Periodic variations of GCR intensity and anisotropy related to solar rotation by ACE/CRIS, STEREO, SOHO/EPHIN and neutron monitors observations

Renata Modzelewska and Agnieszka Gil

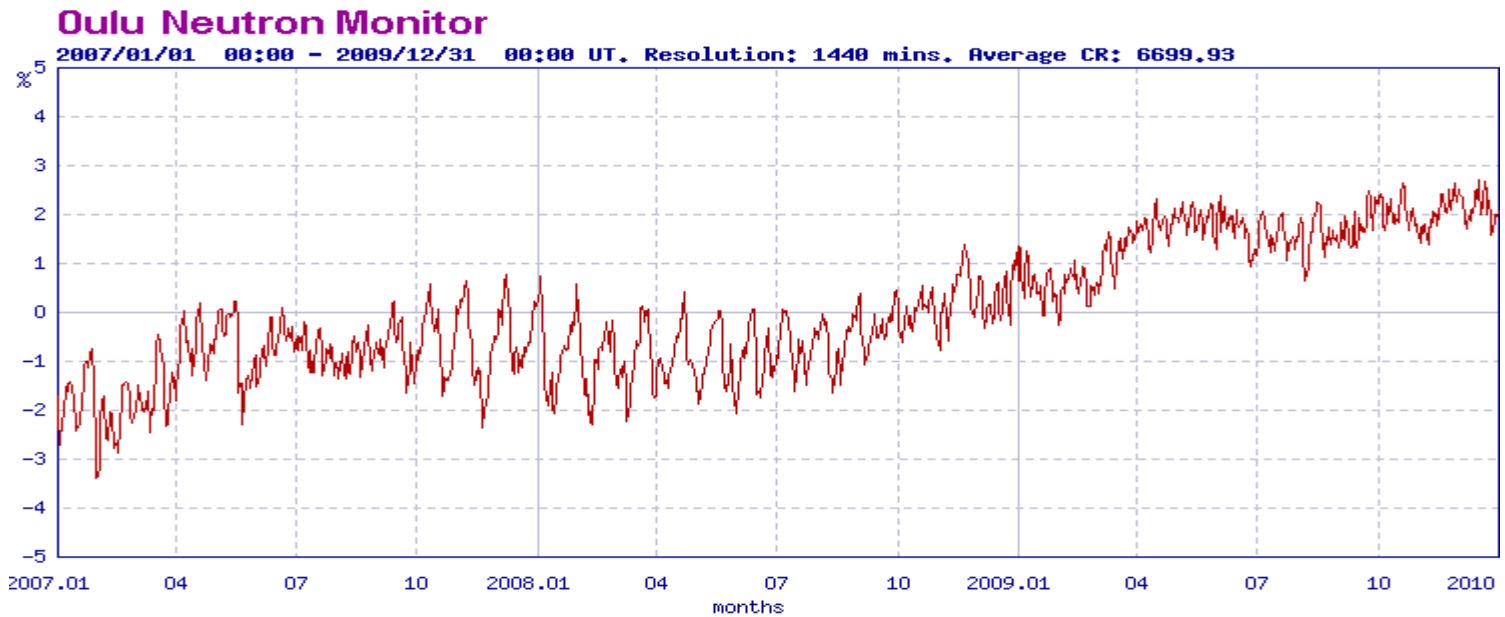
Siedlce University, Poland

renatam@uph.edu.pl

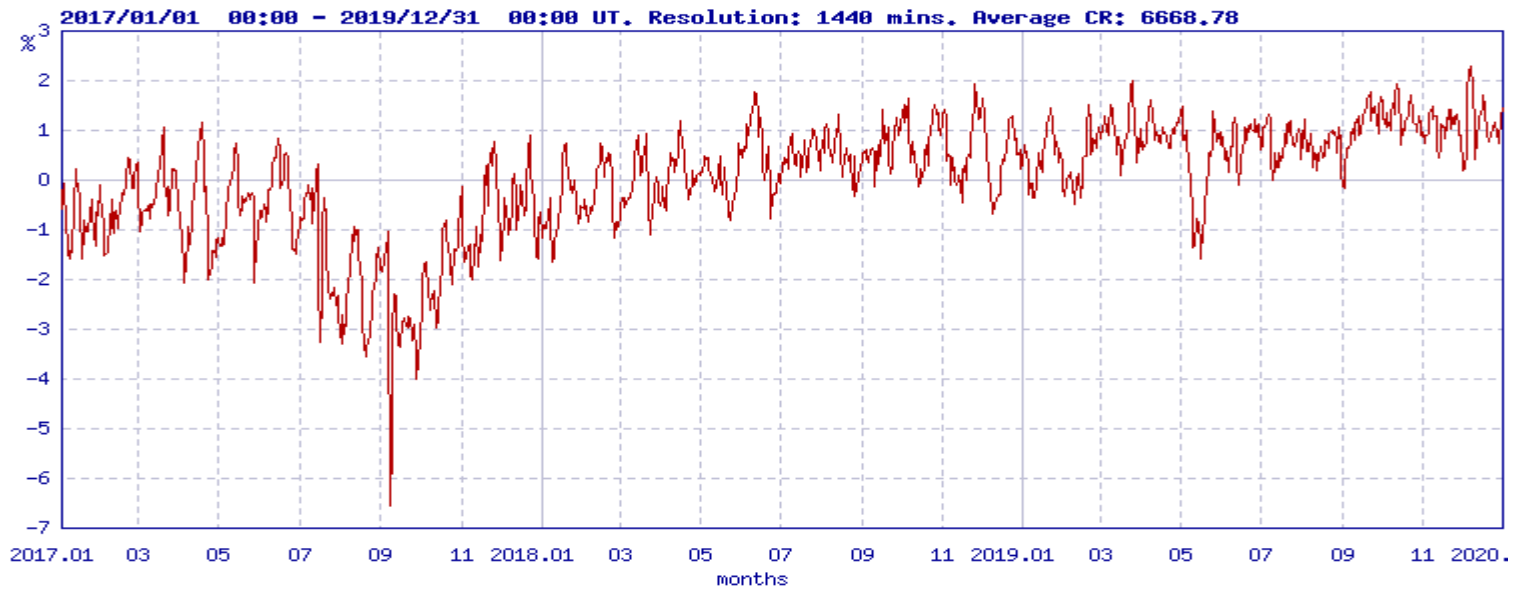
Outline

- **galactic cosmic ray (GCR) anisotropy and intensity near the solar minima 23/24 and 24/25 based on neutron monitor (NM) measurements**
- **27-day variations of GCR anisotropy and intensity in the solar minima: 2007-2009 (A<0) and 2017-2019 (A>0) in the opposite polarities of solar magnetic cycle**
- **27-day GCR variations by ACE/CRIS, STEREO A,B, SOHO/EPHIN**

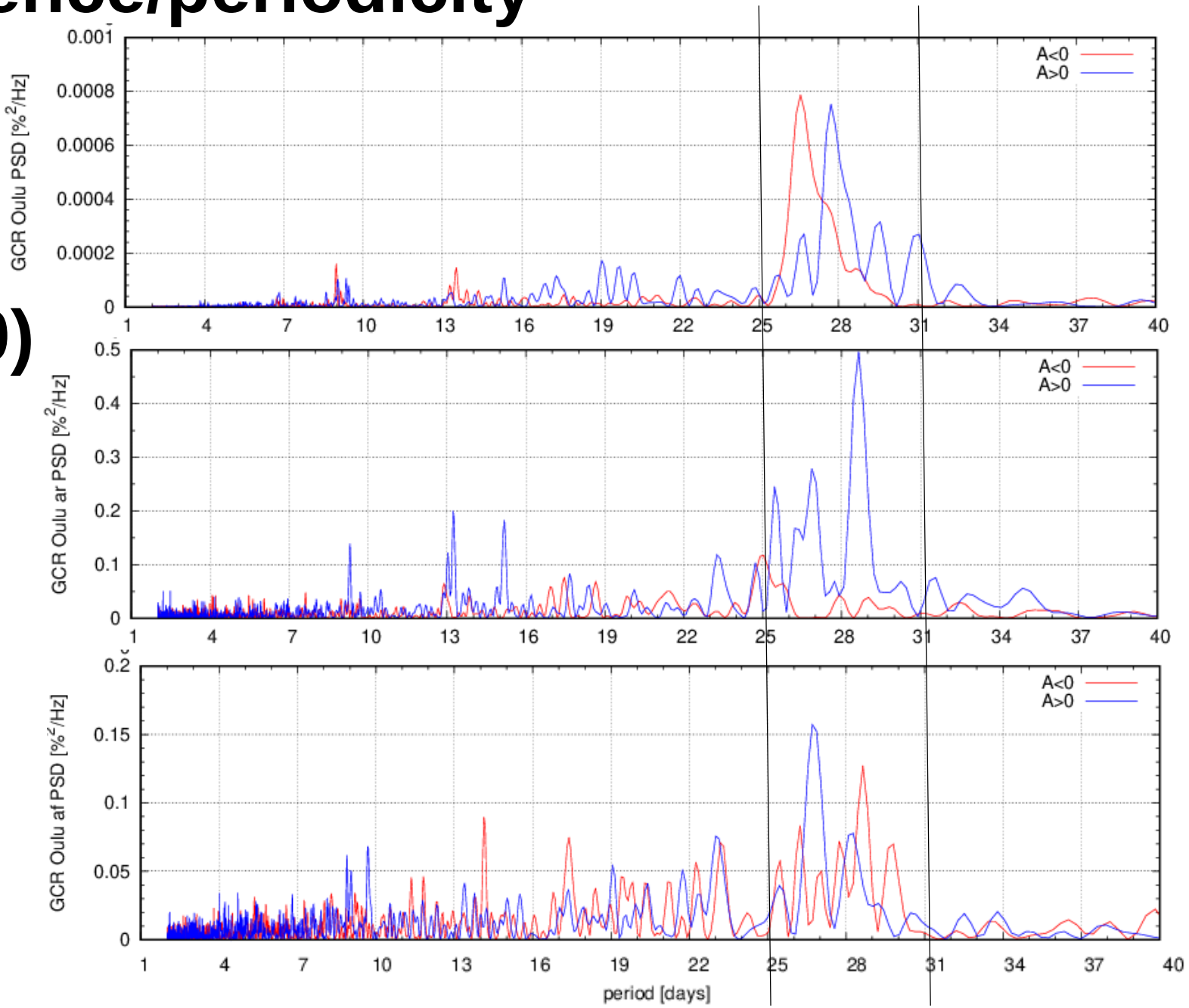
GCR variations 2007-2009 (A<0)



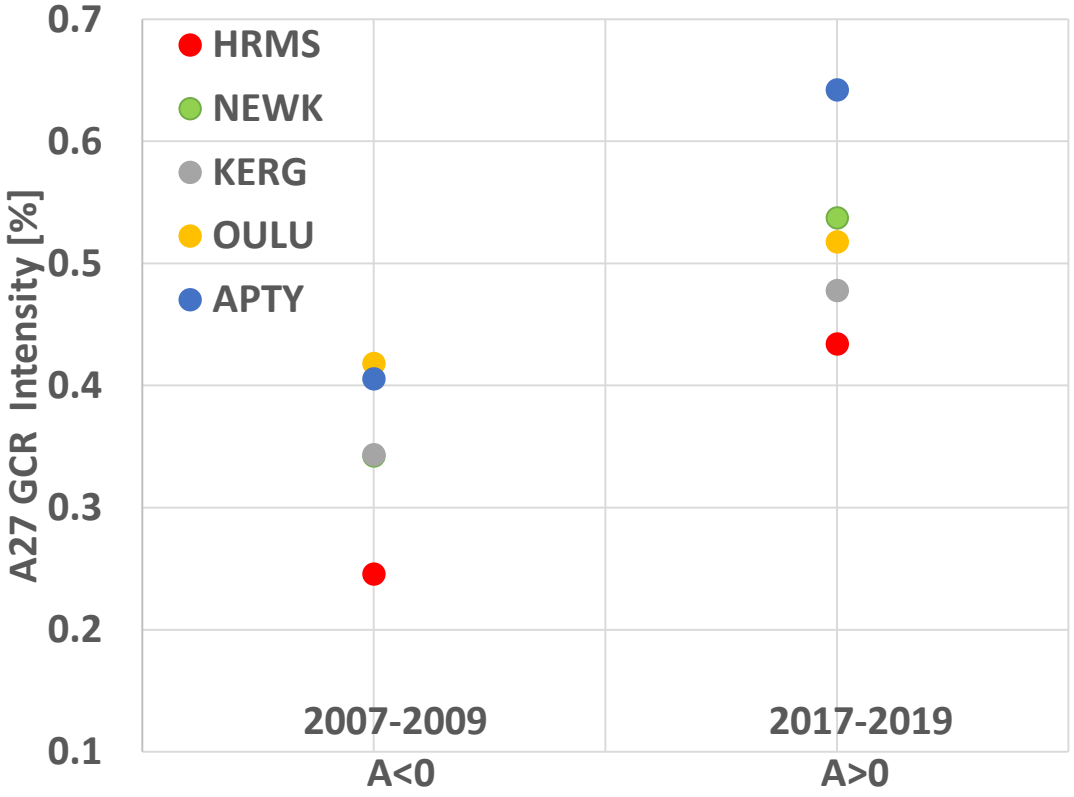
2017-2019 (A>0)

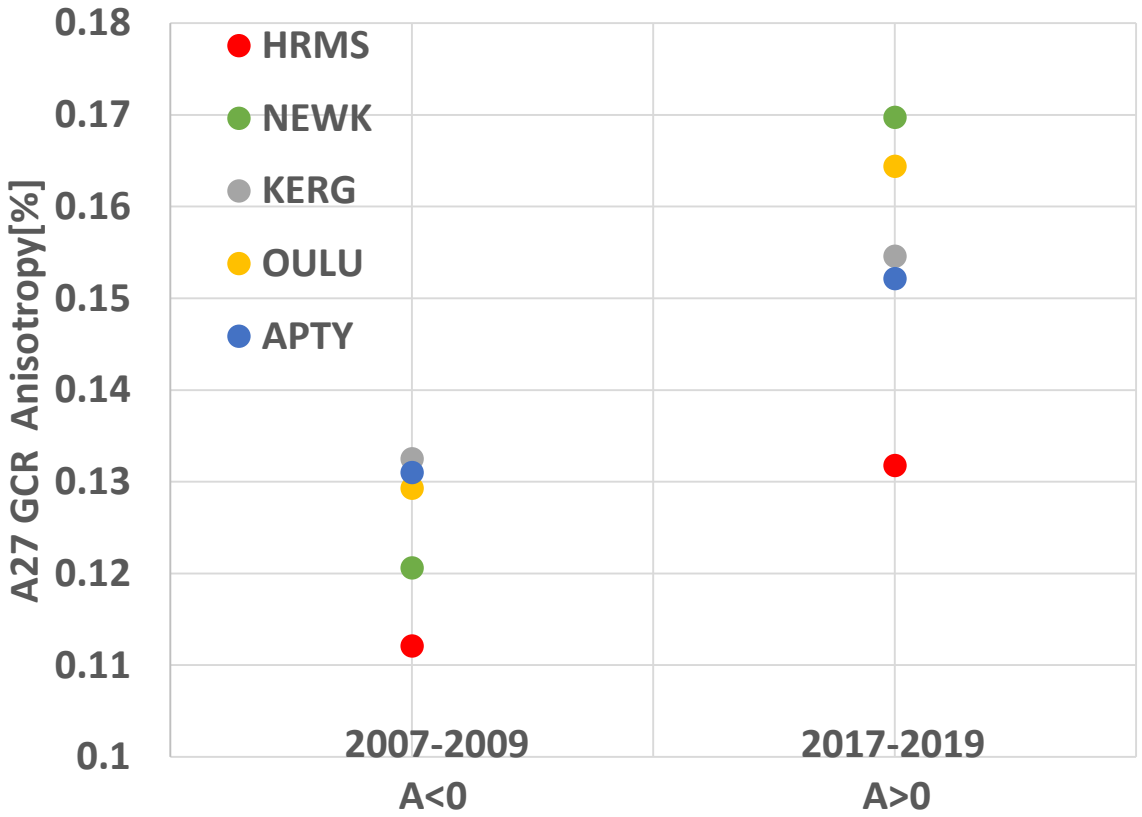


determining recurrence/periodicity of GCR intensity and anisotropy in 2007-2009 (A<0) and 2017-2019 (A>0)



Amplitudes of the 27-day GCR variations by NMs

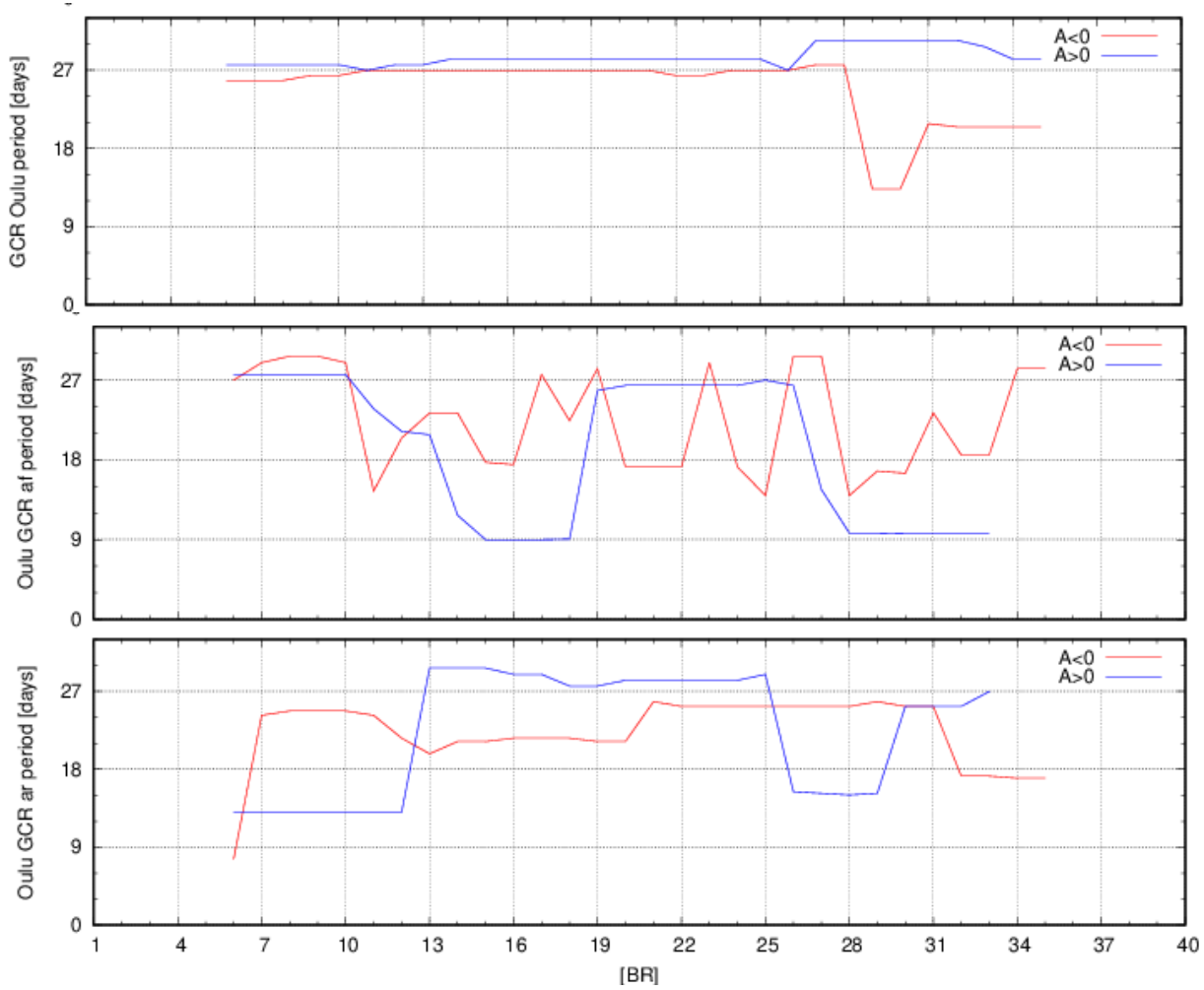


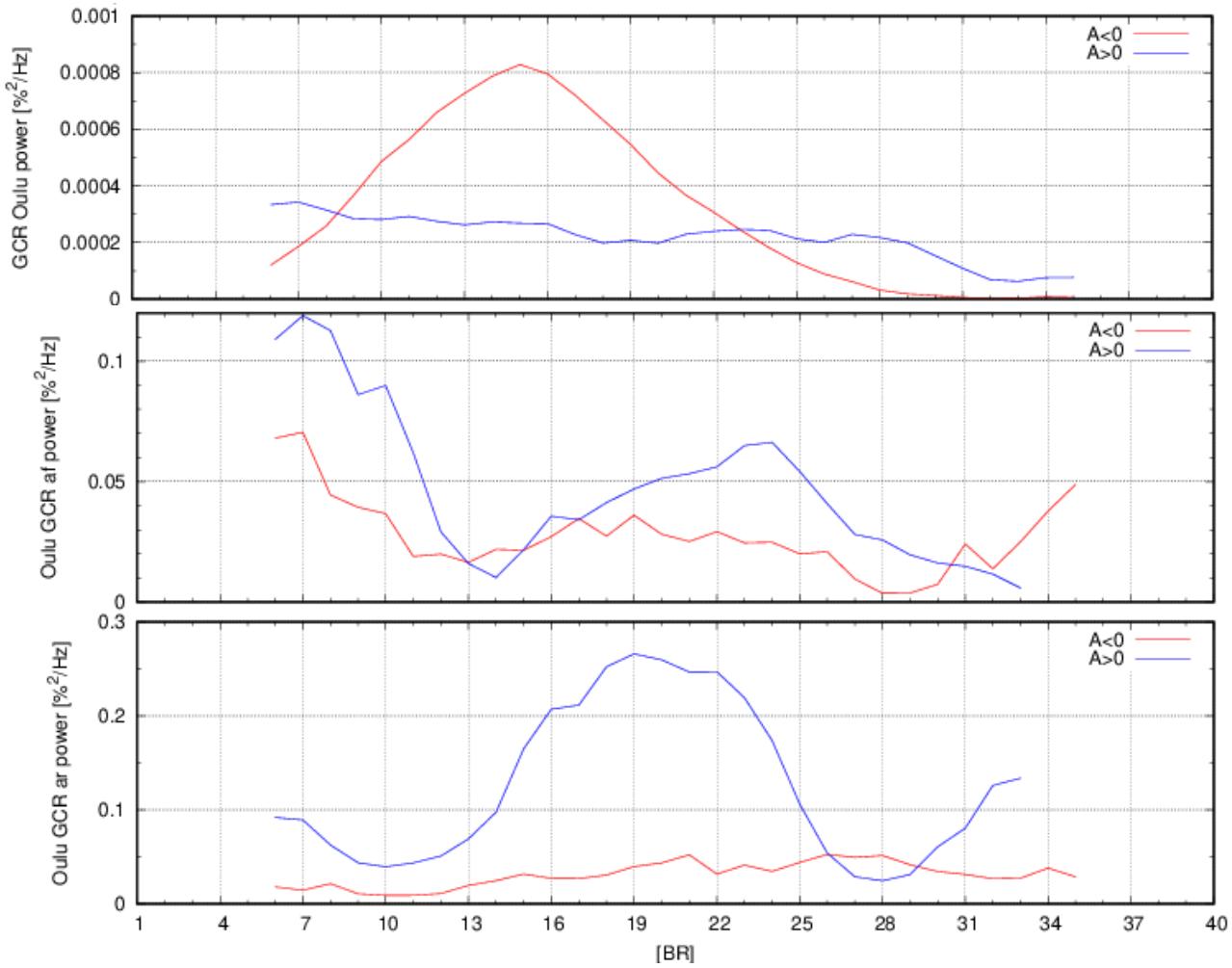


A27I[%]	$A<0$	$A>0$
NM station	2007-2009	2017-2019
Apatity	0.41±0.04	0.64±0.05
Kerguelen	0.34±0.04	0.48±0.05
Newark	0.34±0.04	0.54±0.07
Oulu	0.42±0.05	0.52±0.05
Hermanus	0.25±0.02	0.43±0.05

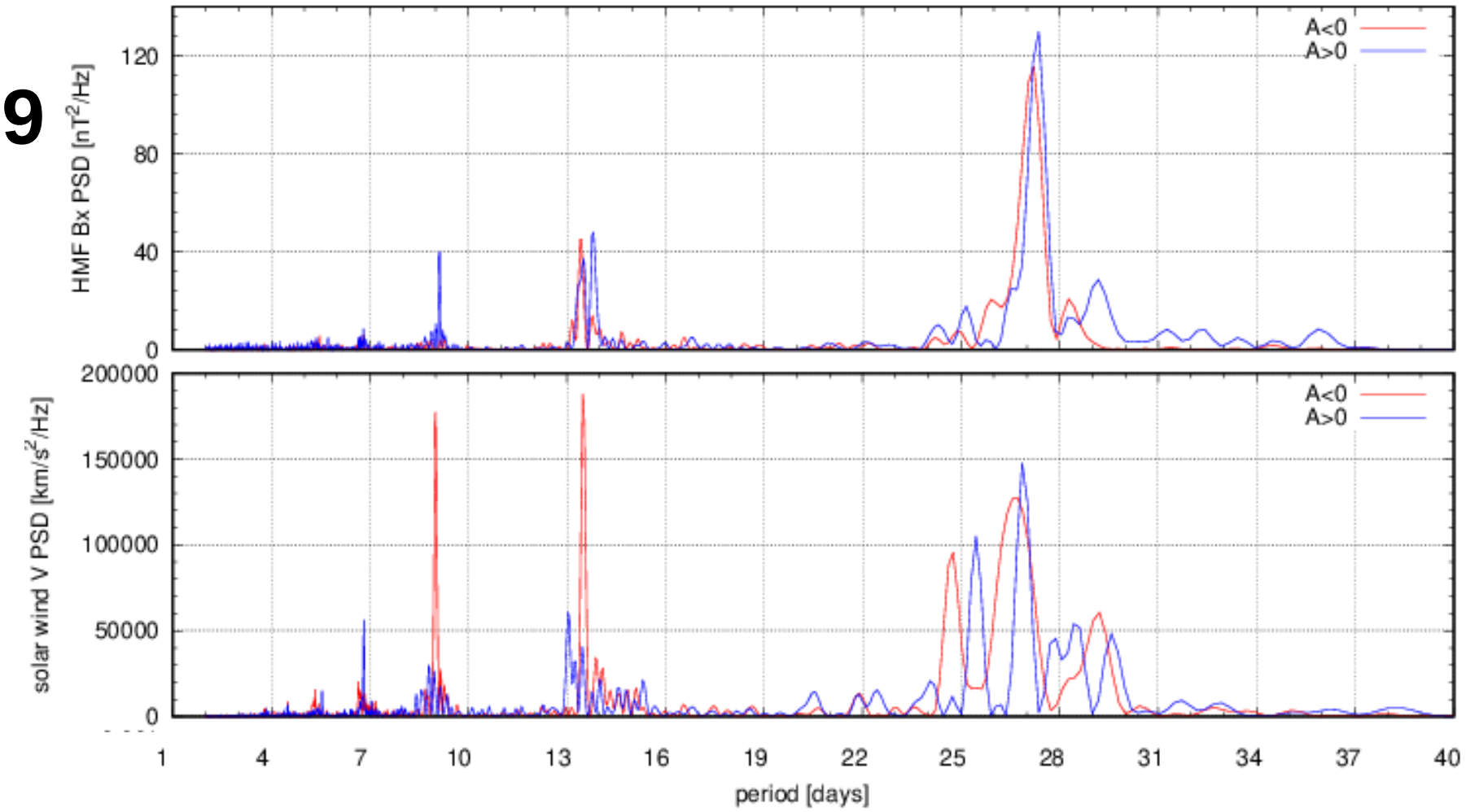
A27A[%]	$A<0$	$A>0$
NM station	2007-2009	2017-2019
Apatity	0.13±0.01	0.15±0.01
Kerguelen	0.13±0.01	0.15±0.01
Newark	0.12±0.01	0.17±0.02
Oulu	0.13±0.01	0.16±0.02
Hermanus	0.11±0.01	0.13±0.01

Dynamics of the periodicity and related maximum power of GCR intensity and anisotropy components

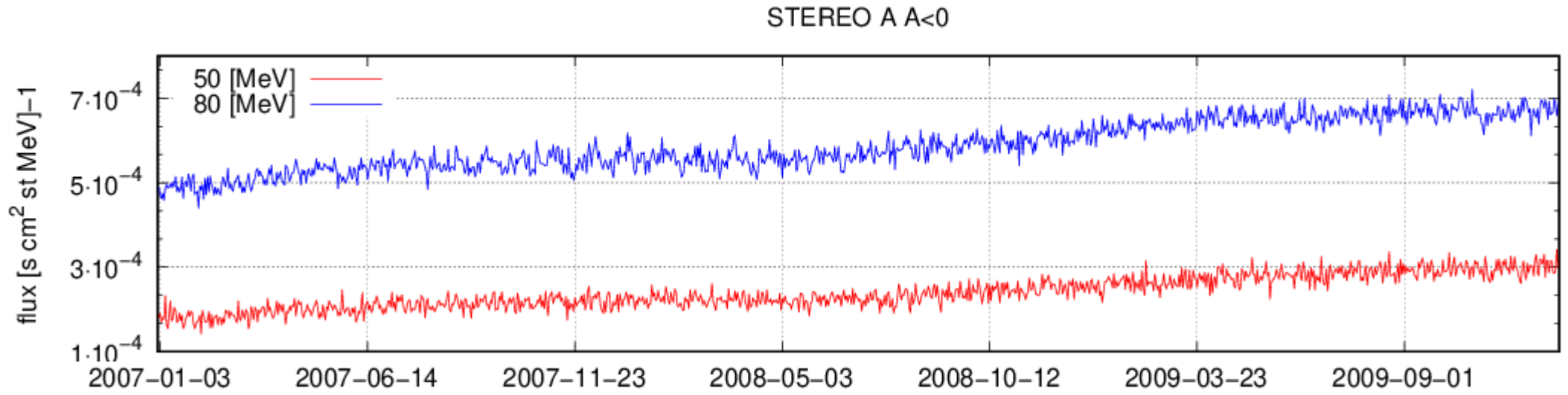




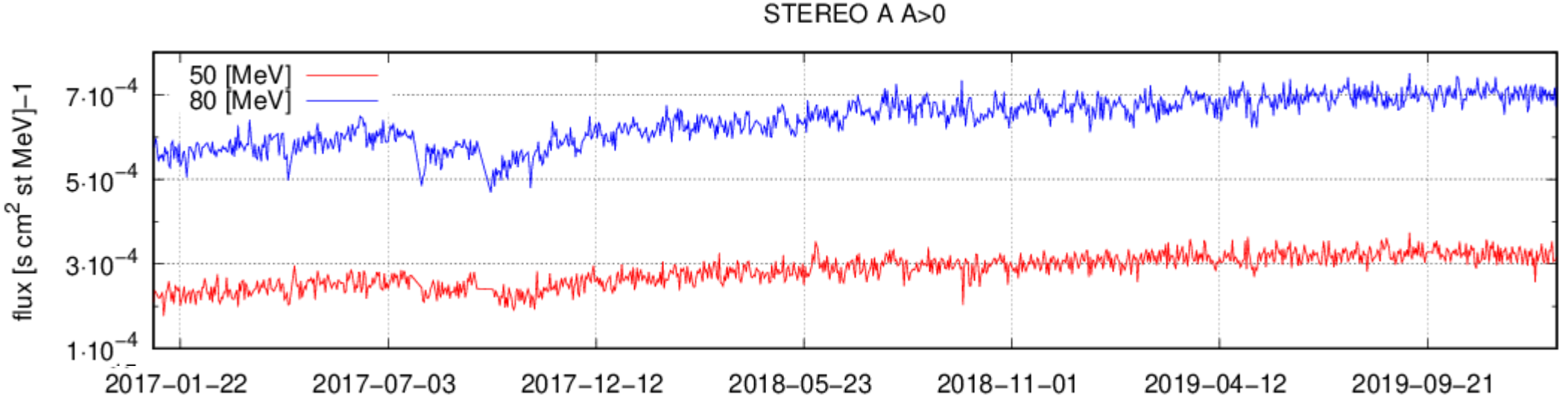
determining recurrence/periodicity in HMF Bx and solar wind velocity in 2007-2009 and 2017-2019



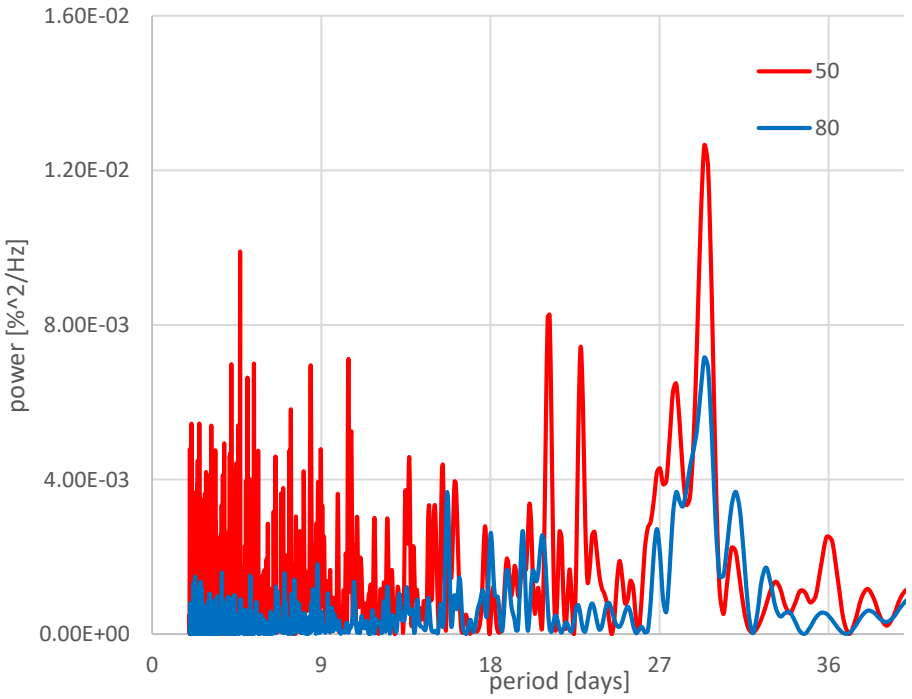
STEREO
2007-2009 (A<0)



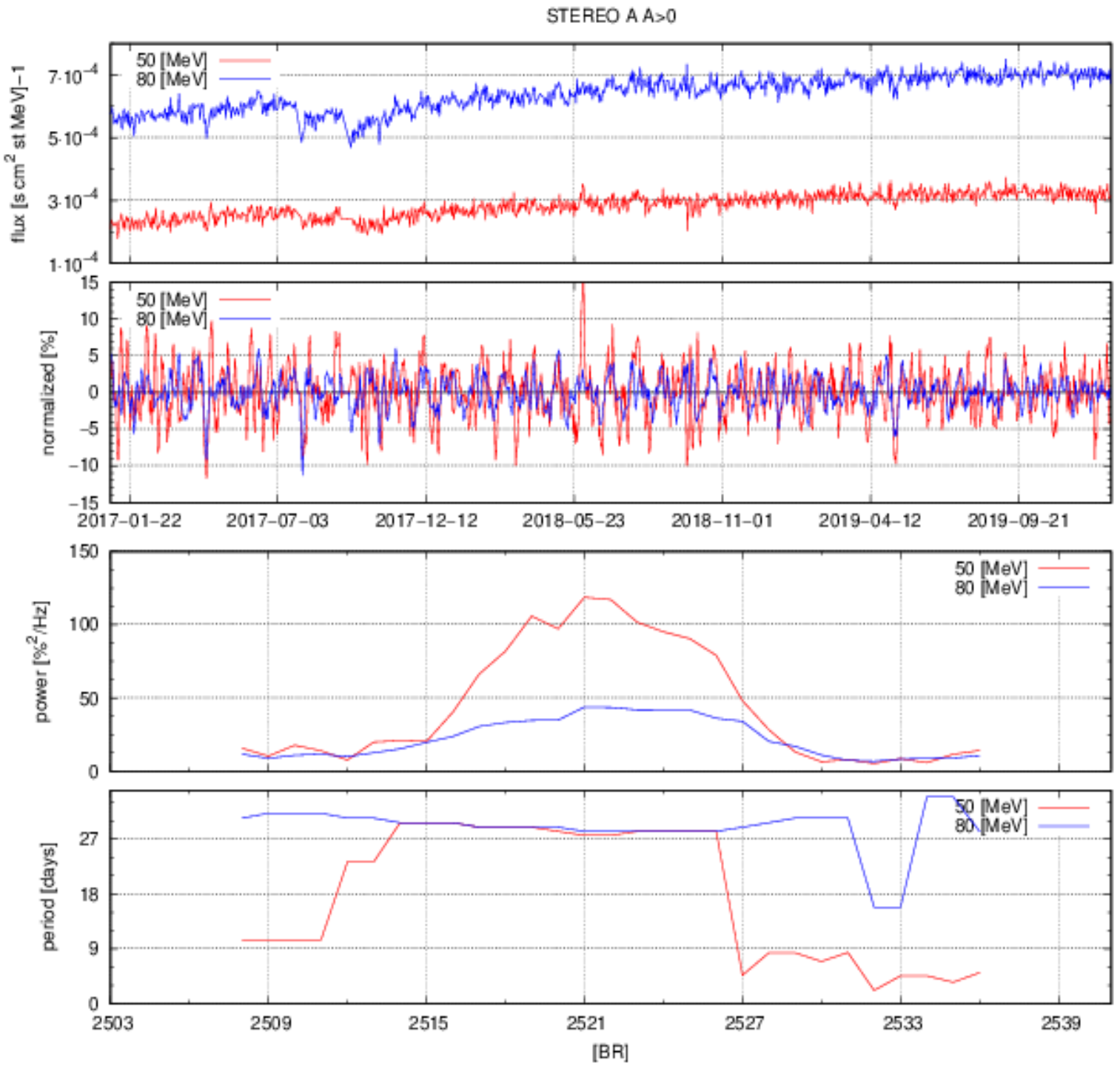
2017-2019 (A>0)



data processing

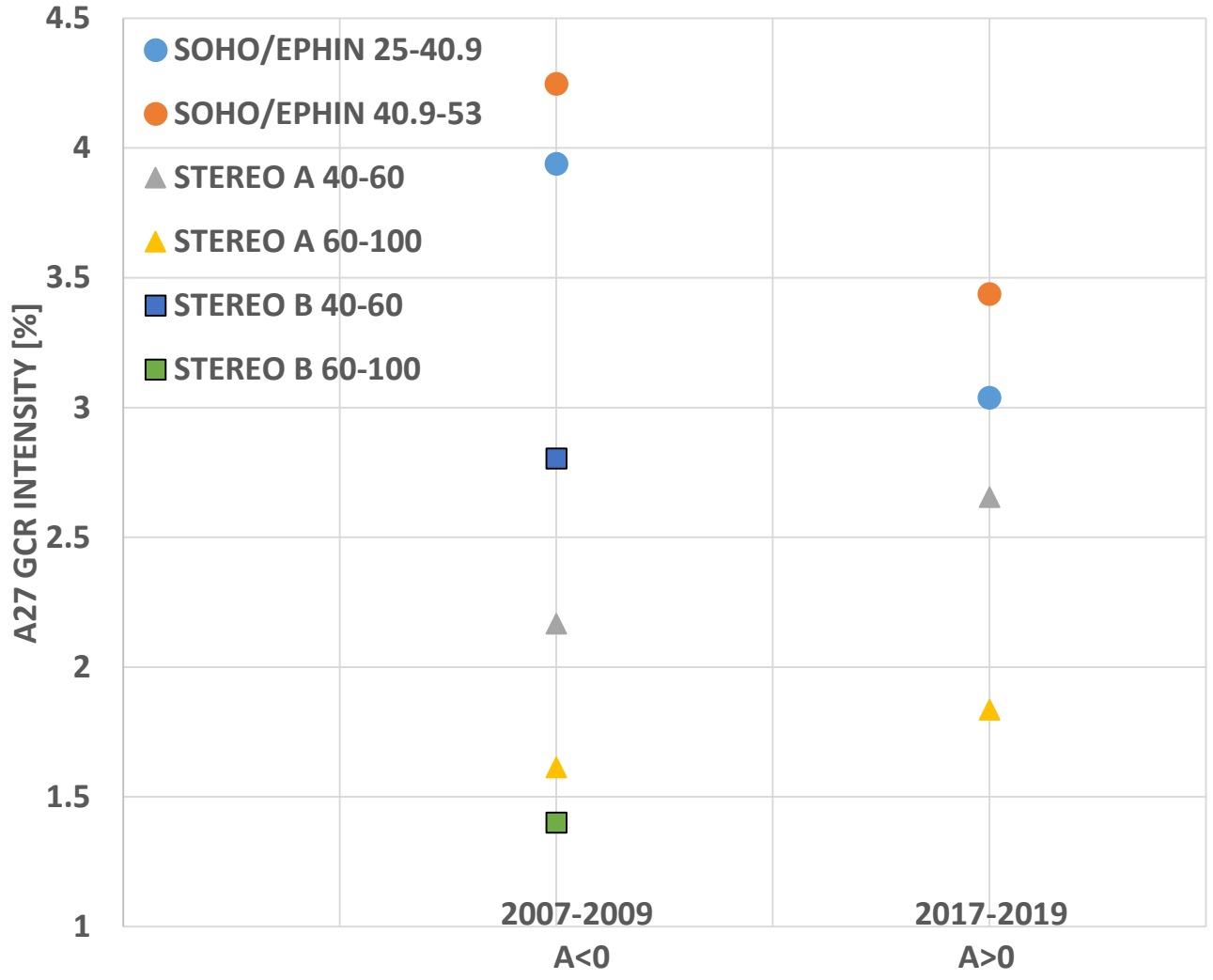


$$\sum_{k=1}^{\infty}(a_r^k cos\frac{2\pi kt}{T} + a_\varphi^k sin\frac{2\pi kt}{T}) = \sum_{i=1}^{\infty} a_k sin(\frac{2\pi kt}{T} + \varphi_k)$$

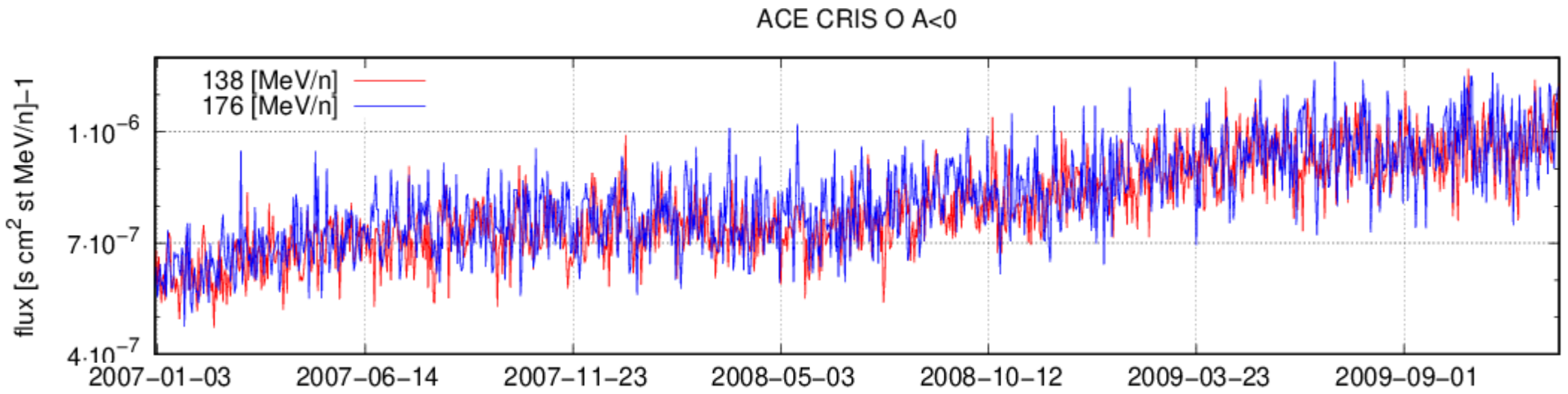


Amplitudes of the 27-day GCR variations SOHO/EPHIN STEREO A and B

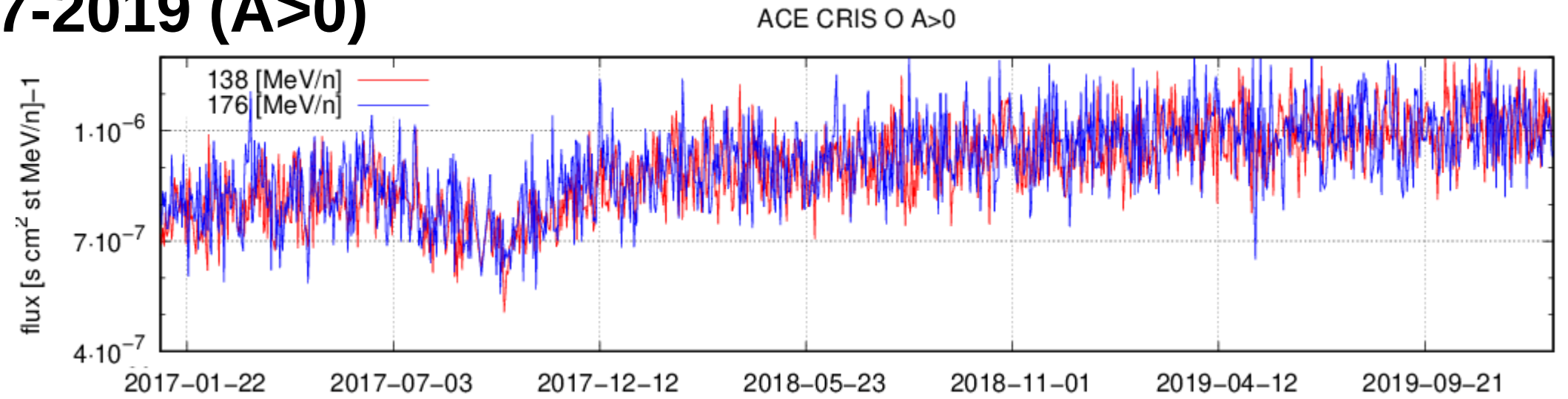
A27I[%]	$A < 0$	$A > 0$
	2007-2009	2017-2019
E[MeV/n]		
SOHO EPHIN		
25-40.9	3.94±0.00	3.04±0.36
40.9-53	4.25±0.00	3.44±0.37
STEREO A		
40-60	2.17±0.20	2.65±0.20
60-100	1.61±0.20	1.83±0.10
STEREO B		
40-60	2.80±0.30	——
60-100	1.40±0.10	——



ACE CRIS Oxygen
2007-2009 (A<0)

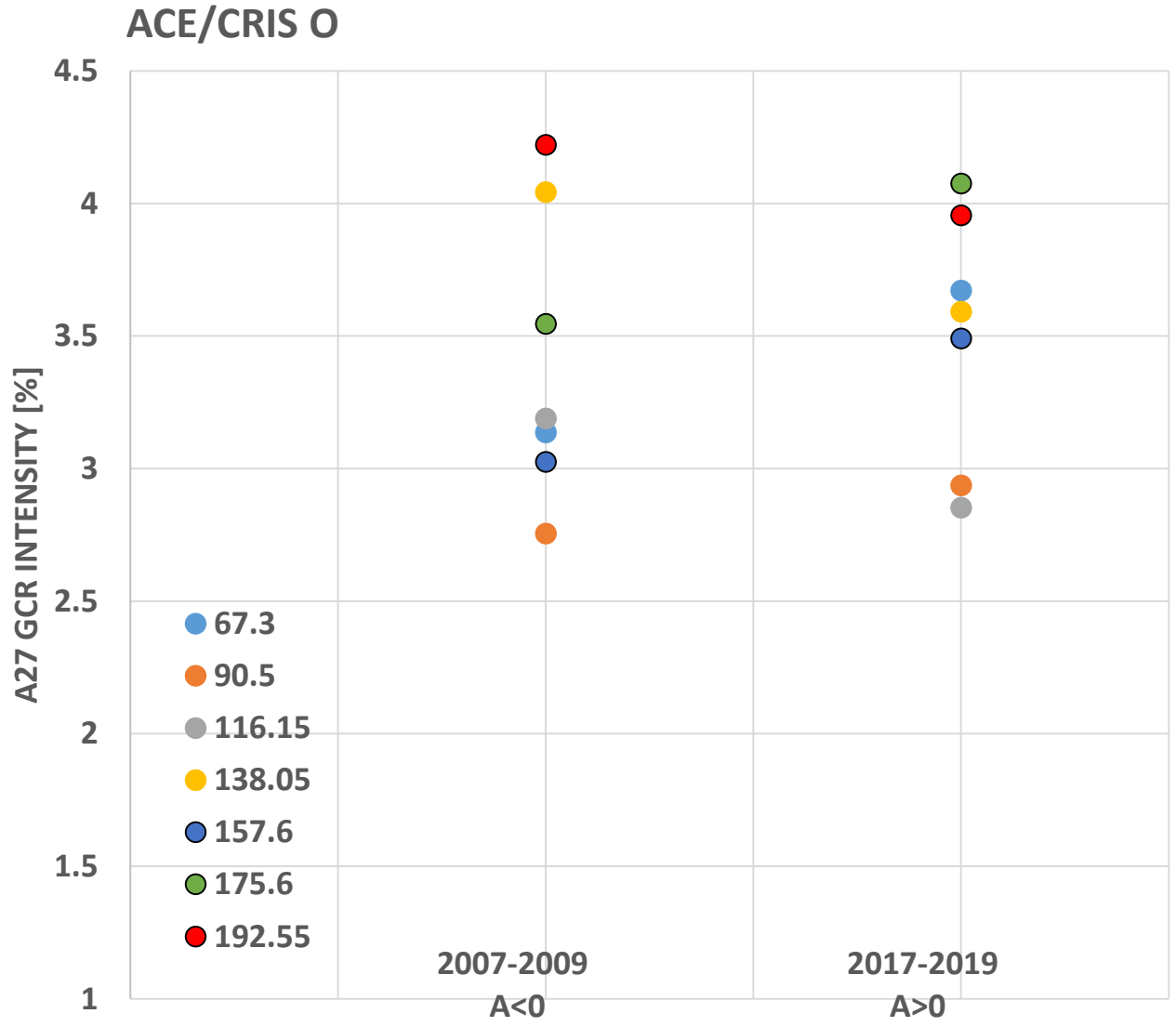


2017-2019 (A>0)

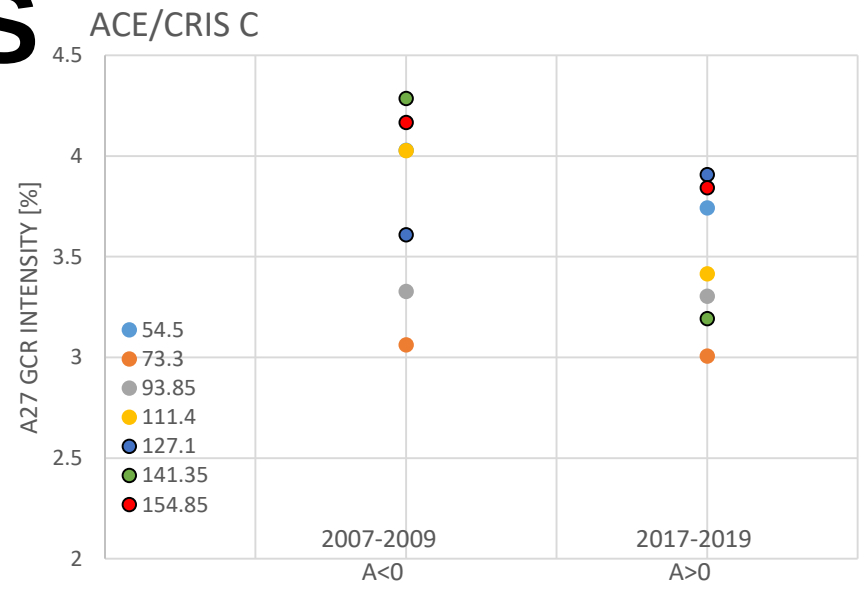


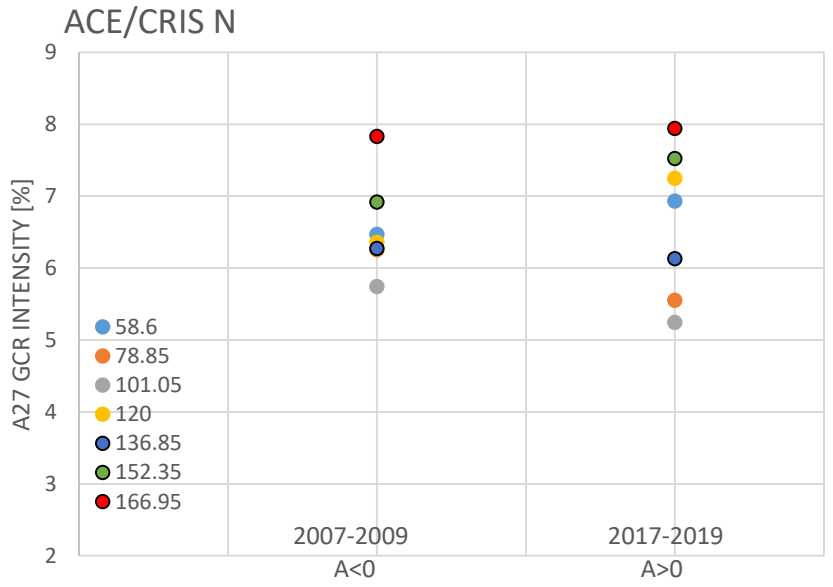
Amplitudes of the 27-day GCR variations ACE/CRIS

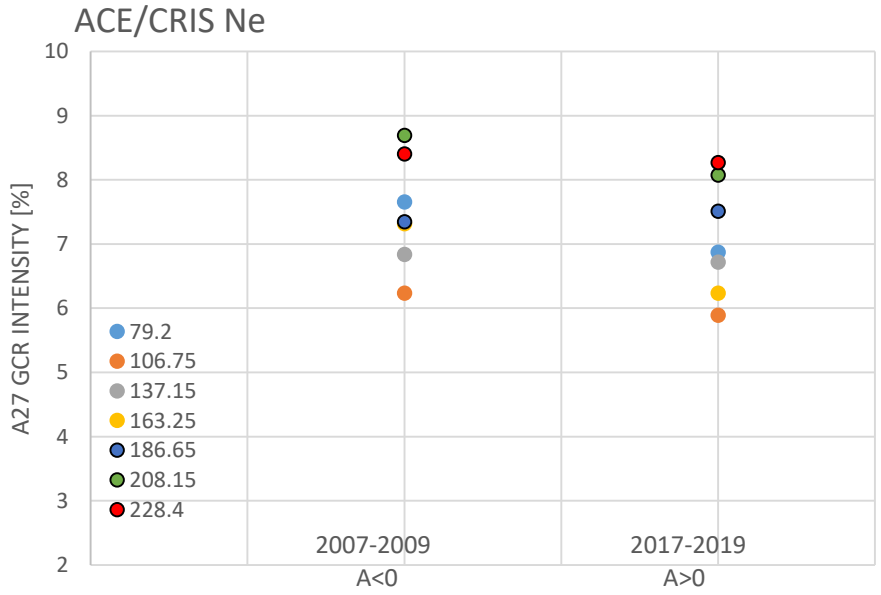
A27I[%]	$A < 0$	$A > 0$
ACE O	2007-2009	2017-2019
E[MeV/n]		
59.0-75.6	3.14±0.19	3.67±0.29
77.2-103.8	2.76±0.26	2.94±0.24
105.1-127.2	3.19±0.25	2.85±0.24
128.3-147.8	4.04±0.40	3.59±0.29
148.7-166.5	3.03±0.21	3.49±0.28
167.4-183.8	3.55±0.33	4.08±0.35
184.7-200.4	4.22±0.32	3.96±0.35

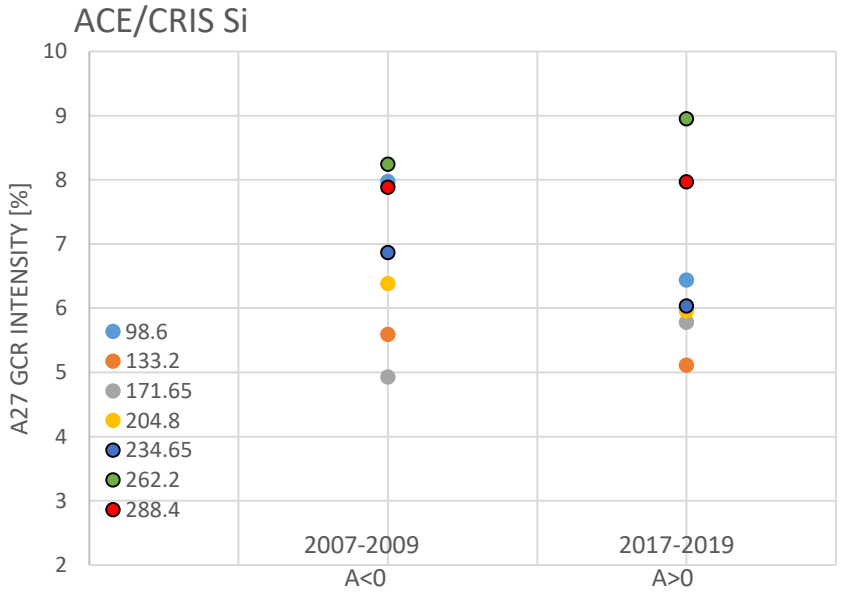


Amplitudes of the 27-day GCR variations ACE/CRIS









Polarity dependence of recurrent GCR modulation – possible explanation

- **Several approaches were proposed, e.g., the polarity dependent diffusion coefficients (Richardson et al. 1999; Richardson 2004), heliolongitudinal asymmetry of the solar wind velocity (Modzelewska & Alania 2012) and convection+drift effects (Gil & Mursula 2017).**
- **Guo & Florinski (2016) pointed out that modulation around CIR is possible only through the perpendicular diffusion effect.**
- **Ghanbari et al. (2019) and Guo et al. (2021) proposed that the convection of solar wind does not play a significant role in the vicinity of CIRs and indicated that the GCR intensity is inversely proportional to the perpendicular diffusion coffiecient around CIR.**
- **Engelbrecht and Moloto (2020) reduction of drift effect for lower energies;**
- **Vrsnak et al., Dumbovic et al., (2022) convection-diffusion approach with reduced diffusion-effect caused by the enhanced magnetic field fluctuations (delta B) in CIR**
- **Future plans for analyzing AMS data at ISS, PSP and SO**
- **Due to the complexity of GCR modulation around CIR future numerical models should be tested…**

Summary

- **The amplitudes of the 27-day variations of GCR anisotropy and intensity observed by NMs in the solar minima: 2007-2009 and 2017-2019 are polarity dependent with larger amplitudes for A>0 which confirms a 22-year cyclic pattern reported earlier (e.g. Alania et al. 2005; 2008).**

- **The amplitudes of the 27-day variations of GCR intensity observed by ACE/CRIS in the solar minima: 2007-2009 and 2017-2019 seem to be NOT polarity dependent.**

- **GCR modulation effect around CIR for lower energies is much more complicated for spacecraft data (ACE, STEREO and SOHO) and needs further study…**

Modzelewska and Gil, Astronomy & Astrophysics, 646, A128 (2021), DOI: 10.1051/0004-6361/202039651, https://doi.org/10.1051/0004-6361/202039651

Thank you!

Amplitudes of the 27-day GCR variations ACE/CRIS

A27I[%] *ACE* Fe E[MeV/n]	$A < 0$ 2007-2009	$A > 0$ 2017-2019
123.5-159.6	5.79±0.45	6.63±0.63
163.3-222.3	5.15±0.44	5.10±0.47
225.1-275.3	5.76±0.56	5.17±0.44
277.8-322.8	6.09±0.42	6.76±0.56
324.9-366.7	7.73±0.77	6.63±0.57
368.6-407.7	8.06±0.74	9.06±0.71
409.9-447.7	9.26±0.76	10.18±0.95