Jet Propulsion Laboratory
California Institute of Technology

Characterizing Solar Energetic Particles, from the Perspective of Engineering and Exploration

Presented by Martin Ratliff on behalf of the

Natural Space Environments Group

Jet Propulsion Laboratory, California Institute of Technology

Solar Energetic Particles, Solar Modulation and Space Radiation:
New opportunities in the AMS Era #3
April 2018 Workshop

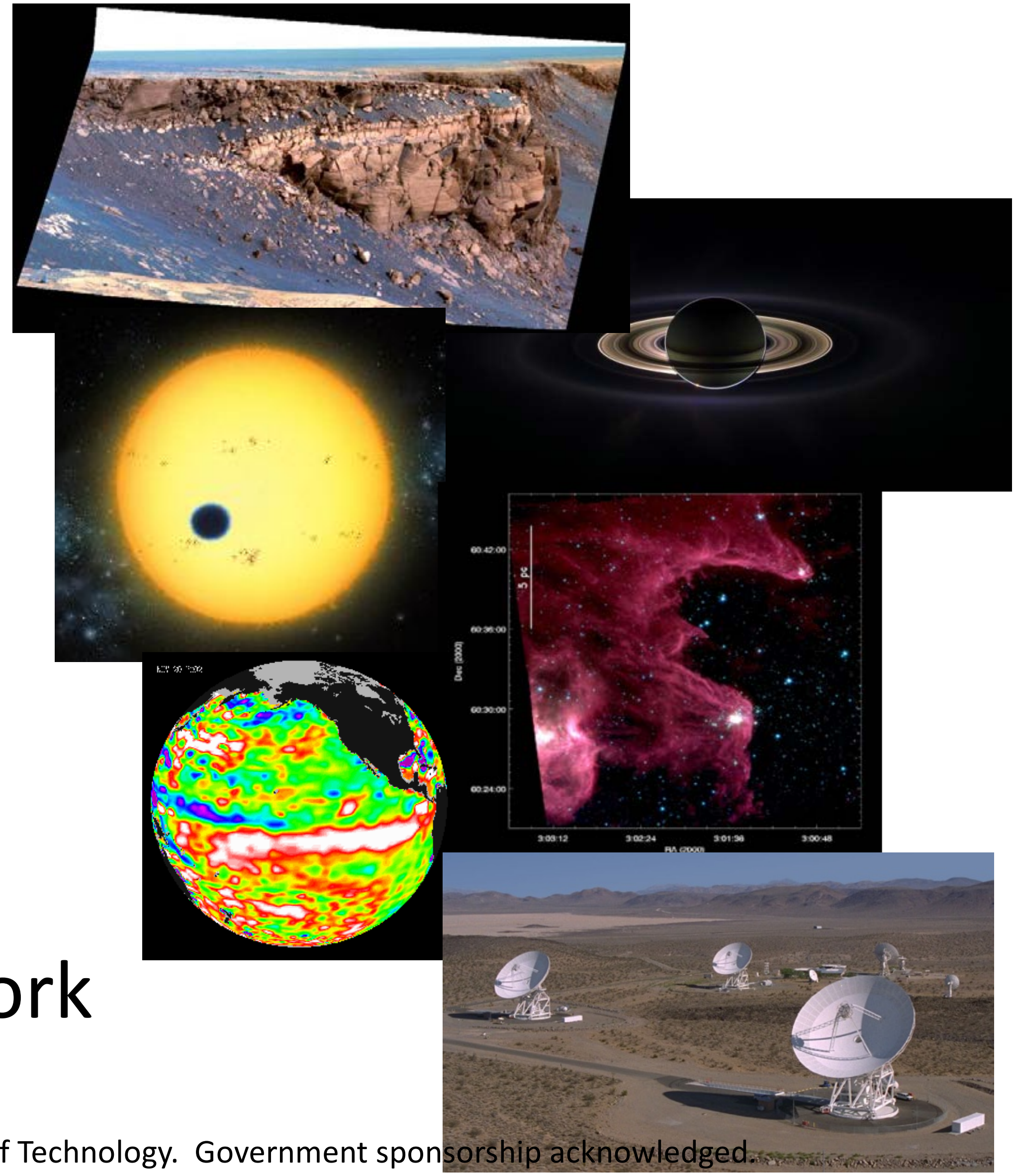
Outline

- Introduction to JPL and Natural Space Environments (NSE) Group
- Priorities for solar energetic proton characterization: Human vs. Robotic exploration
- Solar Proton Environment Specification for robotic Missions
- Need for further science contributions

  Government sponsorship acknowledged.

JPL’s primary mission is robotic space exploration

- Solar system
- Exoplanets
- Astrophysics
- Earth Science
- Interplanetary network



Thirty-two spacecraft and instruments across the solar system (and beyond) – as of 2015

JPL's Natural Space Environment Group

- Supports all JPL space-flight missions for the space environments and effects
  - Radiation (environment, shielding, charging, ….),
  - Meteoroids, Debris (MMOD)
- Is the JPL lead for nuclear planetology (Gamma ray and neutron spectroscopy)

- Tasked with understanding environment hazards, to direct the design of robotic spacecraft we send into the solar system

- We strive to contribute to model development or improvement
  - e.g. models of solar proton fluence, outer-planet trapped radiation, meteoroids

Interplanetary Radiation Issues: Robotic vs Human Exploration

GCR:

serious risk to astronauts

negligible cumulative damage to electronic parts

-> solar-cycle variation matters to astronauts, not to parts

SEP events:

to be avoided by astronauts

must be tolerated by electronics

-> SEP models:

- characterization of onset and flux profile is key so astronauts can hide
- characterization of cumulative exposure is key for part selection

Consequence: Some different aspects of the science are important in the two realms of Exploration.

Solar Energetic Proton (SEP) Fluence contributes to the Mission Dose in amounts that depend on the mission.

Mission	SEP Dose (krad-Si)	Total Dose (krad-Si)	% from SEP
Moon Mission (for 1 yr)	2.68	2.68	**100**
Cassini (Saturn)	7.34	7.5	**98**
MSL (Mars rover)	1.46	3.41*	**43**
SMAP (Earth orbiter)	1.90	4.57	**42**
Europa Clipper (Jupiter)	5.69	3000	**0.2**

For 0.100” (~2.5 mm) aluminum shielding,
Radiation design factor (RDF) = 1.
*** RTG contribution varies across rover.**

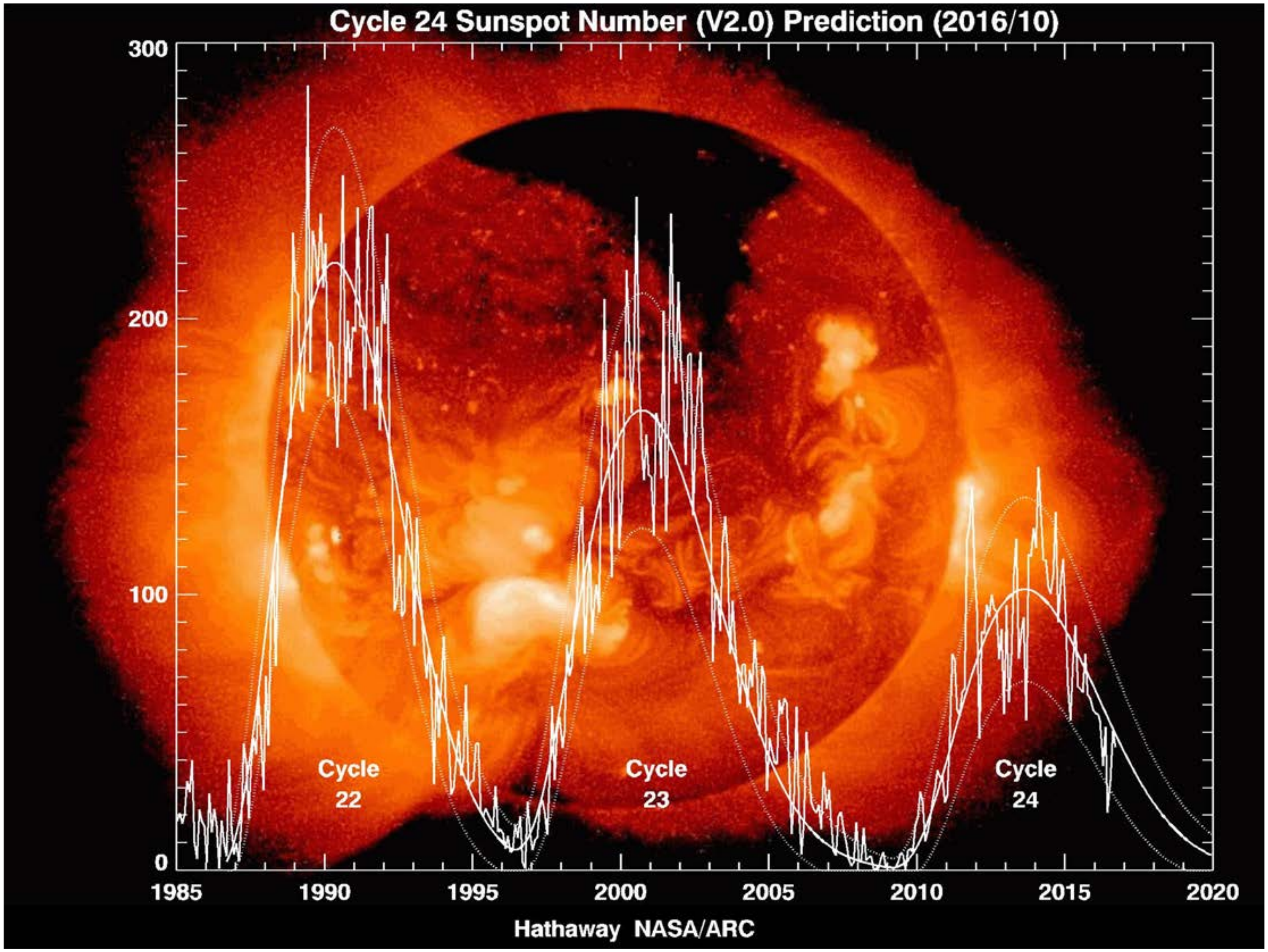
Solar Proton Fluence Model

Current class of models characterize proton fluence over X number of years at 1AU.

A dataset of observed events is fit to an assumed size distribution function of SEP events, and a frequency of events is determined, from which are derived fluence as a function of confidence level (i.e. probability that the fluence level will not to be exceeded).

Follows the lead set by King (1974).

Amount of activity varies from cycle to cycle

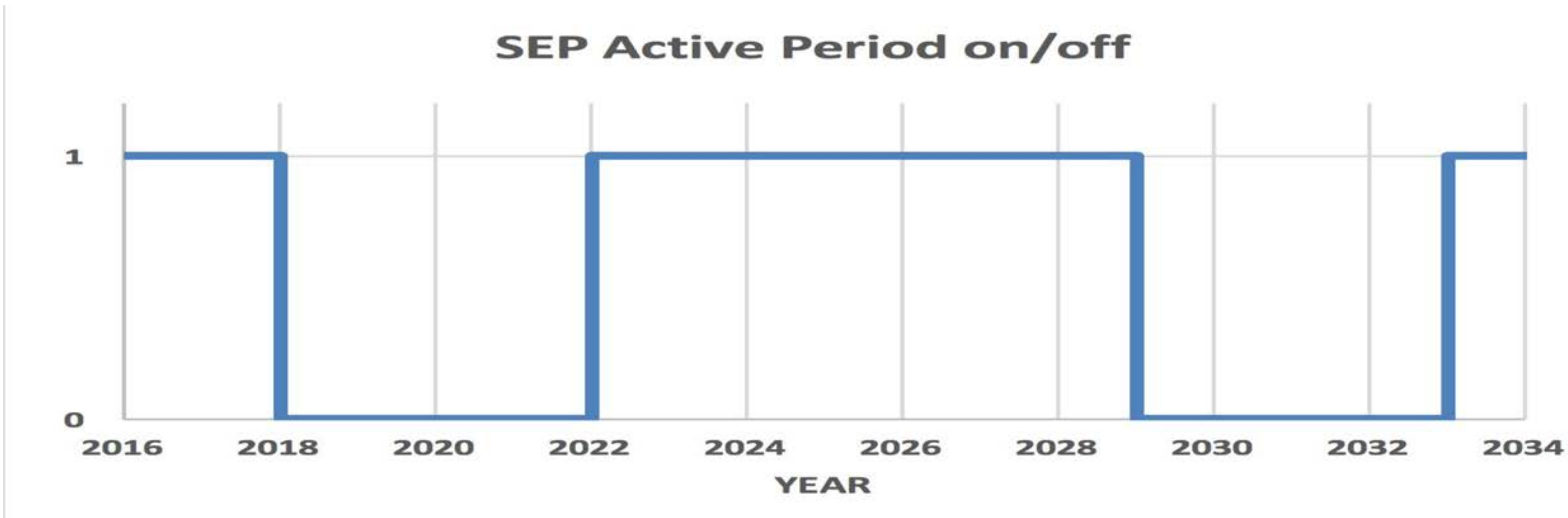


Fluence Model is simple

Does not try to tie SEP activity to SSN peak or temporal variation except for bi-modal “active”/”quiet” periods.

Statistics apply to active period.

Assume ~ 4 years of quiet period around solar minimum.



SEP Characterization for Robotic Exploration

- For probabilistic description of event size and frequency, we

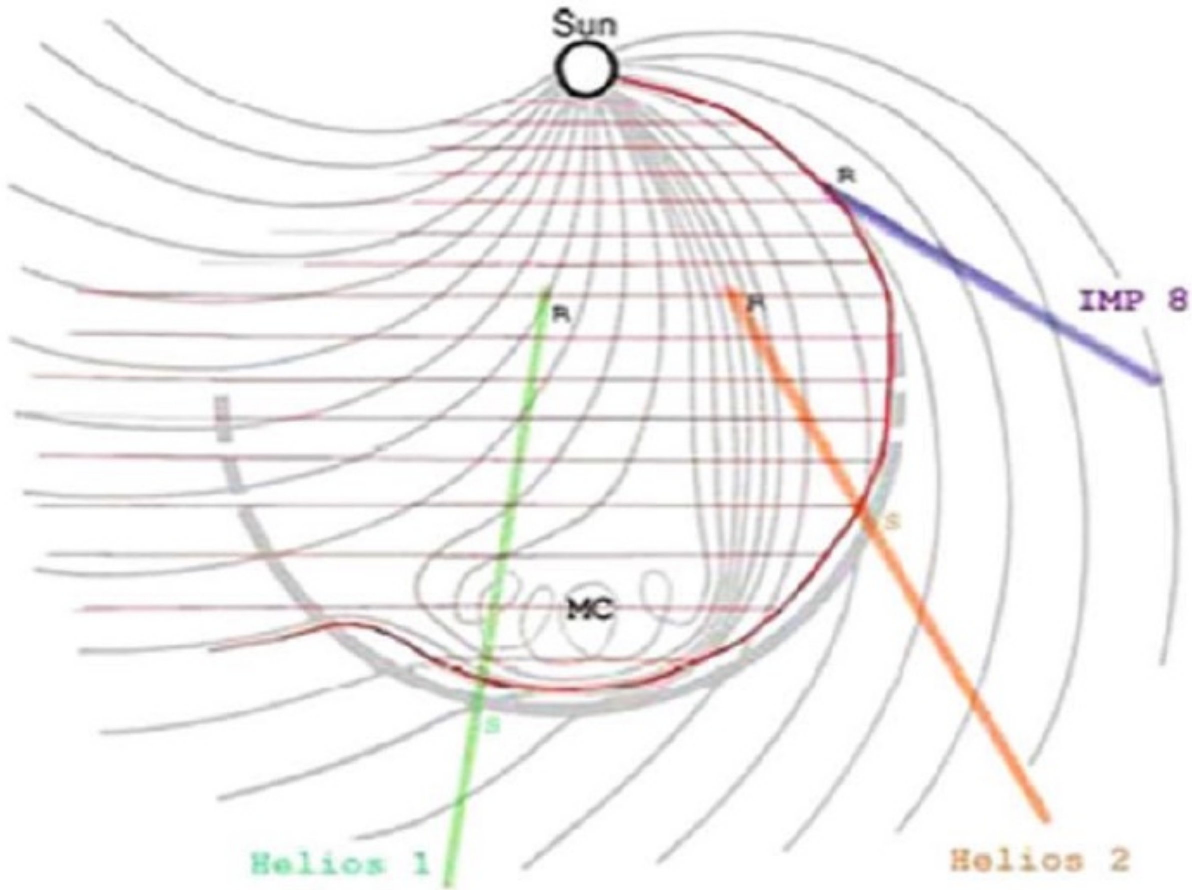
  need continuous, long-timeline observations

- For deep-space missions, we

  need radial dependence of event fluence

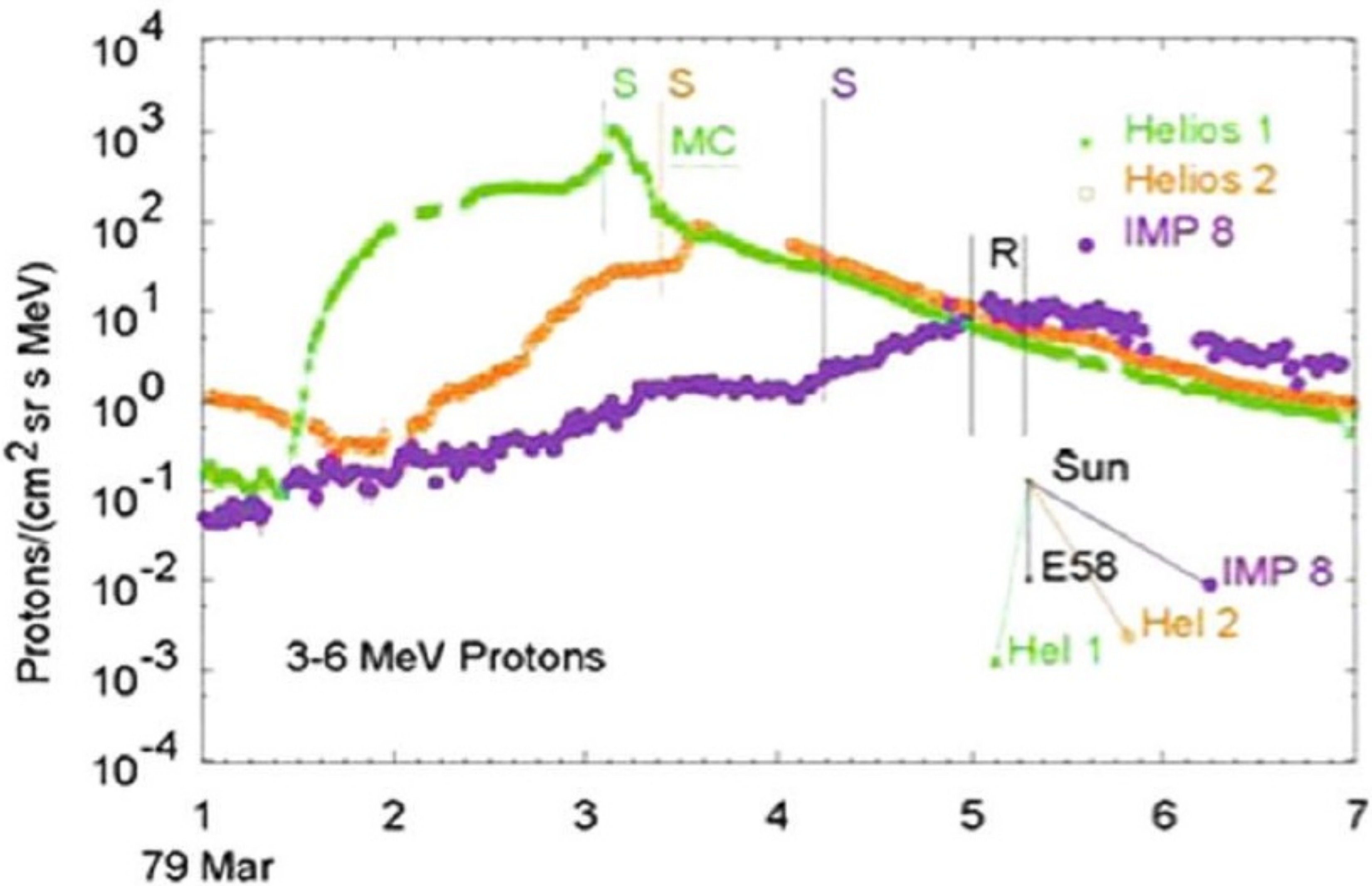
  - Look at events during time periods when Earth and Mars are the same side of the sun
  - look at event Size v. Frequency at different energy thresholds, and compare to statistics seen at 1AU

- **Rare example of simultaneous multi-location measurement: locations**



From D. Reames, Sp. Sci. Rev. (90), 1999.

- **Rare example of simultaneous multi-location measurement: results**



To Fill Knowledge Gap:

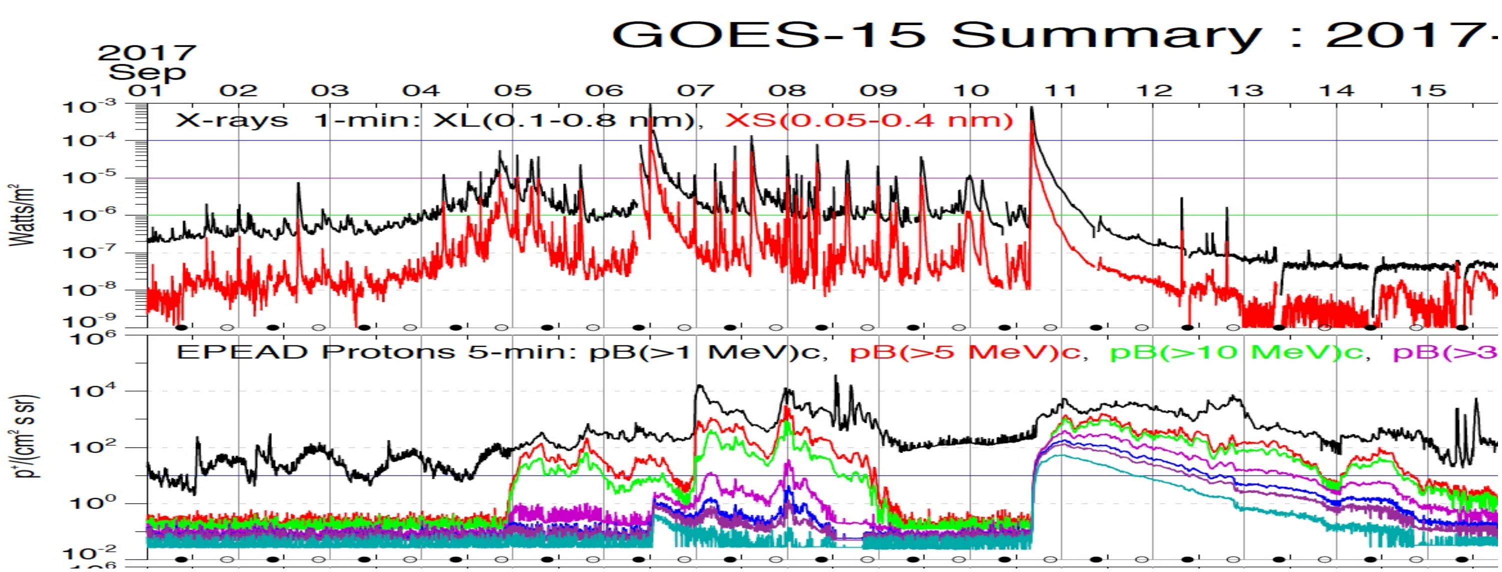
- **Scenario:** Interplanetary space-weather buoy co-orbiting with Mars
  - e.g. spacecraft at Mars-Sun L1
  - With e.g. GOES particle and x-ray spectrometers, Sun disk imaging

    (to correlate active regions to SEP events)

To Fill Knowledge Gap:

- **Benefit:**

- Characterize SEP environment at 1.5 AU (*i.e.*, Mars orbit)
- Enable long-timeline data sets to improve near-Mars & interplanetary weather and climate models



There’s still work to do (pick a curve)

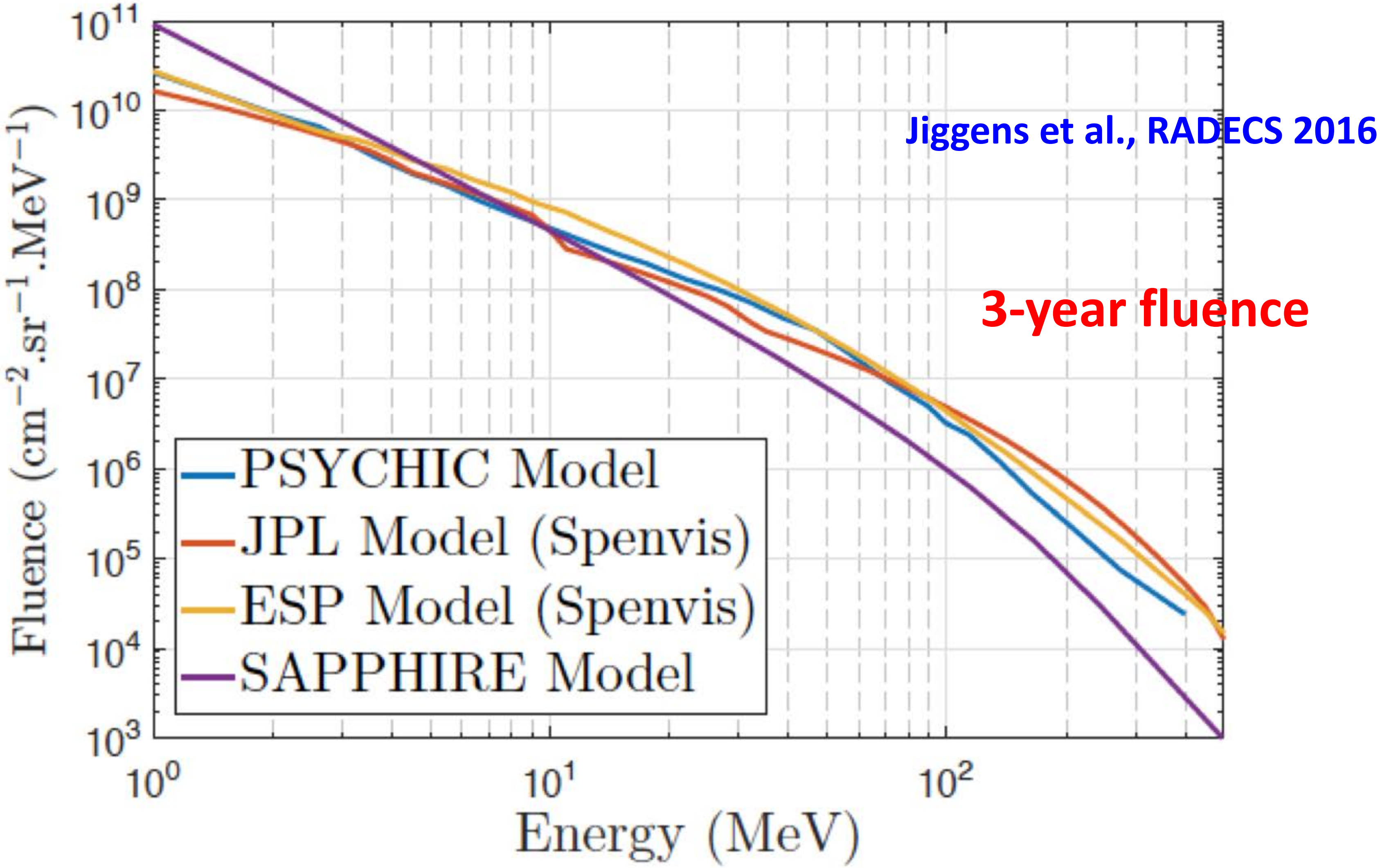


Fig. 5. Comaprison of cumulative fluence model outputs for protons at 95% confidence.

Some References:

- JPL model, also called the Feynman Model (Joan Feynman)
  - Feynman et al., JGR, 1993 (where it is called the JPL 1991 model)
  - Feynman et al., J. Atmos. Solar-Terr. Phys., 2002
- ESP model
  - Xapsos et al., IEEE Trans. Nucl. Sci. 2000
- http://test.sepem.eu/help/index_intro.html
  - Solar Energetic Particle Environment Modelling (SEPEM)

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