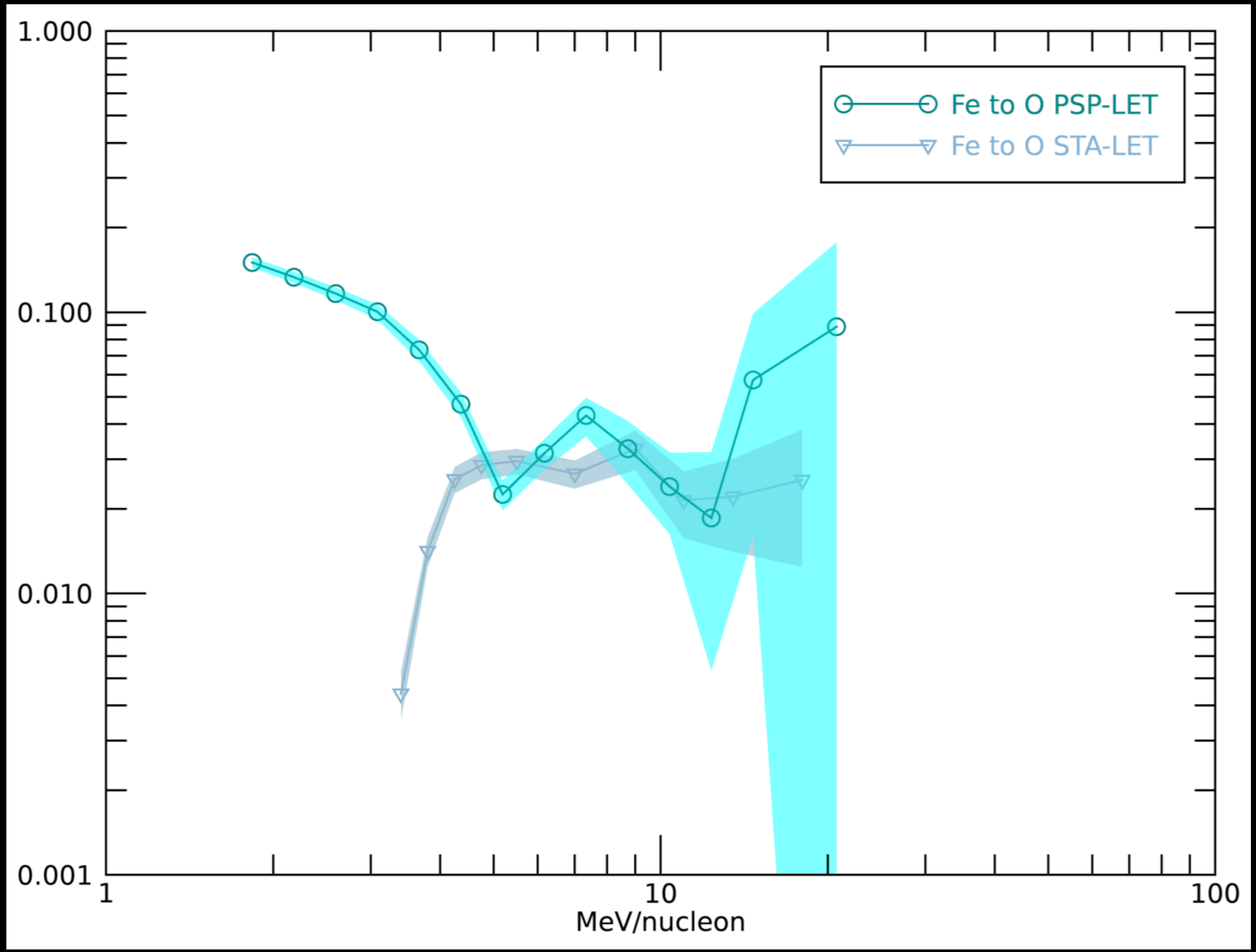


Ion ratios in PSP-LET and STA-LET

Lighter ions He/H+



Heavier ions Fe/O



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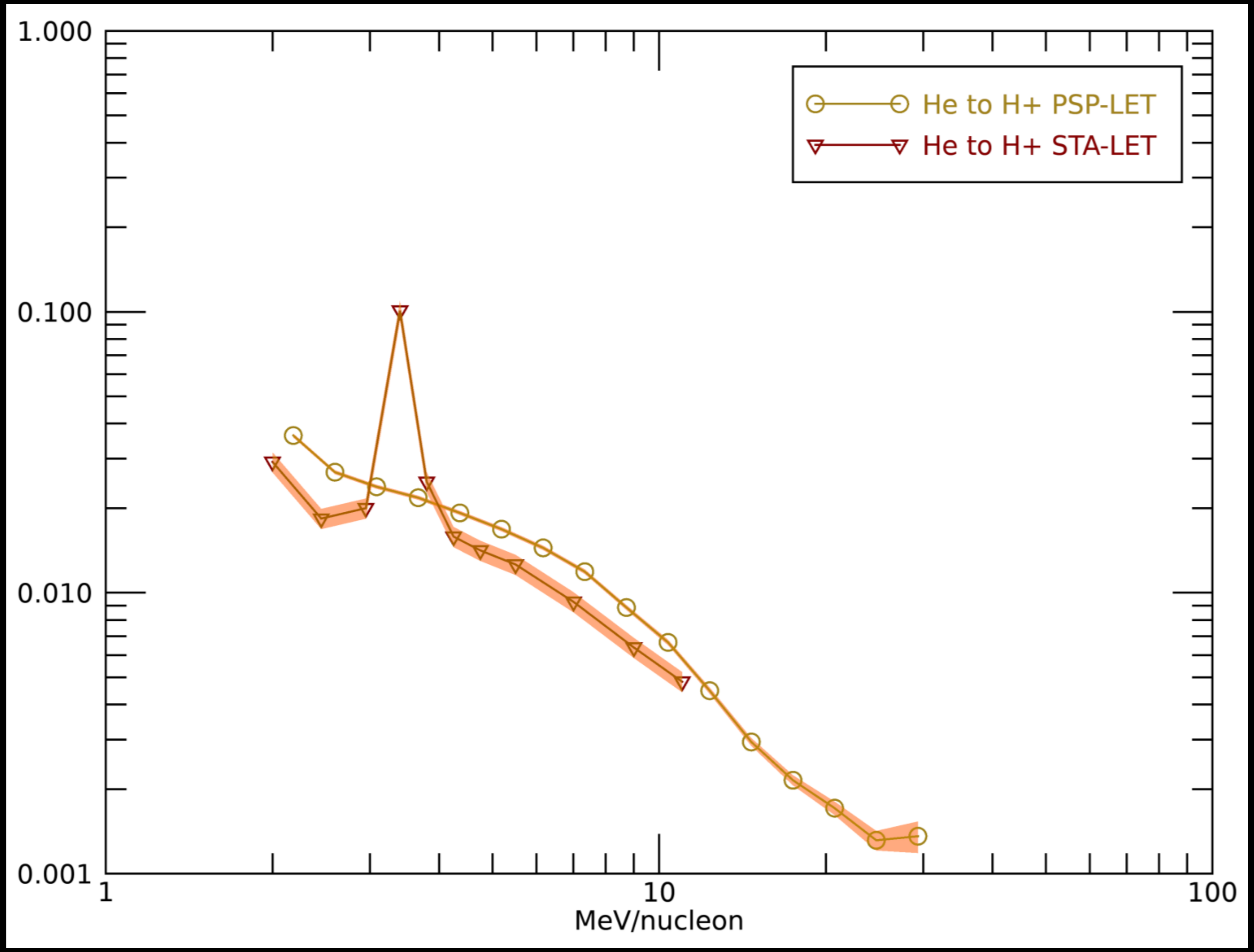
Lighter ions He/H+



Heavier ions Fe/O