Scenarios for the Space Radiation Environment for Solar Cycle 25

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Introduction

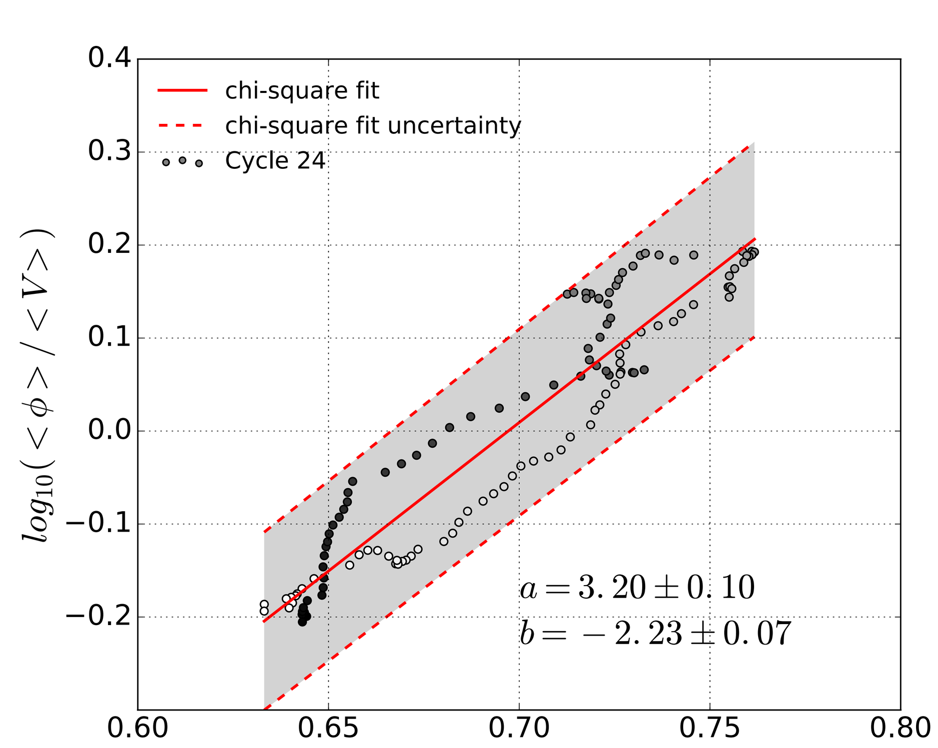
- The persistent decline in the strength of solar cycles indicate that we are at the beginning of a secular solar minimum.
- The fluxes of galactic cosmic rays (GCRs) have increased to levels never reported previously in the space age.
- This might limit safe human space exploration over long-term missions (e.g., to Mars).
- We use data from the Cosmic Ray Telescope for the Effects of Radiation (CRaTER) to investigate the space radiation environment through solar cycle 24.
- We examine the correlation between the heliospheric magnetic field (HMF), the global solar wind speed, and the modulation potential of the GCRs.
- We apply this correlation to past secular minima conditions, including the Dalton (1790-1830) and the Gleissberg (1890-1920) as possible scenarios to predict the modulation potential and dose rates of GCRs through solar cycle 25.

Galactic Cosmic Radiation

- GCRs are energetic charged particles, accelerated in supernova explosions that enter the heliosphere at a constant rate.
- They consist of protons, heavier ions and electrons.
- Most of them are filtered at the interface between the heliosphere and the interstellar medium.
- The remaining ions are modulated by the HMF. Thus, solar cycles affect their flux in the inner heliosphere.
- GCRs are highly energetic and penetrating, albeit with low fluxes. Hence, they need time to build doses and are associated with long-term health problems for the space missions' crew.

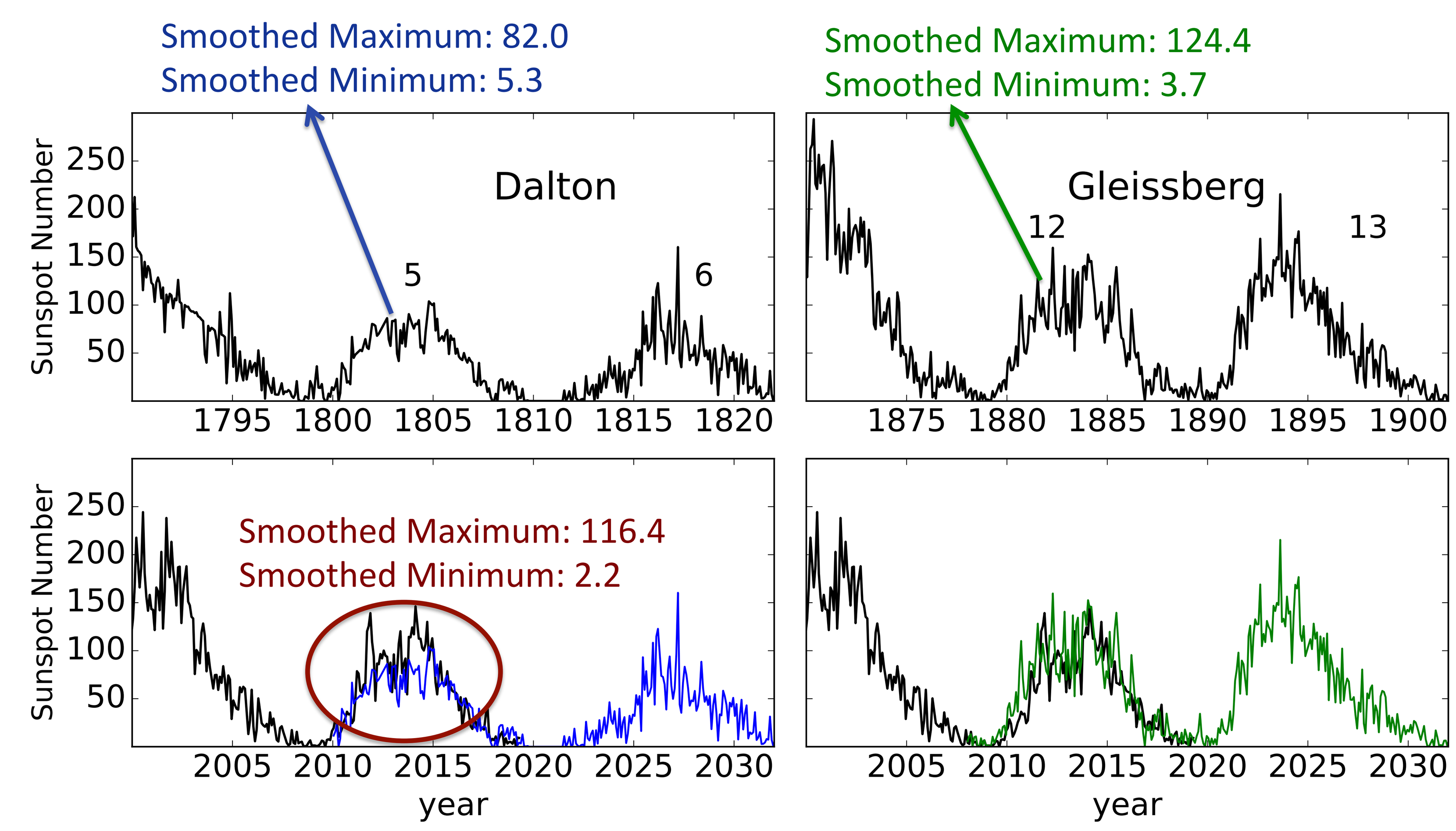
Modulation Potential

- Transport of GCRs in the interplanetary medium can be described by a modulation potential, which is related to rigidity ($P = pc / q$).
- The modulation potential approximately corresponds to the energy lost to GCR particles traveling from the LISM to the inner heliosphere: $f(r, T, t) = f(\infty, T + \Phi, 0)$
- The modulation potential correlates with HMF and solar wind speed (Schwadron 2012, 2014). We examined this correlation:



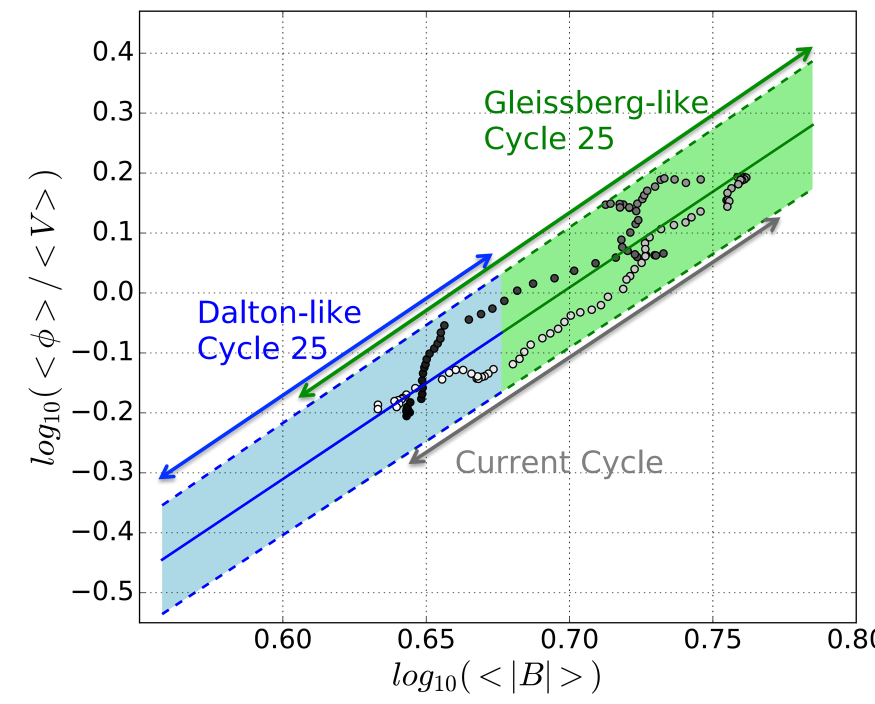
Scenarios for Solar Cycle 25

- The Solar Cycle 25 Prediction Panel has predicted that next cycle is similar to the current.
- Some models predict a deeper phase of a secular minimum.
- As we are reassuming human deep space explorations, we need to consider scenarios close to deeper secular minima.

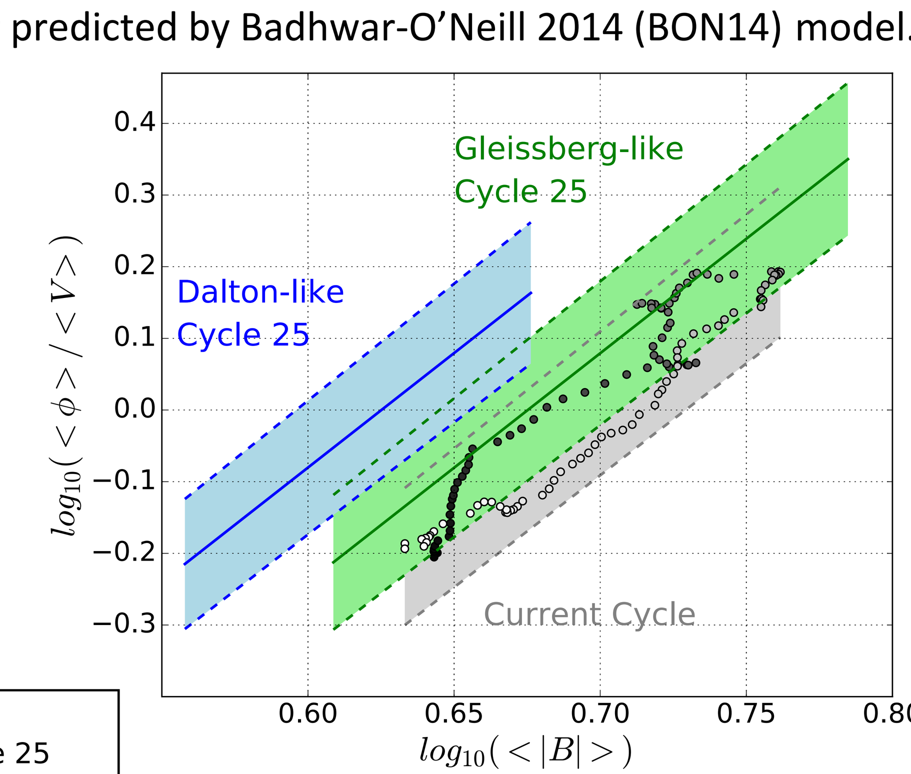


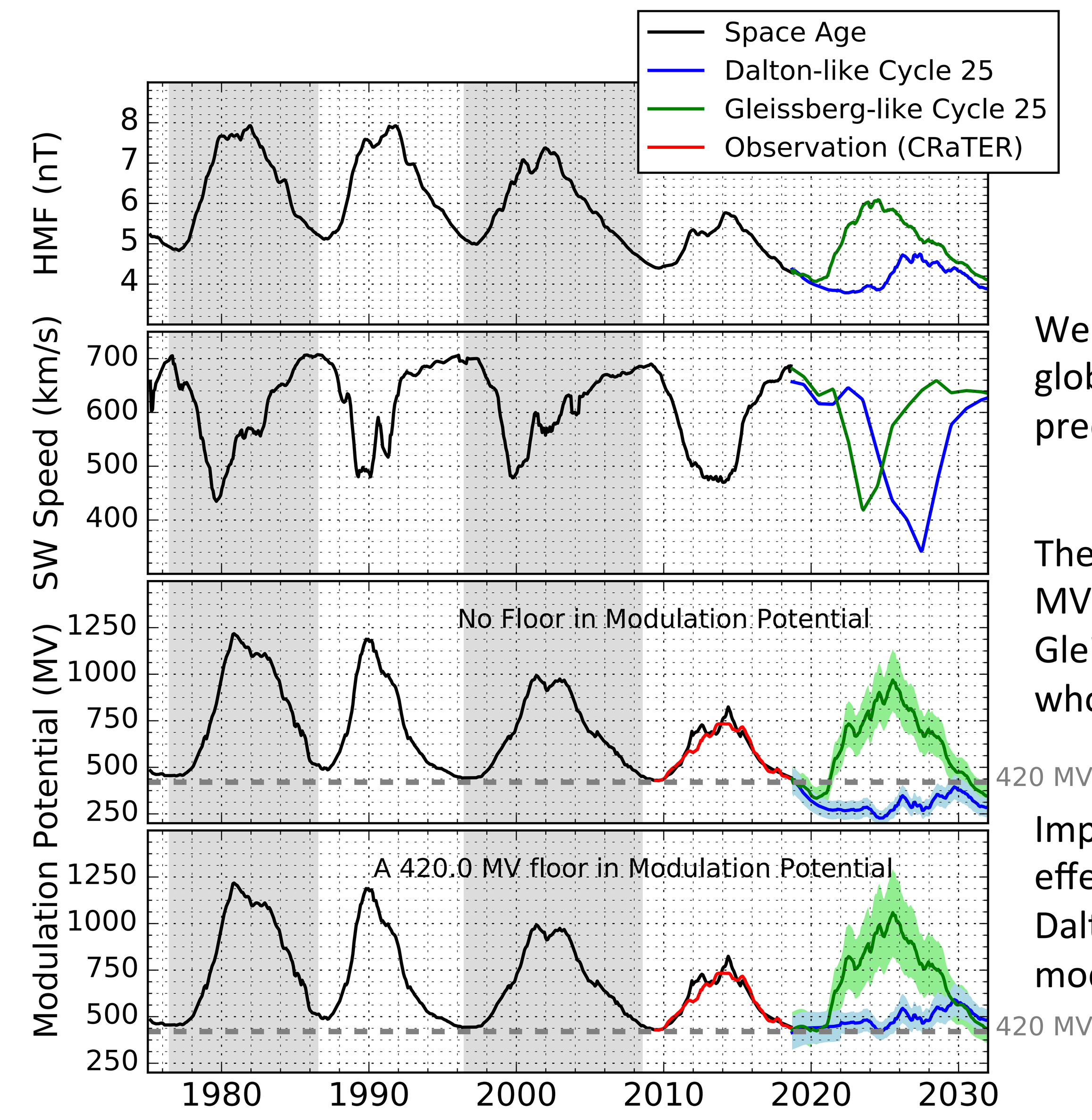
Extreme Scenarios for a Modern Minimum

- A Dalton-like cycle 25 results in an extreme scenario for the radiation environment.
- A Gleissberg-like cycle leads to a less alarming and probably more realistic condition.



The modulation potential decrease to values much lower than the floor predicted by Badhwar-O'Neill 2014 (BON14) model.





We raised the modulation potential to reach a floor of 420 MV based on BON14.

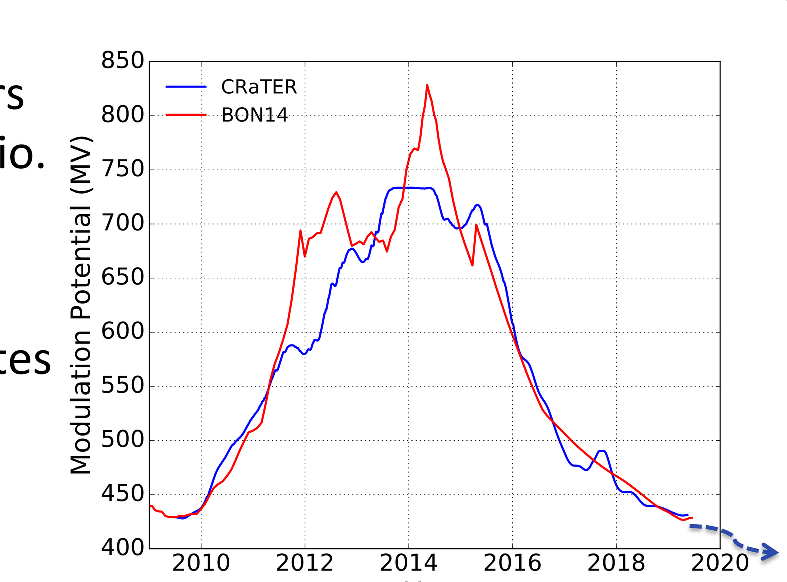
We use HMF from Rahmanifard (2017) and global solar wind speed from Owens (2017) to predict the modulation potential.

The modulation potential falls below the 420.0 MV floor during minimum phases of Gleissberg-like cycle 25 and throughout the whole cycle for a Dalton-like cycle.

Implementing a 420.0 MV floor leads to more effective modulation of the GCRs. However, the Dalton-like case still exhibits remarkably low modulation.

Conclusions

- The trend of weakening solar activity over the last 60 years indicates the possibility of another grand minimum scenario.
- The floor in modulation potential in BON14 has yet to be tested in a grand minimum scenario.
- A persistent steep increase in the level of CRaTER dose rates may lead to values smaller than 420 MV.
- Such a decrease in the modulation of the GCRs leads to a further increase of the radiation hazard from the already unprecedentedly high radiation risks.



References:

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Rahmanifard et al. (2017), DOI: 10.3847/1538-4357/aa6191
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