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The heliosphere is a privileged laboratory to study particle acceleration and transport

- Multi-wavelength, multi-messenger research

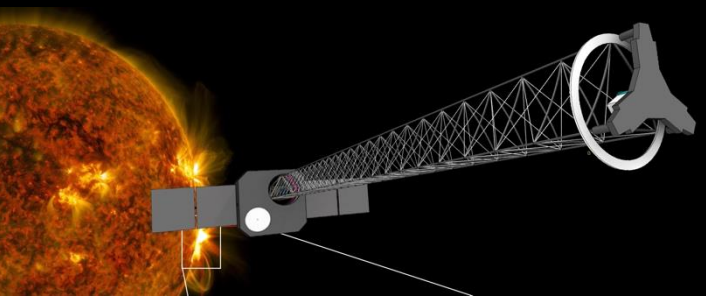
Coronal particle acceleration from a release of magnetic to kinetic energy

- First order Fermi through magnetic islands (e.g. Drake+ 2006, Arnold+ 2021)?
- Second order Fermi in turbulent plasma (e.g. Miller+ 1997, Vlahos+ 2019)?

Impulsively released energy transported and dissipated in the atmosphere

- Energetic electrons produce non-thermal Radio (e.g. White+ 2011, Chen+ 2020), and X-rays (e.g. Holman+ 2011, Warmuth+ 2020, …)
- Energetic ions produce non-thermal γ-rays (e.g. Vilmer+ 2011, Ajello+ 2021)
- Thermal plasma produces **X-rays, EUV (e.g. Fletcher+ 2011, Collier+ 2024)**

- Quasi-periodic pulsations (e.g. McLaughlin+2018, Zimovets+ 2021)
- Energy release simulations (e.g. Allred+ 2015, Kerr+ 2020)



SPARK

A 2022 mission proposal to explore particle acceleration and the consequences of magnetic energy release on the Sun (Reid+ 2023, Ryan+ 2023, Calcines Rosario 2024)

Hamish Reid

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Acceleration of particles that travel through the heliosphere.

- Flare-related particle acceleration (e.g. Petrosian 2012)
- Shock wave acceleration, requiring seed particles (e.g. Krauss-Varban 2010)

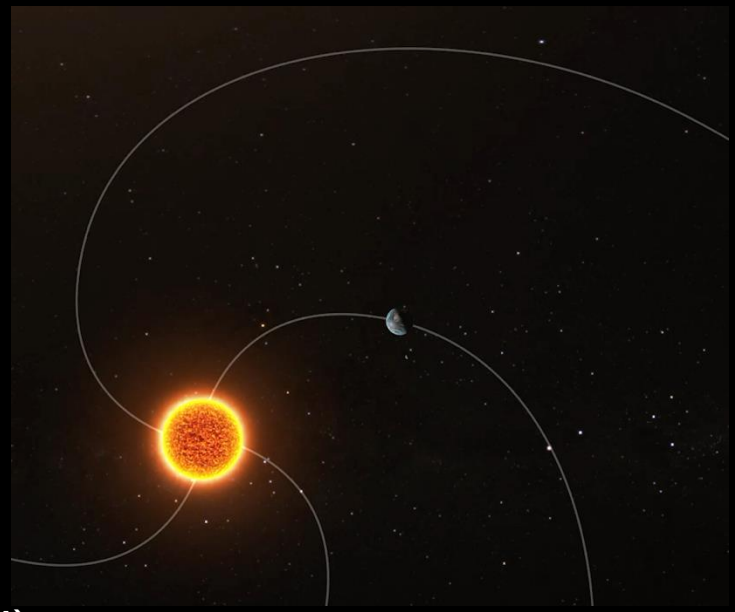
Particle trajectory through heliosphere

- Particle spectra and energy (e.g. Krucker+ 2007, Dresing+ 2021, James+ 2024)
- Particle timing at Sun and Spacecraft (e.g. Cane+ 2010, Wang+ 2016)
- Particle spatial extent (e.g. Wang+ 2012)

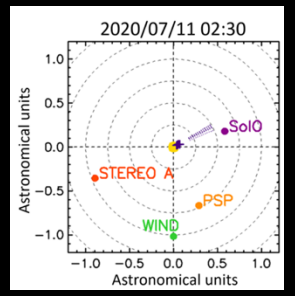
- Simulation of particle transport (e.g. Reid+ 2017, 2018, Laitinen+ 2016, 2023)
- Physics-based forecasts (e.g. Schwadron+ 2010 Marsch+ 2015, Bain+ 2016)

Tracking particles through space via radio emission

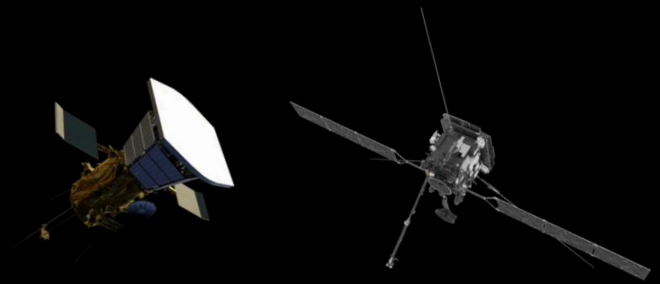
- Type III bursts tracking particle beams (e.g. Reid+ 2014, 2020, Chrysaphi+ 2024)
- Type II bursts tracking shock acceleration (e.g. Vourlidas+ 2020, Klein+ 2021)



NASA SVS



Musset+ 2021



Current suite of in situ particle detectors in the heliosphere giving coverage better than we have ever had it before.

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(Some) Outstanding Scientific Questions

- **How does impulsive energy release accelerate particles in the solar atmosphere?**
  - Unclear which acceleration process is dominant/frequent.
  - Commonality with particle acceleration in planetary magnetospheres.

- **How do energetic particles travel through solar and heliospheric plasma?**
  - Collisional and non-collisional scattering.

- **What is the energy content of accelerated ions, and electrons?**
  - Lack of understanding of solar ions.
  - Transport effects in heliosphere modify particle distributions.

- **Can we forecast solar eruptive events?**
  - Not all flares expel particles into the heliosphere.

Current combined study of energetic electrons observed by Orbiter led by Warmuth