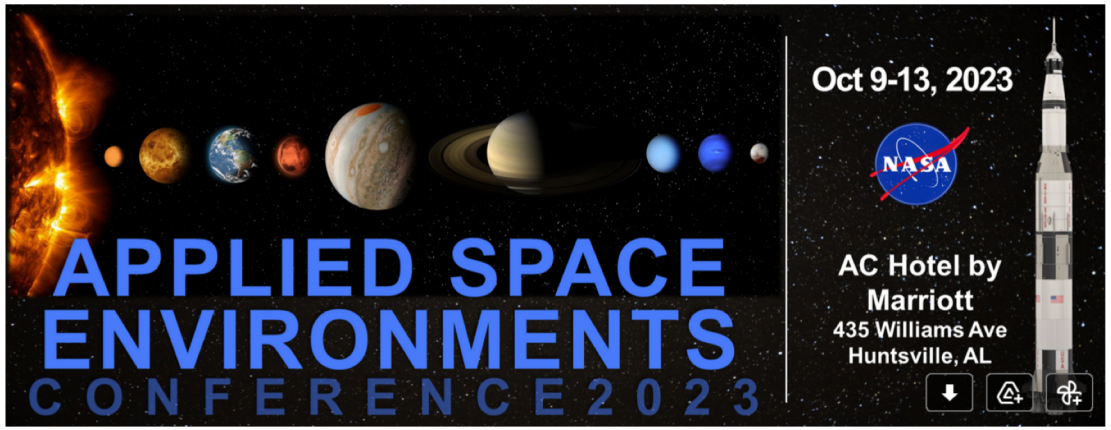
Haspide-space WG5 Updates – Florence June 14, 2023

- ESA SPACEMON presentation on May 17, 2023. Possibility to present HASPIDE-SPACE in October at the NASA twin conference (Huntsville, AL) organized by NASA-JPL .



- Paper submission update: major revisions (in progress)
- The referee comments were useful to refine…
- …the goals for space applications of HASPIDE sensors (trying talking to people of the heliospheric community and space agencies)

SPACEMON 2023

Space environments monitoring workshop

15-17 May 2023 | ESA/ESTEC

A hydrogenated amorphous silicon detector for Space Weather Applications

C. Grimani, L. Servoli, M. Menichelli, M. Villani, M. Fabi, F. Sabbatini and the HASPIDE Collaboration

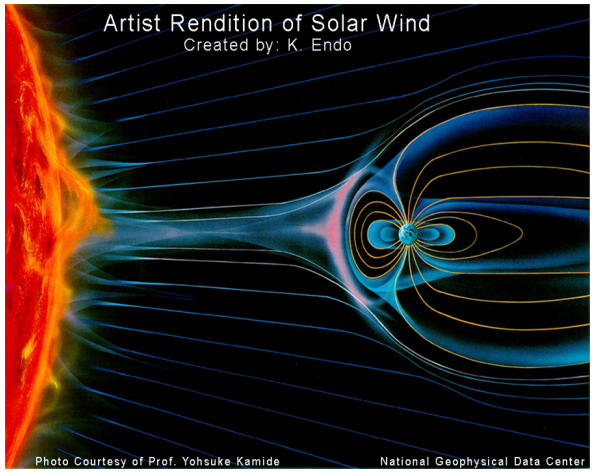
University of Urbino Carlo Bo and INFN Florence, Italy

Highlights

- The majority of space missions monitor SEP differential fluxes below 100 MeV
- Deep charging of instruments on board space missions and astronaut dose rate are associated with particles with energies larger than 100 MeV
- We are studying the possibility of building a detector for solar proton observations up to 400 MeV and stellar flaring monitoring by using a:Si-H as sensitive material

Solar activity and overall particle flux

Solar activity (quasi 11-year cycle)



Solar wind:

10^6 tons/s p, e^-

200-800 km/s

6 particles/cm^3 near Earth

0.3-5 keV

GSMF Polarity effects (quasi 22-year cycle; since 2013 + polarity; next polarity change 2024-2025)

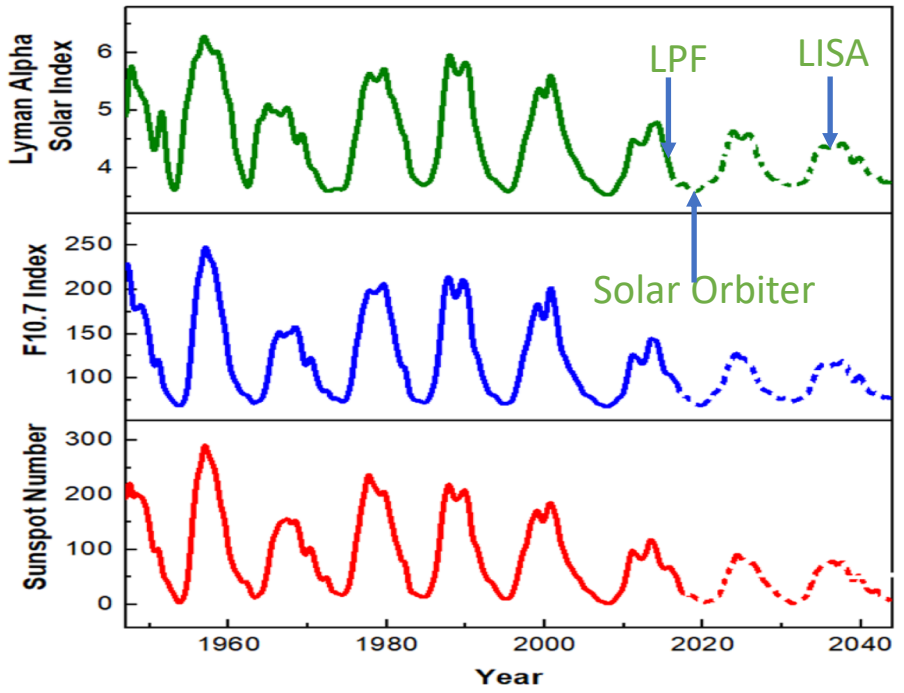
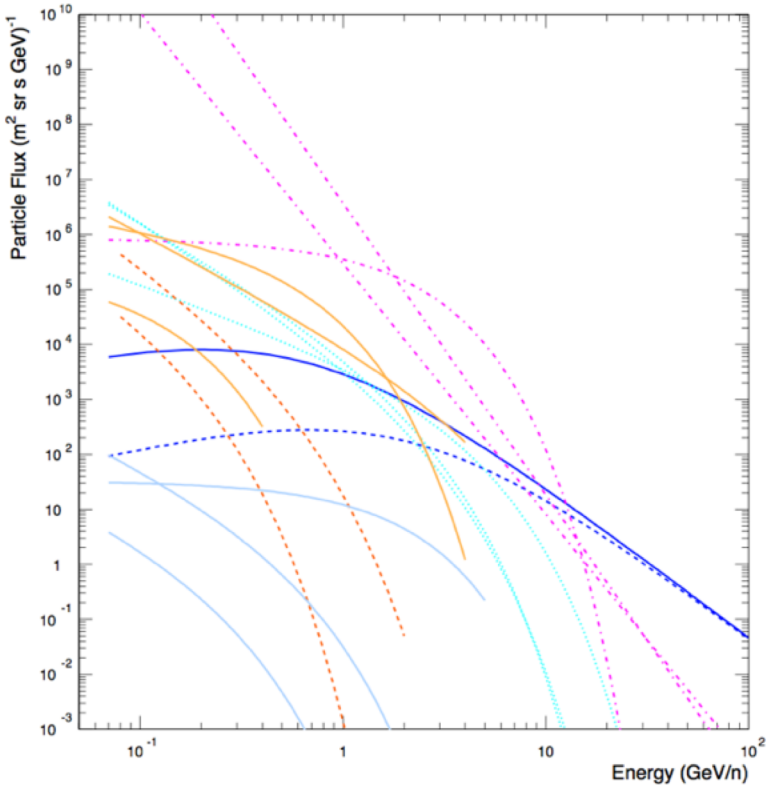


Fig. 5 Monthly variations of the observed and predicted (dotted) values of the sunspot numbers, F10.7 cm index and Lyman alpha index

Singh & Bhargawa Astrophys. Space Sci., 364, 12 (2019)



SEP February 23, 1956 (p)

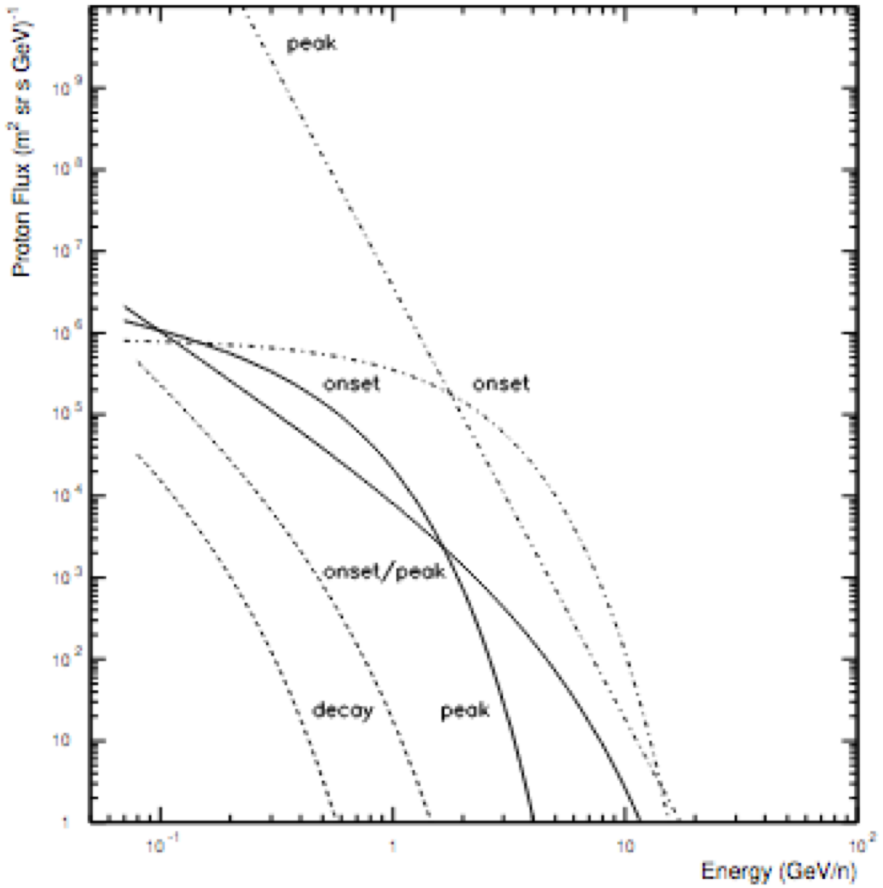
SEP December 13, 2006 (p)

SEP December 14, 2006 (p)

SEP December 13, 2006 (He)/10^4

Galactic cosmic-ray protons

GCR and SEP energy distribution

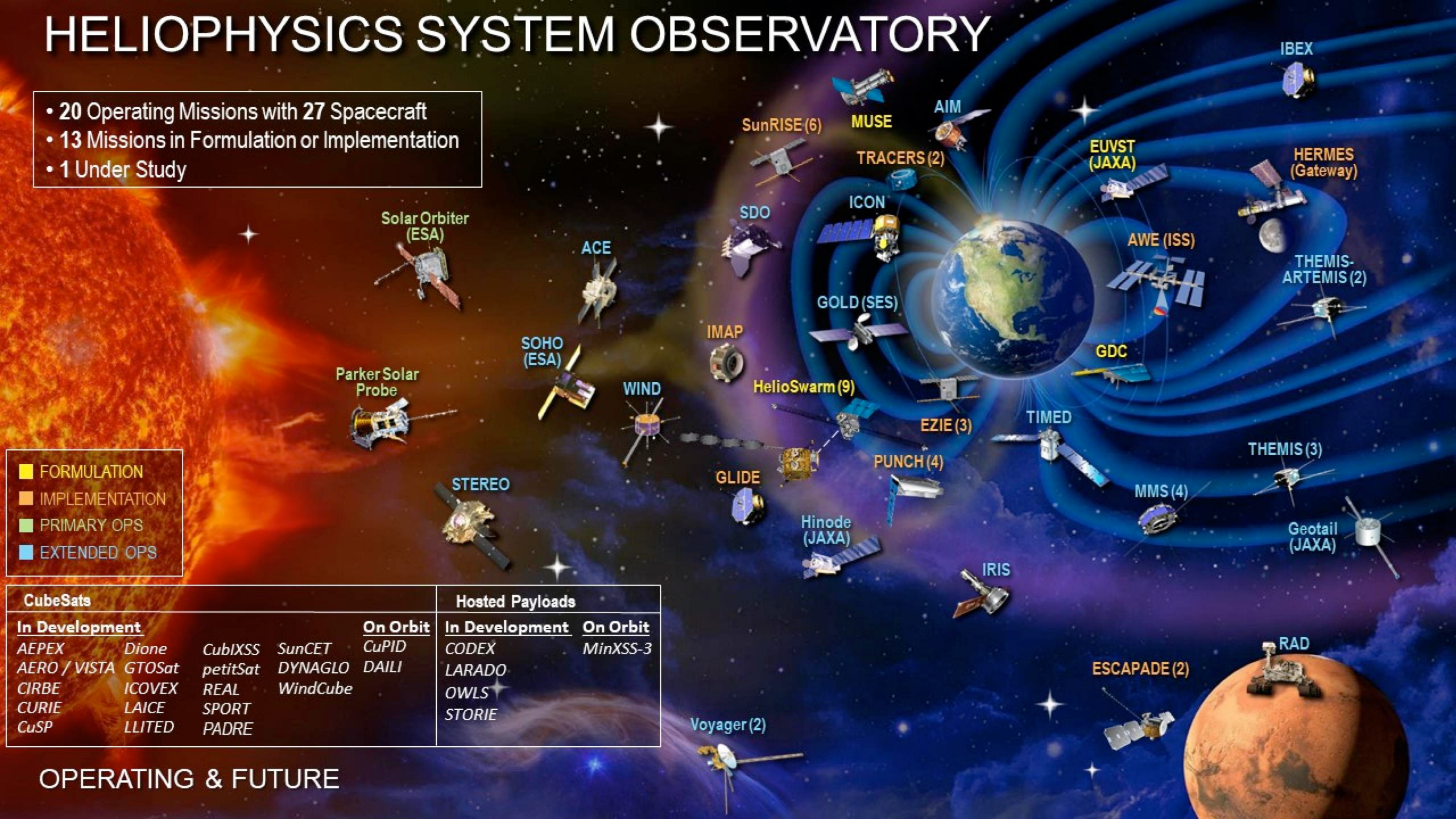


	Solar minimum	Solar maximum	Onset	Peak/Decay
GCR	19%	6%		
SEP 13/12/2006			90%	98% (peak)
SEP 14/12/2006			99%	100% (decay)
SEP 23/2/1956			25%	99.5% (peak)

Proton percentage below 400 MeV

HELIOPHYSICS SYSTEM OBSERVATORY

- **20** Operating Missions with **27** Spacecraft
- **13** Missions in Formulation or Implementation
- **1** Under Study



- FORMULATION
- IMPLEMENTATION
- PRIMARY OPS
- EXTENDED OPS

CubeSats					Hosted Payloads	
In Development				**On Orbit**	**In Development**	**On Orbit**
AEPEX	*Dione*	*CubIXSS*	*SunCET*	*CuPID*	*CODEX*	*MinXSS-3*
AERO / VISTA	*GTOSat*	*petitSat*	*DYNAGLO*	*DAILI*	*LARADO*	
CIRBE	*ICOVEX*	*REAL*	*WindCube*		*OWLS*	
CURIE	*LAICE*	*SPORT*			*STORIE*	
CuSP	*LLITED*	*PADRE*				

OPERATING & FUTURE

SEP flux measurements above 100 MeV

- BepiColombo/BERM protons up to about 200 MeV
- HEPD/CSES-01 protons up to 250 MeV (near Earth)
- SEISS/GOES protons up to 500 MeV (near Earth)
- SOHO/EPHIN protons up to 700 MeV (L1)
- Solar Orbiter/HET protons up to 1 GeV? (within 1 au no on soar)
- AMS-02 on board the Space Station protons > 450 MeV/n (near Earth)

An a:Si-H detector for solar activity monitoring

- We aim to set the characteristics of a detector for long-term monitoring of **medium-intense solar proton events (>10^7 protons cm^{-2} > 30 MeV) with an uncertainty smaller than 30%**
- **This detector can be also considered for soft/hard X-ray and solar electron observations**

October 28, 2021 SEP event - I – communicate with the heliospheric communities

Papaioannu et al., A&A, 660, L5, 9pp (2021)

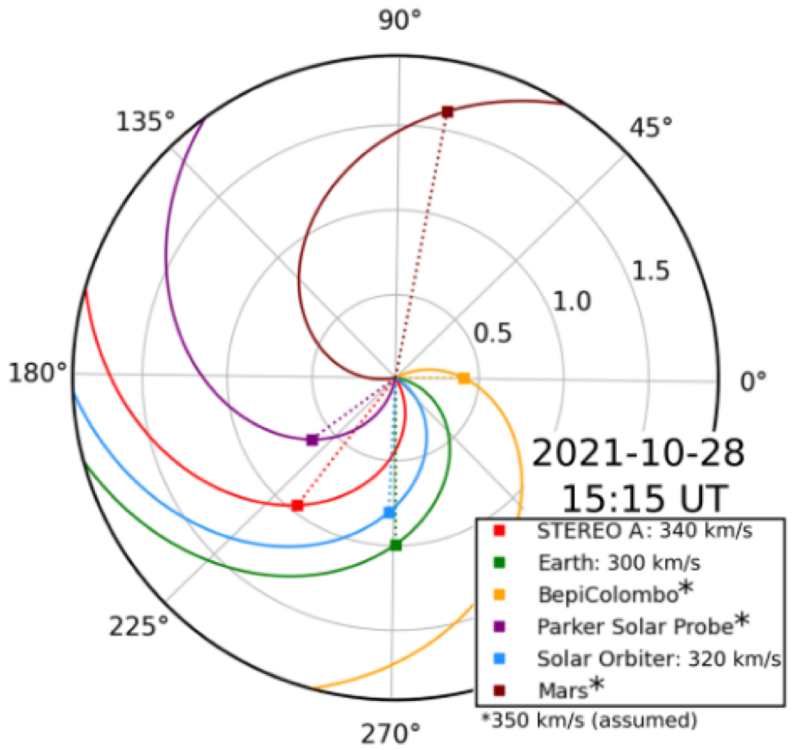


Fig. A.1. A view of the ecliptic plane from solar north showing the positions of various spacecraft on 28 October 2021 at 15:15 UT. The Parker spirals are shown for each spacecraft. From the Solar MAgnetic Connection Haus tool (https://solar-mach.github.io/).

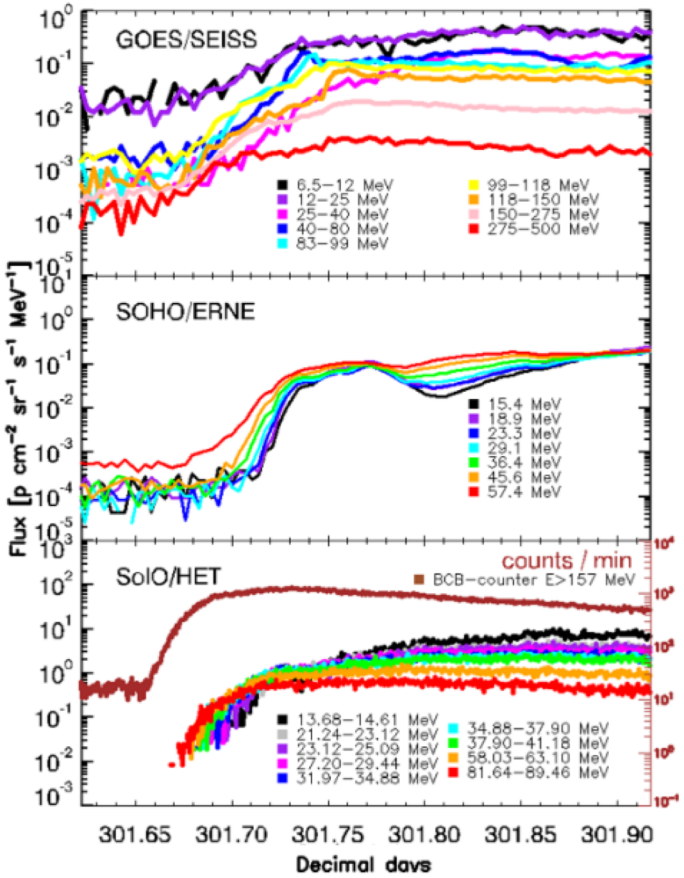


Fig. A.2. Energetic particle recordings of GLE73 in the near Earth space, (from top to bottom) 5-min averaged GOES/SEISS differential fluxes; SOHO/ERNE fluxes and SolO/HET measurements including the recordings of the SolO/HET/BCB-counter.

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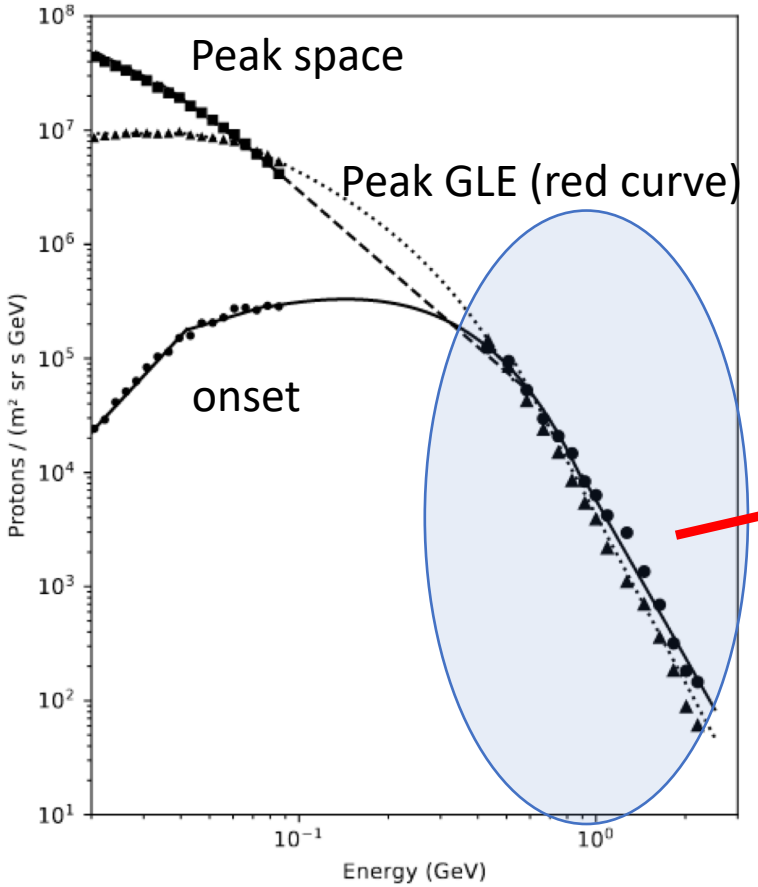
a-Si:H

October 28, 2021 SEP event - II

Papaioannu et al., A&A, 660, L5, 9pp (2021)



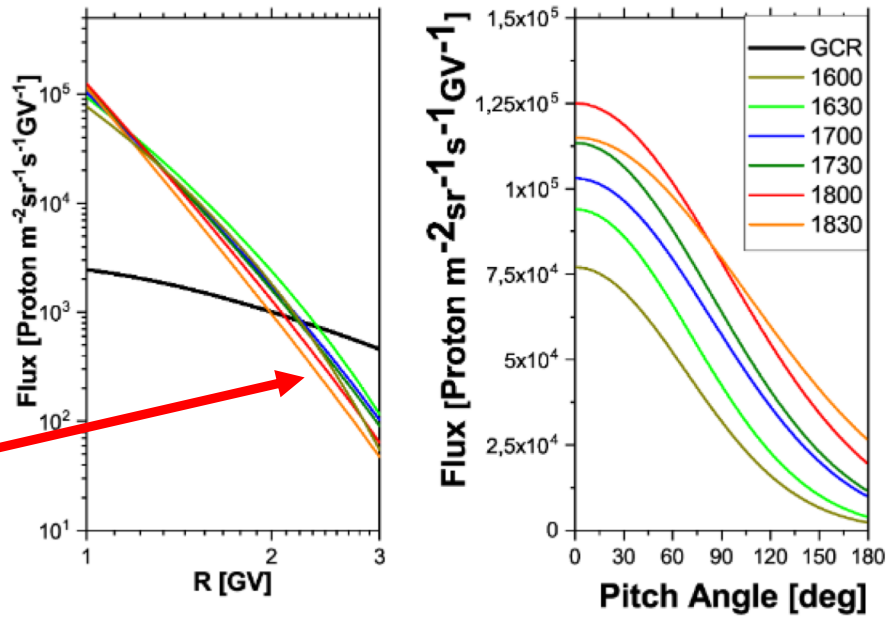


Fig. 4. Derived SEP rigidity spectra (left panel) and PADs (right panel) during GLE73 on 28 October 2021. The solid black line denotes the galactic cosmic ray flux, which corresponds to the time period of the GLE 73 occurrence (see text for details). All time in the legend are in UT and refer to the start of the corresponding five minute interval over which the data are integrated.

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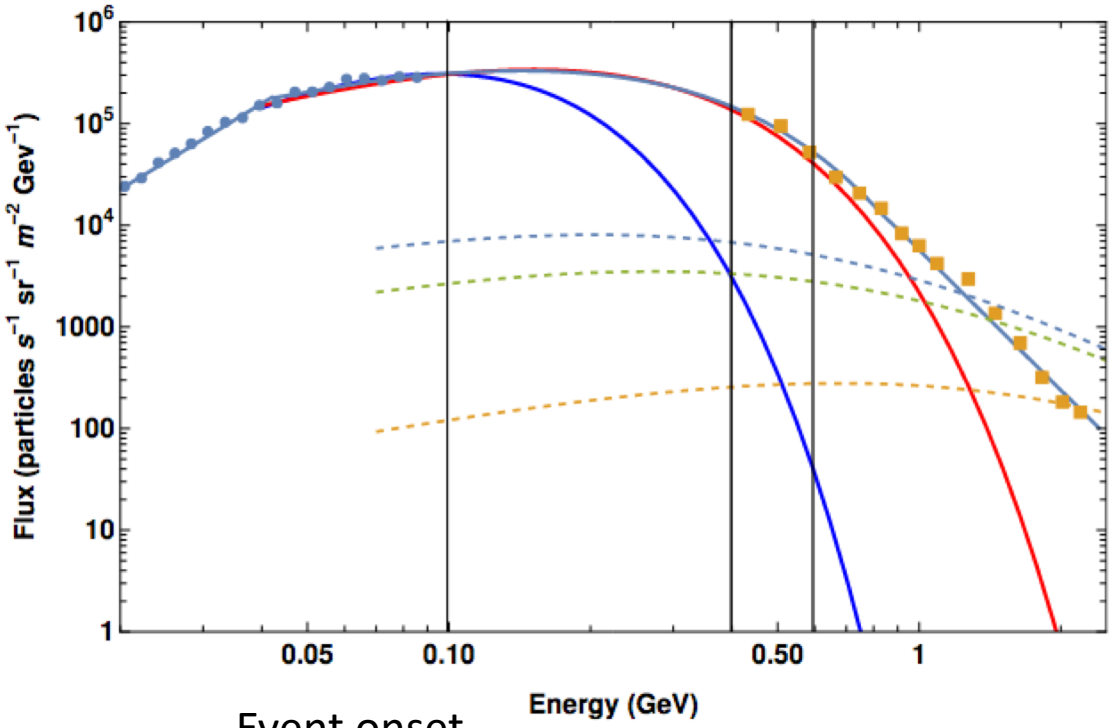
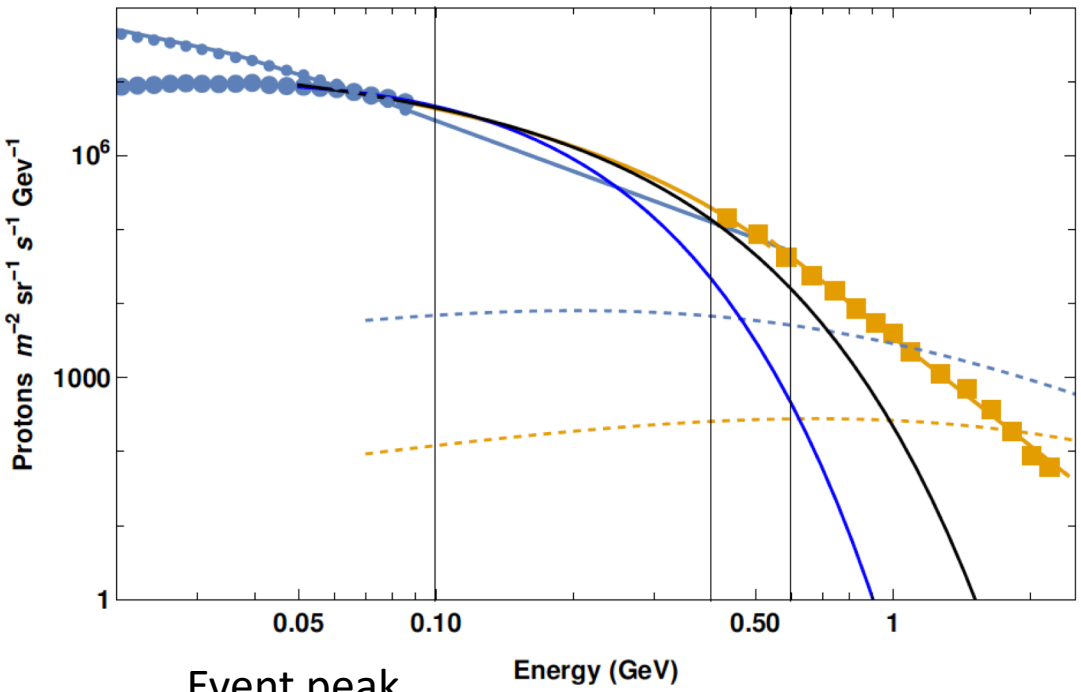
October 28, 2021 SEP event - III

- Small/large blue dots: data gathered in space up to 100 MeV with Solar Orbiter. Orange squares: neutron monitor data.
- The blue curve is the best fit with data up to 100 MeV.
- The red curve is the best fit with data up to 400 MeV-> SEP monitoring in space, far from Earth should be monitored up to minimum energies of 400 MeV.
- Dashed lines GCR protons



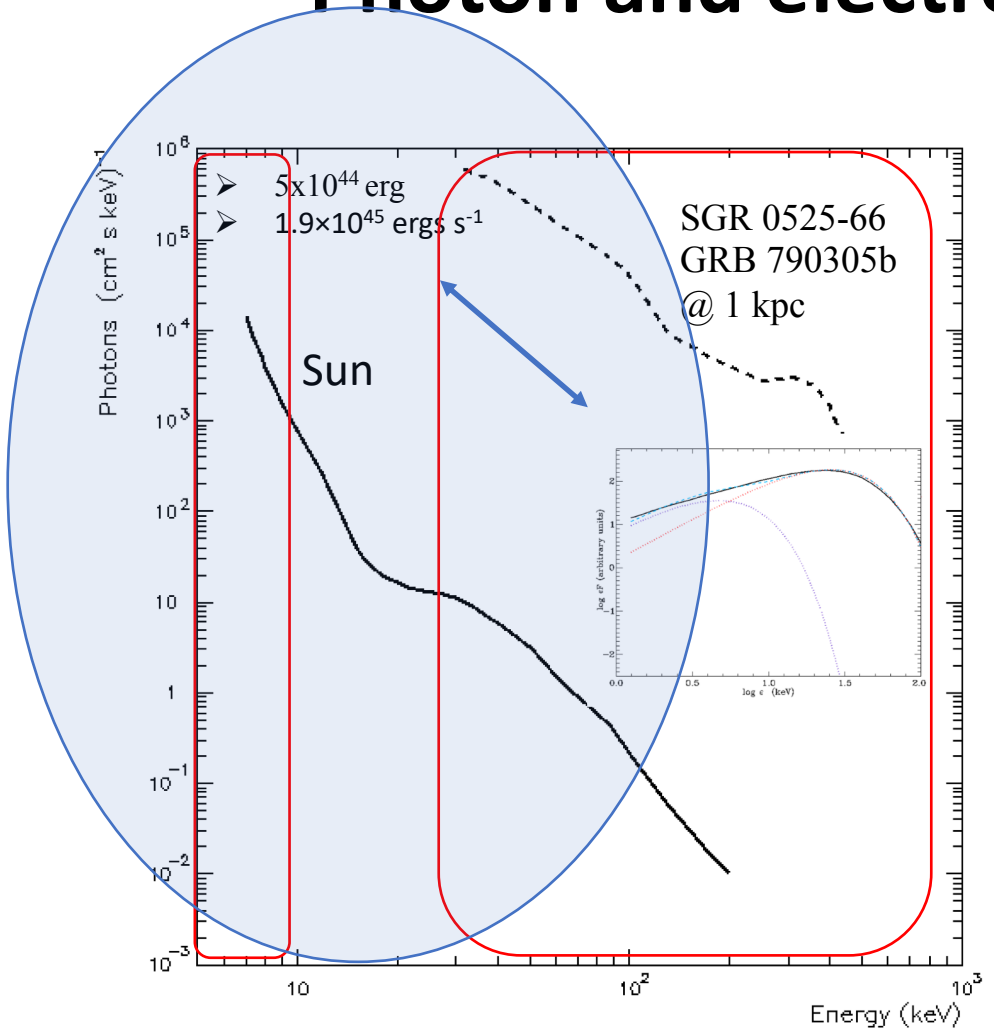
Event onset



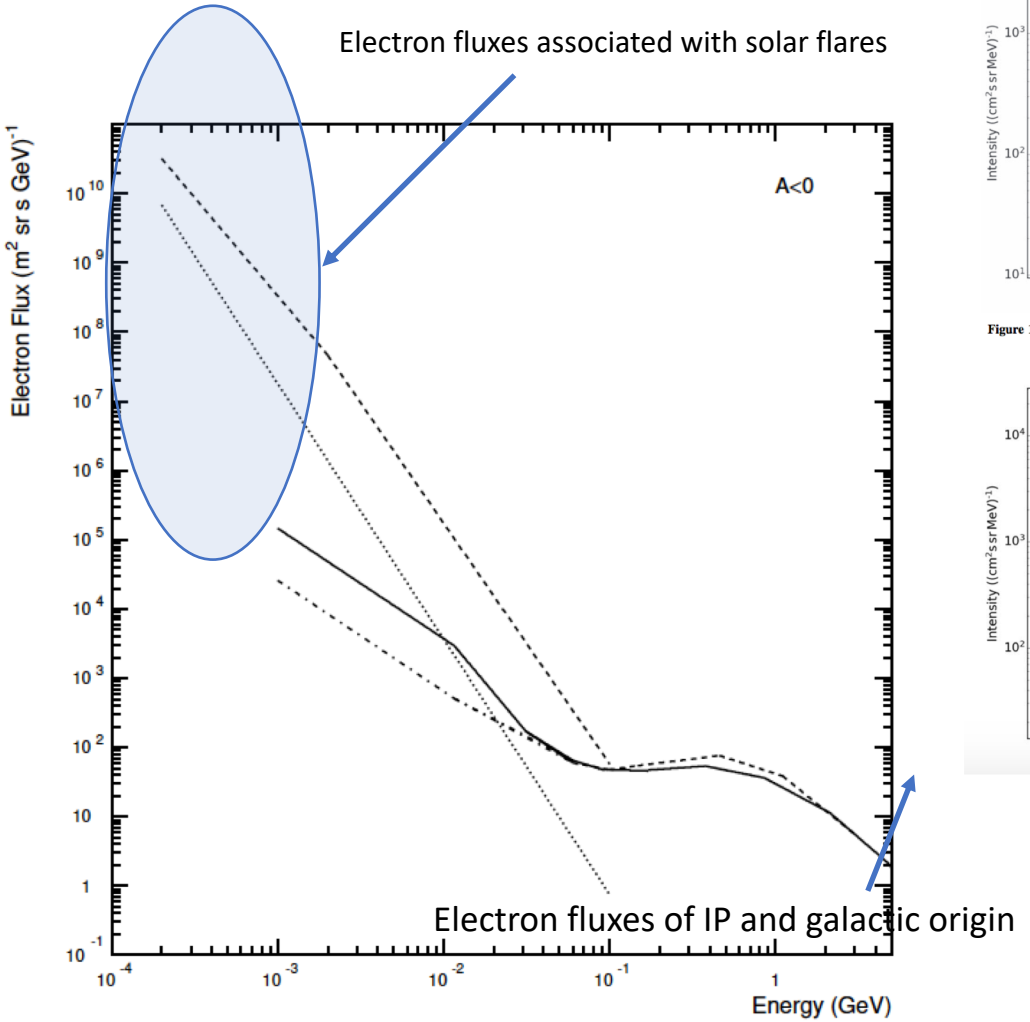
Event peak

C. Grimani et al., arXiv: 2302.00339, submitted to Astroph. Sp. Sc.

Photon and electron fluxes from star flaring



Fenimore, Klebesadel and Laros, ApJ, 460, 964 (1996)



C. Grimani et al., CQG, 26, 26,15004 (2009)

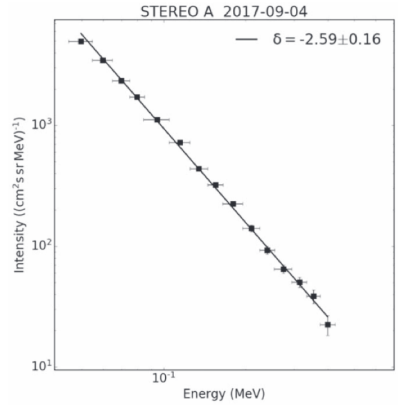
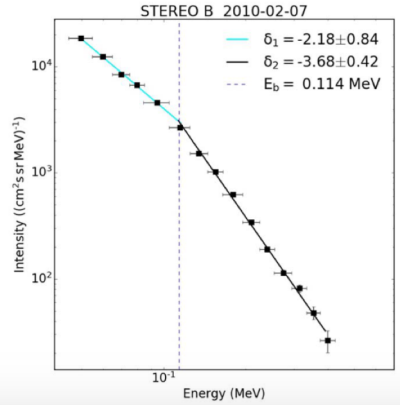


Figure 1. Example of an event with a single power-law peak spectrum.



Some other events

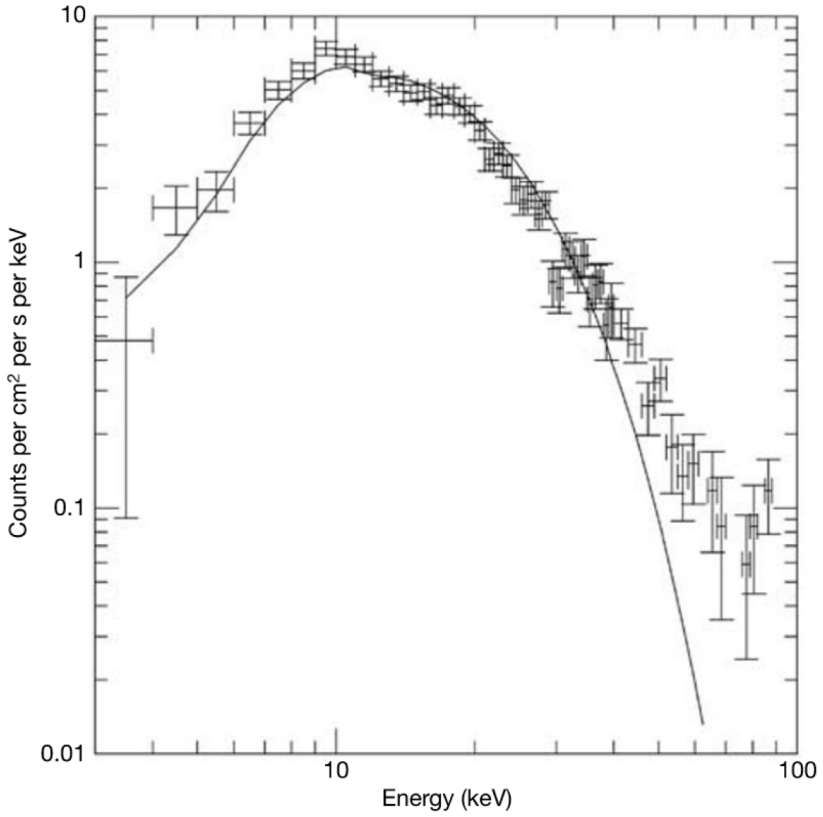
- SGR 1900+14 : August 27, 1998 at 12.5 kpc from Earth, total hard X-ray and soft gamma emission of $2x10^{44}$ erg.
- SGR 1806-20 at 8.7 kpc from Earth was observed on 27 dicembre 2004.
- **Energy most likely beamed**

GRBs and magnetar flaring

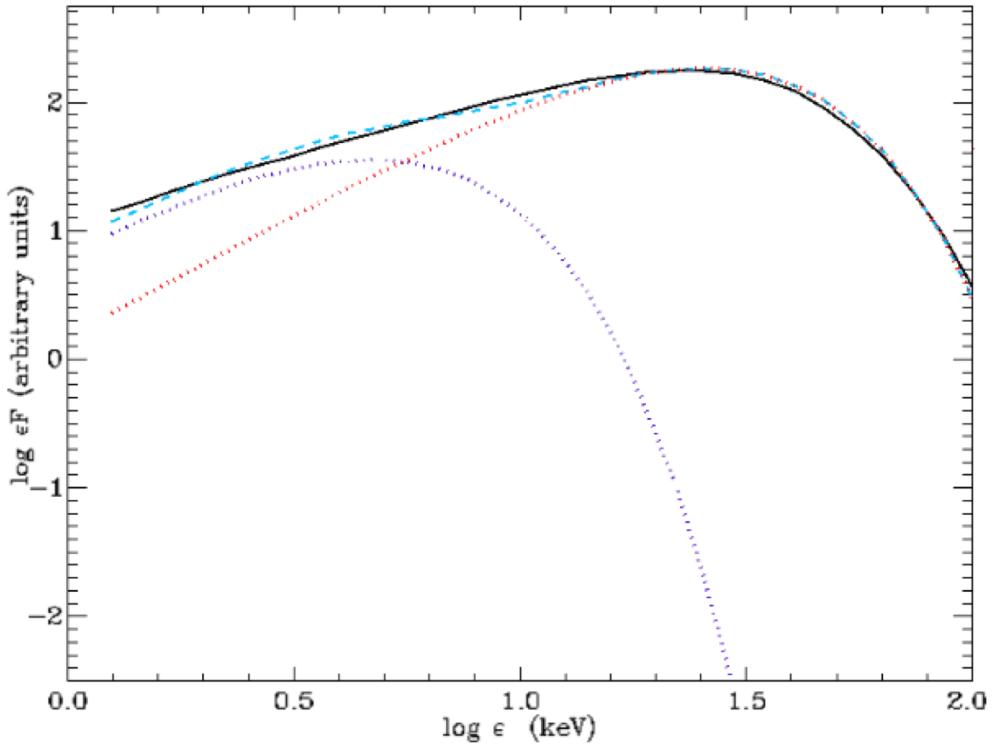
- Continuous X-ray emission characterized by a few second periodicities and a luminosity of 10^{35}-10^{36} erg s^{-1} in the range 1-200 keV.
- Flaring 0.1-1 s (first phase 0.2 s)
- In general magnetars emit 10^{39}-10^{42} erg s^{-1} even though the emission may reach 10^{44} erg s^{-1} and the total energy vary between 10^{44} a 10^{46} erg
- These emissions are weak with respect to extragalactic GRBs (> 10^{51} erg)

Comparison of near-Earth X solar flaring to the March 5th event @ 1 kpc distance

SGR 1806-20



Hurley et al., Nature , vol. 434 , 28 April 2005



Roberto Taverna & Roberto Turolla, Galaxies, 6, 35, 2018

WE MAY BE ABLE TO MONITOR THESE EVENTS WITH **HASPIDE-SPACE**

a-Si:H detector present sensitivity: improvements are expected and necessity of presenting results in the same units

→ photons: by considering the 3-40 keV energy interval the minimum detectable flux lies well below expected solar flux

→ electrons: by considering electrons with energies > 50 keV signal barely noticeable (S/N 1.8): **no from simulations**

→ protons: using the whole spectrum we obtain thousands of protons per second as minimum detectable signal

Detection limits at 5σ for monochromatic photon fluxes.

Photon Energy [keV]	Minimum detectable flux [$\gamma/(cm^2\ sr\ s)$]
3.0	$2.4 \cdot 10^3$
5.0	$3.8 \cdot 10^3$
10.0	$10.2 \cdot 10^3$
15.0	$20.2 \cdot 10^3$
20.0	$33.0 \cdot 10^3$
25.0	$47.8 \cdot 10^3$
30.0	$79.8 \cdot 10^3$
35.0	$150.0 \cdot 10^3$
40.0	$237.0 \cdot 10^3$

Detection limits at 5σ for monochromatic proton fluxes.

Proton Energy [MeV]	S/N ≥ 5 1 Flux [p $(cm^2\ sr\ s)^{-1}$]
5.0	$0.4 \cdot 10^3$
10.0	$0.5 \cdot 10^3$
20.0	$1.0 \cdot 10^3$
50.0	$1.5 \cdot 10^3$
70.0	$3.0 \cdot 10^3$
100.0	$3.5 \cdot 10^3$
200.0	$5.0 \cdot 10^3$
400.0	$10.0 \cdot 10^3$

M. Menichelli et al., arXiv:2211.17114 submitted to Instruments
C. Grimani et al., arXiv: 2302.00339, submitted to Astroph. Sp. Sc.

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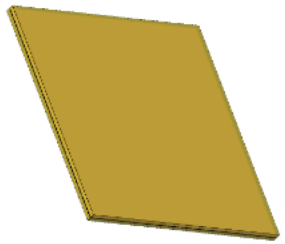
Optimization of a a:Si-H detector

- **a:Si-H active material** and tungsten as passive material
- CSDA proton range in tungsten (Z=74)
- Tungsten density: 19.25 g/cm^3
- Geometrical factor 0.5 cm^2 sr (single sensor) about 1 kg detector (minimum) depending on the material in the region between the sensitive detectors to detect up to 400 MeV protons

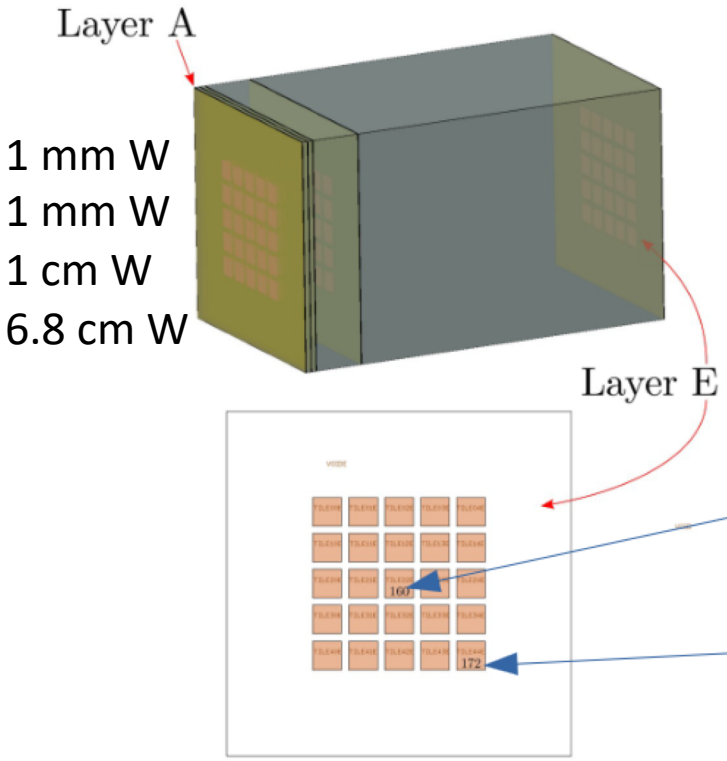
Energia	CSDA range	Range	Massa
300 MeV	99.33 g/cm^2	5.16 cm	2.5x2.5 → 620 g 2.0x2.0 → 397 g 1.5x1.5 → 223 g
350 MeV	127.1 g/cm^2	6.60 cm	2.5x2.5 → 795 g 2.0x2.0 → 508 g 1.5x1.5 → 286 g
400 MeV	156.8 g/cm^2	8.15 cm	2.5x2.5 → 979 g 2.0x2.0 → 627 g 1.5x1.5 → 353 g

HASPIDE-SPACE preliminary simulations with Fluka

75% of protons fully contained @ 400 MeV



- 4×4 mm^2 of silicon 10 μm thickness
- two kapton layers, 75 μm thickness



- Array 5×5 silicon detectors between two kapton foils on 5 layers, the front plane area is 4.8 cm^2

	400 MeV		600 MeV	
Region	Mean (keV)	RMS (keV)	Mean (keV)	RMS (keV)
160	11.7	26.4	4.2	26.1
172	16.1	36.1	2.1	5.0

3.6-4 eV are needed to generate an electron-hole pair
Charge collection efficiency: 30-80%

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Particle containment

- Photons from 5 keV through 100 keV
- Electrons from 100 keV through 1 MeV

Pass the first layer only and arrive at different times: photons within minutes, electrons in not less than tens of minutes and protons in hours (order of magnitude) from flaring.

Fund requests 2024

- No HW further requests
- Travel money (support)
- License Overleaf